# Earthquake Stress Drop values delineate spatial variations in maximum shear stress in the Japanese forearc lithosphere

**G. M. Bocchini[1], A. Dielforder[2], K. B. Kemna[1], R. M. Harrington[1], E. S. Cochran[3]**

[1]Ruhr University Bochum | [2] University of Greifswald | [3] US Geological Survey

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# Motivation

Is earthquake stress drop ($\Delta\sigma$) correlated with maximum shear stress (and depth)?

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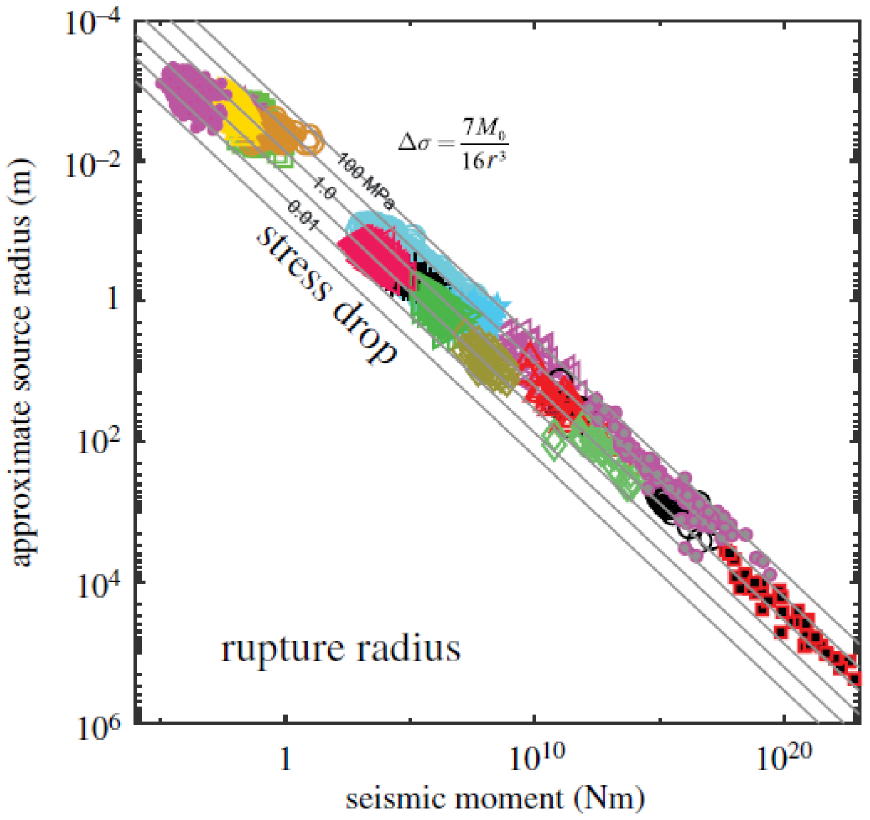
**Why it is important?**

Establishing a relationship between earthquake $\Delta\sigma$ and maximum shear stress would enhance the physical interpretation and implications of $\Delta\sigma$ estimates.

# Why it is difficult to establish?

$\Delta\sigma$ span ~2-3 orders of magnitudes and have large uncertainties




Adapted from Selvadurai (2019) and Abercrombie (2021)

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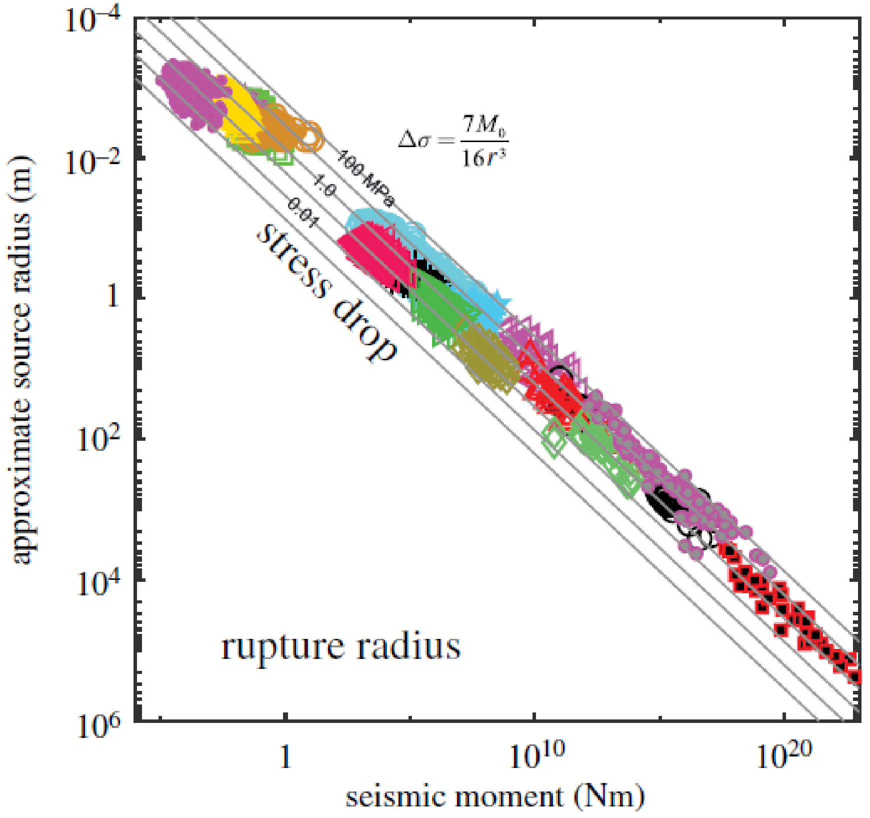


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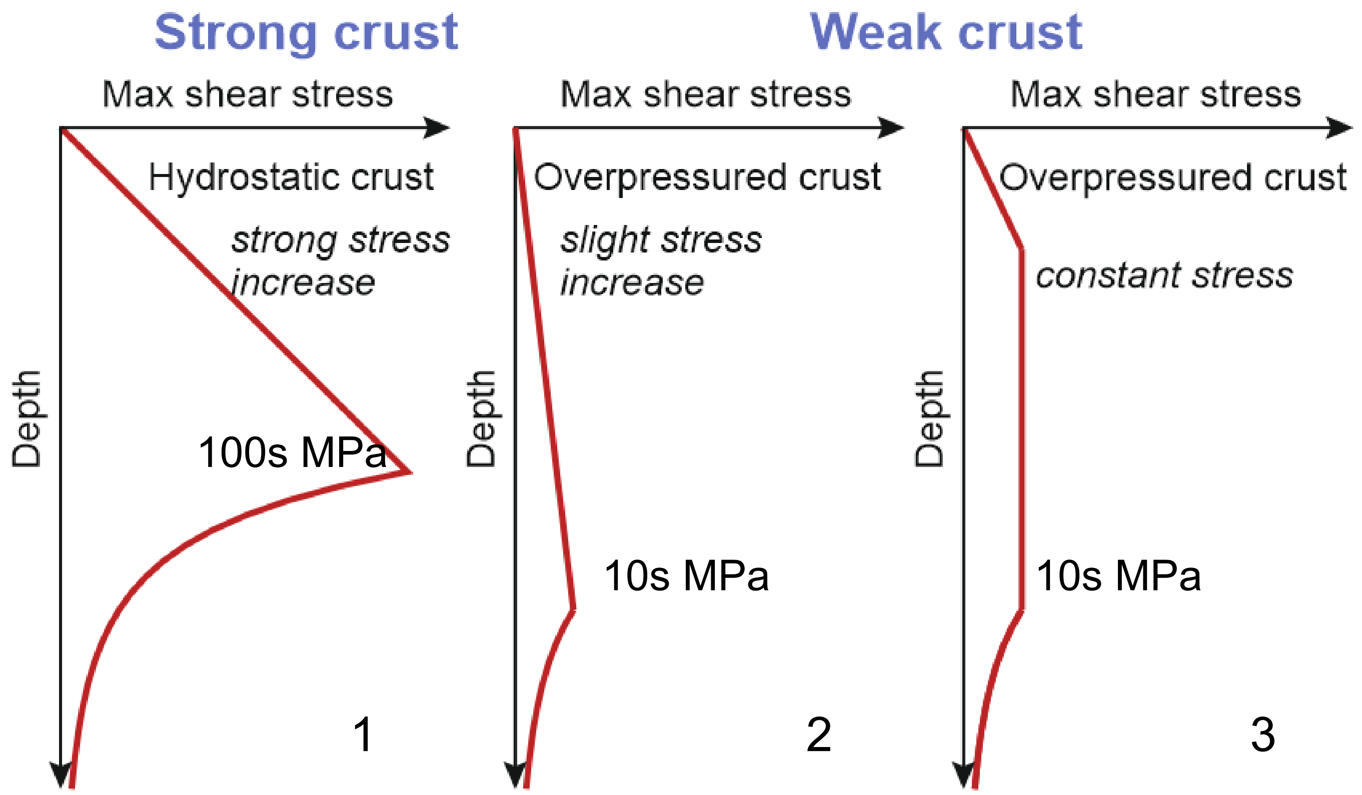
Poor constraints on crustal stress

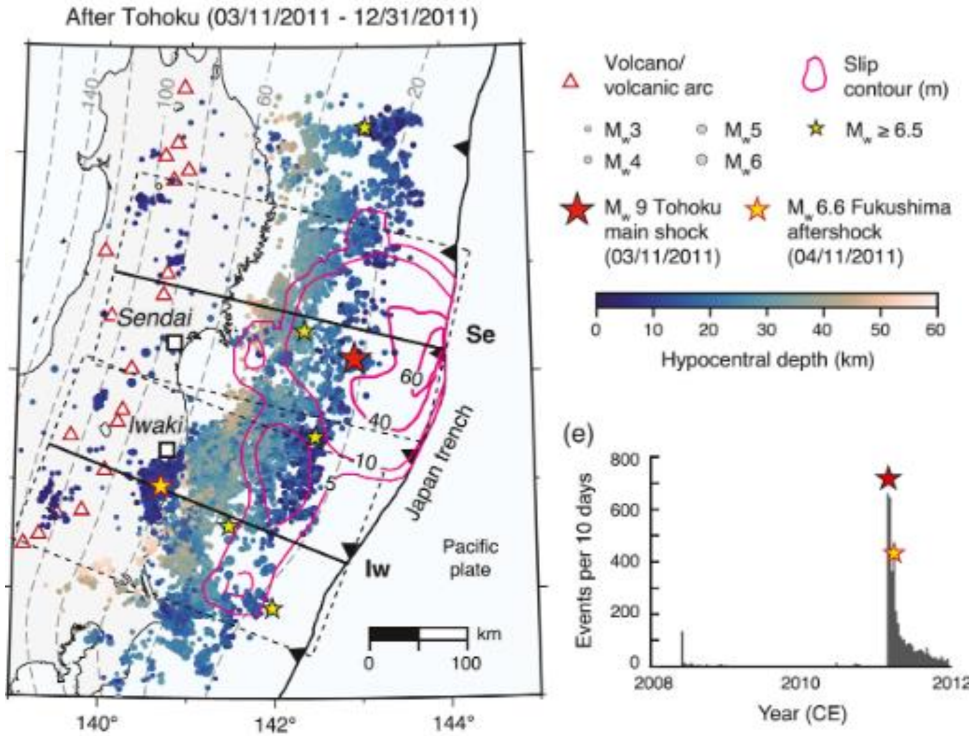


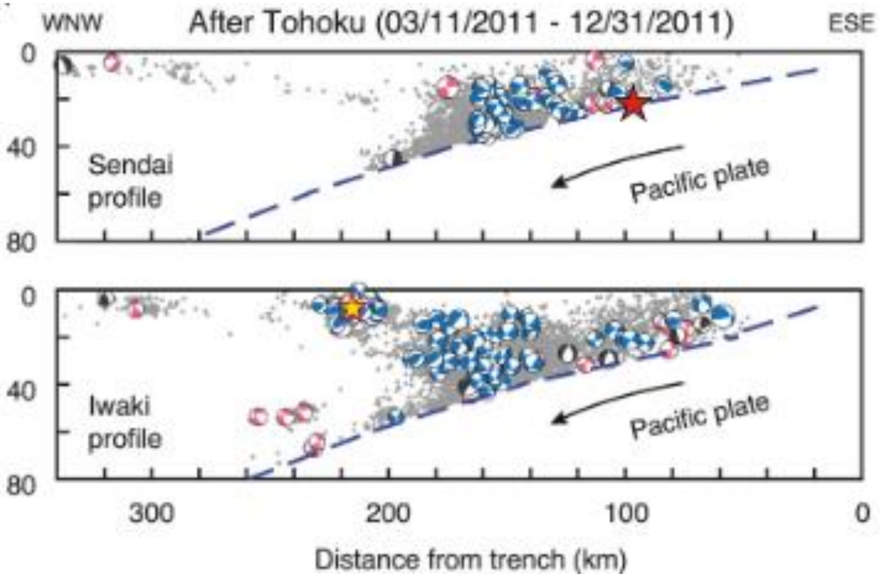

Modified after Suppe (2014)

# Study region

We estimate stress and stress drops ($\Delta\sigma$) in the Japanese forearc following the 2011 Tohoku-Oki megathrust earthquake for the following reasons:

- Widespread forearc seismicity down to 60km depth;
- Earthquakes recorded by a dense network of borehole seismometers (Hi-Net);
- Possibility to obtain relaiable stress estimate (Wang et al., 2019; Dielforder & Hampel, 2021; Dielforder et al., 2023).

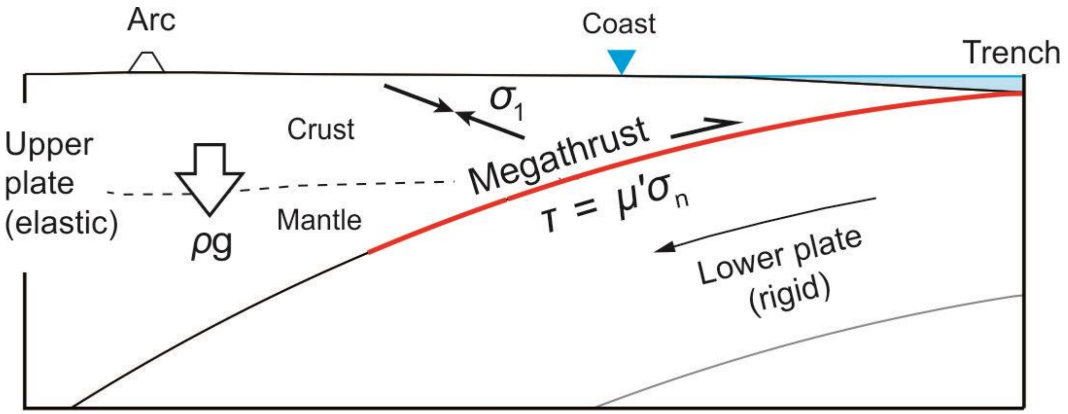



Adapted from Dielforder et al. (2023)

# How do we tackle it? (stress estimates)

- We calculate the total stress in the forearc using two-dimensional finite-element models of force balance (Wang et al., 2019; Dielforder & Hampel, 2021; Dielforder et al., 2023).

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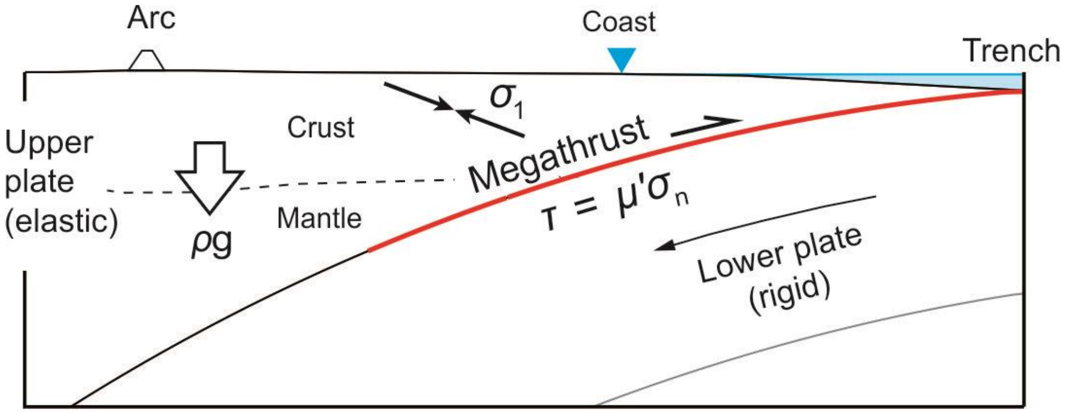
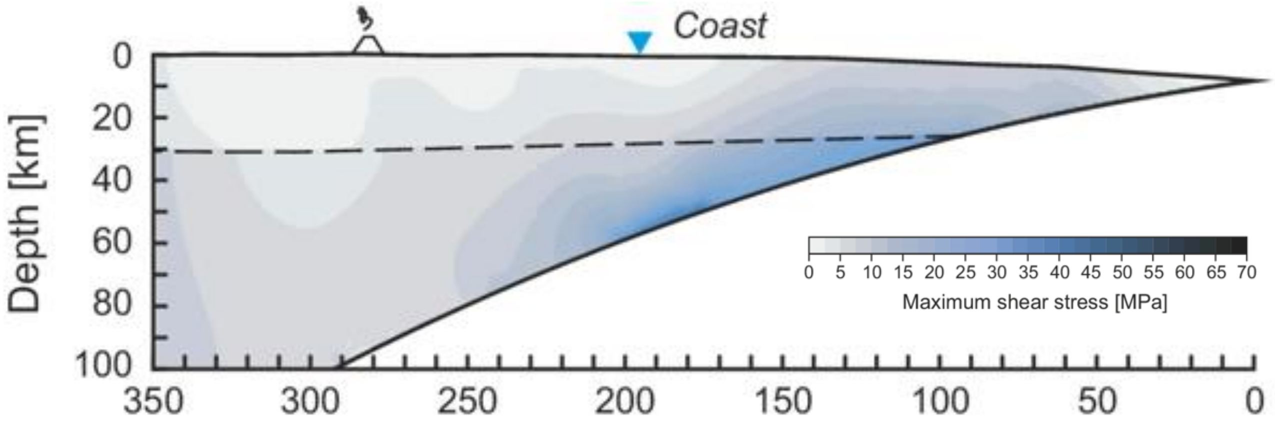



We use focal mechanisms to calibrate the models

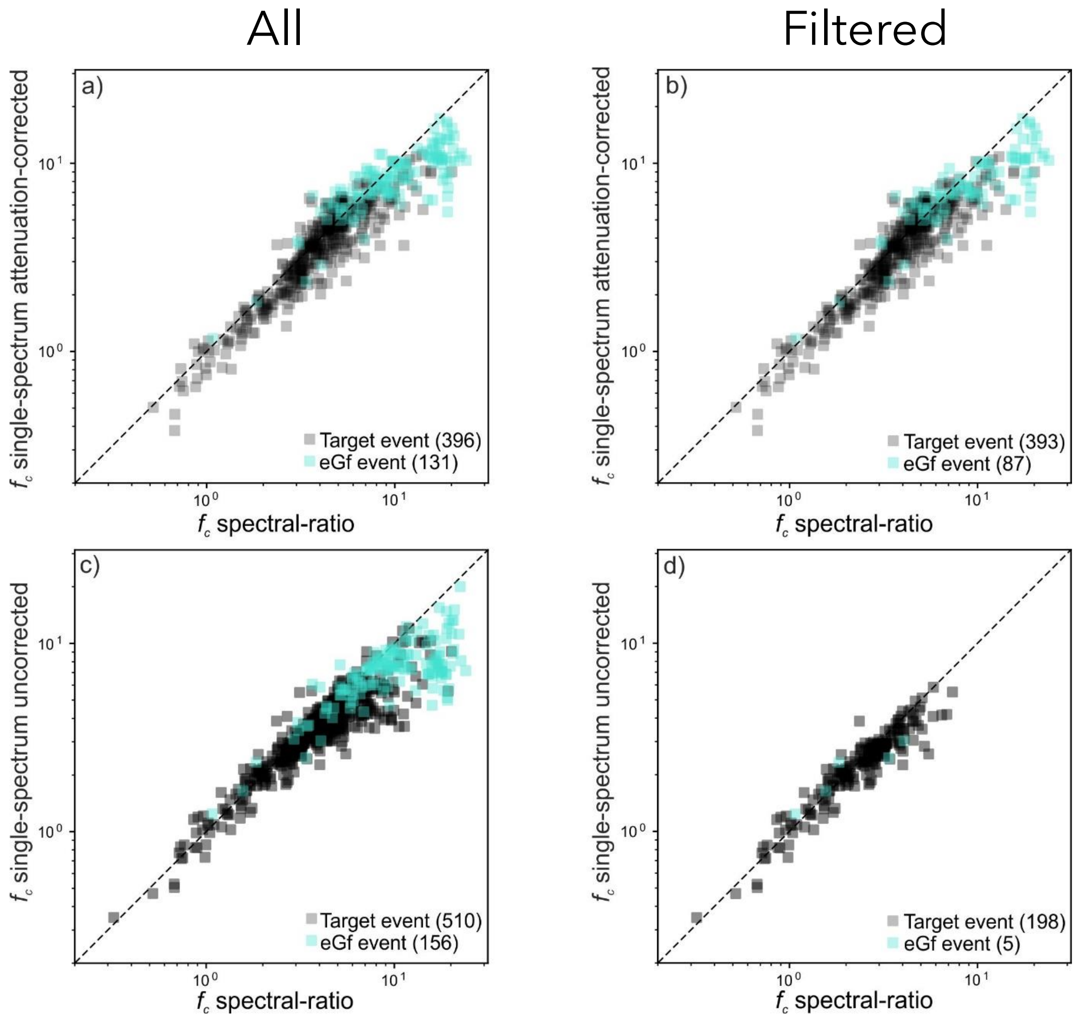
We determine max. shear stress ($\tau_{max}$) = ($\sigma_1$–$\sigma_3$)/2 from the models

# How do we tackle it? (stress drop estimates)

We calculate $\Delta\sigma$ values using S-wave corner frequencies ($f_c$) of M > ~2.5 events from:

- single-spectrum fitting (Brune, 1970; Abercrombie, 1995)
- attenuation-corrected single-spectrum fitting (Ide et al., 2003; Imanishi & Uchide, 2017)
- spectral-ratio fitting (Prieto et al., 2006; Abercrombie, 2014, 2015)

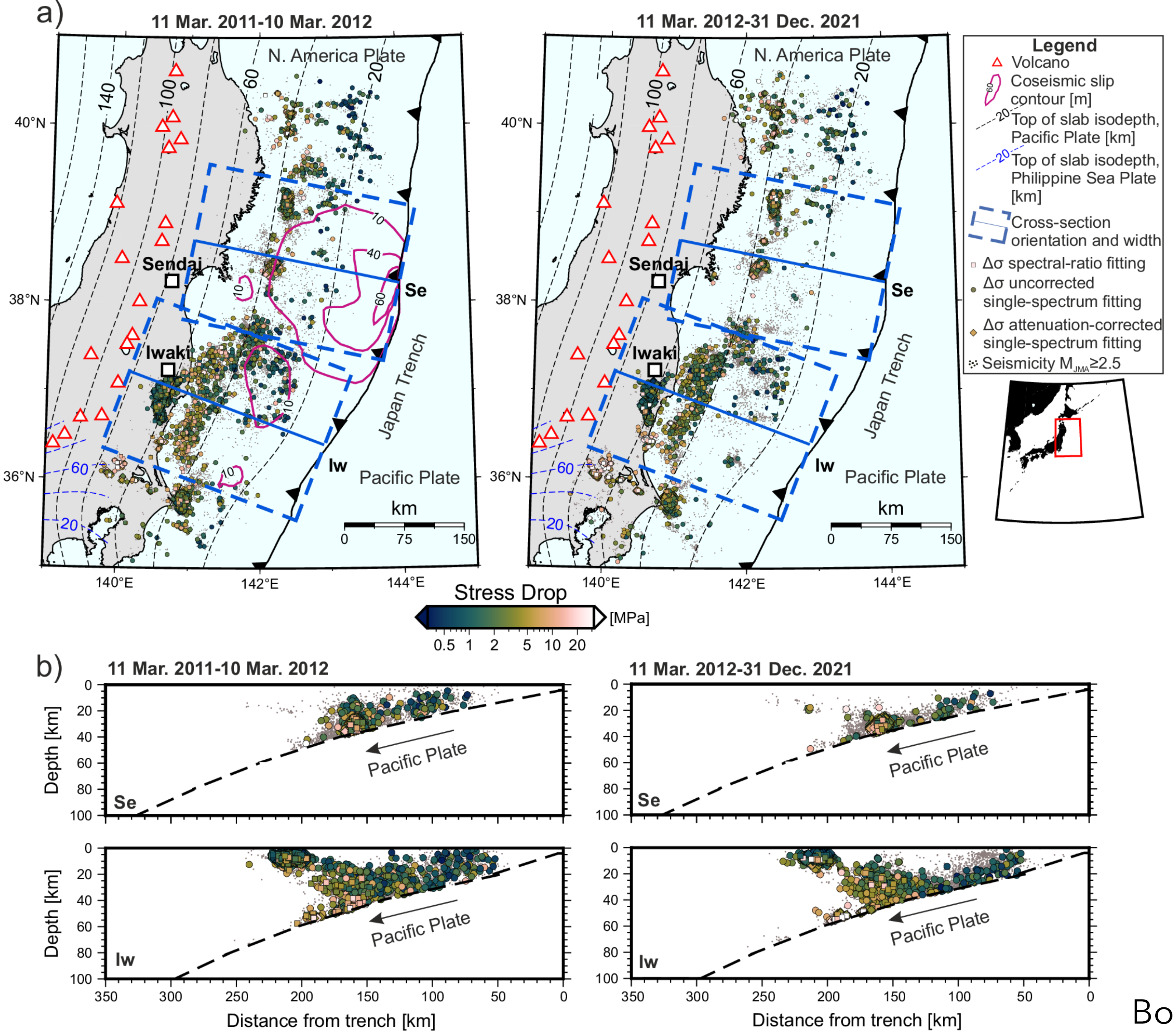
We validate single-spectrum $f_c$ estimates with spectral-ratio fitting (where data quality permits)




Bocchini et al. (2025)

We analyze Δσ dependence on depth and shear stress along two 200 km wide forearc transects: Iwaki, and Sendai.

We investigate two different temporal scales: first year after the mainshock, and the following 10 years.

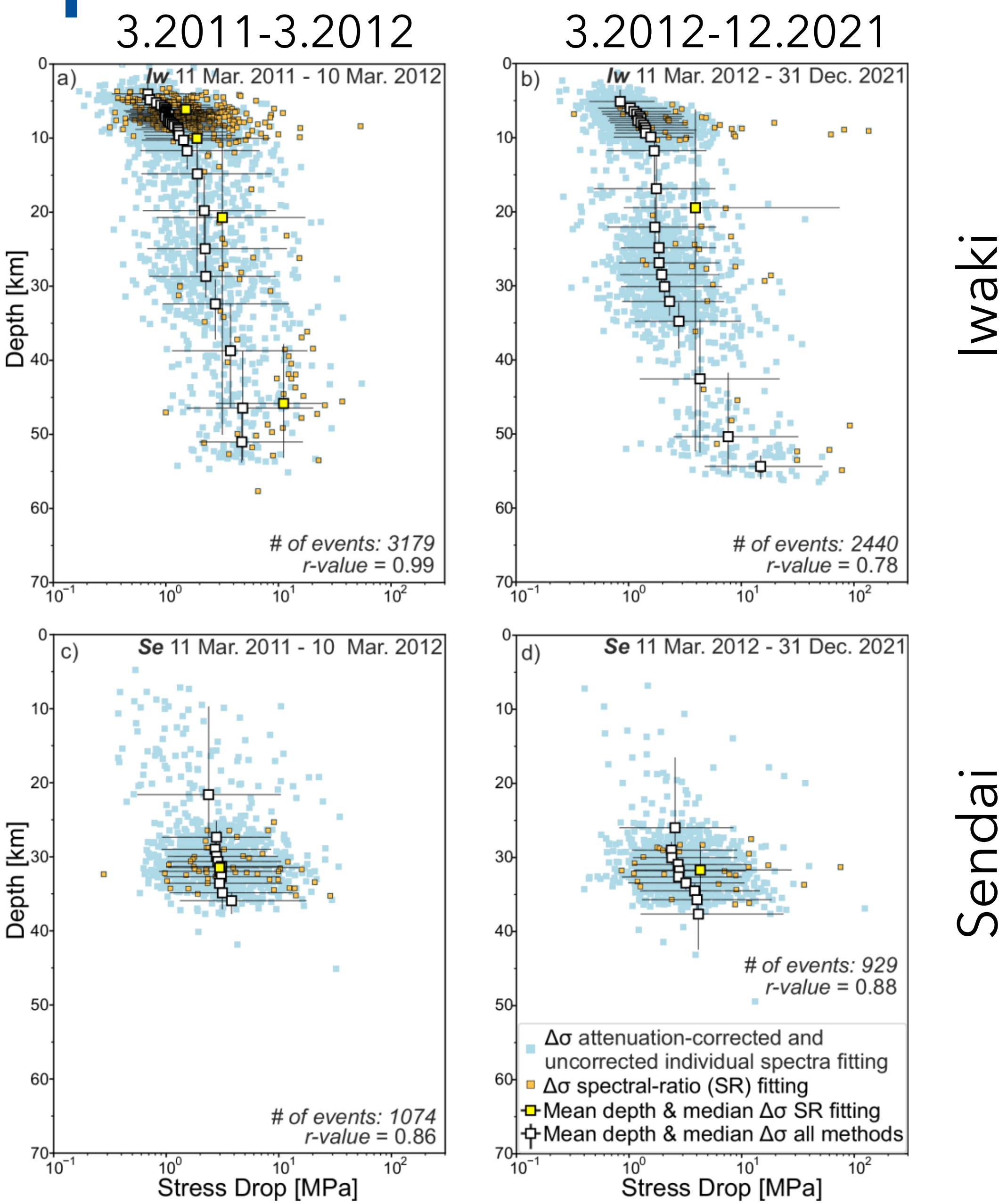



Earthquake catalog from JMA

Bocchini et al. (2025)

# Stress drop vs Depth

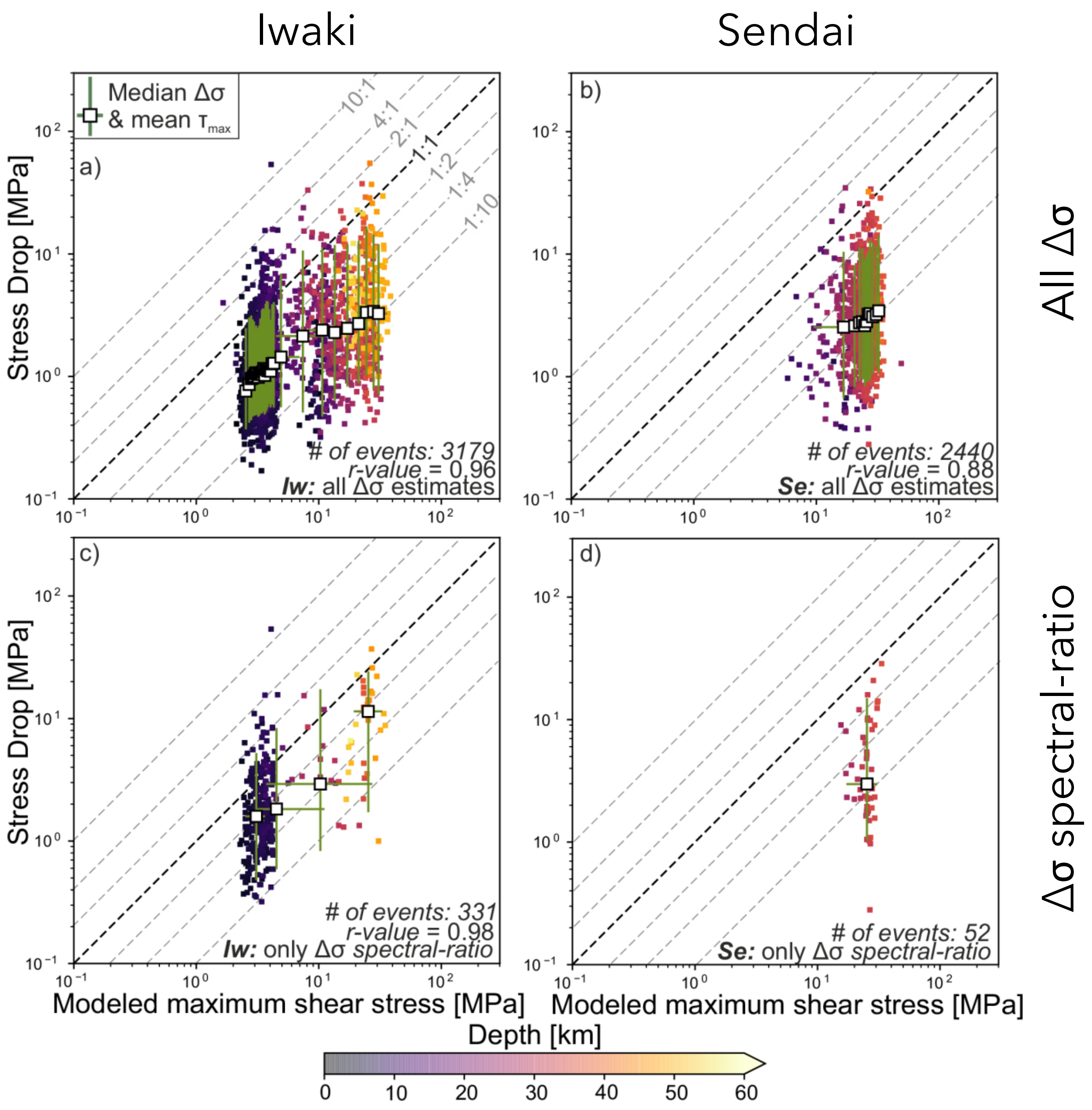
Median stress drop values increase sligthly with depth (~0.08 MPa/km)




Bocchini et al. (2025)

# Stress drop vs modeled max. shear stress

Median stress drop values increase with increasing maximum shear stress

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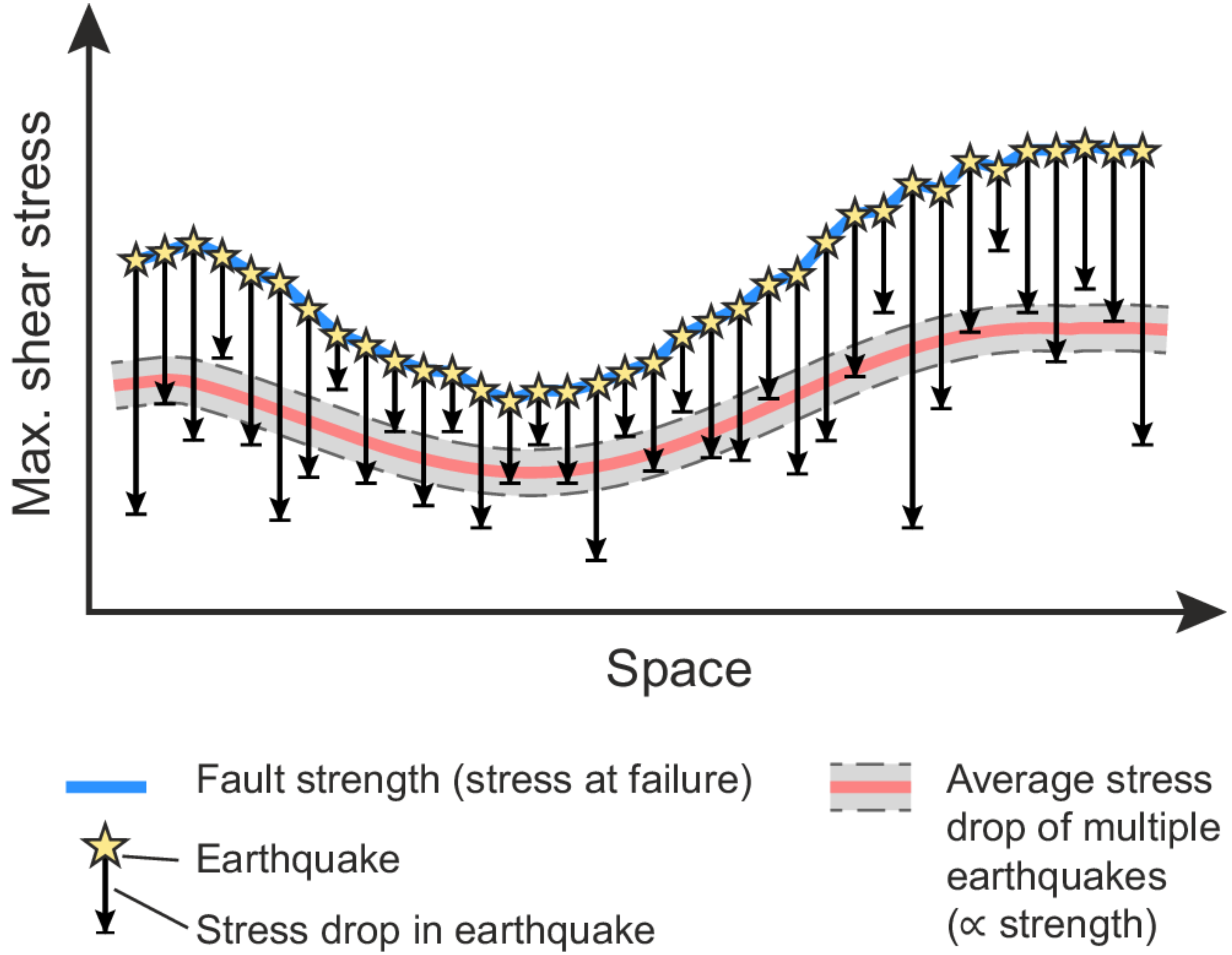
# Concluding remarks

On average, earthquake stress drop ($\Delta\sigma$) values correlate positively with depth in the Japanese forearc.

The $\Delta\sigma$-depth correlation is explained by a dependence of $\Delta\sigma$ on maximum shear stress in the brittle lithosphere.

Average $\Delta\sigma$ values are proportional to stress at failure, i.e. fault strength.

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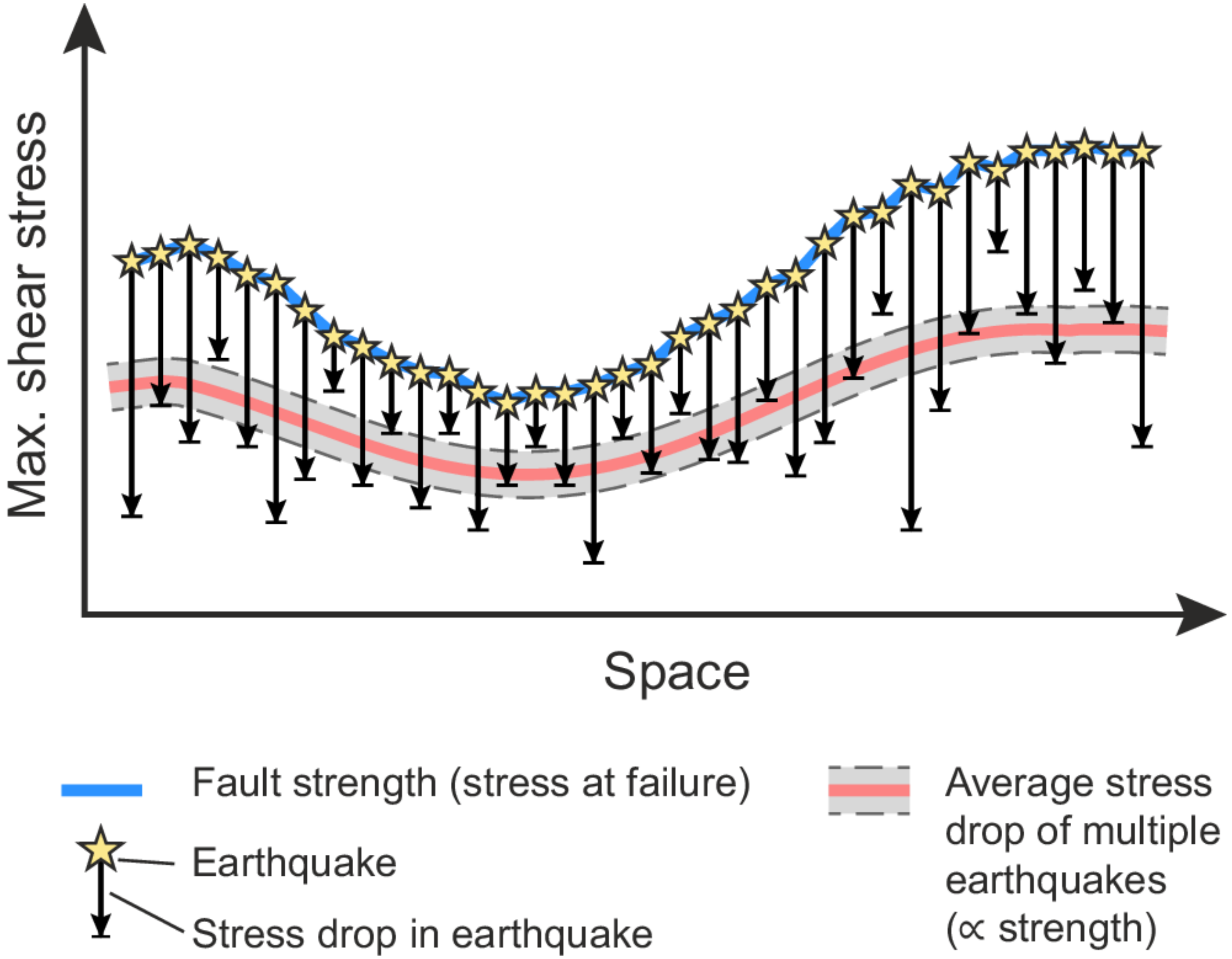
**THANKS FOR LISTENING!**




Bocchini et al. (2025)