USC GEOL557: Numerical Modeling of Earth Systems  
Spring 2016

Instructor

Prof. Thorsten W. Becker (ZHS269; (213)740-8365; twb@usc.edu), with help from Dr. Rob Porritt and Adam Holt

Class Logistics

Class/lab Times: Tue and Thu 12:30-2 pm

Locations: ZHS264.

Software/hardware: Students need to install Matlab on their laptops before class starts to be able to do classwork. (The new computer lab, ZHS100, only has a few PCs with Matlab installed, sorry).

Notify the instructor if you do not have your own laptop, we can arrange loaners.

Outline

This class discusses the numerical solution of problems arising in the quantitative modeling of Earth systems. The focus is on continuum mechanics problems as applied to geological processes in the solid Earth, but the numerical methods have broad applications including in geochemistry or climate modeling. We briefly review math and continuum mechanics fundamentals, then discuss ordinary differential equations (ODEs), and spend the majority of the class covers finite difference (FD) and finite element (FE) solutions to partial differential equations (PDEs).

The class is for advanced undergraduates and graduate students from the Earth sciences, and consists of lectures and joint and individual computer lab exercises. Grading is based on home work/programming project assignments, a final project, and class participation.

• Students have to pick a final project in week ten, after consultation with the instructor, and are encouraged to start work early, in week 12 at the latest.

• Problem sets are due one week after they were issued, Thursday after class. No late problem sets will be permitted.

• The final project (in terms of a 15 page, PDF writeup along with Matlab routines to run the computations, to be submitted electronically) is due on May 3. No late projects will be accepted, nor will extensions be granted.

- Grading
  - 50% home work assignments
  - 40% final project
  - 10% class participation

**Syllabus**

In the following syllabus, all reading and assignments refer to the lecture notes by Becker and Kaus (2015), available from geodynamics.usc.edu/~becker/Geodynamics557.pdf, and updated throughout the course. Individual assignments can also be downloaded from the course website, http://geodynamics.usc.edu/~becker/teaching-557.html.

**Week 1: Jan 12**


Reading: secs. 2.1-2.4. Review content of chaps. 6-8.

Problem set: Scaling analysis (sec. 2.4.3)

**Week 2: Jan 19, 21**


Ordinary differential equations II: 4th order Runge Kutta.

Reading: chap. 3

Problem set: Program and solve Lorentz equations (sec. 3.3)

**Week 3: Jan 26, 28**


Reading: secs. 4.1-4.5
Problem set: Explicit FD, Implicit FD methods (secs. 4.2.1 and 4.4.4)

Week 4: Feb 2, 4
Finite differences IV: Two-dimensional heat equation, solution with fully explicit and fully implicit methods. Comparison with analytical solutions.
Reading: secs. 4.6-4.7
Notes/problem set: 2-D FD heat equation (sec. 4.7.4)

Week 5: Feb 11
Notes/problem set: sec. 4.8
Problem set: sec. 4.8, exercises 1-4

Week 6: Feb 16, 18 (Rob Porritt)
Reading: sec. 4.11
Problem set: Wave propagation

Week 7: Feb 25
Notes: sec. 4.8
Problem set: Semi-Lagrangian in 2D, sec. 4.8, exercises 5-7

Week 8: Mar 1, 3
Reading: secs. 5.1-5.2, 5.4
Problem set: 1-D heat with FE (sec. 5.3)
Week 9: Mar 8, 10 (Adam Holt)


Reading: sec. 5.5

Problem set: 2-D FE heat equation

Week 10: Spring break

Week 11: no class

Week 12: Mar 31


Problem set: 2-D FE elastic

Week 13: Apr 5, 7


Finite elements VII: Time-dependent problems

Reading: secs. 5.8, 5.10

Problem set: 2-D FE incompressible Stokes

Week 14: Apr 14

Solving large systems of equations.

Reading: sec. 5.4

Problem set: Multigrid, sec. 5.4, exercises 1-3

Week 15: Apr 19, 21

Collaborative work on projects.

Week 16: April 26, 28 Collaborative work on projects.

Final projects are due May 3
Textbooks and notes

The main reference for this class are our lecture notes.


No text book is required, but the following openly available sources contain required reading:

- Zhong et al. (2007)


Recommended textbooks include:

- *Numerical Recipes* by Press et al. (1993), 2nd or 3rd edition


  Other good texts on the finite element method include Kwon and Bang (1996), which provides a clear step-by-step introduction to the FEM method with many Matlab program examples. The classic by Bathe (2007) also makes for a good reference.

- Ismail-Zadeh and Tackley (2010) for a broader, less-detailed overview of general methods in computational geodynamics.

- Gerya (2009) for more details on finite difference approaches to geodynamics.

Statement for Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.-5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.
Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one’s own academic work from misuse by others as well as to avoid using another’s work as one’s own. All students are expected to understand and abide by these principles. Scampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

References


