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. The department 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 currently comprises 39 faculty, including two with primary appointments in Civil and Environmental Engineering, and over 109 research staff, postdoctoral appointments, and visiting scholars.

EAPS is notable for emphasis on interdisciplinary problems. The Earth Resources Laboratory brings 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, and EAPS, the Environmental Science Initiative fosters collaboration in both 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 this past academic year, 147 graduate students were registered in the department, including 61 students in the MIT/Woods Hole Oceanographic Institution Joint Program. Women constitute 42% of the graduate student population, and 33% of the graduate population is composed of international students.

The EAPS graduate student mentoring program, developed in AY2003, resulted in an improved experience for first- and second-year graduate students. Student involvement has also contributed to an expansion and strengthening of the orientation program for new graduate students. The department now includes a student representative to the Graduate Education Committee. EAPS awards a prize for excellence in teaching to recognize the excellent work done by teaching assistants in many of our classes. In AY2004, prizes were awarded to Susan Kern and Maureen Long for their service during the fall term and to Michael Person, Arnico Panday, and Joel Johnson for their service during the spring term.

Undergraduate Program

EAPS presents the undergraduate student body with opportunities to become acquainted with the world from an earth sciences perspective. The department remains committed to creating a strong presence in the undergraduate program at MIT. In prior years this has expressed itself in the many UROP projects supervised by EAPS faculty, by participation in freshman advising seminars, and through department sponsorship of a weekly undergraduate seminar. The overwhelming majority of students in these programs have not been EAPS majors.

Over the past three years, EAPS made it a priority to increase the number of undergraduate majors in the department. This past year EAPS added an environmental science option to the existing options of geoscience, physics of atmospheres and oceans, and planetary science and astronomy. The new track integrates science and policy and meets the needs of students who wish to investigate environmental problems on large space or long time scales. Efforts have resulted in an increase of almost 100 percent in the number of EAPS majors over this past year, from 18 to 35.

At the 2004 Commencement, EAPS awarded the Goetze Prize for Undergraduate Research to graduating seniors Leah Hutchison and Katharine Ricke. Jessica Haurin, a senior in EAPS, was elected to Phi Beta Kappa.

Faculty

—Professor Brian Evans was elected a fellow of the American Geophysical Union.

—Professor Raffaele Ferrari was awarded the Victor P. Starr career development chair.

—Professor David Mohrig was awarded the Cecil and Ida Green career development chair.

—Professor Paola Malanotte-Rizzoli serves as a member of the Faculty Advisory Committee in the search for the 16th MIT president.

—Professor Stéphane Rondenay was awarded the Kerr-McGee career development chair.

—Professor Rob van der Hilst was appointed director of the Earth Resources Laboratory.

—Professor Kelin Whipple will be promoted to full professor with tenure on July 1, 2004.

—Professor Maria Zuber was elected to membership in the National Academy of Sciences and was named a fellow of the American Academy of Arts and Sciences.

Zuber also served as a member of the President's Commission on Implementation of US Space Exploration Policy.

Current Research

Professor Samuel Bowring's research group is working on two major themes: the origin and evolution of continental lithosphere and using high-precision geochronology to sequence the history of life. As part of Bowring's long-term interest in sequencing the history of life on this planet, he has proposed a major new initiative entitled EarthTime, which will create a virtual network of geochronology labs that will sequence Earth's history at better than 0.1 percent.

Professor Ed Boyle and his group have been tracing the anthropogenic lead (Pb) transient in the ocean and in corals and sediments. They have found that there is a distinctive pattern of evolution of Pb isotope inputs to the northeastern United States due to the early (1840s) contribution from upper Mississippi Valley ore deposits, so that Pb isotope patterns can be used to "date" sediments and deep ocean waters. In addition, Boyle has participated in an NSF "Biocomplexity" project that is exploring the relationship between Fe and nitrogen fixation in the ocean.

Professor Clark Burchfiel's main research effort continues from 24 years of work in China and focuses on the tectonic evolution of the eastern part of the Tibetan Plateau and regions to the southeast into Indochina. A second area of research has been in the Balkan region of southern Europe, where the Cenozoic history of extensional tectonism has yielded a complex evolution.

Professor Jim Elliot and his colleagues have found that the pressure of Pluto's tenuous nitrogen atmosphere has increased by a factor of 2 since 1988 and that extinction by hazes or clouds pervades the atmosphere. The cause of the pressure increase could be seasonal or climatic changes on Pluto's surface. In analyses of their 2002 stellar occultation data, they found wavelike structures in Pluto's atmosphere and also found that Pluto's atmosphere has a nonspherical shape, likely indicative of high winds.

Professor Kerry Emanuel began AY2004 by flying on a NOAA WP-3D reconnaissance aircraft into Hurricane Fabian to obtain high-density data in the eyewalls of hurricanes. Along with estimating air-sea fluxes of enthalpy and momentum under conditions of very high surface wind, they set a new record for dropwindsonde spatial density and for the amount of time any airplane has spent in the eye of a hurricane. They have also begun work on the problem of hurricane wind risk assessment.

Professor Brian Evans and coworkers are working to understand the evolution of transport properties, including permeability and electrical resistivity, and of mechanical properties, including brittle fracture strength and plastic flow strength. One important result that has emerged is that pore structures may be altered quite rapidly, geologically speaking.

Professor Raffaele Ferrari's research efforts are directed at some of the major issues in the understanding of ocean dynamics: the ocean's circulation and role in the Earth's climatic system. His approach involves observations, theory, and modeling. He works at sea, constructing theories and using numerical models where necessary. Much of the work falls into several broad, overlapping areas.

Professor Frederick Frey was a Joint Oceanographic Institution distinguished lecturer, presenting a talk entitled "Formation of the Kerguelen Large Igneous Province, Gondwana Breakup, Lost Continents and Growth of the Indian Ocean" at 10 universities and colleges.

Professor John Grotzinger was a Science Team member for the Athena Mars Exploration Rover Mission. His work contributed to showing that rocks at the Meridiani Planum landing site were formed by precipitation from acidic brines, and precipitated sediment particles were transported in the presence of flowing water. Professor Grotzinger and students and postdocs are also continuing their studies of biogeochemical events at the Precambrian-Cambrian boundary in Oman and Namibia.

Professor Tim Grove's studies of komatiites from southern Africa have shown that Earth's mantle was only 150 to 250^{o} C hotter 3.5 billion years ago than today. Their work also shows that the melting process that gave rise to komatiites is most likely analogous to the processes that occur in subduction zone environments.

Professor Jim Hansen is exploring the impact of model inadequacy and nonlinearity on state estimation, ensemble construction, and probabilistic forecasting. He is developing a laboratory analog of atmospheric/oceanic flow for both research and education purposes.

Professor Thomas Herring and his group are using high-precision Global Positioning System (GPS) measurements to study tectonic deformation over much of the southern Eurasian plate boundary, southern New Zealand, and the western United States. The group is also involved in monitoring and modeling human-induced deformations in oil fields.

Professor Ronald G. Prinn and his students estimated month-by-month methane emissions and defined seasonal cycles in wetland, rice paddy, and biomass burning sources to conclude that rice emissions exceed—and energy-related emissions are less than—previous estimates. They also studied the effects of widespread dimethyl sulfide emissions from oceanic phytoplankton on the production of cloud condensation nuclei and demonstrated the need for major additional chemical pathways to explain observations.

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

Professor Stéphane Rondenay's group is involved in two key areas of solid-earth seismology: the acquisition of high-quality data sets from seismic arrays and the development and application of new teleseismic approaches to image structure in the Earth's crust and mantle. His principal recent work is seismic imaging of the upper mantle beneath a craton in northern Canada.

Professor Daniel Rothman and his colleagues have shown how major changes in the carbon cycle may have precipitated the "Cambrian explosion" of early animal life. In separate work, Rothman and colleagues developed a model of seepage erosion that may explain the morphology of features cited as evidence for recent liquid water on Mars.

Professor Julian Sachs is discovering episodes of abrupt climate change in the recent geological past. A new effort is aimed at using the hydrogen isotopic ratio of algal lipids preserved in ocean and lake sediments to evaluate past changes in the balance between precipitation and evaporation.

Professor Sang-Heon Dan Shim and his collaborators showed that the unexplained seismic change observed at the mantle and core boundary may be due to a phase transition in the dominant lower mantle mineral. He also published his experimental results on Cr_2O_3 in which he found new phase transitions at high pressure and high temperature.

Professor Roger Summons and his group are studying intact polar lipids of marine cyanobacteria and a range of microbes from culture collections and extreme environments such as Yellowstone National Park and the Lost City hydrothermal vents of the Mid-Atlantic Ridge. They are also studying the dynamics of the carbon cycle during major redox transitions of the ocean-atmosphere system, with emphasis on analysis of sediments from Oman deposited during the radiation of the first animals.

Professor Rob van der Hilst and his coworkers analyzed broadband seismic observations to reveal variations in mantle temperature and bulk composition below 1,000 km depth under the northern Pacific and the Americas. With a technique adapted from application in the oil industry, they also began an ambitious effort to image in unprecedented detail the Earth's core mantle boundary. Van der Hilst also led a seismological field campaign in southwest China to image mantle structure and understand regional tectonics and seismicity.

Professor Kelin Whipple and his group showed that the details of the erosion processes are critically important to the strength and nature of the dynamic coupling between climate-driven erosion and tectonics, controlling the sensitivity of mountain-belt width, topographic relief, and rock uplift rate to climatic and tectonic variables. His work clarified how climate and tectonics combine to exert a fundamental control on particle paths through the crust.

Professor Carl Wunsch and his group are increasingly employing the knowledge and tools of physical oceanography to understanding the record of past climate change. This work involves a combination of modeling, time series analysis, and theory. They are reexamining many of the basic hypotheses commonly used to explain climate variability, including the Milankovitch hypothesis and the spatial structures of changes.

Professor Maria Zuber and colleagues completed development of a laser ranging device to be launched in the probe to Mercury. She assisted the Mars Exploration Rover team at the Jet Propulsion Laboratory in the assessment of landing sites and in risk mitigation in the landings. Her group also developed a new model of the crustal structure of Mars and developed a theoretical formalism to explain a dipole magnetic signature in a planetary crust in the context of remanent magnetization.

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