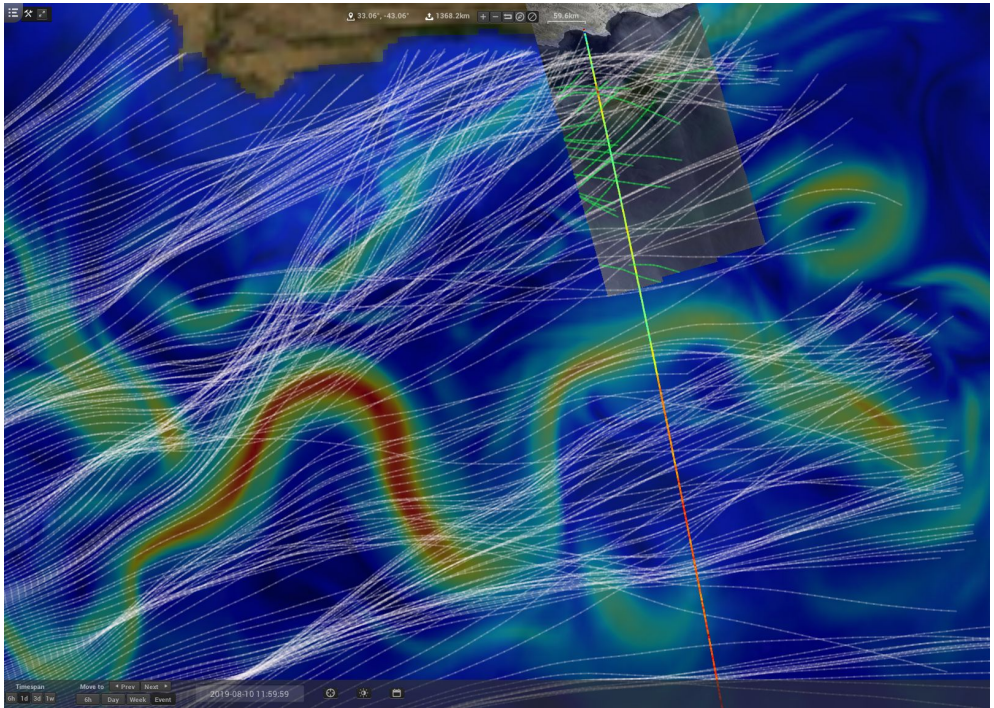
Wave Current interaction lecture

OceanDataLab team

Brest, 2022/06/15



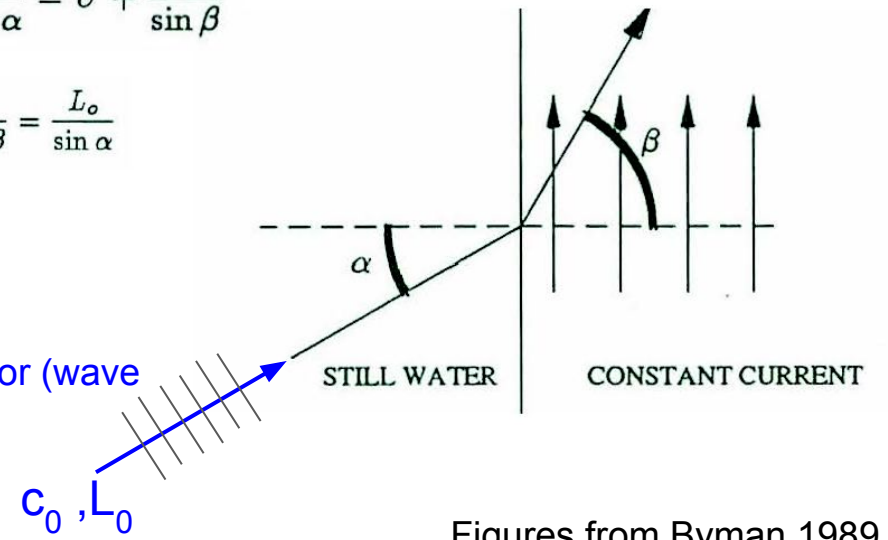
Path of wave orthogonals entering a current

c : vitesse de phase, L : longueur d'onde, U : vitesse du courant

Johnson (1947)

$$\frac{c_o}{\sin\alpha} = U + \frac{c}{\sin\beta}$$

$$\frac{L}{\sin\beta} = \frac{L_o}{\sin\alpha}$$



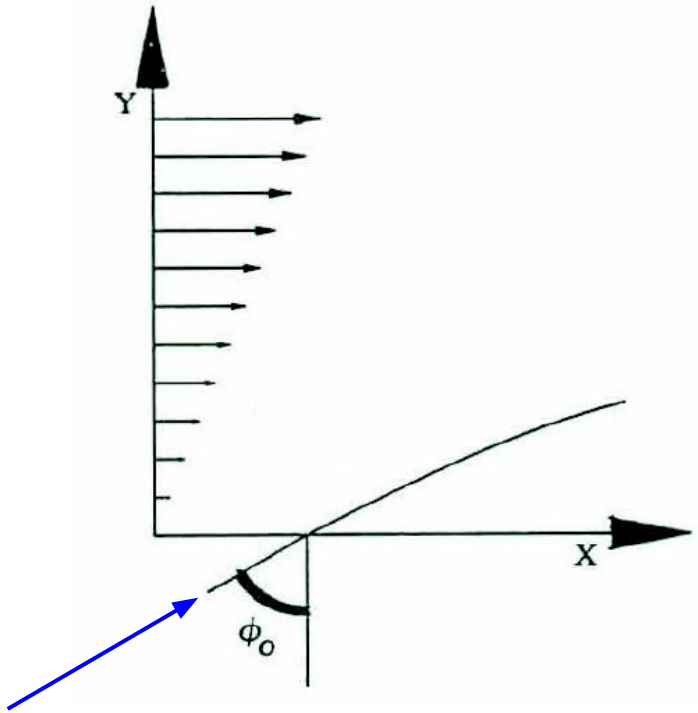
Figures from Byman 1989

Swell in a current shear

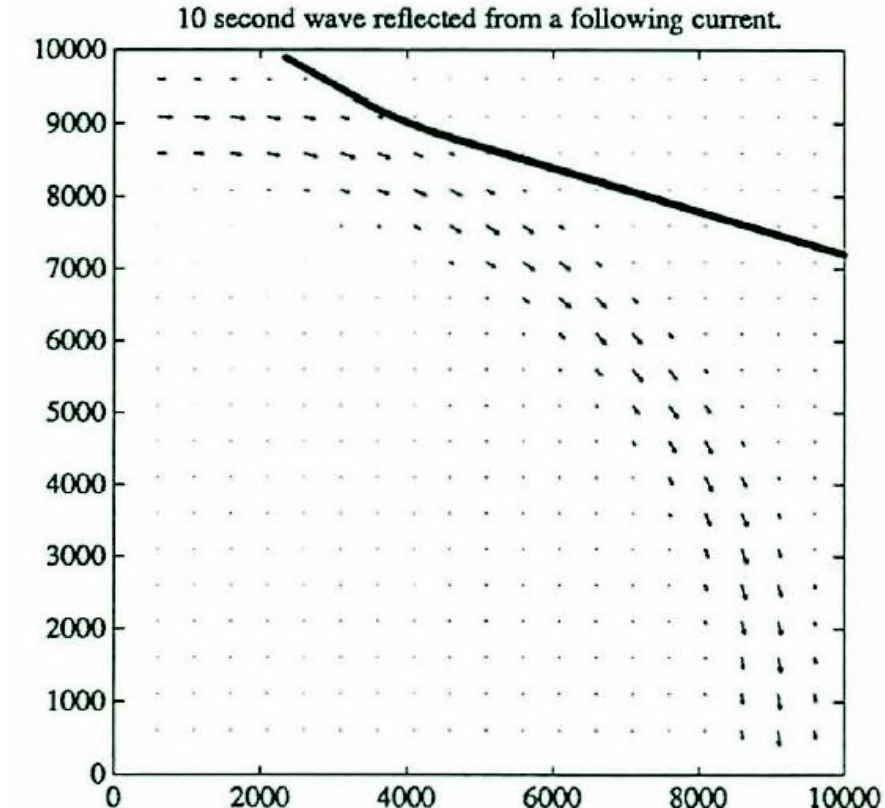
Kenyon (1971)

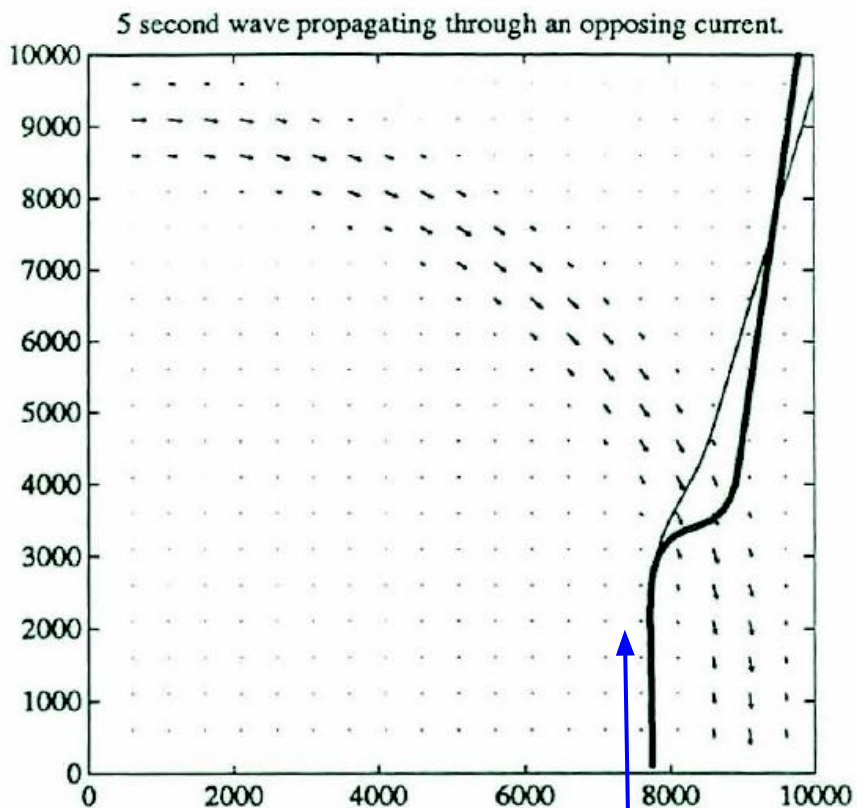
$$R = \frac{c_{gr}}{\xi}$$

$$\xi = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$$

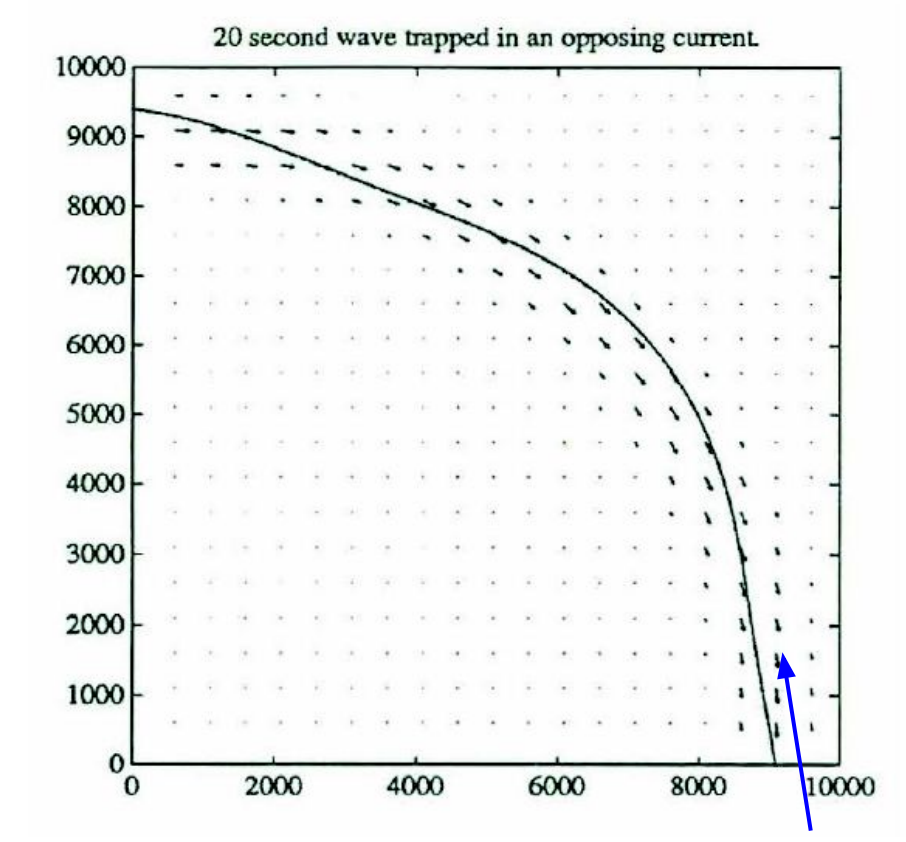


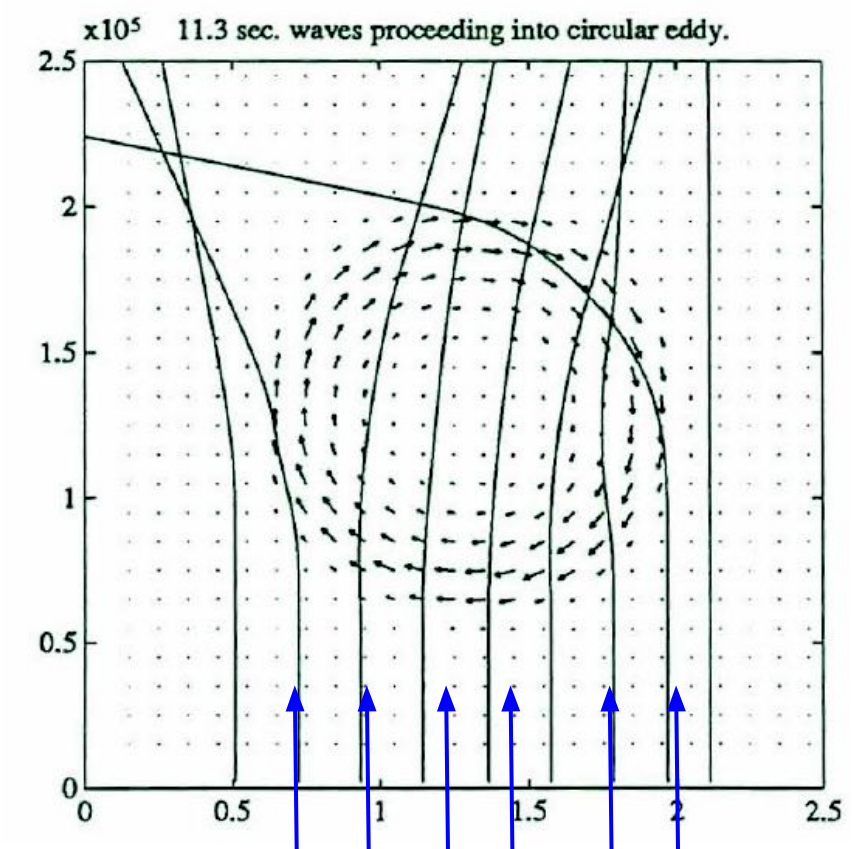
Realistic current profile : Reflexion or crossing





Trapped swell by opposing current



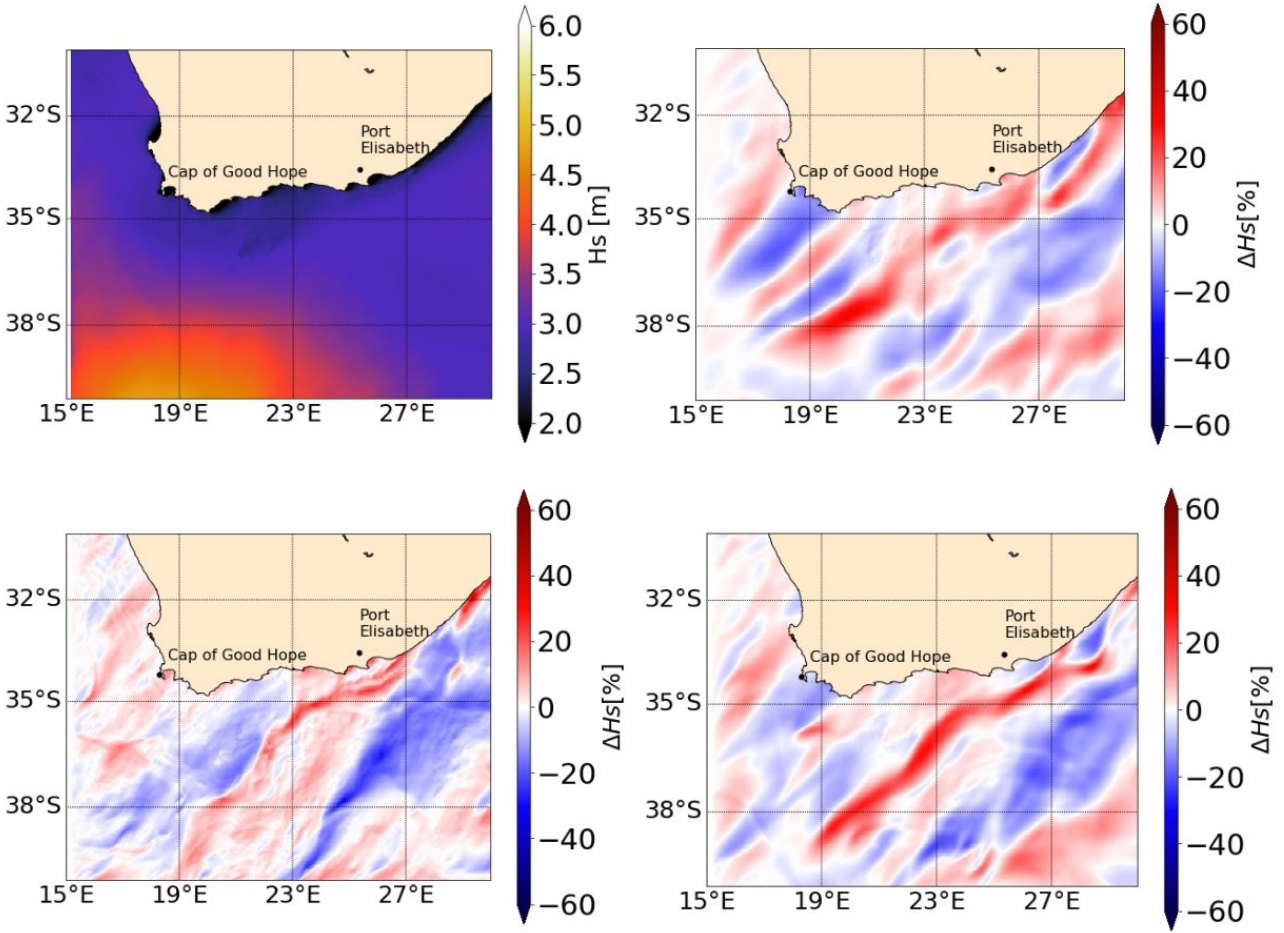


Effective spatial significant wave height variability

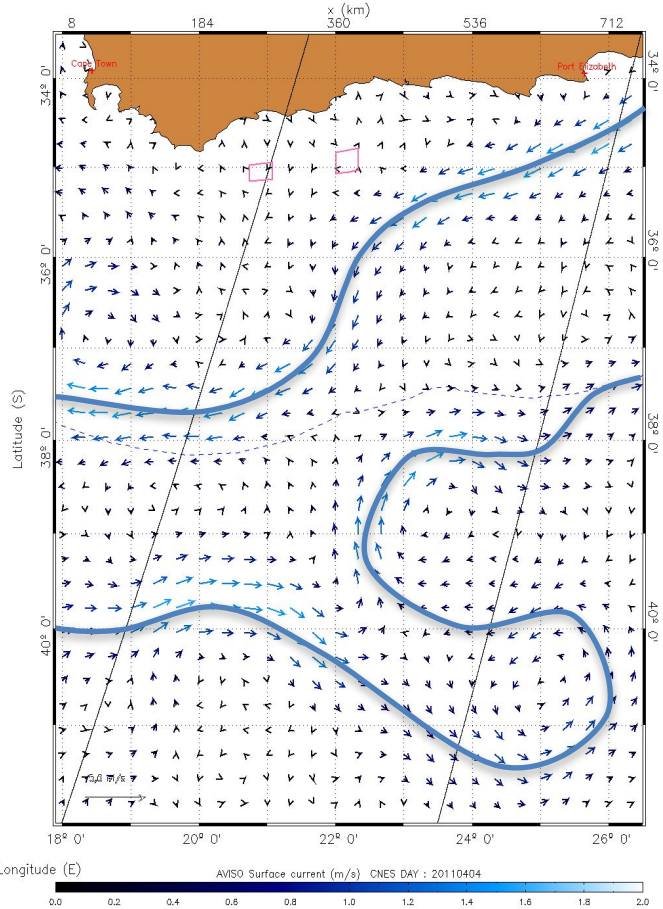
Significant wave height from WW3 sea state model (upper left) without considering ocean surface current

relative variations of significant wave height when considering three different sources of surface current : Geostrophy (upper right), MITGcm (lower left) and CMEMS operational Mercator model (lower right).

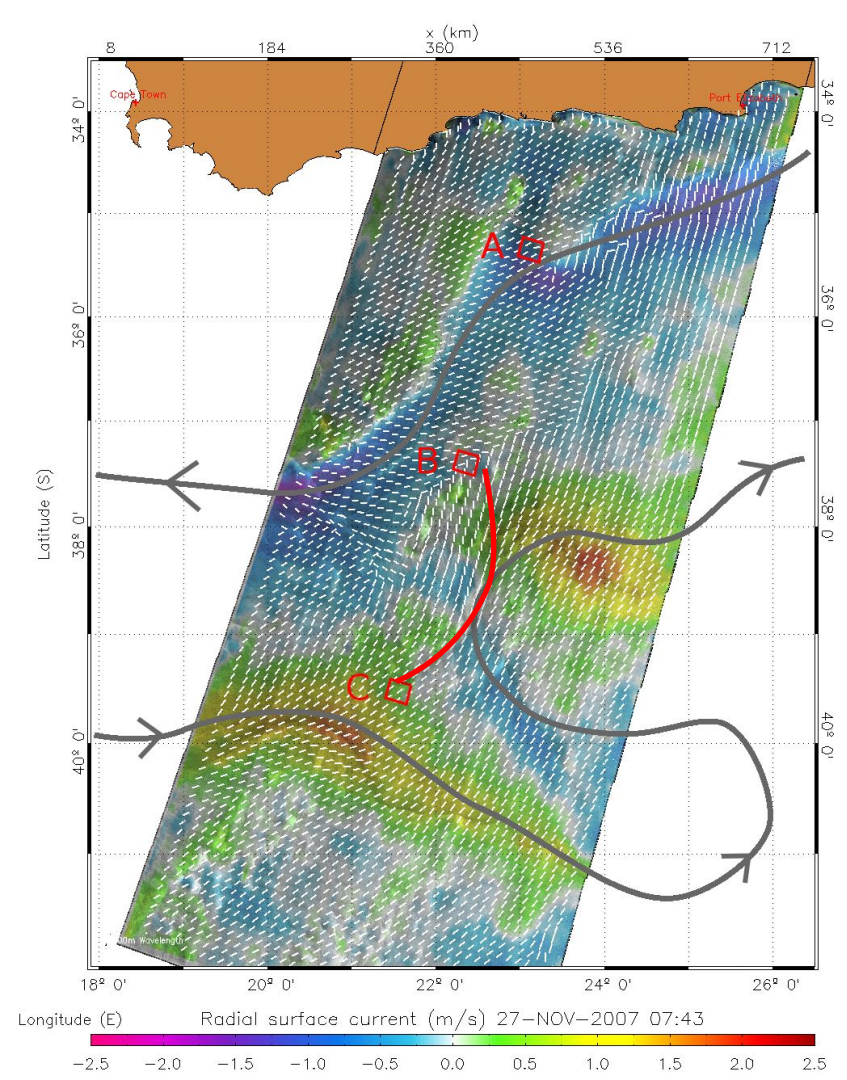
Courtesy Gwendal MARECHAL (IFREMER, Brest)

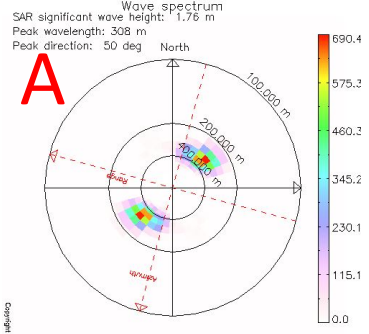


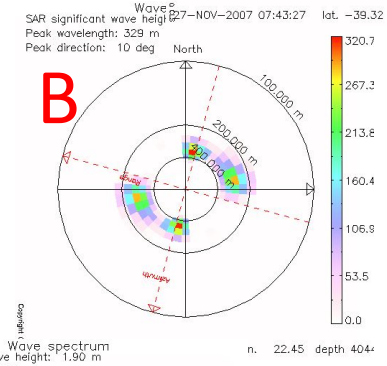
Swell refraction by current as observed by SAR

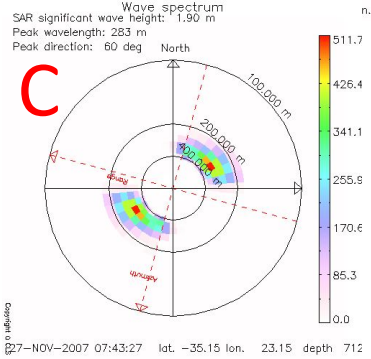


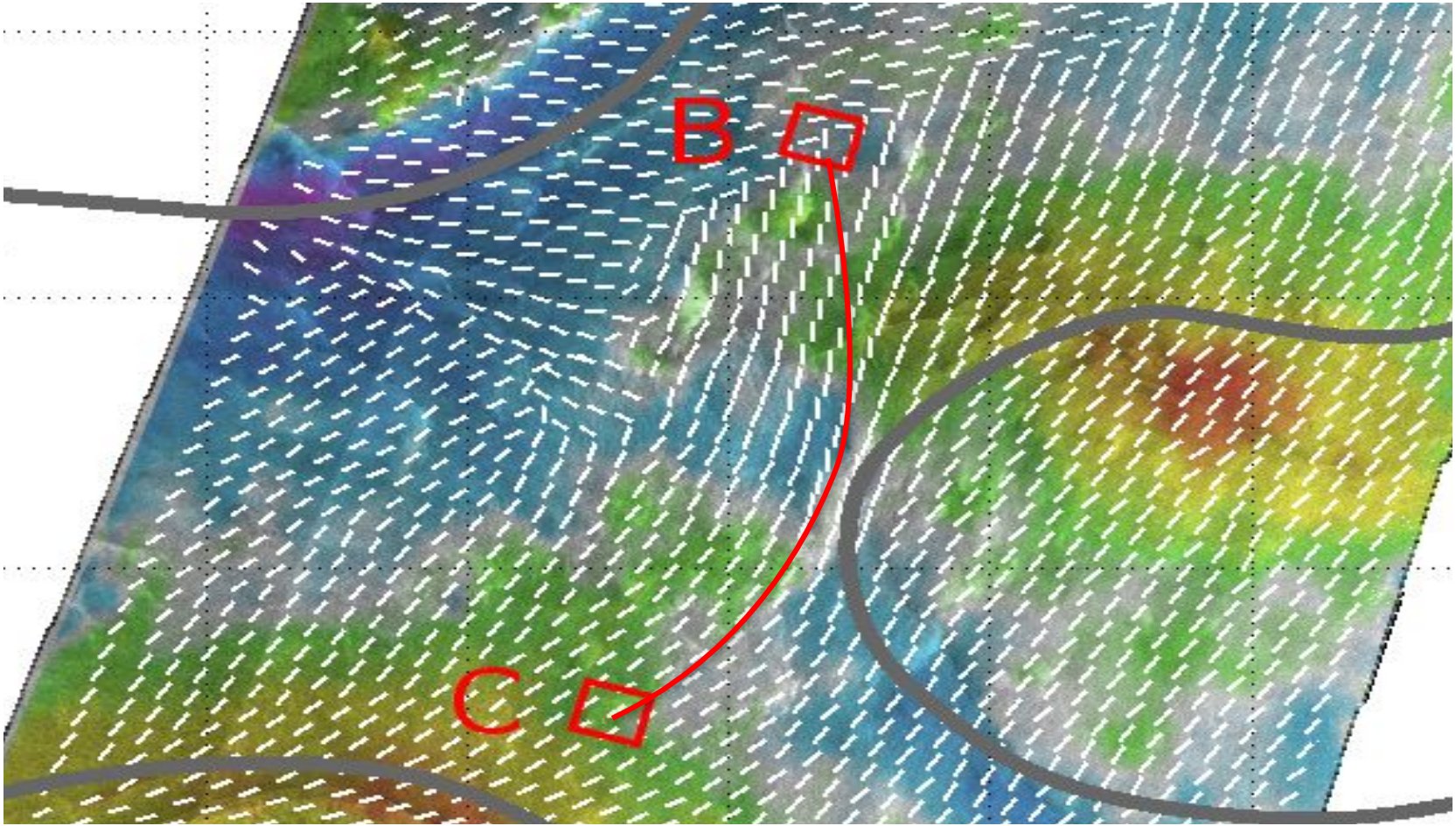
Swell spectra from ENVISAT ASAR







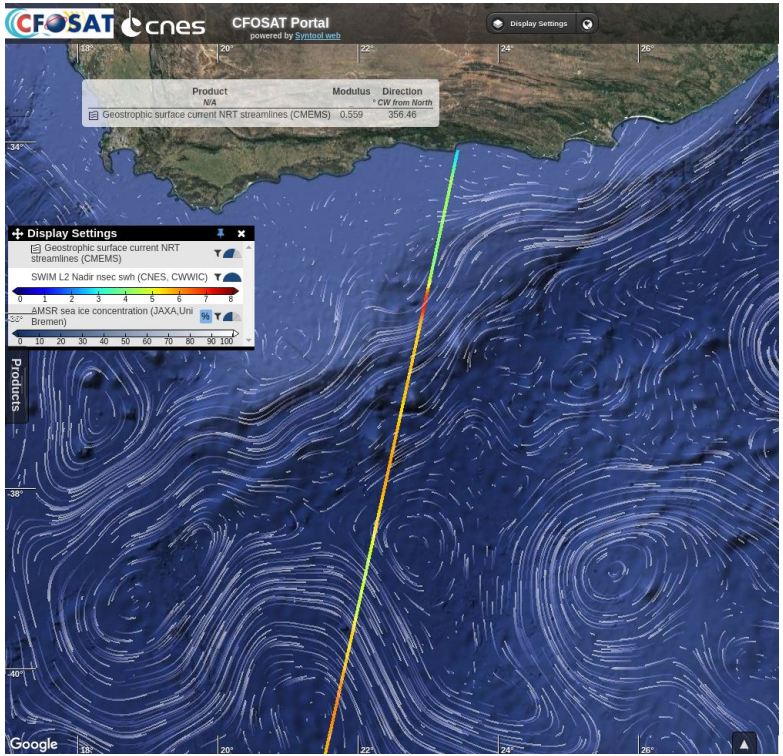



B
C

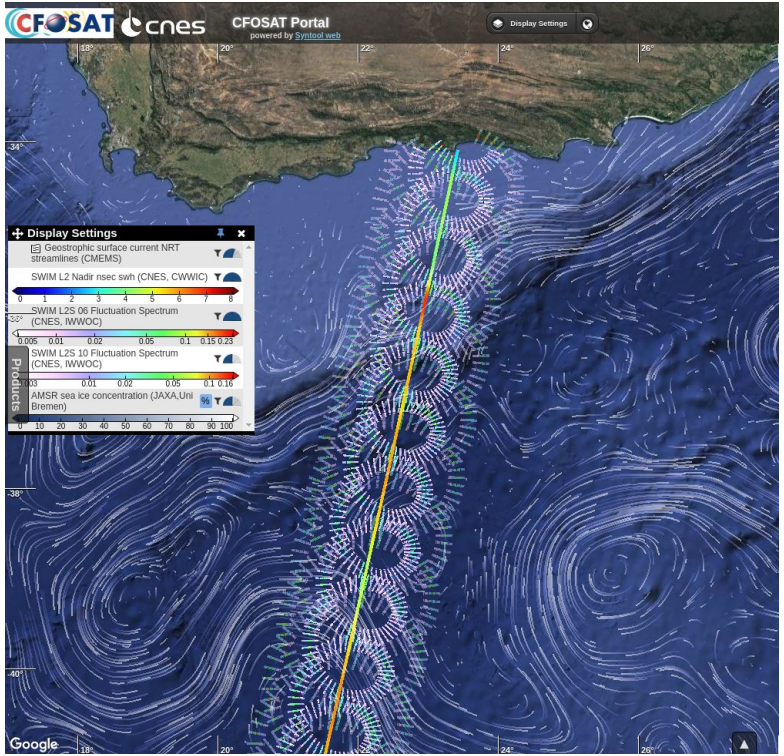
https://odl.bzh/30f2xw1A

Spatial wave variability seen by SWIM (CFOSAT)

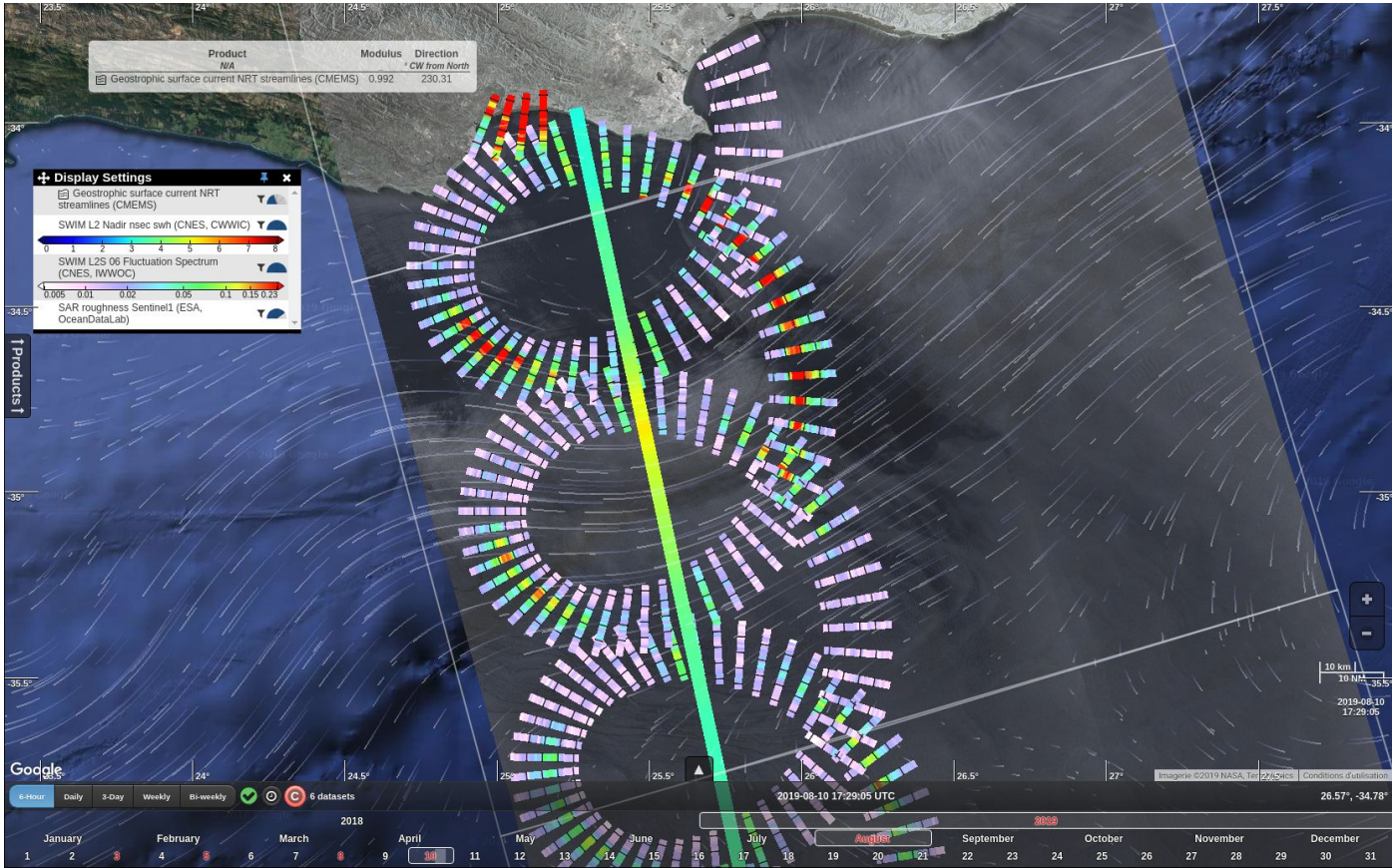
Nadir altimeter wave height

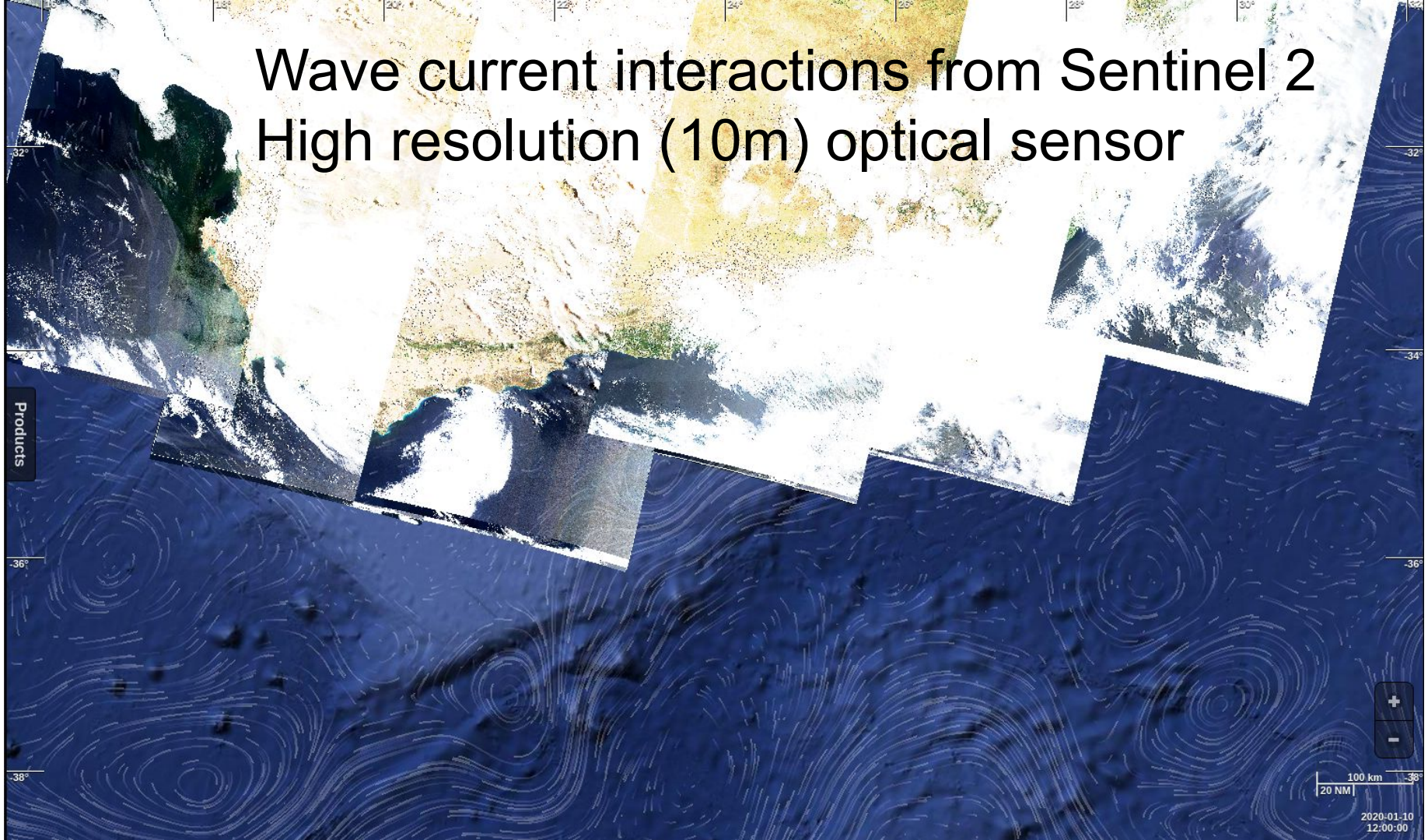


spectral/directional wave spectra



CFOSAT derived ocean wave spectra (cycloid) and along track significant wave height overlaid on observed surface current (streamlines) and Sentinel1 SAR data.




Wave current interactions from Sentinel 2
High resolution (10m) optical sensor
Products
100 km
20 NM
2020-01-10
12:00:00

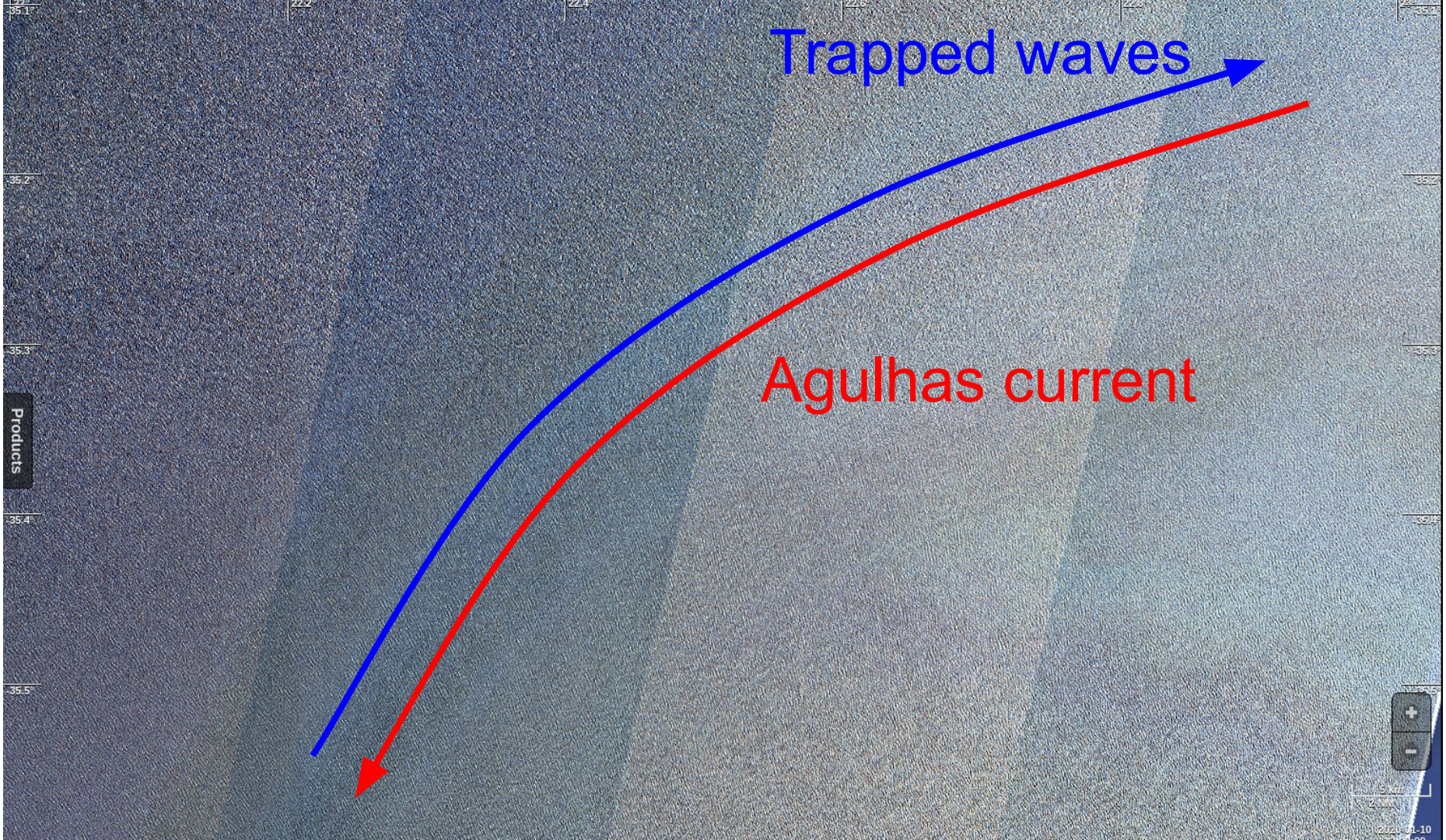
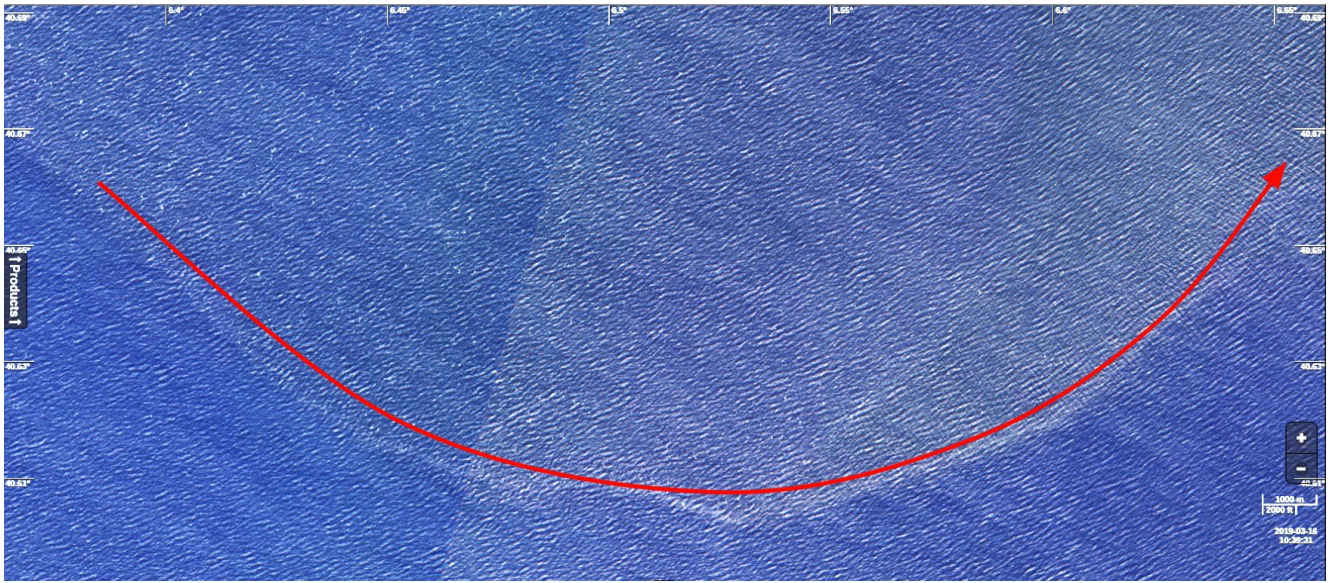
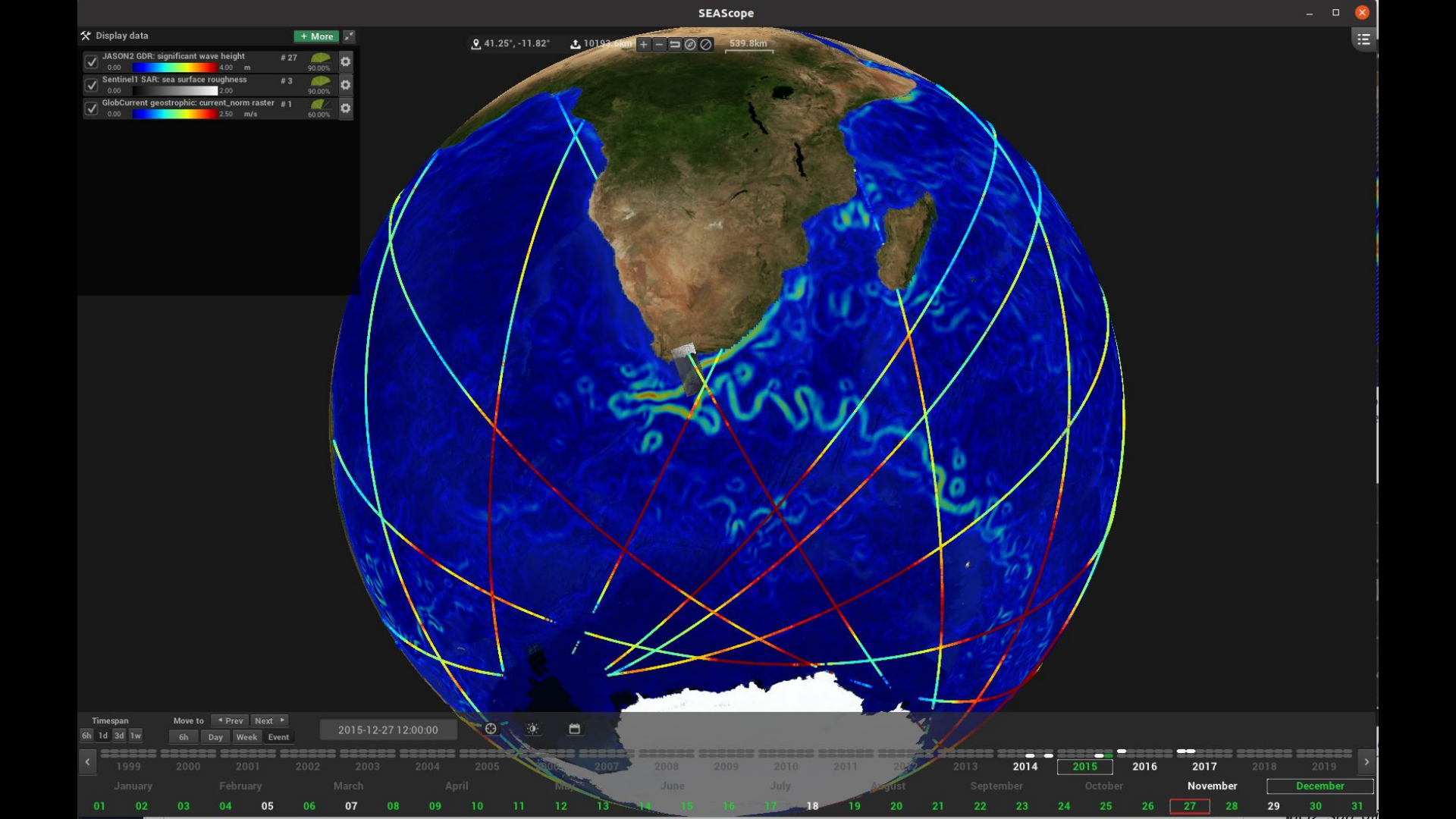
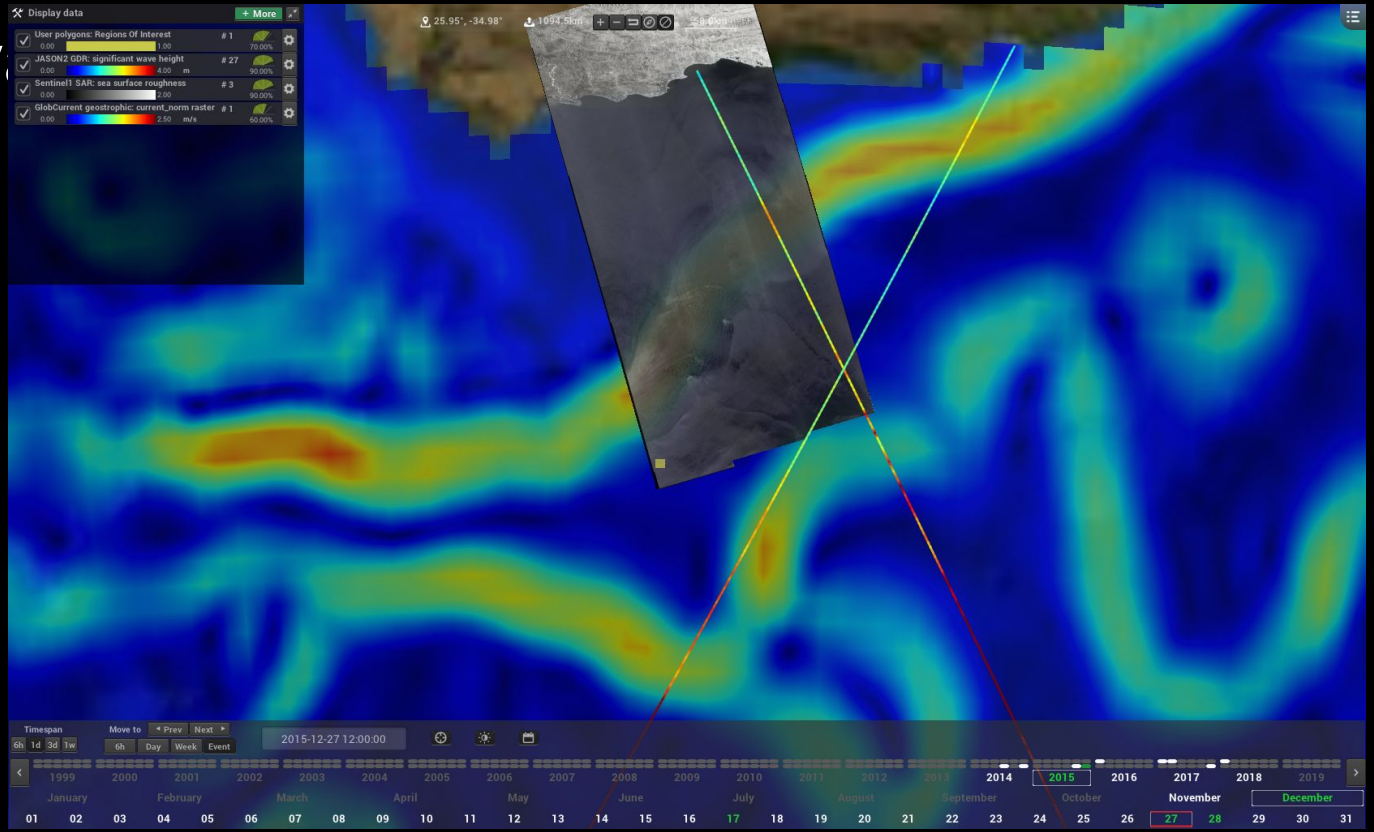

Trapped waves
Agulhas current
Products

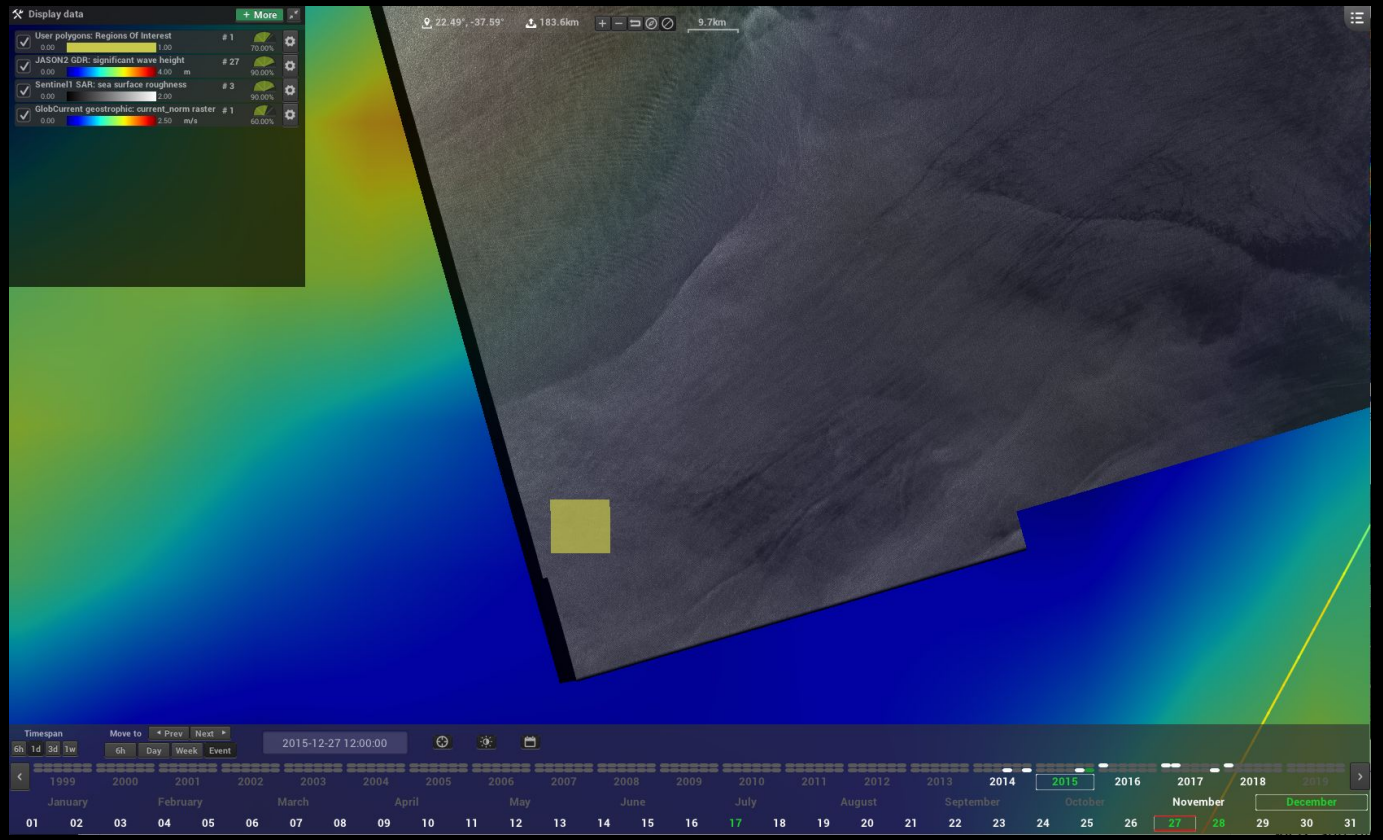
Figure 19. Sentinel 2 from march 16, 2019. The red path shows the wave rays as trapped by the surface current at a surface current front : the surface current acts as a wave guide.



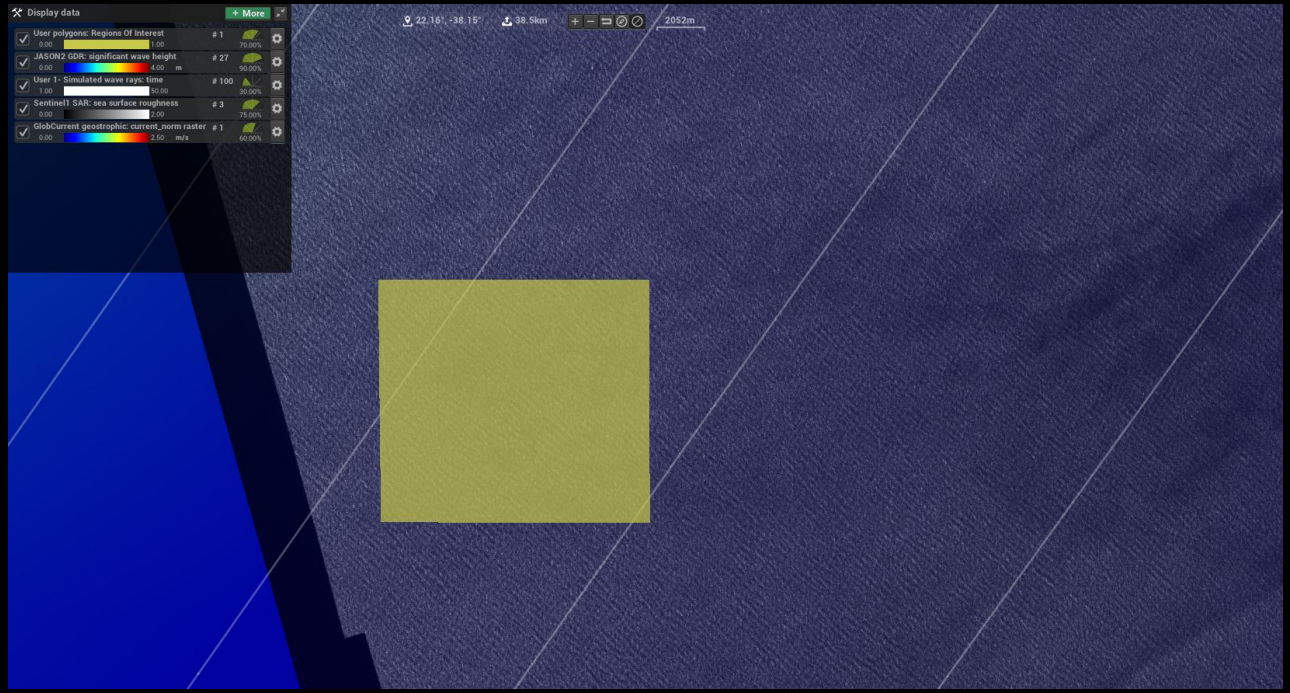

SEAScope
Display data
+ More
JASON2 GDR: significant wave height
27
0.00
4.00
m
90.00%
Sentinel1 SAR: sea surface roughness
3
0.00
2.00
90.00%
GlobCurrent geostrophic: current_norm raster
1
0.00
2.50
m/s
60.00%
41.25°, -11.82°
539.8km
Timespan
6h 1d 3d 1w
Move to
Prev
Next
6h Day Week Event
2015-12-27 12:00:00
1999 2000 2001 2002 2003 2004 2005 2007 2008 2009 2010 2011 2013 2014 2015 2016 2017 2018 2019
January February March April June July September October November December
01 02 03 04 05 06 07 08 09 10 11 12 13 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

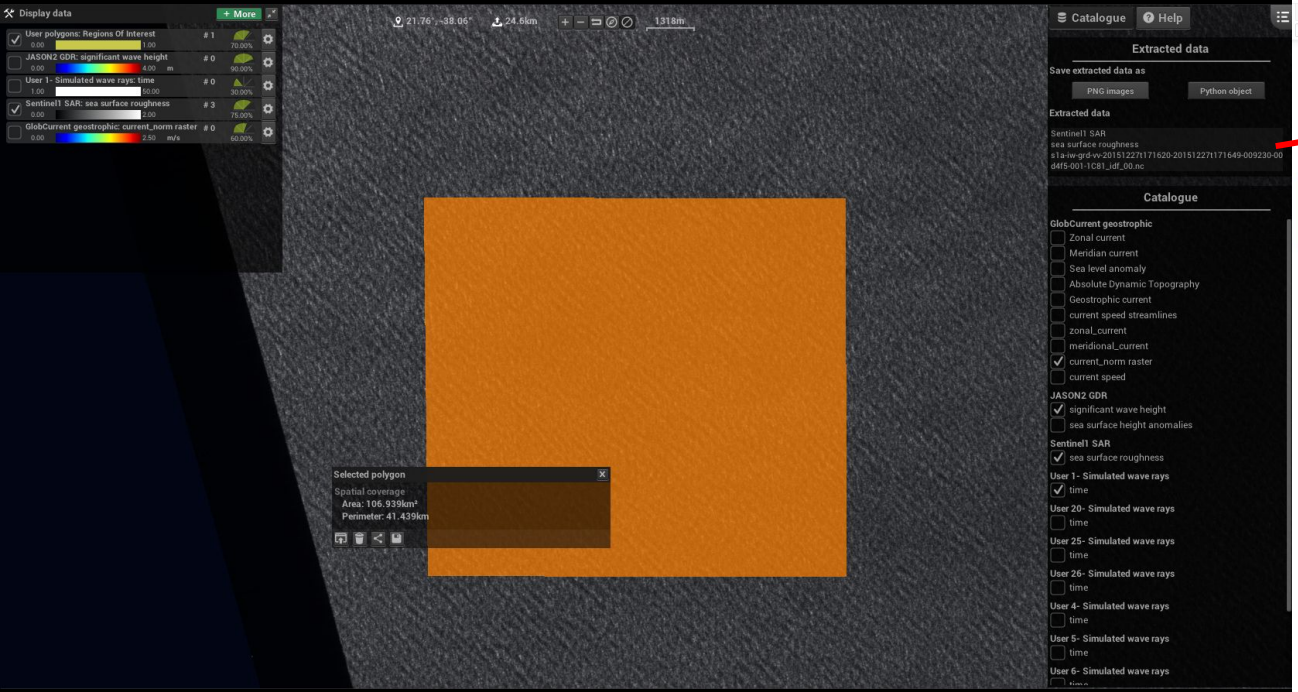
bserva
urrent



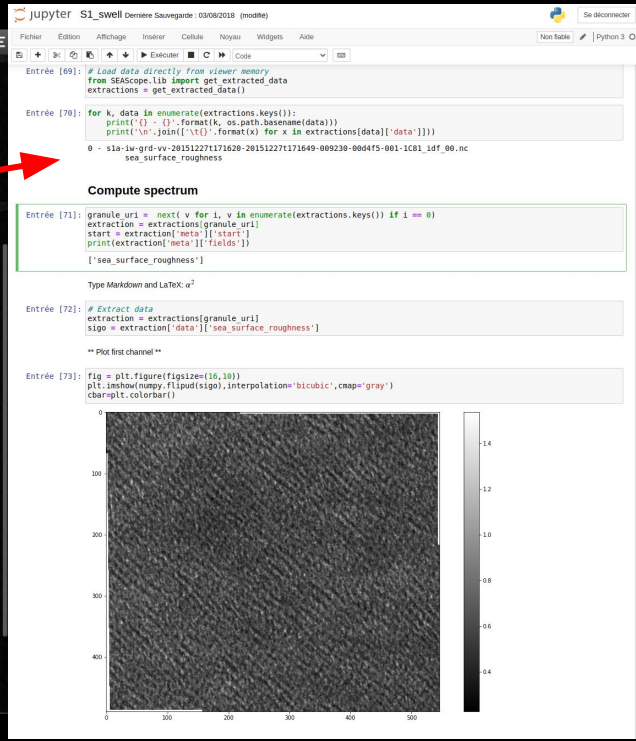

Display data
+ More
User polygons: Regions Of Interest # 1
0.00 1.00 70.00%
JASON2 GDR: significant wave height # 27
0.00 4.00 m 90.00%
Sentinel1 SAR: sea surface roughness # 3
0.00 2.00 90.00%
GlobCurrent geostrophic: current_norm raster # 1
0.00 2.50 m/s 60.00%
22.49°, -37.59°
183.6km
9.7km
Timespan
6h 1d 3d 1w
Move to
Prev Next
6h Day Week Event
2015-12-27 12:00:00
1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
January February March April May June July August September October November December
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Sentinel-1

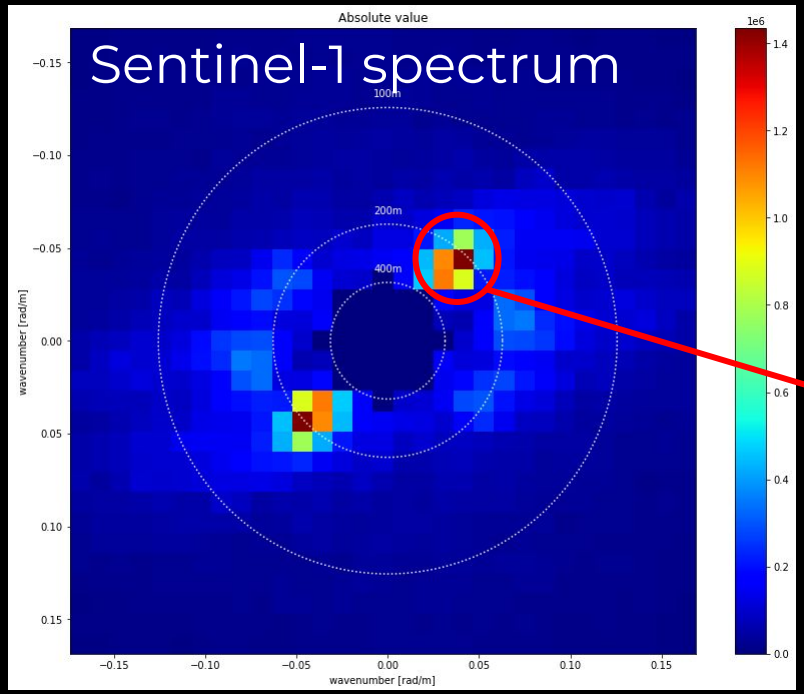

Display data
+ More
User polygons: Regions Of Interest
1
0.00
1.00
70.00%
JASON2 GDR: significant wave height
27
0.00
4.00
m
90.00%
User 1- Simulated wave rays: time
100
1.00
50.00
30.00%
Sentinel1 SAR: sea surface roughness
3
0.00
2.00
75.00%
GlobCurrent geostrophic: current_norm raster
1
0.00
2.50
m/s
60.00%
22.16°, -38.15°
38.5km
2052m


Display data
+ More
User polygons: Regions Of Interest
JASON2 GDR: significant wave height
User 1- Simulated wave rays: time
Sentinel1 SAR: sea surface roughness
GlobCurrent geostrophic: current_norm raster
21.76°,-38.06°
24.6km
1318m
Selected polygon
Spatial coverage
Area: 106.939km²
Perimeter: 41.439km

Catalogue
Help
Extracted data
Save extracted data as
PNG images
Python object
Extracted data
Sentinel1 SAR
sea surface roughness
s1a-iw-grd-vv-20151227t171620-20151227t171649-009230-00d4f5-001-1C81_idf_00.nc
Catalogue
GlobCurrent geostrophic
Zonal current
Meridian current
Sea level anomaly
Absolute Dynamic Topography
Geostrophic current
current speed streamlines
zonal_current
meridional_current
current_norm raster
current speed
JASON2 GDR
significant wave height
sea surface height anomalies
Sentinel1 SAR
sea surface roughness
User 1- Simulated wave rays
time
User 20- Simulated wave rays
time
User 25- Simulated wave rays
time
User 26- Simulated wave rays
time
User 4- Simulated wave rays
time
User 5- Simulated wave rays
time
User 6- Simulated wave rays


jupyter S1_swell Dernière Sauvegarde : 03/08/2018 (modifié)
Se déconnecter
Fichier Édition Affichage Insérer Cellule Noyau Widgets Aide
Non fiable
Python 3
Exécuter
Code
Entrée [69]:
# Load data directly from viewer memory
from SEAScope.lib import get_extracted_data
extractions = get_extracted_data()
Entrée [70]:
for k, data in enumerate(extractions.keys()):
print('{} - {}'.format(k, os.path.basename(data)))
print('\n'.join(['\t{}'.format(x) for x in extractions[data]['data']]))
0 - s1a-iw-grd-vv-20151227t171620-20151227t171649-009230-00d4f5-001-1C81_idf_00.nc
sea_surface_roughness
Compute spectrum
Entrée [71]:
granule_uri = next(v for i, v in enumerate(extractions.keys()) if i == 0)
extraction = extractions[granule_uri]
start = extraction['meta']['start']
print(extraction['meta']['fields'])
['sea_surface_roughness']
Type Markdown and LaTeX: α²
Entrée [72]:
# Extract data
extraction = extractions[granule_uri]
sigo = extraction['data']['sea_surface_roughness']
** Plot first channel **
Entrée [73]:
fig = plt.figure(figsize=(16,10))
plt.imshow(numpy.flipud(sigo),interpolation='bicubic',cmap='gray')
cbar=plt.colorbar()

Estimation du spectre incident sur imagerie SAR



jupyter SWELL_refrac3 (modifié)

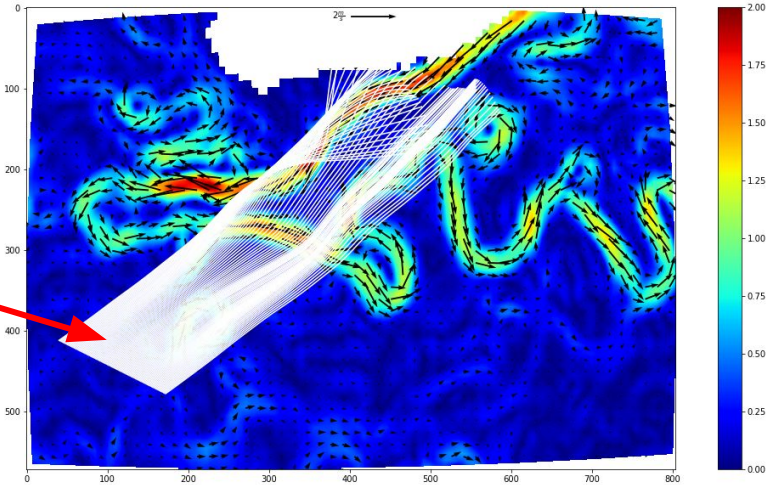
Se déconnecter

Fichier Édition Affichage Insérer Cellule Noyau Widgets Aide

Non fiable | Python 3

Exécuter | Code

```
                numpy.clip(numpy.flipud(u[::15,::15]),-2,2),
                numpy.clip(numpy.flipud(v[::15,::15]),-2,2))
qk = plt.quiverkey(Q, 0.5, 0.98, 2, r'$2 \frac{m}{s}$', labelpos='W',
                   fontproperties={'weight': 'bold'})
for c in range(nseed):
    plt.plot(y[:,c],-x[:,c],color='w',linewidth=1.5)
```



Export wave rays to SEAScope

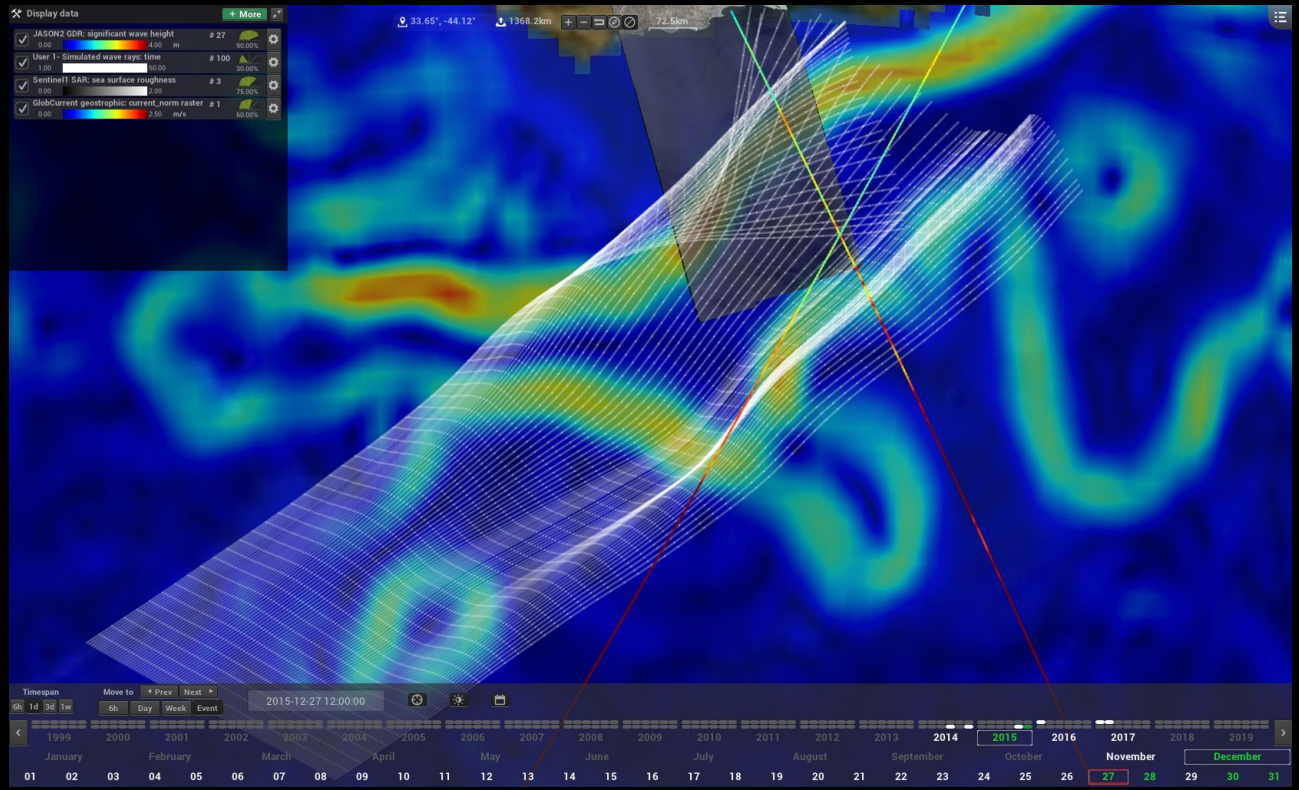
Define Collection:

** A granule has to belong to a collection **

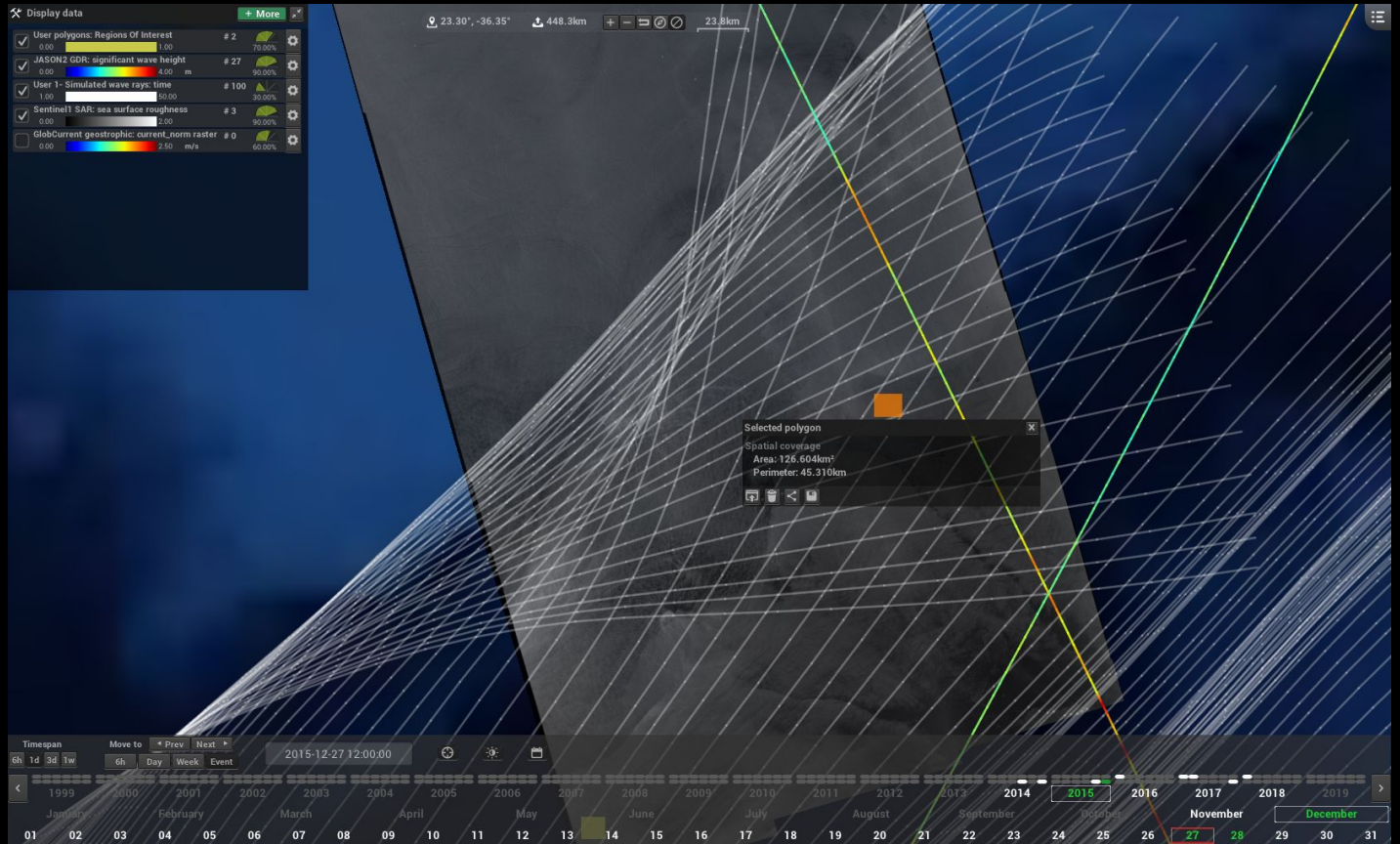
Entrée [349]:

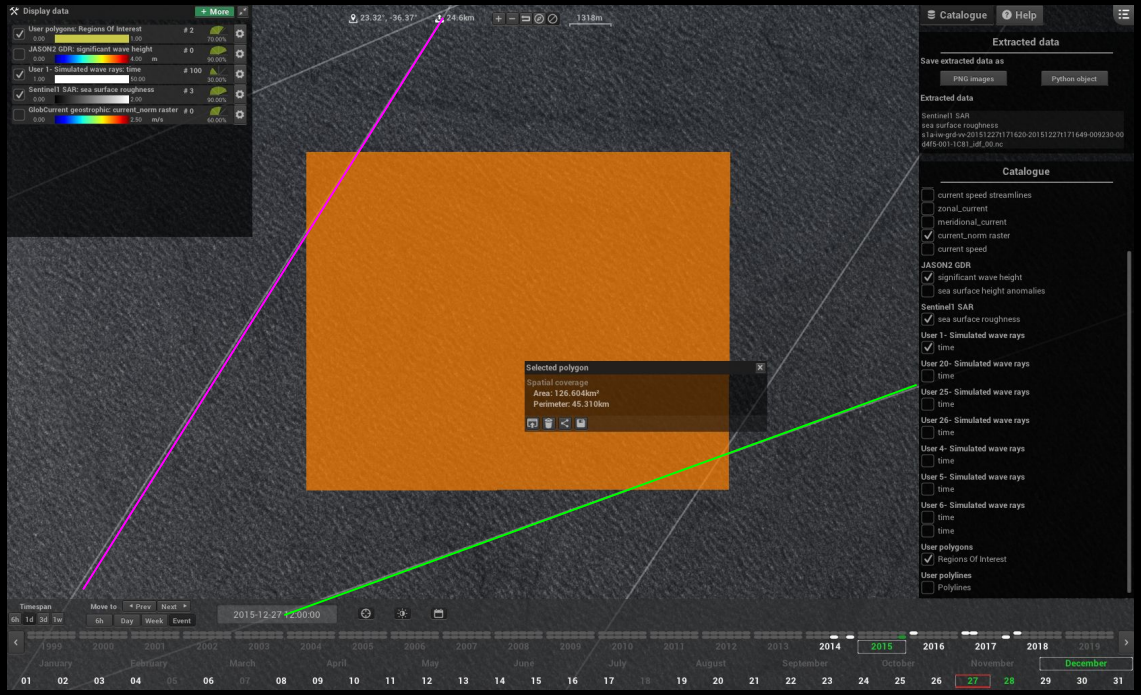
```
from SEAScope.lib.utils import create_collection, init_ids
# Make sure to keep the collection identifier, we will need it later
collection_id, collection = create_collection('User 4- Simulated wave rays')
print(collection_id)
```

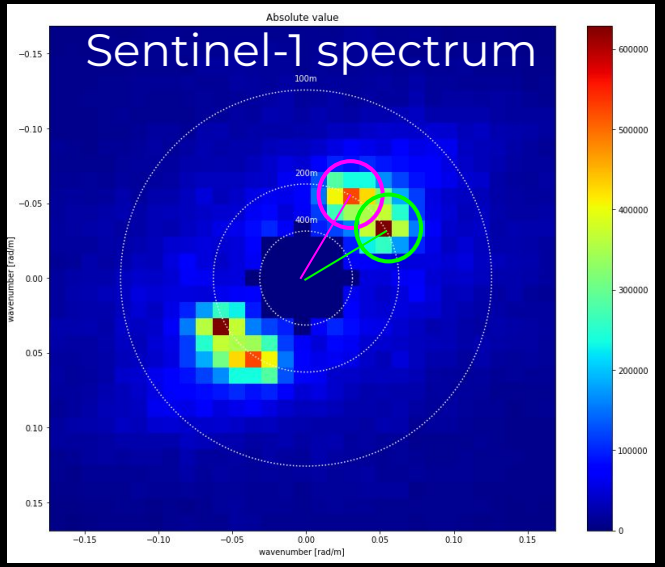
Observation of wave modification by surface current from Sentinel-1 et Jason-2 satellite data



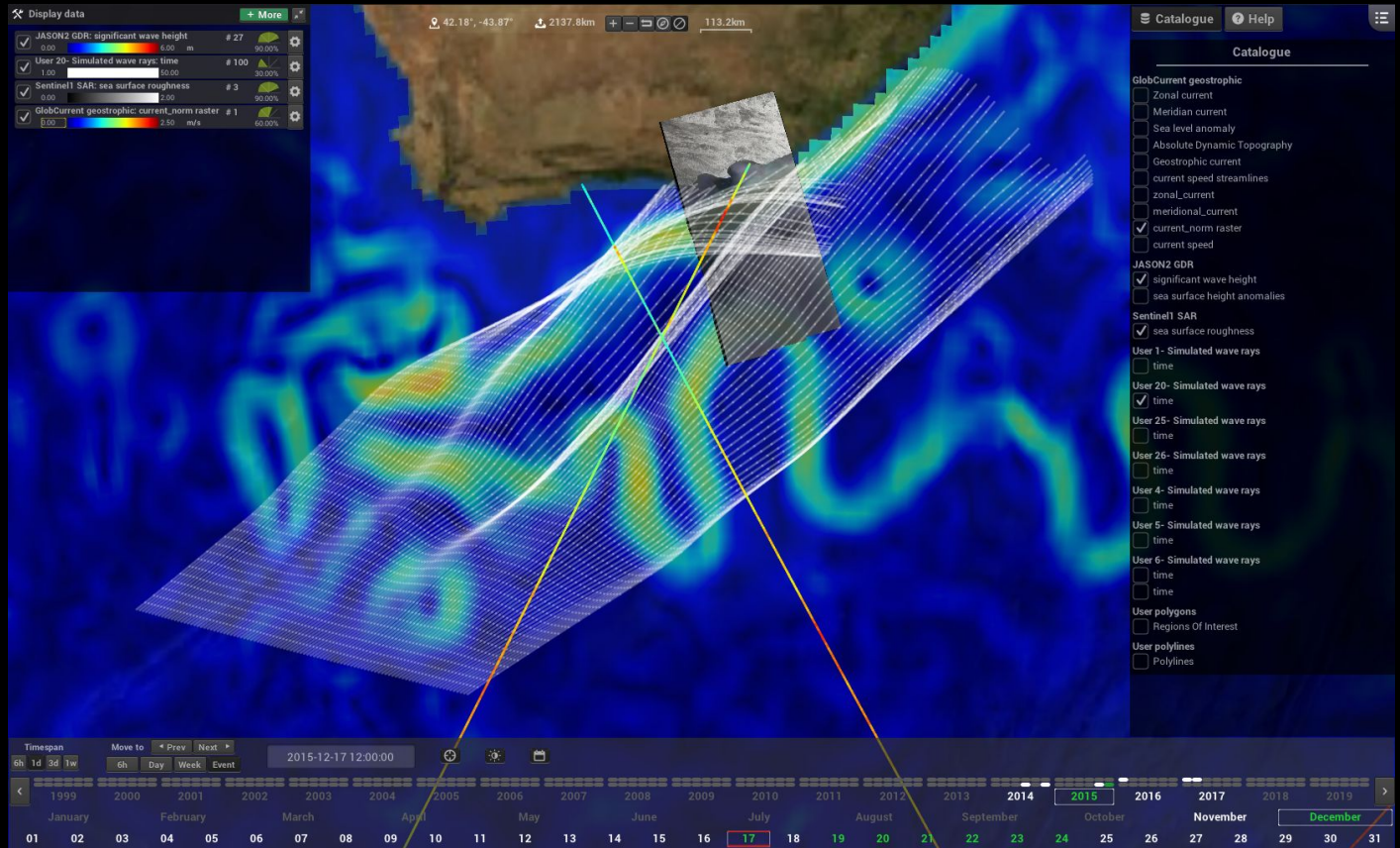
Observation of wave modification by surface current from Sentinel-1 et Jason-2 satellite data



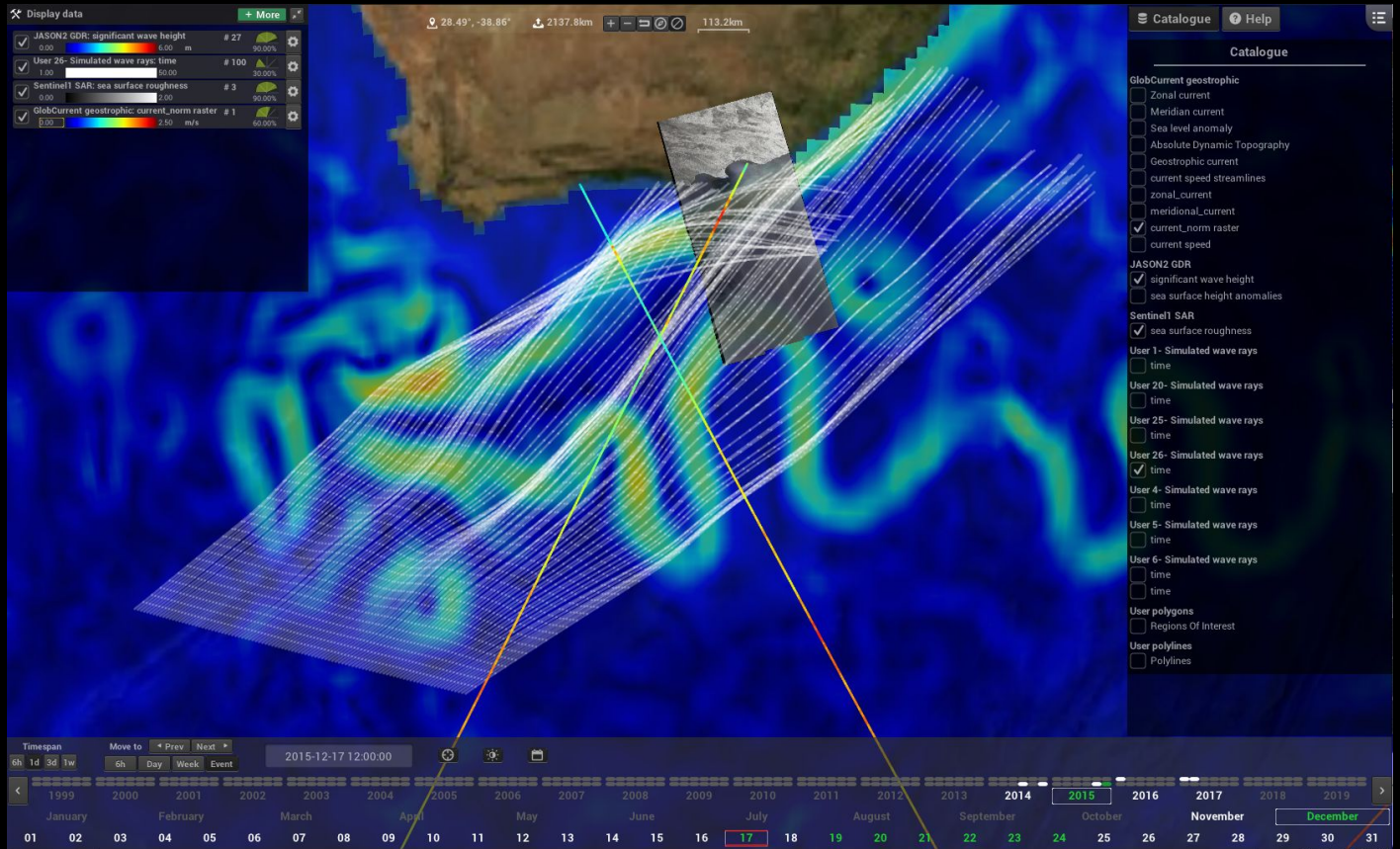

Display data
+ More
User polygons: Regions Of Interest
JASON2 GDR: significant wave height
User 1- Simulated wave rays: time
Sentinel1 SAR: sea surface roughness
GlobCurrent geostrophic current_norm raster
Catalogue
Help
Extracted data
Save extracted data as
PNG images
Python object
Extracted data
Sentinel1 SAR
sea surface roughness
Catalogue
current speed streamlines
zonal_current
meridional_current
current_norm raster
current speed
JASON2 GDR
significant wave height
sea surface height anomalies
Sentinel1 SAR
sea surface roughness
User 1- Simulated wave rays
time
User 20- Simulated wave rays
time
User 25- Simulated wave rays
time
User 26- Simulated wave rays
time
User 4- Simulated wave rays
time
User 5- Simulated wave rays
time
User 6- Simulated wave rays
time
time
User polygons
Regions Of Interest
User polylines
Polylines
Selected polygon
Spatial coverage
Area: 126.604km²
Perimeter: 45.310km
Timespan
Move to
Prev
Next
6h
1d
3d
1w
Day
Week
Event
2015-12-27 12:00:00
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
January
February
March
April
May
June
July
August
September
October
November
December
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31


Absolute value
Sentinel-1 spectrum
100m
200m
400m
wavenumber [rad/m]
wavenumber [rad/m]
−0.15
−0.10
−0.05
0.00
0.05
0.10
0.15
600000
500000
400000
300000
200000
100000
0

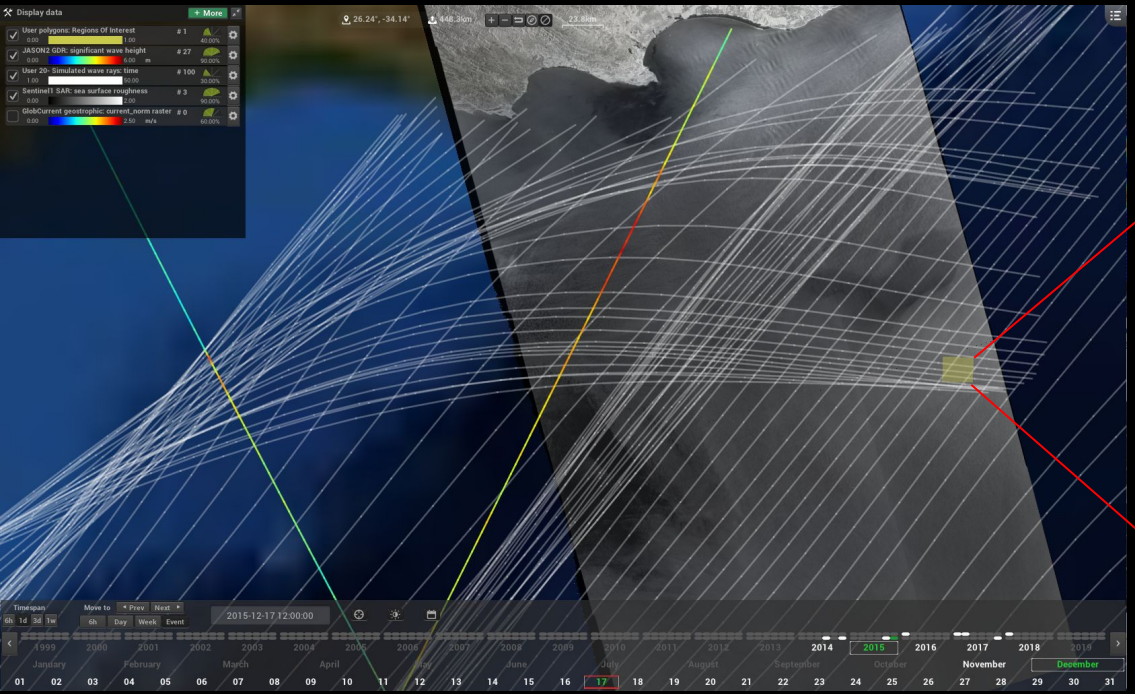
Deterministic model : 17 dec 2015

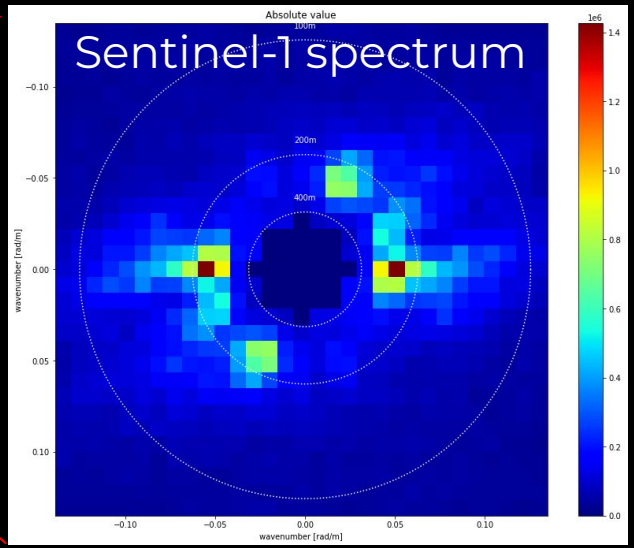


Stochastic model with random small scale velocities

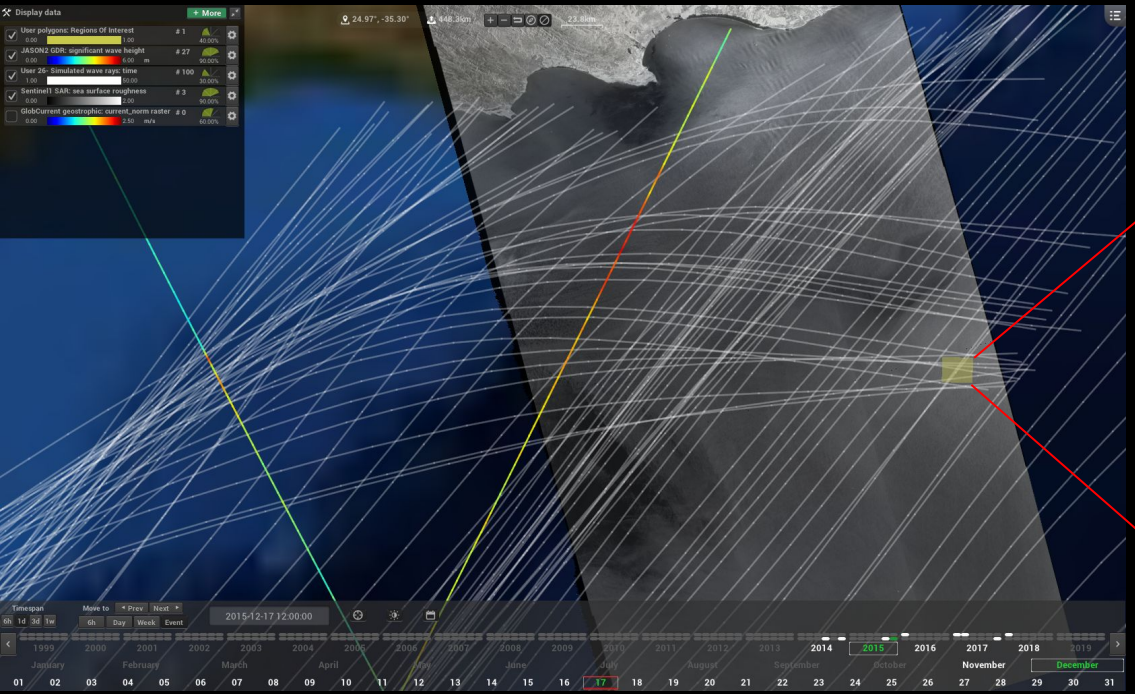


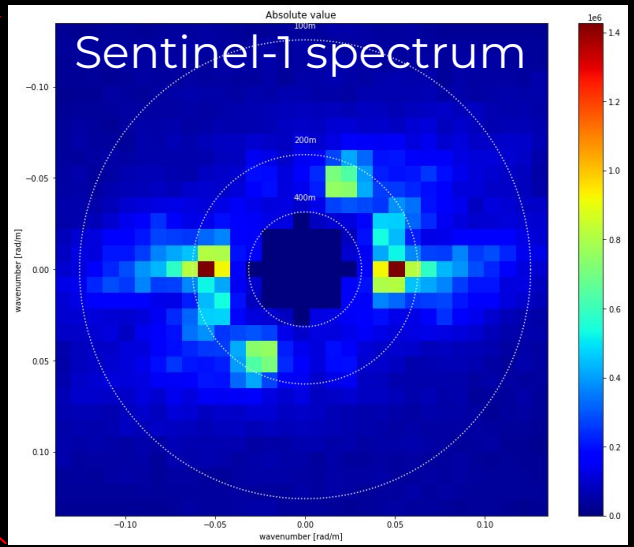
Deterministic model with Sentinel-1 spectrum





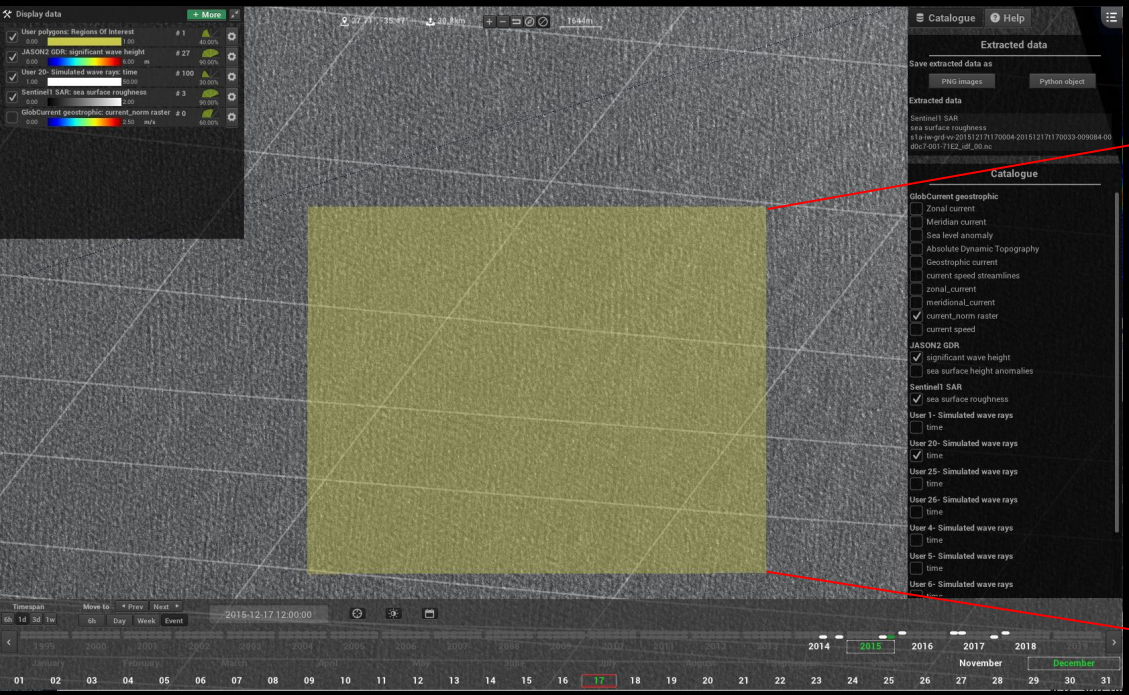
Stochastic model with random small scale velocities

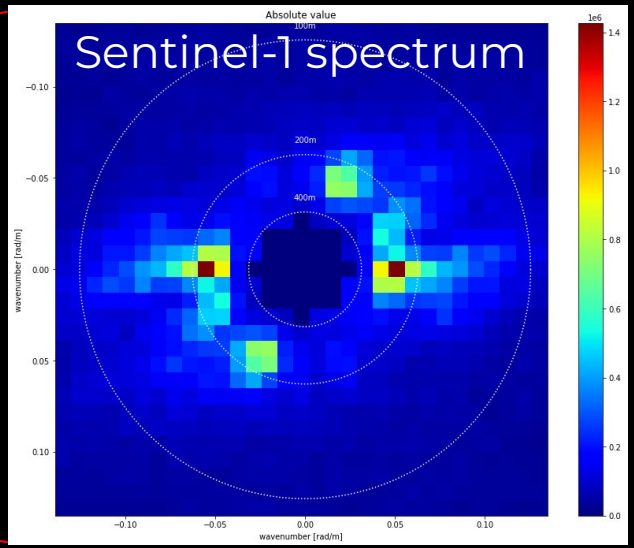




Deterministic model

Sentinel-1 spectrum





Stochastic model

Sentinel-1 spectrum