Rotational Long Period Signals:

From Ring Laser data to Large Seismic Networks Array-Derived Rotations

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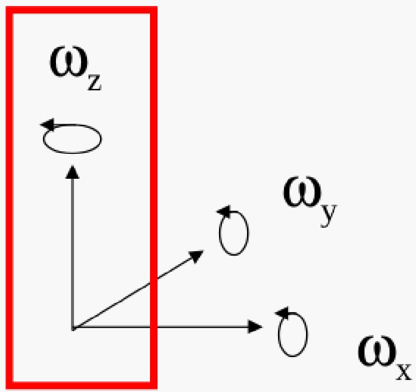
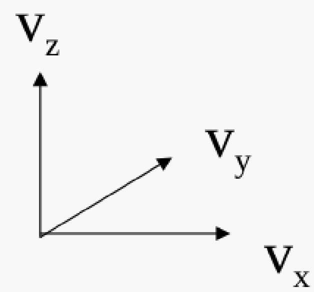
Rotational motions

$$\begin{pmatrix} \omega_x \\ \omega_y \\ \omega_z \end{pmatrix} = \frac{1}{2} \nabla \times \underline{v} = \frac{1}{2} \begin{pmatrix} \partial_y v_z - \partial_z v_y \\ \partial_z v_x - \partial_x v_z \\ \partial_x v_y - \partial_y v_x \end{pmatrix}$$



Rotation rate

Rotation sensor



Ground velocity

Seismometer

Theoretical relation: Rotations & Translations

Considering a plane transversely polarized wave propagating in x-direction

$$u_y(x,t) = F(kx - \omega t) \qquad c = \frac{w}{k}:$$

Acceleration: $$a_y = \ddot{u}_y = \omega^2 F''(kx - \omega t)$$

Rotational rate : $$\dot{\Omega} = \frac{1}{2}\nabla \times \dot{u}_y = -\frac{1}{2}k\omega F''$$

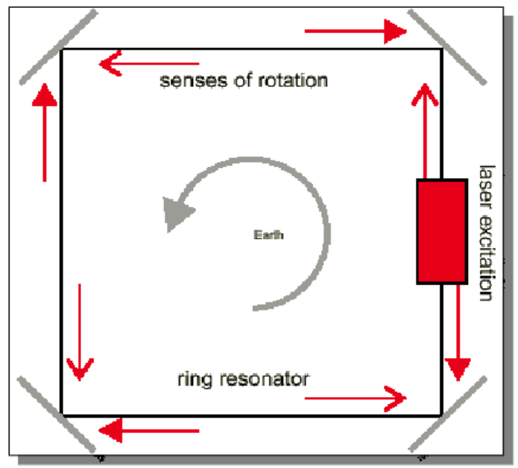
$$\frac{a_y}{\dot{\Omega}} = \frac{\ddot{u}}{\nabla \times \dot{u}} = -2c$$

Rotation rate and acceleration should be **in phase** and the amplitudes scaled by **two times the horizontal phase velocity.**

How do we measure Rotations?

- Direct measurements --Rotational Sensors--
  - Fiber Optic Sensors
  - Rotaphones
  - Ring Laser Gyros
    - *G-Ring Laser*

      (Wettzel, Germany)

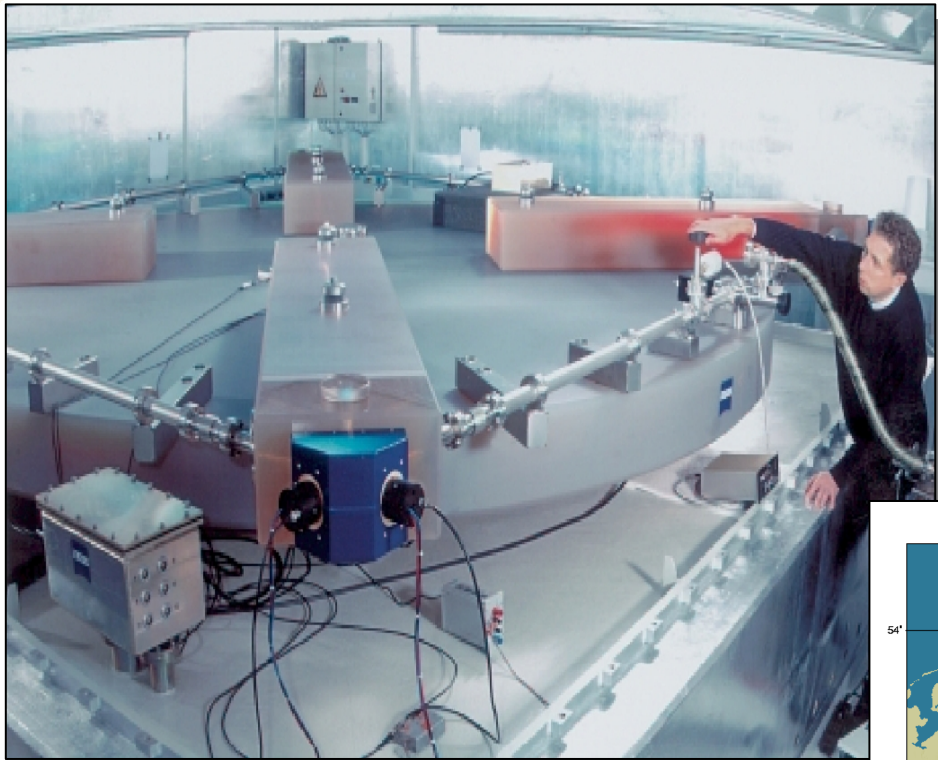


$$\Delta f = \frac{4A}{\lambda P} \cdot \dot{\Omega}$$

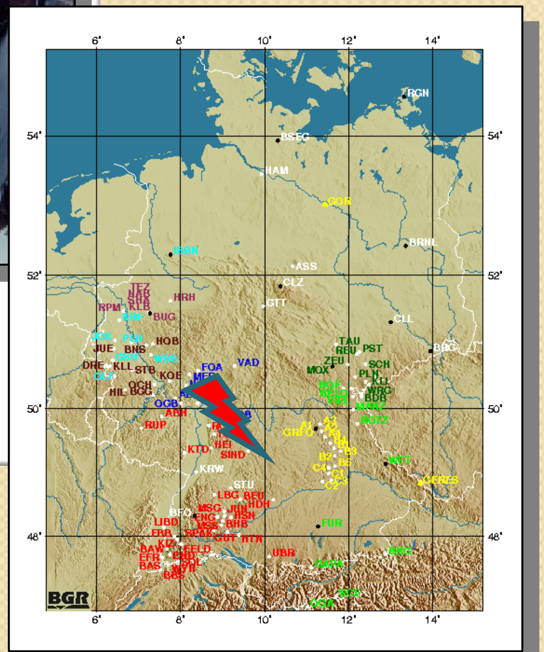
Sensitive to rotations @ the z-axis

- Indirect Methods …

Direct measurements of rotations

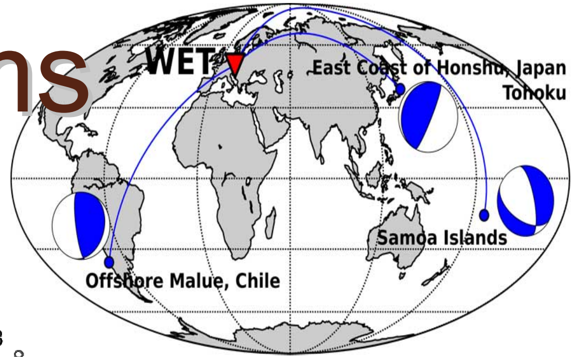


G-Ring Laser

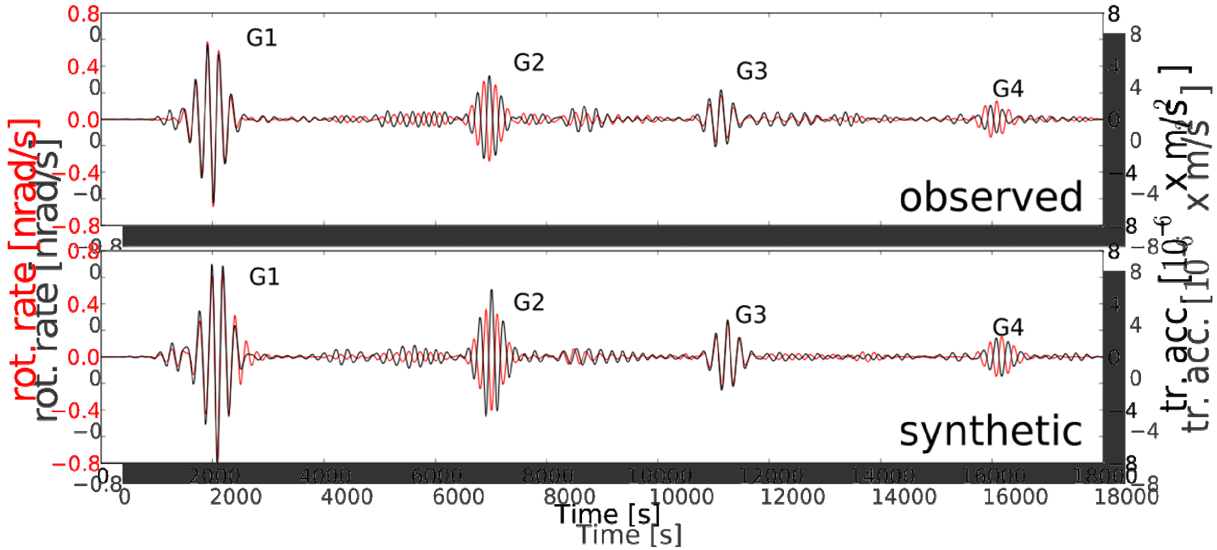


Instrument principle described in Schreiber et al., BSSA, 2009, special issue.

G–Ring Seismograms



Tohoku 9.0



- Tohoku 9.0 (2011)
- Malue 8.8 (2010)
- Samoa 8.1 (2009)

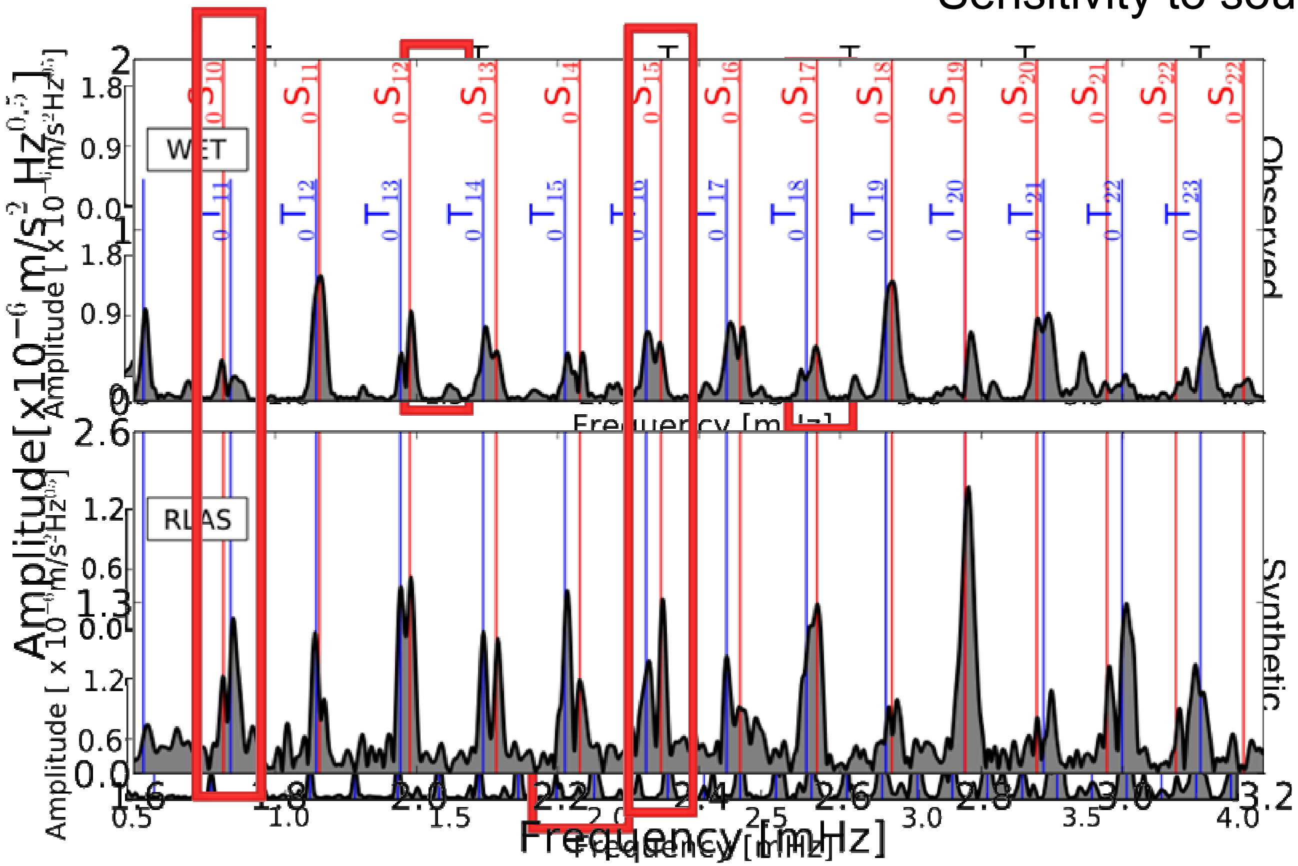
$$\frac{a_y}{\dot{\Omega}} = \frac{\ddot{u}}{\nabla \times \dot{u}} = -2c$$

Event	Phase velocity Data [km/s]	Phase velocity Synthetics [km/s]	Difference %
Tohoku	5.2	4.7	−9.6
Chile	4.6	4.9	+6.5
Samoa	5.1	4.7	−7.8

Spectral Domain

Coupling observations

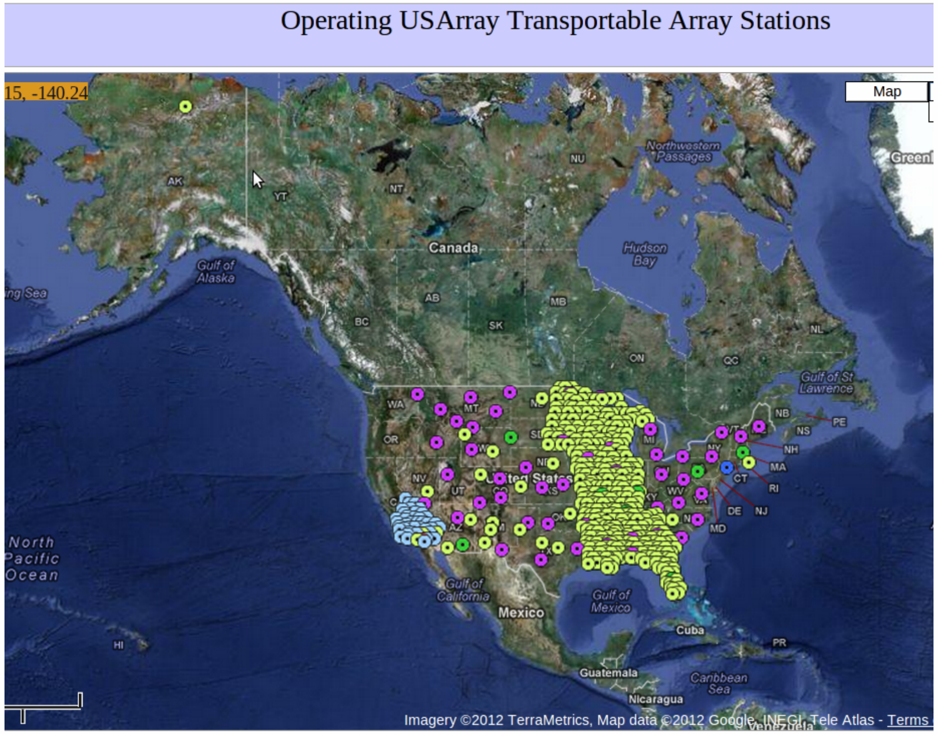
- Contrasting amplitudes –uneven-
- Defines different modalities
- Sensitivity to source parameters



36h Tohoku event

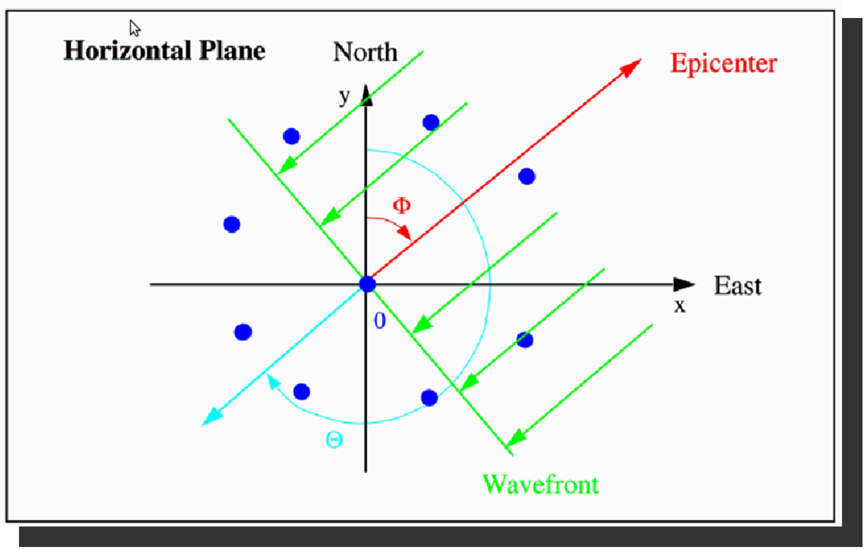
Indirect Methods

Array-derived Rotations



Operating USArray Transportable Array Stations

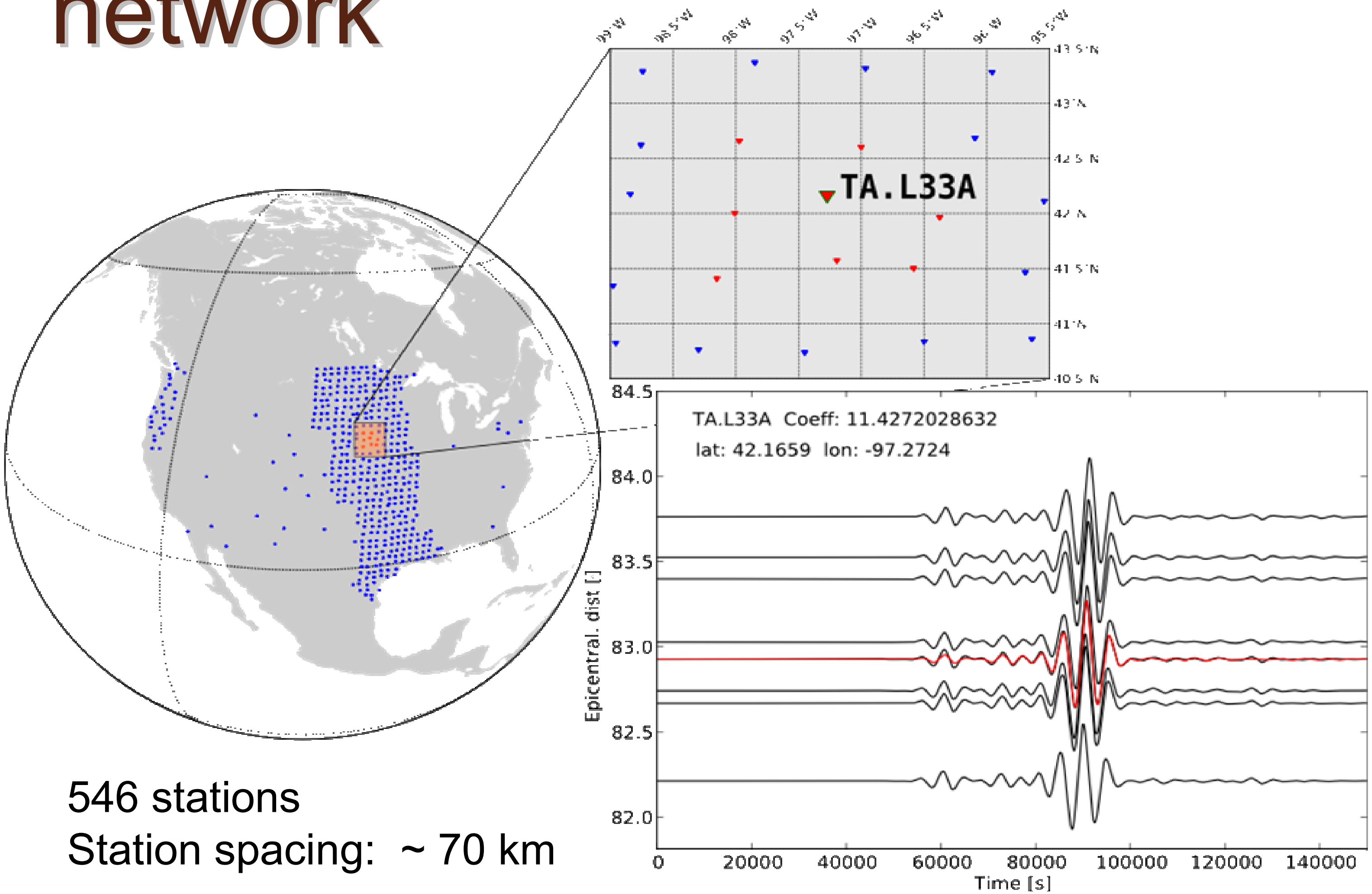
Array-derived Rotations



- Standard method to estimate the static displacement for calculating the spatial derivatives.
  - *(Spudich et al 1995)*

- Good approximation for periods where the associated λ > array dim.
- Assumes the strain tensor to be uniform in the material under the array.

USArray Transportable seismic network



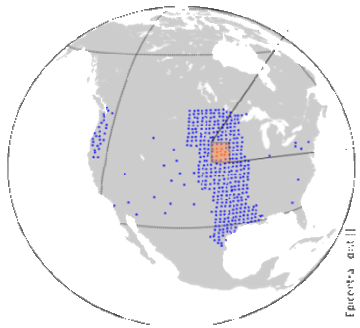
546 stations
Station spacing: ~ 70 km

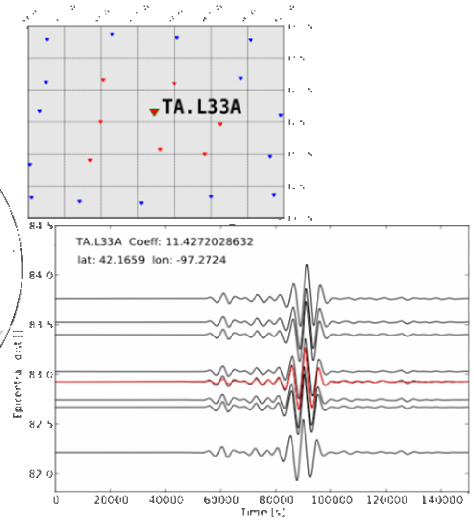
Great Tohoku event

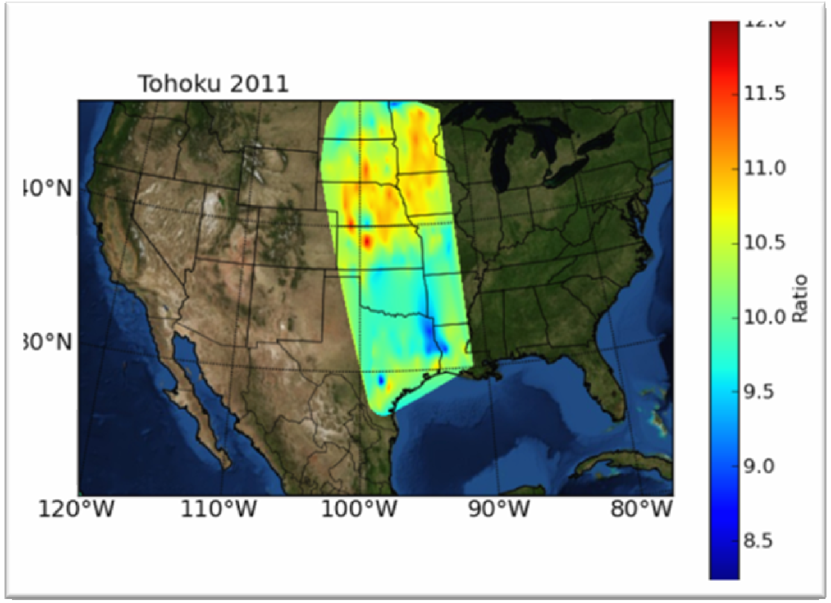
Mapping phase wave velocity

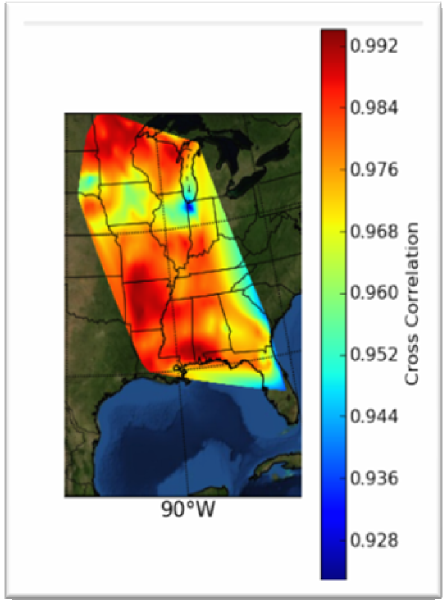
$$\frac{a_y}{\dot{\Omega}} = \frac{\ddot{u}}{\nabla \times \dot{u}} = -2c$$

+



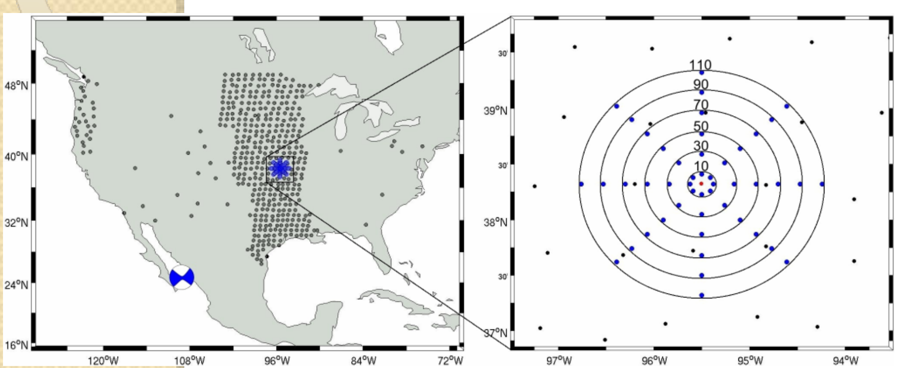


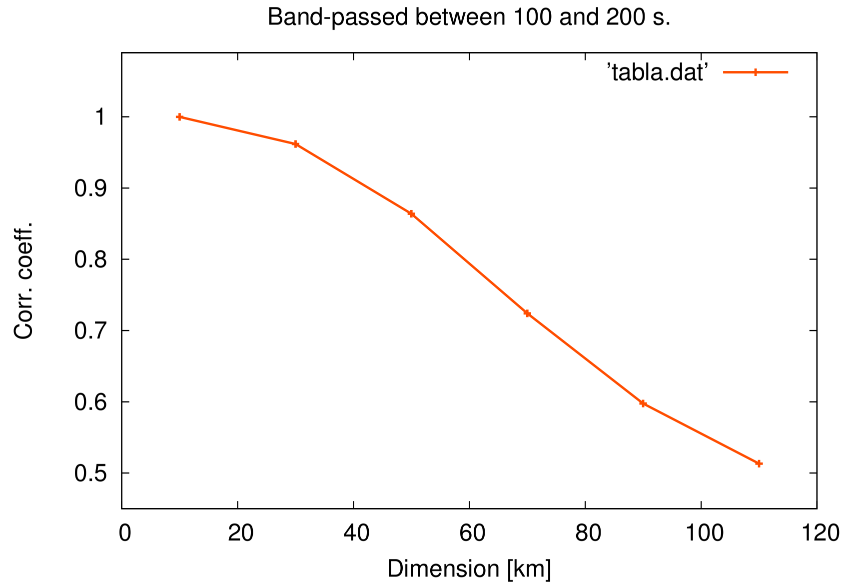


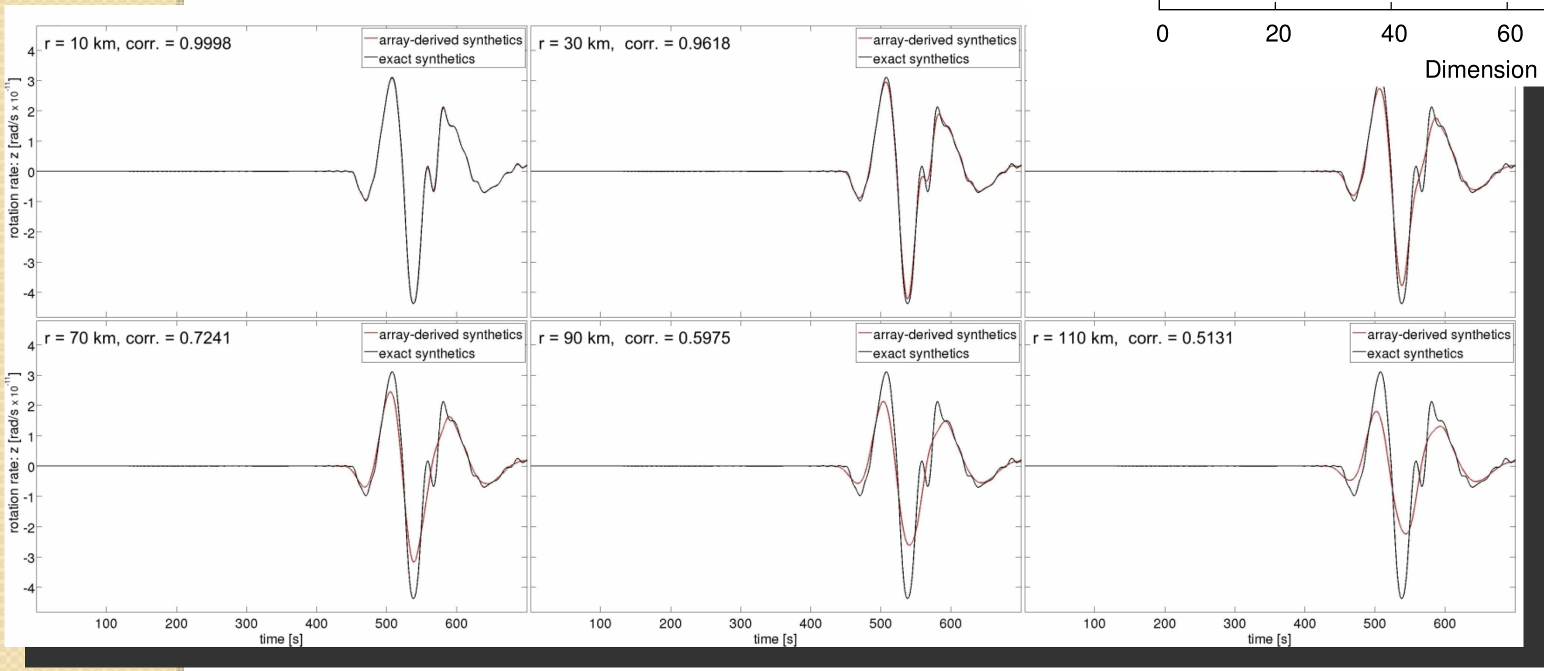


Pure vs. Array-derived rotations

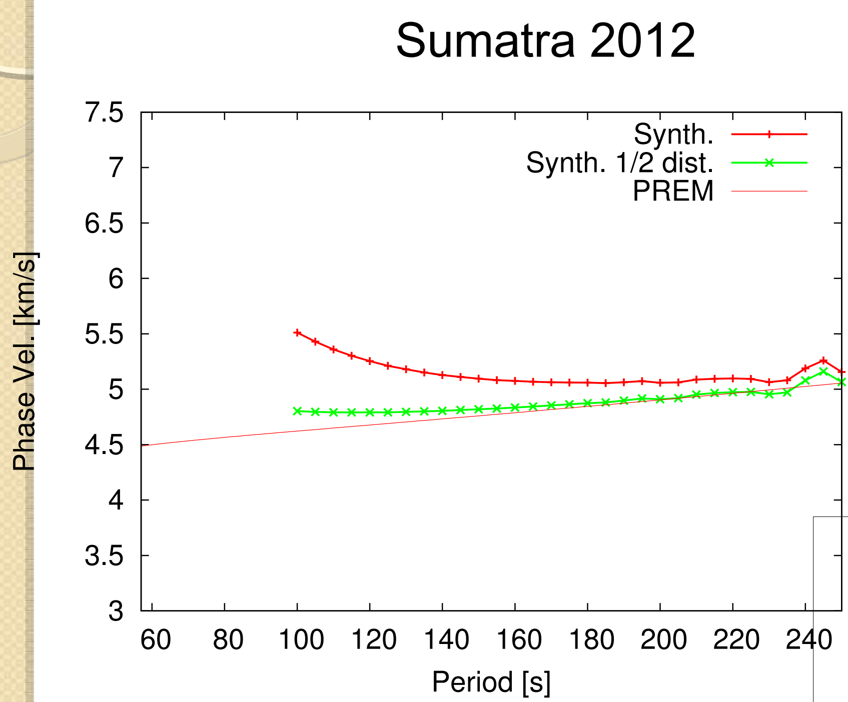
(Moritz Bernauer)

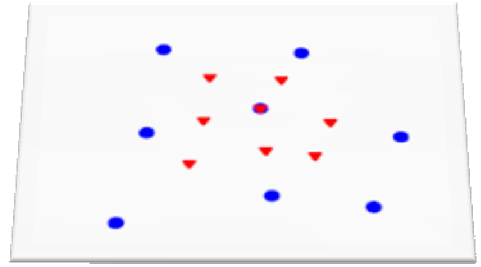






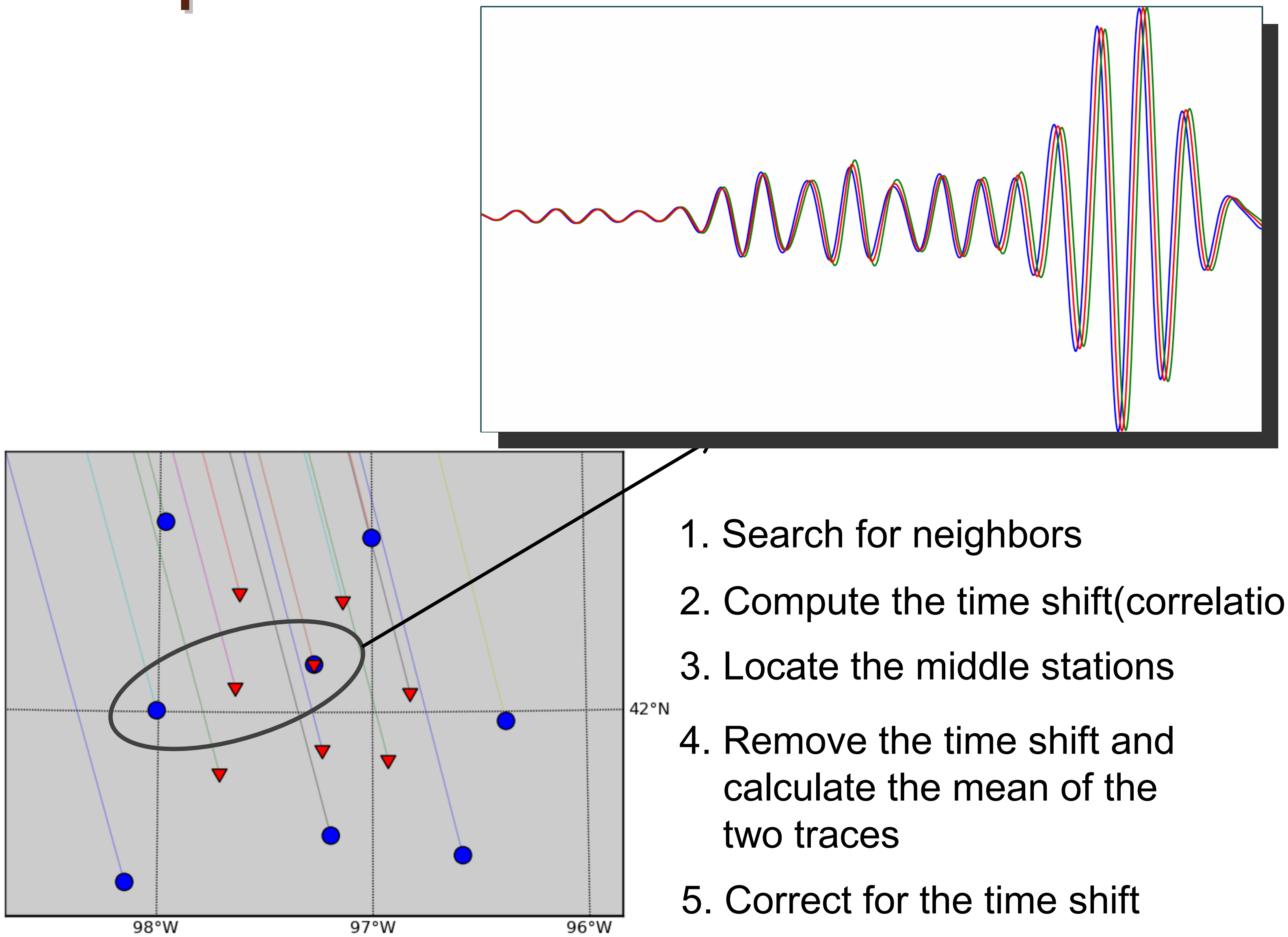
Synthetics.





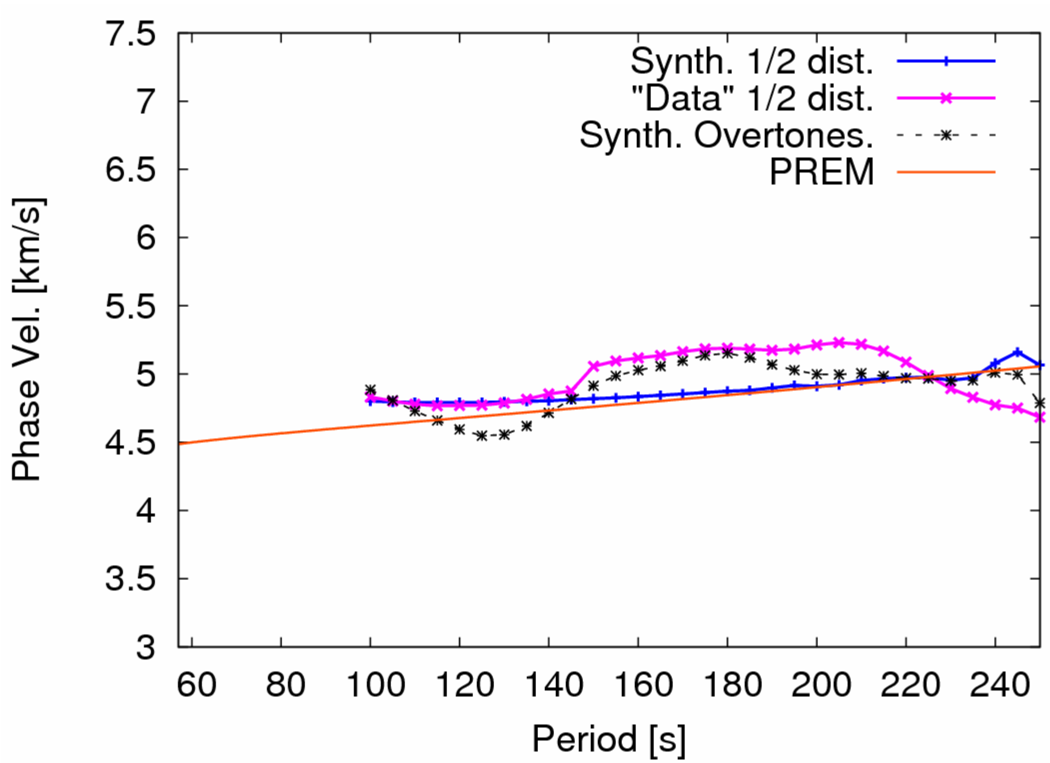
Station distribution

Interpolation method



1. Search for neighbors
2. Compute the time shift(correlatio
3. Locate the middle stations
4. Remove the time shift and calculate the mean of the two traces
5. Correct for the time shift

Interpolation



- Multi-taper analysis to avoid the effect of the overtones
- More sophisticated interpolation techniques.
- Evaluate the possible aliasing between the stations
- Extend the calculation to the whole array

To do…

- Synthetic test for the mapping the phase velocity with the combination of the two observables.
- If it works, apply the method to several earthquake followed by stacking method to get a phase velocity map
- Finding dense arrays.

- Forward modeling for the coupling between fundamental T and S modes
- Spectrograms for the array derived rotations of the UsArray are in progress

ObsPyDMT

For retrieving and management of Large seismic datas

Poster this Thursday!

THANK YOU!