MATH 553 - MATHEMATICAL MODELS, FALL 2013

TOM DELILLO, INSTRUCTOR

- Time: 4:00-5:15 TTh, JB 372
- Contact info.: office: JB 348, 978-3974 (office), 264-7806 (home)
- email: delillo@math.wichita.edu
- webpage: http://www.math.wichita.edu/~delillo/ (Some additional course info. and MATLAB code will be available here.)
- Office hours: 1:00-2:00 TTh, or by appointment

Required text: Hans G. Kaper and Hans Engler, *Mathematics and Climate*, SIAM, 2013 (due out in September/October, but I have and advanced copy and we will work from notes. The text will be available in electronic form, so you may want to order it that way.)

Prerequisite: Math 344 with C or better or departmental consent.

Objectives: To learn some mathematics in the context of specific applications, this semester to simple models of parts of the earth's climate system, to see how such models may elucidate more complex phenomena, and to formulate a problem or project of mathematical interest related to climate and present your results in a clear and professional manner. Use of computational tools such as MATLAB will be encouraged.

As we all know, some of the predictions of climate science in recent decades point to severe problems for human civilization in the next centuries or even decades, if they are not addressed properly, that is, if we don't severely cut down on our burning of fossil fuels. This would require a major restructuring of how the world's energy is supplied and has led to some intense debates over politics, economics, and technology. It is not the purpose of this course to address these serious issues, though they will inevitably arise in readings, discussions, or seminars. Indeed, although climate and weather are interesting scientific disciplines in their own right, this interest is surely now magnified by concern for the environment. I hope that all this gives us more motivation to understand the course material and has the fringe benefit of deepening our understanding of what the climate science is telling us.

Additional reference books:

Most of these books are in or coming to our library. They may provide some sources for reports, projects, or additional reading.

David Archer, *Global Warming–Understanding the Forecast*, Second ed., John Wiley, Hoboken, NJ, 2012. A very good overview written for undergrad, nonscience majors. Has some nice problems and possible projects.

David Archer, *The Global Carbon Cycle*, Princeton U. Press, 2010. Part of the Princeton Primers in Climate series by Princeton U. Press. Other tiles are available or forthcoming.

David Archer and Raymond Pierrehumbert, eds., *The Warming Papers: The Scientific Foundation for the Climate Change Forcast*, Wiley-Blackwell, 2011. A collection of original papers including the 1824 paper by Joseph Fourier first discussing the greenhouse effect and the 1896 paper by Svante Arrhenius with the first estimate of climate sensitivity—how much warming would result from doubling the CO_2 content of the atmosphere. The 1968 papers by Budyko and Sellers on energy balance models are also here.

David Archer and Stefan Rahmstorf, *The Climate Crisis: An Inroductory Guide to Climate Change*, Cambridge Univ. Press, 2010. A good overview for a popular audience.

Kerry H. Cook, *Climate Dynamics*, Princeton U. Press, 2013. The illustrations can be viewed at http://press.princeton.edu/textbooks/illustrations/cook/

M. Ghil and S. Childress, *Topics in Geophysical Fluid Dynamics: Atmospheric Dynamics, Dynamo Theory, and Climate Dynamics*, Springer, 1987. Advanced book. See Part IV on energy balance models, climate oscillations,...

Shawn J. Marshall, *The Cryosphere*, Princeton Primers in Climate, 2012.

J. D. Neelin, *Climate Change and Climate Modeling*, Cambridge, 2001.

R. T. Pierrehumbert, *Principles of Planetary Climate*, Cambridge, 2010. Advanced text.

Joseph Pedlosky, *Geophysical Fluid Dynamics*, 1987. This is the classical reference on the fluid dynamics (partial differential equations) of the atmosphere and oceans. It is probably beyond the scope of this course, but may be useful if we do material in Chap 15 of our text.

David Randall, *Atmosphere, Clouds, and Climate*, Princeton Primers in Climate, 2012.

F. W. Taylor *Elementary Climate Physics*, Oxford, 2005. Good overview including explanation of the physics.

K. K. Tung, *Topics in Mathematical Modeling*, Princeton, 2007. See chapters 8, 11, 12 on energy balance models, Lorentz eqs., and El Nino-Southern Oscillation (ENSO), plus MATLAB code in appendices. I've used this as the text for Math 553.

Steven H. Strogatz, *Nonlinear Dynamics and Chaos with Applications to Physics, Biology, Chemistry, and Engineering*, Westview, 1994. Good for dynamical systems, bifrucation, Lorentz equations.

Geoffrey K. Vallis, *Climate and the Oceans*, Princeton Primers in Climate, 2012.

Tentative speakers of interest in Physics Seminar, Wed. 2-3PM, JB 128.

Exact talk times and titles and some content will be posted on the Physics groups website as they become available

http://webs.wichita.edu/?u=MATHSCI&p=/physics/events/index/

So far we have the following:

David Archer, U. Chicago, Sept. 11.

Hans Kaper, Georgetown, Sept/Oct.?.

Edwin Gerber, Courant CAOS group, Oct. 9

Jerrt Peterson, U CO Boulder, Oct 30.

Kevin Trenberth, NCAR Boulder, Nov 14 (Thursday!)

plus some local speakers tbd.

See also some online talks posted on Mathematics of Planet Earth 2013

http://mpe2013.org.

speaker bureau http://mpe2013.org/mpe-speaker-bureau/.

Grading (approximate)	points
Homework–keep problem notebook	100
Exam on mathematical techniques (around 10/17, after Fall break)	100
(Drop lowest of Homework and Exam.)	
Two 2 to 3 page typed reports on a video, lecture, or portion of a book,	
50 points each, due dates tbd, $2\times$ 50 =	100
About 5 meeings with me to determine projects, 5 $\times$ 20 =	100
Project presentation (times tbd before final, more details below)	50
Project final report due 12/12	150
Total	500

Grading scale: I do not have a fixed grade scale. I usually end up curving final raw scores to your favor. I will assign grades in a reasonable manner and inform you of how you are doing relative to the rest of the class after each exam or project. The rule for converting final grades into your GPA is fixed by WSU and you can look it up.

Attendance policy, etc.: Regular attendance is mandatory. I will pass around an attendance sheet during each class. Good attendance will count in your favor, if your grade is borderline. Part of the *purpose* of this course is to get you to *talk with me and your fellow students about mathematics*. I will arrange individual and team meetings in my office after the course is underway.

If you fall behind or have other problems with the class, please contact me *as soon as possible.* Turning in homework late, missing class, or missing exams for any reason is highly discouraged. I will try to be helpful if you have special difficulties. *If you miss an excessive number of classes, you may fail the course or your grade may be lowered.*

Important dates:

- First day of classes 8/19.
- Labor Day (no class): 9/2.
- Fall break: 10/12–10/15.
- Last day to drop with a "W": 10/29.
- Thanksgiving: 11/27–12/1.
- Last day of classes: 12/5.
- Final exam/project reports: Thursday 12/12, 3:00–4:50 PM, in classroom.

Definition of a Credit Hour: 3 credit hour class: Success in this 3 credit hour course is based on the expectation that students will spend, for each unit of credit, a minimum of 45 hours over the length of the course (normally 3 hours per unit per week with 1 of the hours used for lecture) for instruction and preparation/studying or course related activities for a total of 135 hours.

Syllabus

week	Planned Topics (approximate, subject to revision)
1	Intro, overview, start thermo and greenhouse effect
2	Chap 2, greenhouse effect, energy balance models
3	” ”
4	Chap 3, Oceans and climate, box models
5	” ”
6	Chap 4, Dynamical systems, ODE review
7	” ”
8	Chap 5 Bifurcation theory
9	Exam on math esp. Chaps 4,5 on 10/17
10	Chap 6, Stommel's box model
11	Chap 7, Lorenz equations
12–16	Material to be determined by interests/projects

Possible topics and references for team projects and reports You may do an individual or a team project. Teams should consist of at most two or three students and the final report should be longer. The papers and books listed here are available from me or from journals in the library and are possible bases for projects. In addition, groups of related problems or chapters from the text not covered in class may also serve as bases of projects. Reproduction or extension of computational results from the papers is highly encouraged. I will arrange meetings with your teams. We will try decide on a topic around the time of Fall break. A brief *presentation* (preferably using *power point* or latex *beamer*) and a *typed, referenced, final report* (preferably using *latex*) will be due at the end of the semester. More details will be given later.

The website [MPE] and some of the links below contain a great number of links to videos and interesting material to give you specific ideas for project and also a broader context for the material in the course.

Note carefully: It is absolutely essential that you reference and give proper credit to any sources that you use. If you collaborate or have helpful discussions with someone, that too should generally be acknowledged.

REFERENCES

[MPE] *Mathematics of Planet Earth 2013*, http://mpe2013.org.

[NOVA] *PBS NOVA Earth from Space episode*, http://www.pbs.org/wgbh/nova/earth/earth-from-space.html

[edGCM] Climate model from Columbia U...link to come...

[Ghil] *Michael Ghil's webpage*, http://www.atmos.ucla.edu/tcd/GHIL/.

[IPCC] *IPCC web site*, http://www.ipcc.ch/.

[MC] *Mathematics and Climate research Network*,http://www.mathclimate.org/.

[PT13] US Geological Survey Lawrence Livermore Laboratory Climate Change Viewr *Physics Today*, (July 2103), p. 28, http://regclim.coas.oregonstate.edu/gcv

[RC] *Realclimate*, commentary site on climate science, http://realclimate.org/.

[Sch13] WILLIAM SCHIESSER, *Global C0$_2$ model in MATLAB and R*, send email to Schiesser at wes1@lehigh.edu.

[Tay] F. W. TAYLOR'S BOOK, p. 123, www.columbia.edu/itc/chemistry/chem-c2407/hw/ozone$_$kinetics.pdf Also, p. 174, www.climateprediction.net/science/index.php

[AF07] M. R. ALLEN AND D. J. FRAME, *Call off the quest*, Science, 318 (Oct. 26, 2007), pp. 582–583.

[CLWZ11] G. CHEN, J. LAANE, S. E. WHEELER, AND Z. ZHANG, *Greenhouse gas molecules: a mathematical perspective*, AMS Notices, 58 (Nov. 2011), pp. 1421–1434.

[Go09] K. M. GOLDEN, *Climate change and the mathematics of transport in sea ice*, AMS Notices, (May 2009), pp. 562–584.

[ML12] R. MCGEHEE AND C. LEHMAN, *A paleoclimate model of ice-albedo feedback forced by variation in earth's orbit*, SIAM J. Appl. Dyn. Systems, 11 (2012), pp. 684–707.

[M04] C. MOLER, *Numerical Computing with MATLAB*, SIAM, 2004, Problem 7.21. http://www.mathworks.com/moler/

[P11] R. T. PIERREHUMBERT, *Infrared radiation and planetary temperature*, Physics Today, (Jan. 2011), pp.33–38.

[RB07] G. H. ROE AND M. B. BAKER, *Why is climate sensivity so unpredictable*, Science, 318 (OCT. 26, 2007), PP. 629–632.

[V12] R. J. VANDERBEI, *Local warming*, SIAM Review, 54 (2012), pp. 597–606.

[ZG10] I. ZALIAPIN AND M. GHIL, *Another look at climate sensivity*, Nonlin. Processes Geophys., 17 (2010), pp. 113–122.