

## **6.3 SDP Toolkit Tools—Optional**

### **6.3.1 Digital Elevation Model Tools**

#### **6.3.1.1 DEM Access Tools (HDF-based tools)**

The Digital Elevation Model (DEM) access tools described in this section were introduced for the first time in TK 5.2 of the SDP Toolkit. They have been implemented in response to EOS Science Working Group - AM Platform (SWAMP) and ESDIS requests. These tools are meant to replace the access tools described in Section 6.3.1.2 for DEM access. The older access tools and associated ancillary data will continue to be distributed with the Toolkit, as long as there is an identifiable user requirement for them. Please note that the primary ECS production DEMs will be supplied in HDF-EOS format and will be accessible through the tools in this section. The older ETOP05 data sets will be accessible in the production system through tools described in Section 6.3.2.

The DEM Toolkit tools in Section 6.3.1.1 are intended for accessing a hierarchy of DEM data sets. In order to utilize these functions, a user must install the SDP Toolkit on their machine. This hierarchy of data sets will include data from multiple resolutions. The DEM tools access this information based on resolution; a user indicates from which resolutions they are interested in query data. Each of these resolutions consists of multiple files. For example, the 3 arc second resolution data set (~100 m postings) is divided into 648 10 degree by 10 degree files. The number and extent of these files are transparent to the user. The user indicates interest in a particular resolution with a resolution tag. This resolution tag is initialized by the tool PGS\_DEM\_Open. The resolution tags **MUST** be initialized, either individually or as an array of the resolution tags, **BEFORE** any of the other DEM tools may access the data set at that resolution. These initialized resolution tags allow access of the underlying files (in the case of the 3 arc second resolution, the 10 degree by 10 degree files), without having to actually specify the particular physical file.

As mentioned above, the DEM tools may be used with a hierarchy of DEM data sets. Most of the DEM tools not only are able to accept a single resolution tag, but they may even accept a list, an array, of resolution tags. The first element of the array is the tag for the preferred resolution of the data (generally this will be the highest resolution data set). Each successive entry in the array will be in descending interest of use: in general, lower spatial resolution. If one inputs an array of resolution tags to a DEM tool, then one may be able to gain information across resolutions. For example, one may enter an array of resolution tags into the tool PGS\_DEM\_GetRegion. This tool will go to the data set files of the first resolution tag and extract the region of interest. If any of the points in the region of interest is a fill value, then the tool will access the next data set in the input array (for that particular point). It will continue to step through progressively lower resolution data sets (depending on the order of the elements in the inputted array) until it finds "valid", actual, non fill value, data.

The data sets supported by SDP Toolkit 5.2.3 are the 3 arc second (~100 m postings) and 30 arc second (approximately 1km postings) resolution data sets. The only layers available in both

resolutions are elevation (PGSd\_DEM\_ELEV), water/land (PGSd\_DEM\_WATER\_LAND), slope (PGSd\_DEM\_SLOPE), aspect (PGSd\_DEM\_ASPECT), standard deviation elevation (PGSd\_DEM\_STDEV\_ELEV), and standard deviation slope (PGSd\_DEM\_STDEV\_SLOPE). Also both resolutions include geoid (PGSd\_DEM\_GEOID). In addition, the 30 arc second data files include quality data such as data source (PGSd\_DEM\_SOURCE), geoid (PGSd\_DEM\_GEOID), and quality metric (PGSd\_DEM\_HORIZONTAL\_ACCURACY) and PGSd\_DEM\_VERTICAL\_ACCURACY). Both data sets are in HDF-EOS GRID format. The 3 arc second resolution data set is divided into 648 10 degree by 10 degree tiles. For each tile there are 2 files, one that includes data for elevation, land/sea mask, slope, aspect, and geoid, and another file that includes data for the standard deviations. Only a few tiles are provided at the 3 arc second resolution, as test data, pending delivery of the full set from Eros Data Center. The 30 arc second resolution data set divides the Earth's surface into 6 tiles (2 files per tile as the 2 arc second data set). These are delivered with the Toolkit as a provisional data set; updates are possible, for example to replace regions of fill value with actual data. Both resolutions are in a Geographic Projection. By geographic, we mean that degrees of latitude and longitude are linearly mapped to row and column pixels, respectively.

To access these data sets, they must be included in the PCF\*. The files which make up the 30 arc second resolution should each have a logical ID equal to 10650 for the first file and 10651 for the second file. The logical ID of the 3 arc second resolution files should be 10653 for the first file and 10654 for the second file. For more information on setting up a PCF for DEM access, see both the DEM data set README file and the PCF template which accompanies Toolkit 5.2.5.

The DEM access tools described in Section 6.3.1.1 are:

**PGS\_DEM\_Open():** Open the DEM

**PGS\_DEM\_Close():** Close the DEM

**PGS\_DEM\_DataPresent():** Check for Valid DEM Data Point

**PGS\_DEM\_SortModels():** Check for Data in a Specified Region of the DEM

**PGS\_DEM\_GetPoint():** Return Data at Specified DEM Points

**PGS\_DEM\_GetRegion():** Return Data from a Specified Region of the DEM

**PGS\_DEM\_GetMetadata():** Extract Metadata from the DEM

**PGS\_DEM\_GetQualityData():** Access DEM Quality Data

**PGS\_DEM\_GetSize():** Return Size of Specified DEM Region

\* Currently there is a problem with reading data from a tiled and compressed SDS object (written with HDF4.1r1 on sun5) on DEC machines. The function SD\_readdata returns an error of FAIL.

## Open the DEM

---

**NAME:** PGS\_DEM\_Open()

**SYNOPSIS:**

C: #include <PGS\_DEM.h>

PGSt\_SMF\_status

```
PGS_DEM_Open(  
    PGSt_DEM_Tag    resolutionList[],  
    PGSt_integer    numResolutions,  
    PGSt_integer    layerList[],  
    PGSt_integer    numLayers)
```

FORTRAN: #include <PGS\_SMF.f>

#include <PGS\_DEM.f>

#include <PGS\_DEM\_14.f>

#include <PGS\_MEM\_7.f>

```
integer function pgs_dem_open(resolutionList, numResolutions  
                               layerList, numLayers)
```

integer resolutionList(\*)

integer numResolutions

integer layerList(\*)

integer numLayers

**DESCRIPTION:** This tool initializes a list of resolutions tags which correspond to a series of DEM data sets. These initialized resolution tags are used by the DEM tools. A DEM data set includes all the files of a particular resolution. Presently, only two data sets are available: 3 arc second and 30 arc second resolutions which correspond to the tags PGSD\_DEM\_3ARC and PGSD\_DEM\_30ARC, respectively. A resolution tag **MUST** be initialized before it may be used in any of the other PGS\_DEM tools. Each layer indicated in the layerList will automatically be initialized across all resolutions in the resolutionList.

**INPUTS:**

resolutionList[] -- an array of resolution tags, data sets. See Notes.

numResolutions -- the number of resolution tags in the array resolutionList

layerList[] -- the DEM layers to initialize. See Notes.

numLayers -- the number of DEM Layers in the list.

**OUTPUTS:**

N/A

**RETURNS:**

PGS\_S\_SUCCESS -- success

PGSDEM\_E\_IMPROPER\_TAG - Error, improper resolution tag(s)

PGSDEM\_E\_CANNOT\_ACCESS\_DATA - Error, cannot access the data set

**EXAMPLES:**

C:

```
PGSt_integer numLayers;

PGSt_integer layerList[2];

PGSt_integer numResolutions;

PGSt_DEM_Tag resolutionList[2];

/* initialize input parameters, both resolutions and layer */

resolutionList[0]= PGSD_DEM_3ARC;

resolutionList[1]= PGSD_DEM_30ARC;

numResolutions = 2;

layerList[0] = PGSD_DEM_ELEV;

layerList[1] = PGSD_DEM_WATER_LAND;

numLayers = 2;

/* Open the resolutions and data layer*/

status = PGS_DEM_Open(resolutionList, numResolutions,
layerList, numLayers);

if (status != PGS_S_SUCCESS)

{

/* Do some error handling ... */
```

## FORTRAN:

```
integer      numLayers  
integer      numResolutions  
integer      layerList(2)  
integer      resolutionList(2)  
integer      status
```

## C INITIALIZE

```
resolutionList(1) = PGSd_DEM_3ARC  
resolutionList(2) = PGSd_DEM_30ARC  
layerList(1) = PGSd_DEM_ELEV  
layerList(2) = PGSd_DEM_WATER_LAND  
numResolutions = 2  
numLayers = 2  
status = pgs_dem_open(resolutionList, numResolutions,  
1          layerList, numLayers)
```

## NOTES:

resolutionList:

For ECS Deliveries B.0 and B.1, the data sets that may be inputted are 3 arc second and 30 arc second resolution sets which correspond to the tags PGSd\_DEM\_3ARC and PGSd\_DEM\_30ARC, respectively.

layerList:

For ECS Deliveries B.0, the only layer that may be inputted for the 3 arc and 30 arc second resolution are elevation, (PGSd\_DEM\_ELEV), water/land (PGSd\_DEM\_WATER\_LAND), standard deviation elevation (PGSd\_DEM\_STDEV\_ELEV), slope (PGSd\_DEM\_SLOPE), standard deviation slope (PGSd\_DEM\_STDEV\_SLOPE), and aspect (PGSd\_DEM\_ASPECT). The other layers that will be available are topographical obscuration (PGSd\_DEM\_TOP\_OBSC), and topographical shadow (PGSd\_TOP\_SHAD).

## REQUIREMENTS: PGSTK-0940

## Close the DEM

---

**NAME:** PGS\_DEM\_Close()

**SYNOPSIS:**

```
C:      #include <PGS_DEM.h>

      PGSt_SMF_status

      PGS_DEM_Close(
          PGSt_DEM_Tag    resolutionList[],
          PGSt_integer    numResolutions,
          PGSt_integer    layerList[],
          PGSt_integer    numLayers)
```

```
FORTTRAN:  #include <PGS_SMF.f>
            #include <PGS_DEM.f>
            #include <PGS_DEM_14.f>
            #include <PGS_MEM_7.f>

            integer function pgs_dem_close(resolutionList, numResolutions
1          layerList, numLayers)

            integer    resolutionList(*)
            integer    numResolutions
            integer    layerList(*)
            integer    numLayers
```

**DESCRIPTION:** This tool closes the session begun by the tool PGS\_DEM\_Open. One can close multiple data set sessions simultaneously or independently. If one wants to only close one DEM data set, the array resolutionList should only contain an individual resolution tag. Presently, only two data sets are available: 3 arc second (small test data set) and 30 arc second resolutions (provisional global data) which correspond to the tags PGSD\_DEM\_3ARC and PGSD\_DEM\_30ARC, respectively. Each layer in the layerList will automatically be closed across all the resolutions indicated in the resolutionList.

**INPUTS:** resolutionList[] - an array of resolution tags, data sets. See Notes to PGS\_DEM\_Open().

numResolutions - the number of resolution tags in the array resolutionList.

layerList[] - the number of DEM Layers to initialize. See Notes to PGS\_DEM\_Open().

numLayers - the number of DEM Layers in the list.

**OUTPUTS:** N/A

**RETURNS:** PGS\_S\_SUCCESS - success

PGSDEM\_E\_IMPROPER\_TAG - Error, improper resolution tag(s)

PGSDEM\_E\_CANNOT\_ACCESS\_DATA - Error, cannot access the data set

**EXAMPLES:**

C:

```
PGSt_integer numLayers;

PGSt_integer layerList[2];

PGSt_integer numResolutions;

PGSt_DEM_Tag resolutionList[2];

/* initialize input parameters, both resolutions and layer */

resolutionList[0]= PGSd_DEM_3ARC;

resolutionList[1]= PGSd_DEM_30ARC;

numResolutions = 2;

layerList[0] = PGSd_DEM_ELEV;

numLayers = 1;

/* Close the resolutions and data layer*/

status = PGS_DEM_Close(resolutionList, numResolutions,
layerList, numLayers);
```

## FORTRAN:

```
integer      numLayers
integer      numResolutions
integer      layerList(2)
integer      resolutionList(2)
integer      status

C INITIALIZE

resolutionList(1) = PGSd_DEM_3ARC
resolutionList(2) = PGSd_DEM_30ARC
layerList(1) = PGSd_DEM_ELEV
numResolutions = 2
numLayers = 1
status = pgs_dem_close(resolutionList, numResolutions,
1          layerList, numLayers)
```

## REQUIREMENTS: PGSTK-0948



## Check for Valid DEM Data Point

---

**NAME:** PGS\_DEM\_DataPresent()

**SYNOPSIS:**

C: PGSt\_SMF\_status  
PGS\_DEM\_DataPresent(  
PGSt\_DEM\_Tag resolution,  
PGSt\_integer layer,  
PGSt\_integer positionCode,  
PGSt\_double pntLatitude[],  
PGSt\_double pntLongitude[],  
PGSt\_integer numPoints,  
PGSt\_boolean \*dataPresent)

FORTTRAN: include <PGS\_SMF.f>  
include <PGS\_DEM.f>  
include <PGS\_DEM\_14.f>  
include <PGS\_MEM\_7.f>  
  
integer function pgs\_dem\_datapresent(resolution, layer,  
1 positionCode, pntLatitude, pntLongitude, numPoints, dataPresent)  
integer resolution  
integer layer  
integer positionCode  
double precision pntLatitude(\*)  
double precision pntLongitude(\*)  
integer numPoints  
integer dataPresent

**DESCRIPTION:** This tool checks whether pixel(s), at specified latitude(s) and longitude(s), are data or fill values. In dataPresent, either PGS\_TRUE or PGS\_FALSE will be returned, corresponding to valid data or fill value, respectively.

**INPUTS:** resolution - the resolution tag for a particular data set. An element of the array resolutionList which is initialized by PGS\_DEM\_Open. See Notes to PGS\_DEM\_Open().

layer - indicates which data mask or layers one is accessing. See Notes.

positionCode - flag indicating the format of the position inputs, pntLatitude and pntLongitude. See Notes.

pntLatitude[] and pntLongitude[] - the latitude and longitude of the point(s) of interest. See Notes.

numPoints - the number of points to be queried.

**OUTPUTS:** dataPresent - either PGS\_TRUE or PGS\_FALSE. PGS\_TRUE indicates that a “valid” data value is at the specific location(s). PGS\_FALSE indicates that there is a fill value in the extracted data.

**RETURNS:** PGS\_S\_SUCCESS - success

PGSDEM\_E\_IMPROPER\_TAG - Error, improper resolution tag(s)

PGSDEM\_E\_CANNOT\_ACCESS\_DATA - Error, cannot access the data set

## EXAMPLES:

C:

```
PGSt_SMF_status status;
PGSt_integer layer;
PGSt_DEM_Tag resolution;
PGSt_integer numDataPoints;
PGSt_boolean dataPresent;
PGSt_double pntLatitude[3];
PGSt_double pntLongitude[3];

/* initialize input parameters, both resolutions and layer */

resolution= PGSD_DEM_3ARC;

layer = PGSD_DEM_ELEV;

/* initialize the number of data points and pick position of points one
   interested in. In this case, positions are in signed
   decimal degrees */
```

```

        numDataPoints = 3;

        pntLatitude[0] = 40.05;

        pntLongitude[0] = -105.3

/*see if selected points have real data*/

        status = PGS_DEM_DataPresent(resolution, layer,
        PGSd_DEM_DEGREE, pntLatitude, pntLongitude, numDataPoints,
        &dataPresent);

```

#### FORTRAN:

```

        integer      layer

        integer      resolution

        integer status

        integer numDataPoints

        integer dataPresent

        double precision pntLatitude(3)

        double precision pntLongitude(3)

C INITIALIZE resolution and layers

        resolution = PGSd_DEM_3ARC

        layer = PGSd_DEM_ELEV

C INITIALIZE points of interest. in this case, in signed decimal degrees

        numDataPoints = 3

        pntLatitude(1) = 40.04

        pntLongitude(1) = -105.3

        status = pgs_dem_datapresent(resolution, layer,

1          PGSd_DEM_DEGREE, pntLatitude, pntLongitude,

1          numDataPoints, dataPresent)

```

**NOTES:**

layer:

See NOTES for layerList of PGS\_DEM\_OPEN.

positionCode:

The position inputs may be either in signed, decimal degree format or in global pixel format, which correspond to the flags PGSd\_DEM\_DEGREE and PGSd\_DEM\_PIXEL, respectively. NOTE: global pixel format is the pixel coordinates of a point in the coordinate system for the whole world. This is NOT the same as pixels inside a single HDF-EOS GRID. The pixel coordinate system is unique for each resolution. The origin of all the pixel coordinate systems is the North, West corner of the globe (180W, 90N). The coordinate system is zero based. The 30 arc second resolution has 43200 pixels spanning from 180 West to 180 East and 21600 pixels spanning from North Pole to South Pole. The 3 arc second resolution has 432000 pixels spanning from 180 West to 180 East and 216000 pixels spanning from North Pole to South Pole.

pntLatitude and pntLongitude:

Each longitude point MUST have a corresponding latitude point. The latitude(s) and longitude(s) will be in either signed, decimal degree format or global pixel format, corresponding to the flag indicated by positionCode. If the user is using the flag PGSd\_DEM\_PIXEL, they should be aware that the values for pntLatitude and pntLongitude will be truncated. In other words, if the user passed in a pixel position which had any decimal information, that information would NOT be used in accessing the data. For example, if the user passed in 1267.34 as a pixel position, it would be truncated to 1267.

**REQUIREMENTS:** PGSTK-0941

## Check for Data in a Specified Region of the DEM

---

**NAME:** PGS\_DEM\_SortModels()

**SYNOPSIS:**

**C:**

```
PGSt_SMF_status
PGS_DEM_SortModels(
PGSt_DEM_Tag resolutionList[],
PGSt_integer numResolutions,
PGSt_integer layer,
PGSt_integer positionCode,
PGSt_double latitude[2],
PGSt_double longitude[2],
PGSt_DEM_Tag *completeDataSet)
```

**FORTTRAN:**

```
#include <PGS_SMF.f>
#include <PGS_DEM.f>
#include <PGS_DEM_14.f>
#include <PGS_MEM_7.f>

integer function pgs_dem_sortmodels(resolutionList,numResolutions,
1    layer, positionCode, latitude, longitude, completeDataSet)
integer    resolutionList(*)
integer    numResolutions
integer    layer
integer    positionCode
double precision    latitude(2)
double precision    longitude(2)
integer    completeDataSet
```

**DESCRIPTION:** This tool will check the DEM data sets for complete data in a rectangular region defined by the latitude/longitude pair specified (i.e., upper left hand corner, lower right hand corner). If there are fill values at any of the points in the defined region, then the tool will query the next resolution tag in the array for that region. The first DEM data set to have complete data in the region of interest will have its corresponding resolution tag returned in completeDataSet. If none of the data sets in the input array is "complete", then the PGSd\_DEM\_NO\_COMPLETE\_DATA will be returned.

**INPUTS:**

resolutionList[] - an array of resolution tags, data sets. See Notes to PGS\_DEM\_Open().

numResolutions - the number of resolution tags in the array resolutionList

layer - indicates which data mask one is accessing. See Notes to PGS\_DEM\_DataPresent().

positionCode - flag indicating the format of the position inputs, latitude and longitude. See Notes to PGS\_DEM\_DataPresent().

latitude[2] and longitude [2] - the bounding latitudes and longitudes of the region of interest. See Notes.

**OUTPUTS:** completeDataSet - pointer to a resolution tag, data set identifier. The first DEM data set to have complete data in the region of interest will be returned. If none of the resolution tags in the inputted array is "complete", then the PGSd\_DEM\_NO\_COMPLETE\_DATA will be returned.

**RETURNS:** PGS\_S\_SUCCESS - success

PGSDEM\_E\_IMPROPER\_TAG - Error, improper resolution tag(s)

PGSDEM\_E\_CANNOT\_ACCESS\_DATA - Error, cannot access the data set

## EXAMPLES:

C:

```
PGSt_SMF_status status;  
  
PGSt_integer layer;  
  
PGSt_DEM_Tag resolutionList;  
  
PGSt_integer numResolutions;  
  
PGSt_integer completeData;  
  
PGSt_double latitude[2];  
  
PGSt_double longitude[2];
```

```

/* initialize input parameters, both resolutions and layer */

    resolutionList[0]= PGSd_DEM_3ARC;

    resolutionList[1] = PGSd_DEM_30ARC;

    layer = PGSd_DEM_ELEV;

/* initialize the upper left and lower right corners of the data region.. In
   this case, positions are in signed decimal degrees */

/*upper left corner*/

    latitude[0] = 44.0;

    longitude[0] = -80.0;

/*lower right corner*/

    latitude[1] = 43.0;

    longitude[1] = -79.0;

/* see if region has real data */

    status = PGS_DEM_SortModels(resolutionList, numResolutions,
                                layer, PGSd_DEM_DEGREE, latitude, longitude, &completeData);

    if (status!= PGS_S_SUCCESS)

/* Do some error handling ...*/

    else

/* compare complete data set to the three possibilities to find resolution
   which has complete data across this region.

*/

    if (completeData == PGSd_DEM_3ARC)

/* complete region found in 3 arc second resolution */

        }

        else if (completeData == PGSd_DEM_30ARC)

        {

/* complete region in 30 arc second resolution */

...

```

```

    }
    else if (completeData == PGSd_DEM_NO_COMPLETE_DATA)
    {
/* all resolutions contained fill values within this region */
...
    }

```

# **FORTRAN:**

```

integer status

integer layer

integer resolutionList

double precision latitude(2)

double precision longitude(2)

C initialize input parameters, both resolutions and layer

resolutionList(1)= PGSd_DEM_3ARC

resolutionList(2) = PGSd_DEM_30ARC

layer = PGSd_DEM_ELEV


C initialize the upper left and lower right corners of the data
C region.. In this case, positions are in signed decimal degrees


C upper left corner

latitude(1) = 44.0

longitude(1) = -80.0


C lower right corner

latitude(2) = 43.0

longitude(2) = -79.0

```



```

C  see if region has complete data

        status = pgs_dem_sortmodels(resolutionList,
1      numResolutions, layer, PGSD_DEM_DEGREE, latitude, longitude,
        completeData)

        if (status.NE.PGS_S_SUCCESS) then

C Do some error handling

        else

C compare completeData to determine the resolution with complete data
C  in the specified region

        if (completeData.EQ.PGSd_DEM_3ARC) then

C          complete data in 3 arc second resolution
....

        elseif (completeData.EQ.PGSd_DEM_30ARC) then

C          complete data found in 30 arc second resolution
...

        elseif (completeData.EQ.PGSd_DEM_NO_COMPLETE_DATA) then

C          all resolutions contained fill values within this
C          region

```

**NOTES:**

latitude and longitude:

The first point corresponds to the upper left corner of the rectangular region, and the second point correspond to the lower right corner of the rectangular region. The latitude(s) and longitude(s) will be in either signed, decimal degree format or global pixel format, corresponding to the flag indicated by positionCode. If the user is using the flag PGSD\_DEM\_PIXEL, she or he should be aware that the values for latitude and longitude will be truncated. In other words, if the user passed in a pixel position which had any decimal information, that information would NOT be used in accessing the data. For example, if the user passed in 1267.34 as a pixel position, it would be truncated to 1267.

**REQUIREMENTS:** PGSTK-0942

## Return Data at Specified DEM Points

---

**NAME:** PGS\_DEM\_GetPoint()

**SYNOPSIS:**

C:

```
PGSt_SMF_status  
PGS_DEM_GetPoint(  
PGSt_DEM_Tag resolutionList[],  
PGSt_integer numResolutions  
PGSt_integer layer,  
PGSt_integer positionCode,  
PGSt_double pntLatitude[],  
PGSt_double pntLongitude[],  
PGSt_integer numPoints  
PGSt_integer interpolation,  
void *interpValues)
```

FORTRAN:

```
#include <PGS_SMF.f>  
#include <PGS_DEM.f>  
#include <PGS_DEM_14.f>  
#include <PGS_MEM_7.f>  
  
integer function pgs_dem_getpoint(resolutionList, numResolutions, layer,  
positionCode, pntLatitude, pntLongitude, numPoints, interpolation,  
interpValue)  
  
integer      resolutionList(*)  
integer      numResolutions  
integer      layer  
integer      positionCode  
double precision      pntLatitude(*)
```

double precision      pntLongitude(\*)

integer numPoints

integer interpolation

'user defined' interpValue(\*)

**DESCRIPTION:** This tool attempts to return the data value(s) of the point(s) defined by latitude and longitude. If the latitude and longitude do not exactly correspond to the center (or corner, depending on the manner in which the DEM map has been constructed) of a pixel, the value will be interpolated. Presently, there are only two interpolation methods supported: nearest neighbor and bilinear interpolation. If at this point there is a "hole", a fill value, in the data set, then the tool will access the next resolution tag in the input array. It will continue to step through progressively lower resolution data sets (depending on the order of the elements in the inputted array) until it finds actual data for that point. If all of the DEM data sets have a "hole" at this particular location, then the PGSDEM\_M\_FILLVALUE\_INCLUDED will be returned. Even if some of the queried points are not able to be interpolated (i.e. at the lowest resolution that region is fill value), the value, interpolated value or fill value of the point(s) will be returned in interpValues.

**INPUTS:** resolutionList - an array of resolution tags, data sets. See Notes to PGS\_DEM\_SortModels().

numResolutions - the number of resolution tags in the array resolutionList

layer - indicates which data mask one is accessing. See Notes to PGS\_DEM\_DataPresent().

positionCode - flag indicating the format of the position inputs, pntLatitude and pntLongitude. See Notes to PGS\_DEM\_DataPresent().

pntLatitude[] and pntLongitude[] - the latitude and longitude of the point of interest. See Notes to PGS\_DEM\_DataPresent().

numPoints - the number of points to be queried.

interpolation - type of interpolation. see Notes.

**OUTPUTS:** interpValues - the data value(s) at the designated latitude(s) and longitude(s). See Notes.

**RETURNS:** PGS\_S\_SUCCESS - success

PGSDEM\_E\_IMPROPER\_TAG - Error, improper resolution tag(s)

PGSDEM\_E\_CANNOT\_ACCESS\_DATA - Error, cannot access the data set

PGSDM\_M\_FILLVALUE\_INCLUDED - fill values in the returned data

PGSDM\_M\_MULTIPLE\_RESOLUTIONS - data accessed from multiple resolutions

## EXAMPLES:

C:

```
PGSt_SMF_status status;

PGSt_integer layer;

PGSt_DEM_Tag resolutionList[2];

PGSt_integer numResolutions;

PGSt_integer numDataPoints;

PGSt_double pntLatitude[10];

PGSt_double pntLongitude[10];

short dataPoints[10]);

/* NOTE: The type of data buffer should correspond to the type of data that
one is extracting. Presently, the only available data are
PGSd_DEM_ELEV, PGSd_DEM_SLOPE, PGSd_DEM_ASPECT,
PGSd_DEM_STDEV_ELEV, PGSd_DEM_STDEV_SLOPE, and
PGSd_DEM_WATER_LAND which are of type 2 byte, and 1 byte, 2
byte, 2 byte, and 2 byte integers, respectively. In the
future, there will be data layers added which are NOT 2 byte
or 1 byte integers. If one does not know the data type of
the particular layer, then one should use the tool
PGS_DEM_GetSize.*/

/* initialize input parameters, both resolutions and layer */

resolutionList[0]= PGSd_DEM_3ARC;

resolutionList[1] = PGSd_DEM_30ARC;

layer = PGSd_DEM_ELEV;

/* initialize the location of the points of interest. In this case, positions
are in signed decimal degrees*/

pntLatitude[0] = 40.05;

pntLongitude[0] = -105.3;...
```

```

        status = PGS_DEM_GetPoint(resolutionList, numResolutions,
        layer, PGSd_DEM_DEGREE, pntLatitude, pntLongitude,
        numDataPoints, PGSd_DEM_NEAREST_NEIGHBOR, (void
        *)dataPoints);

/*Possible status returns*/

        if (status == PGS_S_SUCCESS)
        {
            /*no fill points*/

            ...

        }
        else if (status == PGSDEM_M_FILLVALUE_INCLUDED)
        {
/*fill points included in the extracted data*/

            ...

        }
        else if (status == PGSDEM_M_MULTIPLE_RESOLUTIONS)
        {
/*no fill points in data buffer, fill points interpolated from multiple
        resolutions*/

            ...

        }
        else
        {

/*Error in extracting the data */

/* Do some error handling*/

```

**FORTTRAN:**

```

integer status

integer layer

```

```

integer resolutionList(2)

integer numResolutions

integer numDataPoints

double precision pntLatitude(10)

double precision pntLongitude(10)

integer*2 dataPoints(10)

C *** NOTE: The type of data buffer should correspond to the type of
C data one is extracting. Presently, the only available data are
C PGSD_DEM_ELEV, PGSD_DEM_WATER_LAND, PGSD_DEM_SLOPE, PGSD_DEM_ASPECT,
C PGSD_DEM_STD_DEV_ELEV, and PGS_DEM_STDEV_SLOPE which are of type
C 2 byte integers (except for PGSD_DEM_WATER_LAND which is 1 byte
C integer).

C In the future, there will be data layers added which are NOT 2 byte
C or 1 byte integers. If one does not know the data
C type of the particular
C layer, then one should use the tool PGS_DEM_GetSize.

C initialize input parameters, both resolutions and layer

resolutionList(1)= PGSD_DEM_3ARC
resolutionList(2) = PGSD_DEM_30ARC
layer = PGSD_DEM_ELEV

C initialize points of interest. In this case, location is in signed
C decimal degrees.

PntLatitude(0) = 40.05
pntLongitude(0) = -105.3
status = pgs_dem_getpoint(resolutionList,
1 numResolutions, layer, PGSD_DEM_DEGREE, pntLatitude,

```

```

1          pntLongitude, numDataPoints,
1          PGSd_DEM_NEAREST_NEIGHBOR, dataPoints)

C Possible status returns

          if (status .EQ. PGS_S_SUCCESS) then

C no fill values in this region, in the first resolution
          ...
          elseif (status .EQ. PGSDEM_M_FILLVALUE_INCLUDED) then
C fill values included in extracted data
          ...
          elseif (status .EQ. PGSDEM_M_MULTIPLE_RESOLUTIONS) then
C no fill values included in extracted data. All fill values
C interpolated from other resolutions in resolutionList

          else

C Error extracting data

C Do some error handling ...

```

**NOTES:** Both the 30 arc second and 3 arc second DEM data are referenced vertically to mean seal level, which is approximated by the geoid. Thus, the elevation data retrieved by PGS\_DEM\_GetPoint tool will be with respect to the mean seal level. To get height relative to the WGS84 ellipsoid see note for the function PGS\_Dem\_GetQualityData.

interpolation:

Presently there is only one type of interpolation, nearest neighbor, PGSd\_DEM\_NEAREST\_NEIGHBOR. In the future, bilinear interpolation, PGSd\_DEM\_BILINEAR, will be a second option for the interpolation parameter.

interpValues:



If the function locates fill values in the extracted data from the first resolution in the resolutionList, it will attempt to interpolate from the other resolutions. If the point of interest corresponds to a fill value at the lowest resolution (the last resolution tag of resolutionList), then this fill value(s) will be returned.

The land/water classes are described below:

0. Shallow Ocean (Ocean <5k from coast OR <50m deep; i.e., a buffer zone around all coastal areas and islands, plus shallow areas up to 50m deep that are further than 5km from the land). Includes the appropriate parts of the Black Sea, Red Sea, Mediterranean Sea, Hudson Bay, and other ocean-connected seas.
1. Land (not anything else).
2. Ocean Coastlines and Lake Shorelines (an actual boundary line).
3. Shallow Inland Water (Inland Water <5km from shore OR <50m deep; i.e., a buffer zone around all lake shores and inland islands, plus shallow areas up to 50m deep that are further than 5km from the land). Includes the appropriate parts of the Caspian Sea, Aral Sea, Great Lakes, "2-line" rivers, etc.
4. Ephemeral (intermittent) Water (from Digital Chart of the World).
5. Deep Inland Water (Inland water >5km from shoreline AND >50m deep; i.e., Lake waters beyond 5km from their shore or islands, and greater than 50m deep). Includes the appropriate parts of the Caspian Sea, Aral Sea, Great lakes, etc.
6. Continental Shelf Ocean (Ocean >5km from coast AND between 50m and 500m deep); i.e., Oceans beyond 5km from coastal areas and islands, and greater than 50m deep but less than 500m deep. Primarily represents the Continental shelf areas.
7. Deep Ocean (Ocean >5km from coast AND >500m deep); i.e., The really deep oceans.

**IMPORTANT!!** It is the user's responsibility to allocate the appropriate amount of space for interpValue. Note, that each mask has its own data type, see PGS\_DEM\_GetSize.

**WARNING:** Because of memory limitations it is not possible to extract more than a certain number of points by a single call to this function. The maximum number of points that can be extracted by one call to this function depends on the machine configuration at the runtime.

**REQUIREMENTS:** PGSTK-0943

## Return Data from a Specified Region of the DEM

---

**NAME:** PGS\_DEM\_GetRegion()

**SYNOPSIS:**

**C:**

```
PGSt_SMF_status  
PGS_DEM_GetRegion(  
PGSt_DEM_Tag resolutionList[],  
PGSt_integer numResolutions,  
PGSt_integer layer,  
PGSt_integer positionCode,  
PGSt_integer interpolation,  
PGSt_double latitude[2],  
PGSt_double longitude[2],  
void *dataRegion,  
PGSt_double regionSize[2],  
PGSt_double firstElement[2],  
PGSt_double pixelSize[2])
```

**FORTTRAN:**

```
#include <PGS_SMF.f>  
#include <PGS_DEM.f>  
#include <PGS_DEM_14.f>  
#include <PGS_MEM_7.f>  
  
integer function pgs_dem_getregion(resolutionList, numResolutions,  
layer, positionCode, interpolation, latitude, longitude, dataRegion,  
regionSize, firstElement, pixelSize)  
  
integer resolutionList(*)  
integer numResolutions  
integer layer
```

integer	positionCode
integer	interpolation
double precision	latitude(2)
double precision	longitude(2)
'user defined'	dataRegion(*)
double precision	regionSize(2)
double precision	firstElement(2)
double precision	pixelSize(2)

**DESCRIPTION:** This tool returns the data from a rectangular region of the DEM data set. In addition to returning an array of data, this tool will return the dimension of the region in terms of coordinate degrees, the coordinates of the first element of the dataRegion, and the size of the pixel. If any of the points in the region of interest is a "hole", a fill value, then the tool will access the next DEM data set in the input array. It will continue to step through progressively lower resolution data sets (depending on the order of the resolution tags in the inputted array) until it finds "valid", actual data. If all of the inputted resolutions have a "hole" at these specific locations, then the PGSDEM\_M\_FILLVALUE\_INCLUDED will be returned. Even if some of the queried points are not able to be interpolated (i.e., at the lowest resolution that region is fill value), the data region is still returned. The only consequence is that dataRegion will not consist solely of "valid" and interpolated data but will also contain fill values

**INPUTS:**

resolutionList - an array of resolution tags, data sets. See Notes to PGS\_DEM\_SortModels().

numResolutions - the number of resolution tags in the array resolutionList

layer - indicates which data mask or layer one is accessing. See Notes to PGS\_DEM\_DataPresent().

positionCode - flag indicating the format of the position inputs, latitude and longitude. See Notes to PGS\_DEM\_DataPresent().

. latitude[2] and longitude [2] - the bounding latitudes and longitudes of the region of interest. See Notes to PGS\_DEM\_SortModels().

. interpolation - type of interpolation. See Notes to PGS\_DEM\_GetPoint().

**OUTPUTS:**

dataRegion - an array in which the DEM data will be returned. See Notes.

regionSize[2] - an array indicating the size of the region in terms of the degrees of latitude and longitude. The array elements correspond to latitude and longitude respectively. The values will be in decimal format.

firstElement[2] - an array indicating the latitude and longitude, in decimal degree format, of the first element. The elements of the array correspond to latitude and longitude respectively.

pixelSize[2] - an array indicating the size of a pixel in terms of the degrees of latitude and longitude. The array elements correspond to latitude and longitude respectively.

**RETURNS:**

PGS\_S\_SUCCESS - success

PGSDEM\_E\_IMPROPER\_TAG - Error, improper resolution tag(s)

PGSDEM\_E\_CANNOT\_ACCESS\_DATA - Error, cannot access the data set

PGSDEM\_M\_FILLVALUE\_INCLUDED - fill values in the returned data

PGSDEM\_M\_MULTIPLE\_RESOLUTIONS - data accessed from multiple resolutions

**EXAMPLES:**

C:

```
PGSt_SMF_status status;  
  
PGSt_integer layer;  
  
PGSt_DEM_Tag resolutionList[2];  
  
PGSt_integer numResolutions;  
  
PGSt_double latitude[2];  
  
PGSt_double longitude[2];  
  
PGSt_double regionSize[2];  
  
PGSt_double firstElement[2];  
  
PGSt_double pixelSize[2];  
  
short * dataRegion;
```

```

/* initialize input parameters, both resolutions and layer */

    resolutionList[0]= PGSd_DEM_3ARC;

    resolutionList[1] = PGSd_DEM_30ARC;

    layer = PGSd_DEM_ELEV;


/* initialize the location of the region of interest.  In this case, positions
   are in signed decimal degrees*/


/* upper left corner of region */

    pntLatitude[0] = 44.05;

    pntLongitude[0] = -80.0;


/* lower right corner of region */

    latitude[1] = 43.0;

    longitude[1] = -78.8;


/*Allocate space for the buffers GetRegion.  It is the USER's RESPONSIBILITY
   TO ALLOCATE SPACE.  .  If one does not know the data type or
   the extent of one's region in global pixels, then one should
   use the tool PGS_DEM_GetSize. */

    status = PGS_DEM_GetRegion(resolutionList, numResolutions,
    layer ,PGSd_DEM_DEGREE, PGSd_DEM_NEAREST_NEIGHBOR, latitude,
    longitude, dataRegion, regionSize, firstElement, pixelSize);


/* possible status returns */

    if (status == PGS_S_SUCCESS)

    {

        /*no fill points*/

        ...

    }

    else if (status == PGSDEM_M_FILLVALUE_INCLUDED)

    {

```

```

/*fill points included in the extracted data*/

    ...
}

else if (status == PGSDEM_M_MULTIPLE_RESOLUTIONS)
{
/*no fill points in data buffer, fill points interpolated from multiple
resolutions*/

    ...
}

else
{

/*Error in extracting the data */

/* Do some error handling*/

```

#### FORTTRAN:

```

integer status

integer layer

integer resolutionList(2)

integer numResolutions

double precision latitude(2)

double precision longitude(2)

double precision regionSize(2)

double precision firstElement(2)

double precision pixelSize(2)

integer*2 dataRegion(*)

C *** NOTE: The type of data buffer should correspond to the type of data one
C is extracting. Presently, the only available data are PGSd_DEM_ELEV,
C PGSd_DEM_WATER_LAND, PGSd_DEM_SLOPE, PGSd_DEM_ASPECT, PGSd_DEM_STD_DEV_ELEV,
C and PGS_DEM_STDEV_SLOPE which are of type 2 byte integers (except for
C PGSd_DEM_WATER_LAND which is 1 a byte integer). In the future, there will
C be data layers added which are NOT 2 byte or 1 byte integers. It is the

```

```
C USER's RESPONSIBILITY TO ALLOCATE SPACE.  If one does not know the data type
C or the extent of one's region in global pixels, then one should use the tool
C PGS_DEM_GetSize. ***
```

```
C  initialize input parameters, both resolutions and layer
```

```
    resolutionList(1)= PGSd_DEM_3ARC
    resolutionList(2) = PGSd_DEM_30ARC
    layer = PGSd_DEM_ELEV
```

```
C  initialize the region of interest. In this case, the position is in signed
    decimal degrees.
```

```
C  upper left corner of region
```

```
    pntLatitude(1) = 44.05
    pntLongitude(1) = -80.0
```

```
C  lower right corner of region
```

```
    latitude(2) = 43.0
    longitude(2) = -78.8
    status = PGS_DEM_GetRegion(resolutionList,
1      numResolutions, layer ,PGSd_DEM_DEGREE,
1      PGSd_DEM_NEAREST_NEIGHBOR, latitude, longitude,
1      dataRegion, regionSize, firstElement, pixelSize)
```

```
C  possible status returns
```

```
    if (status == PGS_S_SUCCESS)
```

```
C  **no fill points
```

```
    else if (status == PGSDEM_M_FILLVALUE_INCLUDED)
```

```
C  **fill points included in extracted data
```

```
    else if (status == PGSDEM_M_MULTIPLE_RESOLUTIONS)
```

```
C  **no fill points in extracted data.  All fill points
```

```
C interpolated from other resolutions in resolutionList **  
    else  
C  **Error extracting data  
C  **Do some error handling ...
```

**NOTES:** dataRegion:

If the function locates fill values in the extracted data from the first resolution in the resolutionList, it will attempt to interpolate from the other resolutions. If the point of interest corresponds to a fill value at the lowest resolution (the last resolution tag of resolutionList), then this fill value(s) will be returned.

IMPORTANT!! It is the user's responsibility to allocate the appropriate amount of space for dataRegion. Note, that each mask has its own data type, see PGS\_DEM\_GetSize.

**REQUIREMENTS:** PGSTK-0944



## Extract Metadata from the DEM

---

**NAME:** PGS\_DEM\_GetMetadata()

**SYNOPSIS:**

**C:**

```
PGSt_SMF_status  
PGS_DEM_GetMetadata(  
PGSt_DEM_Tag resolution.  
PGSt_integer layer,  
PGSt_double pixLatInfo[2],  
PGSt_double pixLonInfo[2],  
char *positionUnits,  
PGSt_double *scaling,  
PGSt_double *offset,  
PGSt_double *fillValue,  
char *dataUnits,  
PGSt_integer *mapProjection,  
PGSt_boolean *qualityAssurLayer)
```

**FORTTRAN:**

```
#include <PGS_SMF.f>  
#include <PGS_DEM.f>  
#include <PGS_DEM_14.f>  
#include <PGS_MEM_7.f>  
  
integer function pgs_dem_getmetadata(resolution, layer, pixLatInfo,  
pixLonInfo, positionUnits, scaling, offset, fillValue, dataUnits,  
mapProjection, qualityAssurLayer)  
  
integer      resolution  
  
integer      layer  
  
double precision      pixLatInfo(2)  
double precision      pixLonInfo(2)
```

character      positionUnits(\*)  
 double precision      scaling  
 double precision      offset  
 double precision      fillValue  
 character      dataUnits(\*)  
 integer mapProjection  
 integer qualityAssurLayer

**DESCRIPTION:** This tool accesses the general metadata that pertains to a single DEM data set. The metadata is for the whole data set, not for isolated geographic sections of the data. Some of the metadata are valid for all the attributes, but other metadata will be mask specific.

**INPUTS:**

resolution - the resolution tag for a particular data set. See Notes to PGS\_DEM\_DataPresent().

layer - indicates which data mask or layer one is accessing. See Notes to PGS\_DEM\_DataPresent().

**OUTPUTS:**

pixLatInfo - an array of information on the global row pixels. See Notes.

pixLonInfo - an array of information on the global column pixels. See Notes.

positionUnits - units of the position coordinates

scaling - a pointer to the scaling factor to convert attribute data to its appropriate units

offset - a pointer to an offset to convert the attribute data (after scaling) to a meaningful value

resolution - a pointer to the resolution of the attribute data

dataUnits - the units of the attribute data

fillValue - a pointer to the fill value of the specified attribute data

mapProjection - a pointer to the type of geographic projection applied to the attribute data. Corresponds to different projection flags. See HDF-EOS User's Guide for projection codes.

qualityAssurLayer - flag indicating a quality assurance and source layer for the attribute data. This will either have the value PGS\_TRUE or PGS\_FALSE which corresponds to the existence and the absence, respectively, of a quality assurance layer.

**RETURNS:**

PGS\_S\_SUCCESS - success

PGSDem\_E\_IMPROPER\_TAG - Error, improper resolution tag(s)

PGSDem\_E\_CANNOT\_ACCESS\_DATA - Error, cannot access the data set

**EXAMPLES:**

C:

```
PGSt_SMF_status status;

PGSt_integer layer;

PGSt_DEM_Tag resolution;

PGSt_double pixLatInfo[2];
PGSt_double pixLonInfo[2];

PGSt_double scaling;
PGSt_double offset;
PGSt_double fillValue;

character *positionUnits;
character *dataUnits;

PGSt_integer mapProjection;

PGSt_boolean qualityAssuranceLayer;

/* initialize resolution and layer*/

resolution = PGSd_DEM_3ARC;

layer = PGSd_DEM_ELEV;

/* allocate enough space for positionUnits and dataUnits string */

positionUnits = calloc(30. sizeof(char));

dataUnits = calloc(30. sizeof(char));

status = PGS_DEM_GetMetadata(resolution, layer, pixLatInfo,
pixLonInfo, positionUnits, &scaling, &offset, &fillValue,
dataUnits, &mapProjection, &qualityAssuranceLayer);
```

```

        if (status != PGS_S_SUCCESS)
        {
/* Do some error handling */

```

## FORTTRAN:

```

        integer status
        integer layer
        integer resolution
        double precision pixLatInfo(2)
        double precision pixLonInfo(2)
        double precision scaling
        double precision offset
        double precision fillValue
        integer mapProjection
        integer qualityAssuranceLayer
        character positionUnits(30)
        character dataUnits(30)

c  **Note: character arrays should have enough space allocated to hold the
        string.  THIS IS THE USER'S RESPONSIBILITY **

c  initialize resolution and layer

        resolution = PGSd_DEM_3ARC
        layer = PGSd_DEM_ELEV
        status = PGS_DEM_GetMetadata(resolution, layer,
1      pixLatInfo, pixLonInfo, positionUnits, &scaling,
1      &offset, &fillValue, dataUnits, &mapProjection,
1      &qualityAssuranceLayer)

        if (status .NE. PGS_S_SUCCESS) then

c  ** Do some error handling

```

**NOTES:**

pixLatInfo and pixLonInfo:

All of the values of this array are in degree decimal format. The first element of the array indicates the spacing between pixels. The second element is the location within the pixel that is used for requesting the location of that pixel (i.e. the center or corner of the pixel). This second element is the vertical (pixLatInfo) or horizontal (pixLonInfo) offset of this location from the top left corner of a pixel.

**REQUIREMENTS:** PGSTK-0945

## ACCESS DEM Quality Data

---

**NAME:** PGS\_DEM\_GetQualityData()

**SYNOPSIS:**

C:

```
PGSt_SMF_status  
PGS_DEM_GetQualityData(  
PGSt_DEM_Tag resolution,  
PGSt_integer qualityField,  
PGSt_integer positionCode,  
PGSt_double latitude[2],  
PGSt_double longitude[2],  
void *qualityData)
```

FORTTRAN:

```
#include <PGS_SMF.f>  
#include <PGS_DEM.f>  
#include <PGS_DEM_14.f>  
#include <PGS_MEM_7.f>  
  
integer function pgs_dem_getqualitydata(resolution, qualityField,  
positionCode, latitude, longitude, qualityData)  
  
integer      resolution  
integer      qualityField  
integer positionCode  
  
double precision  latitude(2)  
double precision  longitude(2)  
  
'user defined' qualityRegion(*)
```

**DESCRIPTION:** This tool accesses the quality assurance layer of a particular DEM data set. It takes a latitude and longitude of a point of interest and an attribute mask. It returns information concerning the data source, the region over which the quality assurance information is valid, the quality metric of the aforesaid region, or information on the geoid.

**INPUTS:** resolution - the resolution tag for a particular data set. See Notes to PGS\_DEM\_DataPresent().

qualityField - the type of quality information requested. See Notes.

positionCode - flag indicating the format of the position inputs, pntLatitude and pntLongitude. See Notes to PGS\_DEM\_DataPresent().

latitude[2] and longitude [2] - the latitude and longitude of the points of interest in decimal format. See Notes to PGS\_DEM\_SortModels().

**OUTPUTS:.** qualityData - an array containing the quality assurance layer information for the region specified. The information returned is dependent on the flag indicated in the qualityField. For example, one can obtain the data sources for all the data in one's region.

**RETURNS:** PGS\_S\_SUCCESS -- success

PGSDEM\_E\_IMPROPER\_TAG - Error, improper resolution tag(s)

PGSDEM\_E\_CANNOT\_ACCESS\_DATA - Error, cannot access the data set

#### **EXAMPLES:**

```
C: PGSt_SMF_status status;
   PGSt_integer numLayers;
   PGSt_integer layerList[1];
   PGSt_DEM_Tag resolutionList[1];
   PGSt_integer numResolutions;
   PGSt_double latitude[2];
   PGSt_double longitude[2];
   PGSt_integer numVertPix;
   PGSt_integer numHorizPix;
   PGSt_integer pixByte;
   PGSt_integer totalNumPixels;
   int16 *qualityData =NULL;

   /*Some initialization. Initializing resolutions and layers for PGS_DEM
   functionality. */
   resolutionList[0]= PGSd_DEM_30ARC;
   numResolutions = 1;
```

```

layerList[0] = PGSd_DEM_ELEV;
numLayers = 1;
latitude[0] = 40.;
longitude[0] = -100.;
latitude[1] = 38.;
longitude[1] = -97.;

/*Open the resolution and data layer*/
status = PGS_DEM_Open(resolutionList, numResolutions, layerList,
                      numLayers);

if(status != PGS_S_SUCCESS)
{
    /*ERROR intializing*/
    printf("PGS_DEM_Open: error initializing\n");
}
else
{
    printf("PGS_DEM_Open: Successful Open\n");
}

status = PGS_DEM_GetSize(resolutionList[0], PGSd_DEM_GEOID,
                        PGSd_DEM_DEGREE, latitude, longitude,
                        &numVertPix, &numHorizPix, &pixByte);

if(status != PGS_S_SUCCESS)
{
    /*ERROR with GetSize*/
    printf("PGS_DEM_GetSize: error-- %d\n", status);
}
else
{
    /*print the size of region*/

```



```

        printf("PGS_DEM_GetSize: PGSd_DEM_GEOID\n");
        printf("number of bytes in one pixel is %d\n", pixByte);
        printf("number of pixels vertically spanning region %d\n",
            numVertPix);
        printf("number of pixels horizontally spanning region %d\n",
            numHorizPix);
    }
    /* allocate enough space for qualityData */
    totalNumPixels = numVertPix * numHorizPix;
    qualityData = calloc(totalNumPixels, pixByte);
    if (qualityData == NULL)
    {
        /*error callocing*/
        printf("error callocing\n");
    }
    /* Get Quality Data */
    status = PGS_DEM_GetQualityData(resolutionList[0],
        PGSd_DEM_GEOID, PGSd_DEM_DEGREE, latitude, longitude,
        (void *)qualityData);
    if (status != PGS_S_SUCCESS)
    {
        printf("error: PGS_DEM_GetQualityData\n");
    }
    else
    {
        printf("extracted quality data:using PGS_DEM_GetQualityData\n");
    }
    status = PGS_DEM_Close(resolutionList, numResolutions, layerList,
        numLayers);
    if (status != PGS_S_SUCCESS)

```

```

{
    /*ERROR DE-INITIALIZING*/
    printf("Error closing DEM session.\n");
}

```

FORTTRAN: TBD

**NOTES:** Both the 30 arc second and 3 arc second DEM data are referenced vertically to mean sea level, which is approximated by the geoid. The numbers for geoid that one can extract using PGS\_DEM\_GetQualityData, as shown in the example, are added to the DEM value to make the height relative to the WGS84 ellipsoid. Thus in order to get height relative to the WGS84 ellipsoid one calls first PGS\_Dem\_GetPoint (see example for the function PGS\_DEM\_GetPoint) to retrieve the elevation data with respect to the mean sea level. The subsequent call to PGS\_DEM\_GetQualityData, as shown in the example, will retrieve geoid data. Then these values are added together to give the height relative to the WGS84 ellipsoid.

qualityField:

For example, one could query the information on either the data source, the quality metric, or the geoid which corresponds to the flags PGSd\_DEM\_SOURCE, PGSd\_DEM\_HORIZONTAL\_ACCURACY, PGSd\_DEM\_VERTICAL\_ACCURACY, and PGSd\_DEM\_GEOID respectively.

qualityData - Followings are the data types and values for quality fields:

Source: Data type is 1 byte integer

code 0-8:

0 - no data (ocean)

1 - Digital Terrain Elevation Data (DTED)

2 - Digital Chart of the World (DCW)

3 - USGS 1-degree DEM's

4 - Army Map Service 1:1,000,000-scale maps

5 - International Map of the World 1:1,000,000-scale map

6 - Peru 1:1,000,000-scale map

7 - New Zealand DEM

## 8 - Antarctic Digital Database (ADD)

Geoid: Data type is 2 byte integer

Data range is -101 to 75 Meters. Add numbers to Mean Sea Level to achieve WGS84 Geoid.

Method: Data type is 1 byte integer.

accuracy calculation method - code 0-5:

0 - no data (ocean)

1 - accuracy from source DEM metadata

2 - vertical accuracy calculated by comparison with higher resolution DEM; horizontal accuracy from source product specification

3 - accuracy from source DEM product specification

4 - vertical accuracy estimated from contour interval of source;

horizontal accuracy estimated from map scale of source

5 - not calculated

1 is used for DTED.

2 is used for DCW.

3 is used for USGS DEM's.

4 is used for cartographic sources (sources 4, 5, 6, and 7 in source data).

5 is used for Antarctica (where the wide range of contour intervals and map scales in the ADD makes it unreasonable to give a reliable estimate).

Horizontal Accuracy: Data type is 2 byte integer.

absolute horizontal accuracy: RMSE in meters

-9999 = no data (ocean)

9999 = unknown

Vertical Accuracy: Data type is 2 byte integer.

absolute vertical accuracy: RMSE in meters

-9999 = no data (ocean)

9999 = unknown

**REQUIREMENTS:** PGSTK-0946

## Return Size of Specified DEM Region

---

**NAME:** PGS\_DEM\_GetSize()

**SYNOPSIS:**

C:

```
PGSt_SMF_status  
PGS_DEM_GetSize(  
PGSt_DEM_Tag resolution,  
PGSt_integer field,  
PGSt_integer positionCode,  
PGSt_double latitude[2],  
PGSt_double longitude[2],  
PGSt_integer *numPixVertical,  
PGSt_integer *numPixHorizontal,  
PGSt_integer *sizeDataType)
```

FORTTRAN:

```
#include <PGS_SMF.f>  
#include <PGS_DEM.f>  
#include <PGS_DEM_14.f>  
#include <PGS_MEM_7.f>  
  
integer function pgs_dem_getsize(resolution, field, positionCode, latitude,  
longitude, numPixVertical, numPixHorizontal, sizeDataType)  
  
integer      resolution  
integer      field  
integer positionCode  
double precision latitude(2)  
double precision longitude(2)  
integer numPixVertical  
integer numPixHorizontal  
integer sizeDataType
```

**DESCRIPTION:** This tool determines the size of a rectangular region defined by the latitudes and longitudes of its upper left and lower right corners. This tool is meant to facilitate the user's ability to allocate appropriate space for the data returned by PGS\_DEM\_GetRegion and PGS\_DEM\_GetQualityData. Use of this tool can prevent core dumps and other errors due to improper allocation of memory.

**INPUTS:** resolution - the resolution tag for a particular data set. See Notes to PGS\_DEM\_DataPresent().

field - either a mask or a qualityField flag. See Notes.

positionCode - flag indicating the format of the position inputs, pntLatitude and pntLongitude. See Notes to PGS\_DEM\_DataPresent().

latitude[2] and longitude [2] - the latitude and longitude of the points of interest. See Notes to PGS\_DEM\_SortModels().

**OUTPUTS:** numPixVertical - a pointer to the number of pixels spanning the vertical extent of the region

numPixHorizontal - a pointer to the number of pixels spanning the horizontal extent of the region

sizeDataType - a pointer to the size of an individual pixel of data, in bytes

**RETURNS:** PGS\_S\_SUCCESS - success

PGSDEM\_E\_IMPROPER\_TAG - Error, improper resolution tag(s)

PGSDEM\_E\_CANNOT\_ACCESS\_DATA - Error, cannot access the data set

**EXAMPLES:**

C:

```
PGSt_SMF_status status;  
  
PGSt_integer resolution;  
  
PGSt_integer layer;  
  
PGSt_double latitude[2];  
  
PGSt_double longitude[2];  
  
PGSt_integer numVertPix;  
  
PGSt_integer numHorizPix;  
  
PGSt_integer pixByte;
```

```

/* initialize resolution and layer */

    resolution = PGSd_DEM_30ARC;

    layer = PGSd_DEM_ELEV;

/*initialize location of region.  In this case, position is in signed decimal
degrees */

    latitude[0] = 4.0;

    longitude[0] = 112.0;

    latitude[1] = -3.0;

    longitude[1] = 115.5;

    status = PGS_DEM_GetSize(resolution, layer, PGSd_DEM_DEGREE,
latitude, longitude, &numVertPix, &numHorizPix, &pixByte);

    if(status != PGS_S_SUCCESS)

    {

/* Do some error handling ...*/

        ....

```

#### FORTTRAN:

```

integer resolution

integer layer

integer status

double precision latitude(2)

double precision longitude(2)

integer numVertPix

integer numHorizPix

integer pixByte

C  **initialize resolution and layer

    resolution = PGSd_DEM_30ARC

    layer = PGSd_DEM_ELEV

C  **initialize location of region.  In this case, position is in signed
decimal degrees

```

```

latitude(1) = 4.0

longitude(1) = 112.0

latitude(2) = -3.0

longitude(2) = 115.5

status = PGS_DEM_GetSize(resolution, layer,
1    PGSd_DEM_DEGREE, latitude, longitude, numVertPix,
1    numHorizPix, pixByte)

if(status .NE. PGS_S_SUCCESS) then

C  ** Do some error handling ...**

```

**NOTES:** field:

This indicates the layer attribute or field of the quality assurance layer over which the region is "sized". For ECS Deliveries B.0, the layers that may be inputted are elevation, standard deviation of elevation, water/land, slope gradient, standard deviation of slope gradient, aspect, data source, quality metric, and geoid which correspond to the flags PGSd\_DEM\_ELEV, PGSd\_DEM\_STDEV\_ELEV, PGSd\_DEM\_WATER\_LAND, PGSd\_DEM\_SLOPE, PGSd\_DEM\_STDEV\_SLOPE, PGSd\_DEM\_ASPECT, PGSd\_DEM\_SOURCE, PGSd\_DEM\_HORIZONTAL\_ACCURACY, PGSd\_DEM\_VERTICAL\_ACCURACY, and PGSd\_DEM\_GEOID, respectively. The layers that will be available in the future are: topographical obscuration (PGSd\_DEM\_TOP\_OBSC), and topographical shadow (PGS\_DEM\_TOP\_SHAD).

**REQUIREMENTS:** PGSTK-0947

## **6.3.2 Ancillary Data Tools**

### **6.3.2.1 Introduction**

There will be a large number of ancillary data files used in ECS instrument processing. The tools in this section address files already identified at this writing.

Users could utilize language standard input/output functions or the HDF tools to access the ancillary data. However, a suite of higher level tools is required for the following reasons:

- a. to enable data from locations specified by the user to be returned to the user thus avoiding having to know the internal structure of the file.
- b. to shield the user from having to know details of parameter source or source format or to track changes in either, although source changes will be agreed upon with the user.
- c. to provide for certain additional manipulations of extracted data.

For this final point (c), only those data sets that have been specifically identified as requiring particular manipulations will be serviced; i.e., the ancillary tools do not intend to provide a general manipulation service for all types of data. However, the tools that extract from location (a) will be sufficiently generic to allow additional data sets of a similar type to be used.



## Access the Digital Chart of the World Database

---

**NAME:** PGS\_AA\_dcw( )

**SYNOPSIS:**

**C:** `#include <PGS_AA.h>`  
`PGSt_SMF_Status`  
`PGS_AA_dcw (char iparms[][100], coverage name—PO`  
`PGSt_integer nParms, number of coverages`  
`PGSt_double longitude[], longitude of point(s)`  
`PGSt_double latitude[], latitude of point(s)`  
`PGSt_integer npoints, number of points`  
`void *results) result of search`

**FORTTRAN:** `include'PGS_AA_10.f'`  
`integer function`  
`PGS_AA_dcw(parms, nParms, latitude, longitude, npoints, results)`  
`character*99 iparms(*),`  
`integer nParms,`  
`double latitude(*)`

**DESCRIPTION:** This routine receives either a single point or an array of location points and navigates the DCW database in order to find the coverage that the user supplies as parm. Once the coverage is identified, the database path is updated, with each file and table identified, until the table containing the locational information is located. Once this table is found, the table is opened and the result for a latitude/longitude is extracted and returned in results.

```
[start]
PERFORM PGS_AA_dcw_Parm
PERFORM PGS_AA_dcw_Intile
PERFORM PGS_AA_dcw_Inface
PERFORM PGS_AA_dcw_Feature
PERFORM return PGS_S_SUCCESS
[end]
```

## INPUTS:

**Table 6-128. PGS\_AA\_dcw Inputs**

Name	Description	Units	Min	Max
parms	parameter wanted	N/A	N/A	N/A
nParms	number of parameters	N/A	1	1
latitude	latitude location	degrees	-90.0	90.0
longitude	longitude location	degrees	-180.0	180.0
npoints	number of points	N/A	0	Unlimited

## OUTPUTS:

**Table 6-129. PGS\_AA\_dcw Outputs**

Name	Description	Units	Min	Max
results	extracted parameter	char	N/A	N/A

## RETURNS:

**Table 6-130. PGS\_AA\_dcw Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSAA_E_DCW_ERROR	Error in extracting value required
PGSAA_W_DCW_NODATA	No data at that point in data base

The following errors are reported to the error log

PGSAA\_E\_CANT\_FIND\_PARM  
PGSAA\_E\_CANT\_GET\_CONTINENT\_PATH  
PGSAA\_E\_CANT\_GET\_TILE\_DIR  
PGSAA\_E\_CANT\_GET\_POINT\_IN\_FACE  
PGSAA\_E\_CANT\_GET\_POINT\_INFO

## EXAMPLES:

```
C:      #include <PGS_AA.h>

        PGSt_double latitude[2] = {-9.29, -25.34};
        PGSt_double longitude[2] = {110.3, 30.9};
        PGSt_integer results[2];
        char parm[PGSd_AA_MAXNOCACHES][100] = {"po"};

        ret_status = PGS_AA_dcw(parm, 1, longitude, latitude, 2,
                                results);
```

```

FORTRAN:      implicit none

               include      "PGS_AA_10.f"
               include      "PGS_AA.f"
               include      "PGS_SMF.f"

               integer      PGS_AA_dcw
               character*99  parms(PGSd_AA_MAXNOCACHES)
               integer      nParms(2)
               double        latitude(2)
               double        longitude(2)
               integer      npoints(2)
               integer      result(2)
               parms(1)= "po"
               nParms = 2
               latitude = -9.29, -25.34
               longitude = 110.3, 30.9
               npoints = 2

               call pgs_aa_dcw(parms, nParms, longitude, latitude, npoints,
                               results)

```

**NOTES:** For further details of the background to this tool see the Toolkit Primer Ancillary Data section (info on how to access this document can be found in the preface of the Users Guide).

**IMPORTANT:** The PGS\_AA\_dcw code calls a number of library modules, which carry out such actions as mallocing memory for files, opening files, opening tables, reading tables, extracting information from tables and closing tables. These library modules are detailed in the DCW format specification and the associated vector product format (VPF) library software.

**NOTE:** Precision of latitude and longitude is machine specific, not data-base specific.

**REQUIREMENTS:** PGSTK-0840, PGSTK-0870, PGSTK-1360, PGSTK-1362

## Access Available Data from a Set of Standard Digital Elevation Models (DEMs)

---

**NAME:** PGS\_AA\_dem( )

**SYNOPSIS:**

**C:** #include "PGS\_AA.h"

```
PGSt_SMF_status  
PGS_AA_dem(char parms[][100],  
            PGSt_integer      nParms,  
            PGSt_double       latitude[],  
            PGSt_double       longitude[],  
            PGSt_integer      versionFlag[],  
            PGSt_integer      nPoints,  
            PGSt_PC_Logical    fileId,  
            PGSt_integer      operation,  
            void               *results)
```

**FORTTRAN:** include "PGS\_AA\_10.f"  
include "PGS\_AA.f"

```
integer function  
pgs_aa_dem (parms, nparms, latitude, longitude,  
            versionflag, npoints, fileId, operation, results)  
character*99      parms(*)  
integer           nParms  
double precision  latitude(*)  
double precision  longitude(*)  
integer           versionflag(*)  
integer           npoints  
integer           fileId  
integer           operation  
'user specified' results (see Notes)
```

**DESCRIPTION:** This routine provides the interface to retrieve DEM values from the gridded data set.

**INPUTS:****Table 6-131. PGS\_AA\_dem Inputs**

Name	Description	Units	Min	Max
parms	parameter names requested	see notes		
nParms	number of parms	none	1	#defined
latitude	latitude(s) of the requested point	degrees	-90.00	90.00
longitude	longitude(s) of the requested point	degrees	-180.00	180.00
nPoints	no. of points requested	none	1	variable
fileId	logical file number	none	variable	variable
operation	defines user required	none	1	variable

**OUTPUTS:****Table 6-132. PGS\_AA\_dem Outputs**

Name	Description	Units	Min	Max
versionFlag	indicates tile location for a point (see notes)	see notes	1	variable
results	results	see notes		

**RETURNS:****Table 6-133. PGS\_AA\_dem Returns**

Returns	Descriptions
PGS_S_SUCCESS	Successful return
PGSAA_E_NPOINTSINVALID	Number of points invalid
PGSAA_E_TILE_STATUS	Could not establish tile status of the DEM file
PGSAA_E_2DGEO	Error returned from PGS_AA_2Dgeo
PGSAA_E_SUPPORTID	Could not establish support file id
PGSAA_E_MINMAX	Could not establish min/max range for the DEM
PGSAA_E_DATATYPE	Could not establish parameter datatype
PGSAA_E_UNKNOWN_DATATYPE	DEM datafile datatype is unknown

## EXAMPLES:

```
C:      #include <PGS_AA.h>
      PGSt_SMF_status retStatus;

      char parms[PGSd_AA_MAXNOCACHES][100] = { "USAelevation" };
      long nParms = 1;
      PGSt_double latitude[MAX_POINTS] = {51.5, 51.23666,
                                           50.973333} ;
      PGSt_double longitude[MAX_POINTS] = {0.1666666,0.3832,
                                           0.5999};

      PGSt_integer  versionFlag[MAX_POINTS];

      PGSt_integer nPoints = 3;
      long fileId = 210;
      long version = 0;
      long operation = 1;
      short results[3];
      retStatus = PGS_AA_2Dgeo(parms, nParms, latitude, longitude,
                              versionFlag, nPoints, fileId,
                              operation, results);

FORTRAN:      implicit none

      include      "PGS_AA_10.f"
      include      "PGS_AA.f"
      include      "PGS_SMF.f"

      parms(PGSd_AA_MAXNOCACHES)
      integer                pgs_aa_dem
      integer                versionFlag(300)
      integer                nParm
      double precision        latitude(300)
      double precision        longitude(300)
      integer                fileId
      integer                nPoints
      integer                version
      integer                operation
      integer                results(300)
      integer                retStatus
      parms(1)= "USAelevation"
      nParms = 1
      fileId = 202
      operation = 1
      nPoints = 300
      do 10 i = 1, 300
      .
      .
      .
```

```

latitude(i) = calculated_user_lat
longitude(i) = calculated_user_lon
.
.
10      continue

retStatus = pgs_aa_dem( parms, nparms, latitude,
2                longitude, versionFlag, npoints,
1                fileId, operation, results )

```

## NOTES:

The added facility that differentiates this tool from its sister tool PGS\_AA\_2Dgeo is that this routine can handle tiled data sets by selecting from geographically separated tiles. Some of the DEM datafiles can be very large files and are necessarily tiled into smaller files to avoid memory problems.

Also this routine processes all input point data and returns a warning if some of the input points were found to be out of range. In such an event user can examine versionFlag[] to locate the offending points. For such points the corresponding location in versionFlag would contain a value PGSD\_AA\_OUT\_OF\_RANGE, e.g.,

```

      if latitude[3] and longitude[3] is the offending point then
         versionFlag[3] = PGSD_AA_OUT_OF_RANGE.

```

For other points the versionFlag[] would actually contain the number of the tile where the point was located.

For the details of DEM datafiles the user is referred to appendix D.

The FORTRAN result argument returned is not specified since it depends on the data set used; e.g., it could be real or integer.

The results buffer holds the final output sent back to the user. It can hold data of 4 types (long, short, float, double).

For more details the user is referred to information regarding PGS\_AA\_2Dgeo.

Users MUST be aware of the amount of disk space required by the number of calls to the tool (where calls demand the ingestion of separate physical files), and in doing so not exceed the capacity of the machine they are working on.

## DEC—users

DEC users should be aware that for some of the product files a DEC version (e.g., etop05.dat\_dec) is supplied. The user should use these instead of the normal files. This is for backward compatibility with the PGS\_AA\_2Dgeo tool. For the rest of the data files there is an inbuilt facility to swap the bytes. For these files there is a flag 'swapBytes = yes' in the support file. This flag is set to 'no' for the data files with 'dec' versions. Another issue that the user should be aware of is that DEC

represents 'long' datatype as 8 bytes long. Therefore, if there is a datafile created on a different platform (most other platforms represent 'long' as 4 bytes), then that file must be converted first to be used on the DEC. Conversion should simply be reading the file as 'int' (4 bytes) and writing it out as 'long' (8 bytes) on the DEC. To take care of byteswapping the support file for such datafile should contain a flag 'swapBytes = yes'.

**REQUIREMENTS:** PGSTK-0840, PGSTK-0980



## Extract String Parameter from Parameter=Value Formatted File

---

**NAME:** PGS\_AA\_PeVA\_string( )

**SYNOPSIS:**

**C:** #include <PGS\_AA.h>  
  
PGSt\_SMF\_status  
PGS\_AA\_PeVA\_string(  
    PGSt\_uinteger      pevLogical,  
    char                \*parameter,  
    char                \*value[] )

**FORTTRAN:** include "PGS\_AA\_10.f"  
include "PGS\_AA.f"  
  
integer function  
pgs\_aa\_peva\_string( pevLogical, parameter, value )  
    integer          pevLogical  
    character\*(\*)    parameter  
    character\*(\*)    value

**DESCRIPTION:** This routine returns the value associated with a string type parameter from the given file.

**INPUTS:**

**Table 6-134. PGS\_AA\_PeVA\_string Inputs**

Name	Description	Units	Min	Max
pevLogical	file logical for file to be accessed	see notes		
parameter	name of parameter to be retrieved	see notes		

**OUTPUTS:**

**Table 6-135. PGS\_AA\_PeVA\_string Outputs**

Name	Description	Units	Min	Max
value	value associated with retrieved parameter	see notes		

## RETURNS:

**Table 6-136. PGS\_AA\_PeVA\_string Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSAA_E_PEV_ERROR	Error in extracting the required value

The following errors are reported to the error log

```
PGSAA_E_CANT_GET_FILE_ID
PGSAA_E_CANT_OPEN_INPUT_FILE
PGSAA_E_AGG_CANT_BE_INSERTED
PGSAA_E_READLABEL_PARSE_ERROR
PGSAA_E_PARAMETER_INVALID
PGSAA_E_FIRST_NODE_NOT_FOUND
```

**EXAMPLE:**

[illegible]

```

FORTRAN:      implicit none

               include      'PGS_AA.f'
               include      'PGS_AA_10.f'

               integer      pgs_aa_peva_string
               integer      pevLogical, return
               character*30  parameter
               character*20  value

```

```
pevLogical = 876  
parameter = "dataType"  
  
return = pgs_aa_peva_string( pevLogical, parameter, value )
```

**NOTES:** The logical is an integer whose value is supplied through the PC tools. The parameter is a data set dependent character string and the value is also a string as returned from the data file identified by the logical. For

**REQUIREMENTS:** PGSTK-1365

## Extract Real Parameter from Parameter = Value Formatted File

---

**NAME:** PGS\_AA\_PeVA\_real()

**SYNOPSIS:**

**C:**                   #include <PGS\_AA.h>

                  PGSt\_SMF\_status  
                  PGS\_AA\_PeVA\_real(  
                      PGSt\_uinteger            pevLogical,  
                      char                    \*parameter,  
                      PGSt\_double            \*value )

**FORTTRAN:**       include'PGS\_AA\_10.f'  
                  include'PGS\_AA.f'

                  integer function  
                  pgs\_aa\_peva\_real( pevLogical, parameter, value )  
                      integer                    pevLogical  
                      character\*(\*)            parameter  
                      double precision        value

**DESCRIPTION:**   This routine returns the value associated with a string type parameter from the given file.

**INPUTS:**

***Table 6-137. PGS\_AA\_PeVA\_real Inputs***

Name	Description	Units	Min	Max
pevLogical	file logical for file to be accessed	see notes		
parameter	name of parameter to be retrieved	see notes		

**OUTPUTS:**

***Table 6-138. PGS\_AA\_PeVA\_real Outputs***

Name	Description	Units	Min	Max
value	value associated with retrieved parameter	see notes		

## RETURNS:

**Table 6-139. PGS\_AA\_PeVA\_real Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSAA_E_PEV_ERROR	Error in extracting the required value

The following errors are reported to the error log

PGSCUC\_E\_CANT\_GET\_FILE\_ID  
PGSCUC\_E\_CANT\_OPEN\_INPUT\_FILE  
PGSCUC\_E\_AGG\_CANT\_BE\_INSERTED  
PGSCUC\_E\_READLABEL\_PARSE\_ERROR  
PGSCUC\_E\_PARAMETER\_INVALID  
PGSCUC\_E\_FIRST\_NODE\_NOT\_FOUND

## EXAMPLE:

```
C:      #include <PGS_AA.h>

      PGSt_SMF_status   retStatus;
      PGSt_double       myRealValue[10];

      ret_status = PGS_AA_PeVA_real(MY_PEV_FILE,
                                   "MY_STRING_PARAMETER",
                                   &myRealValue);

      if (ret_status != PGS_S_SUCCESS)
      {
          signal ERROR
      }

FORTRAN:  implicit none

          include          'PGS_AA.f'
          include          'PGS_AA_10.f'

          integer          pgs_aa_peva_real
          integer          pevLogical, return
          character*30      parameter
          double precision  value
          pevLogical = 876
          parameter = "maxLat"

          return = pgs_aa_peva_real( pevLogical, parameter, value )
```

**NOTES:** The logical is an integer whose value is supplied through the PC tools. The parameter is a data set dependent character string and the value is a real as returned from the data file identified by the logical.

**REQUIREMENTS:** PGSTK-1365

## Extract Integer Parameter from Parameter = Value Formatted File

---

**NAME:** PGS\_AA\_PeVA\_integer( )

**SYNOPSIS:**

**C:**                   #include <PGS\_AA.h>  
  
                  PGSt\_SMF\_status  
PGS\_AA\_PeVA\_integer(  
                  PGSt\_uinteger           pevLogical,  
                  char                    \*parameter,  
                  PGSt)integer           \*value)

**FORTTRAN:**       include'PGS\_AA\_10.f'  
                  include"PGS\_AA.f"  
  
                  integer function  
pgs\_aa\_peva\_integer( pevLogical, parameter, value )  
                  integer            pevLogical  
                  character\*(\*)   parameter  
                  integer           value

**DESCRIPTION:**   This routine returns the value associated with a string type parameter from the given file.

**INPUTS:**

**Table 6-140. PGS\_AA\_PeVA\_integer Inputs**

Name	Description	Units	Min	Max
pevLogical	file logical for file to be accessed	see notes		
parameter	name of parameter to be retrieved	see notes		

**OUTPUTS:**

**Table 6-141. PGS\_AA\_PeVA\_integer Outputs**

Name	Description	Units	Min	Max
value	value associated with retrieved parameter	see notes		

**RETURNS:**

**Table 6-142. PGS\_AA\_PeVA\_integer Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSAA_E_PEV_ERROR	Error in extracting the required value

The following errors are reported to the error log

```
PGSCUC_E_CANT_GET_FILE_ID
PGSCUC_E_CANT_OPEN_INPUT_FILE
PGSCUC_E_AGG_CANT_BE_INSERTED
PGSCUC_E_READLABEL_PARSE_ERROR
PGSCUC_E_PARAMETER_INVALID
PGSCUC_E_FIRST_NODE_NOT_FOUND
```

**EXAMPLE:**

```
C:      #include <PGS_AA.h>

PGSt_SMF_status   retStatus;
PGSt_integer      myIntValue;

ret_status = PGS_AA_PeVA_integer(MY_PEV_FILE,
                                "MY_STRING_PARAMETER",
                                &myIntValue);

if (ret_status != PGS_S_SUCCESS)
{
    signal ERROR
}

FORTRAN: implicit none

include      'PGS_AA.f'
include      'PGS_AA_10.f'

integer      pgs_aa_peva_integer
integer      pevLogical, return
character*30  parameter
integer*(*)  value
pevLogical = 876
parameter = "size"

return = pgs_aa_peva_real( pevLogical, parameter, value )
```

**NOTES:** The logical is an integer whose value is supplied through the PC tools. The parameter is a data set dependent character string and the value is a real as returned from the data file identified by the logical.

**REQUIREMENTS:** PGSTK-1365



## Extract Data from Gridded Data Sets by Geographic Location

---

**NAME:** PGS\_AA\_2Dgeo()

**SYNOPSIS:**

**C:** #include <PGS\_AA.h>

```
PGSt_SMF_status
PGS_AA_2Dgeo ( char iparms[][100],
               PGSt_integer nParms,
               PGSt_double latitude[],
               PGSt_double longitude[],
               PGSt_integer nPoints,
               PGSt_integer fileId,
               PGSt_integer version,
               PGSt_integer operation,
               void *results);
```

**FORTRAN:** include'PGS\_AA\_10.f'  
include'PGS\_AA.f'

```
integer function
pgs_aa_2dgeo( parms, nparms, latitude, longitude, fileId,
              version, operation, results )
character*99      parms(*)
integer           nParms
real*8           latitude(*)
real*8           longitude(*)
integer          fileId
integer          version
integer          operation
'user specified' results (see Notes)
```

**DESCRIPTION:** The user specifies a parameter, a fileId and version from which the data are to be extracted using the geographic coordinates. Since this tool is similar to the other AA geo and Read tools, a single explanation of the interface is provided in Appendix D.3.

The interface to the calling algorithm that extracts gridded data by geographic location.

```
[start]
PERFORM PGS_AA_Map
PERFORM PGS_AA_GetSupp to get support data
```

```

DO          allocate memory to parmBuffer using
            totalParmMemoryCache
PERFORM     PGS_AA_FF_Setup
DO          set tool used to 2
PERFORM     PGS_AA_GEOGrid
[end]

```

## INPUTS:

**Table 6-143. PGS\_AA\_2Dgeo Inputs**

Name	Description	Units	Min	Max
parms	parameter names	see notes	requested	
nParms	number of parms	none	1	#defined
latitude	latitude(s) of the requested point	degrees	-90.00	90.00
longitude	longitude(s) of the requested point	degrees	-180.00	180.00
nPoints	no. of points requested	none	1	variable
fileId	logical file number	none	variable	variable
version	version of dynamic file	none	1	variable
operation	defines user required	none	1	variable

## OUTPUTS:

**Table 6-144. PGS\_AA\_2Dgeo Outputs**

Name	Description	Units	Min	Max
results	results	see notes		

**RETURNS:****Table 6-145. PGS\_AA\_2Dgeo Returns**

To User/Log File	Return	Description
u	PGSAA_E_GEOERRO	Error in GEO extraction
l	PGSAA_E_AUTOOPERATION	Error in executing autoOperation
l	PGSAA_E_AUTOOPERATIONUNSET	No autoOperation found in support file
l	PGSAA_E_OPERATION	Error in executing operation
l	PGSAA_E_OPERATIONUNSET	Operation not set by user
ul	PGSAA_E_GEOTOSTRUCT	Failure in calculation of structure from lat/lon
ul	PGSAA_E_UNIDENTIFIEDTYPE	Type cannot be identified, results failure
u	PGSAA_E_SUPPORTFILE	Support or format files inaccessible
ul	PGSAA_E_PARMSONOTFOUND	Parameter(s) not found in the support support file
l	PGSAA_E_DATARATEUNSET	dataRate attribute unset in support file
ul	PGSAA_E_PARMSEFROMANYFILES	Parameters requested from more than one physical file
ul	PGSAA_E_INVALIDNOPARMS	No of parms incorrect
ul	PGSAA_E_BADSUPPSUPPORT	Tool support file is corrupted or incomplete
ul	PGSAA_E_CANTFINDFILE	Format of input data file inaccessible
u	PGSAA_E_FFERROR	A freeform error has occurred
l	PGSAA_E_FFDBIN	Failure in Freeform make_dbin function
l	PGSAA_E_FFDBSET	Failure in Freeform db_set function
l	PGSAA_E_FFDBEVENTS	Failure in Freeform db_events function
ul	PGSAA_E_MALLOC	Failure to malloc
u	PGSAA_E_PEV_ERROR	An error has occurred in the PeVA tool
l	PGSAA_E_PEV_XS_SUPPFILES	Too many PeVA files open, increase MAXFILES
l	PGSAA_E_CANT_GET_VALUE	Unable to extract value from dbin
l	PGSAA_E_GETDBIN	Error in PeVA tool obtaining dbin
u	PGSAA_E_GETSUPP	An error was detected while extracting support data
l	PGSAA_E_POSITION_CALC_FAILURE	The position in the parmBuffer of the requested values was miscalculated
u	PGSAA_E_TWOD_READ_ERROR	Function failure to read parameter values from buffer
l	PGSAA_E_EXTRACTORESULTSERROR	Failure to transfer selected values from parmBuffer to results
ul	PGSAA_E_OUTOFRANGE	Input values out of data set range

## EXAMPLE:

```
C:      #include <PGS_AA.h>
      PGSt_SMF_status retStatus;

      char parms[PGSd_AA_MAXNOCACHES][100] = {
                                          "etop05SeaLevelElevM" };

      long nParms = 1;

      PGSt_double latitude[] = {51.5, 51.23666, 50.973333} ;
      PGSt_double longitude[] = {0.1666666,0.3832, 0.5999};

      PGSt_integer nPoints = 3;

      PGSt_integer fileId = 10955;

      PGSt_integer version = 1;

      PGSt_integer operation = 1;

      short results[3];

      retStatus = PGS_AA_2Dgeo(parms, nParms, latitude, longitude,
                              nPoints, fileId, version,
                              operation, results);
```

```
FORTRAN:  implicit none

          include      "PGS_AA_10"
          include      "PGS_AA.f"
          include      "PGS_SMF.f"

          integer      pgs_aa_2dgeo
          character*99  parms(PGSd_AA_MAXNOCACHES)
          integer      nParms
          real*8        latitude(300)
          real*8        longitude(300)
          integer      fileId
          integer      nPoints
          integer      version
          integer      operation
          integer      results(300)
          parms(1)= "fnocMod"
          nParms = 1
          fileId = 10965
          operation = 1
          version = 1
          nPoints = 300
          do 10 i = 1, 300
            .
            .
```

```

latitude(i) = calculated_user_lat
longitude(i) = calculated_user_lon
.
.
10      continue

call pgs_aa_2dgeo( parms, nparms, latitude, longitude,
                  fileId, version, operation, results )

```

## NOTES:

For further details of the background to these tools and the available data sets, support files and the means by which new data sets can be introduced, see the Toolkit Primer Ancillary Data section (info on how to access this document can be found in the preface of the Users Guide) or appendix D in this document. These also include details of the operations that can be set by the user and the autoOperations associated with particular data sets.

The FORTRAN result argument returned is not specified since it depends on the data set used; e.g., it could be real or integer.

The upper limit of the range of input variables is data set specific. The parms input variable is a parameter and data set specific set of strings. The parmBuffer input is a memory buffer holding whatever data is extracted from the data set requested by the user. The results buffer is similar although holds the final output sent back to the user. It can hold data of 4 types (long, short, float, double).

It is critical that the results buffer be declared to be of the same type as that found in the first element of the support file (or PGSt\_integer for short /long when working in FORTRAN) and be dimensioned to exactly contain the requested dimensions.

**REQUIREMENTS:** PGSTK-0840, PGSTK-0931, PGSTK-0980, PGSTK-1030, PGSTK-1362

## Extract Data from Gridded Data Sets by Geographic Location

---

**NAME:** PGS\_AA\_3Dgeo()

**SYNOPSIS:**

**C:** #include <PGS\_AA.h>

PGSt\_SMF\_status

```
PGS_AA_3Dgeo ( char iparms[][100],
               PGSt_integer nParms,
               PGSt_double latitude[],
               PGSt_double longitude[],
               PGSt_integer height[],
               PGSt_integer nPoints,
               PGSt_integer fileId,
               PGSt_integer version,
               PGSt_integer operation,
               void *results);
```

**FORTTRAN:** include'PGS\_AA\_10.f'  
include"PGS\_AA.f"

```
character*99      iparms(PGSd_AA_MAXNOCACHES)
integer           nParms
real*8            latitude(*)
real*8            longitude(*)
integer           height(*)
integer           fileId
integer           version
integer           operation
'user specified'  results (see Notes)
```

```
integer function
pgs_aa_3dread( parms, nparms, latitude, longitude,
              height, fileId, version, operation, results )
```

**DESCRIPTION:** The user specifies a parameter, a fileId and version from which the data are to be extracted using the geographic coordinates. Since this tool is similar to the other AA geo and Read tools, a single explanation of the interface is provided in Appendix D.3.

The interface to the calling algorithm that extract gridded data by geographic location.

```
[start]
PERFORM PGS_AA_Map
PERFORM PGS_AA_GetSupp to get support data
```

```

DO          allocate memory to parmBuffer using
            totalParmMemoryCache
PERFORM     PGS_AA_FF_Setup
DO          set tool used to 3
PERFORM     PGS_AA_GEOGrid
[end]

```

## INPUTS:

**Table 6-146. PGS\_AA\_3Dgeo Inputs**

Name	Description	Units	Min	Max
iparms	parameter names requested	see notes		
nParms	number of parms	none	1	4
latitude	latitude(s) of the requested point	degrees	-90.00	90.00
longitude	longitude(s) of the requested point	degrees	-180.00	180.00
height	height of the requested point	none	1	variable
nPoints	no. of points requested	none	1	variable
fileId	logical file number	none	variable	variable
version	version of dynamic file	none	1	variable
operation	defines user required	none	1	variable

## OUTPUTS:

**Table 6-147. PGS\_AA\_3Dgeo Outputs**

Name	Description	Units	Min	Max
results	results	see notes		

## RETURNS:

**Table 6-148. PGS\_AA\_3Dgeo Returns (1 of 2)**

To User/Log File	Return	Description
u	PGSAA_E_GEOERROR	Error in GEO extraction
l	PGSAA_E_AUTOOPERATION	Error in executing autoOperation
l	PGSAA_E_AUTOOPERATIONUNSET	No autoOperation found in support file
l	PGSAA_E_OPERATION	Error in executing operation
l	PGSAA_E_OPERATIONUNSET	Operation not set by user
ul	PGSAA_E_GEOTOSTRUCT	Failure in calculation of structure from lat/lon
ul	PGSAA_E_UNIDENTIFIEDTYPE	Type cannot be identified, results failure
u	PGSAA_E_SUPPORTFILE	Support or format files inaccessible
ul	PGSAA_E_PARMSNOTFOUND	Parameter(s) not found in the support support file
l	PGSAA_E_DATARATEUNSET	dataRate attribute unset in support file

**Table 6–148. PGS\_AA\_3Dgeo Returns (2 of 2)**

To User/Log File	Return	Description
ul	PGSAA_E_PARMFROMANYFILES	Parameters requested from more than one physical file
ul	PGSAA_E_INVALIDNOPARMS	No of parms incorrect
ul	PGSAA_E_BADSUPPSUPPORT	Tool support file is corrupted or incomplete
ul	PGSAA_E_CANTFINDFILE	Format of input data file inaccessible
u	PGSAA_E_FFERROR	A freeform error has occurred
l	PGSAA_E_FFDBIN	Failure in Freeform make_dbin function
l	PGSAA_E_FFDBSET	Failure in Freeform db_set function
l	PGSAA_E_FFDBEVENTS	Failure in Freeform db_events function
ul	PGSAA_E_MALLOC	Failure to malloc
u	PGSAA_E_PEV_ERROR	An error has occurred in the PeVA tool
l	PGSAA_E_PEV_XS_SUPPFILES	Too many PeVA files open, increase MAXFILES
l	PGSAA_E_CANT_GET_VALUE	Unable to extract value from dbin
l	PGSAA_E_GETDBIN	Error in PeVA tool obtaining dbin
u	PGSAA_E_GETSUPP	An error was detected while extracting support data
l	PGSAA_E_POSITION_CALC_FAILURE	The position in the parmBuffer of the requested values was miscalculated
u	PGSAA_E_THREED_READ_ERROR	Function failure to read parameter values from buffer
l	PGSAA_E_EXTRACTORESULTSERROR	Failure to transfer selected values from parmBuffer to results
ul	PGSAA_E_OUTOFRANGE	Input values out of data set range

**EXAMPLE:**

```
C:
#include <PGS_AA.h>
PGSt_SMF_status retStatus;

char parms[PGSd_AA_MAXNOCACHES][100] =
    {"nmcRucSigPres", "nmcRucSigPot"};

long nParms = 2;

PGSt_double latitude[] = {51.5, 51.23666, 50.973333} ;
PGSt_double longitude[] = {0.1666666, 0.3832, 0.5999};
long height[] = {1,2,1};
PGSt_integer nPoints = 3;

long fileId = 10972;

long version = 1;

long operation = 2;

short results[3][2];
```



```
retStatus = PGS_AA_3Dgeo(parms, nParms, latitude, longitude,
                        height, nPoints, fileId, version,
                        operation, results);
```

**FORTTRAN:**

```
implicit none

include      "PGS_AA_10.f"
include      "PGS_AA.f"
include      "PGS_SMF.f"

integer      pgs_aa_3dgeo
character*99  iparms(PGSd_AA_MAXNOCACHES)
integer      nParms
real*8       latitude(300)
real*8       longitude(300)
integer      height(300)
integer      fileId
integer      nPoints
integer      version
integer      operation
integer      results(2,300)
parms(1)= "nmcRucSigPres"

parms(2)= "nmcRucSigPot"
nParms= 2
fileId = 10972
operation = 2
version = 1
nPoints = 300
do 10 i = 1, 300
.
.
latitude(i) = calculated_user_lat
longitude(i) = calculated_user_lon
height(i) = calculate_user_height
.
.
10      continue

call pgs_aa_3dgeo( iparms, nparms,latitude, longitude,
                  height, fileId, version, operation,
                  results )
```

**NOTES:**

For further details of the background to these tools and the available data sets, support files and the means by which new data sets can be introduced, see the Toolkit Primer Ancillary Data section (info on how to access this document can be found in the preface of the Users Guide) or

appendix D in this document. These also include details of the operations that can be set by the user and the autoOperations associated with particular data sets.

The FORTRAN result argument returned is not specified since it depends on the data set used; e.g., it could be real or integer.

Height or the z dimension is a layer number in the file and is data set dependent.

The upper limit of the range of input variables is data set specific. The parms input variable is a parameter and data set specific set of strings. The results buffer is a memory buffer holding whatever data is extracted from the data set requested by the user. It can hold data of 4 types (long, short, float, double).

It is critical that the results buffer be declared to be of the same type as that found in the first element of the support file (or PGSt\_integer for short /long when working in FORTRAN) and be dimensioned to exactly contain the requested dimensions.

**REQUIREMENTS:** PGSTK-0931, PGSTK-0840, PGSTK-1362

## Extract Data from Gridded Data Sets by File Structure

---

**NAME:** PGS\_AA\_2DRead( )

**SYNOPSIS:**

**C:** #include <PGS\_AA.h>

```
PGSt_SMF_status
PGS_AA_2DRead(
    char iparms[][100],
    PGSt_integer nParms,
    PGSt_integer xStart,
    PGSt_integer yStart,
    PGSt_integer xDim,
    PGSt_integer yDim,
    PGSt_integer fileId,
    PGSt_integer version,
    PGSt_integer operation,
    void *results)
```

**FORTTRAN:** include'PGS\_AA\_10.f'

include"PGS\_AA.f"

```
integer function
pgs_aa_2dread( parms, nparms, xStart, yStart, xDim, yDim, fileId,
               version, operation, results )
    character*99 parms(*)
    integer      nParms,
    integer      xStart,
    integer      yStart,
    integer      xDim,
    integer      yDim,
    integer      fileId,
    integer      version,
    integer      operation,
    'user specified' results (see Notes)
```

**DESCRIPTION:** The user specifies a parameter, a fileId and version from which the data are to be extracted using the data structure coordinates. Since this tool is similar to the other AA geo and Read tools, a single explanation of the interface is provided in Appendix D.3.

The interface to the calling algorithm that accepts the arguments and calls PGS\_AA\_Map, PGS\_AA\_GetSupp, PGS\_AA\_FF\_Setup and PGS\_AA\_2DReadGrid. The first 3 of these modules determine the

validity of the call and initialize support and load the identified data into memory. PGS\_AA\_2DReadGrid performs the extraction requested from the input arguments

```
[start]
PERFORM PGS_AA_Map
PERFORM PGS_AA_GetSupp to get support data
DO allocate memory to parmBuffer using
    totalParmMemoryCache
PERFORM PGS_AA_FF_Setup
PERFORM PGS_AA_2DReadGrid
[end]
```

#### INPUTS:

**Table 6-149. PGS\_AA\_2DRead Input**

Name	Description	Units	Min	Max
parms	parameter names requested	see notes		
nParms	number of parms	none	1	#defined
xStart	the x start point	none	1	variable
yStart	the y start point	none	1	variable
xDim	the x dimension	none	1	variable
yDim	the y dimension	none	1	variable
fileId	logical file number	none	variable	variable
version	version of dynamic file	none	1	variable
operation	defines user required	none	1	variable

#### OUTPUTS:

**Table 6-150. PGS\_AA\_2DRead Output**

Name	Description	Units	Min	Max
results	results	variable	N/A	N/A

## RETURNS:

**Table 6-151. PGS\_AA\_2DRead Returns**

To User/Log File	Return	Description
u	PGSAA_E_SUPPORTFILE	Support or format files inaccessible
ul	PGSAA_E_PARMSNOTFOUND	Parameter(s) not found in the support support file
l	PGSAA_E_DATARATEUNSET	dataRate attribute unset in support file
ul	PGSAA_E_PARMSFROMMANYFILES	Parameters requested from more than one physical file
ul	PGSAA_E_INVALIDNOPARMS	No of parms incorrect
ul	PGSAA_E_BADSUPPSUPPORT	Tool support file is corrupted or incomplete
ul	PGSAA_E_CANTFINDFILE	Format of input data file inaccessible
u	PGSAA_E_FFERROR	A freeform error has occurred
l	PGSAA_E_FFDBIN	Failure in Freeform make_dbin function
l	PGSAA_E_FFDBSET	Failure in Freeform db_set function
l	PGSAA_E_FFDBEVENTS	Failure in Freeform db_events function
ul	PGSAA_E_MALLOC	Failure to malloc
u	PGSAA_E_PEV_ERROR	An error has occurred in the PeVA tool
l	PGSAA_E_PEV_XS_SUPPFILES	Too many PeVA files open, increase MAXFILES
l	PGSAA_E_CANT_GET_VALUE	Unable to extract value from dbin
l	PGSAA_E_GETDBIN	Error in PeVA tool obtaining dbin
u	PGSAA_E_GETSUPP	An error was detected while extracting support data
l	PGSAA_E_POSITION_CALC_FAILURE	The position in the parmBuffer of the requested values was miscalculated
u	PGSAA_E_TWOD_READ_ERROR	Function failure to read parameter values from buffer
l	PGSAA_E_EXTRACTORESULTSERROR	Failure to transfer selected values from parmBuffer to results
ul	PGSAA_E_OUTOFRANGE	Input values out of data set range

## EXAMPLE:

```
C:      #include <PGS_AA.h>
        PGSt_SMF_status retStatus;

        short results[50][20]
        char parm[PGSd_AA_MAXNOCACHES][100] =
                                {"OlsonWorldEcosystems1.3a"};

        PGSt_integer      nParms = 1;
        PGSt_integer      xStart = 4;
        PGSt_integer      yStart = 7;
        PGSt_integer      xDim = 20;
        PGSt_integer      yDim = 50;
        PGSt_integer      fileId = 10952;
```

```
PGSt_integer version = 1;

PGSt_SMF_status = PGS_AA_2DRead (parm, nParms, xStart,
                                yStart, xDim, yDim, fileId,
                                version, 1, results);
```

**FORTRAN:**

```
implicit none

include      "PGS_AA_10.f"
include      "PGS_AA.f"
include      "PGS_SMF.f"

integer      pgs_aa_2dread
character*99  parms(PGSd_AA_MAXNOCACHES)
integer      nParms
integer      xStart
integer      yStart
integer      xDim
integer      yDim
integer      fileId
integer      version
integer      operation
PGSt_integer  results(14, 20)
parms(1)= "OlsonWorldEcosystems1.3a"
nParms = 1
yStart = 102
xStart = 205
yDim = 20
xDim = 14
fileId = 10952
operation = 1
version = 1

call pgs_aa_2dread( parms, nparms, xStart, yStart, xDim,
                   yDim, fileId, version, operation,
                   results )
```

## **NOTES:**

For further details of the background to these tools and the available data sets, support files and the means by which new data sets can be introduced, see the Toolkit Primer Ancillary Data section (info on how to access this document can be found in the preface of the Users Guide) or appendix D in this document. These also include details of the operations that can be set by the user and the autoOperations associated with particular data sets.

The FORTRAN result argument returned is not specified since it depends on the data set used; e.g., it could be real or integer.

The upper limit of the range of input variables is data set specific. The parms input variable is a parameter and data set specific set of strings. The results buffer is a memory buffer holding whatever data is extracted from the data set requested by the user. It can hold data of 4 types (long, short, float, double).

It is critical that the results buffer be declared to be of the same type as that found in the first element of the support file (or PGSt\_integer for short /long when working in FORTRAN) and be dimensioned to exactly contain the requested dimensions.

**REQUIREMENTS:** PGSTK-0931, PGSTK-0980, PGSTK-1000, PGSTK-1030, PGSTK-1360, PGSTK-1362

## Extract Data from Gridded Data Sets by File Structure Parameters

---

**NAME:** PGS\_AA\_3DRead( )

**SYNOPSIS:**

**C:** #include <PGS\_AA.h>

```
PGSt_SMF_status
PGS_AA_3DRead(
    char iparms[][100],
    PGSt_integer nParms
    PGSt_integer xStart
    PGSt_integer yStart
    PGSt_integer zStart
    PGSt_integer xDim
    PGSt_integer yDim
    PGSt_integer zDim
    PGSt_integer fileId
    PGSt_integer version
    PGSt_integer operation
    void *results)
```

**FORTRAN:** include'PGS\_AA\_10.f'  
include"PGS\_AA.f"

```
integer function
pgs_aa_3dread( iparms, nparms, xStart, yStart, zStart, xDim, yDim, zDim,
               fileId, version, operation, results )
    character*99      iparms(*)
    integer           nParms,
    integer           xStart,
    integer           yStart,
    integer           zStart,
    integer           xDim,
    integer           yDim,
    integer           zDim,
    integer           fileId,
    integer           version,
    integer           operation,
    'user specified' results (see Notes)
```



**DESCRIPTION:** The user specifies a parameter, a fileId and version from which the data are to be extracted using the file structure coordinates. Since this tool is similar to the other AA geo and Read tools, a single explanation of the interface is provided in Appendix D.3.

The interface to the calling algorithm that accepts the arguments and calls PGS\_AA\_Map, PGS\_AA\_GetSupp, PGS\_AA\_FF\_Setup and PGS\_AA\_3DReadGrid. The first 3 of these modules determine the validity of the call and initialize support and load the identified data into memory. PGS\_AA\_3DReadGrid performs the extraction requested from the input arguments

```
[start]
PERFORM PGS_AA_Map
PERFORM PGS_AA_GetSupp to get support data
DO allocate memory to parmBuffer using
    totalParmMemoryCache
PERFORM PGS_AA_FF_Setup
PERFORM PGS_AA_3DReadGrid
[end]
```

**INPUTS:**

**Table 6-152. PGS\_AA\_3DRead Inputs**

Name	Description	Units	Min	Max
parms	parameter names requested	see notes		
nParms	number of parms	none	1	#defined
xStart	the x start point	none	1	variable
yStart	the y start point	none	1	variable
zStart	the z start point	none	1	variable
xDim	the x dimension	none	1	variable
yDim	the y dimension	none	1	variable
zDim	the z dimension	none	1	variable
fileId	logical file number	none	variable	variable
version	version of dynamic file	none	1	variable
operation	defines user required	none	1	variable

**OUTPUTS:**

**Table 6-153. PGS\_AA\_3DRead Outputs**

Name	Description	Units	Min	Max
results	results	see notes		

## RETURNS:

**Table 6-154. PGS\_AA\_3DRead Returns**

To User/Log File	Return	Description
u	PGSAA_E_SUPPORTFILE	Support or format files inaccessible
ul	PGSAA_E_PARMSNOTFOUND	Parameter(s) not found in the support support file
l	PGSAA_E_DATARATEUNSET	dataRate attribute unset in support file
ul	PGSAA_E_PARMSFROMMANYFILES	Parameters requested from more than one physical file
ul	PGSAA_E_INVALIDNOPARMS	No of parms incorrect
ul	PGSAA_E_BADSUPPSUPPORT	Tool support file is corrupted or incomplete
ul	PGSAA_E_CANTFINDFILE	Format of input data file inaccessible
u	PGSAA_E_FFERROR	A freeform error has occurred
l	PGSAA_E_FFDBIN	Failure in Freeform make_dbin function
l	PGSAA_E_FFDBSET	Failure in Freeform db_set function
l	PGSAA_E_FFDBEVENTS	Failure in Freeform db_events function
ul	PGSAA_E_MALLOC	Failure to malloc
u	PGSAA_E_PEV_ERROR	An error has occurred in the PeV tool
l	PGSAA_E_PEV_XS_SUPPFILES	Too many PeVA files open, increase MAXFILES
l	PGSAA_E_CANT_GET_VALUE	Unable to extract value from dbin
l	PGSAA_E_GETDBIN	Error in PeVA tool obtaining dbin
u	PGSAA_E_GETSUPP	An error was detected while extracting support data
l	PGSAA_E_POSITION_CALC_FAILURE	The position in the parmBuffer of the requested values was miscalculated
u	PGSAA_E_THREED_READ_ERROR	Function failure to read parameter values from buffer
l	PGSAA_E_EXTRACTORESULTSError	Failure to transfer selected values from parmBuffer to results
ul	PGSAA_E_OUTOFRANGE	Input values out of data set range

## EXAMPLE:

```
C:          PGSt_SMF_status retStatus;

            char parms[PGSs_AA_MAXNOCACHES][100] = {
                "nmcRucSigPres", "nmcRucSigPot"};
            PGSt_integer xStart = 30;
            PGSt_integer yStart = 20;
            PGSt_integer zStart = 2;
            PGSt_integer xDim = 6;
            PGSt_integer yDim = 4;
            PGSt_integer zDim = 2;
            PGSt_integer fileId = 10972; /* contains interleaved
                                           parms */
```

```

float results[2][4][6][2]; /* height,lat,long,parm */

PGSt_integer      nParms = 2

PGSt_SMF_status = PGS_AA_3DRead (iparms, nParms, xStart,
                                yStart, zStart, xDim, yDim,
                                zDim, fileId, 1, 2
                                results);

FORTRAN:      implicit none

include      "PGS_AA_10.f"
include      "PGS_AA.f"
include      "PGS_SMF.f"

integer      pgs_aa_3dread
character*99  parms(PGSd_AA_MAXNOCACHES)
integer      nParms
integer      xStart
integer      yStart
integer      zStart
integer      xDim
integer      yDim
integer      zDim
integer      fileId
integer      version
integer      operation

integer      result(2,50,20,2)
parms(1)= "nmcRucSigPot"
parms(2)= "nmcRucSigPres"
nParms=2
yStart=102
xStart=205
zStart=2
yDim=20
xDim=50
zDim=2
fileId=10972
operation=2
version = 1

call pgs_aa_3dread( iparms, nparms, xStart, yStart, zStart,
                   xDim, yDim, zDim, fileId, version,
                   operation, results )

```

**NOTES:**

For further details of the background to these tools and the available data sets, support files and the means by which new data sets can be introduced, see the Toolkit Primer Ancillary Data section (info on how to access this document can be found in the preface of the Users Guide) or Appendix D in this document. These also include details of the operations that can be set by the user and the autoOperations associated with particular data sets.

The FORTRAN result argument returned is not specified since it depends on the data set used; e.g., it could be real or integer.

The upper limit of the range of input variables is data set specific. The parms input variable is a parameter and data set specific set of strings. The results buffer is a memory buffer holding whatever data is extracted from the data set requested by the user. It can hold data of 4 types (long, short, float, double).

It is critical that the results buffer be declared to be of the same type as that found in the first element of the support file (or PGSt\_integer for short /long when working in FORTRAN) and be dimensioned to exactly contain the requested dimensions.

**REQUIREMENTS:** PGSTK-0931, PGSTK-1360, PGSTK-1362

### 6.3.3 Celestial Body Position Tools

The tools included in this section provide the user with information about the locations of celestial bodies (sun, moon, major planets and bright stars). The vector from the Earth or the spacecraft can be computed and the presence of a body in the instrument field of view can be detected.

#### 6.3.3.1 Celestial Body Position Tool Notes

The following notes apply to several of the Celestial Body Position Tools.

##### TIME RANGE OF CELESTIAL BODY EPHEMERIS

The EOSDIS version of the JPL DE200 ephemeris which is used for the celestial body positions is valid from Dec 14, 1949 through Jan 1, 2021. The user's calling times are internally translated to TDT (dynamical time, similar to the old "ephemeris time") before being used to access the ephemeris itself. This translation depends on leap seconds information. If the leap seconds file is not up to date the error message "PGSTD\_NO\_LEAP\_SECS" is returned but processing continues. Since leap seconds are normally available only six months in advance, results for far future simulations cannot be guaranteed. On the other hand, as time passes, with the leap seconds file properly updated by automatic Toolkit procedures, the positions calculated at any given time, for past times, for the present date, or a few months in advance will be reliable.

##### TIME OFFSETS:

These functions accept an ASCII UTC time, an array of time offsets and the number of offsets as input. Each element in the offset array is an offset in seconds relative to the initial input ASCII UTC time.

An error will be returned if the number of offsets specified is less than zero. If the number of offsets specified is actually zero, the offsets array will be ignored. In this case the input ASCII UTC time will be converted to Toolkit internal time (TAI) and this time will be used to process the data. If the number of offsets specified is one (1) or greater, the input ASCII UTC time will be converted to TAI and each element 'i' of the input data will be processed at the time: (initial time) + (offset[i]).

Examples:

if numValues is 0 and asciiUTC is "1993-001T12:00:00" (TAI: 432000.0),  
then input[0] will be processed at time 432000.0 and return output[0]

if numValues is 1 and asciiUTC is "1993-001T12:00:00" (TAI: 432000.0),  
then input[0] will be processed at time 432000.0 + offsets[0] and  
return output[0]

if numValues is N and asciiUTC is "1993-001T12:00:00" (TAI: 432000.0),  
then each input[i] will be processed at time 432000.0 + offsets[i] and  
the result will be output[i], where i is on the interval [0,N)

## **ERROR HANDLING:**

These functions process data over an array of times (specified by an input ASCII UTC time and an array of time offsets relative to that time).

If processing at each input time is successful the return status of these functions will be PGS\_S\_SUCCESS (status level of 'S').

If processing at ALL input times was unsuccessful the status level of the return status of these functions will be 'E'.

If processing at some (but not all) input times was unsuccessful the status level (see SMF) of the return status of these functions will be 'W' AND all high precision real number (C: PGSt\_double, FORTRAN: DOUBLE PRECISION) output variables that correspond to the times for which processing was NOT successful will be set to the value: PGSd\_GEO\_ERROR\_VALUE. In this case users may (should) loop through the output testing any one of the aforementioned output variables against the value PGSd\_GEO\_ERROR\_VALUE. This indicates that there was an error in processing at the corresponding input time and no useful output data was produced for that time.

Note: A return status with a status level of 'W' does not necessarily mean that some of the data could not be processed. The 'W' level may indicate a general condition that the user may need to be aware of but that did not prohibit processing. For example, if an Earth ellipsoid model is required, but the user supplied value is undefined, the WGS84 model will be used, and processing will continue normally, except that the return status will have a status level of 'W' to alert the user that the default earth model was used and not the one specified by the user. The reporting of such general warnings takes precedence over the generic warning (see RETURNS above) that processing was not successful at some of the requested times. Therefore in the case of any return status of level 'W', the returned value of a high precision real variable generally should be examined for errors at each time offset, as specified above.

## **EPHEMERIS AND ATTITUDE DATA QUALITY CONTROL:**

Some of the Celestial Body Positioning tools access spacecraft ephemeris and/or attitude data in order to effect their respective transformations. In these cases users may define "masks" for the two data quality flags (ephemeris and attitude) associated with spacecraft ephemeris data. The quality flags are (currently) four byte entities (may be 8 bytes on the cray but only the first four bytes will be considered) that are interpreted bit by bit for meaning (see Section L.3 Quality Flags). Currently the only "fatal" bit (i.e. indicating meaningless data) that will be set prior to access by the Toolkit is bit 16 (where the least significant bit is bit 0). Additionally, the Toolkit will set bit 12 of the quality flag returned for a given user input time if NO data is found for that input time. Note that this usage is different from most of the other bits which indicate the state of some existing data point. By default the Toolkit will set the mask for each of the quality flags to include bit 16 (fatally flawed data) and bit 12 (no data). This means that any data points returned from the tool PGS\_EPH\_EphemAttit() with an associated quality flag that has either bit 12 or bit 16 set will be rejected by any TOOLKIT function that makes a call to PGS\_EPH\_EphemAttit() (e.g. these CBP tools) (note that masking is not applied in the tool

PGS\_EPH\_EphemAttit() itself since users calling this tool directly can examine the quality flags themselves and make their own determination as to which data points to use or reject).

Users may use the Process Control File (PCF) to define their own masks which the Toolkit will then use instead of the defaults mentioned above. The user defined mask should set any bit which the user considers fatal for their purpose (e.g. red limit exceeded). WARNING: if the user defined mask does not have bit 16 set, the Toolkit will pass through data the associated quality flag of which has bit 16 set. The toolkit will not, however, process any data points if the associated quality flag has bit 12 set (i.e. no data exists) whether or not the user mask has bit 12 explicitly set.

Below are the PCF entries which control the value of these masks:

```
# -----
# The following parameter is a "mask" for the ephemeris data quality
# flag. The value should be specified as an unsigned integer
# specifying those bits of the ephemeris data quality flag that
# should be considered fatal (i.e. the ephemeris data associated
# with the quality flag should be REJECTED/IGNORED).
# -----
10507|ephemeris data quality flag mask|65536
#
# -----
# The following parameter is a "mask" for the attitude data quality
# flag. The value should be specified as an unsigned integer
# specifying those bits of the attitude data quality flag that
# should be considered fatal (i.e. the attitude data associated
# with the quality flag should be REJECTED/IGNORED).
# -----
10508|attitude data quality flag mask|65536
```

Note that in the examples above, the value 65536 is the unsigned integer equivalent of a 32 bit binary counter with bits 12 and 16 set. See section 6.2.3 (Process Control Tools) and (Appendix C Process Control Files) for a detailed explanation of the use of the Process Control File.

## REFERENCES:

CCSDS 301.0-B-2 (CCSDS => Consultative Committee for Space Data Systems) Astronomical Almanac, Explanatory Supplement to the Astronomical Almanac. Theoretical Basis of the SDP Toolkit Geolocation Package for the ECS Project”, Document 445-TP-002-002, May 1995, by P. Noerdlinger.

## Compute Earth to Celestial Body ECI Vector

---

**NAME:** `PGS_CBP_Earth_CB_Vector()`

**SYNOPSIS:**

**C:** `#include <PGS_CBP.h>`

```
PGSt_SMF_status
PGS_CBP_Earth_CB_Vector(
    PGSt_integer    numValues,
    char            asciiUTC[28],
    PGSt_double     offsets[],
    PGSt_integer     cbId,
    PGSt_double     cbVectors[][3])
```

**FORTRAN:**

```
include'PGS_CBP.f'
include'PGS_TD.f'
include'PGS_SMF.f'
include'PGS_CBP_6.f'
include'PGS_TD_3.f'

integer function
pgs_cbp_earth_cb_vector(numvalues,asciiutc,offsets,cbid,cbvectors)
    integer            numvalues
    character*27       asciiutc
    double precision   offsets(*)
    integer            cbid
    double precision   cbvectors(3,*)
```

**DESCRIPTION:** This function computes the Earth–Centered Inertial (ECI J2000) frame vector from the Earth to the selected bodies of Solar System.

**INPUTS**

***Table 6-155. PGS\_CBP\_Earth\_CB\_Vector Inputs***

NAME	DESCRIPTION	UNITS	MIN	MAX
asciiUTC	UTC time in CCSDS ASCII Time Code A OR B format	time	1961–01–01	see NOTES
offsets	array of offsets of each input UTC time	seconds	see NOTES	see NOTES
cbId	identifier of celestialbody (see list below)	N/A	1	13
numValues	number of required data points 0—only asciiUTC in used any—any time events are used	N/A	0	any



THE DESIGNATION OF THE ASTRONOMICAL BODIES BY  
CELESTIAL BODY IDENTIFIER ( cbId ) IS:

cbId =

1 = MERCURY	8 = NEPTUNE
2 = VENUS	9 = PLUTO
3 = EARTH	10 = MOON
4 = MARS	11 = SUN
5 = JUPITER	12 = SOLAR-SYSTEM BARYCENTER
6 = SATURN	13 = EARTH-MOON BARYCENTER
7 = URANUS	

**OUTPUTS:**

**Table 6-156. PGS\_CBP\_Earth\_CB\_Vector Outputs**

NAME	DESCRIPTION	UNITS	MIN	MAX
cbVectors[][3]	ECI unit vectors from Earth to celestial body first subscript for each time event specified second subscript gives position vector	meter	see NOTES	see NOTES

**RETURNS:**

**Table 6-157. PGS\_CBP\_Earth\_CB\_Vector Returns**

Return	Description
PGS_S_SUCCESS	Successful completion
PGSCBP_W_EARTH_CB_ID	Earth cbId is specified
PGSCBP_E_INVALID_CB_ID	Invalid celestial body identifier
PGSTD_E_BAD_INITIAL_TIME	Initial input time can not be deciphered
PGSCBP_E_BAD_ARRAY_SIZE	Incorrect array size
PGSCBP_E_UNABLE_TO_OPEN_FILE	Ephemeris file can not be opened
PGSCBP_E_TIME_OUT_OF_RANGE	Initial time is outside the ephemeris bounds
PGSTD_E_NO_LEAP_SECS	No leap second correction available
PGSCBP_W_BAD_CB_VECTOR	One or more errors in CB vectors
PGS_E_TOOLKIT	For unknown errors

## EXAMPLES:

```
C:      #define ARRAY_SIZE      3

PGSt_SMF_status   returnStatus;
PGSt_integer      cbId = 10;
PGSt_integer      numValues;
char              asciiUTC[28] = "2002-07-
                        27T11:04:57.987654Z";
PGSt_double       offsets[ARRAY_SIZE] = {3600.0, 7200.0,
                        10800.0};
PGSt_double       cbVectors[ARRAY_SIZE][3];

char              err[PGS_SMF_MAX_MNEMONIC_SIZE];
char              msg[PGS_SMF_MAX_MSG_SIZE];

numValues = ARRAY_SIZE;

returnStatus = PGS_CBP_Earth_CB_Vector(numValues, asciiUTC,
                                       offsets, cbId,
                                       cbVectors)

if (returnStatus != PGS_S_SUCCESS)
{
    PGS_SMF_GetMsg(&returnStatus, err, msg);
    printf ("ERROR: %s\n", msg);
}

FORTRAN:  implicit none

integer      pgs_cbp_earth_cb_vector
integer      returnstatus
integer      cbid
integer      numvalues

double precision  offsets(3)
double precision  cbvectors(3,3)

character*27      asciiutc
character*33      err
character*241     msg

data offsets/3600.0, 7200.0, 10800.0/

asciiutc = '2002-07-27T11:04:57.987654Z'
cbid = 10
numvalues = 3

returnstatus = pgs_cbp_earth_cb_vector(numvalues, asciiutc,
                                       offsets, cbid,
                                       cbvectors)
```

```
if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err, msg
endif
```

**NOTES:** See Section 6.3.3.1 Celestial Body Position Tool Notes  
See Section 6.2.7.5.1 (TAI-UTC Boundaries)

**REQUIREMENTS:** PGSTK-0800

**NAME:** PGS\_CBP\_Sat\_CB\_Vector()

```
C:          #include <PGS_CBP.h>

PGSt_SMF_status
PGS_CBP_Sat_CB_Vector(
    PGSt_tag          spacecraftTag,
    PGSt_integer      numValues,
    char              asciiUTC[28],
    PGSt_double       offsets[],
    PGSt_integer      cbId,
    PGSt_double       cbVectors[][3])
```

```

FORTRAN:
include 'PGS_CBP.f'
include 'PGS_TD.f'
include 'PGS_SMF.f'
include 'PGS_CBP_6.f'
include 'PGS_EPH_5.f'
include 'PGS_CSC_4.f'
include 'PGS_TD_3.f'

integer function
pgs_cbp_sat_cbvectors(spacecrafttag,numvalues,asciutc,offsets,cbid,
                      cbvectors)

integer                spacecrafttag
integer                numvalues
character*27           asciutc
double precision       offsets(*)
integer                cbid
double precision        cbvectors(3,*)

```

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## INPUTS:

**Table 6-158. PGS\_CBP\_Sat\_CB\_Vector Inputs**

Name	Description	Units	Min	Max
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
numValues	number of required data points: 0—only asciiUTC is used any—any time events are used	N/A	0	any
asciiUTC [28]	UTC time in CCSDS ASCII Time code A or B format	time	1961-01-01	see NOTES
offsets[]	array of time offsets from asciiUTC in seconds	seconds	see NOTES	see NOTES
cbId	identifier of celestial bodies (see list below)	N/A	N/A	N/A

THE DESIGNATION OF THE ASTRONOMICAL BODIES BY  
CELESTIAL BODY IDENTIFIER ( cbId ) IS:

cbId =

1 = MERCURY	8 = NEPTUNE
2 = VENUS	9 = PLUTO
3 = EARTH	10 = MOON
4 = MARS	11 = SUN
5 = JUPITER	12 = SOLAR-SYSTEM BARYCENTER
6 = SATURN	13 = EARTH-MOON BARYCENTER
7 = URANUS	

## OUTPUTS:

**Table 6-159. PGS\_CBP\_Sat\_CB\_Vector Inputs**

Name	Description	Units	Min	Max
cbVectors[][3]	vectors in spacecraft reference frame from satellite to the celestial body for each time event	meter	see NOTES	see NOTES

## RETURNS:

**Table 6-160. PGS\_CBP\_Sat\_CB\_Vector Returns (1 of 2)**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_W_BELOW_SURFACE	Output vector from ECtoSC below surface
PGSCBP_W_BAD_CB_VECTOR	One or more bad vectors for requested times
PGSCBP_E_BAD_ARRAY_SIZE	numvalues is less than 0
PGSCBP_E_INVALID_CB_ID	Invalid celestial body identifier
PGSMEM_E_NO_MEMORY	Not enough memory for tmpVectors

**Table 6-160. PGS\_CBP\_Sat\_CB\_Vector Returns (2 of 2)**

Return	Description
PGSCBP_E_UNABLE_TO_OPEN_FILE	Unable to open planetary data file
PGSTD_E_BAD_INITIAL_TIME	Initial time is incorrect
PGSCBP_E_TIME_OUT_OF_RANGE	Initial time is outside the ephemeris bounds
PGSTD_E_SC_TAG_UNKNOWN	Invalid spacecraft tag
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephem files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephem files could be found for input times
PGS_E_TOOLKIT	Toolkit error

### EXAMPLES:

```

C:
    #define ARRAY_SIZE      3

    PGSt_SMF_status          returnStatus;

    PGSt_integer             numValues = ARRAY_SIZE;

    PGSt_double              cbVectors[ARRAY_SIZE][3];
    PGSt_double              offsets[ARRAY_SIZE] = {3600.0,
                                                    7200.0, 10800.0};

    char                     asciiUTC[28] = "2002-07-
                                           27T11:04:57.987654Z";

    char                     err[PGS_SMF_MAX_MNEMONIC_SIZE];
    char                     msg[PGS_SMF_MAX_MSG_SIZE];

    returnStatus = PGS_CBP_Sat_CB_Vector(PGSd_EOS_AM, numValues,
                                           asciiUTC, offsets,
                                           PGSd_MOON, cbVectors);

    if (returnStatus != PGS_S_SUCCESS)
    {
        PGS_SMF_GetMsg(&returnStatus, err, msg);
        printf ("ERROR: %s\n", msg);
    }

FORTRAN:
    implicit none

    integer          pgs_cbp_sat_cb_vector
    integer          numvalues
    character*27      asciiutc
    double precision offsets(3)
    integer          cbid
    double precision cbvectors(3,3)

```

```

character*33      err
character*241     msg

data offsets/3600.0, 7200.0, 10800.0/

asciiutc = "2002-07-27T11:04:57.987654Z"
cbid = 10
numvalues = 3

returnstatus = pgs_cbp_sat_cb_vector(pgsd_eos_am, numvalues,
>                                     asciiutc, offsets,
>                                     pgsd_moon, cbvector)

if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err, msg
endif

```

**NOTES:** See Section 6.3.3.1. Celestial Body Position Tool Notes  
 See Section 6.2.7.5.1 (TAI-UTC Boundaries)  
 See Section 6.2.6.3 Spacecraft Tags Definition File

**REQUIREMENTS:** PGSTK-0680, PGSTK-0810

## Get Solar Time and Coordinates

---

**NAME:** PGS\_CBP\_SolarTimeCoords( )

**SYNOPSIS:**

**C:** #include <PGS\_CBP.h>

```
PGSt_SMF_status
PGS_CBP_SolarTimeCoords(
    char          asciiUTC[28],
    PGSt_double   longitude,
    PGSt_double   *meanSolTimG,
    PGSt_double   *meanSolTimL,
    PGSt_double   *apparSolTimL,
    PGSt_double   *solRA,
    PGSt_double   *solDec)
```

**FORTTRAN:** include 'PGS\_SMF.f'  
include 'PGS\_TD\_3.f'

```
integer function pgs_cbp_solartimecoords(asciiutc, longitude,
                                          meansolting, meansoltiml,
                                          apparsoltiml, solra, soldec)

    character*27  asciiutc
    double precision longitude
    double precision meansolting
    double precision meansoltiml
    double precision apparsoltiml
    double precision solra
    double precision soldec
```

**DESCRIPTION** This tool performs a low accuracy rapid calculation of solar time and coordinates. The accuracy of the equations here is expected to be about 0.5 minutes of time and 0.04 degrees for the coordinates of the sun.



## INPUTS:

**Table 6-161. PGS\_CBP\_SolarTimeCoords Inputs**

Name	Description	Units	Min	Max
asciiUTC	Coordinated Universal Time in CCSDS ASCII Time Code A or B format	N/A	See NOTES	See NOTES
longitude	longitude of observer (positive is East) Not required for solar coordinates; should be set to 0 in that case	radians	-pi	pi

## OUTPUTS:

**Table 6-162. PGS\_CBP\_SolarTimeCoords Outputs**

Name	Description	Units	Min	Max
meanSolTimG	Greenwich Mean Solar Time as seconds from midnight	seconds	0	86400
meanSolTimL	Local Mean Solar Time as seconds from midnight	seconds	0	86400
apparSolTimL	Local Apparent Solar Time as seconds from midnight	seconds	0	86400
solRA	Right Ascension of the Mean sun	radians	0	2*pi
solDec	Declination of the Mean sun	radians	-pi	pi

## RETURNS:

**Table 6-163. PGS\_CBP\_SolarTimeCoords Returns**

Return	Description
PGS_S_SUCCESS	Successful execution
PGSTD_M_LEAP_SEC_IGNORED	Input leap second has been ignored
PGSTD_E_TIME_FORMAT_ERROR	Error in format of input ASCII UTC time
PGSTD_E_TIME_VALUE_ERROR	Error in value of input ASCII UTC time
PGS_E_TOOLKIT	Something unexpected happened, execution aborted

## EXAMPLES:

```
C:          PGSt_SMF_status  returnStatus;
           char              asciiUTC[28];
           PGSt_double       longitude;
           PGSt_double       meanSolTimG;
           PGSt_double       meanSolTimL;
```

```

PGSt_double      solRA;
PGSt_double      solDec;

strcpy(asciiUTC,"1991-01-01T11:29:30");
returnStatus = PGS_CBP_SolarTimeCoords(asciiUTC,longitude,
                                         &meanSolTimG,
                                         &meanSolTimL,
                                         &apparSolTimL,
                                         &solRA,&solDec)

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
       take appropriate
       action **
}
printf("start time:%s",asciiUTC);
printf("\n longitude: %lf",longitude);

printf("Greenwich Mean Solar Time:%lf  Local Mean Solar
       Time:%lf", meanSolTimG,meanSolTimL);
printf("\n Local Apparent Solar Time:%lf  Solar Right
       Asc/Dec:%lf/%lf", apparSolTimL,solRA,solDec);

```

FORTRAN:

```

implicit none

integer          pgs_cbp_solartimecoords
character*27      asciiutc
double precision longitude
double precision meansolting
double precision meansoltiml
double precision apparsoltiml
double precision solra
double precision soldec
integer          returnstatus

asciiutc = '1991-01-01T11:29:30'
longitude = 1.0

returnstatus = pgs_cbp_solartimecoords(asciiutc,longitude,
                                         meansolting,
                                         meansoltiml,
                                         apparsoltiml,solra,
                                         soldec)

if(returnstatus .ne. pgs_s_success) go to 90
write(6,*) asciiutc,longitude
write(6,*)meansolting,meansoltiml,apparsoltiml,solra,soldec

```

```
90 write(6,99)returnstatus
99 format('ERROR:',I50)
```

**NOTES:**

The equations used in this function are referenced on page C24 of the 1994 Astronomical Almanac. They are low precision formulas that give the apparent coordinates of the sun to a precision of 0.01 degrees and the equation of time to a precision of 0.5 minutes between the years 1950 and 2050. Less accuracy is expected for dates before 1950 and after 2050.

More accurate solar time determination requires improved solar coordinates and the value of UT1–UTC. These items are accessible through other SDP tools.

In particular, the Solar ephemeris yields accurate solar coordinates and the function PGS\_TD\_gmst() gives Greenwich Mean Sidereal Time. These can be combined to obtain more accurate Mean Solar Time. The difference UT1–UTC is determined within the coordinate system conversion (CSC) group of functions, in the transformations between Earth Centered Rotating (ECR) and Earth Centered Inertial (ECI).

See Section 6.2.7.5.1 (TAI-UTC Boundaries)

**REQUIREMENTS:** PGSTK–0760

## Celestial Body in Field-of-View Indicator

---

**NAME:** PGS\_CBP\_body\_inFOV()

**SYNOPSIS:**

**C:**

```
#include <PGS_TD.h>
#include <PGS_CSC.h>
#include <PGS_CBP.h>
#include <PGS_EPH.h>
#include <PGS_MEM.h>

PGSt_SMF_status
PGS_CBP_body_inFOV(
    PGSt_integer    numValues,
    char            asciiUTC[28],
    PGSt_double     offsets[],
    PGSt_tag        spacecraftTag,
    PGSt_integer    numFOVperimVec,
    PGSt_double     inFOVvector[][3],
    PGSt_double     *perimFOV_vectors,
    PGSt_tag        cbID,
    PGSt_boolean    inFOVflag[],
    PGSt_double     cb_vector[][3],
    PGSt_double     cb_SCvector[][3])
```

**FORTTRAN:**

```
include 'PGS_TD_3.f'
include 'PGS_CSC_4.f'
include 'PGS_CBP_4.f'
include 'PGS_EPH_4.f'
include 'PGS_MEM_4.f'
include 'PGS_SMF.f'

integer function pgs_cbp_body_infov(numvalues,asciiutc,offsets,
                                   spacecrafttag,numfovperimvec,infovvector,
                                   perimfov_vectors,cbid,infovflag,cb_vector,
                                   cb_scvector)

integer    numvalues
character*27    asciiutc
double precision    offsets(*)
integer    spacecrafttag
integer    numfovperimvec
double precision    infovvector(*)
double precision    perimfov_vectors(3,numfovperimvec,*)
```

integer	cbid
integer	infovflag(*)
double precision	cb_vector(3,*)
double precision	cb_scvector(3,*)

**DESCRIPTION:** Given a celestial body (CB) identifier (as in the CBP tools) and a field of view (FOV) description, tool returns a flag or flags indicating if the CB is in the FOV, as well as the coordinates of the CB in SC coordinates. Alternatively, the user can specify CB identifier 999 or PGSd\_STAR and supply the ECI vector to the body.

**INPUTS:**

**Table 6-164. PGS\_CBP\_body\_inFOV Inputs**

Name	Description	Units	Min	Max
numValues	number of time gridpoints	N/A	1	any
asciiUTC	UTC start time	N/A	1979-06-30T00:00:01	2008-01-01T12:00:00
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
numFOVperimVec	number of vectors defining FOV perimeter	N/A	3	any
inFOVvector	vector in FOV, in SC coordinates	N/A	N/A	N/A
perimFOV_vectors	vectors in SC coords defining FOV's; MUST be sequential around FOV; middle dimension must be exactly the same value as numFOVperimVec because of the way the array dimensioning works in the function.	N/A	N/A	N/A
cbld	celestial body ID (Earth not included—see PGS_CSC_Earthpt_FOV)	N/A	1	13
cb_vector	ECI vectors of CB (this is an input only when cbld = 999, meaning user input of ECI vector for CB—see notes)	Arbitrary	see PGS_CBP_Earth_CB_Vector	

## OUTPUTS:

**Table 6-165. PGS\_CBP\_body\_inFOV Outputs**

Name	Description	Units	Min	Max
inFOVflag	PGS_TRUE if CB is in FOV—see notes	N/A	N/A	N/A
cb_SCvector	vector of CB in SC coords notes	meters	see PGS_CBP_body_inFOV() notes	

## RETURNS:

**Table 6-166. PGS\_CBP\_body\_inFOV Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSCSC_W_BELOW_SURFACE	Vector magnitude indicates subsurface location specified
PGSCBP_E_TIME_OUT_OF_RANGE	Initial time is outside the ephemeris bounds
PGSTD_E_BAD_INITIAL_TIME	Initial time is incorrect
PGSCBP_W_BAD_CB_VECTOR	One or more bad vectors for requested times
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for input time
PGSCSC_W_DATA_FILE_MISSING	The data file earthfigure.dat is missing
PGSCBP_E_UNABLE_TO_OPEN_FILE	Unable to open file
PGSCBP_E_INVALID_CB_ID	Invalid celestial body identifier
PGSCBP_W_EARTH_CB_ID	The tool PGS_CSC_Earthpt_FOV() must be used to check for Earth points in the FOV
PGSMEM_E_NO_MEMORY	No memory is available to allocate vectors
PGSCSC_E_BAD_ARRAY_SIZE	Incorrect array size
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephem files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephem files could be found for input times
PGSEPH_E_NO_DATA_REQUESTED	Both orb and att flags are set to false
PGSCSC_E_INVALID_FOV_DATA	FOV perimeter vectors are invalid
PGSCSC_E_FOV_TOO_LARGE	FOV specification outside algorithmic limits
PGS_E_TOOLKIT	Something unexpected happened

## EXAMPLES:

```
C:      #define      ARRAY_SIZE      3
        #define      PERIMVEC_SIZE  4
        PGSt_SMF_status returnStatus;
        char          asciiUTC[28];
        PGSt_double   offsets[ARRAY_SIZE] =
                                {3600.0,7200.0,10800.0};
        PGSt_integer  numValues;
        PGSt_integer  numFOVperimVec;
```

```

PGSt_double      inFOVvector[ARRAY_SIZE][3] =
                  { {0.0,0.0,100.0},
                    {0.0,0.0,200.0},
                    {0.0,0.0,300.0}
                  };

PGSt_double
  perimFOV_vectors[ARRAY_SIZE][PERIMVEC_SIZE][3]=
    { {100.0,100.0,100.0},
      {-100.0,100.0,100.0},
      {-100.0,-100.0,100.0},
      {100.0,-100.0,100.0},
      {200.0,200.0,200.0},
      {-200.0,200.0,200.0},
      {-200.0,-200.0,200.0},
      {200.0,-200.0,200.0},
      {300.0,200.0,200.0},
      {-200.0,300.0,200.0},
      {-200.0,-300.0,300.0},
      {300.0,-200.0,200.0},
    };

PGSt_boolean      inFOVflag[ARRAY_SIZE];
PGSt_double      cb_SCvector[ARRAY_SIZE][3];

numValues = ARRAY_SIZE;
numFOVperimVec = PERIMVEC_SIZE;
strcpy(asciiUTC,"1995-06-21T11:29:30.123211Z");
returnStatus = PGS_CBP_body_inFOV(numValues,asciiUTC,
                                offsets,PGSd_TRMM,
                                numFOVperimVec,
                                inFOVvector,
                                perimFOV_vectors,
                                PGSd_MOON,
                                inFOVflag,NULL,
                                cb_SCvector);

if(returnStatus != PGS_S_SUCCESS)|
{
  ** test errors,
    take appropriate
    action **
}

FORTRAN:      implicit none

integer      pgs_cbp_body_infov
integer      returnstatus
integer      spacecraftitag

```

```

integer          numvalues
character*27     asciitc
double precision offsets(3)
integer          spacecrafttag
integer          numfovperimvec
double precision infovvector(3,3)
double precision perimfov_vectors(3,4,3)
integer          cbid
integer          infovflag(3)
double precision cb_vector(3,3)
double precision cb_scvector(3,3)
integer          cnt1
integer          cnt2
character*33     err
character*241    msg

```

```

data offsets/3600.0, 7200.0, 10800.0/

```

```

infovvector(1,1) = 0.0
infovvector(1,2) = 0.0
infovvector(1,3) = 0.0

infovvector(2,1) = 0.0
infovvector(2,2) = 0.0
infovvector(2,3) = 0.0

infovvector(3,1) = 0.0
infovvector(3,2) = 0.0
infovvector(3,3) = 0.0

```

```

perimfov_vectors(1,1,1) = 100.0
perimfov_vectors(2,1,1) = 100.0
perimfov_vectors(3,1,1) = 100.0

perimfov_vectors(1,2,1) = -100.0
perimfov_vectors(2,2,1) = 100.0
perimfov_vectors(3,2,1) = 100.0

perimfov_vectors(1,3,1) = -100.0
perimfov_vectors(2,3,1) = -100.0
perimfov_vectors(3,3,1) = 100.0

perimfov_vectors(1,4,1) = 100.0
perimfov_vectors(2,4,1) = -100.0
perimfov_vectors(3,4,1) = 100.0

perimfov_vectors(1,1,2) = 200.0
perimfov_vectors(2,1,2) = 200.0
perimfov_vectors(3,1,2) = 200.0

```



```

perimfov_vectors(1,2,2) = -200.0
perimfov_vectors(2,2,2) = 200.0
perimfov_vectors(3,2,2) = 200.0

perimfov_vectors(1,3,2) = -200.0
perimfov_vectors(2,3,2) = -200.0
perimfov_vectors(3,3,2) = 200.0

perimfov_vectors(1,4,2) = 200.0
perimfov_vectors(2,4,2) = -200.0
perimfov_vectors(3,4,2) = 200.0

perimfov_vectors(1,1,3) = 300.0
perimfov_vectors(2,1,3) = 300.0
perimfov_vectors(3,1,3) = 300.0

perimfov_vectors(1,2,3) = -300.0
perimfov_vectors(2,2,3) = 300.0
perimfov_vectors(3,2,3) = 300.0

perimfov_vectors(1,3,3) = -300.0
perimfov_vectors(2,3,3) = -300.0
perimfov_vectors(3,3,3) = 300.0

perimfov_vectors(1,4,3) = 300.0
perimfov_vectors(2,4,3) = -300.0
perimfov_vectors(3,4,3) = 300.0

asciiutc = '1995-06-21T11:04:57.987654Z'
numvalues = 3
numfovperimvec = 4

returnstatus = pgs_cbp_body_infov(numvalues,asciiutc,
                                offsets,PGSd_TRMM,
                                numfovperimvec,
                                infovvector,
                                perimfov_vectors,moon,
                                infovflag,null,
                                cb_scvector);

if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err, msg
endif

```

#### NOTES:

The FOV is always specified in SC coordinates; for an instrument fixed to the SC, use the same FOV description always; for scanning instruments, user should provide the description appropriate to the scan instant.

numFOVperim must be at least 3. The tool determines if any part of the CB requested lies within the perimeter defined by the vectors perimFOV\_vectors[[3]. The first index in C (last in FORTRAN) is the time offset index, and the second MUST be sequential around the FOV

perimeter. The vector `inFOVvector[ ][3]` MUST lie within the FOV. It need not be central, but there will be loss of efficiency if not. The last index in `C` (first in FORTRAN) on these vectors is for X,Y and Z components in SC coordinates. It is necessary for the user to supply a vector within the FOV for the reason that on the surface of a sphere, a closed curve or "perimeter" does not have an inside nor outside, except by arbitrary definition; i.e., this vector tells the algorithm which part of sky is inside FOV, which outside.

The vectors "`perimFOV_vectors[ ][3]`" defining the FOV perimeter can be in clock- or counter-clockwise sequence .

The tool may be used on the Sun, Moon, and planets other than the Earth, in which case the `cbID` must be selected from the standard set (see the tool `PGS_CBP_Earth_CB_Vector()`). The tool may also be used on another object (such as a star), in which case `cbID` should be set = 999 and the ECI J2000 coordinates of the star must be supplied in `cb_vector[ ]`. The Sun, Moon and planets have finite radii, as specified in the Table below; CB's with `cdID` = 999 (`PGSd_STAR`) are assumed to be of negligible radius.

Note on Finite Size of CB: Since a primary use of this tool will be to determine if the Sun, Moon, or a planet intrudes into the FOV, it is important to allow for the finite size of the object. For this purpose, the Moon and Planets are replaced with spheres of the following radii, which are projected on the celestial sphere:

**Table 6-167. Physical Radii for CB in FOV Tool**

CB	Radius (km)	Explanation
Sun	7 e 5	
Moon	1739	allows for topography
Mercury	2440	
Venus	6055	
Earth	n/a	use tool <code>PGS_CSC_Earthpt_FOV()</code>
Mars	3397	ignore satellites
Jupiter	1890 e 3	include Galilean satellites
Saturn	1225 e 3	include rings, satellites to Titan
Uranus	25600	planet only
Neptune	24800	planet only
Pluto	19600	planet and Charon
999 (STAR)	0.0	a star, or user-defined point

In general, we have included satellites down to the 10th magnitude.

In the case that the celestial body position is invalid for a particular time, then the corresponding `cb_SCvector` will be set to `PGSd_GEO_ERROR_VALUE`.

If the CB disk overlaps the FOV only behind the Earth's equatorial bulge and the overlap is barely hidden by it, and the FOV has a sharp corner protruding past the Earth limb it is possible in rare cases that a false positive answer will issue.

See Section 6.3.3.1 Celestial Body Position Tool Notes

See Section 6.2.7.5.1 (TAI-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

**REQUIREMENTS:** PGSTK-0780

## 6.3.4 Coordinate System Conversion Tools

### 6.3.4.1 Introduction

The ECI system is J2000. Thus in Fig. 6-2 the Z axis is along the Earth's rotation axis at the epoch of J2000. The ECR system is Earth fixed, i.e. rotating with the Earth. Since its definition includes the effect of polar motion, then in Fig. 6-1 the Z axis is actually along geographic North, which differs very slightly and variably (~ 3 to 15 meters) from the rotational North axis.

### 6.3.4.2 Unit Vectors for Input

In some functions, a unit vector or a set of unit vectors is required on input. In these cases, the vectors are generally renormalized internally again, anyway, to prevent obscure errors. Thus, generally, any vector defining the correct direction can be supplied; it need not be normalized. An exception is in the transformations between ECI and Spacecraft Coordinates, `PGS_CSC_ECItoSC( )` and `PGS_CSC_SCtoECI( )`. In these functions, the behavior is different for unit vector input and for input vectors in meters. For these two functions, any input vector whose length is between 0.99999 and 1.000001 is assumed to be a unit vector, while any other vector is assumed to be measured in meters.

### 6.3.4.3 Other Specialized Vectors and Terminology

The vector along a line of sight from the spacecraft may be referred to as a "pixel vector" or "look vector". It could be the boresight of an instrument or it could locate a point in a finite field of view. The "look point" is the intersection of such a vector with the Earth ellipsoid. Vectors designated by the name of a celestial body, such as the "Sun vector" are assumed to point from Earth center or spacecraft center to the celestial body, depending on context. They are in meters unless described as unit vectors. "Latitude" always means geodetic latitude, and the zenith vector at Earth surface is always taken as the normal to the Earth ellipsoid. The "slant range" is from the instrument boresight or spacecraft center to the look point (depending on the accuracy flag). The "field of view" is always defined in spacecraft coordinates. The "subsatellite point" is at the foot of a normal dropped from the spacecraft to the Earth ellipsoid, and its velocity what would be measured by terrestrial instruments on the ellipsoid.

### 6.3.4.4 Altitudes; Altitude Warnings

In almost all the tools, such as transformations between ECR and Geodetic coordinates, in `PGS_CSC_GetFOV_Pixel( )`, and `PGS_CSC_SubSatPoint( )` the altitude is defined in meters off the Earth ellipsoid, as specified by the user through an Earth ellipsoid tag. If an invalid tag is used, then the WGS84 ellipsoid is used. The altitude for `PGS_CSC_ZenithAzimuth( )` is the exception; it must be defined in meters off the *geoid*, because it is used to calculate air density to correct the zenith angle for refraction when that correction is requested. The altitude is ignored otherwise in `PGS_CSC_ZenithAzimuth( )`. All the functions that input or output altitude, or calculate it internally check for reasonableness. When large negative altitudes are input or generated internally, warning messages issue to the log file, and a warning return will be given

unless there is a more serious problem. The exact depth used to trigger a warning varies according to context. For example, in `PGS_CSC_ECItSC( )`, the depth can be as great as 0.02 Earth radii, on the supposition that in an extreme case the user might wish the coordinates of some point that deep in the Earth, while in `PGS_CSC_Earthpt_FOV( )` and `PGS_CSC_Earthpt_FixedFOV()`, the warning is issued if the depth exceeds 50 km. Here, the function is not just a coordinate transformation, but it informs the user if the point can be seen. The 50 km tolerance allows that even if the Earth ellipsoid model is set by the user so large as to include most of the atmosphere, and the Earth point is on the ocean floor, no warning will be returned. For greater depths the point is deemed not to be visible and the answer always `PGS_FALSE`. The maximum altitude of 100 km is set to include noctilucent clouds. Higher altitudes will be processed, with the answer `PGS_TRUE` or `PGS_FALSE` according to the geometry, but a warning is issued. This is the only case in which a large positive altitude results in a warning, because of the context that one is talking about an "Earth point."

#### **6.3.4.5 Lines of sight; visibility of points**

The various functions do not check for obstruction of the line of sight by part of the spacecraft or clouds, nor for the occultation of one celestial body by another. The tool `PGS_CSC_Earthpt_FOV( )` checks for occultation of the specified point by the solid Earth, i.e., on the far side, and `PGS_CBP_body_inFOV( )` checks for occultation by the Earth; in those cases a `PGS_FALSE` answer is reported.

#### **6.3.4.6 Ranges for variables**

The minimum and maximum values specified in the tables are often guidelines only and may not be rigidly enforced. For example, a likely range is indicated for any one component of the spacecraft velocity, but, in principle a velocity component could be anything up to escape velocity. When angles such as latitude or longitude are input, they generally are not be checked against the specified ranges. If they are out of range, the results may be unpredictable. The angles are always in radians. An angle inadvertently supplied in degrees will usually lead to a wrong answer rather than an error return. Various mathematical libraries that vendors supply with compilers may also give degraded performance when given angles that are badly out of range.

#### **6.3.4.7 Updating the UT1 and polar motion file**

The file `$PGSDAT/CSC/utcpole.dat` contains information about UT1 and polar motion used by many tools. Since this information changes with time, the file must be periodically updated. The SDP Toolkit contains utilities to perform this update function. If a new leap second is issued, the data in this file will change for dates after that second. Since the IERS can announce a leap second on as little as 90 days notice, the file will contain data for only 83 days after its last update; this allows time for the posting of a new data set by the U.S. N. O. as described below, and for the running of the Toolkit update. Tools that depend on these data, such as transformations between ECR and ECI, and tools that deliver UT1 or sidereal time, will fail and issue an error return if they are provided input times past the end of the file. The Log Status file will indicate the failure with a message including " `PGSTD_E_NO_UT1_VALUE`".

The shell script `update_utcpole.sh`, which is found in `$PGSBIN`, will update the `utcpole.dat` file to the current date. To maintain a current `utcpole.dat`, this script should be run every week, but twice a week is recommended for optimum accuracy ( $\sim 2\text{m}$ ). The U.S. Naval Observatory file, on which the update depends, is normally replaced by a current one by noon, Eastern Standard Time, each Tuesday and Thursday. The accuracy is discussed in Section 6.2.7.5.2. `Update_utcpole.sh` calls `PGS_CSC_UT1_update`, a C program that performs most of the actual update work. A Clear Case capable version `update_utcpole_CC.sh` is provided, as well, with this version of the Toolkit. It must be used from within a Clear Case view belonging to the process owner.

The update is done by collecting the latest information via ftp from United States Naval Observatory in Washington, D.C.. Their file "finals.data" in the Series 7 directory within server "maia.usno.navy.mil" contains information on UT1-UTC and the x and y pole displacements. The `utcpole.dat` header contains the date of updating and the file date as listed within ftp for the last "finals.data" used to update it. The function `PGS_CSC_UT1_update` reformats the new finals.data information and adds it to the `utcpole.dat` file, overwriting any old information that is superseded. At the DAACs, the process is done automatically by the scheduler. At Science Computing Facilities, for Toolkits through version 5.2.1, drop 4, users will need to have a ".netrc" file in their home directories, as explained in the comments within the scripts. Later releases will not need such a file.

#### **6.3.4.8 Coordinate System Conversion Tool Notes**

The following notes apply to several of the Coordinate System Conversion Tools.

##### **TIME OFFSETS:**

These functions accept an ASCII UTC time, an array of time offsets and the number of offsets as input. Each element in the offset array is an offset in seconds relative to the initial input ASCII UTC time.

An error will be returned if the number of offsets specified is less than zero. If the number of offsets specified is actually zero, the offsets array will be ignored. In this case the input ASCII UTC time will be converted to Toolkit internal time (TAI) and this time will be used to process the data. If the number of offsets specified is one (1) or greater, the input ASCII UTC time will be converted to TAI and each element 'i' of the input data will be processed at the time: (initial time) + (offset[i]). It is recommended that users take advantage of the efficiency that can be gained by processing many time values in one run, using offsets. Many of the tools have been designed to run more efficiently when operating in this mode, and in some cases an internal limit  $\sim 30$  to 50 has been set on error messaging to the log file in this mode, to prevent excessive growth of the log file.

Examples:

if numValues is 0 and asciiUTC is "1993-001T12:00:00" (TAI93: 432000.0),  
then input[0] will be processed at time 432000.0 and return output[0]

if numValues is 1 and asciiUTC is "1993-001T12:00:00" (TAI93: 432000.0),  
then input[0] will be processed at time 432000.0 + offsets[0] and  
return output[0]

if numValues is N and asciiUTC is "1993-001T12:00:00" (TAI93: 432000.0),  
then each input[i] will be processed at time 432000.0 + offsets[i] and  
the result will be output[i], where i is on the interval [0,N)

### **ERROR HANDLING:**

These functions process data over an array of times (specified by an input ASCII UTC time and an array of time offsets relative to that time).

If processing at each input time is successful the return status of these functions will be PGS\_S\_SUCCESS (status level of 'S').

If processing at ALL input times was unsuccessful the status level of the return status of these functions will be 'E'.

If processing at some (but not all) input times was unsuccessful the status level (see SMF) of the return status of this function will be 'W' AND all high precision real number (C: PGSt\_double, FORTRAN: DOUBLE PRECISION) output variables that correspond to the times for which processing was NOT successful will be set to the value: PGSd\_GEO\_ERROR\_VALUE. In this case users may (should) loop through the output testing any one of the aforementioned output variables against the value PGSd\_GEO\_ERROR\_VALUE. This indicates that there was an error in processing at the corresponding input time and no useful output data was produced for that time.

Note: A return status with a status level of 'W' does not necessarily mean that some of the data could not be processed. The 'W' level may indicate a general condition that the user may need to be aware of but that did not prohibit processing. For example, if an Earth ellipsoid model is required, but the user supplied value is undefined, the WGS84 model will be used, and processing will continue normally, except that the return status will have a status level of 'W' to alert the user that the default earth model was used and not the one specified by the user. The reporting of such general warnings takes precedence over the generic warning (see RETURNS section of the tool of interest) that processing was not successful at some of the requested times. Therefore in the case of any return status of level 'W', the returned value of a high precision real variable generally should be examined for errors at each time offset, as specified above.

### **EPHEMERIS AND ATTITUDE DATA QUALITY CONTROL:**

Many of the Coordinate System Conversion tools access spacecraft ephemeris and/or attitude data in order to effect their respective transformations. In these cases users may define "masks" for the two data quality flags (ephemeris and attitude) associated with spacecraft ephemeris data. The quality flags are (currently) four byte entities (may be 8 bytes on the cray but only the first four bytes will be considered) that are interpreted bit by bit for meaning (see Section L.3 Quality Flags). Currently the only "fatal" bit (i.e. indicating meaningless data) that will be set prior to access by the Toolkit is bit 16 (where the least significant bit is bit 0). Additionally, the Toolkit will set bit 12 of the quality flag returned for a given user input time if NO data is found for that

input time. Note that this usage is different from most of the other bits which indicate the state of some existing data point. By default the Toolkit will set the mask for each of the quality flags to include bit 16 (fatally flawed data) and bit 12 (no data). This means that any data points returned from the tool PGS\_EPH\_EphemAttit() with an associated quality flag that has either bit 12 or bit 16 set will be rejected by any TOOLKIT function that makes a call to PGS\_EPH\_EphemAttit() (e.g. these CSC tools) (note that masking is not applied in the tool PGS\_EPH\_EphemAttit() itself since users calling this tool directly can examine the quality flags themselves and make their own determination as to which data points to use or reject).

Users may use the Process Control File (PCF) to define their own masks which the Toolkit will then use instead of the defaults mentioned above. The user defined mask should set any bit which the user considers fatal for their purpose (e.g. red limit exceeded). WARNING: if the user defined mask does not have bit 16 set, the Toolkit will pass through data the associated quality flag of which has bit 16 set. The toolkit will not, however, process any data points if the associated quality flag has bit 12 set (i.e. no data exists) whether or not the user mask has bit 12 explicitly set.

Below are the PCF entries which control the value of these masks:

```
# -----
# The following parameter is a "mask" for the ephemeris data quality
# flag. The value should be specified as an unsigned integer
# specifying those bits of the ephemeris data quality flag that
# should be considered fatal (i.e. the ephemeris data associated
# with the quality flag should be REJECTED/IGNORED).
# -----
10507|ephemeris data quality flag mask|65536
#
# -----
# The following parameter is a "mask" for the attitude data quality
# flag. The value should be specified as an unsigned integer
# specifying those bits of the attitude data quality flag that
# should be considered fatal (i.e. the attitude data associated
# with the quality flag should be REJECTED/IGNORED).
# -----
10508|attitude data quality flag mask|65536
```

Note that in the examples above, the value 65536 is the unsigned integer equivalent of a 32 bit binary counter with bits 12 and 16 set. See section 6.2.3 (Process Control Tools) and (Appendix C Process Control Files) for a detailed explanation of the use of the Process Control File.

#### 6.3.4.9 Coordinate System Conversion Transformation Tools

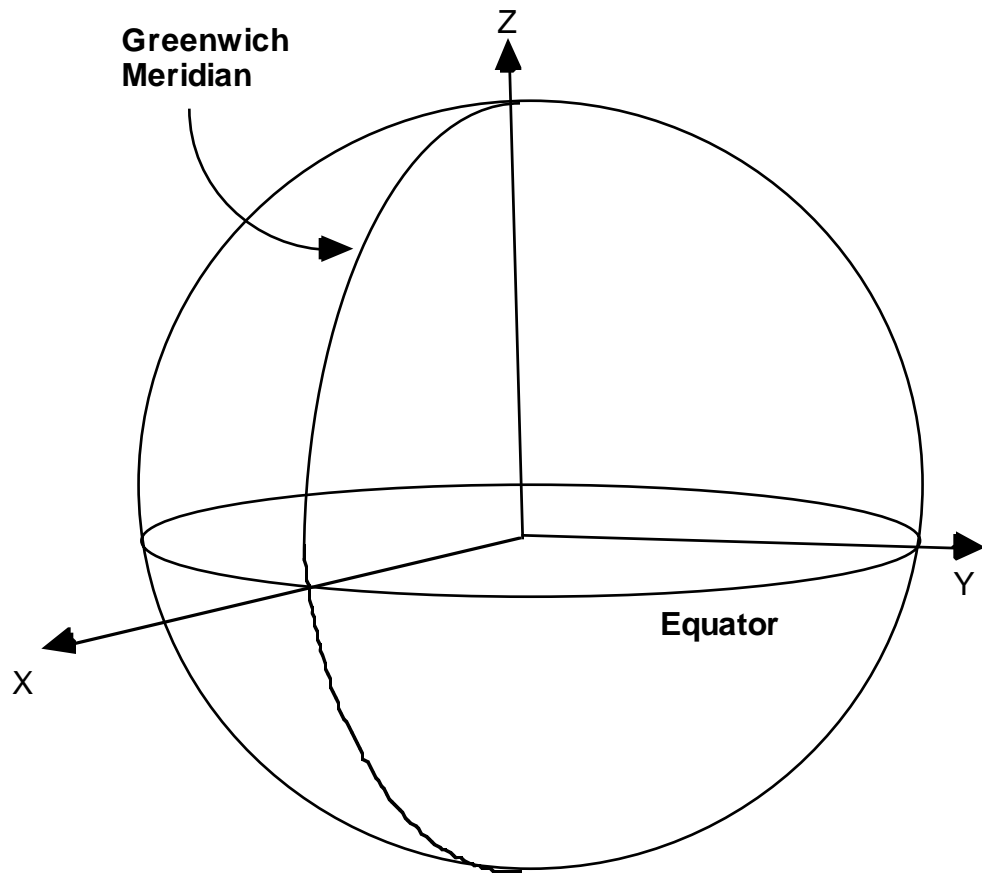
These tools convert between various coordinate systems. This will allow calculations to be computed in the most appropriate coordinate system and allow the conversion of results to a common reference frame. Previously these coordinate transformations were contained in one tool entitled PGS\_CSC\_FrameChange. We have provided separate calls for each transformation, as



one tool proved unwieldy. Also, the user now need not supply extraneous parameters not needed for the desired conversion.

Figures 6–1 through 6–3 show the definitions of the ECR, ECI, and orbital (Orb) reference frames.

The spacecraft coordinate system is defined by the platform engineering firm. For Earth observing spacecraft it normally has its X axis in the direction of the thrusters used for altitude maintenance, the z axis towards nominal nadir, and the y axis along the cross product of z and x. When the spacecraft is flying in nominal zero attitude (no maneuvers), then, the only difference between the spacecraft system and the orbital system consists of very small biases, which are due to original alignment inaccuracies, distortions from launch loads, thermal and aging effects, vibration, etc.



### **EARTH-CENTERED ROTATING (ECR) COORDINATES**

Origin: Center of the Earth

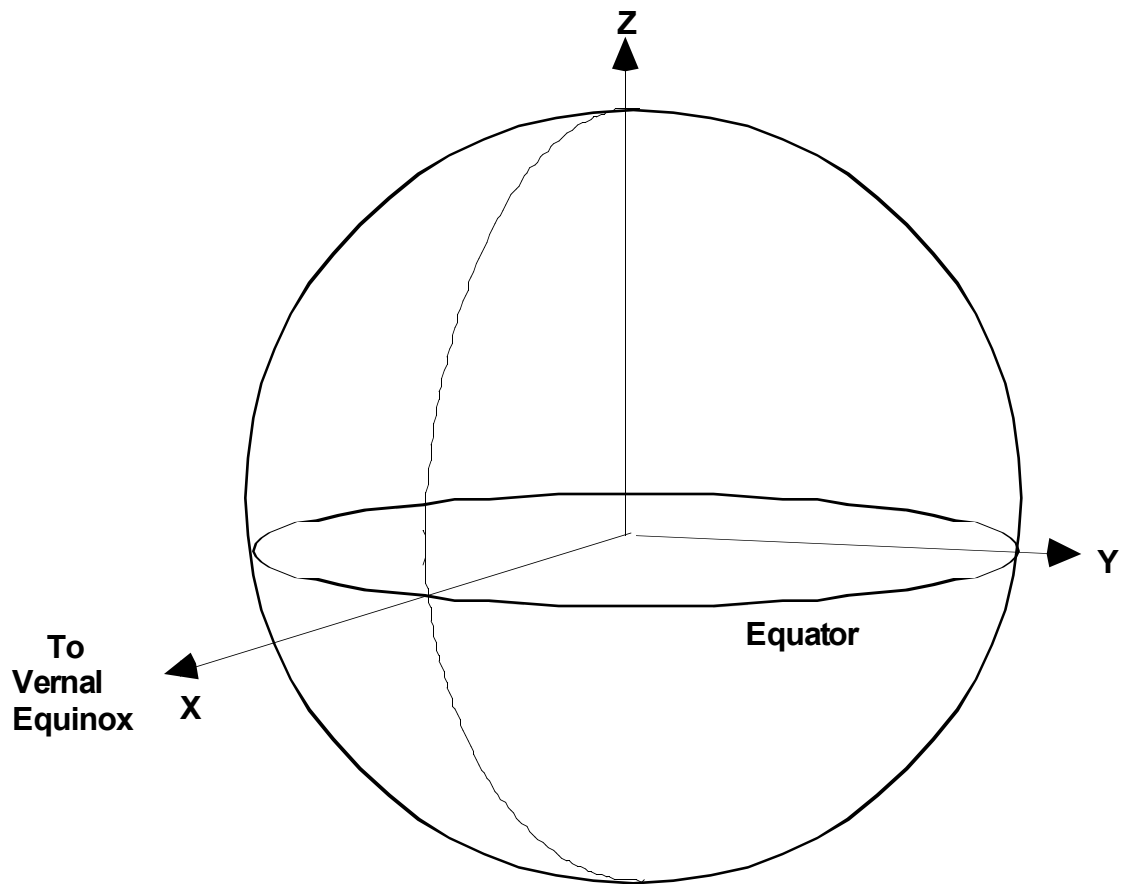
Z-Axis: along Earth's rotational axis, with north positive

X-Y Plane: Earth's equator

X-Axis: directed toward the prime (Greenwich) meridian

Y- Axis: 90 deg from X and Z, completing a right-handed system

***Figure 6-1. Earth-Centered Rotating (ERC) Coordinates***



### **EARTH-CENTERED INERTIAL (ECI) COORDINATES**

Origin: Center of the Earth

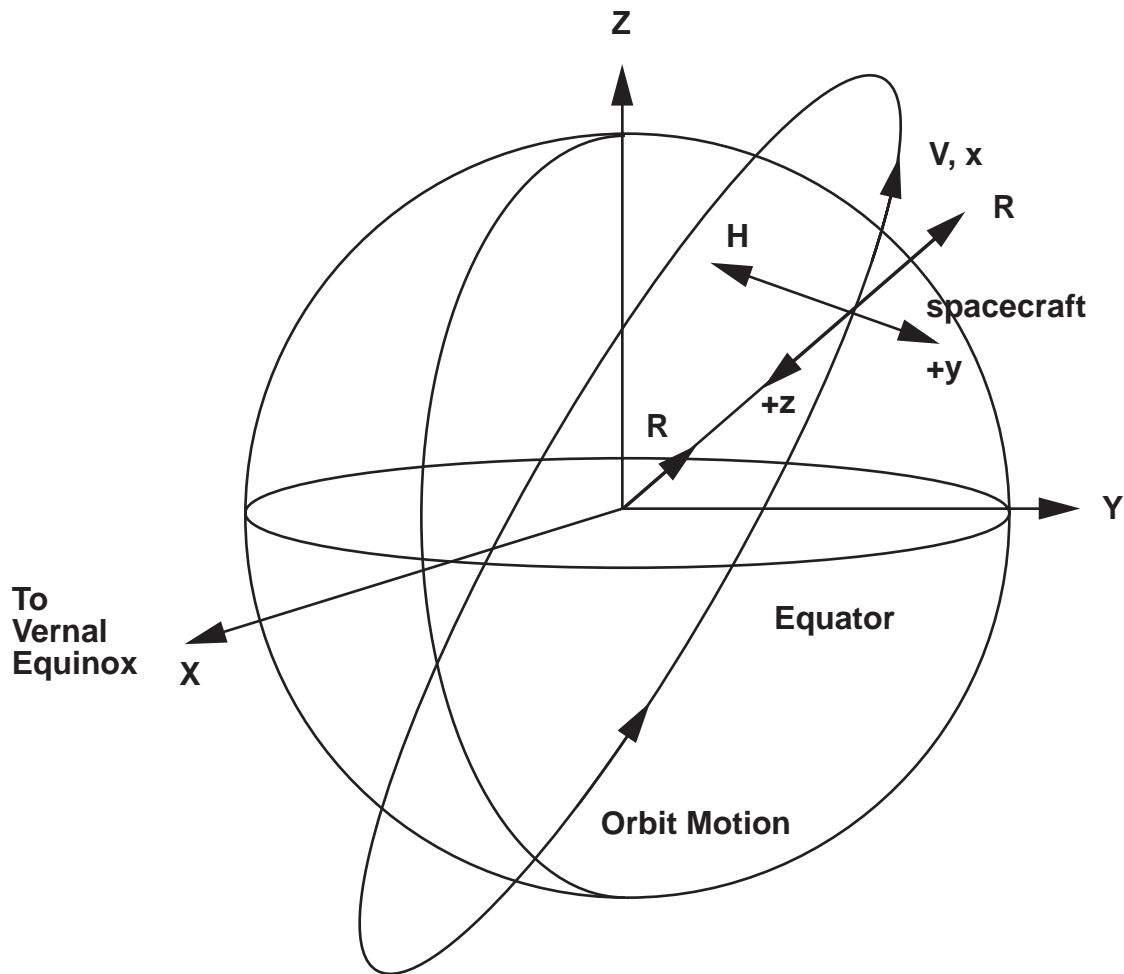
Z-Axis: along Earth's rotational axis, with north positive

X-Y Plane: Earth's equator

X-Axis: directed toward the vernal equinox

Y- Axis: 90 deg from X and Z, completing a right-handed system

***Figure 6-2. Earth Centered Inertial (ECI) Coordinates***



X, Y, Z are inertial coordinates. x, y, z are orbital coordinates, defined as follows:

Origin: Spacecraft Center of Mass

x-z plane: Spacecraft orbital plane

+y (pitch) - Axis: oriented normal to the orbit plane with positive sense opposite to that of the orbit's angular momentum vector H.

+z (yaw) - Axis: positively oriented earthward parallel to the satellite radius vector R from the spacecraft center of mass to the center of the Earth

+x (roll) - Axis: positively oriented in the direction of orbital flight completing an orthogonal triad with y and z.

**Figure 6-3. Relationship Between Earth-Centered Inertial (ECI) Coordinates and Orbital Coordinates**

## Transform from ECI to ECR Coordinates

---

**NAME:** PGS\_CSC\_ECItOECR( )

**SYNOPSIS:**

**C:**           #include <PGS\_CSC.h>  
              #include <PGS\_TD.h>  
              PGSt\_SMF\_status  
PGS\_CSC\_ECItOECR(  
                  PGSt\_integer           numValues,  
                  char                   asciiUTC[28],  
                  PGSt\_double           offsets[],  
                  PGSt\_double           posvelECI[][6],  
                  PGSt\_double           posvelECR[][6])

**FORTTRAN:**   include 'PGS\_CSC\_4.f'  
                 include 'PGS\_TD\_3.f'  
                 include 'PGS\_TD.f'  
                 include 'PGS\_SMF.f'  
                 integer function  
                 pgs\_csc\_ecitoecr (numvalues,asciiutc,offsets,posveleci,posvelecr)  
                 integer                numvalues  
                 character\*27           asciiutc  
                 double precision       offsets(\*)  
                 double precision       posveleci(6,\*)  
                 double precision       posvelecr(6,\*)

**DESCRIPTION:**   This function rotates an array of 6-vectors from ECI (J2000) coordinates to ECR (of date) coordinates. The rotation is done in 4 parts: precession, nutation, Earth rotation about the nutated axis, and polar motion (correction from the rotational North to geographic North).

## INPUTS:

**Table 6-168. PGS\_CSC\_ECItoECR Inputs**

Name	Description	Units	Min	Max
numValues	number of input time offsets	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	1972-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
posvelECI[6]	vector (position and velocity) in J2000 to be transformed to ECR of date			
posvelECI[0]..	x position	meters		
posvelECI[1]	y position	meters		
posvelECI[2]..	z position	meters		
posVelECI[3]	x velocity	meters/ second		
posVelECI[4]	y velocity	meters/ second		
posvelECI[5]	z velocity	meters/ second		

## OUTPUTS:

**Table 6-169. PGS\_CSC\_ECItoECR Outputs**

Name	Description	Units	Min	Max
posvelECR[0]	vector after being transformed to ECR of date - x position	meters		
posvelECR[1]	vector after being transformed to ECR of date - y position	meters		
posvelECR[2]	vector after being transformed to ECR of date - z position	meters		
posvelECR[3]	vector after being transformed to ECR of date - x velocity	meters/second		
posvelECR[4]	vector after being transformed to ECR of date - y velocity	meters/second		
posvelECR[5]	vector after being transformed to ECR of date - z velocity	meters/second		

## RETURNS:

**Table 6-170. PGS\_CSC\_ECItoECR Returns(1 of 2)**

Return	Description
PGS_S_SUCCESS	Successful return
PGSCSC_W_BAD_TRANSFORM_VALUE	Invalid ECItoECR transformation
PGSCSC_E_BAD_ARRAY_SIZE	Incorrect array size
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available input time
PGSTD_E_TIME_FMT_ERROR	Format error in asciiUTC
PGSTD_E_TIME_VALUE_ERROR	Value error in asciiUTC
PGSCSC_W_PREDICTED_UT1	Status of UT1-UTC correction is predicted
PGSTD_E_NO_UT1_VALUE	No UT1-UTC correction available

**Table 6-170. PGS\_CSC\_ECIttoECR Returns(2 of 2)**

Return	Description
PGS_E_TOOLKIT	Something unexpected happened, execution of function ended prematurely

**EXAMPLES:**

```
C:
#define      ARRAY_SIZE  3

PGSt_SMF_status   returnStatus;
PGSt_integer      numValues;
char              asciiUTC[28];
PGSt_double       offsets[ARRAY_SIZE] =
                  {3600.0,7200.0,10800.0};
PGSt_double       posveIECI[ARRAY_SIZE][6] =
                  {
                    {0.5,0.75,0.90,0.3,0.2,0.8},
                    {0.65,1.2,3.65,0.1,3.2,1.7},
                    {0.98,2.6,4.78,0.2,1.5,0.9}
                  };
PGSt_double       posveIECR[ARRAY_SIZE][6];

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30.123211Z");
returnStatus = PGS_CSC_ECIttoECR(numValues,asciiUTC,offsets,
                                posveIECI,posveIECR)

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
       take appropriate
       action **
}
```

```
FORTTRAN:
implicit none

integer      pgs_csc_ecitoecr
integer      returnstatus
integer      numvalues
character*27  asciiutc
double precision  offsets(3)
double precision  posveIECI(6,3)
double precision  posveIECR(6,3)
integer      cnt1
integer      cnt2
character*33  err
character*241 msg

data offsets/3600.0, 7200.0, 10800.0/

asciiutc = '2002-07-27T11:04:57.987654Z'
numvalues = 3
```

```

DO 10 cnt1 = 1,6
  DO 10 cnt2 = 1,3
    posveleci(cnt1,cnt2) = 100 * cnt1 * cnt2
10 CONTINUE

returnstatus = pgs_csc_ecitoecr(numValues, asciiutc,
                                offsets, cbid, cbvectors)

if (returnstatus .ne. pgs_s_success) then
  pgs_smf_getmsg(returnstatus, err, msg)
  write(*,*) err, msg
endif

```

#### **NOTES:**

Users not needing to transform velocity can supply floating point numbers equal to zero for the last three components of each input vector. The Tool cannot transform velocity, however, without correct values for the position. Note that to avoid generating absurdly large velocities for distant objects, no velocity transformation is performed for points more than 500,000,000 m from Earth center.

UTC is: Coordinated Universal Time

J2000 is Julian Date 2451545.0

See Section 6.3.4.8 Coordinate System Conversion Tool Notes.

See Section 6.2.7.5.2 (UT1-UTC Boundaries)

#### **REFERENCES:**

The Astronomical Almanac, Explanatory Supplement to the Astronomical Almanac. “Theoretical Basis of the SDP Toolkit Geolocation Package for the ECS Project”, Document 445-TP-002-002, May 1995, by P. Noerdlinger.

#### **REQUIREMENTS:** PGSTK-1050



## Transform from ECR to ECI Coordinates

---

**NAME:** PGS\_CSC\_ECRtoECI( )

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_ECRtoECI(
    PGSt_integer    numValues,
    char            asciiUTC[28],
    PGSt_double     offsets[],
    PGSt_double     posvelECR[][6],
    PGSt_double     posvelECI[][6])
```

**FORTTRAN:**

```
include'PGS_CSC_4.f'
include'PGS_TD_3.f'
include'PGS_TD.f'
include'PGS_SMF.f'

integer function
pgs_csc_ecrtoeci(numvalues,asciiutc,offsets,posvelecr,posveleci)
    integer            numvalues
    character*27       asciiutc
    double precision   offsets(*)
    double precision   posvelecr(6,*)
    double precision   posveleci(6,*)
```

**DESCRIPTION:** This function rotates an array of 6-vectors from ECR (of date) coordinates to ECI (J2000) coordinates. The rotation is done in 4 parts: polar motion (correction from the geographic North to rotational North), rotation about the true rotation, nutation to the mean of date axis axis, and precession to J2000).

**INPUTS:****Table 6-171. PGS\_CSC\_ECRtoECI Inputs**

Name	Description	Units	Min	Max
numValues	number of input time offsets	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	1972-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
posvelECR[6]	vector (position and velocity) in ECR			
posvelECR[0]..	position	meters		
posvelECR[2]				
posvelECR[3]..	velocity	meters/seconds		
posvelECR[5]				

**OUTPUTS:****Table 6-172. PGS\_CSC\_ECRtoECI Outputs**

Name	Description	Units	Min	Max
posvelECI[6]	vector after being transformed to J2000			
posvelECI[0]..	position	meters		
posvelECI[2]		meters		
posvelECI[3]..	velocity	meters/second		
posvelECI[5]		meters/second		

**RETURNS:****Table 6-173. PGS\_CSC\_ECRtoECI Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSCSC_W_BAD_TRANSFORM_VALUE	Invalid ECIttoECR transformation
PGSCSC_E_BAD_ARRAY_SIZE	Incorrect array size
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available input time
PGSTD_E_TIME_FMT_ERROR	Format error in asciiUTC
PGSTD_E_TIME_VALUE_ERROR	Value error in asciiUTC
PGSCSC_W_PREDICTED_UT1	Status of UT1-UTC correction is predicted
PGSTD_E_NO_UT1_VALUE	No UT1-UTC correction available
PGS_E_TOOLKIT	Something unexpected happened, execution of function ended prematurely

## EXAMPLES:

```
C:      #define      ARRAY_SIZE  3

PGSt_SMF_status   returnStatus;
PGSt_integer      numValues;
char              asciiUTC[28];
PGSt_double       offsets[ARRAY_SIZE] =
                    {3600.0,7200.0,10800.0};
PGSt_double       posveleCR[ARRAY_SIZE][6] =
                    {
                        {0.5,0.75,0.90,0.3,0.2,0.8},
                        {0.65,1.2,3.65,0.1,3.2,1.7},
                        {0.98,2.6,4.78,0.2,1.5,0.9}
                    };
PGSt_double       posveleCI[ARRAY_SIZE][6];

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30.123211Z");
returnStatus = PGS_CSC_ECRtoECI(numValues,asciiUTC,offsets,
                                posveleCR,posveleCI)

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
       take appropriate
       action **
}

FORTRAN:  implicit none

integer      pgs_csc_ecrtoeci
integer      returnstatus
integer      numvalues
character*27  asciiutc
double precision  offsets(3)
double precision  posveleci(6,3)
double precision  posvelecr(6,3)
integer      cnt1
integer      cnt2
character*33  err
character*241 msg

data offsets/3600.0, 7200.0, 10800.0/

asciiutc = '2002-07-27T11:04:57.987654Z'
numvalues = 3
```

```

do 10 cnt1 = 1,6
  do 10 cnt2 = 1,3
    posvelecr(cnt1,cnt2) = 100 * cnt1 * cnt2
10 continue

asciutc = '1991-07-27T11:04:57.987654Z'
numvalues = 3

returnstatus = pgs_csc_ecrtoeci (numValues, asciutc,
                                offsets, posvelecr,
                                posveleci)

if (returnstatus .ne. pgs_s_success) then
  pgs_smf_getmsg(returnstatus, err, msg)
  write(*,*) err, msg
endif

```

#### **NOTES:**

Users not needing to transform velocity can supply floating point numbers equal to zero for the last three components of each input vector. The Tool cannot transform velocity, however, without correct values for the position. Note that to avoid generating absurdly large velocities for distant objects, no velocity transformation is performed for points more than 500,000,000 m from Earth center.

UTC is:            Coordinated Universal Time

See Section 6.3.4.8 Coordinate System Conversion Tool Notes.

See Section 6.2.7.5.2 (UT1-UTC Boundaries)

#### **REFERENCES:**

The Astronomical Almanac, Explanatory Supplement to the Astronomical Almanac. "Theoretical Basis of the SDP Toolkit Geolocation Package for the ECS Project", Document 445-TP-002-002, May 1995, by P. Noerdlinger.

**REQUIREMENTS:** PGSTK-1050

## Convert from ECR to Geodetic Coordinates

---

**NAME:** PGS\_CSC\_ECRtoGEO()

**SYNOPSIS:**

**C:**

```
#include <PGS_CSC.h>

PGSt_SMF_status
PGS_CSC_ECRtoGEO(
    PGSt_double    posECR[3],
    char           *earthEllipsTag,
    PGSt_double    *longitude,
    PGSt_double    *latitude,
    PGSt_double    *altitude);
```

**FORTRAN:**

```
include'PGS_SMF.f'
include'PGS_CSC_4.f'

integer function
pgs_csc_ecrtogeo(posecr,earthellipstag,longitude,latitude,height)
    double precision    posecr(3)
    character*49        earthellipstag
    double precision    longitude
    double precision    latitude
    double precision    altitude
```

**DESCRIPTION:** This function converts from ECR to geodetic coordinates.

**INPUTS:**

**Table 6-174. PGS\_CSC\_ECRtoGEO Inputs**

Name	Description	Units	Min	Max
posECR[3]	geocentric position	meters	N/A	N/A
EarthEllipsTag	Earth model used	N/A	N/A	N/A

**OUTPUTS:**

**Table 6-175. PGS\_CSC\_ECRtoGEO Outputs**

Name	Description	Units	Min	Max
latitude	geodetic latitude	radians	-pi/2	pi/2
longitude	longitude	radians	-pi	pi
altitude	altitude	meters	-.1* Earth	sky's the limit

## RETURNS:

**Table 6-176. PGS\_CSC\_ECRtoGEO Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSCSC_W_TOO_MANY_ITERS	Normal Iteration Count exceeded—could indicate inconsistent units for Spacecraft and Earth data, or corrupted Earth Axis values
PGSCSC_W_INVALID_ALTITUDE	Spacecraft underground—probably indicates bad input data
PGSCSC_W_SPHERE_BODY	Using a spherical Earth model
PGSCSC_W_LARGE_FLATTENING	Issued if flattening factor is greater than 0.01
PGSCSC_W_DEFAULT_EARTH_MODEL	Uses default Earth model
PGSCSC_E_BAD_EARTH_MODEL	The equatorial or polar radius is negative or zero OR the radii define a prolate Earth
PGS_E_TOOLKIT	Something unexpected happened, execution of function ended prematurely

## EXAMPLES:

```
C:      PGSt_SMF_status   returnStatus;
        PGSt_double      longitude
        PGSt_double      latitude
        PGSt_double      altitude
        char              earthEllipsTag[50],
        PGSt_double      posECR[3] = {1000.5,64343.56,34343.92}
        char              err[PGS_SMF_MAX_MNEMONIC_SIZE];
        char              msg[PGS_SMF_MAX_MSG_SIZE];

        strcpy(earthEllipsTag,"WGS84");

        returnStatus = PGS_CSC_ECRtoGEO(posECR[3],earthEllipsTag,
                                         longitude,latitude,
                                         altitude);

        if(returnStatus != PGS_S_SUCCESS)
        {
            PGS_SMF_GetMsg(&returnStatus,err,msg);
            printf("\nERROR: %s",msg);
        }
```

```
FORTTRAN:      implicit none

                integer      pgs_csc_ecrtogeo
                integer      returnstatus
                double precision longitude
                double precision latitude
```

```

double precision  altitude
character*49      earthellipstag,
double precision  posecr(3)
character*33      err
character*241     msg

data posecr/1000.5,64343.56,34343.92/
earthellipstag = 'WGS84'

returnstatus = pgs_csc_ecrtogeo(posecr,earthellipstag,
                                longitude,latitude,altitude)

if(returnstatus .ne. pgs_s_success) then
    returnstatus = pgs_smf_getmsg(returnstatus,err,msg)
    write(*,*) err, msg
endif

```

**NOTES:** The Earth axes will be accessed from the earthfigure.dat.file. The input must always be in meters and should never be a unit vector.

**REQUIREMENTS:** PGSTK-0930, PGSTK-1050

## Convert from Geodetic to ECR Coordinates

---

**NAME:** PGS\_CSC\_GEOtoECR()

**SYNOPSIS:**

**C:**

```
#include <PGS_CSC.h>

PGSt_SMF_status
PGS_CSC_GEOtoECR(
    PGSt_double    longitude,
    PGSt_double    latitude,
    PGSt_double    altitude,
    char            *earthEllipsTag,
    PGSt_double    posECR[3]);
```

**FORTRAN:**

```
include'PGS_SMF.f'
include'PGS_CSC_4.f'

integer function
pgs_csc_geotoecr(longitude,latitude,altitude,earthellipstag,posecr)
    double precision    longitude
    double precision    latitude
    double precision    altitude
    character*49        earthellipstag
    double precision    posecr(3)
```

**DESCRIPTION:** This tool converts a geodetic latitude and longitude to ECR (Earth Centered Rotating) coordinates.

**INPUTS:**

***Table 6-177. PGS\_CSC\_GEOtoECR Inputs***

Name	Description	Units	Min	Max
longitude	longitude	radians	-pi	pi
latitude	latitude	radians	-pi/2	pi/2
altitude	altitude	meters	-.1* radius	N/A
earthellipstag	Earth model used	N/A	N/A	N/A



## OUTPUTS:

**Table 6-178. PGS\_CSC\_GEOtoECR Outputs**

Name	Description	Units	Min	Max
posECR	ECR rectangular coordinates	meters	-100,000,000 (usually each component will be in range [-10,000,000, +10,000,000 m ] but function will work for Geosynchronous cases, e.g. )	100,000,000

## RETURNS:

**Table 6-179. PGS\_CSC\_GEOtoECR Returns**

Return	Description
PGS_S_SUCCESS	Success case
PGSCSC_W_DEFAULT_EARTH_MODEL	The default Earth model is used because a correct one was not specified
PGSCSC_W_SPHERICAL_BODY	Using a spherical Earth model
PGSCSC_W_LARGE_FLATTENING	Issued if flattening factor is greater then 0.01
PGSCSC_W_INVALID_ALTITUDE	An invalid altitude was specified
PGSCSC_E_BAD_EARTH_MODEL	The equatorial or polar radius is negative or zero OR the radii define a prolate Earth
PGS_E_TOOLKIT	Something unexpected happened, execution of function ended prematurely

## EXAMPLES:

```
C:          PGSt_SMF_status   returnStatus
          PGSt_double         longitude
          PGSt_double         latitude
          PGSt_double         altitude
          char                 earthEllipsTag[50],
          PGSt_double         posECR[3]
          char                 err[PGS_SMF_MAX_MNEMONIC_SIZE];
          char                 msg[PGS_SMF_MAX_MSG_SIZE];

          longitude = 0.45;
          latitude = 1.34;
          altitude = 5000.0;
          strcpy(earthEllipsTag,"WGS84");

          returnStatus = PGS_CSC_GEOtoECR(longitude,latitude,altitude,
                                          earthEllipsTag,posECR);
```

```

if(returnStatus != PGS_S_SUCCESS)
{
    PGS_SMF_GetMsg(&returnStatus,err,msg);
    printf("\nERROR: %s",msg);
}

```

**FORTTRAN:**

```

implicit none

integer          pgs_csc_geotoecr
integer          returnstatus
double precision longitude
double precision latitude
double precision altitude
character*49     earthellipstag,
double precision posecr(3)
character*33     err
character*241    msg

longitude = 0.45
latitude = 1.34
altitude = 5000
earthellipstag = 'WGS84'

returnstatus = pgs_csc_geotoecr(longitude,latitude,altitude,
                                earthellipstag,posecr)

if(returnstatus .ne. pgs_s_success) then
    returnstatus = pgs_smf_getmsg(returnstatus,err,msg)
    write(*,*) err, msg
endif

```

**NOTES:** NONE

**REQUIREMENTS:** PGSTK-0930, PGSTK-1050

## Transform from ECI Frame to Spacecraft Reference Frame

---

**NAME:** PGS\_CSC\_ECItoSC()

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_ECItoSC(
    PGSt_tag          spacecraftTag,
    PGSt_integer      numValues,
    char              asciiUTC[28],
    PGSt_double        offsets[],
    PGSt_double        posECI[][3],
    PGSt_double        posSC[][3])
```

**FORTTRAN:** include 'PGS\_MEM\_7.f'  
include 'PGS\_CSC\_4.f'  
include 'PGS\_TD\_3.f'  
include 'PGS\_TD.f'  
include 'PGS\_SMF.f'

```
integer function
pgs_csc_ecitosc(spacecraftTag,numvalues,asciiutc,offsets,poseci,posscc)
    integer          spacecrafttag
    integer          numvalues
    character*27      asciiutc
    double precision  offsets(*)
    double precision  poseci(3,*)
    double precision  posscc(3,*)
```

**DESCRIPTION:** Transforms vector in ECI coordinate system to vector in Spacecraft coordinate system. If a unit vector is input, only its direction is transformed. If a vector in meters is input, it is first corrected for the displacement between Earth center and spacecraft location and then rotated into spacecraft coordinates.

## INPUTS:

**Table 6-180. PGS\_CSC\_ECItoSC Inputs**

Name	Description	Units	Min	Max
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
numValues	number of input time offsets	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	1961-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
posECI	coordinates or unit vector components in ECI reference frame	meter	N/A	N/A

## OUTPUTS:

**Table 6-181. PGS\_CSC\_ECItoSC Outputs**

Name	Description	Units	Min	Max
posSC	coordinates or unit vector components in spacecraft reference frame	meters	N/A	N/A

## RETURNS:

**Table 6-182. PGS\_CSC\_ECItoSC Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSCSC_W_BELOW_SURFACE	vector magnitude indicates subsurface location specified
PGSCSC_W_BAD_TRANSFORM_VALUE	One or more values in transformation could not be determined
PGSTD_E_TIME_FMT_ERROR	Format error in asciiUTC
PGSTD_E_TIME_VALUE_ERROR	value error in asciiUTC
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for input time
PGSMEM_E_NO_MEMORY	No memory is available to allocate vectors
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephem files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephem files could be found for input times
PGSEPH_E_NO_DATA_REQUESTED	Both orb and att flags are set to false

## EXAMPLES:

```
C:      #define      ARRAY_SIZE  3

PGSt_SMF_status   returnStatus;
PGSt_integer      numValues;
char              asciiUTC[28];
PGSt_double       offsets[ARRAY_SIZE] =
                  {3600.0,7200.0,10800.0};
PGSt_double       posECI[ARRAY_SIZE][3] =
                  {
                      {0.5,0.75,0.90,0.3,0.2,0.8},
                      {0.65,1.2,3.65,0.1,3.2,1.7},
                      {0.98,2.6,4.78,0.2,1.5,0.9}
                  };
PGSt_double       posSC[ARRAY_SIZE][3];

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30.123211Z");
returnStatus = PGS_CSC_ECItOsc(PGSd_TRMM,numValues,asciiUTC,
                              offsets,posECI,posSC)

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
       take appropriate
       action **
}
```

```
FORTRAN:  implicit none

integer      pgs_csc_ecitosc
integer      returnstatus
integer      numvalues
character*27  asciutc
double precision  offsets(3)
double precision  poseci(3,3)
double precision  possc(3,3)
integer      cnt1
integer      cnt2
character*33  err
character*241 msg

data offsets/3600.0, 7200.0, 10800.0/

do 10 cnt1 = 1,3
  do 10 cnt2 = 1,3
    posveleci(cnt1,cnt2) = 100 * cnt1 * cnt2
```

```

10 continue

asciiutc = '1991-07-27T11:04:57.987654Z'
numvalues = 3

returnstatus = pgs_csc_ecitosc(PGSd_TRMM, numValues,
asciiutc,
                                offsets, poseci, possc)

if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err, msg
endif

```

#### **NOTES:**

Points are checked to make sure they are not subterranean, but no other visibility check is performed (such as line-of-sight).

Next the function checks the input vector to see if it is a unit vector. If so, it is assumed that the user wishes only to transform its direction. If not, it is assumed that the vector locates some point of interest (for example, a TDRSS satellite, or a lookpoint). Thus, for that case a translation to the spacecraft center is performed first and then a rotation. Aberration correction is also performed in both cases, except in the second case, for points within 120 m of spacecraft center. Vectors to such points are not aberrated. This cutoff is imposed on the supposition that anyone wishing to transform a point within 120 m of the spacecraft center could be dealing with an alignment, glint, or other spacecraft-related problem, in which case there is no aberration. For the purposes of this function, a vector is a unit vector if its magnitude is between 0.99999 and 1.00001.

#### **TIME ACRONYMS:**

UTC is: Coordinated Universal Time

See Section 6.3.4.8 Conversion System Coordinate Tool Notes

See Section 6.2.7.5.1 (TAI-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

#### **REQUIREMENTS:** PGSTK-1050

## Transform Between Spacecraft and ECI Reference Frames

---

**NAME:** PGS\_CSC\_SCtoECI()

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_SCtoECI(
    PGSt_tag          spacecraftTag,
    PGSt_integer       numValues,
    char               asciiUTC[28],
    PGSt_double        offsets[],
    PGSt_double        posSC[][3],
    PGSt_double        posECI[][3])
```

**FORTTRAN:** include 'PGS\_MEM\_7.f'  
include 'PGS\_EPH\_5.f'  
include 'PGS\_CSC\_4.f'  
include 'PGS\_TD\_3.f'  
include 'PGS\_TD.f'  
include 'PGS\_SMF.f'

```
integer function
pgs_csc_sctoeci(spacecraftTag,numvalues,asciiutc,offsets,posscc,poseci)
    integer          spacecrafttag
    integer          numvalues
    character*27     asciiutc
    double precision offsets(*)
    double precision posscc(3,*)
    double precision poseci(3,*)
```

**DESCRIPTION:** Transforms vector in Spacecraft coordinate system to vector in ECI coordinate system. If a unit vector is input, it is simply rotated to ECI coordinates. If a vector in meters is input, it is rotated to ECI axes and then translated from having its origin at the spacecraft center to having its origin at Earth center.

**INPUTS:****Table 6-183. PGS\_CSC\_SCtoECI Inputs**

Name	Description	Units	Min	Max
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
numValues	number of input time offsets	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	1961-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
posSC	coordinates or unit vector components in SC reference frame	meters	N/A	N/A

**OUTPUTS:****Table 6-184. PGS\_CSC\_SCtoECI Outputs**

Name	Description	Units	Min	Max
posECI	coordinates or unit vector components in ECI reference frame	meters	N/A	N/A

**RETURNS:****Table 6-185. PGS\_CSC\_SCtoECI Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSCSC_W_BELOW_SURFACE	Vector magnitude indicates subsurface location specified
PGSCSC_W_BAD_TRANSFORM_VALUE	One or more values in transformation could not be determined
PGSTD_E_TIME_FMT_ERROR	Format error in asciiUTC
PGSTD_E_TIME_VALUE_ERROR	Value error in asciiUTC
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for input time
PGSMEM_E_NO_MEMORY	No memory is available to allocate vectors
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephem files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephem files could be found for input
PGSEPH_E_NO_DATA_REQUESTED	Both orb and att flags are set to false



## EXAMPLES:

C:

```
#define      ARRAY_SIZE  3

PGSt_SMF_status   returnStatus;
PGSt_integer      numValues;
char              asciiUTC[28];
PGSt_double       offsets[ARRAY_SIZE] =
                    {3600.0,7200.0,10800.0};
PGSt_double       posSC[ARRAY_SIZE][3] =
                    {
                        {0.5,0.75,0.90,0.3,0.2,0.8},
                        {0.65,1.2,3.65,0.1,3.2,1.7},
                        {0.98,2.6,4.78,0.2,1.5,0.9}
                    };
PGSt_double       poseCI[ARRAY_SIZE][3];

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30.123211Z");
returnStatus = PGS_CSC_SCToECI(PGSd_TRMM,numValues,
                               asciiUTC,offsets, posSC,
                               poseCI)

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
        take appropriate
        action **
}
```

FORTTRAN:

```
implicit none

integer                pgs_csc_sctoeci
integer                returnstatus
integer                numvalues
character*27           asciiutc
double precision       offsets(3)
double precision       possc(3,3)
double precision       poseci(3,3)
integer                cnt1
integer                cnt2
character*33           err
character*241          msg

data offsets/3600.0, 7200.0, 10800.0/
```

```

do 10 cnt1 = 1,3
  do 10 cnt2 = 1,3
    posveleci(cnt1,cnt2) = 100 * cnt1 * cnt2
10 continue

asciiutc = '1991-07-27T11:04:57.987654Z'
numvalues = 3

returnstatus = pgs_csc_sctoeci (PGSd_TRMM,numValues,
                                asciiutc,offsets,posscc,
                                poseci)

if (returnstatus .ne. pgs_s_success) then
  pgs_smf_getmsg(returnstatus, err, msg)
  write(*,*) err, msg
endif

```

#### NOTES:

This function first checks the input vector to see if it is a unit vector. If so, it is assumed that the user wishes only to transform its direction. If not, it is assumed that the vector locates some point of interest (for example, a TDRSS satellite, or a lookpoint). For that case a rotation to ECI axes is performed first, and then a translation to the Earth center. An aberration correction is also made if the input is a unit vector or is in meters and represents a point more than 120 m from spacecraft center. This cutoff is imposed on the supposition that anyone wishing to transform a point within 120 m of the spacecraft center could be dealing with an alignment, glint, or other spacecraft-related problem, in which case there is no aberration. For the purposes of this function, a vector is a unit vector if its magnitude is between 0.99999 and 1.00001

Certain checks are performed in the case of translation to ensure that the transformed point is not below the Earth's surface; other visibility checks (such as line-of-sight) are not performed.

#### TIME ACRONYMS:

UTC is: Coordinated Universal Time

See Section 6.3.4.8 Coordinate System Conversion Tool Notes

See Section 6.2.7.5.1 (TAI-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

#### REQUIREMENTS: PGSTK-1050

## Transform from Spacecraft Frame to Orbital Frame

---

**NAME:** PGS\_CSC\_SCtoORB()

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_SCtoORB(
    PGSt_tag          spacecraftTag,
    PGSt_integer       numValues,
    char               asciiUTC[28],
    PGSt_double        offsets[],
    PGSt_double        posSC[3],
    PGSt_double        posORB[][3])
```

**FORTTRAN:** include 'PGS\_MEM\_7.f'  
include 'PGS\_EPH\_5.f'  
include 'PGS\_CSC\_4.f'  
include 'PGS\_TD\_3.f'  
include 'PGS\_TD.f'  
include 'PGS\_SMF.f'

```
integer function
pgs_csc_sctoorb(spacecraftTag,numvalues,asciutc,offsets,posscc,posorb)
    integer          spacecrafttag
    integer          numvalues
    character*27     asciutc
    double precision offsets(*)
    double precision posscc(3,*)
    double precision posorb(3,*)
```

**DESCRIPTION:** Transforms vector in Spacecraft reference frame to a vector in Orbital reference frame.

**INPUTS:****Table 6-186. PGS\_CSC\_SCtoORB Inputs**

Name	Description	Units	Min	Max
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
numValues	number of input time offsets	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	1961-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
posSC	coordinates or unit vector components in SC reference frame	meters	N/A	N/A

**OUTPUTS:****Table 6-187. PGS\_CSC\_SCtoORB Outputs**

Name	Description	Units	Min	Max
posORB	coordinates or unit vector components in Orbital reference frame	meters	N/A	N/A

**RETURNS:****Table 6-188. PGS\_CSC\_SCtoORB Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSCSC_W_BELOW_SURFACE	Vector magnitude indicates subsurface location specified
PGSCSC_W_BAD_TRANSFORM_VALUE	One or more values in transformation could not be determined
PGSTD_E_TIME_FMT_ERROR	Format error in asciiUTC
PGSTD_E_TIME_VALUE_ERROR	Value error in asciiUTC
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for input time
PGSMEM_E_NO_MEMORY	No memory is available to allocate vectors
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephemeris files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephemeris files could be found for input times

## EXAMPLES:

```
C:      #define      ARRAY_SIZE  3

PGSt_SMF_status   returnStatus;
PGSt_integer      numValues;
char              asciiUTC[28];
PGSt_double       offsets[ARRAY_SIZE] =
                    {3600.0,7200.0,10800.0};
PGSt_double       posSC[ARRAY_SIZE][3] =
                    {
                        {0.5,0.75,0.90,0.3,0.2,0.8},
                        {0.65,1.2,3.65,0.1,3.2,1.7},
                        {0.98,2.6,4.78,0.2,1.5,0.9}
                    };
PGSt_double       posORB[ARRAY_SIZE][3];

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30.123211Z");
returnStatus = PGS_CSC_SCToORB(pgsd_trmm,numvalues,asciiutc,
                              offsets,possc,posORB)

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
       take appropriate
       action **
}
```

```
FORTRAN:  implicit none

integer      pgs_csc_sctoorb
integer      returnstatus
integer      numvalues
character*27  asciiutc
double precision  offsets(3)
double precision  possc(3,3)
double precision  posorb(3,3)
integer      cnt1
integer      cnt2
character*33  err
character*241 msg

data offsets/3600.0, 7200.0, 10800.0/

do 10 cbt1 = 1,3
    do 10 cnt2 = 1,3
        possc(cnt1,cnt2) = 100 * cnt1 * cnt2
```

```

10 continue

  asciutc = '1991-07-27T11:04:57.987654Z'
  numvalues = 3

  returnstatus = pgs_csc_sctoorb(pgsd_trmm,numvalues,
    asciutc,
                                offsets, possc, posorb)

  if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err, msg
  endif

```

#### **NOTES:**

#### **TIME ACRONYMS:**

UTC is:        Coordinated Universal Time

See Section 6.3.4.8 Coordinate System Conversion Tool Notes

See Section 6.2.7.5.1 (TAI-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

#### **REQUIREMENTS: PGSTK-1050**

## Transform from Orbital Frame to Spacecraft Frame

---

**NAME:** PGS\_CSC\_ORBtoSC()

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_ORBtoSC(
    PGSt_tag          spacecraftTag,
    PGSt_integer      numValues,
    char              asciiUTC[28],
    PGSt_double       offsets[],
    PGSt_double       posORB[3],
    PGSt_double       posSC[][3])
```

**FORTTRAN:** include 'PGS\_MEM\_7.f'  
include 'PGS\_EPH\_5.f'  
include 'PGS\_CSC\_4.f'  
include 'PGS\_TD\_3.f'  
include 'PGS\_TD.f'  
include 'PGS\_SMF.f'

```
integer function
pgs_csc_orbtosc(spacecrafttag,numvalues,asciiutc,offsets,posorb,posscc)
    integer          spacecrafttag
    integer          numvalues
    character*27     asciiutc
    double precision offsets(*)
    double precision posorb(3,*)
    double precision posscc(3,*)
```

**DESCRIPTION:** Transforms vector from Orbital reference frame to a vector in Spacecraft reference frame.

**INPUTS:****Table 6-189. PGS\_CSC\_ORBtoSC Inputs**

Name	Description	Units	Min	Max
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
numValues	number of input time offsets	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	1960-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
posORB	coordinates or unit vector components in Orbital reference frame	meters	N/A	N/A

**OUTPUTS:****Table 6-190. PGS\_CSC\_ORBtoSC Outputs**

Name	Description	Units	Min	Max
posSC	coordinates or unit vector components in spacecraft reference frame	meters	N/A	N/A

**RETURNS:****Table 6-191. PGS\_CSC\_ORBtoSC Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSSC_W_BELOW_SURFACE	Vector magnitude indicates subsurface location specified
PGSCSC_W_BAD_TRANSFORM_VALUE	One or more values in transformation could not be determined
PGSTD_E_TIME_FMT_ERROR	Format error in asciiUTC
PGSTD_E_TIME_VALUE_ERROR	Value error in asciiUTC
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for input time
PGSMEM_E_NO_MEMORY	No memory is available to allocate vectors
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephemeris files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephemeris files could be found for input times



## EXAMPLES:

```
C:      #define      ARRAY_SIZE  3

PGSt_SMF_status   returnStatus;
PGSt_integer      numValues;
char              asciiUTC[28];
PGSt_double       offsets[ARRAY_SIZE] =
                    {3600.0,7200.0,10800.0};
PGSt_double       posORB[ARRAY_SIZE][3] =
                    {
                        {0.5,0.75,0.90,0.3,0.2,0.8},
                        {0.65,1.2,3.65,0.1,3.2,1.7},
                        {0.98,2.6,4.78,0.2,1.5,0.9}
                    };
PGSt_double       posSC[ARRAY_SIZE][3];

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30.123211Z");
returnStatus = PGS_CSC_ORBtoSC(PGSd_TRMM,numValues,asciiUTC,
                               offsets, posORB, posSC)

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
        take appropriate
        action **
}
```

```
FORTRAN:  implicit none

integer      pgs_csc_orbtosc
integer      returnstatus
integer      numvalues
character*27  asciutc
double precision  offsets(3)
double precision  posorb(3,3)
double precision  possc(3,3)
integer      cnt1
integer      cnt2
character*33  err
character*241 msg

data offsets/3600.0, 7200.0, 10800.0/

do 10 cnt1 = 1,3
    do 10 cnt2 = 1,3
        posorb(cnt1,cnt2) = 100 * cnt1 * cnt2
```

```

10 continue

asciiutc = '1991-07-27T11:04:57.987654Z'
numvalues = 3

returnstatus = pgs_csc_orbtosc(pgsd_trmm,numvalues,
asciiutc,
                                offsets, posorb, possc)

if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err, msg
endif

```

#### **NOTES:**

#### **TIME ACRONYMS:**

UTC is:       Coordinated Universal Time

See Section 6.3.4.8 Coordinate System Conversion Tool Notes

See Section 6.2.7.5.1 (TAI-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

#### **REQUIREMENTS: PGSTK-1050**

## Transform from ECI Frame to Orbital Frame

---

**NAME:** PGS\_CSC\_ECItoORB()

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_ECItoORB(
    PGSt_tag          spacecraftTag,
    PGSt_integer      numValues,
    char              asciiUTC[28],
    PGSt_double        offsets[],
    PGSt_double        positionECI[][3],
    PGSt_double        positionORB[][3])
```

**FORTTRAN:**

```
include 'PGS_MEM_7.f'
include 'PGS_EHP_5.f'
include 'PGS_CSC_4.f'
include 'PGS_TD_3.f'
include 'PGS_TD.f'
include 'PGS_SMF.f'

integer function
pgs_csc_ecitoorb(spacecraftTag,numvalues,asciiutc,offsets,positioneci,
                positionorb)
    integer          spacecrafttag
    integer          numvalues
    character*27      asciiutc
    double precision  offsets(*)
    double precision  positioneci(3,*)
    double precision  positionorb(3,*)
```

**DESCRIPTION:** Transforms vector in ECI coordinate system to vector in Orbital coordinate system. If a unit vector is input only its direction is changed. If a vector in meters is input, it is first translated from the Earth centered system to a spacecraft centered origin, and then rotated to orbital coordinate axes.

**INPUTS:****Table 6-192. PGS\_CSC\_ECItOORB Inputs**

Name	Description	Units	Min	Max
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
numValues	number of input time offsets	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	1961-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
positionECI	coordinates or unit vector components in ECI reference frame	meters	N/A	N/A

**OUTPUTS:****Table 6-193. PGS\_CSC\_ECItOORB Outputs**

Name	Description	Units	Min	Max
positionORB	coordinates or unit vector components in orbital reference frame	meters	N/A	N/A

**RETURNS:****Table 6-194. PGS\_CSC\_ECItOORB Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSSC_W_BELOW_SURFACE	Vector magnitude indicates subsurface location specified
PGSCSC_W_BAD_TRANSFORM_VALUE	One or more values in transformation could not be determined
PGSTD_E_TIME_FMT_ERROR	Format error in asciiUTC
PGSTD_E_TIME_VALUE_ERROR	Value error in asciiUTC
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for input time
PGSMEM_E_NO_MEMORY	No memory is available to allocate vectors
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephemeris files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephemeris files could be found for input times

## EXAMPLES:

```
C:      #define      ARRAY_SIZE  3

PGSt_SMF_status   returnStatus;
PGSt_integer      numValues;
char              asciiUTC[28];
PGSt_double       offsets[ARRAY_SIZE] =
                                {3600.0,7200.0,10800.0};
PGSt_double       positionORB[ARRAY_SIZE][3] =
                                {
                                {0.5,0.75,0.90,0.3,0.2,0.8},
                                {0.65,1.2,3.65,0.1,3.2,1.7},
                                {0.98,2.6,4.78,0.2,1.5,0.9}
                                };
PGSt_double       positionORB[ARRAY_SIZE][3];

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30.123211Z");
returnStatus =
PGS_CSC_ECItOORB(PGSd_TRMM,numValues,asciiUTC,
                 offsets, positionECI,
                 positionORB)

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
       take appropriate
       action **
}

FORTRAN:  implicit none

integer      pgs_csc_ecitoorb
integer      returnstatus
integer      numvalues
character*27  asciiutc
double precision  offsets(3)
double precision  positioneci(3,3)
double precision  positionorb(3,3)
integer      cnt1
integer      cnt2
character*33  err
character*241 msg

data offsets/3600.0, 7200.0, 10800.0/
```

```

do 10 cnt1 = 1,3
  do 10 cnt2 = 1,3
    positioneci(cnt1,cnt2) = 100 * cnt1 * cnt2
10 continue

asciiutc = '1991-07-27T11:04:57.987654Z'
numvalues = 3

returnstatus = pgs_csc_ecitoorb(pgsd_trmm,numvalues,
                                asciiutc,offsets,
                                positioneci, positionorb)

if (returnstatus .ne. pgs_s_success) then
  pgs_smf_getmsg(returnstatus, err, msg)
  write(*,*) err, msg
endif

```

#### **NOTES:**

#### **TIME ACRONYMS:**

UTC is:        Coordinated Universal Time

See Section 6.3.4.8 Coordinate System Conversion Tool Notes

See Section 6.2.7.5.1 (TAI-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

#### **REQUIREMENTS:** PGSTK-1050

## Transform from Orbital Frame to ECI Frame

---

**NAME:** PGS\_CSC\_ORBtoECI()

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_ORBtoECI(
    PGSt_tag          spacecraftTag,
    PGSt_integer      numValues,
    char              asciiUTC[28],
    PGSt_double        offsets[],
    PGSt_double        positionORB[][3],
    PGSt_double        positionECI[][3])
```

**FORTTRAN:** include 'PGS\_CSC\_4.f'  
include 'PGS\_SMF.f'

```
integer function pgs_csc_orbtoeci(spacecraftTag,numvalues,asciutc,
                                offsets,positionorb,positioneci)
    integer          spacecrafttag
    integer          numvalues
    character*27      asciutc
    double precision  offsets(*)
    double precision  positionorb(3,*)
    double precision  positioneci(3,*)
```

**DESCRIPTION:** Transforms vector in Orbital coordinate system to vector in ECI coordinate system. If a unit vector is input it is simply rotated from Orbital to ECI axes. If a vector in meters is input, it is first rotated from Orbital to ECI axes and then translated from the system referenced at spacecraft center to the system referenced at Earth center.

**INPUTS:****Table 6-195. PGS\_CSC\_ORBtoECI Inputs**

Name	Description	Units	Min	Max
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
numValues	number of input time offsets	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	1961-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
positionORB	coordinates or unit vector components in Orbital reference frame	meters	N/A	N/A

**OUTPUTS:****Table 6-196. PGS\_CSC\_ORBtoECI Outputs**

Name	Description	Units	Min	Max
positionECI	coordinates or unit vector components in ECI reference frame	meters	N/A	N/A

**RETURNS:****Table 6-197. PGS\_CSC\_ORBtoECI Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSSC_W_BELOW_SURFACE	Vector magnitude indicates subsurface location specified
PGSCSC_W_BAD_TRANSFORM_VALUE	One or more values in transformation could not be determined
PGSTD_E_TIME_FMT_ERROR	Format error in asciiUTC
PGSTD_E_TIME_VALUE_ERROR	Value error in asciiUTC
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for input time
PGSMEM_E_NO_MEMORY	No memory is available to allocate vectors
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephemeris files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephemeris files could be found for input times



## EXAMPLES:

```
C:      #define      ARRAY_SIZE  3

PGSt_SMF_status   returnStatus;
PGSt_integer      numValues;
char              asciiUTC[28];
PGSt_double       offsets[ARRAY_SIZE] =
                                {3600.0,7200.0,10800.0};
PGSt_double       positionORB[ARRAY_SIZE][3] =
                                {
                                {0.5,0.75,0.90,0.3,0.2,0.8},
                                {0.65,1.2,3.65,0.1,3.2,1,7},
                                {0.98,2.6,4,78,0.2,1.5,0.9}
                                };
PGSt_double       positionECI[ARRAY_SIZE][3];

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30.123211Z");
returnStatus =
PGS_CSC_ORBtoECI(PGSd_TRMM,numValues,asciiUTC,offsets,
                 positionORB,positionECI)

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
       take appropriate
       action **
}

FORTRAN:  implicit none

integer      pgs_csc_orbtoeci
integer      returnstatus
integer      numvalues
character*27  asciiutc
double precision  offsets(3)
double precision  positionorb(3,3)
double precision  positioneci(3,3)
integer      cnt1
integer      cnt2
character*33  err
character*241 msg

data offsets/3600.0, 7200.0, 10800.0/
```

```

do 10 cnt1 = 1,3
  do 10 cnt2 = 1,3
    positionorb(cnt1,cnt2) = 100 * cnt1 * cnt2
10 continue

asciutc = '1991-07-27T11:04:57.987654Z'
numvalues = 3

returnstatus = pgs_csc_orbtoeci(pgsd_trmm,numvalues,
                                asciutc,offsets,
                                positionorb,positioneci)

if (returnstatus .ne. pgs_s_success) then
  pgs_smf_getmsg(returnstatus, err, msg)
  write(*,*) err, msg
endif

```

**NOTES:**

**TIME ACRONYMS:**

UTC is:        Coordinated Universal Time

See Section 6.3.4.8 Coordinate System Conversion Tool Notes

See Section 6.2.7.5.1 (TAI-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

**REQUIREMENTS:** PGSTK-1050

### 6.3.4.10 Coordinate System Conversion—Other Tools

These tools provide other location and orientation information to the user.

#### Get Sub–Satellite Point Position and Velocity

---

**NAME:** PGS\_CSC\_SubSatPoint( )

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_SubSatPoint(
    PGSt_tag          spacecraftTag,
    PGSt_integer      numValues,
    char              asciiUTC[28],
    PGSt_double       offsets[],
    char              earthEllipsTag[50],
    PGSt_boolean      velFlag,
    PGSt_double       latitude[],
    PGSt_double       longitude[],
    PGSt_double       altitude[],
    PGSt_double       velSub[][3])
```

**FORTTRAN:**

```
include 'PGS_SMF.f'
include 'PGS_EPH_5.f'
include 'PGS_CSC_4.f'
include 'PGS_TD_3.f'
include 'PGS_TD.f'
include 'PGS_MEM_7.f'

integer function
pgs_csc_subsatpoint(spacecrafttag,numvalues,asciiutc,offsets,
                    earthellipstag,velflag,latitude,longitude,
                    altitude,velsub)

integer          spacecrafttag
integer          numvalues
character*27     asciiutc
double precision offsets(*)
character*49     earthellipstag
integer          velflag
double precision latitude(*)
```

double precision	longitude(*)
double precision	altitude(*)
integer	velsub(3,*)

**DESCRIPTION:** This tool finds the latitude, longitude, and altitude of the subsatellite points at the input times/offsets and, optionally, returns North and East components of each subsatellite point. The third component returned for each subsatellite point, when velocity is requested, is the rate of change of the spacecraft altitude off the Earth ellipsoid (as would be measured by a Doppler radar altimeter, ignoring terrain).

**INPUTS:**

**Table 6-198. PGS\_CSC\_SubSatPoint Inputs**

Name	Description	Units	Min	Max
spacecraftTag	spacecraft identifier	N/A	N/A	N/A
numValues	number of input offset times	N/A	0	any
asciiUTC	timesstart UTC time in CCSDS ASCII Time Code (A or B format)	N/A	1979-06-30	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC + offset is between Min and Max values	
earthEllipsTag	tag selecting Earth ellipsoid model (default is WGS84)	N/A	N/A	N/A
velFlag	flag indicating whether to return the velocity of the subsatellite points	N/A	PGS_FALSE	PGS_TRUE

**OUTPUTS:**

**Table 6-199. PGS\_CSC\_SubSatPoint Outputs**

Name	Description	Units	Min	Max
latitude	array of subsatellite point geodetic latitudes	radians	-pi/2	pi/2
longitude	array of subsatellite point longitudes	radians	-pi	pi
altitude	array of spacecraft altitudes	m	250000	10000000
velSub[0]	North component of the subsatellite point velocity on the ellipsoid	m/s	-7000	7000
velSub[1]	East component of the subsatellite point velocity on the ellipsoid	m/s	-7000	7000
velSub[2]	rate of change of spacecraft altitude relative to nadir on the ellipsoid	m/s	-200	200

## RETURNS:

**Table 6-200. PGS\_CSC\_SubSatPoint Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSCSC_W_ERROR_IN_SUBSATPT	An error occurred in computing at least one subsatellite point
PGSCSC_W_PREDICTED_UT1	At least one of the values obtained from the utcpole.dat file is 'predicted'
PGSCSC_W_PROLATE_BODY	Using a prolate Earth model
PGSCSC_W_SPHERE_BODY	Using a spherical Earth model
PGSCSC_W_LARGE_FLATTENING	Issued if flattening factor is greater than 0.01
PGSCSC_W_DEFAULT_EARTH_MODEL	Default Earth model was used
PGSCSC_W_ZERO_JACOBIAN_DET	Jacobian determinant is close to zero
PGSCSC_E_BAD_ARRAY_SIZE	numValues (and array size) is less than zero
PGSMEM_E_NO_MEMORY	No memory available to allocate vectors
PGSTD_E_SC_TAG_UNKNOWN	Invalid spacecraft tag
PGSEPH_E_BAD_EPHEM_FILE_HEADER	No spacecraft ephemeris files had reasonable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No spacecraft ephemeris files could be found for input
PGSTD_E_TIME_FMT_ERROR	Format error in input asciiUTC
PGSTD_E_TIME_VALUE_ERROR	Error in one of time values in asciiUTC
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for at least one of the input times/offsets—a linear approximation was used to obtain the leapsec value
PGSTD_E_NO_UT1_VALUE	No UT1–UTC correction available
PGSTD_E_BAD_EARTH_MODEL	The equatorial or polar radius is negative or zero OR the radii define a prolate Earth
PGS_E_TOOLKIT	Something unexpected happened—execution aborted

## EXAMPLES:

```
C:          #define      ARRAY_SIZE  3

PGSt_SMF_status  returnStatus;
PGSt_tag         spacecraftTag = PGSD_EOS_AM;
PGSt_integer     numValues;
char            asciiUTC[28];
PGSt_double      offsets[ARRAY_SIZE] =
                {3600.0,7200.0,10800.0};
char            earthEllipsTag[50];
PGSt_boolean     velFlag = PGS_TRUE;
PGSt_double      latitude[ARRAY_SIZE];
```

```

PGSt_double      longitude[ARRAY_SIZE];
PGSt_double      altitude[ARRAY_SIZE];
PGSt_double      velSub[ARRAY_SIZE][3];
PGSt_integer      counter;

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30");
strcpy(earthEllipsTag,"WGS84");

returnStatus = PGS_CSC_SubSatPoint(spacecraftTag,numValues,
                                   asciiUTC,offsets,
                                   earthEllipseTag,velFlag,
                                   latitude,longitude,
                                   altitude,velSub);

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
       take appropriate
       action **
}
printf("start time:%s",asciiUTC);
counter = 0;
while(counter <= numValues)
{
    printf("Offset:  %lf  Latitude:  %lf  Longitude:  %lf
           Altitude:  %lf",  offset[counter],
           latitude[counter], longitude[counter],
           altitude[counter]);
    printf("Velocity of subsatellite point
           (North,East,altitude): %lf, %lf, %lf"  " m/s",
           velSub[counter][0], velSub[counter][1],
           velSub[counter][2]);

    counter++;
}

```

FORTTRAN:

```

implicit none

integer      pgs_csc_subsatpoint
integer      array_size
integer      spacecrafttag
integer      numvalues
character*27  asciutc
double precision  offsets(array_size)
character*49  earthellipstag
integer      velflag

```

```

double precision  latitude(array_size)
double precision  longitude(array_size)
double precision  altitude(array_size)
double precision  velsub(3,array_size)
integer           returnstatus
integer           counter

data offsets/3600.0,7200.0,10800.0/
data earthelliptag/'WGS84'/',velflag/PGS_TRUE/
array_size = 3
numvalues = array_size
spacecrafttag = pgsd_eos_am
asciiutc = '1991-01-01T11:29:30'

returnstatus = pgs_csc_subsatpoint(spacecrafttag,numvalues,
                                   asciiutc,offsets,
                                   earthelliptag,velflag,
                                   latitude,longitude,
                                   altitude,velsub)

if(returnstatus .ne. pgs_s_success) go to 90
write(6,*) asciiutc
do 40 counter = 0,numvalues,1
    write(6,*)offsets(counter), latitude(counter),
           longitude(counter), altitude(counter),
           velsub(1,counter), velsub(2,counter),
           velsub(3,counter)

40 continue

90 write(6,99)returnstatus

99 format('ERROR:',I50)

```

## NOTES:

If an error occurs during computation for one or more input times but does not necessarily affect all input times, latitude, longitude, altitude, and velocity values of PGSd\_GEO\_ERROR\_VALUE are returned for the input times where the error occurred. An indication that an error occurred in this tool is returned in the returnStatus value, and a description of the error is returned in the corresponding message.

If an invalid earthEllipsTag is input, the program will use the WGS84 Earth model by default.

The option to obtain velocity is controlled by setting the velocity flag velFlag to either PGS\_TRUE or PGS\_FALSE. If velFlag is PGS\_FALSE, all components of velSub will be set to zero. If the velocity is not needed it is recommended to use PGS\_FALSE to speed the execution of the code.

The horizontal velocity calculated in function PGS\_CSC\_SubSatPointVel() is that of a mathematical point on the Earth at (nominal) spacecraft nadir, and not that of any material object. It is orthogonal to nadir, so is suitable as a descriptor of ground track but not for Doppler work.

The third (vertical) component of velocity is useful for Doppler work at nadir, but Doppler velocity along ANY look vector (not just nadir) is provided in the lookpoint algorithm in the function PGS\_CSC\_GetFOV\_Pixel().

The condition PGSCSC\_W\_ZERO\_JACOBIAN\_DET is not expected to occur. Its appearance would indicate that the geometry is singular: the altitude of the spacecraft is zero or the spacecraft is exactly at the north or south pole, for example.

#### **TIME ACRONYMS:**

UT1 is: Universal Time

UTC is: Coordinated Universal Time

See Section 6.3.4.8 Coordinate System Conversion Tool Notes

See Section 6.2.7.5.2 (UT1-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

#### **REFERENCES FOR TIME:**

CCSDS 301.0-B-2 (CCSDS => Consultative Committee for Space Data Systems) Astronomical Almanac, Explanatory Supplement to the Astronomical Almanac.

**REQUIREMENTS:** PGSTK-0930, PGSTK-1060



## Get Times of Earth Point in Fixed Field of View

---

**NAME:** PGS\_CSC\_Earthpt\_FixedFOV()

**SYNOPSIS:**

C:

```
#include <PGS_TD.h>
#include <PGS_CSC.h>
#include <PGS_EPH.h>
#include <PGS_MEM.h>

PGSt_SMF_status
PGS_CSC_Earthpt_FixedFOV(
    PGSt_integer    numValues,
    char            asciiUTC[28],
    PGSt_double     offsets[],
    PGSt_tag         spacecraftTag,
    char            *earthEllipsTag,
    PGSt_double     latitude,
    PGSt_double     longitude,
    PGSt_double     altitude,
    PGSt_integer     numFOVperimVec,
    PGSt_double     inFOVvector[3],
    PGSt_double     perimFOV_vectors[][3],
    PGSt_boolean     inFOVflag[],
    PGSt_double     sctoEarthptVec[][3])
```

FORTTRAN:

```
include'PGS_TD_3.f'
include'PGS_CSC_4.f'
include'PGS_EPH_5.f'
include'PGS_MEM_7.f'
include'PGS_TD.f'
include'PGS_SMF.f'

integer function pgs_csc_earthpt_fixedfov(numvalues,asciutc,offsets,
                                         spacecrafttag,earthellipstag,latitude,
                                         longitude,altitude,numfovperimvec,
                                         infovvector,perimfov_vectors,
                                         infovflag,sctoearthptvec)

    integer    numvalues
    character*27 asciutc
    double precision offsets(*)
    integer    spacecrafttag
    character*49 earthellipstag
```

double precision	latitude
double precision	longitude
double precision	altitude
integer	numfovperimvec
double precision	infovvector(3)
double precision	perimfov_vectors(3,*)
integer	infovflag(*)
double precision	sctoearthptvec(3,*)

**DESCRIPTION:** For each time value, the tool, using the FOV description, returns a flag or flags indicating if the Earth point of given latitude, longitude and altitude is in the FOV, and the vector to that point from the SC in SC coordinates.

**INPUTS:**

**Table 6-201. PGS\_CSC\_Earthpt\_FixedFOV Inputs**

Name	Description	Units	Min	Max
numValues	number of time gridpoints	N/A	0	any
asciiUTC	UTC start time	N/A	1972-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
earthEllipsTag	Earth model used	N/A	N/A	N/A
latitude	latitude of Earth point	radians	-pi/2	+pi/2
longitude	longitude of Earth point	radians	-2*pi	+2*pi
altitude	altitude of Earth point	meters	-50000	100000
numFOVperimVec	number of vectors defining FOV perimeter	N/A	3	any
inFOVvector	vector in FOV—preferably near the center in SC coordinates	N/A	N/A	N/A
perimFOV_vectors	vectors in SC coords defining FOV's; MUST be sequential around FOV; the middle dimension must be exactly the same as numFOVperimVec because of the way the array dimensioning works in the function	N/A	N/A	N/A

## OUTPUTS:

**Table 6-202. PGS\_CSC\_Earthpt\_FixedFOV Outputs**

Name	Description	Units	Min	Max
inFOVflag	PGS_TRUE if Earth point is in FOV—see notes	n/a	n/a	n/a
sctoEarthptVec	vector to Earth point in SC coords—returned normalized	meters	-1	1

## RETURNS:

**Table 6-203. PGS\_CSC\_Earthpt\_FixedFOV Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSCSC_W_BELOW_SURFACE	Location is below surface
PGSCSC_W_BAD_TRANSFORM_VALUE	One or more values in transformation could not be determined
PGSTD_E_BAD_INITIAL_TIME	Initial time is incorrect
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for input time
PGSCSC_W_DEFAULT_EARTH_MODEL	The default Earth model is used because a correct one was not specified
PGSCSC_W_DATA_FILE_MISSING	The data file earthfigure.dat is missing
PGSCSC_W_SPHERICAL_BODY	Using a spherical Earth model
PGSCSC_W_PROLATE_BODY	Using a prolate Earth model
PGSCSC_W_LARGE_FLATTENING	Issued if flattening factor is greater than 0.01
PGSCSC_E_INVALID_ALTITUDE	An invalid altitude was specified
PGSCSC_E_NEG_OR_ZERO_RAD	The equatorial or polar radius is negative or zero
PGSMEM_E_NO_MEMORY	No memory is available to allocate vectors
PGSCSC_E_BAD_ARRAY_SIZE	Incorrect array size
PGSCSC_W_PREDICTED_UT1	Status of UT1–UTC correction is predicted
PGSTD_E_NO_UT1_VALUE	No UT1–UTC correction available
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephemeris files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephemeris files could be found for input times
PGSCSC_E_INVALID_FOV_DATA	FOV perimeter vectors are invalid
PGSCSC_E_FOV_TOO_LARGE	FOV specification outside algorithmic limits
PGSCSC_E_INVALID_EARTH_PT	One of the Earth point vectors was zero
PGSCSC_W_ZERO_PIXEL_VECTOR	Instrument pixel vector of zero length
PGSCSC_W_BAD_EPH_FOR_PIXEL	Ephemeris Data missing for some pixels

## EXAMPLES:

```
C:      #define    ARRAY_SIZE    3
      #define    PERIMVEC_SIZE  4
      PGSt_SMF_status    returnStatus;
      char               asciiUTC[28];
      PGSt_double        offsets[ARRAY_SIZE] =
                              {3600.0,7200.0,10800.0};

      PGSt_integer       numValues;
      PGSt_double        latitude;
      PGSt_double        longitude;
      PGSt_double        altitude;
      PGSt_integer       numFOVperimVec;
      PGSt_double        inFOVvector[3] =
                              { {0.0,0.0,100.0},
                                };

      PGSt_double        perimFOV_vectors[PERIMVEC_SIZE][3]=
                              { {100.0,100.0,100.0},
                                {-100.0,100.0,100.0},
                                {-100.0,-100.0,100.0},
                                {100.0,-100.0,100.0} };

      PGSt_boolean       inFOVflag[ARRAY_SIZE];
      PGSt_double        sctoEarthptVec[ARRAY_SIZE][3];

      numValues = ARRAY_SIZE;
      numFOVperimVec = PERIMVEC_SIZE;
      strcpy(asciiUTC,"1995-06-21T11:29:30.123211Z");
      altitude = 10000.0;
      latitude = 0.32;
      longitude = 2.333;
      returnStatus =
      PGS_CSC_Earthpt_FixedFOV(numValues,asciiUTC,offsets,
                              PGSt_TRMM,"WGS84",latitude,
                              longitude,altitude,numFOVperimVec,
                              inFOVvector,perimFOV_vectors,inFOVflag,
                              sctoEarthptVec)

      if(returnStatus != PGS_S_SUCCESS)
      {
          ** test errors,
             take appropriate
             action **
      }
```

```

FORTRAN:      implicit none

               integer      pgs_csc_earthpt_fixedfov
               integer      returnstatus
               integer      numvalues
               character*27  startutc
               double precision  offsets(3)
               double precision  latitude
               double precision  longitude
               double precision  altitude
               integer      numfovperimvec
               double precision  infovvector(3)
               double precision  perimfov_vectors(3,4)
               integer      infovflag(3)
               double precision  sctoearthptvec(3,3)
               integer      cnt1
               integer      cnt2
               character*33  err
               character*241  msg

               data offsets/3600.0, 7200.0, 10800.0/

               perimfov_vectors(1,1) = 100.0
               perimfov_vectors(2,1) = 100.0
               perimfov_vectors(3,1) = 100.0

               perimfov_vectors(1,2) = -100.0
               perimfov_vectors(2,2) = 100.0
               perimfov_vectors(3,2) = 100.0

               perimfov_vectors(1,3) = -100.0
               perimfov_vectors(2,3) = -100.0
               perimfov_vectors(3,3) = 100.0

               perimfov_vectors(1,4) = 100.0
               perimfov_vectors(2,4) = -100.0
               perimfov_vectors(3,4) = 100.0

               infovvector(1) = 0.0
               infovvector(2) = 0.0
               infovvector(3) = 100.0

               asciiutc = '1995-06-21T11:04:57.987654Z'
               numvalues = 3
               numfovperimvec = 4
               altitude = 10000.0
               latitude = 0.32
               longitude = 2.333

```

```

returnstatus =
pgs_csc_earthpt_fixedfov(numvalues,startutc,offsets,
                        PGSD_TRMM,'WGS84',latitude,
                        longitude,altitude,numfovperimvec,
                        infovvector,perimfov_vectors,
                        infovflag,sctoearthptvec)

if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err, msg
endif

```

## NOTES:

At each time, the tool determines if the Earth point at (latitude, longitude, altitude) is in the FOV, setting inFOVflag = PGS\_TRUE if so, else PGS\_FALSE. The vector from SC to Earth point is also returned, whether or not the Earth point is in the FOV, and even if it is on the far side of the Earth. Test for the spacecraft to Earth point being equal to 1.0e50 to avoid processing Earth points that could not be determined because of one or more errors in the transformation.

The FOV is always specified and fixed in SC coordinates. numFOVperimVec should be at least 3. The tool determines if the Earth point lies within the perimeter defined by the vectors perimFOVvectors[][3]. The first index in C (last in FORTRAN) runs around the perimeter and must be sequential. If the altitude is unknown use zero.

The vector inFOVvector[3] must be defined in SC coordinates and must lie within the FOV. It is necessary for the user to supply a vector within the FOV because on the surface of a sphere, a closed curve or "perimeter" does not have an inside nor outside, except by arbitrary definition; i.e., this vector tells the algorithm which part of sky is inside the FOV, which outside. If the vector is well centered in the FOV, the algorithm will be faster.

The vectors "perimFOV\_vectors[][3]" defining the FOV perimeter can be in clock or counter-clockwise sequence. If the FOV perimeter vectors are supplied out of order, the algorithm will run but the results are unpredictable. The input vectors need not be normalized but must not be zero.

See Section 6.3.4.8 Conversion System Coordinate Tool Notes

See Section 6.2.7.5.1 (UT1-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

## REQUIREMENTS: PGSTK-1090

## Get Times of Earth Point in Field of View

---

**NAME:**                **PGS\_CSC\_Earthpt\_FOV( )**

**SYNOPSIS:**

```
C:
#include <PGS_TD.h>
#include <PGS_CSC.h>
#include <PGS_EPH.h>
#include <PGS_MEM.h>

PGSt_SMF_status
PGS_CSC_Earthpt_FOV(
    PGSt_integer      numValues,
    char              asciiUTC[28],
    PGSt_double        offsets[],
    PGSt_tag           spacecraftTag,
    char              *earthEllipsTag,
    PGSt_double        latitude,
    PGSt_double        longitude,
    PGSt_double        altitude,
    PGSt_integer       numFOVperimVec,
    PGSt_double        inFOVvector[][3],
    void              *perimFOV_vectors,
    PGSt_boolean       inFOVflag[],
    PGSt_double        sctoEarthptVec[][3])
```

```
FORTRAN:
include'PGS_TD_3.f'
include'PGS_CSC_4.f'
include'PGS_EPH_5.f'
include'PGS_MEM_7.f'
include'PGS_TD.f'
include'PGS_SMF.f'

integer function pgs_csc_earthpt_fov(numvalues,asciutc,offsets,
                                     spacecrafttag,earthelliptag,latitude,
                                     longitude,altitude,numfovperimvec,
                                     infovvector,perimfov_vectors,
                                     infovflag,sctoearthptvec)

    integer      numvalues
    character*27 asciutc
    double precision offsets(*)
    integer      spacecrafttag
    character*49 earthelliptag
```

double precision	latitude
double precision	longitude
double precision	altitude
integer	numfovperimvec
double precision	infovvector(3,*)
double precision	perimfov_vectors(3,*,*)
integer	infovflag(*)
double precision	sctoearthptvec(3,*)

**DESCRIPTION:** For each time value, the tool, using the FOV description, returns a flag or flags indicating if the Earth point of given latitude, longitude and altitude is in the FOV, and a unit vector to that point from the SC in SC coordinates.

**INPUTS:**

**Table 6-204. PGS\_CSC\_Earthpt\_FOV Inputs**

Name	Description	Units	Min	Max
numValues	number of time gridpoints	N/A	0	any
asciiUTC	UTC start time	N/A	1972-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+offset is between asciiUTC Min and Max values	
spacecraftTag	unique spacecraft identifier	N/A	N/A	N/A
earthEllipsTag	Earth model used	N/A	N/A	N/A
latitude	latitude of Earth point	radians	-pi/2	+pi/2
longitude	longitude of Earth point	radians	-2*pi	+2*pi
altitude	altitude of Earth point	meters	-50000	100000
numFOVperimVec	number of vectors defining FOV perimeter	N/A	3	any
inFOVvector	vector in FOV—preferably near the center in SC coordinates	N/A	N/A	N/A
perimFOV_vectors	vectors in SC coords defining FOV's; MUST be sequential around FOV; the middle dimension must be exactly the same as numFOVperimVec because of the way the array dimensioning works in the function	N/A	N/A	N/A



## OUTPUTS:

**Table 6-205. PGS\_CSC\_Earthpt\_FOV Outputs**

Name	Description	Units	Min	Max
inFOVflag	PGS_TRUE if Earth point is in FOV—see notes	n/a	n/a	n/a
sctoEarthptVec	vector to Earth point in SC coords—returned normalized	meters	-1	1

## RETURNS:

**Table 6-206. PGS\_CSC\_Earthpt\_FOV Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSCSC_W_BELOW_SURFACE	Location is below surface
PGSCSC_W_BAD_TRANSFORM_VALUE	One or more values in transformation could not be determined
PGSTD_E_BAD_INITIAL_TIME	Initial time is incorrect
PGSTD_E_NO_LEAP_SECS	No leap seconds correction available for input time
PGSCSC_W_DEFAULT_EARTH_MODEL	The default Earth model is used because a correct one was not specified
PGSCSC_W_DATA_FILE_MISSING	The data file earthfigure.dat is missing
PGSCSC_W_SPHERICAL_BODY	Using a spherical Earth model
PGSCSC_W_PROLATE_BODY	Using a prolate Earth model
PGSCSC_W_LARGE_FLATTENING	Issued if flattening factor is greater than 0.01
PGSCSC_E_INVALID_ALTITUDE	An invalid altitude was specified
PGSCSC_E_NEG_OR_ZERO_RAD	The equatorial or polar radius is negative or zero
PGSMEM_E_NO_MEMORY	No memory is available to allocate vectors
PGSCSC_E_BAD_ARRAY_SIZE	Incorrect array size
PGSCSC_W_PREDICTED_UT1	Status of UT1–UTC correction is predicted
PGSTD_E_NO_UT1_VALUE	No UT1–UTC correction available
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephemeris files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephemeris files could be found for input times
PGSCSC_E_INVALID_FOV_DATA	FOV perimeter vectors are invalid
PGSCSC_E_FOV_TOO_LARGE	FOV specification outside algorithmic limits
PGSCSC_E_INVALID_EARTH_PT	One of the Earth point vectors was zero
PGSCSC_W_ZERO_PIXEL_VECTOR	Instrument pixel vector of zero length
PGSCSC_W_BAD_EPH_FOR_PIXEL	Ephemeris Data missing for some pixels

## EXAMPLES:

```
C:      #define    ARRAY_SIZE    3
      #define    PERIMVEC_SIZE  4
      PGSt_SMF_status    returnStatus;
      char                asciiUTC[28];
      PGSt_double         offsets[ARRAY_SIZE] =
                                {3600.0,7200.0,10800.0};
      PGSt_integer        numValues;
      PGSt_double         latitude;
      PGSt_double         longitude;
      PGSt_double         altitude;
      PGSt_integer        numFOVperimVec;
      PGSt_double         inFOVvector[ARRAY_SIZE][3] =
                                { {0.0,0.0,100.0},
                                  {0.0,0.0,200.0},
                                  {0.0,0.0,300.0}
                                };
      PGSt_double
      perimFOV_vectors[ARRAY_SIZE][PERIMVEC_SIZE][3]=
                                { {100.0,100.0,100.0},
                                  {-100.0,100.0,100.0},
                                  {-100.0,-100.0,100.0},
                                  {100.0,-100.0,100.0},
                                  {200.0,200.0,200.0},
                                  {-200.0,200.0,200.0},
                                  {-200.0,-200.0,200.0},
                                  {200.0,-200.0,200.0},
                                  {300.0,200.0,200.0},
                                  {-200.0,300.0,200.0},
                                  {-200.0,-300.0,300.0},
                                  {300.0,-200.0,200.0},
                                };
      PGSt_boolean        inFOVflag[ARRAY_SIZE];
      PGSt_double         sctoEarthptVec[ARRAY_SIZE][3];

      numValues = ARRAY_SIZE;
      numFOVperimVec = PERIMVEC_SIZE;
      strcpy(asciiUTC,"1995-06-21T11:29:30.123211Z");
      altitude = 10000.0;
      latitude = 0.32;
      longitude = 2.333;
      returnStatus =
      PGS_CSC_Earthpt_FOV(numValues,asciiUTC,offsets,
                          PGSD_TRMM,"WGS84",latitude,
```

```

                                longitude,altitude,numFOVperimVec,
                                inFOVvector,perimFOV_vectors,inFOVflag,
                                sctoEarthptVec)
if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
        take appropriate
        action **
}

```

FORTTRAN:

```

implicit none

integer          pgs_csc_earthpt_fov
integer          returnstatus
integer          numvalues
character*27     startutc
double precision offsets(3)
double precision latitude
double precision longitude
double precision altitude
integer          numfovperimvec
double precision infovvector(3,4)
double precision perimfov_vectors(3,4,3)
integer          infovflag(3)
double precision sctoearthptvec(3,3)
integer          cnt1
integer          cnt2
character*33     err
character*241    msg

data offsets/3600.0, 7200.0, 10800.0/

perimfov_vectors(1,1,1) = 100.0
perimfov_vectors(2,1,1) = 100.0
perimfov_vectors(3,1,1) = 100.0

perimfov_vectors(1,2,1) = -100.0
perimfov_vectors(2,2,1) = 100.0
perimfov_vectors(3,2,1) = 100.0

perimfov_vectors(1,3,1) = -100.0
perimfov_vectors(2,3,1) = -100.0
perimfov_vectors(3,3,1) = 100.0

perimfov_vectors(1,4,1) = 100.0
perimfov_vectors(2,4,1) = -100.0
perimfov_vectors(3,4,1) = 100.0

```

```

perimfov_vectors(1,1,2) = 200.0
perimfov_vectors(2,1,2) = 200.0
perimfov_vectors(3,1,2) = 200.0

perimfov_vectors(1,2,2) = -200.0
perimfov_vectors(2,2,2) = 200.0
perimfov_vectors(3,2,2) = 200.0

perimfov_vectors(1,3,2) = -200.0
perimfov_vectors(2,3,2) = -200.0
perimfov_vectors(3,3,2) = 200.0

perimfov_vectors(1,4,2) = 200.0
perimfov_vectors(2,4,2) = -200.0
perimfov_vectors(3,4,2) = 200.0

perimfov_vectors(1,1,3) = 300.0
perimfov_vectors(2,1,3) = 300.0
perimfov_vectors(3,1,3) = 300.0

perimfov_vectors(1,2,3) = -300.0
perimfov_vectors(2,2,3) = 300.0
perimfov_vectors(3,2,3) = 300.0

perimfov_vectors(1,3,3) = -300.0
perimfov_vectors(2,3,3) = -300.0
perimfov_vectors(3,3,3) = 300.0

perimfov_vectors(1,4,3) = 300.0
perimfov_vectors(2,4,3) = -300.0
perimfov_vectors(3,4,3) = 300.0

infovvector(1,1) = 0.0
infovvector(1,2) = 0.0
infovvector(1,3) = 100.0

infovvector(2,1) = 0.0
infovvector(2,2) = 0.0
infovvector(2,3) = 200.0

infovvector(3,1) = 0.0
infovvector(3,2) = 0.0
infovvector(3,3) = 300.0

asciiutc = '1995-06-21T11:04:57.987654Z'
numvalues = 3
numfovperimvec = 4
altitude = 10000.0

```

```

latitude = 0.32
longitude = 2.333

returnstatus =
pgs_csc_earthpt_fov(numvalues,startutc,offsets,
                    PGSD_TRMM,'WGS84',latitude,
                    longitude,altitude,numfovperimvec,
                    infovvector,perimfov_vectors,
                    infovflag,sctoearthptvec)

if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err, msg
endif

```

## NOTES:

At each time, the tool determines if the Earth point at (latitude, longitude, altitude) is in the FOV, setting inFOVflag = PGS\_TRUE if so, else PGS\_FALSE. The vector from SC to Earth point is also returned, whether or not the Earth point is in the FOV, and even if it is on the far side of the Earth. Test for the spacecraft to Earth point being equal to 1.0e50 to avoid processing Earth points that could not be determined because of one or more errors in the transformation.

The FOV is always specified in SC coordinates. For an instrument fixed to the SC, use the same FOV description always. For scanning instruments, user should provide the description appropriate to the scan instrument. numFOVperimVec should be at least 3. The tool determines if the Earth point lies within the perimeter defined by the vectors perim-FOVvectors[][][3]. The first index in C (last in FORTRAN) is the time offset index and the second must be sequential around the FOV perimeter. If the altitude is unknown use zero.

The vector inFOVvector[][][3] must be defined in SC coordinates and must lie within the FOV. The last index in C, (first in FORTRAN) on these vectors is for X,Y, and Z, components in SC coordinates. It is necessary for the user to supply a vector within the FOV because on the surface of a sphere, a closed curve or "perimeter" does not have an inside nor outside, except by arbitrary definition; i.e., this vector tells the algorithm which part of sky is inside the FOV, which outside. If the vector is well centered in the FOV, the algorithm will be faster.

The vectors "perimFOV\_vectors[][][3]" defining the FOV perimeter can be in clock or counter-clockwise sequence. If the FOV perimeter vectors are supplied out of order, the algorithm will run but the results are unpredictable. The input vectors need not be normalized but must not be zero.

See Section 6.3.4.8 Conversion System Coordinate Tool Notes

See Section 6.2.7.5.1 (UT1-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

**REQUIREMENTS:** PGSTK–1090

## Estimate Refraction of Ray

---

**NAME:** PGS\_CSC\_SpaceRefract( )

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_SpaceRefract(
    PGSt_double spaceZenith,
    PGSt_double altitude,
    PGSt_double latitude,
    PGSt_double *surfaceZenith,
    PGSt_double *displacement)
```

**FORTTRAN:**

```
include 'PGS_CSC_4.f'
include 'PGS_TD.f'
include 'PGS_SMF.f'

integer function pgs_csc_spacerefract(spacezenith,altitude,
                                     latitude,surfacezenith, displacement)

    double precision    spacezenith
    double precision    altitude
    double precision    latitude
    double precision    surfacezenith
    double precision    displacement
```

**DESCRIPTION:** This function estimates the refraction of a ray incident from space or a line of sight from space to the Earth's surface based on the unrefracted zenith angle (most common algorithms, intended for ground based observation, require knowledge of the refracted, not the unrefracted zenith angle). The algorithm is suitable for:

- a. approximate determination of the apparent Solar zenith angle from the true (geometrical, unrefracted) Solar zenith angle (obviously, also applicable to Lunar zenith angle, etc.)
- b. correction of the viewing angle from space, to approximately remove the effects of refraction

The method is briefly indicated in the NOTES, q.v. for various caveats.

## INPUTS:

**Table 6-207. PGS\_CSC\_SpaceRefract Inputs**

Name	Description	Units	Min	Max
spaceZenith	unrefracted zenith angle	radians	0	pi/2 (90 deg)
altitude	altitude off the geoid	meters	-1000	50000
latitude	latitude	radians	-pi/2	pi/2

## OUTPUTS:

**Table 6-208. PGS\_CSC\_SpaceRefract Outputs**

Name	Description	Units	Min	Max
surfaceZenith	refracted zenith angle	radians	0	n/a
displacement	displacement of the footpoint of ray	radians	0	~0.01

## RETURNS:

**Table 6-209. PGS\_CSC\_SpaceRefract Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGS_CSC_BAD_LAT	a latitude out of the range ( $-\pi/2$ , $\pi/2$ ) was entered
PGS_CSC_E_INVALID_ZENITH	a negative zenith angle was entered
PGSCSC_W_INVALID_ALTITUDE	Attempt to calculate refraction at point too far below Earth's surface
PGSCSC_W_BELOW_HORIZON	Attempt to calculate refraction of ray below horizon

## EXAMPLES:

```
C:          PGSt_SMF_status   returnStatus;
          PGSt_double spaceZenith=0.4;
          PGSt_double altitude=5000.0;
          PGSt_double latitude= - 0.2 ;   **** not implemented at
                                           present ***

          PGSt_double surfaceZenith;
          PGSt_double displacement;

          returnStatus = PGS_CSC_SpaceRefract(spaceZenith,altitude,
                                           latitude,&surfaceZenith,
                                           &displacement)
```



```

{
  ** test errors,
    take appropriate
    action **
}

```

FORTRAN:

```

implicit none

integer          pgs_csc_spacerefract
integer          returnstatus
double precision spacezenith
double precision altitude
double precision latitude
double precision surfacezenith
double precision displacement

data spacezenith /0.4/
data altitude /5000.0/
data latitude /-0.2/

returnstatus = pgs_csc_spacerefract(spacezenith,altitude,
                                     latitude,surfacezenith,
                                     displacement)

if(returnstatus .ne. pgs_s_success) go to 90
write(6,*) surfacezenith,displacement

90  write(6,99)returnstatus
99  format('ERROR:',I15)

```

NOTES:

This algorithm is intended as a mean-atmosphere approximation, valid for white light (for example, sunlight). Refraction is quite wavelength dependent, and in the atmosphere it will also depend strongly on local conditions (e.g., the weather). The present algorithm is intended to be a reasonable approximation such that to do better one would need local and, for large zenith angles, regional weather.

Caveat: The altitude is used ONLY to obtain the air pressure, which is then used to obtain the surface index of refraction. Users who employ an inflated Earth radius in geolocation should be especially careful to replace any derived altitude with the height in meters above the geoid before calling this function.

The method is based on the author's calculations, using a conservation law originally due to W. Chauvenet, for the important difference  $z_0 - z'$ , and an empirical refraction algorithm in Equation 3.283-1, p. 144, Astron. Almanac Supplement (U.S. Naval Observatory) to derive the less important displacement.

The (horizontal) displacement of the ray is in a vertical plane containing the ray and is in the sense that the actual (refracted) ray will meet the

Earth  $d = (\text{displacement}) \times R_e$  meters from the geometrical (unrefracted) position, on the side towards the horizon.

Outer Space Here

. unrefracted ray

refracted ray .\*

. \* unrefracted ray

\_\_\_\_\_.\*\_\_\_\_\_ Earth surface  
d

the angle "displacement" is the angle that the displacement in meters "d" subtends at Earth center.

The following table exemplifies results at sea level, using a conversion of 6371000 m per radian on the displacement.

**Table 6-210. Altitude – Sea Level**

Zenith Angle in Space (deg)	Zenith Angle at Surface (deg)	Refraction (deg)	Linear Displacement (meters)
10.000000	9.997066	0.002934	0.549064
20.000000	19.993944	0.006056	1.222937
30.000000	29.990394	0.009606	2.221314
40.000000	39.986039	0.013961	3.982978
45.000000	44.983363	0.016637	5.464087
50.000000	49.980174	0.019826	7.725334
55.000000	54.976243	0.023757	11.398788
60.000000	59.971192	0.028808	17.845724
61.000000	60.969996	0.030004	19.696711
62.000000	61.968722	0.031278	21.816620
63.000000	62.967361	0.032639	24.256691
64.000000	63.965905	0.034095	27.080360
65.000000	64.964340	0.035660	30.366779
70.000000	69.954333	0.045667	58.380584
75.000000	74.938025	0.061975	136.072953
76.000000	75.933417	0.066583	166.728721
77.000000	76.928121	0.071879	207.384912
78.000000	77.921967	0.078033	262.469333
79.000000	78.914723	0.085277	338.977167
80.000000	79.906069	0.093931	448.379942
81.000000	80.895543	0.104457	610.332976
82.000000	81.882461	0.117539	860.316290
83.000000	82.865762	0.134238	1266.536004
84.000000	83.843713	0.156287	1970.638000
85.000000	84.813286	0.186714	2974.066487
86.000000	85.768718	0.231282	4858.394025
87.000000	86.697712	0.302288	8677.416632
88.000000	87.569758	0.430242	17538.457911
89.000000	88.295108	0.704892	41818.325388
90.000000	88.619113	1.380887	113429.256196

Note that the linear displacement at 88 degrees zenith angle is about 17.5 km—very substantial. Because of the very approximate atmosphere model, this number could vary by perhaps 25% depending on weather in temperate and tropical regions; in the Arctic it would be considerably smaller. The displacement at 90 degrees incidence, over 113 km, is only suggestive and could easily vary by 50%.

The increments in latitude and longitude due to refraction are:

Direction	Value
latitude ( $\phi$ )	$dAng * \cos(\psi)$
longitude ( $\lambda$ )	$dAng * \sin(\psi)/\cos(\phi)$

where  $\psi$  is the azimuth from `PGS_CSC_ZenithAzimuth()`. The expression for longitude is singular at the North and South poles and the user should avoid using it there, or within too close range. When  $|\text{latitude}| > \pi - dAng$ , the point is so near the pole that the displacement of the ray can be assumed to be South at the North pole and North at the South pole; but when starting at either pole, the longitude (not its increment) must be found from  $-\text{atan2}(yray, xray)$  where  $(xray, yray, zray)$  are the components of the look vector in ECR. After calling `PGS_CSC_SpaceRefract()`, then, the user who is interested in the displacement in latitude and longitude needs to implement the equations above and, for the exceptional case at a pole, the alternate just explained: latitude =  $dAng$ , longitude =  $-\text{atan2}(yray, xray)$ . The Toolkit software does not perform these operations, which are a user responsibility if the positional correction is desired.

The composition of the atmosphere was obtained from Allen's "Astrophysical Quantities, 2nd ed." (London, the Athlone Pre, 1976) p. 121, because the U.S. Standard Atmosphere (NOAA, 1976) is bone dry, which is unrealistic.

The atmosphere model is used only to get the index of refraction at sea level. The latitude dependence is that the sea level temperature and mean scale height are functions of latitude.

The calculations are based on the geometry of a spherical Earth. User may employ her/his favorite Earth radius to transform radians of displacement to meters. See also "Theoretical Basis of the SDP Toolkit Geolocation Package for the ECS Project", Document 445-TP-002-002, May 1995, by P. Noerdlinger, where the equation to transform displacement magnitude to North and East components is given.

**REQUIREMENTS:** PGSTK-0860, PGSTK-1080

## Get Field-of-View Footprint and Pixel Centers

---

**NAME:** PGS\_CSC\_GetFOV\_Pixel()

**SYNOPSIS:**

**C:** #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_GetFOV_Pixel(
    PGSt_tag          spacecraftTag,
    PGSt_integer      numValues,
    char              asciiUTC[28],
    PGSt_double       offsets[],
    char              earthEllipsTag[50],
    PGSt_boolean      accurFlag,
    PGSt_double       pixelUnitvSC[][3],
    PGSt_double       offsetXYZ[][3],
    PGSt_double       latitude[],
    PGSt_double       longitude[],
    PGSt_double       pixelUnitvECR[][3],
    PGSt_double       slantRange[],
    PGSt_double       velocDoppl[])
```

**FORTTRAN:** include 'PGS\_MEM\_7.f'  
include 'PGS\_EPH\_5.f'  
include 'PGS\_CSC\_4.f'  
include 'PGS\_TD\_3.f'  
include 'PGS\_TD.f'  
include 'PGS\_SMF.f'

```
integer function pgs_csc_getfov_pixel(spacecrafttag,numvalues,asciiutc,
                                     offsets, earthellipstag,accurflag,
                                     pixelunitvsc,offsetxyz,latitude,
                                     longitude,pixelunitvecr,
                                     slantrange,velocdoppl)

    integer spacecrafttag
    integer numvalues
    character*27 asciiutc
    double precision offsets(*)
    character*49 earthellipstag
    integer accurflag
    double precision pixelunitvsc(3,*)
    double precision offsetxyz(3,*)
    double precision latitude(*)
```

double precision	longitude(*)
double precision	pixelunitvecr(3,*)
double precision	slantrange(*)
double precision	velocdoppl(*)

**DESCRIPTION:** This function obtains the latitude and longitude of the intersection of a line of sight with the spheroidal Earth, the slant range from Spacecraft to look point, and the Doppler velocity along the line of sight. The ECR pixel vector is also returned; it can be used, for example, to determine the zenith angle of the line of sight. The line of sight is defined by a unit vector in the Spacecraft frame of reference and a time. (The unit vector along the line of sight is called a "look vector" in the sequel.)

The Doppler velocity is true, in the sense that it is relative to the Earth's surface.

## INPUTS:

**Table 6-211. PGS\_CSC\_GetFOV\_Pixel Inputs**

Name	Description	Units	Min	Max
spacecraftTag	spacecraft identifier	N/A	N/A	N/A
numValues	number of input time offsets (to use ASCII time with no offsets, set numValues =0 or set it =1 and make first [and only] offset = 0.0)	N/A	0	N/A
asciiUTC	UTC start time in CCSDS ASCII Time A or B format	N/A	1972-01-01	see NOTES
offsets	array of time offsets	SI seconds	Max and Min such that floating equivalent of asciiUTC+offset is between asciiUTC Min and Max values	
EarthEllipsTag	tag selecting Earth Ellipsoid model	N/A	N/A	N/A
accurFlag	flag to regulate accuracy	N/A	PGS_FALSE	PGS_TRUE
pixelUnitvSC	array of pixel unit vectors in SC coords	N/A	-1	1
offsetXYZ	array of displacements of instrument boresight from SC nominal center in SC coordinates(see overall limit for length of this vector in "RETURNS" section) (offsetXYZ is used only when accurFlag == PGS_TRUE)	m	-120	+120

## OUTPUTS:

**Table 6-212. PGS\_CSC\_GetFOV\_Pixel Outputs**

Name	Description	Units	Min	Max
latitude	latitude of the lookpoint	radians	-pi/2	pi/2
longitude	longitude of the lookpoint	radians	-pi	pi
pixelUnitvECR	ECR unit pixel vector	N/A	-1	+1
slantRange	slant range: SC to lookpoint	m	0	100000
velocDoppl	Doppler velocity of the look point (+ meaning "away")	m/s	-8000	8000

## RETURNS:

**Table 6-213. PGS\_CSC\_GetFOV\_Pixel Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_W_MISS_EARTH	Look Vector fails to intersect Earth
PGSTD_E_SC_TAG_UNKNOWN	Invalid Spacecraft tag
PGSCSC_W_ZERO_PIXEL_VECTOR	Instrument pixel vector of zero length
PGSCSC_W_BAD_EPH_FOR_PIXEL	Ephemeris Data missing for some pixels
PGSCSC_W_INSTRUMENT_OFF_BOARD	Instrument offset from SC center is > 120 m which is considered unreasonably large (applicable only when accurFlag = PGS_TRUE)
PGSCSC_W_BAD_ACCURACY_FLAG	Accuracy Flag neither PGS_TRUE nor PGS_FALSE
PGSCSC_E_BAD_ARRAY_SIZE	The user has supplied a negative number of time offsets
PGSCSC_W_DEFAULT_EARTH_MODEL	Invalid EarthEllipsTag; WGS84 model used
PGSCSC_W_DATA_FILE_MISSING	A file such as the ephemeris, utcpole, Earth Model or leap seconds file is missing
PGSCSC_E_NEG_OR_ZERO_RAD	One of the Earth axes is zero or negative
PGSMEM_E_NO_MEMORY	Malloc operation for scratch memory failed
PGSTD_E_NO_LEAP_SECS	no leap seconds data available for input time
PGSTD_E_TIME_FMT_ERROR	format error in asciiUTC
PGSTD_E_TIME_VALUE_ERROR	value error in asciiUTC
PGSCSC_W_PREDICTED_UT1	predicted UT1 value used
PGSCSC_E_NO_UT1_VALUE	no UT1 value available
PGS_E_TOOLKIT	Error in Toolkit—for example, inconsistent error message from a subordinate function
PGSEPH_E_BAD_EPHEM_FILE_HDR	No s/c ephem files had readable headers
PGSEPH_E_NO_SC_EPHEM_FILE	No s/c ephem files could be found for input

## EXAMPLES:

```

C:      #include <PGS_CSC.h>
        char          asciiUTC[28] = "1994-01-15T12:21:33.9939Z";
        PGSt_tag       spacecraftTag = PGSD_EOS_AM;
        char           EarthEllipsTag[50] = "WGS84";
        PGSt_double    offsets[4] = {0.0,0.1,2.0,30.0};
        PGSt_double    pixelUnitvSC[4][3];
        PGSt_double    offsetXYZ[4][3];
        PGSt_integer    numValues = 4;
        PGSt_boolean   accurFlag = PGS_FALSE;

        PGSt_double    latitude[4];
        PGSt_double    longitude[4];
        PGSt_double    velocDoppl[4];
        PGSt_double    slantRange[4];
        PGSt_double    pixelUnitvECR[4][3];

```

```

PGSt_SMF_status    returnStat;
PGSt_SMF_status    code;
char               msg[240];
char               mnemonic[31];
int                i;
int                jj;

for (i=0;i<4;i++)
    for(jj=0;jj<3 ;++jj)
        offsetXYZ[i][jj] = 0.0;

/** initialize pixel unit vectors
    All but the 3rd case hit Earth; to miss Earth reverse
    the last component of any other one **/

pixelUnitvSC[0][0] = 0.03;
pixelUnitvSC[0][1] = 0.12;
pixelUnitvSC[0][2] = 0.08;

pixelUnitvSC[1][0] = -0.2;
pixelUnitvSC[1][1] = 0.12;
pixelUnitvSC[1][2] = 0.6;

/**This case will display error**/

pixelUnitvSC[2][0] = -0.0;
pixelUnitvSC[2][1] = 0.00;
pixelUnitvSC[2][2] = 0.0;

pixelUnitvSC[3][0] = -0.2;
pixelUnitvSC[3][1] = -0.12;
PixelUnitvSC[3][2] = 0.6;

returnStat = PGS_CSC_GetFOV_Pixel(spacecraftTag,numValues,
                                asciiUTC,offsets,
                                EarthEllipsTag,accurFlag,
                                pixelUnitvSC,offsetXYZ,
                                latitude,longitude,
                                pixelUnitvECR,santRange,
                                velocDoppl);

printf("  Toolkit return value:  %d\n\n",returnStat);

PGS_SMF_GetMsg(&code,mnemonic,msg);
printf("  Return %s: %s\n\n",mnemonic,msg);

printf(" accurFlag ==  %d  Earth Tag == %s  ECR Pixels:\n"
       "%15.11lg      %15.11lg      %15.11lg\n"
       "%15.11lg      %15.11lg      %15.11lg\n "

```

```

        "%15.11lg      %15.11lg      %15.11lg\n"
        "%15.11lg      %15.11lg      %15.11lg\n",
        accurFlag,EarthEllipsTag,
        pixelUnitvECR[0][0],pixelUnitvECR[0][1],
            pixelUnitvECR[0][2],
        pixelUnitvECR[1][0],pixelUnitvECR[1][1],
            pixelUnitvECR[1][2],
        pixelUnitvECR[2][0],pixelUnitvECR[2][1],
            pixelUnitvECR[2][2],
        pixelUnitvECR[3][0],pixelUnitvECR[3][1],
            pixelUnitvECR[3][2]);

/** Test for some variable like latitude =
    PGSd_GEO_ERROR_VALUE before further processing to avoid
    processing pixels that missed Earth or had zero pixel
    vector. In multi-pixel processing, results from good and
    bad pixels can be distinguished only by answers being
    PGSd_GEO_ERROR_VALUE; in single pixel processing return
    status indicates any error */

if(returnStatus != PGS_S_SUCCESS)
{
    /** print results - latitude, longitude, etc.; test
        errors, take appropriate action */
}

```

FORTTRAN:

```

implicit none

parameter(numPixels = 4)

integer          pgs_csc_getfov_pixel
integer          spacecrafttag
integer          numvalues
character*27     asciitc
double precision offsets(numPixels)
character*49     earthellipstag
integer          accurflag
double precision pixelUnitvSC(3,numPixels)
double precision offsetXYZ(3,numPixels)
double precision latitude(numPixels)
double precision longitude(numPixels)
double precision pixelUnitvECR(3,numPixels)
double precision slantRange(numPixels)
double precision velocDoppl(numPixels)
character*33     err
character*241    msg

```



```

data offsets/360.0, 720.0, 1080.0, 1600.0/
asciiutc = '1991-07-27T11:04:57.987654Z'
spacecrafttag = PGSD_EOS_AM

do 1 jj = 1,3
do 1 i = 1,4
    offsetXYZ(jj,i) = 0.0;
1      continue
!
!      This puts instrument at the nominal SC center
1      For example, to put instrument on a 20 m boom fore of
!      SC center, make offsetXYZ(1,i) = 20.0 for each i
!
!      initialize pixel unit vectors
!
!      All but the 3rd case hit Earth; to miss Earth reverse the
!      last component of any other one

    pixelUnitvSC(1,1) = 0.03;
    pixelUnitvSC(2,1) = 0.12;
    pixelUnitvSC(3,1) = 0.08;

    pixelUnitvSC(1,2) = -0.2;
    pixelUnitvSC(2,2) = 0.12;
    pixelUnitvSC(3,2) = 0.6;
!
!      This case will display error

    pixelUnitvSC(1,3) = -0.0;
    pixelUnitvSC(2,3) = 0.00;
    pixelUnitvSC(3,3) = 0.0;

    pixelUnitvSC(1,4) = -0.2;
    pixelUnitvSC(2,4) = -0.12;
    pixelUnitvSC(3,4) = 0.6;

    returnstatus = pgs_csc_getfov_pixel(spacecrafttag,numvalues,
>                                     asciiutc,offsets,
>                                     earthellipstag,
>                                     accurflag,pixelUnitvSC,
>                                     offsetXYZ,latitude,
>                                     longitude,pixelUnitvECR,
>                                     slantRange,velocDoppl)
!
!      Print output values

```

```

!           Test for some variable like latitude = 1.0e50 before further
!           processing to avoid processing pixels that missed Earth or had
!           zero pixel vector

           if (returnstatus .ne. pgs_s_success) then
               pgs_smf_getmsg(returnstatus, err, msg)
               write(*,*) err, msg
           endif

```

**NOTES:**

An accuracy flag is required, allowing two accuracy levels:

Normal or PGS\_FALSE

- do ECI to ECR transformation at moment of taking data
- consider instrument axis to pass through nominal center of spacecraft

High or PGS\_TRUE

- do ECI to ECR transformation with approximate allowance for Earth rotation during the light travel time (spherical Earth approximation.) This will slow the calculation slightly.
- user must supply vector offsetXYZ that represents the displacement in meters of the instrument boresight from nominal spacecraft center. (Only the part of the displacement orthogonal to the look vector will have an effect.) Users invoking the High Accuracy option but wishing not to take advantage of this feature should supply zeros for the components of offsetXYZ.

The maximum error in omitting this calculation is approximately as follows for a worst case of a spacecraft at 700 km altitude, crossing the equator and looking E or W:

**Table 6-214. Error due to Earth Motion in Time of Flight of Light**

Nadir Angle (deg)	Slant Range (km)	Worst Case Error (m) if accurFlag = PGS_FALSE
0	700	1.1
30	830	1.3
40	945	1.5
50	1200	1.9
55	1410	2.1
60	1770	2.7
64	2440	3.7

The nature of the error is a smooth distortion such that points near either the East or the West limb would be assigned a longitude slightly to the West in comparison with points near nadir. The effect could be somewhat exaggerated, for some orbits, in terms of illumination changes near the terminator.

Caution: The user is advised that the spacecraft ephemeris refers to the nominal center of the spacecraft. The displacements of individual instruments relative to the center of the spacecraft are taken into account herein through the vector offsetXYZ. When the flag "accurFlag" is set to PGS\_TRUE, the user should specify the instrument coordinates relative to spacecraft center (in meters) with this vector. It WILL be used by the present function, so if the user does not actually wish to employ it, then offsetXYZ must be set to zero (all three components). If "accurFlag" is set to PGS\_FALSE, the displacement is ignored.

#### **TIME ACRONYMS:**

UT1 is:            Universal Time

UTC is:           Coordinated Universal Time

See Section 6.3.4.8 Coordinate System Conversion Tool Notes

See Section 6.2.7.5.2 (UT1-UTC Boundaries)

See Section 6.2.6.3 Spacecraft Tags Definition File

#### **REFERENCES FOR TIME:**

CCSDS 301.0-B-2 (CCSDS => Consultative Committee for Space Data Systems) Astronomical Almanac, Explanatory Supplement to the Astronomical Almanac. See also "Theoretical Basis of the SDP Toolkit Geolocation Package for the ECS Project", Document 445-TP-002-002, May 1995, by P. Noerdlinger.

**REQUIREMENTS:** PGSTK-0930, PGSTK-1080, PGSTK-1083,

## Precesses a Vector Between TDB Julian Date and J2000 Coordinates

---

**NAME:** PGS\_CSC\_precs2000( )

**SYNOPSIS:**

C: #include <PGS\_CSC.h>

```
PGSt_SMF_status
PGS_CSC_precs2000(
    PGSt_integer      threeOr6,
    PGSt_double        jedTDB[2],
    PGSt_boolean       frwd,
    PGSt_double        posVel[])
```

FORTTRAN: include 'PGS\_SMF.f'  
include 'PGS\_TD.4.f'

```
integer function pgs_csc_precs2000(threeor6,jedtdb,frwd,posvel)
    integer          threeor6
    double precision  jedtdb(2)
    integer          frwd
    double precision  posvel(6)
```

**DESCRIPTION:** This tool precesses a vector from Celestial Coordinates of date in Barycentric Dynamical Time (TDB) to J2000 coordinates or from J2000 coordinates to Celestial Coordinates of date in Barycentric Dynamical Time (TDB).

**INPUTS:**

**Table 6-215. PGS\_CSC\_precs2000 Inputs**

Name	Description	Units	Min	Max
jedTDB[2]	TBD (Barycentric Dynamical Time) as a Julian Date to or from which the vector is to be processed	days	ANY	ANY
frwd	flag for sense of precession: PGS_TRUE if precessing from J2000 to jedTDB PGS_FALSE if precessing from jedTDB to J2000	T/F	N/A	N/A
posVel	vector (position and velocity) in final reference frame: posvel[0-2] position posvel[3-5] velocity	m m/s	ANY ANY	ANY ANY

## OUTPUTS:

**Table 6-216. PGS\_CSC\_precs2000 Outputs**

Name	Description	Units	Min	Max
posVel	vector (position and velocity) in final reference frame: posvel[0-2] position posvel[3-5] velocity	m m/s	ANY ANY	ANY ANY

## RETURNS:

**Table 6-217. PGS\_CSC\_precs2000 Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_BAD_ARRAY_SIZE	The size of the vector is not either 3 or 6
PGSCSC_E_BAD_DIRECTION_FLAG	The value of the direction flag is not either PGS_TRUE or PGS_FALSE

## EXAMPLES:

```
C:          PGSt_SMF_status   returnStatus;
          PGSt_double         jedTDB[2]={2449720.5,0.25};
          PGSt_double         posVel[6]={6400000.0,-5000000.0,40000.0,
                                         4000.0,7000.0,-6000.0};

          ** precess the vector **

          returnStatus = PGS_CSC_precs2000(6,jedTDB,PGS_TRUE,posVel);

          ** the input vector "posVel" has been overwritten with the
             precessed value **
```

```
FORTTRAN:  implicit none

            integer          pgs_csc_precs2000
            integer          returnstatus
            integer          threeor6
            double precision  jedtdb(2)
            double precision  posvel(6)

            data jedtdb/2449720.5,0.25/
            data posvel/6400000.0,-5000000.0,40000.0,4000.0,7000.0,-
                        6000.0/

            threeor6 = 6
```

```
returnstatus = pgs_csc_nutate2000(threeor6,jedtdb,frwd,  
                                posvel)
```

! the input vector "posvel" has been overwritten with the precessed value

**NOTES:**

This function is a simplified version of PGS\_CSC\_precs3or6(). This function is specific to the case of precessing to or from the epoch of J2000. The various coefficients used are the constants that result for this epoch.

This function produces an output vector that overwrites the input vector. The code was kept this way to preserve its heritage. The user is cautioned that her/his input vector will be therefore be altered by this function. The underlying rotation functions do not have this property.

**TIME ACRONYMS:**

TDB is: Barycentric Dynamical Time

**JULIAN DATES:**

Format:

Toolkit Julian dates are kept as an array of two real (high precision) numbers (C: PGSt\_double, FORTRAN: DOUBLE PRECISION). The first element of the array should be the half integer Julian day (e.g., N.5 where N is a Julian day number). The second element of the array should be a real number greater than or equal to zero AND less than one (1.0) representing the time of the current day (as a fraction of that (86400 second) day). This format allows relatively simple translation to calendar days (since the Julian days begin at noon of the corresponding calendar day). Users of the Toolkit are encouraged to adhere to this format to maintain high accuracy (one number to track significant digits to the left of the decimal and one number to track significant digits to the right of the decimal). Toolkit functions that do NOT require a Julian type date as an input and return a Julian date will return the Julian date in the above mentioned format. Toolkit functions that require a Julian date as an input and do NOT return a Julian date will first convert the input date (internal) to the above format. Toolkit functions that have a Julian date as both an input and an output will assume the input is in the above described format but will not check and the format of the output may not be what is expected if any other format is used for the input.

Meaning:

Toolkit "Julian dates" are all based on UTC. A Julian date in any other "time" (e.g., TAI, TDT, UT1, etc.) is based on the difference between that "time" and the equivalent UTC time (differences range in magnitude from 0 seconds to about a minute).

**REFERENCES FOR TIME:**

CCSDS 301.0-B-2 (CCSDS => Consultative Committee for Space Data Systems) Astronomical Almanac, Explanatory Supplement to the Astronomical Almanac

**REQUIREMENTS:** PGSTK-0930, PGSTK-1050

## Nutate State Vector Between True of Date and Mean of Date

---

**NAME:** PGS\_CSC\_nutate2000( )

**SYNOPSIS:**

C:                   #include <PGS\_CSC.h>

                  PGSt\_SMF\_status  
PGS\_CSC\_nutate2000(  
                  PGSt\_integer           threeOr6,  
                  PGSt\_double           jedTDB[2],  
                  PGSt\_double           dvnut[4],  
                  PGSt\_boolean          frwd,  
                  PGst\_double           posVel[])

FORTRAN:           include 'PGS\_SMF.f'  
                  include 'PGS\_CSC\_4.f'

                  integer function pgs\_csc\_nutate2000(threeor6,jedtdb,dvnutfwr, posvel)  
                  integer               threeor6  
                  double precision       jedtdb(2)  
                  double precision       dvnut(4)  
                  double precision       frwd  
                  double precision       posvel(\*)

**DESCRIPTION:**   This tool transforms a vector under nutation from Celestial Coordinates of date in Barycentric Dynamical Time (TDB) to J2000 coordinates or from J2000 coordinates to Celestial Coordinates of date.

**INPUTS:**

**Table 6-218. PGS\_CSC\_nutate2000 Inputs**

Name	Description	Units	Min	Max
threeOr6	chooses a 3 or 6 dimensional vector to nutate	N/A	N/A	N/A
jedTDB	TBD (Barycentric Dynamical Time) as a Julian Date to or from which the vector is to be nutated (this variable is generally referred to in Toolkit code as jedTDB)	days	ANY	ANY
dvnut	the two nutation angles and their rates, output from "PGS_CSC_wahr2" (this variable is generally referred to in Toolkit code as dvnut)	rad/s	-1.e-11	1.e-11
posVel	vector (position and velocity) in initial reference frame: posvel[0-2]   position posvel[3-5]   velocity	m m/s	ANY ANY	ANY ANY
frwd	flag for sense of nutation: PGS_TRUE if nutating from True of Date at jedTDB to Mean of Date PGS_FALSE if nutating from Mean of Date to True of Date at jedTDB	T/F	N/A	N/A



## OUTPUTS:

**Table 6-219. PGS\_CSC\_nutate2000 Outputs**

Name	Description	Units	Min	Max
posVel	vector (position and velocity) in final reference frame: posvel[0-2] position posvel[3-5] velocity	m m/s	ANY ANY	ANY ANY

## RETURNS:

**Table 6-220. PGS\_CSC\_nutate2000 Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSCSC_E_BAD_ARRAY_SIZE	The size of the vector is not either 3 or 6
PGSCSC_E_BAD_DIRECTION_FLAG	The value of the direction flag is not either PGS_TRUE or PGS_FALSE

## EXAMPLES:

```
C:
PGSt_SMF_status   returnStatus;
PGSt_double       jedTDB[2]={2449720.5,0.25};
PGSt_double       dvnut[4];
PGSt_double       posVel[6]={6400000.0,-5000000.0,40000.0,
                             4000.0,7000.0,-6000.0};

** get the nutation angles and rates **

PGS_CSC_wahr2(jedTDB,dvnut);

** nutate the vector **

returnStatus = PGS_CSC_nutate2000(6,jedTDB,dvnut,PGS_TRUE,
                                   posVel);

** the input vector "posVel" has been overwritten with the
   nutated value **
```

```
FORTRAN:
implicit none

integer       pgs_csc_nutate2000
integer       returnstatus
integer       threeor6
double precision jedtdb(2)
```

```

double precision  dvnut
double precision  posvel(6)

data jedtdb/2449720.5,0.25/
data posvel/6400000.0,-5000000.0,40000.0,4000.0,7000.0,
           -6000.0/

threeor6 = 6

!      get the nutation angles and rates

      returnstatus = pgs_csc_wahr2(jedtdb,dvnut)

!      nutate the vector

      returnstatus = pgs_csc_nutate2000(threeor6,jedtdb,dvnut,
                                         frwd,posvel)

!      the input vector "posvel" has been overwritten with the nutated
      value

```

#### NOTES:

Purpose: The case of transforming a vector from J2000 to True of Date, requires first procession and then nutation. The intermediate system, processed but not nutated, is the Mean of Date system. With the direction flag at PGS\_TRUE, this function transforms a vector (position and velocity) from Mean of Date to True of Date. True of date has its Z axis along the Earth's true angular velocity and the X axis is toward the true equinox of date-the intersection of the equator perpendicular to Z with the ecliptic. Mean of date is arranged similarly, but ignoring nutation, so its pole has a constant angle to the ecliptic, along which its X axis moves at a constant rate.

In the opposite case, with the direction flag at PGS\_FALSE, i.e. in going from arbitrary epoch to J2000, this function carries the vector from True of Date to Mean of Date, after which it must be precessed to J2000 by the function PGS\_CSC\_precs2000().

This code was modified so it now takes either a 3 or 6 dimensional vector. When 6 dimensions are used, they must be in the order (position, velocity) because the transformation of velocity is slightly different. This function produces an output vector that overwrites the input vector. The code was kept this way to preserve its heritage. The user is cautioned that her/his input vector will therefore be altered by this function. The underlying rotation functions do not have this property.

#### TIME ACRONYMS:

TDB is: Barycentric Dynamical Time

## **JULIAN DATES:**

### **Format:**

Toolkit Julian dates are kept as an array of two real (high precision) numbers (C: PGSt\_double, FORTRAN: DOUBLE PRECISION). The first element of the array should be the half integer Julian day (e.g., N.5 where N is a Julian day number). The second element of the array should be a real number greater than or equal to zero AND less than one (1.0) representing the time of the current day (as a fraction of that (86400 second) day). This format allows relatively simple translation to calendar days (since the Julian days begin at noon of the corresponding calendar day). Users of the Toolkit are encouraged to adhere to this format to maintain high accuracy (one number to track significant digits to the left of the decimal and one number to track significant digits to the right of the decimal). Toolkit functions that do NOT require a Julian type date as an input and return a Julian date will return the Julian date in the above mentioned format. Toolkit functions that require a Julian date as an input and do NOT return a Julian date will first convert the input date (internal) to the above format. Toolkit functions that have a Julian date as both an input and an output will assume the input is in the above described format but will not check and the format of the output may not be what is expected if any other format is used for the input.

### **Meaning:**

Toolkit "Julian dates" are all based on UTC. A Julian date in any other "time" (e.g., TAI, TDT, UT1, etc.) is based on the difference between that "time" and the equivalent UTC time (differences range in magnitude from 0 seconds to about a minute).

## **REFERENCES FOR TIME:**

CCSDS 301.0-B-2 (CCSDS => Consultative Committee for Space Data Systems) Astronomical Almanac, Explanatory Supplement to the Astronomical Almanac

**REQUIREMENTS:** PGSTK-0914, PGSTK-0930, PGSTK-1050

## Transform from ECI J2000 to ECI True of Date Coordinates

---

**NAME:** PGS\_CSC\_J2000toTOD( )

**SYNOPSIS:**

```
C:      #include <PGS_CSC.h>

        PGSt_SMF_status
        PGS_CSC_J2000toTOD(
            PGSt_integer          threeOr6,
            PGSt_double           secTAI93
            PGSt_double           posvelECI[6],
            PGSt_double           posvelTOD[6])
```

```
FORTRAN: include 'PGS_CSC_4.f'
          include 'PGS_SMF.f'

          integer function pgs_csc_j2000totod(threeor6,sectai93,posveleci,
          >                                posveltod)
              integer          threeor6
              double precision  sectai93
              double precision  posveleci(*)
              double precision  posveltod(*)
```

**DESCRIPTION:** This function transforms from ECI (J2000) coordinates to TOD (true of date) coordinates.

**INPUTS:**

**Table 6-221. PGS\_CSC\_J2000toTOD.c Inputs**

Name	Description	Units	Min	Max
threeOr6	dimension of input vector	N/A	3	6
secTAI93	TOD time	seconds		
posvelECI[]	Vector (position and possibly velocity) in ECI J2000			
posvelTOD[0]	x position	meters		
posvelTOD[1]	y position	meters		
posvelTOD[2]	z position	meters		
posvelTOD[3]	x velocity	m/s		
posvelTOD[4]	y velocity	m/s		
posvelTOD[5]	z velocity	m/s		

## OUTPUTS:

**Table 6-222. PGS\_CSC\_J2000to.TOD.c Outputs**

Name	Description	Units	Min	Max
posvelTOD[6]	Vector (position and possibly velocity) in ECI TOD			
posvelECI[0]	x position	meters		
posvelECI[1]	y position	meters		
posvelECI[2]	z position	meters		
posvelECI[3]	x velocity	m/s		
posvelECI[4]	y velocity	m/s		
posvelECI[5]	z velocity	m/s		

## RETURNS:

**Table 6-223. PGS\_CSC\_J2000toTOD Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSCSC_E_BAD_ARRAY_SIZE	incorrect array size

## EXAMPLES:

```
C:
PGSt_SMF_status   returnStatus;
PGSt_double sectAI93 = -44496000.0;
PGSt_double posvelECI[6] = {0.5,0.75,0.90,0.3,0.2,0.8};
PGSt_double posvelTOD[6];

returnStatus=
PGS_CSC_J2000toTOD(6,sectAI93,posvelECI,posvelTOD);

if(returnStatus != PGS_S_SUCCESS)
{
/** test errors, take appropriate action **/
}
```

```
FORTRAN:
implicit none

integer          returnstatus
integer          pgs_csc_j2000totod
integer          threeor6
double precision sectai93
```

```

double precision  posveleci(6)
double precision  posveltod(6)
integer          cnt1
character*33      err
character*241     msg

do 10 cnt1 = 1,6
    posveleci(cnt1) = 100 * cnt1
10 continue
sectai93 = -44496000.0
threeOr6 = 6

returnstatus=s_csc_j2000totod(threeor6,sectai93,posveleci,
                             posveltod)

if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err, msg
endif

```

**NOTES:** If threeOr6 is 3, only position is transformed; if 6 then both position and velocity.

**REQUIREMENTS:** PGSTK - 0910, 1050

NAME: PGS\_CSC\_TODtoJ2000( )

## SYNOPSIS:

```
C:          #include <PGS_CSC.h>

PGSt_SMF_status
PGS_CSC_TODtoJ2000(
    PGSt_integer      threeOr6,
    PGSt_double       secTAI93,
    PGSt_double       posvelTOD[6],
    PGSt_double       posvelECI[6])
```

```

FORTRAN:      include 'PGS_CSC_4.f'

               include 'PGS_SMF.f'

               integer function pgs_csc_todtoj2000(threeor6,sectai93,posveltod,
                                                    posveleci)

               integer
               double precision
               double precision posveltod(*)
               double precision posveleci(*)

```

**DESCRIPTION:** This function transforms from TOD (true of date) coordinates to ECI (J2000) coordinates.

## INPUTS:

**Table 6-224. PGS\_CSC\_TODtoJ2000.c Inputs**

Name	Description	Units	Min	Max
threeOr6	dimension of input vector	N/A	3	6
secTAI93	TOD time posvel TOD[6]	seconds		
posvelTOD[]	Vector (position and possibly velocity) in ECI TOD			
posvelTOD[0]	x position	meters		
posvelTOD[1]	y position	meters		
posvelTOD[2]	z position	meters		
posvelTOD[3]	x velocity	m/s		
posvelTOD[4]	y velocity	m/s		
posvelTOD[5]	z velocity	m/s		

## OUTPUTS:

**Table 6-225. PGS\_CSC\_TODtoJ2000.c Outputs**

Name	Description	Units	Min	Max
posvelECI[]	Vector (position and possibly velocity) in ECI J2000			
posvelECI[0]	x position	meters		
posvelECI[1]	y position	meters		
posvelECI[2]	z position	meters		
posvelECI[3]	x velocity	m/s		
posvelECI[4]	y velocity	m/s		
posvelECI[5]	z velocity	m/s		

## RETURNS:

**Table 6-226. PGS\_CSC\_TODtoJ2000.c Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSCSC_E_BAD_ARRAY_SIZE	incorrect array size

## EXAMPLES:

```
C:          PGSt_SMF_status   returnStatus
           PGSt_double secTAI93 = -44496000.0
           PGSt_double posvelTOD[6] = 0.5,0.75,0.90,0.3,0.2,0.8};
           PGSt_double posvelECI[6];
           returnStatus =
           PGS_CSC_TODtoJ2000(6,secTAI93,posvelTOD,posvelECI);
```



FORTTRAN:

```
if(returnStatus != PGS_S_SUCCESS
{
/** test errors, take appropriate action **/
}
implicit none
integer          pgs_csc_todtojd2000
integer          returnstatus
integer          threeor6
double precision sectai93
double precision posveltod(6)
double precision posveleci(6)
integer          cnt1
character*33      err
character*241     msg
do 10 cnt1 = 1,6
    posveltod(cnt1) = 100 * cnt1
10 continue
sectai93 = -44496000.0
threeor6 = 6
returnstatus=pgs_csc_todtojd2000(threeor6,sectai93,posveltod,
>                                posveleci)
if (returnstatus .ne. pgs_s_success) then
    pgs_smf_getmsg(returnstatus, err, msg)
    write(*,*) err,
endif
```

**NOTES:**

If threeOr6 is 3, only position is transformed; if 6 then both position and velocity.

#### **TIME ACRONYMS:**

TAI is: International Atomic Time

TDB is: Barycentric Dynamical Time

TOOLKIT INTERNAL TIME (TAI):

Toolkit internal time is the real number of continuous SI seconds since the epoch of UTC 12 AM 1-1-1993. Toolkit internal time is also referred to in the toolkit as TAI.

#### **REFERENCES FOR TIME:**

CCSDS 301.0-B-2 (CCSDS => Consultative Committee for Space Data Systems) Astronomical Almanac, Explanatory Supplement to the Astronomical Almanac

**REQUIREMENTS:** PGSTK - 0910, 1050

## Determine if Location on Earth is in Day or Night

---

**NAME:** PGS\_CSC\_DayNight()

**SYNOPSIS:**

C: #include <PGS\_CBP.h>

PGSt\_SMF\_status  
PGS\_CSC\_DayNight(  
    PGSt\_integer           numValues,  
    char                   asciiUTC[28],  
    PGSt\_double           offsets[],  
    PGSt\_double           latitude[],  
    PGSt\_double           longitude[],  
    PGSt\_tag              sunZenithLimitTag,  
    PGSt\_boolean          afterDark[])

FORTRAN: include 'PGS\_MEM\_7.f'  
include 'PGS\_CBP\_6.f'  
include 'PGS\_CSC\_4.f'  
include 'PGS\_TD.f'  
include 'PGS\_SMF.f'

integer function pgs\_csc\_daynight(numvalues,asciiutc,offsets,latitude,  
                                  longitude, sunzenithlimittag, afterdark)  
    integer                   numvalues  
    character\*27              asciiutc  
    double precision          offsets(\*)  
    double precision          latitude(\*)  
    double precision          longitude(\*)  
    integer                   sunzenithlimittag  
    integer                   afterdark(\*)

**DESCRIPTION:** This function determines whether each point in a set of input Earth locations is in day or night at the corresponding input times. The function accepts an input start time, array of offsets from that start time, and an array of corresponding geodetic latitudes and longitudes. It then determines whether each time and point on the surface of the Earth (altitude = 0 km) is night, based on definitions of either civil twilight or night, nautical night, or astronomical night.

**INPUTS:****Table 6-227. PGS\_CSC\_DayNight Inputs**

Name	Description	Units	Min	Max
numValues	number of input time offsets, longitudes, and latitudes	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	1972-01-01	see NOTES
offsets	array of time offsets	seconds	Max and Min such that asciiUTC+ offset is between asciiUTC Min and Max values	
latitude	array of geodetic latitudes for array of time offsets	radians	-pi/2	+pi/2
longitude	array of longitudes corresponding to time offsets	radians	-2*pi	2*pi
sunZenithLimitTag	tag specifying basis of day/night determination Allowed values: PGSd_CivilTwilight—(end of day) sun deemed to set within 90 degrees 50 arc minutes from zenith PGSd_CivilNight—(end of civil twilight) sun more than 96 degrees from zenith (same as start of Nautical twilight) PGSd_NauticalNight—(end of Nautical twilight) sun more than 102 degrees from zenith. PGSd_AstronNight—(end of Astronomical Twilight) sun more than 108 degrees from zenith.	N/A	N/A	N/A

**OUTPUTS:****Table 6-228. PGS\_CSC\_DayNight Outputs**

Name	Description	Units	Min	Max
afterDark	array of answers: Array values will be either PGS_TRUE or PGS_FALSE, according to the tag definition. PGS_TRUE means point is in night, PGS_FALSE means point is in daylight or twilight.	Boolean	see DESCRIPTION	see DESCRIPTION

## RETURNS:

**Table 6-229. PGS\_CSC\_DayNight Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSTD_E_NO_LEAP_SECS	No leap second value available in table for at least one of the input offset times; a linear approximation was used to get value
PGSCSC_E_INVALID_LIMITTAG	Invalid sunZenithLimitTag
PGSCSC_E_BAD_ARRAY_SIZE	numValues (and array size) is less than zero
PGSCSC_W_ERROR_IN_DAYNIGHT	An error occurred in computing at least one afterDark value
PGSCSC_W_BAD_TRANSFORM_VALUE	Invalid ECtoECR transformation
PGSCSC_W_BELOW_HORIZON	Sun is below horizon
PGSCSC_W_PREDICTED_UT1	At least one of the values obtained from the utcpole.dat file is 'predicted'
PGSTD_E_NO_UT1_VALUE	No UT1–UTC correction available
PGSTD_E_BAD_INITIAL_TIME	Initial input time cannot be deciphered
PGSCBP_E_TIME_OUT_OF_RANGE	Start UTC time is not in the range of the planetary ephemeris file (de200.eos)
PGSCBP_E_UNABLE_TO_OPEN_FILE	Ephemeris file cannot be opened
PGSMEM_E_NO_MEMORY	No memory available to allocate vectors
PGS_E_TOOLKIT	Something unexpected happened, execution of function ended prematurely

## EXAMPLES:

```
C:          #define      ARRAY_SIZE  3

PGSt_SMF_status  returnStatus;
PGSt_integer     numValues;
PGSt_integer     counter;
char             asciiUTC[28];
PGSt_double      offsets[ARRAY_SIZE] =
                {3600.0,7200.0,10800.0};

PGSt_double      latitude[ARRAY_SIZE]= {0.5,0.75,0.90};
PGSt_double      longitude[ARRAY_SIZE] = {1.0,2.0,3.0};
PGSt_tag         sunZenithLimitTag = PGSD_CivilTwilight;
PGSt_boolean     afterDark[ARRAY_SIZE];

numValues = ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30");
returnStatus = PGS_CSC_DayNight(numValues,asciiUTC,offsets,
```

```

latitude,longitude,
sunZenithLimitTag,
afterDark);

if(returnStatus != PGS_S_SUCCESS)
{
    ** test errors,
        take appropriate
        action **
}
printf("start time:%s",asciiUTC);
counter = 0;
while(counter <= numValues)
{
    printf("Offset: %lf   Latitude:%lf   Longitude:%lf
        Day/Night:%u", offset[counter],
            latitude[counter], longitude[counter],
            afterDark[counter]);
    counter++;
}

```

FORTRAN:

```

implicit none

integer          pgs_csc_daynight
parameter        (array_size=3)
integer          returnstatus
integer          counter
integer          numvalues
character*27     asciiutc
double precision offsets(array_size)
double precision latitude(array_size)
double precision longitude(array_size)
integer          sunzenithlimittag
integer          afterdark(array_size)

data offsets/3600.0,7200.0,10800.0/
data latitude/0.5,0.75,0.90/
data longitude/1.0,2.0,3.0/
numvalues = array_size
asciiutc = '1991-01-01T11:29:30'
sunzenithlimittag = pgasd_civiltwilight

returnstatus = pgs_csc_daynight(numvalues,asciiutc,offsets,
                                latitude,longitude,
                                sunzenithlimittag,
                                afterdark)

```

```

if(returnstatus .ne. pgs_s_success) go to 90

write(6,*) asciutc
if(numvalues.eq.0) numvalues = 1
do 40 counter = 1,numvalues,1
    write(6,*)offsets(counter),latitude(counter),
        longitude(counter),afterdark(counter)
40 continue
90 write(6,99)returnstatus
99 format('ERROR:',I50)

```

## NOTES:

If there is an error in computing one or more of the afterDark values, which does not affect the computation of the other values for the input offset times, it is set to the returnStatus value.

An Earth model tag is not needed because the latitude is geodetic. Input latitude values should be based on an Earth model (flattening) consistent with that used for other data analysis and processing for the same spacecraft.

User supplies one of the four sunZenithLimitTags as part of the input information. Users wishing to know if a point is in Nautical Twilight or darker should use the Civil Night tag; those wishing to determine whether the point is after the start of Astronomical Twilight should use the Nautical Night tag. An example of tag usage is the following: if the tag is set to Nautical night and the Sun zenith angle is less than 102 degrees, afterDark will be false; if 102 degrees or more it will be true.

## TIME ACRONYMS:

UTC is: Coordinated Universal Time

See Section 6.3.4.8 Coordinate System Conversion Tool Notes

See Section 6.2.7.5.2 (UT1-UTC Boundaries)

**REQUIREMENTS:** PGSTK-0860, PGSTK-0930

## Calculate Nutation Angles

**NAME:** PGS\_CSC\_wahr2()

**SYNOPSIS:**

**C:**

```
#include <PGS_CSC.h>

PGS_CSC_wahr2(
    PGSt_double ddjd[2],
    PGSt_double dvnut[4])
```

**FORTTRAN:**

```
include 'PGS_SMF.f'

integer function pgs_csc_wahr2(ddjd,dvnut)
    double precision    ddjd(2)
    double precision    dvnut(4)
```

**DESCRIPTION:** Calculates nutation angles delta psi and delta epsilon, and their rates of change, referred to the ecliptic of date, from the Wahr series.

**INPUTS:**

**Table 6-230. PGS\_CSC\_wahr2 Inputs**

Name	Description	Units	Min	Max
ddjd[2]	Barycentric Dynamical Time as a Julian Date	N/A	ANY	ANY
ddjd[0]	half-integral Julian day			
ddjd[1]	Julian day fraction			

**OUTPUTS:**

**Table 6-231. PGS\_CSC\_wahr2 Outputs**

Name	Description	Units	Min	Max
dvnut[0]	nutation in longitude	radians	-0.01	0.01
dvnut[1]	nutation in obliquity	radians	-0.001	0.001
dvnut[2]	nutation rate in longitude	radians/sec	-1.16e-1	+1.16e-11
dvnut[3]	nutation rate in obliquity	radians/sec	-1.16e-13	+1.16e-13

**RETURNS:**

**Table 6-232. PGS\_CSC\_wahr2 Returns**

Return	Description
PGS_S_SUCCESS	Successful return

**EXAMPLES:**

**C:**

```
PGSt_SMF_status    returnStatus;
PGSt_double         jedTDB[2]={2449720.5,0.25};
PGSt_double         dvnut[4];
```

```

returnStatus = PGS_CSC_wahr2(jedTDB,dvnut);
** do something with shiny new nutation angles and rates **
      :
      :

```

**FORTTRAN:**

```

implicit none

integer          pgs_csc_wahr2
integer          returnstatus
double precision jedtdb(2)
double precision dvnut(4)

data jedtdb/2449720.5,0.25/

returnstatus = pgs_csc_wahr2(jedtdb,dvnut)

```

```

! do something with shiny new nutation angles and rates
      :
      :

```

**NOTES:**

From table 1, "proposal to the International Astronomical Union (IAU) working group on nutation," John M. Wahr and Martin L. Smith (1979) subroutine to compute nutation angles and rates from expressions given in Supplement to Astronomical Almanac 1984, S21–S26. Ref: P.K. Seidelmann, V.K. Abalakin, H. Kinoshita, J. Kovalevsky, C.A. Murray, M.L. Smith, R.O. Vicente, J.G. Williams, Ya. S. Yatskiv: 1982, "1980 IAU Theory of Nutation", Celestial Mechanics Journal, vol 27., p. 79–105

Changes to code prior to acquisition for ECS project:

Lieske 3/91. NUTATION in the IAU J2000 system. Univac version obtained from Myles Standish, (subroutine WAHR) who had obtained it from USNO. Re-ordered terms to match Astronomical Almanac 1984 table S23-S25 and corrected the rate for dPsi in the 0 0 2 -2 2 term. Eliminated the equivalencies, common block and added necessary SAVES. Corrected the fundamental angles (L, L', F, D, Node) to match Almanac.

Acquired from E. Myles Standish, JPL, 12/93 by Peter Noerdlinger. This is not JPL certified code. Please do not modify the names of the variables in this code. It is heritage code and we may receive updates. We may also receive other related code with the same names for variables.

Users concerned with speed may wish to avoid repeated calls where possible. In this regard, the rates that are provided by Wahr2 can be used either for estimating the error of using nearby times, or for short term extrapolation. Note that in the original JPL code the rates issued by wahr2 are in radians per day; this routine returns the rates as radians per second.

**REQUIREMENTS:** PGSTK–0916, PGSTK–0930, PGSTK–1050



## Get Greenwich Hour Angles

---

**NAME:** PGS\_CSC\_GreenwichHour( )

**SYNOPSIS:**

C: #include <PGS\_CSC.h>

PGSt\_SMF\_status  
PGS\_CSC\_GreenwichHour(  
    PGSt\_integer        numValues,  
    char                asciiUTC[28],  
    PGSt\_double         offsets[],  
    PGSt\_double         hourAngleGreenw[])

FORTRAN: include 'PGS\_CSC\_4.f'  
include 'PGS\_TD\_3.f'  
include 'PGS\_TD.f'  
include 'PGS\_SMF.f'

integer function  
pgs\_csc\_greenwichhour(numvalues, asciutc, offsets(\*),  
                            houranglegreenw(\*))  
    integer                numvalues,  
    character\*27          asciutc,  
    double precision      offsets(\*),  
    double precision      houranglegreenw(\*)

**DESCRIPTION:** This function computes hour angle of the Vernal Equinox at the Greenwich meridian, accepting an input start time plus an array of time offsets.

**INPUTS:**

**Table 6-233. PGS\_CSC\_GreenwichHour Inputs**

Name	Description	Units	Min	Max
numValues	number of input time offsets	N/A	0	any
asciiUTC	UTC start time in CCSDS ASCII Time Code A or B format	N/A	see Notes	see Notes
offsets	array of time offsets	seconds	Max and Min such that asciiUTC + offset is between asciiUTC Min and Max values	

## OUTPUTS:

**Table 6-234. PGS\_CSC\_GreenwichHour Outputs**

Name	Description	Units	Min	Max
hourAngleGreenw	array of values of the hour angle of the Vernal Equinox at Greenwich; a value of 999999.0 is returned for invalid offset times	hours	0	24

## RETURNS:

**Table 6-235. PGS\_CSC\_GreenwichHour Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSCSC_W_ERRORS_IN_GHA	An error occurred in computing at least one Greenwich hour angle
PGSCSC_W_PREDICTED_UT1	Data in utcpole.dat file is predicted (not final) value for at least one input time
PGSTD_E_TIME_VALUE_ERROR	Error in input time value
PGSTD_E_TIME_FMT_ERROR	Error in input time format
PGSTD_E_NO_LEAP_SECS	No leap seconds correction is available in leapsec.dat file for at least one of the input times/offsets
PGS_E_TOOLKIT	Something unexpected happened, execution of function ended prematurely

## EXAMPLES:

```
C:          #define      ARRAY_SIZE  3

PGSt_SMF_status  returnStatus;
PGSt_integer     numValues;
PGSt_integer     counter;
char             asciiUTC[28];
PGSt_double      offsets[ARRAY_SIZE]=
                {3600.0,7200.0,10800.0};
PGSt_double      hourAngleGreenw[ARRAY_SIZE];

numValues=ARRAY_SIZE;
strcpy(asciiUTC,"1991-01-01T11:29:30");
returnStatus = PGS_CSC_GreenwichHour(numValues,asciiUTC,
                                     offsets,
                                     hourAngleGreenw);
```

```

if(returnStatus != PGS_S_SUCCESS)
{
** test errors,
   take appropriate
   action **
}
printf("start time:%s",asciiUTC);
counter = 0;
while(counter < numValues)
{
    printf("Offset: %lf    Hour Angle:%lf",offset[counter],
           hourAngleGreenw[counter]);
    counter++;
}

```

FORTTRAN:

```

implicit none

parameter (array_size=3)
integer      pgs_csc_greenwichhour
integer      array_size
integer      returnstatus
integer      counter
integer      numvalues
character*27  asciiutc
double precision  offsets(array_size)
double precision  houranglegreenw(array_size)

data offsets/3600.0,7200.0,10800.0/
array_size = 3
numvalues = array_size
asciiutc = '1991-01-01T11:29:30'

returnstatus = pgs_csc_greenwichhour(numvalues,asciiutc,
                                     offsets,
                                     houranglegreenw)

if(returnstatus .ne. pgs_s_success) go to 90
write(6,*) asciiutc
if(numvalues.eq.0) numvalues = 1
do 40 counter = 1, numvalues,1
write(6,*)offsets(counter),houranglegreenw(counter)

40 continue

90 write(6,99)returnstatus

99 format('ERROR:',A50)

```

**NOTES:**

Historically, UT1 was used as a measure of time, but since 1958 it has served only as a measure of Earth rotation. The only real difference between UT1 and Greenwich Mean Sidereal Time (GMST) is that UT1 measures Earth rotation in regards to the vector from Earth center to the mean sun (a fictitious point that traverses the celestial equator at the same mean rate that the sun apparently traverses the ecliptic), while GMST measures Earth rotation relative to the vernal equinox. Essentially, the value of GMST in radians is larger than that of UT1 in radians by the ratio of the mean solar day to the sidereal day; however, there are small correction terms due to precession. The equation used in function `PGS_TD_gmst( )` is valid for the period 1950 to well past 2000, as long as the definition of UT1 and the reference equinox (J2000) are not changed. The basic limitation is the accuracy of UT1. Users obtaining UT1 from the SDP Toolkit should observe time limitations in the function `PGS_TD_UTCtoUT1( )`.

**TIME ACRONYMS:**

GMST is: Greenwich Mean Sidereal Time

TAI is: International Atomic Time

UT1 is: Universal Time

UTC is: Coordinated Universal Time

See Section 6.2.7.5.2 (UT1-UTC Boundaries)

**REFERENCE FOR TIME:**

CCSDS 301.0-B-2 (CCSDS => Consultative Committee for Space Data Systems Astronomical Almanac, Explanatory Supplement to the Astronomical Almanac.

**REQUIREMENTS:** PGSTK-0770

## Get Zenith and Azimuth of an ECR Vector at the Look Point

---

**NAME:** PGS\_CSC\_ZenithAzimuth()

**SYNOPSIS:**

```
C:      #include <PGS_CSC.h>

      PGSt_SMF_status
      PGS_CSC_ZenithAzimuth(
          PGSt_double      vectorECR[3],
          PGSt_double      latitude,
          PGSt_double      longitude,
          PGSt_double      altitude,
          PGSt_tag          vectorTag,
          PGSt_boolean      zenithOnlyFlag,
          PGSt_boolean      refractFlag,
          PGSt_double      *zenith,
          PGSt_double      *azimuth
          PGSt_double      *refraction)

FORTRAN: include'PGS_CSC.f'
          include'PGS_CSC_4.f'
          include'PGS_SMF.f'

          integer function
          pgs_csc_zenithazimuth(vectorecr,latitude,longitude,altitude,
                                vectortag,zenithonlyflag,
                                refractflag,zenith,azimuth,
                                refraction)

                                double precision      vectorECR[3]
                                double precision      latitude
                                double precision      longitude
                                double precision      altitude
                                integer                vectortag
                                integer                zenithonlyflag
                                integer                refractflag
                                double precision      zenith
                                double precision      azimuth
                                double precision      refraction
```

**DESCRIPTION:** Computes the zenith and the azimuth of a vector at the look point. This tool allows for refraction if desired.

**INPUTS:****Table 6-236. PGS\_CSC\_ZenithAzimuth Inputs**

Name	Description	Units	Min	Max
vectorECR	ECR vector whose zenith & azimuth is desired (in case of PGSD_MOON do not use a unit vector!—see NOTES)	meters or unit vector	N/A	N/A
latitude	geodetic latitude	radian	-pi/2	pi/2
longitude	longitude	radian	-2*pi	2*pi
altitude	altitude off the geoid (altitude is an input only when refracFlag is PGS_TRUE see NOTES).	meters	-2000	80000
vectorTag	PGSd_CB, PGSd_moon, or PGSd_Look or a CB identifier (see NOTES)	N/A	N/A	N/A
zenithOnlyFlag	omit azimuth calculation	N/A	N/A	N/A
refracFlag	turns on refraction	N/A	N/A	N/A

**OUTPUTS:****Table 6-237. PGS\_CSC\_ZenithAzimuth Outputs**

Name	Description	Units	Min	Max
zenith	zenith angle	radian	0	1.6755 (96 deg)
azimuth	azimuth E from N	radian	-pi	+pi
refraction	increase of zenith angle due to refraction	radian	0	0.1

**RETURNS:****Table 6-238. PGS\_CSC\_ZenithAzimuth Returns**

Return	Description
PGS_S_SUCCESS	Successful execution
PGSCSC_W_BELOW_HORIZON	Warning indicating the object is below horizon
PGSCSC_W_UNDEFINED_AZIMUTH	The object is at the zenith. In this case azimuth is not calculated
PGSCSC_W_NO_REFRACTION	No refraction calculation done due to errors
PGSCSC_E_INVALID_VECTAG	The input vector tag is not PGSd_CB, PGSd_MOON, PGSd_LOOK or a celestial body identifier
PGSCSC_E_LOOK_PT_ALTIT_RANGE	Look point altitude not reasonable
PGSCSC_E_ZERO_INPUT_VECTOR	The input vector has zero length
PGS_E_TOOLKIT	Unknown error occurred

## EXAMPLES:

```
C:      PGSt_SMF_status   returnStatus;
      PGSt_double        vectorECR[3];
      PGSt_double        latitude  = 0.2;
      PGSt_double        longitude = 0.1;
      PGSt_double        altitude  = 0.0;
      PGSt_tag           vectorTag = PGSD_LOOK;
      PGSt_boolean       zenithOnlyFlag = PGS_FALSE;
      PGSt_boolean       refractFlag = PGS_FALSE;
      PGSt_double        zenith;
      PGSt_double        azimuth;
      PGSt_double        refraction;

      vectorECR[2] = -0.26;
      vectorECR[1] = 0.0;
      vectorECR[0] = sqrt(1 - vectorECR[2]*vectorECR[2]);

      returnStatus = PGS_CSC_ZenithAzimuth(vectorECR,latitude,
                                           longitude,altitude,
                                           vectorTag,
                                           zenithOnlyFlag,
                                           refractFlag,&zenith,
                                           &azimuth,&refraction)

      do some error handling
      if desired, convert zenith and azimuth to degrees
      printf("zenith angle = %lf,  azimuth = %lf\n", zenith,
            azimuth);
```

```
FORTRAN:  implicit none

            integer          pgs_csc_zenithazimuth
            double precision  look[3]
            double precision  latitude
            double precision  longitude
            double precision  altitude
            integer          zenithonlyflag
            integer          refractflag
            double precision  zenith
            double precision  azimuth
            double precision  refraction
            integer          vectortag,returnstatus

            vectortag = pgsd_look
            latitude  = 0.2D0
            longitude = -0.3D0
```

```

altitude = 0.0D0
zenithonlyflag = PGS_FALSE
refractflag = PGS_FALSE

look[3] = -0.26;
look[2] = 0.0;
look[1] = sqrt(1 - look[3]*look[3]);

returnstatus = pgs_csc_zenithazimuth(look,latitude,
                                     longitude,altitude,
                                     vectortag,
                                     zenithonlyflag,
                                     refractflag,zenith,
                                     azimuth,refraction)

```

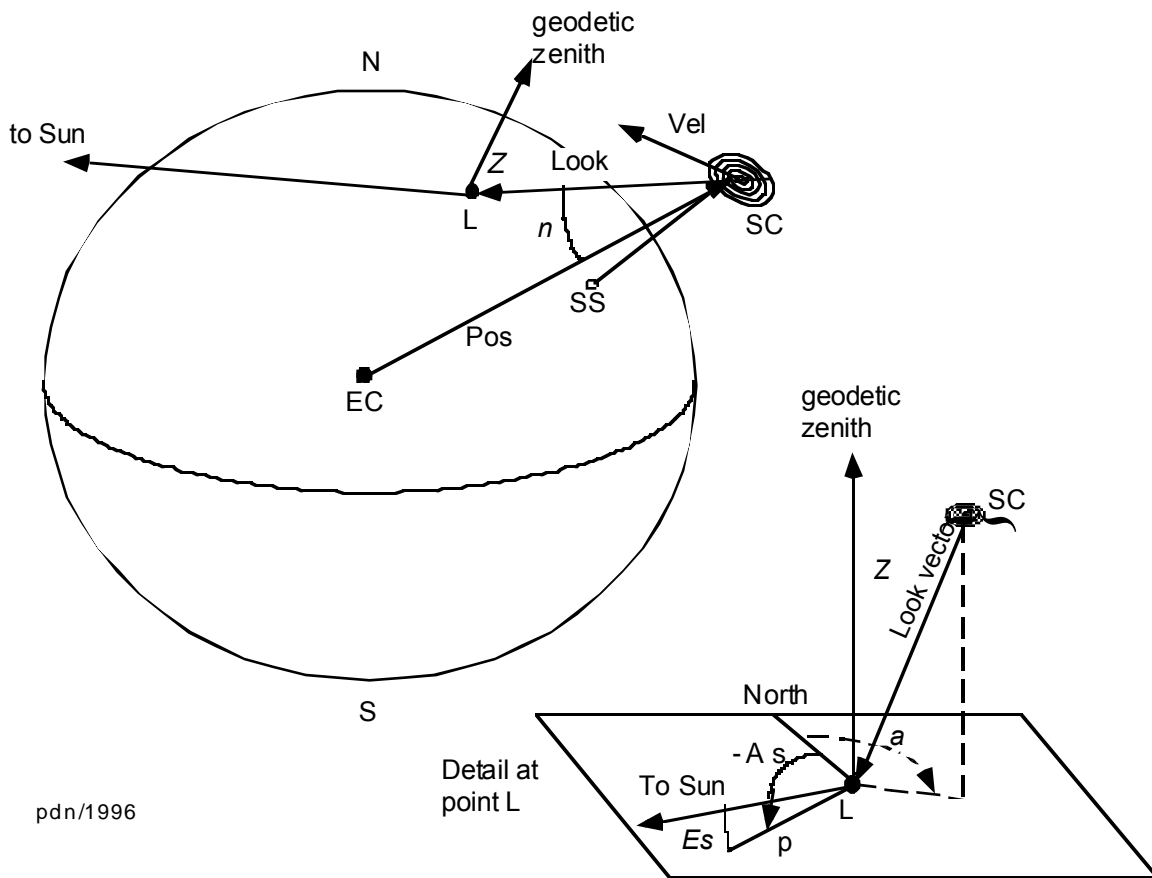
C        do some error handling

C        if desired, convert zenith and azimuth to degrees

**NOTES:**        The vectorECR vector must be in ECR coordinates. For celestial bodies, it is the vector from Earth to the celestial body. It can be obtained by getting the ECI vector to the body from PGS\_CBP\_Earth\_CB\_Vector(), and transforming that vector to ECR rectangular coordinates with PGS\_CSC\_ECItoECR().

The "look vector" (which could as well be called the "boresight vector") is an ECR vector from the instrument to the point being viewed ("look point."). To obtain the zenith and azimuth of the look vector, the vectorTag must be set to PGSD\_LOOK (this allows for the reversed sense of such a vector, which represents a line of sight above the horizon when pointing down). If desired, the unit look vector can be obtained and saved from PGS\_CSC\_GetFOV\_Pixel( ); this will achieve very good performance, as the ECR look vector is calculated there. If the ECR look vector has to be constructed (for example, when starting with already-geolocated data), this can be done, for example, as follows: Convert the latitude, longitude and altitude of the look point to ECR rectangular coordinates with PGS\_CSC\_GEOtoECR(). Then obtain the ECI spacecraft position from PGS\_CSC\_Ephem\_Attil(), and convert it to ECR with PGS\_CSC\_ECItoECR(). Finally, subtract the last result from the first. The geometry is illustrated in Fig 6-4:





**Figure 6-4. Geometry of the Viewing and Sun Vectors**

Notation:

SC = spacecraft

EC = Earth Center

Pos = position vector

Vel = velocity vector

SS = subsatellite point

L = Lookpoint

$n$  = nadir angle

$Es$  = elevation of the Sun =  $(\pi/2 - \text{solar zenith angle})$ .

$p$  = projection of Sun vector on horizontal

$As$  = solar azimuth. All azimuths are measured East from North

$Z$  = zenith angle of look vector.  $a$  = azimuth of the Look vector.

Note that because of Earth curvature, generally  $Z > n$ . Also, in this diagram  $m, n$  is referenced to geocentric, SS to geodetic, a small difference. In other contexts, however, "nadir angle" could refer to the

angle between a direction and either geocentric, geodetic, or nominal spacecraft nadir.

Note: In ECR coordinates, the Look Vector is also called the ECR Pixel Vector, but in SC coordinates, it is called the SC Pixel Vector.

If the zenith and azimuth of a distant celestial body (such as the sun or a planet) are desired, the user may supply PGSd\_CB or any of the identifiers: PGSd\_SUN, PGSd\_MERCURY, PGSd\_VENUS, PGSd\_MARS, PGSd\_JUPITER, PGSd\_SATURN, PGSd\_URANUS, PGSd\_NEPTUNE, or PGSd\_PLUTO. This is purely a convenience for users doing other calculations with a CB identifier; the action of the function is in all cases the same—it finds the zenith and azimuth of the vector at the look point, without regard to parallax (i.e., the vector from Earth center to the Celestial body is regarded as unchanged due to the displacement of the look point from Earth center).

In the case of the PGSd\_MOON, the geocentric parallax is appreciable, meaning that its apparent position is, in general, different as viewed from Earth center or from the look point. The difference can be as large as a degree. Therefore, in this case, a parallax correction is made. It is essential, in this case, of course, that the PGSd\_MOON vector be supplied in meters. In this case, the input vector should be the Earth to PGSd\_MOON vector defined from Earth center (geocentric), as obtained, for example, from the PGS\_CBP\_Earth\_CB\_Vector( ) tool.

In all other cases, the input vector can be in any units, including normalized (unit vector).

Users wishing to take into account the minuscule parallax correction for the sun, or the correction for some other chosen body such as an asteroid, could simply label the vector as PGSd\_MOON. (For the sun, the correction is only ~ 2.5 millidegrees.)

Refraction by the atmosphere is calculated if the flag is set to PGS\_TRUE. This calculation approximately corrects, in the visual band, for the fact that any line of sight, such as the sun, moon, or look vector is bent by the atmosphere.

If the vector is well below the horizon, a warning is returned and no azimuth calculation is done. The present algorithm is fairly forgiving for points slightly below the horizon (to 96 degrees), in order that the user interested in the location of the glow before sunrise or after sunset can find its azimuth; it is user responsibility to take special action between 90 degrees and 96 degrees if these data are not wanted.

The altitude is required only if refraction is to be calculated, and its only effect is to change the mean density of the atmosphere in the refraction function.

If the zenith only flag is defined by the user to be PGS\_TRUE the function will run faster but will not calculate the azimuth.

If the azimuth is requested but the zenith angle is  $< 0.026$  deg, it is deemed that the azimuth calculation is unreliable, because variations in the local vertical as determined from the geoid, and variable refraction in the atmosphere dominate at that level. The azimuth is returned as 0.0 and the warning PGSCSC\_W\_UNDEFINED\_AZIMUTH is returned

The calculation herein is entirely independent of the Earth model except for the parallax correction, where WGS84 is assumed, and any difference in other models introduces negligible error. The use of geodetic latitude as input guarantees that the rest of the algorithm is independent of Earth model.

**REQUIREMENTS:** PGSTK-1091

## Find Point of Closest Miss and Surface Point

---

**NAME:** PGS\_CSC\_GrazingRay()

**SYNOPSIS:**

C:                   #include <PGS\_CSC.h>

PGSt\_SMF\_status  
PGS\_CSC\_GrazingRay(  
    char                   earthEllipsTag[50],  
    PGSt\_double           posECR[3],  
    PGSt\_double           ray[3],  
    PGSt\_double           \*latitude,  
    PGSt\_double           \*longitude,  
    PGSt\_double           \*missAltitude,  
    PGSt\_double           \*slantRange,  
    PGSt\_double           posNEAR[3],  
    PGSt\_double           posSURF[3])

FORTRAN:           include 'PGS\_SMF.f'  
                    include 'PGS\_CSC\_4.f'

integer function pgs\_csc\_grazingray(  
    earthellipstag,pos,ray,latitude,longitude,  
    missaltitude,slantrange,posnear,possurf)

character\*49       earthellipstag  
double precision   posecr(3)  
double precision   ray(3)  
double precision   latitude  
double precision   longitude  
double precision   missaltitude  
double precision   slantrange  
double precision   posnear(3)  
double precision   possurf(3)

**DESCRIPTION:** For rays that miss Earth limb, this function finds the nearest miss point on the ray and the corresponding surface point. For rays that strike the Earth, it finds instead the midpoint of the chord of the ray within the ellipsoid and the surface point of intersection nearest the observer.

**INPUTS:****Table 6-239. PGS\_CSC\_GrazingRay Inputs**

Name	Description	Units	Min	Max
earthEllipsTag	tag selecting Earth ellipsoid model (default is WGS84)	N/A	N/A	N/A
posECR	ECR Spacecraft Position	meters	N/A	see NOTES
ray[3]	unit vector along the line of sight, in ECR coordinates	N/A	-1 per component	+1 per component

**OUTPUTS:****Table 6-240. PGS\_CSC\_GrazingRay Outputs**

Name	Description	Units	Min	Max
latitude	geodetic latitude of posNEAR (q.v. below)	radians	-pi/2	pi/2
longitude	longitude of posNEAR (q.v. below)	radians	-pi	pi
missAltitude	altitude of posNEAR (q.v. below)	meters	N/A	N/A
slantRange	range to posNEAR (q.v. below)	m/s	-7000	7000
posNEAR[0]	X coordinate (in ECR) of the point on ray nearest to the ellipsoid (when ray misses); when ray hits, this point is defined to be midpoint of the ray chord within the ellipsoid (see NOTES)	meters	N/A	N/A
posNEAR[1]	Y coordinate (in ECR) of the point on ray nearest to the ellipsoid (when ray misses); when ray hits, this point is defined to be midpoint of the ray chord within the ellipsoid (see NOTES)	meters	N/A	N/A
posNEAR[2]	Z coordinate (in ECR) of the point on ray nearest to the ellipsoid (when ray misses); when ray hits, this point is defined to be midpoint of the ray chord within the ellipsoid (see NOTES)	meters	N/A	N/A
posSURF[0]	X coordinate (in ECR) of the point on Earth closest to the ray (when the ray misses Earth limb) or where the ray first strikes the Earth ellipsoid, (in the case that it does not miss)	meters	N/A, but normally < 6378140	N/A, but normally > -6378140
posSURF[1]	Y coordinate (in ECR) of the point on Earth closest to the ray (when the ray misses Earth limb) or where the ray first strikes the Earth ellipsoid (in the case that it does not miss)	meters	N/A, but normally < 6378140	N/A, but normally > -6378140
posSURF[2]	Z coordinate (in ECR) of the point on Earth closest to the ray (when the ray misses Earth limb) or where the ray first strikes the Earth ellipsoid (in the case that it does not miss)	meters	N/A, but normally < 6378140	N/A, but normally > -6378140

## RETURNS:

**Table 6-241. PGS\_CSC\_GrazingRay Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSCSC_W_SUBTERRANEAN	User provided a subterranean position for the spacecraft
PGSCSC_W_HIT_EARTH	Line of Sight struck the Ellipsoid
PGSCSC_W_LOOK_AWAY	Line of sight points away from Earth
PGSCSC_W_ERROR_IN_GRAZINGRAY	Generic return for warning in lower level function
PGSCSC_W_SPHERE_BODY	Using a spherical Earth model
PGSCSC_W_LARGE_FLATTENING	Issued if flattening factor is greater than 0.01
PGSCSC_W_DEFAULT_EARTH_MODEL	Default Earth model was used - user's model not found
PGSCSC_W_ZERO_PIXEL_VECTOR	Zero length ray vector supplied (terminates execution)
PGSCSC_E_BAD_EARTH_MODEL	Equatorial or polar radius less than or equal to 0.0 or the model defines a prolate Earth
PGS_E_TOOLKIT	Something unexpected happened—execution aborted

## EXAMPLES:<sup>1</sup>

```
C:      #include <PGS_CSC.h>
        PGSt_SMF_status   returnStatus
            char            earthEllipsTag[50];
            PGSt_double     posECR[3];
            PGSt_double     ray[3];
            PGSt_double     latitude;
            PGSt_double     longitude;
            PGSt_double     missAltitude;
            PGSt_double     slantRange;
            PGSt_double     posNEAR[3];
            PGSt_double     posSURF[3];

        strcpy(earthEllipsTag,"GEM-10B");
        posECR[0] = 4077000.0;
            posECR[1] = 5000000.0;
            posECR[2] = -3200000.0;
        ray[0] = 0.0002;
            ray[1] = -1.0;
            ray[2] = -0.422;
        returnStatus = PGS_CSC_GrazingRay(
            earthEllipsTag,posECR,ray,&latitude,&longitude,
            &missAltitude,&slantRange, posNEAR,
            posSURF);
```

---

<sup>1</sup> Note: As is Toolkit standard, to avoid possible interface problems to outside software that may support different word lengths, the Toolkit renormalizes all unit input vectors at the same time it checks for zero length input vectors. Therefore the inputs shown here are unnormalized.

```

printf("Longitude %f\n",longitude);
printf("Latitude: %f\n",latitude);
printf("Altitude: %f\n",missAltitude);
printf("Slant Range: %f\n",slantRange);
if(returnStatus == PGS_S_SUCCESS)
{
printf("Point on Ray Nearest Earth: %f, %f, %f\n",
posNEAR[0],posNEAR[1],posNEAR[2]);
printf("Point on Surface Nearest Ray: %f, %f, %f\n",
posSURF[0],posSURF[1],posSURF[2]);
}
else if(returnStatus == PGSCSC_W_HIT_EARTH)
{
printf("Midpoint of Ray Chord in Earth: %f, %f, %f\n",
posNEAR[0],posNEAR[1],posNEAR[2]);
printf("Line of Sight Strikes Earth at: %f, %f, %f\n",
posSURF[0],posSURF[1],posSURF[2]);
}
else
{
** test errors,
take appropriate
action **
}

```

FORTTRAN:

```

include 'PGS_SMF.f'
include 'PGS_CSC_4.f'
implicit none
integer          pgs_csc_grazingray
integer          returnstatus
character*19     earthellipstag
double precision posecr(3)
double precision ray(3)
double precision latitude
double precision longitude
double precision missaltitude
double precision slantrange
double precision posnear(3)
double precision possurf(3)

posecr(1) = 4077000.0
posecr(2) = 5000000.0
posecr(3) = -3200000.0
ray(1) = -0.0002
ray(2) = -1.0
ray(3) = -0.422
returnstatus = pgs_csc_grazingray(
earthellipstag,posecr,ray,latitude,longitude,
missaltitude,slantrange, posnear,
possurf)
print*,'Longitude: ',longitude
print*,'Latitude: ',latitude
print*,'Slant Range: ',slantrange
print*,'Altitude: ',missaltitude

```

if(returnStatus .eq. PGS\_S\_SUCCESS) then

```

C ampersands & below are continuation marks in column
    print*, 'Point on Ray Nearest Earth: X = ',
    posnear(1), ' Y = ', posnear(2), ' Z = ', posnear(3)
    print*, 'Point on Surface Nearest Ray: X = ',
&    possurf(1), ' Y = ', possurf(2), ' Z = ', possurf(3)
    else if (returnStatus .eq. PGSCSC_W_HIT_EARTH) then
        print*, 'Midpoint of Ray Chord in Earth: X = ',
&posnear(1), ' Y = ', posnear(2), ' Z = ', posnear(3)
        print*, 'Line of Sight Strikes Earth at: X = ',
&possurf(1), ' Y = ', possurf(2), ' Z = ', possurf(3)
    else
C  ** test errors, take appropriate action **
        endif
        print*, err, msg

```

#### NOTES:

For a line of sight ("ray") that misses Earth limb, this tool calculates the rectangular coordinates of the point Q of closest approach to the Earth and the slant range to Q. It also obtains the latitude and longitude of the surface point P nearest Q (and therefore nearest to the ray) and the geodetic altitude of Q above P (Q and P have the same longitude and geodetic altitude). When the ray, instead, intersects the Earth ellipsoid, the rectangular coordinates of Q are replaced by those of a point halfway between the two "pierce points" where the ray intersects the ellipsoid. The intent is to provide a point with the nearly the same latitude and longitude as the point closest to the Earth's surface on a ray from a background object (such as the Sun) that is actually refracted round the Earth. When the ray intersects the Earth, the latitude and longitude of P are also replaced by those of the nearest pierce point, i.e. where the instrument is looking, and the slant range is replaced by the range to that point. Furthermore, the return value PGSCSC\_W\_HIT\_EARTH issues. If the ray, instead, points *away* from the Earth ellipsoid, the altitude output variable is set to PGSd\_GEO\_ERROR\_VALUE and the return value to PGSCSC\_W\_LOOK\_AWAY, in either case - ray missing the ellipsoid or ray striking it. The return PGSCSC\_W\_ZERO\_PIXEL\_VECTOR terminates execution, even though it is a "warning" level only; the "warning" status was defined for this message to support certain tools that process arrays of pixels at once, in order that if a few pixel vectors were bad, the remainder could be processed. The same return is reused here, but promoted to have a fatal result.

If an invalid earthEllipsTag is input, the program will use the WGS84 Earth model by default.

#### REQUIREMENTS: PGSTK-1085



### **6.3.4.11 CSC Functions**

#### **PGS\_CSC\_DayNight**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

#### **PGS\_CSC\_ECItoECR**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

#### **PGS\_CSC\_ECItoORB**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

#### **PGS\_CSC\_ECItoSC**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

#### **PGS\_CSC\_ECRtoECI**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

#### **PGS\_CSC\_ECRtoGEO**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

#### **PGS\_CSC\_EarthOccult**

Test for earth occultation of a celestial body in the field of view. The test is in three phases. The first phase does not depend on the CB at all - it is just a check if the Earth fills the field of view. The second test (exercised only if the first fails to find total occultation) determines if the celestial body is behind the Earth. If the second test fails, the vector in SC coordinates that points at the part of the CB most distant from the Earth center is returned so that the calling function can determine if the Earth's bulge (difference in radius over that of an inscribed sphere) occults the CB.

#### **PGS\_CSC\_Earthpt\_FixedFOV**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

#### **PGS\_CSC\_Earthpt\_FOV**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

#### **PGS\_CSC\_EulerToQuat**

Transforms Euler angles to Quaternions.

### **PGS\_CSC\_FOVconicalHull**

A circular cone is drawn around the FOV and a check is made as to whether the candidate point is inside it before going any further. The function has two purposes:

- a. it will speed up tasks by obviating complicated algorithms for points well away from the FOV
- b. it will enable detection and rejection of FOV specifications outside our present algorithmic limits. [Present software does not reliably handle fields of view more than 180 degrees across.]

### **PGS\_CSC\_GEOtoECR**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_GetEarthFigure**

This tool gets the equatorial and polar radii from the earthfigure.dat file for the earth model input.

### **PGS\_CSC\_GetFOV\_Pixel**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_GreenwichHour**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_J2000toTOD**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_LookPoint**

Solves the look point equation. method:

Solve the quadratic equation

$$x = p + d*u$$

where x must lie on an ellipsoid, for the slant range, d, corresponding to the intersection of the extended look vector, u, with the surface of the earth. Then compute x directly.

### **PGS\_CSC\_Norm**

This tool computes the norm of a 3-vector.

### **PGS\_CSC\_ORBtoECI**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_ORBtoSC**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_PointInFOVgeom**

For each input point, the function does the processing to determine if a point is in the field of view and returns a flag indicating whether the point is in the field of view.

### **PGS\_CSC\_QuatToEuler**

This function gets Euler angles from a quaternion.

### **PGS\_CSC\_SCtoECI**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_SCtoORB**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_SpaceRefract**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_SubSatPoint**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_SubSatPointVel**

This tool finds the North and East components of the velocity of the subsatellite point and the rate of change of spacecraft altitude.

### **PGS\_CSC\_TODtoJ2000**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_TiltYaw**

Obtains the tipped orbital (geodetic nadir) to orbital transformation quaternion.

### **PGS\_CSC\_UT1\_update**

updates the file "utcpole.dat"

### **PGS\_CSC\_UTC\_UT1Pole**

This tool accesses the file 'utcpole.dat' and extracts using interpolation the x,y pole position in seconds of arc and the difference of UT1 and UTC, given an input Julian date.

### **PGS\_CSC\_ZenithAzimuth**

See description in 6.3.4.9: Coordinate System Conversion Transformation Tools

### **PGS\_CSC\_crossProduct**

Cross product of vectors

### **PGS\_CSC\_dotProduct**

Dot product of vectors

### **PGS\_CSC\_getECItoORBquat**

This function returns a quaternion describing the rotation from the Earth Centered Inertial (ECI) reference frame to the Orbital (ORB) reference frame. That is the quaternion returned will transform a vector in the ECI frame to the equivalent vector in the ORB frame.

### **PGS\_CSC\_getORBtoECIquat**

This function returns a quaternion describing the rotation from the Orbital (ORB) reference frame to the Earth Centered Inertial (ECI) reference frame. That is the quaternion returned will transform a vector in the ORB frame to the equivalent vector in the ECI frame.

### **PGS\_CSC\_getQuats**

Converts a transformation matrix to a quaternion

### **PGS\_CSC\_nutate2000**

This tool transforms a vector under nutation between Mean Celestial Coordinates of date in Barycentric Dynamical Time (TDB) and True Celestial Coordinates of date.

### **PGS\_CSC\_precs2000**

This tool precesses a vector from Mean Celestial Coordinates of date in Barycentric Dynamical Time (TDB) to J2000 coordinates or from J2000 coordinates to Mean Celestial Coordinates of date in Barycentric Dynamical Time (TDB).

### **PGS\_CSC\_quatMultiply**

This file contains the function PGS\_CSC\_quatMultiply(). This function multiplies two quaternions, using a short algorithm with 11 multiplications and 19 additions.

### **PGS\_CSC\_quatRotate**

This function transforms a vector from one coordinate system to a rotated coordinate system with a common origin, where the rotation is defined by a quaternion.

### **PGS\_CSC\_quickWahr**

Wahr nutation with extrapolation for up to 1/2 hour (valid to microseconds of arc)

### **PGS\_CSC\_wahr2**

Calculates nutation angles delta psi and delta epsilon, and their rates of change, referred to the ecliptic of date, from the Wahr series.

### 6.3.5 Geo–Coordinate Transformation Tools

The geo–coordinate transformation tools are required to support the bi–directional transformation between geographic coordinates and various standard map projection frames. The tools are designed to give rapid coordinate transformations for many points. The tool provides transformations from geodetic latitude and longitude as output from the geolocation tool into the required map projection frames.

There are initialization routines for each set of transformations (PGS\_GCT\_Init). PGS\_GCT\_Init routine is used to “save” in memory the projection parameters and to pre–calculate any variables that are required in all subsequent transformations. Following the initialization of a projection there are routines for the forward and reverse transformations combined into a single interface (PGS\_GCT\_Proj).

The tool may be used to perform many transformations in different projections within the same executable program. If the same projection is required twice to perform transformations with two different sets of parameters, then the initialization routine has to be called before each set of transformations.

Every effort should be made to standardize projection definitions throughout the project to enable data sets to be generated in a consistent manner.

In addition to the standard transformations of latitude and longitude to map projection specific transformations from one projection to another are required, these are treated in a similar manner as discussed below.

The tool is based on the commonly available packages general cartographic transformation package (GCTP) for coordinate transformation; this package is based on the projections described by Snyder. *Map Projections—A Working Manual*—J.P. Snyder, USGS professional paper 1395, 1987.

## Initialize Given Projection Parameters

---

**NAME:** PGS\_GCT\_Init()

**SYNOPSIS:**

C: #include <PGS\_GCT.h>

PGSt\_SMF\_status  
PGS\_GCT\_Init(  
    PGSt\_integer        projId,  
    PGSt\_double        projParam[],  
    PGSt\_integer        directFlag)

FORTRAN: include "PGS\_GCT.f"  
include "PGS\_GCT\_12.f"  
include "PGS\_SMF.f"

integer function pgs\_gct\_init( projid, projparam, directflag)  
    integer        projid  
    double precision(30) projparam  
    integer        directflag

**DESCRIPTION:** This tool provides a general interface to perform geo-coordinate transformations in the forward/inverse directions. In general the tool requires a projection id, location of input data vectors and the direction of the conversion. PGSD\_UTM projection is a special case for which zone value is also needed to define a point.

**INPUTS:**

**Table 6-242. PGS\_GCT\_Init Inputs**

Name	Description	Units	Min	Max
projId	projection code	none	1	#defined
projParam	projection parms	rad, m if latitude if longitude	-90(PI/180) -PI	90(PI/180) PI
directFlag	forward/inverse	none	PGSD_GCT_FORWARD	PGSD_GCT_INVERSE

**OUTPUTS:** None

## RETURNS:

**Table 6-243. PGS\_GCT\_Init Returns**

Return	Description
PGS_S_SUCCESS	
PGSGCT_E_NO_DATA_FILES	Data files for state plane could not be found
PGSGCT_E_GCTP_ERROR	Error has occurred in the GCTP lib
PGSGCT_E_BAD_INC_ANGLE	Invalid inclination angle in the Space Oblique Mercator (SOM) projection
PGSGCT_E_BAD_RADIUS	Invalid radius
PGSGCT_E_BAD_MINOR_AXIS	Invalid minor radius
PGSGCT_E_MINOR_GT_MAJOR	Minor radius is greater than major radius
PGSGCT_E_BAD_LONGITUDE	Invalid longitude
PGSGCT_E_BAD_LATITUDE	Invalid latitude
PGSGCT_E_BAD_DIRECTION	Invalid direction
PGSGCT_E_INVD_SPCS_SPHEROID	Invalid State Plane Coordinates Spheroid (SPCS)
PGSGCT_E_INVD_PROJECTION	Invalid Projection

**EXAMPLES:** NONE (see example for PGS\_GCT\_Proj( ))

**NOTES:** This routine simply initializes the parameters required by a particular projection. The user is referred to the following appendices for further details

Projection List—Appendix G

Parameter List and Use—Appendix G

Spheroid List—Appendix G (State Plane Projection only)

Following steps should be taken if a new projection is to be added to the projection library:

Step 1—archive new code to the projection library

Step 2—define projection code for the new projection in proj.h

Step 3—increment the value of MAXPROJ by one in proj.h

Step 4—add calls to the forward and inverse initialization routines at the end of this file.

Parameters 0 and 1 are reserved for major axis and minor axis respectively

Parameter 4 is reserved for longitude values only.

Parameter 5 is reserved for latitude values only.

Parameters 6 and 7 are reserved for false easting and northing values only.

IMPORTANT All blank array elements are set to zero by the user

Latitude and longitude ranges are as defined in the input section above. The routine checks the longitude value as  $-\text{PI} \leq \text{longitude} \leq \text{PI}$  and latitude as  $-\text{PI}/2 \leq \text{latitude} \leq \text{PI}/2$ . The value of PI is defined as 3.141592653589793238 which is available to the user

**State Plane Projection is not available in the Toolkit.**

**REQUIREMENTS:** PGSTK-1500, PGSTK-1502



---

### SYNOPSIS:

**DESCRIPTION:** This tool provides a general interface to perform geo-coordinate transformations in the forward/inverse directions. In general the tool requires a projection id, location of input data vectors and the direction of the conversion. PGSd\_UTM projection is a special case for which zone value is also needed for inverse transformations. Forward PGSd\_UTM transformations return zone values as output.

**INPUTS:****Table 6-244. PGS\_GCT\_Proj Inputs**

Name	Description	Units	Min	Max
projId	projection code	none	1	#defined
directFlag	forward/inverse	none	PGSd_GCT_FORWARD	PGSd_GCT_INVERSE
nPoints	num. of points	none	1	variable
longitude[]	longitude values	radians	-PI	+PI
latitude[]	latitude values	radians	-PI	+PI
mapX[]	x cartesian coordinate (see notes)	meters	variable	variable
mapY[]	y cartesian coordinate (see notes)	meters	variable	variable
zone[]	UTM zones (negative for southern hemisphere)	none	-60	60

**OUTPUTS:**            See description**RETURNS:****Table 6-245. PGS\_GCT\_Proj Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSGCT_E_BAD_ZONE	Invalid universal transverse mercator (UTM) zone
PGSGCT_E_BAD_DIRECTION	Invalid direction
PGSGCT_E_INVD_PROJECTION	Projection doesn't exists
PGSGCT_E_NO_POINTS	Number of points less than one
PGSGCT_E_GCTP_ERROR	Error in the GCTP library
PGSGCT_E_BAD_LONGITUDE	Bad longitude value (out of range)
PGSGCT_E_BAD_LATITUDE	Bad latitude value (out of range)
PGSGCT_W_INTP_REGION	Interrupted region encountered

**EXAMPLES:**

```
C:           #include "PGS_GCT.h"

             PGS_SMF_status   retValue;
             PGSt_double      projParam[15] ;
             PGSt_double      latitude[4];
             PGSt_double      longitude[4];
             PGSt_double      mapX[4], mapY[4];
```

```

PGSt_integer      ProjId = PGSD_UTM;
PGSt_integer      nPoints = 4;
PGSt_integer      directFlag, i;
PGSt_integer      zone[4] = {0, 0, 0, 0};

PGSt_integer      cucFileId;

/* All parameters must be initialized to zero */

for (i = 0; i<15) i++)
{
    projParam[i] = 0;
}

/* C array starts from 0 */

for (i = 1; i<5) i++)
{
    longitude[i-1] = PI/i;
    latitude[i-1] = PI/4;
}
cucFileId = 10999;
retValue = PGS_CUC_cons(cucFileId,"CLRK80_MAJOR_AXIS",
&ProjParam[0]);
retValue = PGS_CUC_cons(cucFileId,"CLRK80_MINOR_AXIS",
&ProjParam[1]);
    ProjParam[5] = PI/2;
    ProjParam[6] = 3000000 /*(false easting in meters) */
    ProjParam[7] = 75000000 /* (false northing in meters)
*/

    directFlag = PGSD_GCT_FORWARD;
retValue = PGS_GCT_Init (projId, projParam, directFlag);
retValue = PGS_GCT_Proj(projId, directflag, nPoints,
    latitude, longitude, mapX, mapY, zone);

    directflag = PGSD_GCT_INVERSE; (cartesian to
    geographical)
retValue = PGS_GCT_Init (projId, projParam, directFlag);
retValue = PGS_GCT_Proj(projId, directflag, nPoints,
    latitude, longitude, mapX, mapY, zone);

```

#### **FORTTRAN:**

```

implicit none

include "PGS_GCT.f"
include "PGS_GCT_12"
include "PGS_SMF.f"

```

```

integer          PGS_GCT_Proj
integer          retValue
double precision projParam(15)
double precision latitude(4)
double precision longitude(4)
double precision mapX(4), mapY(4)
integer          ProjId
integer          nPoints
integer          directFlag, i
integer          zone(4)

integer          cucFileId

ProjId = PGSd_UTM

nPoints = 4

C      Projection parameters must be initialized to zero

do 10 i= 1, 15

        projParam(i) = 0

10    continue

C      FORTRAN array starts from 1

do 20 i= 1, 4

        longitude(i) = PI/i
        latitude(i) = PI/4

20    continue

cucFileId = 10999
pgs_cuc_cons(cucFileId,"CLRK80_MAJOR_AXIS", ProjParam(0));
pgs_cuc_cons(cucFileId,"CLRK80_MINOR_AXIS", ProjParam(1));
ProjParam(5) = PI/2

C      false easting in meters
ProjParam(6) = 3000000

C      false northing in meters
ProjParam(7) = 75000000

directFlag = PGSd_GCT_FORWARD
retValue =      PGS_GCT_Init (projId, projParam, directFlag)
retValue =      PGS_GCT_Proj(projId, directflag, nPoint
                           latitude, longitude, mapX, mapY, zone)

C      cartesian to geographical

```

```

directflag = PGSd_GCT_INVERSE
pgs_gct_init (projId, projParam, directFlag)
pgs_gct_proj(projId, directflag, nPoints,
             latitude, longitude, mapX, mapY, zone)

```

## NOTES:

The units of output cartesian coordinates essentially depends on the units used for the Earth's radii, false easting and northing, etc., in the parameters list. The only requirement is that the units used should be consistent.

The zones[] parameter is at present only used for UTM transformations. It's an output parameter in the FORWARD direction and input parameter in the INVERSE direction.

All points are processed even if there is an error condition for some points. If bad point(s) are encountered the routine returns PGSd\_GCT\_IN\_ERROR in the output vector. The user can find out the offending input values by searching for the PGSd\_GCT\_IN\_ERROR in the output vector. For example, if the third point is in error then:

### Input Vector

Longitude	1, 2, 3, 4, 5
latitude	1, 1, 1, 1, 1

### Output Vector

X	.01, .02, PGSd_GCT_IN_ERROR, .04, .05
Y	.1, .2, PGSd_GCT_IN_ERROR, .4, .5

For the inverse transformations, two projections, namely Interrupted Goode and Interrupted Mollweide sometimes encounter a point that is in an interrupted region. In such cases the tool does not abandon processing but puts a value PGSd\_GCT\_IN\_BREAK in the output vector. At the end of processing the tool returns a warning that an Interrupted region was encountered. The user can find out the offending input values by searching for the PGSd\_GCT\_IN\_BREAK in the output vector. For example, if the third point is in the interrupted region:

### Input Vector

X	1, 2, 3, 4, 5
Y	1, 1, 1, 1, 1

### Output Vector

Longitude	.01, .02, PGSd_GCT_IN_BREAK, .04, .05
latitude	.1, .2, PGSd_GCT_IN_BREAK, .4, .5

**REQUIREMENTS:** PGSTK-1500, 1502

### **6.3.6 Math and Statistical Support Tools**

IMSL has been selected to provide a suite of standard mathematical manipulation functions in a uniform package. This package is available to SCF and DAAC facilities through the EDHS server. Usage of the functionality supplied by the math package will not be mandatory and user developed or shareware routines may be included in science processing software. Users will be responsible for the functionality and long term maintenance of their homegrown software. IMSL service will be provided gratis.

We note that internal Toolkit software does not depend on IMSL.

### **6.3.7 Constants and Unit Conversions**

#### **6.3.7.1 Introduction**

The constants and unit conversion tools provide a means to access commonly used mathematical and physical constants, and a coherent means to perform unit conversions and parameter translations.

When the units conversion required is a linear conversion (e.g., degrees to radians) the most efficient mechanism for the programmer is to be given access to a physical constant that describes that transformation and then for the programmer to use this as appropriate. Providing a calling routine to perform the transformation would be inappropriate to most unit conversions and therefore specific API's for this are not provided.

#### **6.3.7.2 Requirements Compliance**

- a. PGSTK-1521 states that the Toolkit shall provide a means of accessing constant values related to an instrument. Constants that relate to instrument parameters are treated as ancillary data (static internal and dynamic internal) to the algorithms. The mechanism for retrieving instrument ancillary data is described elsewhere in section 6.2.1.6; this requirement is fulfilled by that tool.
- b. An external file using some standard parameter=value mechanism will be used to store the mathematical and physical constants, in a similar way as performed in the ancillary data access tools. In this way the values are capable of adjustment without recompilation (requirement PGSTK-1522)
- c. PGSTK-1531 states that unit conversion tools shall transform multiple values in a single call. As described above, the most efficient way for the programmer to perform unit conversions is to be given access to the conversion factor, which will be provided by the following tool. This requirement is therefore redundant.

## Obtain a Value for a User Specified Constant

---

**NAME:** PGS\_CUC\_Cons

**SYNOPSIS:**

**C:** #include <PGS\_CUC.h>

```
PGSt_SMF_Status  
PGS_CUC_Cons (  
    PGSt_integer    inpfleid,  
    char            *inpParameter,  
    PGSt_double     *outvalue)
```

**FORTTRAN:** include'PGS\_CUC\_11.f'  
include'PGS\_SMF\_.f'

```
integer function PGS_CUC_Cons (inpfleid, inpParameter, outvalue)  
    integer    inpfleid,  
    character  inpParameter,  
    double precision outvalue)
```

**DESCRIPTION:** This routine receives the fileid and the constant name from the user. The fileid allows more than one input file to be used, thus allowing the user to implement his or her own specialized input files with constants. The parameter is a character string representing the constant whose numerical value is sought by the user. The resulting value is passed back to the user.

**INPUTS:**

**Table 6-246. PGS\_CUC\_Cons Input**

Name	Description	Units	Min	Max
fileid	file identifier	N/A	N/A	N/A
parameter	constant wanted	N/A	N/A	N/A

**OUTPUTS:**

**Table 6-247. PGS\_CUC\_Cons Output**

Name	Description	Units	Min	Max
value	constant value	N/A	N/A	N/A

## RETURNS:

**Table 6-248. PGS\_CUC\_Cons Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGSCUC_E_ERROR	error in finding the constant value
The following are returned to the error log:	
PGSCUC_E_CANT_GET_FILE_ID	
PGSCUC_E_CANT_OPEN_INPUT_FILE	
PGSCUC_E_AGG_CANT_BE_INSERTED	
PGSCUC_E_READLABEL_PARSE_ERROR	
PGSCUC_E_PARAMETER_INVALID	
PGSCUC_E_FIRST_NODE_NOT_FOUND	

## EXAMPLES:

```
C:      char parameter[] = {"PI"};
      int  fileid = 19701;
      double result;

      ret_status = PGS_CUC_Cons(parameter, fileid, result);
```

```
FORTRAN:  implicit none

           include      'PGS_CUC_11.f'
           include      'PGS_SMF.f'

           integer      pgs_cuc_cons
           integer      ret_status
           integer      inpfileid
           character*100 inpParameter
           double precision outvalue
           inpfileid = 10790
           inpParameter = 'pi'

           ret_status = pgs_cuc_cons(inpfileid, inpParameter, outvalue)
           ret_value = PGS_CUC_get_parameter("pi", pi)
```

**NOTES:** User defines key word to be searched for within a logical file. User also defines fileid so that location of file can be found. Tool uses ODL libraries to conduct a parameter equals value search. For further information see Constant and Unit Conversions (CUC) Tools Primer, Object Description Language (ODL) documentation.

**REQUIREMENTS:** PGSTK-1520, PGSTK-1521, PGSTK-1522, PGSTK-1530



## Obtain Slope and Intercept to Calculate Conversion Between Specified Units.

---

**NAME:** PGS\_CUC\_Conv

**SYNOPSIS:**

**C:**

```
#include <PGS_CUC.h>

PGSt_SMF_Status
PGS_CUC_Conv (
    char      inpUnit[],
    char      outUnit[],
    PGSt_double *outSlope,
    PGSt_double *outIntercept)
```

**FORTTRAN:**

```
include'PGS_CUC_11.f'
include'PGS_SMF.f'

integer function PGS_CUC_Conv(inpUnit, outUnit, outSlope,
                             outIntercept)

    character*100    inpunit,
    character*100    outunit,
    pgst_double      outslope,
    pgst_double      outintercept)
```

**DESCRIPTION:** This routine receives two character descriptions of Units as inputs. The first input is the unit that the user has; the second input being the unit the user wants to transform to. Both Unit descriptions are held in a file, after a search identifies whether each unit is held within the file the slope and intercept of the conversion between units is calculated. The resulting values for slope and intercept are then passed back to the user.

**INPUTS:**

***Table 6-249. PGS\_CUC\_Conv Inputs***

Name	Description	Units	Min	Max
inpUnit	unit you have	N/A	N/A	N/A
outUnit	unit you want	N/A	N/A	N/A

**OUTPUTS:**

***Table 6-250. PGS\_CUC\_Conv Outputs***

Name	Description	Units	Min	Max
outSlope	mathematical slope	N/A	N/A	N/A
outIntercept	mathematical intercept	N/A	N/A	N/A

## RETURNS:

**Table 6-251. PGS\_CUC\_Conv Returns**

Return	Description
PGS_S_SUCCESS	Successful return
PGS_E_CUC_ERROR	error in performing conversion match
The following are returned to the error log:	
PGSCUC_E_COULDNT_INIT_UDUNITS3	
PGSCUC_E_DONT_KNOW_INP_UNIT	
PGSCUC_E_DONT_KNOW_OUTP_UNIT	
PGSCUC_E_UNITS_ARE_INCOMPATIBLE	
PGSCUC_E_A_UNIT_IS_CORRUPTED	

## EXAMPLES:

```
C:      char inpUnit[] = {"centigrade"};
      char outUnit[] = {"fahrenheit"};
      double *outSlope;
      double *outIntercept;

      ret_status = PGS_CUC_Conv(inpUnit, outUnit, outSlope,
                                outIntercept);
```

```
FORTTRAN:      implicit none

      include      'PGS_CUC_11.f'
      include      'PGS_SMF.f'

      integer      PGS_CUC_Conv
      integer      ret_status
      character*100 inpUnit
      character*100 outUnit
      double precision outSlope
      double precision outIntercept
      InpUnit = 'metres'
      OutUnit = 'feet'
      ret_status = pgs_cuc_conv(inpUnit, outUnit, outSlope,
                                >                                outIntercept)
```

**NOTES:** For further details on this tool, see Appendix I. Background on library units used, Units available for conversion and adding own conversion Units to the file.

**REQUIREMENTS:** PGSTK–1520, PGSTK–1521, PGSTK–1522, PGSTK–1530

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### 6.3.8 Dynamic Memory Management Tools

## Allocate Memory

---

**NAME:** PGS\_MEM\_Malloc( )

**SYNOPSIS:**

C:                   #include <PGS\_MEM.h>

                  PGSt\_SMF\_status  
                  PGS\_MEM\_Malloc(  
                      void   \*\*addr,  
                      size\_t  numBytes);

FORTTRAN:           None

**DESCRIPTION:**   This tool allocates an arbitrary number of bytes in memory.

**INPUTS:**           numBytes—number of bytes to allocate

**OUTPUTS:**          addr—pointer to beginning of address that has been allocated

**RETURNS:**

***Table 6-252. PGS\_MEM\_Malloc Returns***

Return	Description
PGS_S_SUCCESS	Success
PGSMEM_E_NO_MEMORY	No memory space available for current process
PGSMEM_W_MEMORY_USED	Memory address has been allocated previously

**EXAMPLES:**

```
int                   i;  
int                   *intPtr = (int *)NULL;  
PGSt_SMF_status      returnStatus;  
  
returnStatus = PGS_MEM_Malloc((void  
                              **)&intPtr,sizeof(int)*10);  
if (returnStatus == PGS_S_SUCCESS)  
{  
    for (i=0 ; i < 10 ; i++)  
    {  
        intPtr[i] = i;  
    }  
}
```

**NOTES:**

This tool will control the amount of memory that may be allocated at any one time. You should call `PGS_MEM_Free( )` to free the memory allocated once you are done using it; failure to do so may cause future memory allocation requests to fail within the same process.

Because the Toolkit memory functions track memory usage, it is imperative that pointer variables, which have been freed, be initialized to `NULL` prior to re-use. As a reminder, ALL local pointer variables **MUST** be initialized to `NULL` prior to use. Failure to heed these warnings may result in anomalous behavior within your process

**REQUIREMENTS:** PGSTK-1240

## Allocate Memory

---

**NAME:** PGS\_MEM\_Calloc()

**SYNOPSIS:**

**C:** `#include <PGS_MEM.h>`  
  
`PGSt_SMF_status`  
`PGS_MEM_Calloc(`  
    `void   **addr,`  
    `size_t num_elems,`  
    `size_t elem_size);`

**FORTTRAN:** None

**DESCRIPTION:** This tool allocates an arbitrary number of bytes in memory. All bytes of the allocated memory will be initialized to zero.

**INPUTS:** `num_elems`—number of elements  
  
`elem_size`—size of the element in bytes

**OUTPUTS:** `addr`—pointer to beginning address of the memory that has been allocated

**RETURNS:**

**Table 6-253. PGS\_MEM\_Calloc Returns**

Return	Description
PGS_S_SUCCESS	Success
PGSMEM_E_NO_MEMORY	No memory space available for current process
PGSMEM_W_MEMORY_USED	Memory address has been allocated previously

**EXAMPLES:**

```
int          i;
int          *intPtr = (int *)NULL;
PGSt_SMF_status  returnStatus;

returnStatus = PGS_MEM_Calloc((void
                             **)&intPtr,10,sizeof(int));
if (returnStatus == PGS_S_SUCCESS)
{
    for (i=0 ; i < 10 ; i++)
    {
        intPtr[i] = i;
    }
}
```

**NOTES:**

This tool will control the amount of memory that may be allocated at any one time. You should call `PGS_MEM_Free( )` to free the memory allocated once you are done with it; failure to do so may cause future memory allocation requests to fail within the same process.

Because the Toolkit memory functions track memory usage, it is imperative that pointer variables, that have been freed, be initialized to `NULL` prior to re-use. As a reminder, ALL local pointer variables **MUST** be initialized to `NULL` prior to use. Failure to heed these warnings may result in anomalous behavior within your process.

**REQUIREMENTS:** PGSTK-1240, PGSTK-1241

## Re-Allocate Memory

---

**NAME:** PGS\_MEM\_Realloc()

**SYNOPSIS:**

C: #include <PGS\_MEM.h>  
  
PGSt\_SMF\_status  
PGS\_MEM\_Realloc(  
    void \*\*addr,  
    size\_t newsize);

FORTRAN: None

**DESCRIPTION:** This tool reallocates the number of bytes requested.

**INPUTS:** addr—pointer to the starting address of previously allocated memory  
newsize—new total memory size to reallocate

**OUTPUTS:** addr—pointer to starting address of newly allocated memory

**RETURNS:**

***Table 6-254 . PGS\_MEM\_Realloc Returns***

Return	Description
PGS_S_SUCCESS	Success
PGSMEM_E_NO_MEMORY	No memory space available for current process
PGSMEM_E_ADDR_NOTALLOC	Address is not allocated previously

**EXAMPLES:**

```
int          i;  
int          *intPtr = (int *)NULL;  
PGSt_SMF_status  returnStatus;  
  
returnStatus = PGS_MEM_Calloc((void  
    **)&intPtr,10,sizeof(int));  
if (returnStatus == PGS_S_SUCCESS)  
{  
    for (i=0 ; i < 10 ; i++)  
    {  
        intPtr[i] = i;  
    }  
}
```



```

returnStatus = PGS_MEM_Realloc((void
    **)&intPtr,sizeof(int)*20);
if (returnStatus == PGS_S_SUCCESS)
{
    # Realloc success #
}

```

## NOTES:

This tool will control the amount of memory that needs to be reallocated to a pointer that has already been used to obtain an initial allocation of memory through one of the available Toolkit routines. You should call PGS\_MEM\_Free( ) to deallocate the memory once you are done using it; failure to do so may cause future memory allocation requests to fail within the same process.

Because the Toolkit memory functions track memory usage, it is imperative that pointer variables, that have been freed, be initialized to NULL prior to re-use. As a reminder, ALL local pointer variables MUST be initialized to NULL prior to use. Failure to heed these warnings may result in anomalous behavior within your process.

## REQUIREMENTS: PGSTK-1240

## Initialize Memory to Zero

---

**NAME:** PGS\_MEM\_Zero()

**SYNOPSIS:**

**C:**               #include <PGS\_MEM.h>  
  
                  void  
                  PGS\_MEM\_Zero(  
                      void   \*addr,  
                      size\_t  numBytes);

**FORTTRAN:**       None

**DESCRIPTION:**   This tool initializes a memory block or structure to zero.

**INPUTS:**        addr—beginning address of the memory block or structure  
  
                  numbytes—number of bytes

**OUTPUTS:**       None

**RETURNS:**       None

**EXAMPLES:**      Typedef        struct  
                  {  
                      int        i;  
                      char       c;  
                      float      f;  
                  }TestStruct;  
  
                  TestStruct        test  
                  int                \*intptr = (int \*)NULL  
                  returnstatus       returnstatus  
  
                  PGS\_MEM\_Zero(&test,sizeof(test));  
                  returnstatus = PGS\_MEM\_Malloc((void  
                      \*\*)&intPtr,sizeof(int)\*10 );  
                  if (returnstatus == PGS\_S\_SUCCESS)  
                  {  
                      PGS\_MEM\_Zero(intPtr,sizeof(intPtr)\*10)  
                  }  
  
                  PGS\_MEM\_Zero( s, sizeof(longint)\*10 );

**REQUIREMENTS:** PGSTK-1240

## De-Allocate Memory

---

**NAME:** PGS\_MEM\_Free( )

**SYNOPSIS:**

**C:**               #include <PGS\_MEM.h>  
  
                  void  
                  PGS\_MEM\_Free(  
                      void   \*addr);

**FORTTRAN:**       None

**DESCRIPTION:**   This tool deallocates memory that was previously allocated through the use of a Toolkit allocation routine.

**INPUTS:**         addr—address of previously allocated memory

**OUTPUTS:**       None

**RETURNS:**       None

**EXAMPLES:**

```
int                   *intPtr = (int *)NULL;
returnStatus       returnStatus;

returnStatus = PGS_MEM_Malloc((void
                              **)&intPtr,sizeof(int)*10);
if (returnStatus == PGS_S_SUCCESS)
{
    PGS_MEM_Free(intPtr);
    intPtr = (int *)NULL;
}
```

**NOTE:**           Because the Toolkit memory functions track memory usage, it is imperative that pointer variables, which have been freed, be initialized to NULL prior to re-use. As a reminder, ALL local pointer variables MUST be initialized to NULL prior to use. Failure to heed these warnings may result in anomalous behavior within your process.

**REQUIREMENTS:** PGSTK-1240

## De-Allocate Memory

---

**NAME:** PGS\_MEM\_FreeAll()

**SYNOPSIS:**

**C:** `#include <PGS_MEM.h>`  
`void`  
`PGS_MEM_FreeAll(`  
`void);`

**FORTTRAN:** None

**DESCRIPTION:** Deallocates all memory that was previously allocated through the use of Toolkit allocation routines, within an executable. Calls to PGS\_MEM\_Free() and PGS\_MEM\_FreeAll() may be interlaced.

**INPUTS:** None

**OUTPUTS:** None

**RETURNS:** None

**EXAMPLES:**

```
typedef struct
{
    int      i;
    char     c;
    float    f;
}TestStruct;

TestStruct  *test      = (TestStruct *)NULL;
int         *intPtr    = (int *)NULL;

PGS_MEM_Malloc((void **)&intPtr,sizeof(int)*10);
PGS_MEM_Malloc((void **)&test,sizeof(TestStruct)*10);
PGS_MEM_FreeAll();

test        = (TestStruct *)NULL
intPtr      = (int *)NULL
```

**NOTES:** This tool should only be called near the end of processing, or when no further allocation of dynamic memory will be required.

Due to the comprehensive nature of this tool, all allocated memory references, that have not yet been freed, will be disposed of. Because the Toolkit memory functions track memory usage, it is imperative that pointer variables, which have been freed, be initialized to NULL prior to

use. Failure to heed these warnings may result in anomalous behavior within your process.

**REQUIREMENTS:** PGSTK-1240

### **6.3.9 Graphics Support Tools**

These tools will support the analysis of graphics, quicklook and quality assurance (QA) data output from science production processes. It is assumed that the exchange format of the data files will be HDF, although specific graphics formats are TBD at the time of this document. These tools will contain an image processing capability, which will be used in conjunction with the math library chosen for the Toolkit (section 6.3.6), or with user supplied math functions. It is expected that this functionality will be a subset of the data visualization capability supplied by EOSVIEW, a package being developed to display EOS data structure