TPOS 2020 Project

Review and re-design the Tropical Pacific Observing System

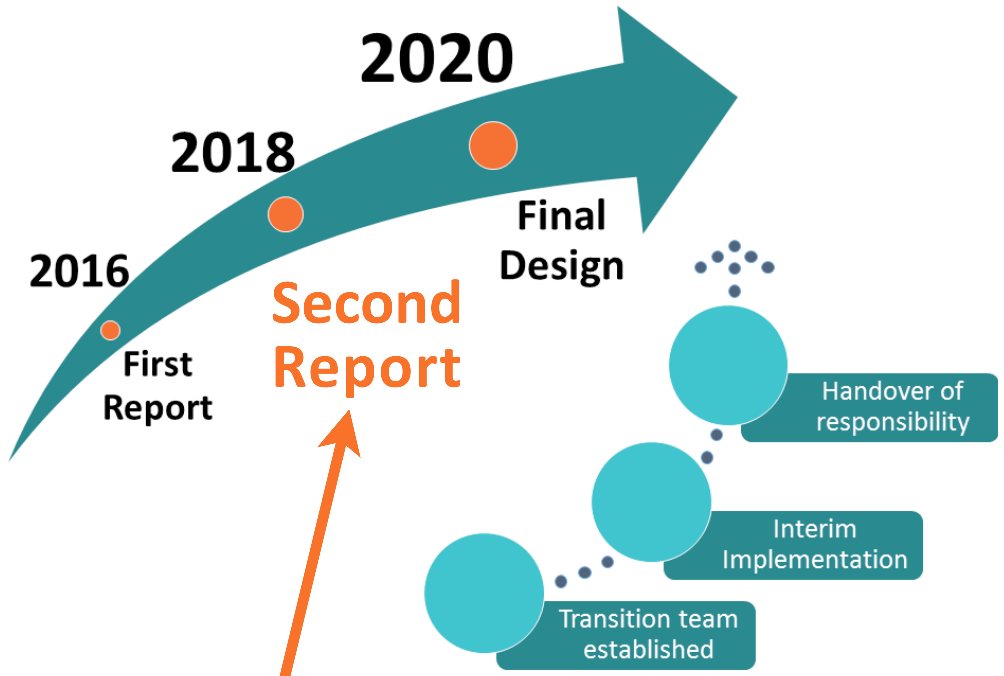
– Rethink in response to new needs, purposes, challenges: Define requirements
– Renew the interagency and intergovernmental cooperation that has been the hallmark of the TPOS since the mid-1980's
– Take advantage of new science and technology

Today's outline:

– Overview of the project (15 mins)
– Recommended process studies (15 mins)
– Discussion!!!

TPOS 2020 Goals

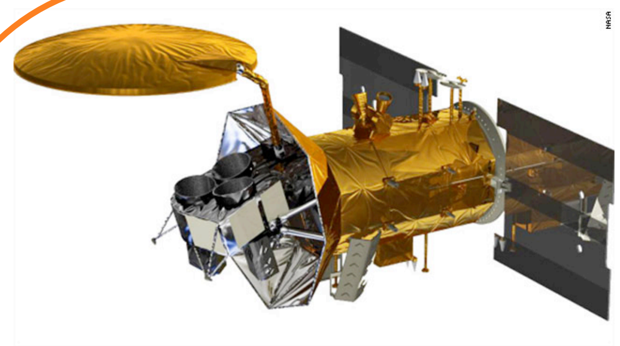
- To redesign and refine the T.P.O.S. to observe ENSO and advance understanding of its causes
- To determine the most efficient and effective observational solutions to support prediction systems for ocean, weather and climate services
- To advance understanding of tropical Pacific physical and biogeochemical variability and predictability.

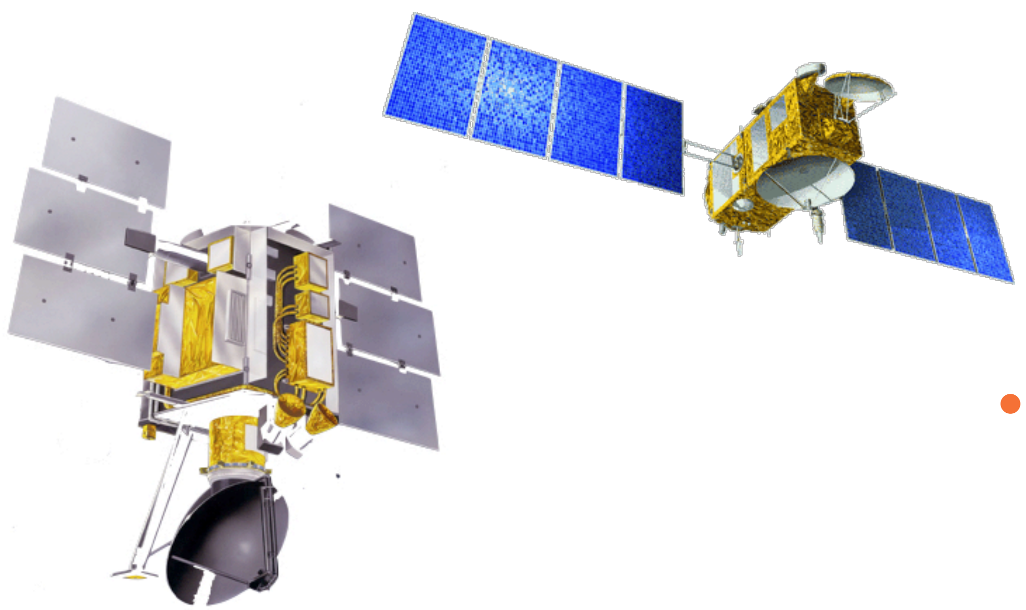


Second report foci:

- Improving modelling and data assimilation
- Biogeochemical and ecosystem observations (Beyond pCO_2, what?)

An integrated view

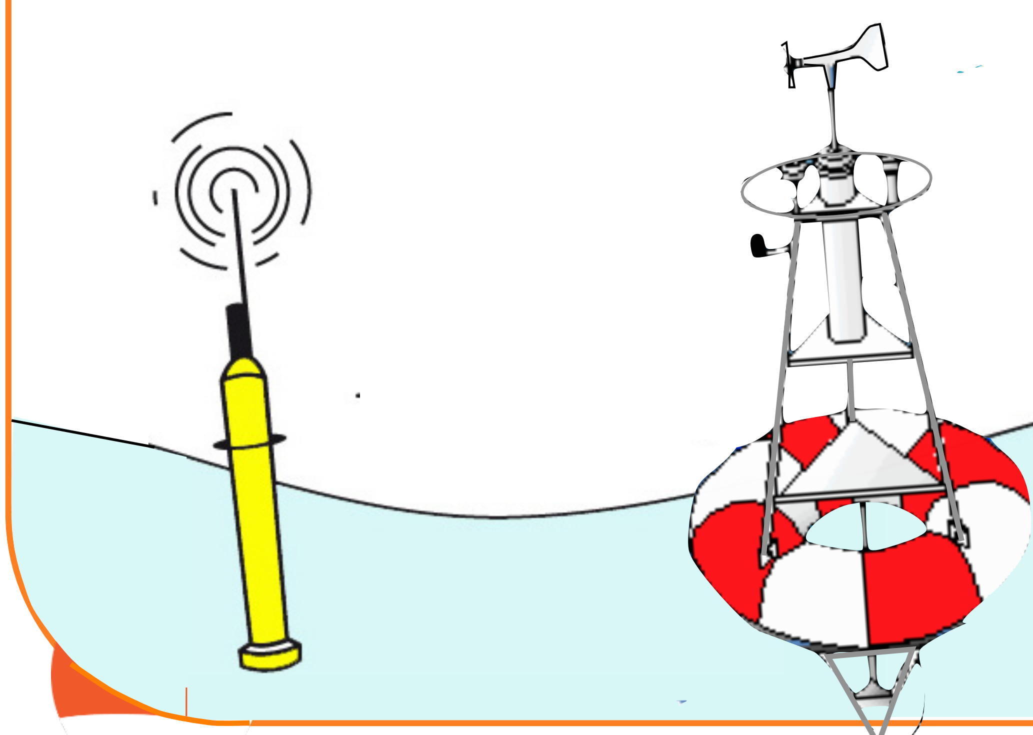


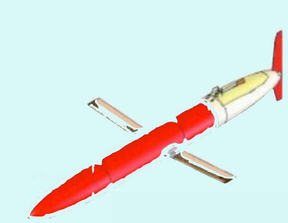


- Complementary "backbone" technologies:
  - Satellites give global coverage, fine horizontal detail)
  - Moorings sample across timescales, allow co-located ocean-atmosphere observations, velocity sampling
  - Argo resolves fine vertical structure, adds salinity, maps subsurface T and S and connects to subtropics
- New scientific understanding and issues:
  - Role of high-frequencies, especially the diurnal cycle
  - Focus on the coupled boundary layers
  - Physical-biogeochemical connections and impacts

Assimilating models integrate diverse observations

→ Users will increasingly rely on gridded products



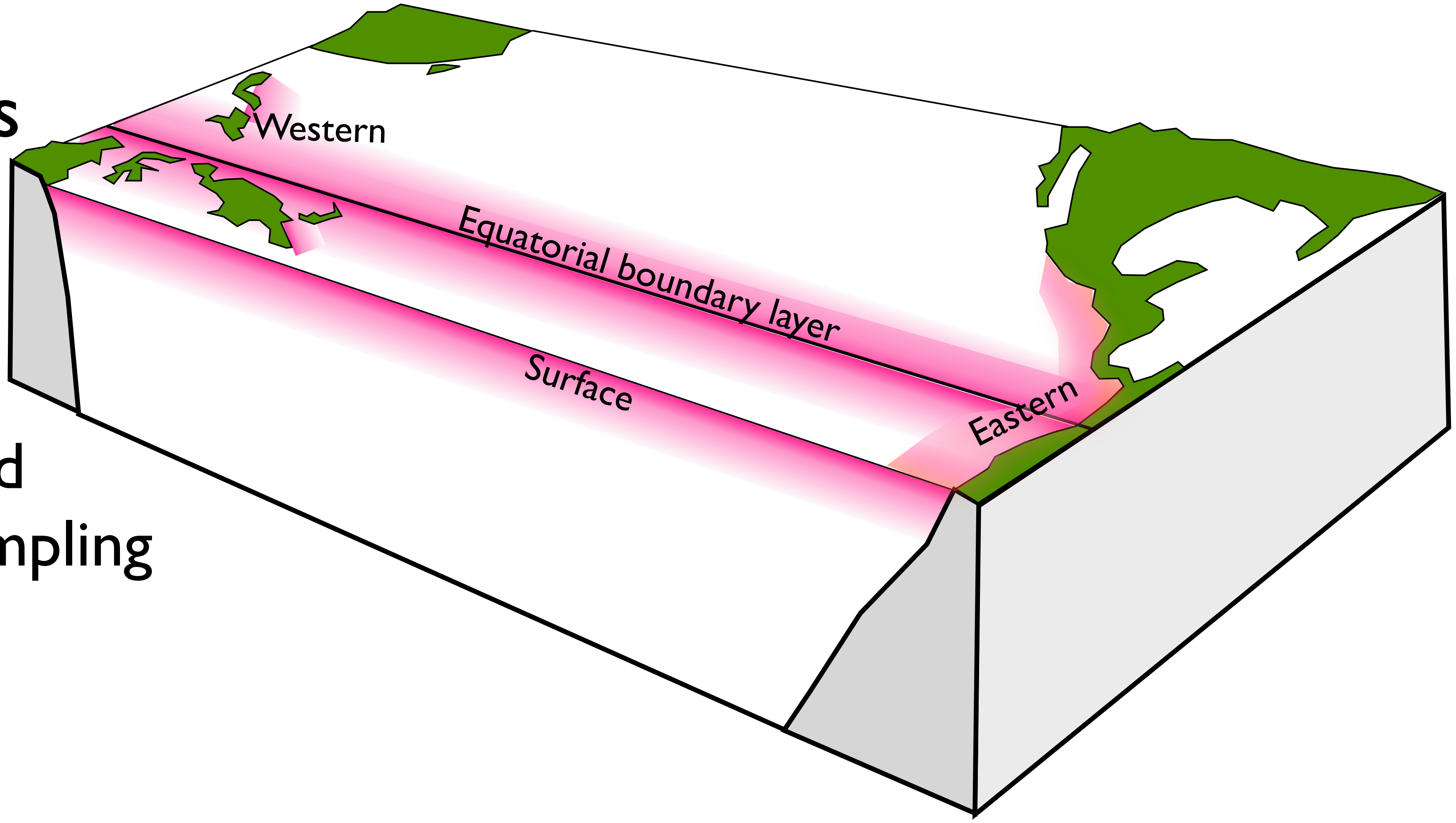


We view the tropical Pacific as consisting of a broad interior plus four "boundary layers":

Surface, Equatorial, Eastern and Western

The boundary layers are the hard parts

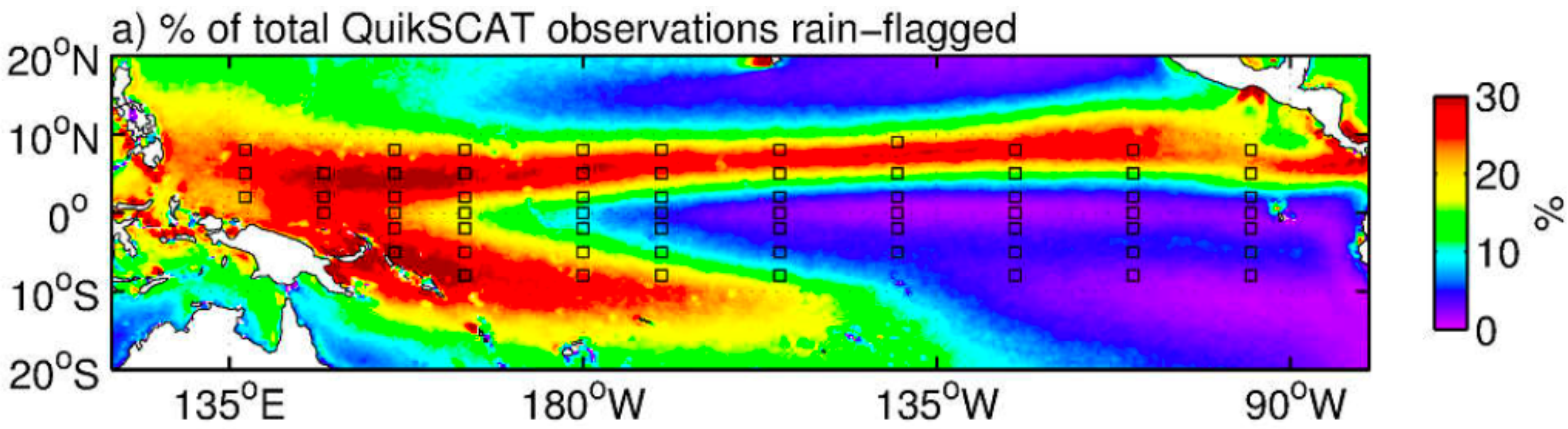
In an integrated system that includes satellites, we are less tied to a grid and can focus in situ sampling on key regimes.



Requirements for the backbone

What drives our recommendations?

<u>Example</u>: Vector winds



QuikSCAT rain-flag frequency during 1999-2009.
Over much of the Pacific ~25% of QuikSCAT samples are flagged as <u>potentially</u> invalid due to rain.

This does not mean that scatterometer winds are unusable under rain, but they are in question. It is also true that wind <u>products</u> from different centers differ significantly.

The global climate is exquisitely sensitive to the equatorial zonal wind, so we must get this right.

Winds with a reduced moored array

TAO was originally designed to map winds, before scatterometry.

Now we propose to reduce buoy locations, relying more on scatterometer winds.

Two distinct issues:

1) How well do scatterometers measure winds themselves?

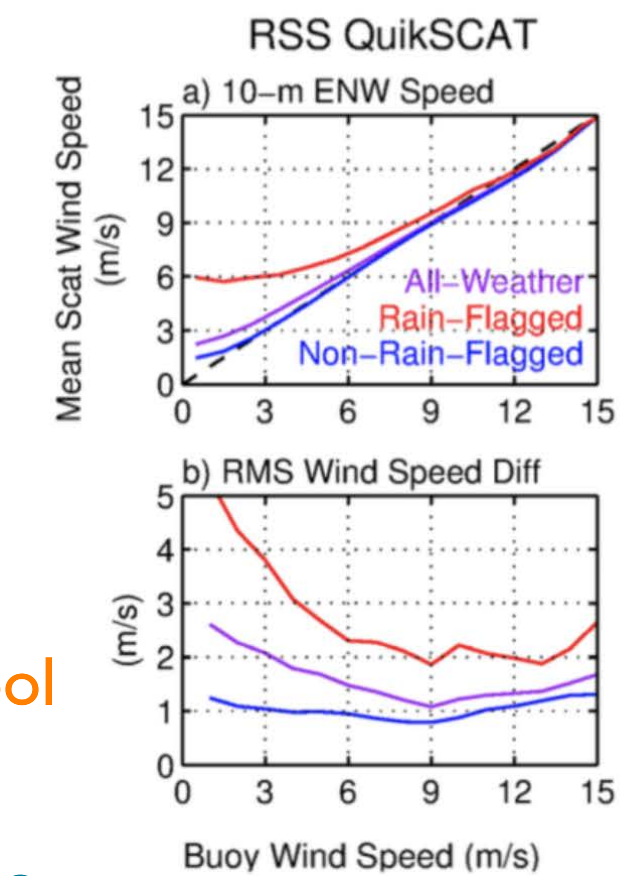
Extensive investigation:

- Only a few ongoing cal/val points are needed in the tropics
- Specific regions need in situ referencing (heavy rain / low winds)
- Equator needs referencing between satellite generations

These considerations were influential in shaping our design:

In situ wind sampling in heavy rain regimes: ITCZ, SPCZ, Warm pool

Maintain full sampling along the equator



2) How well do present analyses produce credible wind fields?

The mapping issues are more difficult:

Products from different centers differ considerably! Work is needed!

→ TPOS 2020 must provide the in situ observations for adequate referencing of scatterometer winds as wind-gridding improves

The First Report

- Published 30 December 2016 (ref. GCOS-200)
- 22 Recommendations
- 15 Actions
- First published design following the GOOS Framework
- 2 rounds of review and revision

tpos2020.org/first-report

(much of this applies to the other tropical oceans!)

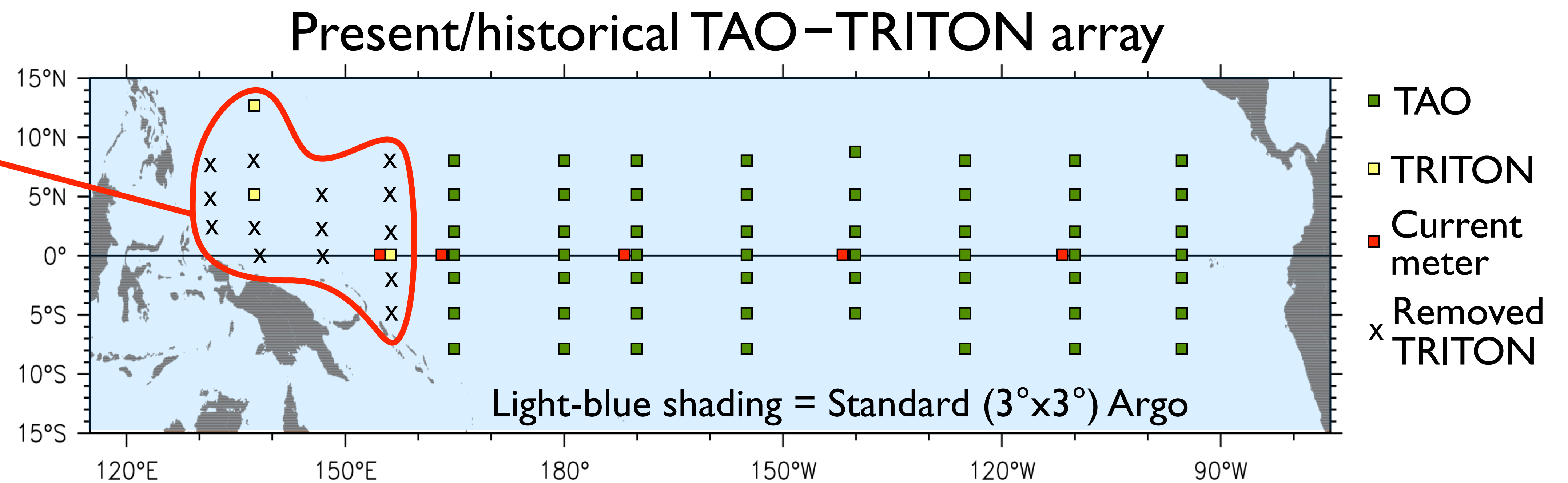
Specific Recommendations

- Double Argo within 10°S-10°N
- Reconfigure the moored array

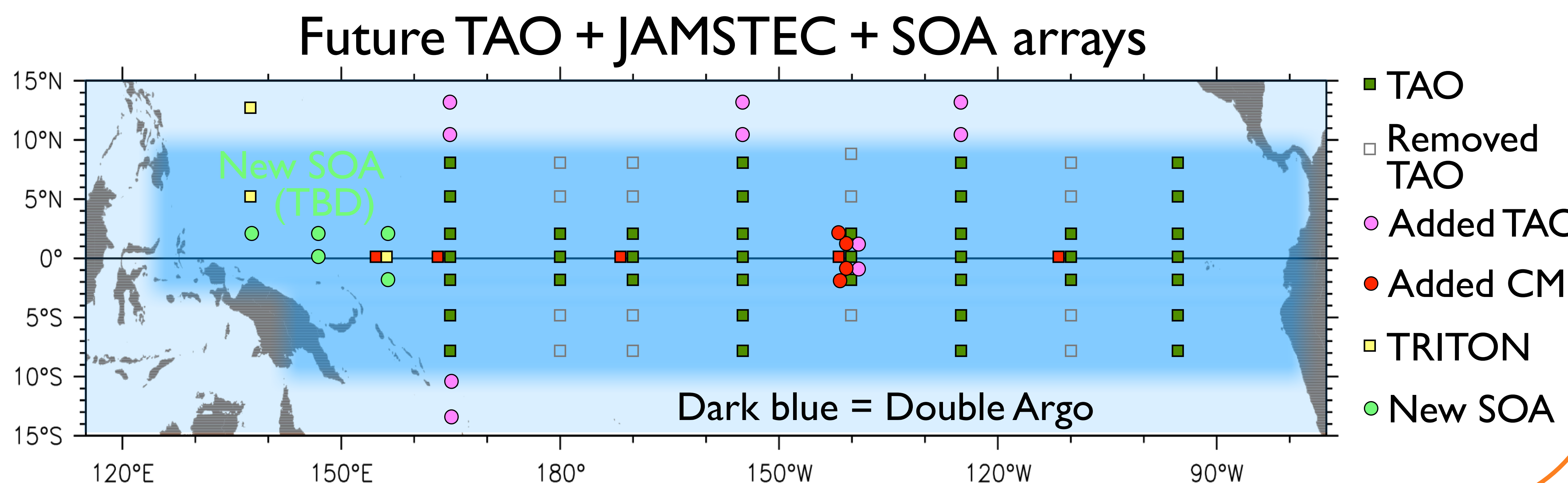
More-capable moorings, targeting:

the equatorial circulation, the mixed layer, its interaction with the atmosphere, key regimes

Only 3 TRITON sites remain



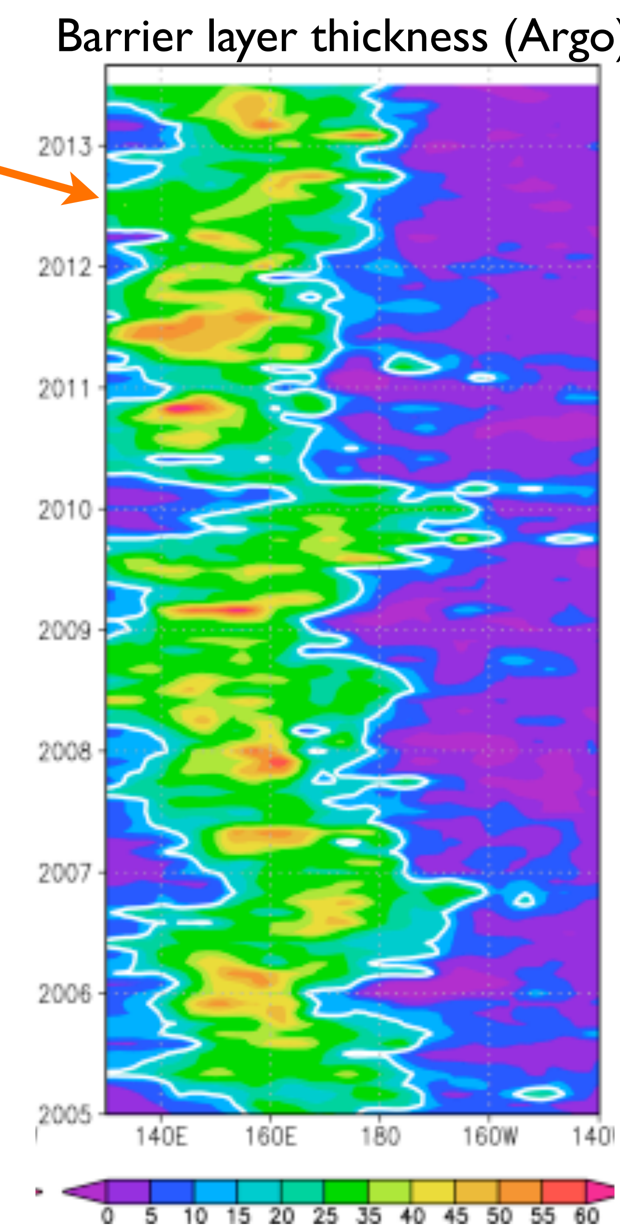
Proposed eventual in situ "backbone"

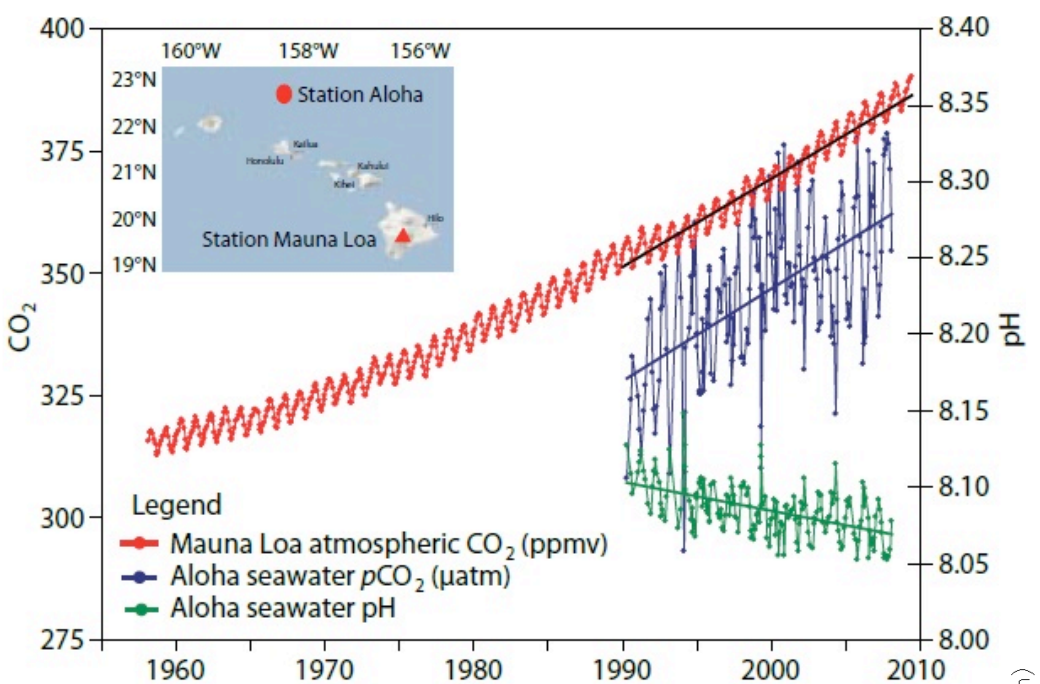


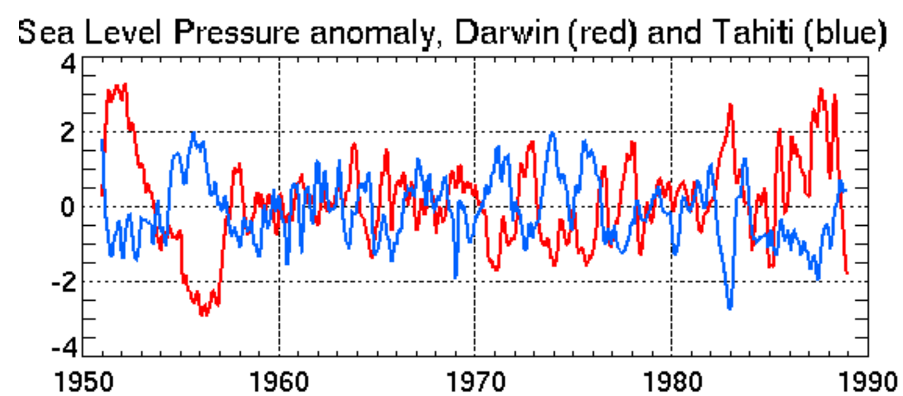
The climate record in an evolving observing system

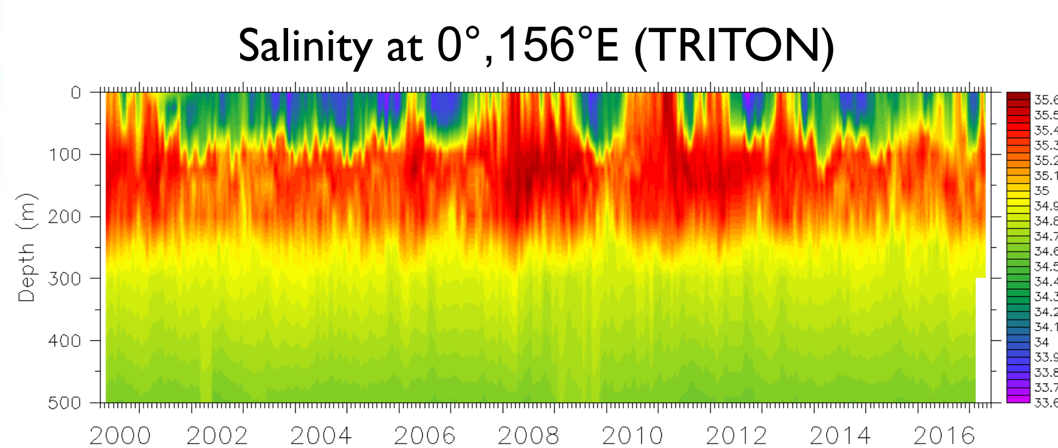
A "climate data record" is a time series at a point (examples).

A "climate record" is a <u>set</u> of measurements that enable detection and accurate description of an element of climate variability in its longterm context.









Conclude overview: Successes, challenges

- Large amount of talent, thought, interest
- Concrete redesign proposed
- Strong endorsement by sponsors (US and international)
  Already considerable investment underway
- Risks of change:
  - We will live with the new design for O(decade) ...
    hard to guess future needs. Where are the models going?
    Where are the data assimilation systems going?
  - In a world of sparse funding, how do we avoid damaging
    the climate record?

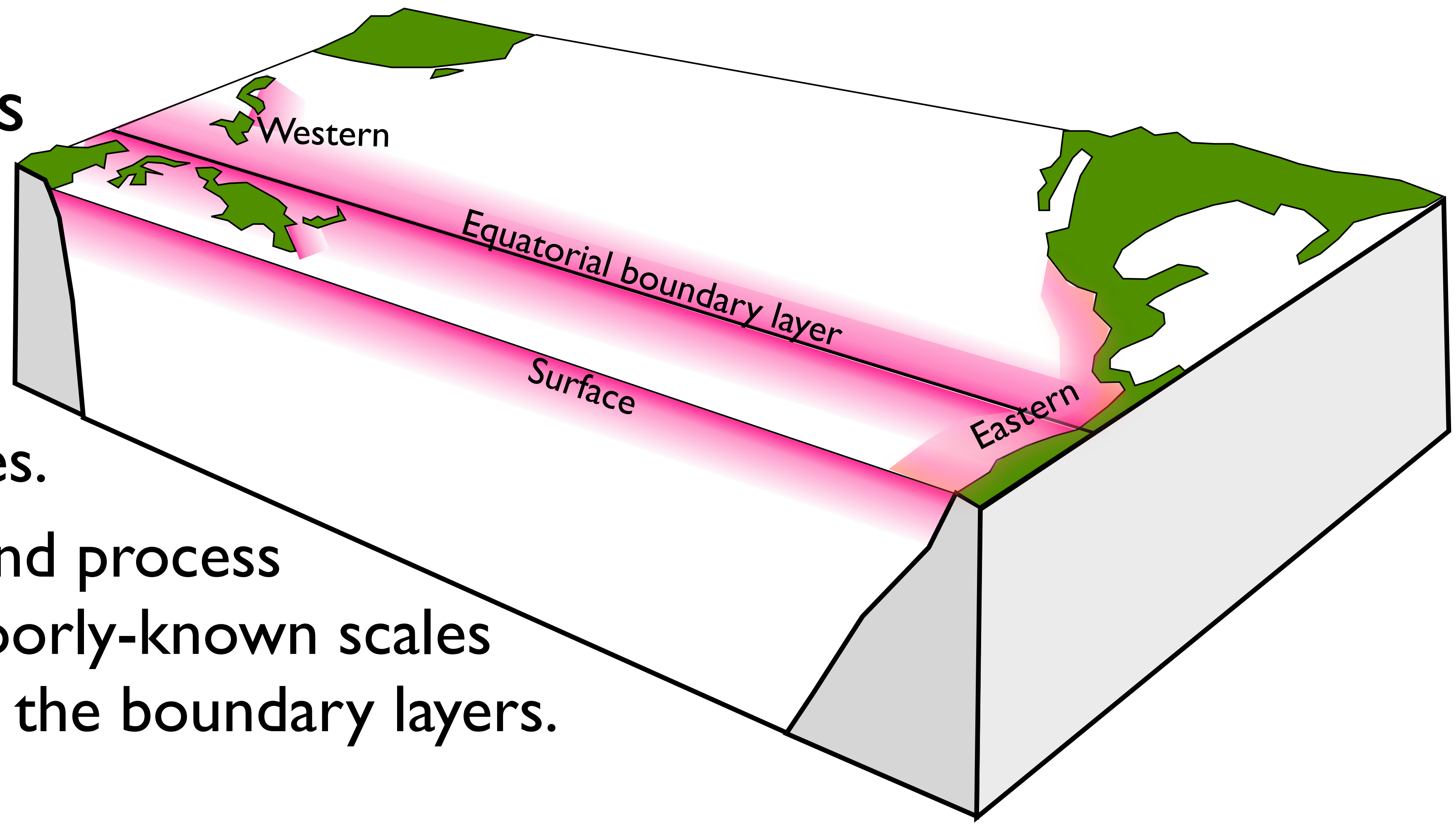
  Requires process studies (rest of session)

Pilot and Process studies

The boundary layers
are the hard parts

For the broad interior
we can often specify
goals and sampling scales.

But many of our pilot and process
studies are driven by poorly-known scales
or unclear objectives in the boundary layers.



Criteria for TPOS 2020 process studies

- Our fundamental responsibility is to build the backbone observing system (which makes everything else possible)
- Sustained diagnoses will occur largely through model products that integrate diverse data sources, remote and in situ

Thus, we seek process studies that:

- are explicitly coordinated with parameterization development: Must identify a path to improvement that needs specific observational guidance not available from the sustained obs (CPT model)
- point towards increasing ability of models to infer the action of the process from ongoing sparser sampling, and to refinements of the sustained sampling

Proposed studies are not pre-wired! Open to everyone!
Our present list is not complete or exclusive!

Pilot/process studies now underway:

Autonomous vehicles and platform enhancements

NOAA (OAR/OOMD)
- Autonomous surface vehicles: PBL and surface BGC
- Argo enhancements: rainfall, windspeed and BGC
- Enhanced ocean boundary layer sampling from TAO
- Direct covariance flux measurements from TAO

JAMSTEC
- Autonomous surface vehicles: surface fluxes
- Upgrade 3 TRITON sites to flux Supersites
- Shallow/new-mission Argo floats
- Research cruises

NASA
- SPURS-2 Experiment at 10°N,125°W (ITCZ)

Other pilots expected (China):
-Warm pool array
-Indonesian Throughflow
-Western boundary currents


Wave glider

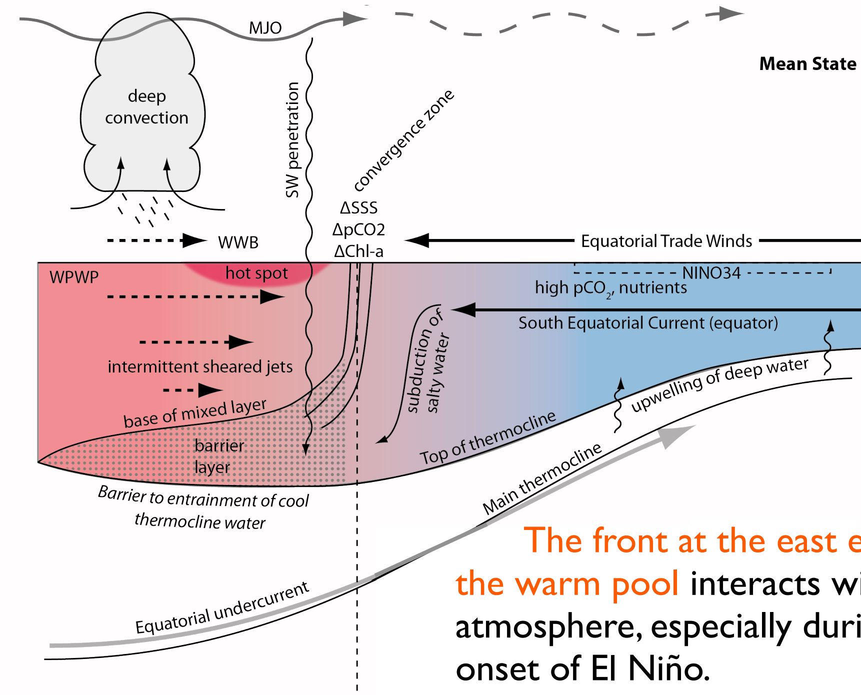
Autonomous surface vehicles have great promise, but need testing in real-world conditions to prove their possibilities and learn their limitations.

New investments will advance these technologies.

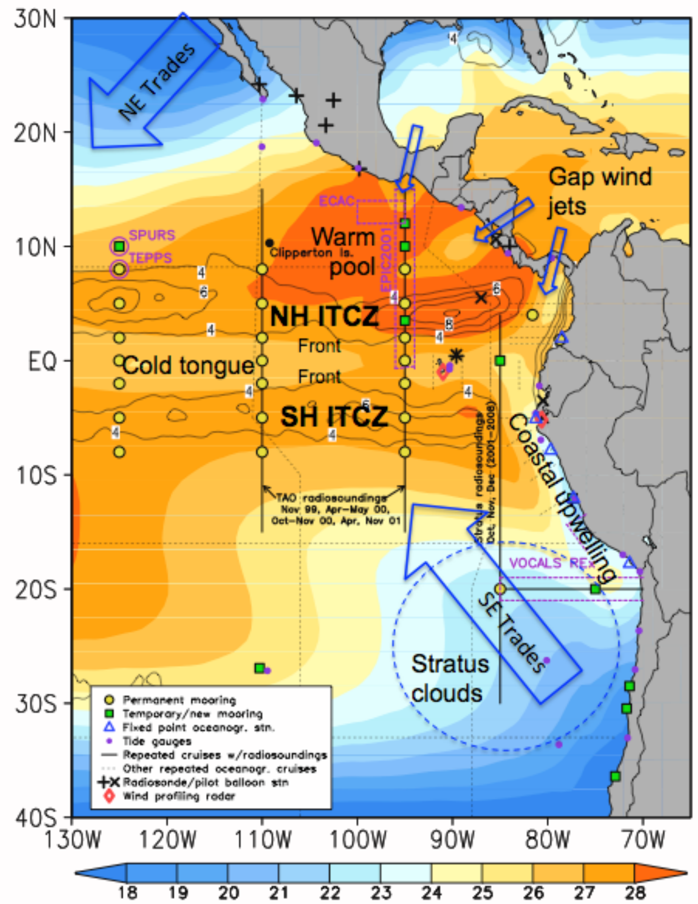
Saildrone

Advance: Research required!

- Pilot studies enhance TPOS capability
- Process studies to understand phenomena
- Modeling studies add value to observations, assess their impact

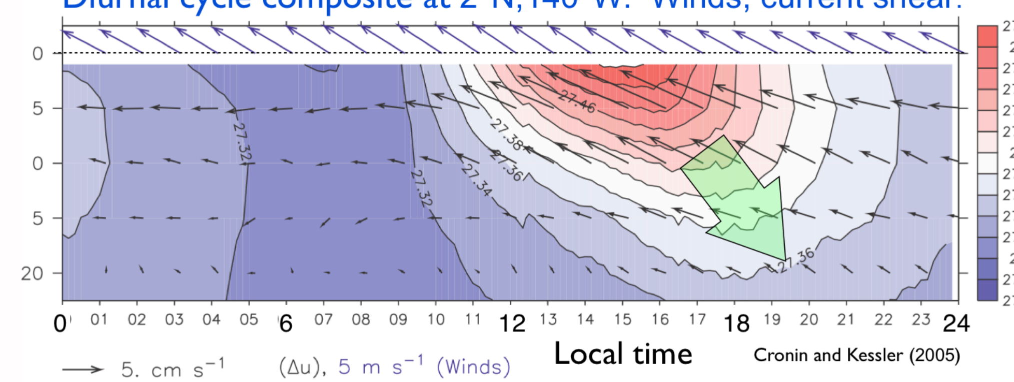


The front at the east edge of the warm pool interacts with the atmosphere, especially during the onset of El Niño.

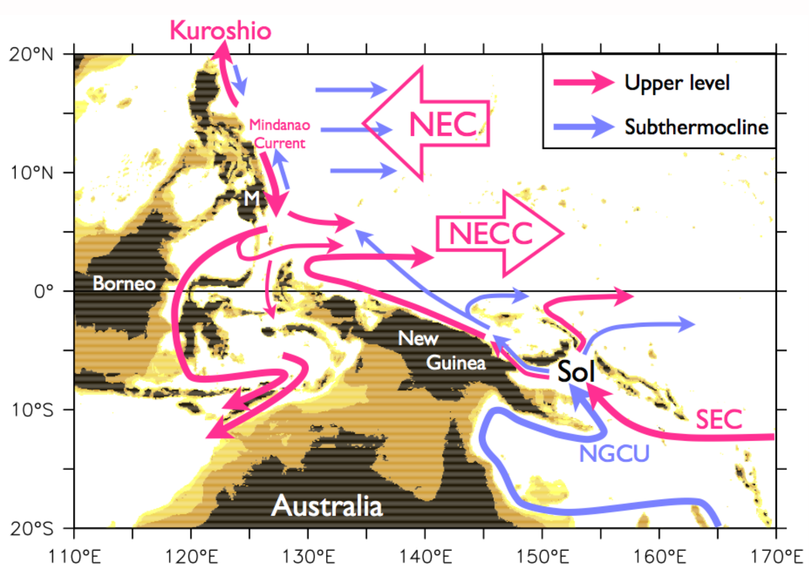


Critical processes in the east include the stratus/cold tongue front/ITCZ system and coastal upwelling.

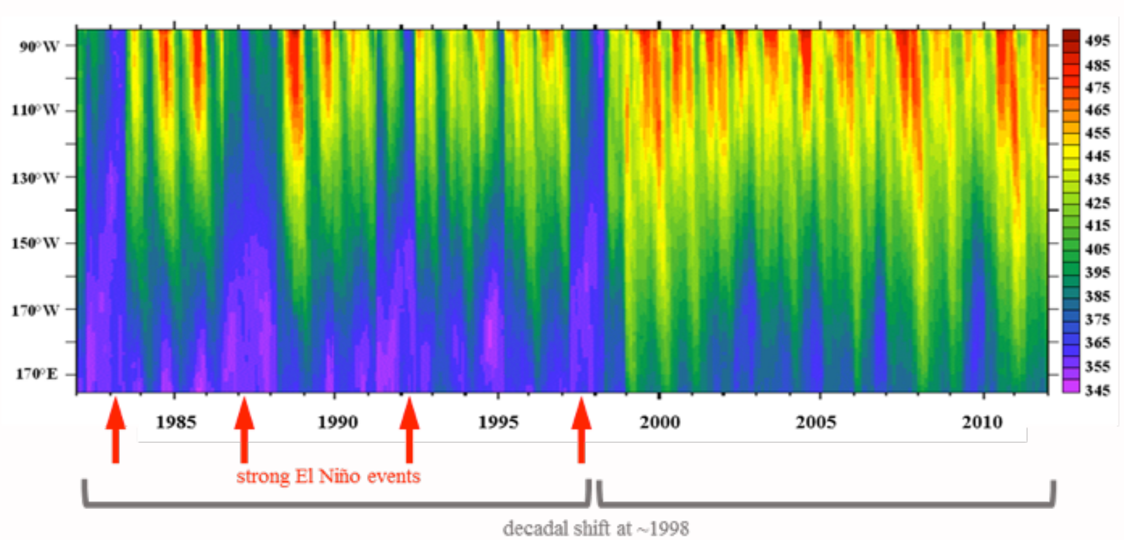
Diurnal cycle composite at 2°N,140°W: Winds, current shear.



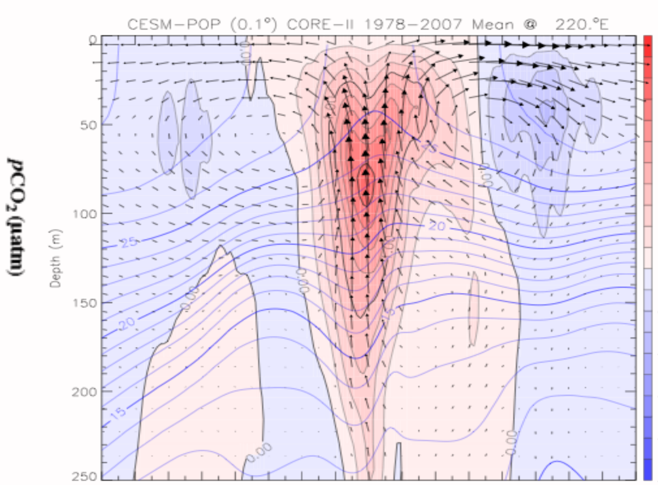
The diurnal cycle can be an important mechanism allowing downward propagation of heat and momentum fluxes.



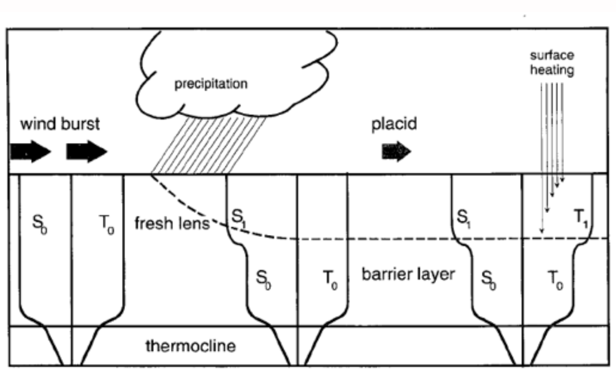
Low-latitude western boundary currents and the Indonesian Throughflow are principal conduits of tropical-subtropical interaction.



The 30-year record of surface pCO_2 shows strong annual, interannual and decadal variability of CO2 fluxes in the east Pacific cold tongue.



Equatorial upwelling is fundamental but poorly known; its modeling is uncertain.



Barrier layers in the west Pacific warm pool affect the penetration of momentum fluxes.

TPOS 2020 Tropical Pacific Observing System

Pilot / process studies in the First Report

Pilots (not discuss today?)

6.1.1 Strategy/feasibility for observing LLWBCs

6.1.2 Peru coastal upwelling

6.1.3 Determining time/space scales for BGC observations

6.1.4 Direct measurements of air-sea fluxes

6.1.5 Pilot climate observing station at Clipperton Island

6.1.6 Assessing the impact of changes to the backbone

6.1.7 Assessing utilization of TPOS observations

Process studies

6.2.1 Equatorial upwelling and consequences

6.2.2 Air-sea interaction at the northern edge of the warm pool

6.2.3 Air-sea interaction at the eastern edge of the warm pool

6.2.4 East Pacific ITCZ/warm pool/cold tongue/stratus complex

PUMP: Pacific Upwelling and Mixing Physics

The equatorial zone in the Pacific has global significance .

Coupled equatorial feedbacks underlie all Pacific climate variability.

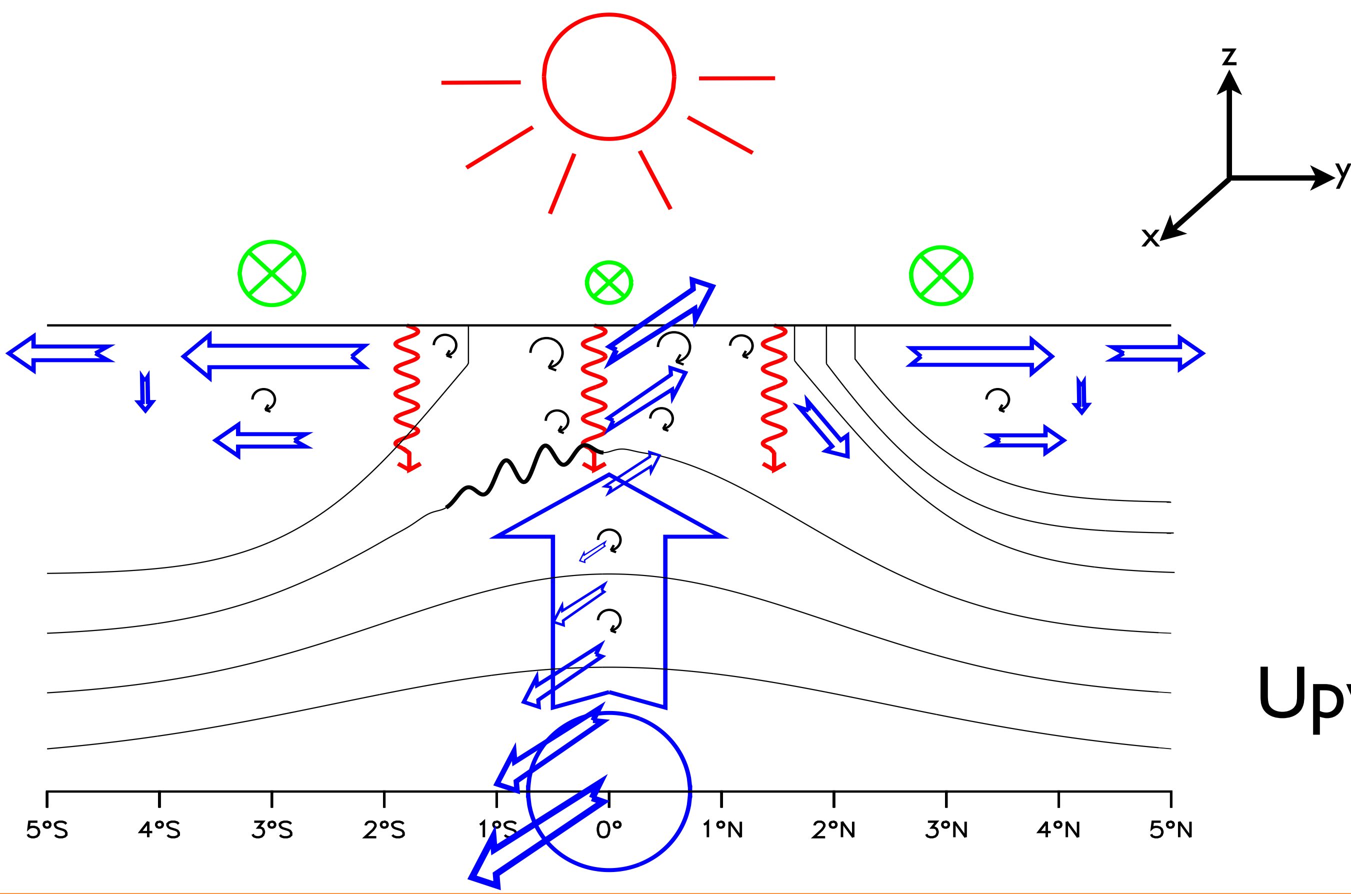
Upwelling is the main driver of property emergence (heat, CO_2 , ...).

At present, this circulation is almost unconstrained by observations.

Meridional and time scales are short (100km or less, hours/days)

Our sampling is further from the actual scales than anything else in this region.

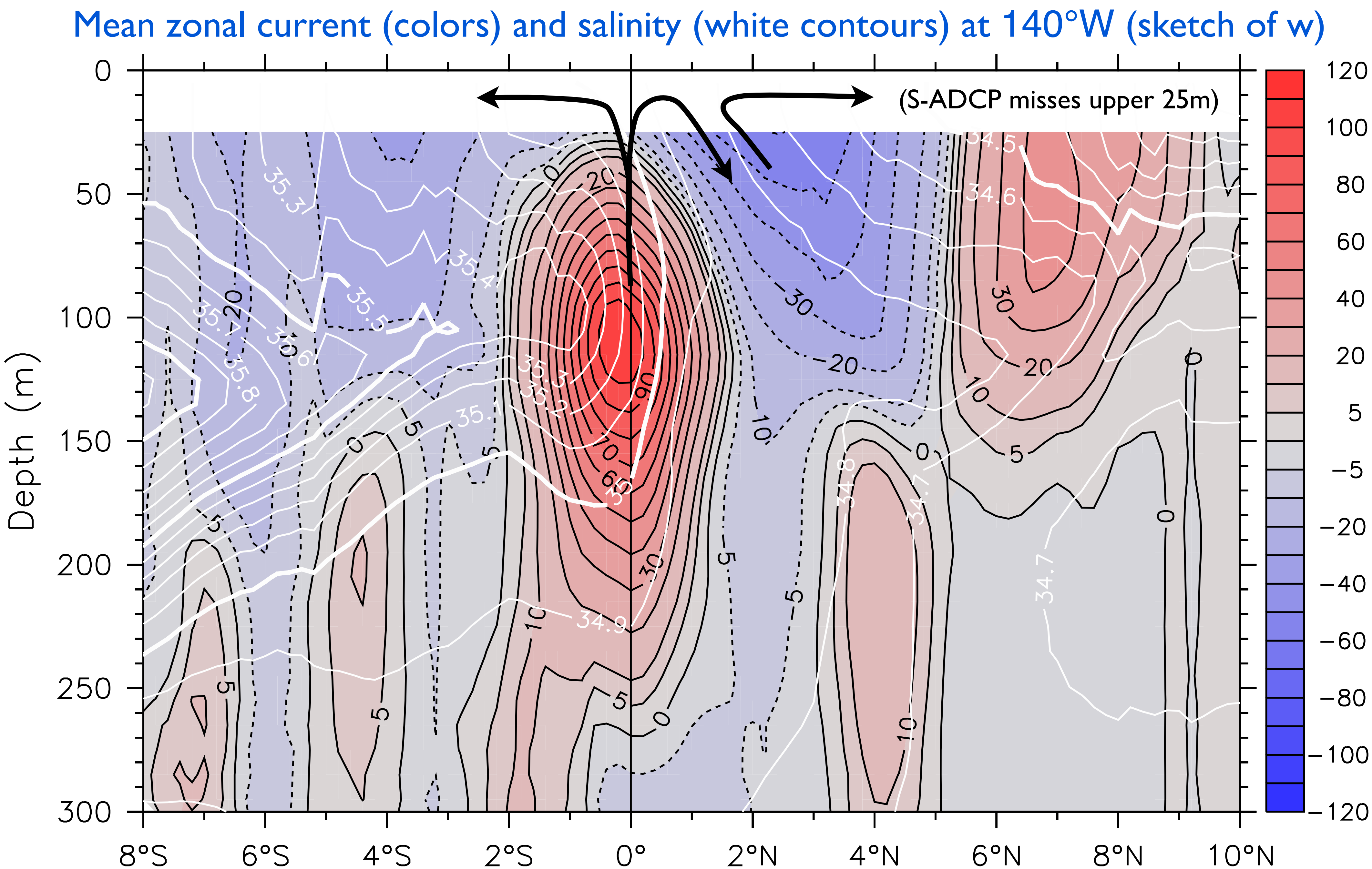
We must teach models how to infer the action of upwelling from sparse clues.



Red = Solar
Green = Wind
Blue = Velocity
= Mixing

Upwelling is O(m/day) → vertical mixing must be very strong

Equatorial boundary layer



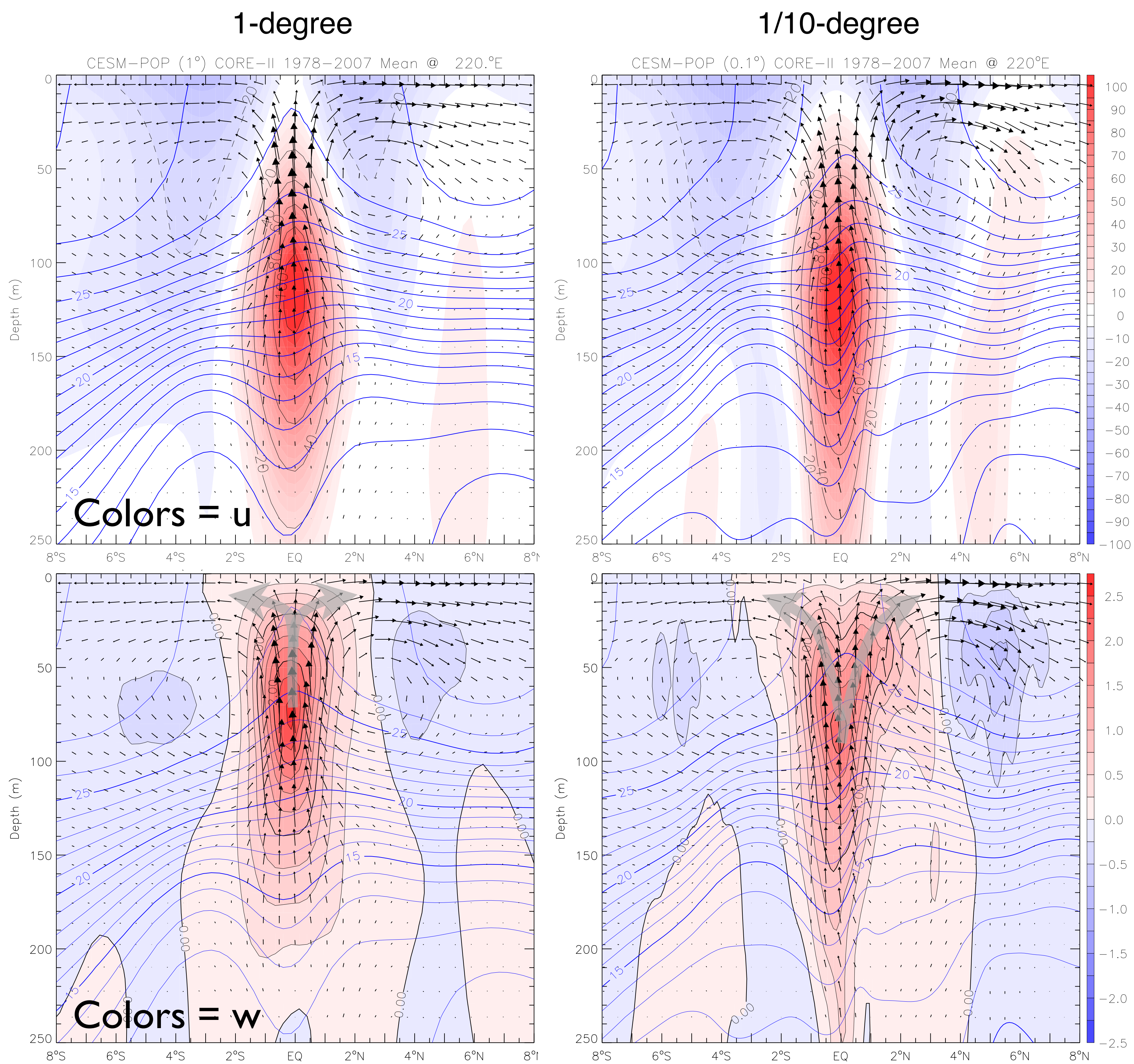
Johnson et al. (2001)
(Shipboard ADCP mean)

Modern model meridional circulations

u(eq,z) nearly identical: With TAO eq current profiles, modelers have learned to tune this.

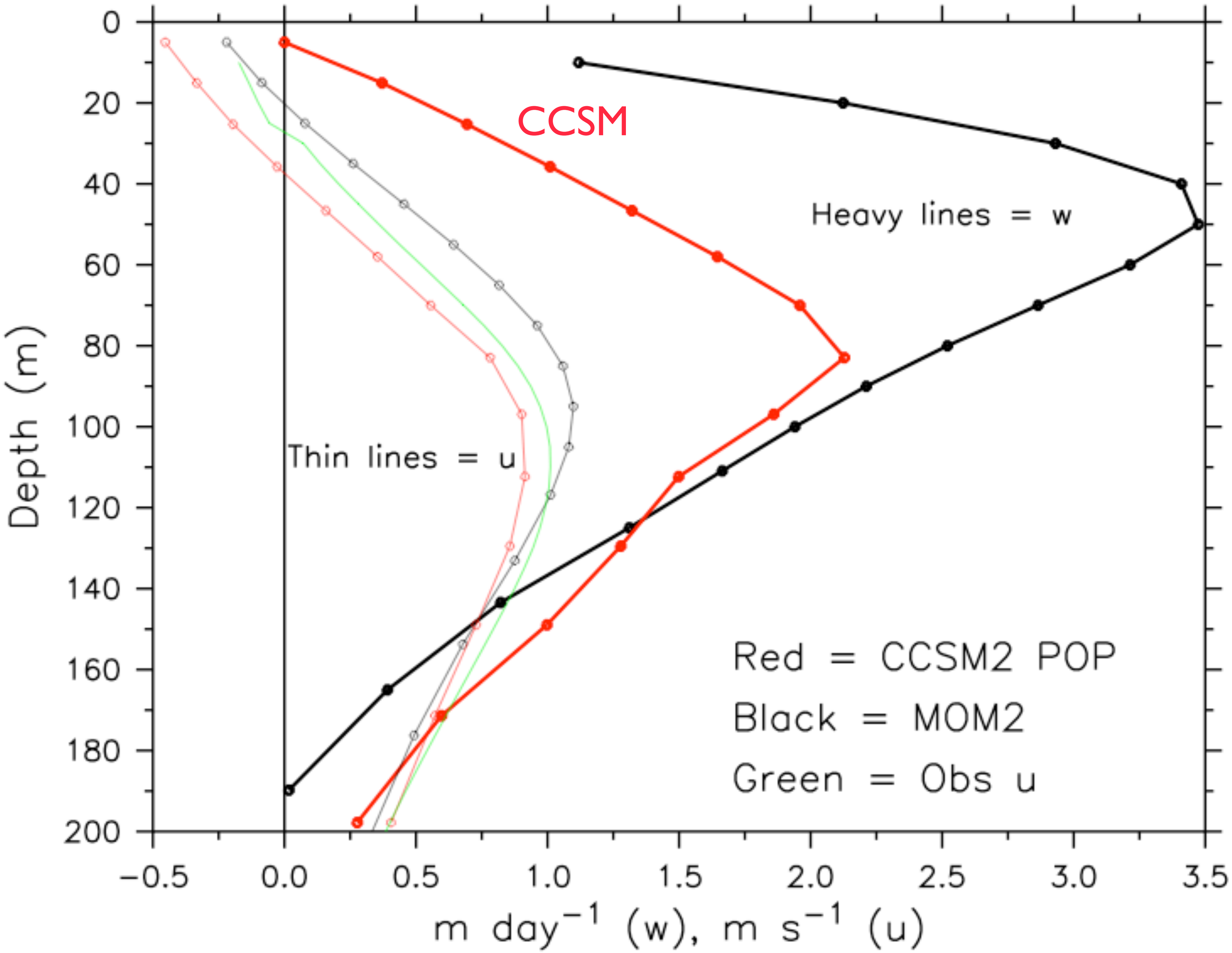
w quite different, as is T(eq,z):
Implications for air-sea interaction diverge.
Vertical circulation is now unconstrained by observations.
Guidance needed.

CESM-POP with different horizontal resolutions (mean)



(Frank Bryan)

Unconstrained models ....



CCSM (Bryan), MOM (Vecchi)

Mean u and w at 0°, 140°W

Compare two forced OGCMs: MOM2 (1/3°) vs CCSM2 (1/10°)

Two models with very similar u (close to observations) but very different w

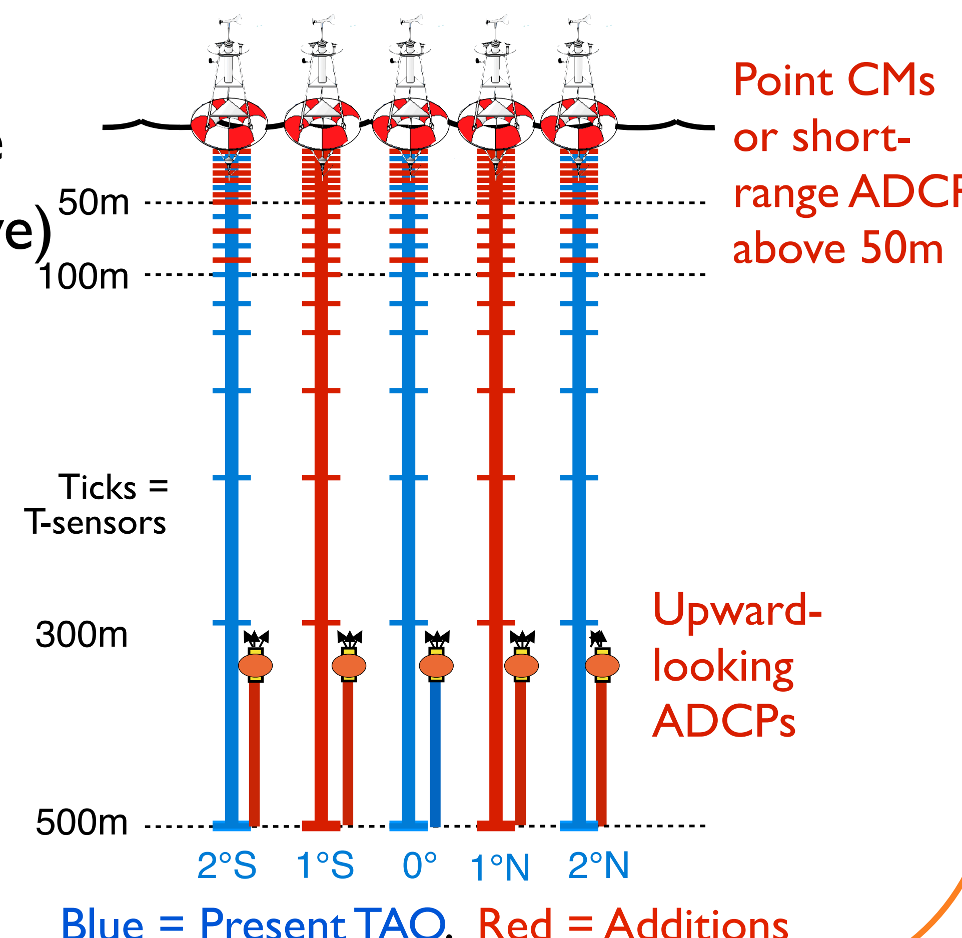
How to conduct an upwelling experiment?

Goals:

- Guide model parameterizations to represent upwelling and its consequences from sparse sustained sampling
- Learn what sustained sampling is needed to allow upwelling inference: Meridional density of moorings, Argo floats
- How does equatorial SST change when the wind changes?

Challenges:

- w is a velocity derivative; hard to measure accurately, requires time-averaging
- Fast-timescale and strong TIW variability hard to overcome
- Unknown meridional scales require oversampling (expensive) (Is du/dx important? more expensive)
- Ideally would include turbulence measurements, depending on model needs

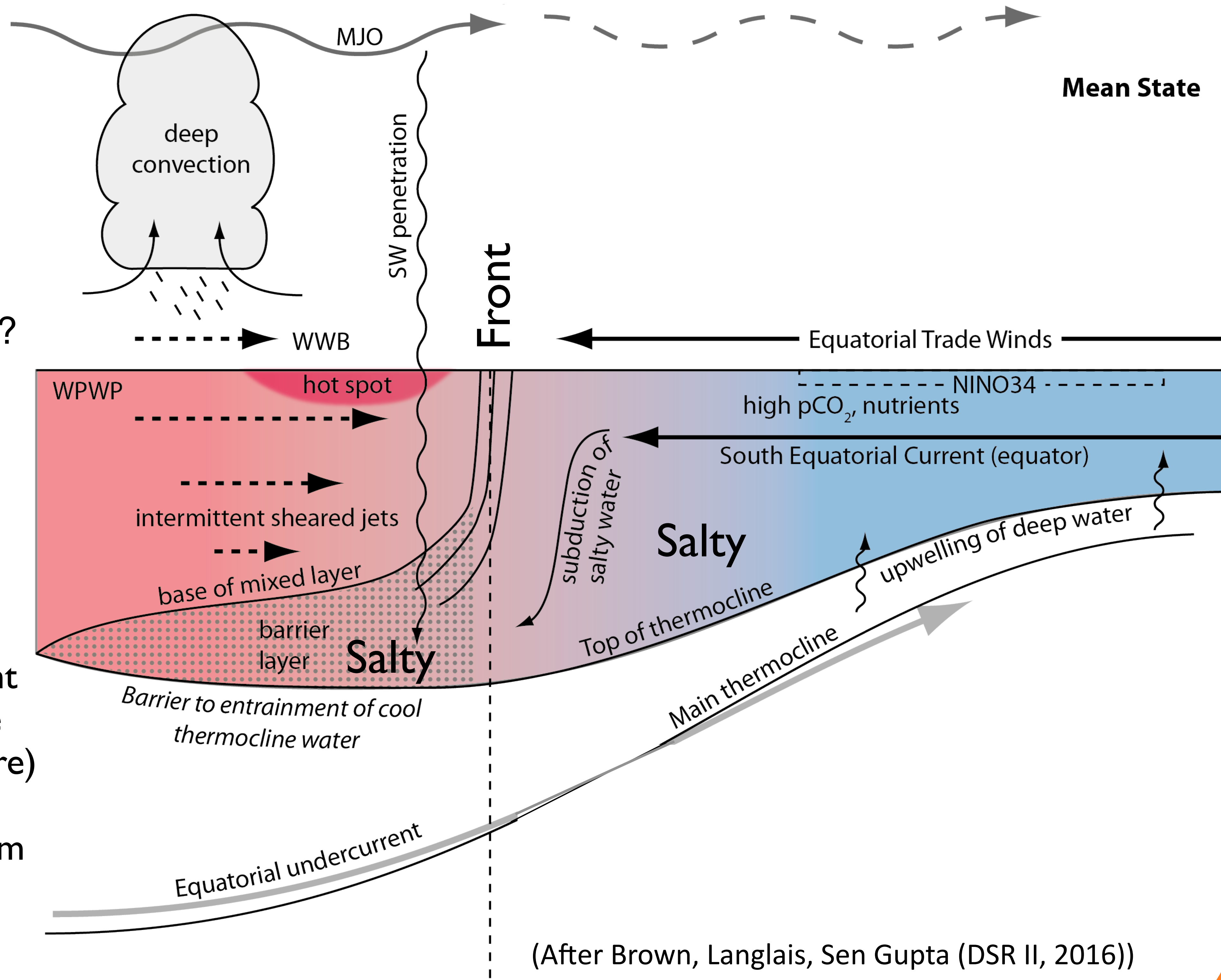


Air-sea interaction at the east edge of the warm pool

The barrier layer inhibits entrainment cooling, and traps wind-input momentum in a thin layer: Encourages surface heating? Allows more convection?

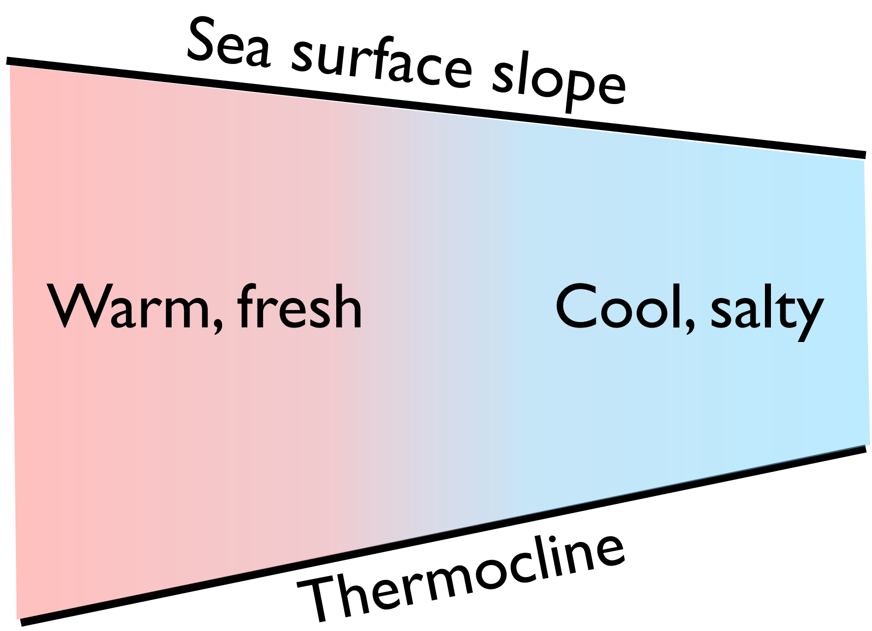
The isolated, shallow surface layer also gives faster, stronger response to wind changes.

One part of this experiment would test the near-surface (both ocean and atmosphere) response to barrier layers at the east edge of the warm pool.

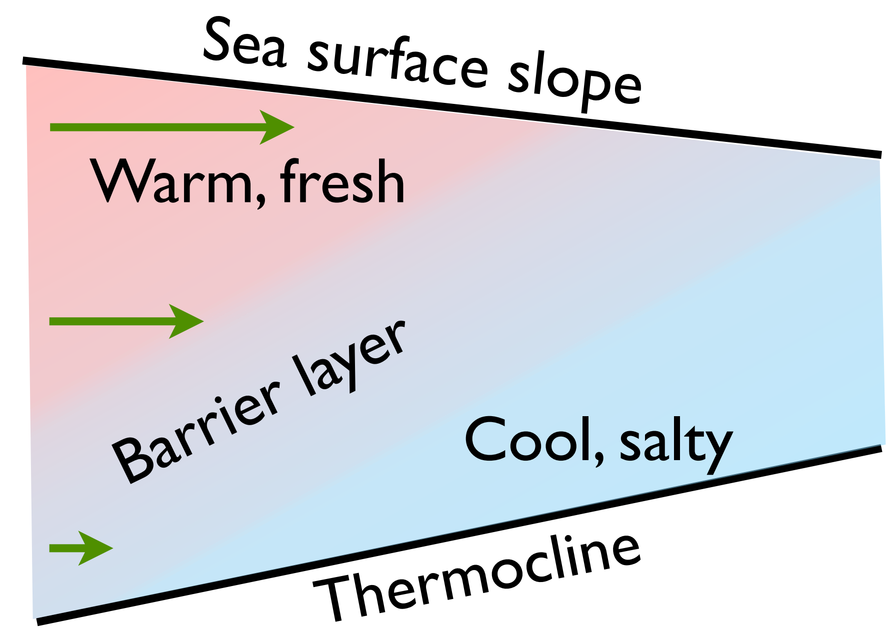


(After Brown, Langlais, Sen Gupta (DSR II, 2016))

Ocean processes creating the barrier layer



(Relaxed easterlies)

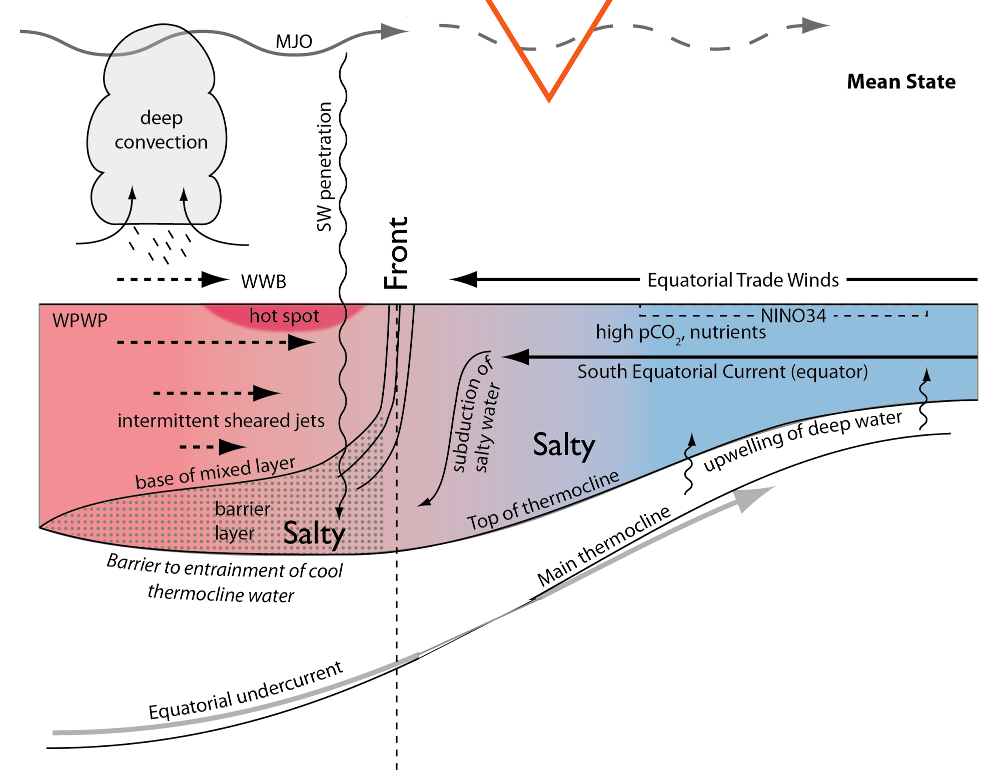


If there is no density gradient in the mixed layer, the zonal pressure gradient is due only to the sea surface slope, and is independent of z.

With a zonal density gradient as shown, the pressure gradient is stronger at the surface than just above the thermocline.

In that case, relaxation of the easterlies implies stronger eastward acceleration at the surface: tilting.

Air-sea interaction consequences follow ...



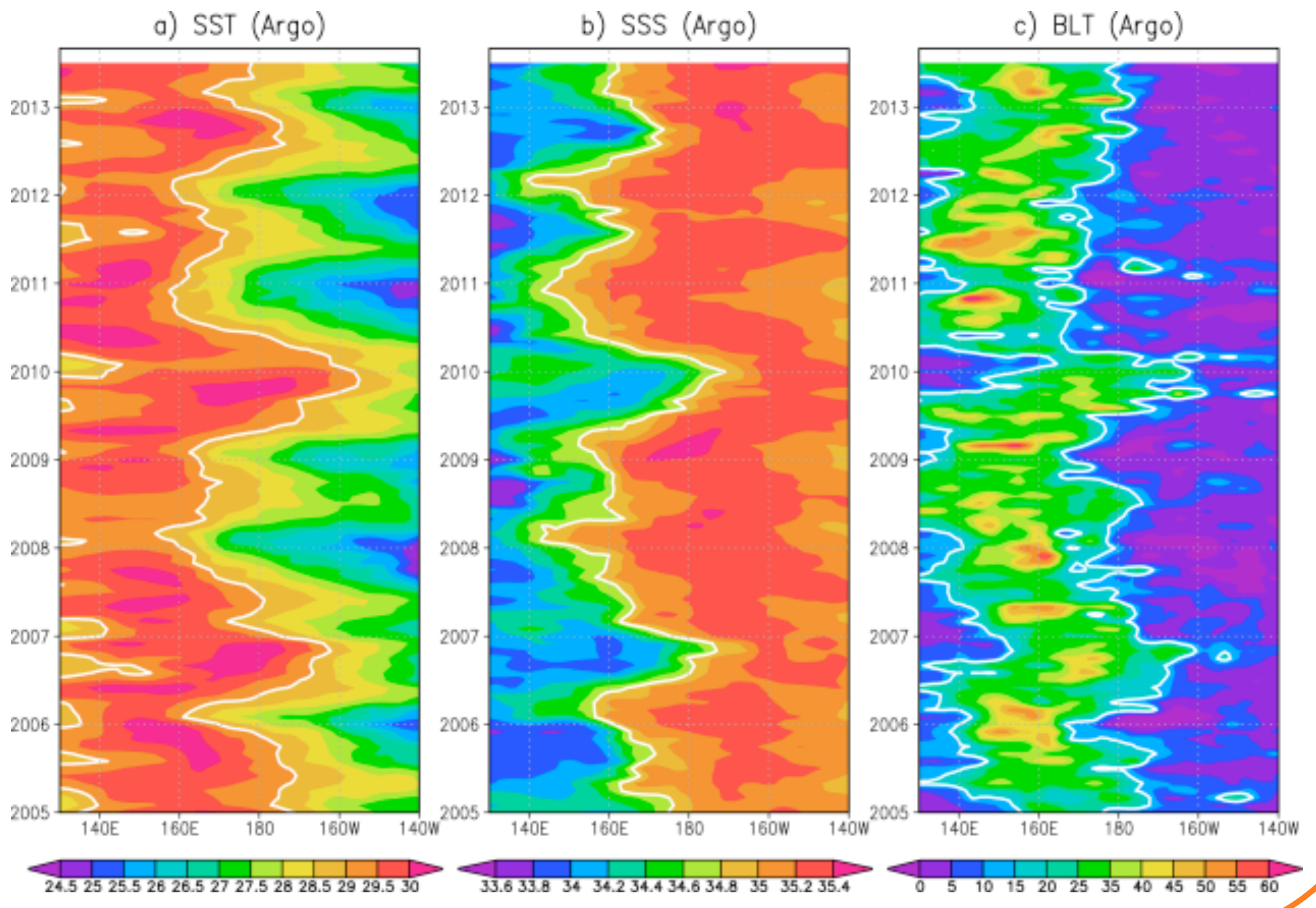
How to conduct a warm pool edge experiment?

Goals:

- Better ability to define needed sustained sampling:
  Zonal density of moorings? Argo floats? Regular, controllable, autonomous samplers?

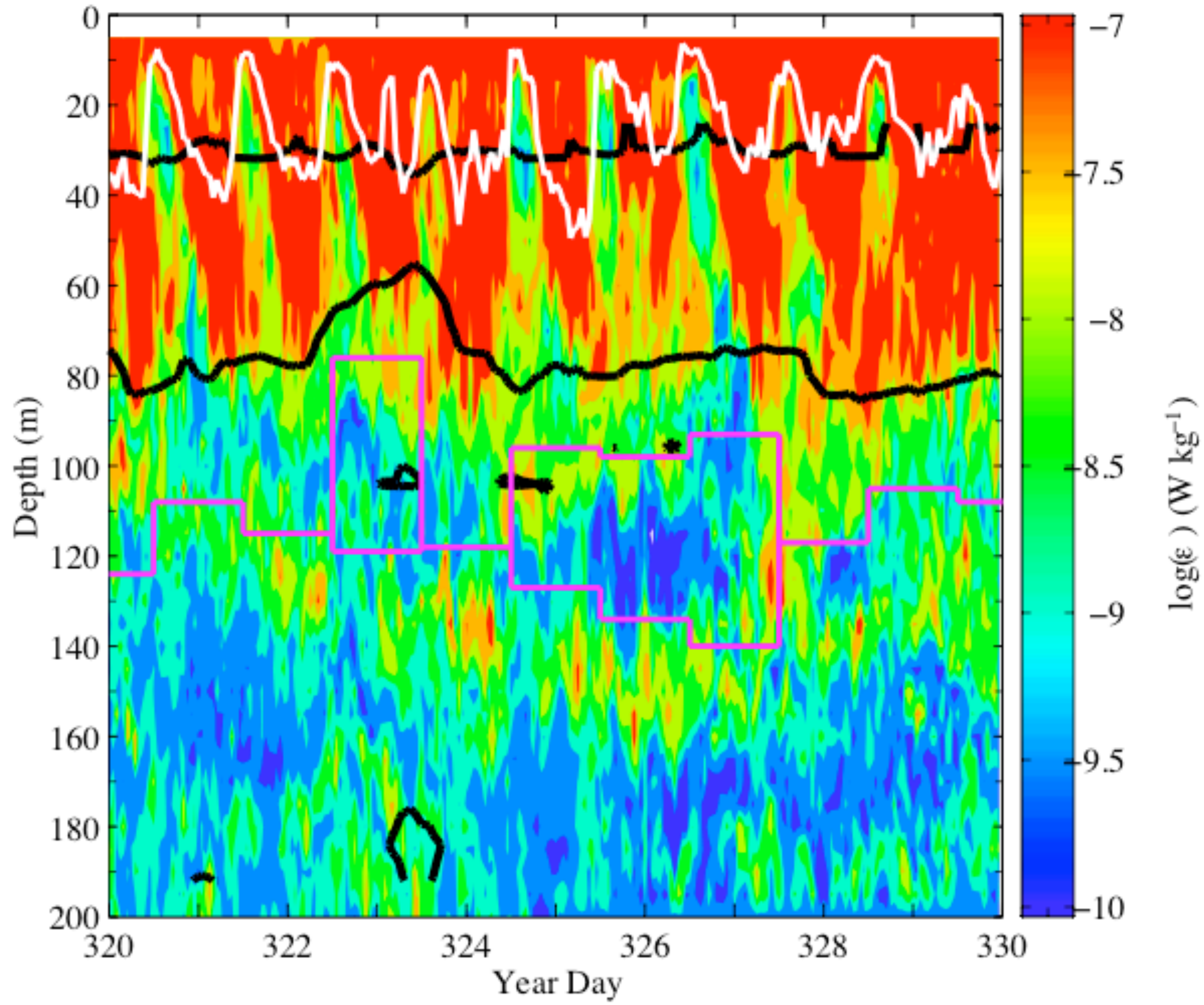
Challenges:

- Front is fast-changing (days), may be hard to arrange and position observing assets.
- Results require both ocean and atmosphere observations (how deep into both fluids?)
- Need velocity measurements (where? how much?)
- What does this teach models?
  (What parameterizations?)



Extra slides below

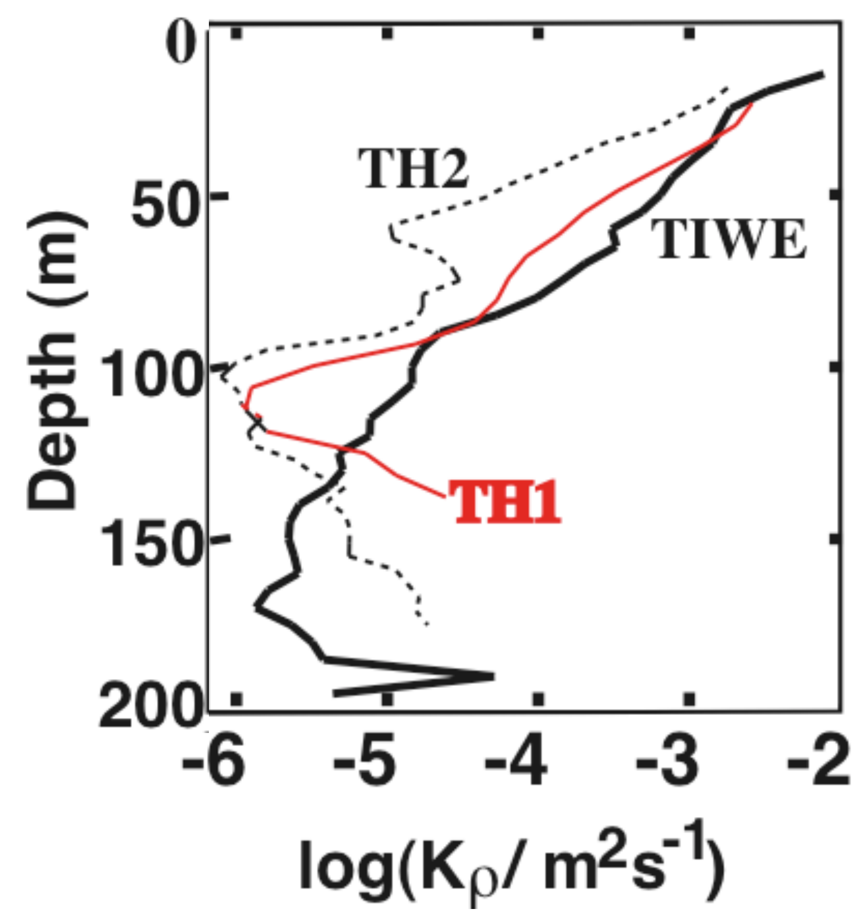
Downward mixing on the equator



Dissipation rate during 10 days of TIWE

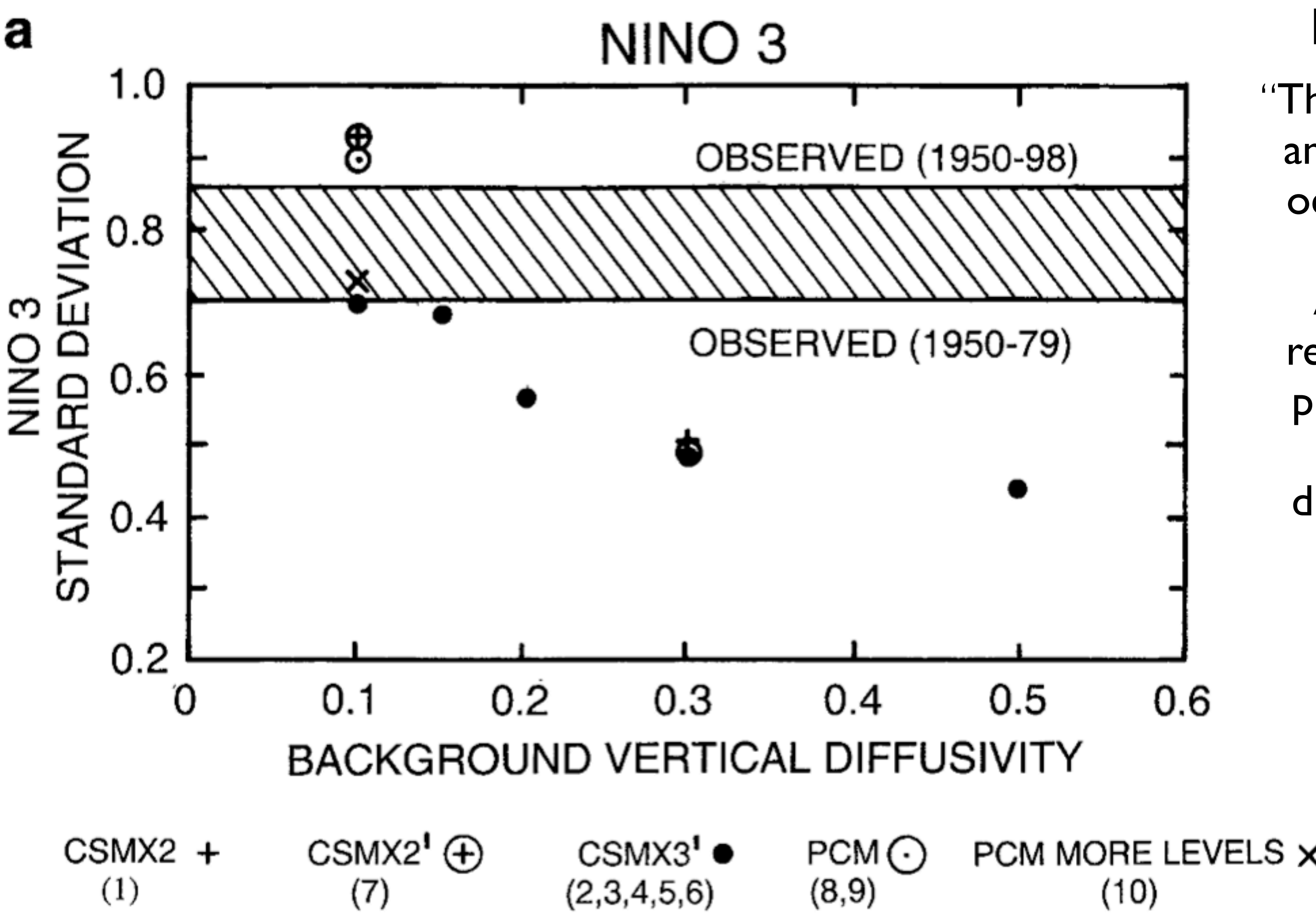
Lien and D'Asaro

<u>All</u> existing eddy diffusivity profiles in the cold tongue



Gregg (1998)

ENSO sensitivity



Meehl et al (2001)

"The dominant influence on El Nino amplitude is the magnitude of the ocean model background vertical diffusivity.
Across all model experiments, regardless of resolution or ocean physics, the runs with the lowest values of background vertical diffusivity have the largest Nino3 amplitudes."

Lower diffusivity gives shallower, sharper thermocline
→ more coupling sensitivity

Surface boundary layer

How does the thermocline communicate with the atmosphere?

The diurnal cycle is surprisingly important ...

Can we teach this to models?

Diurnal cycle composite at 2°N,140°W: Winds, current shear.

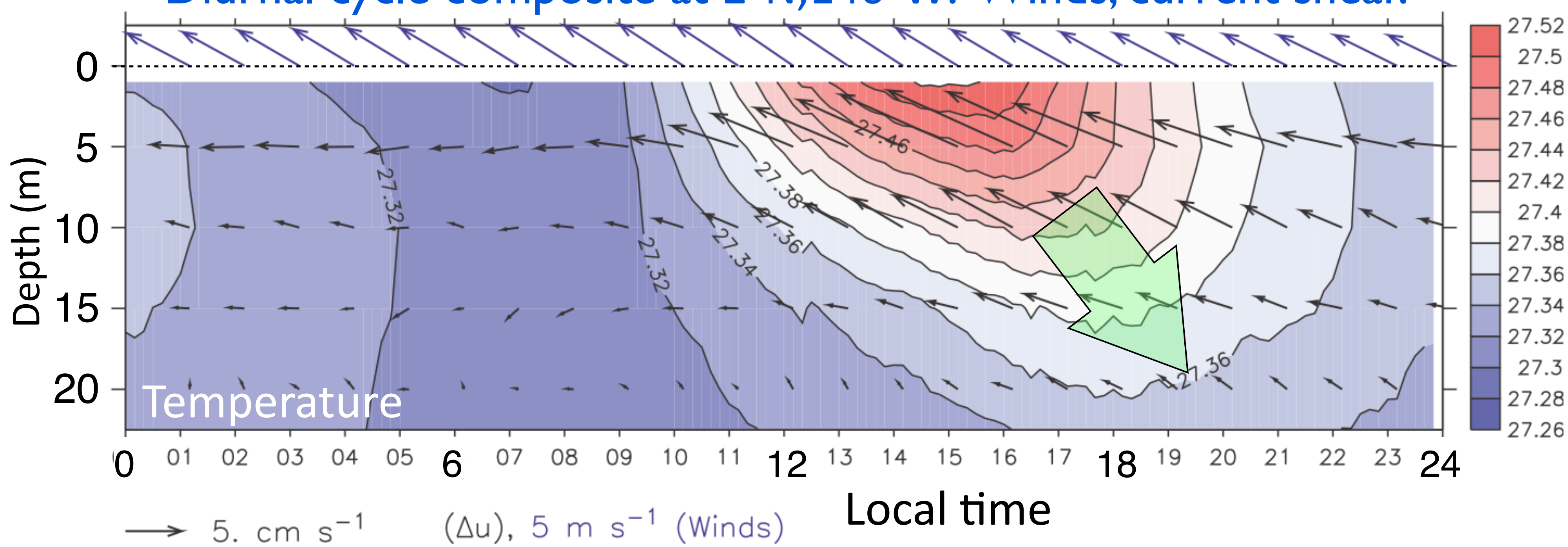
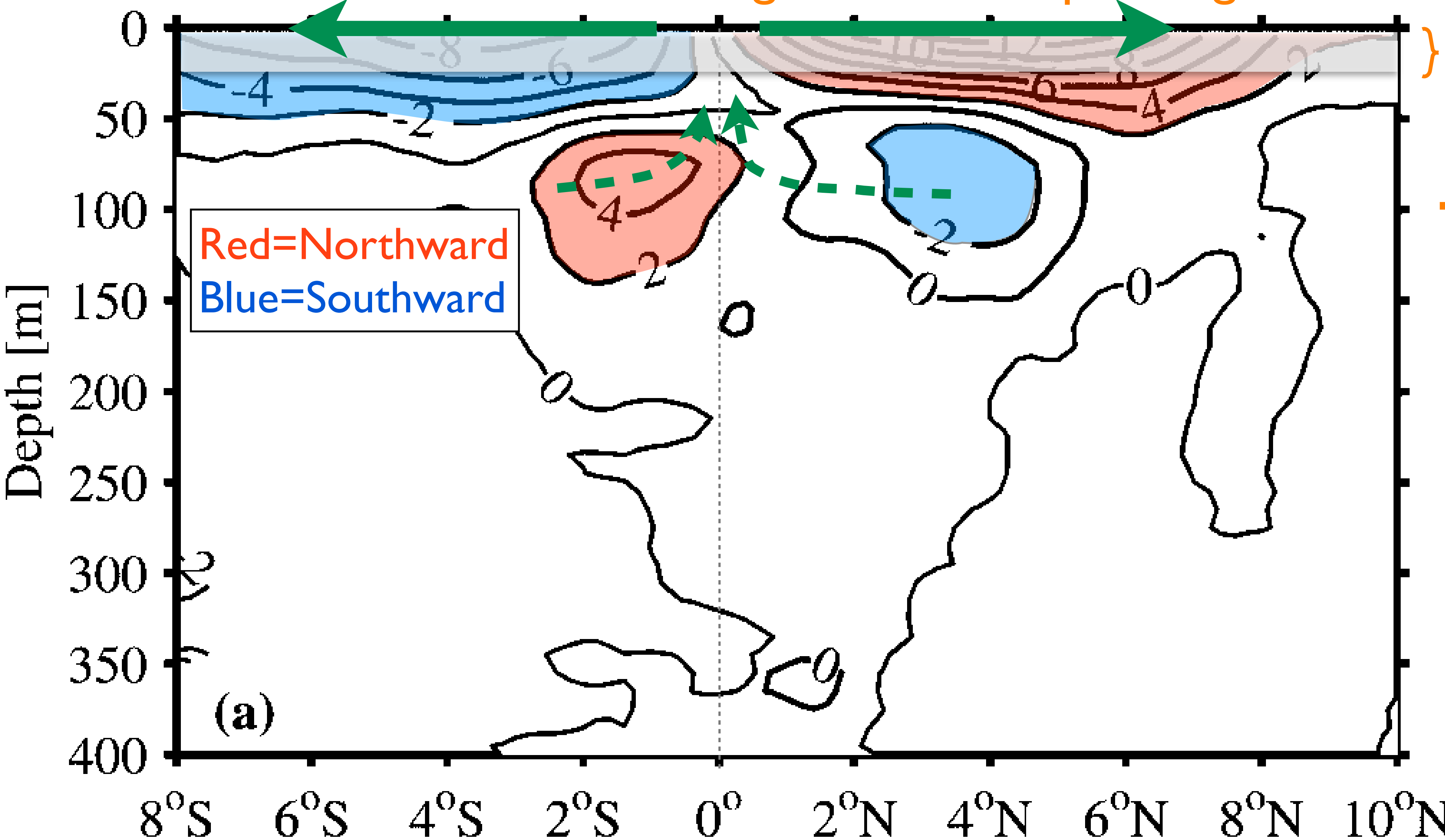


FIG. 5. Mean diurnal composite (24 May 2004–7 Oct 2004) of wind (blue vectors), temperature (color shading), and currents relative to 25 m (black vectors). The vector scale is shown at the bottom. Cronin and Kessler (2009)

Much of the work of heat and momentum transmission to the thermocline is accomplished by the diurnal cycle. ⇨ Requirement to observe the near-surface, including currents ... but how much is needed?

Surface and equatorial boundary layers

Near-surface Ekman divergence drives upwelling, but ...



} (Ship ADCP does not see upper 25m)

- Requirement for near-surface currents, especially near the equator.

Another driver: Referencing scatterometer winds where currents are strong

Mean meridional current in the east-central Pacific

Shipboard ADCP over 170°W-95°W

10-year average

Johnson et al. (2001)

Guiding principles

0. Do not repeat the mistake of changing observing systems without adequate overlap and evaluation!

1. Advance by observing the mechanisms connecting the equatorial thermocline and the free atmosphere. Challenge and guide model improvement.

2. Foster a diverse-platform observing system to adequately sample ENSO's rich multi-scale variability. Integrate tools that did not exist when TAO was designed:
   Satellites, Argo, new autonomous samplers, …

3. Beyond its monitoring capability, TPOS should serve as the backbone for essential ancillary and process studies (allowing others to propose and participate).