Pre-Field Modeling Studies in Support of TPOS Process Studies

A Focus on the Warm Pool Edge

Ho-Hsuan Wei
Aneesh Subramanian
Kris Karnauskas
Charlotte DeMott
Matthew Mazloff
Joseph Tribbia
Magdalena Balmaseda
Danni Du
Beena Sarojini
Frederic Vitart
Janet Sprintall
Ulla Heede

Kris Karnauskas
Department of Atmospheric & Oceanic Sciences
Cooperative Institute for Research in Environmental Sciences
University of Colorado, Boulder, Colorado, USA

NOAA CVP
NA18OAR4310406
NA22OAR4310599

CLIVAR Melbourne | 2023

9/2018 – 8/2021

Improved understanding of air-sea interaction processes and biases in the Tropical Western Pacific using observation sensitivity experiments and global forecast models

- **PIs:** Aneesh Subramanian, Kris Karnauskas, Charlotte DeMott, Matthew Mazloff
- **Collaborators:** Joseph Tribbia, Magdalena Balmaseda
- **Other:** Ho-Hsuan Wei, Danni Du, Beena Sarojini, Frederic Vitart

9/2022 – 8/2025

Optimizing coupled boundary layer process studies in the tropical Pacific using high-resolution models and *in situ* observations

- **PIs:** Aneesh Subramanian, Kris Karnauskas, Charlotte DeMott, Janet Sprintall
- **Collaborators:** Ho-Hsuan Wei, Magdalena Balmaseda
- **Other:** Ulla Heede

NOAA CVP
NA18OAR4310406
NA22OAR4310599

In the western Pacific:

- Warmer, fresher water (than EP)
- Deep atmospheric convection
- Deeper mixed layer & thermocline
- Barrier layers form due to intense rainfall, weak winds, subduction of saltier water from the east, and more
- Wind bursts locally impact mixed layer
- Strong MJO variability

At the warm pool edge:

- Convergence & sharp gradients
- Shifts in response to heat content variations and zonal current anomalies

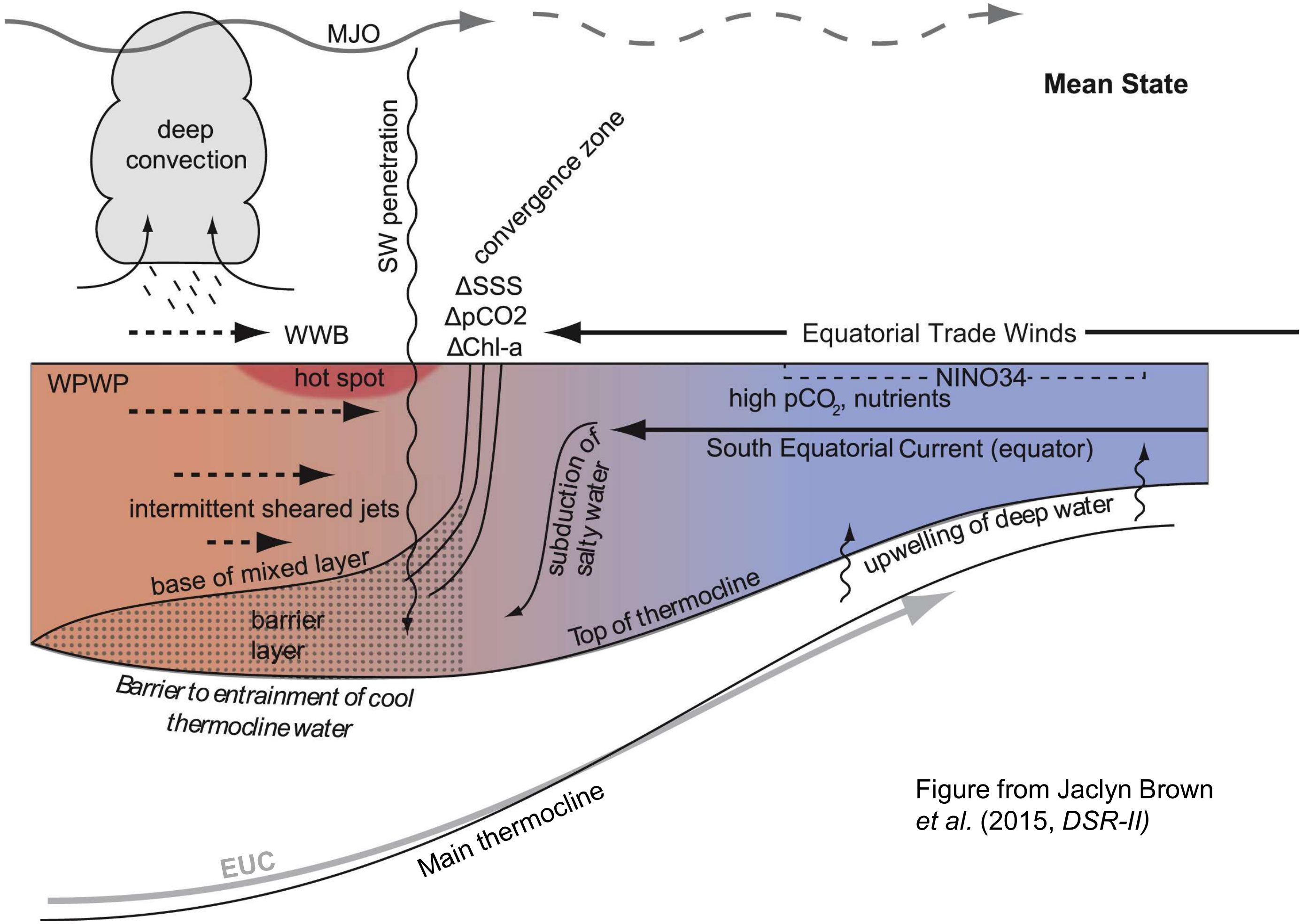


Figure from Jaclyn Brown *et al.* (2015, *DSR-II*)

Key processes at the warm pool edge

9/2018 – 8/2021

Improved understanding of air-sea interaction processes and biases in the Tropical Western Pacific using observation sensitivity experiments and global forecast models

- **Tropical Pacific Air-sea Interaction Processes and Biases in CESM2 and their Relation to El Niño Development**
  Wei *et al.* (2021, *JGR-Oceans)* < Published in CESM2 Special Collection

- **The role of in-situ ocean data assimilation in subseasonal forecasts of the tropical Pacific Ocean**
  Wei *et al.* (in review, *QJRMS)*

9/2022 – 8/2025

Optimizing coupled boundary layer process studies in the tropical Pacific using high-resolution models and *in situ* observations

- Quick introduction to our **objectives** & **plans.**

NOAA CVP
NA18OAR4310406
NA22OAR4310599

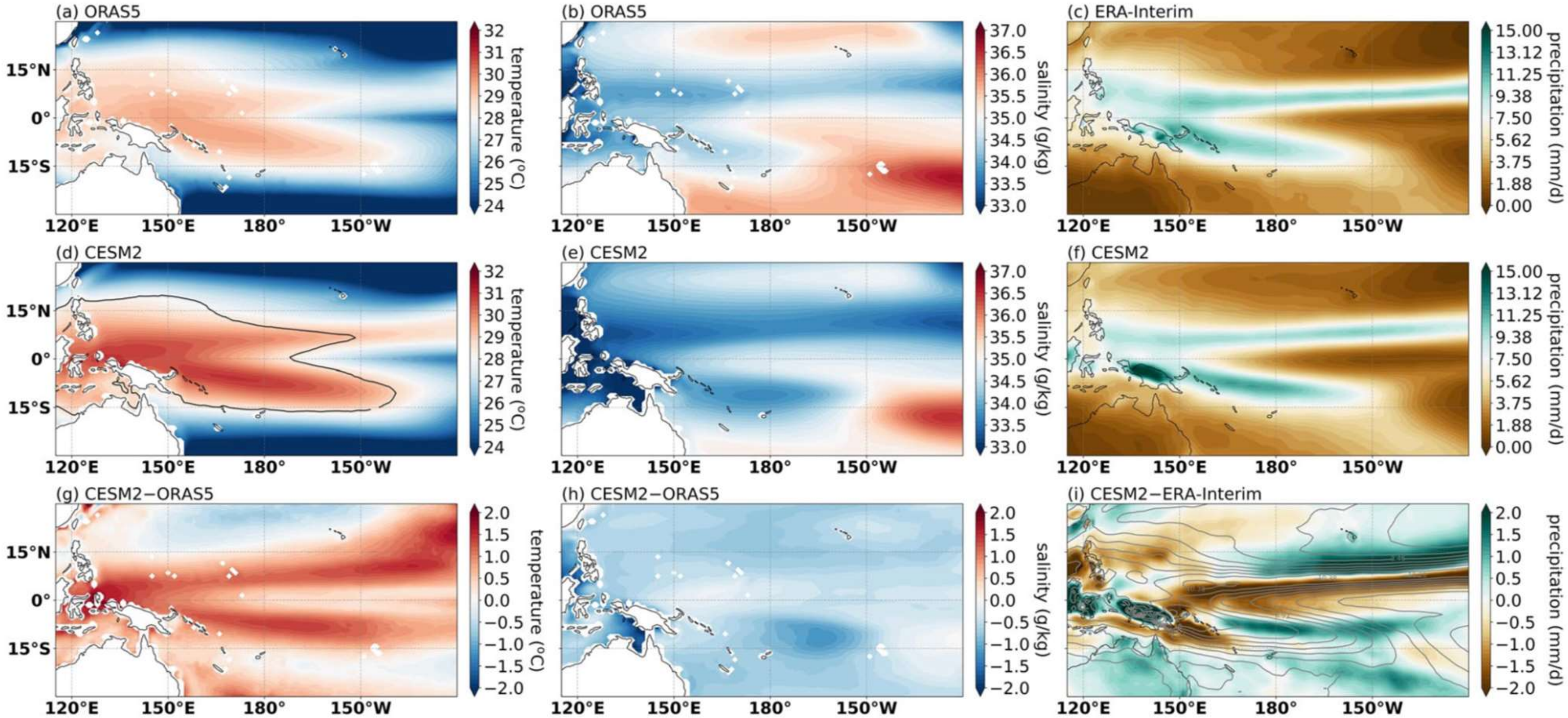
Tropical Pacific Air–Sea Interaction Processes and Biases in CESM2 and Their Relation to El Niño Development

Ho-Hsuan Wei[1,2], Aneesh C. Subramanian[2], Kristopher B. Karnauskas[1,2], Charlotte A. DeMott[3], Matthew R. Mazloff[4], and Magdalena A. Balmaseda[5]

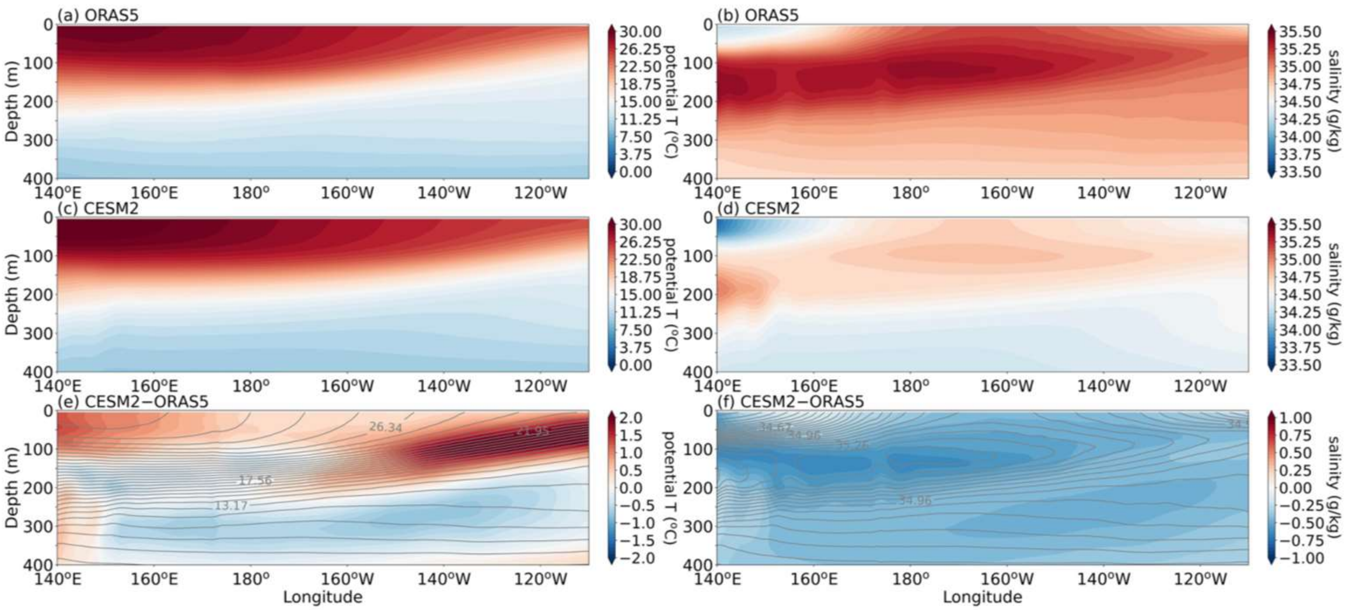
[1]Cooperative Institute for Research in Environmental Sciences, Boulder, CO, USA, [2]University of Colorado, Boulder, CO, USA, [3]Colorado State University, Fort Collins, CO, USA, [4]Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA, [5]The European Centre for Medium-Range Weather Forecasts, Reading, UK

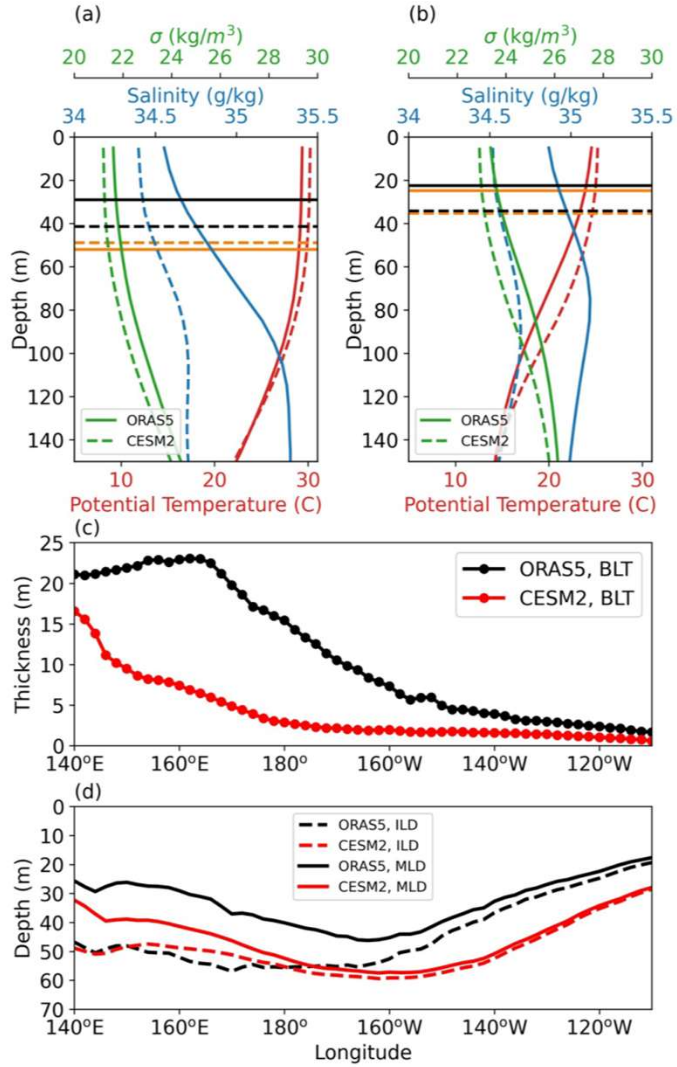
- Examining **surface and subsurface biases** in **CESM2** historical run from 1980-2014 (35 yr), compared to **ORAS5** and **ERA-Interim**
- Investigating the **implications for ENSO** simulation

Wei *et al.* (2021, *JGR-Oceans)*

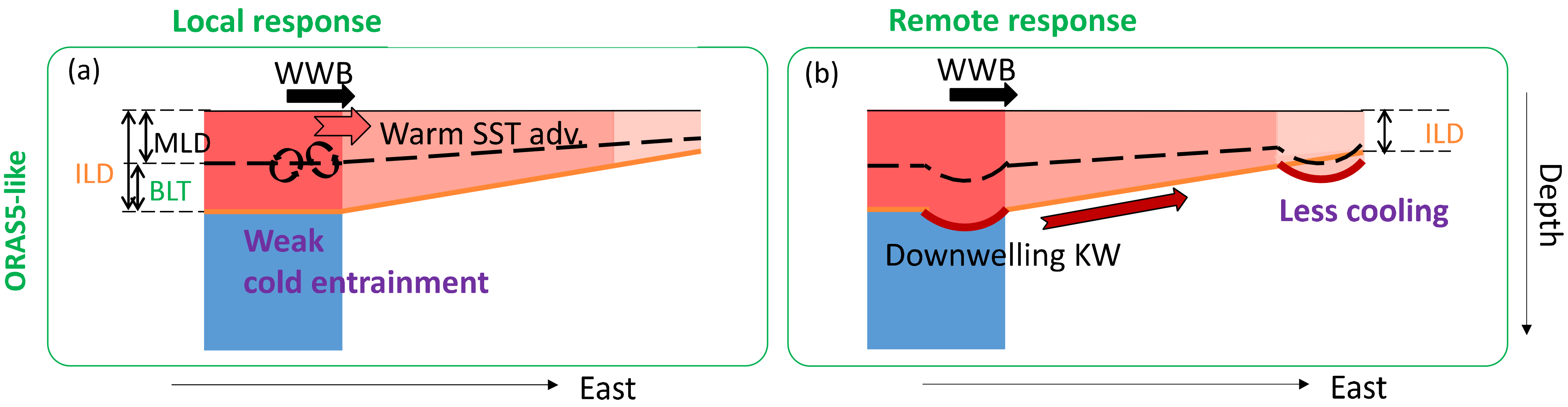


- Overall, the warm/fresh pool is a bit *too* warm & fresh in CESM2
- Northward ITCZ bias and strong SPCZ bias
- Off-equatorial warm bias linked to **weaker STCs, despite *not-too-weak* easterly wind stress**
- Spatial pattern of warm & fresh biases have interesting relationships to that of rainfall

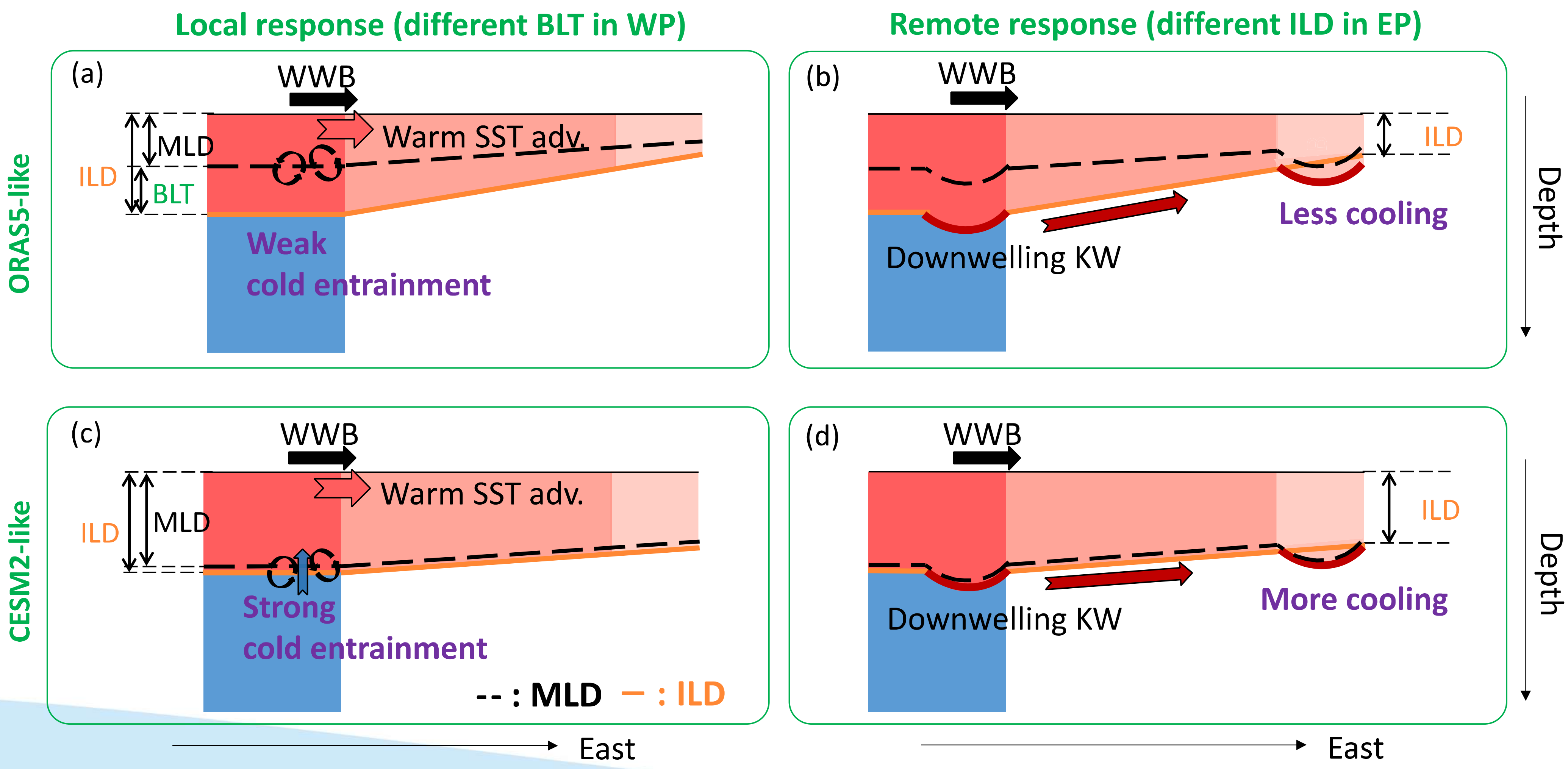




- Warm bias in EP thermocline → ILD too deep (consistent w/ STC bias)
- Fresh bias in WP salinity maximum → MLD too deep → BLT too thin
- ILD tilt and BLT can influence ENSO dynamics (generally 👎 in this case)



Framework: Mechanisms for mean state biases to influence ENSO

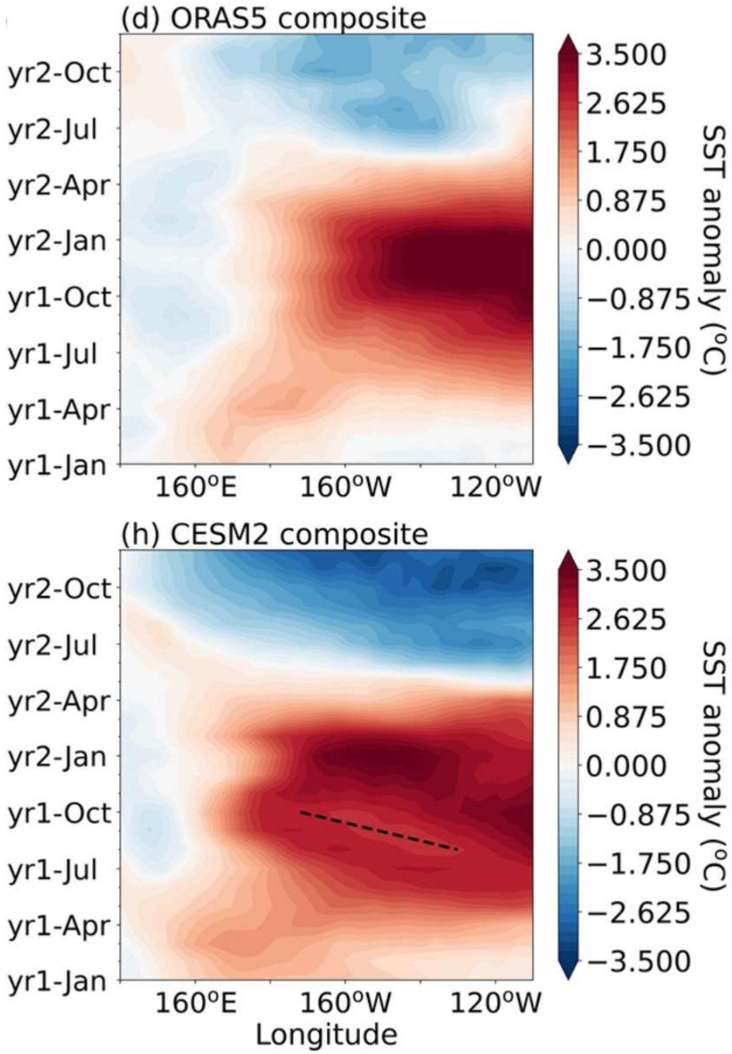


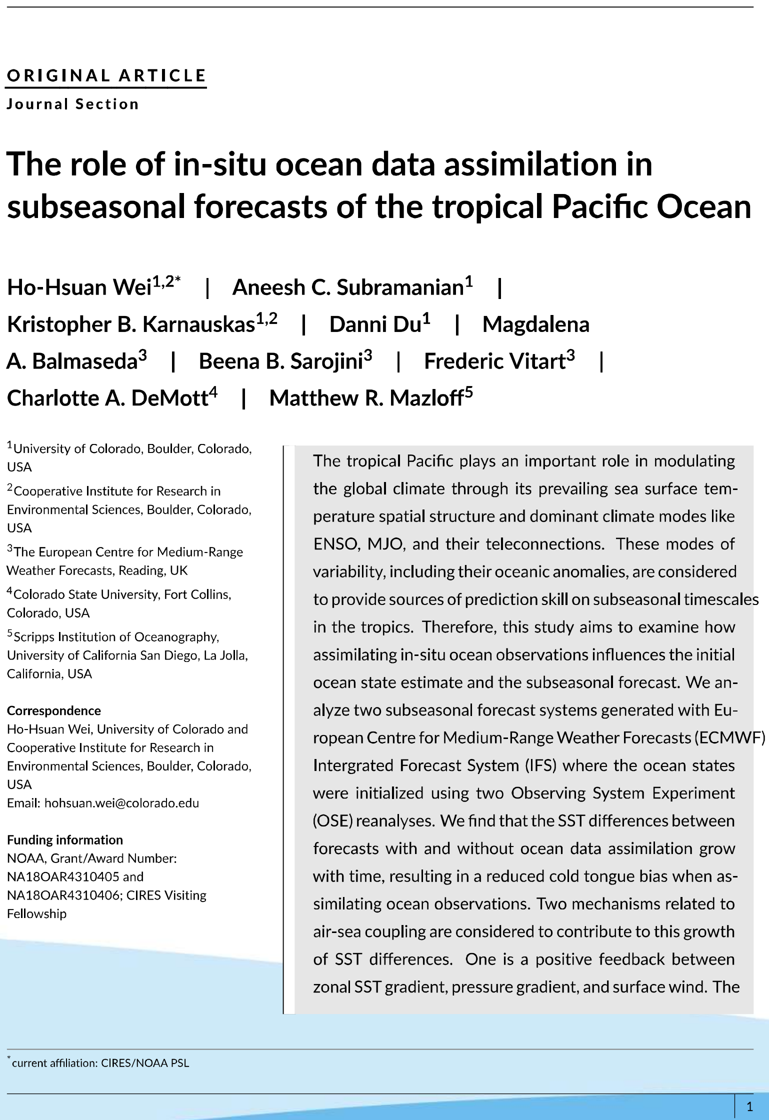
Framework: Mechanisms for mean state biases to influence ENSO

Summary (without the details) of the impact of mean state biases on ENSO

- Composite equatorial SSTA evolution of strong El Nino events
- ILD and BLT biases are significant before the onset of El Nino
- They influence vertical mixing and entrainment processes (which we calculated), ultimately inhibiting warming
- Annual cycle also too strong, which aligns with an odd yet consistent "break" in the onset of El Nino events (dashed line)

For details, please read Wei *et al.* (2021, *JGR-Oceans)*





ORIGINAL ARTICLE
Journal Section

The role of in-situ ocean data assimilation in subseasonal forecasts of the tropical Pacific Ocean

Ho-Hsuan Wei[1,2*] | Aneesh C. Subramanian[1] | Kristopher B. Karnauskas[1,2] | Danni Du[1] | Magdalena A. Balmaseda[3] | Beena B. Sarojini[3] | Frederic Vitart[3] | Charlotte A. DeMott[4] | Matthew R. Mazloff[5]

[1]University of Colorado, Boulder, Colorado, USA
[2]Cooperative Institute for Research in Environmental Sciences, Boulder, Colorado, USA
[3]The European Centre for Medium-Range Weather Forecasts, Reading, UK
[4]Colorado State University, Fort Collins, Colorado, USA
[5]Scripps Institution of Oceanography, University of California San Diego, La Jolla, California, USA

Correspondence
Ho-Hsuan Wei, University of Colorado and Cooperative Institute for Research in Environmental Sciences, Boulder, Colorado, USA
Email: hohsuan.wei@colorado.edu

Funding information
NOAA, Grant/Award Number: NA18OAR4310405 and NA18OAR4310406; CIRES Visiting Fellowship

The tropical Pacific plays an important role in modulating the global climate through its prevailing sea surface temperature spatial structure and dominant climate modes like ENSO, MJO, and their teleconnections. These modes of variability, including their oceanic anomalies, are considered to provide sources of prediction skill on subseasonal timescales in the tropics. Therefore, this study aims to examine how assimilating in-situ ocean observations influences the initial ocean state estimate and the subseasonal forecast. We analyze two subseasonal forecast systems generated with European Centre for Medium-Range Weather Forecasts (ECMWF) Intergrated Forecast System (IFS) where the ocean states were initialized using two Observing System Experiment (OSE) reanalyses. We find that the SST differences between forecasts with and without ocean data assimilation grow with time, resulting in a reduced cold tongue bias when assimilating ocean observations. Two mechanisms related to air-sea coupling are considered to contribute to this growth of SST differences. One is a positive feedback between zonal SST gradient, pressure gradient, and surface wind. The

*current affiliation: CIRES/NOAA PSL

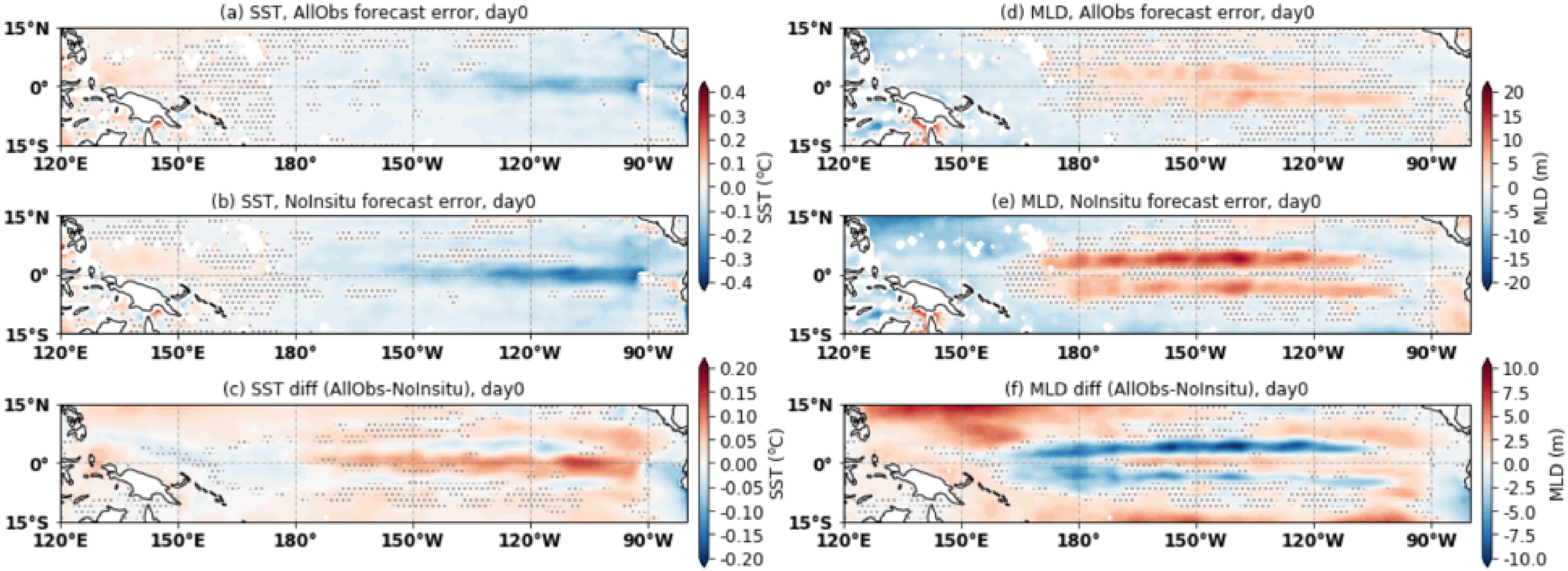
1

- Examining influence (of *in situ* ODA) on both **initial conditions** and **forecast evolution**, since forecast models tend to drift to a model-dependent, biased mean state

- Using ECMWF-IFS coupled subseasonal forecasts initialized with two OSEs: **with ODA** and **without ODA**

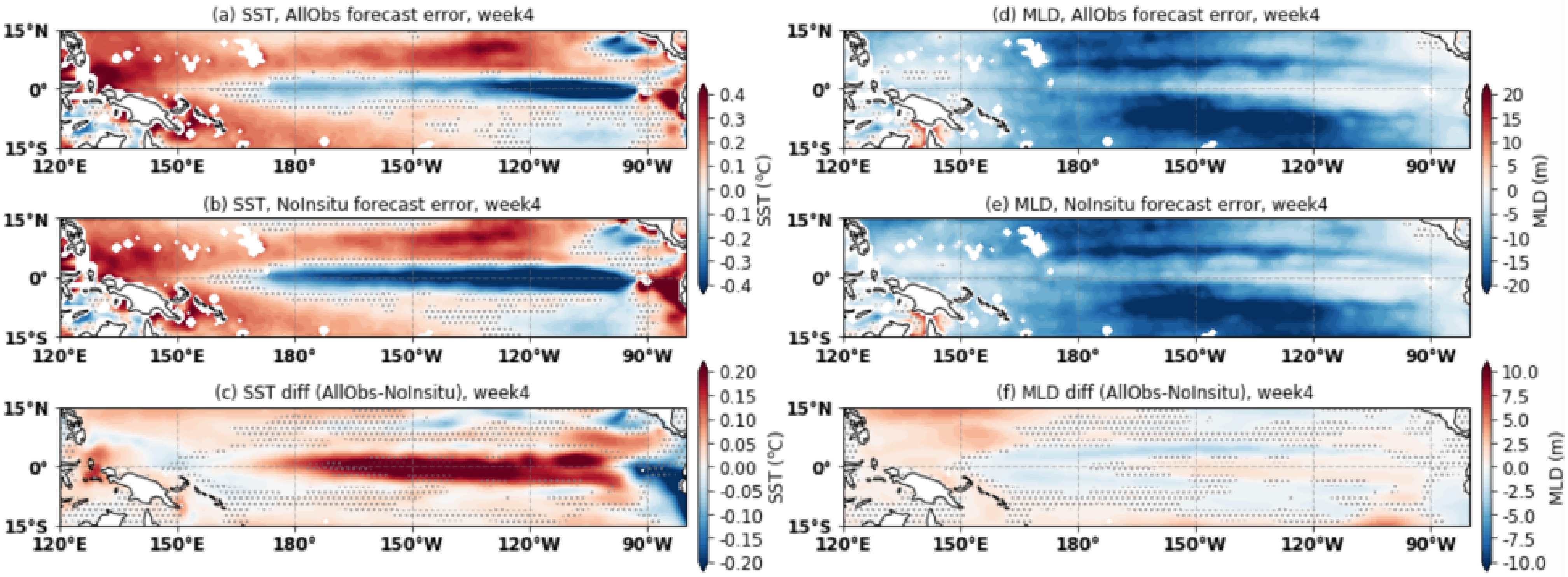
    

Wei *et al.* (in review, *QJRMS)*



SST differences **grow with time** (ODA reduces cold bias)

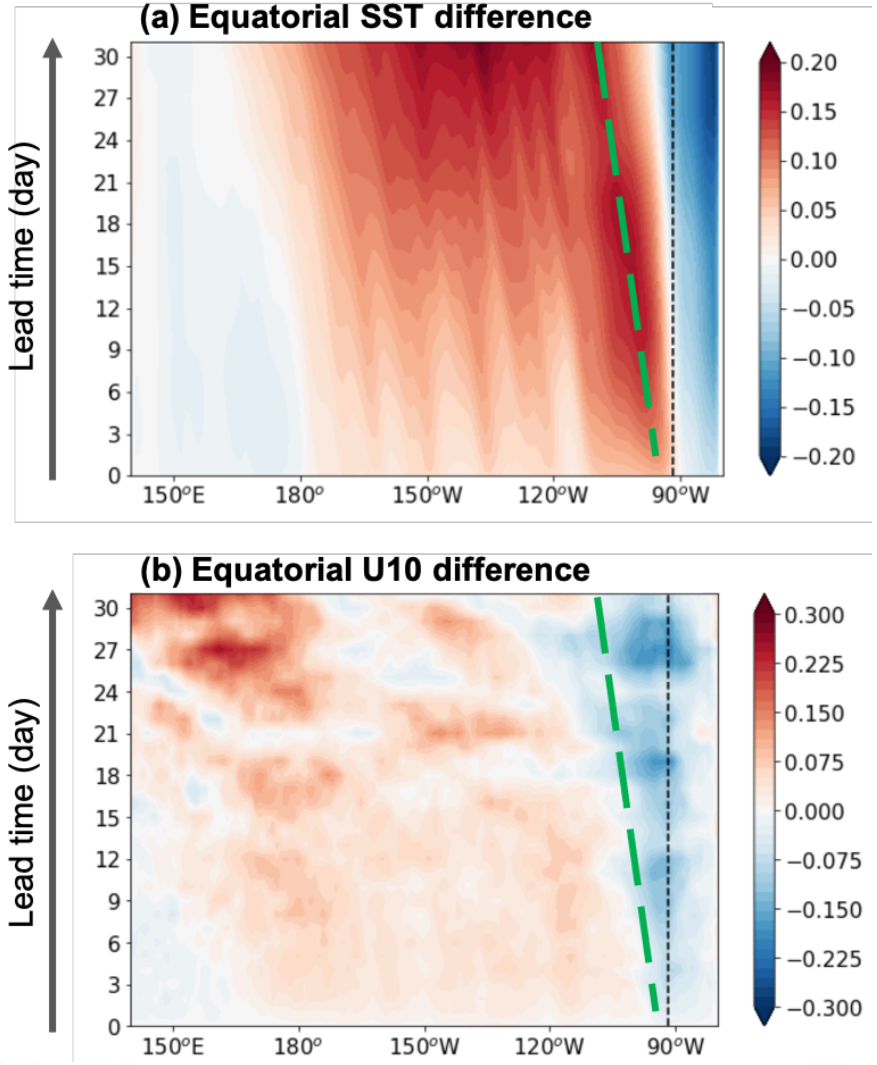
Forecast error at day 0



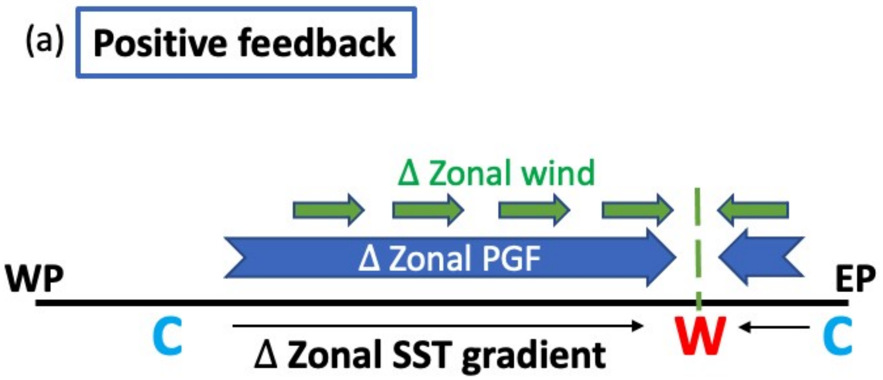
SST differences **grow with time** (ODA reduces cold bias)

SST differences **grow with time** in a fashion that **implicates coupling**

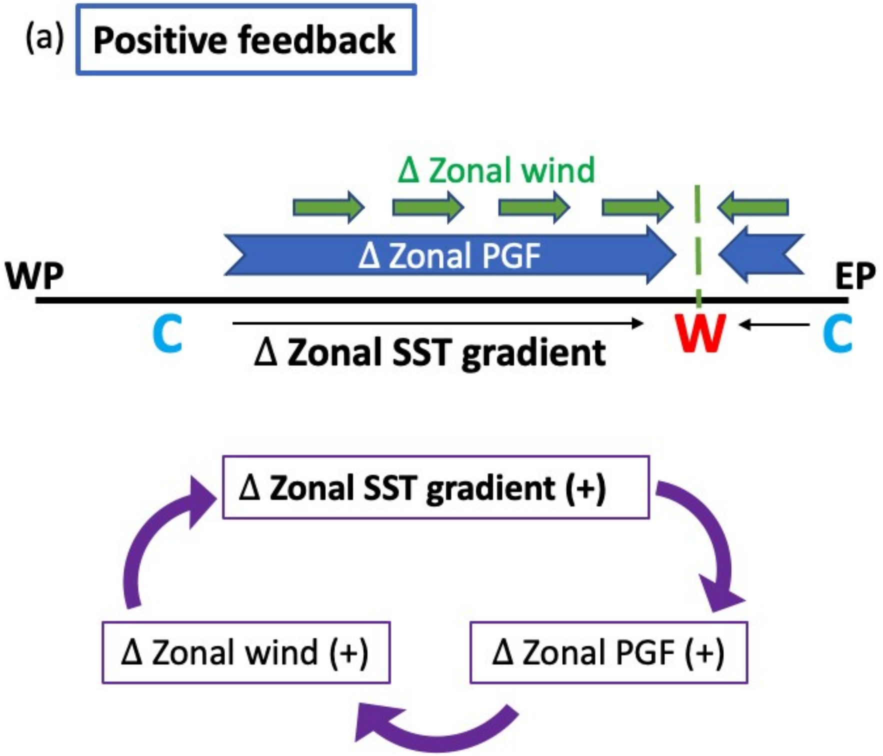
P.S. The surface heat flux term has opposite contribution to the SST difference (not shown here) so we suspect ocean and coupled processes…

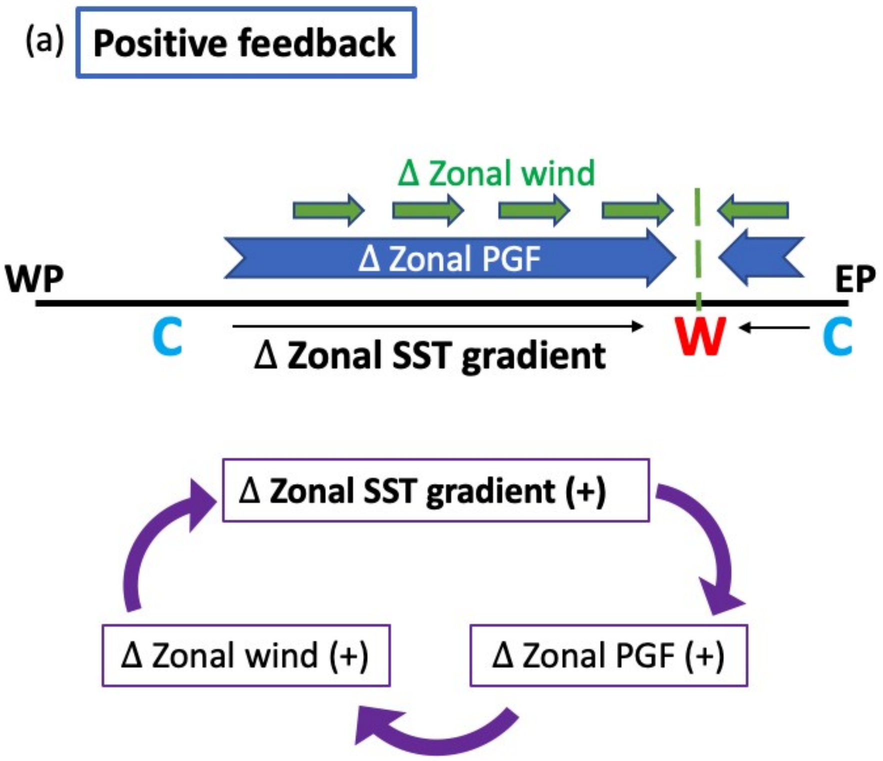


(a) **Positive feedback**

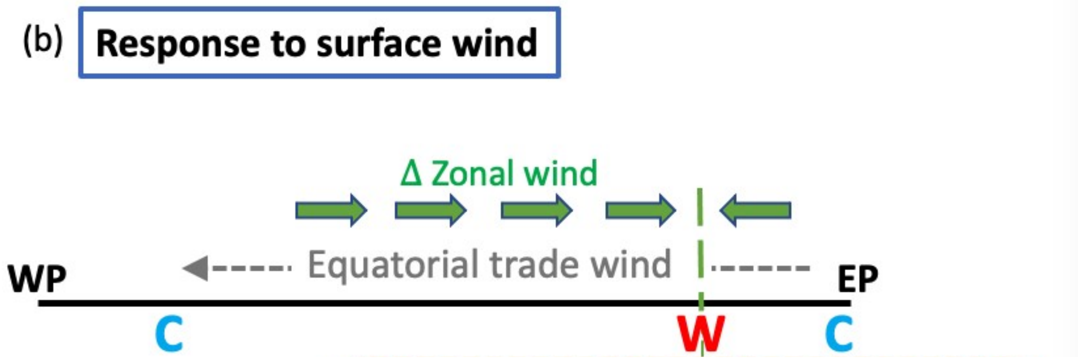

(a)
Positive feedback
Δ Zonal wind
Δ Zonal PGF
WP
EP
C
W
C
Δ Zonal SST gradient

(a)

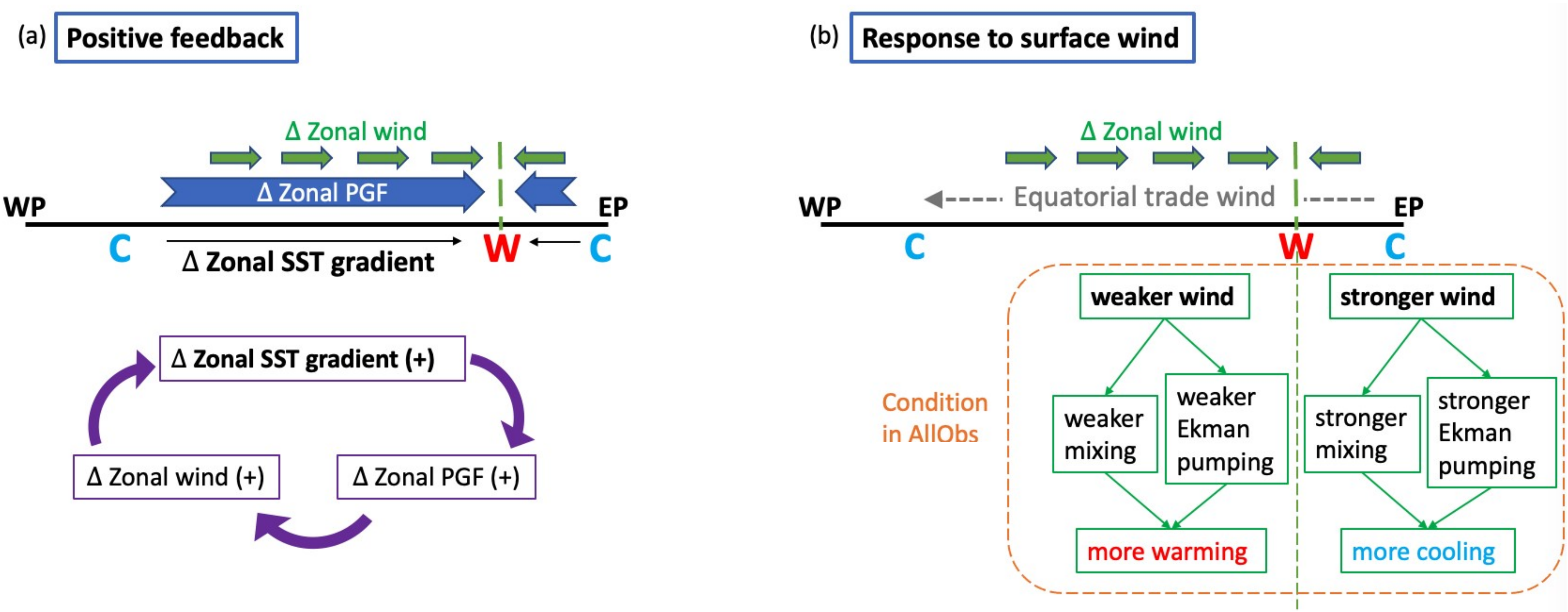

Positive feedback
Δ Zonal wind
Δ Zonal PGF
WP
EP
C
W
C
Δ Zonal SST gradient
Δ Zonal SST gradient (+)
Δ Zonal wind (+)
Δ Zonal PGF (+)



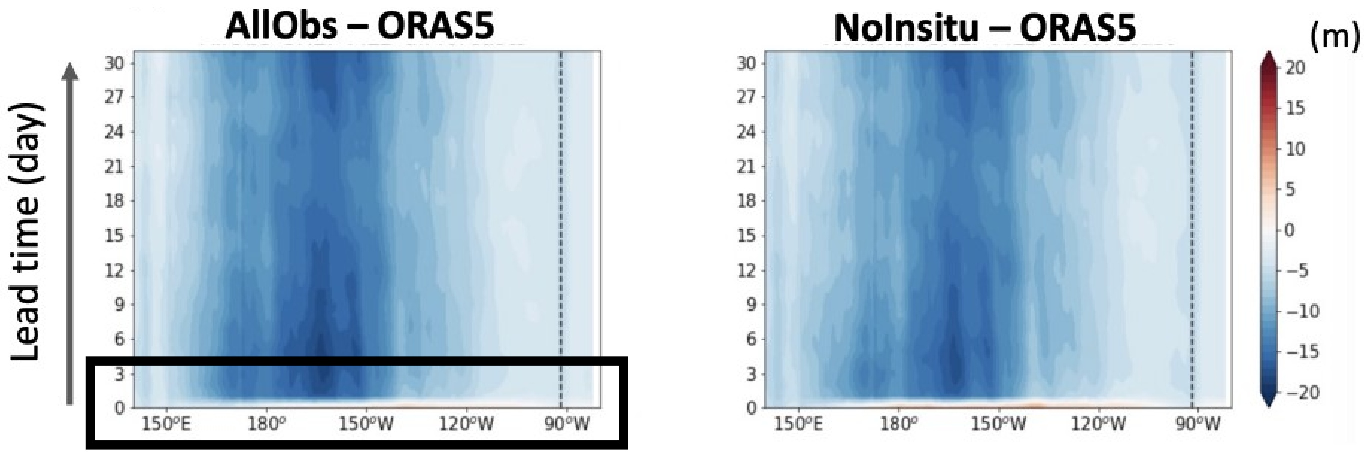
(a)
Positive feedback
Δ Zonal wind
Δ Zonal PGF
WP
EP
C
W
C
Δ Zonal SST gradient
Δ Zonal SST gradient (+)
Δ Zonal wind (+)
Δ Zonal PGF (+)



(b)
Response to surface wind
Δ Zonal wind
Equatorial trade wind
WP
EP
C
W
C



Coupled mechanisms constraining forecast error growth



What about the mixed layer depth?

The initial conditions **can be improved** through *in situ* ODA, but in both cases, the MLD **rapidly shoals.**

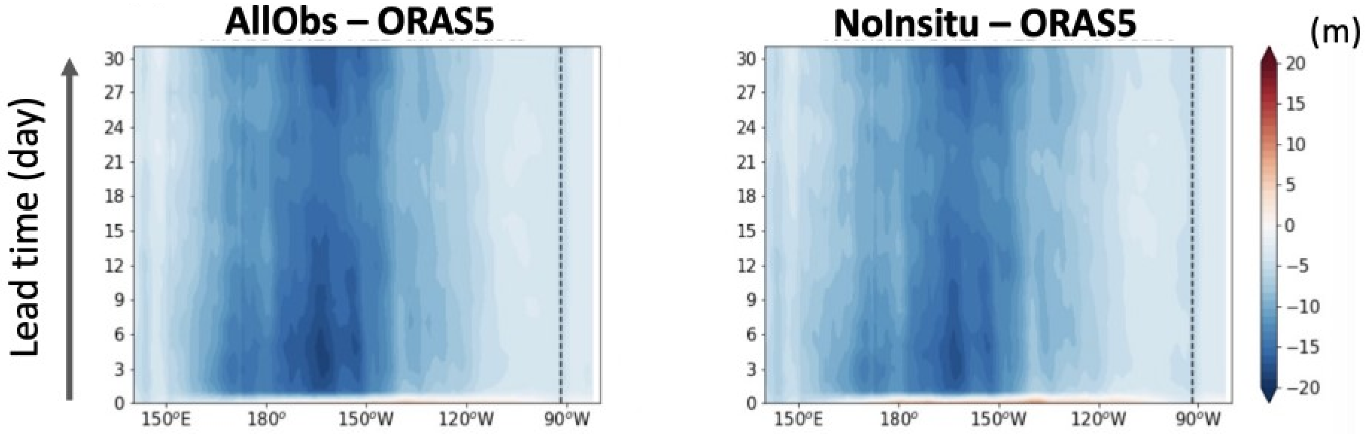
We are still investigating this initialization shock in these ECMWF-IFS OSEs.

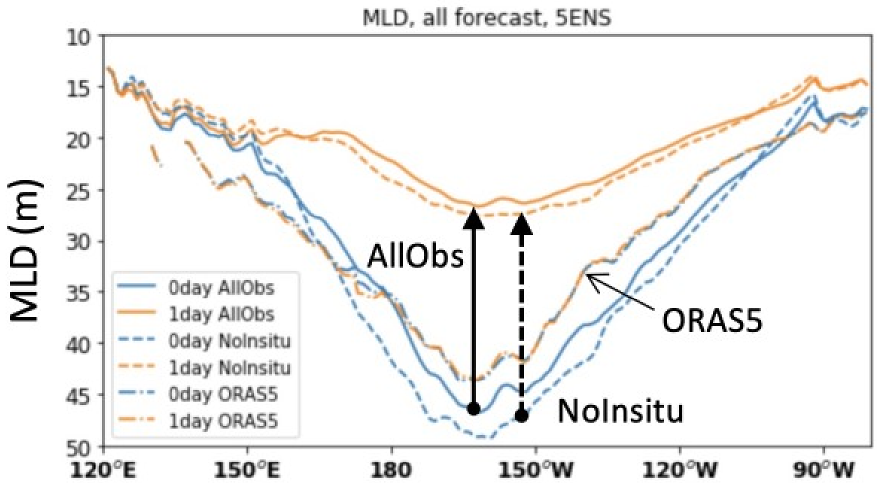

3
0
150°E
180°
150°W
120°W
90°W

As for MLD…

The initial conditions **can be improved** through *in situ* ODA, but in both cases, the MLD **rapidly shoals.**

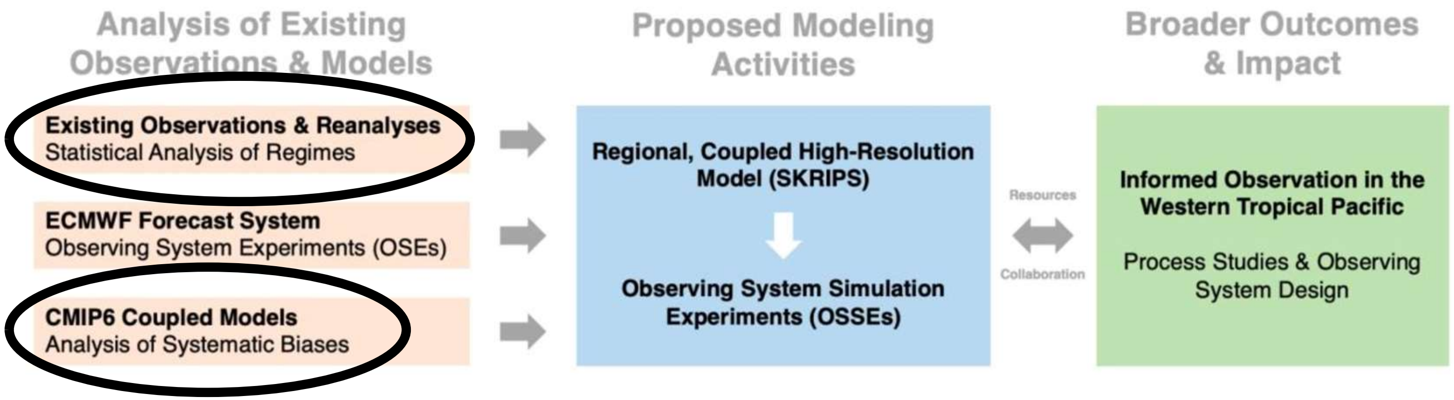
We are still investigating this initialization shock in these ECMWF-IFS OSEs.





9/2022 – 8/2025

Optimizing coupled boundary layer process studies in the tropical Pacific using high-resolution models and *in situ* observations



Objectives

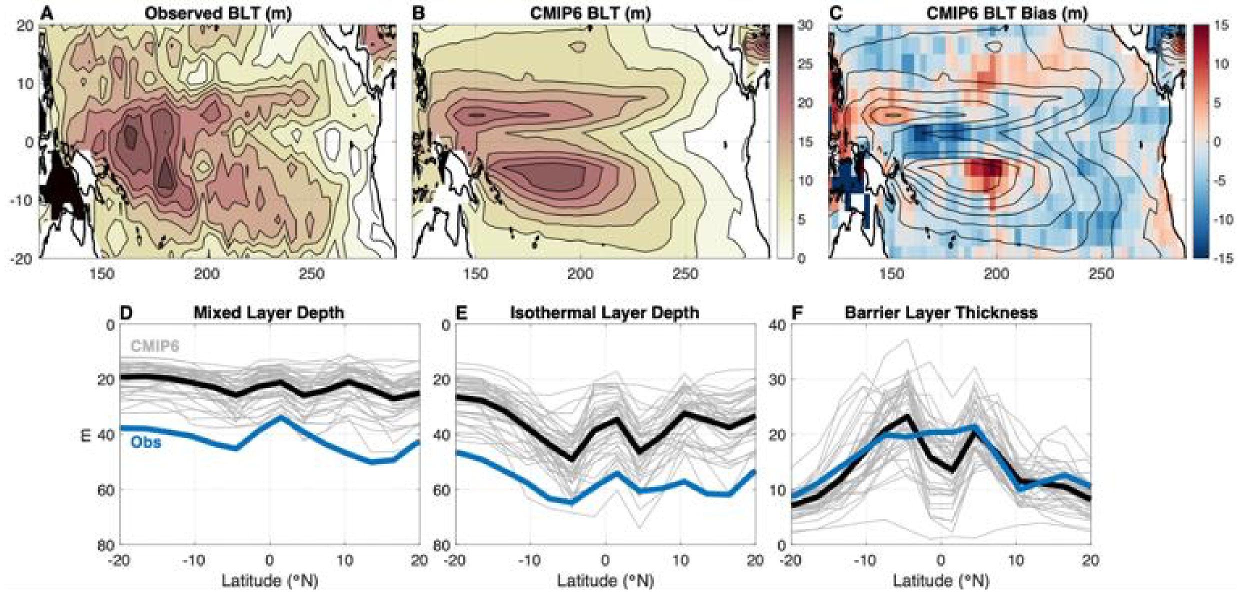
1. Identify and study the physical mechanisms that play a key role in the evolution of the coupled boundary layer and air-sea interaction at the eastern edge of the warm pool

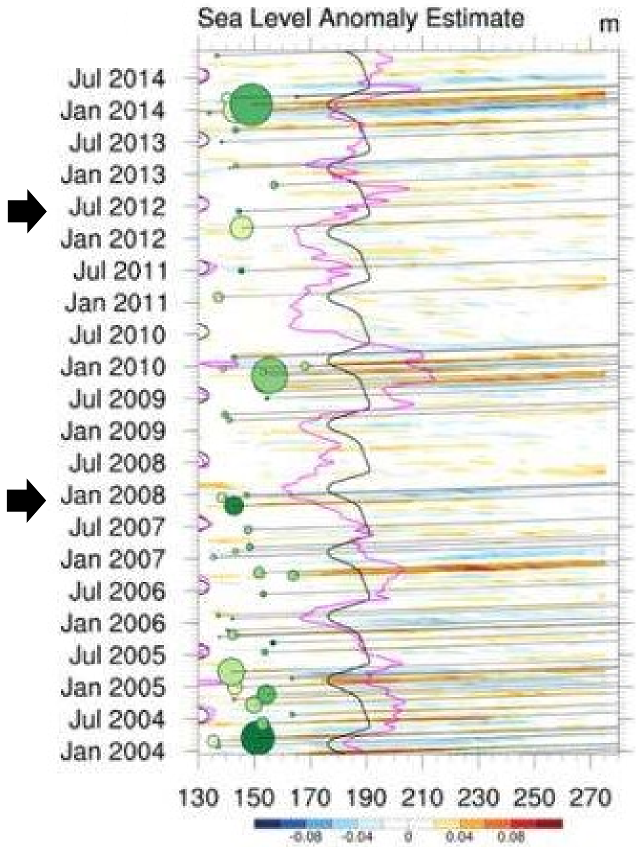
2. Identify optimal strategies to observe these processes by isolating coupled and uncoupled processes using short-term high resolution coupled and uncoupled regional model experiments and observing system simulation experiments

Focusing on barrier layer formation mechanisms, momentum/heat/salt budgets, and air-sea fluxes east & west of the SST front, and the scales required to optimally observe them (temporal, horizontal, vertical)

9/2022 – 8/2025

Optimizing coupled boundary layer process studies in the tropical Pacific using high-resolution models and *in situ* observations





Size: WWE intensity
Color: BLT thickness

New project

Questions or suggestions?