

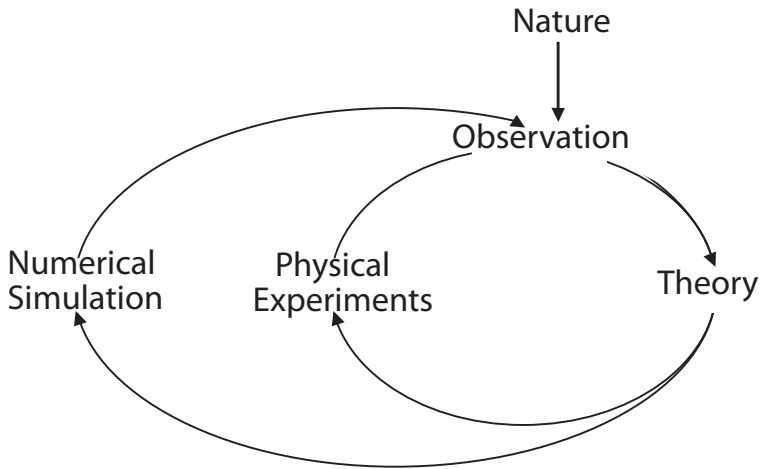
An Approach to Teaching Programming to Geology Students: Understanding Geodynamics Through MATLAB

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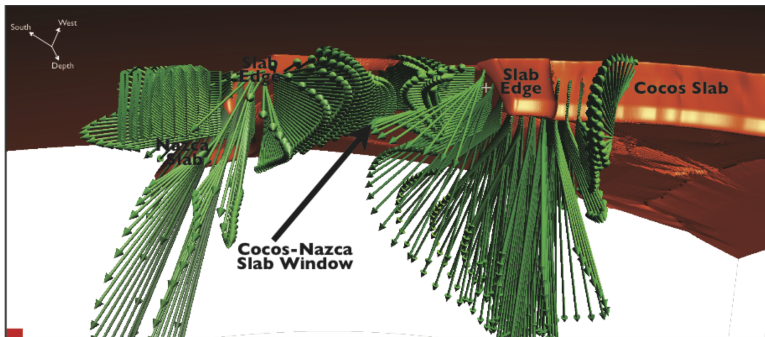
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Numerical Simulation Vital in Modern Science



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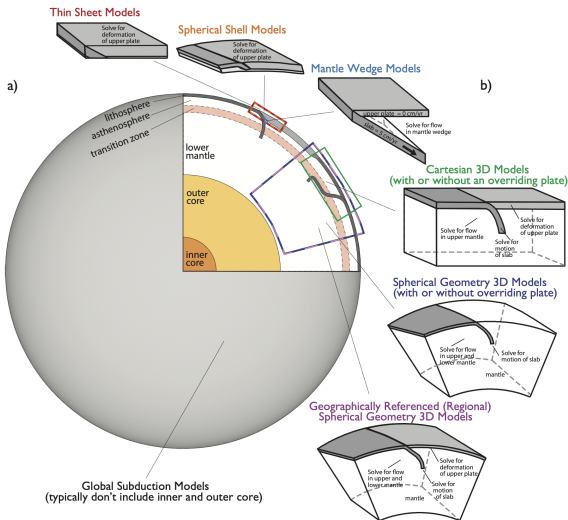
“Computational scientists simulate on supercomputers (the) phenomena too complex to be reliably predicted by theory or too dangerous or expensive to be reproduced in the laboratory.”



Quote - Gropp et al., 2014. *Using MPI: Portable Parallel Processing with the Message-Passing Interface*, 3rd Edition);

Image - Jadamec, M., 2016. *Journal of Geodynamics*, vol. 100, p. 51-70.

How To Teach Computing to *Science* Students (who may not necessarily also be *Computer Science* Students)?



Jadamec et al. (2024) in

AGU Monograph 290 - Tectonics and Seismic Structure of Alaska and Northwestern Canada: EarthScope and Beyond

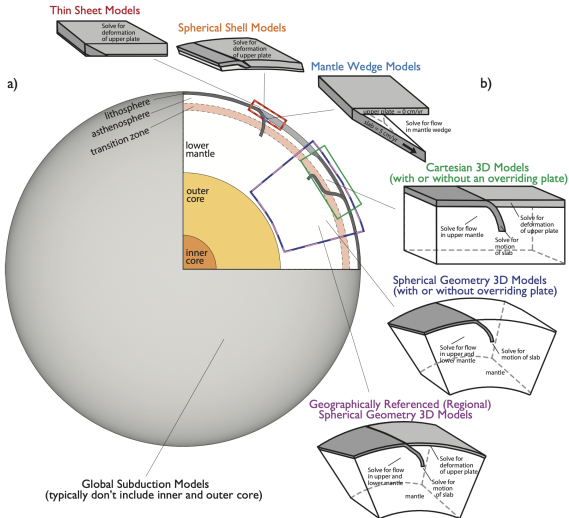
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MATLAB/SERC 2026

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What is a Model and How Can We Use Computing to Model the Earth?



Jadamec et al. (2024) in

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Concept 1: Software Development Method

- 1 Specify problem requirements
- 2 Analyze the problem
- 3 Design the algorithm to solve the problem
- 4 Implement the algorithm
- 5 Test and verify the completed program
- 6 Maintain and update the program

Concept 2. Lecture/Lab Integration

GEODYNAMICS Spring 2025: Lecture and Lab Schedule

Week	Date	Topic	Reading
Week 1	Jan. 22	Earth Structure <i>No Lab</i>	Chpt. 1
Week 2	Jan. 27, Jan. 29	Plate Tectonics <i>Lab 1: Introduction to MATLAB</i>	Chpt. 1 Chpt. 11
Week 3	Feb. 3, Feb. 5	Stress and Strain in Solids <i>Lab 2: Earth Volumes</i>	Chpt. 2
Week 4	Feb. 10, Feb. 12	Stress and Strain in Solids <i>Lab 3: Lithostatic Stress</i>	Chpt. 2
Week 5	Feb. 17, Feb. 19	Elasticity and Flexure <i>Lab 4: Isostasy</i>	Chpt. 3
Week 6	Feb. 24, Feb. 26	Seismic Imaging of the Earth <i>Lab 5: Slab Geometries Part 1</i>	Handout
Week 7	Mar. 3, Mar. 5	Heat Transfer <i>Lab 6: Slab Geometries Part 2</i>	Chpt. 4
Week 8	Mar. 10, Mar. 12	Heat Transfer <i>Lab 7: Half-Space Cooling Model</i>	Chpt. 4
Week 9	Mar. 17, Mar. 19	<i>Spring Break (no class, no lab)</i>	
Week 10	Mar. 24, Mar. 26	Fluid Mechanics <i>Lab 8: Plate Cooling Model</i>	Chpt. 6

Concept 2. Lecture/Lab Integration

Week 12	Apr. 7, Apr. 9	Rock Rheology <i>Lab 10: Viscosity</i>	Chpt. 7
Week 13	Apr. 14, Apr. 16	Rock Rheology <i>Lab 11: Subduction Analysis</i>	Chpt. 7
Week 14	Apr. 21, Apr. 23	Revisiting Plate Tectonics <i>Lab 12: Project Debugging</i>	Handout
Week 15	Apr. 28, Apr. 30	Subduction Dynamics along the Pacific Ring of Fire <i>No lab this week - prep for presentations next week</i>	Handout
Week 16	May 5	Student Presentations - Part 1 during lecture time Student Presentations - Part 2 during lab time	

- Geodynamics studies the forces that govern Earth processes and structure.
- Semester long course (16 weeks) with weekly 2 hour lecture & 2 hour lab.
- Lecture component uses Geodynamics (Turcotte and Schubert, 2014) textbook.
- Suite of 12 labs designed by M. Jadamec as part of NSF CAREER Award.

Concept 3. Lab Design Framework

- Developed for Upper-Level Undergraduate or Graduate Course in Earth Sciences
(Physics, Math, and Engineering students also take course)
- Labs designed around physics-based concepts and data sets facilitates software design and implement of Software Development Method
- Systematically increase in programming and geodynamic complexity
- Students write every line of code themselves during lab time avoiding a black-box approach to the programming gateway
- Labs completed during lab time, thus students not left alone with broken code which can be a major impediment for novice users

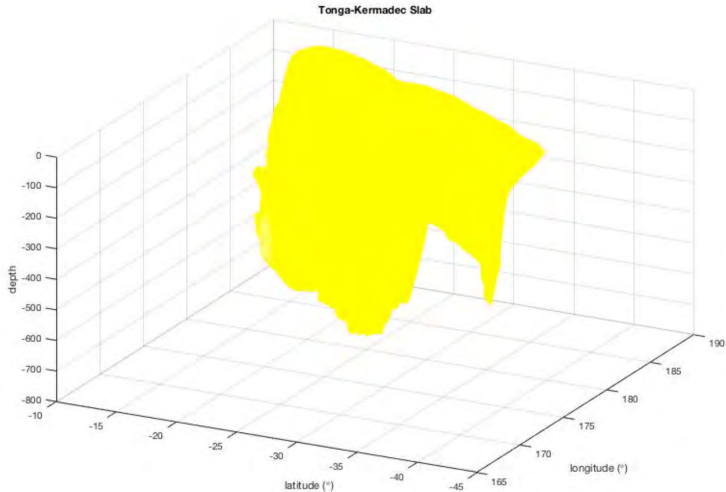
Concept 3. Lab Design Framework

- Lab suite designed for students with no prior programming experience, although students with prior experience have opportunities to deepen programming skills with direct applications to geodynamics-based problems
- Labs designed to be achievable, but mid-semester include question that cannot be completed during lab time because in practice when doing research that is often the case
- Labs include later repetition to gain practice in code re-use and scientific reproducibility
- Culminates in course project for which most of the code is written in lab

Concept 4. Learning Outcomes - Programming Independence and Abstracting Physical Systems

- Students become proficient in programming in MATLAB by the end of the semester writing codes with:
variables,
logical statements,
nested loops,
automated plot and output file naming,
understanding of directory structure
- Students able to abstract physical problem into workable concepts, algorithms, code design, and implementation
- Systematic design and layout of programming lab collection makes the labs easily portable to other upper-level undergraduate and graduate Earth Science and Science courses

Concept 5. In Lab Learning Assessment - Code Output Example



Data from: Hayes et al. (2018)

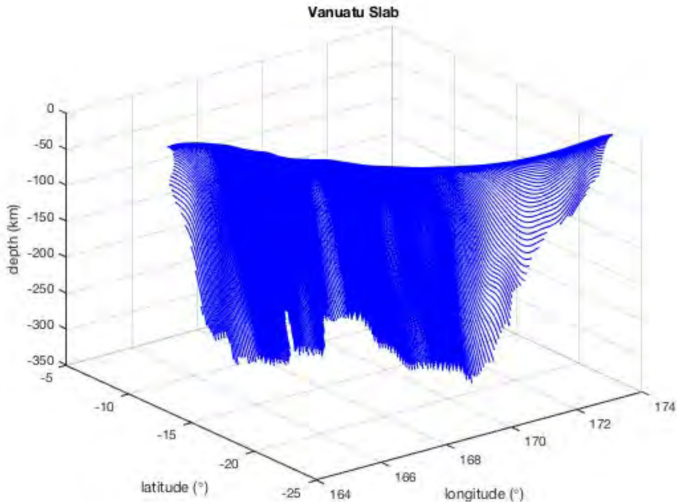
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MATLAB/SERC 2026

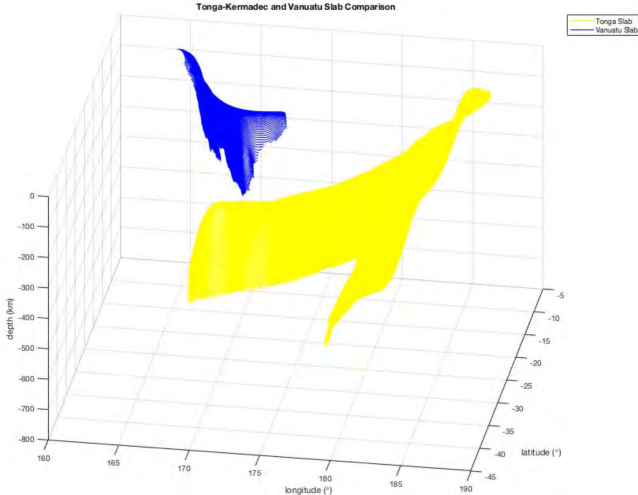
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Concept 5. In Lab Learning Assessment - Code Output Example



Data from: Hayes et al. (2018)

Concept 5. In Lab Learning Assessment - Code Output Example



Data from: Hayes et al. (2018)

Concept 6. Post Lab Learning Assessment - Example Grading Rubric

Geodynamics: Lab #6 Grading Rubric

Name: _____ Total Score: _____/3.5

P1: MATLAB function to Query and Plot Slab

- ___/0.20 Generalized program using function
- ___/0.20 Specify input data at function call
- ___/0.20 Test with Kermadec data
- ___/0.15 Variables for lon, lat, dep
- ___/0.15 Determine min lon, lat, dep
- ___/0.15 Determine max lon, lat, dep
- ___/0.20 Use of fprintf to print values
- ___/0.20 Use plot3 for slab, yellow
- ___/0.20 Title on plot named dynamically
- ___/0.20 Output file named dynamically
- ___/0.10 Label axes
- ___/0.05 Use of grid on
- ___/2.0 Total

P2: Used Function to Plot Three Other Slabs

- ___/0.50 Ran program on Second Slab
- ___/0.50 Ran program on Third Slab
- ___/0.50 Ran program on Fourth Slab
- ___/1.5 Total