Upper Ocean Variability during the SPURS-2 Field Campaign under the ITCZ

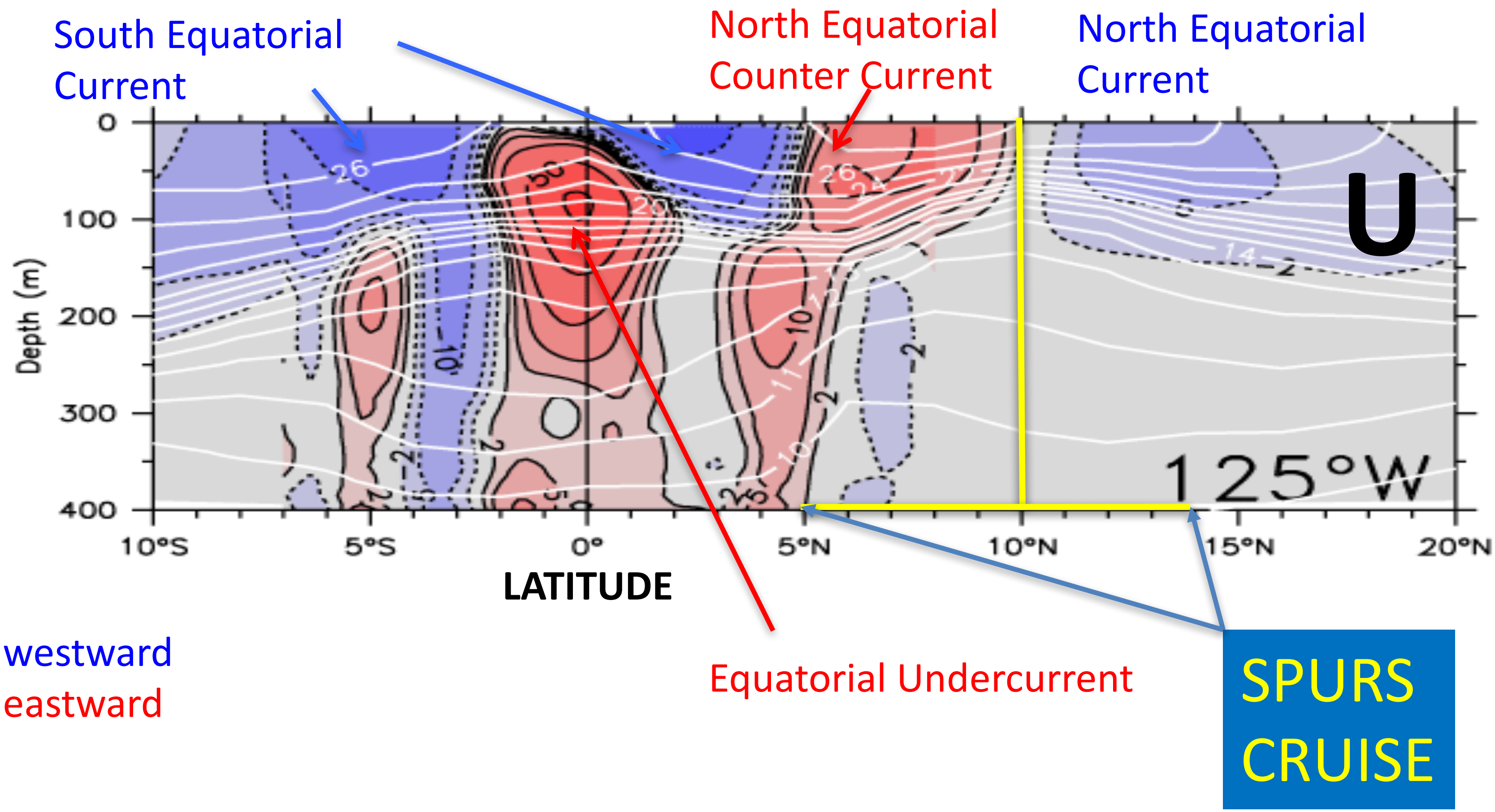
Janet Sprintall
Scripps Institution of Oceanography
and the SPURS-2 uCTD/CTD Teams!

Credit: Kristin Fitzmorris

Science Objectives

1. Quantify the vertical and horizontal structure of the variable large-scale upper ocean circulation and water masses in the SPURS-2 region under the ITCZ
2. Determine what regional scale processes (e.g. advection vs surface freshwater etc.) are responsible for the evolution and presence of upper ocean salinity stratification (e.g. barrier layers).

Zonal Currents at 125W: An Average Look at the Big Picture



westward
eastward

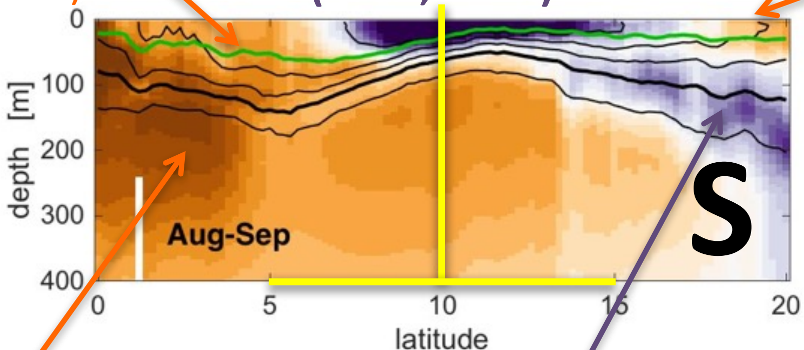
Kessler, 2006

Water Masses at 125W:
An Average Look at the Big Picture

Equatorial
Surface Water
(S>34; T<25)

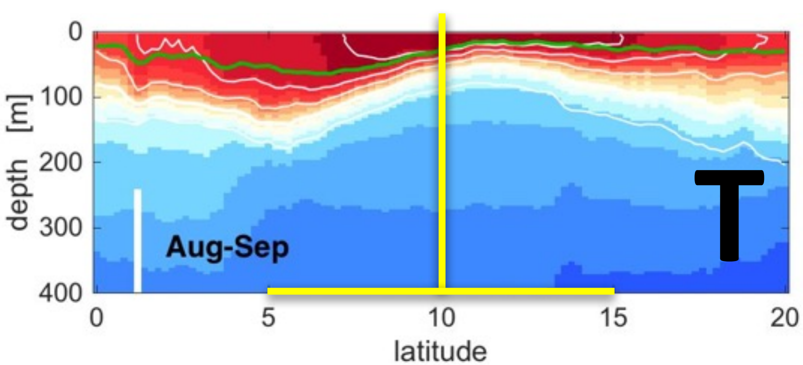
Tropical Surface Water
(S<34; T>25)

Subtropical Surface Water (S>35)

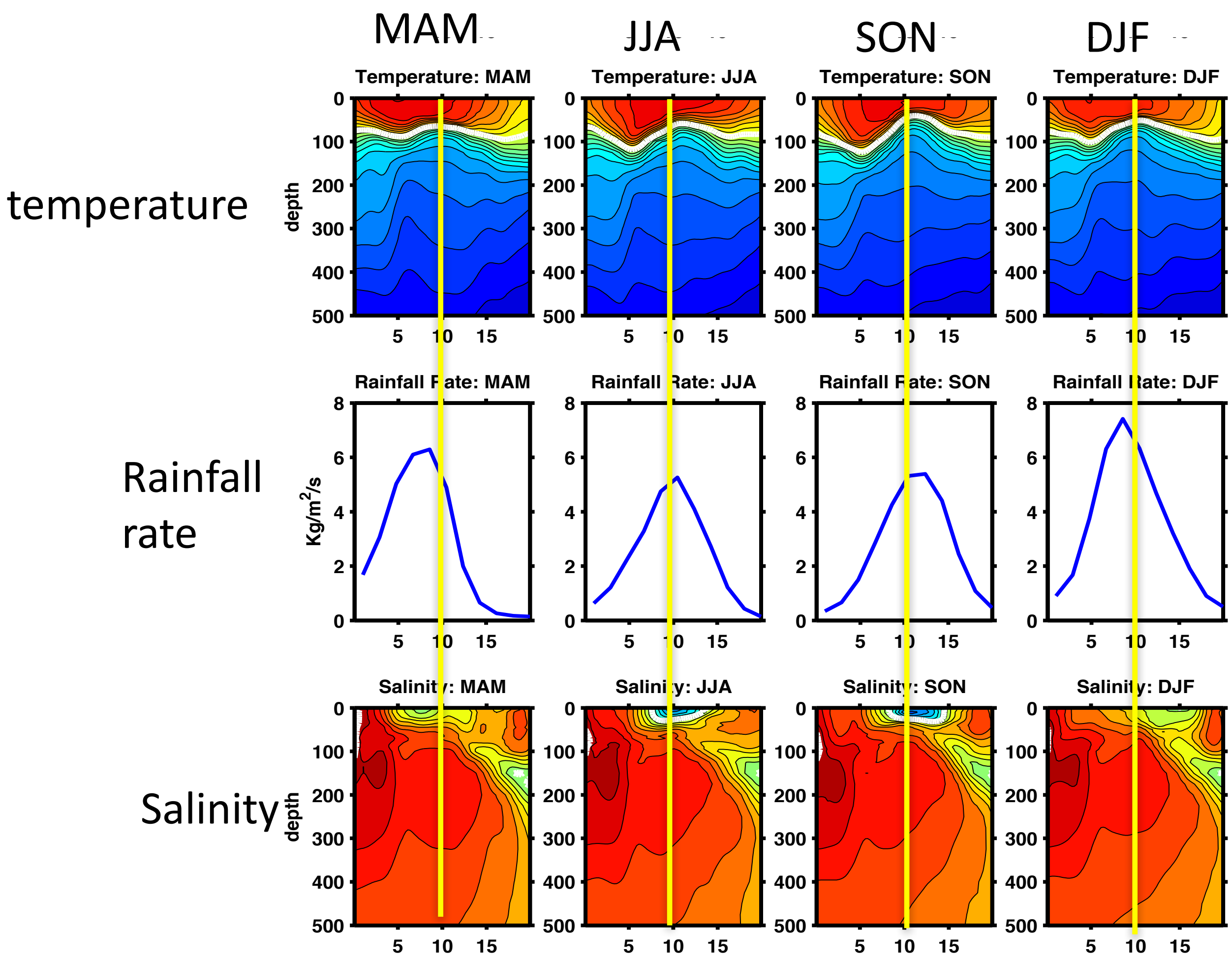


Subtropical
Under Water

North Pacific
Intermediate Water (S~34)

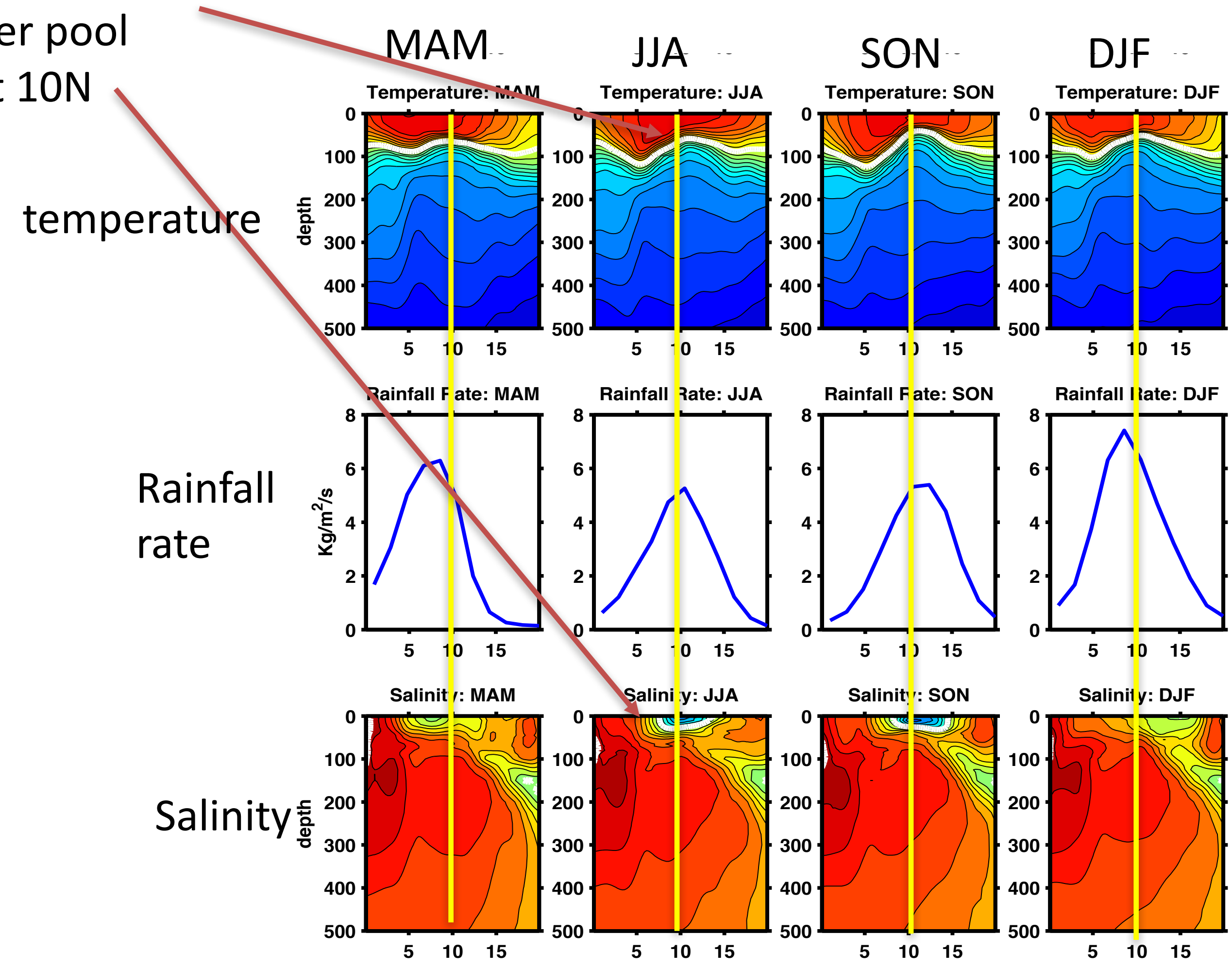


Seasonal Variability



Seasonal Variability

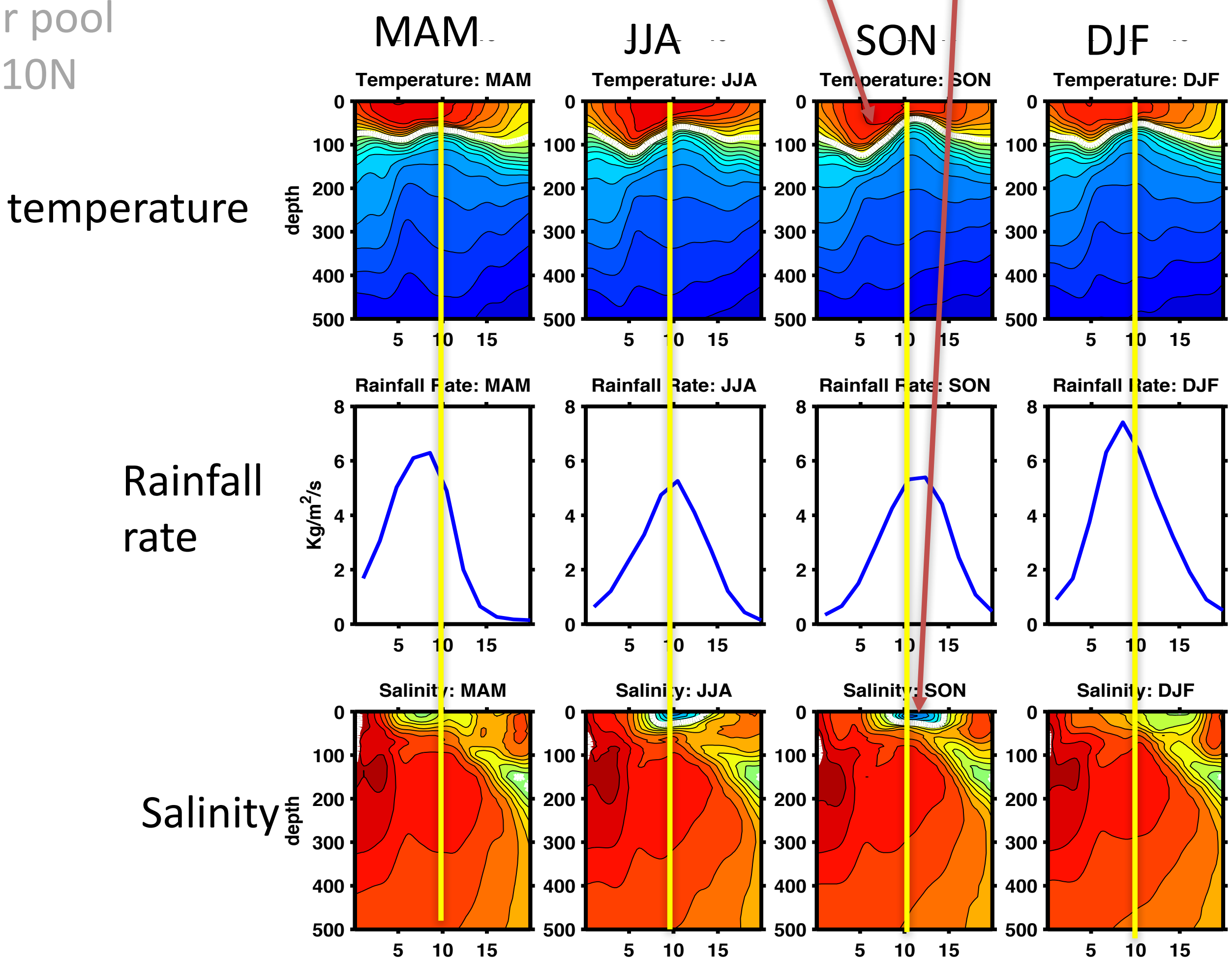
JJA: warm surface and freshwater pool are aligned at 10N



Seasonal Variability

SON: fresh pool north of warm pool at thermocline ridge (the NECC)

JJA: warm surface and freshwater pool are aligned at 10N



Seasonal Variability

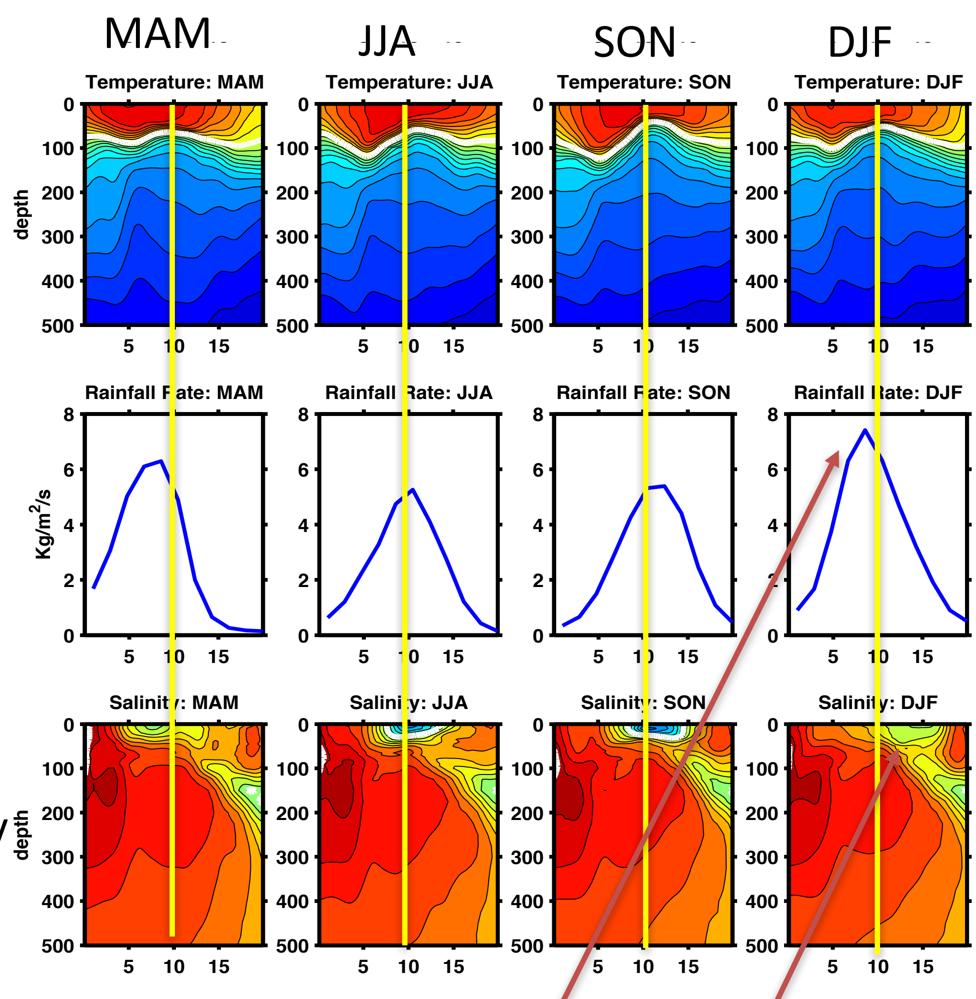
SON: fresh pool north of warm pool at thermocline ridge (the NECC)

JJA: warm surface and freshwater pool are aligned at 10N

temperature

Rainfall rate

Salinity



DJF: max in P located at 8N, well south of S min

Seasonal Variability

SON: fresh pool north of warm pool at thermocline ridge (the NECC)

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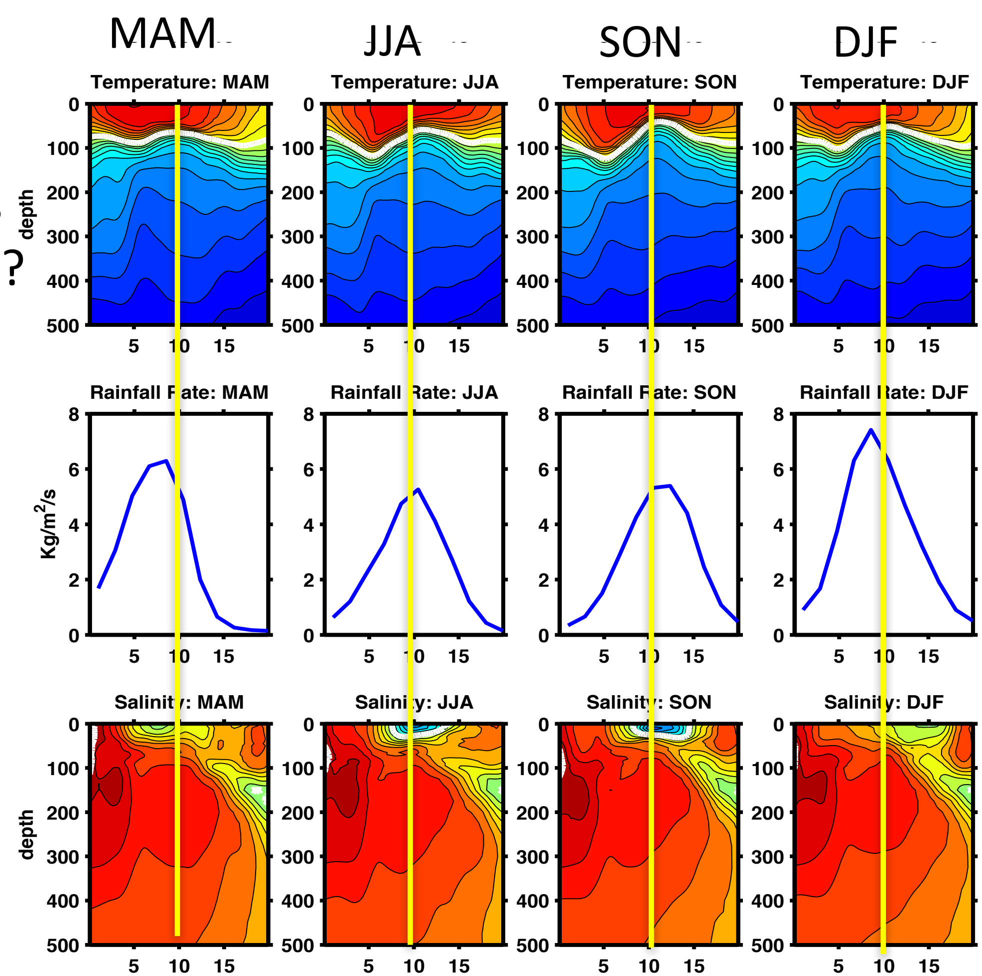
What processes are responsible for this – the ocean alone or air-sea interaction?



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Seasonal Variability

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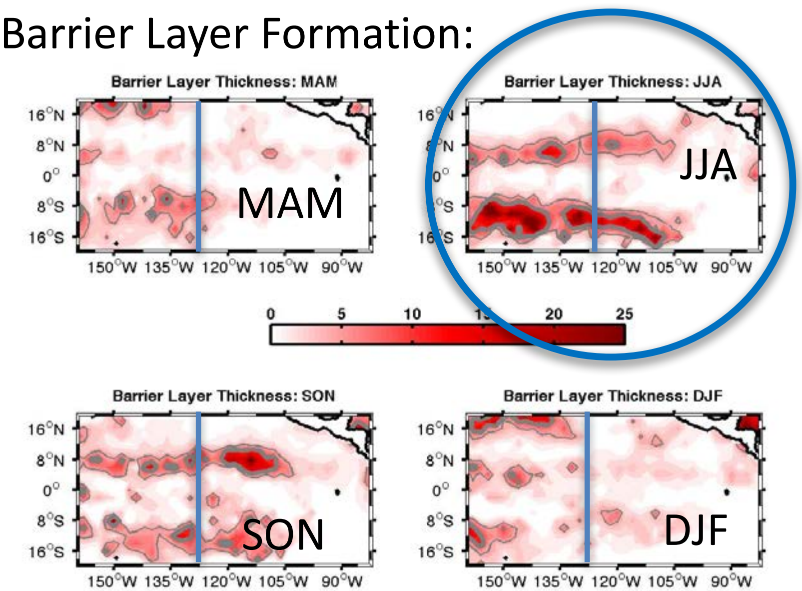
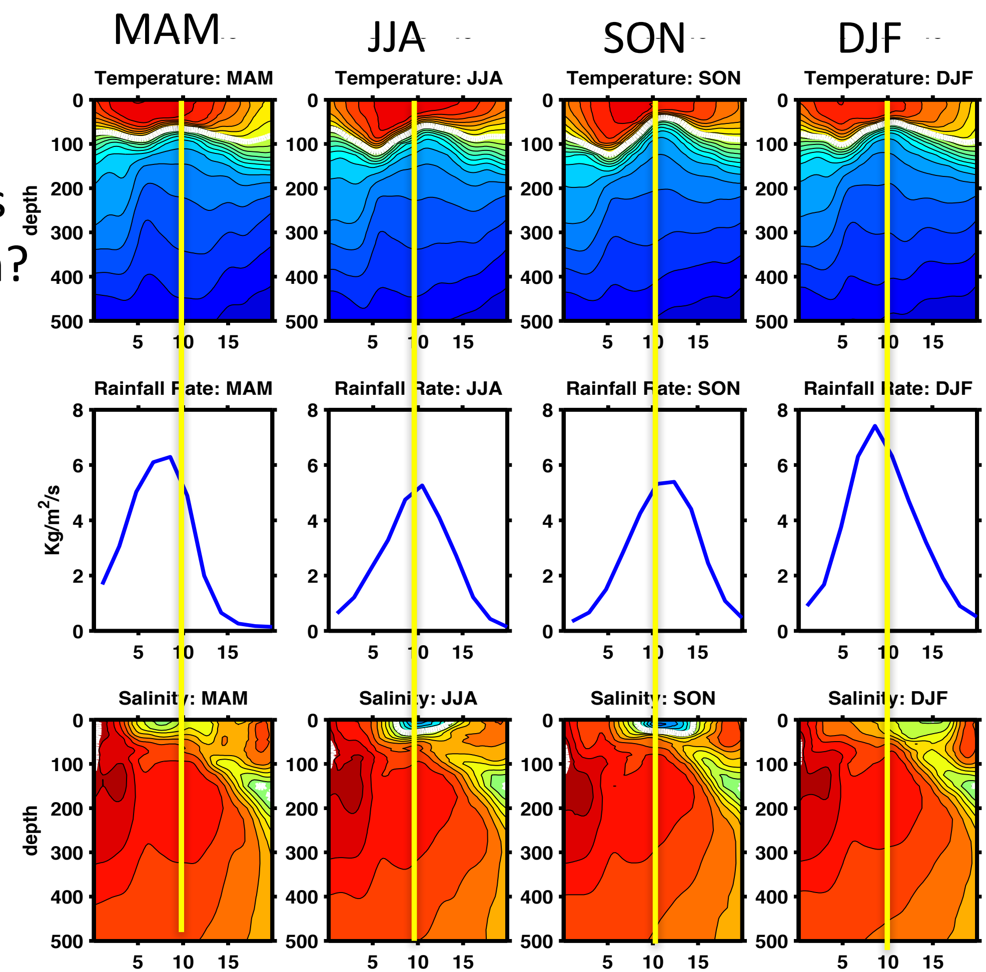
What processes are responsible for this – the ocean alone or air-sea interaction?

Fronts, eddies, freshening from storms and advection also contribute to salinity gradients

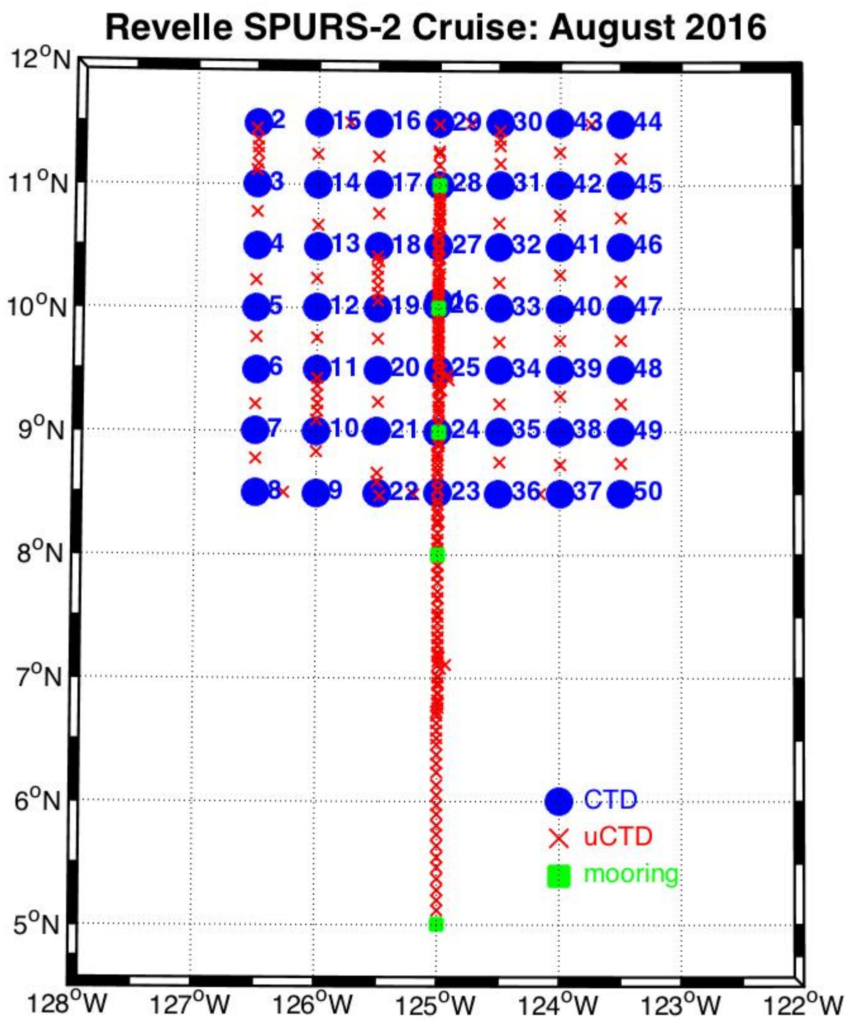
Barrier Layer Formation:





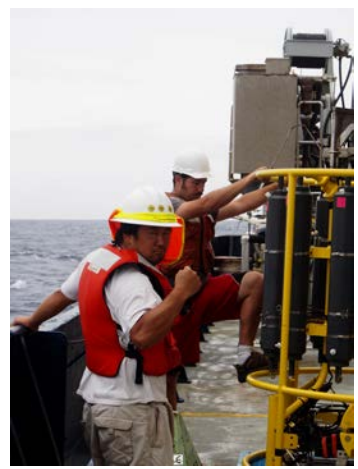
DJF: max in P located at 8N, well south of S min

Experimental Approach

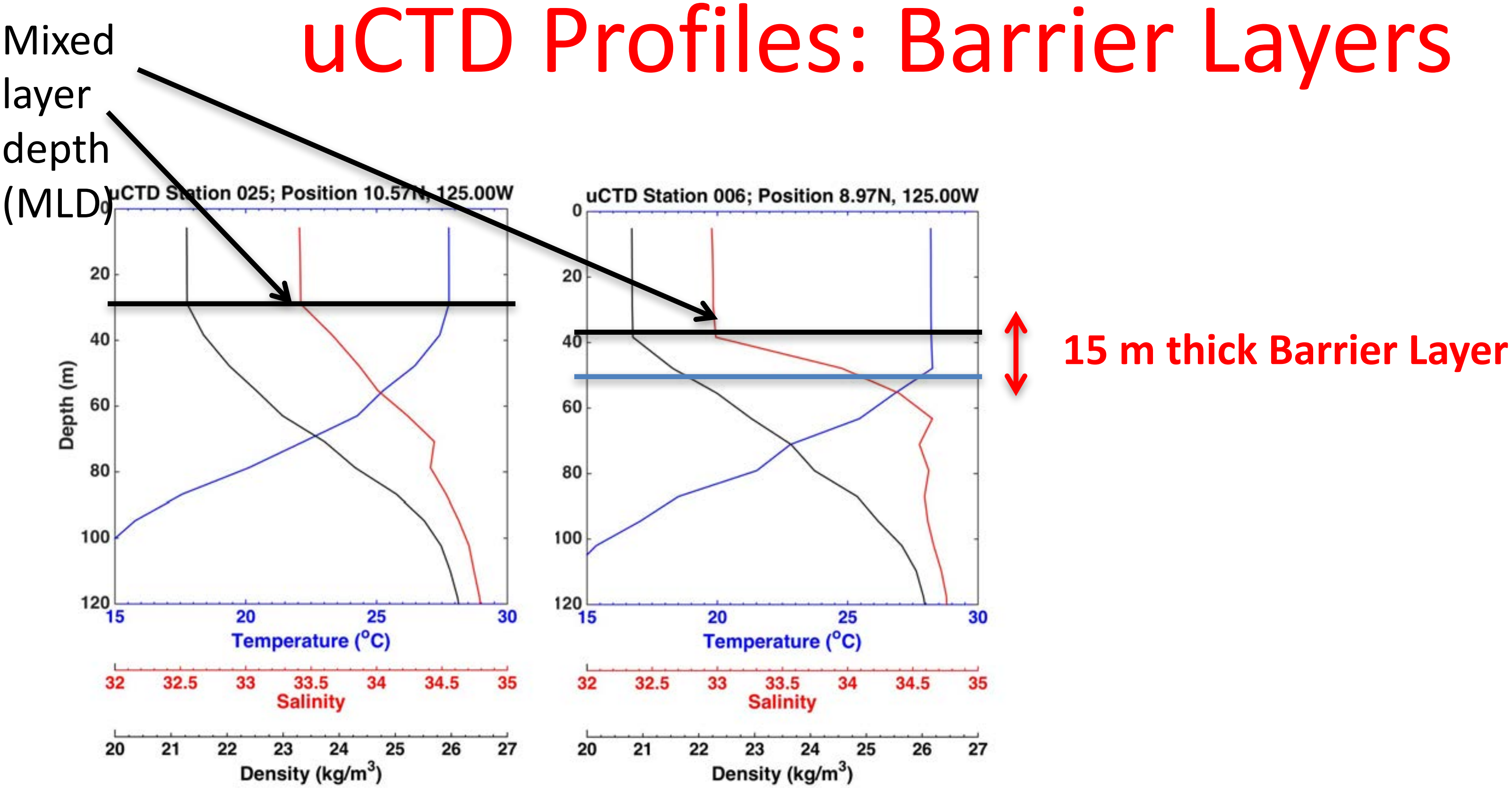


26 August – 13 September 2016

- CTD/uCTD T-S-oxygen profiles in 3x3 degree box to provide background for smaller scale measurements
- 5 repeat surveys of 125W
- 50 CTD-O2/LADCP profiles
- 262 uCTD profiles (all corrected for salinity spikes ala Ullman and Hebert, JAOT, 2014)

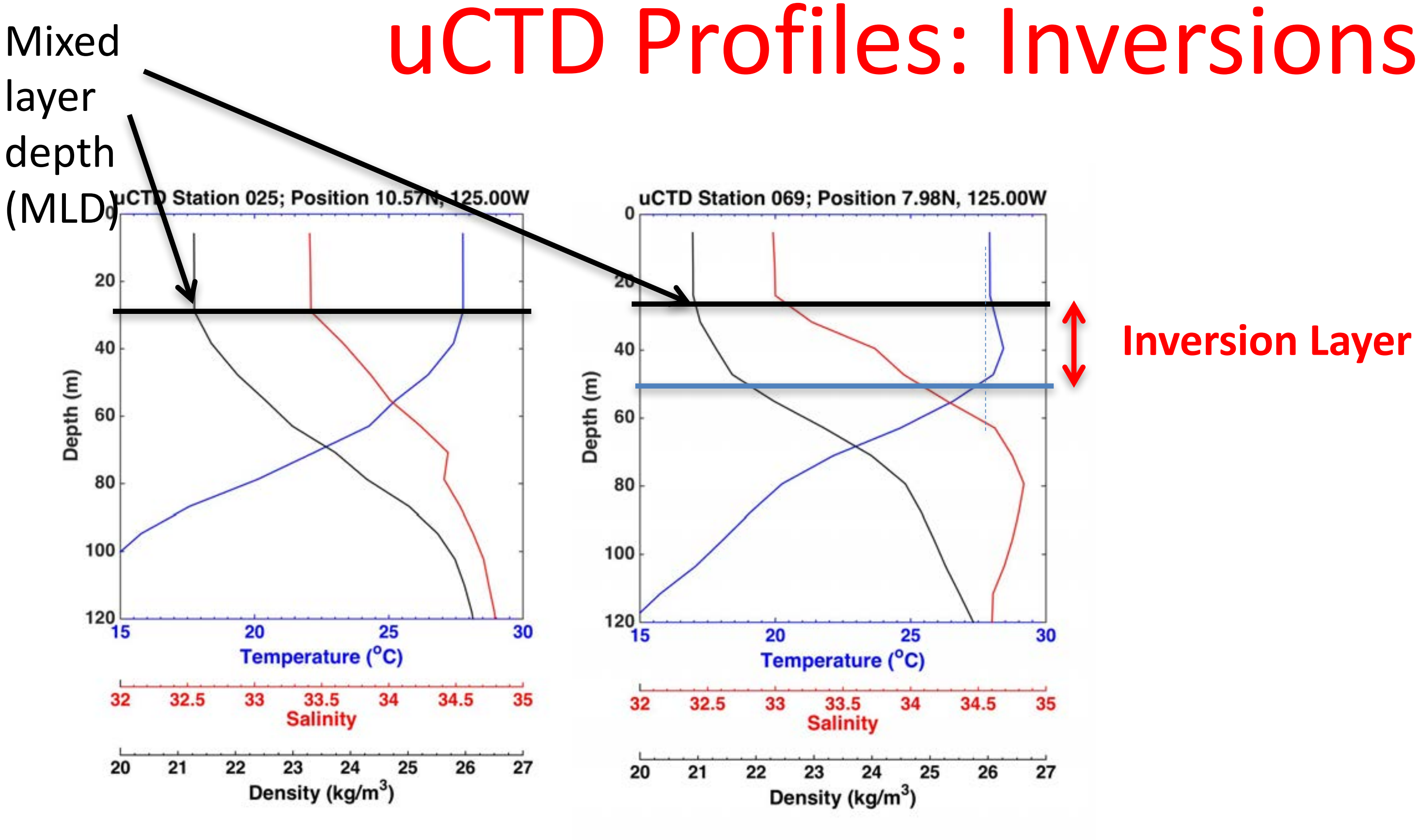


uCTD Profiles: Barrier Layers



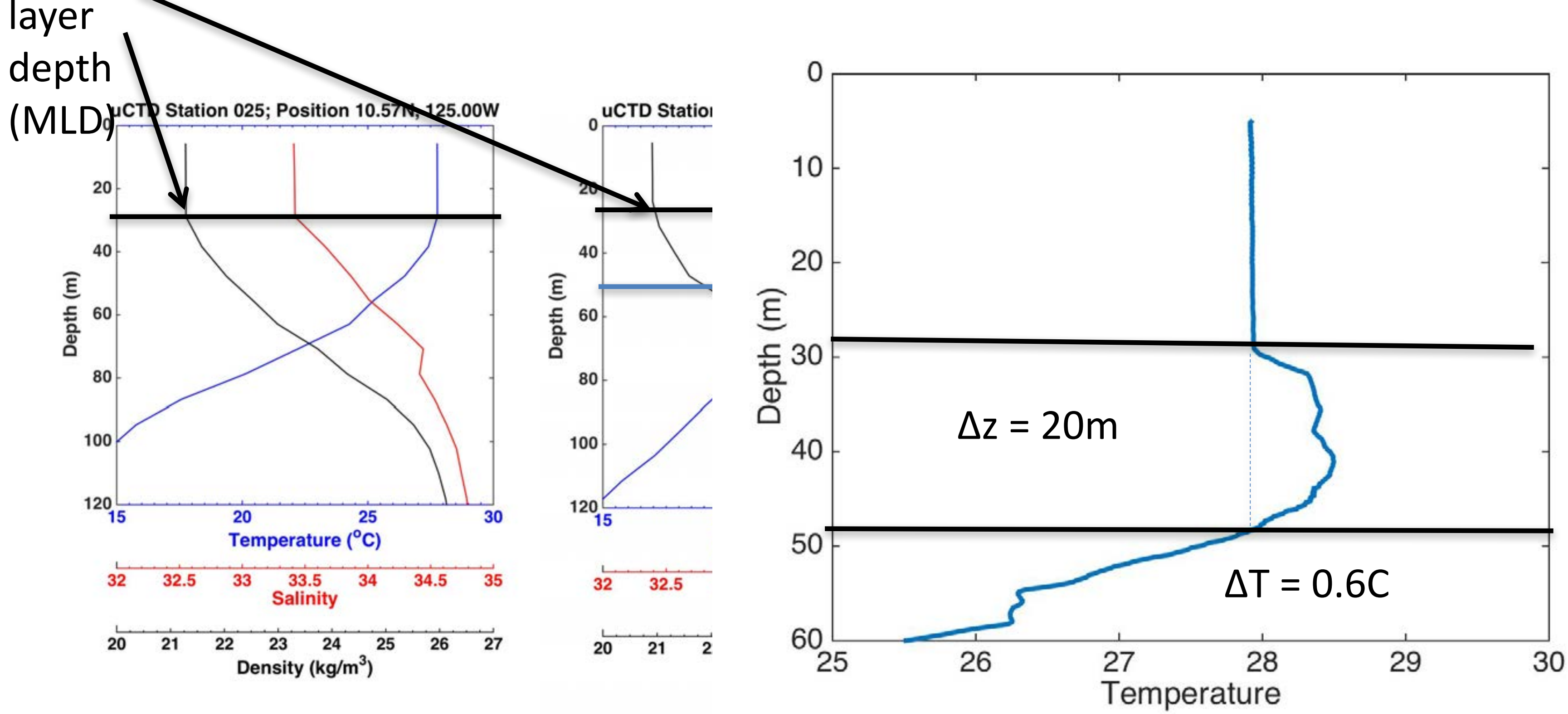
- Salt-stratified barrier layers: warm surface is deeper than fresh surface layer.
- Barrier to heat transfer:-
  - Reduced entrainment cooling through bottom of the MLD.
  - Heat and freshwater trapped in near surface layer, enhances their impact on SST and air-sea interaction
- Formation: rainfall? advective processes (current shear and S-gradients)?
- Common in tropical Pacific regions (e.g. Lukas and Lindstrom, 1991 etc.)

uCTD Profiles: Inversions



- Transient features – time scales? Causation?
- net heat loss at the sea surface?
- advection of cooler fresher water over warm saline water?
- Fronts? Water mass interleaving?

uCTD Profiles: Inversions



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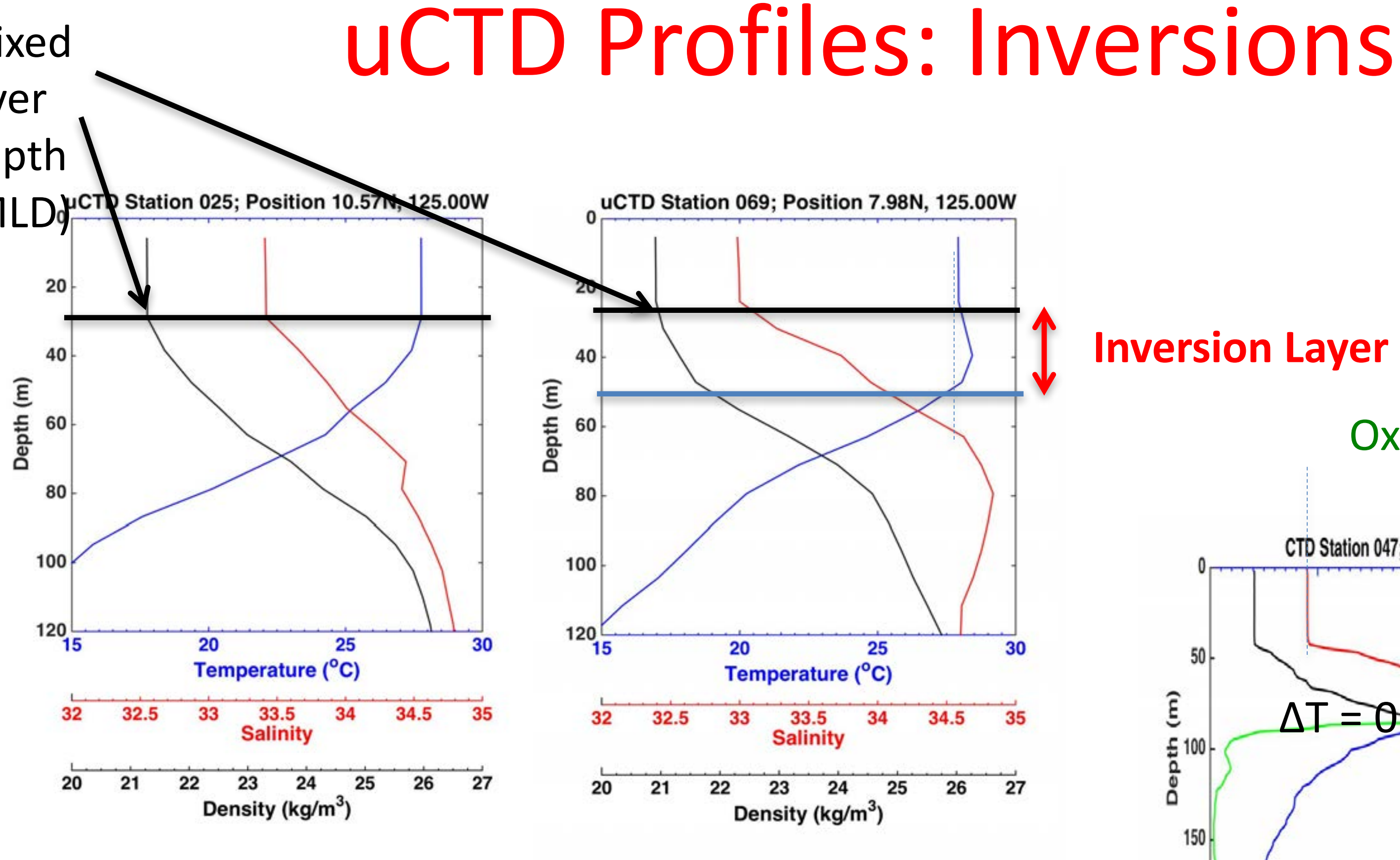

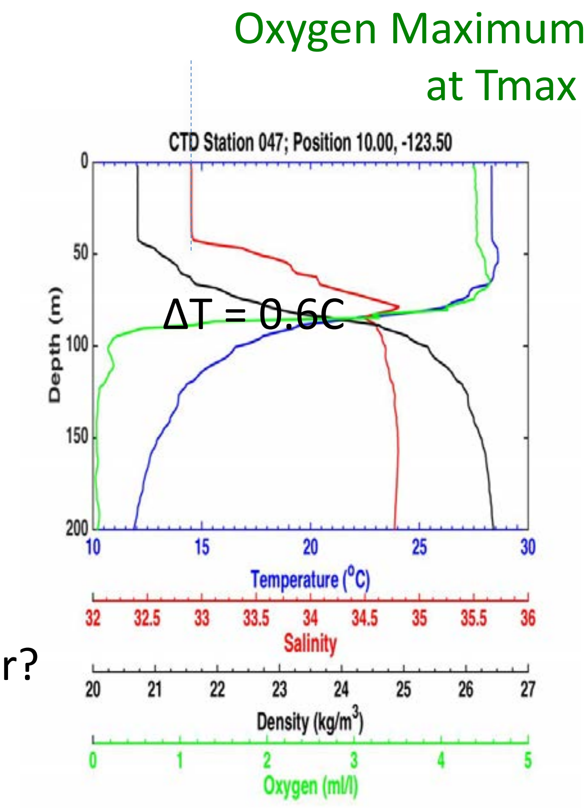

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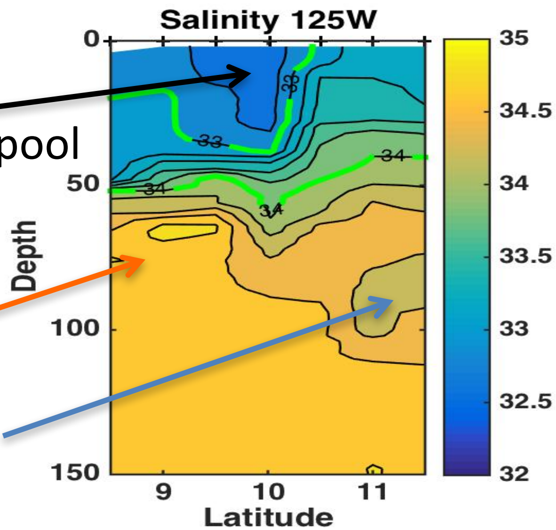
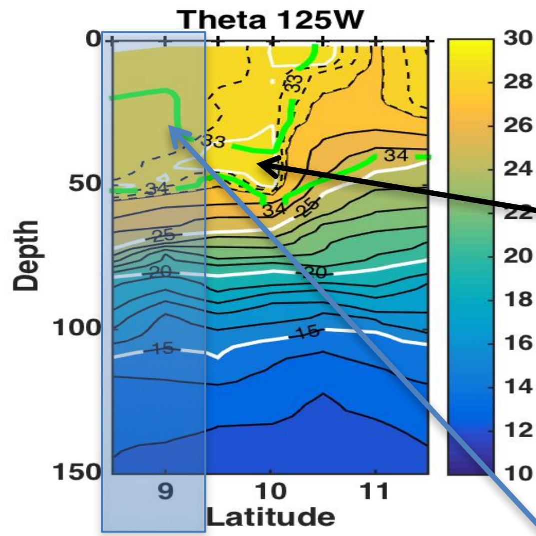
CTD Survey Along 125W

Strong S/ρ front
fresh TSW/
saltier isohaline pool
of STSW
N of front

Salty
STUW

Fresh
NPIW

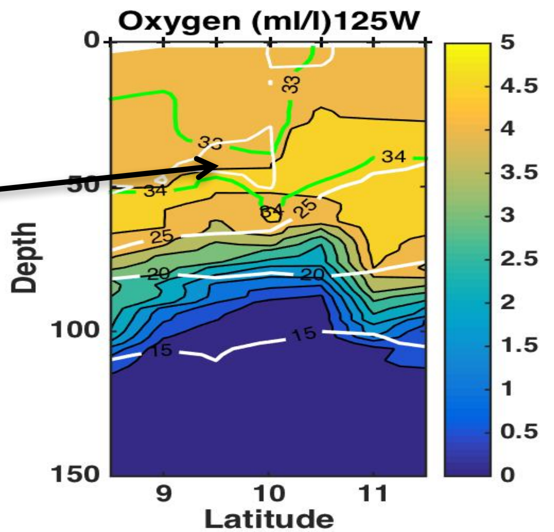




Warm deep
surface layer

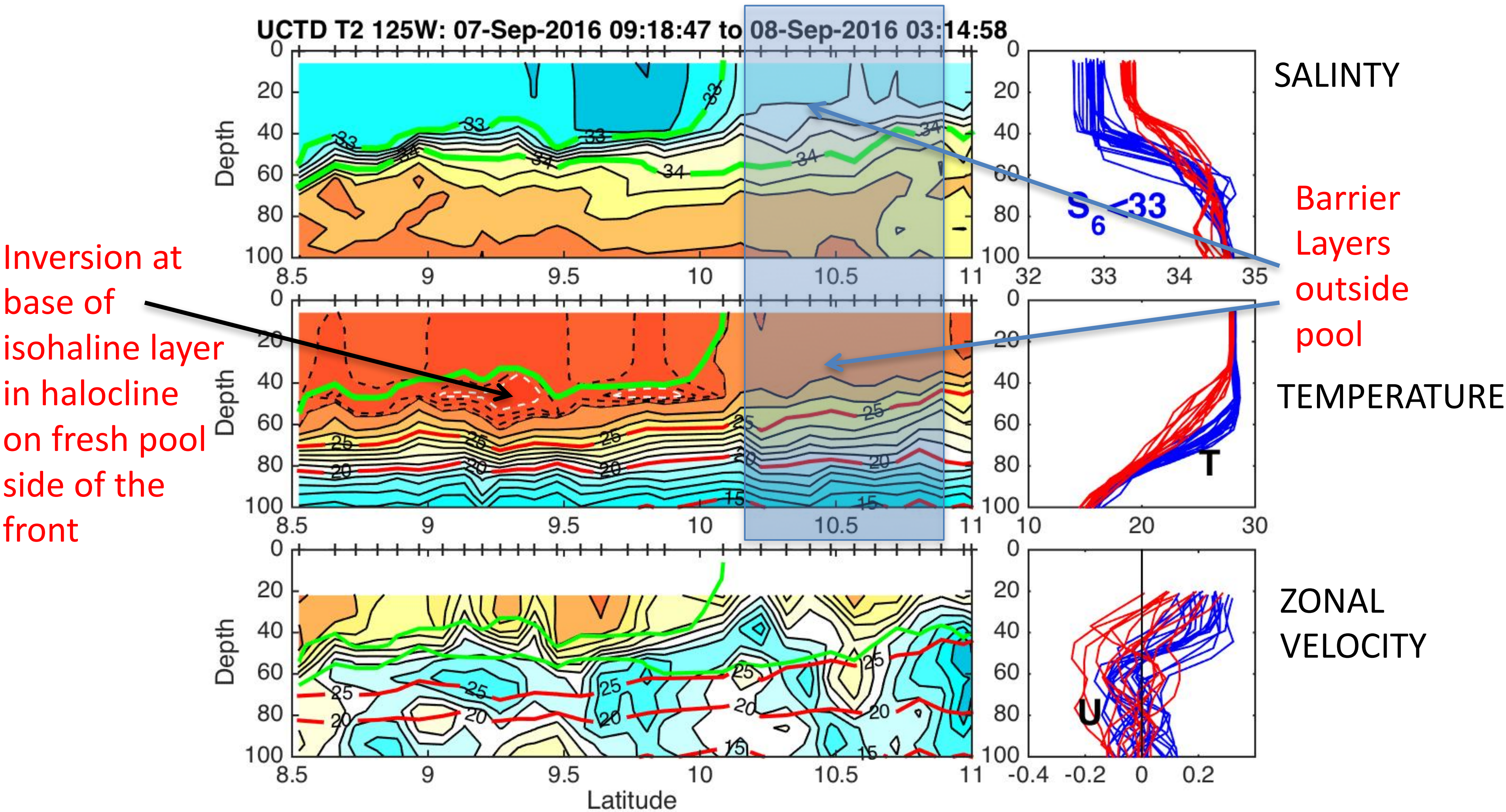
T-inversion (28.5C)
at base of halocline
on fresh pool side
of front

Salinity stratified
barrier layers
within the
freshwater pool



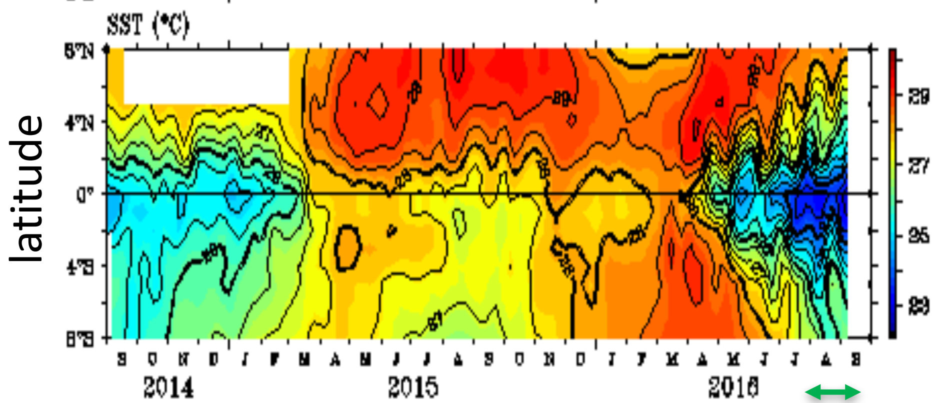
T-inversion
layer is highly
oxygenated

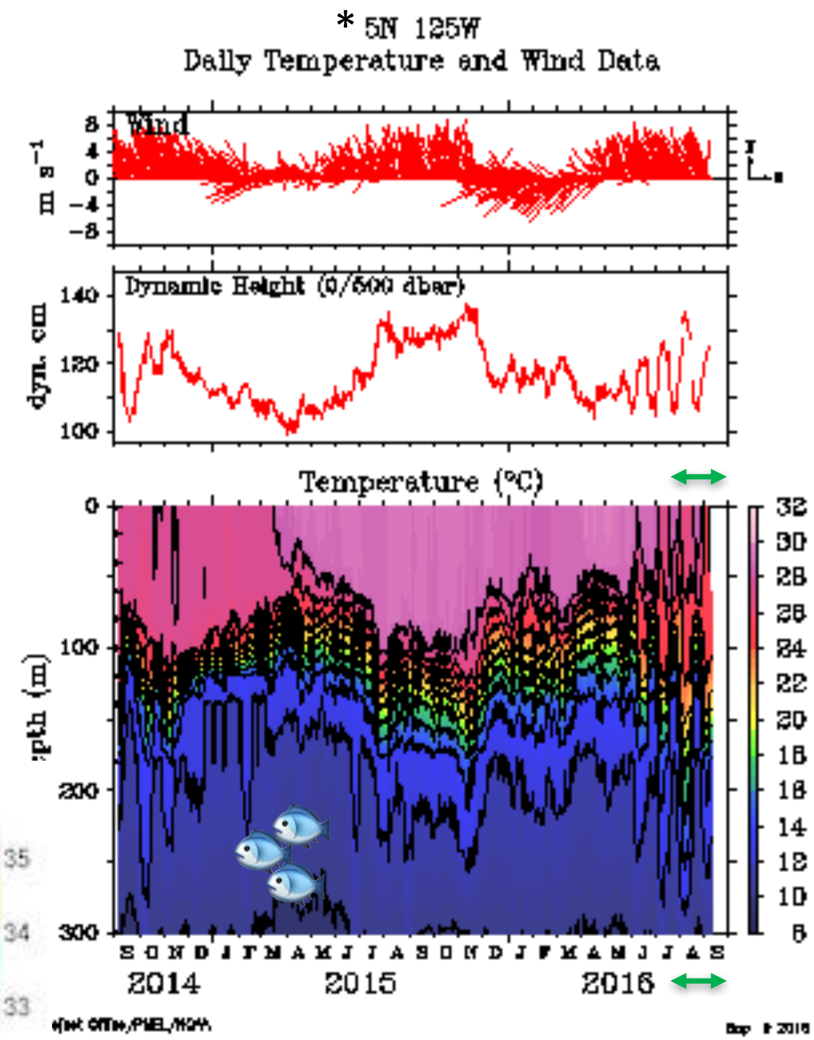
uCTD Survey Along 125W



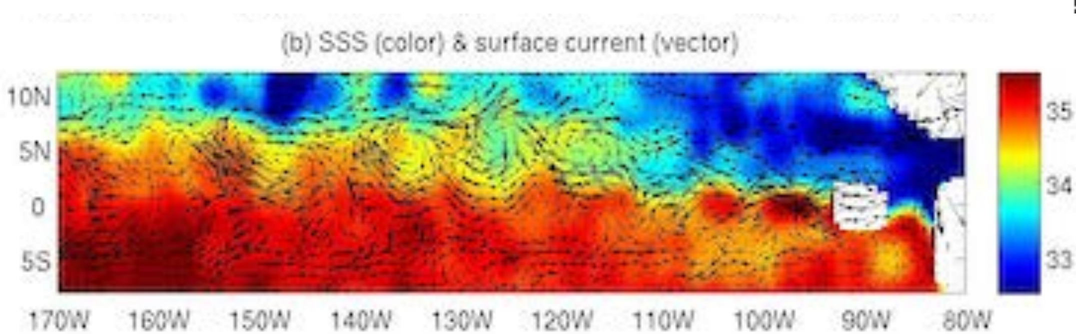
Sources of Variability: Tropical Instability Waves

SST from TAO Buoys along 125W





- Prevalent during cruise period
- Westward travelling waves that redistribute heat, freshwater and nutrients



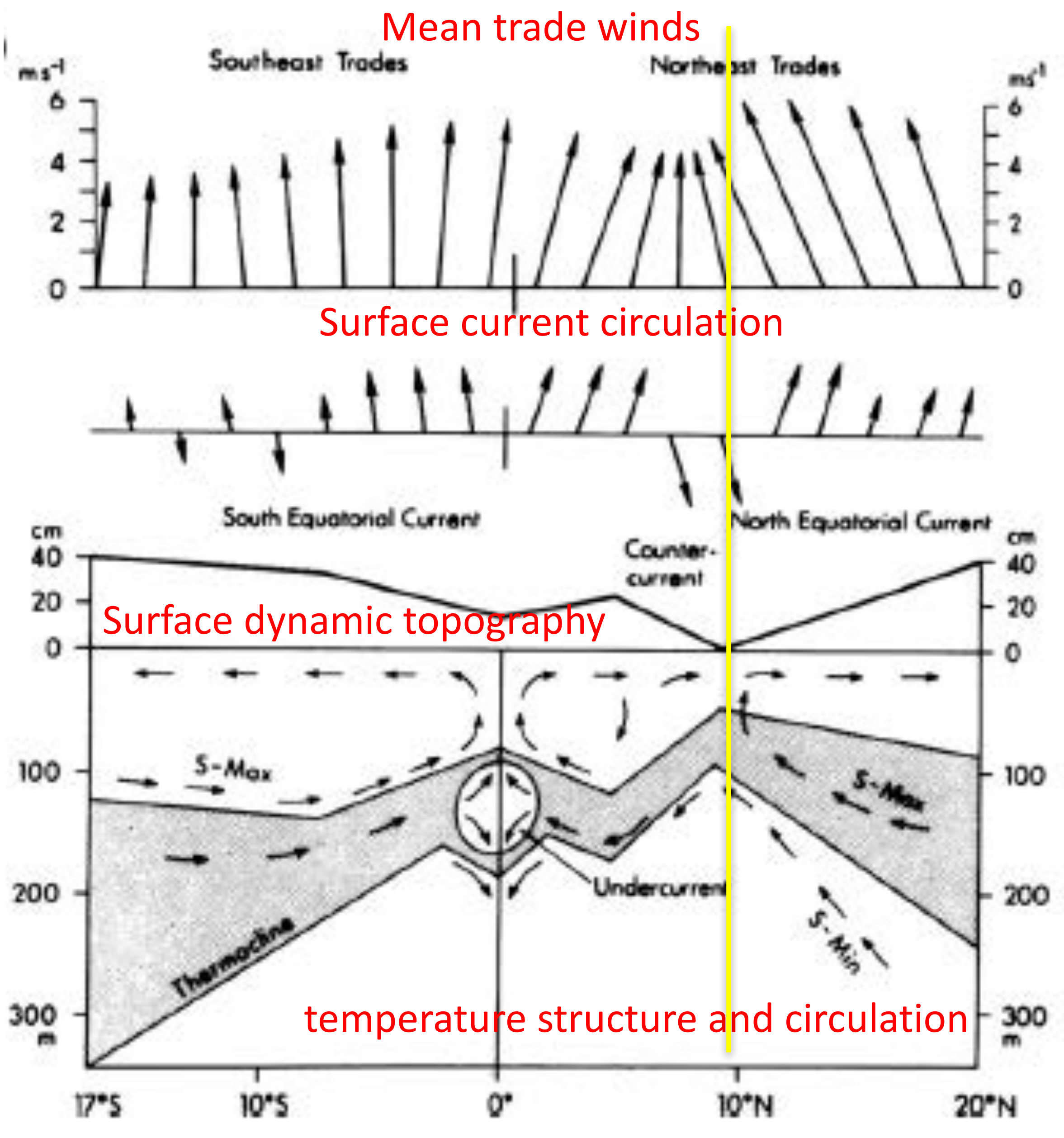
Lee et al., JGR, 2012

What's Next?

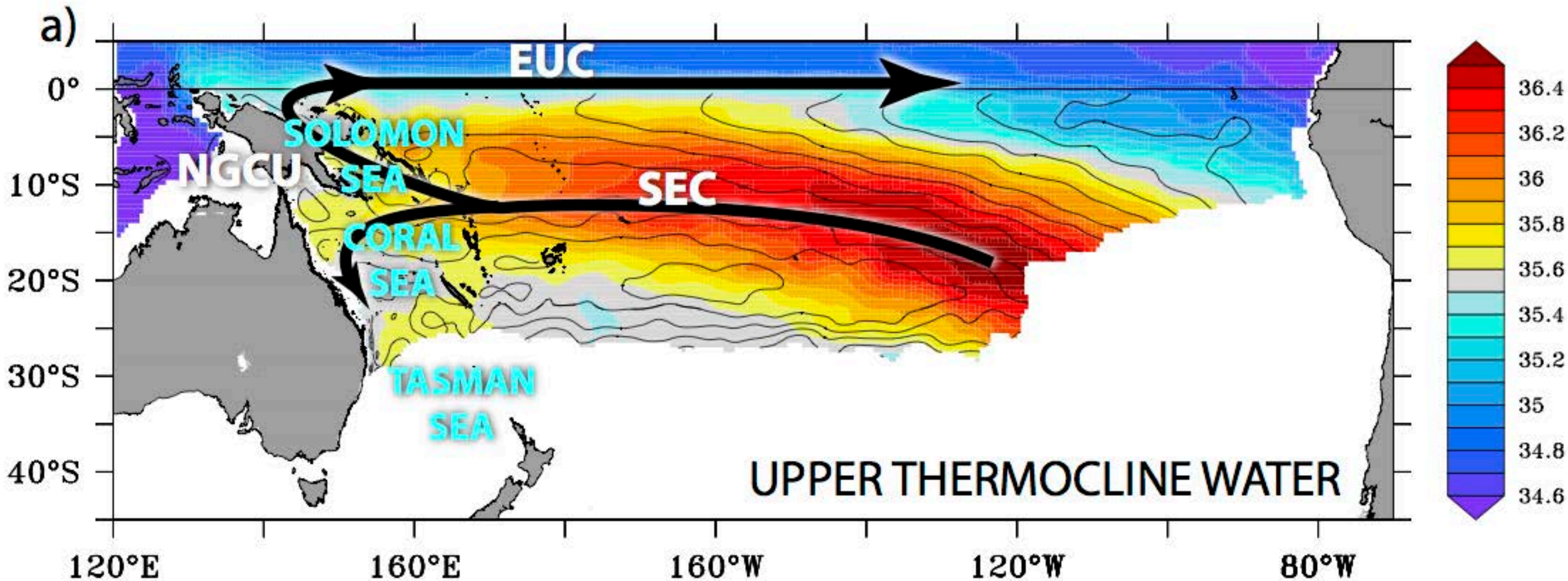
- strong horizontal and vertical salinity gradients on regional spatial scales exists as a result of numerous processes, including the presence of fronts, eddies, and filaments, and freshening from local rainstorms and the advection of surface freshwater anomalies.
- What is the interplay of these processes in forming the barrier layers?
- Some fresh pools extend into upper surface layer, while others appear skin deep – why?
- Humungous T-inversions ubiquitous at the base of the fresh pools in the halocline, especially in the vicinity of fronts. What process leads to their formation?
- Looking forward to sailing with my SPURS-2b shipmates!

The Tropical Circulation: Schematic

Schematic meridional sections derived from 12-month Hawaii-Tahiti shuttle experiment (Wyrtki and Kilonsky, 1984)

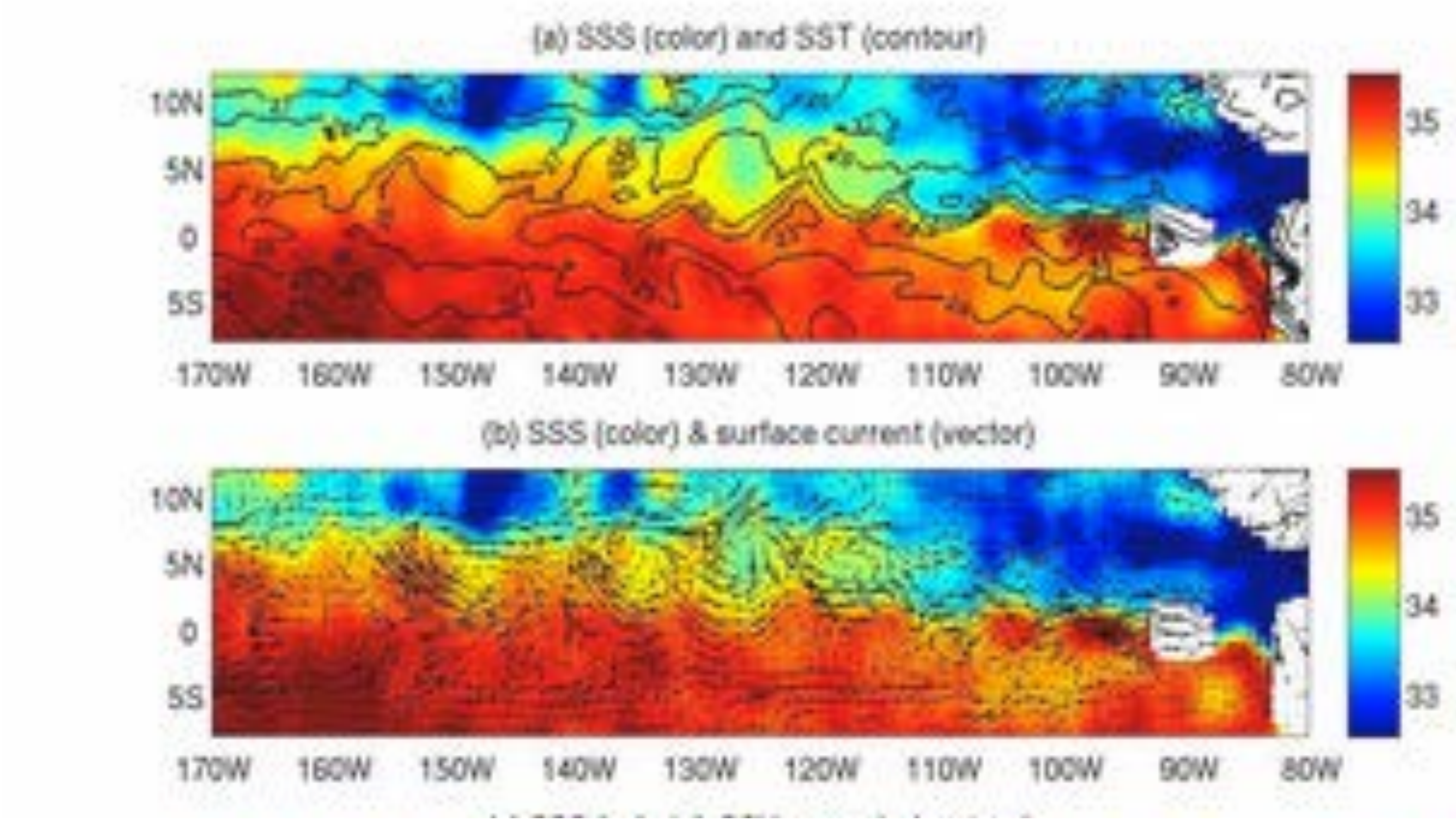


big brownie points to all those who helped with our survey – thank-you!!!!

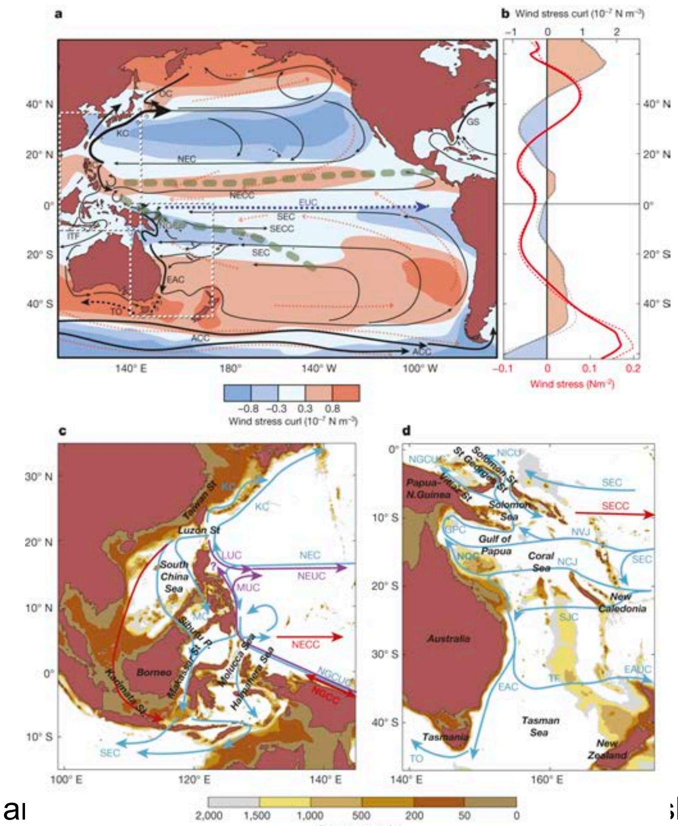


a)
EUC
SOLOMON
SEA
NGCU
SEC
CORAL
SEA
TASMAN
SEA
UPPER THERMOCLINE WATER
0°
10°S
20°S
30°S
40°S
120°E
160°E
160°W
120°W
80°W
36.4
36.2
36
35.8
35.6
35.4
35.2
35
34.8
34.6

Sources of Variability: Tropical Instability Waves



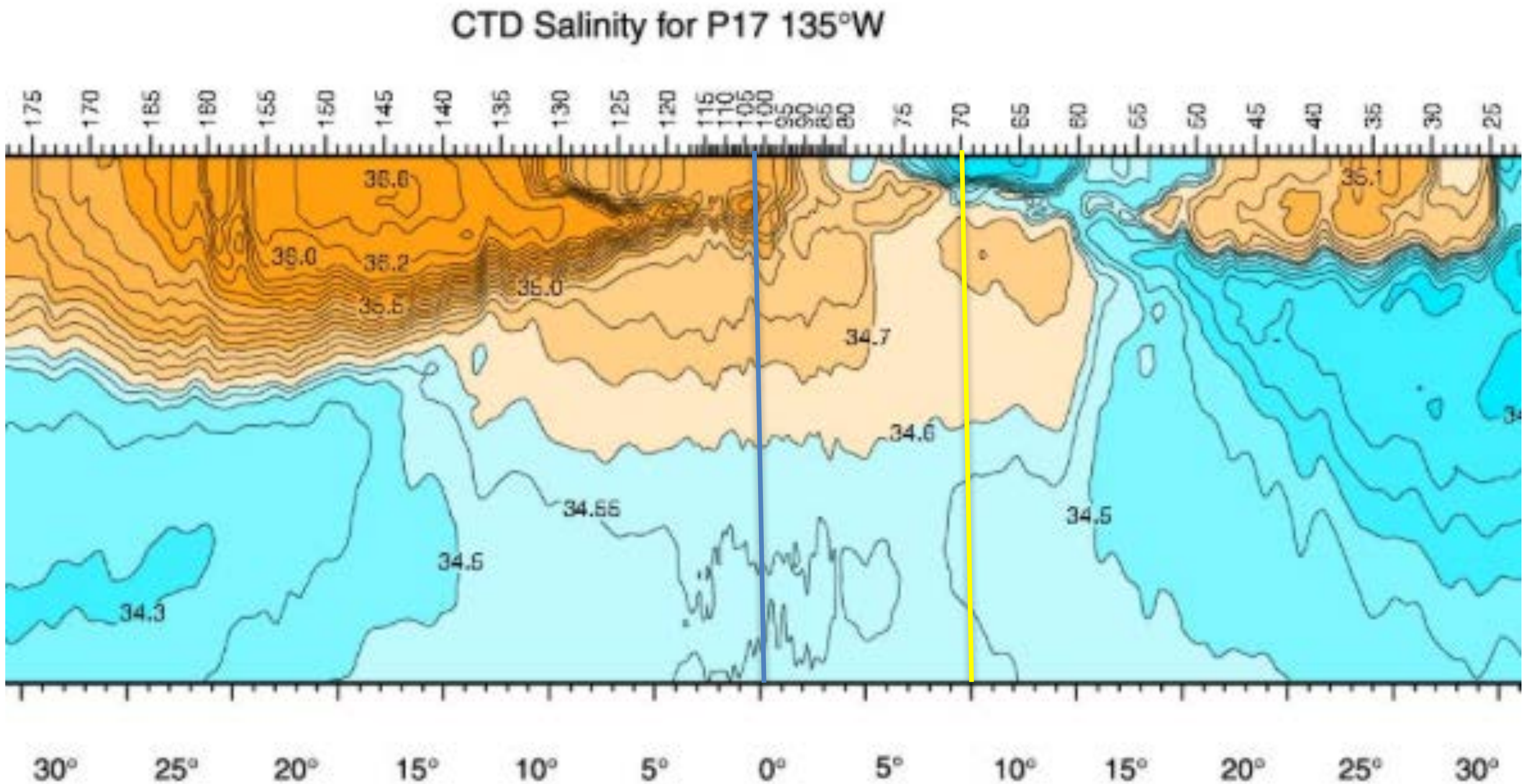
Pacific Ocean circulation and boundary currents.



Schematic of major currents a... ...shed lines) and wind stress curl (shading: positive curl in red; negative in blue). The Intertropical Convergence Zone and the South Pacific Convergence Zone are indicated by thick grey-dashed lines. Red and blue shading in the Southern Hemisphere corresponds to anticyclonic and cyclonic curls, respectively, and vice versa in the Northern Hemisphere. **b**, Pacific zonally averaged zonal wind stress (grey curve) and wind stress curl (red curve) for the present day (solid lines) and the latter half of the twenty-first century (dashed lines). Projected changes are calcula... model mean difference between 2050–2100 future winds under RCP8.5 and 1900–2000 his...

D Hu *et al.* *Nature* **522**, 299-308 (2015) doi:10.1038/nature14504

Salinity (upper 500 m) at 135W

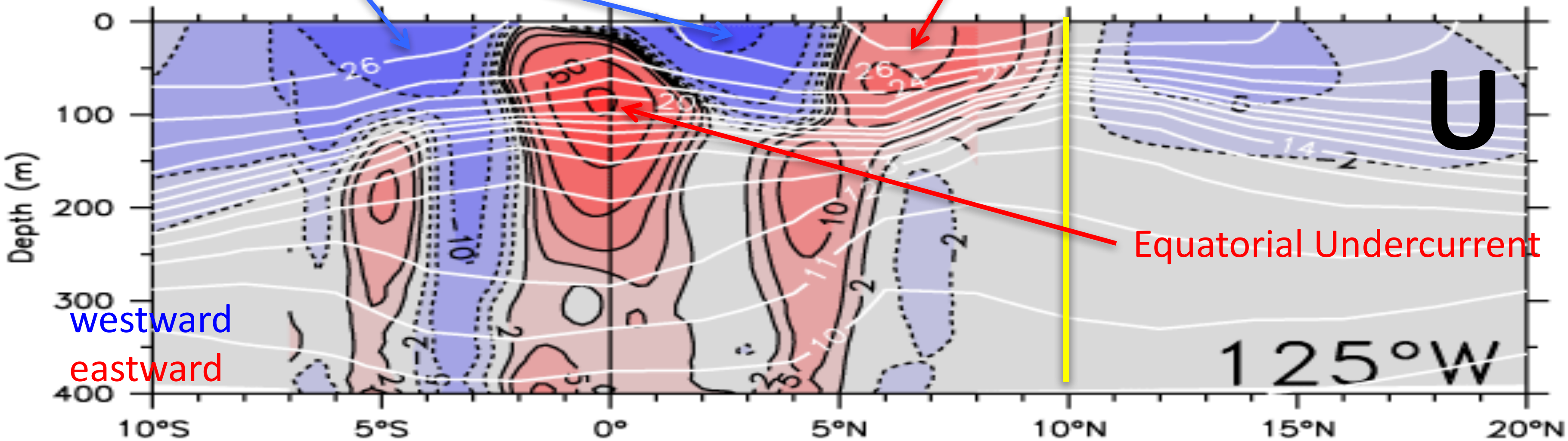


The Circulation at 125W: An Averaged Look

South Equatorial Current

North Equat. Counter Current

North Equatorial Current



Equatorial Undercurrent

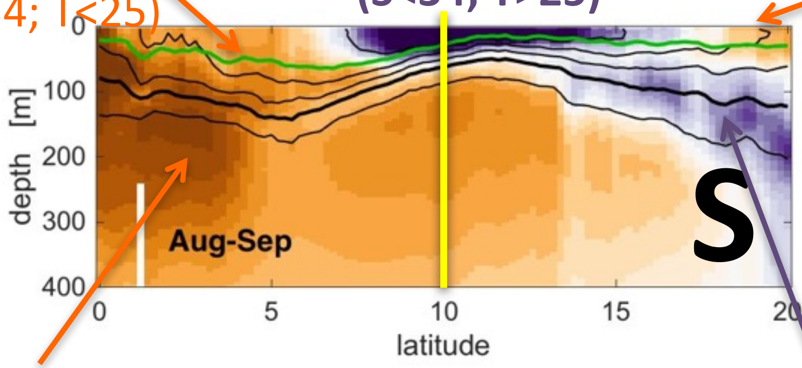
westward

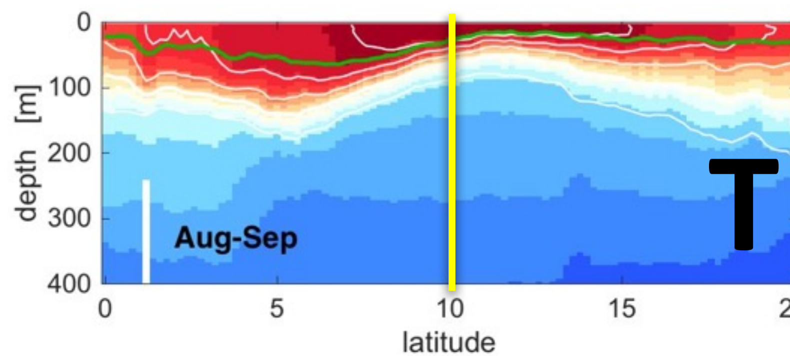
eastward

Equatorial Surface Water (S>34; T<25)

Tropical Surface Water (S<34; T>25)

Subtropical Surface Water (S>35)





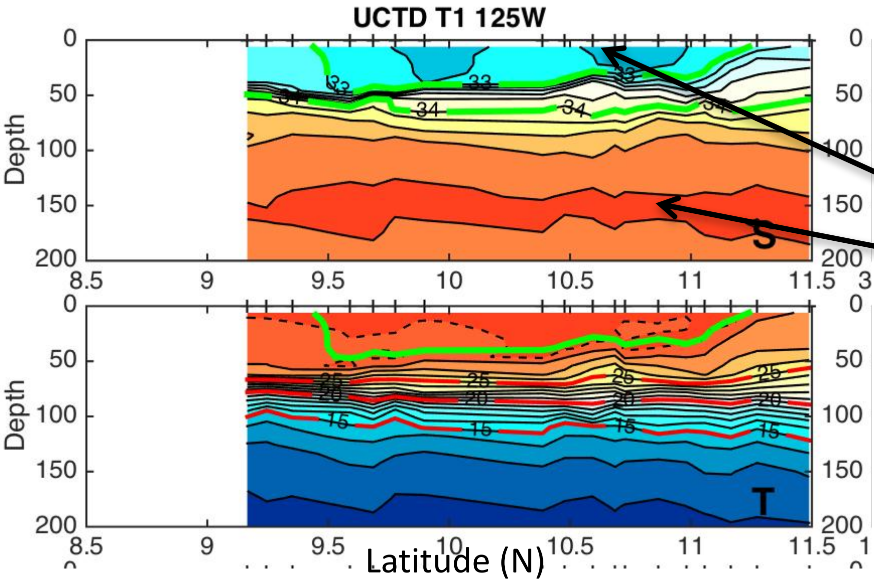
Subtropical Under Water

North Pacific Intermediate Water (S<34.2)

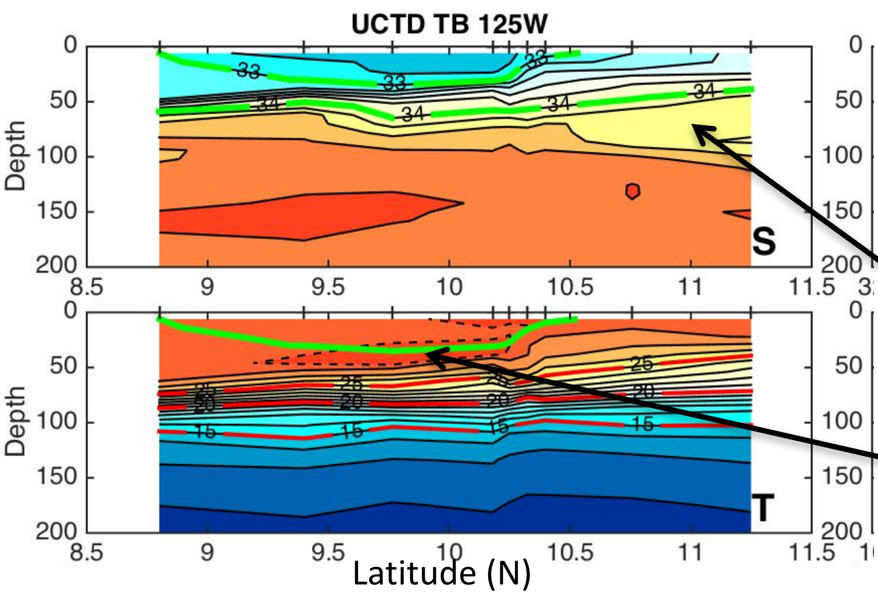
Argo Climatology

Kessler, 2006

Hydrographic Surveys Along 125W

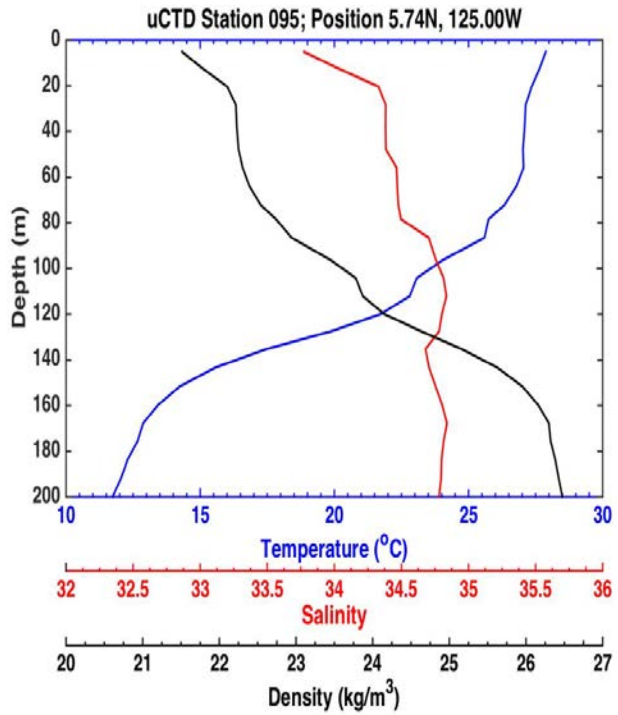


T1: 21/09/16 21:50 – 22/09/16 12:20
- Mostly sunny (early morning shower)
- Tropical Surface Water pools and
- Smax of STUW
- Warm surface layer (>28.2)
- Strong salinity/density front ~11.3N



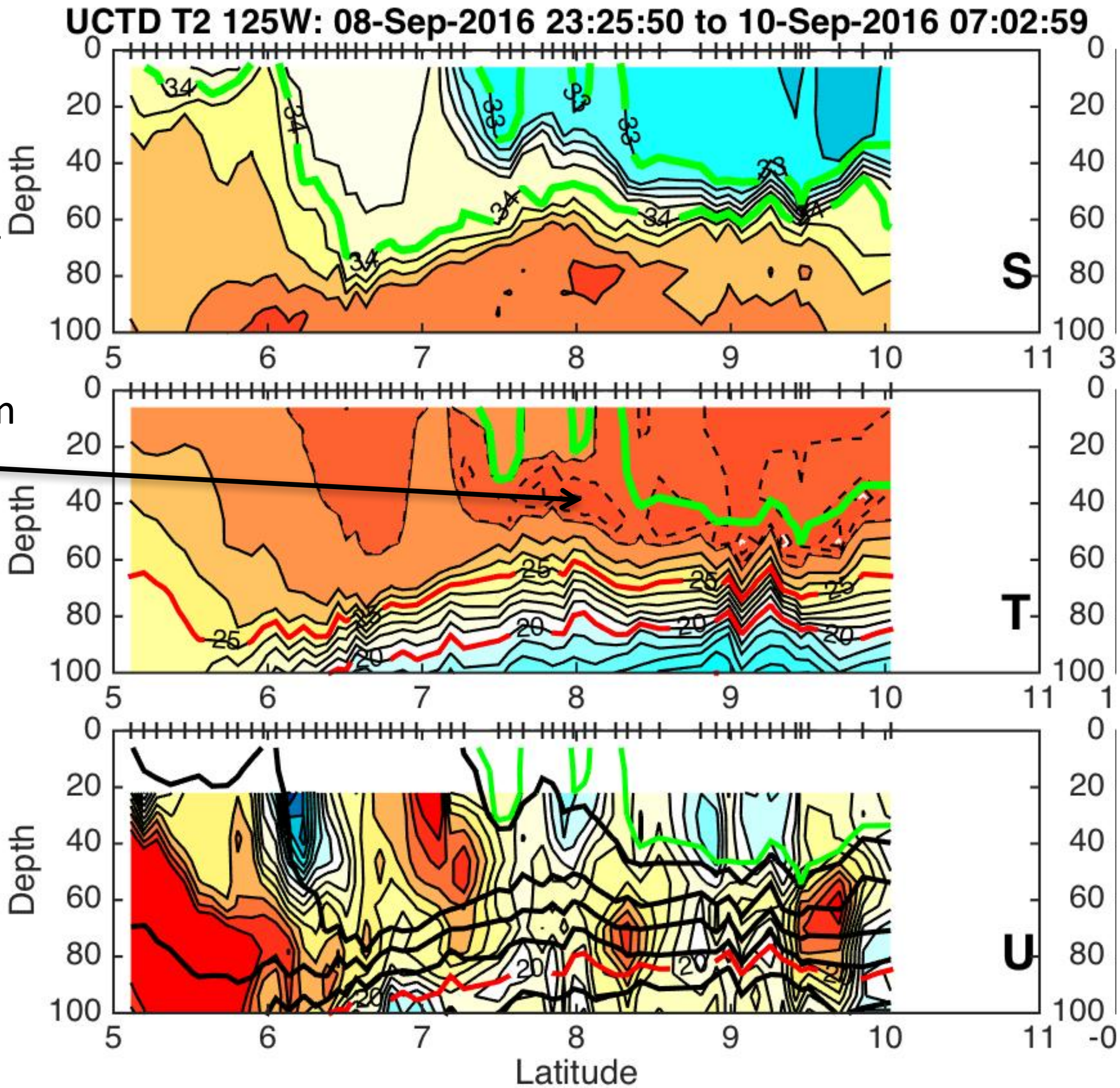
T1: 01/09/16 09:46 – 02/09/16 18:15
- Fair conditions but heavier rain yesterday
- Tropical Surface Water pool
- Broken Smax in STUW
- Thick isohaline pool north of front
- Cooler surface layer
- Strong inversion (>28.2) below salinity layer
- Salinity/density front more diffuse

uCTD Profiles: Remnant Mixed Layers

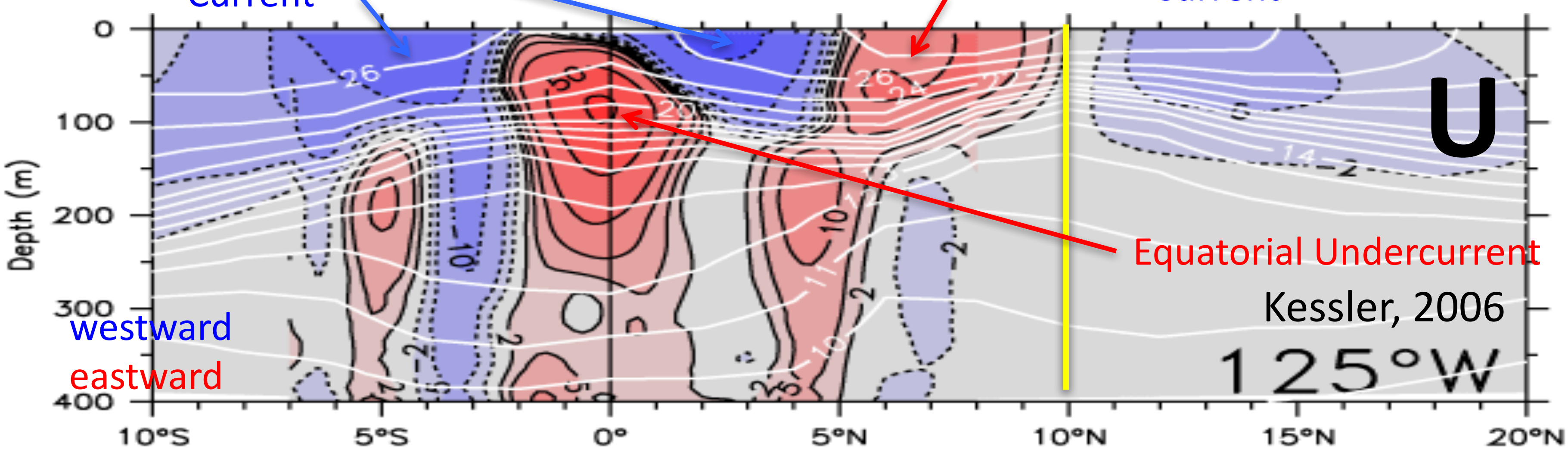


Hydrographic Surveys Along 125W

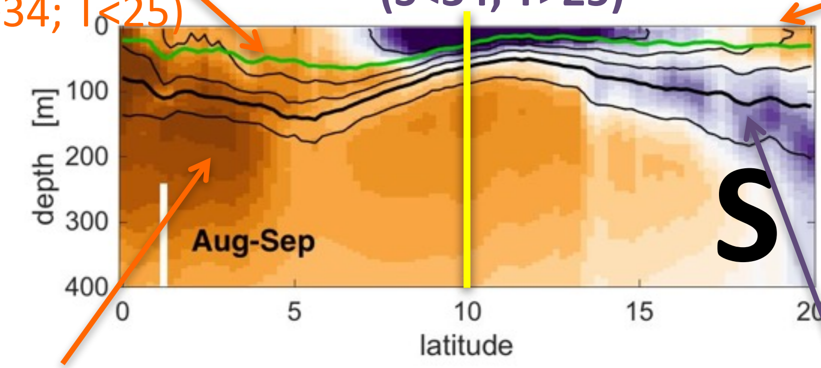
Inversion at base of isohaline layer in halocline just beyond front – 20 m thick!!

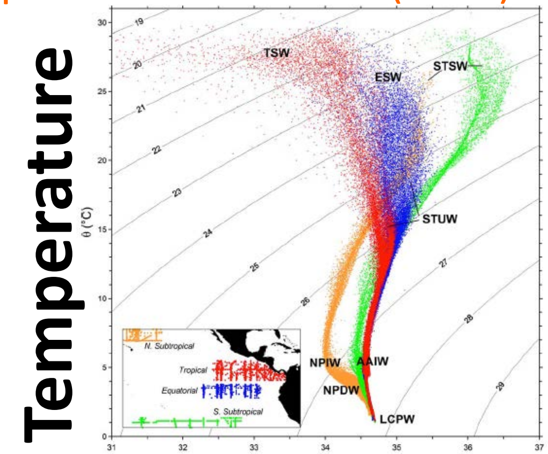


The Circulation at 125W: An Averaged Look



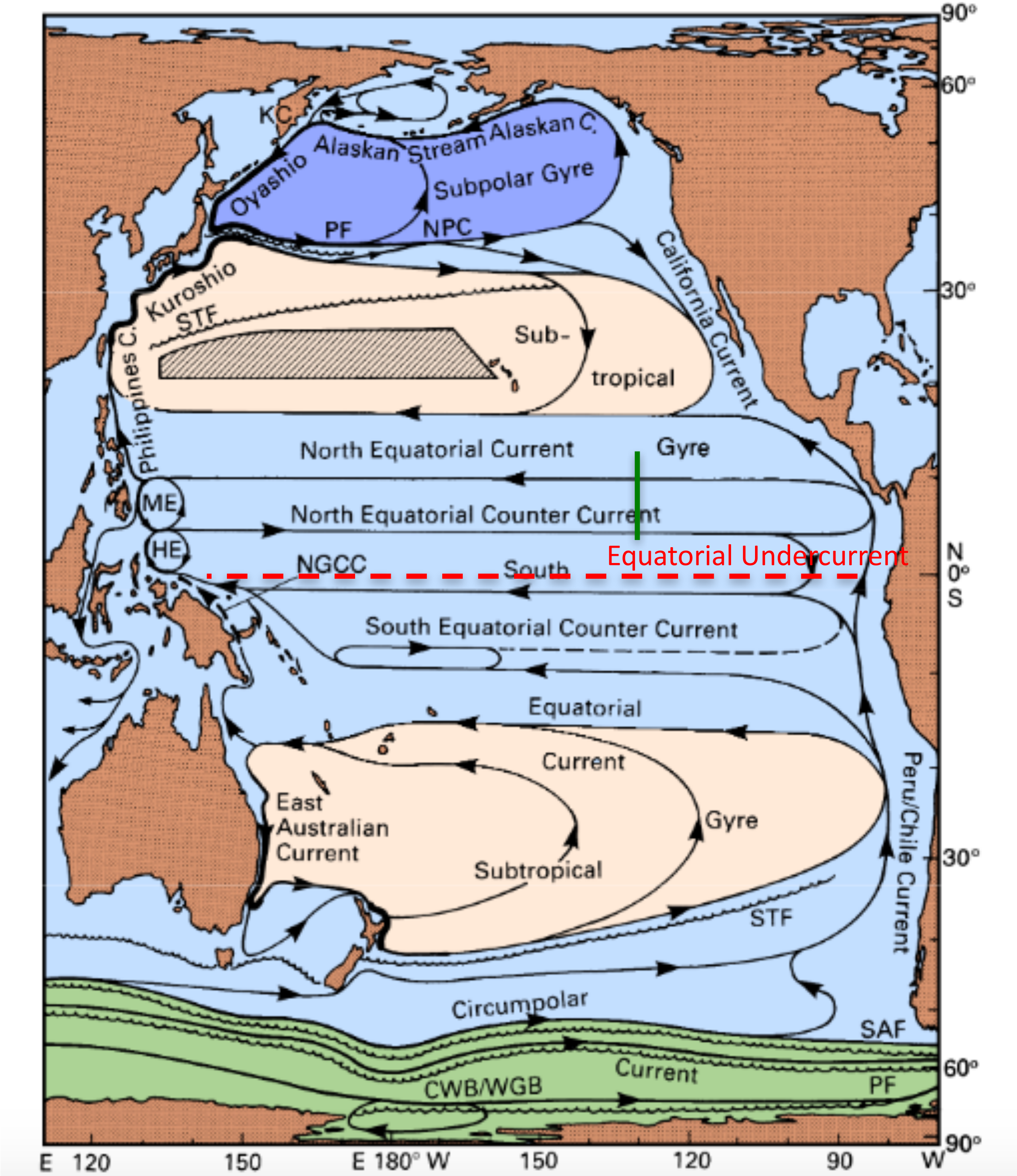
Kessler, 2006





Feidler &Talley, 2006

Pacific Large-Scale Circulation



- North of the ITCZ: NE trade winds drive the NEC
- South of ITCZ: SE trade winds drive the SEC also to west
- NECC driven by positive wind stress curl
- Equatorial Undercurrent (EUC) flows toward the east and shoals WPac to EPac, driven by zonal pressure gradient and confined by f to the equator.

Tomczak and Godfrey (2001)