



The relationship between past radiative forcings and ENSO activity

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Background/Introduction

- El Niño Southern Oscillation (ENSO) is one of the most influential impacts on the climate of the tropical Pacific, where it occurs, as well as having far-reaching global consequences (Glantz et al., 1991).
- ENSO varies irregularly even in the absence of significant external radiative forcings, but **will future anthropogenic radiative forcings have a significant impact on these cycles** (Collins et al., 2010)?
- Various studies based on the Zebiak-Cane climate model (1987) indicate that:
 - negative radiative forcings, such as those caused by large volcanic events, will likely decrease the zonal sea surface temperature gradient resulting in positive feedbacks that increase the tendency for warm-phase events to occur, and
 - positive forcings may increase the tendency for cold-phase events (Clement et al., 1996; Adams et al., 2003; D'Arrigo et al., 2006; Mann et al., 2005; Emile-Geay et al., 2008).
- Specifically, Mann et al. (2005) found a tendency for El Niño events to occur in the year following a major eruption (Mann et al., 2005).

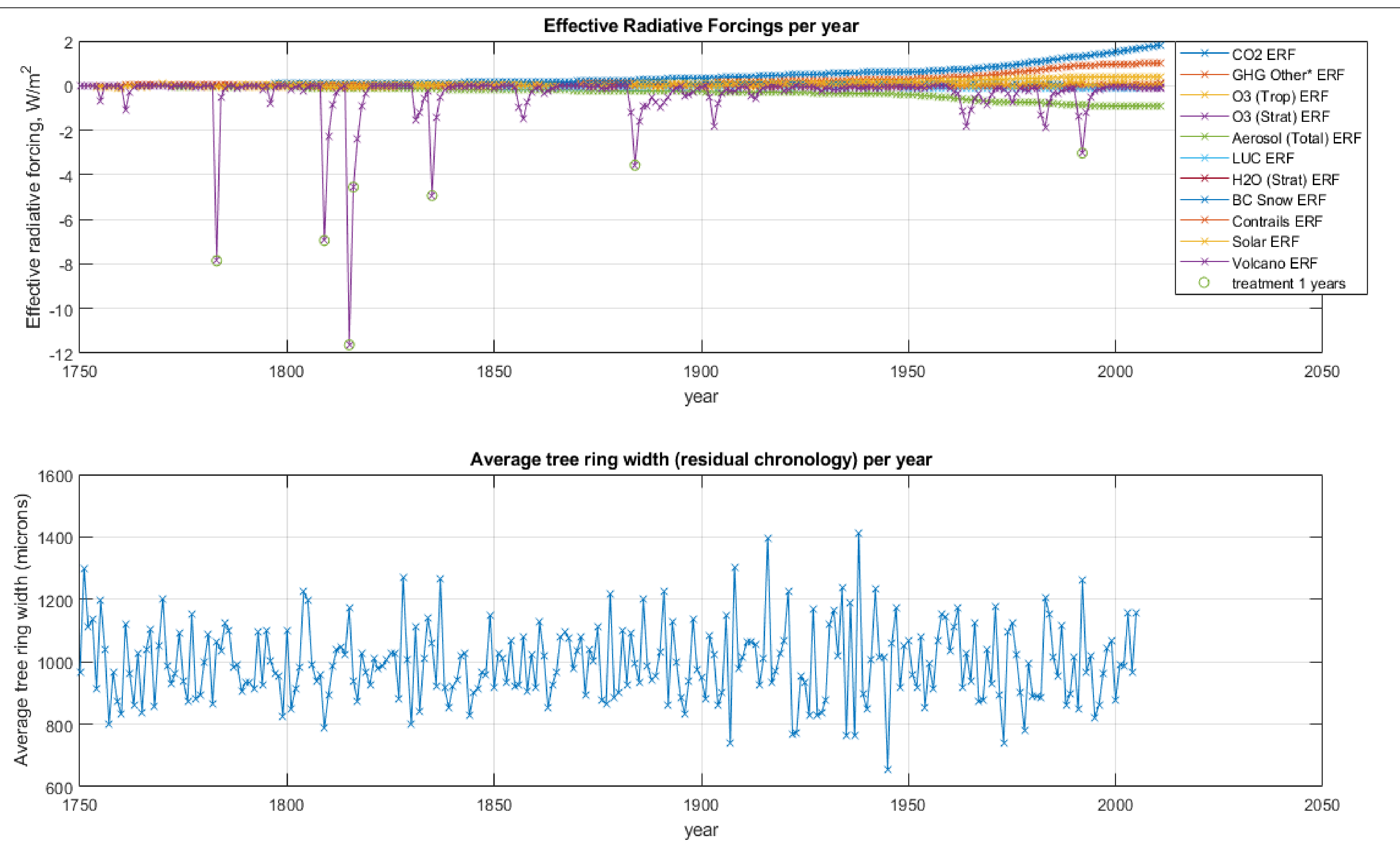


Figure 2: *Top:* Effective radiative forcings per year from 1750 to 2005, based on IPCC AR5 report, Annex II, Table AII.1.2 (2013). Years in which volcanic forcings fell into the 95th percentile are marked.

Bottom: Residual chronology from 1750 to 2005 of average tree width values from D'Arrigo et al. (2010).

Demonstration of Feasibility / Preliminary Results

- The first treatment was selected using years in which the 95th percentile of volcanic forcing events occurred (IPCC, 2013) (Figure 2).
- The second treatment was randomly selected from remaining years once the decades starting with each of the first treatment years were excluded (to ensure independence of treatments, based on the observation of Mann et al. (2005) that ENSO variation might be affected for the ten years following a major volcanic forcing).
- Due to the random nature of the second treatment, the analysis was run 20 times. The resulting F ratio was significant for only 5% of these runs, so at a pcrnt value of 0.05, this indicates that there is no significant variation between years of volcanic forcings and non-forcing years.

Possible implications:

- External radiative forcings may not significantly affect ENSO variation.
- Teak TRWs may not be as clear an indicator of ENSO activity as previous research (e.g., D'Arrigo et al. (2006) has indicated.

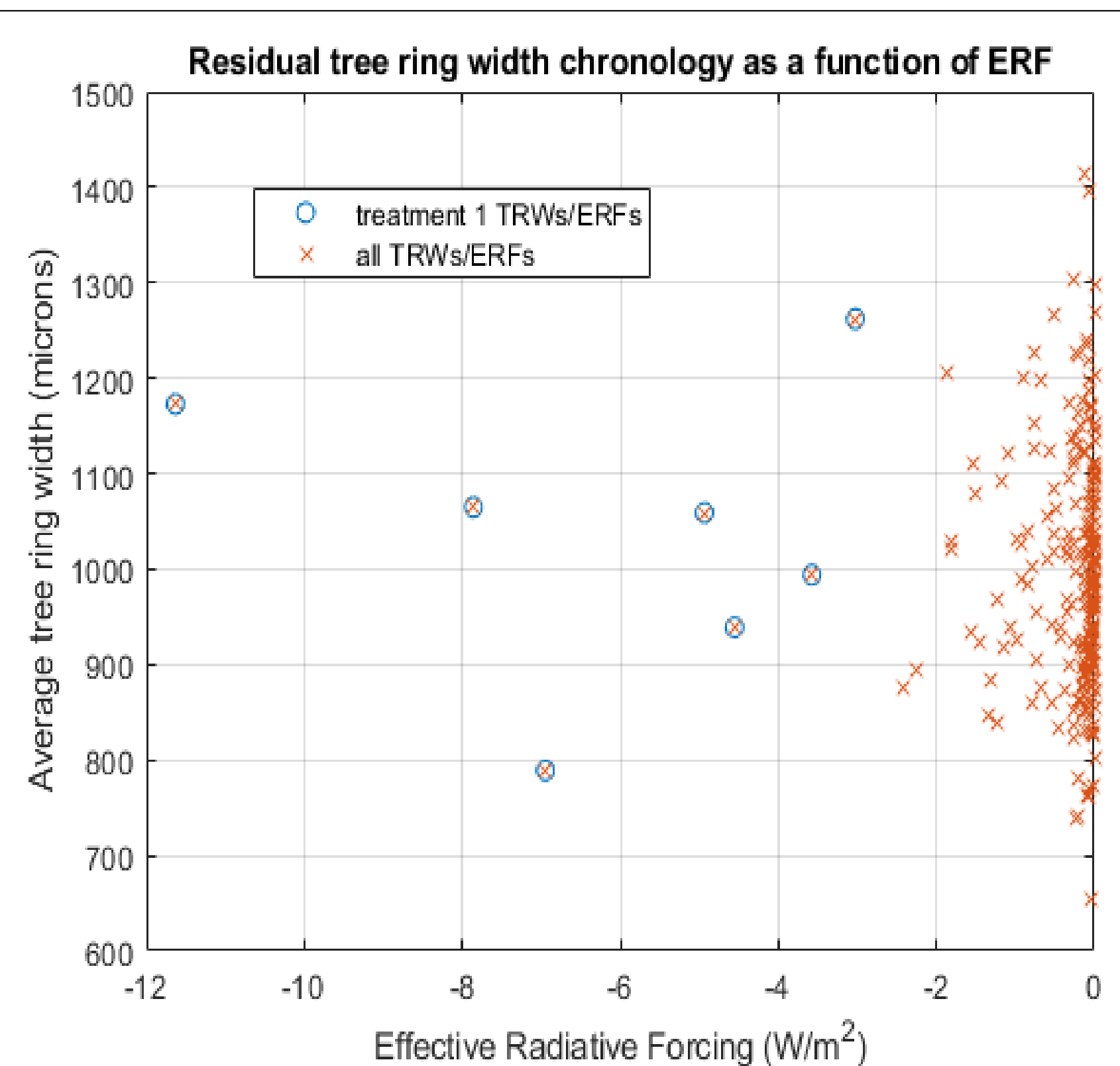


Figure 3 (above): Average tree ring width as a function of effective volcanic radiative forcing for 1750 to 2005. ERF does not appear to have a significant effect on TRW here. TRW values from D'Arrigo et al. (2010); volcanic ERF values from IPCC (2013).

Future Work

- More runs of the analysis, as the non-forcing years are randomly selected, which may skew results without replication
- Testing assumptions behind the hypothesis (e.g., performing the same analysis directly on Indonesian rainfall records or on ENSO sea surface temperature indices to compare to and evaluate accuracy of TRW as a proxy for ENSO)
- Analysis of TRWs from the individual increment cores used to calculate the averaged dataset (D'Arrigo et al., 2010)
- If possible, $\delta^{18}\text{O}$ analysis of tree rings ($\delta^{18}\text{O}$ data from tropical tree rings often provides an even more sensitive record to precipitation variations and can serve as another ENSO proxy (Scholleen et al., 2015; Evans et al., 2007), which could be useful for comparison)

Experimental Design and Methods

- Indonesian teak (*Tectona grandis*) tree ring width (TRW) is mainly controlled by precipitation in Indonesia, which is controlled primarily by ENSO (Bijaksana et al., 2007).
- Thus, Indonesian tree ring widths can be used as a proxy for variation in ENSO in any given year.
- During the El Niño phase, Indonesia experiences drought, which should result in narrower teak TRWs.
- Working hypothesis:** the tree ring widths of Indonesian teak increment cores will be significantly narrower during the years in which major volcanic forcings occurred, indicating an increase in warm phase ENSO events as predicted by Mann et al. (2005), than for years in which there were no major radiative forcings.
- Null hypothesis:** the tree ring widths of Indonesian teak increment cores will not be significantly narrower during the years in which major volcanic forcings occurred, indicating that there was no increase in warm phase ENSO events, than for years in which there were no major radiative forcings.
- Statistical test: Single factor fixed effects ANOVA
- Statistical model: Total variance = treatment variance + error variance
- Sample location: Muna, Indonesia (-4.8686, 122.7094) (Figure 1)

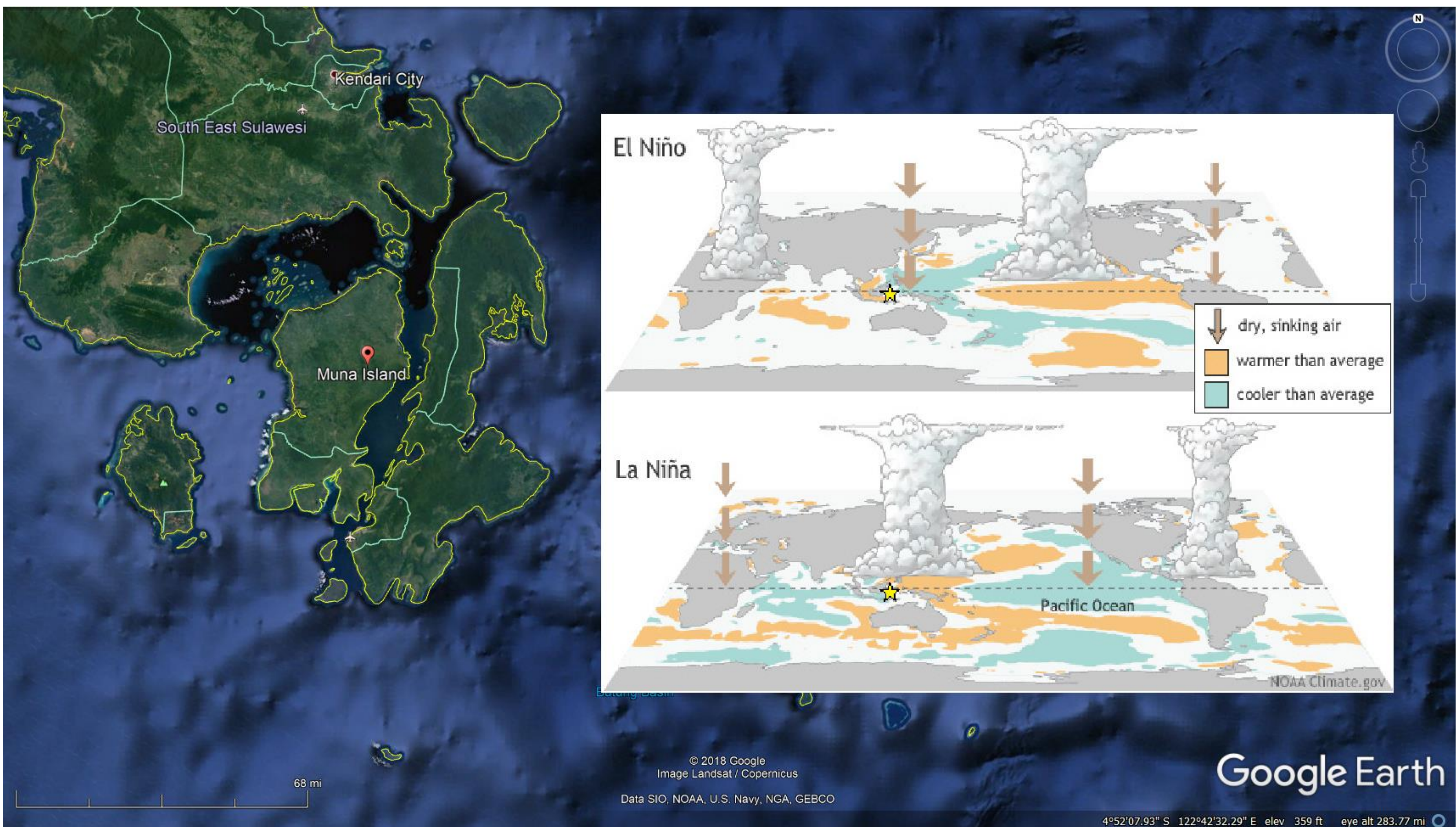


Figure 1: Muna, Indonesia, where samples (D'Arrigo et al., 2010) originate.

Inset from https://www.climate.gov/sites/default/files/ENSOPageWhatIsElNinoTest_0.png; stars (added) mark Muna's location in relation to ENSO-related precipitation (clouds).

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