Science Challenges

1. Thermo-chemical internal dynamics and volatile distribution
2. Faulting and deformation processes
3. Change and interactions among climate, hydrology, surface processes, and tectonics.

CHARGE:

- To revisit regularly the scientific goals and strategies as articulated by the SAGE proposal
- To identify the key facilities and services required to achieve their scientific goals
- To evaluate the efficacy of the facilities in meeting their scientific needs
- To identify new infrastructural needs that are required to meet their scientific challenges

This morning:

- 30-minute presentations from each group
- Forum

Science Challenges

1. Thermo-chemical internal dynamics and volatile distribution
2. Faulting and deformation processes
3. Change and interactions among climate, hydrology, surface processes, and tectonics.

Colleen Dalton
Brown

Ed Garnero
ASU

Greg Hirth
Brown

Maureen Long
Yale

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Talking points for this morning's forum

1. Scientific themes

- interaction between lithosphere and mantle convection
  - What drives plate tectonics?
  - How well are plates and underlying flowing mantle coupled?
  - The LAB – delamination – lower crust – cratonic keels
- melt and volatiles and their impact on mantle dynamics
  - What do melts tell us about mantle rheology and chemistry?
  - How are melts generated?
  - Melt pathways?
- the style of convection in the mantle
  - What is the imprint of mantle convection on the transition zone?
  - Do mantle plumes generate LIPs and volcanic hotspots?
  - What are the LLSVPs in the lowermost mantle?
- the core

  …

Talking points for this morning's forum

2. Approaches and opportunities

- instrumentation
  - large-N arrays – longer deployments
  - attain truly global coverage (i.e., oceans)
  - consider tradeoffs between PI- and community-driven experiments
- analysis of existing data and new interpretations
  - the full waveform, 3D theories, address massive data volumes
- earth-system and interdisciplinary approaches
  - integration between deep Earth and surface research
  - link seismology to tectonics, MT, dynamics, petrology, etc.
- evaluation
  - reflect on how USArray and other dense arrays have changed interpretations?

Talking points for this morning's forum

3. What is needed

- sensor development
  Define the benefits of different sensor designs (e.g., miniature, band limitations, etc) for different research targets

- obs and ocean floats
  Partner with other communities to instrument the ocean floor?

- global and TA-style arrays
  large and small spatial scales –
  a GSN backbone and dense deployments

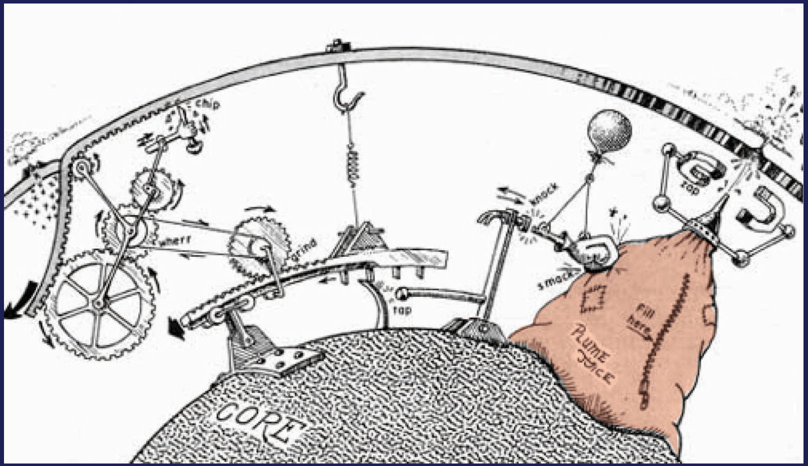
- organization of IRIS, CIG, COMPRES, UNAVCO around common scientific themes
  how do we strengthen multidisciplinary connections?
  the *seismic* Earth – the *petrologic* Earth – the *dynamic* Earth

Next ....

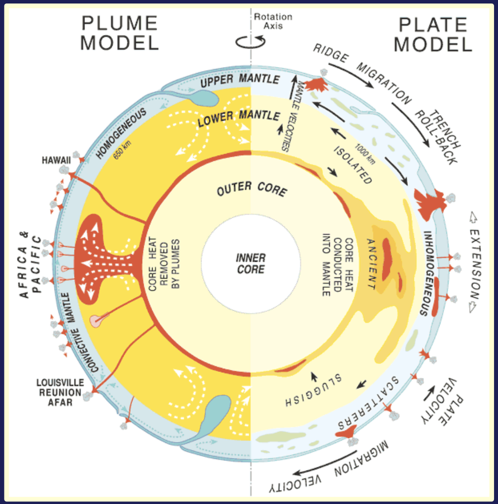
An example from the upper mantle (Colleen)

An example from the lower mantle (Jeroen)

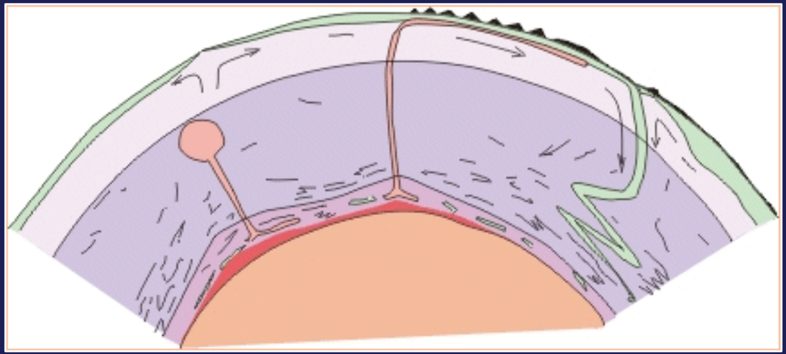
The imaging of plumes;
an example of a long-standing Science Challenge



Vogt and Holden. 1977



Foulger et al. 2005



Davis, 1991

Talking points for this morning's forum

1. Scientific themes

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- melt and volatiles and their impact on mantle dynamics
  - What do melts tell us about mantle rheology and chemistry?
  - How are melts generated?
  - How do melts move?
- the style of convection in the mantle
  - What is the imprint of mantle convection on the transition zone?
  - Do mantle plumes generate LIPs and volcanic hotspots?
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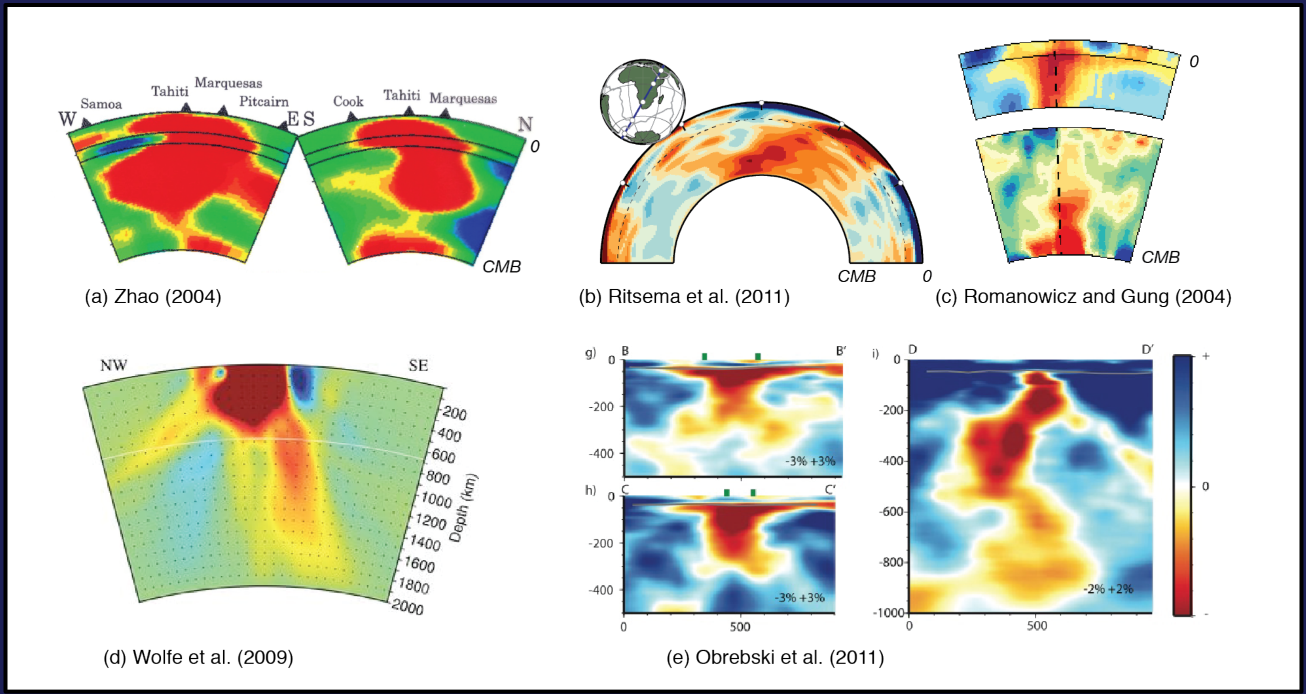
…

Are these plumes?



(a) Zhao (2004)
(b) Ritsema et al. (2011)
(c) Romanowicz and Gung (2004)
(d) Wolfe et al. (2009)
(e) Obrebski et al. (2011)

- Scales of δV_S and δV_P — broad in the high-viscosity lower mantle?
- amplitude of δV_S and δV_P — consistent with thermo/chemical upwelling?
- Extent in the mantle — rooted in D”?
- Tilt — deflection during rapid ascent?
- Interaction with the TZ — 660 upwarping (scale?)

Next steps

1. new data

- coverage and station density
  - currently we only see the “red” spectrum of heterogeneity
- use 30 years of existing data
  - extract info from wiggles without proper phase names

2. better interpretations

- proper data and model resolution analysis
  - going beyond the checkerboard tests
  - 3D synthetics – hypothesis testing
- interpretations of images
  - physics

Imaging of small anomalies

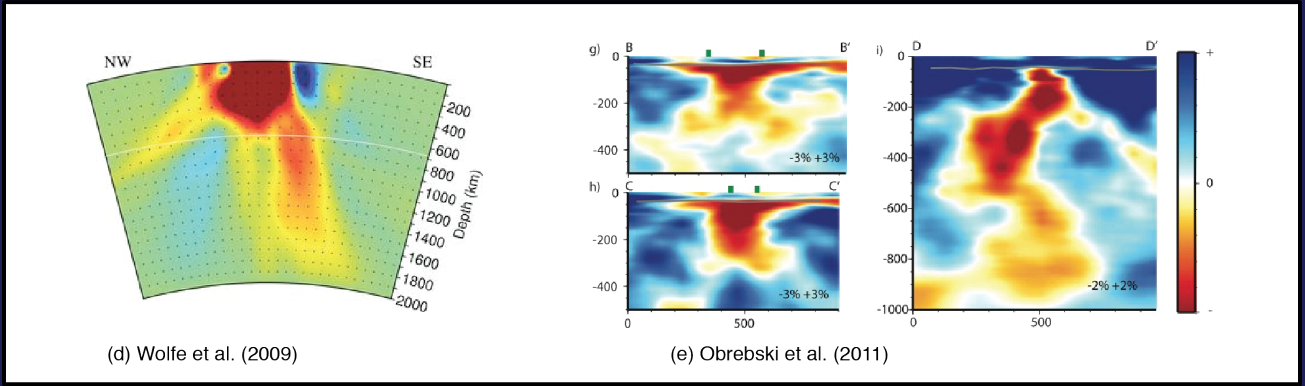
1. new data

- coverage and station density

  currently we only see the "red" spectrum of heterogeneity

PLUME network
on islands and the sea floor

USArray
on a continent



(d) Wolfe et al. (2009)

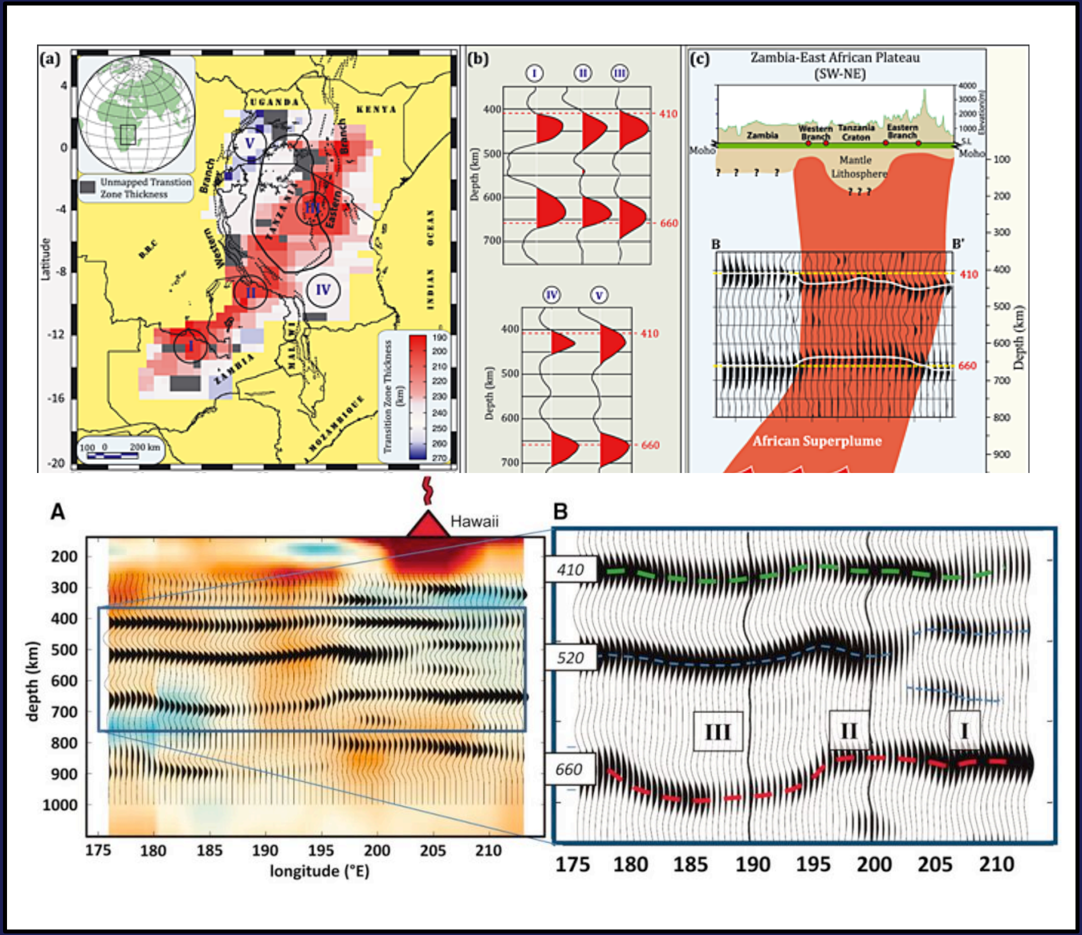
(e) Obrebski et al. (2011)

Wolfe et al. 2009
Porritt et al. 2014

dense, wide aperture arrays are necessary to detect small anomalies in the lower mantle

Tilted plumes?

- Undulations of the 410 and 660 not directly beneath hotspots
- What is the underlying dynamics?



Mulibo & Nyblade 2013

AfricaArray

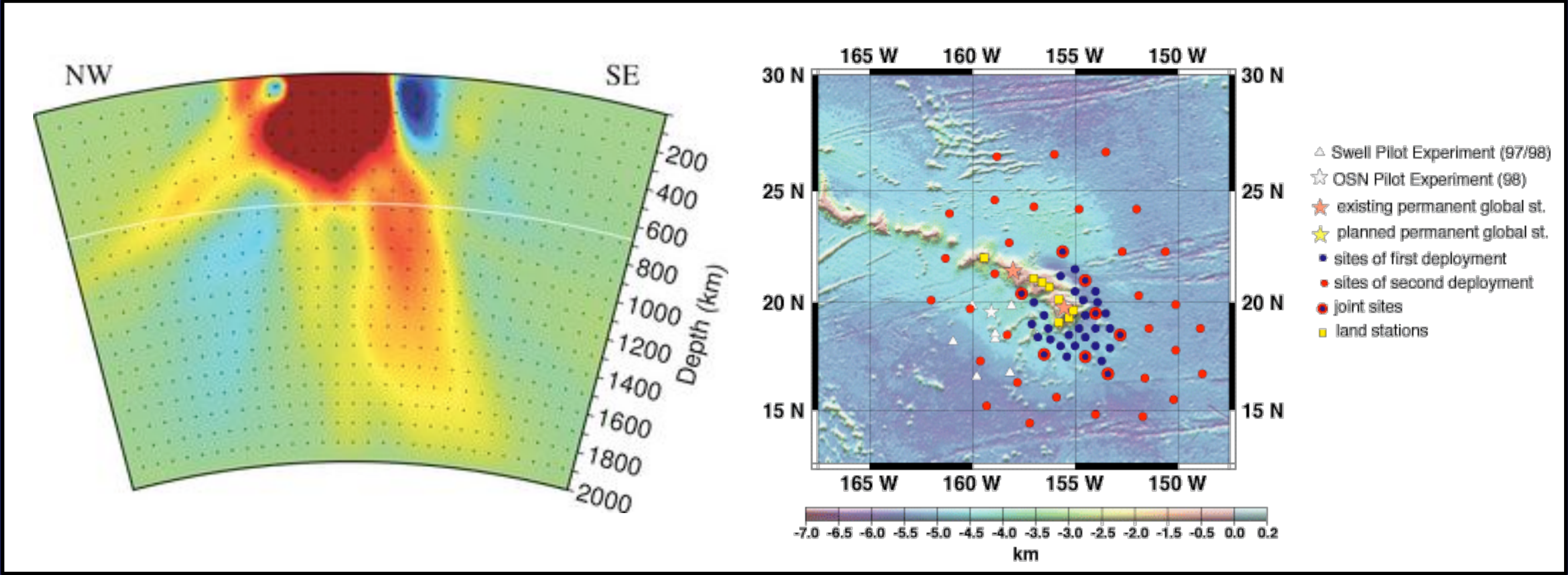
Cao et al. 2011

USArray

Seismometers on the sea floor

Wide aperture arrays are necessary to see the lower mantle …

Wolfe et al. 2009, Laske et al. 2011

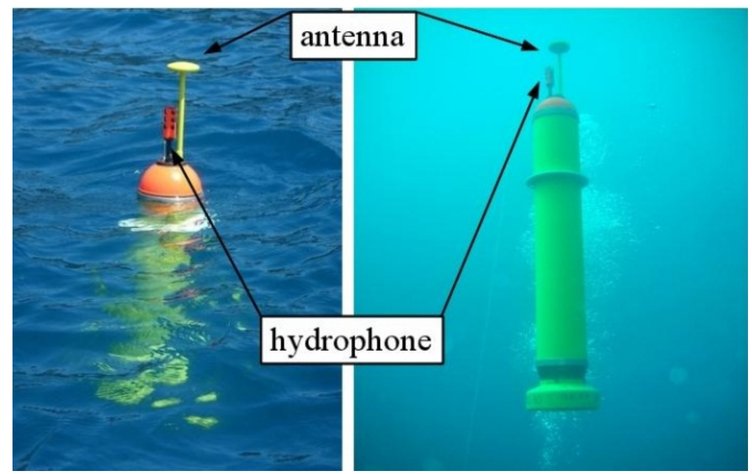


Seimometers in the oceans

… Complete ocean coverage will provide global context

Mermaid, Son-of-mermaid (Simon and Simons), Mariscope (Nolet)

Argo.ucsd.edu



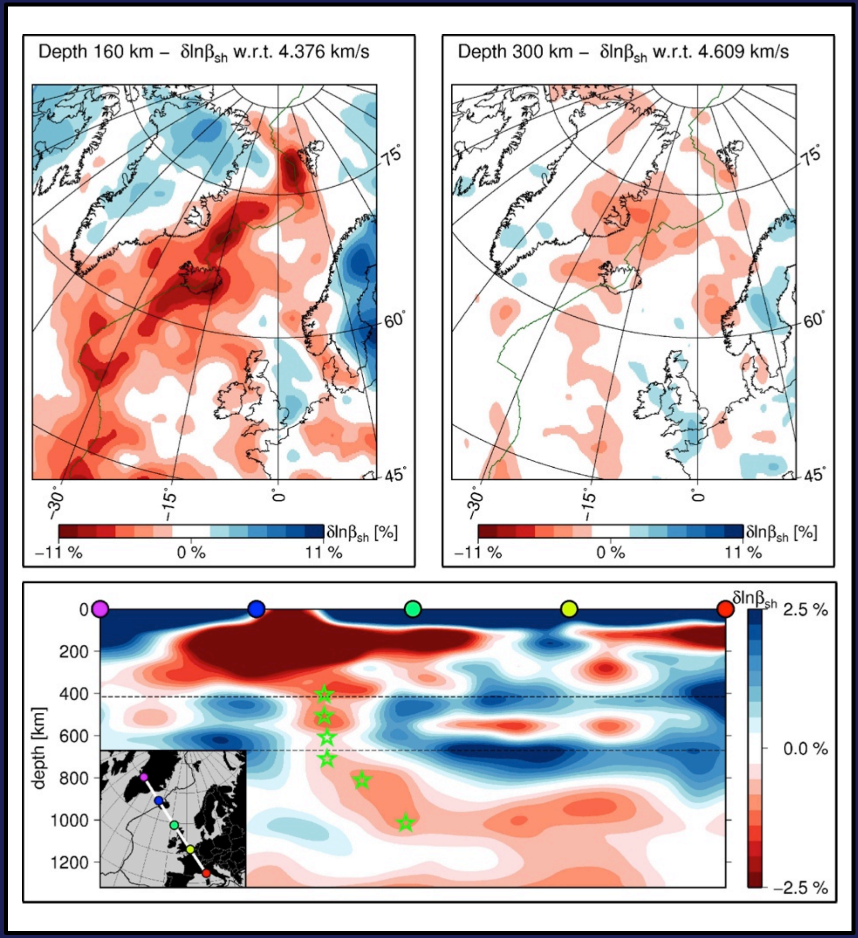
Project Mermaid
Simons et al., *JGR*, 2009

See also the CIG meeting on Tuesday

Imaging of smaller scales

1. We need new data
- use 30 years of existing data
  extract info from wiggles without proper phase names

Fichtner et al. 2012



Full waveform tomography
3D synthetics and kernels
Cluster computing

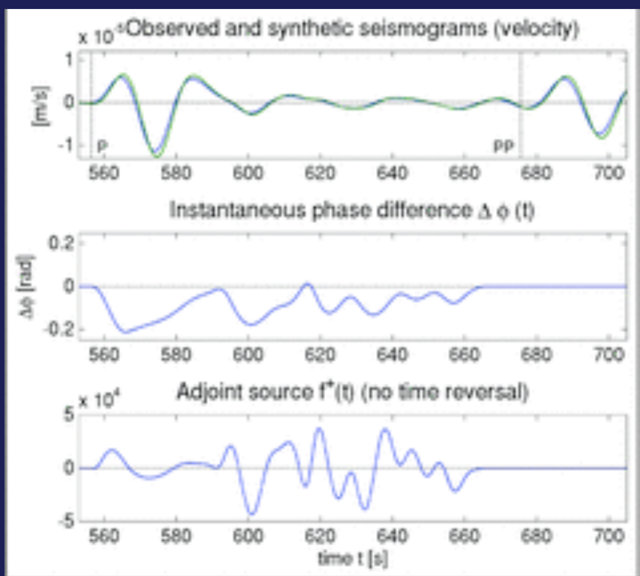
See also Tape et al. 2009, Bozdag et al. 2011, Lekic et al. 2012, Takeuchi 2012, Zhu et al., 2012

New data interpretations

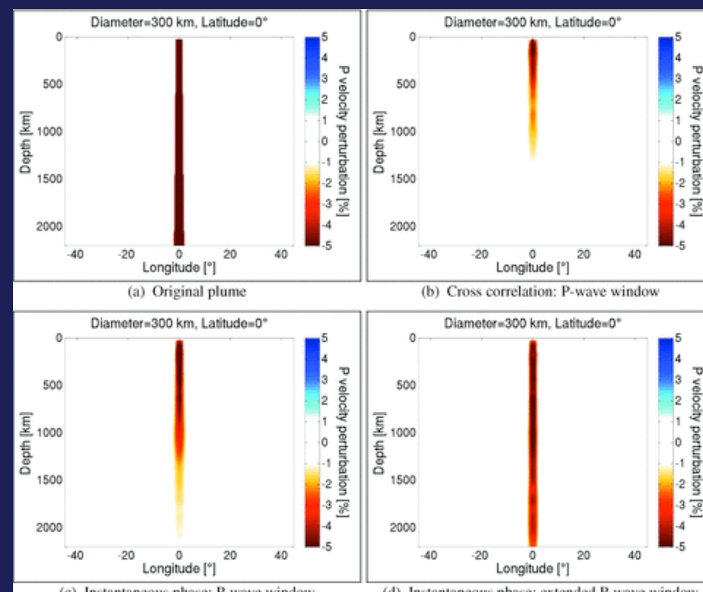
1. We need new data

- use 30 years of existing data

  extract info from wiggles without proper phase names



(a) A receiver located behind the plume



Rickers et al. 2012

Analysis of the first-arrival and coda
("*instantaneous phase*" in this example)

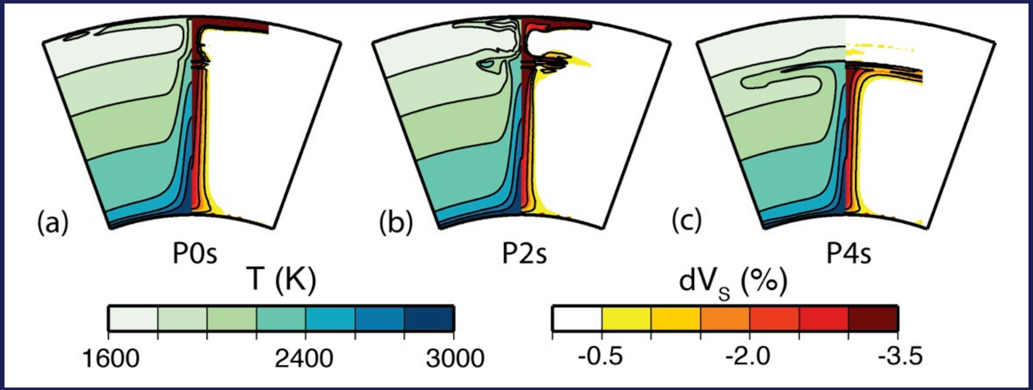
See also Wielandt 1987, Ji & Nataf 1998,
Allen & Tromp 2005, Malcolm & Trampert 2011

The seismic expression of plumes

2. We need better interpretations

- interpretations of images

  physics



- rheology
- compressibility of mantle
- phase changes
- from P / T / X to δV_S / δV_P / $\delta\rho$, …

Lin and van Keken 2005
Styles et al. 2011

See also Ribe & Christensen 1994, Farnetani and Samuel 2003, Tan and Gurnis 2005, King & Redmond 2007, Leng and Zhong 2011, Ballmer et al. 2013,

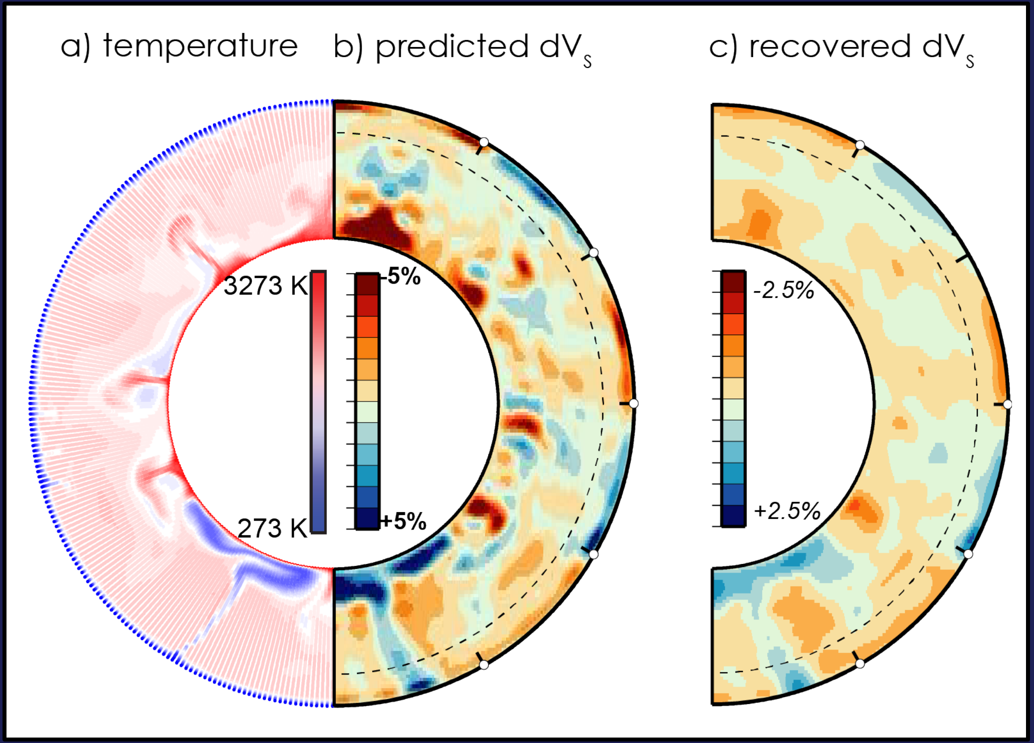
Seismologists apply a low pass filter

2. We need better interpretations

- proper data and model resolution analysis

  going beyond the checkerboard tests

Van Keken 2013



See also Bunge & Davies 2001, Ritsema et al. 2007, Bull et al. 2009, Schuberth et al. 2009, Styles et al. 2011, Davies et al., 2012,

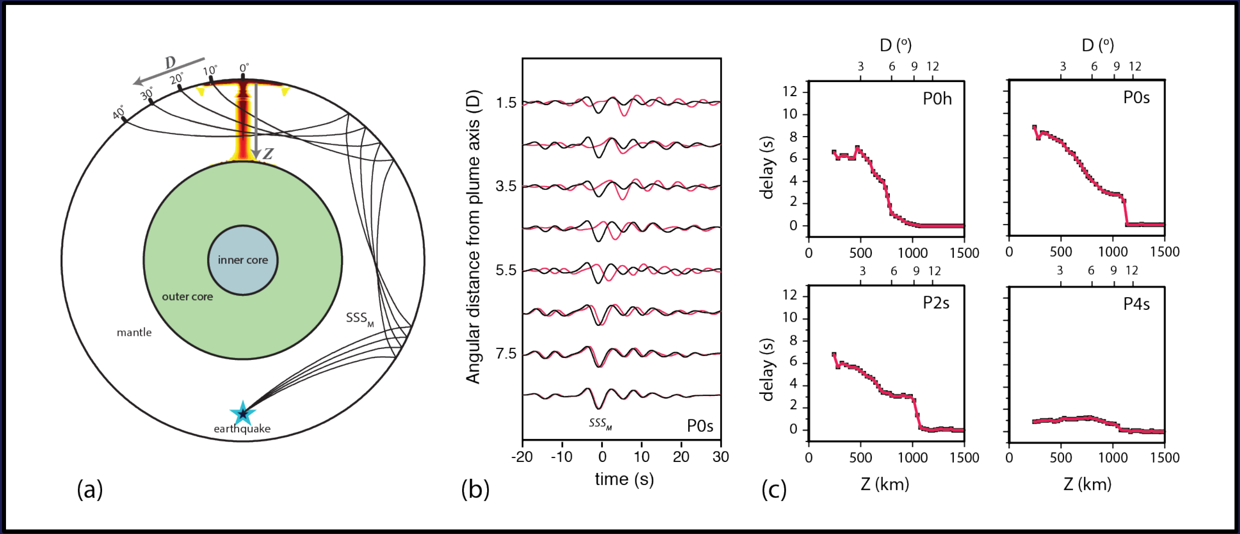
Do plumes perturb seismic waves?

2. We need better interpretations

- proper data and model resolution analysis

3D synthetics – hypothesis testing

plume model 3D synthetics cross-correlations



Hwang et al. 2012

Are traveltimes useful data to search for narrow plume stems?

Talking points for this morning's forum

2. Approaches and opportunities

- improved seismic imaging
  - the oceans
- analysis of existing data and new interpretations
  - exploit the full waveform
  - High Performance Computing
- organization of IRIS, COMPRES, CIG, UNAVCO around common scientific themes
  - the *seismic* Earth – the *petrologic* Earth – the *dynamic* Earth