

# How earthscope and its Data Inspired a Generation of Geophysicists



*Work by hundreds of people  
Presented by Suzan van der Lee (NU)*

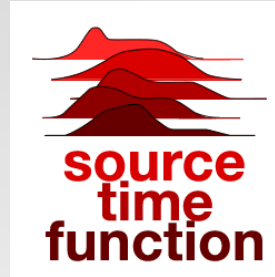
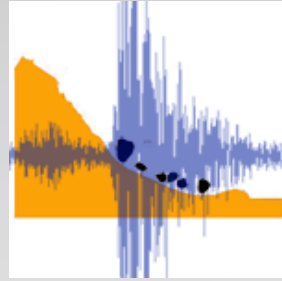
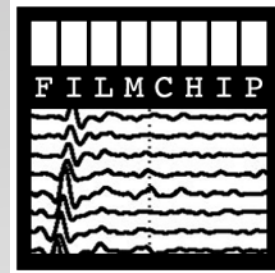




## Data Revolution in Geophysics

15 years 200 Tbytes

... inspired entire generation of geophysicists to be data-driven **explorers, discoverers, problem solvers, innovators, and leaders.**



Former PhD student:

*Thank you so much for [ ] the other amazing opportunities you've opened up for me over the last 9 years...not least of all pushing me to take that Earthscope siting gig!*

Siting gig: Finding land and owners amenable to having EarthScope sensors installed on their land – for science.



# Siting gig: Finding land and owners amenable to having EarthScope sensors installed on their land – for science.

From a student siter:

*Even though he started the summer dreading interactions with strangers, Johnson*

From a student siter:

*Now I include “Seismic site locator for Earthscope, Summer 2010” **on every resume.** I talk it up about it. **It was a big thing in my life.***

From a student siter:

*Working for Earthscope **changed the course of Taylor’s studies.** Sitting in countless kitchens and living rooms explaining the science behind Earthscope made him want to answer people’s questions more thoroughly. **He stayed at Auburn U. for a Master’s Degree.***

## Student Siting Program:

- 8 summers
- 9 workshops
- ~ 135 students
- More than 50 institutions
- ~1375 sites identified

# Siting workshops

- How-to-Site, incl. practice:
  - Site criteria
  - Communicate with landowners
  - Assess suitability and write reports
- Overview of EarthScope facility, a TA station, incl. technical aspects of instrumentation
- Place-based (regional) Earthscope science\*



# Siting workshops

Brilliant, because students:

- Learn transferrable skills in real settings where outcomes matter,
- Reach public where they are, also those that do not voluntarily come to lectures, museums, etc.,
- Help reach “across the aisle”, for example Auburn U. & U. of Alabama.
- Leverage local and regional knowledge,
- More likely to engage landowners,
- Get motivated and prepared to further their education and use their new/improved confidence, communication & scouting skills.

Photo: Perle Dorr/IRIS

PhD thesis acknowledgement:

*Thanks to all of the landowners who volunteered to host USArray stations, especially the SPREE landowners who made my own fieldwork immensely enjoyable.\**



DATA

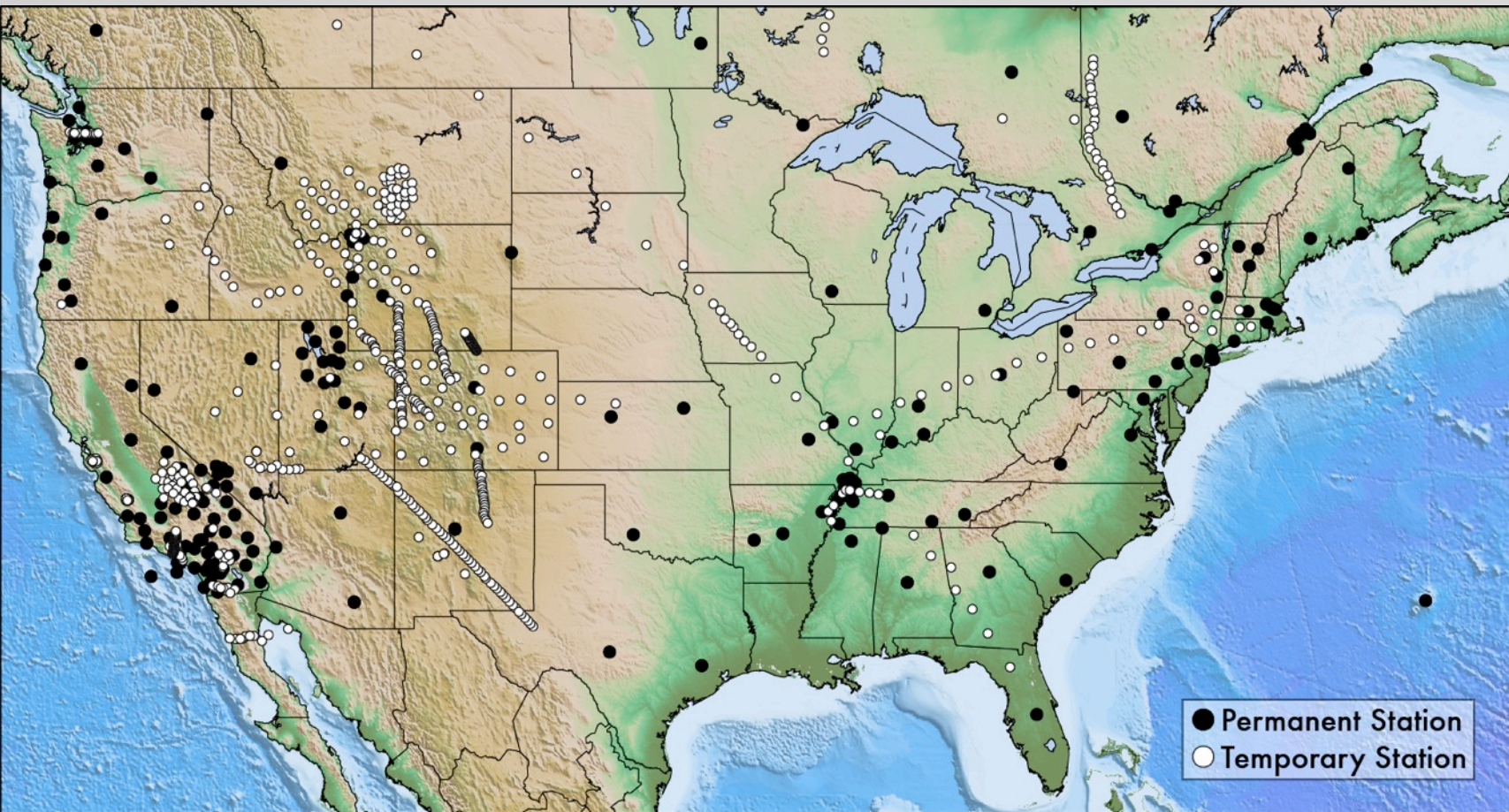
Big Data



# EarthScope Data Revolution

- EarthScope worked continuously & successfully optimizing data quality\*
- EarthScope added about 200 Tb of raw data in 15 years
- EarthScope data follows Open Data principle pioneered in geophysics
  - *You* can get this data, even now, on your smart device
- Also openly shared:
  - EarthScope Data Products
  - EarthScope Research Products
  - EarthScope Education and Public Outreach Products

# DATA: Before Earthscope (USArray)

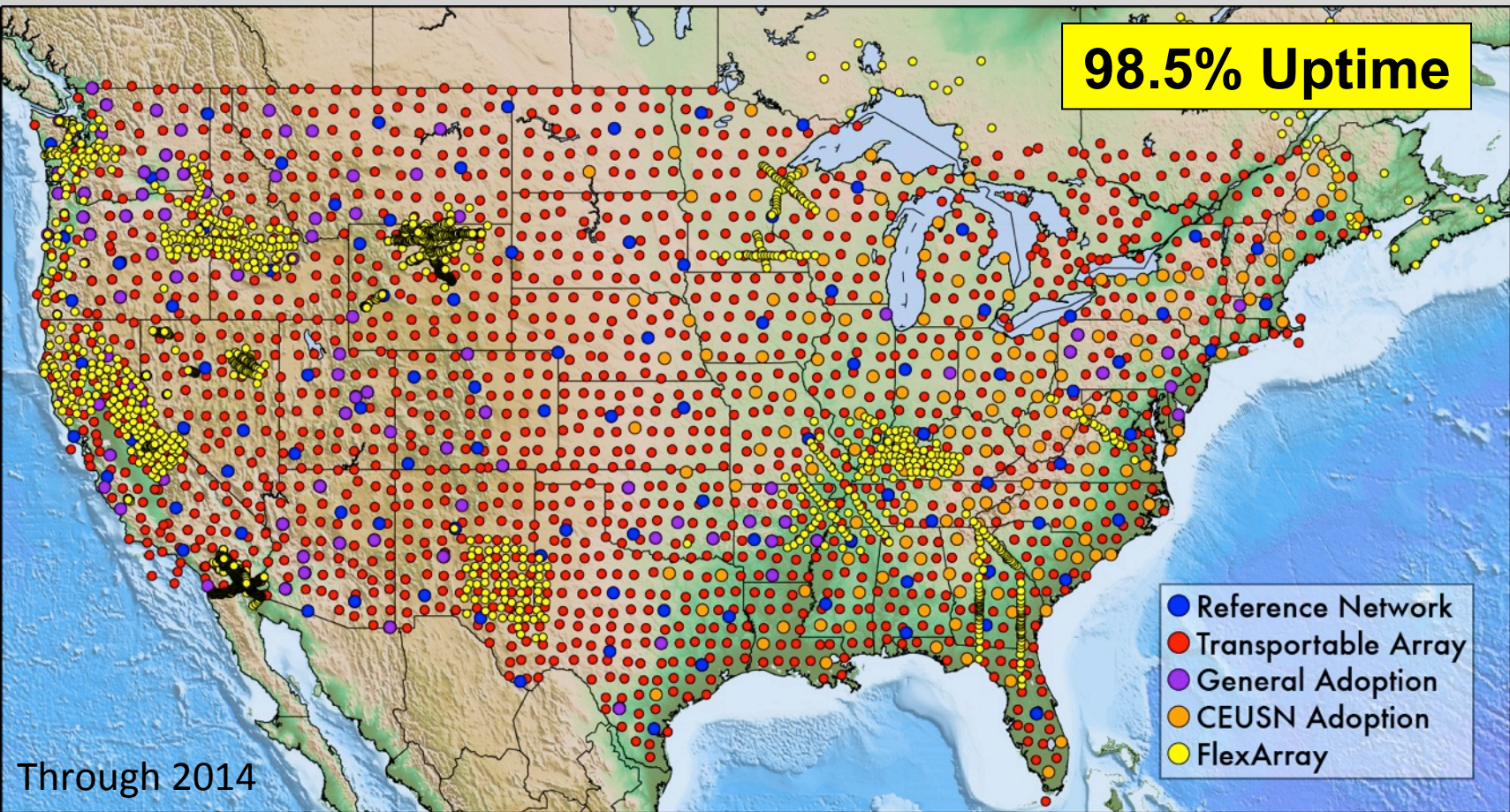




# DATA: Cumulative Earthscope (USArray)

1679 + 2146 + 1100 sites  
5+ thousand Earthscope  
sensors  
(total\*)

**98.5% Uptime**

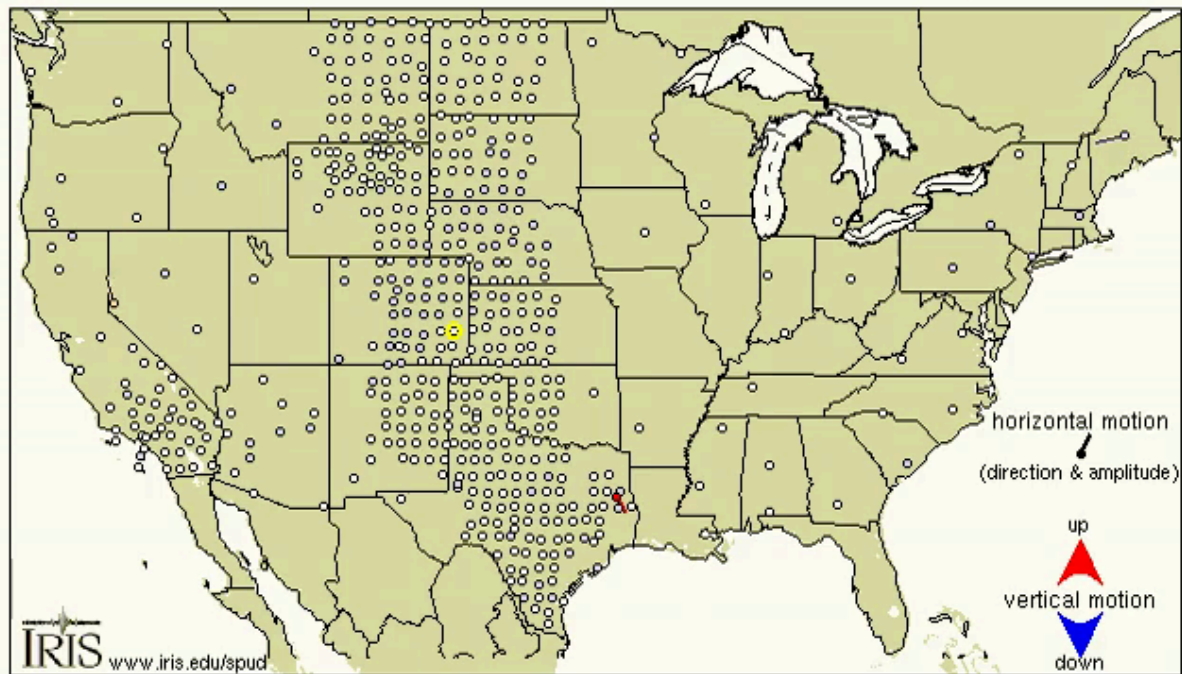


- Reference Network
- Transportable Array
- General Adoption
- CEUSN Adoption
- FlexArray

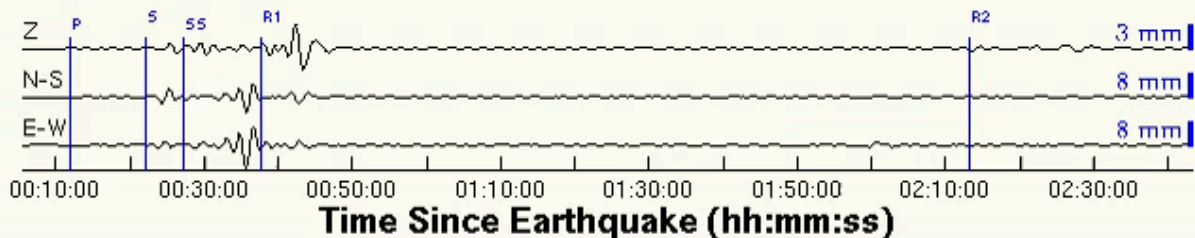
Through 2014

Map: IRIS

# February 27, 2010, NEAR COAST OF CENTRAL CHILE, M=8.8



2010/02/27 06:39:39 UTC (328 s) Distance 79.0°/8784 km Azimuth 336.4° Reference R27A



## Things we study with Earthscope data...

- Co-seismic Deformation
- Postseismic Deformation
- Volcano in/de-flation
- Triggered Quakes
- Solid-Earth Tides
- Ground Truth

- Noise sources
- Noise diagnostics
- Noise imaging
- Soil Water
- Snow Depth
- Aquifers

- Earthquakes
- Smaller quakes
- Even smaller quakes
- Induced Quakes
- Tremor and Slip

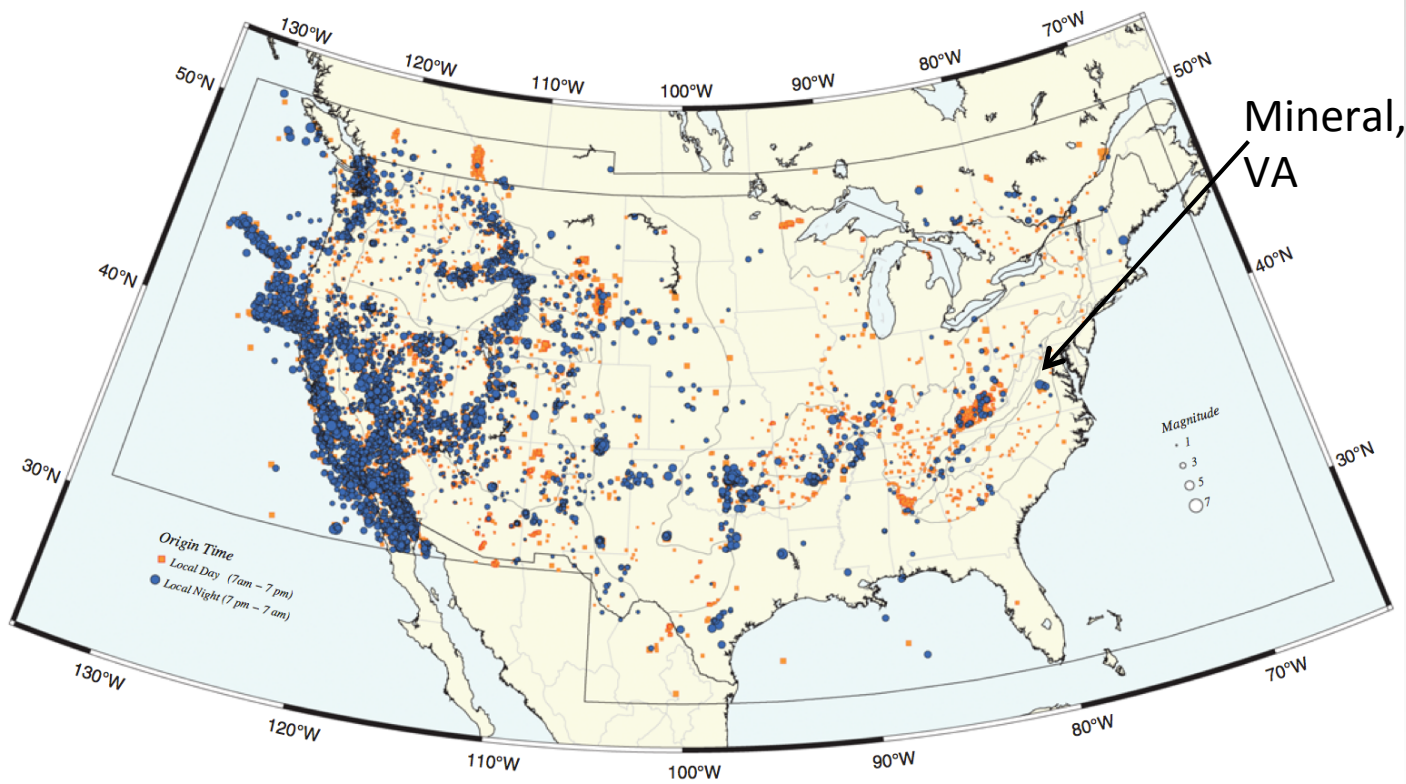
... that you hear about in other talks

... but for 2 examples:

# Example 1: More stations record more seismic events

About 10 years of earthquakes

Local Day/Night seismicity in the ANF Bulletin from April 2004 to November 2013

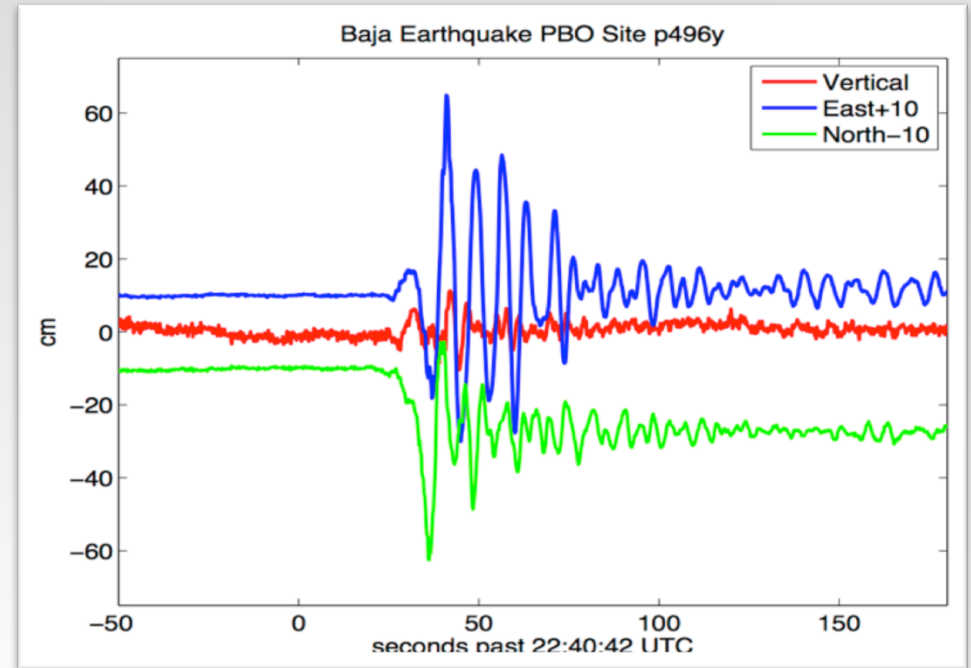
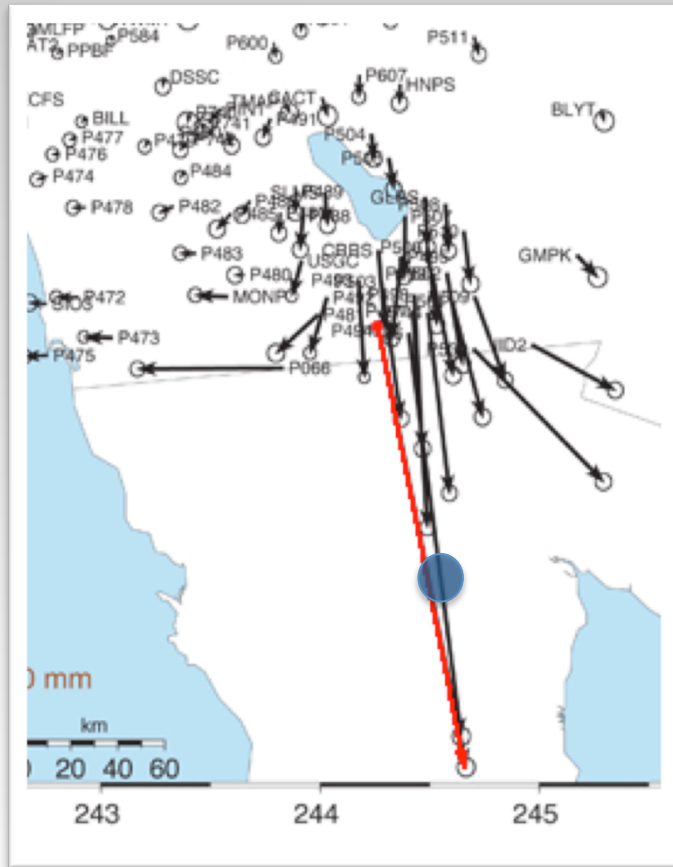


In CEUS,  
64-83% of  
seismic events  
located only by  
Earthscope

Data and Figure: Luciana Astiz

## Example 2: El Mayor Cucapah earthquake, M7.2

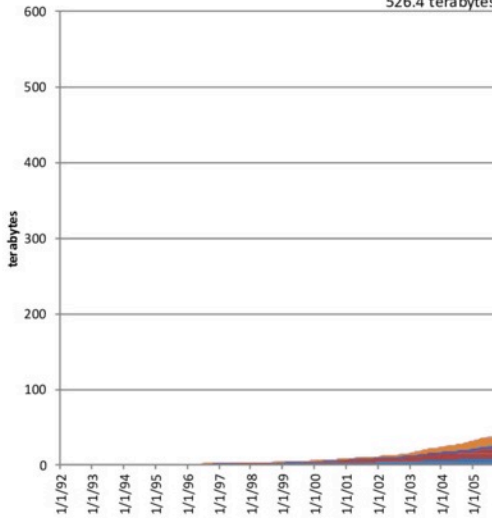
- Area S. of Salton Sea move 20 cm towards Mexico within a minute
- After overshooting by a whole meter



# DATA

- At IRIS

**IRIS DMC Arcl**  
as of 1 Apr 2011  
526.4 terabytes

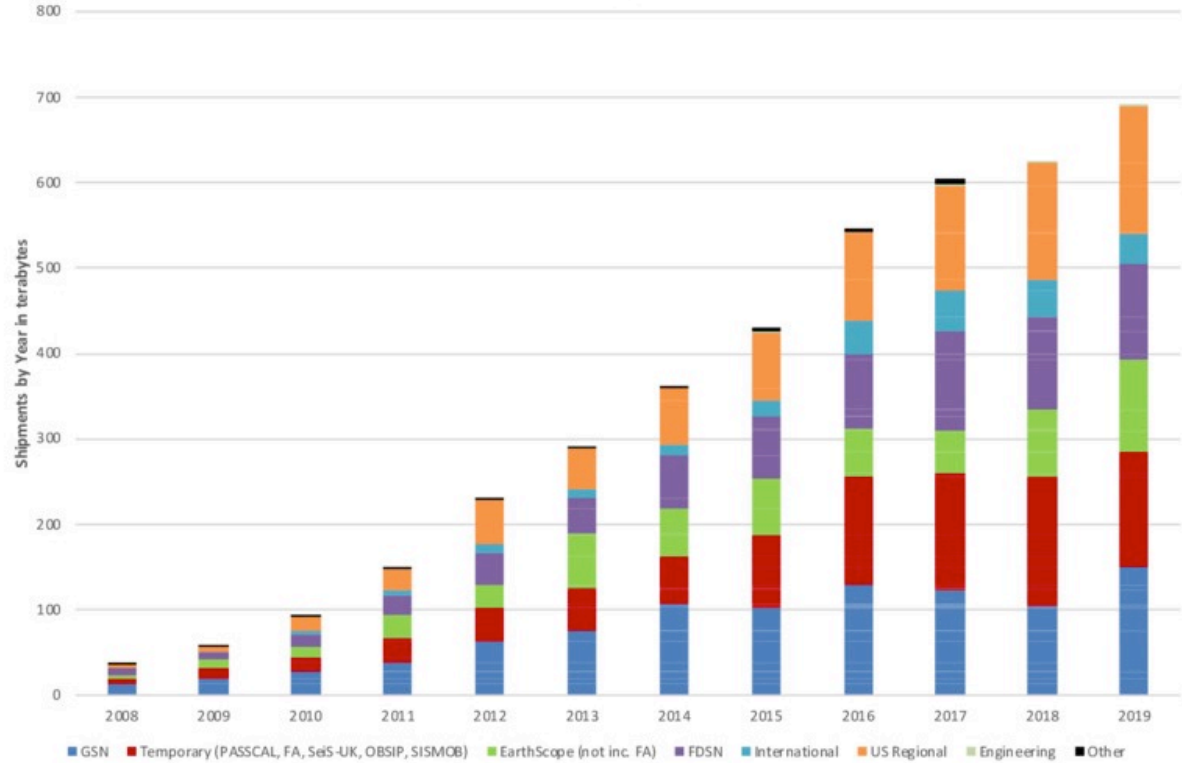


■ GSN ■ Portable (PASSCAL, SEIS-UK, OBSIP, SISMOB) ■ EarthScope ■ FDSN ■ International ■ US Regional ■ Engineering ■ Other

## Shipments by Network Category

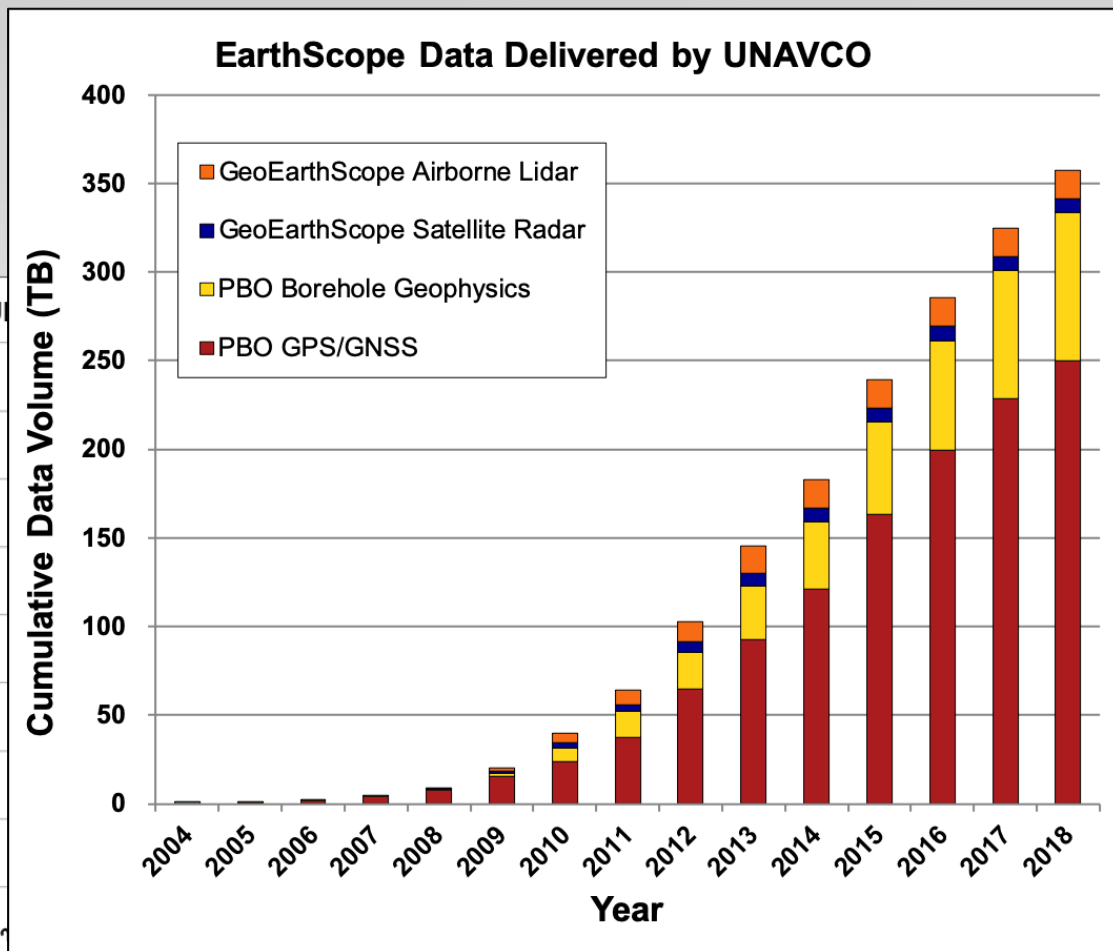
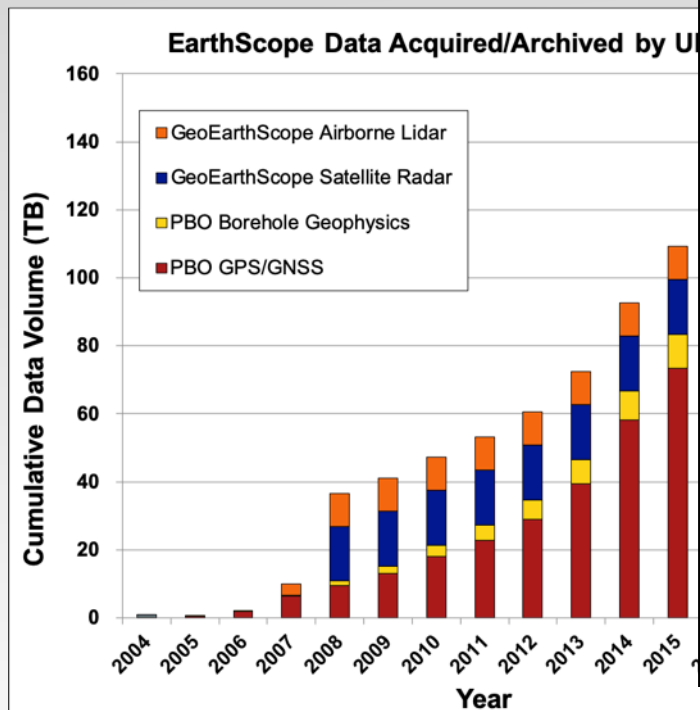
Projected on April 1, 2019

698.25 terabytes



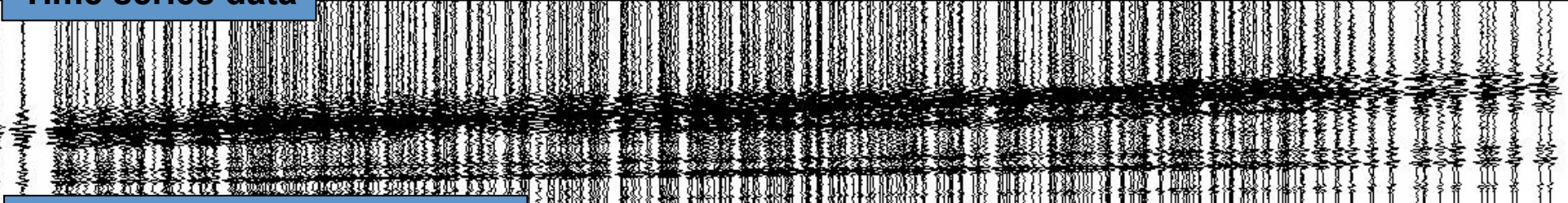
# DATA

- At UNAVCO

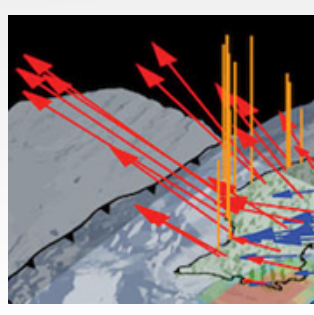
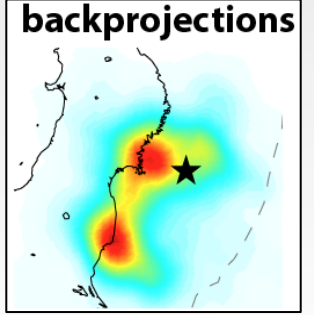
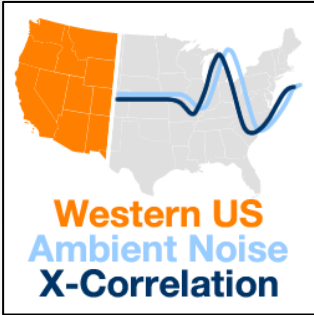
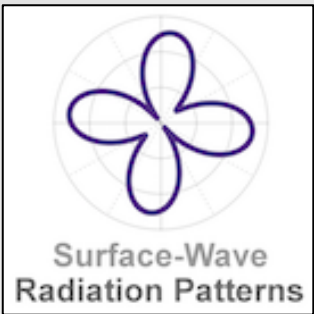
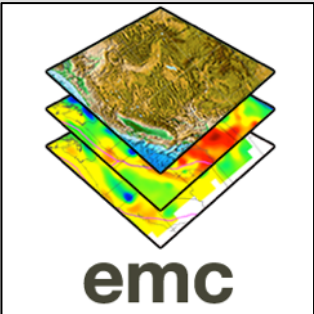
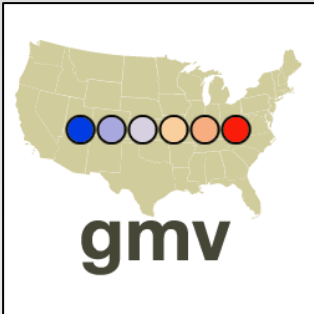


Level 0-1  
Time series data

# DATA PRODUCTS



Level 2-3 Products

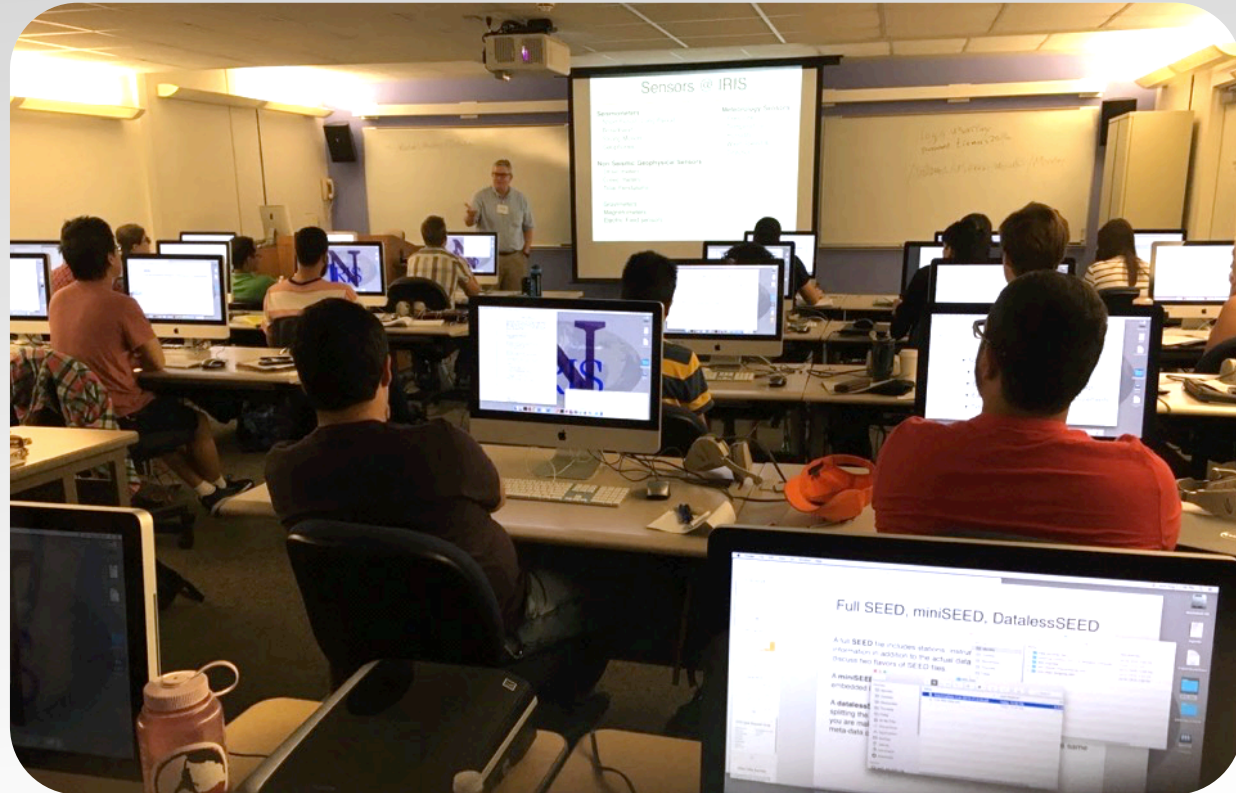




## USArray

### data processing for the next generation of seismologists

- Graduate students\*
- One week in summer
- Hands-on
  - EarthScope data
  - analysis tools
- Identify
  - challenges
  - opportunities
- Work together
- Final group project
- Base of Data Science



## USArray

data processing for the next generation of seismologists



2009-2011, 2013-2014, 2016-2017:  
200 graduate students in 8 courses

# USArray

## data processing for the next generation of seismologists

# Short Course



In demand: In 2013 & 2014 twice as many applicants as spots

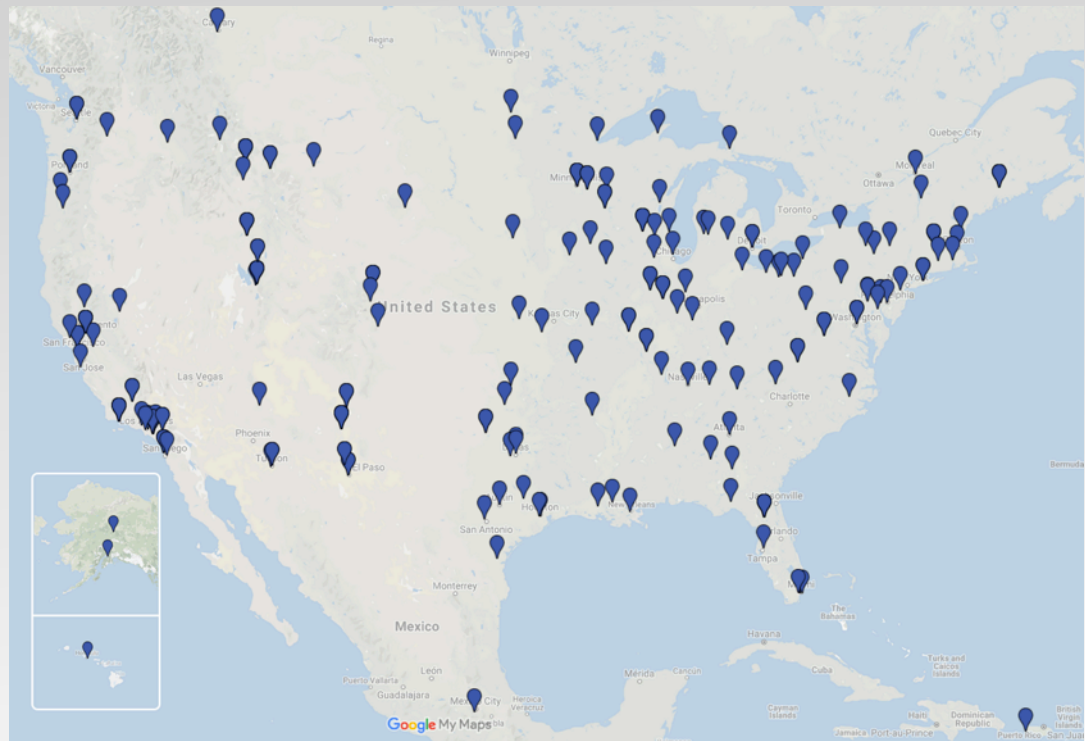


# National Opportunity

## Outreach-Education-Workforce Training



# Distinguished Speaker Series Location (2007-2019)



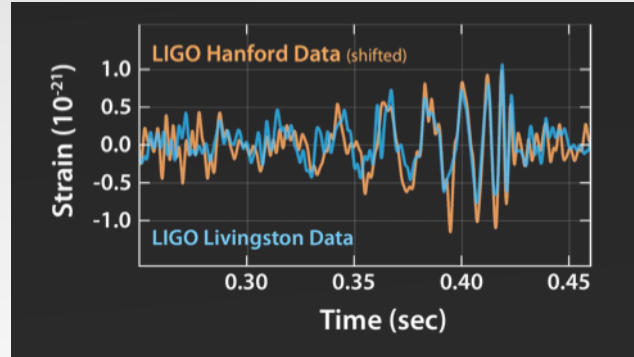
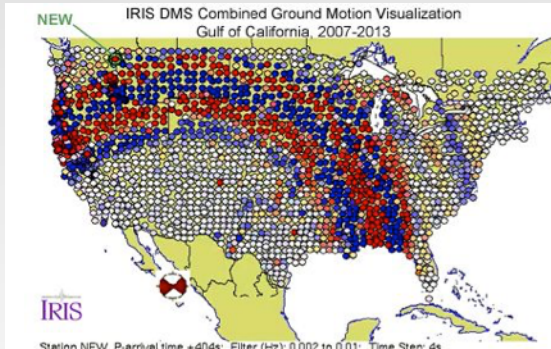
- 55 speakers over 11 years
- 210 colleges/universities visited
- Over 15,000 people reached

Photos & map: EarthScope web site

# NSF Research Traineeship (NRT) – utilizes EarthScope, LIGO, and LSST data



- Established *Integrated Data Science Certificate*
- Students from EPS, P&A, EE, CS, Chem, LS, Mat.Sci., etc.
- Trains students in transferable skills, values careers outside of academia
- Funds research fellowships for some trainees in program

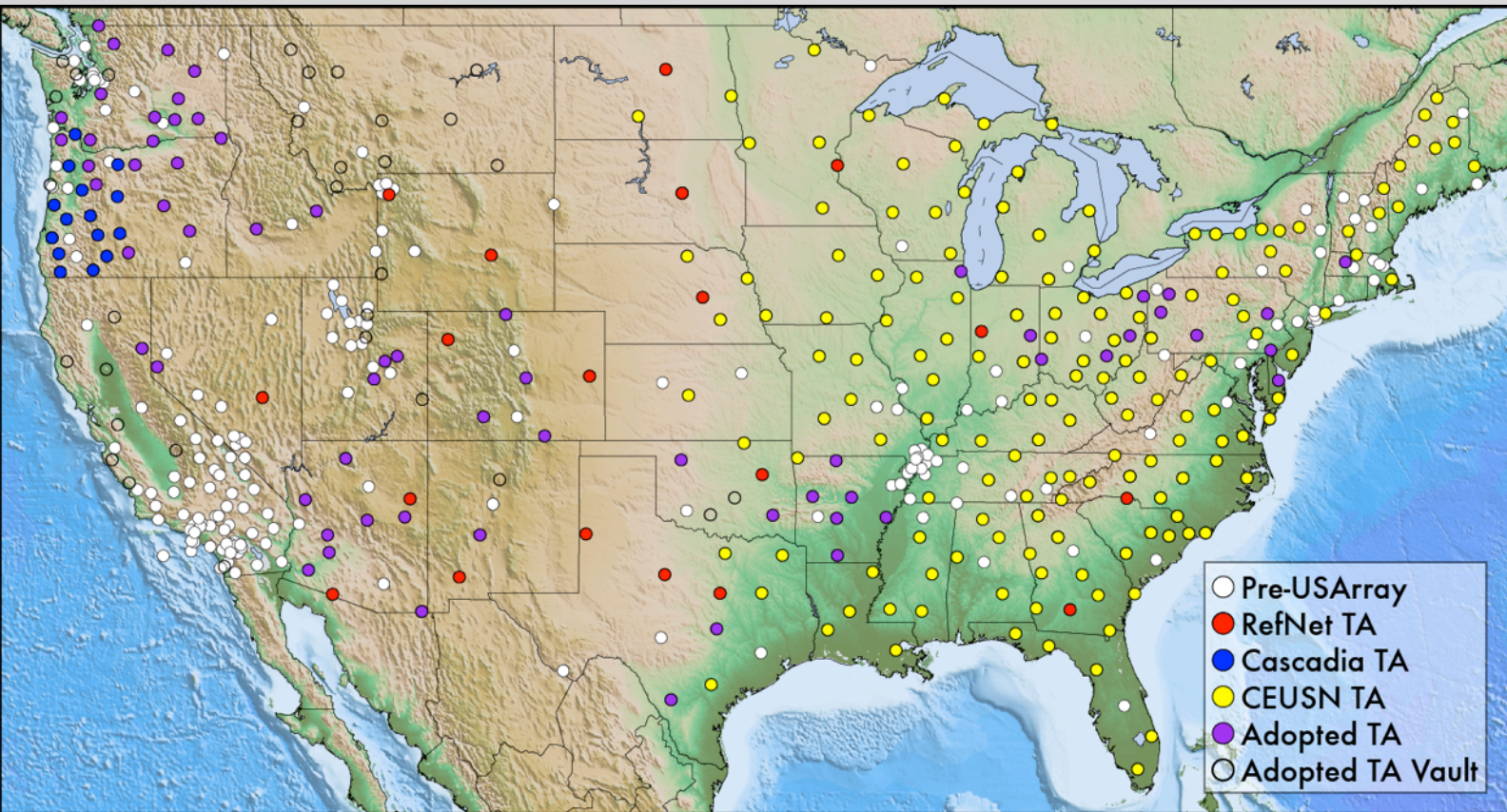


# earthscope Station Adoption Program

- PBO is adopted into Network Of The Americas
- Over 60 TA stations adopted by local & regional networks linked to academia
- Nearly 200 TA stations adopted by the USGS, about 150 in CEUS



# DATA: After USArray (USGS and regional efforts)





# earthscope Citizen Science

- Small events “illuminate” mechanics of hazards
- Detecting weak signals from small events is hard bc
  - Signal similar to noise
  - Too much data
- Citizens help (over one thousand already do):
  - All hands on deck
  - Ears could hear more than eyes can see



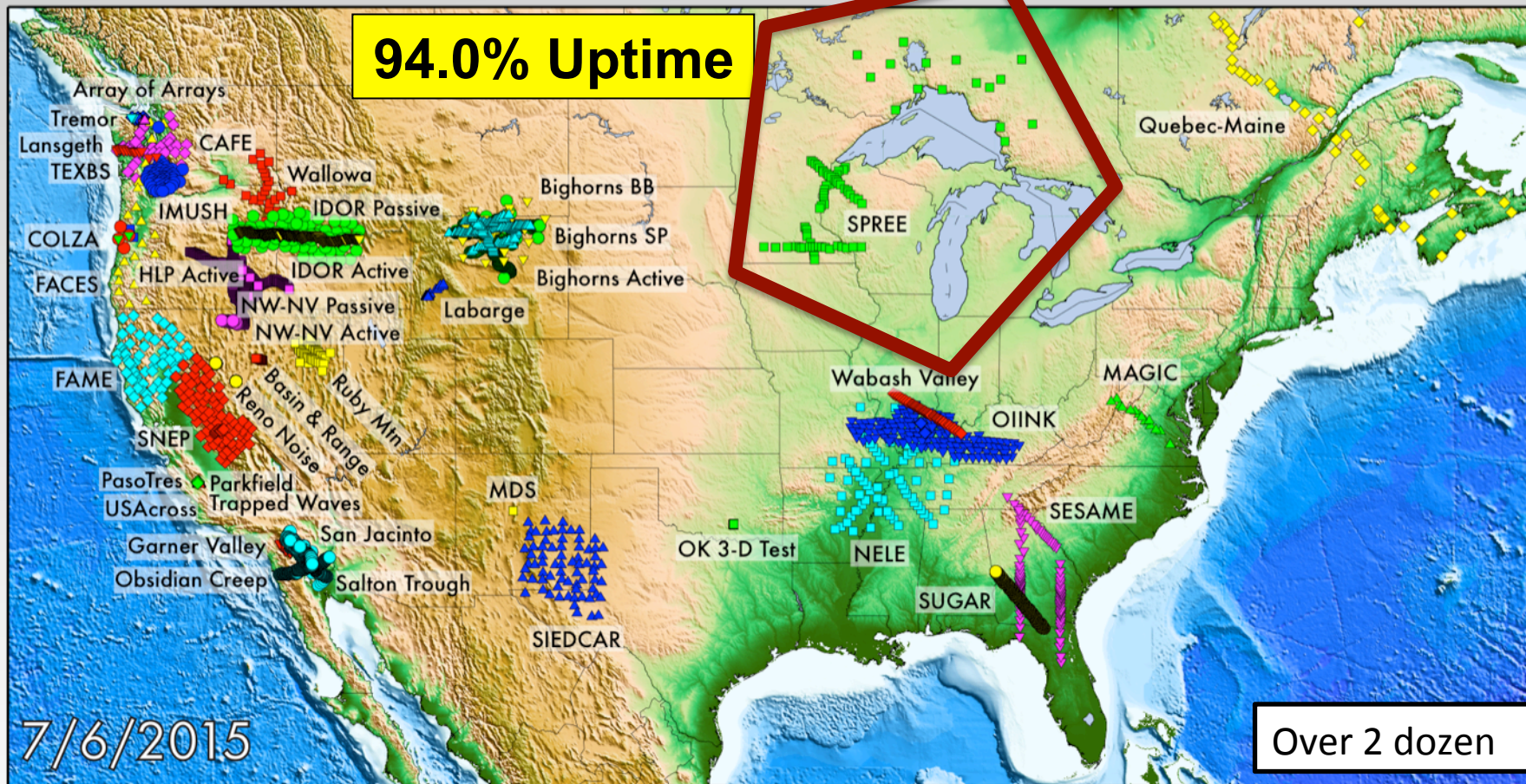
[www.zooniverse.org](http://www.zooniverse.org)

Design: Vivian Tang & Boris Rösler



# earthscope Researcher Field Experiments

94.0% Uptime

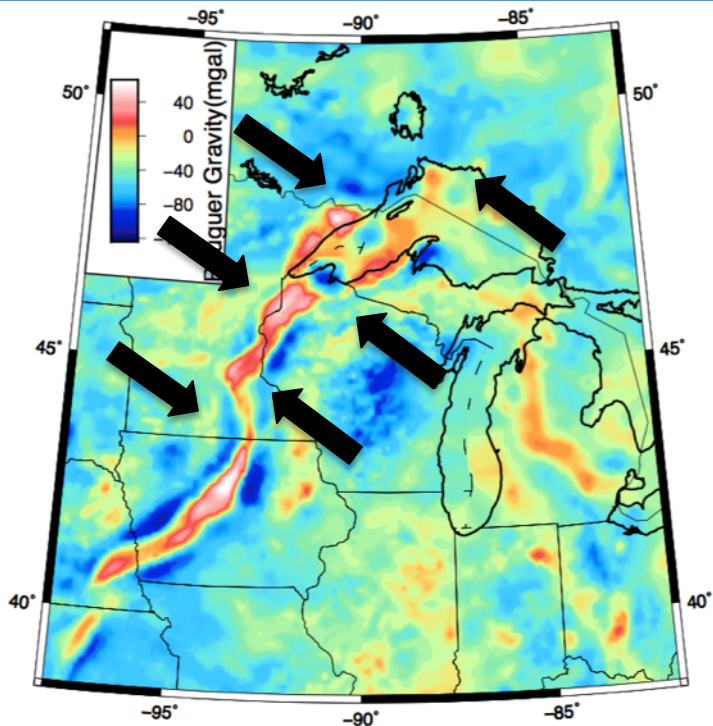


7/6/2015

Over 2 dozen

# SPREE

Superior Province Rifting Earthscope Experiment



Mid-continent Rift



October



April

Newsletters  
for landowner  
sensor hosts



## Seismic Recording Station TA\_L44A Summary Report

Thank you for hosting station TA\_L44A on your property. We hope that you find the enclosed report interesting.

Your station is one of the 2000 USArray seismic stations being installed as part of the National Science Foundation's EarthScope initiative. Research scientists are analyzing the data that was recorded at your station to learn how earthquakes are initiated and to gain a better understanding of our deep earth's dynamic structure and processes.

This station detected 5 regional earthquakes and 120 distant earthquakes (occurring over 10 degrees or 1100 km from the station). The magnitudes of these earthquakes ranged from very small (magnitude < 2.0) which are not felt by humans anywhere, to large events which can result in significant destruction. (On the following pages, we present a summary report of the data we obtained from this station.)



### Station summary

Network	TA
Station ID	L44A



Station  
Digest

# SPREE

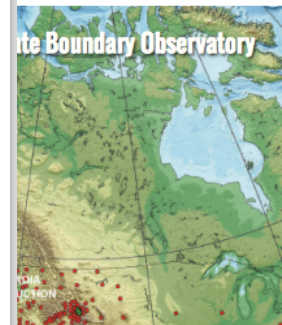


Experiment

NAVCO



Plate Boundary Observatory



One fifth of a petabyte (PB) of **earthscope**  
Data will remain available for creative new analyses.

**earthscope** = all the components of  
a **framework** of models for *sensor networks*  
and *sensor arrays*, including data flow and  
data sharing.

# Geoscience Education Workshops

- Working with educators: impact of science learning & preparedness
- Over 1300 educators directly reached (teachers, park/museum interpreters, emergency/safety educators)
- Over 600,000 learners & other educators impacted
- Over 40 workshops

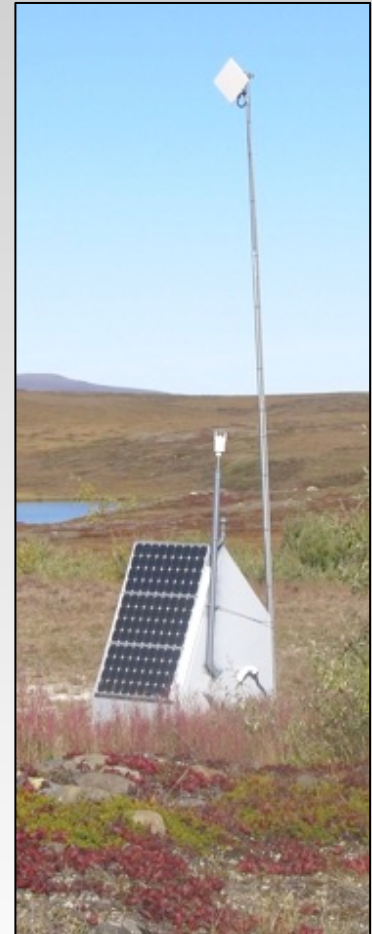


Slide: Beth Pratt-Sitaula



# earthscope On-line Statistics

- IRIS YouTube: Videos and animations  
Embedded in 10 education/textbook sites  
5 million views, +0.5M via 3<sup>rd</sup>-party web sites  
12 thousand subscribers, 5k added in 2018
- TeacherTube: 95 thousand views
- InClass: 170k views and 130k downloads in 2018.
- SpotLight: 11 thousand unique visitors in 2018.
- Museums: 730 thousand visitors
- Webinars: Over a dozen  
100 attend each live, 100s view each later
  
- Total: Over 6 million views of animations and videos



# QUOTES

Former short-course participant, now associate professor:  
*Without Earthscope in general, and the USArray short course in particular, I would not have become the data driver.*

Mid-career Harvard and Yale professors:  
*Just as we were establishing our independent scientific careers, along comes this data set, this opportunity. It completely changed the game.*

Former postdoc became a Data Science Scholar and now helps save lives:  
*In my new job I detect abnormal signals -- that correlate with heart diseases -- from body sensors using similar techniques I used for detecting abnormal*

PhD thesis acknowledgement:  
*This research would not have been possible without the staff of IRIS and Earthscope making it easy to acquire a mind-boggling amount of high-quality seismic data.*

Former PhD student:  
*Thank you so much for [ ] the other amazing opportunities you've opened up for me over the last 9 years...not least of all pushing me to take that Earthscope siting gig!*



*The End*



**Emily Wolin** @GeoGinger · 4/4/19



!! VERY EXCITING NEWS !! I have accepted a permanent position as Seismic Network Manager at the USGS Albuquerque Seismological Laboratory! I will be directing the operations of 300 seismic stations in the US and around the world.



50

23

599

