Routine Doppler analysis from Envisat and Sentinel-1 and first oceanographic applications

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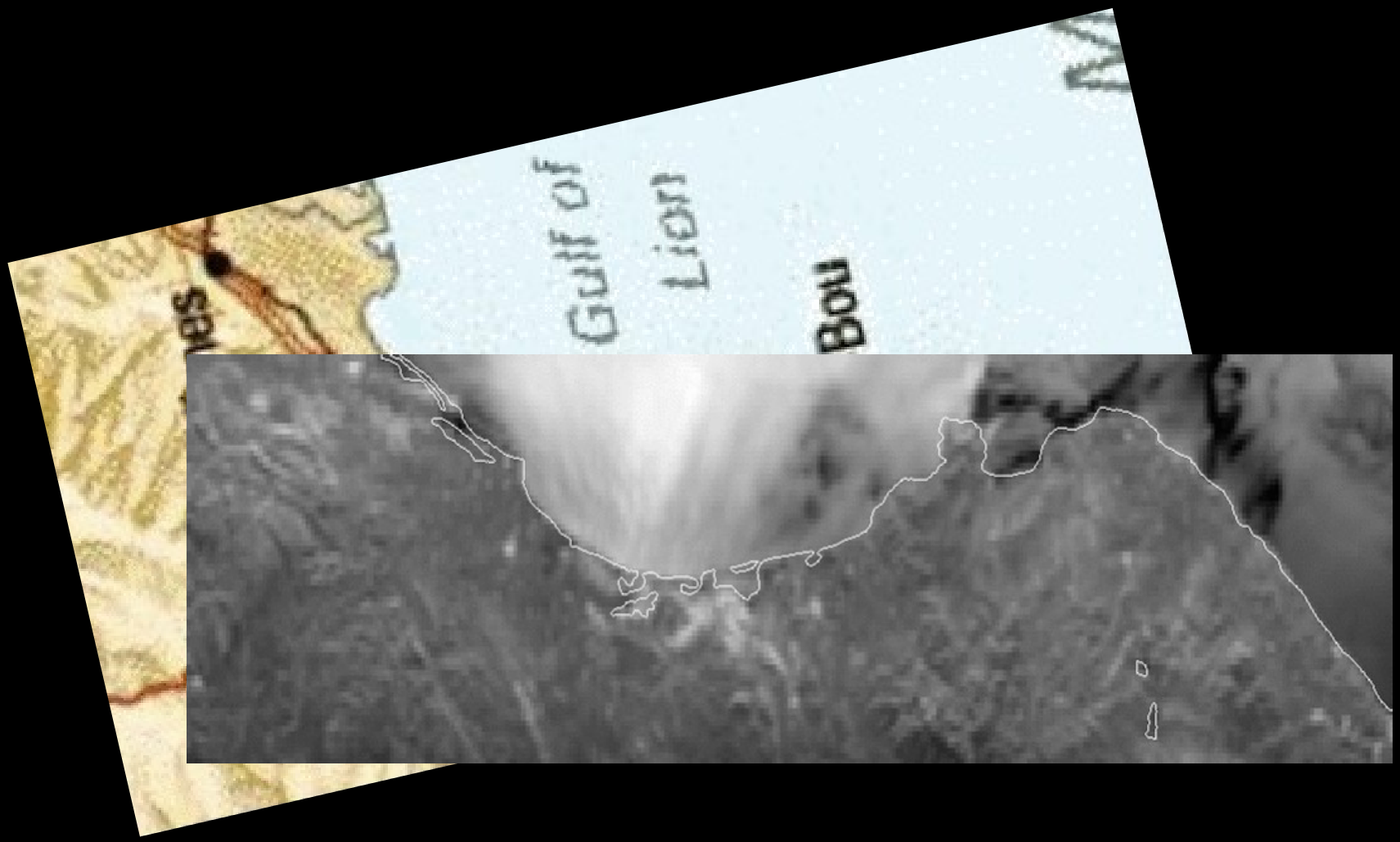
NORUT, Tromso, NORWAY
NERSC, Bergen, NORWAY
CSIR, Cape Town, SOUTH AFRICA

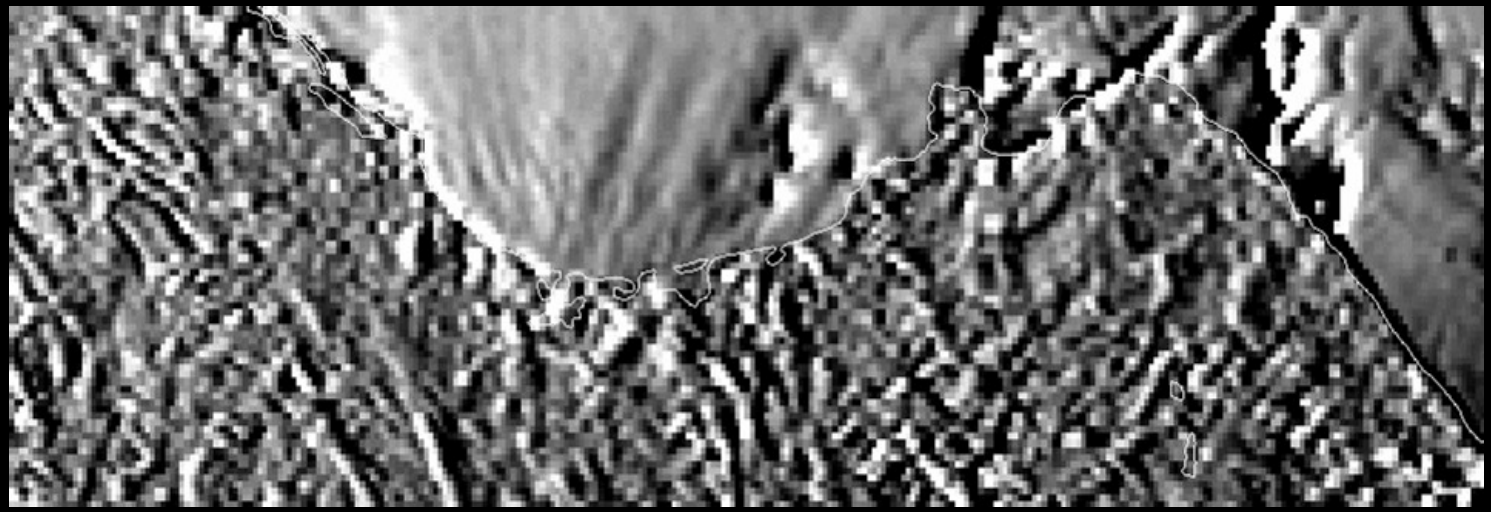
Where it all started !

ERS 2 SLC image doppler centroid analysis
triggered by a doppler-map case study from Andrea Monti-Guarnieri in 2000



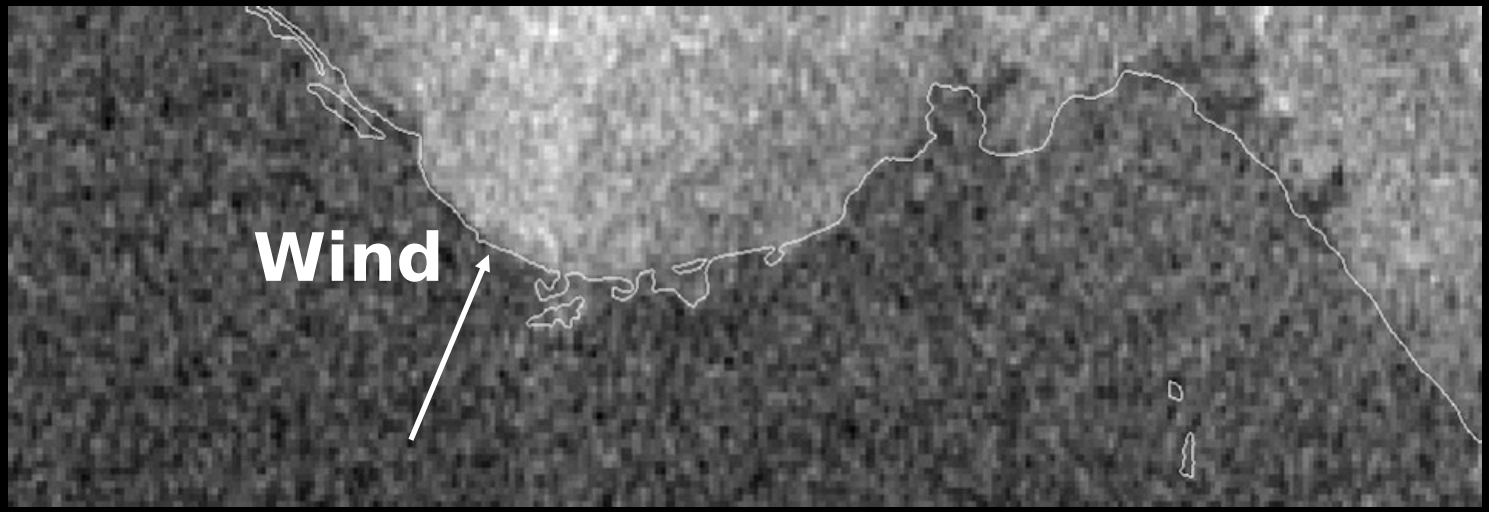
Where it all started !

Doppler estimated on range compressed data



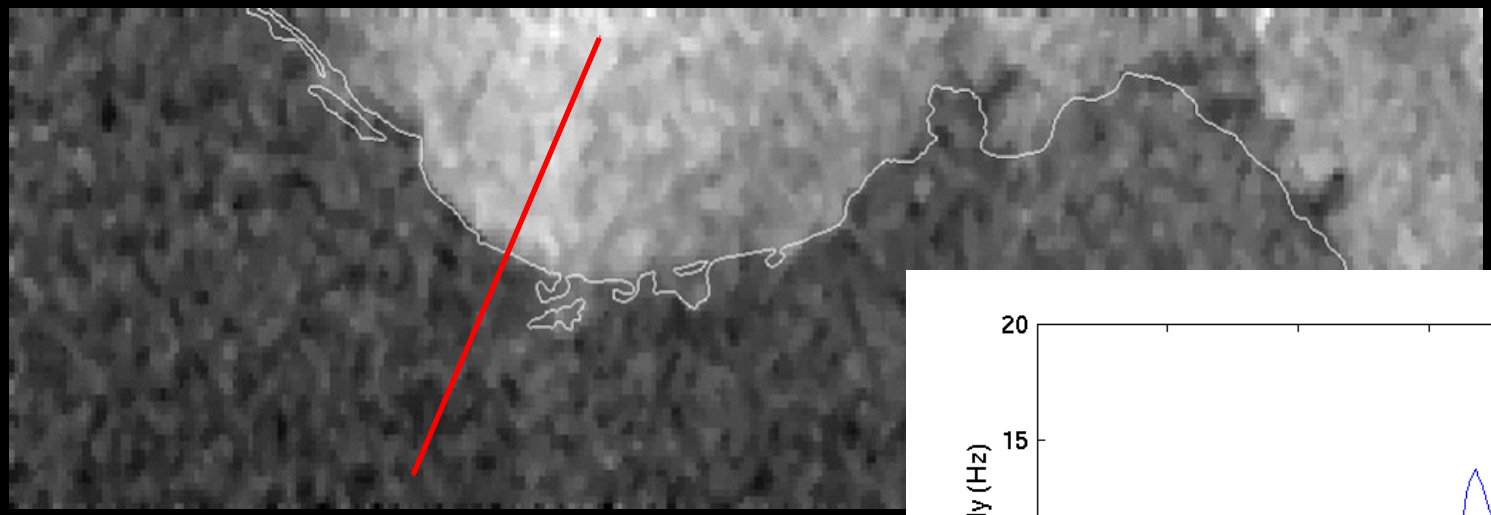
Where it all started !

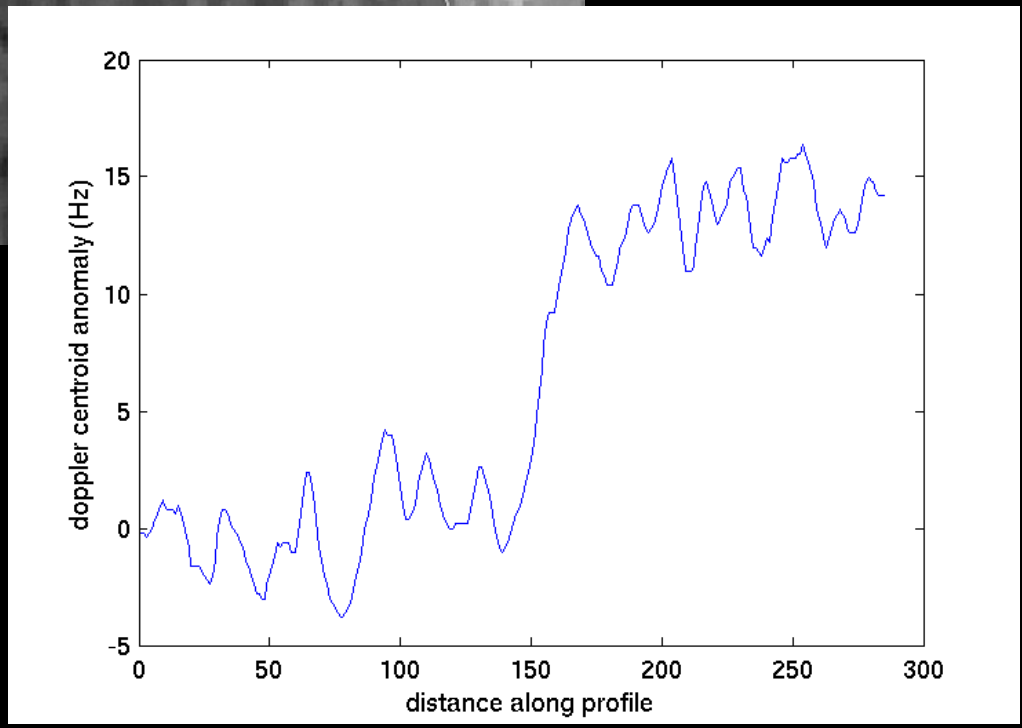
Doppler estimated on range and azimuth compressed data



Where it all started !

Doppler anomaly chart





Lessons from ERS :

SAR Doppler is related to wind

is not fetch dependant (weighting towards short scales)

is more accurately estimated on azimuth compressed data (SLC)

Dec 2002 : ASAR Cal/Val workshop

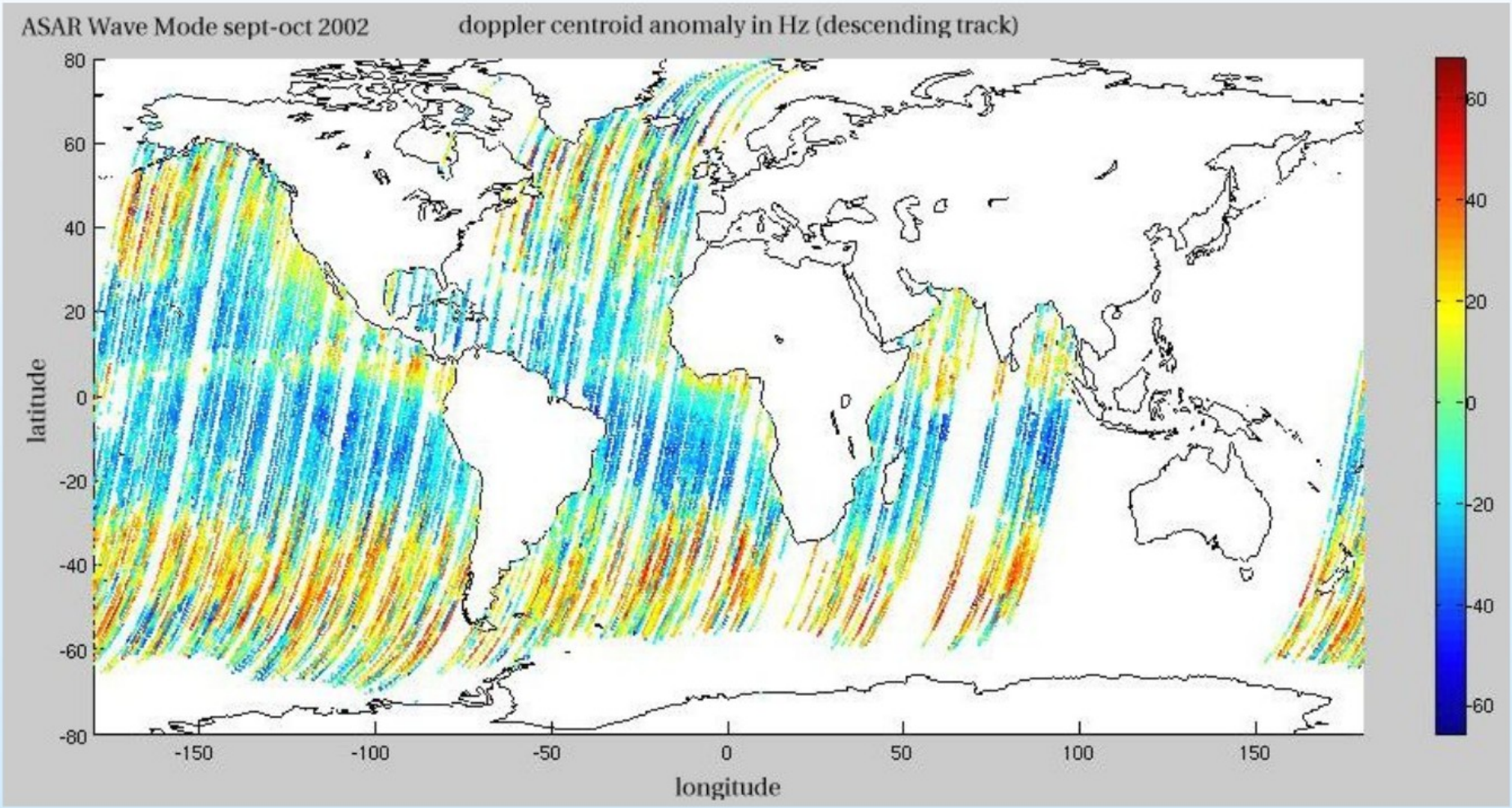
NORUT Informasjonsteknologi as

ifremer

esa

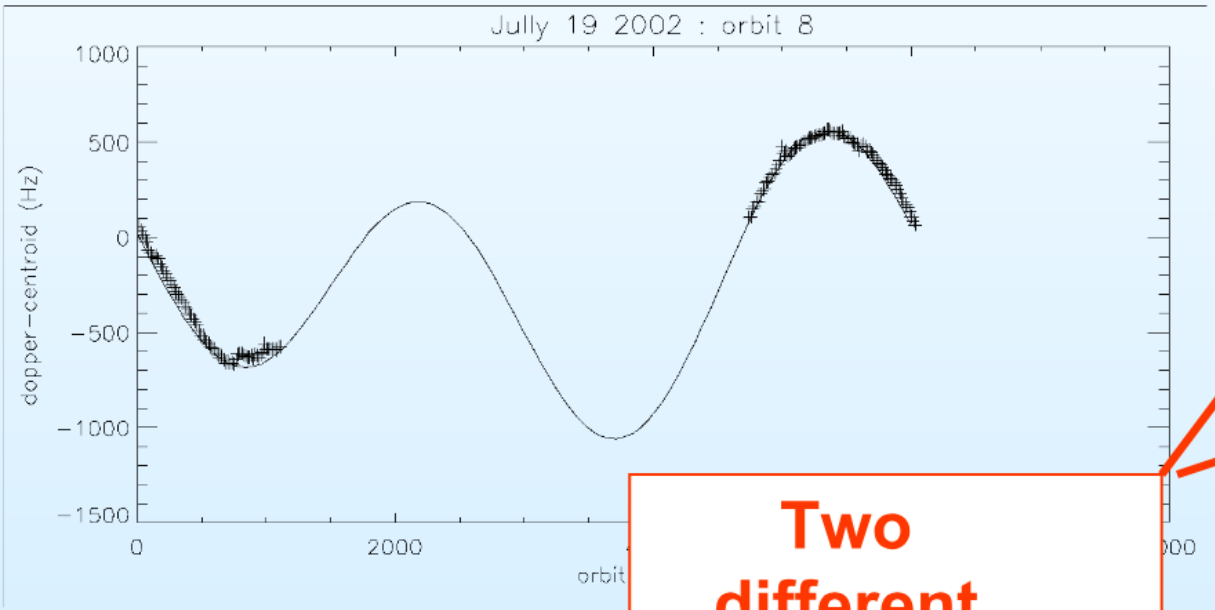
ENVISAT
CARING FOR THE EARTH

Doppler centroid anomaly on Wave mode level1b (descending tracks)

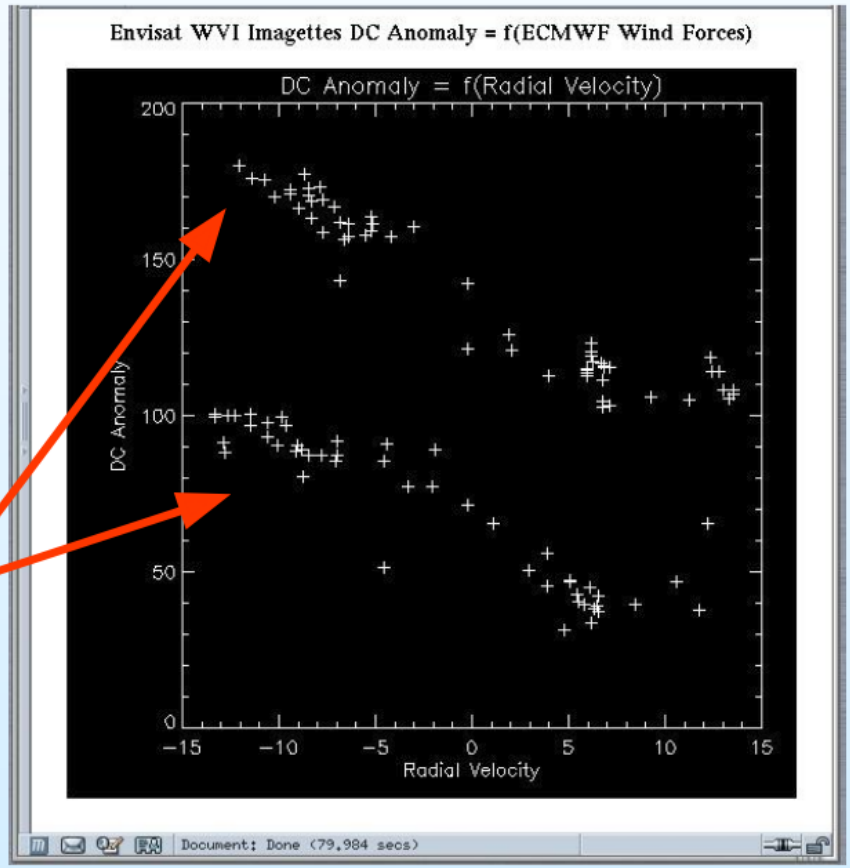


Dec 2002 : ASAR Cal/Val workshop

doppler centroid anomaly



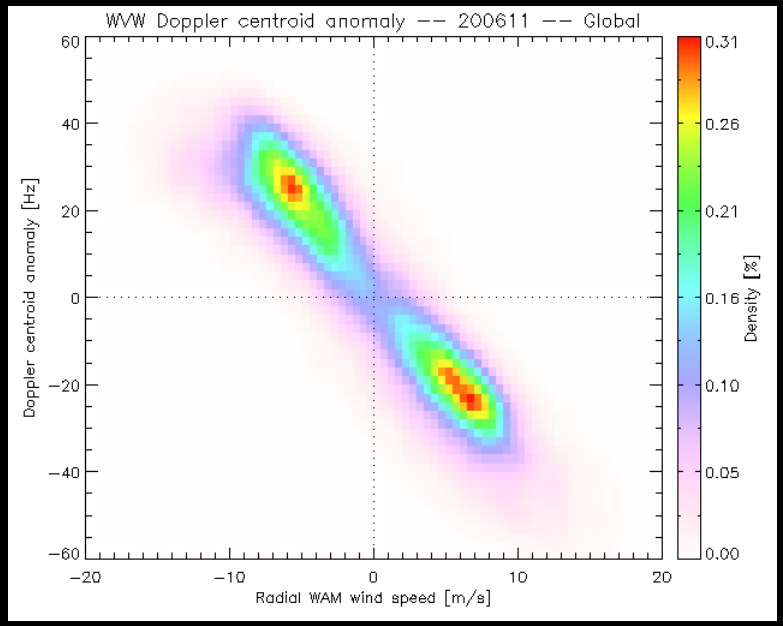
Two different tracks



2005 : CDOP Empirical model function

CDOP geophysical model function

- Published in JGR 2005 using wave mode at 23° incidence angle.
  - Modeled using tilt+breaking
  - largest influence from the largest steepness (typically in equilibrium with the wind stress)
  - **First order** : only wind dependance
  - empirical law only based on wind speed and direction relative to radar look

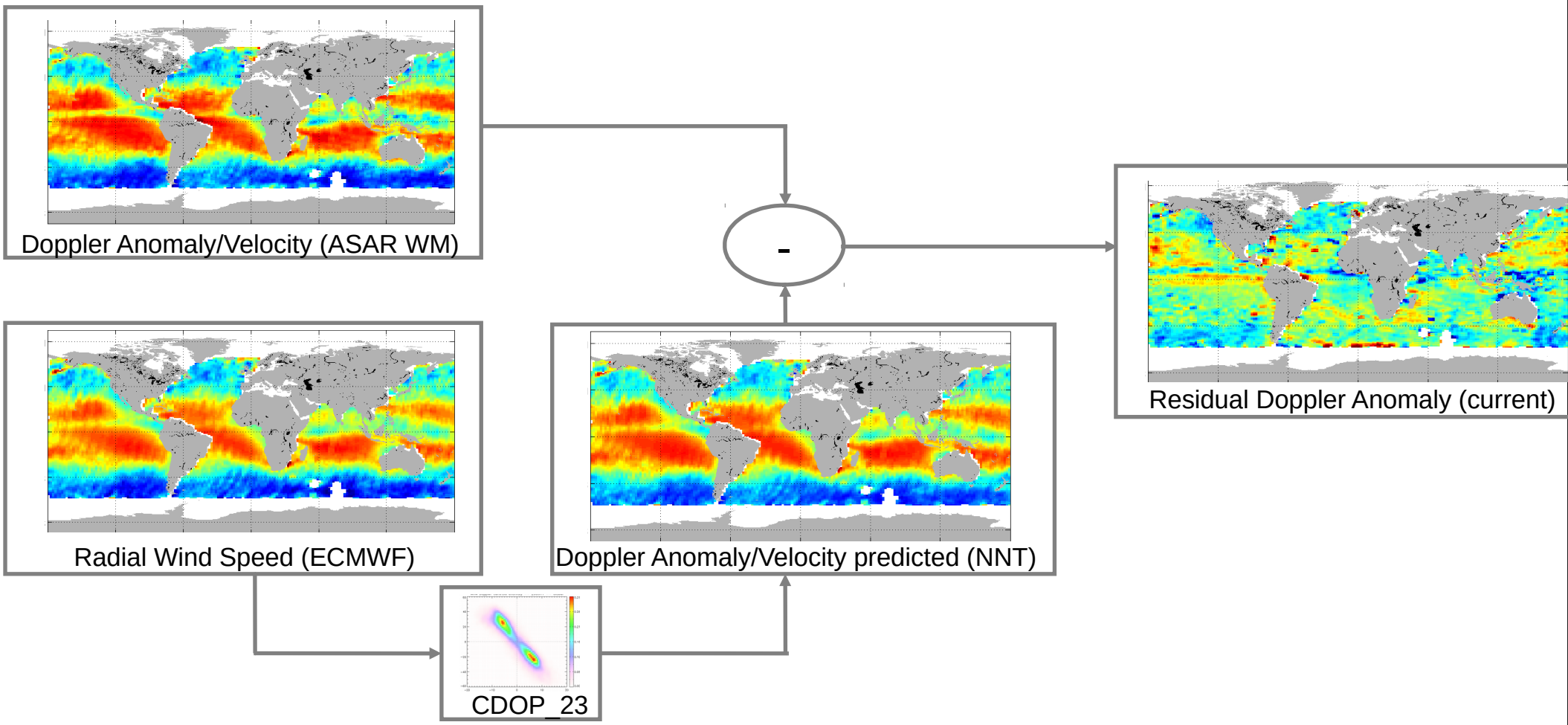


Neural Network training

CDOP_23 = f(wind speed/direction)

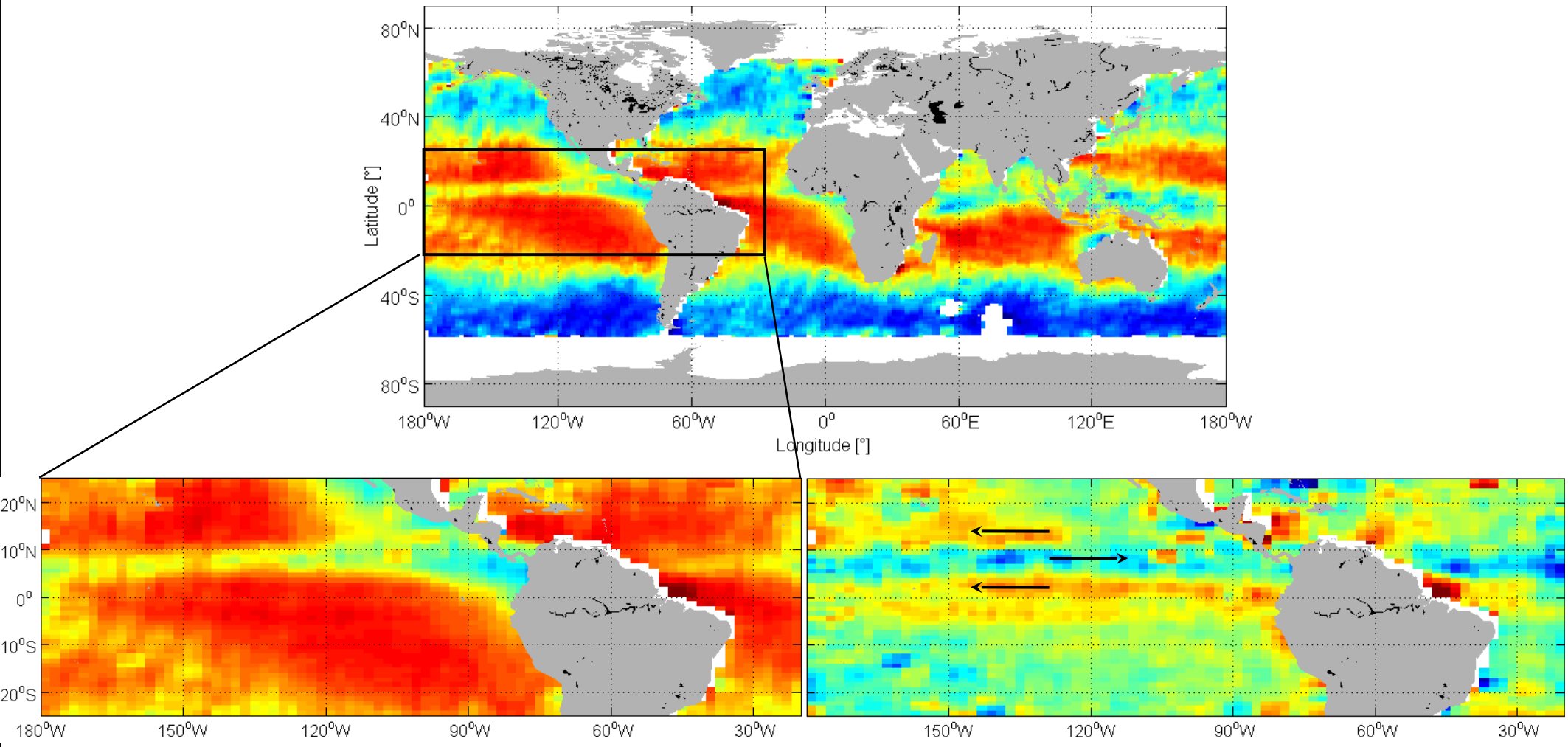
2005 : CDOP Empirical model function

Simple methodology to remove sea state Doppler bias



2008 : Equatorial current monitoring

Equatorial Pacific Zone monitoring

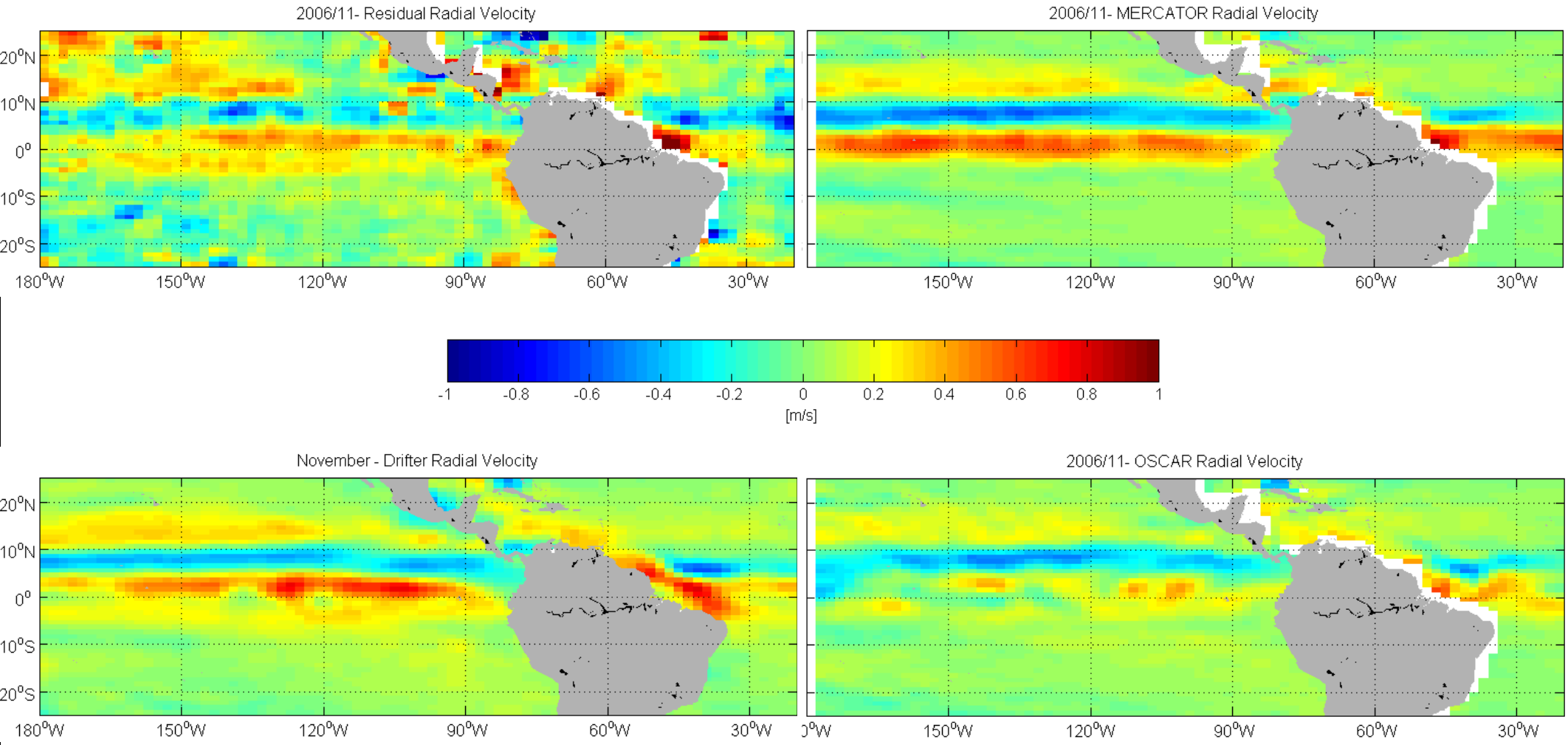


Radial Velocity (wind effect no removed)

Radial Current Velocity (wind effect

2008 : Equatorial current monitoring

Equatorial Pacific Zone monitoring
2D comparisons



2008 : Equatorial current monitoring

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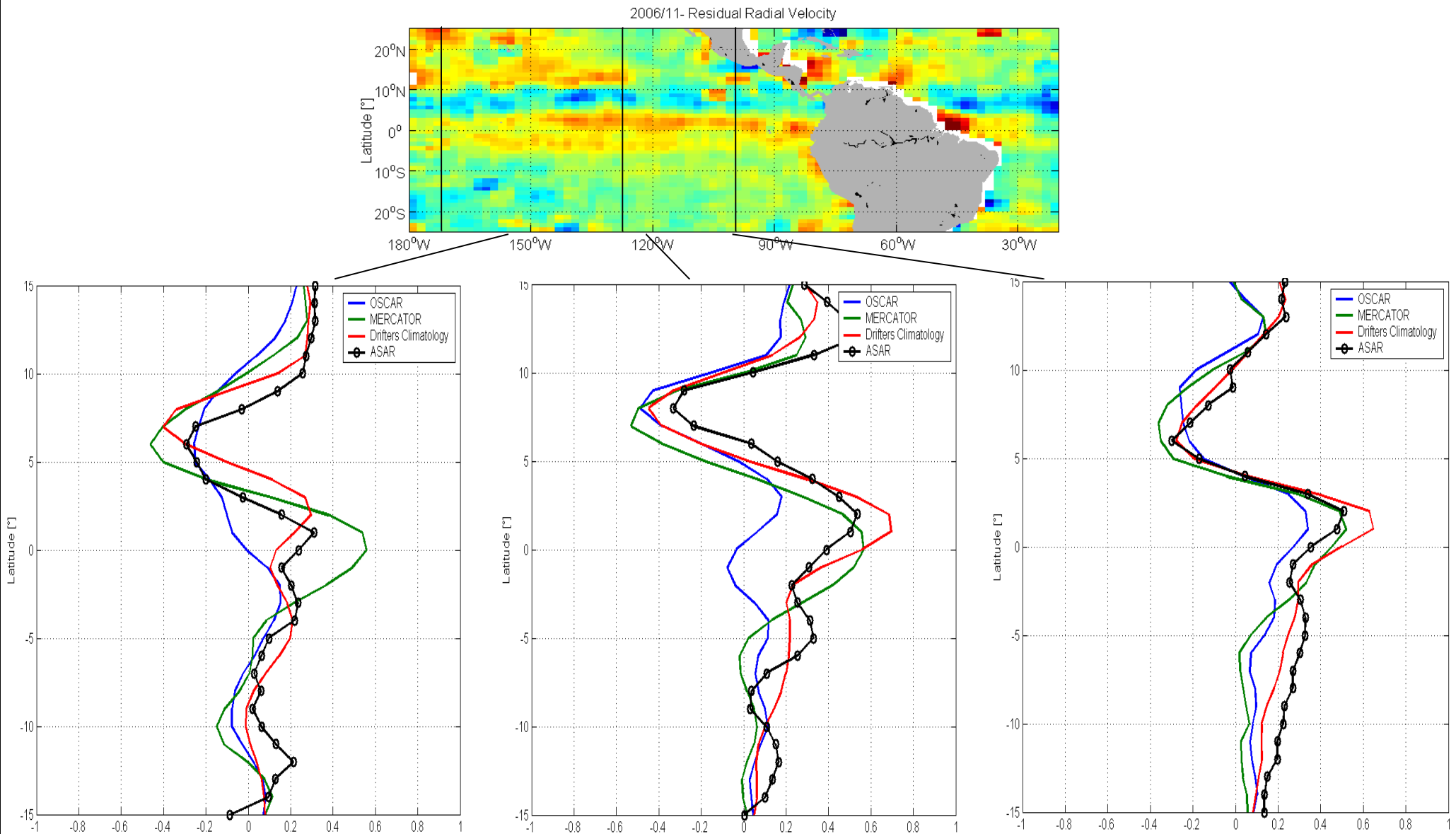
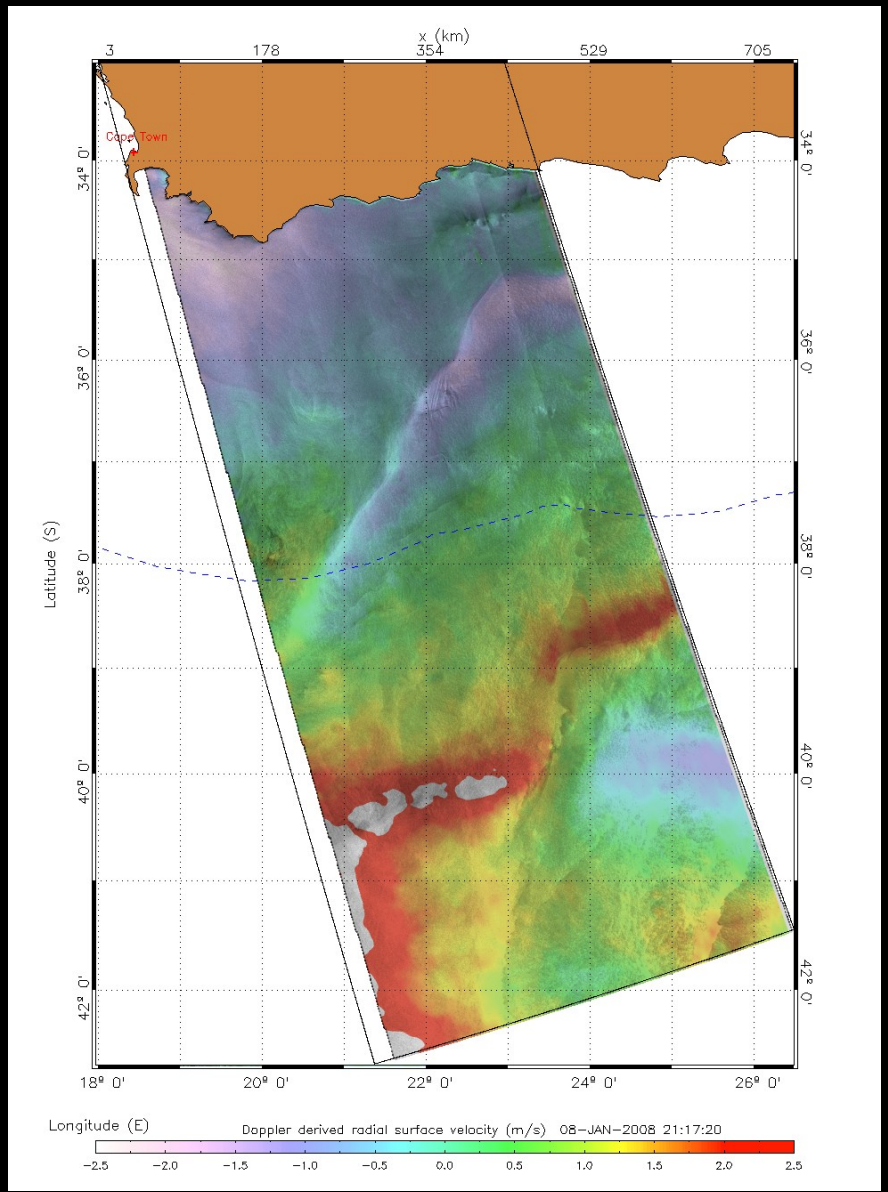
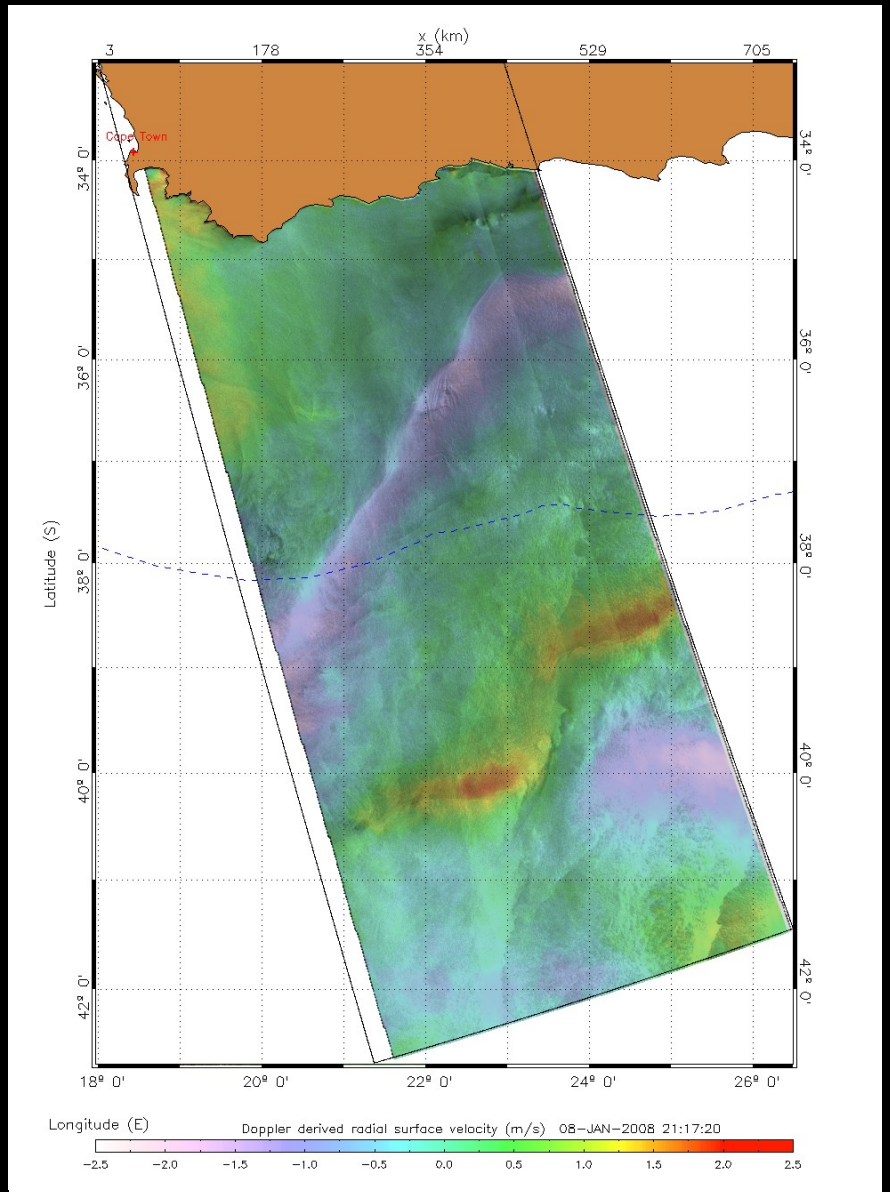


2008 : Wide swath Agulhas monitoring

Total velocities



CDOP correction
Residual velocities



2008 : Wide swath Agulhas monitoring

Estimation of Doppler anomaly on ASAR Wide Swath Doppler grid.

Anomaly = measured – predicted from geometry

Compensated non-geophysical sources of anomaly :

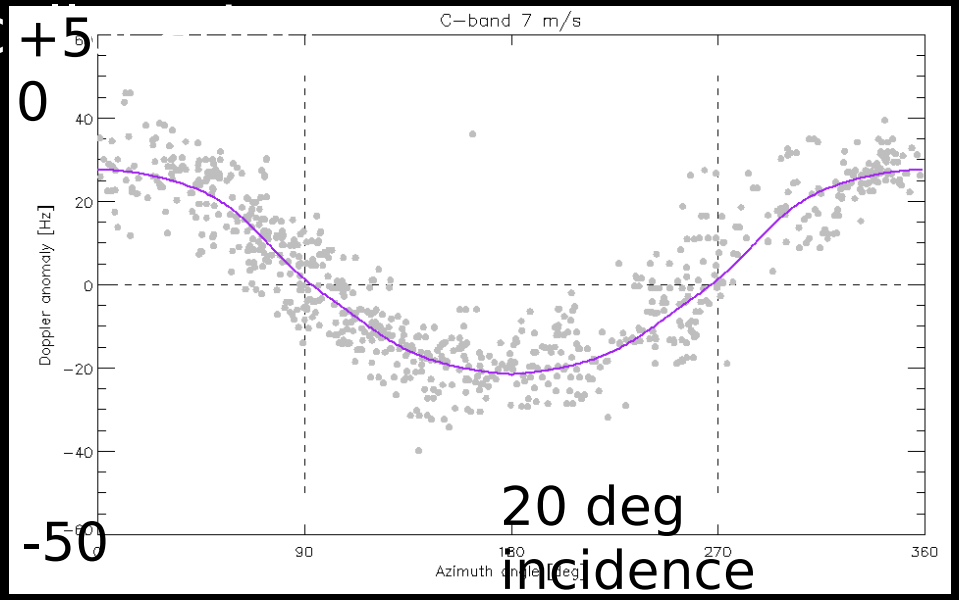
1. Antenna misspointing (constant bias)
2. Electronic misspointing (bias in the radial direction)
3. Doppler estimator bias caused by azimuthal variation of backscatter (artificial correlation between doppler and sigma0).

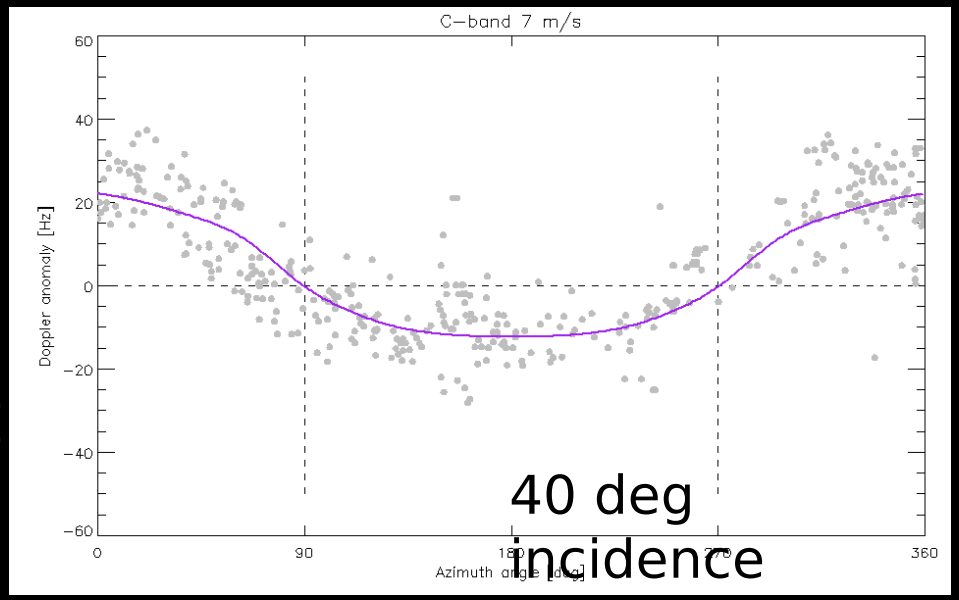
C band VV polarization Doppler shift GMF

CDOP : Cband VV pol Doppler GMF based on ASAR/ASCAT

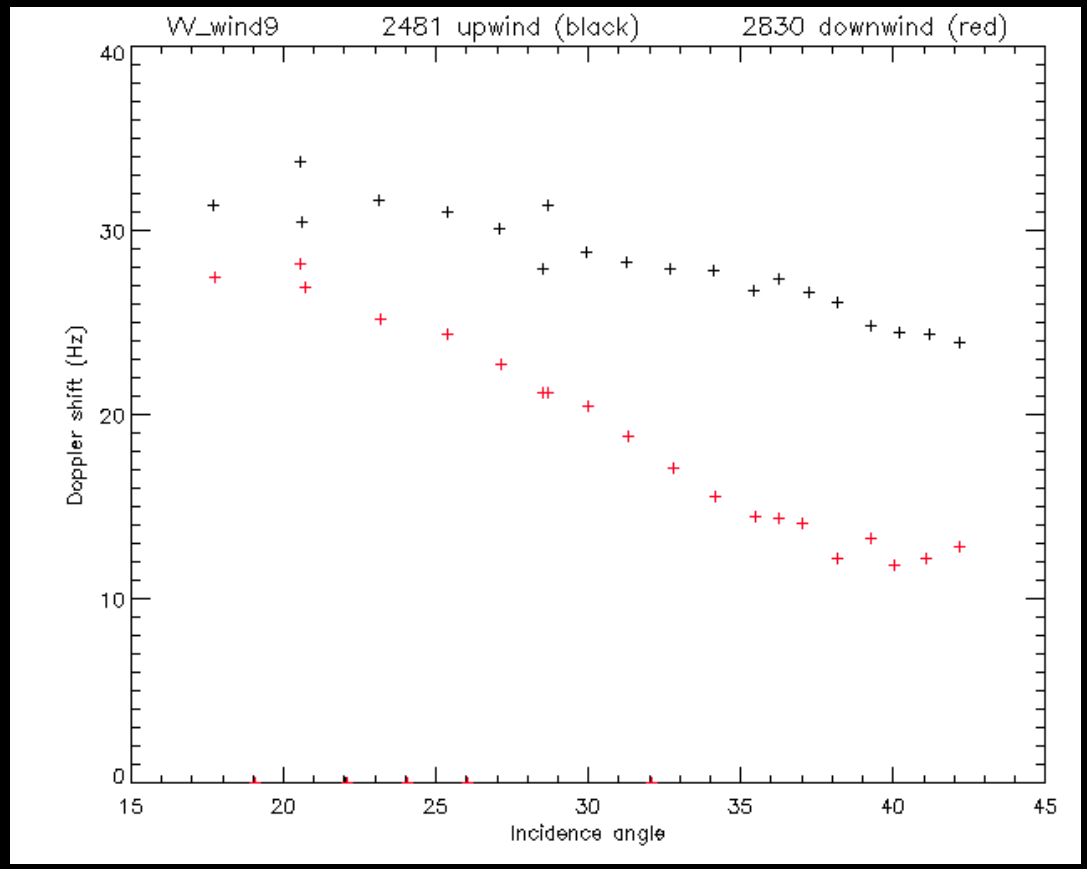
c +5
0
-50

Doppler shift





Azimuth



Incidence angle

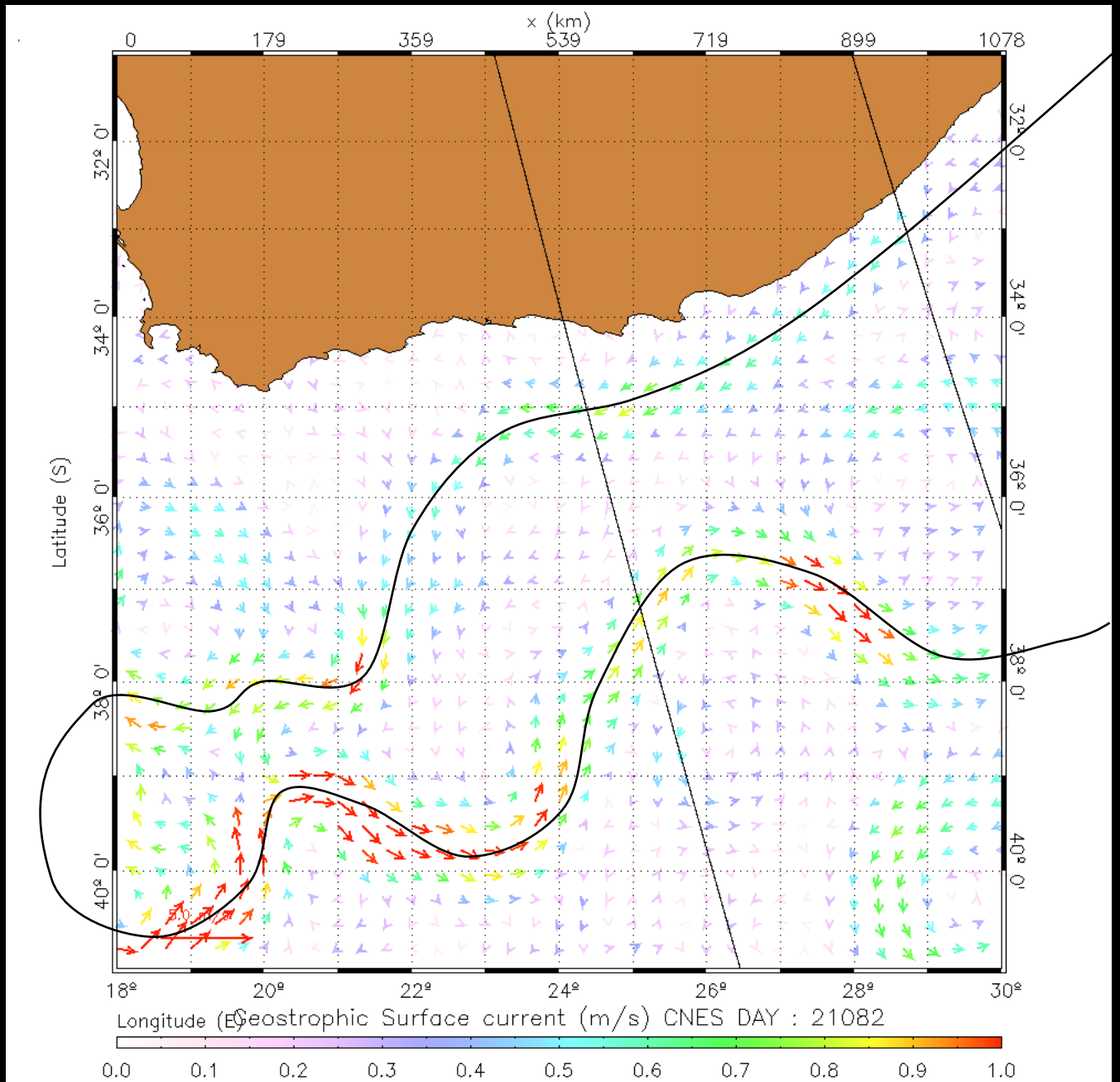
CDOP GMF Published in TGRS VOL. 50, NO. 7, JULY 2012
Alexis A. Mouche, Fabrice Collard, Bertrand Chapron, Knut-Frode Dagestad, Gilles Guitton, Johnny A. Johannessen, Vincent Kerbaol, and Morten Wergeland Hansen

On the Use of Doppler Shift for Sea Surface Wind Retrieval From SAR

2008 : Wide swath Agulhas monitoring

Altimetry derived surface current :

Altimetry derived surface current : 3 days mean



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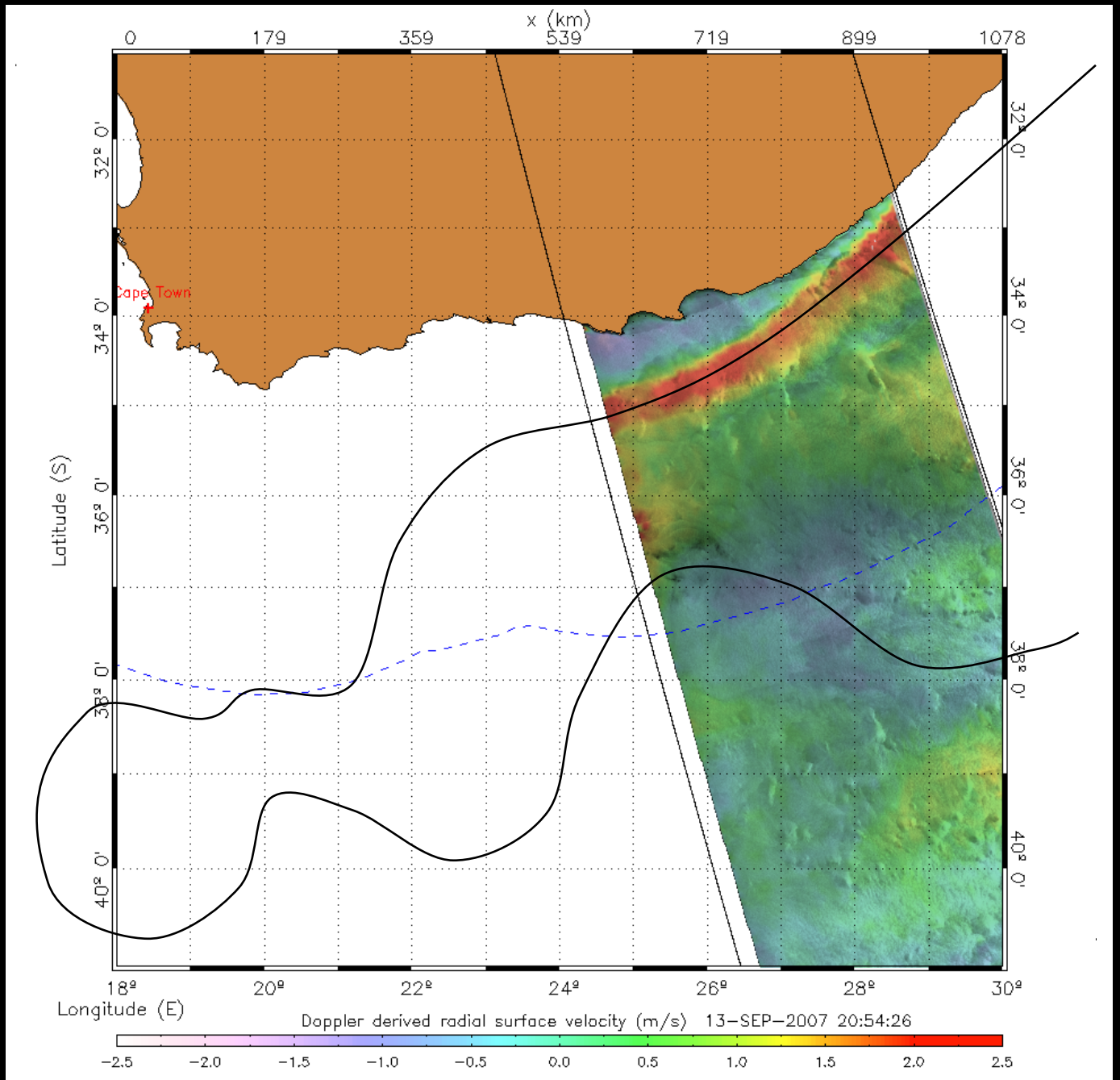

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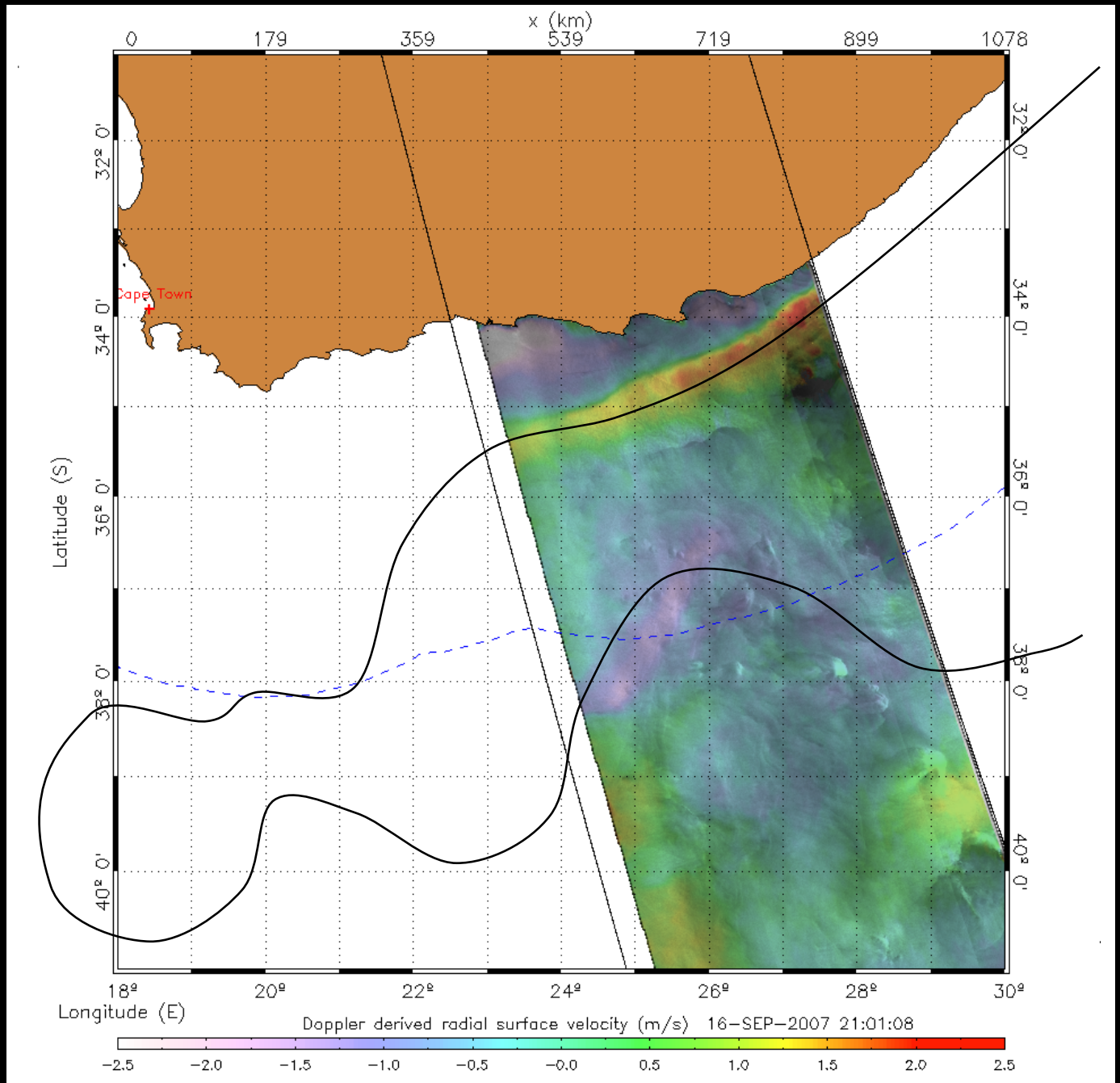

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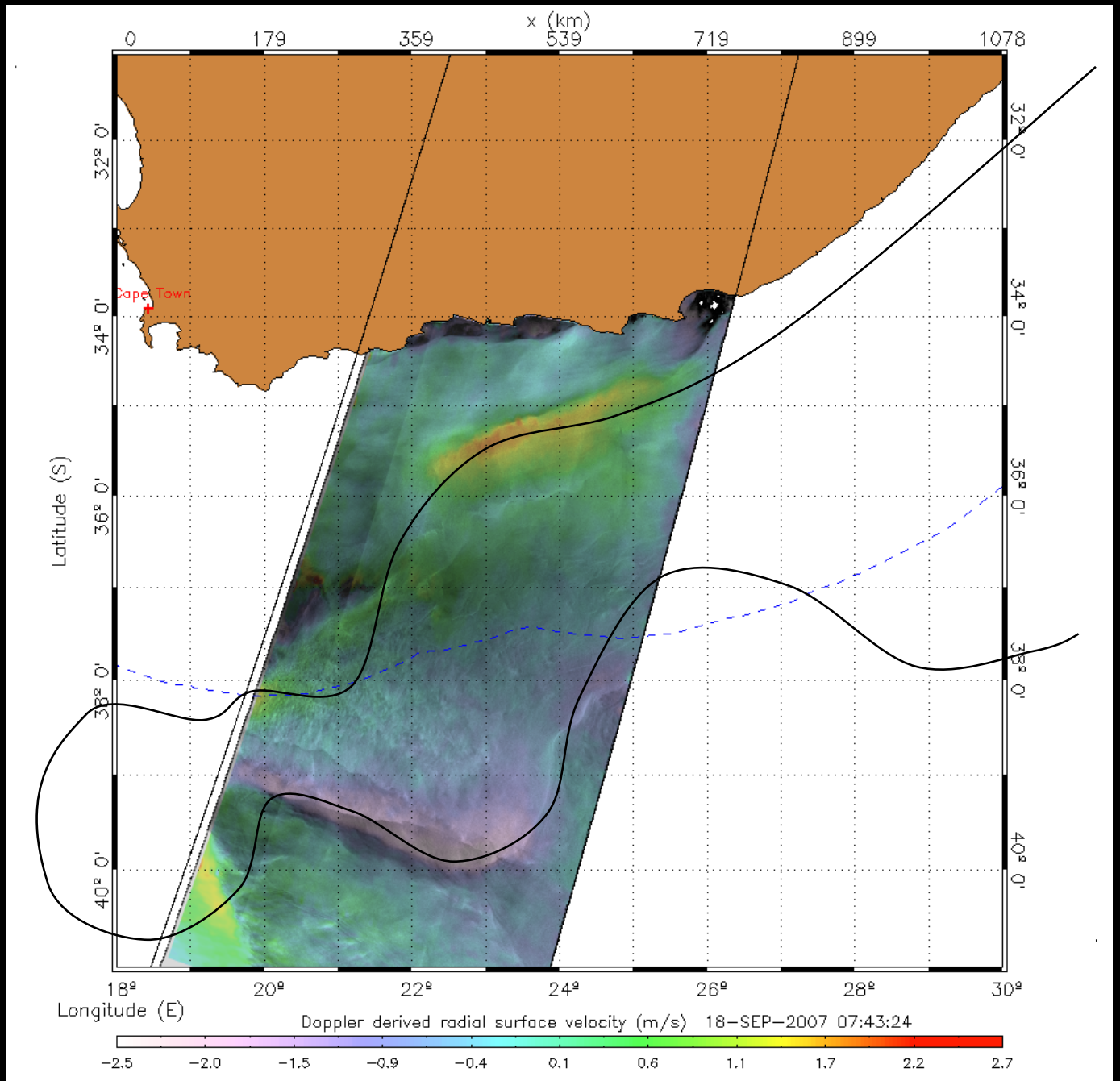

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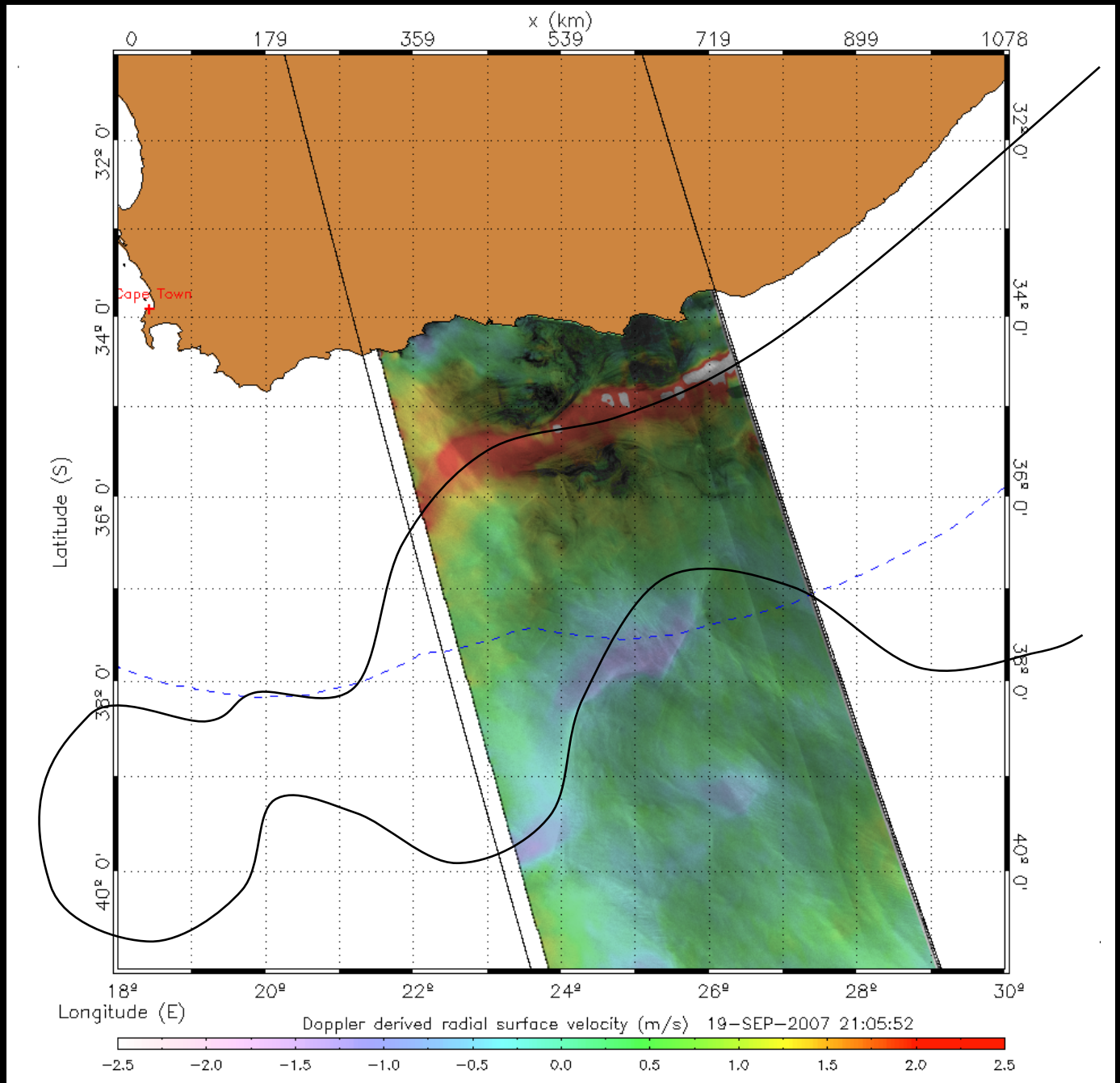
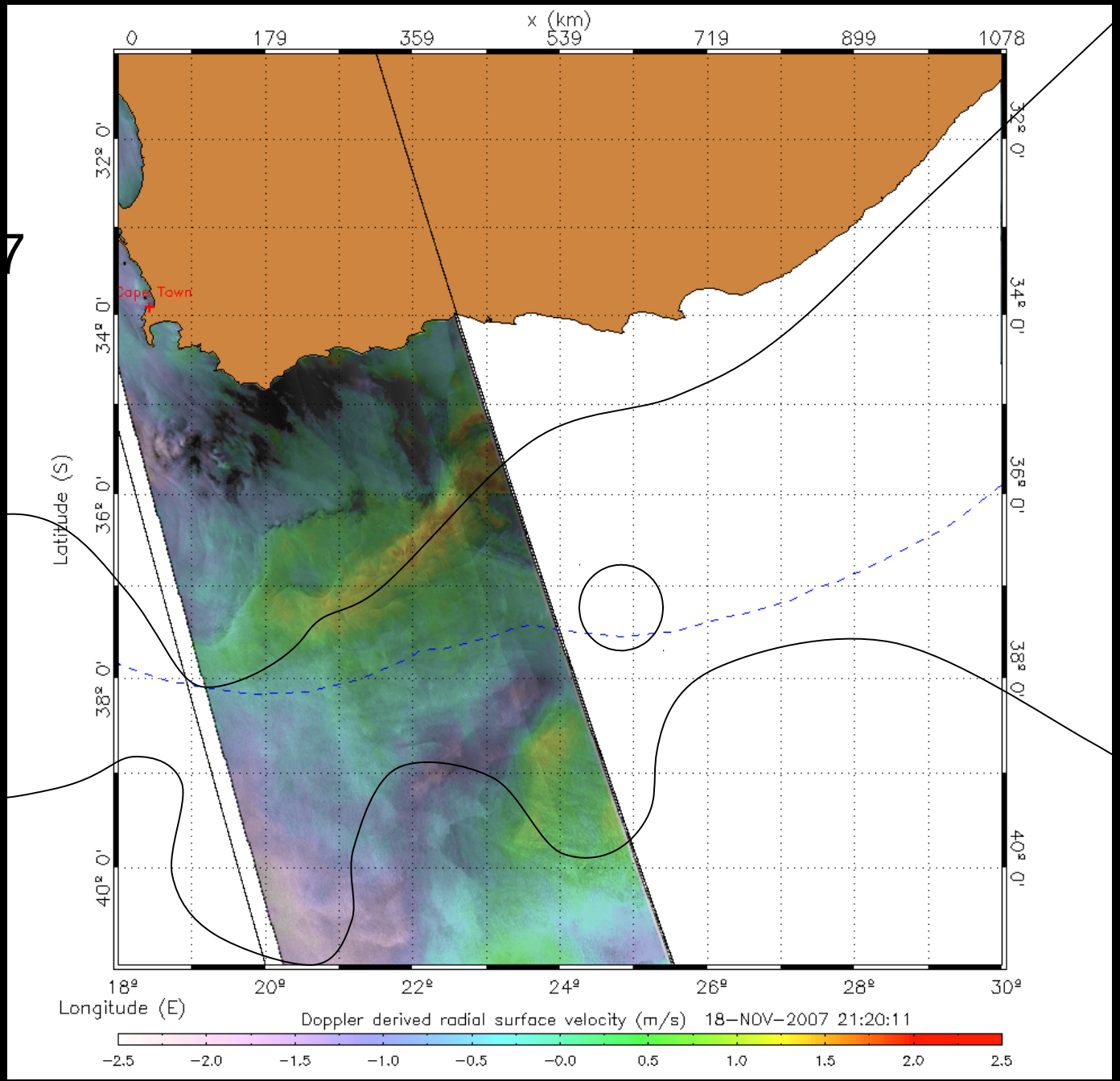


2008 : Wide swath Agulhas monitoring

- 7



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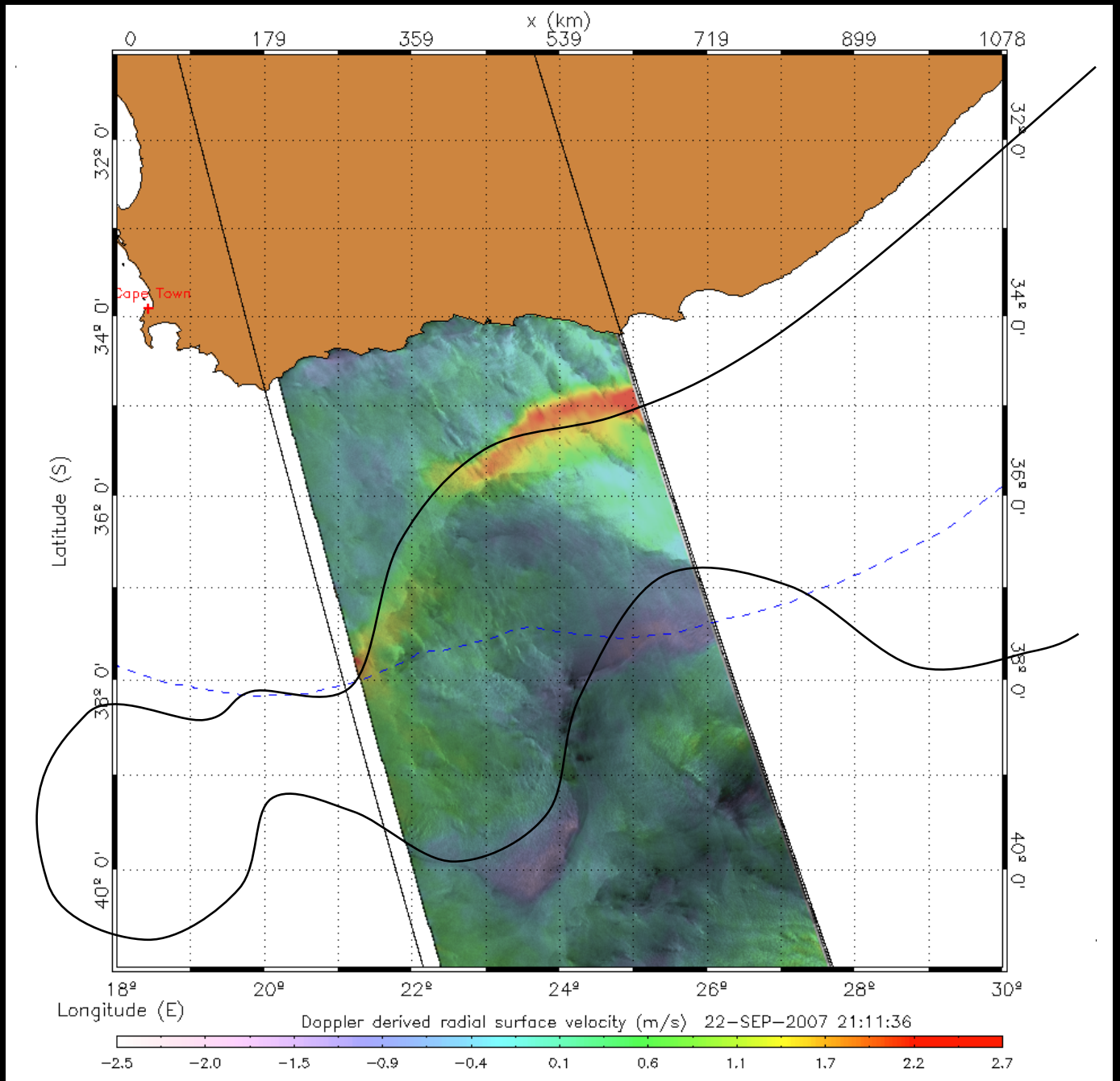

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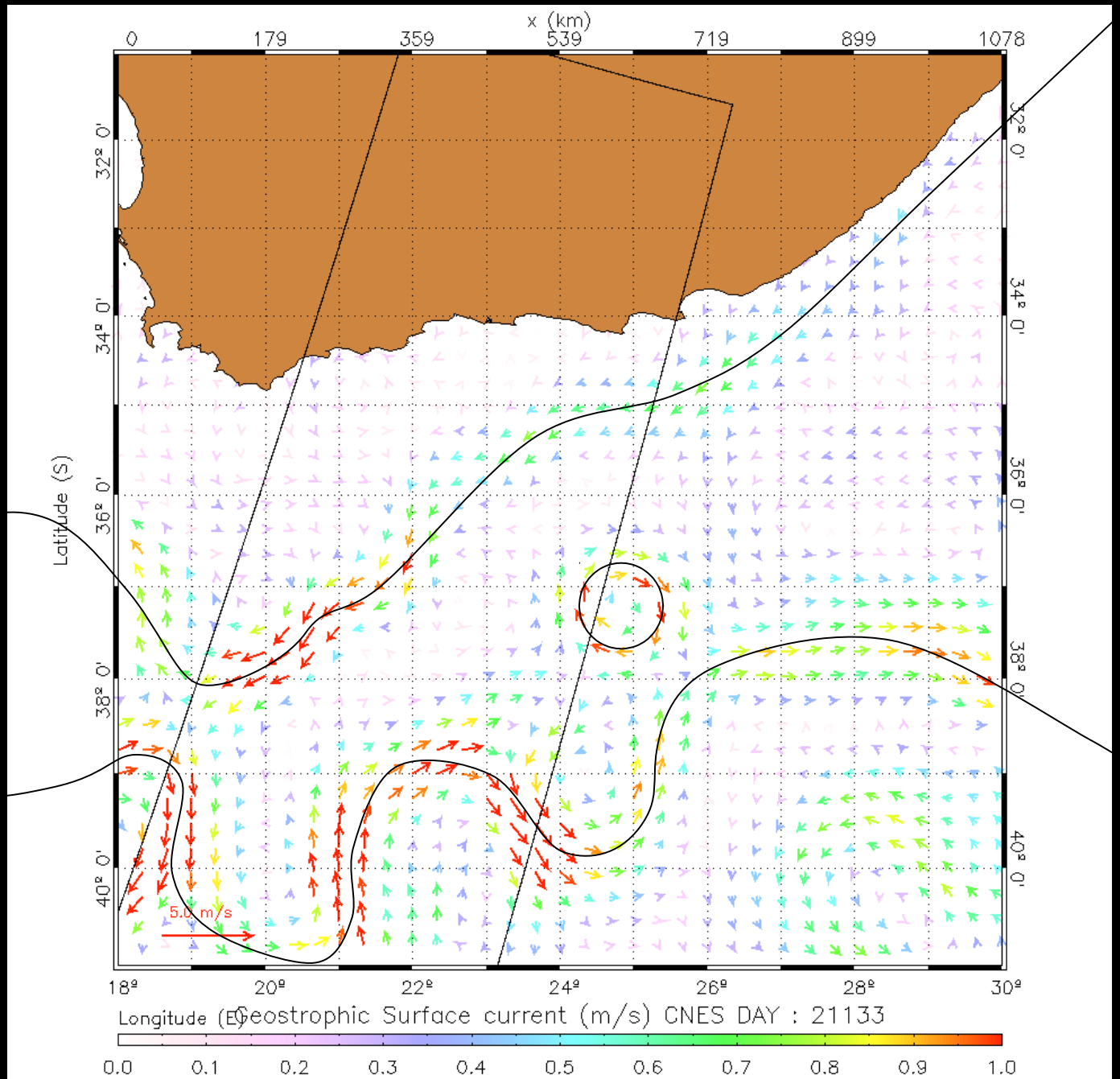
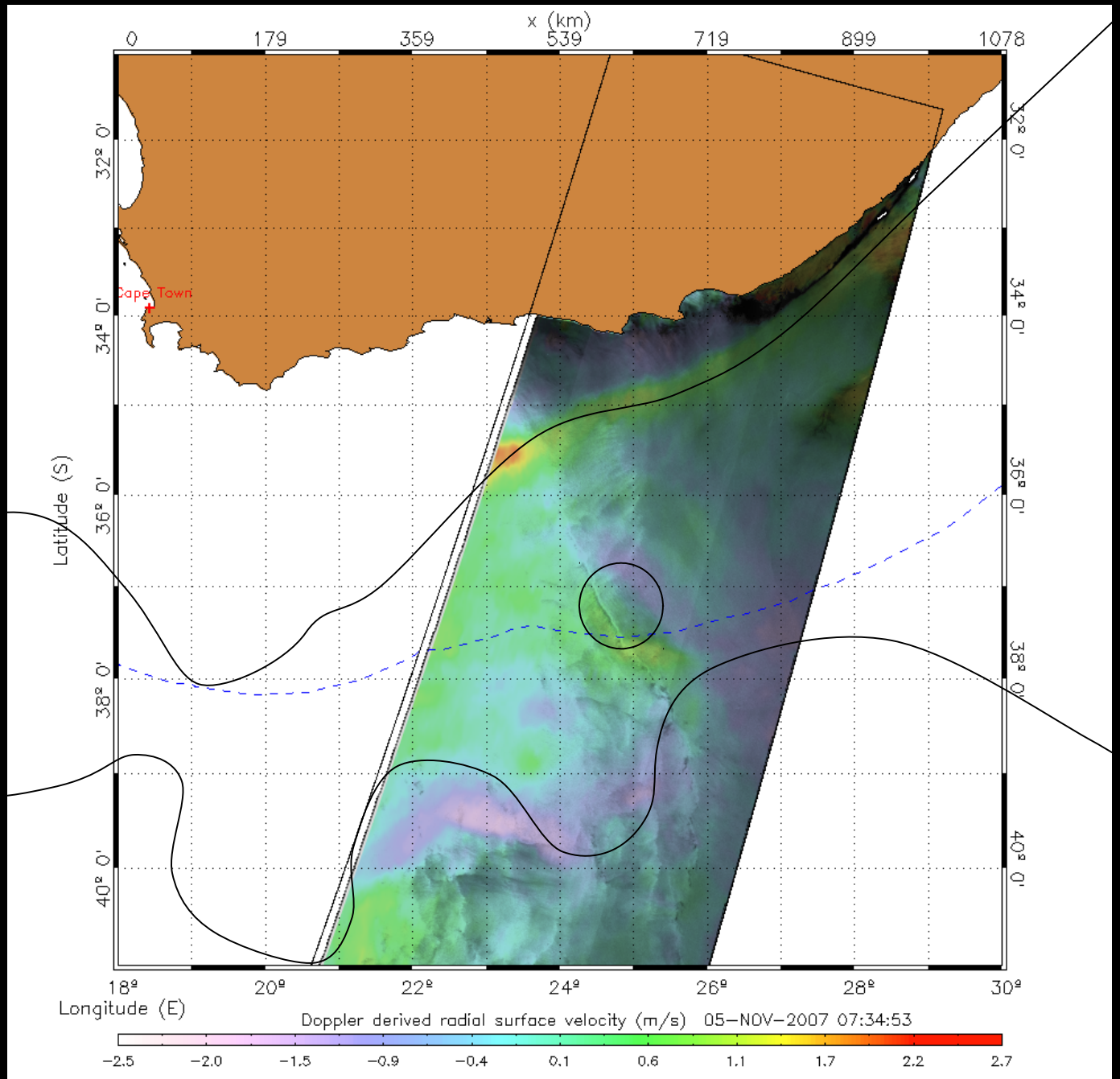


2008 : Wide swath Agulhas monitoring

- Nov 5, 2007



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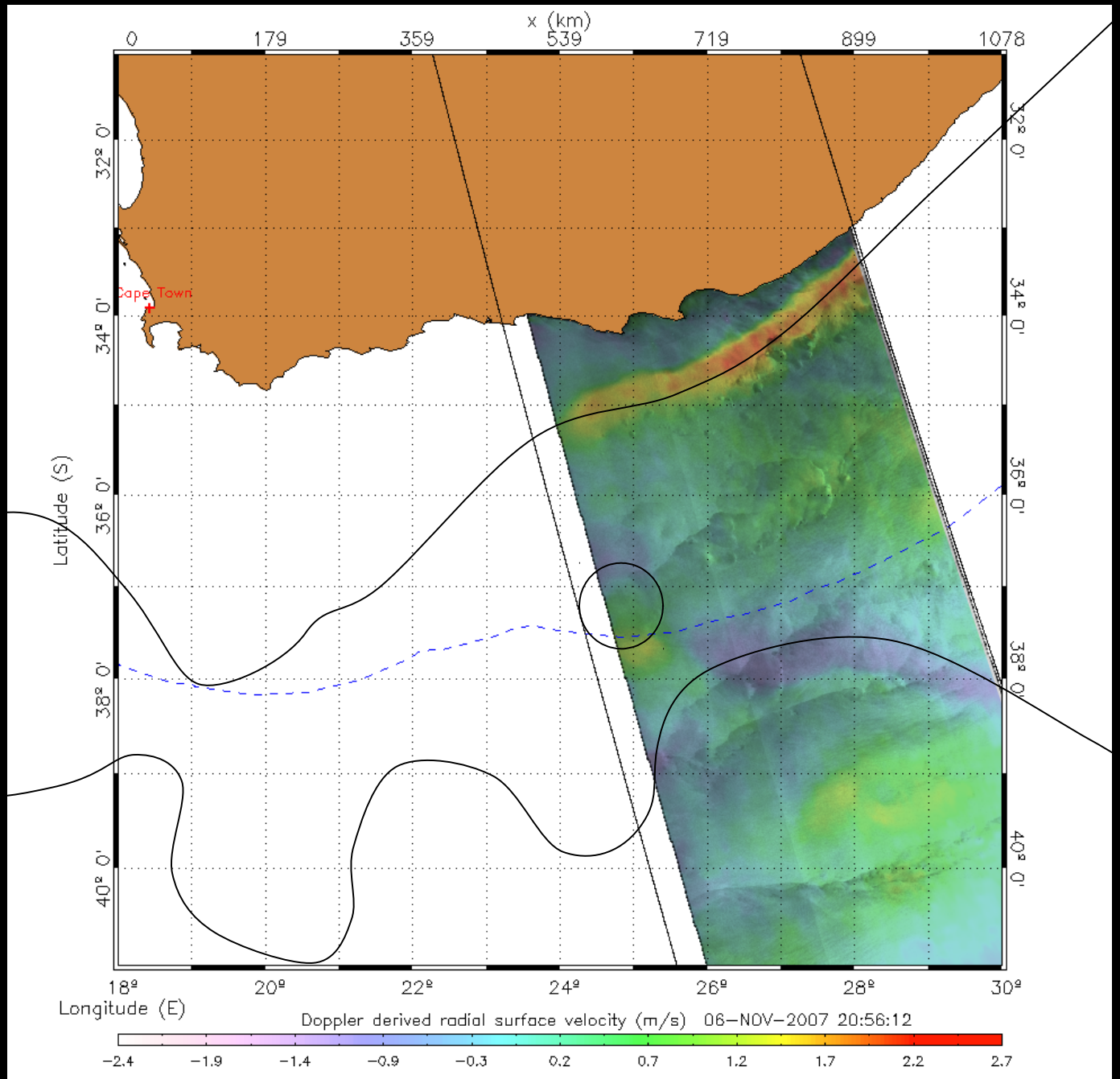

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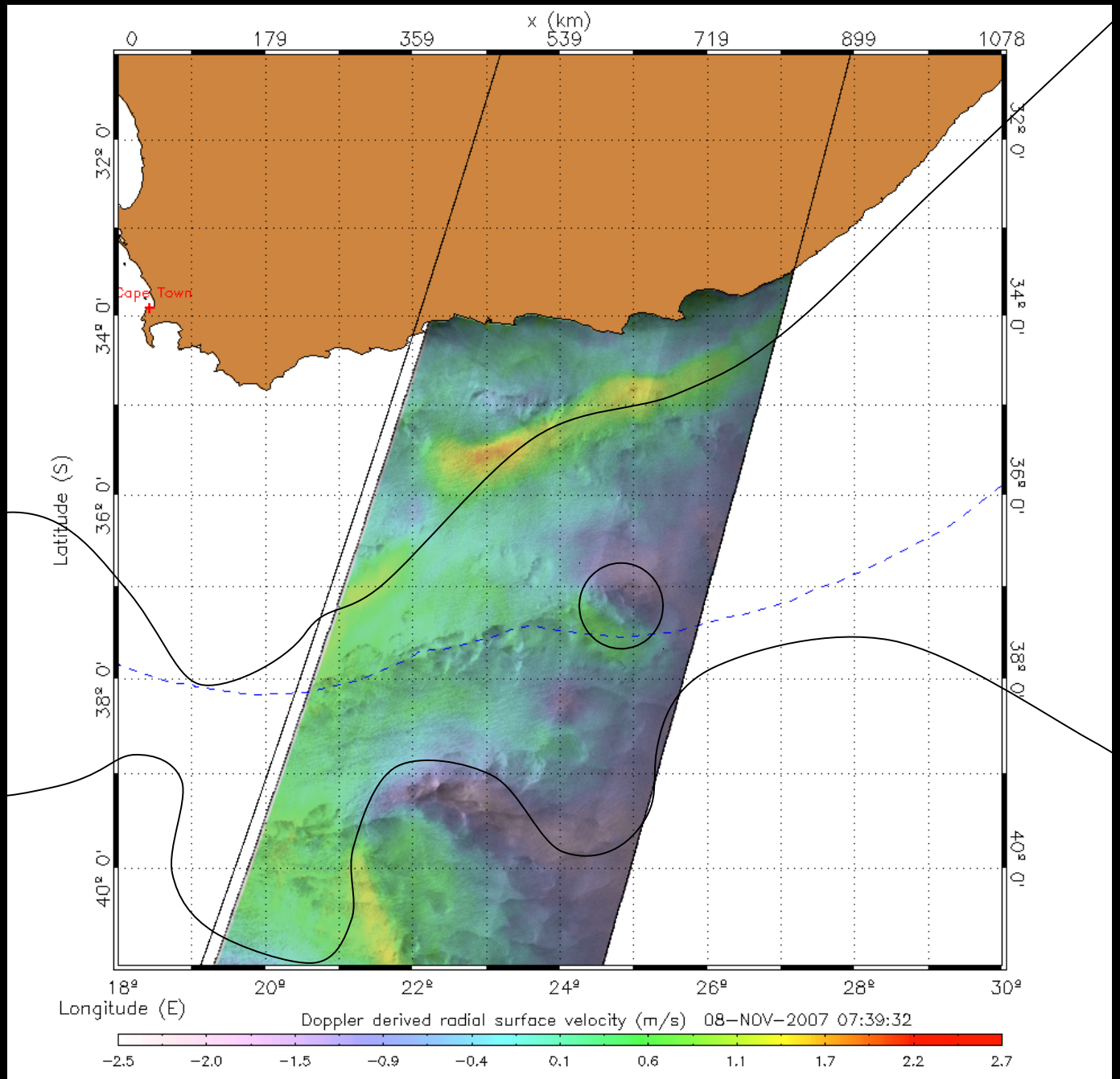

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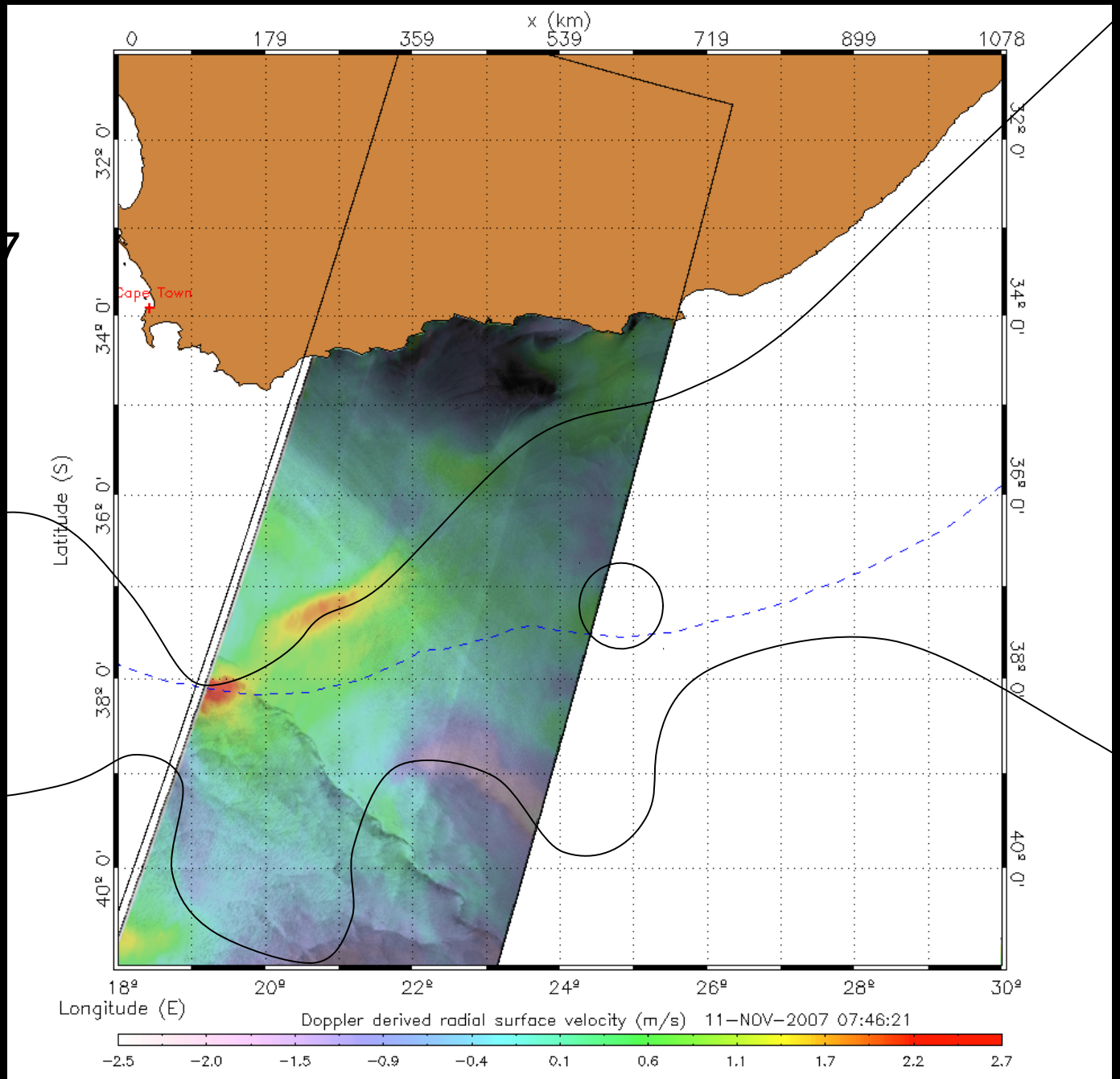

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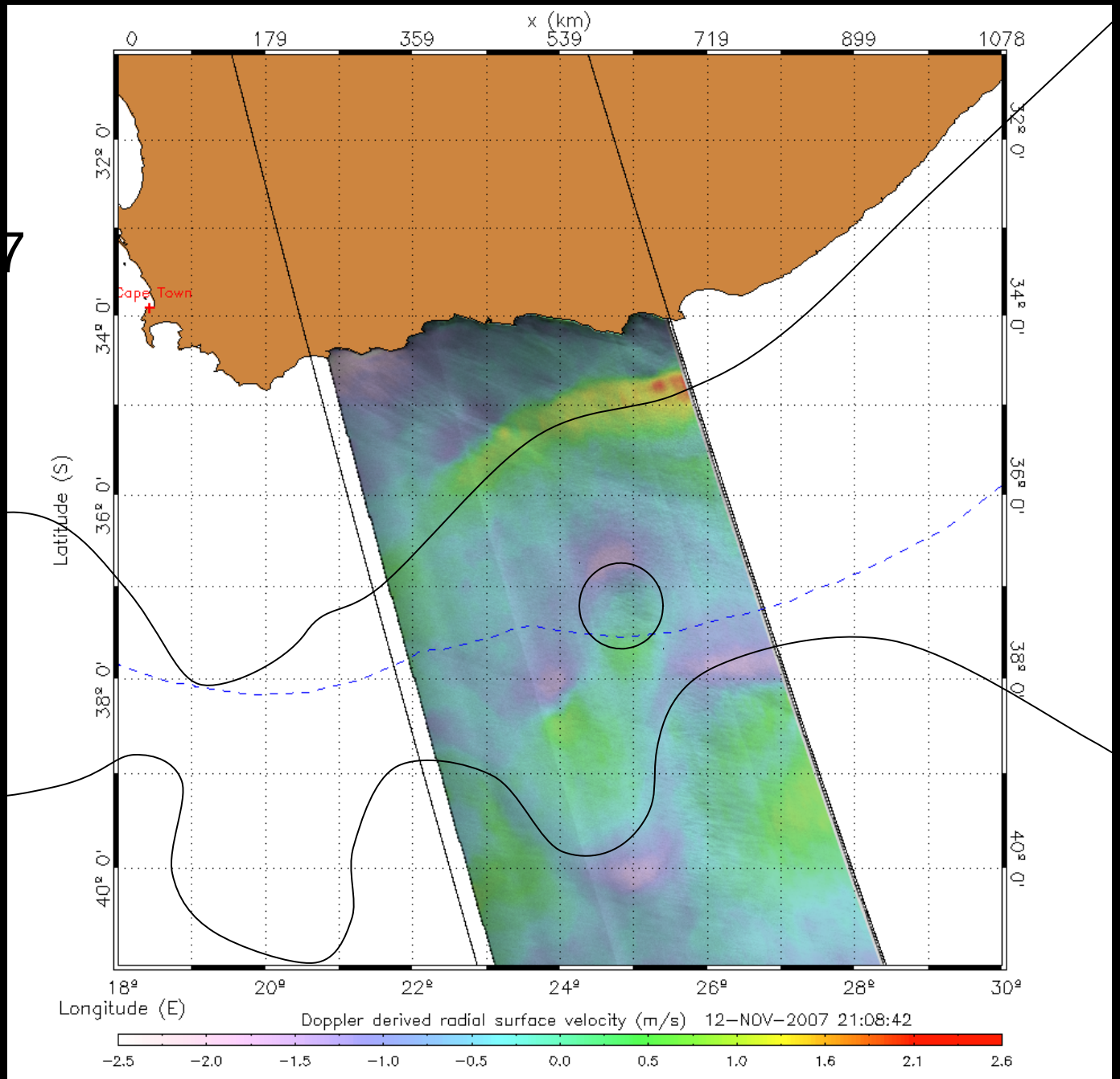

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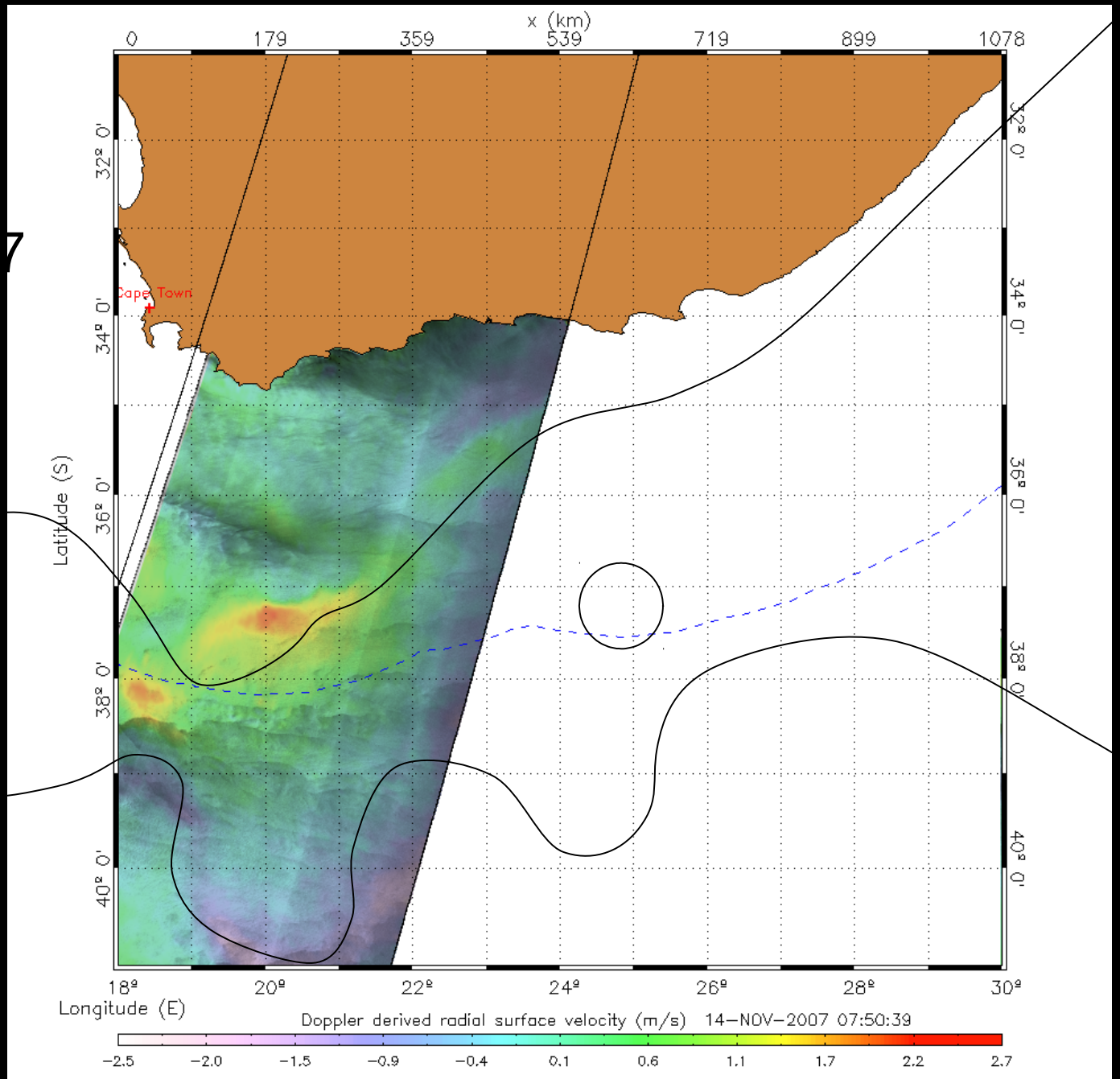

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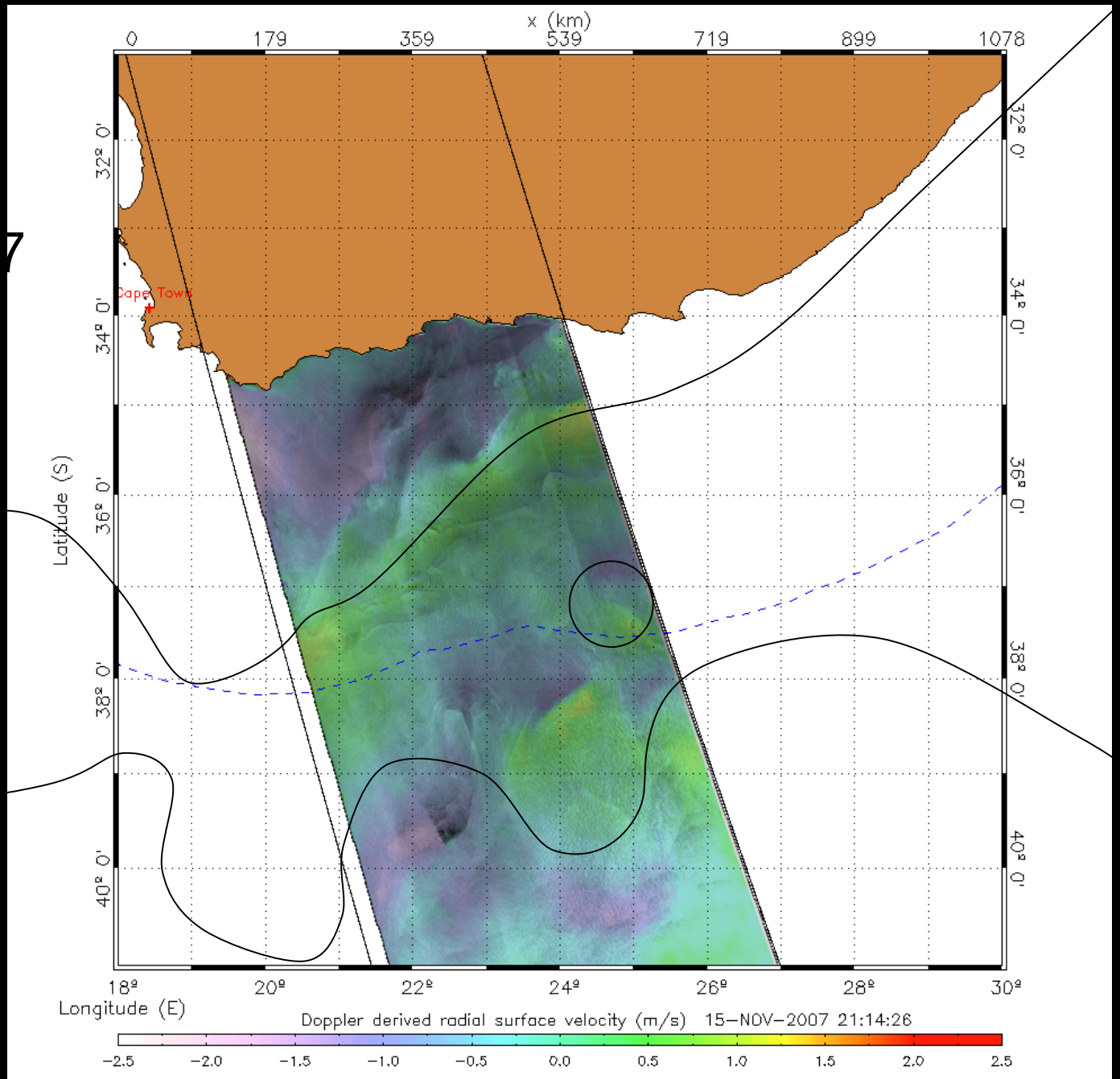
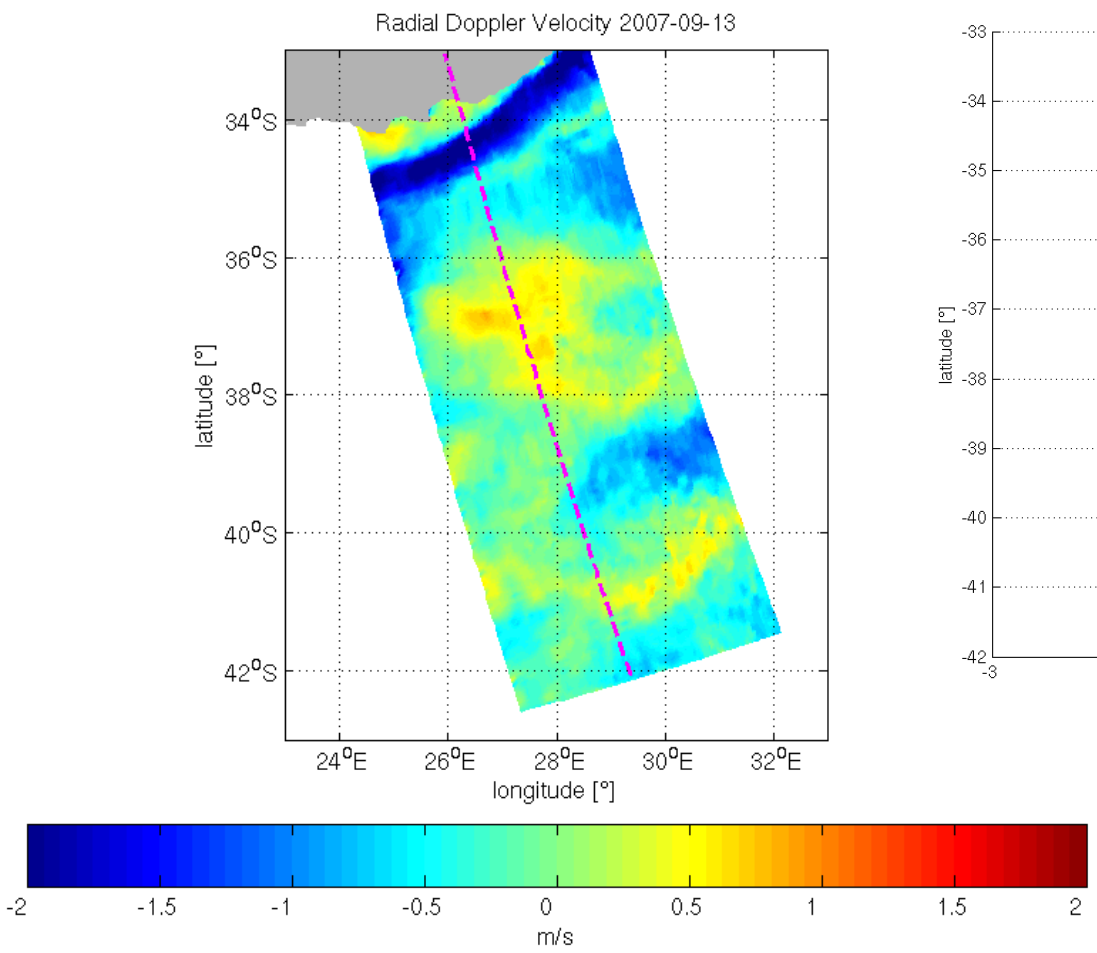
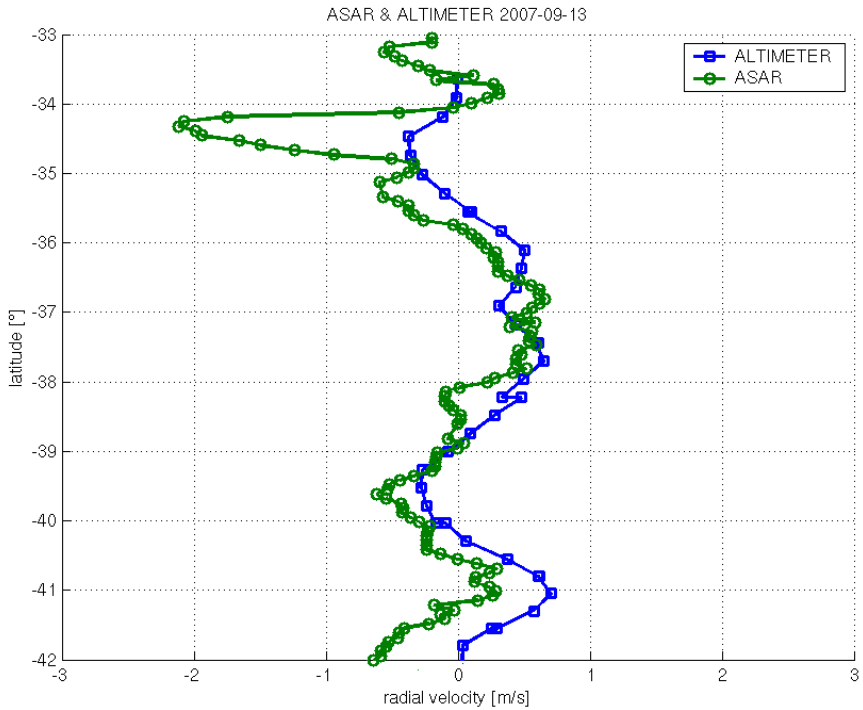


2008 : Wide swath Agulhas monitoring

Comparison with altimeter geostrophic currents





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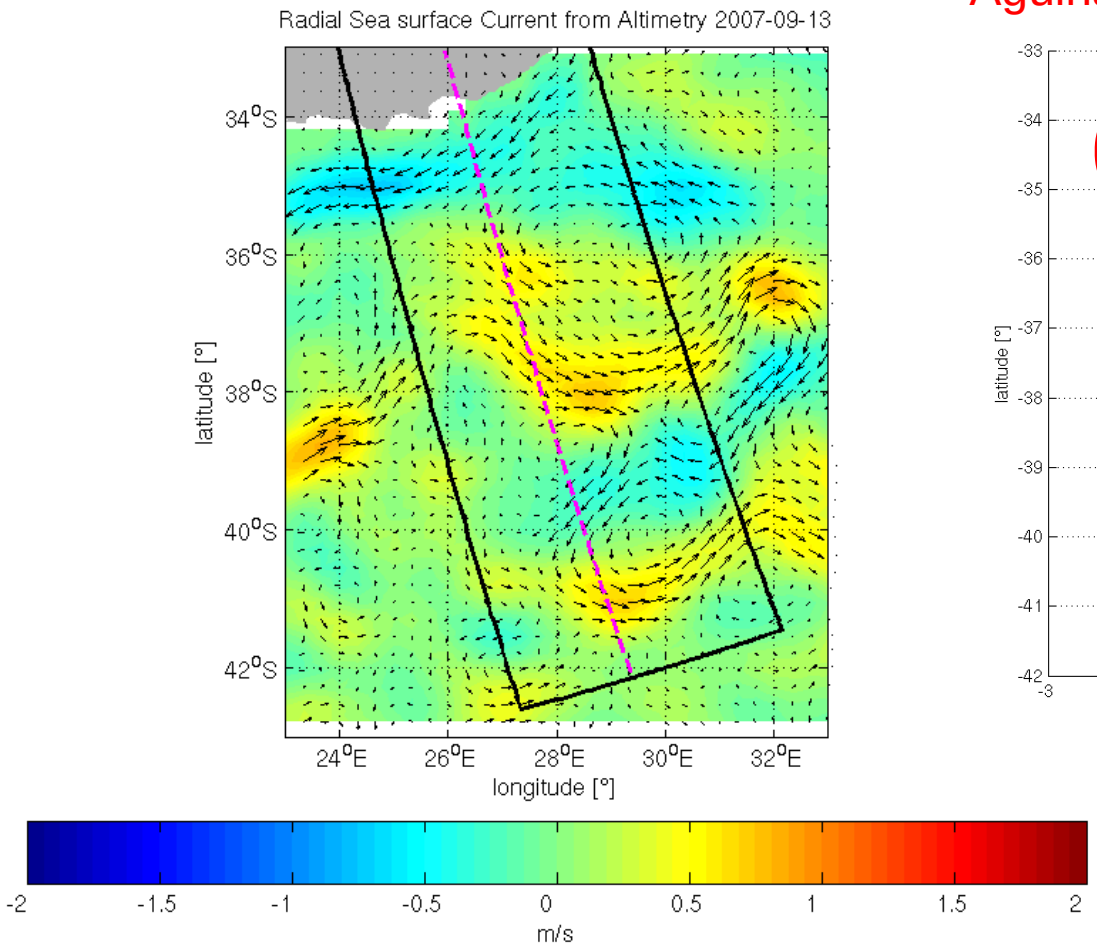
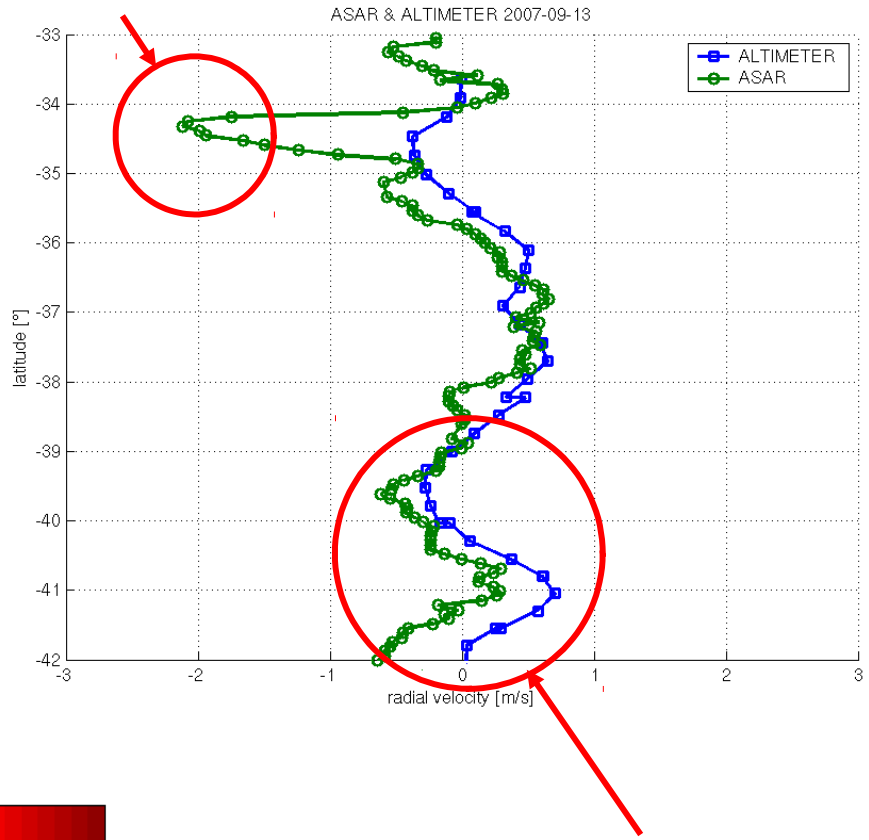


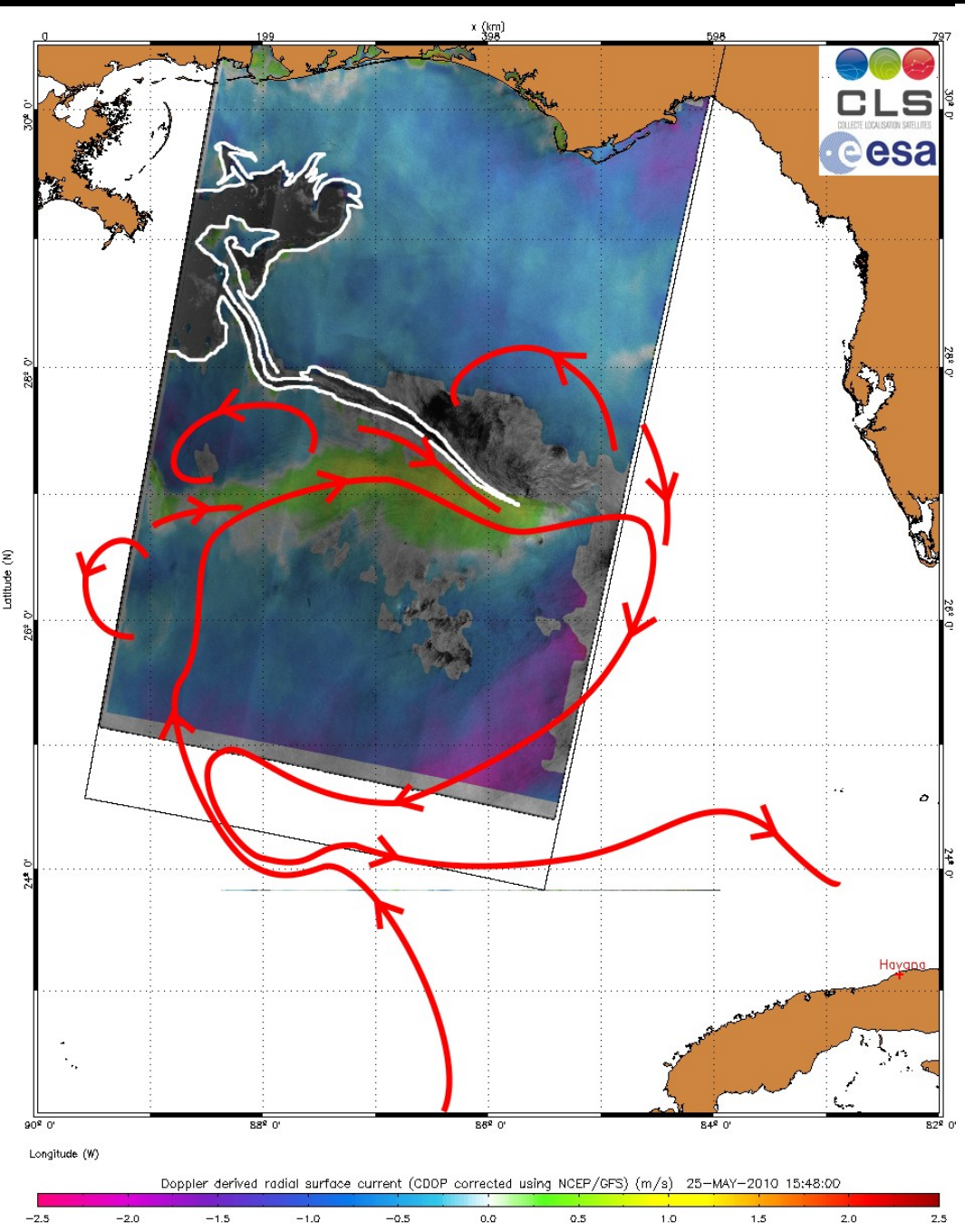
Agulhas main stream

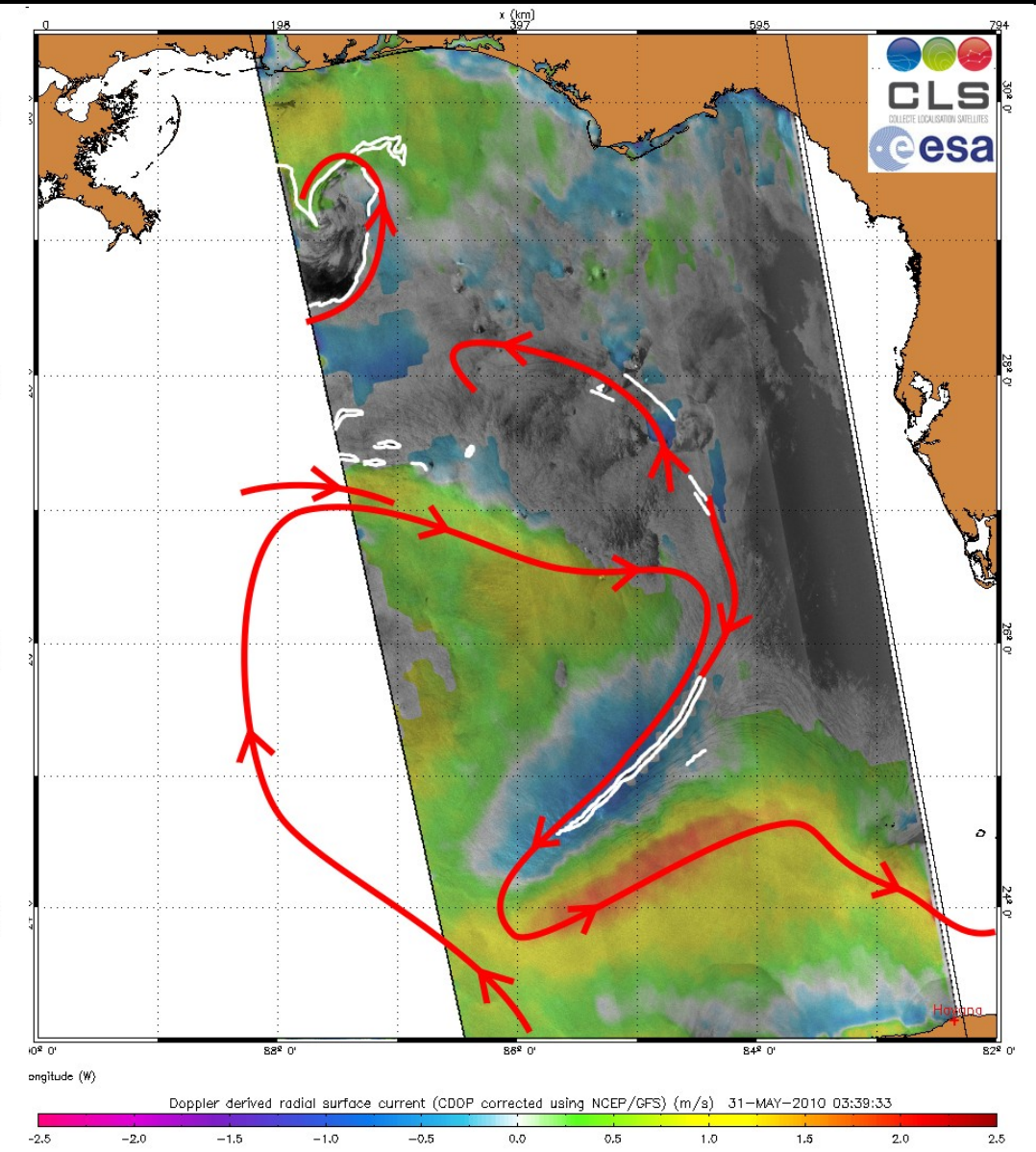


Mesoscale eddie

2010 : Deep Horizon Oil Spill

Red contours from IR imagery thermal fronts





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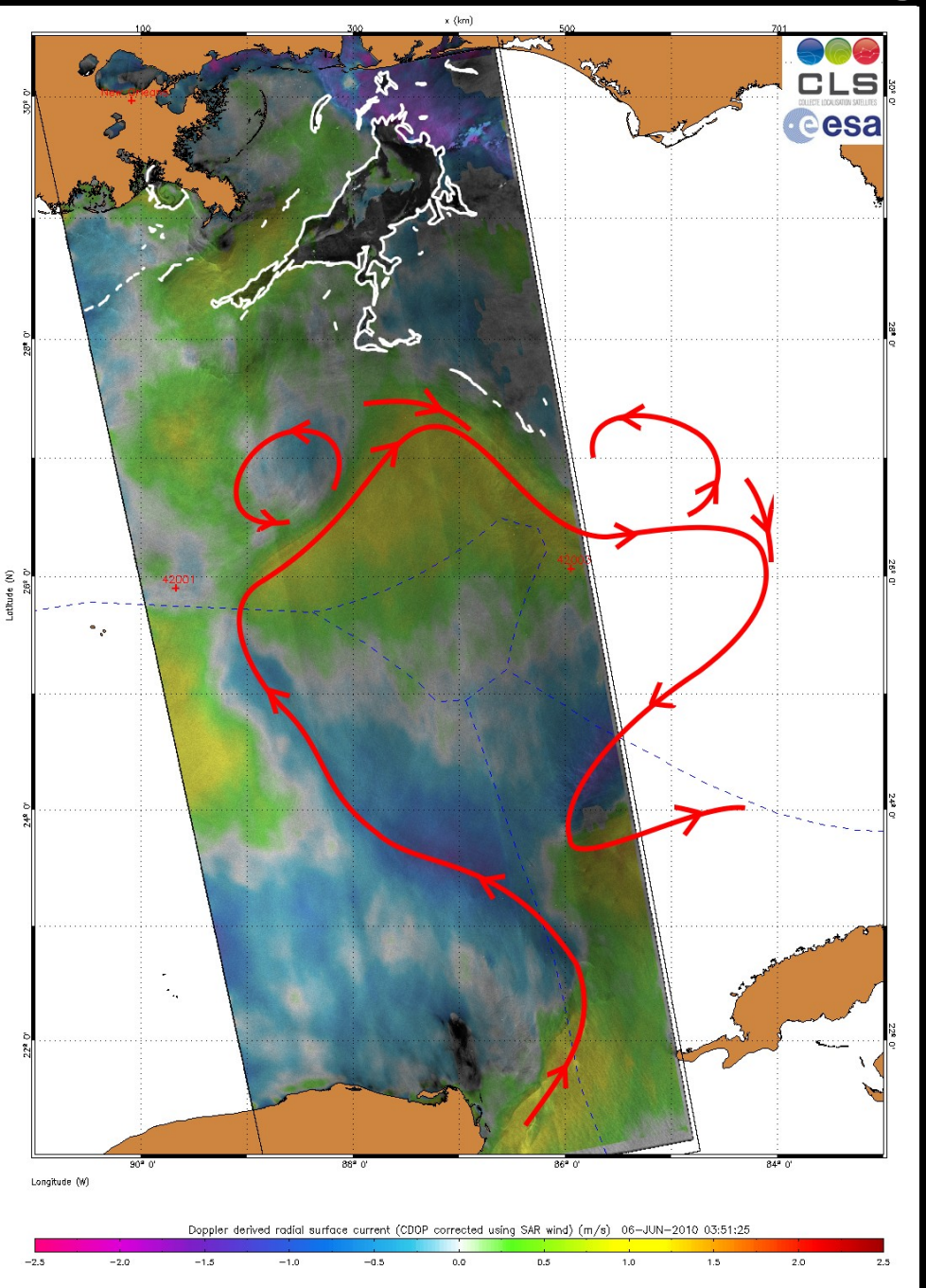
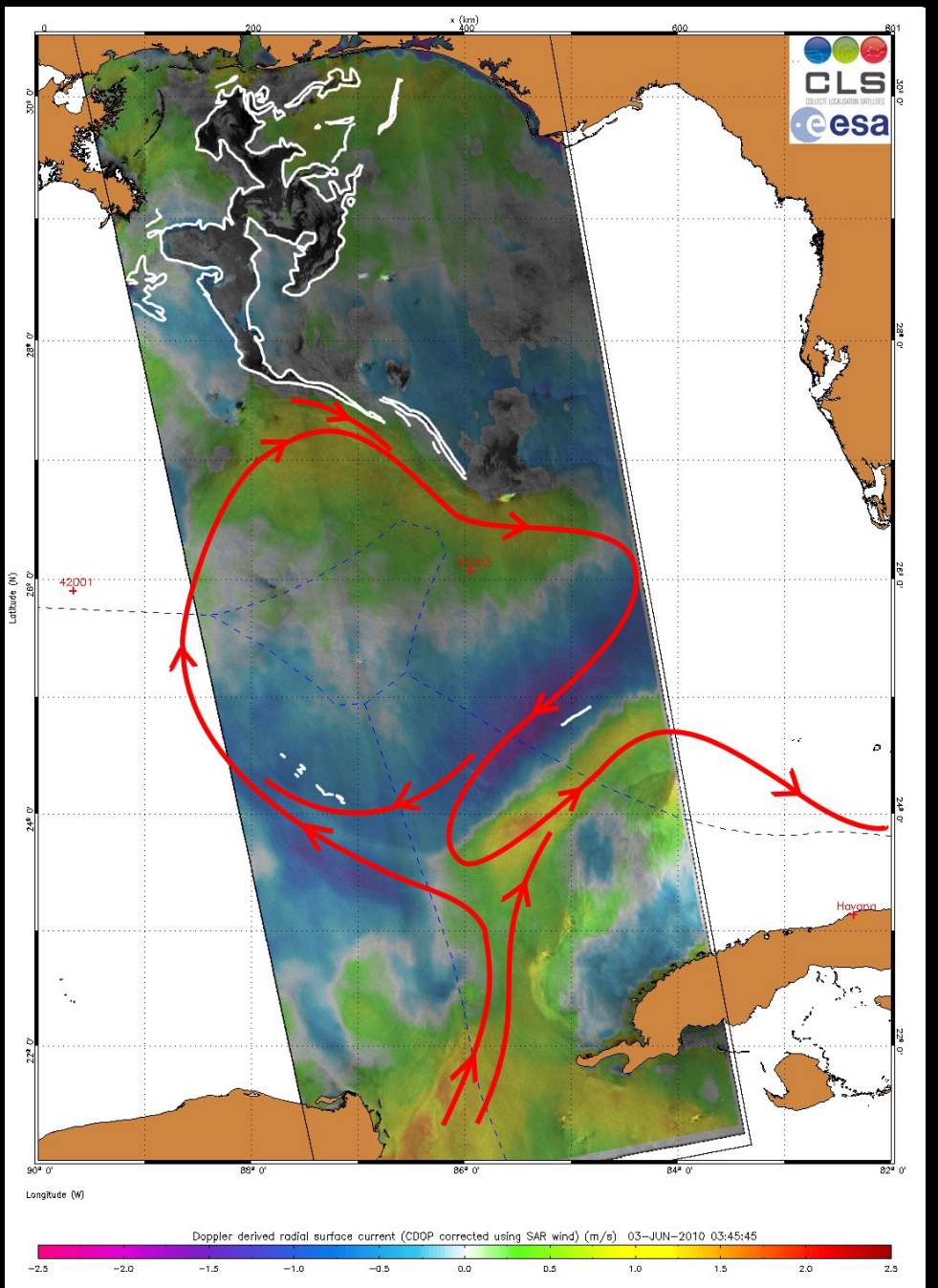
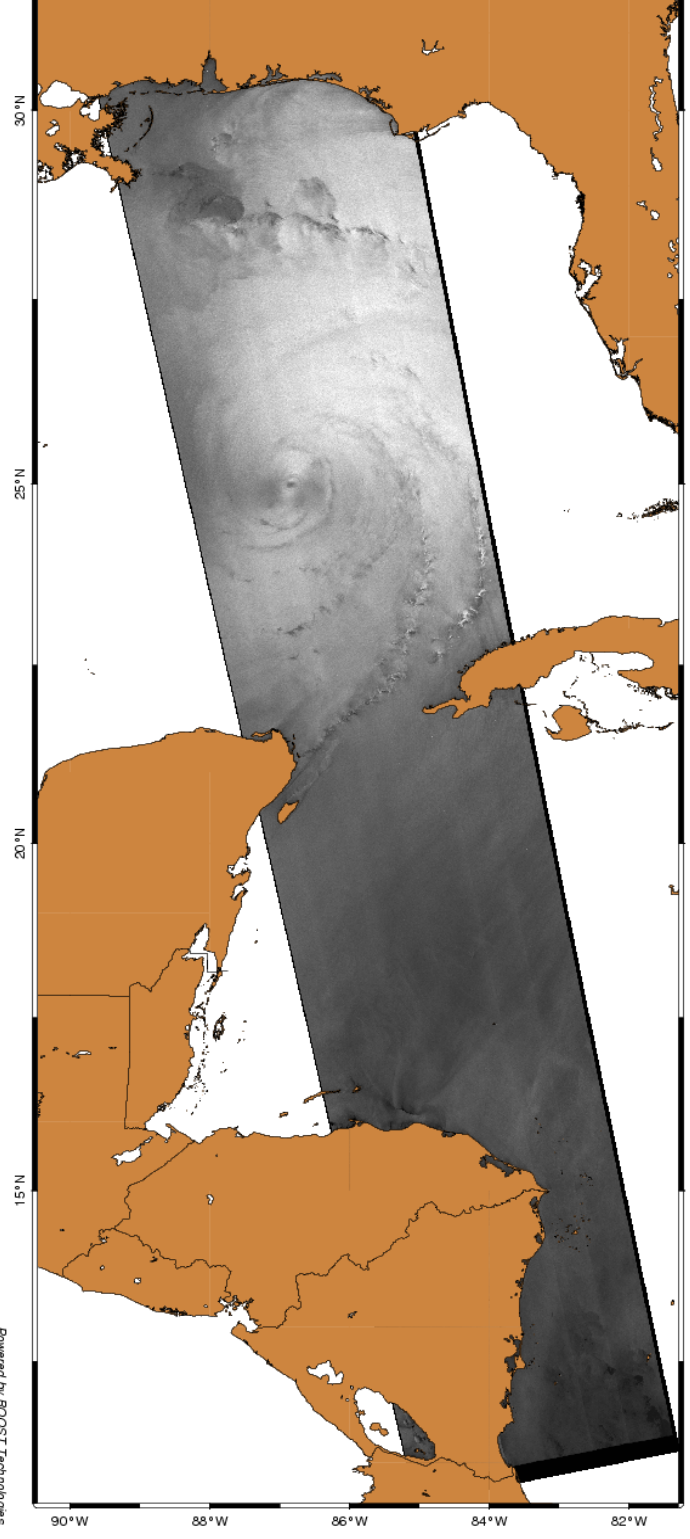
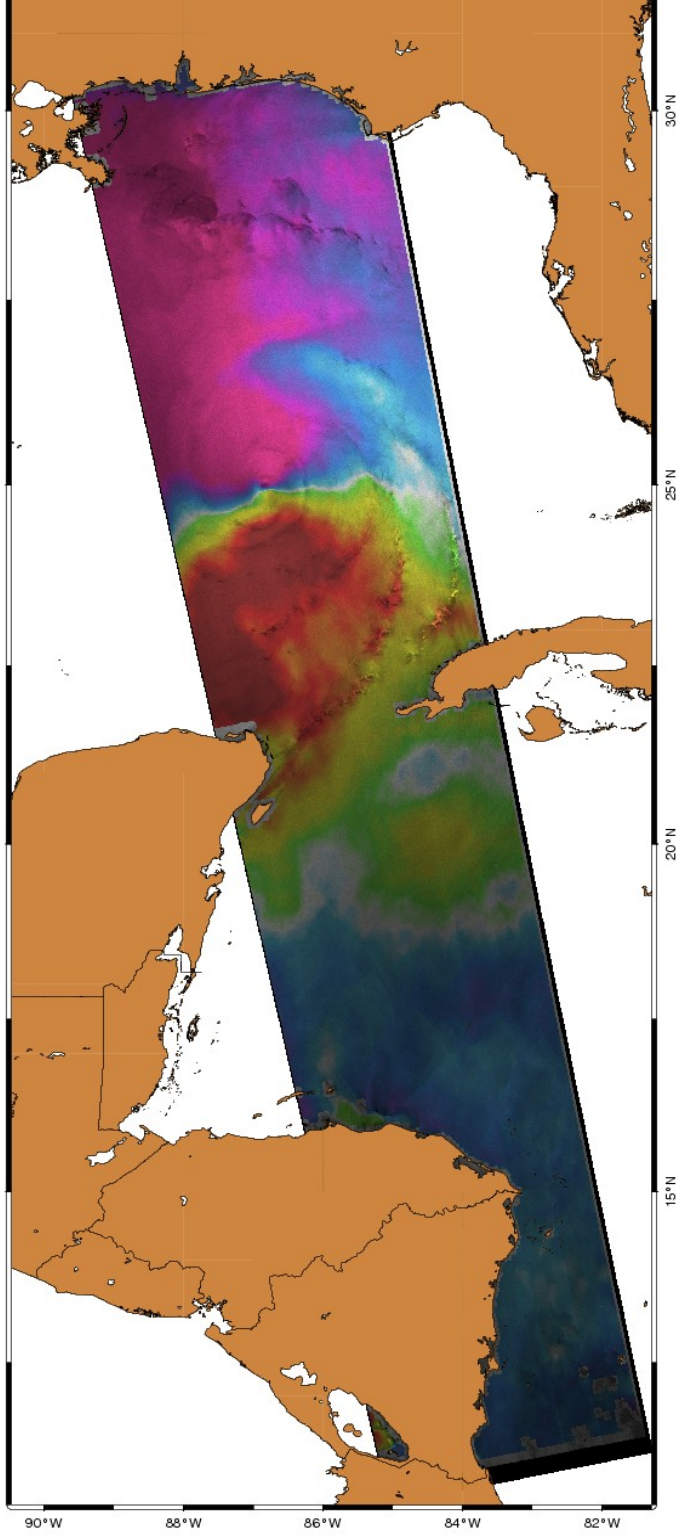
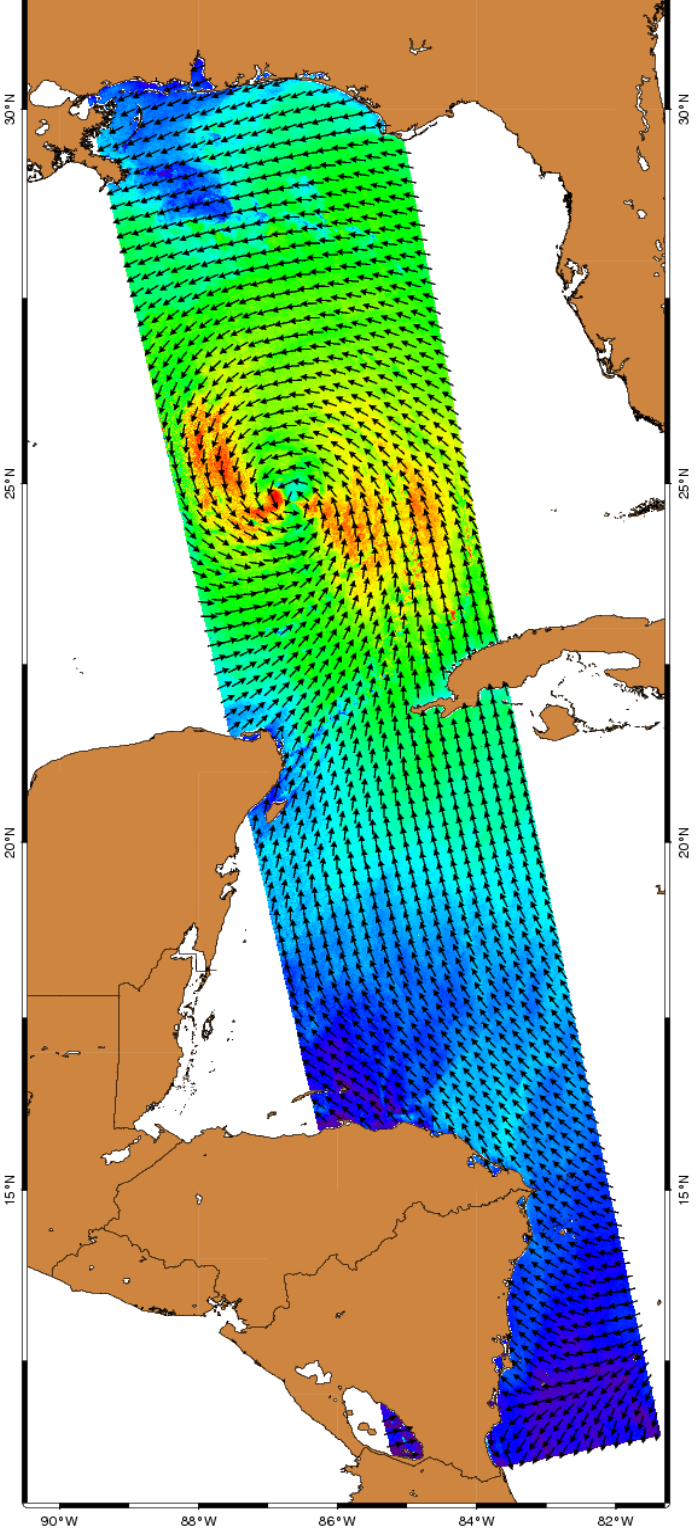




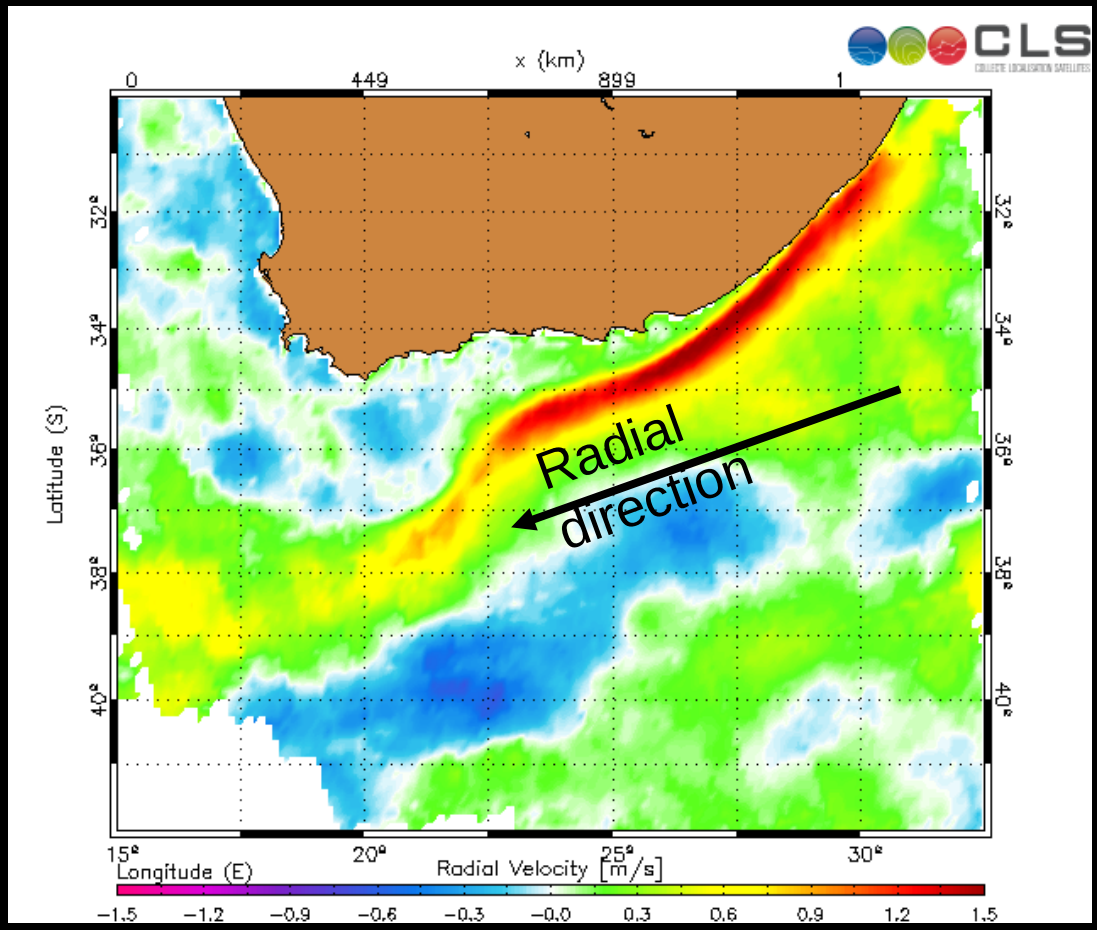


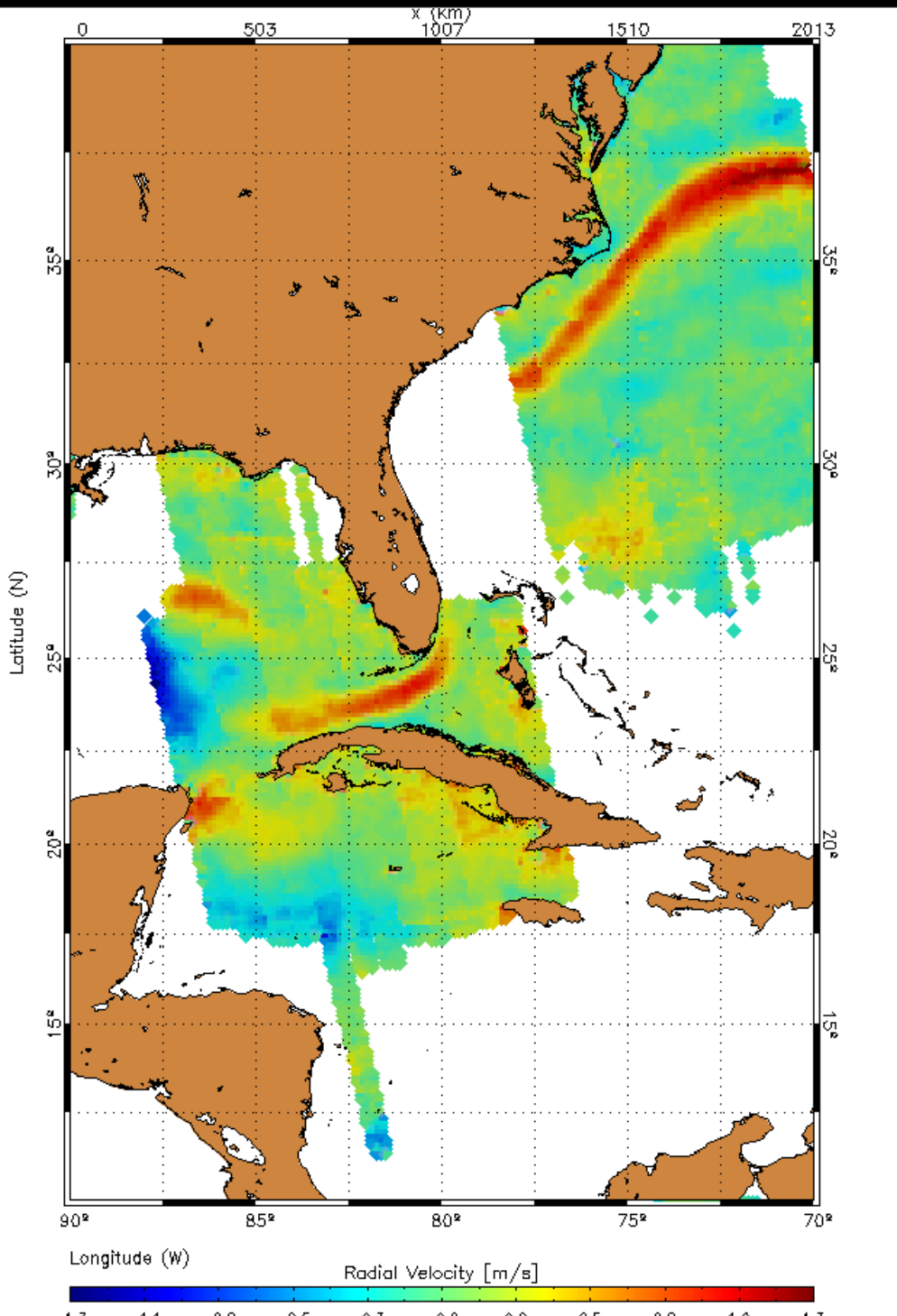


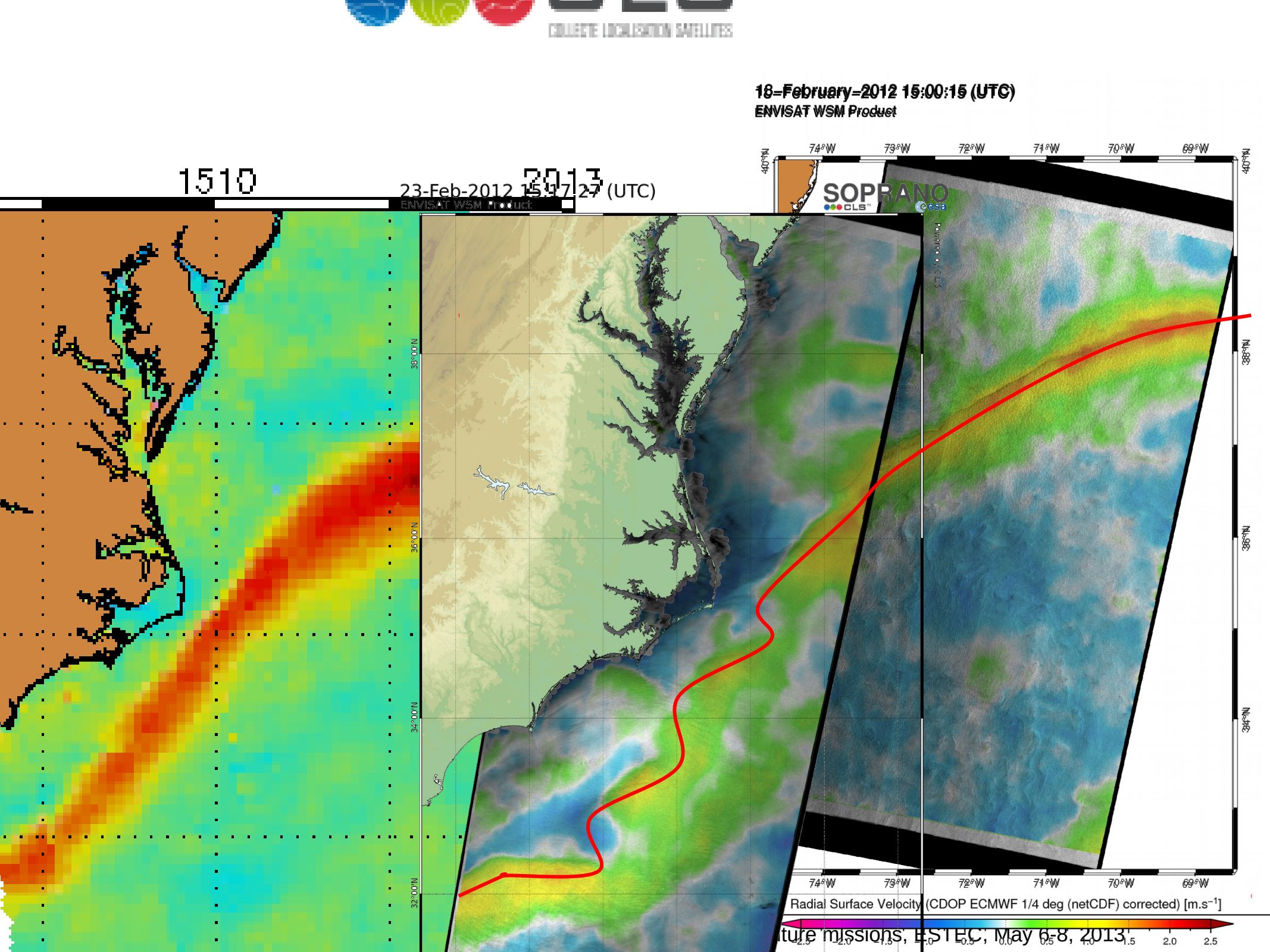


2013 ESTEC : Ocean current from space

Annual mean over Agulha
and Gulf stream
using ASAR Wide swath
ascending tracks



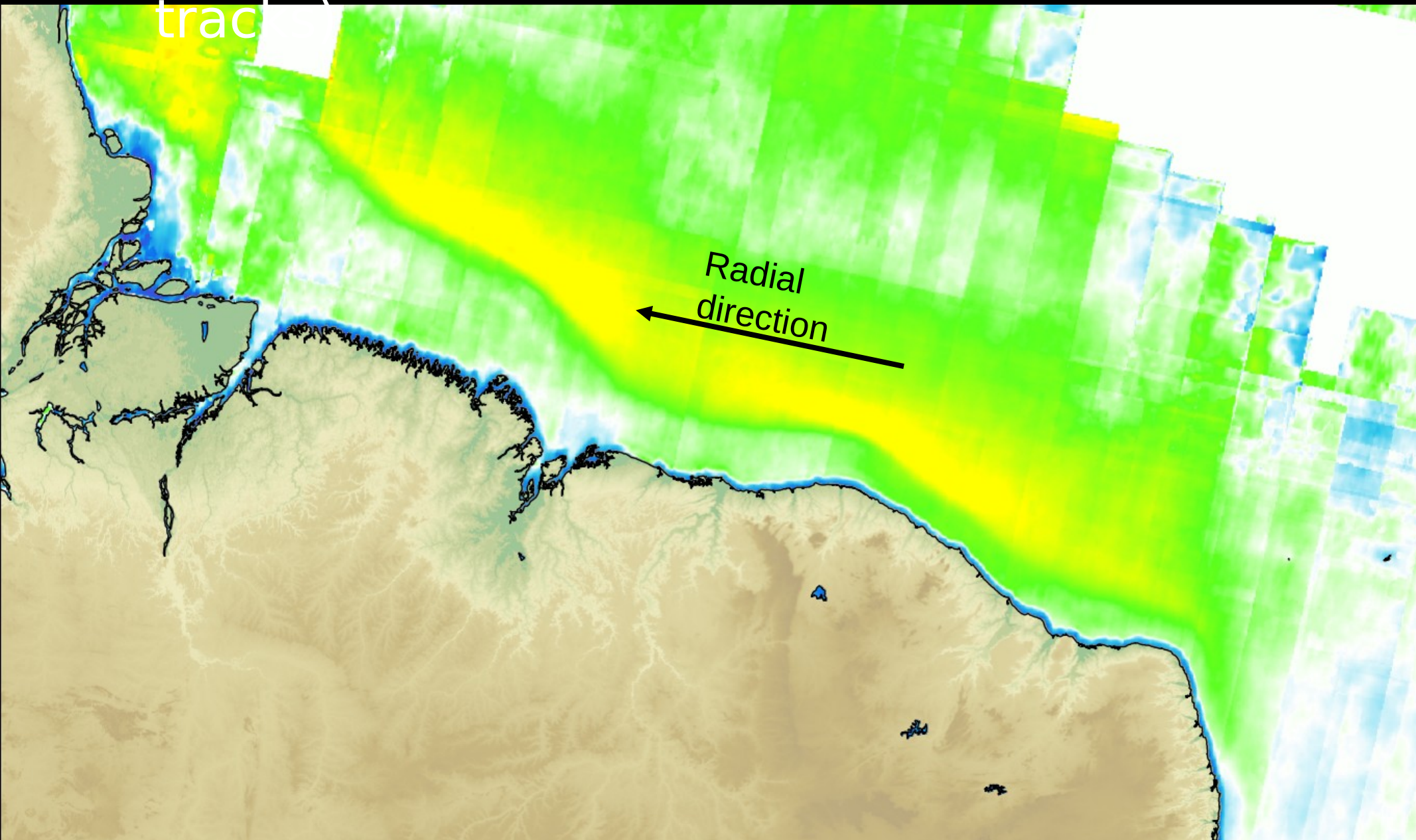




ture missions, ESTEC, May 6-8, 2013

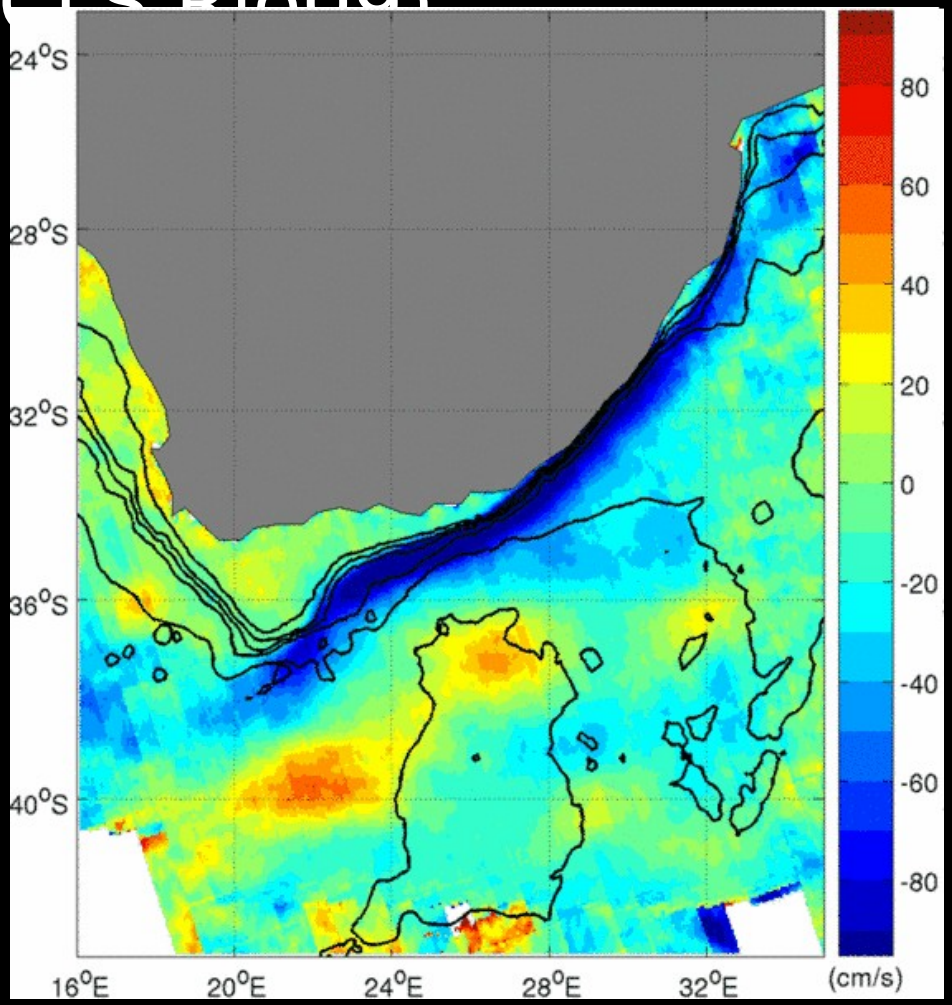
2013 ESTEC : Ocean current from space

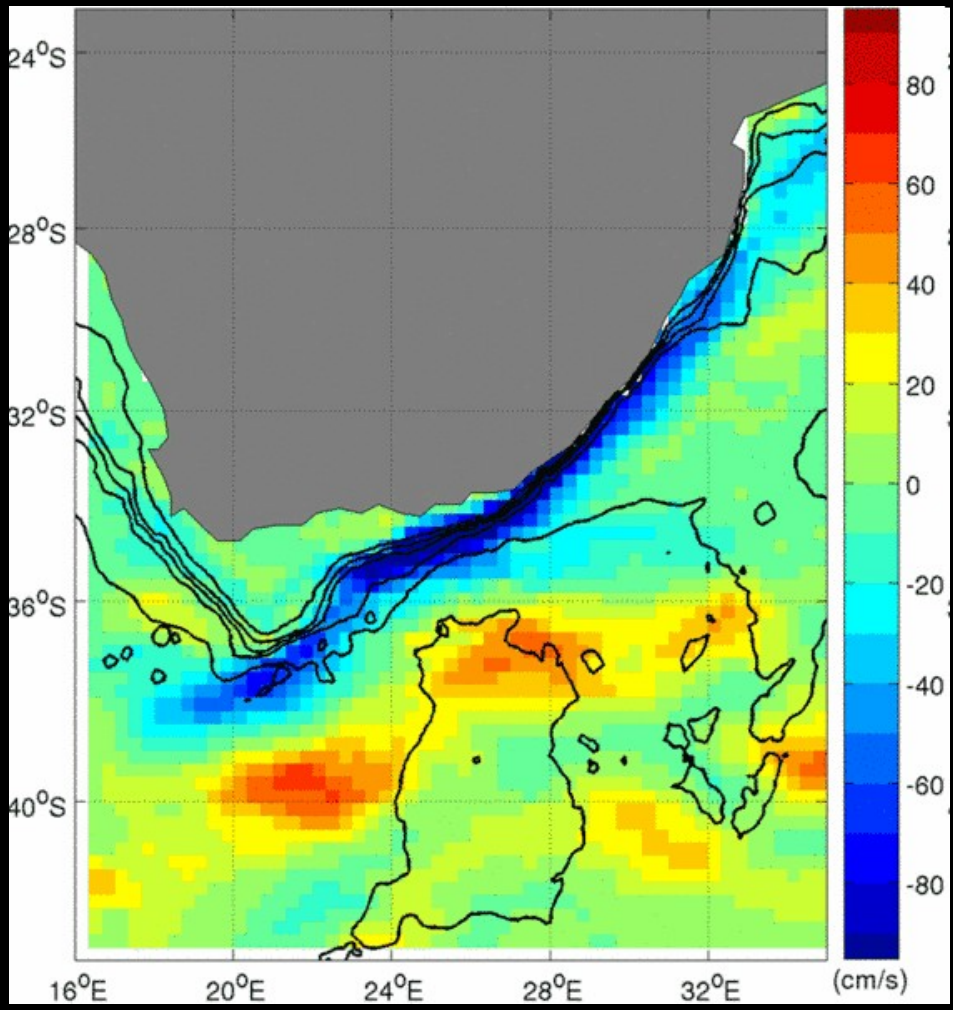
North Brazilian current (Descending track)



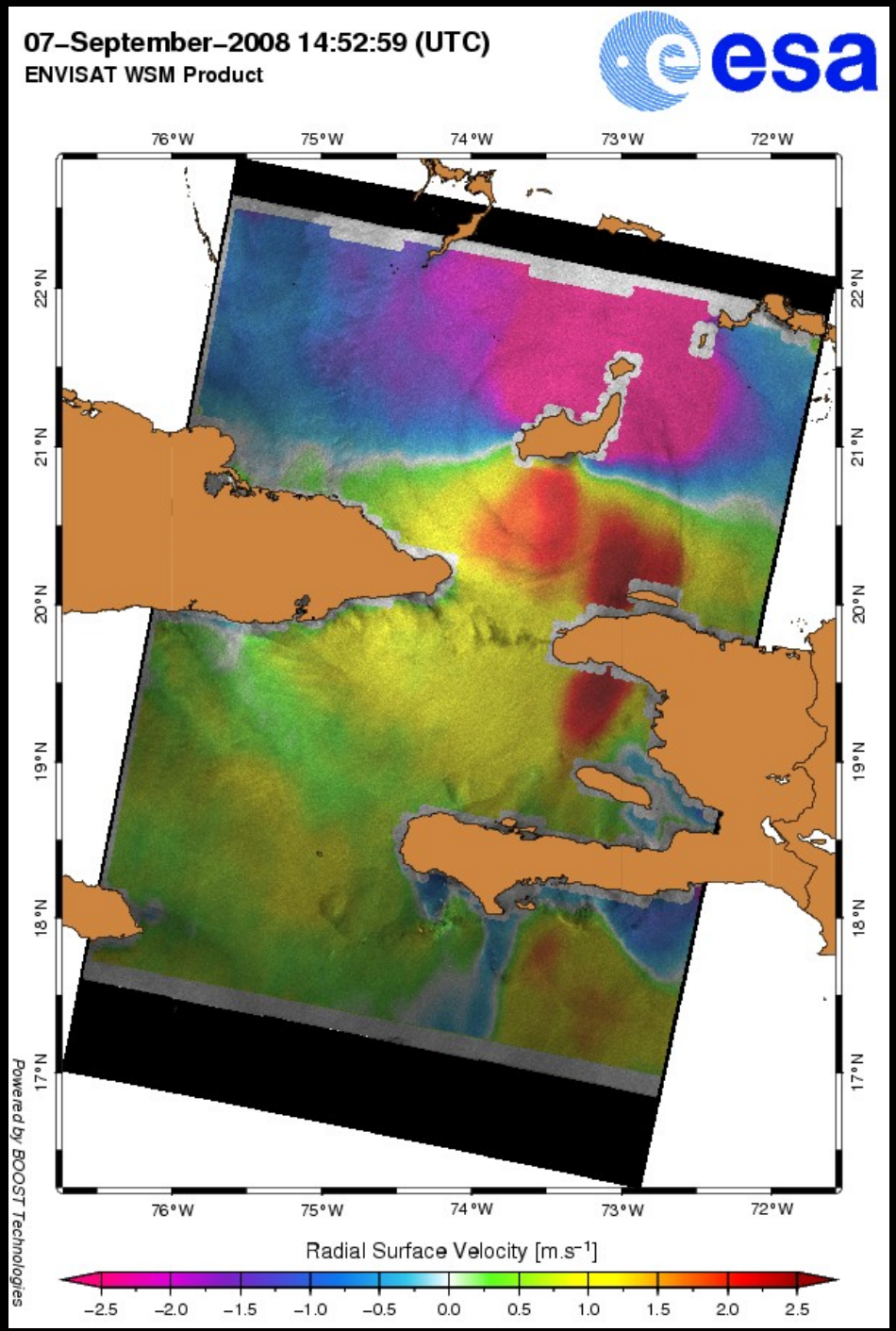
2013 ESTEC : Ocean current from space

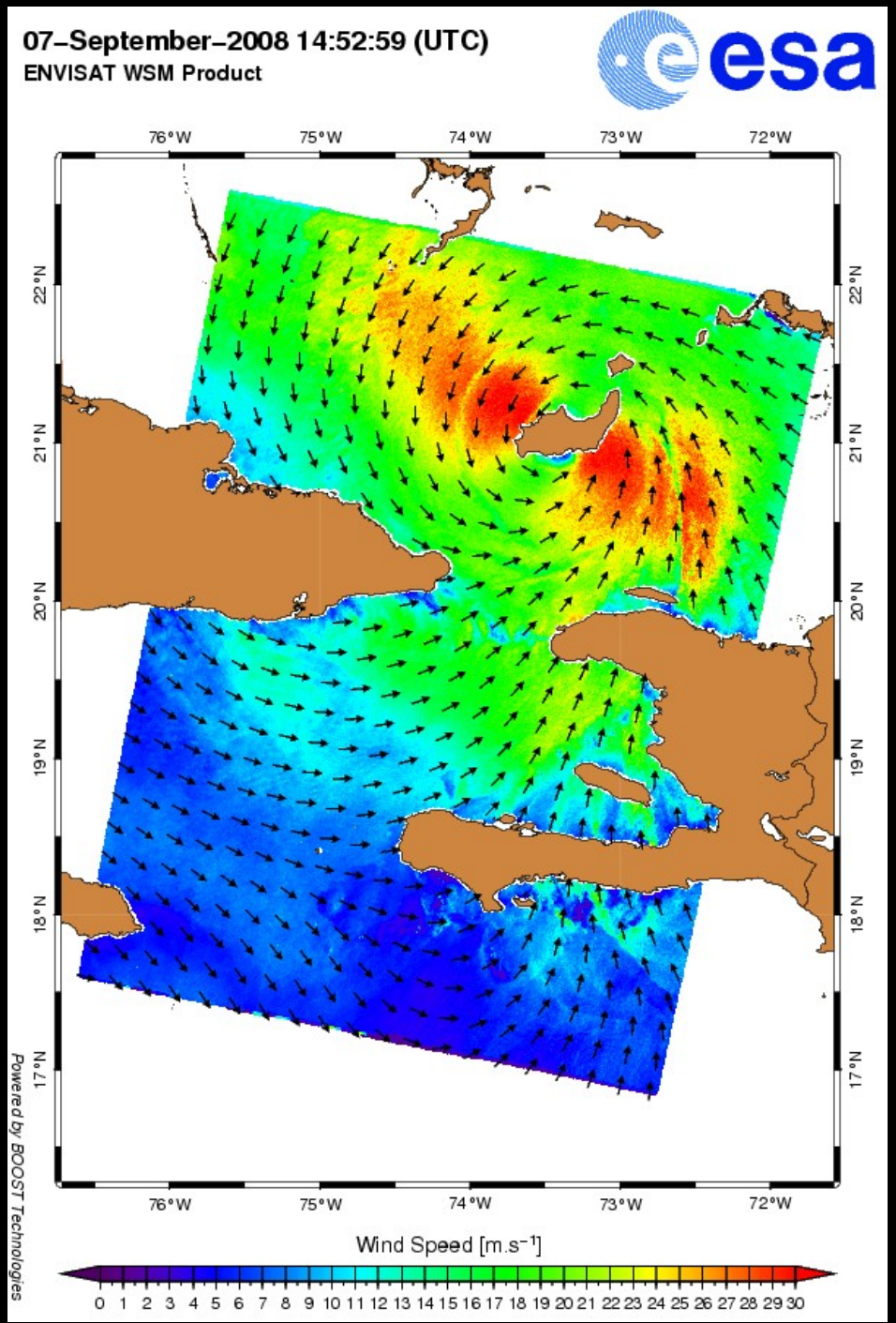
Mean radial velocity of the Agulhas current by ASAR on Envisat (left, 2007-2009 mean) and by altimetry (right, Mean Dynamic Topography CNES/CLS Rio09)



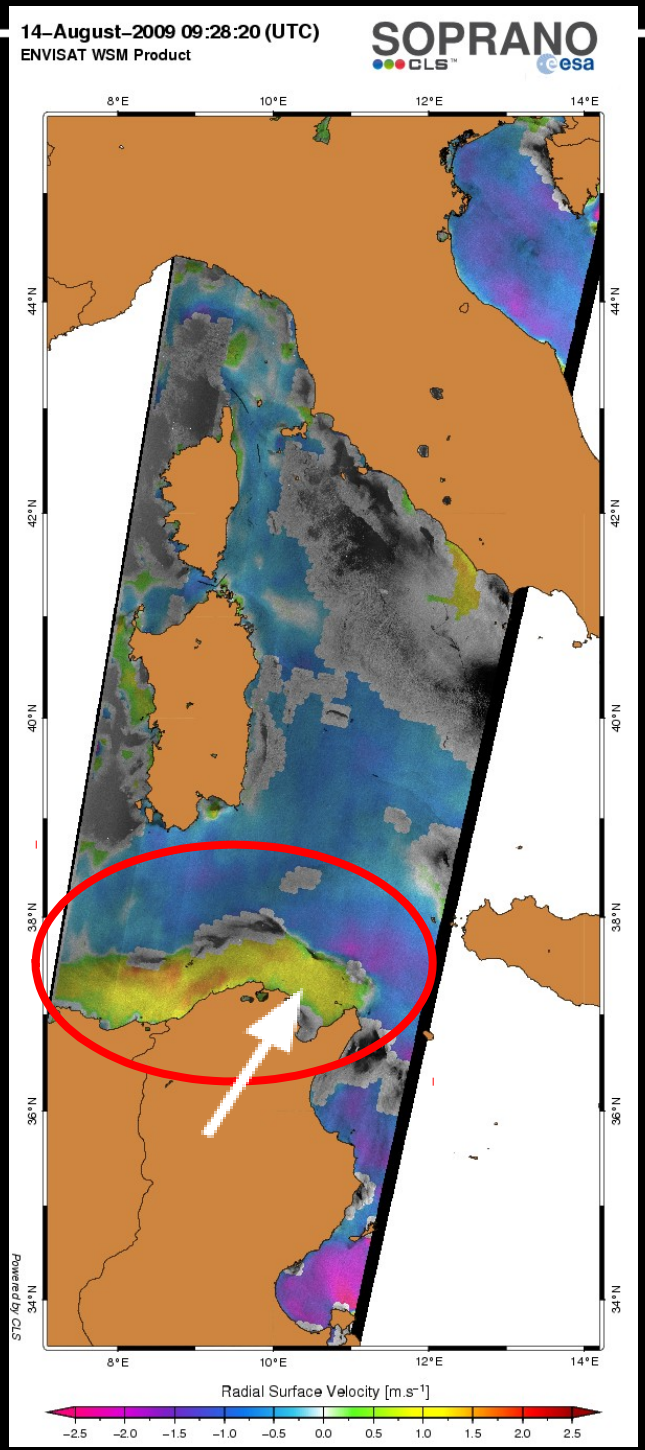


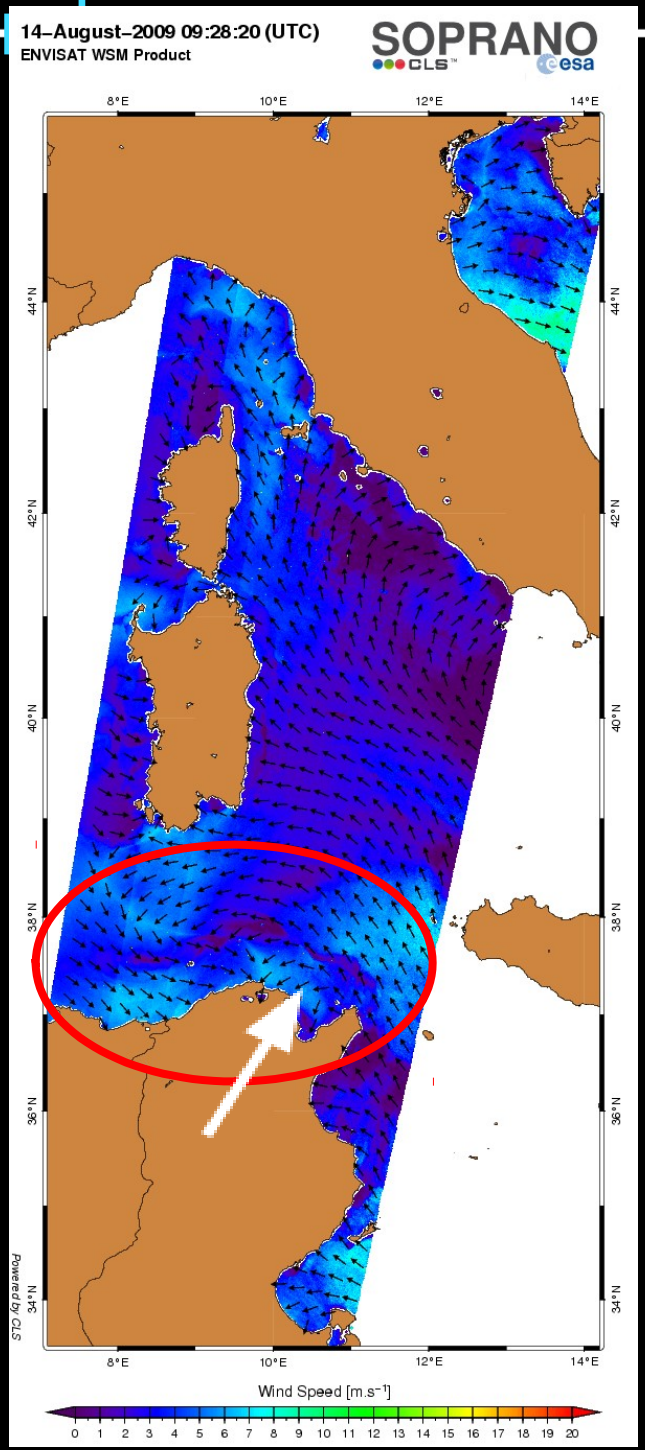
2010 IOVWST Barcelona : Doppler velocities vs. SAR wind



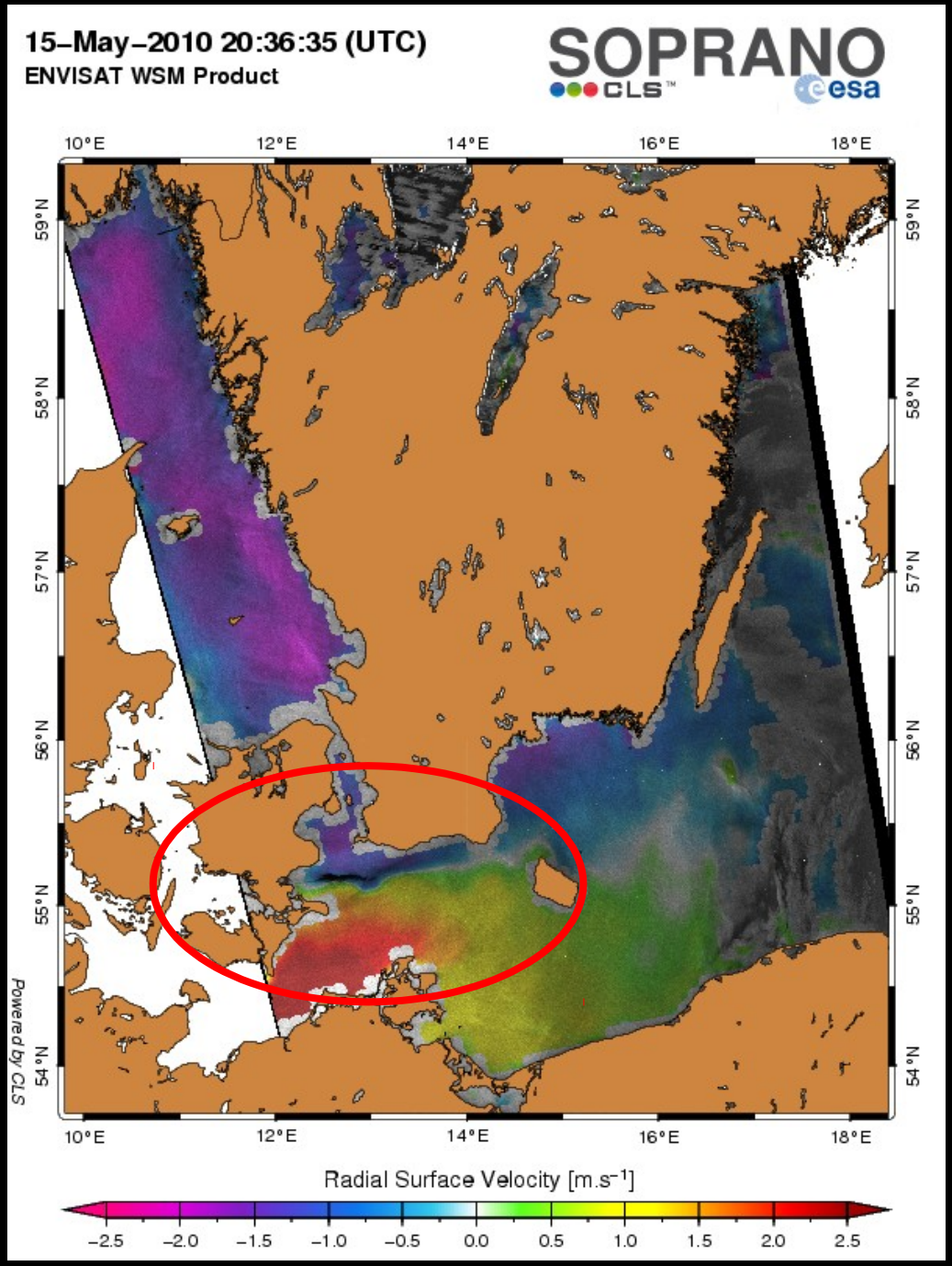


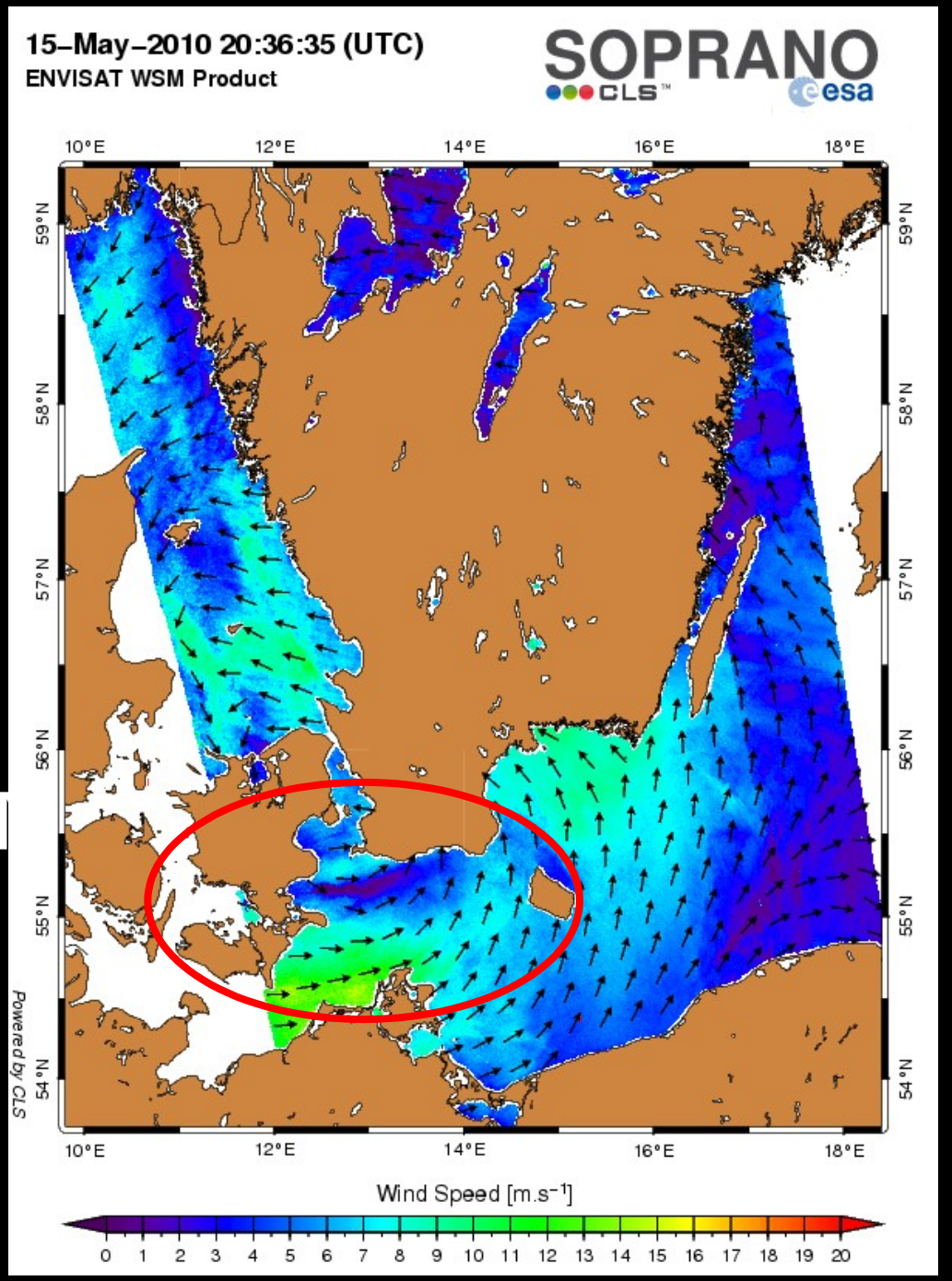
2010 IOVWST Barcelona : Doppler velocities vs. SAR wi



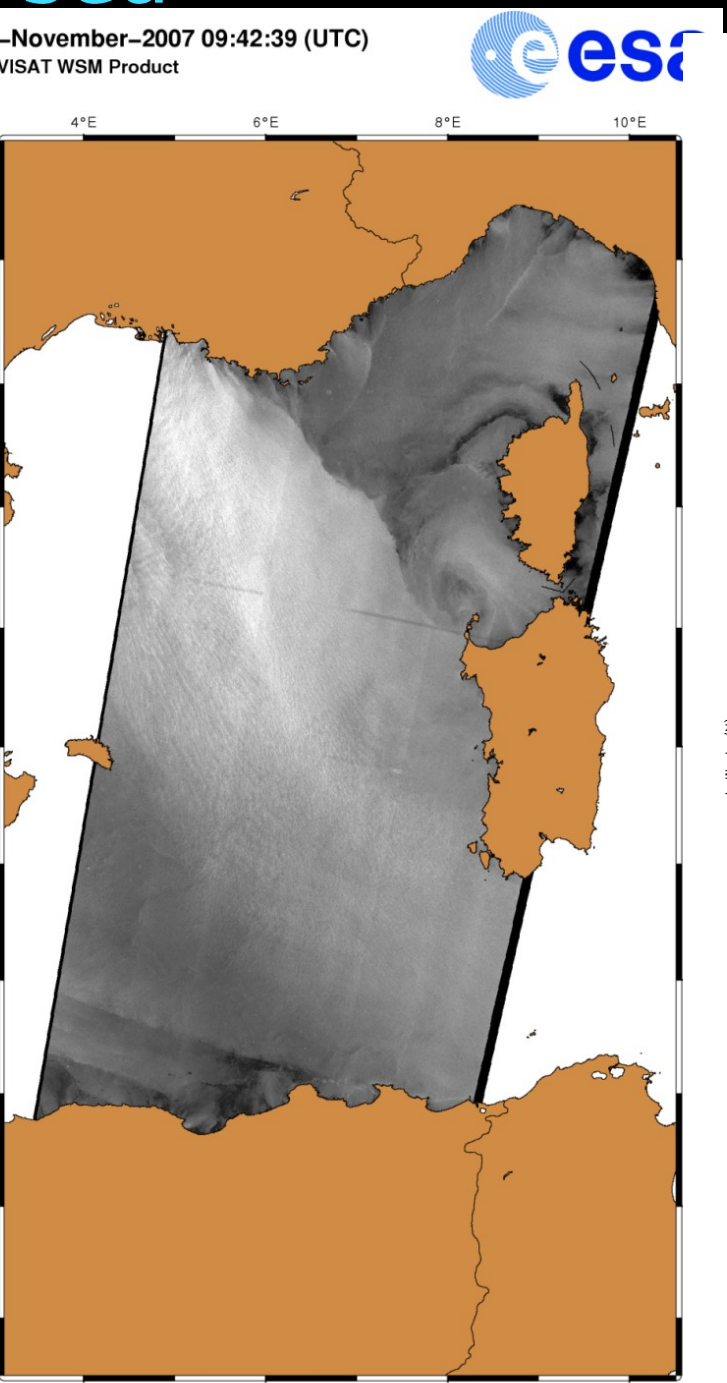


2010 IOVWST Barcelona : Doppler velocities vs. SAR wind

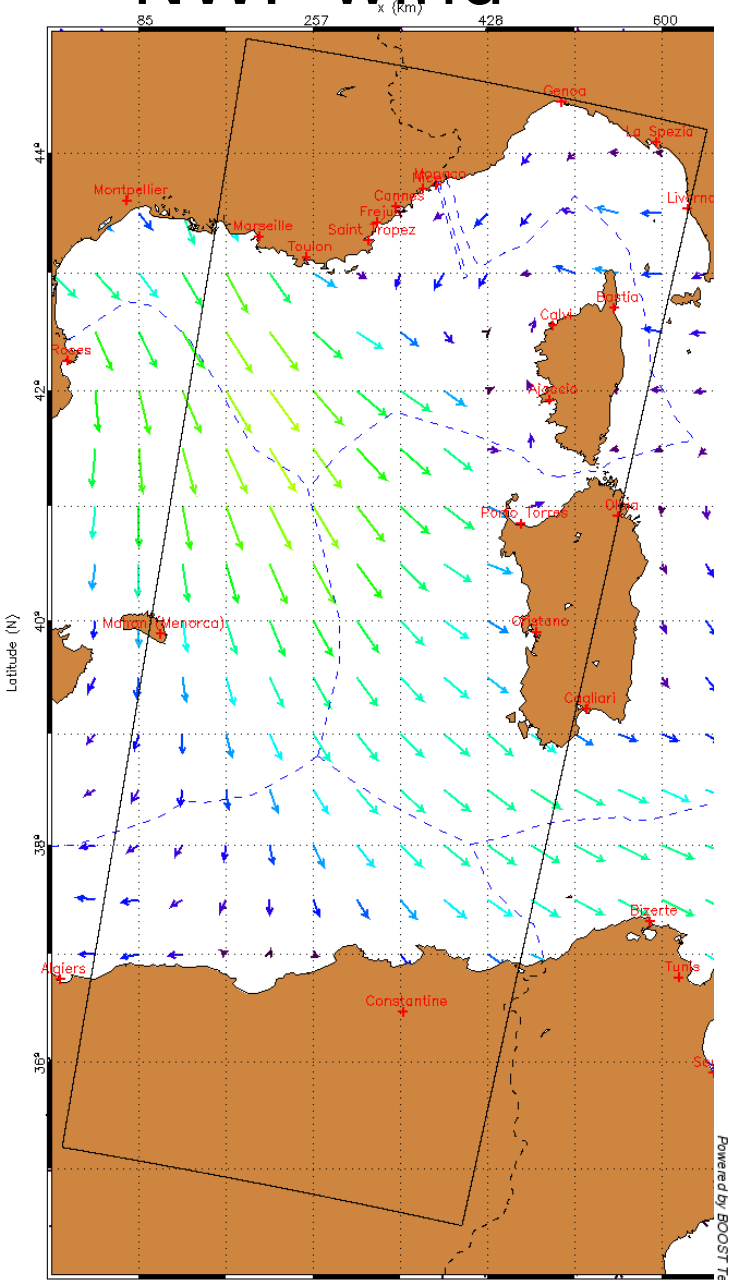


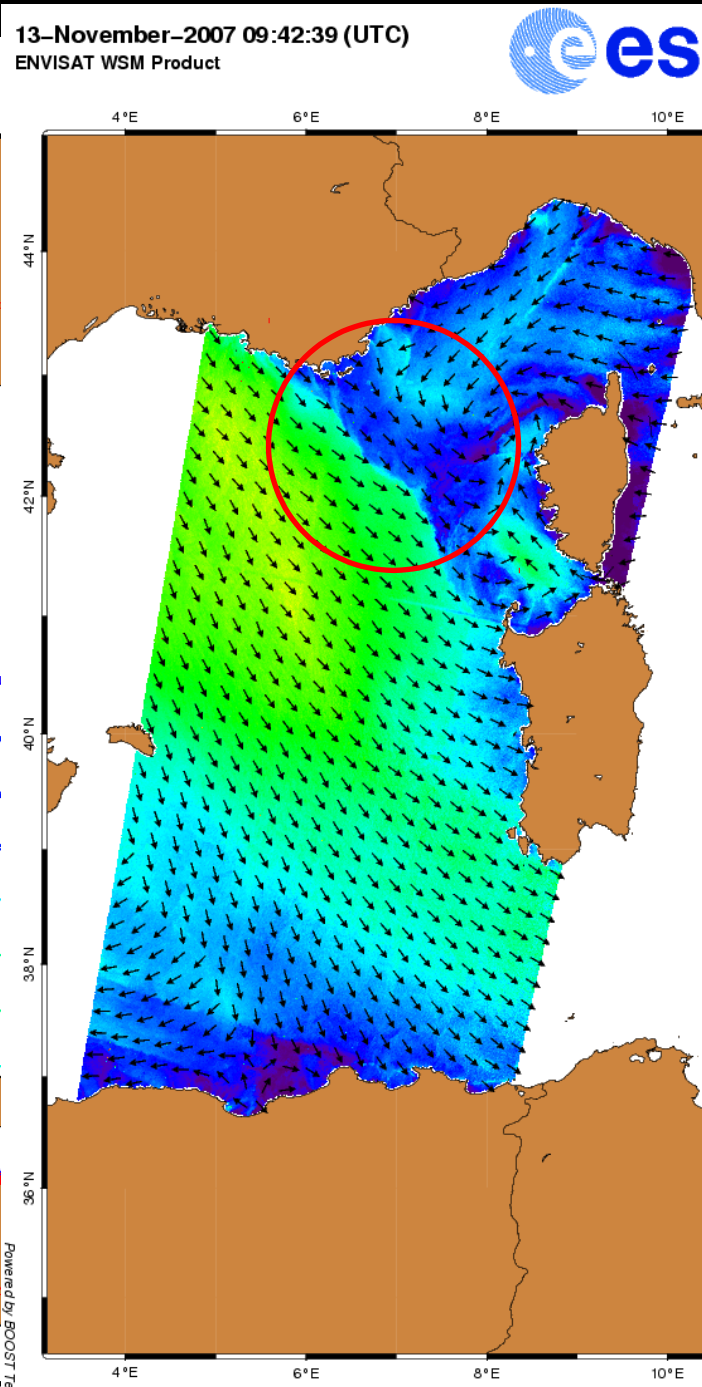


Case analysis : atmospheric front in the med sea



NWP wind

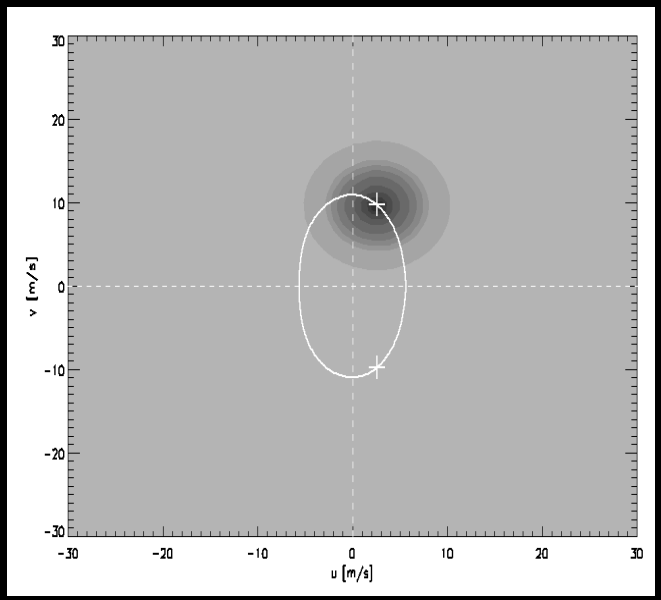




Bayesian Wind inversion scheme using Doppler

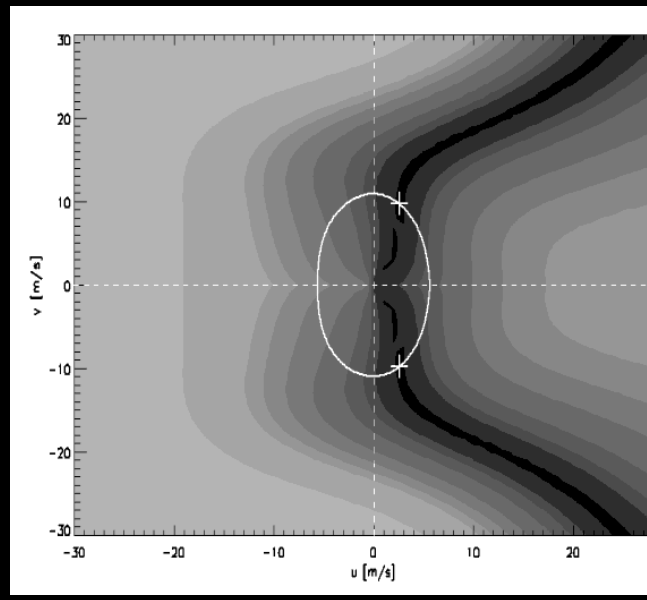
Bayesian scheme to combine SAR observation(s) with a priori ancillary information and its associated uncertainties.

$\{u,v\} = GMF^{-1}(NRCS,\varphi)$, where $\varphi \in [0,360]$ °



NRCS with NWP MODEL

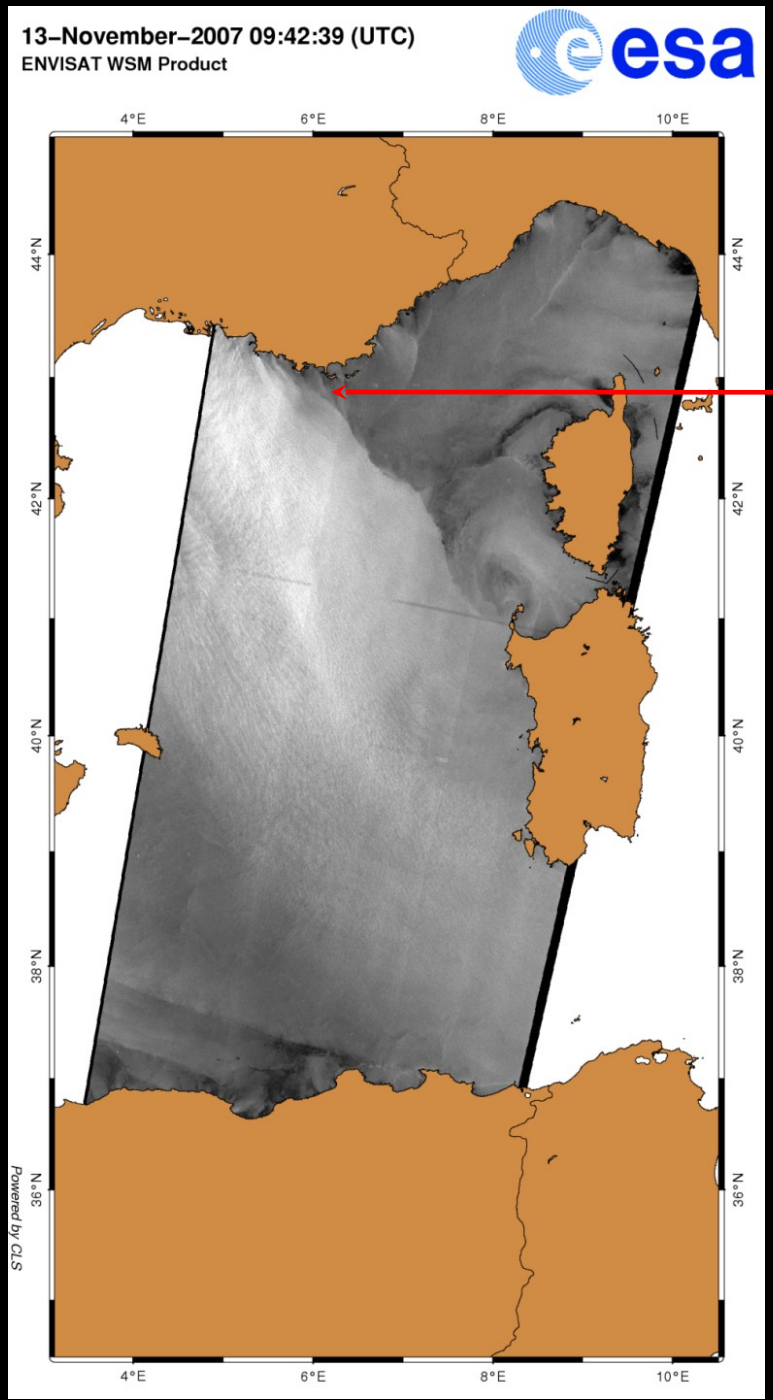
NRCS with DOPPLER

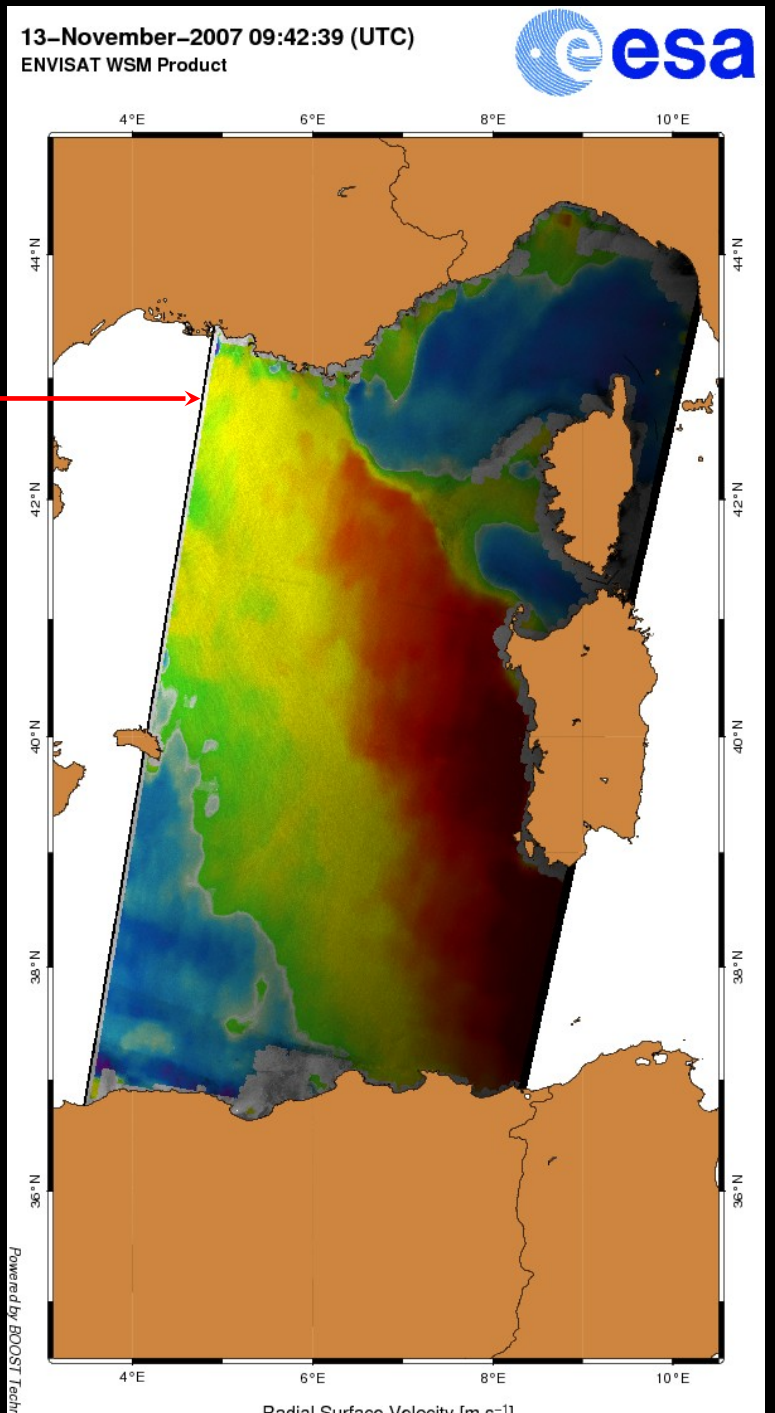


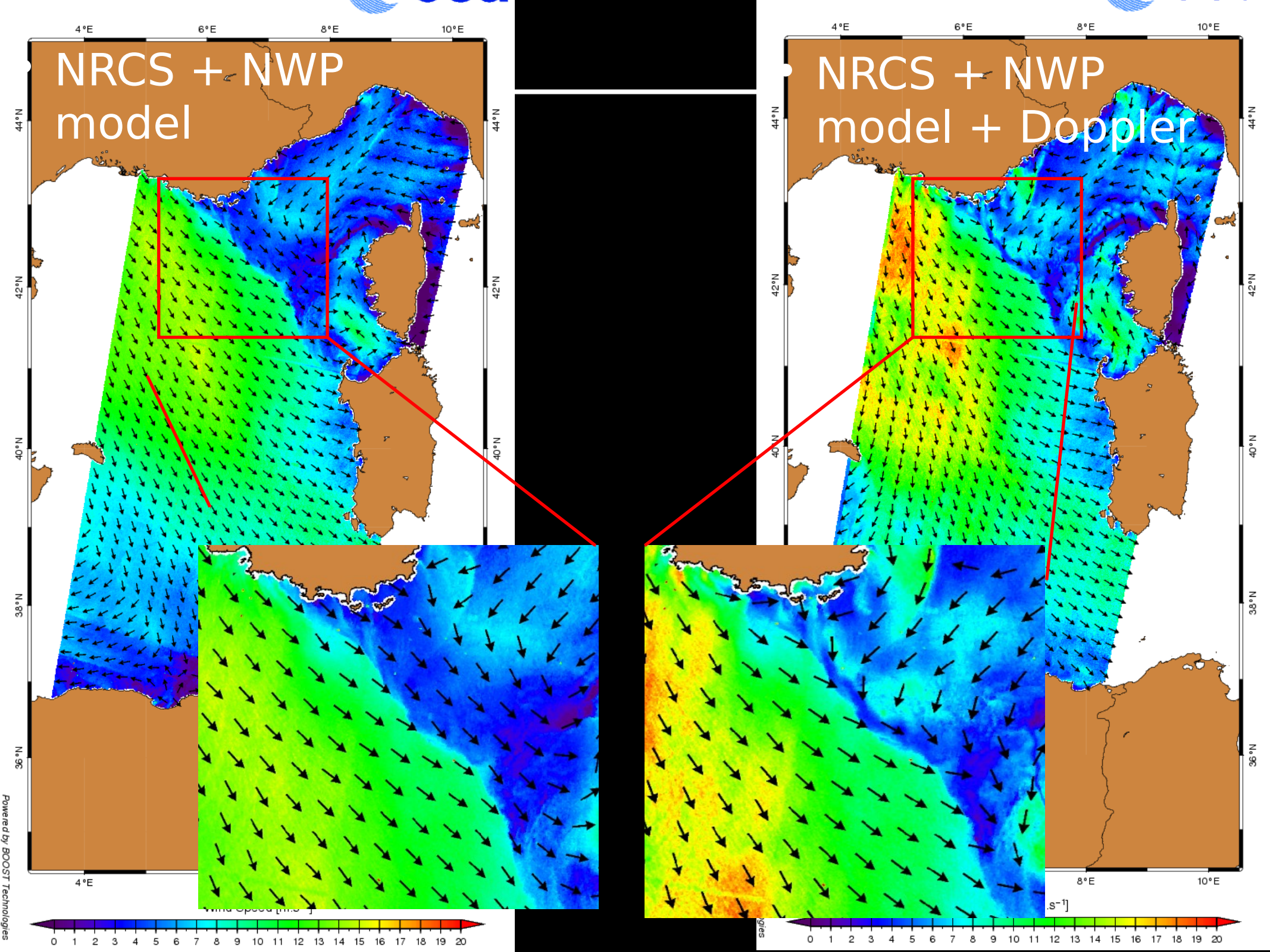
$$J = \left(\frac{u_b - v}{\Delta u}\right)^2 + \left(\frac{v_b - v}{\Delta v}\right)^2\Bigg|_{\{u,v\}\in\mathcal{G}_{SAR}}$$

$$J = \left(\frac{f_{CDOP}^{D_{ca}}(\theta,\phi) - f^{D_{ca}}(\theta,\phi(u,v))}{\Delta f^{D_{ca}}}\right)^2\Bigg|_{\{u,v\}\in\mathcal{G}_{SAR}}$$

Can Doppler help ?

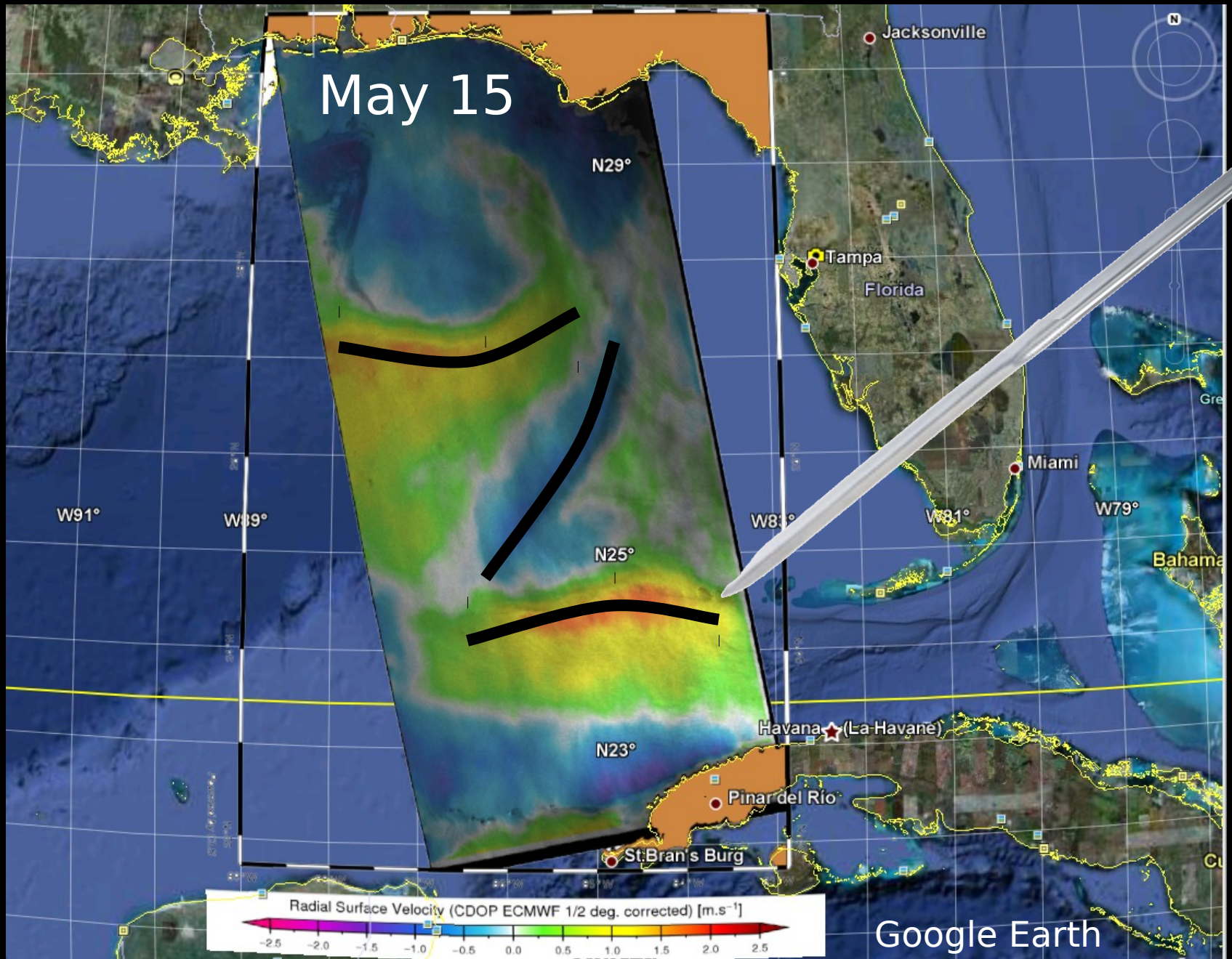





NRCS + NWP model
NRCS + NWP model + Doppler
4°E
6°E
8°E
10°E
44°N
42°N
40°N
38°N
36°N
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Powered by BOOST Technologies

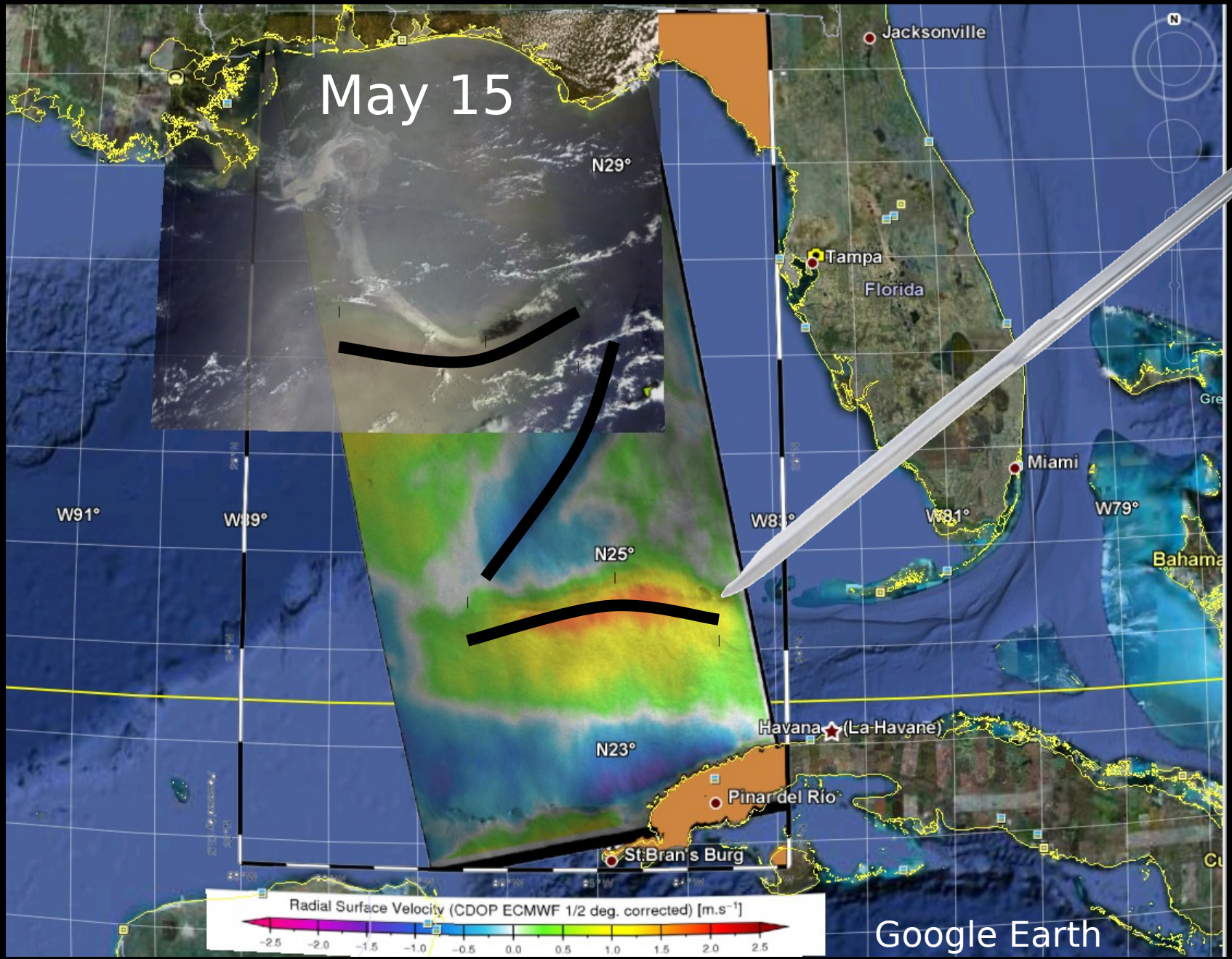
Combined retrieval of Winds and Surface Currents

SWath Ocean Radar Doppler



Combined retrieval of Winds and Surface Currents

SWath Ocean Radar Doppler



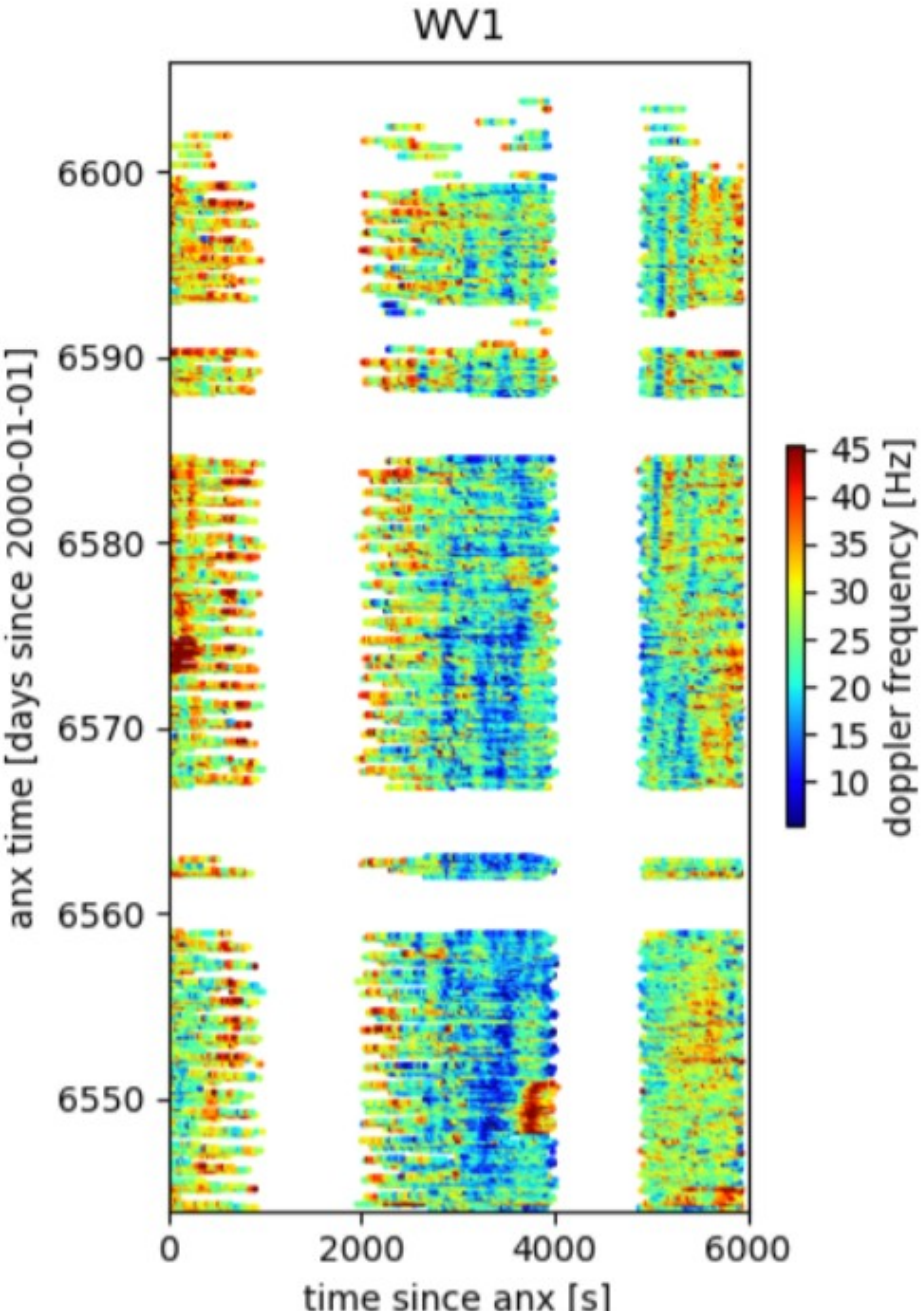
ENVISAT ASAR : Lessons learned

Lessons from ENVISAT ASAR :

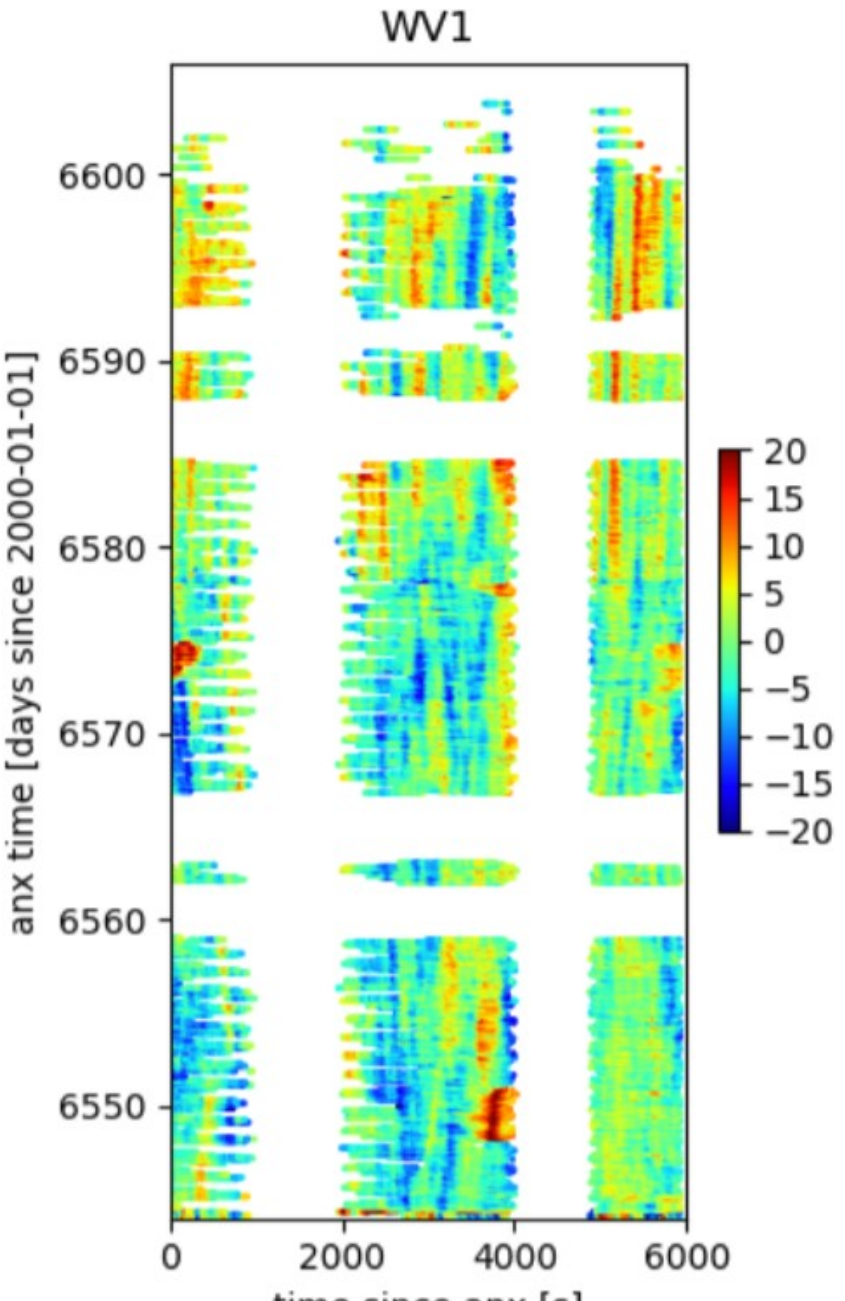
1. SAR Doppler correlates with radial wind speed -> CDOP
2. Electronic misspointing of active antenna is elevation dependant and evolves slowly with TR modules health.
3. Pointing knowledge is of critical importance for Doppler calibration
4. If no good attitude information is available, slow attitude variations can be propagated from land measurements

Sentinel-1 Doppler calibration issue

Observed geometric Doppler

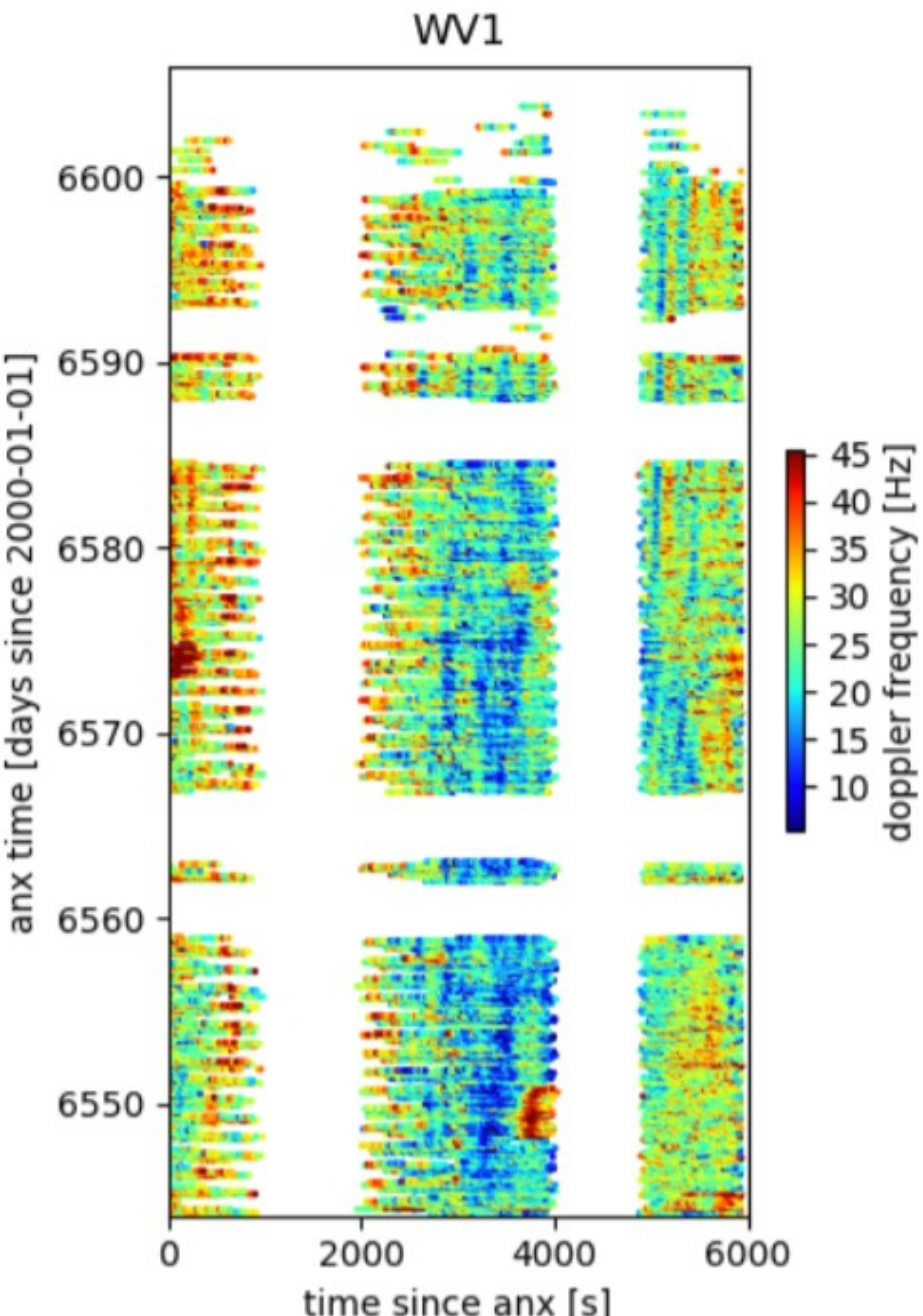


On ground Restituted attitude Doppler

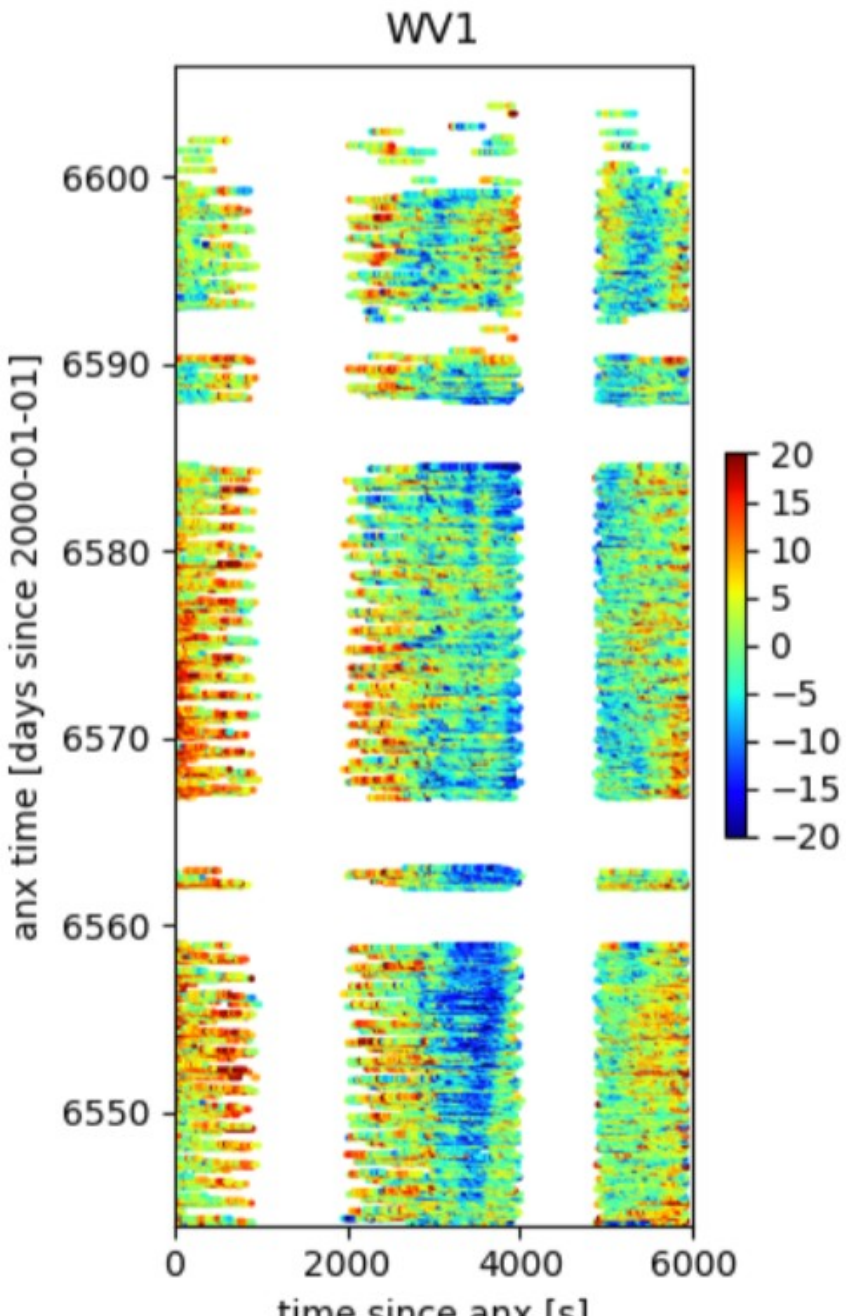


Sentinel-1 Doppler calibration issue

Observed geometric Doppler

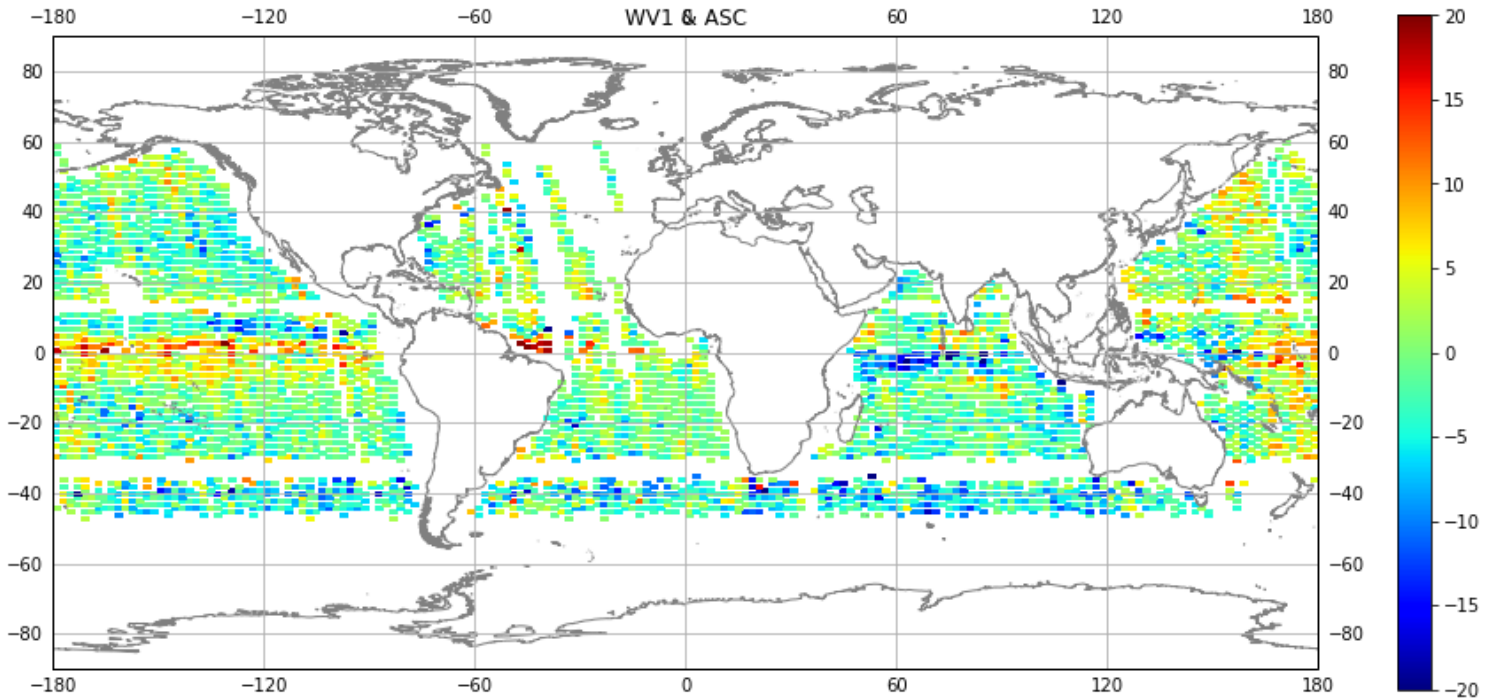


Residual geometric Doppler

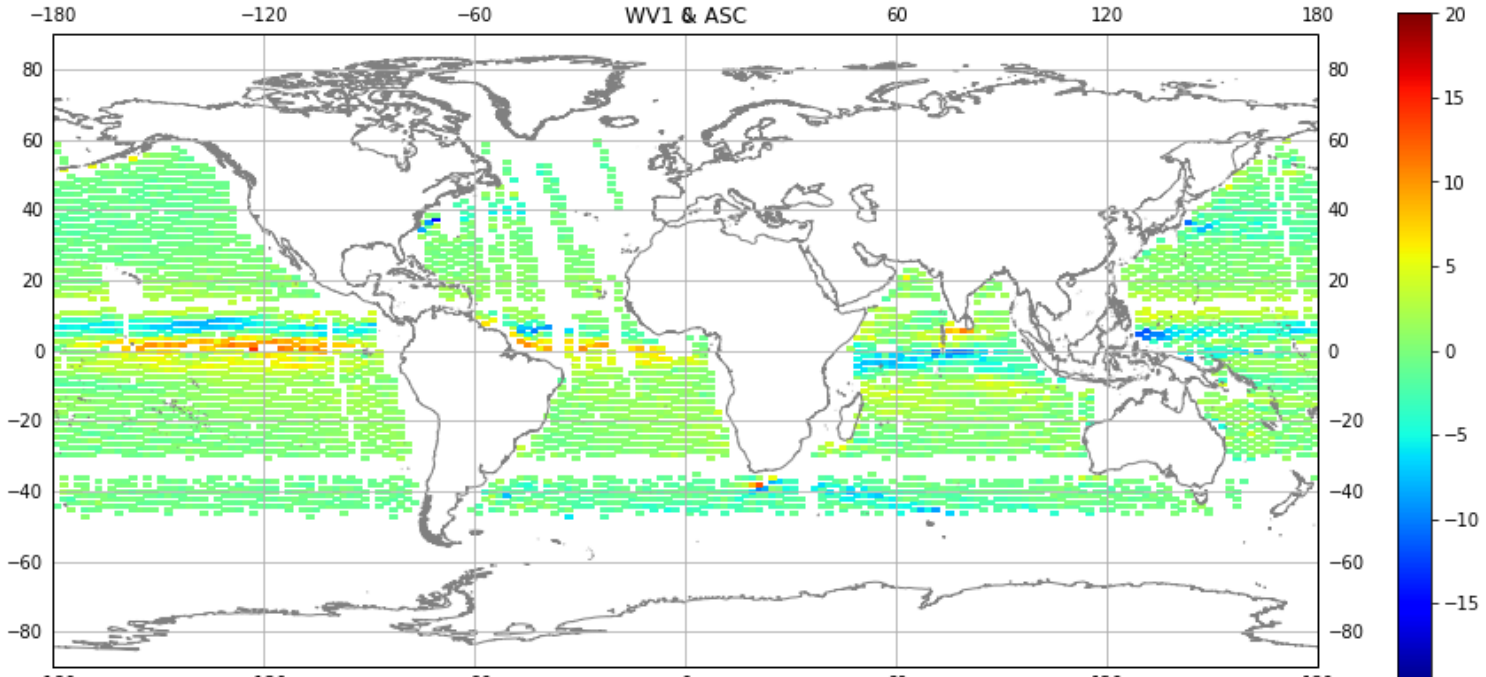


Sentinel-1 Doppler calibration issue

Doppler residual calibrated from neighbouring orbits land data. for two month of Sentinel-1B early 2018

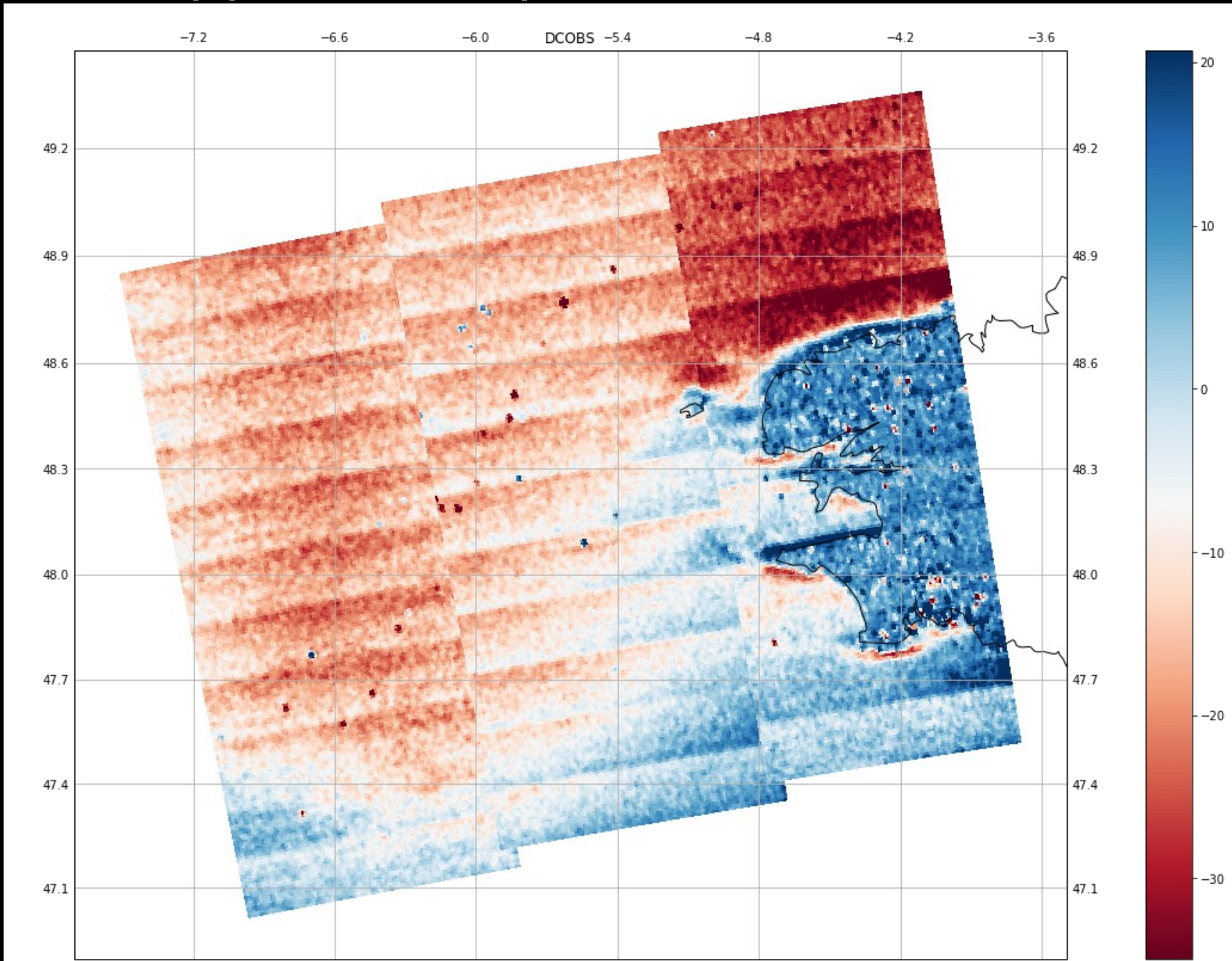


Drifter climatology



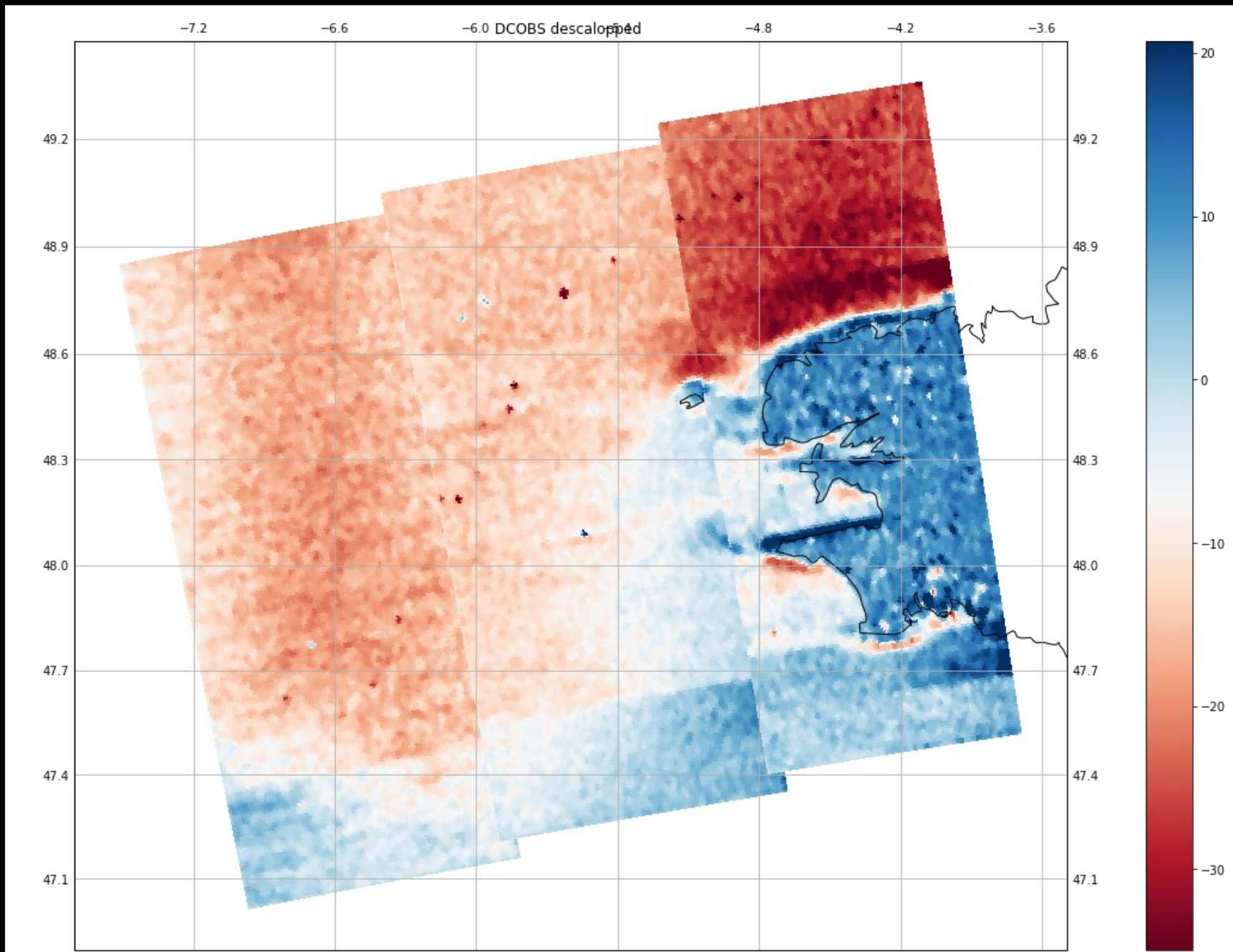
Sentinel-1 Doppler calibration issue

Wide swath Doppler : RVL product



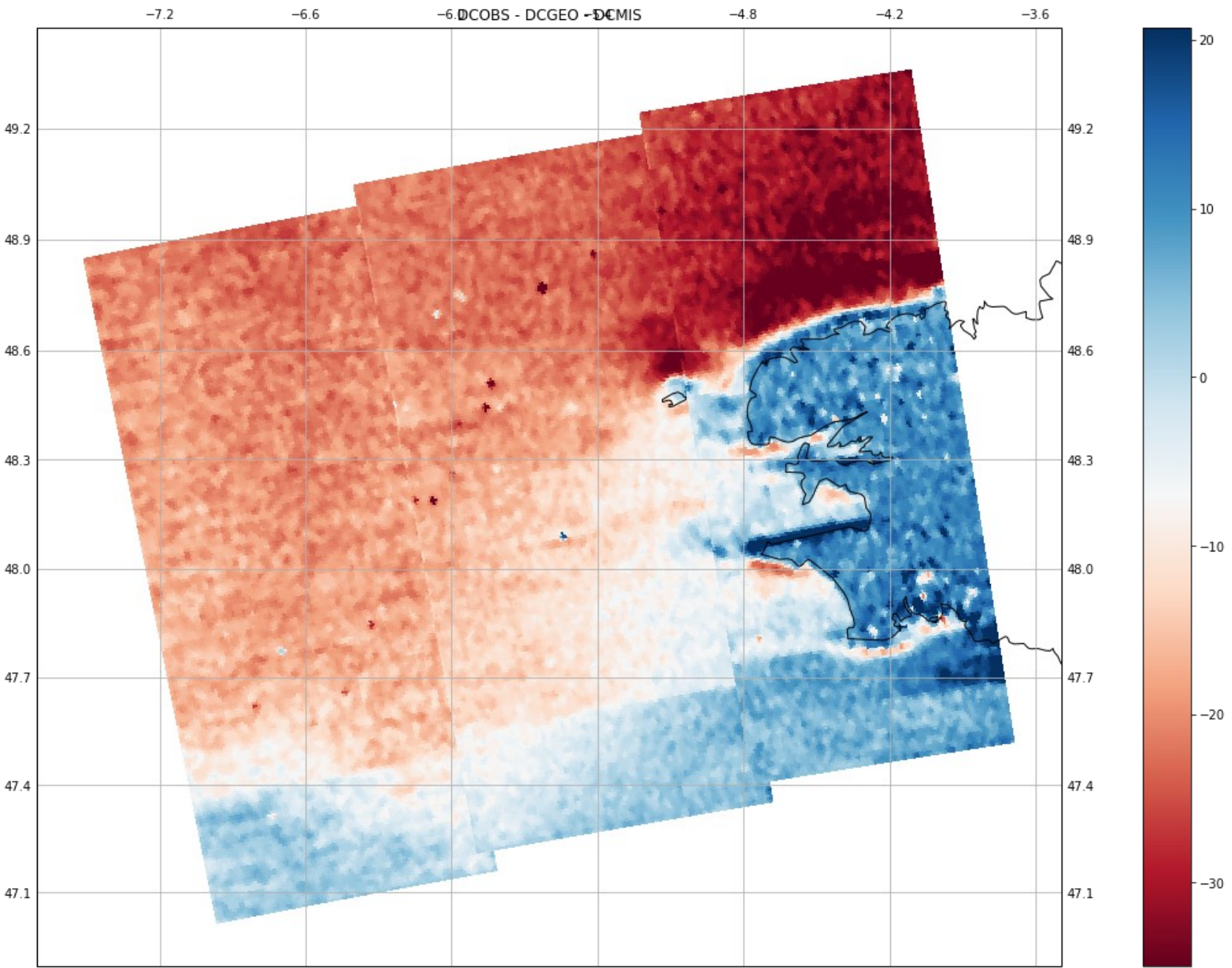
Sentinel-1 Doppler calibration issue

Wide swath Doppler : After descalopping



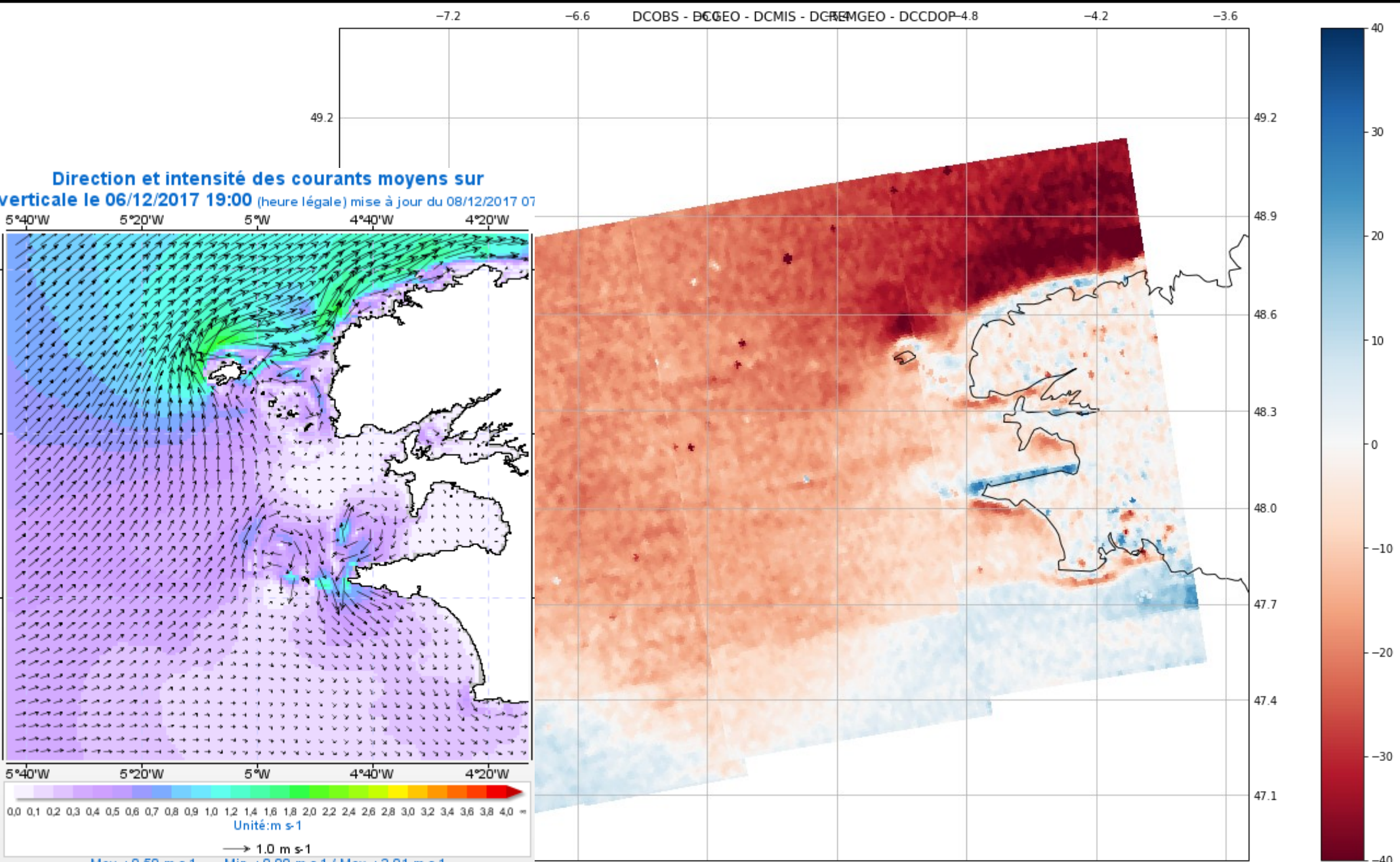
Sentinel-1 Doppler calibration issue

Wide swath Doppler : After electronic misspointing



Sentinel-1 Doppler calibration issue

Wide swath Doppler : After all corrections (including CDOP)



Sentinel-1 : Lessons learned

Lessons from Sentinel-1 :

1. Zero Doppler steering with small margin tolerance causes AOCS continuous steering at a rate too fast to be restituted by middle class star trackers in the AOCS -> need on ground processing of telemetry.

2. Miss pointing from zero Doppler steering observed on land data is very reproductible from one orbit to the next (similar field of view of star trackers) and land Doppler on neighbouring orbits can be used for Doppler calibration.