Ocean simulator for science applications

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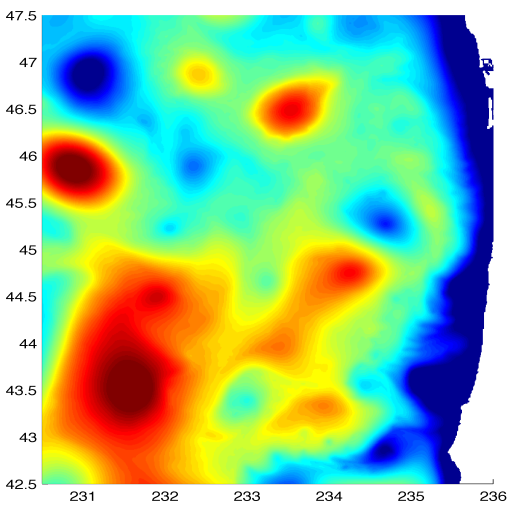
SWOT simulator for Ocean Science

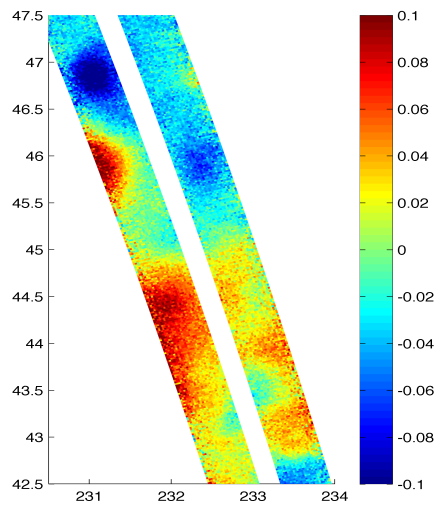
- The needs for a light/portable tool to easily simulate SWOT L2 data with realistic sampling and errors/noise was pointed during the last SDT

- **The tool relies on spectral error budget specifications from the project team**
  → It is NOT an instrument simulator.

- Open source, download online: https://swot.jpl.nasa.gov/science/ and use git version

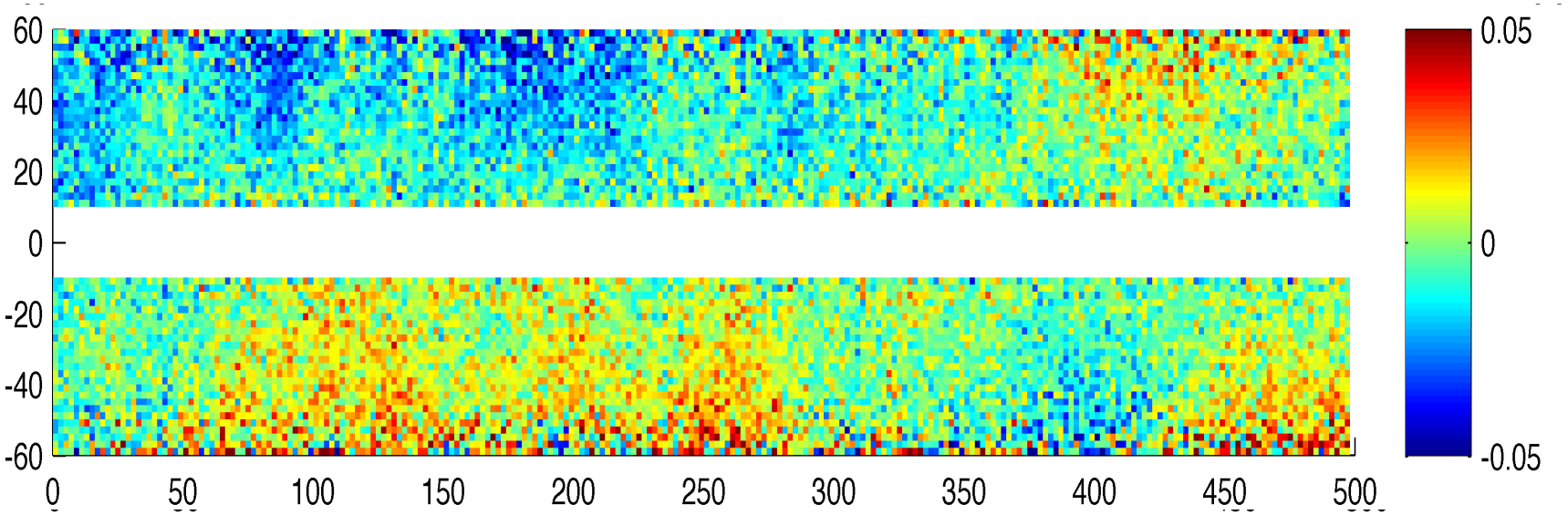
INPUTS: user's model Sea Surface Height

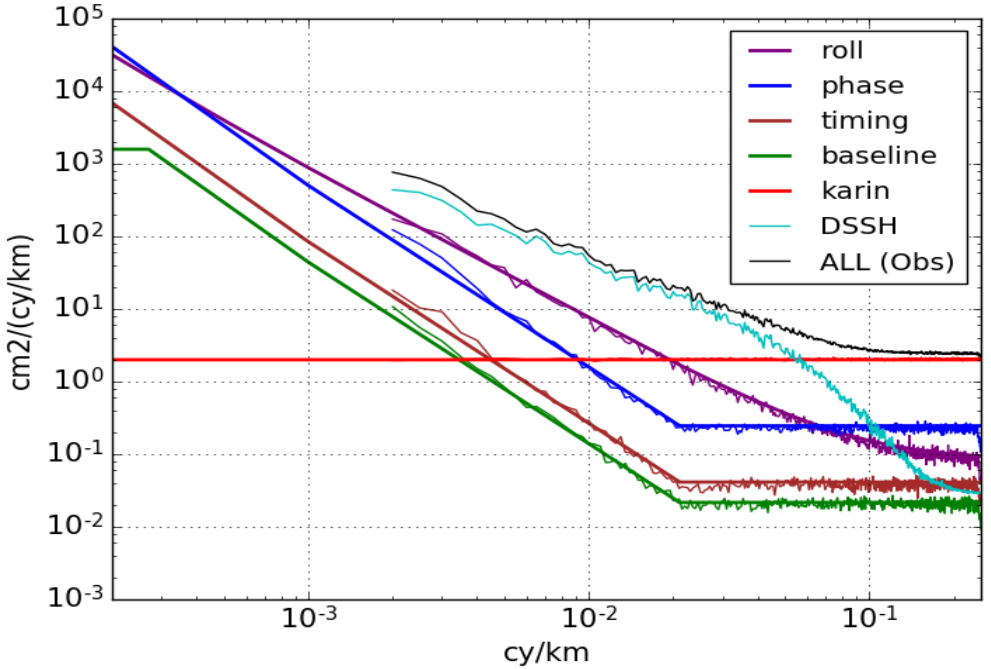




OUTPUTS: SWOT synthetic data sampled on a swath grid

Random error realizations





Playing with the simulator

Fill the parameter file:

```
# -----------------------#
# Files and directories
# -----------------------#
# ------ Directory that contains orbit file:
dir_setup='[yourpath]/SWOT_simulator/data/'
# ------ Directory that contains your own inputs:
indatadir='[yourpath_to_yourdata]/'
# ------ Directory that contains your outputs:
outdatadir='[yourpath_to_outputs]/'
# ------ Orbit file:
filesat=dir_setup+'/orbit292.txt'

# -----------------------#
# SWOT swath parameters
# -----------------------#
# ------ Satellite grid file root name:
#        (Final file name is root_name_[numberofpass].nc)
filesgrid=outdatadir+'/[your_grid_root_name}'
# ------ Force the computation of the satellite grid:
makesgrid=True or False
# ------ Give a subdomain if only part of the model is needed:
#        (modelbox=[lon_min, lon_max, lat_min, lat_max])
#        (If modelbox is None, the whole domain of the model is considered)
modelbox=None or [yourlon_min, yourlon_max, yourlat_min, yourlat_max]
# ------ Distance between the nadir and the end of the swath (in km):
halfswath=60.
# ------ Distance between the nadir and the beginning of the swath (in km):
halfgap=10.
# ------ Along track resolution (in km):
delta_al=1.
# ------ Across track resolution (in km):
```

A few technical possibilities

- Consider the provided orbits for the two phases of the mission:

Orbit	Repeat cycle (days)	Number of passes (orbits)
Fast Sampling orbit	0.99349	14
Science orbit	20.8646	292

- Test cross calibration algorithm : remove the 1,500 km cutoff that 'simulate' cross calibrations

- Possibility to simulate other altimetric observations (e.g. Jason, AltiKa, …): OSSEs with a constellation of nadir altimeters

Release of a new version

Summary of Change log:

- Compatibility with Python 3
- Format of netcdf output files have changed: more efficient storage, CF compliant, similarity with current practice in altimetry (nadir data in a separate file, passes split in ascending/descending passes …)
- More options for interpolation: runs faster and globally
- Readability and Flexibility of the code improved
- Altimeters noise improved
- Handle low resolution orbit

Bottom line: ⚠ Format of outputs have changed
Simulator is more efficient, runs faster, noise is more realistic …

Applications

- **The tool is designed to explore science applications:**

→ Consider the two mission phases: 1-day orbit and 21-day orbit: What science can we learn during the fast sampling phase

→ Reconstruct the 2D signal: Deal with long time gaps to reconstruct continuous SSH, deal with high frequency waves and short mesoscales, Impact of the noise for high-order derivative quantities (e.g. vorticity)

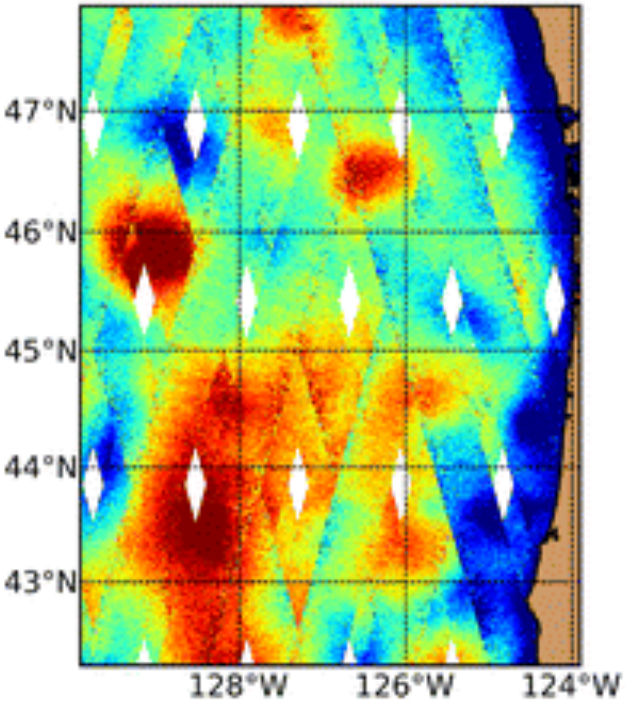
→ Reconstruct 3D dynamics: Retrieve vertical velocities?

- **The tool can also be used to test calibration algorithms to improve L2 products:**

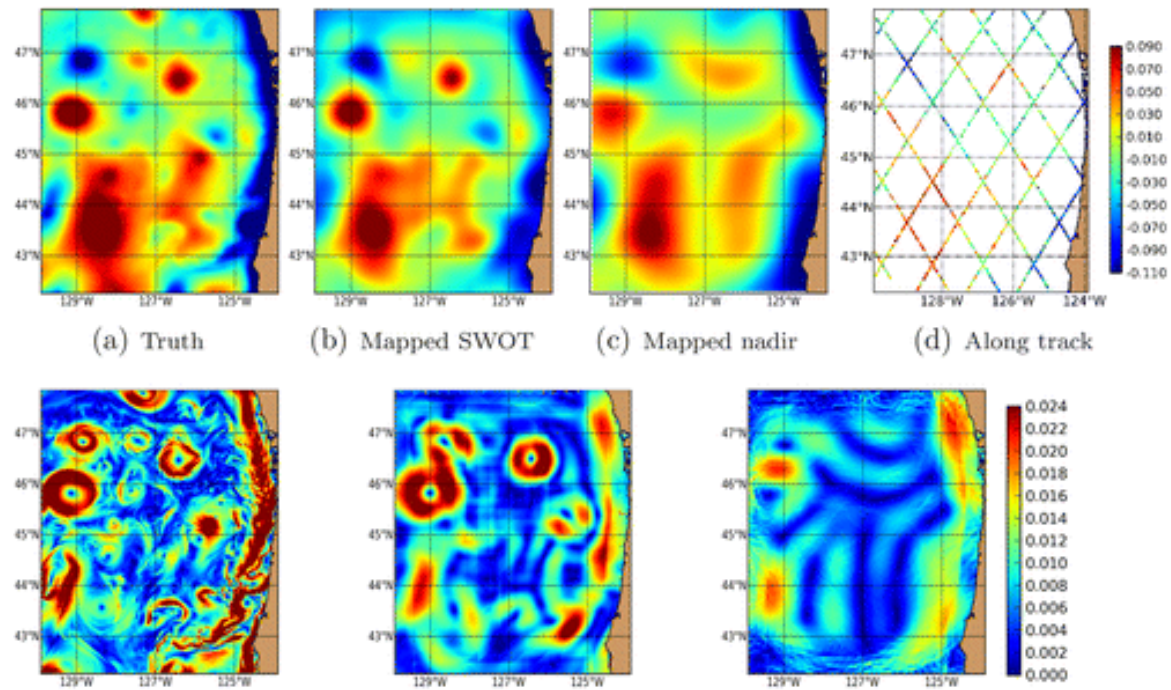
→ Roll error: test cross calibration techniques

A few examples of studies using the simulator

The Challenge of Using Future SWOT Data for Oceanic Field Reconstruction (Gaultier&al., JTECH, 2016)



(c) SWOT-like SSH



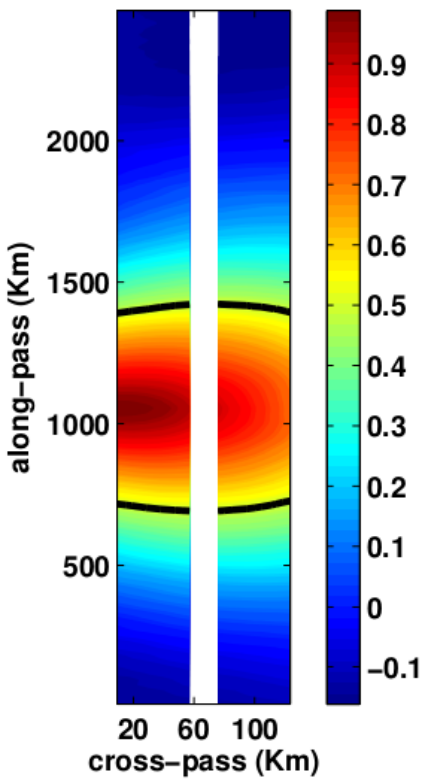
(a) Truth (b) Mapped SWOT (c) Mapped nadir (d) Along track

(e) True Velocity (f) From SWOT-like mapped observations (g) From Nadir-like mapped observations

Evaluate how standard interpolation methods would work on SWOT data

An efficient way to account for error correlations in the assimilation of SWOT observations (Cosme&al., 2016)

Using the simulator to build covariance error matrices for state estimation problems



Error correlation for a point in outer boundary of the left swath

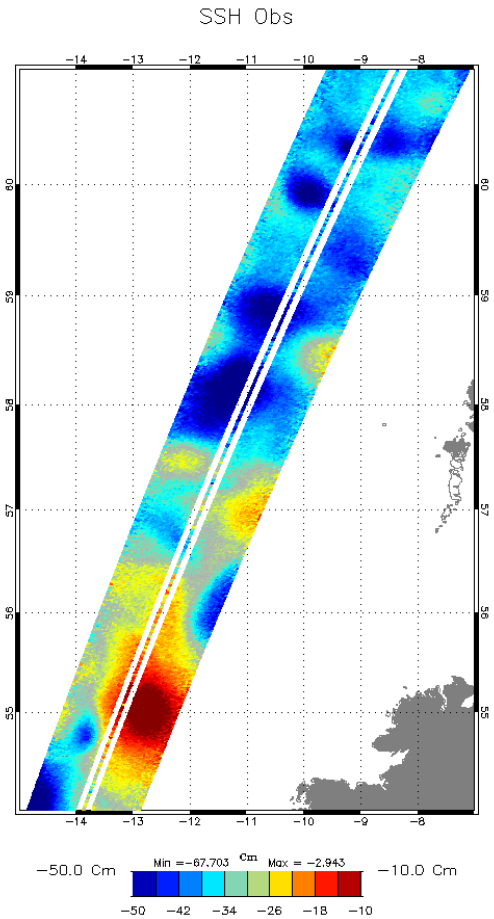
$$\mathbf{R}^{+} = \begin{pmatrix} \mathbf{D_0} & 0 & 0 & 0 & 0 \\ 0 & \mathbf{D_{1a}} & 0 & 0 & 0 \\ 0 & 0 & \mathbf{D_{1c}} & 0 & 0 \\ 0 & 0 & 0 & \mathbf{D_{2a}} & 0 \\ 0 & 0 & 0 & 0 & \mathbf{D_{2c}} \end{pmatrix}, \tag{6}$$

with diagonal blocks $\mathbf{D_0}, \mathbf{D_{1a}}, \mathbf{D_{1c}}, \mathbf{D_{2a}}$ and $\mathbf{D_{2c}}$, we can use the definition of the operator $\mathbf{T}$ and the Eq.(3) to calculate the inverse of $\mathbf{R}^{+}$ on the space of the observations $\vec{y}$:

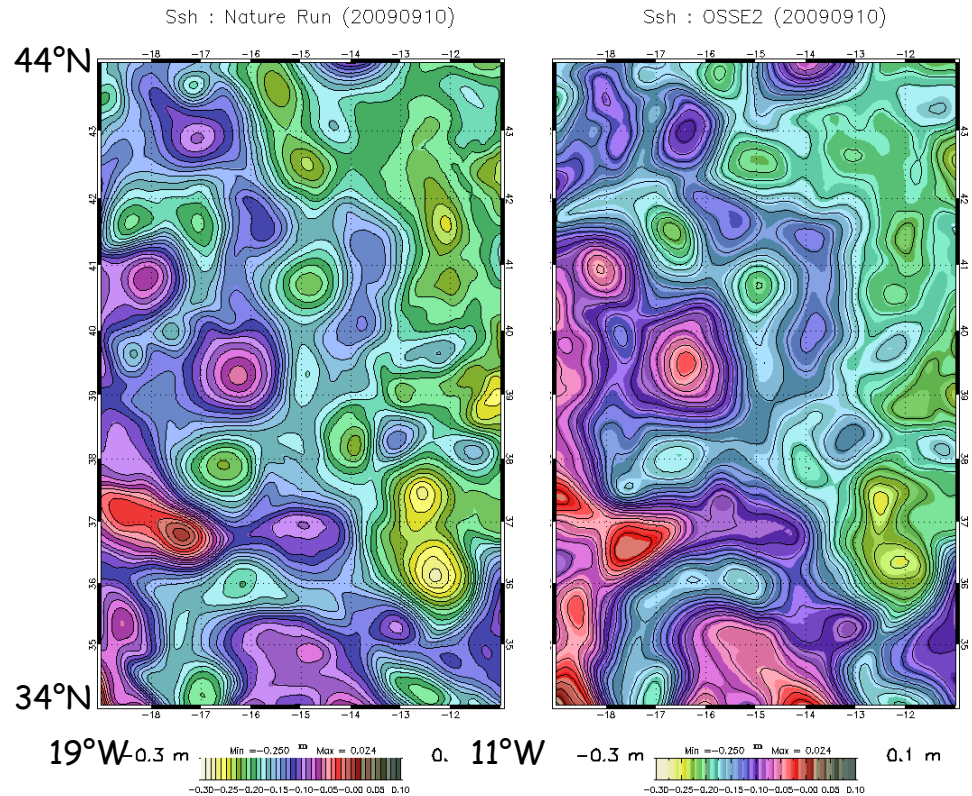
$$\mathbf{T}^T\mathbf{R}^{+-1}\mathbf{T} = \mathbf{D_0}^{-1} + \mathbf{T_{1a}}^T\mathbf{D_{1a}}^{-1}\mathbf{T_{1a}} + \mathbf{T_{1c}}^T\mathbf{D_{1c}}^{-1}\mathbf{T_{1c}} + \mathbf{T_{2a}}^T\mathbf{D_{2a}}^{-1}\mathbf{T_{2a}} + \mathbf{T_{2c}}^T\mathbf{D_{2c}}^{-1}\mathbf{T_{2c}}$$

where $\mathbf{T_{1a}}, \mathbf{T_{1c}}$ and $\mathbf{T_{2a}}, \mathbf{T_{2c}}$ are the discrete forward first and second order derivative operators in the along and cross swath direction respectively.

Assimilation of SWOT altimetry data in Mercator Ocean system (Benkiran&al., 2016)



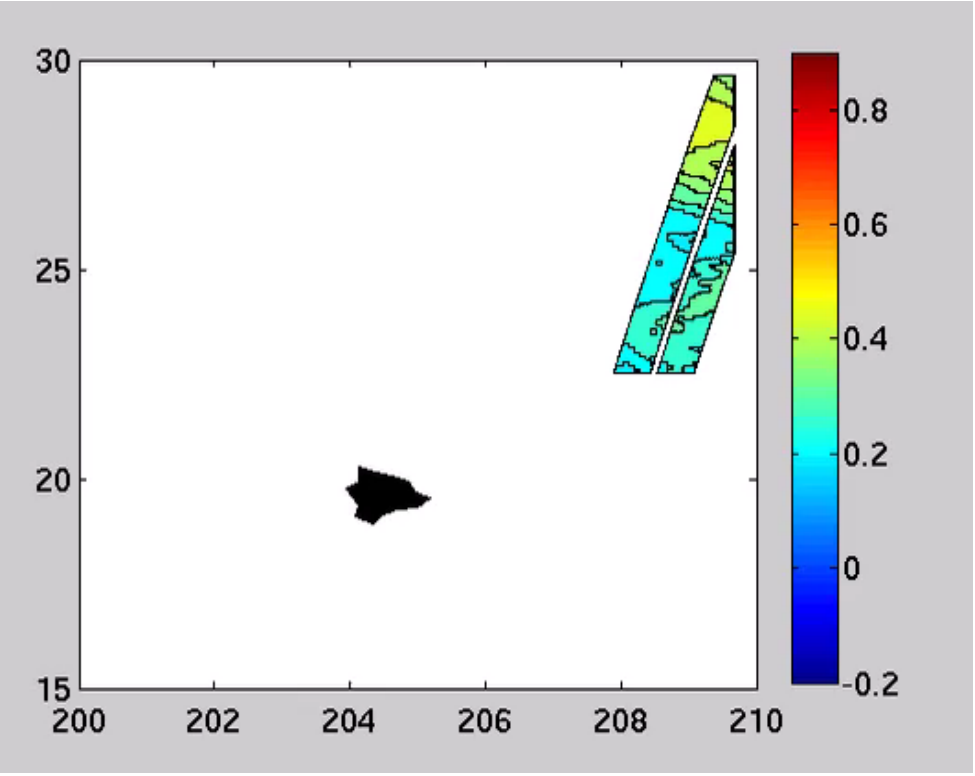
Simulated Karin+nadir altimeter data

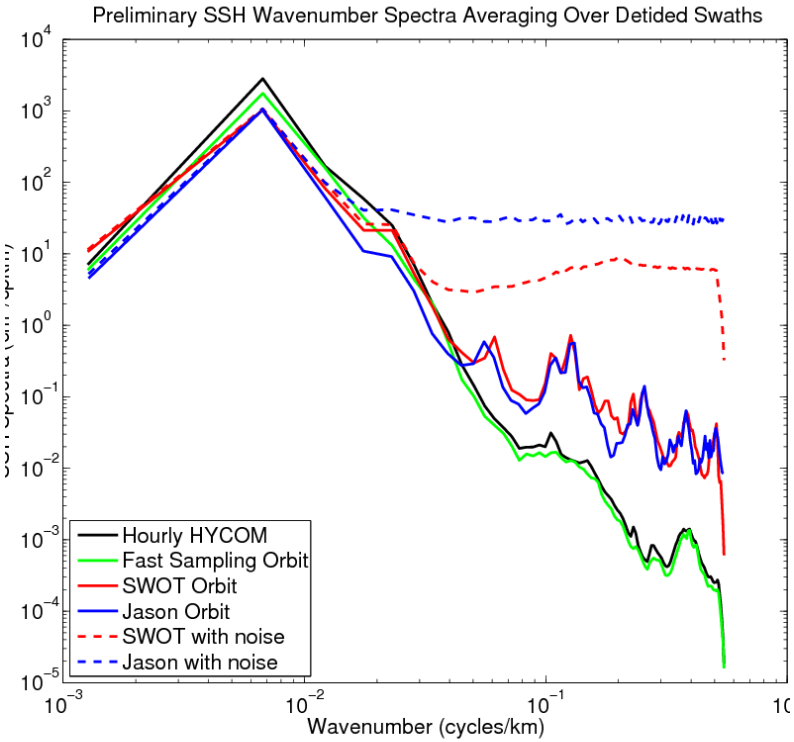


NR : Data IBI36

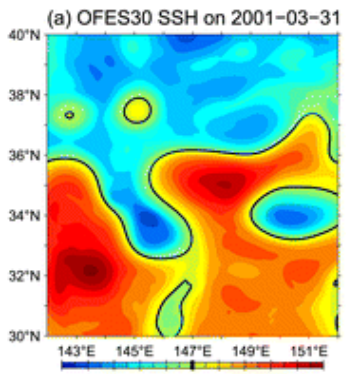
OSSE2: Assim SWOT (Forecast)

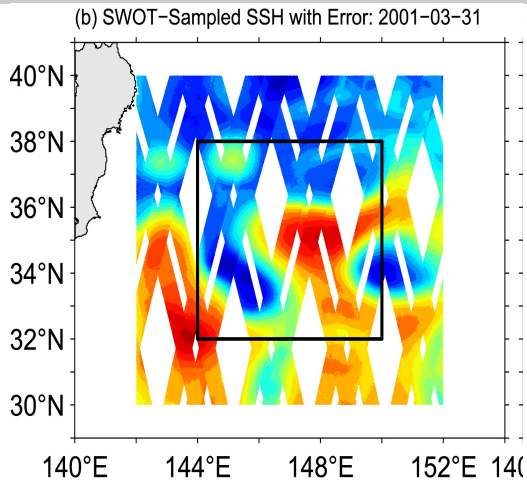
Explore possibilities to separate high-frequency signals (Savage&al.)



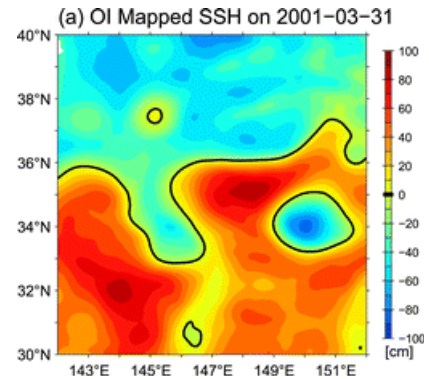


Reconstructability of Three-Dimensional Upper-Ocean Circulation from SWOT Sea Surface Height Measurements (Qiu et al., JPO, 2016)

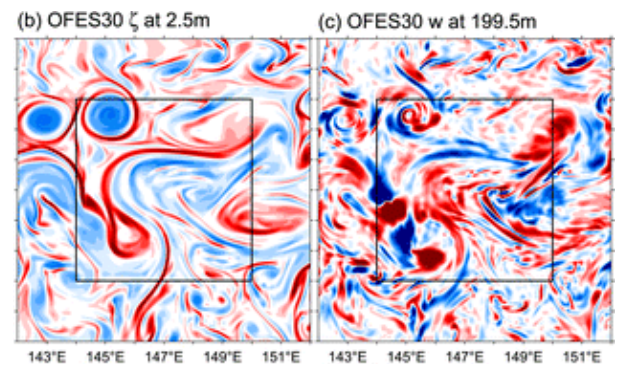




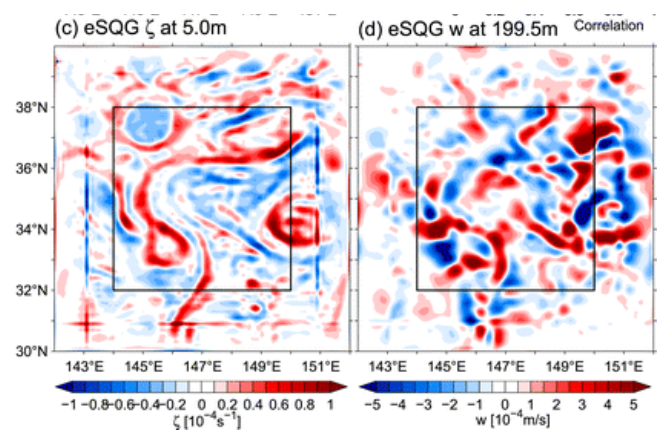
Simulator inputs



Model reference:

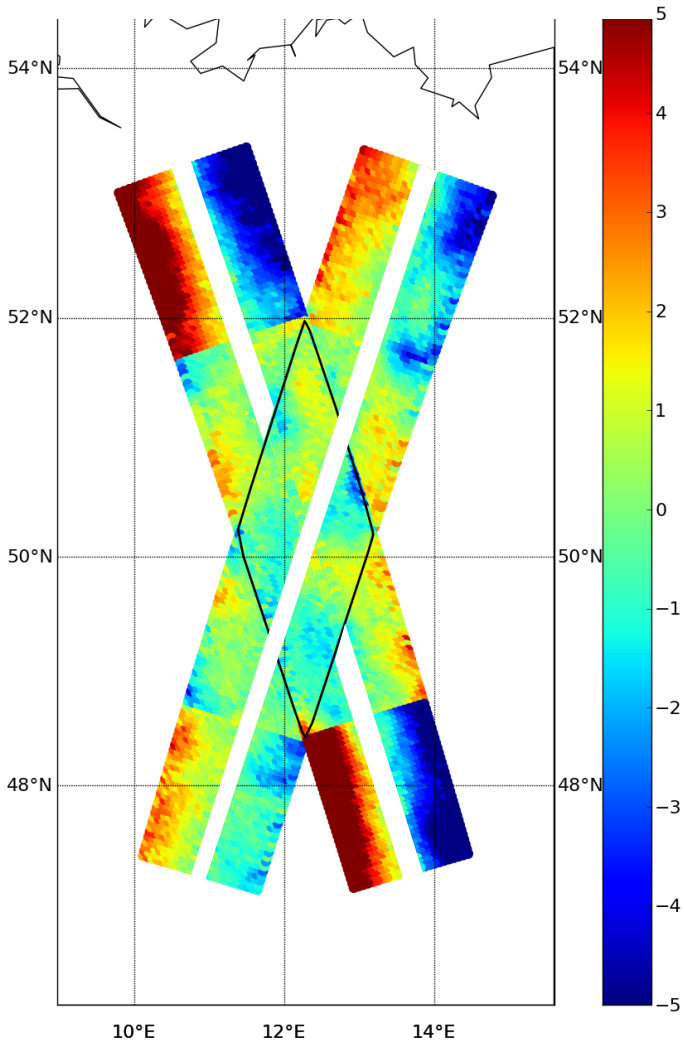


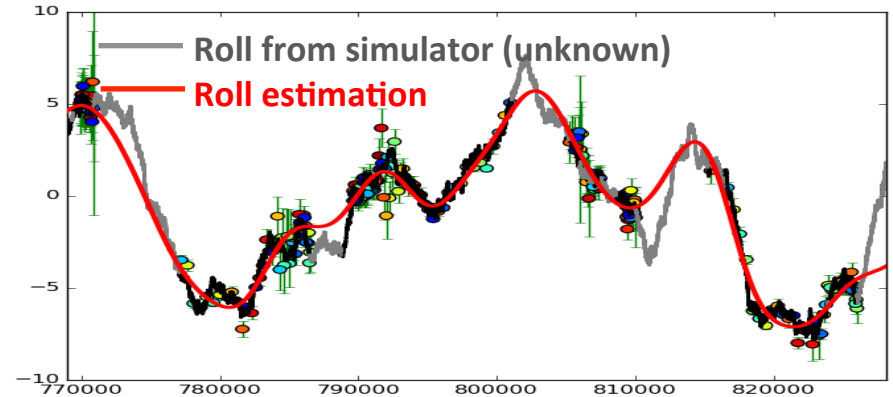
Reconstruction from the SWOT simulator data:



SWOT crossover calibration and inland propagation (Dibarboure&al.)

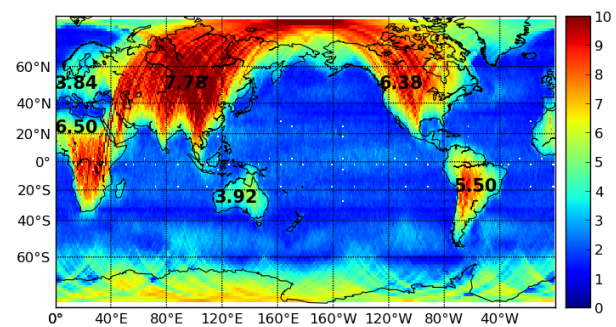
Example of XOVER diamond in the simulator and local calibration





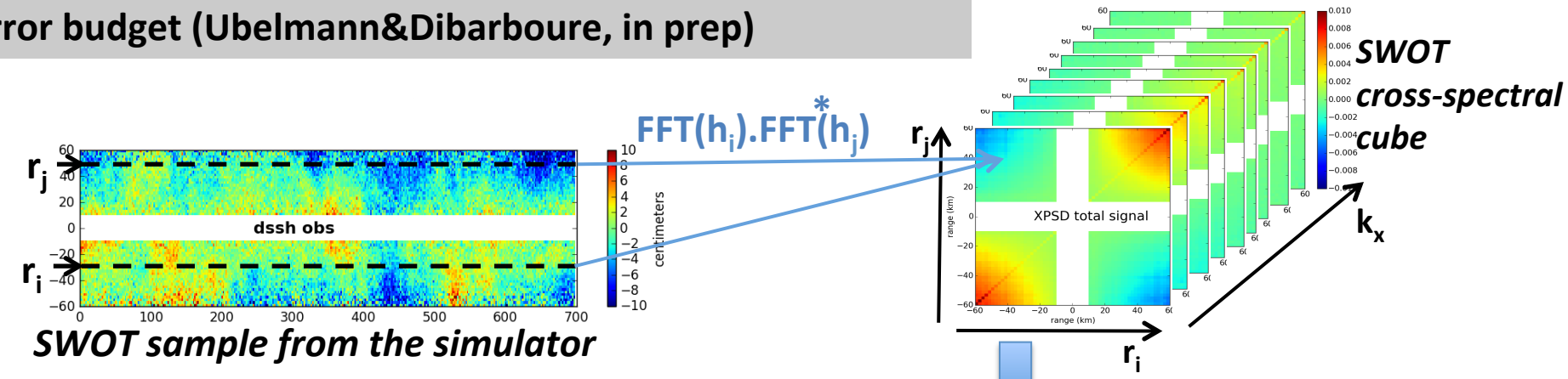
Xover inversions for roll, phase and baseline dilation errors

The Xover inversions are propagated inland with a 1D-Optimal Interpolator

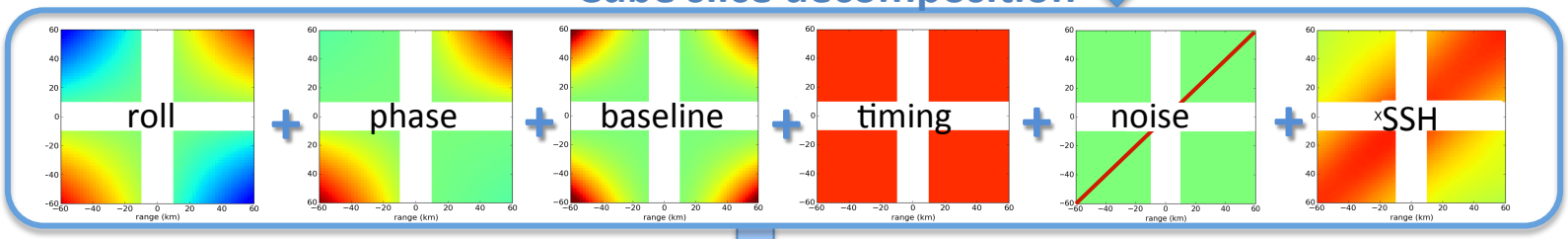


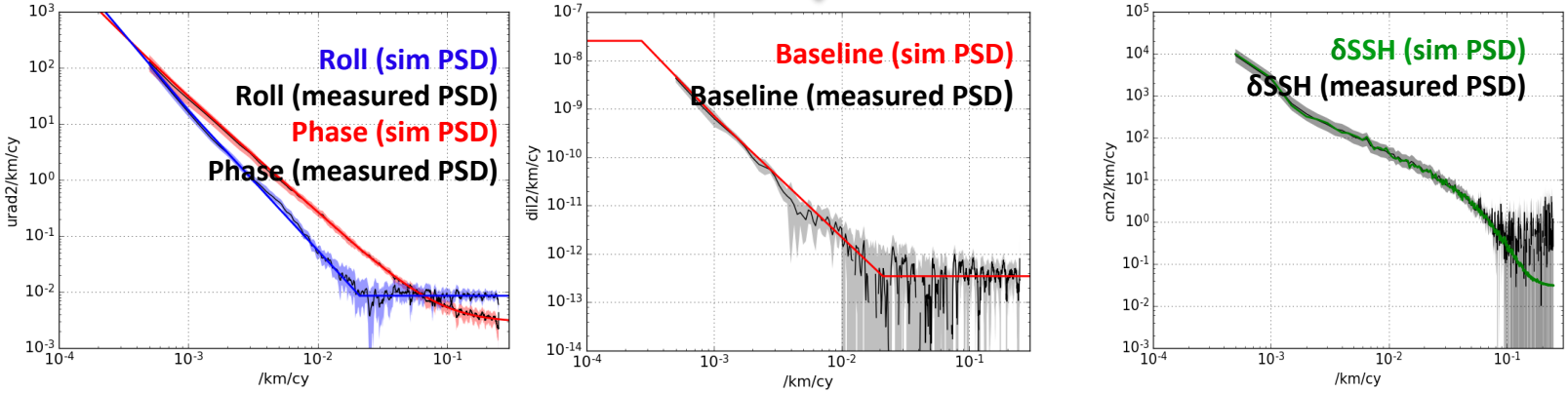
Residual error after Xover calibration

Test of a cross-spectral method to measure SWOT error budget (Ubelmann&Dibarboure, in prep)



Cube slice decomposition



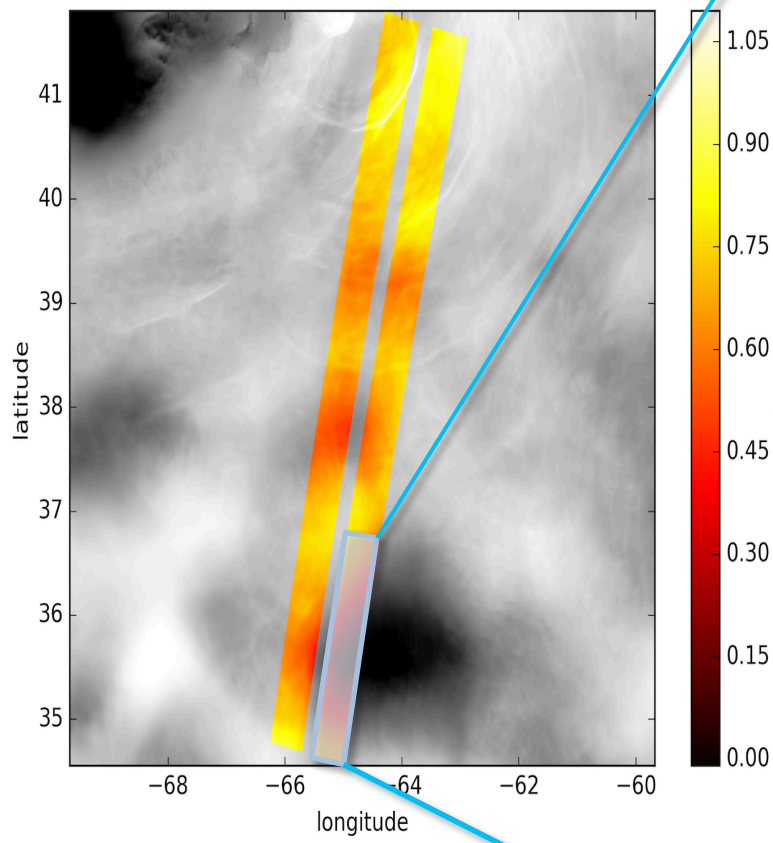


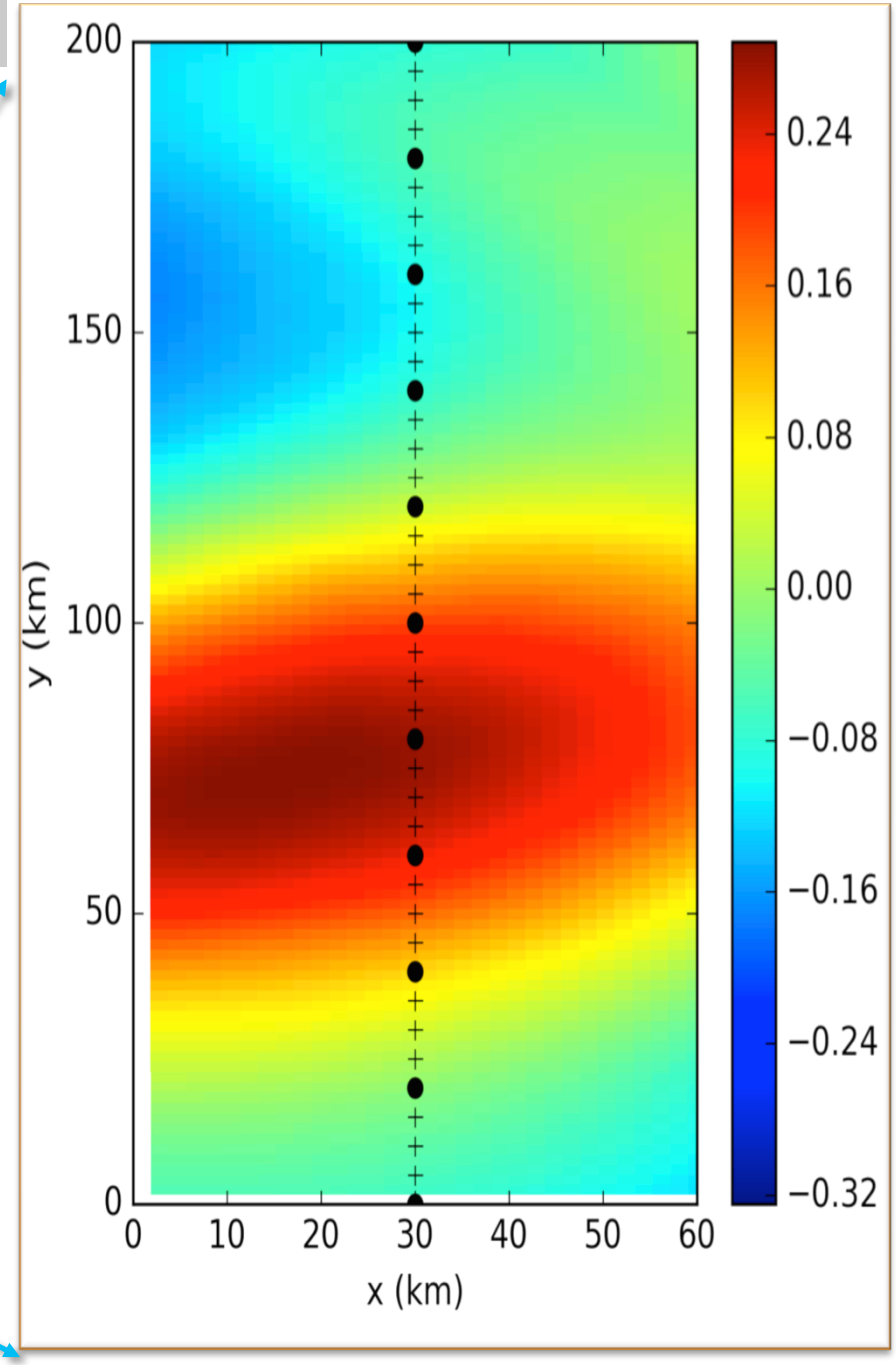
From the observed field, we can retrieve the simulated breakdown of SWOT error budget

Applications: CalVal and high-level products

Building a realistic OSSE for CalVal: simulator run on the 1/48 MITgcm model run (Wang&Fu)

Simulator sample from LLC 4320





+ different in-situ scenarios including PIES, UCTD and moorings

How it will evolve ?

- ~20 active users so far
- Many inputs from users have been integrated in the current version. Thank you!

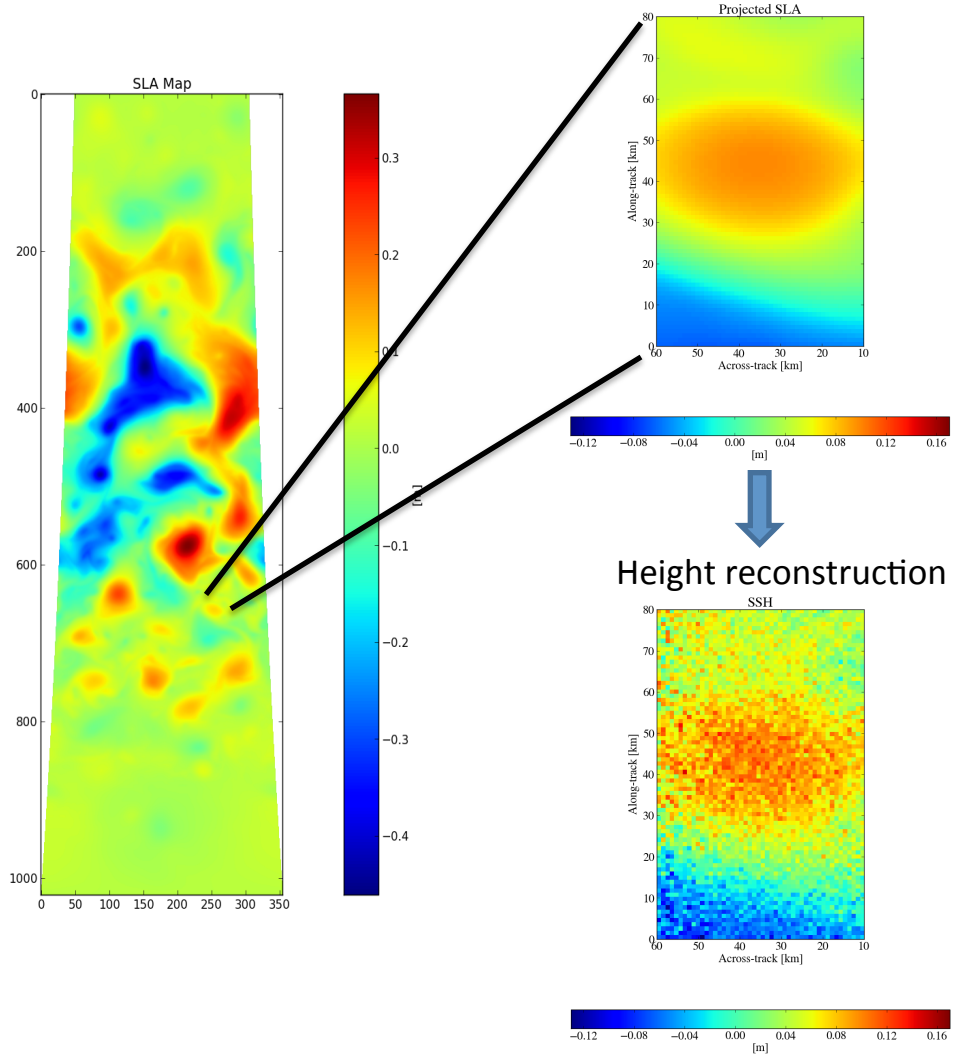
- Possible upcoming improvements:

  - SWH (x,y,t)
  - More realistic Karin noise (not just white)
  - Wet-tropo(x,y,t)
  - Ocean L3 calibration inputs (not just a spectral cutoff)

KaRIn Simulator & Prototype

- Illustration of estimated height based on simulated data

- Ocean scene with realistic MSS, SLA and wave field (e.g., SWH=2m).

- KaRIn transfer function including instrument noise.

- 10x50 km^2 simulation tested at several resolutions and postings, with real orbit scenario, but perfect attitude knowledge.