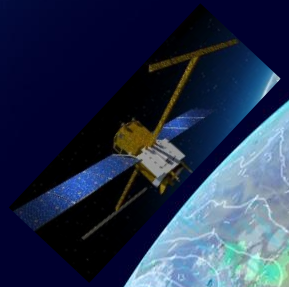
Met Office

S3NG constellation:

Assessing the impact of S3NG scenarios in two global ocean forecasting systems



Robert King[1], Mounir Benkiran[2], Lucile Gaultier[3],

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1. Met Office
2. MOi
3. OceanDataLab
4. DATLAS

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Preparing for future altimeters

Part of the A-TSCV project

- ESA requested evaluation of 2 proposals for S3NG
- Building on infrastructure of A-TSCV project

WiSA vs multiple Sentinel-3 altimeters in a Global System

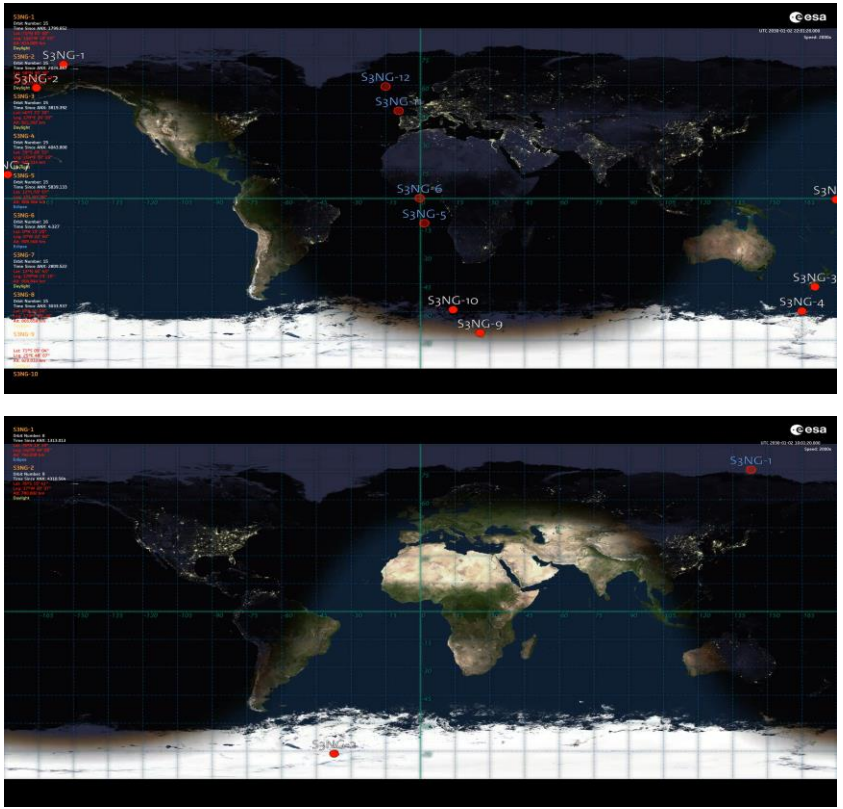
- 2 Wide-Swath Altimeters (2xWiSA) flying along-side Sentinel-6
- 12 Sentinal-3-like SAR altimeters flying along-side Sentinel-6.
- Compared against current network of observations.

Although S3NG decision made

- useful to illustrate potential impacts of each scenario
- and that OSSE impacts can be highly system dependent

Challenges

- Making best use of both in situ and altimeter observations
- Uncertain magnitude of correlated errors – problematic for DA



Example coverage from 12 x S3 constellation (top) and 2 x WiSA (bottom) over 1 day.

OSSE design – 12xS3 vs 2xWiSA

OSSE design

- Similar set-up as described in Matt's overview.
- 1/12º Nature Runs (NR), previously assessed by Gasparin et al. (2018) and Benkiran et al. (2021)
- Observations simulated from NR with realistic errors, inc. SST, in situ T/S, SLA
- WiSA obs simulated using SWOTsimulator presented by L. Gaultier. Include KaRIn and residual WetTropo errors. **Not yet with correlated phase/roll errors**.
- OSSE experiments: 1/12º NEMO model, NEMOVAR (Met Office) and SAM2 (Mercator) DA systems, different initial conditions and fluxes.

Expt	Fluxes	Std Obs	S3A, S3B,	S6	12 x S3	2 x WiSA
Nature Run	ECMWF-OS (MetOffice) ERA-Interim (MOi)					
Control	ERA-5	✓	✓	✓		
NADIR	ERA-5	✓		✓	✓	
WISA	ERA-5	✓		✓		✓

System differences

- Assimilation window (1day vs 7days)
- Assimilation scheme (obs/bkg errors, lengthscales, balances, etc.)
- Nature Runs (NEMOv3.1 vs NEMOv3.6, etc.)
- Surface forcing of NR (ECMWF operational vs ERA-Interim)

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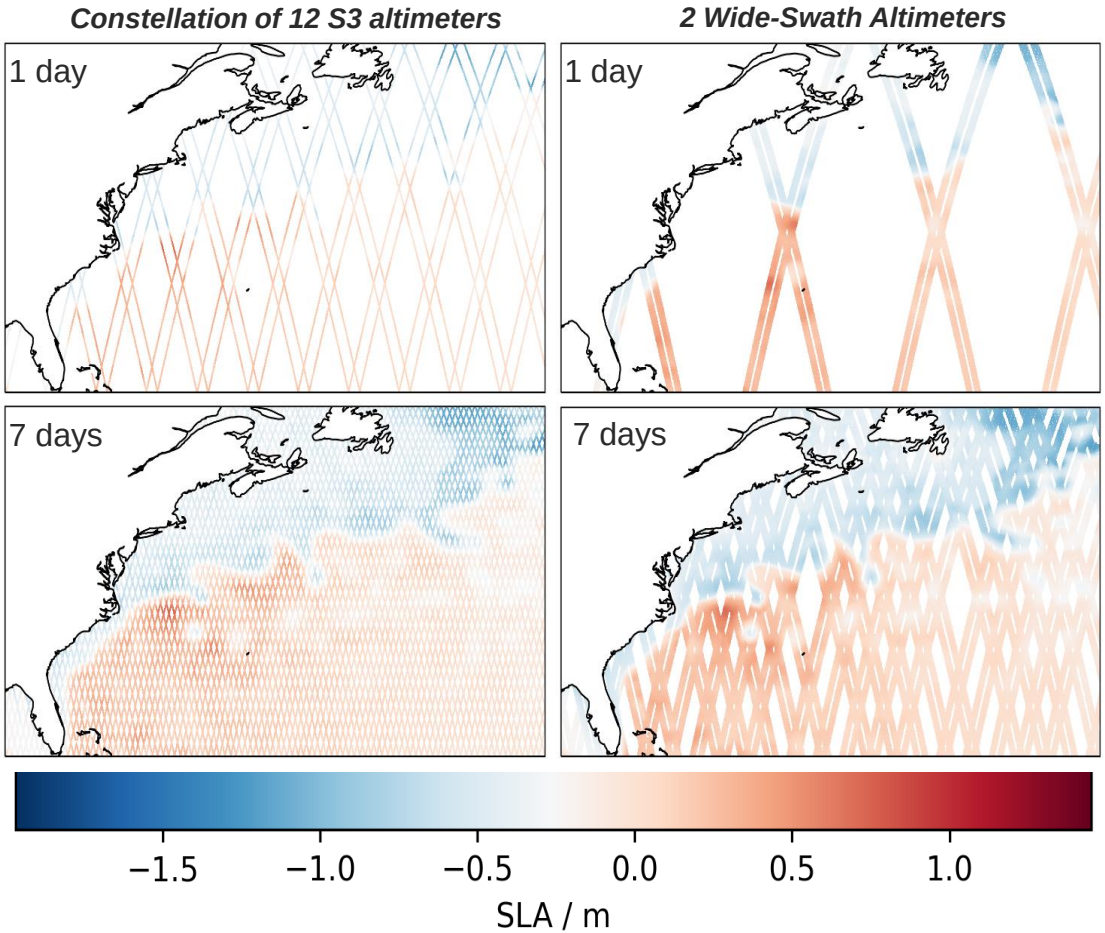
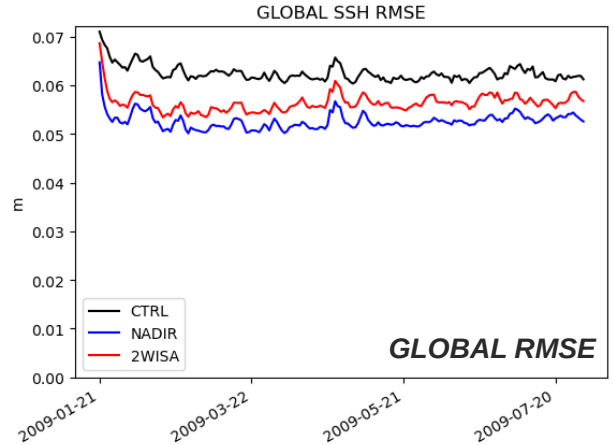
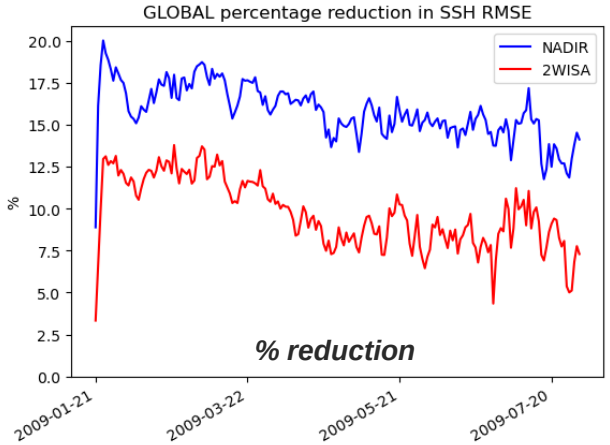
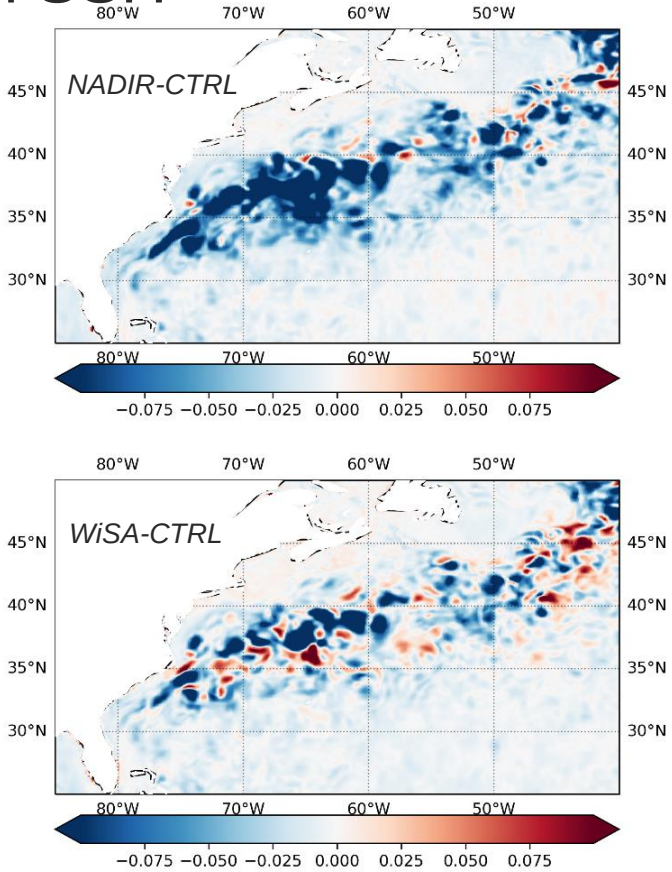


Met Office OSSEs: Impact on SSH

- Both NADIR and WiSA experiments reduce SSH RMSE compared to Control
  - Global RMSE reduction of **10% (WiSA) and 16% (NADIR)**
  - Greatest improvement in WBCs approx. 25% (WiSA) and 50% (NADIR)
- NADIR experiment shows improvement or neutral impact almost everywhere.
- Although positive overall, WiSA experiment highlights some regions of negative impacts.
- **Similar global impact on RMSE reduction (~16%) in NADIR experiment and A-TSCV assimilation experiment in Met Office system**







SSH RMSE difference *(July 2009 compared to control, blue shows reduction in RMSE)*

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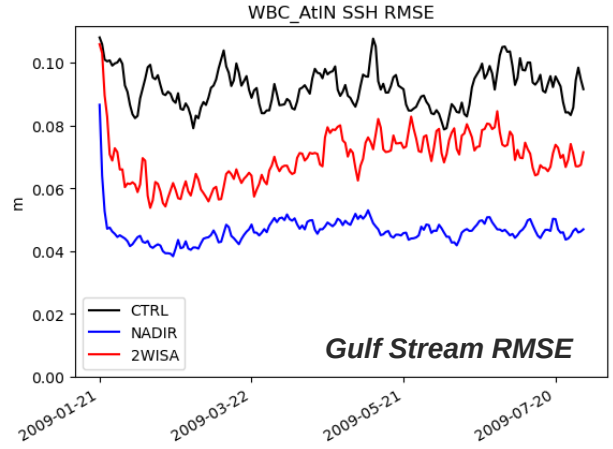

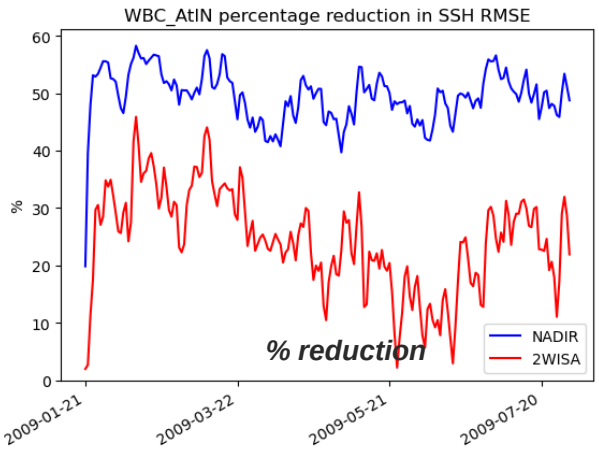

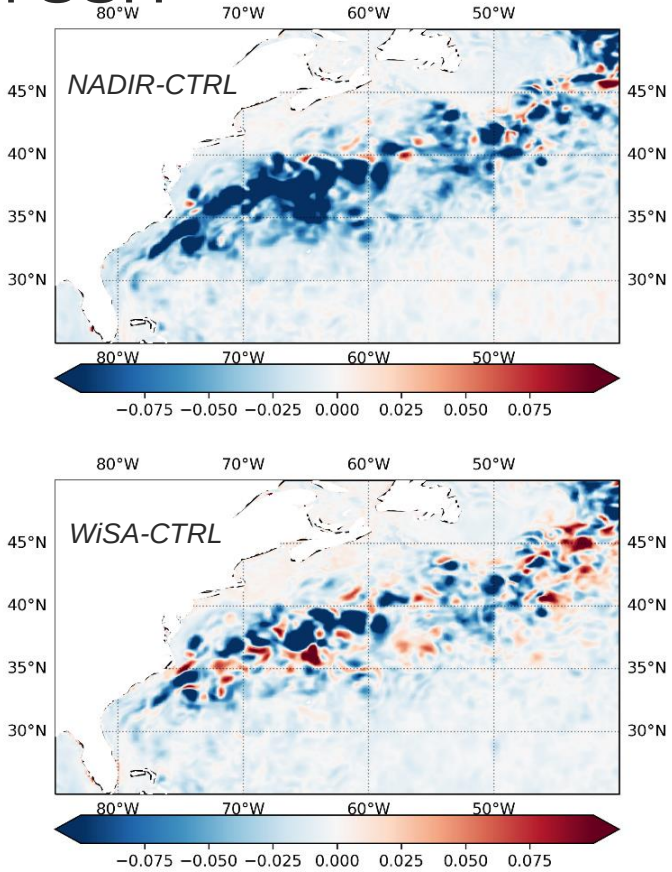

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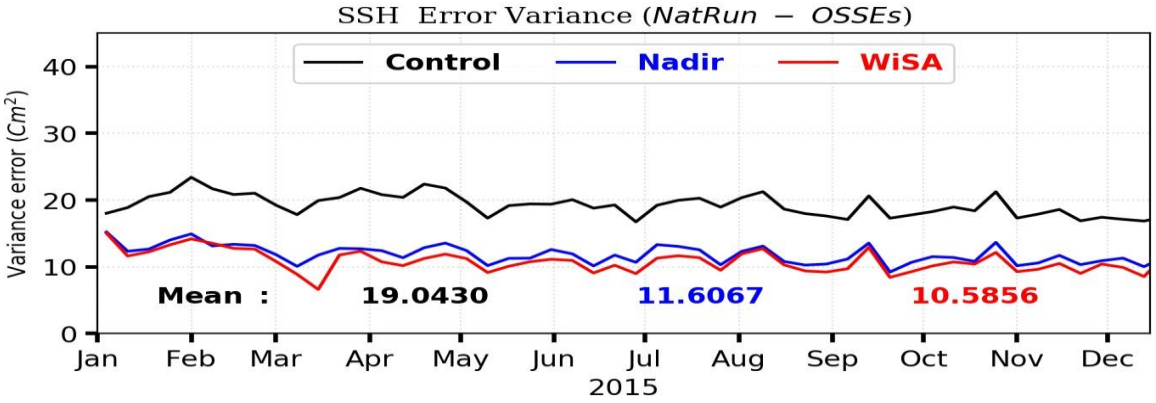
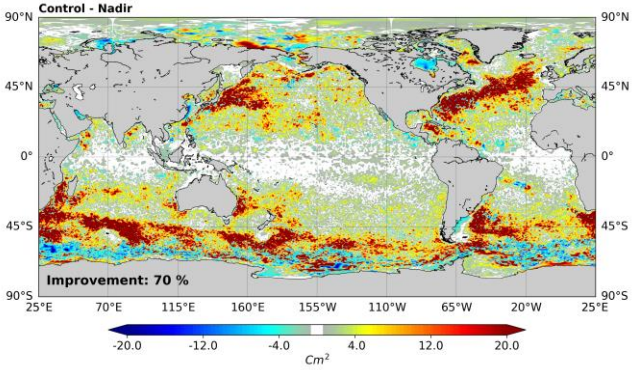
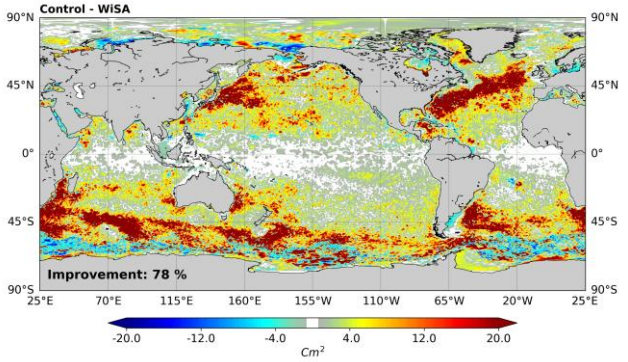
MOi OSSEs: Impact on SSH

- Both NADIR and WiSA experiments reduce SSH RMSE compared to Control
  - Global RMSE reduction of **25% (WiSA) and 22% (NADIR)**
  - Greatest improvement in WBCs
- **Greater impact in the 2WiSA experiment (than NADIR) and larger impact than in Met Office system.**



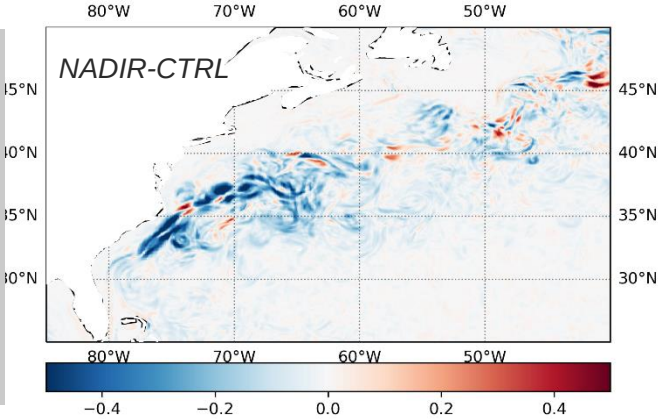


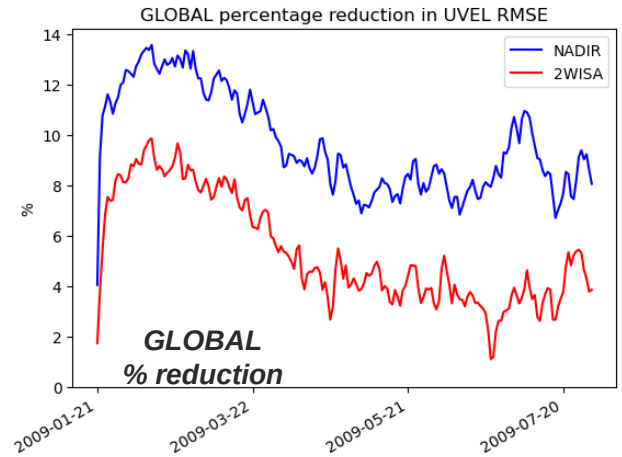


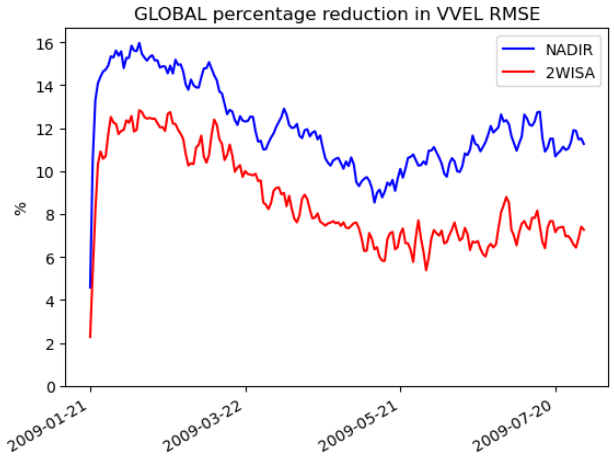
SSH variance difference *(July 2009 compared to control, red shows reduction in RMSE)*

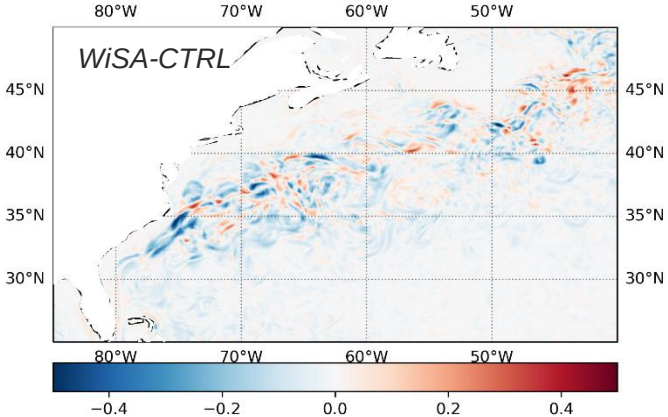
Met Office OSSEs: Impact on Surface Currents

- For surface velocities, both experiments show a reduction in global RMSE compared to Control
  - Global U/V velocity RMSE reduction of approx. **6% (WiSA) and 10% (NADIR)**
  - Greatest improvement in WBCs approx. 15% (WiSA) and 30% (NADIR).
- Overall structure of impacts reflects that seen for SSH.









Current speed RMSE difference *(July 2009 compared to control, blue shows reduction in RMSE)*

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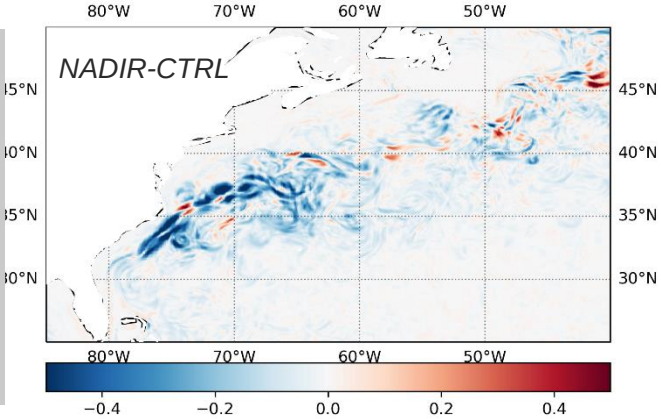
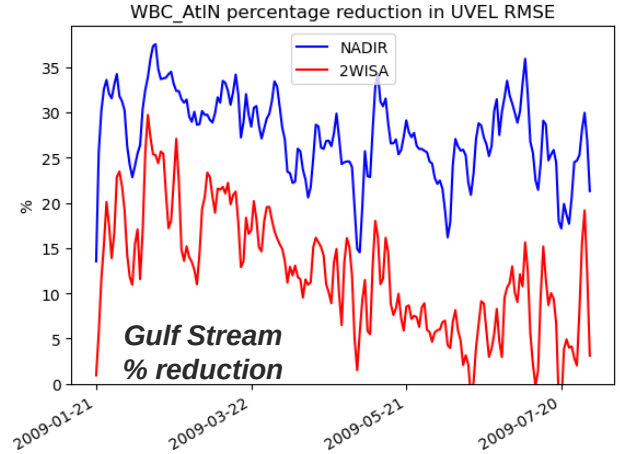
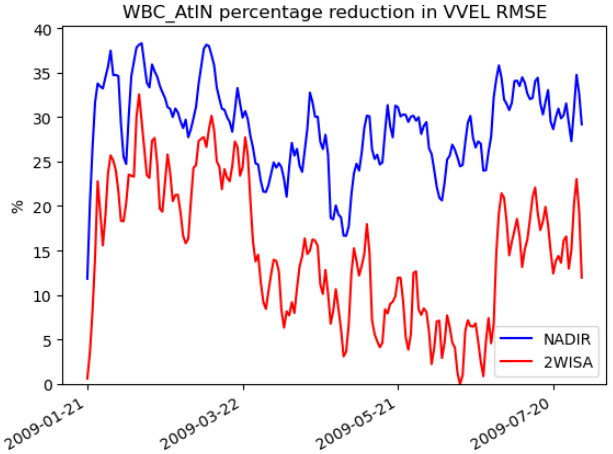
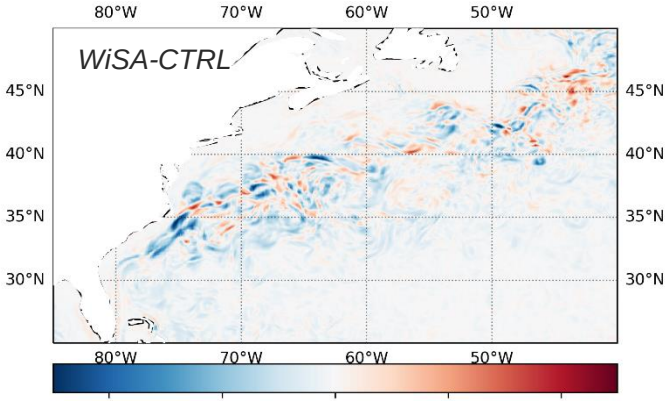




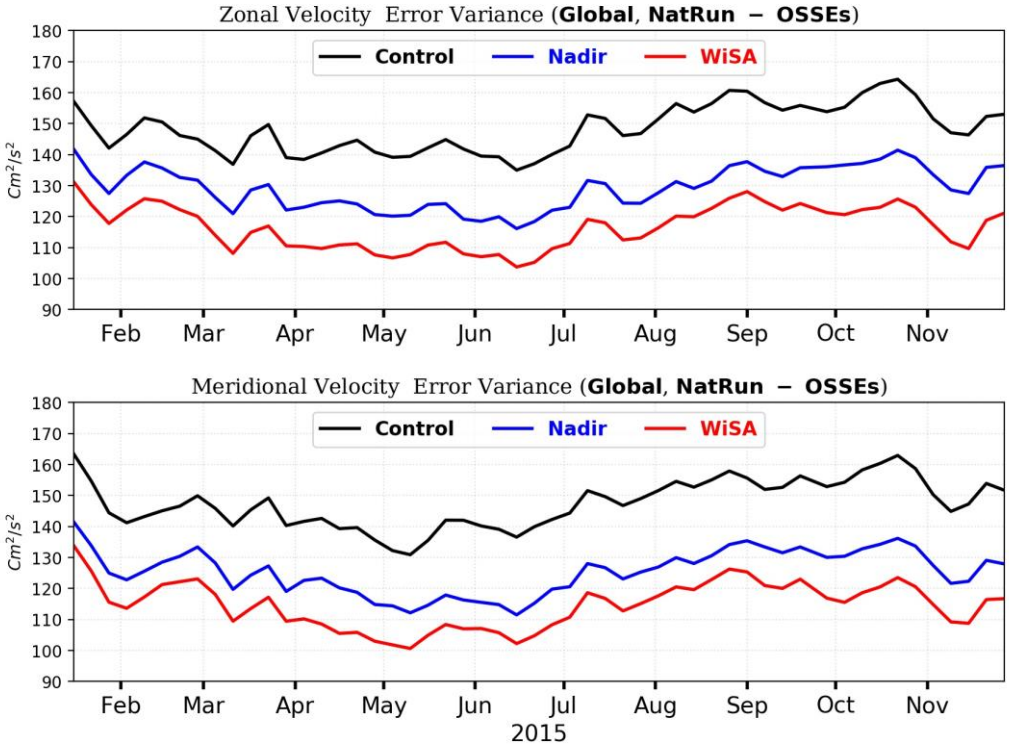




Current speed RMSE difference *(July 2009 compared to control, blue shows reduction in RMSE)*

MOi OSSEs: Impact on Surface Currents

- For surface velocities, both experiments show a reduction in global RMSE compared to Control
  - Global U/V velocity RMSE reduction of approx. **12% (WiSA) and 7% (NADIR)**
- Greater impact in the 2WiSA experiment (than NADIR)
  - **2WiSA: larger impact than in Met Office system.**
  - **NADIR: smaller impact than in Met Office system.**



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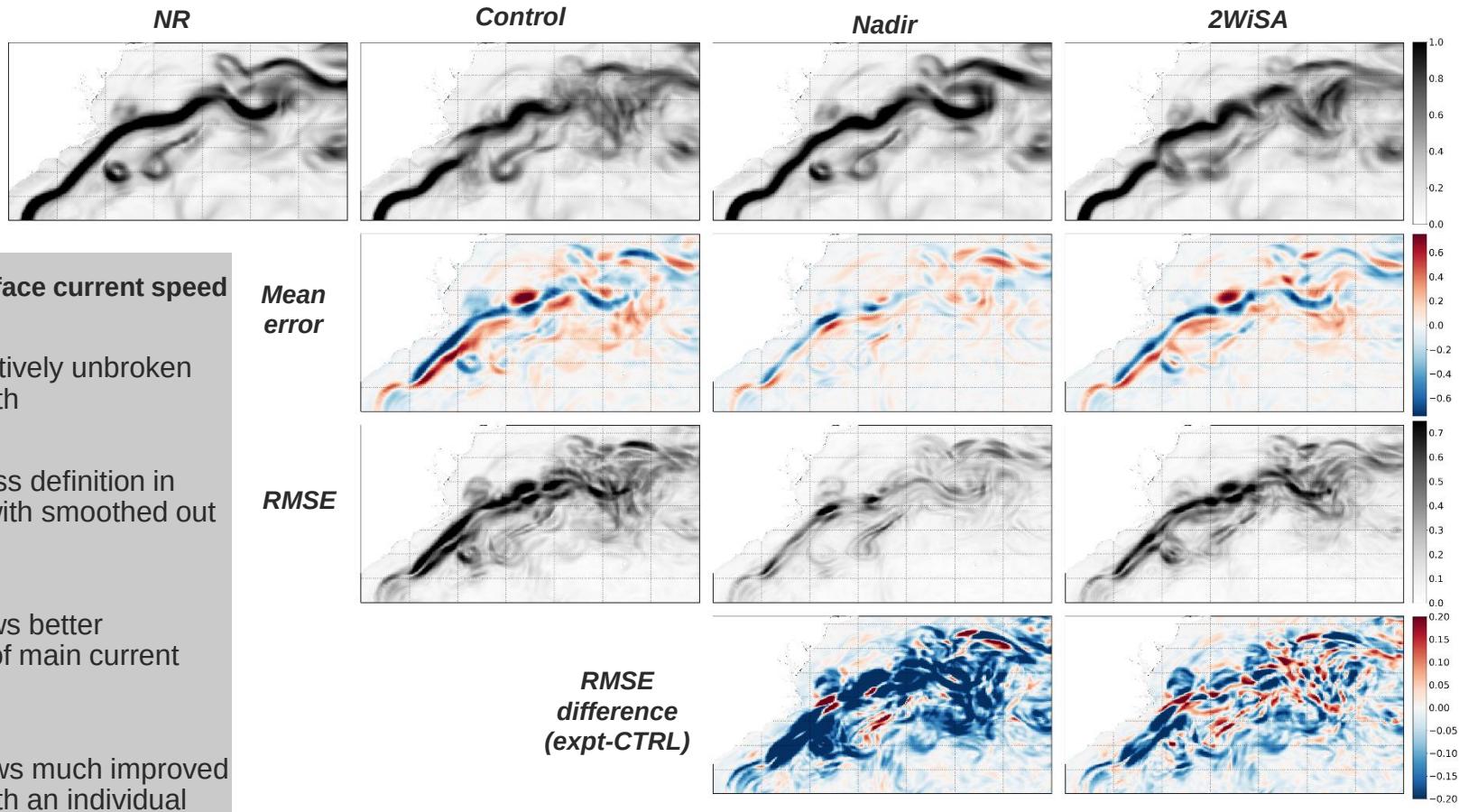


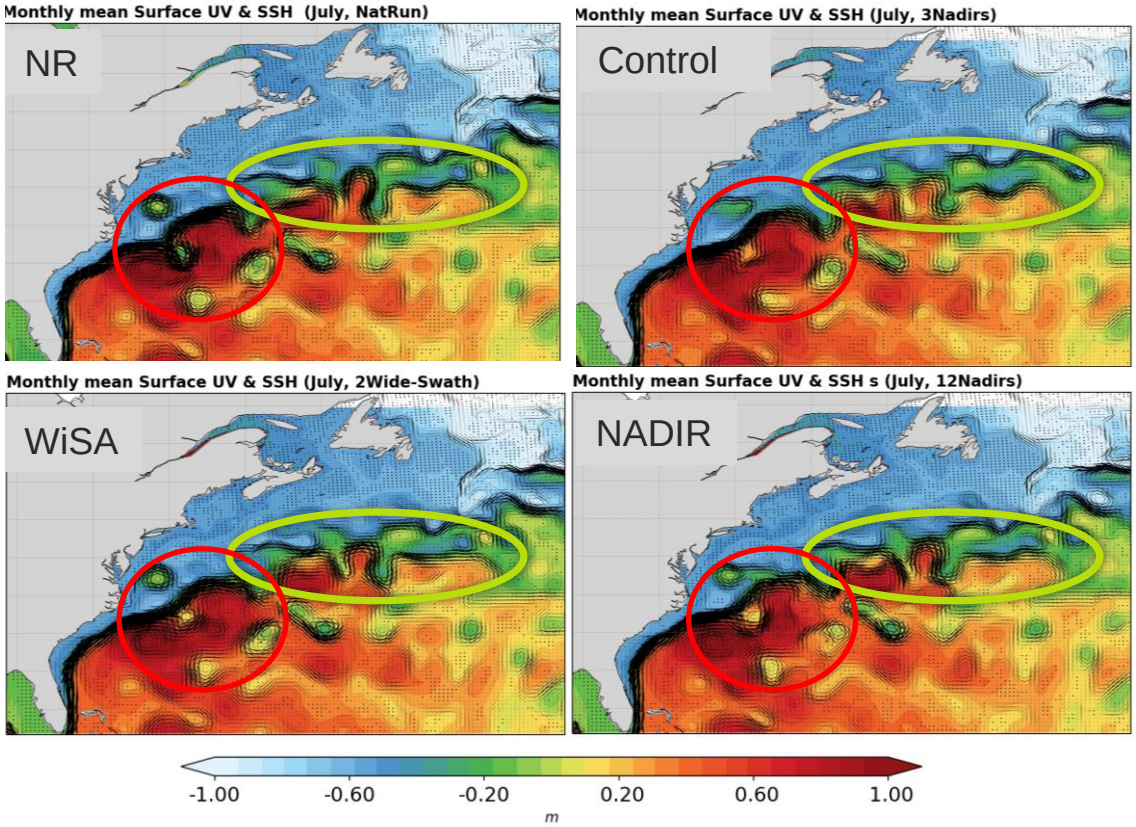
Monthly mean surface current speed

- Nature Run relatively unbroken main current path
- Control show less definition in northern parts with smoothed out eddies
- 2WiSA run shows better representation of main current path
- NADIR run shows much improved main current path an individual eddies.

MOi OSSEs: Impact on Surface Currents

Monthly mean surface current speed and SSH (July, 2015)

- Gulf Stream extension best represented by Swath and Nadirs experiments.
- Control represents well the large structures
- The assimilation of the 12xNADIR brings more correlation with the Nature Run, more mesoscale structures.
- With 2 WiSAs the model best represents the eddies and the mesoscale present in the Nature Run.



Mean monthly surface current speed (black lines) and SSH (background field)

Conclusions & Outlook

Global OSSEs to assess two S3NG scenarios

- Aimed to run as-similar-as-possible OSSEs while using our separate systems
- OSSEs often tell us more about our system than about impact of new observations…

System	SSH	SSH	currents	currents
	NADIR	WiSA	NADIR	WISA
Met Office	16%	10%	10%	6%
Mercator	22%	25%	7%	12%

Both scenarios lead to significant improvements in analyses

- Different winner in each system!
  - Relative impacts of NADIR vs 2WiSA within each system most important.
- Absolute impacts unlikely to be exactly what we'd see in operational systems
  - Larger in Mercator system, except for surface currents in the NADIR experiment which is better in the Met Office system
  - Largest in WBCs with 50%, 25% in SSH and 30%, 15% in surface currents (for NADIR, 2WiSA) in the Met Office system

Perspectives

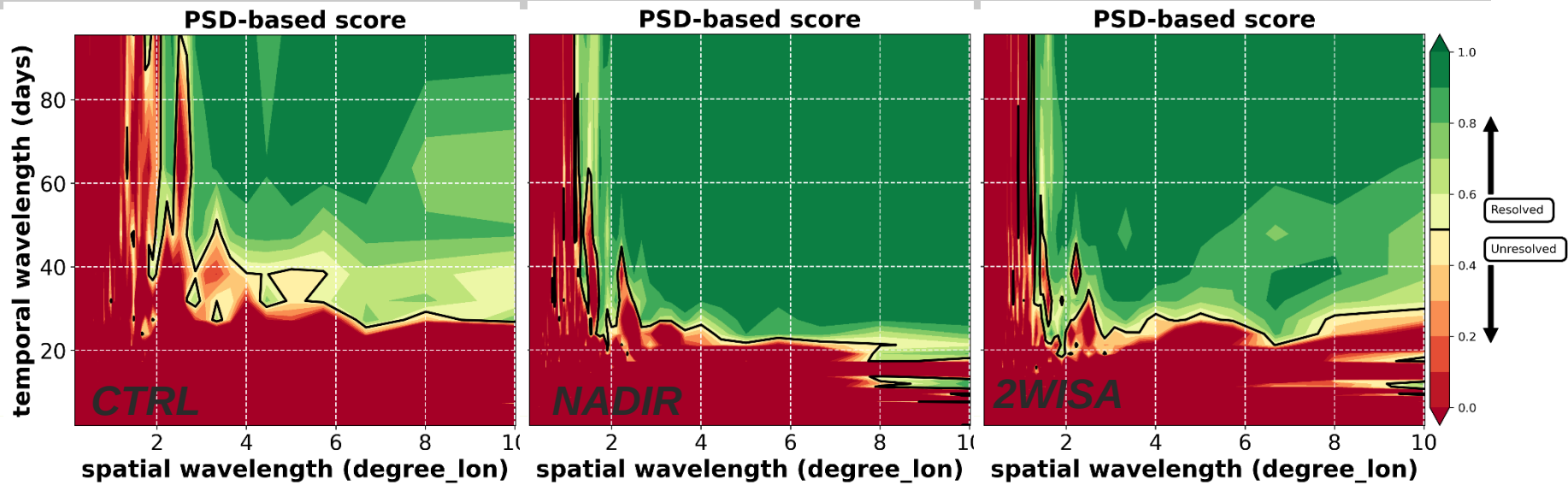
- Systems will evolve significantly by launch of S3NG (or TSCV missions)
- Expect complementary impacts from wide-swath altimetry and satellite TSCV observations
- Correlated errors will pose a challenge – previous regional OSSEs highlighted potential limitations due to correlated errors (King et al. 2021).
- Currently using power spectra to assess the minimum resolved length and time-scales in the analysed SSH fields

Extra Slides

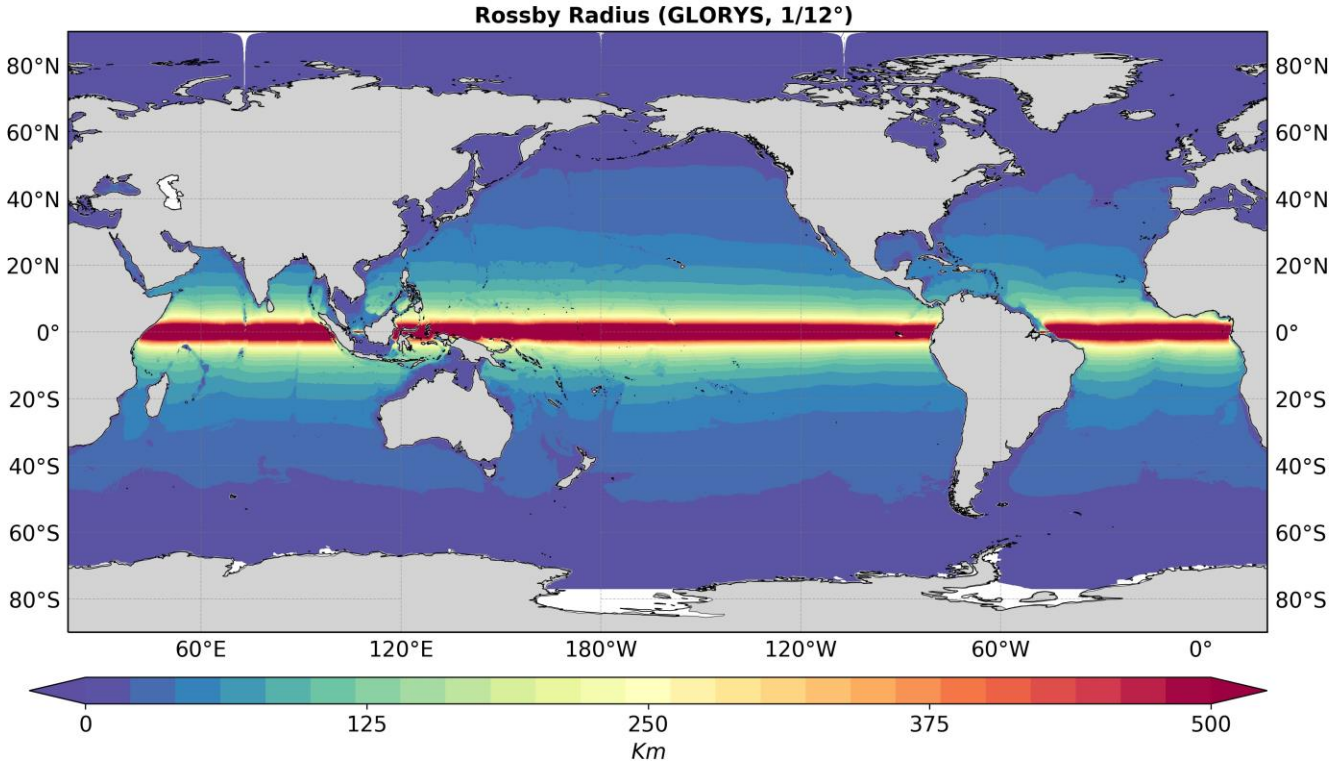
Altimeter OSSEs: Power Spectra

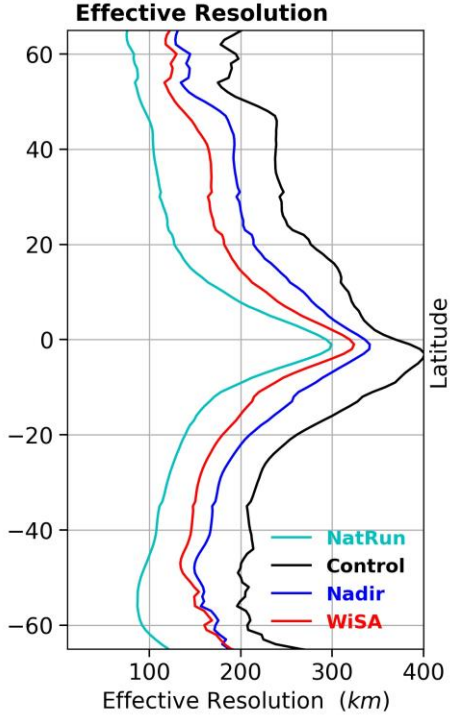
Gulf Stream PSD-scores

- Spatio-temporal power spectra used to generate PSD-score of Ballarota et al. 2019.
  - Focussed on Gulf Stream region
- Minimum resolved length-scales similarly improved in NADIR and 2WISA runs compared to Control.
- Minimum resolved length-scales more consistent across time-scales in the NADIR experiment, perhaps as a result of the more evenly-sampled observations possible with a 12-satellite constellation.

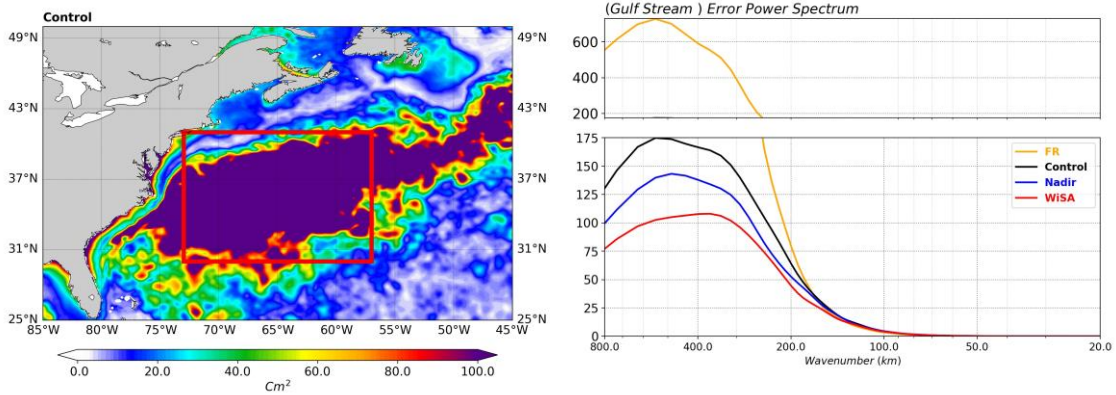


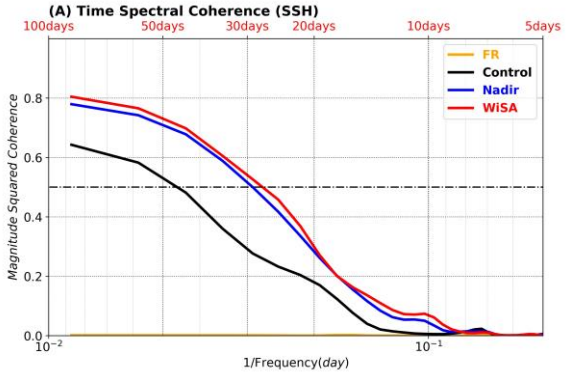
Effective resolution NatRun vs Control vs WiSA vs Nadir vs SWOT

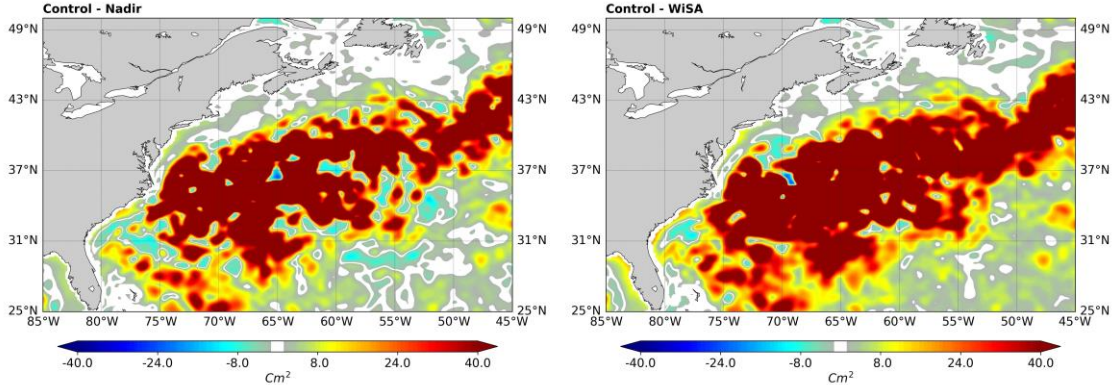




Variance of SSH Error: Nadir vs WiSA (Analysis, **2015, Gulf Steam**)







- Power spectra SSH error (variance-preserving) : **WiSA** (red line) reduction from 150 Km.
- Time Spectral coherence : A slight improvement of this coherence with **WiSA** on all frequencies.

➢ significant improvement in the Golf Stream

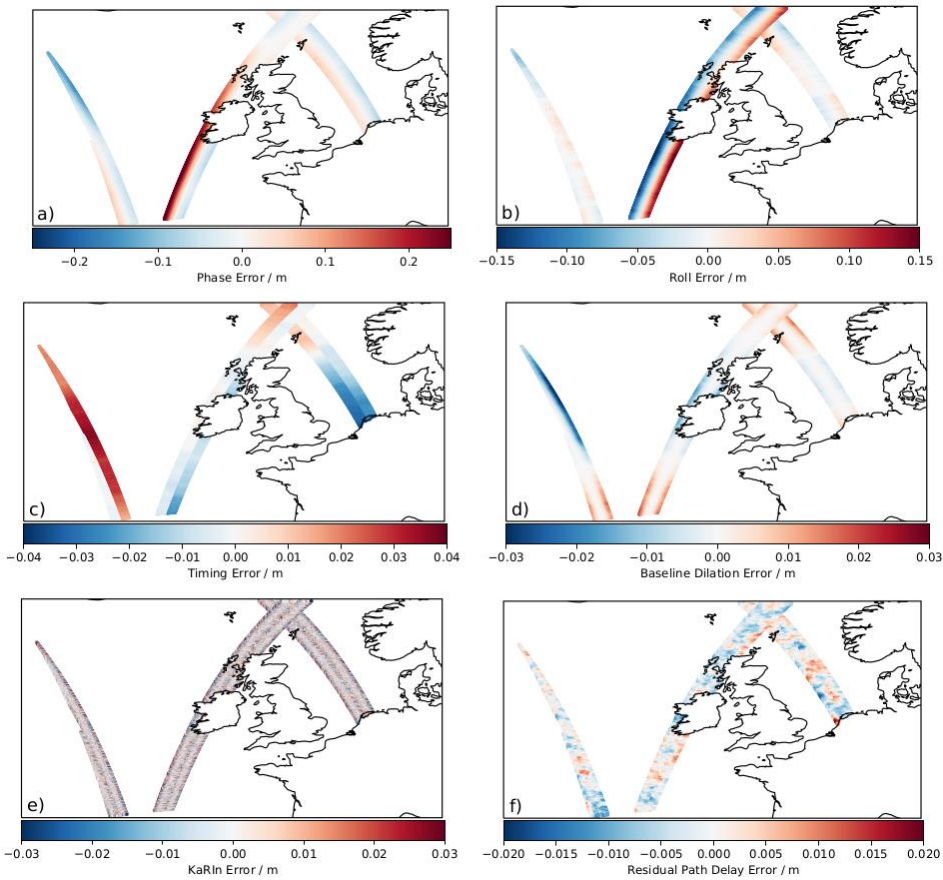
Wide-swath Altimetry

Wide-swath altimetry observations will be subject to **large correlated geophysical and instrumental errors**.

- Presents a challenge for data assimilation schemes.
- These errors are significantly larger than that associated with current nadir SLA observations.
- Phase and roll errors in particular can introduce **spatially correlated errors in excess of 10 cm**.

Error (cm)	RMSE	Extrema
All	6.2	39
Phase	4.9	26
Roll	3.1	16
Timing	1.8	6
KaRIn	1.2	7
Baseline Dilation	0.6	4
Residual Path Delay	0.5	3
All nadir		
All	1.4	6

SWOT and nadir altimeter error statistics for 1-month of simulated observations (see King & Martin 2021).



Individual components of the SWOT errors for an example day. Note the difference in the scales for each error component. Created using the SWOTsimulator of Gaultier et al. (2016).