

Data Modelling of Marine Paleoclimate Observations for Reconstructing El Niño

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Introduction

- Motivation: to address questions about changes in El Niño Southern Oscillation (ENSO) behavior due to anthropogenic forcing through reconstruction
- Can use paleoclimate observations to improve skill of paleo-reconstructions through data assimilation (DA)
- Paleoclimate observations archive past environmental data through proxy system models (PSM) which can be approximated with simple, linear data models.
 - Data models act as forward operators in DA
- Coral chemistry ($\delta^{18}\text{O}$, Sr/Ca) stores information about paleo sea surface temperature (T) and precipitation (P)
- Zebiak-Cane (ZC) anomaly model simulates T and atmospheric heating (AH) (which can be related to P through latent heating)

Scientific Working Hypothesis

Gridded time series data sets of tropical Pacific paleoclimate proxy data, specifically coral $\delta^{18}\text{O}$ and Sr/Ca ratio, when regressed with Zebiak-Cane model associated gridded historical climate observations of sea surface temperature and precipitation, will yield significant, linear data models with non-zero slope coefficients, allowing for data assimilation.

Methods

Data Model Framework (Alternate Hypotheses):

$$\delta^{18}\text{O} = h_1 * T + \delta^{18}\text{O}_r$$

$$\text{Sr/Ca} = h_2 * T + (\text{Sr/Ca})_r$$

$$P = h_3 * T + P_r$$

$$\delta^{18}\text{O}_r = h_4 * P_r + r$$

- Null Hypothesis: $h_n = 0$
- Critical P Value: 0.05
- Data Sources:
 - Paleoclimate: Steiger et al. (2018)
 - T: Kaplan et al. (1998)
 - P: Baker et al. (1995)

- MATLAB's "regress" function

Results

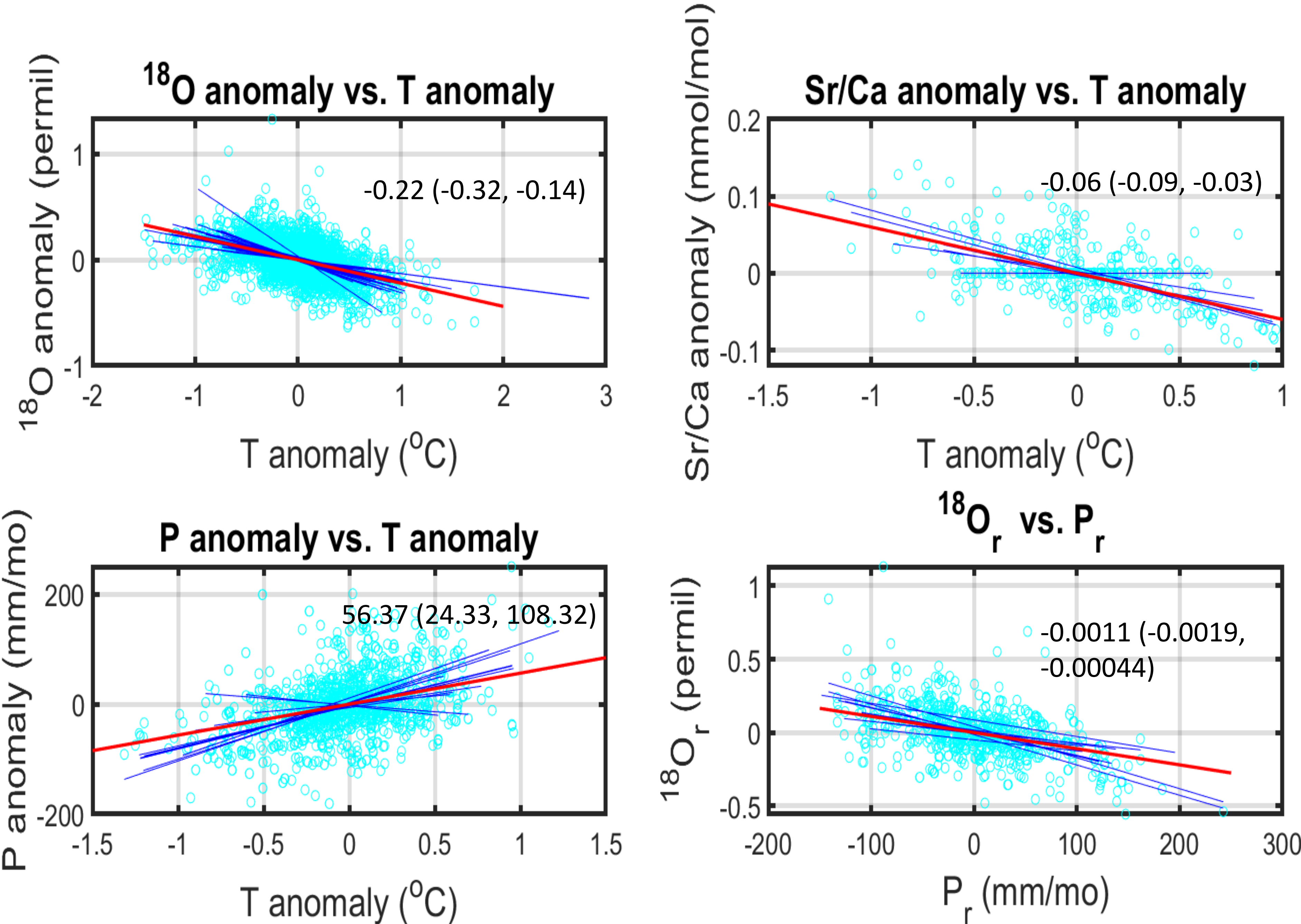


Figure (1): Figures displaying the results of each regression series in the data model framework. Cyan circles represent each significant data pair, blue lines represent each significant coefficient, and red lines represent the median significant coefficient of each respective regression. Median slope coefficients are reported in the space of each figure, with uncertainties at a 95% confidence interval.

Discussion

- Reject null for all significant coefficients
- $\delta^{18}\text{O}/\text{T}$ coefficients from previous literature:
 - 0.18 (+/- 0.080) (McCrea 1950)
 - 0.23 (+/- 0.020) (Epstein et al. 1953)
 - 0.22 (+/- 0.024) (Grossman and Ku 1986)
- (Sr/Ca)/T coefficient from previous literature:
 - 0.09 (+/- 0.03) (Kinsman and Holland 1969)
- Agreement within uncertainty between results (Figure 1) and independent, previous literature, points to stationarity and uniformity of chemical relationships
- $\delta^{18}\text{O}_r/P_r$ results reasonable at first order

Conclusions

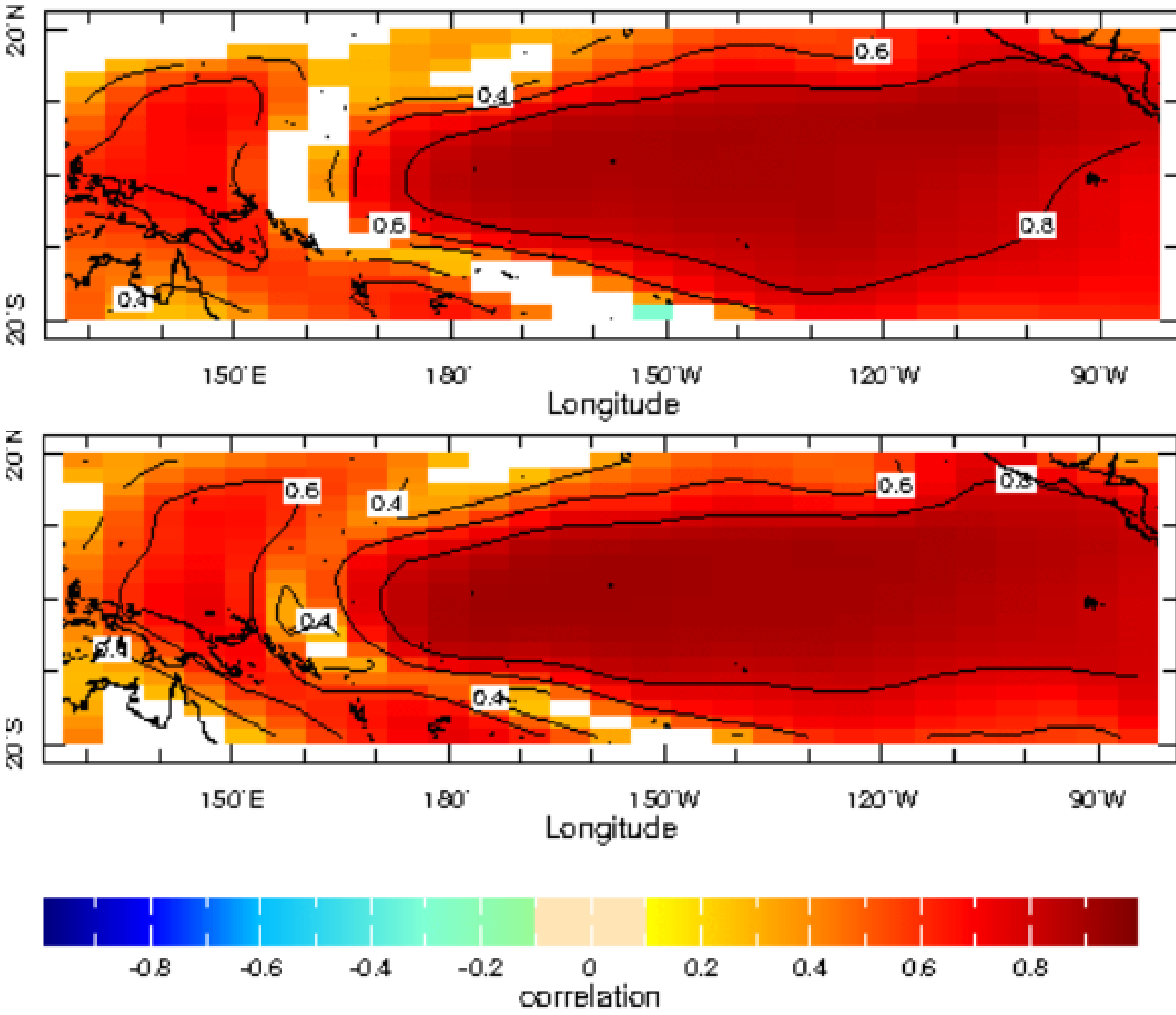


Figure (2): (Top): Correlation map between DA-estimated T with data models trained on 1920-2000 and T observations from Kaplan et al. (1998,2000) for the period 1871-1919. (Bottom): As for top panel, except T observations were for the period 1920-2000. Correlations are masked for significance at the $p < 0.05$ level. Validation performed by Alexey Kaplan.

- All significant $\delta^{18}\text{O}/\text{T}$ and (Sr/Ca)/T data models usable in DA
 - Assumptions of stationarity acceptable, ENSO reconstruction viable well into the past using these data models
 - Preliminary validation performed using DA (Figure 2)
- Further work: connecting P to AH, allowing $\delta^{18}\text{O}_r/P_r$ model to be used for DA

References

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