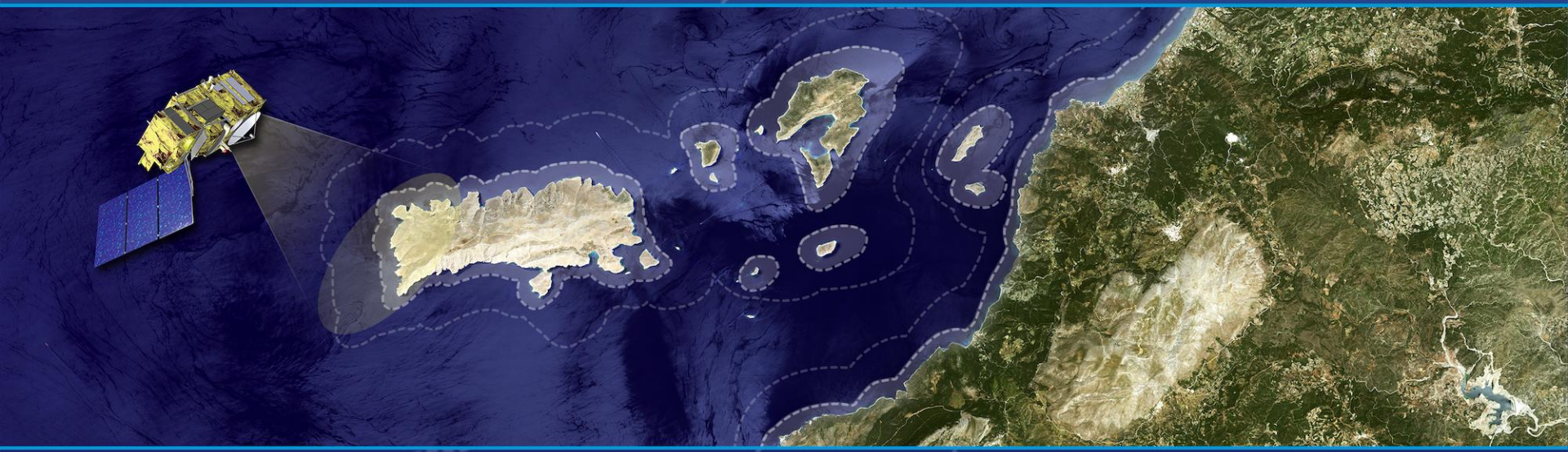
Altimetry in coastal oceanography:
Highlights from the 10th Coastal Altimetry Workshop

John Wilkin

→ 10th COASTAL ALTIMETRY WORKSHOP

SAR Altimetry Training Course



21–24 February 2017 | Florence, Italy

Altimetry for Regional and Coastal Models

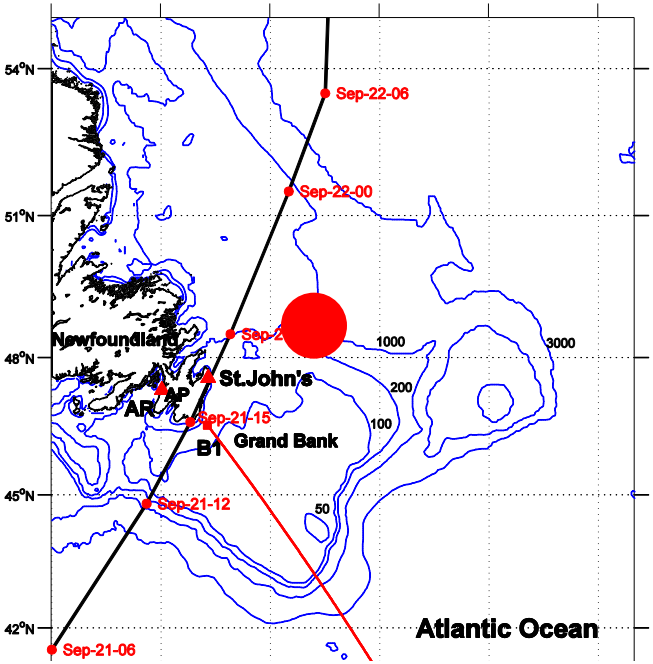
- Sea level processes:
  - Borrione: AUV-based dyn. topo. compared to assim. altimetry
  - Hirose: Tsushima Strait dynamics
  - Wakamatsu: Tsugaru Warm Current dynamics
  - Meloni: NW Med integrated obs. sys. compared to model
  - Wilkin: wavenumber and freq. spectra; compare nested models
  - Roggenbuck: altimeter, tide gauge & ship-based sea level dyn.
  - Han: Storm surge observation
  - Qazi: Complementing altim. with SAR imagery of biogenic slicks

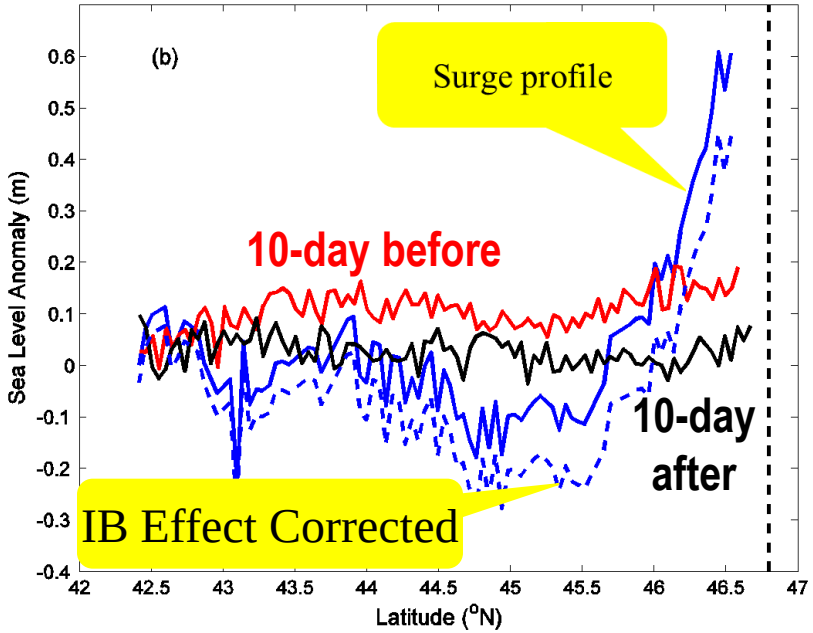
Altimetry for Regional and Coastal Models

- Altimeter Data Assimilation
  - Moore: Quantifying impact of DA on circulation metrics
  - Kamachi: downscaling DA-constrained estimates
  - Olita: DA within a nested model Sardinia
  - Bonaducce (Passaro): Black Sea 3DVAR
  - Brandini: Tuscan coastal observing system

Fisheries and Oceans Canada Pêches et Océans Canada

Using Satellite Altimetry to Observe Storm Surges: Guoqi Han





Hurricane Igor observed by Jason-2

By along-track least squares fitting, we estimate the surge magnitude at coast and exponential decay scale.

Surge magnitude at the coast:

- Tide gauge: 0.96 m
- Altimetry: 1.01 ± 0.02 m

Cross-shelf decay scale:

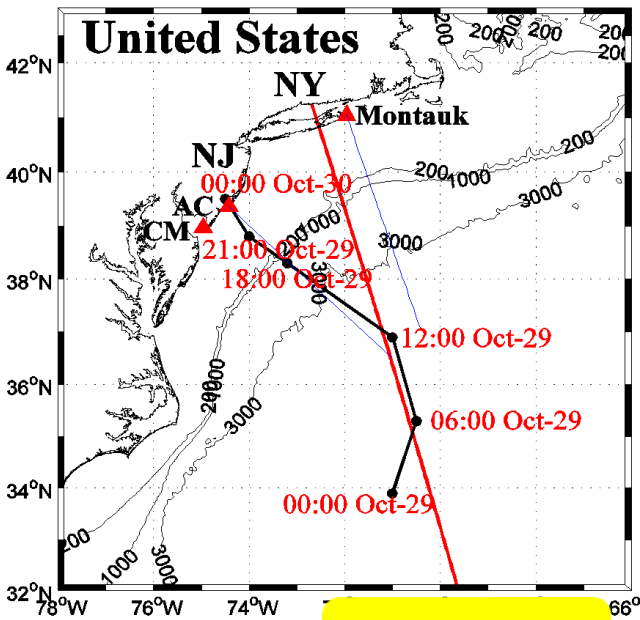
- Tide gauge: 100-120 km
- Altimetry: 96 ± 6 km

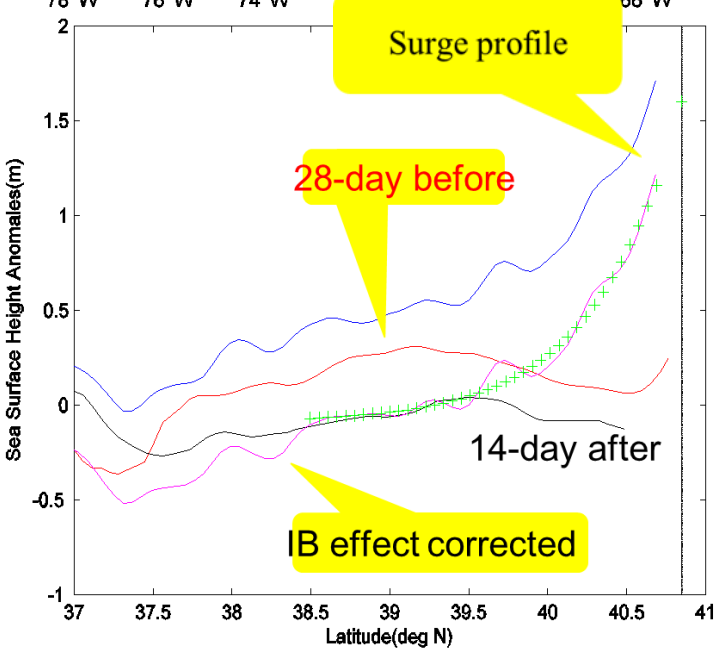
Han et al., 2012

Canada

Fisheries and Oceans Canada Pêches et Océans Canada

Using Satellite Altimetry to Observe Storm Surges: Guoqi Han





Hurricane Sandy observed by HY-2A

Surge magnitude at the coast:

- Tide gauge: 1.73 m
- Altimetry: 1.83 ± 0.04 m

Cross-shelf decay scale:

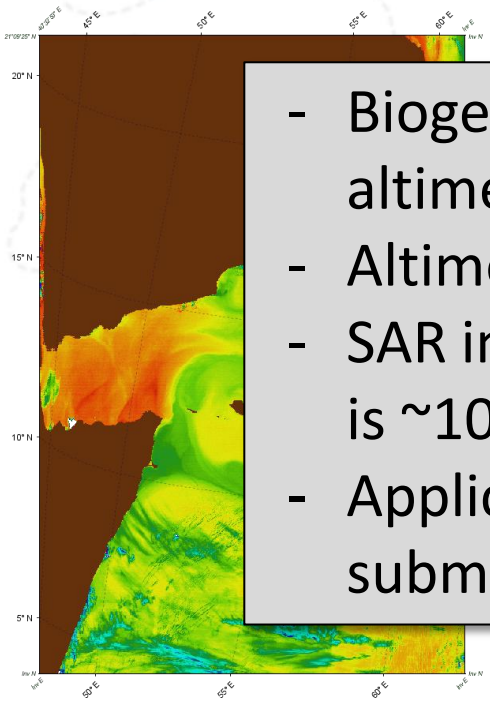
- Tide gauge: 75 km
- Altimetry: 68 ± 5 km

Chen, N., G. Han, J. Yang, and D. Chen (2014), Hurricane Sandy storm surges observed by HY-2A satellite altimetry and tide gauges, JGR Oceans, 119, doi:10.1002/2013JC009782.

Canada

Altimetry and SAR imagery in the coastal Arabian Sea

Waqas Qazi: Institute of Space Technology, Pakistan



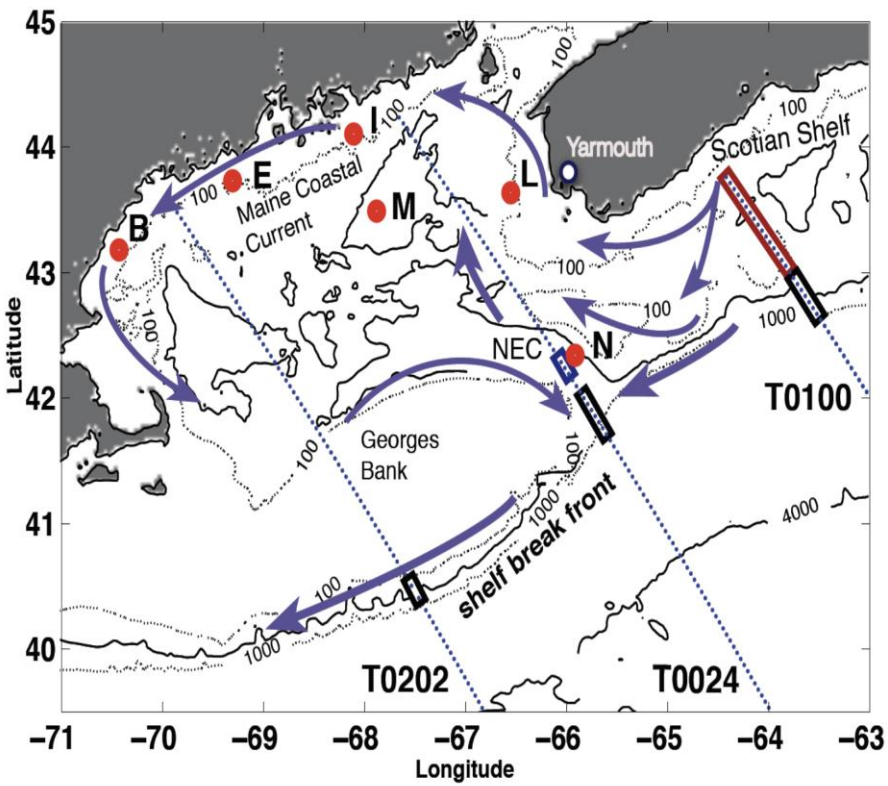
- Biogenic slicks give specular bright σ° in altimetry (σ° blooms)
- Altimetry resolution is ~300 m (SAR/DDA)
- SAR imaging wide-swath mode resolution is ~100 m
- Applications now possible at edge of ocean submesoscale

Monsoon drives upwelling along Somalia/Oman coast.
Blooms create biogenic slicks.

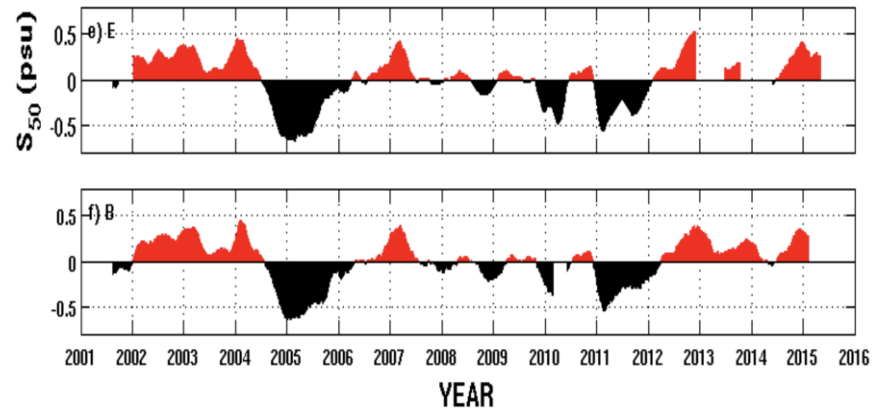
In SAR imagery, biogenic slicks dampen σ°
Work underway to automate processing to detect upwelling / slicks in SAR imagery

Operational altimeter-derived ocean currents for shelf sea applications: D. Vandemark, H. Feng and J. Wilkin

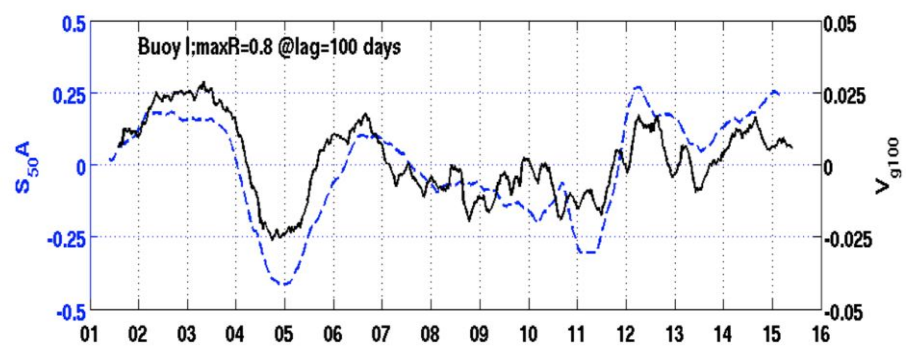
Remote currents are linked to coastal salinity and biochemistry – study used coastal-processed along-track altimeter data



Salinity anomalies Gulf of Maine 2001-2015



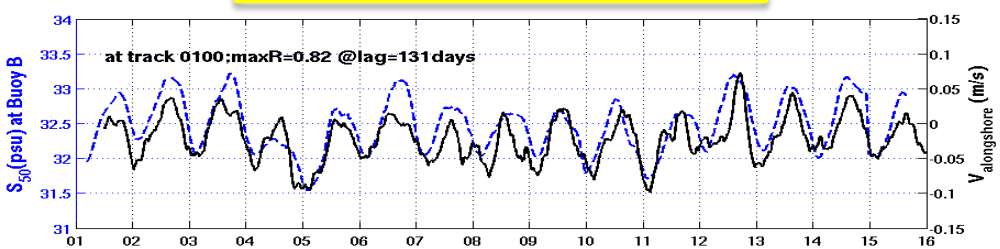
Anomalies highly correlated with altim-derived currents upstream 2-4 months ahead of observed GoM change

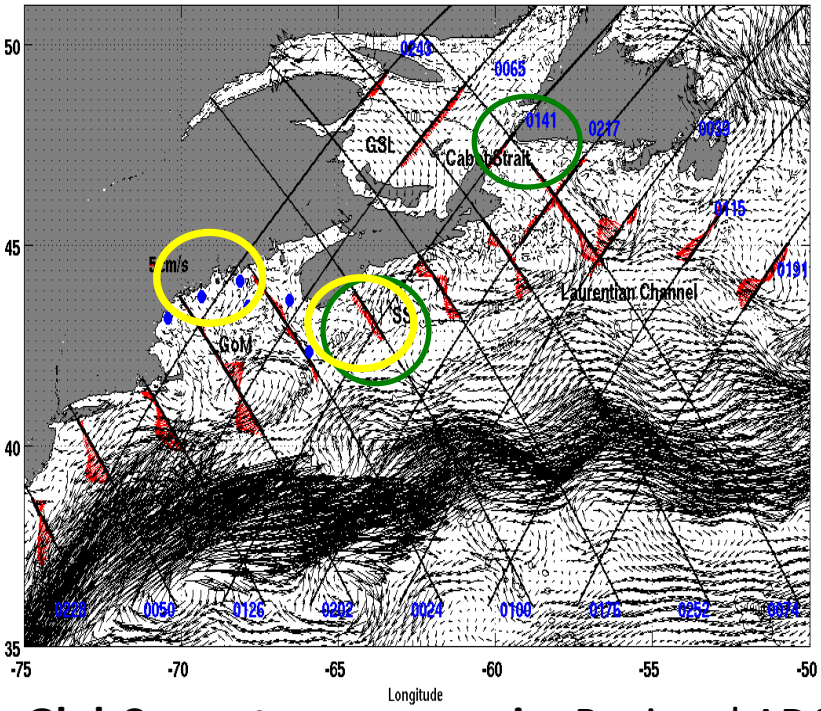


Feng, H., et al. (2016), JGR Oceans, 121, 8585–8607, doi:10.1002/2016JC012337.

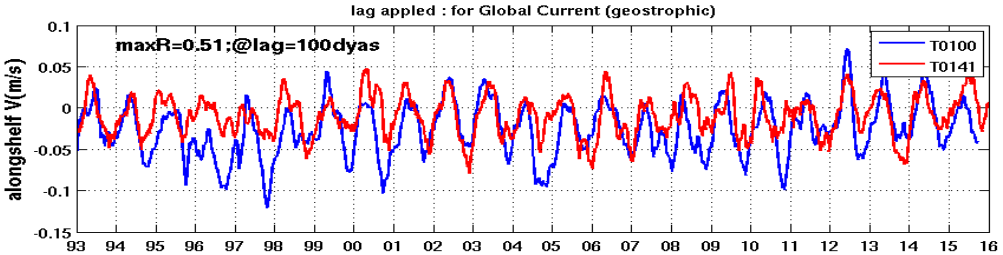
New Question: Can routine multi-mission products (**Globcurrent**, OSCAR) serve science application needs in similar coastal studies?

Gulf Maine salt anomalies correlated with upstream Globcurrent Scotian Shelf estimates





Reasonable GlobCurrent results also seen in the correlation between along-coast currents in Gulf of St. Lawrence vs. distant Scotian Shelf

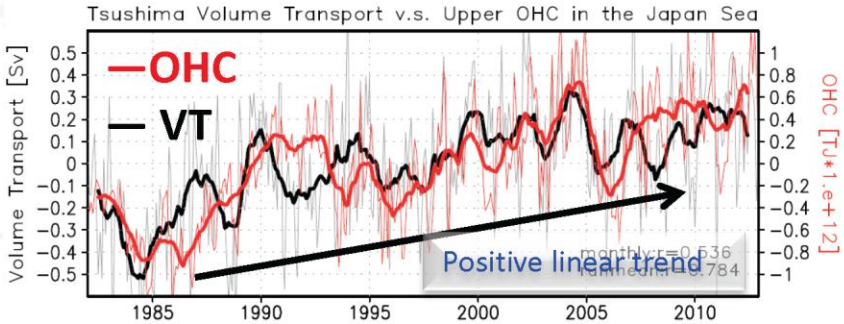


GlobCurrent errors remain: Regional ADCP cal/val shows MDT problems & near-coast issues

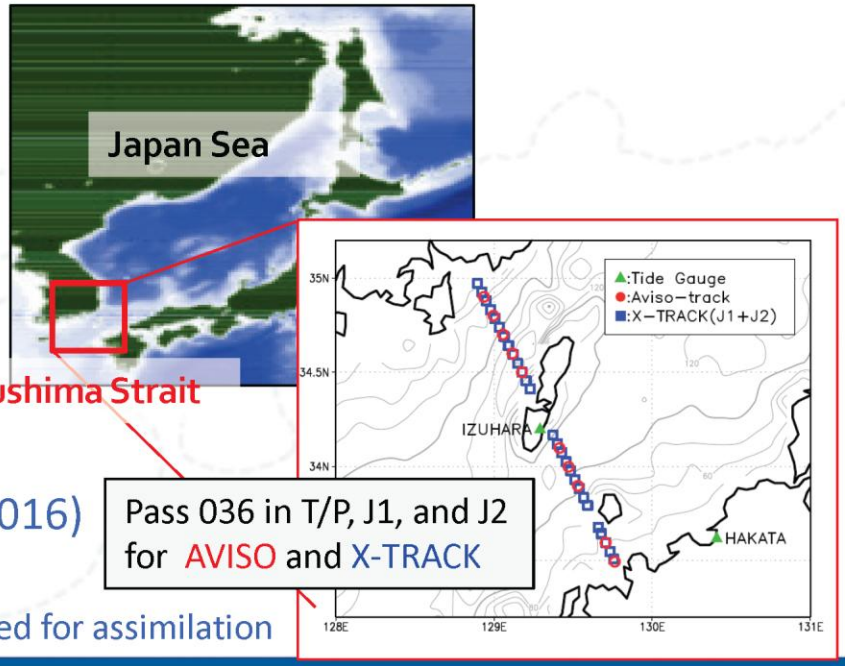
Intercomparison of sea level variation across the Tsushima Strait among tide gauge data, a coastal altimetry product and an ocean reanalysis FORA-WNP30.

N. Hirose, N. Usui, T. Wakamatsu, Y. Tanaka, T. Toyoda, Y. Fujii, Y. Takatsuki, T. Kuragano, M. Kamachi

- **Background and Motivation**
  - Increasing of the **ocean heat content (OHC)** in the Japan Sea and **volume transport (VT)** through the Tsushima Strait can be found in ocean reanalysis.
  - Volume transport is related to the sea level difference across the strait.
  - Intercomparison of the sea levels among tide gauge data, altimetry product and ocean reanalysis



- **Dataset**
  - Tide gauge data(1982-2012)
  - **Altimetry products** (1993-2012)
    - (AVISO along-track and X-TRACK data)
  - **Ocean reanalysis** (FORA-WNP30, Usui et al., 2016)
    - 4DVAR, eddy-resolving, 1982-2012
    - Along-track SLA at the depth deeper than 600 m is used for assimilation



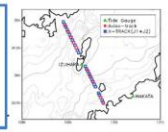
Pass 036 in T/P, J1, and J2 for AVISO and X-TRACK

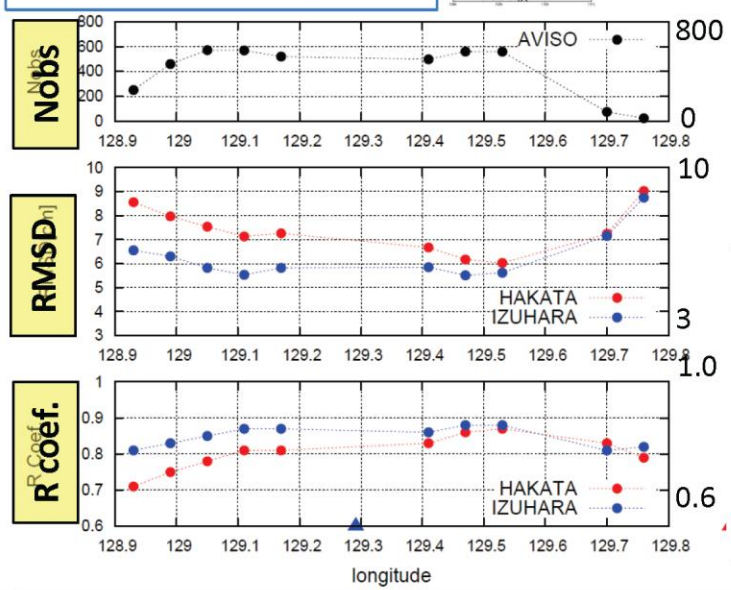
Intercomparison of sea level variation across the Tsushima Strait among tide gauge data, a coastal altimetry product and an ocean reanalysis FORA-WNP30.

N. Hirose, N. Usui, T. Wakamatsu, Y. Tanaka, T. Toyoda, Y. Fujii, Y. Takatsuki, T. Kuragano, M. Kamachi

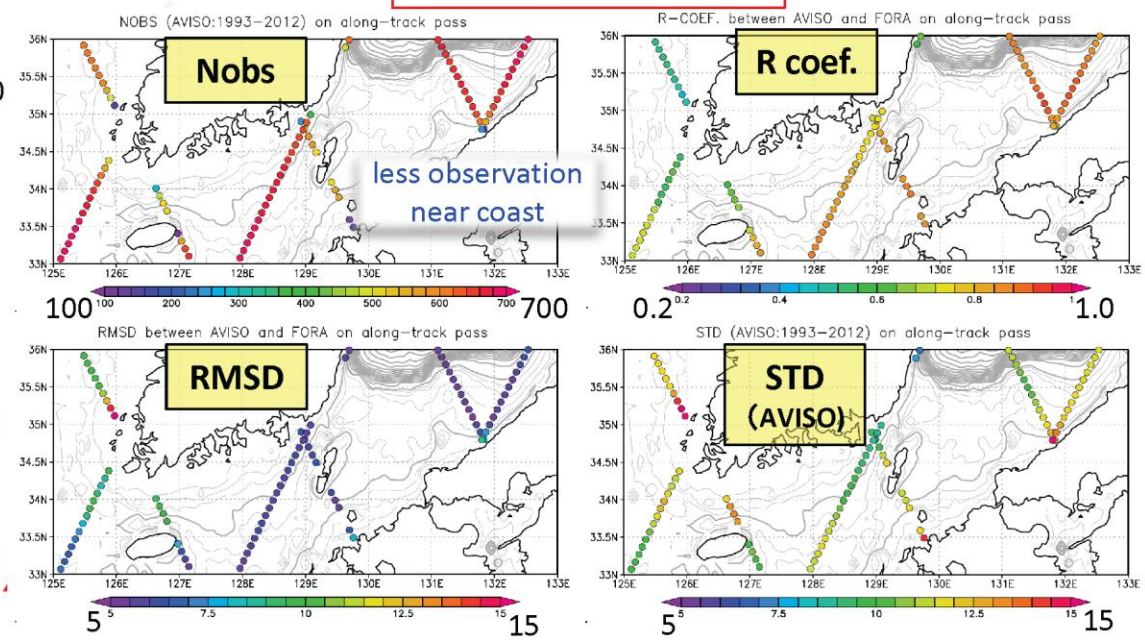
- Comparison of sea level anomaly between AVISO and tide gauge data/FORA.
  - AVISO track data on pass 036 (across the Tsushima Strait) has high correlation (about 0.8) with tide gauge data and FORA except for near coast.
  - FORA captures the variation of AVISO track data well, even though SLA in coastal areas shallower than 600 m is not assimilated.

AVISO (pass 036) vs. tide gauge



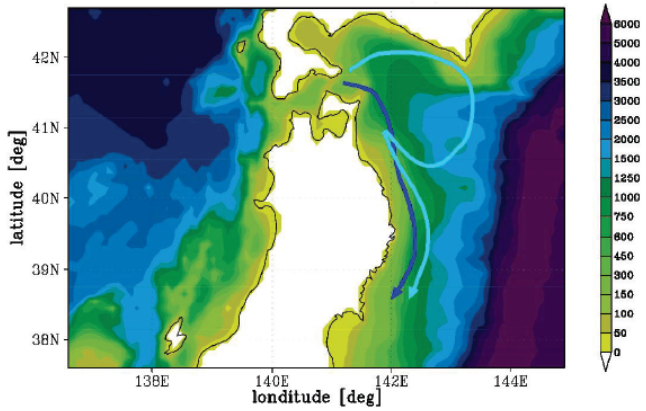


AVISO vs. FORA



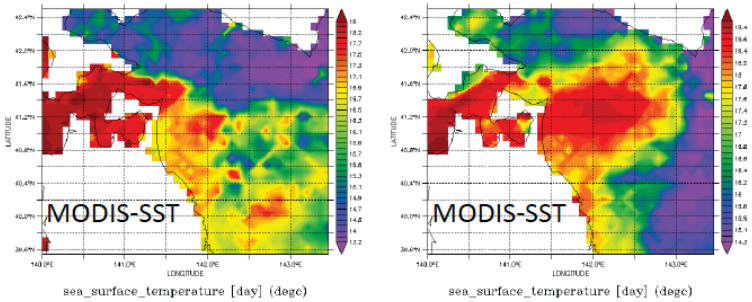
Inter-annual variation of the Tsugaru Warm Current revealed from the long-term coastal ocean reanalysis: FORA-WNP30

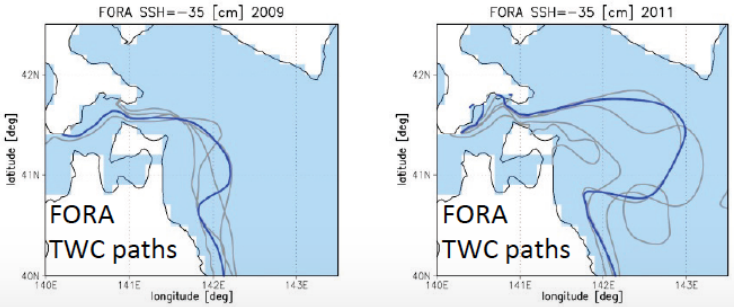
○T. Wakamatsu[1], N. Hirose[2], Y. Tanaka[1], S. Nishikawa[1], N. Usui[2], Y. Takatsuki[2], T. Kuragano[2], *M. Kamachi[1], Y. Ishikawa[1]
1. JAMSTEC, 2. MRI/JMA, ○Corresponding Author. *Presenter



- Tsugaru Warm Current (TWC) exhibits bimodal patterns: Gyre mode (light blue curve) and Coastal mode (dark blue curve), seasonally and inter-annually.
- Inter-annual bimodality of TWC has strong influence on formation of fishing grounds along the down stream Sanriku coast, however, its controlling factors are not fully understood.
- Recently, eddy resolved ocean reanalysis data, FORA, was compiled for the period from 1982 to 2012 over the North Western Pacific.

Q. How good can FORA reproduce inter-annual bimodality of TWC?
Q. How important satellite altimeter data are in reproducing the TWC bimodality?



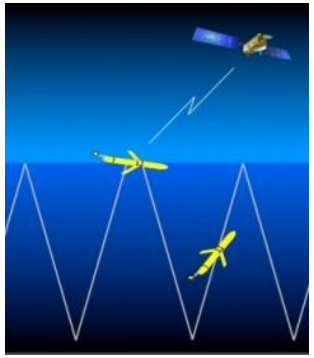


- FORA successfully reproduces inter-annual bimodality of TWC, and the coastal mode can be identified only three times in 1992, 1997 and 2009 during the FORA analysis period.
- Observation sensitivity experiments (OSEs) indicates satellite altimeter data are necessary information for reproducing life cycle of TWC gyre with precise timing and size.
- OSEs also revealed that, it is suffice to assimilate only in-situ data to reproduce inter-annual bimodality, which suggests importance of upstream hydrographic condition in controlling the TWC bimodality.

Understanding altimetry signals in near-coastal areas using underwater autonomous vehicles:

Ines Borrione, P. Oddo, A. Russo and E. Coelho

CMEMS: Altimetry – NRT 7 km along-track TAPAS (Tailored Product for Data Assimilation) filtered & unfiltered SLA (and corrections: DAC, tides, long wavelength error) and MDT. Ocean Color – L3, AQUA MODIS, daily, RT data @ 1 km resolution.

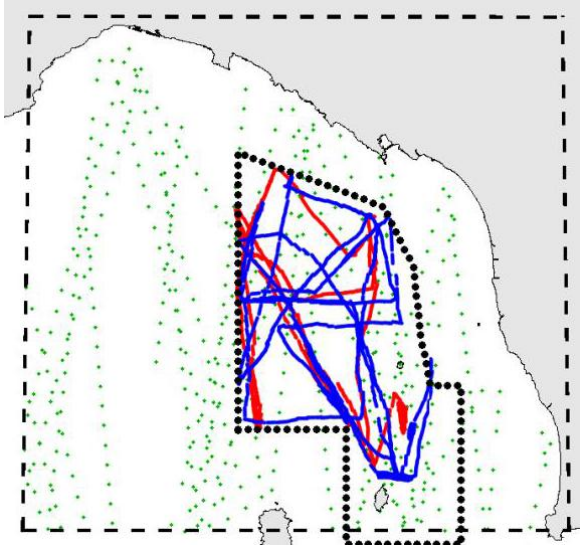


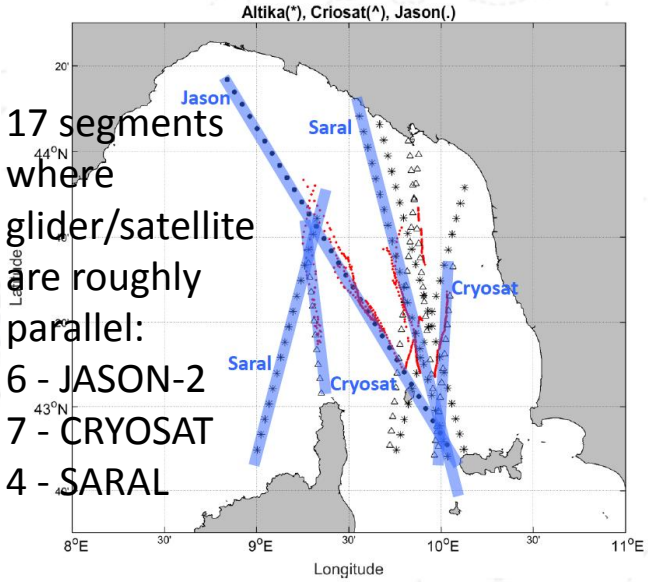
In situ: T,S from glider paths co-localized with altimeter tracks give dynamic height anomaly referenced of 400 m, added to CMEMS MDT (MDT_CNES-CLS13)

NEMO –horizontal resolution 600 m with atmospheric pressure included in surface forcing. Glider and altimetry SLA are assimilated using 3DVar.

LOGMEC16 Long-term glider mission for environmental characterization

- Patterns/scales in filtered SLA are comparable to glider measurements; differences explained by gliders having sampled the same structures at different times.
- SLA variability not fully captured by in-situ. Possibly due to 7 km resolution of the altimetry
- Glider profiles allow for characterizing baroclinic structures.
- Gliders and SLA show evidence of mesoscale variability (meanders) of the current, with scales agreeing with previous studies and ocean color.
- Model results improve significantly when both glider and altimetry data are assimilated.

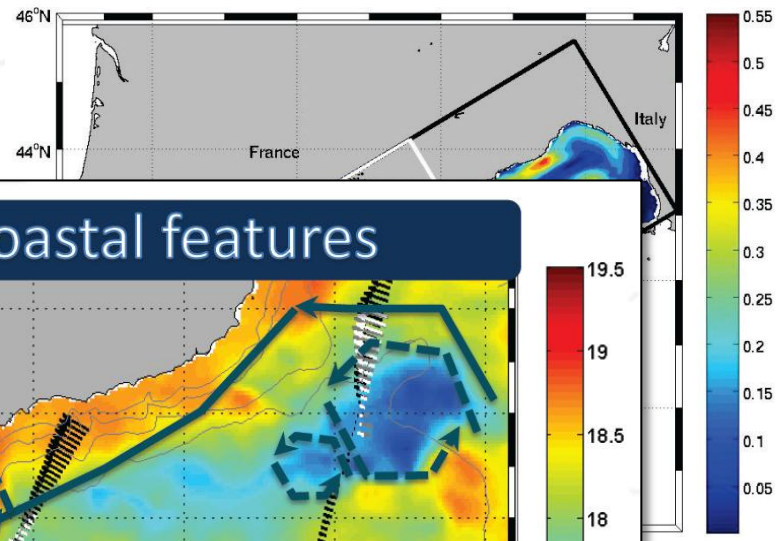




17 segments where glider/satellite are roughly parallel:
6 - JASON-2
7 - CRYOSAT
4 - SARAL

Multi-scale analysis of coastal altimetry data, multi-sensor observations and numerical modeling of the NW Med Sea:

M. Meloni, J. Bouffard, A. Doglioli, A. Petrenko



Context:

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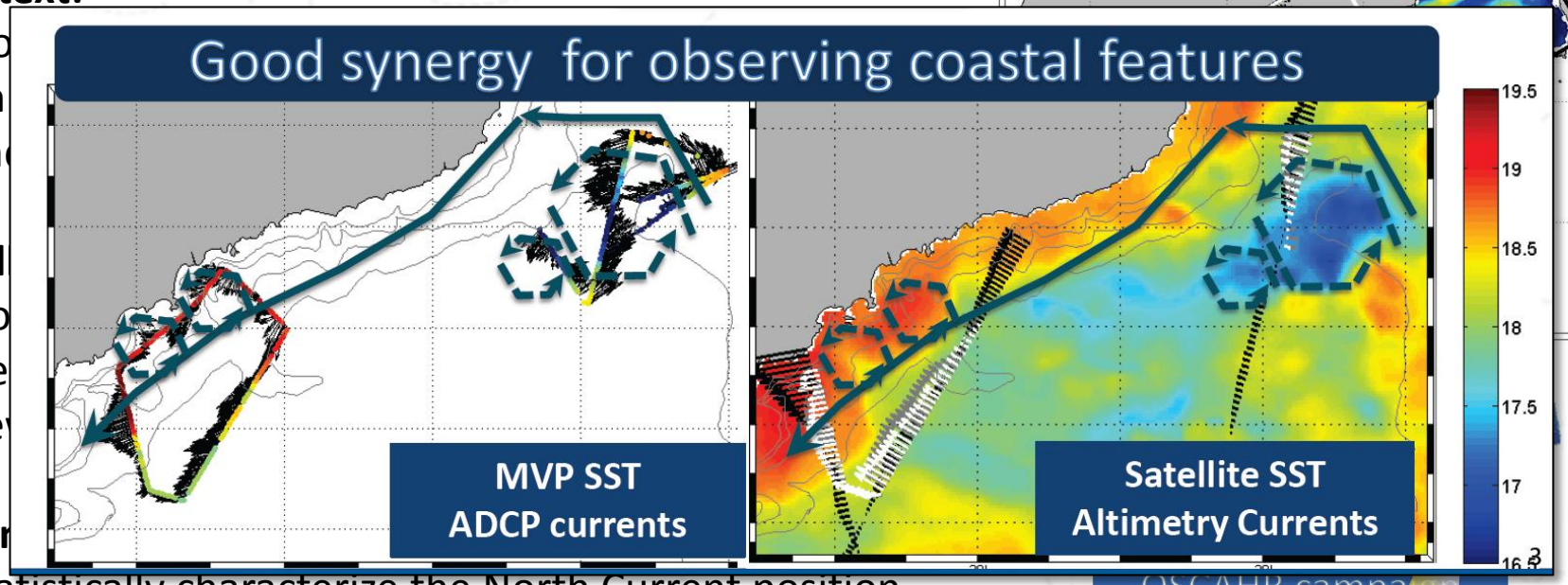
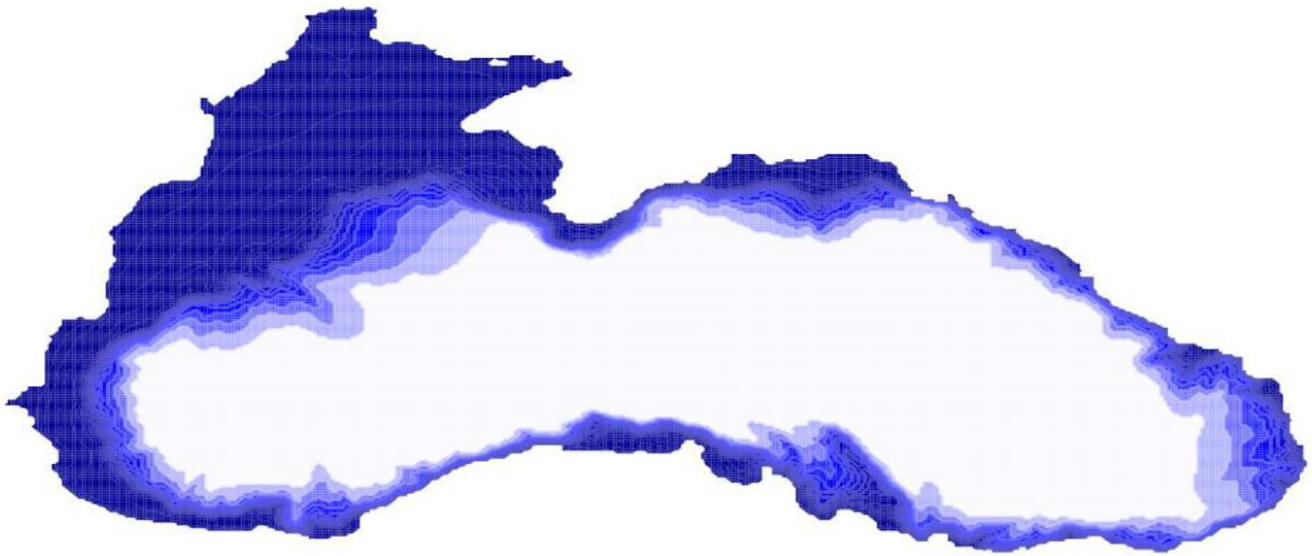
- Statistically characterize the North Current position and intensity over the NW Med Sea
- Better assess the physical content and limitations of each observing system



Impact of coastal altimetry data in the Black Sea physical ocean analysis system: A. Bonaduce, M. Passaro, A . Storto

1. Ocean General Circulation Model** (OGCM) **NEMO** in the **Black-Sea

- *3 km horizontal resolution*
- *31 vertical z-levels with partial steps*

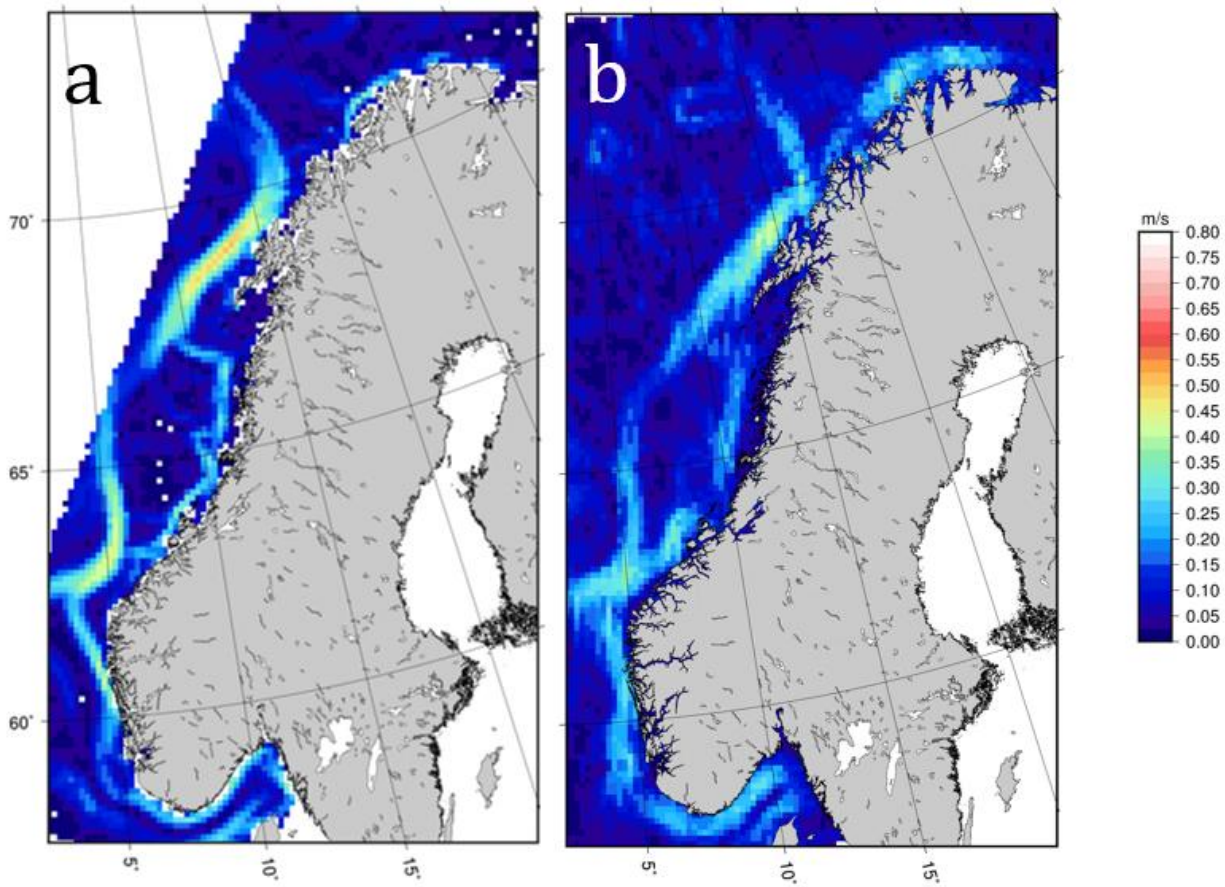


***2. Three Dimensional Variational Assimilation Scheme** (**3D-VAR**; Storto et al., 2011)*

SST Data	BLACK_SEA SST L4 (CNR/CMEMS)
SST Assimilation	Nudging (Heat flux adjustment) + 3DVAR assimilation
SLA Data	BLACK_SEA Along-track CLS/AVISO [Jason-2, Altika, Cryosat-2], **ALES Jason-2**
SLA Assimilation	T/S correction with basin-averaged SLA removed
MDT	Mean SSH from model simulation – Time-Mean Mapped SLA during model simulation for referencing to 1993-2012 SLA reference period
In-situ Data	CMEMS In-situ Real-Time data
In-situ Assimilation	Vertical thinning for floats with high vertical sampling
Background-error Covariances	15-mode gridpoint-wise multivariate monthly EOFS computed from 5-year long model simulation
Assimilation time-window	7-day
Assimilation frequency	3-days

***- SLA** propagated in the vertical using the dynamic height equation (height related to density (T,S)).*

Norwegian Coastal Current observed by CryoSat-2 SARin altimetry: Martina Idzanovic, O. Vegard, Ole B. Andersen



Nordkyst MDT (800 m res) **CryoSat-2 MSS - NKG geoid**

Dear Coastal Altimetry Colleagues,

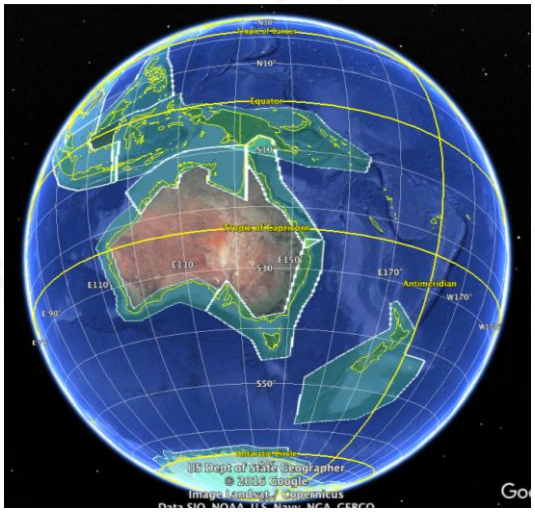
As discussed during CAW-10, ESA could now consider changing the CryoSat-2 SAR mask to accommodate Coastal Altimetry Community needs and improve coastal MDT/MSS using the CS2 drifting orbit and the SAR/SARin HR capabilities via:

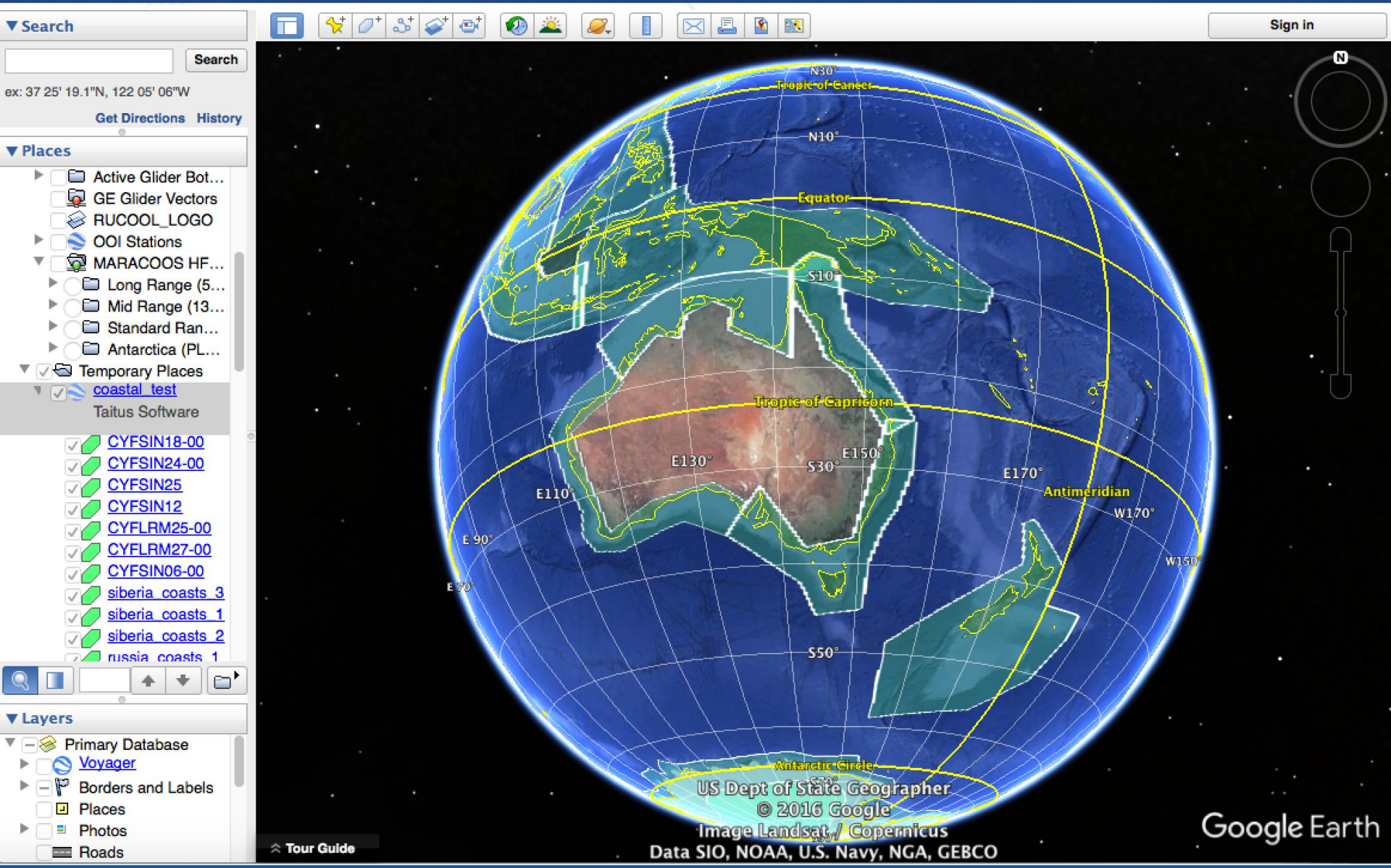
- Global Coastal SAR coverage
- A few targeted SARin patches over complex coastal zones to be proposed/added (fjord, archipelago, river mouth etc.

We invite CAW community input on the SAR/SARin masks.

…

Best Regards,
Tommaso Parrinello, CryoSat Mission Manager
Jérôme Bouffard, CryoSat Mission Geophysicist

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S50°
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