Most relevant “Grand Challenges”:

#5. Where are water & hydrocarbons beneath the surface?

#6. How do magmas ascend and erupt?

#7. What is the lithosphere-asthenosphere boundary?

#9. How do temperature & composition control mantle convection?

#10. How are Earth’s internal boundaries affected by dynamics?
Thermo-chemical Internal Dynamics & Volatile Distribution

Scientific Themes
- Structure of the Lithosphere and Asthenosphere
- Lithosphere-Asthenosphere Interactions
- Distinguishing Melt, Volatiles, Composition, & Temperature

Future Directions
- Improving seismic images
  --new analysis of existing data [utilizing more of the waveform; integrating different measurement types; HPC]
  --collection and analysis of new data

- Improving interpretations of seismic images
  --collection of experimental data
  --utilizing data sets from other disciplines

- Improving coverage in the oceans
Structure of the Lithosphere and Asthenosphere

depth (km) to negative discontinuity in Ps phase [Rychert & Shearer, 2009]

long-period SS modeling [Rychert & Shearer, 2011]

short-period SS precursors [Schmerr, 2012]
Structure of the Lithosphere and Asthenosphere

- Relationship between azimuthal anisotropy (direction & magnitude) and seismic discontinuities

**Pacific**

170 Ma  ocean age  0 Ma

(a) strength of azimuthal anisotropy

(b) direction of azimuthal anisotropy

(c) vertical gradient of direction of azi. anisotropy

**North America**

NW  SE

after Beghein et al. 2014  Yuan & Romanowicz 2010
Lithosphere-Asthenosphere Interactions

High $V_S$ & $V_P$ beneath western U.S.:
slab fragments? delaminating lithosphere?

modified from Wang et al., PNAS 2013
Distinguishing Melt, Volatiles, Composition, Temperature

Subduction zones: High attenuation in the mantle wedge due to melt
- high temperature, water not enough

predictions: dry, melt-free olivine
predictions: effect of water
predictions: effect of melt

Abers, Fischer, Hirth, Wiens, Plank, Holtzman, McCarthy, & Gazel, submitted 2014
Distinguishing Melt, Volatiles, Composition, Temperature

Dalton et al., Science, 2014
Improving Coverage in the Oceans

Results from USArray have challenged previously-held assumptions about continents. What currently-held assumptions about oceans would be challenged?

Provides an opportunity to target fundamental concepts:
-- relationship between mantle flow and seismic anisotropy
-- relationship between plate motion and mantle flow
-- details of melt generation and ascension
-- small-scale convection beneath plate
-- image plate-boundary shear zones
Two Final Examples

1. Rayleigh wave phase velocity (60 s): Using amplitude in addition to phase provides new information

<table>
<thead>
<tr>
<th>Phase only</th>
<th>Phase and amplitude</th>
<th>Difference</th>
</tr>
</thead>
</table>

Resolution of small-scale features & agreement between anisotropy and geodetic strain-rate field Illustrates value obtained from utilizing full waveform + investment in HPC

Lin & Ritzwoller 2011

2. $V_s$ and azimuthal anisotropy beneath Europe and Northern Atlantic from adjoint tomography

Resolution of small-scale features & agreement between anisotropy and geodetic strain-rate field Illustrates value obtained from utilizing full waveform + investment in HPC

Zhu & Tromp 2013