Tracking Magma Ascent in the Aleutian Arc

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Outline

I. Imaging magmatic systems

II. Geophysical signs of magma ascent

III. Katmai Experiment:
A targeted NSF/AVO funded project

Key Questions

How deep can we go?
Principal challenges?
Opportunities with new datasets?

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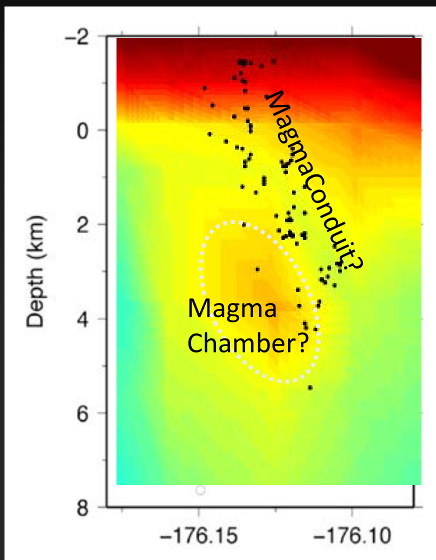
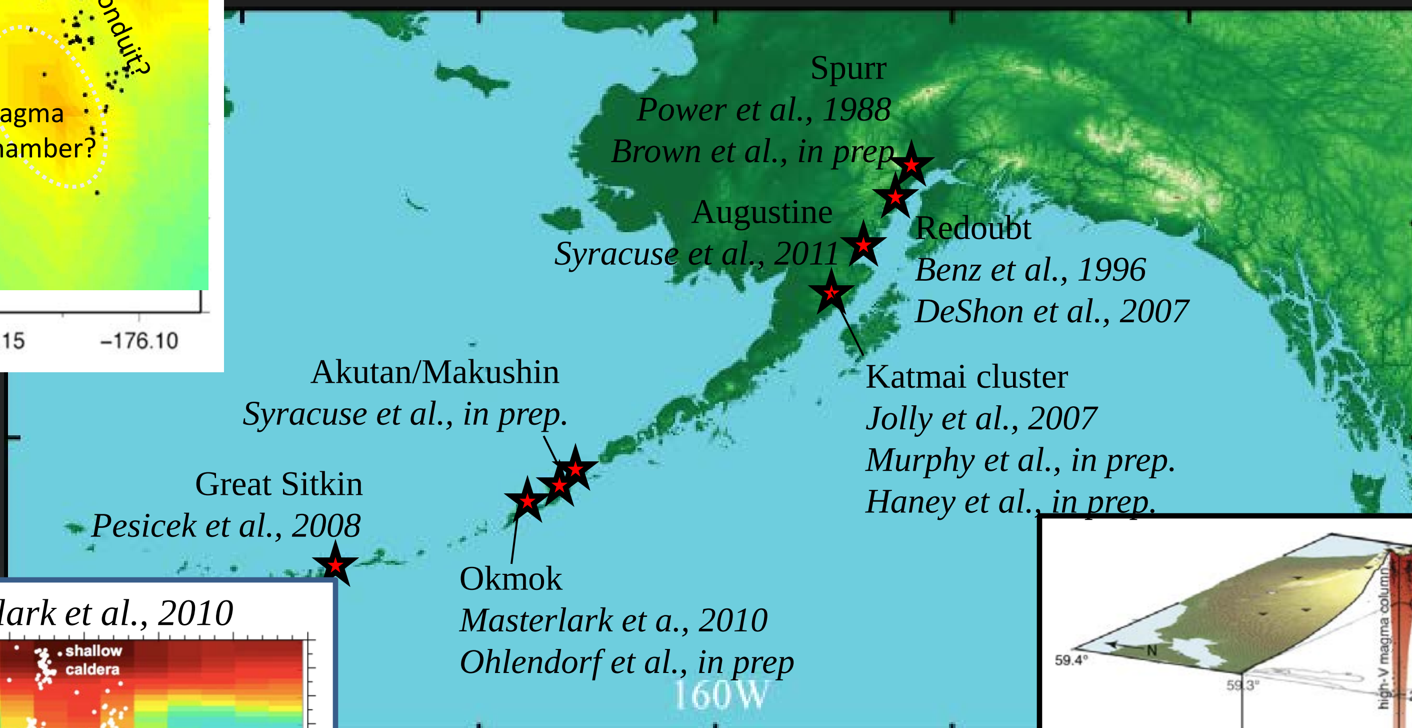
I. Imaging: Volcano specific tomography

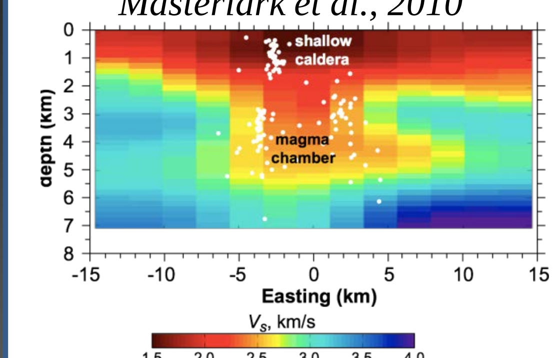
- Resolution generally in upper 10 km
- *Challenges* -geometry of earthquakes and stations
  -depth resolution in ANT

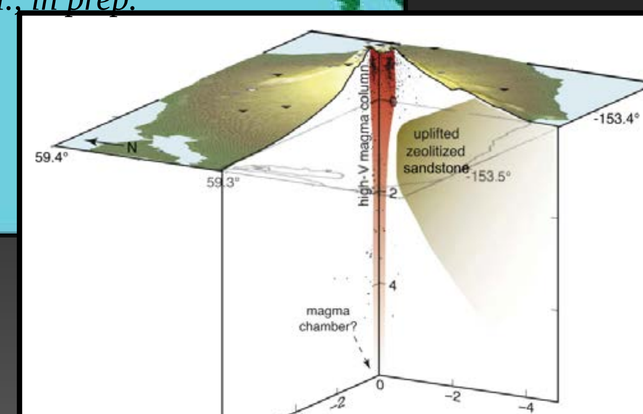
Pesicek et al., 2008





Masterlark et al., 2010



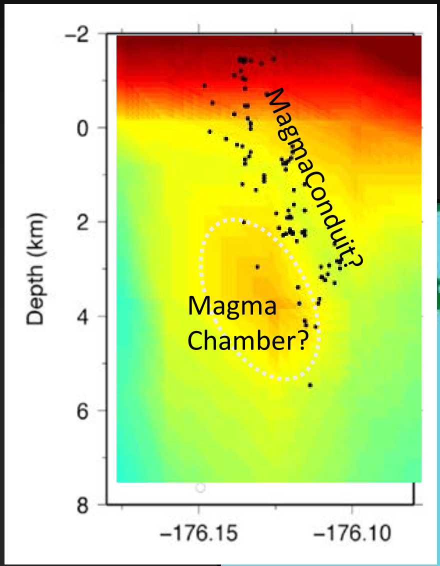


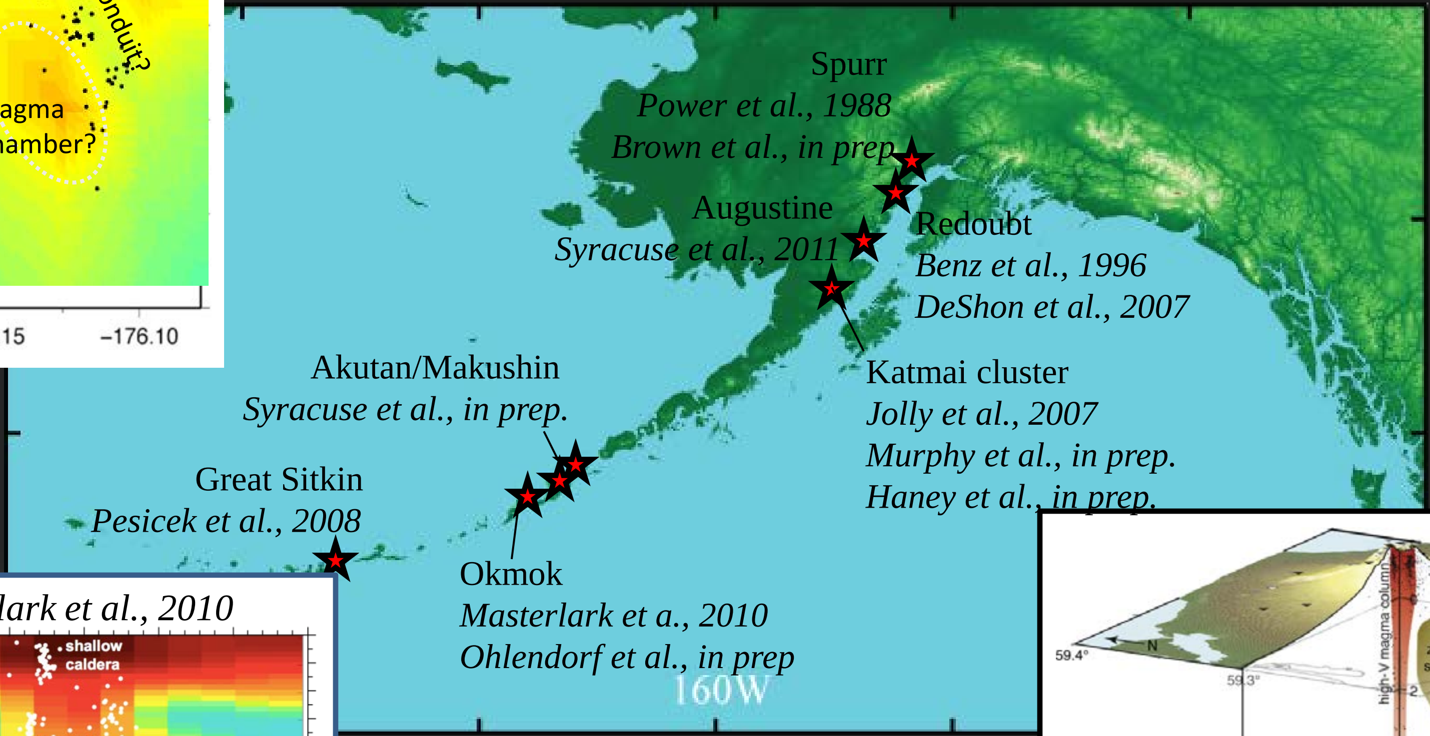
Syracuse et al., 2011

I. Imaging: Volcano specific tomography

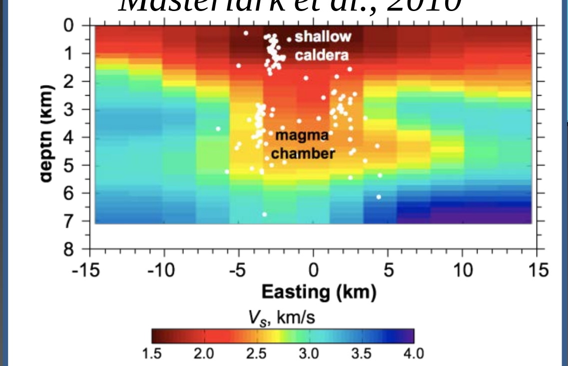
- Lays the ground work for high quality rapid locations and more targeted research.
- Many networks are new (96-05) .

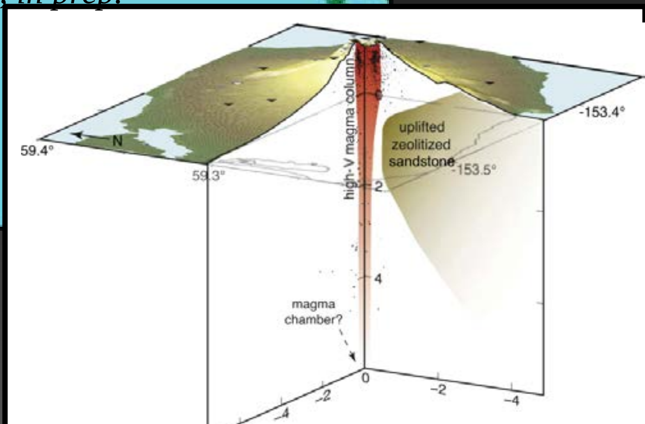
Pesicek et al., 2008





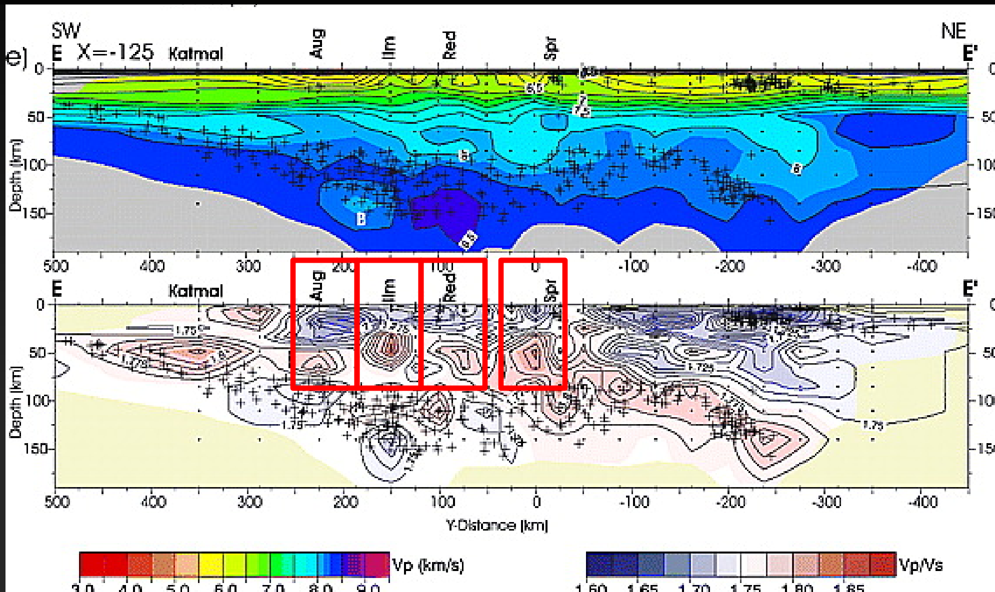
Masterlark et al., 2010





Syracuse et al., 2011

I. Imaging: Regional tomography



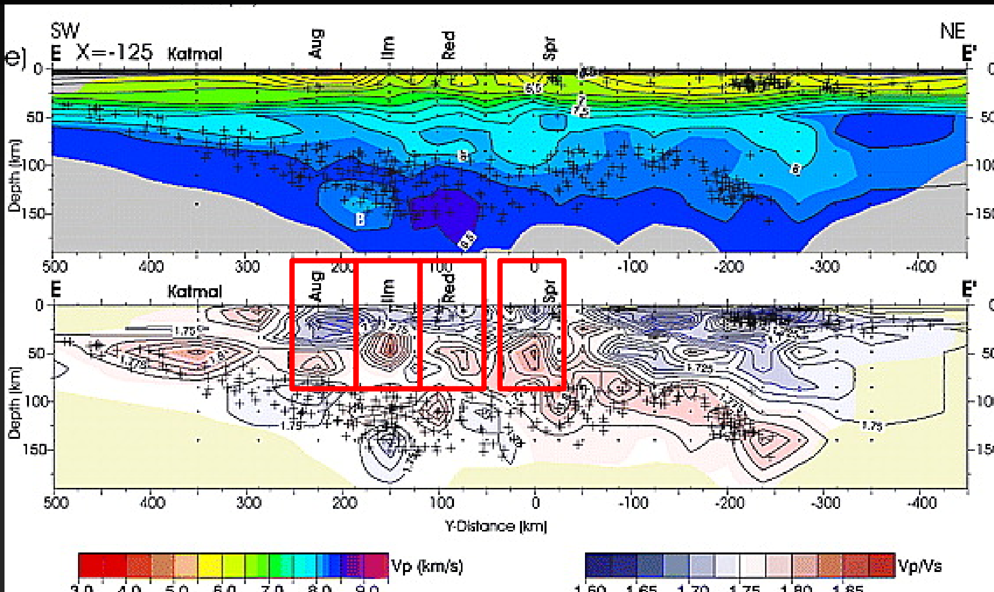
Eberhart-Phillips et al., 2006:

Active and Passive sources

Good station coverage

Vp/Vs anamolies at 40-65 km

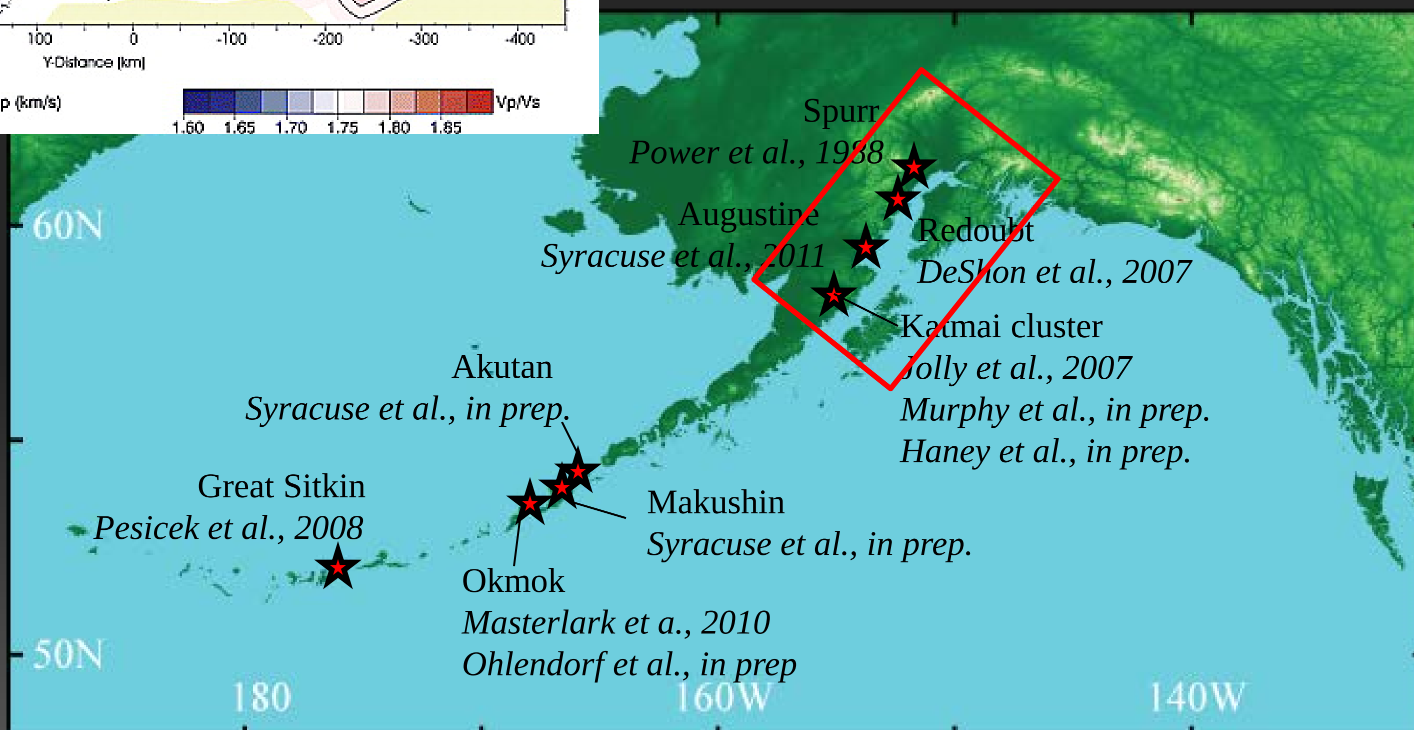
I. Imaging: Regional tomography



Challenges:

Station/earthquake geometry

Regional studies not focused on volcanic conduits



II. Indicators of Magma Ascent:

Dynamic processes resulting from pressure changes and mass flux.

Interplay of:
- changes in magma supply rate
- degassing and crystallization on path
- existing physical and thermal environment
- regional tectonic stress and strain

Challenge - Interpreting geophysical clues which could have multiple driving processes.
- Need multi-disciplinary data sets.
- Geophysical source studies critical to evaluating hazards.

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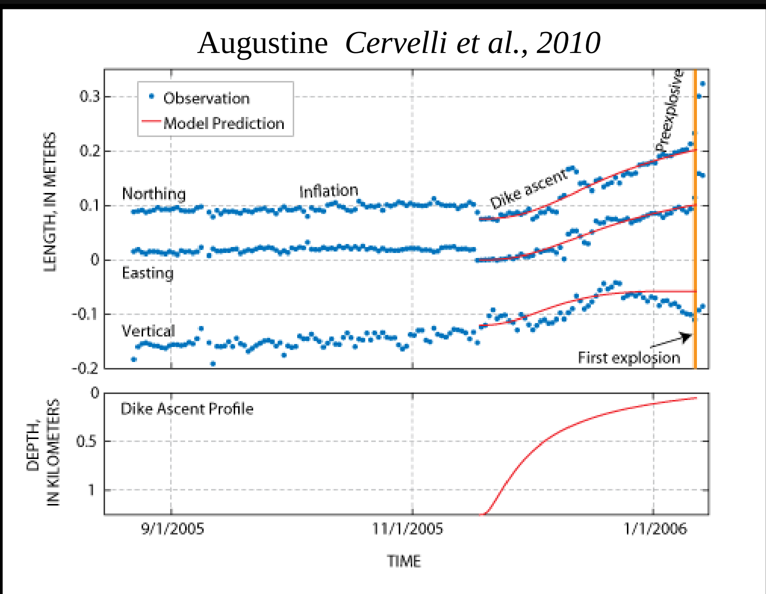
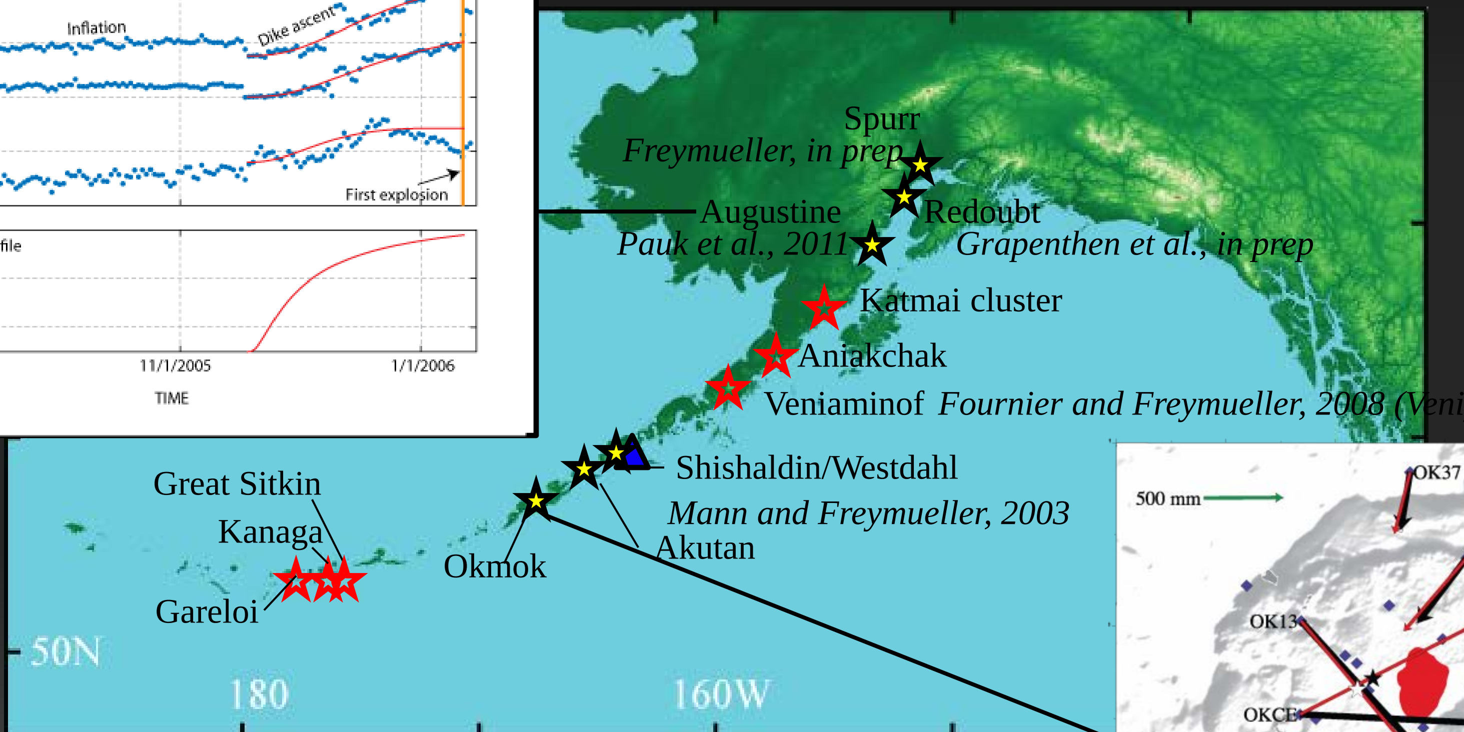
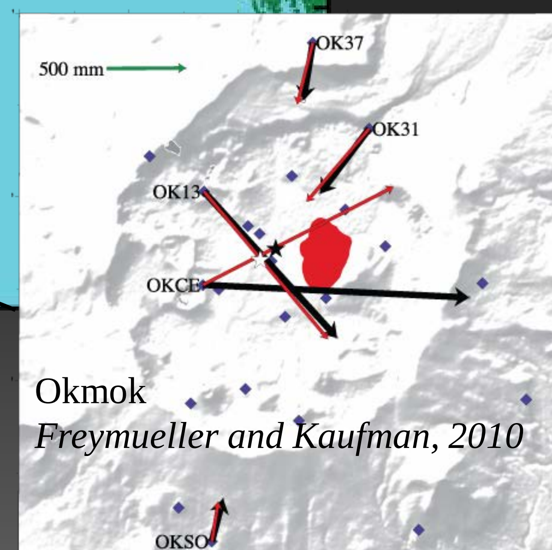
II. Indicators of Magma Ascent:

CGPS (★ *PBO and AVO*), tilt (▲ *PBO*), Campaign GPS (☆)

- Potential to measure magma ascent in shallow crust
- Depth resolution limited to upper 10 km



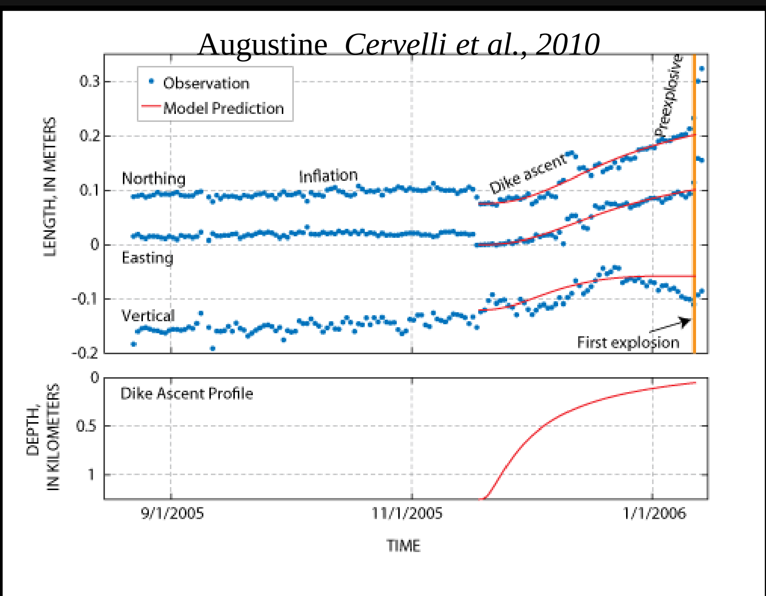


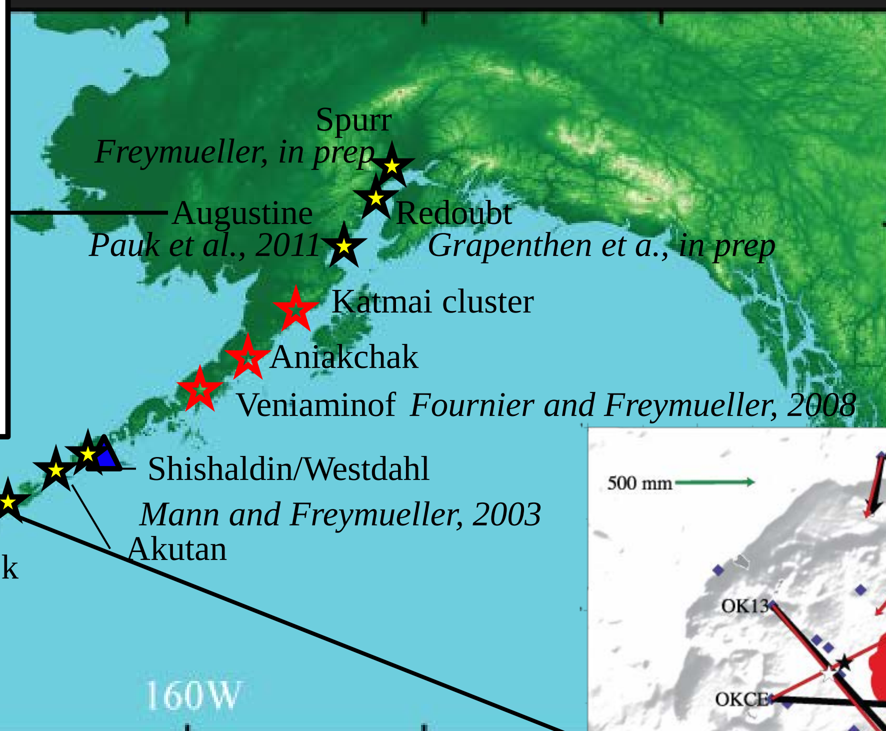


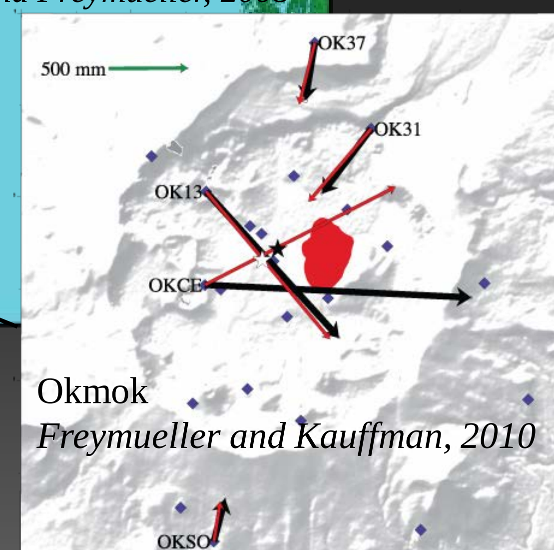
II. Indicators of Magma Ascent:

CGPS (★ *PBO and AVO)*, tilt (▲ *PBO)*, Campaign GPS (☆)

Challenges: - Station coverage
- Multiple signals from volcanoes, tectonics, ice
- Trade-off in depth/pressure change
- Simple models fit data well, but what are we missing?





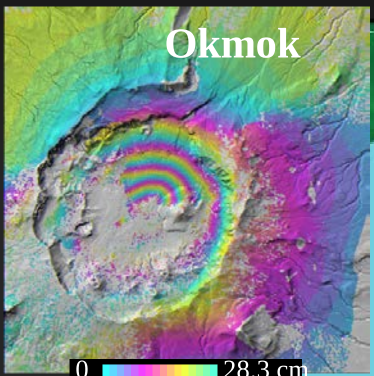


II. Indicators of Magma Ascent: InSar (16)

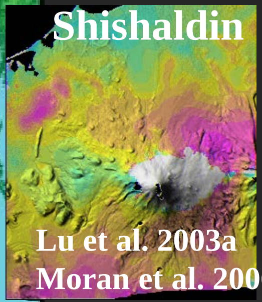
Temporal and spatial resolution compliments GPS.

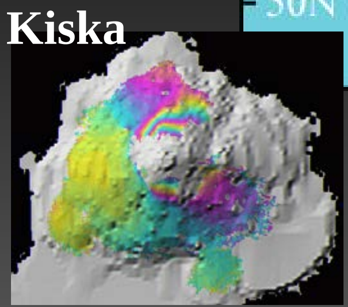
Resolution limited to upper 10 km generally.

Challenges: Land area, ice and snow, tephra, temporal coverage.

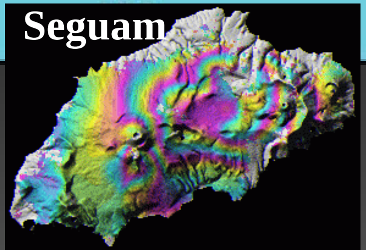


Lu et al. 2000a, 2003c, 2005a, 2010a+b
Mann et al. 2002;
Patrick et al., 2003
Masterlark et al., 2010
Ohlendorf et al., in prep



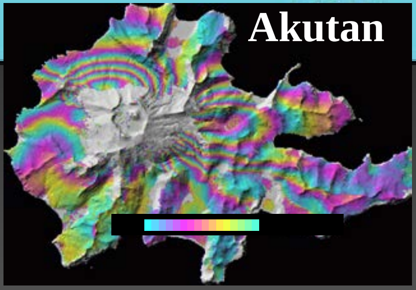


Lu et al. 2002b

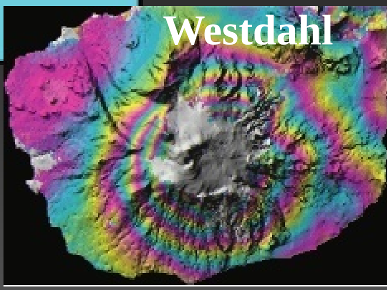


Lu et al. 2003a
Masterlark & Lu, 2004

Lu et al. 2002c



Lu et al. 2000c, 2005b

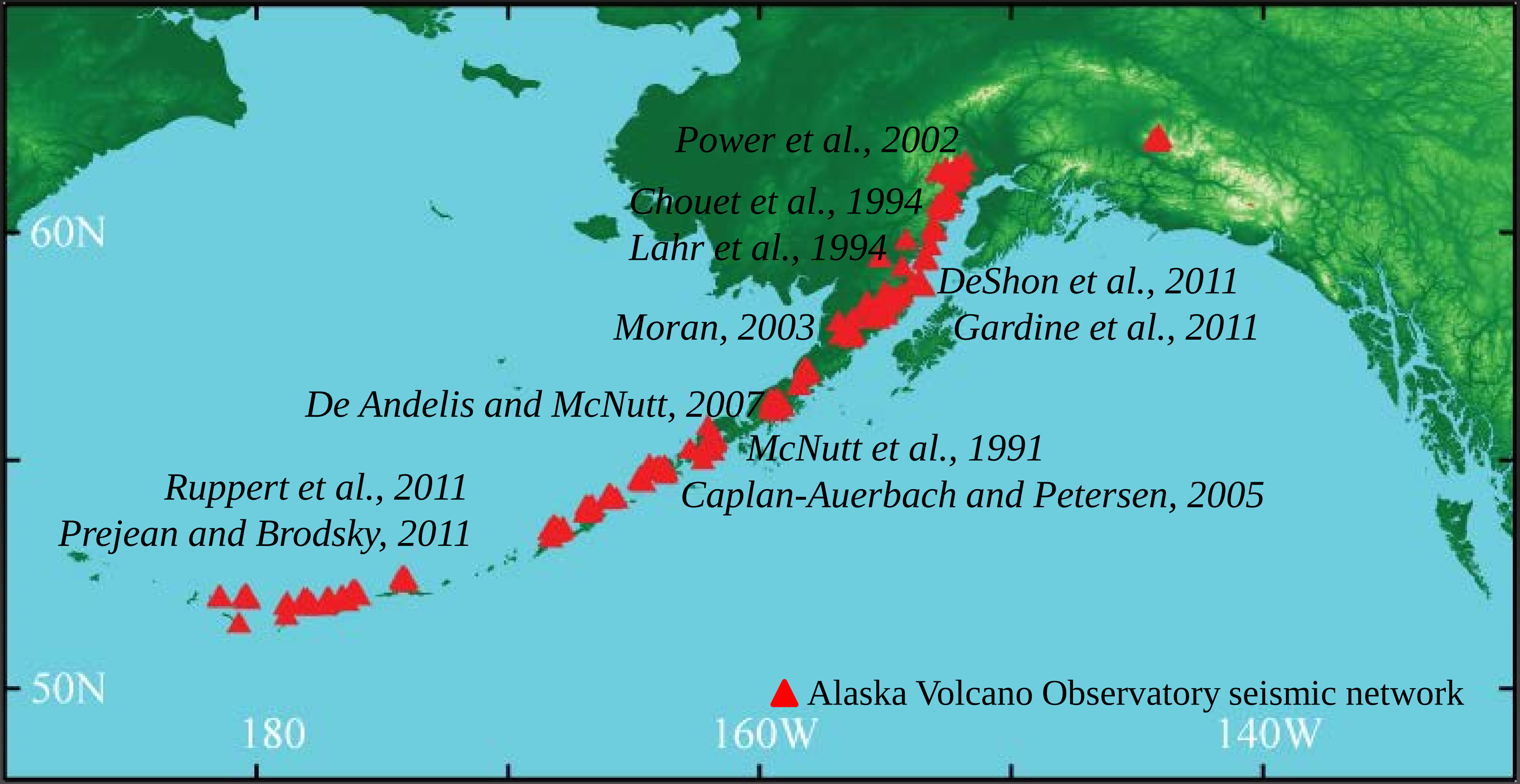


Lu et al. 2000b, 2003b, 2004

II. Indicators of Magma Ascent:

Volcano seismology: Rich history of using earthquake and tremor characteristics to infer magma migration and state of volcanic systems.

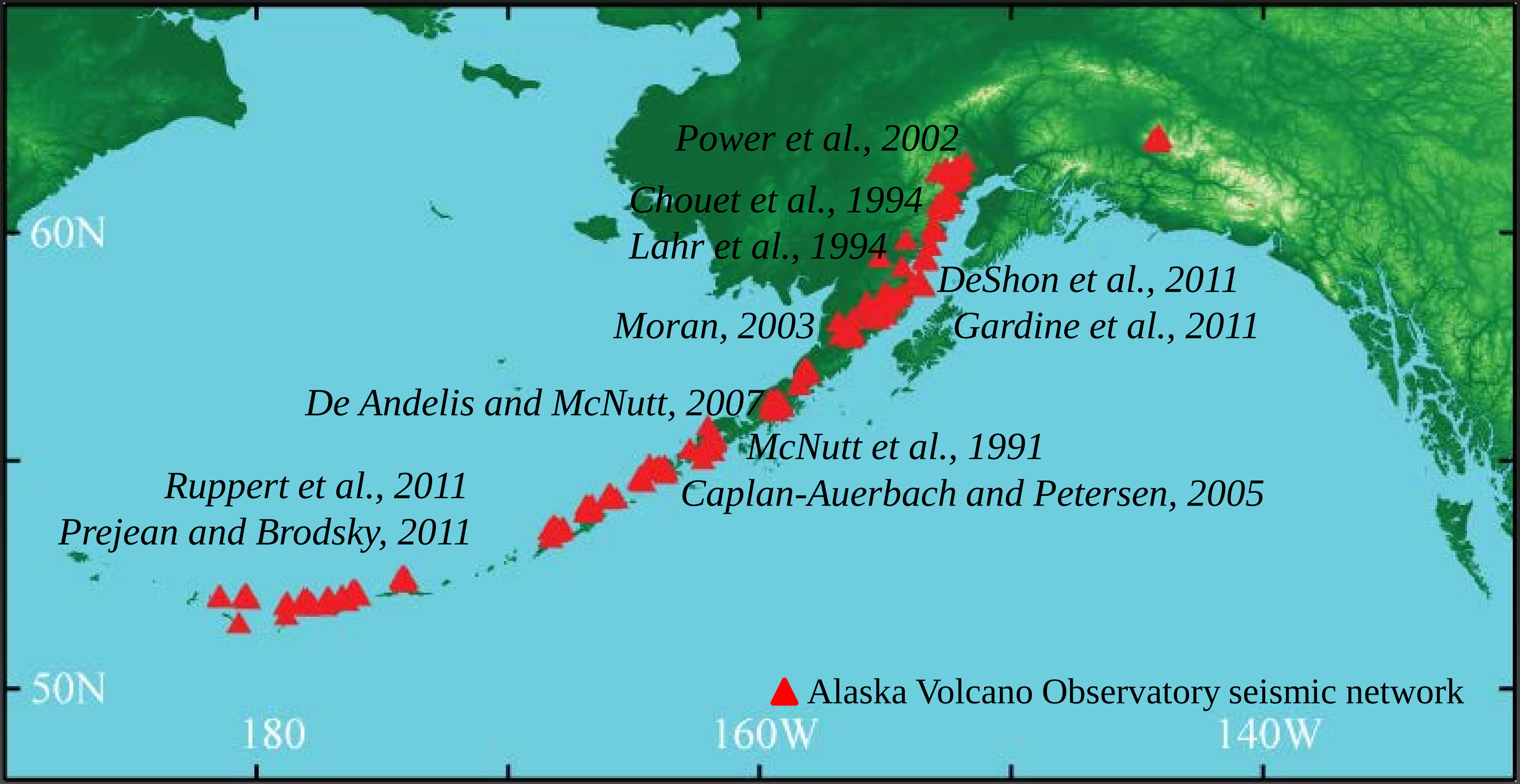
Resolution limited to upper 10 km, but occasionally deeper.



II. Indicators of Magma Ascent:

Volcano seismology: Rich history of using earthquake and tremor characteristics to infer magma migration and state of volcanic systems.

Challenges: - Interpreting earthquake triggers, source process, and relation to tectonics and magma ascent.
- Active volcanoes, small earthquakes



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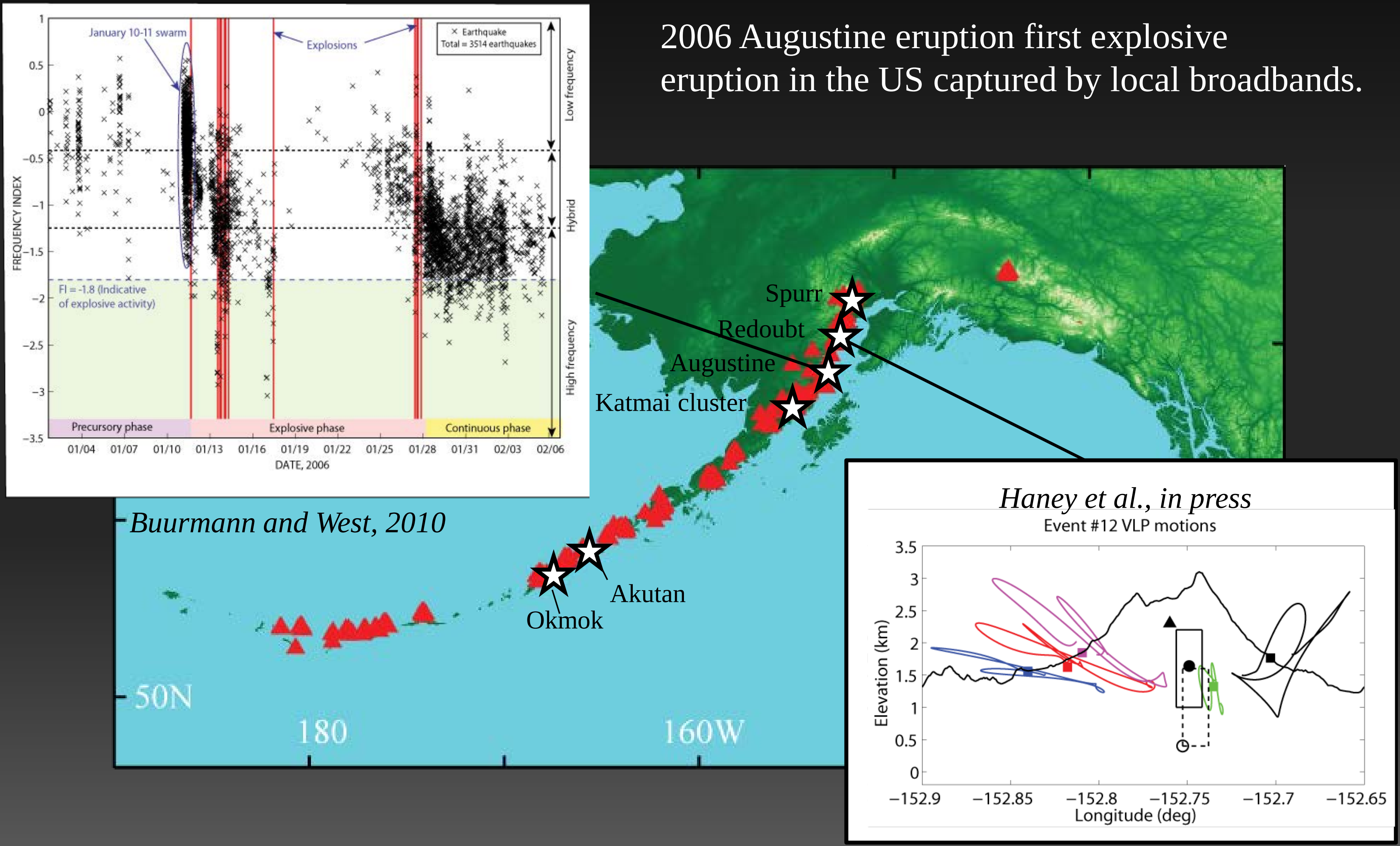
II. Indicators of Magma Ascent:

Broadband Seismic Source Observations and Modeling

2006 Augustine eruption first explosive eruption in the US captured by local broadbands.

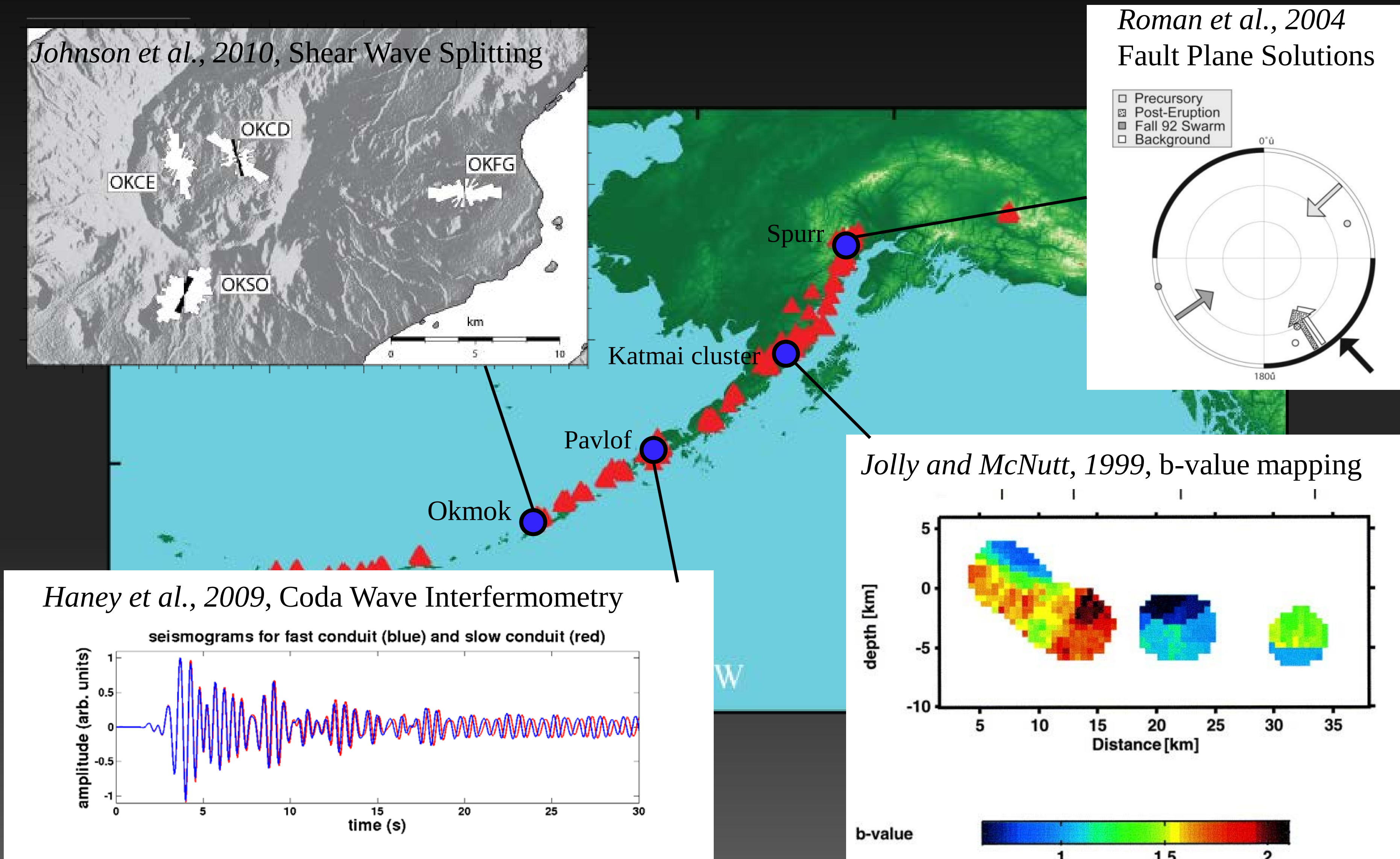


Buurmann and West, 2010

Haney et al., in press

II. Indicators of Magma Ascent:

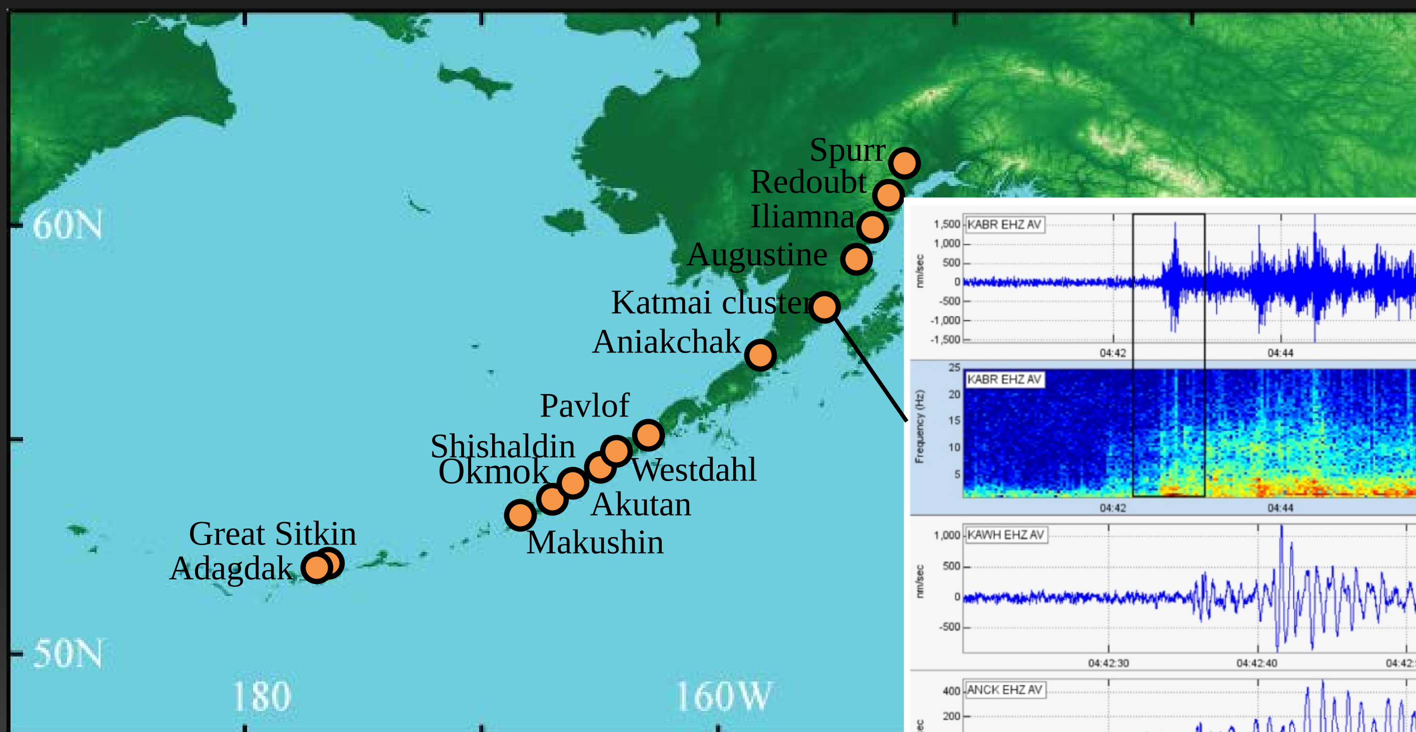
Time dependent path and source studies.

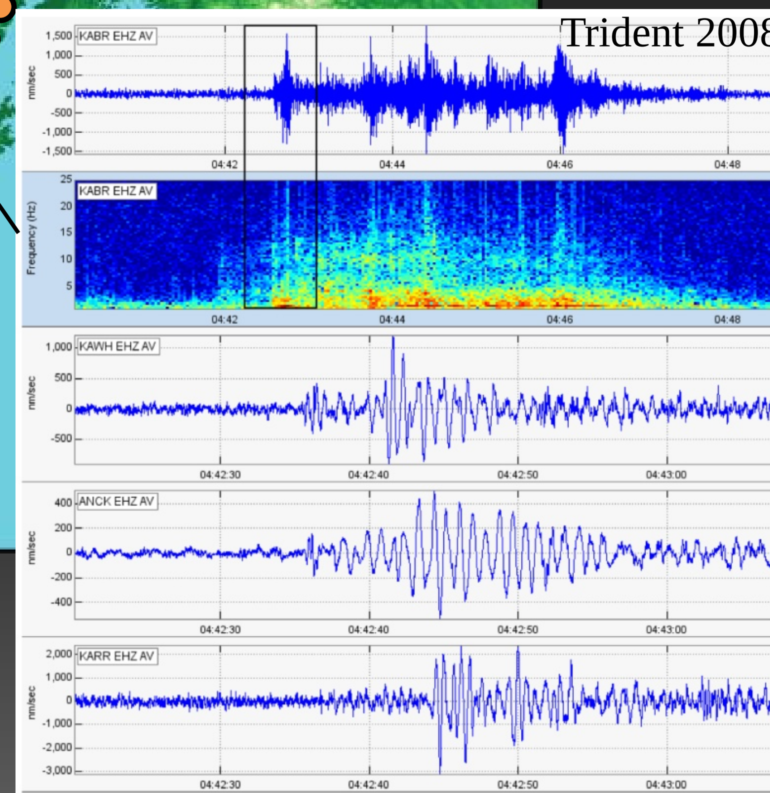


II. Indicators of Magma Ascent: DLPs

20-50 km depth, often occur in bursts *(Power et al., 2004)*

Moment tensors suggest fluid flow *(eg. Nakamichi et al., 2003)*

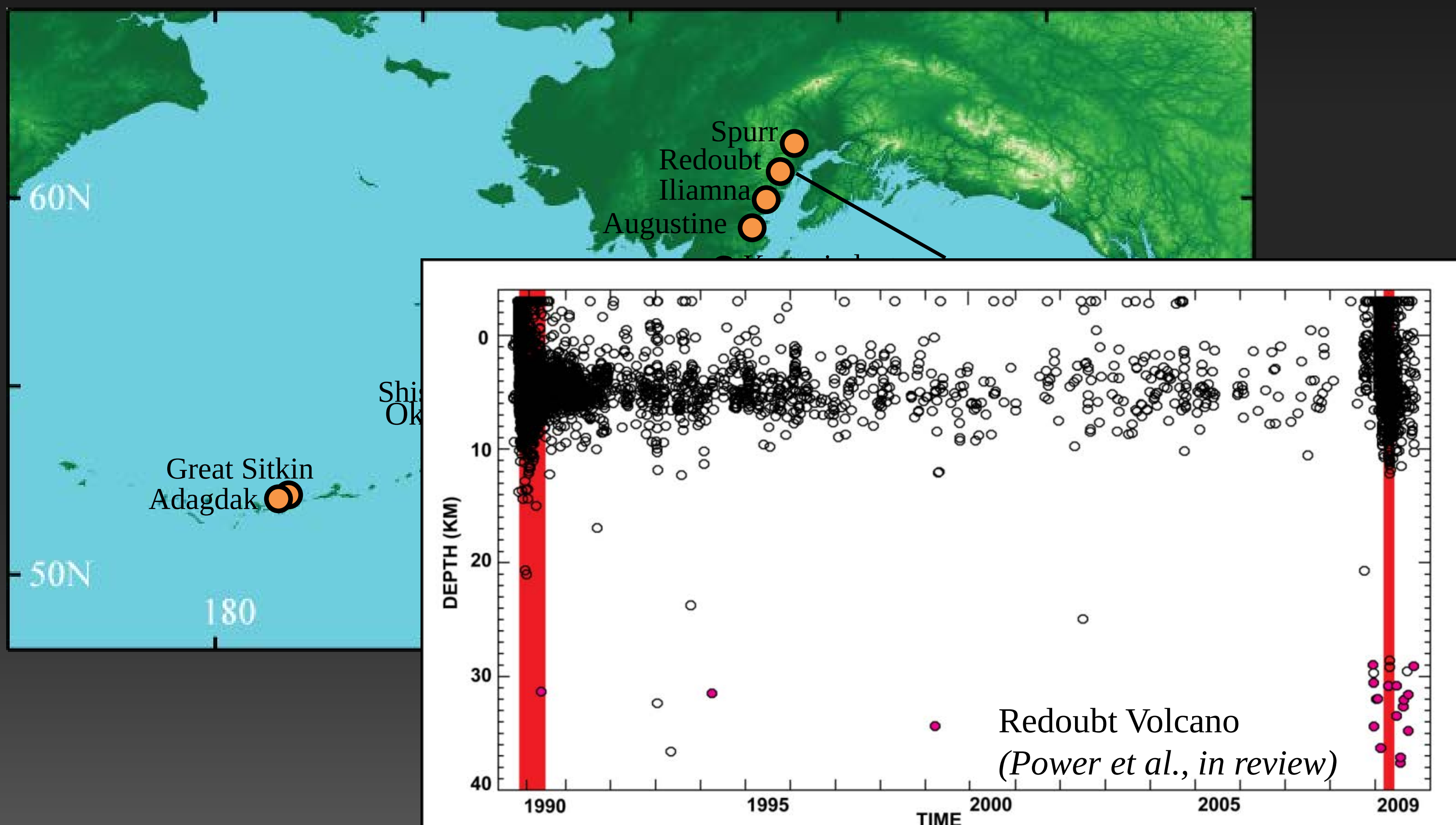




II. Indicators of Magma Ascent: DLPs

DLPs have important implications for volcanic hazards

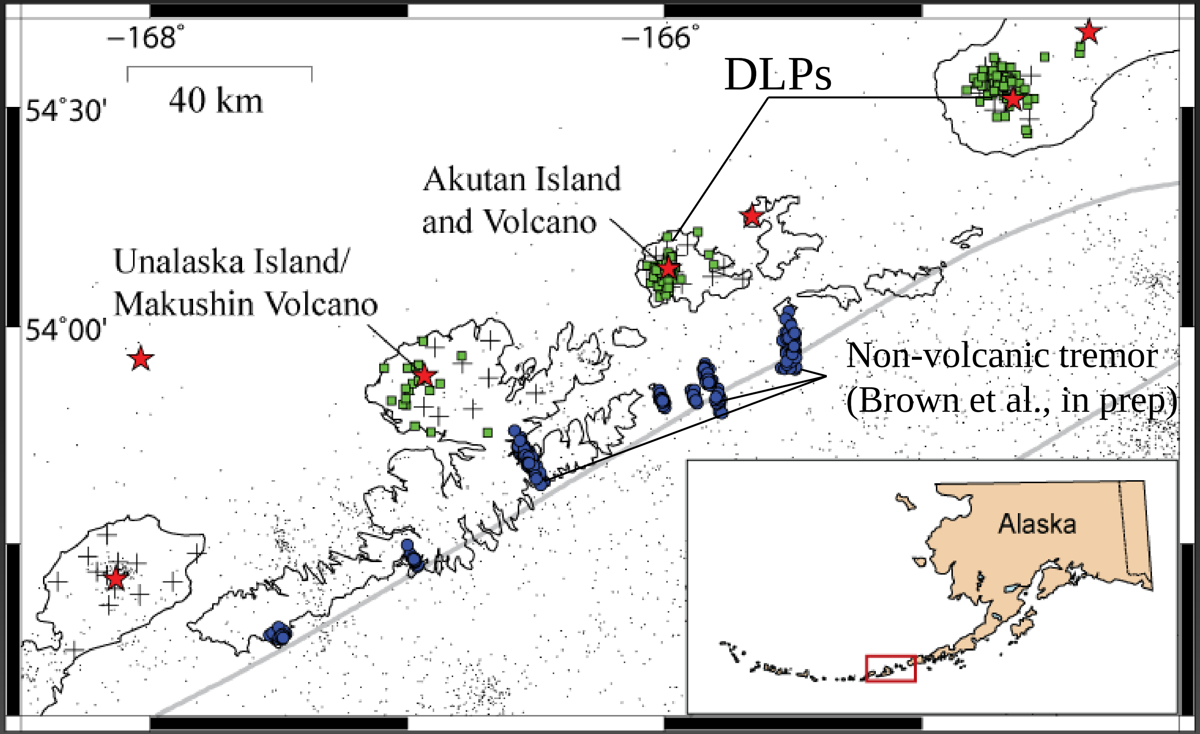
Challenges: Difficult to locate, difficult to model source



II. Indicators of Magma Ascent: DLPs

Unalaska/Akutan target area for small aperture seismic arrays (following Ghosh et al., 2009, 2011)

- -most common source of deep non-volcanic tremor
- -near E edge of 1957 M8.6 rupture zone
- -at transition from oceanic to continental subduction.
- -cost effective, compliment to PBO, USGS, etc.



Prejean et al. GeoPrisms in Alaska White Paper

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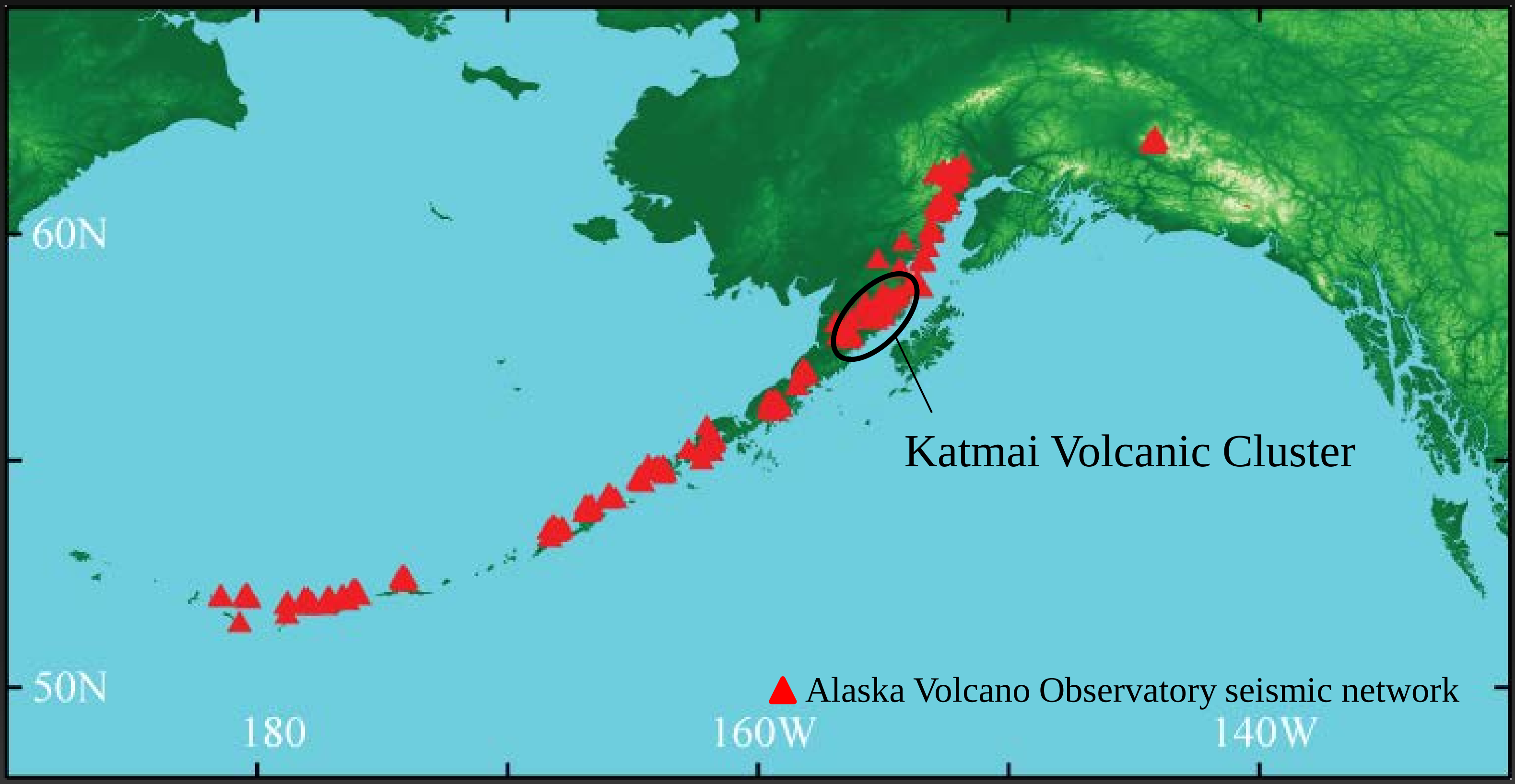
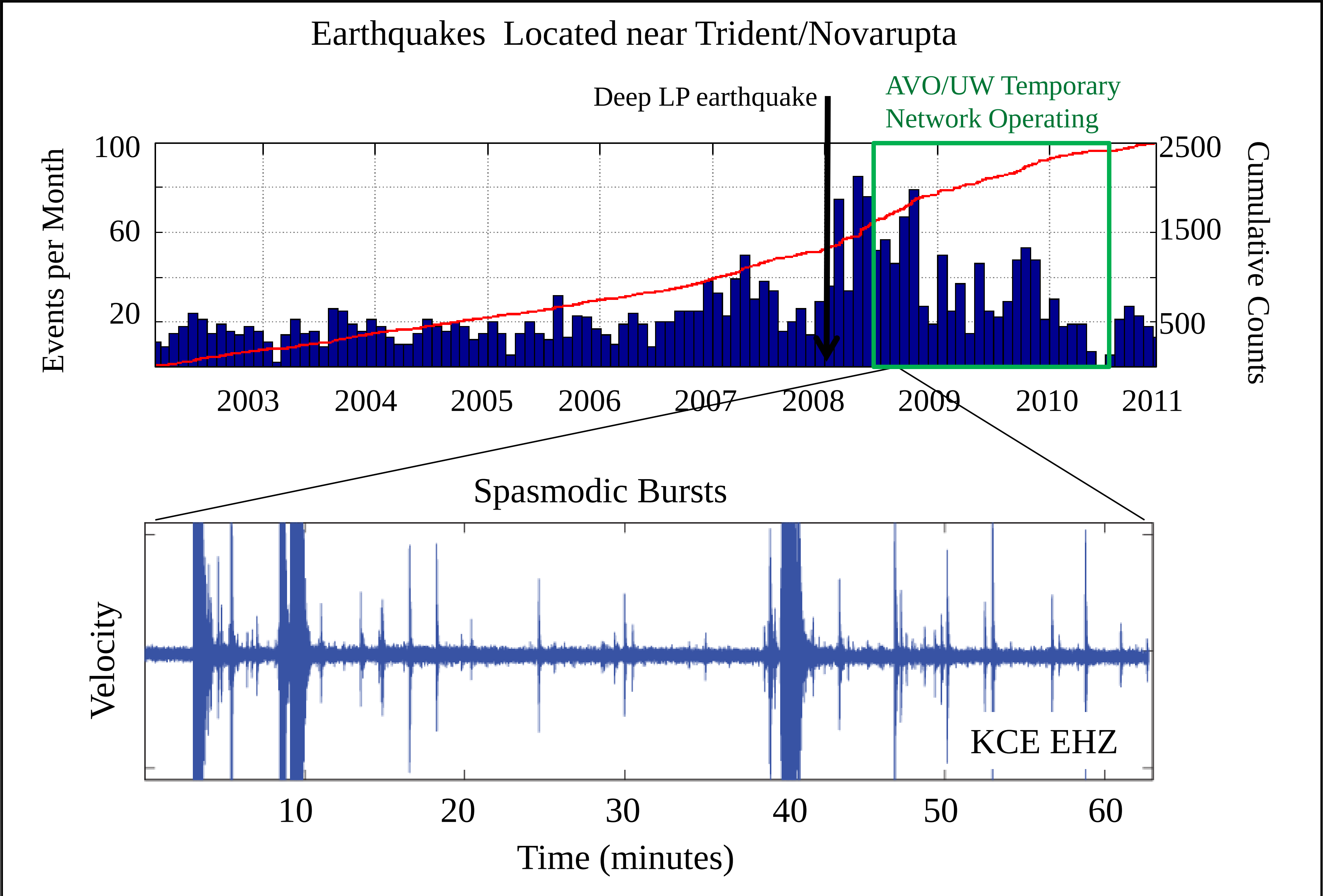
III. Katmai Experiment: AVO – UW

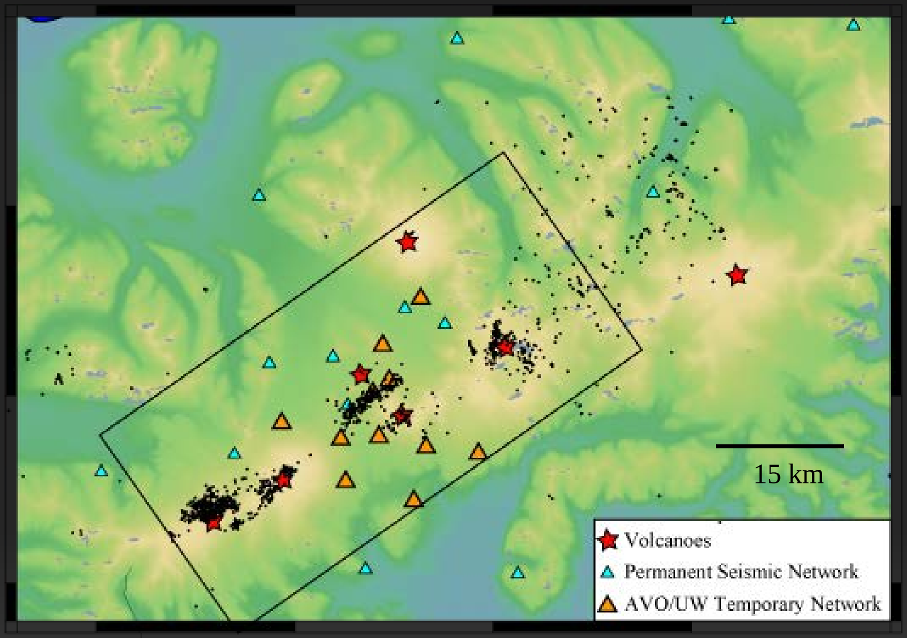


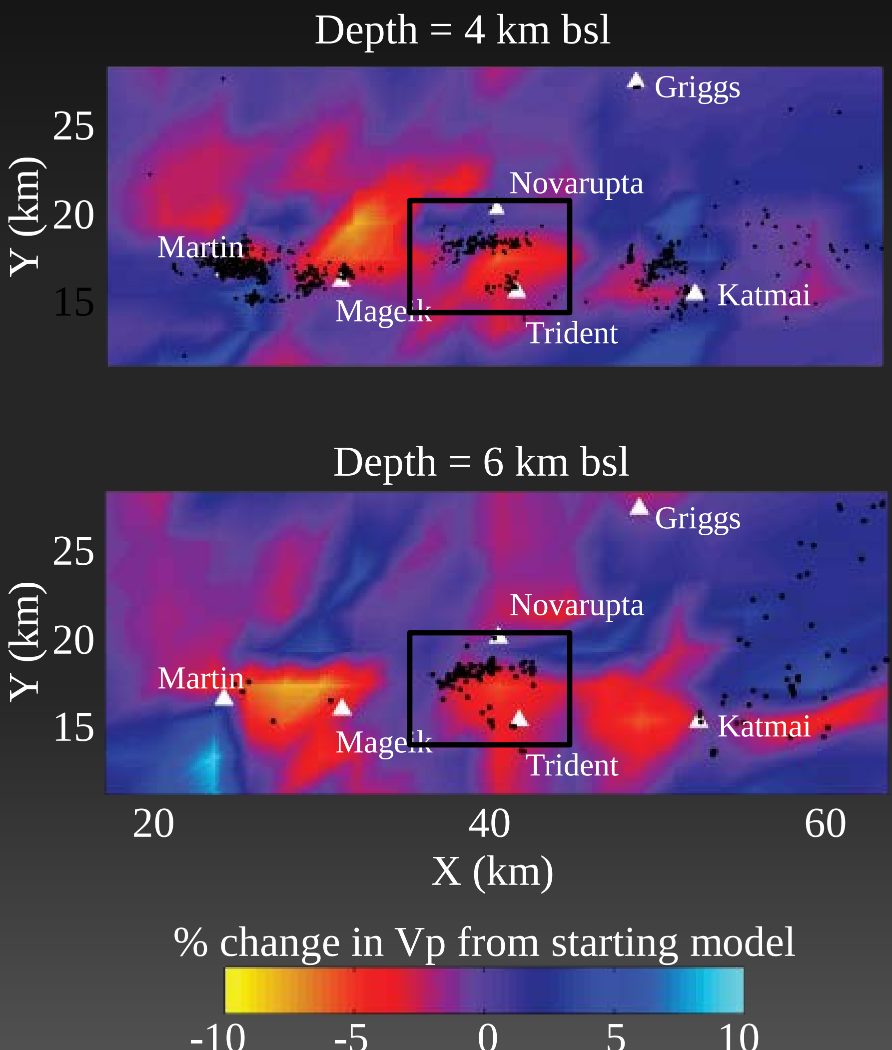
III. Katmai Experiment: AVO – UW



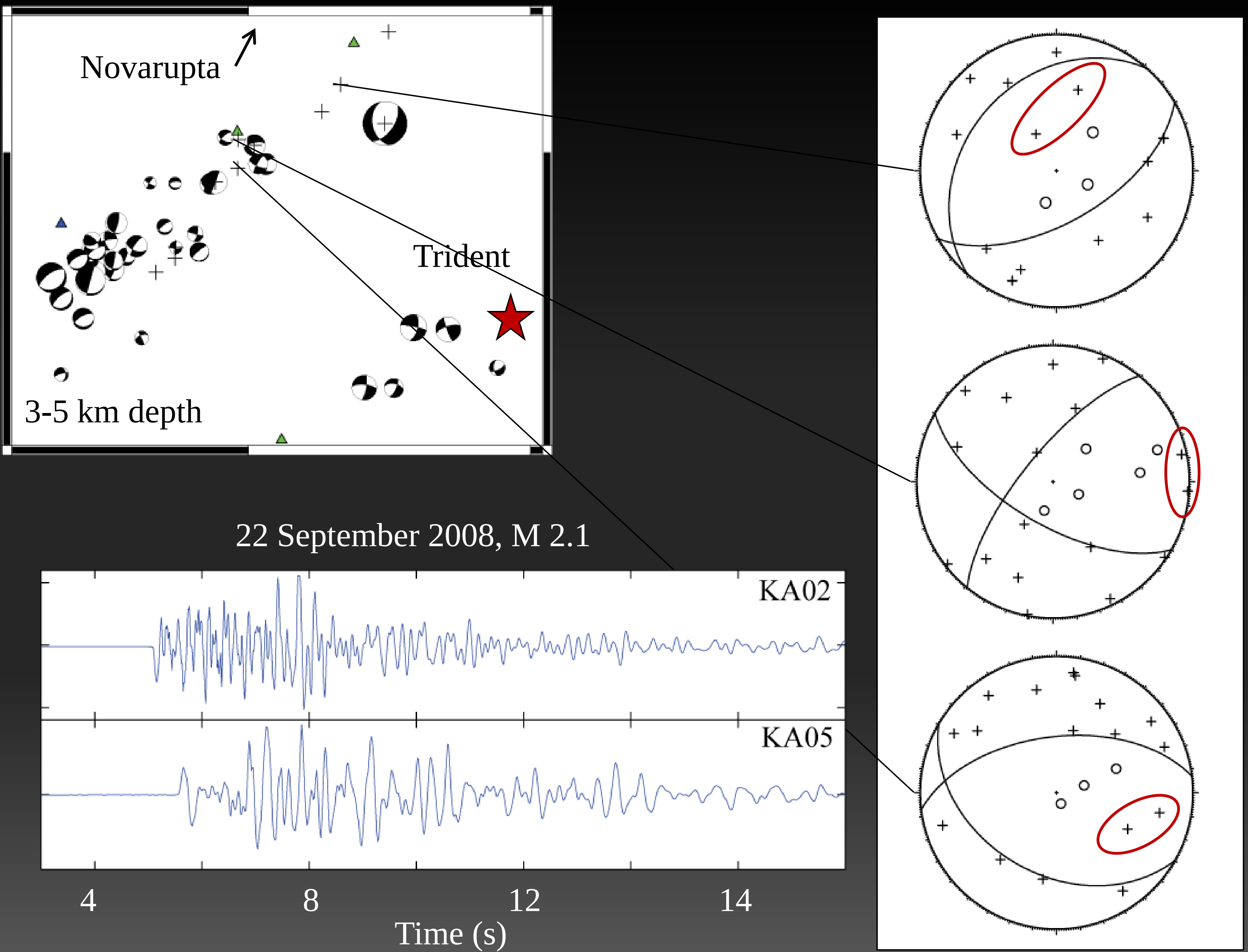
III. *Katmai Experiment:* AVO – UW

P-wave Tomography and Earthquake Relocations





Murphy et al., in prep


Novarupta
Trident
3-5 km depth
22 September 2008, M 2.1
KA02
KA05
4
8
12
14
Time (s)

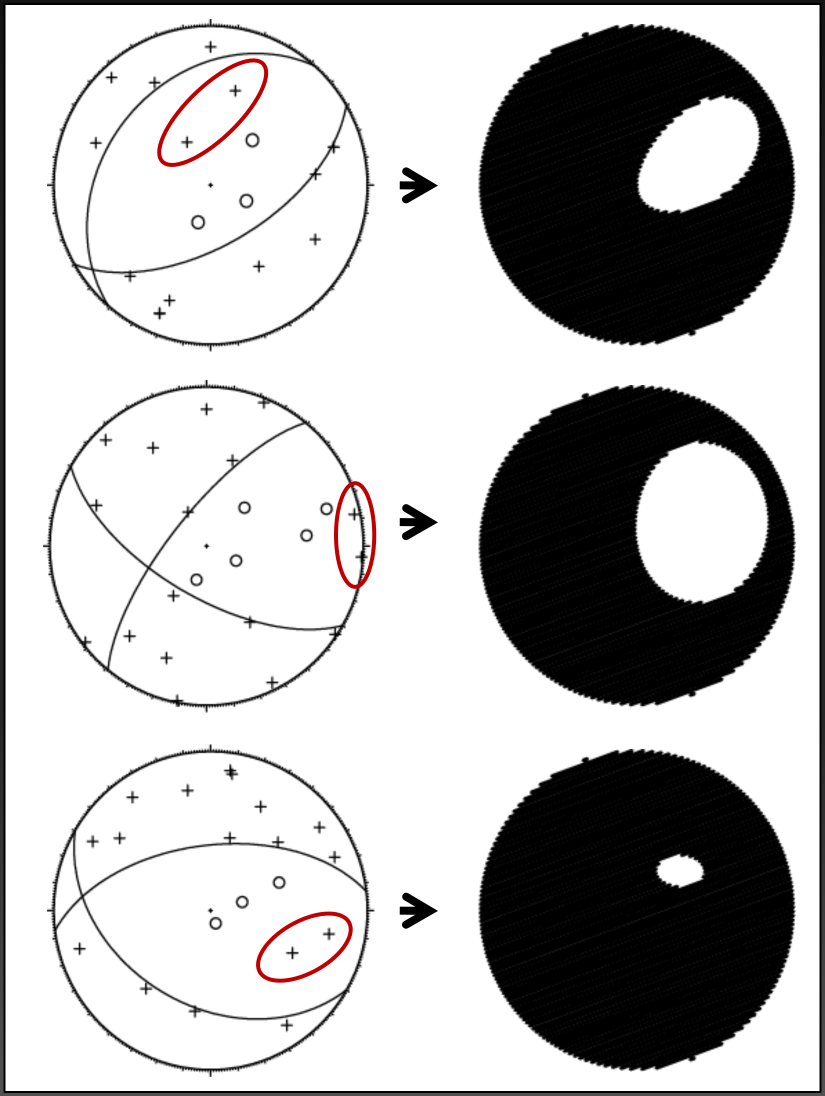
III. Katmai Experiment: AVO – UW

Full moment tensor inversions *(Julian, 1986, Foulger et al., 2004)*

Isotropic: 20 – 30%
Volume change, k=.13-.29

Opening of tensile cracks with fluid intrusion during shear failure (*Foulger et al., 2004; Dreger et al., 2000, Miller, 1996)*

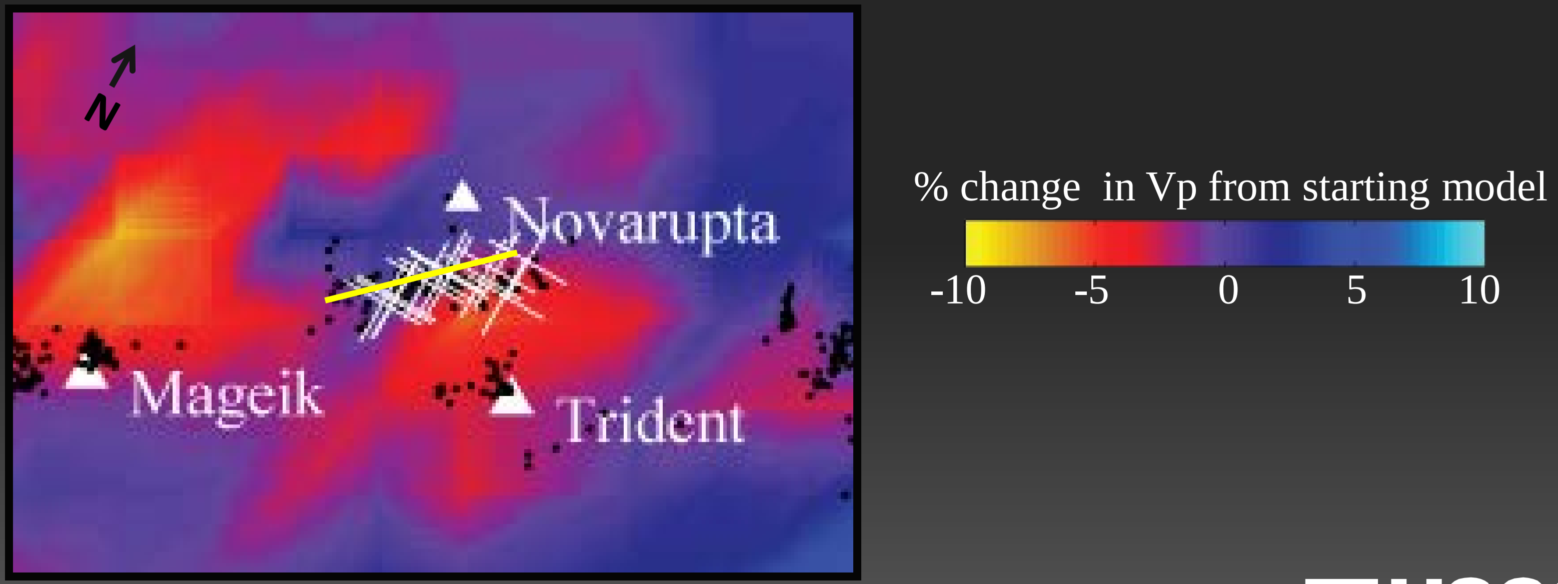
Sources reflect fluid migration in high Pp geothermal system.



Model for 2008 Trident/Novarupta Swarm

- Moment tensors suggest fluid intrusion during earthquake rupture and very high Pp.
- Normal faulting zone bounding Vp anomaly (partial melt ?)
- Deep LPs suggest that swarm likely triggered by renewed fluid movement at 25+ km depth

Fluid driven swarm in a high pressure geothermal system



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Summary

To image roots of systems we need more active/passive, on-land/OBS imaging studies.

We have many tools to investigate magma ascent in the top 10 km, but deep LPs provide a unique opportunity to investigate dynamic fluid flow near the base of the crust.

To address dynamic ascent and hazards active sources need to be studied in conjunction with regional imaging/modeling.

Cook Inlet and the Unimak-Unalaska region are prime targets for research corridors.

Look forward to unexpected opportunities….

2009 Redoubt ‘Screams” (Pre-eruptive Gliding Tremor)

(Hotovec, Prejean, Vidale, Gomberg, in review)