

Pacific ORCA: Science update

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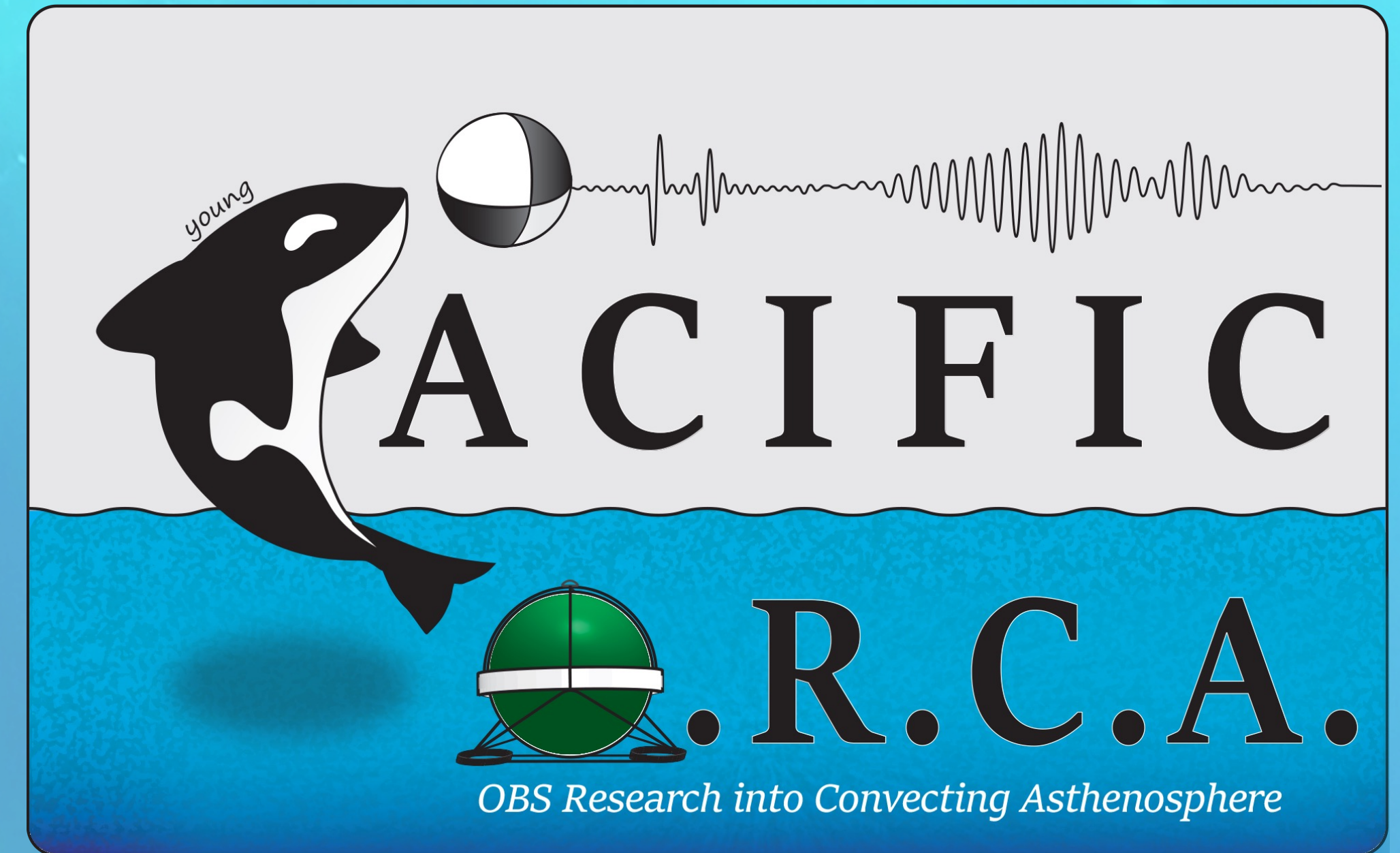
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Don Forsyth (Brown U.)

Lun Zhang (UC Santa Barbara)

Colleen Dalton (Brown U.)

Zach Eilon (UC Santa Barbara)

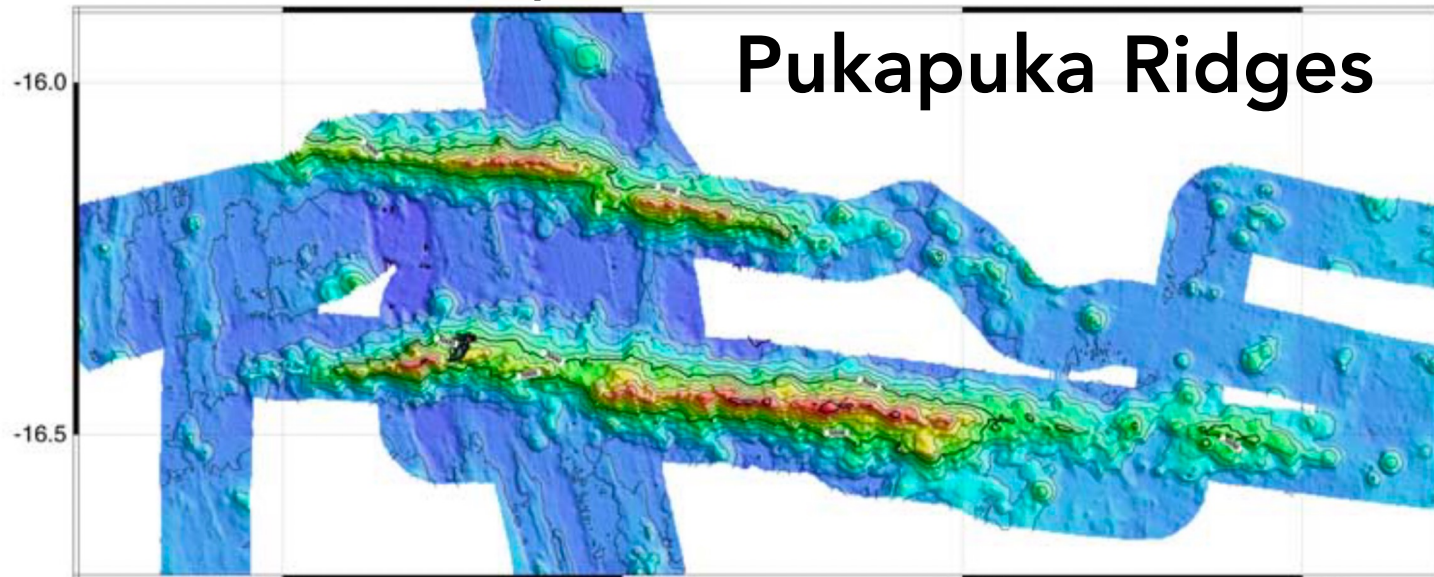


Funding: NSF OCE
#1658214, #1658491,
#2051265, #1658070

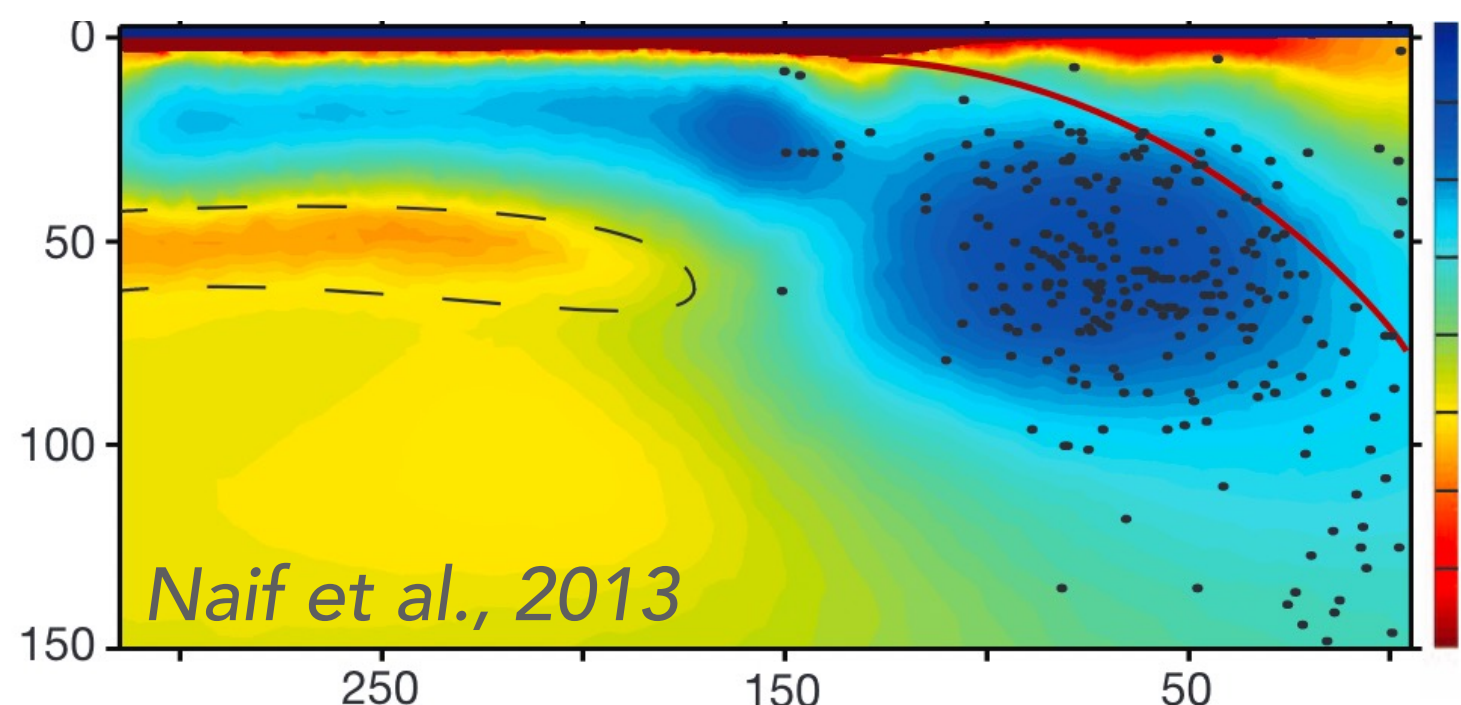
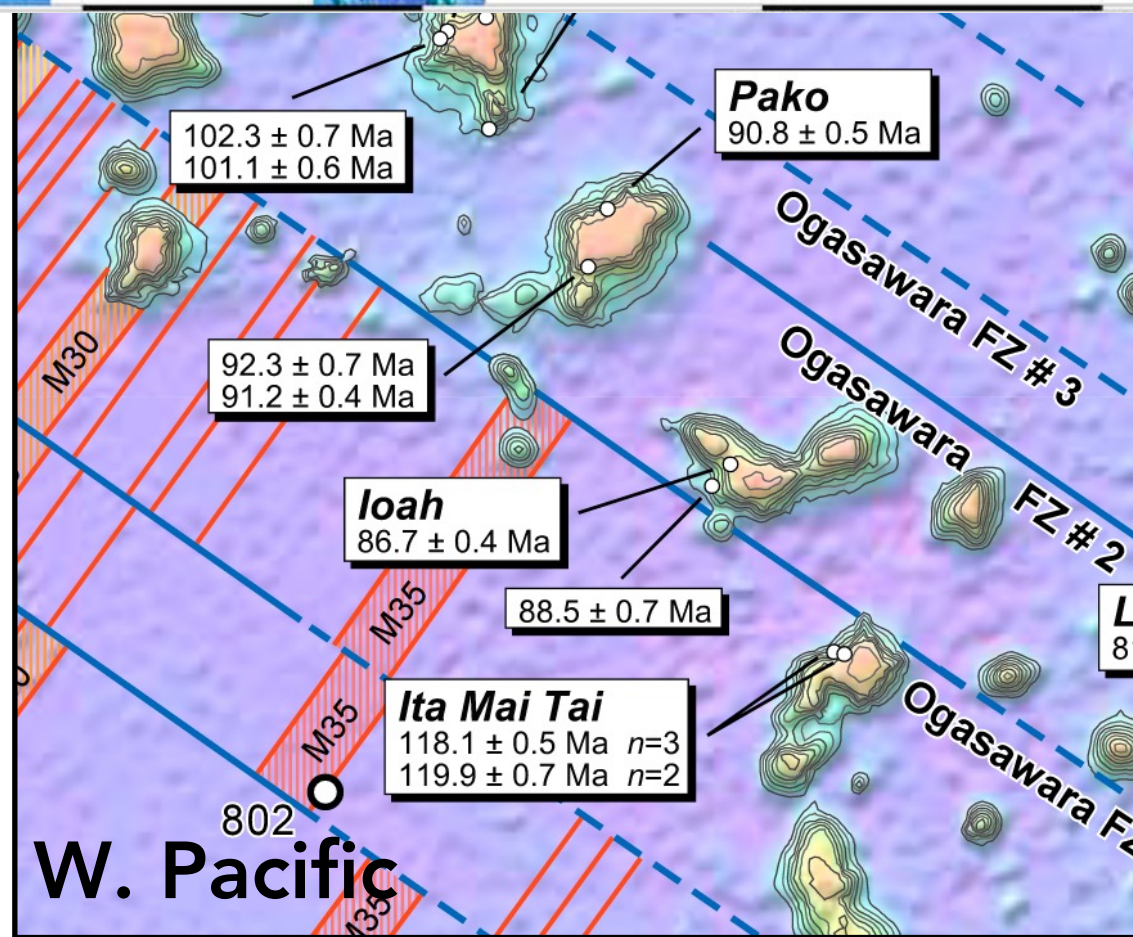
MSROC Community Meeting Science Update (pre-AGU 2023)

Science questions - dynamic oceanic LAB

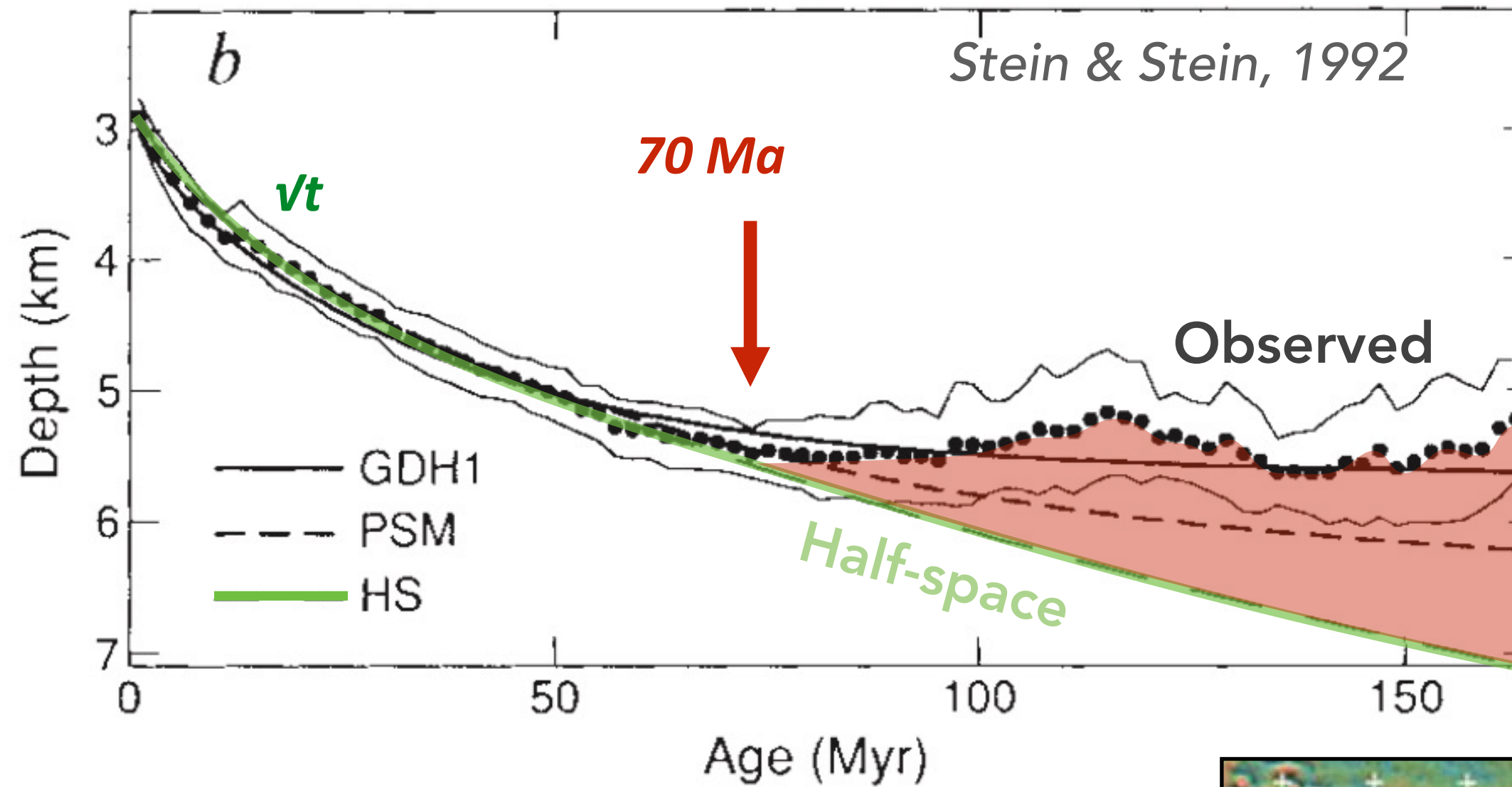
Sandwell et al., 1995



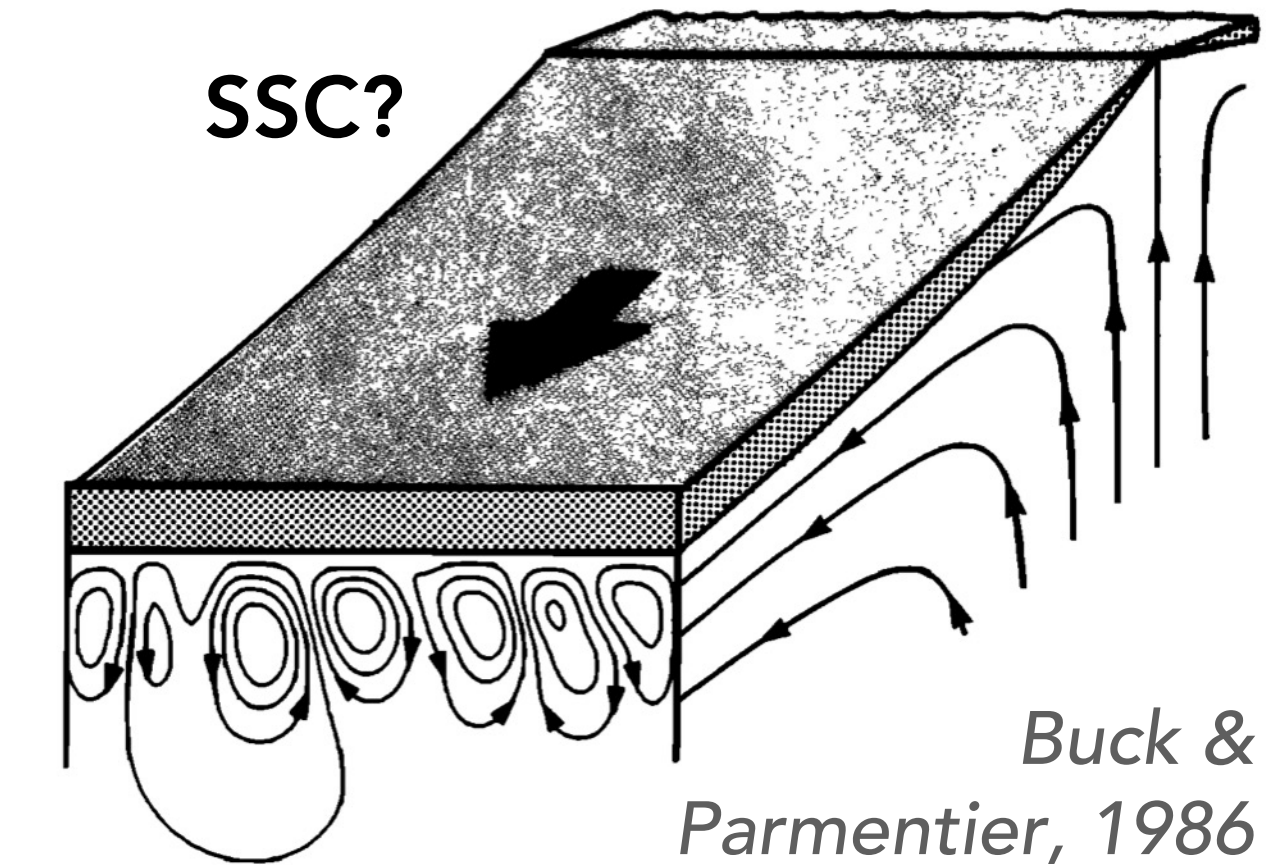
Koppers et al., 2003



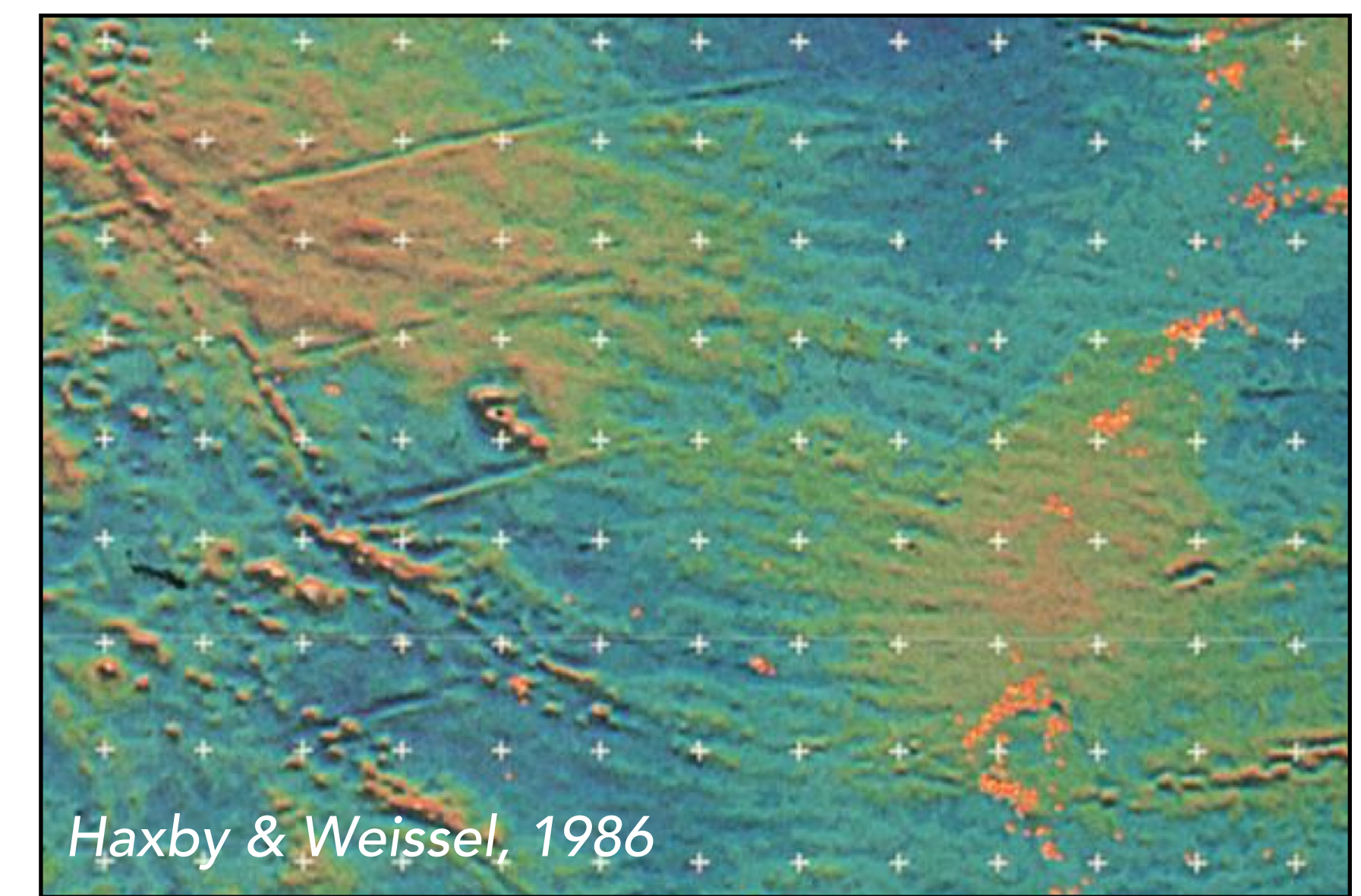
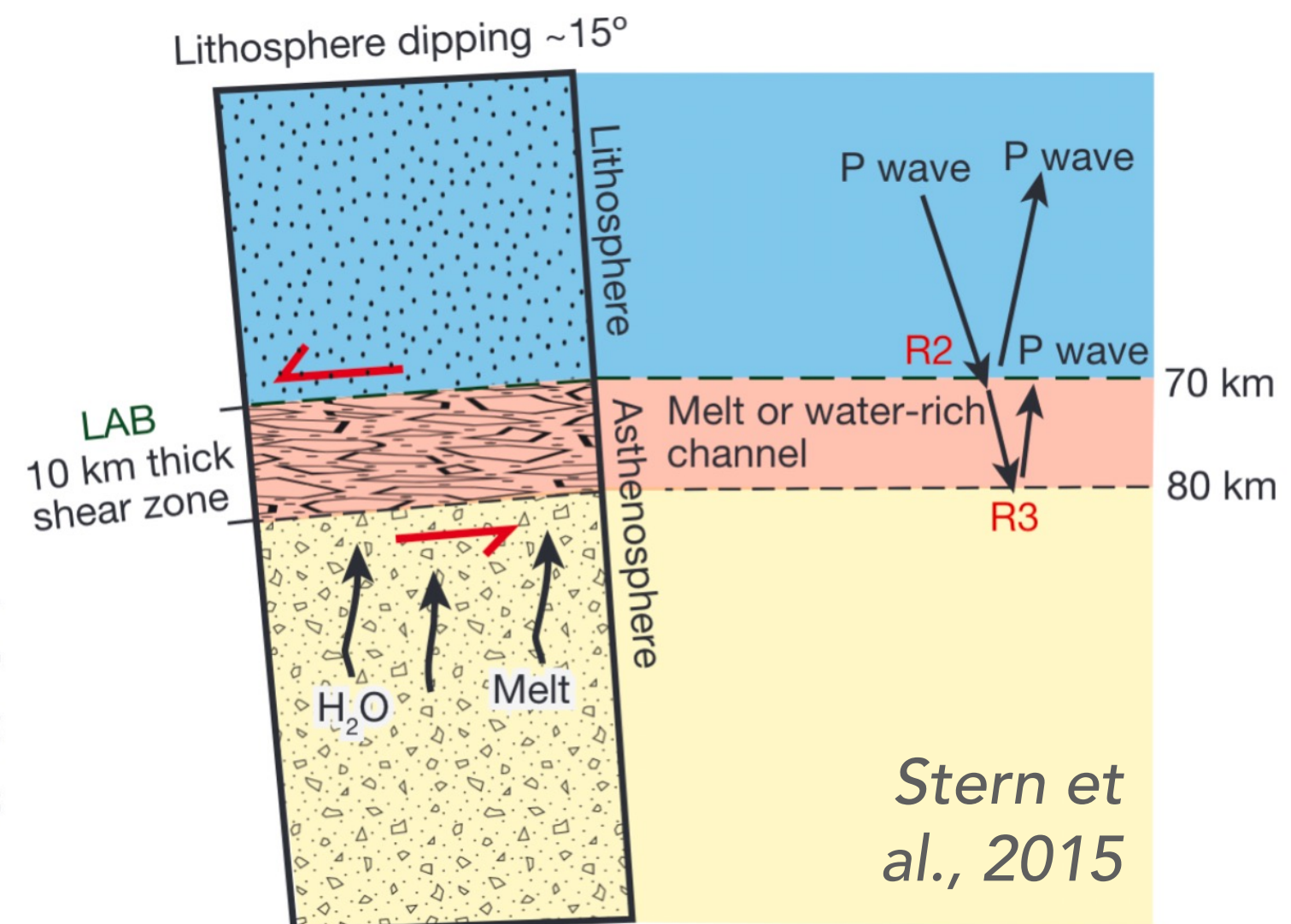
Ocean cooling - plate model?



SSC?



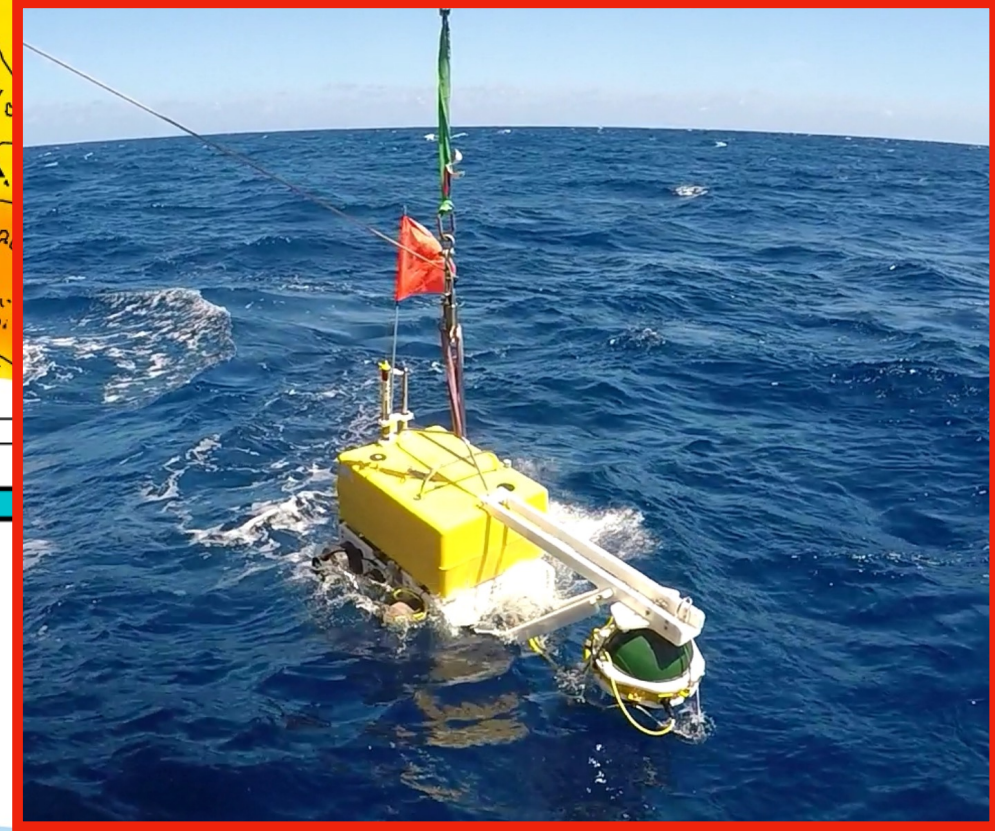
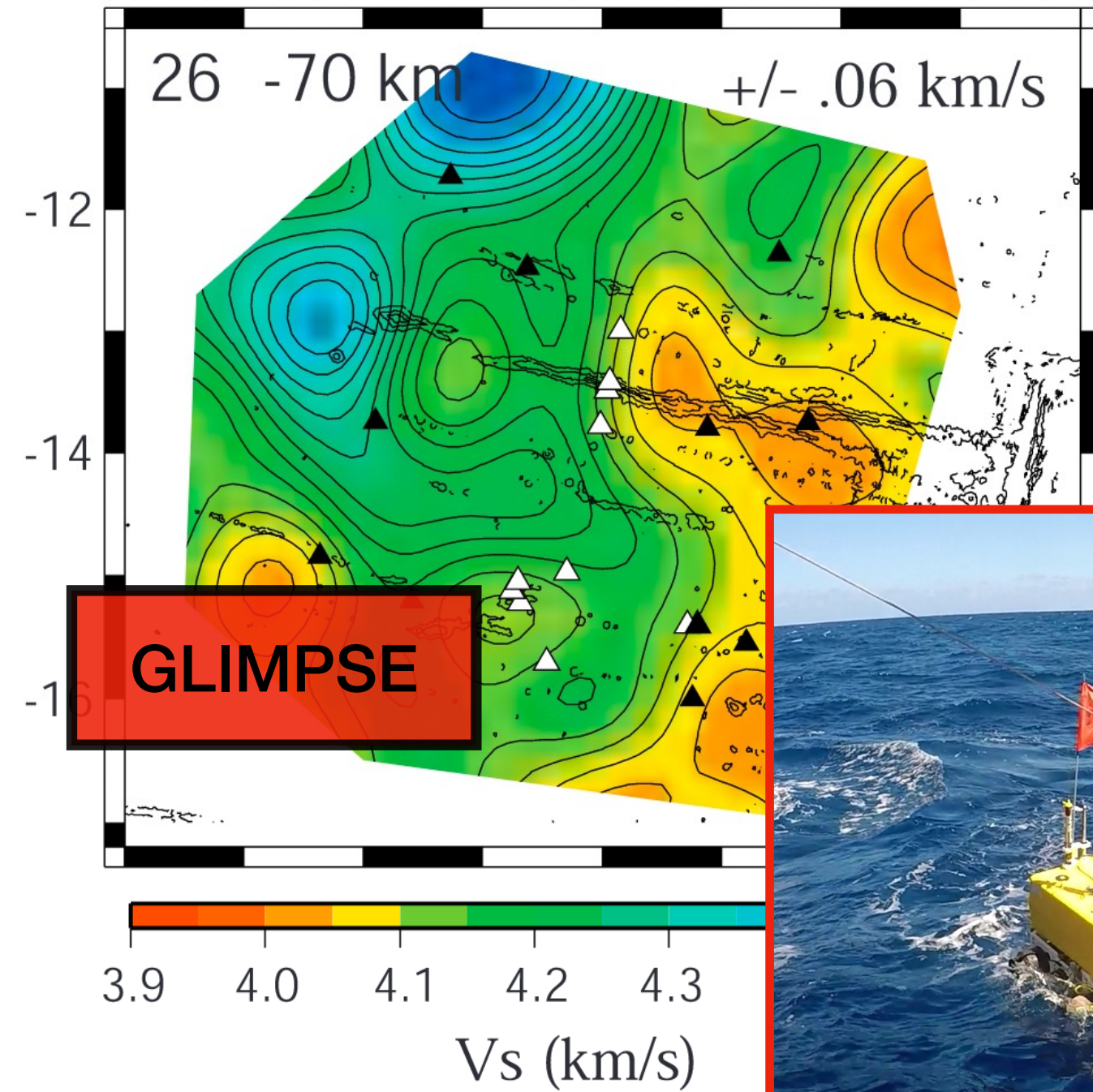
FA Gravity lineations



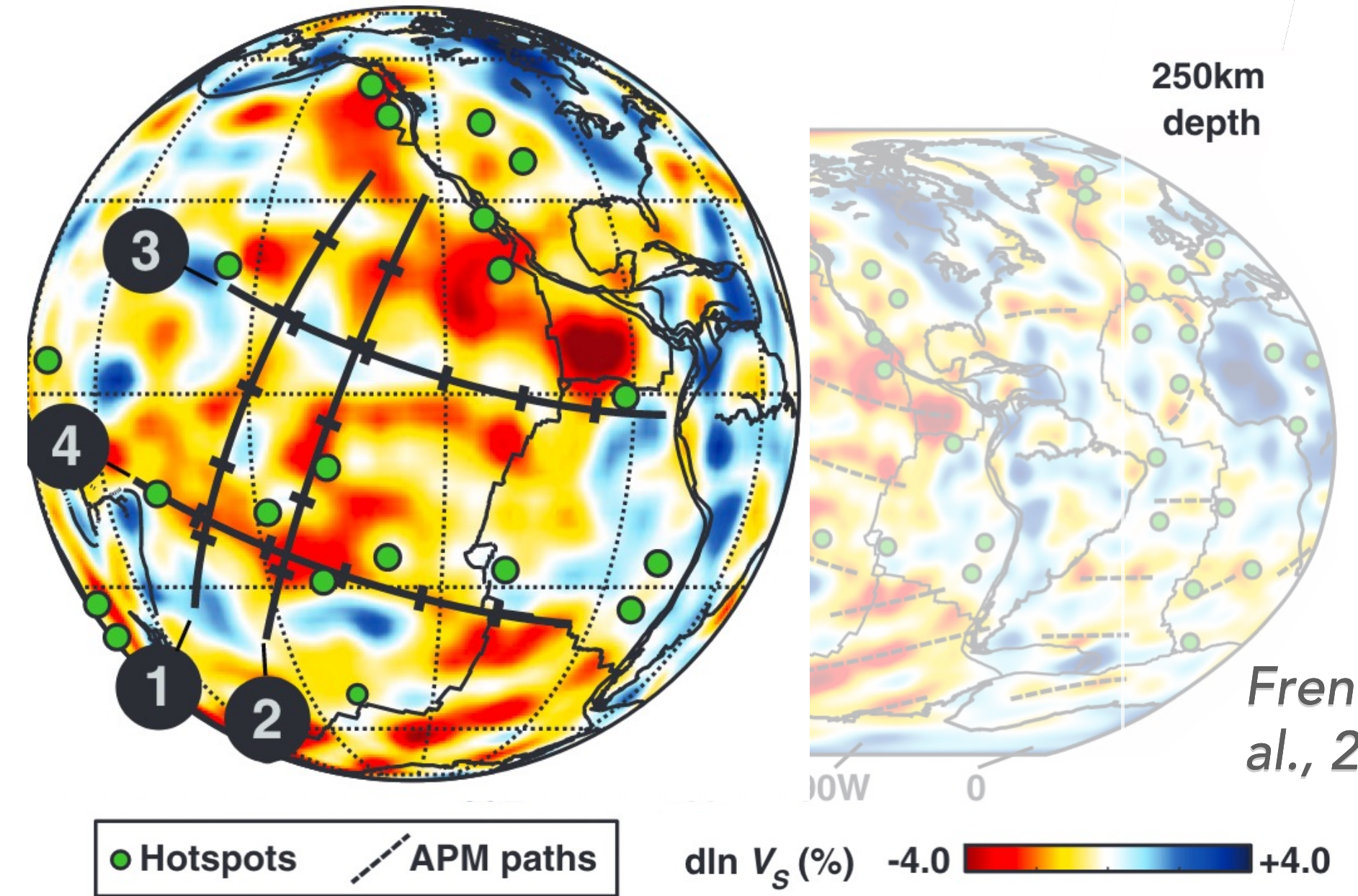
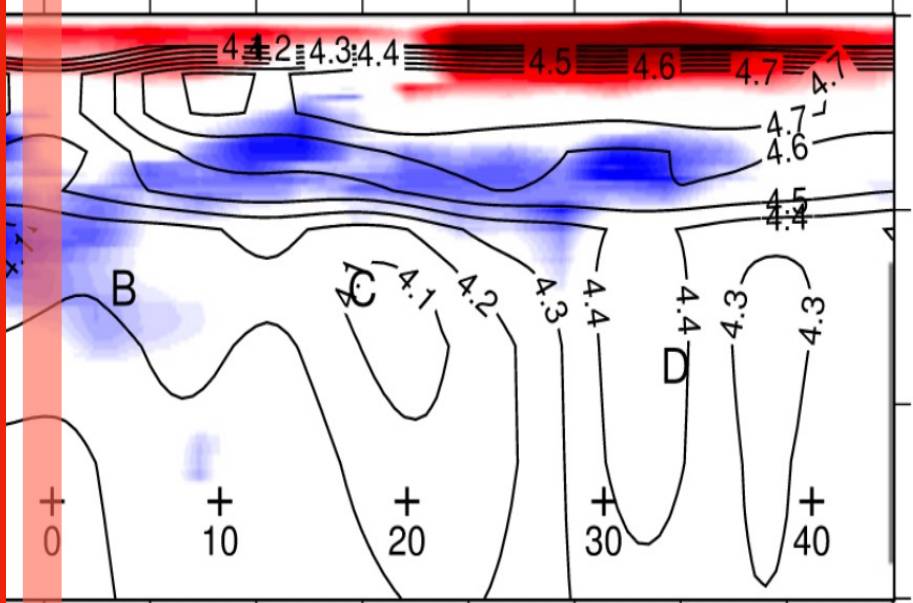
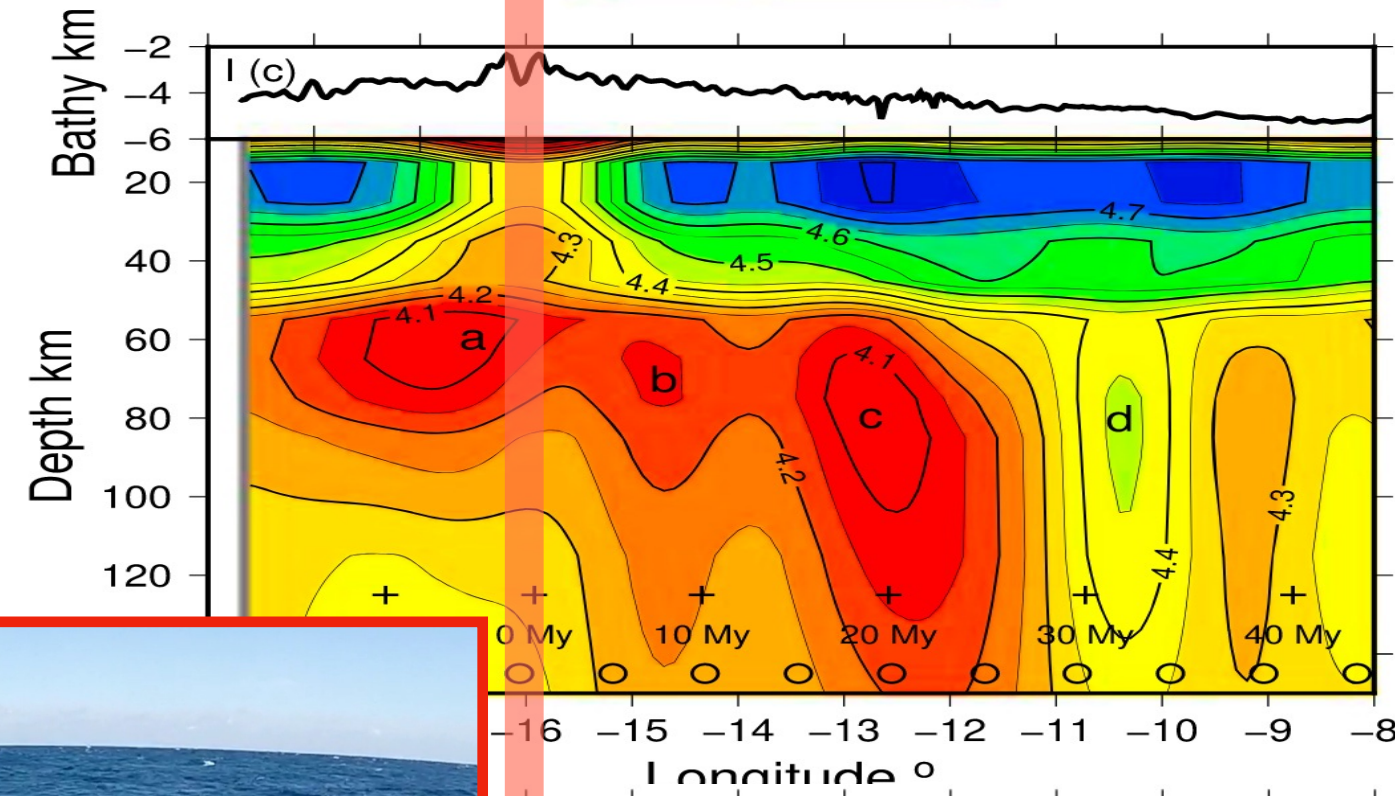
Imaging SSC

PI-LAB

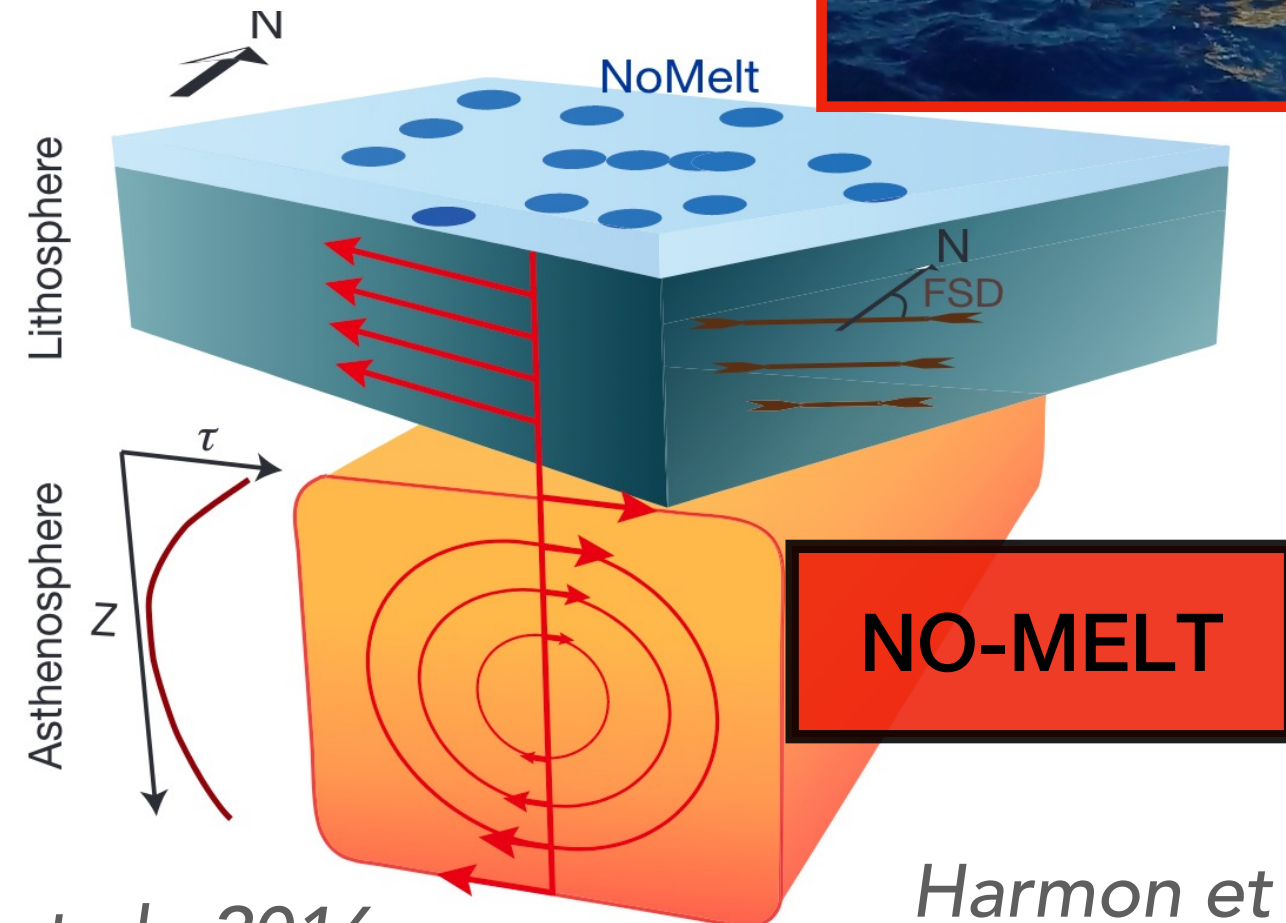
Weeraratne et al., 2007



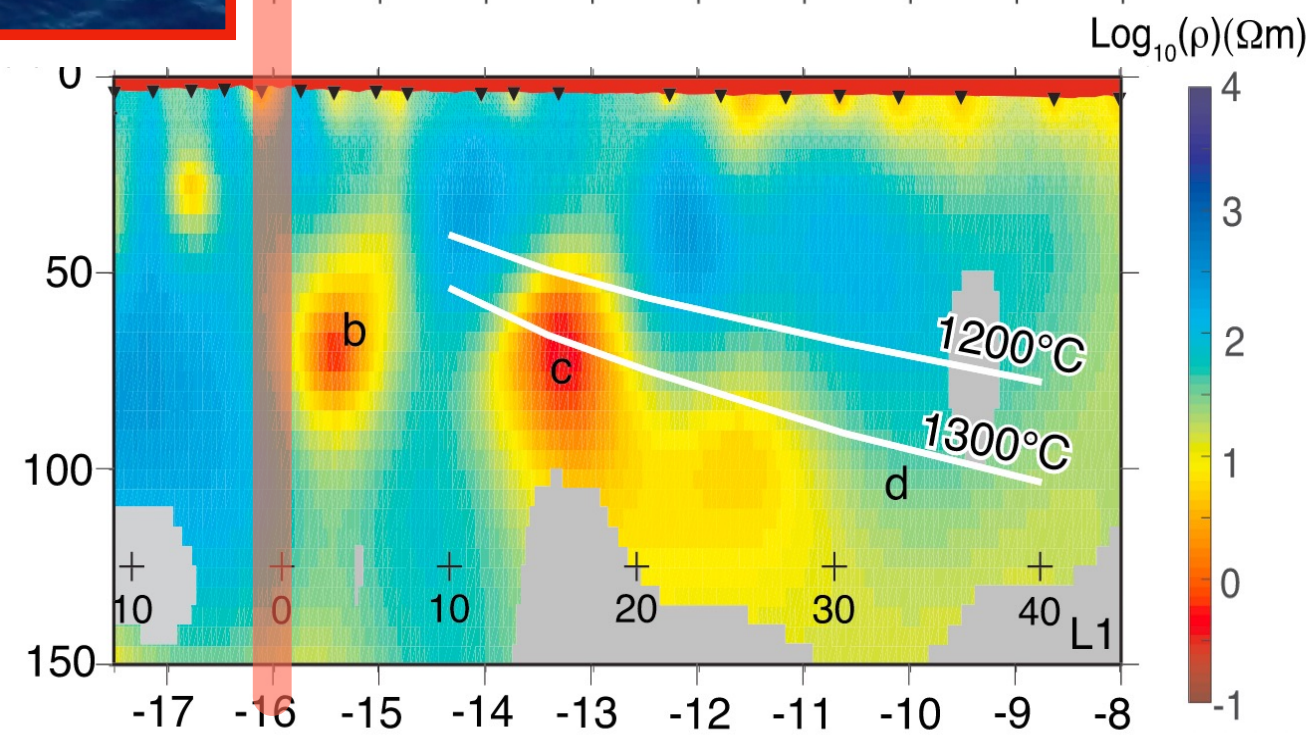
MAR



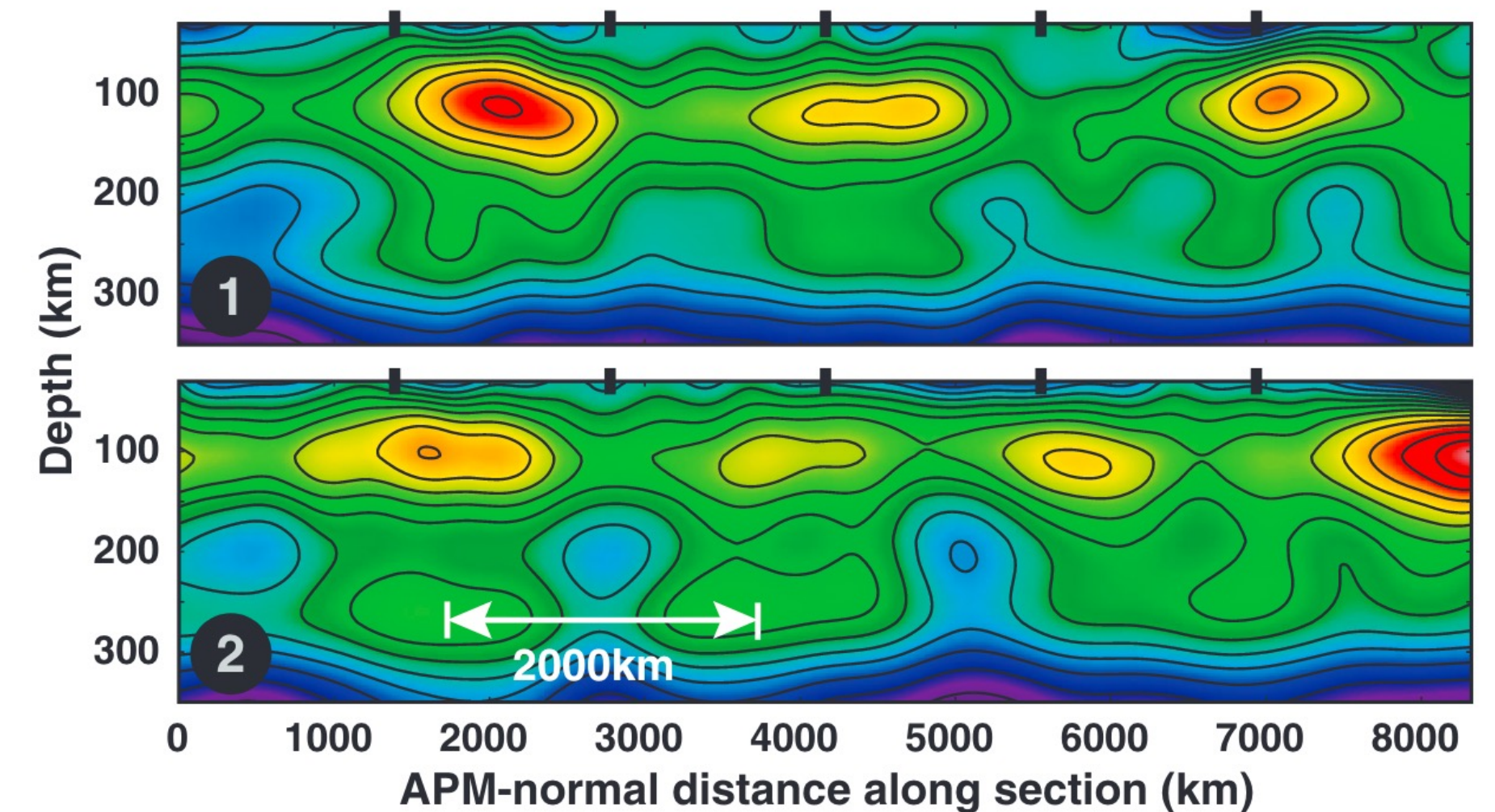
French et al., 2013



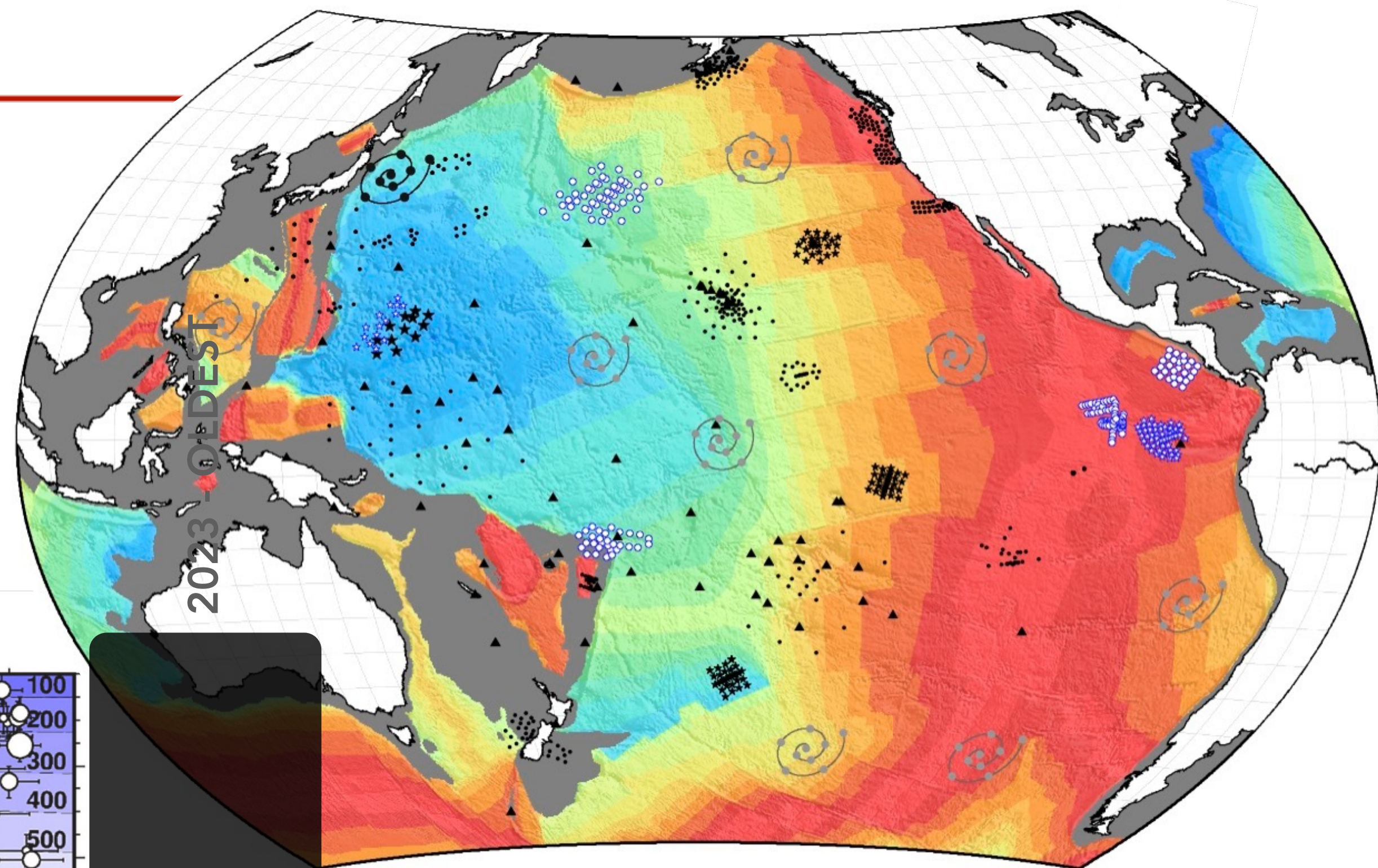
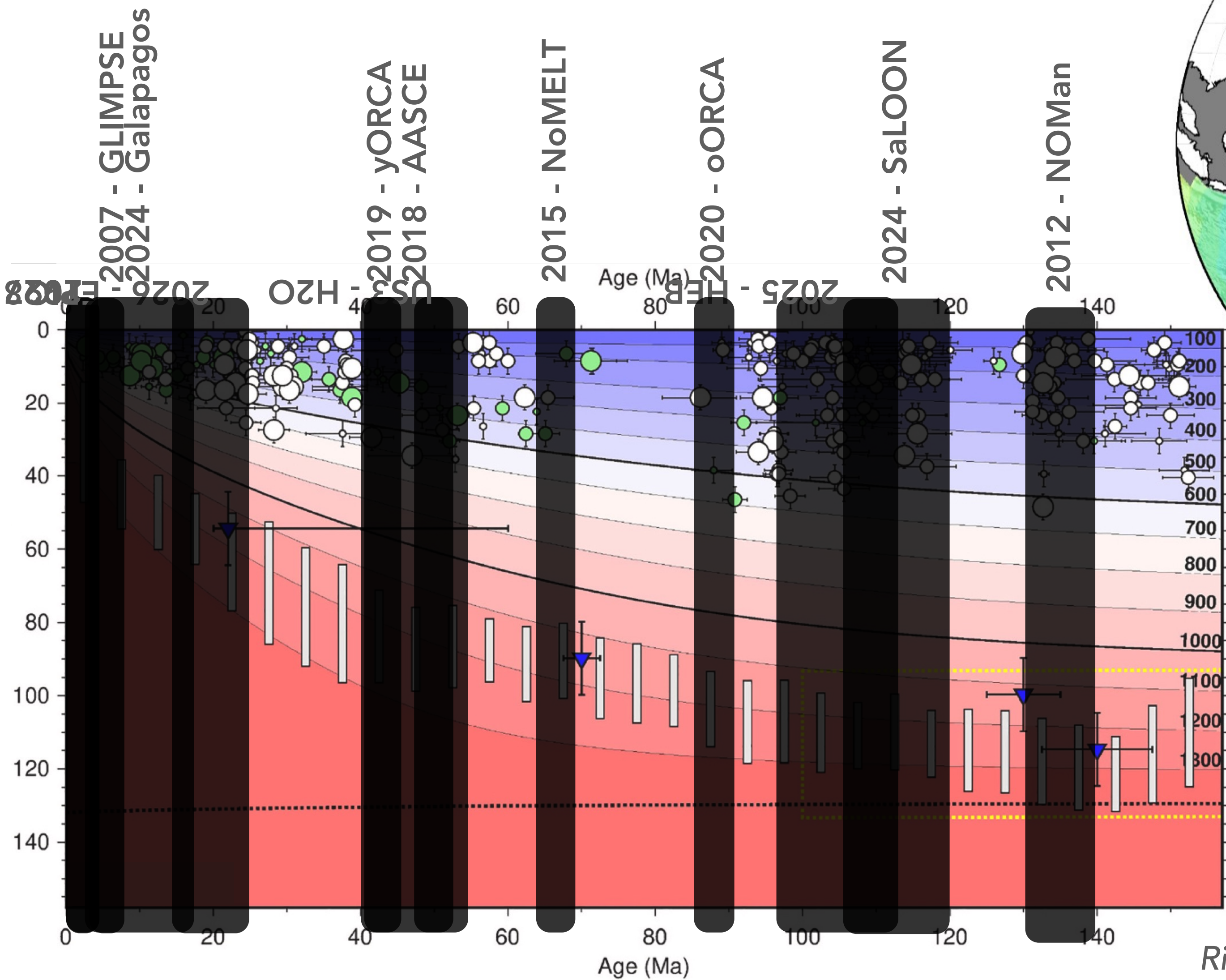
Lin et al., 2016



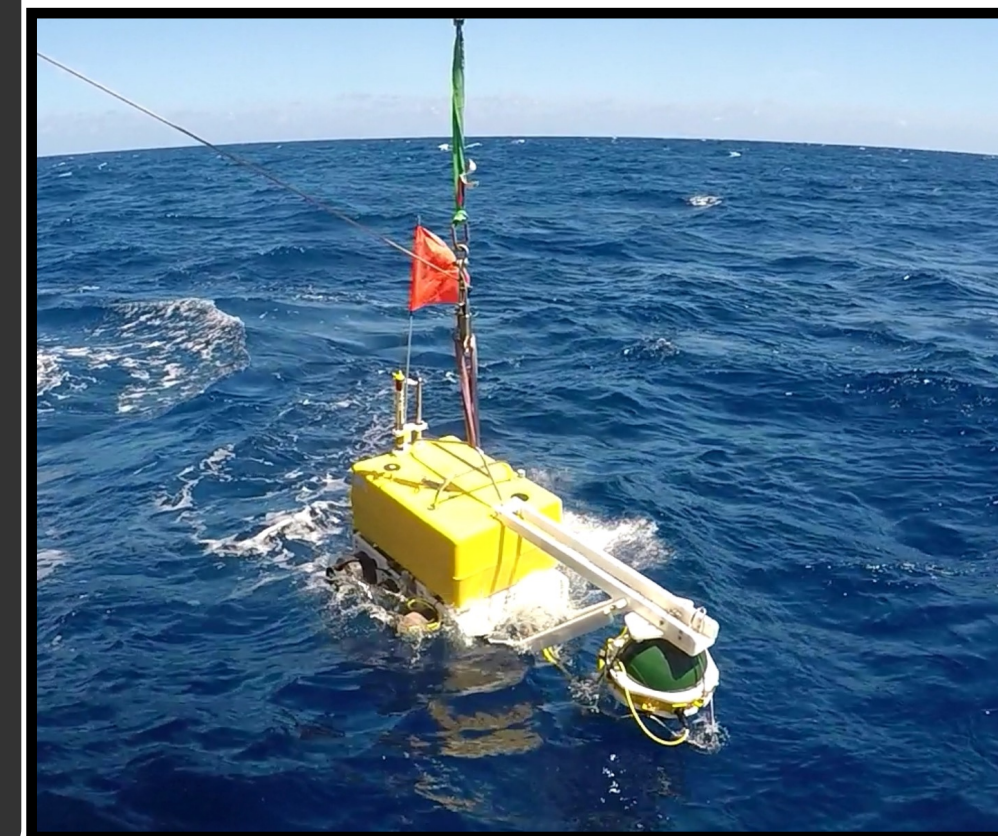
Harmon et al., 2020; Wang et al., 2020; Rychert et al., 2021



Pacific Array of Arrays



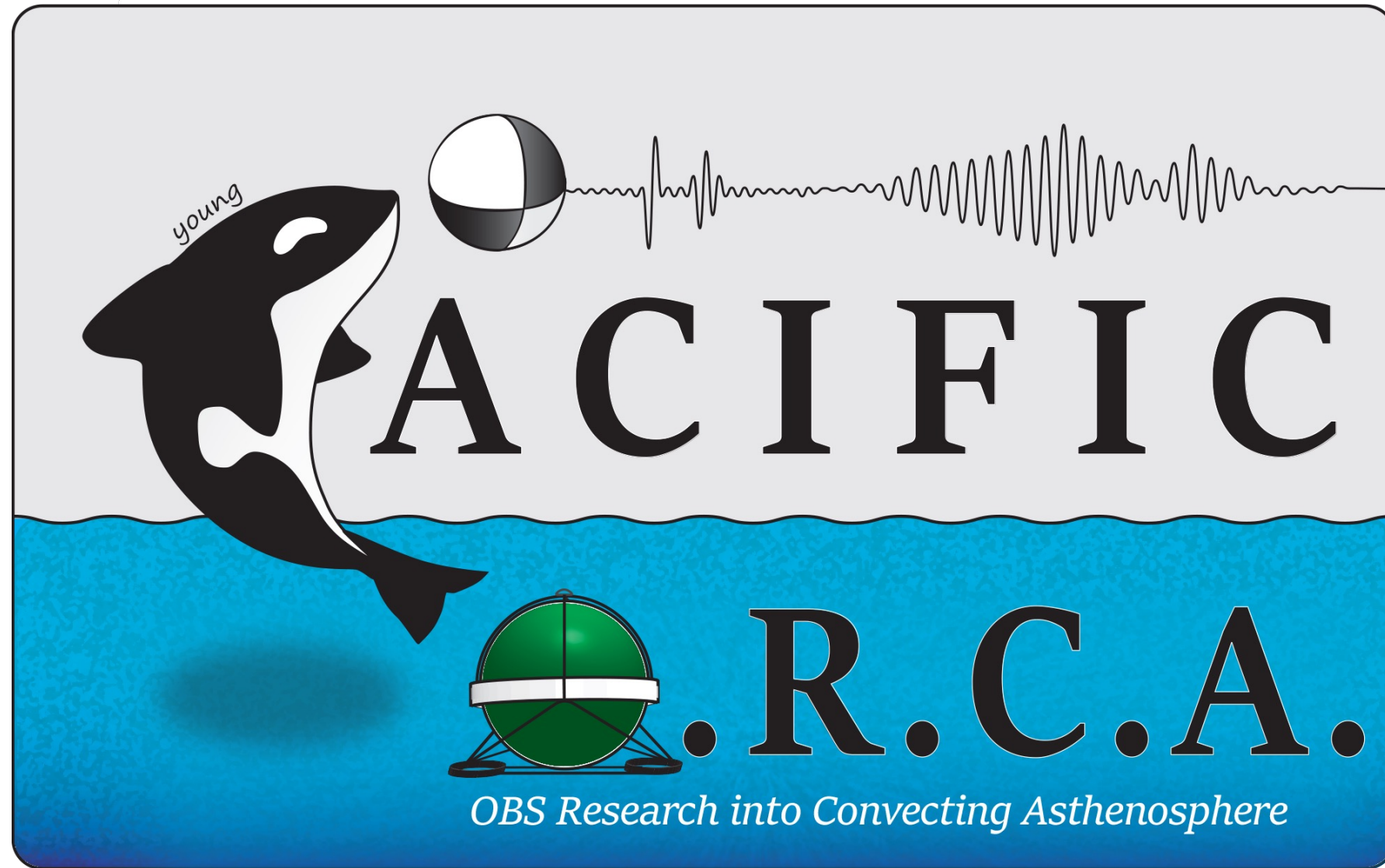
○ Funded ☆ Deployed ★ Completed



Richards et al., 2020

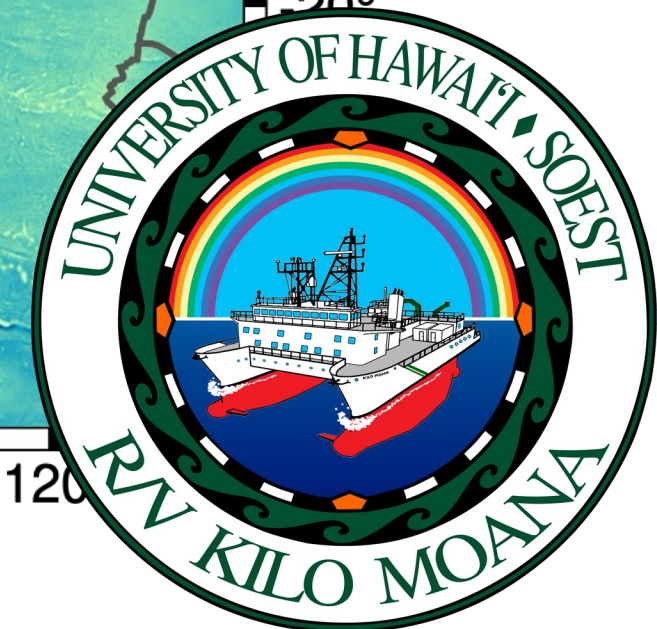
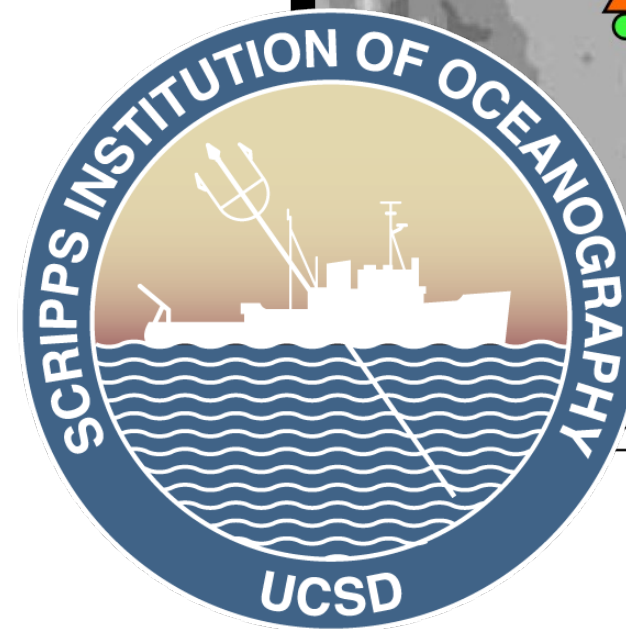
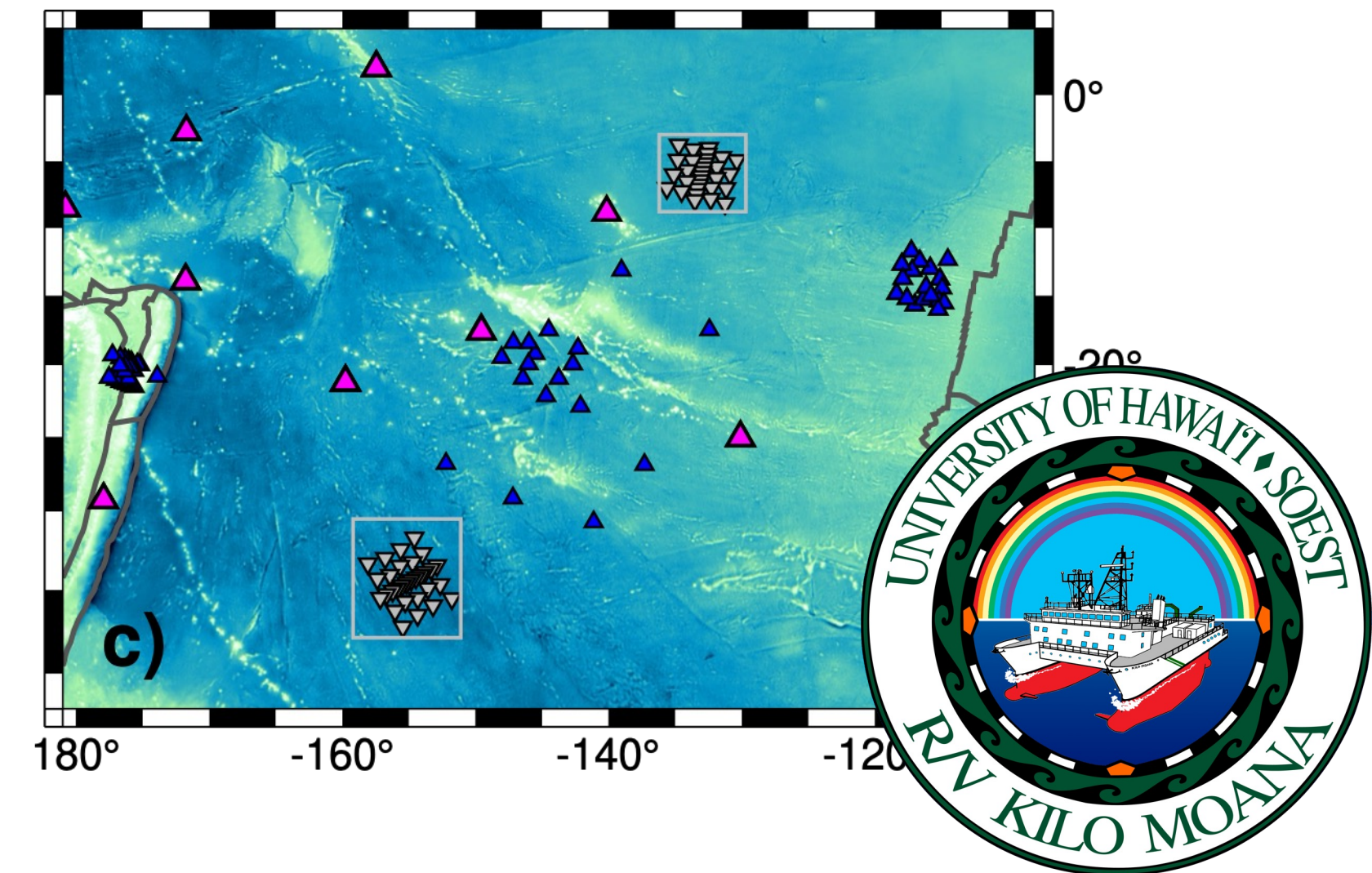
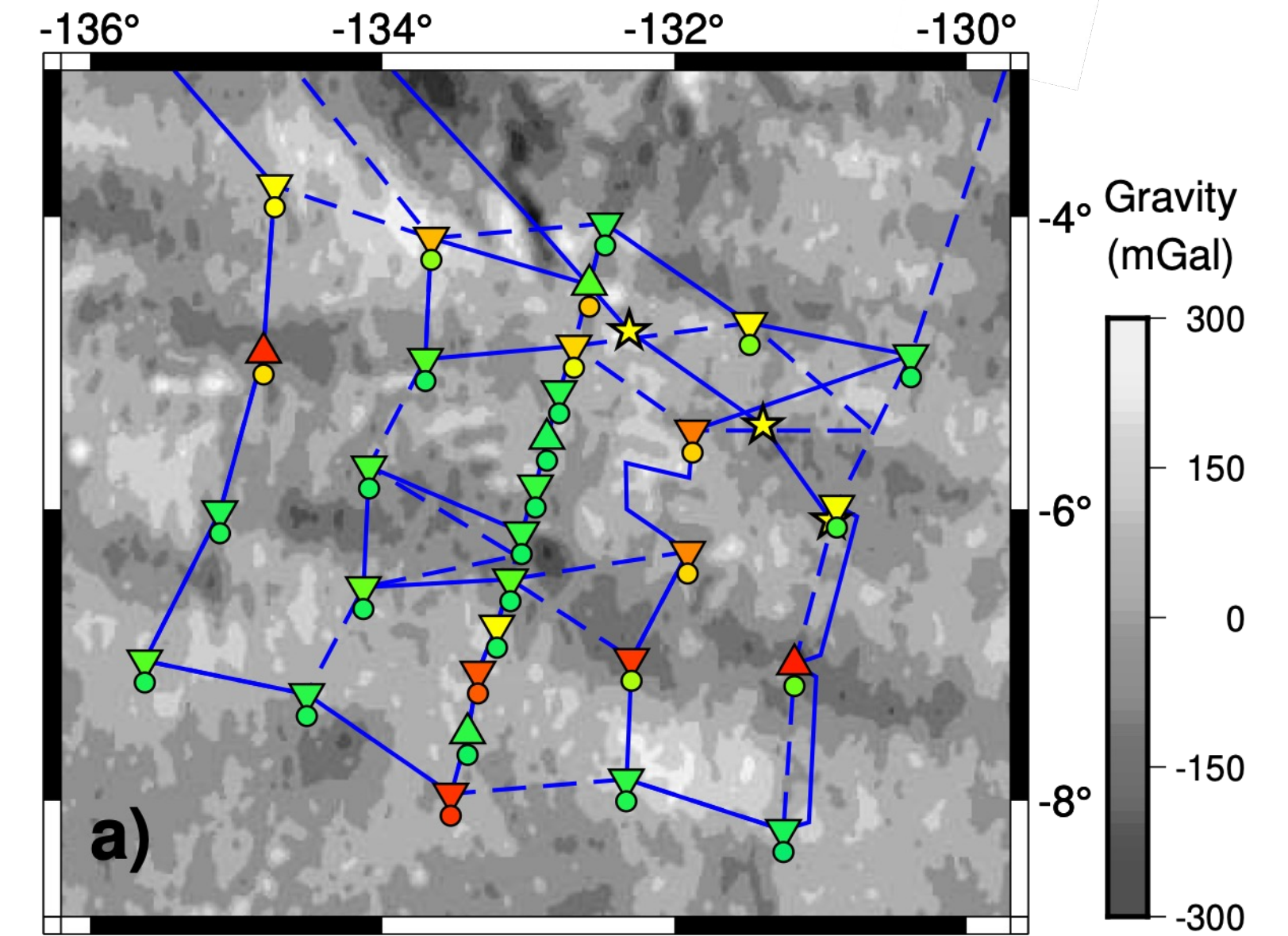
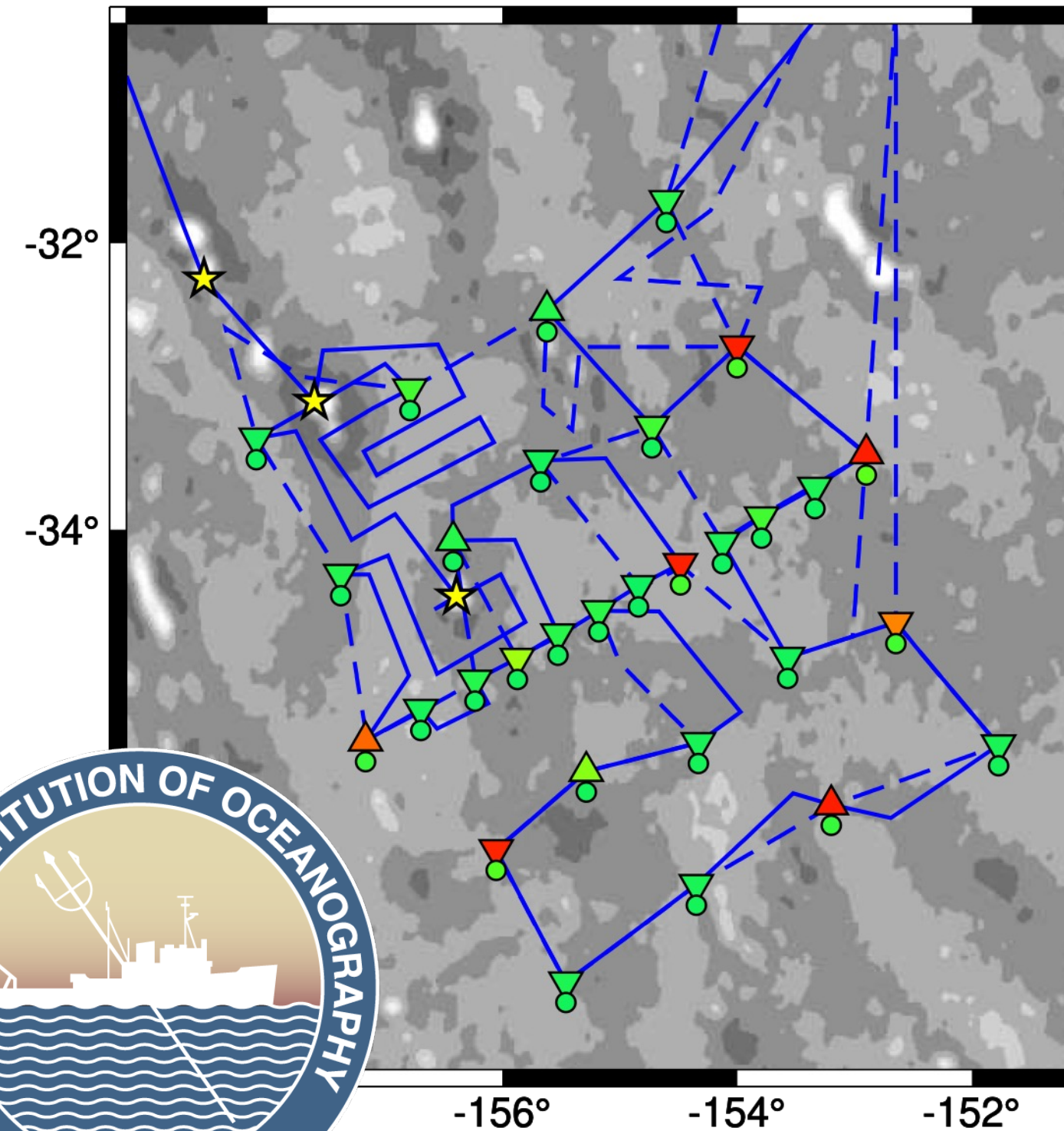
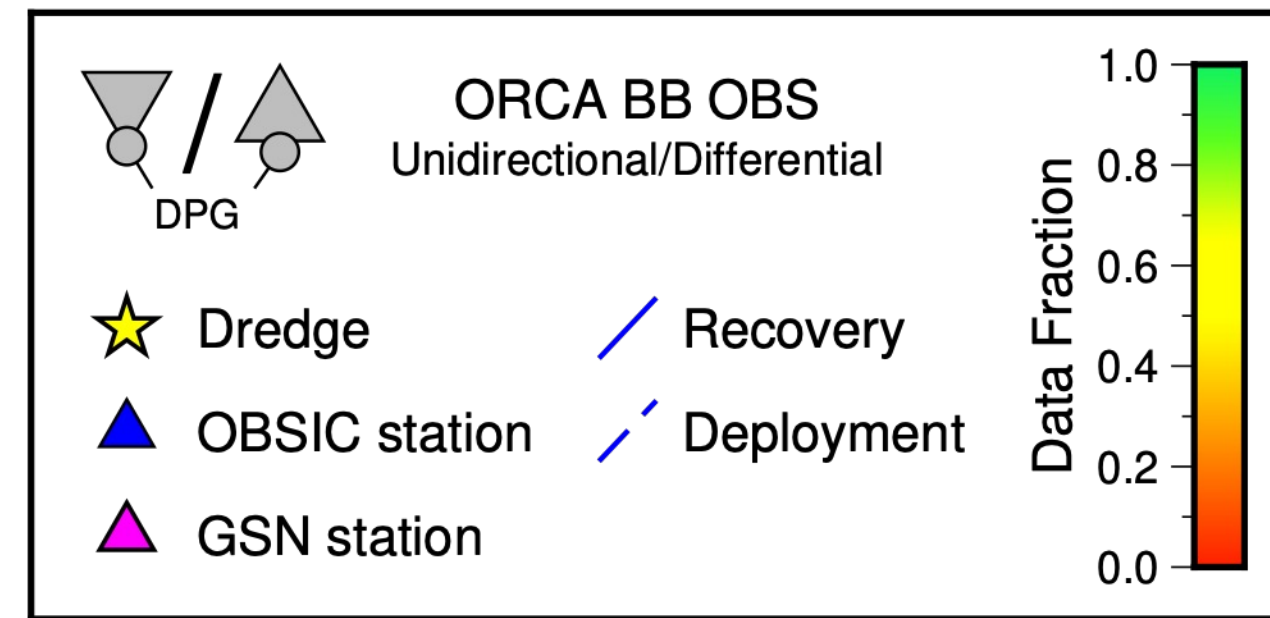
H. Kawakatsu
<http://eri-ndc.eri.u-tokyo.ac.jp/PacificArray/>
 as of 26/4/2023

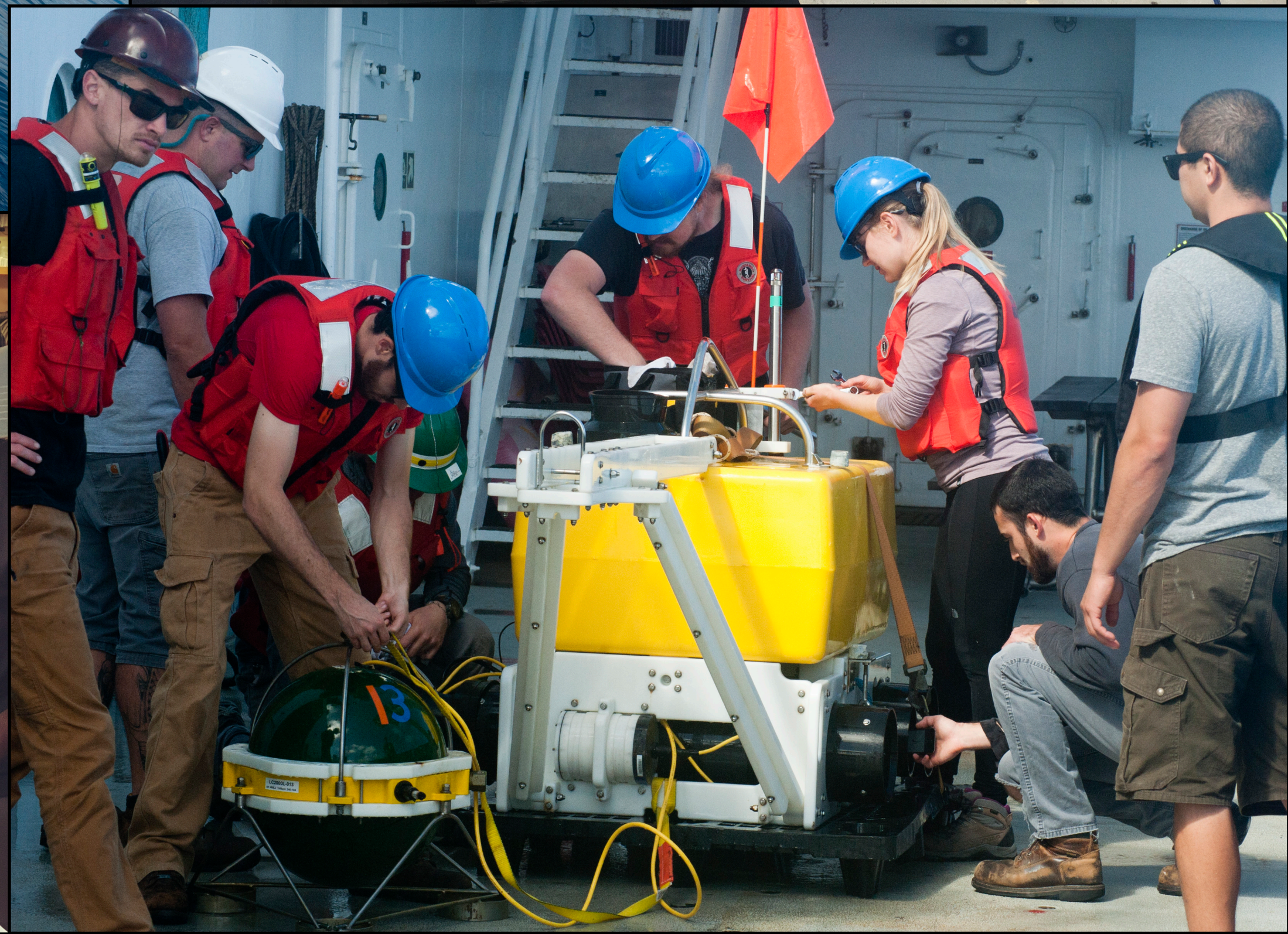
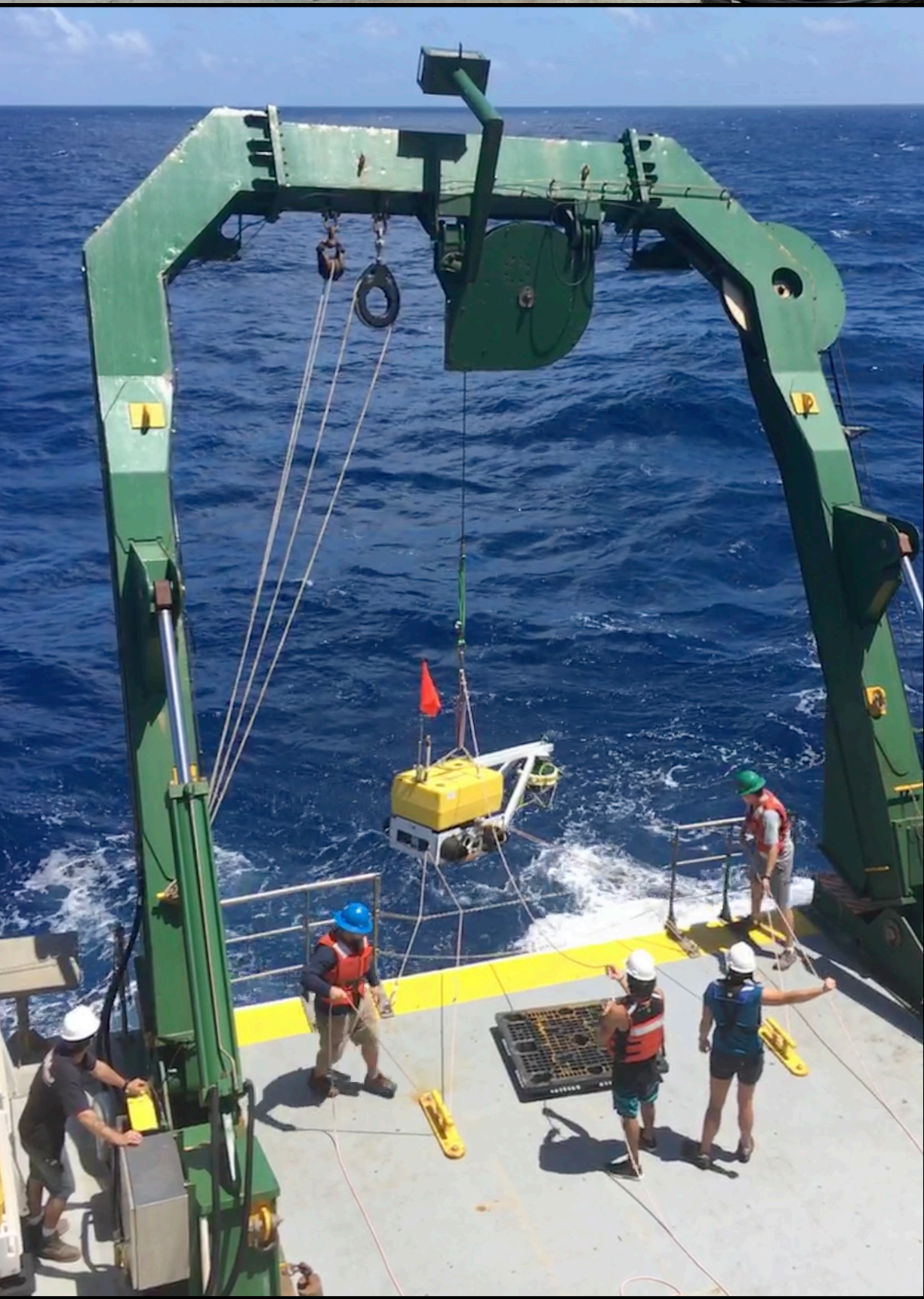
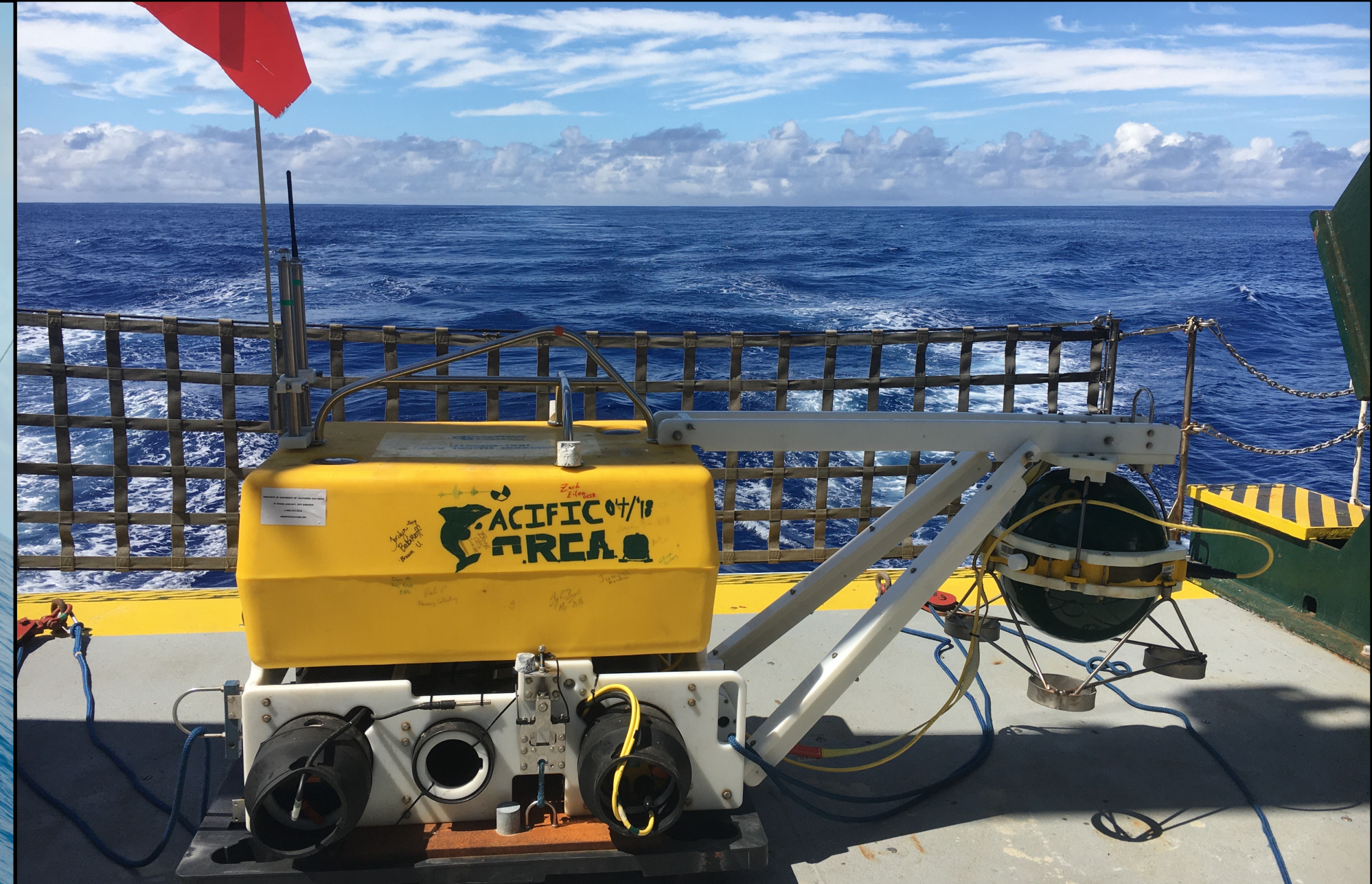
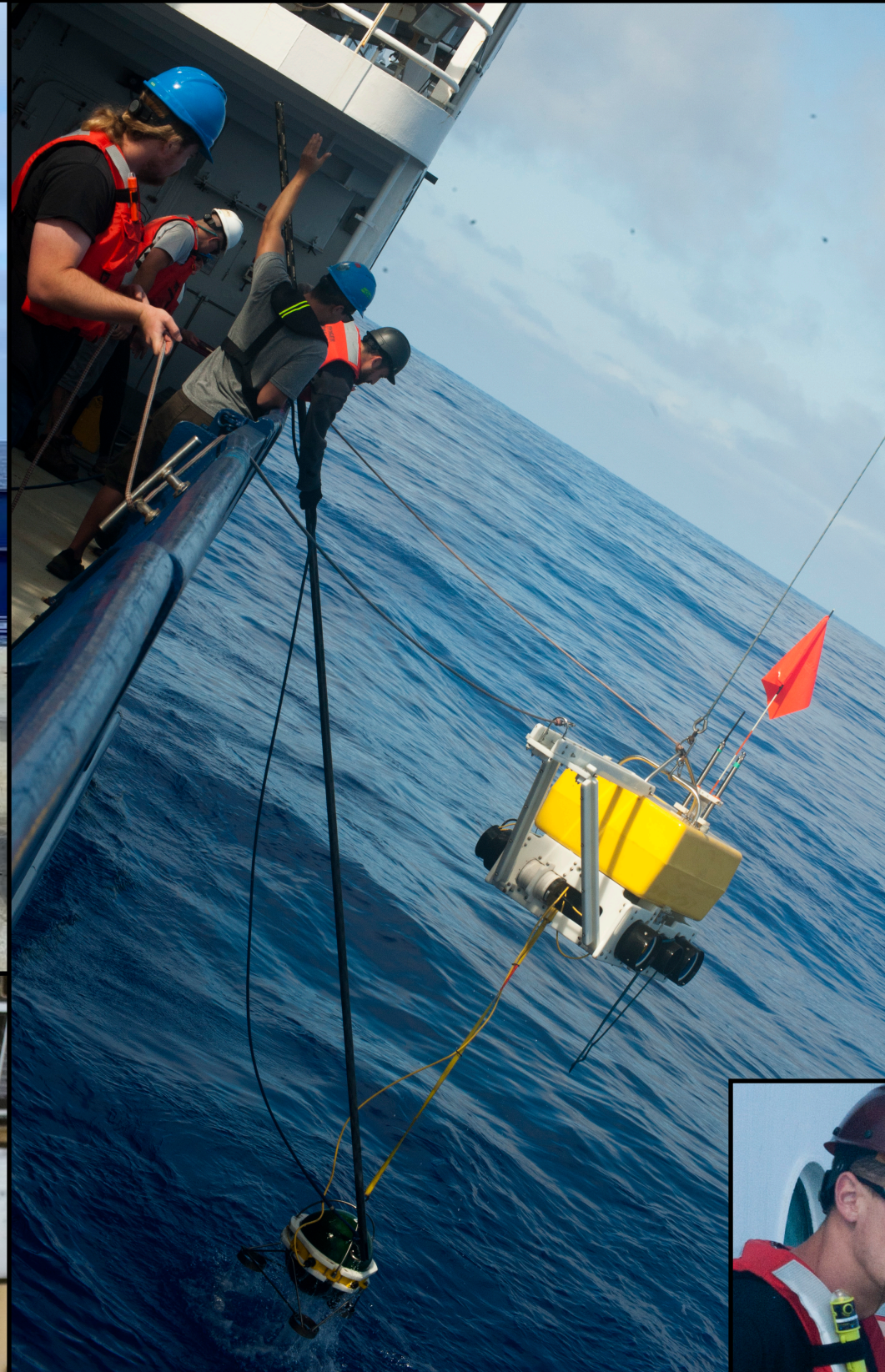
Pacific ORCA experiment



Pls Gaherty (NAU), Eilon (UCSB), Forsyth (Brown)

- ▶ 2 arrays
- ▶ 30 SIO BBOBS
- ▶ 3x R/V Kilo Moana
1x R/V Roger Revelle
- ▶ ~13 months
- ▶ 100% instrument recovery

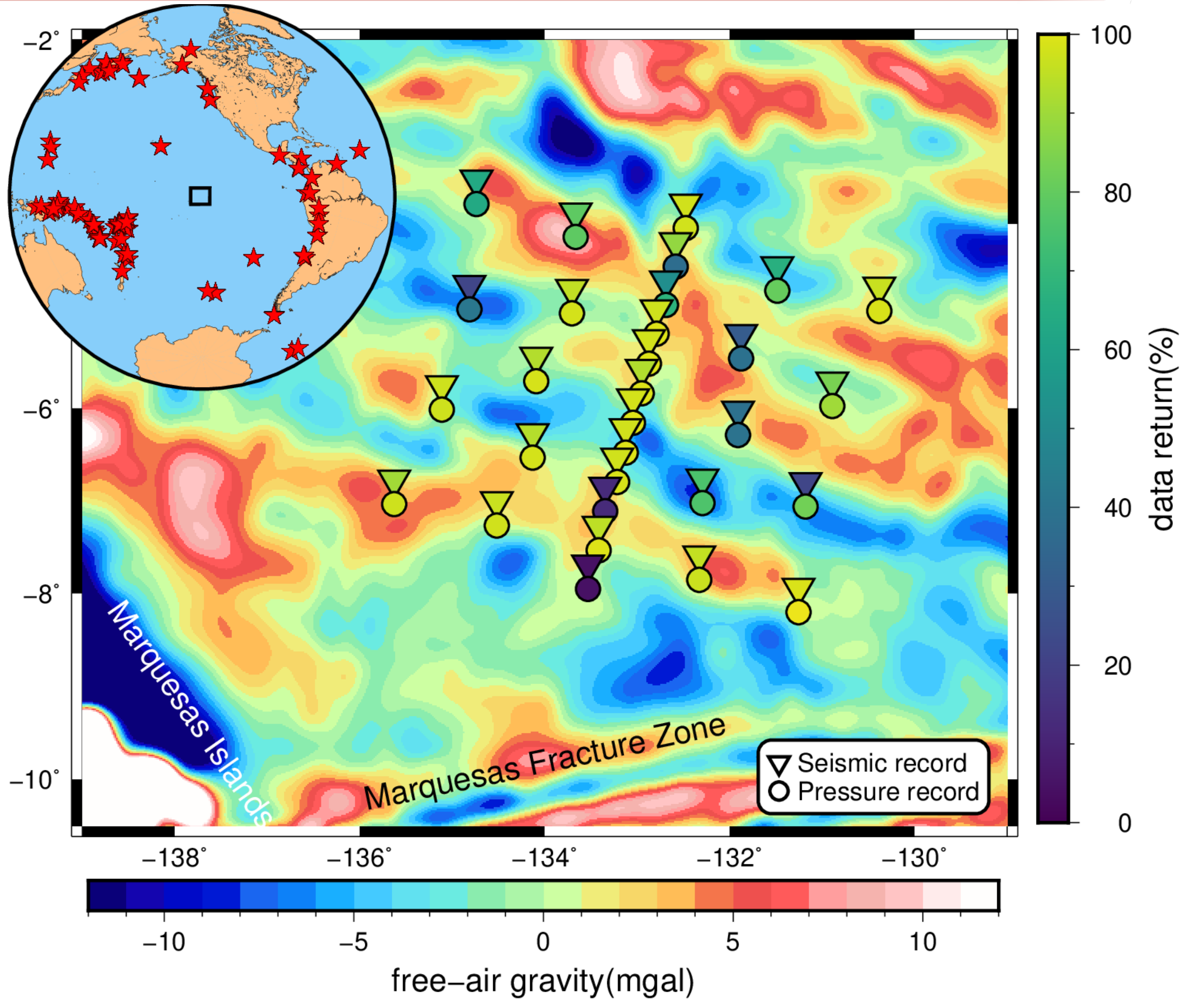
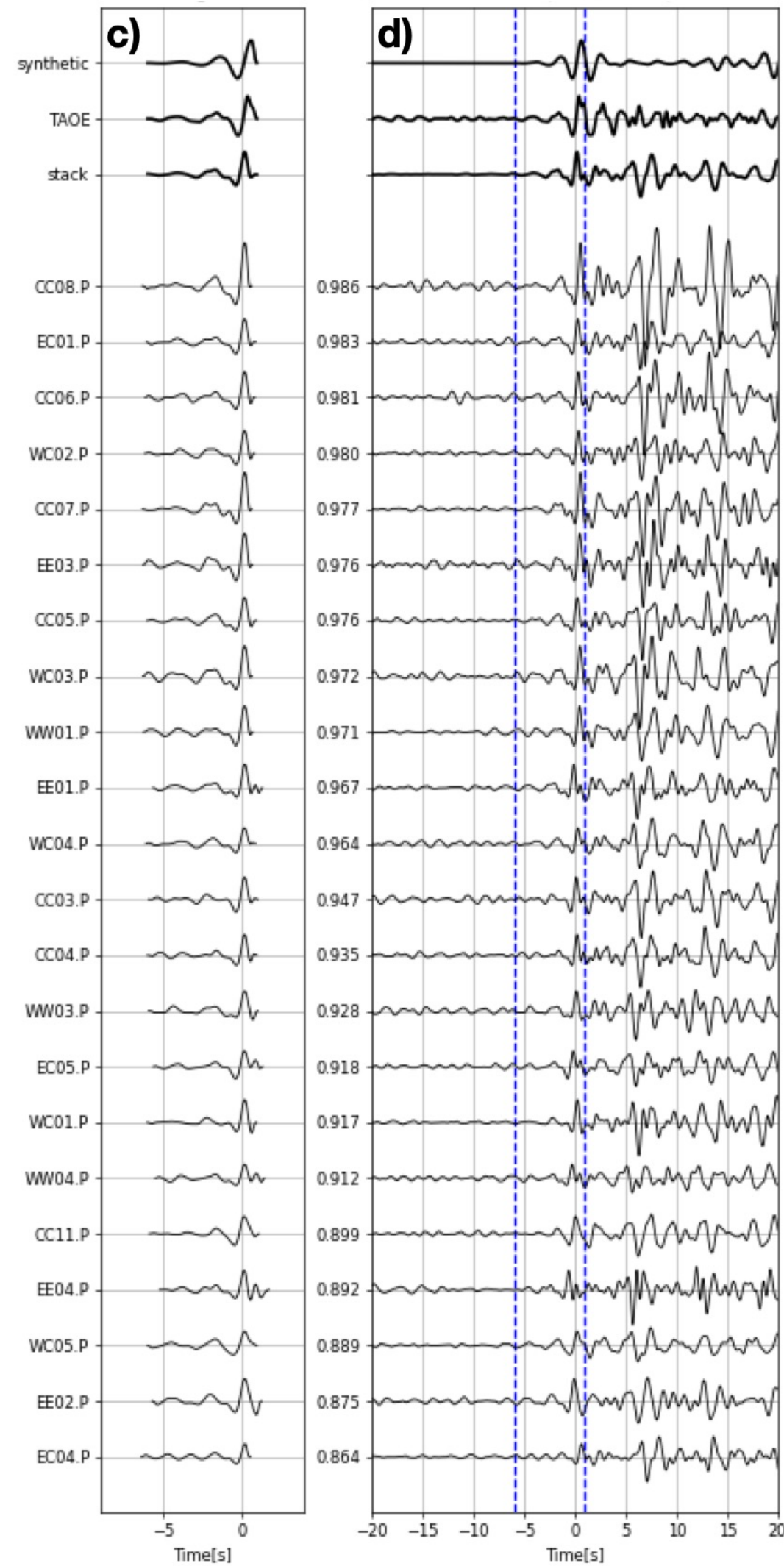
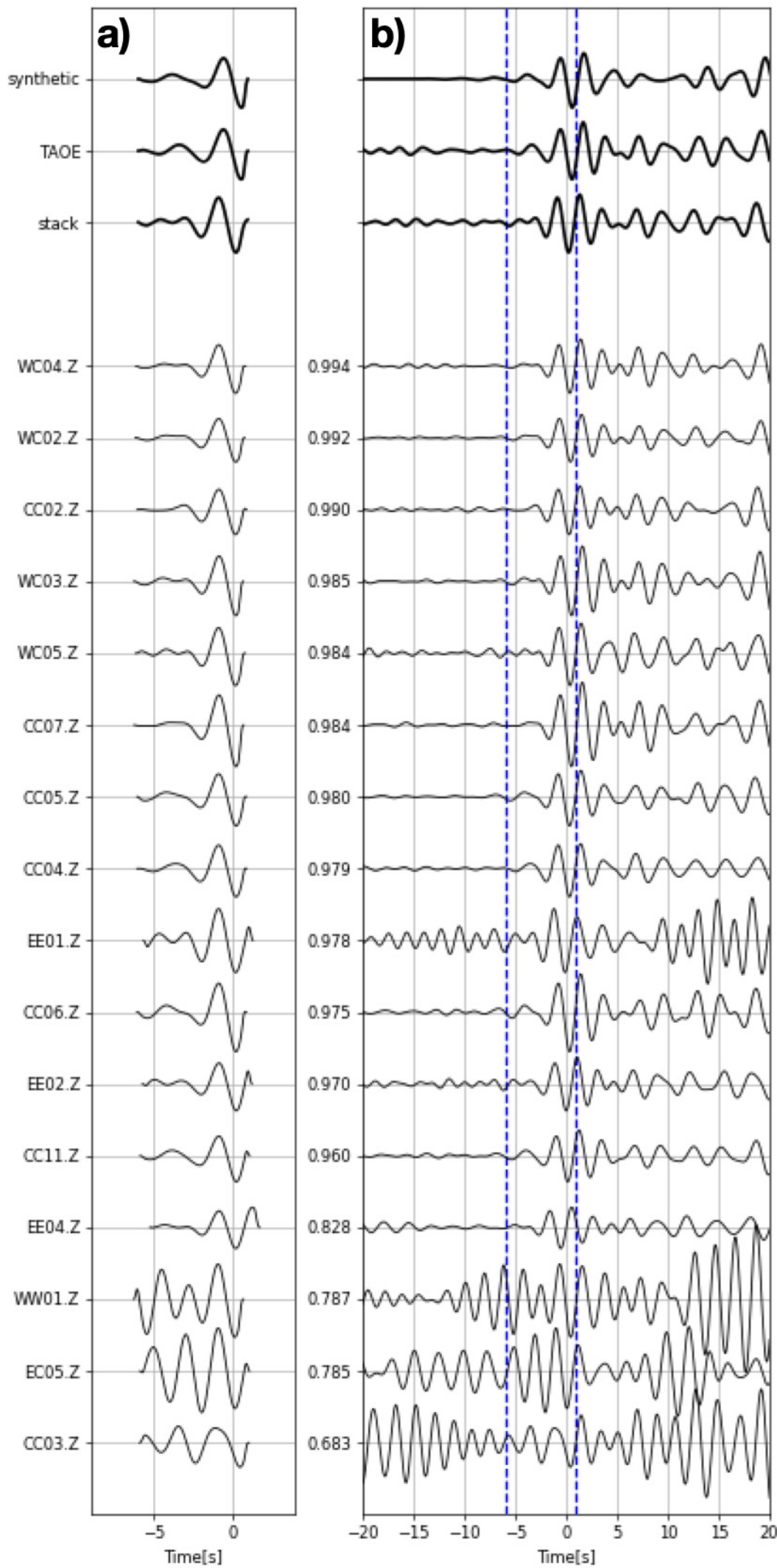




Telesismic data

BHZ 0.3-0.6 Hz

BDH 0.4-2.0 Hz

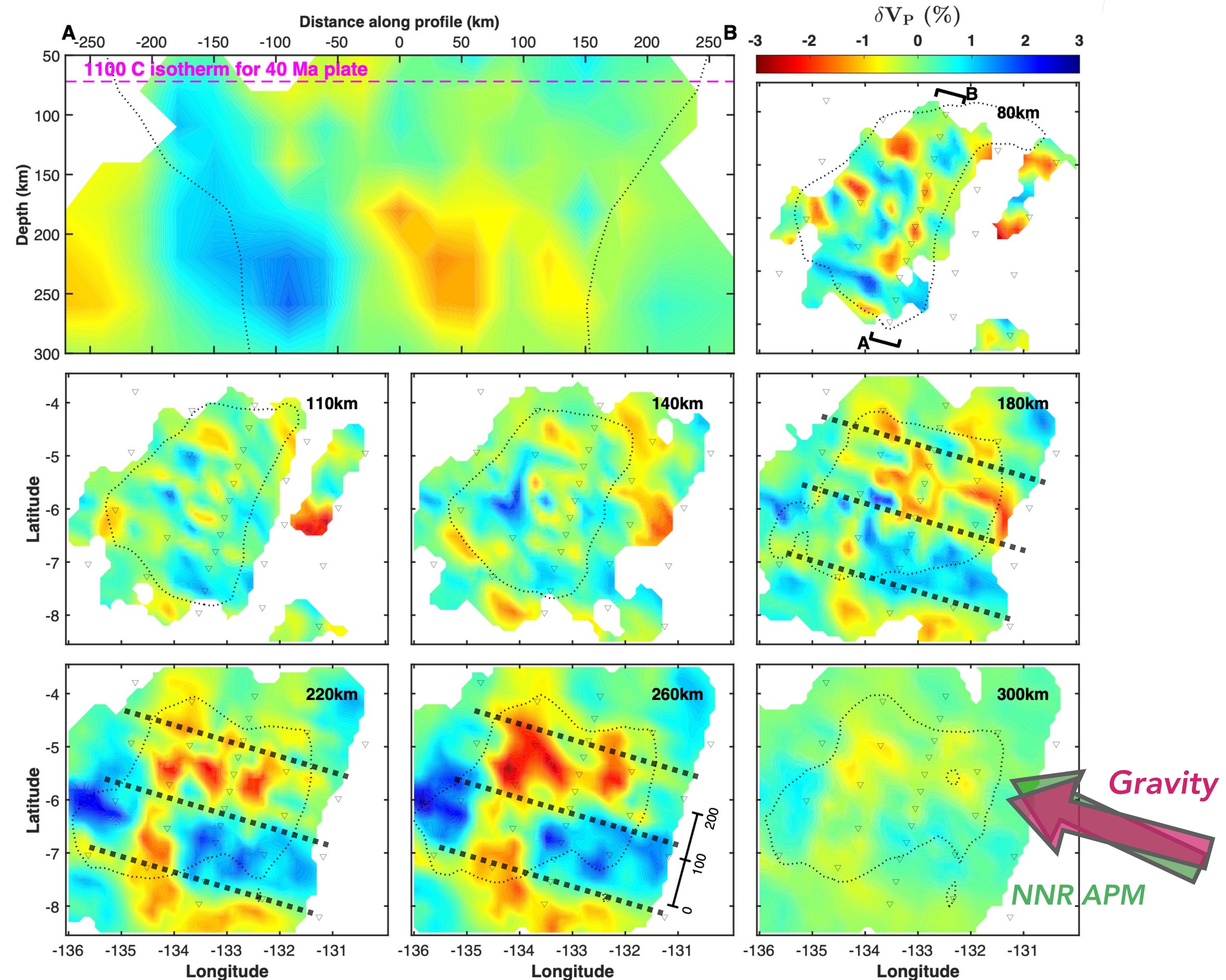


Example for $M_w 7.1$ on
2018-11-30, $\Delta \sim 68^\circ$

Travel time tomography - SSC imaged!

Key observations

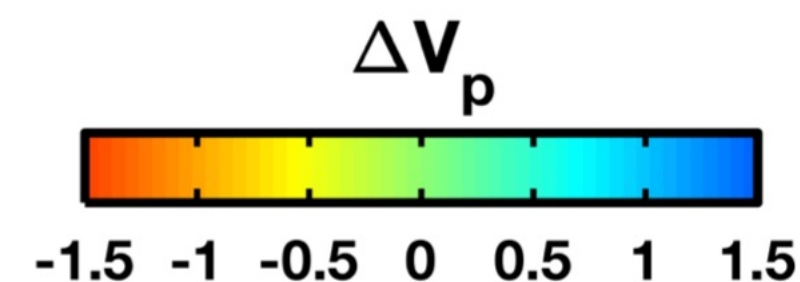
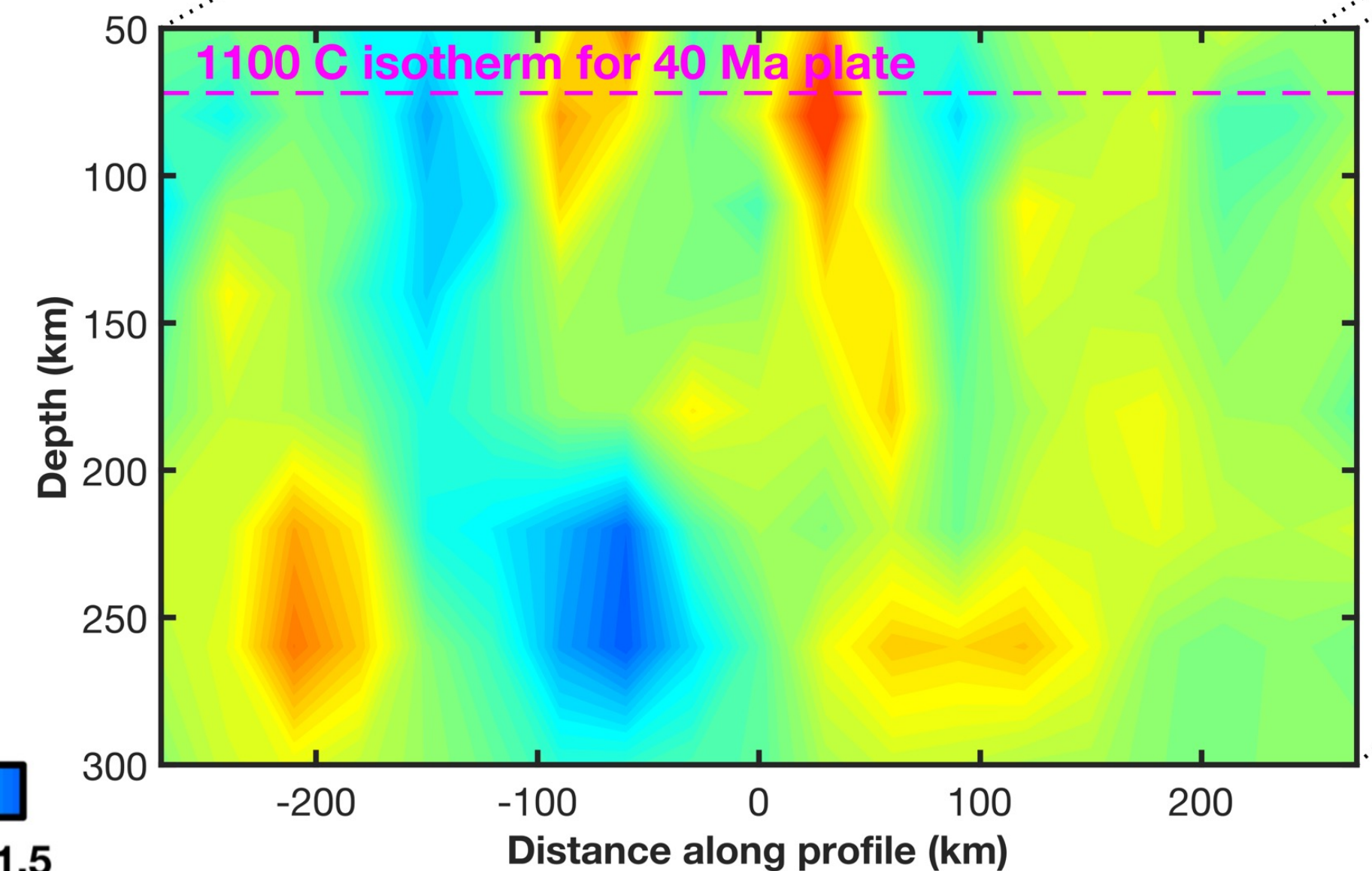
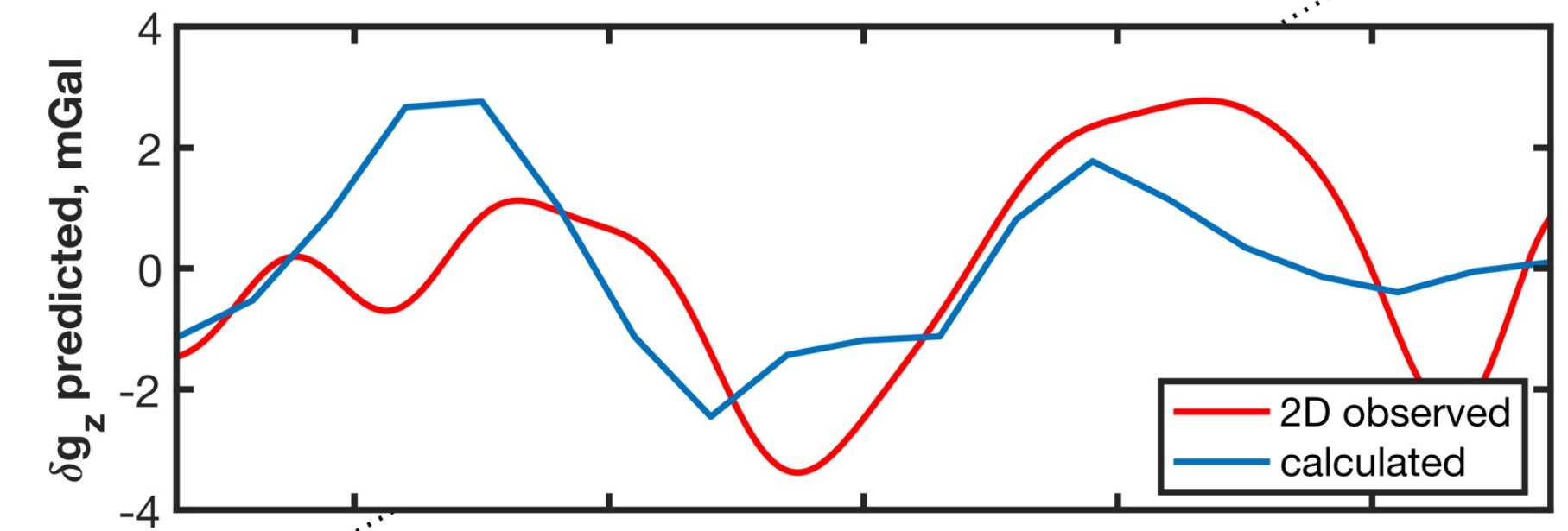
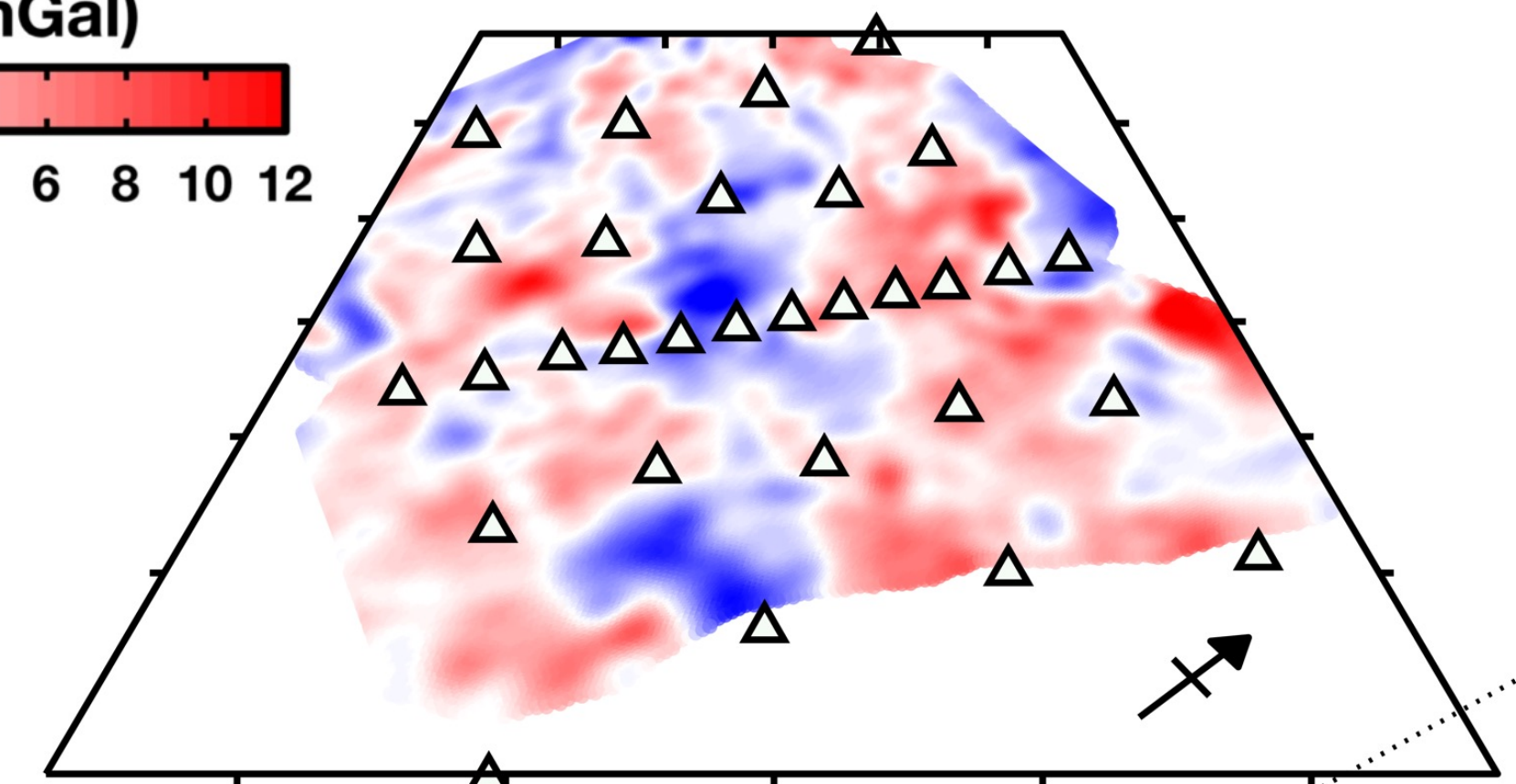
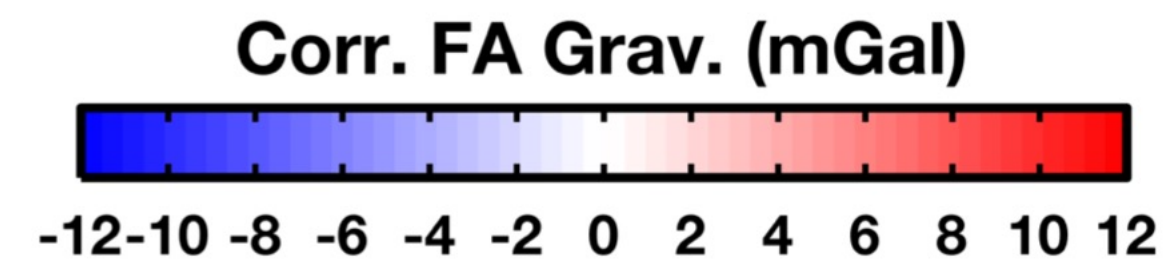
- ▶ $\pm 2\%$ P-wave velocity anomalies in upper mantle
- ▶ Lineations parallel to plate motion + gravity anomalies
- ▶ Wavelength 200-300 km
- ▶ Depth of strongest anomalies 180-280 km
- ▶ 40 Ma Onset age (hmmm..)



Eilon et al., 2022

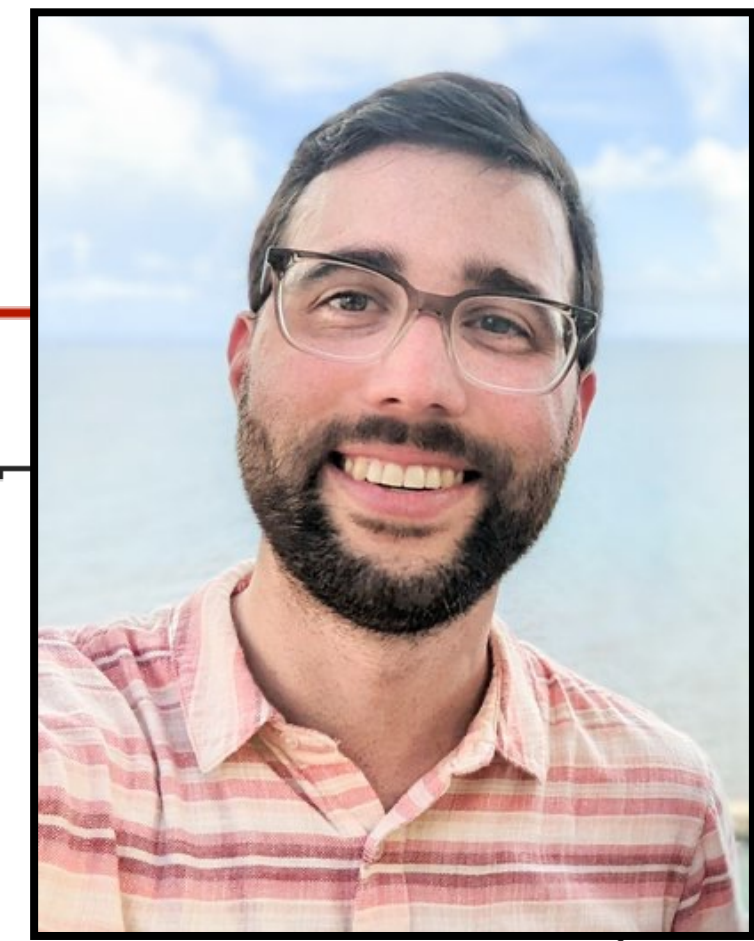
Vs to Gravity

- ▶ Collapse tomography to 2.5-D (along rolls)
- ▶ Collapse gravity variations down to 1-D (along rolls)
- ▶ Predict 1-D grav. from 2-D tomo.
 - ▶ Convert from velocity variation to temperature variation (**fraught**)
 - ▶ Convert from temperature to density variation (assume α)
 - ▶ Compute surface gravity anomalies (upward continuation)

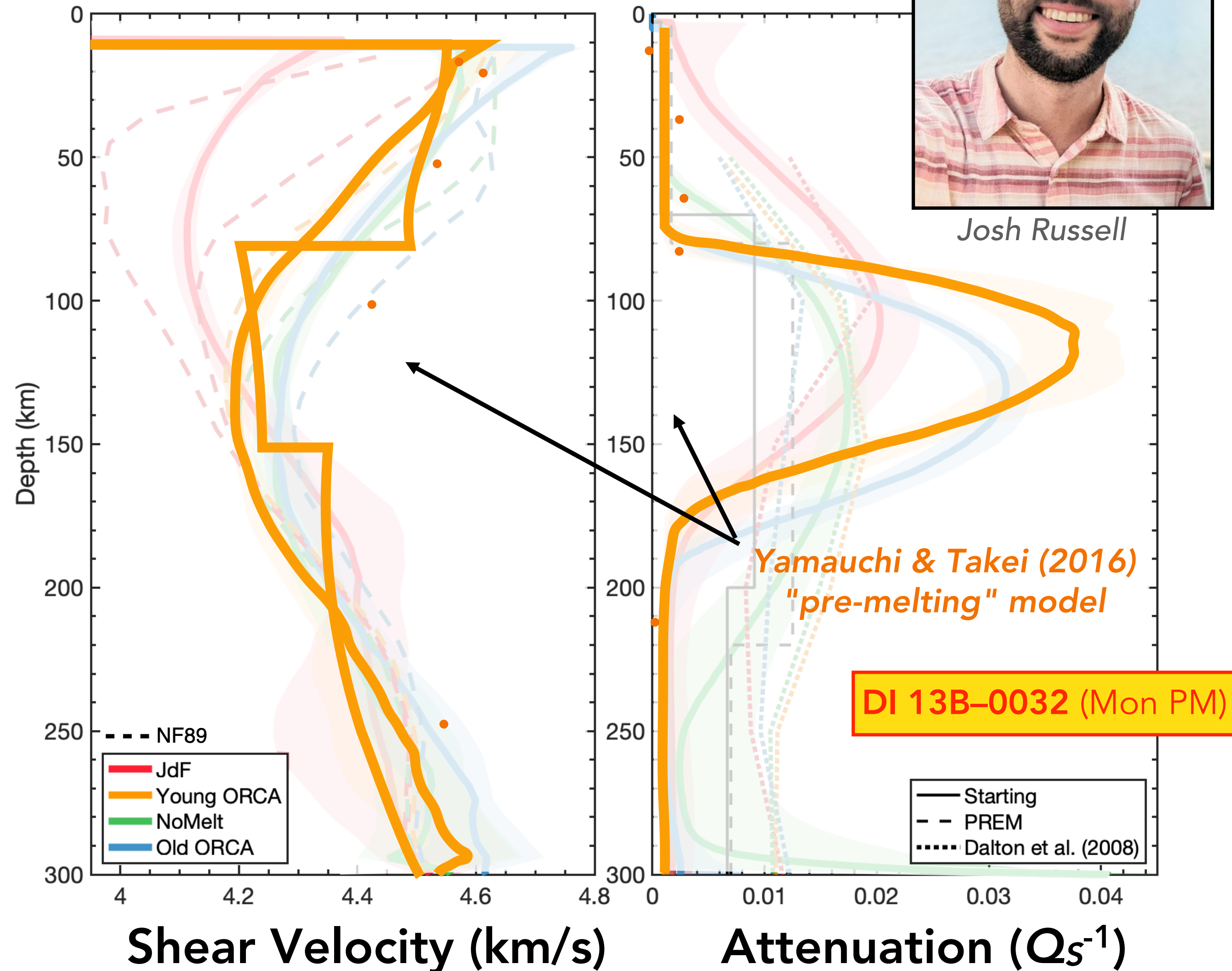


Velocity, attenuation from surface waves

- ▶ Earthquake and ambient noise Rayleigh waves
- ▶ Low velocities of Young ORCA upper mantle
- ▶ VERY high attenuation ($Q_s \sim 30$) in confined layer
- ▶ Observations not reconcilable with simple cooling - if temp. alone



Josh Russell



Russell et al., in prep

MCMC Bayesian approach

Initialize: $S = \{C_{H_2O}(z), d(z), T_P, z_{plate}\}$

Forward Modeling

$plate_cooling(t_{age}, T_P, z_{plate}) \rightarrow \{T\}$

$melting_model(T, P, C_{H_2O}, C_{CO_2}) \rightarrow \{\phi, C_{H_2O,s}, C_{CO_2,s}, T_{sol}\}$

$Perple_X(T, P, C) \rightarrow \{\rho, G, K\}$

$VBR(T, P, \rho, G, K, d, \phi, C_{H_2O,s}, T_{sol}) \rightarrow \{Q_\mu, V_S\}$

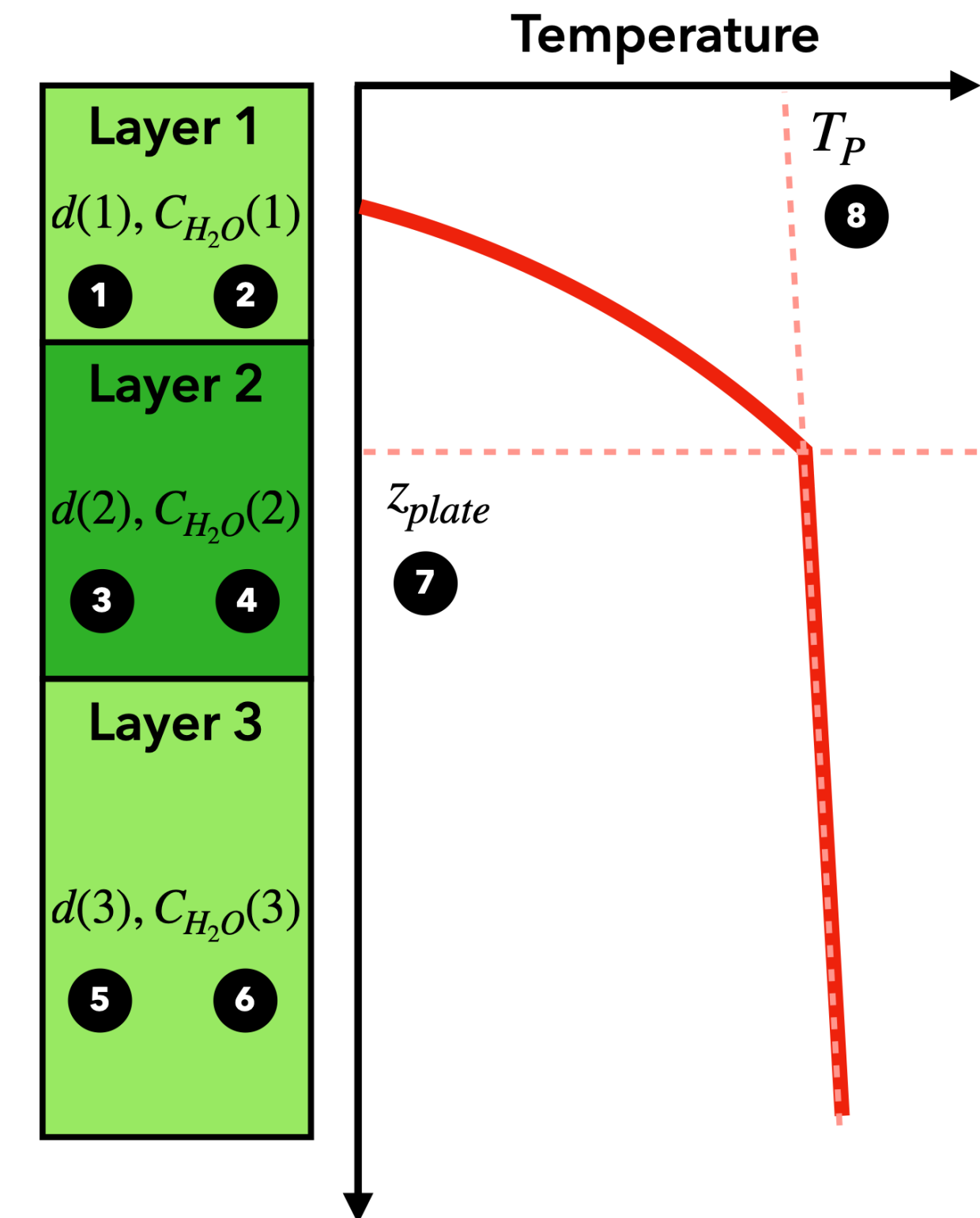
Perturb: $S = \{C_{H_2O}(z), d(z), T_P, z_{plate}\}$

Acceptance criterion

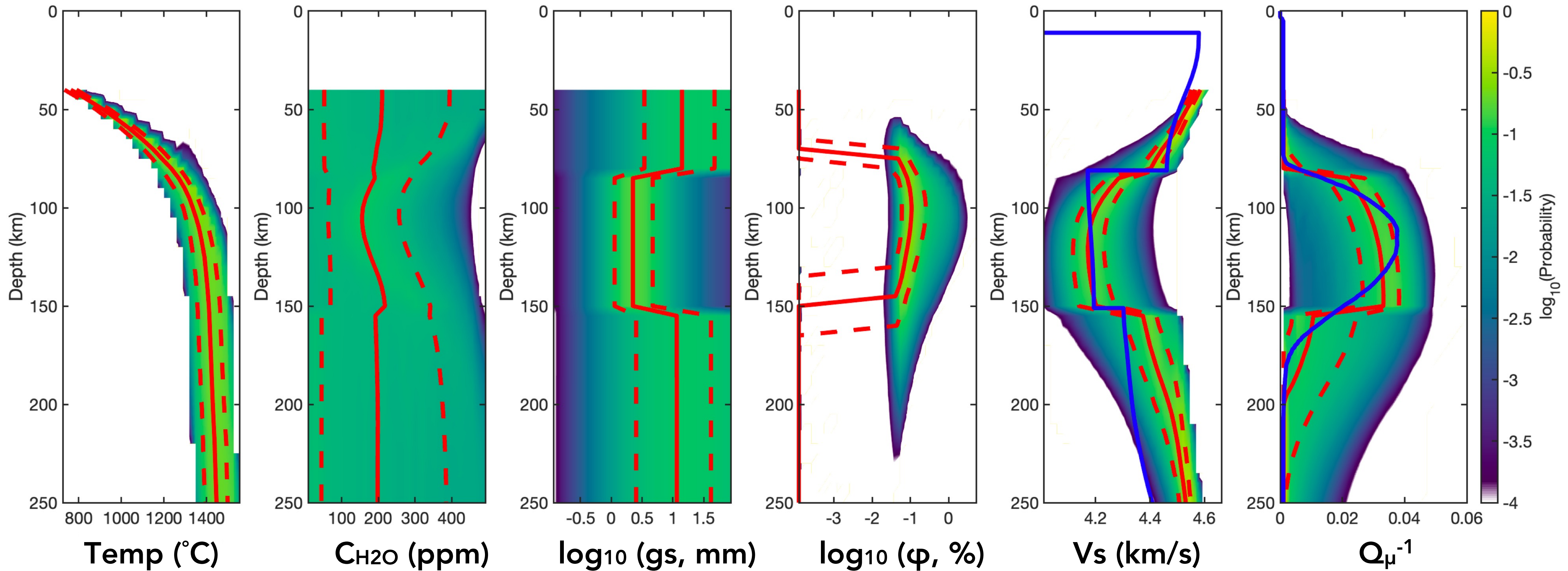
**Yes = save
No = discard**

$misfit(V_S, Q_\mu, V_S^{obs}, Q_\mu^{obs}) \rightarrow \chi^2$

$p(S|V_S, Q^{-1}) = p(V_S|S) \cdot p(Q^{-1}|S) \cdot p(S)$



A refined picture of the oceanic asthenosphere



*Somewhat hydrated
upper end of MORB*

LgZ?

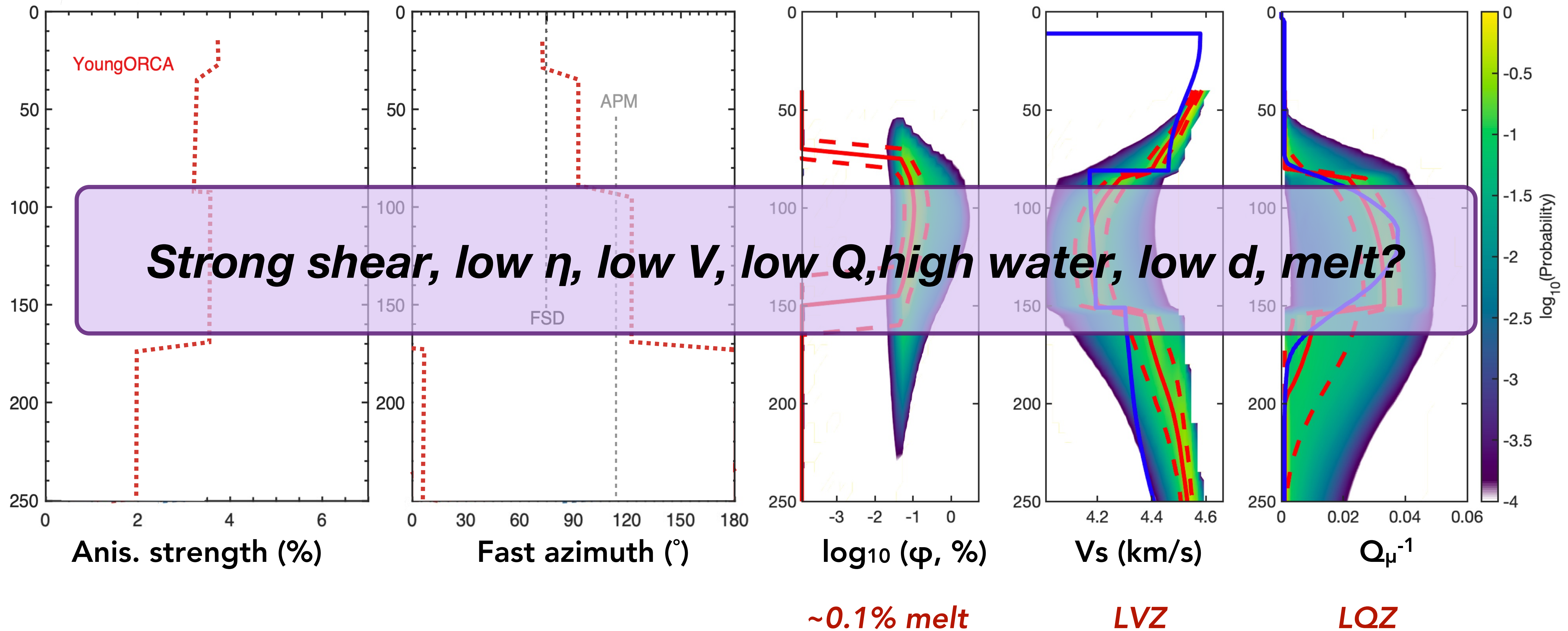
~0.1% melt

LVZ

LQZ

Russell et al., in prep

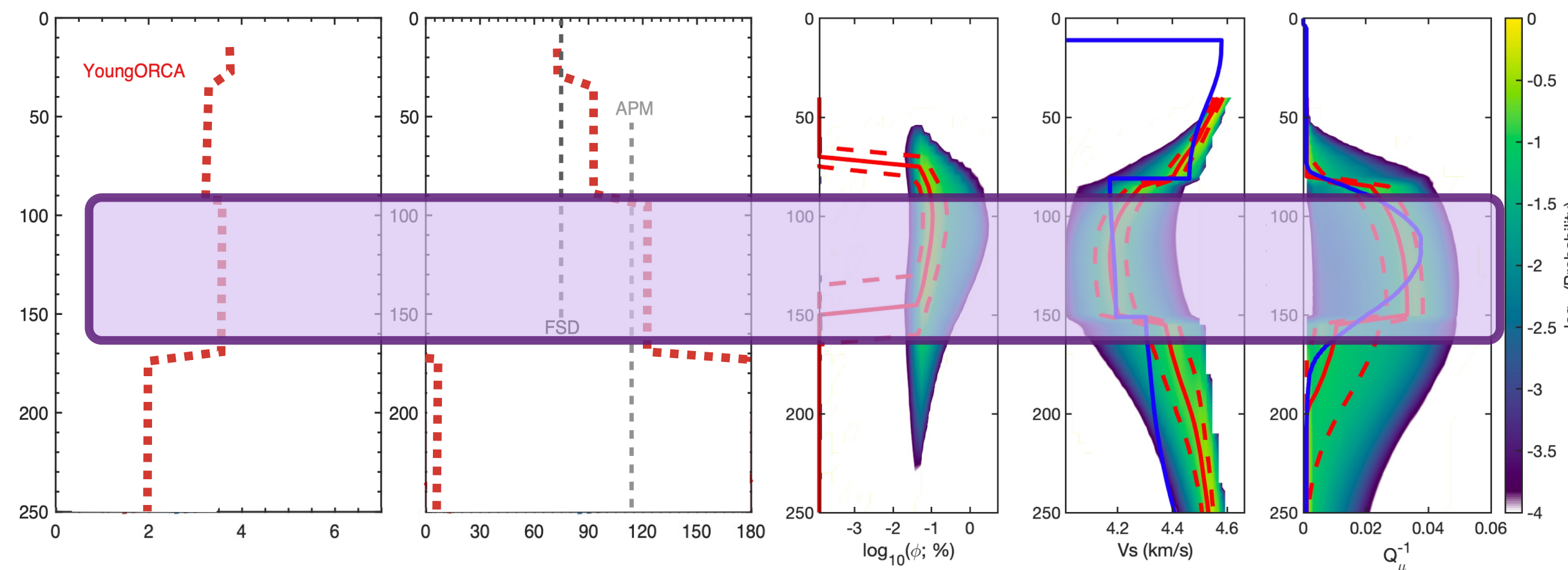
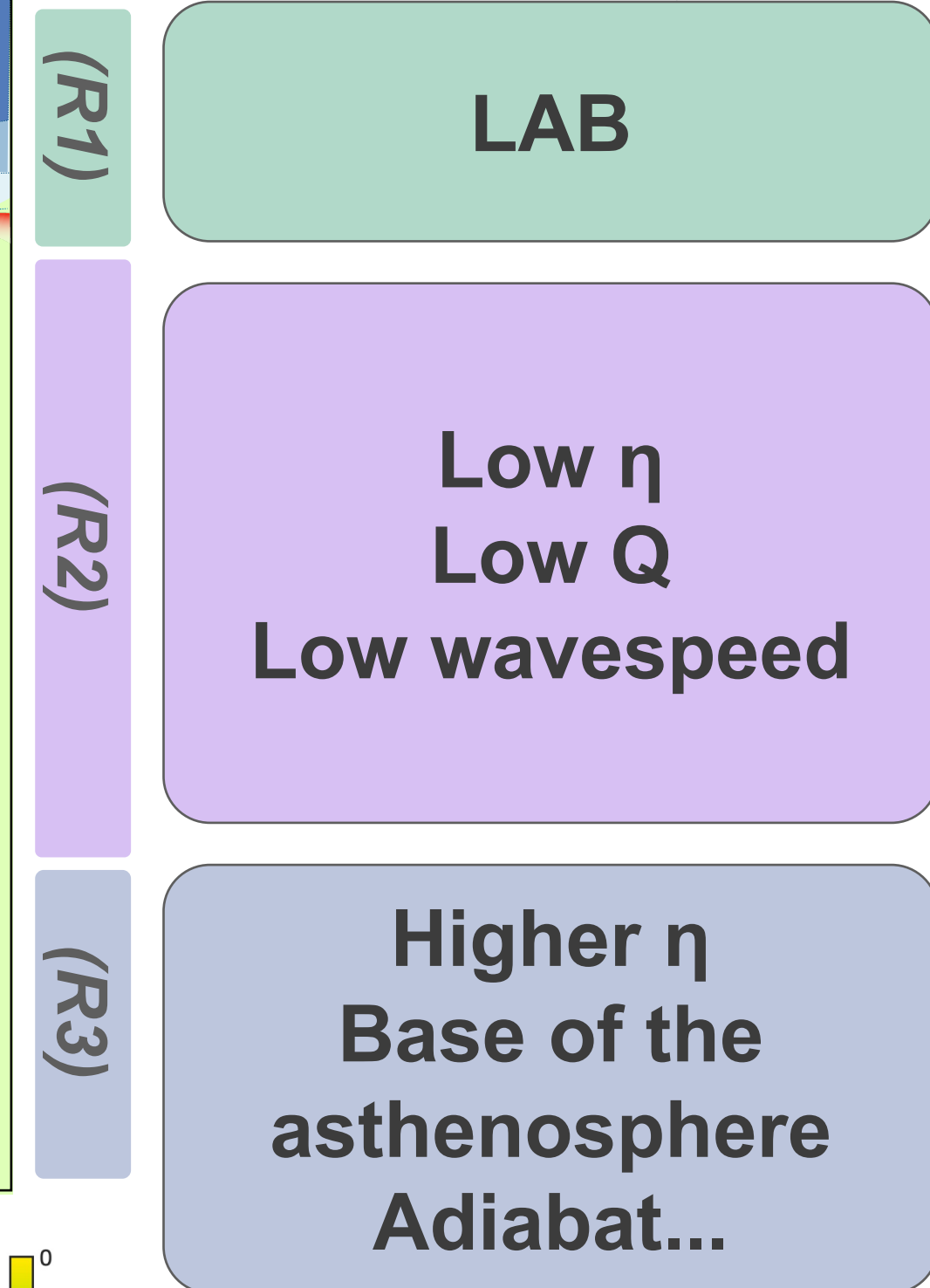
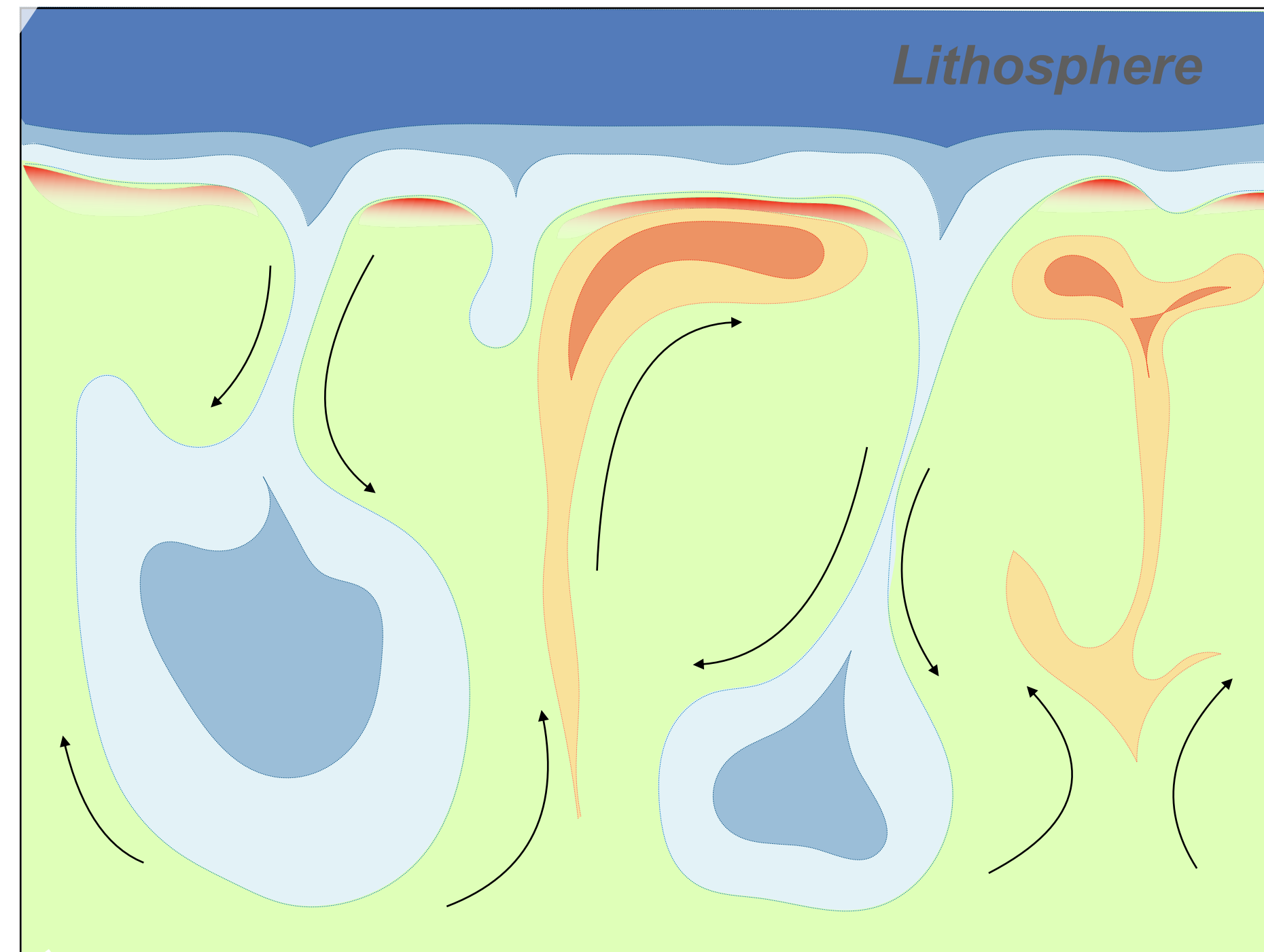
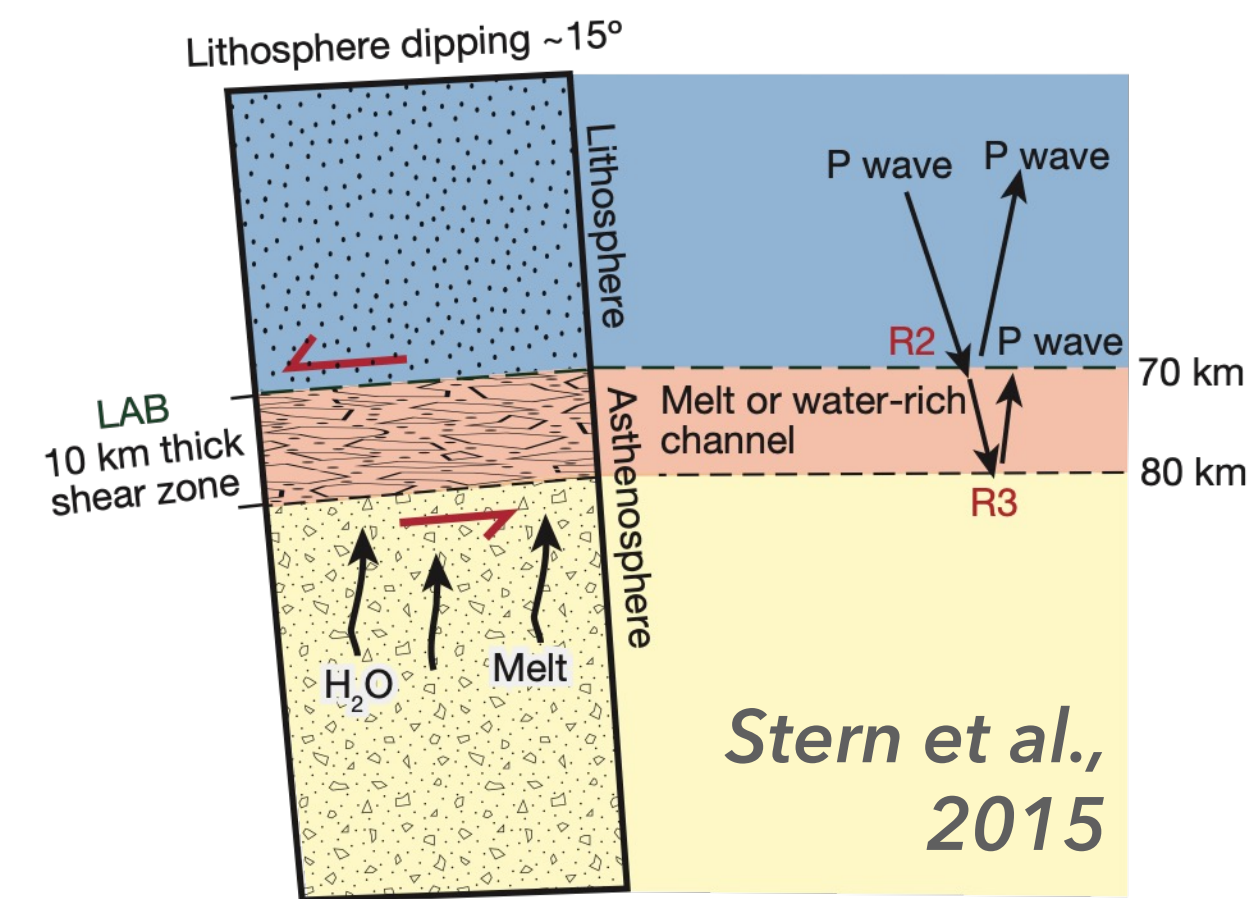
A refined picture of the oceanic asthenosphere



Russell et al., in prep

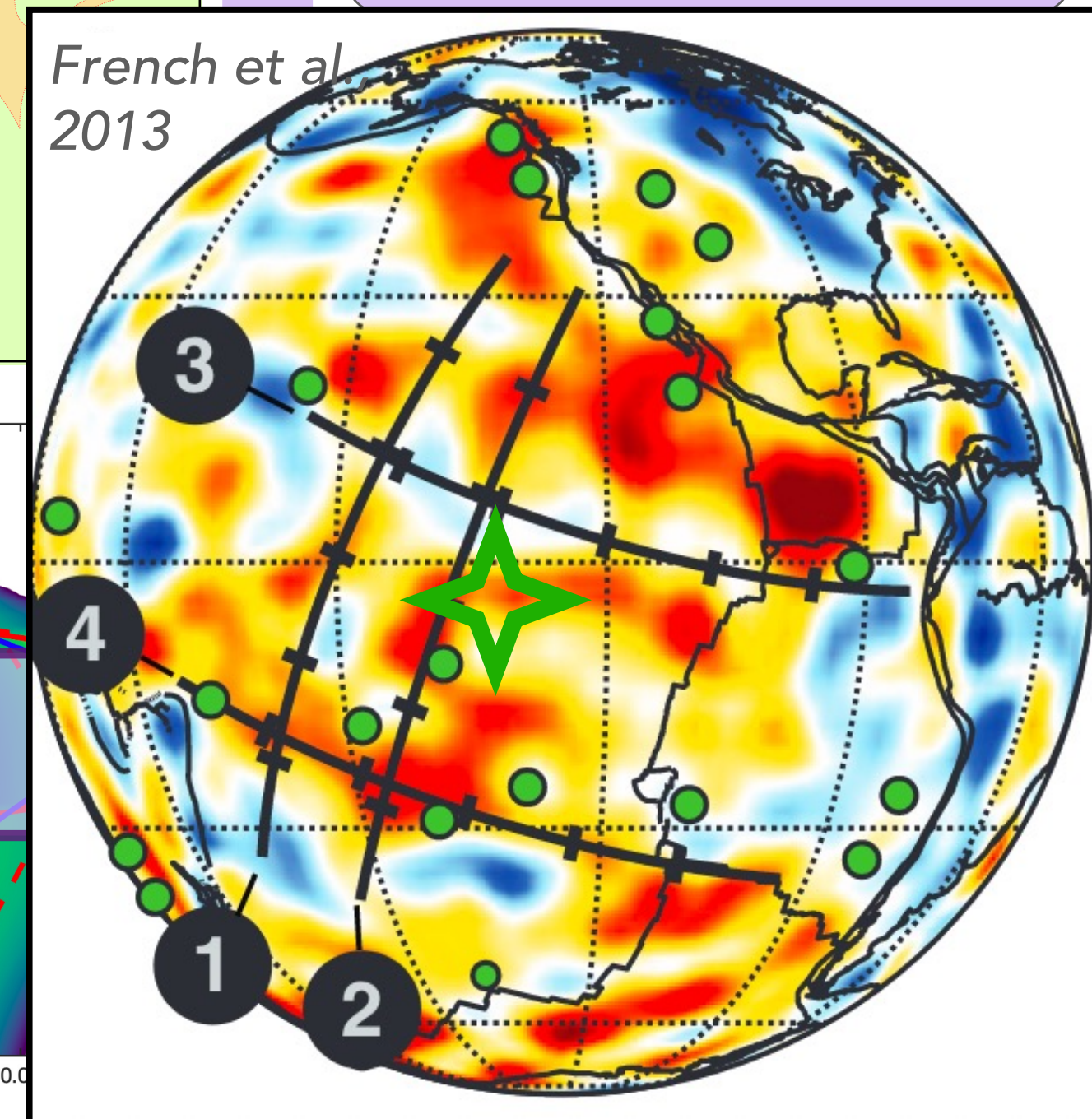
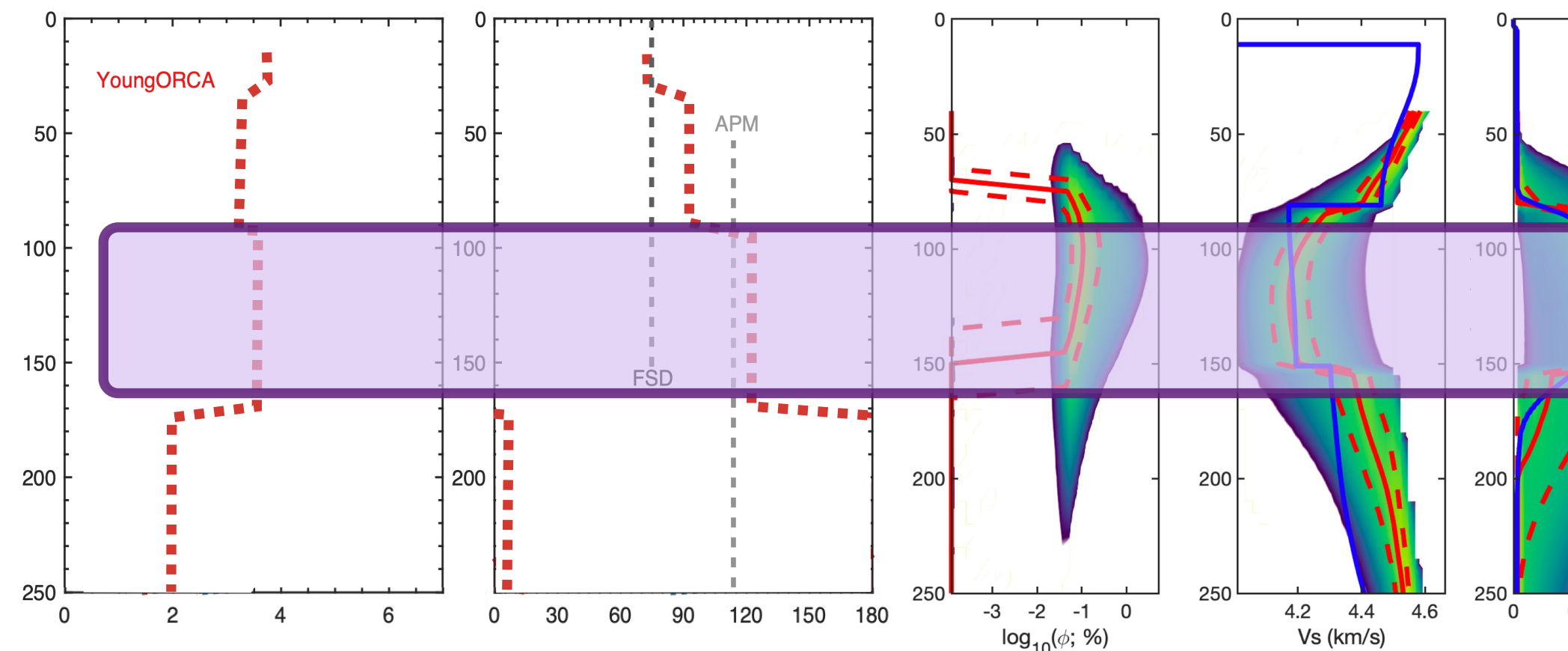
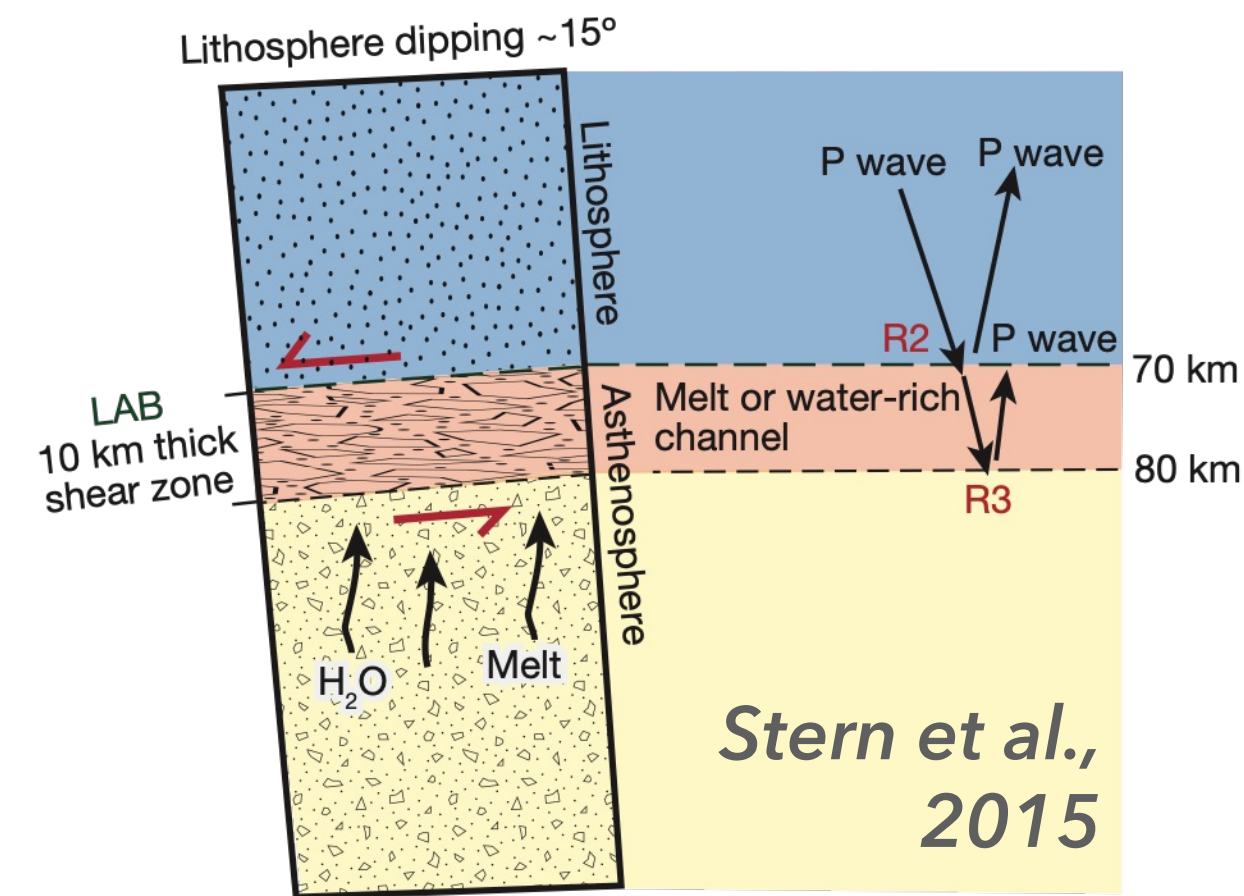
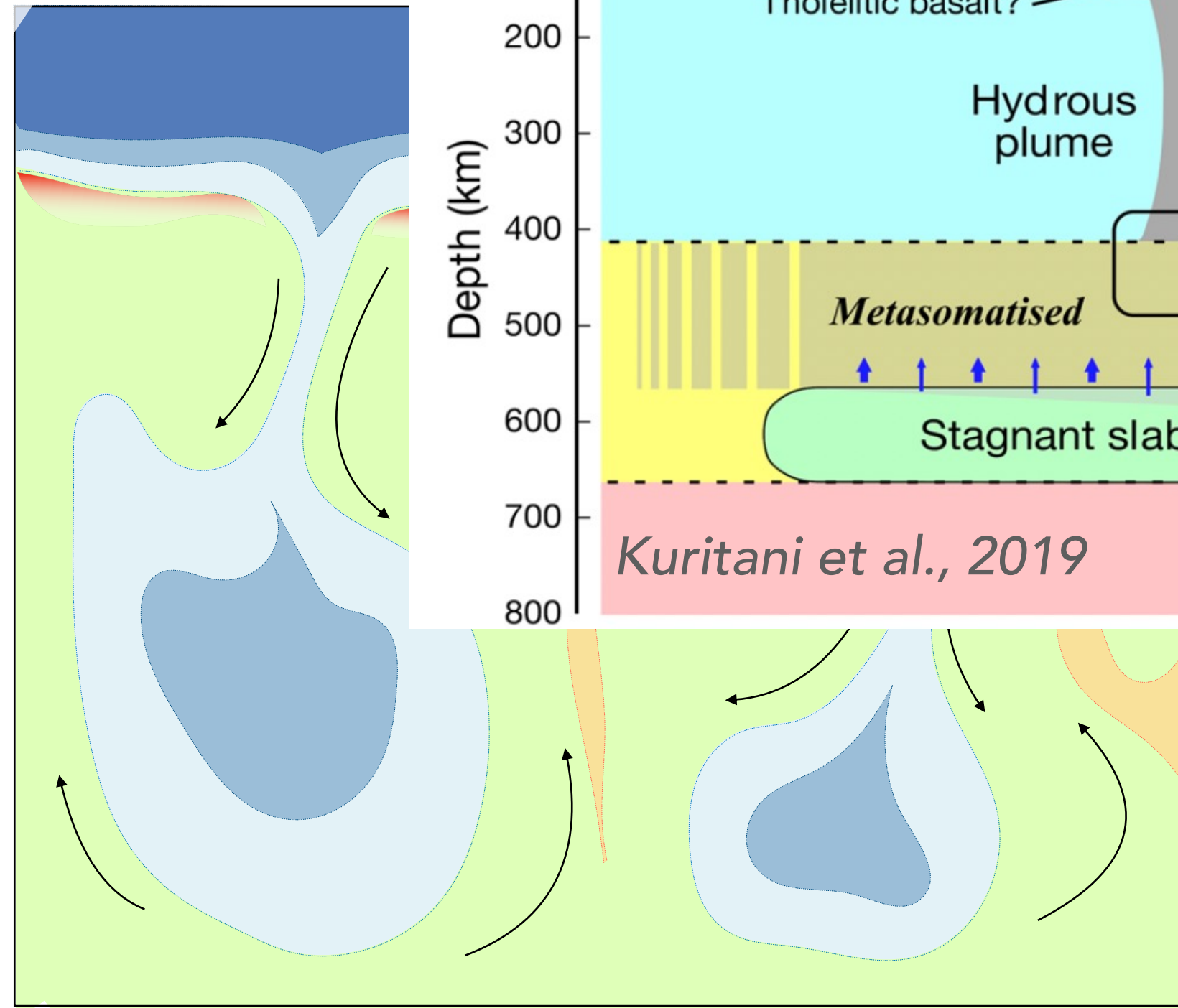
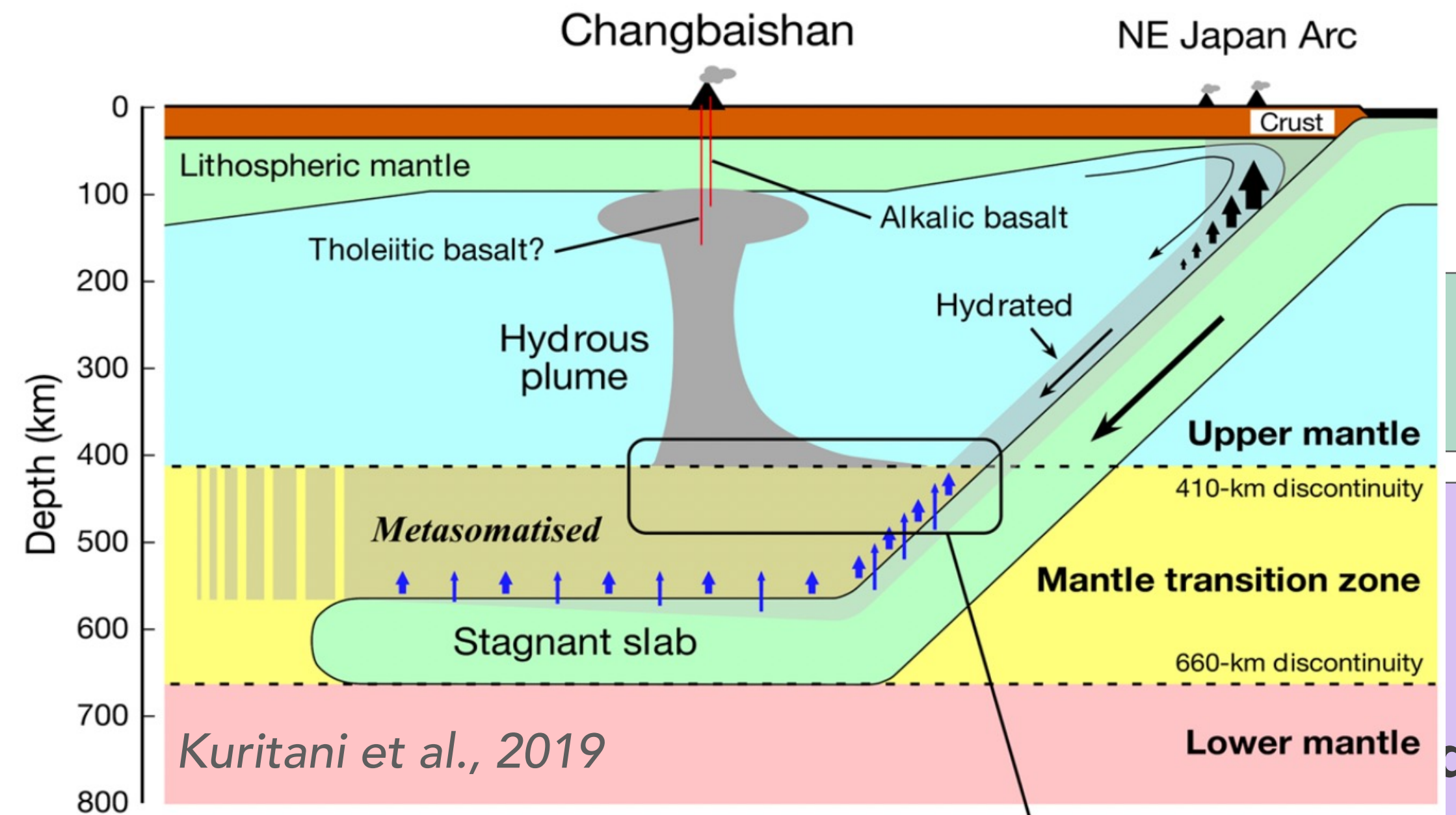
Emerging story

- ▶ Highly dynamic small scale convective system
- ▶ Thin, dynamically crucial asthenosphere (damp, melt-laden, deformed)
- ▶ Rheological gradients

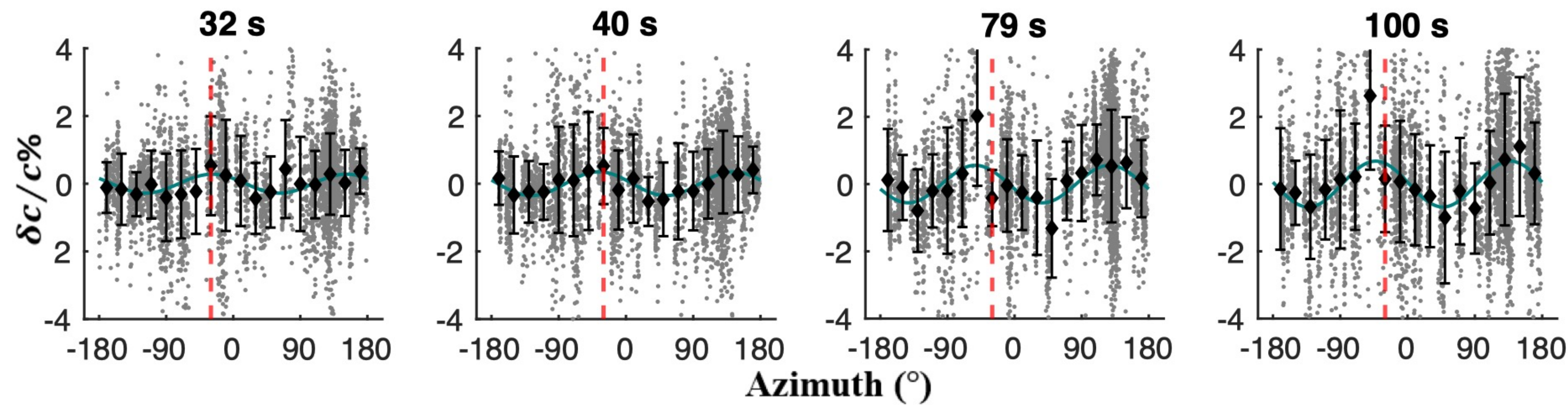
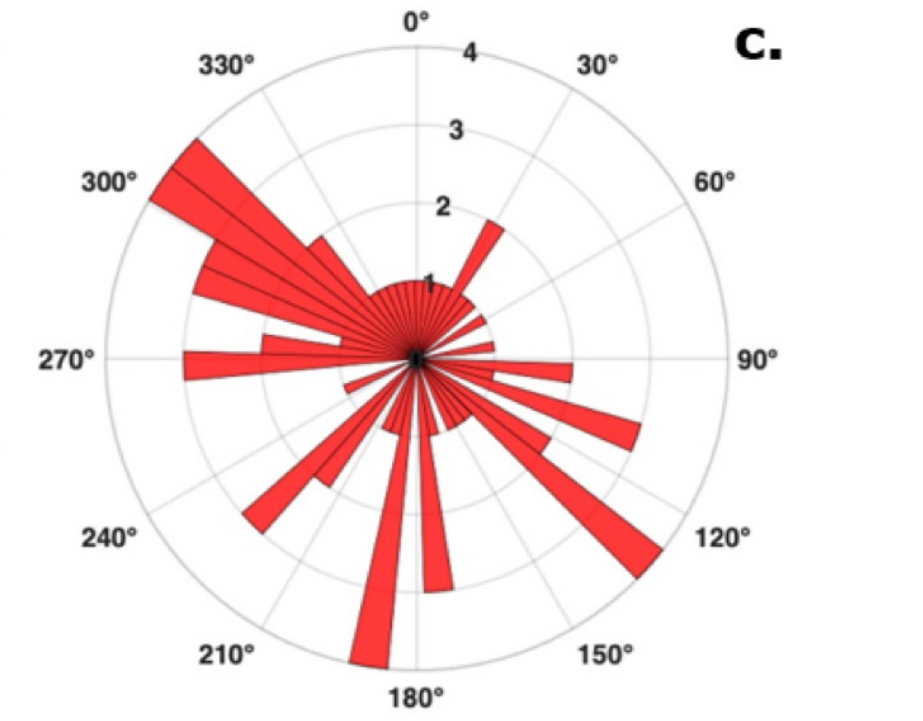
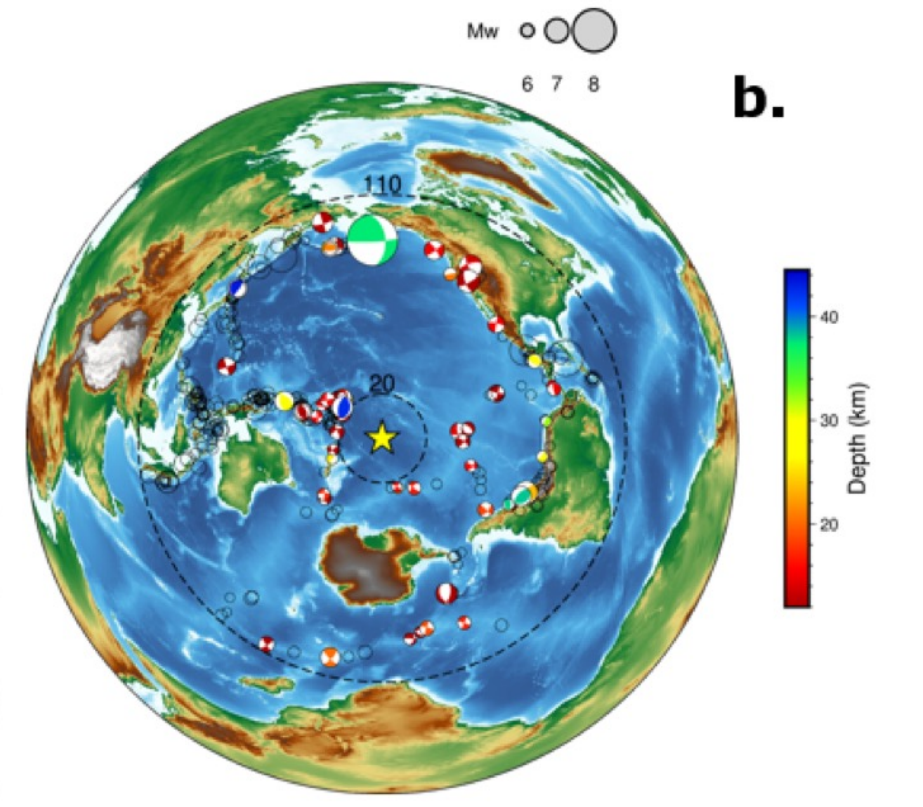
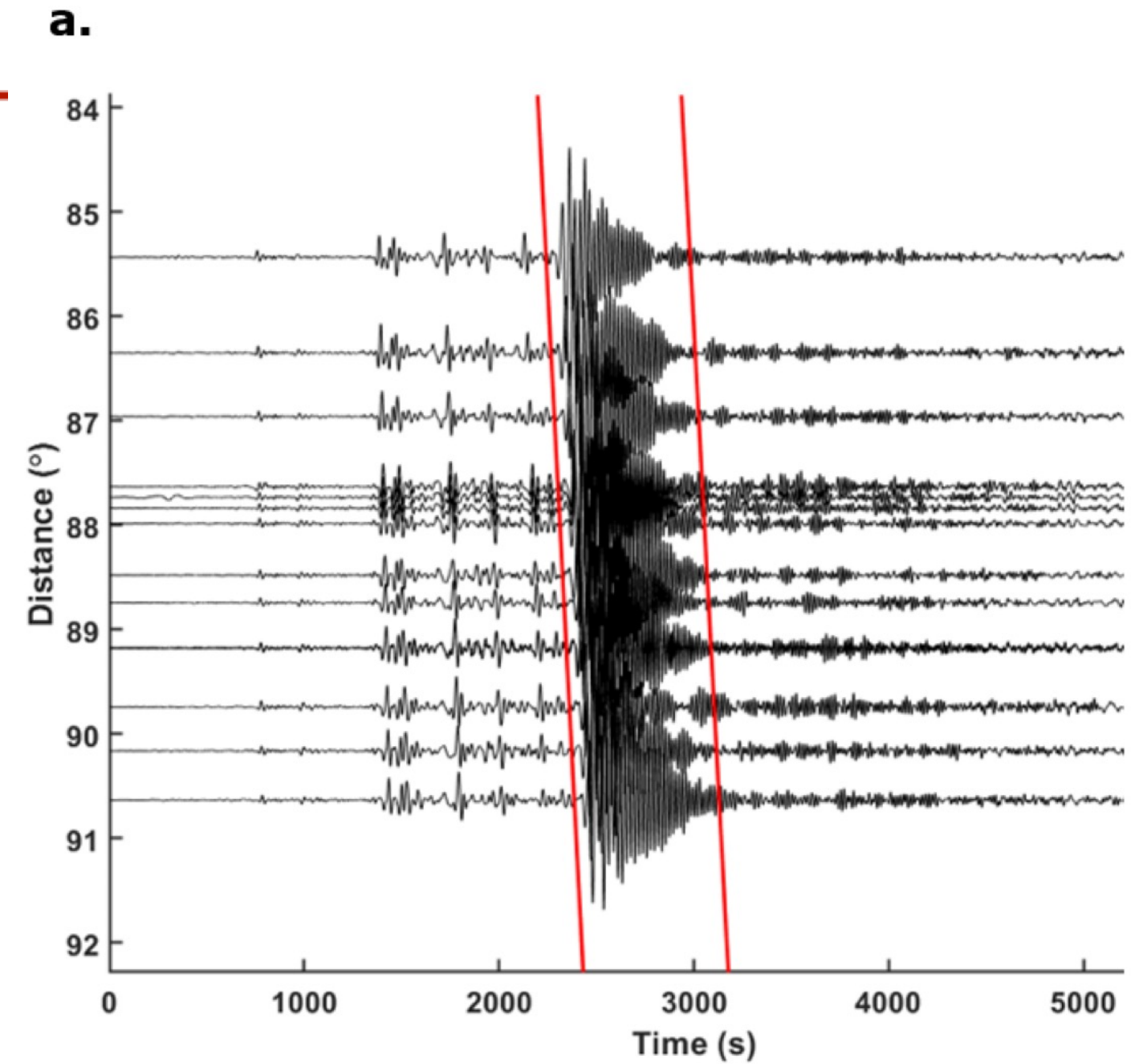
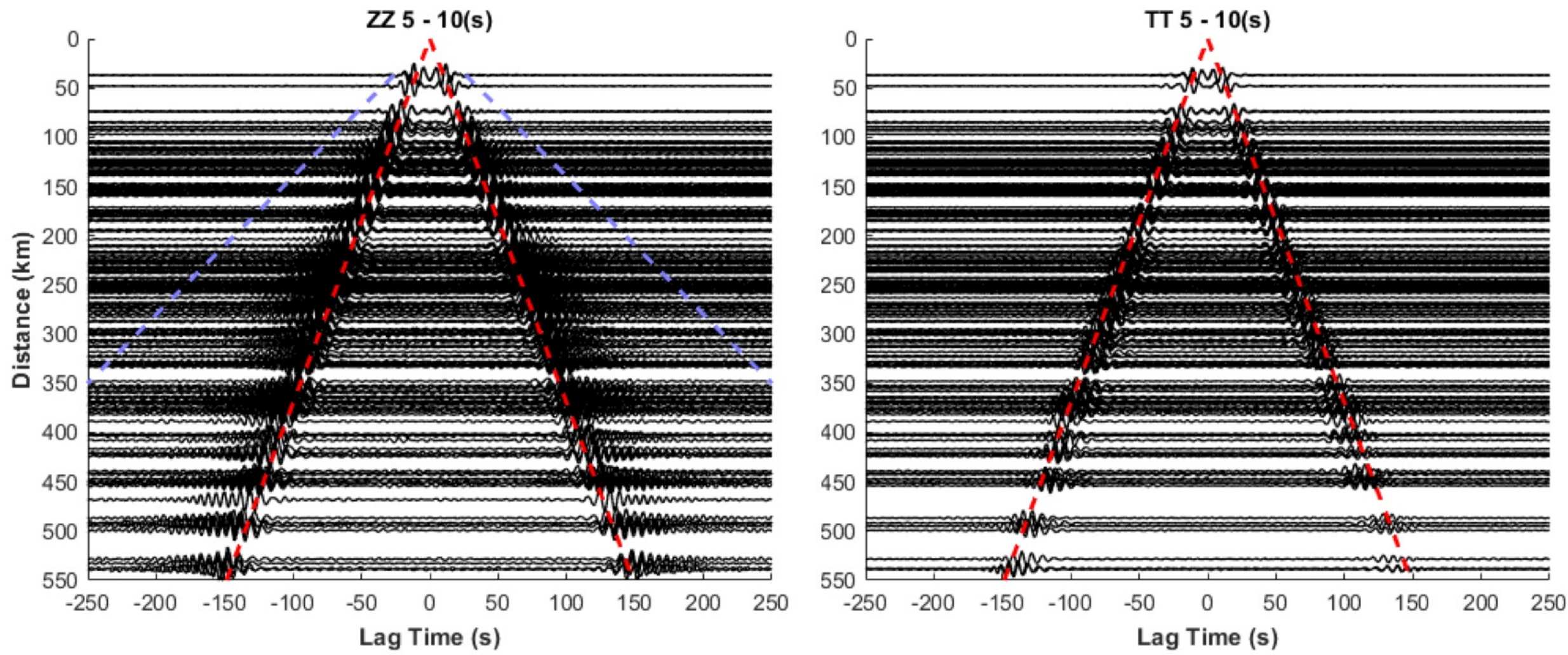


Emerging story

- ▶ Is this area typical?
- ▶ Early for SSC
- ▶ Extra warm?
- ▶ Extra wet?



SW phV and anisotropy



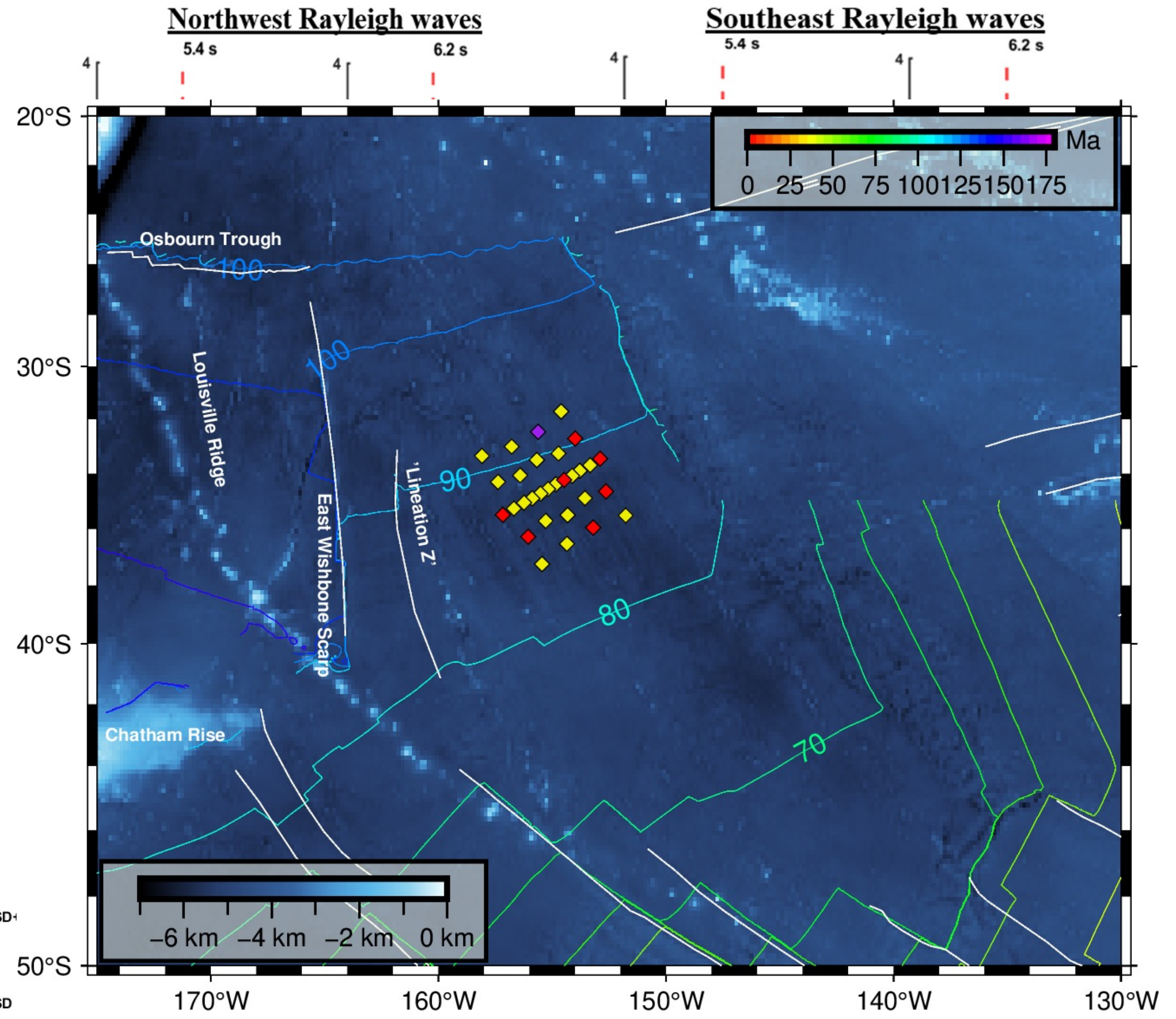
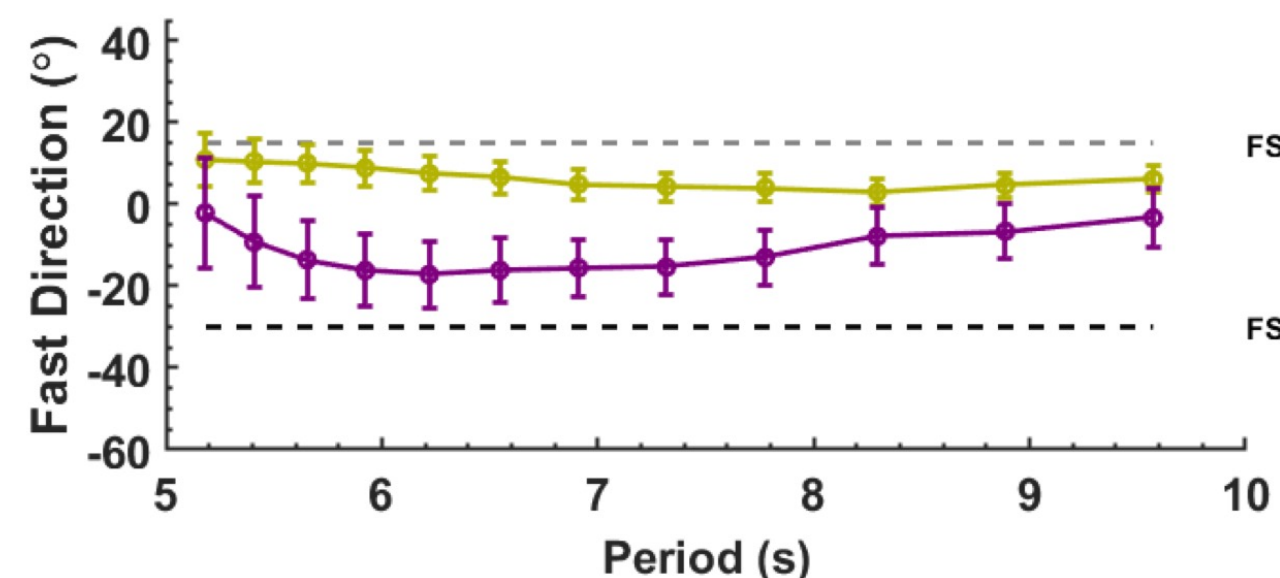
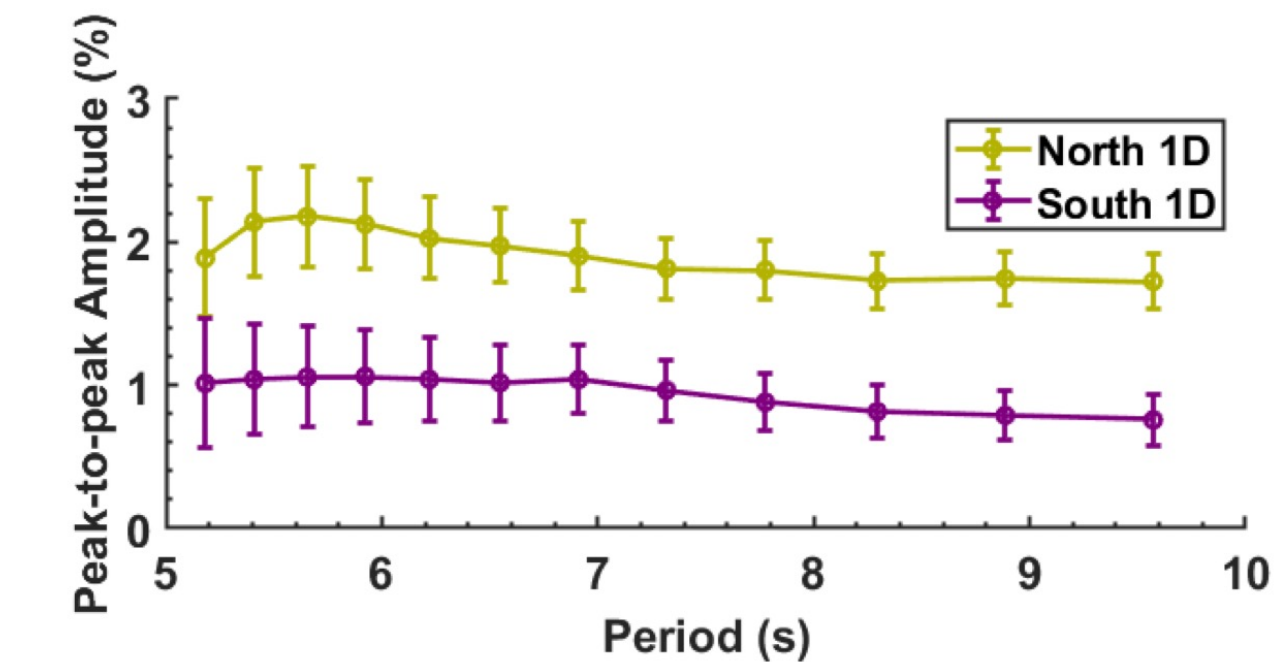
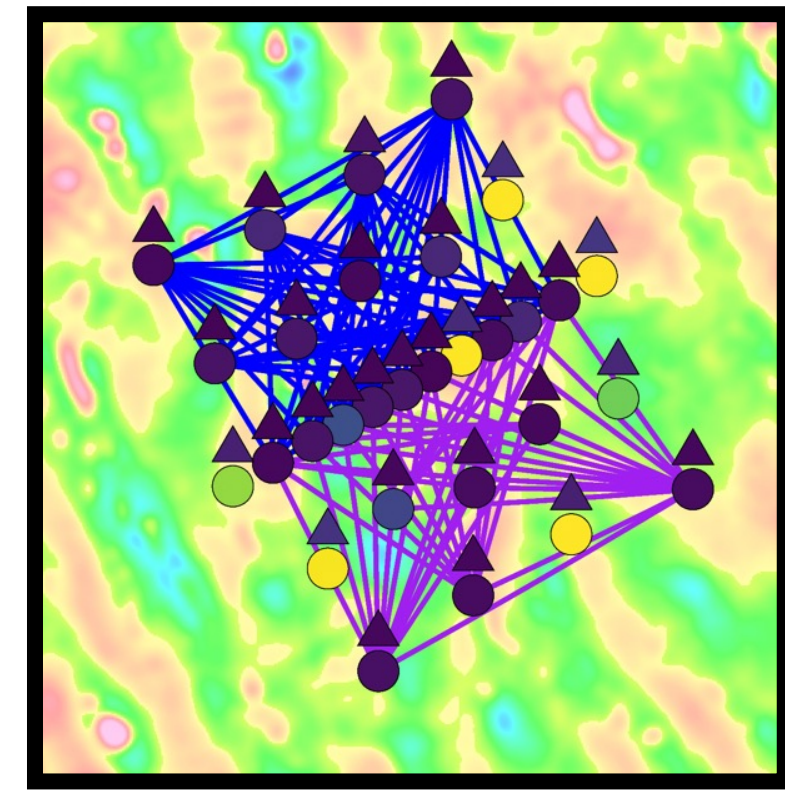
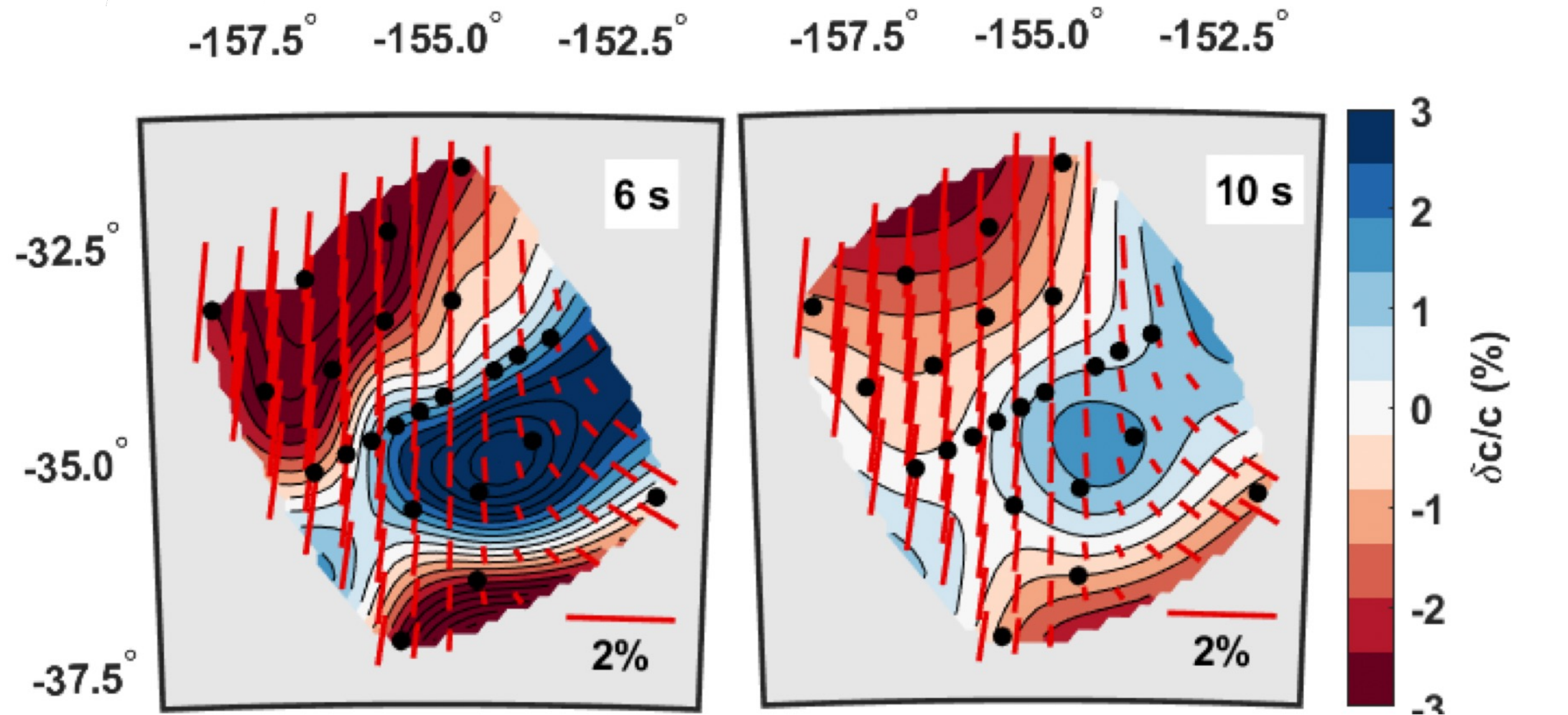
Joey Phillips

Phillips et al., in prep



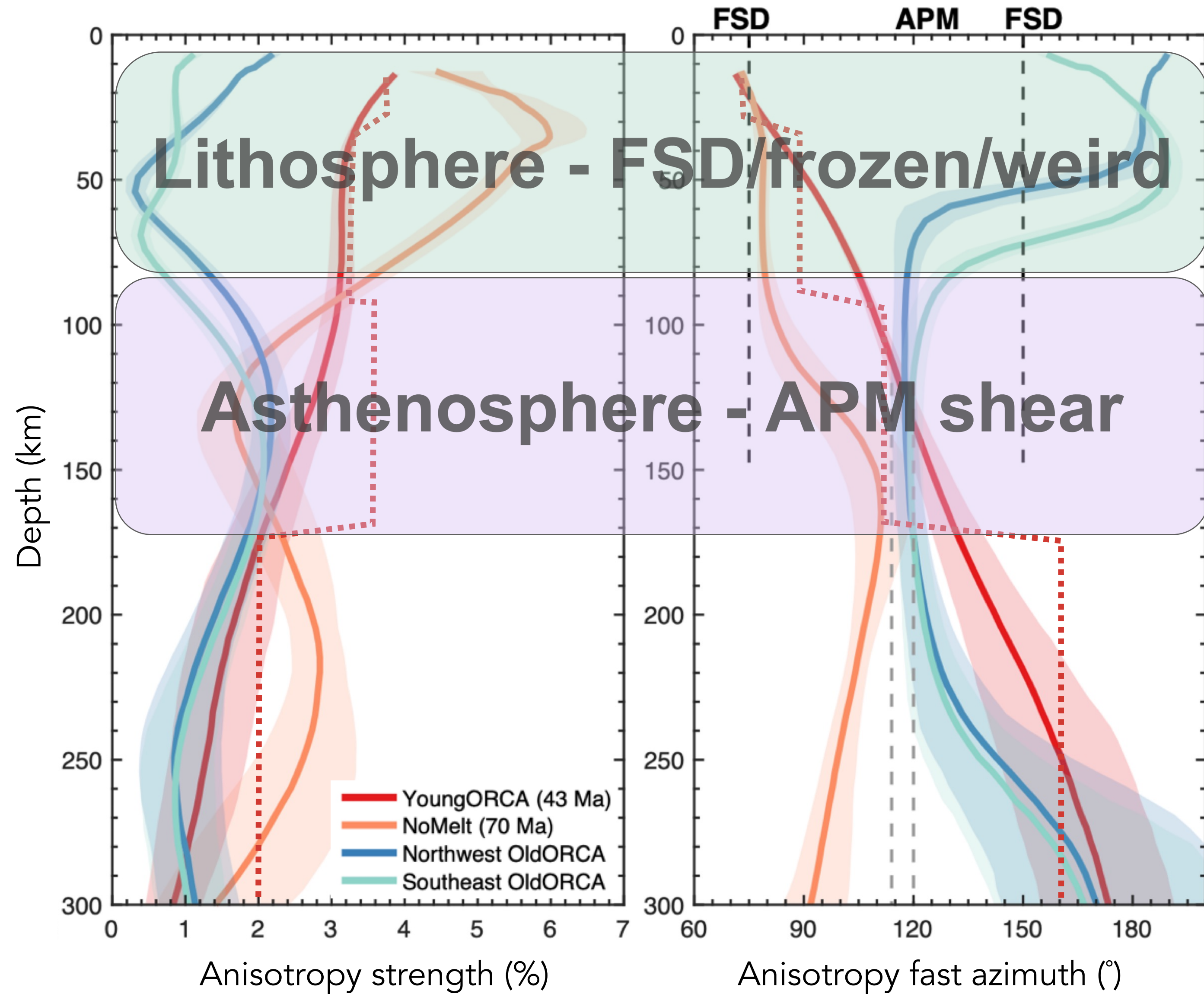
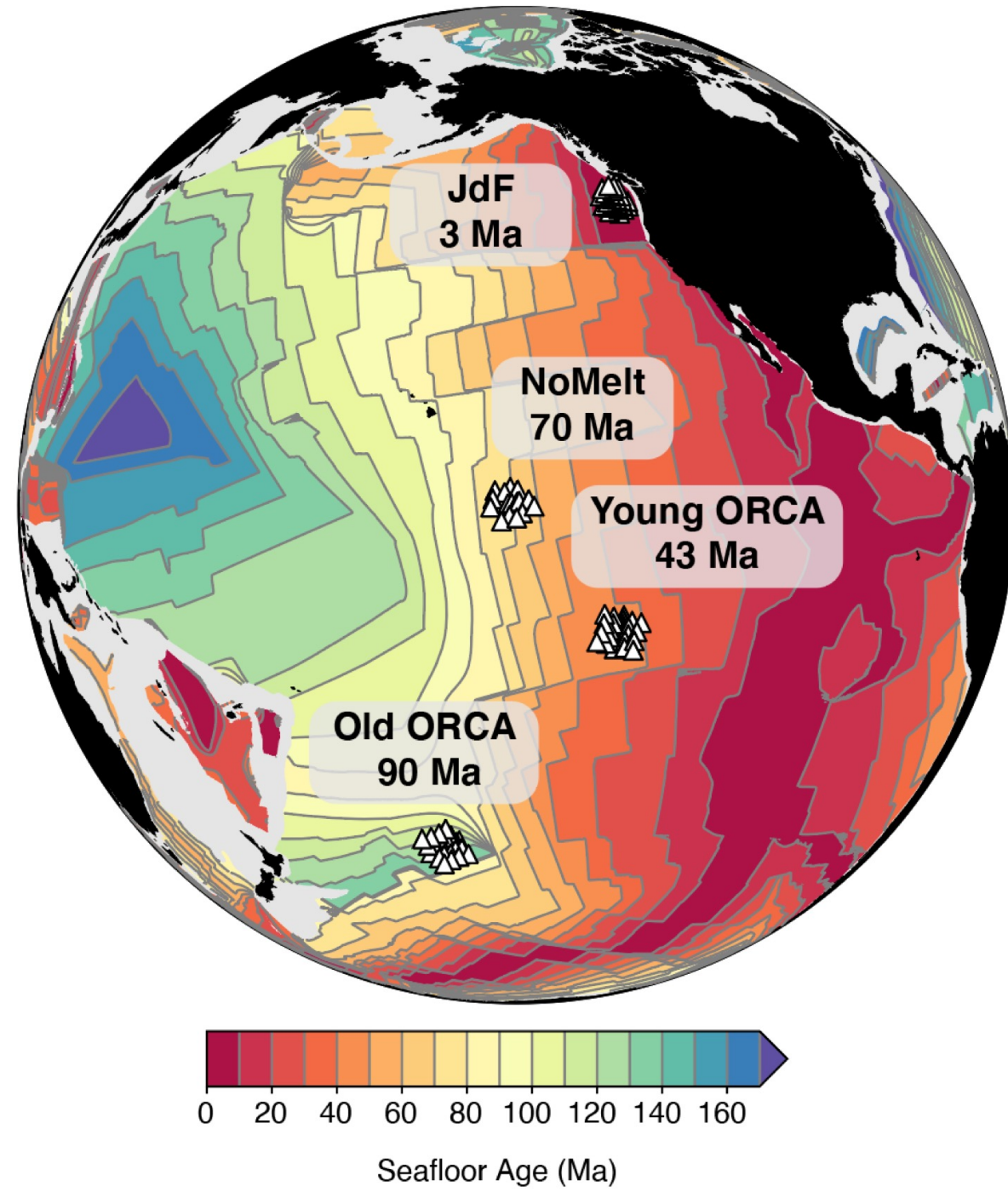
DI 42A-01 (Thurs AM)

SW anisotropy



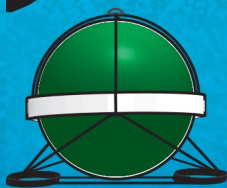
Phillips et al., in prep

SW anisotropy

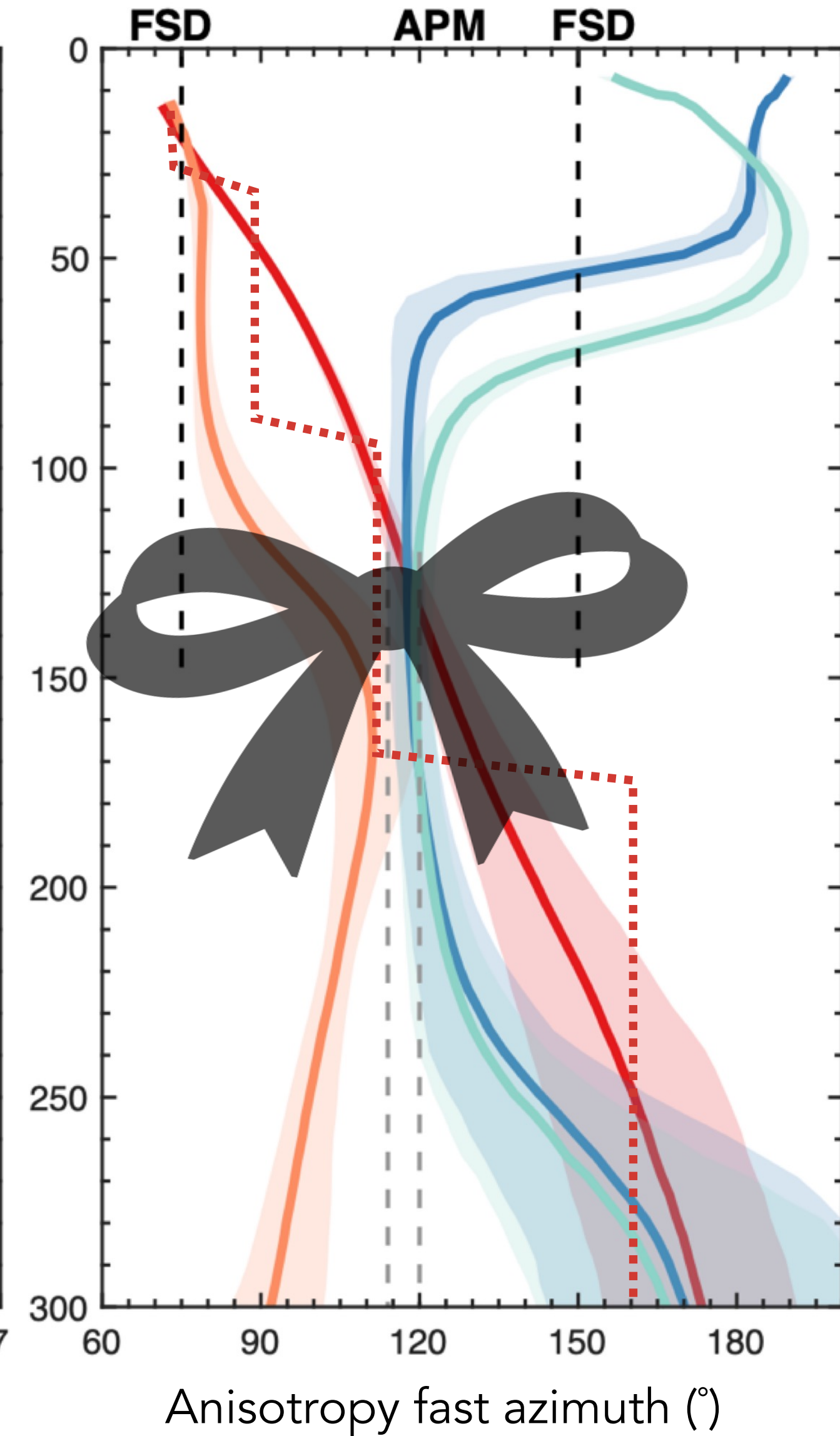
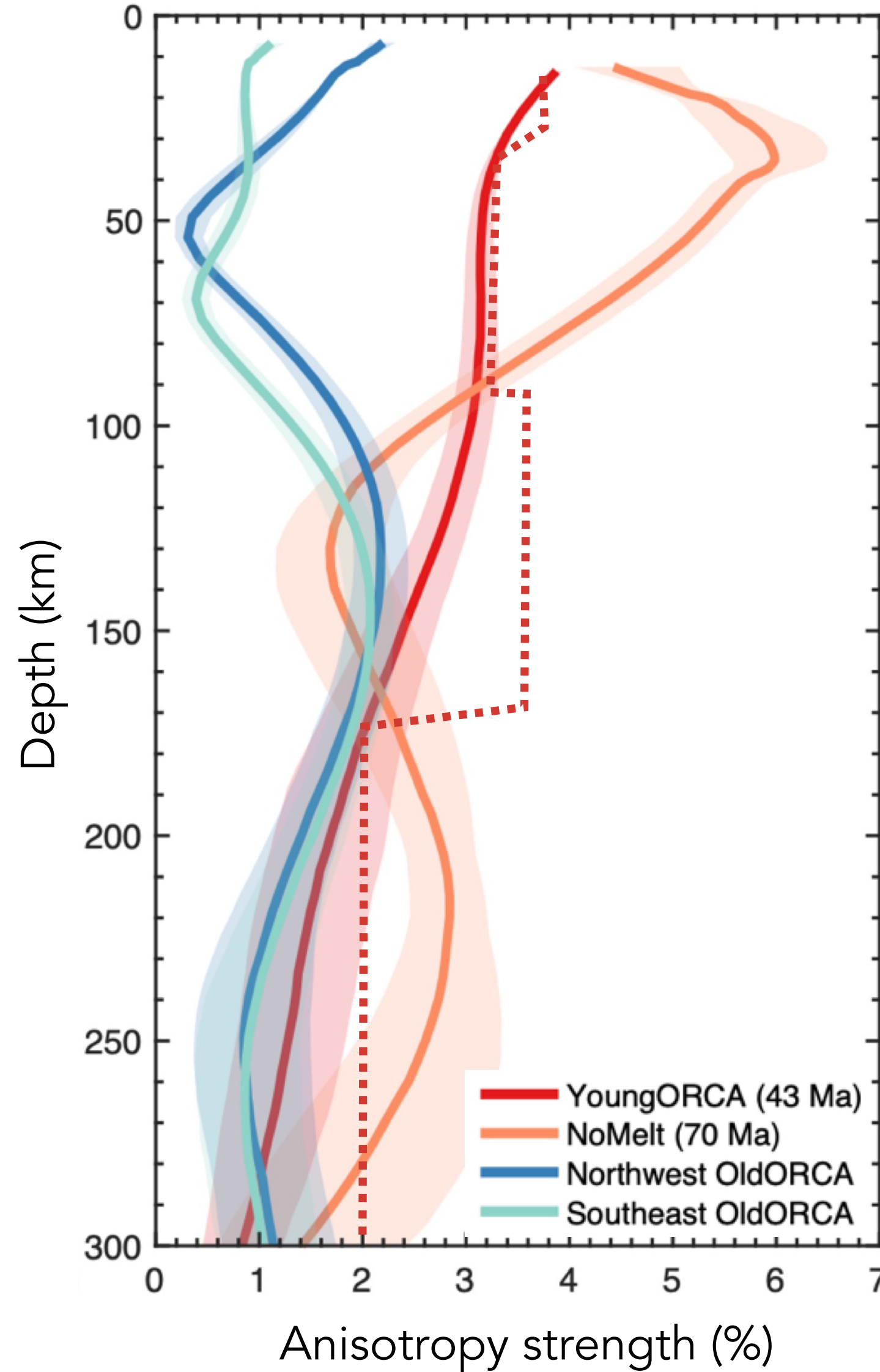
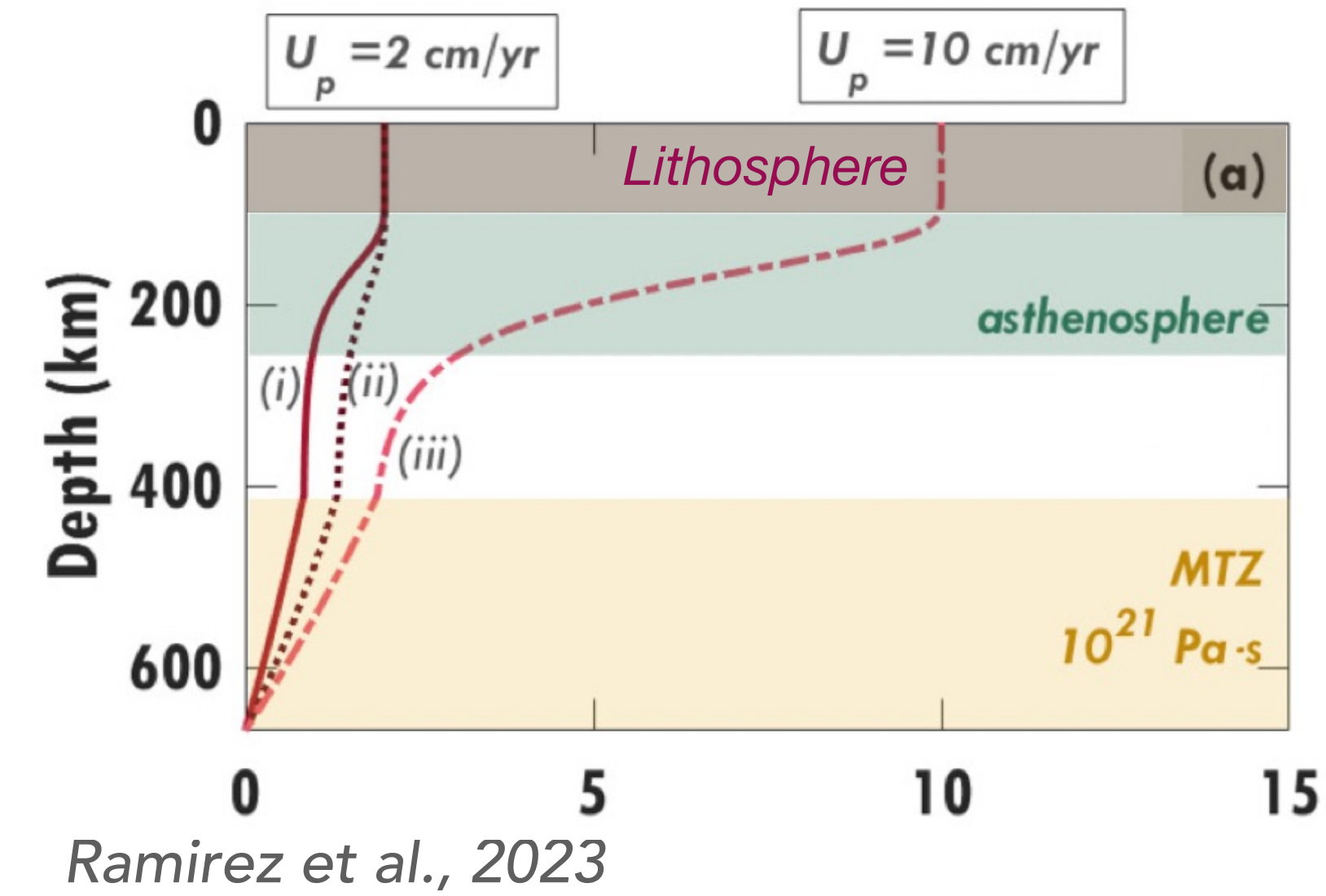


Phillips et al., Russell et al., in prep

Old  .R.C.A.


Young  .R.C.A.

SW anisotropy



Phillips et al., Russell et al., in prep

Old  .R.C.A.

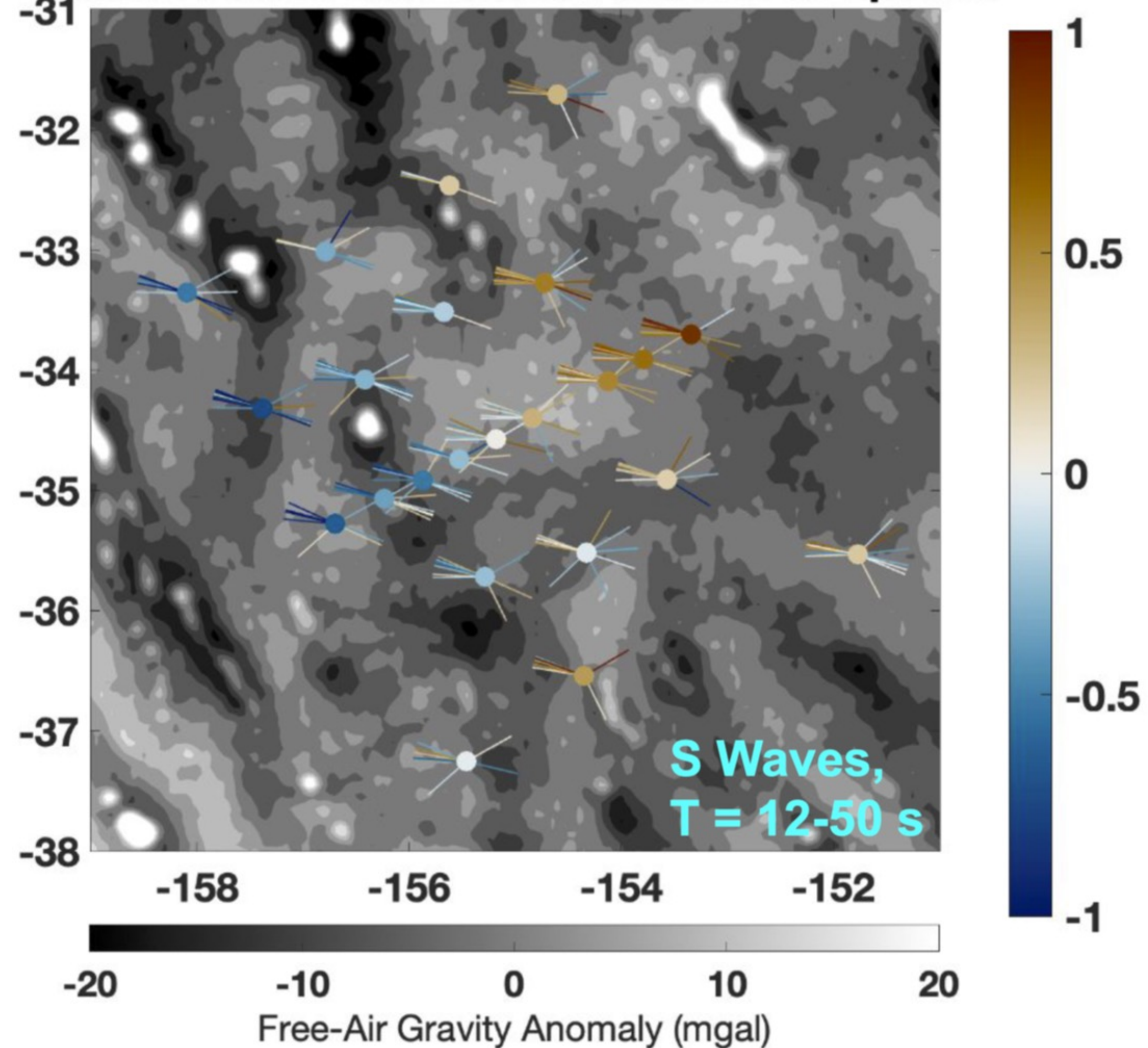
Young  .R.C.A.

Travel time tomography - more mysteries

Key observations

- ▶ ± 0.5 s P-wave travel time variations
- ▶ ± 1 s S-wave travel time variations
- ▶ Consistent across frequency bands
- ▶ Coherent back-azimuthal patterns

Station Terms/Raw Measurements as Spokes

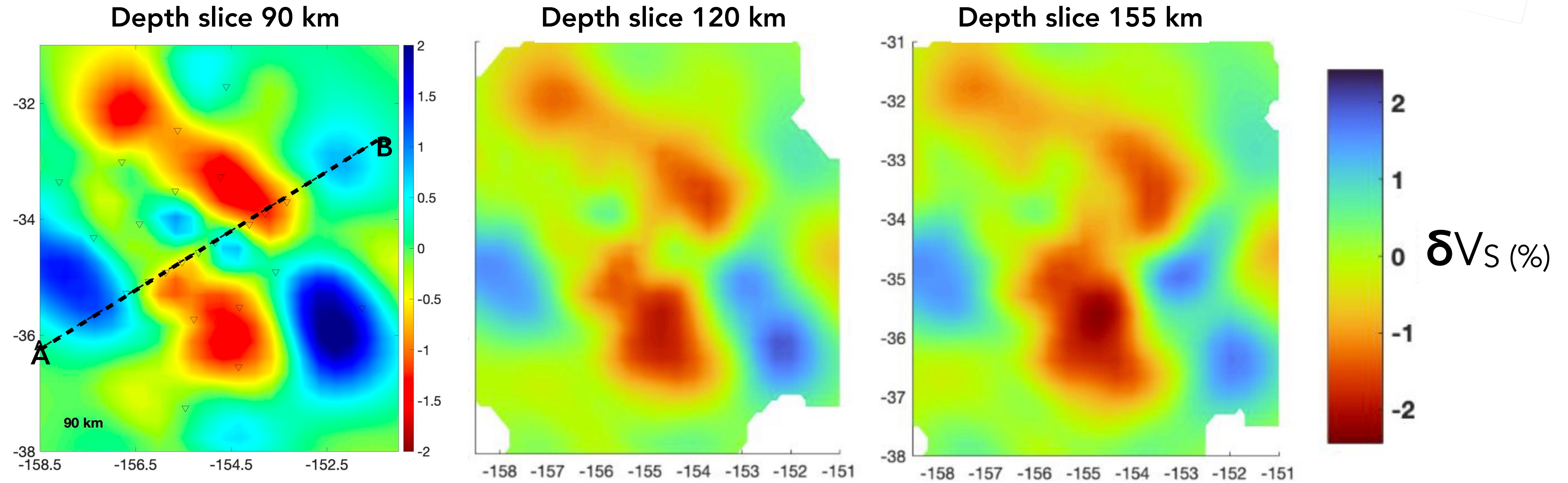


Anant Hariharan

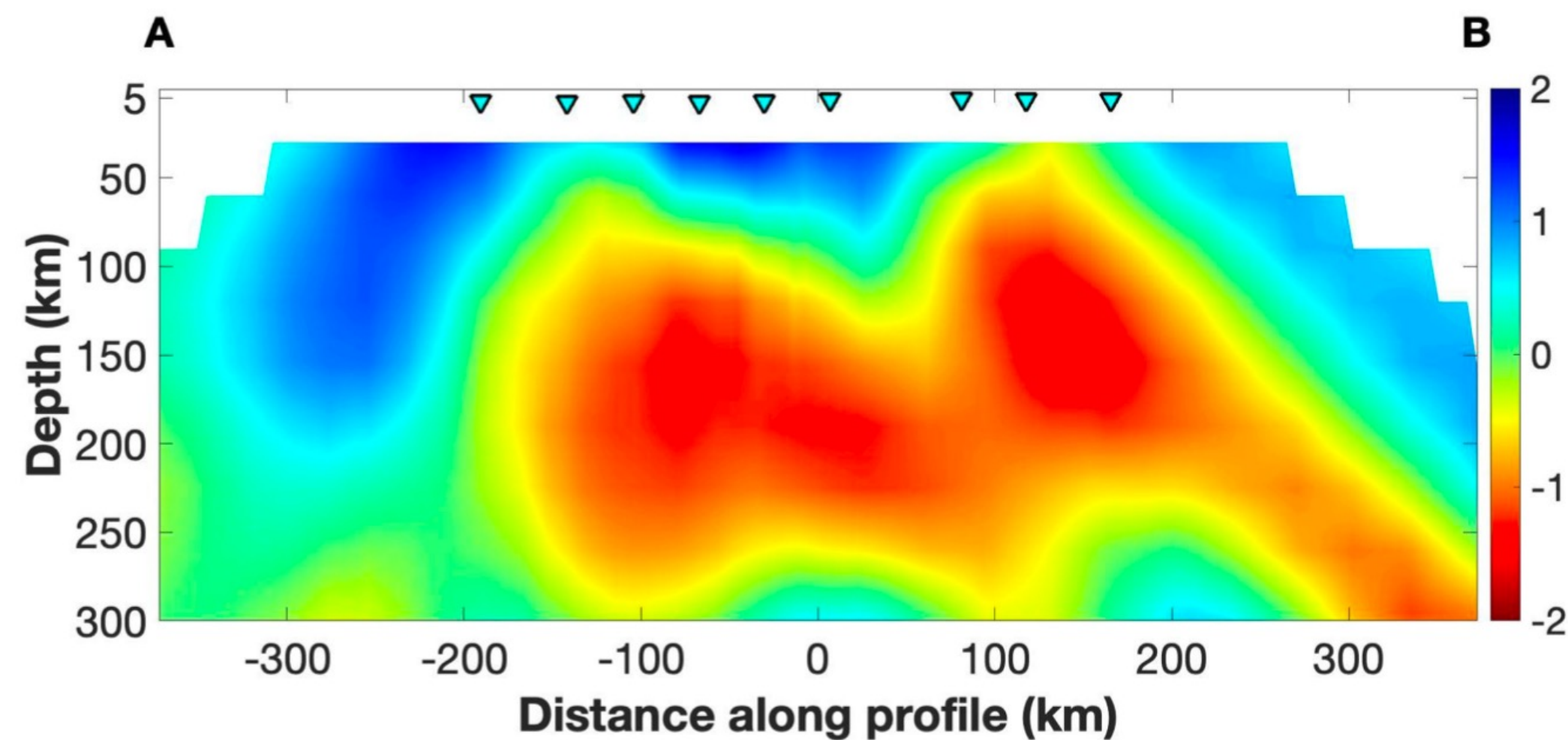
Tomography



Travel time tomography - more mysteries



- ▶ $\pm 2\%$ δV_S variations
- ▶ Perhaps lineations
Perhaps APM-parallel



Hariharan et al., in prep

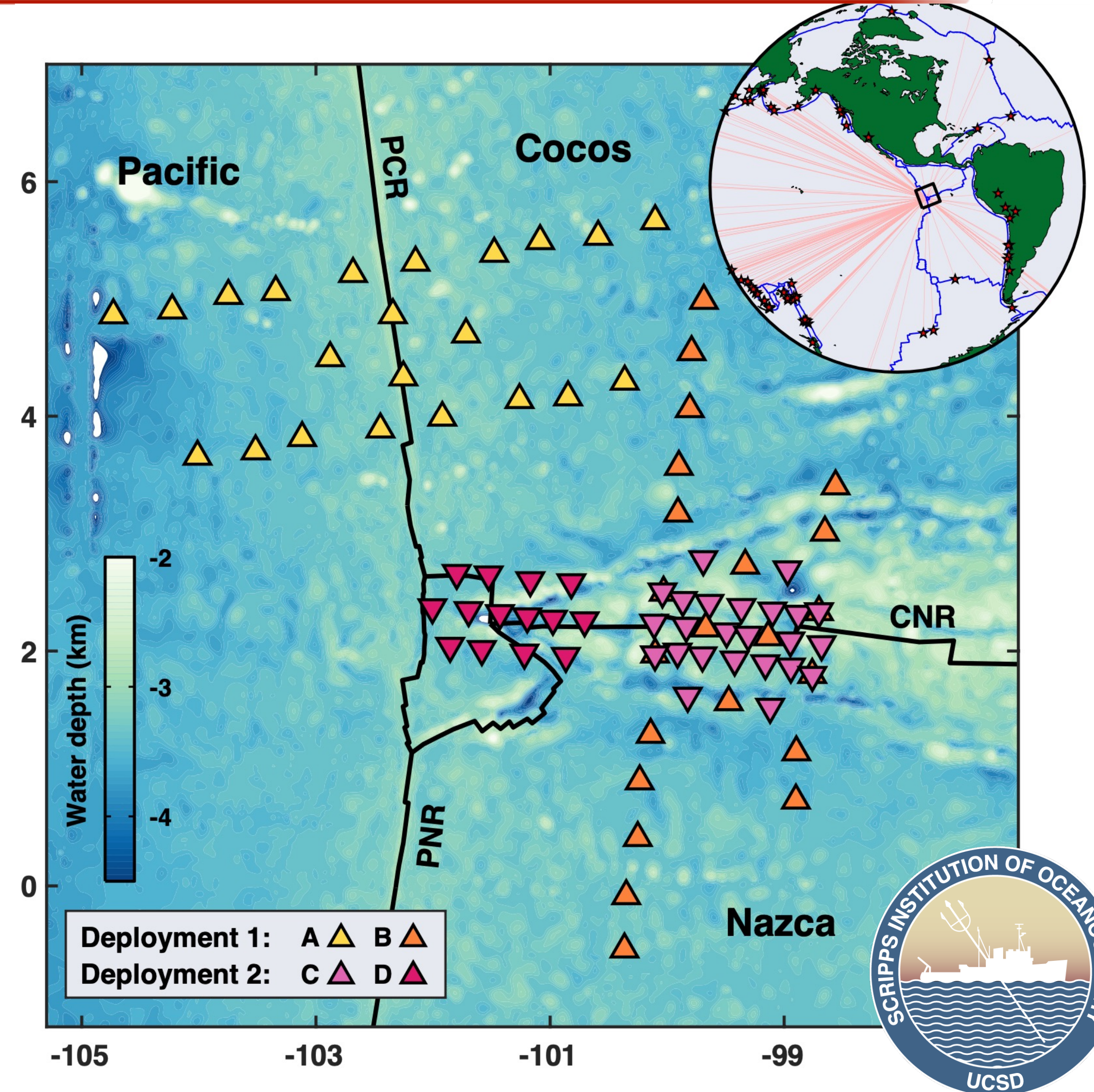
Plug - upcoming experiment

Galapagos triple-junction MORfest

Emphasis	Deploy	Recover	Stations
CNR, PCR	01/2025	~03/2026	A&B 44 BBOBS
CNR, TJ	~03/2027	~05/2028	C&D 42 BBOBS

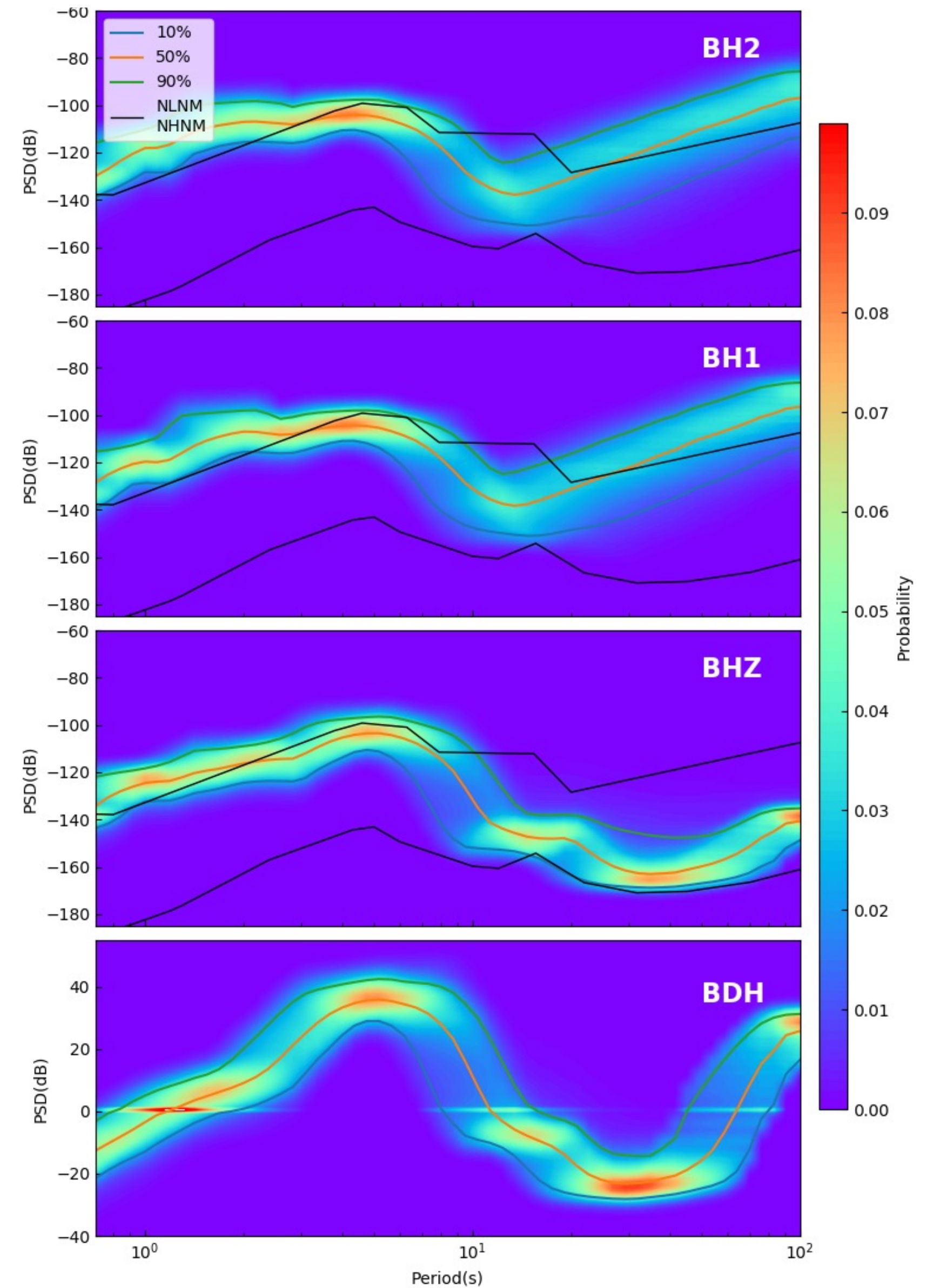
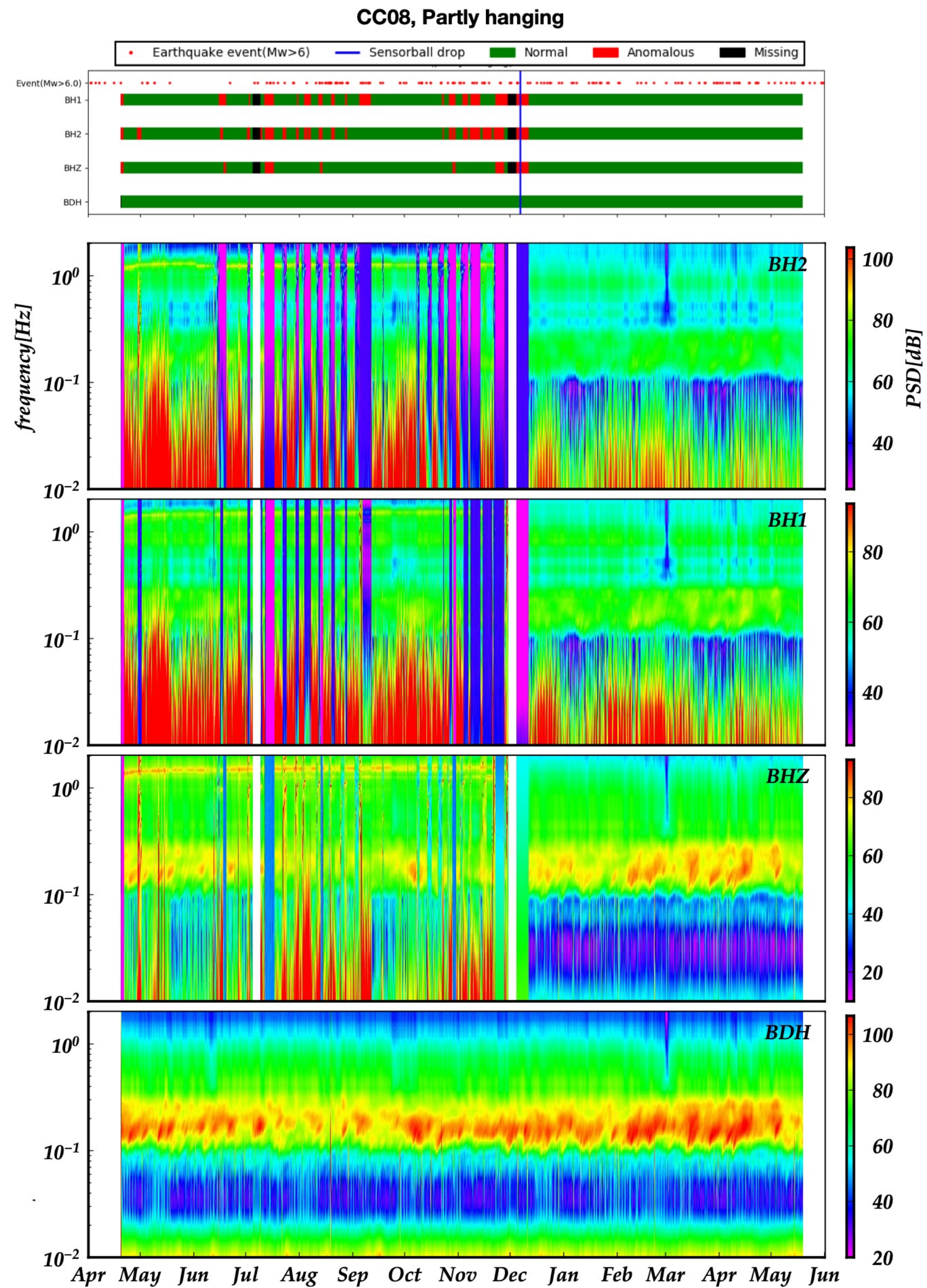
Science party on each cruise

- ▶ 1 Jr faculty/postdoc co-Chief Sci.
- ▶ 3-6 watch standers
- ▶ Bonus science opportunities...



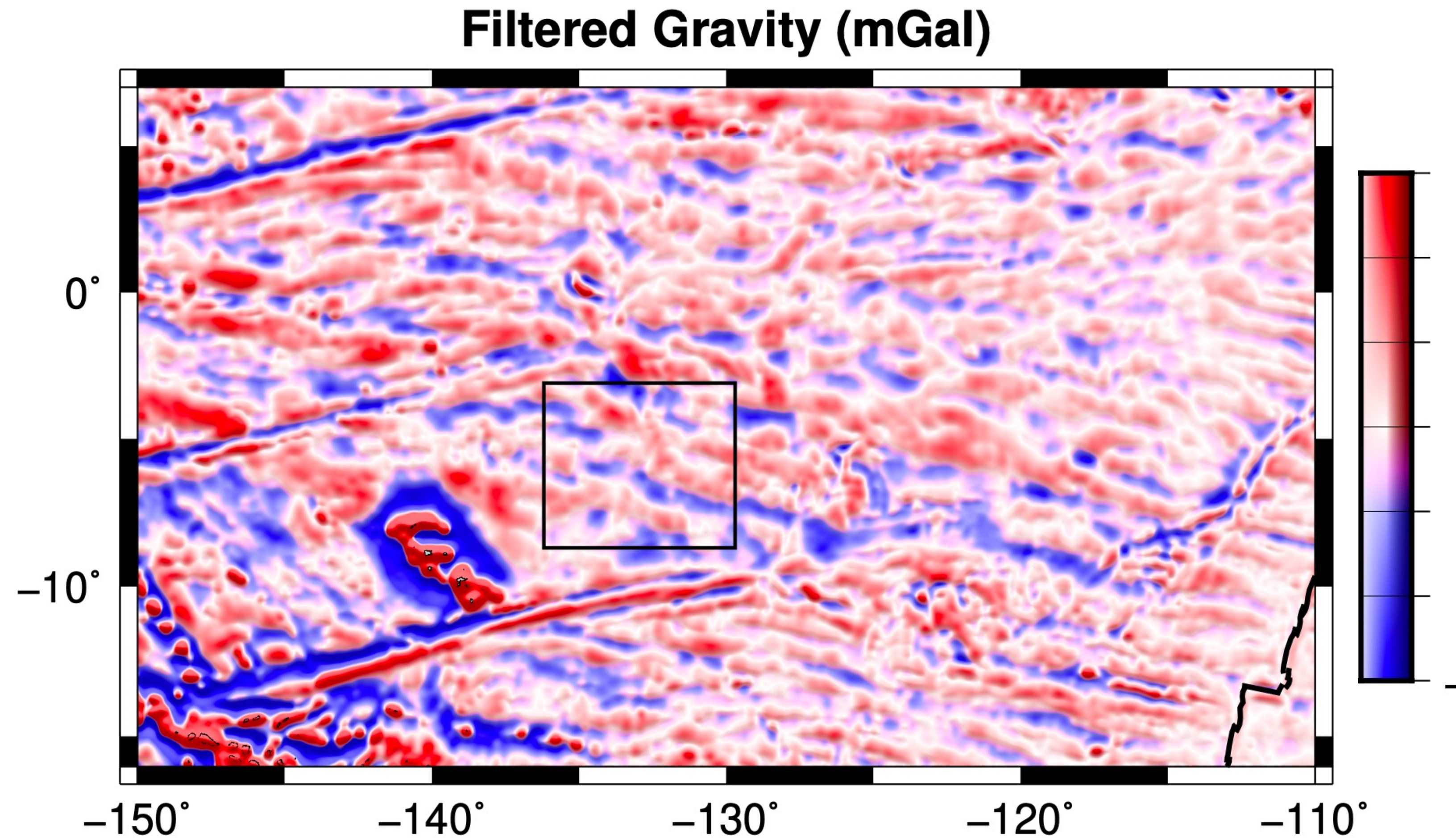
Questions?

Pacific ORCA experiment - data issues



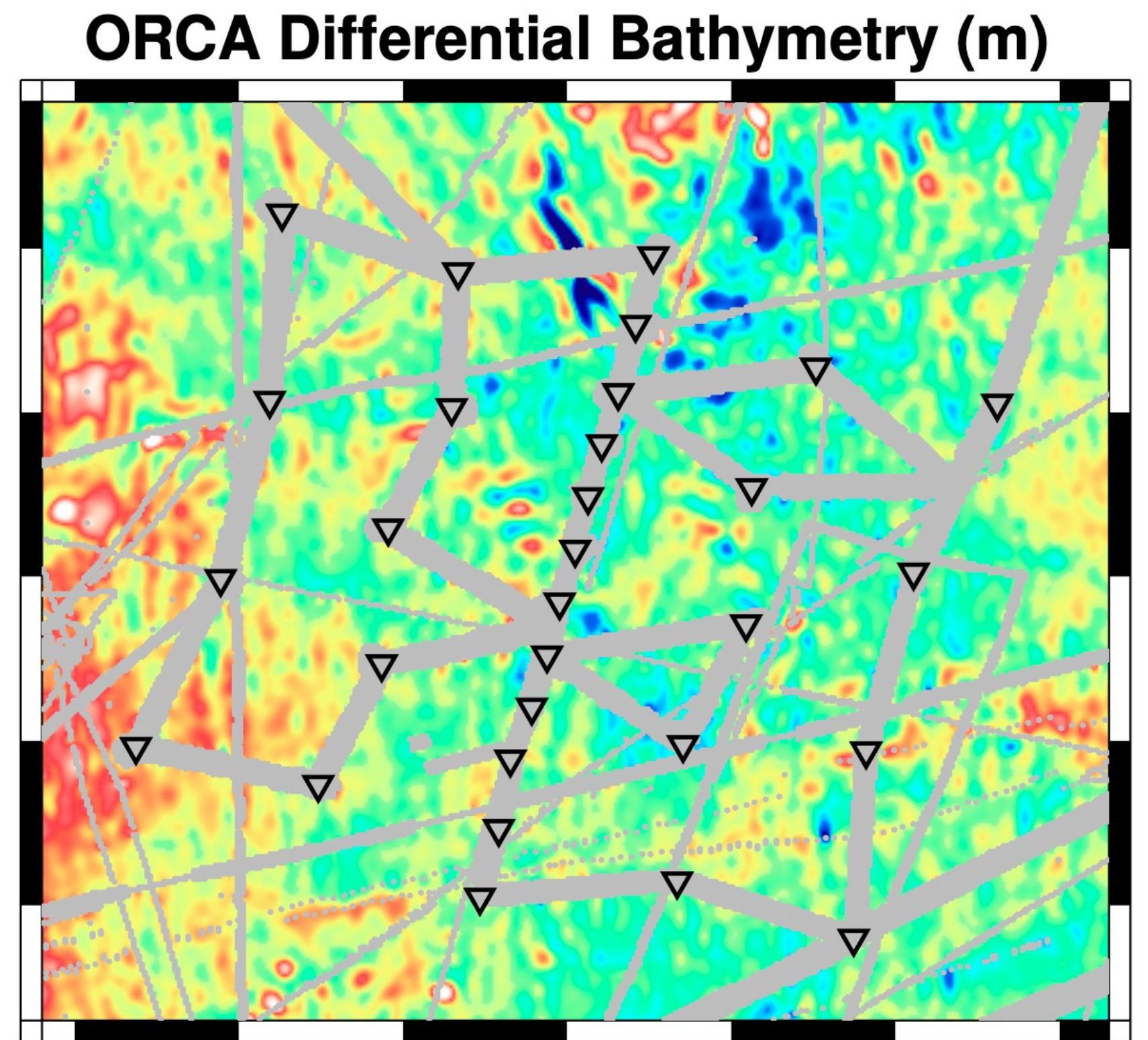
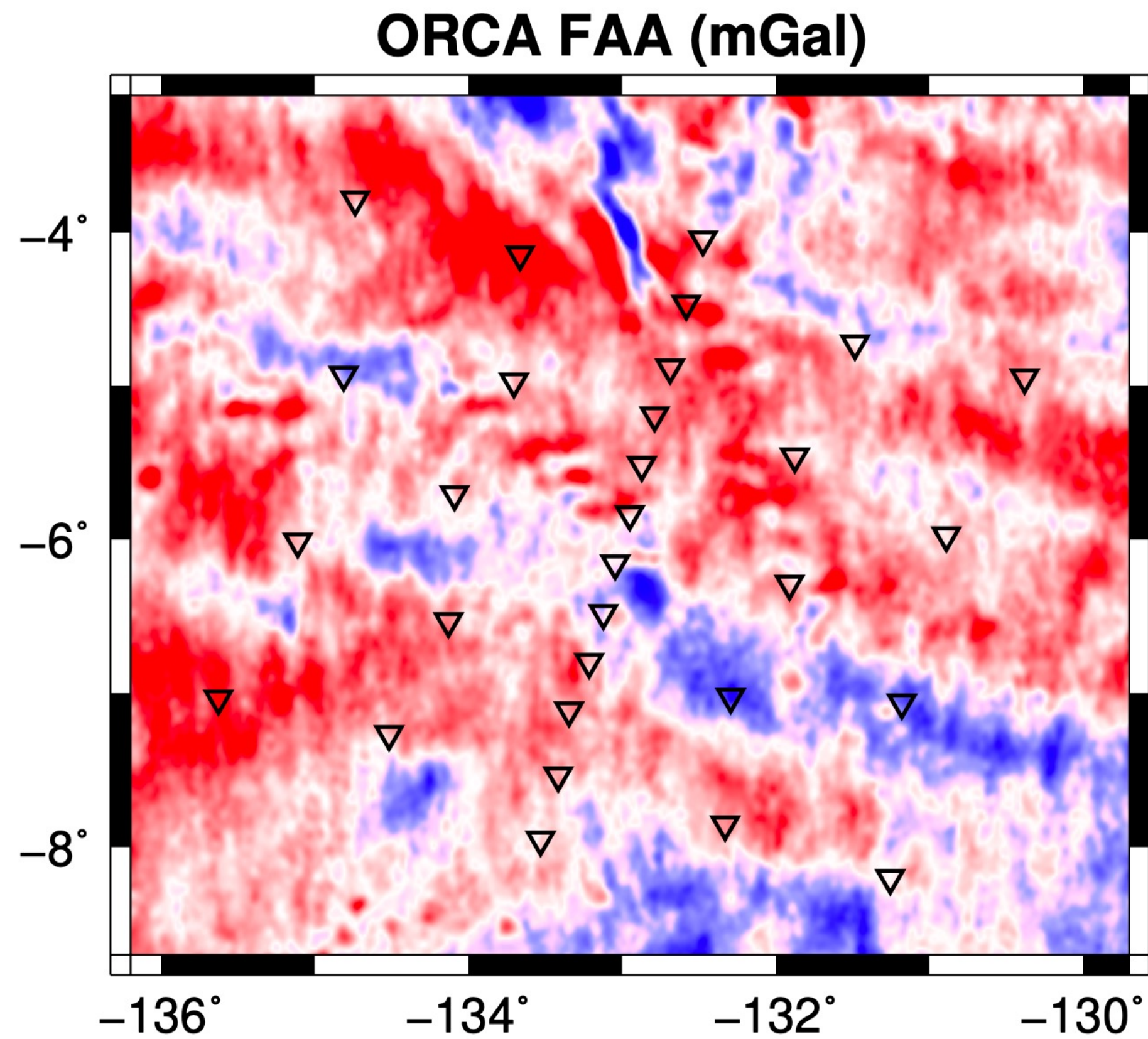
Science questions - dynamic oceanic LAB

- How do plates cool?
- What causes seismic NVGs (if not the plate)?
- What gives rise to off-axis, non-age-progressive volcanism?
- **What causes elongated free-air gravity anomalies?**
- Does lithosphere chemically exchange with asthenosphere?
- How does lithosphere move over asthenosphere?



Gravity and Topography

- ▶ De-spike (remove seamounts)
- ▶ 80km gaussian convolution filter
- ▶ 10^6 - 10^1 m gaussian bandpass filter



Gravity and Topography

Free Air Coherence

Normalized cross spectrum -
measure of similarity of gravity
and bathymetry fields averaged
over wavenumber bands

Free Air Admittance

Ratio of power in gravity vs.
bathymetry spectra (2-D Fourier)
averaged over
wavenumber
bands

$$Z_{FA}(k) = \frac{G_{FA}(k)}{H(k)}$$

