

Altimetry for Coastal Ocean Modeling and Analysis

John Wilkin

Representing also the efforts of

*Claire Dufau, *Baptiste Mourre, #Paolo Cipollini,
+Villy Kourafalou and +Pierre De Mey, and participants in ...

*ARCOM (Altimetry for Regional and Coastal Ocean Models)

CAW (Coastal Altimetry Workshops)

+ COSS-TT (Coastal Ocean and Shelf Seas Task Team of GODAE)

jwilkin@rutgers.edu

marine.rutgers.edu/wilkin

The coast is at the center of human-ocean interactions

Safety



New York City 86th St metro station after hurricane Sandy

- Ocean rescue
- Storm surge
- Oil spill tracking



Oil-covered rocks at Refugio State Beach (photo: NOAA)

Economy

Maritime economy contributed \$282 billion & 2.8 million jobs to the U.S. economy in 2011.

- Sustainable fisheries
- Harmful Algal Bloom tracking and prediction
- Offshore energy design, development and operation
- Navigation systems prevent groundings in busy ports
- Forecast ocean conditions for the fishing fleet (safety, harvest) and fishing survey
- Predicting ocean acidification events for shellfish hatcheries

Environment



“Chá bă,” a new buoy off the coast of Washington, contributes better information about the ocean conditions that oysters can and cannot tolerate.
(photo: J Payne, Pacific Ocean Shelf Tracking Project)

The coast is at the center of human activities

Safety



New York City 86th St metro station after hurricane Sandy

- Ocean rescue
- Storm surge
- Oil spill tracking



Oil-covered rocks at Refugio State Beach (photo: NOAA)

Economy

Maritime economy contributes \$282 billion & 2.8 million jobs to the U.S. economy in 2012

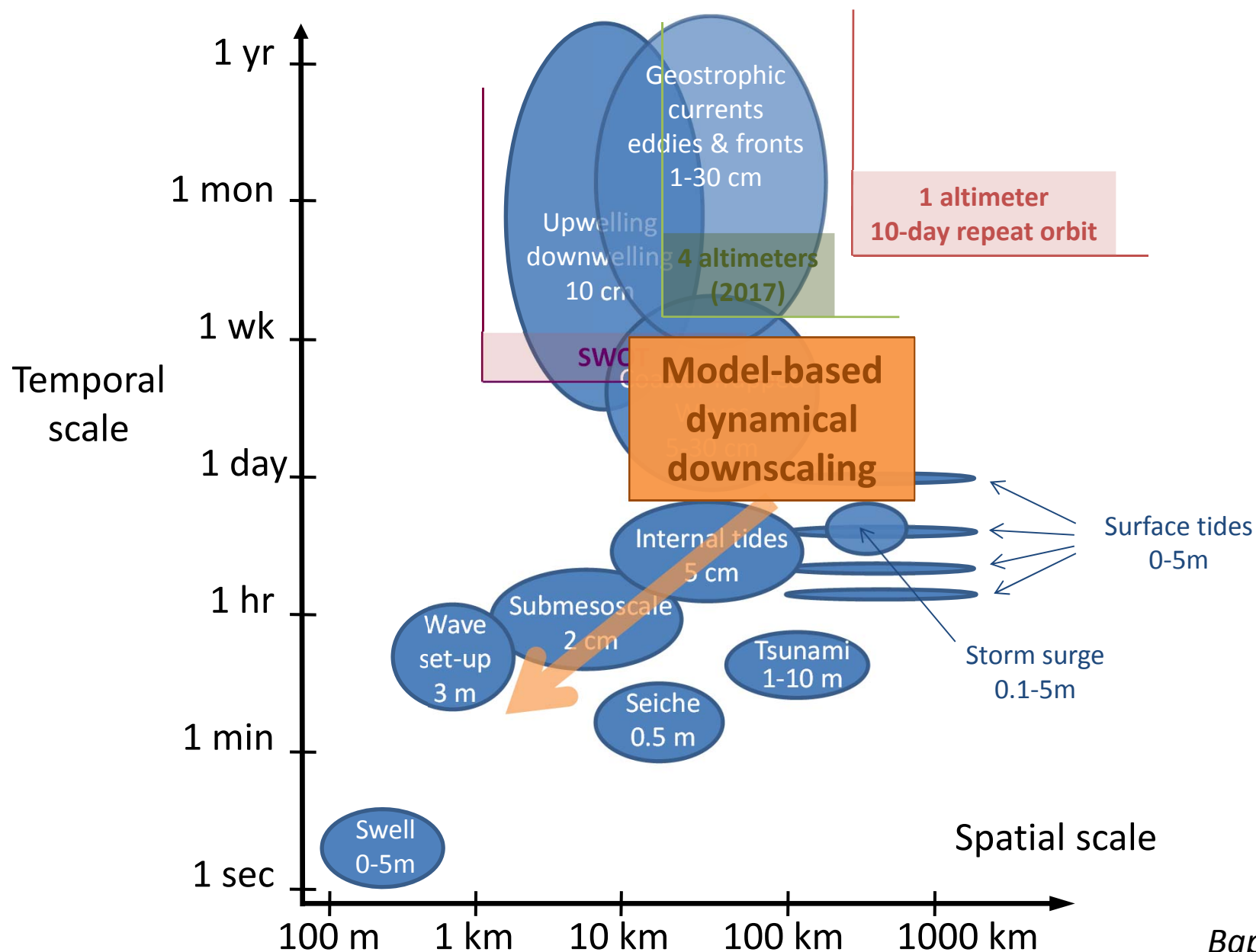
- Sustainable fisheries
- Harmful Algal Bloom tracking and prediction
- Offshore energy design, development and operation
- Navigation systems prevent groundings in busy ports
- Forecast ocean conditions for the fishing fleet (safety, harvest) and fishing survey
- Predicting ocean acidification events for shellfish hatcheries

Coastal ocean modeling and data analysis provides **actionable guidance** for...



“Chá bă,” a new buoy off the coast of Washington, contributes better information about the ocean conditions that oysters can and cannot tolerate. (photo: J Payne, Pacific Ocean Shelf Tracking Project)

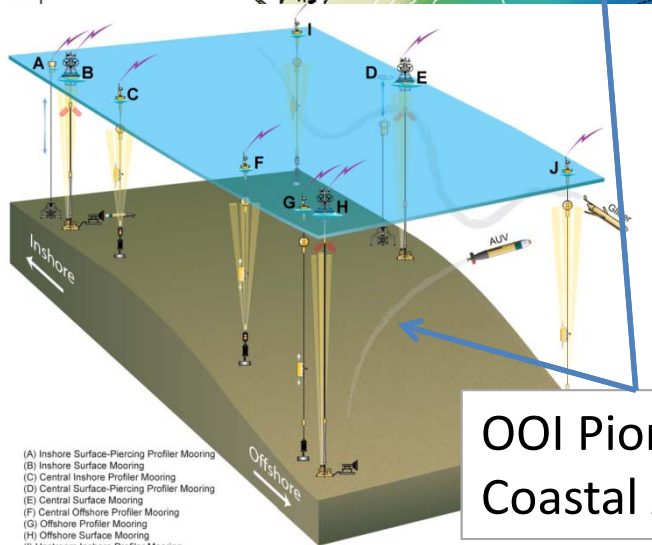
Coastal sea level variability: Dynamics and scales



ROMS model domain
for MARACOOS ocean
forecast system

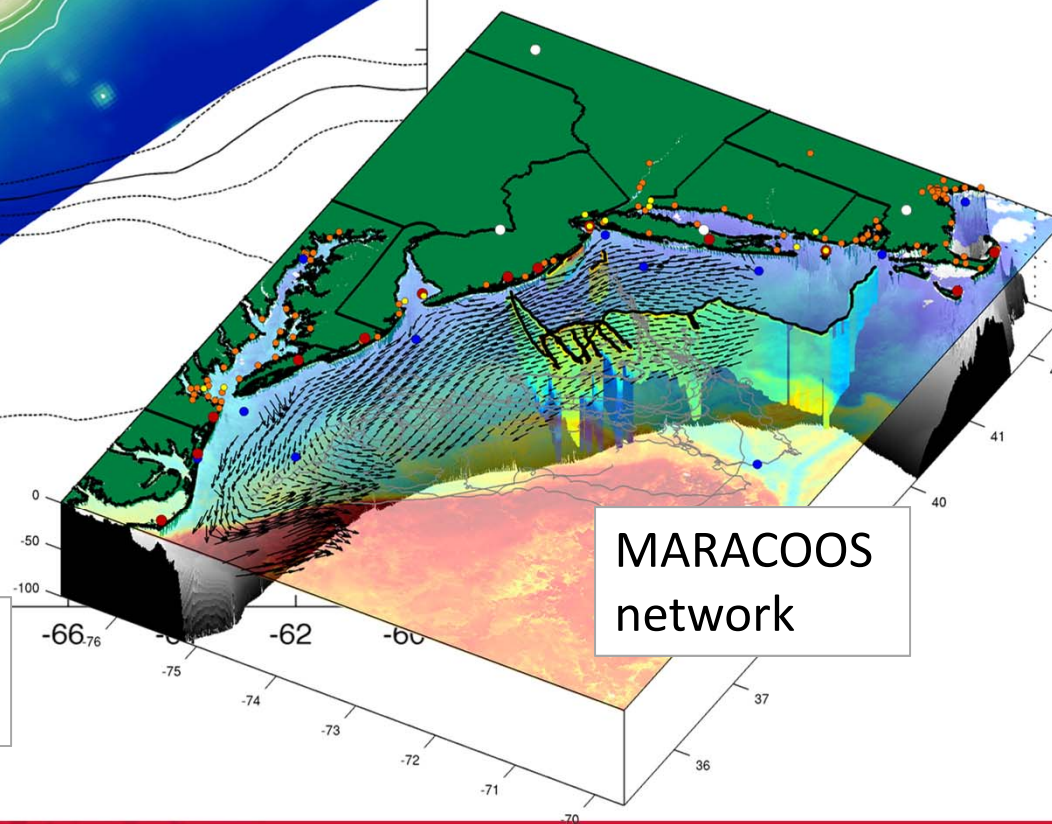
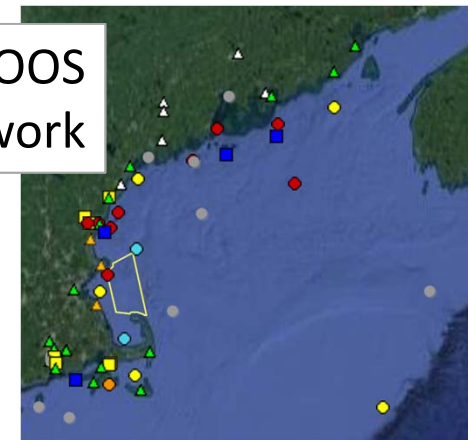
NERACOOS
buoy network

42
40
38



OOI Pioneer
Coastal Array

(A) Inshore Surface-Piercing Profiler Mooring
(B) Inshore Surface Mooring
(C) Central Inshore Profiler Mooring
(D) Central Surface-Piercing Profiler Mooring
(E) Central Surface Mooring
(F) Central Offshore Profiler Mooring
(G) Offshore Profiler Mooring
(H) Offshore Surface Mooring
(I) Upstream Inshore Profiler Mooring
(J) Upstream Offshore Profiler Mooring



MARACOOS
network

RUTGERS

<https://maracoos.org>
Mid-Atlantic Regional Association of Coastal Ocean Observing Systems

GODAE OceanView



Altimetry for Regional and Coastal Ocean Models

- I. Discuss the interest of sea level measurements for the regional/coastal ocean modellers and COFS
- II. Present the available altimetry missions and products; discuss recent advances and projects
- III. Discuss how altimetry can improve the forecast quality and enable new applications in the regional/coastal oceans
- IV. Discuss how to use altimetry products in R/COFS for assimilation and validation
- V. Establish a community of practice to advance complementary uses of coastal altimetry in regional/coastal modelling and prediction, involving the COSS community and the regional altimetry groups



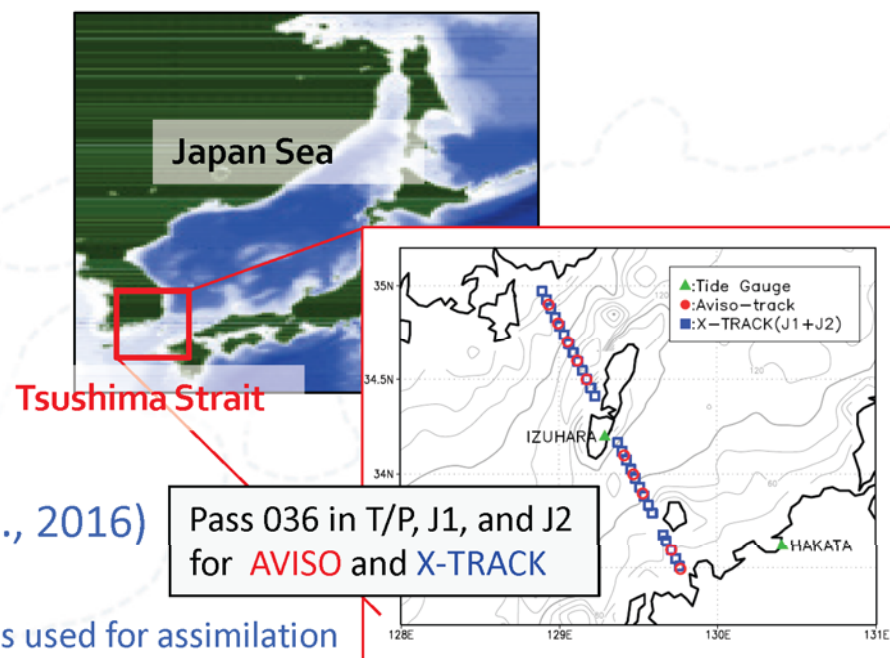
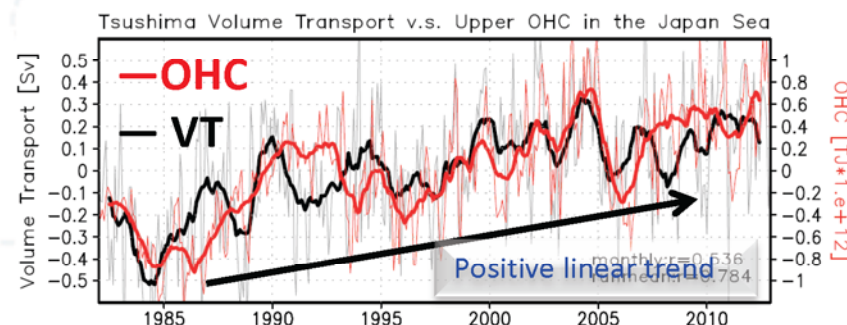
Altimetry for Regional and Coastal Ocean Models

- 2015: Pilot workshop at the 4th International Coordination Workshop of the GODAE OceanView Coastal Ocean and Shelf Seas Task Team (COSS-TT)
 - Tutorials on altimeter fundamentals and products
- 2017: ARCOM themed session at 10th Coastal Altimetry Workshop (CAW-10)
 - Applications of altimetry to coastal dynamics – analysis and data assimilation
- 2017: ARCOM themed session at 5th COSS-TT Workshop

Tsushima Strait sea level variability: tide gauges, coastal altimetry and model reanalysis: N. Hirose, N. Usui et al.

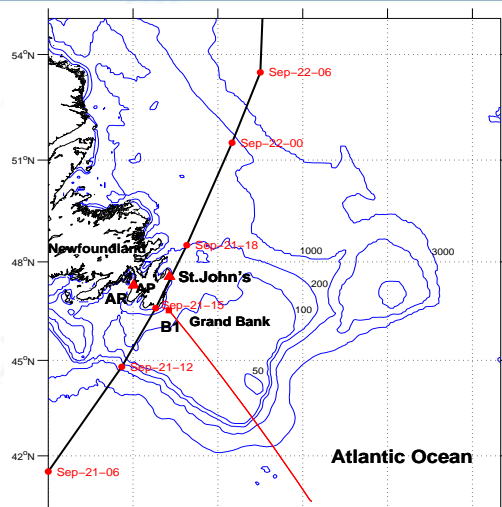
• Background and Motivation

- 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



Using Satellite Altimetry to Observe Storm Surges: Guoqi Han

Hurricane Igor observed by Jason-2

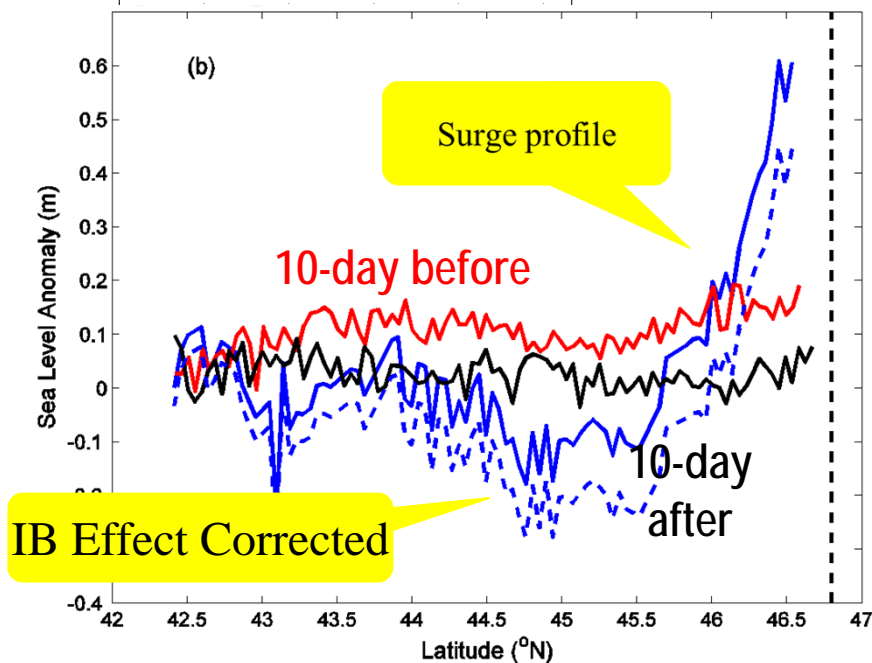
By along-track least squares fitting, we estimate the surge magnitude at coast and exponential decay scale.

Surge magnitude at the coast:

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

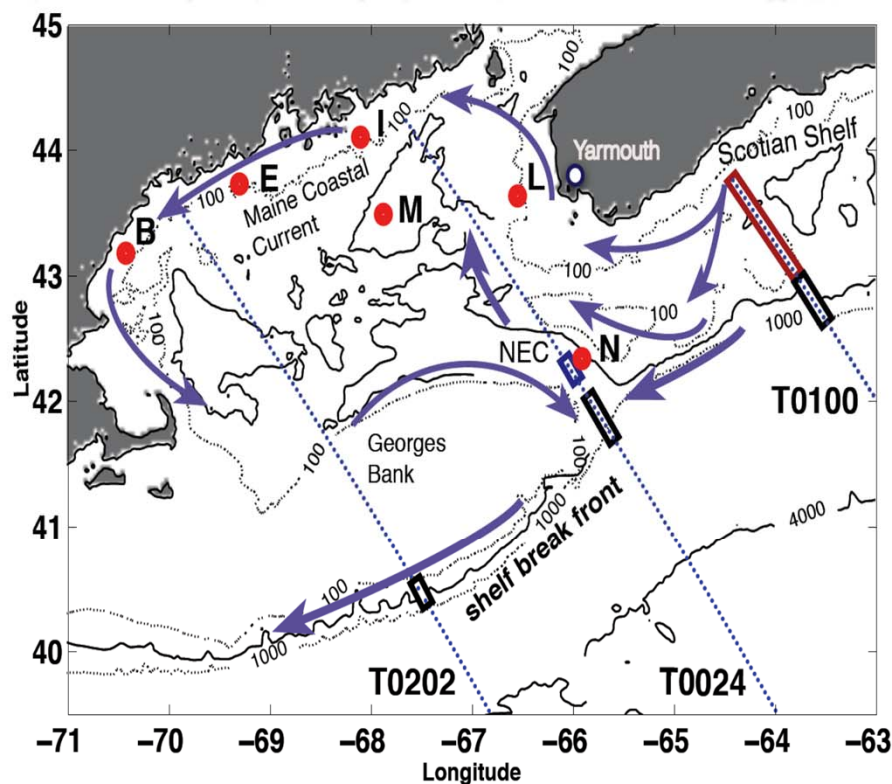
Cross-shelf decay scale:

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

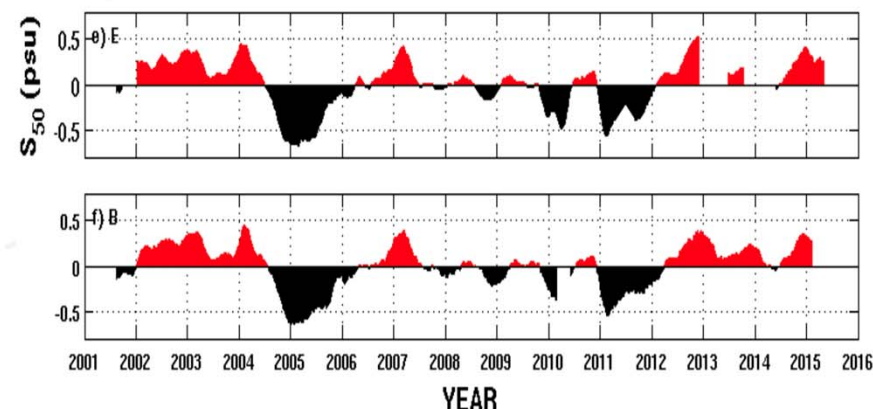


Operational altimeter-derived ocean currents for shelf sea applications: D. Vandemark, H. Feng and J. Wilkin

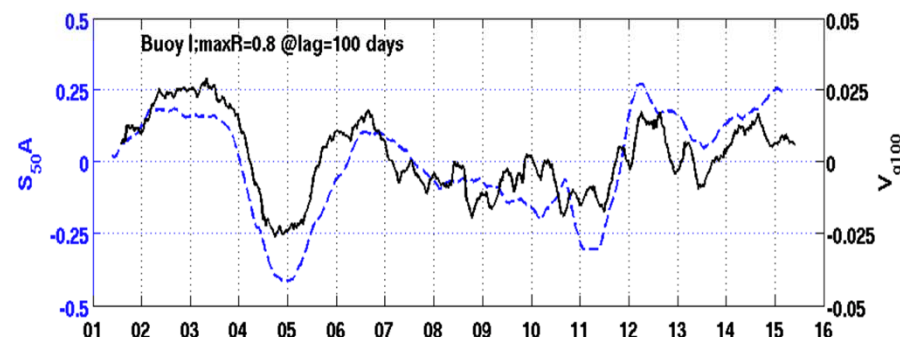
Remote currents are linked to coastal
salinity and biochemistry



Salinity anomalies Gulf of Maine 2001-2015



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



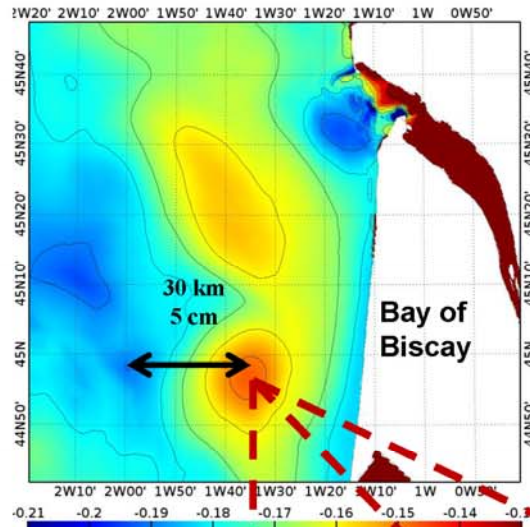
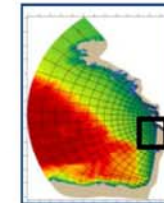


Observability with the SWOT ocean simulator in coastal regions (Toublanc et al. 2016)

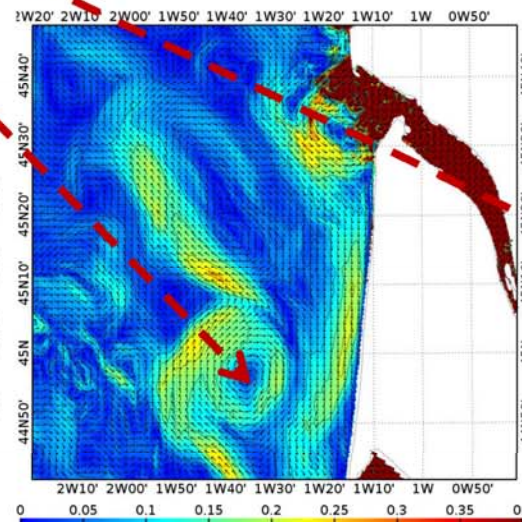
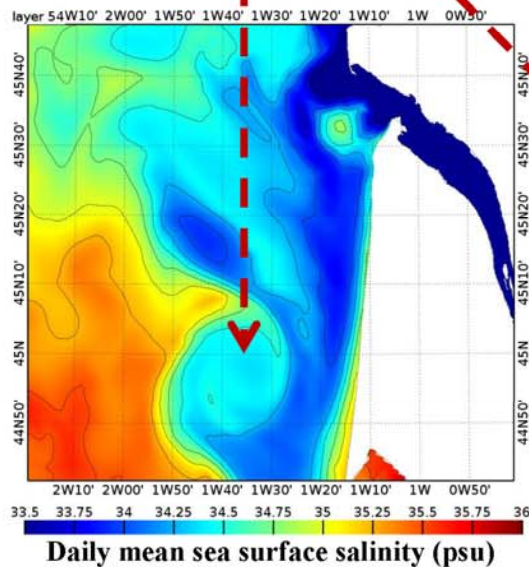


How well will SWOT identify the coastal structures linked to plume-circulation interactions?

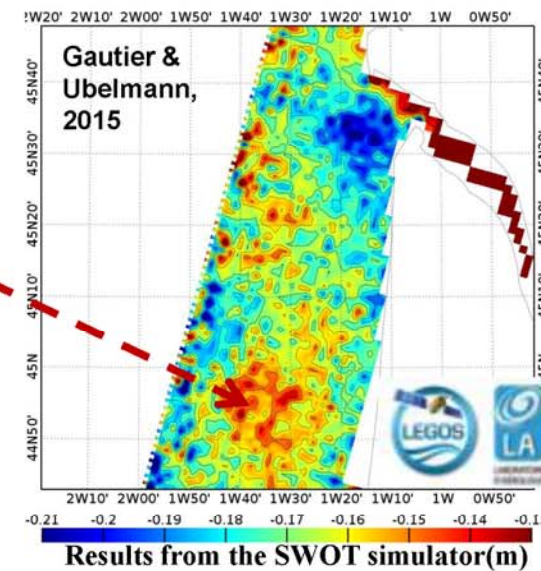
- Coastal ocean model in Bay of Biscay
- SWOT ocean simulator



Daily mean sea surface elevation (m)
August 2012



Geostrophic currents calculated from the
ssh gradient (m/s)



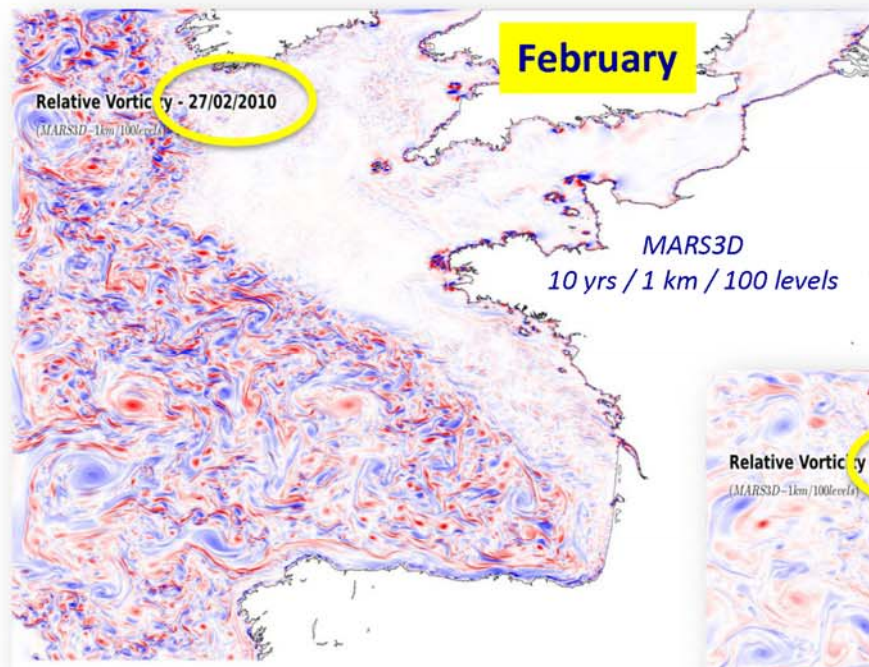
Results from the SWOT simulator(m)

P. De Mey

<https://tinyurl.com/coss-tt-2017>



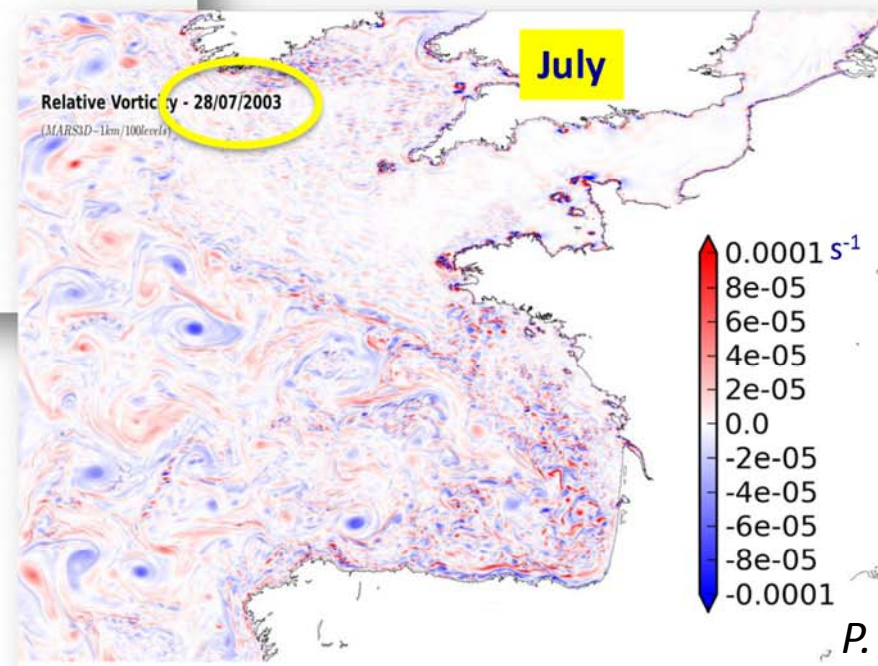
Small-scale dynamics in the Bay of Biscay



Surface relative vorticity

as an indicator of the meso- and submeso-scales activity

MARS 3D
10-year simulations



*Charria, Yelekci, Theetten,
Vandermeirsch et al., 2016*

P. De Mey

<https://tinyurl.com/coss-tt-2017>

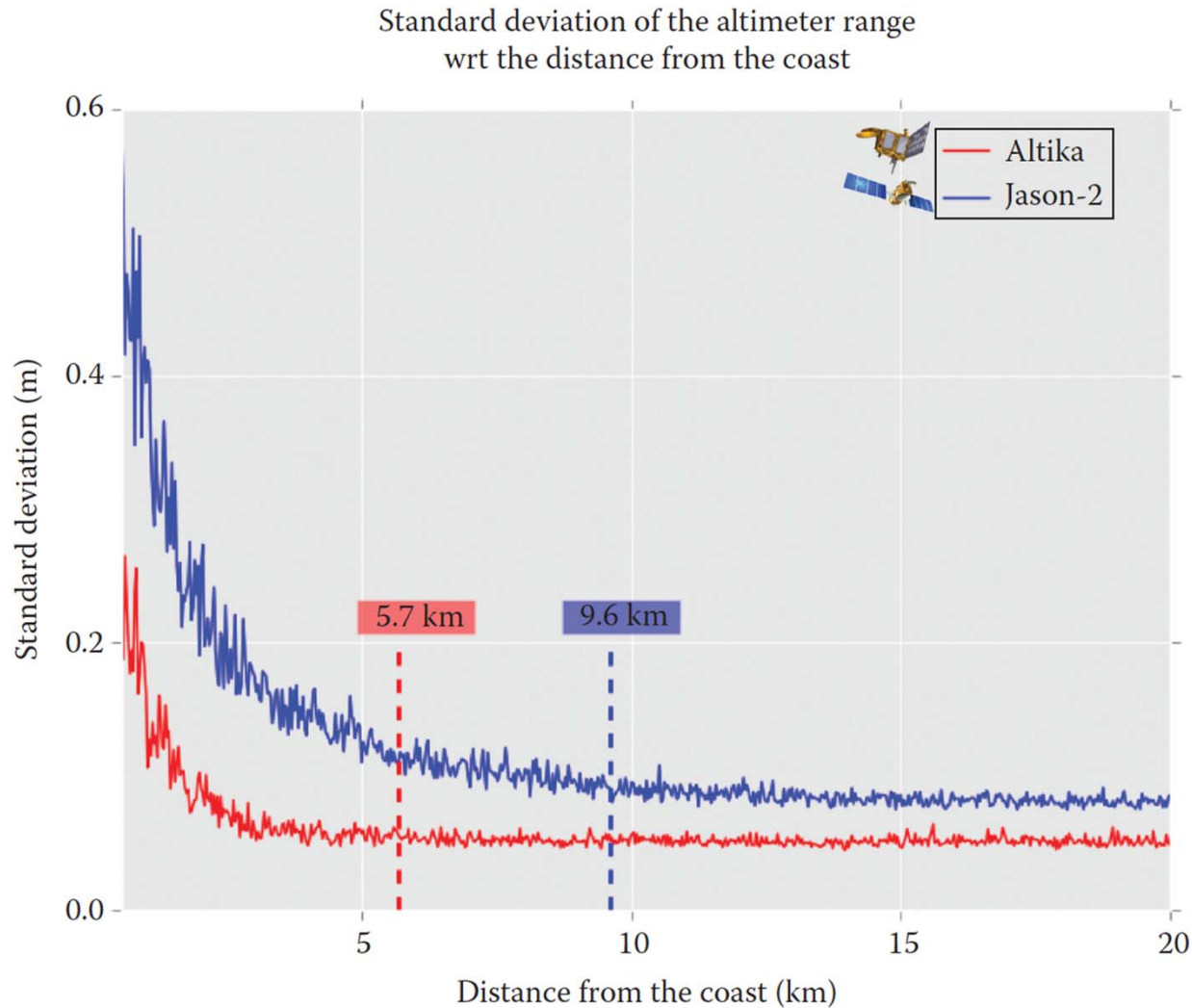


FIGURE 11.10 Performance of SARAL/AltiKa and Jason-2 altimeters near the coast: standard deviation of the altimeter range with respect to the distance from the coast. AltiKa (red curve) is remarkably more precise. (From Cipollini, P., et al., *Surv. Geophys.*, 38, 33, 2017.) Available under the terms of the Creative Commons Attribution 4.0 International License.

*Cipollini et al. 2017, in Satellite Altimetry
Over Oceans and Land Surfaces, CRC Press*

Historically, coastal oceanographers have made extensive use of coastal sea level (tide gauge) data.

Why has there not been greater uptake of new coastal processed altimeter data by this community?

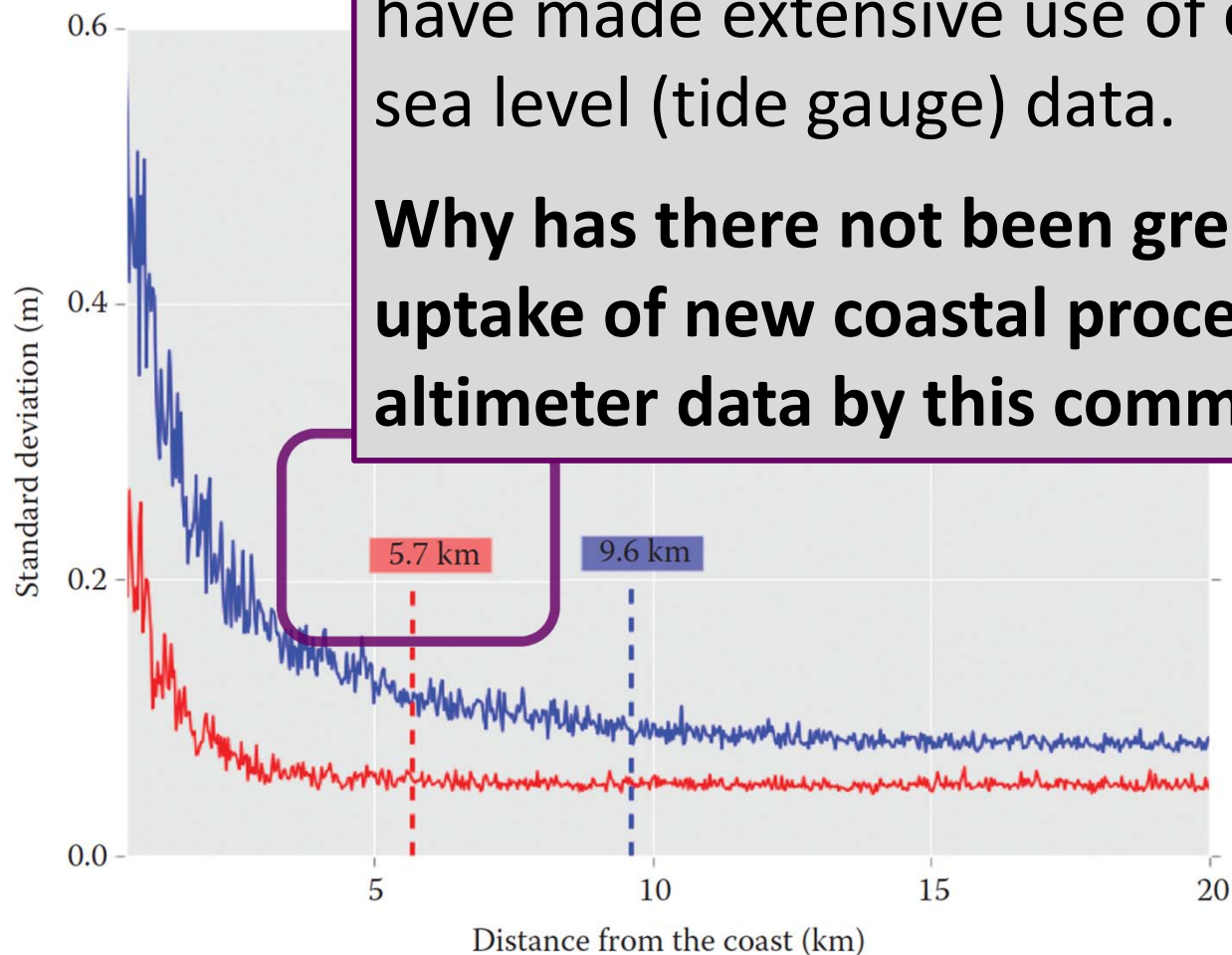


FIGURE 11.10 Performance of SARAL/AltiKa and Jason-2 altimeters near the coast: standard deviation of the altimeter range with respect to the distance from the coast. AltiKa (red curve) is remarkably more precise. (From Cipollini, P., et al., *Surv. Geophys.*, 38, 33, 2017.) Available under the terms of the Creative Commons Attribution 4.0 International License.

Cipollini et al. 2017, in Satellite Altimetry Over Oceans and Land Surfaces, CRC Press

Available Coastal Altimetry Products as of July 2017

<http://www.coastalt.eu/community#datasets>

ID	Produced by	Altimeter	Product level	Posting rate	Coverage	Download from	Comments
PISTACH	CLS CNES	j2	L2	20 Hz	Global	AVISO+	Experimental Jason-2 products for Hydrology and Coastal studies with specific processing. Will be discontinued at the end of 2016 in favour of PEACHI
PEACHI	CLS CNES	sa, (j2 to be added soon)	L2	40 Hz	Global	AVISO+ / ODES	Experimental SARAL/AltiKa products including dedicated retracking and corrections leading to more accurate products for coastal zones, hydrology and ice. From 2017 expected to generate also j2 products
XTRACK	LEGOS-CTOH	tx, j1, j2, gfo, en (sa to be added soon)	L2, L3	1 Hz 20Hz (test)	23 regions covering the whole coastal ocean	CTOH AVISO+ / ODES	Specific processing using improved data screening and latest corrections available
ALES	NOC	j2, n1, (j1, j3 to be added soon)	L2	20 Hz	Global, <50 km from coast	PODAAC	Experimental products from the ALES processor included in SGDR-type files alongside the standard products and corrections.
SARvatore	ESA-ESRIN	c2 (SAR only)	L2	20 Hz	SAR mode regions	ESA GPOD	On-demand Processing service for the CryoSat-2 SAR mode data where the user can configure some processing parameters to meet specific requirements (for instance for the coastal zone)
COP	ESA	c2 (LRM/PLRM)	L2	20 Hz	Global	ESA	Global products for CryoSat-2 from an Ocean processor (output is in PLRM over the SAR mode regions) - but no specific coastal processing
COSTA	DGFI-TUM	e2,en (j1,j2,e1 to be added soon)	L3	1 Hz 20 Hz	Mediterranean and North Sea	PANGAEA	Dedicated coastal altimetry sea level measurements based on enhanced ALES retracker

Abbreviations: **e1**: ERS-1; **tx**: TOPEX; **e2**: ERS-2; **gfo**: GEOSAT Follow-On-1; **j1**: Jason-1; **n1**: Envisat; **j2**: Jason-2; **c2**: CryoSat-2; **sa**: SARAL/AltiKa; **j3**: Jason-3. For CryoSat-2 (c2) LRM/PLRM are Low-Resolution Mode and Pseudo-LRM and SAR for Synthetic Aperture Radar mode. Product levels: L2: along-track data with corrections; L3: data projected to reference points along nominal satellite ground track.

Cipollini et al. 2017, in Satellite Altimetry Over Oceans and Land Surfaces, CRC Press

Recurring messages from the Coastal Ocean (ARCOM) community:

1/3

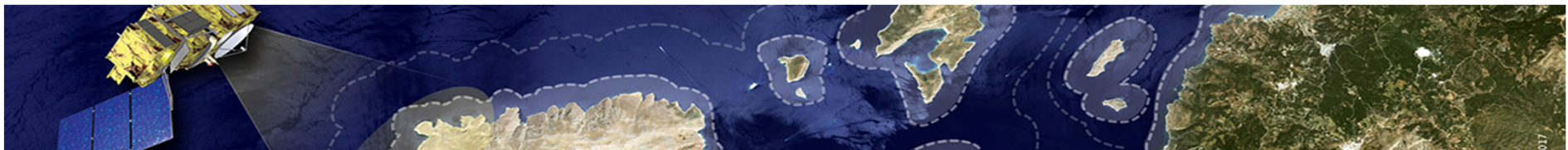
Coastal altimetry products vary in ease (difficulty) of use:

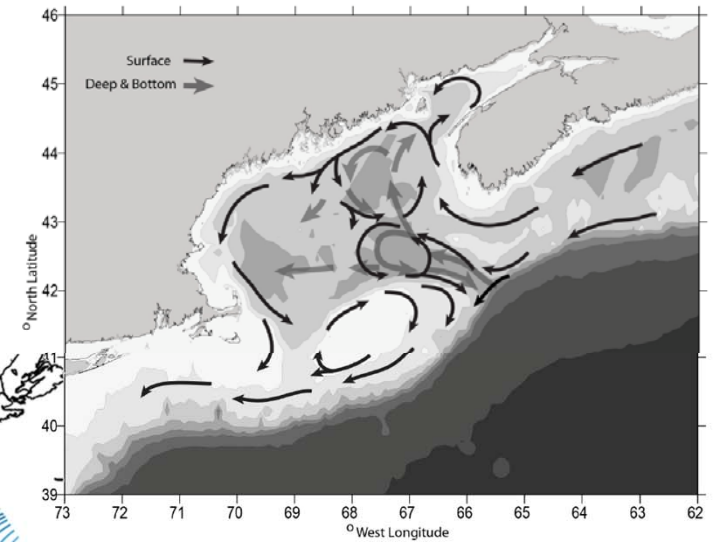
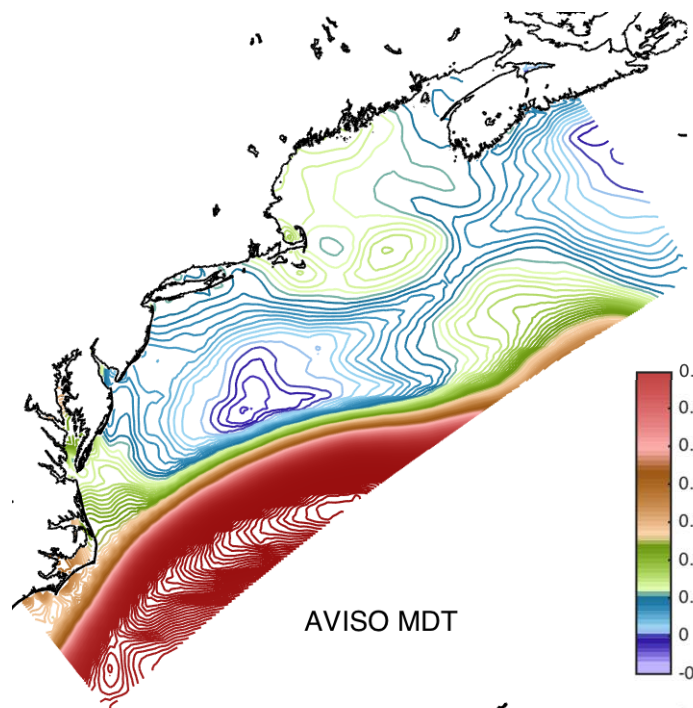
- Coastal oceanographers need help from expert altimetrists to access products and make informed choices on range adjustments

Need unified products:

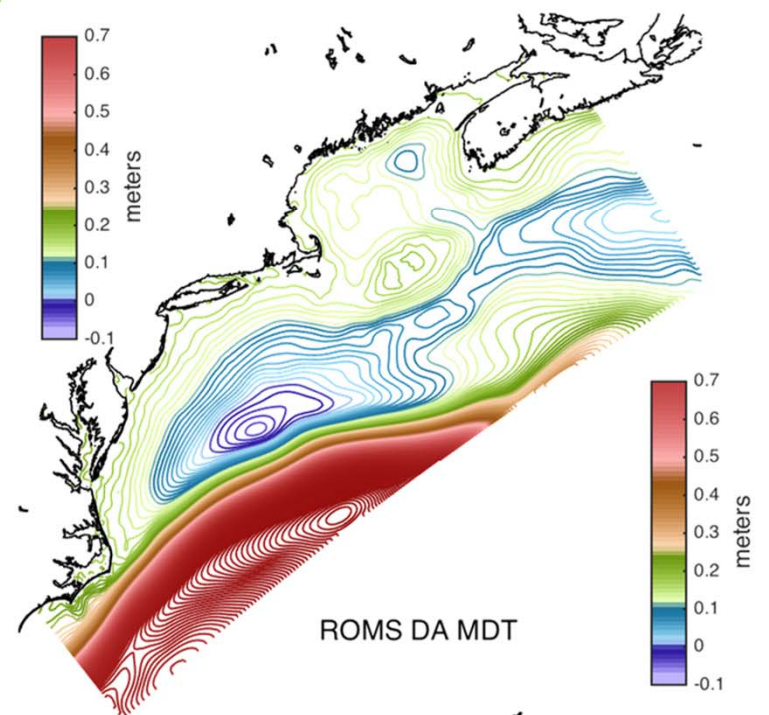
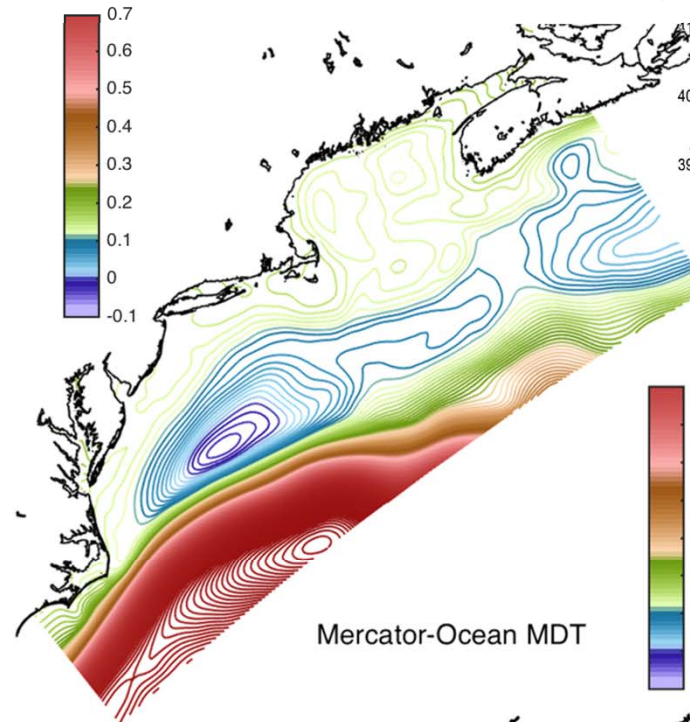
- Multi-mission merged; consistent format; high along-track resolution; limited set of documented default adjustments (coastal users will check and verify versus independent data)
- Notionally: all missions Level-3 enriched with tides, DAC, options...
- Community interest for Level-4 multi-mission coastal product
- Need community tools to support applications (e.g. *rads2roms.m*, *convert_aviso.f90* for DART* *obs_seq*)
- Desire a wiki or active User Forum to get expert help to novice users.

*Data Assimilation Research Testbed (NCAR)

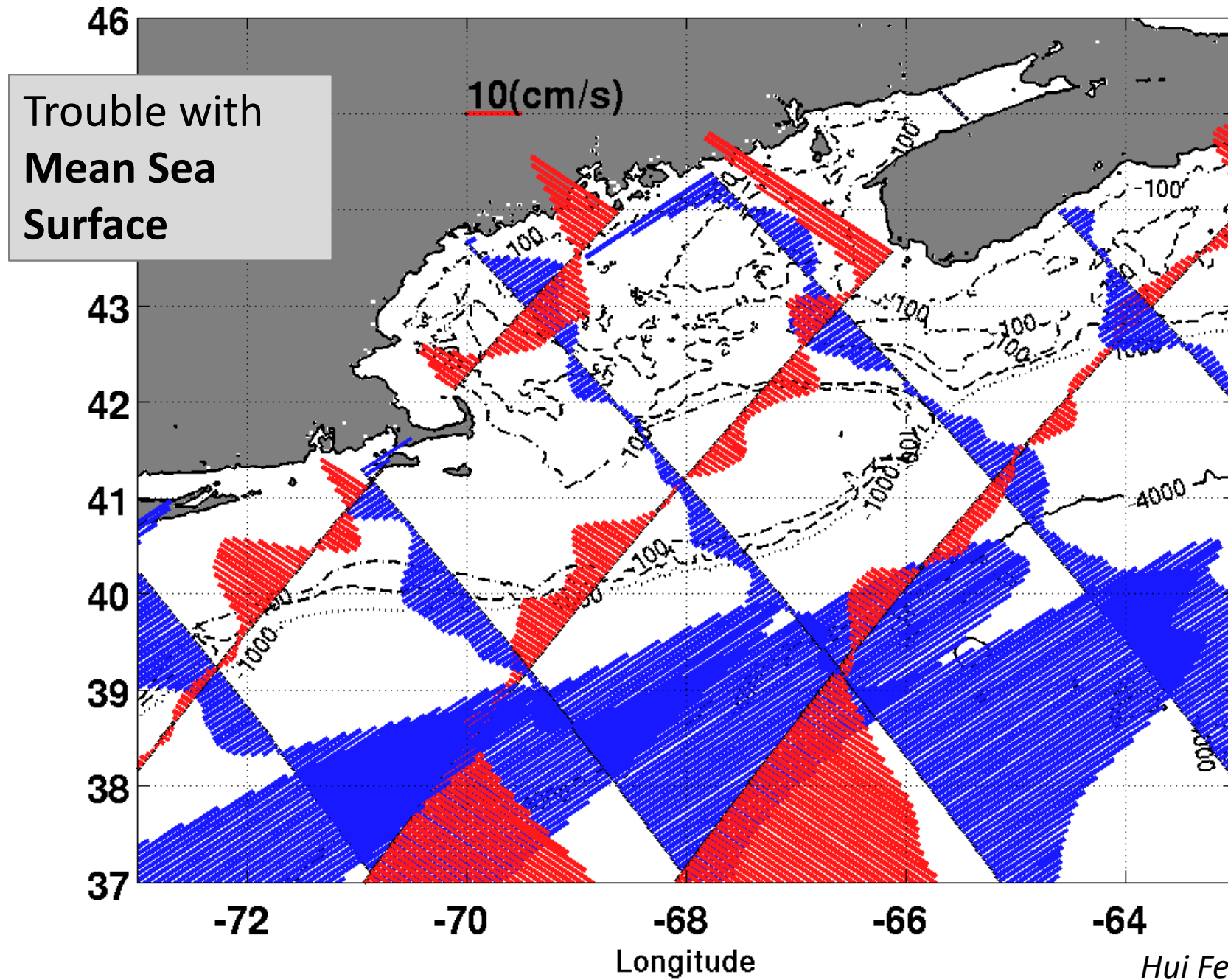




Trouble with
**Mean Dynamic
Topography**

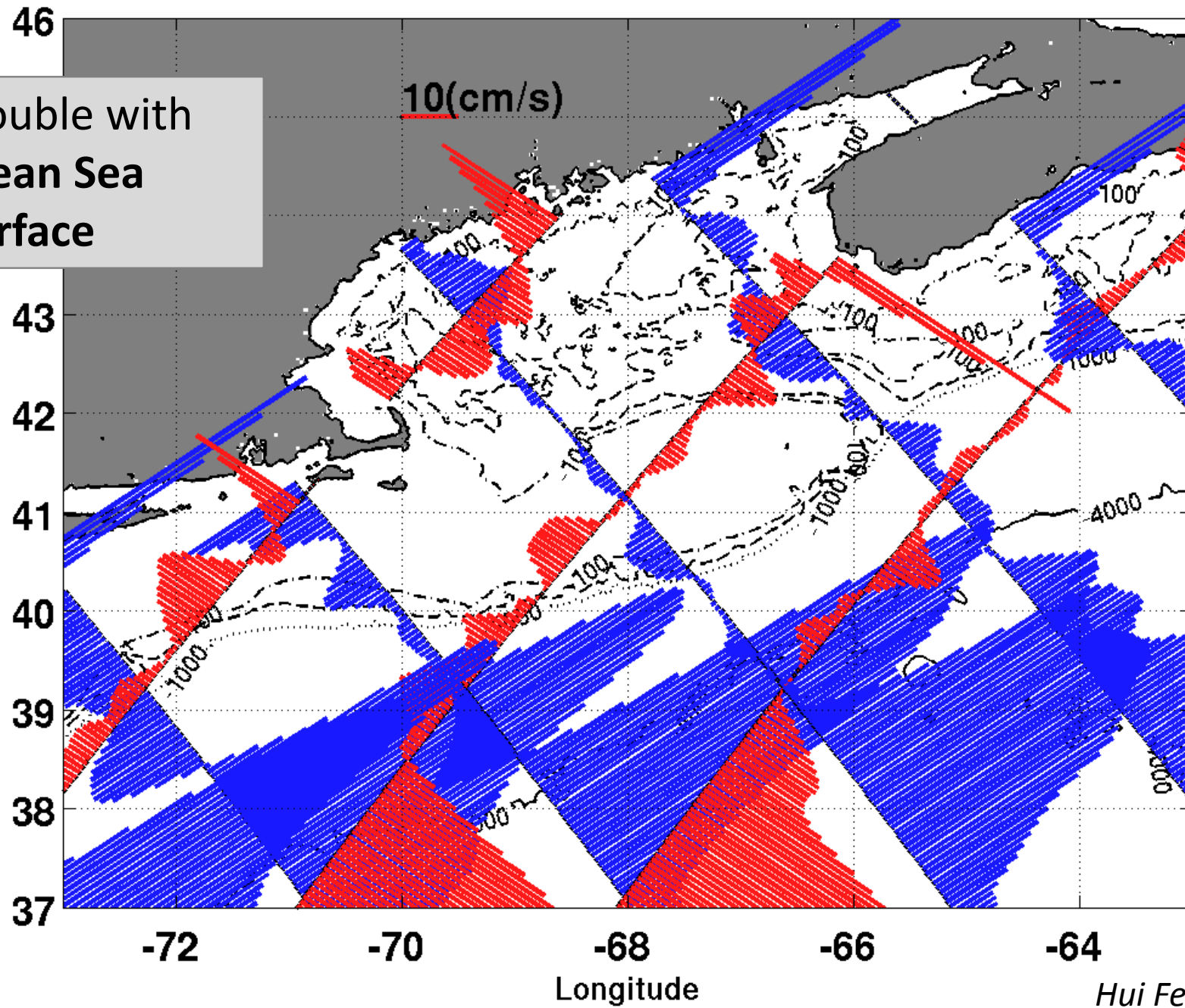


j1a :VgMDT3 N1 by mssCLS11-G



j1a :VgMDT1 N1 by mssDTU10-G

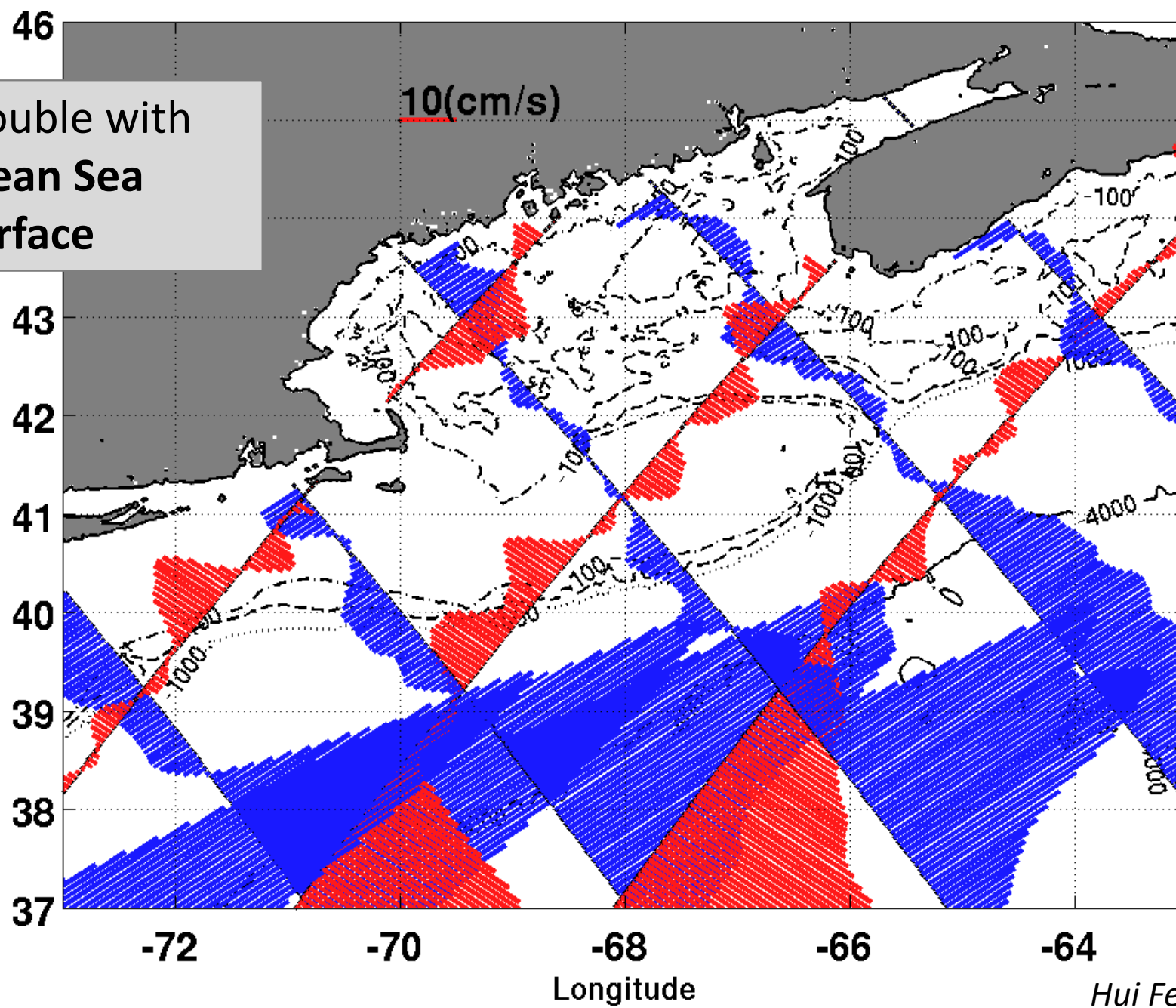
Trouble with
Mean Sea
Surface



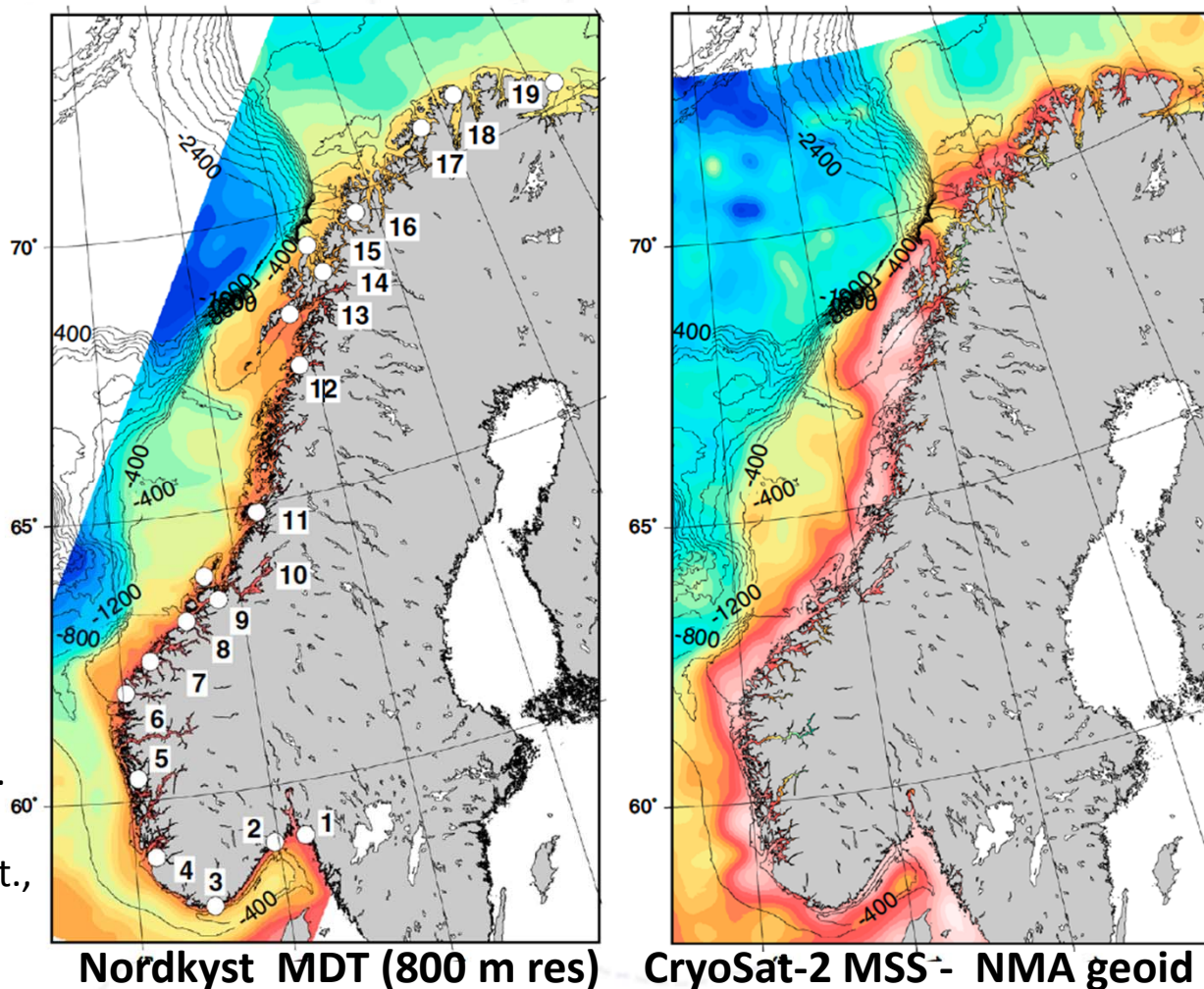
Hui Feng, UNH

j1a :VgMDT2 N1 by mssCTOH-G

Trouble with
Mean Sea
Surface

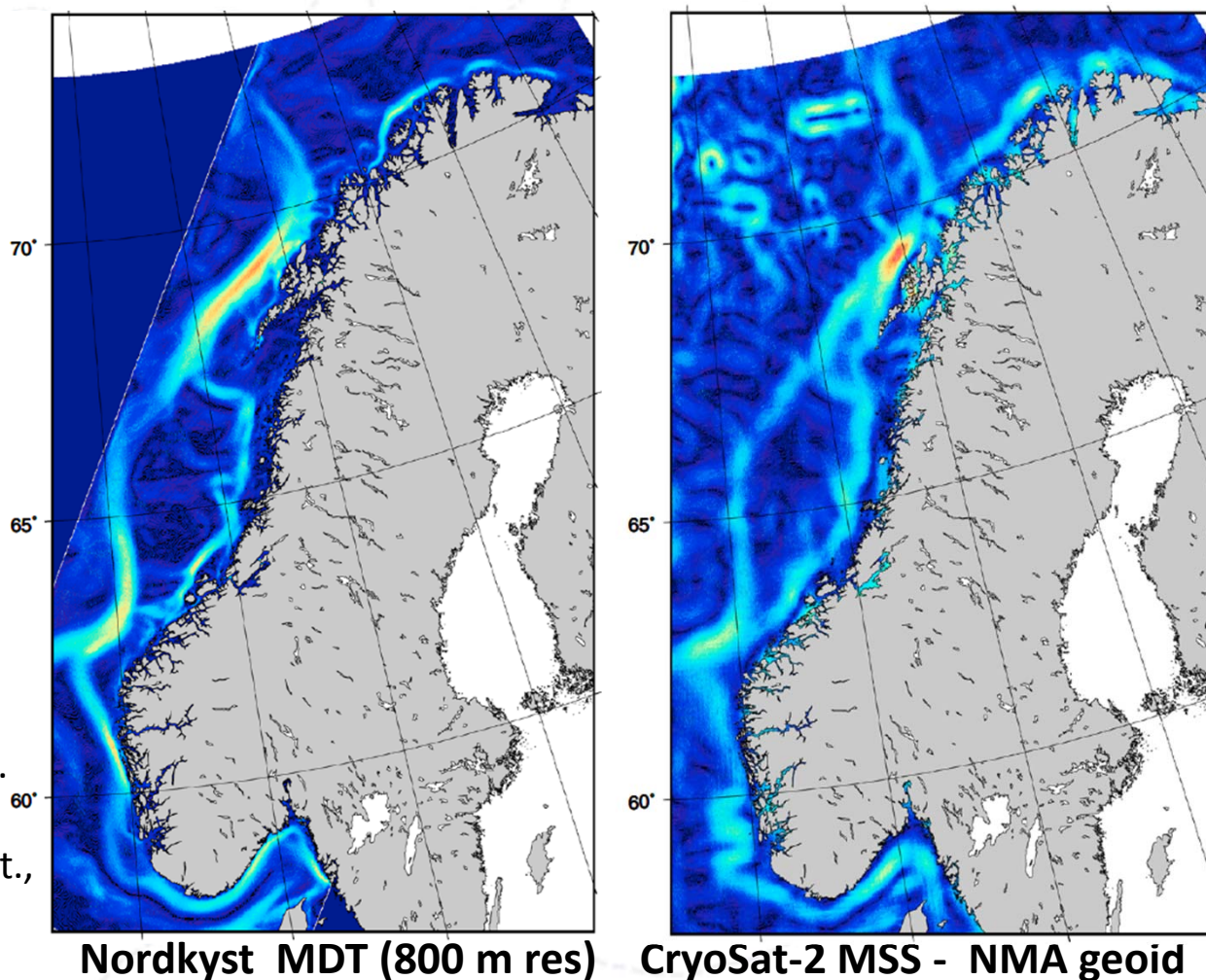


Norwegian Coastal Current observed by CryoSat-2 SARin altimetry: Martina Idzanovic, V. Ophaug, Ole B. Andersen



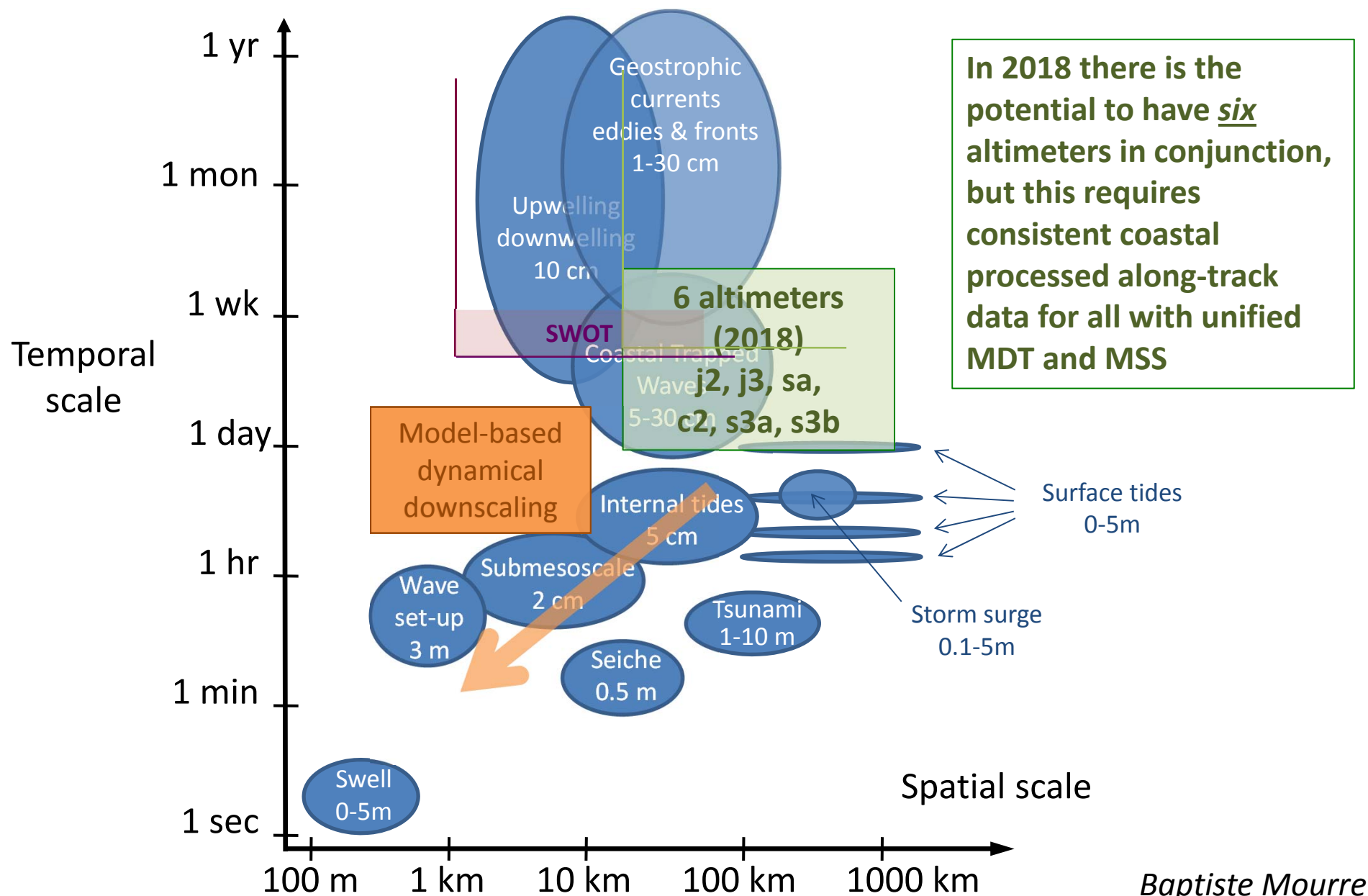
Idžanovic, M., V.
Ophaug, and O. B.
Andersen (2017),
Geophys. Res. Lett.,
44, 5609-5617

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



Idžanovic, M., V.
Ophaug, and O. B.
Andersen (2017),
Geophys. Res. Lett.,
44, 5609-5617

Coastal sea level variability: Dynamics and scales



Recurring messages from the Coastal Ocean (ARCOM) community:

2/3

Modeling can raise the visibility of coastal altimetry products

- Demonstrating value-added by comprehensive use of coastal altimetry (emphasize processes not platforms)
- Encouraging greater focus on sea level in model analysis
- Identifying coastal regimes (river plumes, fronts, internal waves, estuaries) potentially informed by altimetry
- NOTE: Submesoscale studies (SWOT etc.) are unifying the coastal and open ocean modeling communities through convergence in resolution and dynamics
- A joint community wiki or user forum could exchange experience and use case examples (within and between communities)

GODAE OceanView



coastal altimetry workshop series

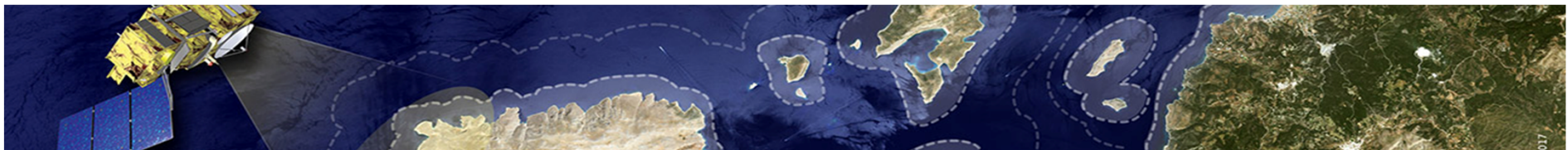
European Space Agency

Recurring messages from the Coastal Ocean (ARCOM) community:

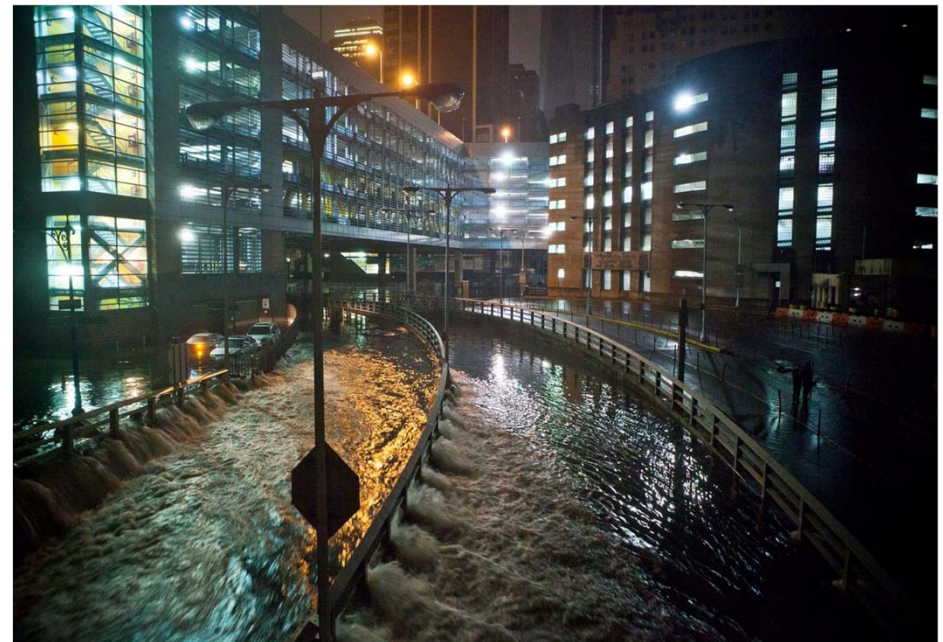
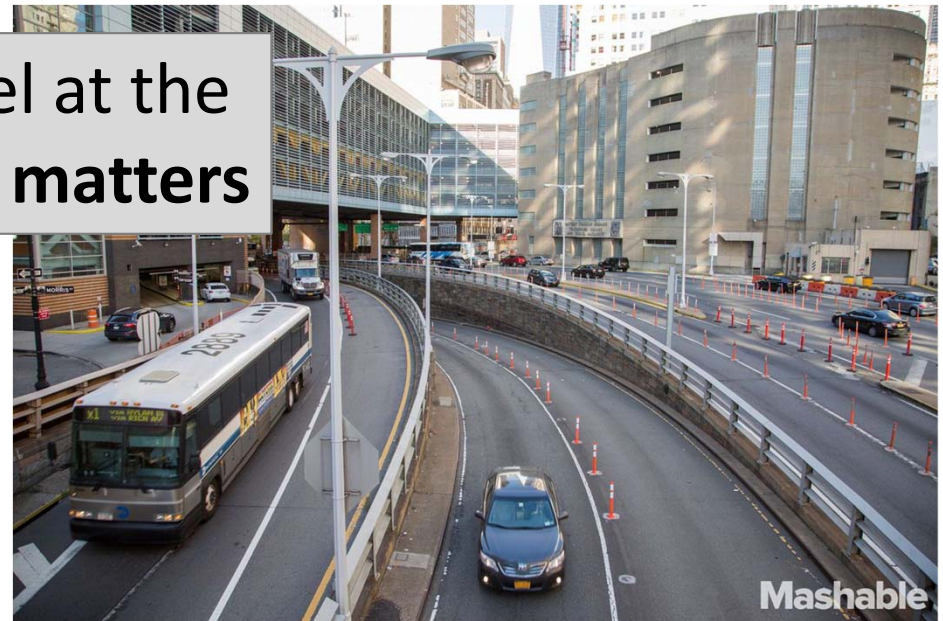
3/3

Coastal oceanographers and ocean modelers say:

- Altimeter ~~corrections~~ are radar range adjustments that remove coastal ocean physics
- IB and DAC are different dynamics and must be considered independently in the coastal ocean
- Using altimeter data in conjunction with tide gauges is not straightforward (issues of dynamics/datum)
- MDT and MSS are in general inadequate for total water level near the coast, on broad shelves, and in marginal seas
 - *Shouldn't MSS be recomputed from multi-mission coastal processed altimetry and re-mapped acknowledging coastal ocean dynamical scales and kinematic constraints?*



Sea level at the coast: **It matters**



<http://mashable.com/2013/10/24/hurricane-sandy-photos-retaken/#PV4GBUnzdaqV>