Small Scales of variability of the Sea Surface Salinity: a regional and global survey

Christophe Maes (LOPS/IRD)

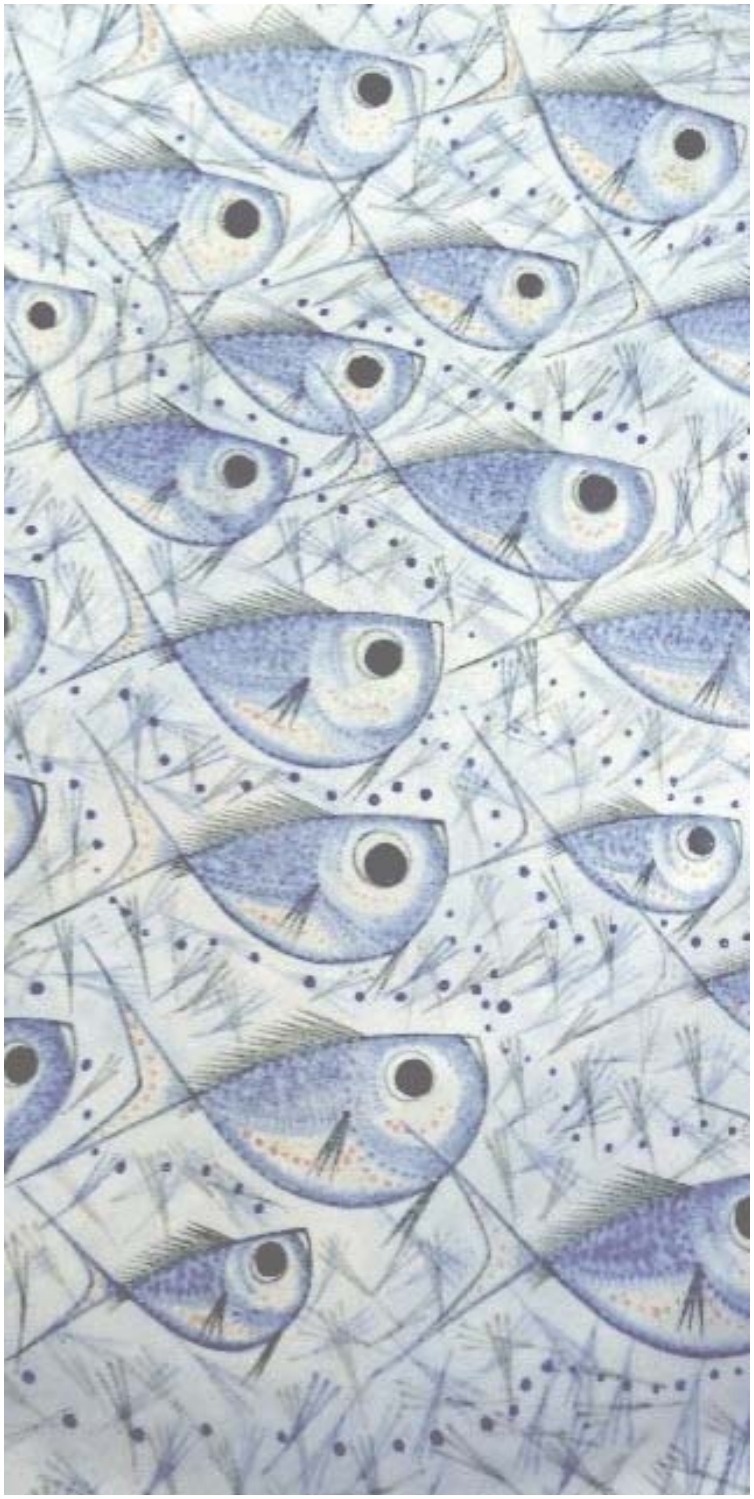
in collaboration with

L. Rousselet, S. Guimbard, K. Drushka, A. Doglioli, N. Kolodziejczyk, N. Reul, G. Charria, J. Reagan, B. Blanke, E. Martinez, A. Petrenko, J. Boutin and I. Ansorge

And a special thanks to C. Sejeng (UCT) A. de Verneil (MIO) and T. O'Kane (CSIRO)

Support from the sponsors is greatly acknowledged.

Third International Workshop
NONLINEAR PROCESSES IN OCEANIC AND ATMOSPHERIC FLOWS
6-8 July 2016 | ICMAT, Campus Cantoblanco UAM, Madrid, Spain



OUTLINE

- **General context**
- **Meso- to Submeso-scales of the SSS variability**
- **Stirring by the mesoscale eddies: a case study**
- **Relationships with the biogeochemical fields**
- **Conclusions and perspectives**

CONTEXT

Goals as presented in the white paper on «Mesoscale / sub-mesoscale dynamics in the upper ocean» by Klein et al.

* Future improvements in our ability to model and predict accurately the ocean's role in the Earth's climate system and the functioning and evolution of global ocean ecosystems will depend importantly on new advances in understanding :

(1) Mesoscale variability and the associated lateral exchange processes ("eddy fluxes") and
(2) Submesoscale variability and the associated upper-ocean vertical exchange processes ("vertical exchange")

Note that these exchange processes are not independent,
and
they include a variety of potential mechanisms for the nonlinear transfer of energy between different scales.

** A complete understanding of mesoscale variability and the associated eddy fluxes also will not be possible without a simultaneous understanding of sub-mesoscale dynamics.

CONTEXT

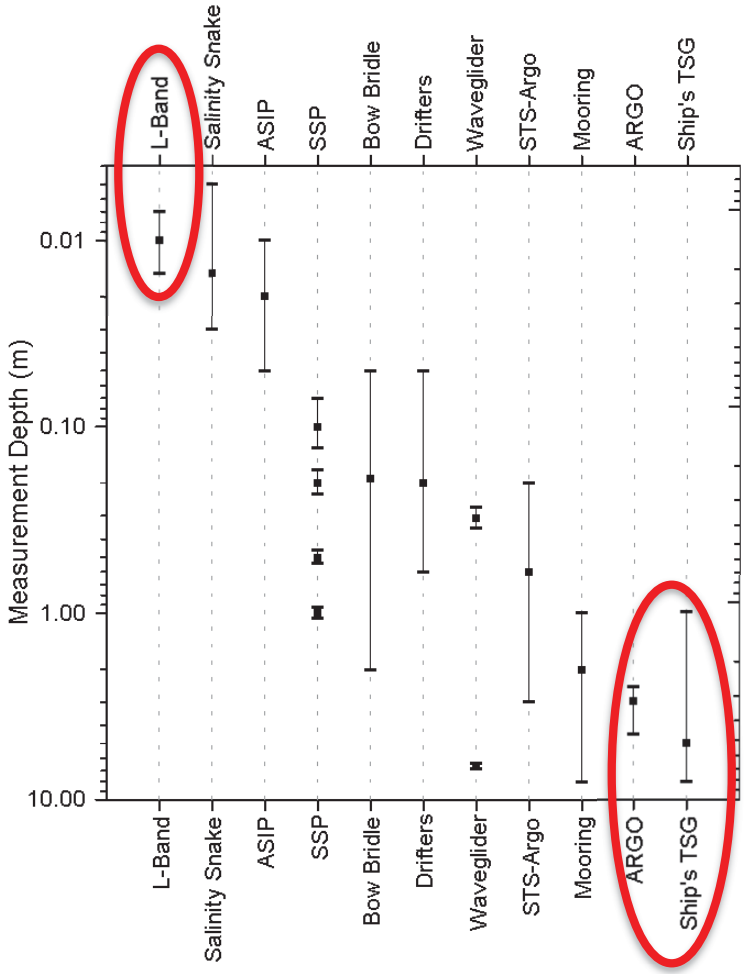
What do we know about such variability in salinity ?

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

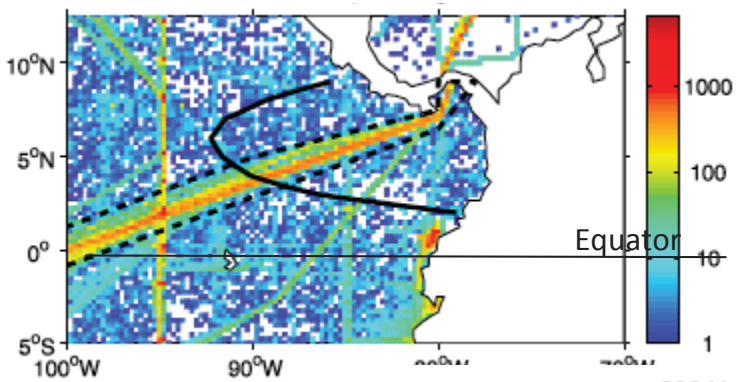
- High resolution *in situ* data across large distance across the oceans are only available from TSG mounted on research vessels and ships.



(Boutin et al. BAMS 2016, in press)

CONTEXT

What can we access with TSG data?



Density of data in the eastern Pacific Ocean

Contents lists available at ScienceDirect

Deep-Sea Research I

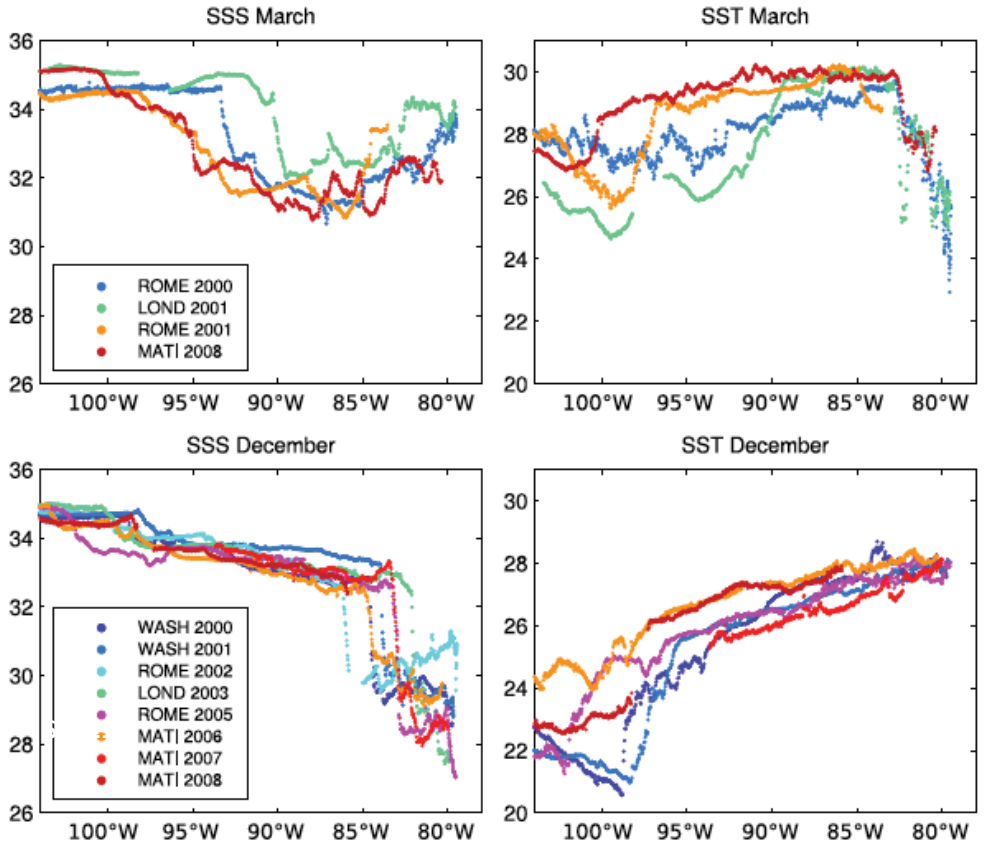
journal homepage: www.elsevier.com/locate/dsri

The French contribution to the voluntary observing ships network of sea surface salinity

G. Alory [a,b,c,h,i,*], T. Delcroix [a,h], P. Téchiné [a,j], D. Diverrès [d,h], D. Varillon [d,e,h], S. Cravatte [a,e,h], Y. Gouriou [d,h], J. Grelet [d,h], S. Jacquin [d,h], E. Kestenare [a,h], C. Maes [f,h], R. Morrow [a,i], J. Perrier [d,e,h], G. Reverdin [g,j], F. Roubaud [d,h]

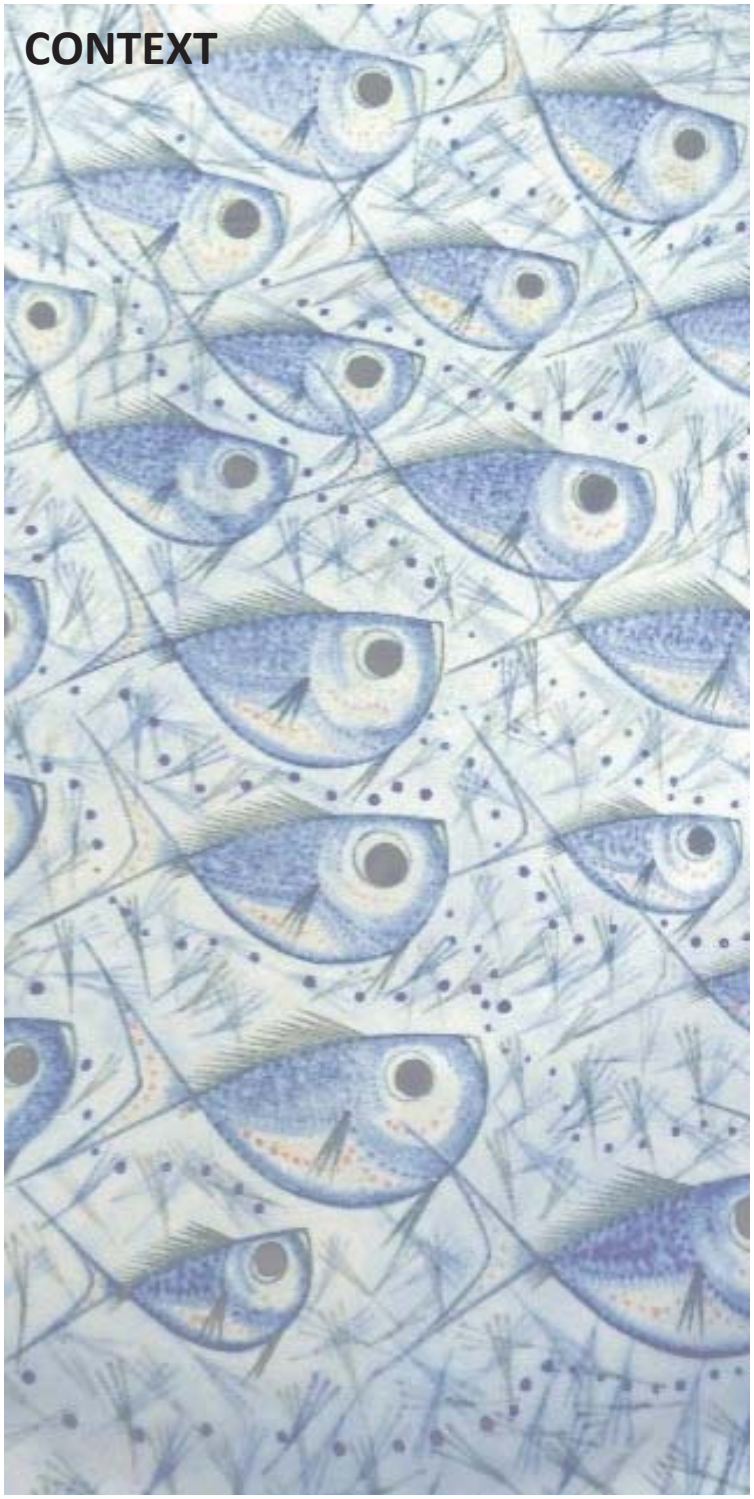
Data from SBE21, cross calibrated in DM with samples, 1-5 min

Seasonal dynamics of sea surface salinity off Panama: The far Eastern Pacific Fresh Pool



(Alory et al. 2012)

More on the interannual variability could be found in Guimbard *et al.*, 2016 (*submitted*)



MAIN QUESTIONS

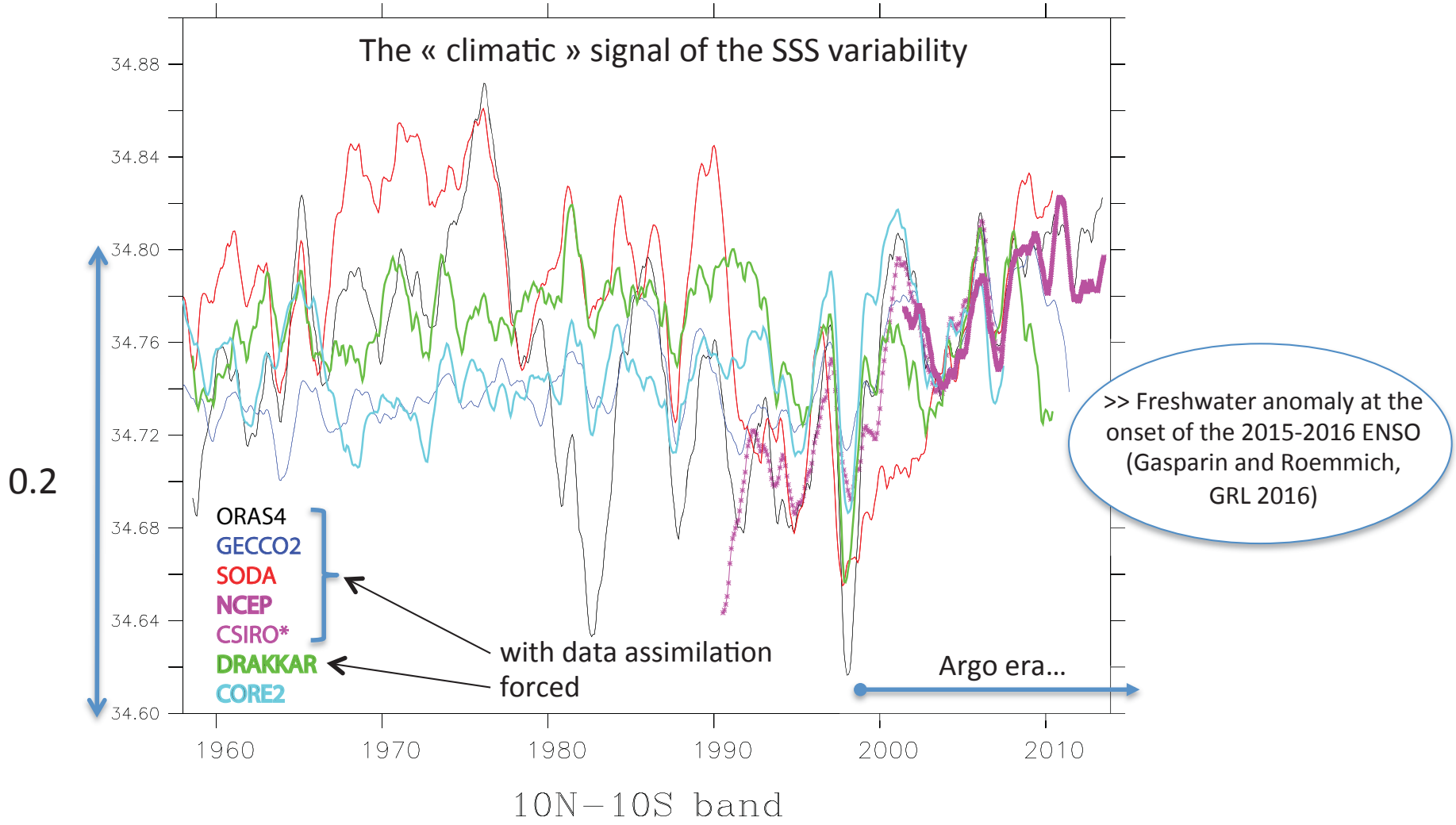
1/ What are the statistical and dynamical properties (as well as their associated physical processes) of the small scale variability in SSS? (what are the limits of the SMOS mission?)

2/ How uniform are stirring and mixing processes? (particularly in association with the topography)

3/ What aspects of stirring and mixing affect biological/ biogeochemical processes?

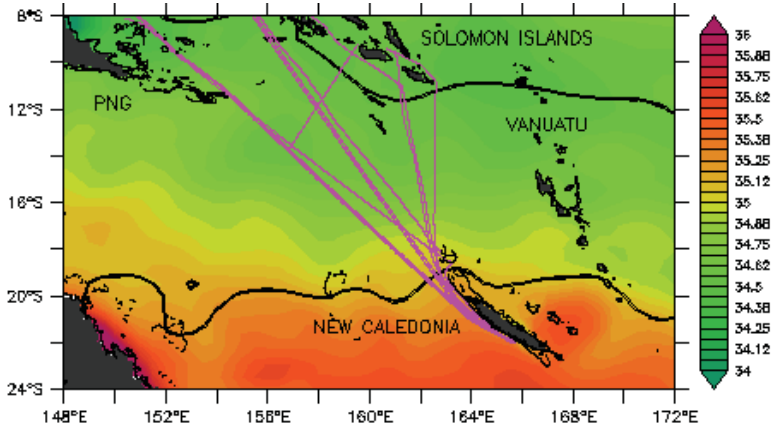
From the large-scale and long term variability of SSS…

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

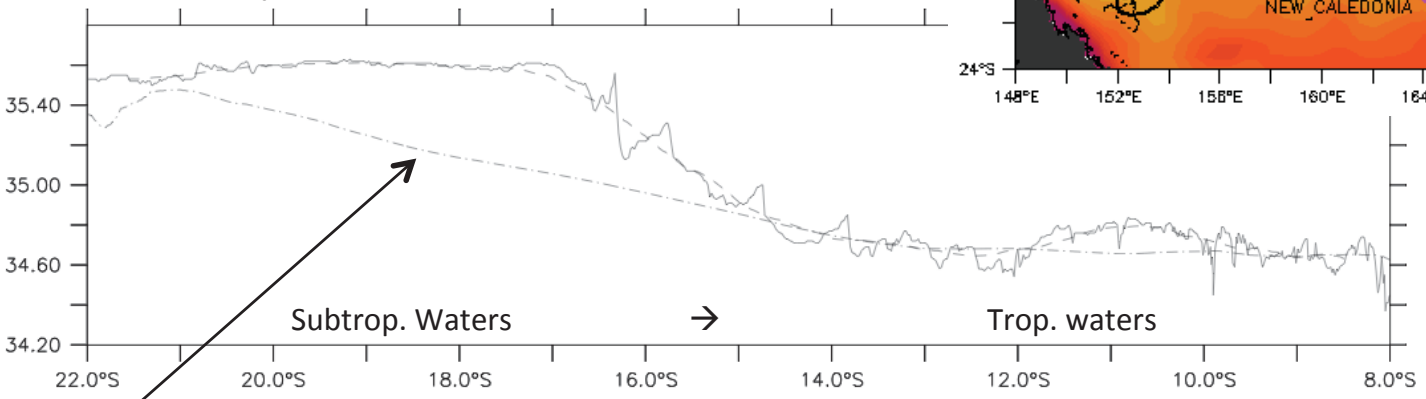


… to the small-scale variability of the SSS

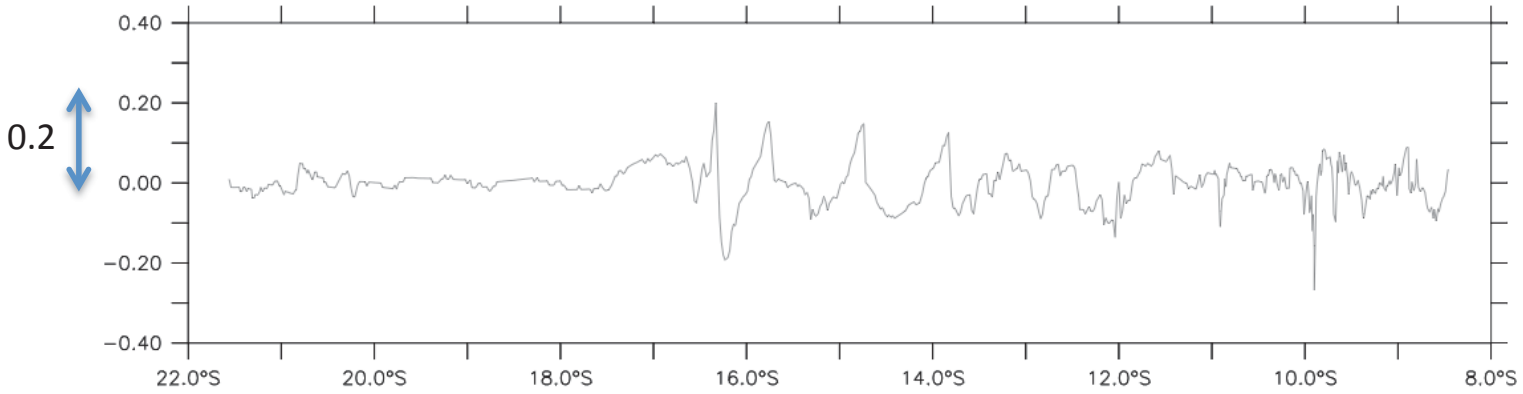
ThermoSalinograph (TSG) data along a track across the Coral Sea, South-west Pacific



27-30 Sept. 2010



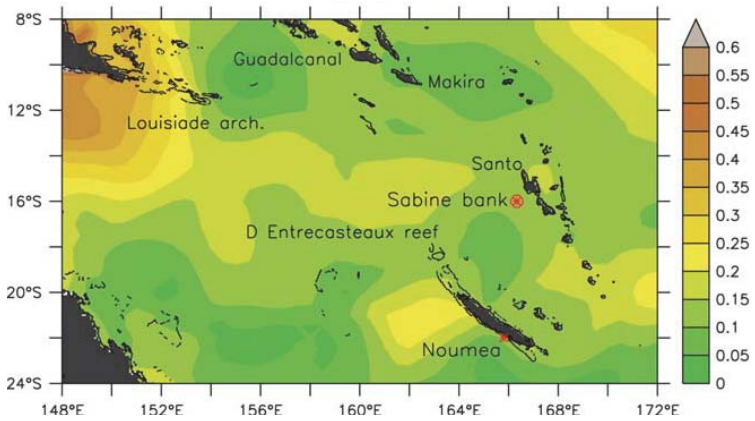
CARS09 clim.

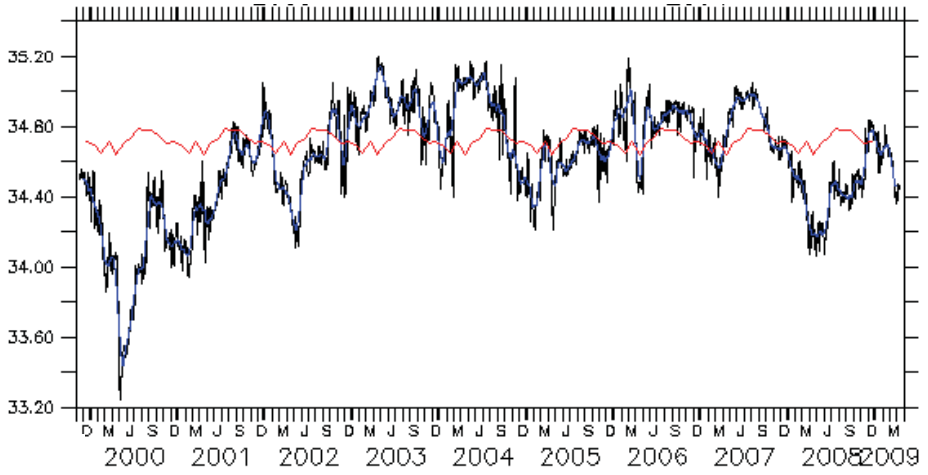


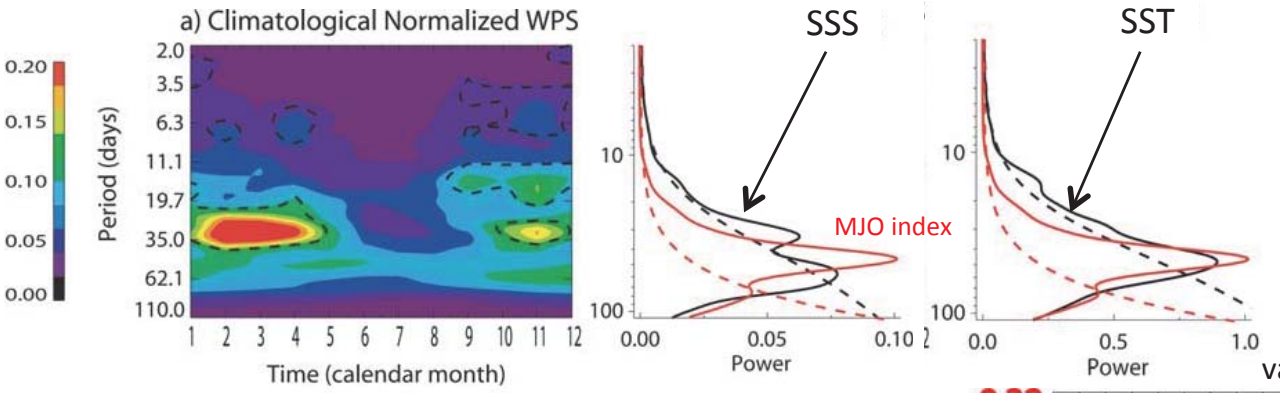
Nouméa

Solomon Sea

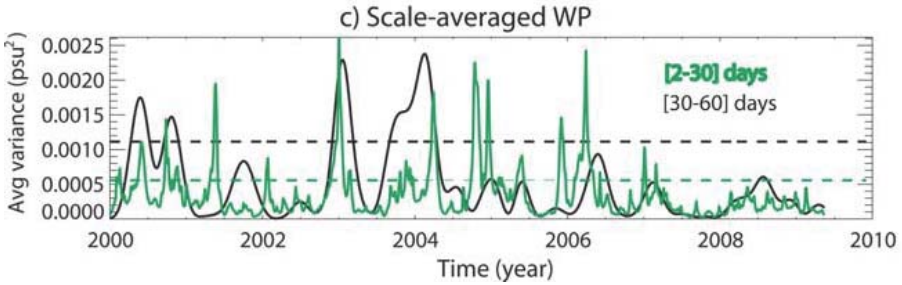
And high-frequency variability: a case study at the Sabine bank



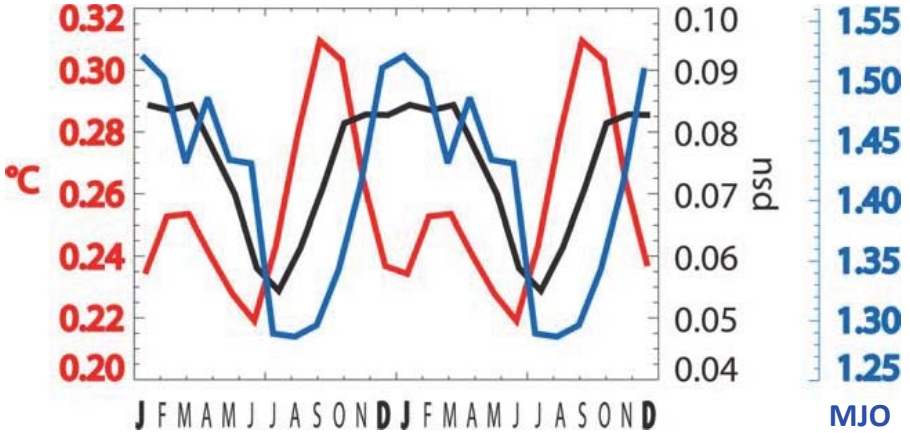




The intraseasonal activity in SST is out of phase with that for the MJO and SSS. Our result suggests that there is a larger impact of MJO-induced precipitation (evaporation) on SSS than of MJO-induced wind stress on SST in the Coral Sea.



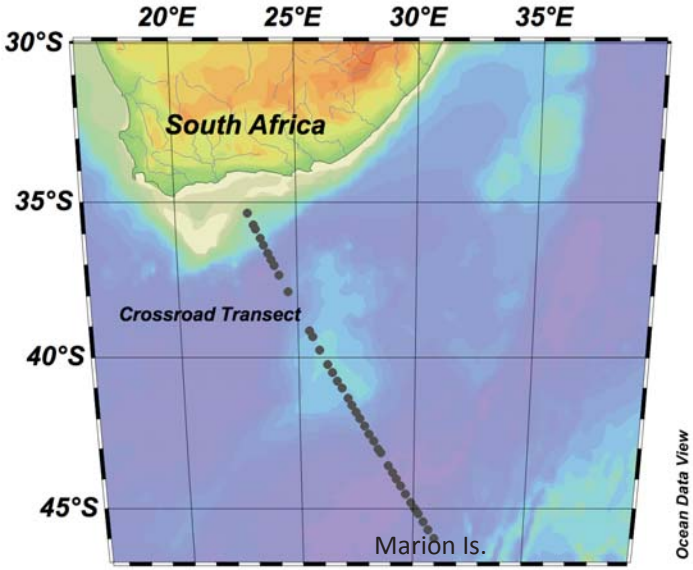
variance of intraseasonal anomalies

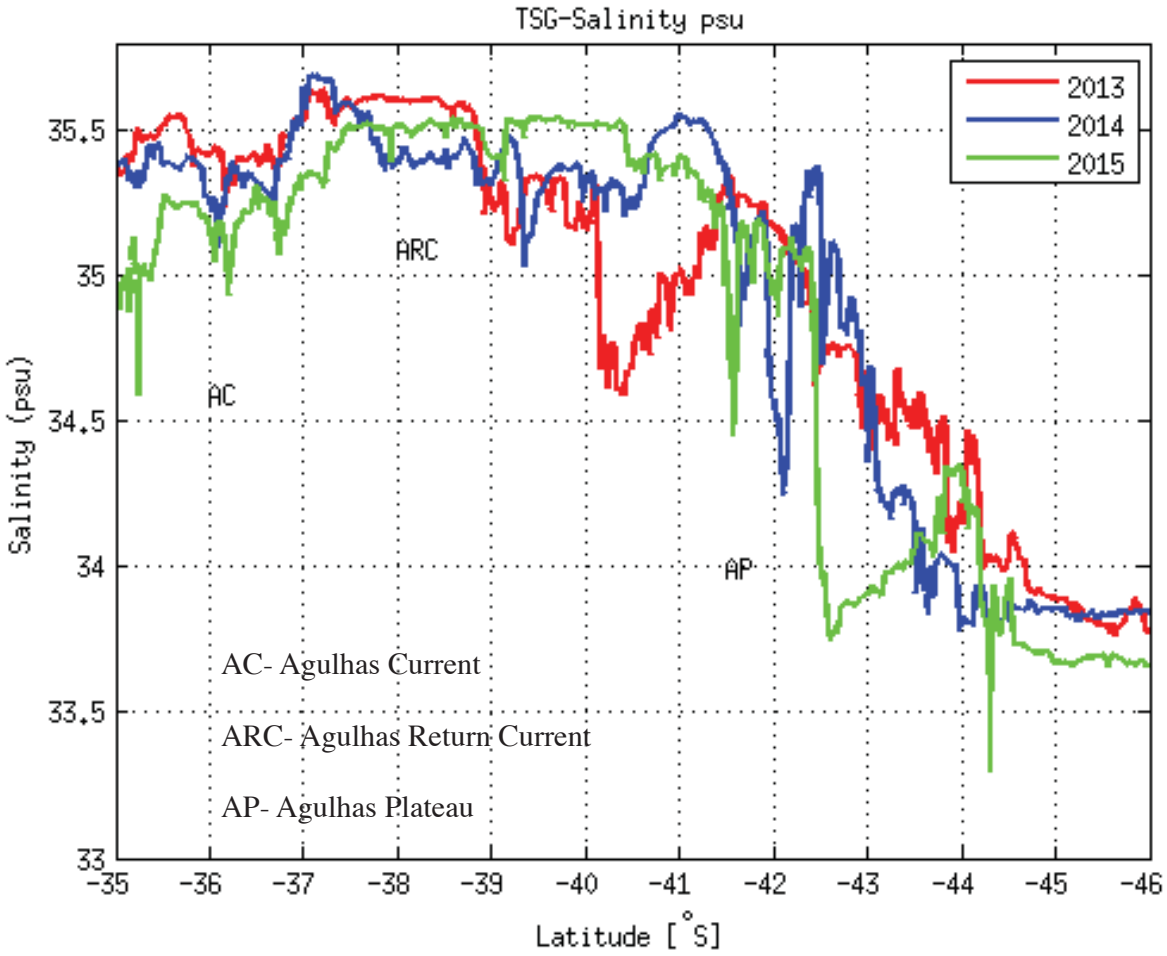


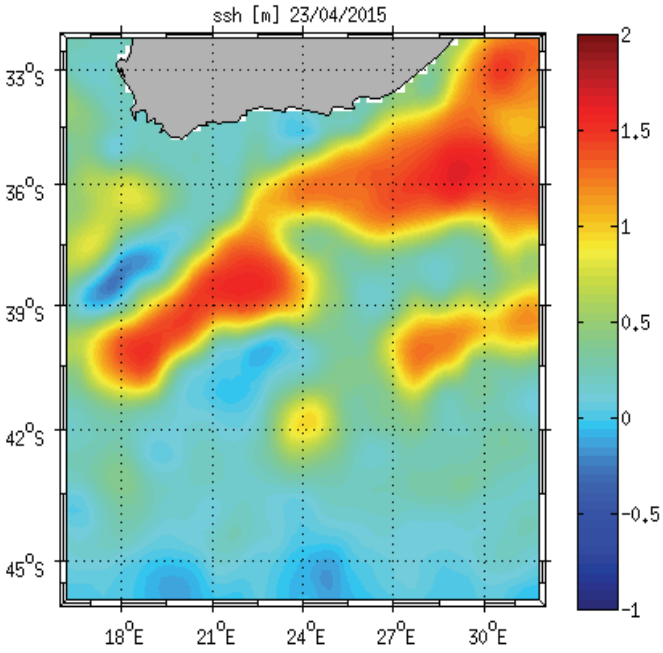
Maes et al., JGR 2013

Courtesy of Caroline Sejeng (UCT)

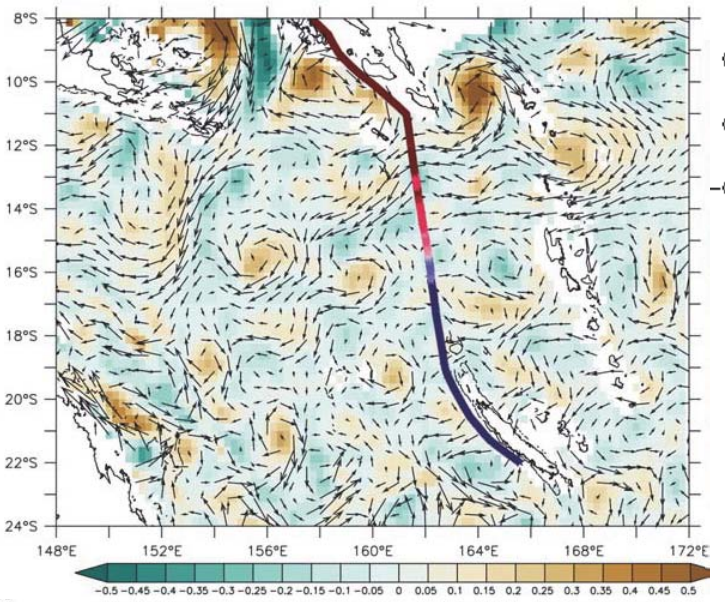
Repeated sections of TSG *in situ* data require to replace the SSS variability within the context of the large-scale and mesoscale dynamics of the flow.



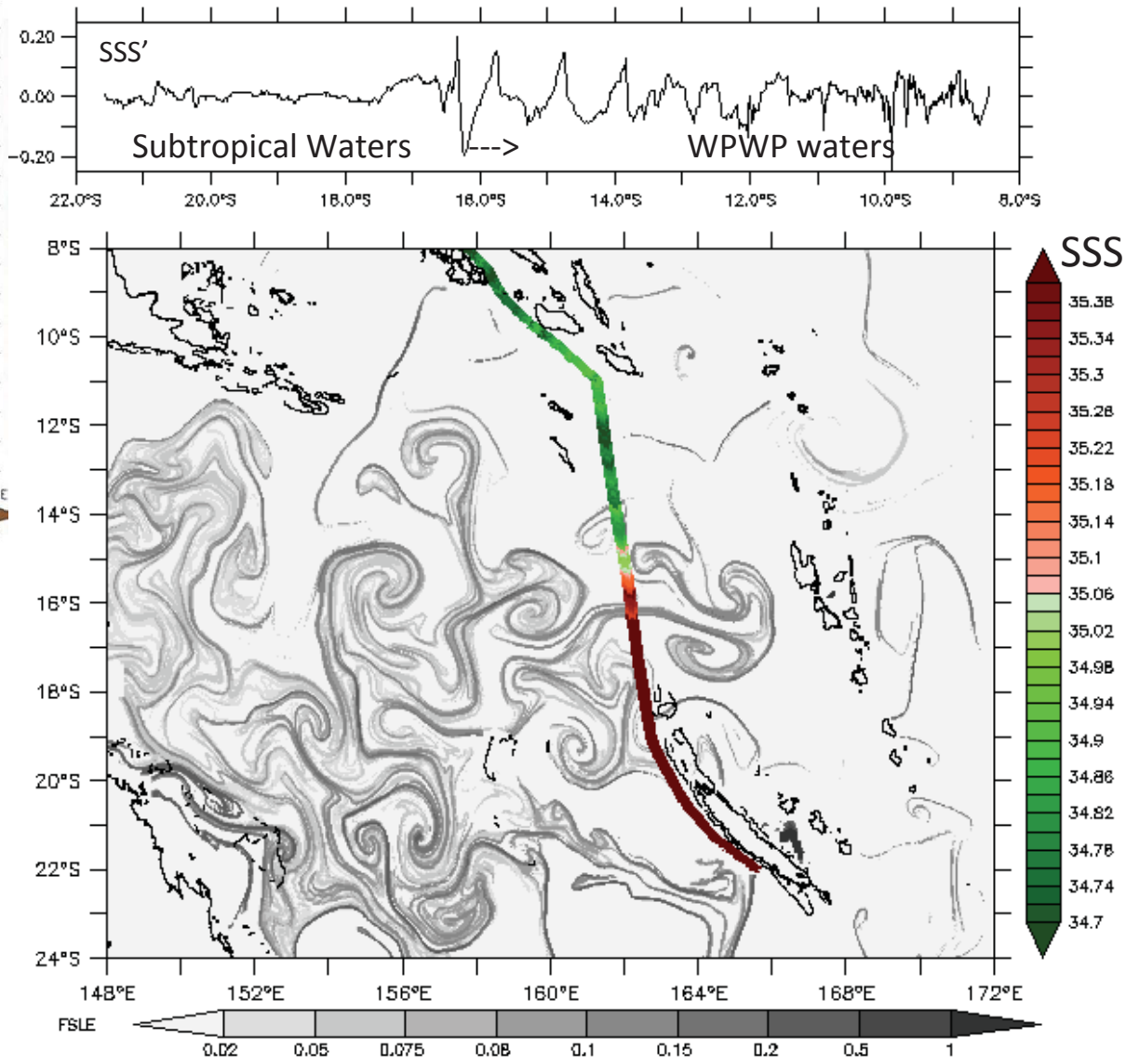




One example of the impact of eddies stirring: a study case in the Coral Sea



Vorticity/f

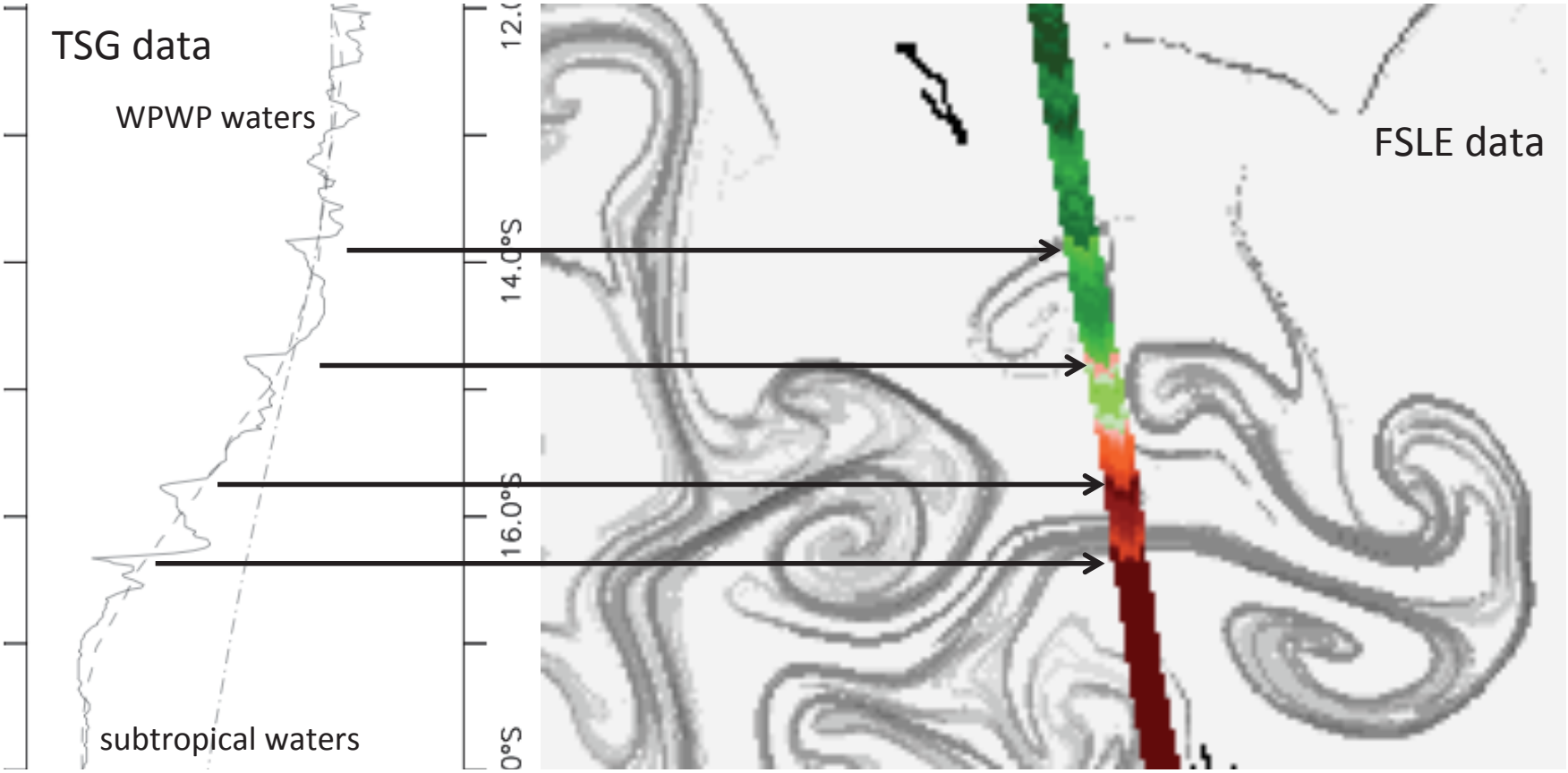


Finite Scale Lyapunov Exponents (FSLE): one metric for the mesoscale flow deformation. Backward in time to track the convergent fronts.

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

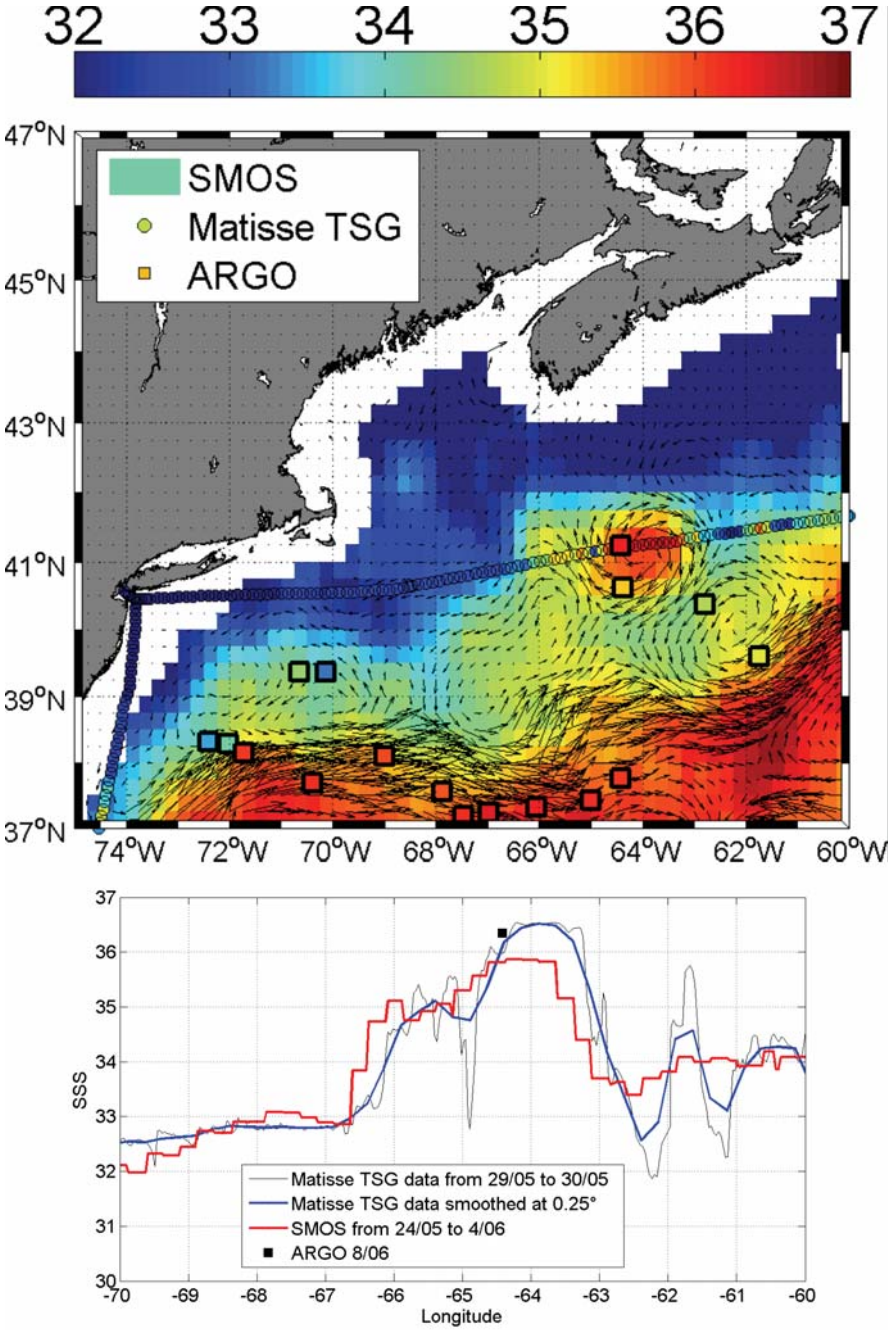
Maes et al., JGR 2013

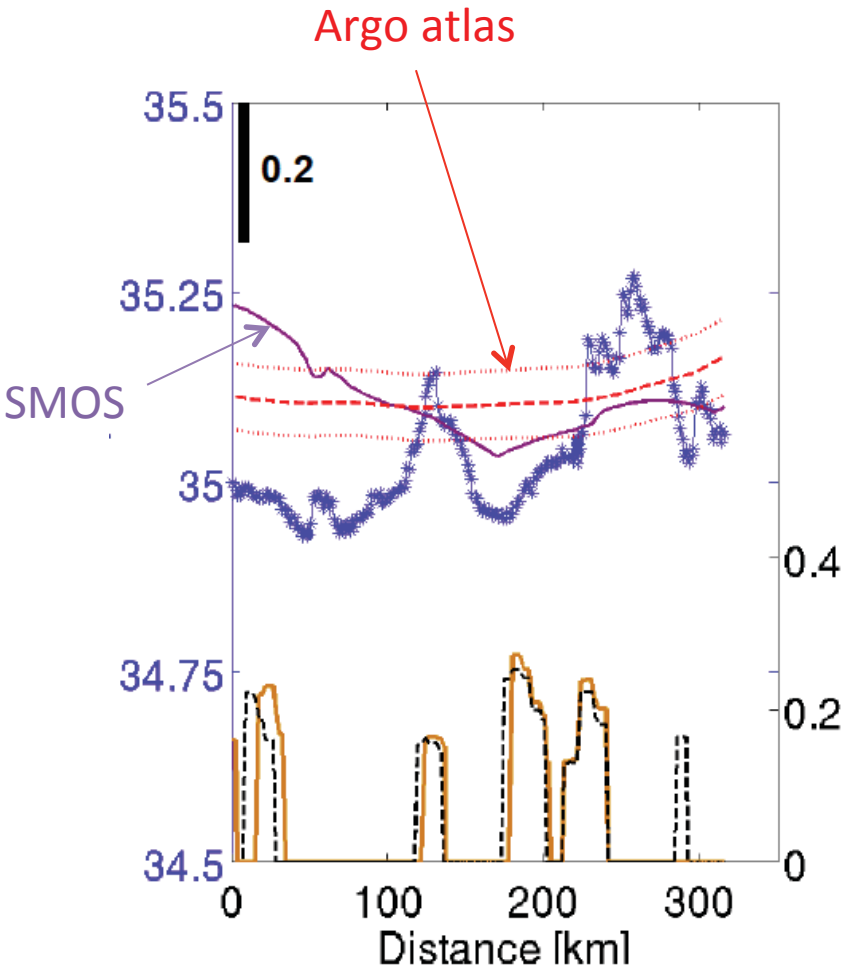
One example of the impact of eddies stirring /submesoscale structures



What is really seen by SMOS?

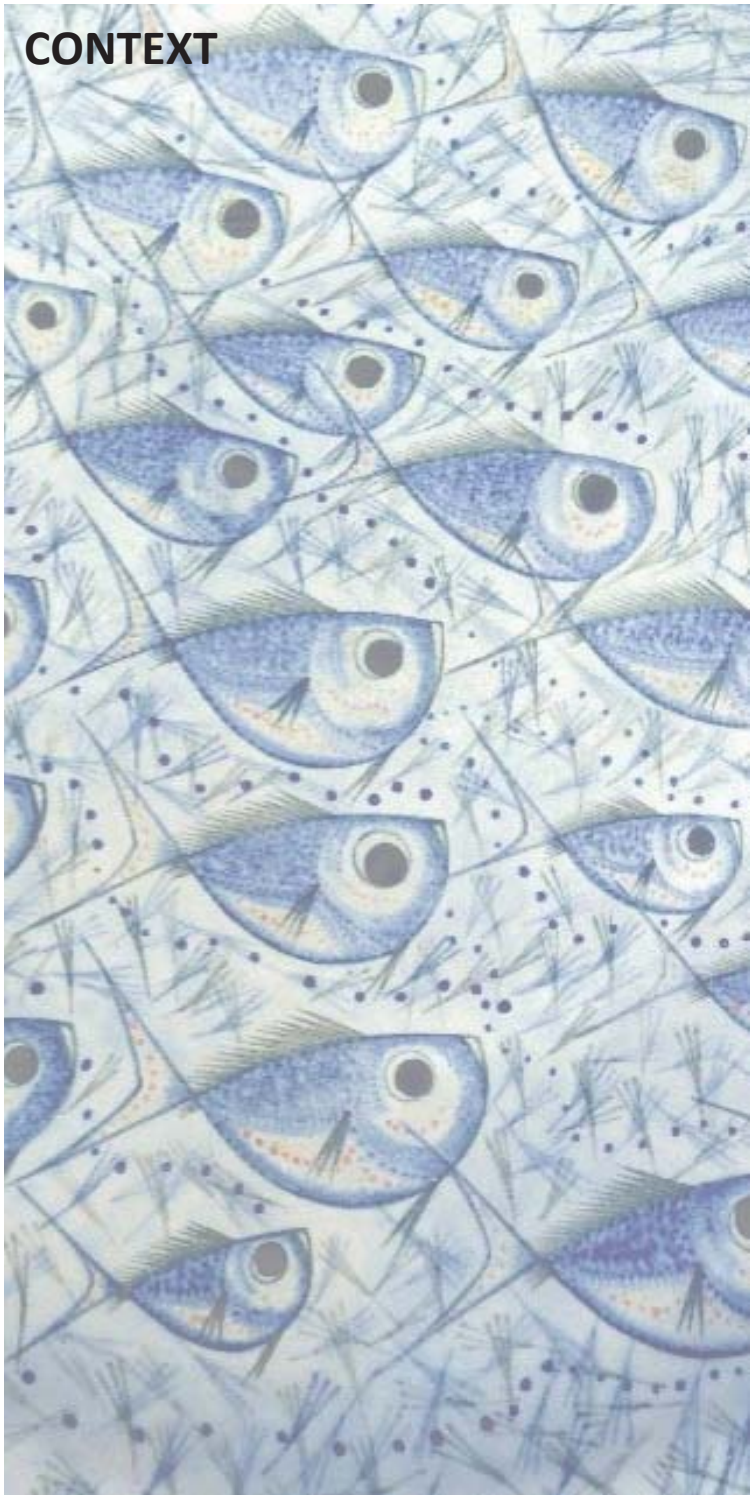
(Reul et al. GRL 2014)





TSG and FSLE data : 09/09/2012

(extract from the master report of L. Rousselet, 2015)



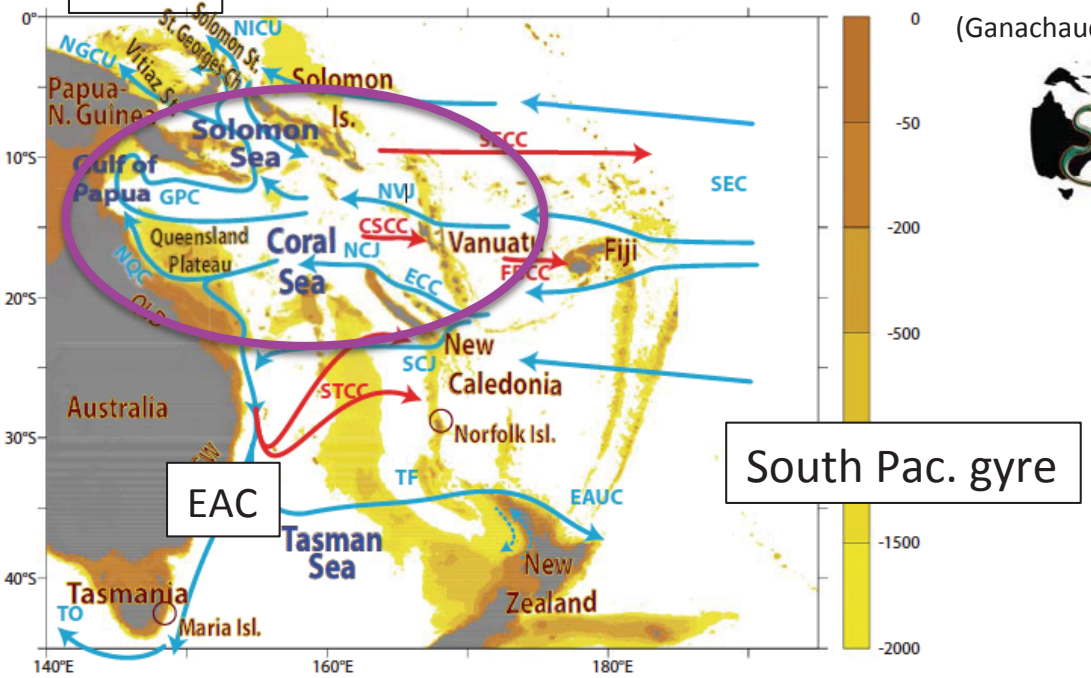
MAIN QUESTIONS

1/ What are the statistical and dynamical properties (as well as their associated physical processes) of the small scale variability in SSS? (what are the limits of the SMOS mission?)

2/ How uniform are stirring and mixing processes? (particularly in association with the topography)

3/ What aspects of stirring and mixing affect biological/ biogeochemical processes?

ENSO



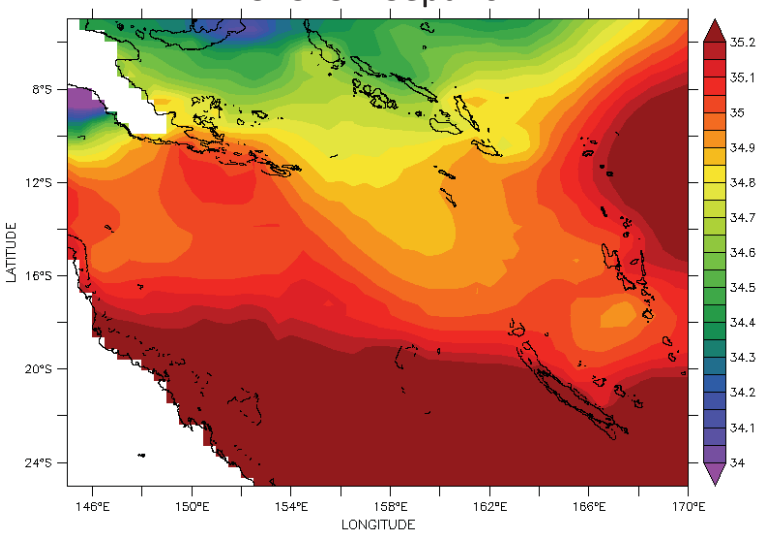
(Ganachaud et al., JGR 2014)

EAC

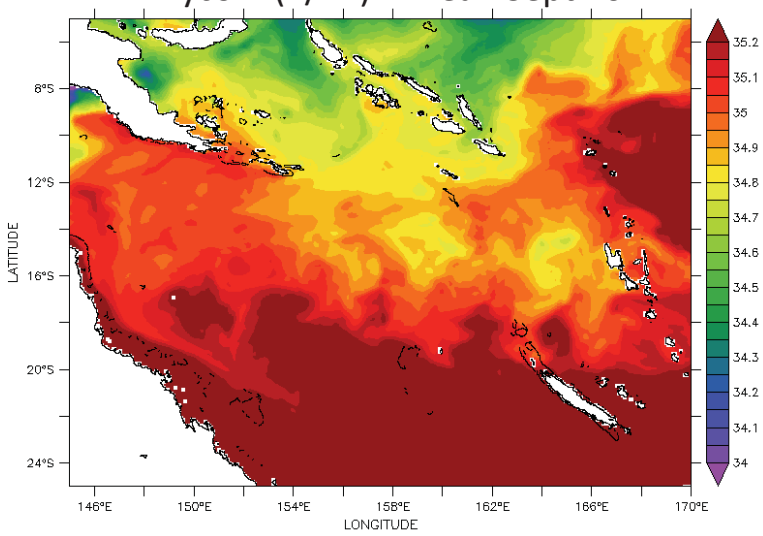
South Pac. gyre

Monthly SSS

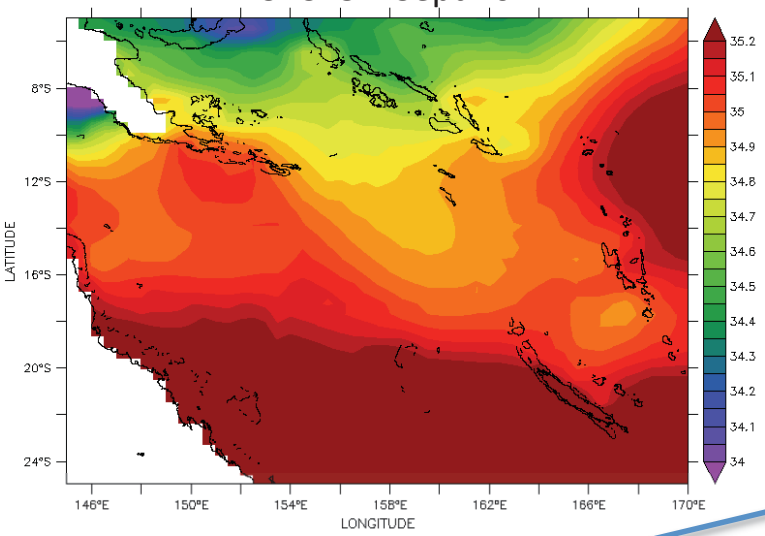
ISAS13 – Sept 2012



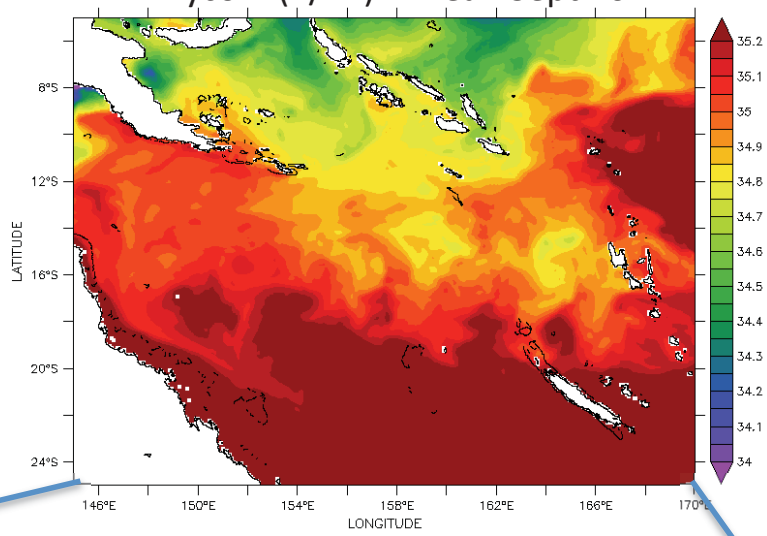
Hycom (1/12) – mean Sept 2012



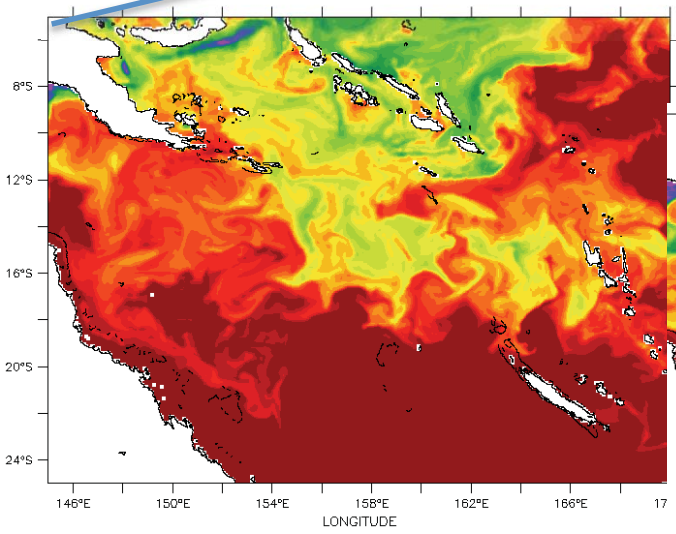
ISAS13 – Sept 2012



Hycom (1/12) – mean Sept 2012

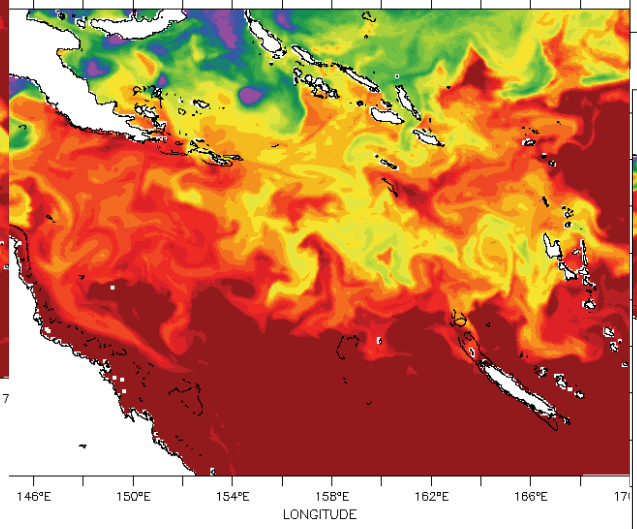


4th



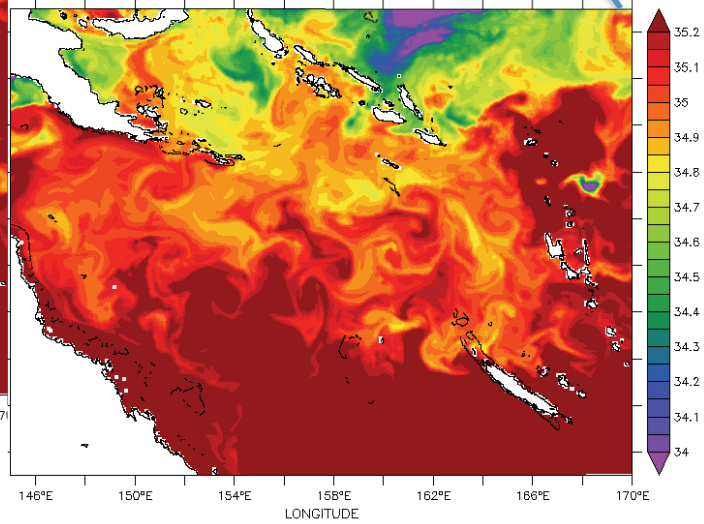
Salinity (psu)

15



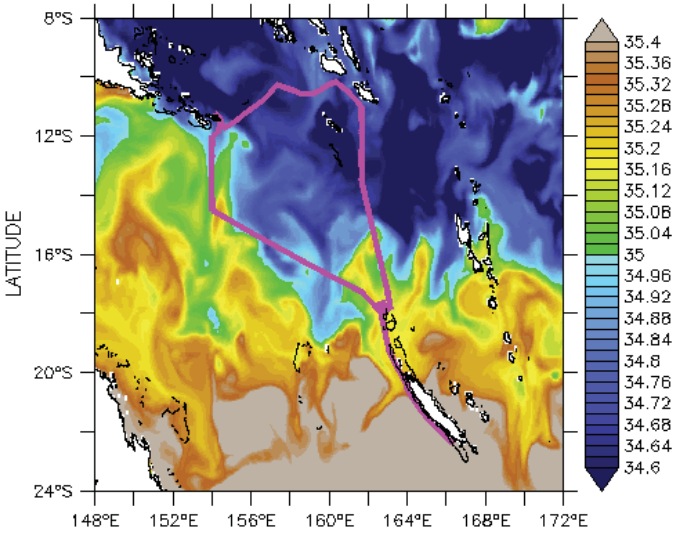
Salinity (psu)

29

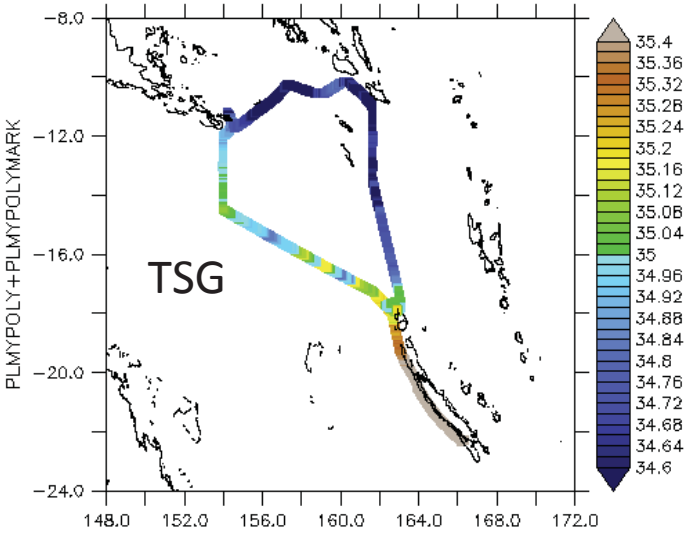


Can we validate the small-scale variability in HR models?

Aug. 2007

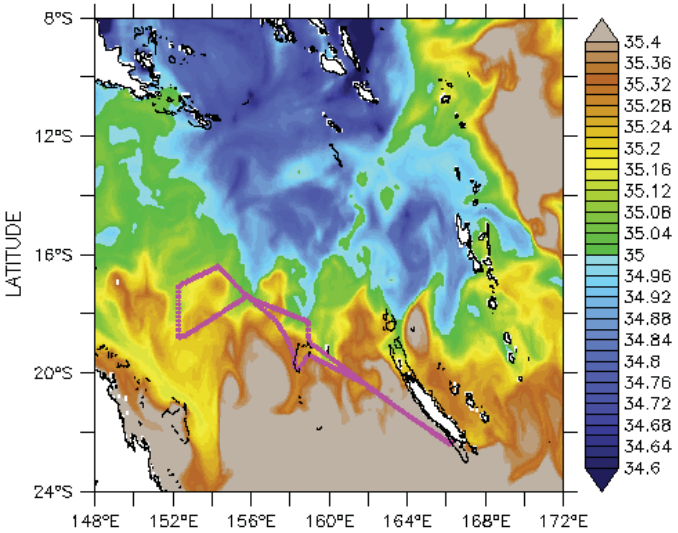


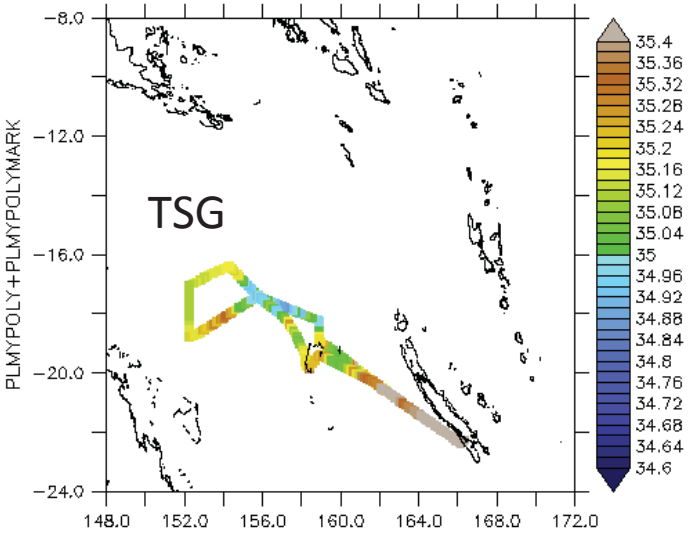
Hycom12 (daily outputs)



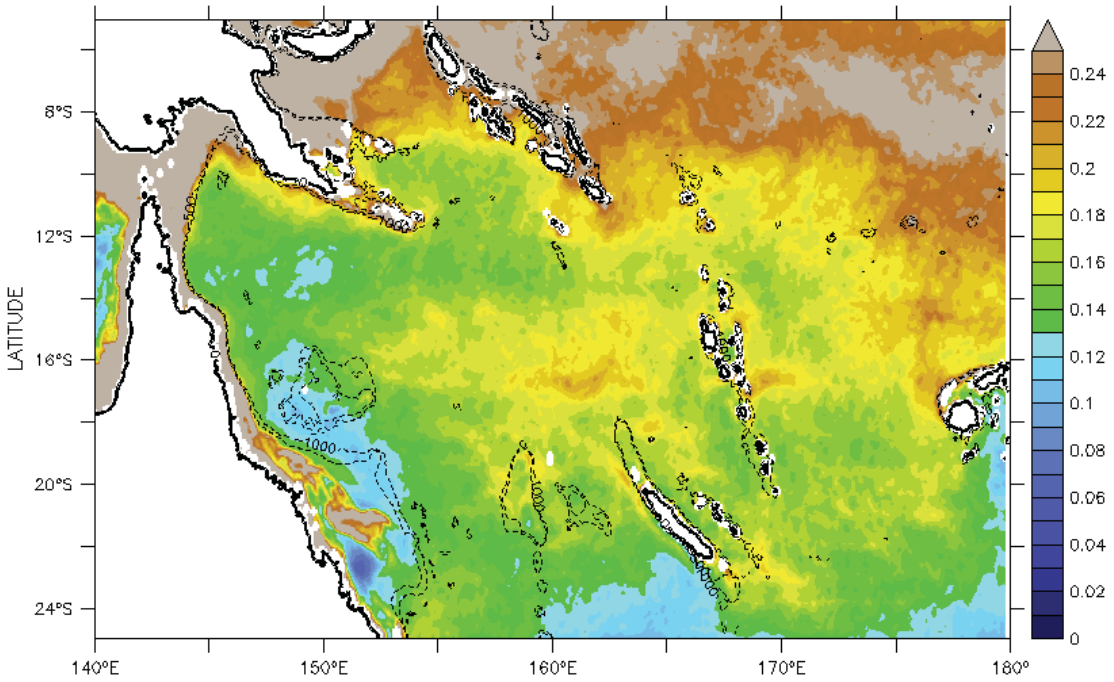
Flusec01 cruise (18days, hourly data)

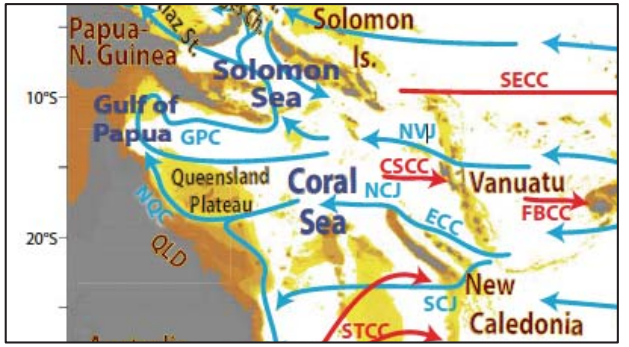
Sep. 2012





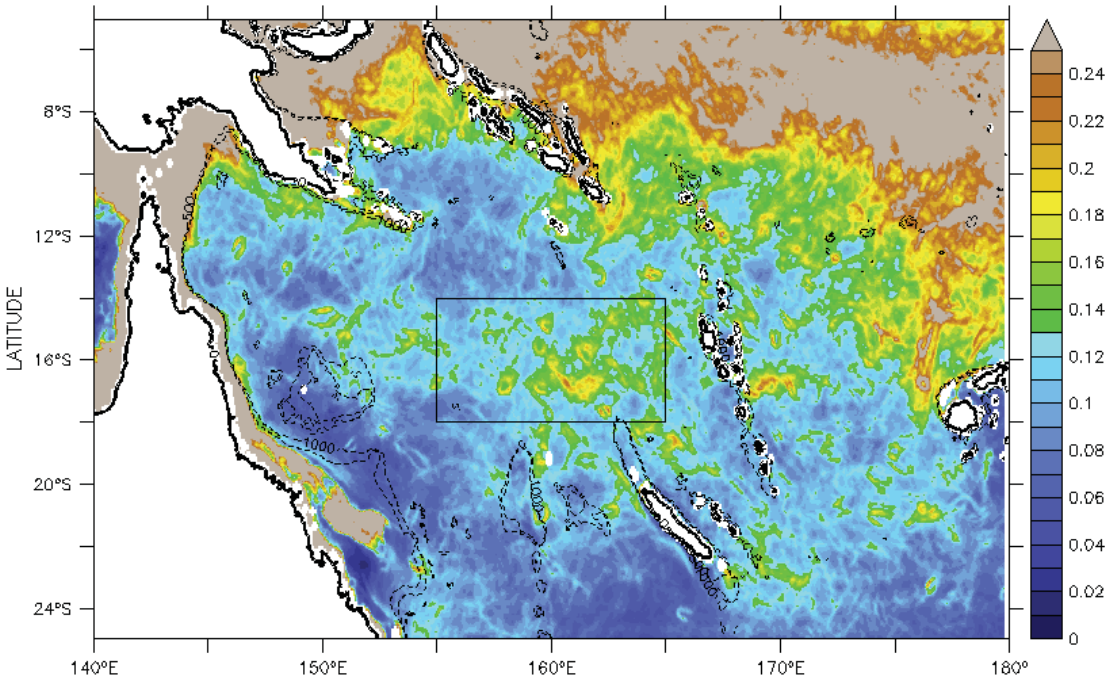
Bifurcation cruise (15days, hourly data)

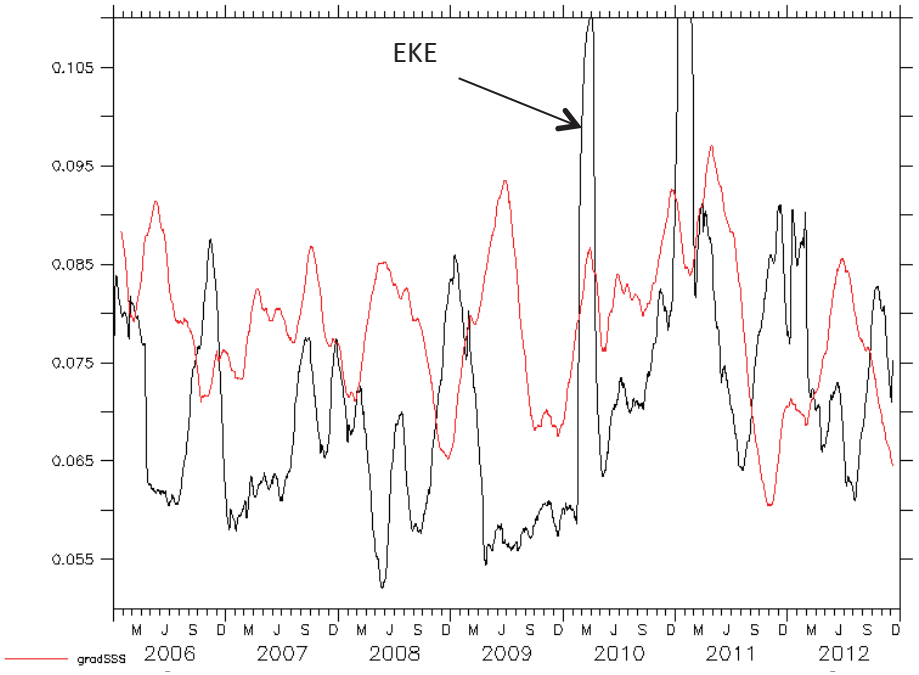


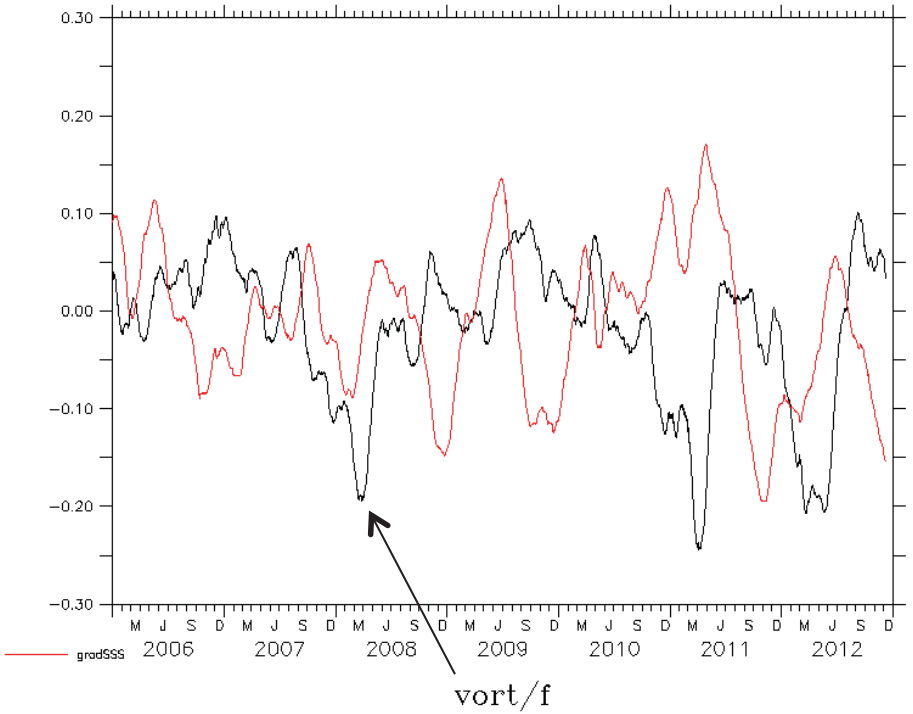


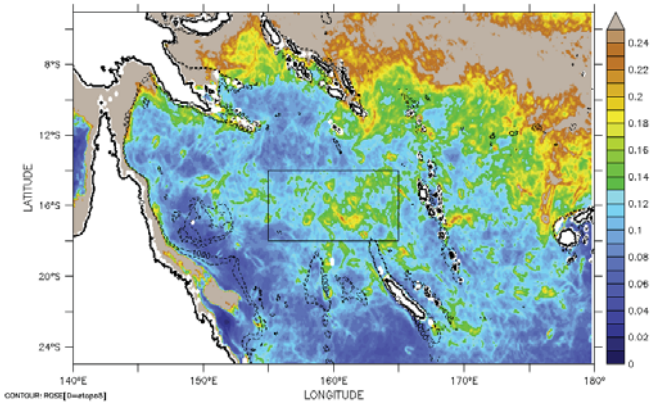
$Grad_H SSS = (grad_x^2 SSS + grad_y^2 SSS)^{(0.5)}$

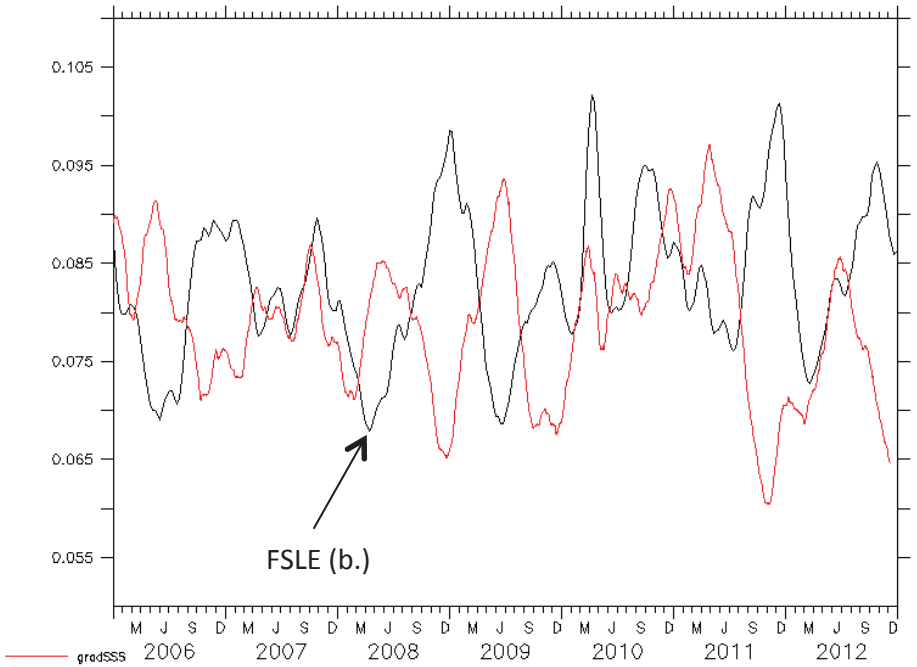
Variance of $grad_H SSS$





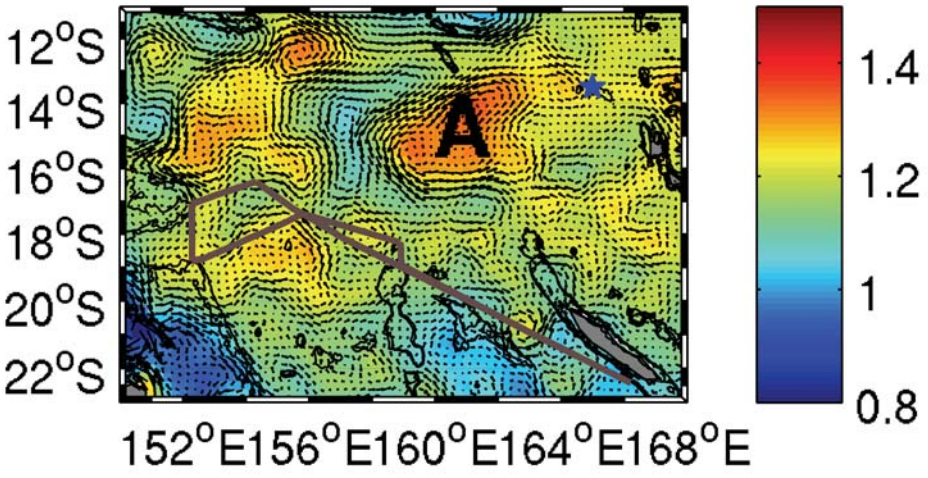




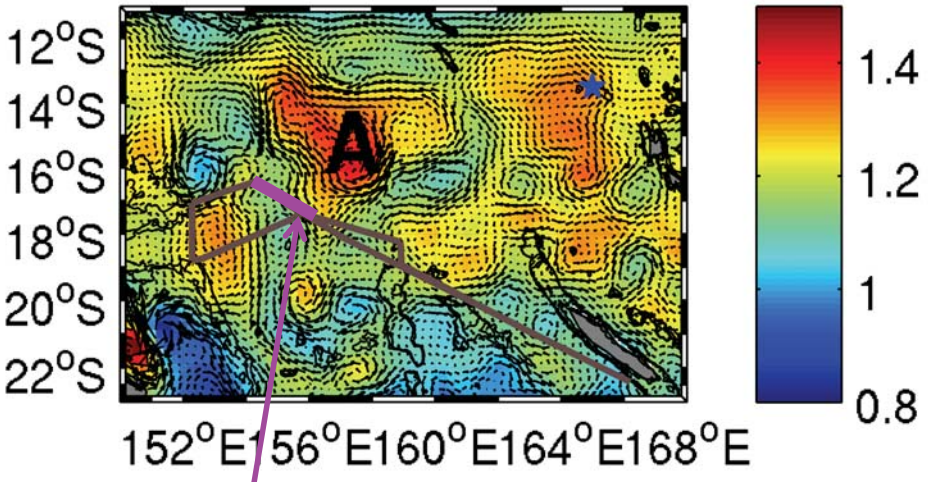


Variance in the salinity gradient at small scales is tightly coupled to the convergent frontal activity and less to the mesoscale variability.

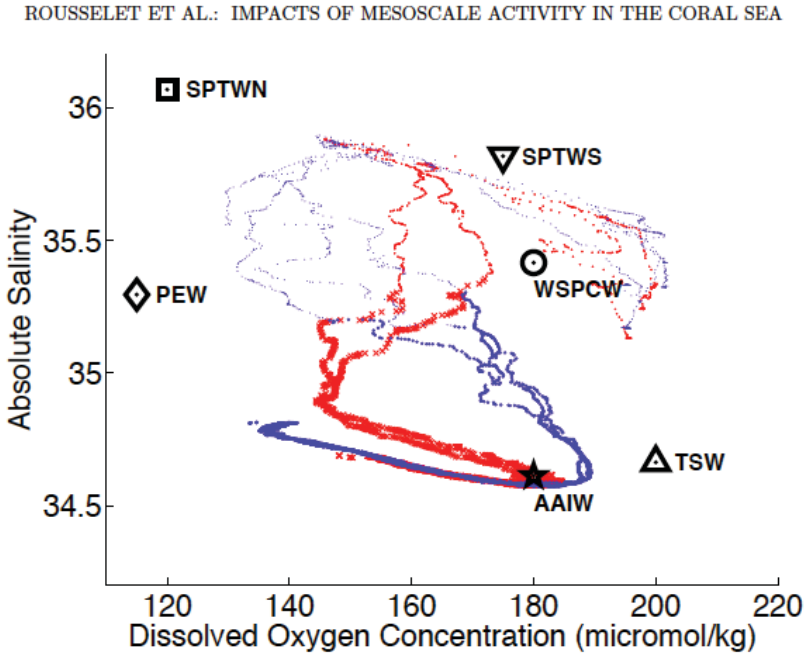
Stirring vs. Transport? what is the role of non linear eddies?

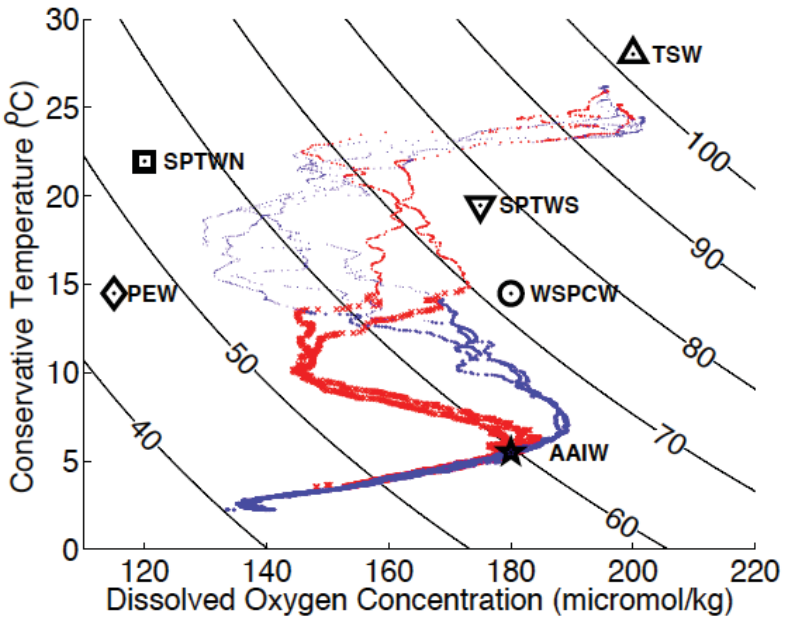


Pre-cruise period



Bifurcation cruise (sept. 2012)

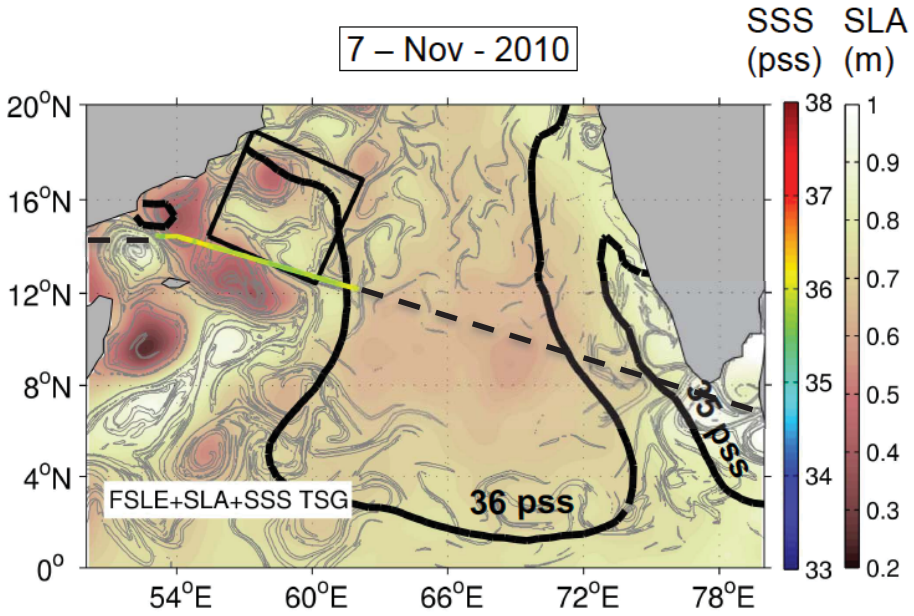




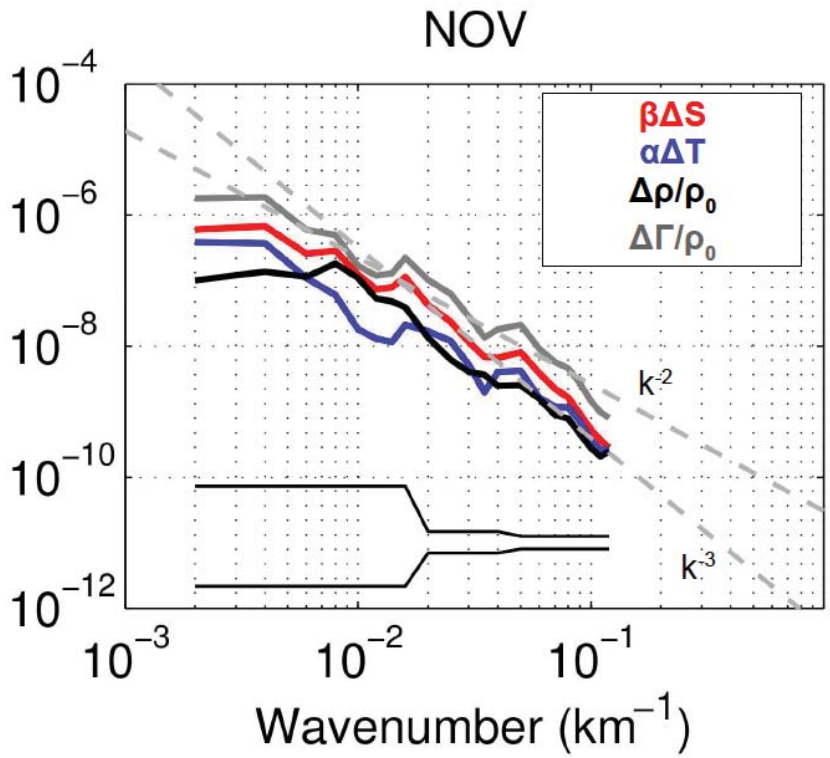
(Rousselet et al., JGR 2016, *in revision*)

Another view of the surface horizontal thermohaline structure: spicy fronts

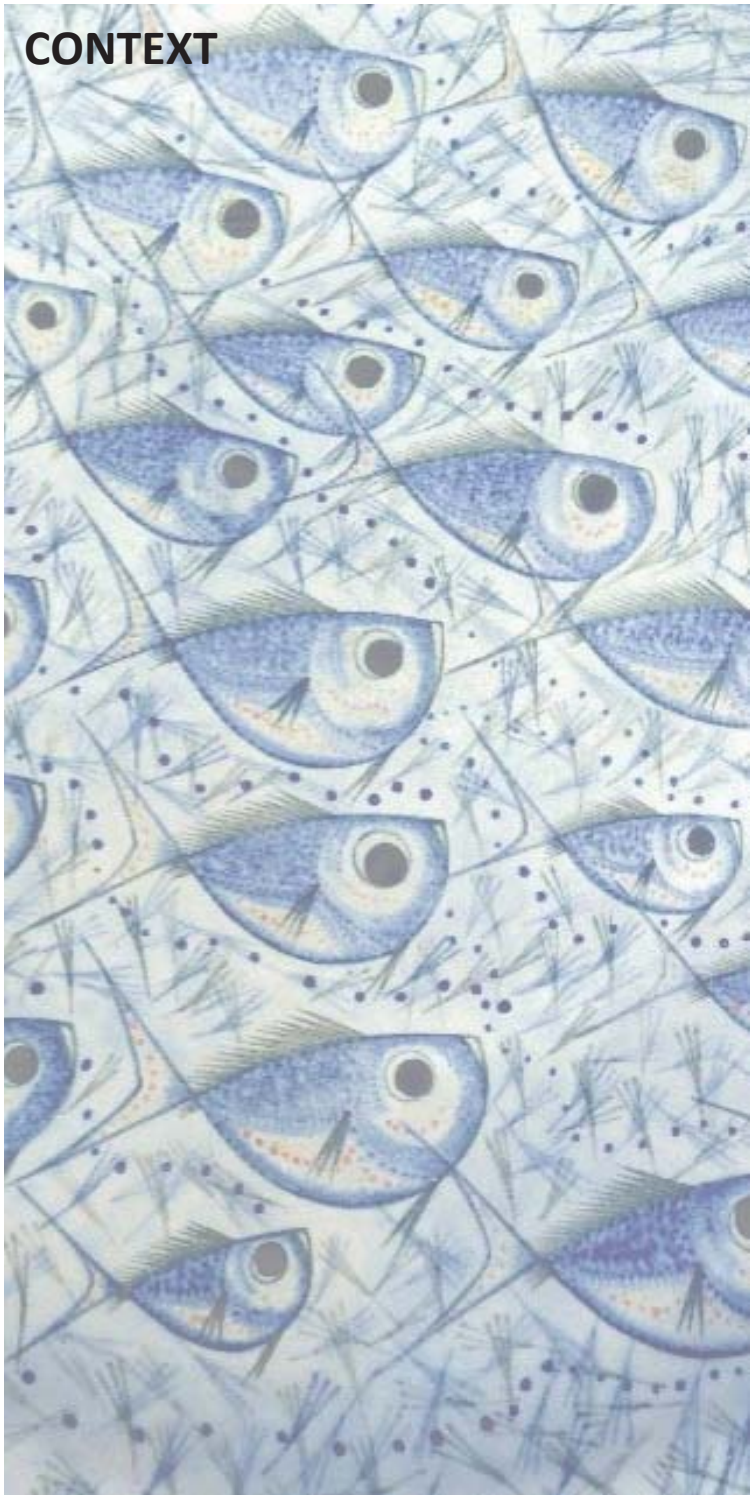
TSG transects are used to compute the horizontal temperature, salinity and density fluctuations, as well as spiciness. Very contrasted regimes are identified depending on the region, on the part of compensated/non-compensated nature of the fronts and on the seasonal cycle of mixed layer.



(presented at Liège GHER meeting by Kolodziejczyk et aL. 2016)



See also:
Kolodziejczyk, N., G. Reverdin, J. Boutin, and O. Hernandez (2015), Observation of the surface horizontal thermohaline variability at mesoscale to submesoscale in the north-eastern subtropical Atlantic Ocean, *J. Geophys. Res.*, 120, doi:10.1002/2014JC010455.



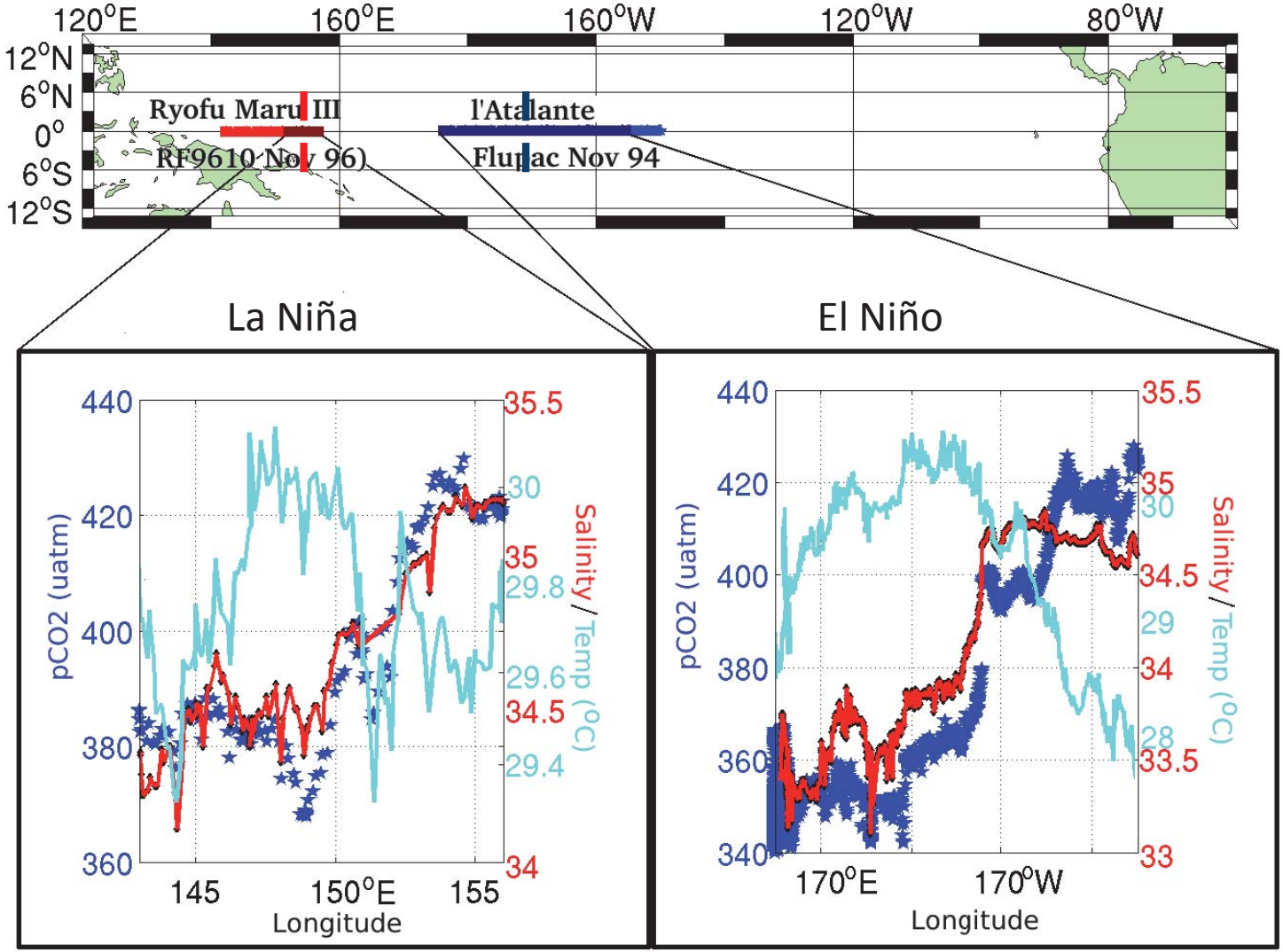
MAIN QUESTIONS

1/ What are the statistical and dynamical properties (as well as their associated physical processes) of the small scale variability in SSS? (what are the limits of the SMOS mission?)

2/ How uniform are stirring and mixing processes? (particularly in association with the topography)

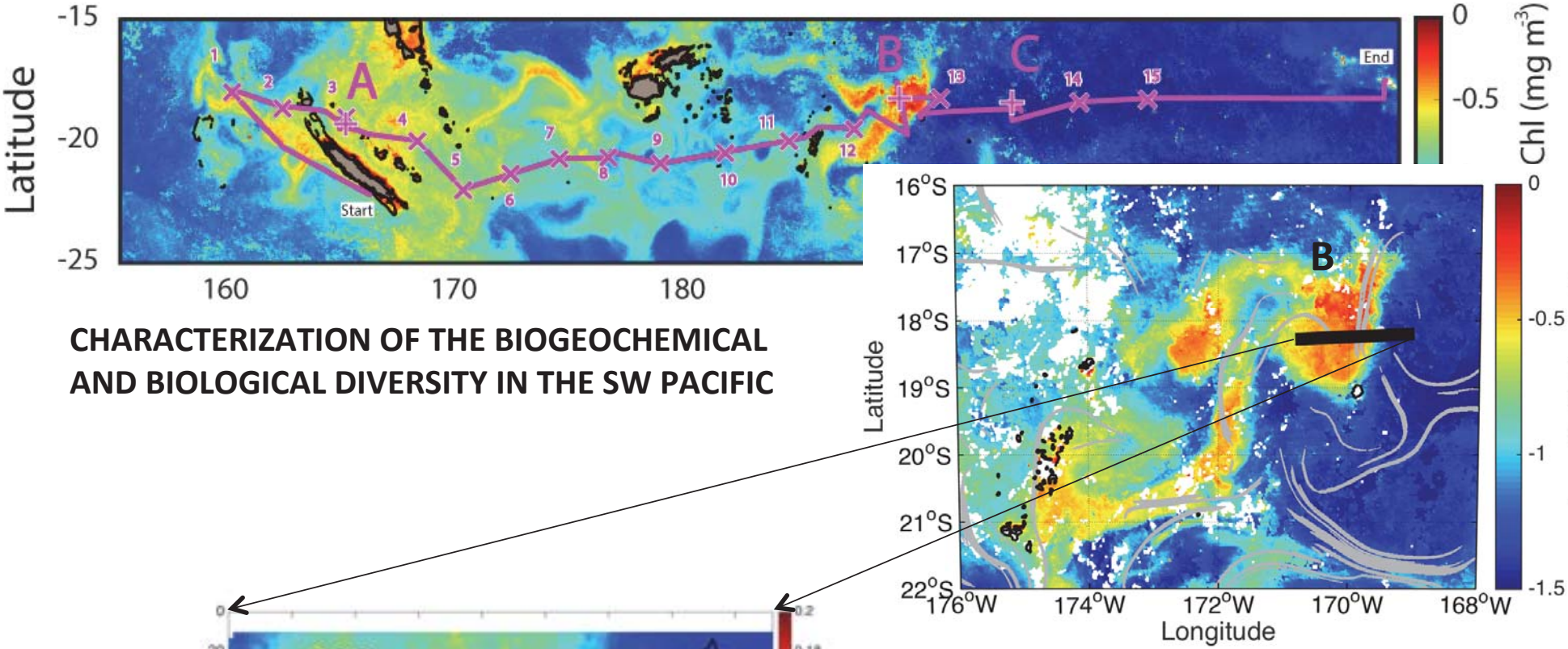
3/ What aspects of stirring and mixing affect biological/ biogeochemical processes?

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 (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)

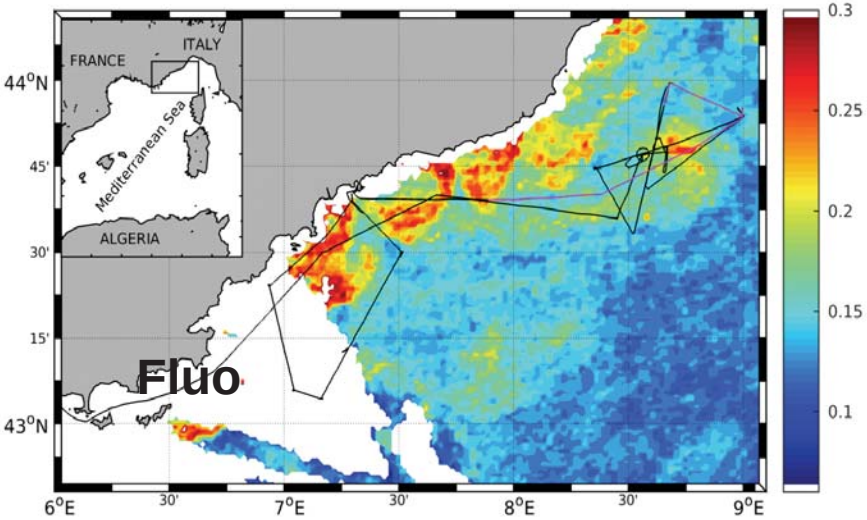
Courtesy of A. de Verneil (MIO)

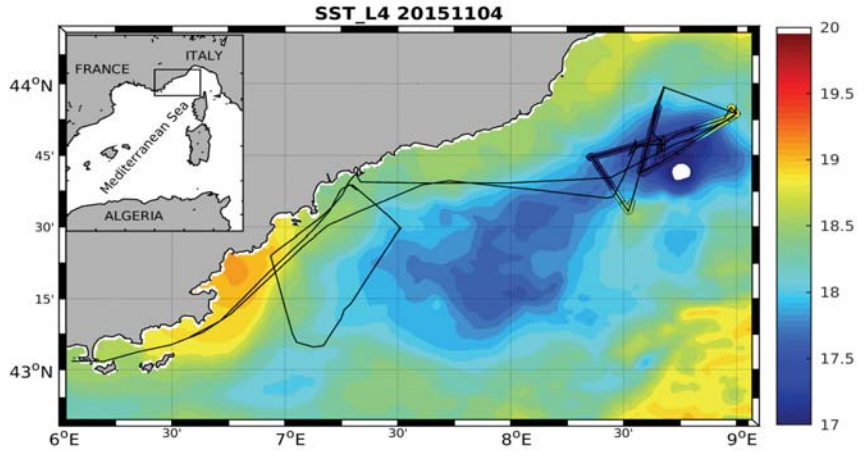
OSCAHR

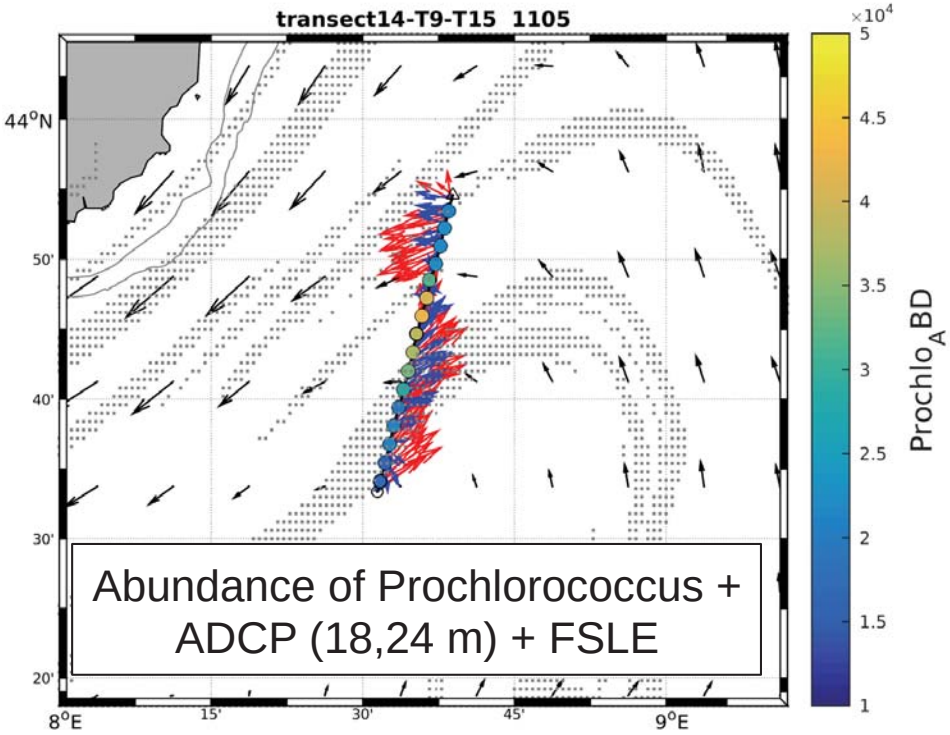
***O**bserving **S**ubmesoscale **C**oupling **A**t **H**igh **R**esolution*

Doglioli A. (PI) and MIO team

NW Mediterranean Sea cruise, 29 Oct to 6 Nov 2015







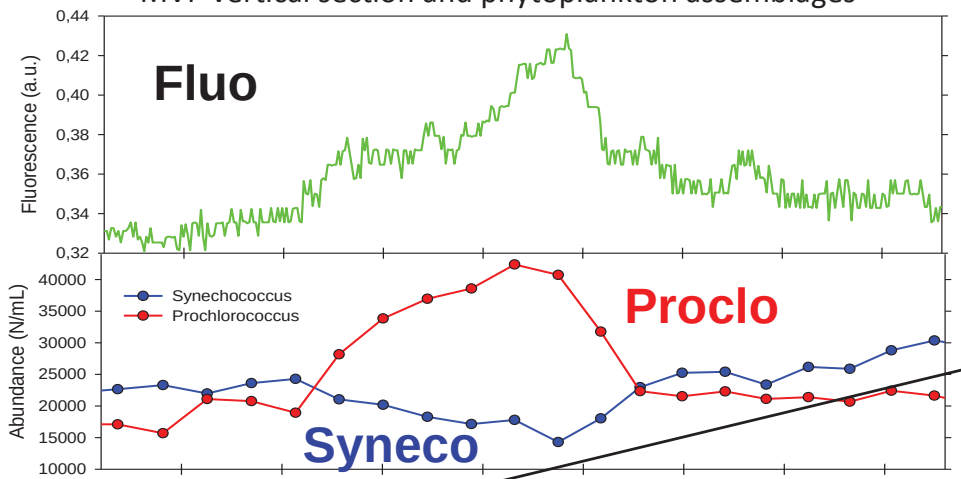
Goal: sampling of a (sub)mesoscale structure characterized by
a cyclonic re-circulation, a local min of SST and a local max of Chl-a

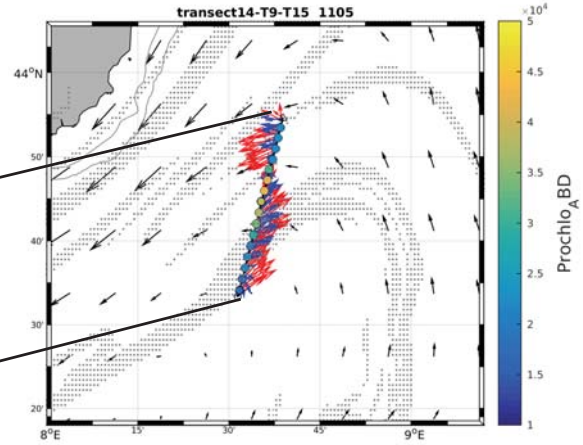
OSCAHR

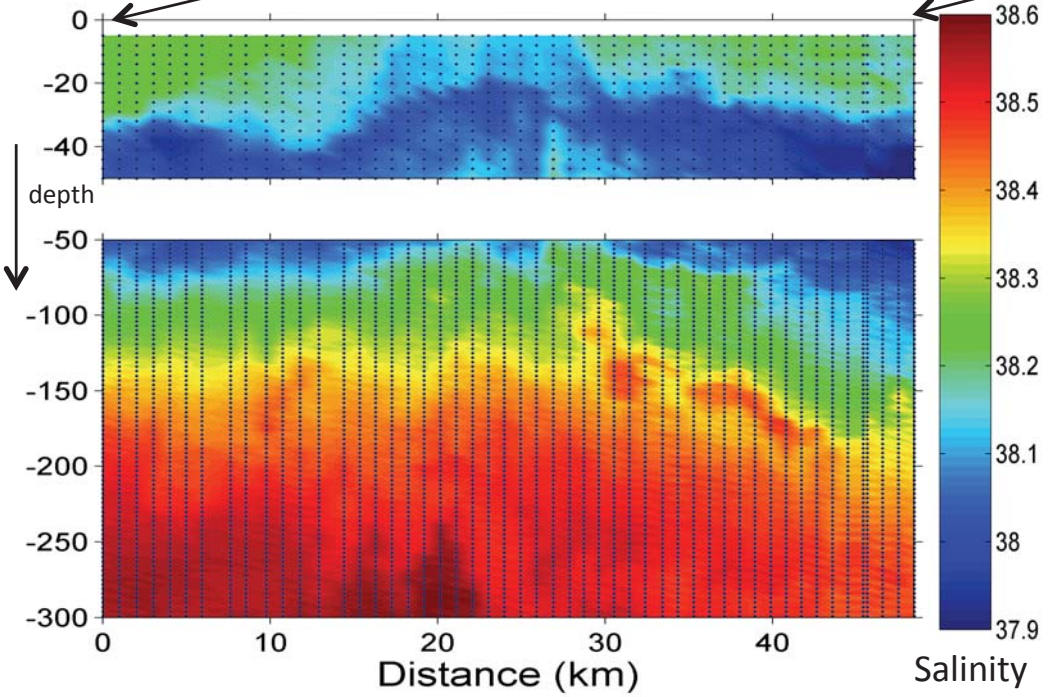
Observing Submesoscale Coupling At High Resolution

andrea.doglioli@univ-amu.fr

MVP vertical section and phytoplankton assemblages







Preliminary conclusion:

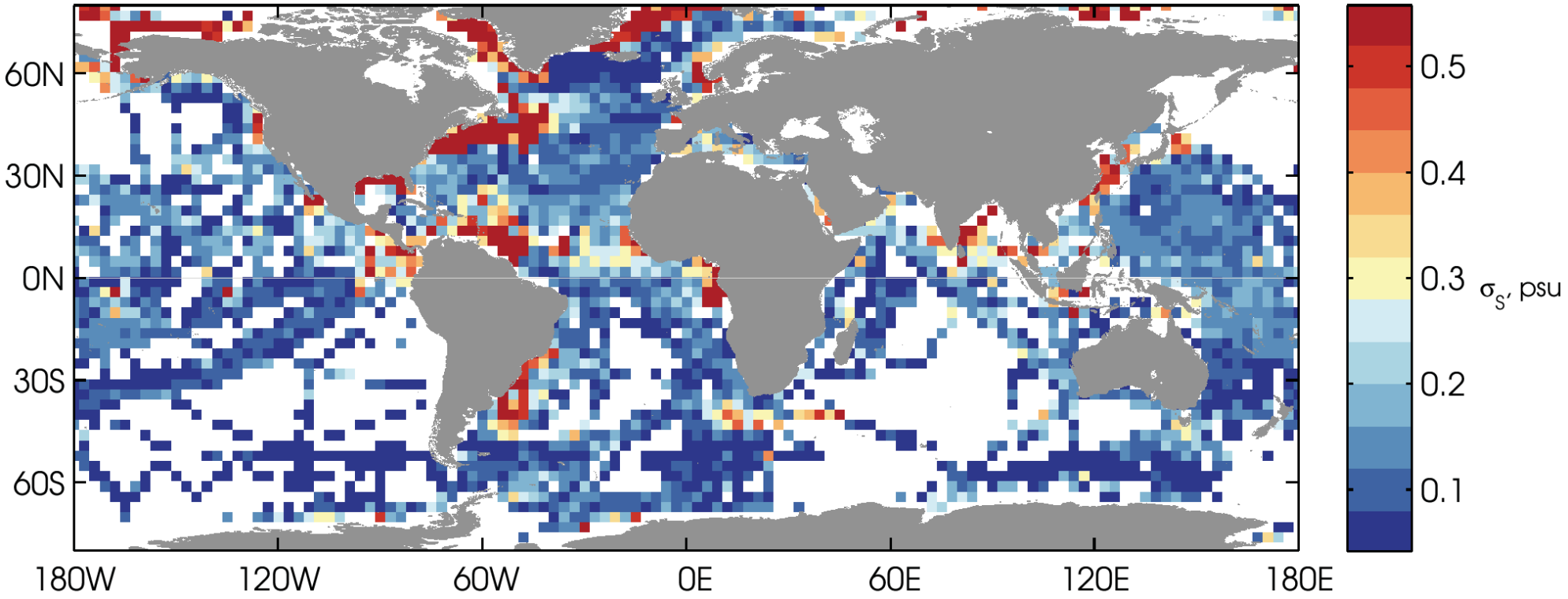
the fine-scale structure of the physical field drives the spatial organization of the plankton functional groups

Need to specify the role of salinity

CONCLUSIONS AND PERSPECTIVES

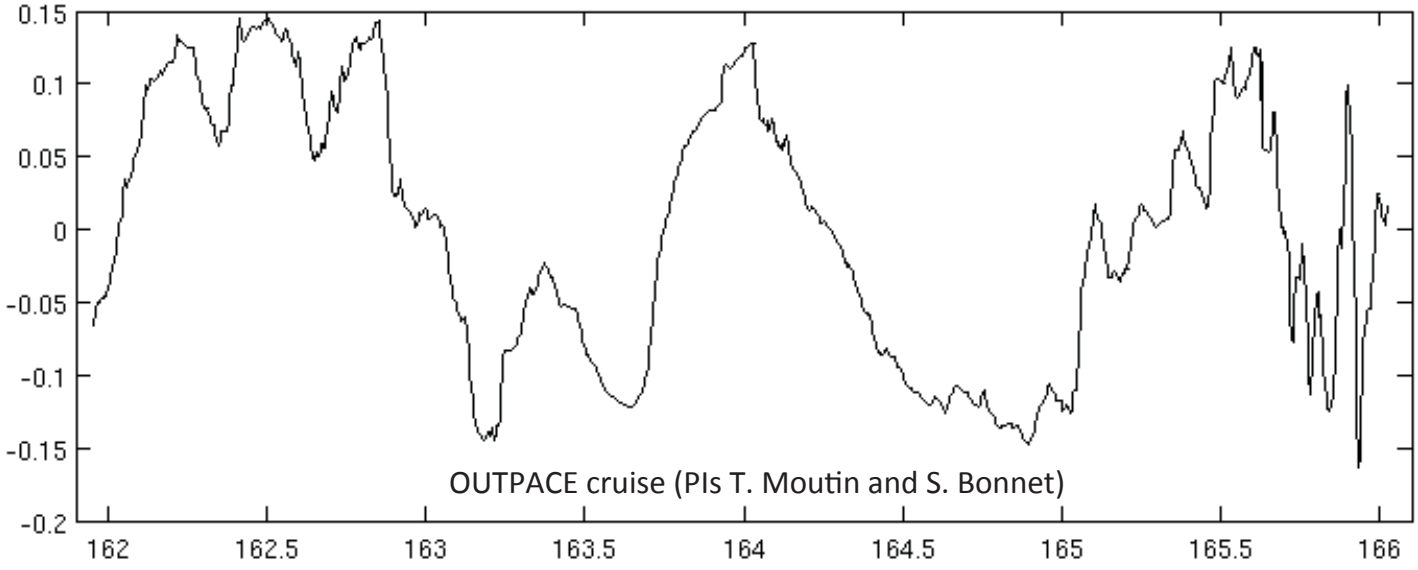
- Observation of mesoscale ocean dynamics: eddies, turbulence, and lateral fluxes are improving, but it remains necessary to understand the growth and decay processes of the associated eddy structures that can also depend on sub-mesoscale dynamics,

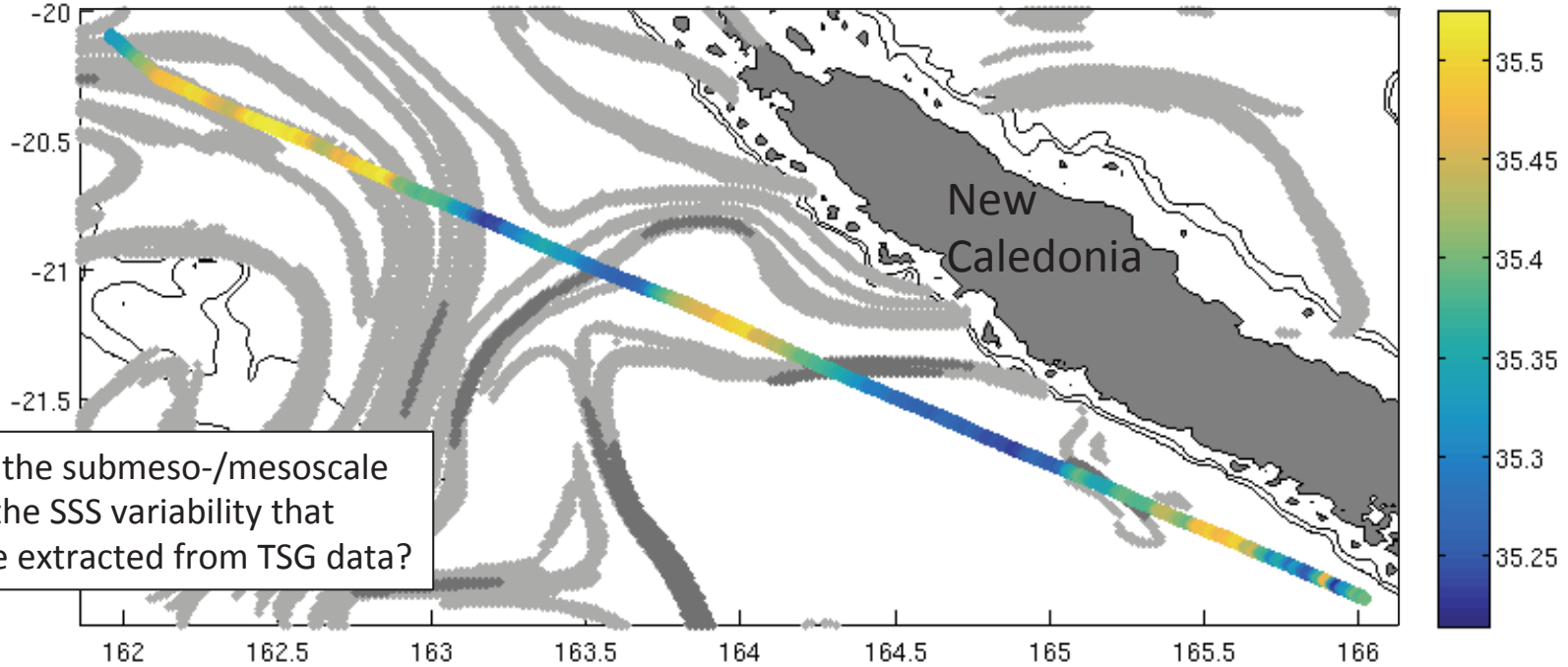
- The specific role of salinity (in part as a passive tracer and, in another part, as a dynamical field) should be elucidated at global scales.



Global SSS small scale variability as seen by the TSG data sets (adapted from Boutin et al. BAMS, 2016)

Perspectives: Identification of the energy pathways involving sub-mesoscales





What is the submeso-/mesoscale part of the SSS variability that could be extracted from TSG data?

REFERENCES

Alory, G. *et al.*, The French contribution to the Voluntary Observing Ships network of Sea Surface Salinity, ***Deep Sea Res. I***, 105, 1–18, 2015.

Boutin, J. *et al.*, Satellite and in situ salinity: Understanding Near-surface Stratification and Sub-footprint Variability, ***BAMS***, doi: 10.1175/BAMS-D-15-00032.1, in press, **Aug. 2016**.

Maes, C., B. Dewitte, J. Sudre, V. Garcon, and D. Varillon, Small-scale features of temperature and salinity surface fields in the Coral Sea, ***J. Geophys. Res. Oceans***, 118, 5426–5438, doi : 10.1002/jgrc.20344, 2013.

O'Kane, T. J., D. P. Monselesan, and C. Maes (2016), On the stability and spatiotemporal variance distribution of salinity in the upper ocean, ***J. Geophys. Res. Oceans***, 121, doi: 10.1002/2015JC011523.

Reul, N., B. Chapron, T. Lee, C. Donlon, J. Boutin, and G. Alory (2014), Sea surface salinity structure of the meandering Gulf Stream revealed by SMOS sensor, ***Geophys. Res. Lett.***, 41, doi: 10.1002/2014GL059215.

Rousselet, L., A. Doglioli, C. Maes, B. Blanke, and A. Petrenko, Impacts of mesoscale activity on the water masses and circulation in the Coral Sea, *submitted to* ***JGR-Oceans***, in revision, 2016.

Christophe.Maes@ird.fr