Tropical Pacific Decadal Variability: Current Understanding and Open Questions

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Tropical Pacific Decadal Variability can modulate El Niño Southern Oscillation (ENSO) and its impacts. It can also control the increasing rate of globally-averaged surface temperatures. Ocean processes underpinning Tropical Pacific decadal variations in response to atmospheric forcing can be expected to operate also in the context of anthropogenically forced trends. Understanding these processes in observations and observationally-based products can help assess the ability of climate models to realistically simulate decadal variability and longer-term trends. Here, we review the leading processes involved in Tropical Pacific Decadal Variability using observations, ocean reanalyses, and model simulations (Capotondi et al. 2023, https://www.nature.com/articles/s43017-023-00486-x)

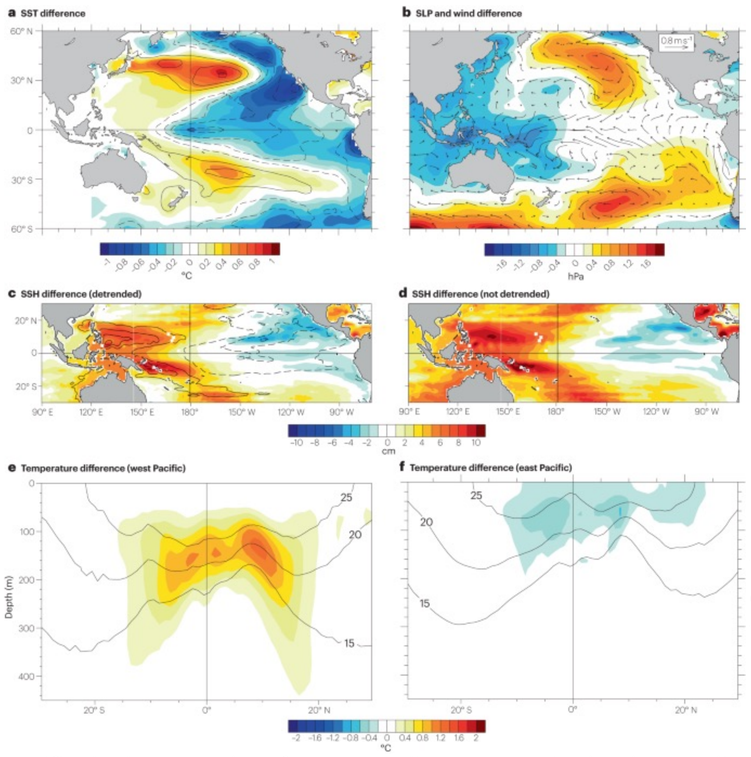
A Decadal Phase Transition (1999-2014 minus 1984-1999)

A transition from warm (1984-1999) to cold (1999-2014) tropical Pacific epochs

Detrended SST difference is ENSO-like, but with largest anomalies in the central tropical Pacific and broader meridional scale relative to ENSO.

Detrended SSH difference. Positive SSH is indicative of enhanced upper ocean heat content.

Detrended temperature difference west of the dateline.



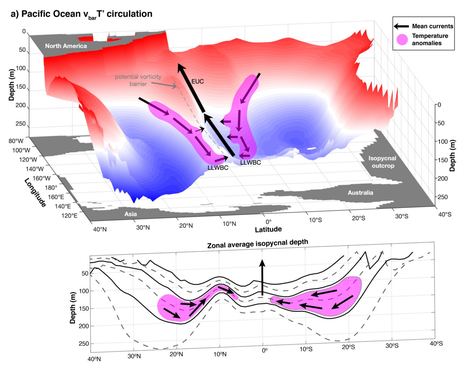
Detrended SLP and surface winds difference: SLP anomalies contribute to an intensification of the trade winds in the tropics.

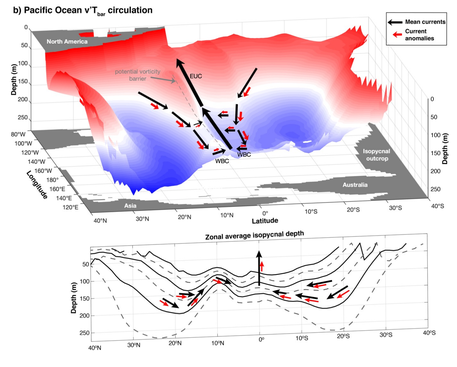
SSH difference with trend

Detrended temperature difference east of the dateline.

In the western tropical Pacific the largest subsurface anomalies are seen in the thermocline (as indicated by the mean isotherms). This suggest that subsurface anomalies are associated with vertical movements of the thermocline, due to Rossby wave activity.

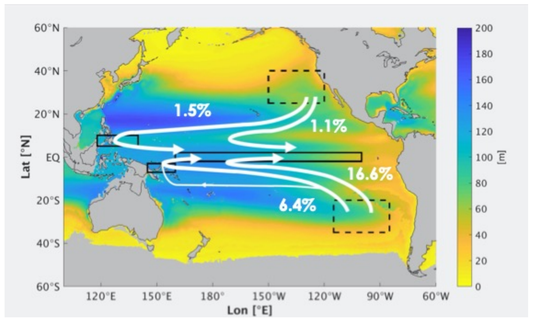
Three-dimensional structure of the STCs: the $\bar{v}T'$ vs. the $v'\overline{T}$ hypothesis



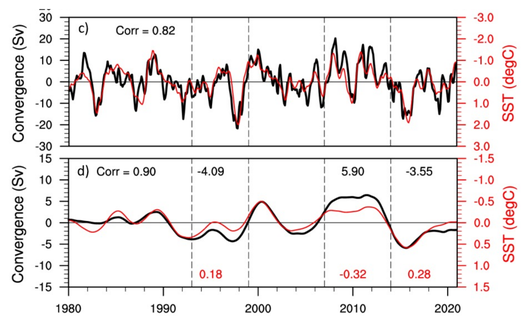


According to the $\bar{v}T'$ hypothesis, density-compensated temperature anomalies are advected by the mean STCs to the equator, where they can be brought to the surface by equatorial upwelling and alter equatorial SSTs.

According to the $v'\overline{T}$ hypothesis, changes in the strength of the STCs will result in variations of equatorial upwelling:
Stronger STCs -> Colder SST anomalies
Weaker STCs -> Warmer SST anomalies



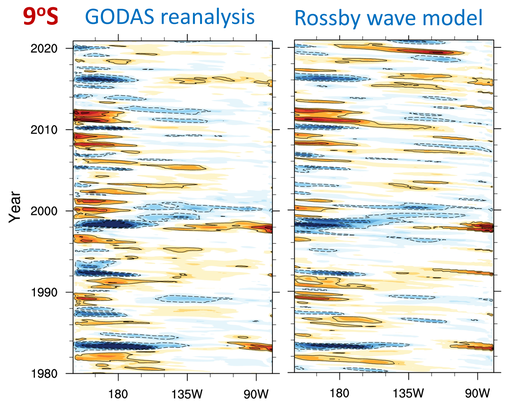
Model simulations show the existence of spiciness pathways from the subtropics to the equator, but impact on equatorial SSTs seems small.

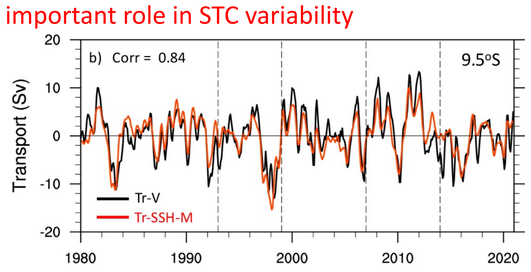


Large correlations are found between STC transport and equatorial SSTAs, but at zero lag, calling into question causal relationships.

Rossby wave activity plays an important role in STC variability

$$\frac{\partial \eta_m}{\partial t} - c_R \frac{\partial \eta_m}{\partial x} = -\frac{g'}{g} W_E - \epsilon \eta_m$$

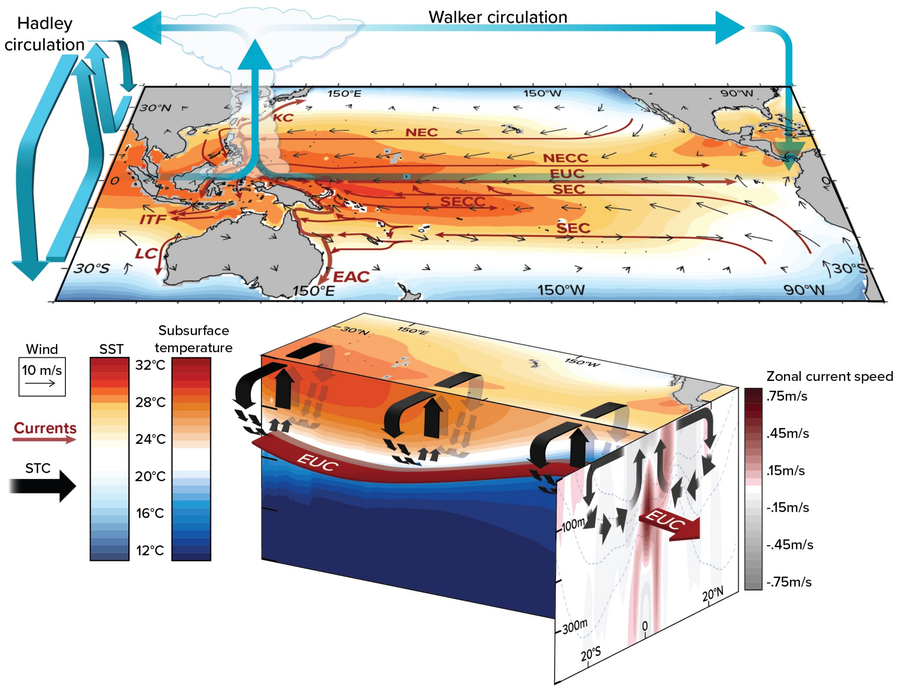




The simple Rossby wave model forced by the same Ekman pumping used for GODAS, can reproduce well the evolution of SSH at 9°S.

The cross-basin gradient of SSH from the Rossby wave model, which is related by geostrophy to the zonally-integrated meridional pycnocline transport, captures the transport computed directly from the meridional velocity (Capotondi & Qiu, 2023).

Mean Tropical Pacific Circulation



The tropical Pacific ocean circulation exhibits a complex set of zonal currents and low-latitude western boundary currents, that are in balance with the surface wind forcing. Important components of the ocean circulation are the Subtropical Cells (black arrows), which connect the subtropical regions with the equator. They can transport temperature anomalies to the equator, where anomalies are brought to the surface by equatorial upwelling, or can modify upwelling itself.

Conclusions

A key process involved in Tropical Pacific Decadal Variability is the ocean adjustment to varying wind forcing through Rossby wave propagation. Similar to ENSO, the adjustment timescale is not simply associated with the transit time of one wave, but with the integrated effect of multiple waves over a broad latitude range. **A key open question is the nature of the anomalous wind forcing. Are the winds involved in TPDV a response to decadal equatorial SST anomalies, due to influences from the extra-tropical Pacific, or originating from other basins?**