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CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

BGR Bundesanstalt für Geowissenschaften und Rohstoffe
GEOZENTRUM HANNOVER

Measurement of Rotational Ground Motions for CTBT

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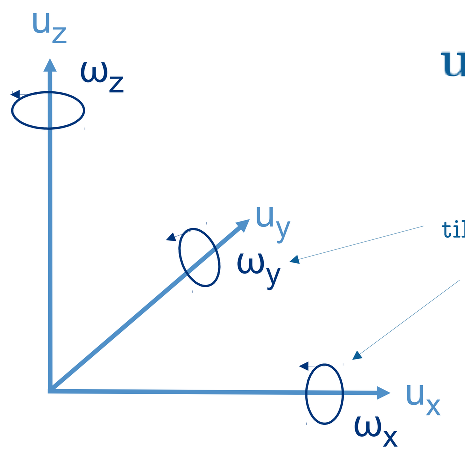
T2.3-P20

Questions

What are rotational ground motions?

Assuming an infinitesimal deformation within an elastic medium, the entire wavefield due to a seismic source is described by 12 components.



$$\mathbf{u}(\mathbf{x}+\delta\mathbf{x}) = \mathbf{u}(\mathbf{x}) + \epsilon\cdot\delta\mathbf{x} + \omega\times\delta\mathbf{x}$$

translation   strain   rotation

$$\omega(\mathbf{x},t) = \frac{1}{2}[\nabla\times\mathbf{u}(\mathbf{x},t)]$$

- information on the vertical displacement gradient
- not available from conventional arrays on Earth's surface

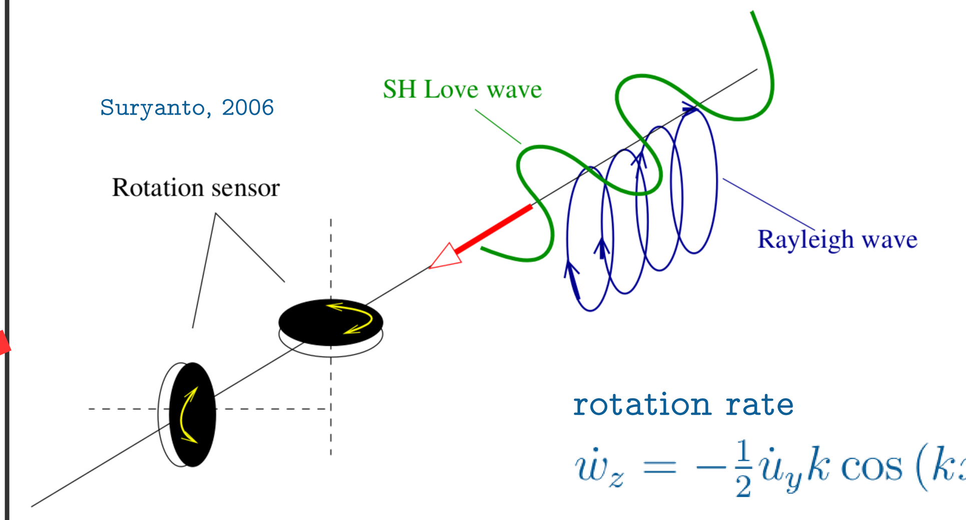
How can they serve CTBT?

In very manifold ways. Follow the red line.

All methods shown are **single station aproaches**. Test case is the Mw 7.2 Tadjikistan earthquake from 7 December 2015 measured at the ringlaser in Wettzell, Germany, recording vertical rotation rate.

How does the magic work?

By collocated measurement. Assume a plane SH/Love wave in X direction.



velocity
$$\dot{u}_y = \dot{u}_y \sin(kx-\omega t)$$

acceleration
$$\ddot{u}_y = -\dot{u}_y\omega\cos(kx-\omega t)$$

rotation rate
$$\dot{w}_z = -\tfrac{1}{2}\dot{u}_y k\cos(kx-\omega t)$$

$$\frac{\ddot{u}_y}{\dot{\omega}_z} = -2c$$

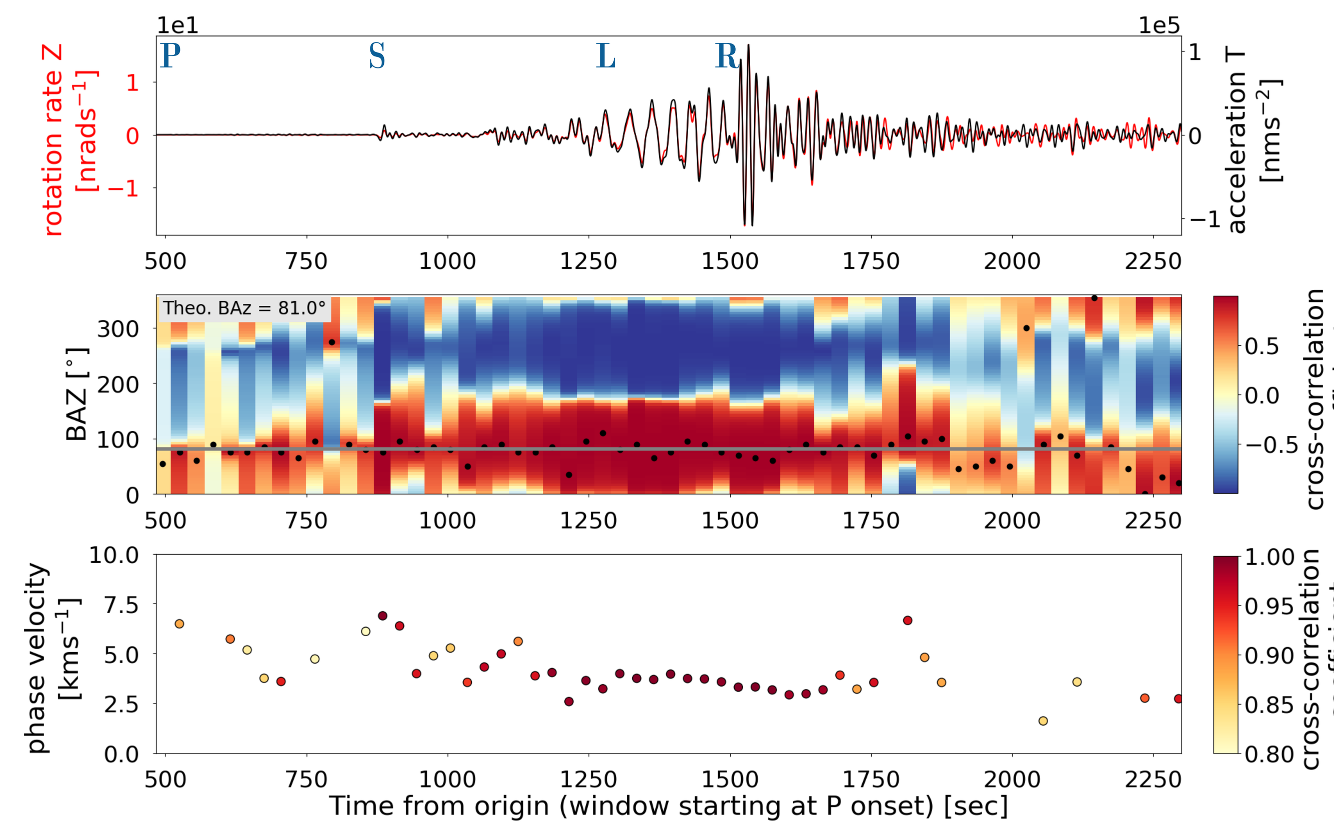
local phase velocity

similarly for Rayleigh waves: $\frac{\ddot{u}_z}{\dot{\omega}_y} = c$

Rotational ground motion components act as wavetype filters!

Get direction and local phase velocity

Cross-correlation of translation and rotion in sliding time window (30 sec)



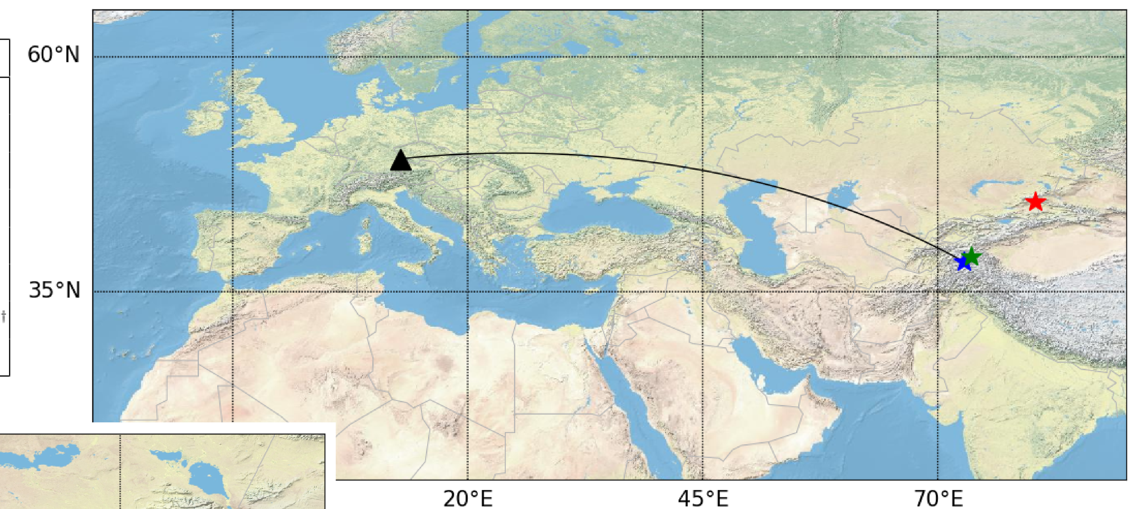
bandpass 10-100 sec

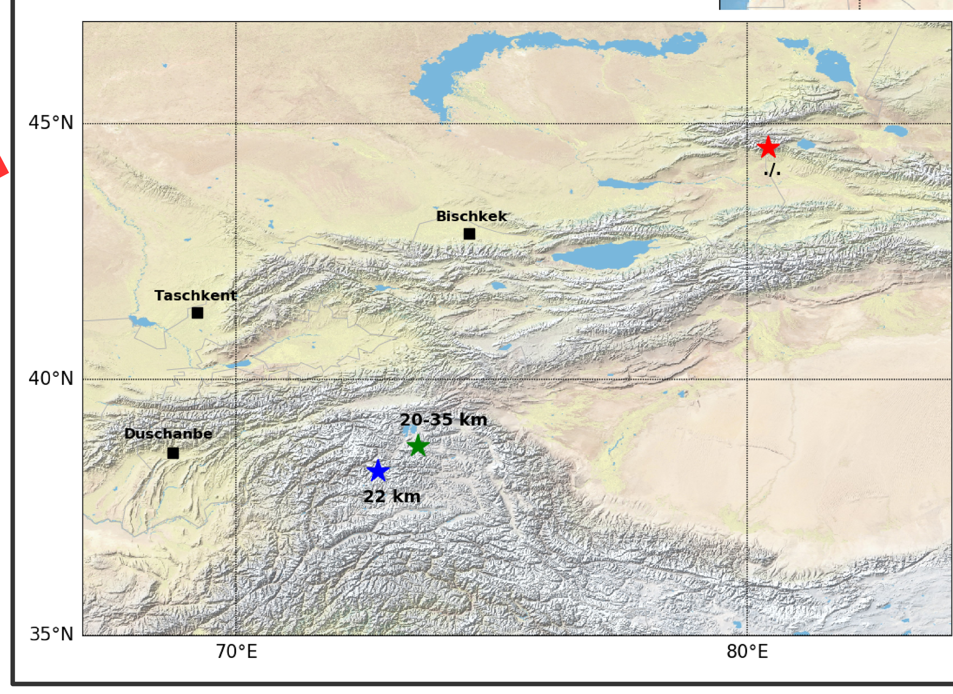
cc looped over BAz 0-360°

phase velocity for each sliding time window

Earthquake location (without knowing model)

	IRIS	3C	4C
travel time difference [s]	388	392	390
source time UTC [h:m:s]	07:50:05	07:50:04	07:50:06
distance [°]	43.48	44.05	43.70
distance [km]	4834	4898	4859
latitude [°]	38.21	44.54	38.71
longitude [°]	72.77	80.41	73.55
backazimuth [°]	81	69 (55-81)†	80 (60-95)†
depth [km]	22	-	20-35





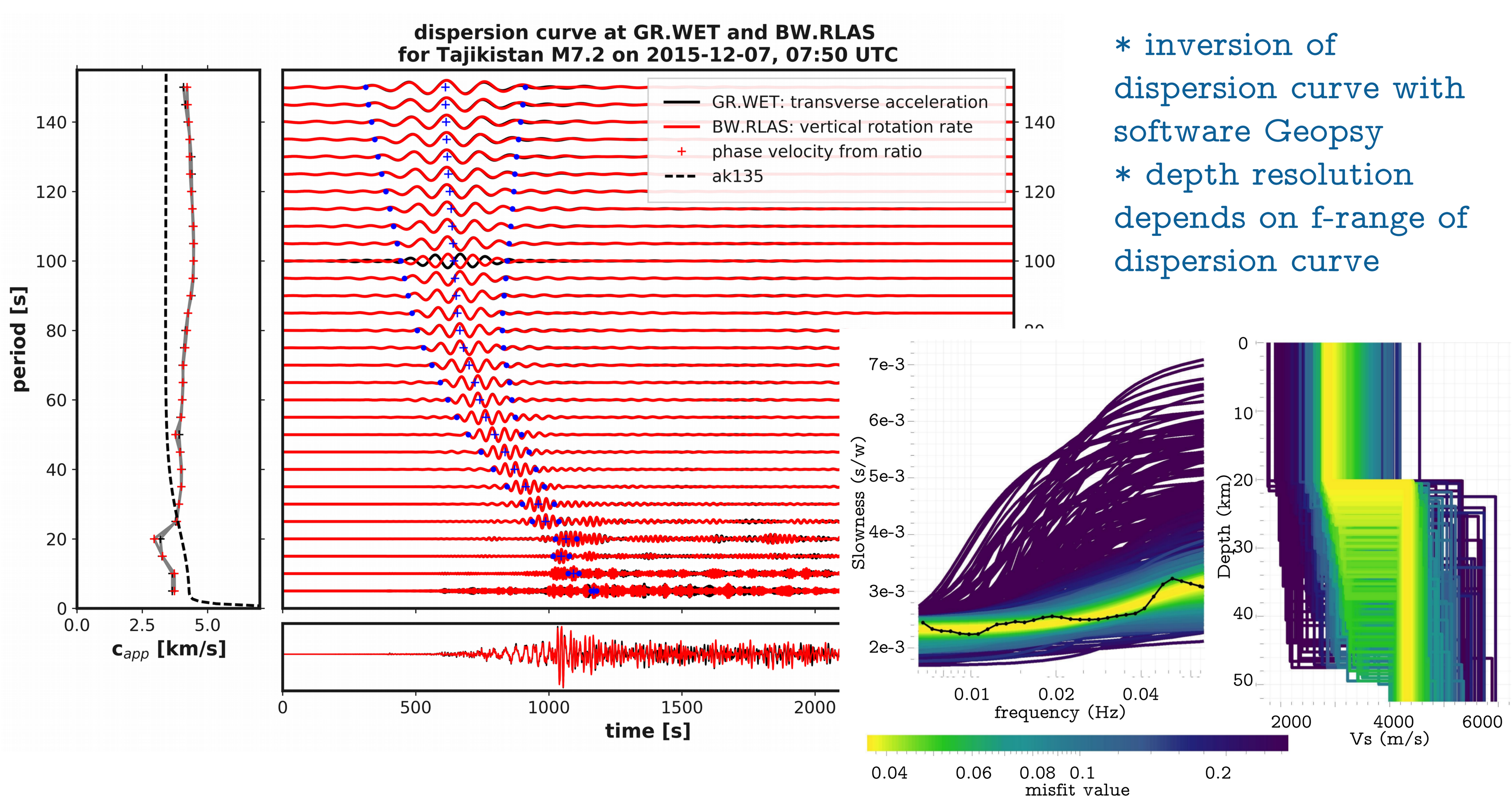
* get S-P arrival time → distance
* get P arrival from distance → origin time
* get BAz from CC → location
* get v-model from dispersion curve inversion
* get rough depth estimate via ray-tracing; backshooting and comparing incident angle via :

$$\frac{v_S}{v_{S_{app}}} = \sin i \pm e = \frac{180}{\pi}\cdot\frac{v_P}{r_h}\cdot p(\Delta,h)$$

(from model: v_S; from CC: $v_{S_{app}}$)

Get local structure via dispersion curve

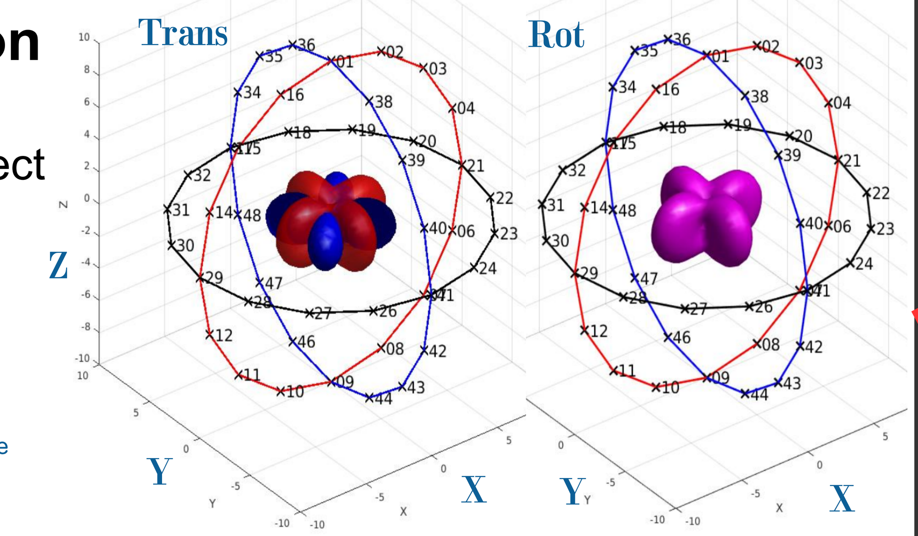
Get amplitude ratios in different frequency/period bands (cc with real BAz)



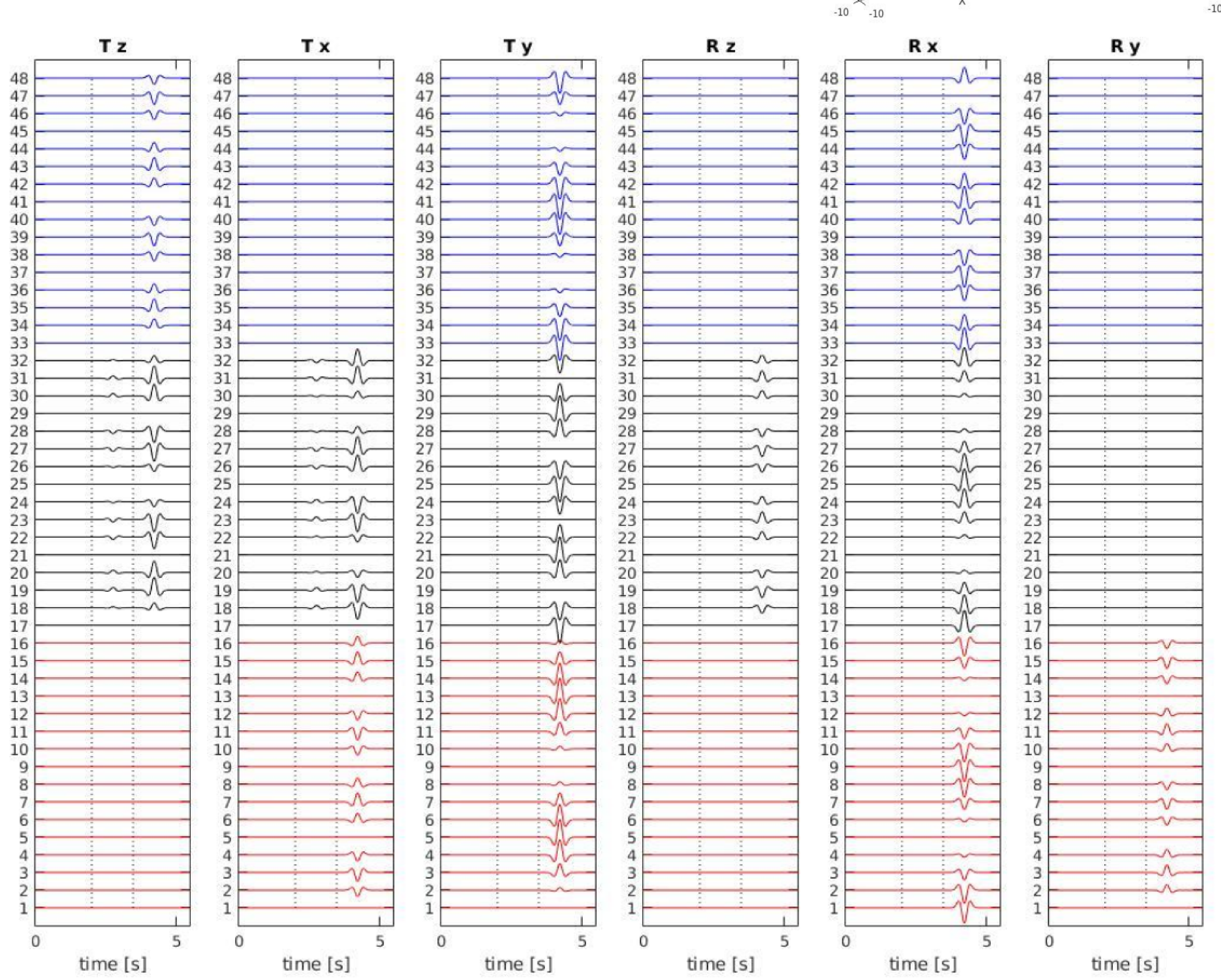
* inversion of dispersion curve with software Geopsy
* depth resolution depends on f-range of dispersion curve

Source discrimination

Was it an explosion or tectonic? Wavetype filter effect of rotations compared with translations may help to decide.



radiation pattern of a strike slip source with slip in XY plane in X direction



differences of amplitudes on single components in comparison to each other bring additional information on the mechanism

Summary

(not everything shown here)

Structural engineering
* torsional modes
* interstory drift
* ...

Structure
* phase velocity
* dispersion curve
* shallow surface structure
* sensitivity kernels
* toroidal mode

Wavefield
* wavefield separation
* wavetype ratios
* scattering
* tilt (OBS)

Exploration
* wavefield characterization
* wavefield re construction
* P-S separation in VSP
* surface wave suppression

Source
* direction, location
* source discrimination
* microseism, earthquakes
* inversion for mechanism

References

* Schmelzbach, C., **Donner, S.**, Igel, H., Sollberger, D., Taufiqurrahman, T., Bernauer, F., Häusler, M., Renterghem, C. V., Wassermann, J. & Robertsson, J. (2018) *Advances in 6C seismology: Applications of combined translational and rotational motion measurements in global and exploration seismology.* GEOPHYSICS, vol. 83, pp. WC53-WC69.

… and references therein.

* http://romy-erc.org → Publications