Cooling and freshening of the Eastern Equatorial Pacific over the last 2000 years

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Sea surface temperatures in the eastern equatorial Pacific exert powerful influence on the climate beyond the tropics through strong atmosphere-ocean coupling. Despite this importance, the climatic record of this region remains poorly known over the past two millennia. Here we reconstruct EEP SST and $\delta^{18}O_{sw}$ from paired Mg/Ca and $\delta^{18}O$ in the mixed-layer foraminifera *Globigerinoides ruber* from an EEP sediment core from near the Galápagos archipelago in the EEP cold tongue. We find significant trends in both SST and $\delta^{18}O_{sw}$ over the last 2000 years. These trends are consistent with previously reported western Pacific trends thus suggesting a basin-wide phenomena. Our reconstruction of the tropical zonal SST gradient does not support equatorial Pacific ocean-atmosphere dynamics as the source of these trends. Rather, we propose that these signals originate in the extra-tropics and are transmitted to the EEP via advection, likely in response to orbital forcing.

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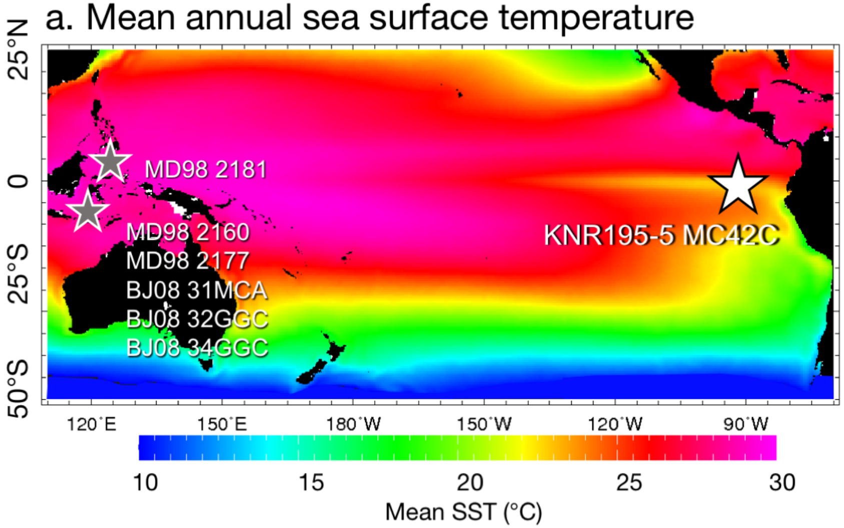
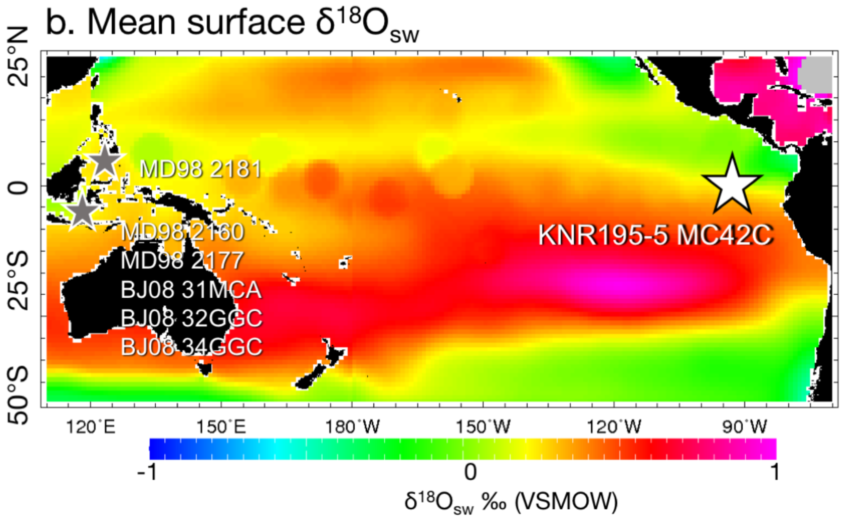
Study Site: Eastern Equatorial Pacific

- Sediment core KNR195-5 MC42C
  - 01° 15.58´S, 89° 41.13´W, 615m depth
- Highly dynamical SSTs
  - Upwelling strength
  - Strong ENSO (dynamical) influence





a. Mean SST , 1958-2008 (Carton and Geise, 2008)
b. Mean surface δ18Osw (Legrande and Schmidt (2006)

White star shows EEP core MC42C location. Gray stars show Western Pacific cores referenced in the study

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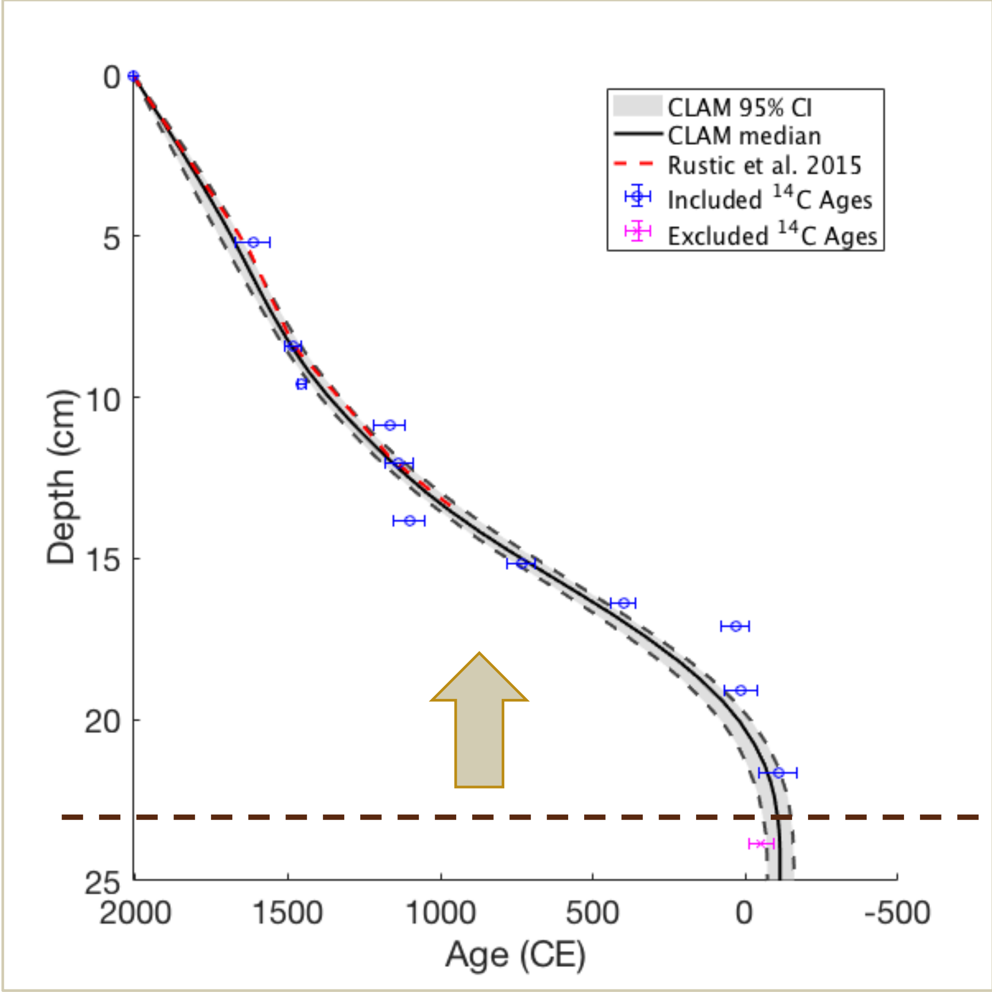
MC42C age model

- 11 ^{14}C ages, CLAM calibration (Blaaw, 2010)
- Core-top from date of retrieval (2009)
- Avg. sedimentation rate of 11cm/ky in top 24cm
  - Range between 6-21cm/ky
- ^{14}C reversals and distinct change in sed. rate below @24cm



Rustic et al., unpublished data

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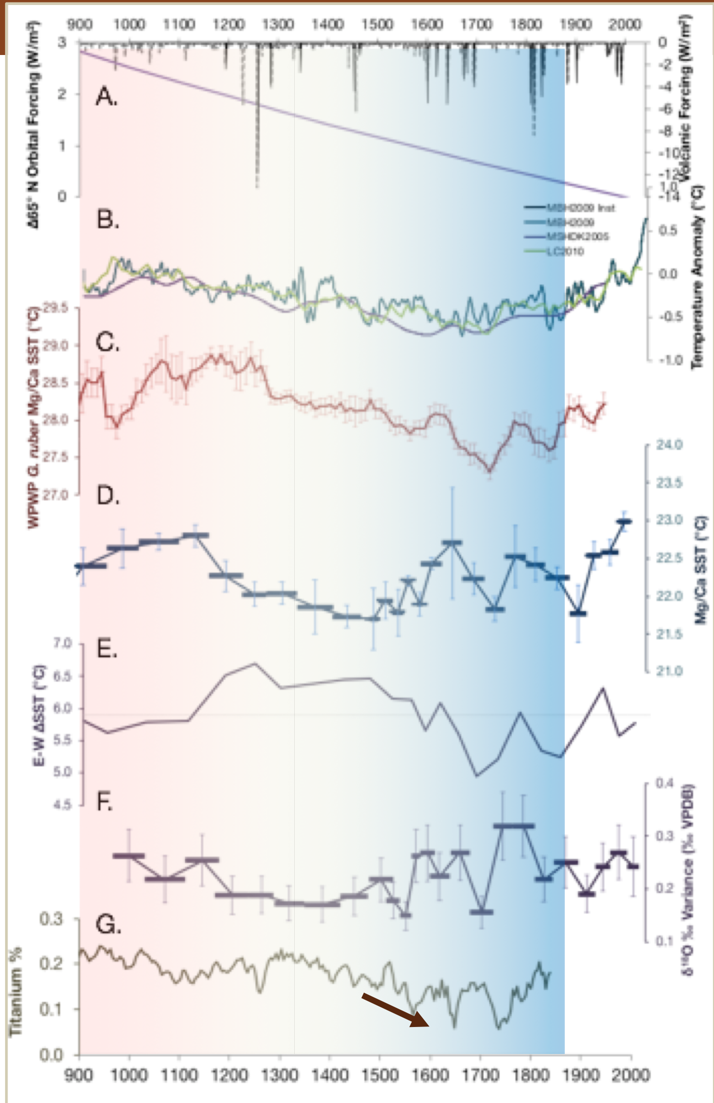
Previous EEP research: ENSO and SST of the last millennium

- Distinct changes in EEP SST
- Distinct changes in ENSO variability from individual foraminifera $\delta^{18}O$
- Linked to dynamical changes
  - E-W SST gradient
  - ITCZ location

- Record ends at 900CE
- No same-sample multi-specimen $\delta^{18}O_{calcite}$ for reconstructing $\delta^{18}O_{sw}$



(A) Volcanic forcing and 65°N June orbital forcing as anomaly from present (Laskar et al. 2011, Crowley et al. 2003) (B) NH temperature reconstructions. Instrumental record in black. (C) EEP Mg/Ca SST from KNR195-5 MC42C. (D) WPWP G. ruber Mg/Ca SST (Oppo et al. 2009). (E) Zonal SST gradient (difference between C and D) (F) EEP δ18Oc variance from individual G. ruber (G) Titanium % in the Cariaco Basin (Haug et al. 2001) From Rustic et al. 2015, see paper for refs.)

Modified from Rustic et al., Science, 2015

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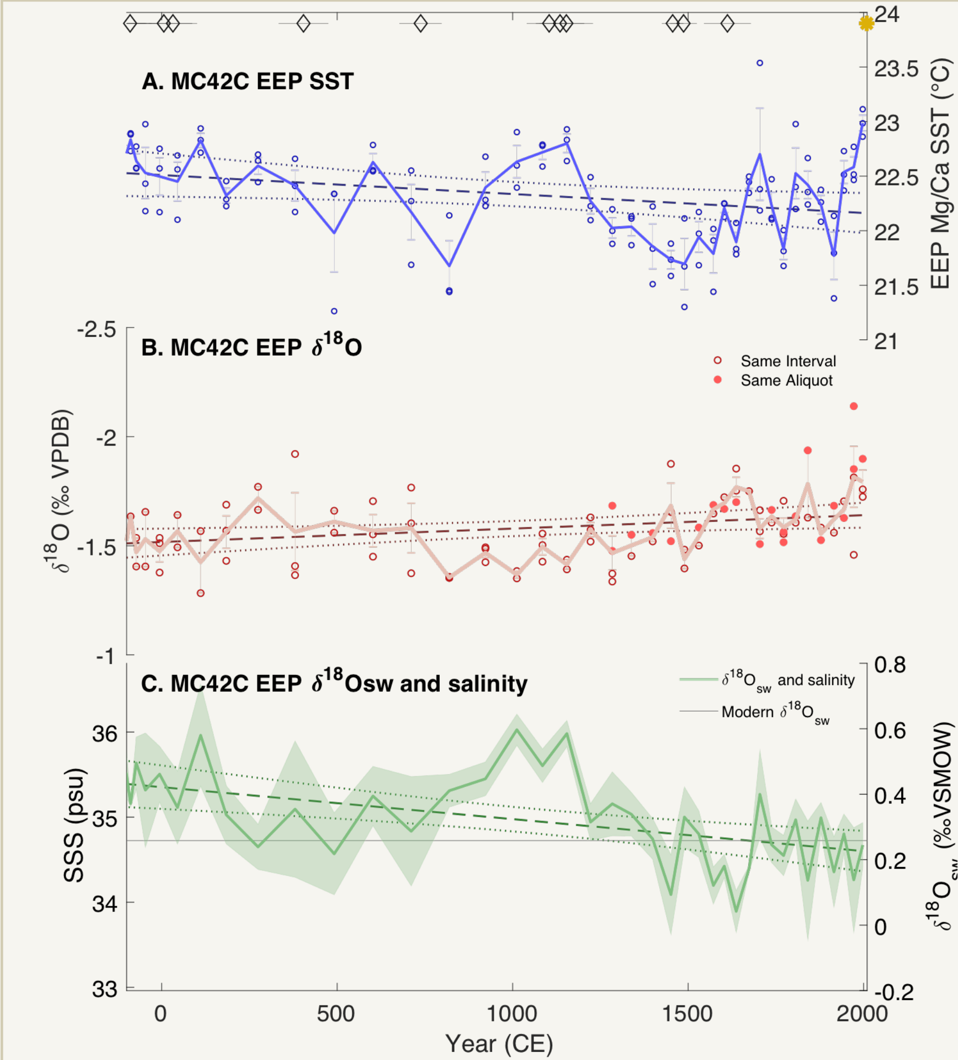
This study:
2000 year record of EEP Mg/Ca SST, $\delta^{18}O$

- Mg/Ca SST cooling
  - -0.17°C/ky
- *G. ruber* $\delta^{18}O_c$ decrease
  - -0.07 ‰/ky
- Compensating change in $\delta^{18}O_{sw}$
  - -0.11‰/ky
- SST Cooling + trend toward lower $\delta^{18}O_{sw}$ / lower salinity
  - Salinity – $\delta^{18}O_{sw}$ equation from Fairbanks et al. 1992



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Cooling across the tropical Pacific over the last 2000 years

- SST cooling in EEP and Western Pacific
- Intermediate water cooling in the Western Pacific
- Reduced $\delta^{18}O_{sw}$ in EEP and Western Pacific

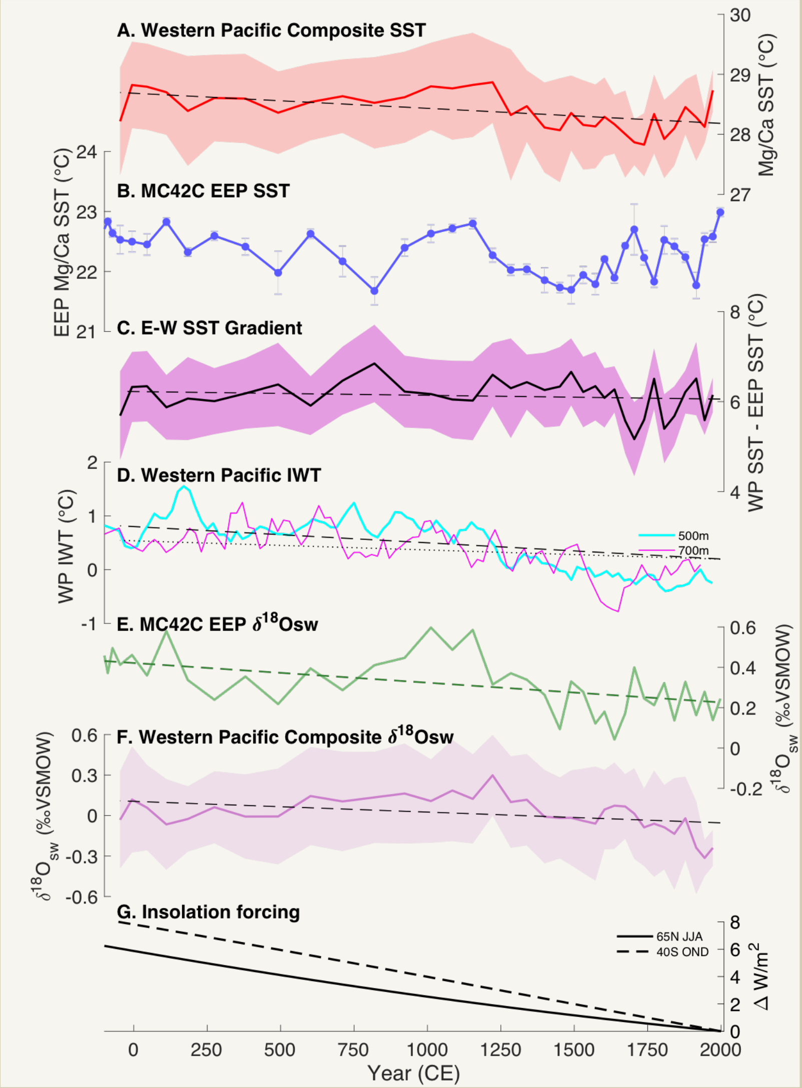
- Reduced insolation during Common Era
  - 65°N boreal summer

    OR
  - 40°S austral summer

Drivers: Insolation?

Western Pacific records: MD2160 and MD2177 (Newton et al., 2011), MC31, 32GGC and 34GGC (Oppo et al., 2009) and MD2181 (Khider et al., 2014) . Intermediate water temperatures from Rosenthal et al. 2017. Insolation change relative to 2010 (Laskar et al. 2011.)

Rustic et al., unpublished data



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Insolation forcing via cooling of source waters

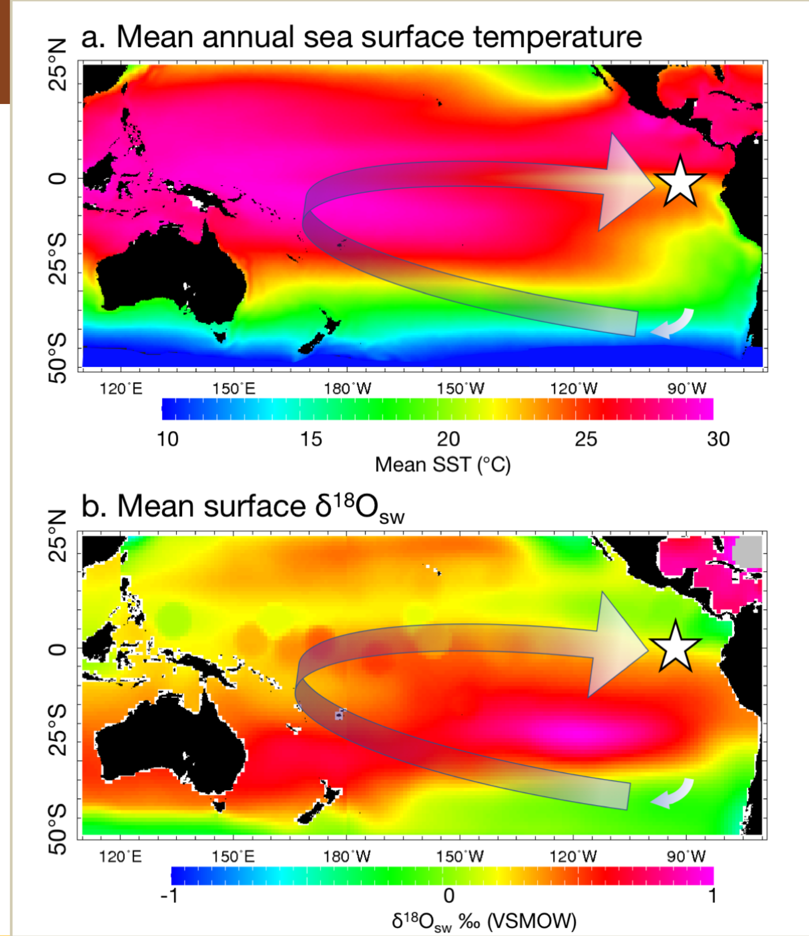
- Extra-tropical source waters of EEP
  - Antarctic Intermediate Water (AAIW)
  - Sub-Antarctic Mode Waters (SAMW)

- Evidence: Common Era cooling of regions sourced from SAMW and AAIW
  - Peru thermocline (Kalansky et al. 2015)
  - W. Pacific intermediate waters (Rosenthal et al. 2017)

- Insolation forced cooling of AAIW

  or

- Cooling of North Atlantic Deep Water (NADW)
  - AAIW via NADW and Antarctic Surface Water



Schematic diagram showing advective pathways from AAIW source region to EEP. Shallower depths are denoted by lighter arrow fill, deeper depths are darker. (Based on Gu, 1997)

Conclusions

✗ Dynamical explanations result in cooling + increased salinity or warming + freshening

✓ Cooling and freshening from advection + increased influence of cooler, low-salinity source waters in EEP

- Consistent with cooling / freshening of EEP **and** Western Pacific surface & subsurface

▸ Role for insolation

- 65°N – Cooling of NADW ➞ AAIW
- 40°S – Cooling of source region for AAIW

Take away:

(Insolation-forced) cooling and freshening of the EEP source waters

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