# Department of Earth, Atmospheric and Planetary Sciences

The Department of Earth, Atmospheric and Planetary Sciences (EAPS) has broad intellectual horizons that encompass the solid Earth, its fluid envelopes, and its diverse neighbors throughout the solar system and beyond. EAPS seeks to understand the 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 members, including 2 with primary appointments in the Department of Civil and Environmental Engineering (CEE), and more than 112 research staff, postdoctoral appointments, and visiting scholars.

EAPS is notable for emphasizing interdisciplinary problems. The Earth Resources Laboratory and recently formed 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 CEE, Chemistry, 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, 165 graduate students were registered in the department, including 73 students in the MIT–Woods Hole Oceanographic Institution Joint Program. Women constitute 38 percent of the graduate student population, and international students account for 31 percent.

The excellence of the EAPS graduate program is built not only on the strength of teaching and supervision by the faculty but also on the involvement of EAPS graduate students in the department's activities. Students develop formal and informal ways to improve their educational experience as well as their 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 are using their experiences in EAPS to make positive changes for the entire graduate student population. EAPS awards a prize for excellence in teaching to recognize the superior work done by teaching assistants in many of our classes. Last year, prizes were awarded to Nicholas Austin, Alexander Bradley, Einat Lev, Kyle Straub, and Christopher Studnicki-Gizbert for their service during the academic year.

## Undergraduate Program

Increasing the number of undergraduate majors in the department continues to be a priority. In AY04 the number of undergraduate majors increased by 95%. In AY06, the undergraduate major population increased to the highest level in more than 20 years. As we enter AY07, the new cohort of majors is slightly larger than the group of seniors who graduated in AY06. We view the AY04 increase in majors as a sustainable response to department efforts, and we are committed to continue building on this new level of undergraduate involvement. The rapid increase in the number of majors presents a welcome intellectual challenge. EAPS is reviewing the curricula for the four tracks within the major to ensure the relevance and rigor of each. 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 2006 Commencement, the Goetze Prize was awarded to graduating seniors Francesca DeMeo, Marion Dumas, and Solomon Hsiang. Ms. DeMeo was also elected to Phi Beta Kappa.

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 was named a MacVicar Faculty Fellow in recognition of his commitment to undergraduate education.

Professor Kerry Emanuel was selected to *Time* magazine's TIME 100 list of people who shape our world and was elected to deliver the Bernard Haurwitz Lecture at the American Meteorological Society's Annual Meeting in January 2007. He was also named to the Breene M. Kerr chair.

Professor Raffaele Ferrari was promoted to associate professor with tenure.

Professor Frederick Frey received the Distinguished Alumni Award in the Department of Geology and Geophysics at the University of Wisconsin.

Professor Timothy Grove was elected president of the American Geophysical Union.

Professor James Hansen has accepted a position at the Naval Research Laboratory in Monterey, CA.

Professor David Mohrig has relocated to the Jackson School of Geosciences at the University of Texas.

Professor Richard Lindzen served as a National University Lecturer in Hokkaido, Japan, and was the first recipient of the Leo Prize of Sweden's Walin Foundation for independent achievements in science.

Professor Paola Malanotte-Rizzoli was elected a fellow of the American Geophysical Union.

Professor Peter Stone was named the Bernard Haurwitz Memorial Lecturer by the American Meteorological Society for pioneering contributions to the understanding of planetary general circulations and ocean-atmosphere feedbacks that operate on climate timescales. Professor Stone will retire effective July 1, 2006.

Professor Roger Summons was elected a fellow of the American Geophysical Union.

Professor M. Nafi Toksöz was named to the Schrock professorship and was honored with the Harry Fielding Reid Medal of the Seismological Society of America for outstanding contributions in seismology and earthquake engineering.

Professor Robert van der Hilst was named president elect of the Seismology Section of the American Geophysical Union.

Professor Benjamin Weiss was named to the Victor P. Starr career development chair.

Professor Carl Wunsch was selected to receive the 2006 William Bowie Medal of the American Geophysical Union.

Professor Maria Zuber was awarded Brown University's Horace Mann Medal, the highest award given to alumni of the graduate school.

## Research and Administrative Staff

Roberta Allard received the Dean's Unsung Hero Staff Recognition Award.

Dr. Michael Follows received the MIT Global Habitability Longevity Award, awarded for an outstanding contribution toward understanding long-term environmental trends affecting the Earth and its habitat for supporting life.

Dr. Christopher Hill was promoted to principal research engineer.

Dr. Lodovica Illari was promoted to senior lecturer and has led MIT's team in the National Collegiate Weather Forecasting Contest for their fifth consecutive win.

Dr. Vicki McKenna, education director, was awarded a MIT Excellence Award in the Unsung Hero category, representing one of the highest recognitions of MIT staff.

## Current Research

Professor Richard Binzel is a science team coinvestigator for the New Horizons mission to Pluto that successfully launched from Cape Canaveral, FL, on January 19, 2006. He

continues to observe near-Earth asteroids with a NASA telescope in Hawaii operated remotely from the MIT campus. Research results include finding evidence that up to 20 percent of all "asteroids" near the Earth may in fact be dormant or extinct comets.

Professor James Elliot, his students, and research scientists successfully observed a stellar occultation by Charon, in collaboration with colleagues at Williams College. They established a stringent upper limit on a possible atmosphere and accurately determined the radius, from which they derived a density consistent with a collisional formation of the Pluto–Charon binary.

Professor Kerry Emanuel's efforts focused almost exclusively on the effects of climate change on hurricane activity. He published a paper in *Nature* in August 2005 showing that hurricanes are already responding to global warming by becoming more intense and lasting longer. Subsequent work analyzing observed hurricanes and running advanced numerical models supports these conclusions. His group also made major progress in developing advanced techniques for hurricane risk assessment, including the effects of past and projected climate change.

Professor Raffaele Ferrari and his group are studying the processes that control the heat transport of the global ocean and their impact on Earth's climate. They showed that most heat transport is associated with wind-driven circulations in the upper kilometer of the world's oceans. This finding is in contrast to a large literature that emphasizes the role of abyssal circulations, implying that the ocean's role in climate and climate change is associated more with shifts in wind patterns at midlatitudes and less with cooling and warming at high latitudes.

Professor Fred Frey's current research focuses on the largest terrestrial volcanoes, which exist in midocean settings distant from the volcanism associated with plate boundaries. Recent Hawaiian volcanoes form two parallel trends; Frey and colleagues are determining geochemical characteristics of the lavas from these trends to obtain spatial and temporal constraints on the Hawaiian hot spot magma source.

Professor Thomas Herring is using 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 and regional scales. He is also using satellite-based laser altimetry to study earth and ice sheet height changes.

Professor Richard Lindzen and his research group are working to improve techniques for using geostationary satellite data to measure rainfall and to determine cumulus mass flux, which is important in its own right, and for assessing climate feedbacks. In addition, work has been done in collaboration with Maria Zuber and her group to show that atmospheric tides on Mars are incapable of accounting for the needed tidal dissipation and that the dissipation therefore must come from the solid planet.

Professor Ronald G. Prinn and Dr. Yu-Han Chen have used global observations, an atmospheric circulation model, and statistical inverse methods to estimate 1996–2001 emissions, by month, of methane, an important greenhouse gas. They concluded that

energy-related emissions are smaller and rice paddy and biomass burning emissions are larger than previously thought. They also attributed the unusually large 1998 global increase in methane largely to enhanced global wetland emissions in that very warm El Niño year.

Professor Paola Malanotte-Rizzoli continues to 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's recent research has centered on understanding Earth's carbon cycle. In an attempt to explain patterns in marine respiration, Rothman and his group discovered a general mechanism that leads to a slow logarithmic decay of organic matter. These findings should lead to a new understanding of the short-term controls on atmospheric $CO_2$ levels and the long-term increase in atmospheric oxygen.

Professor Sang-Heon Dan Shim and his group are studying the texture of newly discovered phase, "post-perovskite," stable at the lowermost mantle—i.e., a depth of 2,500–3,000 km from the surface of the Earth. They showed that texturing of the post-perovskite changes with stress conditions and temperature, which has significant implications for interpreting seismic observations.

Professor Peter Stone and colleagues published their latest analysis for how temperature changes constrain major uncertain climate parameters. For the first time, they were able to get a strong constraint on how rapidly heat is being mixed into the deep oceans. The result shows that current state-of-the art climate models are overestimating the rapidity of this mixing and therefore are underestimating how much warming will occur over the next century.

Professor Roger Summons' laboratory is addressing biogeochemical aspects of the major transitions in Earth's history. They have studied the environmental conditions associated with the biotic extinction at the end of the Devonian era and found that hydrogen sulfide was a possible causative agent. This finding is consistent with results for the Permian-Triassic extinction and suggests that at least some of these events have a common cause.

Professor M. Nafi Toksöz and his research group have developed a method to determine focal depths of regional earthquakes. Among the earthquake hypocentral parameters, the depth of focus is most prone to error because of the tradeoff between the depth and origin time. The new method, based on time-reversed acoustic concepts, back-propagates the seismic waves to the source.

Professor Carl Wunsch and colleagues are combining global measurements of the ocean from a 15-year period, with ocean meteorological estimates, and a numerical general circulation model. The result is the best existing estimate of the ocean circulation from 1992 to 2004 and permits them to calculate societally important quantities such as trends in the North Atlantic circulation, the global rise in sea level, and many other phenomena.

Professor Maria Zuber leads the Radio Science Gravity on the Mars Reconnaissance Orbiter that arrived at Mars in March 2006. She was also named team lead of a laser ranging experiment to improve orbit determination on the Lunar Reconnaissance Orbiter to be launched in 2008.

**Maria T. Zuber**
**Department Head**
**Earle Griswold Professor of Geophysics and Planetary Science**

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