Earth System Modeling
EAS 4610 / 6130
Fall Semester 2012

Scheduling: Monday, Wednesday and Friday 9:00 - 10:00 am Room L1116

Monday and Wednesday are reserved for lectures and introduction to new fundamental concepts. Students are required to bring their laptop on Friday, where we will revisit the fundamental notions introduced in class the preceding Monday and Wednesday and apply them during practical sessions.

Instructors

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Office Hours

To determine in class

Grading

Homework	25%
Exams (2)	40%
Term project	25%
Presentation	10%

Matlab

We will use "Introduction to Matlab 7 for Engineers" by Palm as a Reference book. Through the Georgia Tech license, students will have network access to Matlab 7 on the computers in the EAS Computer Lab Room L1110. Each student will have a computer account for easy access to Matlab and computer storage space.

Important Dates (subject to changes)

October 1 - Selection of model topic due
October 12 - Exam I
December 3 - Exam II

Last week of class - Presentations
Final Exam day - Presentations

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TENTATIVE LECTURE TOPICS

- Introduction to computer modeling
  Why resorting to computer models?
  When are computer models necessary?
  What are their limitations?

- Root-finding methods

- Numerical Integration

- Box models

One box:	Volcano model Atmospheric chemistry Calcium isotopes in seawater
Multiple boxes:	Biogeochemical cycles Radioactive decay chains

- Equations of interest for Earth System modeling
  Ordinary differential equations
  Systems of ordinary differential equations
  Partial differential equations

- Numerical methods - Finite Differences
  Discretization: explicit, implicit and semi-implicit schemes
  Round-off, truncation and computational errors
  Convergence, consistency, and stability
  Stiff set of equations

- Nonlinear systems and chaos
  Lorenz system, the logistic equation

- Inverse methods
  Source-receptor models

Seismic tomography

- Stochastic models and Monte-Carlo methods
  - Numerical Integration with Monte-Carlo methods
  - Diffusion-limited aggregation

- Short introduction to other numerical methods (FEM,Finite-Volume)
- Introduction to particle methods:
  - Elastic wave propagation with a discrete particle model
  - Introduction to cellular automata and lattice Boltzmann methods

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GEORGIA TECH HONOR CODE

Students in this class are expected to abide by the Georgia Tech Honor Code and avoid any instances of academic misconduct, including but not limited to:

- Possessing, using, or exchanging improperly acquired written or oral information in the preparation of a paper or for an exam.

- Substitution of material that is wholly or substantially identical to that created or published by another individual or individuals.

- False claims of performance or work that has been submitted by the student.

See the published Academic Honor Code for further information. The complete text of the Academic Honor Code may be found at

http://www.deanofstudents.gatech.edu/integrity/policies/honor_code.html

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TERM PROJECT INFORMATION

Project Guidelines

An important part of this course is the numerical model that you will develop for an atmospheric, geochemical, geophysical, geotechnical, environmental, hydrologic, or biogeochemical process or system. As a general guideline for the choice of a project, consider some of the physical or chemical systems or processes that you have studied within EAS.

Non-EAS students should use examples from their own fields of study. Graduate student projects are distinguished from undergraduate projects by being more sophisticated, more challenging, and directly related to their research.

As a general rule, you should choose a modeling project that relied on solving fundamental equations of mathematical physics numerically in space and/or time. Ideally, your project should be based on relatively simple equations that can first be solved analytically for some easy case (e.g., a steady-state solution or a solution that reduces the spatial dimensions of the problem). Then you want to discretize your equations (we will study this in the first half of the course) and develop a computer program that solves the equations numerically. This computer program will allow you to test your numerical approximations against the analytical solution, to test the sensitivity of the process/system to variations in important parameters in the problem, to calibrate the model using a data set, and (possibly) to verify the model using multiple data sets. We strongly encourage the use of the scientific computing language Matlab, although we will consider requests to use compiled languages such as Fortran, C, or Pascal.

It is desirable that the modeling be motivated by the need to understand a process or system. Thus, it is helpful to develop a model for a system for which you have existing real data. These data can be taken from any literature source, from something you have done in another EAS course, or from a Web site that provides real data. The data do not have to pertain directly to the final model, but may instead be relevant to some intermediate step in your model (e.g., a steady-state solution).

Project Report Outline

1. Introduction
   What is the main theme?
   Why is it important?
   What are the motivations for the study?
   How is it currently being studied?
2. Modeling approach
   What are the fundamental physical/chemical/etc. processes?
   Include all relevant equations.
   Describe all terms and parameters.
   Describe all assumptions being made.
   Describe the numerical methods used.
3. Results
   What tests did you run with the model?
   Describe the results.
   How do the results compare with any analytical solution you developed?
   How do the results compare with those in the literature?
   How do the results compare to data that pertain to this process?
   How can you explain any differences?
4. Conclusions
   What did the model tell you about the process you were studying?
   How could the model be improved?
5. References
   Follow the format described in the next section
6. Appendix
   Printout of model code with commentaries

Some Specific Guidelines

- The project report may be a **maximum** of 12 (undergraduates) and 16 (graduate students) double-spaces (12 point font, with 1 inch margins) pages. Figures, references, tables, appendices, and program listings are NOT included within the 12/16 page count. Please use an appropriate equation editor for all equations and spell-check before handing in the documents.
- Figures must be sequentially numbered and clearly labeled. Every figure requires an explanatory caption. Any figure taken from other scientists' work should be clearly labeled as, for example, "After [Jones et al., 1996]". You may not use the original author's figure caption.
- Any values you use in your model should be attributed to a reference. You must also provide an explanation for why this value was chosen in the first place.
- You must detail your assumptions.
- You should compare your model results to at least one set of real data and statistically quantify the agreement. You must also explain why your model

results may not provide a good agreement to the data and give suggestions for ways in which the model might be improved.

- You must include a listing of your code as an appendix to your paper.
- References should be clearly made using the standard mode of reference for the Earth Sciences. Within the text, a reference is made as: [Jones et al., 1996]
- Journal reference: Jones, R. L., S. Davis, and R. Smith, Article's title in small letters (except for proper names like Kansas), *Jour. Hot Air*, 67, p.33-87, 1999.
- Book article: Jones, R. L., Chapter's title, in: eds. S. Chimera and D. Boondoggle, Book's name, New York, McDuffy-Holt and Col, p.110-128, 1996.

Examples of Project Topics

3-body gravitation and orbits
Chemistry of the ozone layer
Urban pollution chemistry
Dispersion of pollution plumes
Carbon or nitrogen cycling
Oceanic nutrient cycling
Evolution of spreading ridges and initiation of magmatism
Ocean circulation
Biogeochemical reactions in soils
Hydrothermal processes
Atmospheric radiative balance
Chaos in some natural system
Temperature structure and heat transfer of solid Earth
Growth of volcanoes
Geyser eruptions
Magma differentiation from mantle partial melting
Plant uptake of groundwater
Melting of an iceberg
Erosion, sediment transport, and deposition
River meandering
Seismic wave travel time through multi-layered Earth
Contaminant transport through soils or water
Eutrophication of lakes
Evolution of propagating rifts
Slope failure
Brittle faulting in the crust
Heat, chemical and/or fluid flow in porous or fractured rocks
Shallow water waves
Coupled flow and saline intrusion in a coastal aquifer
Tidal pumping of a phreatic aquifer
Stalagmite growth
Climate change due to solar variability
Vertical infiltration of heavy metals in soils
Seismic tomography