MERCATOR OCEAN INTERNATIONAL

The impact of assimilating simulated satellite surface velocities in the Mercator analysis and forecasting global system

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Outline

- Validation of velocities accuracy in the Mercator Océan system
  - Examples of validation performed by the Mercator Océan team
- The A-TSCV project
  - OSSE design
  - Global validation
  - Regional validation
  - Lagrangian validation
- Summary and conclusions

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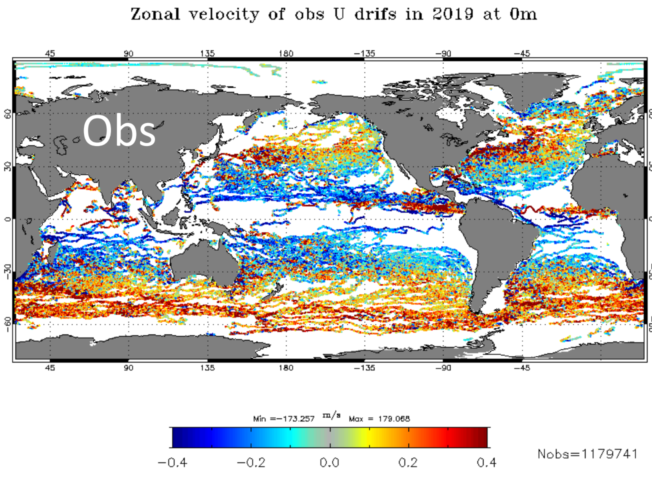
The MOI analysis and forecasting system

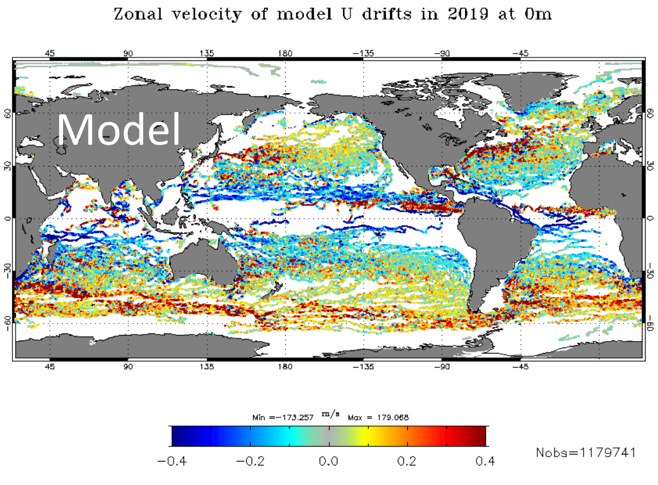
- Ocean model: NEMO 3.6
- Sea Ice model: LIM3
- Configuration:
  - Horizontal: 1/12° (~7 km at the Equator)
  - Vertical: 50 levels (22 levels in the upper 100 m)
- Atmosphere forcings: IFS (ECMWF)
- Assimilation system:
  - Reduced-order Kalman filter (SEEK)
  - 7-day assimilation window
  - Forecast error covariances based on statistics from unconstraint model state anomalies
- T and S bias correction using a 3D-VAR scheme

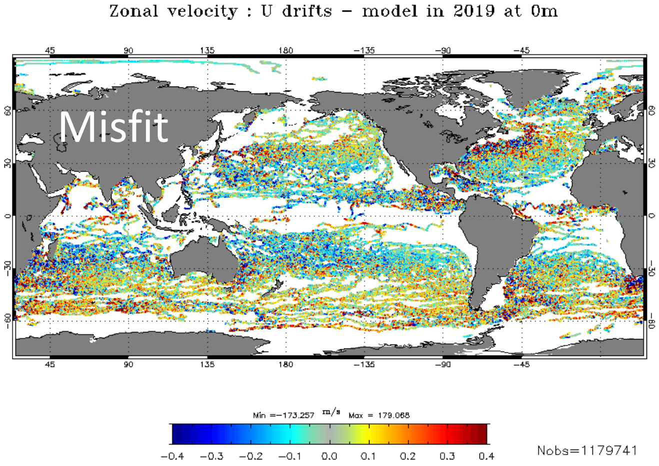
Eulerian validation at surface 1/12°

Zonal velocity comparison:

- Obs: undrogued drifters and Argo floats available in 2019
- Model: analysis counterpart

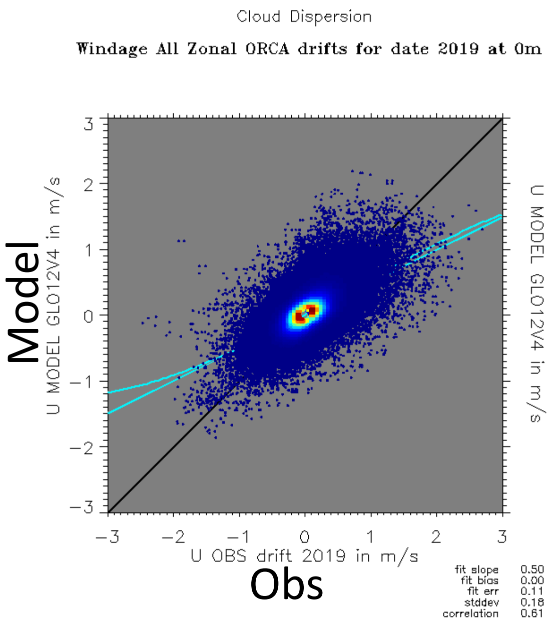


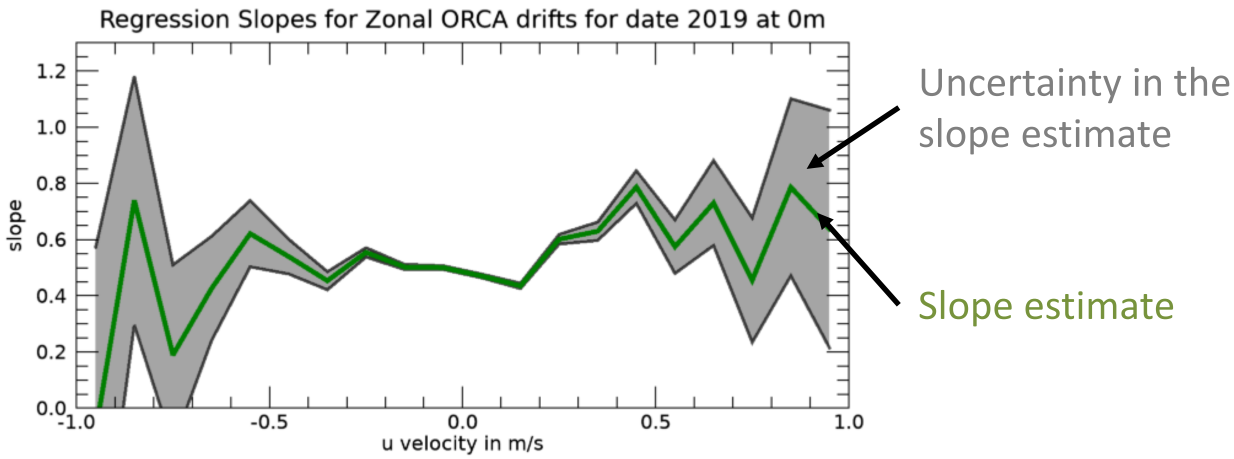




- Structures are well represented
- Velocities are generally underestimated
- This is also true for meridional velocity

Eulerian validation at surface 1/12°





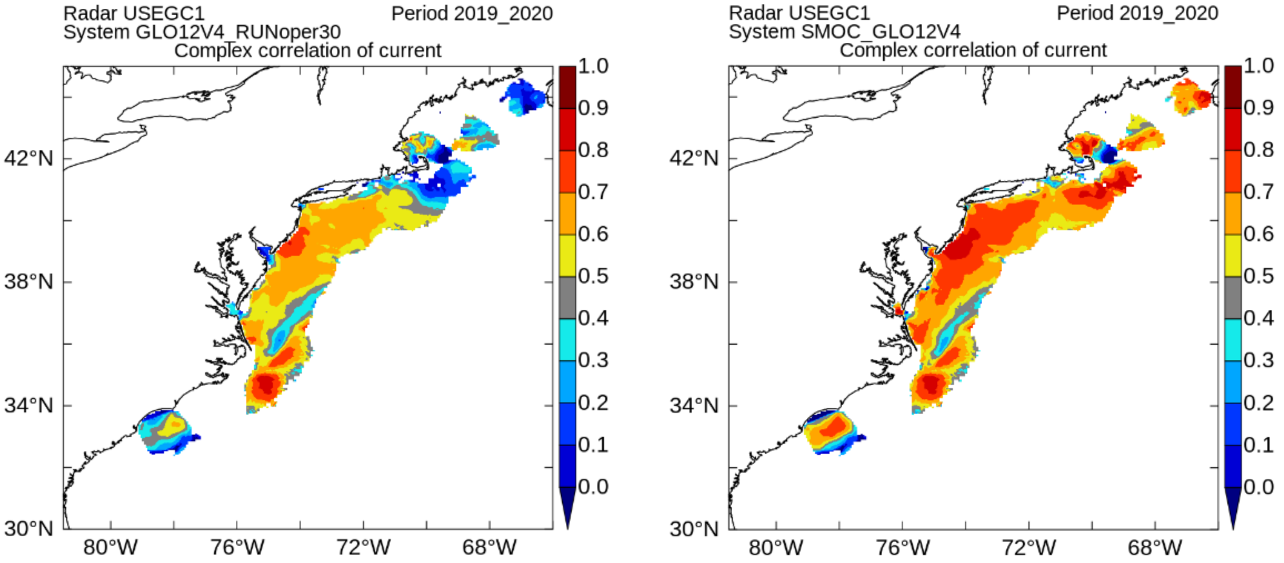
Scatter plot of observed vs modelled zonal velocity

- The general stretching of the cloud follows the y=x axis
  => linear correlation of about 0.6
- Regression slope about 50%
  => underestimation of the zonal velocities
- Slope at 70% for positive velocities > 5 cm/s
  => WBC intensity is better represented

High frequency nearshore validation 1/12°

Current correlation along the coast of New Jersey, US:

- Obs: USEG1 coastal radars for 2019-2020, including tidal signal
- Model: analysis
  - Left: alone
  - Right: with tide and Stokes drift*



Adding the tidal signal and the Stokes drift to the modelled current improves clearly the correlation with the observations.

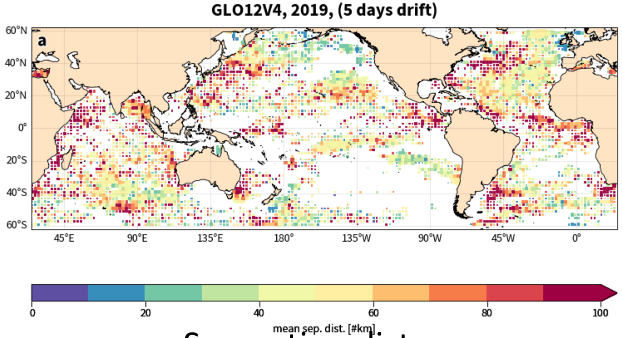
* SMOC: Surface and Merged Ocean Currents dataset.

Lagrangian validation 1/12°

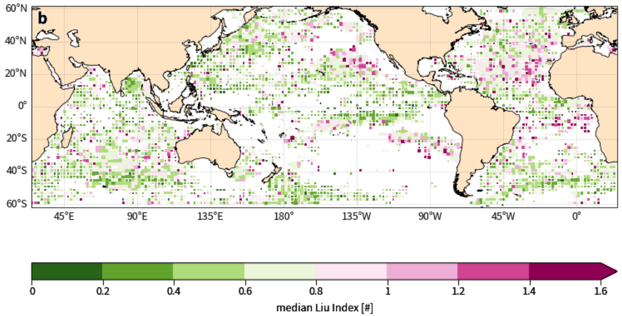
- Particle tracking software Parcels
  (Lange and Sebille, 2017)
- Comparison to obs. or other simulation
- To evaluate the distance between particles during and/or at the end of their trajectory

- Large scale Lagrangian transport well represented
- After 5 days drift, separation distance is
  - larger for dynamical regions (~100 km, up to 200 km after 5 days drift)
  - smaller for quitter regions (~30 km)
- After 5 days drift, Liu index suggests that larger error are located in outskirts of subtropical gyres

Drogued drifters vs model equivalent
15m depth, after 5 days drift



Separation distance



Sep. dist. normalised by length of trajectory
Liu index < 0.5: small error
Liu index > 1: large error

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OSSE design

Control

- Restart files: PSY3V4R1 07/01/2009
- Configuration: 1/4° (~25 km at Eq.)
- Atmosphere forcing: ERA5
- T&S bias correction off
- Forecast error covariances as oper.

A-TSCV No Err

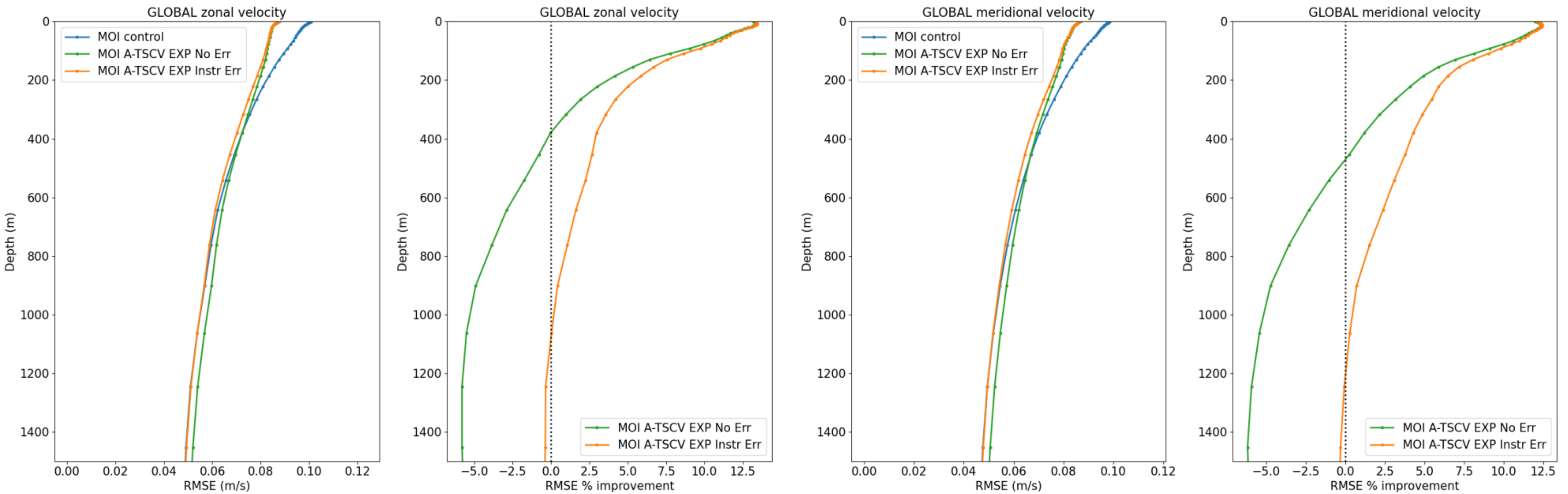
- Restart files: Control 21/01/2009
- Configuration: 1/4° (~25 km at Eq.)
- Atmosphere forcing: ERA5
- T&S bias correction off
- Forecast error covariances as oper.

A-TSCV Instr Err

- Restart files: Control 21/01/2009
- Configuration: 1/4° (~25 km at Eq.)
- Atmosphere forcing: ERA5
- T&S bias correction off
- Forecast error covariances as oper.

Experiment	Assim SST	Assim T/S profiles	Assim SSH	Assim SIC	Assim TSCV	TSCV Errors
Control	✓	✓	✓	X	X	
A-TSCV No Err	✓	✓	✓	X	✓	mapping only
A-TSCV Instr Err	✓	✓	✓	X	✓	Mapping + Instrument error

Global assesment : 25/02/2009 – 29/12/2009



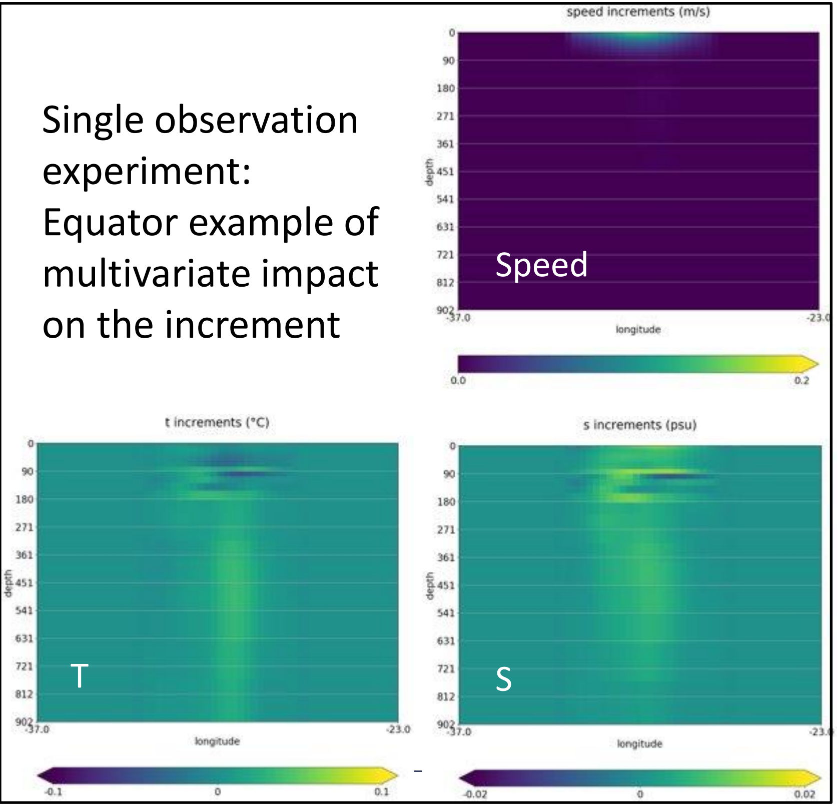
m/s Zonal velocity % m/s Meridional velocity %

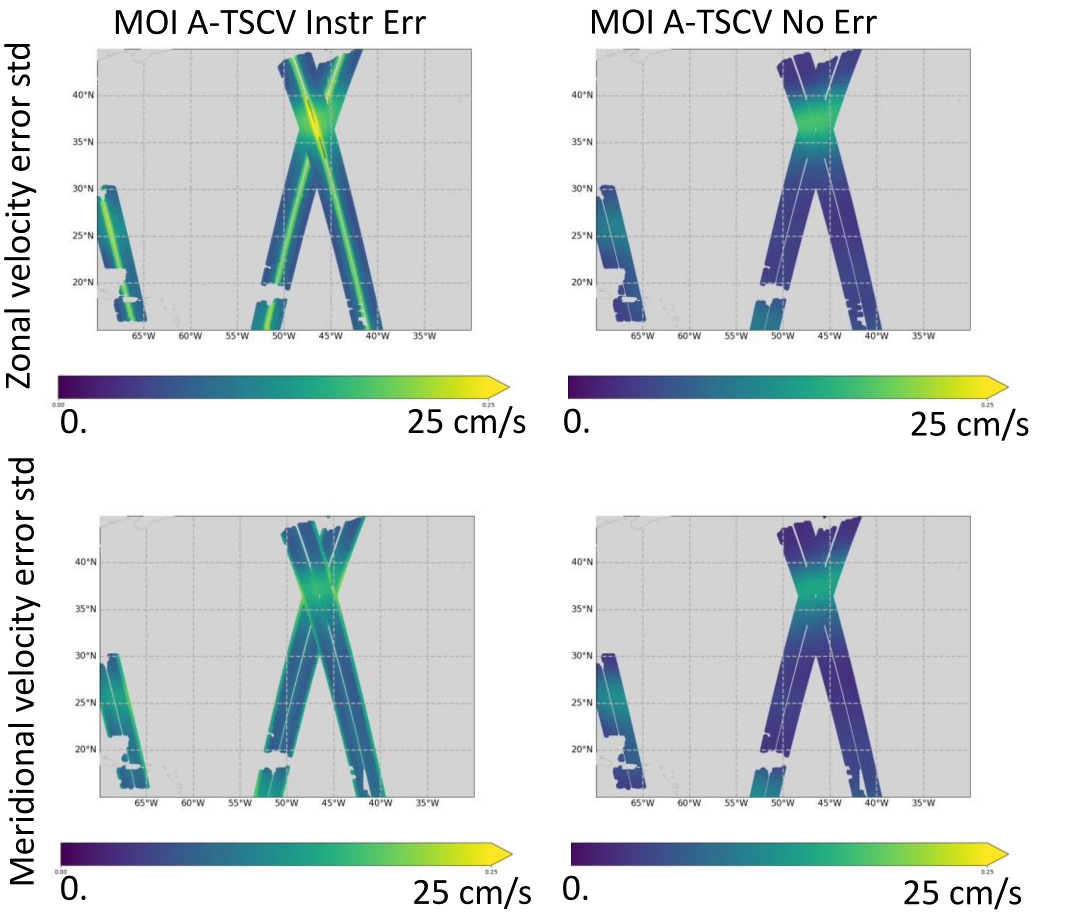
- Velocity is improved of 12.5% (~1.2 cm/s) at surface
- Velocity is improved down to 400m (No Err) and 1000 m (Instr Err)
  - Discrepancy possibly due to “inconsistency” between number of obs. and σ°

TSCV observation error standard deviation

Number of observations: ~3.3 millions / day
Thinning 1/2 observations: ~1.6 millions / day

Single observation experiment:
Equator example of multivariate impact on the increment

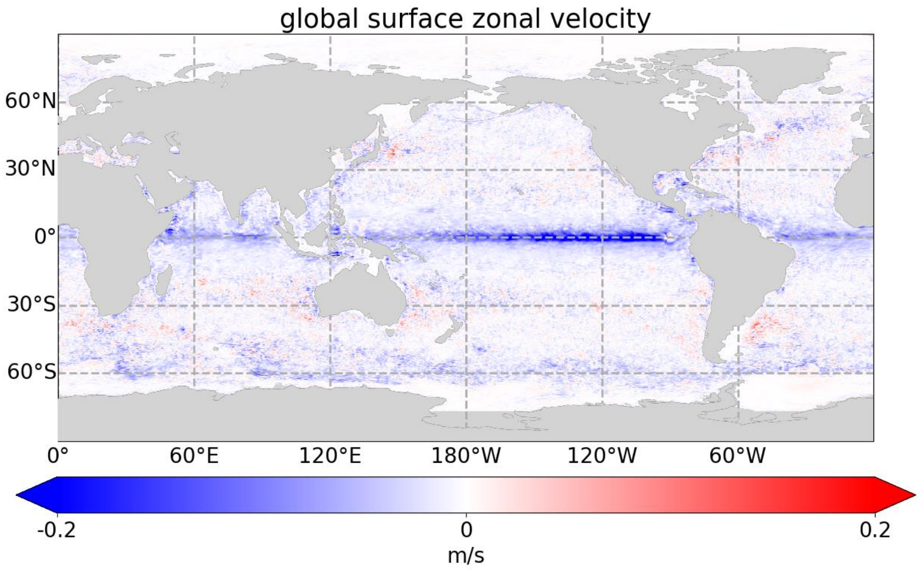


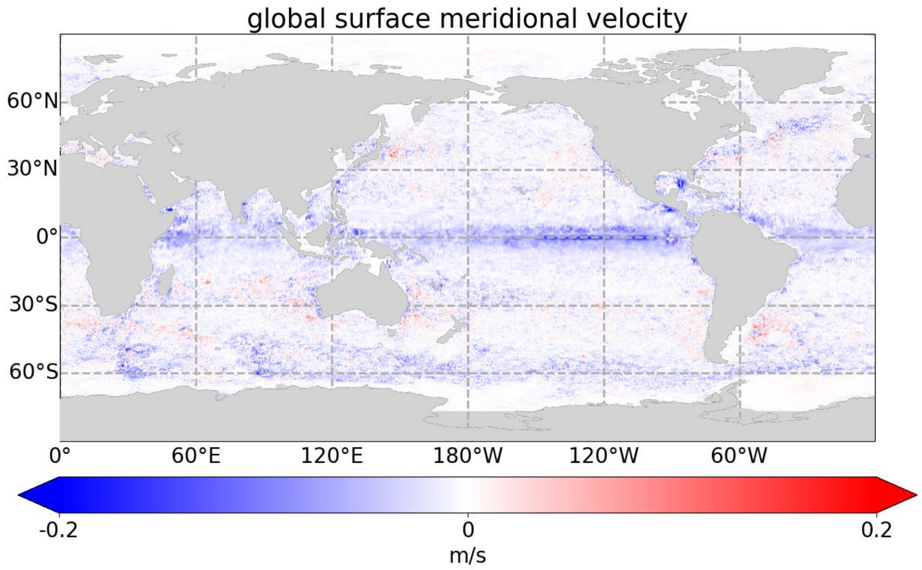


Global assesment : 25/02/2009 – 29/12/2009

|A-TSCV – NR| RMS - |Control – NR| RMS

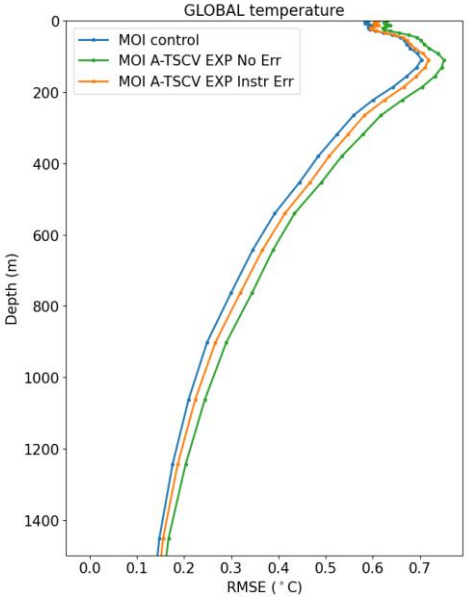
No Err closer to NR
Control closer to NR

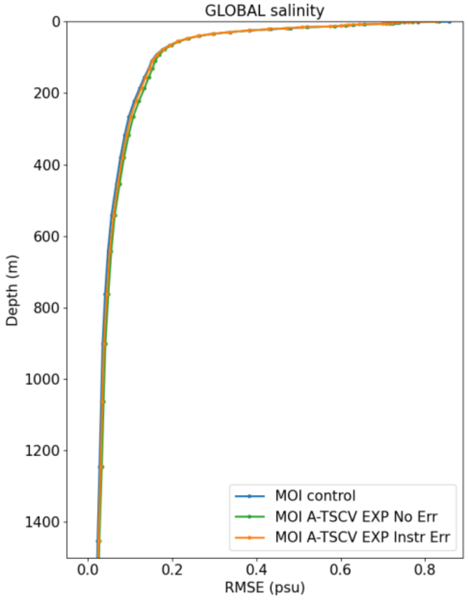


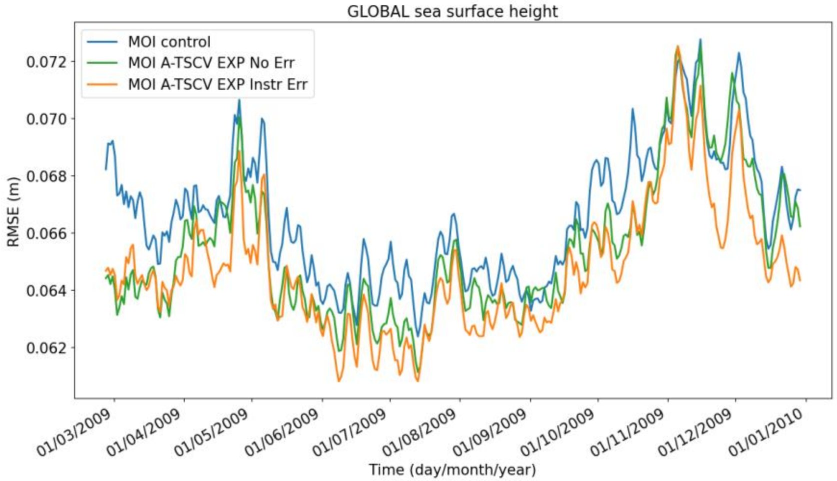


Assimilating TSCV data has a general positive impact at surface globally
The best improvement is located at the Equator

Global assesment : 25/02/2009 – 29/12/2009

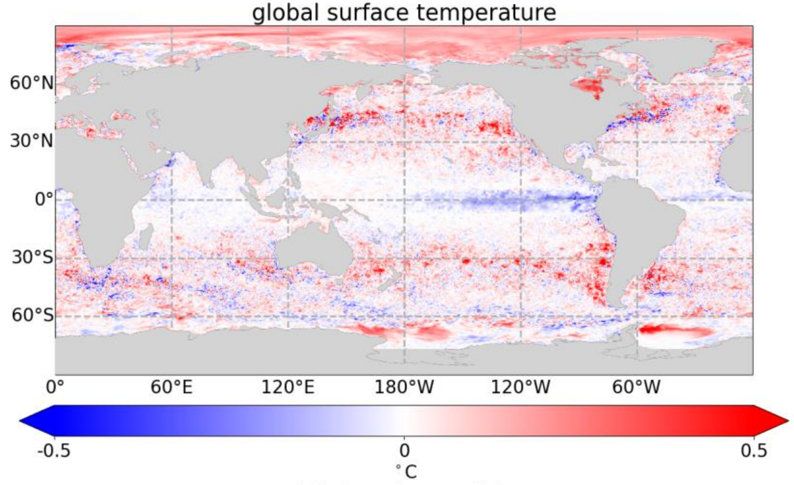






- Degradation of ~0.06°C (No Err) and ~0.03°C (Instr Err) for temperature
- Slight degradation below surface for salinity
- Some seasonal variations for temperature and salinity at surface
- Slight improvement of ~2 mm for SSH

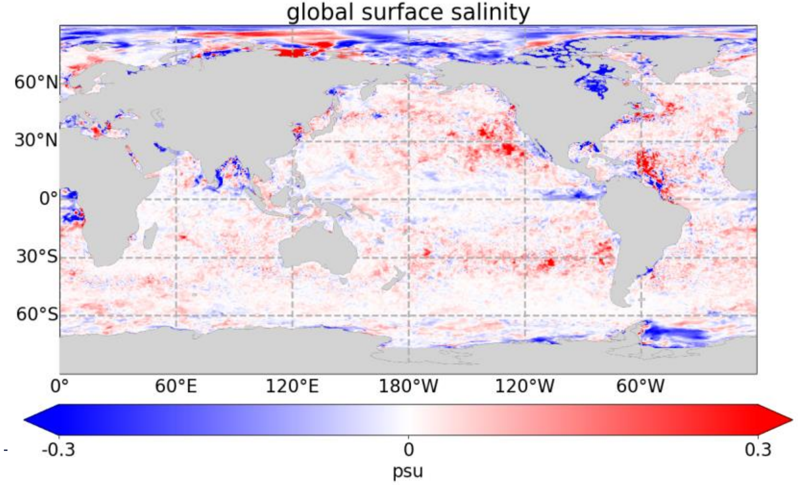
Global assesment : 25/02/2009 – 29/12/2009

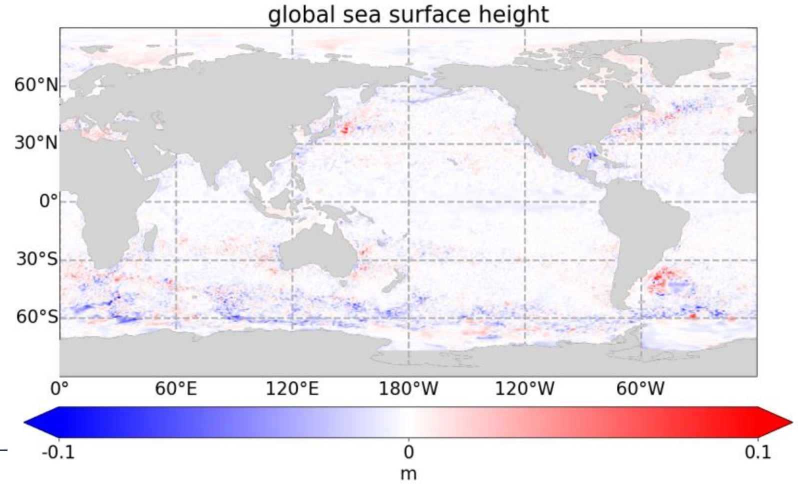


|A-TSCV – NR| RMS - |Control – NR| RMS

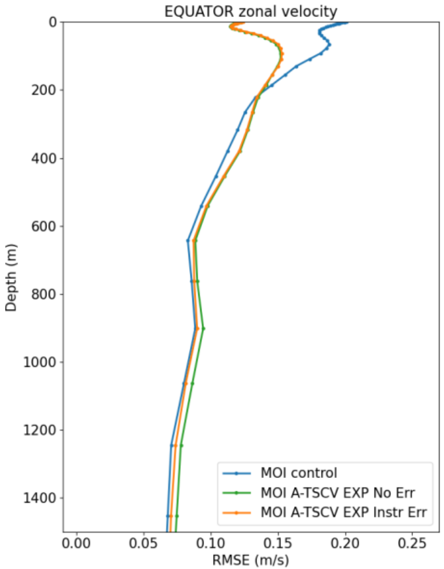
No Err closer to NR / Control closer to NR

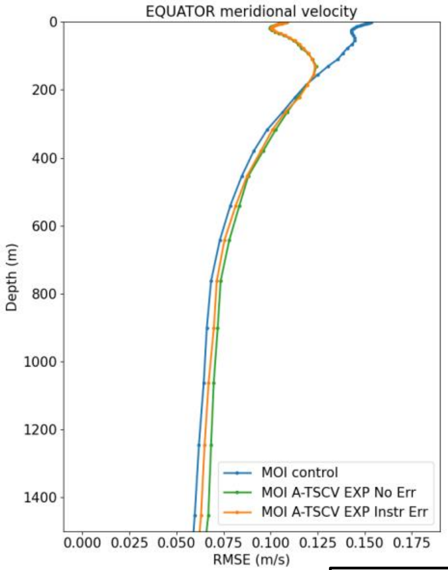
- Temperature and salinity are mostly degraded out of the Equator
- SSH patterns are similar to velocity patterns (except Equator) => geostrophy

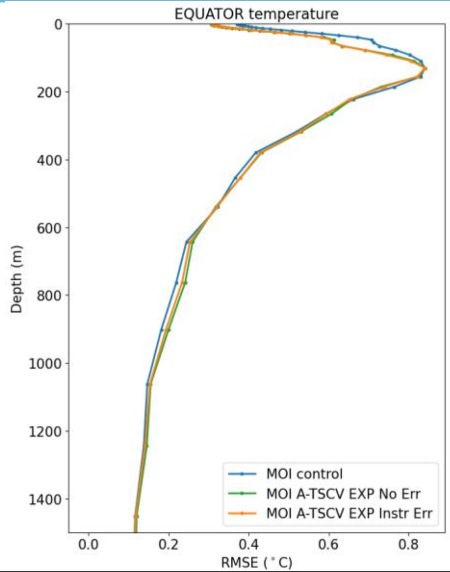


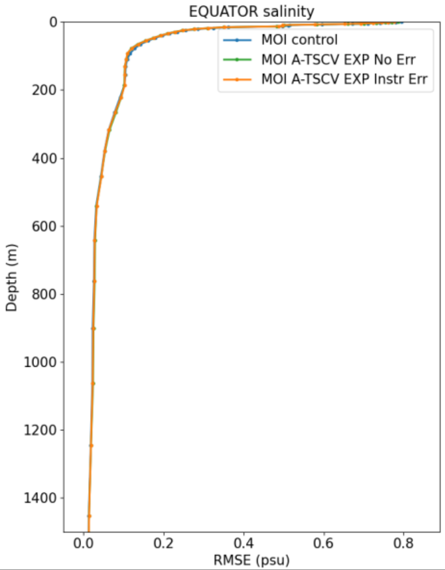


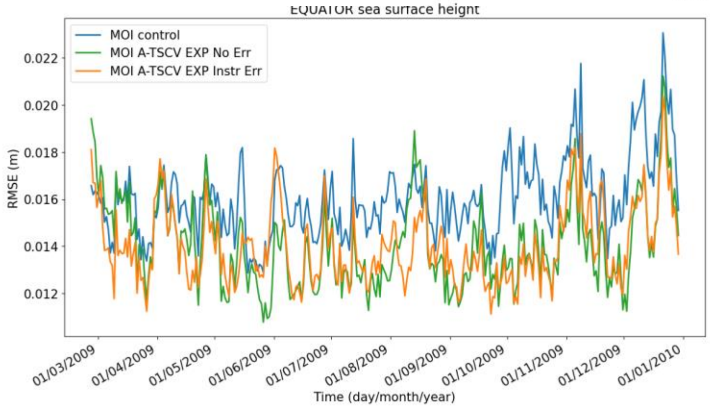
Equator assesment : 25/02/2009 – 29/12/2009





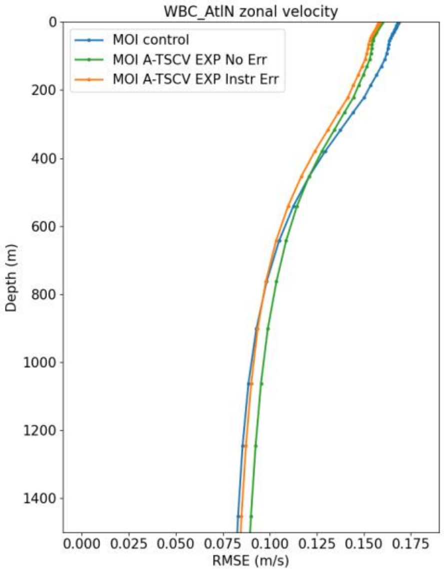


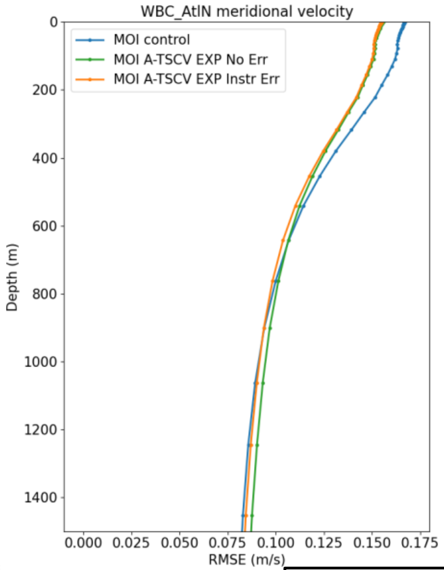


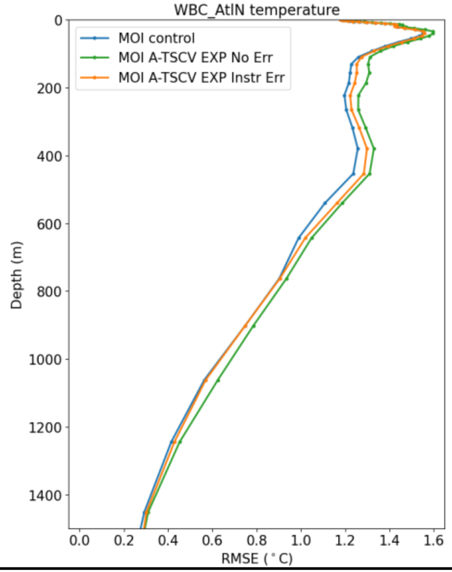


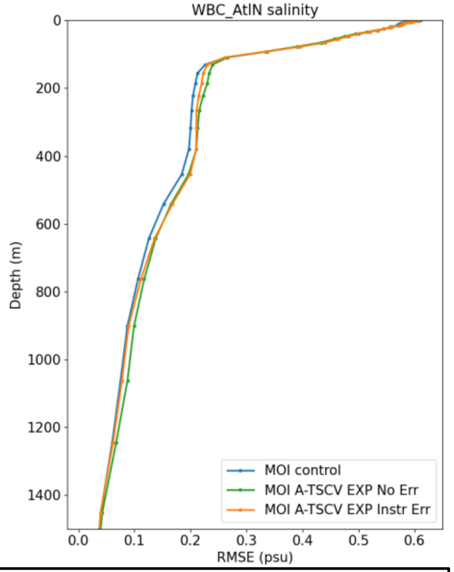
- Improvement at surface for all variables (up to 40% and 30% for U and V, respectively)
- Slight degradation below 200 m for all variables => spurious multivariate impact?
- Improvement of 10% (~2 mm) for SSH => ageostrophy from multivariate error covariance

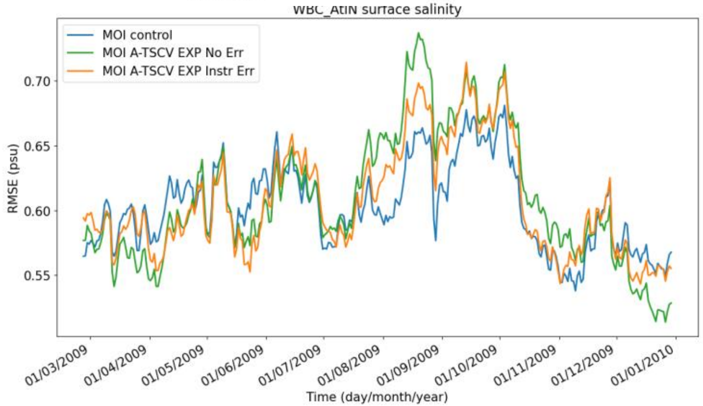
Gulf Stream assesment : 25/02/2009 – 29/12/2009











- Velocity improved of 6% (~1 cm/s), degradation below 500 m (No Err) and 800 m (Instr Err)
- Slight degradation for temperature and salinity below surface
- Some seasonal variations for temperature and salinity at surface

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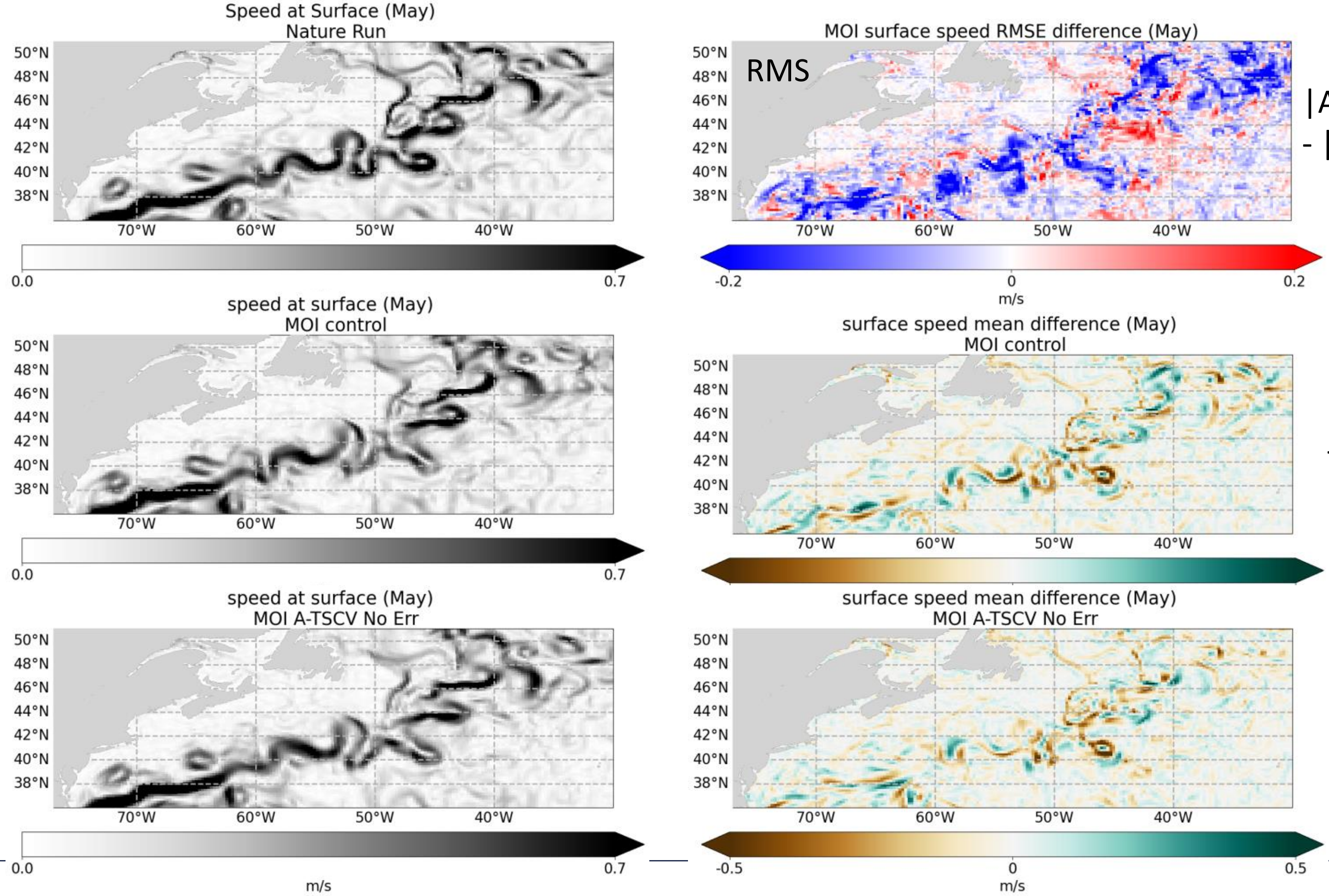
Gulf Stream assesment : May 2009 mean

NR mean

Control Mean

A-TSCV mean

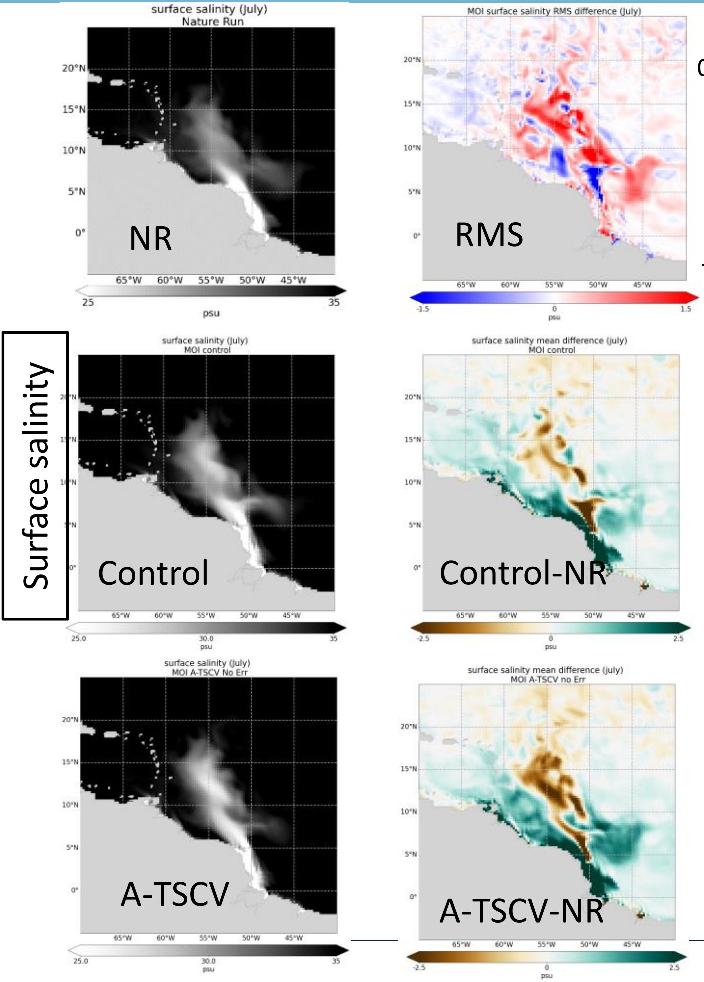


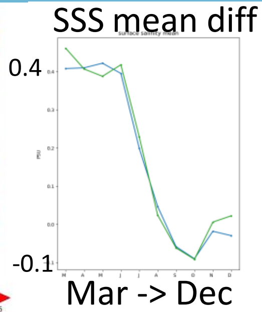
|A-TSCV – NR| RMS
- |Control – NR| RMS

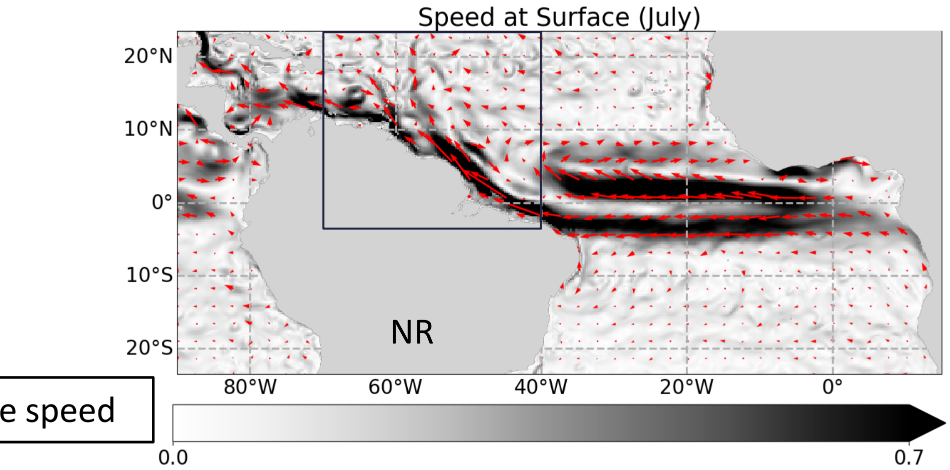
|Control mean|
- |NR mean|

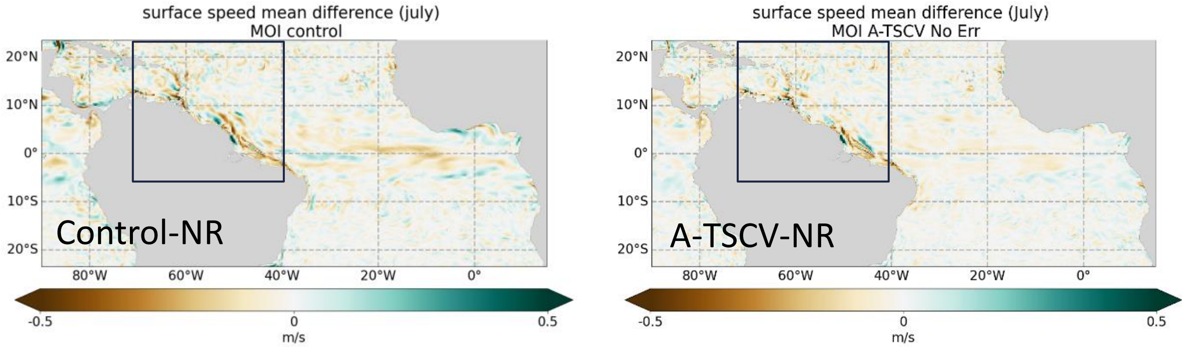
|A-TSCV mean|
- |NR mean|

Amazon mouth: July 2009 mean



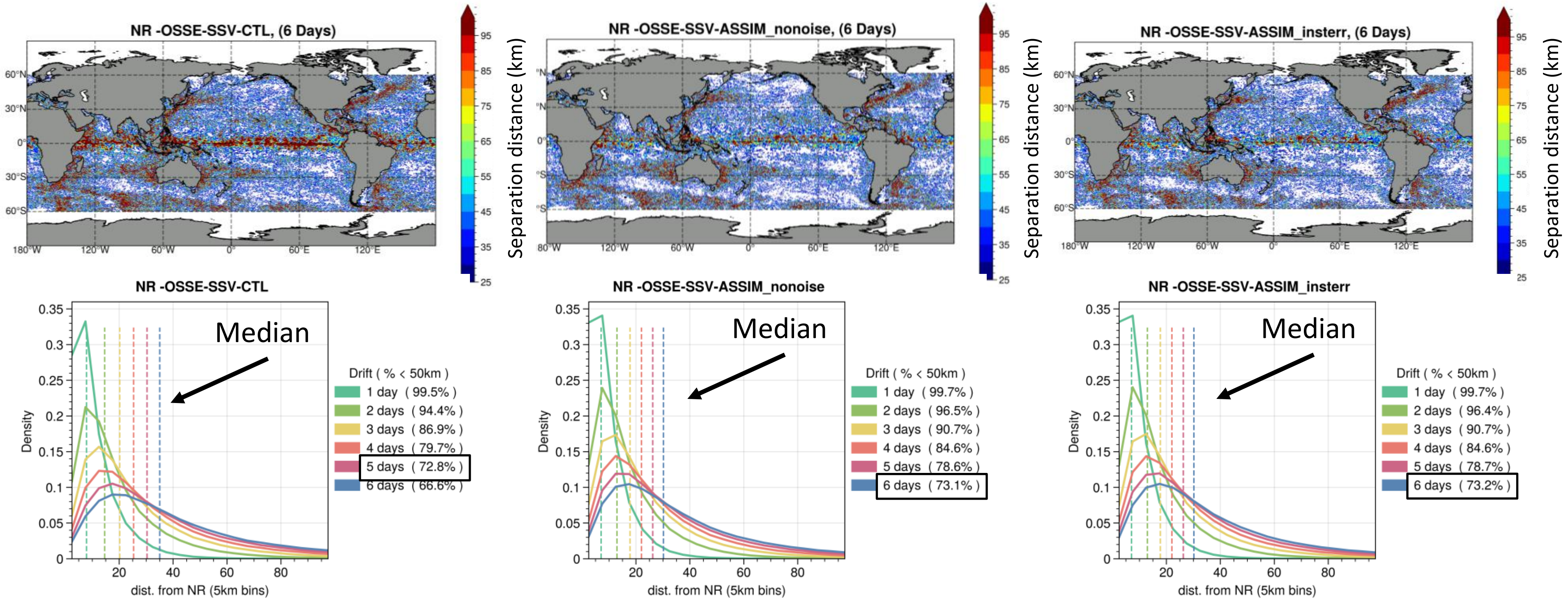






A better representation of a strong Guiana current degrades the surface salinity in the Amazon plume

Lagrangian assesment: 09/09/2023 – 15/09/2023



511 963 particles
Released on 09/09
6 days advection

- Average of 5 km improvement after 6 days drift for A-TSCV exp.
- Proportion of particles < 50 km improves by 10% wrt Control
  => 1 day drift gain

Thanks to Simon Van Gennip

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Summary and conclusions

- Diagnostics are performed to assess the velocities in the MOI system
  - Velocity structures well represented but intensity generally underestimated
  - Tidal signal and Stokes drift are important components of the total current

- OSSEs designed for assessing the impact of assimilating TSCV data
  - Surface velocities are improved in all dynamical regions
  - Velocities are slightly degraded at depth
  - Temperature and salinity are often slightly degraded
  - Few impact on SSH
  - Error covariances possibly need some work

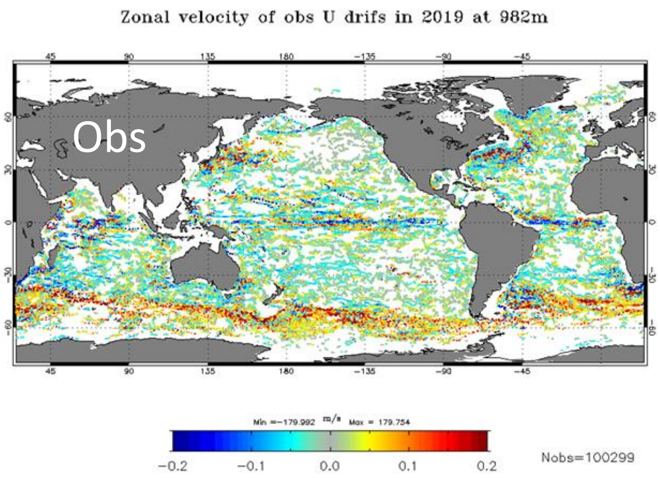
Summary and conclusions

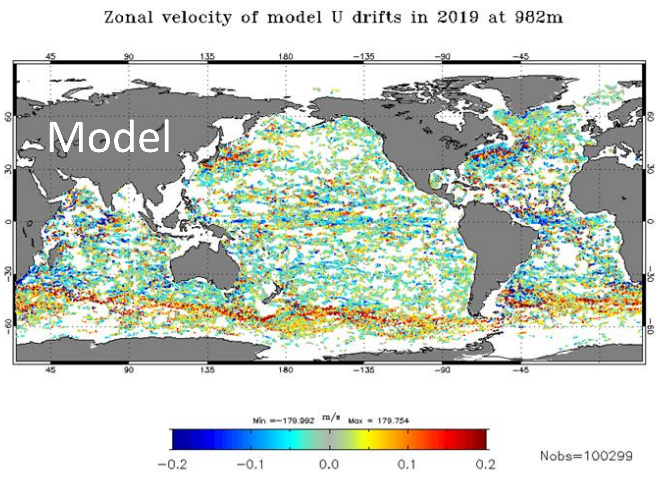
- OSSEs designed for assessing the impact of assimilating TSCV data
  - Equator region is improved in the upper 200 m for all variables
  - Velocities are improved in the upper 800 m of Gulf Stream but temperature and salinity are slightly degraded
  - A better representation of the currents has a detrimental effect on the salinity in the Amazon plume
    - River mouth strategy? need salinity obs around river mouths?
  - Assimilating TSCV data allows us to gain a 1-day drift in the separation distance of particles

- Future work
  - Thinning / superobbing of observations wrt to observation error
  - Multivariate error covariances
  - Rethinking specific strategies at particular locations

Extra slides

Eulerian validation at 1000 m 1/12°





Zonal velocity comparison:

- Obs: YomaHa drifts at 1000 m
- Model: 10-day averaged analysis

Note that this validation can be very rough locally

- Large scale structures are well represented
- Velocities are not underestimated out of the Tropics
- This is also true for meridional velocity