An Undergraduate Course on Mathematics and Climate

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MCRN

www.mathclimate.org

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SCHOOL OF **MATHEMATICAL & STATISTICAL SCIENCES**

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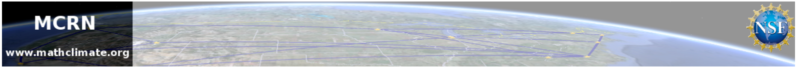
Background: the Mathematics and Climate Research Network

- mathclimate.org
- MAA short course on climate modeling, Jan. 7–8
- First of a new class of NSF research centers
- Headed by Chris Jones from the University of North Carolina, Chapel Hill
- Consortium of 12 university math & geoscience departments plus the National Climatic Data Center



Background: the ASU CSUMS program

- Computational Science Training for Undergraduates in the Mathematical Sciences (CSUMS) program
- Joint effort by DMS and DUE in NSF
- ASU received $1 million for 5-year effort from 2008–2013
- 65 students supported for 11 months on long-term research experiences (including 2-month summer program)
- Requirements: Projects must be genuine research experiences rather than rehearsals of research methods

Background: the ASU MCTP program: 2012–present

- Mentoring through Critical Transition Points (NSF DMS)
- Program solicitiation: Provides funds to develop a system of mentoring devoted to points of transition in a mathematical sciences career path that are critical for success . . . [and] emphasizes department-wide activities
- Partnership with the Maricopa Country Community College District to mentor promising transfer students majoring in mathematics and statistics
- Also includes a summer research component

Some lessons learned so far

- Core requirements of calculus, differential equations, and linear algebra are sufficient for students to undertake interesting projects
- Applications often motivate students to take advanced courses in pure mathematics
- The 8-week summer format is ideal for in-depth project
- But not every qualified student (or faculty member) can commit to 2 months in summer
- Need to institutionalize some activity to get transfer students "plugged in" to research opportunities

The “project seminar” format

- Adapt some aspects of the summer REU to a 3-credit course during the regular academic year
- Prerequisites are 3 semesters of calculus plus differential equations and linear algebra (sophomore/junior level)
- Goals: provide a “path forward” to advanced courses in mathematics and applications
- Use real data in a nontrivial way
- Anticipated topics: (1) Math and Climate; (2) Math and Cancer; (3) Math and Imaging; (4) Math and Networks

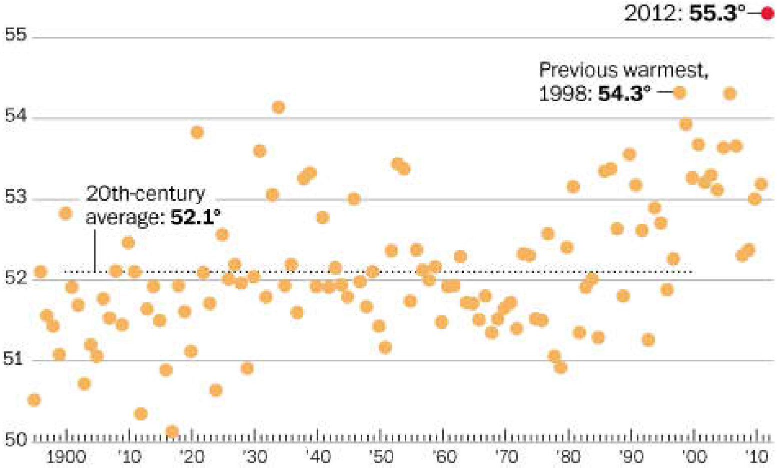
The math & climate conundrum

- Co-developer of this course: Alex Mahalov
- Course must contains topics appropriate for a mathematics department and student audience
- It’s not practical to offer a comprehensive course in climate science in one semester
- Most textbooks are geared toward graduate students in the geosciences
- We don’t want students running computer simulations without understanding what they are doing

Our approach—the mathematics of heat

- Principal focus: The mathematics of urban heat islands
- Motivation: Rapidly urbanizing cities in arid climates have very warm nights, especially in summer
- Start with simple cases and hand computation
- Work up to realistic domains and more sophisticated computer models
- Real data: on nighttime temperatures, electiricity consumption
- Possible future scenarios: What happens in mid-century based on expected demographic trends? global climate change?

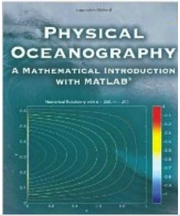
Average annual temperature in the continental U.S.



- Jan. 8 *Washington Post* article on NOAA results

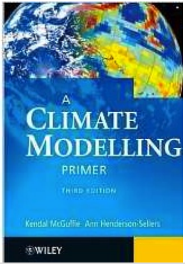
Textbooks

- Main resource: Reza Malek-Madani, *Physical Oceanography: A Mathematical Introduction with MATLAB* (CRC Press)
- Chapters: MATLAB, matrices, review of calculus, ODEs, numerical methods for ODE, geophysical fluid dynamics, shallow water equations, wind-driven ocean circulation (Stommel & Munk models)



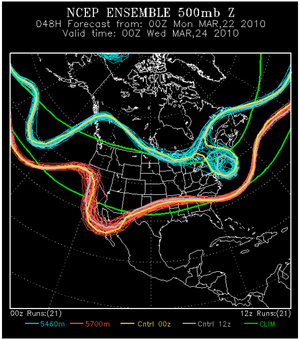
Supplementary resource

- Kendal McGuffie and Ann Henderson-Sellers, *A Climate Modelling Primer*, 3rd ed. (Wiley)
- Chapters: Climate, history & introduction to climate models, energy balance models, intermediate complexity models, coupled climate system models, practical climate modeling



Other course topics

- Monte-Carlo methods: ensemble forecasting
- Chaos and predictability
- Exposure to the Weather Research and Forecasting model



Where can students go from here?

- Partial differential equations
- Nonlinear dynamics
- Fluid dynamics
- Numerical methods
- Probability and stochastic processes
- High-performance computing
- . . . plus related offerings in other units

Other potential “seminar project” courses

- Metropolis algorithm
- Fast Fourier transform
- Simplex algorithm
- Public-key cryptography
- Kalman-Bucy filter
- Viterbi algorithm
- Shotgun genome sequencing

Acknowledgments

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