Geo-Hazards Natural Laboratory for the Asia Pacific Arc and Western North America
Meeting Report, July 13th, 2004

An international meeting was held 24th to 26th May 2004 in Maui, Hawaii, to explore options for expanding several international Solid Earth programs into the larger framework of a Geo-Hazards Natural Laboratory for the Asia Pacific Arc and Western North America. This meeting topic falls within the larger context of Natural Laboratories worldwide, including discussions in Europe about the Alpine-Himalayan belt and the Mediterranean region. There were 33 participants from the U. S., Canada, Japan and Russia, including attendees with observer status from the American, Japanese and Canadian space agencies (NASA, JAXA and CSA). They met to (1) review the status of existing *in situ* networks and currently available remote sensing data sets; (2) determine what additional remote sensing observations are needed to achieve Natural Laboratory goals; and (3) draft recommendations to be forwarded to the international space agencies.

The purpose of this report is to briefly present the current status of Earth Science Natural Laboratory (ESNL) remote sensing, identify future needs, and recommend actions which will lead to fulfilling these needs. Recommendations are summarized immediately below and details follow in 3 subsequent sections.

Recommendations

• Recognizing the immense scientific value of the existing archives of satellite radar data to ESNL research worldwide, and noting their declining commercial value, we recommend that international space agencies make these data archives openly and freely available to the scientific research community.

• To address immediate needs in EarthScope and APANL study regions (broadly, western North America and the North Pacific Arc from Alaska to Japan) for satellite radar data and high resolution optical and digital elevation data, WinSAR and APANL Executive Committees should define initial acquisition priorities in a number of "pilot sites". They should communicate these needs, as well as their more extensive, longer-term requirements, to the international space agencies.

• To maximize the volume of acquired remote sensing data the international space agencies, working with the natural laboratories, should develop mechanisms to communicate needs and promote cooperative sharing of resources and capabilities to ensure adequate global coverage and acquisition of data at frequent sampling intervals over high priority targets.

• Geo-hazard scientists should work directly with international space agencies to communicate near real time imaging requirements and the feasibility of quicker data delivery for visible, TIR, and UV optical images and InSAR geodetic imaging needed for short-term volcano eruption forecasting and eruption plume tracking.

• International space agencies should work cooperatively with the geo-hazard science communities to plan and implement a dedicated InSAR mission for the detection of crustal deformation and land surface change.

I. Earth Science Natural Laboratories (ESNL)

The ESNL concept provides a unifying theme under which research on earthquake, volcano and landslide geo-hazards may be studied. An ESNL is a geographical region designated for the study of Earth processes through detailed field observations and *in situ* measurements. Familiar examples include the Hawaiian volcanic complex, the Japanese subduction system, southern California's active faults, the Africa-Europe collision zone in the Mediterranean region, and the Indo-Eurasian collision zone of the Himalayan-Tien Shan mountain ranges.

In the broadest context, the worldwide distribution of plate boundary deformation zones and regions of mid-plate volcanism like Hawaii constitute Earth's true natural laboratory. Particular portions of this Earth-girdling system may be profitably cordoned off for detailed study. However, the interactive nature of the global system and the broad range of behaviors observed at particular sites mandates a global approach to ESNL studies. It is the global nature of the problem that makes satellite remote sensing uniquely suited to contribute to ESNL research through (1) long-term site-specific monitoring; (2) broader regional characterization; and (3) globally synoptic studies of comparable environments. Participants also identified a need for quick-response, high spatial resolution data, as might be provided by airborne systems.

The importance of ESNL programs to Earth Science and geo-hazards research was recognized in the 2001 U.S. National Research Council report, *Basic Research Opportunities in the Earth Sciences,* that recommends "establishment of an ESNL program, open to all problem areas and disciplines, to support multi-disciplinary research at a number of promising sites in the United States and its territories." Apart from a U.S. national perspective, the ESNL programs can strengthen the geohazards approach of the Integrated Global Observing Strategy (http://dup.esrin.esa.it/igos-geohazards/theme.asp) by focusing ground-based observations, space-based sensors, and international intellectual resources upon regions and geohazards of significant scientific and social importance. In this context the ESNL concept also supports the European Space Agency's program of Global Monitoring Environment and Security (GMES) (http://www.gmes.info/) by helping to develop the analytical tools, the intellectual resources, and the operational infrastructural resources necessary for a truly international and global management of geohazards and natural disasters.

There is a strong recognition within the geohazards research and disaster management communities of the importance of space-based remote sensing techniques. Unfortunately, in recent years the availability of these data has been limited to various extents and for varying reasons. In an effort to identify and meet the growing needs of geo-hazards research and disaster management the Maui meeting addressed the development of a pilot program of enhanced data availability that might be applied to all geo-hazards natural laboratories. Meeting participants were encouraged to focus

particular attention to the remote sensing needs for the Asia-Pacific Arc Natural Laboratory (APANL) and the western North America EarthScope study region as pilot models for the support of geo-hazards natural laboratories by the international space agencies. Briefly put, these two ESNL projects seek further understanding of earthquake and volcano processes and the hazards they pose through multi-disciplinary observation, analysis and modeling. Readers seeking further detail on the EarthScope and APANL projects are referred to their two websites (http://www.earthscope.org and http://www.asiaoceania.org/proposals/iwg/iwg3b.html). These and other ESNL sites worldwide are regions of intense ground-based geological and geophysical observations and burgeoning remote sensing programs.

In summary, there is a clear recognition of the importance of the ESNL concept and a unique niche the international space agencies can fill in furthering ESNL programs.

II. The Importance of Remote Sensing Data Sets

Topical research projects carried out in many of the world's ESNL regions use remote sensing data as well as ground-based measurements to fully characterize earthquake and volcano hazards and their associated geo-hazards. These remotely sensed data support

- Basic research studies,
- ESNL site characterization
- Focused monitoring with an immediate goal of hazard assessment.

Remote sensing supports basic research in disciplinary studies (e.g., SRTM topography and Landsat 7 images for fault or volcano mapping) and is itself a central data source in focused topical studies (e.g., using ERS, JERS or Radarsat1 satellite radar for interferometric (InSAR) mapping of surface ground displacement to image earthquake fault slip).

Site characterization ranges from regional mapping to very local studies. For example, Landsat 7 images in conjunction with higher resolution optical images (e.g., Spot, QuickBird, and Ikonos) are used to construct geologic maps at a range of scales. The stacking of many InSAR interferograms has permitted regional mapping of earthquake-related elastic strain accumulation in several areas within the EarthScope ESNL as well as in Turkey and central Asia. Site-specific InSAR imaging can be used to map landslides on local scales.

Thermal IR and UV imaging plays a crucial role in monitoring the more than 100 active volcanoes of the North Pacific for geohazard assessment. APANL scientists at the Alaska Volcano Observatory (AVO) and elsewhere routinely use MODIS, AVHRR, ASTER and Hyperion data to monitor for evidence of impending eruption and production of ash clouds that may be hazards to aircraft within the busy North Pacific aviation corridor. Longer term monitoring of surface deformation using InSAR mappings have been used to pinpoint current unrest and evidence for emplacement of magma or magmatic fluids in the upper crust beneath volcanic edifices in Sicily as well as in the Aleutian, Cascade and Andean arcs.

III. Future Needs for Remotely Sensed Data

Having agreed upon the importance of continued and enhanced access to remote sensing data for the objectives of the natural laboratory. **The attendees made five specific recommendations regarding**

- **Access to existing data archives;**
- **New data acquisitions from current and future missions;**
- **Advocacy and planning for future missions.**

Access to Existing Data Archives:

Aging radar remote sensing data archives are of declining commercial interest but are often of great scientific value. In particular, the existing archive of satellite radar data accumulated over the past 12 years by ESA, JAXA and CSA represent a valuable and only partially tapped resource. Although these archives are nominally open to research users they are not cost free, with charges ranging from less than $US 25 to as much as $US 4,000 per scene. Since individual research projects typically require as few as 20 to as many as several hundred scenes, access to data ranges from merely daunting to effectively impossible. In either case the result is that scientific research is slowed and progress in geo-hazard assessment suffers. It is recognized that some classes of remote sensing data have commercial value and space agencies sell these data to partially recover mission costs. However, it is also true that as newer and higher quality data become available the old archives have an ever-diminishing commercial value. For scientific purposes longer archives are often the most useful, so while their commercial value declines their scientific value increases.

> **Recommendation 1:**
> ***Recognizing the immense scientific value of the existing archives of satellite radar data to ESNL research worldwide, and noting their declining commercial value, we recommend that international space agencies make these data archives openly and freely available to the scientific research community.***

New Data Acquisitions from Current and Future Missions:

Given the worldwide scope of ESNL research and geo-hazard assessment and its requirement for frequent repeat pass imaging, new satellite missions offer the potential to greatly expand the volume and quality of available data. However, many satellite platforms support multiple sensors and/or operate in multiple modes tailored to diverse scientific objectives. Furthermore, data volume is often constrained by limited onboard memory and power or by available downlink sites.

To begin addressing ESNL needs while recognizing current data acquisition realities, EarthScope and APANL scientists need to carefully stage their new acquisition requests, define initial priorities, and engage the international space agencies in constructive dialogue to achieve both their immediate and long term goals. EarthScope's remote sensing needs, especially for satellite radar data, can best be addressed by the Executive Committee (EC) of WinSAR, the western U. S. InSAR consortium, in conjunction with Canadian colleagues. The APANL EC can perform the same role for the North Pacific

region. Cooperation with international groups studying the Earth's other natural laboratories will in addition lead to advances worldwide in anticipating and responding to geo-hazards and the effective utilization of remote sensing data sets.

Recommendation 2:
To address immediate needs in EarthScope and APANL study regions (broadly, western North America and the North Pacific Arc from Alaska to Japan) especially for satellite radar data but also for high resolution optical and digital elevation data, WinSAR and APANL Executive Committees should define initial acquisition priorities in a number of "pilot sites" and communicate these needs, as well as their more extensive, longer term requirements, to the international space agencies.

Data acquisition volumes may be limited by the resources available to an individual national space agency, for example too few ground sites to downlink data from satellites with necessarily finite on board data storage. Developing better communication mechanisms among space agencies can lead to better understanding of such limitations and needs, and foster the sharing of resources to better optimize data acquisition.

Recommendation 3:
To maximize the volume of acquired remote sensing data the international space agencies, working with the natural laboratories, should develop mechanisms to communicate needs and promote cooperative sharing of resources and capabilities to ensure adequate global coverage and acquisition of data at frequent sampling intervals over high priority targets.

Effective geo-hazard assessment often depends crucially on data that are accessible in near real-time. In particular, volcanic eruptions often result from very rapid (hours to days) transport of magma from mid-crustal depths to Earth's surface. The importance of timely transmission and analysis of all monitored data (e. g., seismic, geochemical, thermal, ground deformation) is widely recognized. All remotely sensed data are important in this regard, but more timely direct-transmission of IR, UV, and optical images would be especially valuable to volcano observatories with hazard monitoring missions.

The natural laboratories should pursue the development of standards, software and systems to promote the effective transfer and utilization of remote sensing data with the objective of near real-time data access to new data acquisition and archived data sets alike. Likewise the natural laboratories should promote the development of a distributed computing environment and analysis capability to effectively synthesis and understand the ground and remotely sensed data sets.

Recommendation 4:
Geo-hazard scientists should work directly with international space agencies to communicate near real-time imaging requirements and the feasibility of quicker data delivery for visible, TIR, and UV images and InSAR geodetic

imaging needed for short-term volcano eruption forecasting and eruption plume tracking.

Advocacy and planning for future missions:

A widely perceived need within the earthquake and volcano science communities is a dedicated InSAR satellite tailored to the requirements for monitoring of the entire global plate boundary deformation zone. Major advances in scientific understanding and geo-hazard assessment have occurred during the past decade using radar satellites neither designed nor optimized for InSAR imaging. However, neither the quality of the available data nor its limited quantity satisfy geo-science and geo-hazard needs. Nor are these requirements satisfied by the radar missions due to fly during the next several years. During the past 8 years, several independent attempts in Europe and the United States to promote and finance such a dedicated InSAR mission have been unsuccessful. A recent NASA-sponsored report by the Solid Earth Science Working Group (SESWG, 2002), *Living on a Restless Planet*, makes, as their top recommendation, establishment of "A single dedicated InSAR satellite operating at L-band, with left/right looking capability and weekly access to anywhere on the globe". It is time for the international space agencies to work cooperatively with the scientific community to plan and implement such a mission.

Recommendation 5:

International space agencies should work cooperatively with the geohazards science communities to plan and implement a dedicated InSAR mission for the detection of crustal deformation and land surface change.