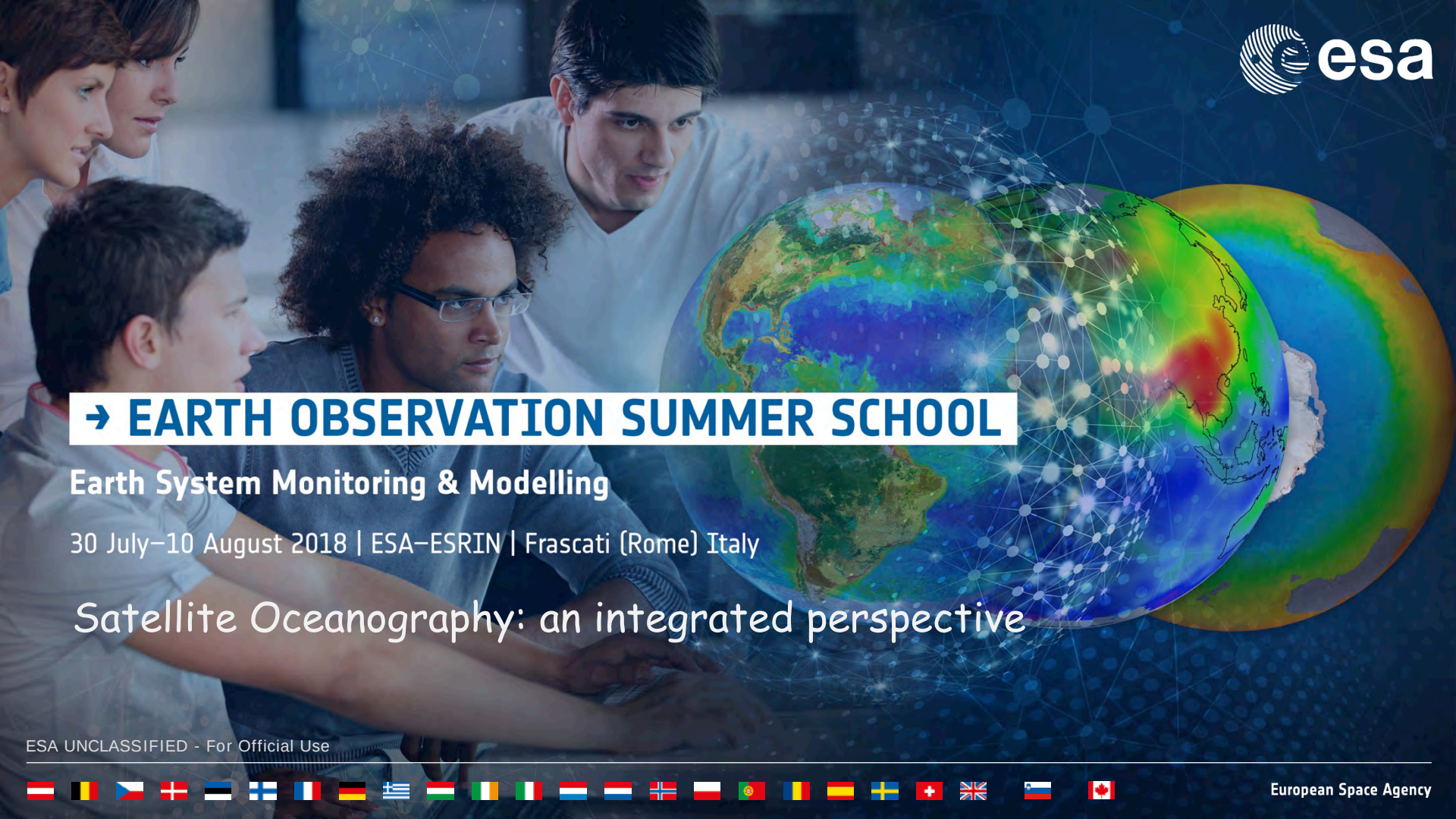


→ EARTH OBSERVATION SUMMER SCHOOL

Earth System Monitoring & Modelling

30 July–10 August 2018 | ESA–ESRIN | Frascati (Rome) Italy

Satellite Oceanography: an integrated perspective

Problem: 1/100(0) year events now occur yearly!

- … most observations are not yet sufficiently explored and used

Synergy between high and medium resolution observations to reveal mean states and trends, near-surface ocean-atmosphere dynamics, local and non-local interactions, convergence/divergence surface fronts and numerous roughness contrasts

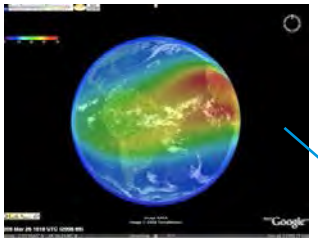
Atmospheric and Oceanic observations generally produce high quality data, but it is often too sparse (many gaps where information is missing, and/or often too local in both space and time)

How can we use observed data in combination with the physical knowledge of stochastic processes in nonlinear dynamical systems to estimate and model those effects on the variability of computationally resolvable scales of motion that are caused by the small, rapid, unresolvable scales of fluid motion that upscaling in data assimilation leaves out?

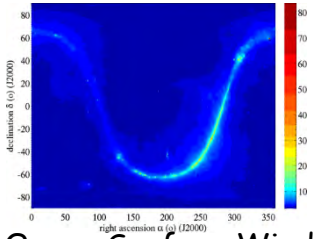
Sea Surface Salinity from Space

SMOS

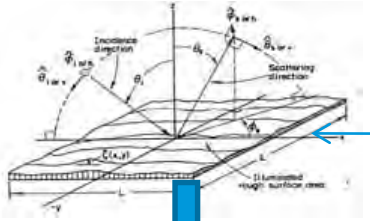
Ionosphere



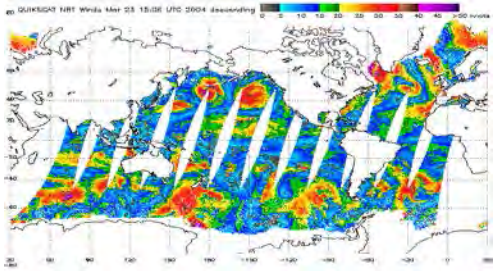
Galactic Brigthness



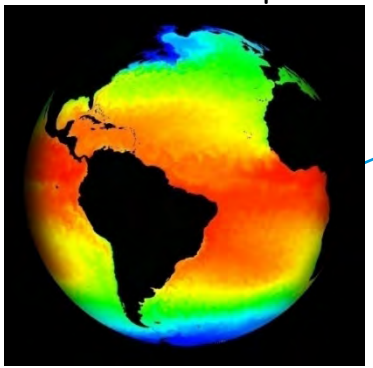
Electromagnetic Models



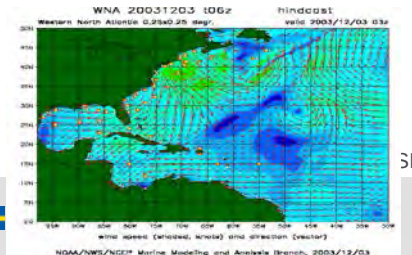
Ocean Surface Winds



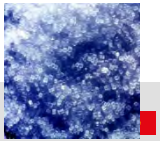
Sea Surface Temperature

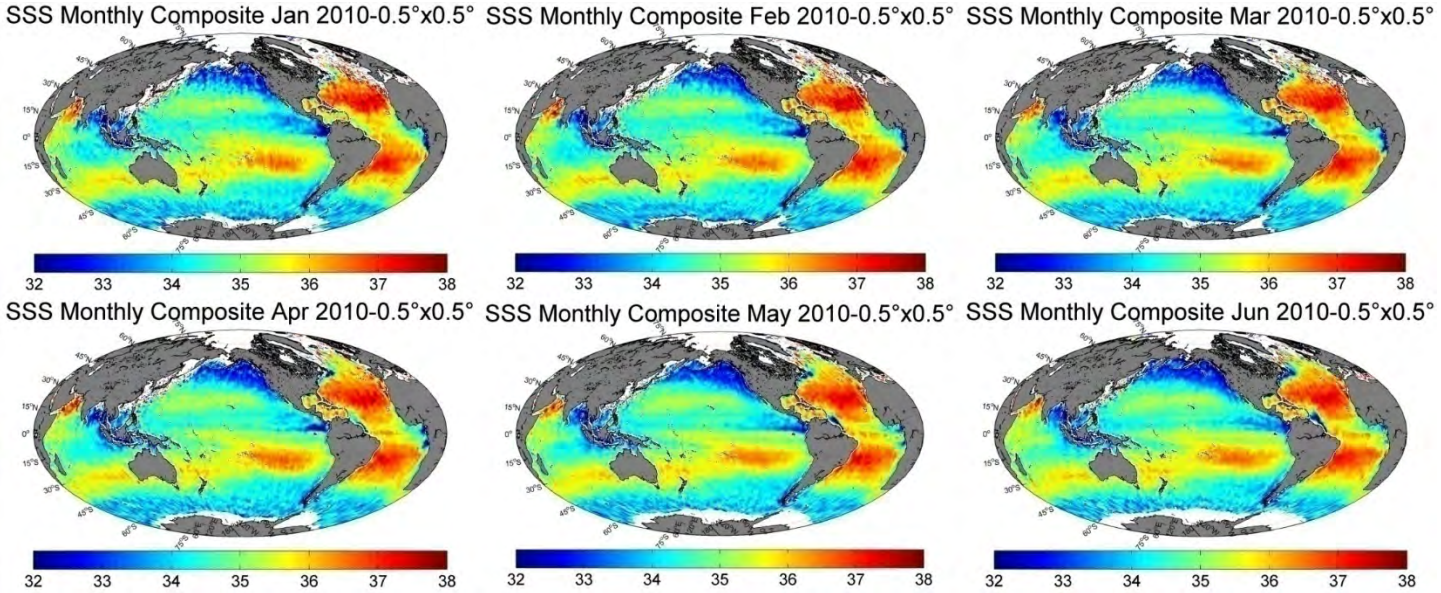


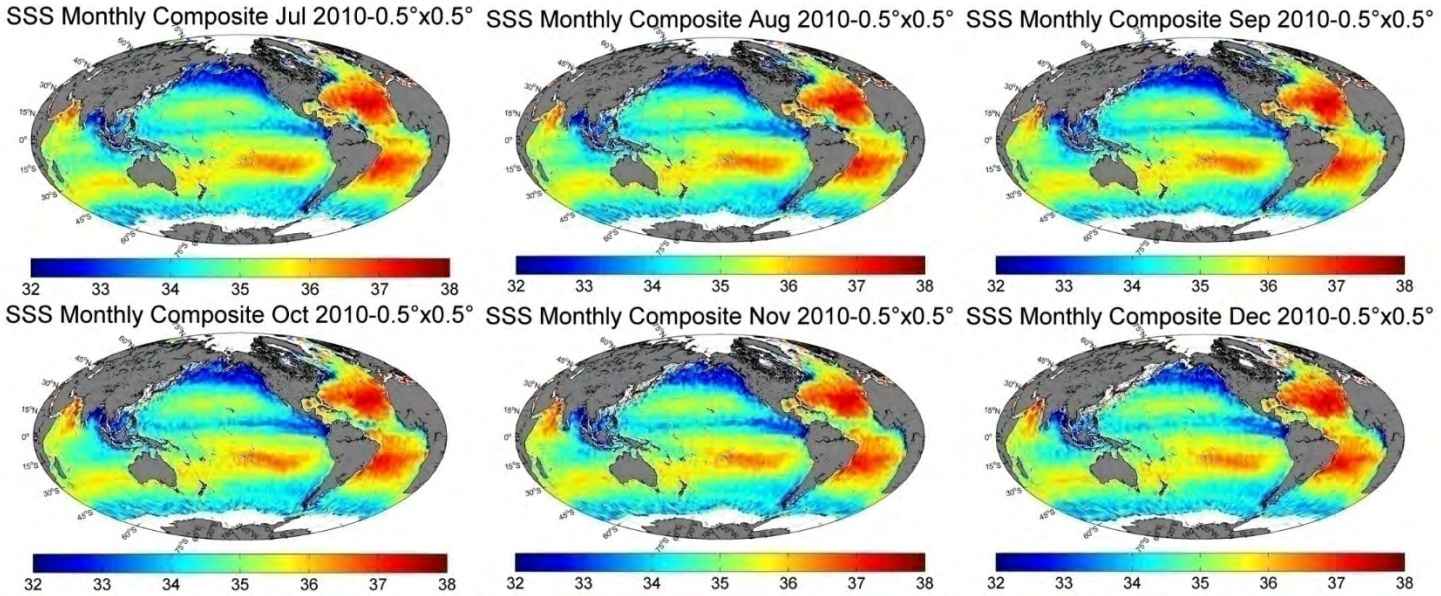
Sea State



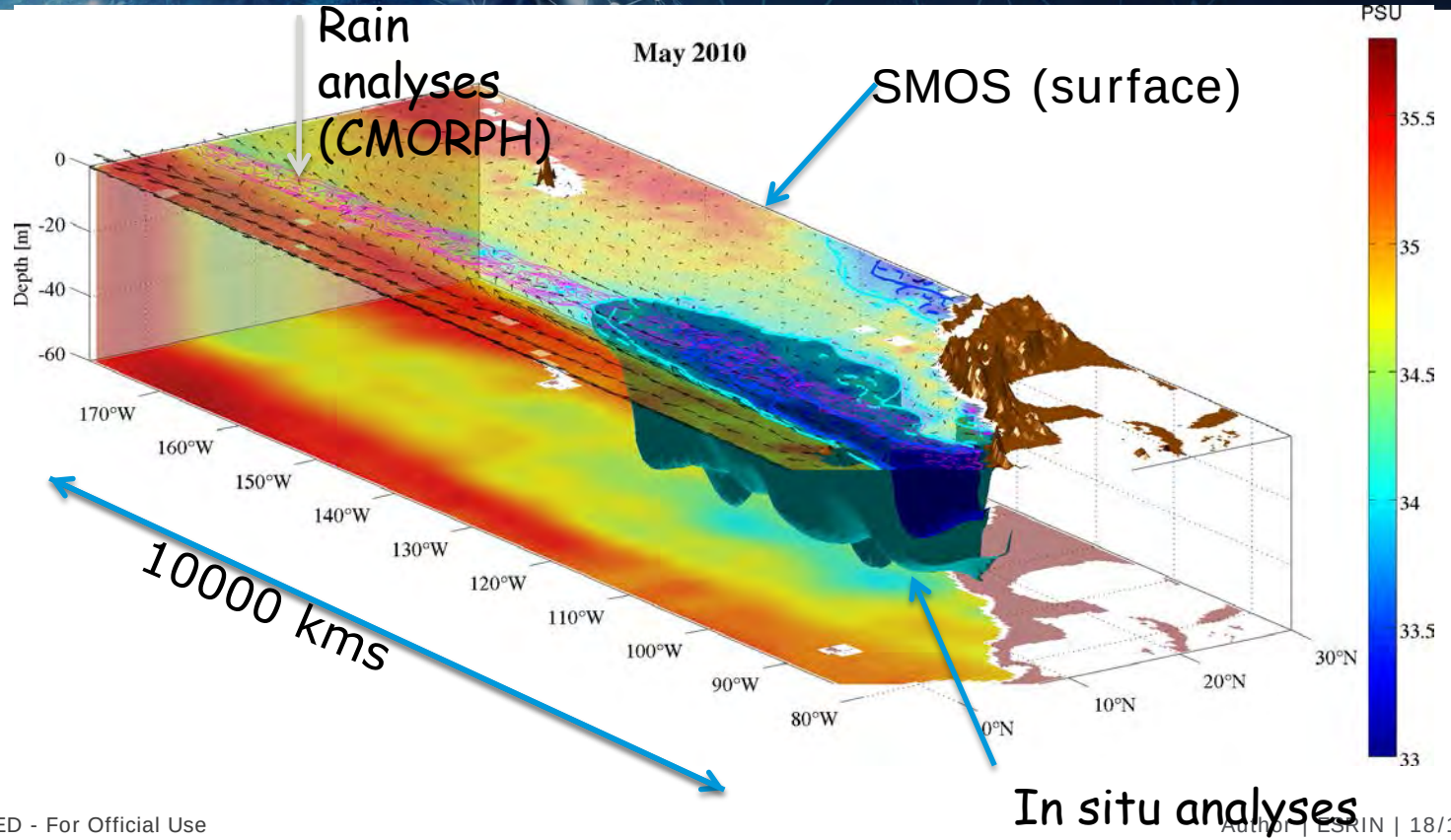
Sea Surface Salinity



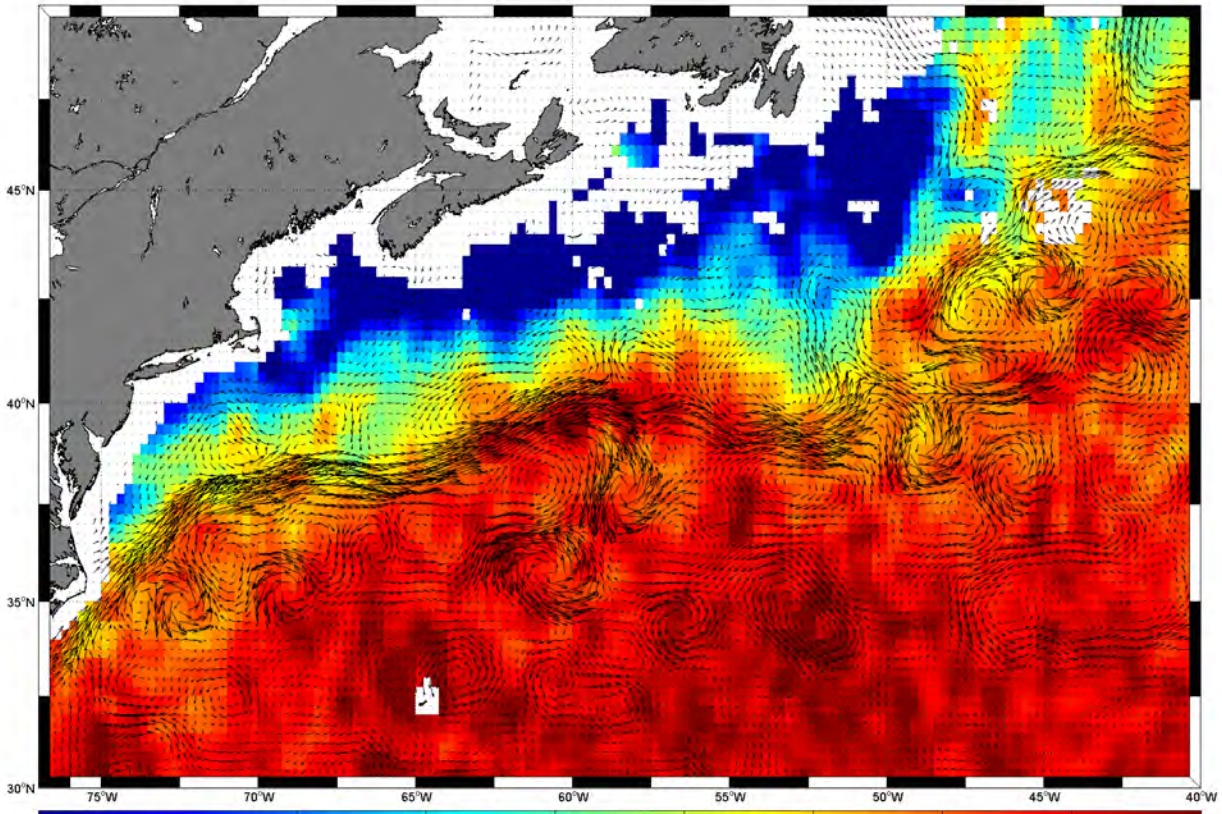

SSS Monthly Composite Jan 2010-0.5°x0.5°
SSS Monthly Composite Feb 2010-0.5°x0.5°
SSS Monthly Composite Mar 2010-0.5°x0.5°
SSS Monthly Composite Apr 2010-0.5°x0.5°
SSS Monthly Composite May 2010-0.5°x0.5°
SSS Monthly Composite Jun 2010-0.5°x0.5°
32 33 34 35 36 37 38

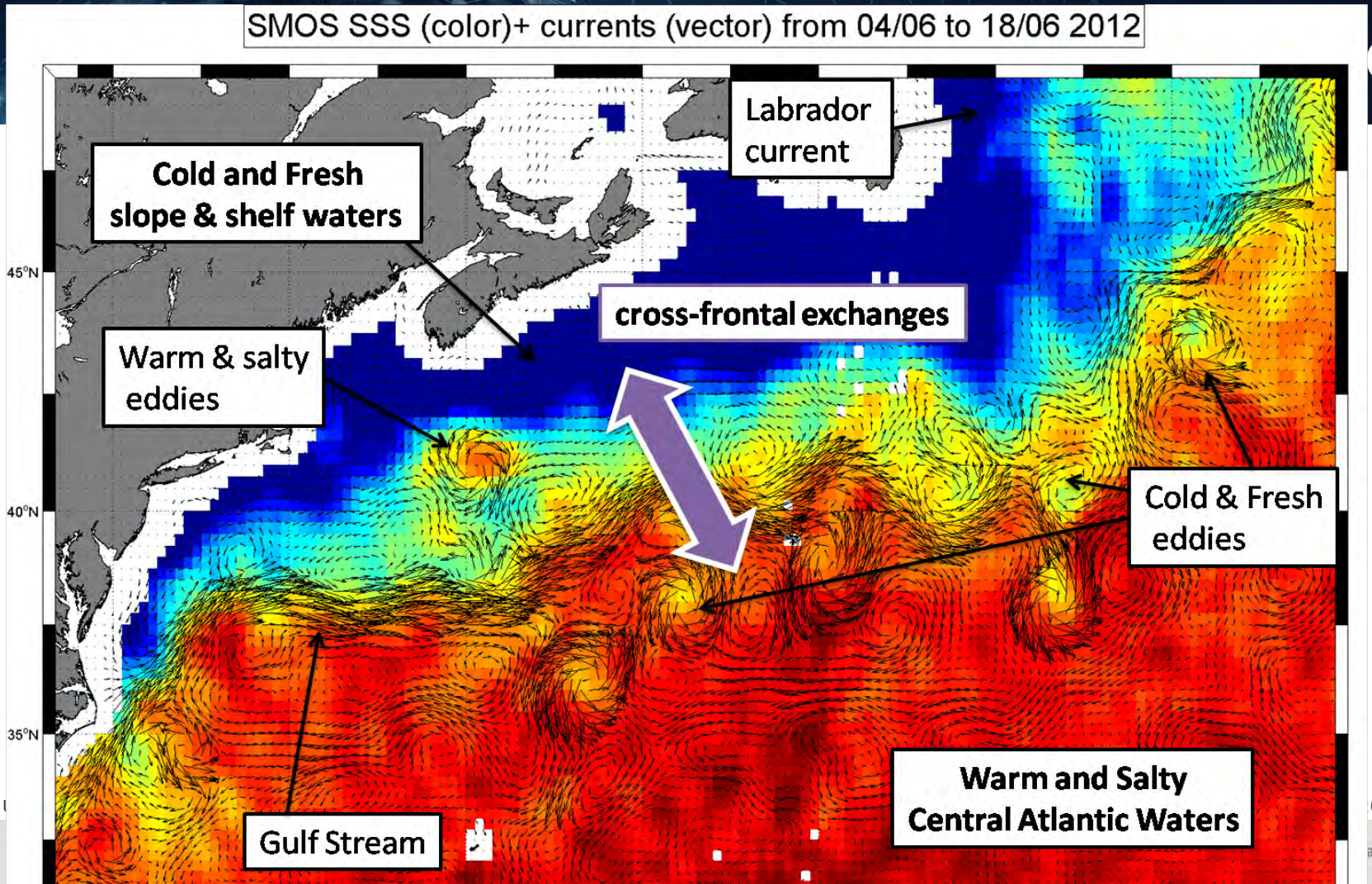

SSS Monthly Composite Jul 2010-0.5°x0.5°
SSS Monthly Composite Aug 2010-0.5°x0.5°
SSS Monthly Composite Sep 2010-0.5°x0.5°
SSS Monthly Composite Oct 2010-0.5°x0.5°
SSS Monthly Composite Nov 2010-0.5°x0.5°
SSS Monthly Composite Dec 2010-0.5°x0.5°
32 33 34 35 36 37 38

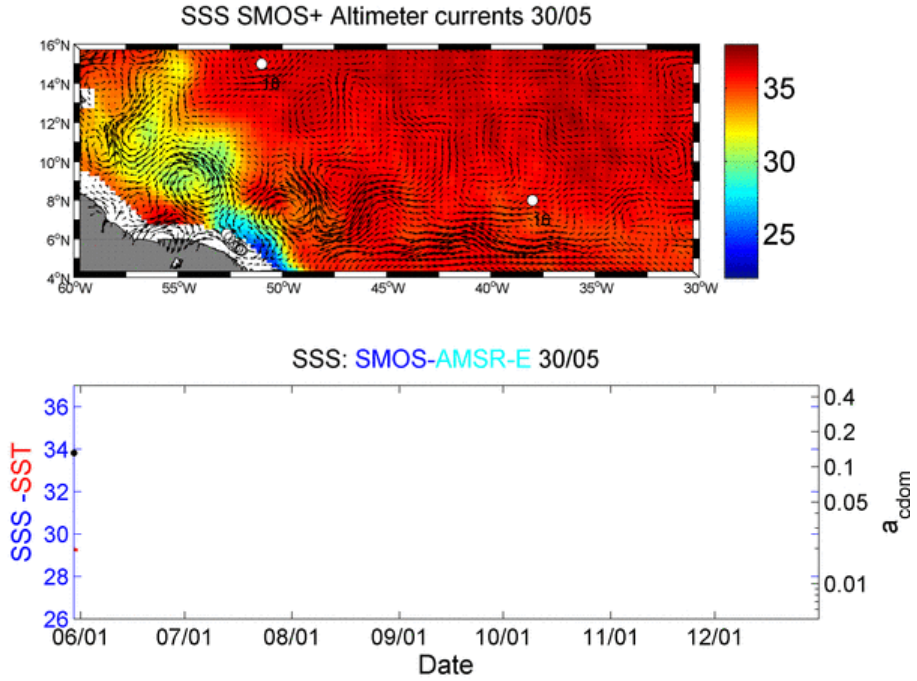
Eastern Pacific Freshpool & 3D monitoring of the pool



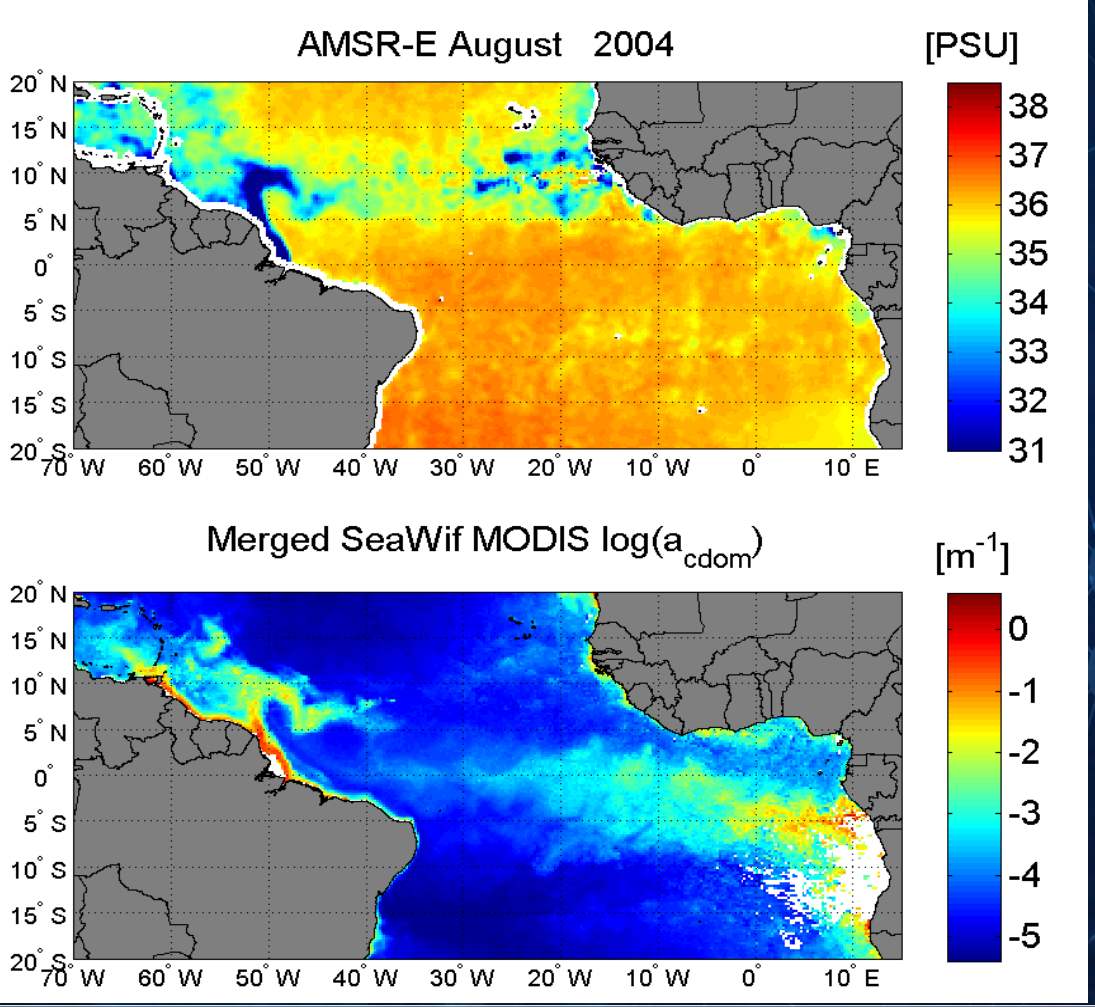
SMOS SSS (color)+ currents (vector) from 03/03 to 17/03 2012



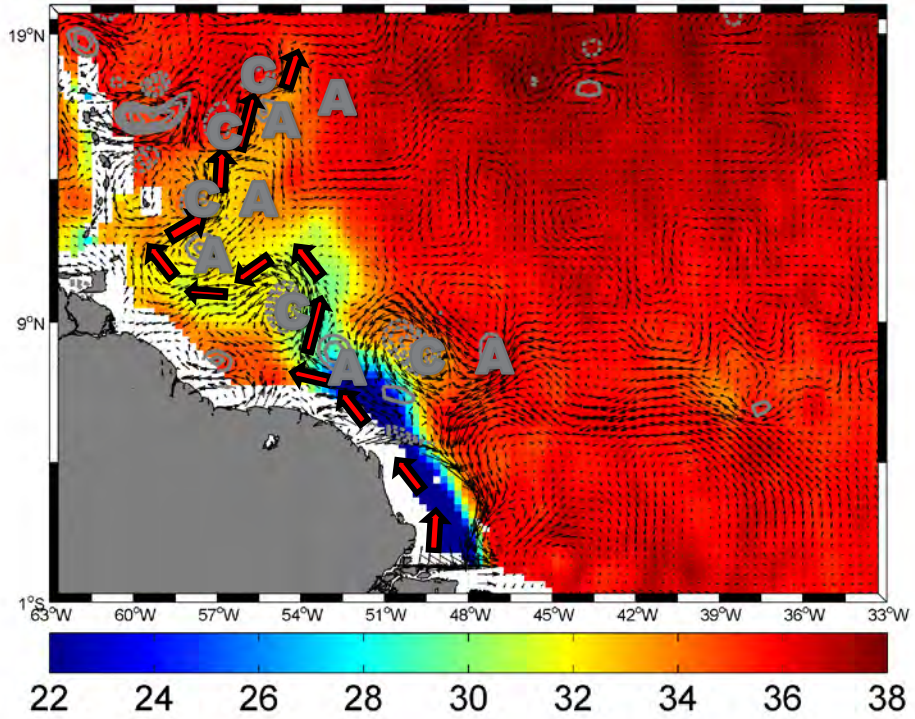

SMOS SSS (color)+ currents (vector) from 04/06 to 18/06 2012
Labrador current
Cold and Fresh slope & shelf waters
45°N
cross-frontal exchanges
Warm & salty eddies
40°N
Cold & Fresh eddies
35°N
Warm and Salty Central Atlantic Waters
Gulf Stream



Lagrangian Optical-Physical properties



SSS Averaged from Jun 04 through Jun 14



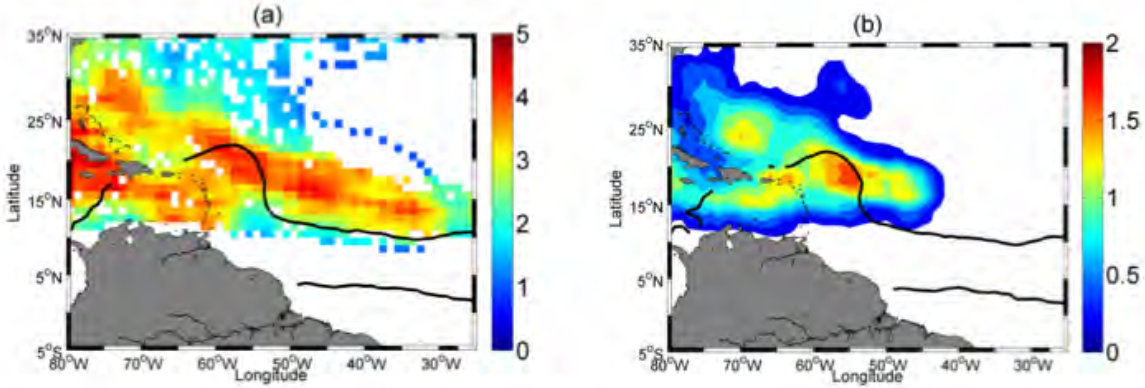
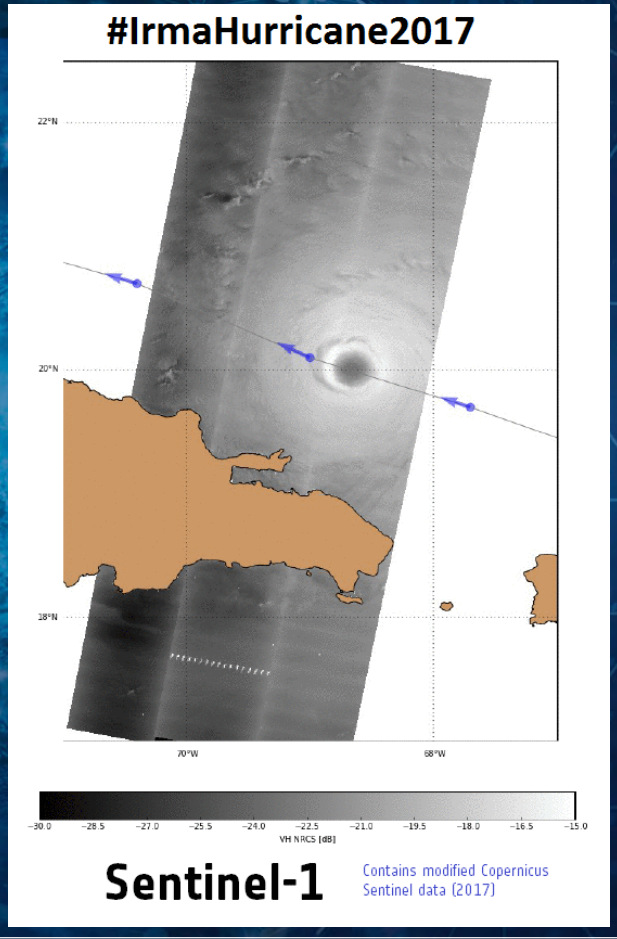


FIG.2 The number of 1950 through 2010 "best track" TC per one degree square (smoothed by a 3° x 3° block average) (a) that evolves as Cat 4-5 somewhere along their path and (b) that intensified locally to Cat 4-5. The black curve is showing the historical extent of the Amazon-Orinoco river plume during the hurricane peak season (August to October).



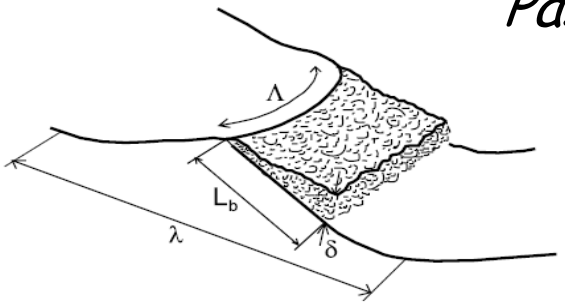
Upper ocean responses to extreme wind forcing by tropical cyclones remains a central problem in physical oceanography

Parameterization of wind forcing at high-wind speeds is still a matter of debate and active research

To accurately model air-sea coupled processes, it is of central importance to quantify how efficiently surface winds and waves, within storm cores, increase the momentum of surface currents

Energy transfer to upper currents mostly occurs in front of the extremes and is nearly balance with the increase in kinetic energy of the upper ocean currents

Passive measurements

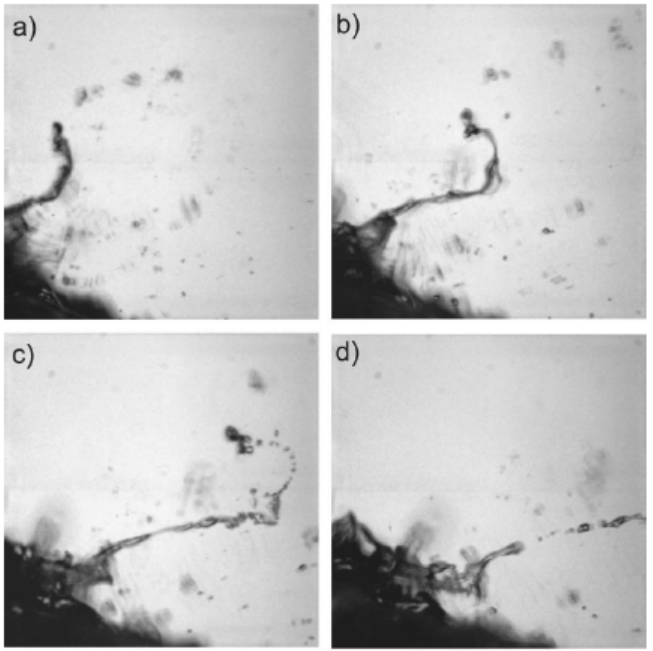


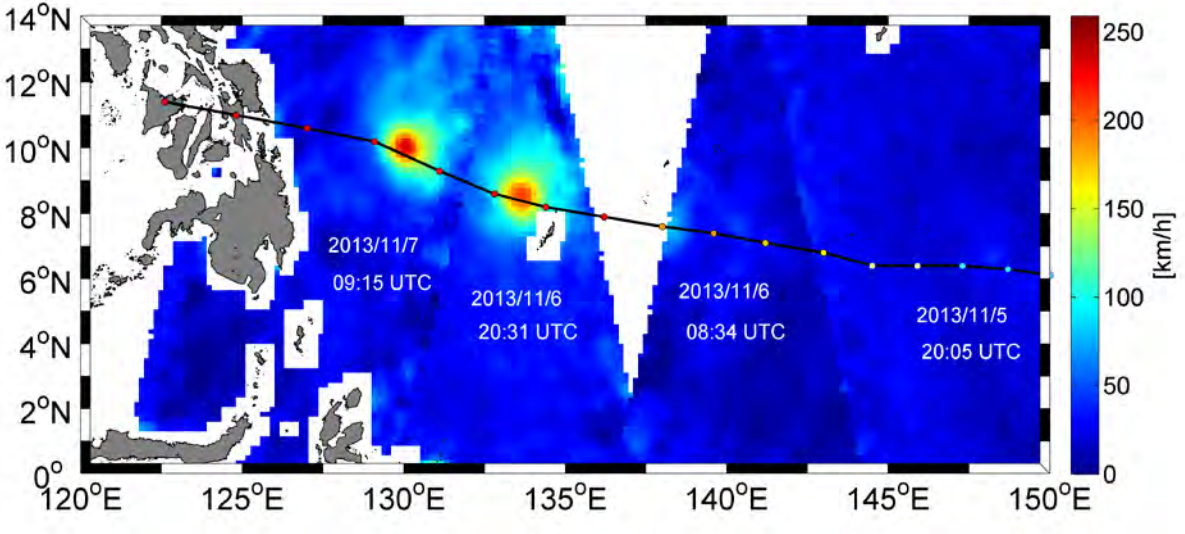
Semi-empirical model (Reul and Chapron, 2003)

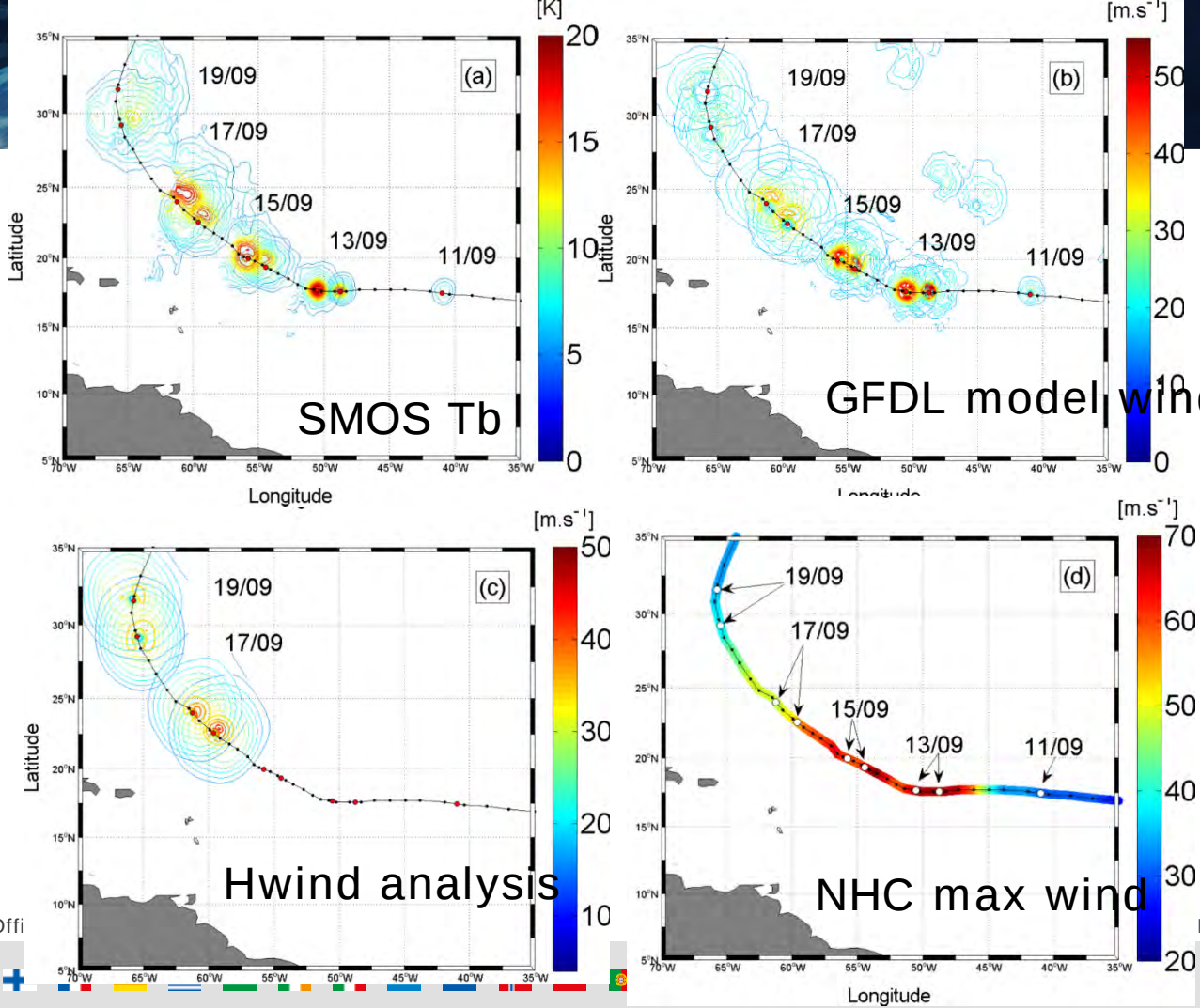
-Self-similar breaker-scale distribution

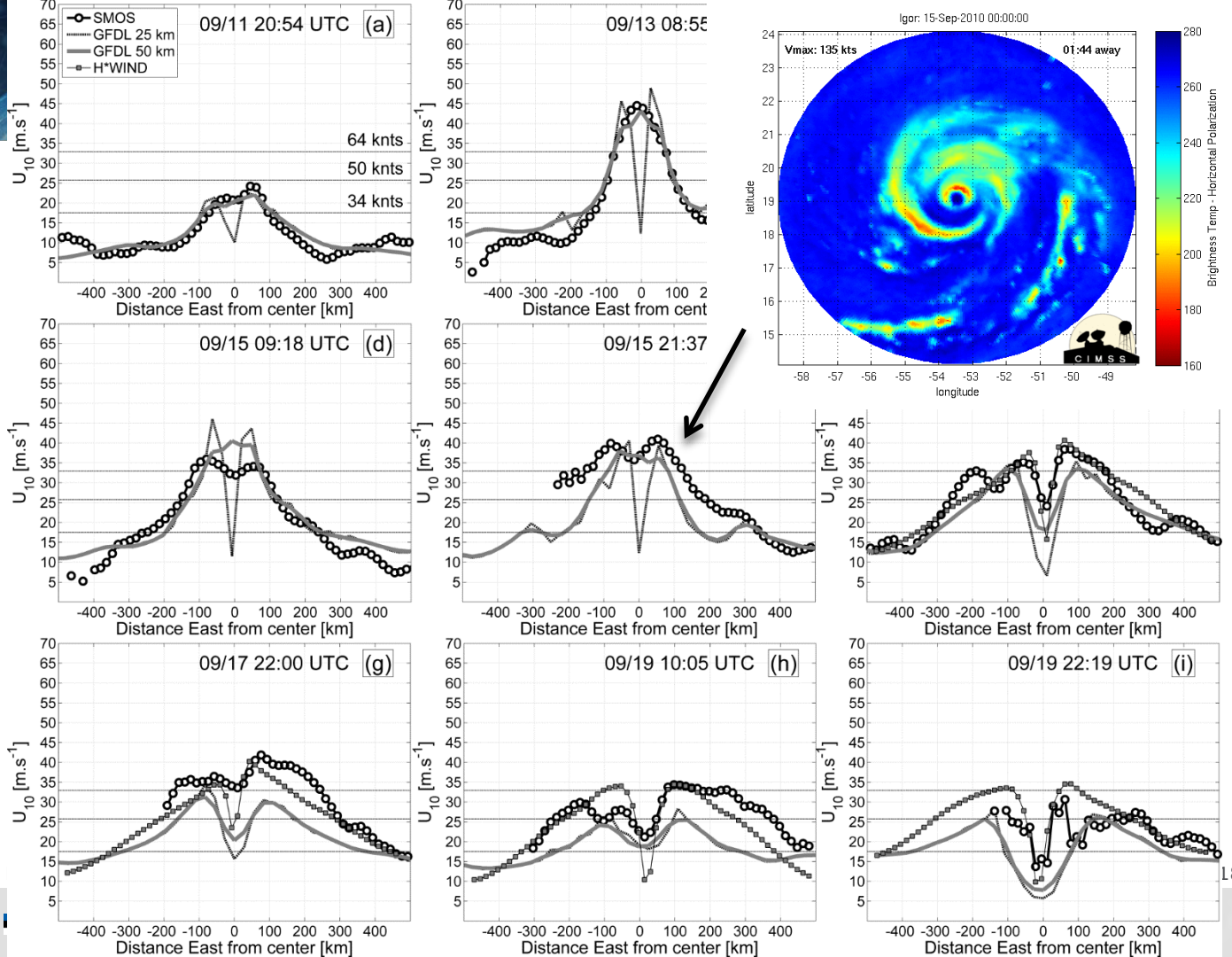
-Foam coverage and thickness → wavelength sensitivity

At some wind exceeding a threshold level, Kelvin – Helmholtz instability emerges, which disrupt short-scale waves and breaking crests roughness

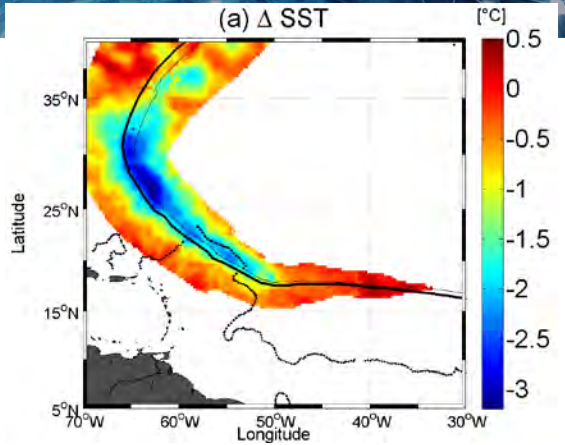


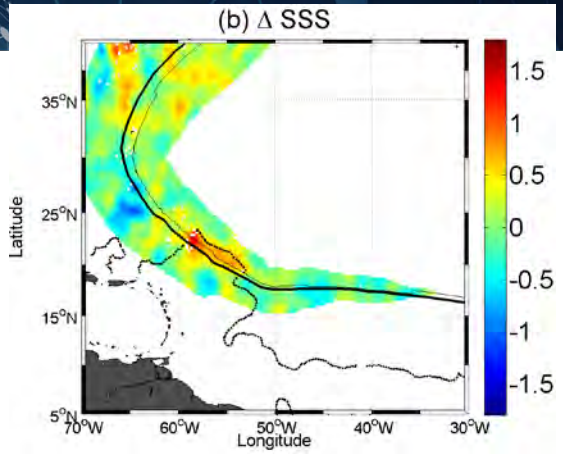

14°N
12°N
10°N
8°N
6°N
4°N
2°N
0°
120°E
125°E
130°E
135°E
140°E
145°E
150°E
2013/11/7
09:15 UTC
2013/11/6
20:31 UTC
2013/11/6
08:34 UTC
2013/11/5
20:05 UTC
250
200
150
100
50
0
[km/h]

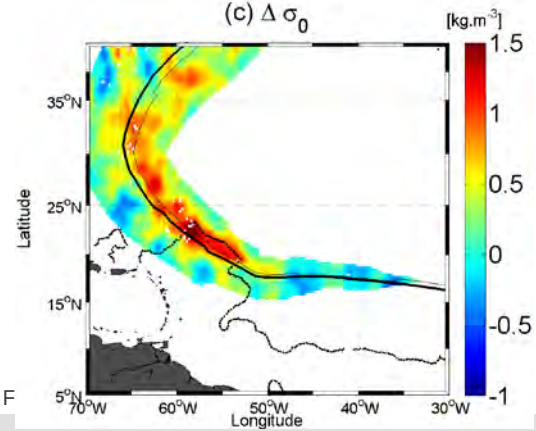

[K]
19/09
17/09
15/09
13/09
11/09
(a)
SMOS Tb
Latitude
Longitude
[m.s-1]
(b)
GFDL model wind
(c)
Hwind analysis
(d)
NHC max wind

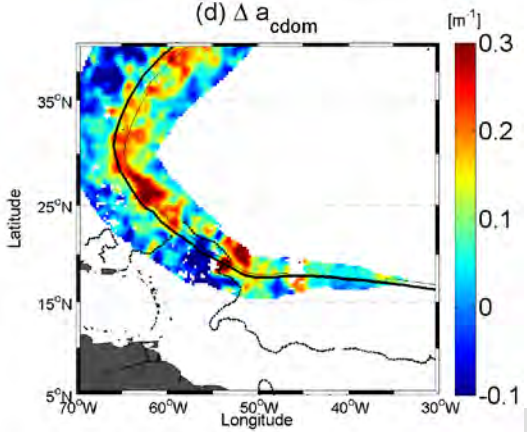


Surface wakes of Igor









Six days of data centered on t_0– (+) 4 days have been averaged to construct the pre (post)-cyclonic quantities.

Surface area~ 89000 km^2> Lake Superior, the world largest freshwater lake: a transfer of 1 GTo of Salt in 5 days

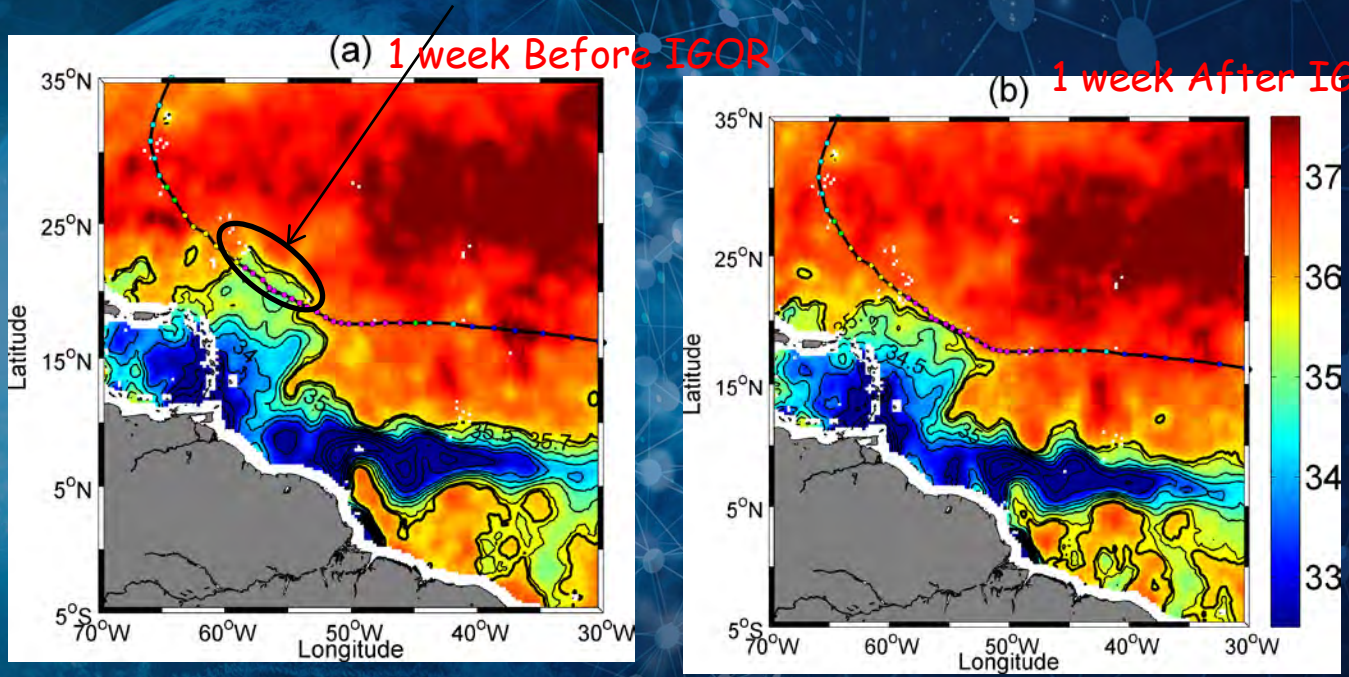
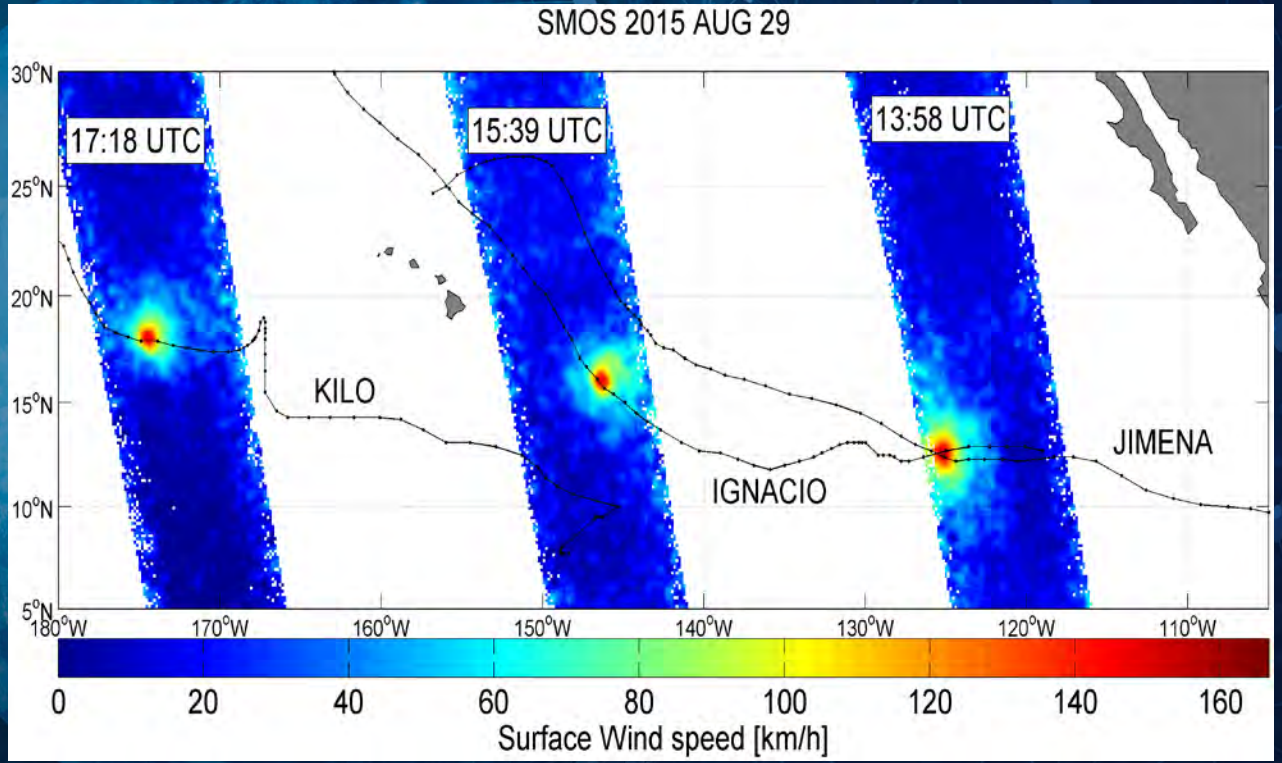
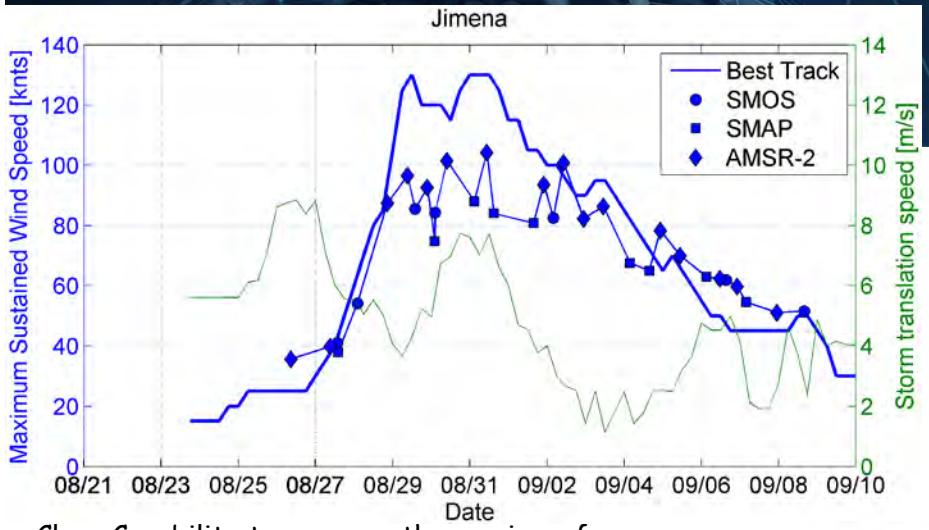
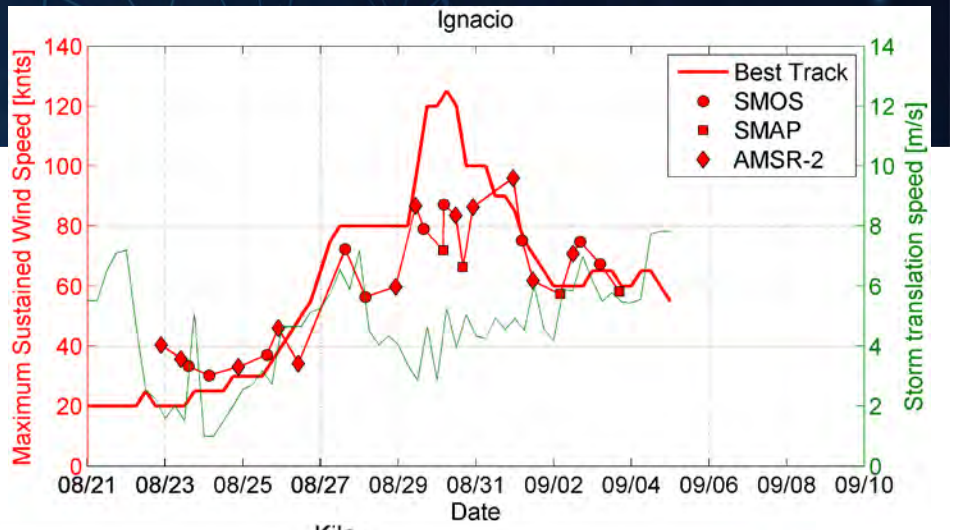


Figure 2: Two SMOS microwave satellite-derived SSS composite images of the Amazon plume region revealing the SSS conditions (a) before and (b) after the passing of Hurricane Igor, a category 5 hurricane that attained wind speeds of 136 knots in September 2010. Color-coded circles mark the successive hurricane eye positions and maximum 1-min sustained wind speed values in knots. Seven days of data centered on (a) 10 Sep 2010 and (b) 22 Sep 2010 have been averaged to construct the SSS images, which are smoothed by a 1° x 1° block average.

Signatures of 3 co-evolving 2015 major Hurricanes from 22 Aug to 9 Sep in the East and Central tropical Pacific as seen from SMOS, SMAP and AMSR-2 observations (beyond others)



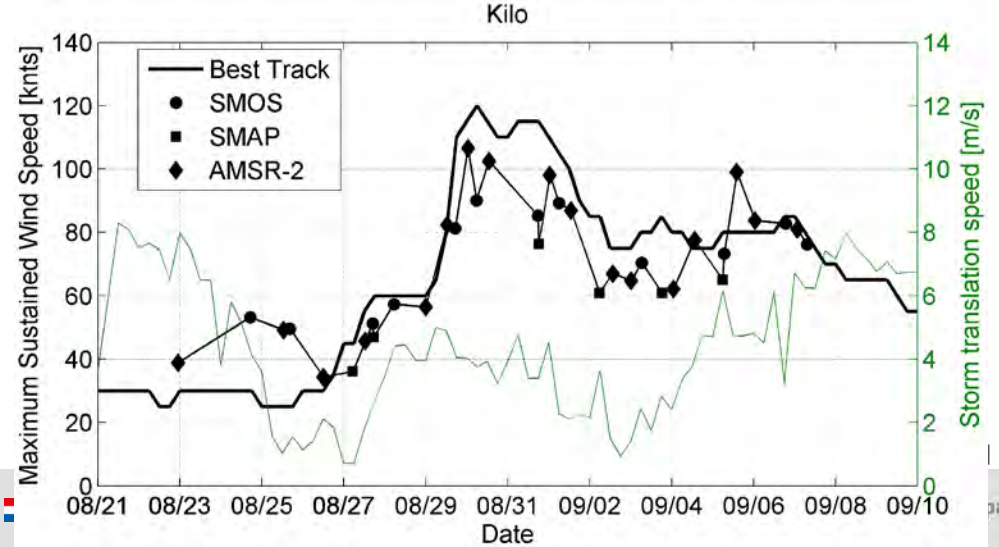


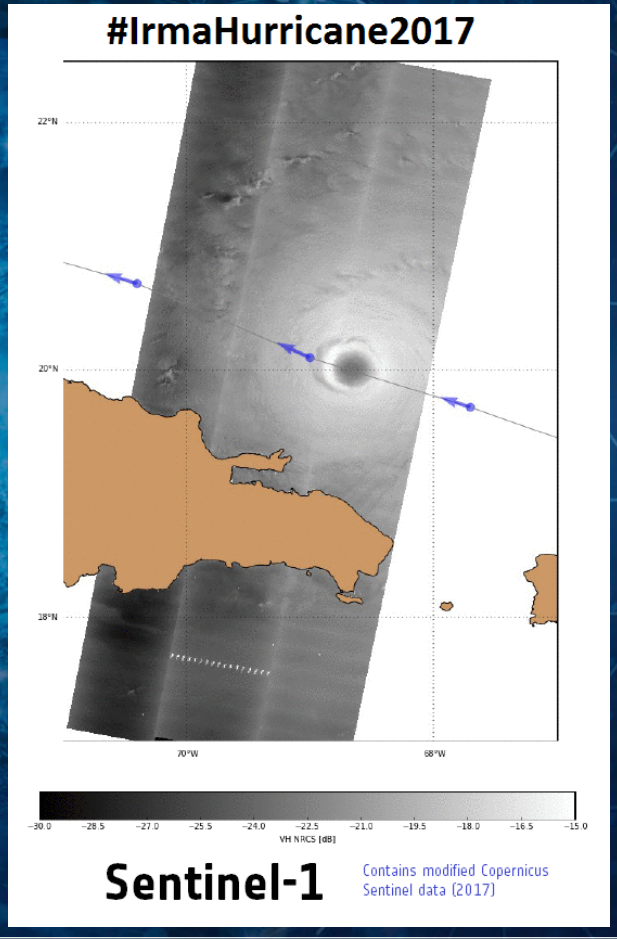


Clear Capability to measure the maxima of Surface winds up to 90 knots (=up to Category 2) .

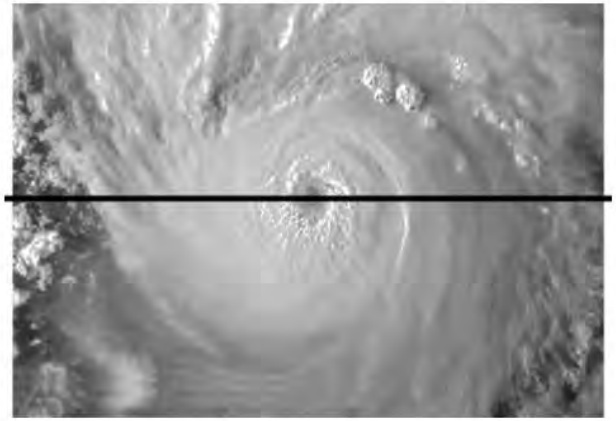
Consistent estimate from the three sensors
Regular and frequent temporal coverage thanks to the combination of their data.

Limitations in the highest wind domains
Is not due to Tb saturation
But to the 30-40 km spatial resolution
Smoothing effect (Highest-wind generally occur in a narrow region of radius < ~100km around the eyes with very high Wind speed radial gradients)

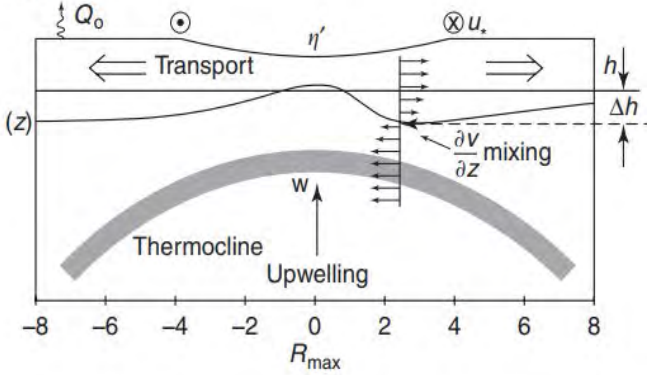




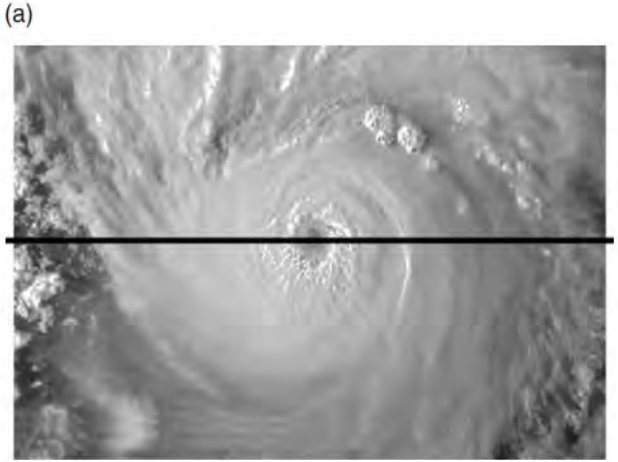
(a)

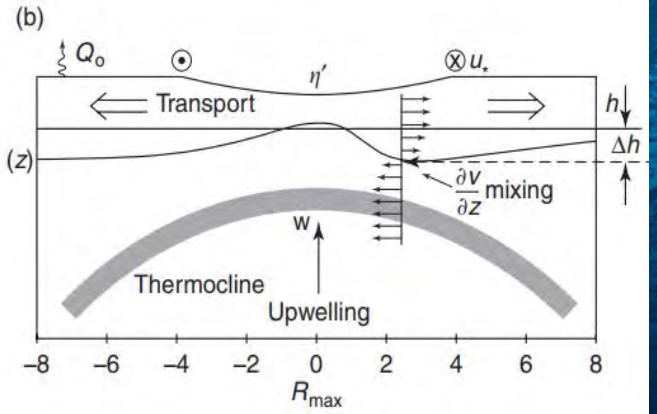


(b)

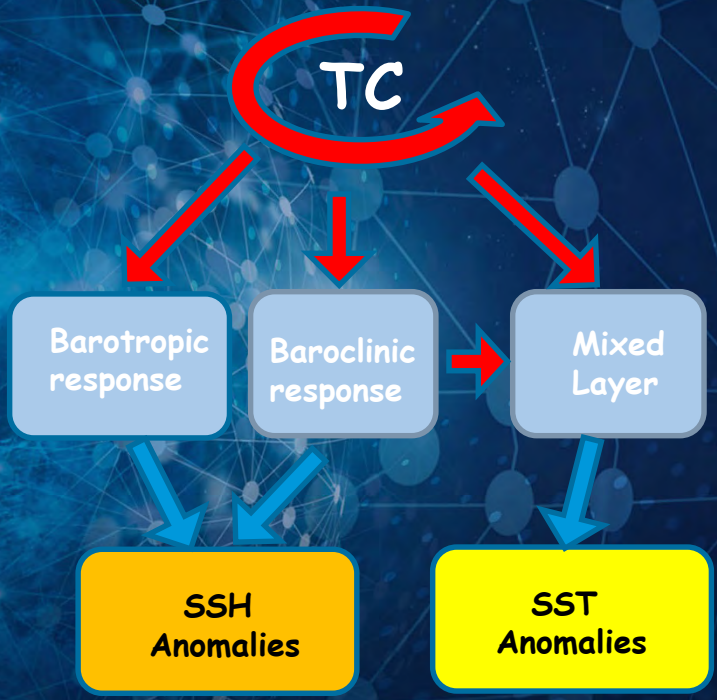


Far from the coasts, Extreme Events are opportunities of high scientific values to investigate how natural processes at their peaks can transfer energy and matter within and across boundaries, and to identify the mechanisms involved and their rates, jointly with their local and/or long term impacts

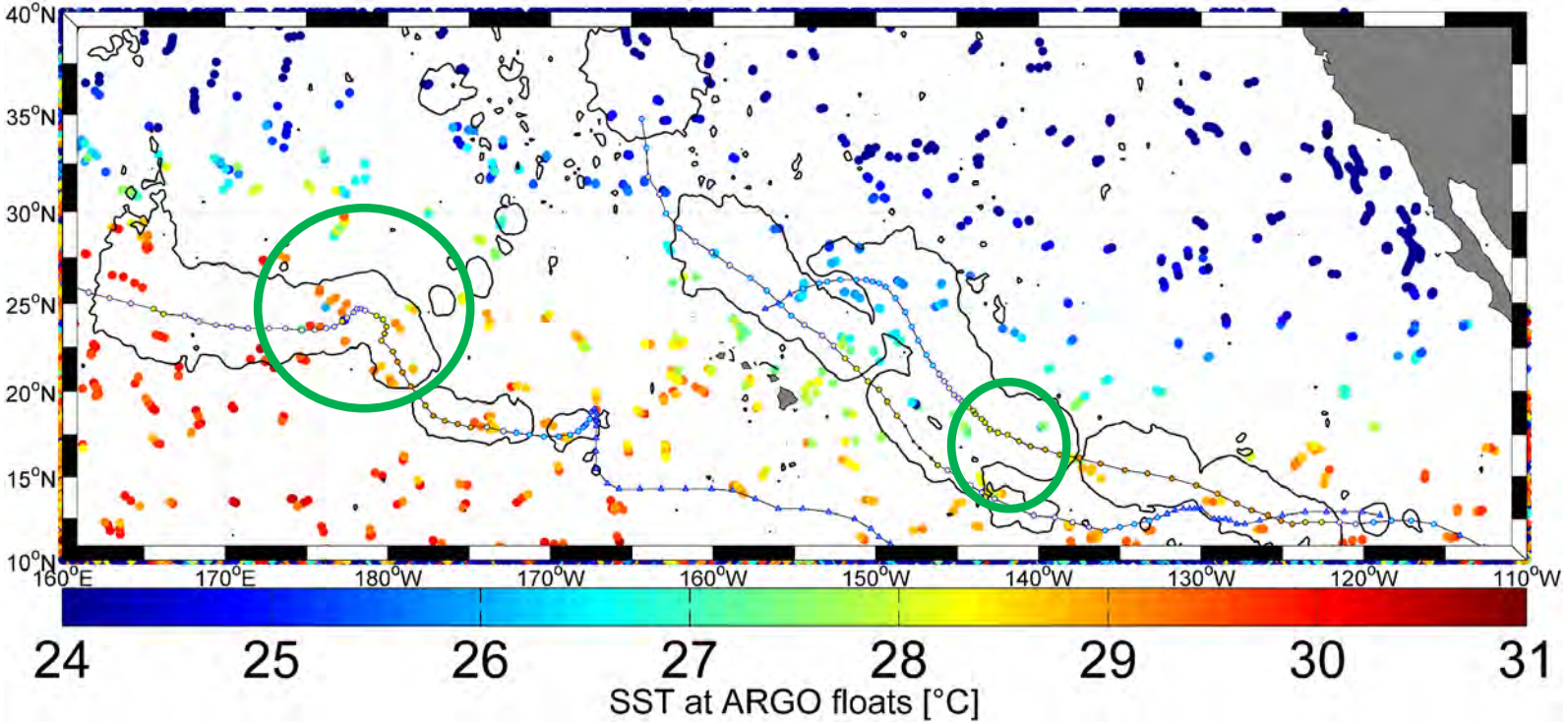


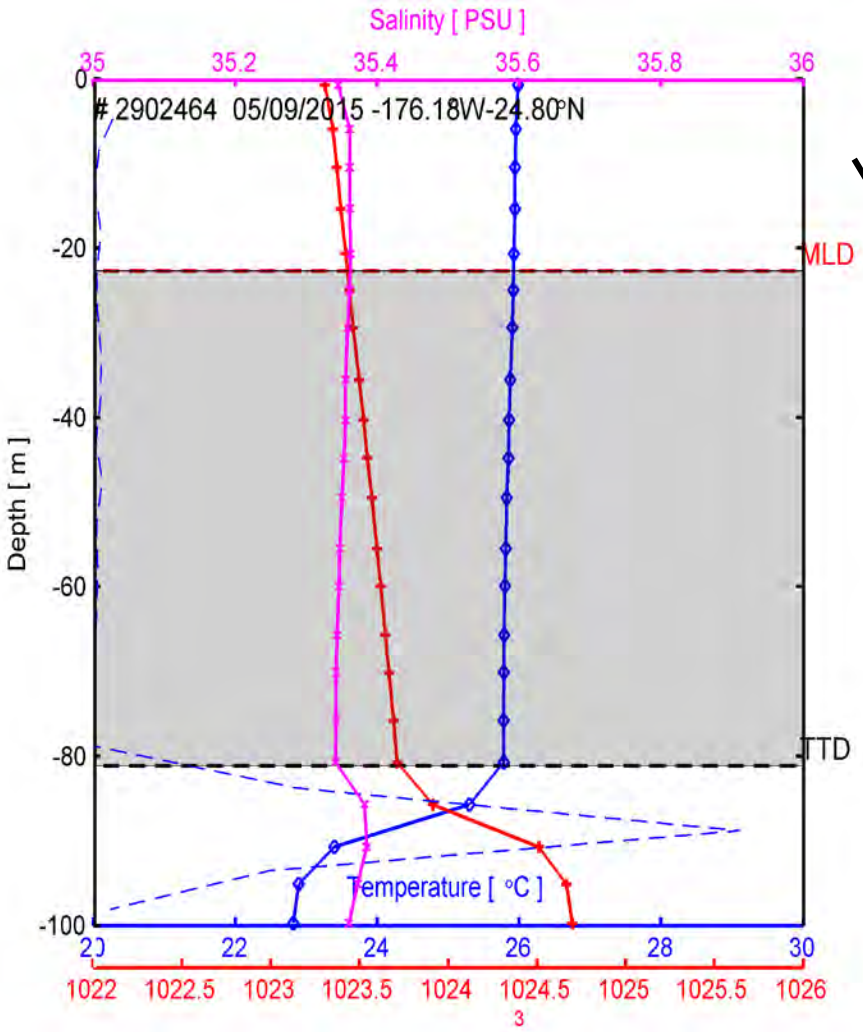


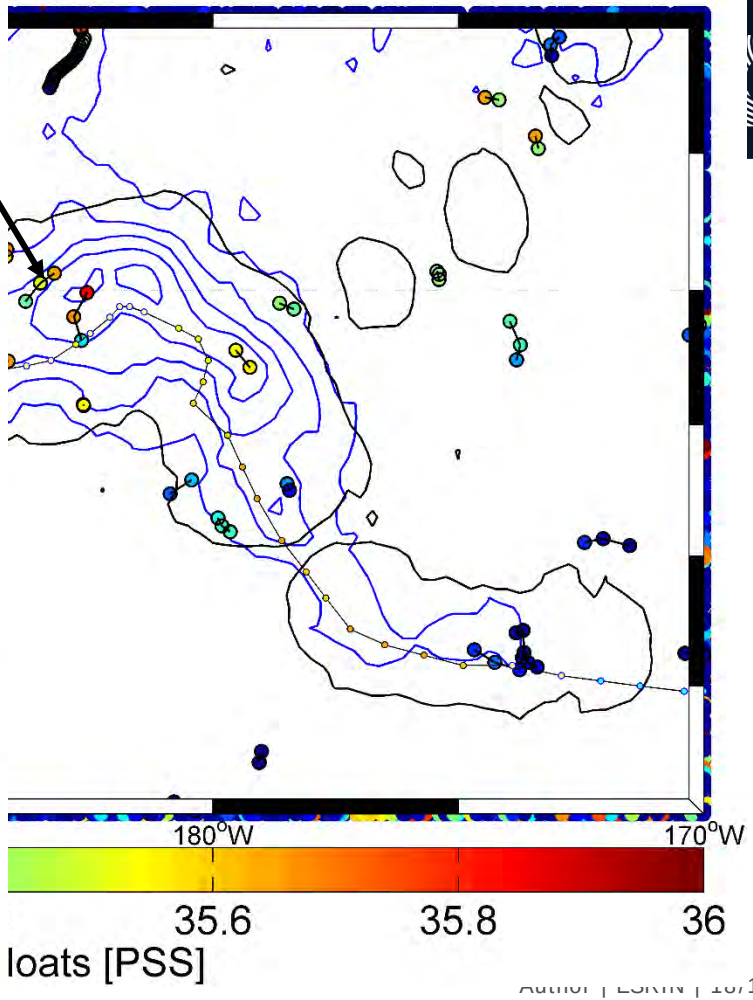
Simplified TC Wake Model



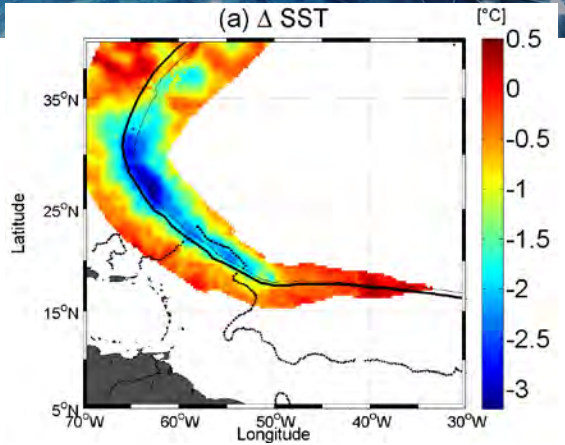
ARGO Floats

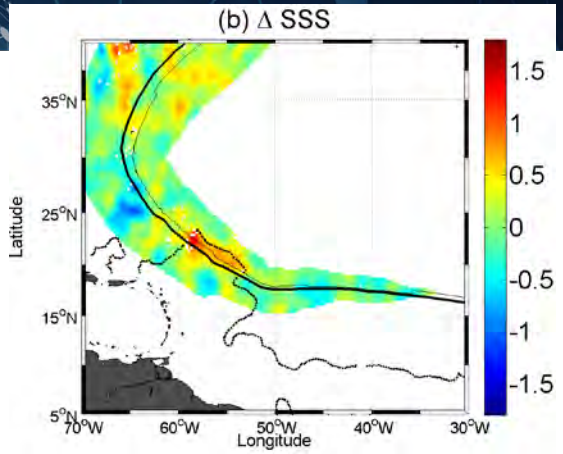

40°N
35°N
30°N
25°N
20°N
15°N
10°N
160°E
170°E
180°W
170°W
160°W
150°W
140°W
130°W
120°W
110°W
24
25
26
27
28
29
30
31
SST at ARGO floats [°C]

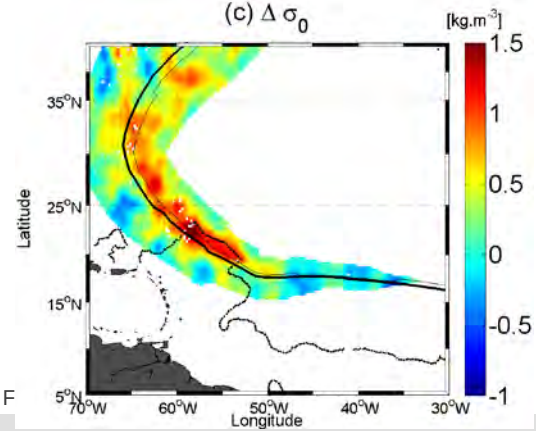

Salinity [PSU]
35
35.2
35.4
35.6
35.8
36
2902464 05/09/2015 -176.18W-24.80°N
MLD
TTD
Depth [m]
0
-20
-40
-60
-80
-100
Temperature [°C]
20
22
24
26
28
30
1022
1022.5
1023
1023.5
1024
1024.5
1025
1025.5
1026
3

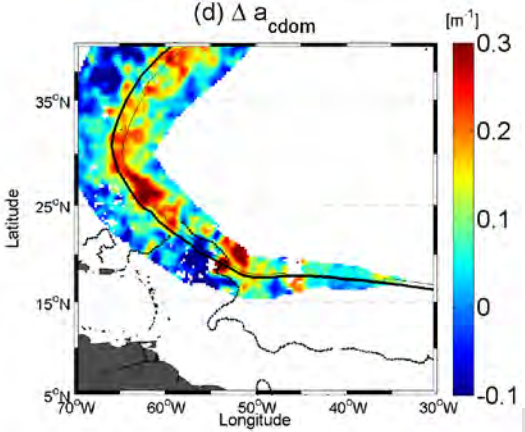

180°W
170°W
35.6
35.8
36
loats [PSS]

Surface wakes of Igor



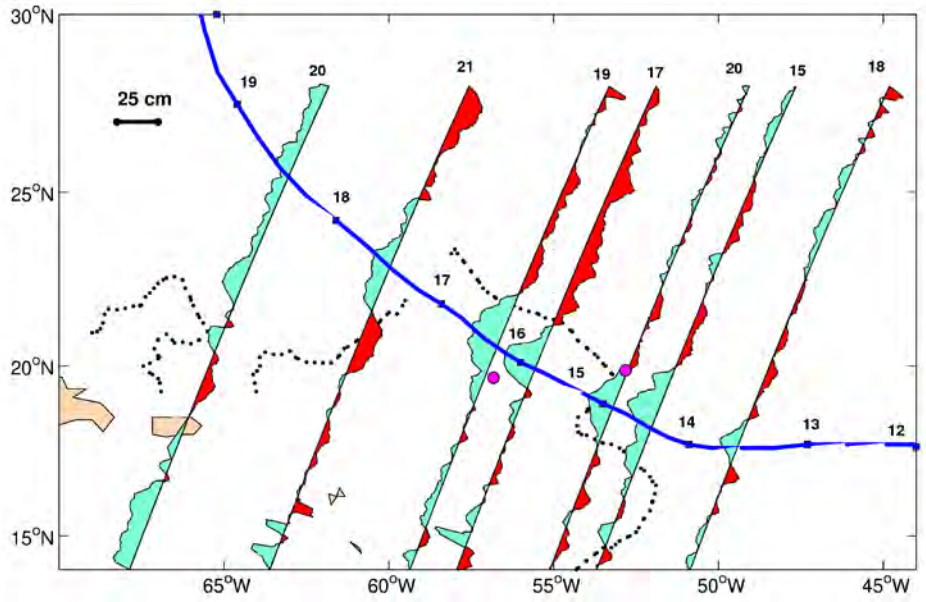




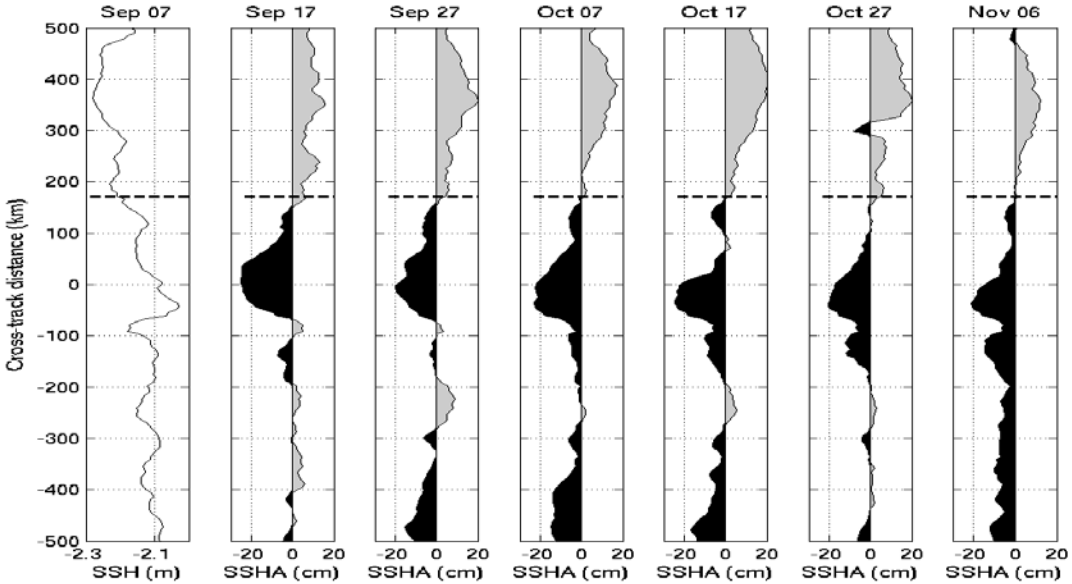


Six days of data centered on t_0– (+) 4 days have been averaged to construct the pre (post)-cyclonic quantities.

Surface SSH wakes of Igor

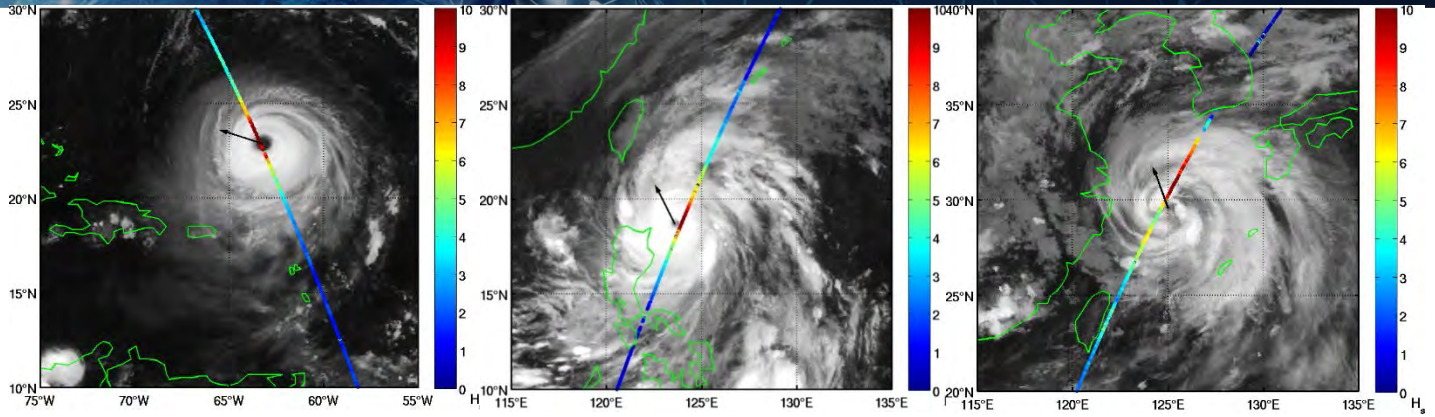


Surface SSH wake and persistency of Igor



Examples: IR images with overlapped altimeter tracks

Isabel (2003) Songda (2011) Muifa (2011)



Altimeter Significant Wave heights