Columbia Climate School
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Historical Lack Of Warming In The Tropical Pacific And Its Dynamics

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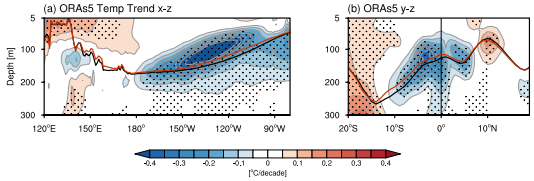
Introduction

✦ The tropical eastern Pacific has experienced lack of warming in recent decades, and it remains debated whether this trend is predominantly driven by internal variability or anthropogenic forcings.

✦ The long-term subsurface cooling in the tropical Pacific contributes to the surface lack of warming in recent decades, yet its dynamical origin is not clear.

Subsurface Temperature Trend During 1958-2022



Questions

✦ Is there an observed forced SST pattern distinguishable from internal variability and robust across different datasets?

✦ How does this SST pattern form?

Methodology

(1) Heat Budget analysis for climate change variability

✦ Identifying a climatology period and a climate change period.

$$\overline{\frac{\partial T}{\partial t}}_{P2} \approx \overline{\frac{\partial T}{\partial t}}_{P2} - \overline{\frac{\partial T}{\partial t}}_{P1} = \overline{ADV}_{P2} - \overline{ADV}_{P1} + R_{P2} - R_{P1}$$

(2) Wind-driven Ekman transport & pumping

$$U = \frac{r_s \tau + f(\tau \times k)}{\rho_0 (f^2 + r_s^2)} \qquad w_E = \nabla_H \cdot U$$

(3) Geostrophic zonal current and its relevance to surface wind stress

$$u_g = -\frac{g}{fa}\frac{\partial h}{\partial \varphi}$$

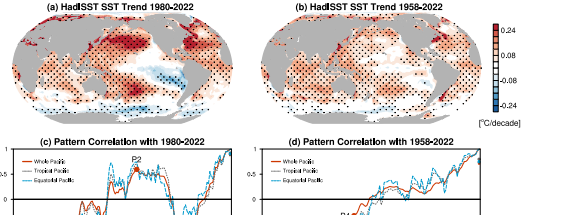
$$h = \frac{\rho_2 - \rho_1}{\rho_2} \int_{\lambda_e}^{\lambda} \frac{a}{g'h} \left(-\frac{sin\varphi}{cos\varphi}\frac{\partial(\tau^{\lambda'} cos\varphi)}{\partial \varphi} + \frac{sin\varphi}{cos\varphi}\frac{\partial \tau^{\varphi'}}{\partial \lambda} + \tau^{\lambda'} cos\varphi \right) e^{\frac{a^2 r f sin\varphi}{g'h}(\lambda - \lambda')} d\lambda'$$

(4) Mixing and gradient Richardson number

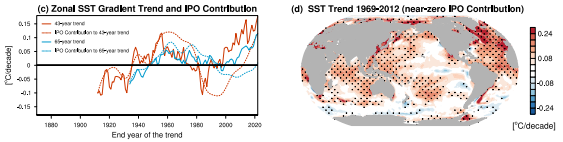
$$Ri = \frac{N^2}{S_z^2} = \frac{-\frac{g}{\rho_0}\frac{\partial \rho}{\partial z}}{(\frac{\partial u}{\partial z})^2 + (\frac{\partial v}{\partial z})^2} \sim \frac{-\frac{g}{\rho_0}\frac{\partial \rho}{\partial z}}{(\frac{\partial u}{\partial z})^2}$$

An Emerging Climate Change Signal

Recurring/Emerging Features Of Short-term/Long-term Trends

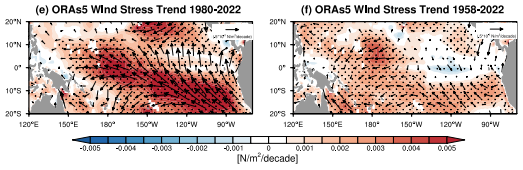


Quantification Of IPO's Contribution

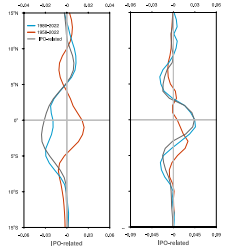


Distinct Ocean Dynamics

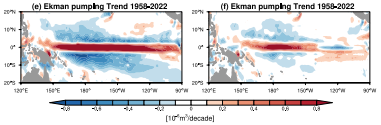
Different Surface Wind Stress Pattern



Distinct Zonal & Vertical Current Change

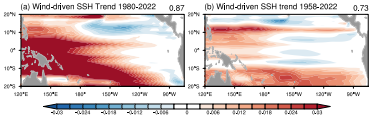


Distinct Ekman Pumping Change



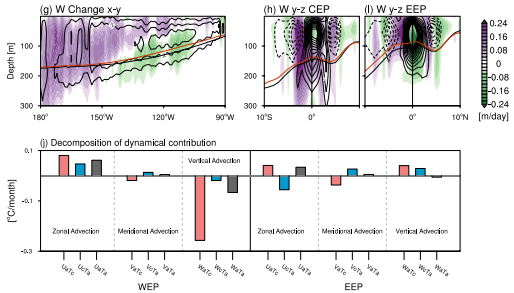
Distinct Wind-Driven Sea Surface Height Change

(responsible for the geostrophic component)



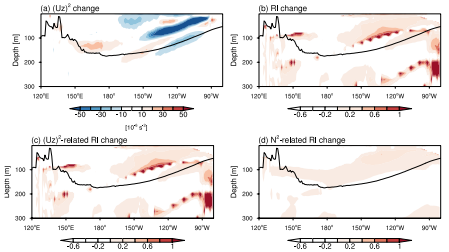
Dynamics For Central Pacific Cooling

Enhanced Upwelling In The Central Pacific Promotes Local Cooling



Dynamcis For Eastern Pacific Cooling

Weakening Of Both SEC & EUC Reduces Vertical Current Shear And Hinders Mixing



Conclusions

(1) A distinctive SST pattern is emerging beyond the internal variability linked to the IPO in the tropical Pacific, which is accompanied by unique air-sea processes.

(2) The emerging SST pattern is related to the substantial cooling along the thermocline, which is established to be linked to changes in Ekman pumping and vertical mixing.

(3) Surface wind stress changes are largely responsible for these long-term oceanic adjustments in the tropical Pacific.