Workshop Report:

Leveraging USArray: Opportunities for Onshore/Offshore Experiments
and
USArray and EarthScope Science in Alaska

I. Overview

Two related pre-meeting workshops were held on May 12, the day before the 2009 EarthScope National Meeting in May 2009. The objective of "Leveraging USArray: Opportunities for Onshore/Offshore Experiments," held in the morning from 9-12, was to discuss the potential contributions of offshore seismic instrumentation towards achieving EarthScope objectives at the edges of North America. After a joint lunch, a workshop on "USArray and EarthScope Science in Alaska" was held to discuss EarthScope scientific targets in Alaska, with a focus on planning for the upcoming USArray deployment there. The workshops were linked because of their synergistic scientific themes. Alaska was one of the three regions targeted by the onshore/offshore group, and any discussion of scientific targets in the coastal regions of Alaska should consider how offshore data could contribute. The common interests between the two groups were reflected in the large number of participants who attended both workshops.

Workshop Organizers: Leveraging USArray
Dayanthie Weeraratne, Cal State University Northridge, Northridge CA.
Anne Trehu, Oregon State University, Corvallis OR.

Workshop Organizers: USArray and EarthScope Science in Alaska
Jeff Freymueller, University of Alaska, Fairbanks AK.
Douglas Christianson, University of Alaska, Fairbanks AK.

II. Leveraging USArray

II.1 Overview of meeting objectives

The need for this workshop was first identified based on the enthusiastic display of scientific interest from the seismological community at an impromptu Special Interest Group meeting at the bi-annual IRIS workshop in June 2008, organized by Dayanthie Weeraratne and Jim Gaherty an attended by ~20 scientists (standing room only!). The objectives of this workshop, which attracted 45 participants, were to:

Identify the scientific goals and objectives aligned with the USArray EarthScope program that can be uniquely addresses on the continental margins of North America.
Show how offshore seismic instrumentation will contribute to these scientific goals.
Discuss the quality of seismic data and the coverage required to meet these objectives.
Outline the instrumentation needs for obtaining high data quality data on the continental shelf and in fresh water lakes.
Identify costs for necessary instrumentation and potential funding sources such an MRI

proposal.

These objectives were discussed in the context of USArray's approach in the coming years to the Great Lakes, the Gulf of Mexico, the U.S. East Coast, and Alaska.

II.2 Summary of meeting presentations and discussions:

II.2.a – Facilities overviews

Greg Anderson (NSF - EarthScope program manager) presented a summary of the recently announced plan to increase the OBS pool as part of the 2009 economic stimulus package. These instruments will initially be used as part of a community experiment in Cascadia, with details of the experiment plan to be determined at a workshop on June 30-July 1, 2009. After the initial deployment in Cascadia, these instruments will be available to support other good science experiments on a competitive basis, including proposals to extend USArray offshore in the Great Lakes, Atlantic continental margin, and Alaska. Some of these instruments may be designed specifically for shallow water deployments, thus avoiding some of the problems related to high noise levels or fishing activity that affect the current instruments in the OBS pool.

His presentation was followed by considerable discussion. Bob Detrick pointed out that the Cascadia initiative is not the only option available for extending USArray offshore. Other options include instruments from the existing OBS pool. Adam Schultz asked whether efforts were being coordinated with the Ocean Observing Initiative (OOI). Bill Leith informed the group that USGS was planning 3 demonstration projects – in Southern California, the Pacific Northwest, and the mid-continent – and was coordinating with NSF. In response to a question, Greg Anderson indicated that EarthScope was also coordinating with the Canadians for studies of Cascadia, the Great Lakes, the East Coast and Alaska.

Bob Woodward (IRIS – USArray program manager) summarized the current status USArray and the timetable for the future. To date, almost 800 stations have been commissioned. Map of quarterly station migration plans includes ~50 stations in SE Canada in 2012 for total of ~75 stations when integrated with the Canadian Polaris array. Flexarray stations are heavily committed through 2010, but station availability is good after 2010.

Adam Schultz (Oregon State University – USArray-MT manager) summarized the status of the magneto-telluric component of USArray. The transportable array component of this effort consists of ~50 stations/yr. Each station is occupied for ~3 wks. Because of the shorted recording time, USArray-MT can cover the continent with similar spacing using fewer instruments. However, the current plan, which goes through 2010 and includes Yellowstone, Montana and Wyoming, does not include covering the

entire region covered by USArray. Preliminary results from USArray-MT in the Pacific Northwest have recently been published by Patro and Egbert (2009). Intriguing correlations and anti-correlations are observed between electrical resistivity and seismic velocity (Roth et al., 2009).

Steve Constable (Scripps Institution of Oceanography; presented by Adam Schulz) summarized the status of offshore magneto-telluric instrumentation. WHOI and SIO both have instruments: WHOI instruments are optimized for mantle work whereas SIO instruments are optimized for shallower targets. SIO has a pool of 150 instruments and can deploy up to 25 instruments in one day and recover 25 in one day. WesternGECO has constructed a similar number of instruments for exploration work. Offshore EM is 600-million/yr industry – useful for finding oil. A USArray-type offshore deployment of 160 sites at 20 km spacing deployed for several days or weeks would cost ~$366K to deploy plus 35 days of ship time (~1.2 million)
Mike Jackson provided an overview of the Plate Boundary Observatory (PBO), including the GPS backbone, portable pool of GPS instruments, borehole strain meters and GeoEarthScope.

Doug Toomey (University of Oregon - chair of the NSF Ocean Bottom Seismometer Facility Oversight Committee) described the opportunity for OBS construction provided by stimulus funds. He discussed possible deployment schemes to introduce the question of whether long-term deployments in shallow water (<1000m) were needed. Shallow water deployments may require modifications of current instruments to mitigate the effect of bottom currents and fishing. The tradeoff between instrument cost and total numbers for broadband and intermediate period sensors was also discussed. At present, the broadband OBS pool is fully booked through 2010, with 24-32 instruments booked through 2011. **Jim Gaherty** continued the discussion by showing some preliminary work done by the instrument centers to shield instruments to make them resistant to bottom trawlers and currents, addition of accelerometers, near-shore buoyed telemetry, the possible use of ROVs to recover buried sensors, and other technical issues related to OBSs.

Geoff Abers (Lamont-Doherty Earth Observatory – chairs of the NSF MARGINs program steering committee) summarized the MARGINS program, which began as a decadal program in 2000. The external decadal review committee, which met in February 2009, has recommended a successor program that will be significantly different from the current program. In particular, the decadal review recommended that passive (as well as active) margins be studies, that the focus site concept be continued but that it be flexible enough to have new sites gear up as old sites wind down, and that MARGINs collaborate more closely with other large facilities like EarthScope, OOI and IODP. He also pointed out that there is considerable overlap between the EarthScope and MARGINS communities, and suggested that MARGINS and EarthScope continue co-funding workshops and coordinate development of science plans and the Cascadia facility.

II.2.b Science objectives:

Dave Dolenc (University of Minnesota Duluth - shown by Bob Woodward) discussed structural issues related to the Midcontinent rift and coupling of infragravity waves into the lakebed. A proposal has been submitted to NSF to instrument Lake Superior while USArray is in the region (201x). However, it was not funded. During the ensuing discussion, it was noted that the Ocean Bottom Seismometers in the current instrument pool might not be suitable for this experiment because they depend on an acoustic release that triggers an electrical current in a burn wire for instrument recovery. However, ocean bottom seismometers with an acoustic/mechanical release mechanism have been successfully deployed in Lake Superior in the past.

Yev Kontar presented a proposal to image fault systems in Lake Michigan and discussed applications of seismic imaging to carbon sequestration.

Summary of science objectives in the Great Lakes:

Is there a signature in the upper mantle of extensive magmatism associated with the mid-continent rift? Lake Superior overlies the Mid-Continent Rift. GLIMPSE (Great Lakes Interdisciplinary Multi-institutional Program for Seismic Exploration), an active source seismic experiment held in
Is coupling of infragravity waves into the lake bed a major source of seismic noise?

Jay Pulliam discussed scientific objectives along the margin of the Gulf of Mexico. In spite of many years of seismic imaging for oil exploration in this region, fundamental questions about rifting along this margin remain. One important question is whether through-going lithosphere faults lead to focusing of extension. It has been speculated that the Balcones fault system onshore may be the main boundary fault for the Gulf Coast. Other questions are whether there is feedback between sedimentation and extension and whether uplift around rim is due to sediment loading. Good constraints on timing of loading of loading are available, which, when combined with new information on lower crustal and mantle structure that could be obtained by an onshore/offshore broadband array, could be used to test geodynamic models of rifting in this environment.

Multidisciplinary proposals for combined active/passive/seismic/MT data acquisition are being proposed. An active source onshore/offshore transect that includes 33 OBSs has been proposed to industry, and plans are being developed for a broadband component.

Beatrice Magnani continued the discussion of the Gulf of Mexico continental margin. She pointed out that the Mississippi Delta is subsiding at a rate that is normal for delta subsidence; however, delta shoulders in Alabama and Texas are not subsiding. Why? GPS observations suggest that the Mississippi delta is sliding offshore on a large fault. Relationship of this activity to deeper structure is unknown since very little is known about the crust in this area. Scattered wave crustal structure suggests that the ocean/continent crustal boundary may actually be onshore.

Summary of science questions in the Gulf of Mexico:

Where is the continent/ocean boundary?
Was there a feedback between sedimentation and focusing of extension, as has been suggested for the Gulf of California?
What is the structure of the lower crust and upper mantle in this region?

Karen Fischer discussed offshore science targets along the Atlantic Coast. The Atlantic margin records the history of lithospheric evolution through the Wilson cycle. Among questions to be addressed are: the structure of old oceanic lithosphere; ocean/continental crustal mass balance; the geometry of the suture between Laurentia and Gondowana lithospheres. Was G/L suture a weak zone that acted as pathway for magma? Is there a relict signature in the mantle corresponding to the source of region for the magma that formed the rift pillow that has been documented beneath the margin? Was rifting driven by a mantle plume or by edge-driven convection? On a larger scale, offshore measurements are needed to address fundamental questions about the ocean/continent transition. What are the contrasts in thickness, viscosity between continental and oceanic mantle lithosphere? Are they large enough to result in edge-driven convection? Is the oceanic plate still cooling >160 MA? A proposal is being prepared for one possible instrument configuration to address these questions through active source and passive broadband seismic recording.

Summary of science questions on the Atlantic continental margin:

What is the structure of old oceanic lithosphere?
What is the geometry of the suture between the Laurentia and Gondowana lithospheres?
Is there are relict structure in the mantle that indicates the source region for melt that formed the rift pillow

Jeff Freymueller discussed science targets in Alaska. He pointed out that most of the subduction zone boundary is offshore. This boundary is very active, generating a magnitude 8 event every 13-14 years and displays distinct locked and creeping segments. The boundaries may be correlated with a number of different observables including: reflectivity of the plate boundary (as reported for Cascadia); seismic velocity variations in overriding forearc crust (as reported for Japan, New Zealand); seamounts and other downgoing plate structures (as reported for Costa Rica and Nankai); variations in slab geometry; and variations in magmatism (central segment has more basalt). Changes in subduction style do not correlate with continent/ocean transition in the upper plate. Are they due to variations in the mantle wedge or in deep arc structure? Almost all problems require more than a linear array. Active source imaging of the forearc needed (not much new data since the 1980s).

Summary of science questions offshore Alaska:

How is apparent segmentation of large earthquake activity along the arc manifested in offshore microseismicity, tremor activity and forearc structure?
What is the deformation offshore? Is there slow slip and/or elastic strain accumulation? How can offshore deformation be measured?

What does crust and mantle structure in the Bering Sea indicate about the process of assembling the lithosphere of Alaska?

II.2.c. Special considerations for offshore seismic work:

Spahr Webb discussed more details of LDEO efforts towards 1) developing an ocean bottom seismometer suitable for shallow deployments and 2) high-resolution measurements of seafloor pressure for seafloor geodesy. He pointed out that a deployment scheme that uses trawl mounts and a small ROV for recovery can be cost-effective because the cost of the ROV is balanced by lower costs for the instrument package, which does not need expensive flotation and release systems. He also reported on his recent experiments with ultra-high resolution Paros seafloor pressure gauges. For geodetic work, Scott Nuetter is close to getting accuracy of ~1 cm for measurements of vertical displacement.

Jeff McGuire showed data from recent ocean bottom seismometer (OBS) experiment on the Gofar transform fault, which involved 10 short period and 20 broadband OBSs from the Ocean Bottom Seismology Instrument Program (OBSIP) and10 instruments equipped with both broadband seismometers and strong-motion accelerometers that were developed with funding from the Keck Foundation and belong to WHOI. He clearly showed the importance of having accelerometers on OBSs deployed in an active fault zone. A magnitude 6 event occurred in middle of array during the deployment, and the OBSIP instruments clipped for events with magnitude >4.0 and then took a significant amount of time to recenter and relevel the seismometers. The accelerometers, on the other hand, remained on scale for even this large event, providing unique data on rupture propagation along an oceanic transform fault.

Bob Busby described a hypothetical experiment that would extend USArray across the entire Atlantic Ocean.

Doug Weins showed comparisons between Lamont L4 semi-broadband OBSs and stations deployed on land. Vertical component OBS data compare favorably to onshore data and can be successfully used for applications like P and S tomography, attenuation tomography, Rayleigh wave tomography and long-period waveform inversion. Coupling for the horizontal components remains problematic, which limits the use of OBSs for applications like Love wave analysis, high frequency receiver functions and noise correlations. Doug showed an example of successful P-wave attenuation tomography from a combined onshore/offshore dataset.
He also emphasized that need to build some redundancy into an OBS deployment plan because one cannot count on having all the instruments successfully record data. He recommended minimizing the number of instruments deployed in <1 km water (although shallow deployments are sometimes required to address objectives) and looking for flat bathymetry but avoiding thick sediments.

Dayanthie Weeraratne described a recently funded experiment in which 24 broadband OBSs will be deployed in 2010 on the California borderland. Eight additional short

period OBSs have been requested.

Summary of conclusions about OBS performance:

Performance of vertical broadband components is better than performance of horizontal components.

Accelerometers are highly recommended when earthquakes with magnitude >4 are expected within the array.
Avoid deploying instruments of the current design in water <1000 m deep.
New designs suitable for shallow water are being developed.
Seafloor geodesy to resolve vertical motions using high-resolution absolute pressure gauges may be possible.
Plan for some redundancy in an OBS experiment because it is not realistic to expect all OBS to work properly for a year-long unattended deployment.

III. USArray and EarthScope Science in Alaska

III.1 Overview of meeting objectives

In a few years EarthScope will deploy USArray to Alaska, providing, for the first time, dense broadband seismic array data across the area that will complement the maturing geodetic time series data of PBO. This workshop will bring together interested attendees from the EarthScope community to present recent results, discuss, and refine scientific goals for EarthScope studies in Alaska and adjacent Canada. This workshop will inspire future scientific investigations using EarthScope data and will provide the starting point for an upcoming planning workshop envisioned for spring 2010, which will aid in guiding the USArray deployment.

Alaska is the most active part of North America, both tectonically and volcanically, and its geography and sparse settlement pose unique logistical and operational challenges. In addition to subduction of the Pacific plate beneath North America at the Alaska-Aleutian trench, Alaska features an active example of terrane accretion. These two tectonic drivers cause active tectonism and seismicity extending as far north as the Arctic Ocean and inland into NW Canada. Alaska and the adjacent part of Canada feature by far the highest topography in North America and the steepest coastal mountains in the world. Vigorous active volcanism extends along almost the entire length of the Aleutian arc and the Wrangell volcanic field (south-central Alaska) includes some of the largest continental volcanoes on the planet. Logistical and operational challenges for the USArray TA deployment will be very different than those faced in the Lower 48, and plans for the deployment need to be informed from the beginning by an understanding of the most important scientific goals.

The objectives of this workshop are to:

Identify and refine scientific goals and objectives of the USArray EarthScope program that can be addressed in Alaska.
Inform potential EarthScope investigators about the state of knowledge of Alaska tectonics and crustal/mantle structure, and stimulate new research ideas that will exploit the existing and forthcoming data, including combinations of USArray and PBO data.
Provide information to IRIS to begin the planning for the USArray TA deployment in Alaska, so that logistical and operational decisions are informed by the scientific needs.
Identify topics that need further discussion at a more comprehensive planning workshop, which we will organize in about a year.

III.2 Summary of meeting presentations and discussions:

Jeff Freymueller opened the workshop with a brief introduction, and outlined some of the potential science targets for EarthScope and USArray in Alaska, including: deformation of the entire Northern Cordillera from British Columbia to Alaska and the Yukon, accretion of the Yakutat block, crustal-scale faulting on the Denali fault, and broad-scale deformation of the overriding plate in the subduction zone. Nearly all of Alaska is seismically active, with the causes of seismicity in northern and western Alaska being poorly understood. Crustal structure is known only along the TACT line, which more of less follows the Trans-Alaska Pipeline from the Pacific to the Arctic. Prominent targets and questions include:

• Alaska is being broken, but we don't always know where
• Does the Denali fault continue as an active structure into western Alaska? Is there convergence across Western Alaska Range?
• What is the role of faults in E. Brooks Range, seismicity belts in NW and NE Alaska?
• Study accretion in action: Yakutat terrane collision
• USArray will have a dramatic impact on earthquake location capability in much of Alaska
• Geometry of subducting plate(s) and properties of mantle wedge
• Crustal architecture of accreted terrane assemblage
– Accreted both from north and south
– Oroclinal bending or other large-scale deformation of crust
• Paleo-slabs: Kula Plate and Resurrection Plate
• Inner core rotation

Max Enders presented a summary of the PBO network in Alaska. Alaska posed some significant challenges to PBO, but installation was on time and on budget. Permitting was a major challenge, in part because so much of Alaska is Federal land. Federal agencies were not always easy to deal with; in one case (Unimak Island volcanoes), USGS obtained the permits and PBO sites are co-located with Alaska Volcano Observatory seismic stations. PBO employed several different monumentation designs, some unique to Alaska (i.e., permafrost monument), and several types of telemetry. Some stations have no telemetry. Most PBO sites required helicopter access. Many lessons were

learned, under the general headings of permitting, logistics, access and weather. PBO can help IRIS a lot in understanding the scope of the task.

Doug Christensen described the permanent seismic network and previous PASSCAL deployments. The seismic network remains dominated by analog, short-period instruments although many upgrades to broadband are in progress. Large areas of Alaska have never been instrumented, even with short-period instruments. There have been 4 major PASSCAL deployments, of which 3 have been along the road system. The fourth, the NSF-CD STEEP project, is in the St. Elias range and was installed by helicopter. Christensen summarized receiver function, shear wave splitting, and tomography results from these data. Shear wave splitting, in particular, displays a sharp transition from Pacific-parallel to Pacific-normal directions, at about the point where the mantle wedge begins. Existing data cover Pacific to Arctic but only one transect. There ought to be some interesting edges to the subduction system, but we don't have any data from there.

Gary Fuis presented the TACT results and their current interpretation. TACT was shot nearly 20 years ago, but a lot of work has been done on the data after the Denali earthquake, and this has led to some new insights. This is really the only section of Alaska where we know the structure. The southern end of the line shows crustal duplexing and complex structure related to subduction, but the limited off-line data suggests this changes very abruptly normal to the transect. There is a step in the crustal thickness at the Denali fault (thin to the north), and what is interpreted to be a tear or hole in the slab beneath the line. TACT runs very close to the edge of the Pacific slab, based on seismicity.

Geoff Abers discussed subduction zone imaging. Existing broadband experiments have imaged a package of thick, low velocity material on top of the oceanic crust in the "flat slab" section of the subduction zone. Receiver functions and attenuation measurements provide useful constraints to geodynamic models of the mantle wedge, useful for studying the question of where melting occurs to produce arc magmas. However, most of the Alaska subduction zone remains un-imaged. There are past studies from the Shumagins and eastern Aleutians, but not much else because there is no data. We have little information about the "normal" subduction segments, because most data is restricted to the unusual flat slab section.

Patrick Brennan presented new results of crustal imaging in the Alaska Range, based on the BEAAR PASSCAL deployment. Receiver function images show evidence for steps in the Moho at the Denali fault and also to the south end of the BEAAR line, beneath the Susitna valley at the Talkeetna fault. These Moho offsets are several km and apparently abrupt. There is some evidence for additional interfaces within the crust that cause P-S conversions. Outstanding problems include the need to better characterize the accreted terranes and their boundaries, the large-scale plutons of the McKinley and Foraker group. The Copper River Basin is an intriguing feature, being distinctively low-lying in the midst of enormous mountains – is that controlled b crustal structure or composition? Where are the slab edges?

Roger Hansen and Gary Pavlis presented imaging results from the Yakutat collision in the St. Elias Range. Some of the velocity variations within the St. Elias orogen are so dramatic that they cause arrival time variations larger than anything seen in the lower 48, yet vary over distance scales of 10s of km. The STEEP project has imaged the downgoing Wrangell slab, which appears to be connected to the Yakutat block. However, the Wrangell slab might be a rollover feature, it may not mean underthrusting in the downdip direction. Better imaging of that will require data from farther north than STEEP, a good USArray target. Within the St. Elias, structure appears to be very complex.

Science Targets Discussion

The science targets discussion was divided into several themes: crustal imaging, mantle, seismicity, and PBO/USArray Synergy. Logistics crept into the science discussion a number of times, despite intentions to leave it for later. This reflected not a love for logistical details but the fact that, unlike in the lower 48, logistics exerts a very strong control on what you can actually do in Alaska. The sections below briefly summarize key points of the discussion for each topic. The summaries are largely in note form, without extensive polishing, so that the full range of ideas in the discussion comes through with less filtering.

Crustal Imaging. The structure of the Alaska-Aleutian arc and adjacent crust was a major topic of discussion. This is a feature of global significance; a long island arc that has been building for the last 50 million years. Crustal thickness and a reasonable velocity model for the arc crust is available only for one place (eastern Aleutians). Is this typical? What about arc crust in the continental part of the arc, where the present volume of volcanics is surprisingly small (all planed off by glaciation?)? Arc segmentation was another topic. The arc shows strong segmentation/seismogenic zone variations; are these reflected in structures? Are there variations in reflectivity or other properties of the plate interface that correlate with seismogenic zone variations? How do these relate to forearc structures? Are variations in volcanic style reflective of structural variations (presence or absence of large tholeiitic volcanoes, for example)? If so, is this because structural controls determine how much magma gets to the surface? There was some discussion of crustal structure in other areas, mainly to note that it is almost totally unknown outside of the TACT corridor. Offset on faults like the Denali and Tintina faults in western Alaska is unknown. The Denali fault system offsets the Moho in central Alaska; does this continue to the west? The Arctic margin and Brooks Range offer additional targets for imaging. There is substantial distributed deformation in the "Yakutat corner", where the strike slip and subduction boundaries meet; what is just in the crust and how much involves the mantle lithosphere? Is the motion and shortening across the Northern Cordillera a result of intra-crustal shortening or lithospheric scale faulting? Central Alaska looks like the Mojave – thin crust, is the lithospheric mantle gone?

Mantle. What is the 3D mantle flow field around the complex subducting slab(s)? How many slabs? Are Pacific and Yakutat slabs separate, resulting in a slab window? Does heat flow from a slab window dynamically support topography in parts of southern

Alaska (Copper River Basin)? How is mantle strain distributed and what is the contribution from mantle buoyancy, positive or negative? Is there a tear in the slab, as interpreted from the TACT line? There are hints of layering in the mantle north of the Alaska Range; is this an indication of a more classic continental signature? Where are the edges of the stable subcontinental lithosphere? The Cordillera is underlain by old Proterozoic rocks, but what about the regions outboard of that? How deep is the lithosphere-asthenosphere boundary? How does it vary from the less deformed parts of Central Alaska to the Pacific and Arctic margins? What is the deeper structure of the subducting plate? In some places there may be a slab-like structure in the mantle transition zone – what is it? Why is it there? Where did the Kula slab go, and the other paleo-slabs of the last 50+ million years?

Seismicity. There have been many surprises in tremor and slip; Alaska is almost virgin territory. How does tremor relate to the seismogenic zone, and to the along-strike variations in the seismogenic zone? Is tremor always found at downdip end of seismogenic zone, even when the depth of that boundary changes radically along strike? Do along-strike boundaries in the seismogenic zone also produce tremor and episodic creep, or only the downdip boundary? Is there tremor along the Denali fault? Other strike-slip faults? How does the Denali fault (or Tintina, or another) compare and contrast to the San Andreas? Could be a good place for an intensive deployment. Seismicity not adequately recorded over most of western Alaska. Quite a few big earthquakes but no microseismicity located because of lack of network. Expect to see surprises.

Grand Challenges were proposed: Can we predict the location of the next M8+ earthquake along the subduction zone? What controls rupture in M9 events vs. M8 events?

PBO/USArray Synergy. Study magma from slab to volcano. Understand seismic vs. aseismic slip; tremor and slip are an obvious synergy between geodesy and seismology. What major active faults in Alaska do we NOT know about? How do deformation at the surface and at mantle depths relate? How to combine geodesy, seismicity/active faults and crustal structure in a poorly understood but highly active region?

USArray TA logistics and deployment discussion

Permits are a big issue, and can take a long time to resolve. Alaska Earthquake Information Center has permits for several sites within Wrangell-St. Elias National Park, and these could be very useful. Different mode of installation required. How many lower 48 TA sites were installed by some means other than driving a truck there? Zero. Majority of Alaska sites will be fly-away. Weight matters, may control how sites are installed. Pros and cons of telemetered (high-power) vs. non-telemetered (can be very low power) sites were discussed. There will need to be a mix of both. Data connection links: schools, towns, PBO sites. Start rough site map by using every: (1) village with a school; (2) PBO stations and repeaters; (3) airstrips.

Key Recommendations

The USArray deployment in Alaska should start out with a design like the rest of the country. USArray TA should cover all of Alaska and should be dense. The site density is likely not going to match the rest of the TA in all parts of the state, and there will be some irregularity and gaps due to permitting restrictions (i.e., National Park Wilderness) and impossible logistics in some places. But the goal must be to do the whole thing – backing off to just the road-covered area would miss most of the interesting problems. Creativity and flexibility are called for in the deployment. In totally virgin territory, sites that look more like a superior PASSCAL deployment rather than a lower 48 USArray site will still provide new and unique data for solving interesting problems. Don't lock in to the idea that it has to be done just like the lower 48, when doing so might cut the number of sites and completeness of coverage drastically. Try out some site designs and deployment strategies before the proposal is due to get a better idea of what works.
50 million years of subduction punctuated by several terrain accretions means a lot of similarities to the western lower 48, plus some interesting differences.
The Northern Cordillera of Canada ought to be an intrinsic part of the Alaska deployment. Understanding the tectonic problems will require data from both sides of the border.
Similarly, crossing over into the marine part of the boundary will provide critical data. The subduction boundary in particular needs complementary OBS and marine seismic data, as well as seafloor geodetic data.
Alaska is an incredibly target-rich environment. We know that a lot is going on, but don't know the details. The prospects for discovery are among the highest in all of North America.

There was general enthusiasm for a future, focused EarthScope Alaska workshop, which might be held in spring or fall 2010.

IV. **Workshop participants:**

Both workshops attracted a broad range of scientists from both the traditionally land-based and marine seismology communities, reflecting the strong interest in amphibious experiments for the future as an extension of EarthScope's USArray (Appendix 2).

Appendix 1: Meeting Agendas

Leveraging USArray: Opportunities for Onshore/Offshore Experiments
Organizers: Dayanthie Weeraratne, Anne Trehu

9:00-10:30 am Presentations

- USArray — Bob Woodward
- OBSIP — John Collins, Jim Gaherty
- NSF-OCE/EAR — Rick Carlson, Greg Anderson
- Great Lakes — David Dolenc, Yevgenie Kontar
- East Coast — Karen Fischer
- Alaska — TBD
- Gulf Coast — TBD
- Margins — Geoff Abers
- PBO — Mike Jackson
- Participants — Spahr Webb, Anne Trehu, D. Weeraratne, Doug Wiens, others...

(1-2 slides)

10:30-10:45 am Break

10:45-12:00 am Discussion, including development of an outline of instrumentation needs and a funding strategy.

12:00-1:00 pm Lunch - joint with Alaska Workshop

USArray and EarthScope Science in Alaska
Organizers: Jeff Freymueller, Doug Christensen

1:00-2:30 pm Presentations

- Introduction, Goals, Alaska Tectonics and Science Targets — Jeff Freymueller
- PBO in Alaska — Max Enders
- Seismic network & PASSCAL deployments — Doug Christensen
- Subduction Zone imaging — Geoff Abers
- Crustal imaging, Alaska Range — Patrick Brennan
- Imaging the Yakutat collision — Roger Hansen and Gary Pavlis
- Offshore seismic targets — TBD (coordinating with Offshore workshop above)

2:30-4:00 pm Discussion of Science Targets

Focus topics: crustal imaging, mantle imaging, seismicity, deformation regimes, scientific synergy between USArray and PBO.

4:00-5:00 pm USArray TA logistics and deployment discussion

AEIC and STEEP network ops — Roger Hansen
Insight from PASSCAL deployments — Doug Christensen
Focus topics: Town/village logistics vs. remote sites, helicopter and aircraft installs

Appendix 2a. Attendence at the Leveraging USArray workshop, based on self-sign-in.

Abers	Geoff	LDEO	Research Scientist
Alvarez	Marcos	IRIS	Staff
Anderson	Greg	NF	Program Manager
Beaudoin	Bruce	PASSCAL	Administrator
Beck	Susan	University of Arizona	Faculty
Braunmiller	Jochen	Oregon State University	Research Associate
Busby	Robert	IRIS	Staff
Calkins	Josh	LDEO	Post-doc
Christianson	Doug	Un. of Alaska Fairbanks	Faculty
Weeraratne	Dayanthie	Cal.State UnNorthridge	Faculty
Detriech	Robert	NSF	Administrator
Eakins	Jennifer	UC San Diego-ANF	Staff
Ekstrom	Goran	LDEO	Faculty
Fischer	Karen	Brown University	Faculty
Fowler	Jim	IRIS	Staff
Freymueller	Jeff	University of Alaska	Faculty
Gaherty	Jim	LDEO	Faculty
Hafner	Katrin	IRIS	Staff
Hansen	Roger	Un. of Alaska Fairbanks	Faculty
Kontar	Yev	Ill. State Geol. Surv.	Staff
Leith	Bill	USGS	Staff
Magnani	Beatrice	CERI	Faculty
McGuire	Jeff	WHOI	Faculty
Neuhauser	Doug	UC Berkeley	Staff
Porritt	Rob	UC Berkeley	Student
Pulliam	Jay	Baylor University	Faculty
Sauter	Allan	IRIS/PASSCAL	Staff
Schultz	Adam	Oregon State University	Faculty
Sheehan	Anne	University of Colorado	Faculty
Shillington	Donna	CDFO	Research Scientist
Simpson	David	IRIS	Staff
Sit	Stefany	Un. of Miami of Ohio	Student
Snyder	Dave	GSC Ottawa	Staff
Toomey	Doug	University of Oregon	Faculty
Trehu	Anne	Oregon State University	Faculty
van der Lee	Suzanne	Northwestern	Faculty
Vernon	Frank	UC San Diego	Research Scientist
Webb	Spahr	LDEO	Faculty
Whitcomb	Jim	NSF	Administrator
Wiens	Doug	Washington University	Faculty
Williams	Mark	Oregon State University	Student
Winester	Dan	NOAS-NAS	Staff
Woodward	Bob	IRIS	Staff

Appendix 3. Attendence at the USArray in Alaska workshop.

Abers	Geoff	LDEO	Research Scientist
Alvarez	Marcos	IRIS	Staff
Anderson	Greg	National Science Foundation	Program Manager
Beaudoin	Bruce	PASSCAL	Administrator
Beck	Susan	University of Arizona	Faculty
Braunmiller	Jochen	Oregon State University	Research Associate
Busby	Robert	IRIS	Staff
Calkins	Josh	LDEO	Post-doc
Christianson	Doug	University of Alaska Fairbanks	Faculty
Weeraratne	Dayanthie	California State Univ Northridge	Faculty
Detriech	Robert	National Science Foundation	Administrator
Eakins	Jennifer	UC San Diego-ANF	Staff
Ekstrom	Goran	LDEO	Faculty
Fischer	Karen	Brown University	Faculty
Fowler	Jim	IRIS	Staff
Freymueller	Jeff	University of Alaska	Faculty
Gaherty	Jim	LDEO	Faculty
Hafner	Katrin	IRIS	Staff
Hansen	Roger	University of Alaska Fairbanks	Faculty
Kontar	Yev	Illinois State Geological Survey	Staff
Leith	Bill	USGS	Staff
Magnani	Beatrice	CERI	Faculty
McGuire	Jeff	WHOI	Faculty
Neuhauser	Doug	UC Berkeley	Staff
Porritt	Rob	UC Berkeley	Student
Pulliam	Jay	Baylor University	Faculty
Sauter	Allan	IRIS/PASSCAL	Staff
Schultz	Adam	Oregon State University	Faculty
Sheehan	Anne	University of Colorado	Faculty
Shillington	Donna	CDFO	Research Scientist
Simpson	David	IRIS	Staff
Sit	Stefany	University of Miami of Ohio	Student
Snyder	Dave	GSC Ottawa	Staff
Toomey	Doug	University of Oregon	Faculty
Trehu	Anne	Oregon State University	Faculty
van der Lee	Suzanne	Northwestern	Faculty
Vernon	Frank	UC San Diego	Research Scientist
Webb	Spahr	LDEO	Faculty
Whitcomb	Jim	National Science Foundation	Administrator
Wiens	Doug	Washington University	Faculty
Williams	Mark	Oregon State University	Student
Winester	Dan	NOAS-NAS	Staff
Woodward	Bob	IRIS	Staff