

Department of Earth, Atmospheric, and Planetary Sciences

The Department of Earth, Atmospheric, and Planetary Sciences (EAPS) has broad intellectual horizons encompassing the solid Earth, its fluid envelopes, and its diverse neighbors throughout the solar system and beyond. The Department seeks to understand fundamental processes that define the origin, evolution, and current state of these systems and to use this understanding to predict future states. The Department comprises 34 faculty (including two with primary appointments in Civil and Environmental Engineering and one with a primary appointment in Biology), and more than 112 research staff, postdoctoral appointments, and visiting scholars.

EAPS is notable for its emphasis on interdisciplinary problems. The Earth Resources Laboratory and Kuwait Center at MIT bring together faculty, staff, and students in intensive and multidisciplinary efforts to investigate geophysical and geological problems in energy and resource development. The Center for Global Change Science builds on the programs in meteorology, oceanography, hydrology, chemistry, and satellite remote sensing in the Schools of Science and Engineering. The Center joins with the Center for Energy and Environmental Policy Research to form the Joint Program on the Science and Policy of Global Change. This program conducts policy analysis and public communication on issues of global environmental change. With faculty from Civil and Environmental Engineering, Chemistry, Biology, and EAPS, the Environmental Science Initiative fosters collaboration in research and education on the physical, biological, and chemical interactions that define the Earth.

Educational Activities

Graduate Program

EAPS has vigorous graduate educational programs in geology and geochemistry, geophysics, atmospheres, oceans, climate, and planetary science. During the past academic year, 160 graduate students were registered in the Department, including 75 students in the MIT/Woods Hole Oceanographic Institution Joint Program. Women constitute 46 percent of the graduate student population, and 32 percent of the graduate population is composed of international students.

The excellence of the EAPS graduate program is built not only on the strength of teaching and supervision by the faculty but also on involvement of EAPS graduate students in departmental activities. Students develop formal and informal ways to improve educational experience as well as student life. The departmental Graduate Student Mentoring Program continues as a well-received approach to provide peer support for new students. Many graduate students are involved in Graduate Student Council activities, and they use their experiences in EAPS to make positive changes for the entire graduate student population. EAPS awards a prize for excellence in teaching to recognize superior work of teaching assistants in many of our classes. Last year prizes were awarded to Elisabeth Adams, Darrell Coles, Katrina Cornell, Yohai Kaspi, Taylor Schildgen, and Brian Tang for service during the academic year. Arnico Panday received the Program in Atmospheres, Oceans, and Climate's Rossby Award for his PhD thesis, "The Diurnal Cycle of Air Pollution in the Kathmandu Valley, Nepal."

Undergraduate Program

EAPS continues to make increasing the number of undergraduate majors in the department a priority. In AY2004, we had a 95 percent increase in the number of undergraduate majors. In AY2006, we again increased our undergraduate major population to the highest level in more than 20 years. EAPS enters AY2008 with 37 undergraduate majors, and we believe we can build on the enthusiasm of these majors and the strengths of our new faculty to attract an even larger number of majors in the coming years. EAPS continues to review the curricula for our four tracks within the major to ensure the relevance and rigor of each course. We believe one of the greatest challenges for EAPS and MIT is to find a pathway to expose every undergraduate at MIT to the earth sciences. With the rise of energy, environmental, and climate change issues as central foci of policy debate, it is critical that our graduates have a knowledge base for discussion and decision making in their role as citizens.

The Department's commitment to fostering undergraduate research is illustrated by our annual award of the Goetze Prize for Undergraduate Research, presented for research conducted within the Undergraduate Research Opportunities Program (UROP) or for a senior thesis. At the 2007 commencement, the Goetze Prize was awarded to graduating seniors Augusta Dibbell, Mariela Perignon, Jessica Thompson, and Andrew Wickert. The opportunities for undergraduates to discover the challenges and rewards of research in atmospheric dynamics were increased this year by Dr. David P. Bacon's (1977) establishment of a fund supporting UROP research in EAPS. Dr. Bacon was motivated by the desire to encourage exceptional undergraduate research and to honor the career achievements of Professor Kerry Emanuel.

EAPS presents the undergraduate student body with opportunities to become acquainted with the world from an earth sciences perspective. The Department acts on its belief that EAPS should have a strong presence in the undergraduate program at MIT beyond our population of majors. The Department remains committed to Terrascope and its problem-based approach to education during the first year at MIT. We continue to provide many UROP projects supervised by EAPS faculty, participate in freshman advising seminars, and sponsor a weekly undergraduate seminar. The overwhelming majority of students in these programs have not been EAPS majors.

Faculty

Professor Samuel Bowring received MIT's Everett Moore Baker Memorial Award for Excellence in Undergraduate Teaching. This is the only teaching award in which recipients are nominated and selected entirely by the students in recognition of exceptional interest and ability in the instruction of undergraduates.

Professor Edward Boyle was elected chair of the Gordon Conference on Chemical Oceanography, the premiere meeting of chemical oceanographers.

Professor Kerry Emanuel was elected to the National Academy of Sciences. He also received the Carl-Gustaf Rossby Medal and the Louis J. Batten Author's Award (for his book *Divine Wind*), both from the American Meteorological Society, and the David B.

Stone Medal from the New England Aquarium. He was also selected to be a Sigma Xi Lecturer and American Meteorological Society Haurwitz Lecturer in 2007.

Professor Raffaele Ferrari received the Nicholas P. Fofonoff Award from the American Meteorological Society in recognition of research achievements in the field of physical oceanography, specifically for profound insights and important discoveries on eddy and mixing processes in the ocean.

Professor Thomas Herring was awarded the Vening Meinesz Medal by the European Geosciences Union in recognition of his scientific achievements of the field of geodesy.

Professor Daniel Rothman received the MIT Global Habitability Award, given for an outstanding contribution toward understanding long-term environmental trends affecting the Earth and its habitat for supporting life.

Professor Sara Seager was appointed as the Ellen Swallow Richards Professor for a five-year term, beginning January 1, 2007. The Ellen Swallow Richards Professorship was established in 1973 to honor MIT's first woman graduate and first woman teacher.

Professor Roger Summons was honored with the 2007 Humboldt Research Award "in recognition of lifetime achievements in research."

Professor Carl Wunsch was presented with the William Bowie Medal on December 13, 2006 "for his wide-ranging research in the study of the ocean and its roles in shaping Earth's climate and its changes, and for unselfish cooperation in the field of physical oceanography." The Bowie Medal is the American Geophysical Union's highest honor.

Professor Maria Zuber was the Geological Society of America's 2007 recipient of the G.K. Gilbert Award in recognition of outstanding contributions to the interdisciplinary field of planetary geology.

Research and Administrative Staff

Ms. Jacqueline Taylor received the dean's Unsung Hero Staff Recognition Award.

Current Research

Professor Richard Binzel performed telescopic observations of a particularly hazardous asteroid, 99942 Apophis, showing it to have the composition of ordinary chondrite meteorites. This information is necessary for mission planning before the close approach of this asteroid in the year 2029.

Professor Edward Boyle and his research group mapped out the distribution of lead in the surface waters of the Atlantic Ocean for three key time periods: 1979–1985 (immediately after the phasing out of leaded gasoline in the US), 1986–1993 (the years of peak decline in lead transport to the ocean), and 1997–2005. They discovered that there is a concentration-dependent stable isotope fractionation of zinc by phytoplankton, with the isotopic fractionation being highest under zinc-replete conditions.

Dr. William B. Durham and colleagues have set up an experimental research program in the deformation of geological materials at rather opposed extremes of temperature and pressure. One focus of the group is on icy materials that compose the large icy moons of the outer solar system. The other focus is on olivine-bearing rocks from Earth's mantle, which he and his associates deform in a completely different kind of apparatus to temperatures and pressures simulating Earth conditions to a 400-km depth.

Professor James Elliot successfully observed a stellar occultation by Pluto. The data show that the expansion of Pluto's atmosphere that occurred between 1988 and 2002 has ceased, and hazes have been dissipating. Since Pluto is receding from the sun, the atmosphere should begin collapsing within the next few years, but a substantial atmosphere should still be present when New Horizons flies by Pluto in 2015.

Professor Kerry Emanuel's research this year focused on the connection between hurricanes and climate. He developed a new technique for inferring tropical cyclone climatologies from the output of global climate models, which themselves do not resolve such storms. With an undergraduate, he developed a technique for estimating hurricane intensity from satellite-based cloud radar.

Professor Brian Evans and his research group are collaborating on an integrated field and laboratory study of shear zones along the base of the Morcles Nappe in the Swiss Alps. The investigation has unearthed intriguing evidence of the micromechanical processes that allow the construction of fold and thrust belts during alpine tectonics.

Professor Raffaele Ferrari and his group showed that lateral instabilities at upper ocean fronts have a profound effect on two properties of the upper ocean because they set sea surface temperature and mixed layer depth. These two variables are crucial in regulating air-sea fluxes and, hence, Earth's climate. Previous studies of the upper ocean ignored these instabilities and were proven to be in error.

Professor Frederick Frey initiated a research project focused on understanding the long, linear trend of volcanoes that form the Ninetyeast Ridge in the Indian Ocean. During summer 2007, he was a member of the oceanographic research vessel RV *Revelle*, using geophysical measurements to determine the structure of the ridge and obtaining volcanic samples for geochemical studies.

Professor Timothy Grove and colleagues are working to understand the controls on magma generation processes in subduction zones, particularly the close spatial association of wet and dry melting. He is also currently serving as president of the American Geophysical Union.

Professor Thomas Herring is using the Global Positioning System and very long baseline interferometry data to develop geophysically based models of changes in the rotation of the Earth and Earth deformations on global, regional, and local scales. Research areas include the southern Eurasian plate boundary, southern New Zealand, and the western United States.

Professor Richard Lindzen and his research group are studying the temperature dependence of the cirrus outflow from tropical cumulus using observation and modeling. They are also studying the nature of arctic inversions and whether they extend throughout the troposphere.

Professor John Marshall is part of a large collaboration that is developing models and methodologies for ocean state estimation in the Estimating the Circulation and Climate of the Ocean (ECCO) project. At MIT, he and his group began a series of geophysical fluid dynamics experiments to study the equilibrium state(s) of an aqua planet (like Earth, but without land). The approach provides a bridge between conceptual models of climate and high-end coupled modes that are being used to speculate about climates of the past and projections into the future.

Professor Ronald Prinn and members of the Advanced Global Atmospheric Gases Experiment have used global atmospheric measurements of molecular hydrogen, an atmospheric circulation model, and statistical inverse methods to estimate the global source and sinks of this gas. The findings are important because hydrogen is being proposed as a significant secondary fuel in the future.

Professor Paola Malanotte-Rizzoli continues work on transport and heat exchanges between the subtropical and the tropical Atlantic Ocean and how they affect the global thermohaline circulation. She is also developing ensemble data assimilation approaches to improve the predictability of ocean circulation models.

Professor Daniel Rothman and student David Forney published a new theory for marine respiration. Their work suggests that decay and preservation of organic matter in marine sediments depends primarily on its physical protection from microbial degradation.

Professor Leigh Royden continues to lead the MEDUSA (Multidisciplinary Experiment for Dynamic Understanding of Subduction beneath the Aegean). The group has shown that the current tectonic disruption of Greece stems directly from the dynamics of subduction along the Hellenic trench and to the arrival of oceanic lithosphere at the southern trench.

Professor Sang-Heon (Dan) Shim and his research group are using high-resolution optical spectroscopy to measure thermodynamic properties and crystal structures of materials at extreme pressure-temperature conditions. They found that a new mineral phase may have much lower thermal expansivity than was previously thought, which supports the dynamic stability of the mantle structures with the new phase at the lowermost mantle.

Professor Peter Stone and his group have analyzed the performance of the atmosphere-ocean general circulation models used for the climate change projections made by the Intergovernmental Panel on Climate Change in their recently released Fourth Assessment Report. Only two of the models were in reasonably good agreement with the observed 20th-century changes; most of them significantly overestimated how rapidly heat was being mixed into the deep oceans.

Professor Carl Wunsch is working to characterize global and regional variability and trends in oceanic heat content, sea level, and transports. Many of these elements are important in understanding how and why the climate system is changing.

Professor Maria Zuber leads the Radio Science Gravity Team on the Mars Reconnaissance Orbiter that is currently mapping Mars. She and her group recently estimated the water ice and dust content of Mars's south polar layered deposits and, in a separate study, used global hydrological modeling to show that the Meridiani Planum (Opportunity) landing site may have been a zone of sustained groundwater upwelling.

Maria T. Zuber
Department Head

More information about the Department of Earth, Atmospheric, and Planetary Sciences can be found at <http://leapsweb.mit.edu/>.