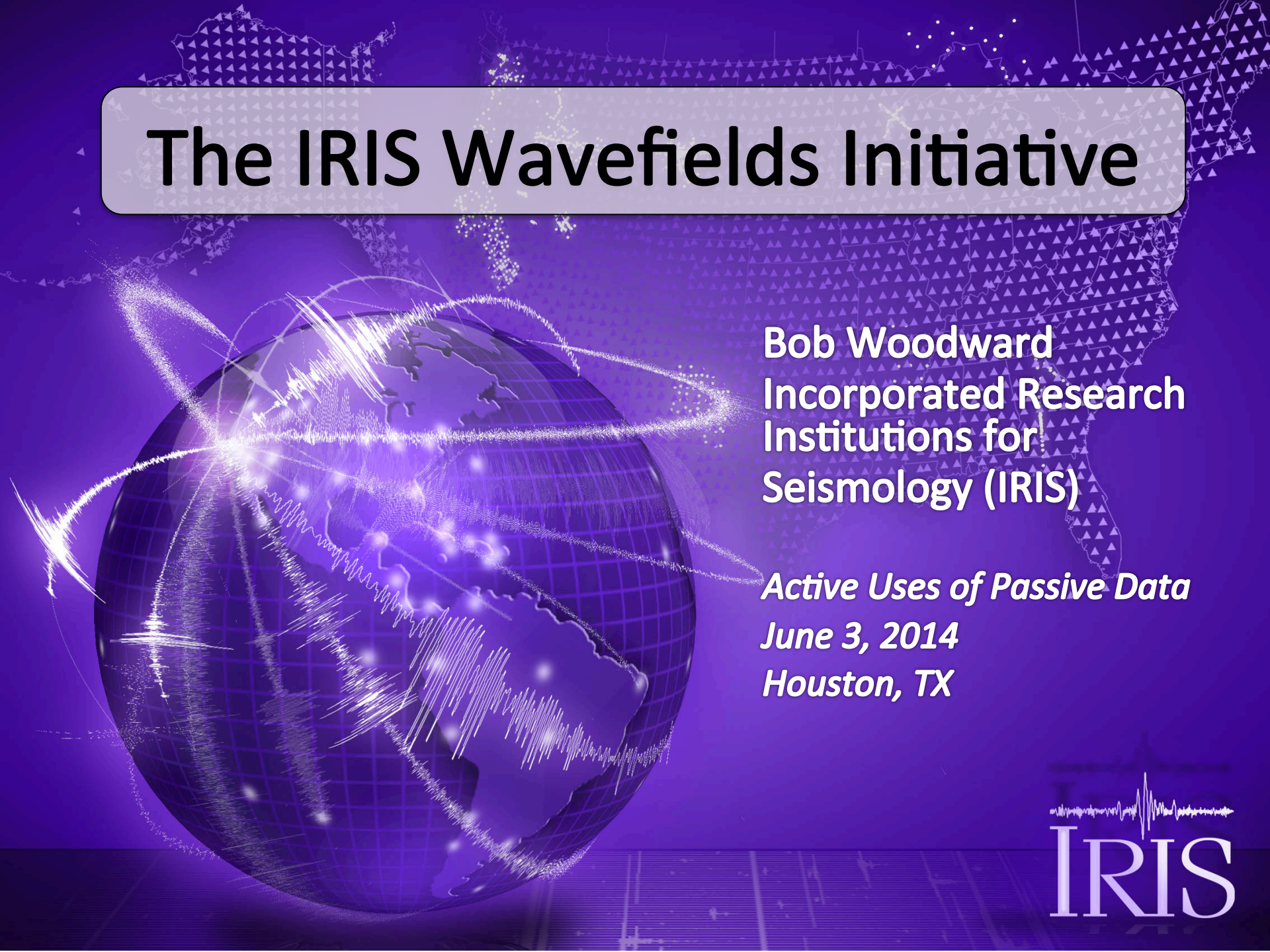
The IRIS Wavefields Initiative



Bob Woodward
Incorporated Research Institutions for Seismology (IRIS)

Active Uses of Passive Data
June 3, 2014
Houston, TX

IRIS

IRIS - Some Guiding Principles

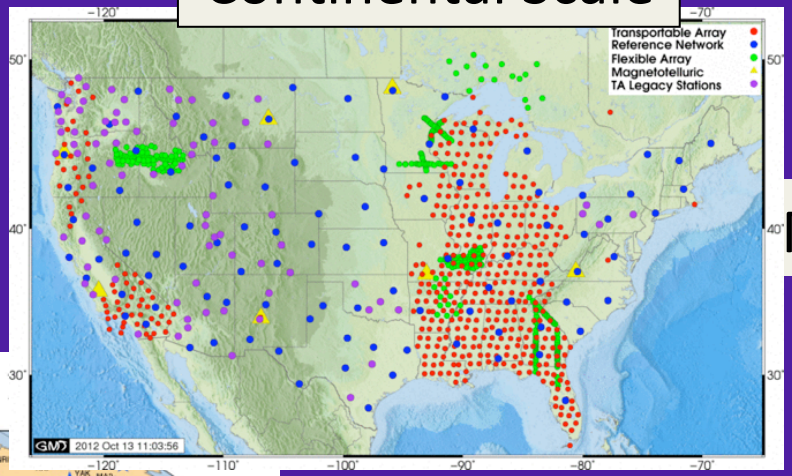
- Let intellectual drivers drive
- **Build facilities that facilitate**
  - **Evolve in response to scientific needs and opportunities**
- **Encourage use of facilities and data**
  - **Free and open data access to all**
- Develop and adhere to standards
  - That remain flexible
- Maintain support and ensure sustainability
- Engage the next generation

An integrated approach to science across the community

IRIS

Multiple Observing Programs

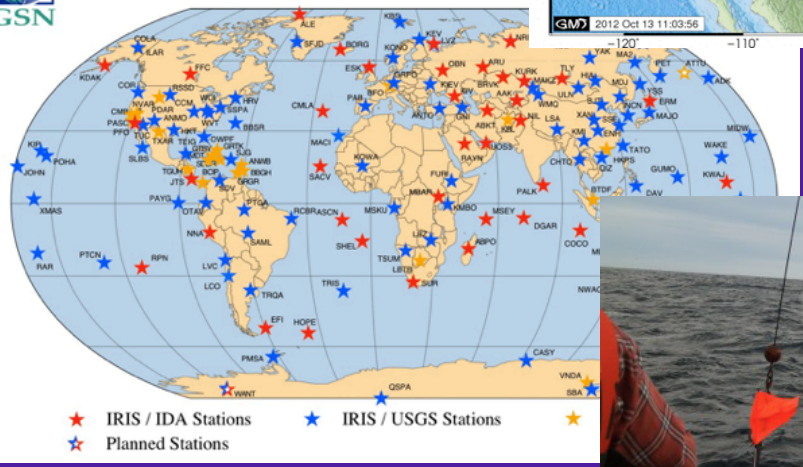
Continental Scale



Meters to Basin Scale

Global Scale

GLOBAL SEISMOGRAPHIC NETWORK

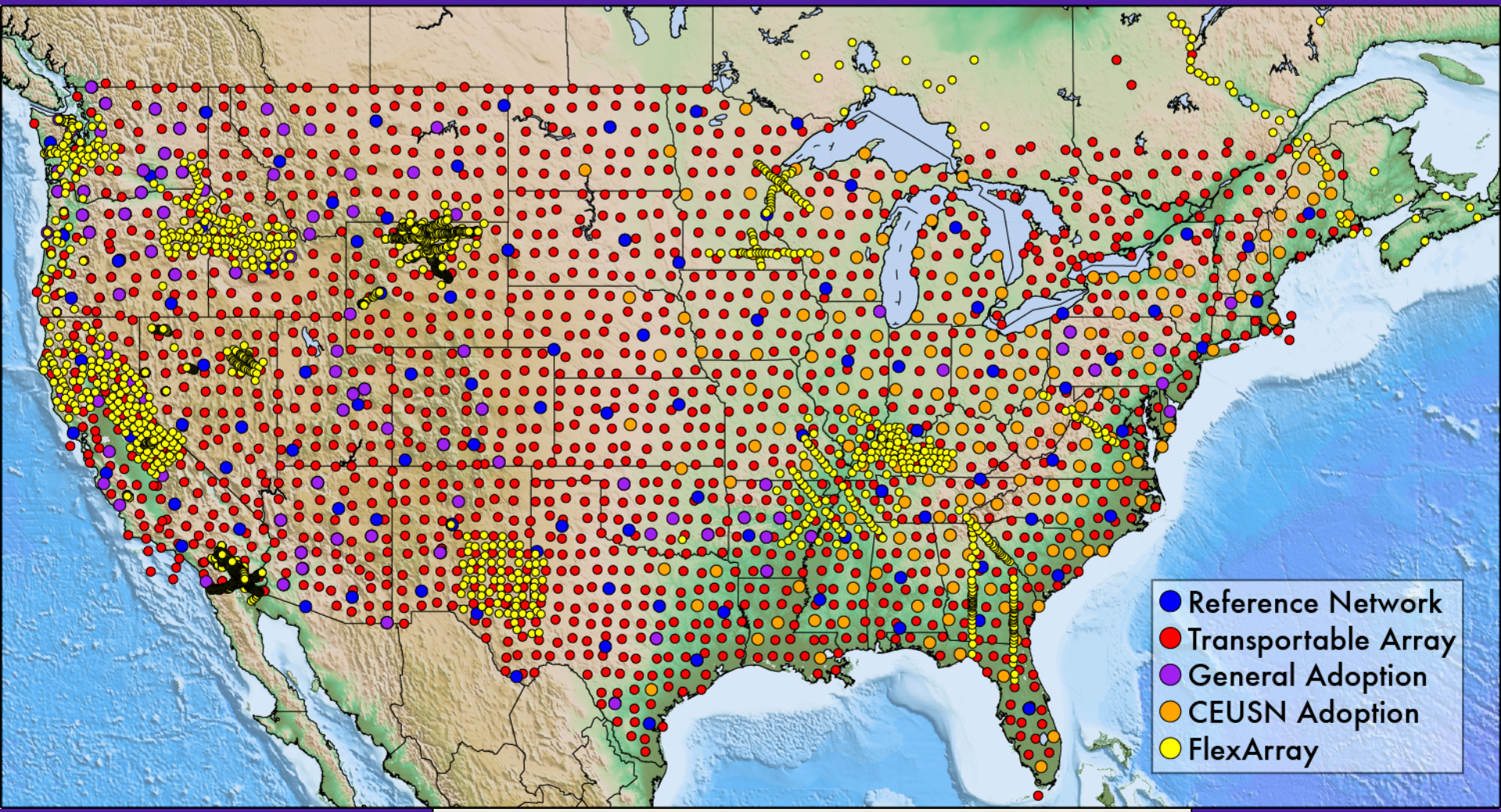


Oceans

Science drives approach, scale, frequency band

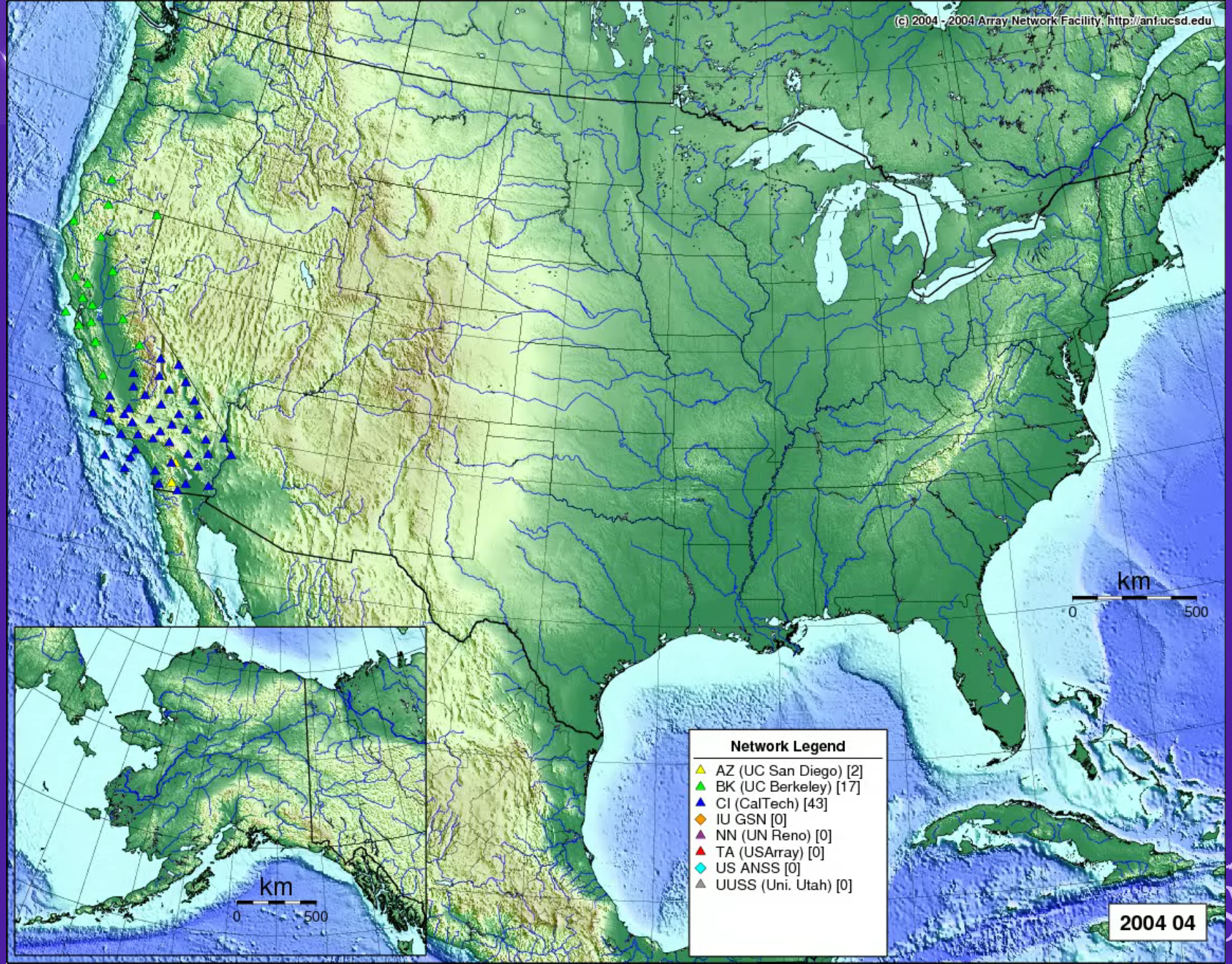
IRIS

EarthScope USArray: Wavefield Imaging at the Continental Scale

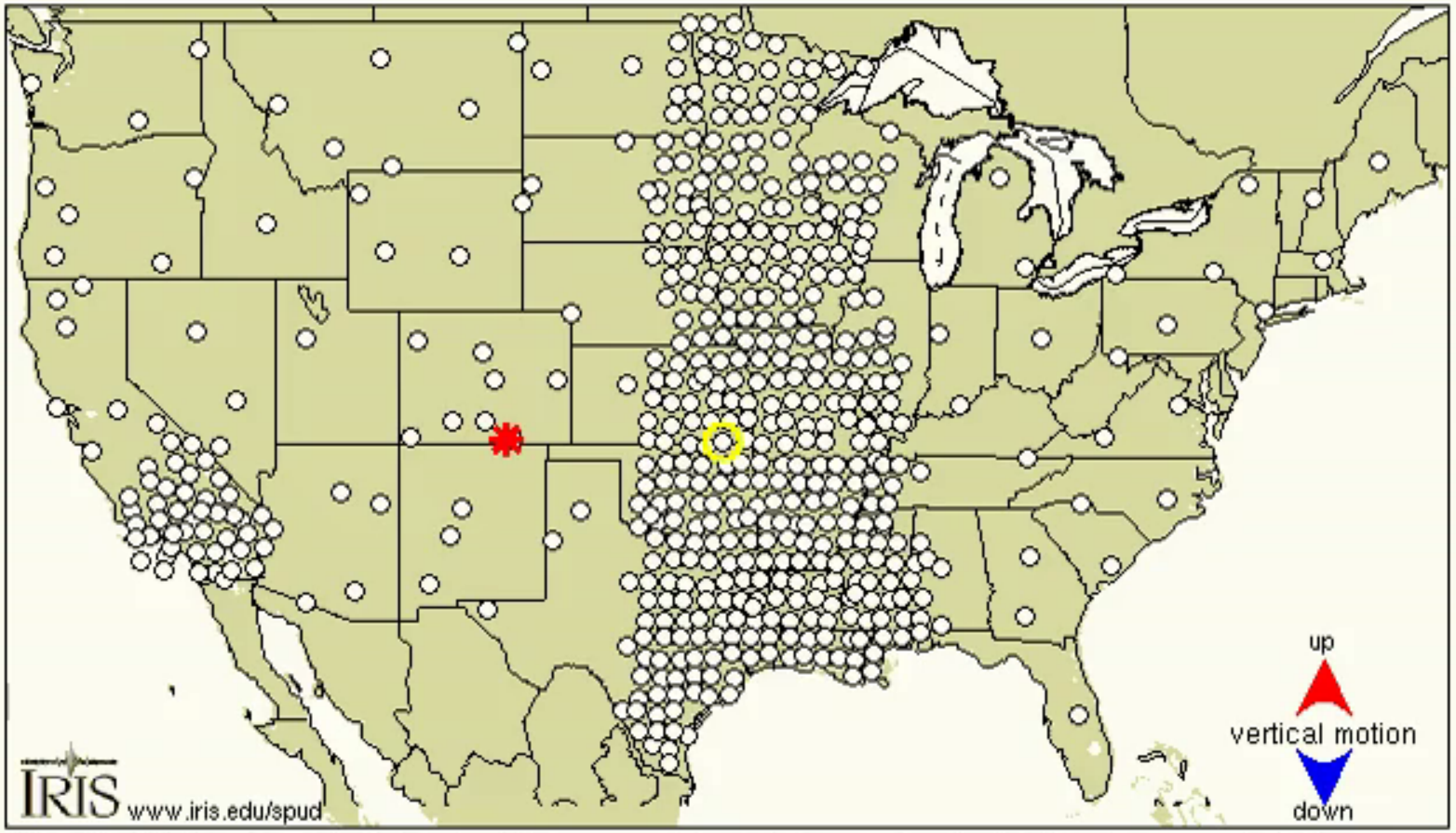


- > 1700 Transportable Array station sites
- > 15 major Flexible Array experiments
- > 350 Magnetotelluric station sites

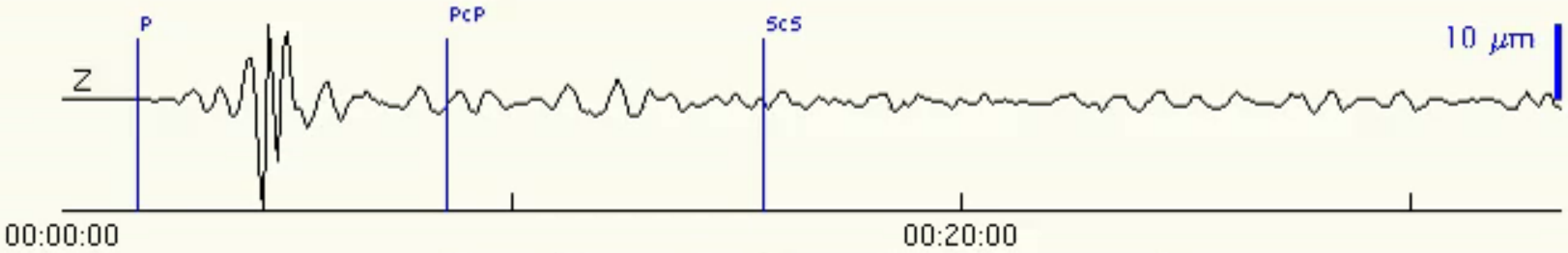
IRIS


(c) 2004 - 2004 Array Network Facility, http://anf.ucsd.edu
km
0
500
km
0
500
Network Legend
AZ (UC San Diego) [2]
BK (UC Berkeley) [17]
CI (CalTech) [43]
IU GSN [0]
NN (UN Reno) [0]
TA (USArray) [0]
US ANSS [0]
UUSS (Uni. Utah) [0]
2004 04

August 23, 2011, COLORADO, M=5.4

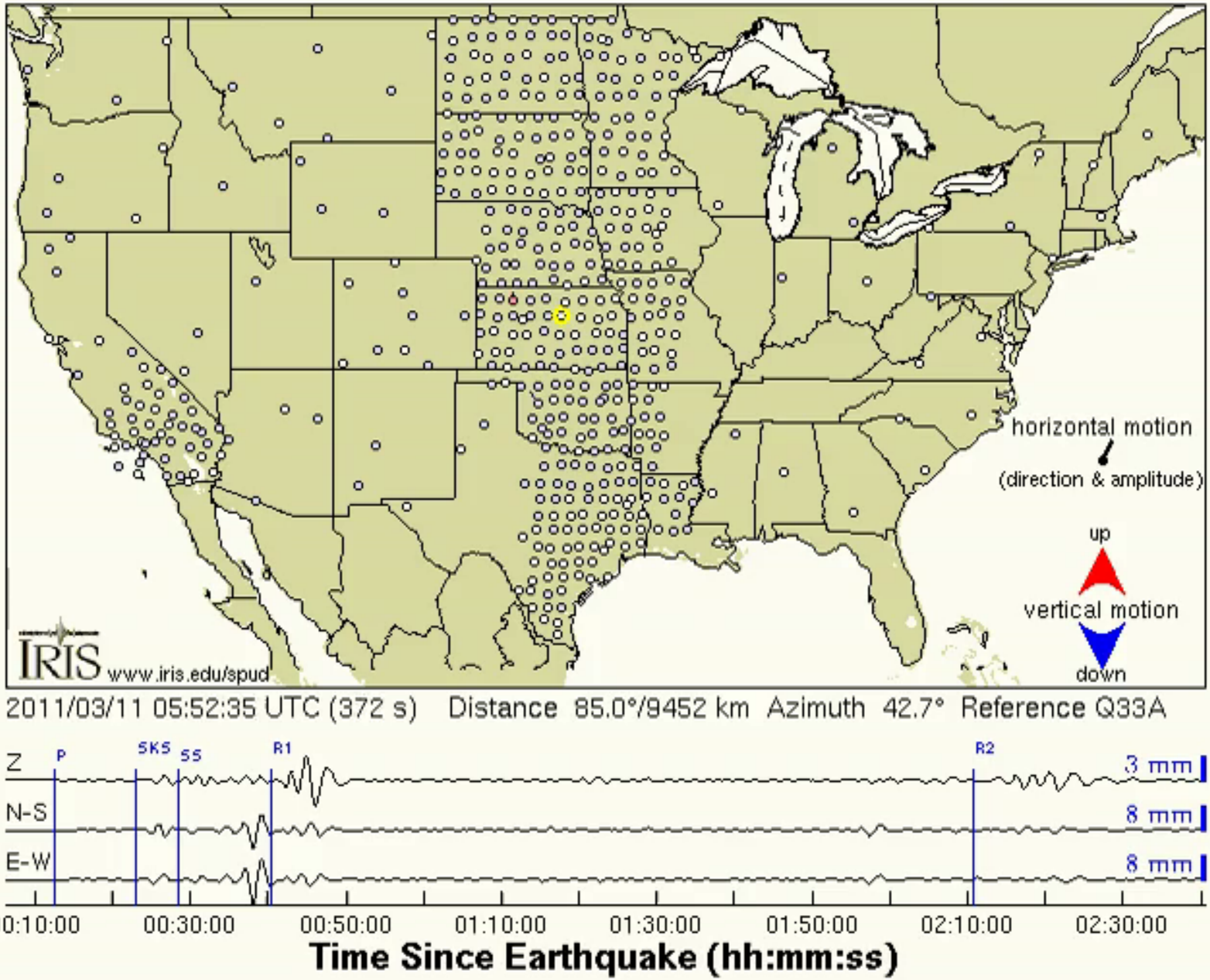


2011/08/23 05:46:19 UTC (0 s) Distance 7.0°/778 km Azimuth 87.8° Reference T36A



Time Since Earthquake (hh:mm:ss)

March 11, 2011, NEAR EAST COAST OF HONSHU, JAPAN, M=8.9



IRIS DMS Combined Ground Motion Visualization

GULF OF CALIFORNIA 2007 - 2013

IRIS DMS Combined Ground Motion Visualization

Gulf of California, 2007-2013

Max Lat: 26.20

Min Lon: 110.60 | 100.10 | Max Lon:

Min Lat: 24.67

Start Date: 2007-09-01 00:00

End Date:

Magnitude: 5.5 - 7.7

Depth (km): 0 - 700

Strike: 0 - 360

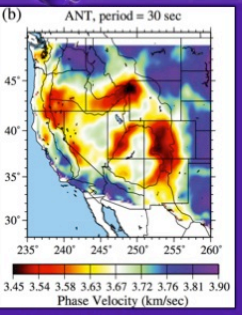
Dip: 0 - 90

Rake: -180 - 180

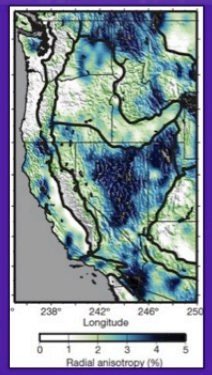
	Event Time (UTC)	Depth (km)	Mag	Latitude	Longitude	FM	Region
1	2013-10-19 17:55:03	15.1	6.6	26.17	-110.58		GULF OF CALIFORNIA
	2013-01-15 16:28:27	18.4	5.7	25.88	-110.28		GULF OF CALIFORNIA
2	2012-10-06 06:28:25	19.7	6.0	26.17	-109.73		GULF OF CALIFORNIA
	2012-09-25 23:45:27	12.0	6.3	24.92	-110.29		BAJA CALIFORNIA, MEXICO
3	2011-07-26 17:44:22	17.5	6.0	25.06	-109.58		GULF OF CALIFORNIA
	2011-08-12 13:26:02	20.6	5.6	25.27	-109.87		GULF OF CALIFORNIA
4	2010-10-21 17:53:19	14.2	6.7	24.83	-109.29		GULF OF CALIFORNIA
	2010-10-20 06:58:16	15.5	5.8	24.72	-109.16		GULF OF CALIFORNIA
	2010-10-20 04:15:36	17.4	5.7	24.69	-109.15		GULF OF CALIFORNIA
	2010-10-20 04:09:47	19.4	5.8	24.74	-109.19		GULF OF CALIFORNIA
5	2009-07-03 11:00:17	14.4	5.9	25.20	-109.87		GULF OF CALIFORNIA
6	2007-09-01 19:14:26	14.9	6.1	24.78	-109.89		GULF OF CALIFORNIA

Wavefield Studies

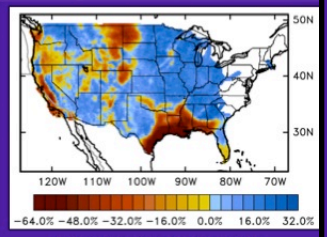
Earth Structure



Ambient Noise Tomography
Shen, et. al., *JGR* 2013



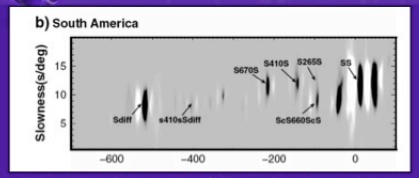
Crustal anisotropy
Moschetti, et. al., *Nature*, 2010



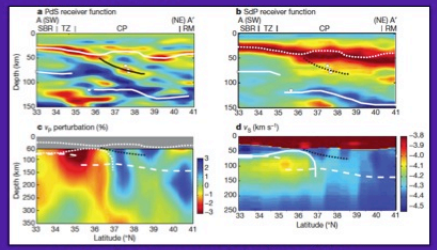
Love wave phase velocity at 5s
Ekström, *EPSL*, 2013

- Exploiting ambient noise and earthquakes via multi
  constrain velocity, anisotropy, and anelastic attenua
- Relies on the spatial coverage, calibration, and unifo

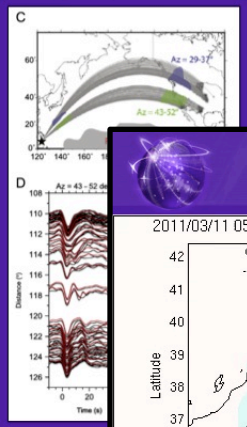
Boundaries



Broadband array observations of the 300 km seismic discontinuity
Schmerr, et. al., *GRL*, 2013

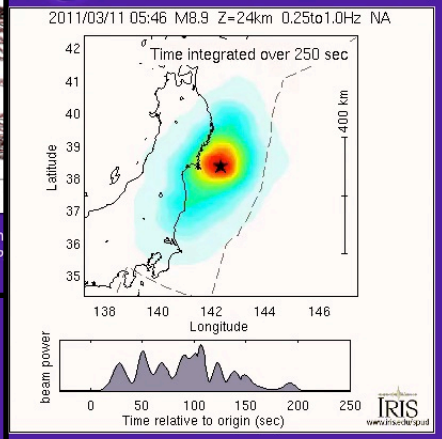


Receiver functions to study Moho and LAB
Levander, et. al., *Nature*, 2011



SKS waveform
Sun, et. al., *EP*

Earthquake Source Characteristics

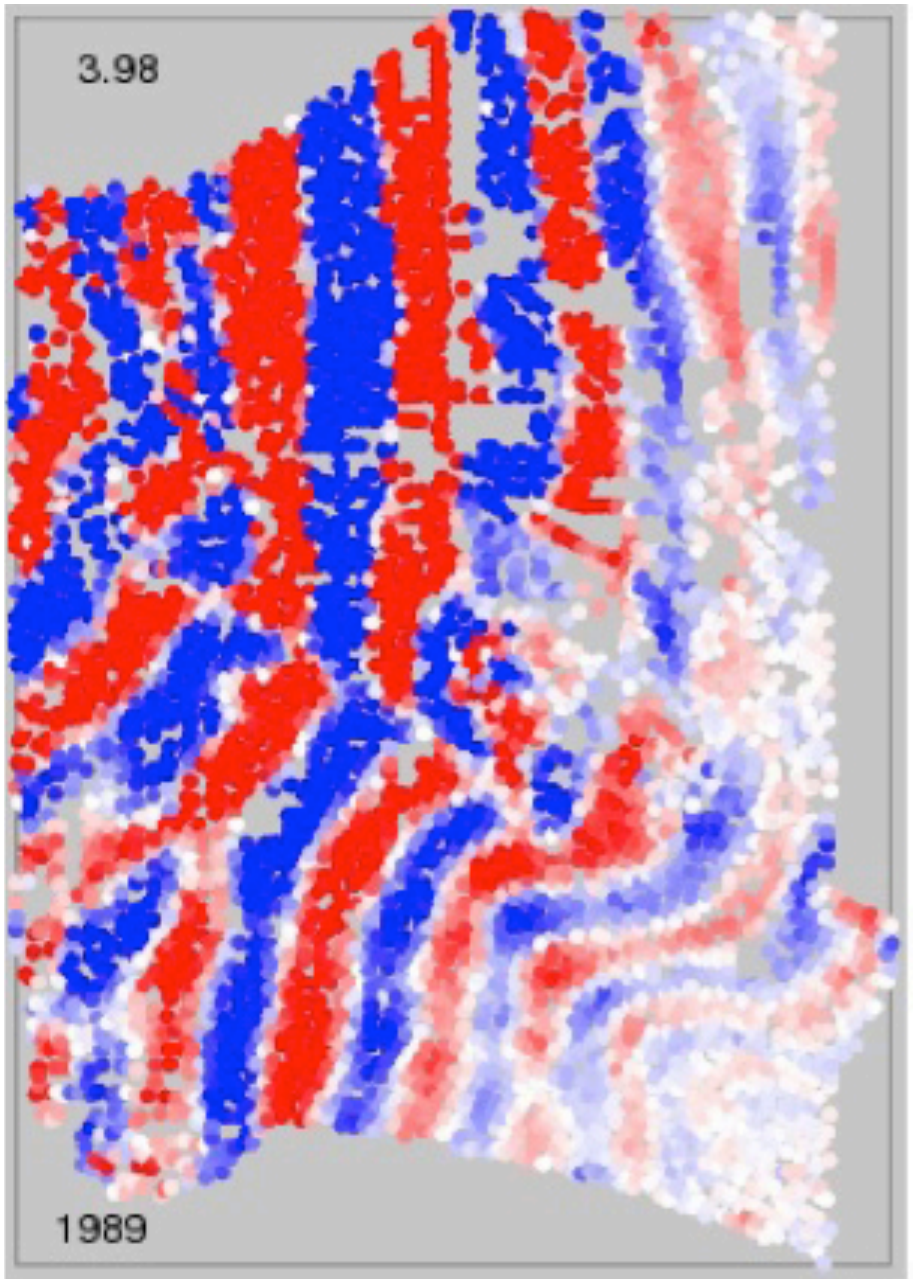


Backprojection using dense, broad spatial sampling of the teleseismic wavefield enables detailed analyses.

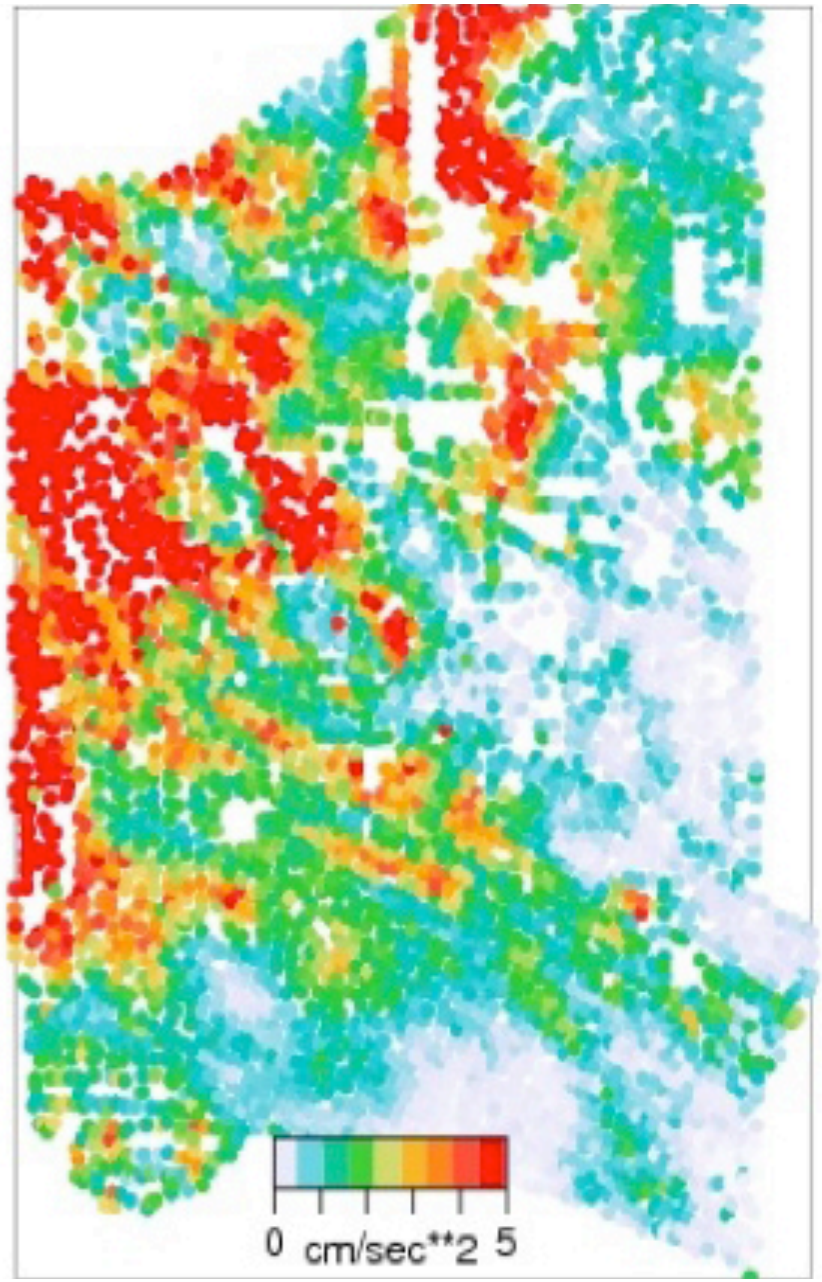
Rupture of Tohoku earthquake

IRIS

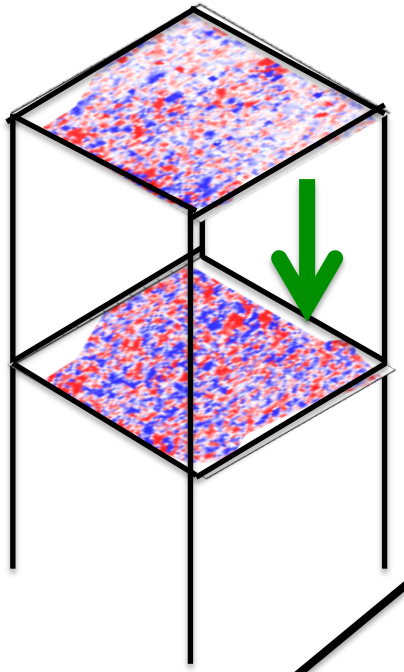
Snapshot



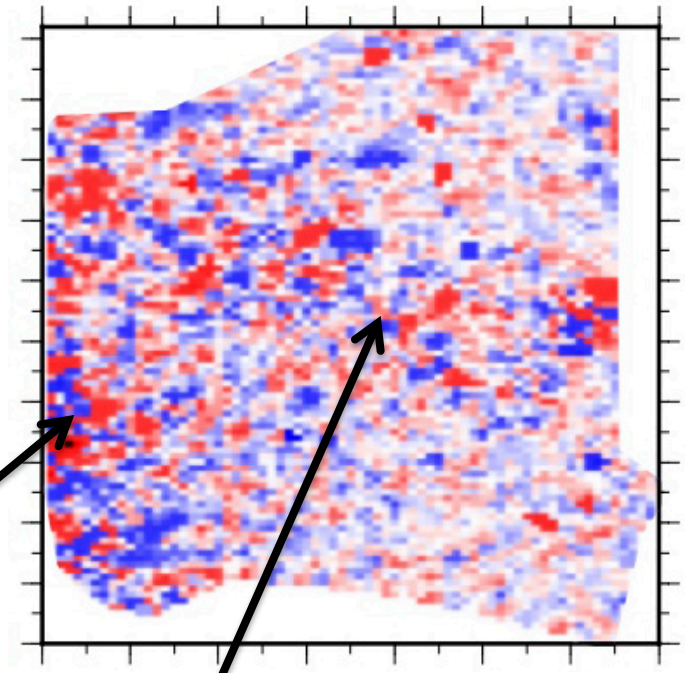
Peak Acceleration



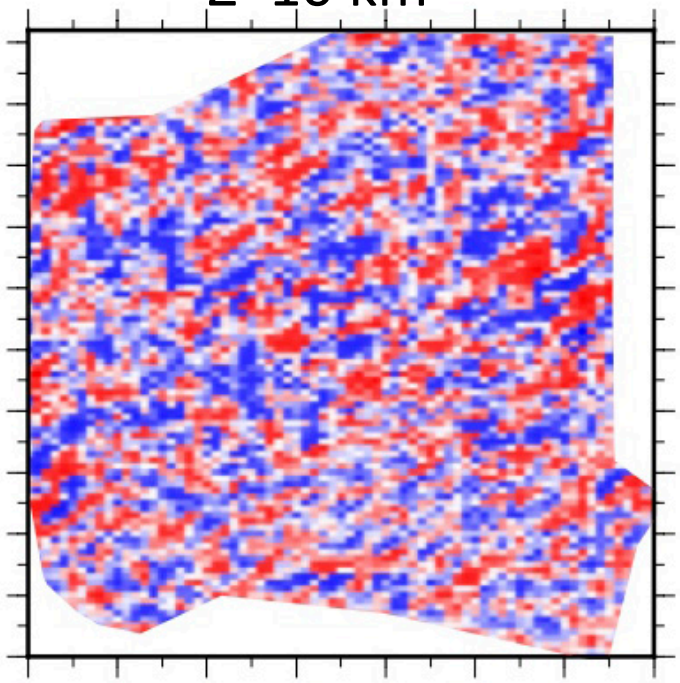
Downward Continue the Data



Z=0 km



Z=10 km



710 Fwy + Port

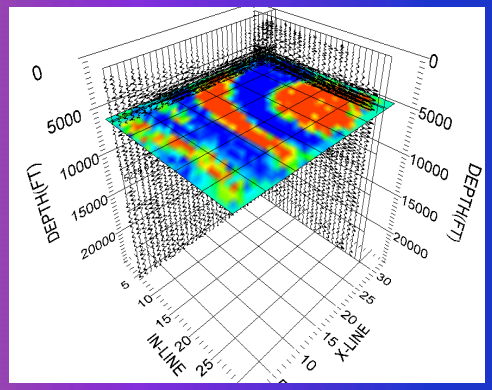
405 Fwy + Oilfield

Data: 5-10 Hz
FT Mesh: 0.1x0.1 km
Method: Phase-Shift (Gazdag, 1978) Method

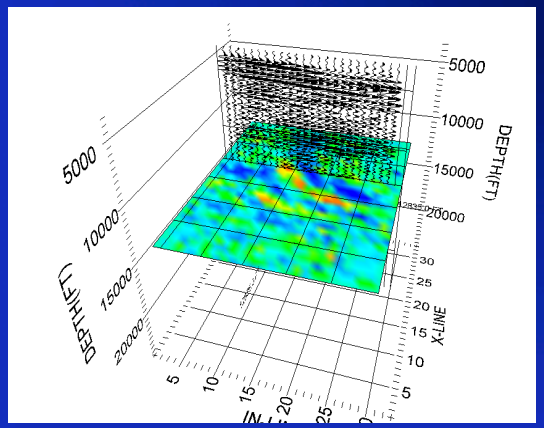
Asaf Inbal

Imaging the Crust in 3D with Exploration "leftovers"

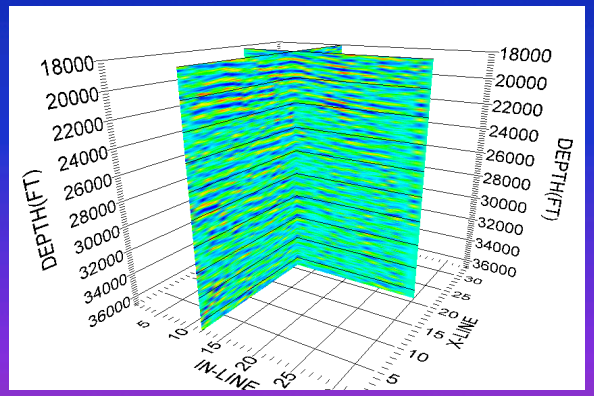
Sedimentary



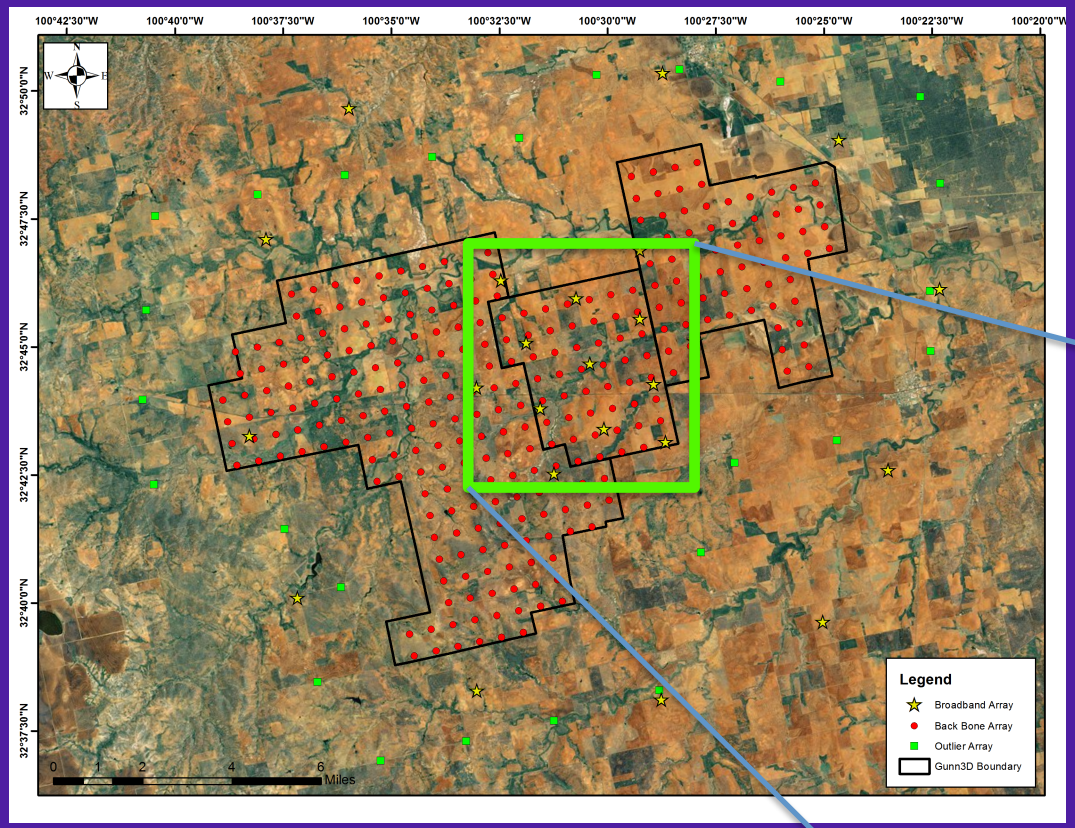
Basement



Lower Crust

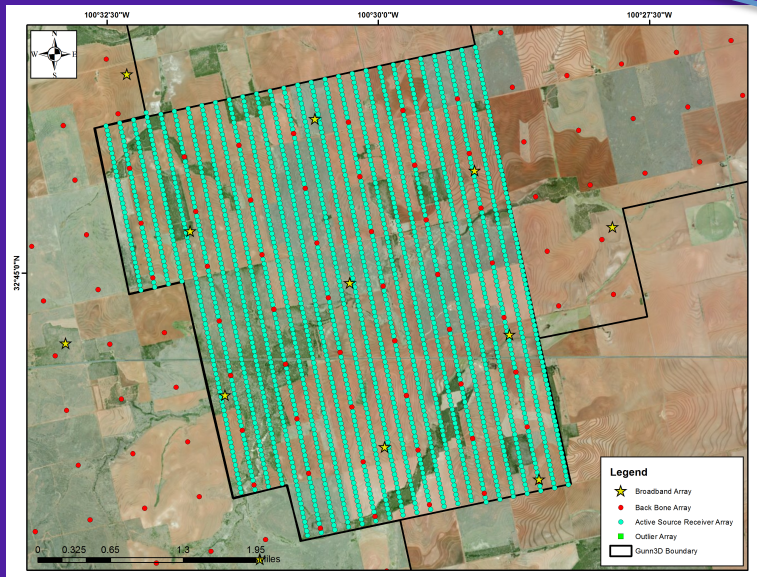


Sweetwater, TX Collaborative Active-Passive, Multi-mode Dataset



Collaborative data collection

- Nodal Seismic
- Nanometrics
- IRIS



25 broadband
2639 Zland nodes
Open data set

The IRIS Wavefields Initiative

- Targeting full wavefield recording
  - Reduce spatial aliasing
  - Enable wavefield imaging and analysis
  - Improve resolution
- What is required: Many more sensors - “Large N”
- Requires a new generation of instruments

Students staging quick deploy sensor packages for the Bighorns Experiment

Goal: New science enabled by new technology

IRIS

Wavefields : The Enabling Technology

- Reduced Size, Weight, and Power (SWaP)
- Simplify logistics and reduce field costs
  - Reduced installation and recovery time
- Streamline handling of data and metadata from dirt to the desktop
- Enable deployment of larger numbers and mixed mode (mixed bandwidth)
- Enable science in extreme environments

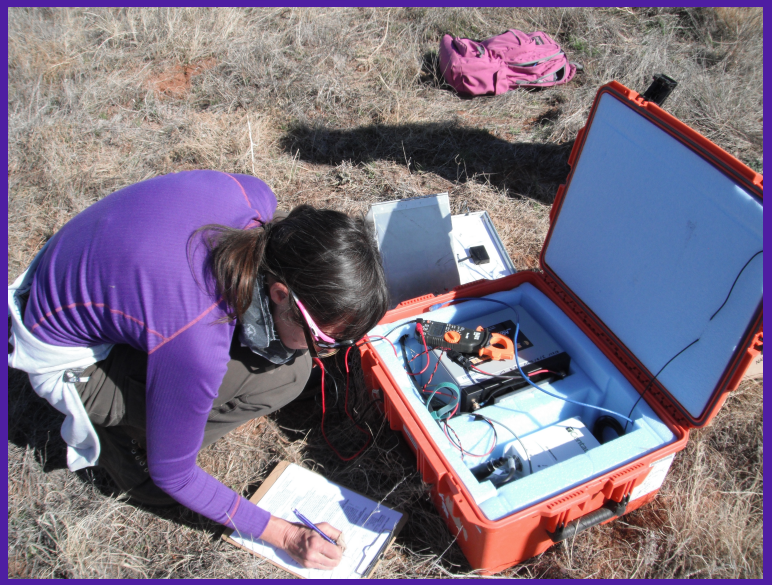
Mendenhall glacier – sensor in the ice

Industry interests and buying power driving the technology

IRIS

A Proposed Collaboration

- Create an industry-funded Large N instrument pool
- Address industry and academic interests in wavefield / Large N observations
- Leverage common industry and academic interests in “broadband”, full waveform inversion, microseismic techniques, etc.
- Leverage existing IRIS expertise in providing turnkey portable instrumentation support



Telemetered broadband station deployment – Sweetwater, TX

Address common academic and industry interests in observing capability, frequency bands, methods

IRIS

Wavefields Collaboration: The Benefits

- Technology applied to diverse and creative targets
- Stimulating developments in acquisition, processing and interpretation
  - Combined active – passive datasets
  - Combined broadband and high frequency
  - Array geometry, sensor emplacement, etc.
- Exposing students to cutting edge technology and real-world data acquisition

Summary

- The IRIS Wavefields Initiative is pursuing dramatic improvements in wavefield observations through the use of new technology
- Key opportunity for industry-academic collaboration to address common interests
- Benefits
  - Innovations in data acquisition and processing strategies
  - Innovations in methods, such as full waveform, microseismic, etc.
  - Workforce development
- But, there are plenty of other possibilities for collaboration

Win-win for industry and academic seismology

IRIS

Contact Information

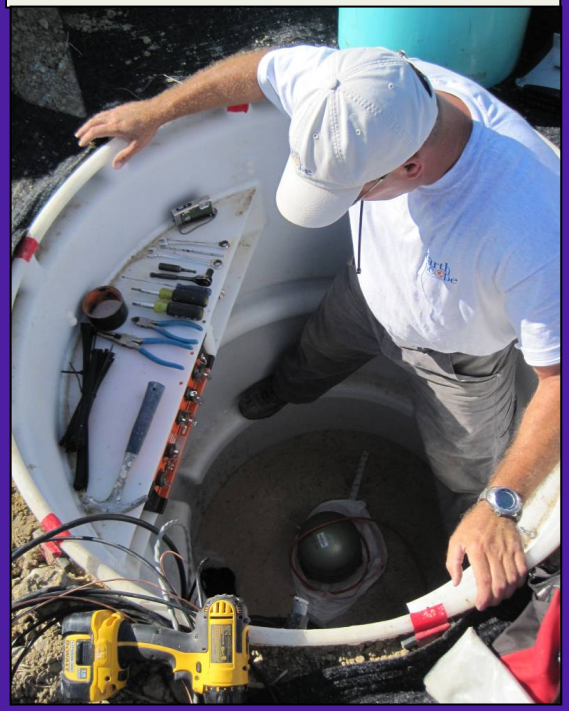
Bob Woodward

woodward@iris.edu

www.iris.edu

Types of Installations

Temporary to Permanent



Vaults

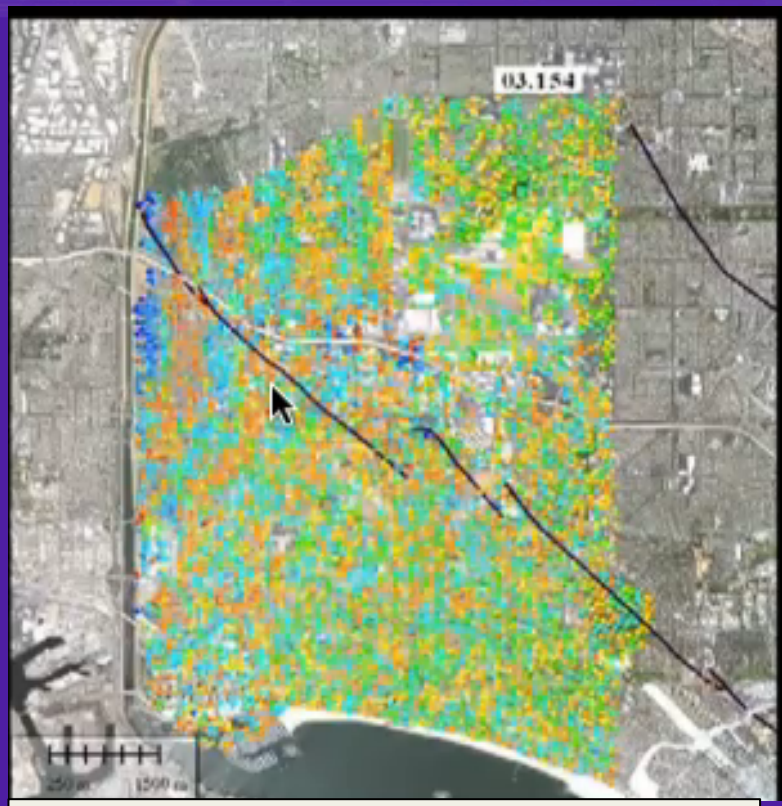
Temporary

Harsh Environments

Ocean Bottom

Wavefields at Other Scales . . .

- Not just at the continental scale
  - Excitement and discovery has carried over to other scales
- Continuous recording enabling dual active – passive datasets
- Multiple frequency bands of interest
- Depending on perspective:
  - Higher frequencies than “normal”
  - Lower frequencies than “normal”



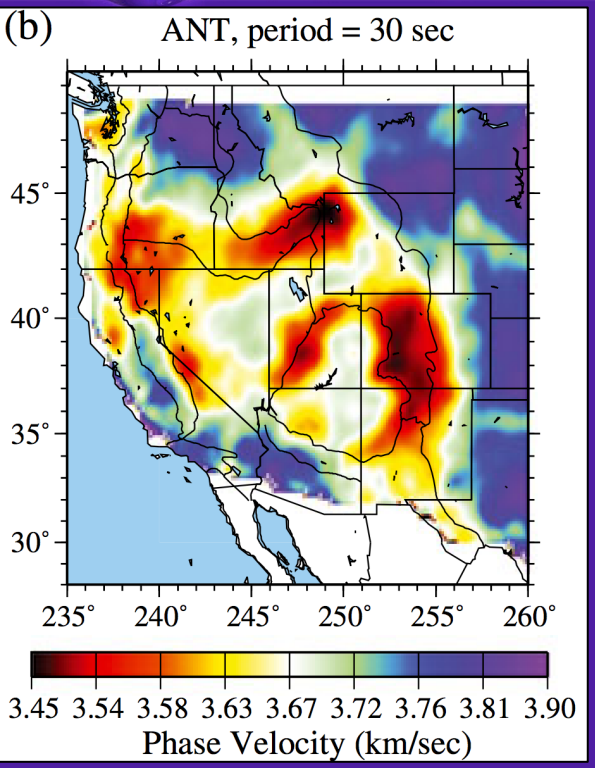
Long Beach, CA
5000 receivers, 100 m spacing
5x7 km area

Data acquisition: Nodal Seismic, Inc. and Signal Hill Petroleum
Visualization: Clayton, et al, CalTech

Multipurpose datasets are “wave” of the future

IRIS

Earth Structure



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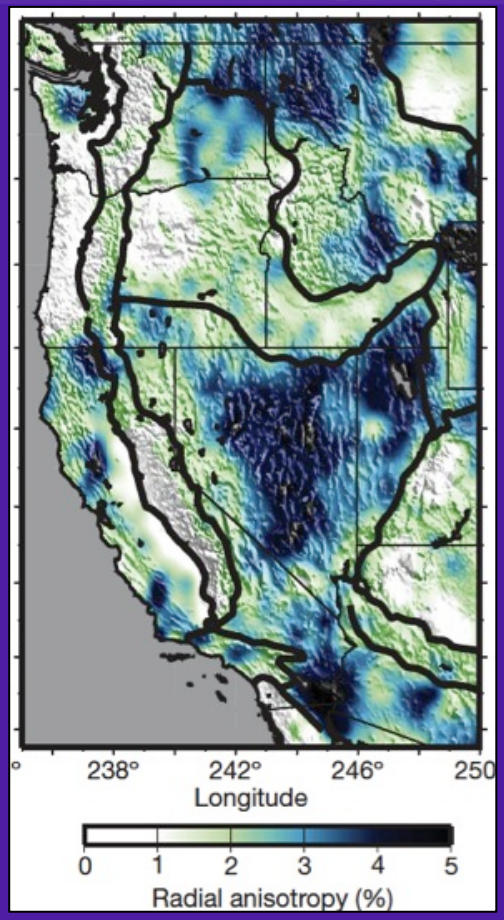

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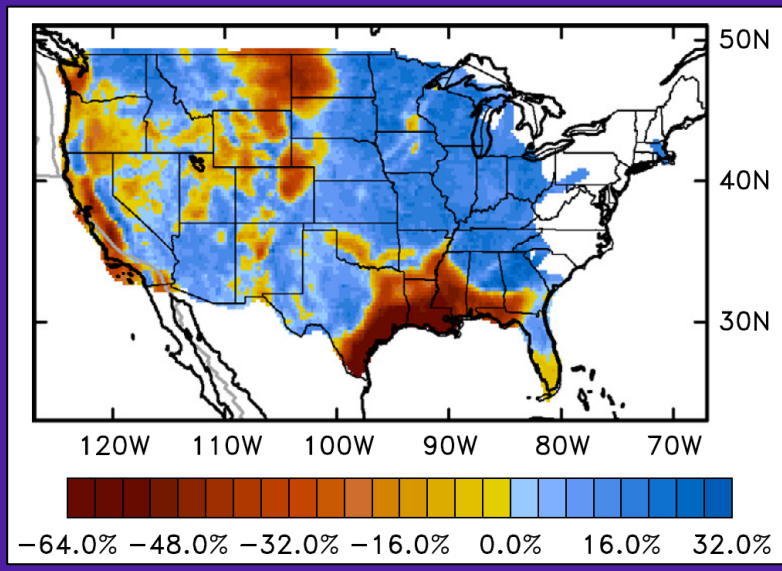

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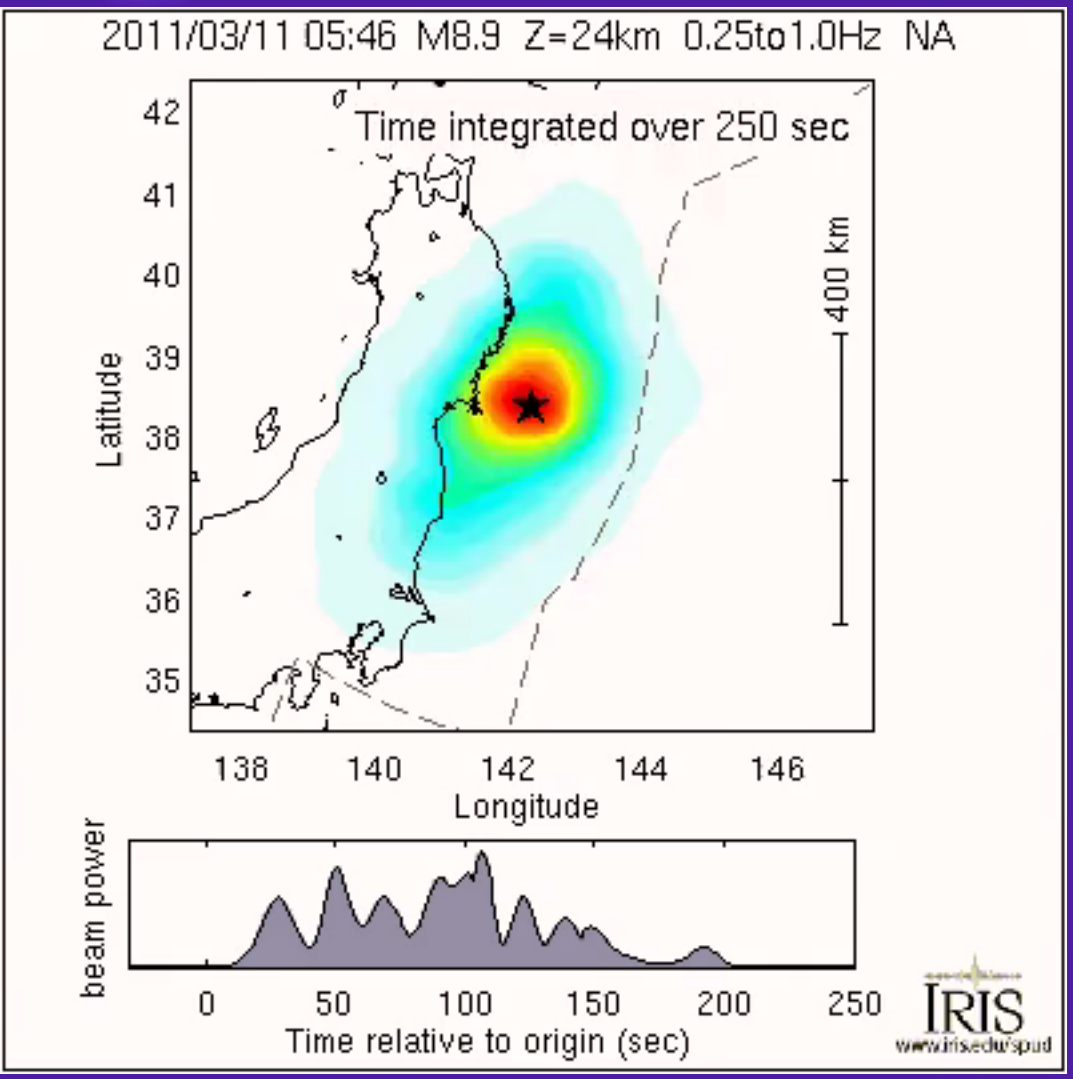
Earthquake Source Characteristics



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IRIS

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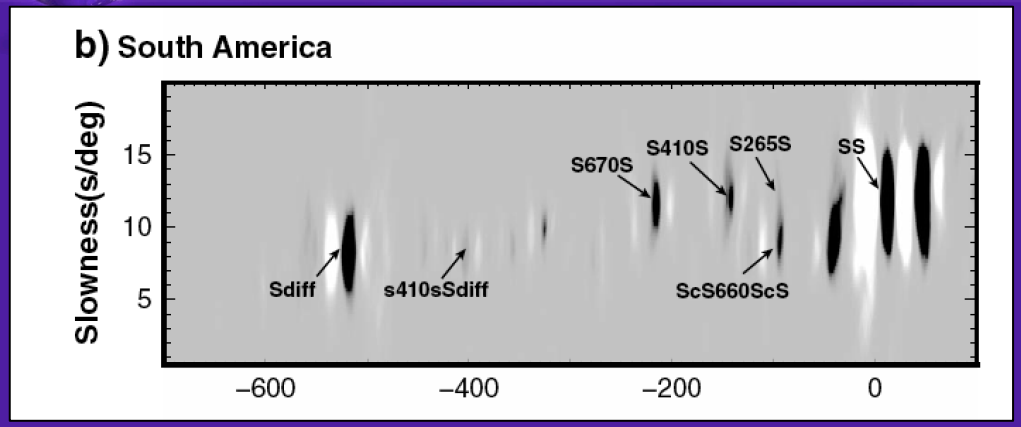

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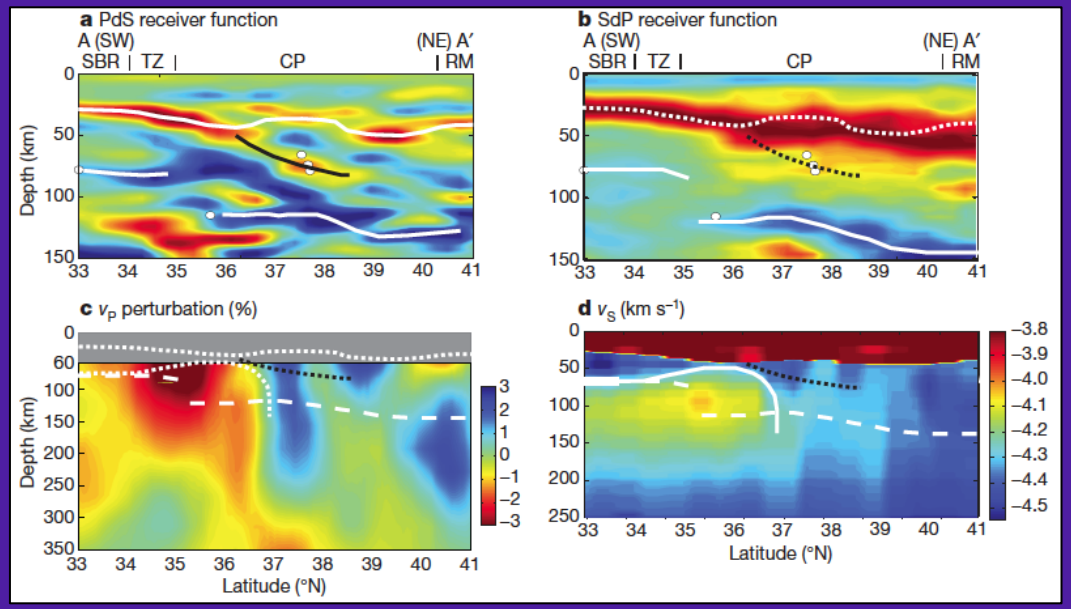

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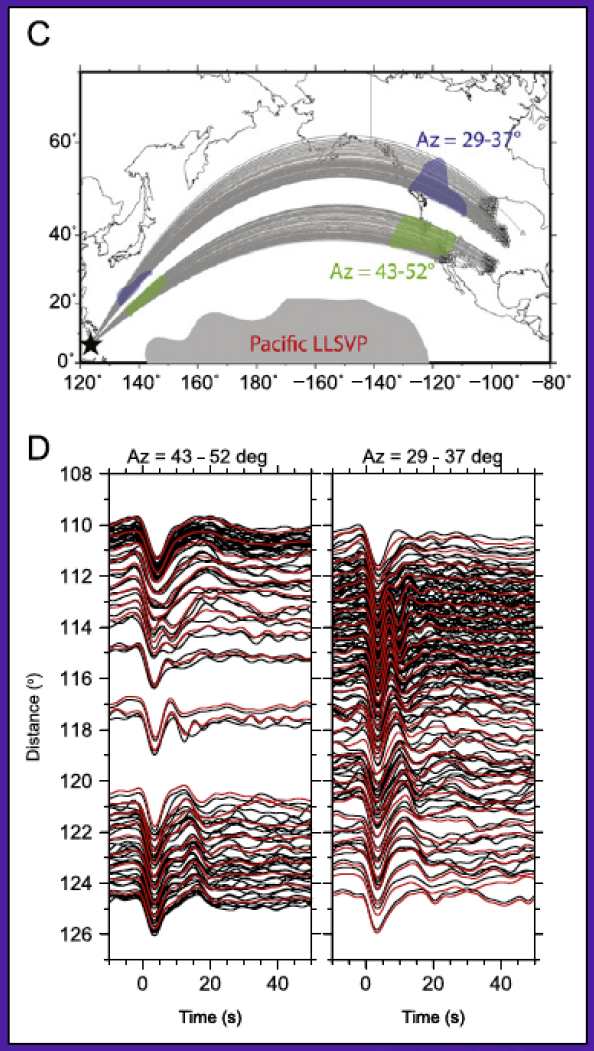

SKS waveform modeling
Sun, et. al., *EPSL*, 2013