ISTerre

Institut des Sciences de la Terre

UNIVERSITÉ Grenoble Alpes

# Passive, noise-based seismic monitoring

**Florent Brenguier**

In collaboration with Michel Campillo, Nikolai Shapiro, Yosuke Aoki, Tetsuya Takeda, Gerrit Olivier, Pierre Boué, Nori Nakata, Philippe Roux, Taka'aki Taira, Qingyu Wang, Thomas Lecocq, Helle Pedersen…

Seismic velocities are sensitive to transient stress changes

# Laboratory experiments show pre-seismic velocity decrease

nature geoscience
LETTERS
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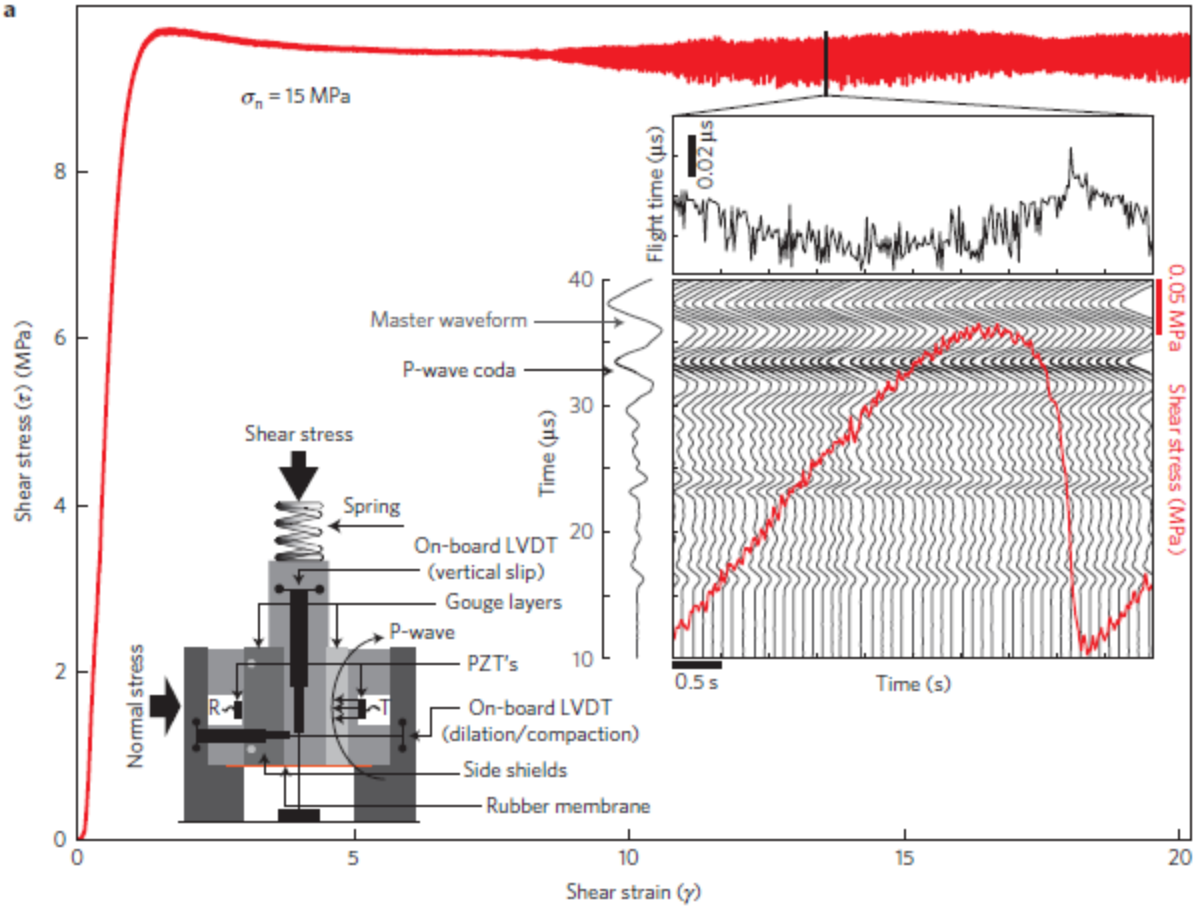
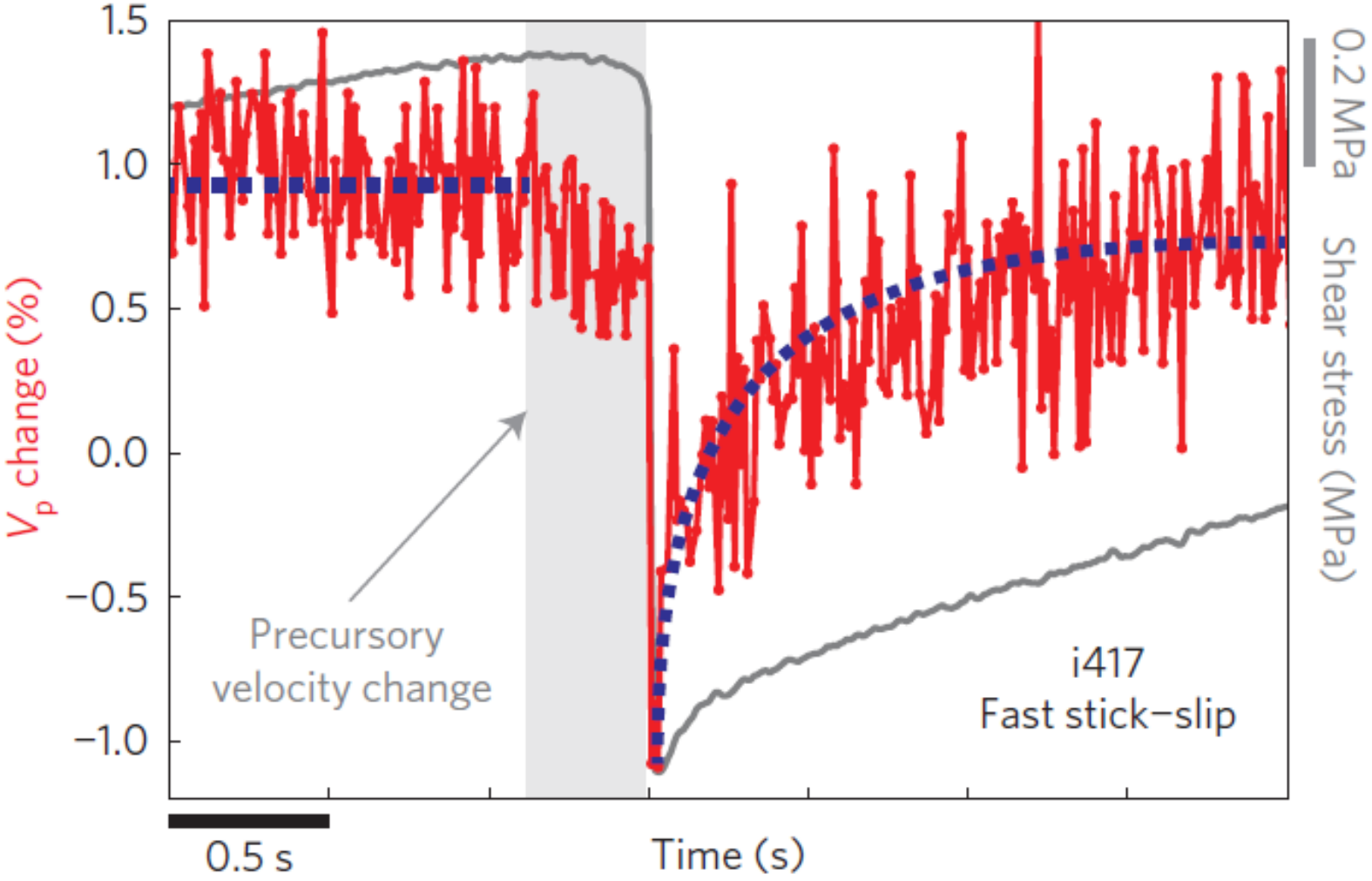
## Precursory changes in seismic velocity for the spectrum of earthquake failure modes

M. M. Scuderi[1,2]*, C. Marone[3], E. Tinti[2], G. Di Stefano[2] and C. Collettini[1,2]

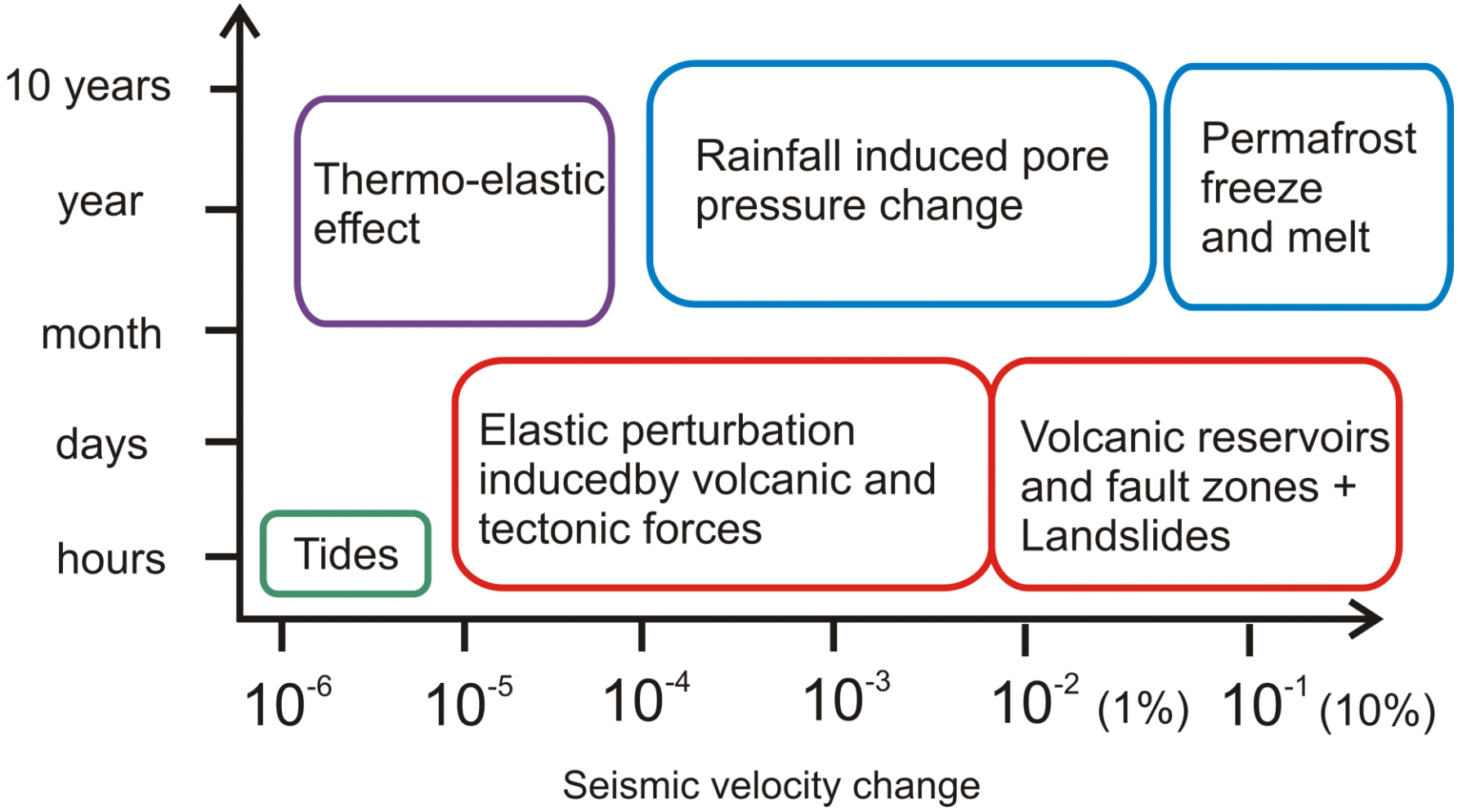


# Laboratory experiments show pre-seismic velocity decrease

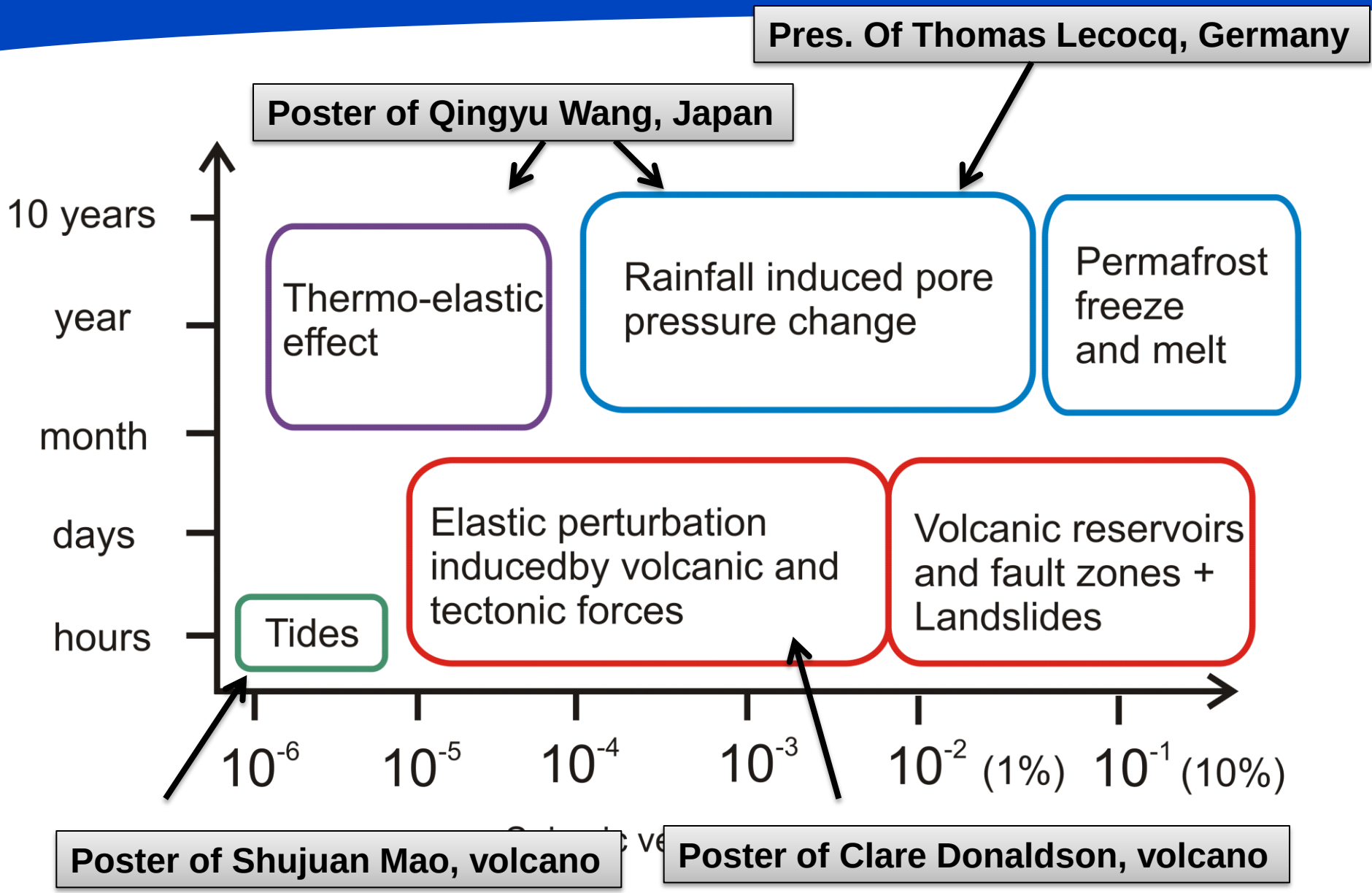


# Temporal seismic velocity changes in nature

# Velocity changes in nature



# Velocity changes in nature



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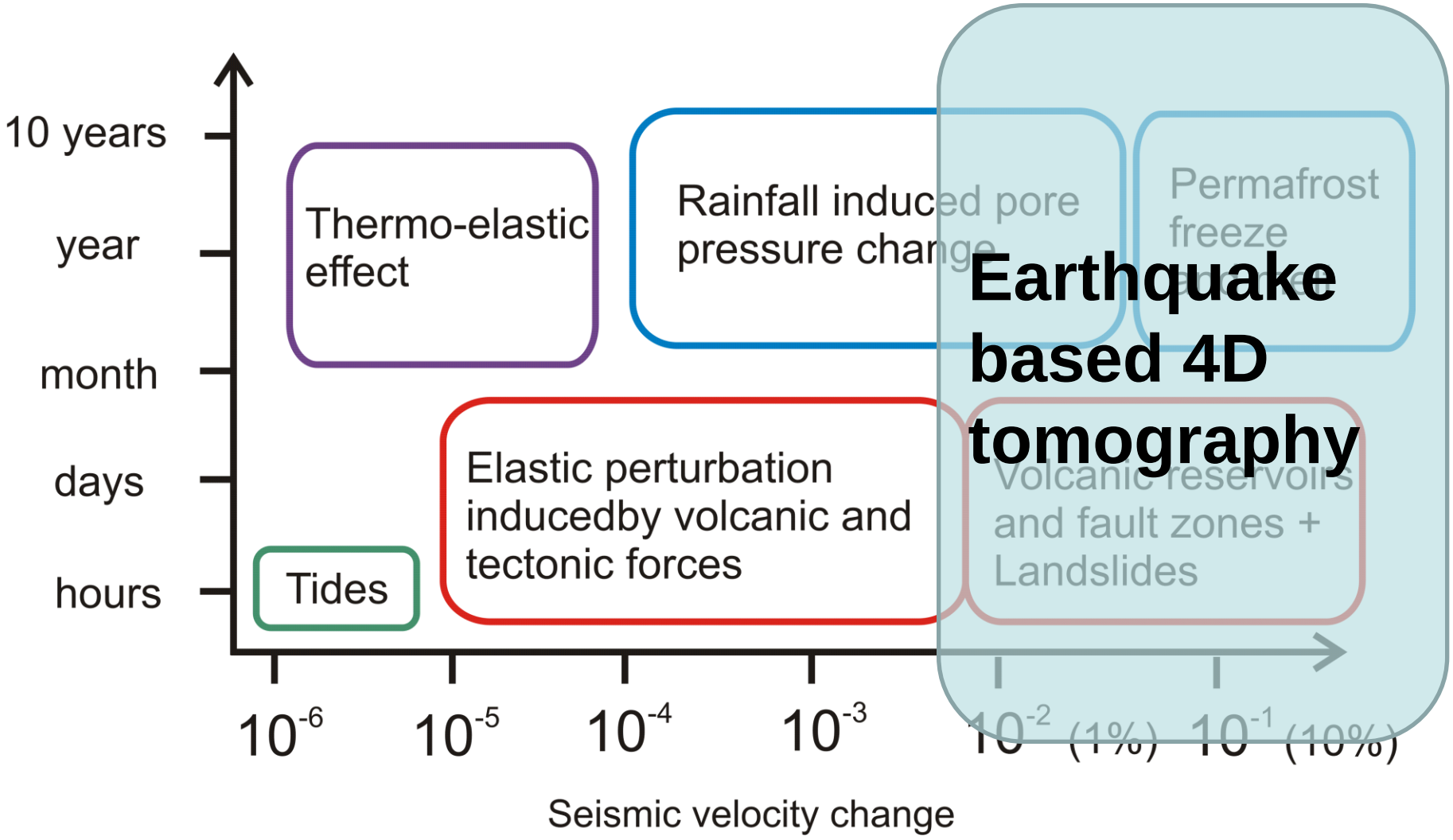

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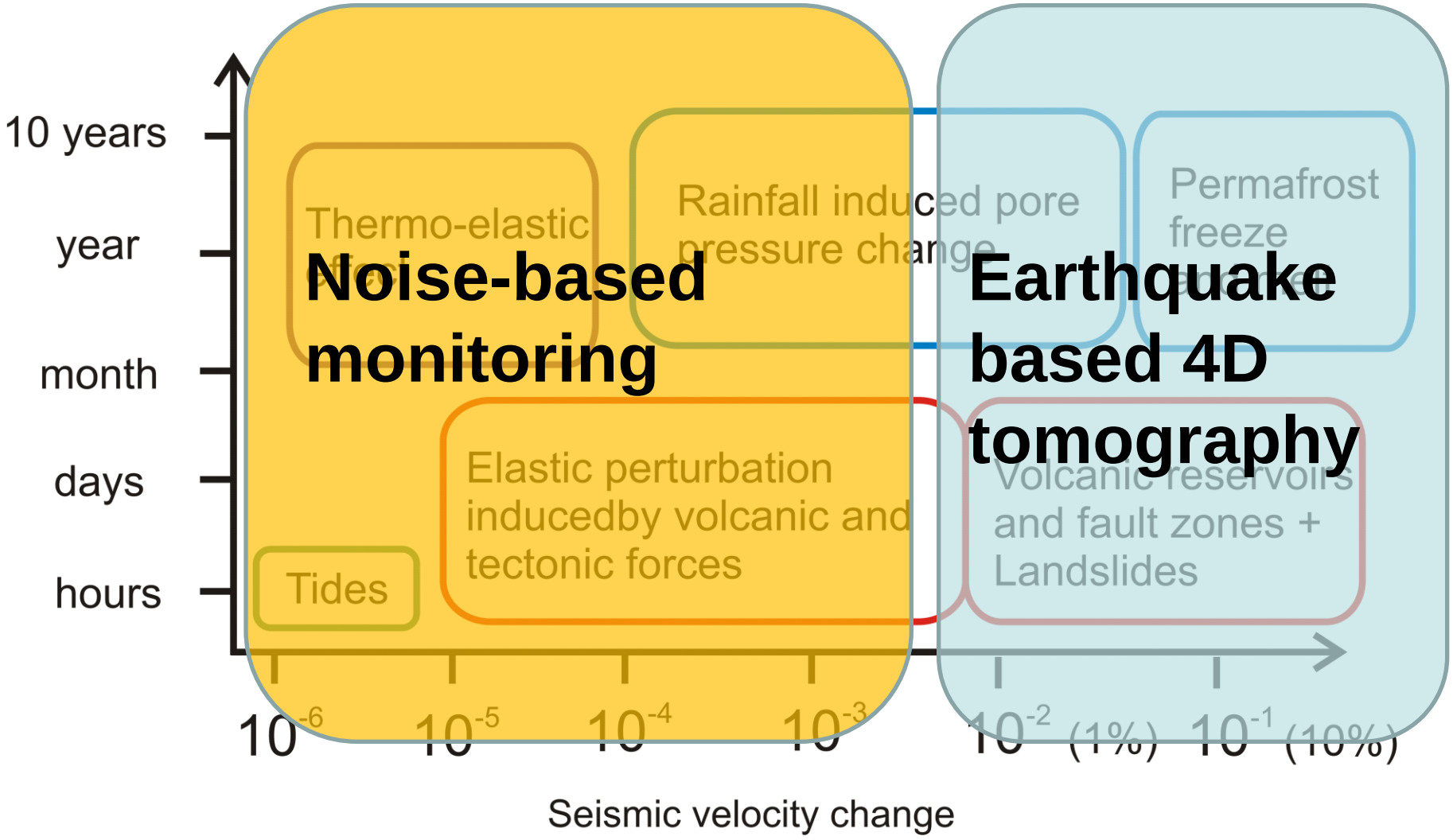
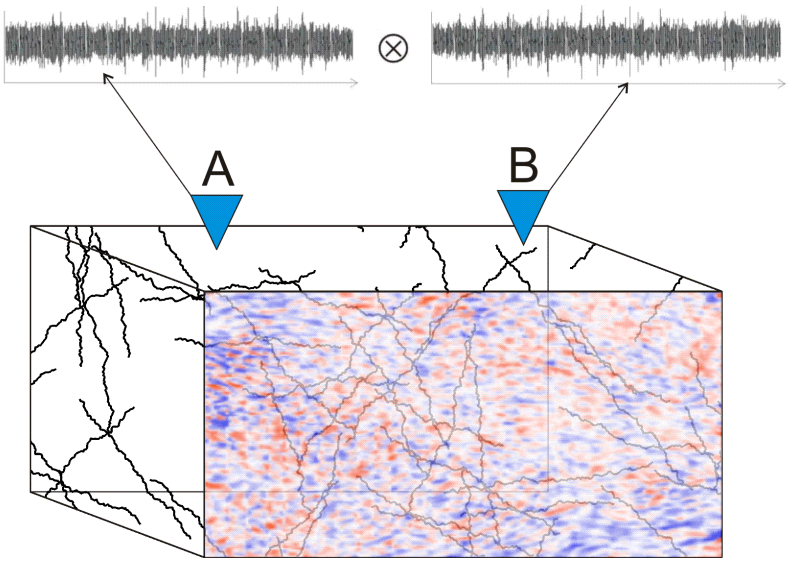


# Noise-based seismic monitoring

# 4D noise-based seismology: principles

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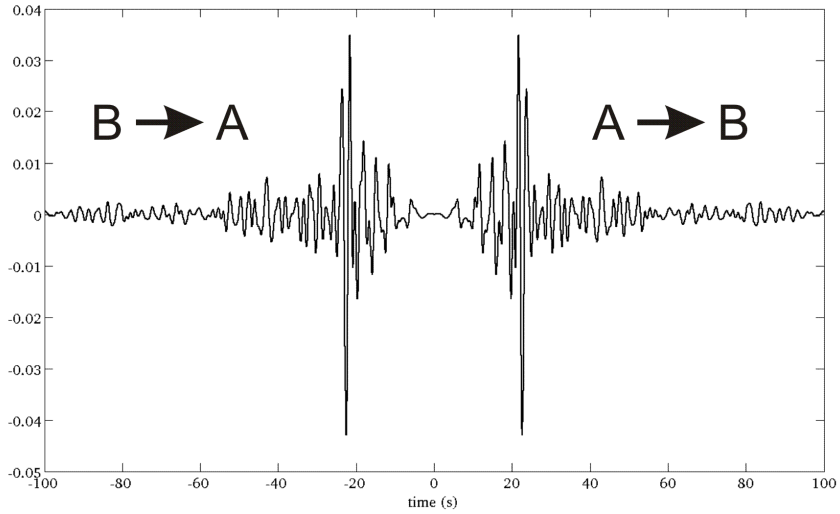
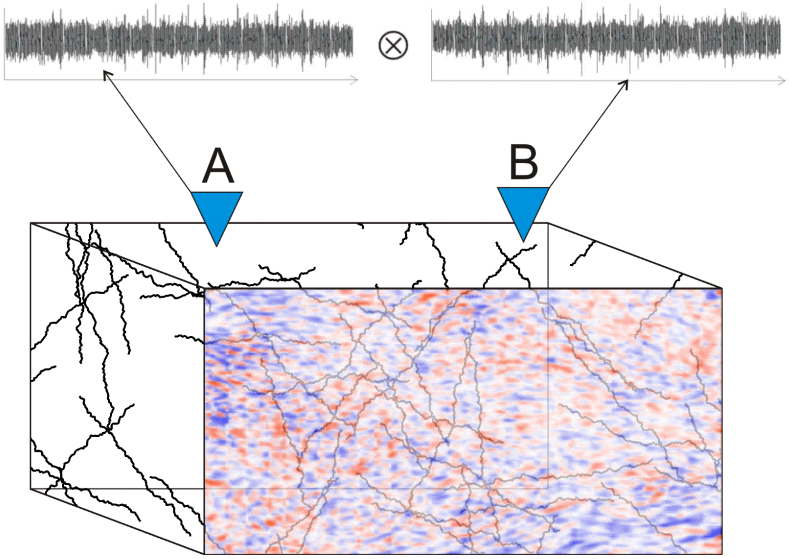



Campillo and Paul, *Science*, 2003; Shapiro and Campillo, *GRL*, 2004

# 4D noise-based seismology: principles

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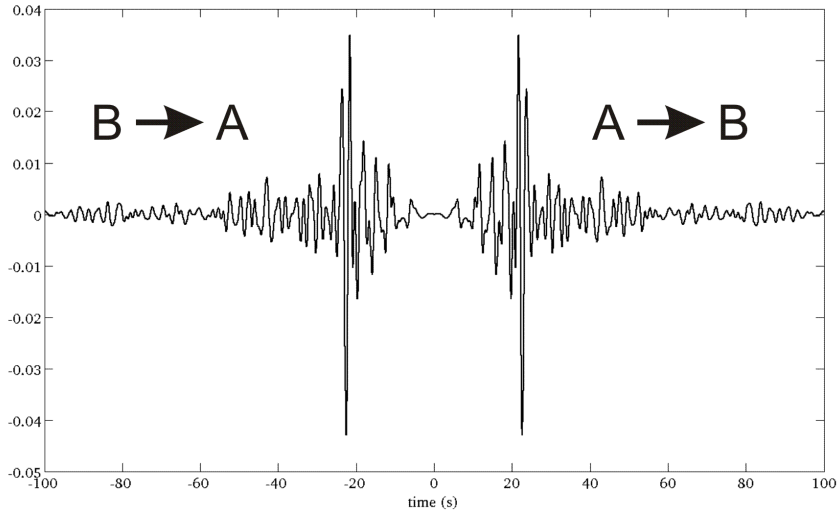


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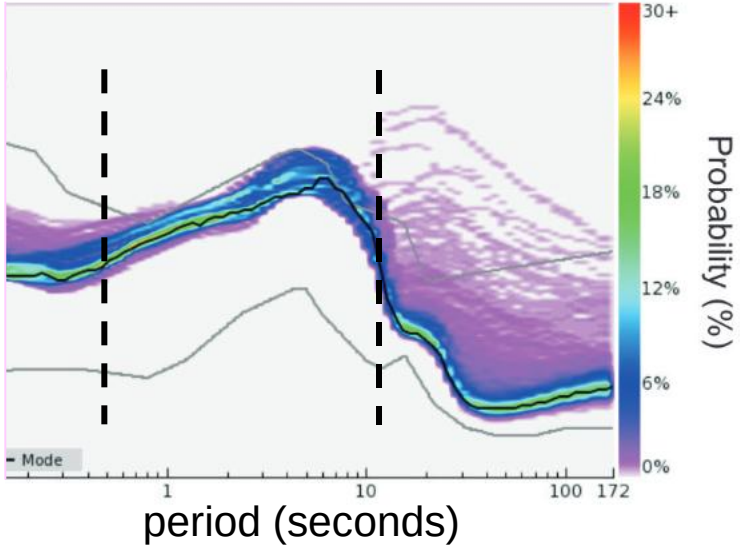


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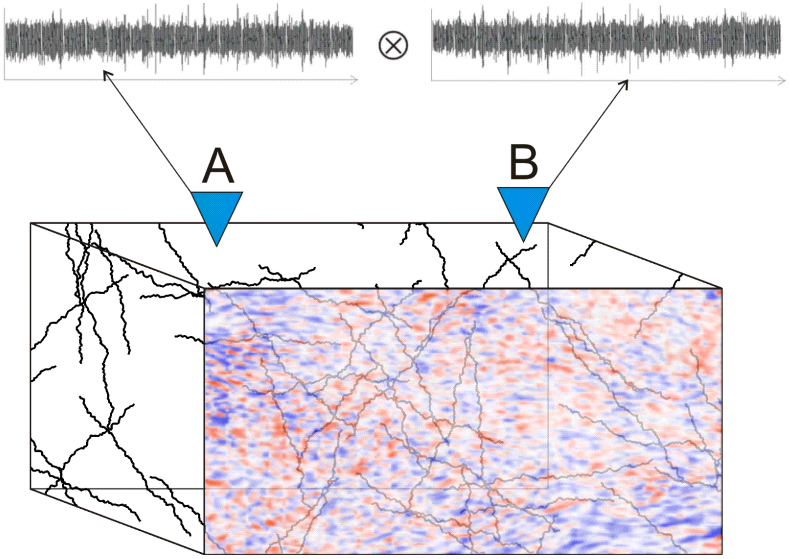


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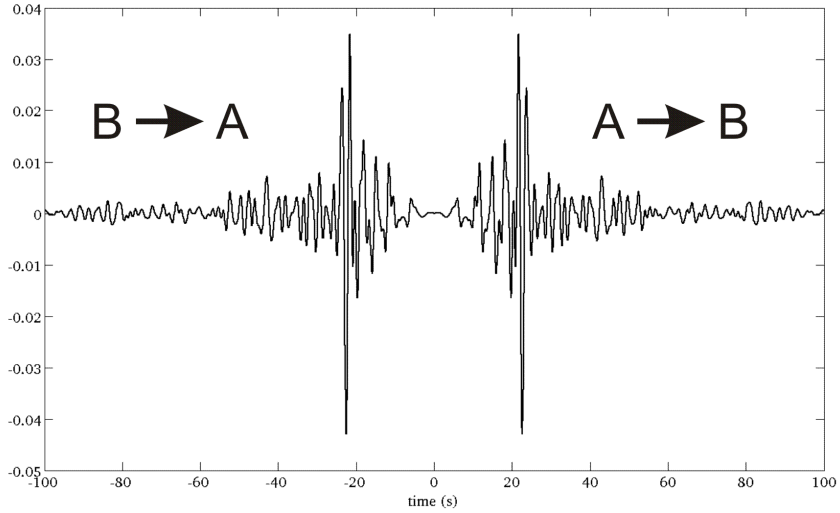
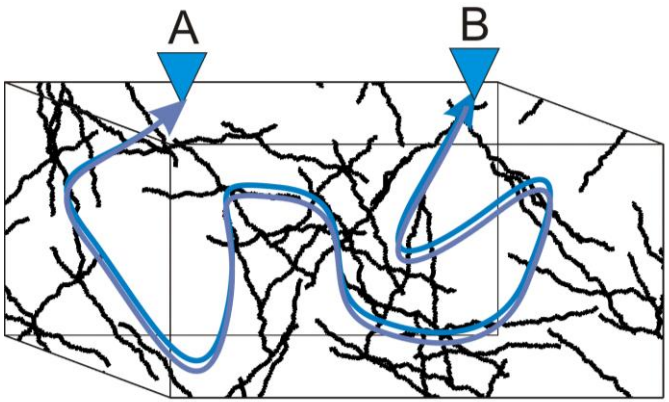
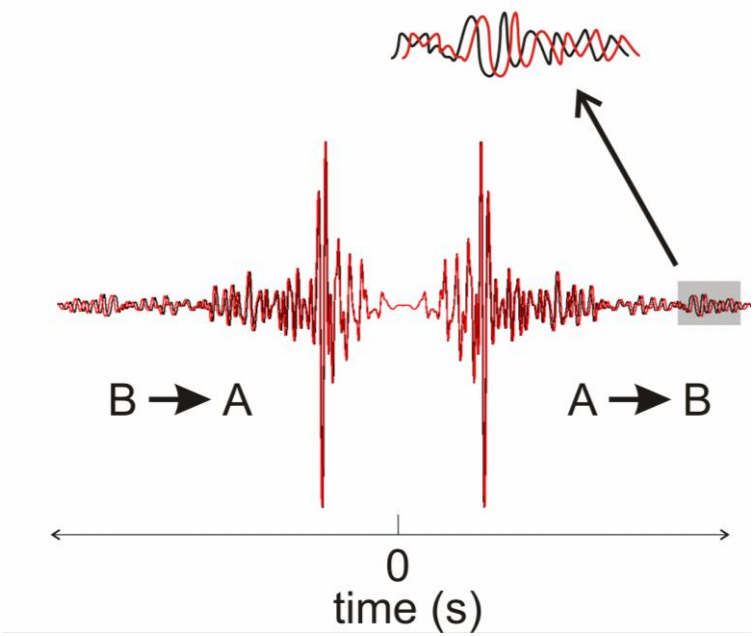



The medium changes



# 4D noise-based monitoring: current state

## Advantages

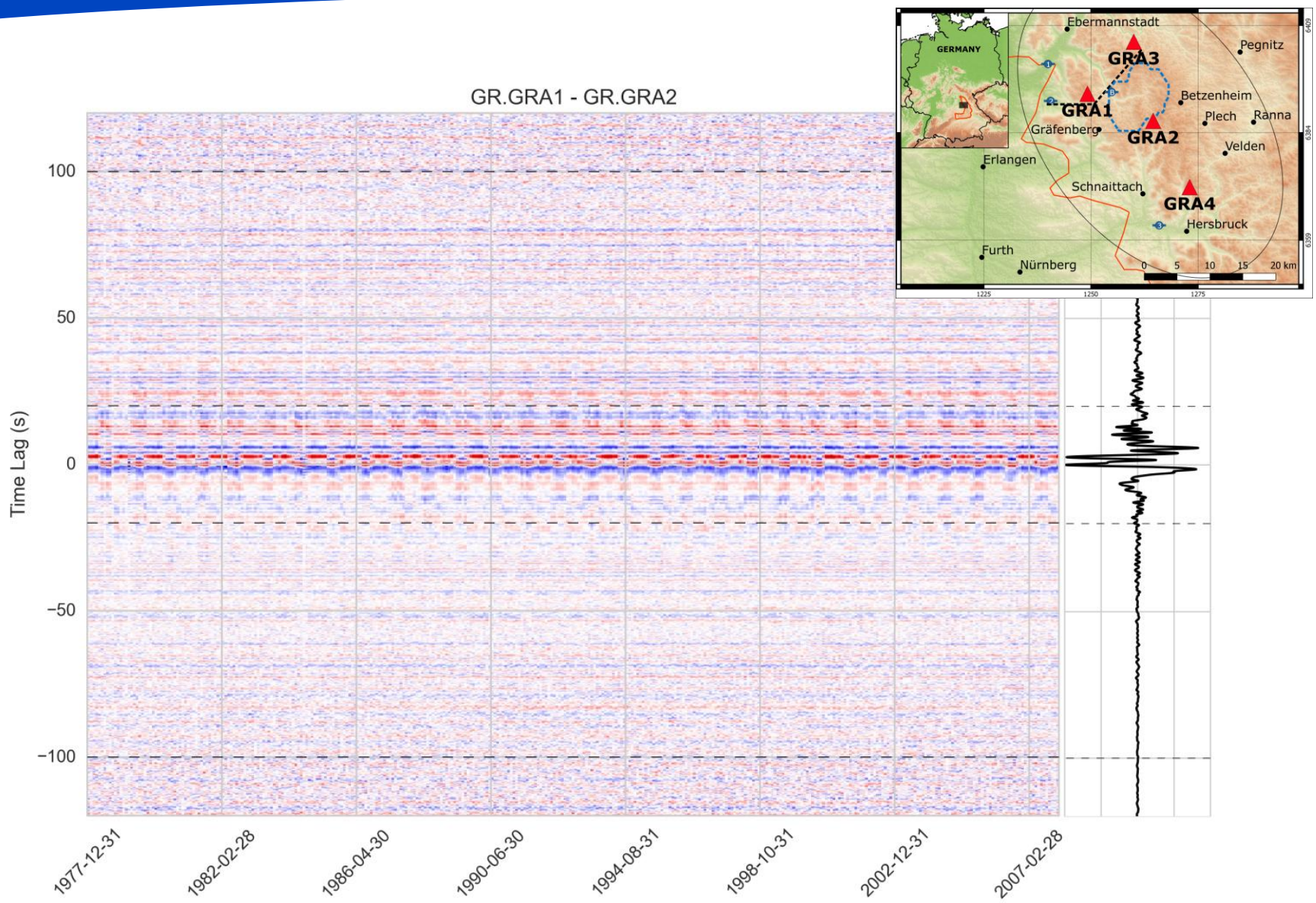
- ✓ Continuous in time
- ✓ Very high accuracy ($10^{-5}$)

## Drawbacks

- ✓ Not valid for strong perturbations > 1%
- ✓ Low spatial resolution (coda waves)

# Examples: environmental changes

# Environmental changes over 30 years in Germany



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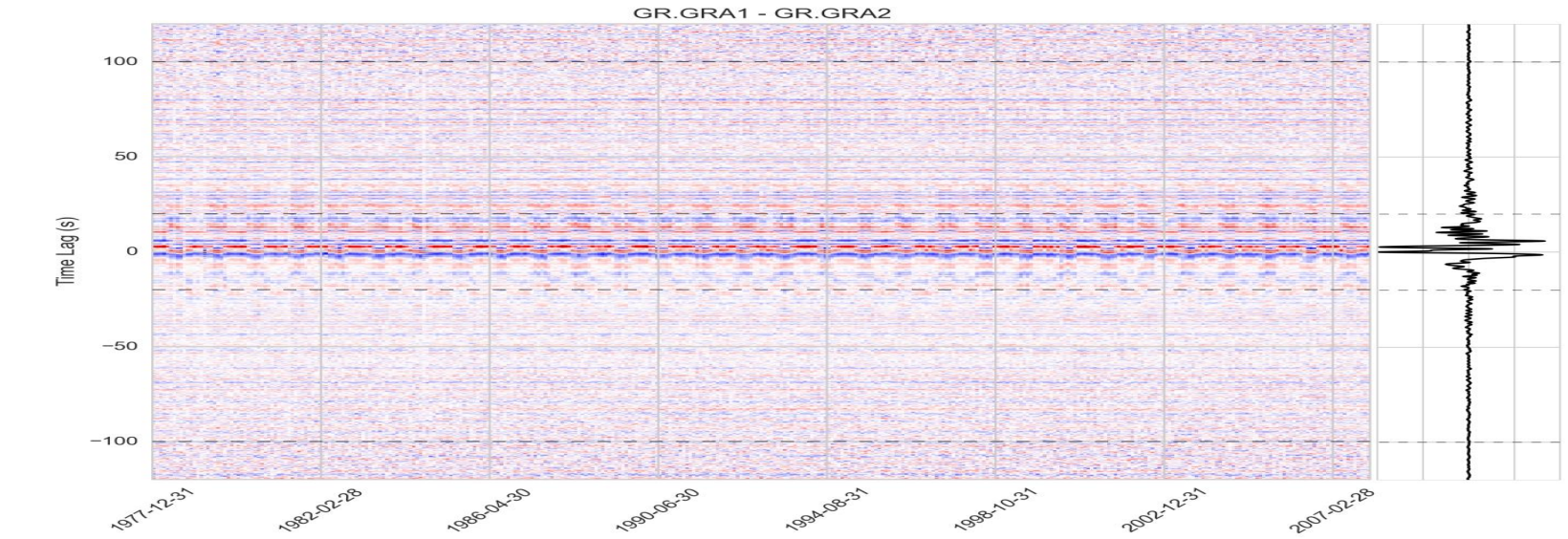
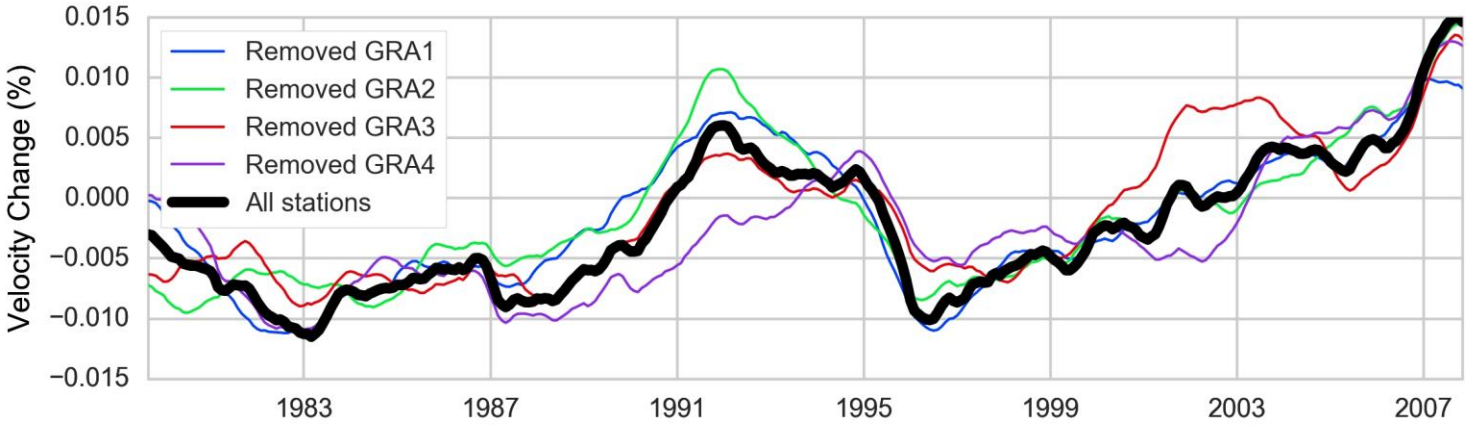
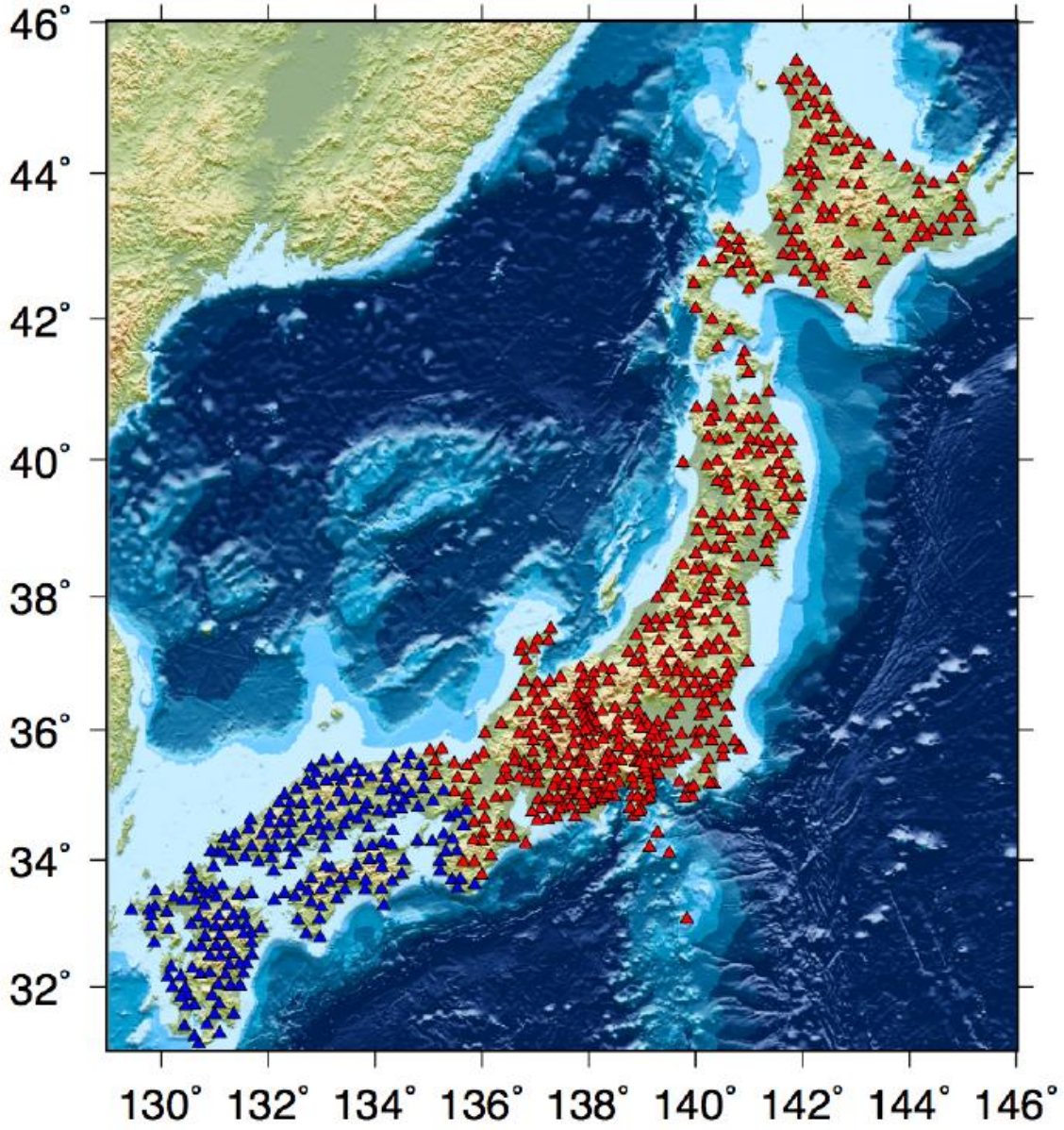



Lecocq et al., 2017

# Japan

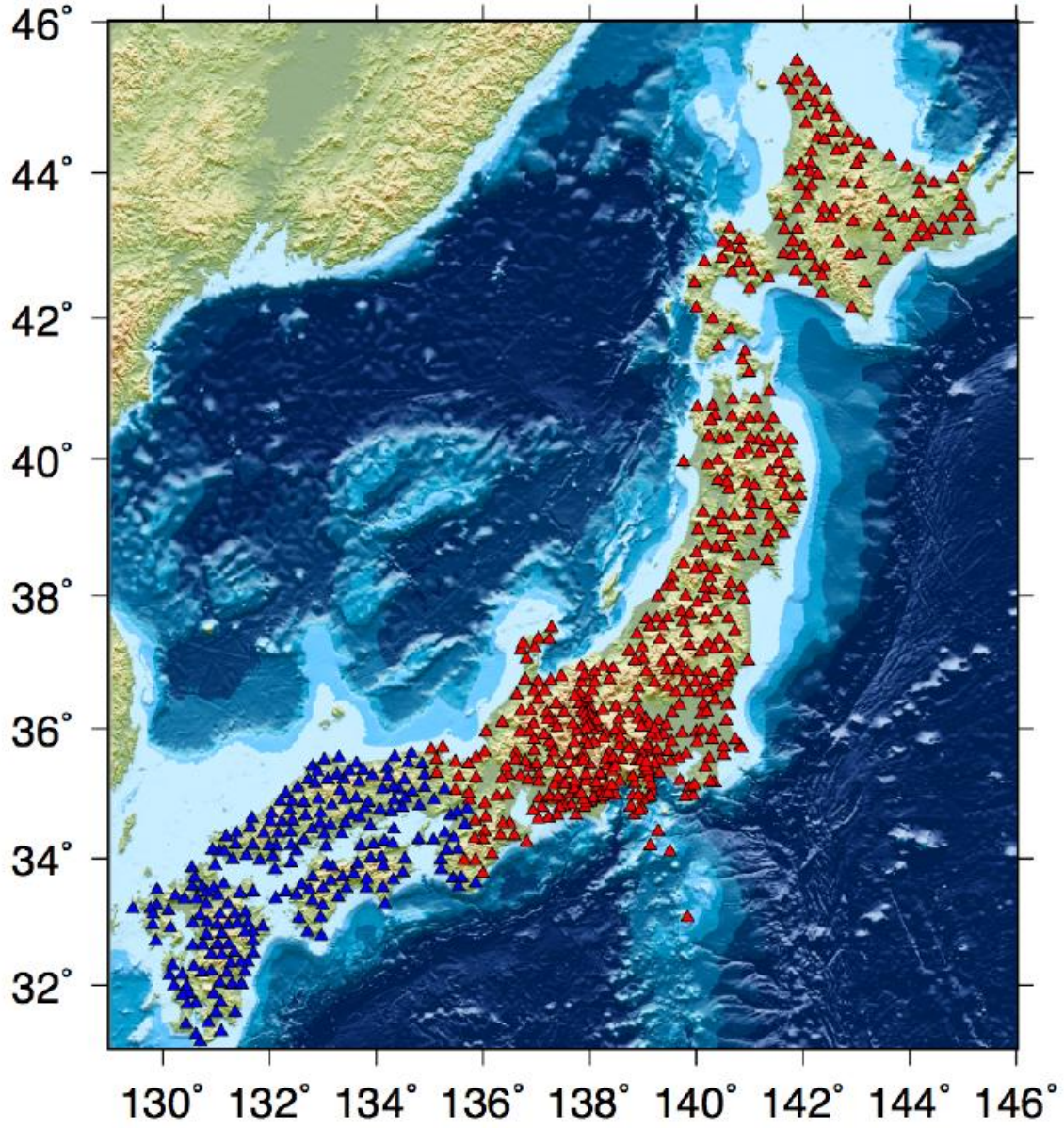


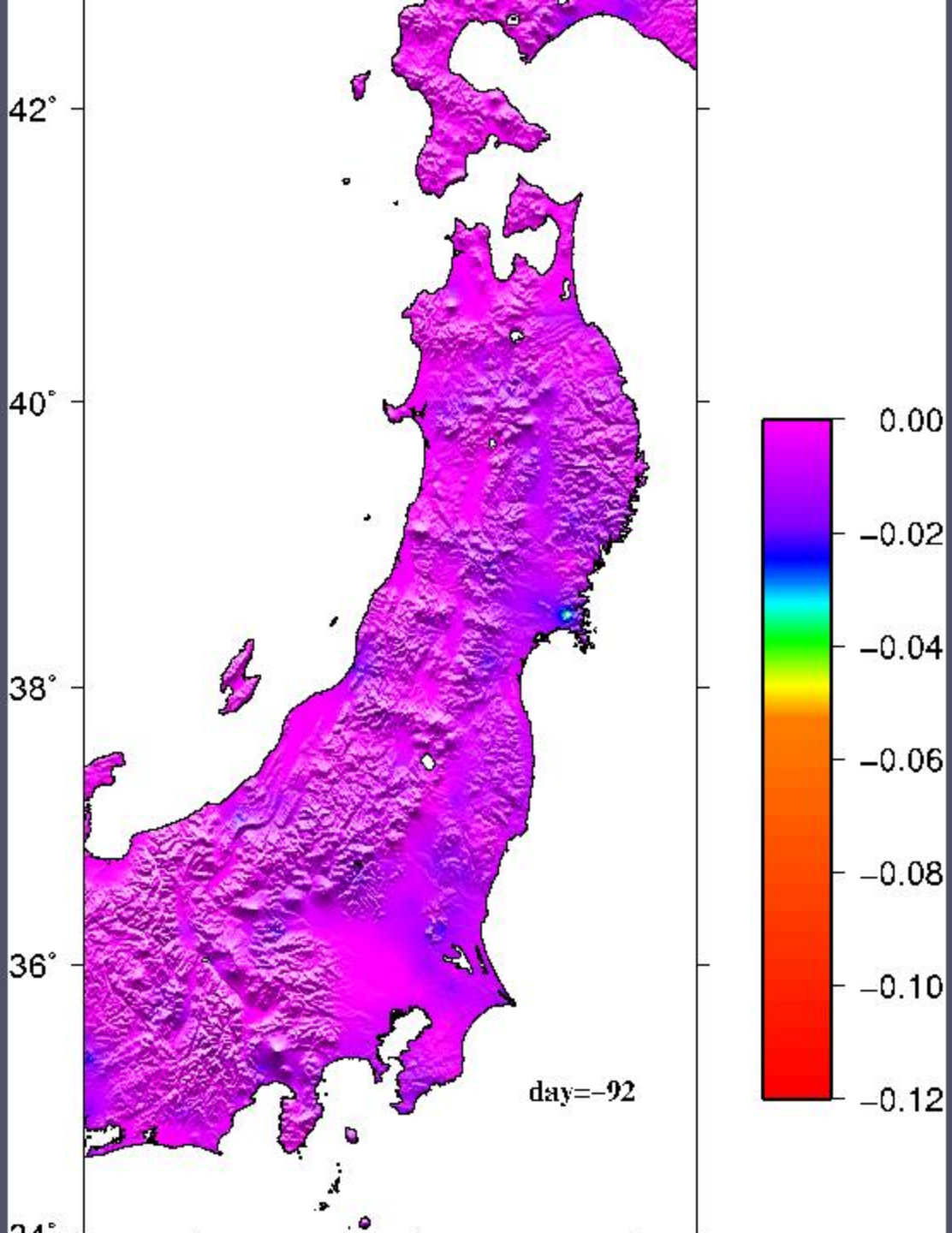
# Seasonal crustal changes in Japan

Movie Qingyu

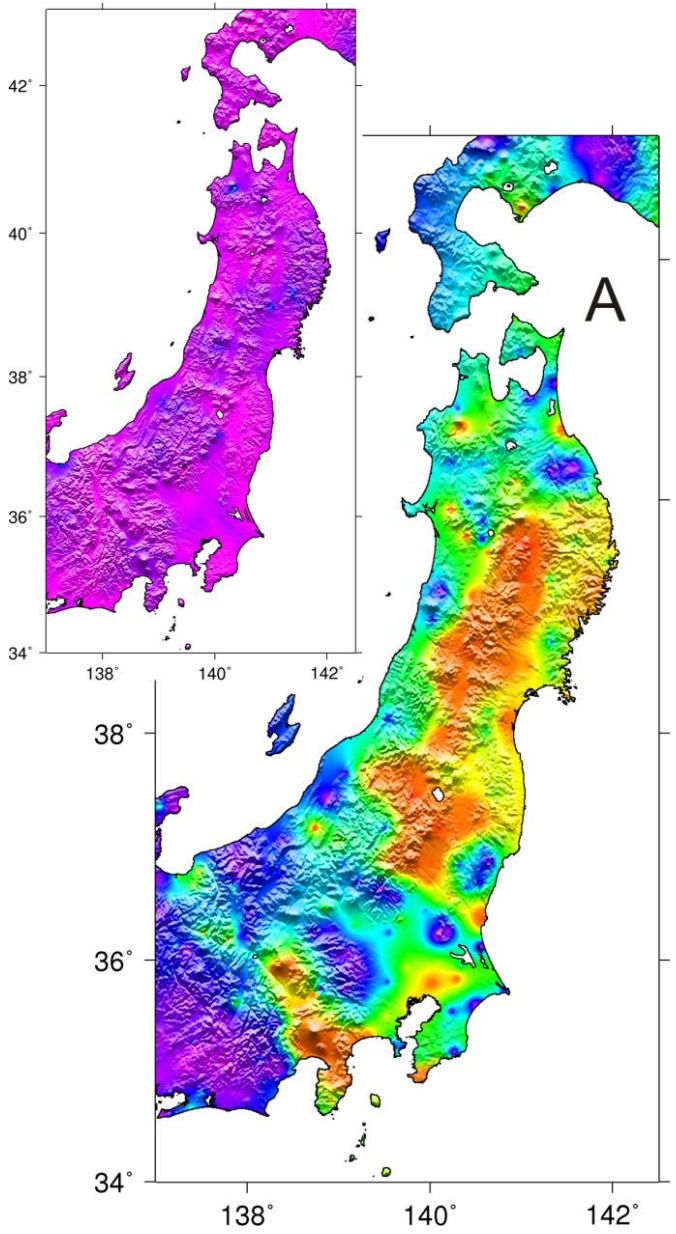
# Examples: monitoring tectonic and volcanic-linked processes

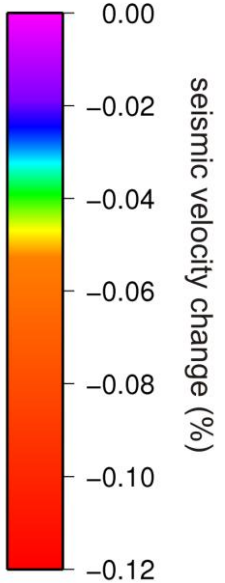
# The 2011, M9, Tohoku-oki earthquake




42°
40°
38°
36°
day=−92
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12

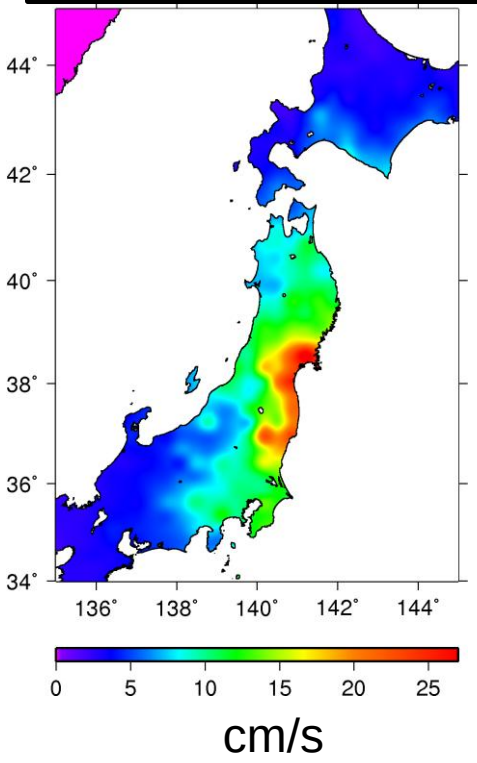
# Coseismic velocity reduction



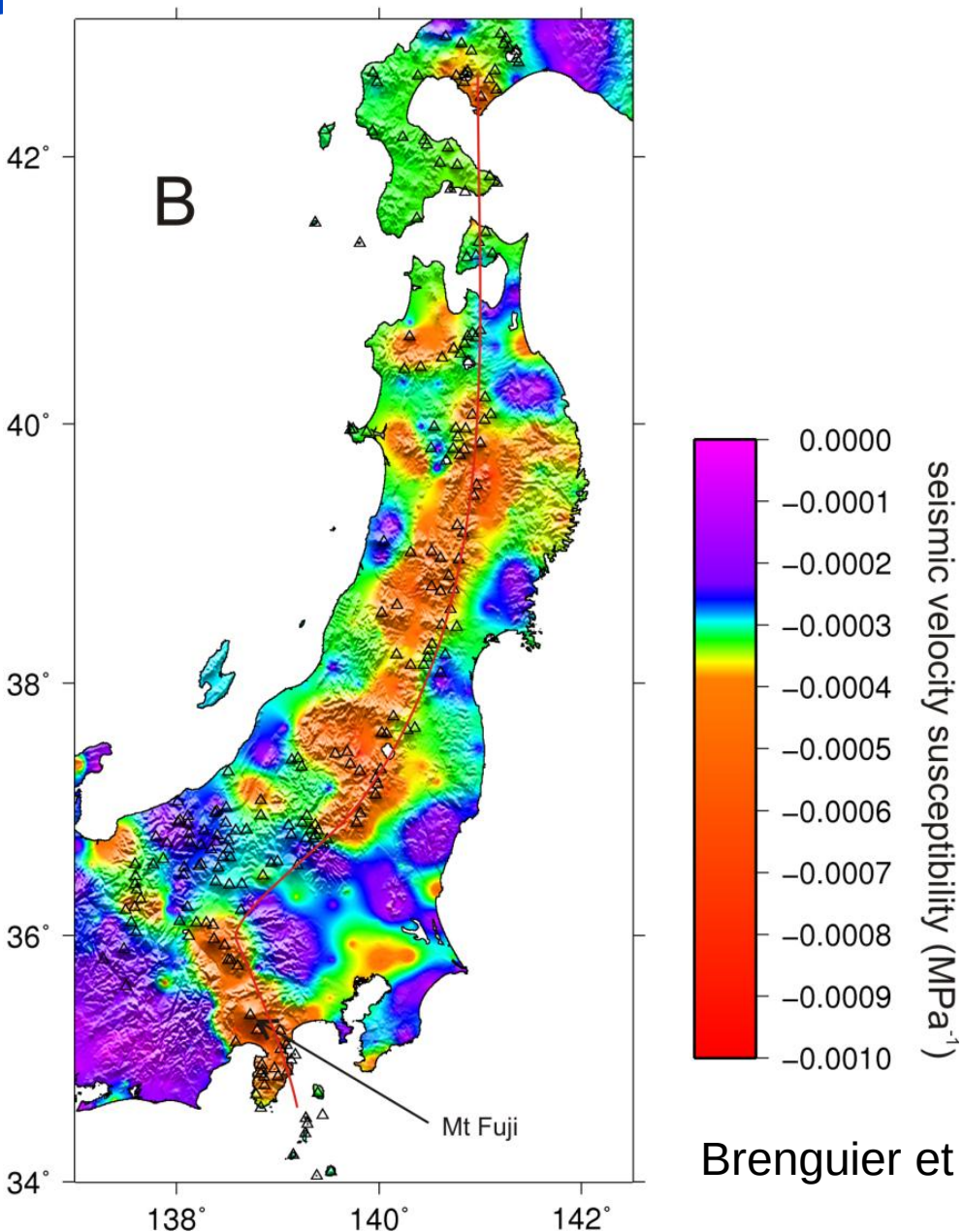




The large patches of maximum velocity reduction **do not** correlate with the level of shaking

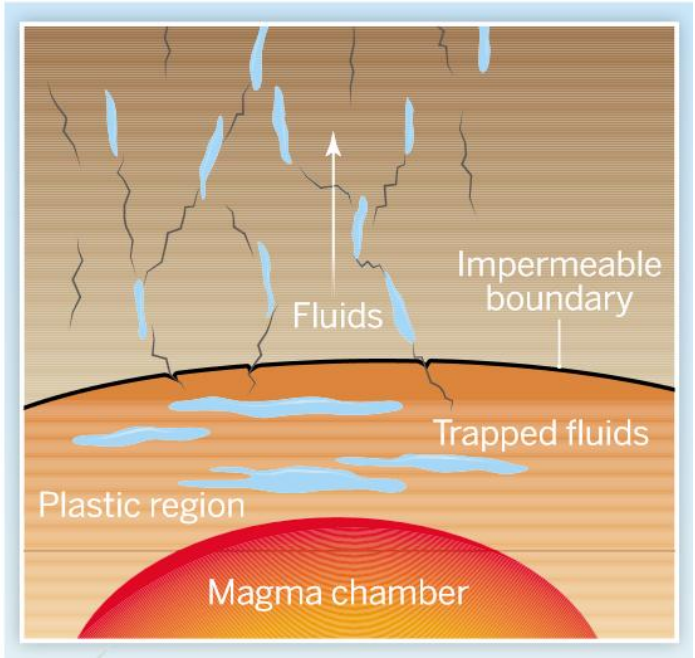
Peak ground velocity



# High seismic susceptibility below volcanic regions



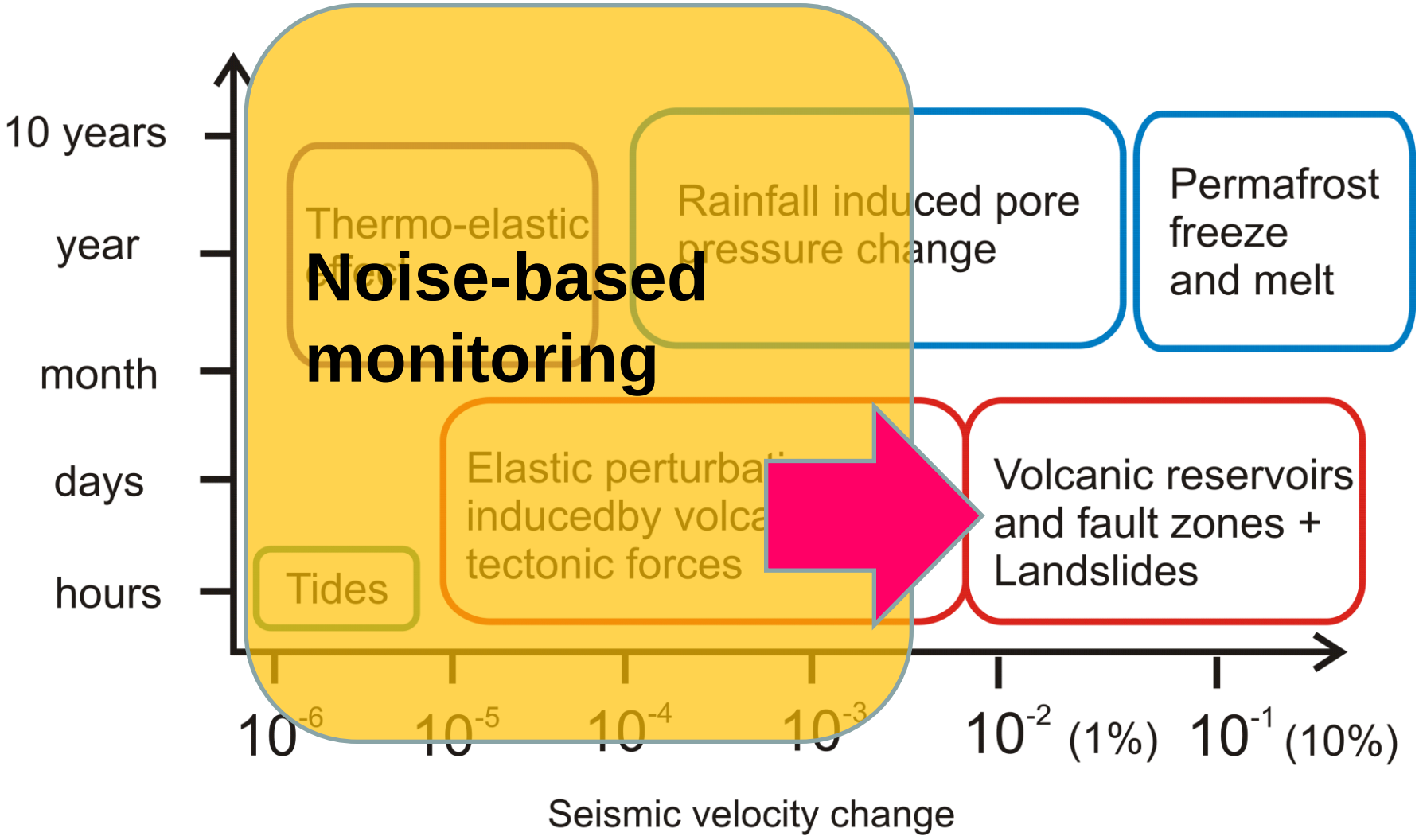

We interpret the **high level of seismic susceptibility** ($\Delta V/\Delta\sigma$) as being caused by **high volcanic fluid pressure** in the upper crust.




Sketch from Prejean and Haney

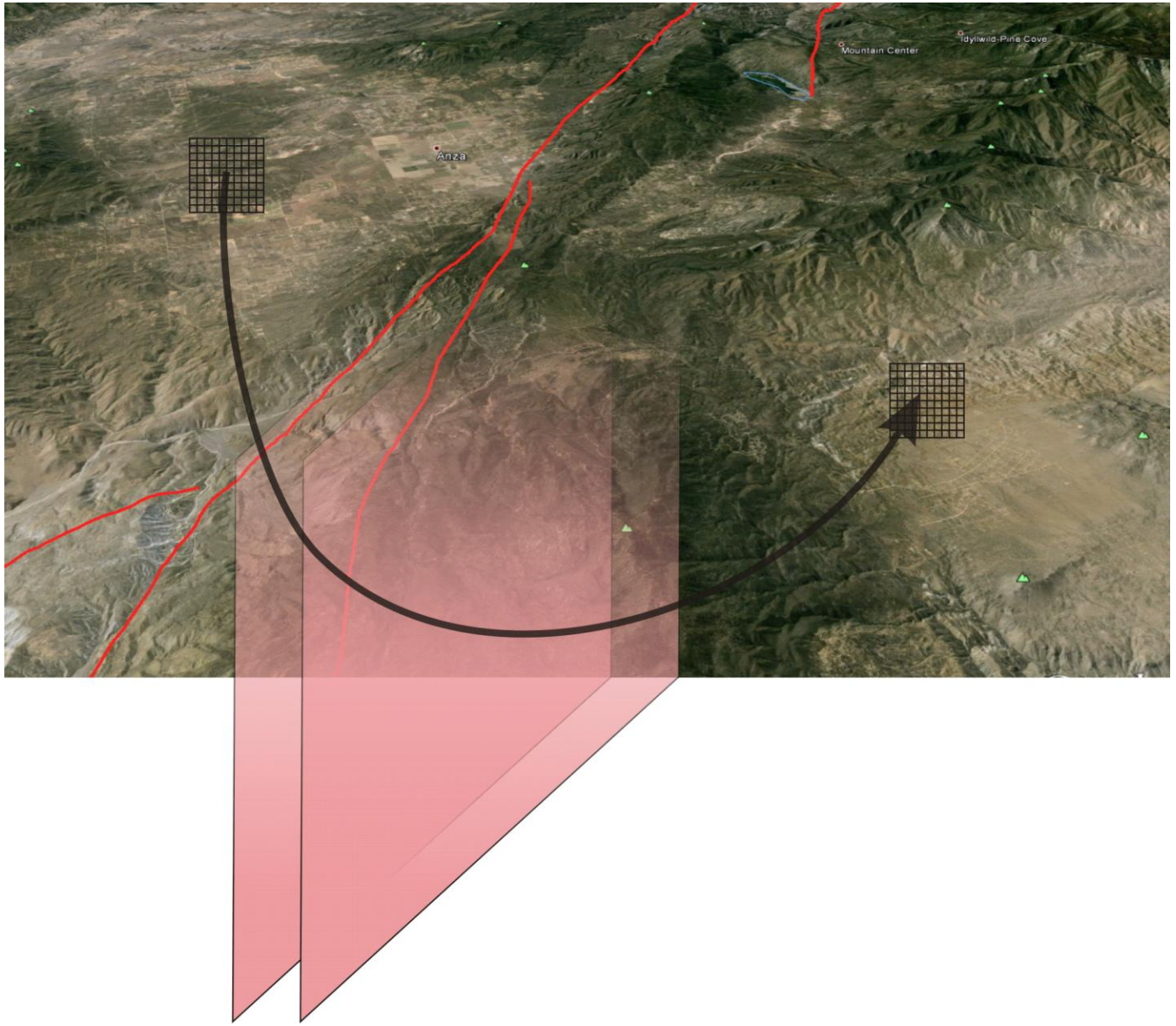
Brenguier et al. 2014

# Velocity changes in nature

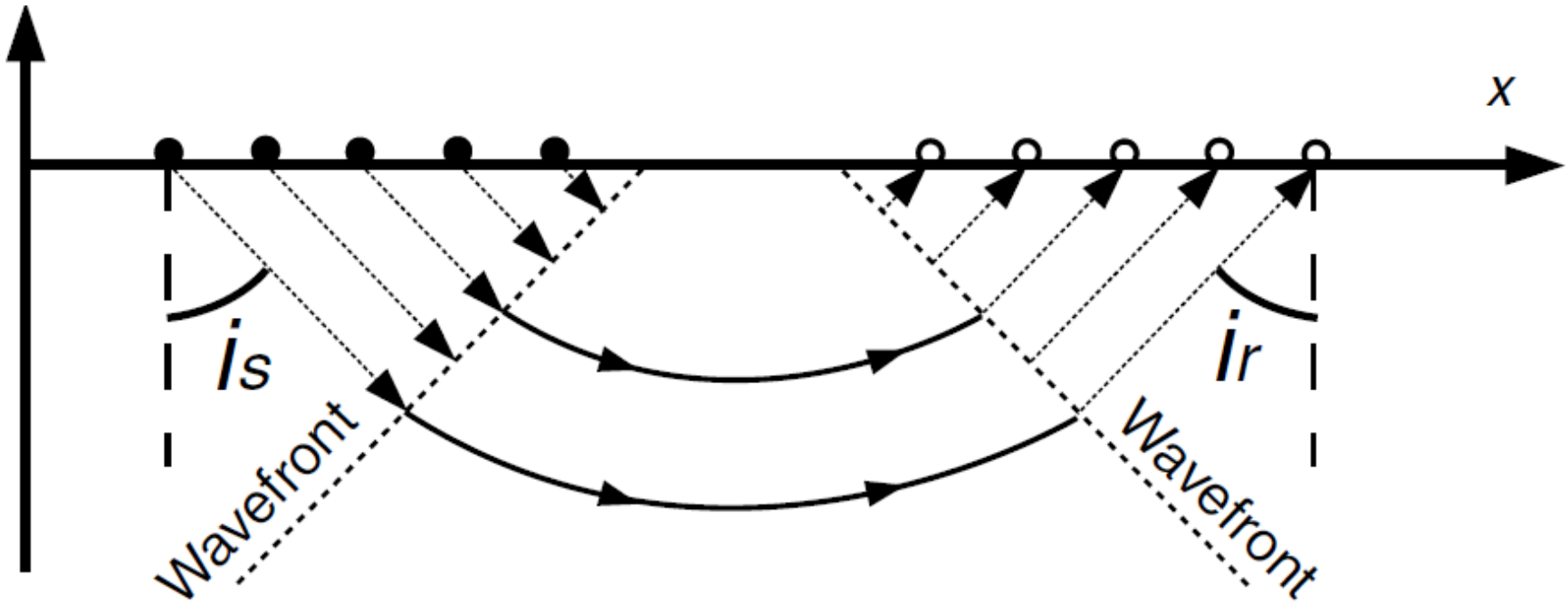


How can we get closer to a real fault at seismogenic depth??

# Extracting body-waves instead of surface waves

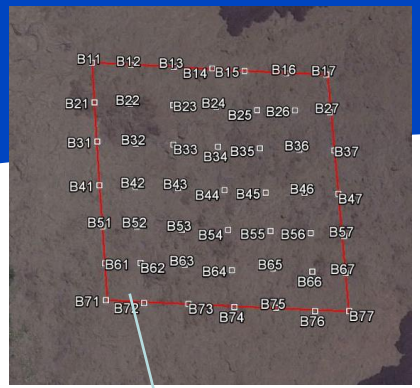


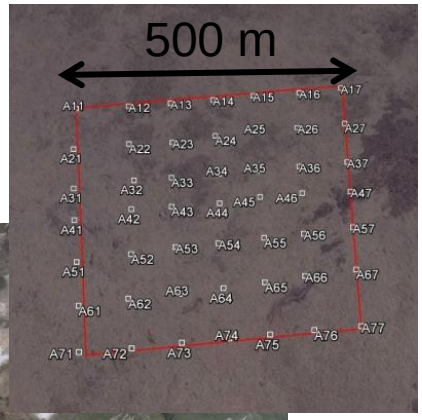
# Source and receiver arrays: double-beamforming

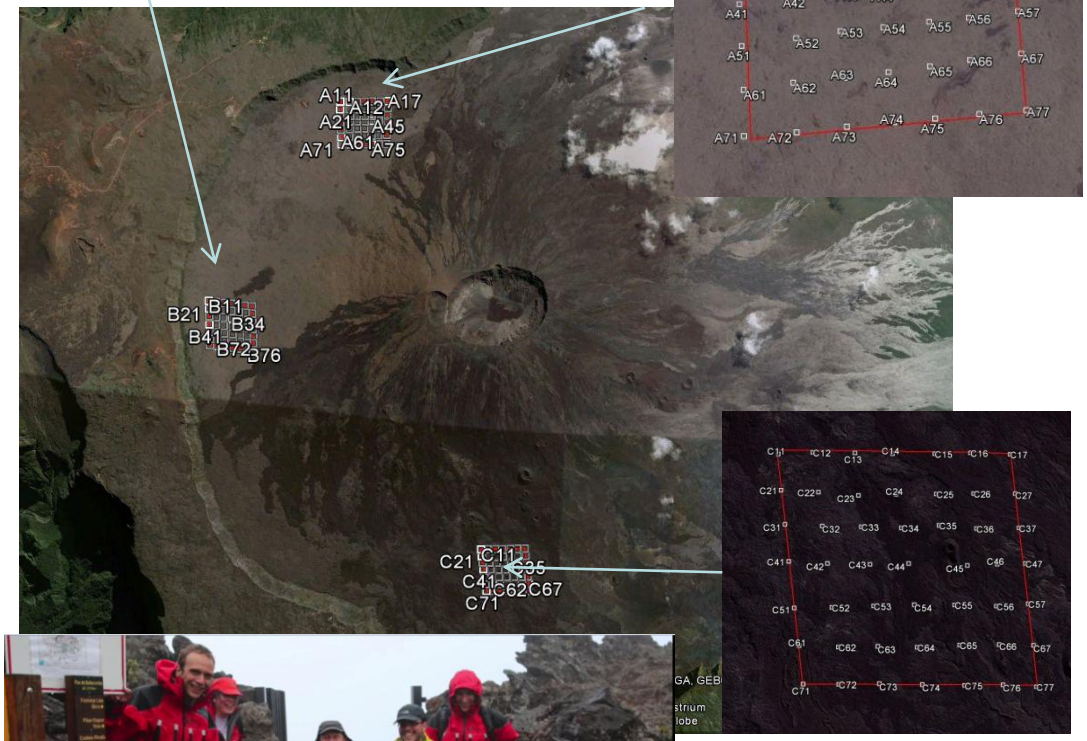



Boué et al. 2013

# Piton de la Fournaise Volcano, 2014



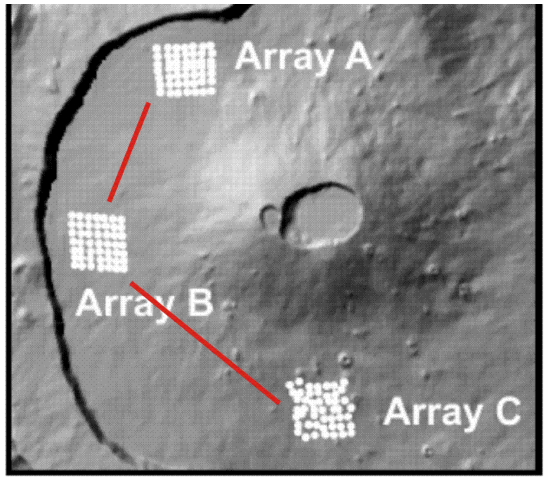



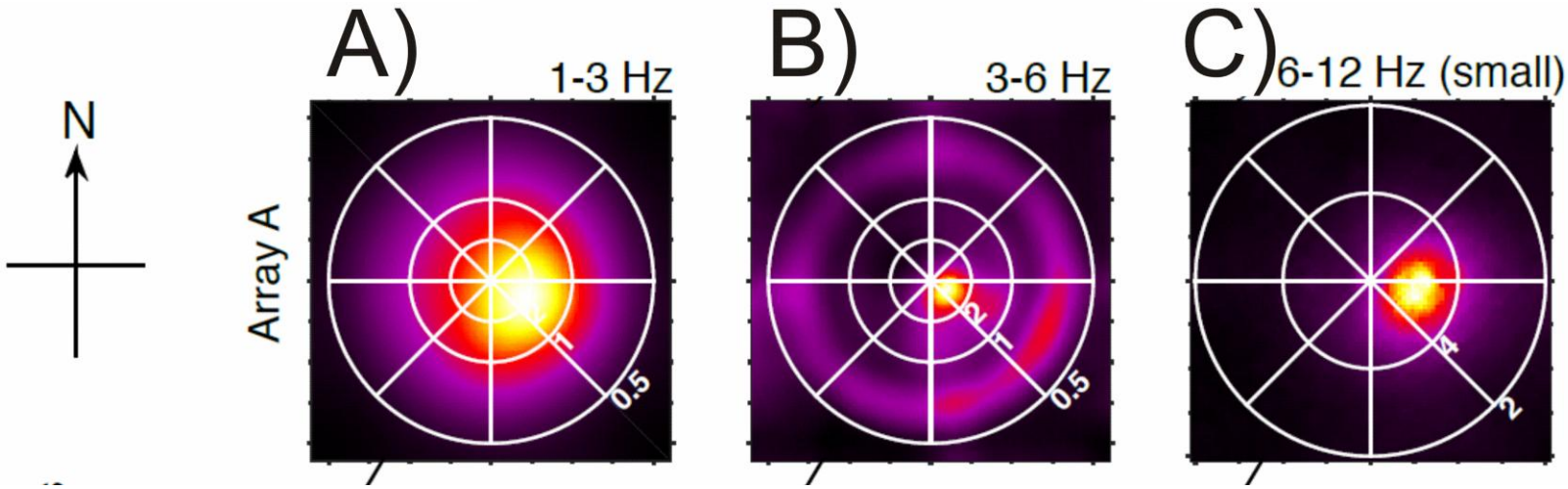



The data and metadata are available **without restrictions** from the RESIF and EIDA datacenters (www.portal.resif, http://www.orfeus-eu.org/eida/) under the FDSN network code XP (doi:10.15778/RESIF.XP2014).

**Brenguier et al. 2016**

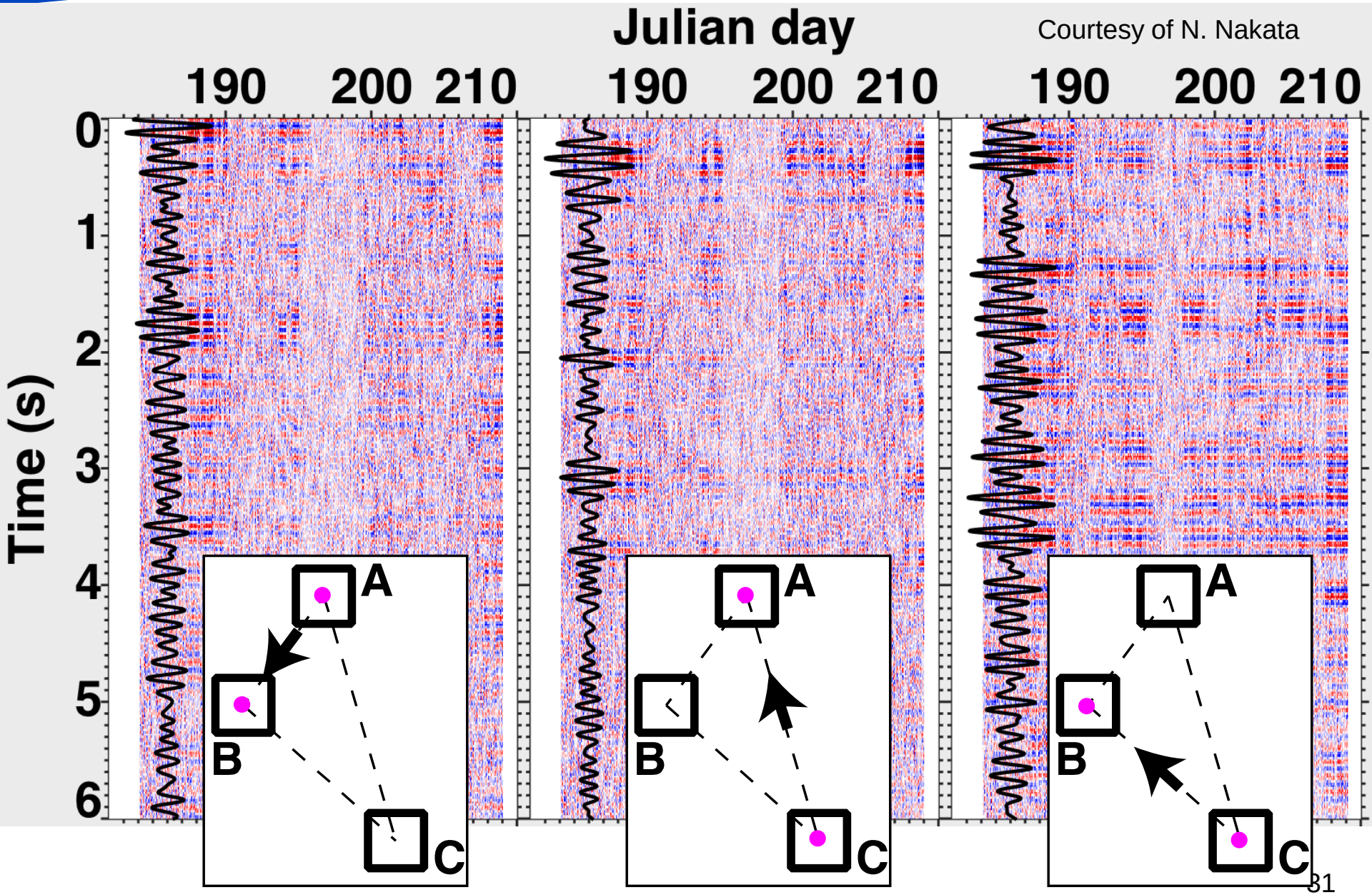
# An unexpected source of body waves



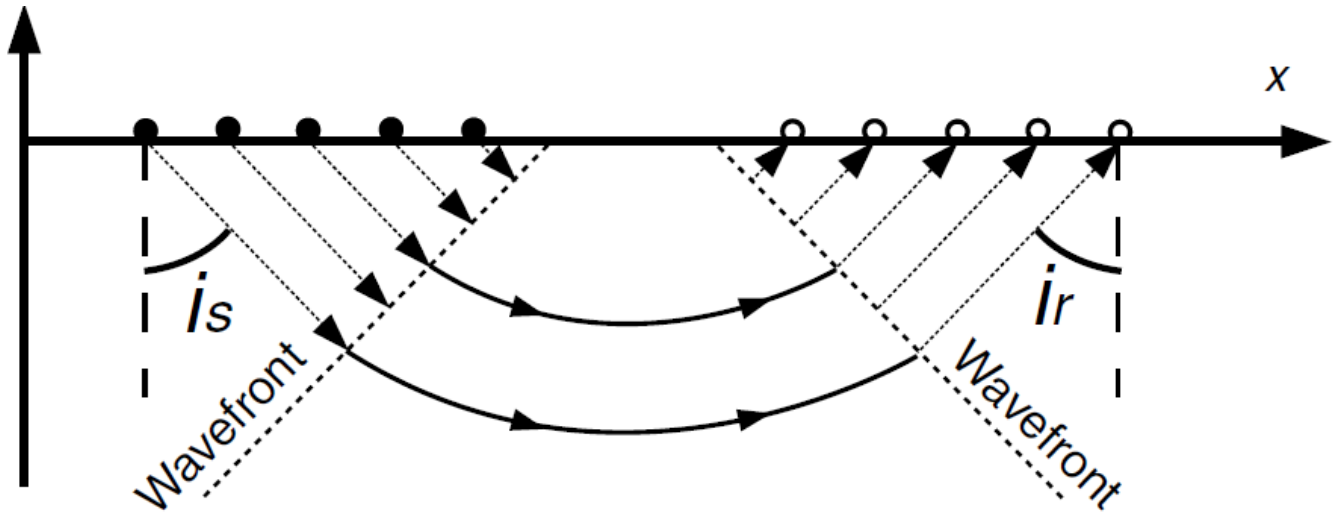




Courtesy of N. Nakata

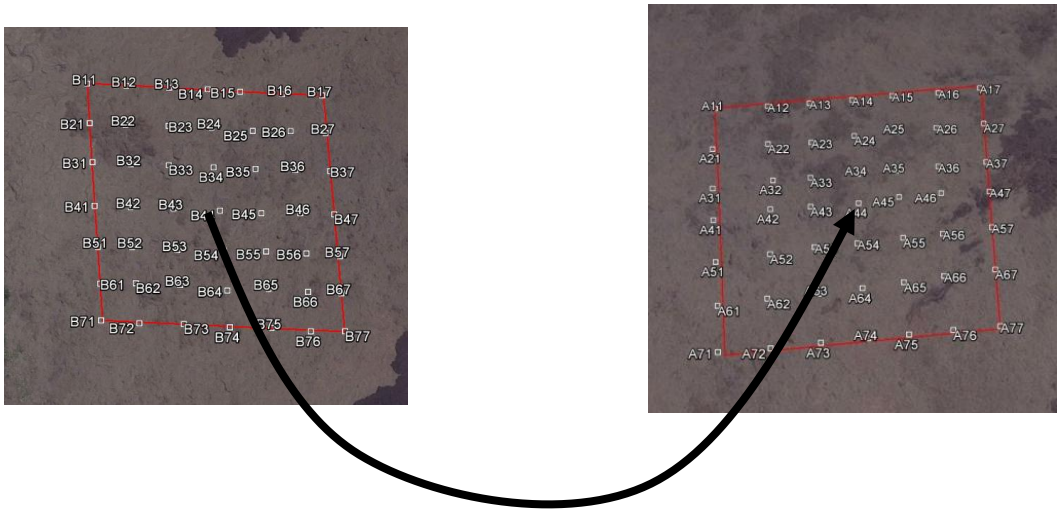
# station cross-correlations



# Requires double beam-forming (DBF)



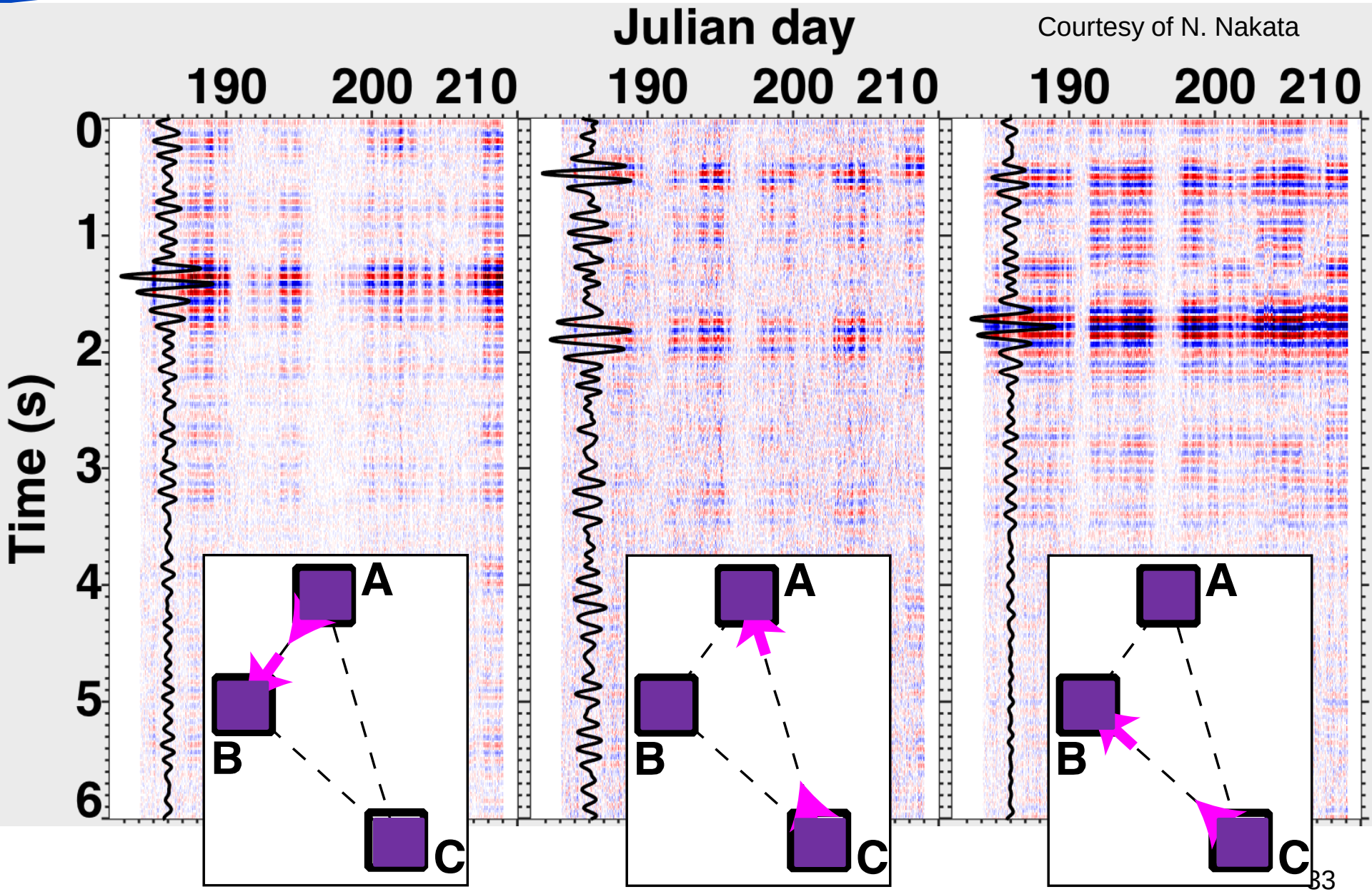

Boué et al. 2013



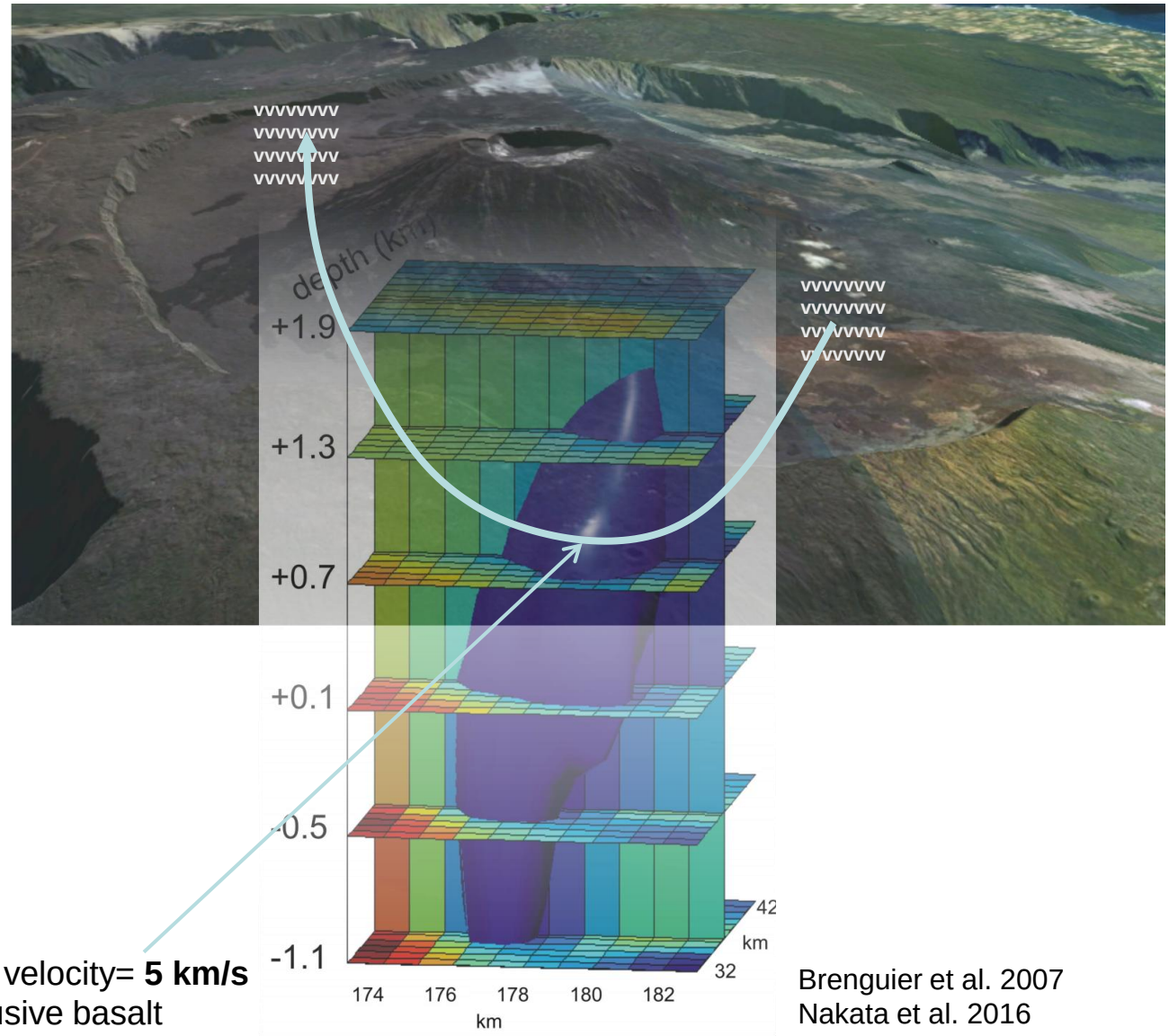
**2401 cross-correlations** between arrays

**1 double-beamformed cross-correlation** = Body-wave part of the Green's function between arrays

# Arrays correlations + DBF



# Combining surface and P-wave imaging




From DBF:
Local P-wave velocity= **5 km/s**
Solidified intrusive basalt

Brenguier et al. 2007
Nakata et al. 2016