



# **Geosciences Research Plan**

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# **1. About the College of Geosciences**

The College of Geosciences at Texas A&M University is one of the world's preeminent comprehensive university geosciences programs. The focus of the College is on the physical, biological and human systems of our planet and the ways in which they interact. We investigate the forces which shape the past, present and future of the solid earth, the oceans, the atmosphere, the biosphere and human cultures and societies. We work with society to develop, sustain and enhance our planet's resources within the bounds of responsible environmental stewardship. We address the needs of the people of Texas, the nation, and the world in rising to the challenge posed by a changing global environment.

Formally established in 1964 and opened in 1965, the College of Geosciences initially was home to three academic departments: Oceanography, Meteorology, and Geology & Geophysics. In 1969, Geography, which was formerly part of Geology, became a separate department. Texas A&M University was designated a Sea Grant College in 1971, and the Texas Sea Grant College Program was placed under the auspices of Geosciences. In 1981, the Geochemical and Environmental Research Group (GERG) was established in the College, and in 1985, when Texas A&M University was awarded a National Science Foundation contract to be the science operator for the Ocean Drilling Program (ODP), it was added to the College of Geosciences. ODP became the Integrated Ocean Drilling Program (IODP) when the contract was renewed in 2003.

Today, the College is comprised of its four academic departments – Geography, Oceanography, Atmospheric Sciences, and Geology & Geophysics – and three research centers – GERG, IODP and Texas Sea Grant. The College also administers two interdisciplinary programs – the Environmental Programs in Geosciences and the Water Degree Program. Its broad mix of basic and applied research and academics allows the College to provide its students an excellent undergraduate education and premier graduate experiences. As of Fall 2008, the College had a total of 836 students enrolled, with 526 of those in undergraduate programs and 310 in graduate programs. The College has 109 tenure or tenure-track faculty, 4 research faculty, 24 research scientists, 133 research staff, 14 post-doctoral fellows, and 61 administrative staff.

## **2. Scope and Process for the College of Geosciences**

### **Research Plan**

This College of Geosciences Research Plan is intended to describe existing College strengths and new College research initiatives. The focus of this plan is on strengths and initiatives that involve two or more units within the College of Geosciences. There are many outstanding research activities and initiatives housed entirely within individual departments; due to time and space limitations, those activities and initiatives will not be discussed here. Interested readers are encouraged to contact individual College units for more information regarding these unit-specific endeavors.

This Plan is also not intended to describe all College strengths or all potential research initiatives. In the area of existing strengths, this Plan limits itself to describing four areas of technological expertise (Section 3) and five existing research themes (Section 4). For future initiatives, the Plan describes four initiatives that would involve broad participation from across the College. These involve climate change in Texas and the Tropics, science education, health effects of human impacts on the local environment, and the challenge of obtaining adequate supplies of energy and water during the next century. Other research initiatives exist, and new ones will emerge in coming years, but the College of Geosciences selects these five to emphasize in its College-wide planning for the next decade.

The preparation of this Plan began with a call to faculty and research scientists in the College to suggest major research themes for the College for the next decade. The nineteen ideas that resulted were presented and discussed in a College-wide meeting on October 3, 2008. At that meeting, several ideas were consolidated and merged into five coherent initiatives. Faculty then met informally to flesh out these initiatives.

To oversee the process of converting themes into a plan, the College Research Plan Oversight Committee was formed. This committee consists of the Dean, the Associate Deans, the Department Heads, the Unit Directors, the members of the Geosciences Faculty Advisory Committee (GFAC), a representative of the Geosciences External Advisory Committee, and a graduate student representative.

The Oversight Committee met on October 31, 2008, and endorsed the four research initiatives. The Oversight Committee also approved the overall organization of the Research Plan document, and discussed which College-wide research strengths deserved highlighting in the Plan. The Oversight Committee settled on the strengths described in Sections 3 and 4 below, and identified faculty members to serve as authors.

In support of the drafting process, a College web site was created for news and information. Drafts were posted as they became available, and faculty, research scientists, and students were encouraged to review the drafts and submit comments to the authors. Various connecting sections were contributed by persons in the Dean's Office.

A second Oversight Committee meeting took place on November 26, 2008. The Oversight Committee conducted a final review of the drafts, and the Executive Associate Dean incorporated the suggestions and applied a consistent style and formatting. The final version was posted the morning of December 1, 2008 for last-minute corrections prior to submittal to the Provost.

The following is a partial list of those who contributed ideas or text to the College of Geosciences Research Plan:

Jack Baldauf	Bruce Herbert	Heath Mills
Robert Bednarz	William Heyman	John Nielsen-Gammon
Sarah Bednarz	Chris Houser	Steven Quiring
Steve Bohlen	Luc Ikelle	Ramalingam Saravanan
Ping Chang	Mahlon Kennicutt	Gunnar Schade
Don Collins	John Kessler	Jonathan Smith
Steven DiMarco	Andrew Klein	Robert Stewart
Benjamin Giese	Robert Korty	Michael Tice
Ethan Grossman	Mitch Lyle	Carol Trono
Norman Guinasso	Andrew Millington	Renyi Zhang

The following are the members of the College of Geosciences Research Plan Oversight Committee:

Steve Bohlen	Norman Guinasso	Steven Quiring
Ken Bowman	Andrew Klein	Crystal Reed
Sarah Brooks	Andreas Kronenberg	Les Shephard
Piers Chapman	Mitch Lyle	Douglas Sherman
Don Collins	Franco Marcantonio	Robert Stickney
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Technical assistance was provided by:

Diane Barron	John Nielsen-Gammon	Constance Toon
Tim Copple	Jennifer Rumford	Carol Trono

### **3. Areas of Technological Expertise**

Advances in knowledge often involve using scientific or conceptual breakthroughs to observe and understand the physical, biological, and social world in new and unexpected ways. The College of Geosciences has developed and implemented a variety of new technologies that make new discoveries possible. In some cases, the College of Geosciences is a worldwide leader because of the sophistication of the technologies it has developed and deployed; in other cases it is a leader because of the uniquely comprehensive ways that technologies are applied to understand all facets of the physical environment and our role in it. Five such areas of technological expertise are highlighted here.

#### ***3a. Ocean Drilling***

*Research Geonugget: Most present-day volcanic rock-building occurs along spreading ocean ridges. Yet the Earth's surface and seafloor include miles-thick deposits of volcanic basalts that do not lie along mid-ocean ridges. What caused the massive volcanic eruptions that formed them? The conventional explanation has them being produced by a plume of hot magma that originates deep in the Earth's mantle and penetrates the surface in a cataclysm of volcanic activity. However, no such deposits studied to date seem to fit the mantle plume hypothesis very well. Oceanography's William Sager will be scientific co-leader on a cruise to extract six 1000 m long cores from the Shatsky Rise, a plateau beneath the Pacific Ocean east of Japan. Because the Shatsky Rise formed during a time when the Earth's magnetic field reversed polarity, the sequence of its formation and the actual roles of mantle plume rise and oceanic spreading in creating this and other such massive volcanic deposits may become clear for the first time.*

The College of Geosciences manages the US scientific drilling vessel *D/V JOIDES Resolution* for the Integrated Ocean Drilling Program (IODP), a 23-nation international scientific consortium whose focus is to better understand natural processes active on this planet. From 1983 to 2003 TAMU College of Geosciences also managed the *D/V JOIDES Resolution* for the Ocean Drilling Program, the predecessor to IODP. The *JOIDES Resolution's* scientific capability is used to study an array of fundamental earth science problems, including plate tectonics and the genesis of earthquakes, the construction of continental margins, reconstruction of past earth conditions to understand earth's climate processes, and the structure of the deep biosphere. There are 121 IODP staff members on campus that operate the drilling vessel, implement the scientific expeditions, oversee science laboratories, complete technological development, manage core repositories, produce scientific publications, and perform educational outreach.

Not only has the College of Geosciences received large contracts for operations and management of the drillship (\$55M dollars for FY2009), but faculty and students leverage significant additional NSF funding for participation in drilling expeditions and post-cruise science. The College of Geosciences is the host of the Gulf Coast Repository (GCR), one of three IODP geologic 'libraries' worldwide. The GCR archives more than 100 km of marine rock and

sediment cores for scientific study, and stores much of the data that has been collected on the core material.

Over the last 4 years, TAMU has hired 11 new faculty members in 3 colleges to be part of the Ocean Drilling and Sustainable Earth Sciences (ODASES) program to create and strengthen linkages between research, education, and technology in ocean drilling science within Texas A&M University. The new faculty hires will take research and education related to ocean drilling in new and interesting directions, even as IODP itself expands its reach to encompass a mixture of basic and applied scientific ocean drilling. Current faculty and research scientists include Mitch Lyle, Jack Baldauf, Heath Mills, Annette Olivarez Lyle, William Sager, Matthew Schmidt, and Debbie Thomas (Oceanography), Ethan Grossman and Bridget Wade (Geology and Geophysics), Robert Korty (Atmospheric Sciences), Brendan Roark (Geography), Steve Bohlen, Ann Klaus, Mitch Malone, Adam Klaus, Carlos Alvarez-Zarikian, Kusali Gamage, Jörg Geldmacher, Jay Miller, John Firth, Peter Blum, and Katerina Petronotis (IODP), and from outside the College of Geosciences, Gioia Falcone and Catalin Teodoriu (Petroleum Engineering) and Scott Slough and Bugrahan Yalvac (Teaching, Learning, and Culture).

### ***3b. Geospatial Technologies***

*Research Geonugget: Floods are a product of weather systems and the basin in which the rain falls, and coastal floods are also affected by sea level changes. If floods become more frequent or more severe, is it because the weather is changing, because the basin is changing, or because the height of land and ocean are changing? Honxing Liu and Inci Gunaralp of the Department of Geography are working to understand and predict flood hazards in a coastal watershed in Texas. The research incorporates airborne LIDAR data, time series satellite imagery (Landsat and IKONOS), and NEXRAD rainfall data to examine the complex interrelationships between the climate, topography, hydrology, and land use/cover and simulated stream run-off, and flood extent and magnitudes. An integrated hydrological and hydraulic model is employed to simulate and evaluate the impacts of human-induced land cover changes, construction of detention basins, land subsidence, and global climate changes on the magnitude and frequency of flood hazards.*

Research in the Geosciences inherently encompasses a spatial dimension. Over the past several decades, the emergence of Geographic Information Systems (GIS) and Science (GISci), advances in Remote Sensing, and the creation of the Global Positioning System (GPS) have markedly increased our ability to employ geospatial technologies in studying the Earth and other planets. The growing importance of geospatial technology was highlighted in 2004, when the US Department of Labor identified geotechnologies, along with nanotech and biotech, as one of the most important emerging and evolving technology fields (Gewin, 2004, doi:10.1038/nj6972-376a).

Geospatial technologies underpin many facets of ongoing research throughout all divisions of the College of Geosciences. Its use within the College is diffuse and ranges from faculty involved in sophisticated algorithm development to those employing GIS as a mapping tool. In many instances, our graduate students' abilities to synthesize geospatial information in many forms

will be a key to their success both in their academic research but also are a key skill for their future employment.

The College's research strengths in the geospatial technologies are dispersed among its academic units and these geospatial technologies are applied to many different research problems. Within Atmospheric Sciences faculty focus on retrieval of cloud optical properties (Ping Yang, Shiama Nasiri) as well as studies of the basic scattering and absorption properties of atmospheric particles that are fundamental in retrieving cloud and aerosols properties from satellites. Researchers continue the department's long history of work with passive microwave remote sensing both from an algorithm development standpoint (Thomas Wilheit) as well as the use of data from the TRMM satellite to study storm structure in the tropics (Courtney Schumacher). Dr. Mark Lemmon is actively involved in remote sensing on Mars and other planets and is operating the Mars Spirit and Opportunity rovers as well as several future missions.

Geospatial research in Geography focuses on the development and validation of remote sensing and GIS algorithms for studying the Earth's cryosphere (Andrew Klein, Hongxing Liu) as well as its coastal and urban environments (Hongxing Liu, Antony Filippi). Geospatial technologies are also being applied in the study of land use/land cover change in Latin America (Andrew Millington, Christian Brannstrom, Wendy Jepson). Geography researchers are also studying the societal impact of these technologies (Daniel Sui) and on the ways in which they support the development of spatial thinking (Robert and Sarah Bednarz).

In addition, researchers in Geology and Oceanography employ a variety of allied geophysical remote sensing tools to study the ocean floor, the Earth's near surface environments and its earth's interior.

### ***3c. Environmental Chemistry and Geochemistry***

*Research Geonugget: Aerosols are tiny particles of liquid or solid matter suspended in the atmosphere. Fine particles, those about a hundredth the width of a human hair, can penetrate deep inside the lungs and lodge there. Many of them include hydrocarbon compounds, but how do they get there? Renyi Zhang and colleagues have discovered, through laboratory experiments and theoretical analysis, that some aromatic organic compounds bind with sulfuric acid, forming a stable nucleus that can merge with similar molecules and form nanometer-scale droplets. The resulting aerosol particles have essentially formed out of thin air. Thus the burning of fossil fuels, which produces carbon dioxide and can lead to ozone formation, also produces harmful aerosols that contain aromatic compounds and sulfuric acid and deposit them into human lungs.*

Within the College of Geosciences there is a broad array of research activities that involve the study of the chemical makeup of the atmosphere and atmospheric pollution, the chemical

makeup of the ocean and oceanic pollution, the chemical records left in rocks and sediments and what they tell about the history of the Earth, and the interaction between chemistry and life on this planet. These activities cut across conventional departmental boundaries, and several interdisciplinary laboratories and centers have been established to facilitate collaboration.

Research activities in atmospheric chemistry in the Department of Atmospheric Sciences include investigation of formation and transformation of gaseous and particulate matter (PM) pollutants (Sarah Brooks), aerosol-cloud-climate interaction (Sarah Brooks, Don Collins, Renyi Zhang), agricultural and urban air quality (Sarah Brooks, Don Collins, Gunnar Schade, Renyi Zhang), air pollution meteorology (John Nielsen-Gammon), upper troposphere/lower stratosphere chemistry and dynamics (Kenneth Bowman), and urban boundary layer meteorology (Gunnar Schade, John Nielsen-Gammon). Research projects vary from laboratory experiments, field measurements, and numerical simulations. Several state-of-art instruments and laboratories in atmospheric chemistry research have been developed.

Environmental and Isotope Geochemistry in the Department of Geology & Geophysics encompasses the study of Earth's current environment, its past environments, and its chemical and isotopic make-up and geochronology. Research projects vary from studies of hypoxia in Texas coastal waters to studies of anoxia in Earth's early atmosphere. The program boasts five new faculty members and three new laboratories. The centerpiece of our facilities is the \$3M Williams Radiogenic Isotope Geosciences Laboratory with its clean labs, new thermal ionization mass spectrometer (TIMS), and new high resolution ICP mass spectrometer (HR-ICPMS). Additional facilities include a stable isotope ratio mass spectrometer for with peripherals for H, C, N, O, and S isotopic analyses of carbonates, waters, and organic matter, an X-ray analytical microscope capable of mapping elemental distributions from Na to U on over several square centimeters at 0.1 mm resolution, and a gas chromatography-tandem mass spectrometer for analysis of trace organic biomarkers. General areas of investigation include biogeochemistry (Bruce Herbert), climate change (Ethan Grossman and Bridget Wade), environmental geology (Bruce Herbert), geobiology (Mike Tice), geochronology (Brent Miller), micropaleontology (Bridget Wade), paleoceanography (Debbie Thomas), radiogenic isotopic geochemistry (Franco Marcantonio), and stable isotope geochemistry (Ethan Grossman).

Research activities in chemical oceanography in the Department of Oceanography spans air-sea exchange, chemistry within the oceanic biosphere, and the chemical record beneath the sea. Specific research includes global oceanic uptake and emission of climatically important trace species (Shari Yvon-Lewis), kinetic behavior of sediments and sedimentary rocks with particular emphasis on carbonate and sulfide minerals (John Morse), use of organic matter as a tracer for environmental processes (Rainer Amon), the carbon cycle within coastal and estuary waters (Tom Bianchi), and the global carbon and nitrogen cycles and their interaction with climate (John Kessler, Daniel Thornton).

### ***3d. Environmental Observations, Assimilation, and Modeling***

*Research Geonugget: There is a growing need to document and explain recent changes in Earth's climate. To do this requires accurate depictions of the state of the oceans provided by*

*observations or computer models. Data assimilation brings together these two emerging and rapidly developing areas: ocean reanalyses use a global ocean model in conjunction with ocean observation to provide the most realistic estimate possible of the state of the oceans. Benjamin Giese, in the Department of Oceanography, is preparing to conduct the first global ocean estimate for the entire 20th Century using the SODA (Simple Ocean Data Assimilation) software that he has developed. Results from this research will be used to identify climate change over the past 100 years, to distinguish between anthropogenic and natural climate variability, and to provide a starting point for prediction of climate change in the future. The reanalysis will provide the first detailed description of the unusual El Niño of 1918 and will be used to identify possible causes of the Dust Bowl drought and the rapid climate change that took place in the mid-1970s. The results will also be made available to other researchers who need accurate estimates of the ocean state to initialize climate prediction models.*

One very important application of the geosciences is the prediction of the future state of the Earth, ocean, and atmosphere, and the resulting impacts upon humanity and the biosphere. Can we distinguish changes that occur because of human activity from changes that arise naturally from within the climate system? Can altering our behavior mitigate the effects of human activity? Can environmental change patterns be predicted? And how could we use the knowledge of those predictions in a manner that benefits the environment and its fragile ecosystems? Addressing these issues represents a tremendous research and educational challenge, and begins with a solid understanding and documentation of the environmental changes that have already occurred. This requires the ability to detect and observe the current state of the Earth, the ability to integrate these observations into a coherent and consistent portrait of the entire system, and the ability to use knowledge of the current state to accurately predict the future state and to understand how the current state arose. These three abilities fall under the categories of observations, assimilation, and modeling. The College of Geosciences has comprehensive expertise in each of these three areas.

The College of Geosciences designs, deploys, and maintains a broad range of environmental observational systems and networks. These systems have been deployed terrestrially, coastally, and in the deep ocean across the globe from the tropics to polar regions as part of local, regional, national, and international initiatives. Observations are reported in real-time, in near real-time, or are internally recorded for later download and processing.

Local facilities include the Yellow Cab Tower observing site for urban air quality investigations and the Center for Atmospheric Chemistry and the Environment (CACE) Trailer for mobile air quality measurements within and outside of Texas. Several investigators have been involved in monitoring atmospheric chemistry and air quality of Houston, Texas using specially-designed instrumentation. The Total Lightning Mapping Array was deployed by College researchers in Houston, Texas, to study the impact of air pollution and coastal winds on lightning and precipitation.

Regionally, the Texas Automated Buoy System (TABS) has operated continuously since 1995 to provide real-time oceanographic data used in oil spill response and mitigation. Instrumentation to continuously monitor rain drop-size and S-band radar are currently deployed regionally to

study the evolution of convective systems and storm microphysics. Also, Texas A&M University is one of four host institutions for the NOAA mobile units known as the Shared Mobile Atmospheric Research and Teaching Radar Facility (SMART-R).

International programs such as CLIVAR, the Global Earth Observation System of Systems (GEOSS), Global Climate Observing System (GCOS), and Global Ocean Observing System (GOOS) have international mandates to provide long-term, integrated, observations to improve predictions of climate change and its effects, minimize public health risks, sustain living resources, and protect and restore healthy ecosystems. The College is host to the Regional Office of the Gulf Coast Ocean Observing System, which is one of twelve Regional Associations that constitutes the U.S. Integrated Ocean Observing System, the U.S. contribution to GOOS. Several researchers of the College have been active in these global initiatives by participating in repeated and long-term observational programs particularly in the Southern Ocean, the Gulf of Oman, the Congo Canyon (Africa), and the Flower Garden Banks National Marine Sanctuary (Gulf of Mexico).

Recent research activities in the Department of Oceanography include observing ocean climate change in the Antarctic environment. This initiative started with the collaborative international (U.S.-Italy) AnSlope-CLIMA program (Orsi) in the northwestern Ross Sea, with multi-year records of current and properties measured on an array of moored instruments under the sea-ice. This long-term observing effort continues in the Weddell-Scotia Seas as the Department (Orsi, Yvon-Lewis, Slowey) is leading ACROSS, an interdisciplinary U.S. program contributing to the International Polar Year in collaboration with scientists from Spain, Argentina, and Brazil. These programs represent basic building blocks to the coordinated Southern Ocean Observing System (SOOS) component of GOOS.

Real-time reporting systems measuring biochemical and physical properties of coastal Louisiana have been developed to monitor the area of low dissolved oxygen concentrations known popularly as the Deadzone and to detect harmful algal blooms. College investigators have deployed observing networks monitoring coastal erosion processes in the Gulf of Mexico and the Caribbean Sea. Texas A&M University at Galveston houses marine facilities and research vessels, which College investigators use for analysis and collection of marine and estuarine samples.

Taking advantage of recent trends in global and national initiatives, the College is host to the crosscutting, interdisciplinary graduate-level Certificate in Ocean Observing Systems, which requires coursework from existing College programs in climate change, GIS, and operational and applied oceanography. The environmental observational programs have many obvious connections to current and planned College research foci.

A diverse, multi-disciplinary group of scientists (David Cairns, George Jackson, Charles Lafon, Steven Quiring) uses models to understand ecosystem dynamics in environmental systems. These efforts seek to understand issues such as how physical and chemical processes affect biological interactions in the oceans, predator-prey relationships, the temporal and spatial dynamics of forests, and a study of crop growth and its relationship to drought. There is also an

ongoing study of the transition zones between major vegetation types, with studies that focus on the treeline in northern Sweden, shrub expansion in the Alaskan Arctic, and salt marsh vegetation in Texas. These studies are relevant to pressing global issues such as carbon flux into the ocean, drought cycles, and ecosystem response to disturbances such as from fires, ice storms, and insect outbreaks.

The Department of Atmospheric Sciences has considerable expertise in the area of meso-scale atmospheric modeling (Craig Epifanio, Robert Korty, John Nielsen-Gammon, Lee Panetta, and Courtney Schumacher). Efforts include the use of models such as MM5, WRF, and CAM to understand problems such as storm development, the response to heating in the tropics, the waves that form in the lee of mountains, thermally driven flows such as the sea-breeze, and the development of turbulent flows on regional scales. There are also efforts to develop and analyze the numerical methods used in modeling which include an analysis of time-splitting methods and a method for imposing stress conditions on curved boundaries.

There is a focused effort (Rob Hetland, David Brooks) to understand the physics of coastal flows and their impact on the environment. These studies address issues such as the interaction between mixing and lateral buoyancy in strongly stratified systems and the coastal and near-shore circulation driven by tides, rivers, winds, and off-shore currents. These studies allow the examination of plankton bloom dynamics, the formation and destruction of continental shelf hypoxia, and the dispersion of larvae, harmful algae, and pollutants in the coastal environment.

An active effort to model surface and shallow subsurface land and hydrologic changes involves scientists from the Departments of Geology and Geophysics and of Geography (David Cairns, Mark Everett, Charles Lafon, Hongbin Zhan). This research involves near-surface applied geophysics, groundwater flow, surface water and groundwater interaction, the fate and transport of contaminants in the subsurface, and the simulation of crop growth. Model systems include crop growth models (e.g., Decision Support System for Agrotechnology Transfer), soil moisture models (e.g., Variable Infiltration Capacity, Climatic Water Balance), and models that make use of data collected from ground-penetrating radar, resistivity/IP, electromagnetic induction, seismic reflection and refraction, gravity and magnetics. The results are used to understand important environmental issues such as water use and management, the monitoring/predicting drought conditions, and an understanding of environmental processes and any natural or anthropogenic hazards that might pose a risk to the safety, health and well-being of society, infrastructure, or ecosystems.

Modeling the Earth's changing climate is performed by scientists in all departments of the College of Geosciences (David Cairns, Ping Chang, Andrew Dessler, Benjamin Giese, Robert Korty, Gerald North, Lee Panetta, Steven Quiring, Ramalingam Saravanan, Achim Stössel, Hongbin Zhan). As a result there is a broad range of models used to study climate change on scales that range from regional to global. Models used include energy balance models and low-dimensional models of water vapor and ozone; stand-alone models of the oceans, the atmosphere, and land; and coupled models that include interactions between the oceans, the atmosphere, the cryosphere, and land. A broad range of topics are explored using these models, including the impact of Antarctic sea-ice and convection on deep-ocean properties and

circulation, the behavior of planetary scale circulations across a wide range of climates, and how climate change impacts hurricane formation in the Atlantic Ocean. An especially important climate effort involves the development of coupled models that can be used for prediction of climate of the Atlantic basin, the prediction of drought conditions using crop and soil moisture models, and the prediction of how the spatial pattern and location of vegetation will change under changing climates.

Recent technological advances have dramatically changed the ways that humans observe and understand change in the earth's environment. Global environmental observing systems have grown rapidly through the development of satellite observations, autonomous sensors, and platforms from which the Earth's environmental state is recorded with unprecedented accuracy. Advances in computer technology has allowed models of environmental systems to be developed that have a fidelity of resolution that ranges from meters to global scales. Data assimilation represents the synthesis of these two emergent areas of research, with models that are constrained by observations. There are several data assimilation efforts that are underway or are planned in the College of Geosciences (Benjamin Giese, John Nielsen-Gammon, Istvan Szunyogh). These include studies of meteorological data assimilation using the Ensemble Kalman Filter, including some of the first attempts at parameter estimation in a meteorological context and an effort to create an ocean reanalysis for the 20th Century. The results show that chemical observations can be used to improve a meteorological analysis and that important forms of climate variability reside in the oceans on decadal timescales.

At shorter timescales, geomorphologists in the Department of Geography are concerned with modeling surficial processes as agents of landform change. Chris Houser and Doug Sherman measure and model beach and nearshore change as driven by sediment transport processes. They are also interested in understanding the physical mechanisms of sand transport in aeolian and coastal environments, as elucidated through field experimentation. Inci Guneralp is concerned with the modeling and prediction of river channel morphologies, especially those associated with meandering.

## **4. Prominent Research Themes**

The technological expertise in the College of Geosciences outlined in the previous chapter are brought to bear on a wide range of problems relating to the Earth and its oceans and atmosphere. Here we highlight five research themes that are particularly prominent within the College and which set it apart nationally and internationally.

### ***4a. Climate Research from Deep to Future Time***

*Research Geonugget: Hurricane winds cause considerable damage to infrastructure in the United States. For example, Hurricane Andrew led to total insured losses of approximately \$22 billion, the insured losses during Hurricane Katrina were approximately \$60 billion and estimates from Hurricane Ike suggest that insured losses from this “minor” hurricane will exceed \$12 billion. Dr. Steven Quiring and his team have been working on modeling both short-term (e.g., days before landfall) and long-term (e.g., next 100 years) hurricane risks. The short-term work is in partnership with an electrical utility company that is interested in forecasting the number and location of power outages prior to a hurricane making landfall. These forecasts are used to make decisions about where to position crews and equipment in order to minimize the duration of the power outages. Dr. Quiring’s team is also studying the risks that hurricane winds and surge pose to the long-term reliability of regional electric power systems in hurricane-prone areas. They are assessing the influence of climate change on hurricane formation location, strength, and track and are using this information to support informed decision-making about changes in design wind loads and building standards.*

The College of Geosciences carries out research on climate variations over a range of timescales, ranging from the deep past (i.e., hundreds of millions ago) to the near future (i.e., the next century or two). The use of isotopes and trace metals (‘paleothermometers’) to understand the occurrence of Earth’s warm climates is an important area of paleoclimatic research. Researchers are also studying the evolution of ocean circulation patterns over tens of millions of years. These studies focus on topics such as the origin of tropical currents and the Pacific El Nino-Southern Oscillation phenomenon. El Nino is also the focus of several other research groups working on past and modern climates. The analysis of fossil corals and ocean sediments provides clues as to the behavior of El Nino over the past several centuries. Other research topics include the magnitude of ice volume when carbon dioxide levels were higher than today, the role of carbon dioxide in climate change and refining geochemical proxies for marine temperatures.

With regard to the present and future climate, research is being carried on a variety of topics such as climate-fire relationships, hurricane impacts on forests, and other topics falling in the broad area of climate-ecology interactions. Regional climate models are also under development to address the issue of downscaling, i.e., using future climate projections from coarse-resolution global climate models to make inferences regarding regional climate change. Analysis of satellite data is being carried out to elucidate important processes affecting climate change, such as the role of aerosols, clouds and, upper tropospheric humidity. Observational ocean data is being incorporated into numerical models of the ocean using data assimilation techniques. A

hierarchy of coupled ocean-atmosphere models are being used to simulate and predict El Nino on seasonal to interannual timescales. Forecasting El Nino remains one of the great challenges in the area of climate prediction, and is closely tied to the problems of forecasting floods, droughts, and tropical Atlantic hurricane frequencies.

Another important area of research in the college is abrupt climate change, where large climatic changes can occur on timescales as short as a few decades. Paleoclimatic proxy records are being used to quantify large fluctuations in the strength of the North Atlantic thermohaline circulation, and associated changes in the atmospheric circulation. Abrupt climate change is also a feature of warm climates, as evidenced by important rapid transitions that occurred 25-65 million years ago. On much slower timescales, alterations of past climates have also been attributed to tectonic events, such as the opening of Drake Passage, the closing of tropical ocean gateways, and mountain building events such as the rise of the Tibetan Plateau. The climate-tectonics relationship is an important area of research that brings together geologists, oceanographers, and meteorologists.

#### ***4b. Sedimentary Geology and Geobiology***

*Research Geonugget: As decaying plants and animals are covered by mud and buried beneath the Earth's surface, they remove carbon from the atmosphere and ecosystem. Hundreds of millions of years ago, those same processes eventually led to one of society's primary sources of energy. The Organic Carbon Burial Project (OCBP) is a program in the Department of Geology and Geophysics to investigate the mechanisms and patterns of organic carbon burial and preservation in mud-rich sedimentary systems. The team, led by Mike Tice, is composed of nine faculty members with expertise in sedimentology and stratigraphy, geobiology, geochemistry, and paleontology, as well as graduate students who conduct their thesis research on related projects. Organic-rich fine-grained deposits are potential petroleum source rocks and reservoirs for natural gas. By working to understand better the fundamental physical, chemical, and biological processes involved in production of such deposits, we aim to develop predictive models useful for exploring for conventional and unconventional hydrocarbon resources.*

Sedimentary geology in the College of Geosciences encompasses the study of sediment transport, depositional processes, sedimentary environments, and stratigraphy. Our work spans a broad range of terrestrial and marine environments from the modern to the ancient. The geomorphology group in Geography (Douglas Sherman, Inci Guneralp, Vatche Tchakerian, and Chris Houser) focuses on sediment transport dynamics and morphological change within aeolian, coastal and fluvial systems. Thomas Olszewski focuses on developing and using sequence stratigraphy, particularly in the late Paleozoic, to understand sea level and climate change. A group including Thomas Yancey, Brent Miller, and Ethan Grossman is working on the sedimentary record of environmental change spanning the late Paleocene-early Eocene. Bridget Wade uses cyclic changes in deep-sea sediment cores to study the influence of orbital forcing on climate during greenhouse periods. Robert Weiss conducts analytical and process modeling of sedimentation and erosion during extreme events such as tsunamis and meteorite impacts, as

well as landslides and turbidity currents. Anne Raymond focuses on organic carbon storage in wetlands. Mike Tice conducts research on the sedimentary record of Archean life and surface environments, as well as on sedimentary processes in mud-rich systems.

Geobiology is the study of how living things interact with geological systems. Research in this emerging discipline in the College of Geosciences is unusually broad, encompassing the three domains of life, terrestrial, marine, and deep subsurface ecosystems, and the past, present, and future of the biosphere. Our methods are highly interdisciplinary, drawing upon the tools of organic and inorganic chemistry, molecular microbiology, paleoecology and evolutionary biology, sedimentary geology, isotope geochemistry, hydrogeology, and climatology. Heath Mills studies gene expression and biogeochemical processes in complex microbial communities in the deep subsurface and a variety of sedimentary environments. Tom Bianchi conducts research in organic geochemistry, biogeochemical dynamics of aquatic food chains, carbon cycling in estuarine and coastal ecosystems, and biochemical markers of colloidal and particulate organic carbon. David Thornton studies carbon and nitrogen cycling in marine ecosystems. Thomas Olszewski focuses on using fossil data to study the response of ecological communities to environmental change. Bridget Wade analyzes microfossil assemblages to study mechanisms of extinction and biotic change in relation to critical climate events. Ethan Grossman applies stable isotope geochemistry to understand environmental and paleoenvironmental change and its causes, as well as the functioning of subsurface microbial ecosystems. Anne Raymond studies the evolution of land plants and the effect of land plants on Earth Systems. Mike Tice studies the history and evolution of microorganisms in surface environments, as well as the functioning of modern microbial communities in sedimentary environments. Bruce Herbert focuses on the organic geochemistry and biogeochemistry of soils.

#### ***4c. Coastal Processes***

*Research Geonugget: As the population of coastal towns and cities continues to grow, coastal pollution is becoming more of a problem, and Texas is not immune. One of the more obvious signs of coastal pollution is the appearance of "red tides," dense blooms of phytoplankton that not only cause discoloration of the water but may also result in fish kills, human illnesses, and sometimes death. The latter occurs when particular species of phytoplankton release toxins into the water, and these are then taken up by shellfish, which concentrate the toxins in their tissues. Yet not all red tides are toxic, and it is vital to be able to determine rapidly which species of phytoplankton is growing. Dr. Lisa Campbell and her team are working on methods to identify and enumerate phytoplankton species automatically at remote sites, as well as the conditions that affect which species dominate the local phytoplankton community. This work is important for food safety, since about one third of the U.S. catch of oysters comes from the Gulf of Mexico, and a toxic red tide can shut down the industry for weeks to months.*

Coasts include watersheds adjacent to large bodies of water, bays, lagoons, barrier islands, estuaries, the continental shelf and slope and the populations, infrastructure and industries that occupy these areas. A large portion of the nation's natural resources and economic assets are concentrated within coastal regions. Significant change, degradation, and loss of coastal environments have already occurred including resource depletion, pollution, and deterioration

of ecosystem services. Recent hurricane-related events in the Gulf of Mexico emphasize how unprepared the nation is for the growing crises and risks associated with human occupation of coasts. A holistic and systematic approach to understanding resilience, vulnerability and adaptability of human, natural and engineered systems is essential for a sustainable future. The College of Geosciences has the intellectual capital, infrastructure and experience to contribute to critical needs for knowledge and information about coastal areas and the populations that occupy them.

The College has strengths in its disciplinary units, integrated research programs and centers, and interdisciplinary research that inform the most intractable issues faced by coastal regions. Areas of research in the atmospheric sciences applicable to coastal regions include: aerosol research, atmospheric chemistry and air quality, climate, weather and weather forecasting. Geographers bring expertise in human geography, human-environment interactions, physical geography, geomorphology, and GIS and remote sensing. Geological and geophysical coastal research includes the study of geochemical and biogeochemical cycles, environmental change, energy and water resources, and geological hazards. Oceanographic and geomorphological research in coastal regions includes the study of marine biology and ecosystems, marine microbiology, harmful algal blooms, eutrophication and trophic dynamics, the estuarine chemistry, fisheries, biogeochemical cycles, contaminant and nutrient chemistry, coastal processes and morphology, coastal circulation and near-shore processes, climate, coupled ocean-atmosphere modeling, and ocean observations. There is also research expertise in contaminant chemistry, ocean observing, geochemistry, and fate and effects of pollutants that has application in coastal regions. Sea Grant's work is almost exclusively concentrated in the coastal region. Its strategic focus includes aquaculture, resilient coastal communities, ocean observing, invasive species, and seafood safety and quality.

Exemplar College programs include the Texas Automated Buoy (TABS) system that has saved the state \$100,000's of dollars in directing oil spill response along the coast. The study of the "Deadzone" offshore of Texas and Louisiana has highlighted the need for control of fertilizer usage along the Mississippi River basin. The study of pre-conditions for harmful algal blooms has allowed for more accurate prediction of the onset of these event lending clues to potential preventative efforts.

#### ***4d. Coupled Natural-Human Systems***

*Research Geonugget: Vast acreages in the USA have been converted from food production to production of biofuels. Meanwhile, food demand in China and other emerging economies is increasing in line with rising standards of living. The global economy is increasingly turning to the semi-arid ecosystems of South America which are being converted into a Soy Belt extending from NE Brazil to central Argentina. The resulting multi-billion dollar industry exports soybeans to China, the USA and the European Union. Geographers Christian Brannstrom, Andrew Millington and Wendy Jepson have been studying this new development using a coupled natural-human systems approach. They are using techniques drawn from new economics, the politics of environmental governance, remote sensing, and biogeography to understand and monitor the impacts on ecosystem services in what are becoming some of*

*the most threatened biomes in the world. This work is important for understanding how global economic growth and changing fuel sources as part of our energy security package in the USA are connected to declining environmental conditions globally.*

A theme in geosciences research since the 1970s has been to understand and evaluate the impacts of society on the environment, and how resulting environmental change influences society. As our understanding of the processes underlying these impacts has matured, we have realized that these impacts are complex in two ways: (i) that at any one time and in any one place many processes are operating which have the potential to interact with each other, and (ii) the resulting impacts have positive and negative feedbacks on processes and on society. Early attempts to synthesize these interactions and feedbacks relied on systems theory. During the 1990s the area of complexity science -which drew not only on the sciences, but mathematics, computing and social science - was developed to research the linkages between society and environment. The ecological origins of this research endeavor were acknowledged in the concept of biocomplexity at this time. However, the science has evolved and it is now recognized that interactions between human and natural systems is greater in scope than biocomplexity and the term coupled natural and human systems is applied to these interactions. So much so, in fact, that NSF has developed a permanent interdisciplinary program entitled the 'Dynamics of Coupled Natural and Human Systems' (CNH) which supports basic research and related activities that enhance fundamental understanding of the complex interactions within and among natural and human systems. Research funded under CNH focuses on complex interactions at diverse spatial, temporal, and organizational scales.

Research under coupled natural-human systems has the following themes: (i) it advances basic knowledge of system dynamics, i.e. processes which either relate to system functioning or interactions between other systems, and (ii) it examines natural and human systems - ideally examining a wide range of coupled interactions and feedbacks among systems simultaneously.

One area of reinvestment hires under Vision 2020 in the College of Geosciences at Texas A&M has been to develop research in human interactions with the (geosciences) environment. This maps directly onto coupled natural-human systems. Hires in this area are spread across the College of Geosciences, they have added to expertise that already exists within the College. Existing College strengths include the broad array of subdisciplines represented within the College involving coupled systems, the extensive mathematical and computing expertise, and the strong presence of social science expertise. Yet, substantial potential for collaboration and growth remains. There is little doubt that the potential to expand our research is enormous.

Here we provide some examples of research currently underway. Research on linkages between external (human) drivers and responses in a part of the environment include: the role of infrastructure development on the initial responses and recovery of the Gulf coast barrier island to extreme storms; the impact of over-sand vehicle on 'natural' transfer and balance of sediment on the beach to beach and dune morphology and change; impacts of commercial vessel wakes on bank and salt marsh erosion in California and Georgia; and PCB contamination in Antarctica.

Research on linkages between environmental forcing factors and societal responses includes

climate-induced changes in hurricane winds, surge, and risk to electric power systems.

Research investigating complexity in coupled natural-human systems includes: linking and modeling underlying multi-scale societal drivers and environmental forcing factors on land clearance (in savanna and forest biomes) to vegetation to a range of environmental impacts (Appalachia, Texas, Argentina, Bolivia, Brazil, Peru); reconstructing human-induced and natural forest fire regimes in the Appalachians; coupling economics and ecological impacts of marine tourism versus extractive fishing (Texas, Belize); integrative research on deep-sea coral bed ecology and fishery management plans applied to coral harvested for jewelry making and commercial deep-sea fishing; and investigating the development of rules and organizations for allocating irrigation water in south Texas.

Applications of coupled natural-human systems research to environmental management include: exchanges of practitioners in developing countries as a means of increasing local ownership of coastal ecosystem management programs; investigating new models of environmental governance in commercial farming in South America savannas; and understanding how the management of groundwater-based water supply schemes affects access to domestic water supply in India.

#### **4e. Geoscience Education**

*Research Geonugget: In recent years, interest in spatial thinking has exploded with the advent of sophisticated visualization tools, geospatial technologies, and increasing concern with the need to prepare a spatially literate workforce. However, geospatial technologies (GST) have been slow to diffuse into science and social studies classrooms. After nearly 15 years of working with science and social studies teachers to adopt such technologies, geographers led by Robert and Sarah Bednarz have become convinced that a fundamental barrier to GST's diffusion is teachers' lack of understanding of the nature and importance of spatial thinking, that is, the cognitive skills underlying these powerful technologies. Until now, there has been no application of spatial-thinking research in psychology, cognitive science, and geography to develop science or social science curriculum or improve instruction in spatial analysis and problem solving. Their new project, Advancing Geospatial Skills in Science and Social Science (AGSSS), connects geospatially skilled graduate students with science and social studies teachers, grades 6-12, in a collaborative three-year cycle to enhance teachers' and students' spatial-thinking knowledge and skills. The program will focus on three fundamental questions: 1) What is the nature of spatial thinking in classroom settings? 2) What practical, classroom-based strategies can be used develop spatial thinking? and 3) What is the role of spatial thinking in the implementation of GST?*

Efforts to reform secondary and tertiary science education often call for the participation of academic scientists in the reform effort through the development of partnerships between scientists and educators because only scientists know which questions are worthy of attention and what barriers students encounter when addressing these questions. Unfortunately the suggested roles for scientists are often poorly conceived and rewarded. Research regarding the

nature of scientists' participation in geoscience education and how more effective teaching and learning strategies can be developed is lacking.

According to the National Research Council, numeracy (mathematical skills) and graphicacy (including multiple representations, visualization, and other spatial-thinking skills) are especially important to STEM education generally and geoscience education specifically (NRC Committee on Support for Thinking Spatially 2006). Inquiry-based learning that incorporates information technologies—especially geo-spatial technologies such as GIS, remote sensing, and GPS—represent one approach to support student development of critical thinking skills and competency in scientific practices including learning with understanding, problem-solving, knowledge transfer, strong metacognitive skills, and decision making.

Considerable expertise in geoscience education exists among faculty in all of the College's departments, and these faculty (R. Bednarz, S. Bednarz, B. Herbert, R. Stewart) have been successful in attracting external funding to conduct several major projects. These programs have generated more than \$6 million in funding from NSF and other Federal agencies including the U S Department of Education and NASA. The National Geographic Society has also provided more that \$200,000 for staff-development institutes for geography and earth science teachers conducted by Geography Department faculty.

Faculty activity has extended beyond winning external funding. Several geoscientists (R. Bednarz, S. Bednarz, B. Herbert) have published peer-reviewed journal articles and book chapters over the past decade. In addition, faculty have edited books on geoscience education and related topics. Finally, geoscientists have reached out to collaborate with colleagues in other colleges including Education and Human Development, Science, Engineering, and Agriculture.

## **5. Interdisciplinary Research Initiative: CHANGES 30/30: Changing Human and Natural GeoEarth Systems in the 30°N/30°S Tropics Belt**

The emerging research initiative described here focuses on the connection between changing human and natural geoearth systems (CHANGES) within the global tropical region. The tropics are herein defined as the 30/30 belt (i.e., 30°N to 30°S) that includes Texas, the Gulf of Mexico, and the global tropical belt). This initiative will examine how these natural systems are currently changing due to past and present global events, how they continue to respond to external forcing, and how we can improve our understanding of these systems for risk mitigation and improved stewardship of this planet. The geographic location of Texas A&M University places it on the doorstep to the tropics and thus provides bidirectional access to study the tropics and how changes within this region affect the rest of the world. The diverse faculty at TAMU and current facilities and international collaborations provide a strong base to address such a broad subject. Further investment of personnel and infrastructure will allow TAMU to become a world leader in a globally important line of research.

### ***5a. Scientific Rationale***

Tropical regions play a key role in controlling global climate by i) absorbing solar energy, ii) exchanging carbon dioxide with the atmosphere, and iii) sequestering carbon in shallow carbon reservoirs. Within these regions are some of the highest documented concentrations of marine and terrestrial biodiversity, with sensitive linkages between upland and coastal/marine systems. Many tropical systems are already heat stressed and highly vulnerable to additional warming. This exacerbates pressure from localized overexploitation of marine resources including economically and socially important fisheries (FAO, 2004). The IPCC (2007) predictions have been continuously exceeded by rising temperatures on land and in the ocean, while increasing atmospheric and dissolved carbon dioxide has increased ocean acidification such that coral calcification will become impossible by 2100. Increasing regional frequency and intensity of cyclonic storms has also increased the cumulative threats to marine and coastal systems in general, and to coral reef ecosystems in particular. The world's tropics have already shown and will continue to show drastic effects from global change. In turn, changes in tropical areas will induce drastic effects in other areas of the world through climate teleconnections affecting global natural and human systems.

In the last two centuries, the world population has increased almost exponentially, while access to clean water, sufficient food, and basic sanitation and health have become unavailable to over half of the world's 6.6 billion people (World Resources, 2005). There has been growing recognition among the world's leading scientists and resource economists that functional and productive ecosystems provide the fundamental goods and services that maintain human populations (Browman and Stergiou, 2005, Daly 1990, Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). Yet the enormous values of ecosystems are not adequately

represented in national and global accounting systems. As the receiving basin for society's terrestrial and atmospheric pollution, marine systems are particularly undervalued common property resources. The cumulative value of ecosystem services and products provided from the world's coastal ecosystems has been estimated to exceed \$25,000 billion per year (Martinez et al., 2007). Now is the time to understand the effects of these changes within the tropics, and with proper guidance and support, TAMU is poised to become a leader in this emerging area of applied multidisciplinary research.

Thus, to address climate-induced changes within tropical human and natural systems, research should focus on three main objectives:

1. Define the tropical system from a human and natural prospective and determine how and to what extent the tropics affect the rest of the globe. The tropical system as a whole must be defined in terms of biological, chemical, atmospheric, geographical, societal, climatic and geologic factors.
2. Identify the responses of the tropical human and natural systems to climate change and how they will be altered over the next 50 years. Changes in climate, population, biodiversity and natural resources must be identified and predictive models constructed.
3. Determine the adaptation potential and level of resilience of human and natural systems in the tropics. The natural response to change must be described and management strategies must be developed.

A multidisciplinary approach will be required to address seven action items related to this tropical research initiative. Although such a number appears large, many of these research topics have complementary drivers and impacts, and thus are naturally encompassed within obtainable objectives and can be grouped into two main categories, "Human System" and "Natural System". Both of these areas will require joint efforts between the geosciences, pure sciences, and political sciences as oceanography, chemistry, biology, agriculture, geology and geophysics blend with geography, economics and public policy. Below are listed specific research action items along with multiple associated themes/drivers.

#### Human System

1. Population Demographics – migration/immigration patterns; managing food supplies and land habitability; identifying and combating emerging diseases
2. Human Resource Use and Adaptation – balances between land and water uses for crop and fishery sustainability; acquisition, utilization and management of natural energy resources (i.e., oil, wind and geothermal heating)

#### Natural System

1. Sea Level Rise – effects of global ice reduction; increased thermosteric and dynamic forces; enhanced land subsidence
2. Weather Patterns/Tropical Storms – rising sea surface temperatures; fluctuating ocean/atmospheric circulation patterns; changing land use practices; varying storm frequency, intensity and pathways; increasing storm tide magnitude
3. Water Availability – change in precipitation patterns; increased fire regimes

4. Ecosystem Adjustment – expanding hypoxic zones; changing oceanic biogeochemistry; increasing coastal erosion and land use on barrier islands and in coastal wetlands; identifying climatic ecotone migration patterns; varying levels of primary productivity
5. Natural Resource Sustainability – maintenance of food and water resources; changing patterns of carbon sequestration as a result of shifts in primary production; increasing green house gas emission

For these reasons, the College of Geosciences at Texas A&M wishes to partner with relevant departments, colleges, and other domestic and international agencies in order to address what we see as the grand challenge: environmental and economic sustainability, resilience and adaptability in tropical regions.

### ***5b. College Expertise***

The impressive level of research diversity within the College of Geosciences faculty provides a solid platform from which the CHANGES 30/30 initiative can build momentum. Current faculty members have multiple active projects within the global tropics. Field sites include coastal Texas, the Gulf of Mexico, Costa Rica, Panama, the Galapagos, Palmyra Atoll, Equatorial Pacific, Nankai Trough, Changjiang (Yangtze) river margin, and Oman. International programs include CLIVAR, the Global Earth Observation System of Systems (GEOSS), Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS), and Integrated Ocean Drilling Program (IODP). In addition, the College of Geosciences is the host of the Gulf Coast Repository (GCR), one of three IODP geologic ‘libraries’ worldwide. Listed below are some of the areas of research expertise within each of the departments. Detailed descriptions of individual research projects can be easily accessed on newly designed and developed departmental websites.

Oceanography Department – Ocean current dynamics, sea level rise dynamics, ocean chemistry flux, biogeochemical cycling, geomicrobiology, molecular microbial ecology, organic matter degradation, primary production shifts, paleoclimate and paleoecology trends, and carbon sequestration rates.

Geography – Population demographics, coastal and urban environmental monitoring, land use/land cover changes, climate and drought, hydrology and fluvial geomorphology, coastal and marine geomorphology with emphasis on barrier island dynamics and reefs, and marine fisheries.

Atmospheric Sciences – Tropical storm intensity predictors, meso-scale atmospheric modeling, air-sea interactions, coastal flow patterns.

Geology and Geophysics – Paleoclimate and paleoecology, subsurface exploration through geophysics and drilling, natural energy source identification and acquisition, geobiology.

### ***5c. University Collaboration Potential***

As a product of the physical location of the university at the edge of the 30/30 belt, and the fundamental agricultural nature of this campus, key components of this initiative require collaboration outside the College of Geosciences. Each of the colleges and programs listed below have the potential to provide distinct research collaborations with Geosciences faculty.

College of Agricultural and Life Sciences – Research either currently linked to the tropics or easily transferable to this region abound within this college. From the Departments of Wildlife and Fisheries Science and Plant Pathology and Microbiology to Soil and Crop Science and Ecosystem Science and Management, collaborative projects can, will and should be developed based on the objectives within this initiative.

College of Architecture – Current collaborations with faculty from this college are being utilized in the construction of a research station in the Galapagos. This project, led by Dr. Niall Slowey, will provide a cornerstone for TAMU tropics research, with the lab itself being a hallmark of “Green” architecture and design.

Bush School of Government and Public Service – The study of tropic systems requires a full examination of the impact of humans on the tropics and the tropics on humans. Collaborations with the Bush School are imperative for the implementation of policies that will ultimately mitigate these effects. Without the Bush School, many applied findings and predictions will not reach intended targets.

Dwight Look College of Engineering – Multiple aspects of the tropical initiative fall within the scope of the College of Engineering. Petroleum Engineering can collaborate in energy resource identification and acquisition projects. Additional departments are also involved in the construction of the Galapagos Lab. As models are developed to describe coastal impact of increased sea levels and tropical storm intensity, collaborations with the Civil Engineering Department will be required to determine habitation and construction strategies on barrier islands and in coastal cities.

College of Sciences – Research resources in the Biology and Chemistry Departments will provide additional leverage in ecosystem adaptation, biodiversity estimates and migration/immigration pattern determination. The Physics and Statistics Departments can provide additional fluid flow data and model building expertise.

College of Liberal Arts – With shifts in populations due to rising sea levels, changing precipitation patterns, and varying energy reserves, collaborations with faculty in Economics, Hispanic Studies, Political Science and Sociology become critical to understand and predict our changing human system.

NSF-IGERT Applied Biodiversity Science (ABS) Doctoral Program - Recently funded for 5 years, this program offers a perfect platform to integrate our program’s initiatives in the tropics. Research teams of students and faculty collaborate with international partners on projects of

ecological function and biodiversity and communities and governance. CHANGES offers a strong addition to this program, and could help to institutionalize ABS at Texas A&M University.

### ***5d. Funding Opportunities***

Funding opportunities exist from all major governmental agencies including NSF, NIH, DOE, EPA, USDA, NASA and NOAA, as well as those government agencies included within the Cooperative Ecosystem Studies Unit (CESU). Current faculty have active grants from these agencies, however a focused initiative in the tropics, well supported by the College and the University will provide additional leverage for increasing research funding potentials. Significant private foundation resources are available for this type of research. Donor support is high within the Geology and Geophysics Department for energy research. Such a lucrative funding stream may be achieved in the other departments and possibly enhanced within Geology and Geophysics when requests are linked to this publicly hot topic.

### ***5e. Plan with Limited or No New College Resources***

As a result of the critical nature of this research and the current level of involvement, research within the college will continue in the tropics. Portions of this initiative are obtainable with no new resources, however the speed and degree to which these initiatives can be obtained will be reduced. Current collaborations with the Ocean University of China, Kochi University, Max Planck Institute for Marine Microbiology, Oman, Ecuador, Mexico, Belize, and Victoria University of Wellington can continue to be used to study the tropics. However, a lack of financial support and resource allocation will make the leveraging for leadership roles on future grants difficult. Thus, members of the faculty will be more likely to seek collaborations outside the college and university rather than have other colleges and universities come to our door. Current trends suggest that the dire need for a better understanding of the impact on and from the tropics due to changing global climates will provide increased federal and private grant money. As a whole the College of Geosciences is well positioned to take advantage of this shift in funding, if support is supplied to the faculty.

### ***5f. Plan Forward with Additional College or University***

#### ***Resources***

Additional resources associated with the CHANGES 30/30 initiative can place the College and University at the forefront of tropics research. More resources will have a direct impact on the speed in which the objectives can be achieved and the resolution in which data is collected. By showing a commitment to the Tropics, Geosciences can become a leader in the field and will be the focal point for grant writing, not a farm team for other colleges and universities.

Resources can be allocated in the form of money, personnel or infrastructure. Increased funding for more field and observation sites, and the completion of the Galapagos lab will not only give the college a better platform from which research can be conducted, but also provide additional

incentive for top-ranked faculty hires to join our ranks. Further support of IODP will increase the prospect for renewal of this valuable resource for the college as well as the university.

The centerpiece of this initiative, given the appropriate resources, would be the Center for CHANGES. This center would initially build upon the existing tropics based research and personnel currently on campus. Field sites will be linked so that data sharing would allow a more global view to be obtained, not the individual, un-coordinated measurements currently being collected. A focused cluster hire will be used to bring in a national academy senior level faculty, with multiple junior level positions in support of this initiative to develop both an observational and a modeling capability. Although the Galapagos lab will be integral in this Center, the use of other sites from around the globe will be encouraged, including but not limited to the new Casa Verde Student Center in Costa Rica, possible marine field laboratory in Antigua, field sites in Belize and the research station on Palmyra Atoll. Lab space and startup funds will be required to acquire these new faculty members. Grouping them together in the same physical location on campus will aid in collaborations and grant writing potential. Class development and student mentoring will support VISION 20/20 and begin to train the next generation of tropics-literate scientists.

## **6. Interdisciplinary Research Initiative: Science Education**

### ***6a. Scientific Rationale***

National and international efforts to reform secondary and tertiary science education often call for the participation of academic scientists in the reform effort through the development of partnerships between scientists and educators, though suggested roles are often poorly conceived and rewarded. Improved models of the roles of scientists in the reform effort are required to ensure that the potential synergy between science research and science education is realized.

Scientists and educational leaders are needed to support the development and implementation of effective learning environments designed around inquiry-based (experiential) learning that supports the transfer of science research to the classroom. Only scientists know what questions are worth answering, from what deficiencies students suffer, and what barriers to effective teaching and learning prevent success.

Research suggests that numeracy (mathematical skills) and graphicacy (including multiple representations, visualization, and other spatial-thinking skills) are especially important to STEM education generally and geoscience education specifically (NRC Committee on Support for Thinking Spatially 2006). Unfortunately research that informs science educators about which strategies are effective in transferring knowledge and skills or remediating deficits is lacking. Inquiry-based learning is one of the best pedagogical practices to support student development of critical thinking skills and competency in scientific practices including learning with understanding, problem-solving, knowledge transfer, strong metacognitive skills, and decision making. Information technologies are often a central component of effective learning environments because these tools support student manipulation of data, the development and testing of conceptual models based on available evidence, and exposure to authentic, complex and ill-constrained problems. Geo-spatial technologies such as GIS, remote sensing, and GPS have become especially important in the geosciences.

With the collaboration of colleagues in the Colleges of Education and Science, Geoscience faculty can help to provide educators with research results that identify the importance of spatial-thinking skills and the deficits students suffer from, that test strategies to eliminate deficits and strengthen the skills of geoscience students, that evaluate the role of technology in addressing these problems, and that assess the changes in student learning produced by these interventions.

### ***6b. College Expertise***

Several College faculty members have engaged in externally funded geoscience education projects. Faculty from three departments (Geography—R. Bednarz, S. Bednarz, A. Klein;

Geology & Geophysics—B. Herbert; and Oceanography—R. Stewart) participated in the NSF-sponsored, University-wide ITS project, which focused on using information technology to improve STEM education. The program included participation by College graduate students as well as faculty. These students interfaced with K-12 teachers and conducted research as part of their assistantships.

Faculty members from at least three departments (Geography—R. Bednarz, Geology & Geophysics—B. Herbert, and Atmospheric Sciences—S. Nasiri) have participated in the activities of the Center for the Integration of Research, Teaching, and Learning (CIRTL) as members of the steering committee and as associate director. This multi-university program focuses on connecting the developing disciplinary expertise of graduate students with the scholarship of teaching and learning.

For a more extensive overview of College expertise in this area, see Section 4e.

### ***6c. Collaboration Potential***

Geoscience faculty have already collaborated with colleagues from the Colleges of Agriculture, Education, Engineering, and Science. These efforts have included participation in externally funded projects, co-authorship of publications, and as a member of the NRC Committee on Support for Thinking Spatially that generated *Learning to Think Spatially*, the recent volume reviewing research findings and outlining a research agenda for spatial thinking (NRC Committee on Support for Thinking Spatially 2006).

Faculty have also explored collaborative programs with other geoscientists at the University of California Santa Barbara Spatial Center and with cognitive scientists from the Spatial Intelligence Learning Center, a multi-university center funded by NSF.

### ***6d. Funding Opportunities***

As College faculty members have demonstrated, funding opportunities for this research area are available. Both Federal agencies and public and private foundations have sponsored projects led by College faculty members. Increased collaboration with faculty from other colleges and other universities should lead to increased probability of securing awards and to winning more awards of larger sizes. College faculty members are currently participating in the generation of a University white paper in this area. If it is successful, additional University resources will be available.

### ***6e. Plan with Limited or No New College Resources***

Without College resources, faculty will continue to work in this area and to take advantage of funding opportunities. The activities will, of necessity, remain limited in length (of time) and most likely independent of similar projects supervised by other researchers within the College or in other colleges. For the most part, this environment would maintain the situation as it now exists, that is, individuals or departmental collaborators seek out funding for projects with little

connection to the efforts of others. Frequently these projects run for a few years, concluding when the funding runs out, and thus, creating no lasting impact on the research program of the College nor an increase in the College's capacity to conduct additional research. In general, Geoscience's education research programs have been relatively numerous but have been short-lived, unrelated, and of limited impact on the College's direction.

## ***6f. Plan Forward with Additional College or University***

### ***Resources***

With additional resources, geoscience education faculty will have the opportunity to plan for both longer-term and more interdisciplinary projects. Planning, organizing, writing, and revising multi-departmental or inter-college proposals would be facilitated by giving faculty release time to undertake these efforts. Besides freeing up faculty time, minimal administrative support would also contribute to the success of these activities. Depending on the nature of external funding acquired and the type of projects conducted, modest physical resources (i.e., space and equipment) may be required. Based on experience, it is unlikely that these resources would over-stretch the College's resources, physically or fiscally.

In addition to allocating faculty time and effort to geoscience education, increased attention by the College administration to opportunities in this area would also increase faculty members' ability to win external funding and to participate in University efforts. In the past, College administrators were unaware of (or uninterested in) faculty participation in geoscience education projects and sometimes failed to inform interested faculty of planned or existing programs. The duties of the Associate Dean for Academic Affairs should be reviewed to consider allowing for her/his more active participation in the College's geoscience education research and engagement activities.

Resources will also be required to increase the College's capacity to conduct geoscience education research as this area continues to develop and grow in the College. First, a commitment to hiring faculty who are interested and able to work in geoscience education is necessary. Second, as research programs increase, additional faculty will likely be required. Considering researchers who have a significant research interest and capability in geoscience education during hiring decisions will require a change in the mindsets of College leaders.

### ***6g. References***

National Research Council (NRC), Committee on Support for Thinking Spatially. 2006. *Learning to think spatially*. Washington DC: National Academies Press.

## **7. Interdisciplinary Research Initiative: The Health of the Human Environment**

We have not yet fully developed the potential linkages between researchers within the College in coupled natural-human systems, nor have we fully exploited linkages outside the College but within the Texas A&M system. Therefore, the College's current research in the area of coupled natural-human systems has not yet realized its high potential in terms of research volume and significance. There is little doubt that the potential to expand our research is enormous: external funding sources for large (>\$1 million) grants is established through the permanent CNH program in NSF, and internal sources – World Bank, UN system; this area will grow because it addresses major national and global concerns; and it is a key area for graduate research training. Our interests in ecological aspects which overlap with geosciences may be best served by linkages with ecologists as Texas A&M and elsewhere, something that is currently being done through the NSF-funded applied biodiversity science initiative.

A subset of research on interactions between the environment and human development should focus on large urban areas and how they interact with the environment and the people who live in them. The remainder of this section describes this program, entitled “Metropolises – Impacts and Feedbacks of Large Urban Areas on Environment and Society” (INFLUENCE).

### ***7a. Scientific Rationale***

Approximately half of the global human population already lives in large conurbations. The UN predicts that this number will increase to 60% by 2030, with estimates as high as 90%. Simultaneously, the number of large urban areas exceeding 10 million inhabitants ('megacities') is increasing – there were 5 in 1970, 19 in 2000 – and it is likely that 30 megacities will house 10% of the world's population two decades from now. The environmental impacts of these areas are already enormous. For example, a resource footprint analysis of Toronto (approx. 4.5 million inhabitants) concluded that to support its food, housing, transportation and service needs, as well as waste disposal, it required an area equivalent to 126,427 km<sup>2</sup>, or 610 times the area it covers (Figure 1). Cities represent major focal points of human influence on the planet, spanning from systematic land cover/land use changes, to climatological and hydrological changes, to greenhouse gas and air pollutant emissions, to the perturbation of geochemical sinks of industrial and domestic pollution. The situation is further complicated by secondary effects (including feedbacks), such as the urban heat island effect, increased severe weather vulnerability, and deteriorating public health. As migration into and areal growth of cities accelerates, comprehensive, integrated research into these centers of human influence on our planet is both timely and essential.

### ***7b. College Expertise***

*Land cover/Land use change (LCLUC)*

The expansion of urban areas is primarily associated with large changes in LCLU. These include the expansion of urban, and related, industrial land uses onto agricultural land, encroachment onto natural ecosystems and changes in land use within cities as they grow and/or regenerate. LCLUC analysis facilitates an understanding of

- the socio-economic drivers and environmental forcing factors which generate past, present, and future LCLUC through a combination of mapping (mainly from remote sensed data), socio-economic analysis and numerical (spatial) modeling;
- the physical and socio-economic indicators of these changes, both in space and time; and
- the indirect effects of these changes on rural areas beyond the city through footprint analysis (e.g. the case of Toronto mentioned above).

Key to the future of cities agenda, LCLUC analysis enables us to predict the impacts and feedbacks of future development in a spatial-temporal framework which can be used by researchers in allied disciplines, e.g. meteorologists, hydrologists, geochemists and urban planners. Both classic mapping and modern remote sensing and GIS technologies, together with sub-fields within human geography, provide us with the concepts and tools for this type of analysis and the predictive power required to look into the future.

#### *Climate, severe weather and hydrological impacts*

Past research into the influences of large urban areas on their own and the adjacent rural climate has revealed that

- urban temperatures are elevated: the urban fabric creates a relatively large temperature gradient towards the urban center, with warmer urban air temperatures, especially at night, caused by heat storage in man-made structures and surfaces. The size of this urban heat island (UHI) effect is directly related to urban population number (Figure 2);
- urban hydroclimate is enhanced: average rainfall downwind of large urban areas is increased, particularly during the warm season. The number and intensity of mesoscale convective storms and associated rainfall is increased both above and downwind of urban areas, and this enhancement of convection has also led to increased lightning activity around urban areas;
- urban wind turbulence is enhanced: the relative lack of natural momentum sinks as compared to rigid man-made structures increases horizontal and vertical dispersion, and both slows and accelerates wind speeds in urban areas; and
- urban areas are flood-prone: the increased amount of impervious area in cities alongside compacted soils and runoff management has accelerated hydrological cycling, lead to an increased vulnerability of urban areas to flash flooding and increased the frequency of flooding in downstream areas.

There is a wealth of past studies, but few have been carried out in very large urban areas – the world's megacities. The college is well-positioned to use increasingly sophisticated microclimatological and hydrological studies combined with numerical modeling to predict the feedback of urban growth onto urban climate.

### *Urban Air Quality*

Epidemiological studies show that public health, in particular that of children, youths and the elderly, is seriously affected by continuously poor or deteriorating air quality, such as

- high fine and ultrafine PM (Particulate Matter) concentrations,
- high ozone and related photochemical smog chemical concentrations, and
- high loadings of primary and secondary indoor air pollutants.

Air quality research shows that poor conditions are directly linked to urban transportation and industrial sources, and therefore indirectly linked to both urban population and personal, public, and corporate choices. College of Geosciences researchers are actively working on these and related air quality issues and relationships.

### *Geochemical sinks*

The multitude of pollution sources in cities leads to chemical build-up in soils and watercourses, and a resulting percolation into groundwater aquifers. Urban development has resulted in

- hotspots of elevated chemical loadings in soils due to their proximity to roads or to industrial complexes. These loadings can be highly persistent (e.g. lead);
- pollution of watercourses by end-of-pipe and non-point source chemical effluents; and
- contamination of aquifers through a consistently high load of environmental pollutants from urban areas and their footprints.

Although environmental geochemistry is not yet a strong expertise, our College's focus on geochemistry, combined with our expertise in earth surface processes and computer mapping (GIScience) are the key foundations to provide basic products for planners and researchers, such as distribution maps of chemicals in soils.

## ***7c. University Collaboration Potential***

### *College of Architecture (with Texas Transportation Institute, TTI)*

INFLUENCE has direct ties to the Department of Landscape Architecture and Urban Planning (LAUP), which describes its own core strength as “Integrating Health, Energy, Transportation, Community, and Sustainability through the Built and Natural Environments”. A close collaboration with the College and LAUP will strengthen and broaden our own college's research foci.

### *College of Agriculture and Life Sciences*

INFLUENCE needs expertise on urban-rural interactions as they pertain to research areas surrounding food and agriculture, and urban ecosystems. The College's signature (research) areas of “Food: Security, Safety & Nutrition”, “Healthy Ecosystems and Conservation of Natural Resources”, and “Bioenergy and Alternative Energy” can represent important interdisciplinary links, through which we can strengthen existing and build new ties.

*Bush School of Government and Public Service (also College of Liberal Arts)*

INFLUENCE has a clear public policy dimension in that it is necessary to develop, implement, and maintain policies for sustainable future urban living. The Bush School is already researching the impacts of 'Climate Change' policies, as well as relationships between 'Infrastructure, Built Environment and Public Policy', and 'Energy, Environment, and Natural Resources Policy'. The Bush School lists these as Landmark Public Policy Research Areas, which is why we need to consider engaging more closely with respective Bush School faculty.

*College of Engineering (also College of Science)*

INFLUENCE is intimately connected to questions of energy production, distribution, and use in urban areas. With the College of Engineering working on several landmark areas related to 'Energy', it becomes clear that interdisciplinary research ties to selected projects should be sought to enhance and broaden our own research.

*Mexico City Center and Texas A&M Qatar*

Texas A&M has access to one of the world's largest megacities through the Texas A&M Mexico City Center. Furthermore, Texas A&M Qatar provides access to the rapidly urbanizing Persian Gulf coastline, which has some of the most innovative but environmentally and socio-economically untested urban planning in the world.

### ***7d. Funding Opportunities***

All major federal funding agencies (NSF, DOE, EPA, USDA) have programs that are directly (e.g. the NSF 'Coupled Natural Human Systems' program, or EPA 'Air Quality and Public Health' programs) or indirectly (e.g. DOE 'Carbon Cycle Science' programs) related to INFLUENCE. In addition, both NSF through its MIRAGE (Megacities Impacts on Regional and Global Environment) project, and the European Union through its 7<sup>th</sup> Framework Program 'Megacities and regional hot-spots, air quality and climate' (funding, e.g., the "CityZen" project) have already recognized the importance of this research.

### ***7e. Plan with Limited or No New College Resources***

College of Geosciences faculty shall convene in 2009 to coordinate current research activities and plan future proposal activities with the goal to improve interdisciplinary foci and submit to respective large federal funding programs. Cross-college collaboration as described above remains an additional option and is strongly encouraged in select circumstances, particularly with the LAUP department. Likely project locations would be limited to Texas conurbations.

### ***7f. Plan Forward with Additional College or University***

#### ***Resources***

Should additional college or university funding become available, College of Geosciences faculty shall also convene with other college's interested faculty in 2009. Funds may be used to initiate collaborative within- and cross-college projects and/or to collect preliminary data that can be

used as input to large proposals or to initiate funding agency interest in interdisciplinary, cross-sectional funding of larger scale, inter- and multidisciplinary INFLUENCE projects, possibly including non-Texas conurbations.

## **8. Interdisciplinary Research Initiative: The Energy-Water Challenge**

### ***8a. Scientific Rationale***

As the world uses more and the rate of finding replacements is less, the challenges to provide future supplies of energy for our security and economic needs could not be more compelling. In addition, as population has increased, demand for both energy and water has grown. Petroleum and water resources are inextricably linked. Water is an integral part of electric-power generation. It is used directly in hydroelectric generation and is also used extensively for cooling and emissions scrubbing in thermoelectric generation. Construction of needed electric power plants has been scaled back or postponed due to water concerns. Nonconventional domestic energy sources have the potential to further increase demand for water as we move toward replacing foreign with domestic energy supplies. We propose to respond to that challenge by creating an internationally recognized Landmark Program in addressing the Energy-Water Challenge. Our mission is to bring together a wide range of expertise to address in the broadest possible terms the challenge of energy and water resources acquisition and allocation.

The scientific problems facing finding and extracting fluids for societal use are many. At the center of nearly all of them is the behavior of fluids in and on the earth. The National Research Council Committee on Grand Research Questions identified fluid flow as one of the top 10 grand challenges in the Solid Earth Sciences. In their view, the major scientific objectives are to understand “how fluids flow, how they transport materials and heat, and how they interact with and modify their surroundings.” Some of the specific unknowns are: 1) how subsurface fluids are distributed in heterogeneous materials, 2) how fast they flow, 3) how effectively they transport petroleum or contaminants, and 4) how they change through interaction with rock and soil. The long-term goal is the construction of mathematical models that can predict the performance of fluids in natural systems far into the future.

Our specific goals are the following:

- Conduct cutting edge science to understand the fundamentals of petroleum occurrence, location and extraction coupled with sustainable water resources.
- Develop and commercialize technologies to put those fundamentals to use,
- Address the public policy implications of a depleting petroleum resource, and growth in others, in a world climate of increased competition and nationalism
- Understand the policy implications of growing population yet fixed water resources especially in light of increased demand for water to produce energy.
- Aggressively disseminate all results to those who can use them through a variety of direct communication and outreach programs,
- Train the very finest future leaders in resource sustainability.

Our outlook is long term. The concepts and technologies that are needed will require the application of fundamental physics, chemistry and biology to understand petroleum accumulation. Likewise, the location of an ever more scarce resource will require new concepts for subsurface exploration. While politics and petroleum have always be intertwined, the increased move of many petroleum-rich countries toward nationalization makes understanding global movements and pressures particularly timely. We commit ourselves to addressing the grand challenge of resource sustainability through basic science, technology transfer and first-rate student education.

The advantages to the State of Texas are clear. We are home to many of the largest publicly-traded petroleum companies. Consequently, we anticipate even greater support and interaction with them as we together address the problems of sustainable resources. In addition, Texas has its share of water resource problems and, in common with many western states, is perpetually facing conflicts from the local to the international level. By establishing this highly visible multidisciplinary program, Texas A&M will better elicit the support from important segments of our economy to solve problems of interest not only to our State but also the global community.

### ***8b. College Expertise***

Nearly since the inception of the petroleum industry Texas A&M has been a leader in the science and technology of providing energy to the nation. At present, the College boasts over 30 faculty members engaged in research related to hydrology and petroleum geoscience, broadly defined. We enjoy excellent working relationships with our colleagues in industry and government and will strengthen these through this Program.

Some of this effort would build on the strengths of the International Ocean Drilling Program (IODP) and the Ocean Drilling and Sustainable Earth Science (ODASES) Program. Texas A&M University presently has a leadership role in the Earth Sciences through IODP and ODASES; fully integrating Ocean Drilling with the Energy-Water Challenge would expand the College of Geosciences' leadership into broad issues of water and other resources critical to society's future.

### ***8c. University Collaboration Potential***

The potential for collaboration and Texas A&M University is strong. The core of the program will consist of researchers in the Departments of Geology and Geophysics, Petroleum Engineering, and Civil Engineering addressing fundamental scientific questions surrounding the exploration and extraction of petroleum in the framework of finite water resources. Because of the latter political issues, a strong part of the program will be public policy. We anticipate involving colleagues in Political Science and Economics to address constraints on implementation of best practices for exploration, extraction and water use.

### ***8d. Funding Opportunities***

The Department of Energy, Department Homeland Security and the National Science Foundation currently fund work in the areas of interest to us in this Program. However, petroleum companies and both state and federal governments are keenly interested in devising plans by which resources are equitably used for the long-term. Given the excellent relationship between Texas A&M and our petroleum colleagues, we anticipate significant support from them as the resource becomes scarce and opportunities for exploration internationally shrink.

### ***8e. Plan with Limited or No New College Resources***

With no college resources, we anticipate a somewhat longer ramp up to both acquire the funding and research staff to conduct and grow the programs that we envision. Our goals will not change although the scope and rate of progress will be reduced. The immediate need would be for some common office space, research scientist and postdoctoral positions to aggressively pursue funding opportunities.

### ***8f. Plan Forward with Additional College or University***

#### ***Resources***

College resources would allow us to speed up our pursuit of funding, and place a down payment on staffing needs. In order to coordinate a multidisciplinary program such as we envision, it will be necessary to have common space, shared research scientists and students in order for a meaningful collaborative environment to be built.

One important collaborative facility would be a Center for Scientific Drilling and Earth Exploration. The center would consist of the following elements: a. Regional core and data centers – Maximizing our resource efficiency and research potential by providing an integrated infrastructure for core and data collections; b. Analytical scientific laboratories – Build the nation's premier state-of-the-art facility for core archiving and physical and chemical analysis. Become a one-stop shop for the study of the Earth's subsurface; c. Teaching facilities - Build upon the successful teaching programs such as the Teacher at Sea and the School of Rock to bring the scientific drilling experience and its science to students and teachers at all levels, from k-12 through graduate school; d. Technological development center – Take advantage of Texas A&M's unique position as the home of the world's premier scientific drilling program and the nation's best Petroleum Engineering program to develop and commercialize new drilling technologies for an energy hungry world. Such a Center would better position TAMU for renewal of IODP in 2013 by demonstrating TAMU's commitments and vision through the building of infrastructure, programs, and synergy, and would provide an alternative research and teaching strategy, not solely dependent upon a single funding stream, that builds upon existing resources.

## **9. Next Steps**

The new research initiatives described in Sections 5 through 8 describe activities with major participation from multiple departments and units within the College of Geosciences. Each could potentially move forward in some fashion with participation exclusively within the College, but each has been designed with broader problems in mind that require broader participation throughout the University.

The Texas A&M University Research Roadmap process provides an excellent immediate mechanism for identifying and establishing these broader collaborations. The four Geosciences research initiatives were proposed and developed by faculty members rather than administrators. These faculty members have reported that one or more white papers will be produced for each of the four research areas. College administrators will assist faculty in identifying possible collaborators among other colleges and within the context of other white papers that have been proposed. Should one or more of the research initiative ideas in this document become one of the five or six areas of emphasis in the Research Roadmap, the College will evaluate its commitment and plans in light of the broad commitment being made by the University and the excellent possibilities for joint projects and shared facilities.

Other College research initiatives will, inevitably, not attain the rarefied status of University initiatives. For these, the College of Geosciences should take action both internally and externally to facilitate these interdisciplinary ideas and help them to grow into sustained research foci.

For broad research themes to take hold, it is critical for the individual researchers to know and trust each other. Toward that end, the College of Geosciences will consider sponsoring joint seminar series with other colleges. Each series would be focused on one of the research initiatives, and would include multiple short presentations from members of different colleges to maximize cross-college interaction.

Broad research themes, to be successful and self-sustaining, typically involve large multidisciplinary research projects such as NSF Science and Technology Centers or the equivalent from other funding agencies. Such multidisciplinary proposals are difficult and time-consuming to write. The College already sponsors a portion of an FTE devoted to (primarily large) proposal preparation for the College. In addition, the College of Geosciences will consider offering faculty leave time for major proposal preparation, perhaps with salary support from an endowment designated for that purpose.

Another important way that the College of Geosciences can help establish interdisciplinary research programs is through hiring plans that span multiple departments. This Research Plan bears the strong mark of the success of recent hiring plans associated with the faculty reinvestment and the International Ocean Drilling Program renewal. The College has hired approximately 30 new faculty members in four theme areas: climate change; oceans, atmospheres, and human health; environmental and hydrologic sciences; and ocean drilling and

sustainable Earth sciences. All four of these areas contribute strongly to most of the new research initiatives being proposed here. The College will consider to what extent future faculty hires should be favored in areas proposed and endorsed for multidisciplinary research initiatives.

The Dean of the College of Geosciences, Björn Kjerfve, is stepping down as of May 31, 2009, and presently the College is in the middle of a search for a new Dean. Major steps will not be taken by the College until the new College leadership is in place sometime in 2009. The extent to which the major research initiatives proposed here will be a focal point of College investment over the next ten years will be partly determined by the new Dean, in consultation with the rest of the College. In any event, this College Research Plan shall serve as a foundation for broad interdepartmental collaborations among faculty members over the next ten years.