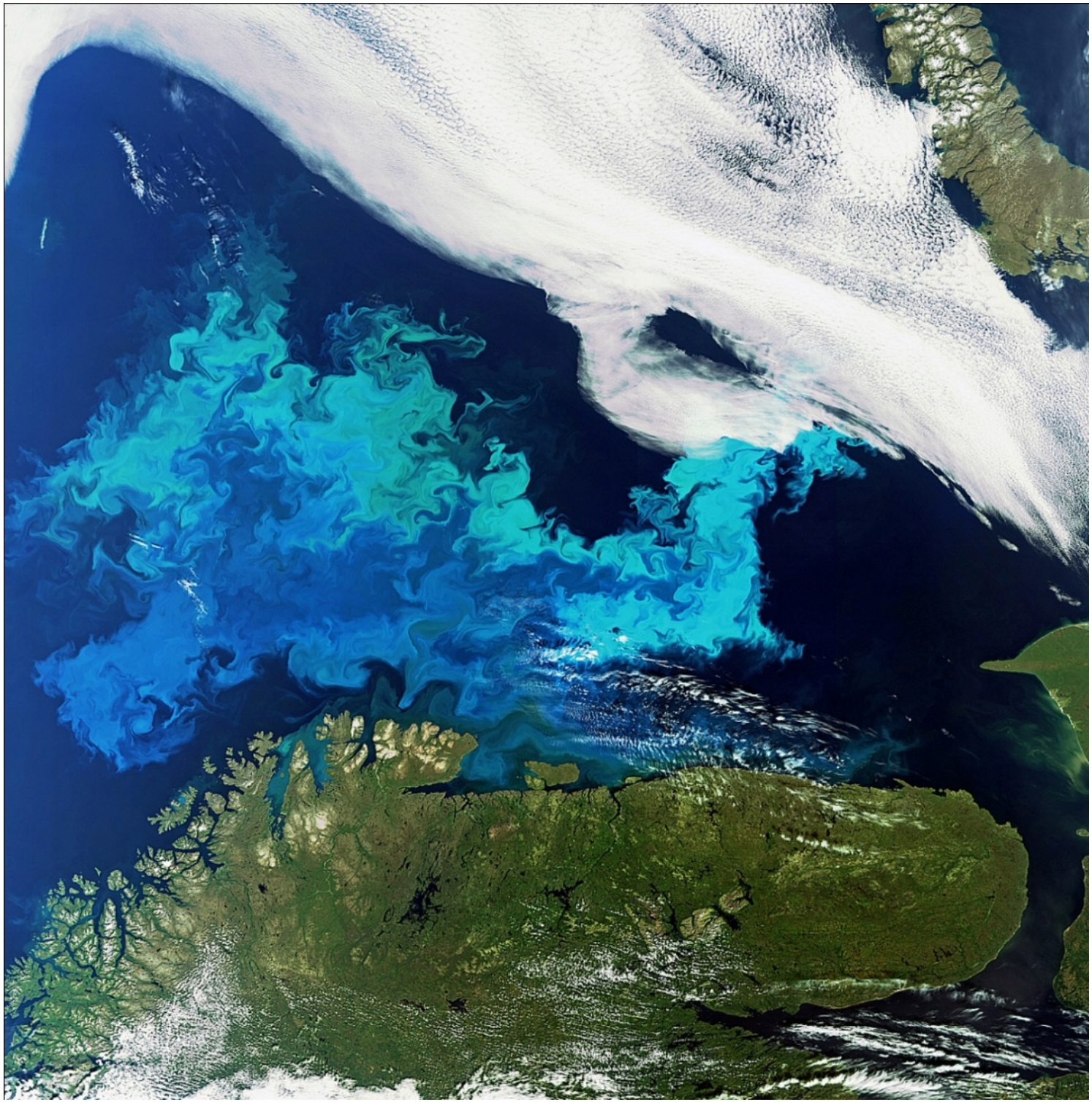
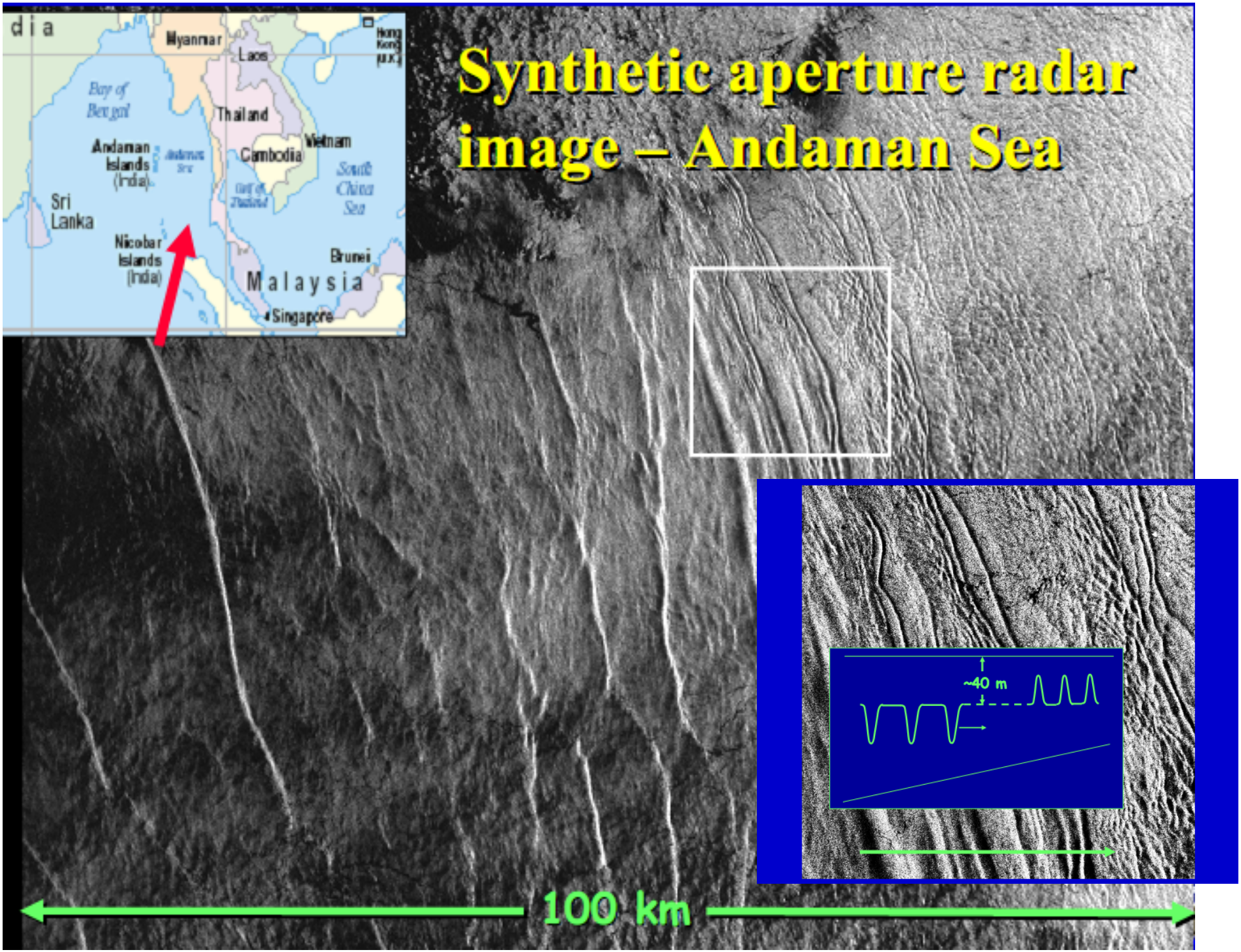
Discovering Ocean Dynamics from Space:Sensor synergies in studies of mesoscale and submesoscale dynamics (E. Autret, N. Rascle)

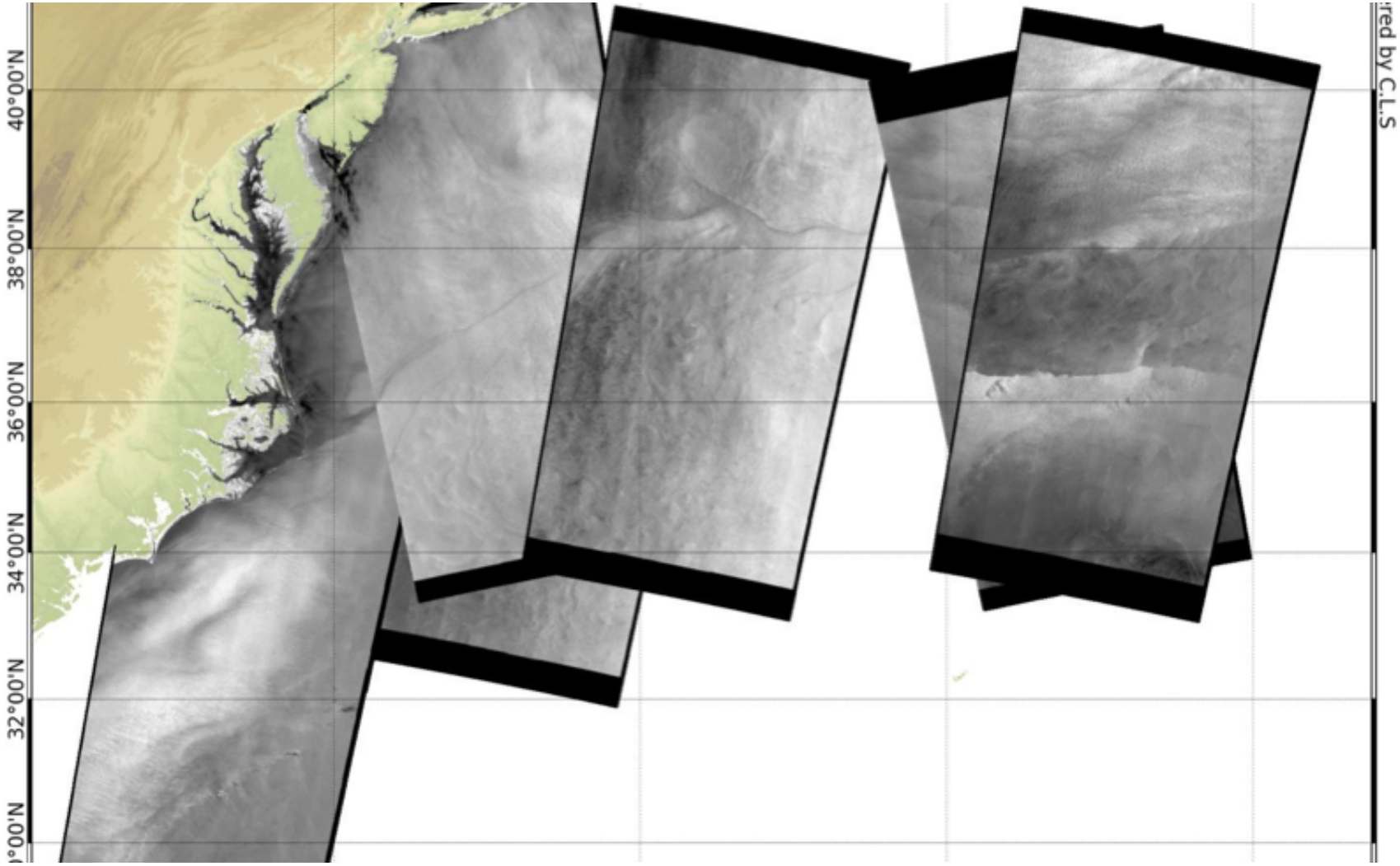
- Numerous Remote sensing measurements
  - Very high resolution (100 m – 1 km) SST, Ocean Colour, radar roughness images
  - Low resolution Altimetry (80 km)
  - Mesoscale Ocean Wind Vector Scatterometry and Microwave SST and SSS (25 km)

- Increased In Situ measurements
  - Fixed networks
  - ARGO floats
  - Drifters

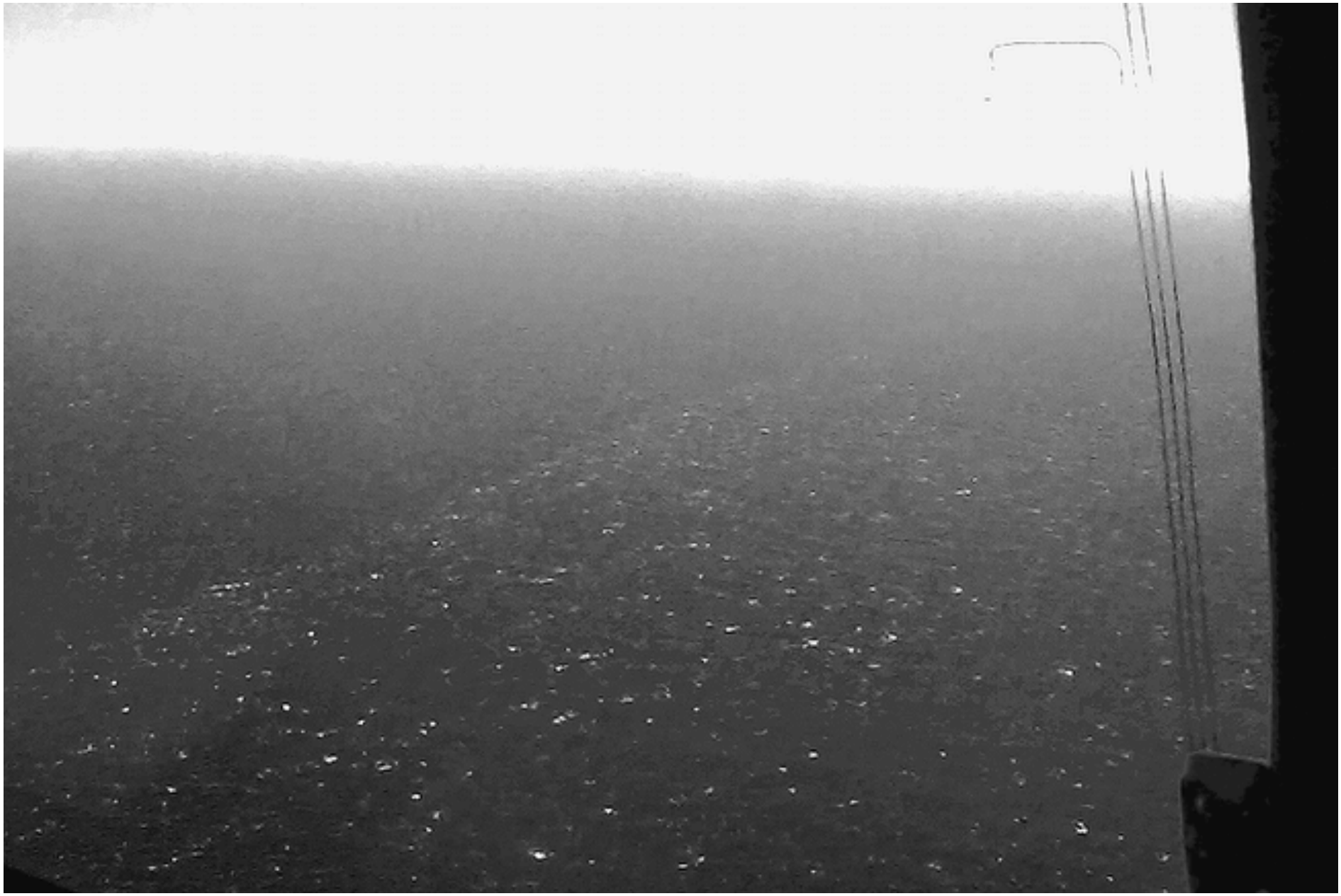


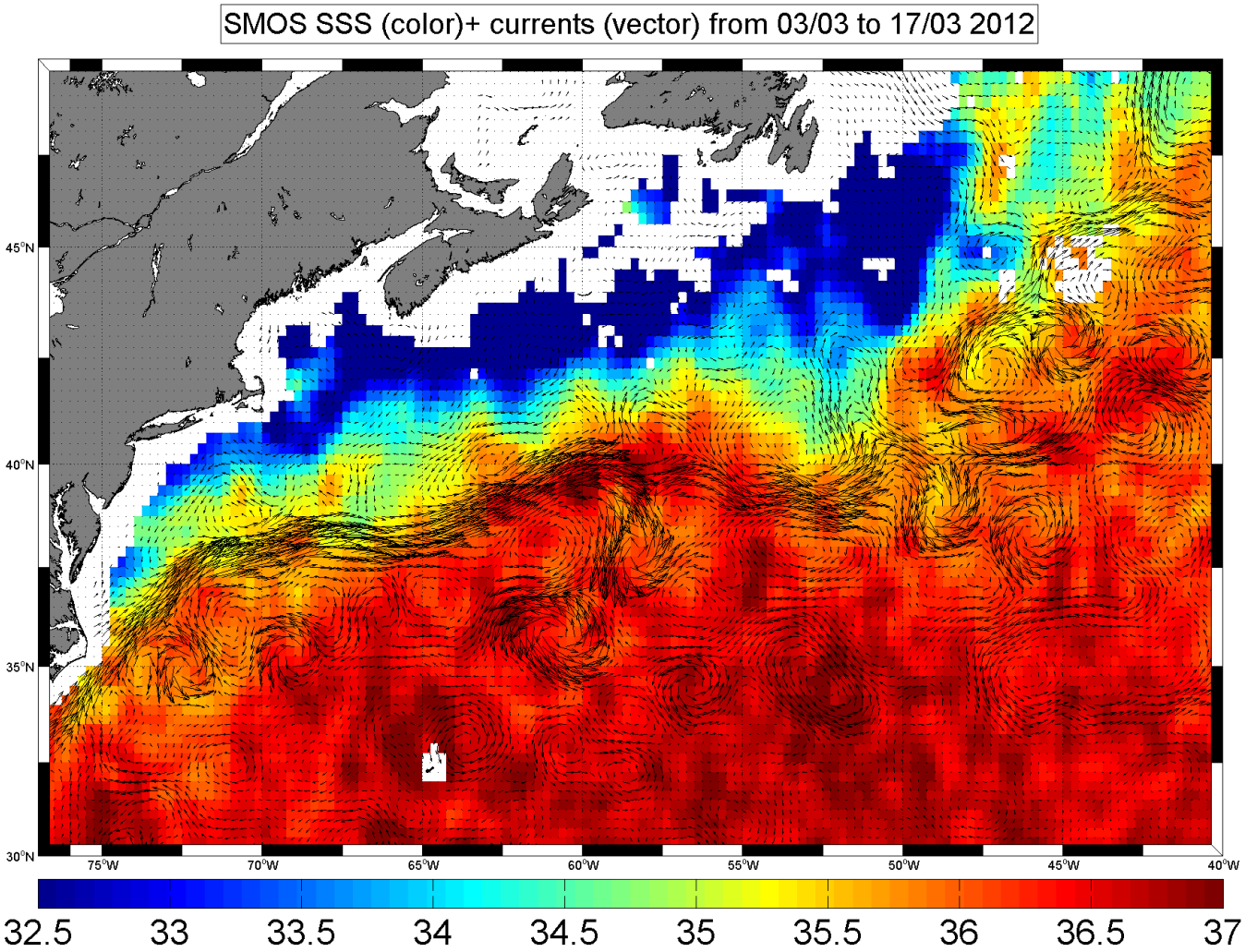

Synthetic aperture radar image – Andaman Sea
dia
Myanmar
Laos
Bay of Bengal
Thailand
Andaman Islands (India)
Cambodia
Vietnam
South China Sea
Sri Lanka
Nicobar Islands (India)
Brunei
Malaysia
Singapore
~40 m
100 km

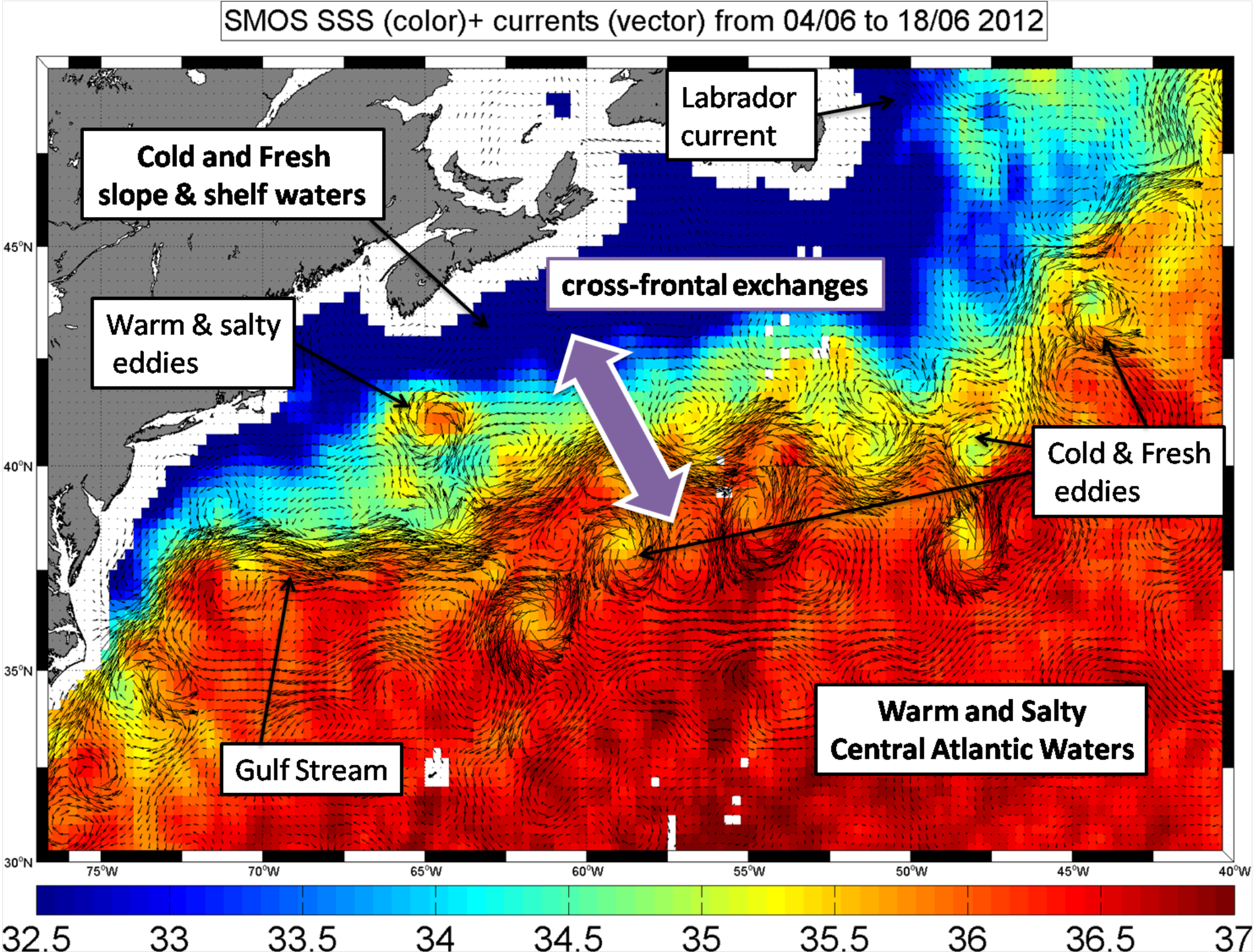
Gulf Stream roughness changes



Gulf Stream roughness changes



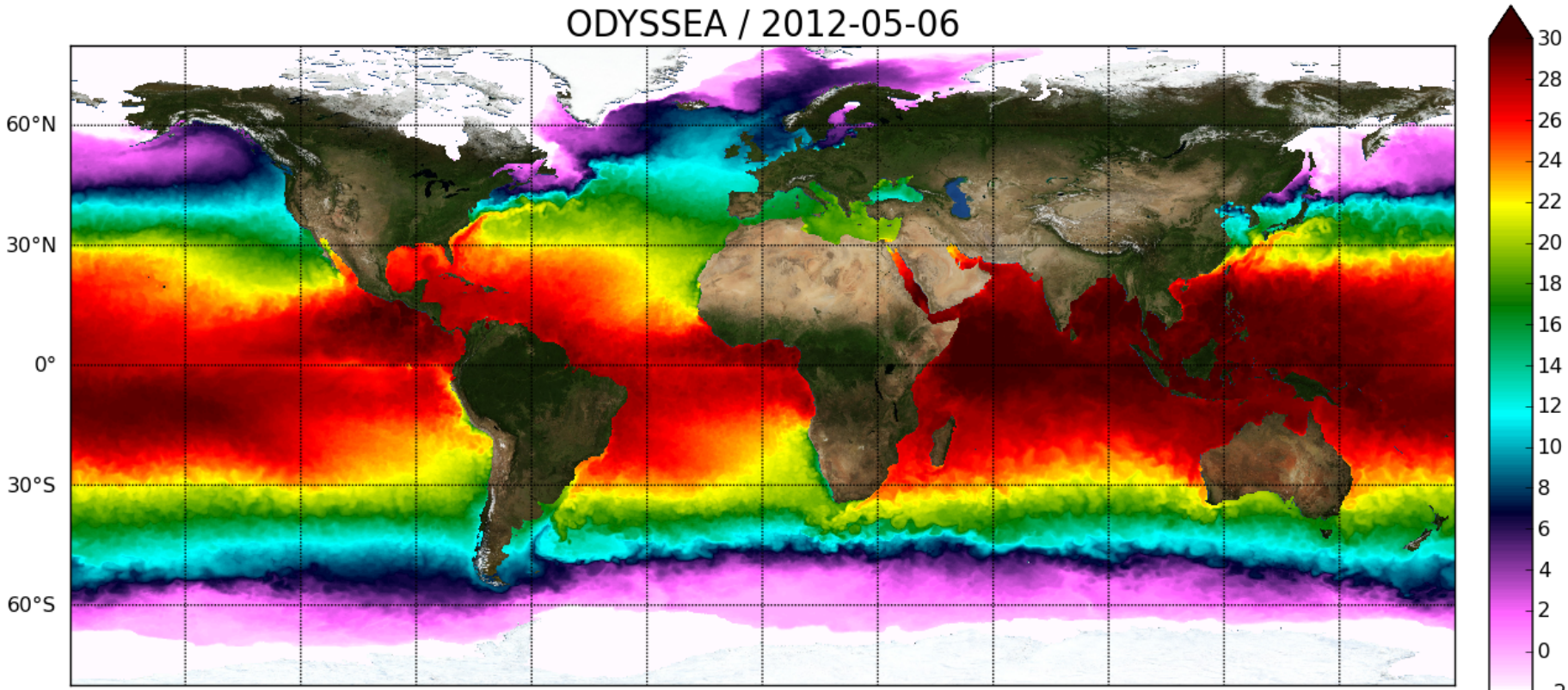

SMOS SSS (color)+ currents (vector) from 03/03 to 17/03 2012
45°N
40°N
35°N
30°N
75°W
70°W
65°W
60°W
55°W
50°W
45°W
40°W
32.5
33
33.5
34
34.5
35
35.5
36
36.5
37


SMOS SSS (color)+ currents (vector) from 04/06 to 18/06 2012
Labrador current
Cold and Fresh slope & shelf waters
cross-frontal exchanges
Warm & salty eddies
Cold & Fresh eddies
Gulf Stream
Warm and Salty Central Atlantic Waters
45°N
40°N
35°N
30°N
75°W
70°W
65°W
60°W
55°W
50°W
45°W
40°W
32.5
33
33.5
34
34.5
35
35.5
36
36.5
37

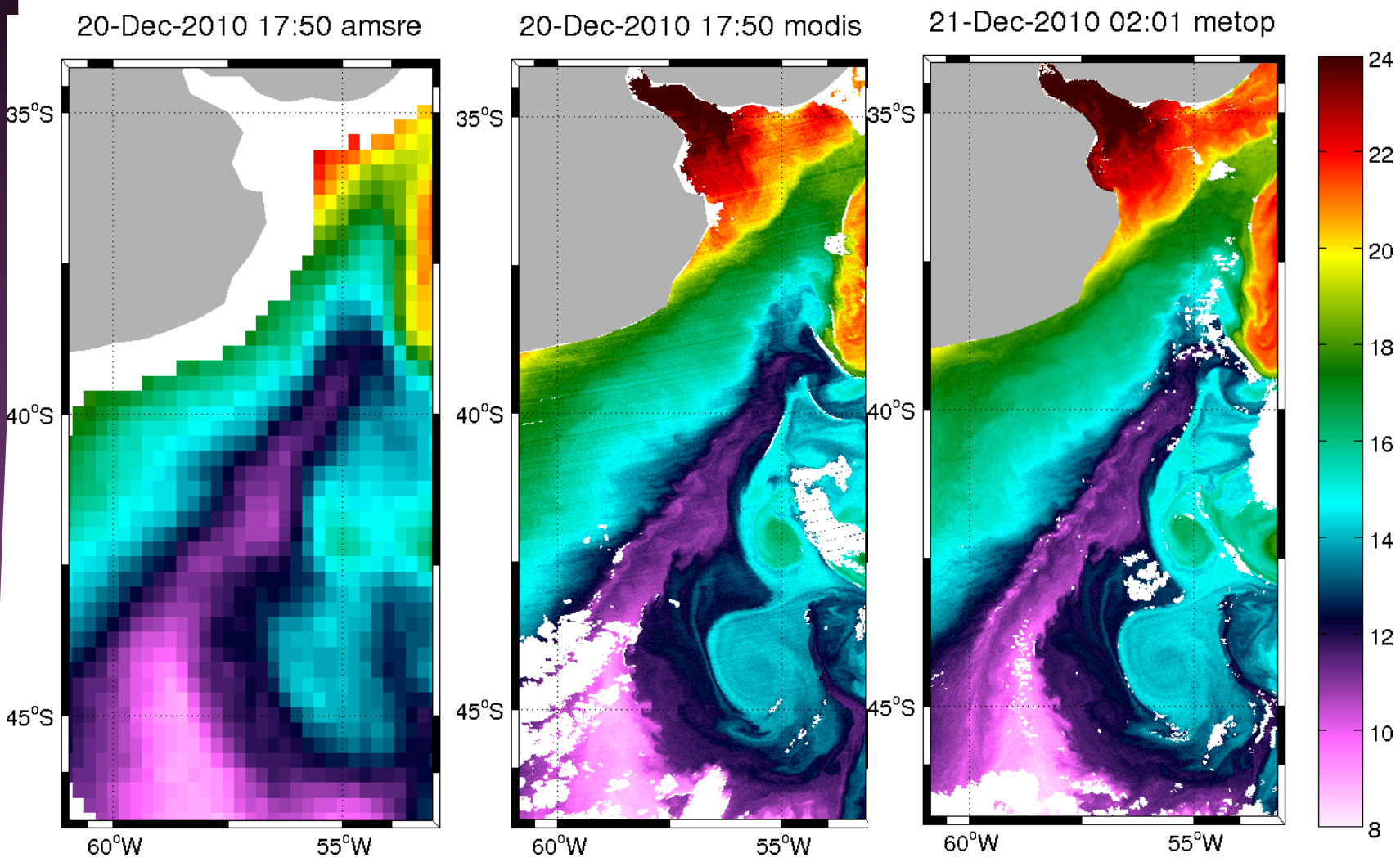
Satellite SST observations

Production of « high resolution » SST data sets :

- ~ 10 global SST analysis (2 km to 25 km) produced on a daily basis currently available.

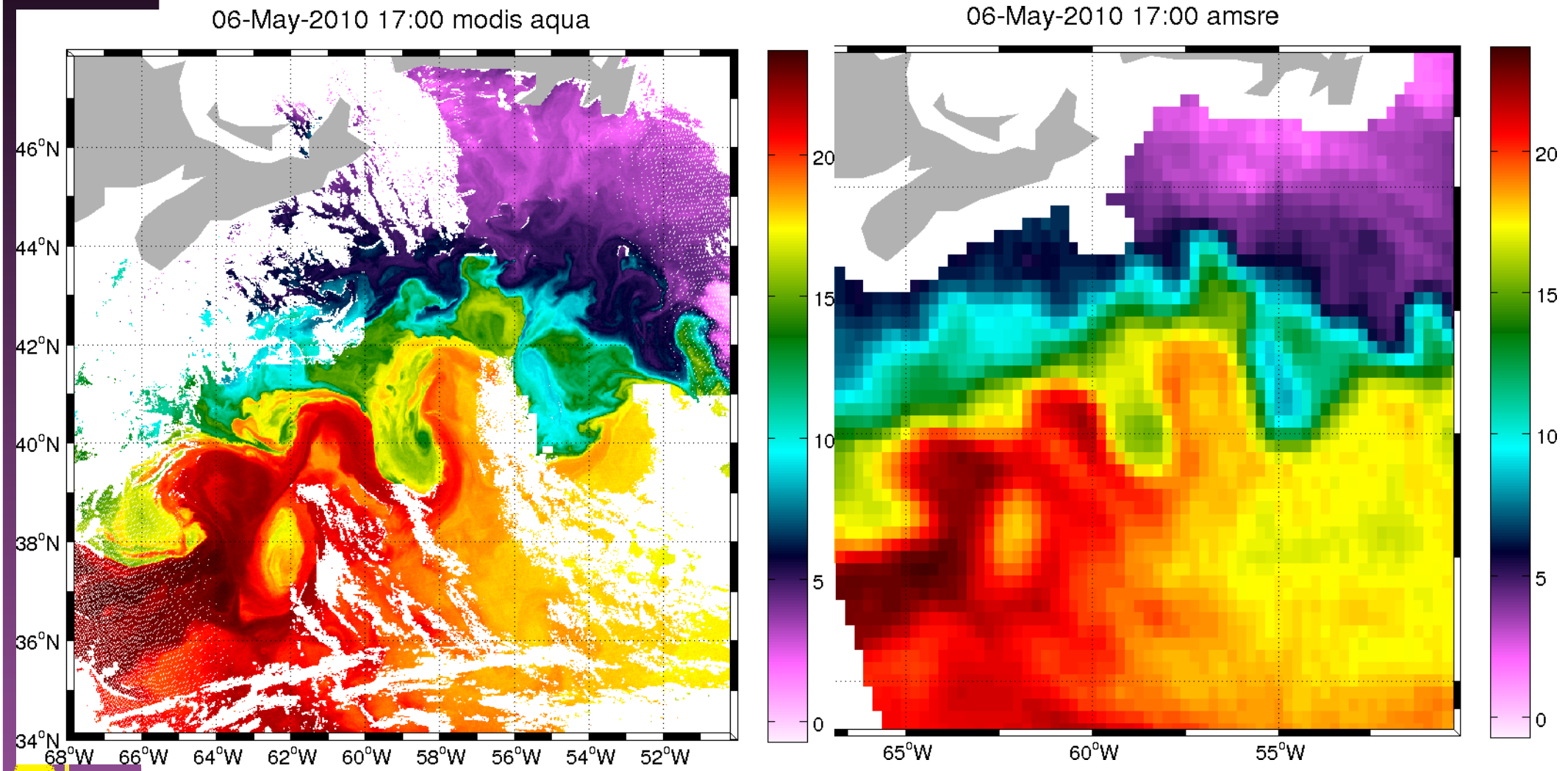


Satellite SST observations

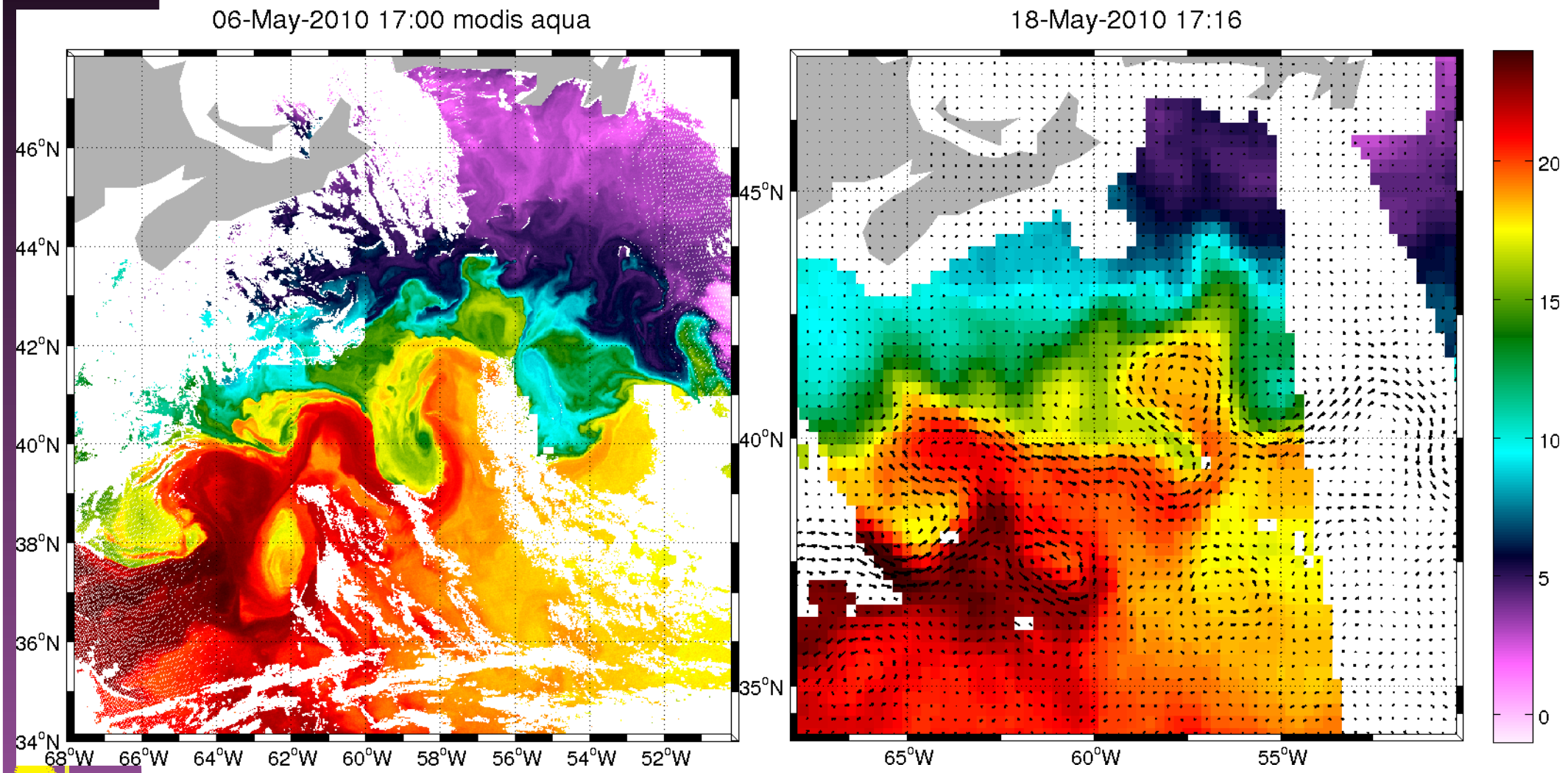


www.ifremer.fr

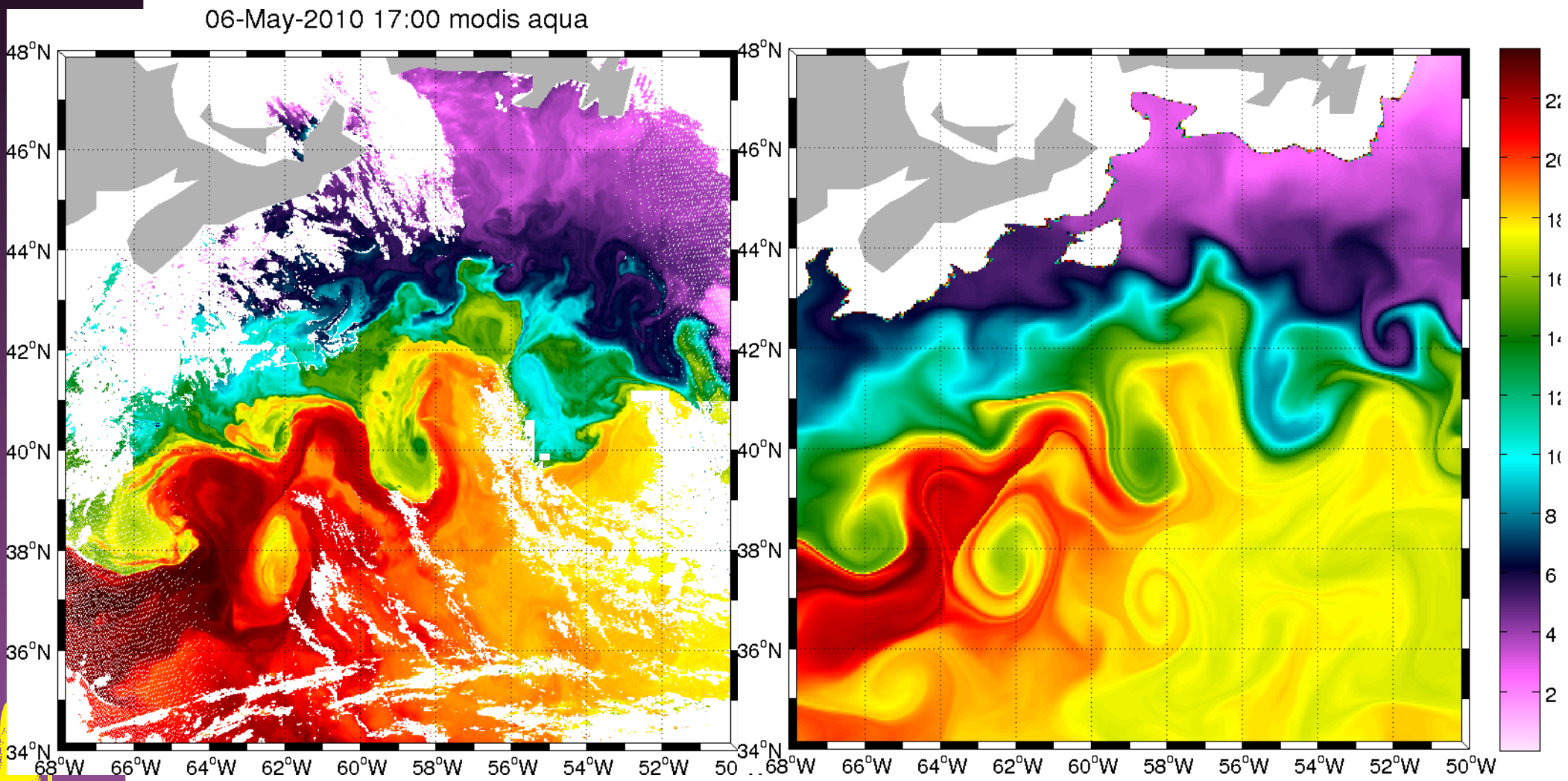
Small scales / mesoscale



Small scales / mesoscale

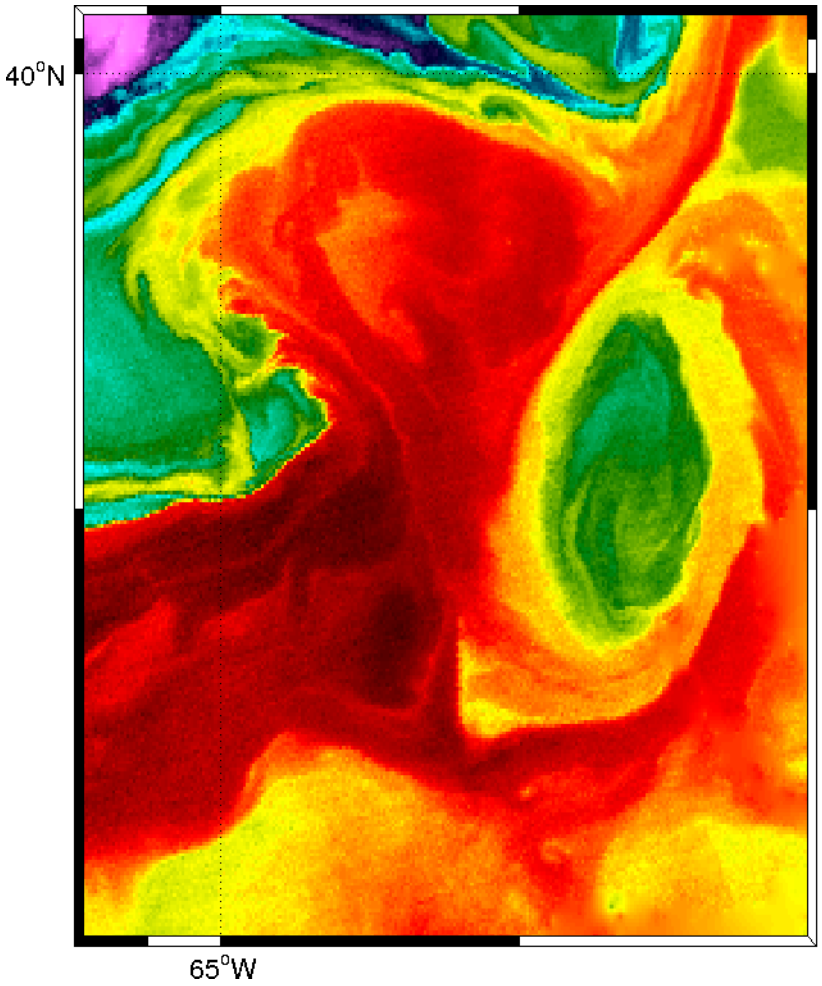


Small scales / mesoscale

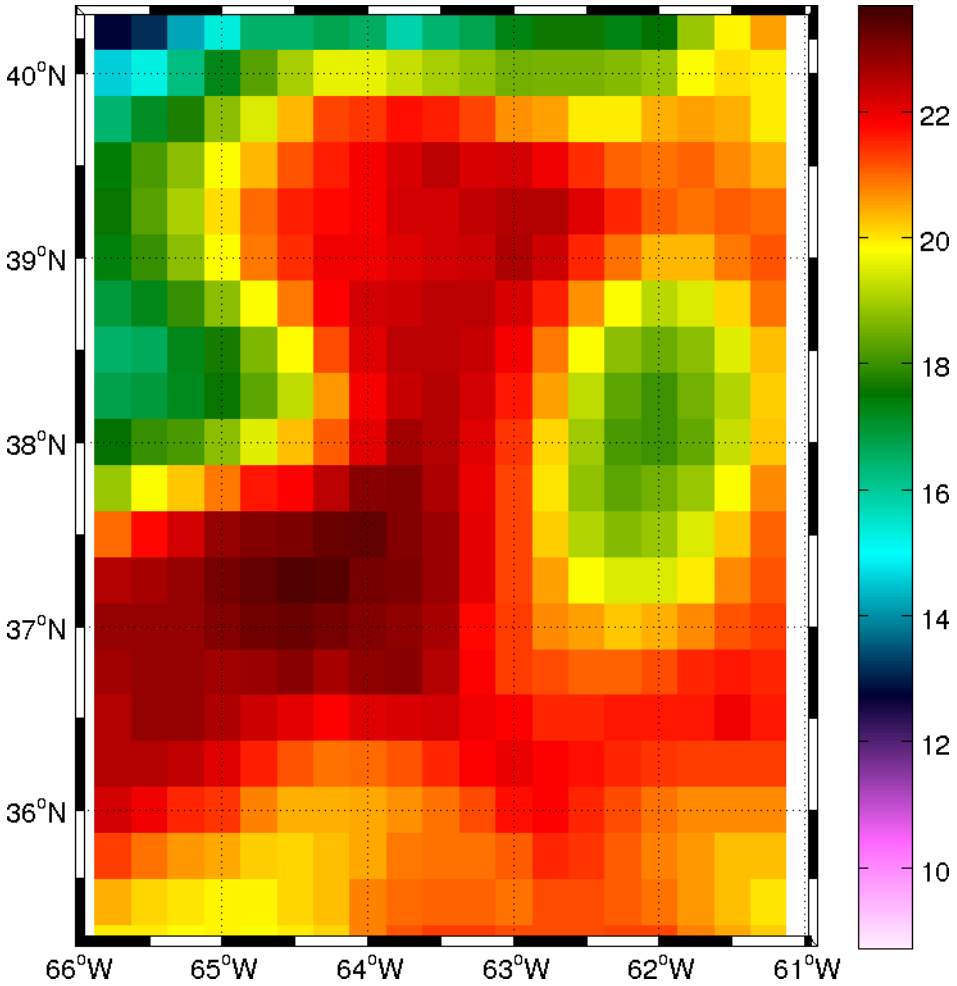


Small scales / mesoscale

SST – Modis(L2P)



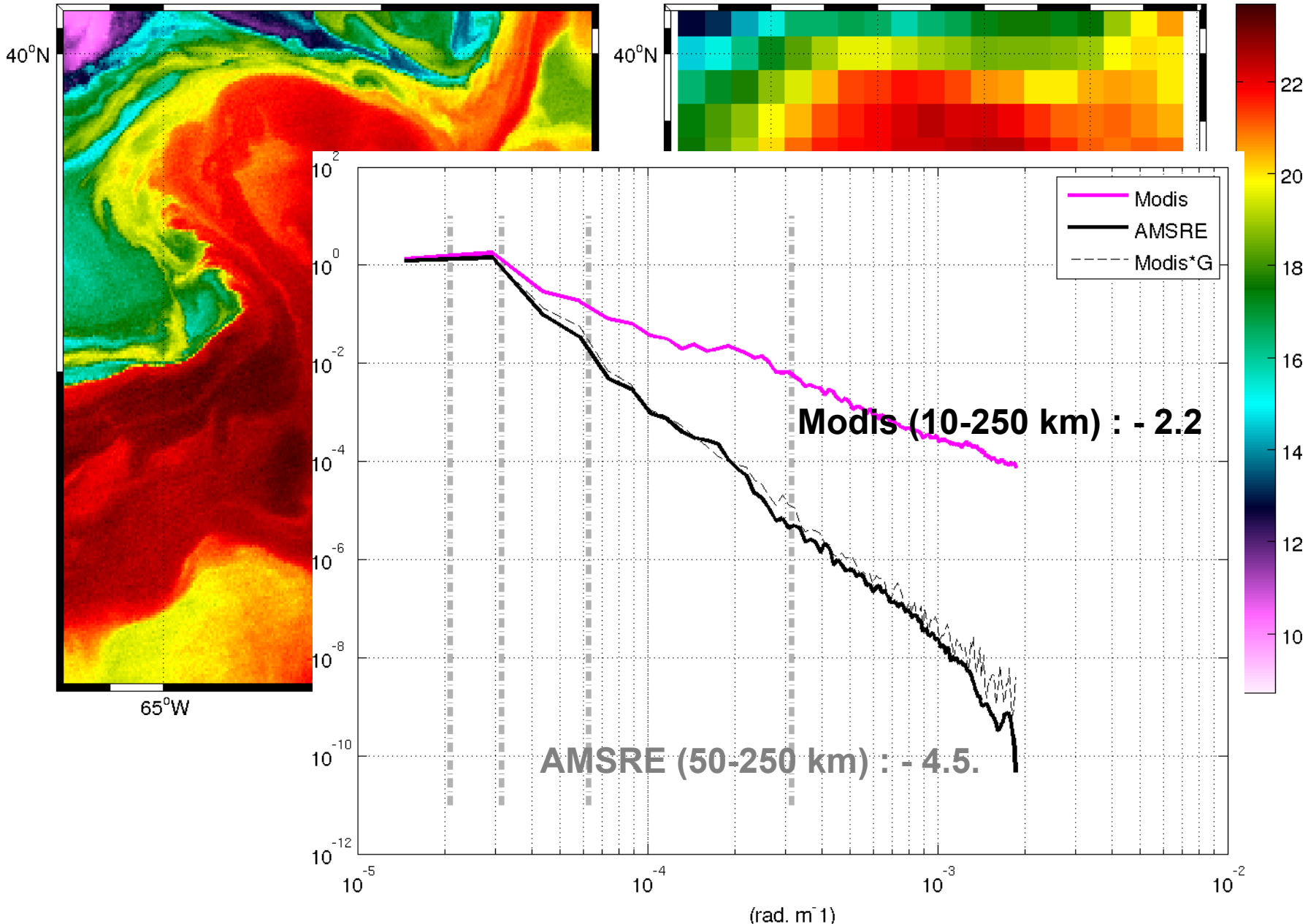
SST – AMSRE(L3)



Small scales / mesoscale

SST – Modis(L2P)

SST – AMSRE(L3)



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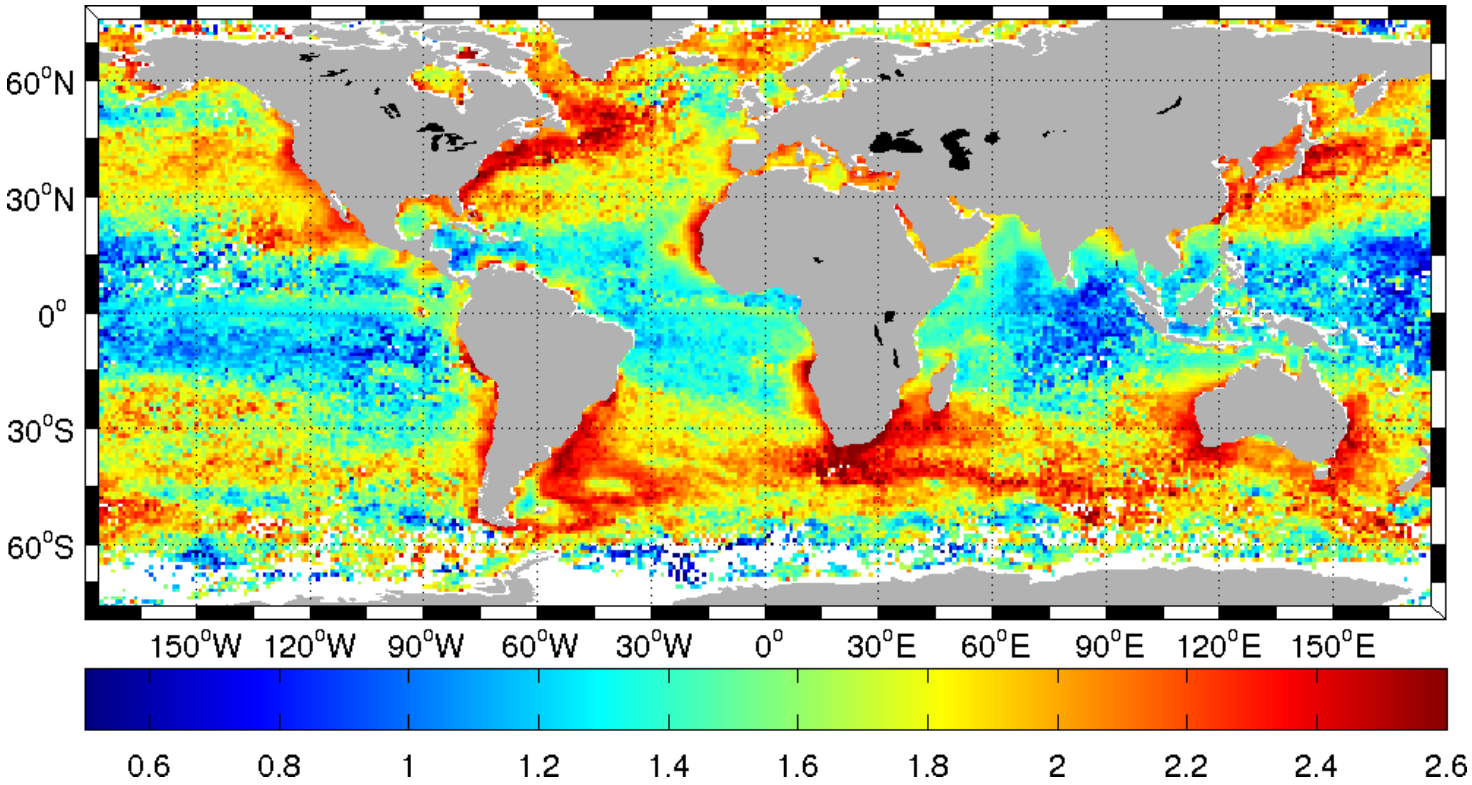
Spectral approach

SST wavenumber spectra in the 8-70 km band



2008-2013 wavenumber spectral slopes mean at 1°x1° resolution in the 8-70 km wavelength band calculated from METOP-A-AVHRR SST data (~1 km resolution).

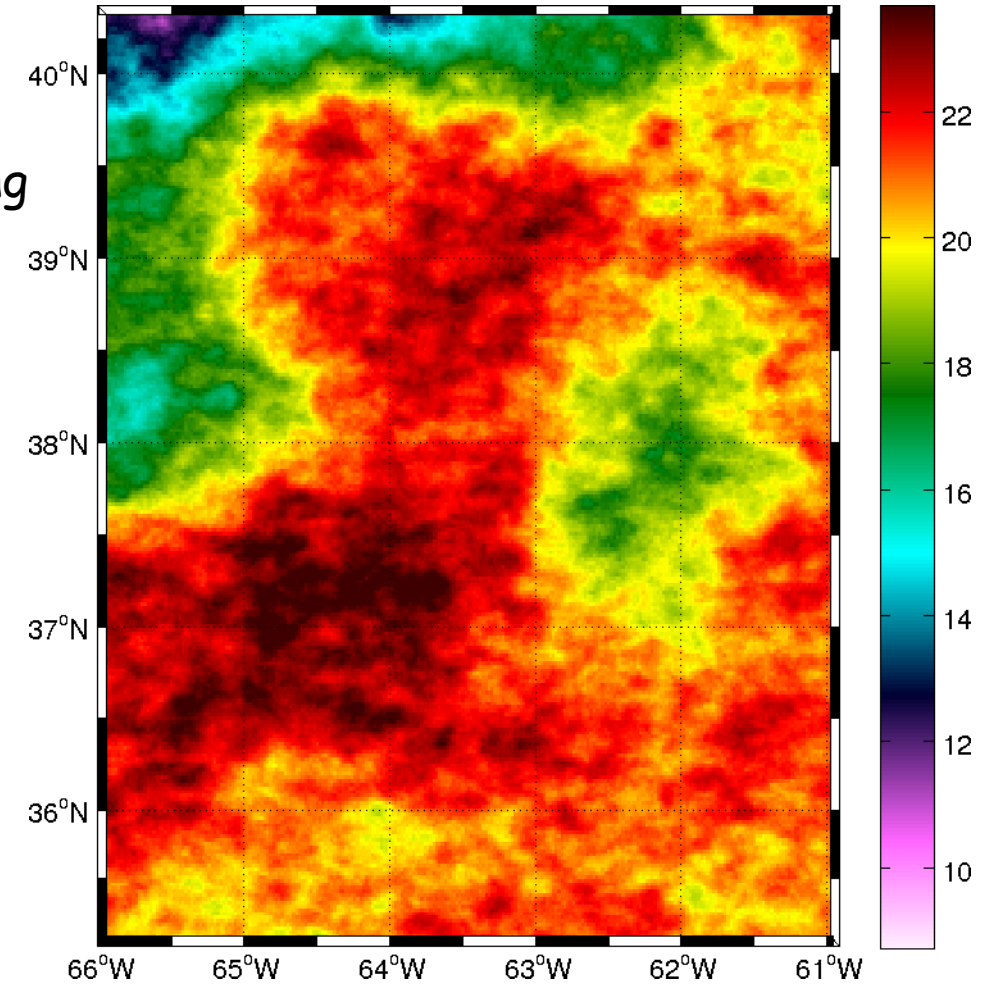
Small scales / mesoscale

- MW observation system could be considered as an average filter (here ~60 km) ~ 1/k filter for scales smaller than 250 km

- => Inverse filter ?

  Proposition 1 : x k

  Proposition 2 : add the missing energy whith random phases



Small scales / mesoscale

- MW observation system could be considered as an average filter (here ~60 km) ~ 1/k filter for scales smaller than 250 km

- => Inverse filter ?

  Proposition 1 : x k

  Proposition 2 : add the missing energy whith random phases

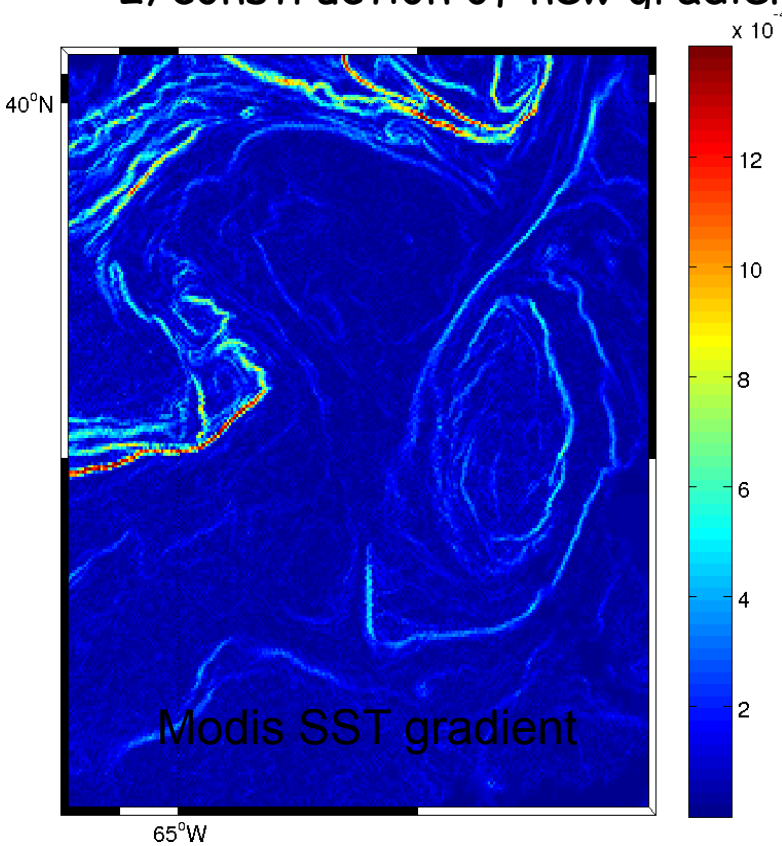
Proposition 3 : add a phase information. Estimate the variance explained by the enhancement of large gradients present in low resolution field

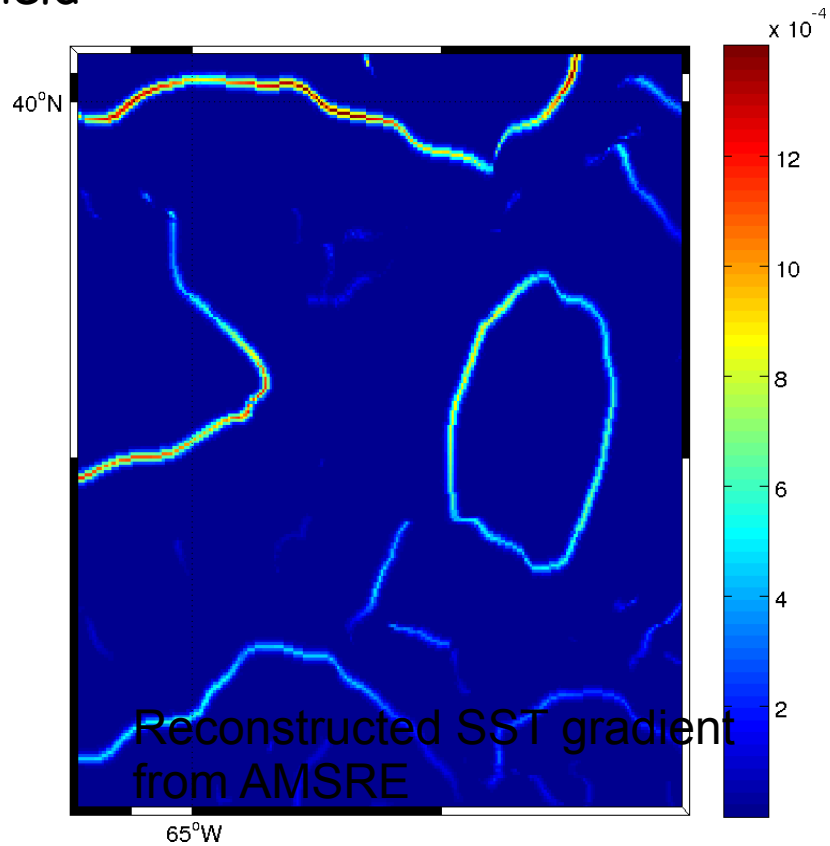
Small scales / mesoscale

Proposition 3 :

1/ gradient profile model (density function of a generalized exponential distribution) for HR and LR-> 'transformation model'

2/construction of new gradient field





Small scales / mesoscale

Proposition 3 :

1/ gradient profile model (density function of a generalized exponential distribution) for HR and LR-> 'transformation model'

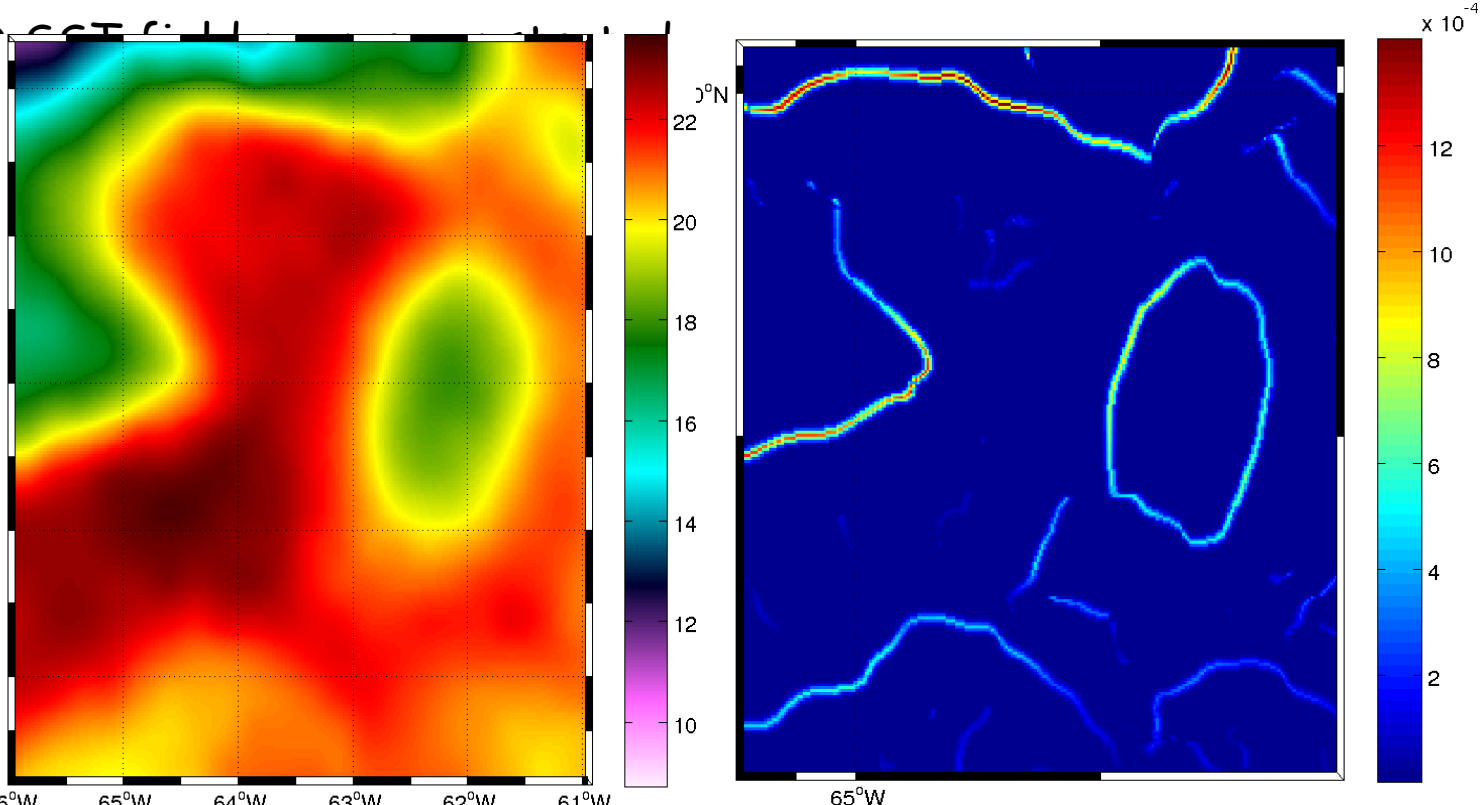
2/construction of new gradient field

3/ [illegible]

Mir

wit

=> r



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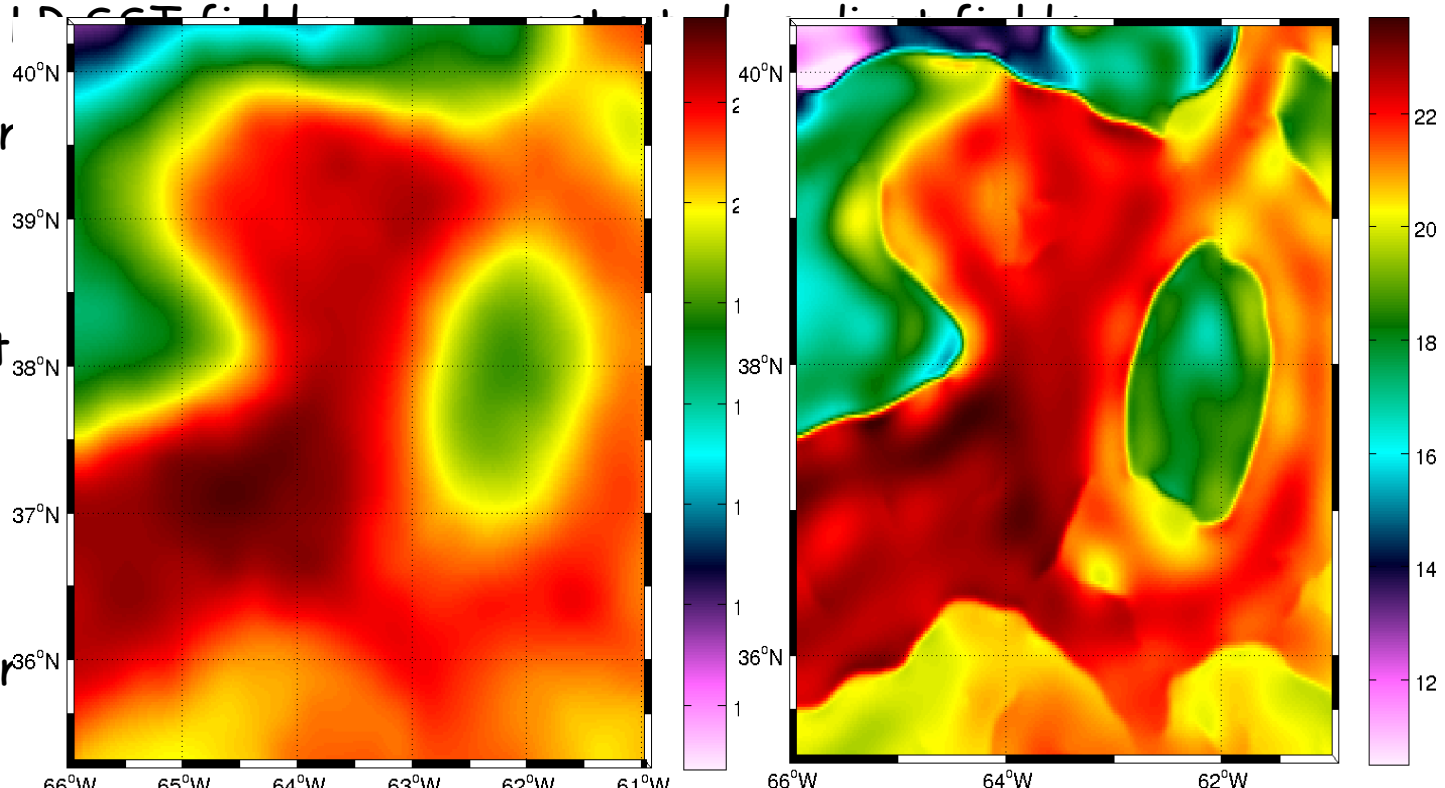
wit

=> r



Small scales / mesoscale

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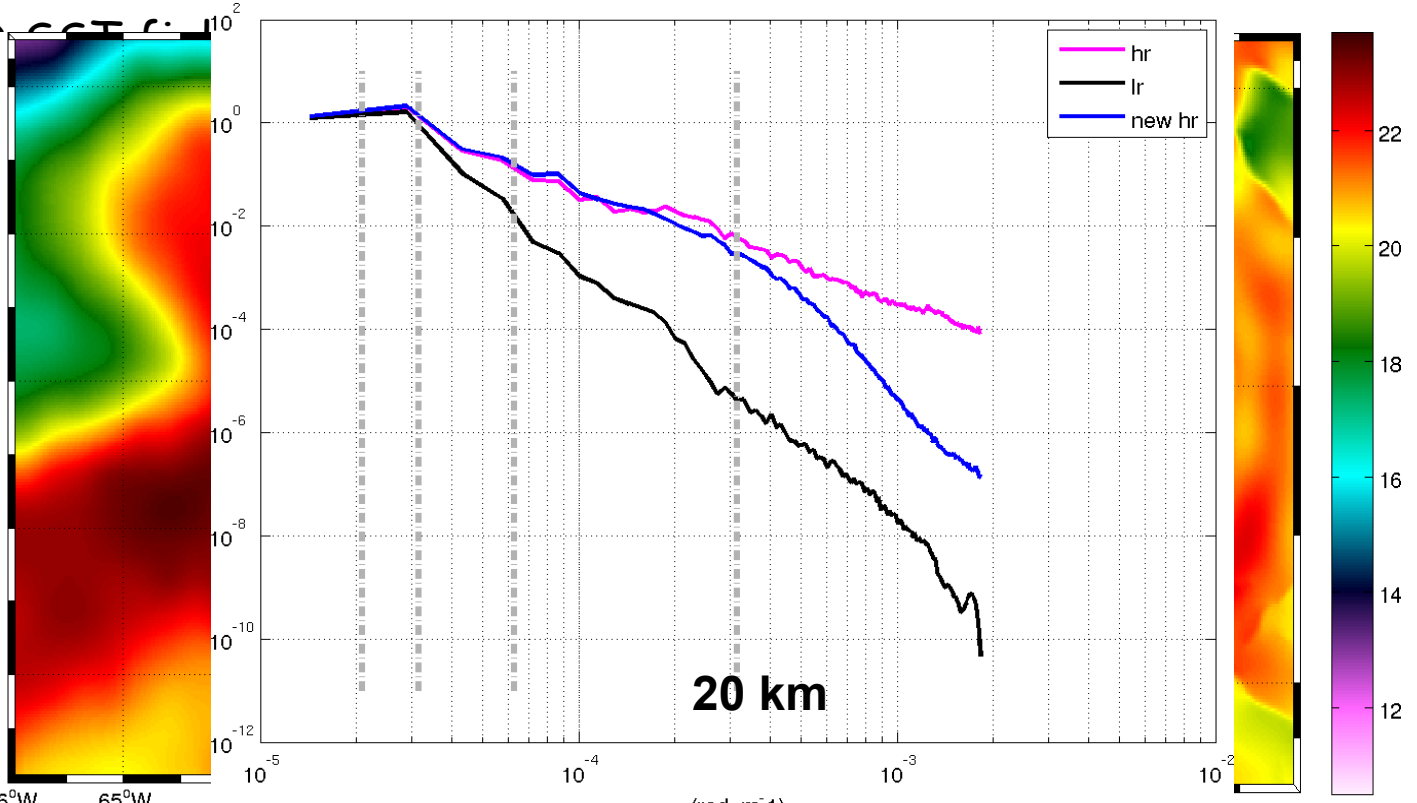
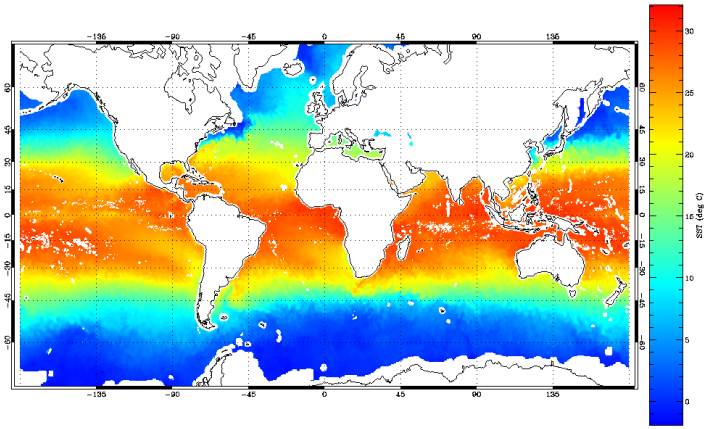
wit

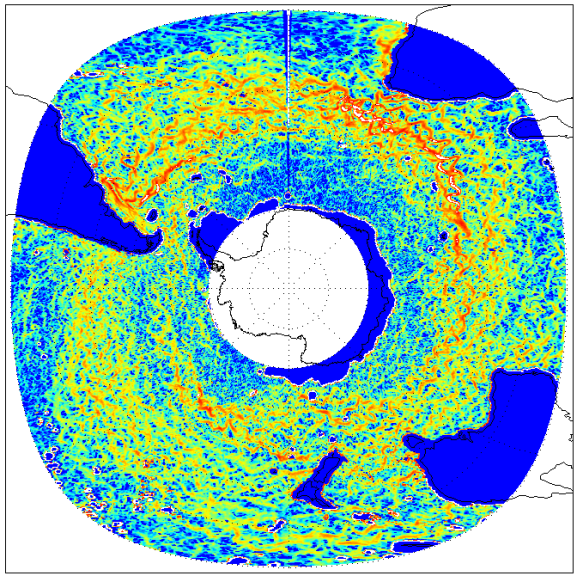
=> r

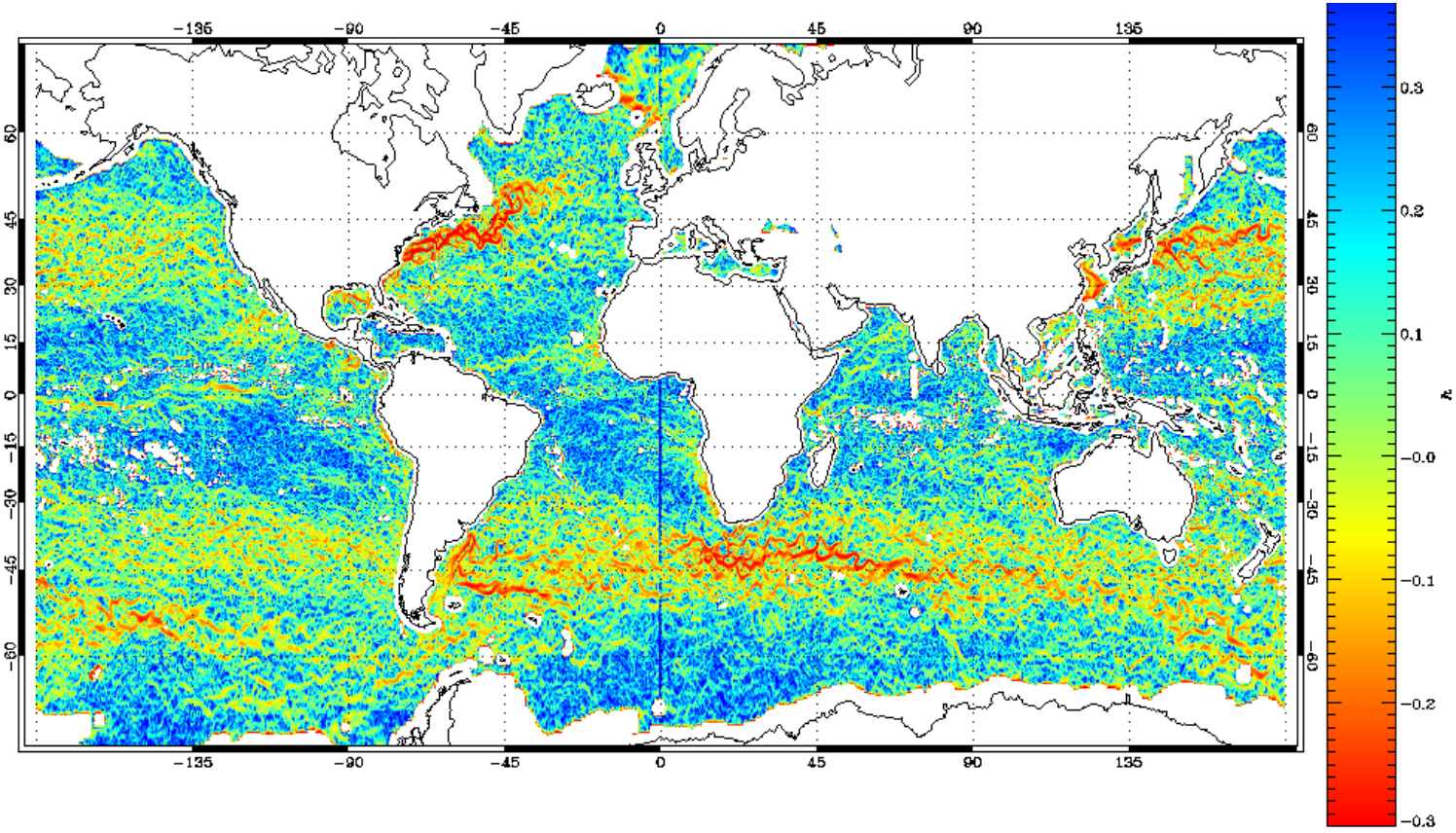


SST Global Singularity Analysis

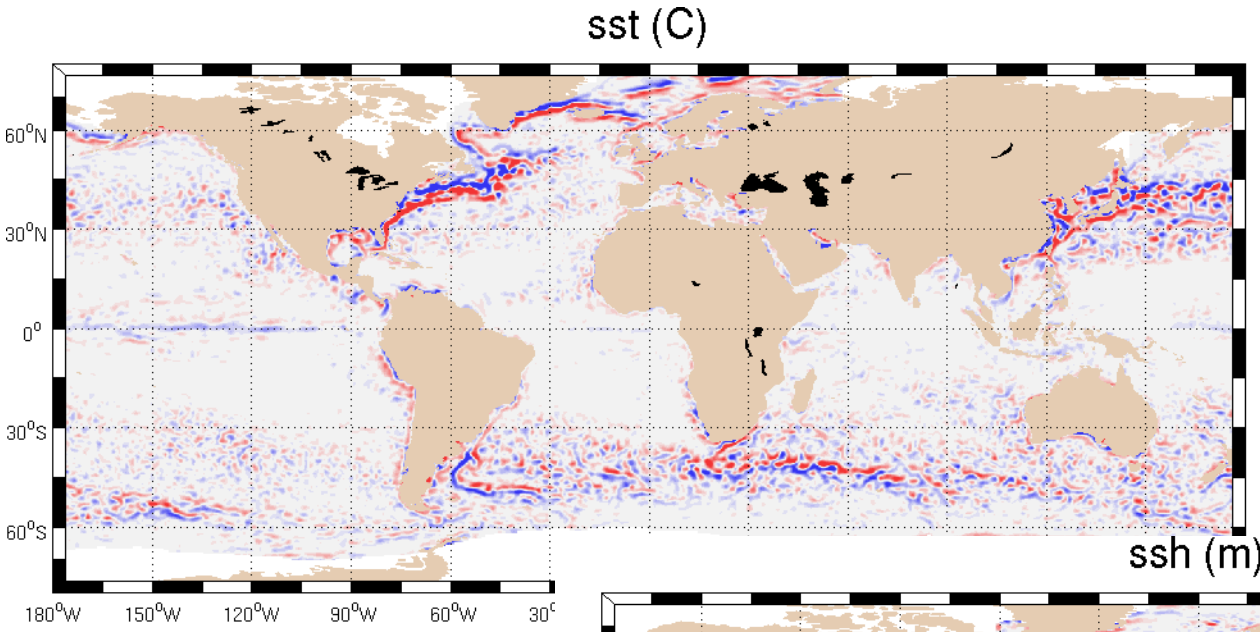
- AMSR-E SST 3 day mean

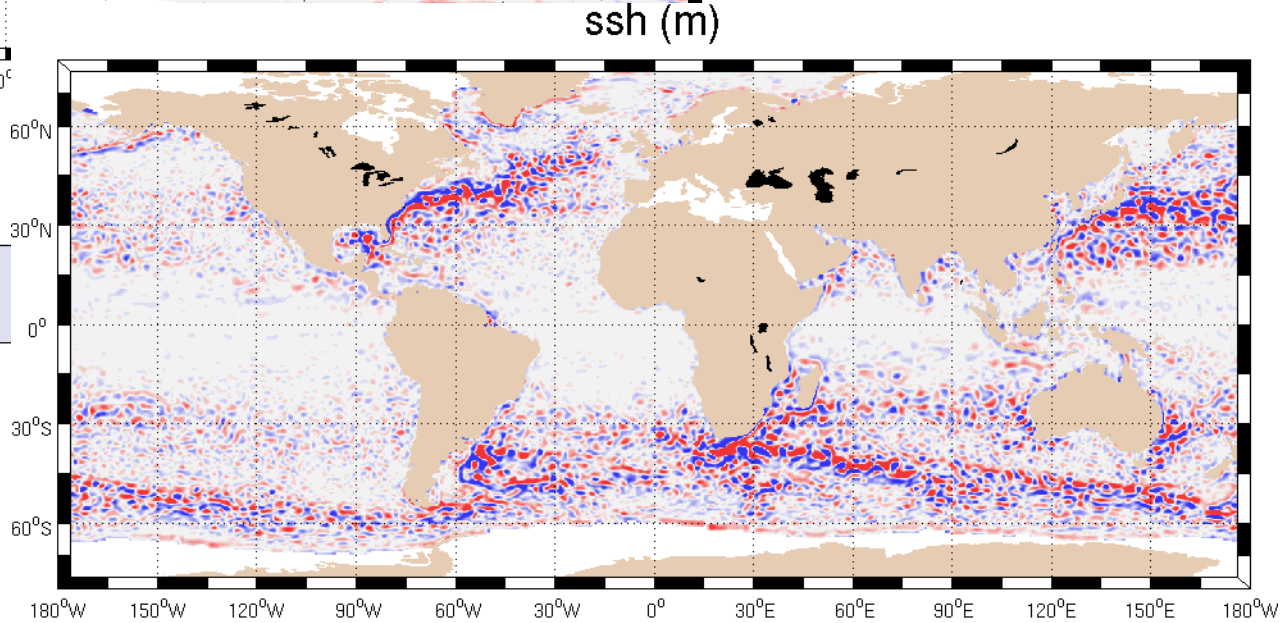






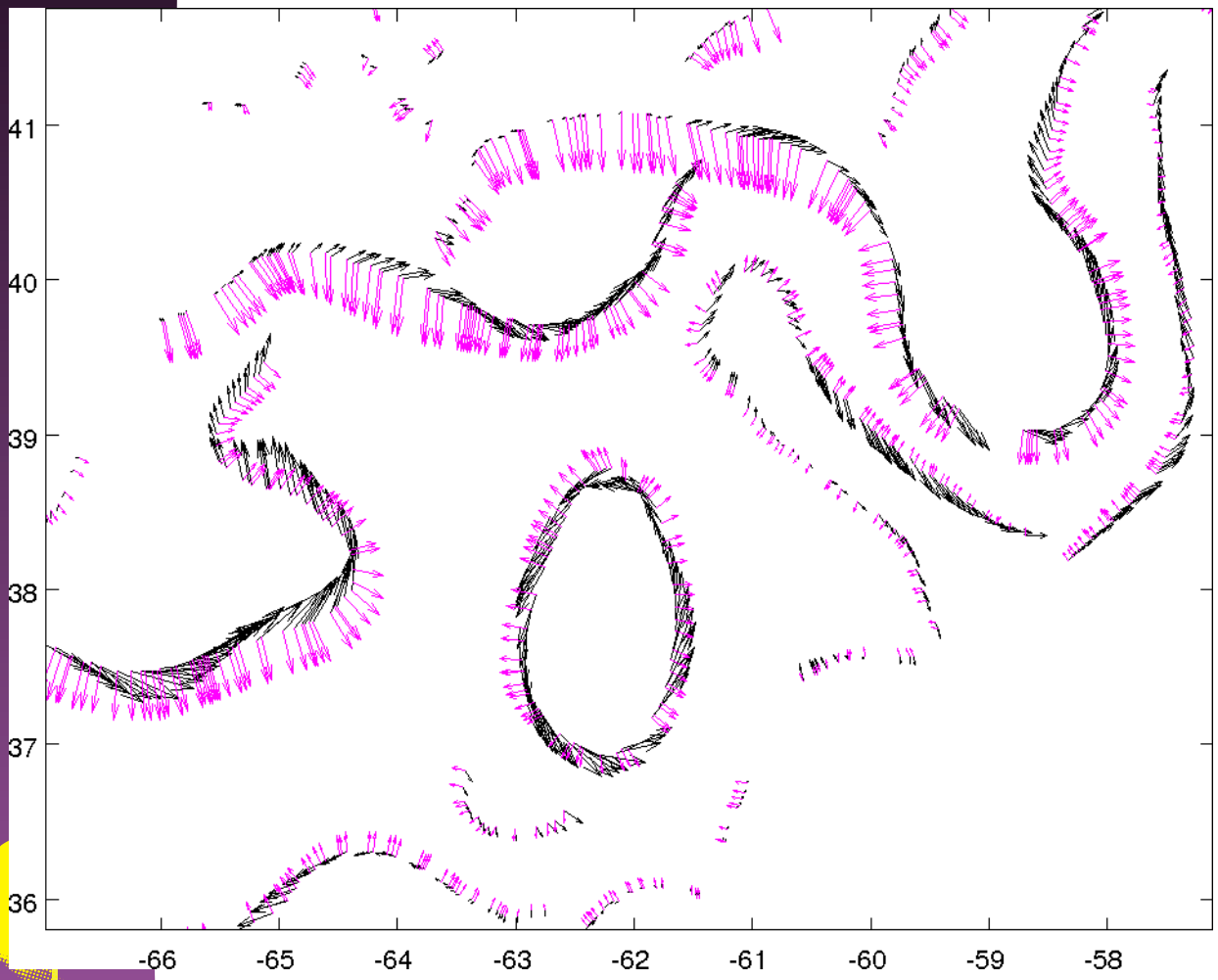
SSH and SST in the 100-300 km band

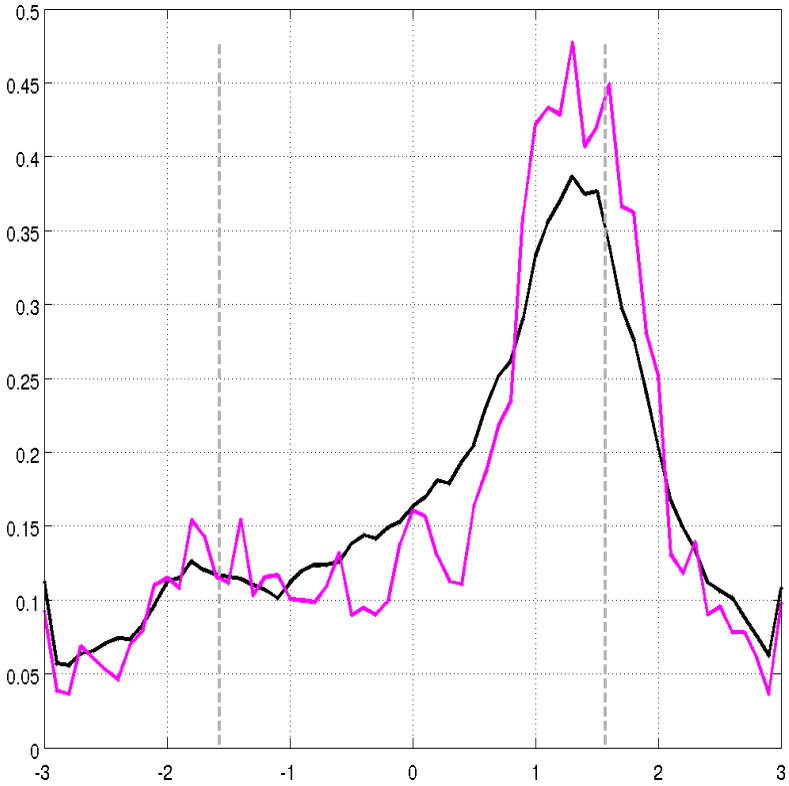




Monthly mean of SSH and SST, filtered in the 100-300 km band. Calculated with interpolated products

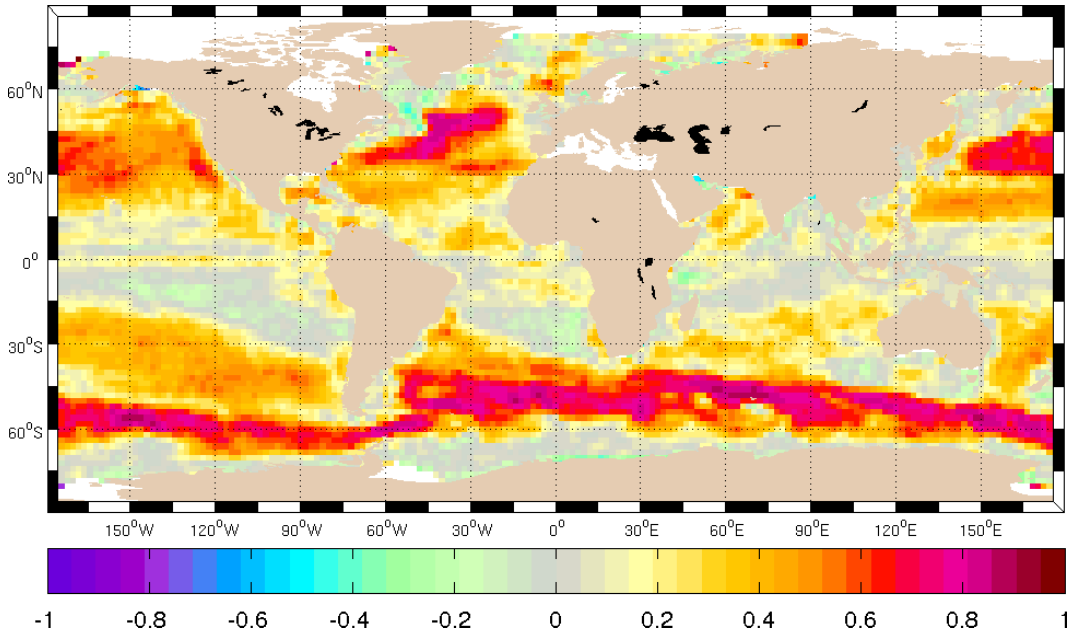
Small scales / mesoscale



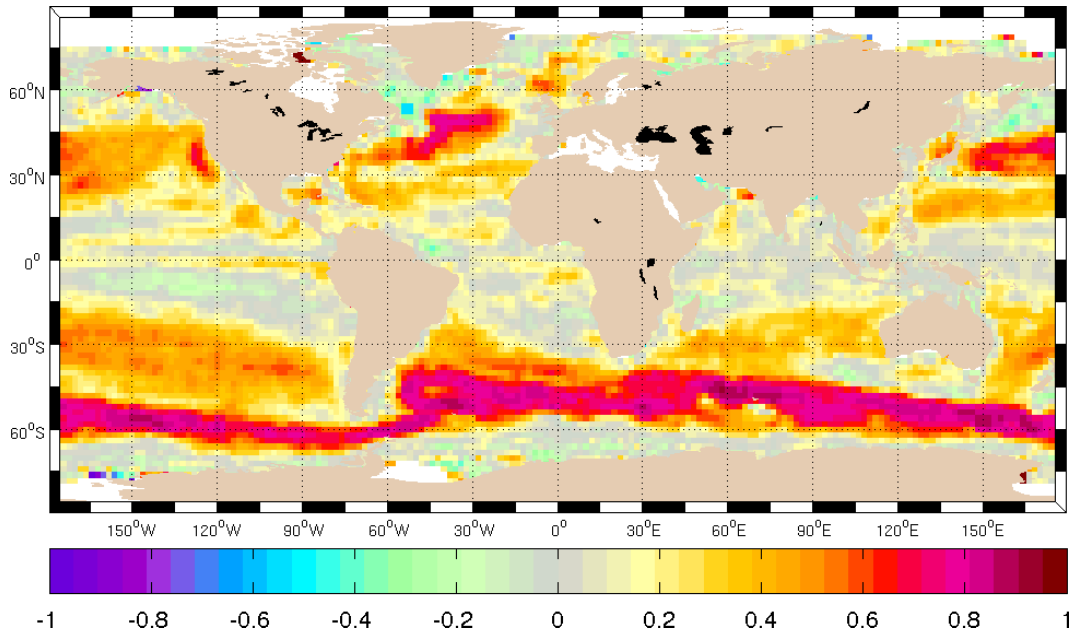


SSH/SST correlation in the 100-300 km band

Jan-Feb-Mar

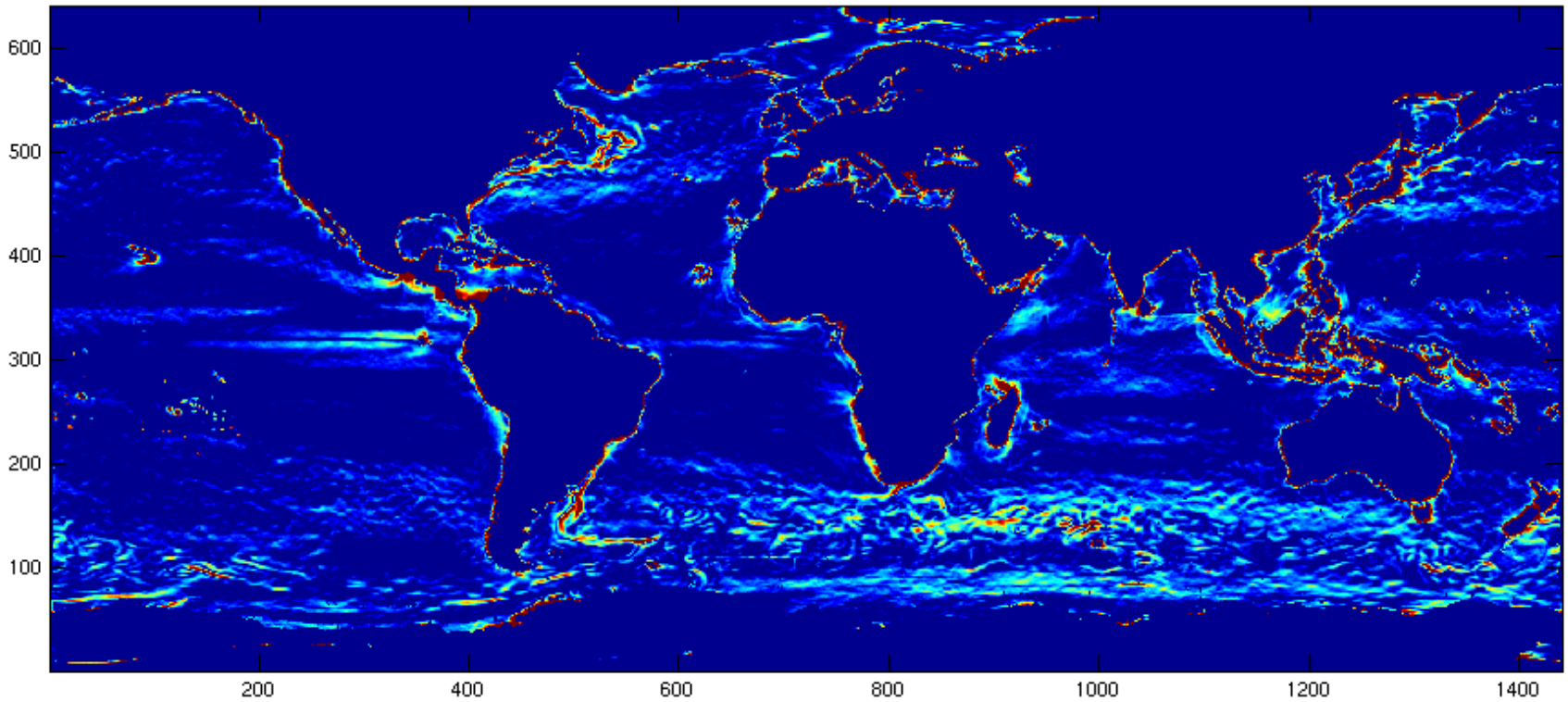


Jul-Aug-Sep



2003-2009 seasonal mean of correlation coefficients. Calulated from weekly 0.25° grid resolution OI products (MADT and AMSRE-TMI OI) within 8°x8° box at 2°x2° grid resolution

Meso-scale Air-Sea Interactions (High-pass filtered surface wind speed)



Positive correlation between SST and wind speed on ocean mesoscales

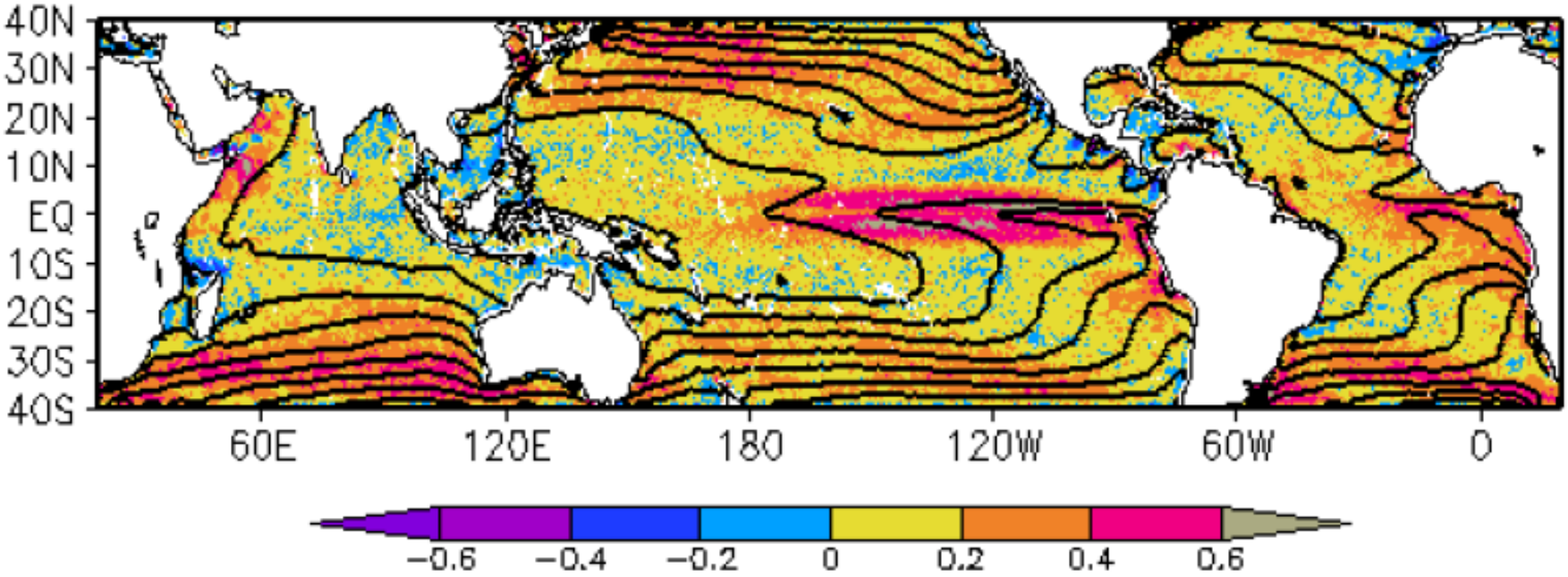
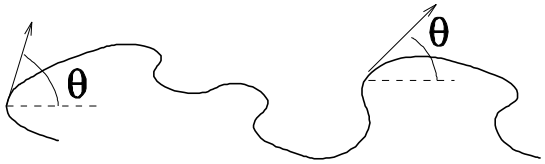


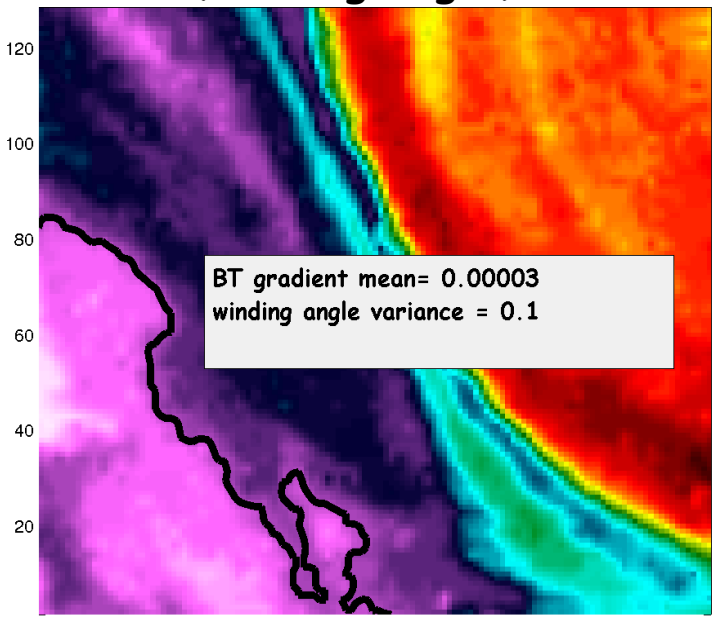
Figure 1. A map of the correlation of SST and wind speed, both pre-filtered to emphasise meso-scale features. The mean SST (interval 3K) is overlaid. Data from TRMM, 1997-2004. The data was filtered as follows. The first three annual harmonics were first removed, then a Fourier filter has been applied to retain only features of around 40 week period or less.

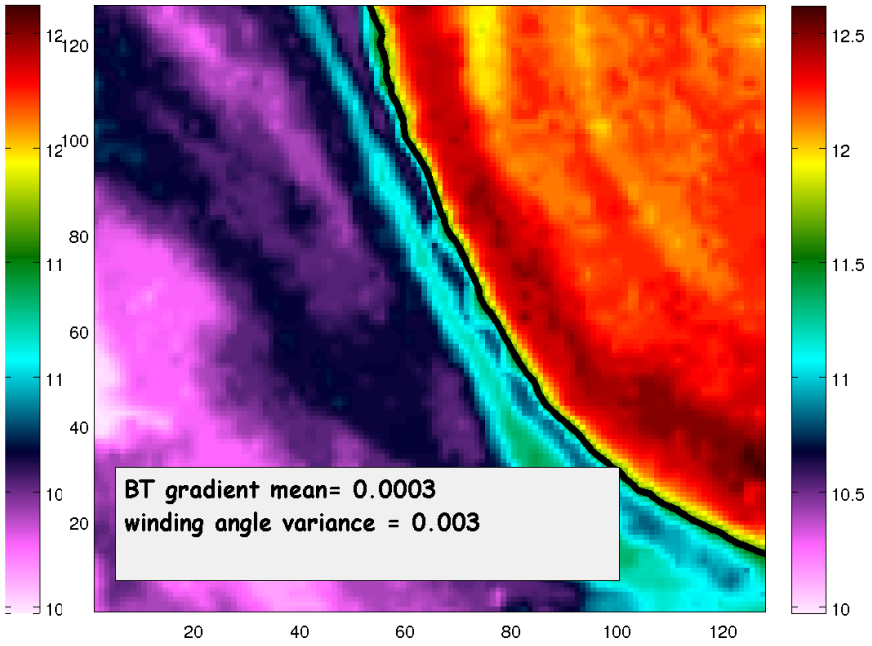
Small et al. "A review of air-sea interaction over ocean fronts and eddies." Dyn. Atm. Ocean.

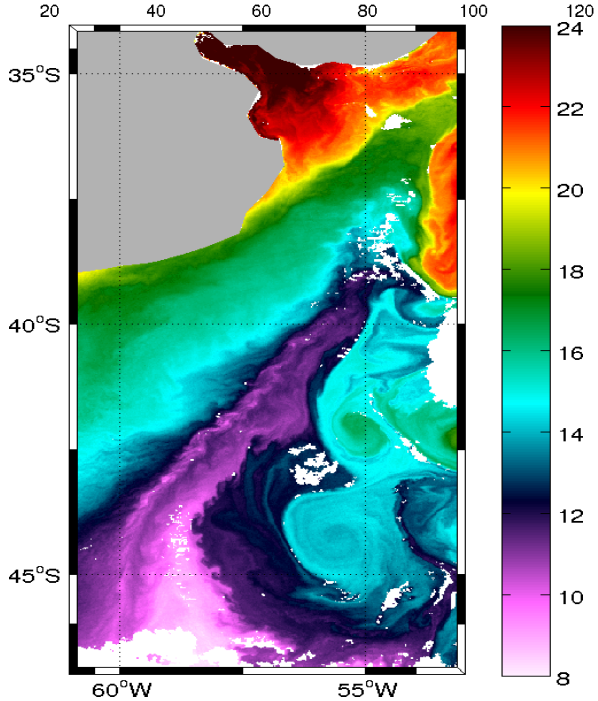
Small scales / mesoscale



contour (winding angle) characterization



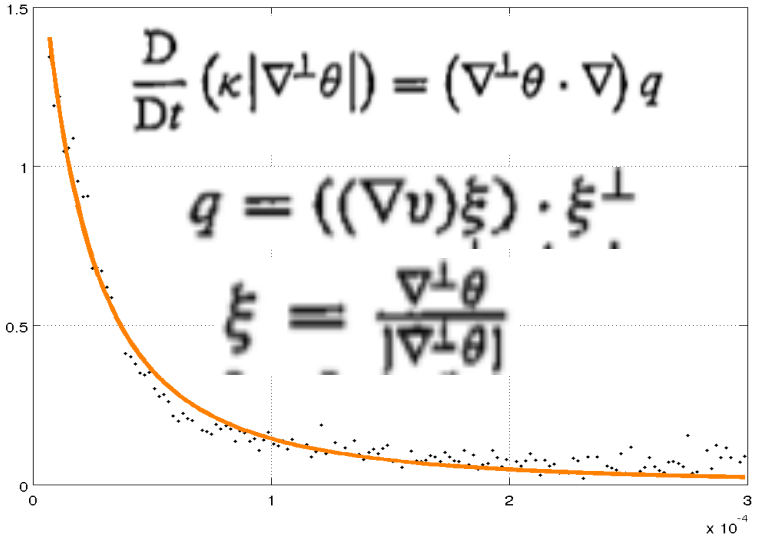




$$\frac{D}{Dt}\left(\kappa|\nabla^{\perp}\theta|\right) = \left(\nabla^{\perp}\theta \cdot \nabla\right) q$$

$$q = \left((\nabla v)\xi\right) \cdot \xi^{\perp}$$

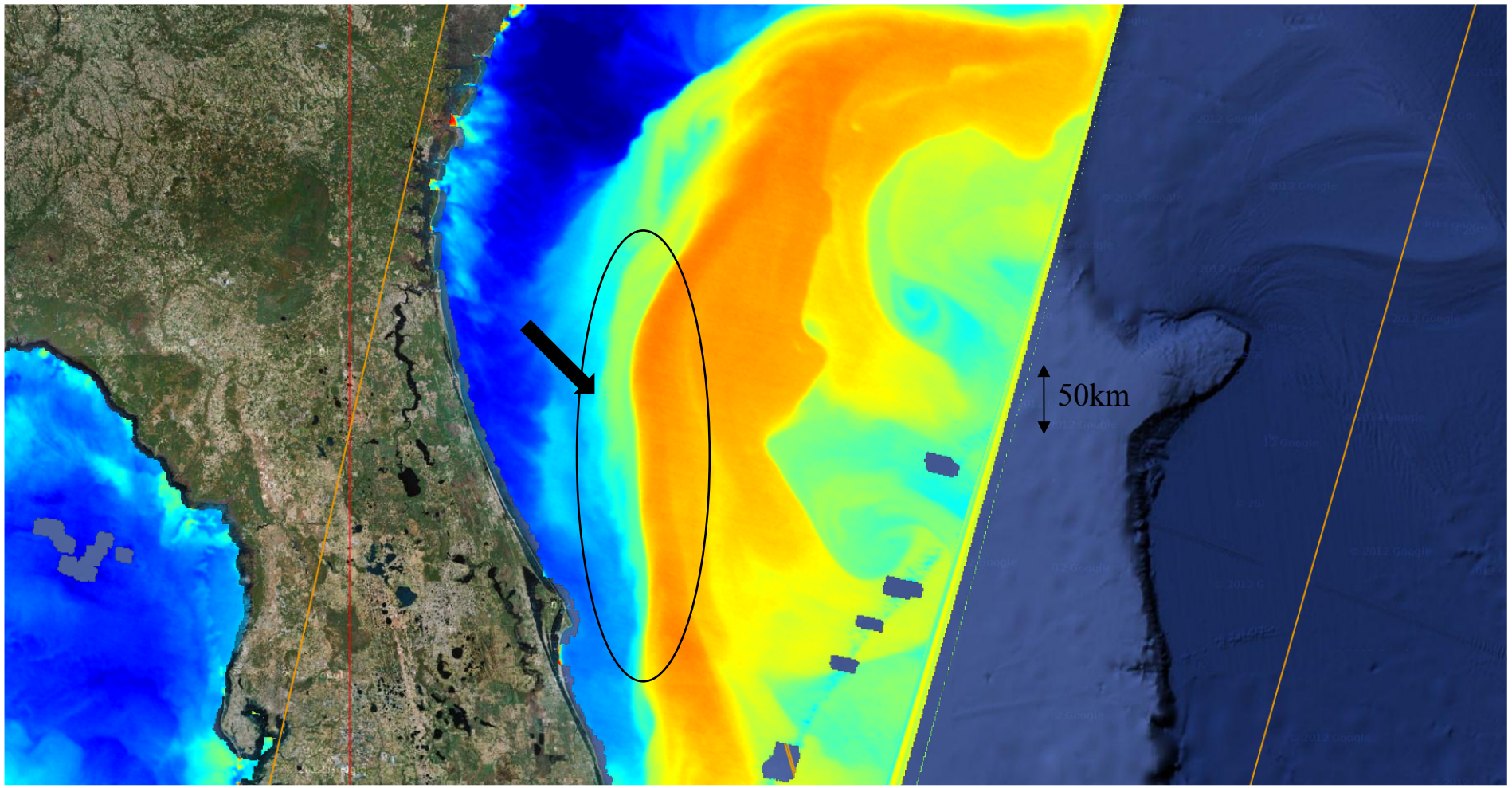
$$\xi = \frac{\nabla^{\perp}\theta}{|\nabla^{\perp}\theta|}$$



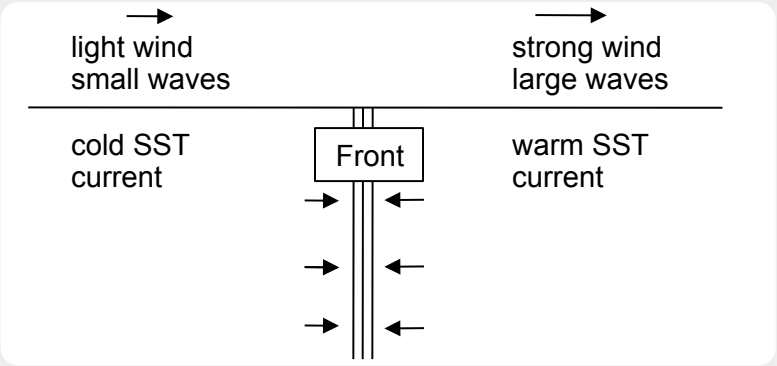
SST fronts and roughness gradients collocated

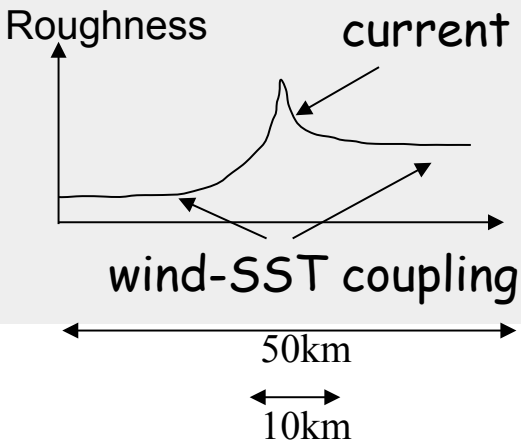
1) scales 10-50 km SST/wind coupling : SST = wind

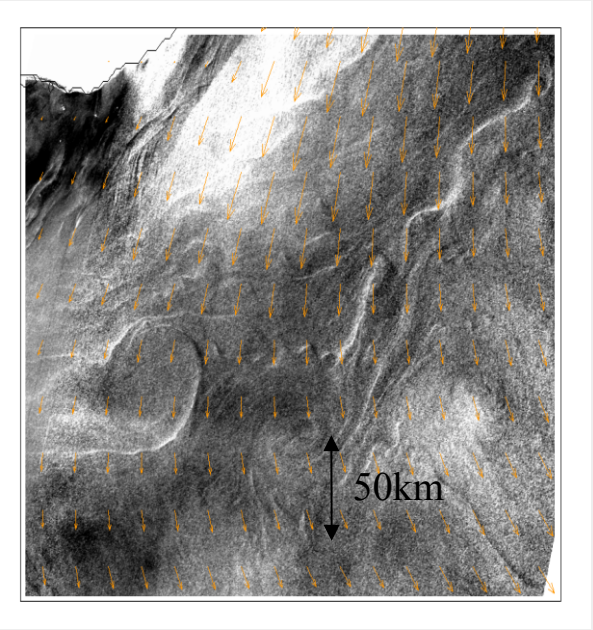
2) scales 2-10 km wave/current coupling : dSST = du



Modis SST



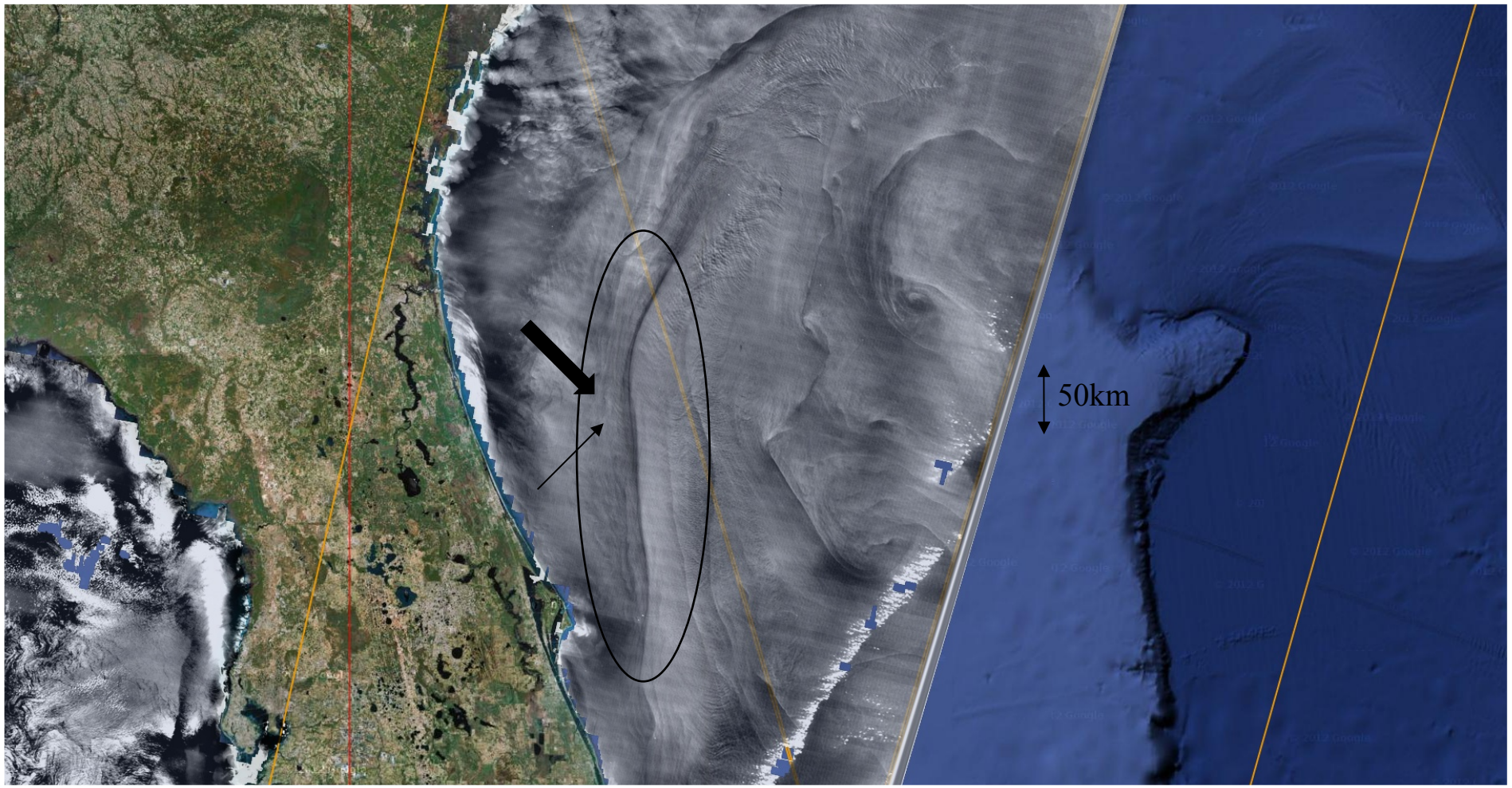




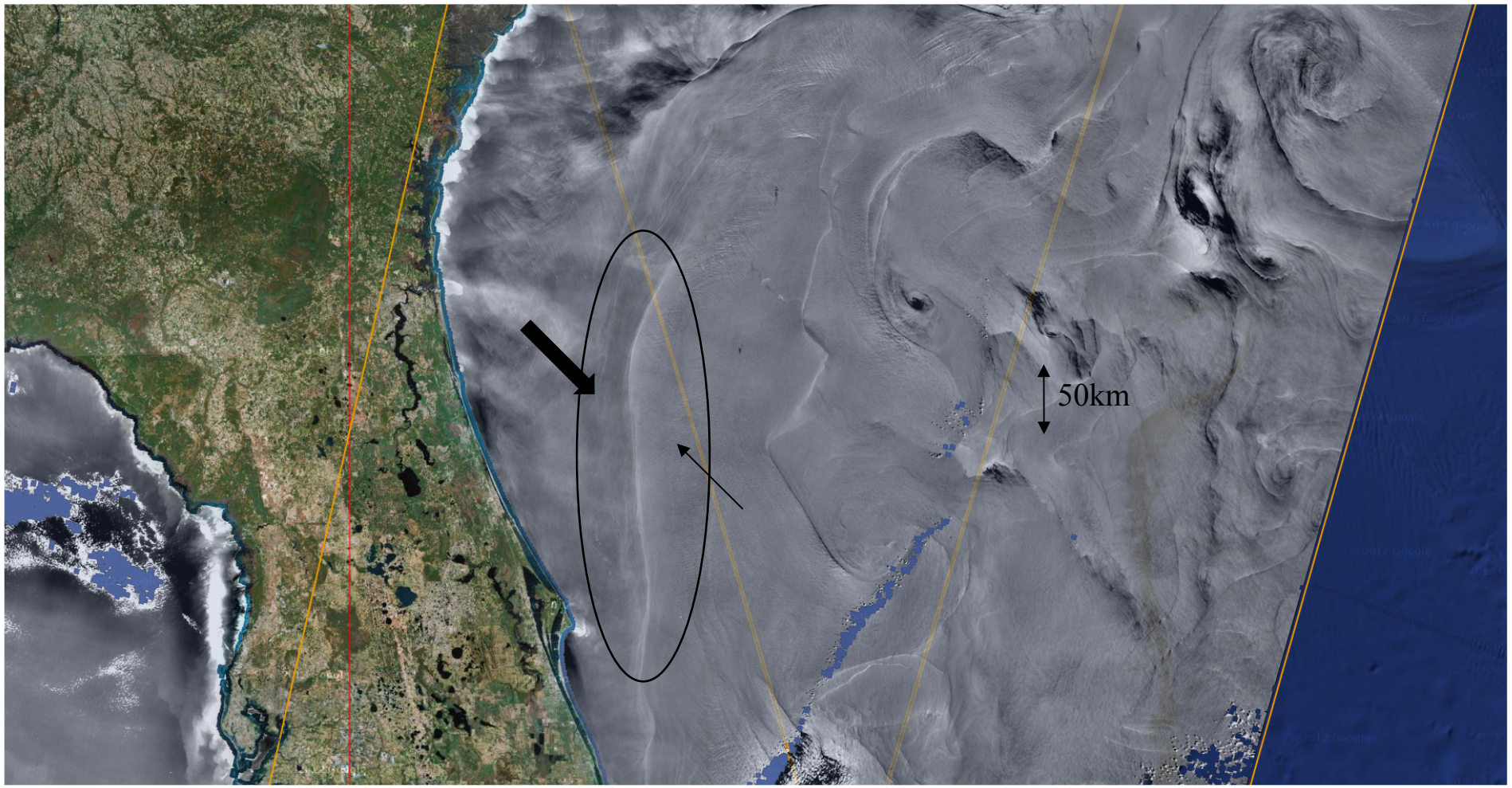
SST fronts and roughness gradients collocated

1) scales 10-50 km SST/wind coupling
2) scales 2-10 km wave/current coupling

Essentially related to the surface slope (mean square slope MSS) of short waves (roughly 1-10 cm)
Those waves are related to local wind and **current** (and surfactants)



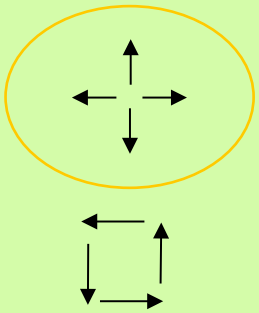
Modis Terra glitter



Meris glitter

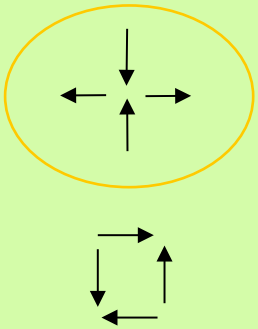
Only 2 over 4 types of current deformations will sign on the roughness image.

$$\begin{bmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} D + S_t & -R + S_h \\ R + S_h & D - S_t \end{bmatrix}$$



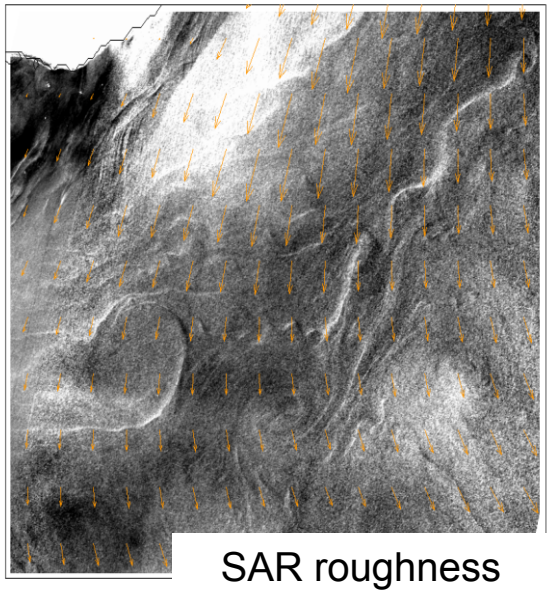
$$D = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y},\ S_t = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y},$$

$$R = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y},\ S_h = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}.$$



Which type of currents will sign?

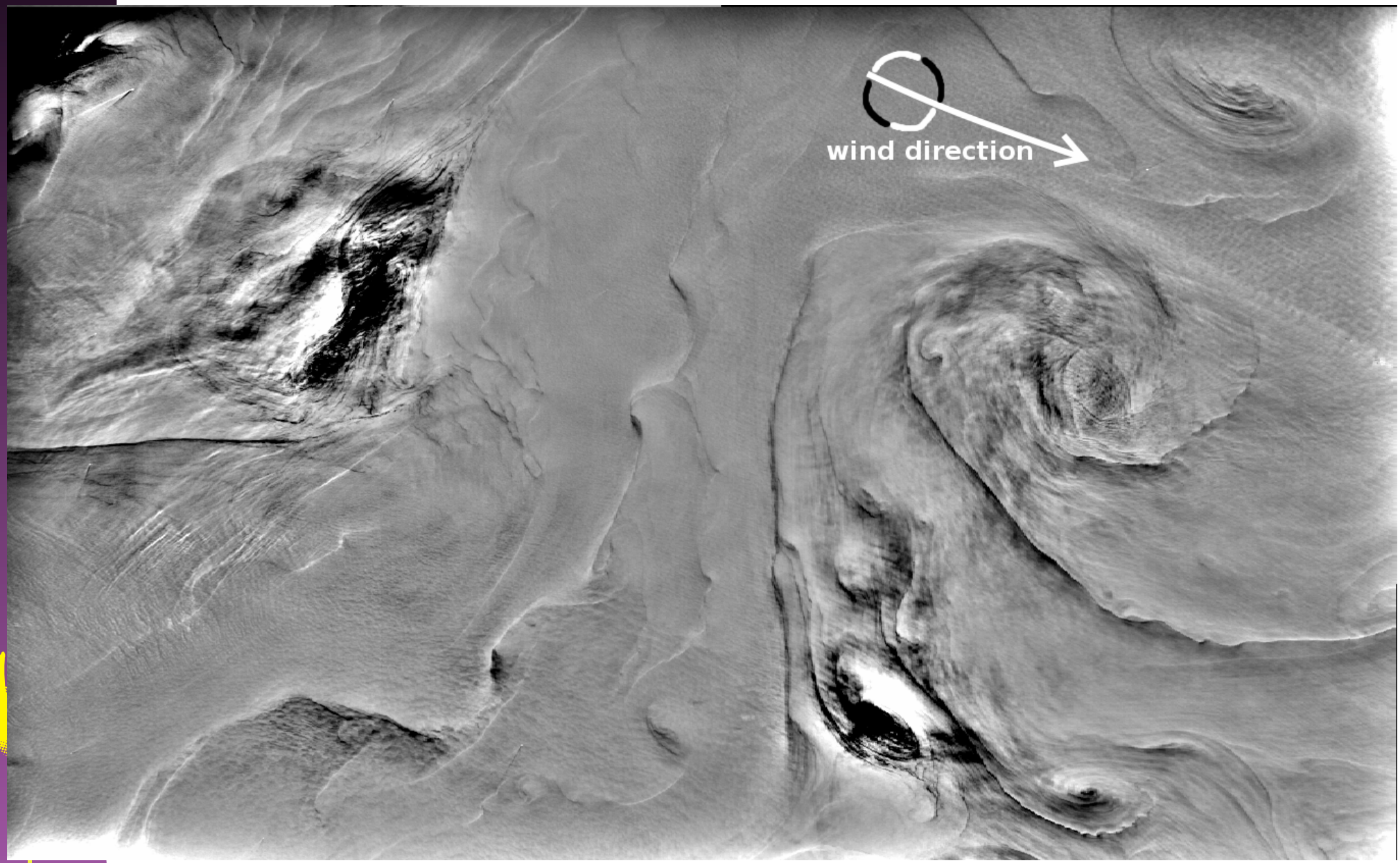
- rotational currents
- **divergent currents**
- shear in the wind direction
- **strain in the wind direction**

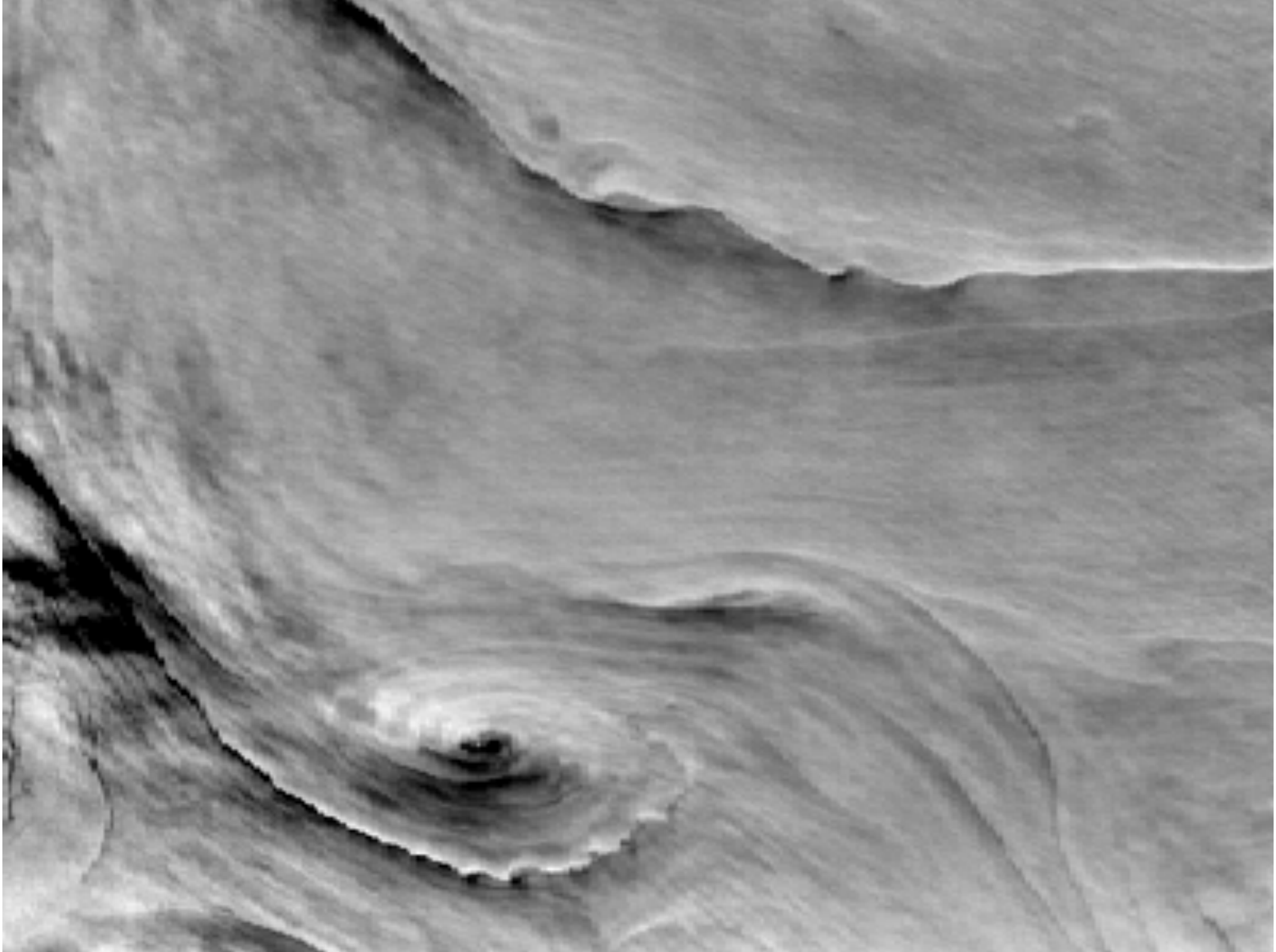


SAR roughness

- Divergent currents appear independently of the wind direction
- Non divergent currents appear with a 45°-sensitivity to the wind/current angle.

Meso- and submeso-scale details





- … most observations are not yet sufficiently explored and used, especially to detail OA interactions

Synergy between high resolution observations, numerical simulations and theory to reveal mean states and trends, near-surface ocean-atmosphere dynamics, local and non-local interactions, especially convergence/ divergence surface fronts, roughness contrasts, related to near-surface vertical velocities