SSH/SST synergy to improve surface currents

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CLS

MARIE CURIE ACTIONS

cnes
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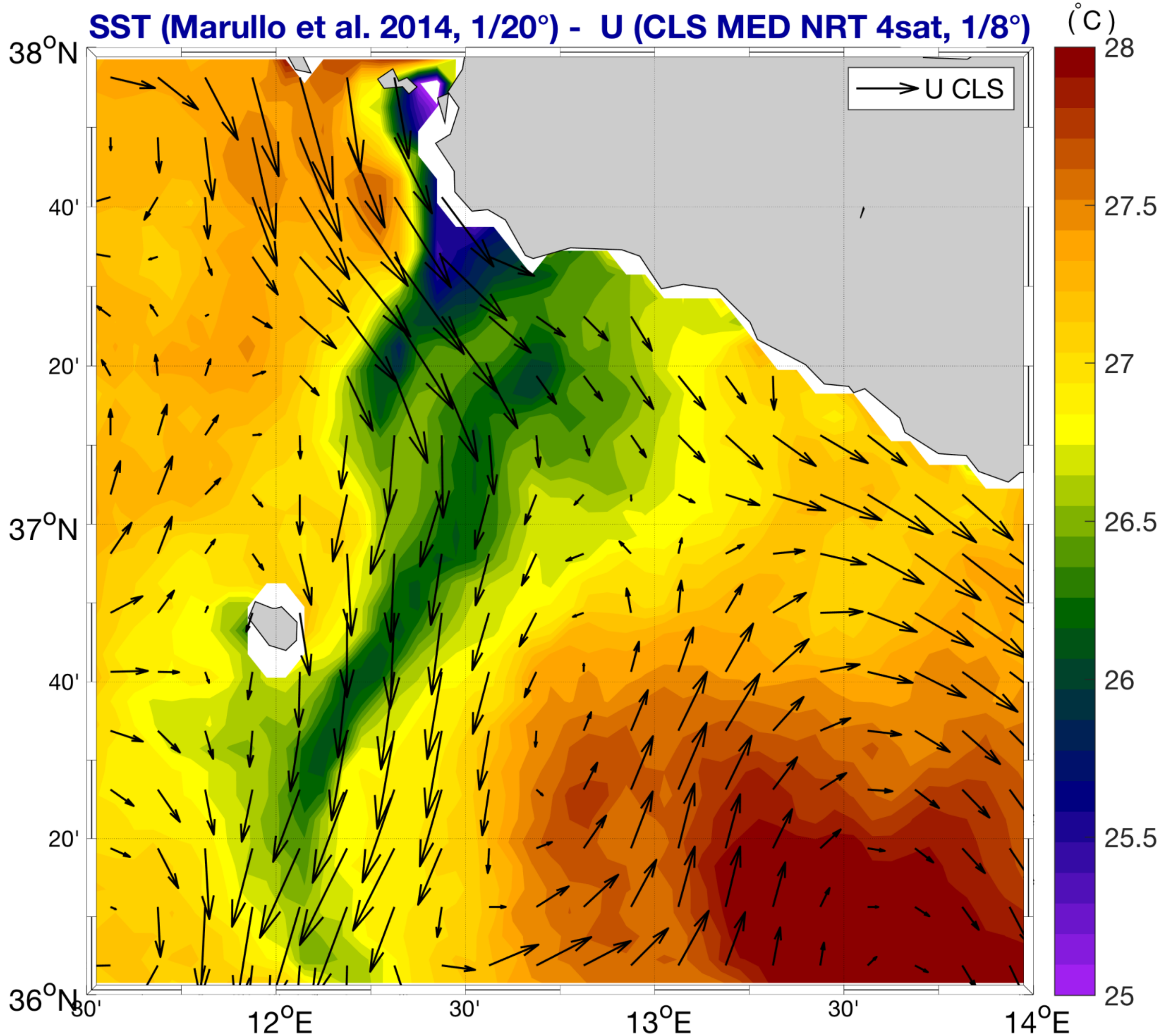
GLOBCURRENT



CLS
SST (Marulloet al. 2014, 1/20°) - U (CLS MED NRT 4sat, 1/8°)
(°C)
U CLS
38°N
40'
20'
37°N
40'
20'
36°N
30'
12°E
30'
13°E
30'
14°E
28
27.5
27
26.5
26
25.5
25

METHOD

Require the velocity field (u,v) to obey the SST evolution equation and inverse it for the velocity vector:

$$\frac{\partial SST}{\partial t} + u\frac{\partial SST}{\partial x} + v\frac{\partial SST}{\partial y} = F(x,y,t)$$

F(x,y,t) represents the source and sink terms (insolation, net infrared radiation, latent and sensible heat fluxes)

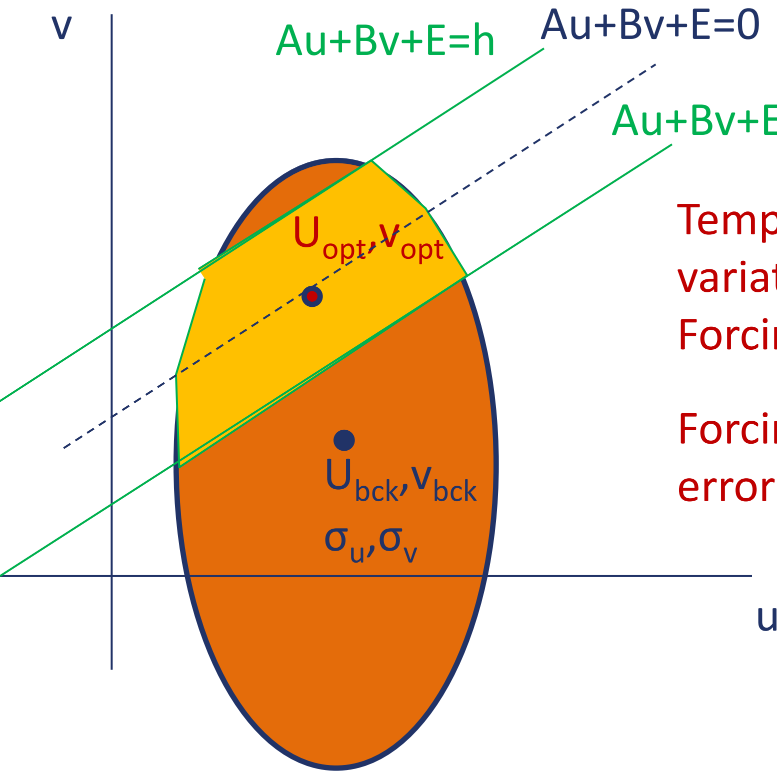
Challenge: only **along-gradient velocity** information can be retrieved from the tracer distribution at subsequent times in **strong gradients areas**.

Piterbarg et al, 2009; Mercatini et al, 2010 : Use a background velocity information (u_{bck}, v_{bck}) so that the satellite tracer information is used to obtain an optimized 'blended' velocity (u_{opt}, v_{opt}).

We applied the methodology on successive SST images using the low resolution, geostrophic altimeter velocities as background velocities

METHOD

$$A = \frac{\partial SST}{\partial x} \qquad B = \frac{\partial SST}{\partial y} \qquad E = \frac{\partial SST}{\partial t} - F_{bck} \qquad |F-F_{bck}|<h$$



Spatial SST variations

Temporal SST variations

Forcing term

Forcing term error

Background velocity error

$$q = \sqrt{\left(\sigma_u^2 \sin^2\varphi + \sigma_v^2 \cos^2\varphi\right)} \qquad \varphi = \operatorname{Arctan}\left(-\frac{A}{B}\right)$$

$$\alpha = \frac{Au_{bck} + Bv_{bck} + E - h}{\sqrt{A^2+B^2}} \qquad \beta = \frac{Au_{bck} + Bv_{bck} + E + h}{\sqrt{A^2+B^2}}$$

$$d = \frac{\left|Au_{bck} + Bv_{bck} + E\right|}{\sqrt{A^2+B^2}} \qquad p = \frac{\sin\varphi\cos\varphi\left(\sigma_v^2 - \sigma_u^2\right)}{q^2}$$

$$u_0 = \frac{F(\min(\beta,q)) - F(\max(\alpha,-q))}{G(\min(\beta,q)) - G(\max(\alpha,-q))} \qquad v_0 = pu_0$$

$$F(x) = -\frac{2\left(q^2 - x^2\right)^{3/2}}{3}$$

$$G(x) = x\left(q^2 - x^2\right)^{1/2} + q^2 \sin^{-1}(x/q)$$

$$u_{opt} = u_{bck} + u_0\sin\varphi + v_0\cos\varphi \qquad v_{opt} = v_{bck} - u_0\cos\varphi + v_0\sin\varphi$$

Piterbarg et al, 2009

DATA used

- Altimetry: DUACS L4 gridded products: « twosat » and « allsat »

- Sea Surface temperature: L4 OI maps from REMSS (100km, 4 days):
  MW: based on microwave sensors only
  resolution ¼°, daily maps
  MW_IR: based on both microwave and infrared sensors
  resolution ~9 km, daily

- Drifting buoy velocities, SVP drogued, 6 hourly resolution along the buoy trajectory, 1993-2015

  - To calculate the background velocity (=altimeter velocities) error
  - To calculate the forcing error
  - To validate the obtained optimally merged velocities

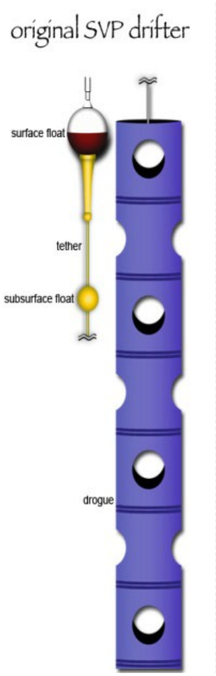
Forcing term (F_{bck}) and forcing term error (h) estimate

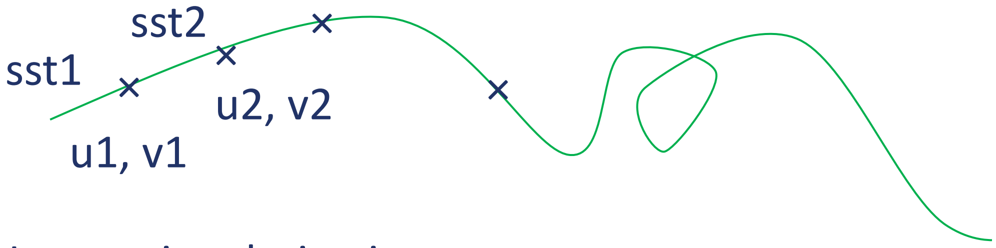
The source and sink terms F

$$F = \frac{1}{H}\int_{z=0}^{z=H} -w(z)\frac{\partial T(z)}{\partial z}dz + \frac{\kappa_x}{H}\int_{z=0}^{H}\frac{\partial^2 T(z)}{\partial x^2}dz + \frac{\kappa_y}{H}\int_{z=0}^{H}\frac{\partial^2 T(z)}{\partial y^2}dz + \frac{\kappa_z}{H}\int_{z=0}^{H}\frac{\partial^2 T(z)}{\partial z^2}dz + \frac{Q(H)}{\rho C_p H} - \frac{w_e}{H}(T_m - T_b)$$

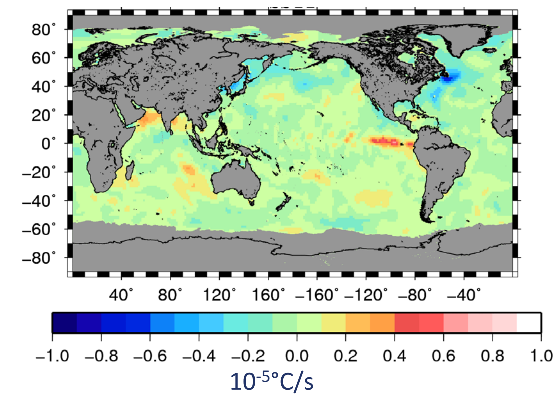
Rio et al, 2016

F_{bck} =Large spatial scale of $\frac{\partial SST}{\partial t}$





Example on September, 20th 2010



Lagrangian derivative

$$sst1 - sst2 = \frac{dsst}{dt} = \frac{\partial sst}{\partial t} + u\frac{\partial sst}{\partial x} + v\frac{\partial sst}{\partial y} + w\frac{\partial sst}{\partial z}$$

F_{obs} ⟷ $F_{bck} = \left(\frac{\partial SST}{\partial t}\right)_{>500km}$

sst=in-situ sensor
SST=space borne sensor

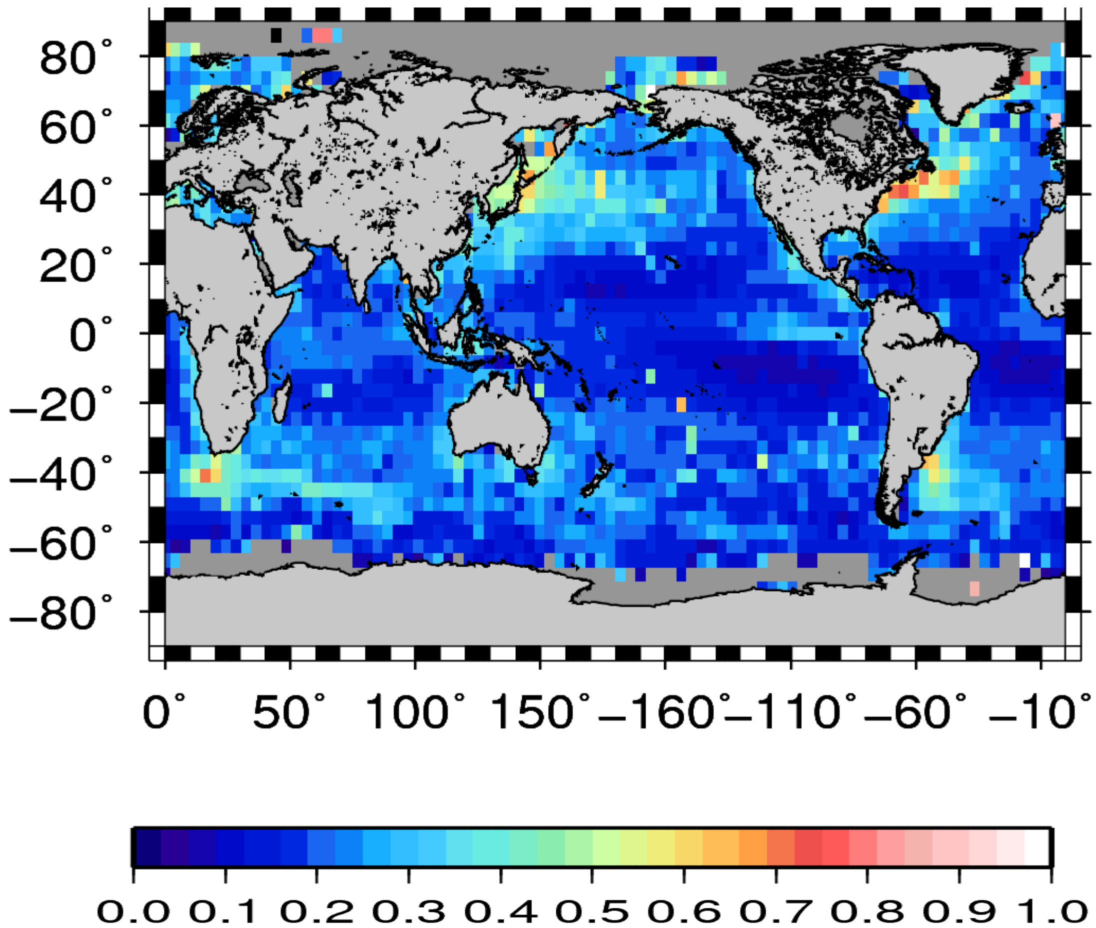
Along the buoy trajectory:

$$h_{buoy}(t) = sst(t+12h) - sst(t-12h) - \left(SST(t+12h) - SST(t-12h)\right)_{>500km}$$

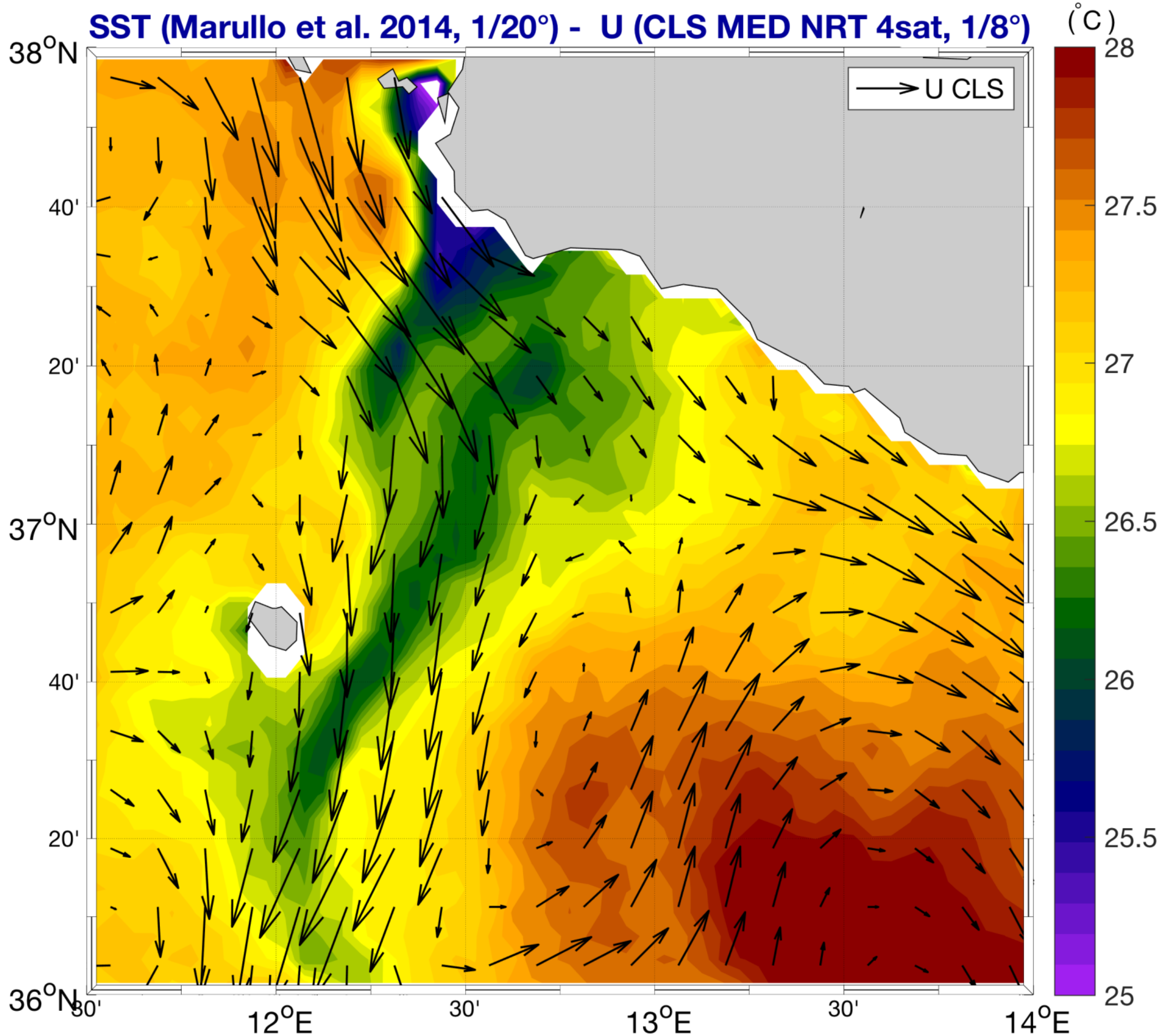
Forcing term error estimate (h)

$$\mathrm{RMS}[\mathrm{sst}(t+12h) - \mathrm{sst}(t-12h) - \left(\mathrm{SST}(t+12h) - \mathrm{SST}(t-12h)\right)_{>500km}]$$

- ✓in 4° boxes
- ✓1993-2015 period



10^5°C/s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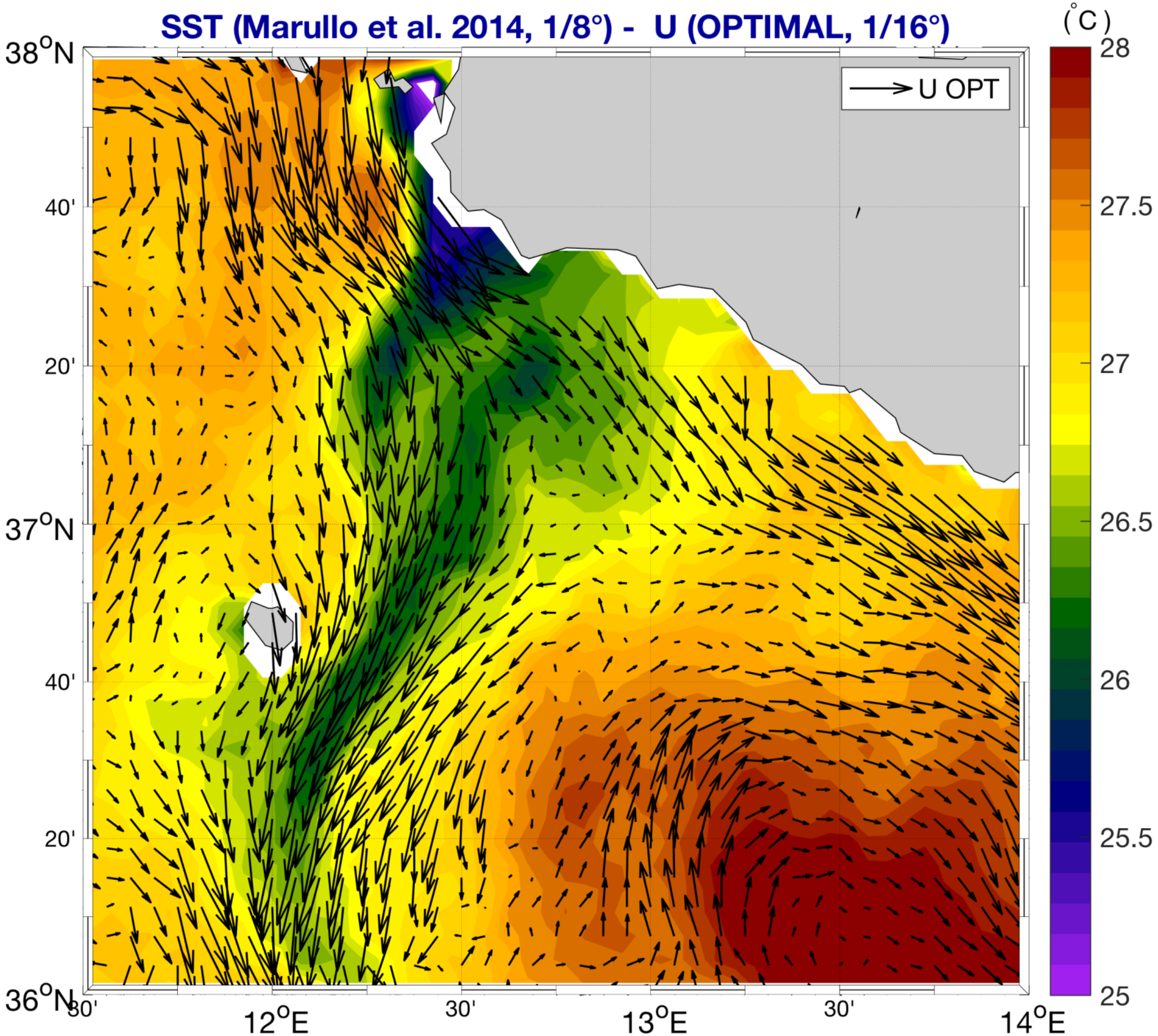
SST (Marullo et al. 2014, 1/8°) - U (OPTIMAL, 1/16°)
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(°C)
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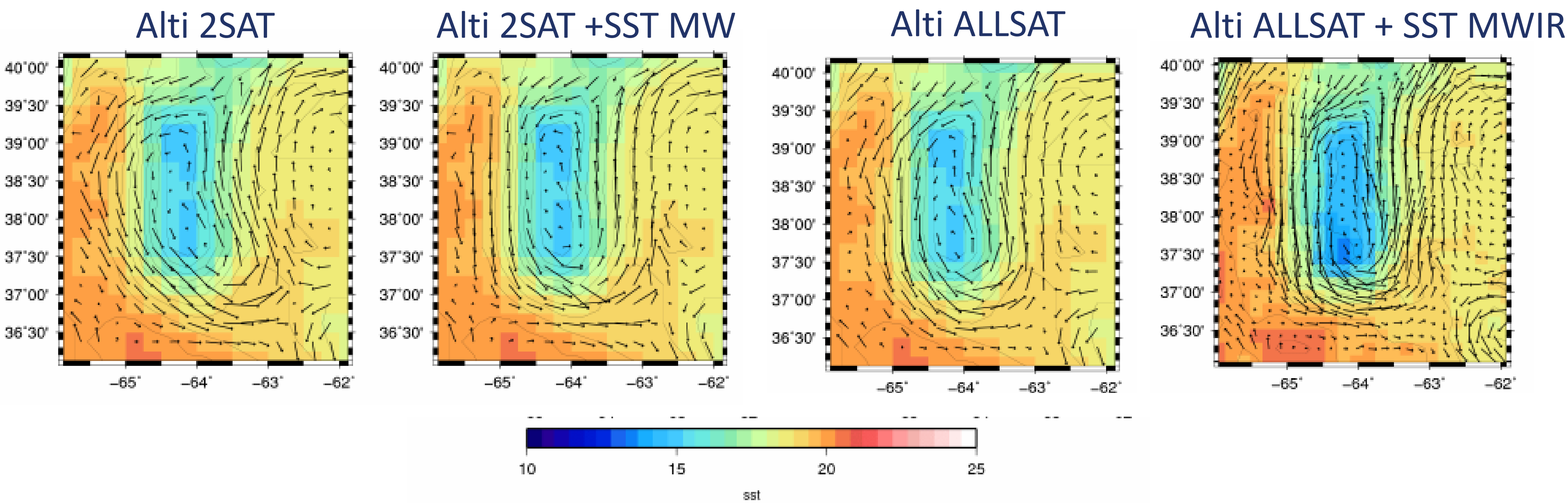
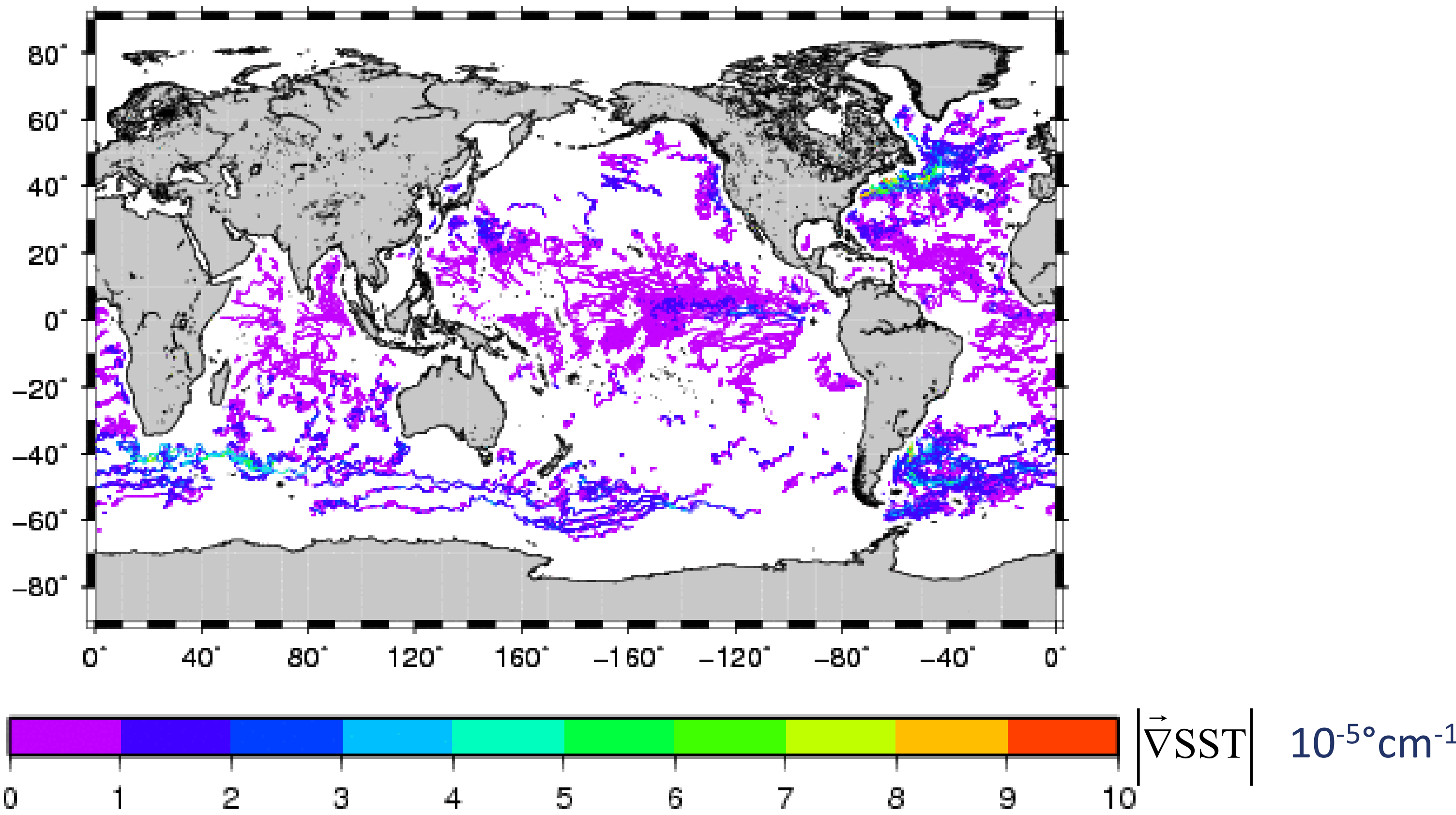
RESULTS

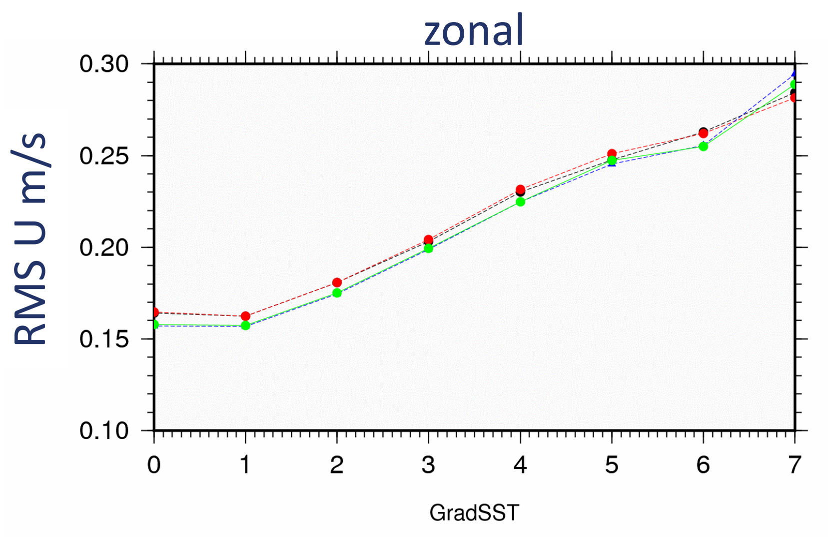
Example : Gulfstream, March 24st 2015



VALIDATION

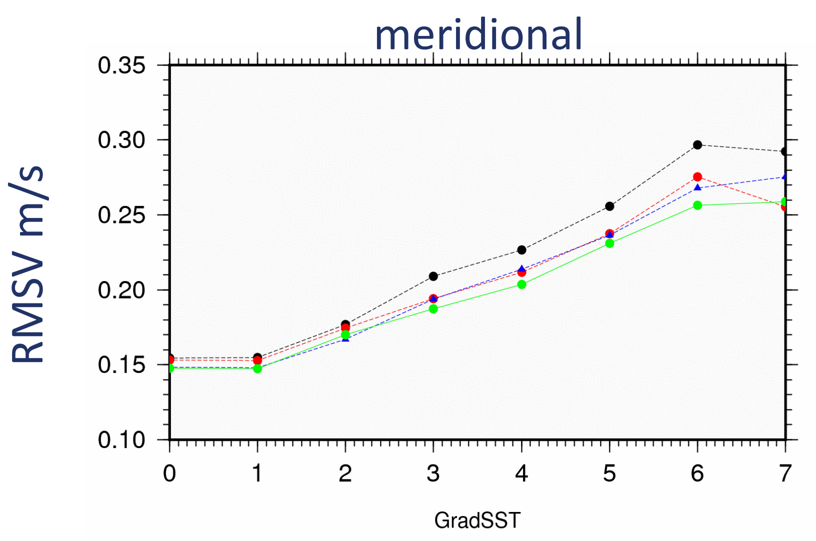
1 year (2003) of global maps of optimal velocities have been calculated and compared to SVP-drogued drifting buoy velocities





Altimetry 2sat
Optimal (background=2SAT)
Altimetry AllSat
Optimal (backgound=Allsat)

➢Zonal component, low SST gradient area:
No improvement, but **no degradation** either

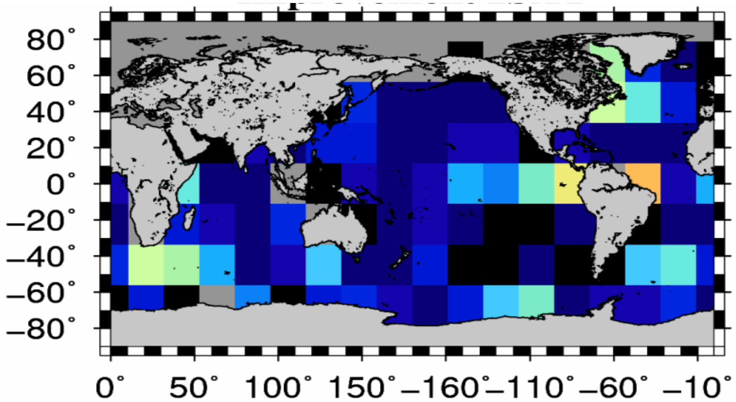


➢Meridional component:
Significant improvement in strong SST gradient areas
« twosat »+SST ~ « allsat »
« allsat » +SST brings further improvement

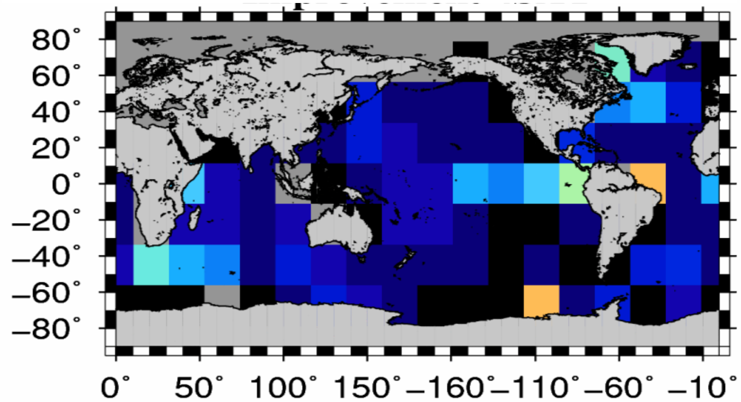
Regional Improvement Alti+SST MW

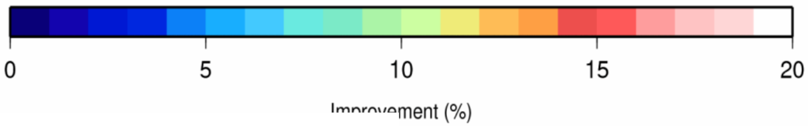
$$100 * (1 - \sum |v_{opt} - v_{buoy}|^2 / \sum |v_{bck} - v_{buoy}|^2)$$

Improvement “twosat”->”twosat”+SST



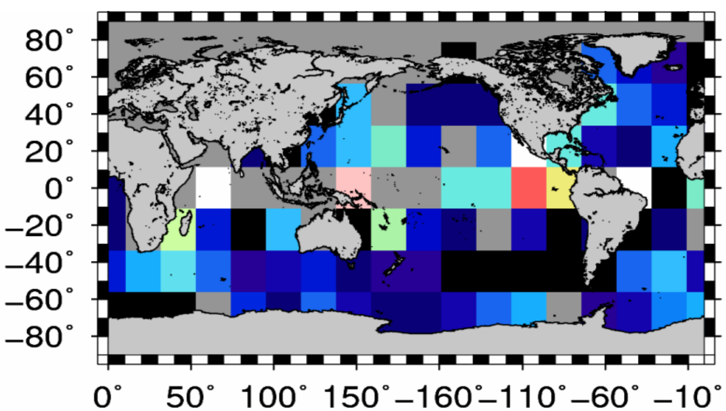
Improvement “allsat”->”allsat”+SST



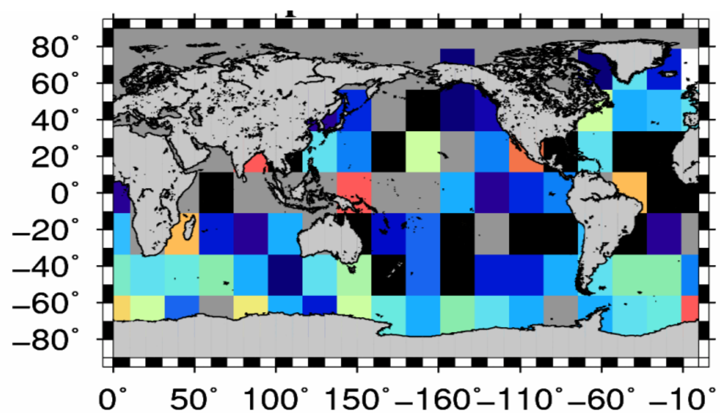


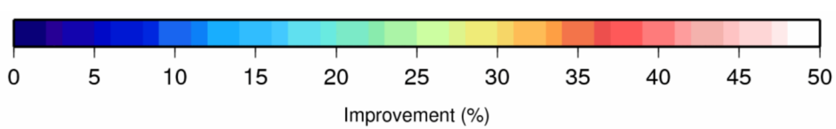
GradSST>1.10^{-5}C/m

Improvement “twosat”->”twosat”+SST



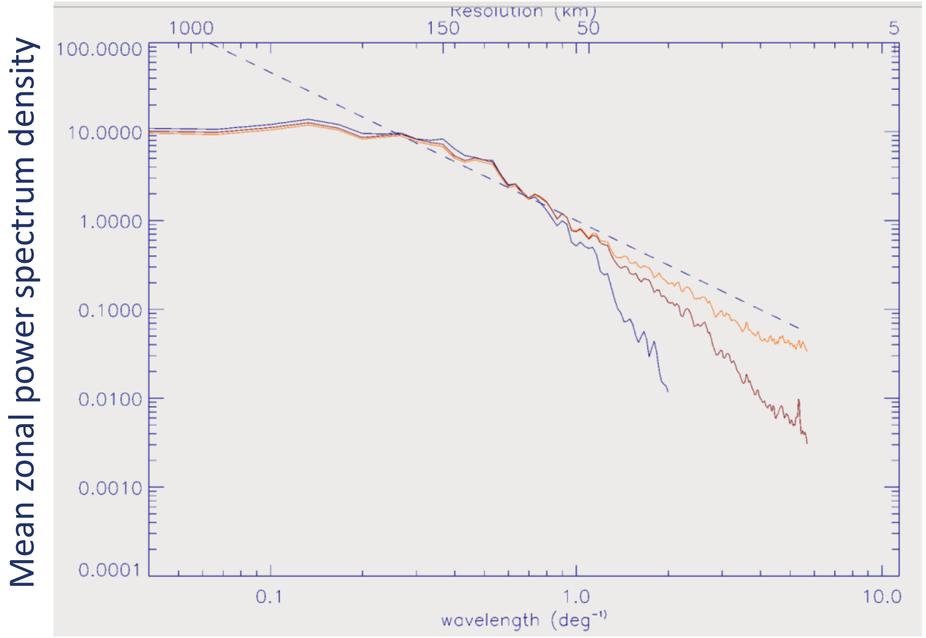
Improvement “twosat”->”allsat”





Power Density Spectrum

One month (January 2003) mean zonal power spectrum density in the Gulfstream area [290-320; 20-40]



Altimeter velocities (“allsat”)

Optimal velocities using MW SST

Optimal velocities using MWIR SST

CONCLUSIONS

- A method has been implemented which **successfully combines SST and altimeter data** to **improve the altimeter derived surface currents**.

- **Systematic application for one year over the global ocean has been done and validated** through comparison to independent drifting buoy velocities.

- **Significant improvements (up to 20-30% locally, and up to 50% in the equatorial band)** are obtained in strong SST gradients areas for the meridional component of the velocity.

- In low gradients areas and for the zonal component of the velocity, weaker improvement is expected **by construction**. Still, a few % of improvements is obtained locally. In these areas, taking into account the forcing and background errors is **essential**.

- **Further improvements are expected** by:
  - Using higher quality, higher resolution (spatial and temporal) SST products
  - Better estimating the forcing term F and its error h.

- Altimeter velocities might now systematically be improved in particular in the **equatorial band**, and in particular **over periods where only two altimeters were operated simultaneously** (1993-2001 for instance)