SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Time residuals at HA11 and HA03 for T-phases from deep earthquakes in the Ring of Fire

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CTBTO PREPARATORY COMMISSION | PUTTING AN END TO NUCLEAR EXPLOSIONS

INTRODUCTION AND MAIN RESULTS

Time residuals, differences between observed and theoretical arrival times, were analyzed for T-phases from Ring of Fire earthquakes (2008–2025) at IMS hydrophone stations HA03 and HA11.

Time residuals range from –150 to +150s, shifting from negative to positive as earthquake depth decreases along the subduction plate toward the Ocean Trench, suggesting influence from the seismic-to-acoustic wave conversion mechanism.

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Introduction and Motivation

- **Time residuals:** differences between the observed arrival times and their theoretical values.
- This work is focused on **T-phases from earthquakes in the Ring of Fire** recorded between 2008 and 2025 at IMS hydrophone **stations HA03 and HA11**. Time residuals of T phases from these regions can typically range from minus 150 to 150 seconds.
- **Main motivation:** disparities between expected and observed arrival times can present significant challenges when associating T-phases to events.

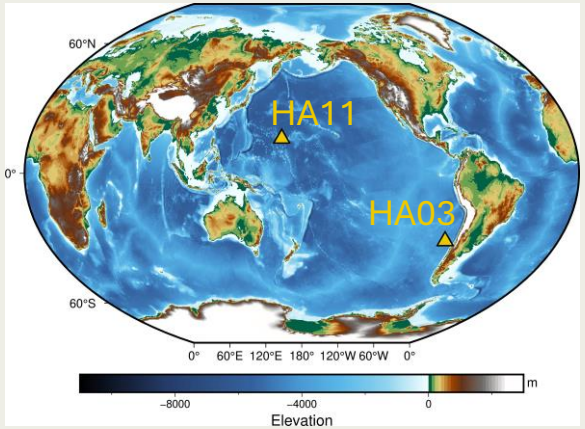

Figure 1: IMS hydrophone stations in the Pacific Ocean.

T-phases from earthquakes in the Tonga–Kermadec subduction zone

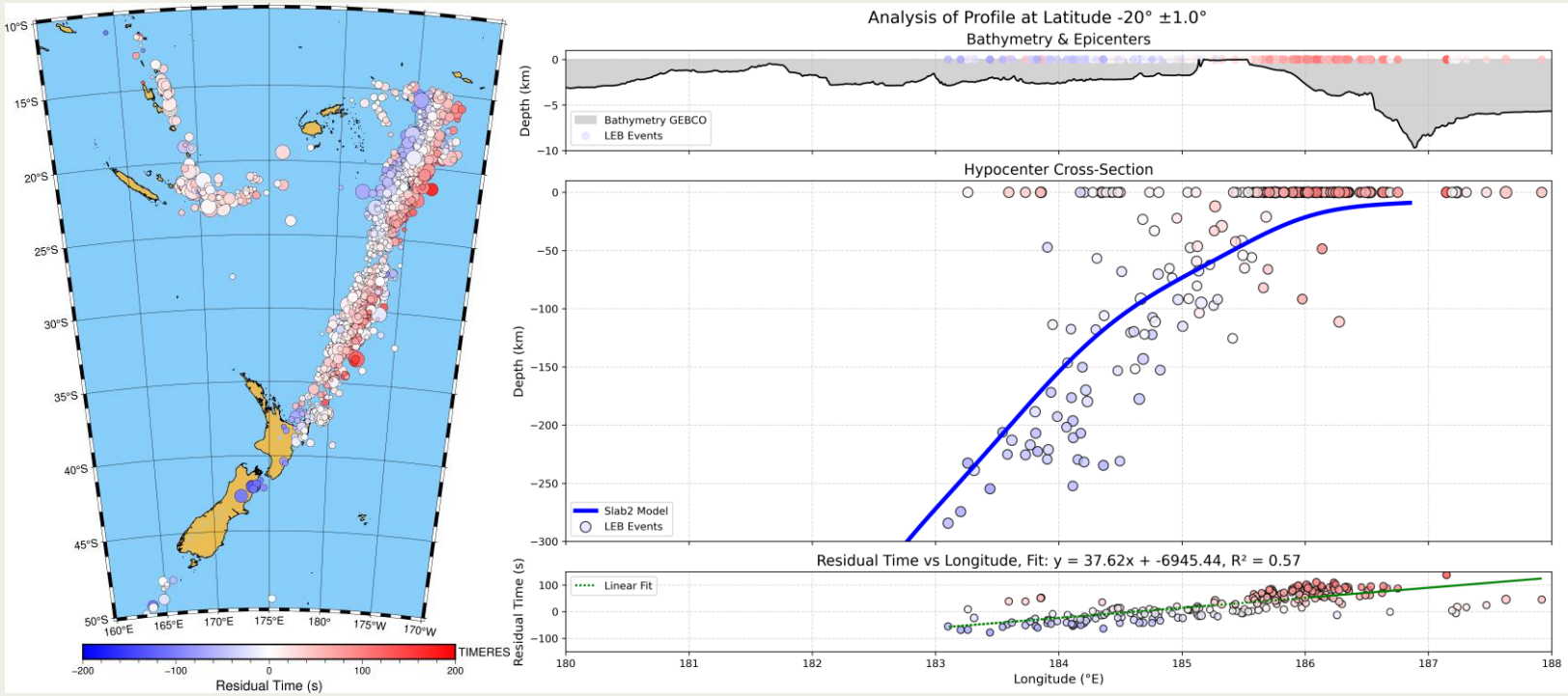

Figure 2: (left) Time residuals at H03S in the Late Event Bulletin (LEB) for T-phases from earthquakes in the Tonga–Kermadec subduction zone between 2014 and 2025. (right) Profile at 20deg south (± 1deg) for the same data set presented on the left plot. The bathymetry in the right top plot is from GEBCO 2024. The slab in the middle plot is from the Slab2 Model from Hayes et al. (2018). Time residuals range from –150 to +150s, shifting from negative to positive as earthquake depth decreases along the subduction plate toward the Ocean Trench.

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Location of conversion of seismic to underwater sound waves for selected earthquakes

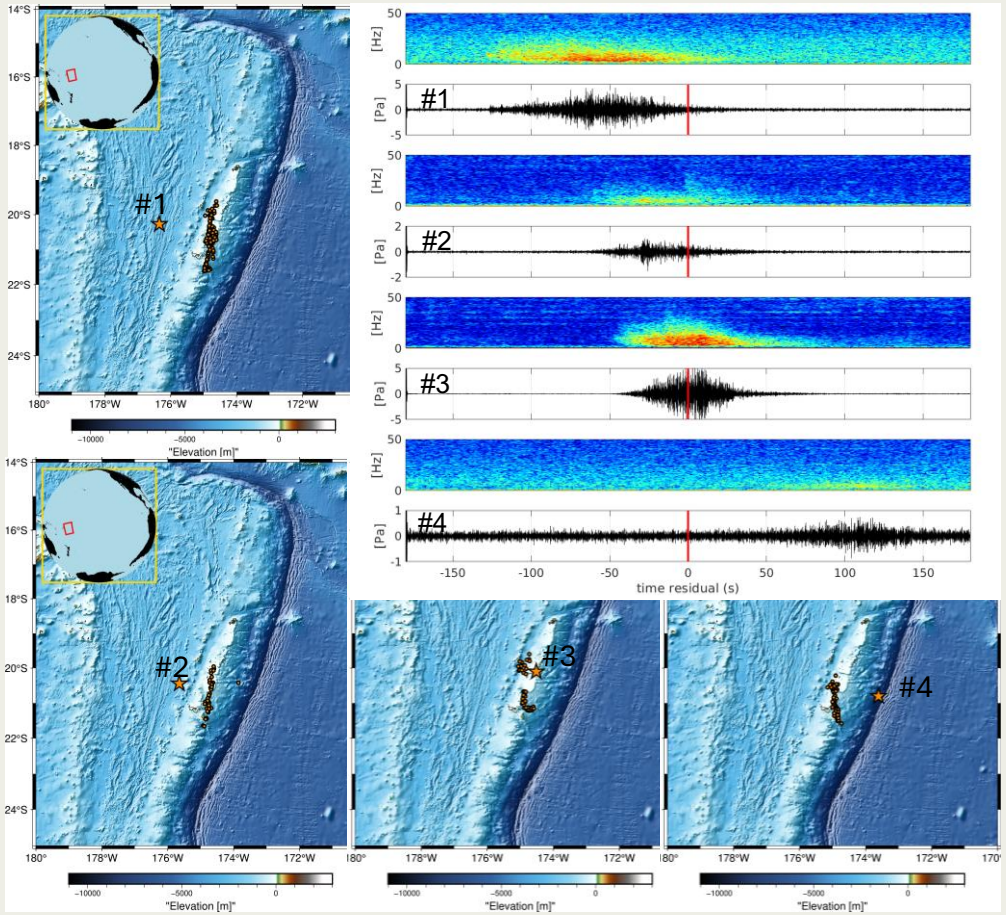

Figure 3: **Spectrograms and waveform** data recorded at H03S1 for earthquakes in the Tonga–Kermadec subduction zone with hypocenter at the depth of 293.5(#1), 151.6(#2), 57.2(#3) and 10km (#4). Vertical red line indicates the theoretical T-phase arrival time being the time residuals for the earthquakes -68.5, -23.6, 5.8 and 101.2s. **Maps** present the locations of the conversion from seismic to underwater sound waves for the four earthquakes. Each circle represents a detection pixel at H03S back-projected onto the map based on arrival times and azimuths computed by PMCC and considering 4.4 km/s for solid Earth propagation between the epicenter and the conversion point and a nominal value of 1.48 km/s for in-water propagation along the geodesic path from the conversion point to the hydrophone station. The earthquake epicenters are indicated by orange stars.

Inputs for wavefield simulation

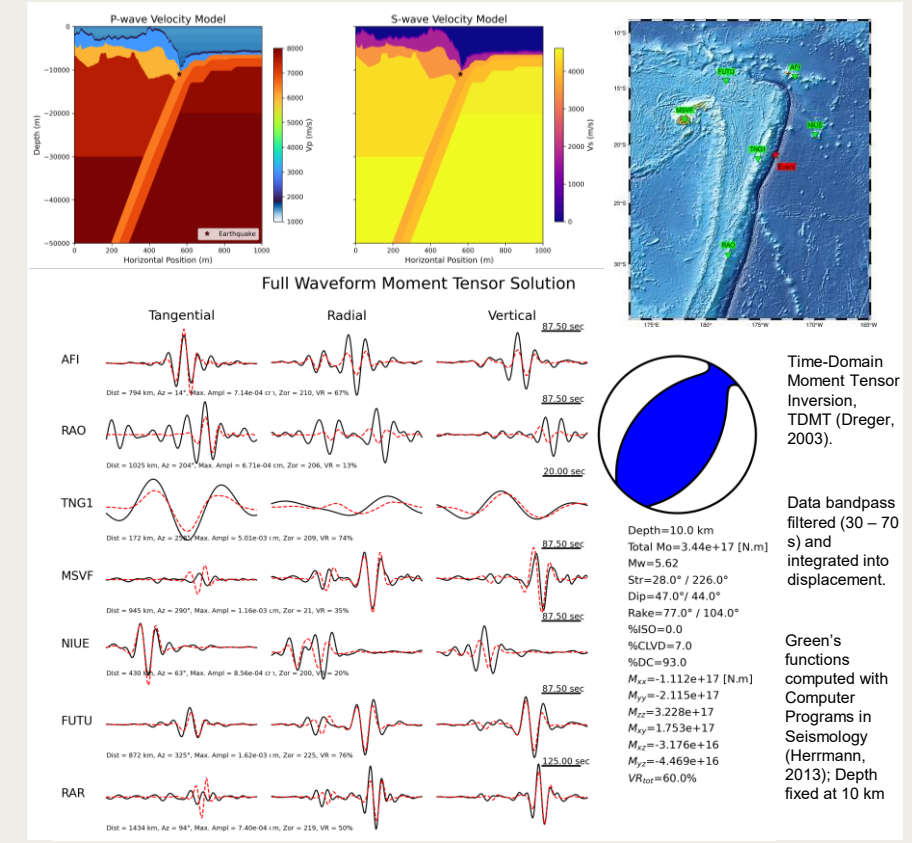

Figure 4: Earth (Crawford et al., 2003) and water (HYCOM) velocity models, and moment tensor calculated for earthquake #1 to be used as input for wavefield simulation with SPECFEM (work in progress).

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T-phases from earthquakes in the Philippines and Chile subduction zone

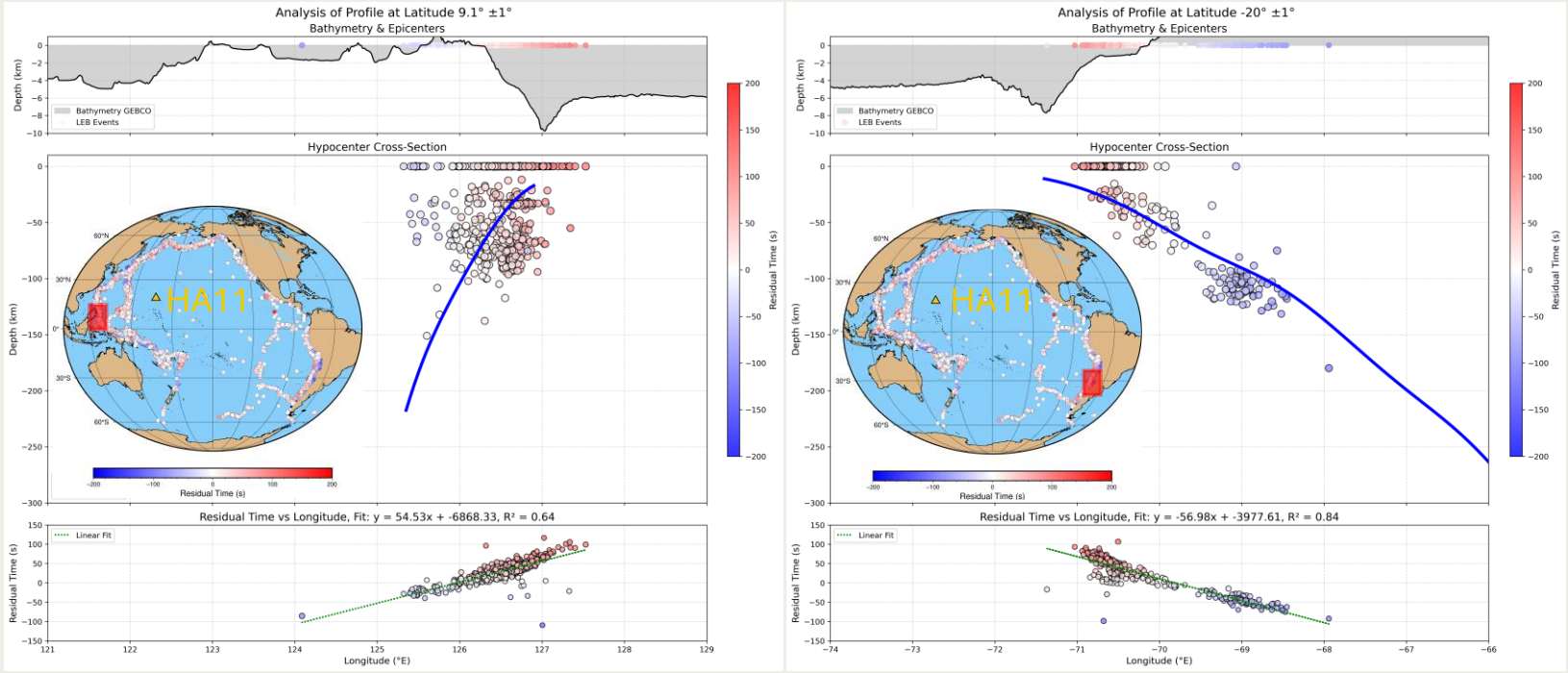

Figure 5: Time residuals at H11S in LEB for T-phases from earthquakes in the Philippines subduction zone (left) and in the Chile subduction zone (right) between 2008 and 2025. Profiles are shown at 9.1deg north (± 1deg) for the Philippines and 20.0deg south (± 1deg) for the Chile subduction zones. Like as observed for the Tonga–Kermadec subduction zone (Figure 2), time residuals in the Philippines and Chile subduction zones range from about –150 to +150s, shifting from negative to positive as earthquake depth decreases along the subduction plate toward the Ocean Trench.

Conclusions

- Time residuals at HA11 and HA03 for T-phases from deep earthquakes in the Ring of Fire depend on the location of the hypocentre along the subduction plate.
- Overall, time residuals go from negative (T phases arrive earlier than expected) to positive (later than expected) as the earthquake depth decreases along the subduction and approaches the Ocean Trench.
- It is suggested that the observed time residuals are due to the conversion from seismic to underwater sound waves mechanism.
- We are working on using wavefield simulation (SPECFEM) to confirm the location of conversion from seismic to underwater sound waves.

Data availability

- The IMS data used in this article are available to the IDC authorized users or via the vDEC platform at the CTBTO. More information on accessing the vDEC platform is available at www.ctbto.org/specials/vdec/.