Formation of the South Pacific Subtropical Surface Salinity Maximum

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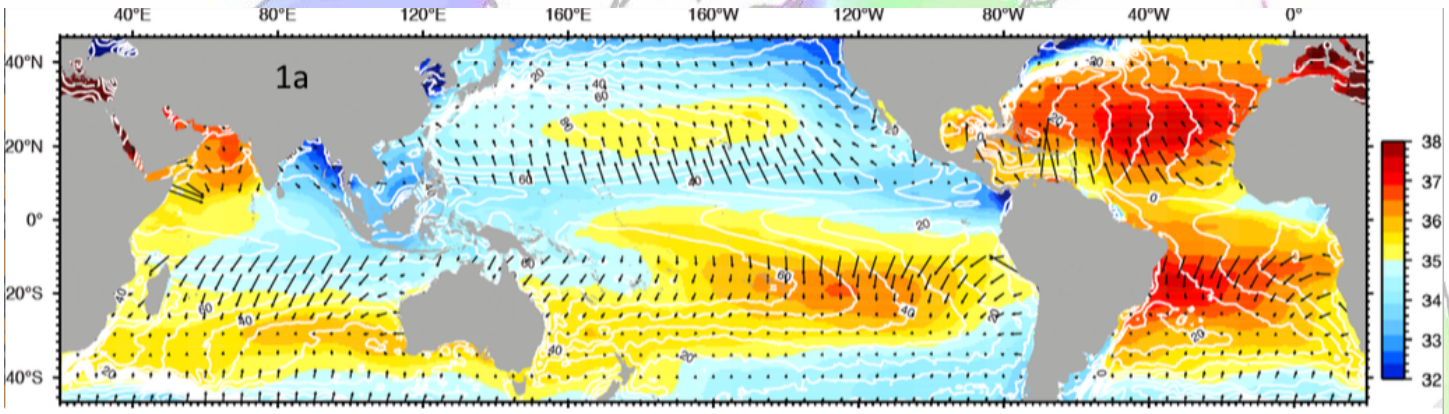
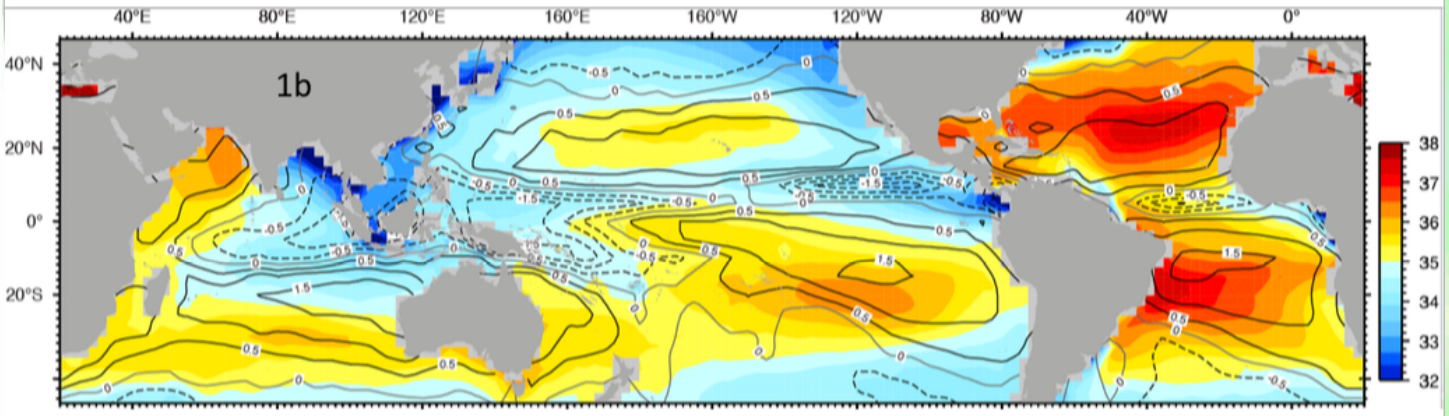
With help from Z. Li and others
Work funded by NASA

High SSS regions



Gordon et al., 2015

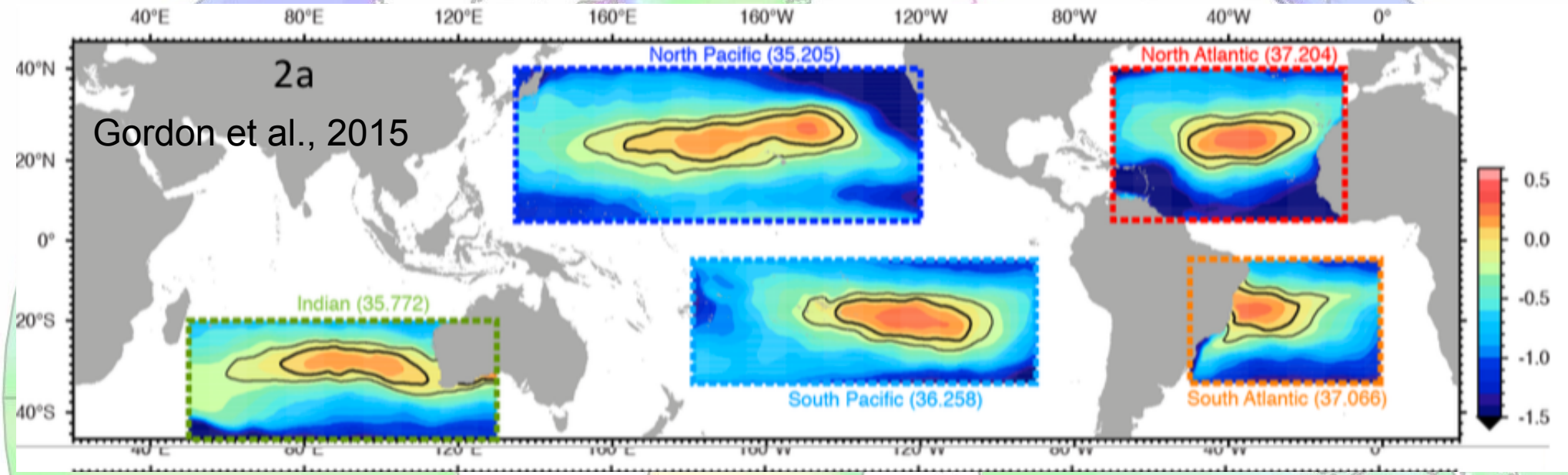
Color – SSS
Arrows – Ekman transport
White contours – surface dynamic topography



Color – SSS
Contours – evaporation-precipitation (dashed negative)

Isolated high SSS regions are present in every ocean basin except the North Indian

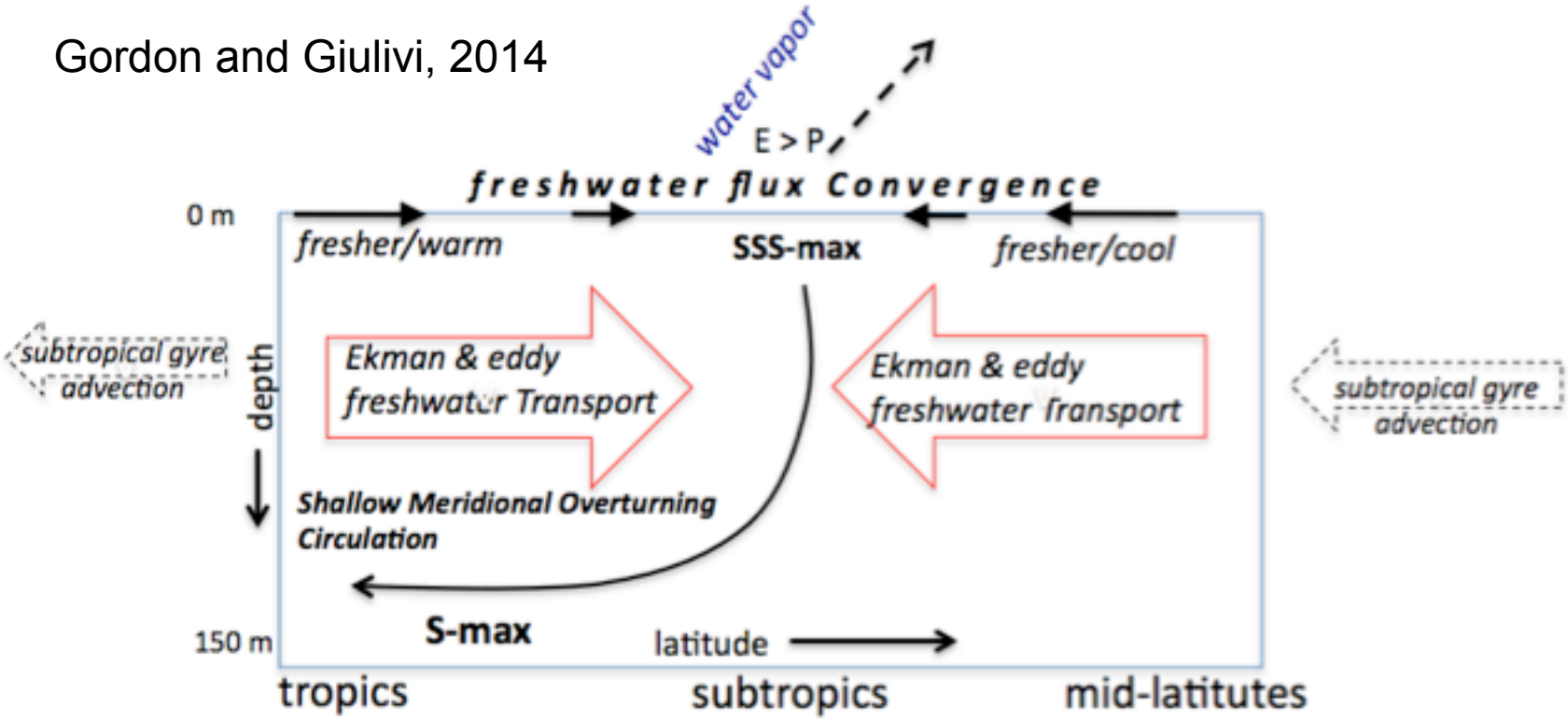
High surface salinity regions



SSS relative to the given reference SSS in each ocean basin

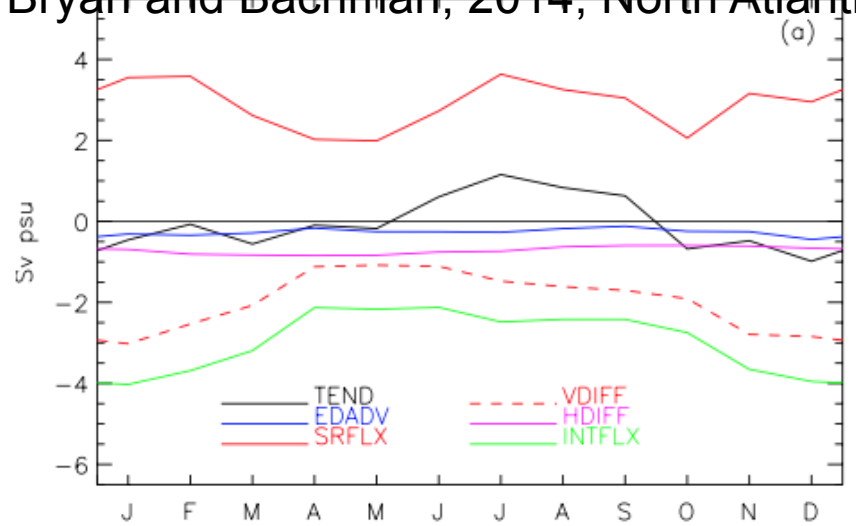
Formation of the SSS max

Gordon and Giulivi, 2014



Salinity budget within the SSS max

Bryan and Bachman, 2014, North Atlantic



Salinity in the SSS-max is largely a balance between surface flux and vertical and horizontal diffusion or advection

See also Farrar et al., 2015, Dong et al., 2015, Shcherbina et al., 2015, etc. in the North Atlantic

HASSON ET AL.: SOUTH PACIFIC

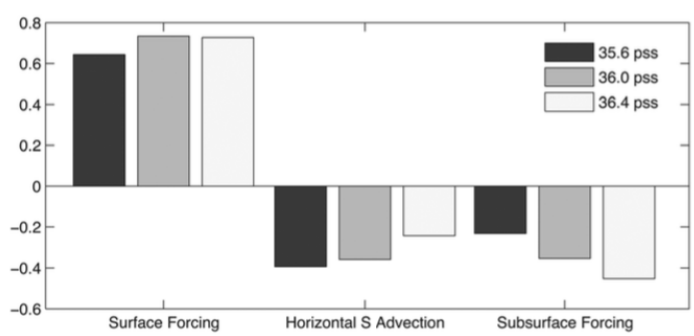
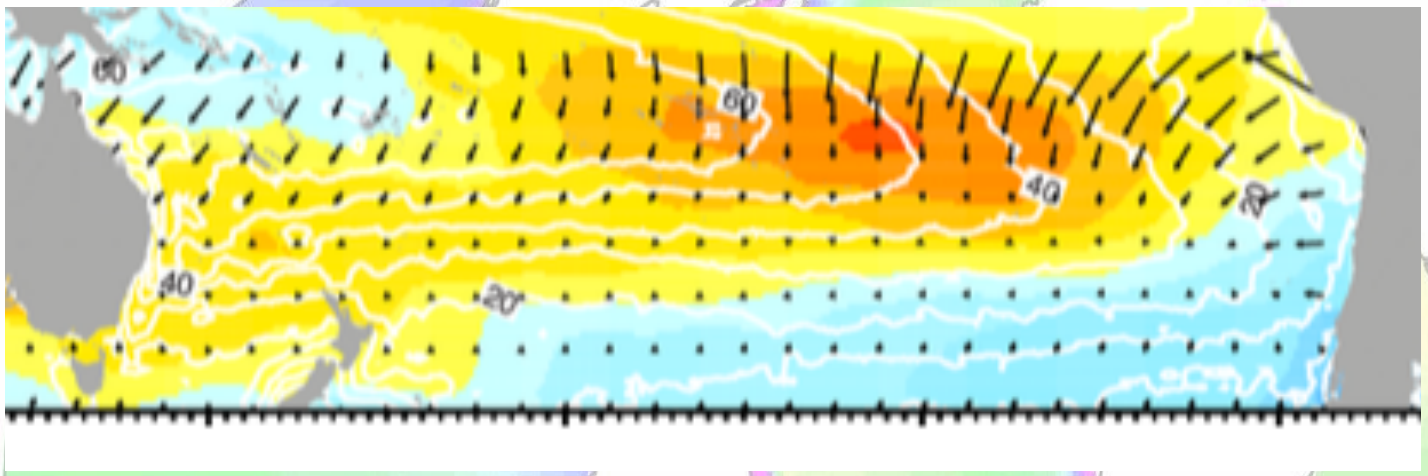
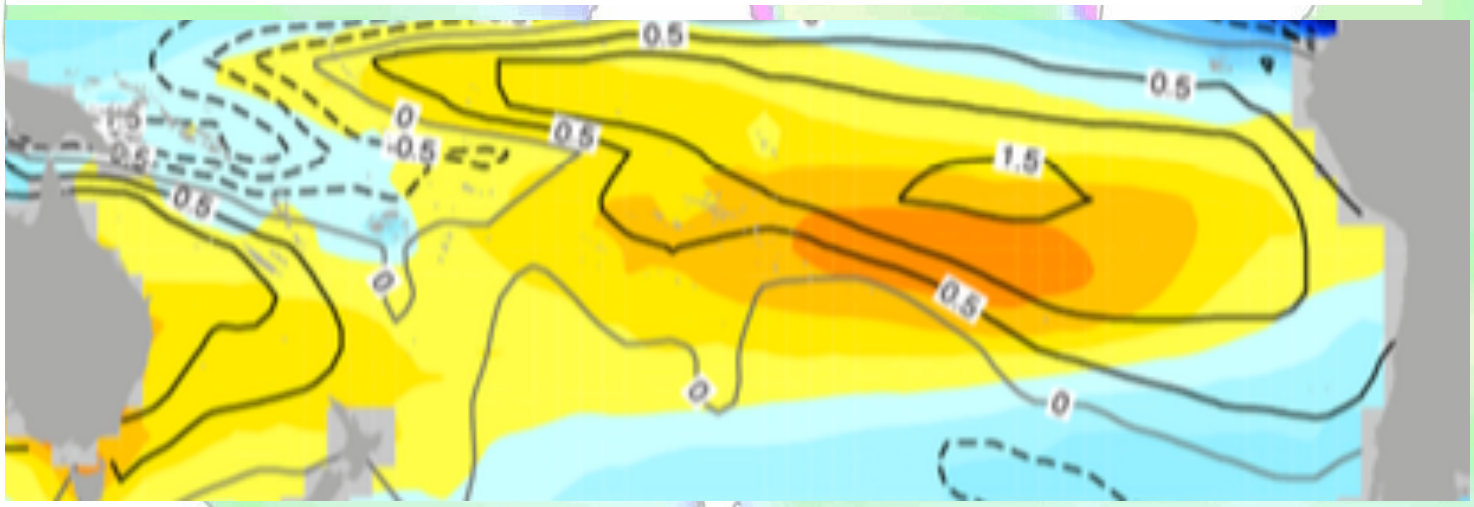


Figure 3. Mean modeled mixed-layer salinity budgets (pss/yr) in the high-salinity regions bounded by the 35.6, 36, and 36.4 isohalines shown in Figure 1a.

The South Pacific SSS-max



Ekman transport (arrows)
SSS from MIMOC (colors)
Surface dynamic height (white contours)



SSS from Aquarius (colors)
Evaporation minus precipitation (black contours)

Gordon et al., 2015

Reid, 1986

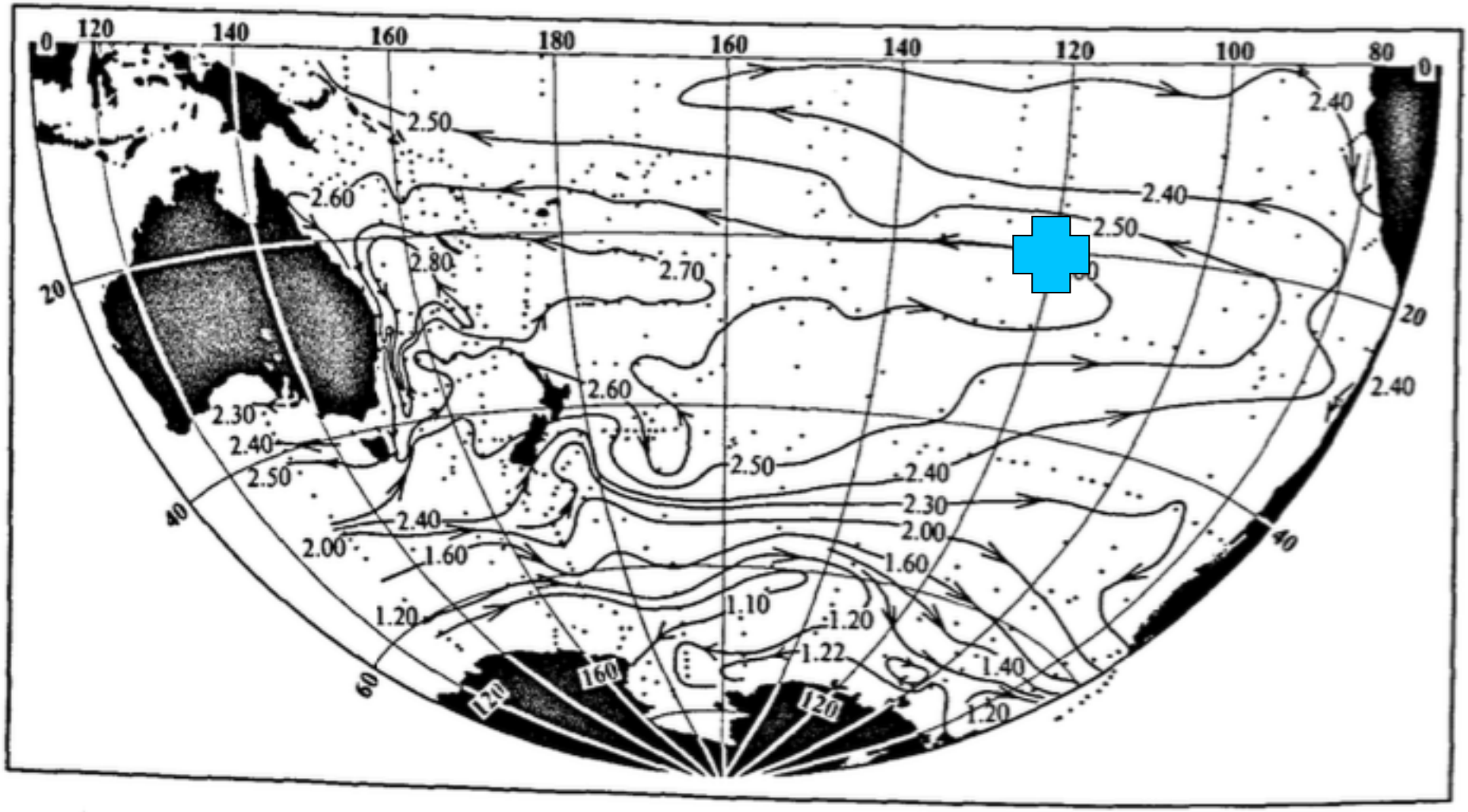


Fig. 10. Adjusted steric height Φ_A, 200 db, or 2 MPa (10 $m^2 s^{-2}$ or 10 J kg^{-1}).

Hasson et al. 2013

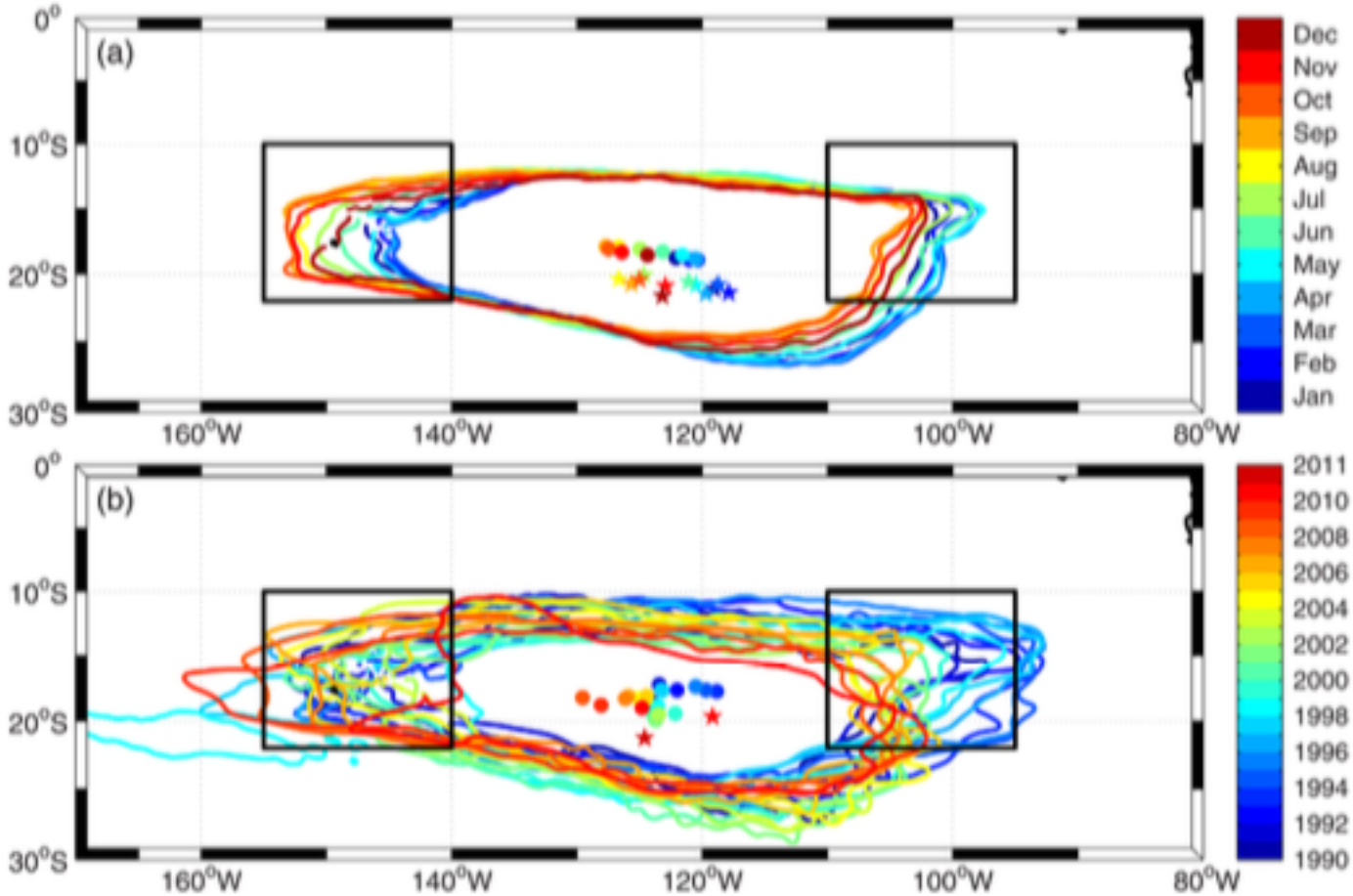
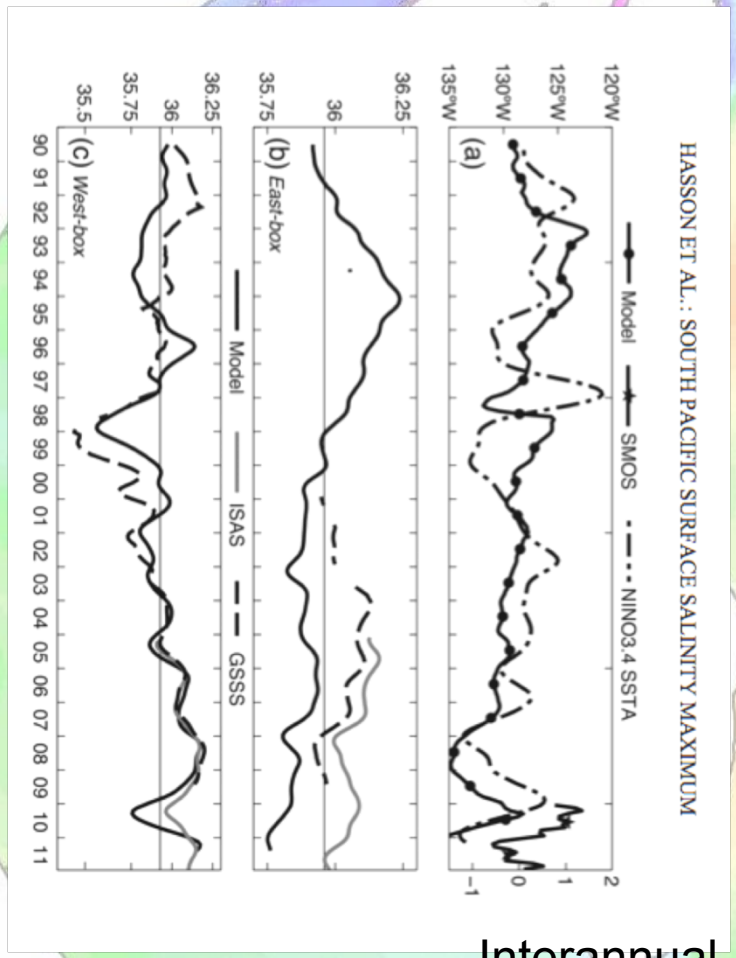
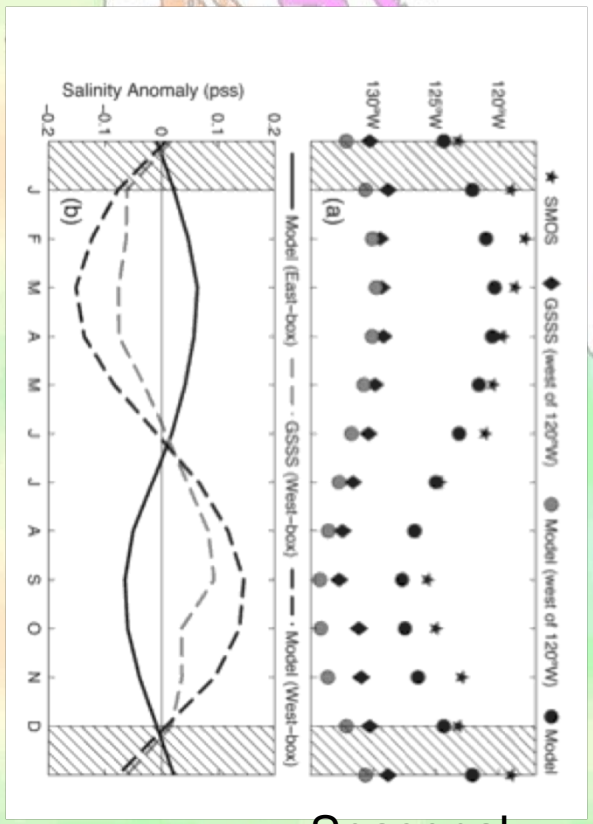


Figure 4. (a) Monthly and (b) annual mean positions of the modeled 36 isohaline. In both figures, the colored dots and stars show, respectively, the barycenter of the modeled and SMOS-derived 36 isohalines. The two rectangles denote the *east* and *west-boxes* discussed in section 4.

Hasson et al. 2013



Interannual longitude



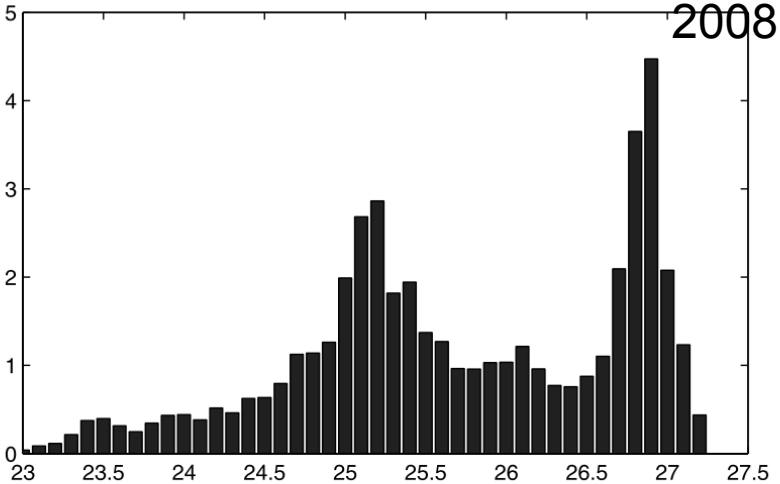
Seasonal longitude

South Pacific SSS-max position is correlated with ENSO.

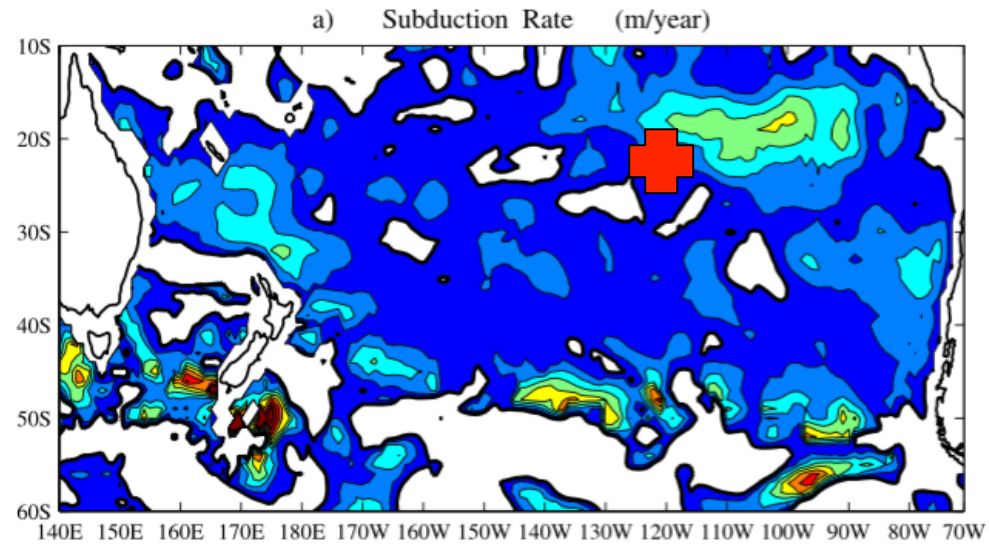
Seasonality

Subduction of SSS-max water

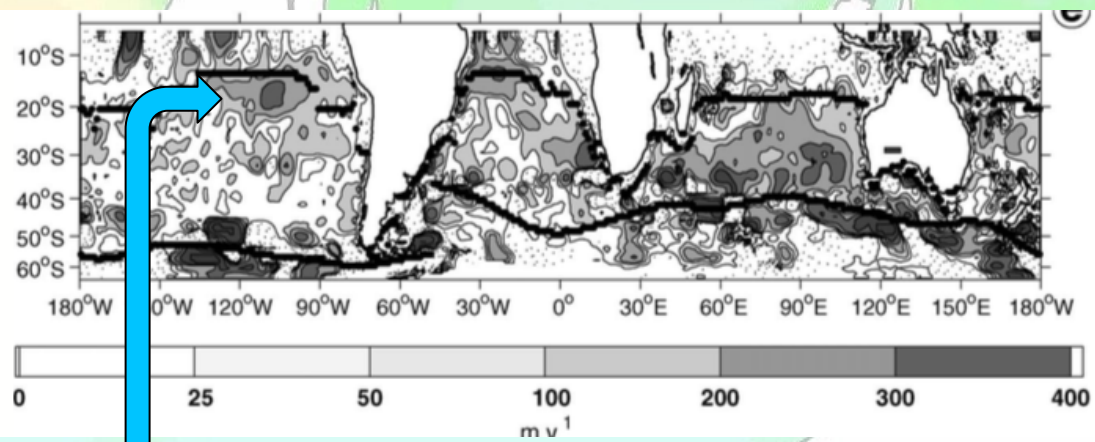
Qu, Gao and Fukumori, 2008



4. Annual subduction (S r 0.1 σ_θ as a function of winter mixed layer density.



Salinity maximum water at 24.5 σ_θ



Karstensen and Quadfasel, 2002
Mean annual subduction rate (m/yr)

Subduction of SSS-max water

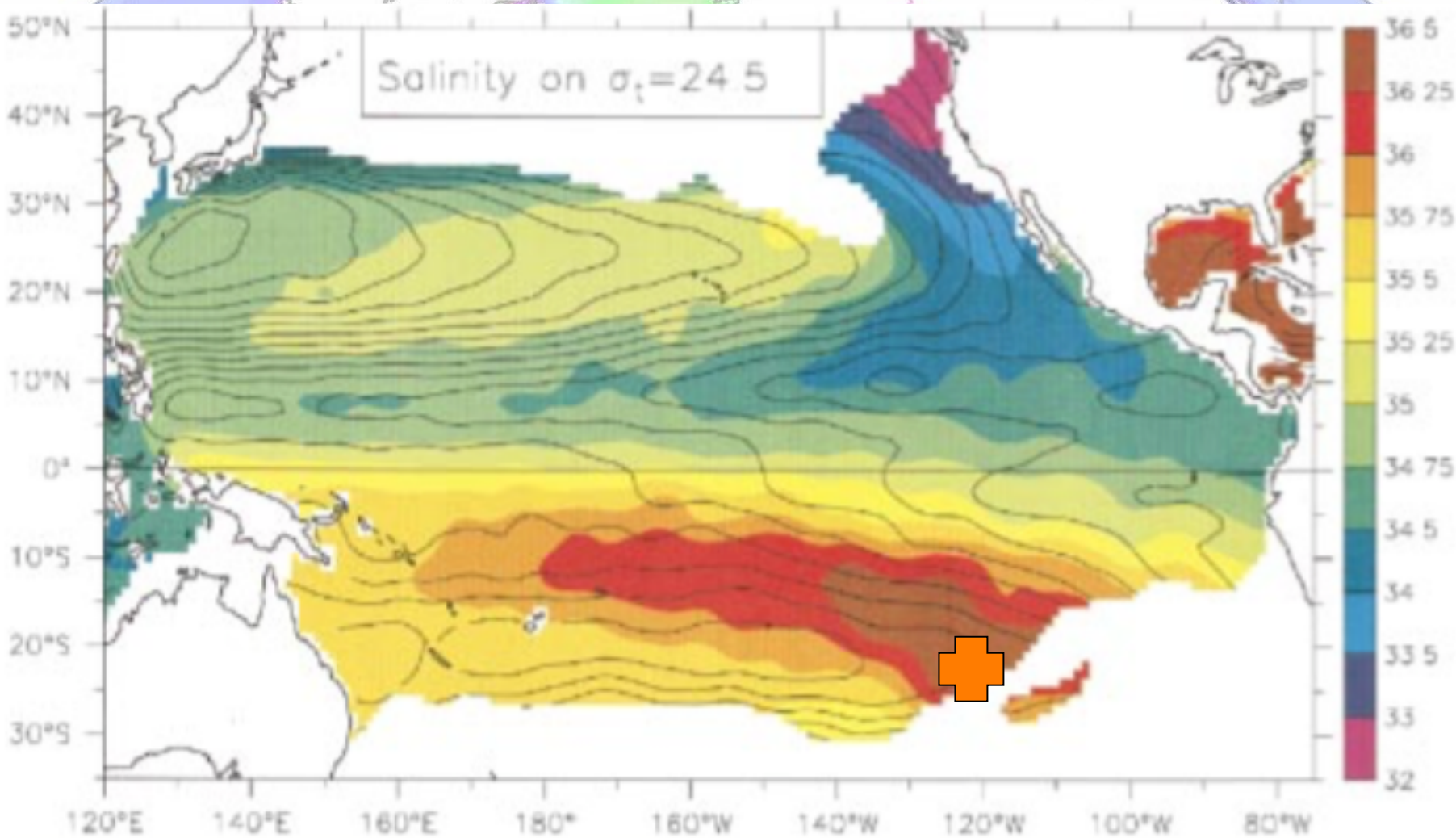


FIG. 5. Mean salinity and geostrophic streamlines on the surface σ_t = 24.5 from the Levitus et al. (1994) World Ocean Atlas. Top: Color shading indicates the depth of the σ_t = 24.5 surface (red = deeper). Bottom: Color shading indicates salinity on the σ_t = 24.5 surface (red

Kessler, 1999

SE Pacific Subtropical Mode Water

SEPSTMW core extent at density ~25.5 σ_θ

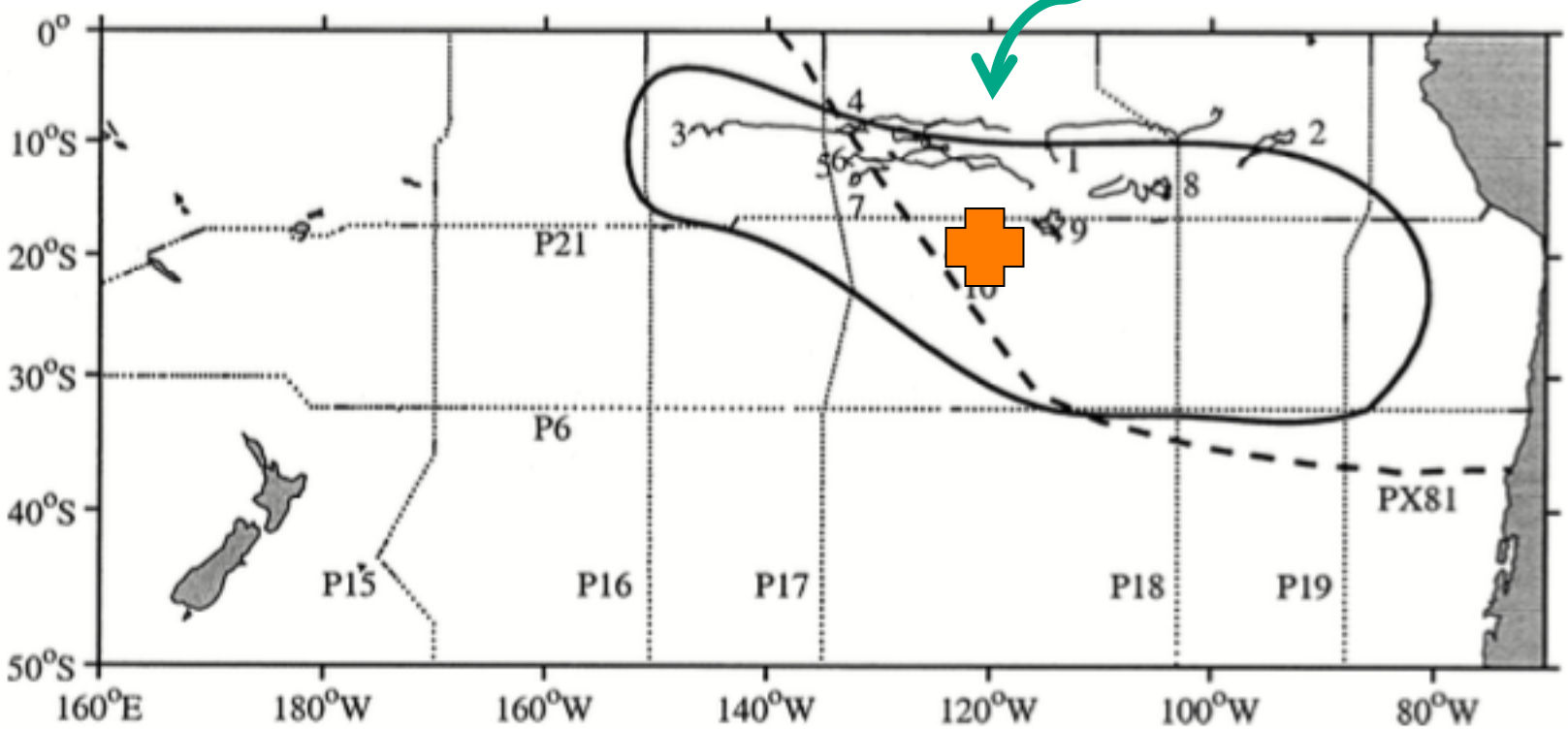


FIG. 1. Locations of vertical profile data used in this study: WOCE one-time CTD sections (dots labeled P6, P15–P19, P21), Argo float tracks (thin solid lines, labeled 1–10), and the Aug–Sep 1998 PX81 high-resolution XBT track line (thick dashed line). Spatial extent of SPESTMW (thick solid line) as determined by the WOCE sections is also shown.

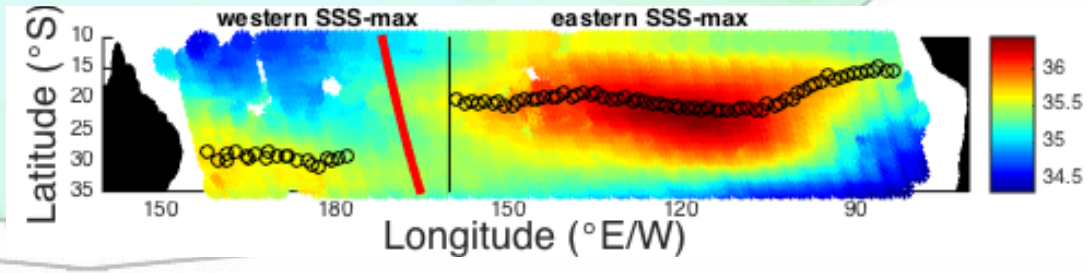
Wong and Johnson, 2003

Questions

- What processes form and maintain the SSS-maximum in the South Pacific (and by inference other ocean basins)?
- Why is it so stable?
- How does it interact with the underlying circulation?

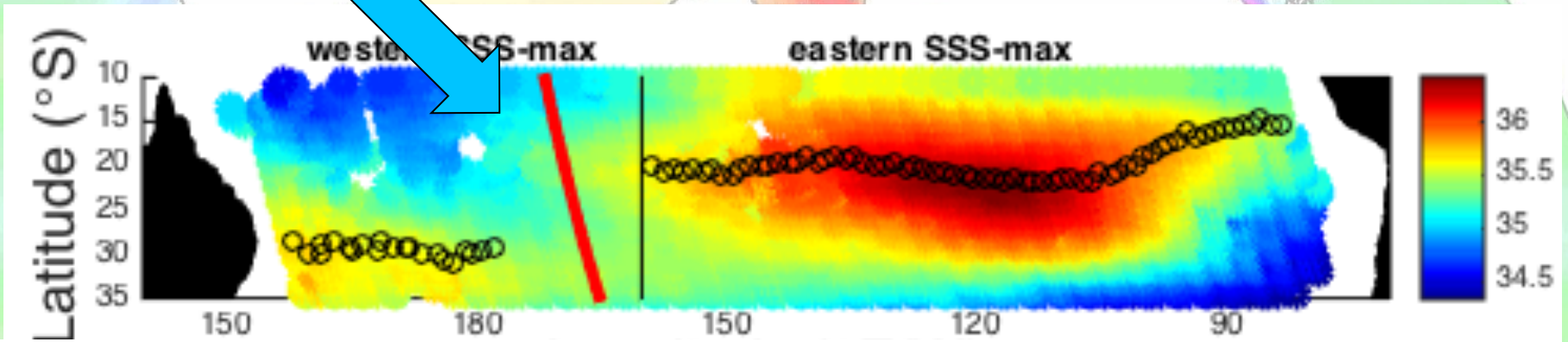
Datasets Used

- Aquarius, V4.0, L2, 31-Aug-2011 – 1-Sep-2014
- Evaporation – OAFlux
- Precipitation – TRMM 3B47 Daily
- MIMOC Climatology
- Reynolds SST
- OSCAR Surface Currents (1993-2014 mean)
- Freshwater forcing, $FWF=S_0(E-P)/h$



Mean SSS from Aquarius

SPCZ

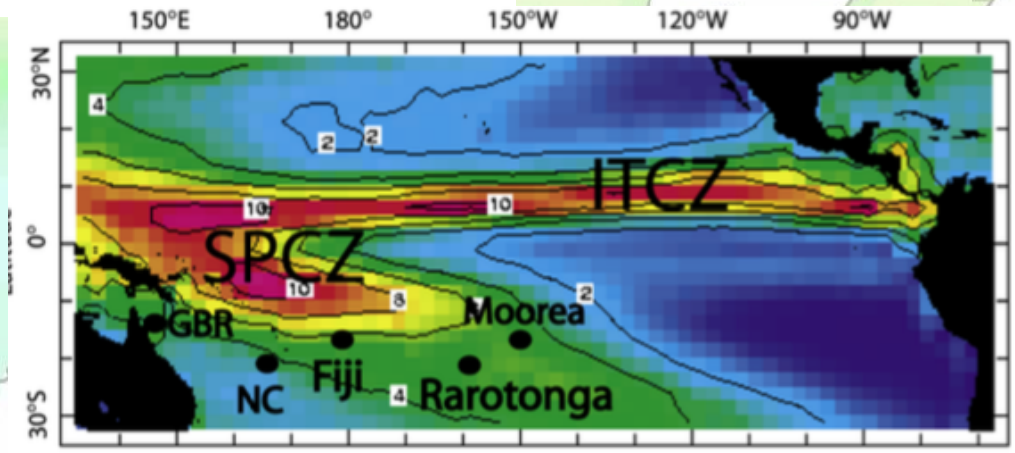


Black circles – maximum SSS along each L2 track

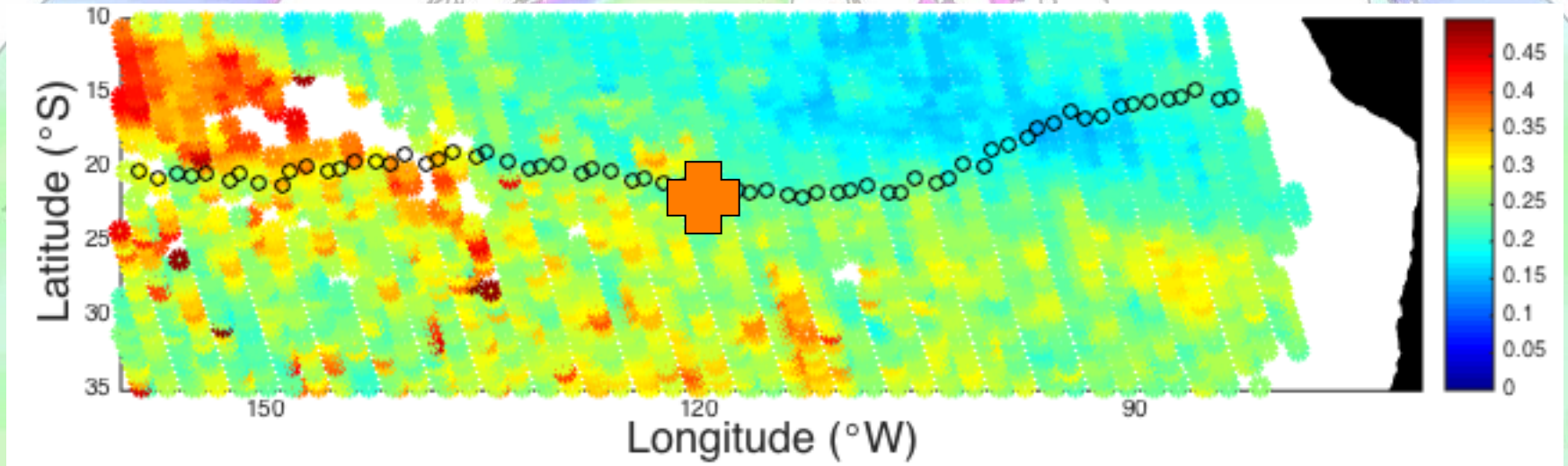
Core of SSS-maximum is at 21°S, 120°W

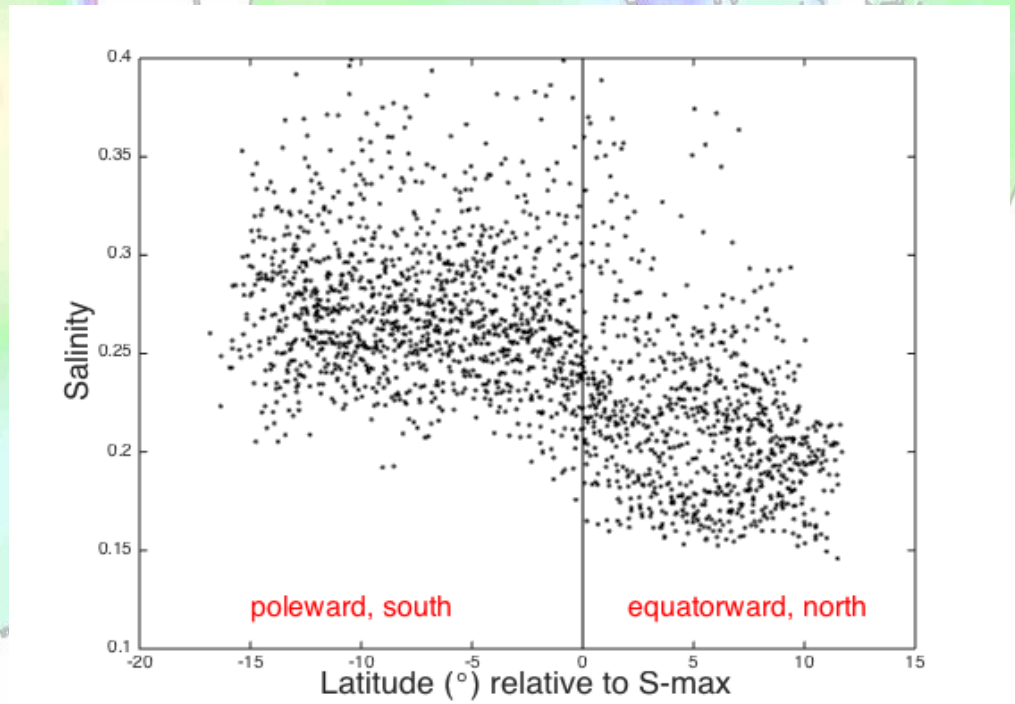
Note secondary surface maximum around 30°S, close to Australia

Linsley et al., 2006



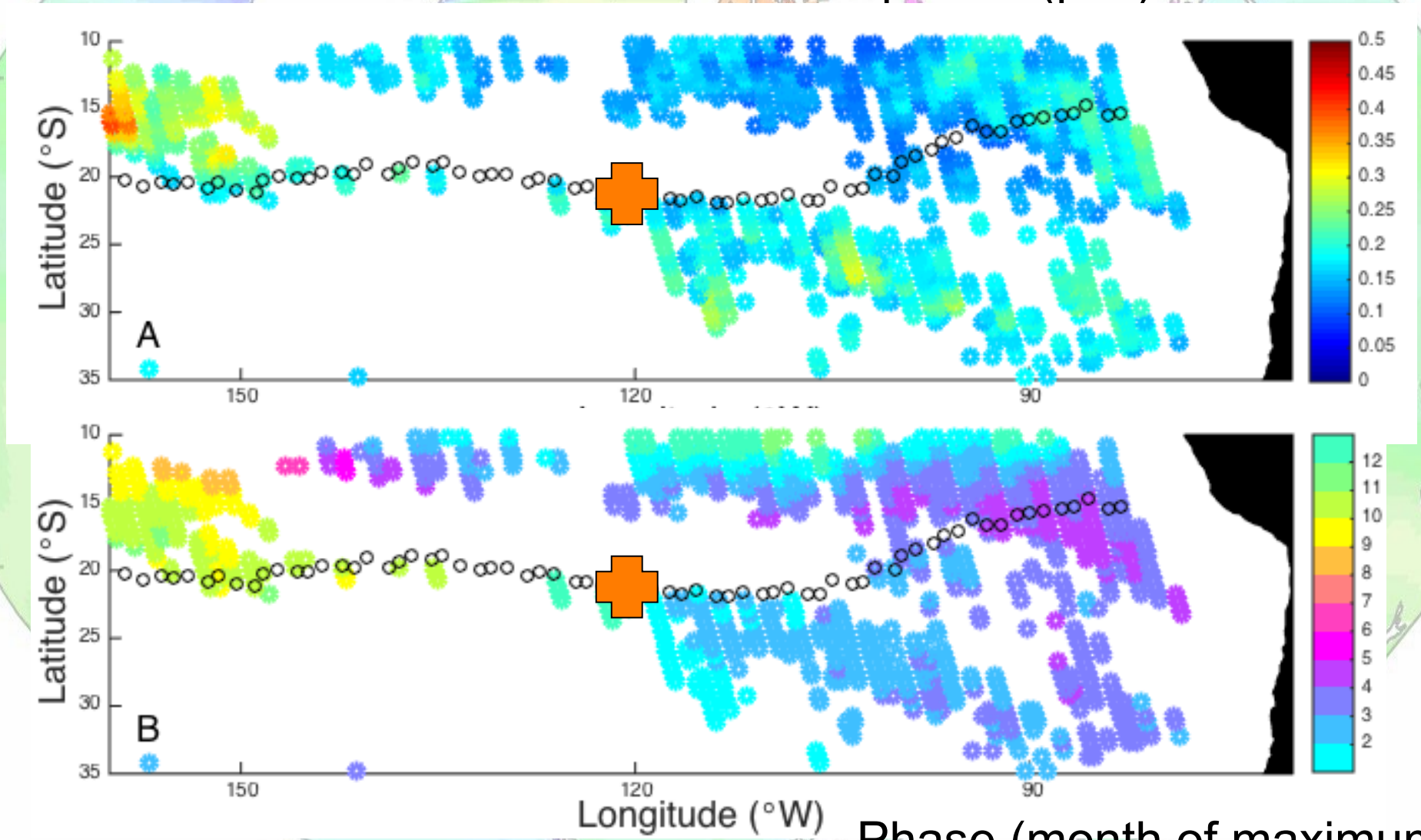
Standard Deviation of SSS from Aquarius





Seasonality of SSS from Aquarius

Amplitude (psu)

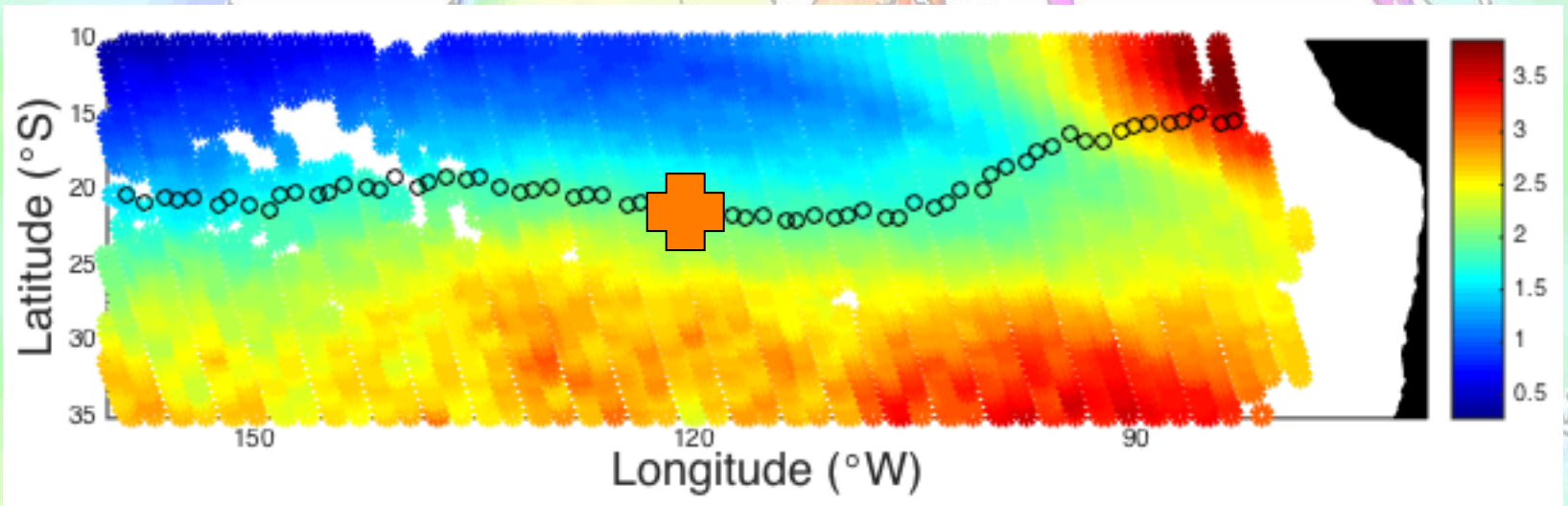


Phase (month of maximum)

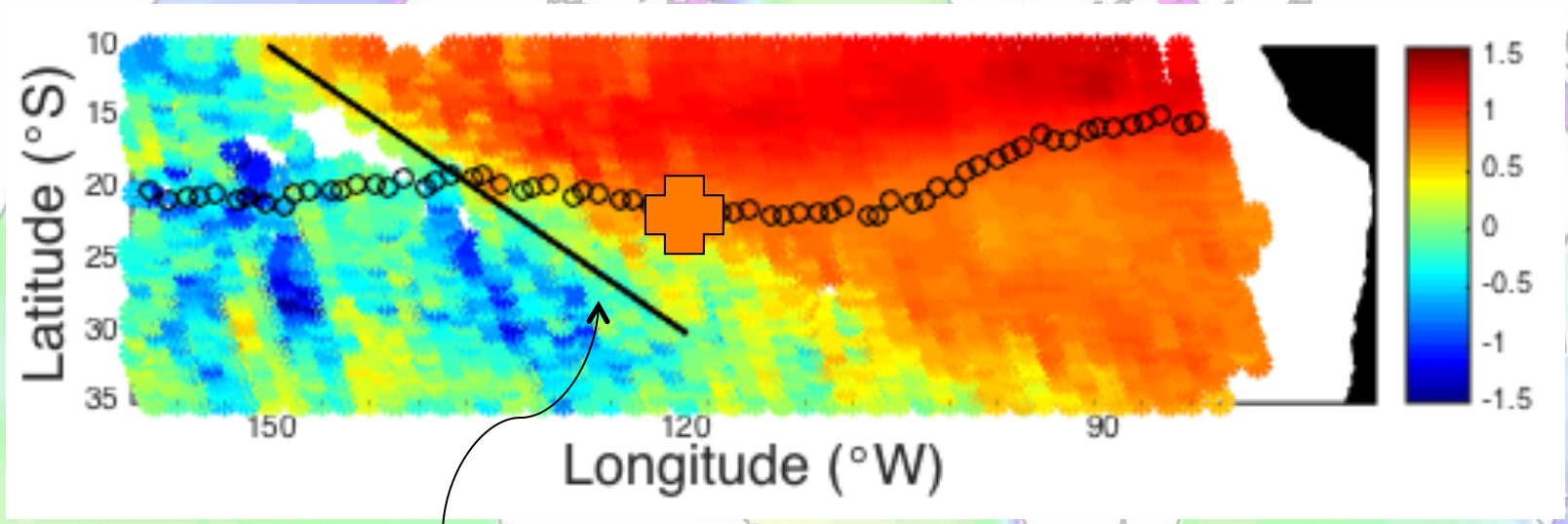
Blank area = not significant

Seasonality of SST

Amplitude (°C)

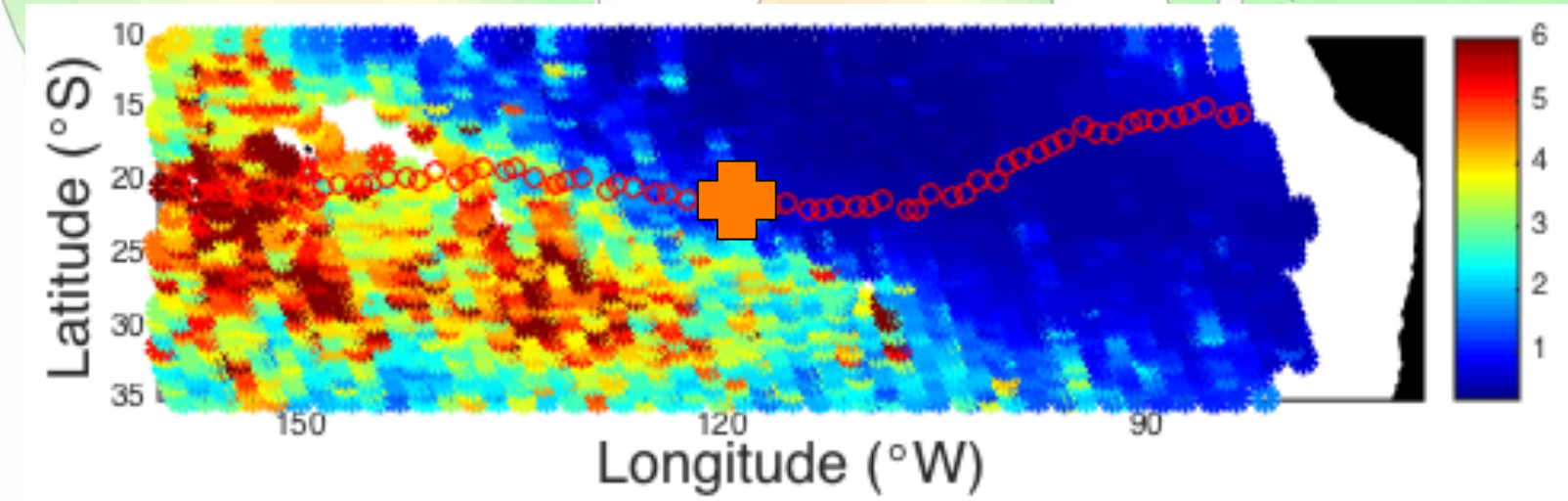


Freshwater forcing (psu/year)



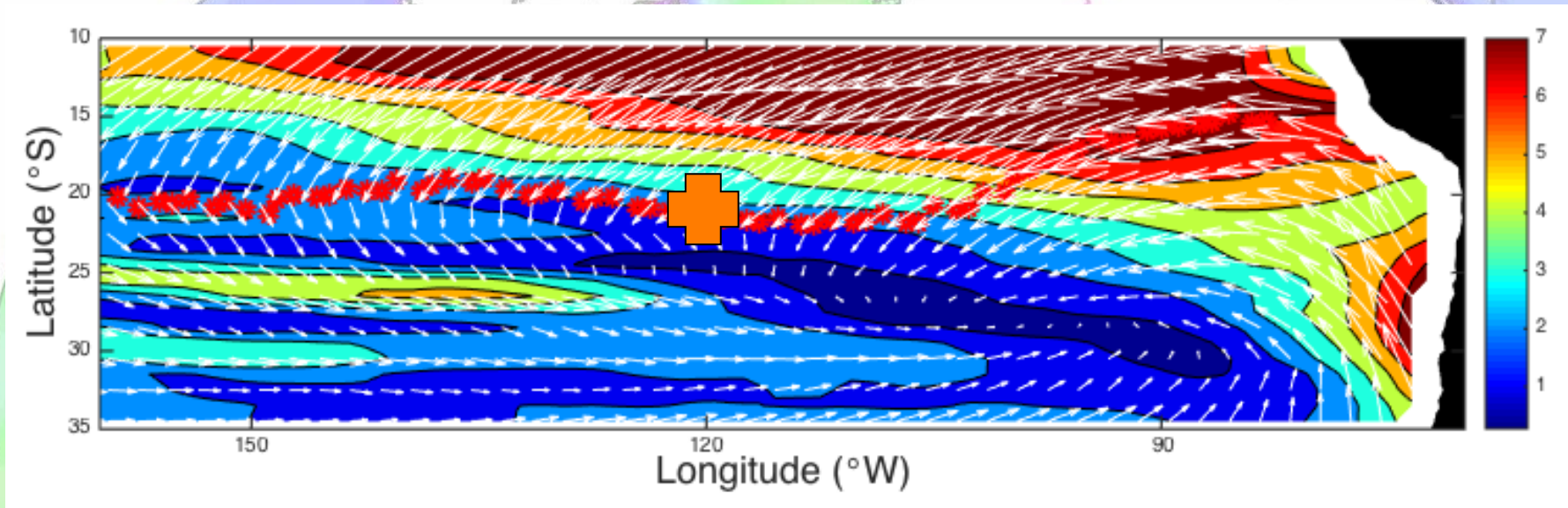
Mean

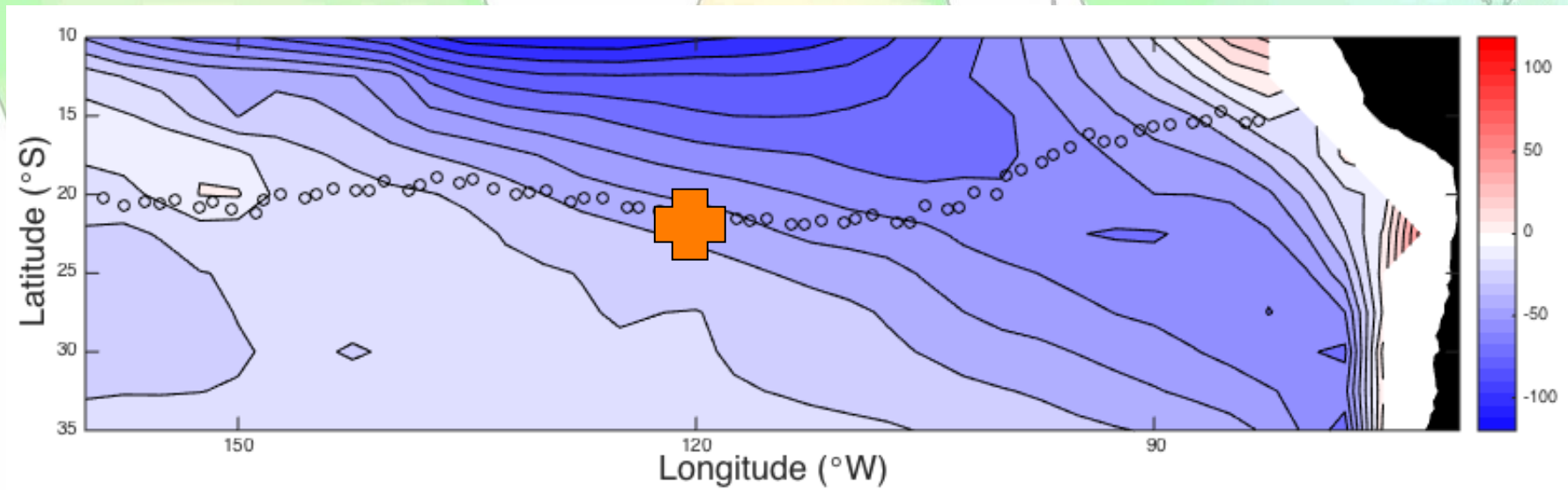
Eastern edge of the SPCZ



St. Deviation

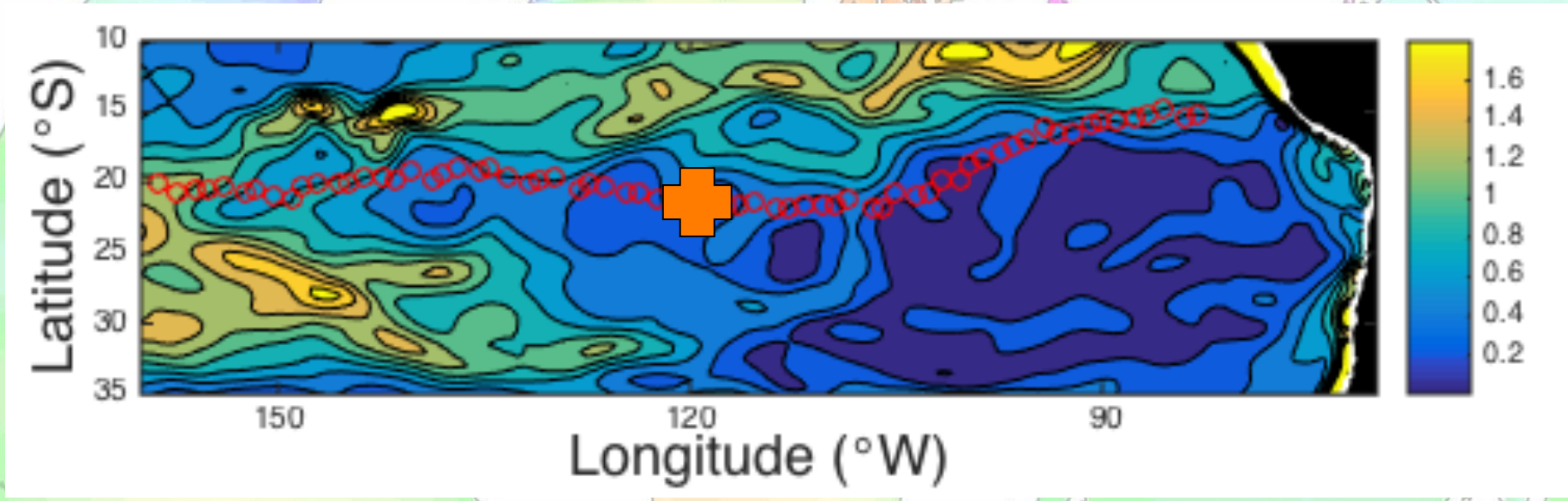
Surface currents





Ekman pumping from ERA-40

Surface density gradient



From MIMOC data

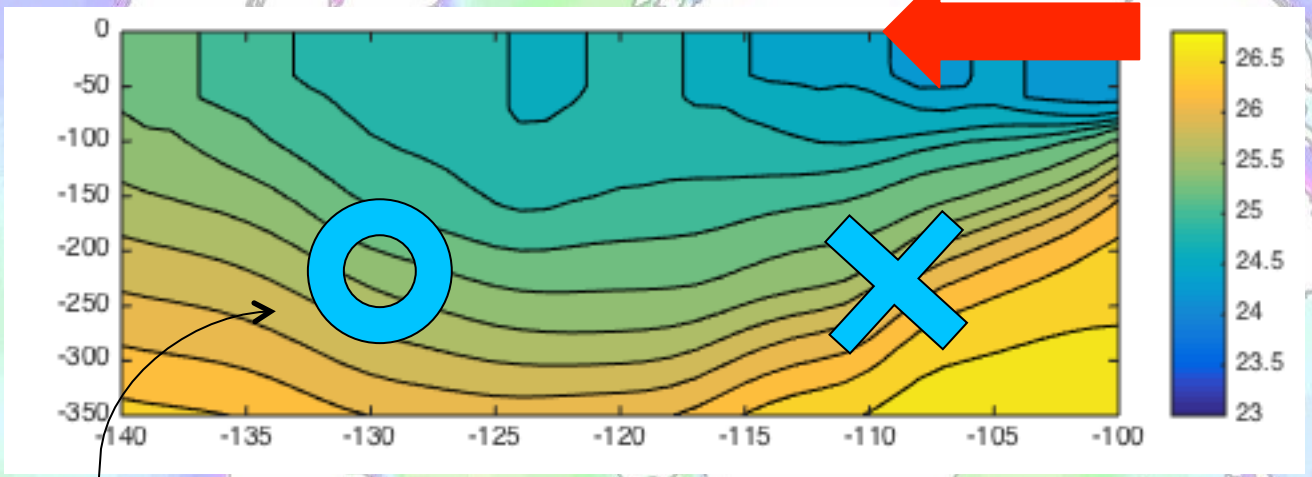
10^{-6} kg/m^3 / m

Summary of different conditions north and south of the SSS-max line

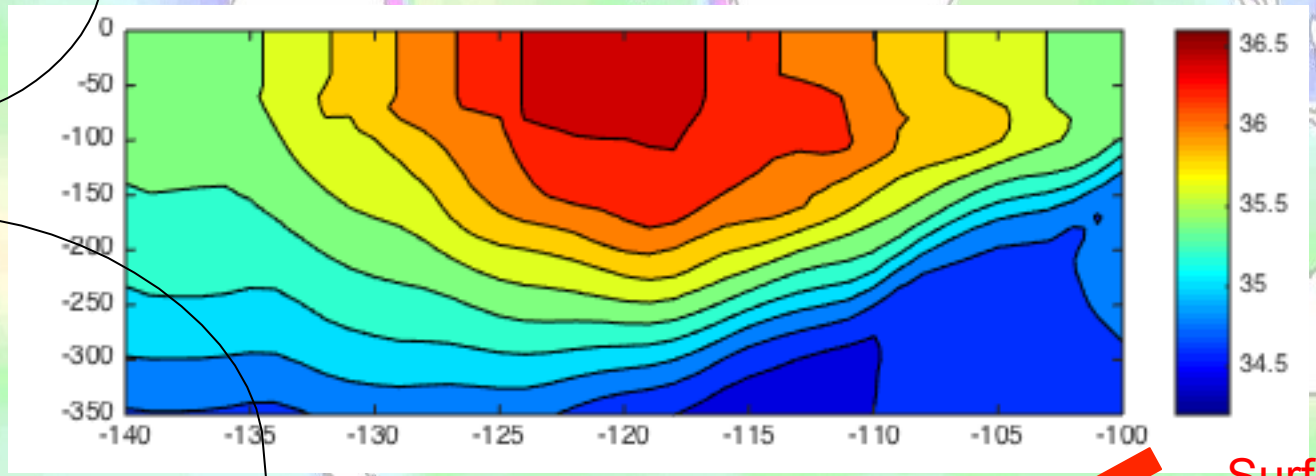
	North	South
SSS variability	Low	higher
SSS seasonal cycle	None	Weak but significant, max SSS in summer
Mean FWF	Highly evaporative, but steady	Balanced, but variable
Thermocline	Strong and shallow	Deeper and weaker
Surface flow	Convergent, southwestward and Ekman-dominated	Weak
Surface density gradient	T and S gradients reinforce	T and S gradients compensate
Subduction	Strong downward pumping	Weak
Interior flow	Northeastward	Northeastward turning northwestward

Vertical Sections

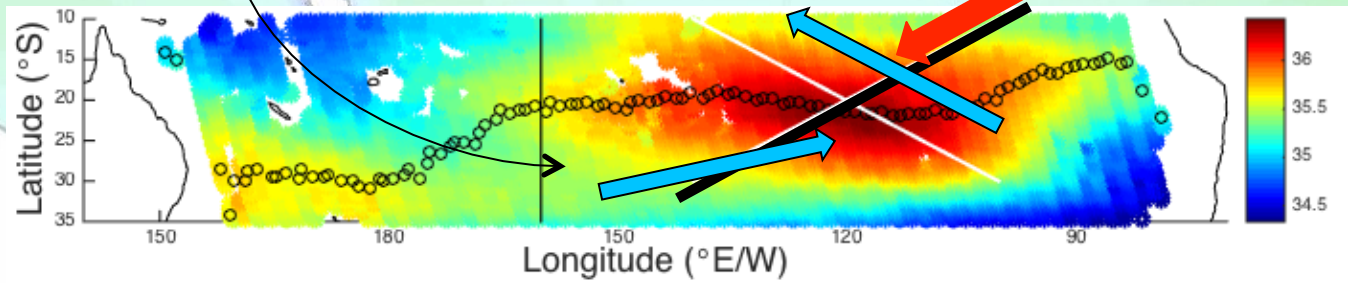
Surface flow



Interior flow

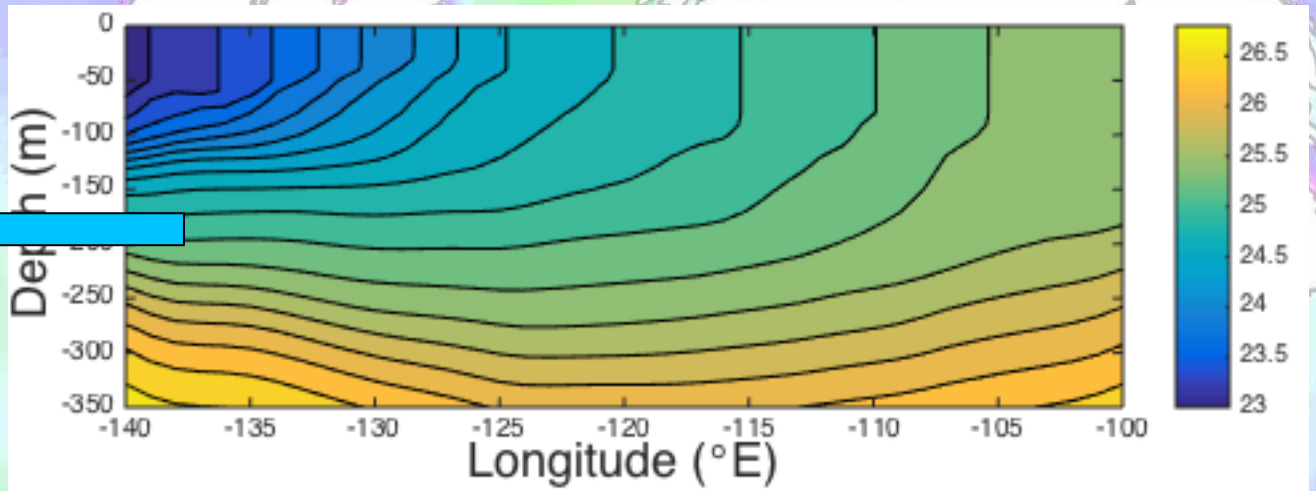


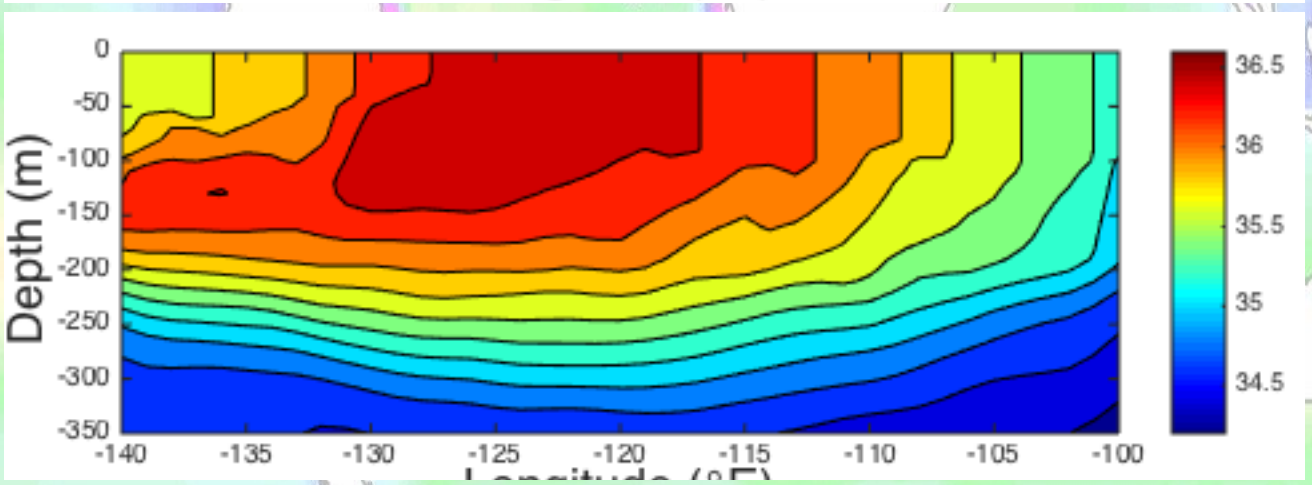
Surface flow

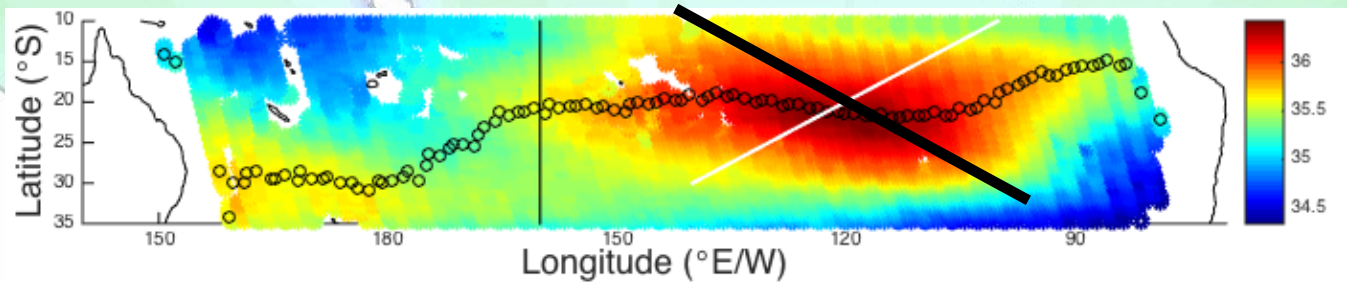


Vertical Sections

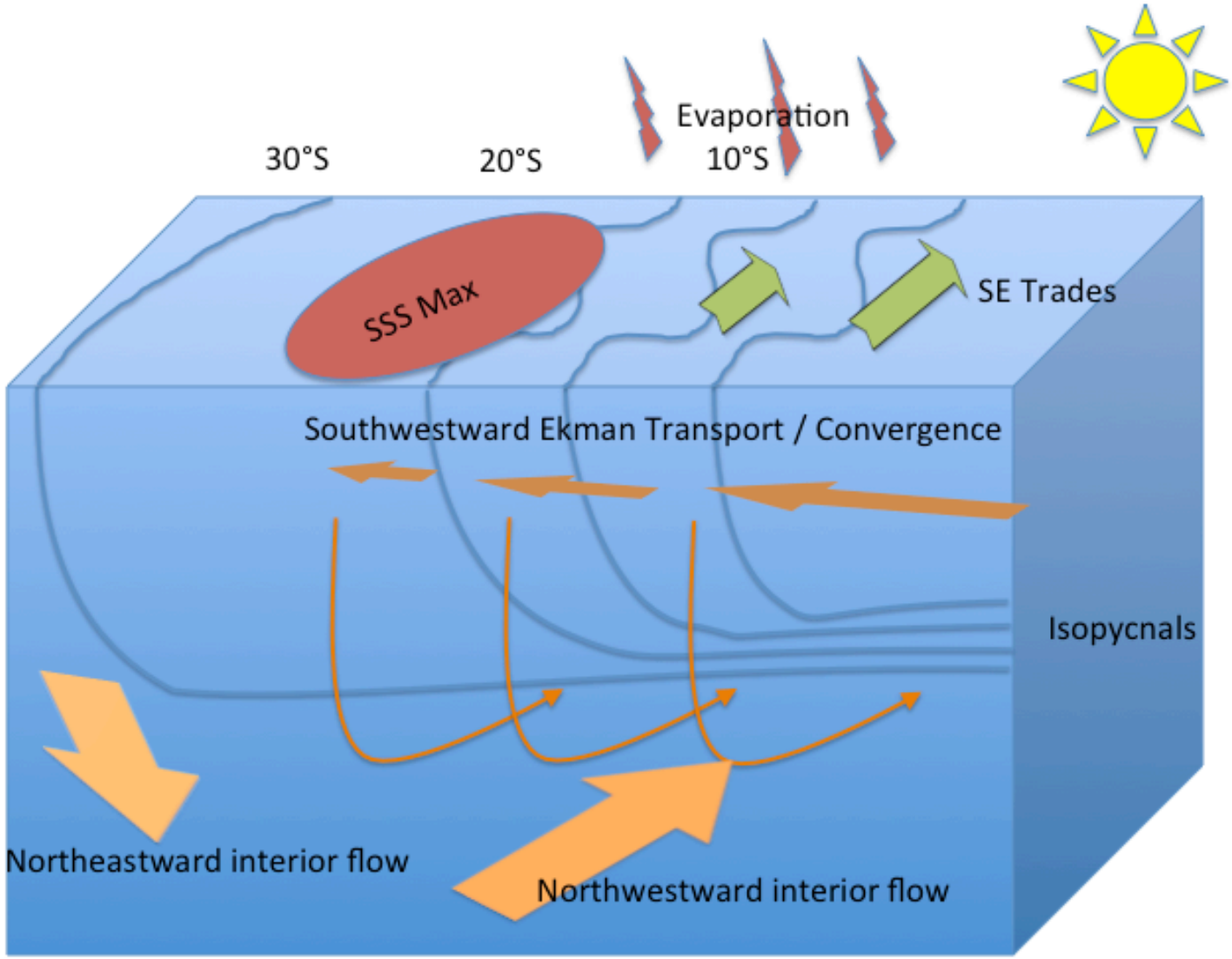
Spread of S-max water







Schematic Picture



Summary

- The SSS maximum is not a stagnation point, but a boundary between very different regimes

- In order to understand the location and formation of the SSS-max, you need to consider
    - the strength of evaporation
    - Ekman convergence
    - the enhancement of subduction by mesoscale turbulence
    - the underlying subsurface flow
    - The underlying distribution of water masses
    - the T/S compensation (or enhancement) of horizontal surface density gradients

- In other words, the entirety of the 3D circulation that moves water into under and through this feature

- Future studies could be done in a Lagrangian framework, focusing not as much on freshwater budgets, but on how budgets change as a function of proximity to the SSS-max line