Thermohaline variability of the upper ocean: documenting the specific role of salinity in the Tropics

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Colloque CNFG2 à Brest du 14 au 16 novembre

OUTLINE

General context

* PART-1 On the impact of salinity on the stratification and

  the dynamics of ENSO

  the edge of the Western Pacific Warm Pool

  the specific role of salinity stratification in N^2

** PART-2 On the importance of the small scale variability

  emergence of interest

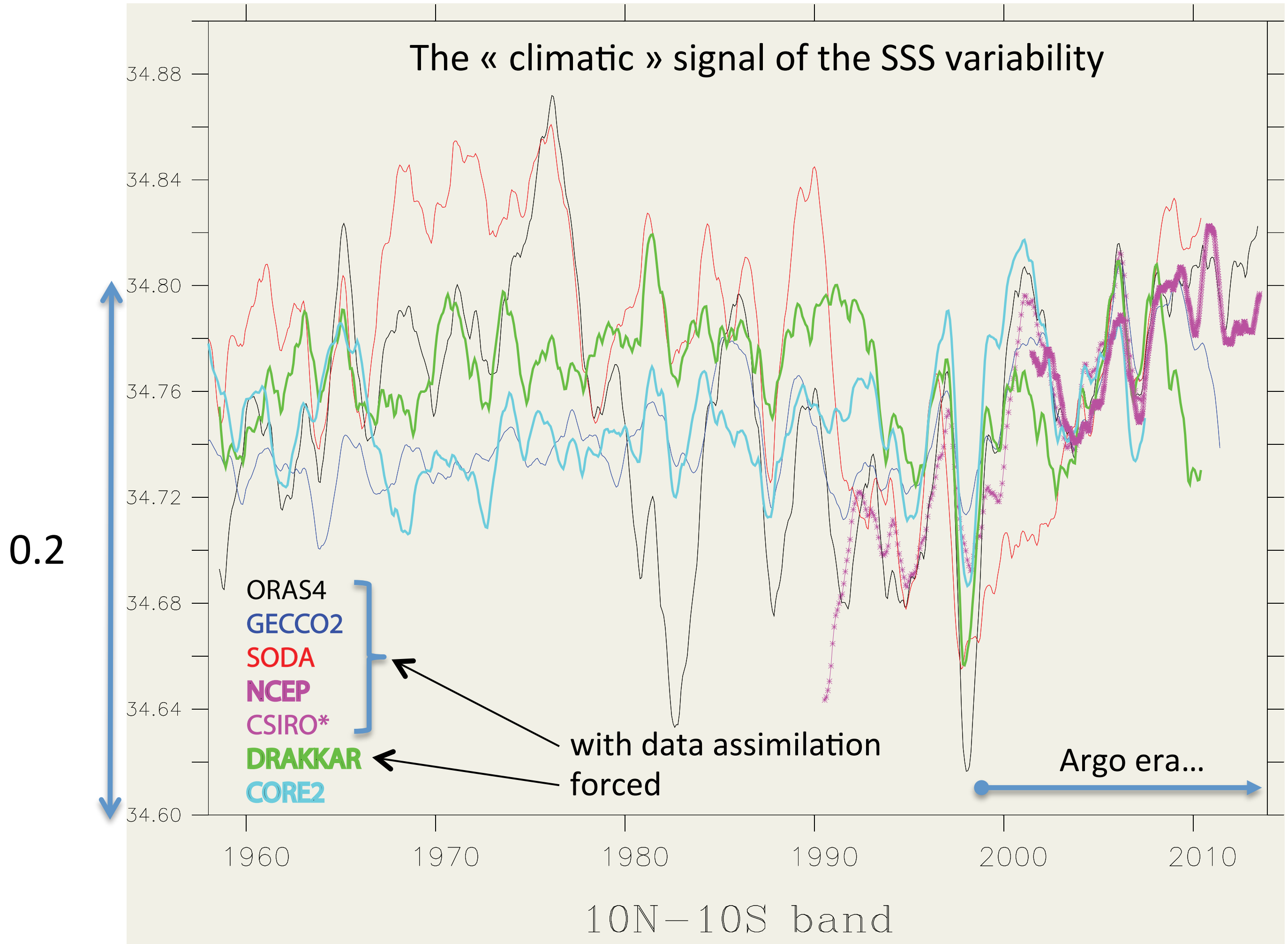
  stirring by the mesoscale eddies: a case study

  (relationships with the biogeochemical fields)

Conclusions

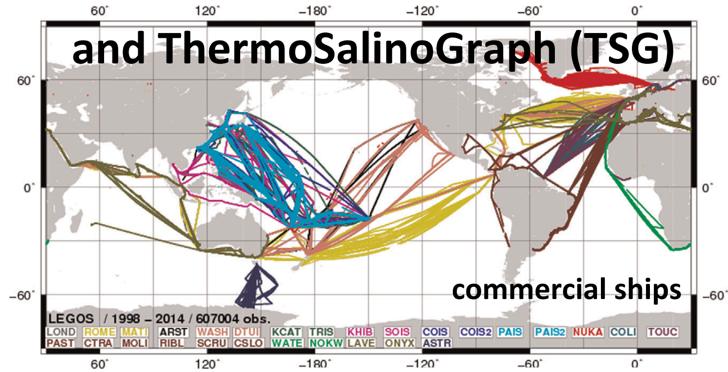
From the large-scale and long-term variability of SSS…

O'Kane et al., JGR 2016: Global view of the SSS variability resulting from intrinsic, internal and coupled processes

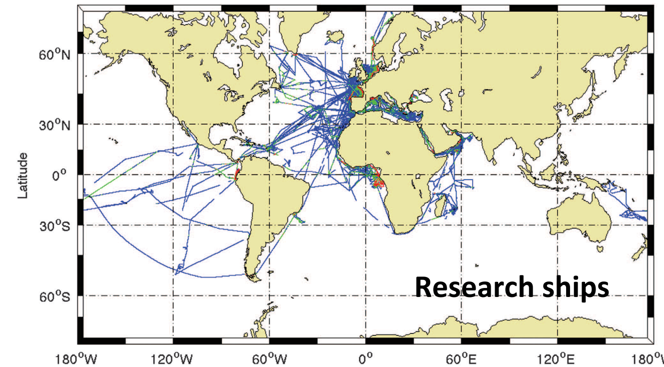


But *in situ* Observations contain also some small scale variations (unsolved)

(Riser et al. 2016)

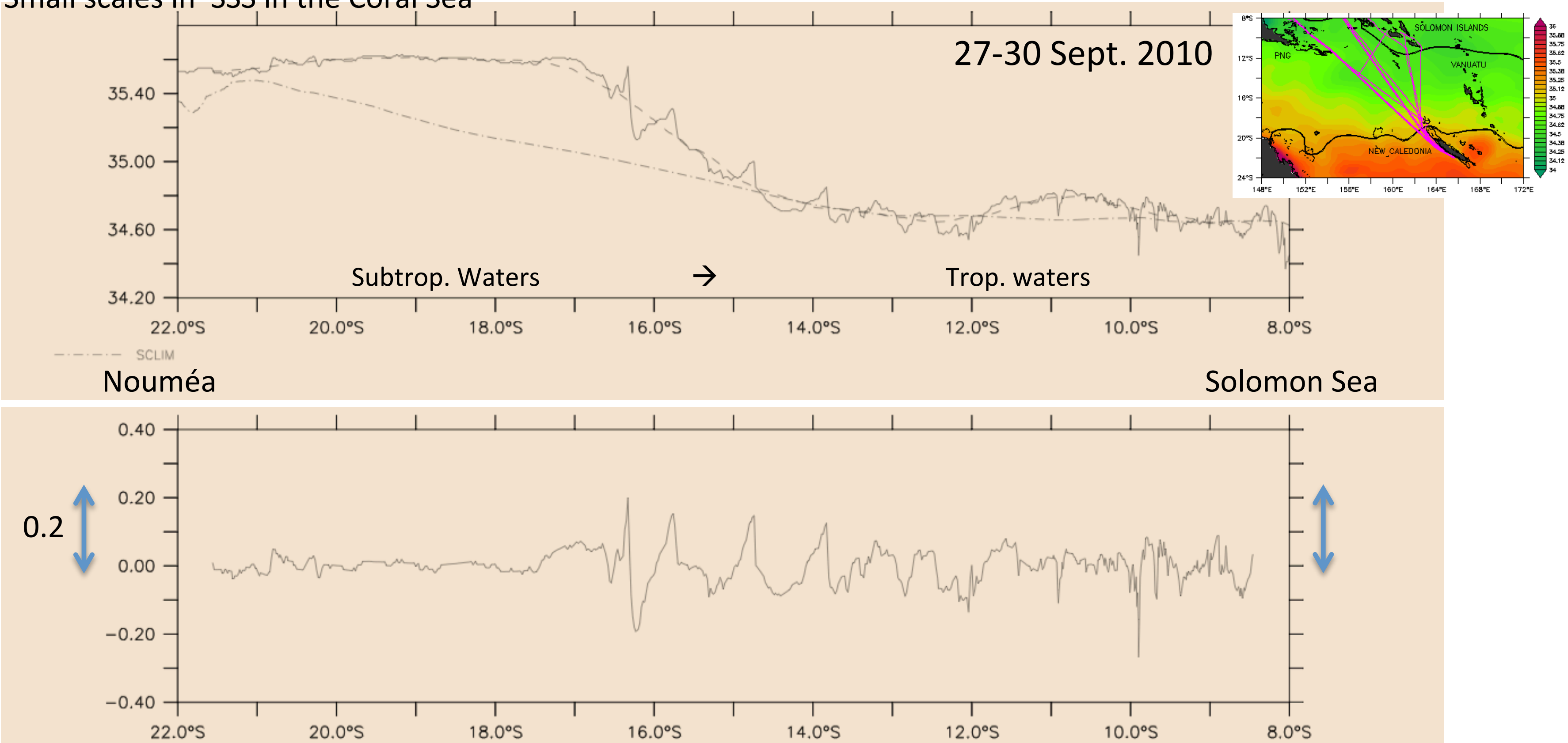


Alory et al. (2015)



Gaillard et al. (2015)

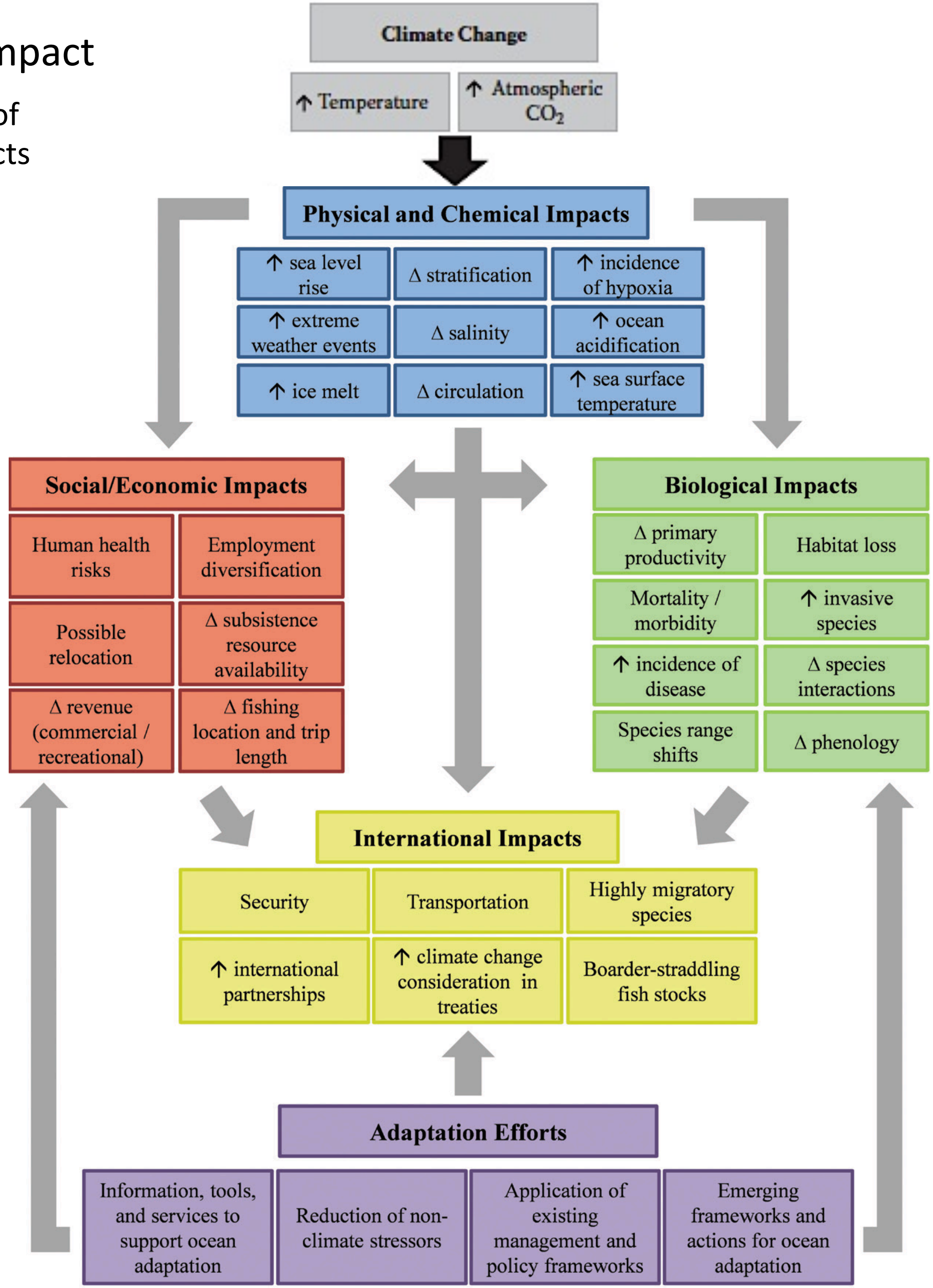
Small scales in SSS in the Coral Sea



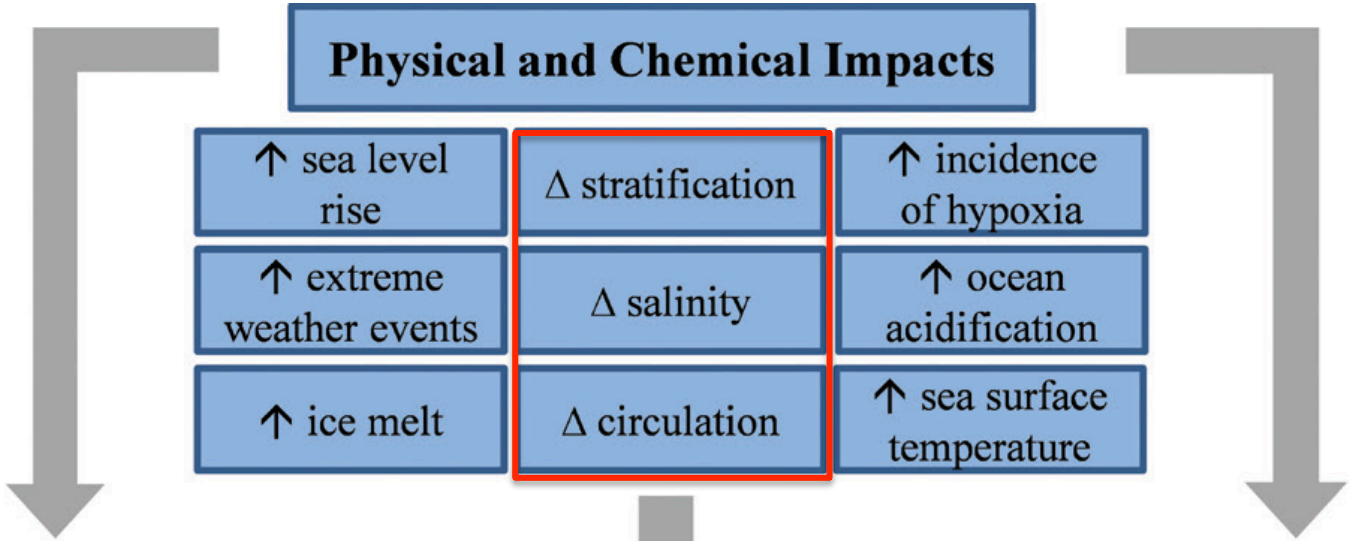
Maes et al. (JGR 2013)

Part 1. climate impact

Conceptual diagram of climate change impacts

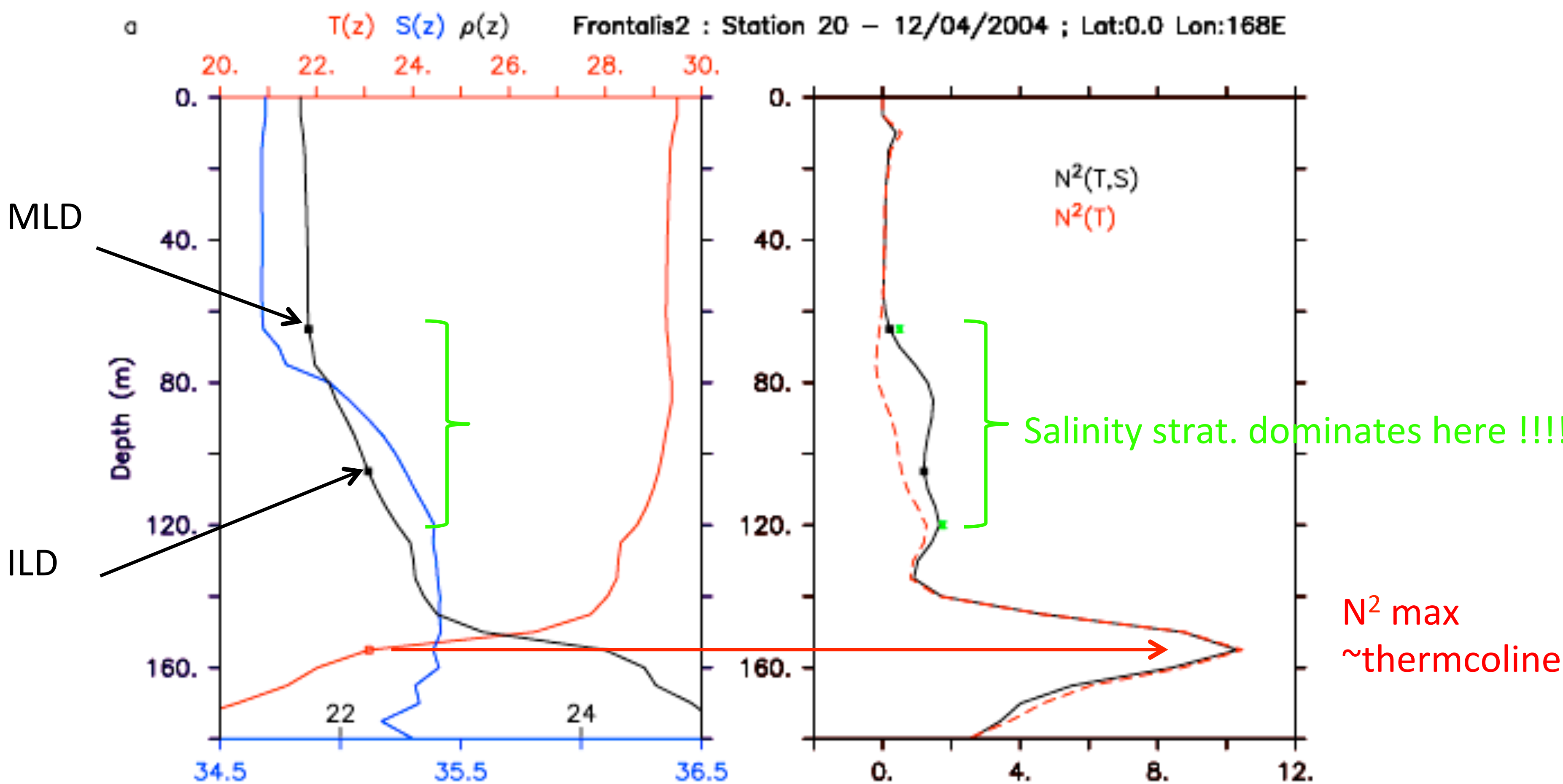


↑ indicates where climate change is predicted to increase the incidence or magnitude of that attribute,
Δ indicates attributes where the impact of climate change on that attribute is variable



Examples will be shown for the
dynamics of ENSO & Western Pacific Warm Pool,
detection of the edge of the WPWP,
the global variance of SSS
and salinity stratification in N^2

Barrier layer thickness or Ocean salinity stratification



Definition of the BL : pycnocline controlled by the salinity stratification (halocline within quasi-isothermal layer)

What are the effects of removing the BL in a coupled model framework?

Profiles from a coupled model

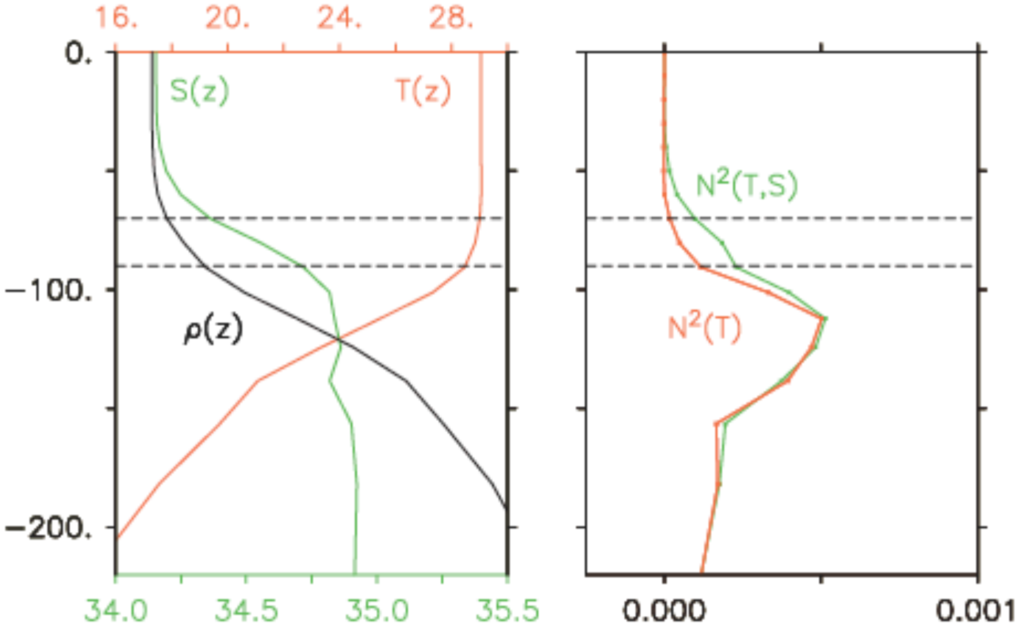
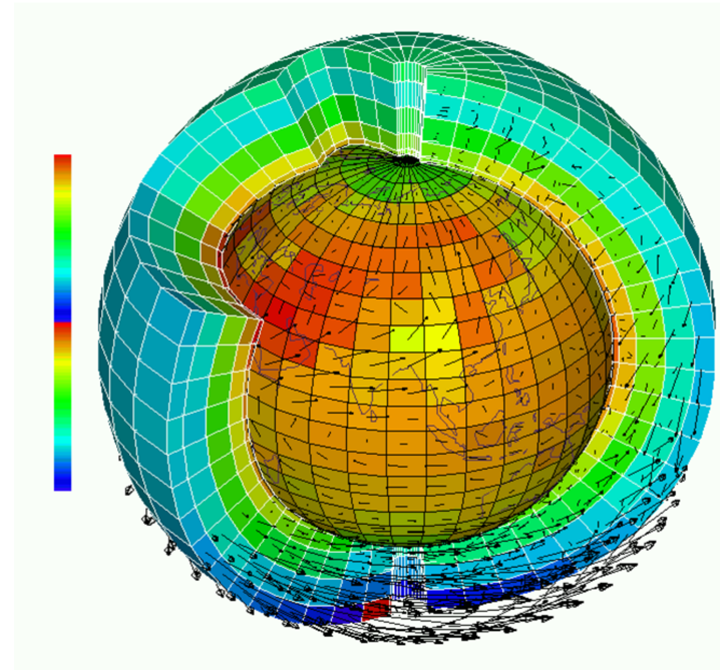


Figure 2. Vertical profiles of temperature, salinity and density (left), and of the resulting profiles of Brunt-Väisälä frequency (right) when the salinity stratification is considered or not. Dashed horizontal lines indicate the upper and lower limits of the barrier layer.



(more details on the coupled model may be found in Belamari et al. *JClim* 2003)

We defined <u>pertubated experiments</u> (PERT) as :

$N^2(T,S)$ ➢ $N^2(T)$:
In the TKE vertical diffusion scheme when
4°N [SST > 28°C] 4°S

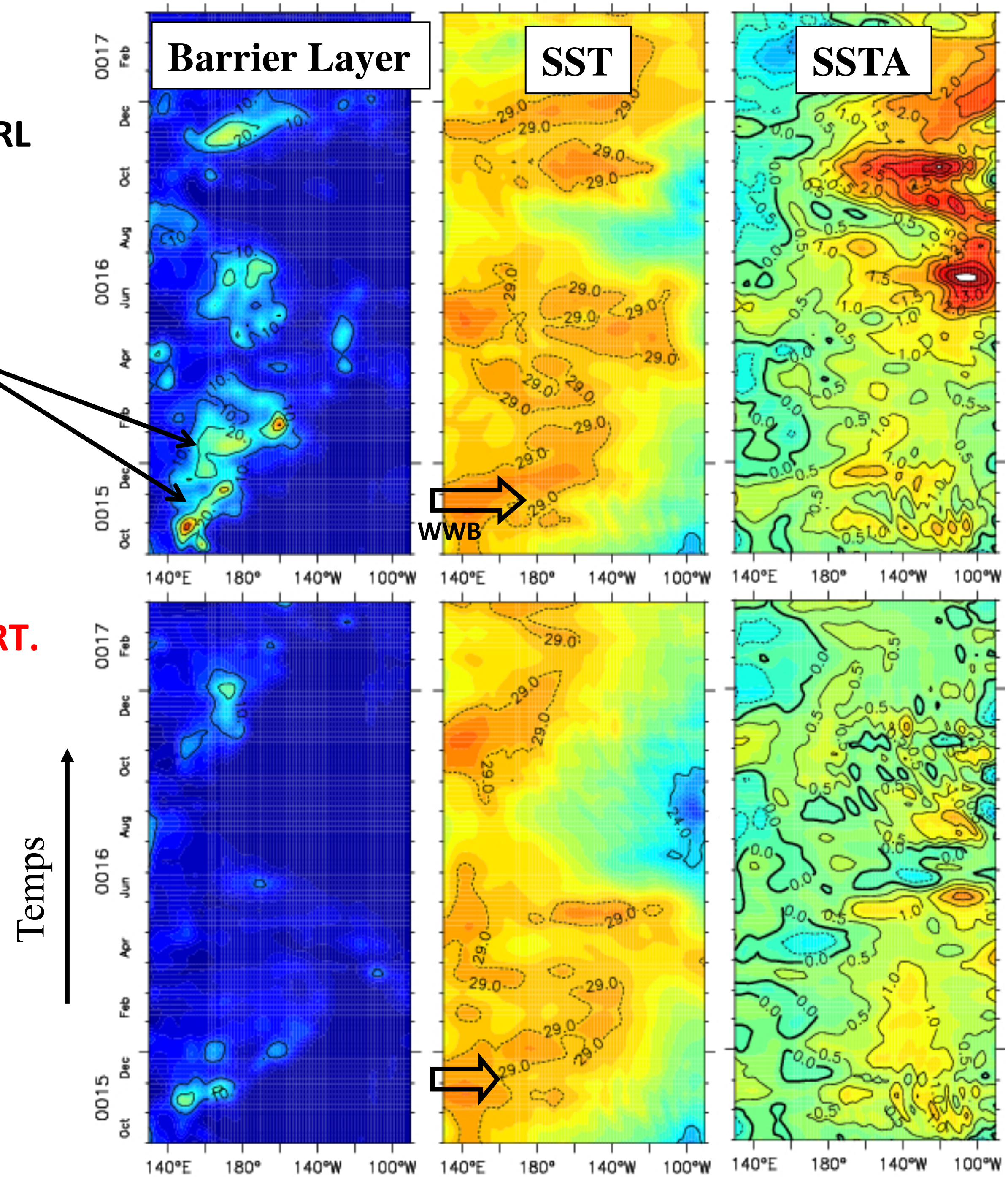
From Maes et al. (2002)

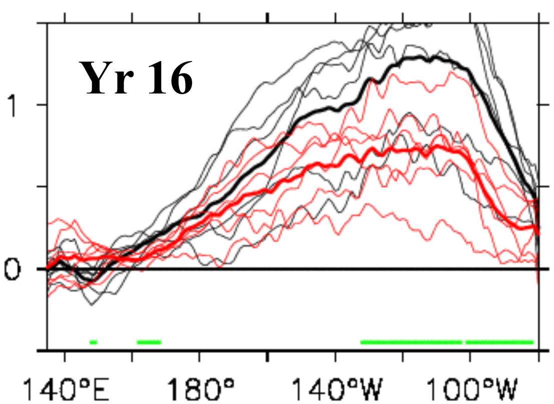
What are the effects of removing the BL in a coupled framework?

CTRL

BLT larger than 15 m

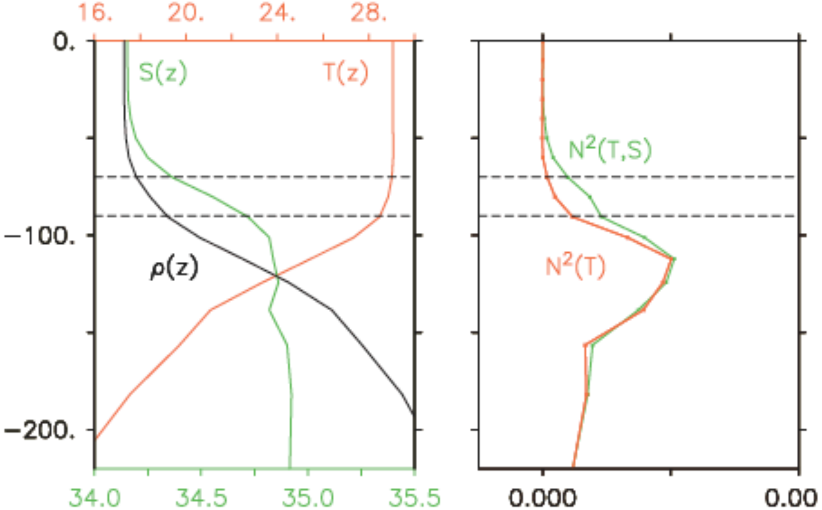
PERT.





(Maes et al. 2002)

What are the effects of removing the BL in a coupled framework?



Robust results obtained from the coupled model between the N^2(T,S) and N^2(T) simulations:

1. BLT plays a role on the depth of the mixed layer, with no systematic (cooling) impact on the SST (as may be expected),

2. BLT may affect the onset, the heat build-up and the mean state of the Pacific Ocean and ultimately ENSO dynamics

3. The most important O/A interactions for the warm pool region occur near its eastern edge (i.e., oceanic convergence zone),

The edge of the WPWP

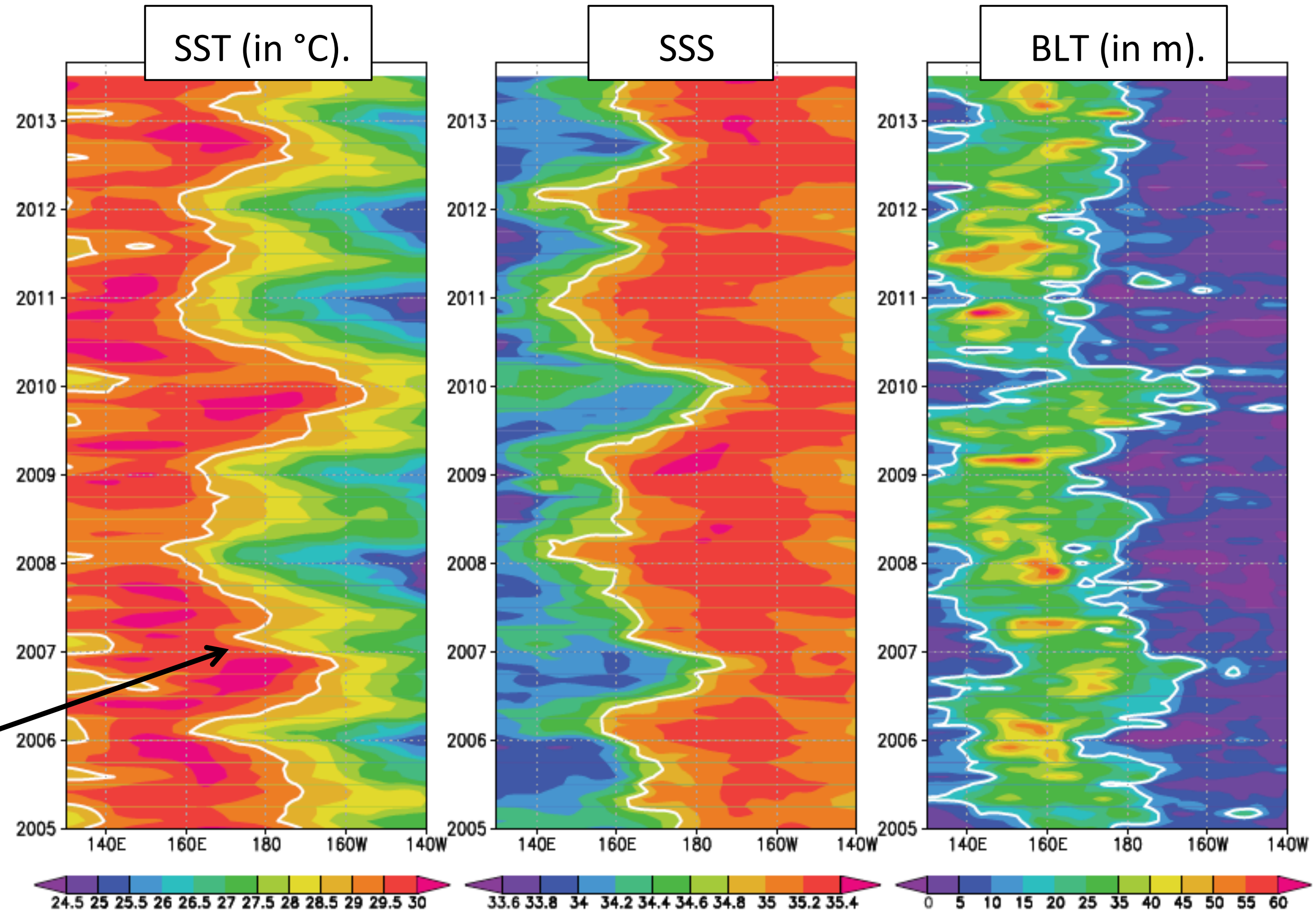
The ENSO «variability is generated primarily by a coupled ocean-atmosphere instability near the eastern edge of the western equatorial Pacific warm pool. » A. Clarke (2014)

Bosc et al. (2009) and Qu et al. (2014) confirm from direct observations based on Argo data that the BLT signal follows the expected dynamics near the WPWP.

Pt 1: SSS features are now well captured by satellite products.

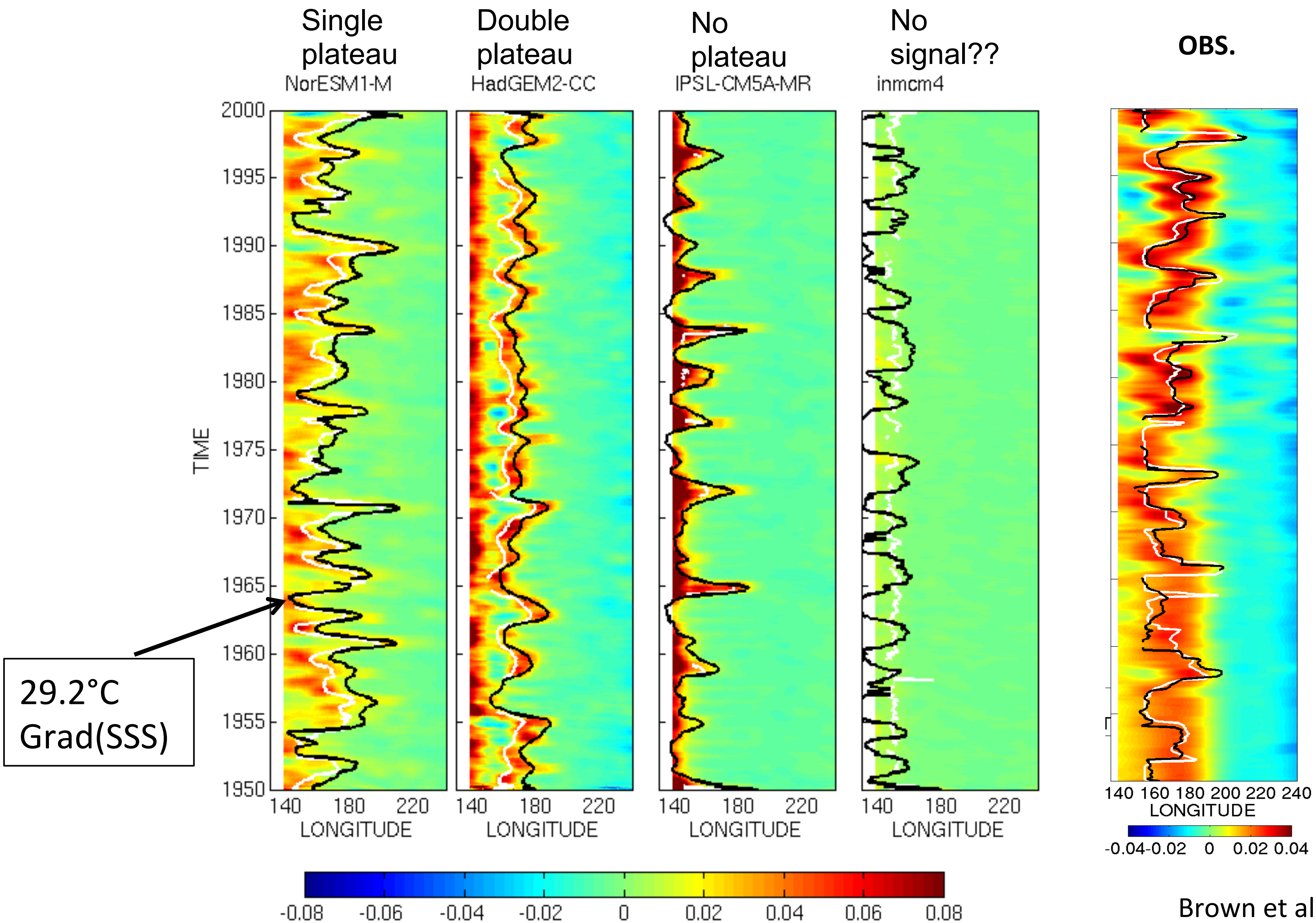
Pt 2: Eastern edge of the WPWP is also marked in the ocean color and biogeochemistry fields.

White lines mark the 29°C, 34.8 and 15 m values



(Qu et al. 2014)

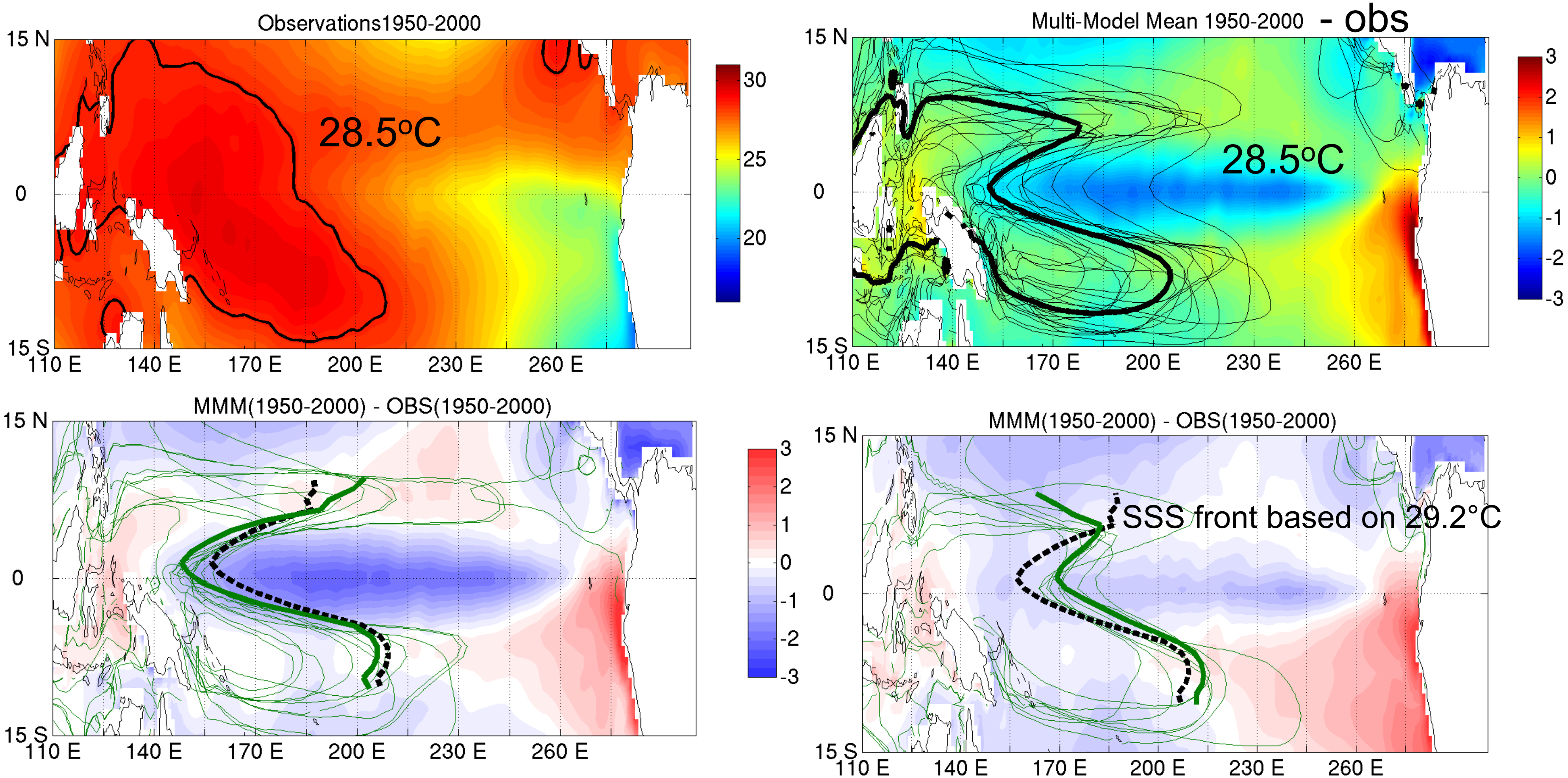
How well is the eastern edge of the WPWP reproduced by coupled models?
The simulation of the WPWP edge is examined in 19 models from CMIP5



Brown et al. (2014)

2. Results on detection of the edge of the WPWP

SST Observations 1950-2000 | SST anomaly Multi-model mean



New metric – the warm pool edge is better simulated in CMIP5 than if assessed only on temperature. The eastern edge of the WPWP is crucial to represent the full dynamical response at the scale of the Pacific basin.

↑ indicates where climate change is predicted to increase the incidence or magnitude of that attribute,
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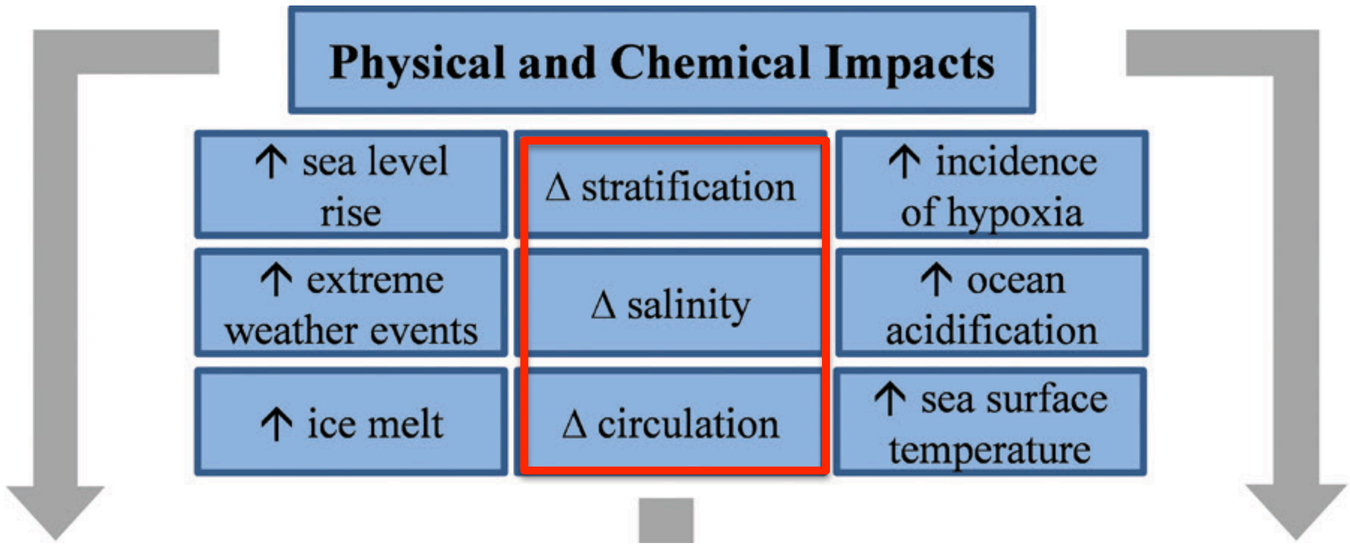

Examples will be shown for the
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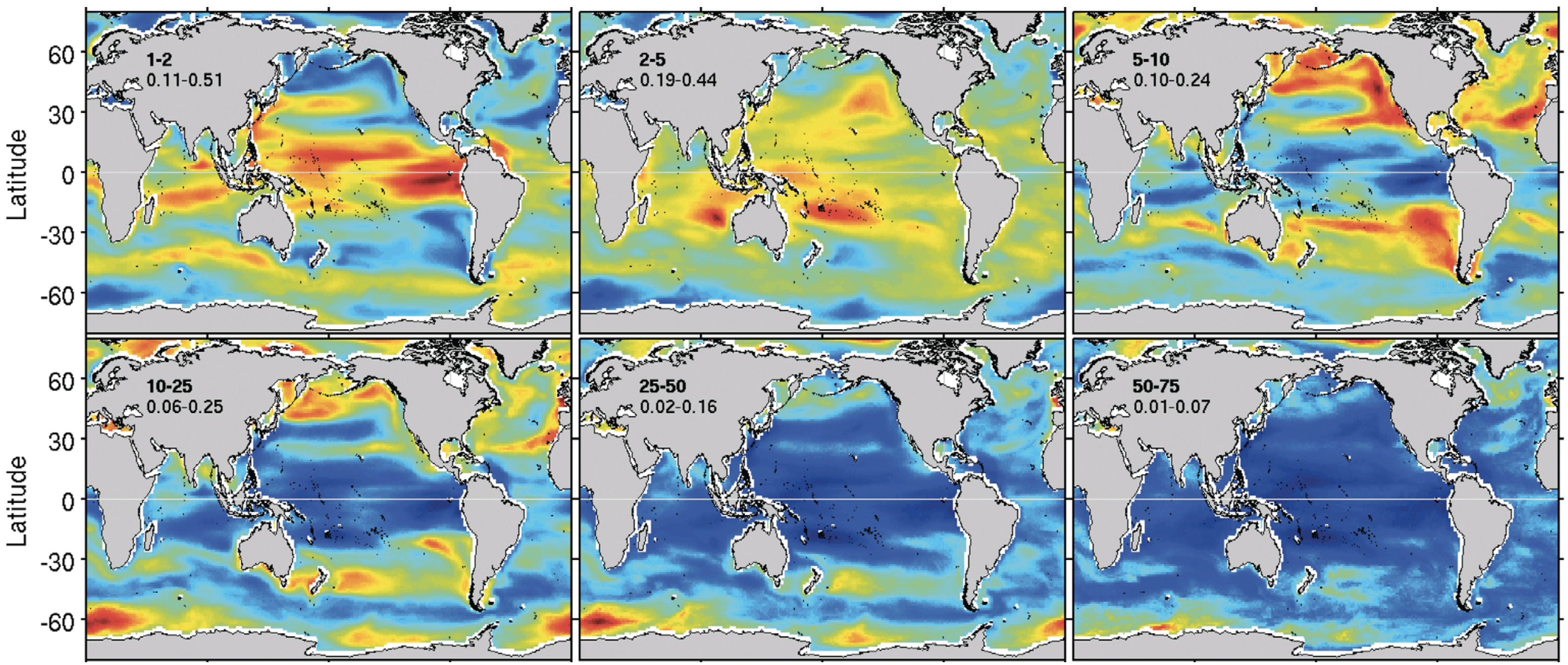
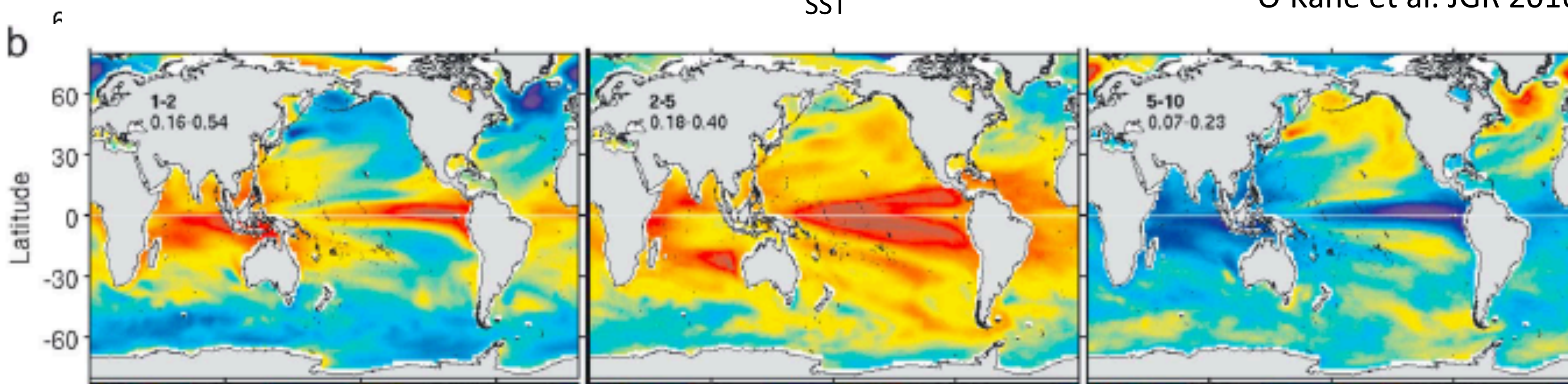
CMIP5 ensemble mean fractional inband variance of internal SSS variability

SSS



O'Kane et al. JGR 2016

SST



Monselesan et al. GRL 2016

2.3 Examples for the salinity stratification in N^2

Q3: Are we able to determine the precise role of the salinity stratification?

Methodology:

$$N^2(T,S) = -\frac{g}{\rho}\frac{\partial \rho}{\partial z} \approx \left(g\alpha\frac{\partial T}{\partial z} - g\beta\frac{\partial S}{\partial z}\right)$$

$$= N^2{}_T(T,S) + N^2{}_S(T,S)$$

where

$$N^2{}_T(T,S) = g\alpha\frac{\partial T}{\partial z}$$

$$N^2{}_S(T,S) = N^2(T,S) - N^2{}_T(T,S)$$

$$\alpha = -\rho^{-1}\frac{\partial \rho}{\partial T}$$

$$\beta = \rho^{-1}\frac{\partial \rho}{\partial S}$$

We define the Ocean Salinity Stratification (OSS) as:

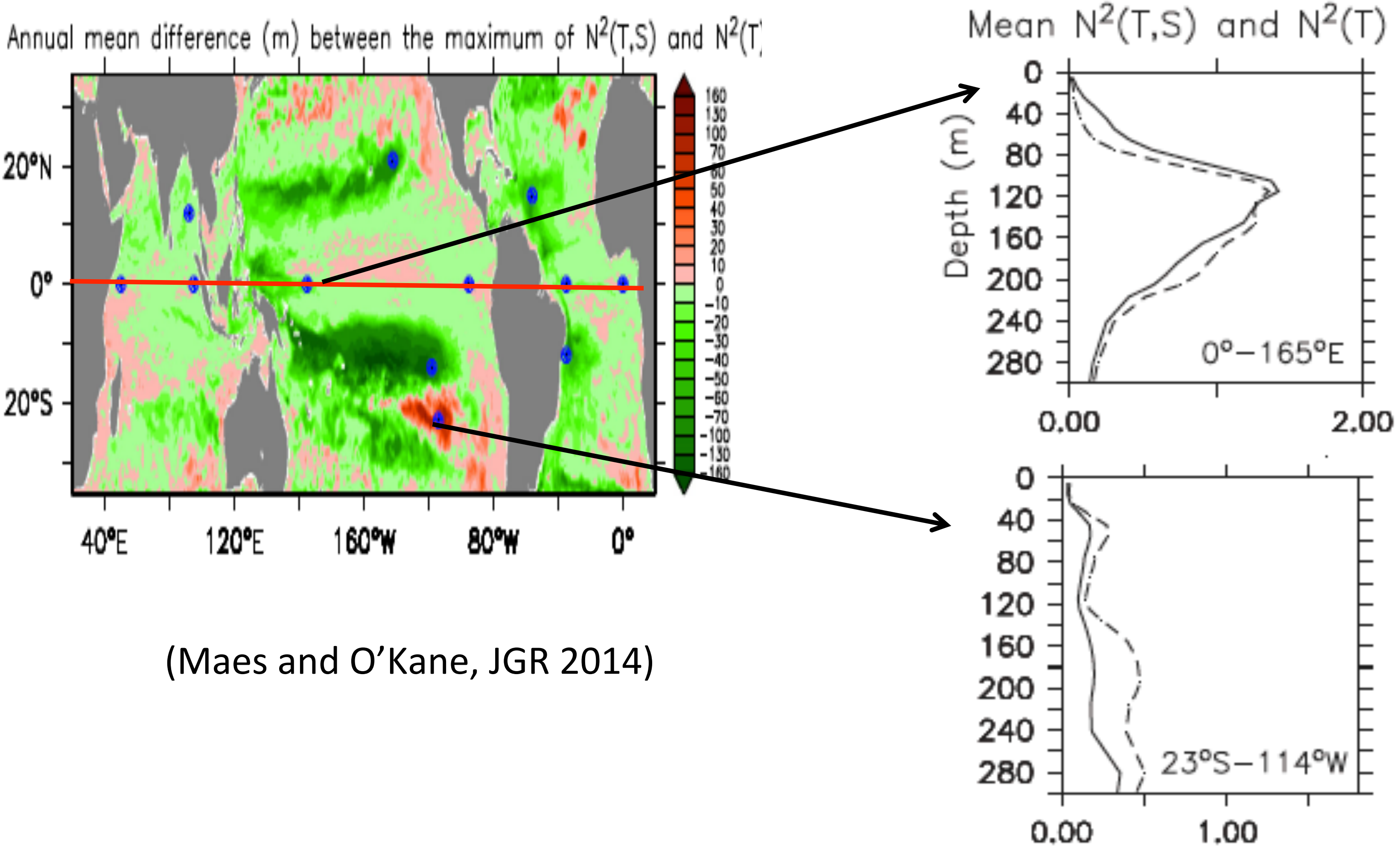
$$OSS = \langle N^2(T,S) - N^2(T)\rangle_{0-300\text{m}}$$

where

$$N^2(T,S) - N^2(T) > 0$$

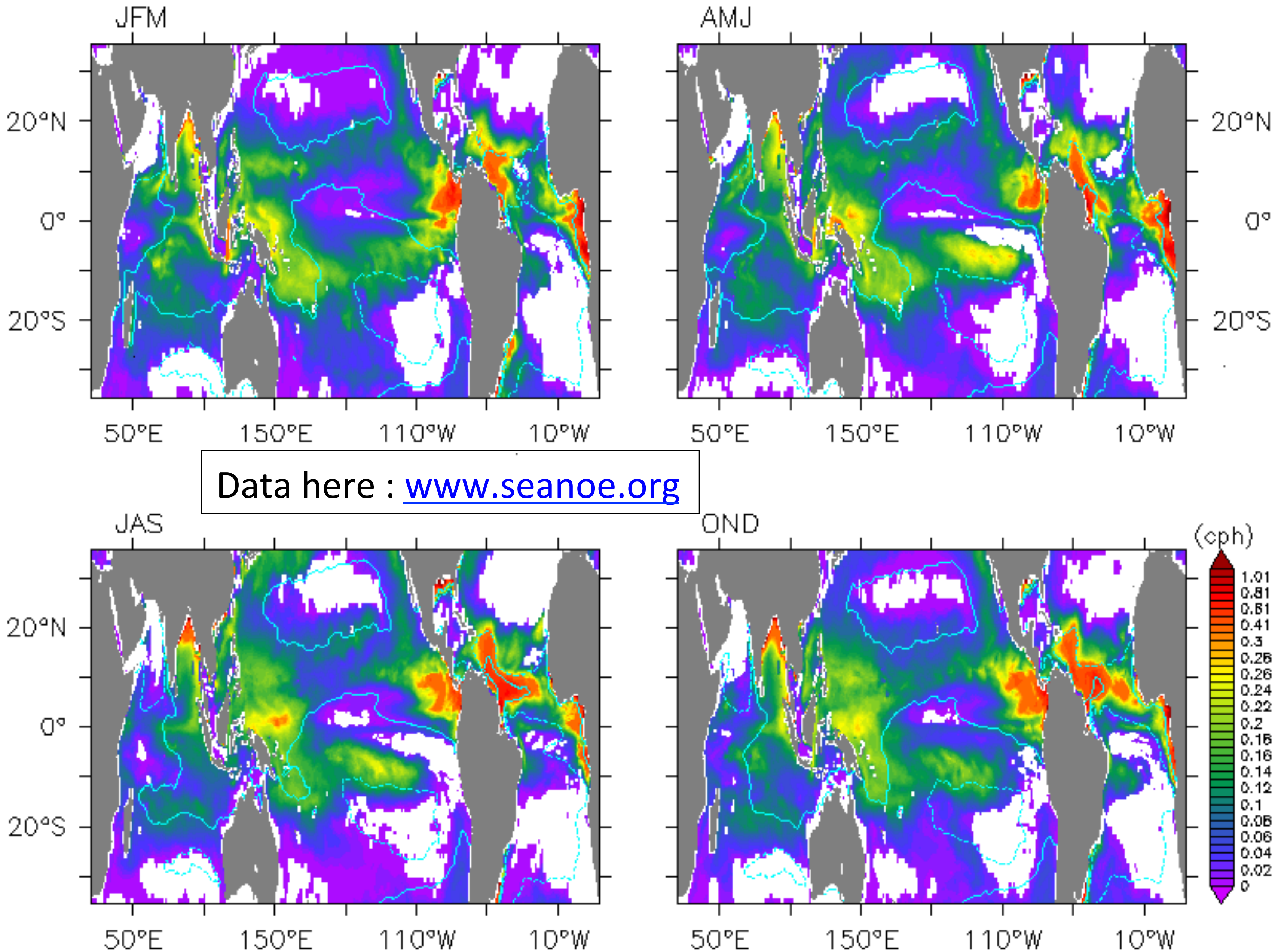
2.3 Examples for the salinity stratification in N^2

Q3: Are we able to determine the precise role of the salinity stratification?



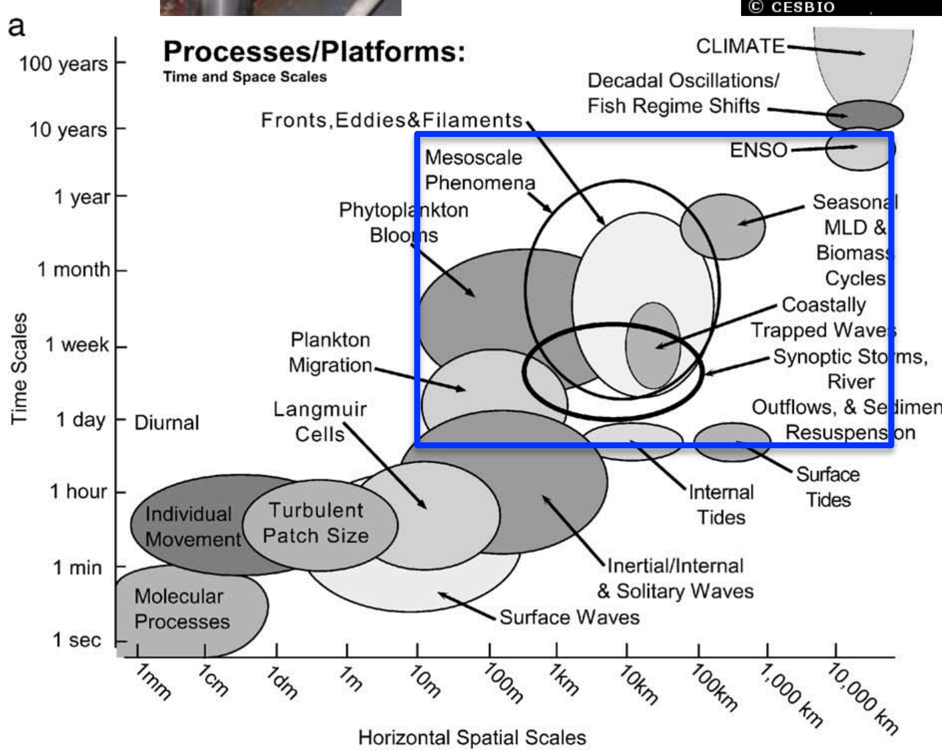
(Maes and O'Kane, JGR 2014)

Ocean Salinity Stratification (OSS) as $N^2(T,S)-N^2(T) > 0$. (i.e., stabilizing)



Data here : www.seanoe.org

PART-2: On the importance of the small scale variability



(from Dickey, 2003)

PART-2: On the importance of the small scale variability

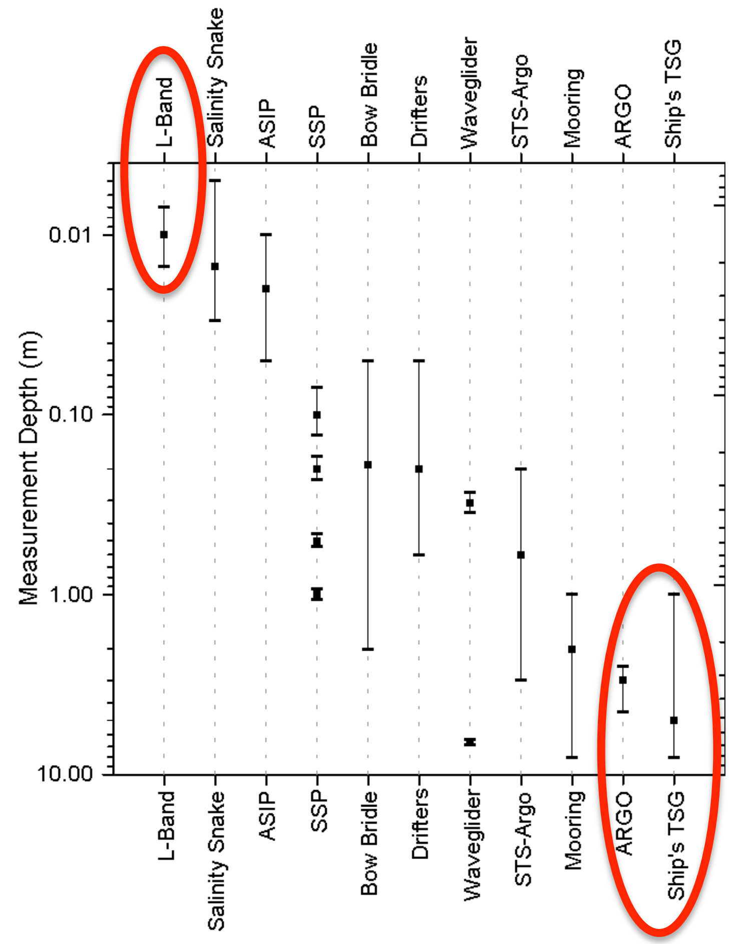
What do we know about such variability in salinity ?

Tangible progresses have been achieved with recent satellite observations (SMOS & Aquarius), BUT…

- Microwave radiometers measure the salinity in the top few centimeters of the ocean

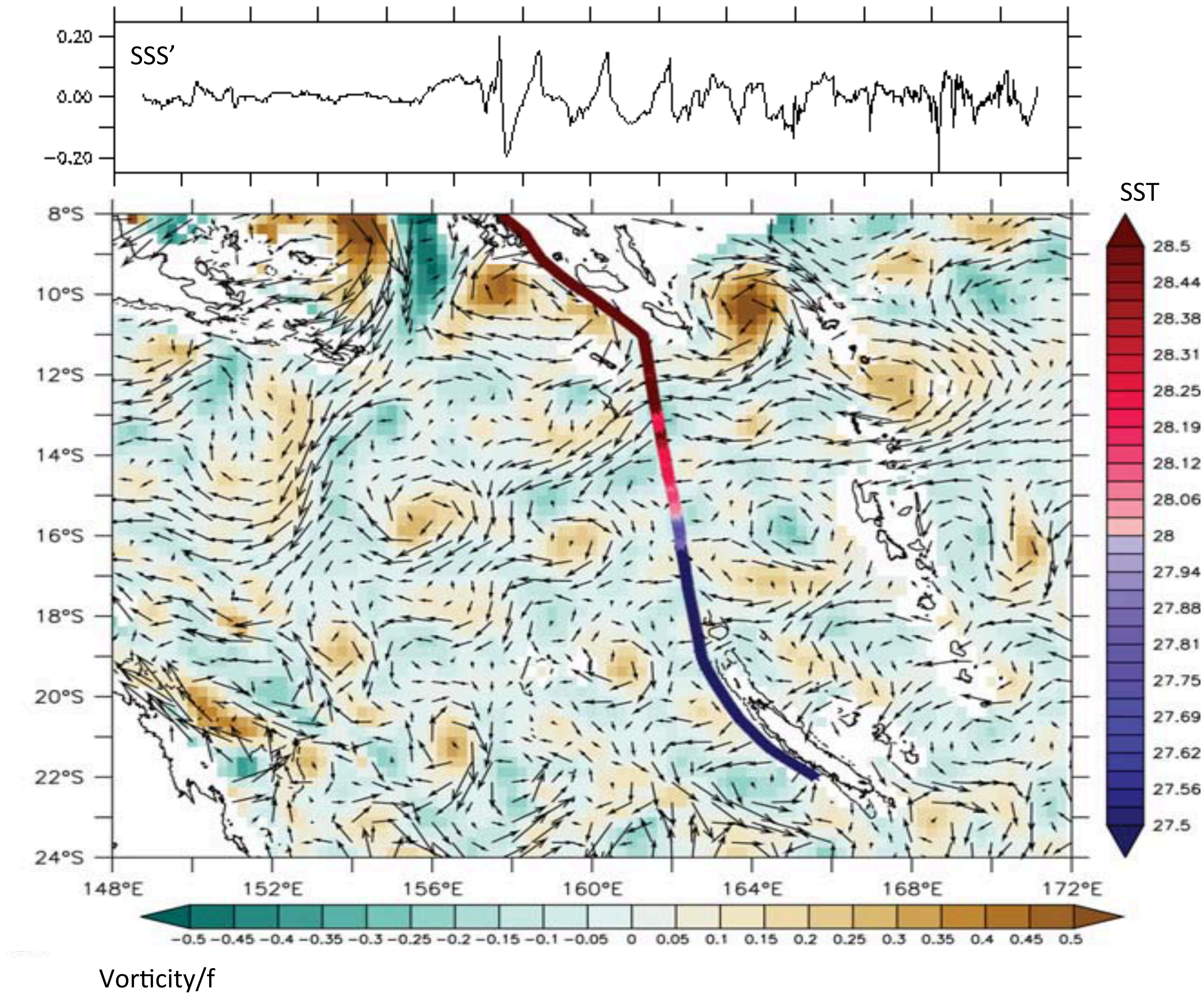
- Satellites measure salinity as a spatial average over an area of about 50 or 100x100 km^2

- High resolution *in situ* data across large distance across the oceans are only available from TSG mounted on research vessels and ships.



(Boutin et al. BAMS 2016)

One example of the impact of eddies stirring: a study case in the Coral Sea



Maes et al., JGR 2013

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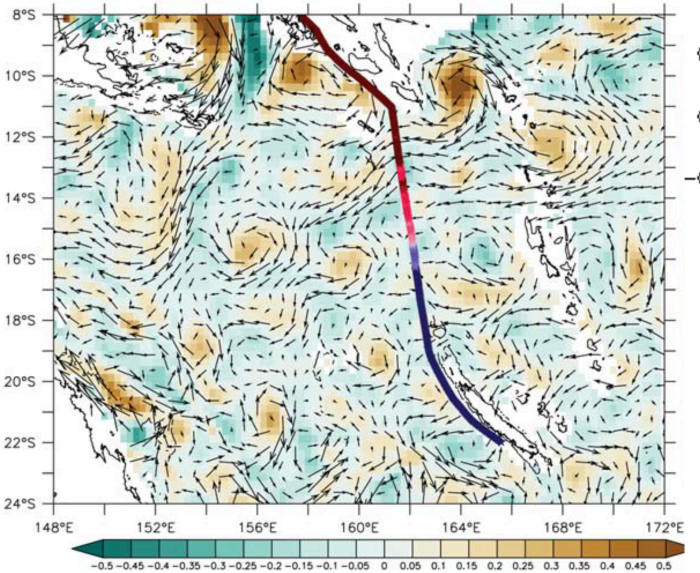
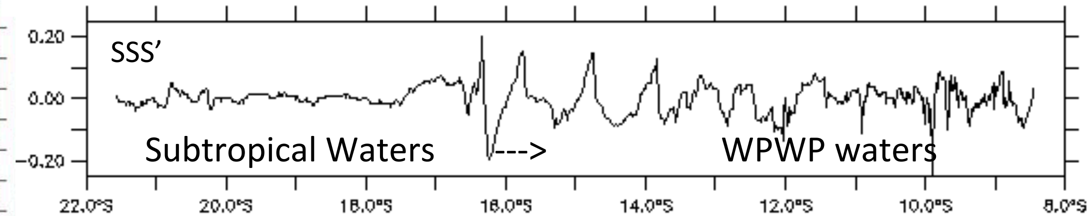
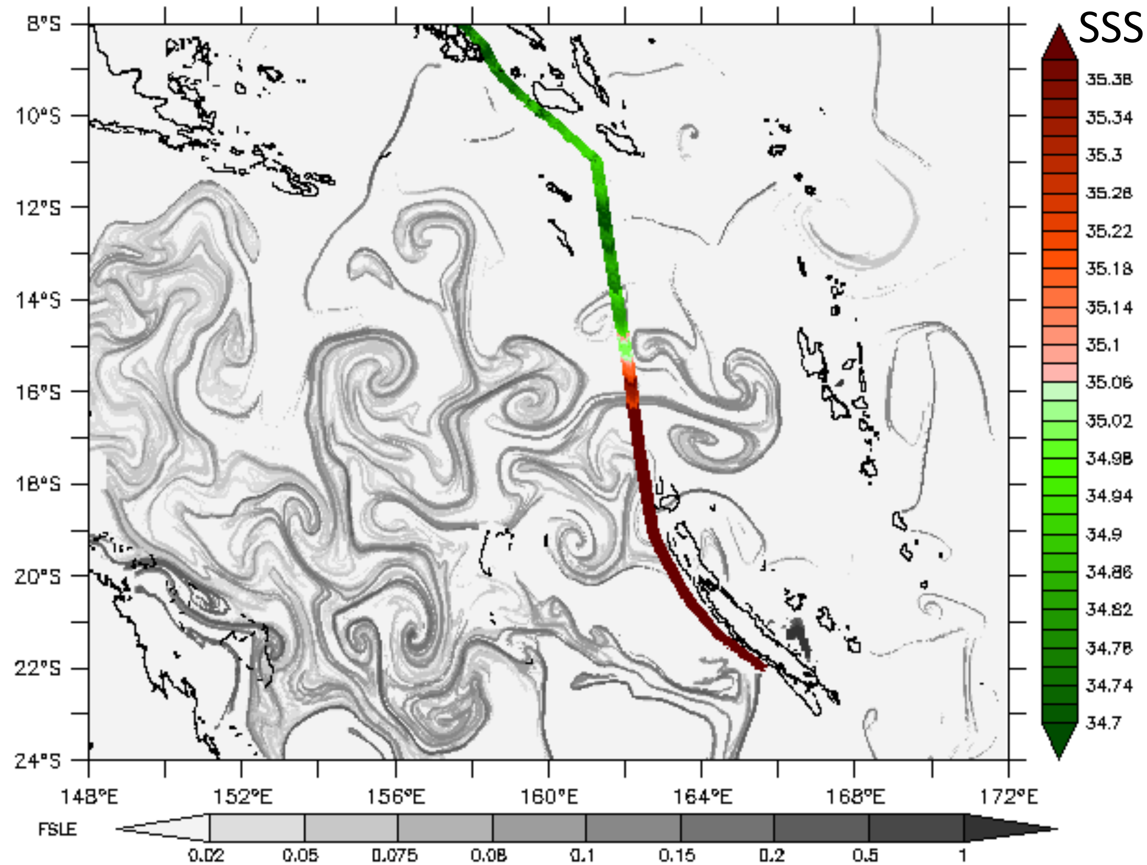


Vorticity/f



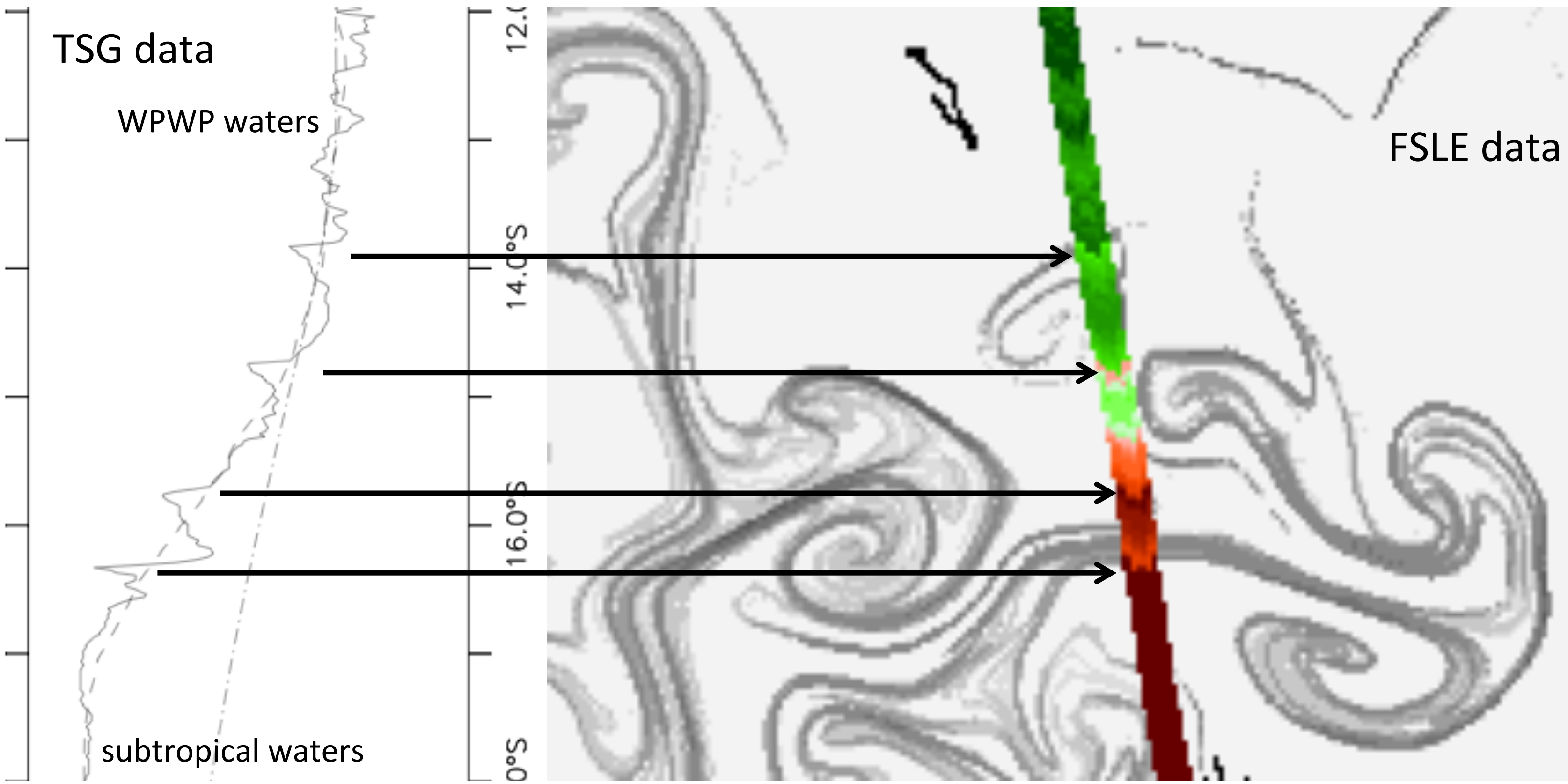


Finite Scale Lyapunov Exponents (FSLE): a metric for the mesoscale flow deformation.
Backward in time to track the convergent fronts.

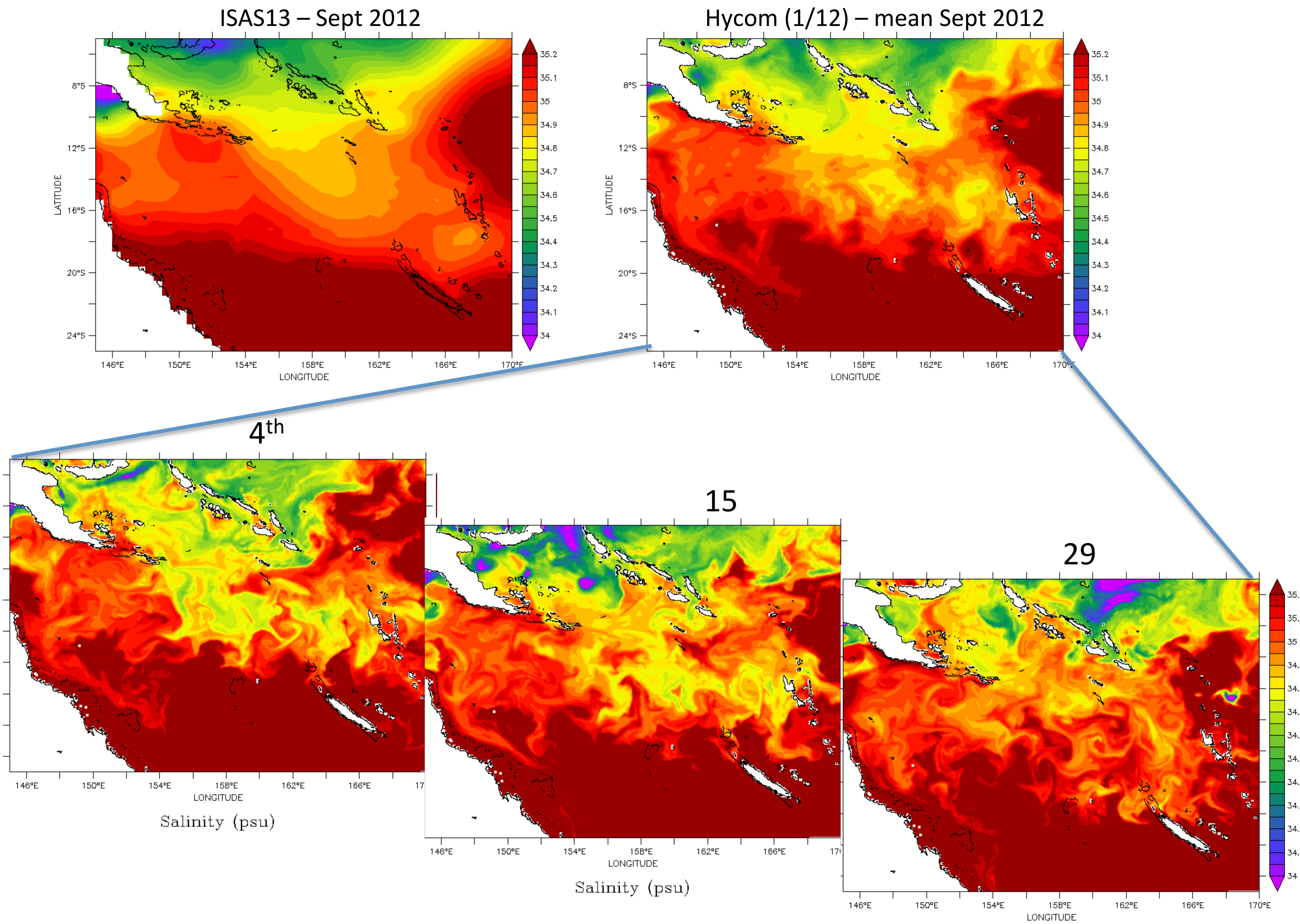
FSLE from the GEKCO surface currents (Sudre et al. 2013)

Maes et al., JGR 2013

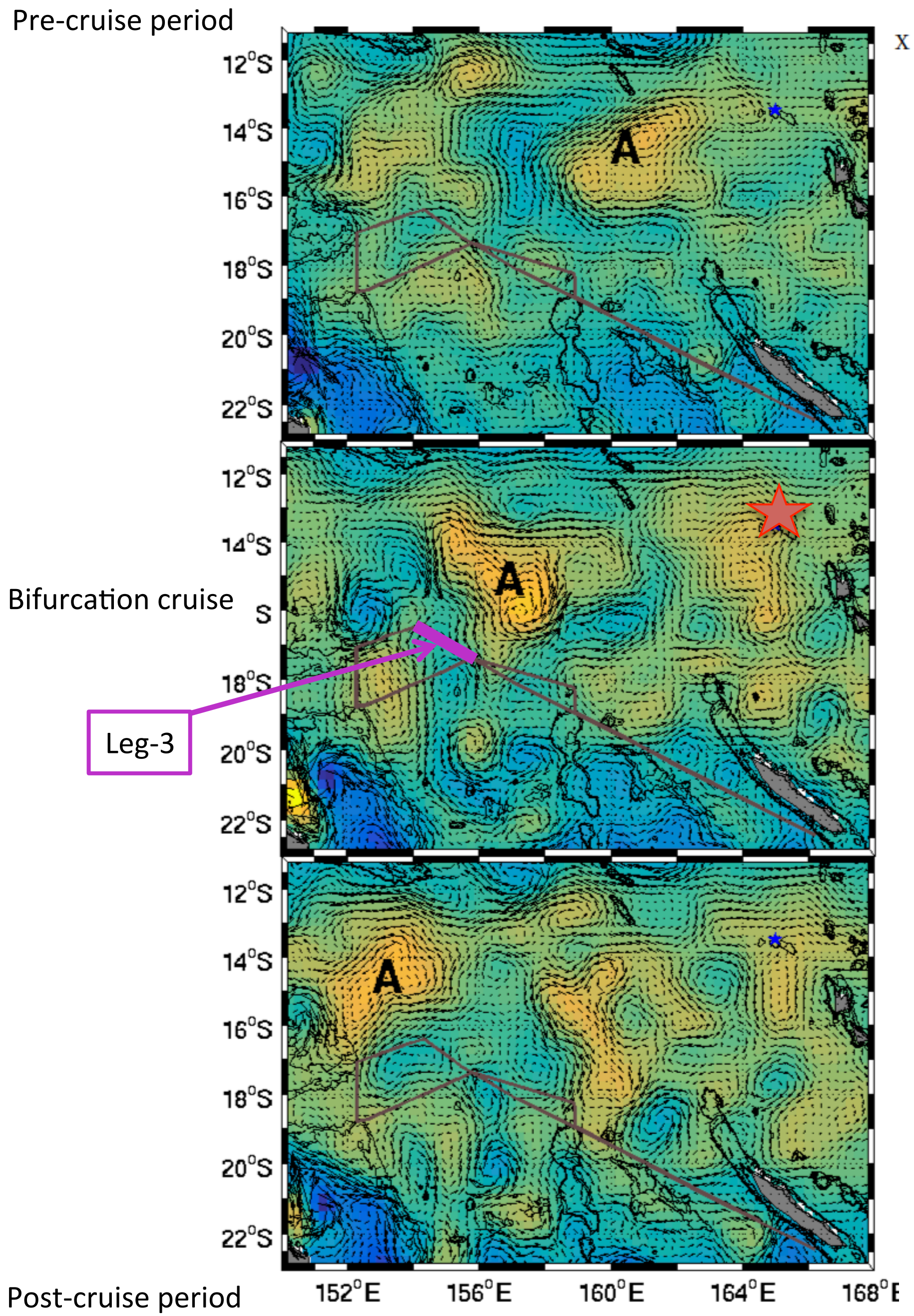
One example of the impact of eddies stirring /submesoscale structures

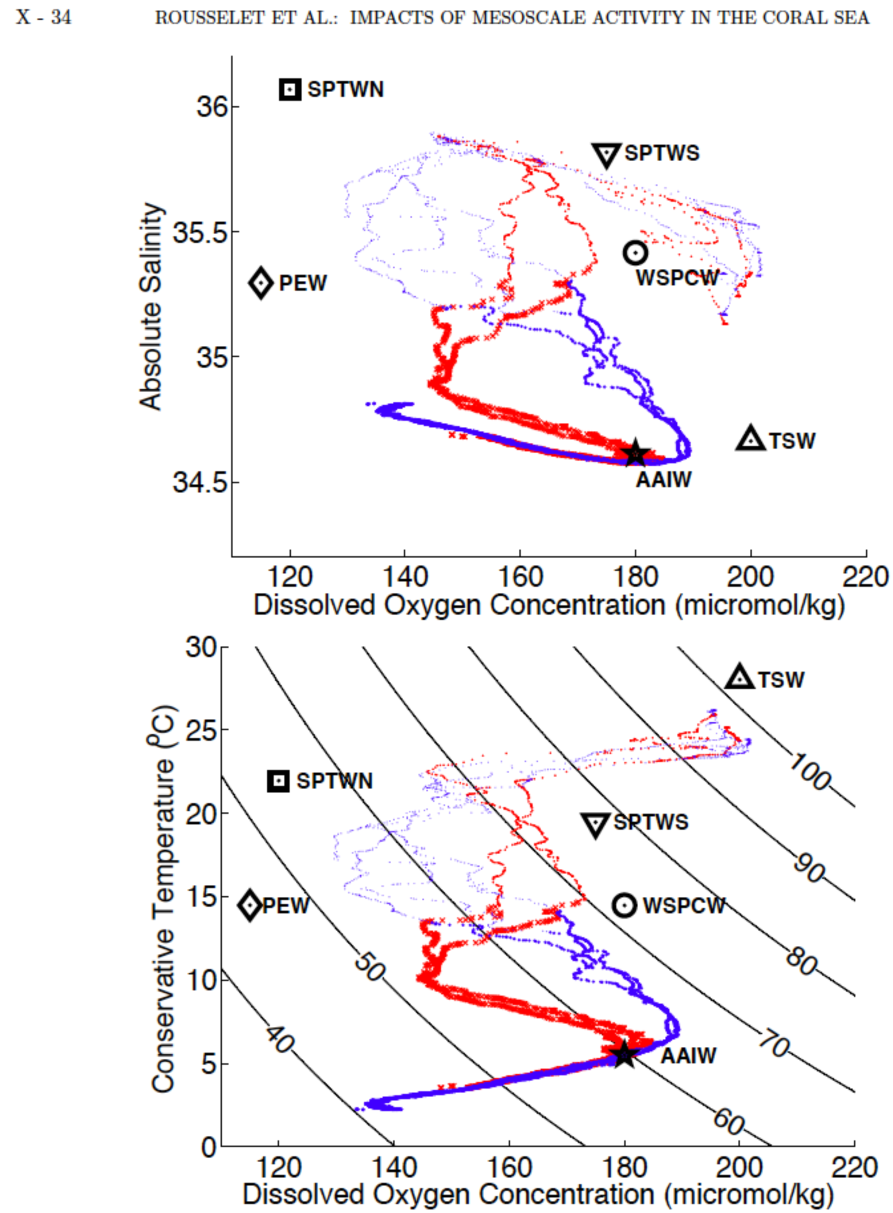


How to measure the impact of mesoscale eddies?



What is the role (in subsurface) of non linear eddies?





(Rousselet et al., JGR 2016)

CONCLUSIONS

* Salinity is seen as a proxy (indicator) for identifying climate-driven changes in global Earth's hydrological cycle (acceleration in response to climate change), BUT…

* Salinity should be also viewed and considered as one (main) actor in the ocean response to climate forcing,

* Ocean Salinity Stratification-OSS (stabilizing part of N^2 that is due to salinity only, i.e. also known as the barrier layer in some regions) is a natural variable of ocean dynamics (mean state, variability and ENSO dynamics…),

* OSS can be significant in regions where both T and S are mixed over the same depth, and overall, the contribution of the OSS to N^2 could be as large as 40-50% of the contribution of the thermal stratification at the seasonal timescales,

* Observation of mesoscale variability: eddies, turbulence, and lateral fluxes are improving, but it remains necessary to understand the growth and decay processes of the associated eddy structures that can also depend on sub-mesoscale dynamics.

References…

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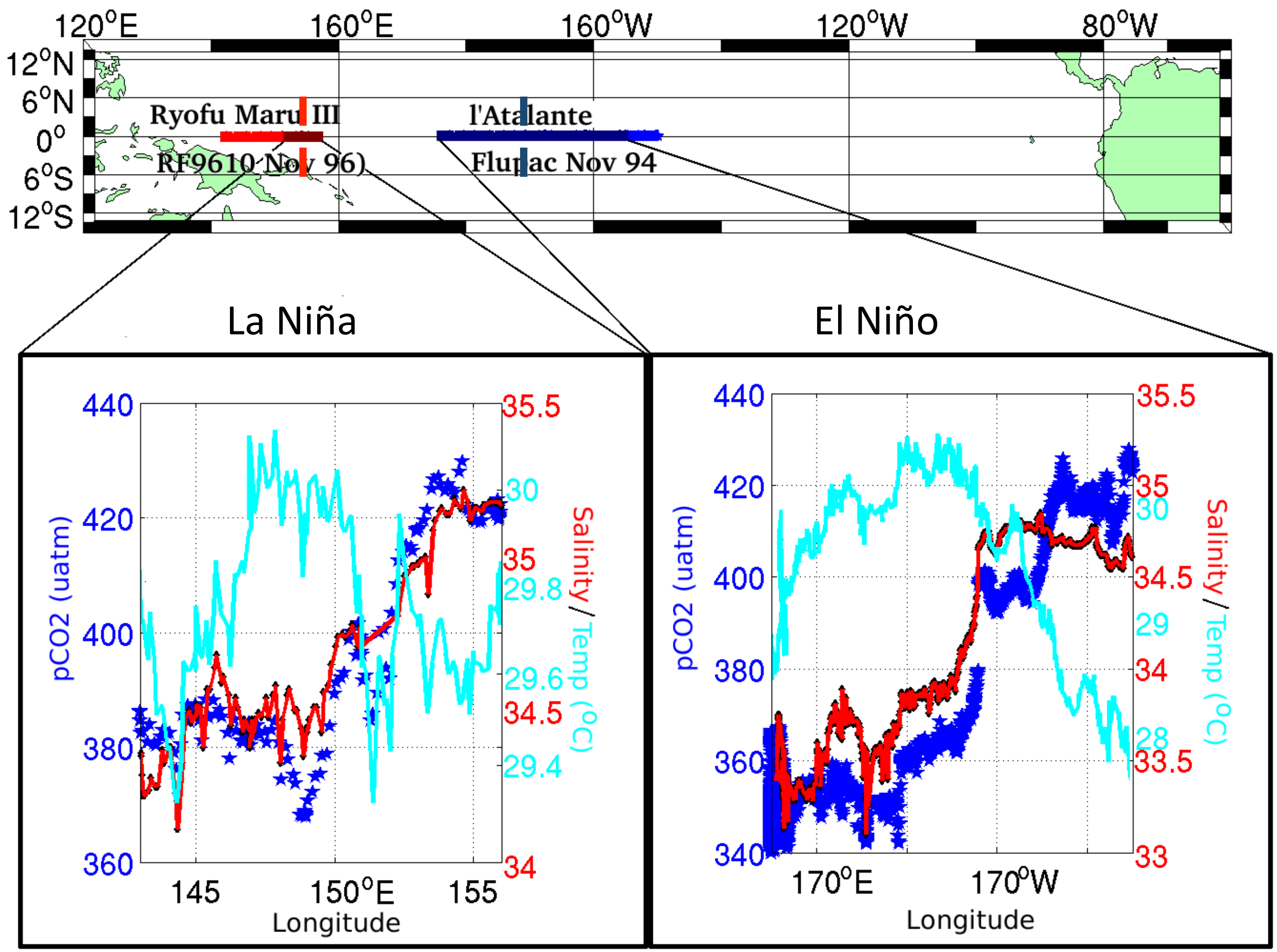
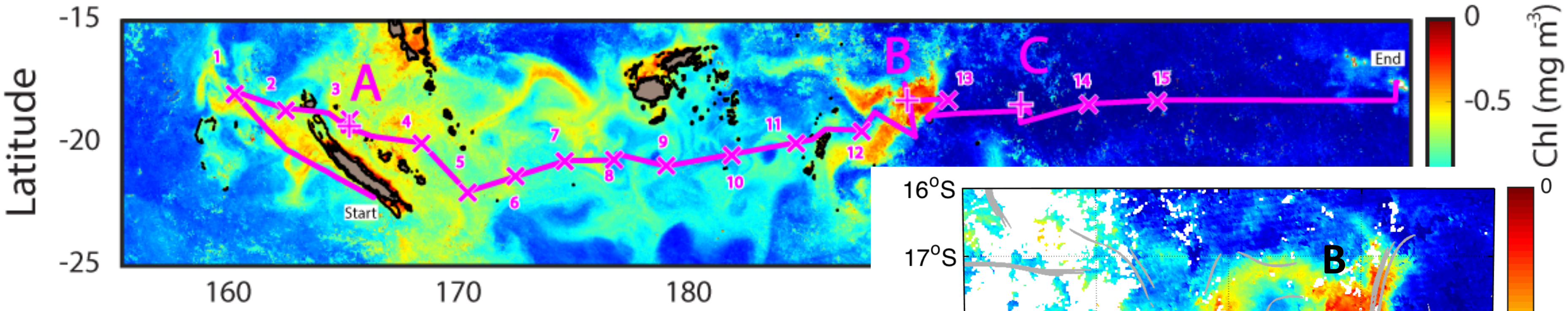
SSS as a pertinent tracer of biogeochemical provinces:
One example in the equatorial Pacific Ocean

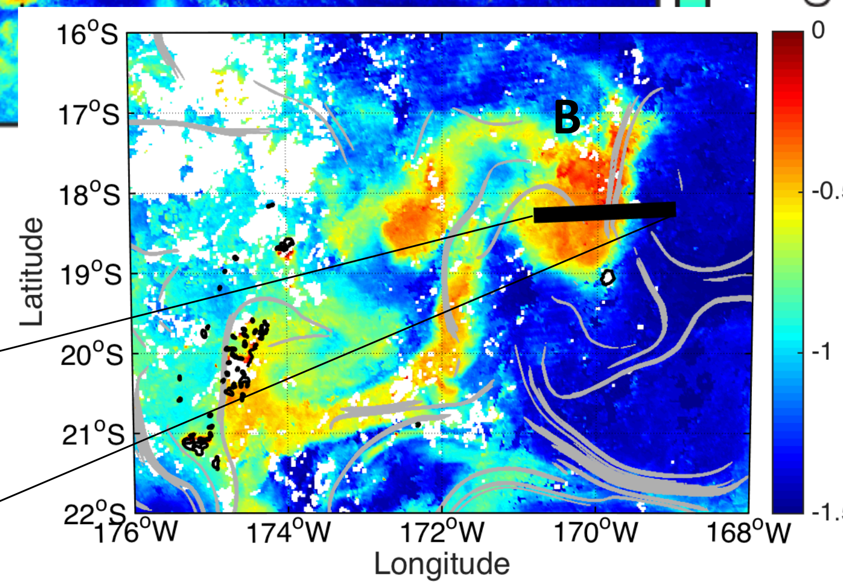


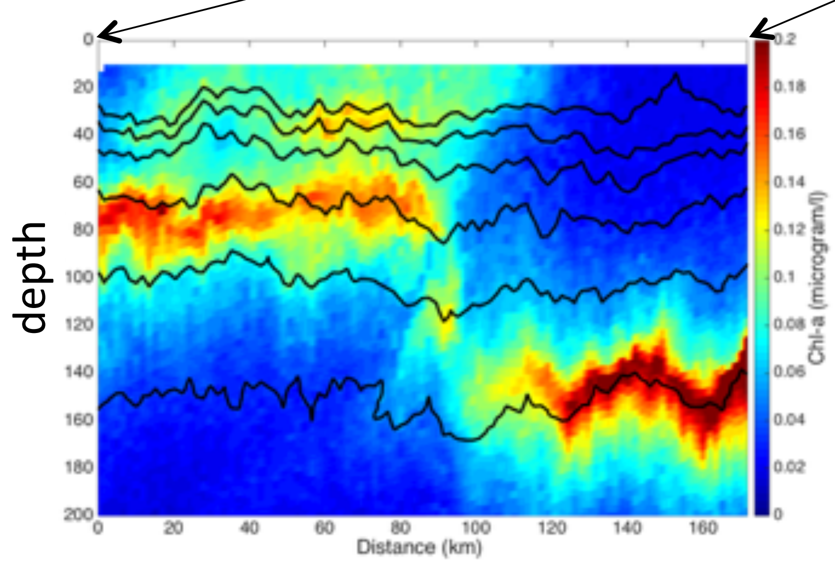
Relationship with chl-a is also pertinent at the eastern edge of the Warm Pool (see also Maes et al., SOLA 2010)

OUTPACE cruise (18 Feb-03 Apr 2015)
Southwest Pacific Ocean
T. Moutin and S. Bonnet (PIs)



CHARACTERIZATION OF THE BIOGEOCHEMICAL AND BIOLOGICAL DIVERSITY IN THE SW PACIFIC





From the surface front to the Deep Chlorophyll Max (DCM)

Courtesy of A. de Verneil (MIO)