Met Office

Assessing the impact of proposed satellite observations in a global ocean forecasting system

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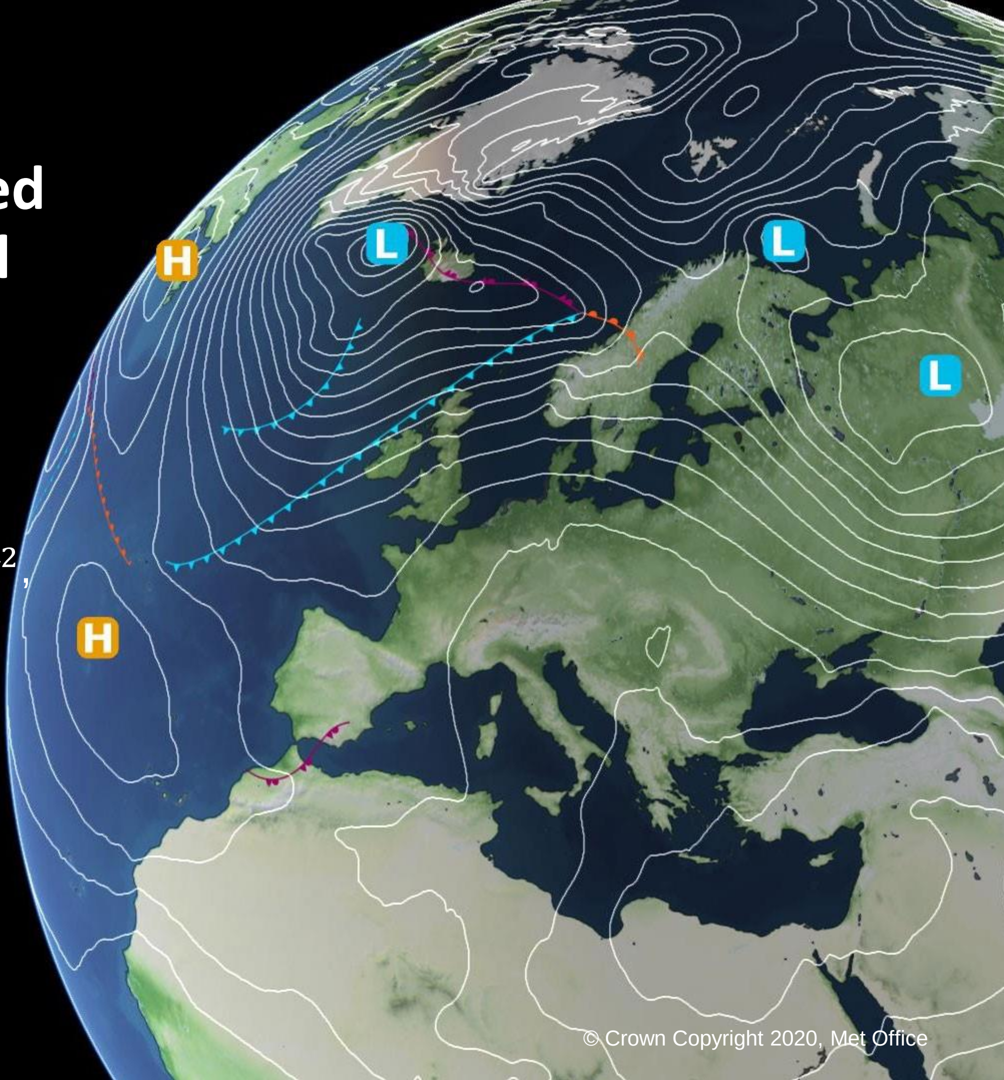


Met Office

Introduction

- Provide an overview of recent Observing system simulation experiments (OSSE) activity at the Met Office

- Present results from two studies commissioned by ESA testing the assimilation of proposed observations in the Met Office global ocean forecasting system (FOAM):
    1. Satellite Total Surface Current Velocities (TSCV)
    2. Wide Swath Altimetry (WiSA)

- **Synthetic observations** are generated from a model run for all standard data types as well as the new observations expected from the proposed satellite.

Total Surface Current Velocity OSSEs: Motivation

- New satellite concepts with the capability to observe Total Surface Current Velocities (TSCV) are now being proposed

- Velocity observations aren't currently assimilated in the Met Office Ocean Forecasting System

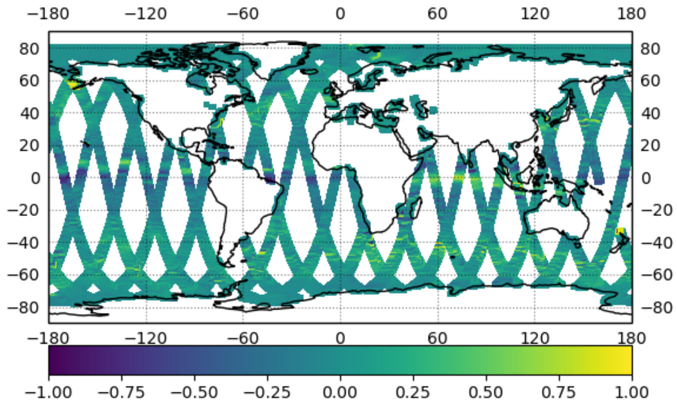
- We want to assess the potential impact of assimilating these novel observations in our global ocean forecasting system
    - Provide supporting evidence on the usefulness of the data for future missions
    - Test DA methodology
    - Provide feedback on observation requirements

- Mercator are running coordinated experiments – today focus on FOAM results

TSCV OSSEs: Design

Experiment	Resolution	Fluxes	Assim SST	Assim T/S profiles	Assim SSH	Assim SIC	Assim TSCV
Nature Run	1/12 °	ECMWF IFS					
Control	1/4 °	ERA5	✓	✓	✓	✓	
A-TSCV	1/4 °	ERA5	✓	✓	✓	✓	✓

- 1/12º Nature Run (NR), previously assessed by Gasparin et al. (2018)
- **Observations simulated from NR** with realistic errors for all standard observation types
- TSCV observation only include a mapping error of approx. 2cm/s
- NEMOVAR data assimilation
    - 3D-VAR FGAT
    - 1 day assimilation window
    - Incremental Analysis Update
    - Multivariate balance
- **Control**: No assimilation of velocity observations but adjustments are made to the velocities through the balance relationship (geostrophic)
- **A-TSCV**: geostrophic and ageostrophic increments are produced for velocity. The geostrophic component gets transferred to the other variables though the balance relationships.



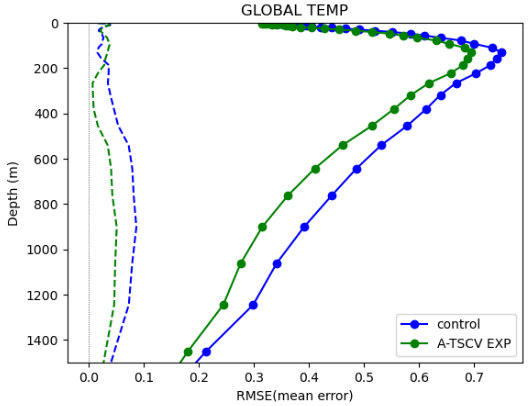
Example daily TSCV coverage from a skim like satellite

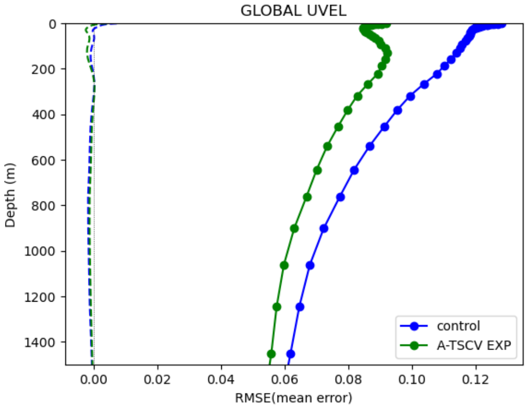
TSCV OSSEs: Global Results

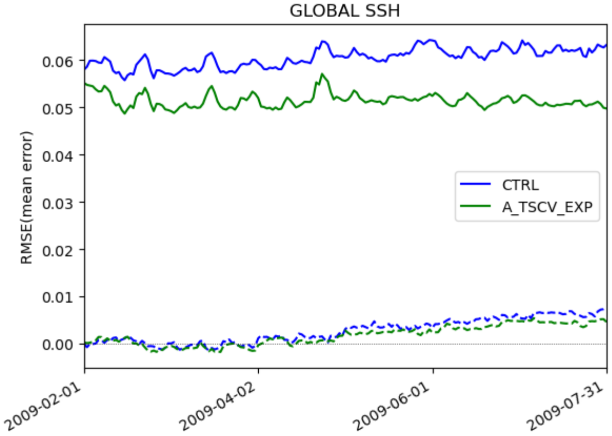
TSCV assimilation produces an improvement in the global RMSE at all depths.

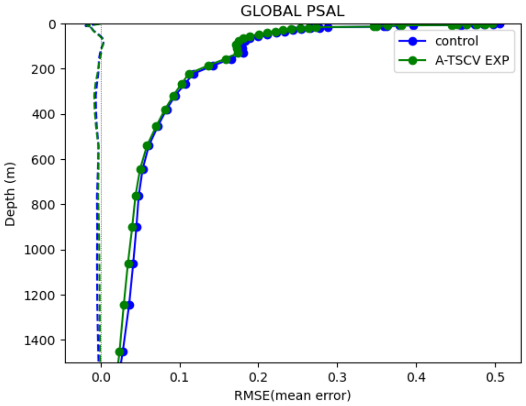
Surface U and V improved by ~27%

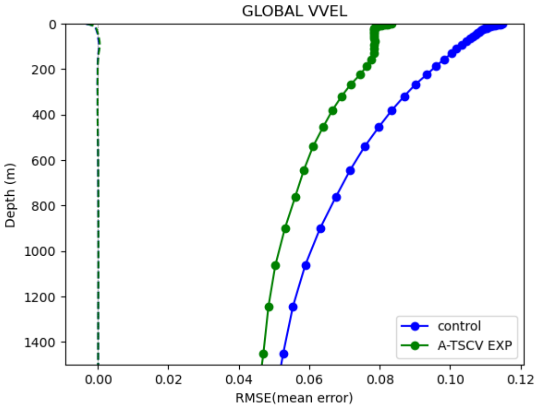
SSH RMSE reduced by ~1cm or 15%.











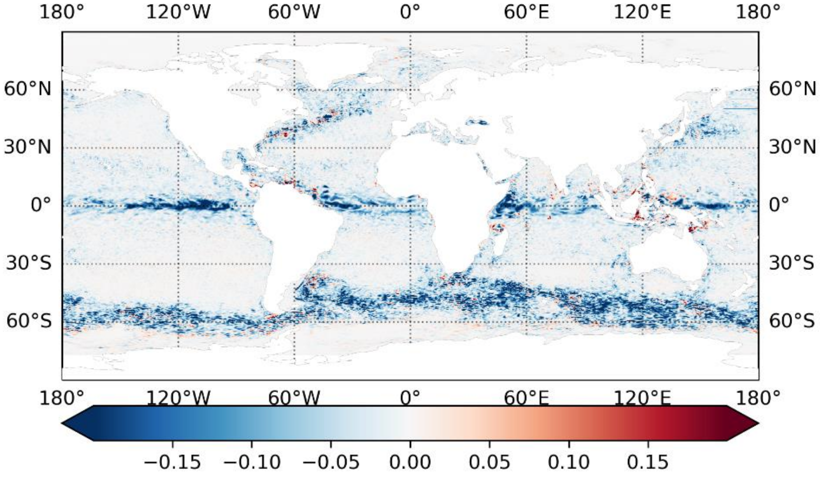
Global RMSE (compared to Nature Run) *calculated for February - July 2009*

TSCV OSSEs: Global Results

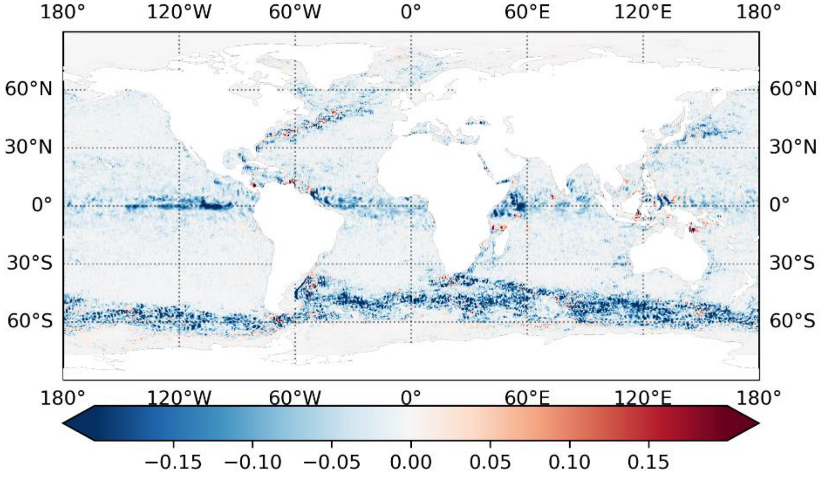
Largest improvements in surface velocity RMSE seen in the Western Boundary Currents, ACC and equatorial region

Improvements to Temperature and SSH RMSE are also predominantly in the Western Boundary Currents and ACC.

SSU



SSV



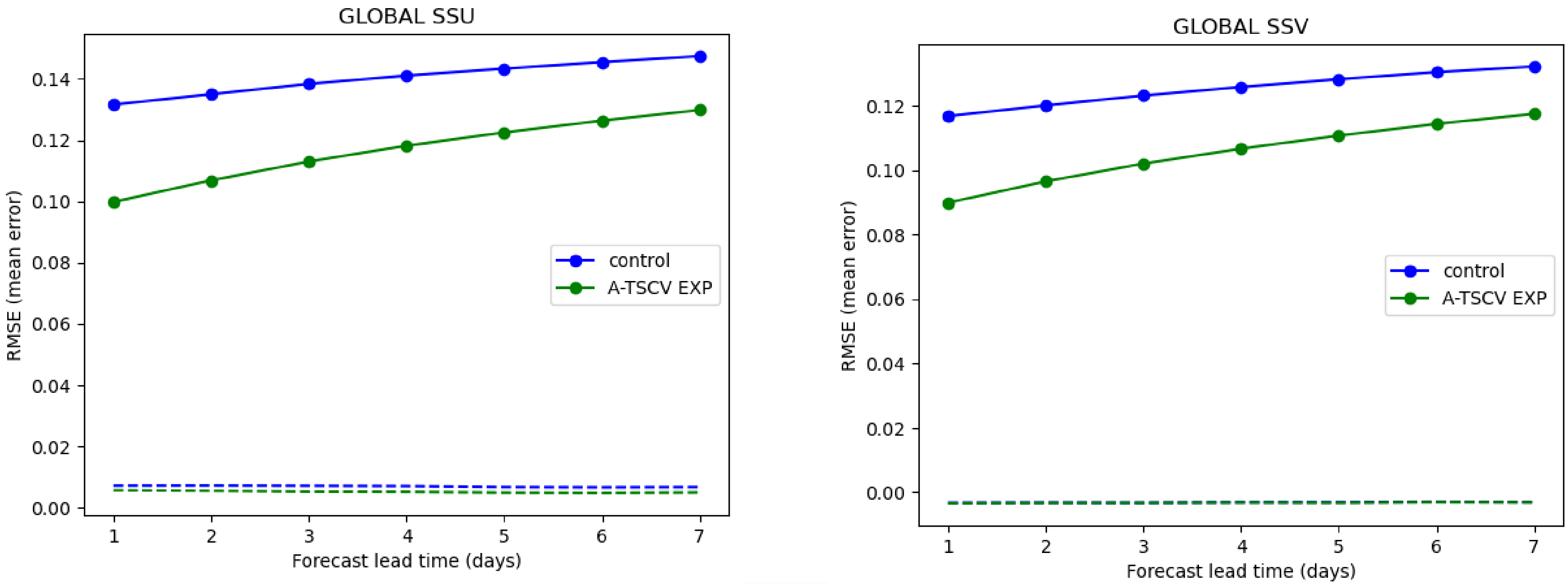
Difference in RMSE for the control and A-TSCV experiment: July 2009

(blue shows reduction in RMSE)

TSCV OSSEs: Global Forecast Results

Ran 7 day forecast every 7 days between February and December 2009 – total of 47 forecasts.

Improvement in surface velocity RMSE relative to the control is well retained over a 7 day forecast

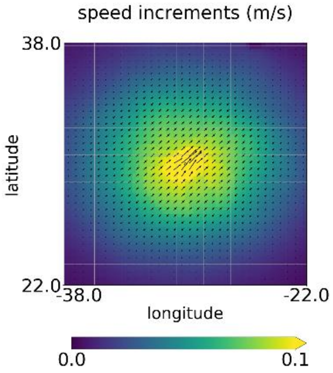


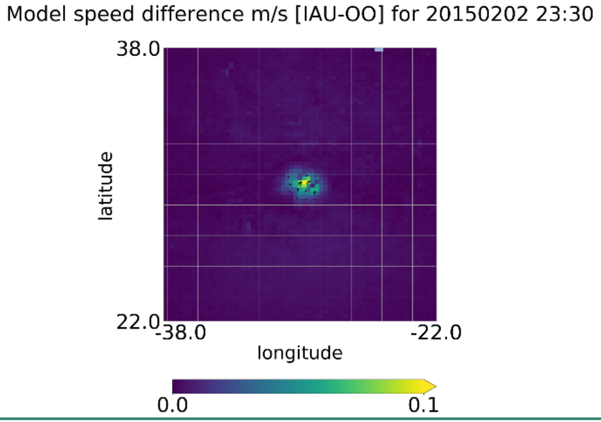
Global RMSE (compared to Nature Run) *calculated for February - July 2009*

TSCV OSSEs: Ageostrophic Velocity Assimilation

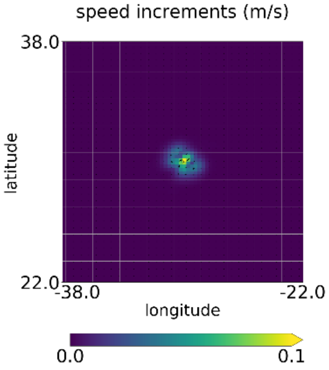
Model response to increments in FOAM: end of 24 hour forecast

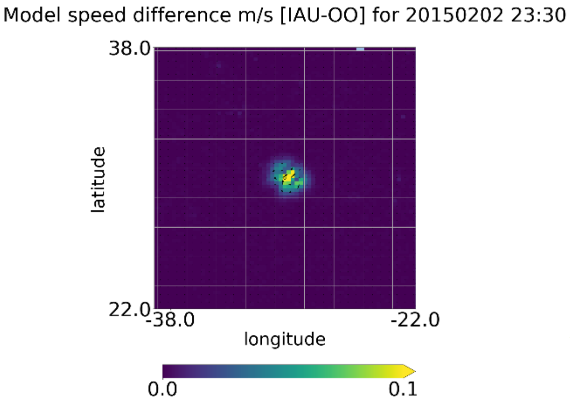
Total increments





Balanced increments only





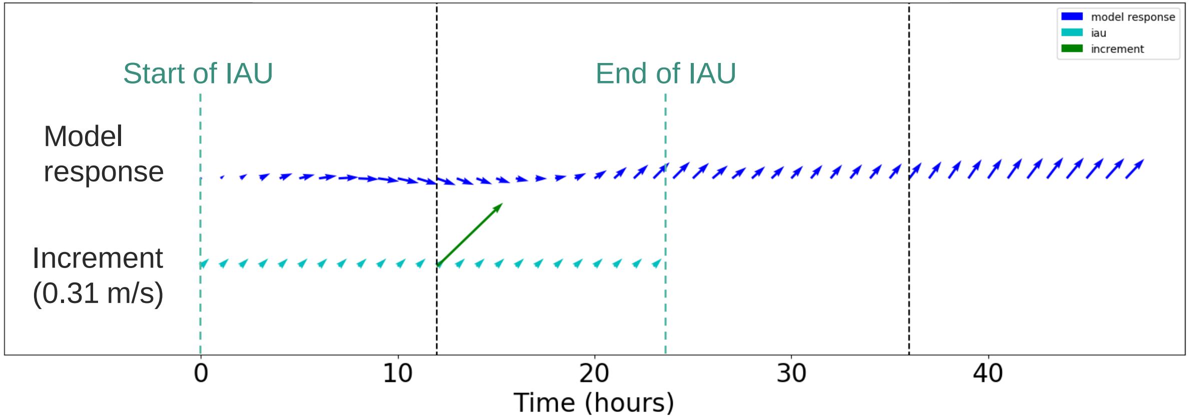
- The ageostrophic or unbalanced component of the increment is not being properly retained in the model
- An area for potential improvement in the assimilation

Away from the equator, inertial oscillations are a large component of the ageostrophic velocities.

When the IAU is used to apply an ageostrophic velocity increment, the model responds by rotating the applied increment on subsequent time steps. Meanwhile, the IAU continues to apply the increment in the direction of the original increment. This means that the applied increment on subsequent time steps can act to cancel each other out.

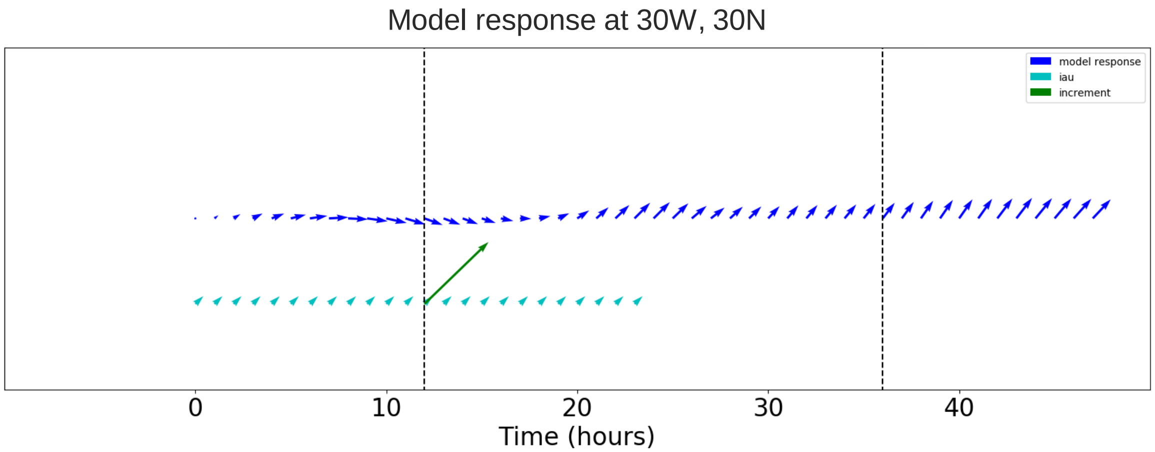
This figure shows how the surface model velocity (at the obs location) responds to an ageostrophic velocity increment.

Model response at 30W, 30N



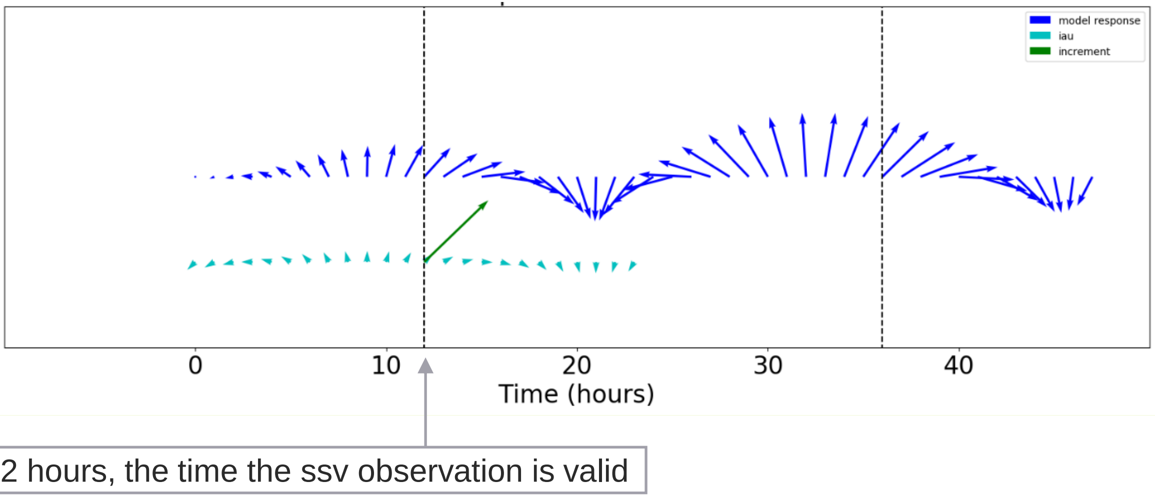
We propose to rotate the ageostrophic component of the increments by the inertial period in the IAU. This should allow us to correct the inertial oscillations in our system.

Model response in the **standard IAU.**



Model response in the **rotated IAU**

The applied increments are rotated at each time step by the inertial period



TSCV OSSEs: Conclusions & Outlooks

- Assimilation of simulated TSCV observations in an OSSE framework produces an improvement in global RMSE statistics for all variables
  - SSU and SSV errors reduced by ~27% and SSH errors are reduced by ~15%
  - Globally improvements are seen throughout the water column
  - The improvements are retained during a 7 day forecast

- Initial results from an experiment with more realistic observation errors, but still excluding the large correlated component associated with the wave doppler effects, produce a similar impact (not shown).

- Assimilation could potentially be improved further by improving retention of the unbalanced increments through the correction of inertial oscillations.

Altimeter OSSEs : Motivation

Altimetry routinely assimilated in operational systems, but

- Large gaps between tracks**, long repeat cycles** (10–35 days)
- Along-track obs have high sampling frequency (~7 km), but feature **resolution only ~100 km** (Xu and Fu, 2013)

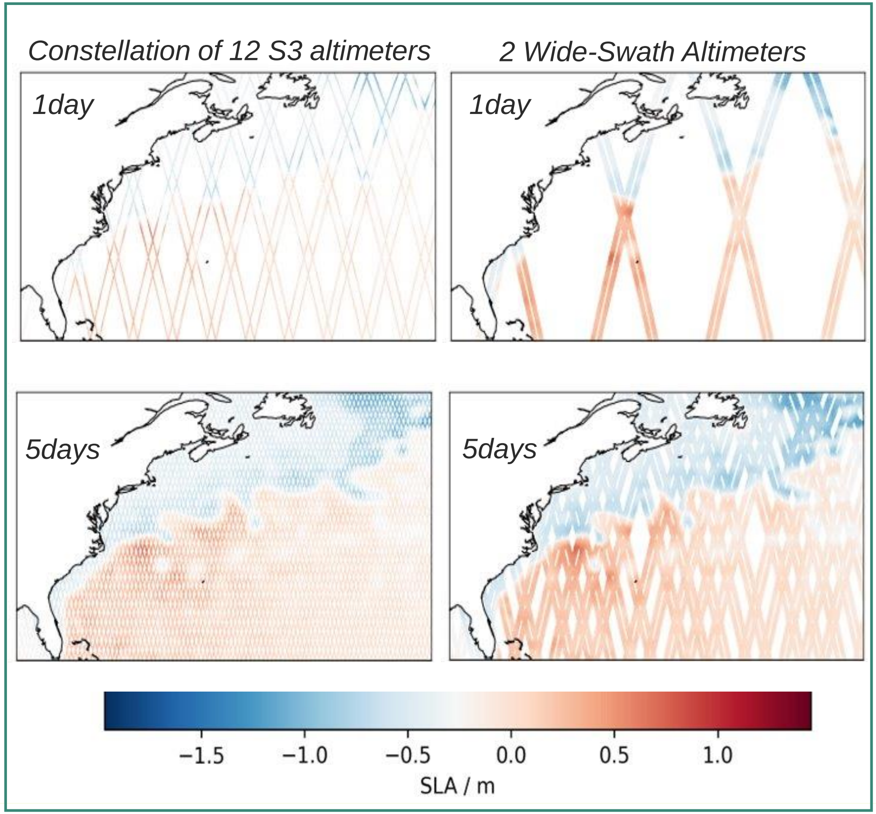
Sub-optimal for the initialisation of mesoscale features

- Disparity between observed and modelled scales will increase as model resolution increases

SWOT due to launch on 5th December 2022

Project comparing impact of two proposed scenarios

- 2 Wide-Swath Altimeters (2xWiSA) flying along-side Sentinel-6
- 12 Sentinal-3-like SAR altimeters flying along-side Sentinel-6



Altimeter OSSEs : Design

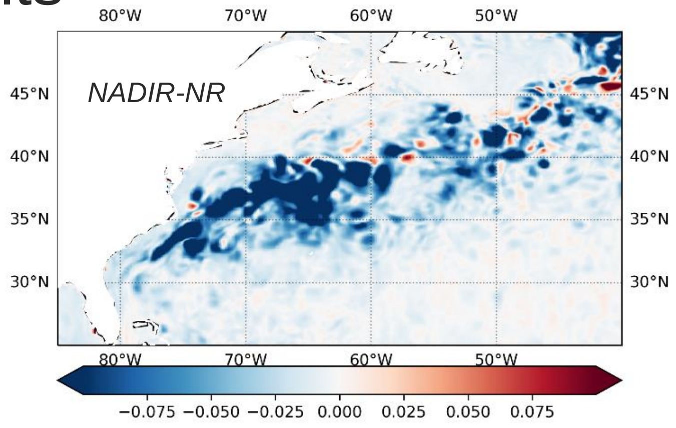
OSSE design

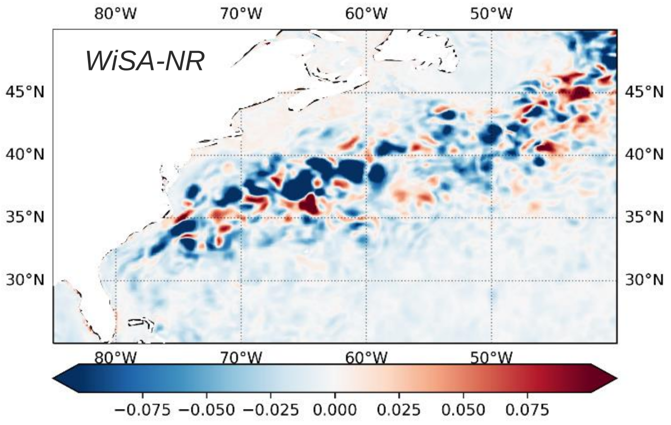
- Similar set-up as TSCV experiments
- **Observations simulated from NR** with realistic errors, inc. SST, in situ T/S, SLA
- WiSA obs simulated with KaRIn and residual WetTropo errors. Not yet with correlated phase/roll errors.
- OSSE experiments: 1/12º NEMO model, NEMOVAR DA, different initial conditions and fluxes.
- Mercator are running coordinated experiments – we are getting quite different results for the relative impacts!.

Expt	Fluxes	Std Obs	S3A, S3B	S6	12 x S3	2 x WiSA
Nature Run	ERA-I					
Control	ERA-5	✓	✓	✓		
NADIR	ERA-5	✓		✓	✓	
WISA	ERA-5	✓		✓		✓

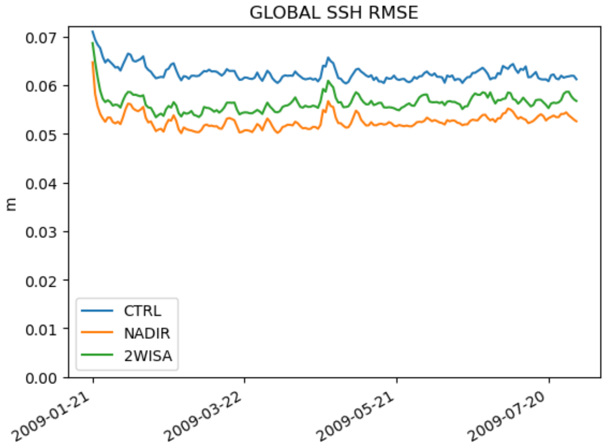
Altimeter OSSEs: SSH Results

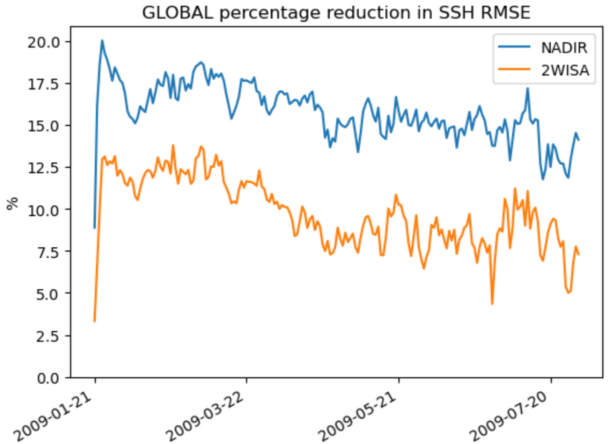
- Both NADIR and WiSA experiments reduce SSH RMSE compared to Control
  - Global RMSE reduction of 10% (WiSA) and 16% (NADIR)
  - Greatest improvement in WBCs
- NADIR experiment shows improvement or neutral impact almost everywhere.
- Although positive overall, WiSA experiment highlights some regions of negative impacts.





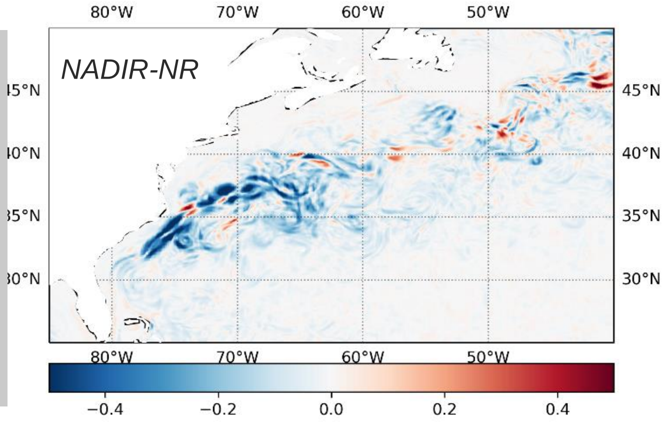
***SSH RMSE difference** (July 2009 compared to control, blue shows reduction in RMSE)*

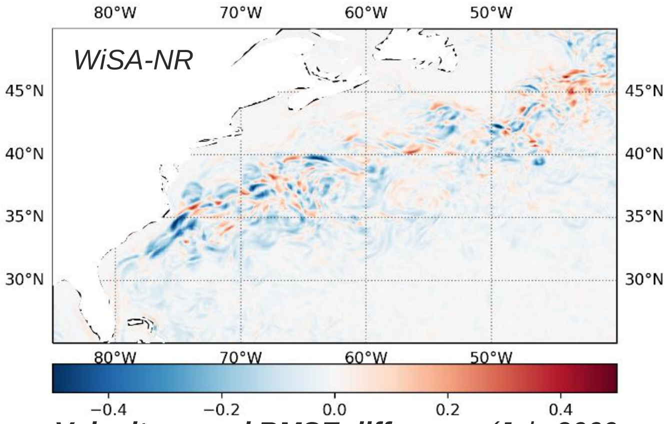




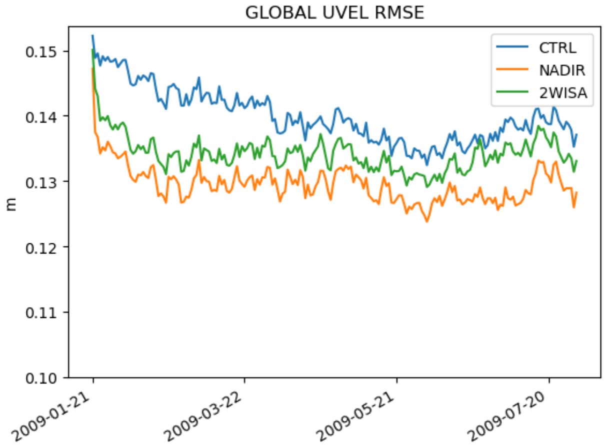
Altimeter OSSEs: Velocity Results

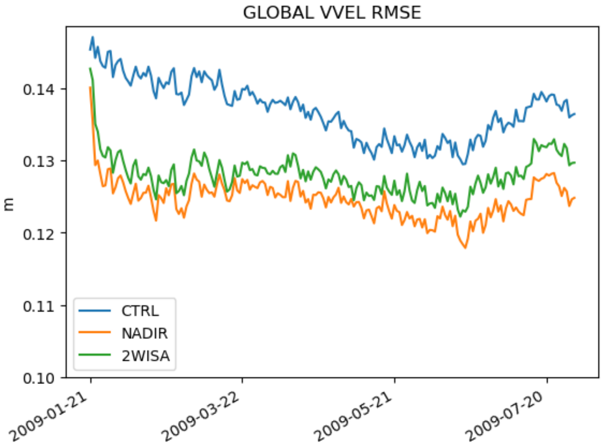
- For surface velocities, both experiments show a reduction in global RMSE compared to Control
  - Global U/V velocity RMSE reduction of 4/7% (WiSA) and 7/9% (NADIR)
  - Greatest improvement in WBCs
- Overall structure of impacts reflects that seen for SSH.





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





Altimeter OSSEs: Conclusions & Outlooks

Assimilation of simulated altimeter observations from two proposed scenarios produces significant improvements in global RMSE statistics for SSH and surface currents

- Two scenarios differ in their spatial and temporal sampling

A 12-nadir altimeter constellation has greater impact in our global system than 2 WiSAs

- Caveat – OSSEs don't tell us the impact of observations, but the impact of those obs in the system tested!
- Impact differences may be due to combination of higher obs density + our 1-day assimilation window
- These experiments have not included the correlated errors expected with WiSAs, so there is a challenge to overcome in making use of real wide-swath data!

SWOT launches next month!

- Will soon be testing will real data.
- Will help us to understand the impact of correlated errors and to test strategies to extract maximum use from obs (superobbing, restricting swath width)