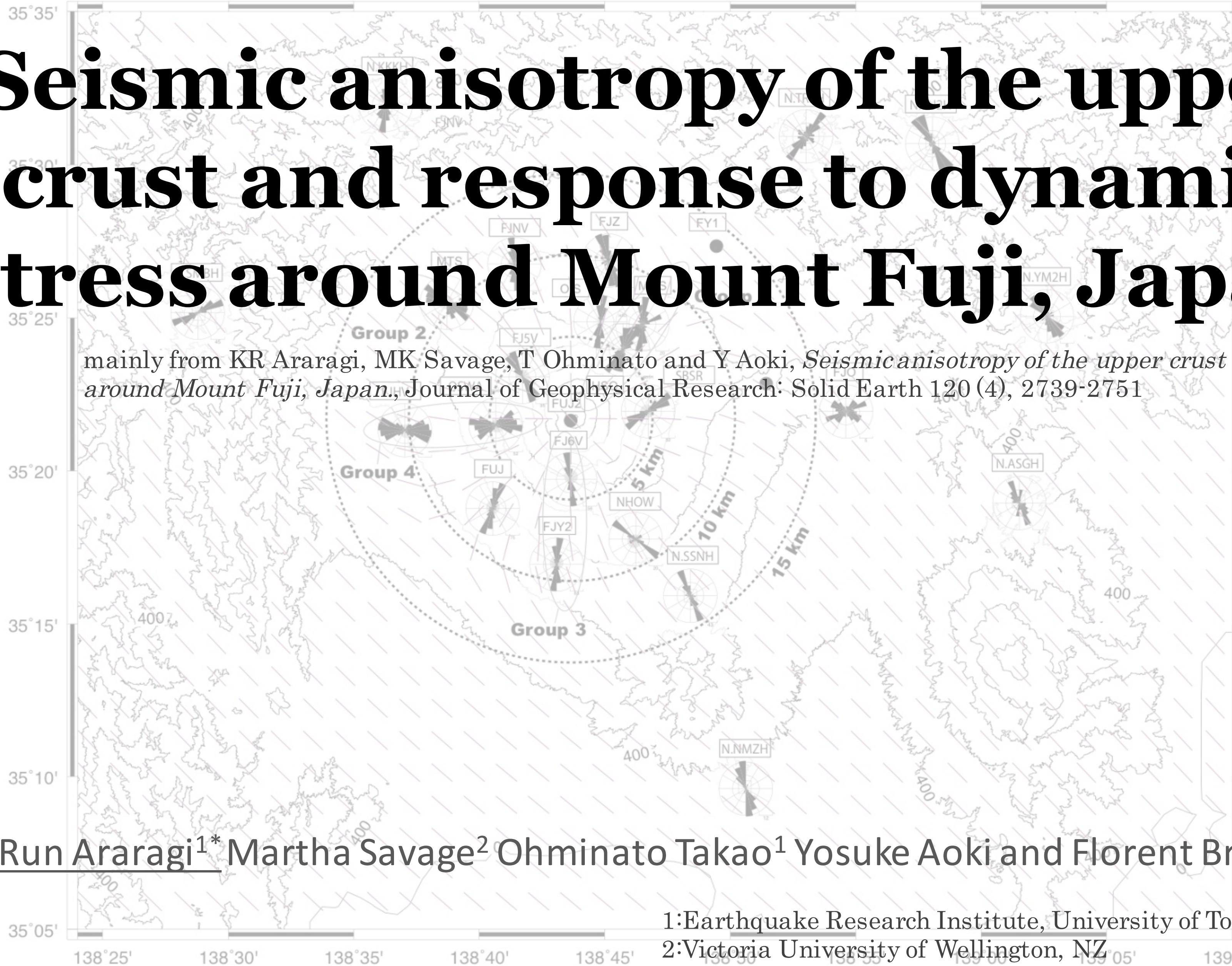
Seismic anisotropy of the upper crust and response to dynamic stress around Mount Fuji, Japan

mainly from KR Araragi, MK Savage, T Ohminato and Y Aoki, *Seismic anisotropy of the upper crust around Mount Fuji, Japan.*, Journal of Geophysical Research: Solid Earth 120 (4), 2739-2751



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Contents (Araragi et al., 2015 + α)

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- Stress estimation
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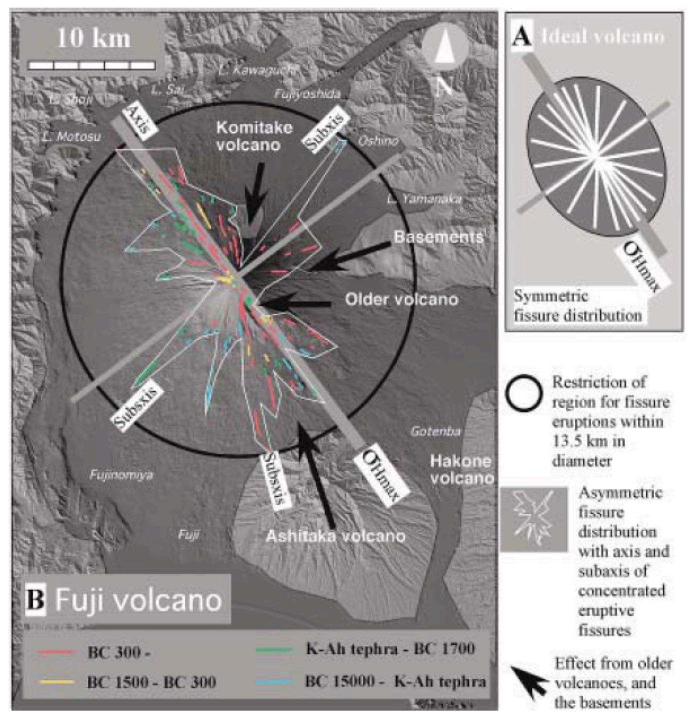
- Subtle seismic velocity change

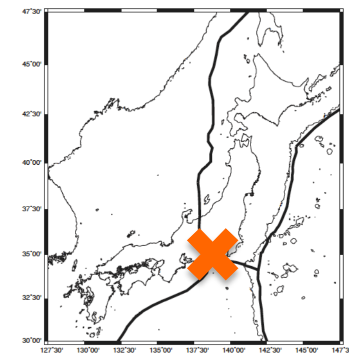
Purpose of research:

Using seismic anisotropy around Mt. Fuji for interpretation of the regional and local geologic structure and/or processes of the area.

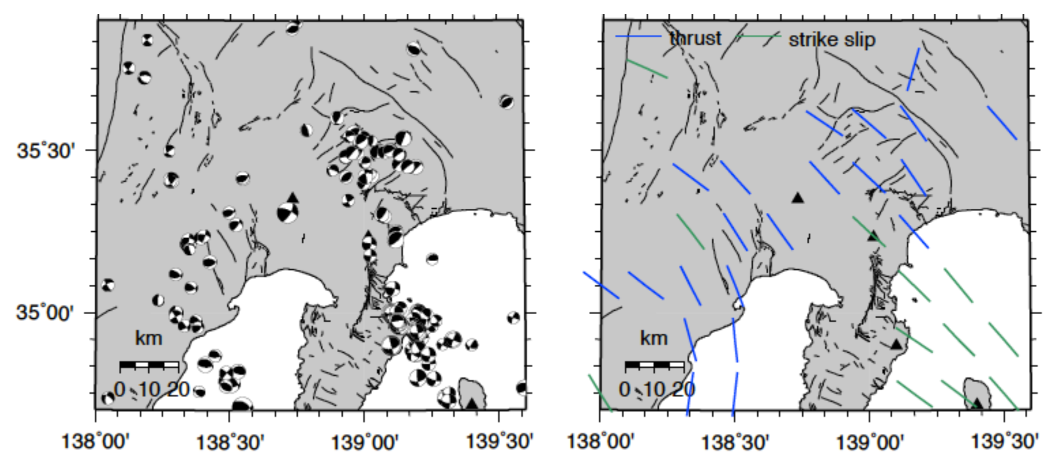
Introduction

- No eruption (- AD 1707)
- The triple junction of PHS, NAM, and EUR.
- Radial pattern of dyke near the summit [e.g. Takada, 2007]
- Regional NW-SE compressive stress field [e.g. Nakamura, 1977].





Takada et al. [2007]



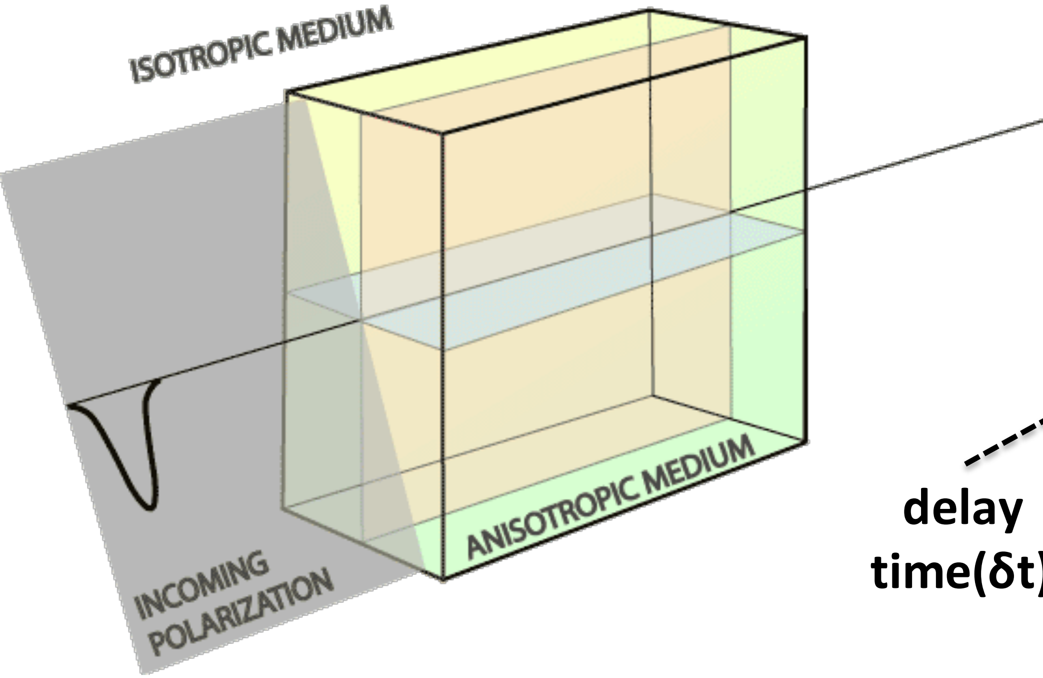
Calculated by Hardebeck et al. [2004]

Why do we study Mt. Fuji with SWS ?

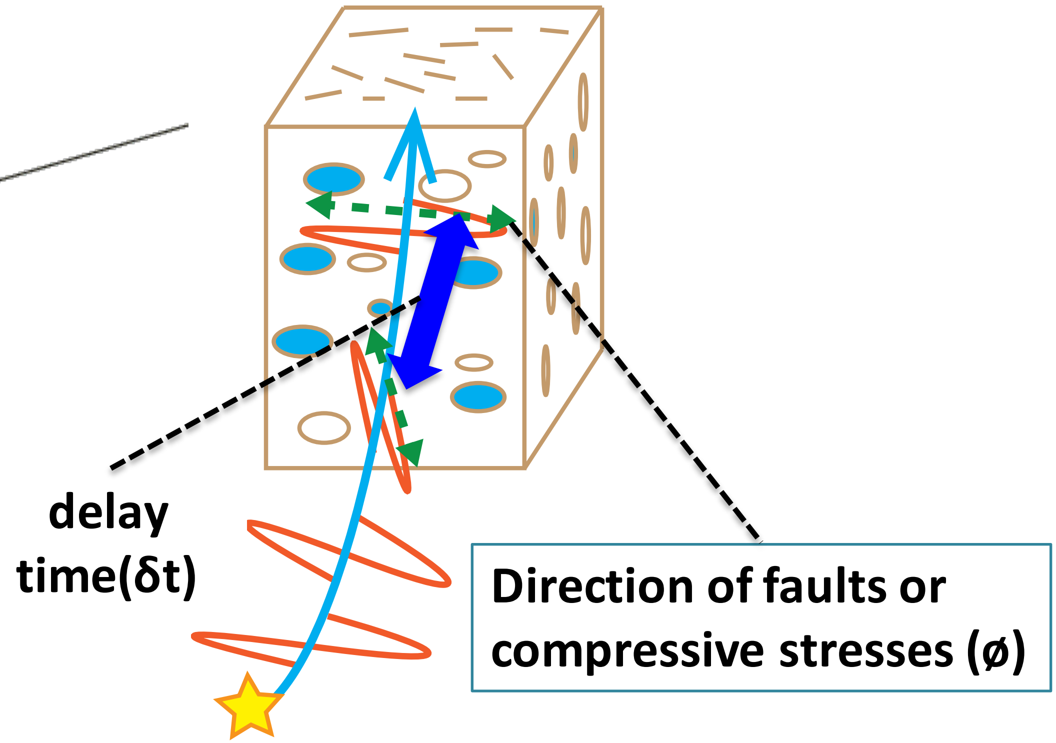
Geologic background	Triggering factors for the change of geologic processes
• Dike distribution and the formation processes of the mountain edifice. • Regional stress field (NW-SE)	• Increase of dilatation strain [Harada et al., 2010] • Change of regional stress field by the 2011 Tohoku-Oki earthquake • Mw5.9 event on 15, March, 2011

Seismic anisotropy/velocity change around Mt. Fuji may constrain the geologic structure and/or stress-related processes of the area.

What is shear wave splitting (SWS) ?



http://en.wikipedia.org/wiki/Shear_wave_splitting

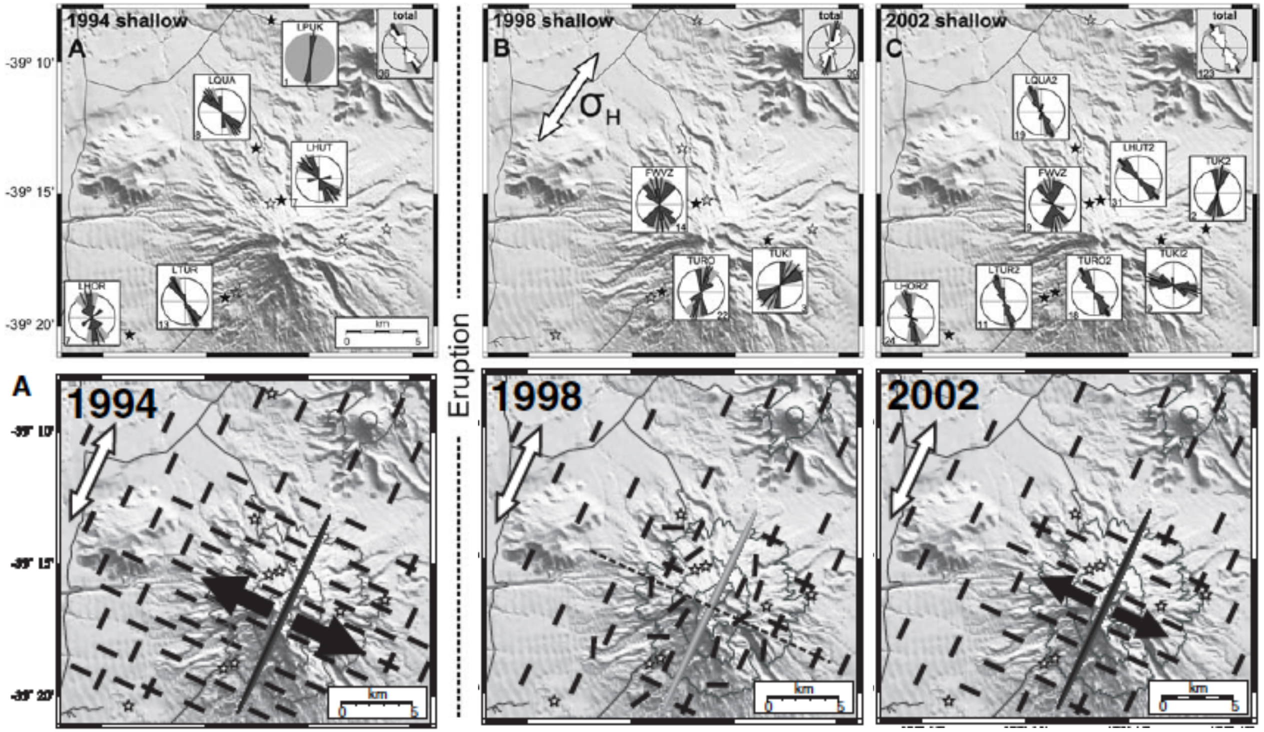


Fast polarization (ø): Direction in which shear wave propagates faster than other directions

Delay time (Δt) : Difference of waves along the fast direction and along the slow direction.

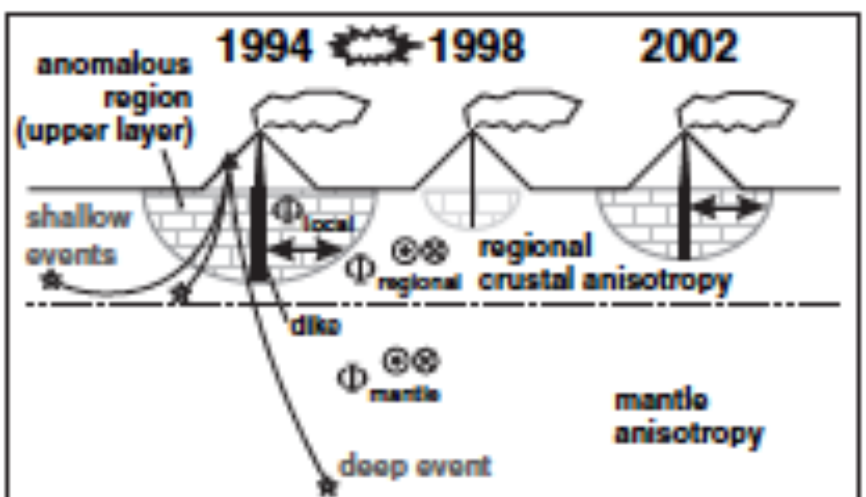
In anisotropic media, seismic wave is **projected** in fast direction (ø) and slow direction. In slow direction, seismic wave cause delay time (δt).

SWS in volcanic region



Anisotropy

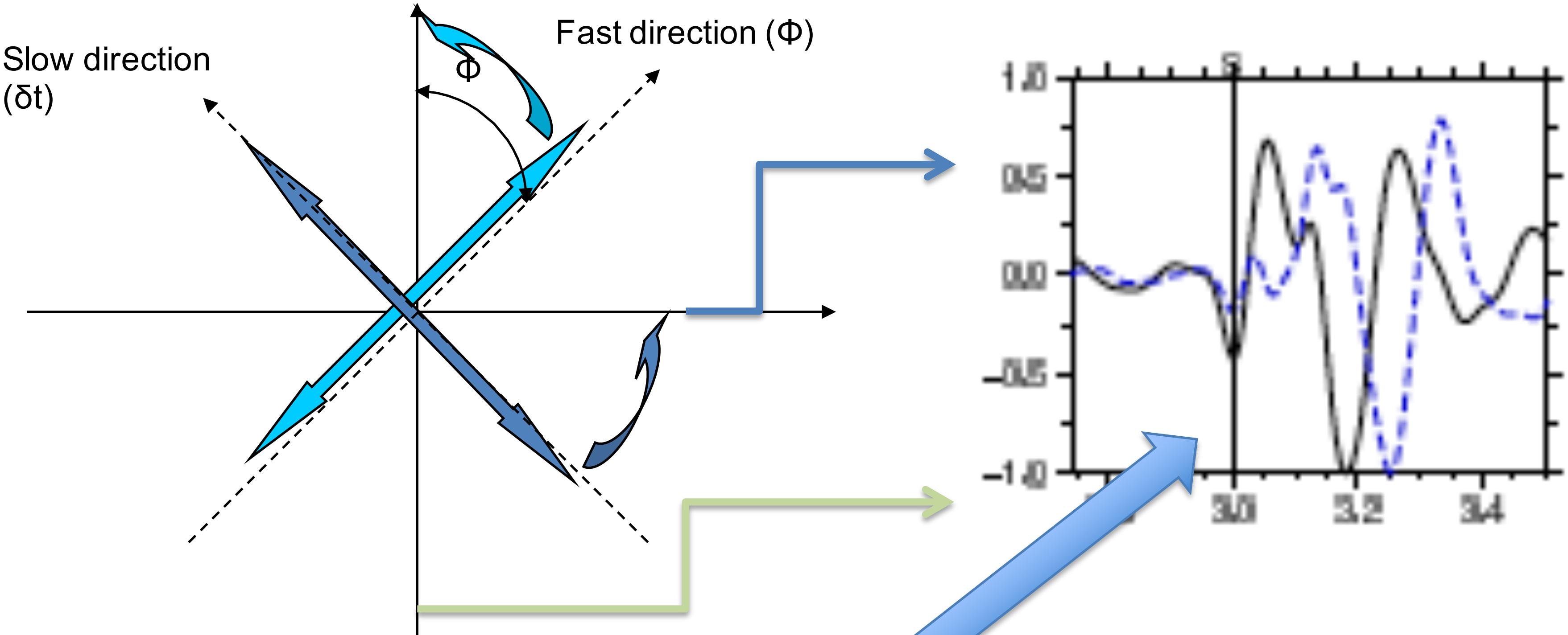
Maximum compression



SWS can be used for detection of stress-related events. (e.g. Gerst and Savage, 2004)

Structural or **stress-related** anisotropy?

What are the problems of SWS measurements?



I **hate** Φ = 20˚. I need Φ = 45˚ and δt = 0.05!

I think the **shapes** of waves are similar. Shear wave splitting occurs!

The results may be **subjective**.

We use automated methodology "**MFAST**"(Savage et al., 2011)

Procedure of MFAST (Savage et al., 2010)

Select data

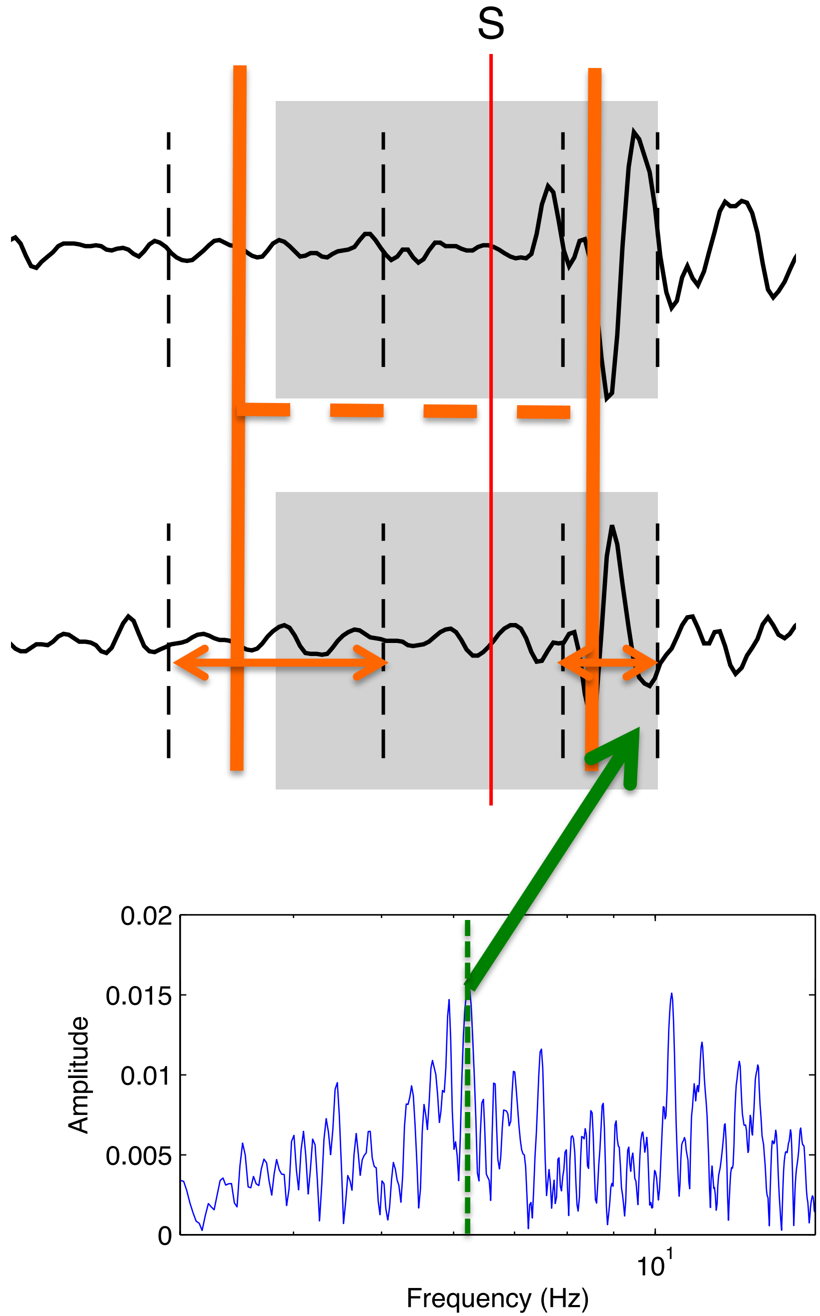
Apply multiple filters / choose three

SNR>3?

Determine measurement window based on period and S-pick

Splitting measurement by clustering method (Teanby et al., 2004)

Selection criteria (quality of cluster, polarity of waveforms, consistency of results, and delay<0.8 maximum)



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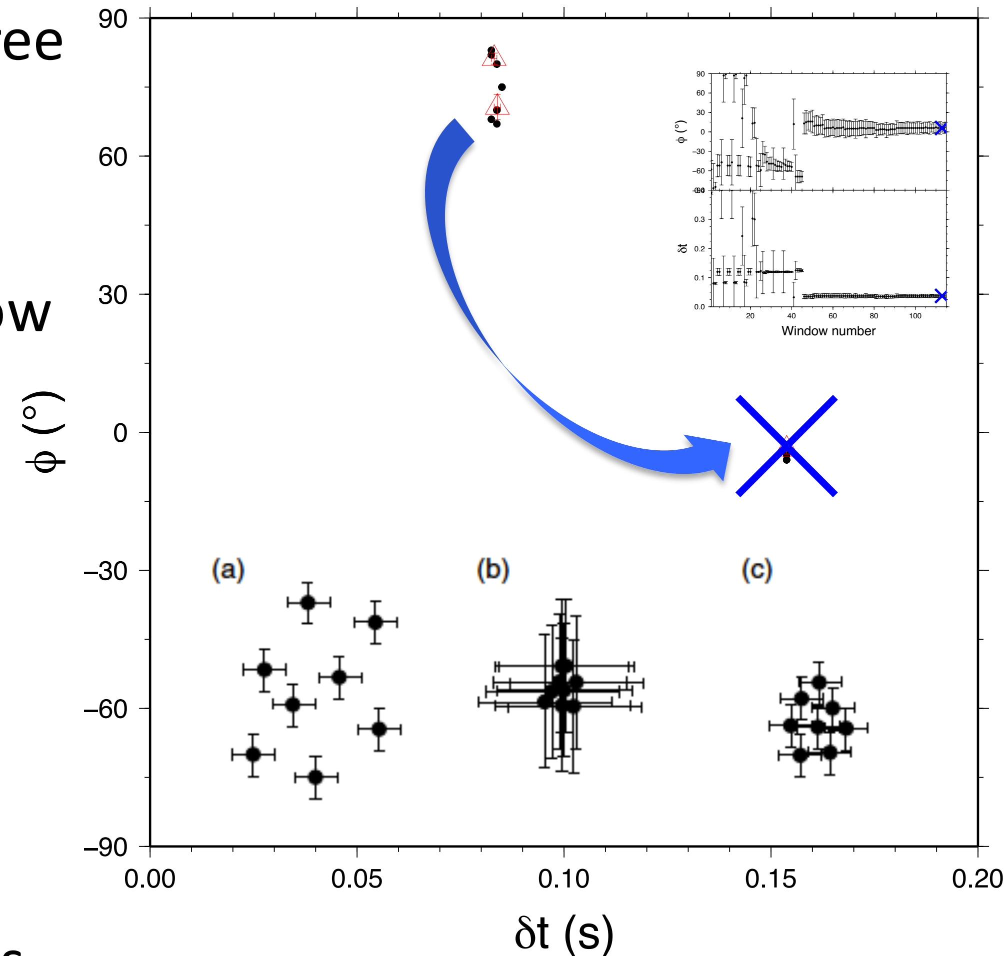
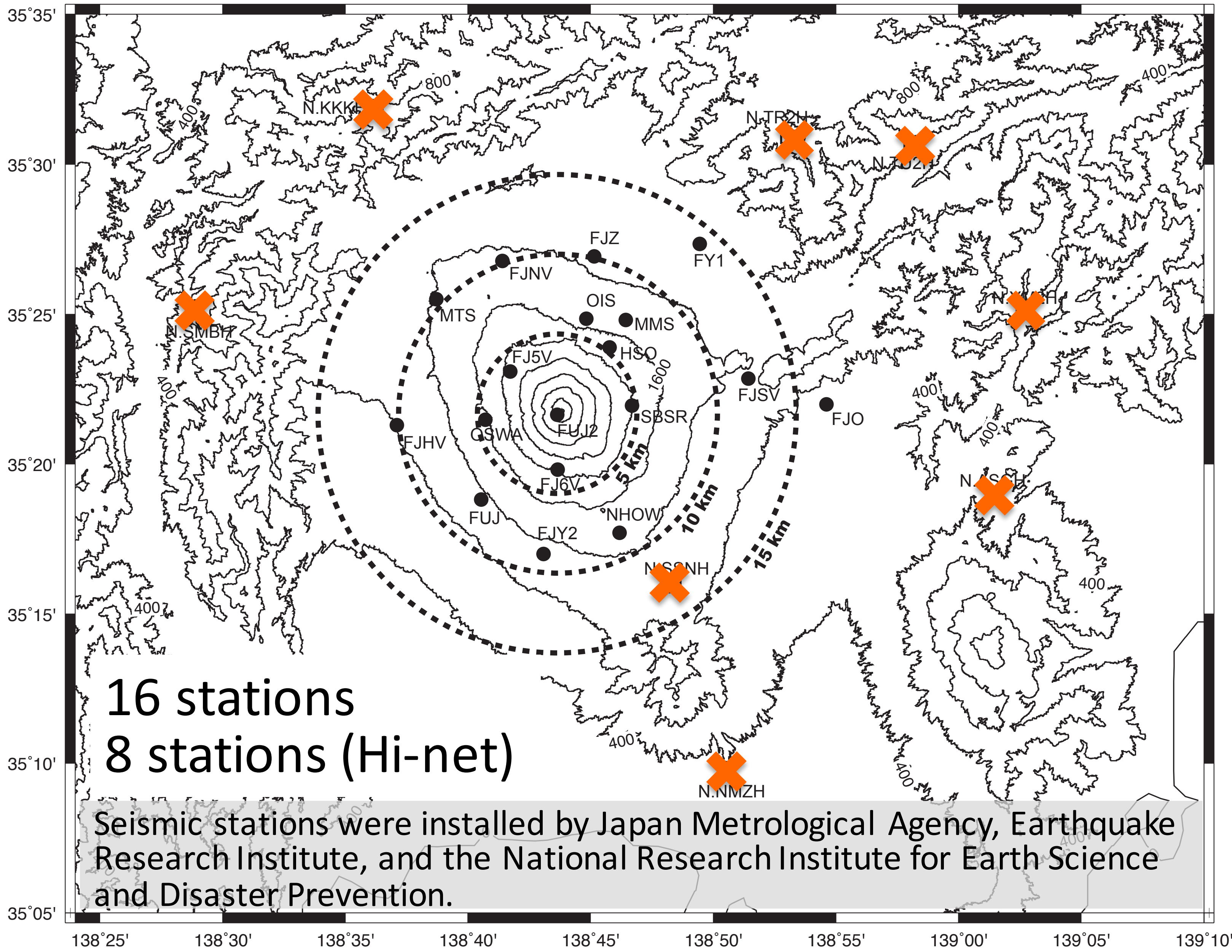


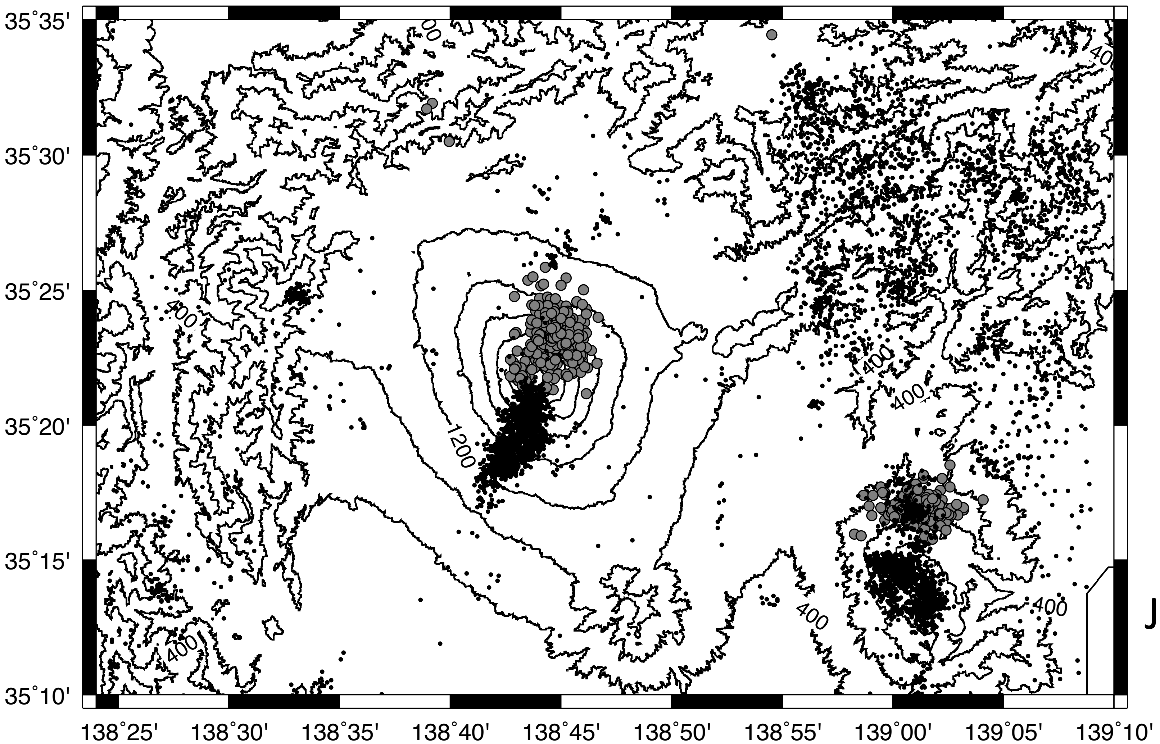
Station locations (JMA, ERI and NIED)

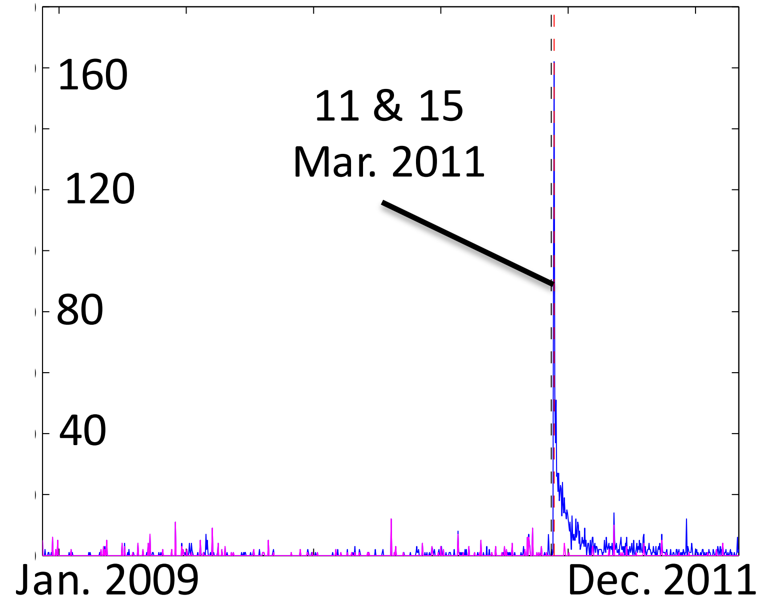


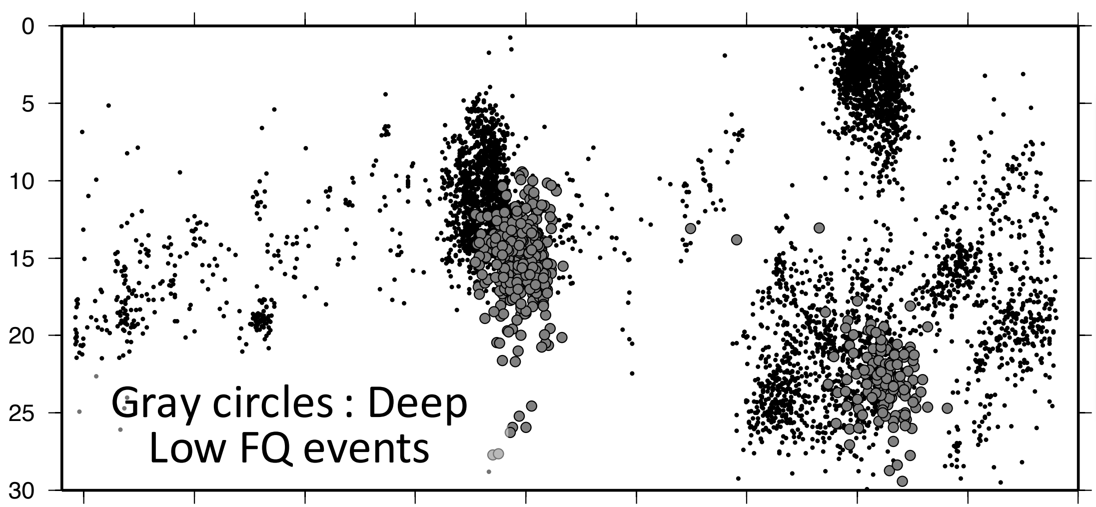
16 stations
8 stations (Hi-net)

Seismic stations were installed by Japan Metrological Agency, Earthquake Research Institute, and the National Research Institute for Earth Science and Disaster Prevention.

Events used for SWS measurements







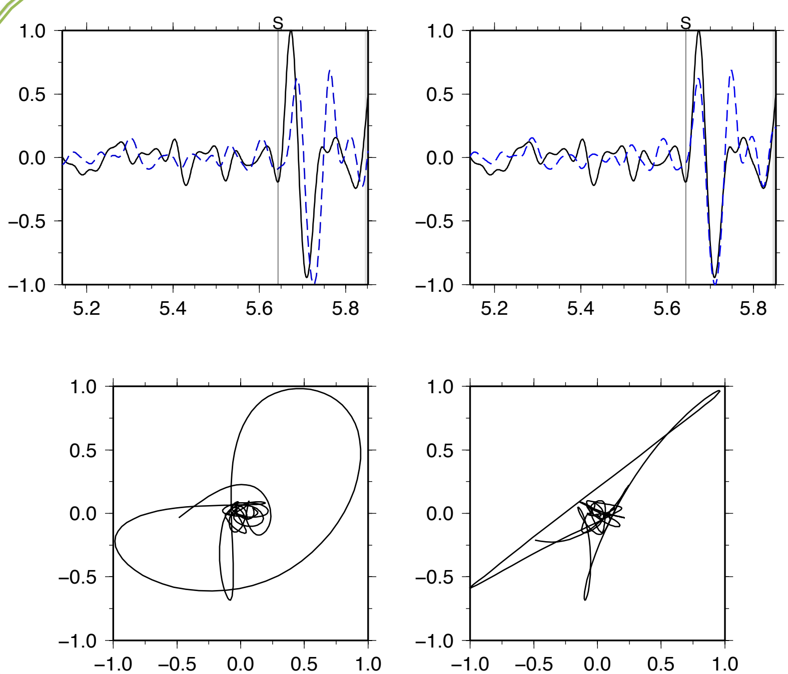
2009.1.1-2012.10.31

Depths: 0-20 km

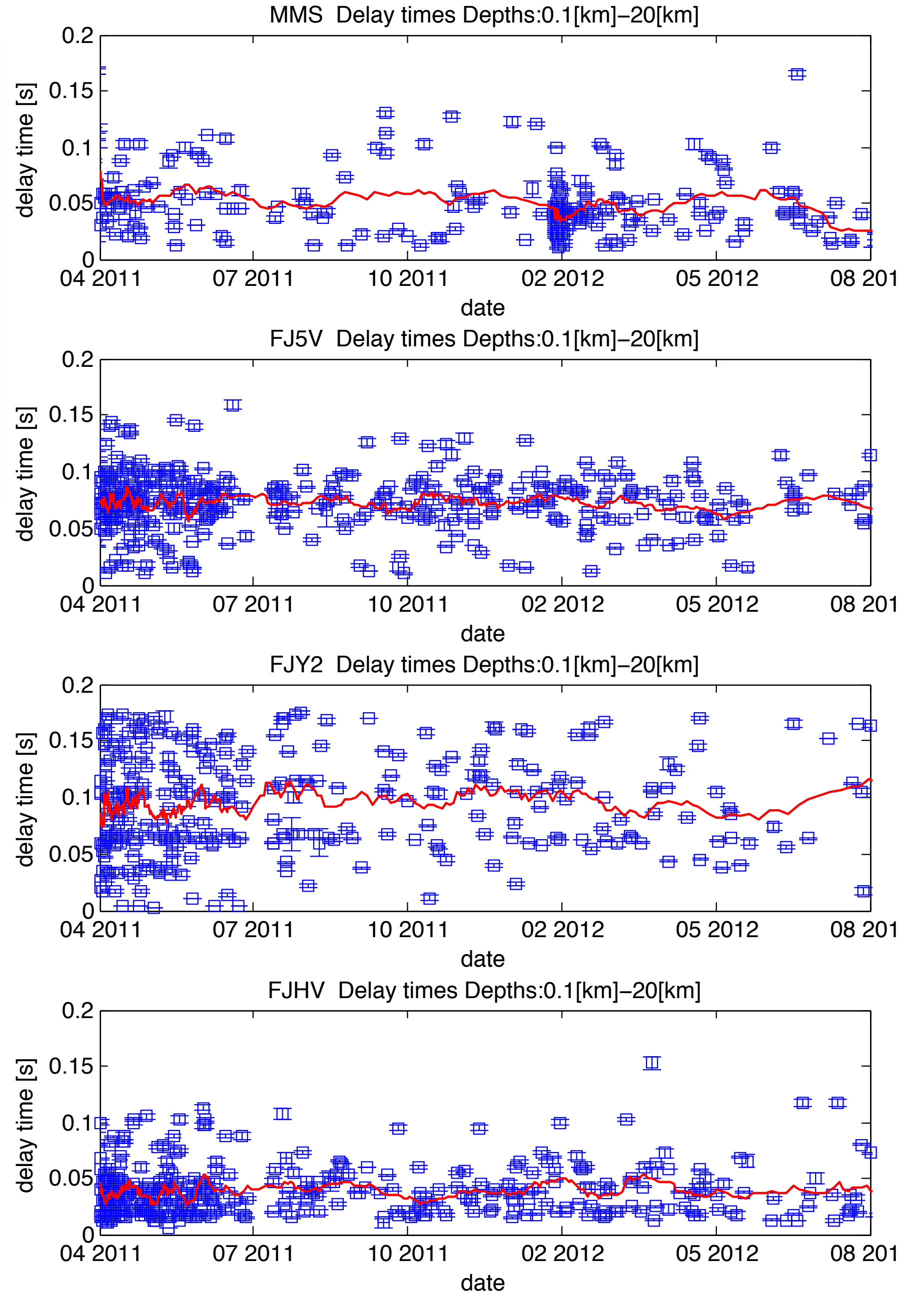
Maximum distance to stations: 25 km

Measured SWS

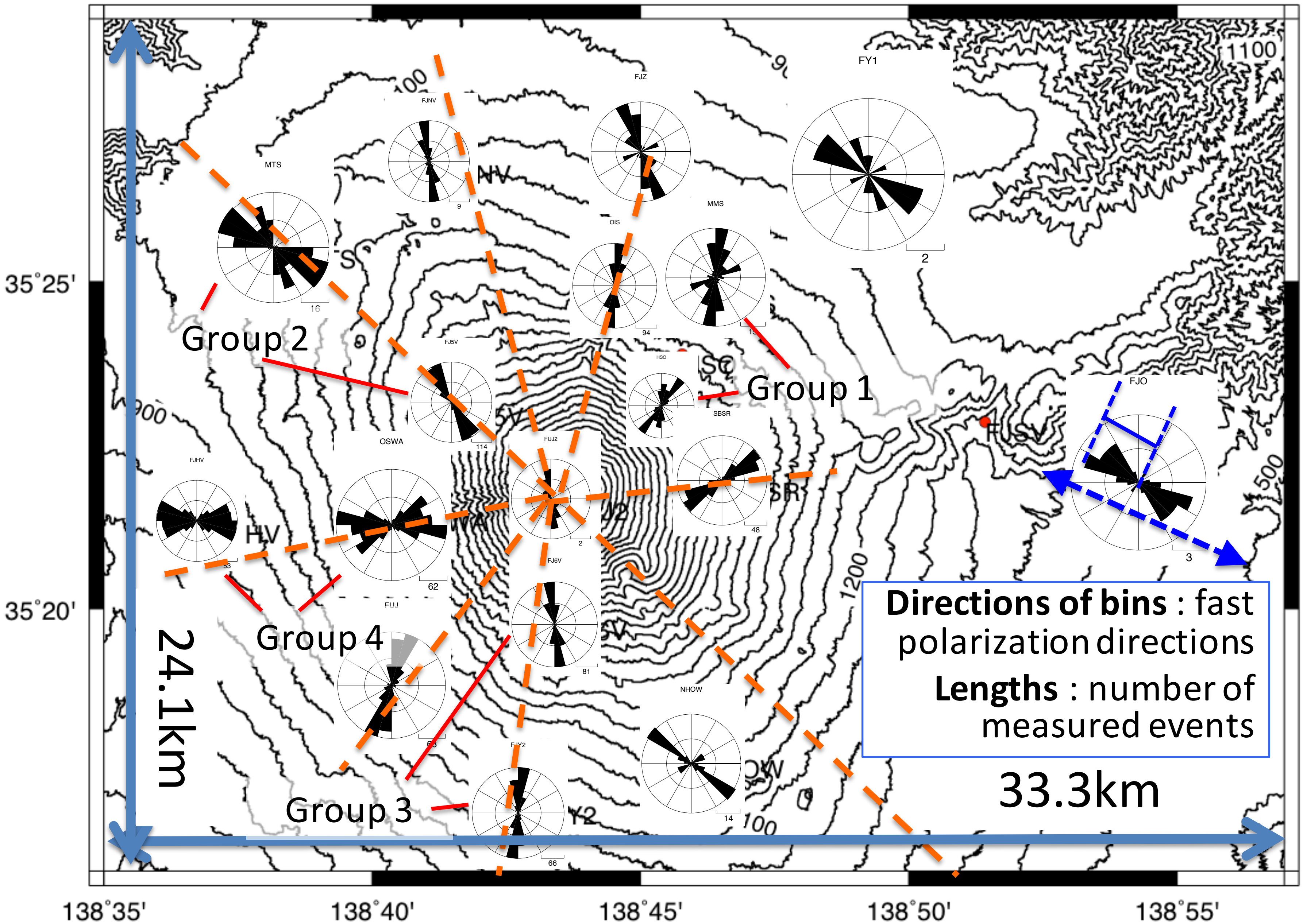
- Dominant frequency: ~ 7 Hz or less than 5 Hz
- Delay times : 0.04-0.09 [s]
- Consistent fast and delay at each station
- Temporal consistency



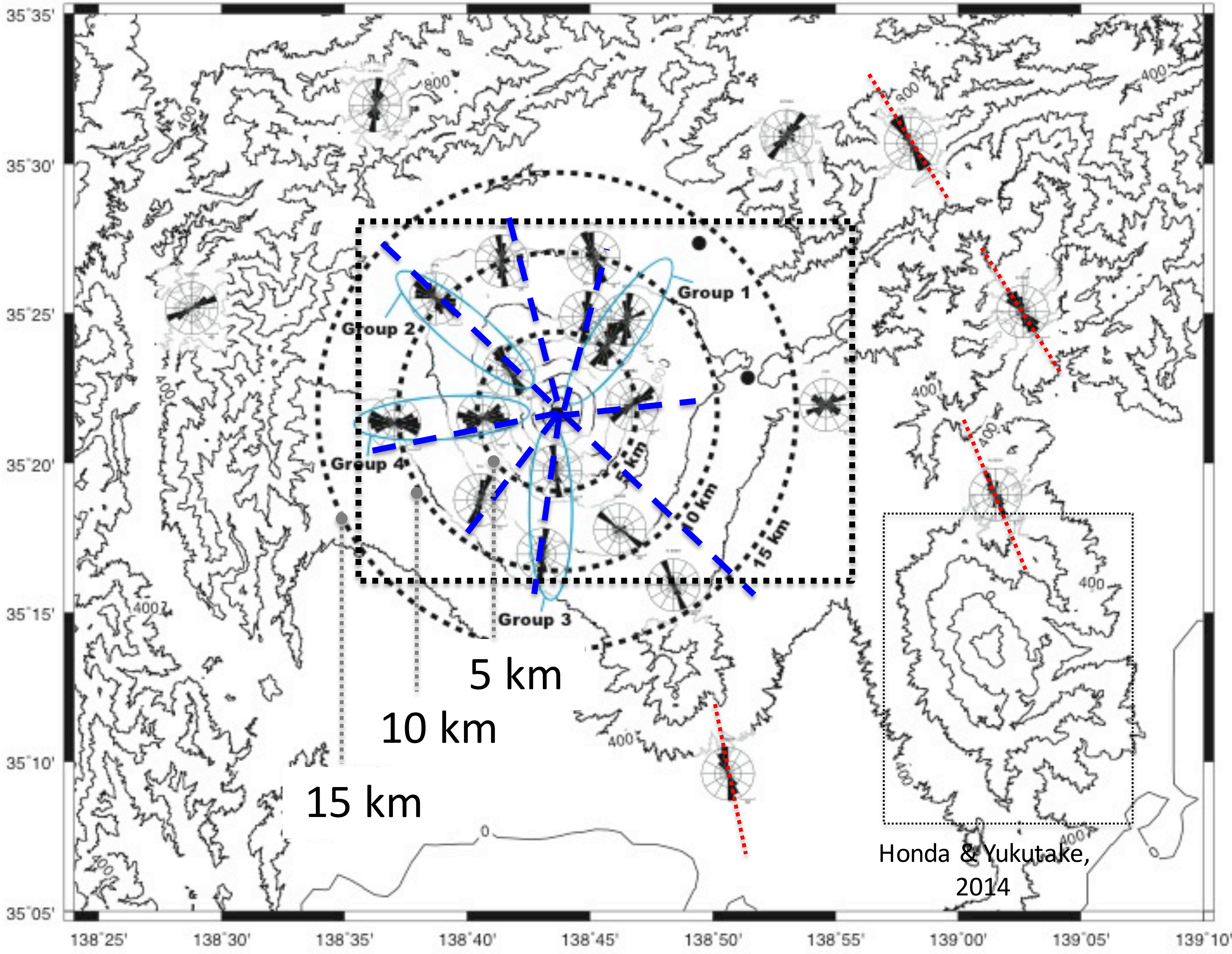
Example of station FJHV



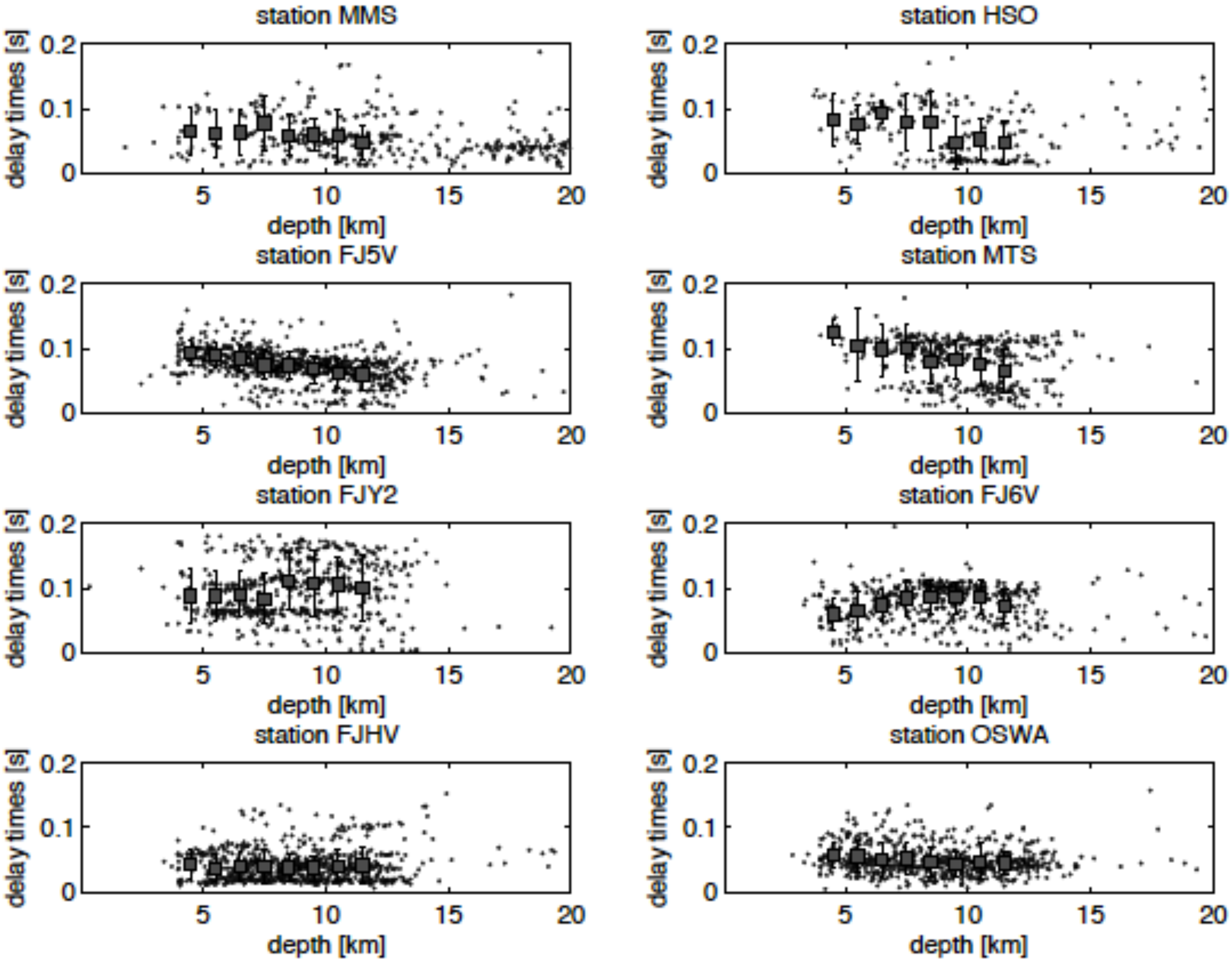
Spatial distribution of SWS

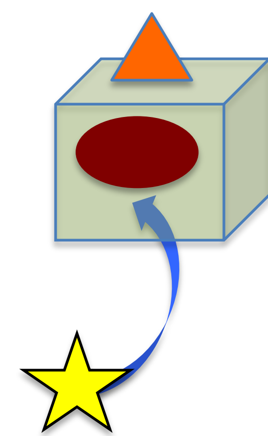


SWS in regional scale



Depths of anisotropy





Interpretation of radial pattern

SWS close to the summit

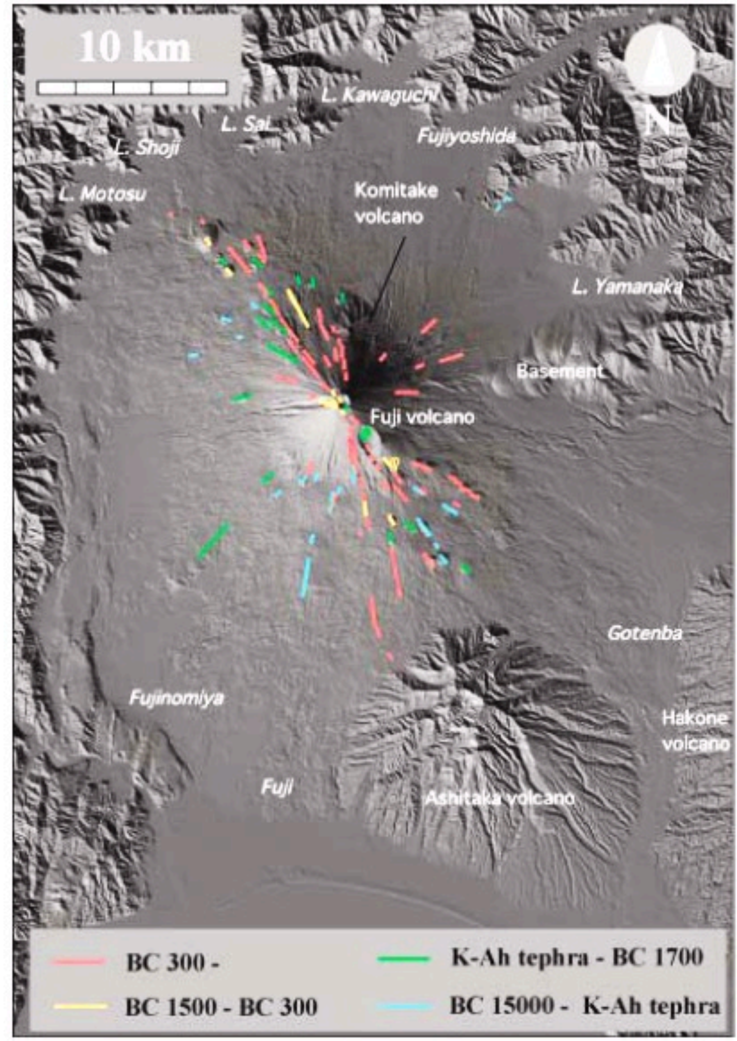
Fast polarization directions

the spatial distribution of dyke structure.

The gravitational stresses due to the mass of the volcanic edifice [e.g. Acocella and Neri, 2009]

SWS far from the summit

Regional stresses



Takada et al. (2007)

Quantitative analysis of stress fields

Tectonic stresses

We estimated stresses from lithostatic pressure(σ_2) at depths.

$$R = \frac{(\sigma_1 - \sigma_2)}{(\sigma_1 - \sigma_3)}$$

$$\sigma_1 = A\sigma_2$$

The factor(A) was determined by trial and error.

Gravitational effects

Boussinesq's problem.

We assumed a point load beneath the summit of Mt. Fuji.

$$\tau_{xx} = \frac{N}{2\pi}\left[\frac{3x^2 z}{r^5} + \frac{(1-2\nu)(y^2+z^2)}{r^3(z+r)} - \frac{(1-2\nu)z}{r^3} - \frac{(1-2\nu)x^2}{r^2(z+r)^2}\right]$$

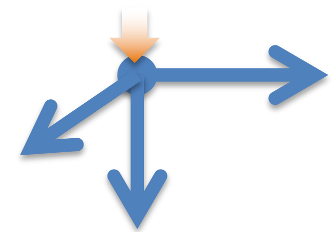
$$\tau_{yy} = \frac{N}{2\pi}\left[\frac{3y^2 z}{r^5} + \frac{(1-2\nu)(x^2+z^2)}{r^3(z+r)} - \frac{(1-2\nu)z}{r^3} - \frac{(1-2\nu)y^2}{r^2(z+r)^2}\right]$$

$$\tau_{zz} = \frac{N}{2\pi}\left[\frac{3z^3}{r^5}\right]$$

$$\tau_{xy} = \frac{N}{2\pi}\left[\frac{3xyz}{r^5} - \frac{(1-2\nu)xy(z+2r)}{r^3(z+r)^2}\right]$$

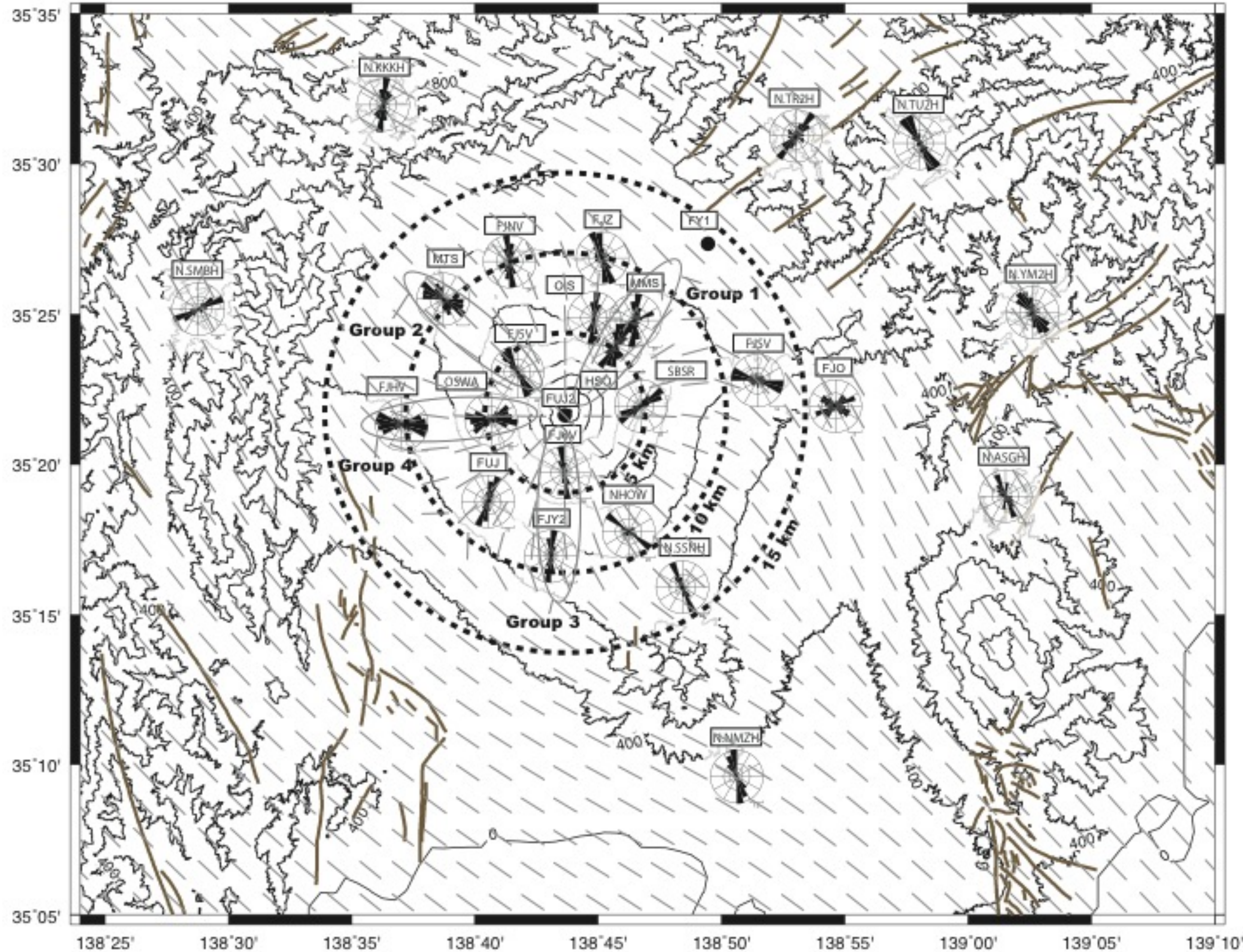
$$\tau_{yz} = \frac{N}{2\pi}\left[\frac{3yz^2}{r^5}\right]$$

$$\tau_{xz} = \frac{N}{2\pi}\left[\frac{3xz^2}{r^5}\right]$$



Generating stress tensors & their eigenvectors

Stress fields and SWS



Summary

Our SWS measurement shows that the anisotropy around Mt. Fuji has clear spatial variations. We interpreted them and made the following conclusions:

- Radial pattern of fast directions is consistent with the directions of the strikes of dikes around Mt. Fuji.
- The regional NW-SE trends of fast directions, and radial anisotropy around Mt. Fuji are consistent with stress fields in the region.
- Stress modeling supports the interaction of stresses and anisotropic structure in the Mt. Fuji volcanic regions.

Thank you for your kind attention!