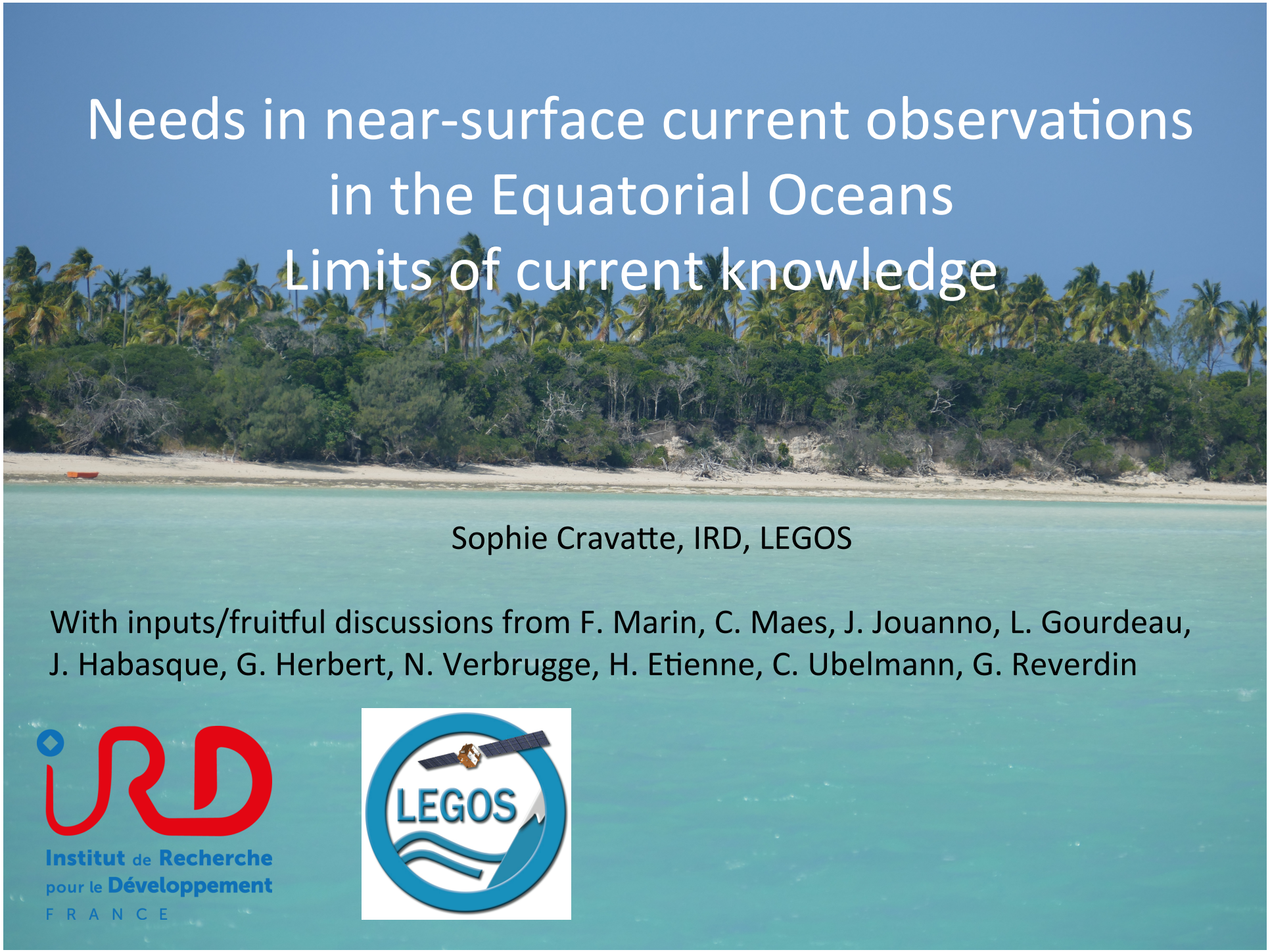
Needs in near-surface current observations in the Equatorial Oceans
Limits of current knowledge



Sophie Cravatte, IRD, LEGOS

With inputs/fruitful discussions from F. Marin, C. Maes, J. Jouanno, L. Gourdeau, J. Habasque, G. Herbert, N. Verbrugge, H. Etienne, C. Ubelmann, G. Reverdin

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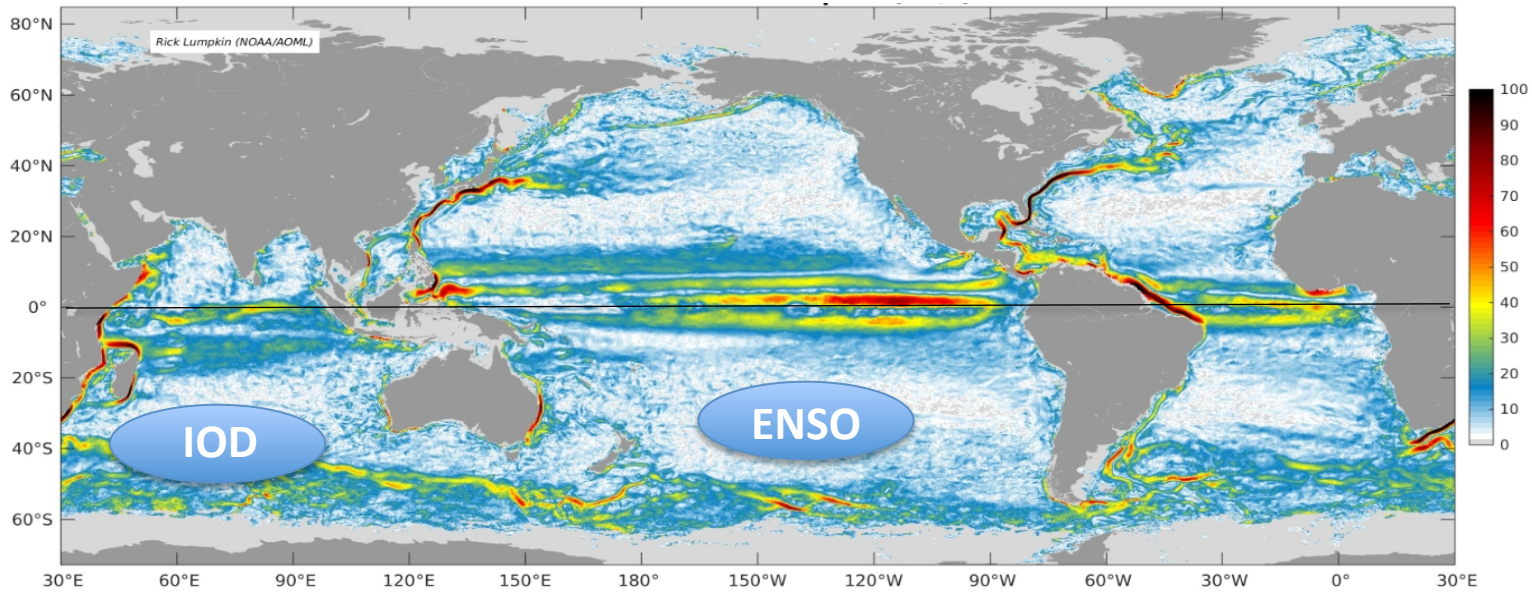
FRANCE

LEGOS

Why focusing on the equatorial regions?

- ✓ Strongly coupled O-A system
- ✓ Key regions for climate variability, with impacts reverberating globally
- ✓ Strong mean currents, instabilities, fronts
- ✓ Equatorial singularity

Annual mean drifter speed (z=15m) (cm/s)



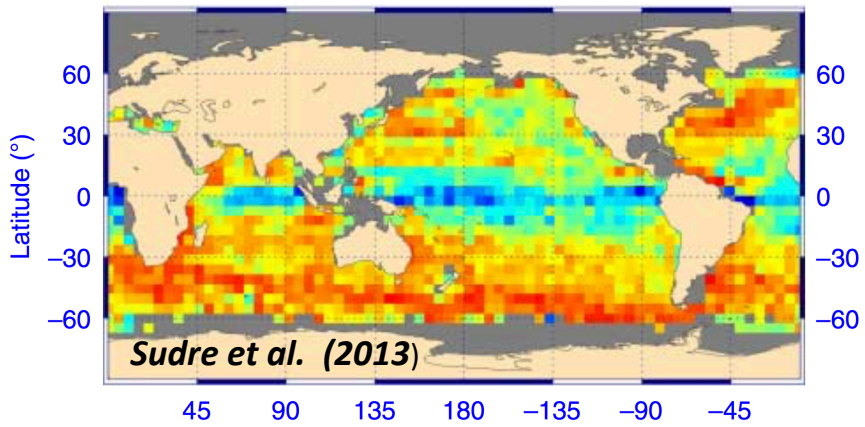
Surface currents are an essential variable at the interface between ocean and atmosphère

Observational challenges in the equatorial regions

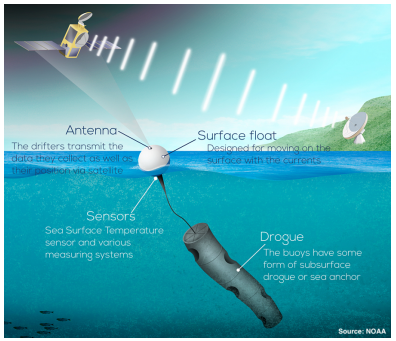
✓ Geostrophy and Ekman do not hold (f -> 0)
Satellite based products (OSCAR, GEKCO, SURCOUF) have deficiencies
U: correct for L>400km, T> 40days problems for V
(Johnson et al. 2007; Sudre et al., 2013, CMEMS)

C

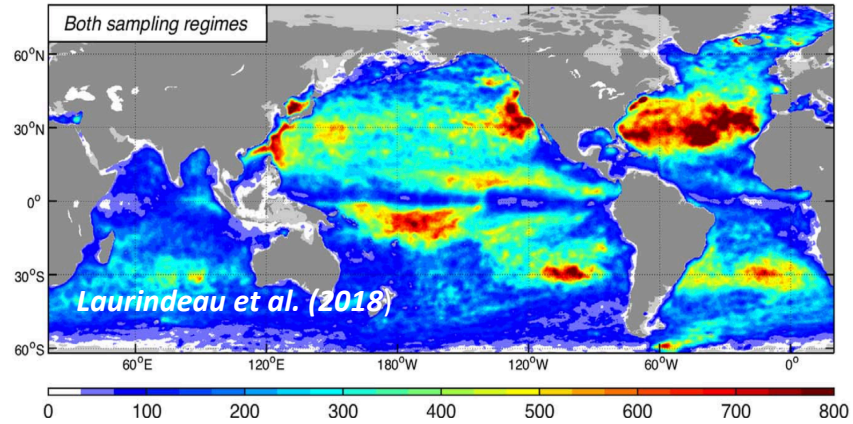
Correlation V GEKCO/Argo displacements



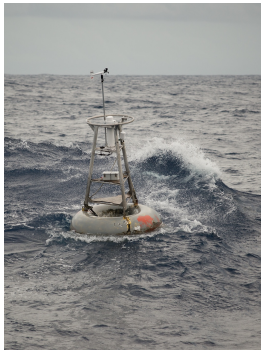
✓ Surface drifters (15m) (and Argo) diverge from the equatorial band (*Laurindeau et al., 2018; Lumpkin and Johnson, 2013)*

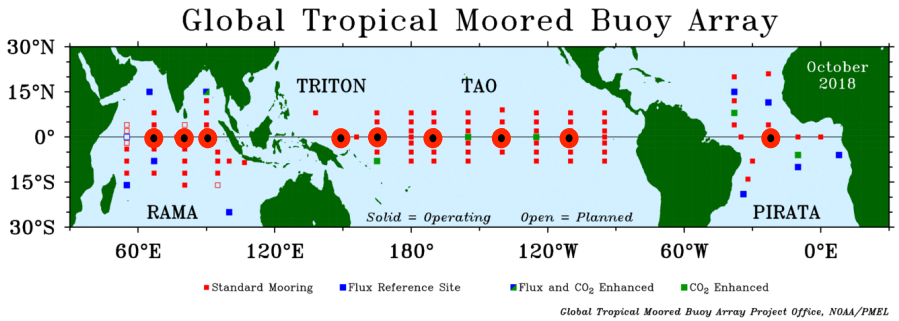


Number of drifter days for 1979-2015 per 1°.1°

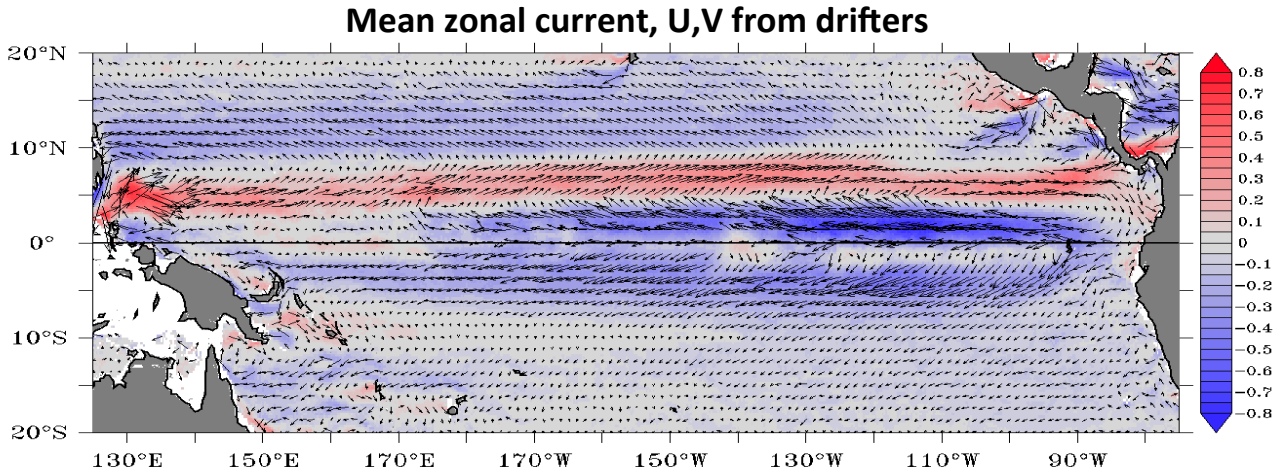


✓ Moorings at the equator
ADCP at best sample to 25m
Some currentmeters at 10m



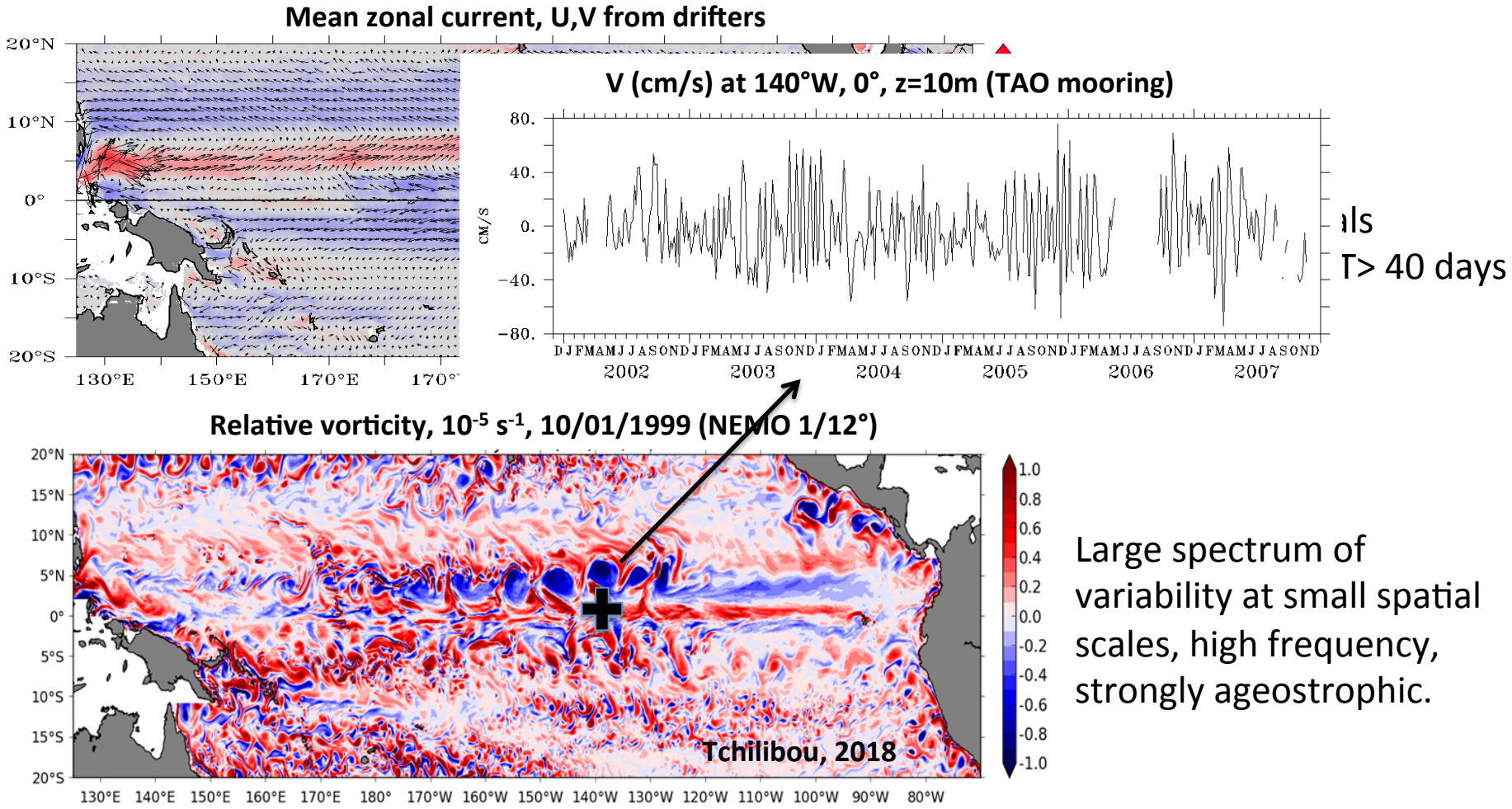


Current knowledge on surface currents



Present OS:
Mean, seasonal,
interannual signals
for U: L>400km, T> 40 days

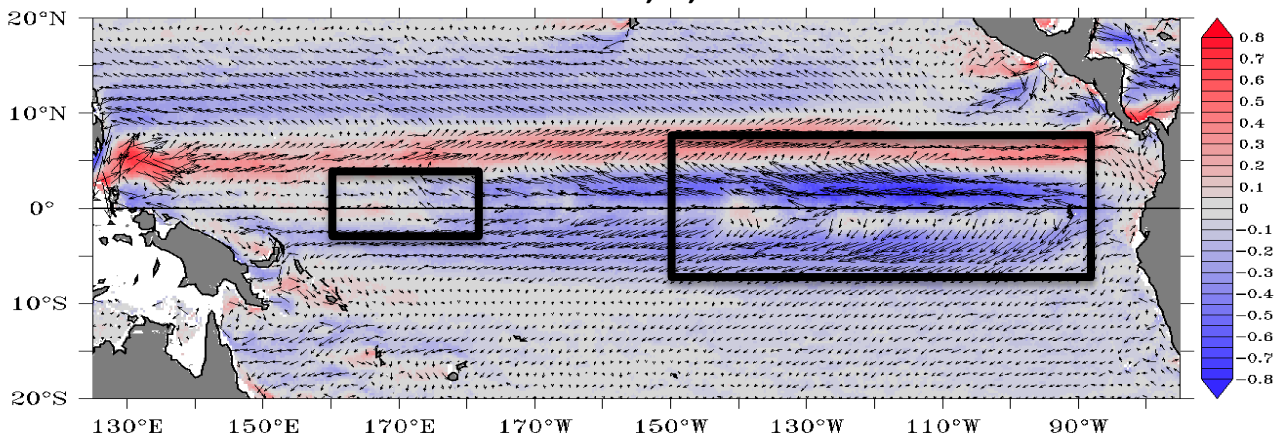
Current knowledge on surface currents



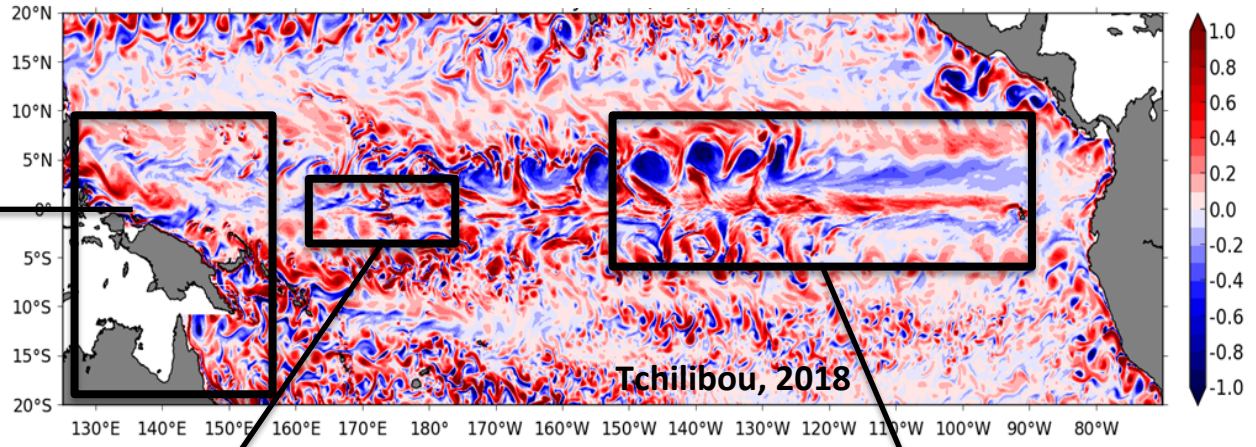
At first order, surface currents from space (global, repeated coverage) would provide:
- improved knowledge of currents variability at intraseasonal timescales, and at mesoscale
- new insights on the associated dynamics of the equatorial oceans

Current knowledge on surface currents

Mean zonal current, U,V from drifters



Relative vorticity, 10^{-5} s^{-1}, 10/01/1999 (NEMO 1/12°)



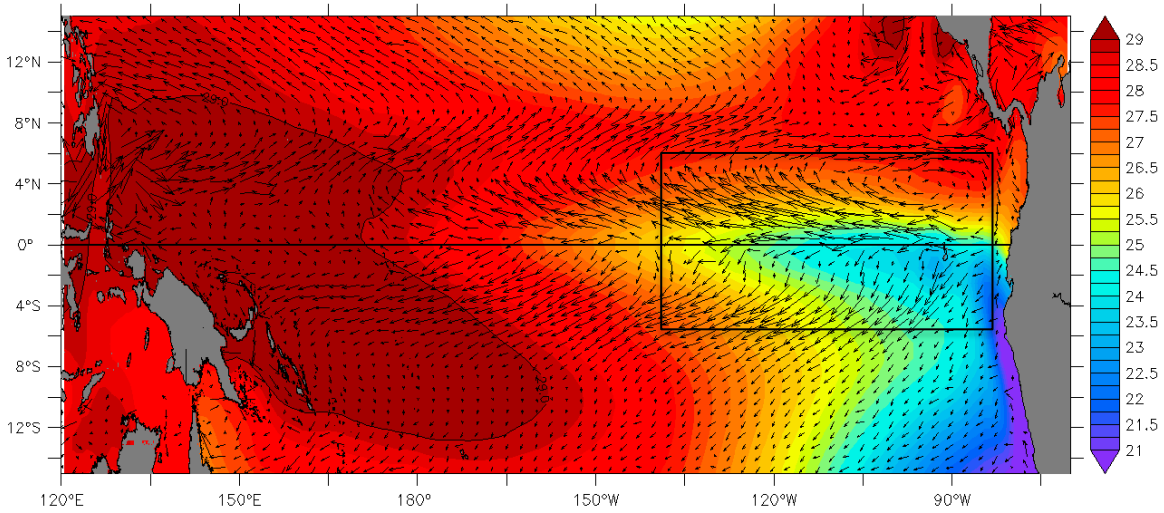
~~Boundary currents~~

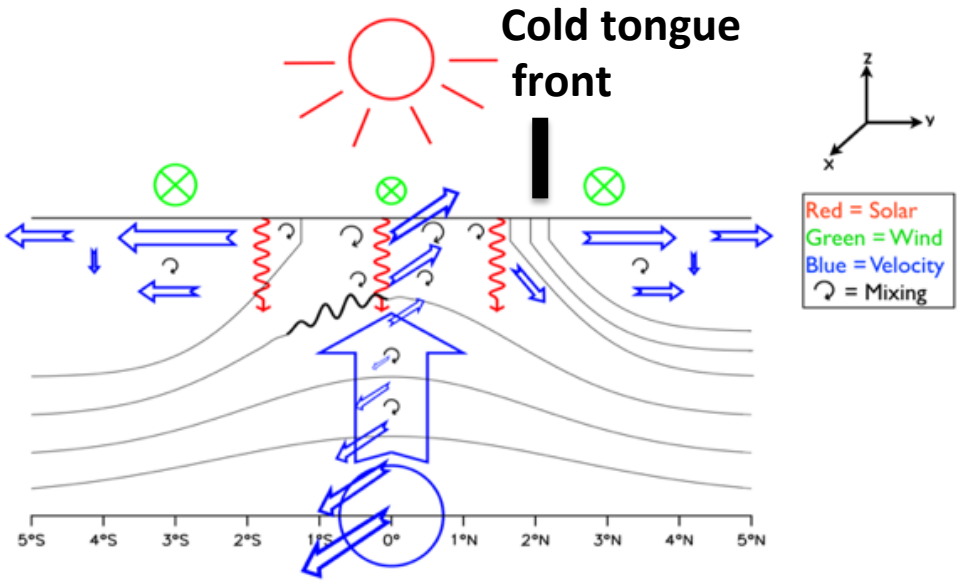
Warm Pool eastern edge

Cold tongue, equatorial upwelling region

Cold tongue, equatorial upwelling region

Mean SST, mean 15m currents (Drifters)





Courtesy of W. Kessler

-region of largest oceanic heat gain
-largest natural oceanic source of CO2 to the atmosphere)

Complex dynamics!
SST results from a subtle balance among upwelling, vertical mixing and horizontal advection

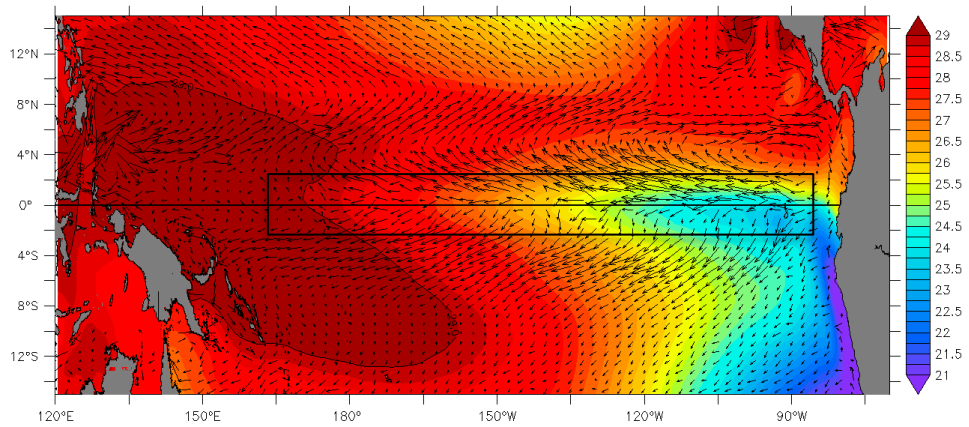
⇒ Must have these terms right
Currently, we don't
(nor in models, nor in obs)

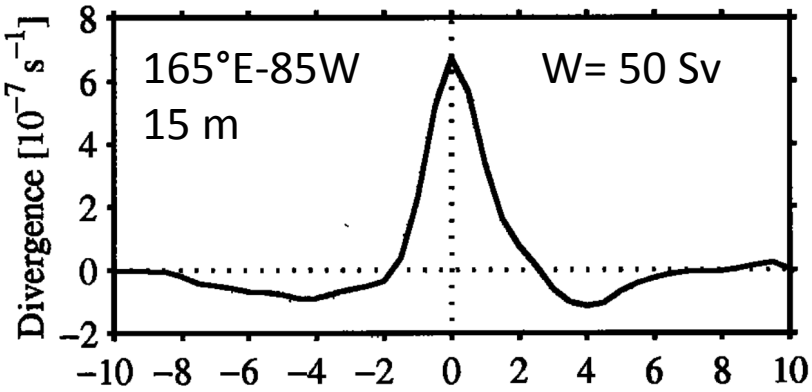
How could surface currents lead to progress?

Estimating the upwelling patterns/variability

No direct W measurements: through horizontal divergence.

Mean SST, mean 15m currents (Drifters)

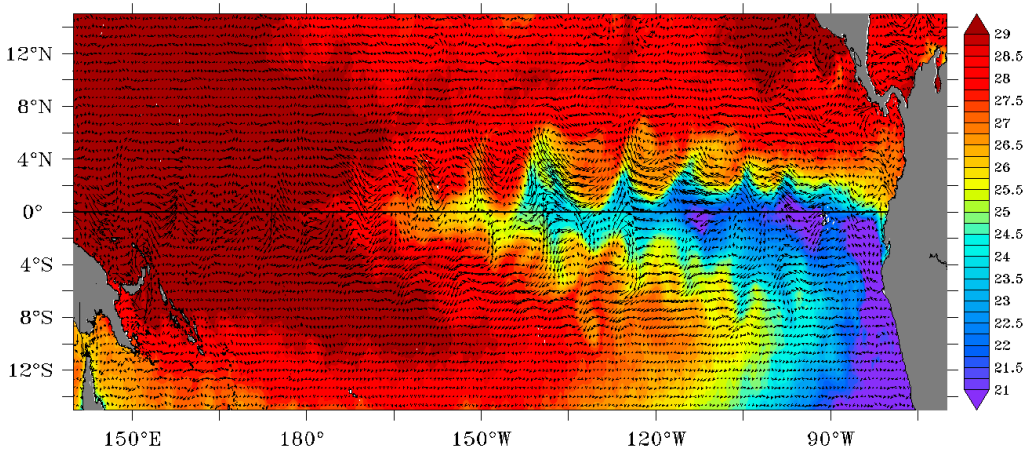




Johnson et al., 2001a,b

Observations (drifters, SADCP): only a mean, broadscale view, missing the upper 15m

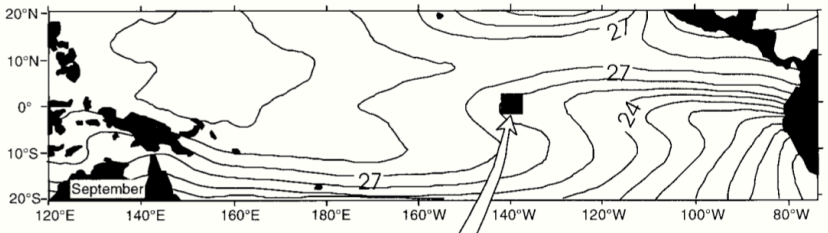
SST, OSCAR currents, 1 August 2016



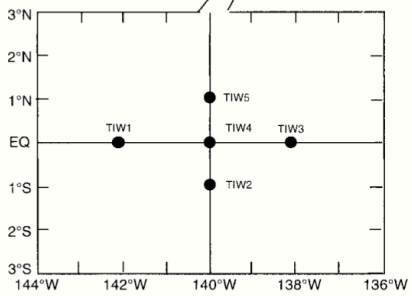
Surface current from space would for the first time give access to the upwelling spatial and temporal scales

Estimating the upwelling patterns/variability

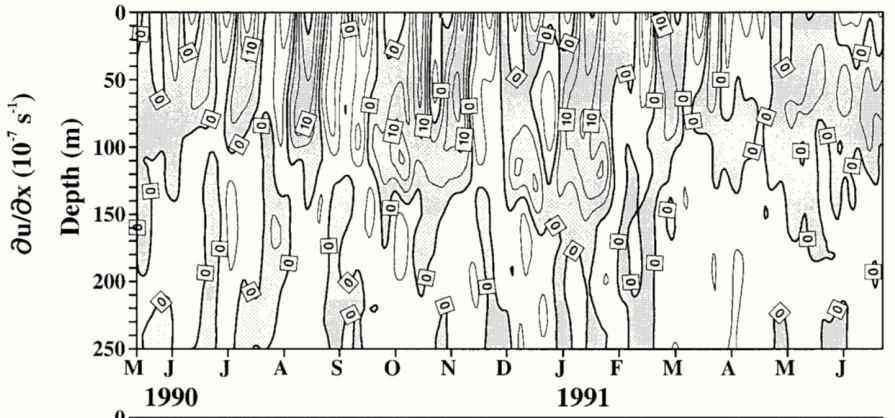
Weisberg and Qiao, 2000

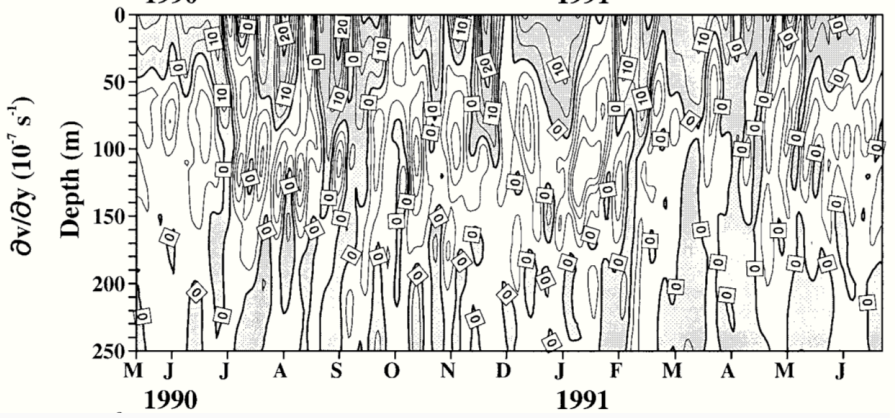


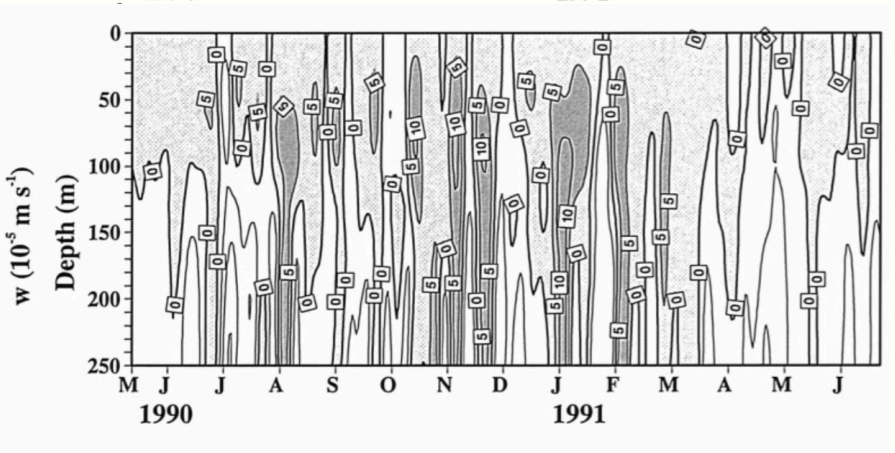
140°W
0°



● : UNIVERSITY OF SOUTH FLORIDA, TIWE MOORINGS

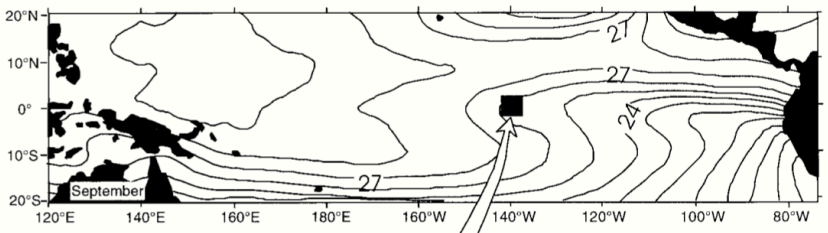


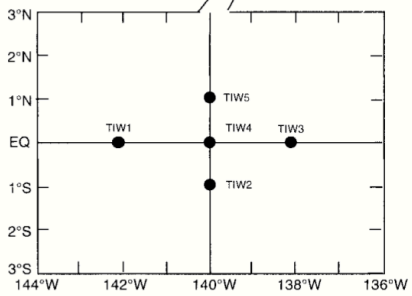




Having access to the upwelling patterns/variability

Weisberg and Qiao, 2000





140°W
0°

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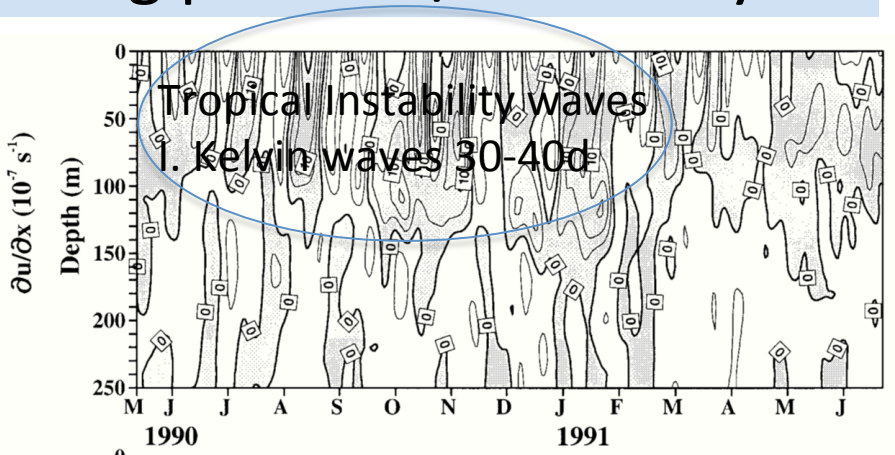
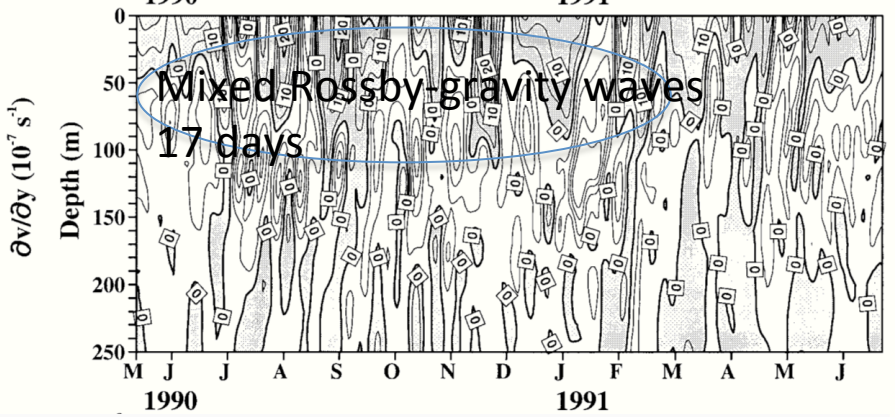
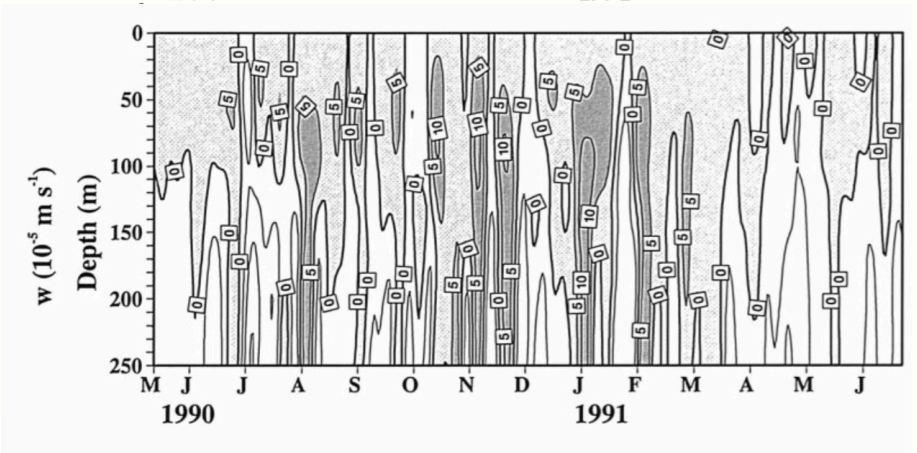
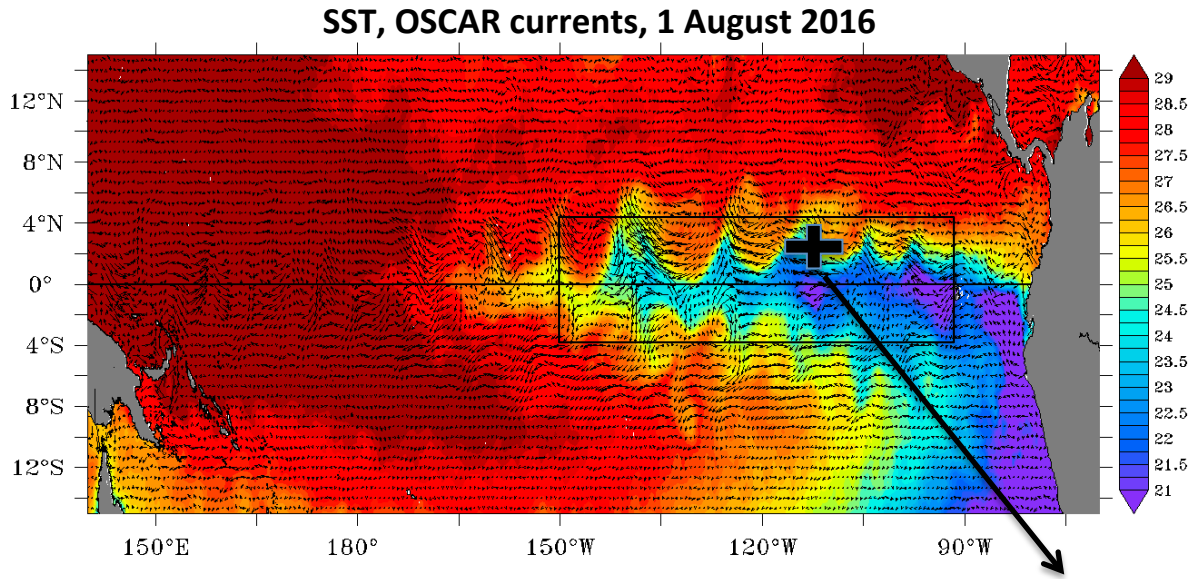




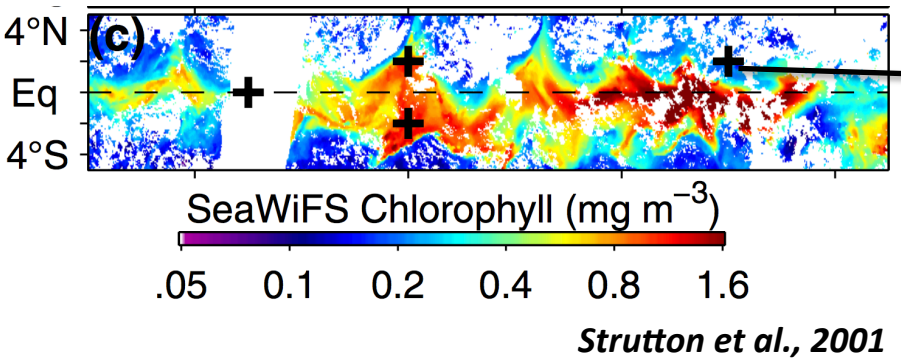


Requirements:
U, V, W varying at 15-40 days
Spatial scales?
(100 km? Less?)
=> Stringent

Horizontal advection terms at intraseasonal timescales

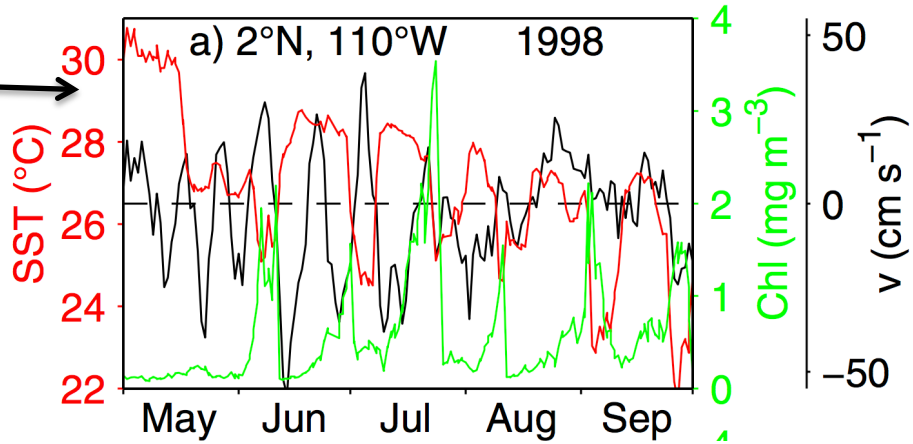


TIWs impact heat and freshwater budgets, productivity *(e.g. Jochum et al., 2006; Menkes et al., 2006; Lee et al. 2012; Strutton et al., 2001)*



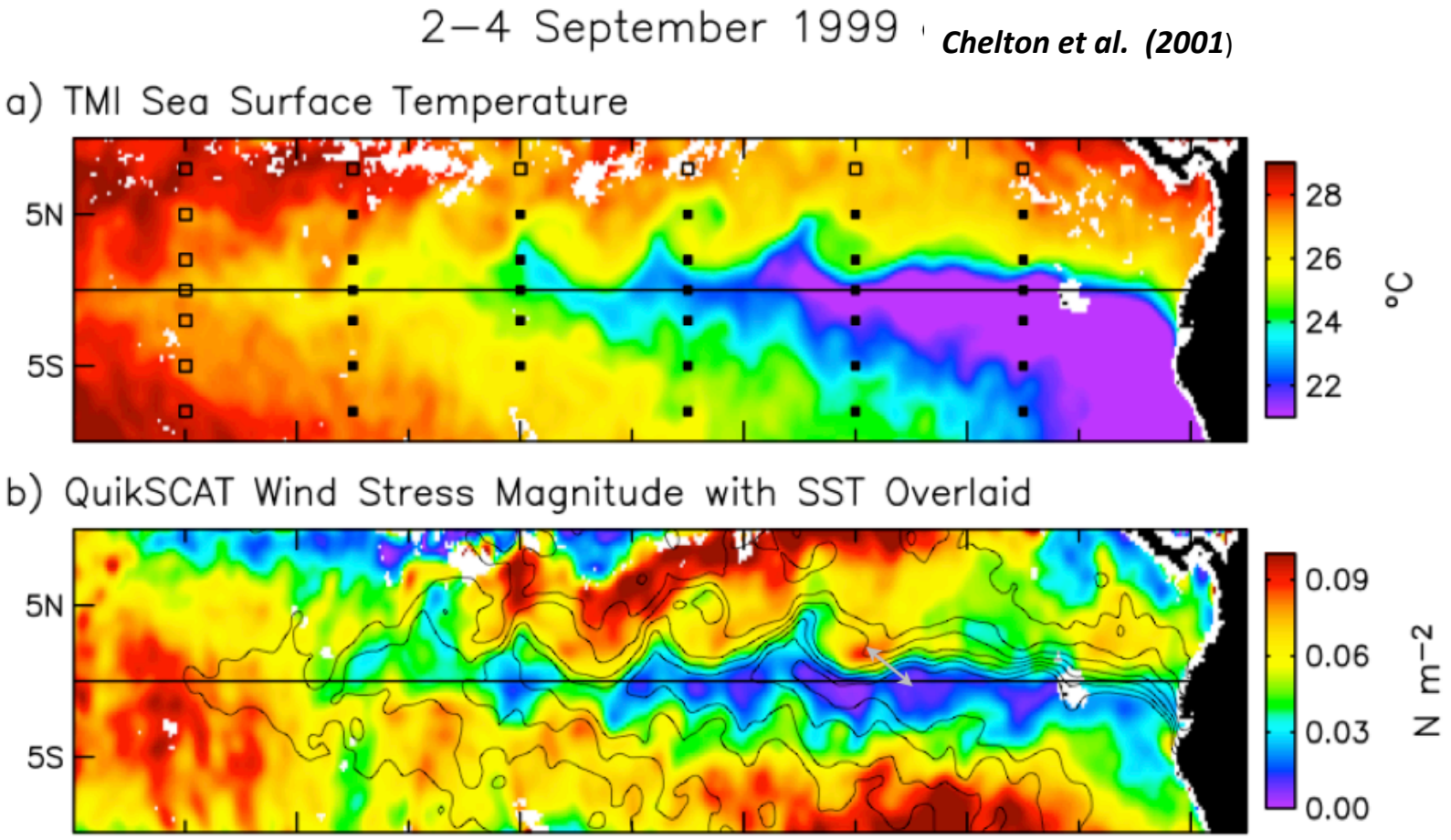
Strutton et al., 2001

TAO Mooring



Surface currents from space would help quantify relative roles of horizontal advection, vertical advection, and turbulent mixing for SST, other tracers budgets

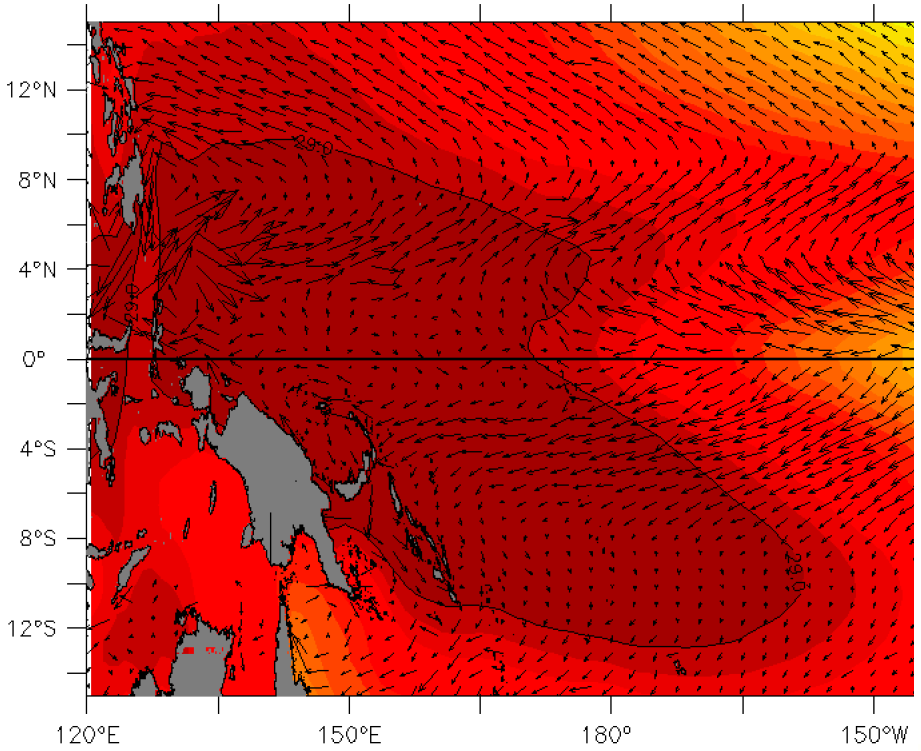
O-A coupling at small scales



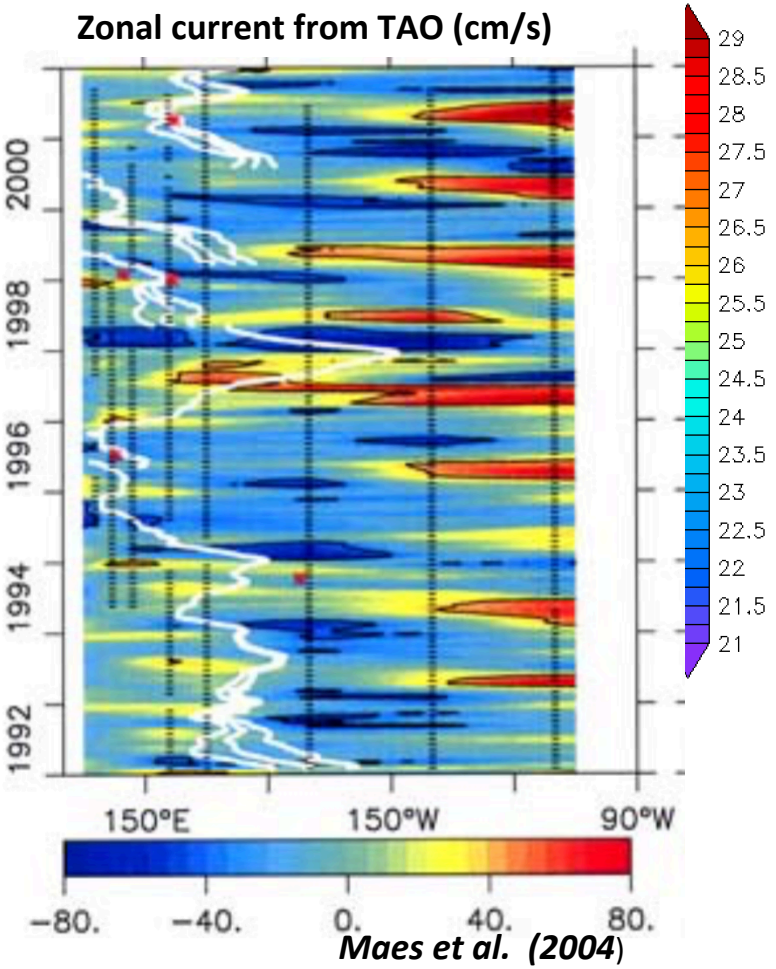
Tight O-A coupling at small-scale (0.05N/m^2 over 100km, a few hours).
Surface currents would help to understand the response of the ocean, and dynamical feedbacks

Following the convergence zone at the eastern edge of the Warm Pool

Mean SST, mean 15m currents (Drifters)



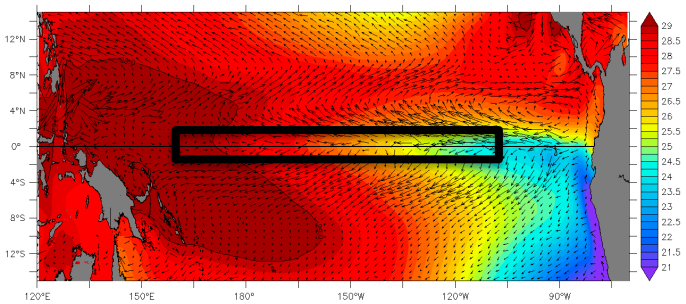
Zonal current from TAO (cm/s)

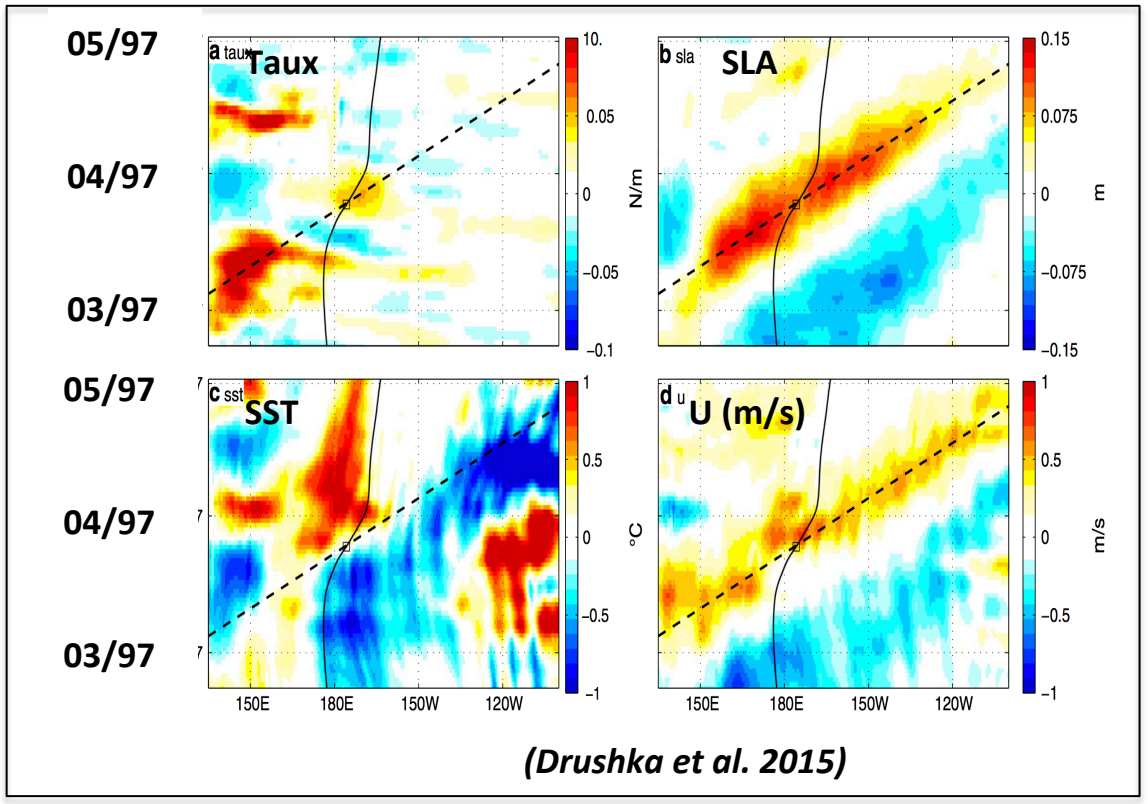


Maes et al. (2004)

Eastern edge of the Warm Pool: zonal convergence zone whose displacements are key for ENSO dynamics *(Picaut et al., 1997)*

Intraseasonal displacements of the Warm Pool edge



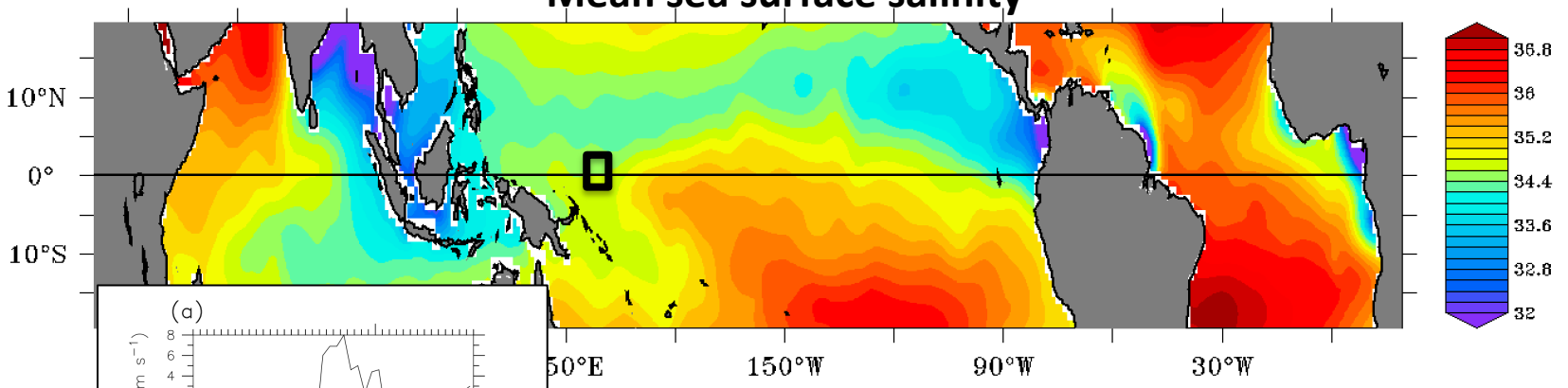


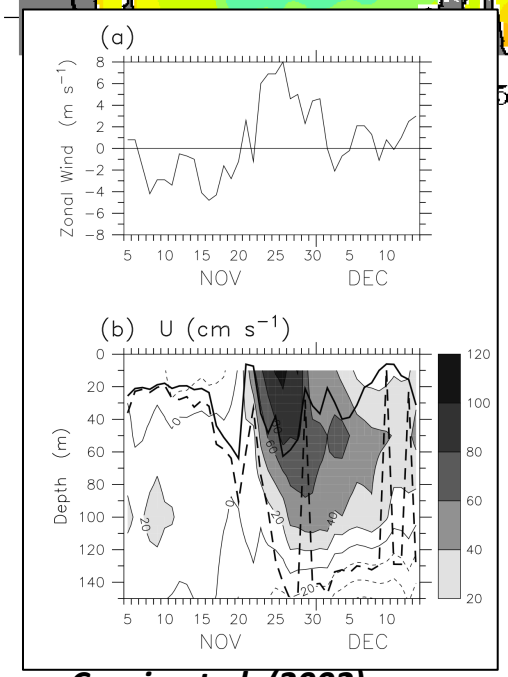
Moves at intraseasonal timescales (WWEs, MJO, zonal jets and Kelvin waves, heat fluxes)

Surface current observations would help to understand what drives these displacements (advection? Heat fluxes?) ; information on the dynamics of the frontal area

Near-surface trapping of momentum

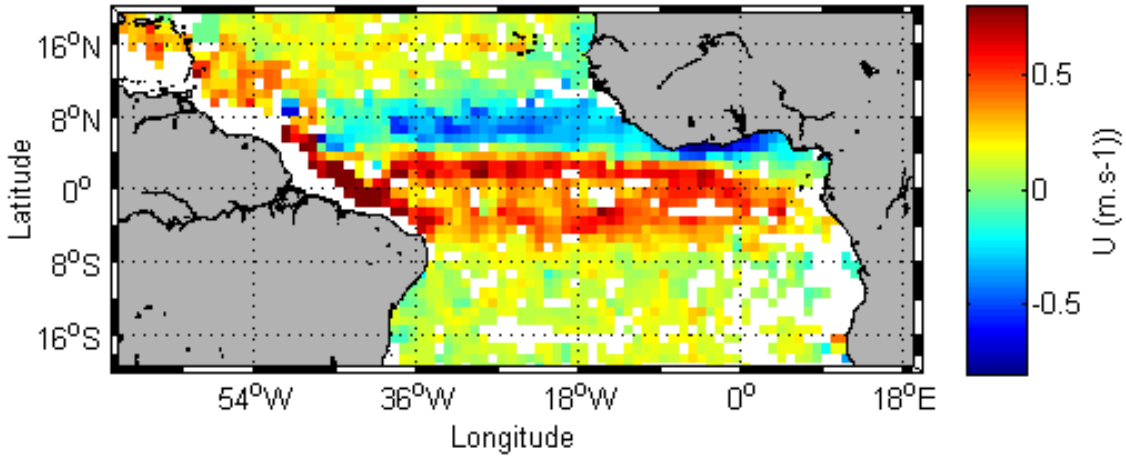
Mean sea surface salinity





Cronin et al. (2002)

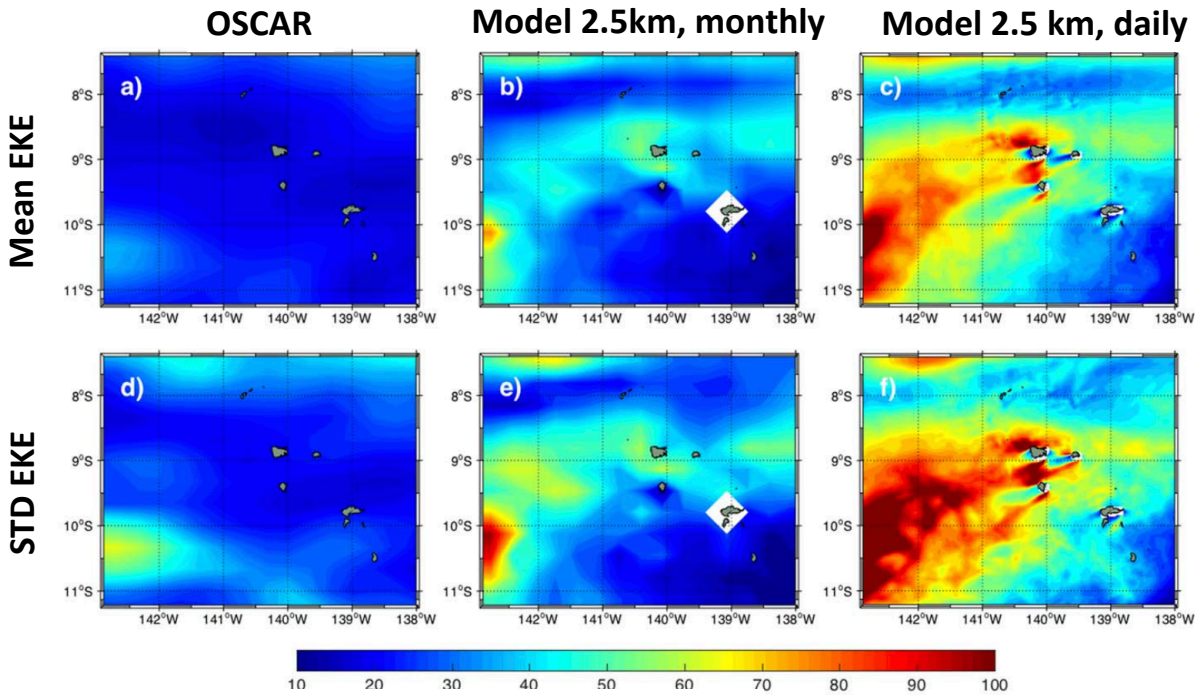
Mean zonal shear, July (Drifter(15m)-Argo surface drift)



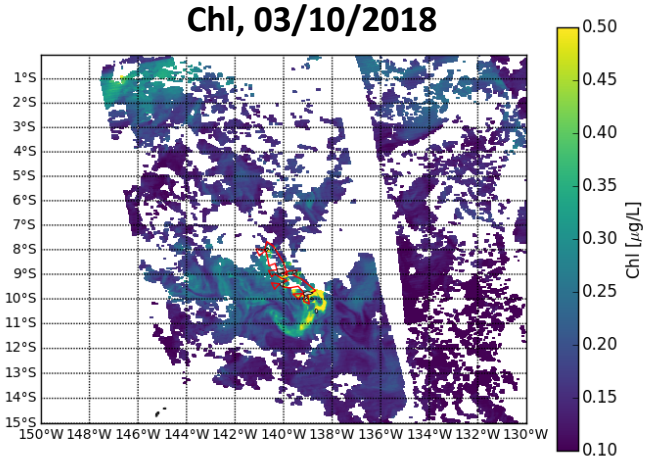
Courtesy of Herbert and Habasque

Strong stratification and gradients = > presence of equatorial shallow trapped jets.
Surface currents would help to understand the trapping of momentum and impacts

Island effects: Marquises Islands (140°W, 8°S)



Raapoto et al., 2018



Courtesy of C. Maes

Needs in HR surface currents, to understand the effects of islands on fine-scale dynamics and biology.
Small Islands: a few km

Summary

Present current observations: not at the surface (best: z= 10, typically 15-30m)
limited to large-scale (L> 500km), T> 40 days
Surface currents from space would provide improved knowledge of currents variability at intraseasonal timescales, mesoscale

- ✓ Would help to constrain SST, tracers budgets:
  - estimates of upwelling intensity, at small spatial scales (50 km or less), HF (15 days)
  - intraseasonal horizontal advection terms
  - vertical shear, and first-order estimation of turbulent mixing

- ✓ Would help to better understand the dynamics of the frontal regions at intraseasonal timescales, the associated O-A coupling

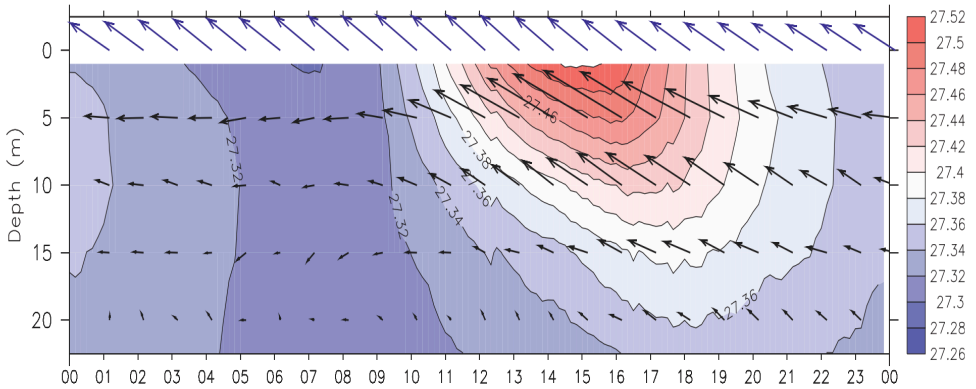
- ✓ Would help to better understand the trapping of momentum into the ocean (T= a few days)

- ✓ Would help to better understand the islands effects on productivity (a few days, L= a few km)

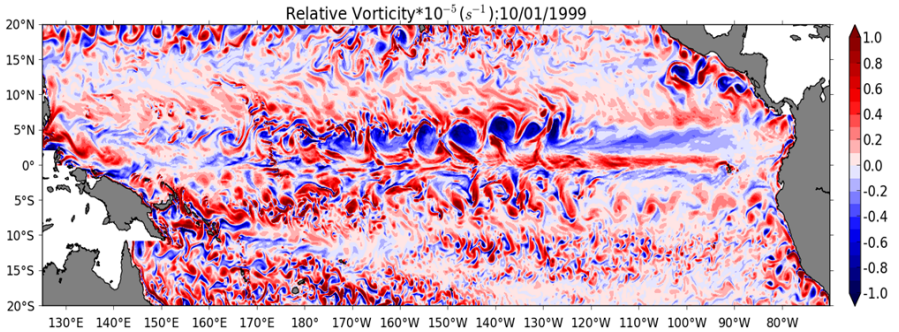
Challenges for SKIM, open questions

Diurnal cycle in surface currents
Implications for the repeativity??

140°W, 2°N: Diurnal composite of winds, T, currents

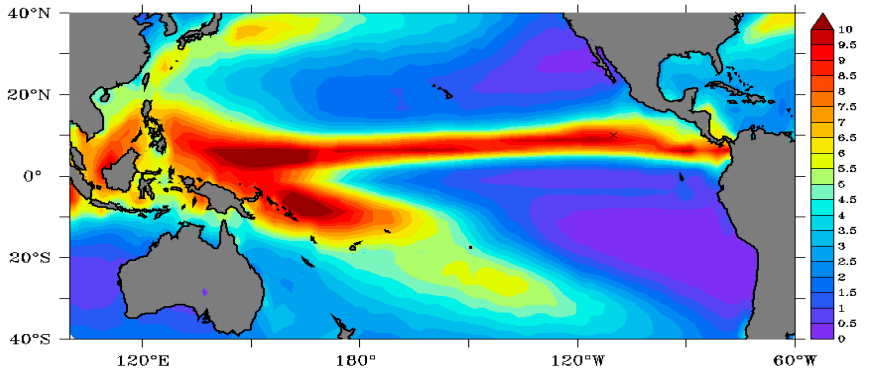


Cronin and Kessler (2002)



Stringent spatial and temporal
Requirements needed to make progress
(resolve 15-40 days, 50km or less)
What would SKIM be able to bring?

Precipitations (mm/day)



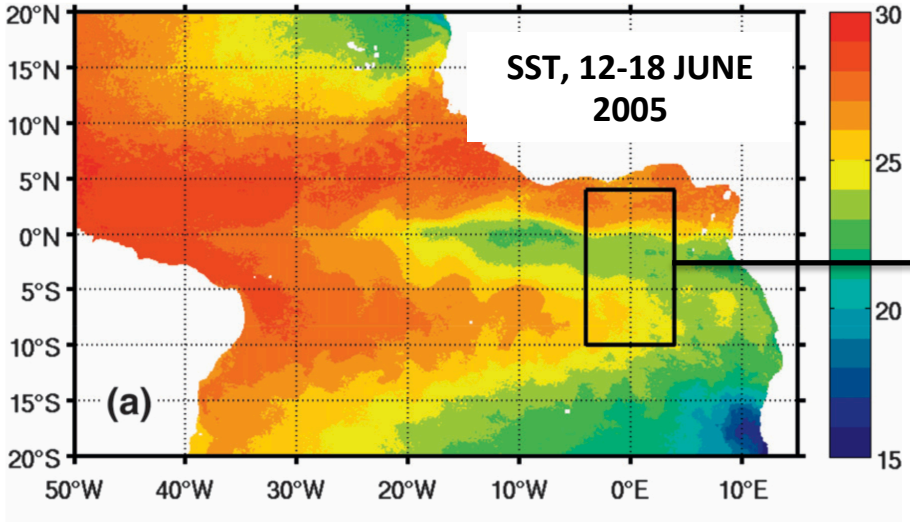
Rainy areas: issue for Ka band?

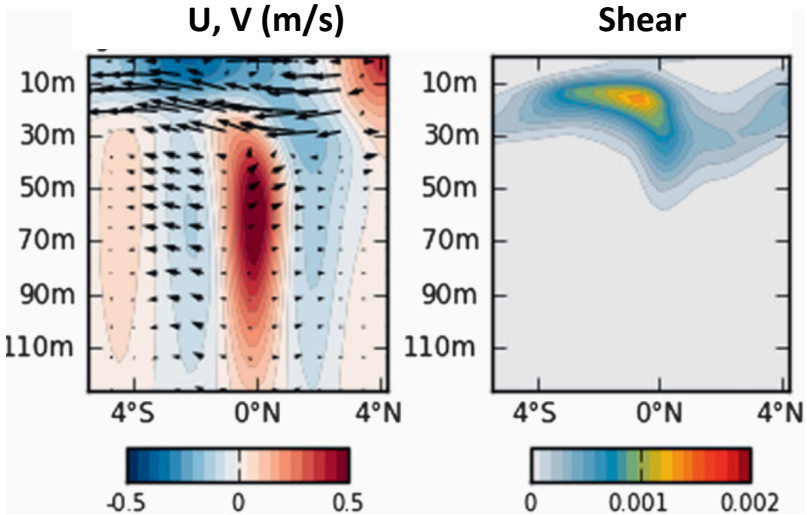
Additional slides

Other needs

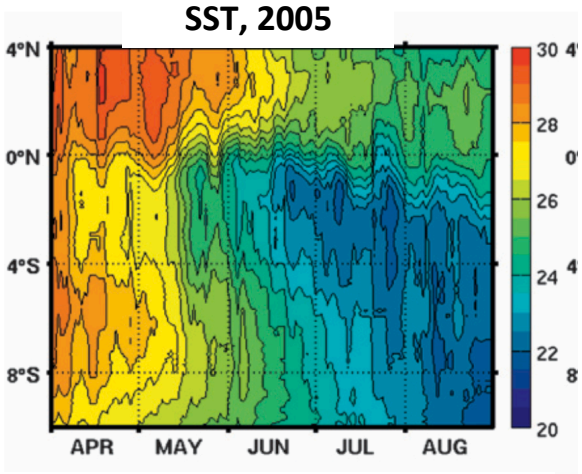
- ✓ Coastal currents
- ✓ Currents in narrow straits or passages
- ✓ Surface currents under cyclones
- ✓ Rivers plumes
- ✓ Estimation of wind work (in these regions with strong currents)
- ✓ …….

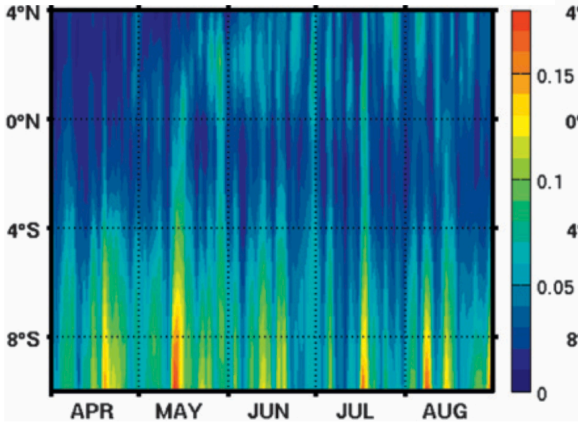
Response of the ocean to Intraseasonal winds in the Gulf of Guinea





Jouanno et al., 2013



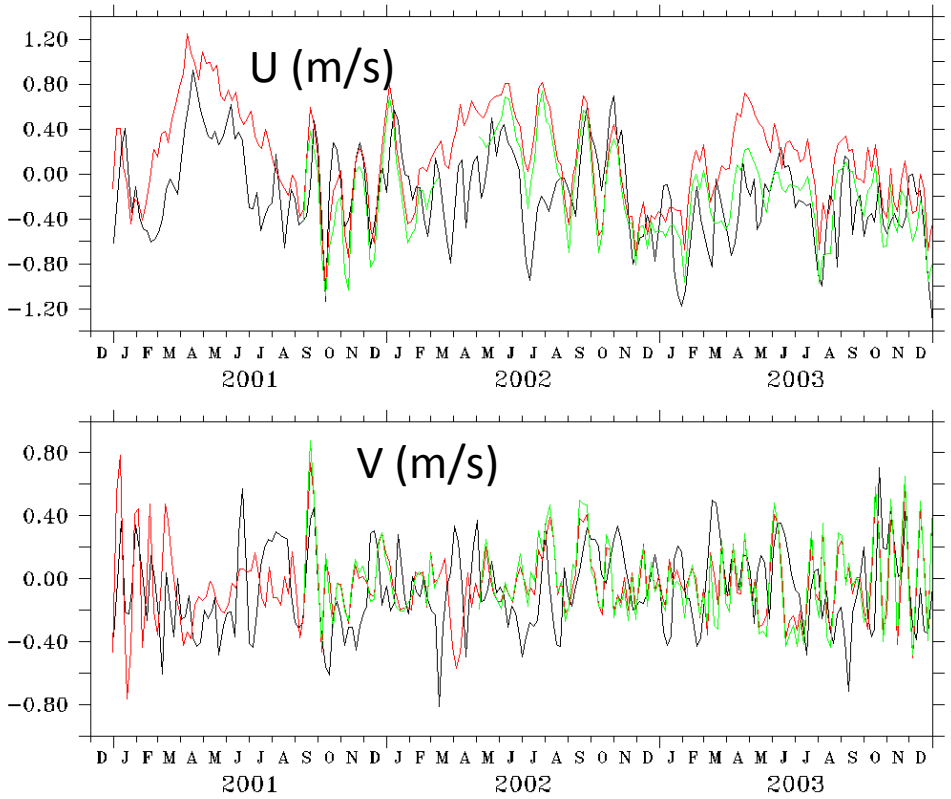


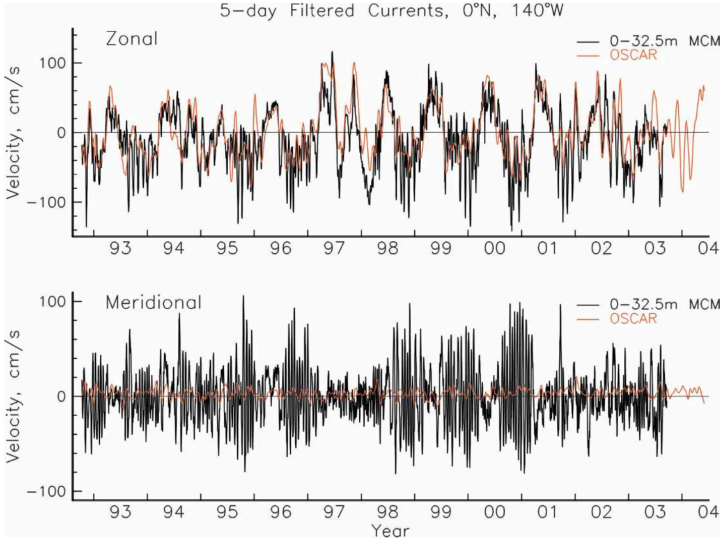
Marin et al., 1999

Surface currents would help to understand the relative roles of horizontal advective and turbulent cooling (via enhanced vertical shear) processes for the SST evolution

How well (bad) do satellite-derived products do?

140°W, 0°



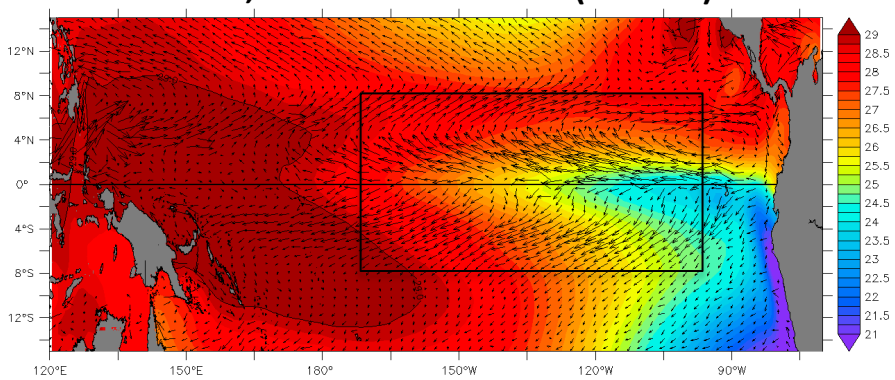


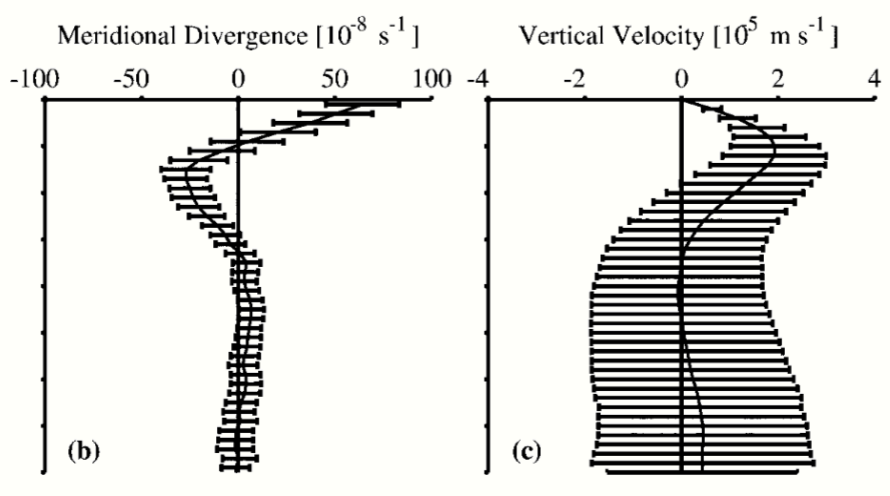
Johnson et al., JAOT, 2007,
« old » OSCAR product

OSCAR 2018 product
TAO ADCP, 35m
TAO Ucur, 10m

Estimating the upwelling

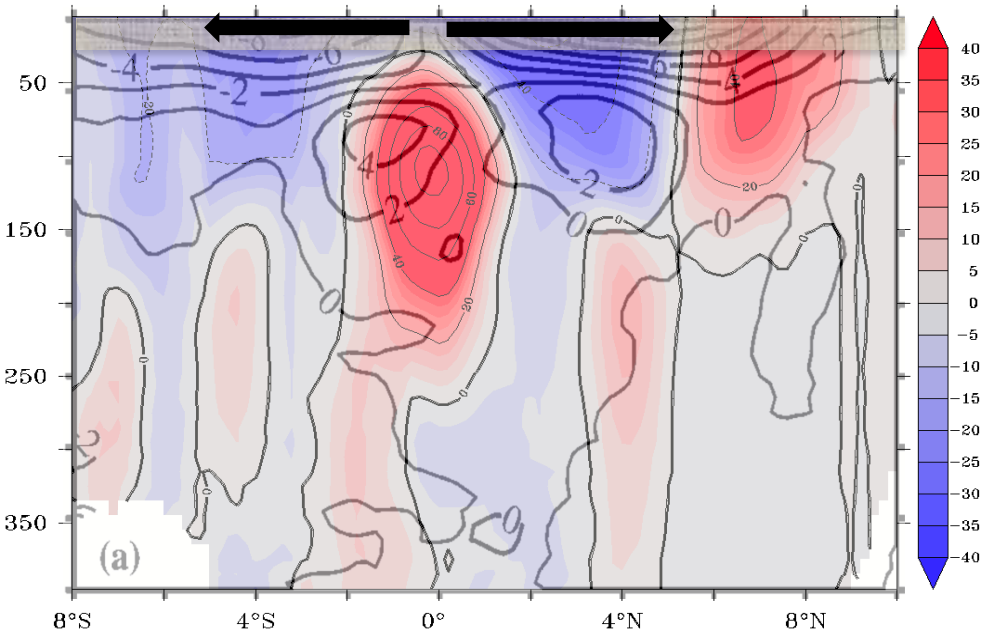
Mean SST, mean 15m currents (Drifters)





Johnson et al., 2001

Mean U at 140°W, mean V (170°W-95°W) from SADCP

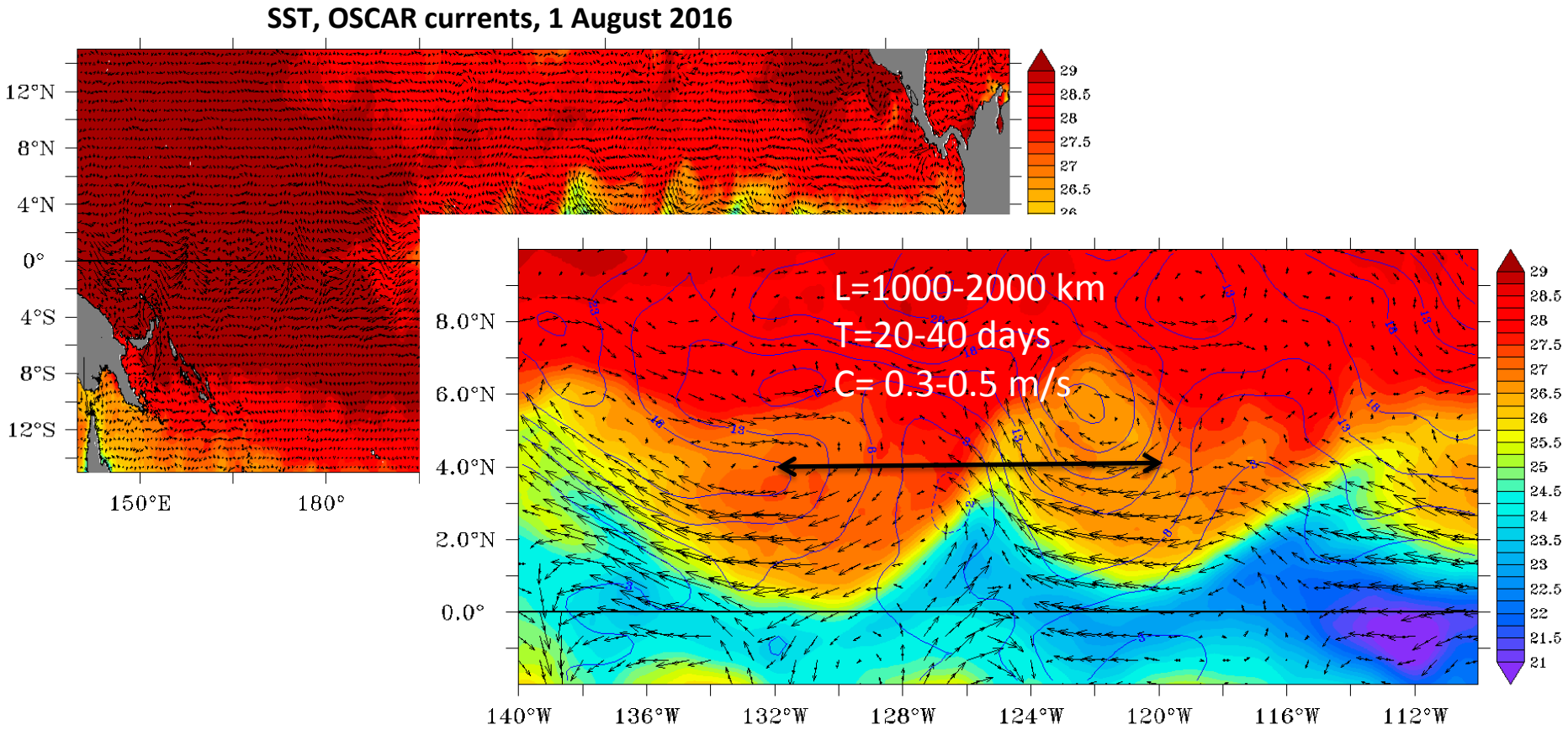


Only a mean, broadscale view

Very shallow thermocline and thin ML: more than 50% of the meridional poleward transport lies above 15 m

Needs of surface currents

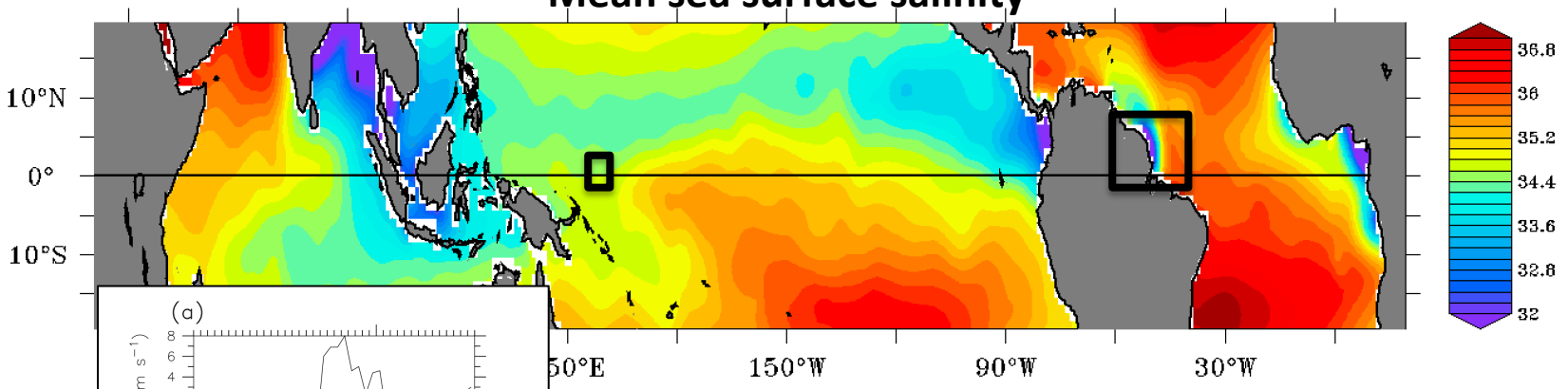
Horizontal advection terms

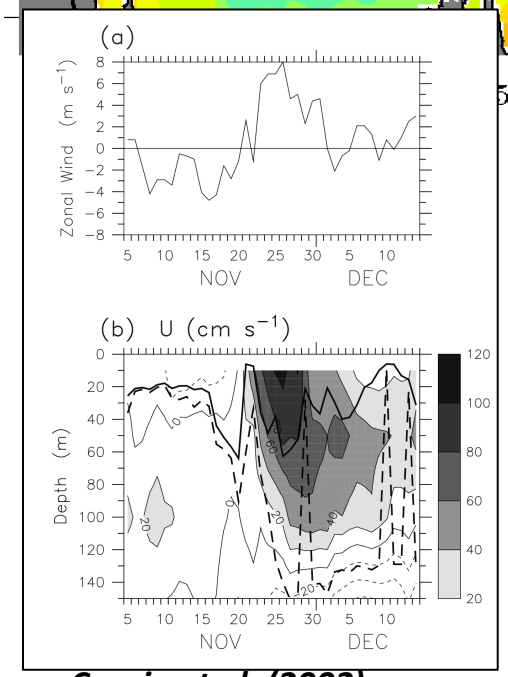


Tropical Instability Waves impact heat and freshwater budgets, productivity (e.g. Jochum et al., 2006; Menkes et al., 2006; Lee et al. 2012; Strutton et al., 2001)

Near-surface trapping of momentum

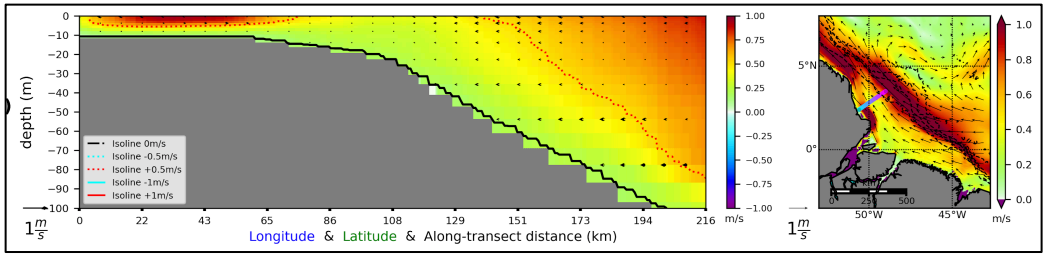
Mean sea surface salinity





Cronin et al. (2002)

Amazon Plume: Velocity, NEMO 1/36°



Ruault et al. (2018)

Near-surface shear highly sensitive to the vertical and horizontal density distribution.
= > presence of equatorial shallow trapped jets.
Surface currents would help to understand the penetration of momentum into the ocean (concurrently with subsurface observations)