

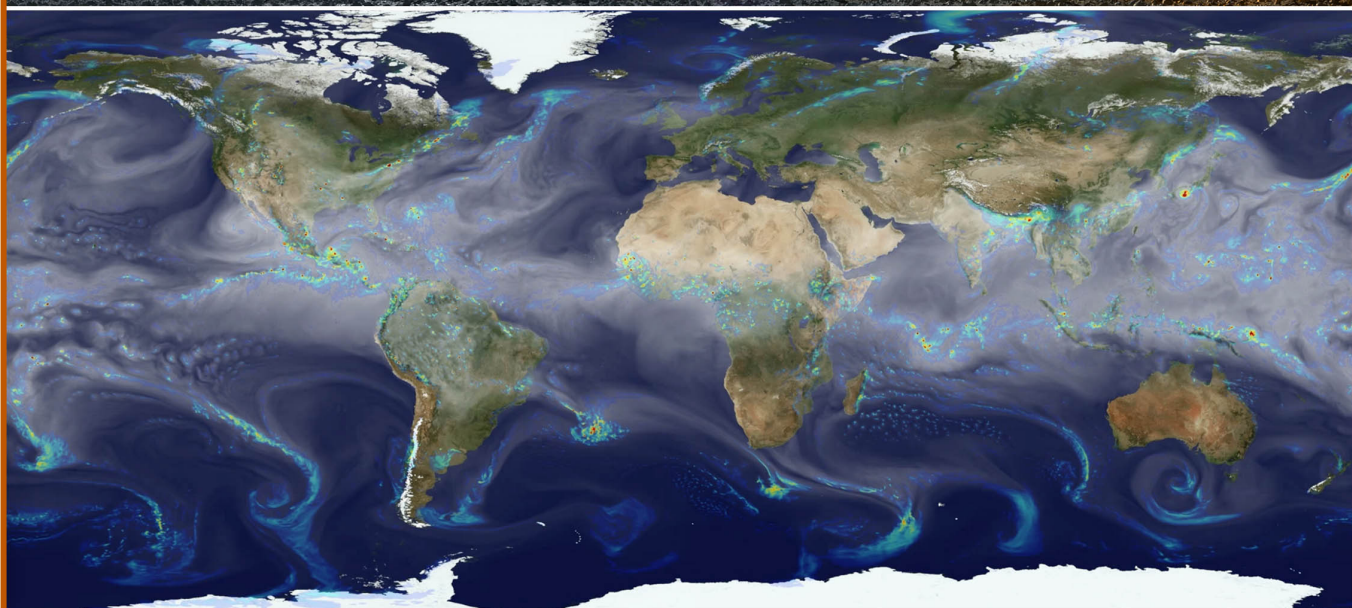


INSTITUTE FOR GEOPHYSICS  
THE UNIVERSITY OF TEXAS AT AUSTIN

# Science Vision

Executive Summary

2015 - 2025





## Understanding How Worlds Work

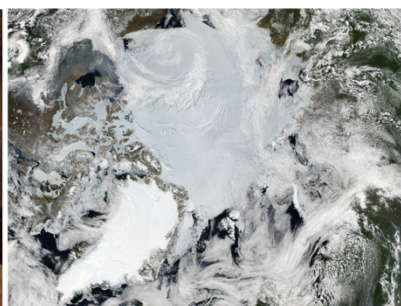
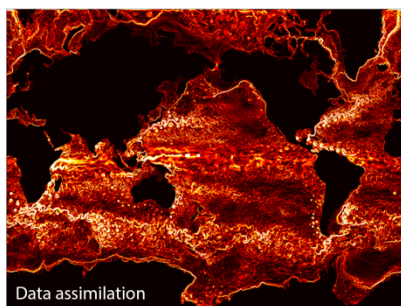
The next decade poses numerous challenges where society will look to geophysicists to provide answers to key problems. Earth is undergoing climate change while its inhabitants face a transformation in resource use and availability, and urbanization and global change will lead to increased exposure to catastrophic natural events. Using the Earth as a laboratory for geophysical processes on planets, we can also ask fundamental questions about the evolution and habitability of bodies across the solar system.

The University of Texas Institute for Geophysics, with its identity of combining daring expeditions and data analysis with state-of-the-art computing, has identified four major, interconnected research directions to address earth and planetary science questions of global significance in the coming decade. These initiatives in climate dynamics, polar and planetary geophysics, marine geosciences, seismology and tectonophysics, and energy geosciences provide a collaborative research environment where creativity can flourish and UTIG science will lead the community.

UTIG will bring a comprehensive geophysical campaign, experiment, and instrumentation development perspective to these problems with an international and entrepreneurial outlook. However, it is clear that these problems also cross disciplines, as does UTIG, and the Institute is fortunate to be able to rely on the additional resources of the co-located Bureau of Economic Geology and the Department of Geological Sciences at the Jackson School, along with other collaborators within the University of Texas at Austin, such as the Texas Advanced Computing Center.

In pushing to answer some of the key geophysical questions that face society, UTIG recognizes that a wide range of outlooks and backgrounds is an institutional and community strength. UTIG is also committed to educating the next generation of geophysical problem-solvers for academia and industry through the critical involvement of graduate students and postdoctoral fellows, coupled to substantive undergraduate research.

## Priorities and Opportunities in Climate Dynamics



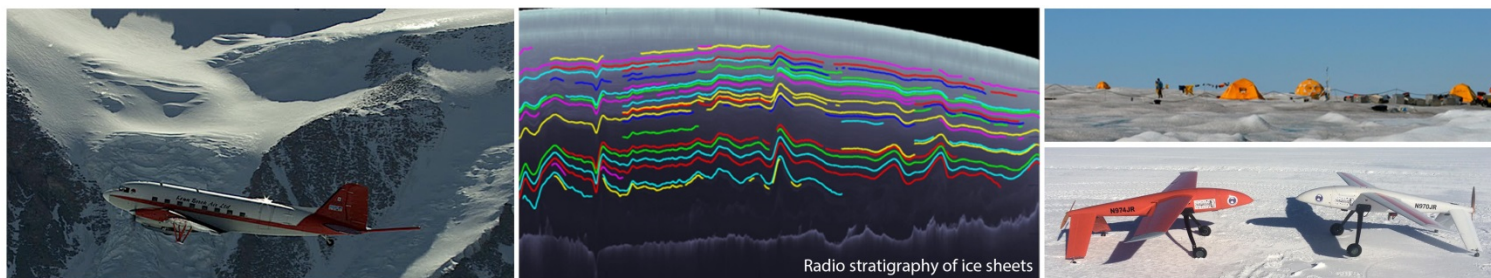
*UTIG is becoming a community leader in the use of global and regional data-assimilating climate and ocean models (e.g. snapshot of upper 16-meter ocean current from MITgcm/ECCO2 project, left) necessary to quantify global heat storage and transport to the polar regions susceptible to ice loss (right, NASA MODIS Rapid Response Team image of the Arctic). UTIG has established expertise with paleoclimate proxies, such as stalagmites (center), for climate reconstructions and constraints on hindcasts.*

**Climate Variability and Regional Climate Change** Understanding the basic dynamical mechanisms of climate variability is crucial not only for the regional climate prediction but also for detection and attribution of observed climate changes. A challenge is that instrumental records have been inadequate to fully characterize natural climate variability. In order to further our understanding of basic mechanisms and test model predictions, we need to be more creative with our strategies to observe and test hypotheses with instrumental and paleoclimate proxy data. UTIG is uniquely positioned to tackle this important scientific problem through the development of decadal resolved paleoclimate proxies and their interpretation in terms of theory and modeling.

**Water Availability** The global hydrological cycle is expected to accelerate over the next few decades as the water content of the atmosphere increases. Evaporation will increase, resulting in drying of subtropical areas and increasing precipitation in the deep tropics and higher latitudes. While models agree on these broad latitudinal patterns, they offer little consistency on the regional details of how rainfall will change. UTIG can contribute with the following approaches to increase our confidence in these model projections: improve our understanding of patterns of warming, improve the simulation of key climate variables such as the formation and dynamics of clouds, and quantify the full spectrum of rainfall variability, particularly on multi-decadal and centennial timescales using paleoclimate data.

**Bounds to Future Sea Level Rise** The potential exists for significant losses to Earth's ice sheets, which would lead to dramatic sea level rise. There are large uncertainties in potential rates of change in the ice sheets, largely because of hard-to-observe processes that govern melt at the ice-ocean interface and sliding at the ice-bed interface. In addition, polar atmospheres and the surface mass balance of ice sheets are affected by uncertain local and global cloud feedbacks. UTIG can play a significant role in addressing these uncertainties through its ability to field observational campaigns, exploit of geophysical data collection tools and interpretation, utilize data assimilation, and forward modeling of component systems.

## Priorities and Opportunities in Polar and Planetary Geophysics

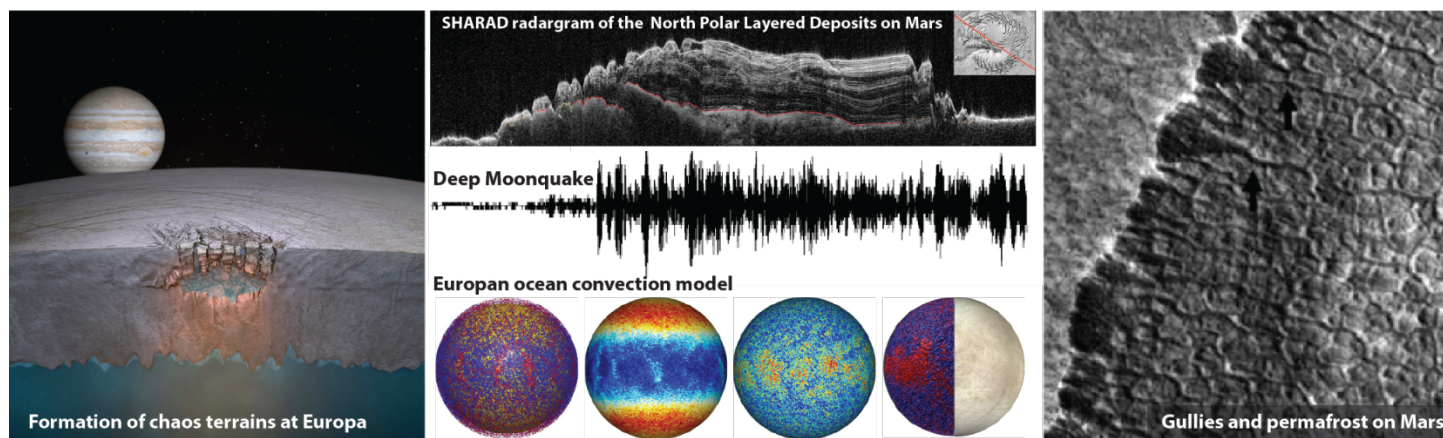


*UTIG is a leader in the acquisition and analysis of ground-based and airborne data to understand ice-covered lithosphere and water bodies. In the lab, UTIG develops piloted and autonomous fixed wing and rotary aerogeophysical platforms as well as instrumentation such as ice sounding radar and centralized data acquisition systems. In the field, UTIG leads science planning and operations for acquisition of diverse but complementary data. Our goal is to produce boundary conditions and perform monitoring activities for assimilation within regional and global earth system models.*

**Ice-Oceans Interactions** Interactions between ice sheets and their bounding oceans remain a critical community topic, and UTIG is poised to build on its legacy of leadership on this front. Expanding upon this, UTIG should broaden our expertise to include geological and hydrological controls on grounded ice evolution and ocean forcing on floating ice to better understand the ice sheet-ice shelf transition and its response to our changing climate. UTIG should also continue to support existing strengths in observationally-driven field and remote sensing science as well as lead the development and deployment of polar terrestrial/ocean observing networks, marine, and airborne research platforms. This research frontier synergistically expands and builds on the strengths of the UTIG climate dynamics group.

**Ice Sheet Mass Balance** UTIG should develop new expertise in the surface mass balance and runoff of water from the surface, subsurface, and base of the ice sheets. Negative surface mass balance and runoff plays a role comparable to marine ice discharge in governing Greenland Ice Sheet change. Surface melt and runoff will increase in importance along the Antarctic Peninsula and potentially West Antarctica as the climate warms.

**Biogeochemistry** UTIG should identify the connections between surface and subsurface processes pertinent to biogeochemistry, including carbon and sulfur cycles, climate modeling, hydrocarbons, terrestrial-atmosphere interactions and ice-ocean interactions.



*UTIG is building the foundations to lead the next generation of planetary missions, instruments, and discoveries. We use the tools of mission science related to radar sounding and seismology, terrestrial analog observations, and geophysical modeling to study planetary systems. In particular, we focus on processes relating to planetary cryospheres and hydrospheres, deep interiors, and shallow subsurfaces and specialize currently in problems related to Mars, Europa and other icy bodies, and the Moon.*

**Geophysical Processes in Planetary Bodies** UTIG should further develop its expertise in understanding the physical processes that control solar system objects and their implications for habitability. In addition to UTIG's traditional focus on the cryosphere/hydrosphere, deep interior, shallow subsurface, and impacts, new directions should build collaborations across the Institute and include: understanding crustal deformation, mantle dynamics, and core processes of other planets; understanding the processes that control planetary atmospheres, oceans, and ice shells/glaciers; and understanding the formation and release of clathrates on planetary bodies and implications for their physical and chemical environments.

**Planetary Geophysics across the Solar System** UTIG is well-poised to expand from our contemporary targets of the Moon, Mars, and Europa to include the other inner planets, the outer giant planets, additional ocean worlds such as Titan and Enceladus, dwarf planets such as Pluto and Ceres, and exoplanets.

**Mission Science, Terrestrial Analog Observations, and Geophysical Modeling** To address these challenges, UTIG will continue to use the large spectra of investigation techniques we have developed over the institute's history: radar sounding, seismology, and imagery technologies through expeditions to terrestrial analogs and participation in orbital, flyby and lander missions. UTIG should also further utilize existing mission data and numerical models to better understand geophysical processes of the solar system bodies.

# Priorities and Opportunities in Marine Geosciences, Seismology, & Tectonics



*UTIG applies an array of platforms and methods to address problems in marine geosciences, seismology and tectonics including IODP drilling (left), GPS reference stations (center), multibeam swath mapping, multi-channel seismic imaging, ocean bottom seismometers (cover image) and develops new avenues for acquisition with emerging tools such as Autonomous Underwater Vehicles (right).*

**Deep Earth - Surface Interactions** Planetary evolution is controlled by thermo-chemical mantle convection and the interactions between tectonics and the hydro- and biospheres. UTIG should harness its expertise to develop plate reconstructions for the last 500 Ma with full uncertainties and robustness estimates for a flexible range of geological and geophysical constraints. UTIG should also undertake the "first principles" modeling of thermo-chemical convection in Earth-like planets using large-scale computations including the mechanics of strain-localization, plate boundary formation, and deformation memory in continental plates.

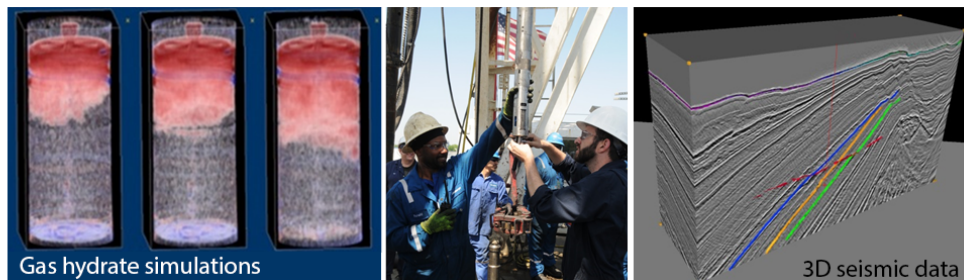
**Evolution of Oceanic Lithosphere** At spreading centers, UTIG should focus on how ocean crust forms with special emphasis on fault controlled hydrothermal circulation and vent distribution as well as fluid linkages to sub-seafloor processes. In addition, UTIG should elucidate lithospheric evolution from ridge to trench, emphasizing interactions via mantle convection with the underlying asthenosphere.

**Subduction Zones and Slip** Subduction zones are significant as a mechanism for crustal growth linking the crust with the mantle and one of the Earth's most violent natural hazards via large earthquakes and tsunamis. UTIG should focus on the subduction zone interface including where it is "locked" and the role of episodic slow slip and geofluids at this boundary.

**Geologic Record of Rifts and Passive Margins** Passive margins and rifts evolve at the intersection of climate, tectonics, and deep-earth volcanism, so UTIG should focus on using seafloor morphology and the sediment record to constrain the spatial and temporal scale of extreme events and natural hazards associated with passive margins and rifts including the role of geofluids and climate variability in triggering submarine slides.

**Natural Hazards and the Coastal Zone** The world's coastlines are characterized by rising sea level with the potential for hurricanes and tsunamis to have great impacts on both population and infrastructure. Because of this, UTIG should focus on investigating natural hazards and coastal sedimentary processes with an emphasis on establishing the "sediment budget" of a hurricane and the sustainability of the coastal barrier island system, including offshore sand migration.

## Priorities and Opportunities in the Energy Geosciences



*UTIG Energy Research spans the pore to the plate scale. Active projects relate to nano-pore systems, laboratory simulations of gas hydrate formation (left), development of new downhole measurement tools (center) and analysis of three dimensional seismic data (Gulf of Mexico depositional systems, right).*

**Frontier Exploration** UTIG will build on its strength in plate tectonic reconstructions and illuminate the next hydrocarbon-rich conjugate margin play area. Global warming is dramatically reducing Arctic ice cover which will open a largely unexplored environment. UTIG will also build on its deep historical understanding of Gulf Basin processes to pursue new carefully targeted field programs.

**Unconventional Resources and Induced Seismicity** UTIG is well poised to contribute to understanding of hydraulic fracture and its effectiveness in increasing production. Topics include flow behavior, permeability, and storage capacity of these systems; well instrumentation and seismic data observations, and monitoring water-injection induced earthquakes, all coupled to geomechanical simulation.

**Big Data** UTIG should lead in combining disparate data types including surface geology, cores, time-lapse surface seismic, and Vertical Seismic Profiling, distributed acoustic sensors, distributed temperature sensors and microseismic data; understanding fracture growth through three-dimensional numerical simulations, seismic predictions, and seismological observations; and improve diverse, continuous real-time downhole measurements.

**Simulation** UTIG will build on its strength in large scale inverse problems and uncertainty quantification for the following: coupled thermo-geo-poro-mechanical modeling of basin evolution; poro-elastic seismic wave numerical simulations of wave propagation in reservoirs; simulation of genesis and production of unconventional reservoirs.