# The Tropical Pacific: A changeable communicator of Holocene solar forcing


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## Summary

1. Our statistical analysis of continuous, high resolution Holocene climate reconstructions shows that solar irradiance forced changes in the Coupled Ocean-Atmosphere System in the Tropical Pacific throughout the Holocene
2. The response to solar irradiance forcing was opposite between the Early and Late Holocene owing to the superposition of solar and orbital forcings. In the Early Holocene, the Tropical Pacific warmed during solar maxima whereas in the Late Holocene it cooled during solar maxima.
3. The changeable response of Tropical Pacific modified how solar forcing was communicated to the climate system during the Holocene


## Introduction

The Coupled Ocean-Atmosphere System of the Tropical Pacific (COASTP) is one of the principal mechanisms for communicating solar irradiance variations to the climate. However, during the Holocene the dynamics of the COASTP were changing as a result of longer-term orbital trends. We set out to find evidence of how these orbital forced changes in the COASTP modified solar irradiance forcing of Holocene climate.

## Methods

In order to understand the response of the COASTP to solar forcing throughout the Holocene, we performed cross correlation and change-point analysis between a reconstruction of solar irradiance and continuous, high resolution oceanic and atmospheric proxies from the Tropical Pacific region.

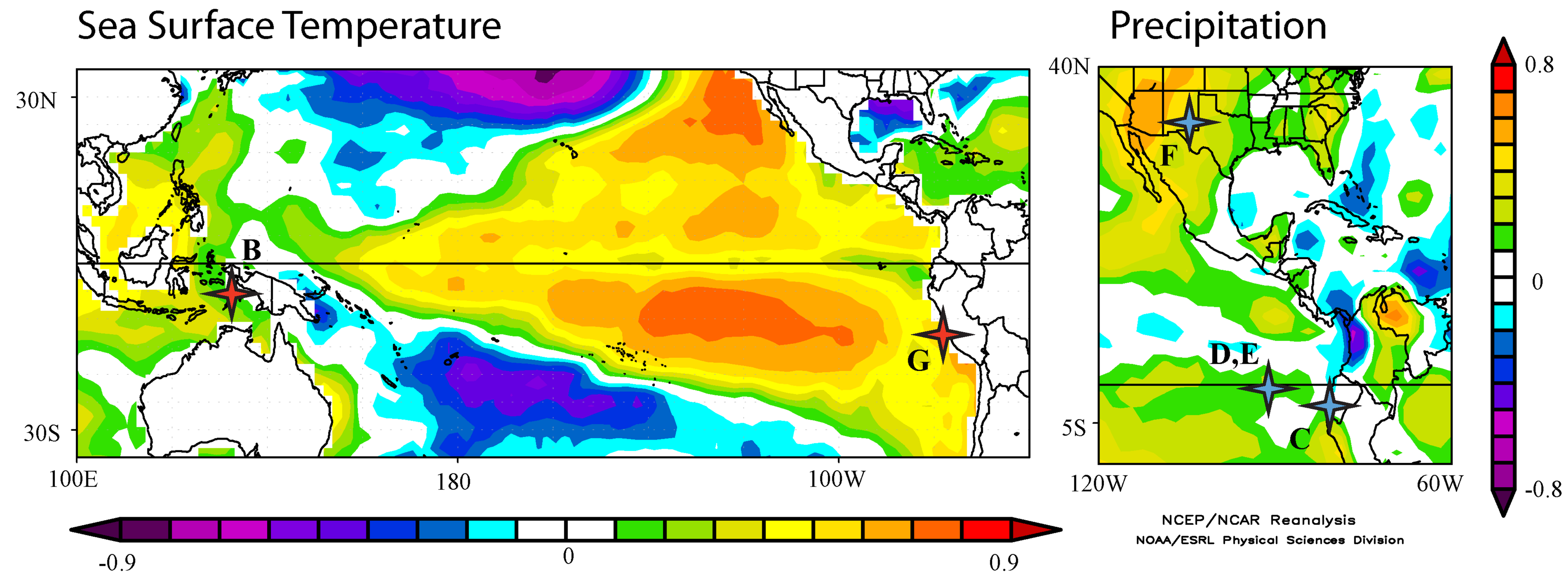


**Figure 1. NCEP/NCAR reanalysis correlations between the Pacific Decadal Oscillation (PDO) index with SST and precipitation.** Locations of proxy timeseries shown. Letters correspond with Figure 2 (solar not shown).

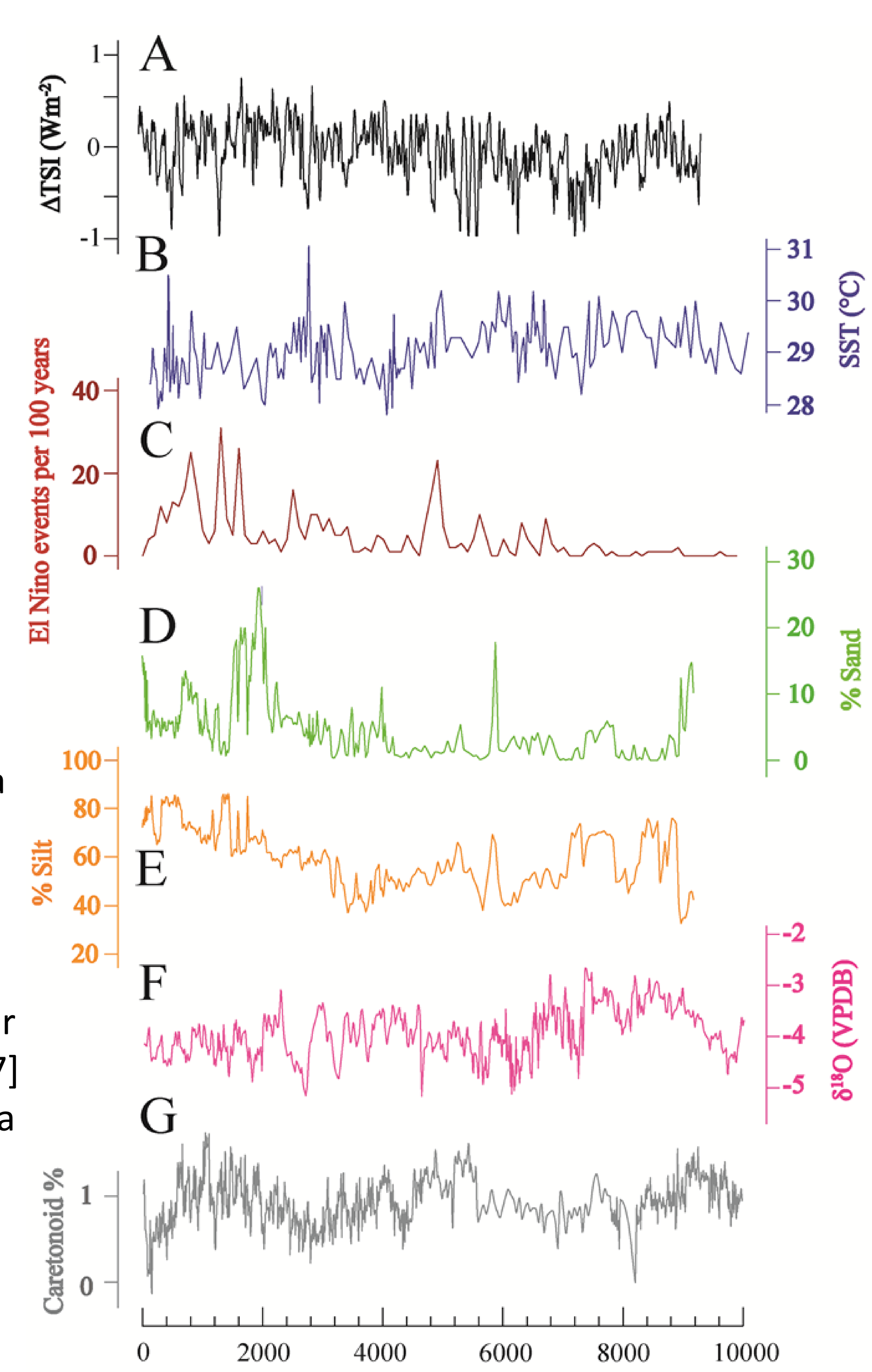


**Figure 2. Proxy timeseries used in our analysis**. A) Total Solar Irradiance (TSI) anomaly reconstructed from $^{10}$Be isotopes in ice cores [*Steinhilber et al.,* 2009] (B) Sea surface temperature of the Indo Pacific Warm Pool reconstructed from Mg/Ca in planktonic foraminifera *Globigerinoides ruber* from a core located off the Southwest of Papua [*Stott et al.,* 2004] (C) Frequency of El Niño events derived from clastic laminae in sediments from Laguna Pallcacocha, Southwest Ecuador [*Moy et al.,* 2002] (D) Percentage of sand in a lake core from El Junco Lake, the Galapagos Islands, which is an indicator of the frequency of El Niño events [*Conroy et al.,* 2008] (E) Percentage of silt in in a lake core from El Junco Lake, the Galapagos Islands, which is an indicator of background wetness [*Conroy et al.,* 2008] (F) δ$^{18}$O in speleothem from Pink Panther cave in New Mexico which is an indicator of changes in winter and summer precipitation [*Asmerom et al.,* 2007] (G) Log of carotenoid percentage in a core from a basin at the edge of the continental shelf of the coast of Peru which is an indicator of changes in upwelling intensity [*Rein et al.,* 2005]

See A4 hand-out for full citations

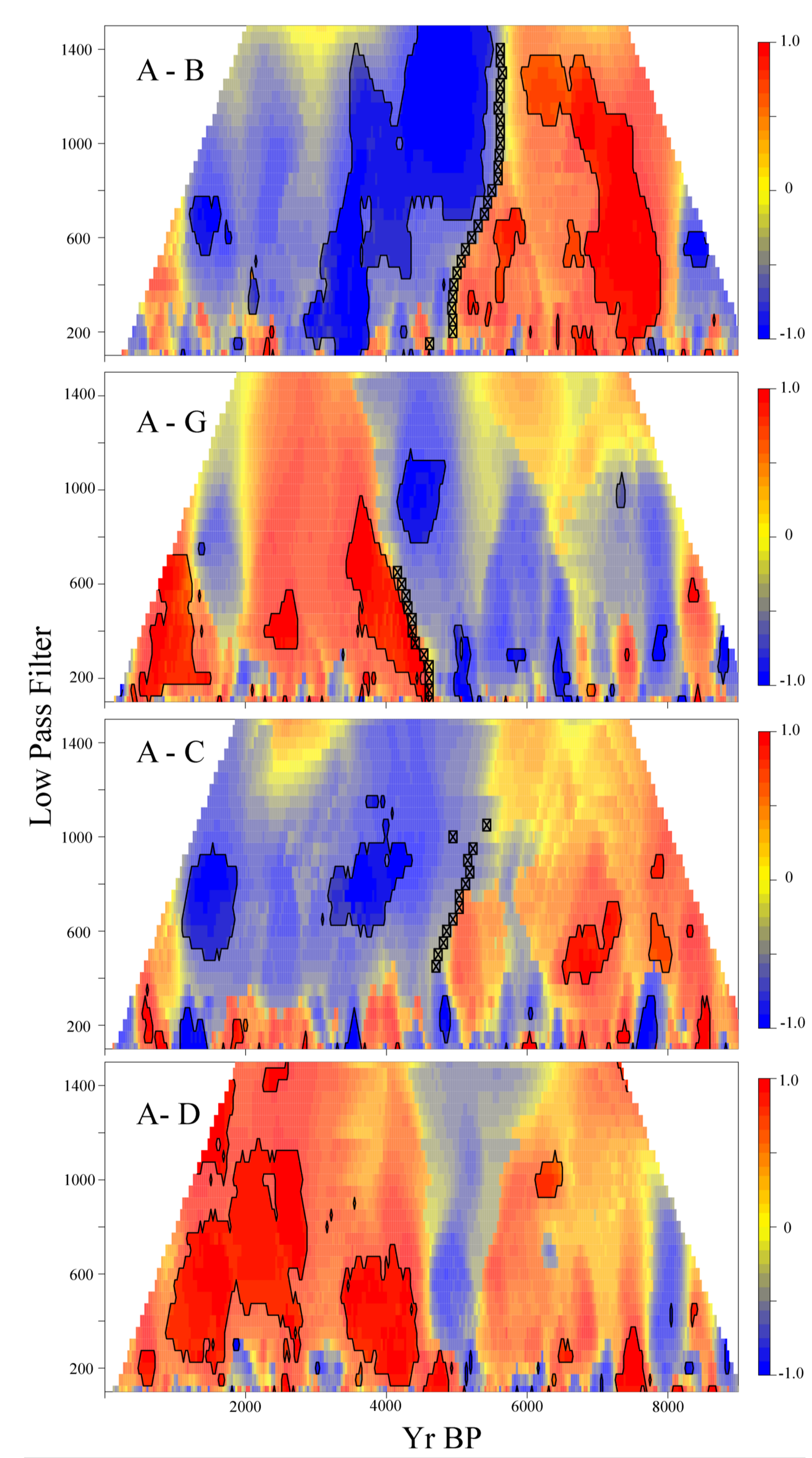


**Figure 3. Shift in response of the COASTP to solar forcing.** Cross correlation and change point analysis between solar irradiance and 4 climate reconstructions from the Tropical Pacific. Correlations within the bold black outlines are significant at 95% confidence interval. X's indicate the switch point when a statistically significant (95% CI) change in correlation occurred.Letters coincide with Figure 2.

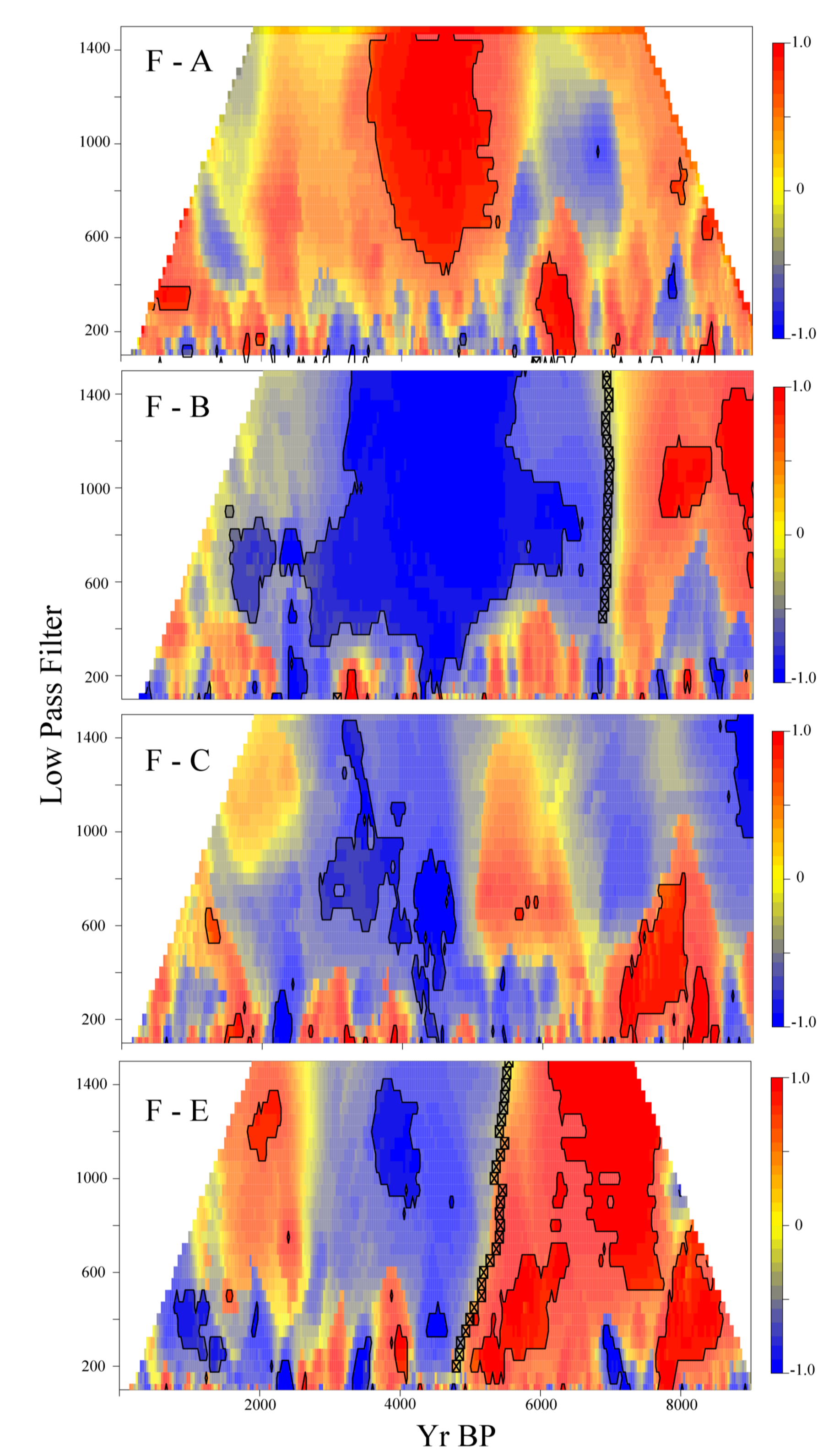


**Figure 4. Teleconnections between Tropical Pacific and New Mexico precipitation.** Cross correlation and change point analysis between δ$^{18}$O from a speleothem in New Mexico and solar irradiance and 3 climate reconstructions from the Tropical Pacific (higher δ$^{18}$O indicative of drier conditions). Correlations within the bold black outlines are significant at 95% confidence interval. X's indicate the switch point when a statistically significant (95% CI) change in correlation occurred.Letters coincide with Figure 2.

## Results

Our results show that throughout the Holocene centennial-scale changes in the COASTP were forced by variations in irradiance emitted from the sun. Importantly, our analysis demonstrates that the response of the coupled ocean-atmosphere system to solar forcing changed during the Holocene likely owing to the superposition of solar irradiance and orbital forcing of the COASTP (Figure 3).

Cross correlation analysis between indicators of temperature of the Tropical Pacific and precipitation in New Mexico show that in the Early Holocene solar-forced warming of the Tropical Pacific weakened the monsoon, bringing drier conditions to New Mexico. However, in the Late Holocene solar-forced strengthening of Walker Circulation [*Emile-Geay et al.* 2007] at centennial timescales brought about PDO-negative-like conditions and reduced rainfall over the SW USA (Figure 4).