GPHY491/489: Programming for GIS

K. Arthur Endsley
Numerical Terradynamic Simulation Group
W.A. Franke College of Forestry and Conservation

January 16, 2025

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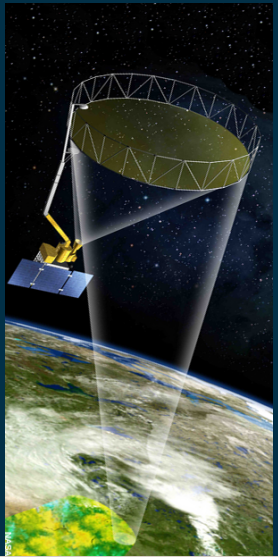
Introductions



Hi, My Name is Arthur!

- Taught programming at Lawrence Berkeley National Labs, NASA Langley, the Federal Reserve Board...
- Maintaining the **NASA Soil Moisture Active Passive (SMAP) satellite** mission's Level 4 Carbon (L4C) model: 1-km resolution, global coverage, over 500 million pixels!
- Leading NASA-funded research into how satellite microwave measurements can be used to study forest water stress and fire risk.

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Introductions

Teaching Assistant: Bryan Tutt

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Outline

- GIS programming workflows: An example
- Some role-playing: How can programming improve GIS tasks?
- Thinking like a Computer Scientist
- Course overview

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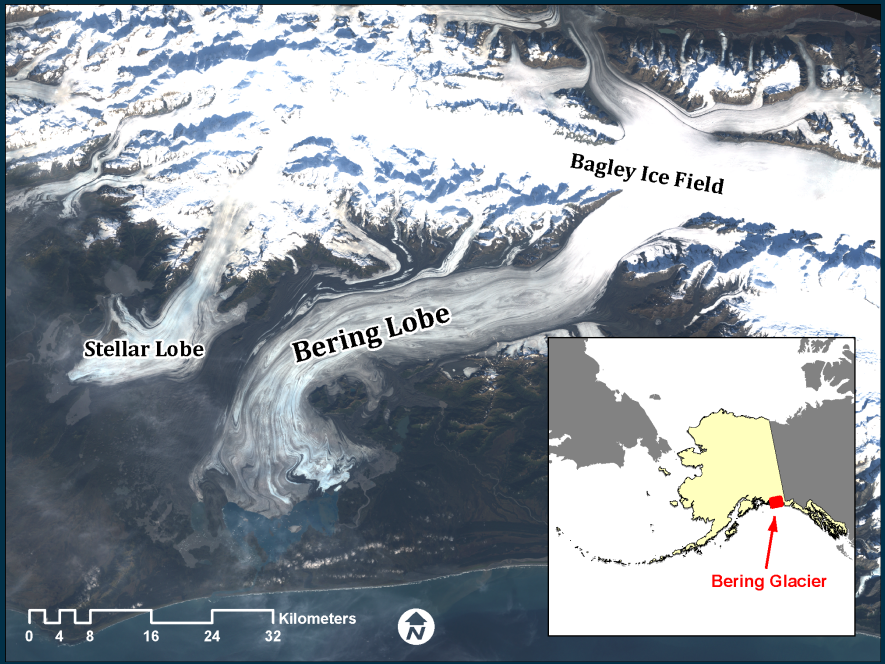
Bagley Ice Field
Stellar Lobe
Bering Lobe
Bering Glacier
Kilometers
0 4 8 16 24 32
N

Motivation: Ice Motion Tracking

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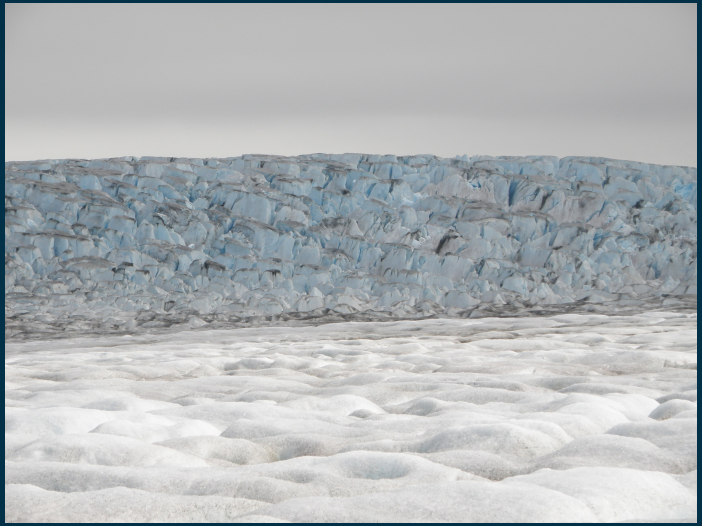

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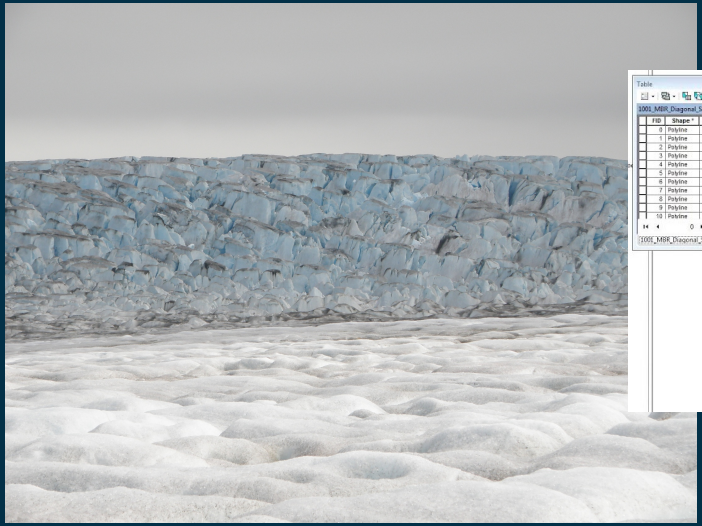

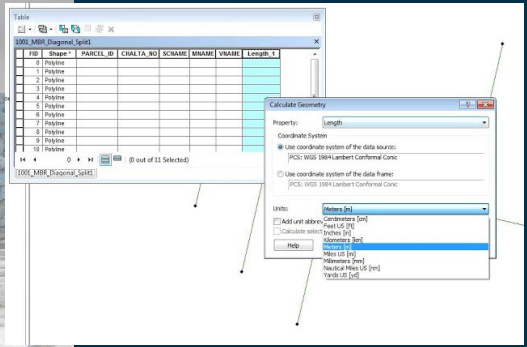

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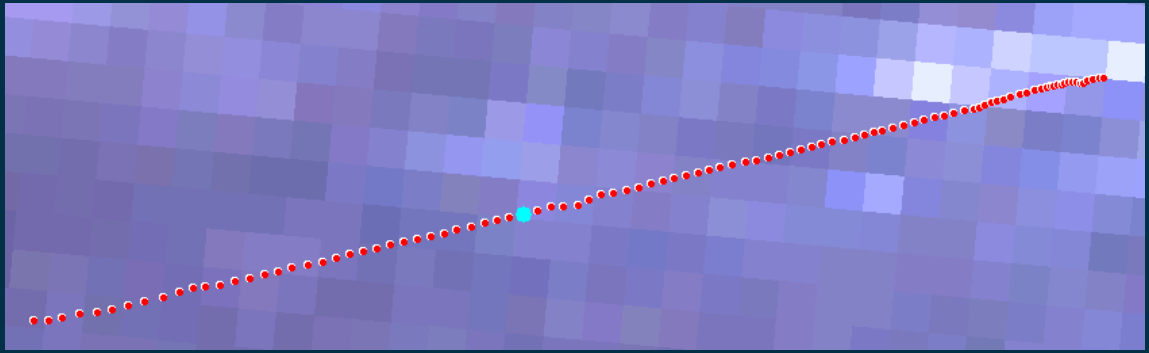

```
import scipy
scipy.signal.filtfilt(1, 2, gps_coords)
```

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Live-Action Role-Playing: GIS Edition

Pair up! There are two roles: **Manager and Analyst.** Take 5 minutes in one role for Prompt A, then **switch roles** and read Prompt B. The Analyst should describe how they would achieve the goal using ArcGIS Desktop.

Questions to consider:

- How will the data be handled?
- What specific tools would you use, in what order?
- How long will it take?
- What are the possible sources of error?

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So: Why Programming?

- Humans are terrible at repetitive tasks.

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- A computer program or script is a documentation of your workflow.

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- Computer code is transferable and re-useable; it can be used to verify that your analysis was done correctly and to obtain the same result.

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So: Why Programming?

- Humans are terrible at repetitive tasks.
- A computer program or script is a documentation of your workflow.
- Computer code is transferable and re-useable; it can be used to verify that your analysis was done correctly and to obtain the same result.
- **$$$:** U.S. average annual salary (2023):[1]
  - "GIS Analyst:" $72,530
  - "GIS Programmer:" $86,743

[1] ZipRecruiter.com

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Thinking Like a Computer Scientist

Computational thinking is a *problem-solving* activity.[1]

[1] Cynthia Selby & John Woolard (2013)

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Abstraction: Representing only what is essential.

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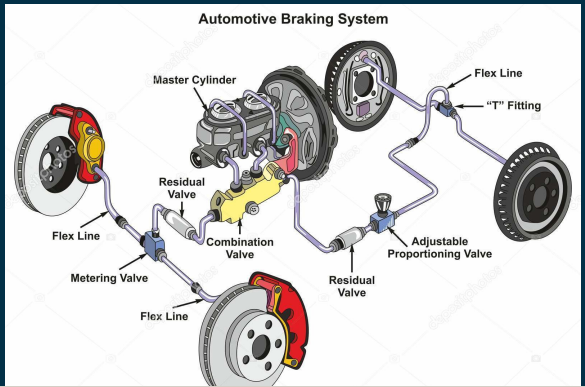
Decomposition: Decomposing a complex problem or system into manageable parts.



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Thinking Like a Computer Scientist

Computational thinking is a *problem-solving* activity.

Abstraction: Representing only what is essential.

Decomposition: Decomposing a complex problem or system into manageable parts.

Algorithms: Logical and ordered instructions for carrying out a task.

- Order and precedence; what is required before the next thing?
- Design the fewest number of steps; remove unnecessary steps

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Debugging and Continuous Improvement

- Detect and identify errors
- Start with an initial, acceptable solution
- Then iteratively refine the solution, as needed

Valerie Shute et al. (2017)

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Debugging and Continuous Improvement

Collaboration, Reflection, and Feedback

Valerie Shute et al. (2017)

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Thinking Like a Computer Scientist (2)

Don’t be afraid to experiment!

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Thinking Like a Computer Scientist (2)

Don't be afraid to experiment!

You should be asking yourself:

```
pyplot.scatter(data)
```

- "Is there a pyplot.histogram() or pyplot.lineplot() function?"

```
array.min()
```

- "Will array.max() calculate the maximum?"

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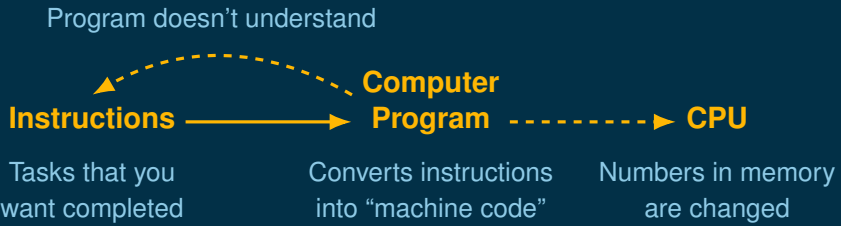
Thinking Like a Computer Scientist (3)



(CPU: Central Processing Unit)

Thinking Like a Computer Scientist (4)

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Assembly Language

```
DOSSEG
.MODEL TINY
.DATA
TXT DB "Hello, world!$"
.CODE
START:
  MOV ax, @DATA
  MOV ds, ax
  MOV ah, 09h
  MOV dx, OFFSET TXT
  INT 21h
  MOV AX, 4C00h
  INT 21h
END START
```

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2nd-Generation Language (C)

```
include <stdlib.h>
include <stdio.h>

int main(void)
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  printf("Hello, world!\n");
  return EXIT_SUCCESS;
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3rd-Generation Language (Python)

```
print("Hello, world!\n")
```

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Thinking Like a Computer Scientist (4)

Compiled Languages

e.g., C, Java, Fortran

- Code is *compiled* into machine code (binary) *before* the program is executed

Interpreted Languages

e.g., Python, R

- Code is translated into machine code automatically when the program is run

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Thinking Like a Computer Scientist (4)

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Interpreted Languages

e.g., Python, R

- Code is translated into machine code automatically when the program is run
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- Compiled programs can be very fast: Programs executed as binary
- Can take a long time to write and debug a program

Interpreted Languages

e.g., Python, R

- Code is translated into machine code automatically when the program is run
- Interpreter figures out what data types and memory are required
- Never as fast: Programs are executed as low-level instructions
- Much easier to learn; programs can be written quickly

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Who is a Computer Programmer?

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Who is a Computer Programmer?

Hedy Lamarr (1914-2000)

- Invented frequency-hopping technology, initially for radio-guided torpedoes
- Same technology later used in cellular phones
- **Self-taught!** Collaborated with friend George Antheil to use a player-piano reel for timing the changes in frequency

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Who is a Computer Programmer? (2)

The most famous faces in the tech industry tend to look very similar...
and they're making the world less fair and less free.

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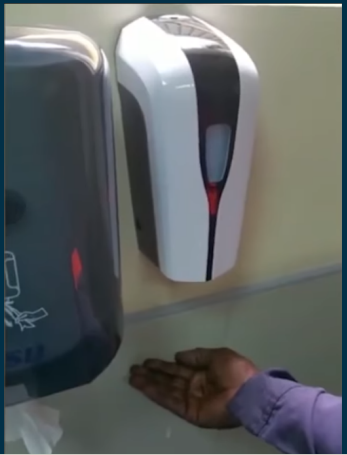

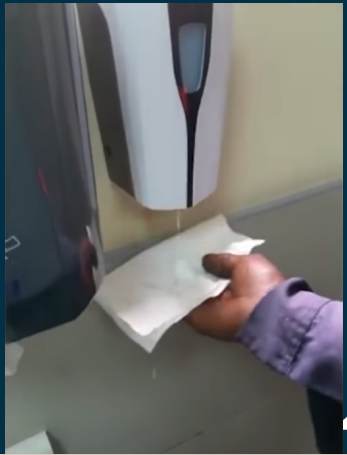

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A 2017 memo by Google employee James Damore claimed that participation and success in computer science is *biologically determined.*

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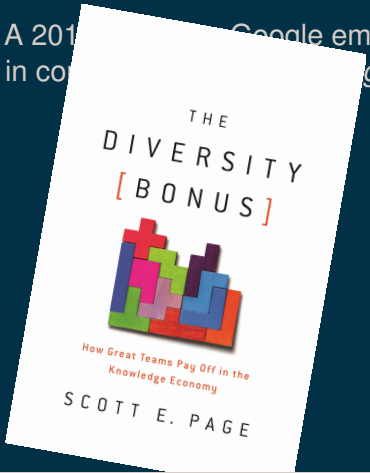

"As the initial pool of problem solvers becomes large, the best-performing [programmers] necessarily become similar...Their relatively greater ability is *more than offset* by their lack of problem-solving diversity."

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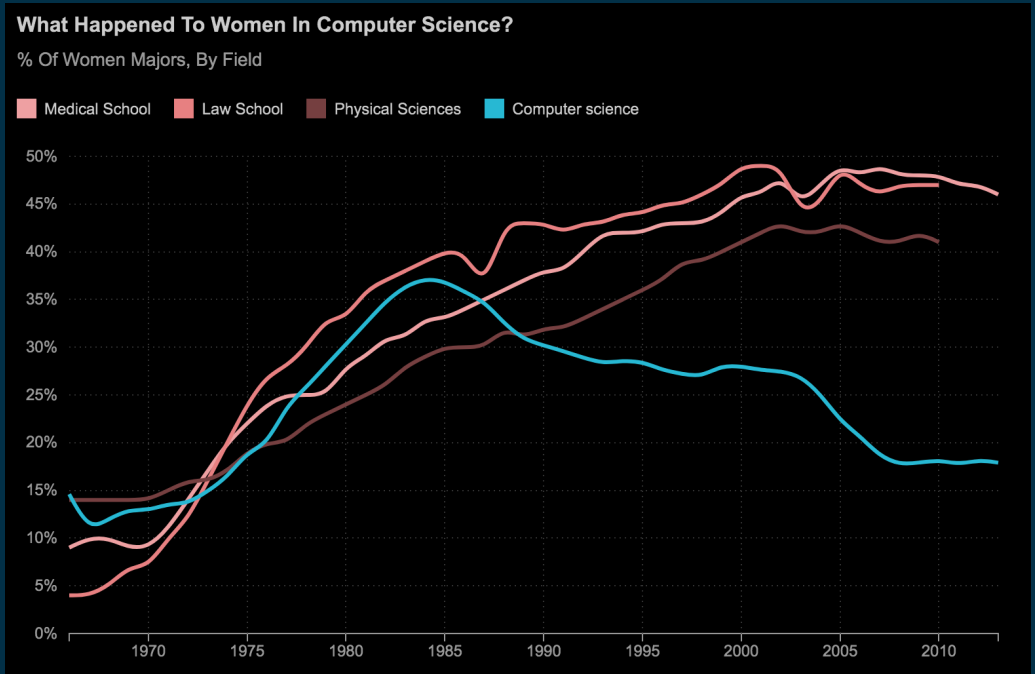
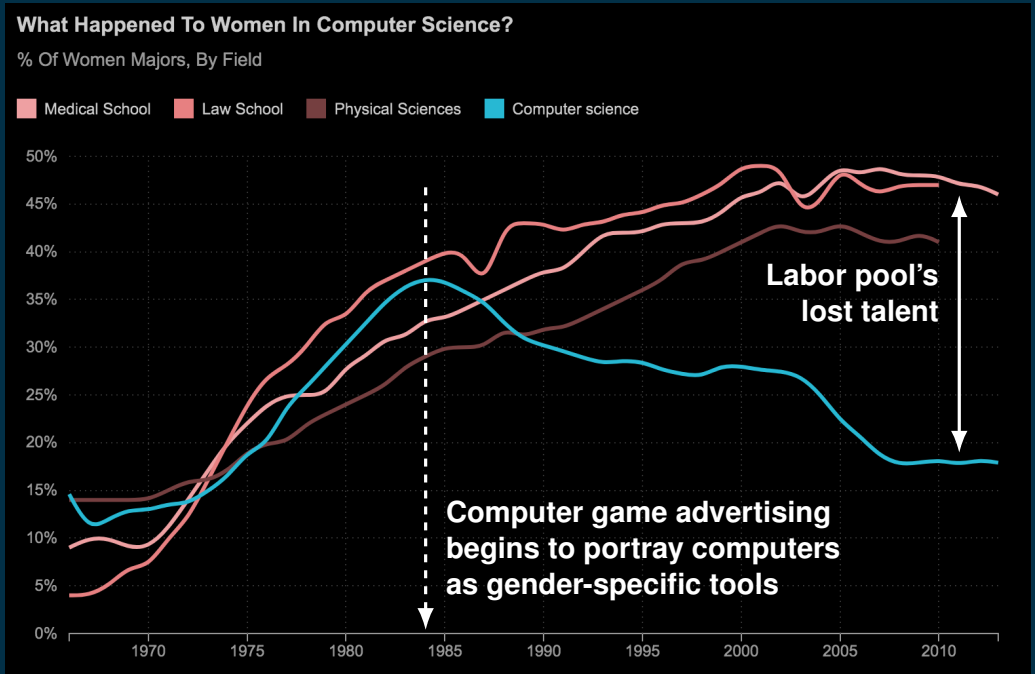

What Happened To Women In Computer Science?
% Of Women Majors, By Field
Medical School
Law School
Physical Sciences
Computer science
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
1970
1975
1980
1985
1990
1995
2000
2005
2010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Medical School
Law School
Physical Sciences
Computer science
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
1970
1975
1980
1985
1990
1995
2000
2005
2010
Labor pool's lost talent
Computer game advertising begins to portray computers as gender-specific tools

This is a challenging course, but you already have all the tools you need to be successful.

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Course Overview

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How You Will Learn

We'll use two learning strategies in this course:

1. **Hands-on-Keyboards** with real data
2. **Peer Programming** with real data

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It's not Chemistry, it's Carpentry!

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What You Will Learn

- **Python programming** (currently the most popular language in the world[1])
- **R for data analysis**

[1] https://www.tiobe.com/tiobe-index/

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What You Will Learn (2)

How to choose the best language for the job:

Python

- **Higher performance**
- **Raster and array data processing**
- Batch processing of multiple files
- Machine learning
- Plotting large raster datasets
- Process-based or multi-criteria modeling (e.g., habitat suitability)
- Cellular automata/ Agent-based models
- Creating your own algorithm

R

- **Vector data analysis**
- Working with an Attribute Table
- **Plotting vector data and coarse-resolution raster data**
- Geostatistics
- Spatial point pattern analysis
- Spatial autoregressive models
- Using algorithms written by others

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How You Will Be Evaluated

Lab Exercises: 60%

For graduate students or for undergraduate extra credit:

Midterm Project: 20%

Final Project: 20%

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For Next Time

Make sure to sign up for *both* GPHY 491 and GPHY 489 (Lab).

Lab meets on Wednesdays at 9:00a in Stone Hall 106!

Please listen and read!

- NPR Planet Money Podcast: **"When Women Stopped Coding"**
- Dynamic Ecology blog post: **"Stereotype threat: A summary of the problem"**

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