Mean Sea Surface (MSS) Working Group for SWOT

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- Need high resolution MSS for isolating ocean dynamics.
- MSS should have long wavelength accuracy from multidecadal repeat-track altimetry (ERM) and short wavelength precision from geodetic mission (GM) phases and now SWOT.
- Need uncertainty map as well as error spectrum.
- MSS should have an epoch and a linear variation with time.

Agenda for Today

- Hybrid 2023 MSS: Status and update using SWOT data – Isabelle Pujol
- Python software to replace the MSS on SWOT L2 data – David Sandwell
- What is next in the MSS/SWOT plans?
- General discussion items

Hybrid 2023 MSS + SWOT – Isabelle Pujol

Python software to replace the MSS on SWOT L2 - expert

David Sandwell, Yao Yu (10 min)

https://github.com/SWOT-community/SWOT_SIO

one must install pygmt using the instructions linked below

https://www.pygmt.org/v0.3.0/install.html#installing-gmt-and-other-dependencies

In [1]:

```
import xarray as xr
import matplotlib.pyplot as plt
import pygmt
import os
import pandas as pd
```

get the global MSS grids the first time only

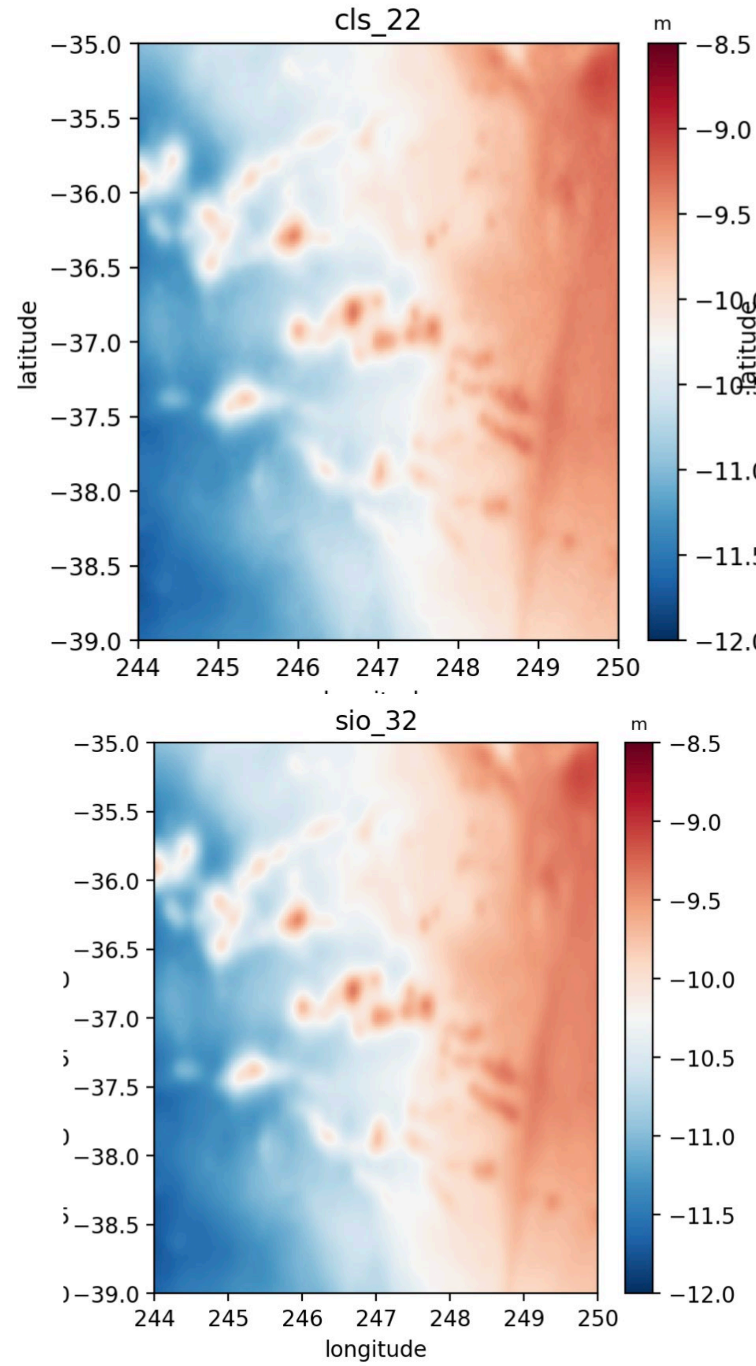
In [2]:

```
#!wget -q --no-check-certificate https://topex.ucsd.edu/pub/MSS_replace/CNES_CLS_22_H_WGS84.nc
#!wget -q --no-check-certificate https://topex.ucsd.edu/pub/MSS_replace/mss_sio_32.1_WGS84.nc
```

open the two mss grid and display an area

In [3]:

```
grid_file32 = xr.open_dataset("mss_sio_32.1_WGS84.nc")
cgrid32 = grid_file32.sel(lon=slice(244,250), lat=slice(-39,-35))
grid_file22 = xr.open_dataset("CNES_CLS_22_H_WGS84.nc")
cgrid22 = grid_file22.sel(lon=slice(244,250), lat=slice(-39,-35))
plt.figure(figsize=(10, 10), dpi=200)
plt.subplot(222); plt.pcolormesh(cgrid32.lon, cgrid32.lat, cgrid32.z, cmap='RdBu_r', shading='auto', vmin = -12,
plt.xlim([244,250]); plt.ylim([-39,-35]); plt.title('sio_32'); plt.xlabel('longitude'); plt.ylabel('latitude')
clb = plt.colorbar(); clb.ax.set_title('m',fontsize=8);
plt.subplot(221); plt.pcolormesh(cgrid22.lon, cgrid22.lat, cgrid22.z, cmap='RdBu_r', shading='auto', vmin = -12,
plt.xlim([244,250]); plt.ylim([-39,-35]); plt.title('cls_22'); plt.xlabel('longitude'); plt.ylabel('latitude')
clb = plt.colorbar(); clb.ax.set_title('m',fontsize=8);
plt.show()
```



read a netcdf file of L2 expert

In [4]:

```
ds_Foundation = xr.open_dataset("SWOT_L2_LR_SSH_Expert_547_011_20230609T190904_20230609T200011_PIB0_01.nc")
num_lines = ds_Foundation.sizes['num_lines']
num_pixels = ds_Foundation.sizes['num_pixels']
num_lines
```

Out[4]:

```
9866
```

extract the sio_32 MSS at the locations of the SWOT data using grdtrack

In [5]:

```
grid32 = "mss_sio_32.1_WGS84.nc"
data32 = {'longitude': ds_Foundation["longitude"].values.flatten(),
        'latitude': ds_Foundation["latitude"].values.flatten()}
track_points = pd.DataFrame(data32)
# Use grdtrack to sample the grid along the track
track_data32 = pygmt.grdtrack(points=track_points, grid=grid32,newcolname="sio32")
```

extract the cls_22 MSS at the locations of the SWOT data using grdtrack

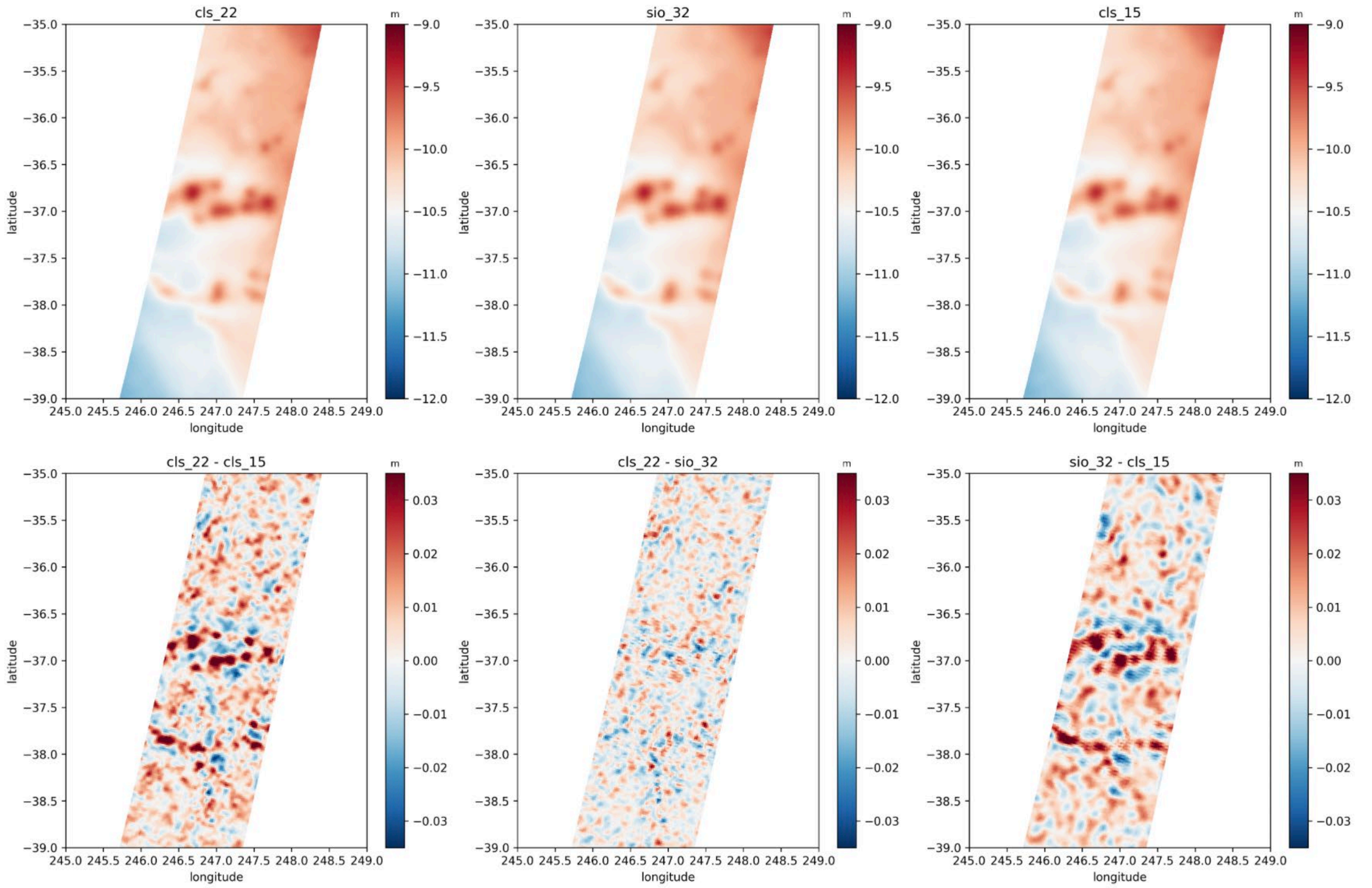
In [6]:

```
grid22 = "CNES_CLS_22_H_WGS84.nc"
data22 = {'longitude': ds_Foundation["longitude"].values.flatten(),
        'latitude': ds_Foundation["latitude"].values.flatten()}
track_points = pd.DataFrame(data22)
# Use grdtrack to sample the grid along the track
track_data22 = pygmt.grdtrack(points=track_points, grid=grid22,newcolname="cls22")
```

take the three-way differences of the models

7]:

```
cls22_mss_hy = track_data22.cls22.to_numpy().reshape(num_lines, num_pixels) - ds_Foundation.mean_sea_surface_cnes
sio32_mss_hy = track_data32.sio32.to_numpy().reshape(num_lines, num_pixels) - ds_Foundation.mean_sea_surface_cnes
cls22_sio32 = track_data22.cls22.to_numpy().reshape(num_lines, num_pixels) - track_data32.sio32.to_numpy().reshap
```



What is next?

- The new Hybrid 23 MSS will be added to the mix soon.
- In the Fall of 2024, the CLS/CNES group will work with Sandwell and Anderson to construct a new MSS by combining SWOT small scale MSS with Hybrid 23 large scale MSS.
- The Hybrid 23 MSS is the average 1993 – 2012. Anderson and Nerem will use newer data (nadir and SWOT) to construct a linear variation of MSS with time to create MSS(t). CLS will use DUACS to change reference time.

Discussion Items

Is SWOT meeting requirements, pre-launch expectations?

- **Yes!!,** we are seeing real geoid signals down to 8 km wavelength.
- Data coverage in areas of seasonal ice is better than nadir altimeters.
- Coastal data coverage seems excellent although more work needs to be done to understand the SWOT data.

New results (what you love about SWOT)?

- SWOT reveals the defects in the nadir MSS
- SWOT reveals small scale features of the seafloor such as abyssal hills and small seamounts.
- SWOT will improve coastal tide models for improved coastal MSS.

Discussion Items

Challenges and steps forward

- No new gravity information in diamond gaps.
    - Need to recover the data on edges of swaths.
    - AND/OR **shift the orbit** in longitude at some point in the mission.
- One year of data does not average out the ocean variability – especially solitons.
    - Need several years of SWOT to suppress ocean variability.
- Need to explore gravity recovery in polar areas and coastal areas.
- How to construct an MSS(t) using older nadir data and newer SWOT data.
- Using the improved gravity resolution from SWOT for improved bathymetric prediction.
    - Physics-based Nettleton or machine learning?