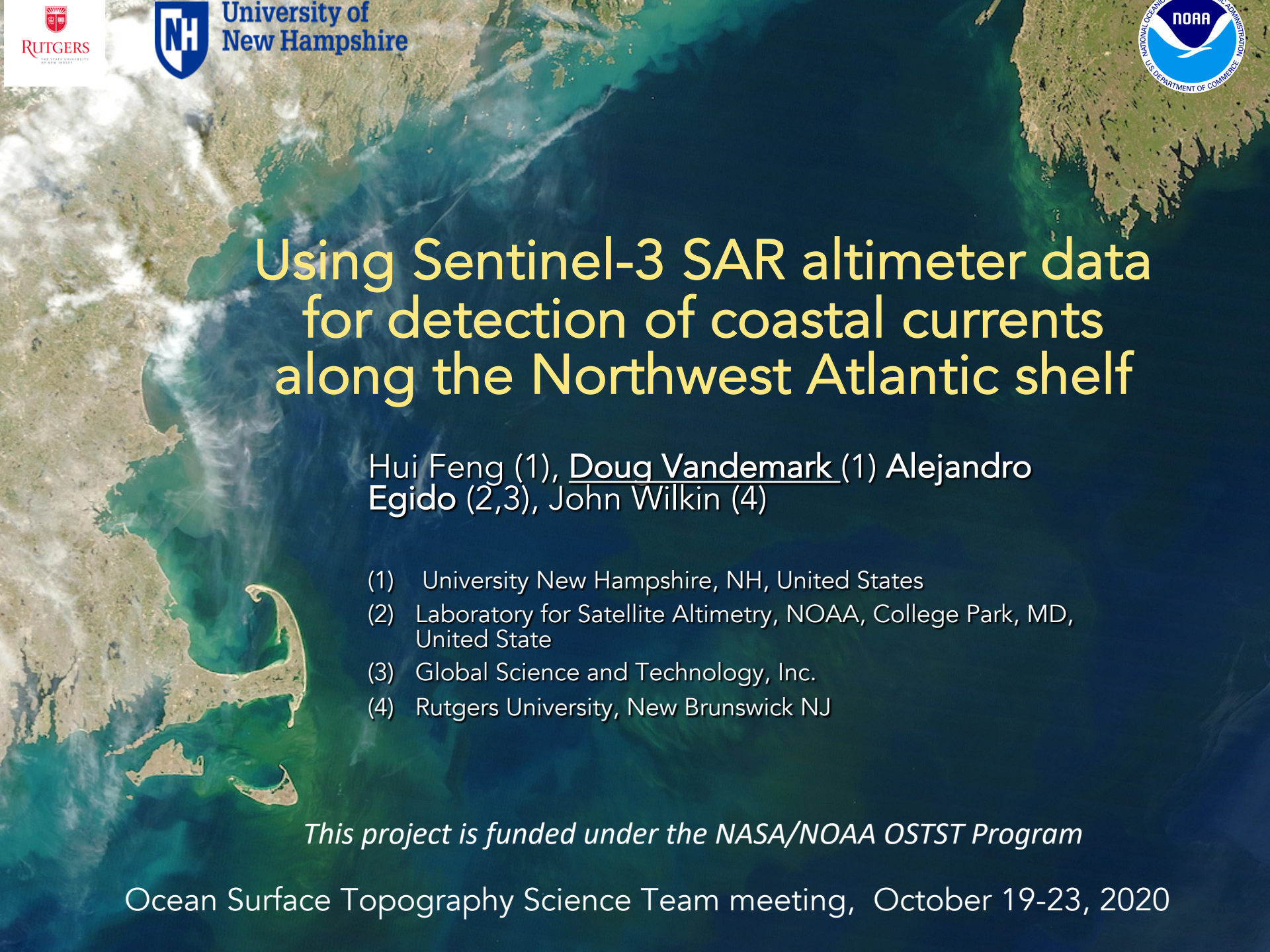

Using Sentinel-3 SAR altimeter data for detection of coastal currents along the Northwest Atlantic shelf

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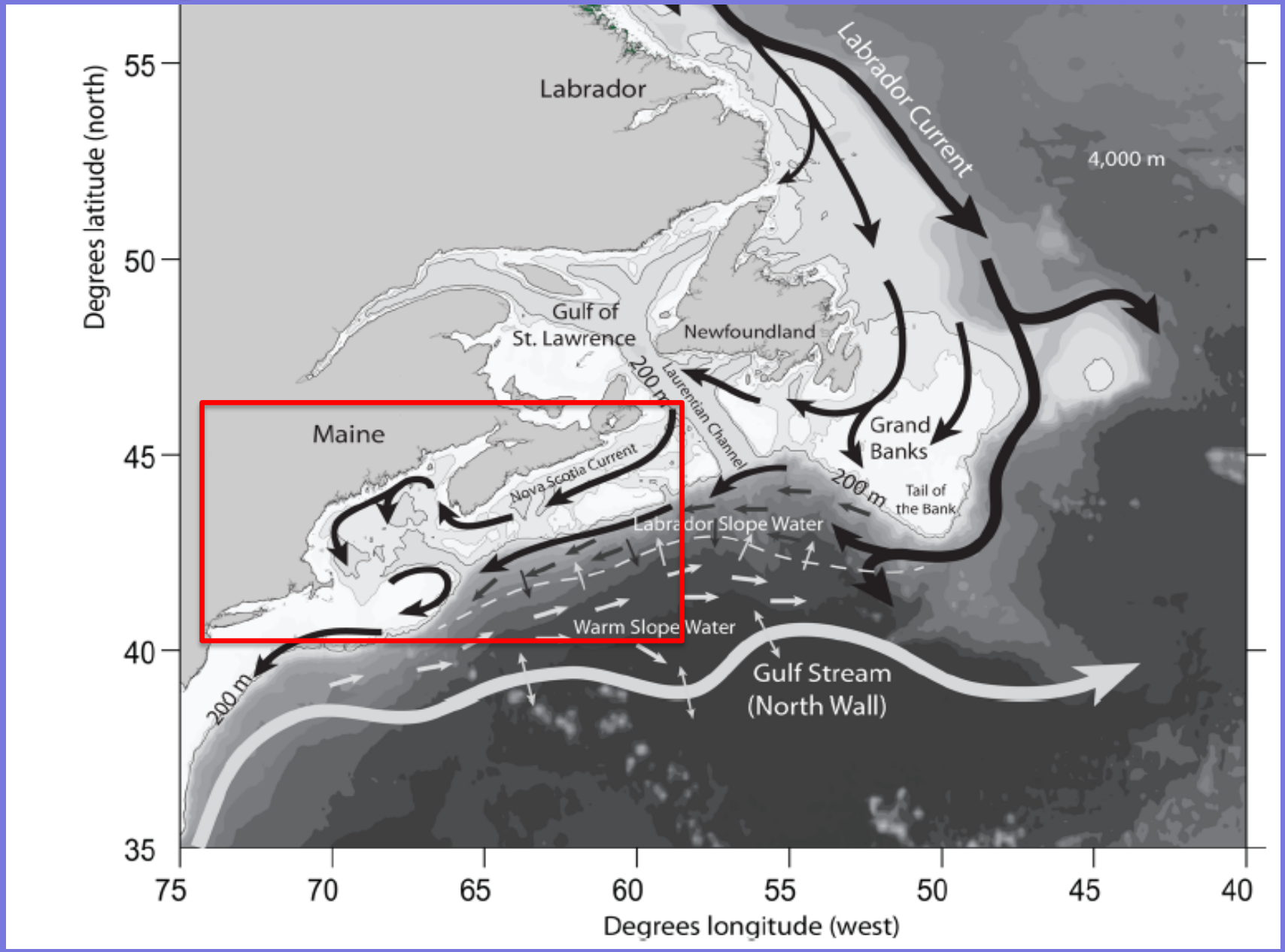
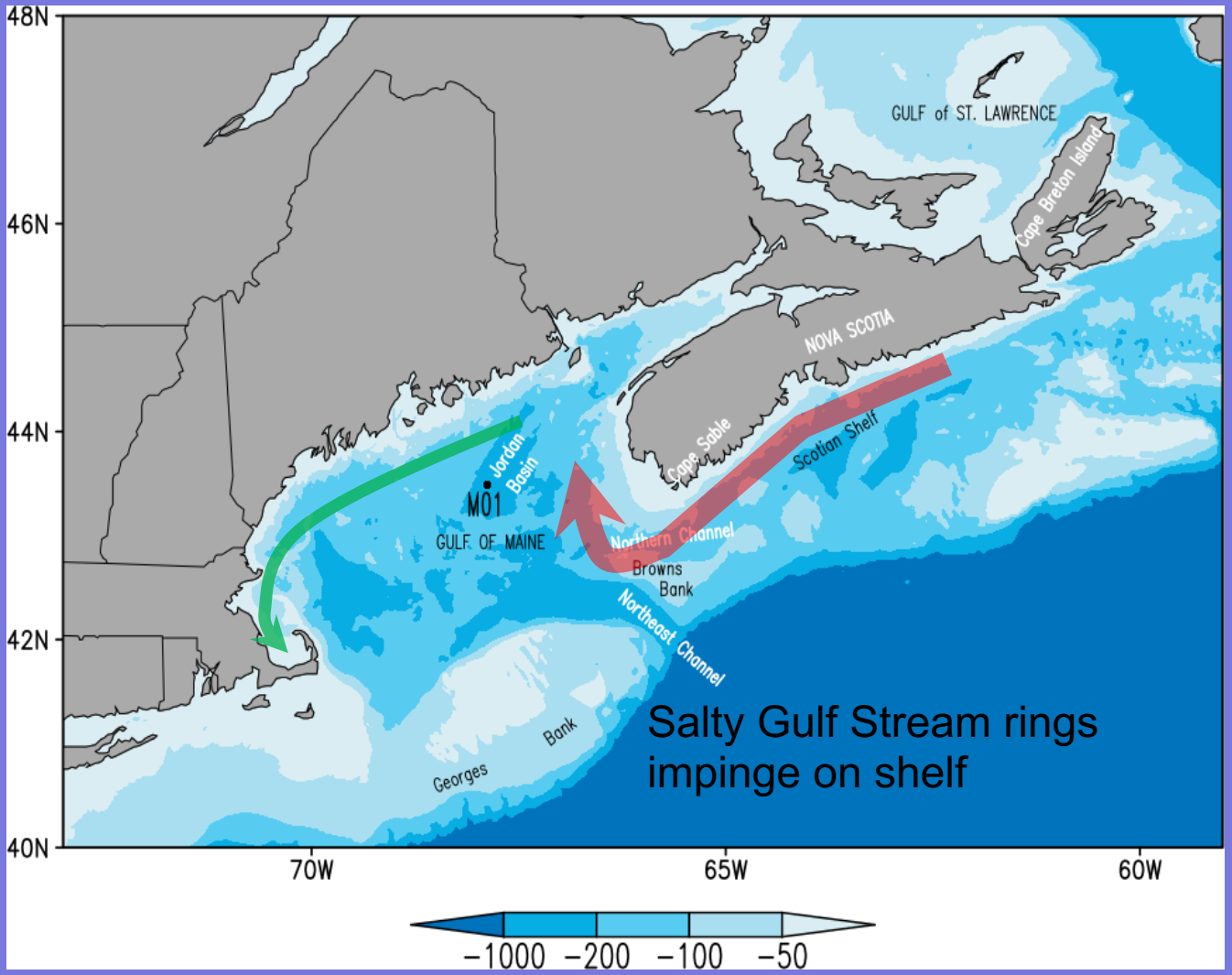
Region of Interest – NW Atlantic shelf



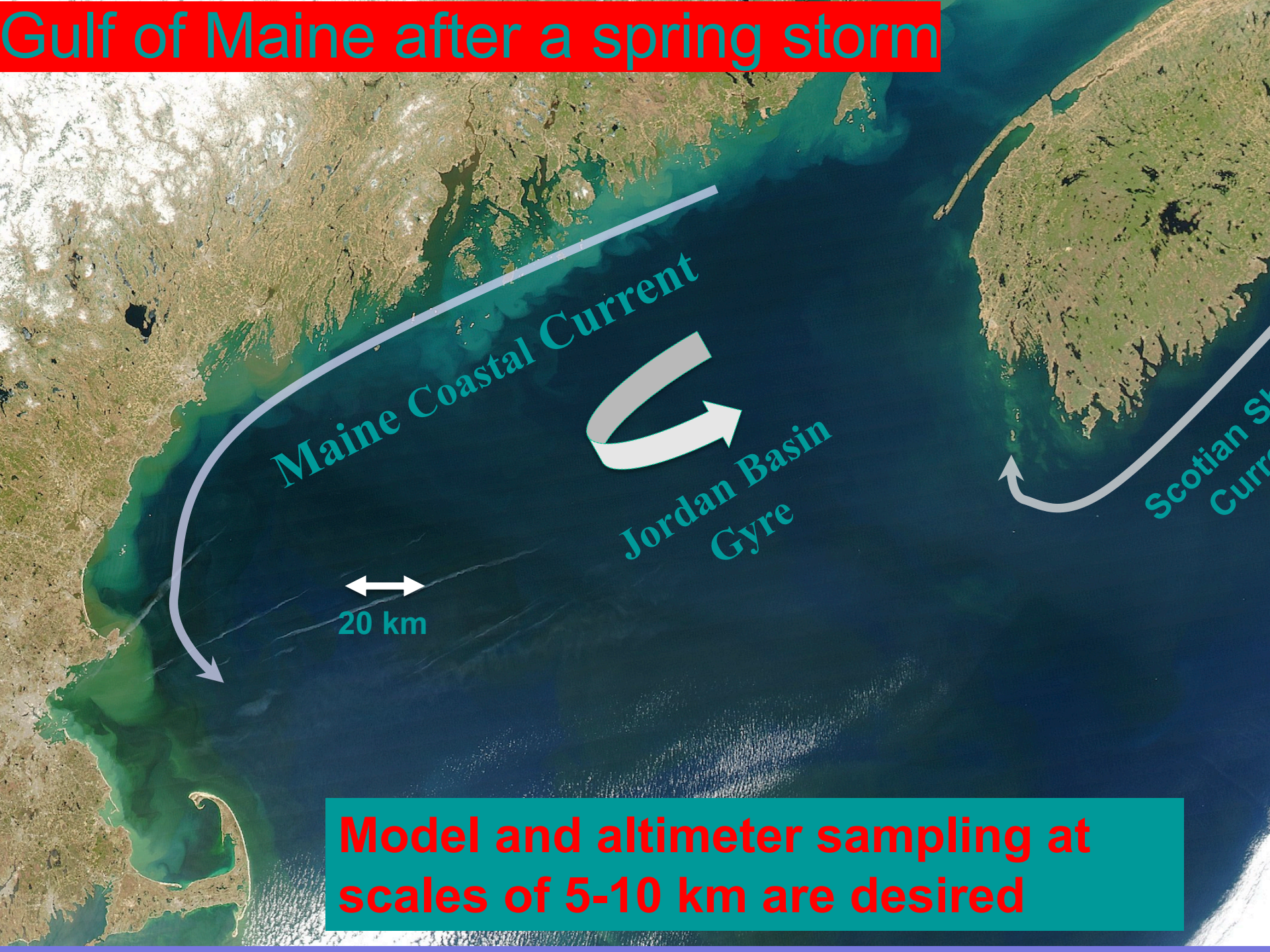
Motivations: improved monitoring and prediction



- High productivity and large U.S. fishery activity
- Recent nutrient and pelagic change including Right Whale losses
- Recent significant warming and Gulf Stream instability changes

Coastal salinity and SST changes are associated with all three, 1995-present

Gulf of Maine after a spring storm



Model and altimeter sampling at scales of 5-10 km are desired

Approach and Objectives

Approach

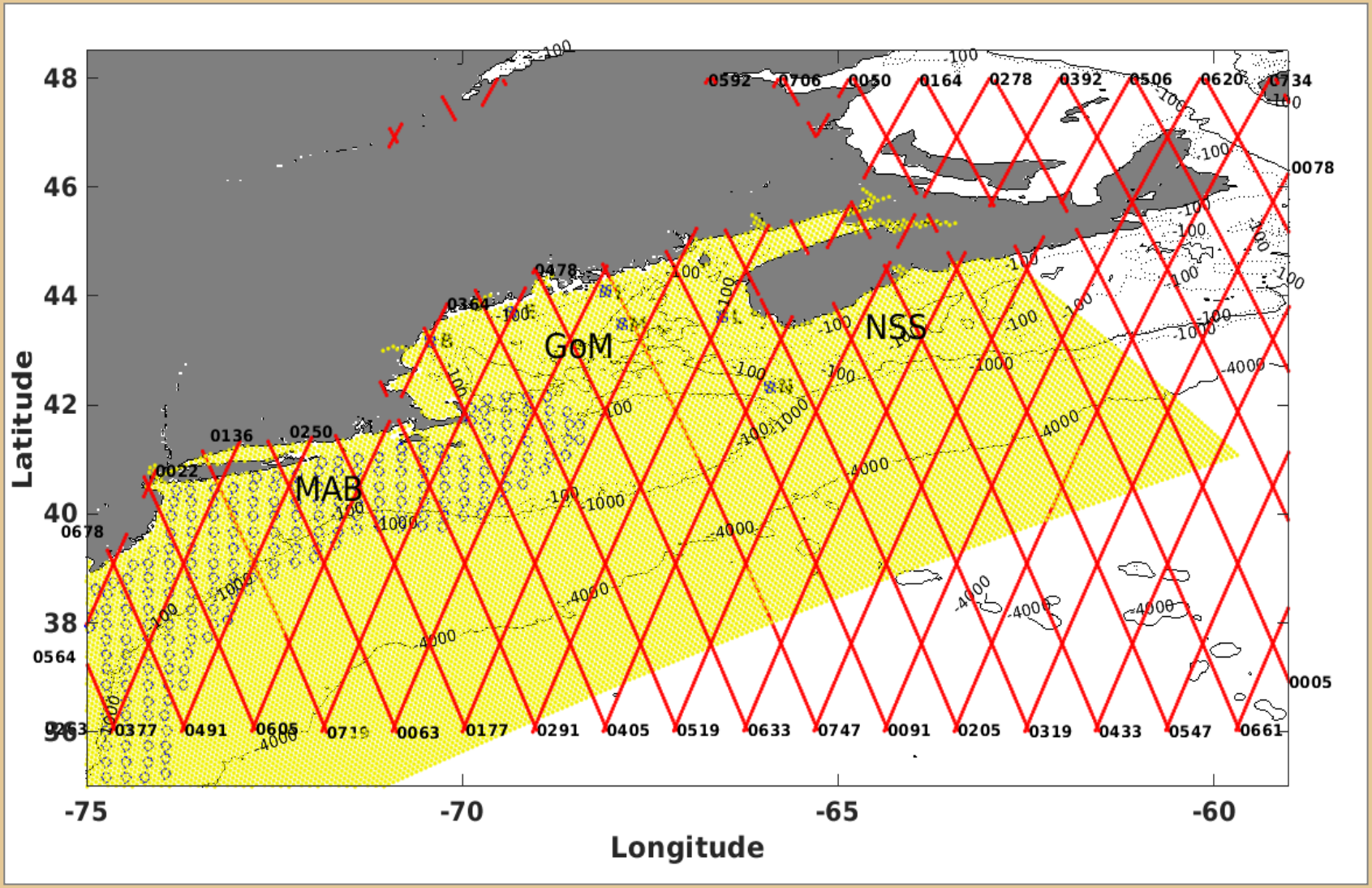
- Along-track Fully Focusing SAR (FFSAR) processing was applied to S3 at 80 Hz. FFSAR processed data has shown promise for improving upon even DDA unfocused SAR (UNSAR) data products on open ocean in terms of SSHA noise reduction (Egido and Smith, 2017)
- Is performance gain evident near coast and does it expand possible altimeter data applications?

Study objectives are to provide a cross-evaluation for S3 PLRM, UFSAR, and FF-SAR data to quantify:

- data recovery rates near to the coast
- noise in SSH data across the shelf (Depth < 500 m isobath)
- SSH-based geostrophic velocity estimates at scales of 10-40 km

S3 FFSAR processed data

Sentinel-3A SRAL DDA Altimeter data processed using FFSAR approach (yellow area is regional ROMS model domain)



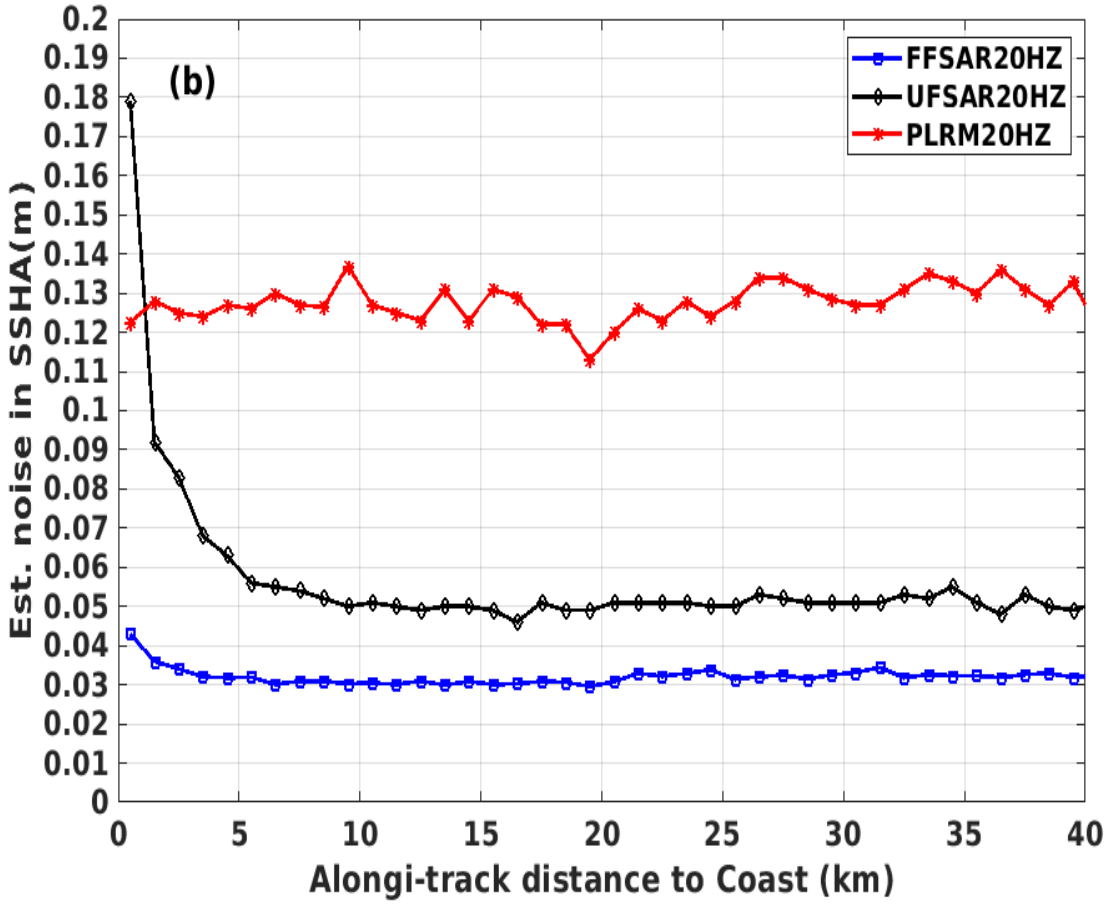
Details of Sentinel-3A data

Summary of Sentinel-3 SRAL altimeter datasets used in this study
(S3A cycles 26-52 for 2018-2019)

FFSAR (NOAA) (-80Hz; ~70m) FFSAR: Fully-Focused SAR	SRAL L2 (EUMESAT) (1Hz, 7km; 20Hz, 300m) Non-Focused SAR (UFSAR) Pseudo LRM (PLRM)	RADS (1Hz, 7km)
Range, SSH[a], SSHA[b], SWH, Sigma0, Geoid, Orbit_altitude, GeosCorrs[c], MSS[d]		
Goodness of fit	Quality flags of parameterts rms in Range, SSH,SWH,Sigma0	

- Range: instrument correction applied.
- Orbit_altitude; in GDR-F standard
- SSH[a] (Sea surface Height) =Orbit_altitude –Range
- SSHA[b] =Sea surface Height Anomaly =SSH-(Range +GeosCorrs)-MSS
- GeosCorrs[c] =
  (dry_tropo_ecmwf+wet_tropo_rad+iono_alt_smooth+inv_bar_mog2d+
  tide_solid+tide_ocean_fes14 +tide_load_fes14 + ssb_cls)
- MSS[d] =(Mean Sea Surface)=MSS_DTU18;
- rms[e] (of parameters is in 1Hz, estimated with valid data at 20Hz data rate)

20 Hz Alongtrack noise via differencing



- SSHA noise levels, estimated as the absolute value difference between consecutive 20Hz SSHA measurements (Cipollini et al., 2017).
- Median statistic estimated in 1-km wide bins.
- FFSAR shows improved performance - having the lowest noise, nearly 1cm lower than un-focused SAR(UFSAR).

Note [FFSAR QC flag = goodness of fit < 0.05], and the analysis from the S3A data in 2018-2019

Along-shore Geostrophic Current Estimation

Estimate cross-track geostrophic current Vg (*orientation typically for along-shore currents*)

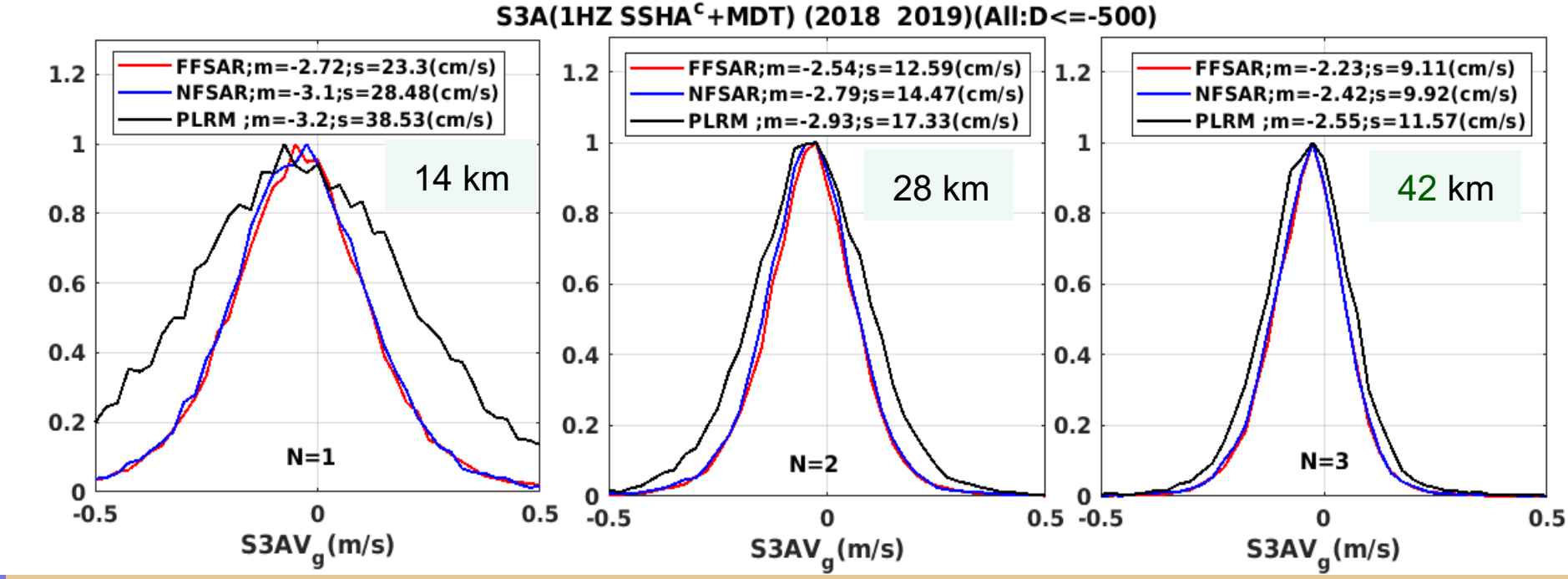
$$Vg = \frac{g}{f}\frac{\partial(ADT)}{\partial(s)} = \begin{cases} \frac{g}{f}\frac{ADT(j+N) - ADT(j-N)}{\Delta(s)}, N > 0 \\ \frac{g}{f}\frac{ADT(j) - ADT(j-1)}{\Delta(s)}, N = 0 \end{cases}$$

where ADT=SSH-Geoid is the instant Absolute Dynamic Topography, FFSAR, UFSAR, PLRM (1hz) with all geophysical corrections; f is the Coriolis parameter; s is along-track position, n is the span of the data points along a track.

N =1, 2, 3 represent differing Vg length scales (2*N); approximately 14 km, 28km and 42km, respectively, for 1Hz data.

Along-shore Geostrophic Current: Bulk statistics

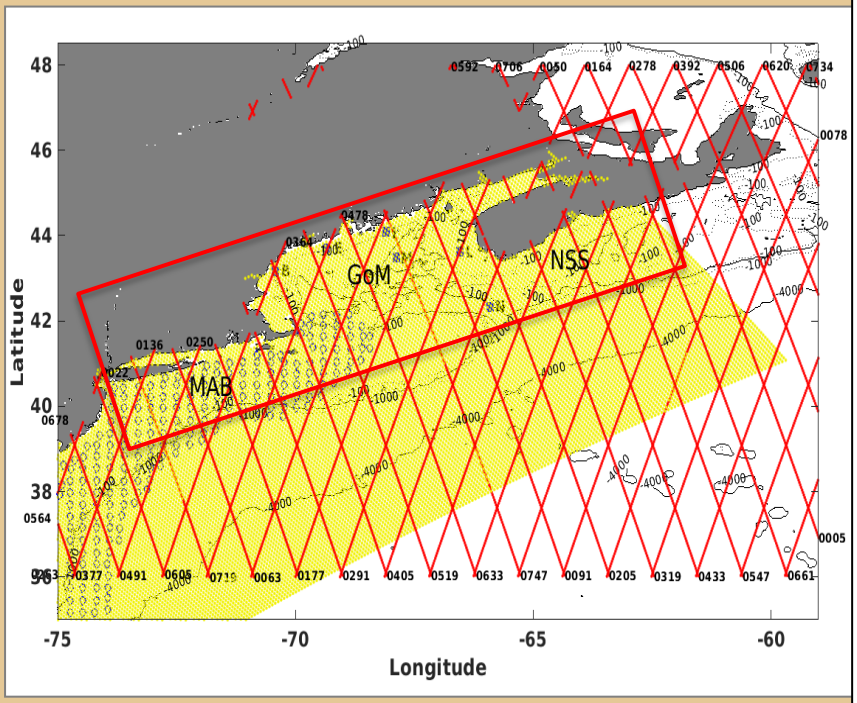
Note that mean (m) and standard deviation (s) in cm/s are given in inset boxes.
(Analysis is based on the data with water depth< -500m from 2018 to 2019).

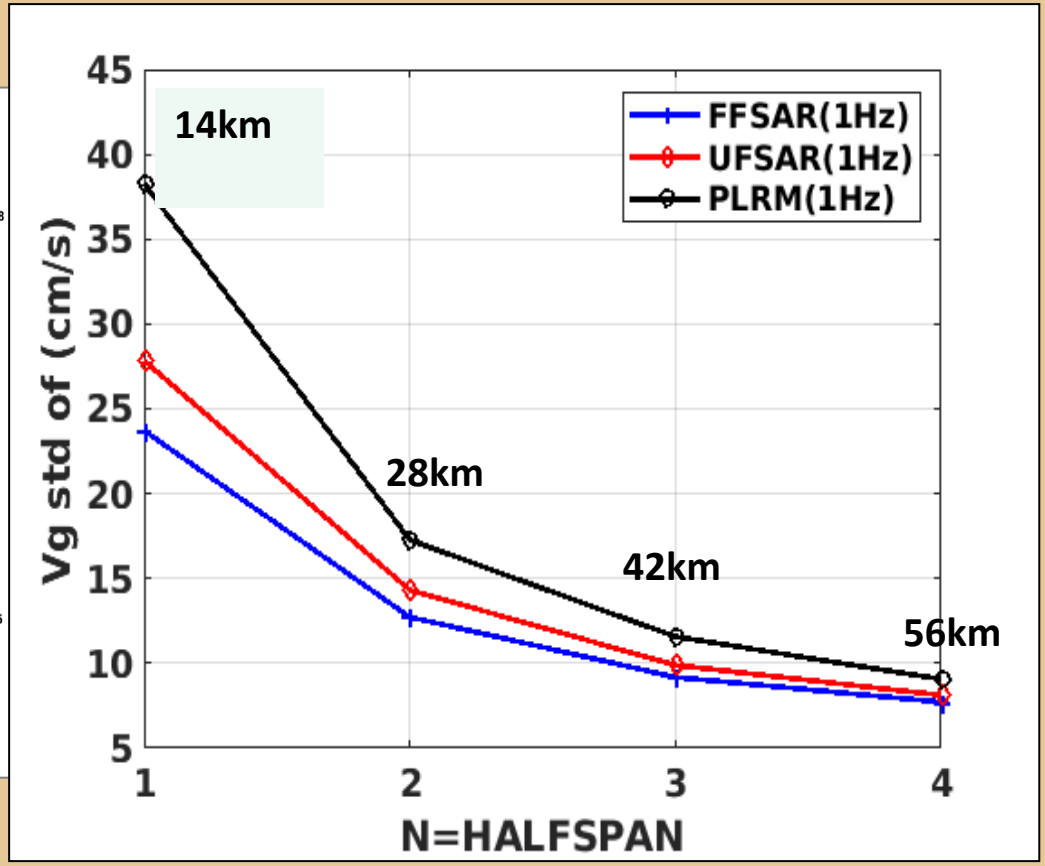


- PLRM much noisier at shortest scale, all are similar at estimate scale of 42 km
- Similar 'bulk' performance for FFSAR and UFSAR S3 at 3 scales
- Consistent decrease in mean alongshore current and rms noise for PLRM -> UFSAR - > FFSAR
- FFSAR rms is ~20% lower than UFSAR

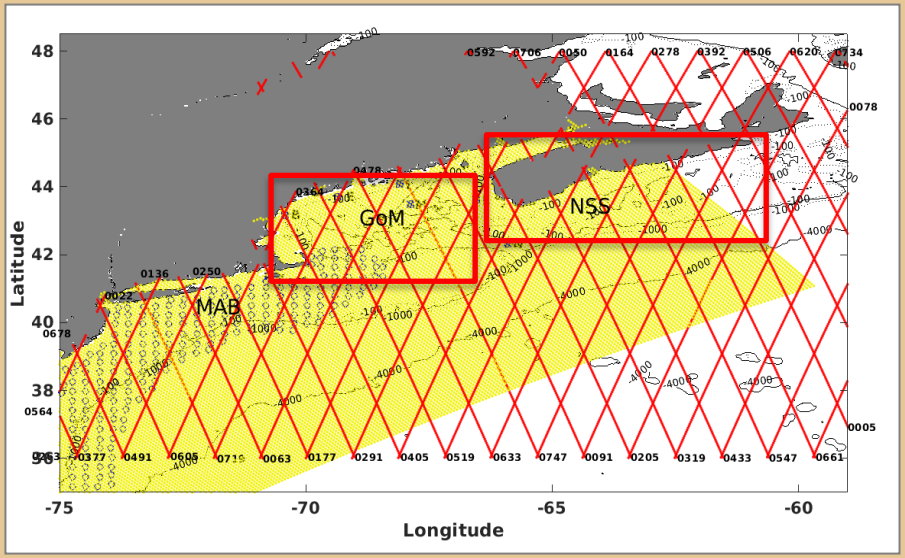
Noise in geostrophic current Vg vs. length scales

Analysis is based on data over the whole shelf region
(Analysis is based on the data with water depth< -500m from 2018 to 2019)



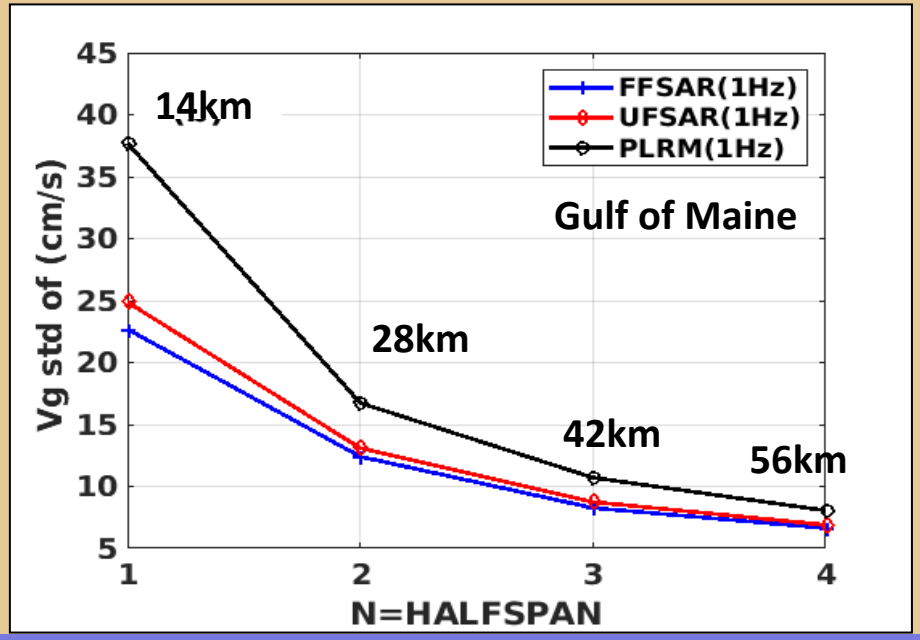


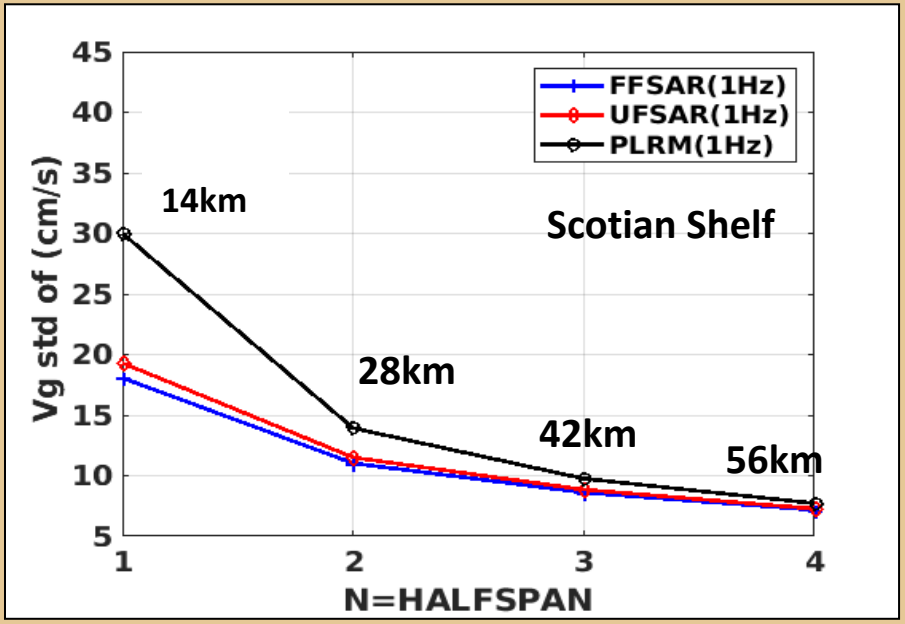
Noise in geostrophic current Vg vs. length scales



Again see SAR altimeters outperform LRM if the length scale for velocity observations is 14 km

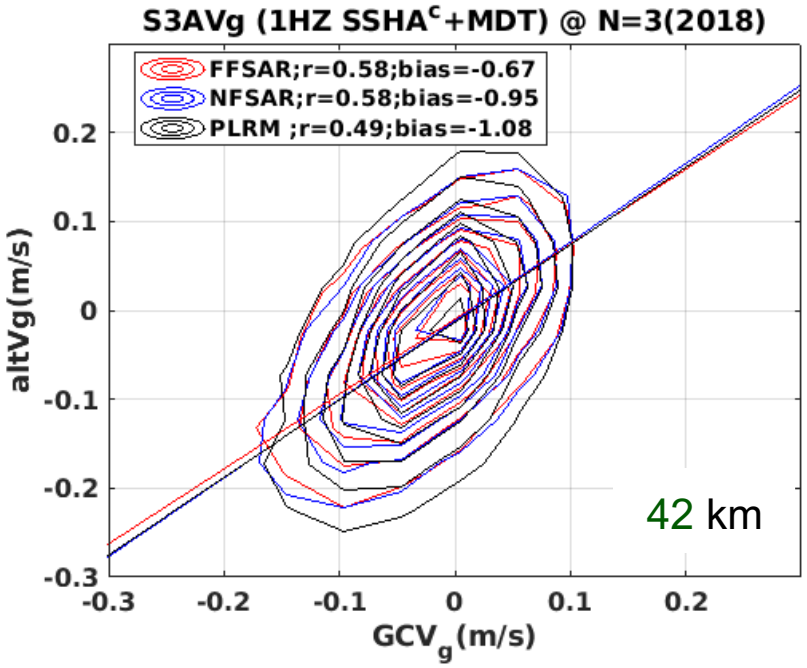
Slightly more improvement inside the Gulf of Maine compared to Scotian Shelf



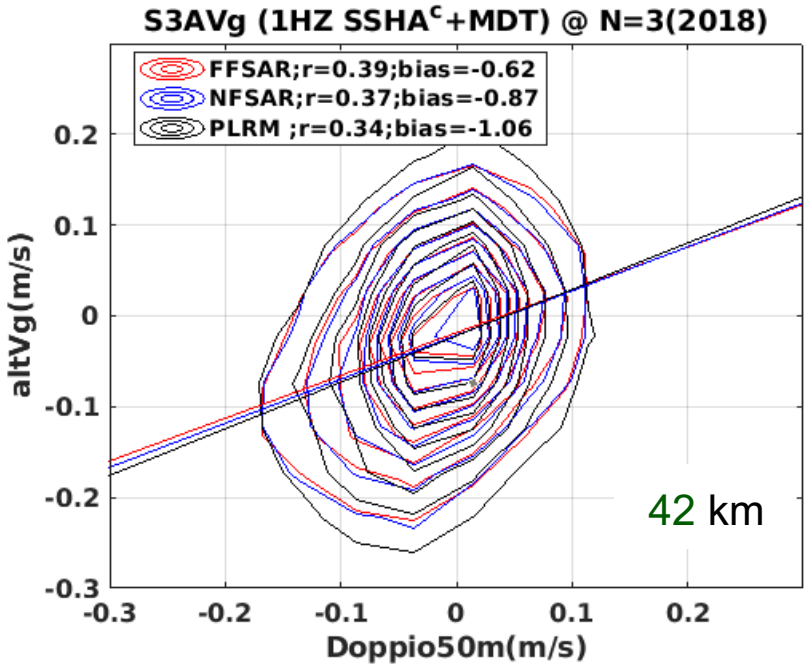


Current estimations compared to references

Three products compared to 0.25 deg. GlobCurrent (including Ekman)



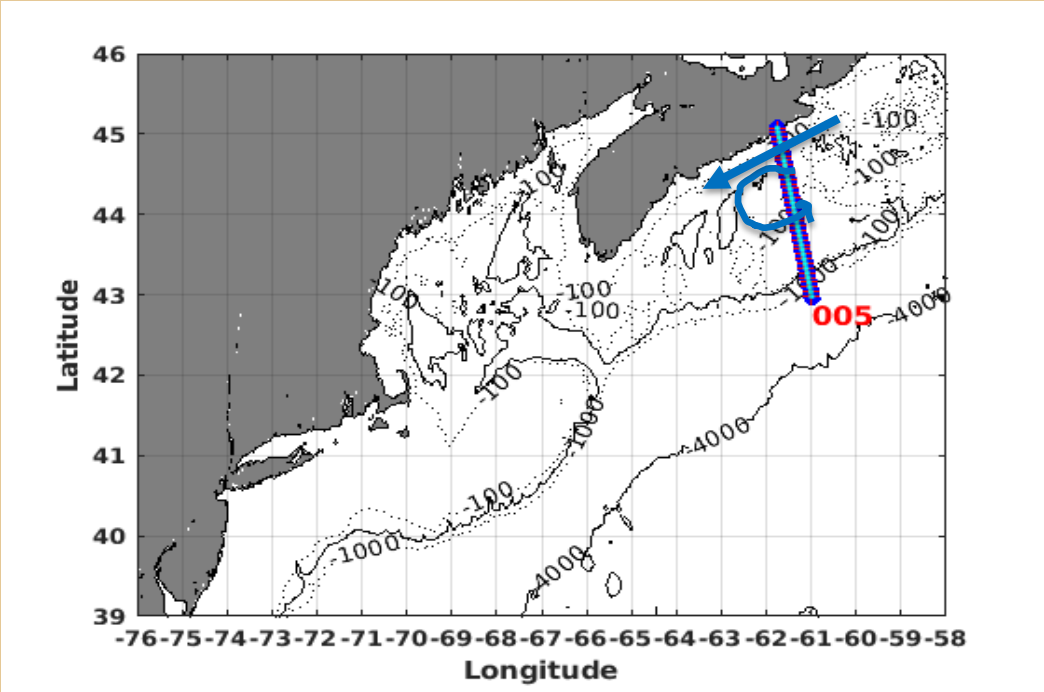
Three products compared to 7 km ROMS model (total current)



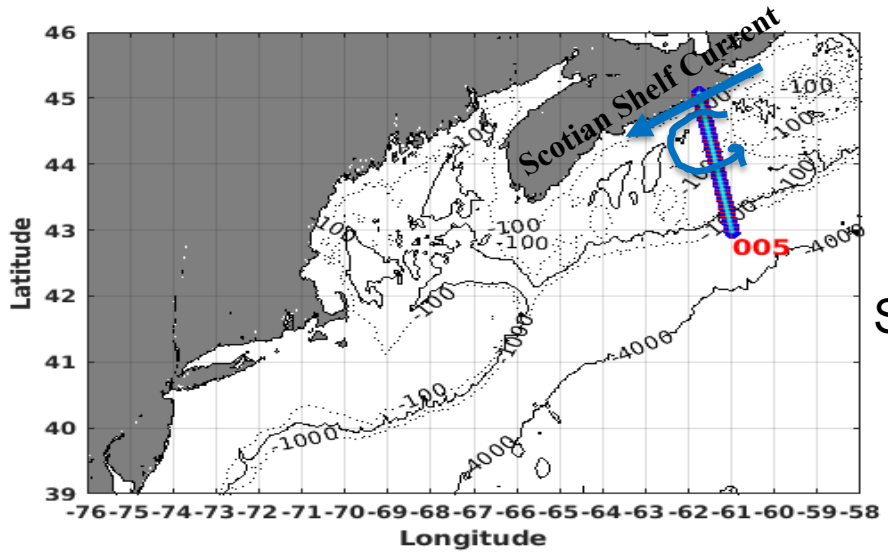
- Similar ‘bulk’ performance for FFSAR and UFSAR S-3 at this scale
- Consistent decrease in bias PLRM -> UFSAR - > FFSAR
- Weak correlations not unexpected given winds, mixed layers, scales, etc.

Example geostrophic current V_g on single tracks

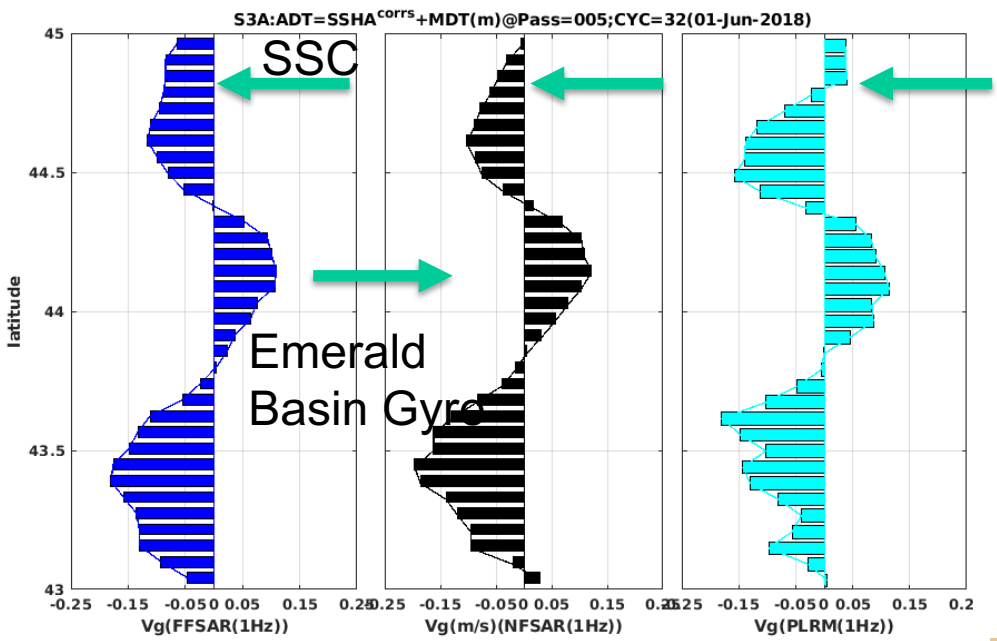
- Objectively compare amongst derived along-trock geostrophic velocities at short scale (14 km) between for coastal currents and shelf-sea gyres
- Also include views from GlobCurrent and regional ROMS model output as references



Along-track Geostrophic Currents : SSC

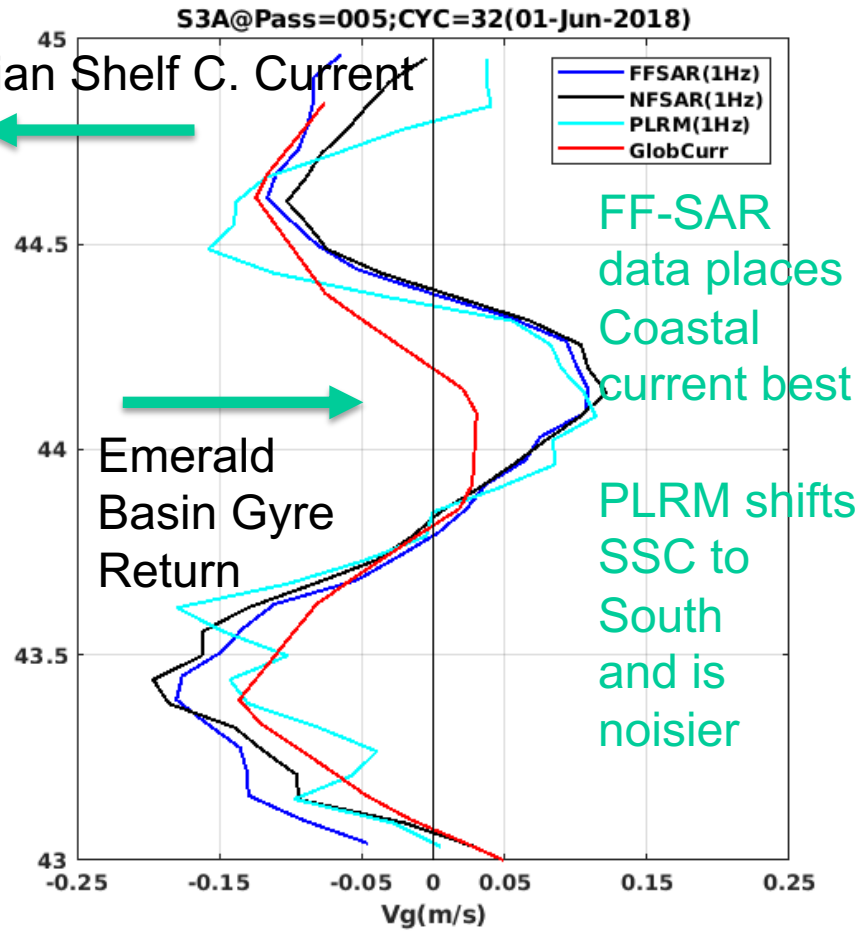


Example single pass V_{geo} on Scotian Shelf



Scotian Shelf C. Current

Emerald Basin Gyre Return

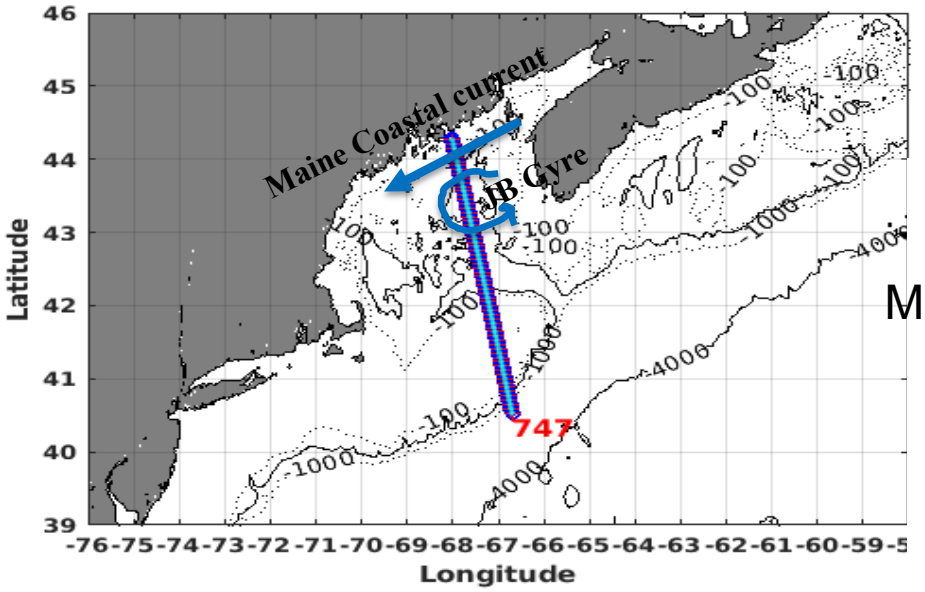


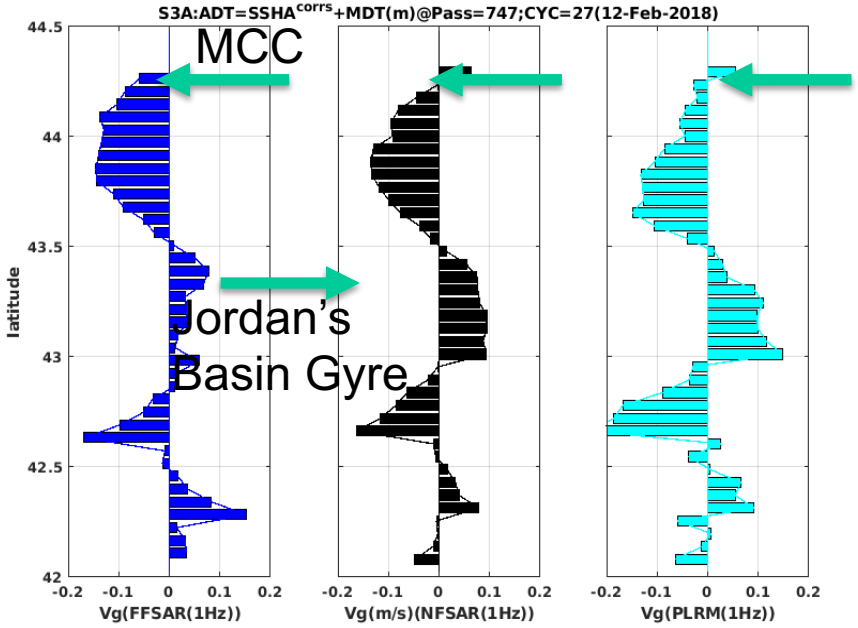
FF-SAR data places Coastal current best

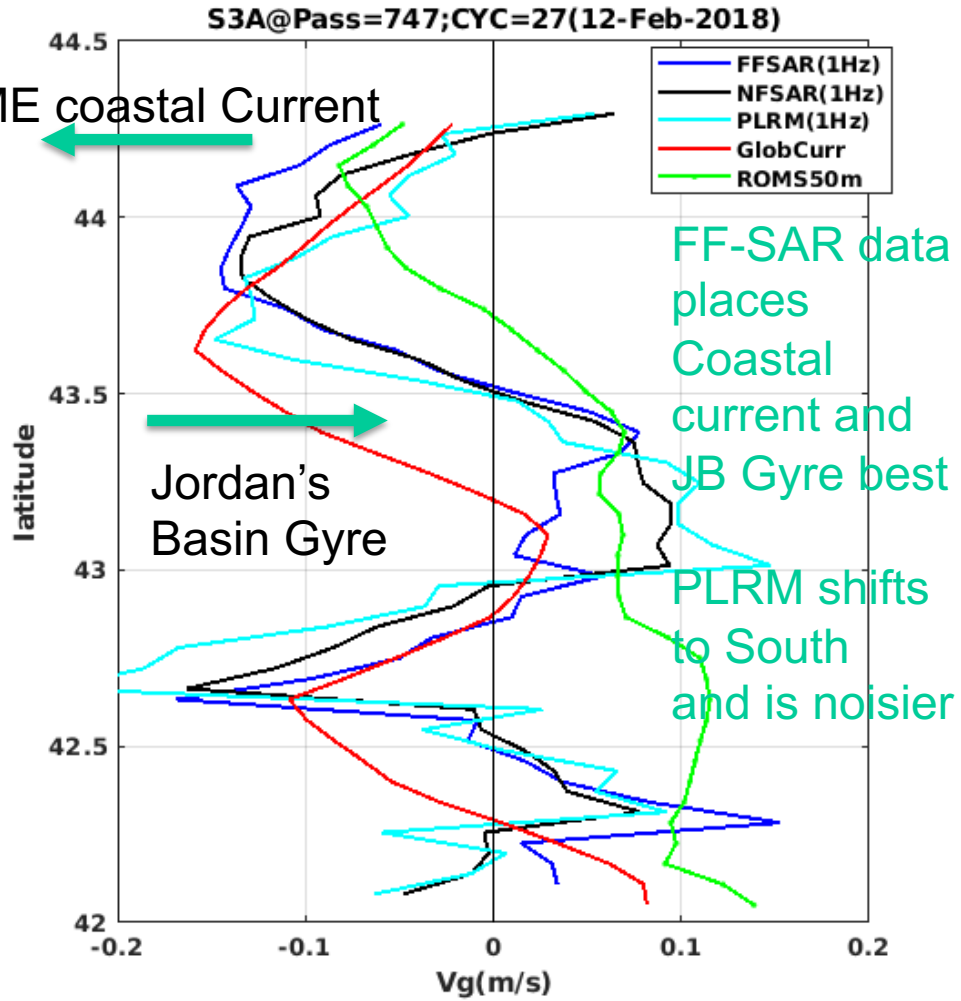
PLRM shifts SSC to South and is noisier

Along-track Geostrophic Currents : GoM

Example single pass V_{geo} inside Gulf of Maine



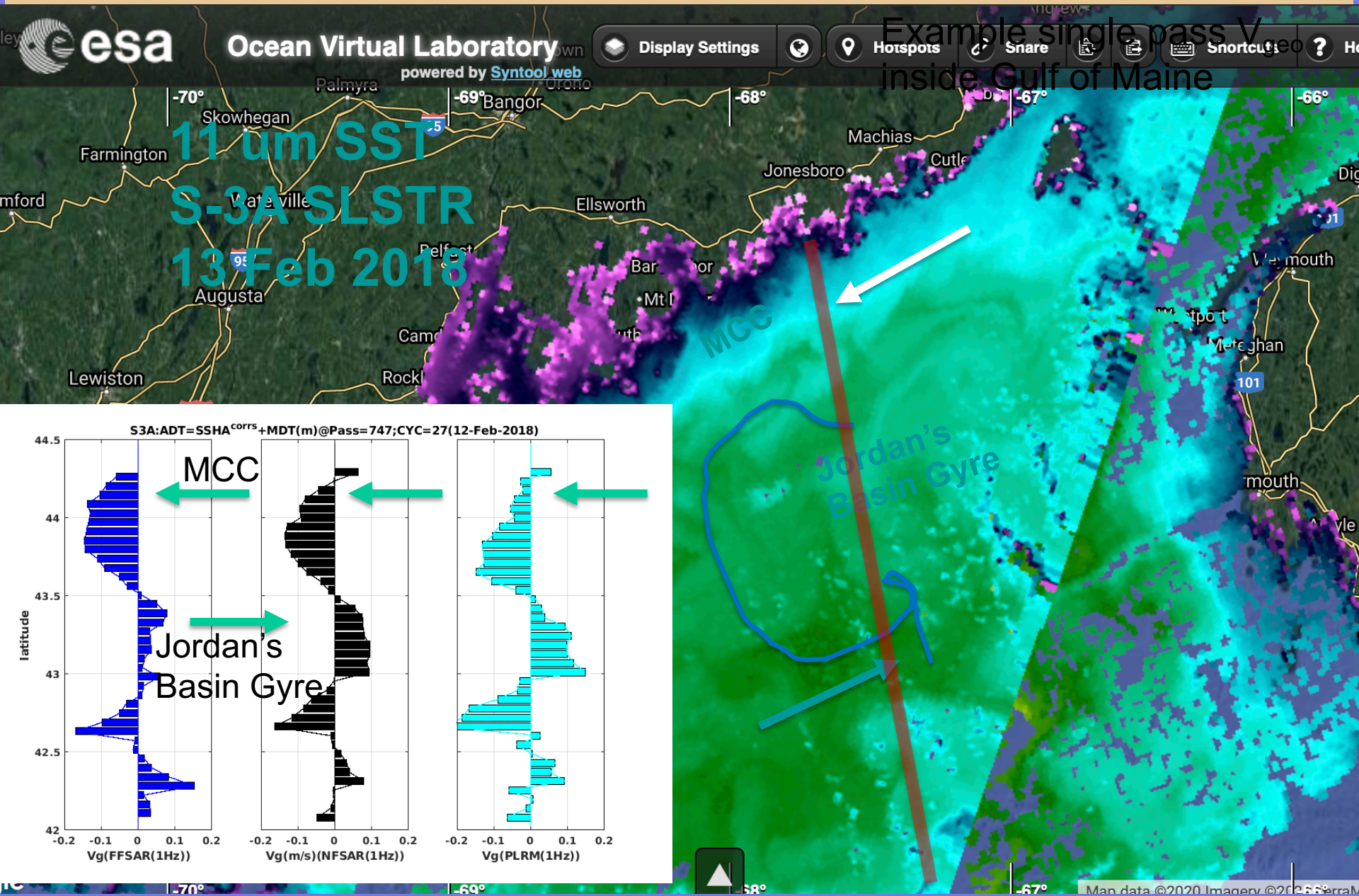




FF-SAR data places Coastal current and JB Gyre best

PLRM shifts to South and is noisier

Along-track Geo. Currents : atop S3-SLSTR



Conclusions

The assessment of S3A FFSAR, UFSAR , and PLRM SSH S3A along the Northwest Atlantic shelf, shows the following:

- SSHA noise in SAR mode measurements is significantly reduced, compared to in PLRM,
- SSHA noise reduction in FFSAR is noticeable, compared to UFSAR, particularly close to the coastline without degradation (inside of 5 km),
- FFSAR derived geostrophic current estimates are less biased and exhibit the lowest noise, quite equivalent to UFSAR performance in the bulk sense, and
- fine-scale (~20 km) analysis across nearshore currents and small-scale gyres reveals SAR data provide sharper and more realistic altimetry based circulation observations in this coast/shelf region.