Assessing the impact of assimilating Total Surface Current Velocities in global ocean forecasting systems.

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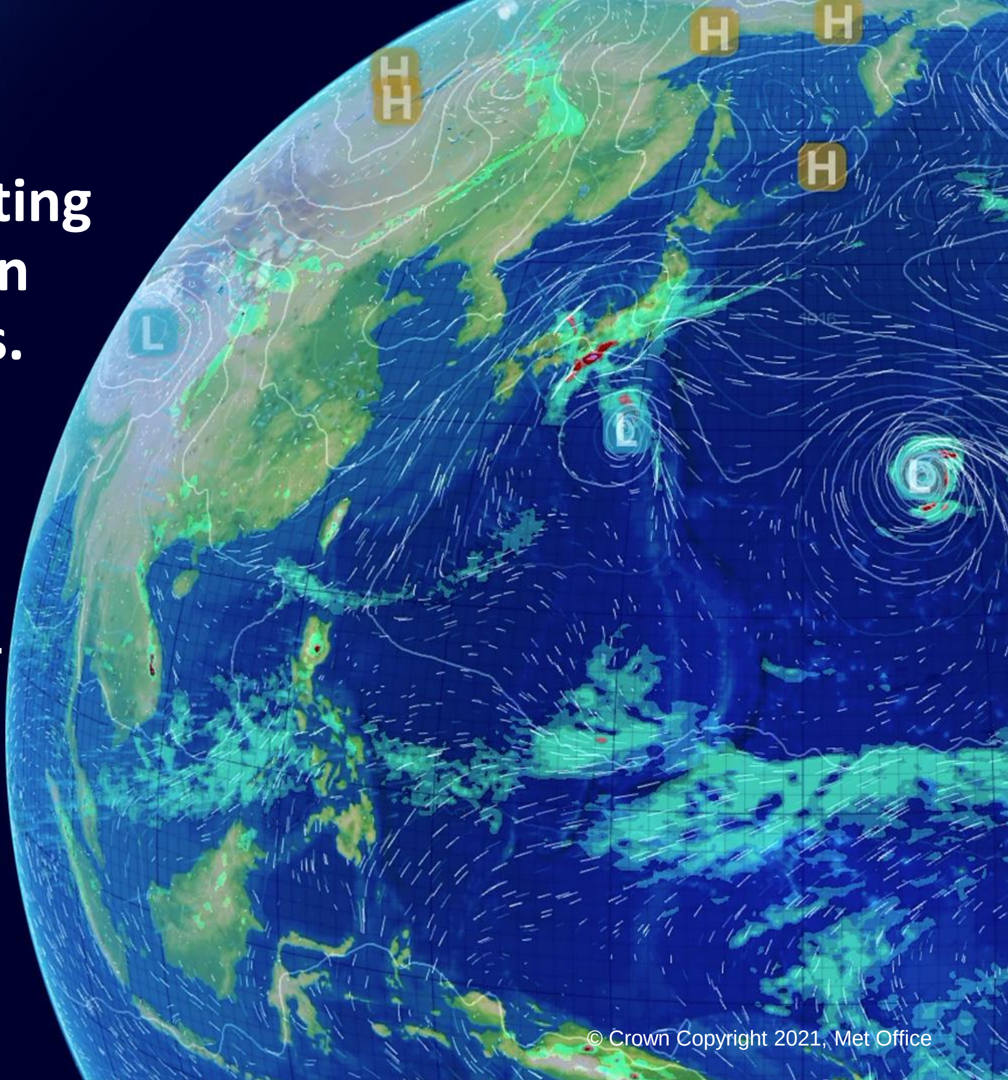

Introduction and OSSE design

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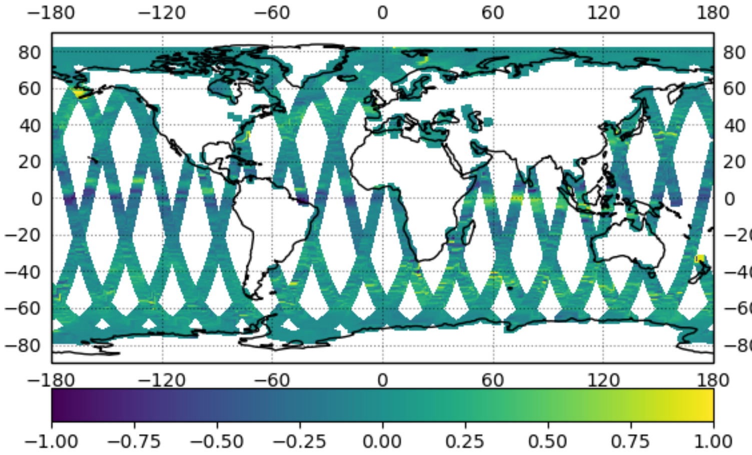
Introduction

- Accurate forecasts of total surface current velocities (TSCV) are important for search and rescue, tracking marine plastic and for coupled forecasting.
- Various satellite missions are being proposed to measure TSCV globally(e.g SKIM, SEASTAR)
- The **ESA A-TSCV project**[1] will use observing system simulation experiments (OSSEs) to test the assimilation of satellite TSCV.
- Synthetic observations are generated for all standard data types (SST, SIC, SLA and profiles of temperature and salinity) as well as the new observations expected from SKIM-like satellite missions using the SKIMulator tool .
- Two operational global ocean forecasting systems are being developed to assimilate these data in a set of coordinated OSSEs: the FOAM system run at the Met Office and the Mercator Ocean (MOI) system – focus on the Met Office system today.



- **Aims of the project are to test the assimilation methodology and provide feedback on the observation requirements for future satellite missions.**

1. https://oceanpredict.org/science/cross-cutting-projects/a-tscv

OSSE design

- Synthetic observations are generated from a Nature Run: 1/12° global ocean simulation with the Mercator Ocean real time system model without assimilation forced with 3 hourly ECMWF IFS fluxes.
- Realistic obs errors are generated for all standard obs
- Obs error for TSCV obs – only includes the mapping error associated with the OI method used to map radial currents to the 2D currents using 20km length-scales (approx 2cm/s)
- OSSE experiments: NEMO-CICE, 1/4° resolution, different initial conditions, ERA5 fluxes
- NEMOVAR
  - 3D-VAR FGAT
  - 1 day assimilation window
  - Incremental Analysis Update
  - Multivariate balance relationships defined through linearised balances
  - Standard control vector: Temperature, salinity, SSH, sea ice concentration, balanced U and V

OSSE experiments

Control

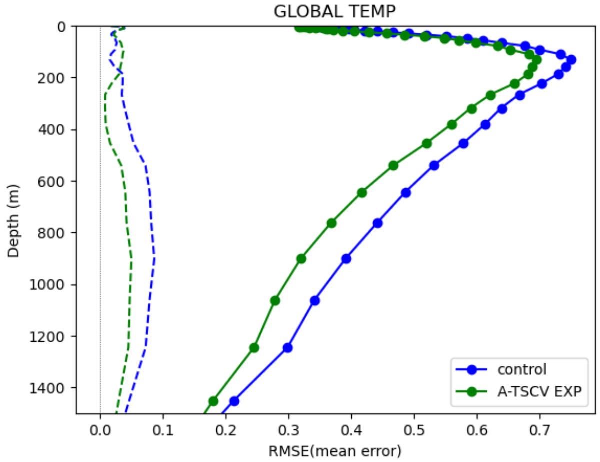
- Observations generated from NR for:
  - SST L2
  - ARGOx1, XBT, Mooring, Drifters
  - SIC
  - SSH: Altika, Cryosat2, S3a, S3b
- No assimilation of velocity observations but adjustments are made to the velocities through the balance relationship (geostrophic balance)
- No velocity balance at the equator
- Verification period (01/02/2009 -> 31/07/2009)

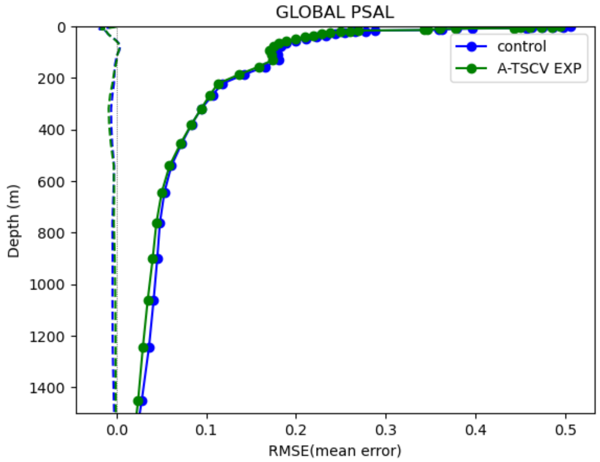
TSCV Assimilation Exp

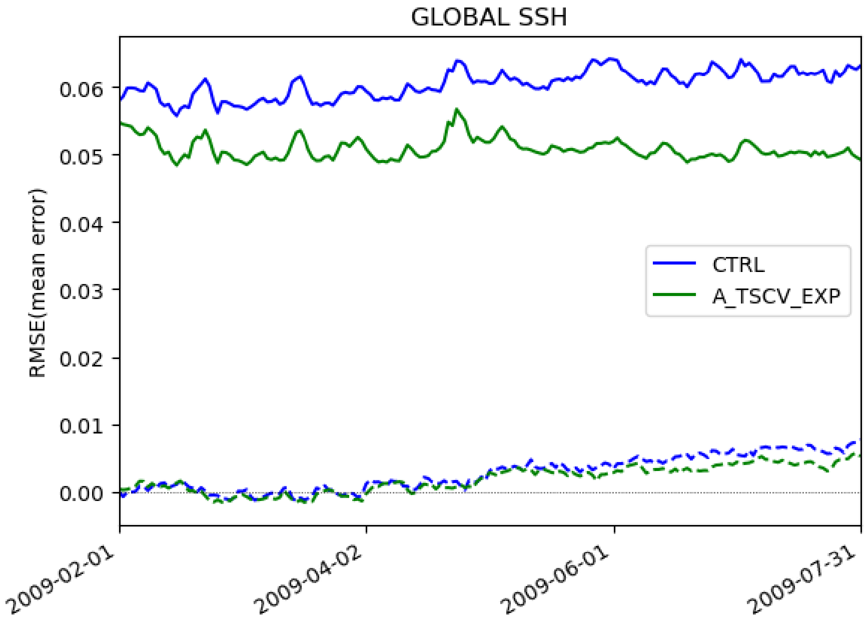
- additional observations:
  - TSCV L2
- Both balanced (geostrophic) and unbalanced (ageostrophic) increments are produced for velocity. The geostrophic component gets transferred to the other variables though the balance relationships.
- New bkg error covariances are defined for unbalanced U and V
  - 2 horizontal correlation scales estimated using the NMC method
  - Single vertical correlation scale parametrised using mxld
- New obs error estimated for U and V

Global results

Global statistics: Feb-July 2009 – standard variables

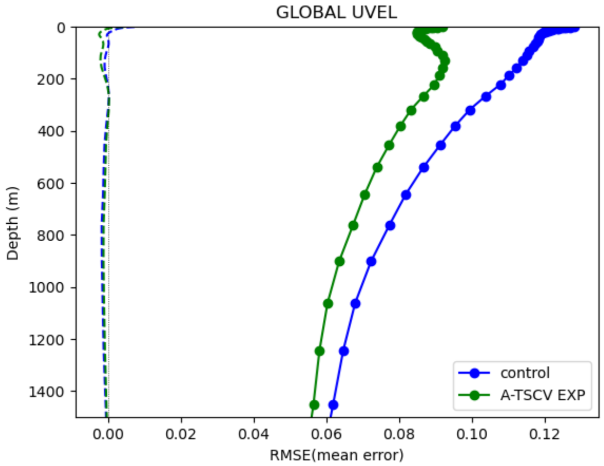


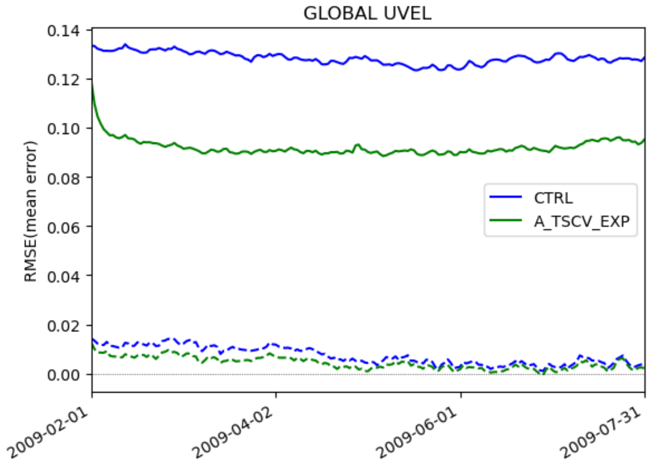


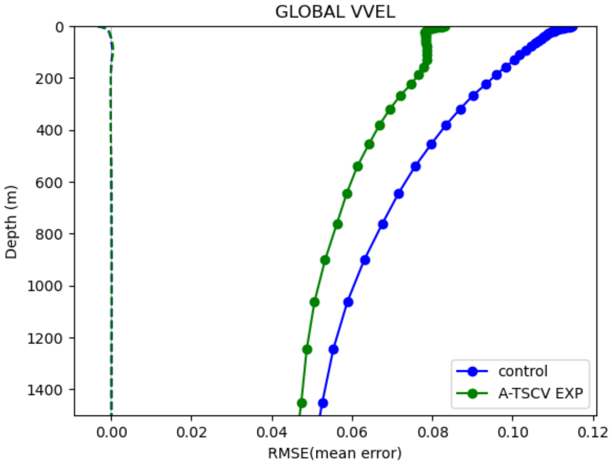


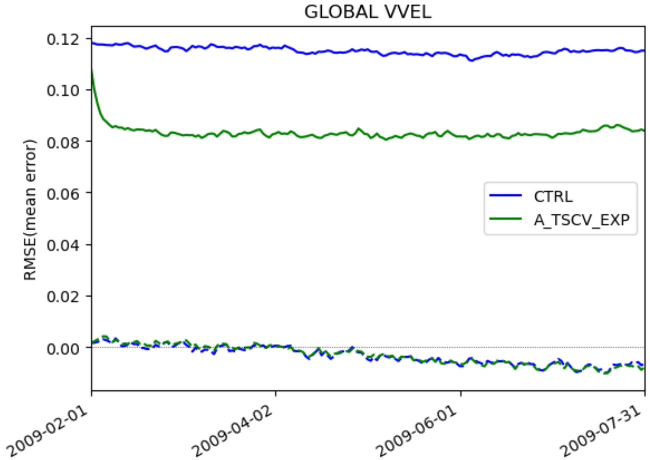
Comparisons are against the Nature run

Global statistics: Feb-July 2009 – velocities









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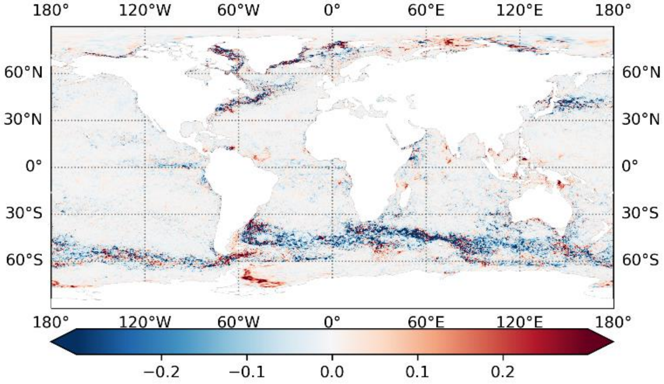
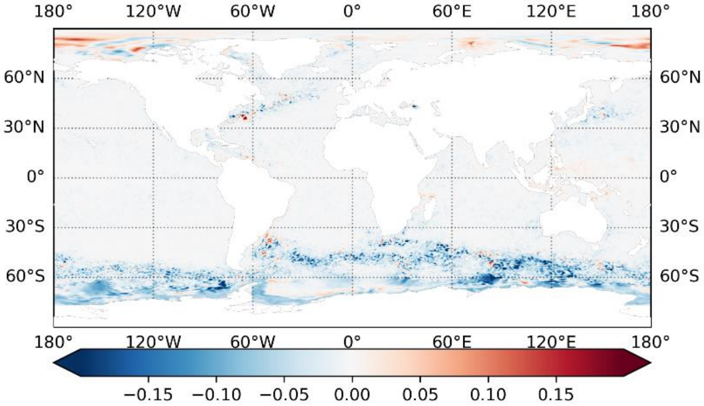
Difference in RMSE for the control and T-SCV assimilation experiment: July 2009

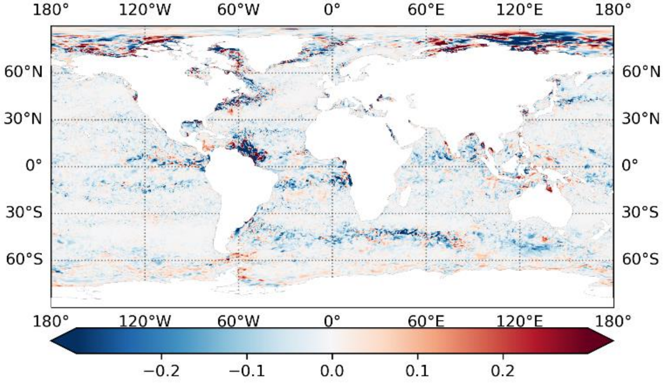
SST



SSH



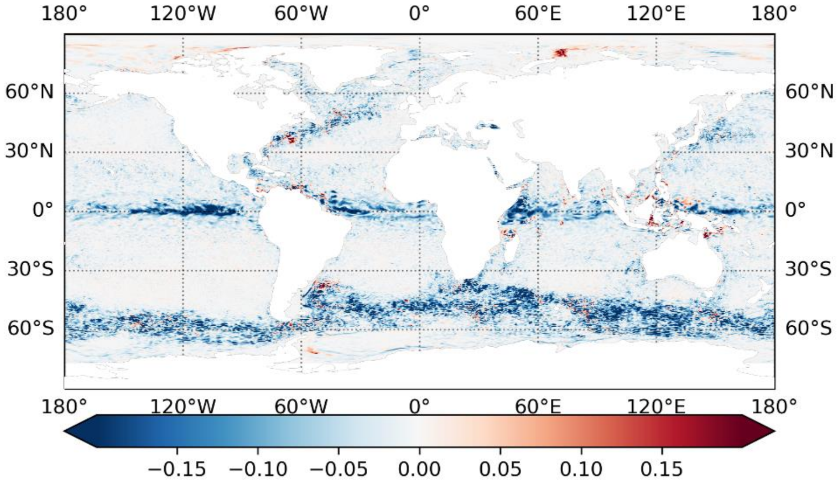
SSS



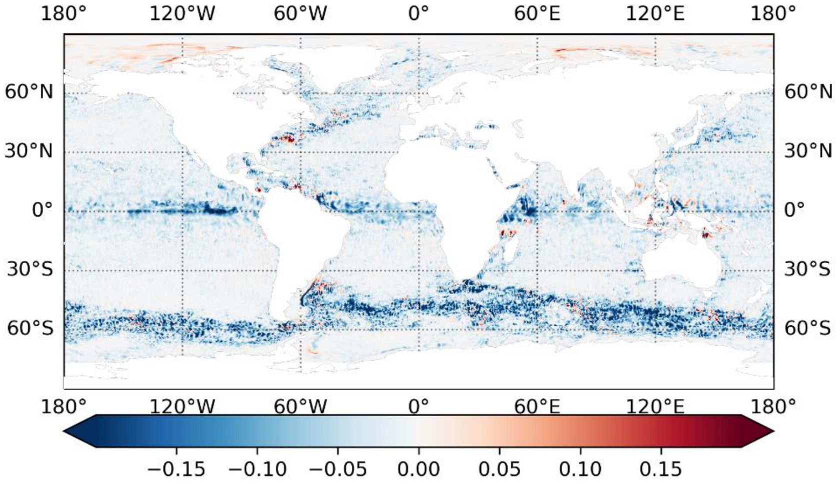
Blue shows regions where the TSCV assimilation experiment has a lower RMSE than the control

Difference in RMSE for the control and T-SCV assimilation experiment: July 2009

SSU



SSV

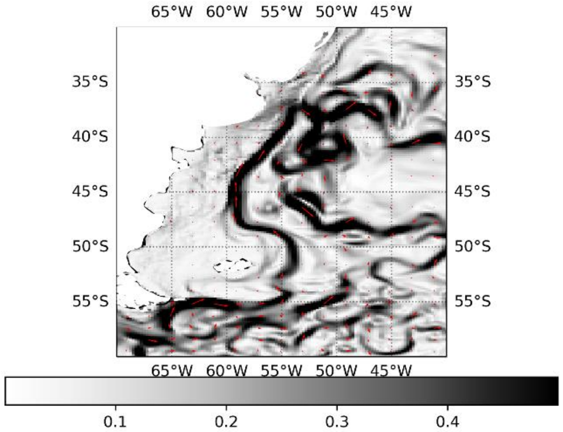


Blue shows regions where the TSCV assimilation experiment has a lower RMSE than the control

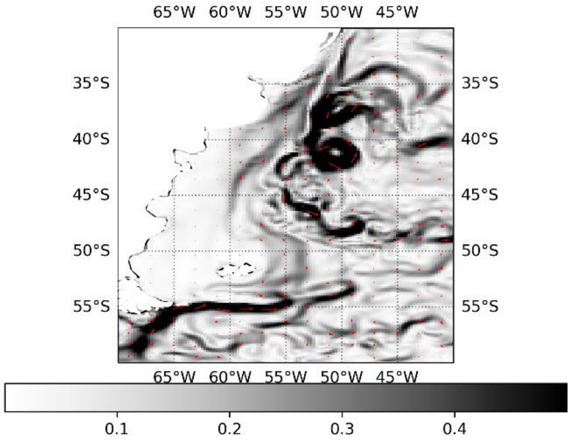
Regional results

Mean surface velocities fields for July 2009: S Atl WBC

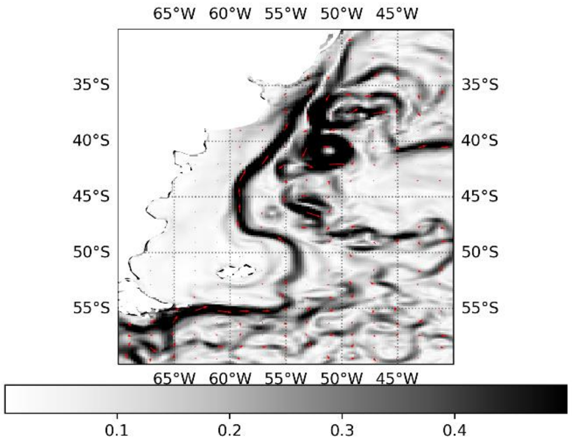
NR



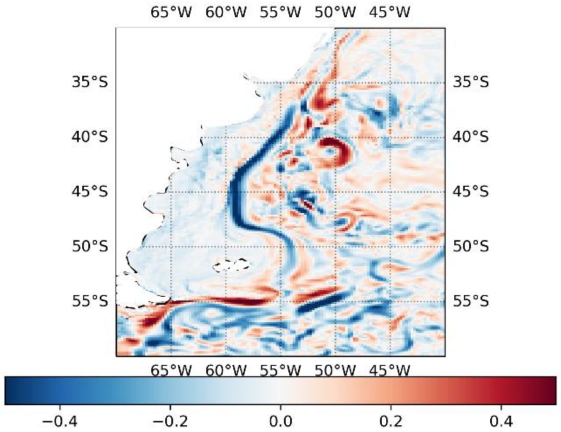
control

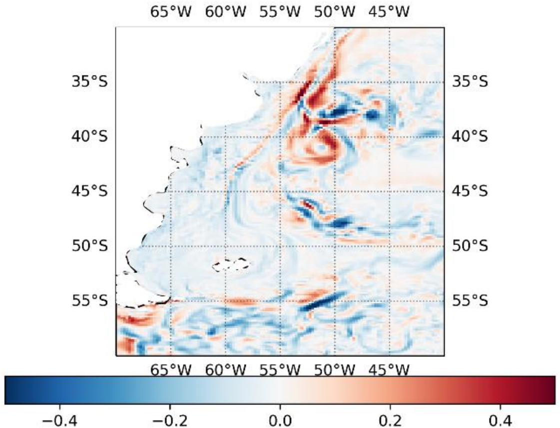


TSCV assim exp

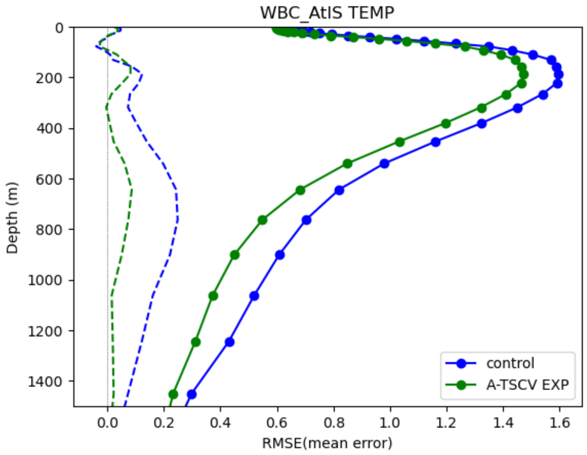


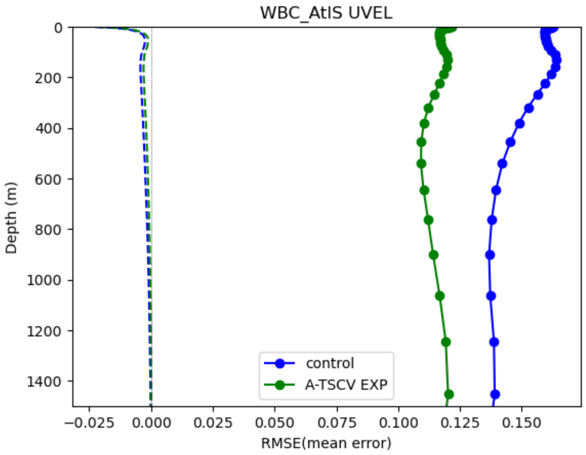
Exp minus NR

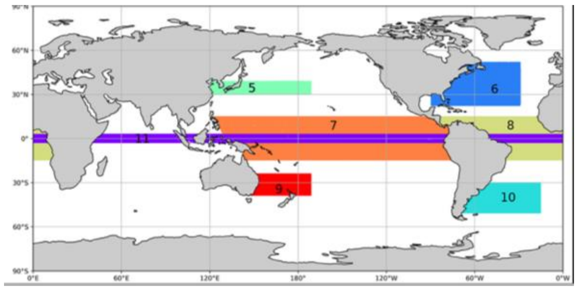


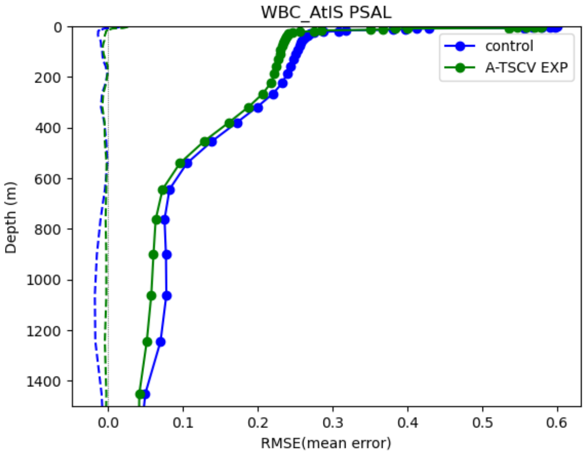


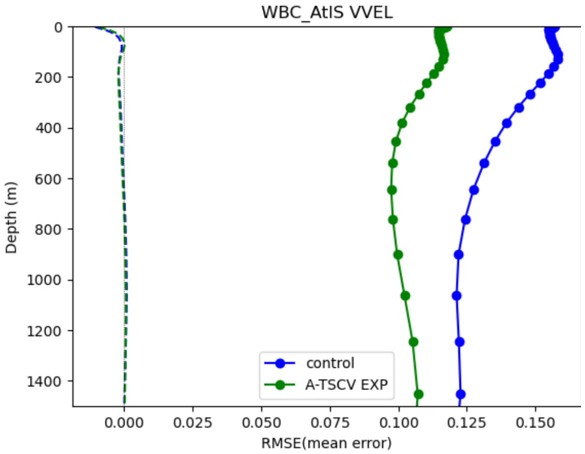
Regional statistics: Feb-July 2009 – S Atl WBC

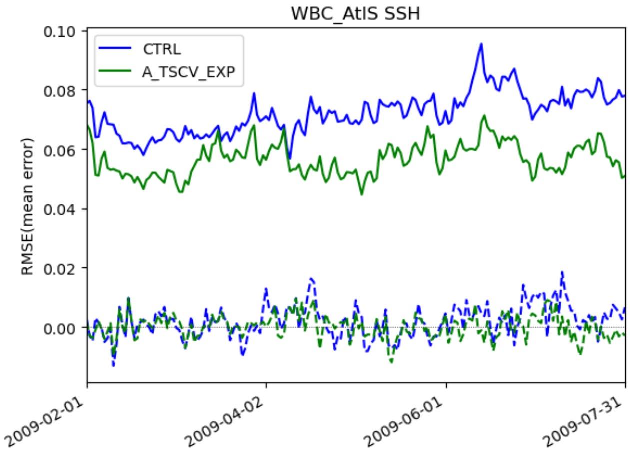






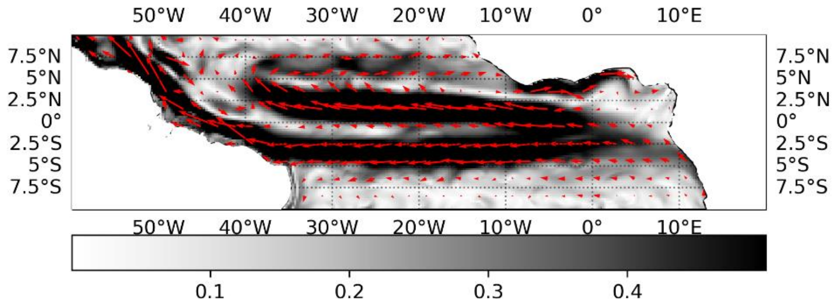






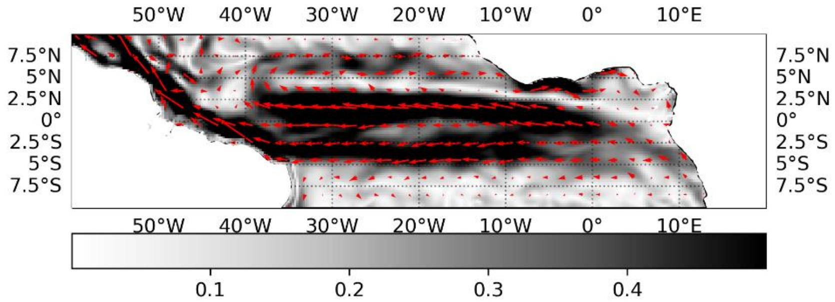
Mean surface velocities fields for July 2009: Tropical Atl

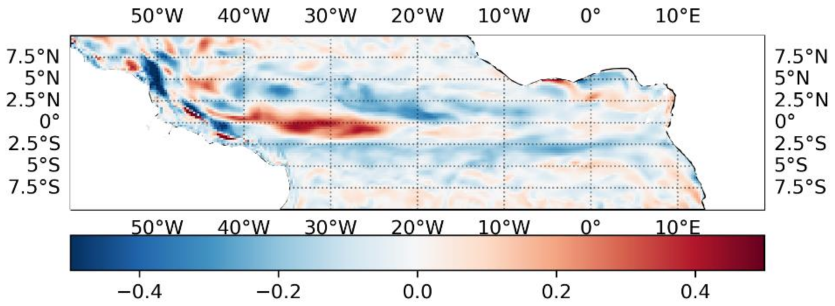
NR



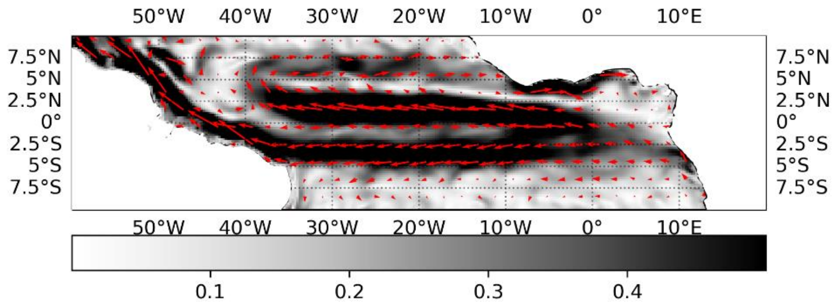
Exp minus NR

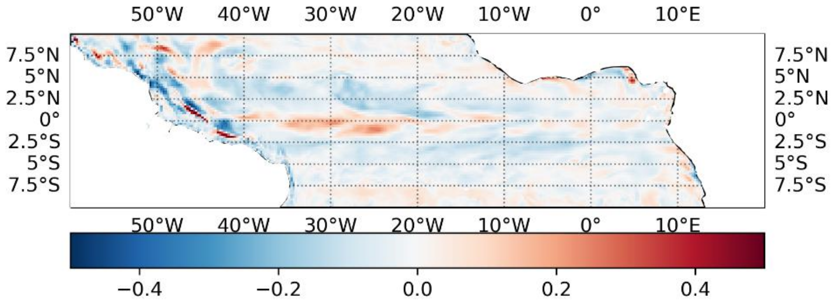
control



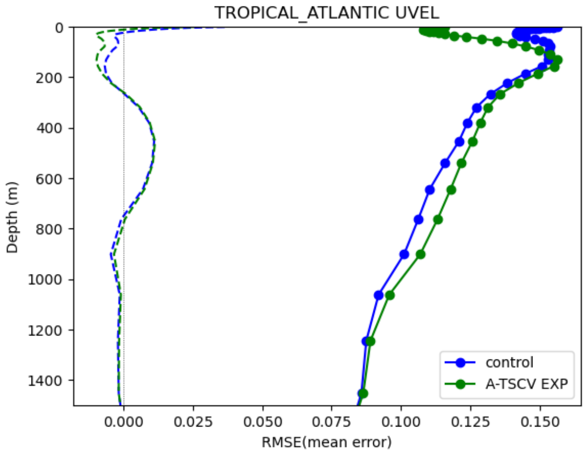


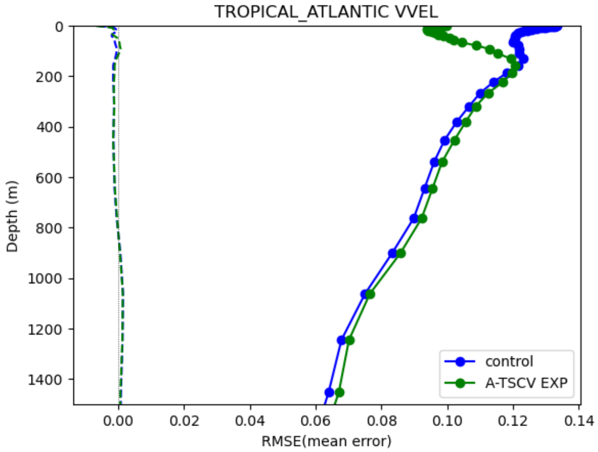
TSCV assim

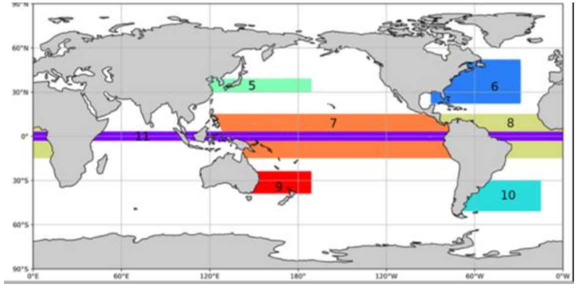


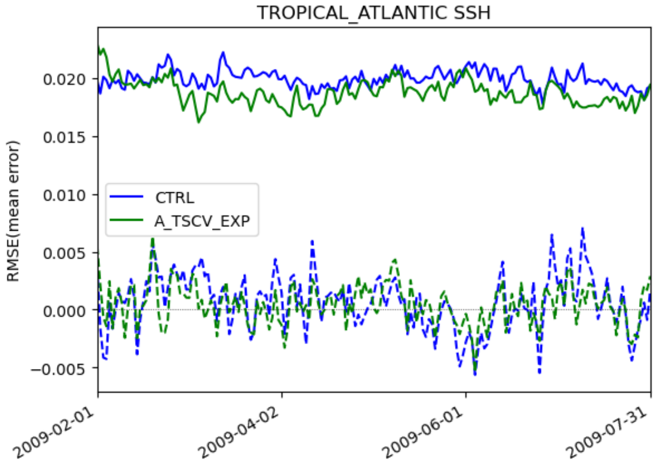


Regional statistics: Feb-July 2009 – Tropical Atl



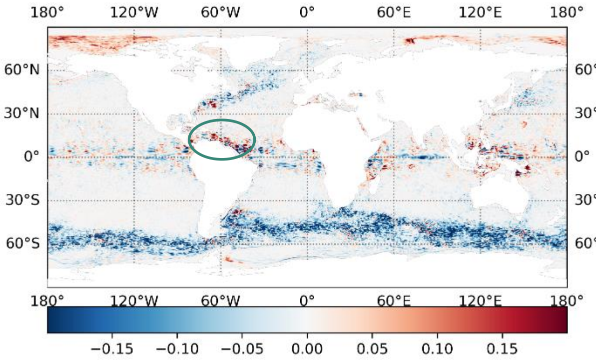






Subsurface degradations to U RMSE in the Tropical Atlantic primarily occur in the Amazon outflow region – known deficiency in this region which appears to be exacerbated by extra obs sampling.

Difference in U RMSE for the control and A-TSCV exp: July 2009 at 220m depth

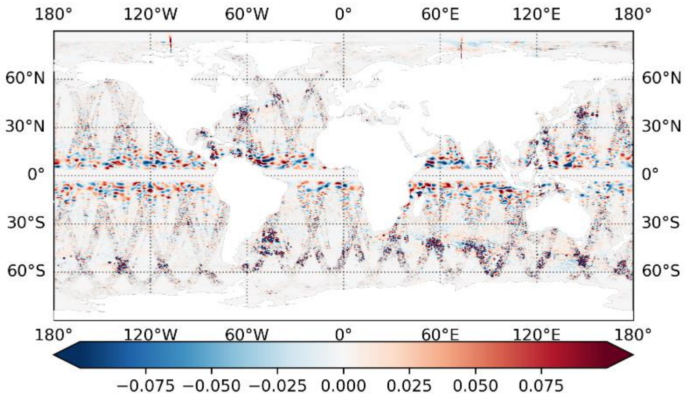


Assessing the ageostrophic component of the assimilation

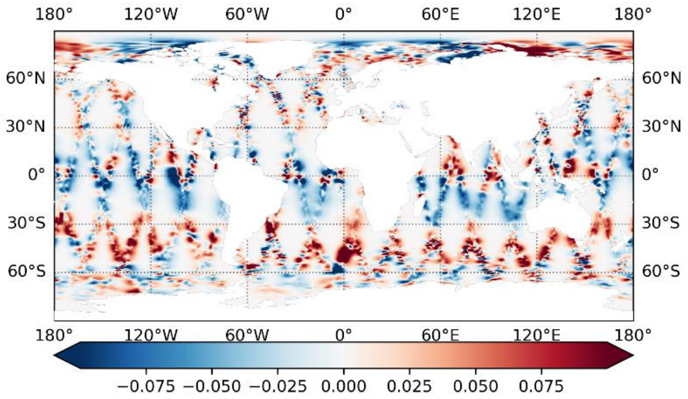
Balanced and unbalanced increments for 1st July 2009

TSCV assim

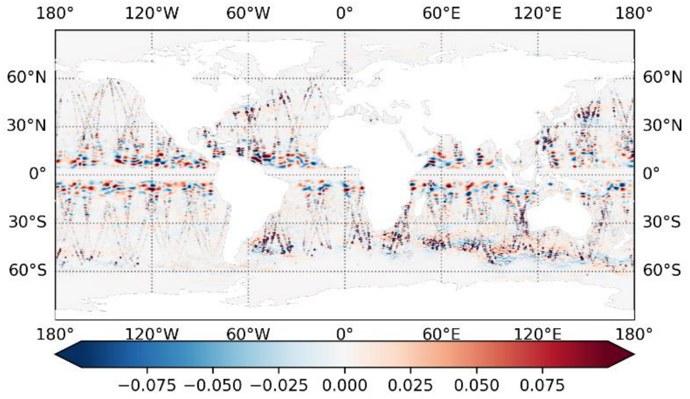
Bal (geostrophic) U increment



Unbal (ageostrophic) U increment



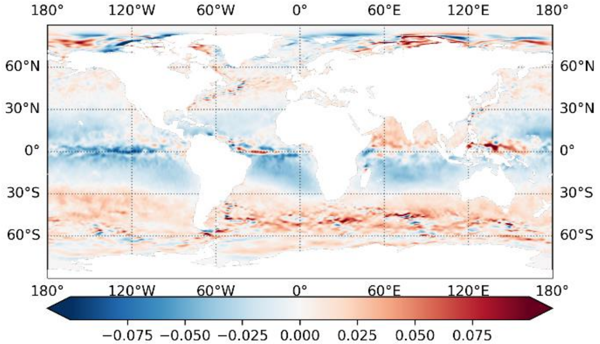
control



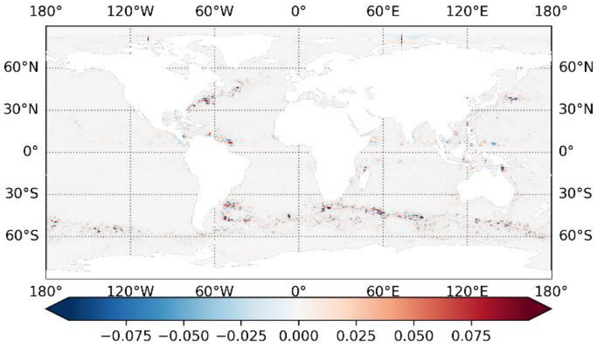
Mean fields for July 2009

TSCV assim

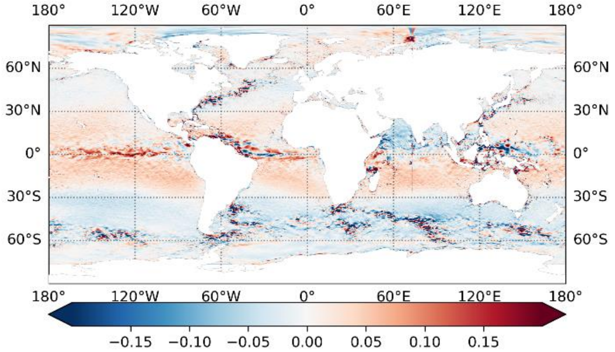
Mean Unbal U increment



Mean Bal U increment

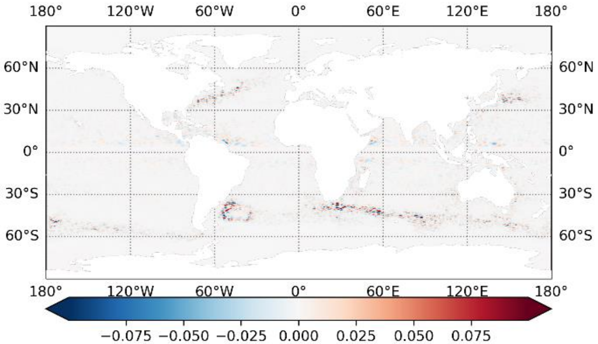


TSCV assim minus NR - SSU

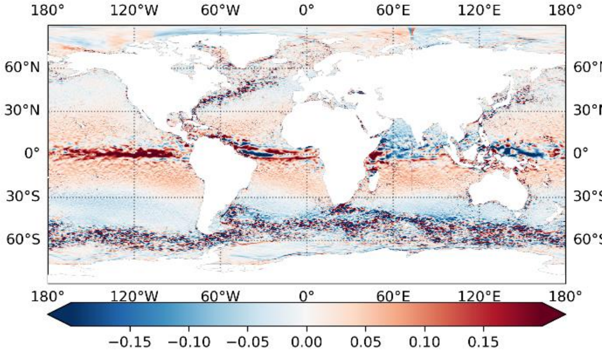


control

Mean Bal U increment



control exp minus NR - SSU

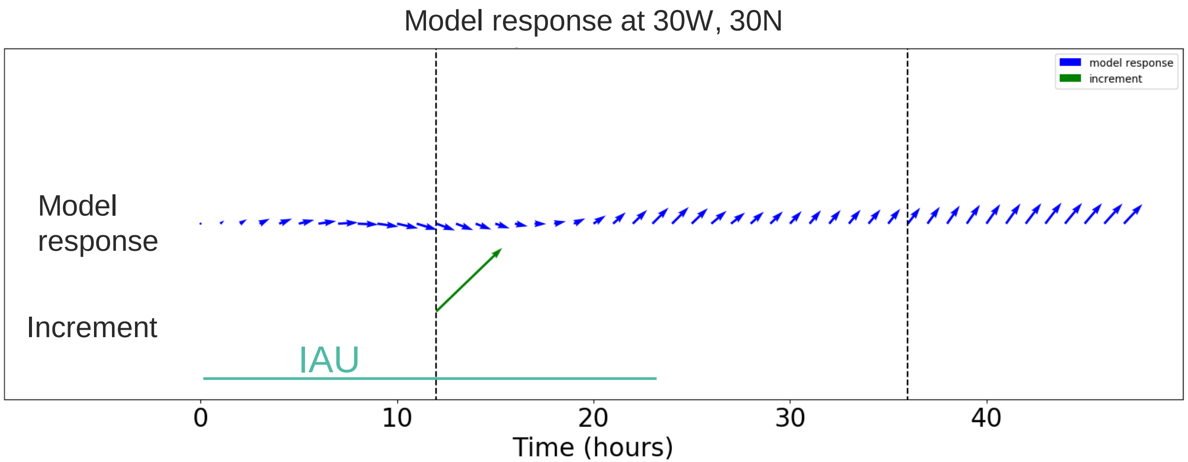


Areas for improvement

- Large scale increments relating to a bias in the mean wind driven component of the TSCVs do not appear to be well retained in the model – a bias in the forcings?

- Increments will also not be well retained in regions where near inertial oscillations dominate
  - 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.

Model response when an increment valid at 12 hours is incrementally applied during the 24 hour IAU



Summary

- Assimilation of simulated TSCV observations in an OSSE framework produces an improvement in global RMSE statistics for all variables
    - SSU errors are reduced by ~3cm/s, SSV errors are reduced by ~3.5 cm/s and SSH errors are reduced by 1cm.

- Degradations in the subsurface in some complex regions such as the Amazon outflow

- Significant improvements in the boundary current regions (e.g the Malvinas current), the ACC and the equatorial currents.

- Assimilation could potentially be improved further by improving retention of the unbalanced increments

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Future work

- Assessment for full year
- Assess on which timescales the TSCV assimilation is improving the currents
  - Spectral assessment
  - Lagrangian drift assessment
- Assimilation of TSCV data with further obs error (unbiased white noise initially)
- Implement inertial oscillation assimilation
- Comparisons to the MOI OSSEs

Determine a set of requirements from the operational ocean forecasting community for future satellite missions measuring surface ocean currents