

## Introduction

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The scope of research facilitated by IRIS is truly remarkable. This section of the proposal provides an exciting scientific exercise: the assembly of a sample of the broad variety of topics directly influenced and enabled by IRIS facilities. As you look through the following “1-pagers,” observe not only the enormous progress that has been achieved in addressing many long-standing questions in geophysics, but also the large number of new areas of research that have begun since this exercise was last carried out five years ago. A few words of explanation are appropriate here. The 1-pagers have been divided up into several categories for the convenience of handling the more-than-200 entries. However, this categorization is arbitrary: many of the 1-pagers could easily be placed into several different categories, and there are many different choices of categories that could have been used. In addition, a set of five “2-pager” essays are included in order to provide some context for understanding the broad diversity of research within some of these topics, and of the critical role that IRIS has played within them.

### *Earthquakes*

The value and importance of IRIS was never better demonstrated than with the success in recording and disseminating high-quality data from the Sumatra-Andaman earthquake of December, 2004. This earthquake and the devastating tsunami it caused captured the whole world’s full attention. The rapid availability of GSN data demonstrated to world governments that a real-time tsunami warning system could have saved more than a hundred-thousand human lives, and is providing the basis and justification for new tsunami warning systems in both the Indian and Atlantic Oceans. A fundamental part of IRIS-facilitated research will continue to focus on earthquakes and understanding the rupture process. This is important, not only for providing the best advice for earthquake hazard mitigation efforts, but also for addressing fundamental questions concerning seismotectonics, crustal deformation, and the state and composition of the lithosphere.

### *Monitoring Other Seismic Sources*

Lots of things make waves. An increasing number of studies are using IRIS data to examine sources that generate seismic energy other than earthquakes. An important part of this has been the ongoing efforts to improve our ability to monitor nuclear tests and other man-made explosions. The reasons include the political, making sure that there are no clandestine nuclear tests, and the forensic, trying to understand the causes of an accidental explosion. Scientifically, however, IRIS data have allowed for significant new discoveries in the interpretation of seismic signals that have traditionally been considered “noise.” The continuous low-level excitation of normal modes is now being analyzed in terms of interactions between the atmosphere, oceans, and solid earth. Array data are now being used to understand the connection between ocean storms and the ubiquitous microseismic noise. In volcanic regions, a new form of seismic tremor is being studied, and unusual CLVD sources may be related to caldera collapse. In glacial regions, PASSCAL experiments are examining the dynamics of glacial calving and of the seafloor scraping of giant ice sheets. There are now whole new areas of interdisciplinary research being pursued with IRIS data.

### *Signals and Systems*

For research to be done and for the public (and that includes governments!) to remain informed, it is vital for seismic signals to be generated, transmitted, processed, archived, retrieved, analyzed, interpreted, and the lessons learned distributed in efficient and standardized means. IRIS has, and will continue to play the leading role in the oversight of these activities for the field of seismology. This means that IRIS is involved in discussions on the creation of the next generation of seismometers. IRIS has been at the forefront of bringing satellite communications to many parts of the world in order to provide reliable real-time access to seismograms. IRIS is at the technological vanguard in the area of database management and web services in order to provide scientists with instant and user-friendly access to a huge amount of data. And through the E&O, IRIS is increasingly involved in distributing the scientifically, socially, and politically important information that has been obtained from the seismic data.

### *Surface of the Earth: North America*

“North American” seismology is at a very exciting point in time, gearing up for the deployment of the USArray component of EarthScope, which will rectify the long-standing lack in sufficient seismic coverage for most of the U.S. Several excellent recent PASSCAL experiments have made preliminary investigations of the lithosphere of North America, and as

is typical for a new area of research, have raised more questions than given answers. IRIS is providing and will continue to provide the guiding hand for USArray, and the data from this project will provide an important basis for addressing questions like the structure of fault systems, the current state of stress of the North American lithosphere, the composition and layering of the crust, the thermal structure of and the amount of water in the crust and mantle, the role of the subducting Farallon slab in the formation of the western U.S., the reasons that North America is moving westward, the connection between deep tectosphere structure and crustal geology, and the assessment of seismic hazards.

### ***Surface of the Earth: Global Studies***

There are as many 1-pagers studying the lithosphere outside of the U.S. as there are studying areas within it. This is a remarkable feat, given that funding for PASSCAL experiments goes to PIs who reside at universities within the U.S. Seismology is one of the most successfully international sciences, and this is a very important direction for IRIS to continue. IRIS PASSCAL research over the past 5 years has spanned all of the continents, including Alaska, and has addressed important geological questions such as the formation of mountains, the roots of cratons, and the evolution of continents. In the process, these experiments have forged important scientific and educational bonds between scientists of many different countries, to every country's benefit. IRIS is also playing an increasingly important role in the establishment of IRIS-like programs in other countries, sharing the technical and scientific knowledge that has been gained. One very important direction for continental studies has been in the use of telemetered arrays, such as in South Africa, where data are recorded and monitored for quality in a real-time mode, and this will likely see a greatly expanded use over the next several years.

### ***Upwelling and Downwelling***

Plate tectonics is the surface expression of mantle dynamics, and seismology is addressing the nature of vertical mass flow in several important directions. Because so many earthquakes occur within subduction zones, great advances are being made in using migrated array data to image the structures of plate collisions, increasing our understanding of water cycles, mineral phase changes, mantle flow, and magma generation in these regions. We are still missing a complete explanation for deep earthquakes, however, as rupture seems to occur outside of the cold wedge of the subducted plate. While seismic tomography has shown unequivocally that subducted lithosphere then proceeds to sink into the lower mantle, the question of how mass is returned to the upper mantle is still very actively debated, and the nature and ubiquity of hotspot mantle plumes is currently a topic for much discussion. Imaging mantle plumes is a challenge for seismology, due to a lack of seismic sources in most of these regions and to the process of waveform annealing through low-velocity regions. However, more creative ways of using the seismic wave field (e.g., finite-frequency sensitivity kernels, attenuation, anisotropic splitting for flow directions) have begun to allow for the identification of regions of upward flow between the lower and upper mantles, and these techniques will play an increasingly important part within future seismic analyses of mantle convection.

### ***Global Mantle Structures***

Whole-mantle seismic tomography is more than 20 years old, and for most of it the studies involved two elastic parameters. Current global studies are now quantifying the degree to which the mantle is neither isotropic nor elastic. This can be seen in the large number of 1-pagers in this section that involve either anisotropy or attenuation (and in some cases, both!). The mantle is now viewed not as a static onion-like layered spherical shell, but as a fluid, mobile body. Mantle discontinuities are not barriers, but rather dynamic phase transitions that are indicators of lateral temperature variations. Lateral variations in attenuation and anisotropy are being interpreted as indicators of mantle flow. For many years, seismic tomography provided us with a scalar field of three-dimensional variations in elastic parameters. Currently, however, the diversity of seismic techniques is moving toward providing all of Earth sciences with a vector field of mass flow, and therefore significant clues as to the history and evolution of plate tectonics.

### ***Core Mantle Boundary Region***

The very base of the mantle continues to be a remarkably rich area for seismological discovery, with a variety of structures and textures varying significantly over short distances. As such, seismologists are taking advantage of the close station spacing of PASSCAL arrays and regional networks in order to quantify these variations, and significant advances are being made using array migration techniques. It seems to be the case that we observe lateral variations at spatial scales as fine as we are able to resolve, reinforcing our idea that the core-mantle boundary is a thermal and chemical boundary layer that rivals

the surface in complexity. Perceptions of this region were greatly altered by the recent mineral physics discovery of the transformation of perovskite to a higher-pressure phase, leading to the possibility of a means of detecting lateral temperature variations and the strength of the thermal boundary layer. Another area of recent interest is the giant megaplume of seismically-slow rock that extends upward from the core beneath Africa, and many efforts are underway to interpret this in terms of mantle dynamics.

### ***Inner Core***

At 7/10 of one percent of the volume of the earth, the inner core attracts more than its fair share of attention because of its unusual nature. In spite of the remarkable challenge of viewing this small, frozen ball of iron across two passes through a very heterogeneous mantle, some very unusual results are emerging. The inner core has long been thought to be anisotropic, with an axis-parallel fast direction, but it now seems that this anisotropy may only occur in the eastern hemisphere, and below an isotropic layer at the inner core boundary. The means by which such hemisphere-scale variation could occur is still unclear, especially if conclusions about the inner core's super-rotation are correct. The big challenge for inner core studies is that there is poor geographical coverage of many parts of the inner core, particularly along axis-parallel paths, due to the distance requirements of PKP waves and the surface distribution of earthquakes and continents. With an increase in global station coverage, particularly in places like Antarctica, there will be significant advances in our understanding of the inner core in the near future.

### ***Education and Outreach***

We live in a challenging time for science education. The incredible expansion of media information provides many distractions and sources of competition for people's attention, particularly that of the students we would most like to reach. Science used to be able to rest upon the laurels of its inherent "coolness," but now realizes that it must communicate to the public at a higher level of sophistication and aggressiveness. In addition, there currently exists an unfortunate wave of anti-intellectualism that includes an anti-scientific attitude, tied to the focused agendas of certain political and religious interests. As the E&O 1-pagers show, IRIS is meeting these challenges across a wide variety of fronts, often taking advantage of the very technologies that can also be distractions. IRIS is involved with educating students, teachers, and the general public through web-based programs and services, museum displays, lectureships, video formats, teacher training workshops, school programs, teaching materials, curriculum development, and textbooks. Earthquakes are, and always will be, inherently "cool," but the IRIS E&O program is making sure in a wide variety of ways that everybody knows this.