Oceanographic Studies for the SWOT Project

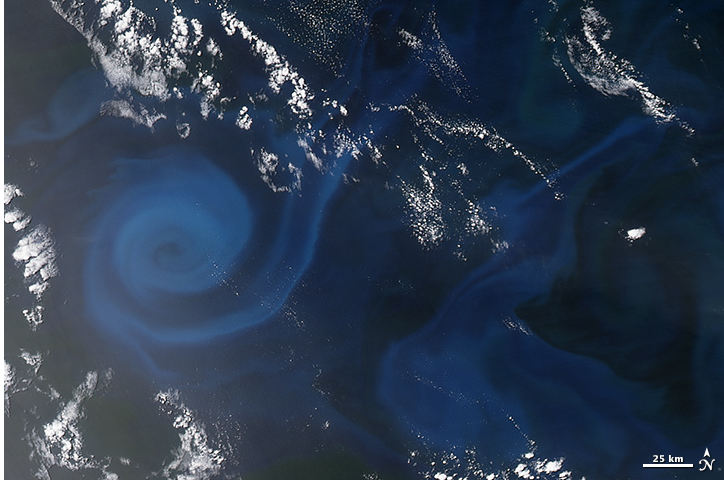


Image MODIS, acquired December 30, 2013

Understanding the 2-D sea surface height signal

High-frequency dynamics from tides, internal tides, internal waves, surface waves

Coastal and Estuarine SSH

Understanding the 2-D error budget contributing to SSH

Projecting fine-scale SWOT observations into sampling holes & vertically

Data Products & Applications

CalVal activities

1. Understanding the 2-D sea surface height signal

- Study the 2-D ocean signals impacting on SSH – especially in the 15-200 km wavelengths not well observed by nadir altimetry. These include **mesoscale eddies, sub-mesoscale fronts, internal waves, internal tides, coastal tides, certain surface waves.**

- Understand the **instability mechanisms** leading to these SSH variations

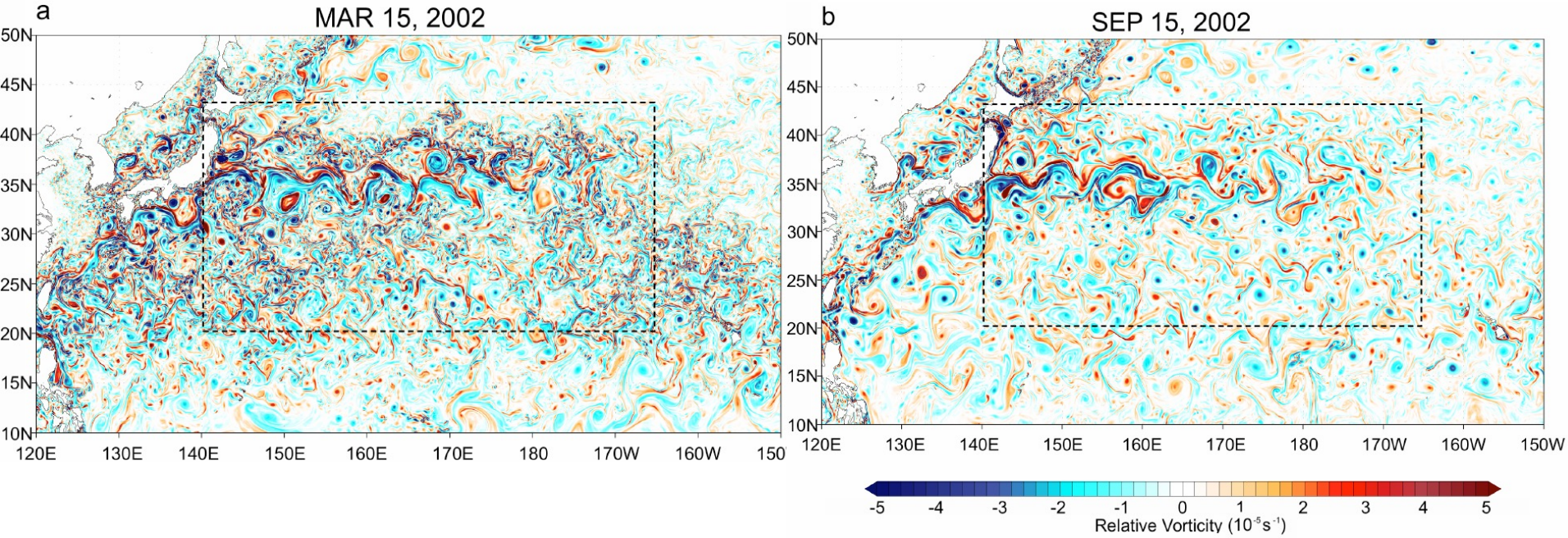
- Study and understand their **geographical variations** (high and low eddy energy regions, tropics, mid-latitudes and high-latitudes) and their **seasonal and interannual variations** (role of varying stratification, temperature and salinity changes, different atmospheric forcing)

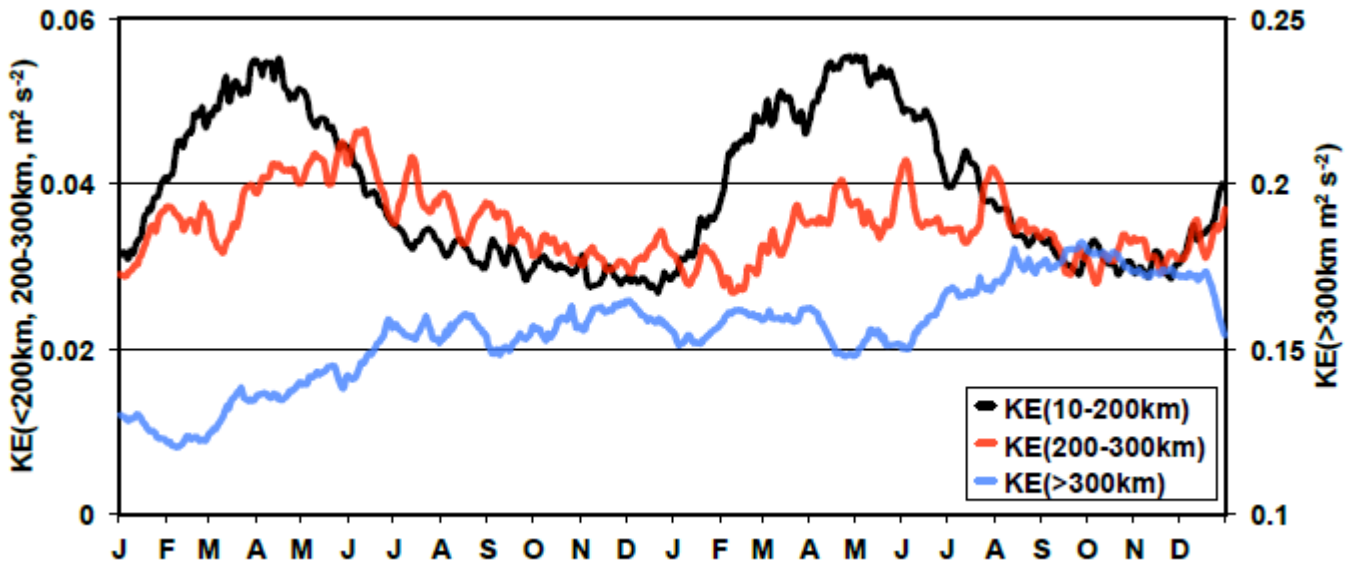
- Issues in analysing/exchanging large volume of HR modelling output

Types of study :

- *High resolution model simulations of ocean currents and internal waves & tides, wave models,*
- *analysis of alongtrack altimeter data (J2, AltiKa, S3-SAR),*
- *multi-satellite data (SST, ocean colour, SAR),*
- *in-situ observations, `*
- *AirSWOT*

Winter submesoscales feed energy to summer mesoscales





Sasaki et al., 2014

2. High-frequency dynamics for SWOT—tides, internal waves, surface waves

SWOT covers an ocean basin in a few minute "snapshot" of SSH

Scientific goals:

To better understand and characterize the aliasing of high-frequency tides, internal tides, internal waves, and surface waves, and implications for estimating geostrophic motions

Technical issues:

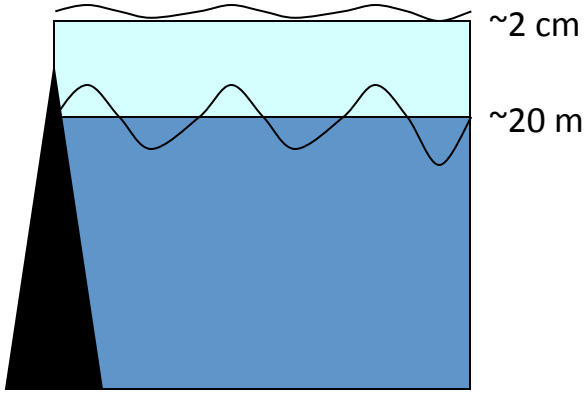
- Providing global 1 km models for barotropic tides and coherent internal tides,
- Providing global 1 km models for barotropic wind & pressure forcing effects (Dynamical Atmospheric Correction – DAC)
- Aliasing due to 21-day temporal sampling
- Dealing with incoherent internal tides & internal waves – flags?

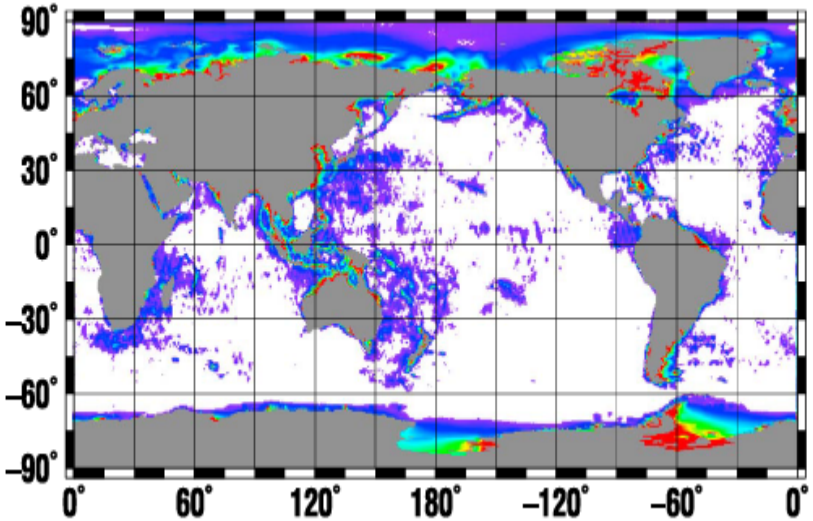
Orbit chosen to better observe coastal and internal tides

Coastal tides are observed today by tide gauges or alongtrack data – 3 years of SWOT data will provide finer-scale 2D data

2D propagation of Internal tides observed by SWOT – important for ocean mixing & energy dissipation

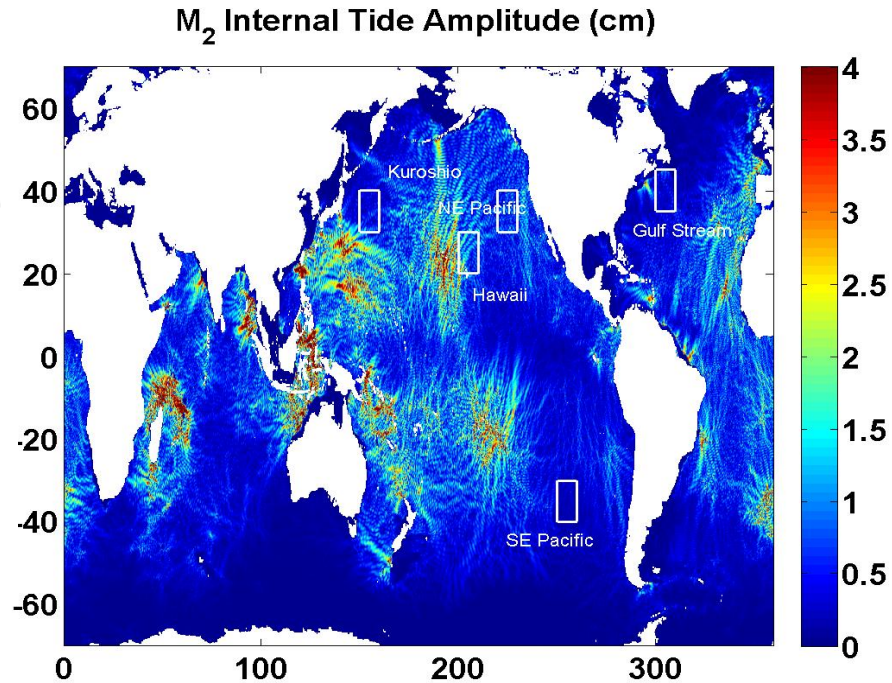
Interaction between ocean circulation & internal tides





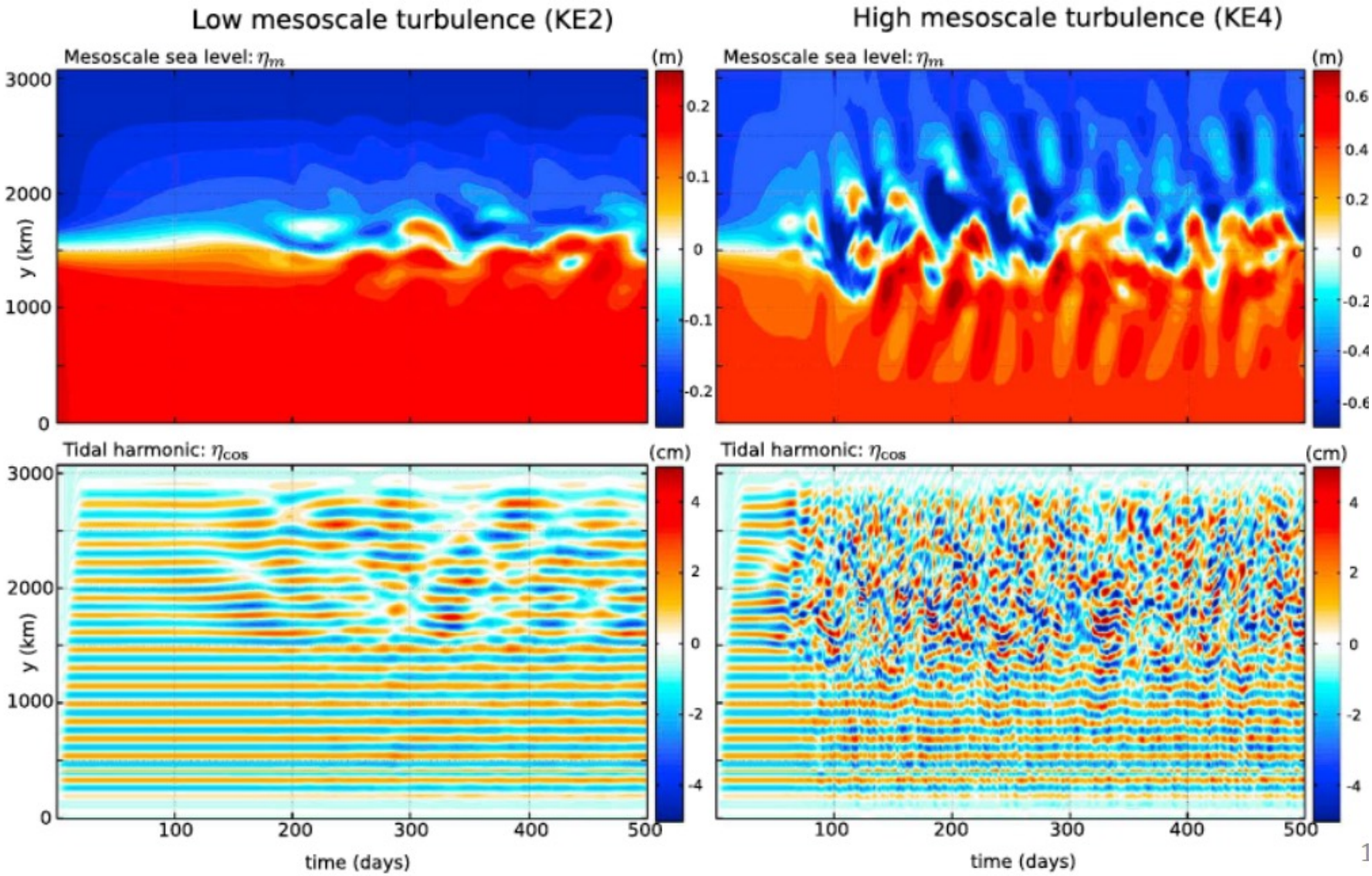
St. Dev of 7 global tide models, M2

Stammer et al., 2014

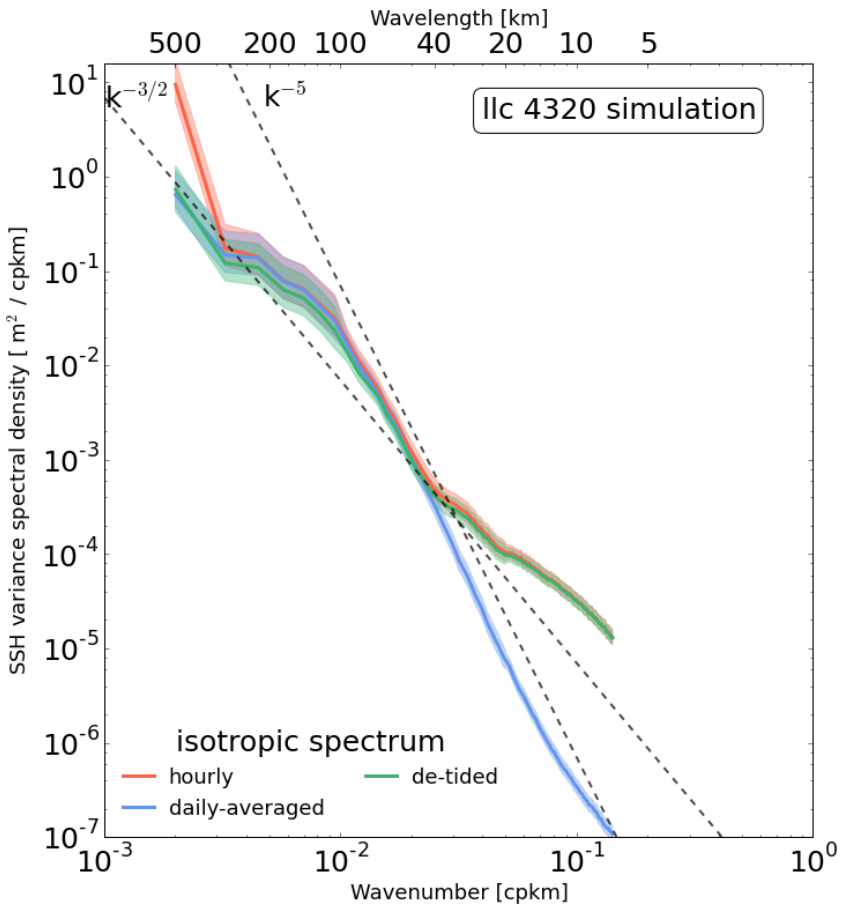


Model : HYCOM 1/12° *Arbic et al., 2012*

Ponte and Klein (2015) idealized experiments on internal tide incoherence



Understanding & separating the effects of internal waves & tides from SWOT SSH



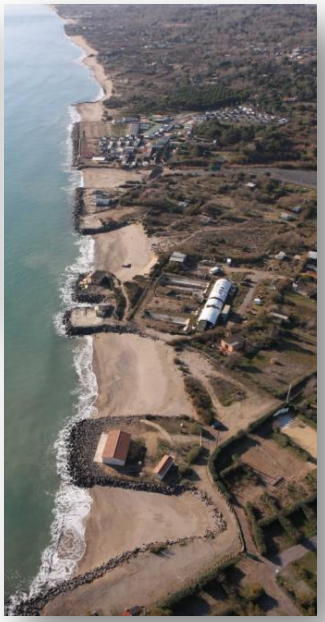
(Rocha et al. 2015)

ASAR scene of internal waves: Strait of Gibraltar (ESA 2002)

High-frequency session in Oceanography splinter - Wednesday

3. Coastal zones (including estuaries & deltas)

The coast can range from a few hundred meters to several kilometers on either side of the land-sea interface : shelf, nearshore zone (narrow band within ~2 or 5 km of the shoreline), coastline & river mouths (estuaries & deltas)



Continuum => coastal regions, littoral, estuaries, rivers
Strongly non-linear coastal and estuarine tides
Specific data products & processing (HR and LR data in 3 km coastal band)
….

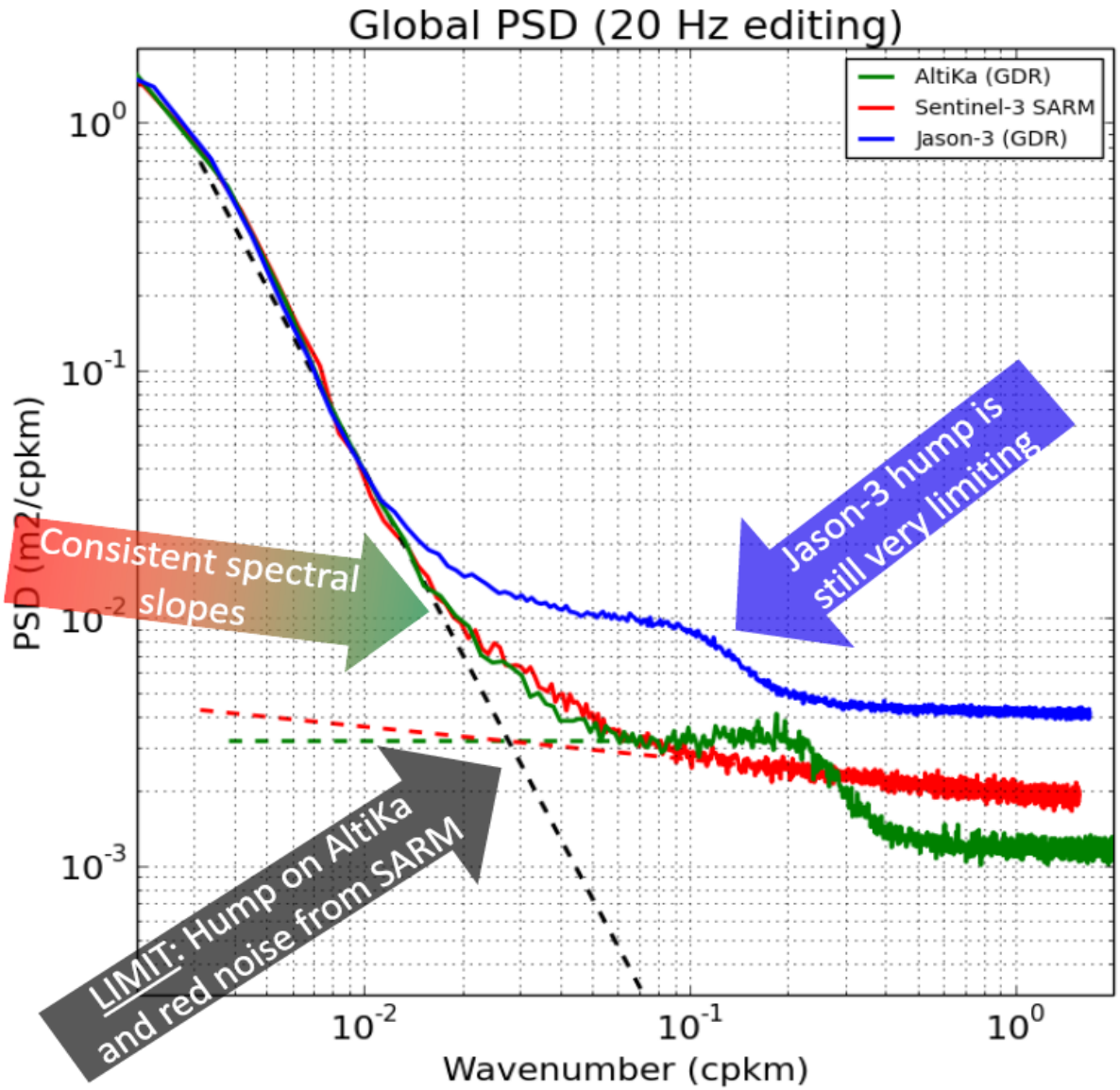
Specific coastal/estuarine issues to be discussed Wed afternoon.

4. Understanding the 2-D SSH error budget over the swath

- **Science Team** can contribute via the **Algorithm Development Team** – work on estimating and improving 1 km error estimates (SWOT systematic instrument errors, Random interferometric errors, Orbit errors, Sea-state errors, atmospheric corrections)
- Error estimates available over ocean using ocean scientific simulator (or full JPL ocean simulator)
- Science Team can work on testing and improving error estimates in regional studies (eg local wind-wave conditions, tides, etc)
- Analysing alongtrack altimetry from Jason-3, Saral and Sentinel-3 SAR to help improve our SSH error estimates
- Impact of these errors on estimating 2D SSH, velocity, vorticity
- Techniques to remove these errors before estimating velocity, vorticity (image processing techniques?)

- *Types of study : Ocean simulator : interferometry -> L2, along-track altimetry with different wind-wave models, AirSWOT observations under different wind-wave conditions*

Understanding the SSH noise in alongtrack altimetry – different technology, different noise



First global SARM spectrum from Sentinel-3

Experimental processor from Cal/Val phase

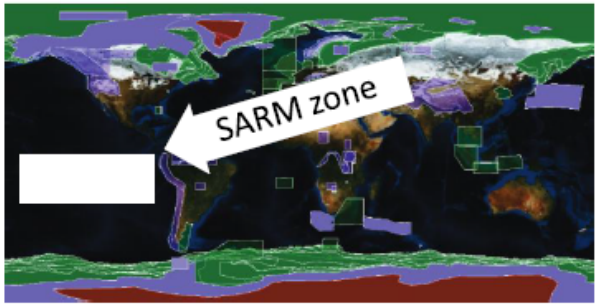
TBC with official products

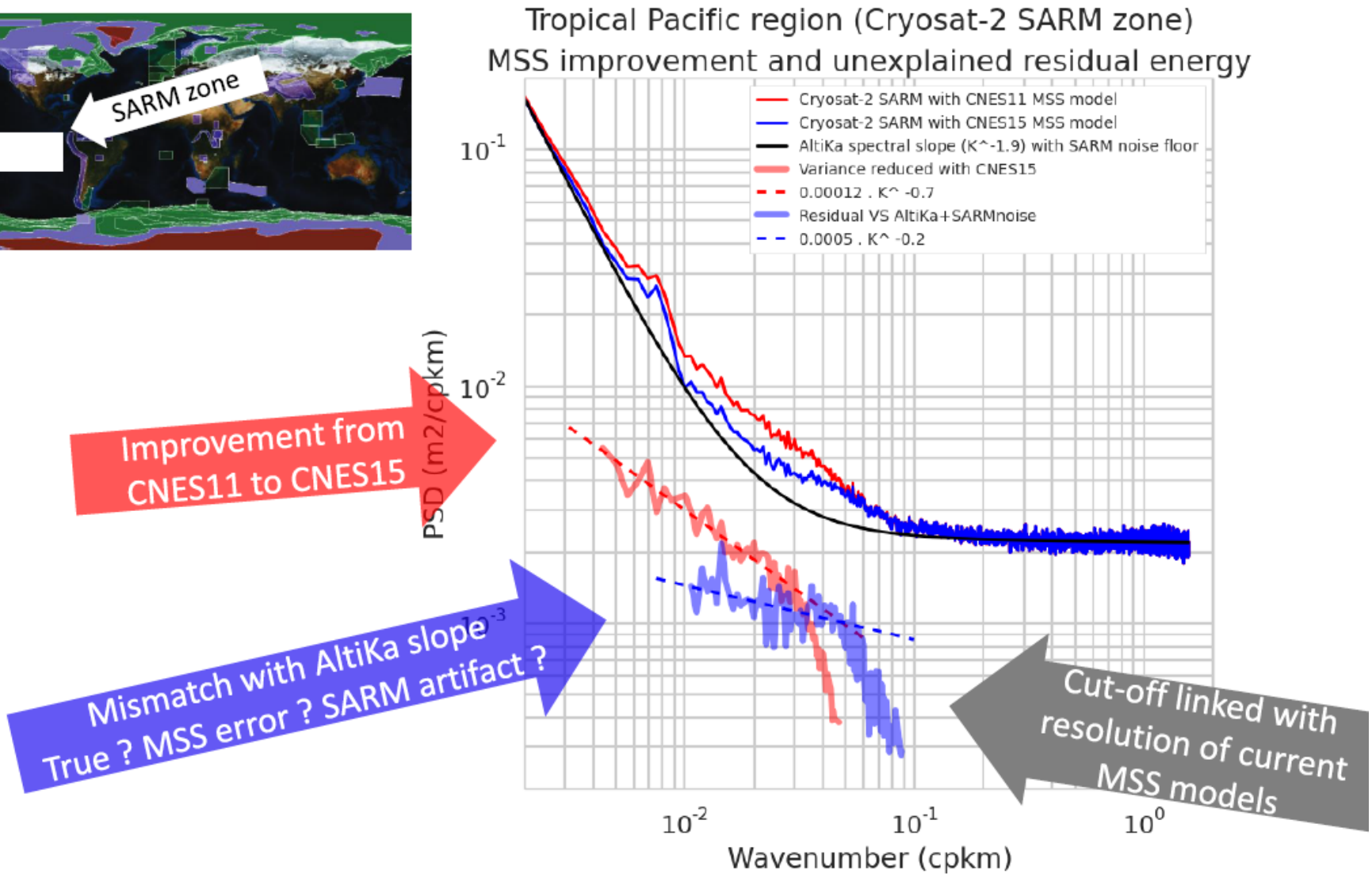
Regional analyses ongoing

Credits : CNES/CLS

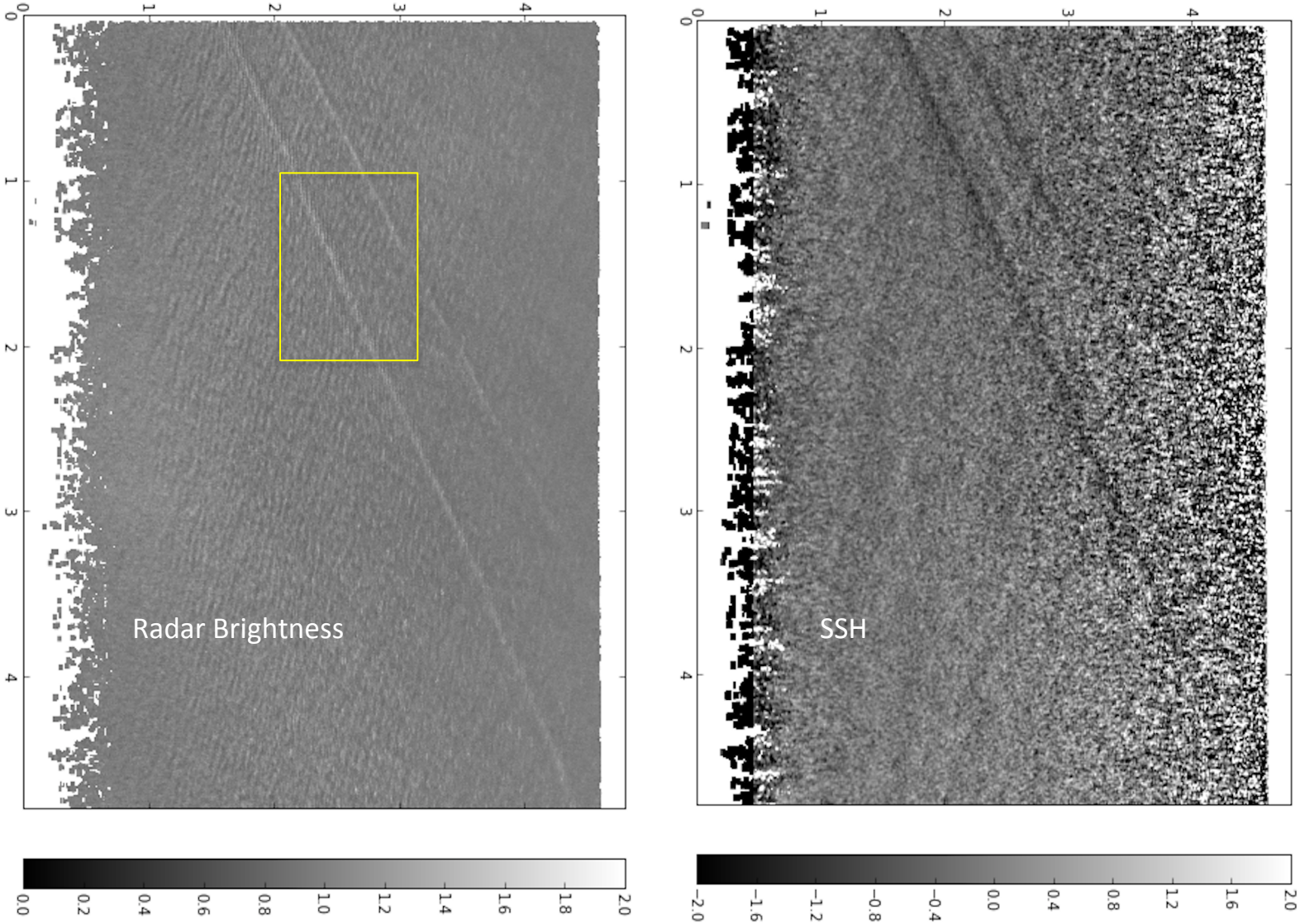
Reduced error with MSS model CNES/CLS 2015

(also observed with DTU15 model)

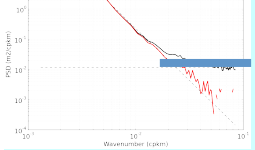




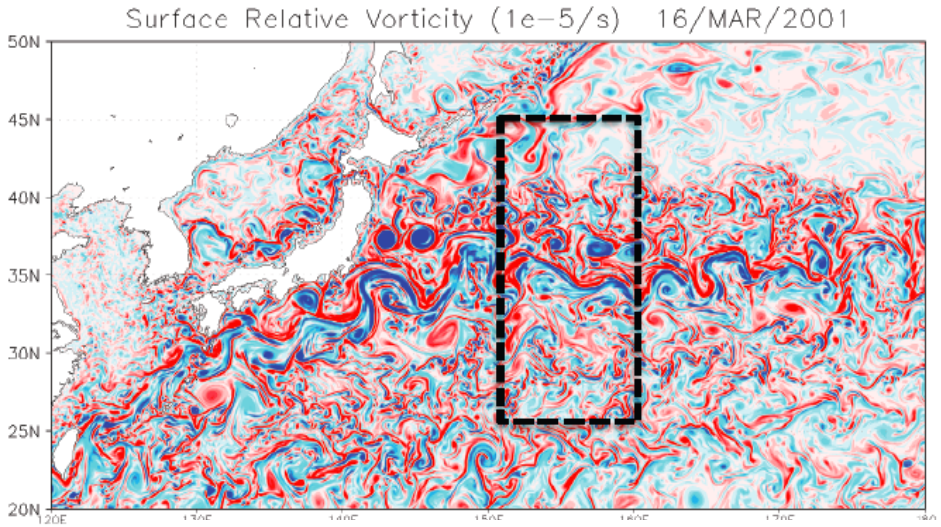
Noise from waves & Ship Wakes on 1 km2 pixels: AirSWOT in the Santa Barbara Channel



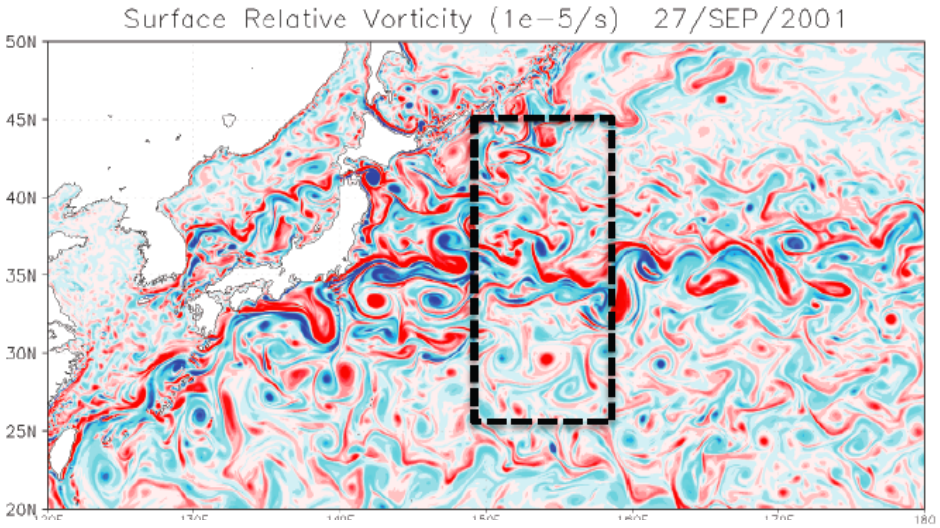
SWOT Challenge : observability of these processes



WINTER

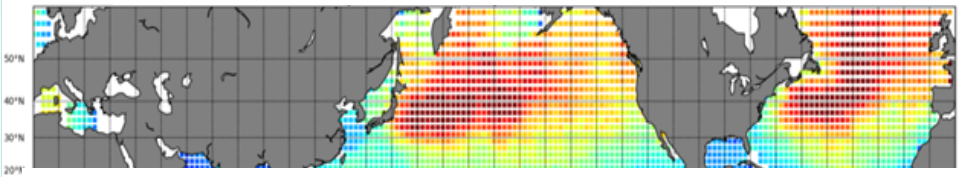


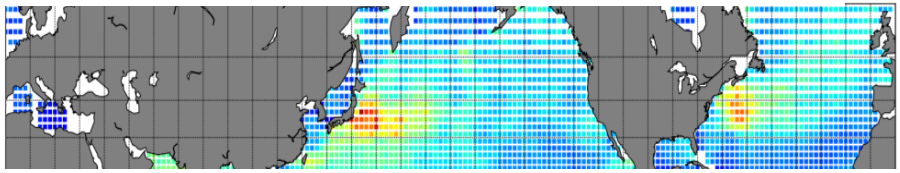
SUMMER



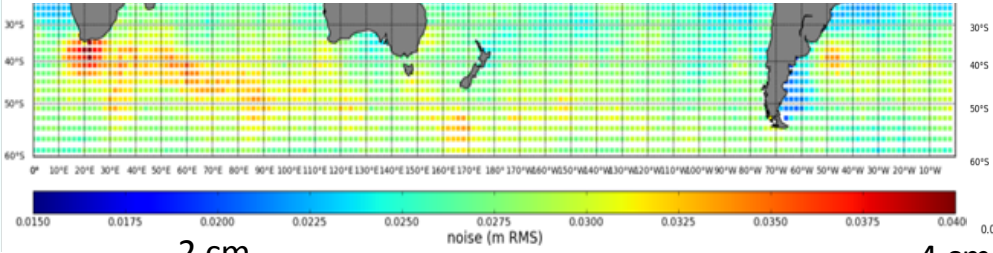
J2 Altimeter noise floor

Dufau et al., 2016

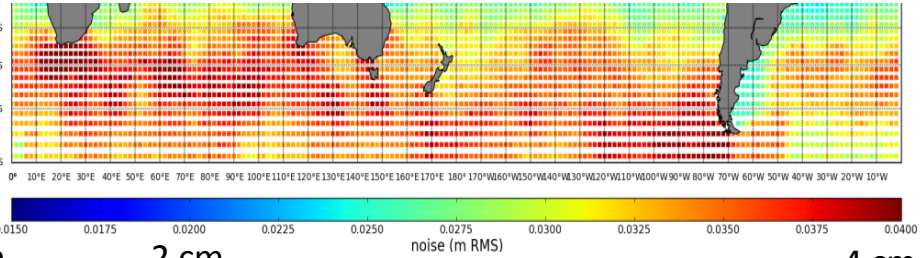




SWOT will have an order of magnitude lower noise than conventional altimetry, but still have a wave dependency – larger noise in winter with higher SWH

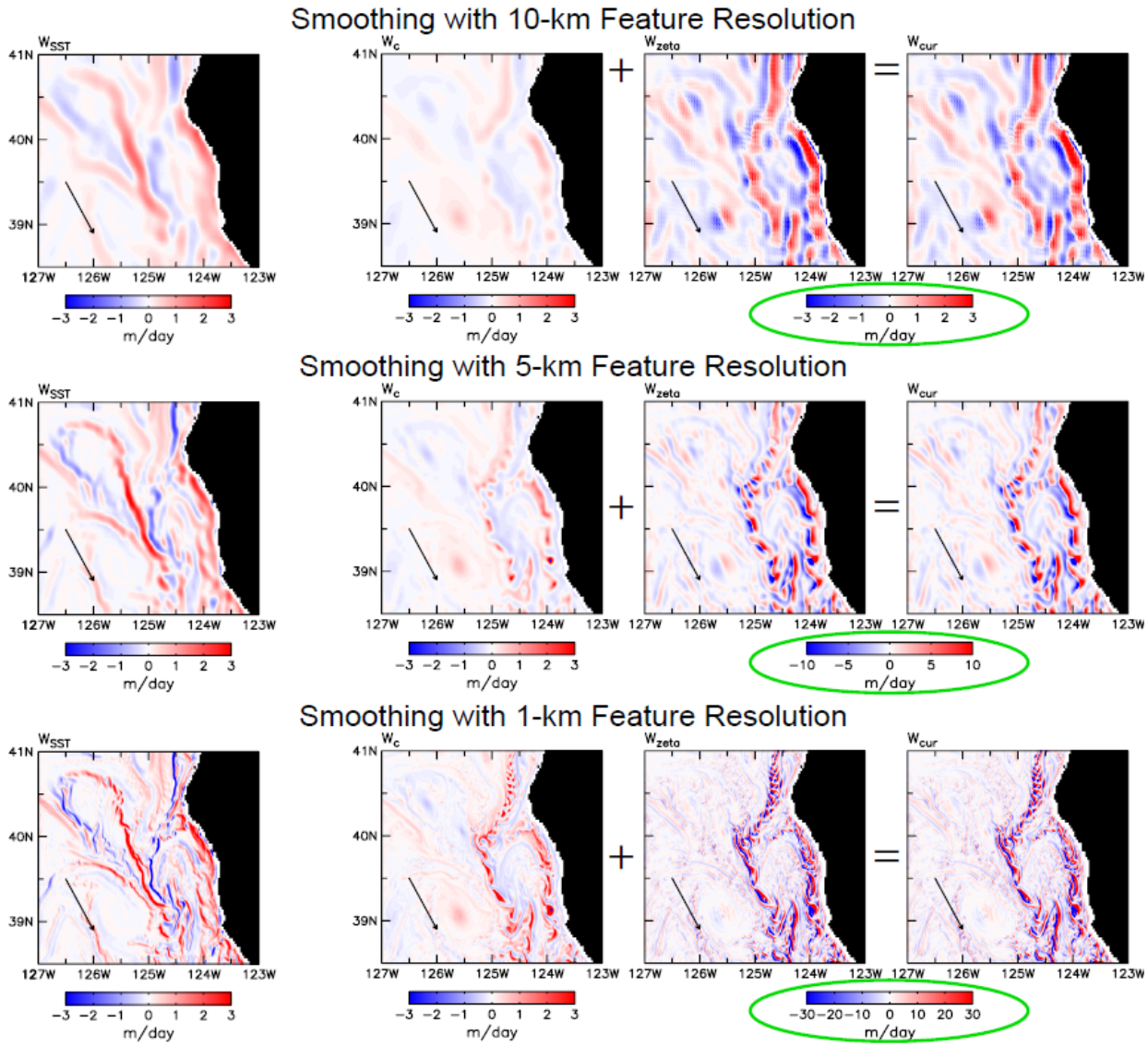


2 cm 4 cm



2 cm 4 cm

Effect on vertical velocities of horizontal smoothing – Californian Current region.

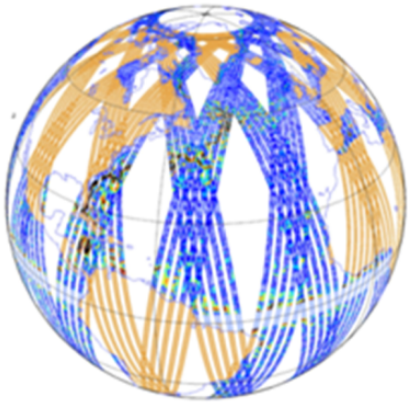


10-km feature resolution

~ 20-km wavelength

D. Chelton et al.

5. Projecting fine-scale SWOT observations horizontally & vertically

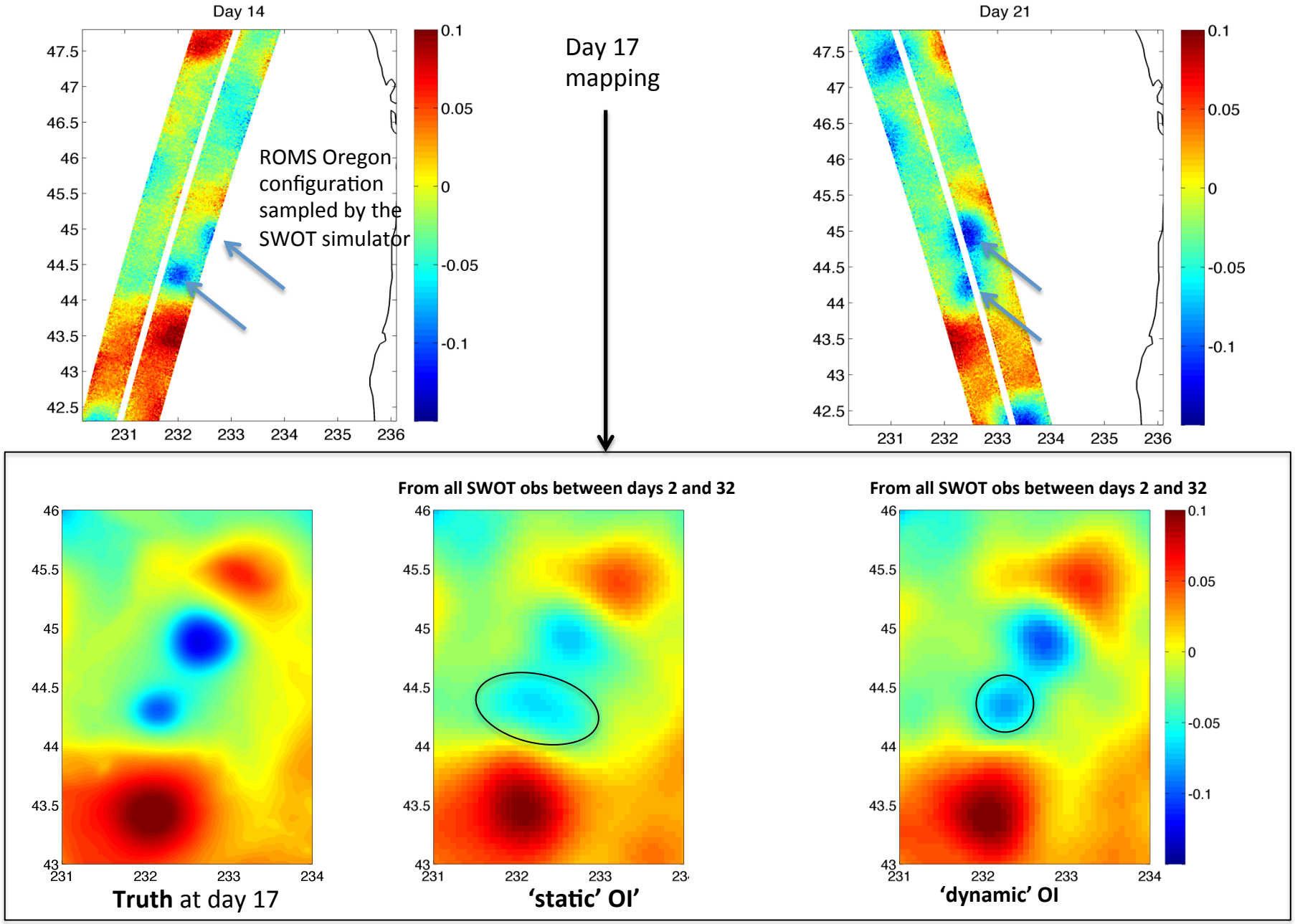


5-day SWOT coverage

- Techniques for multi-mission, multi-scale **mapping of altimetric SSH** from 2D SWOT and nadir missions (S3, J-CS, ..)
- **Impact of errors** on mapped SSH & velocity
- **Surface currents in mixed layer** from multi-captor mapping (SWOT and nadir altimetry velocity, SST, ocean colour, SAR velocities, …)
- **Vertical projection techniques** based on HR SSH and atmospheric forcing (SST, wind) (eg sQG, other, …)
- **Data assimilation**

- *Types of study : High resolution model simulations needed to test mapping and reconstruction techniques. Models including ocean currents, tides, waves & HF (hourly) forcing. Combine with Ocean L2 error simulations. Multi-captor and multi-mission studies based on existing satellite observations, techniques could be tested with AirSWOT observations*

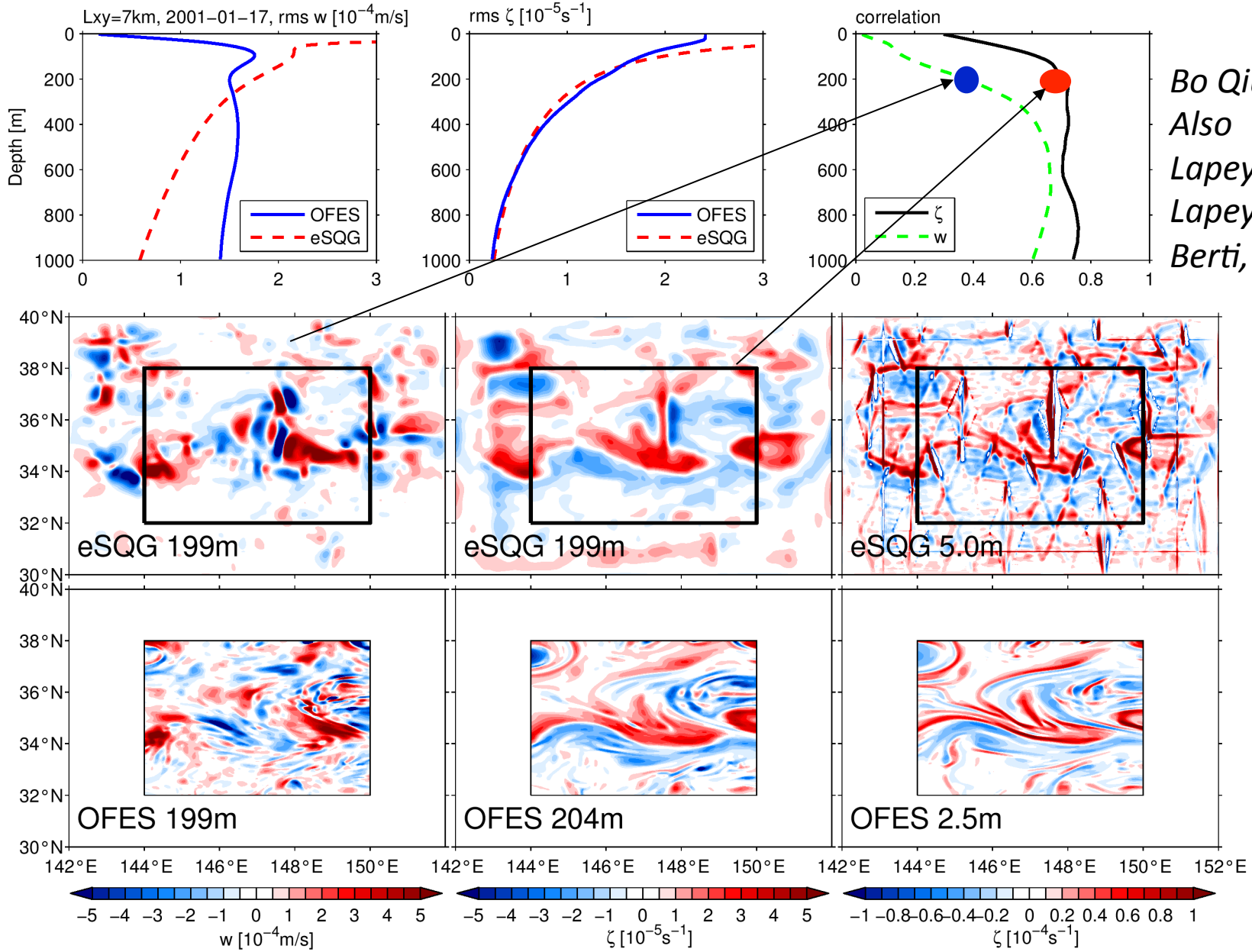
2D reconstruction using simple dynamical QG models:



Open ocean example : Ubelmann et al., 2014

3D Dynamical Reconstruction : Scenario with optimal smoothing:

simulator-sampled η field, with noise and swath gaps



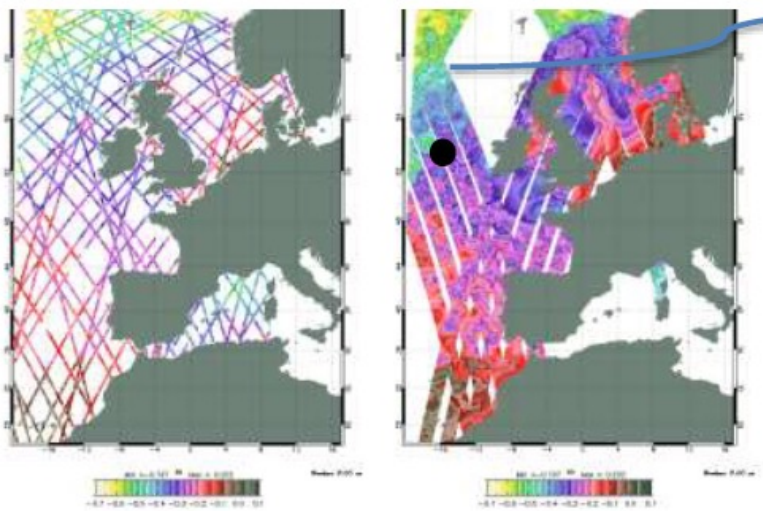
Bo Qiu et al
Also
Lapeyre & al
Lapeyre & Berti, 2014

Assessing the impact of SWOT for global ocean analysis and forecasting

The large swath SWOT mission is a challenge and a great opportunity for ocean monitoring centers offering a 2D VERY high spatial description of the sea surface height.

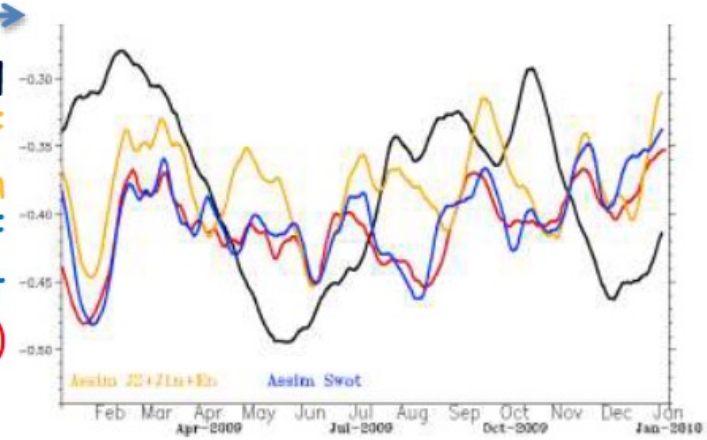
OSSEs are currently performed:

- ✓ To prepare the Mercator Ocean data assimilation system to ingest such data set,
- ✓ To estimate how SWOT data will constrain our data assimilation systems (space and time scales, physical processes, analyses and forecasts).



5-day *SSH observations (09-14/03/2009)*

Free Model
Assimilation of J2,J1n, En
Assimilation of Swot Data (IBI36)



SSH times series: estimations vs simulated observations at 16°W-54°N

(Mounir Benkiran, CNES study)

6. Data Products & Applications
(via ADT group)

- 1 km L2 SSH ocean products (swath & fixed grid products) will be produced by the project
- External HR data products are required (geoid, bathymetry MSS, tide models, internal tide models, …)
- Techniques for optimal gridding and beam-combination may be explored for different applications (MSS, ice studies, data editing).
- Use of a 9-beam SSH product being discussed

- *Types of study : Analyses of simulated downloaded OBP output data (interferograms), or L2 GDR swath and fixed grid SSH formats.*

- *=> Discussion Wednesday ocean spliner*

CalVal Activities

- Global operational **SWOT-SWOT crossover analysis** of SSH + errors
- **SWOT-nadir altimeter crossover analysis** (SWOT nadir & J-CS, S3)
- **SWOT-in-situ analyses** for SSH & velocities – glider lines, tide gauges, bottom pressure gauges, current meter arrays and ship-borne ADCP, underway CTDs or MVPs, surface drifters, GPS SSH buoys, longterm altimetric CalVal sites (Harvest, Corsica, …)
- **Specific Airborne campaigns** – AirSWOT, Lidar, Kuros (CFOSat) wind-waves, high-resolution radiometry for SST & wet tropo

Types of study :

- *AirSWOT observations compared to airborne Lidar, SST and other satellite and in-situ data. Sampling of projected SWOT sampling & errors derived from high resolution model simulations of ocean currents and waves & tides combined with Ocean L2 error simulations. Projected CalVal sites tested or chosen from error analysis.*

=> Discussion Thursday

Conclusions

- SWOT SSH « snapshots » will provide an unprecedented view of the ocean SSH from 15-200 km wavelength. Promise of SWOT has already provided new science understanding
- Needs a careful analysis of different rapidly moving signals at these scales, and their observability given the SSH errors
- Separating balanced & unbalanced motions for reconstructing velocity / vorticity is a key issue
- Ocean OBP and 250 m data products are available over all global surfaces (ocean, ice, coasts, terrestrial water surfaces) careful analyses is needed over these surfaces
- We ask for your active participation in these different SWOT working groups

Global 1 km « ocean » data products
Swath co-ordinates & fixed-grid

2D data provided in swath
Latitude, Longitude
Surface type
SSH, σ0, SWH
Associated uncertainties, quality indicators
Ice and rain flags
Corrections (geophysical and calibration)
Geophysical parameters (MSS, tides, …)

2D data provided in swath
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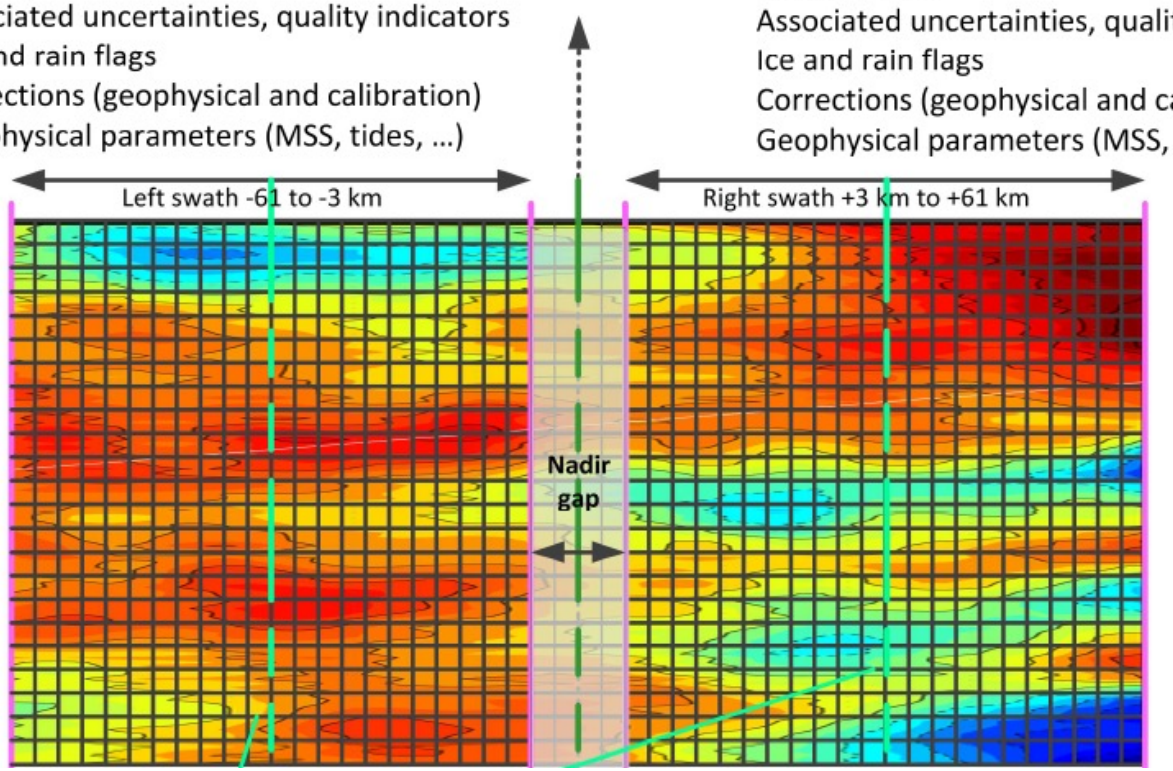

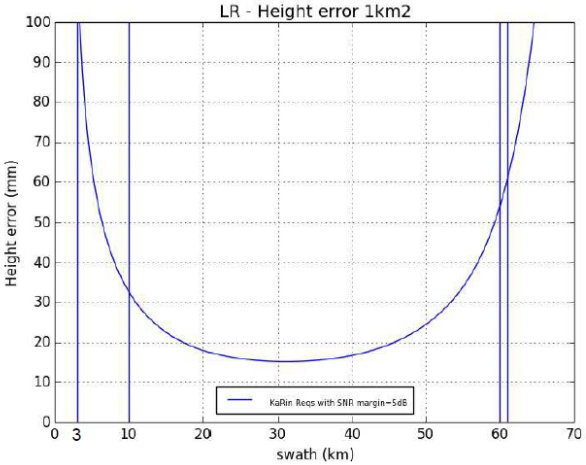

Height error is an order of magnitude less than Jason !
Varies across each swath (instrument, SWH dependent)