COUPLED AIR-SEA INTERACTION IN THE WESTERN AND CENTRAL PACIFIC OCEAN

Motivation for experiments at the edge of the western Pacific warm pool

Kyla Drushka
Applied Physics Lab, Univ. of Washington

with input from: Meghan Cronin, Andrew Wittenberg, Eric Guilyardi, Sulagna Ray, Jérôme Vialard, Matthieu Lengaigne…

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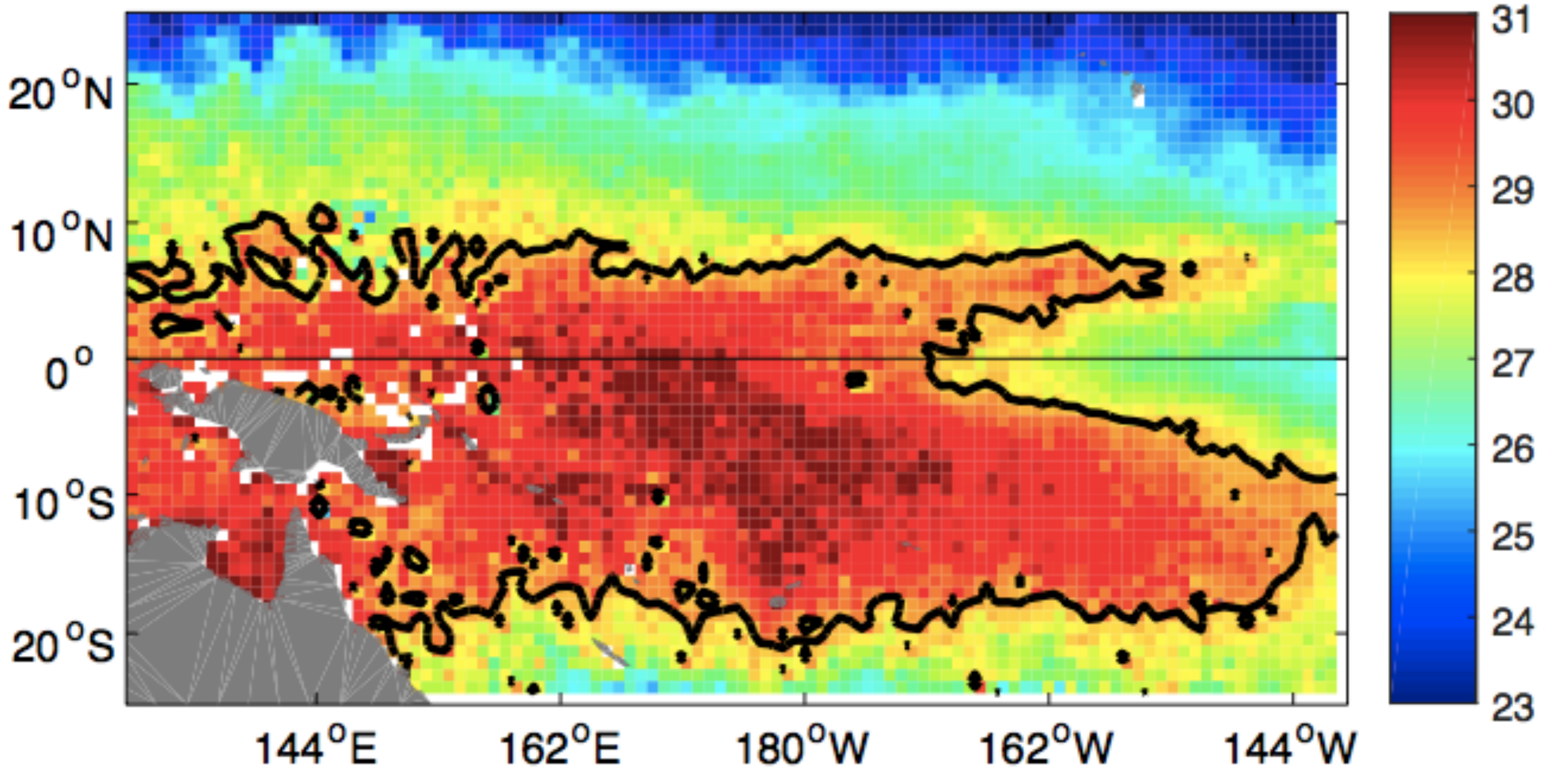
The eastern edge of the western Pacific warm pool (WPWP) is an important region for air-sea interaction

- A **sharp SST front** defines the warm pool eastern edge (WPEE):
  - **Deep convection** within the WPWP but not to the east (cold tongue)
  - **Air-sea fluxes** are very different on either side of the front

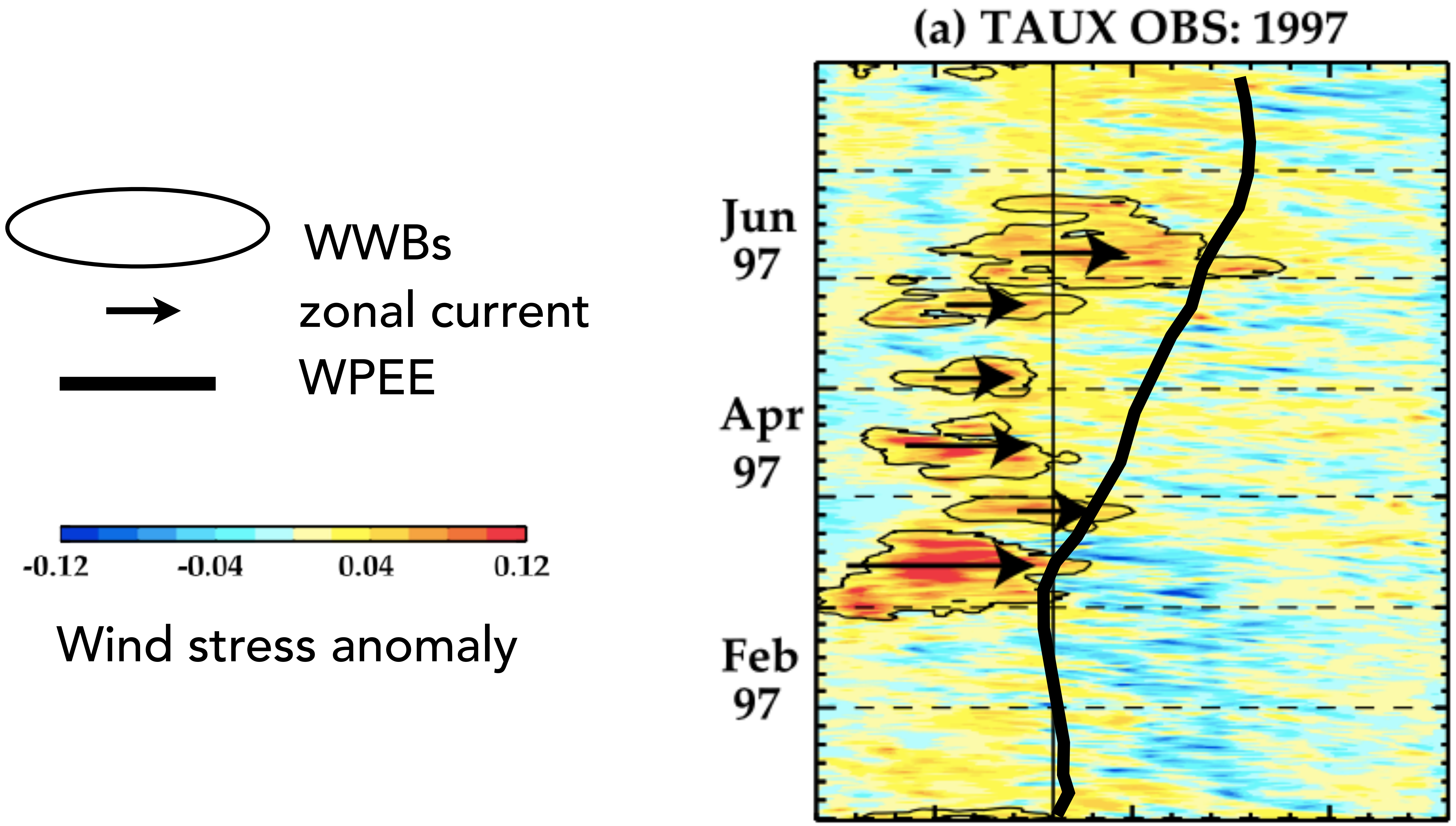
SST 28.5°C contour



MODIS SST – Jan 2015

E.g., successive westerly wind bursts (WWBs) shift the warm pool east during El Niño onset

– but if the modeled WPEE is in the wrong place or the SST gradient has the wrong strength, or the WWBs have the wrong structure, the impact of WWBs may be incorrect



Adapted from Menkes et al. 2014

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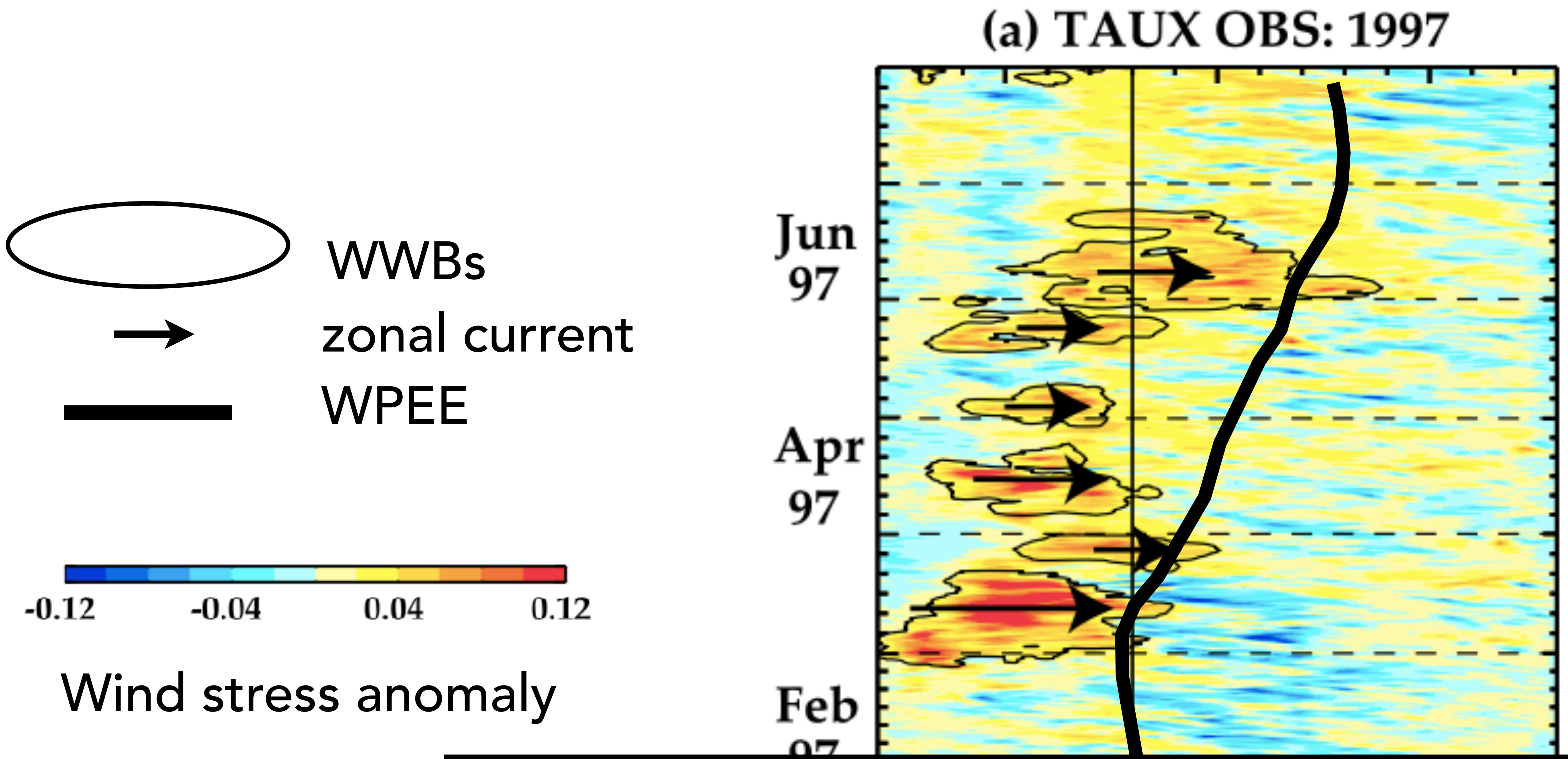


Correctly modeling the location/dynamics of the WPEE is important for getting coupled air-sea processes right

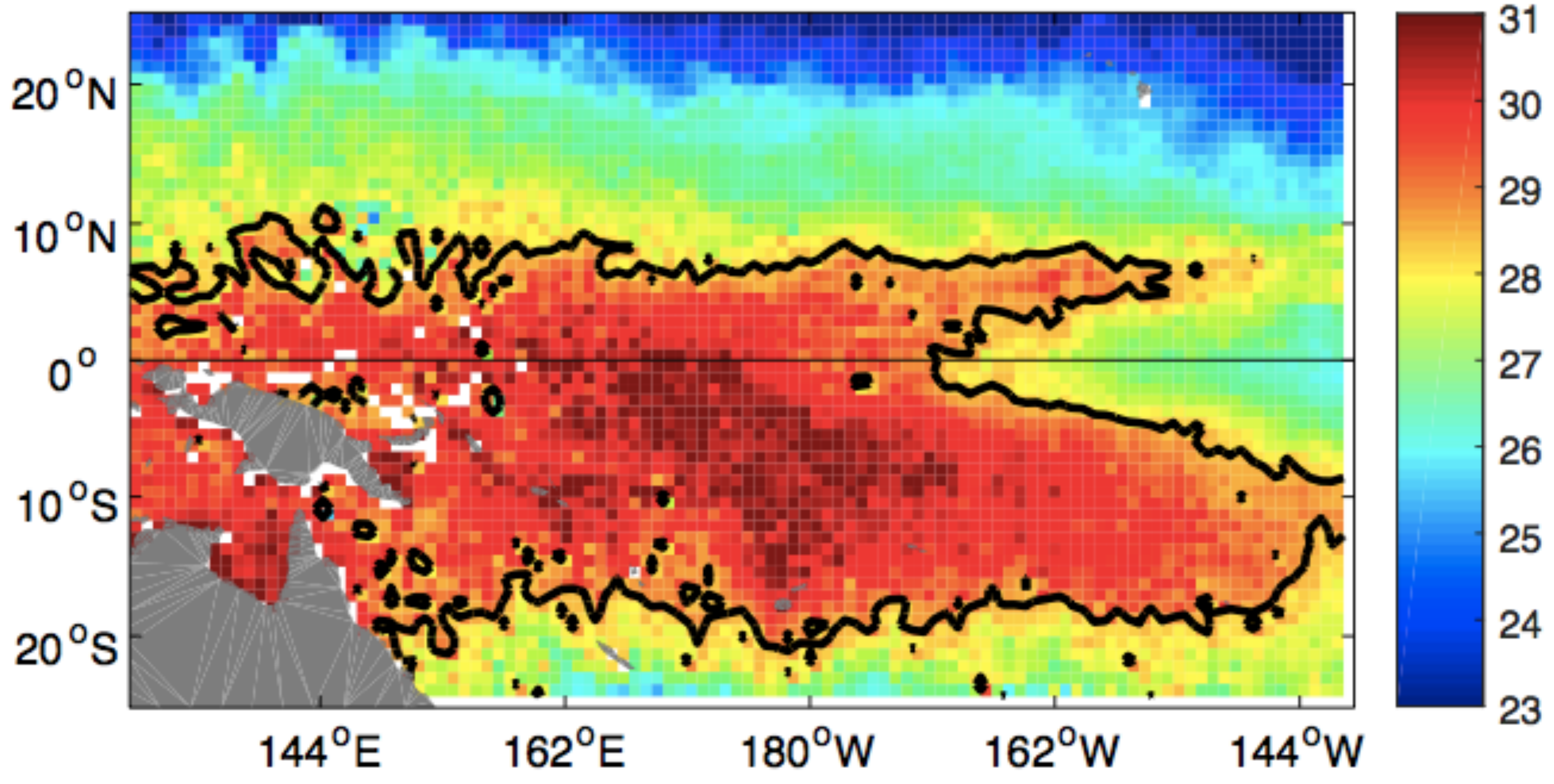
dapted from Menkes et al. 2014

The warm pool is also fresh

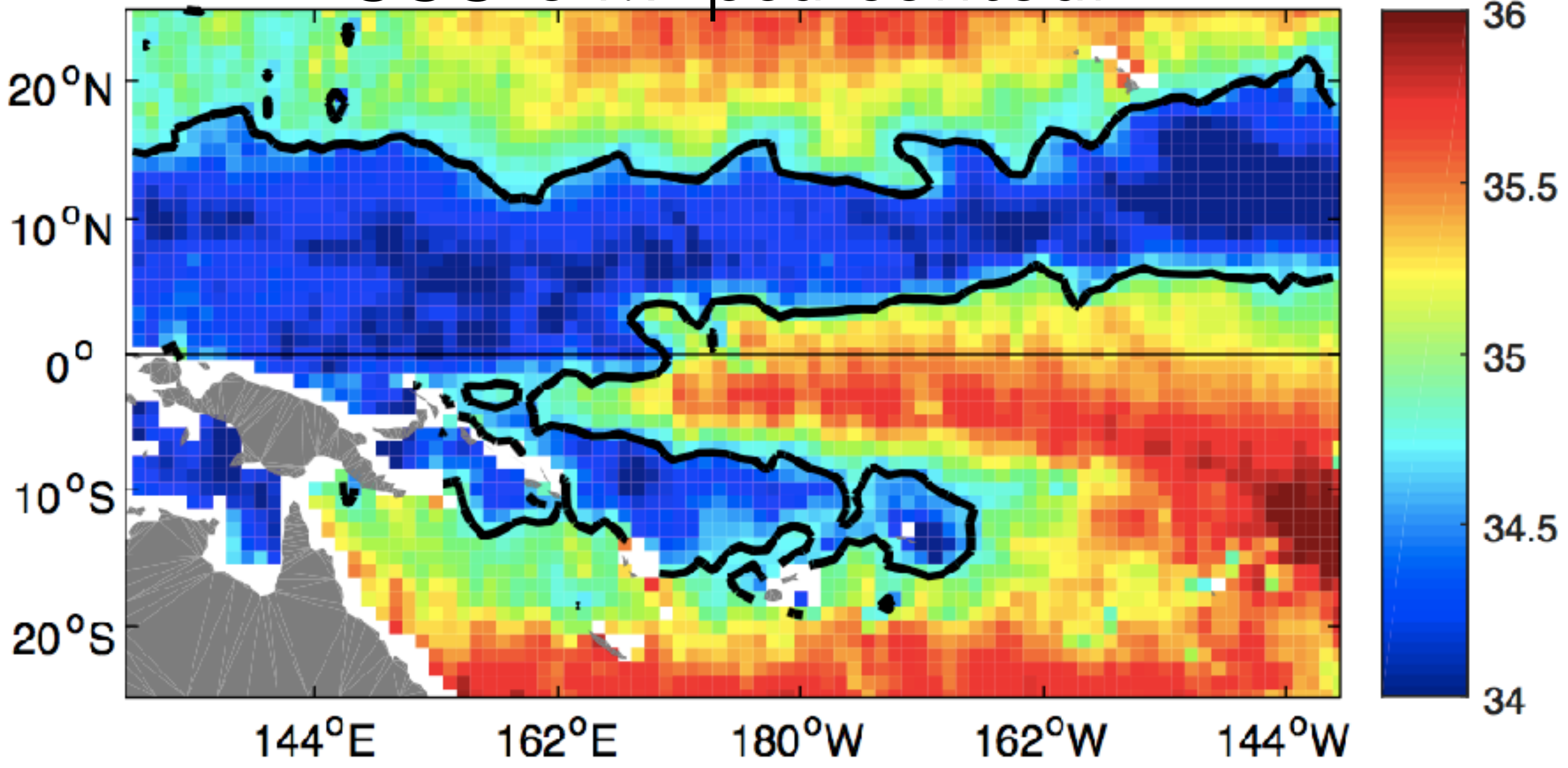
But the SSS and SST fronts do not exactly overlap

– The timescales and reasons for the differences are not well known.

SST 28.5°C contour



SSS 34.7 psu contour

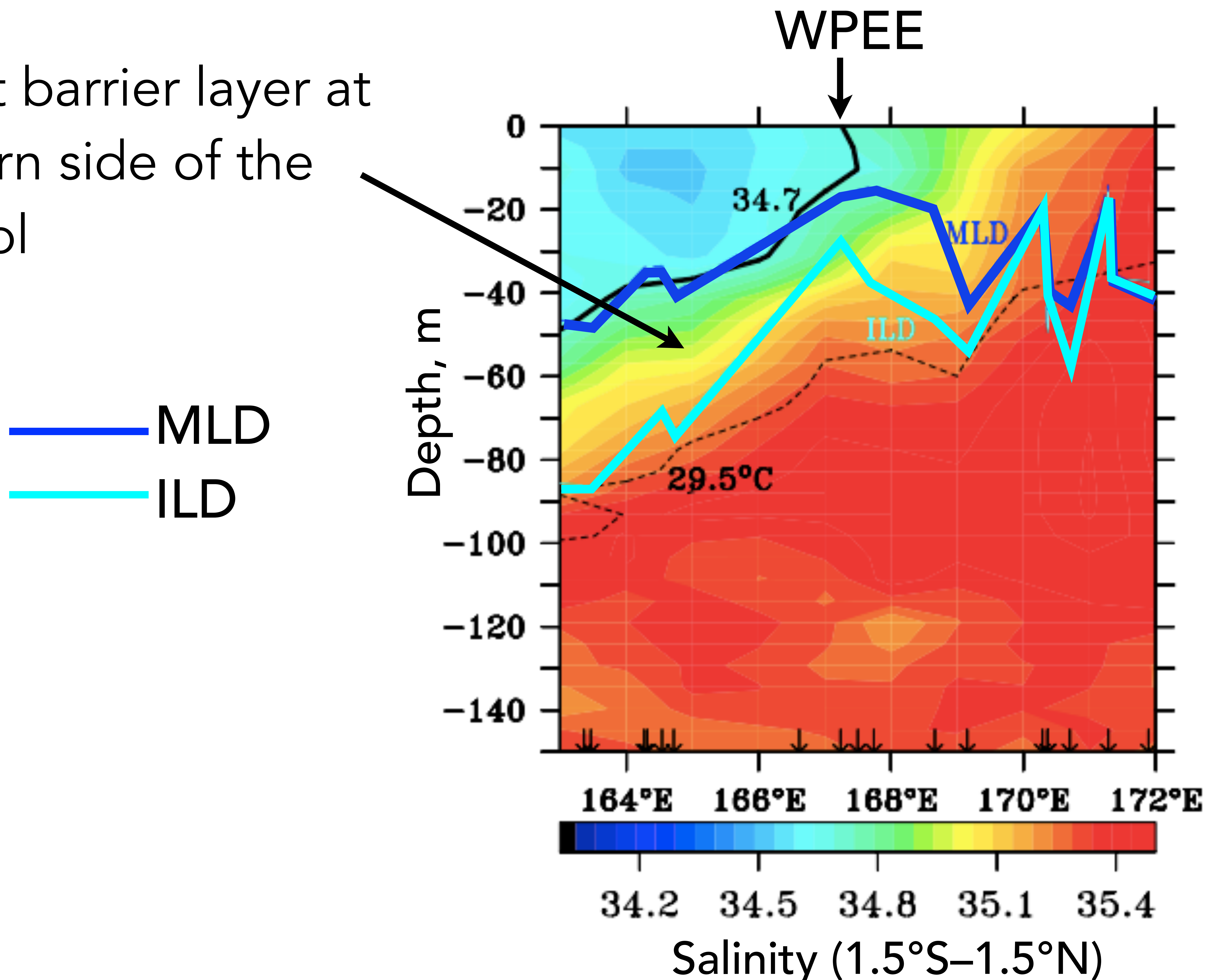


MODIS SST – Jan 2015
Aquarius SSS – Jan 2015

Upper ocean stratification at the WPEE is critical for air-sea interaction

Salinity controls the mixed-layer depth, and hence a **barrier layer** exists between the base of the mixed layer and isothermal layer

Persistent barrier layer at the eastern side of the warm pool



Adapted from Bosc et al. 2009

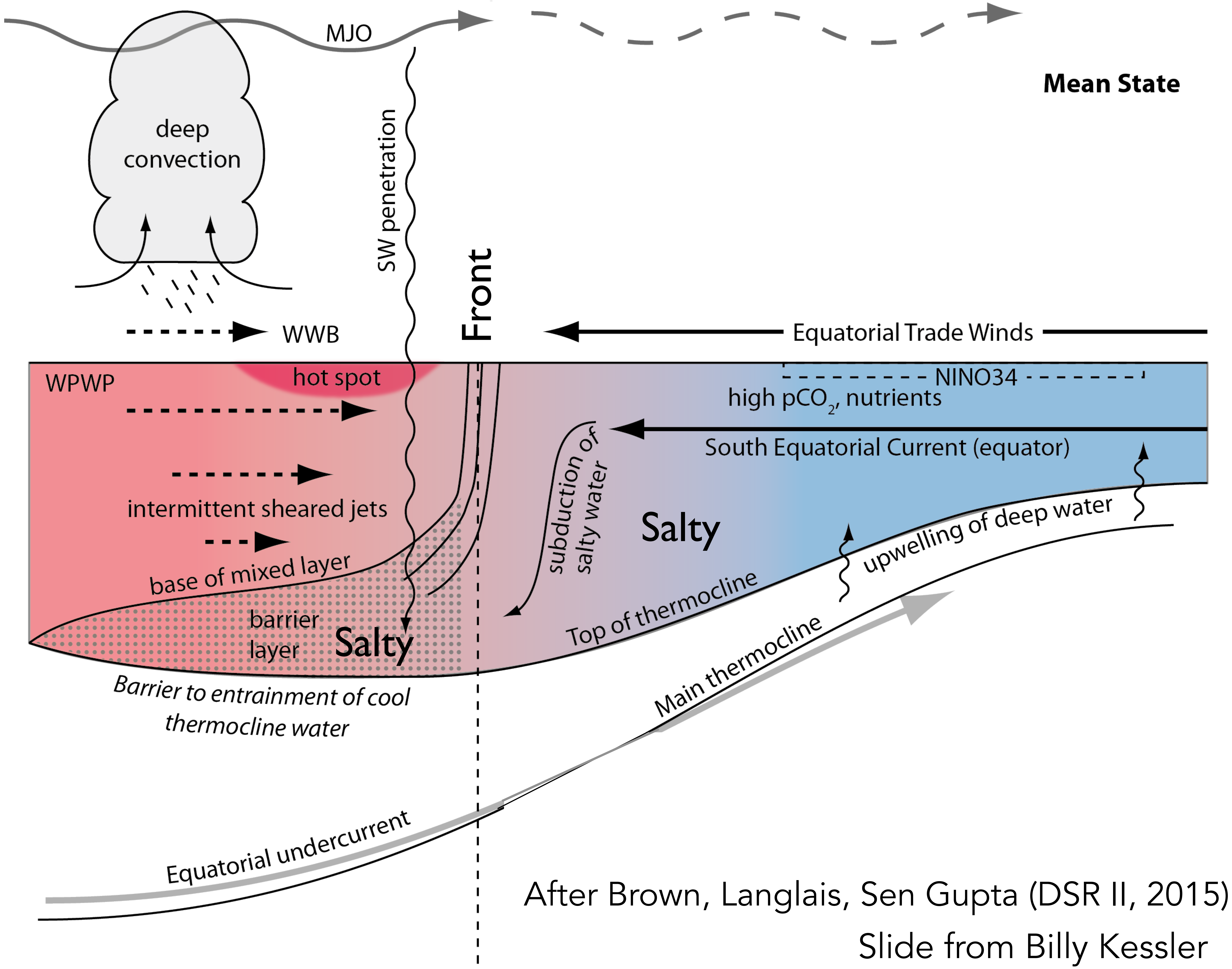
The barrier layer inhibits entrainment cooling, and traps solar flux and wind-input momentum into a thin layer

– Encourages surface heating?
– Allows more convection?
– Enhances eastward jets?

The isolated, shallow surface layer also gives faster, stronger response to wind changes.

Thickness of barrier layer and depth of mixed layer vary in time and space.

E.g., thick barrier layer is associated with El Niño onset (Maes et al. 2005).



After Brown, Langlais, Sen Gupta (DSR II, 2015)
Slide from Billy Kessler

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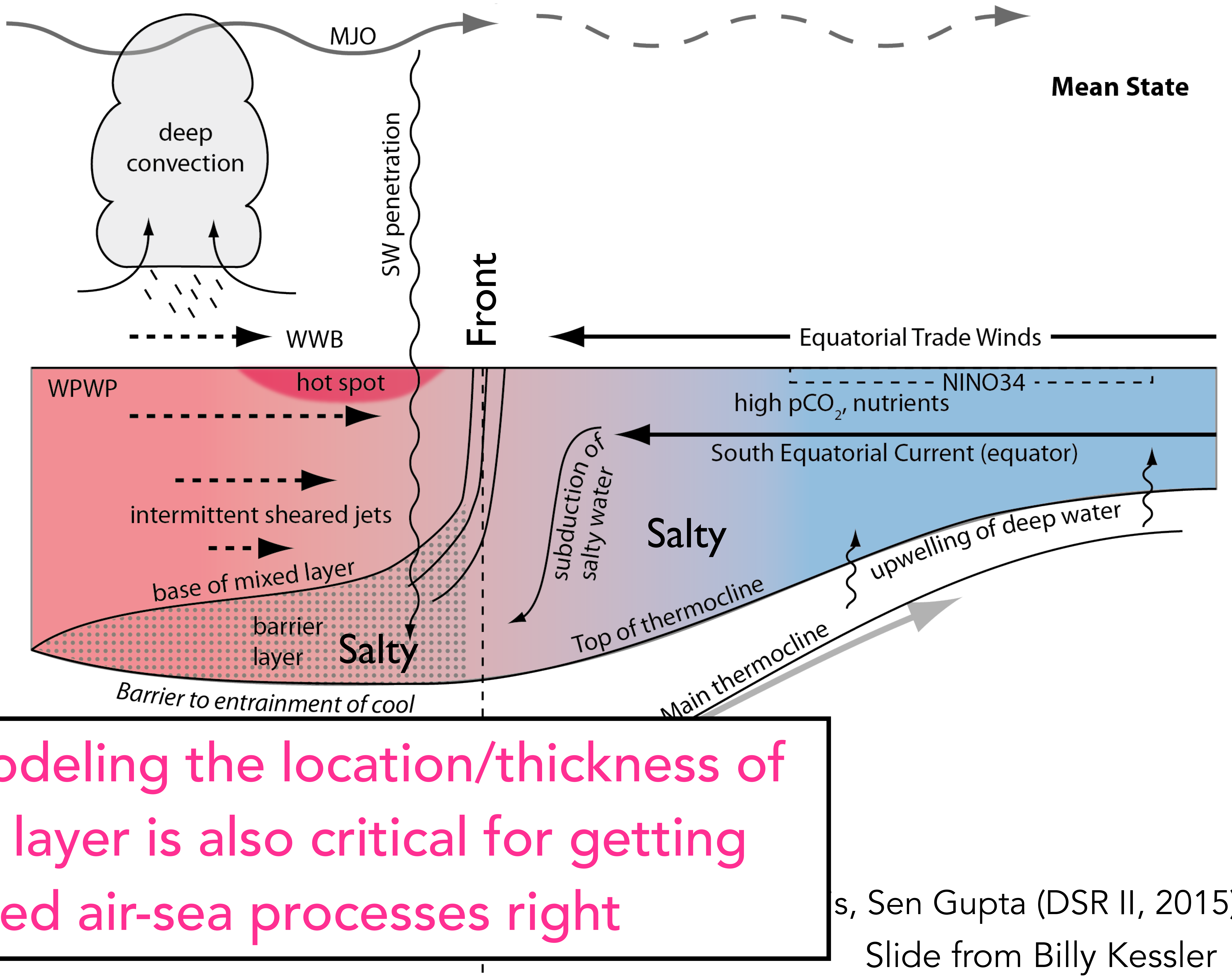
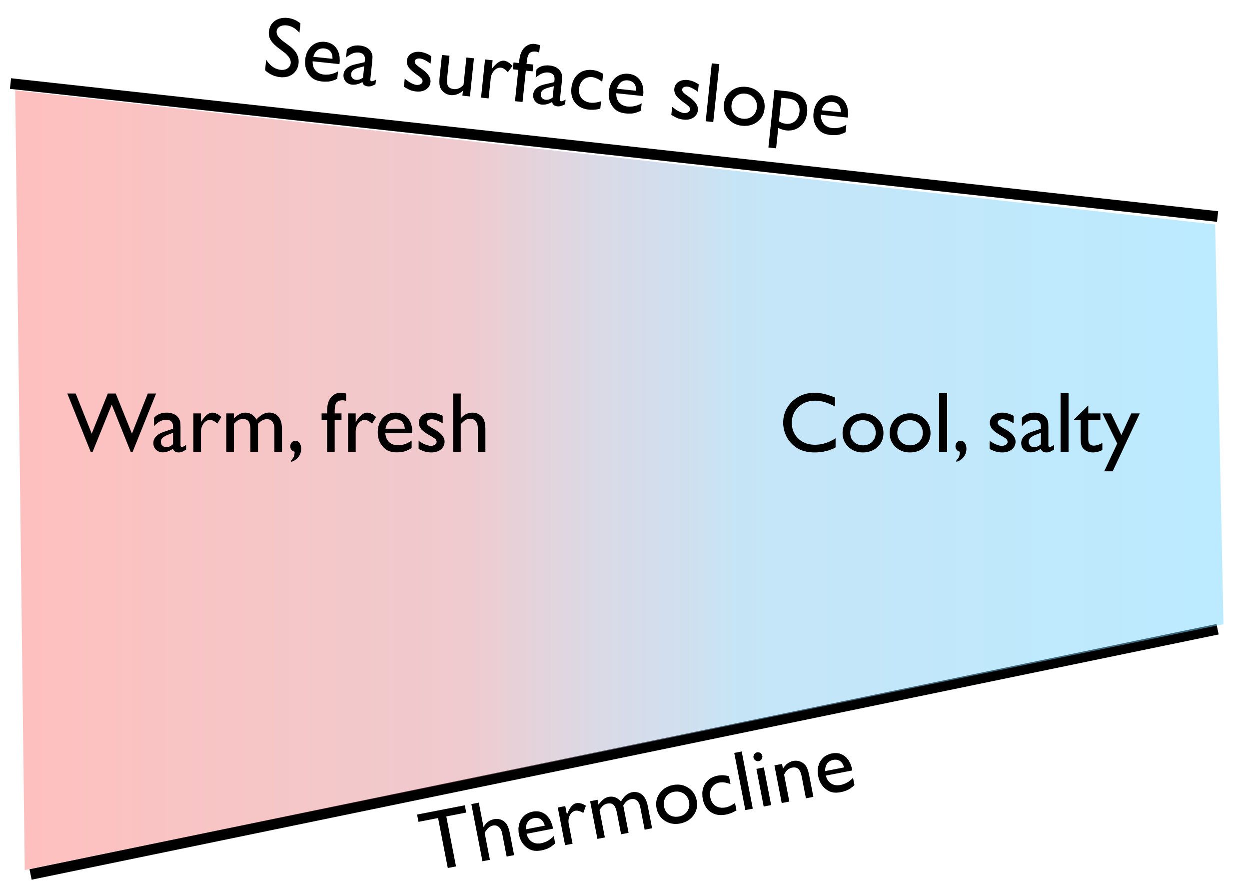
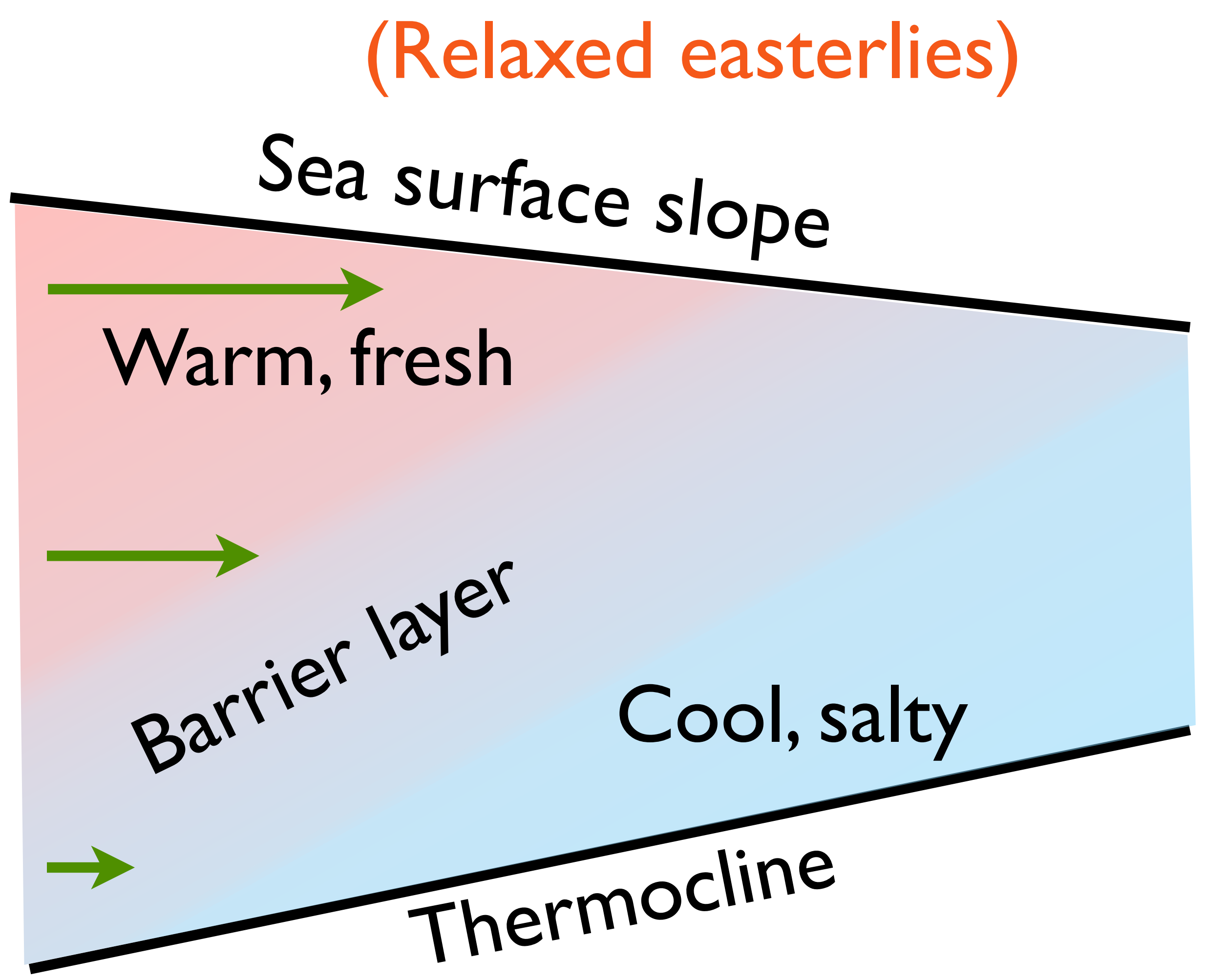


Correctly modeling the location/thickness of the barrier layer is also critical for getting coupled air-sea processes right

s, Sen Gupta (DSR II, 2015)
Slide from Billy Kessler

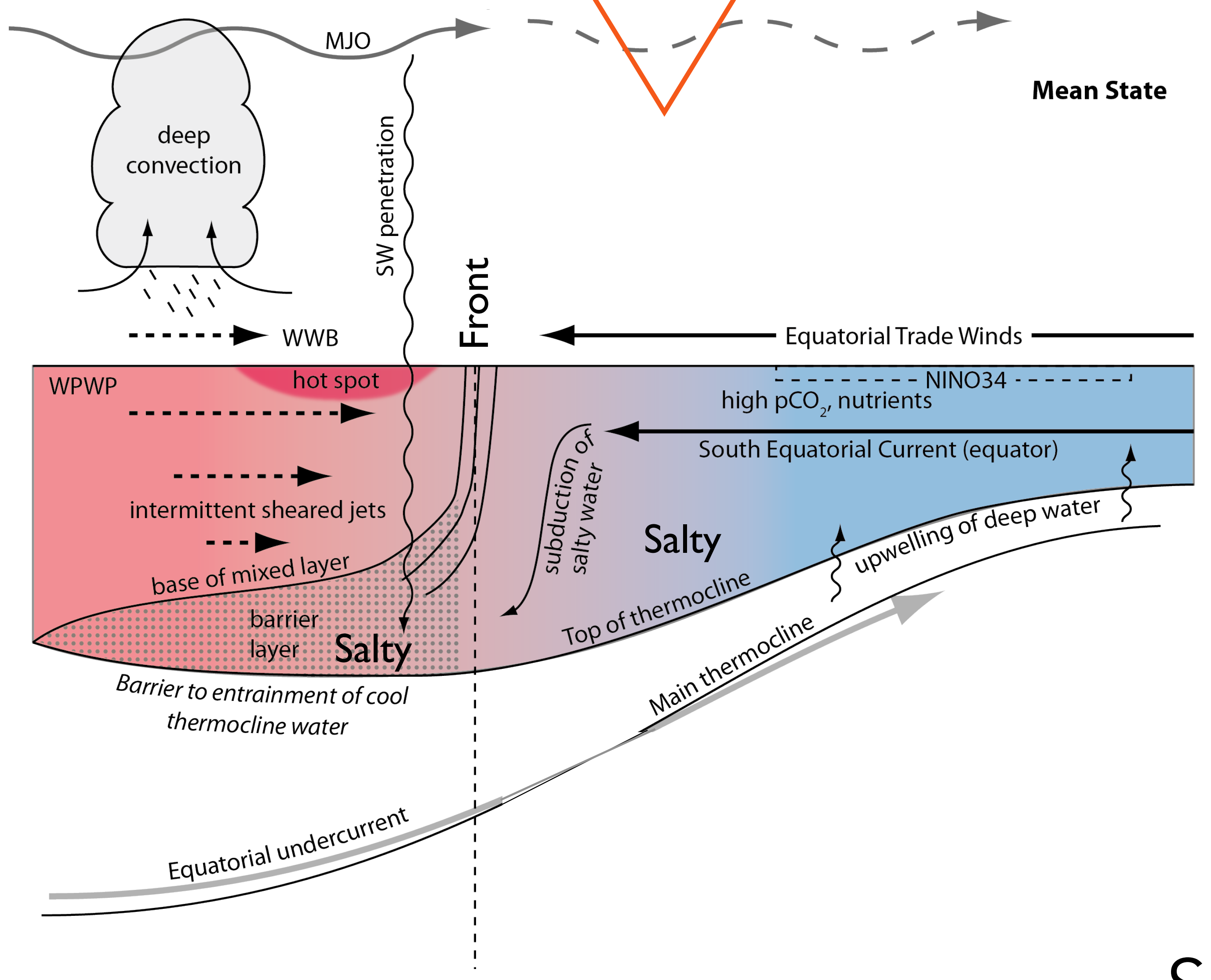
What ocean processes create the barrier layer?





Zonal density gradient: the pressure gradient is stronger at the surface than just above the thermocline.

Relaxation of the easterlies implies stronger eastward acceleration at the surface: **tilting.**



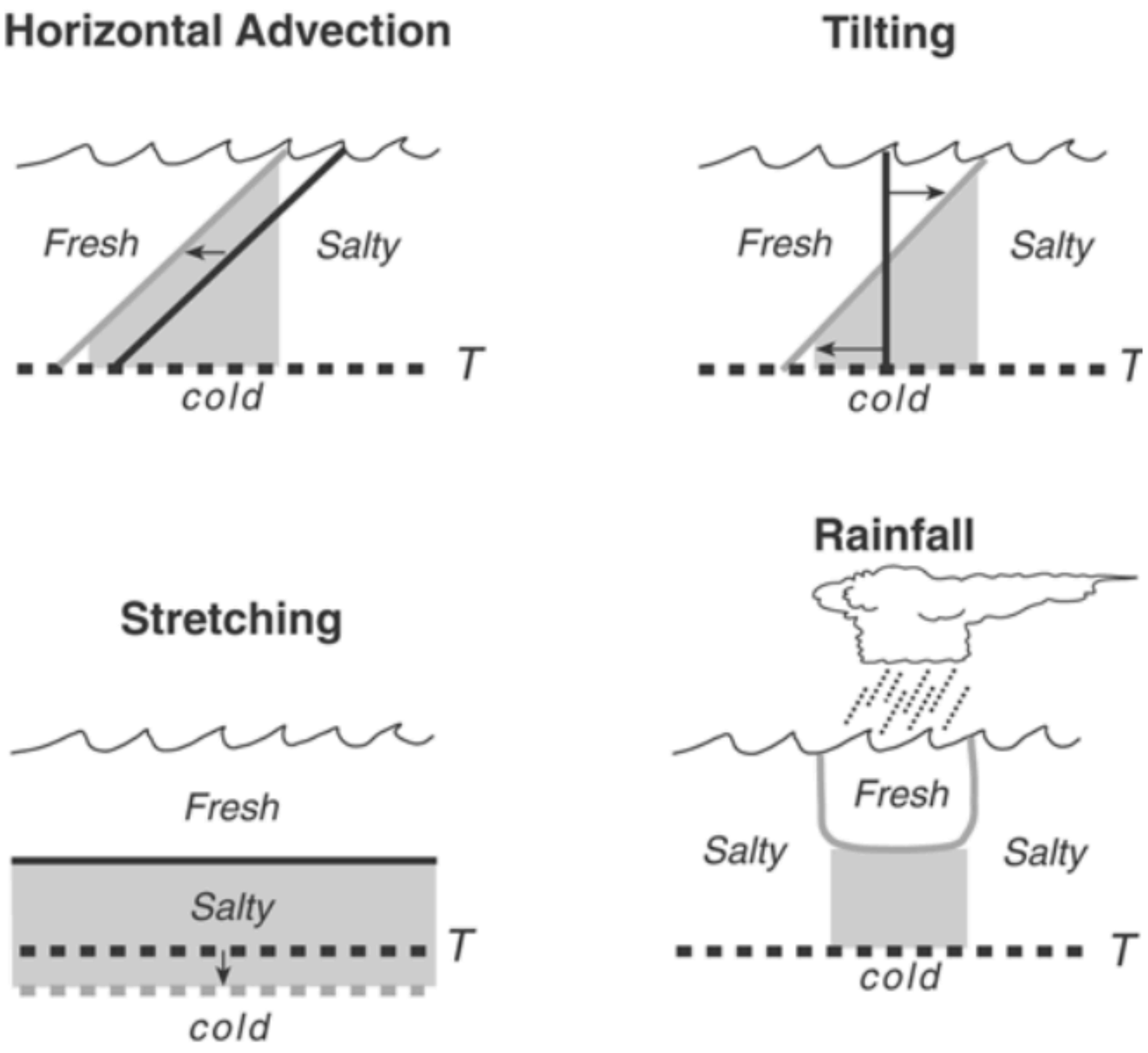
Slide from Billy Kessler

Local forcing + advection can also create a barrier layer

– likely, all have different time and space scales

Zonal or meridional

E.g. from Kelvin or Rossby waves

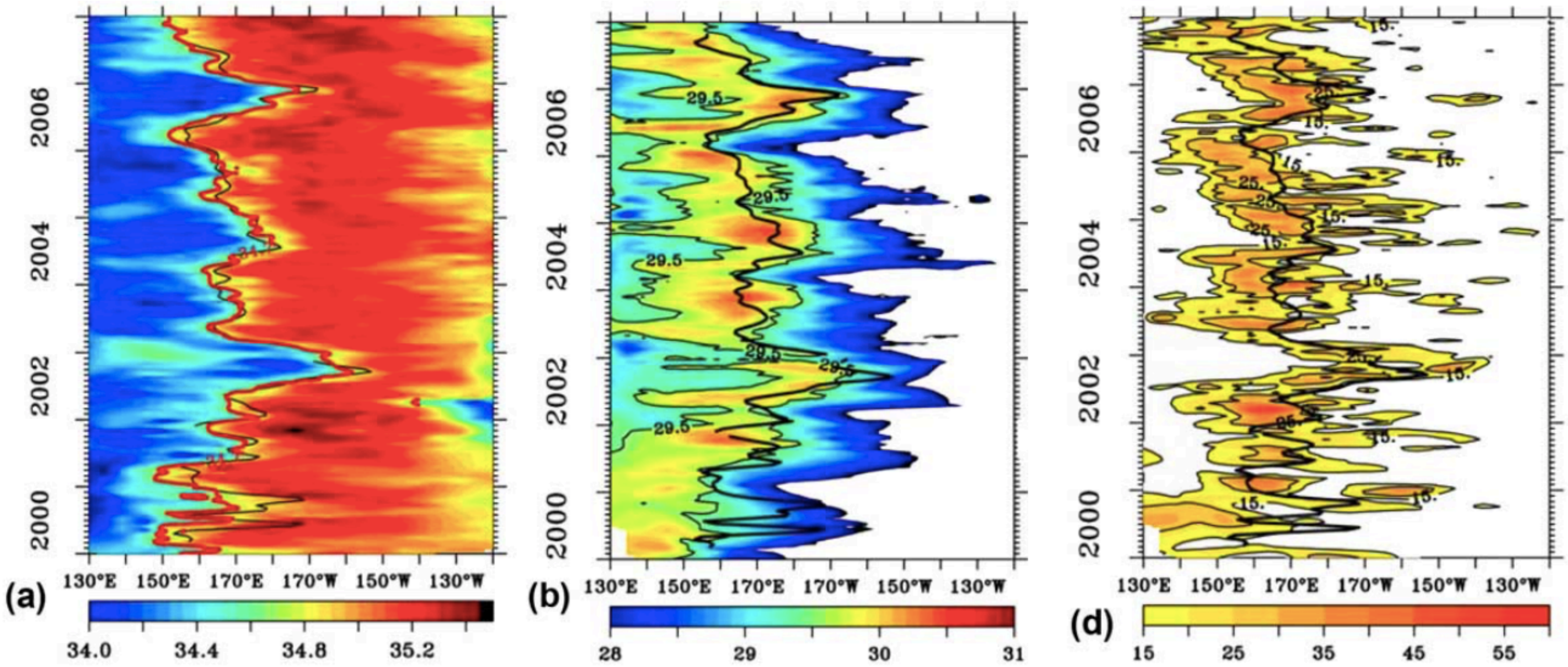


Initially surface-trapped, then mixed in.

Adapted from Cronin and McPhaden 2002

What drives variations in the warm/fresh pool edge?

- Interannual variations are driven by horizontal advection related to ENSO
- Seasonal variability is relatively weak
- Subseasonal and faster variations are hard to capture – but T/S have significant differences
- Barrier layer shifts with the warm/fresh pool but has complex dynamics



SSS

SST

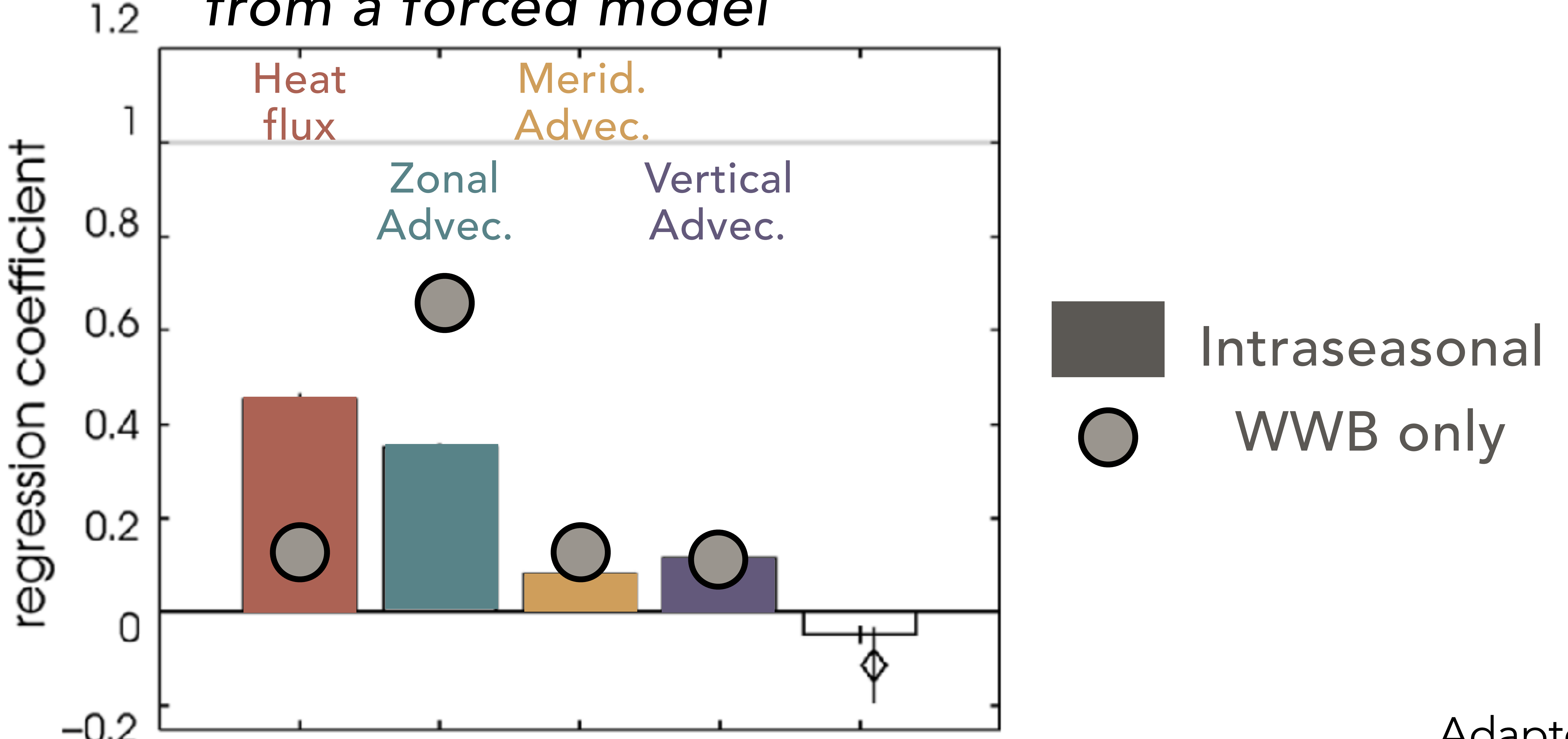
Barrier Layer Thickness

Adapted from Bosc et al. 2009

Intraseasonally, heat flux + advection control the position of the WPEE

- But during WWBs, **wind- and Kelvin wave-driven advection** drive eastward displacements
- Intraseasonal and faster variations in the fresh pool edge: open question
- The warm/fresh pool edge is a fundamentally challenging region to sample because it moves (O(0.1)°/day, occasionally faster).

Heat budget at the WPEE from a forced model



Adapted from Drushka et al. 2014

Some limitations with models and observations in the WPWP

- **Net heat flux – particularly evaporation**
  - Flux observations are poorly constrained.
  - TPOS flux moorings will help, but are too sparse to resolve shifts in the WPEE.

- **Surface wind stress and its variability**
  - Satellite wind products are diverse, don't work well in rain, and do not capture gustiness.
  - WWBs are not well modeled (structure, seasonality, relationship to MJO and warm pool).

- **Diurnal variability**
  - Significant in the WPWP, but models typically do not resolve (poor vertical structure and temporal coupling).

- **Salinity stratification and its variability**
  - Satellite SSS is too coarse to resolve fast or small-scale variations.
  - Models don't capture fresh layers well (coarse rain forcing, poor vertical structure).

Open questions to address in a field experiment

Expanded from the TPOS2020 first report

1. What maintains the temperature and salinity fronts at the WPEE?
    - What drives variability of the T/S fronts on diurnal to interannual timescales?
    - How independent are the T/S fronts, and on what time scales, and why?

2. What processes create and modulate the ocean structure (barrier layer thickness) at the WPEE on diurnal to interannual timescales?
    - How well can we infer the vertical stratification from the surface structure?

3. What is the variability and importance of off-equatorial and meridional WPWP structure?

Strawman:

Two nested field experiments to capture the coupled dynamics on either side of the shifting edge of the warm pool (cf. TOGA-COARE)

1. **Medium-term enhancement of the TPOS backbone (e.g., 1+ years)**

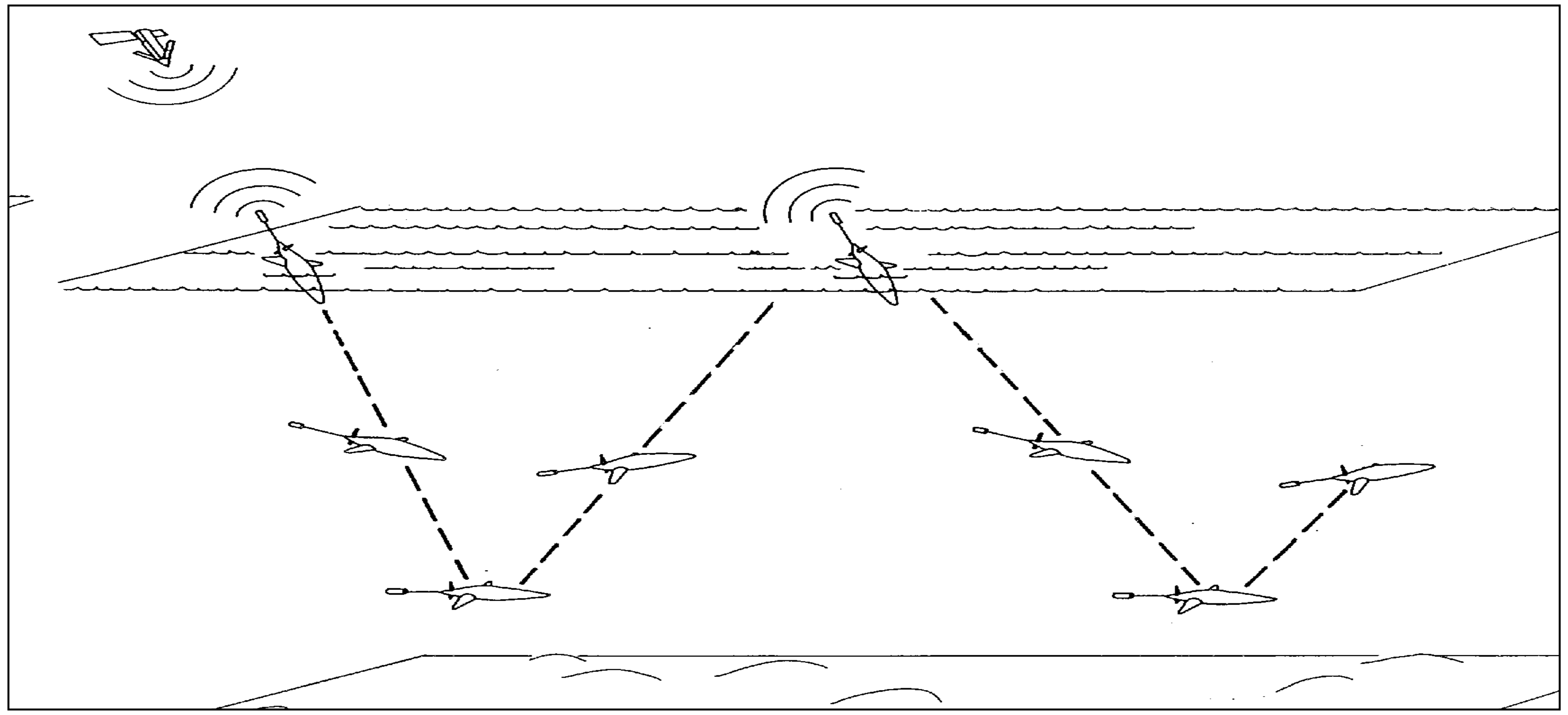
2. **Process study (e.g., 1-2 MJO cycles or WWBs, as in DYNAMO)**

1: Medium-term experiment.

Goal: Characterize the structure, dynamics, and variability within and outside the warm pool, over multiple intraseasonal cycles during 1+ years

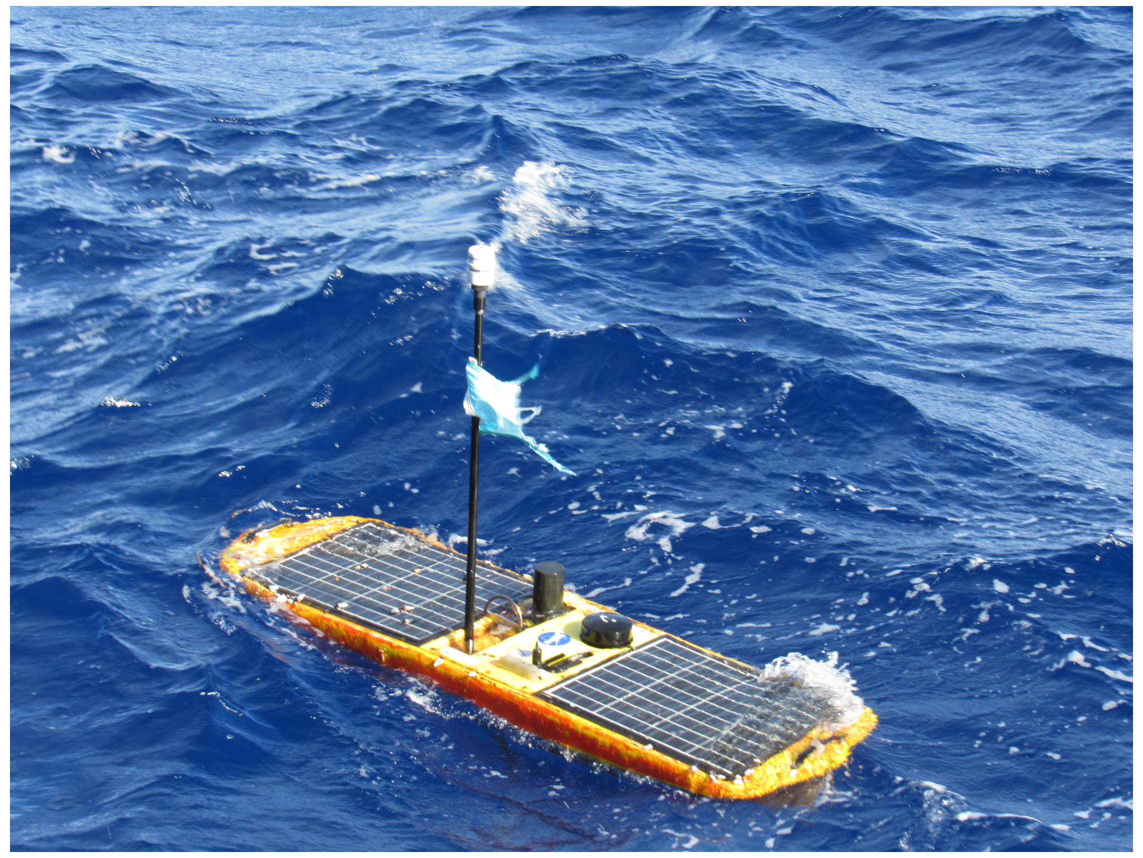
- **Surface and vertical ocean structure**
  - SST/SSS gradients (and their latitudinal displacements)
  - Upper ocean stratification: barrier layer thickness, mixed-layer depth, relationship to surface signature
  - Horizontal currents and shear from the surface through the thermocline
- **Atmospheric properties**
  - Surface fluxes and winds
  - Relationship to ocean structure and properties

1: Possible platforms/strategy

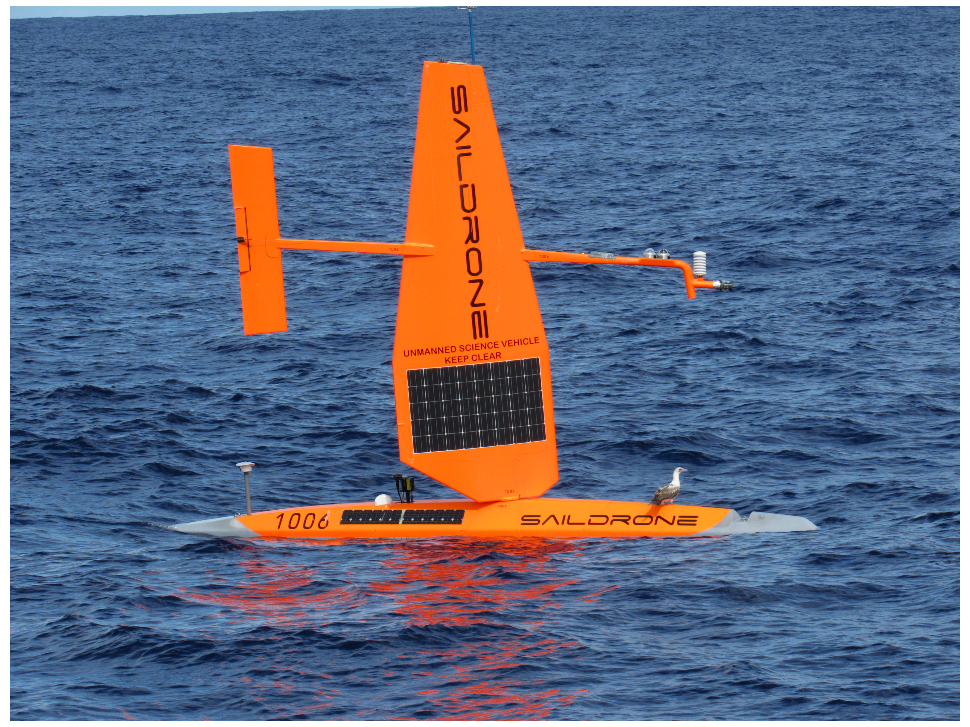


In addition to the TPOS backbone

- **Subsurface gliders making regular WPEE crossings**
  - Gliders make repeated sawtooth dives
  - Provide profiles of T,S, currents, shear, dissipation rate
  - New: wind and rain (passive acoustics)
  - Cover ~25 km/day, which is the max speed of the WPEE
  - Multiple gliders would capture both equatorial and off-equatorial structure
- **Wave Gliders**
  - Wave-propelled surface vehicles with a subsurface component
  - Surface and near-surface T/S/currents, and meteorology (winds, air pressure/temp)



- **Manned or autonomous sailing vessels**
  - E.g., Saildrones (met, flux, SST/SSS, ADCP), Schooner Lady Amber (met, flux and T/S measurements)



- **Surface drifters**
  - High-resolution SST/SSS and surface currents across the front

2. Process study

Goal: Observe dynamics at the WPEE on diurnal to intraseasonal timescales

- **Momentum, heat, and salinity budgets at the WPEE**
  - During different conditions (westerly wind bursts vs. calm)
  - As the warm pool shifts east/west
- **Barrier layer formation, evolution and impacts**
  - BL formation mechanisms (tilting, advection, stretching, buoyancy production vs shear-driven mixing) and time/space evolution
  - Impacts of BL on SST, near-surface jets, advection
- **Atmospheric forcing and response**
  - Surface momentum, heat, and freshwater fluxes
  - Atmospheric convection

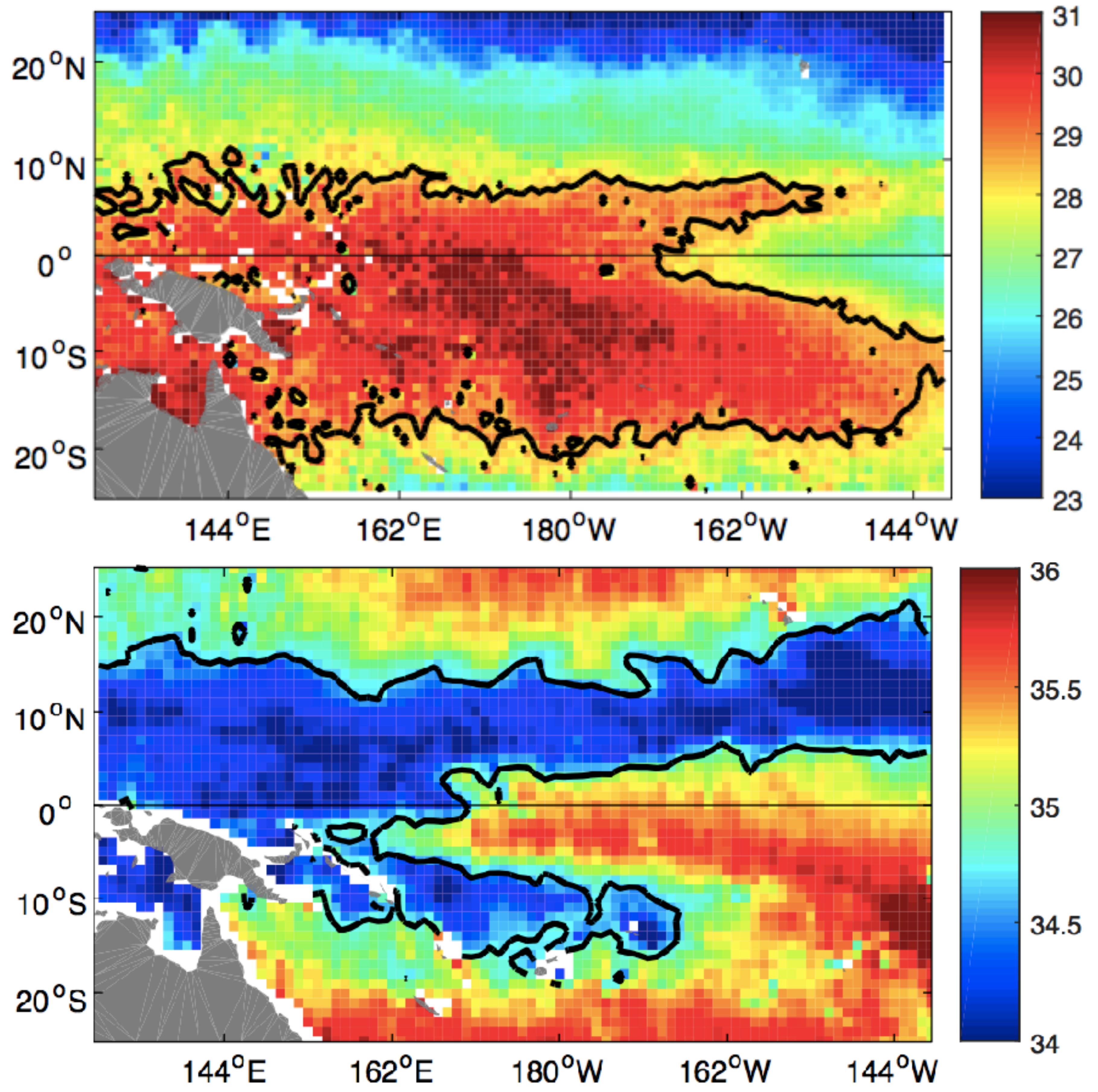
2. Possible platforms/strategy

Embedded in the medium-term experiment

- **Ship survey: multiple crossings of the WPEE as it moves, to capture the changing horizontal/vertical structure and associated fluxes**
  - Surface and vertical profiles of T,S,u, shear at high resolution (underway CTD, ADCP)
  - Near-surface stratification (thermosalinograph)
  - Fluxes, atmospheric soundings
- **Autonomous assets**
  - E.g., Subsurface gliders or Wave Gliders
  - Slower than a ship – could capture the diurnal cycle
- **Flux measurements from manned or autonomous sailing vessels?**
- **Land based atmospheric component**
  - Soundings, radar?

Field experiment challenges

And thoughts on mitigation



- Identifying the edge of the warm/fresh pool
  - Isotherm? Isohaline? Max. gradient?
- Location is unpredictable, transit times are long
  - E.g., Guam to 0N,170E is 6 days; to 170W is 12 days
  - Two ships (from different ports) – international collaborators?
- Strong winds/currents during WWBs, so autonomous or wind-driven platforms will have trouble staying in the region
  - Could reposition with the ship during the process study, with another vessel (e.g., Lady Amber) during the year-long experiment
- WWBs are unpredictable, so might not capture one
  - DYNAMO had this challenge also => 4 cruises

Important!

- Any field experiment must be designed with effective data assimilation and modeling in mind
- It is critical to make measurements that will complement and inform TPOS, e.g.:
    - Where do we need to know the ocean vertical structure versus being able to rely on satellites?
    - Where do we need the highest density of Argo floats?
    - What locations and depth resolution/range are necessary to measure currents?

Discussion…

- How can we most effectively make measurements that will lead to model improvements?
- How far off the equator should we sample?
- What else do we need to measure? (e.g., pCO_2, biogeochemistry?)