Environmental Science and Climate Studies

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Why Environmental Science and Climate Studies?

Global climate change is real [1]. It is incumbent upon us all to address numerous questions at local, regional and global levels, such as these:

! Who and what will be significantly affected?
! When and where will we see major changes?
! How can we prepare?

When put in context of specific situations, these problems require knowledge in one or more disciplinary fields, including natural and/or social sciences, to obtain a quantitative result. Mathematics plays an important role in the investigation of environmental science and climate studies (ESCS) issues.

As evidenced by the participation of over 100 institutions and organizations in the Mathematics of Planet Earth 2013 thematic year, mathematicians are well aware of the need to apply mathematical knowledge to better understand our dynamic planet. Many academic institutions are adding courses and degree programs in sustainability and environmental studies to meet the student interest and demand, and a growing job market in the area [2,3,4].

Outside of environmental engineering programs (see [5] for many examples), however, undergraduate ESCS-related programs seldom require upper-level mathematics. This is so despite broad awareness of mathematical needs of students who continue in ESCS at the graduate level. For example, *Applied Math for Environmental Studies*, a graduate course in the Yale School of Forestry & Environmental Studies, aims to "help students refresh or acquire new math skills and succeed in content and 'toolbox' graduate-level courses … the course assumes that, at a minimum, students took college algebra and perhaps a semester of calculus (but might not really remember it)" [6].

The need for mathematically-focused ESCS programs at the undergraduate level is clear. Finding viable approaches to implementation is the focus of this report.

ESCS in the undergraduate mathematics curriculum

"Our populace is becoming less able to evaluate or assess the trade-offs between

solvable analytically or the fact that they are data-driven (thus emphasizing the need for the previously listed courses), a course in numerical analysis or operations research can be a powerful tool for students to seek solutions to a broad range of ESCS problems.

A course in numerical analysis offers students a theoretical understanding of numerical methods, experience using software to implement numerical methods, and the ability to choose numerical methods appropriate to particular applications. For example,

Overview of academic program

Undergraduates earning a math degree with an ESCS specialist should obtain the content knowledge and experience necessary to develop environmental intuition that supports meaningful real-world problem solving. Mathematical knowledge is crucial, but so are depth in an outside area and

1. National Aeronautics and Space Administration. "Global Climate Change: Vital Signs of the Planet".
2. Vincent, S., S. Bunn and S. Stevenson, "Sustainability Education: Results from 2012 Census of U.S. Four Year College and Universities", National Council for Science and the Environment, January 2013.
3. Lepisto, M., "Growth field: Environmental studies a 'college major with a future'", September, 2012.
4. Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, 2014-15 Edition, Environmental Scientists and Specialists .
5. "Schools Offering Degree Programs in Environmental Engineering".
6. Fenichel, E., "[F&ES 762a] Applied Math for Environmental Studies", Yale School of Forestry & Environmental Studies website.
7. Fusaro, B. et al. (1992) "Environmental Mathematics". In Steen, L. A. (Ed.), "Heeding the Call for Change: Suggestions for Curricular Action", (pp. 83-92) MAA.

Resources

Books and textbooks

Drake, J. B., *Climate Modeling for Scientists and Engineers*, SIAM 2014.

Fusaro, B.A., *Environmental Mathematics via the Visual, Qualitative & Computational*, Online textbook.

Fusaro, B. A. and P. C. Kenschaft (eds.), *Environmental Mathematics in the Classroom*, MAA 2003.

Hadlock, C. R., *Mathematical Modeling in the Environment*, MAA 1998.

Hadlock, C. R., *Six Sources of Collapse*, MAA 2012.

Kaper, H. G. and H. Engler, *Mathematics and Climate*, SIAM 2013.

Kaper, H. G. and C. Rousseau, *Mathematics of Planet Earth*, SIAM 2015.

MacKay, D. JC., *Sustainable Energy – without the hot air*, UIT Cambridge 2009. Full text is available online for download.

Slingerland, R. and L. Kump, *Mathematical Modeling of Earth's Dynamical Systems: A Primer*, Princeton University Press 2011.

Walter, M., *Mathematics for the Environment*, CRC Press 2011.

Reports

Levin, S. A., and W. C. Clark, (eds.), *Toward a Science of Sustainability: Report from the NSF toward a Science of Sustainability Conference*, 2009.

Rehmeyer, J. *Mathematical and Statistical Challenges for Sustainability*, 2011.

Other resources
The listed websites contain links to ESCS-focused mathematics resources including data, articles, and information about relevant activities and events. Some websites contain links to developed ESCS curricular materials.

MAA Special Interest Group on Environmental Mathematics (SIGMAA EM)

Mathematics and Climate Research Network (MCRN)

Mathematics of Planet Earth (MPE)

Maths of Planet Earth (Australia)

NASA's Sustainability Portal

National Renewable Energy Laboratory (NREL)

The Science Education Resource Center (SERC) at Carleton College
(SERC Sustainability Site Guide)

SIAM Activity Group on Mathematics of Planet Earth (SIAG/MPE)

Sample degree programs
Examples of existing Mathematics and Environmental Science and Climate Studies related B.S. degree programs

Lancaster University (England) Environmental Mathematics, program website.

St. Lawrence University, Environmental Studies – Mathematics Combined Major, program website.

University of California at Los Angeles, Mathematics/Atmospheric & Oceanic Sciences, program website.

University of Exeter (England), Mathematics and the Environment (B.S.), program website.