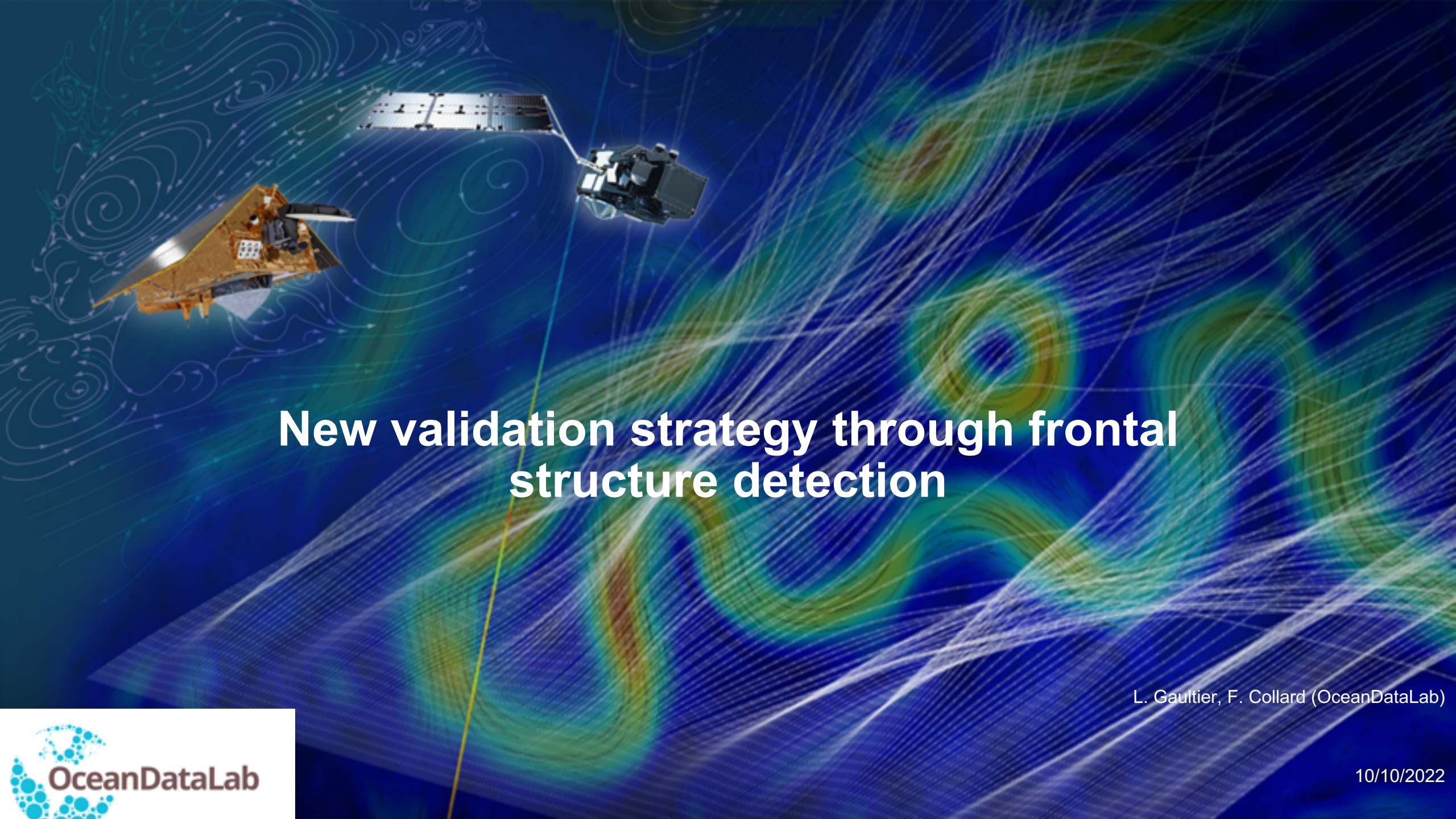


New validation strategy through frontal structure detection

L. Gaultier, F. Collard (OceanDataLab)

OceanDataLab

10/10/2022

Context

In-situ observations provide a good temporal sampling but are sparse in space and their distribution is quite heterogeneous. They are used to perform surface current validation using RMS at a given point.

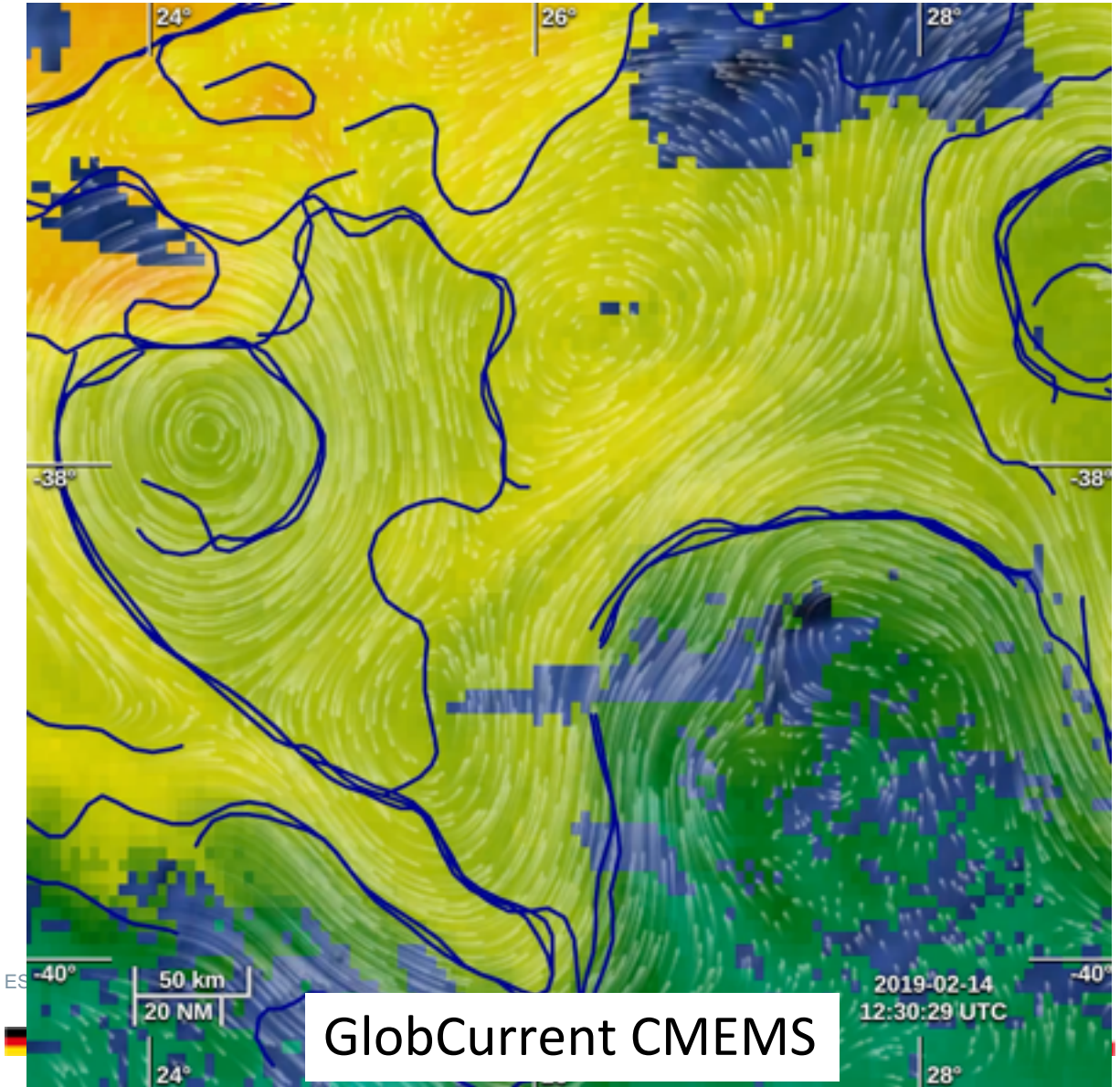
More and more remote sensing observations of the ocean surface are available with a wide variety of satellites:

- MicroWave Low Resolution (50 km) SST (AMSR2 / GMI)
- Infra Red Medium Resolution (3-10km) geostationary SST (SEVIRI / GOES)
- Infra Red High Resolution (<1km) SST (SLSTR / VIIRS) and Chl (OlCI / VIIRS)

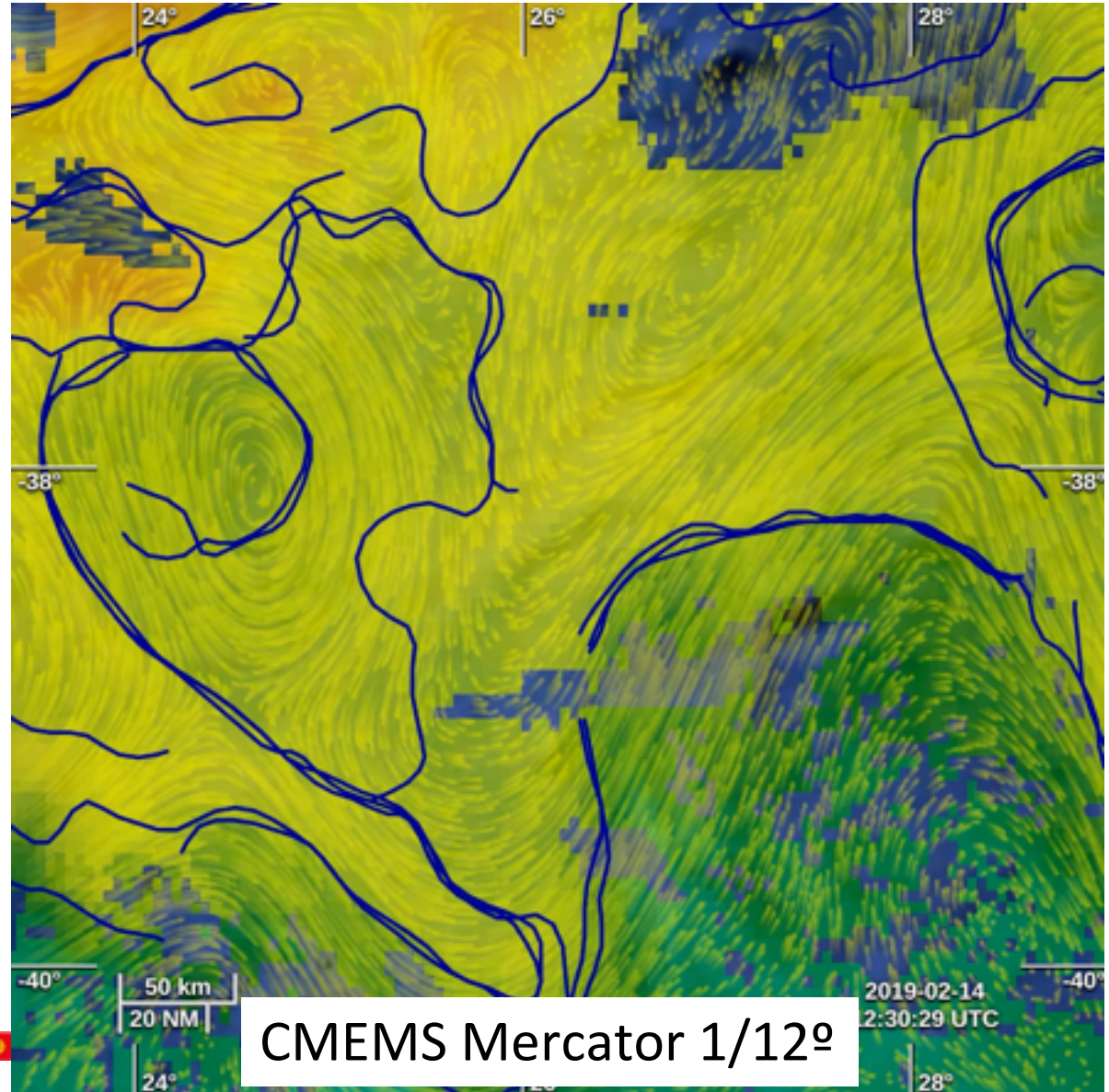
Objectives:

- Benefit from the synergy of tracer images to retrieve upper ocean dynamics information. Sea Surface Temperature (SST) and Chlorophyll concentrations gradient locations are good tracers of the upper ocean dynamics
- Perform current validation in term of spatial structure rather than pointwise: Use SST / Chl Images as structured information

Context



GlobCurrent CMEMS



CMEMS Mercator 1/12º

Overview

1. Ocean surface current retrieval from SST Images
   - Fronts detection algorithm
   - WOC Fronts products available

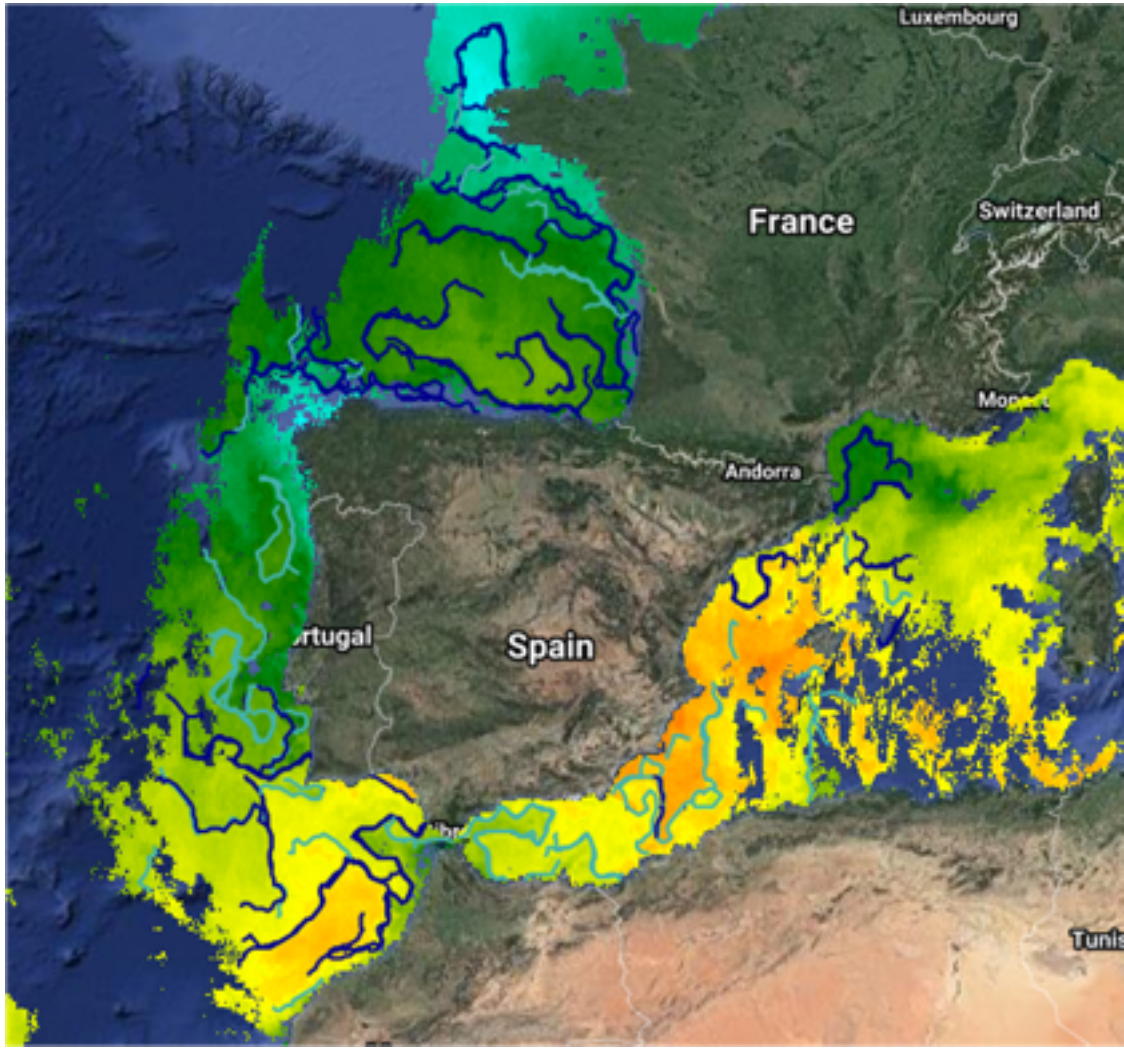
2. Use frontal structures to perform upper ocean current validation
   - Method
   - Validation of WOC BFN product
   - Preliminary study of MIOST AIS products
   - Helping model ranking for ship routing

Fronts detection algorithm

- Principle is similar to the one implemented in Cayula & Cornillon, 1992 and Cayula & Cornillon, 1994 for the histogram analysis:
  - Single Image Edge Detection Algorithm
  - Multiple Images Edge Detection Algorithm

- Ridge line following relies on contour following algorithm

- Open source python code will be available at the end of the project (fronts detection + validation tools)

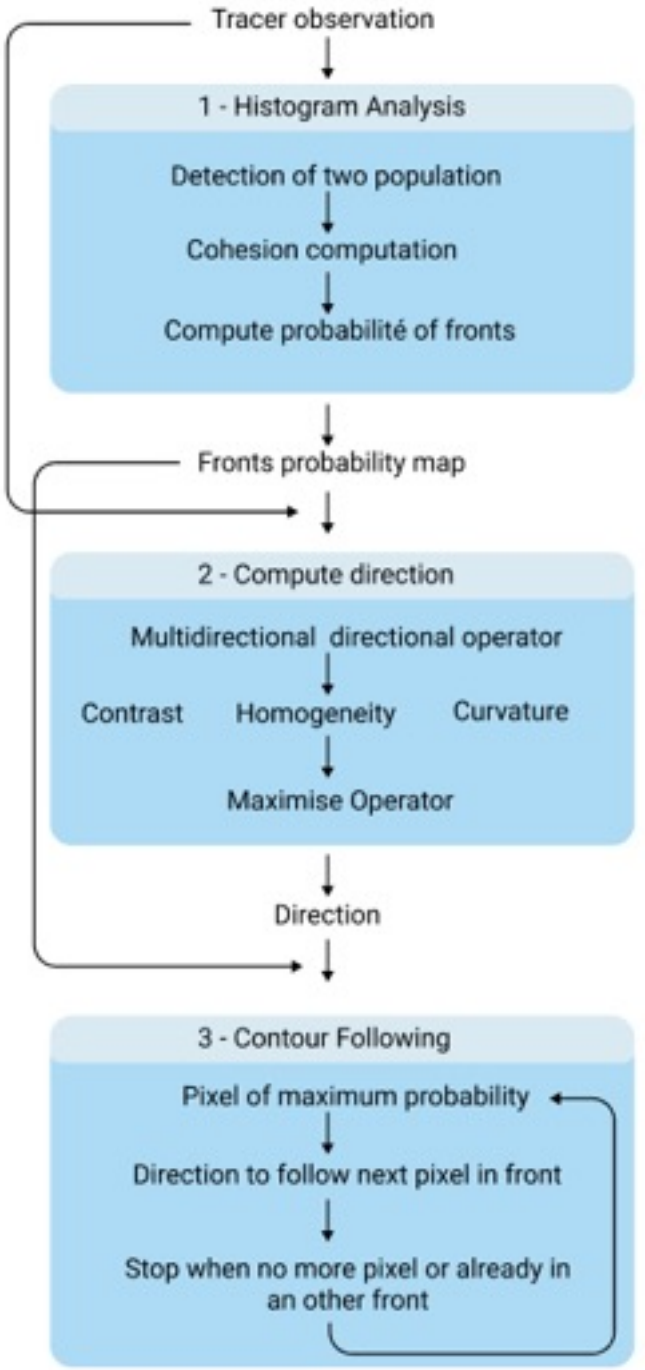


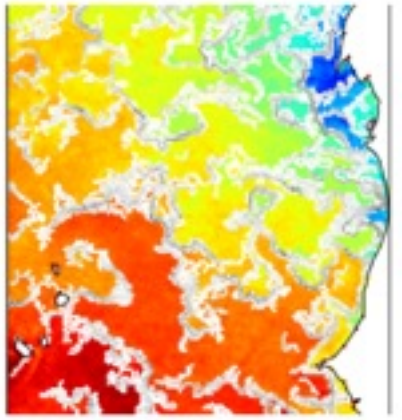
Fronts detection algorithm

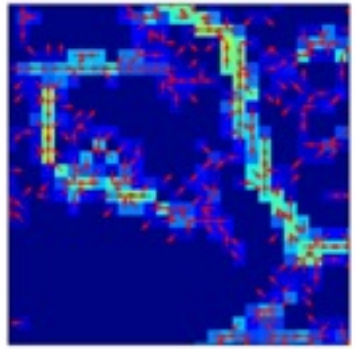
Input: SST image observation

Three step processing:
1- Histogram Analysis (similar to Cayula and Cornillon 1992 population detection algorithm)
2- Ridge line detection using fronts probability
3 - Contour Following using maximum of probability and direction of ridge line

Output: Fronts line as 1D vector



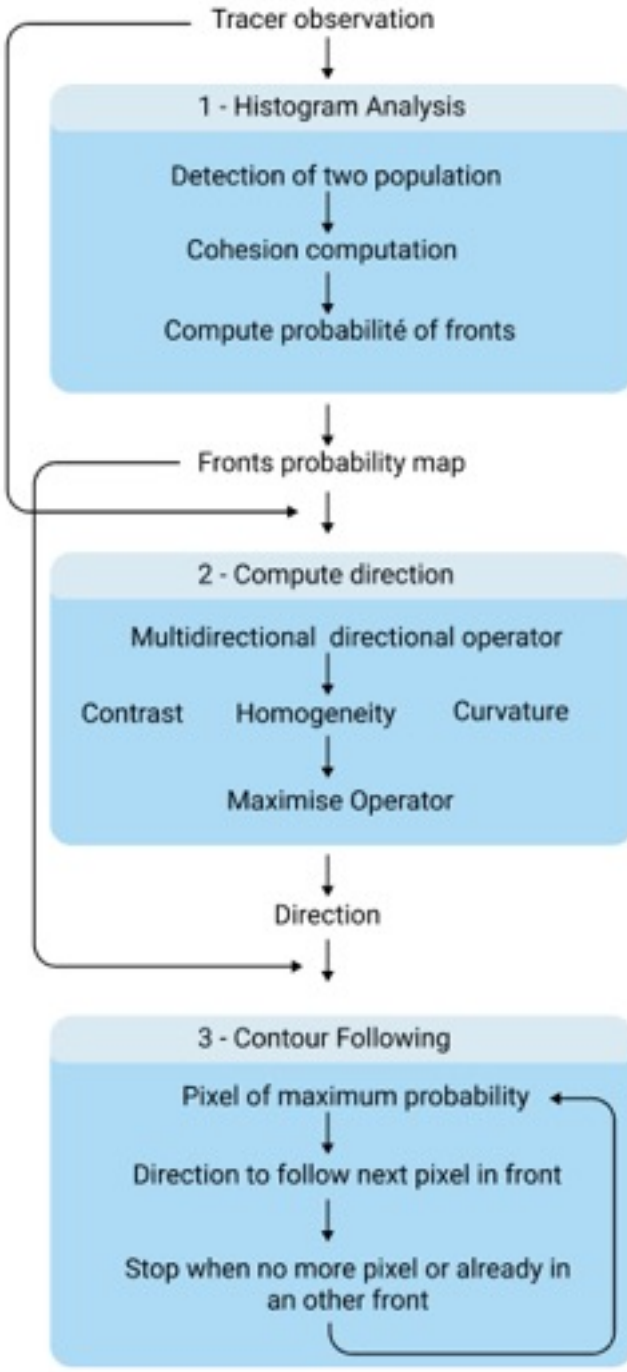


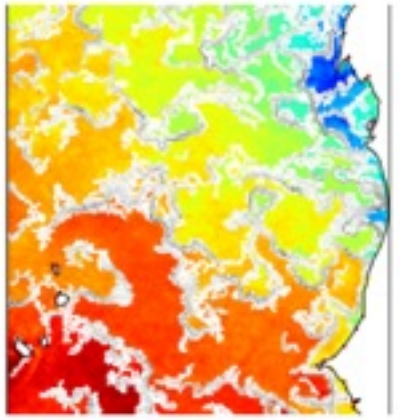


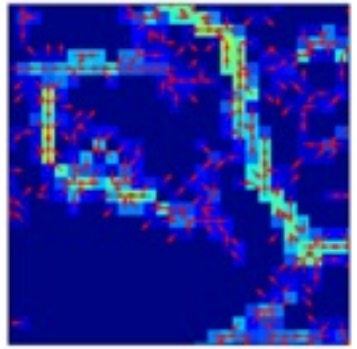
Fronts detection algorithm

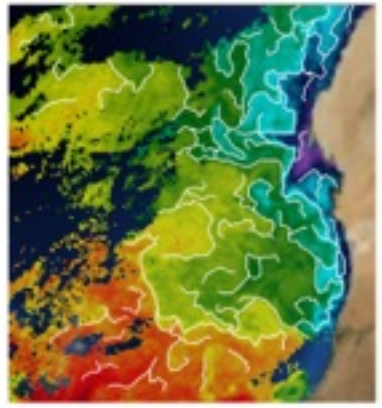
Capability to use it with WOC Visualisation tools:

- Save fronts as shapes to be imported in Syntool portal or SEAScope
- Run algorithm with jupyter notebooks and interact with SEAScope









WOC fronts products

- Data for theme 1 and theme 2 regions have been processed on ~10 years, 4 products are available:

Product	Resolution	Time range	Domain	Comments
fronts_t1_seviri	5 km / 1 h	2011/08/01 -> 2021/12/31	Agulhas	Quality of SST before 2011/08/01 not good
fronts_t1_mw_oi	25 km / 1 d	2010/01/01 -> 2021/12/31	Agulhas	SST before 2012 may be degraded (no AMSR)
fronts_t2_seviri	5 km / 1 h	2011/08/01 -> 2021/12/31	North Atlantic	Quality of SST before 2011/08/01 not good
fronts_t2_mw_oi	25 km / 1 d	2010/01/01 -> 2021/12/31	Western Europe	SST before 2012 may be degraded (no AMSR)

WOC fronts products

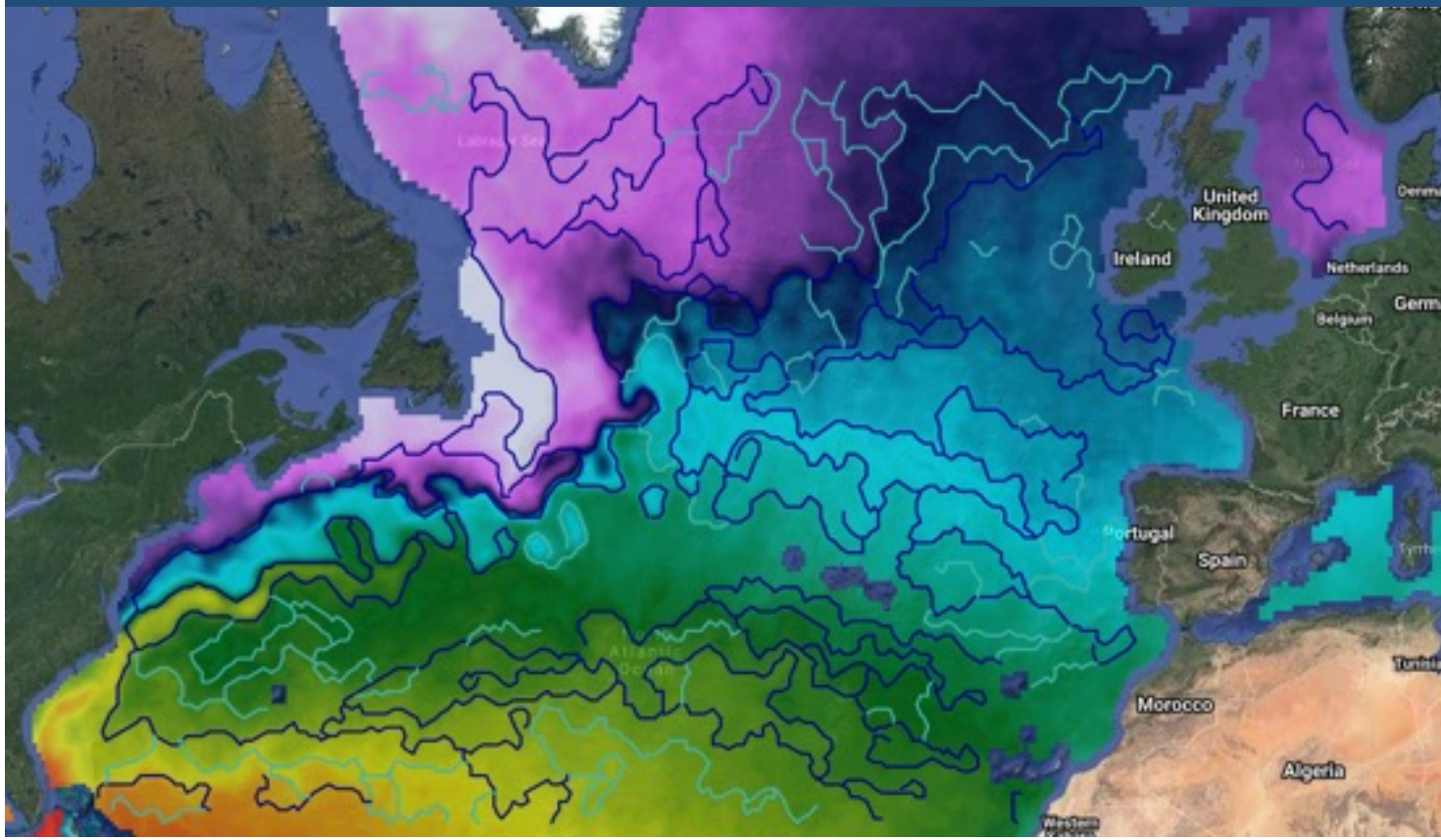
Microwave :

- L4 from REMSS (AMSR2 + GMI)
- daily
- 25km x 25km resolution

Processing:

- domain: [-80, 5, 25, 60],
  [12, 32, -43, -28]
- 2 windows: [250km, 150km]
- threshold between 2 pop: [0.72,0.7],
- Single Cohesion: [0.82,0.72],
- Global Cohesion: [0.88,0.78],

1d of fronts, flag 2 (33% of the strongest fronts), April 10th 2018



WOC fronts products

SEVIRI:

- L3C from EUMETSAT
- hourly
- 5km x 5km resolution

Processing:

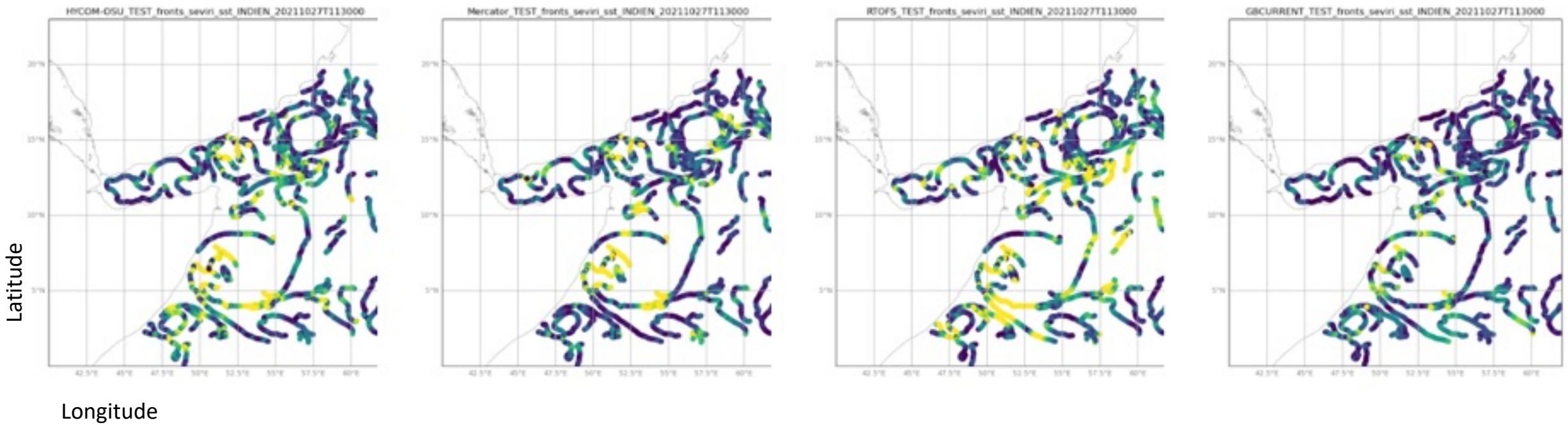
- domain: [-25, 5, 30, 60] and [12, 32, -43, -28]
- 3 windows: [80km, 50km, 30km]
- threshold between 2 pop: [0.74,0.72,0.71],
- Single Cohesion: [0.88,0.82,0.78],
- Global Cohesion: [0.92,0.88,0.86],

6h of fronts, flag 2 (33% of the strongest fronts), October 24th 2018

Comparison Fronts / velocity

Validate direction of currents using the normalized flow that is crossing a front for each point [i, j] that belongs to a front:

$$metric[model_k][i,j] = \frac{(u_k[lat[i], lon[j]], v_k[lat[i], lon[j]]).\,(lon[i+1] - lon[i-1], lat[j+1] - lat[j-1])}{||(u_k,\, v_k)||\;||(\delta lon,\, \delta lat)||}$$



HYCOM OSU 1/12 | MERCATOR CMEMS 1/12 | HYCOM RTOFS 1/12 | GLOBCURRENT CMEMS

Comparison Fronts / velocity

Compute statistics on the flow on temporal and spatial box:

- Temporal window can be 3-7 days for real time forecasting assessment
  monthly to look at seasonality
  longer to intercompare different sources of current

- Spatial windows can be 1ºx1º / 2ºx2º (depends on the number of validation points available)

- Parameters studied in each box:
  Mean and STD of the flow for each current
  Mean and median of Ranking for each current
  Mean of the differences between two different currents

Comparison Fronts / velocity

Pros:

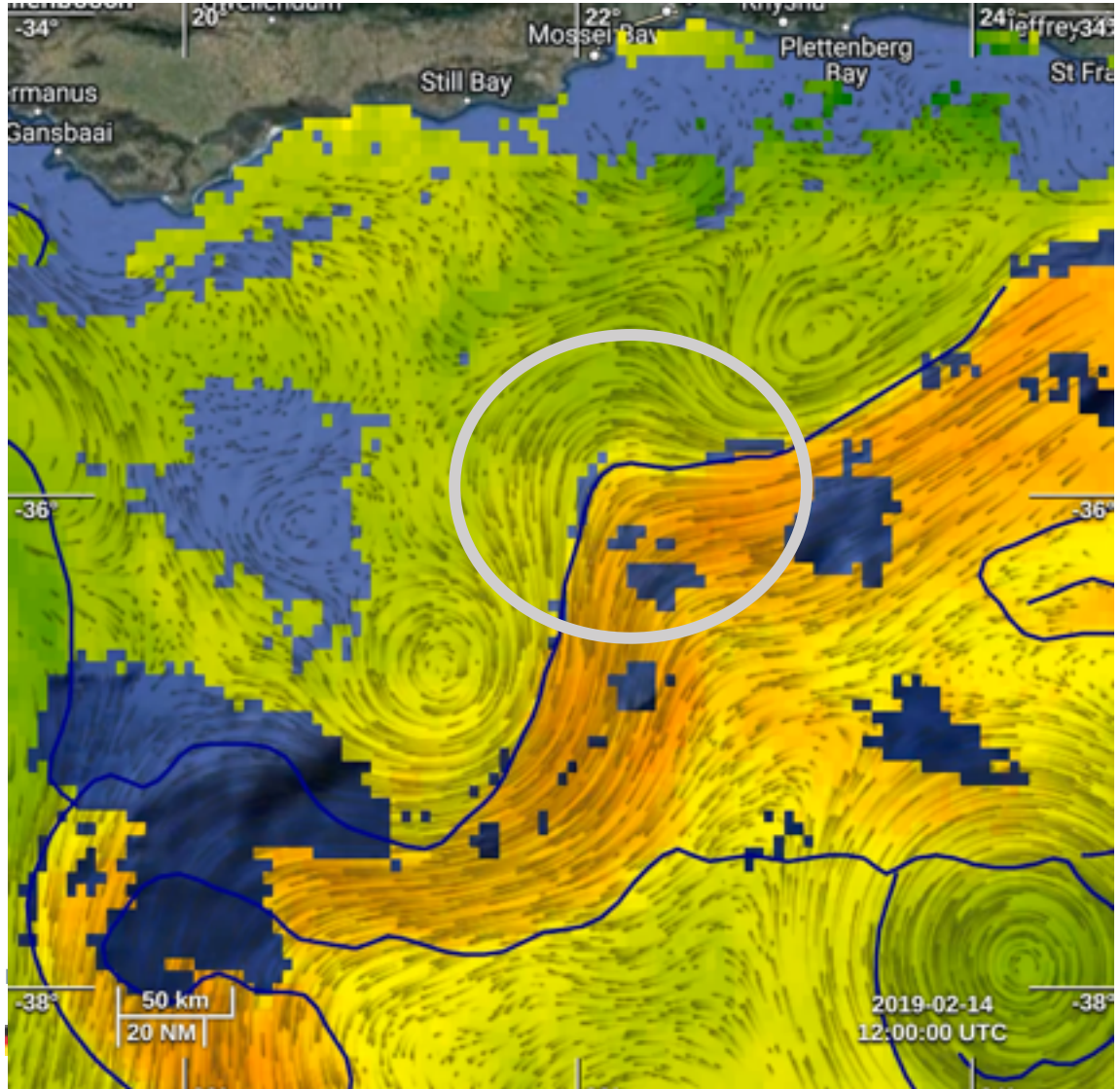
- Many validation points available in each box
- Different Resolution can be looked at
- Position of a mesoscale structure can be assessed in near real time in many cases
- Reliable validation in term of position of eddies and fronts

Limitations:

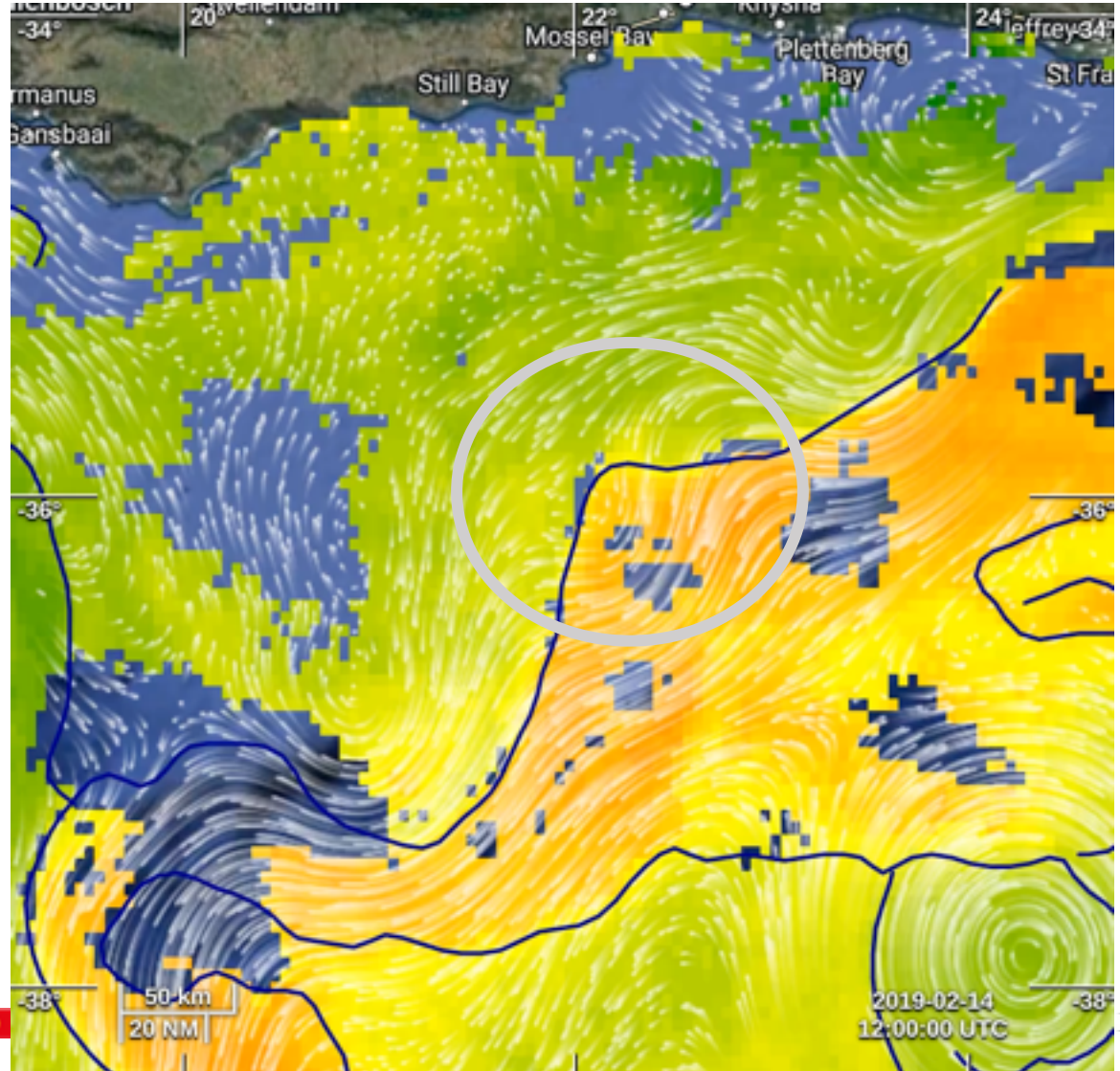
- Results depends on quality of frontal detection, presence of a tracer gradient
- So far, only relative comparison between different sources of current
- Advection component is not considered but can be computed using fronts tracking
- No validation of the current norm

Validation WOC BFN product

Geostrophic WOC BFN

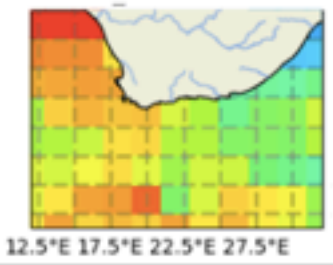
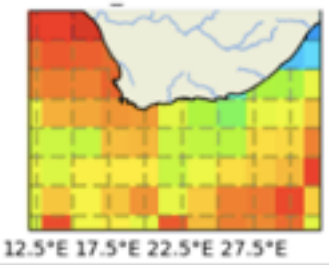
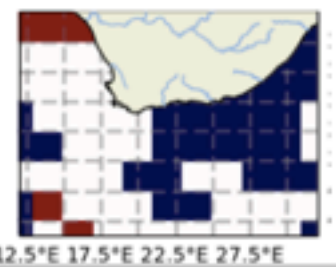
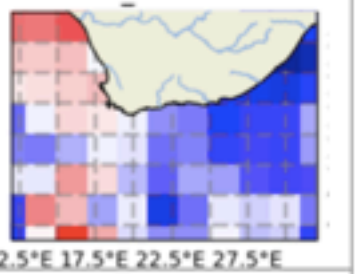
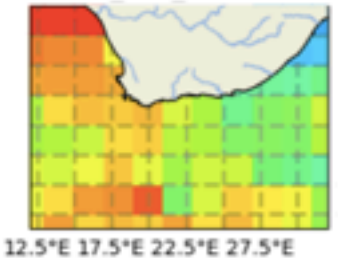
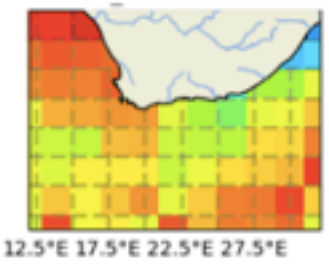
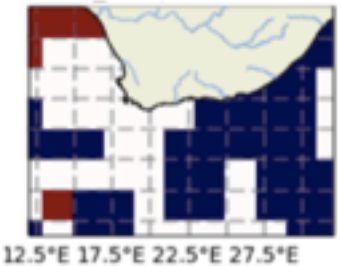
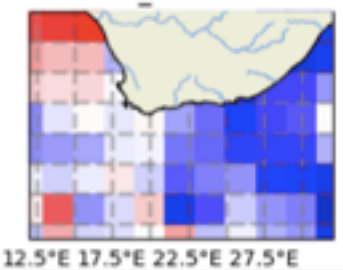
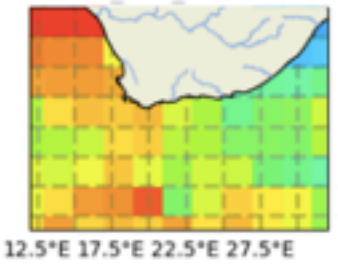
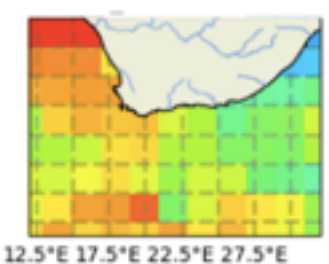
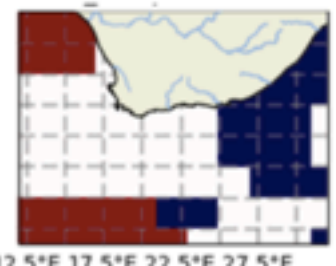
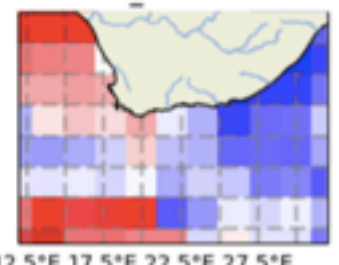


Geostrophic GlobCurrent CMEMS



Validation WOC BFN Product

- Optimize algorithm by comparing several products or several versions of the product is possible as there is a good spatial sampling of the fronts

Data	Mean data 0	Mean data 1	Best	mean difference
BFN v3 - GlobCurrent				
BFN v2 - GlobCurrent				
BFN v2 - BFN v3				

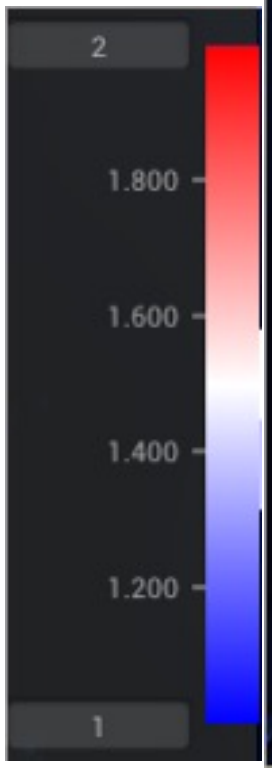
Statistics on 2ºx2º box
January 2019

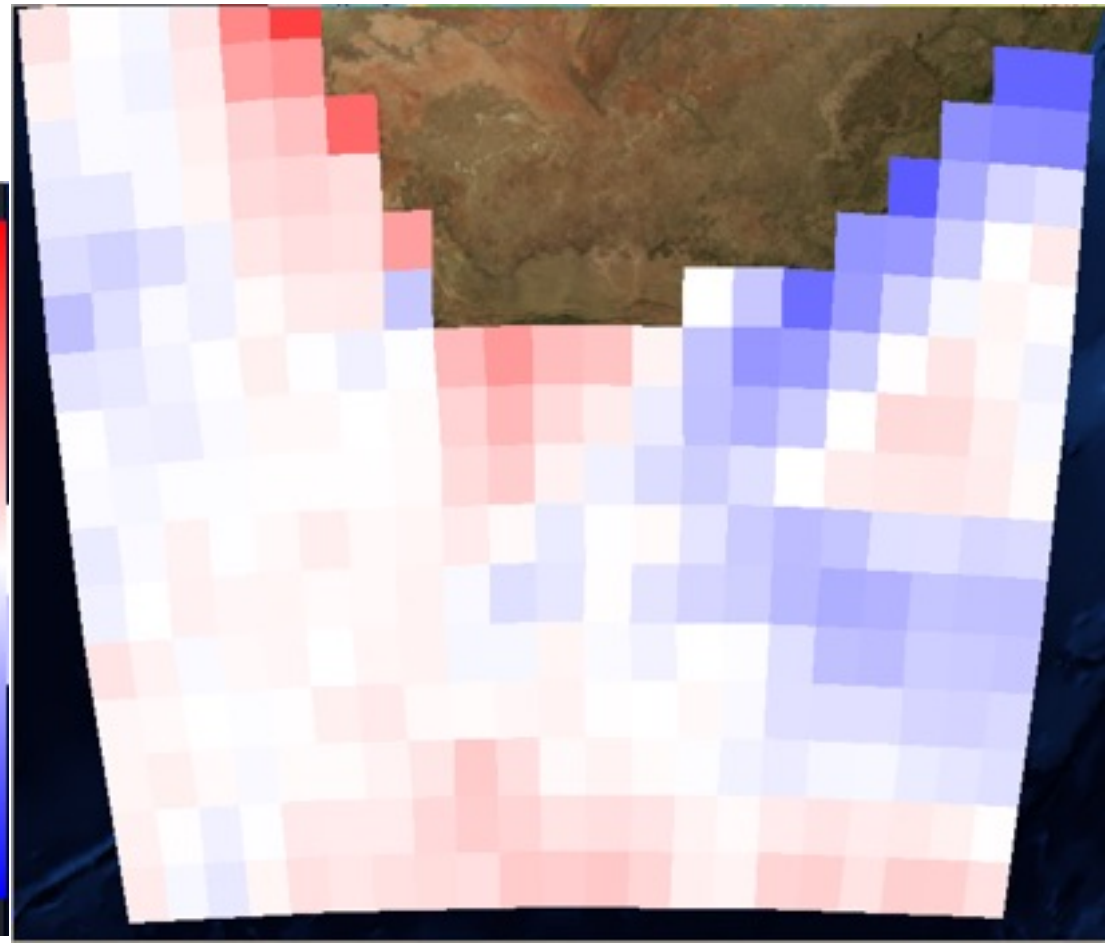
blue: First
red: Second

Validation WOC BFN product

- Compute flow across fronts derived from SEVIRI on the 2013-2020 period
- Compute statistics on 1ºx1º box
- 10 000 -> more than100 000 points in each box

Blue: WOC BFN is better (smaller flow)
Red: GlobCurrent CMEMS is better



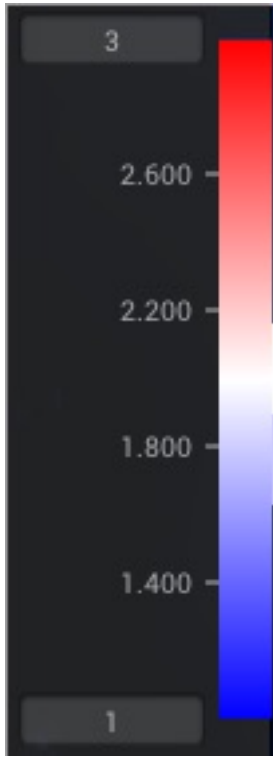


Good improvement in the Agulhas current, still to be improved in coastal areas

Study MIOST AIS current

Preliminary results: comparing GlobCurrent – WOC BFN – MIOST AIS for 2020

Blue: Good ranking for product (1st), Red: Bad ranking for product (3rd)



Validation of Currents in NRT for CMA CGM

- Two voyages evaluated: End of May and end of June 2022

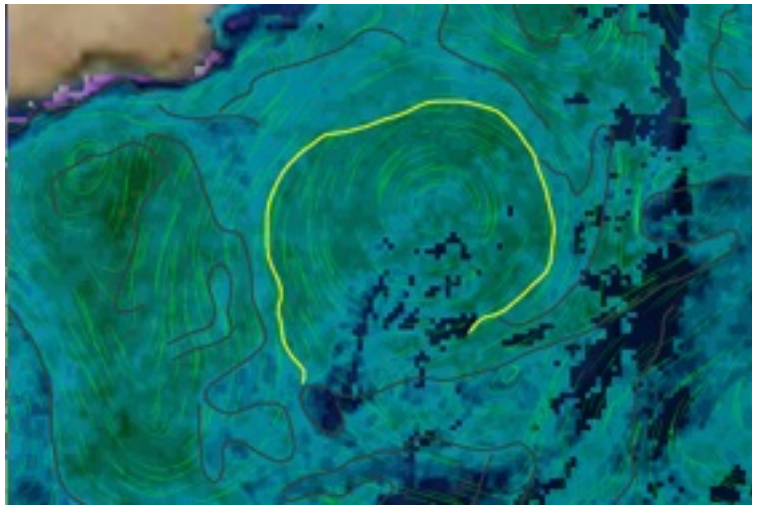
- Experience in NW Indian Ocean: depart from Colombo (Sri Lanka), arrives at Canal Suez
  ⟹ area quite cloudy

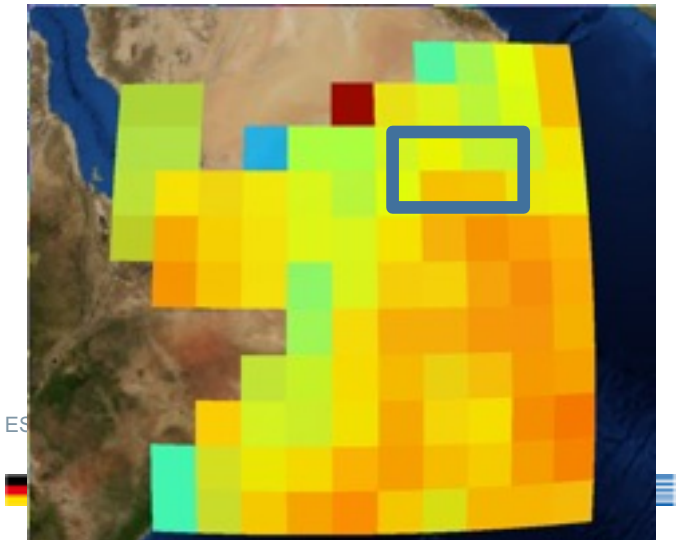
Product that has been assessed: Hycom OSU 1/12
Hycom RTOFS 1/12
CMEMS Mercator 1/12
CMEMS Geostrophic current (008_046)

Sensors used for the evaluation: SEVIRI SST, MWOI, Drifters, for automatic validation

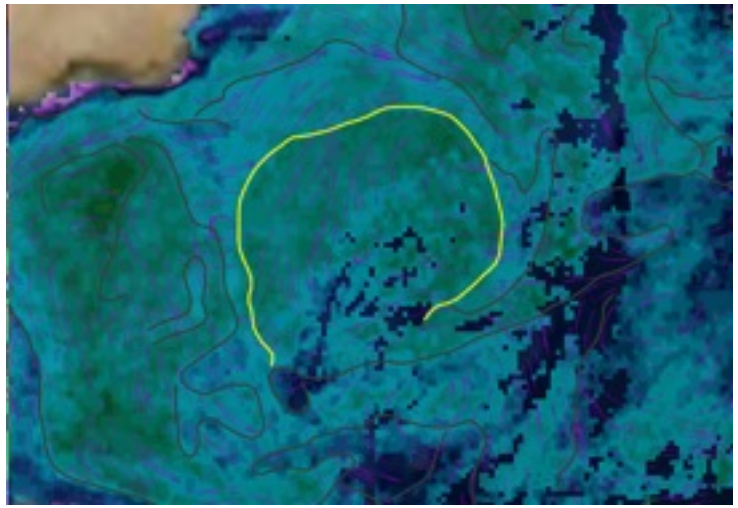
Validation of Currents in NRT for CMA CGM

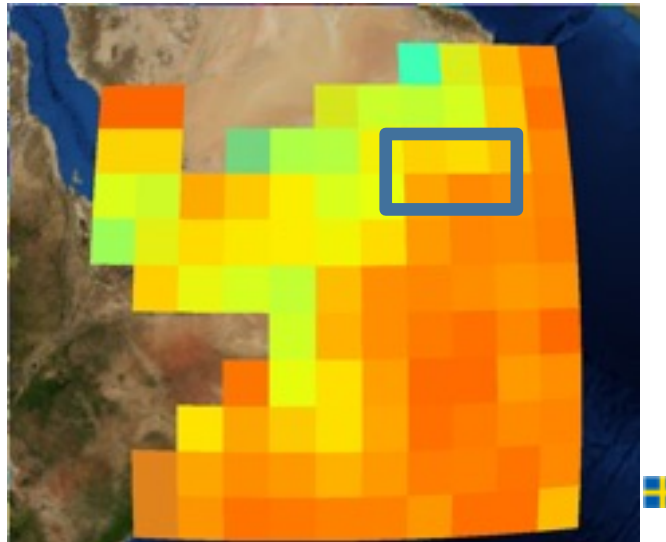
HYCOM OSU 1/12º



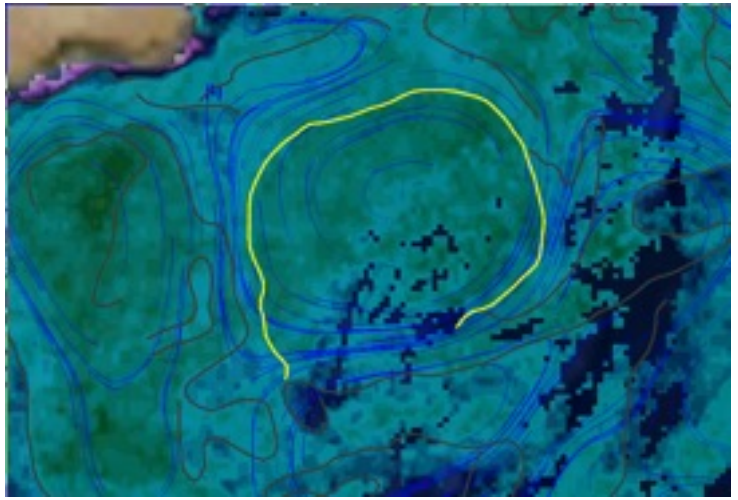


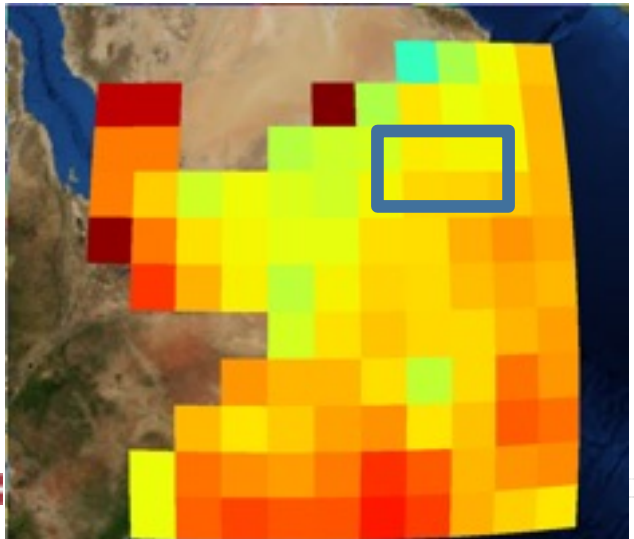
Mercator CMEMS 1/12º





GlobCurrent CMEMS



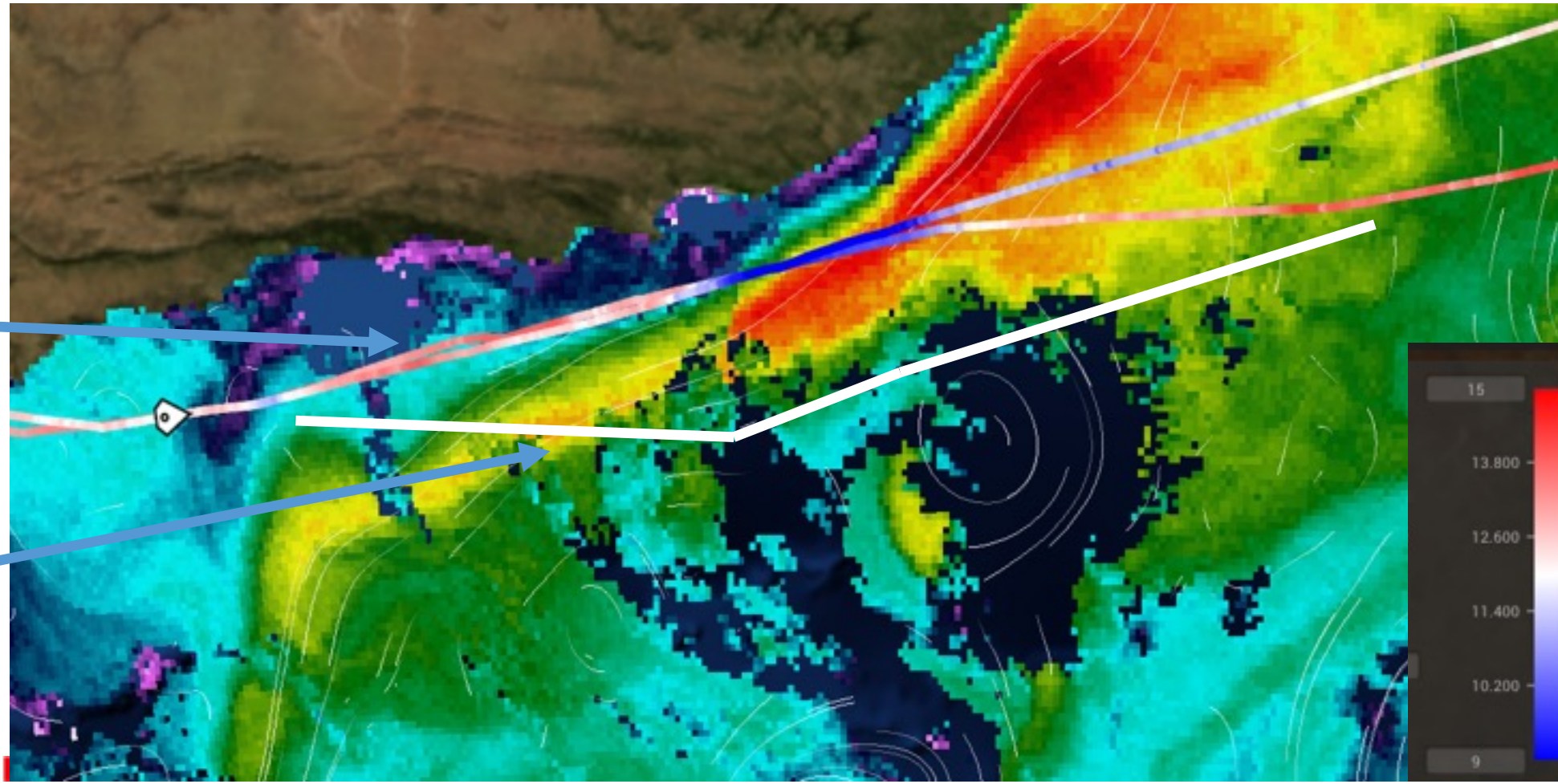


Grieg Star voyage 2022-01-23 and 2022-01-27

Show the current crossed during the voyage collocated with their AIS speed, explain the importance of structures properly located

AIS speed
(blue: 9 nkts, red: 15 nkts)

Alternate route, to benefit more from current



Conclusion

- Validation using SST images enables to compare the validity of different currents every few days or on a long period. Spatial validation complementary to pointwise.
- Validation quite homogeneous in space and time

Applications:

- Optimize methods to compute current
- Choose best forecast when performing ship routing

Perspectives:

- Calibrate the methodology using a model (ongoing)
- Use higher resolution SST and study related limitations
- Develop algorithm to retrieve frontal structures from Chlorophyll concentration

Backup slides

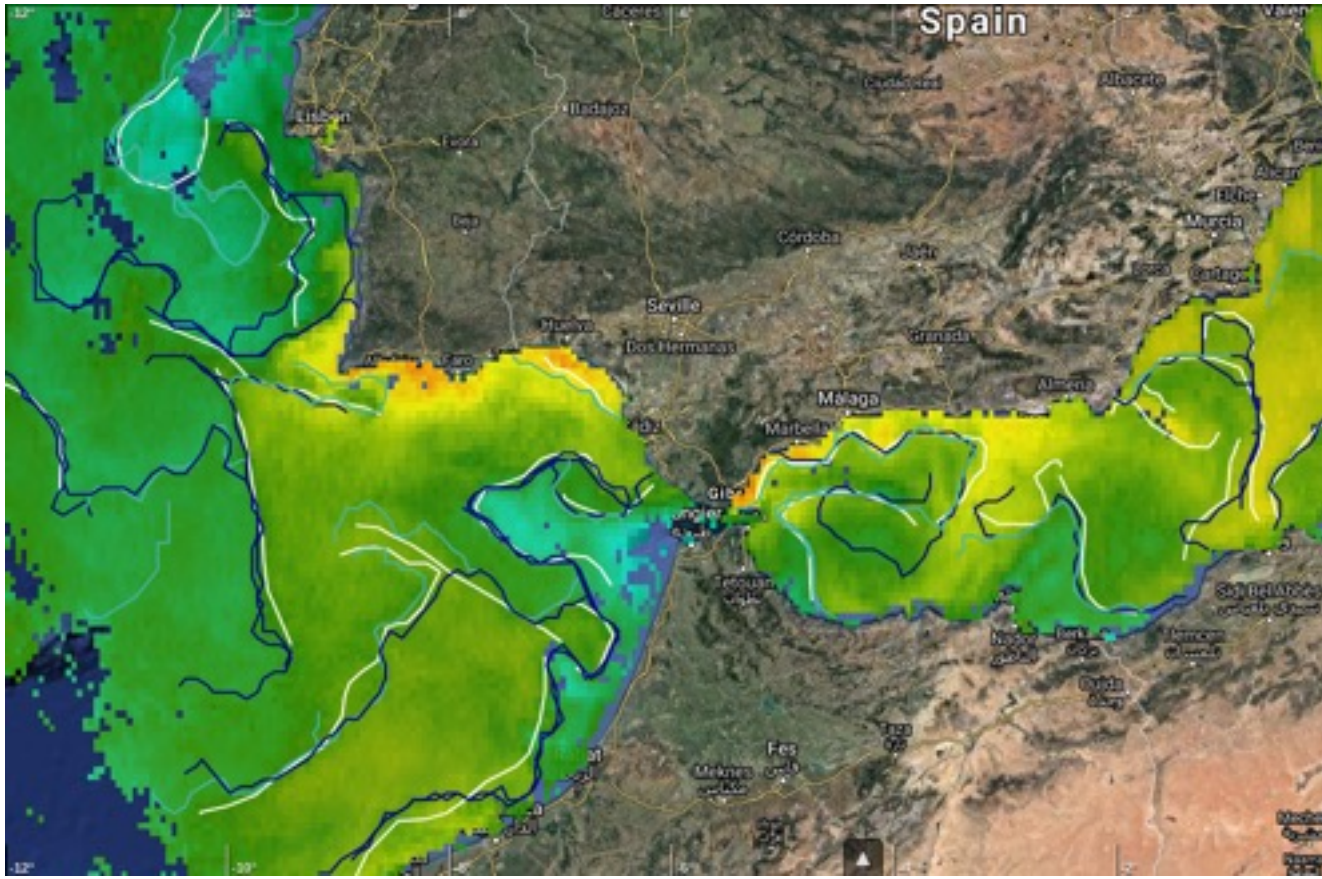
Validation Fronts

Reference: manually drawn front

For each manually drawn front, look for the closest one in the automatically detected
database (flag 1 and 2)

3 metrics are of interest for the validation:

- fail rate: percentage of front that did not find any match
- mean distance (yellow segment) between front pixel
- Barycentre displacement



Results depend on season / tracer gradient

- Winter in T2 area (weak gradient)
  - fail rate: 18%
  - mean distance: 8.5 km (std 6.5km)
  - Barycentre displacement: 6.5 (std 5km)
- Fall in T2 area (strong gradient)
  - fail rate: 10%
  - mean distance: 8.7 km (std 7km)
  - Barycentre displacement:6.8 (std 6km)

Location of fronts seems ok but results to be confirmed with more tests and validation