Fractional open water cover dynamics for the ABoVE domain & pan-Arctic region, 2002-2015

Summary

This data set provides land surface fractional open water (*fw*) inundation dynamics over the Arctic-Boreal Vulnerability Experiment (ABoVE) domain and pan-Arctic region for the period 2002-2015. The *fw* parameter is defined on a per grid cell basis and represents the aerial portion of a grid cell covered by open water. The *fw* parameter is estimated from daily satellite microwave brightness temperature (T_b) retrievals, and averaged to a 10-day time step. The data were developed using high frequency (89 GHz) T_b observations from the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) and the Advanced Microwave Scanning Radiometer 2 (AMSR2), with other ancillary inputs from AMSR-E/2 and MODIS (Moderate Resolution Imaging Spectroradiometer) land parameter records. The *fw* data have 10-day temporal fidelity and 5 km spatial resolution. Unlike open water maps derived from satellite optical-Infrared (IR) remote sensing, the *fw* record benefits from strong microwave T_b sensitivity to surface water and relative insensitivity to potential data loss from cloud cover and atmosphere aerosol contamination, and low solar illumination. The resulting satellite environmental data record for *fw* is suitable for documenting open water patterns and inundation dynamics in boreal-Arctic ecosystems experiencing rapid climate change.

For both the ABoVE domain and pan-Arctic region, there are 469 data files in GeoTIFF (.tif) format describing the *fw* dynamics. Two additional data quality flag files are included that describe granule and grid cell level retrieval quality and reliability to facilitate appropriate data usage and interpretation.

Related Publication:

Du, J., Kimball, J. S., Jones, L. A., & Watts, J. D. (2016). Implementation of satellite based fractional water cover indices in the pan-Arctic region using AMSR-E and MODIS. *Remote Sensing of Environment*, *184*, 469-481.

Data Characteristics

Spatial Coverage:

(a) ABoVE Domain: Core and extended ABoVE regions
(b) pan-Arctic region: circumpolar regions with latitudes ≥ 45˚N.

Spatial Resolution: 5 km

Temporal Coverage: Jun.20, 2002-Oct.4, 2011; and Jul.19, 2012-Dec.31, 2015.

Temporal Resolution: 10 day

Data File Information

For the respective ABoVE domain and pan-Arctic region, there are 469 data files in GeoTIFF (.tif) format with this dataset. The two additional quality flag files provide information regarding: (a) retrievable pixels within the study domain; (b) ocean areas excluded from the *fw* retrievals; (c) land-ocean boundary pixels subjected to larger *fw* retrieval errors; (d) non-retrievable pixels including those within large water bodies (i.e. water area > 312.5km^2), frozen conditions or with permanent ice/snow cover; and (e) areas outside of the product domain.

The ABoVE and pan-Arctic *fw* data are stored in the "ABoVEData/" and "PanArcticData/" directories; Quick visual browse (.png) files are also included in the corresponding data directories. The data files are named by study domain and temporal coverage, while the data quality (QA) files are named by study domain. For example, the file "PanArctic_FW_2002_271_280.tif" denotes *fw* data for the pan-Arctic domain for year 2002 and Day of Year (DOY) 271 to 280. Similarly, "ABoVE_FW_2002_271_280.tif" denotes the *fw* data for the ABoVE domain for year 2002 and DOY 271 to 280. The two quality flag files "ABoVE_FW_QA.tif" and "PanArctic_FW_QA.tif" are stored in "QualityFlag/" directories under the respective "ABoVEData/" and "PanArcticData/" directories.

GeoTIFF Spatial Data Properties for *fw* Data Files

Spatial Representation Type: Raster

Data Type: 2-byte integer

Number of Bands: 1

Number Columns: 805 for the ABoVE domain; 1957 for pan-Arctic region

Column Resolution: 5000 meter

Number Rows: 713 for the ABoVE domain; 1957 for pan-Arctic region

Row Resolution: 5000 meter

Fill value: -999

Projection: Canada Albers projection for the ABoVE domain; EASE-GRID Version 2 for pan-Arctic region (Brodzik et al., 2014)

DATUM: NAD83 for the ABoVE domain; WGS_1984 for the pan-Arctic region

Cell value: fractional open water multiplied by 1000

GeoTIFF Spatial Data Properties for Data Quality Files

Spatial Representation Type: Raster

Data Type: byte

Number of Bands: 1

Number Columns: 805 for the ABoVE domain; 1957 for pan-Arctic region

Column Resolution: 5000 meter

Number Rows: 713 for the ABoVE domain; 1957 for pan-Arctic region

Row Resolution: 5000 meter

DATUM: NAD83 for the ABoVE domain; WGS_1984 for pan-Arctic region

Projection: Canada Albers projection for the ABoVE domain; EASE-GRID Version 2 for pan-Arctic region (Brodzik et al., 2014)

Cell value: 0 – retrievable land; 1 – ocean; 2 – ocean-land boundary; 3 – un-retrievable land pixels; 255 – land areas outside of retrieval domain.

Methods and Assessment

Methods

The dataset was generated primarily using 89 GHz T_b retrievals from similar calibrated AMSR-E and AMSR2 sensor records under dynamic atmospheric and land surface conditions defined by three geospatial datasets. The AMSR2 multi-frequency T_b retrievals were calibrated against similar T_b retrievals from AMSR-E using overlapping T_b observations from the Microwave Radiation Imager (MWRI) on-board the Chinese FY3B satellite using an empirical approach (Du et al., 2014). The ancillary datasets used for algorithm development include the University of Montana (UMT) AMSR-E/2 global land parameter record (Jones and Kimball, 2012; Jones et al., 2010); a AMSR-E/2 frequency ratio (*FR*) data record defined as the V- and H-polarization difference ratio between 89 and 36 GHz channels; and a MODIS 1 km resolution global land cover classification (MOD12Q1) derived using the IGBP classification scheme (Friedl et al., 2006). Based on the above datasets, a look-up table was first established to provide reference microwave emissivities for water and land endmembers under a range of atmosphere and land surface conditions. The *fw* retrievals

were then obtained on a per pixel basis as described by Eqs.1-2 and Fig.1. For vegetated soil conditions, *fw* was estimated using Double Difference Ratio (DDR) method:

$$fw = \frac{(e_v^{obs} - e_h^{obs}) - (e_{vl}^{ref} - e_{hl}^{ref})}{(e_{vw}^{ref} - e_{hw}^{ref}) - (e_{vl}^{ref} - e_{hl}^{ref})} = \frac{(T_{bv}^{obs} - T_{bh}^{obs}) - (T_{bvl}^{ref} - T_{bhl}^{ref})}{(T_{bvw}^{ref} - T_{bhw}^{ref}) - (T_{bvl}^{ref} - T_{bhl}^{ref})} \quad (1)$$

where T_{bp}^{obs} represents the actual satellite T_b observation for p (either H or V) polarization, T_{bpw}^{ref} denotes the T_b from the reference water endmember pixel and T_{bpl}^{ref} is the T_b from the reference land endmember pixel. The corresponding variable emissivity terms are expressed as e_{bp}^{obs}, e_{pw}^{ref} and e_{pl}^{ref} respectively. For barren land conditions, fw is determined using a Difference Ratio (DR) of only H-Polarization emissivities:

$$fw = \frac{(e_{hl}^{ref} - e_h^{obs})}{(e_{hl}^{ref} - e_{hw}^{ref})} = \frac{(T_{bhl}^{ref} - T_{bh}^{obs})}{(T_{bhl}^{ref} - T_{bhw}^{ref})} \quad (2)$$

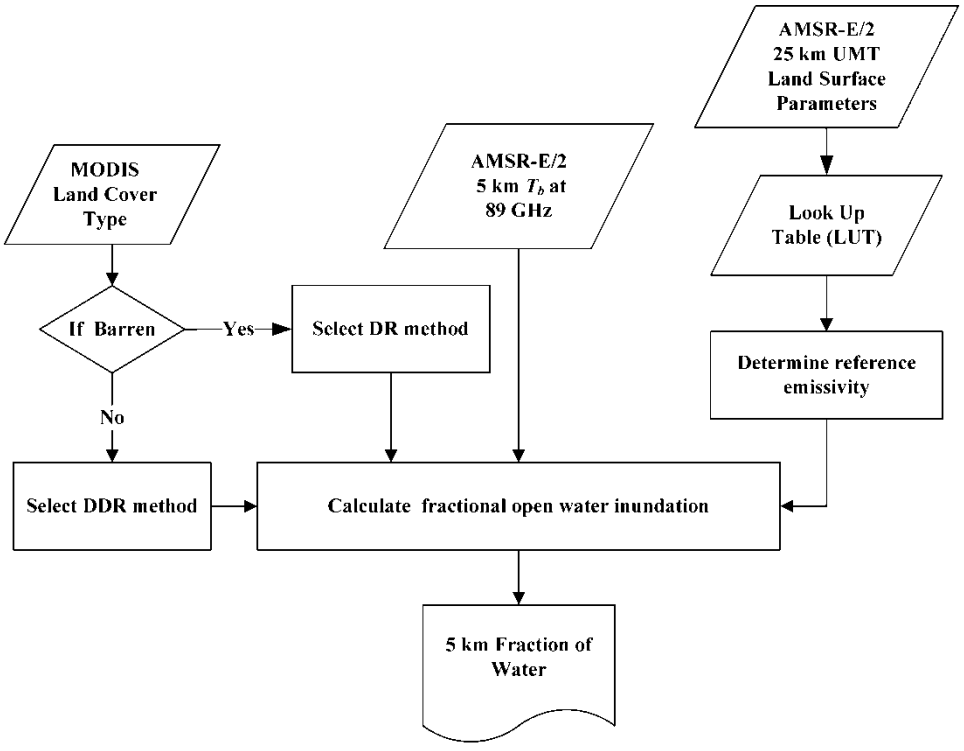

Fig. 1. General data processing flowchart describing the methodology used to derive the 5 km resolution fractional open water inundation retrieval from AMSR-E/2 89 GHz brightness temperatures (T_b) and the 25 km UMT Land Parameter data record. A Difference Ratio (DR) method was applied to classified barren land pixels and a Double Difference Ratio (DDR) method

was used for vegetated pixels.

Assessment

Three fine-scale (≤ 300 m) static open water maps were used to evaluate the *fw* dataset. The 30 m resolution Global Land 30-water 2010 (GLC30) map is provided by the National Geomatics Center of China (NGCC) and was generated using imagery from Landsat TM/ETM+ and HJ-1 sensors collected over the 2010 base year; the GLC30 data also has a reported 96% overall global water spatial classification accuracy (Liao et al., 2014). The 300 m resolution European Space Agency (ESA) ENVISAT Advanced Synthetic Aperture Radar (ASAR) Global Water Bodies map (ASAR300) was also obtained for this study and was derived from multi-temporal ASAR acquisitions in wide swath mode for years 2005 through 2010; The ASAR300 data has a reported 95% global water spatial classification accuracy (Kirches et al., 2014). The 250 m resolution MOD44W product is derived from a compilation of the SRTM Water Body dataset and the MODIS (MOD44C) Collection 5 (2000–2008) open water classification product (Carroll et al., 2009). The MOD44W product shows a 2% commission error in the region between 60° and 90° N in North America relative to the National Land Cover Dataset (NLCD) product (Carroll et al., 2009).

The resulting AMSR-E *fw* summer (JJA) seasonal composites from 2003 to 2010 correspond favorably ($R \geq 0.86$, $p < 0.001$) with alternative, finer resolution (≤ 300 m) static open water maps derived from satellite radar and optical-infrared sensors over a pan-Arctic (≥ 45°N) domain as shown in Fig.2 and Table 1. The *fw* retrievals also capture significant seasonal drought and flooding events inferred from river discharge records within the major Arctic basins (Du et al., 2016). The *fw* retrievals are found to be reliable for discriminating open water in moderately dense vegetation areas, but with greater uncertainty over barren land. The ability of the *fw* retrievals to detect surface water under vegetation also decreases exponentially with increasing canopy optical thickness (Du et al., 2016). In addition, AMSR2 T_b has been calibrated against AMSR-E, but the impacts of different sensor spatial resolutions and instrument calibration systems on *fw* retrievals cannot be completely removed. Possible retrieval biases may exist between the AMSR-E and AMSR2 retrievals.

Table 1 Comparisons of four fractional open water inundation products over the pan-Arctic domain. All products were projected into a consistent EASE-GRID Version 2 format and 5.0 km spatial resolution; positive/negative bias indicates AMSR-E *fw* (referred as fw_{WBand}) summer composites from 2003 to 2010 over/under estimation relative to the static water products.

Comparisons of fw_{WBand} (summer composite: JJA), ASAR300, GLC30 and MOD44W						
	R*		RMSD*		Bias	
	Mean	SD*	Mean	SD	Mean	SD
fw_{WBand} vs ASAR300	0.89	0.006	0.050	0.001	-0.001	0.001
fw_{WBand} vs GLC30	0.86	0.010	0.053	0.002	-0.008	0.001
fw_{WBand} vs MOD44W	0.90	0.005	0.051	0.002	-0.005	0.001

* R is for Pearson correlation coefficient; RMSD is for Root Mean Square Difference; and SD is for Standard Deviation.

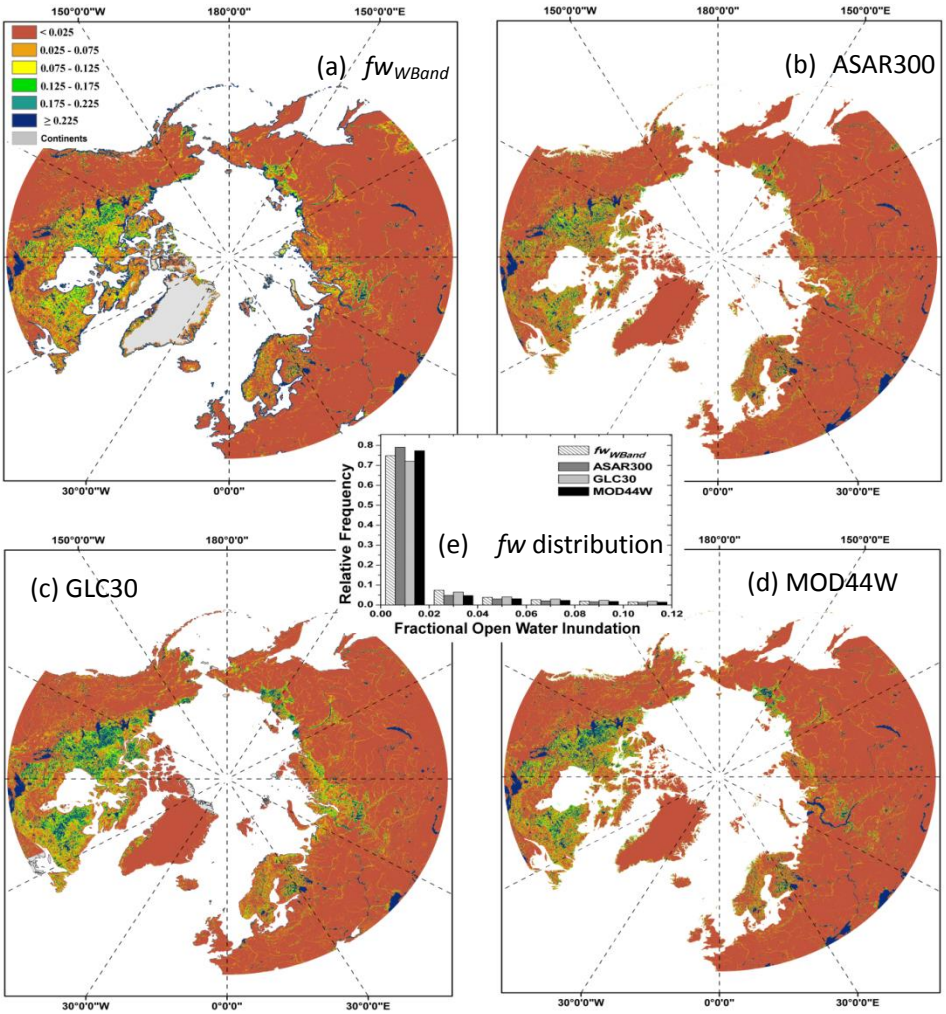

Fig. 2. (a) Mean fractional open water map generated at 5 km resolution from AMSR-E 89 GHz observations (fw_{WBand}); the fw_{WBand} results are presented for the 2006 reference year and mean summer (JJA) conditions; reference *fw* maps generated from other finer resolution satellite data records including: (b) 300m resolution ASAR300, (c) 30m GLC30, and (d) 250 m MOD44W land cover maps; all reference *fw* maps are spatially aggregated to the same 5 km polar EASE-grid format consistent with the fw_{WBand} results. The grey color denotes land areas without *fw* retrievals and white areas denote ocean areas outside of the domain; (e) histogram of fractional open water distributions of the above fw_{WBand}, ASAR300, GLC30 and MOD44W maps.

Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

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