Ocean Predict

SYMPOSIUM OP'24 In partnership with unesco Intergovernmental Oceanographic Commission

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Observing and assimilating total surface velocities from space: Challenges and perspectives for OOF with the ODYSEA mission

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Ocean surface velocity in Operational Oceanography

Accurate ocean surface currents are critical for a large diversity of short-term real-time ocean prediction applications but also for improved interaction with the atmosphere for weather and climate.

Today observation platforms for direct and indirect estimation of surface velocities:

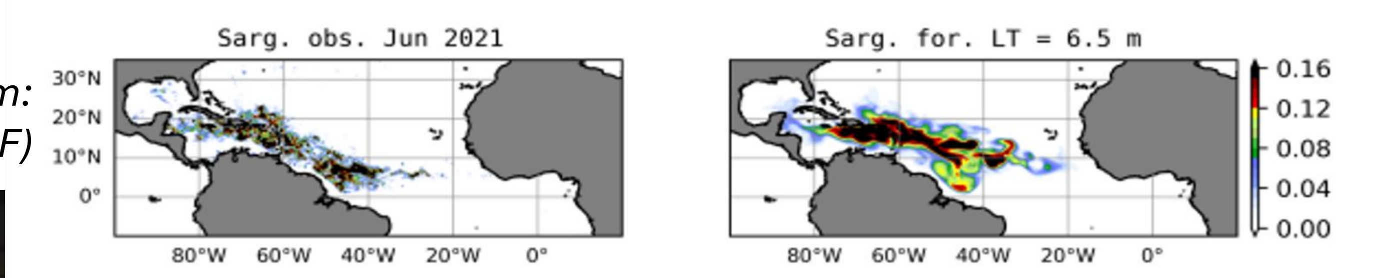
Open ocean: Moored current meters, fixed and ship-based ADCPs, geostrophic currents from altimetry except in the tropics, total current from drogued and undrogued drifter, *AIS -> sparse*

Coastal ocean: High-Frequency Radars (HFR) -> *local*

Expected benefits to operational ocean forecasting of observing TSCV data from space at global scale:

- Improved accuracy of surface current forecasts through their assimilation, and associated improvements to the currents at depth and other model variables for transport of pollutants and harmful algae, navigation, search and rescue, ...
- Improved representation of surface currents through ocean model improvements based on model-observation comparisons.
- More reliable qualification of surface current in ocean analysis and forecast for provision to users.
- Improved coupled models through better representation of momentum exchanges between ocean, waves, sea-ice and atmosphere.

Sargassum drift prediction system:
SeSaM project (CNES/IRD/CLS/MF)

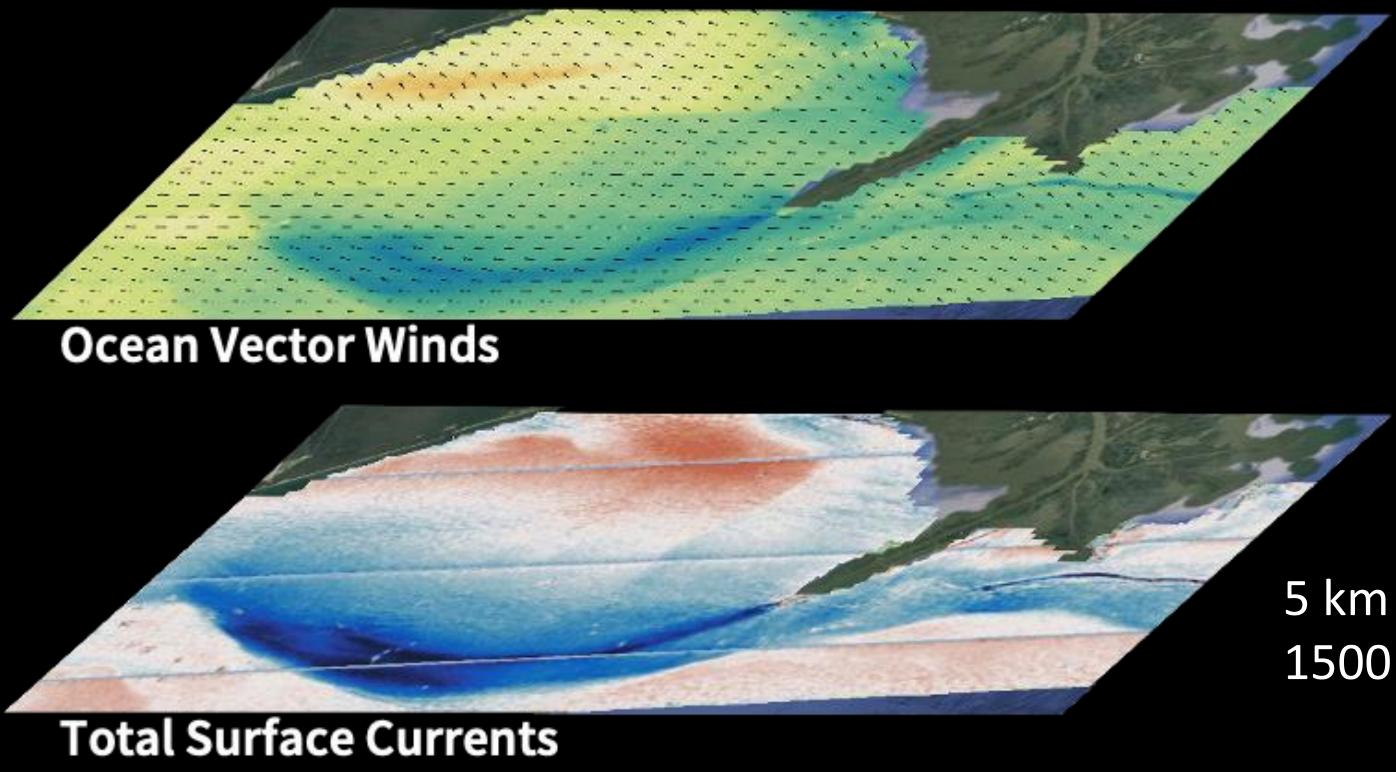


ODYSEA

Ocean Dynamics and Surface Exchange with the Atmosphere

ODYSEA's Ka-band Doppler Scatterometer

Provides the **first-ever** global measure of total surface currents.
Includes simultaneous ocean vector winds with improved resolution for coupled air-sea science and applications closer than ever to the coast.



Earth System Explorer proposal to NASA with strong support from CNES (+ US Space Force).

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PI: Sarah Gille sgille@ucsd.edu

Deputy PIs: Melanie Fewings (Oregon State), Mark Bourassa (Florida State)

Project Scientist: Tong Lee, tlee@jpl.nasa.gov

French lead: Fabrice Ardhuin

5 km postings
1500 km swath

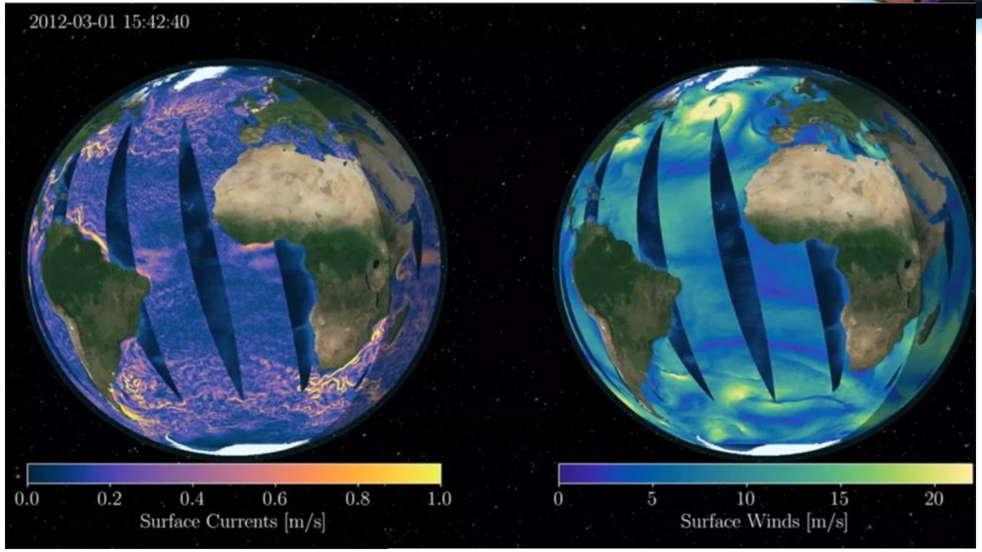
Daily coverage, near-real time

Odysea mission

The ODYSEA (Ocean Dynamics and Surface Exchange with the Atmosphere) satellite mission is a NASA/JPL and CNES proposal which will provide colocalized ocean and wind observations with a doppler scatterometer.

ODYSEA is one of four Earth System Explorer missions selected into a competitive phase A by NASA. Two will be selected in 2025 for flight in 2030 and 2032.

Having satellite measurements at the interface between the ocean and the atmosphere will help to advance our understanding of the mechanisms that drive ocean-atmosphere interaction and will improve ocean and coupled ocean/atmosphere systems.

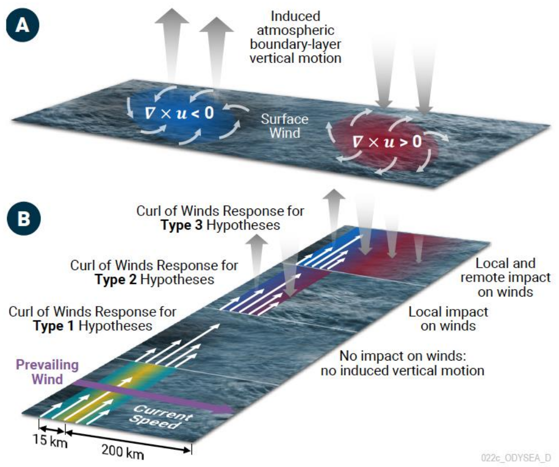


Science Objective 1: Unravel competing hypotheses of wind—current coupling

Science Objective 2: How do currents respond to wind?

Application objectives:

- Near real time winds and currents
- Storm evolution, surface waves, maritime safety, debris transport
- Support NOAA, Navy, Coast Guard Search and Rescue, Mercator Ocean international



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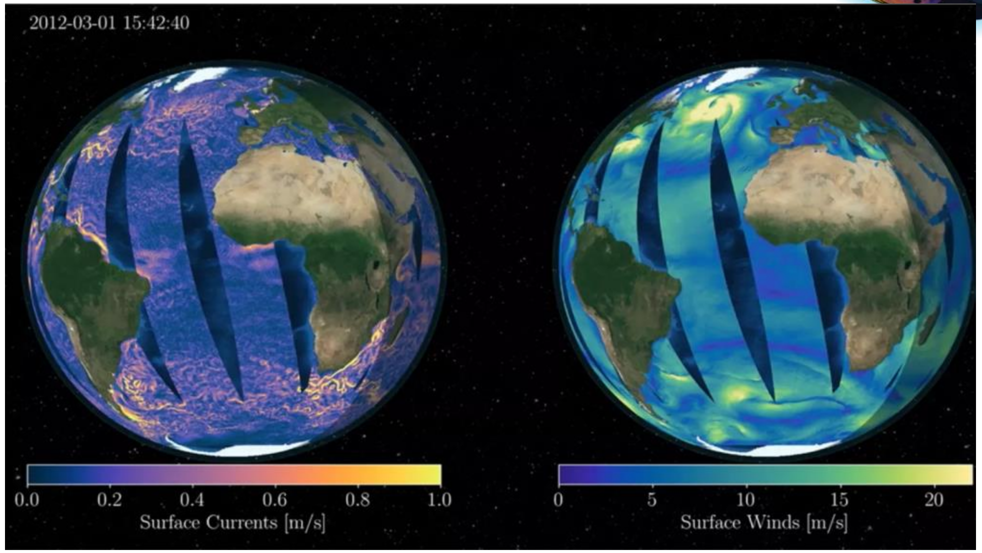

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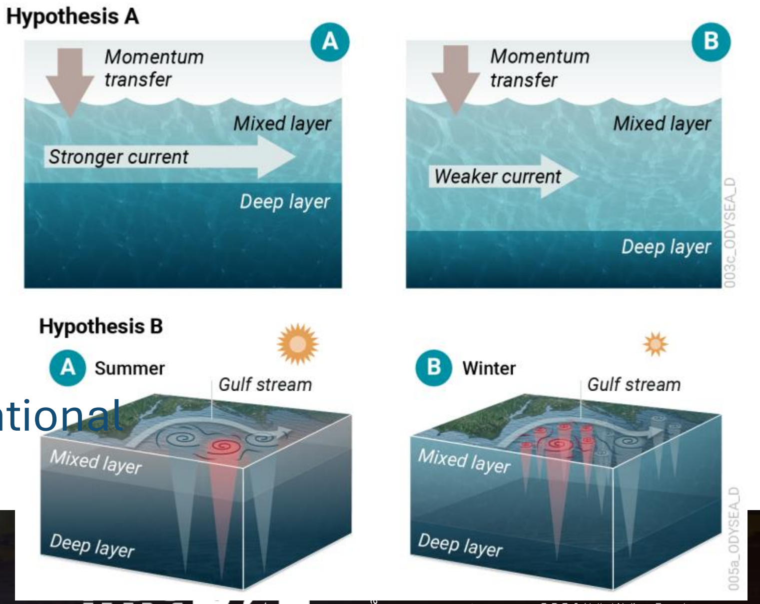
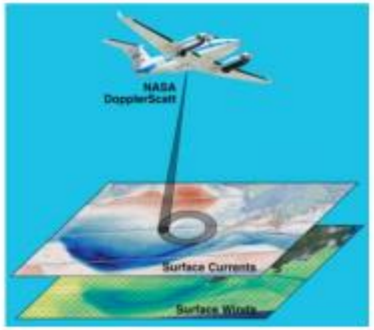
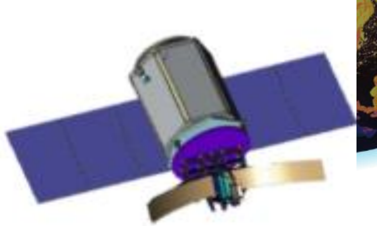


Instrument

- A single radar can measure vector winds and currents with 5 km posting.
- Building on NASA technological heritage of scatterometry (e.g., QuikSCAT) & DopplerScatt (mature airborne radar, being used in NASA EVS-3 Mission S-MODE).





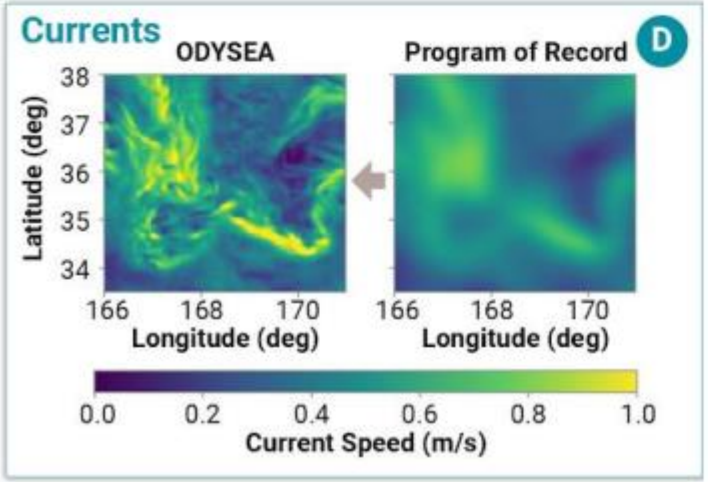
Mission Design

Swath width: >1,500 km	Orbit: sun-sync, 600 km	~90% global coverage <1 day
NRT winds/currents (<6 hour latency)	Partner organizations: JPL, Ball Aerospace, CNES, DoD, NOAA	Science Team: US and French institutions (incl. NRL & Mercator for operational ocean forecasts)

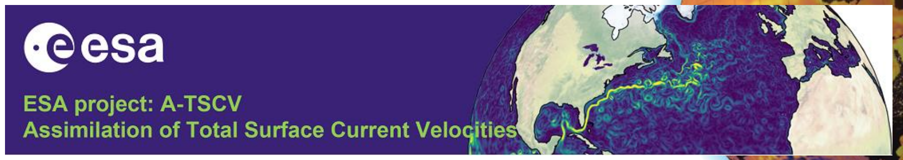
PI:
Prof. Sarah Gille
SIO/UCSD

ODYSEA (vs. present) capabilities for vector winds & currents

	Resolution	Accuracy for stated resolution	Sampling	Coastal Sampling
Vector winds	5 km (~20 km)	Speed: greater of 10% or 1m/s Direction: 20 degrees	< daily (< daily)	~2 km from coast (~25 km)
Vector surface currents	5 km (>200 km)	U/V components: < 50 cm/s	< daily (~weekly)	~2 km from coast (~30 km)



Global OSSEs – ESA A-TSCV project

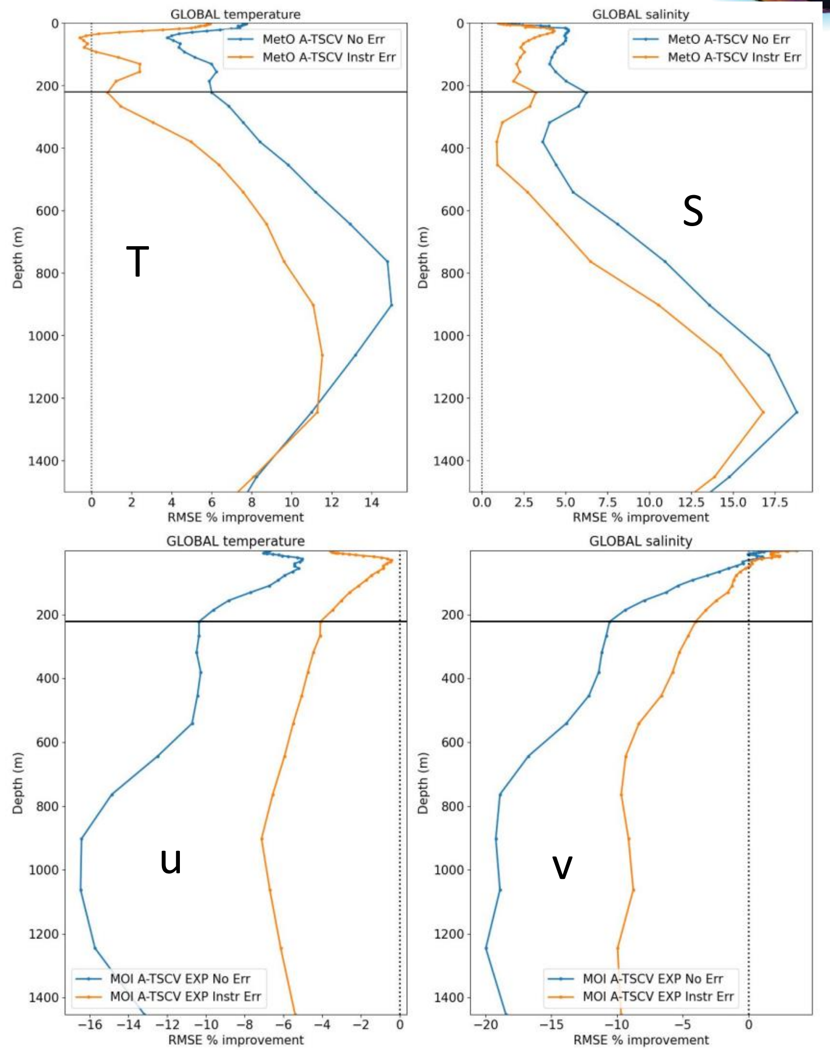


Nature Run: NEMO free run at 1/12°, RT ECMWF IFS forcing

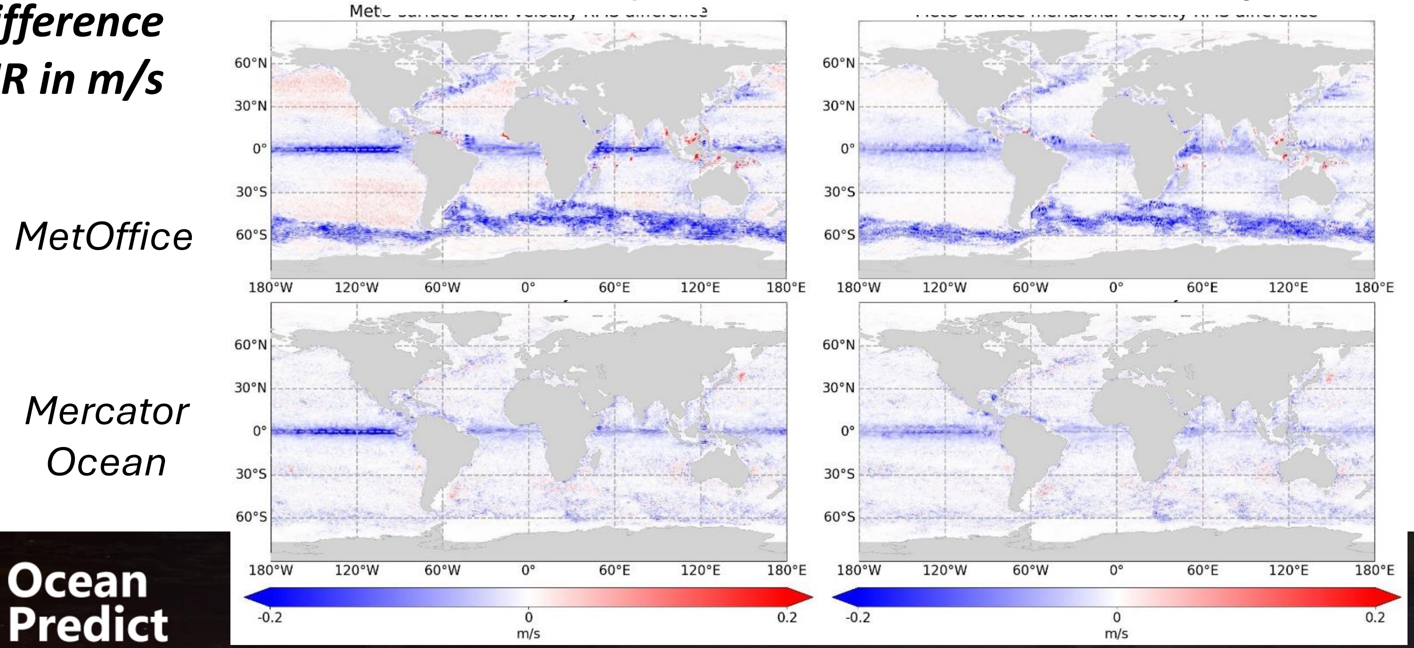
MetOffice OSSE design: global ¼° system with 3DVar DA, ERA5 forcing

Mercator Ocean OSSE design: global ¼° system with SAM (localized, climatological covariance – Kalman filter) DA, ERA5 forcing

Simulated observations: SLA, SST, in situ T and S profiles w/wo L2C SKIM observations with their error (use of the SKIMulator)



RMS difference to NR in m/s



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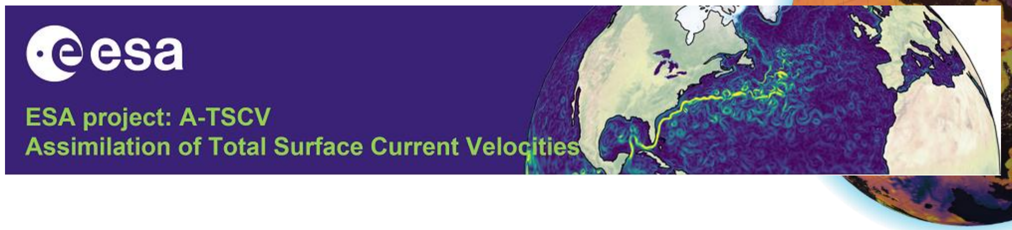
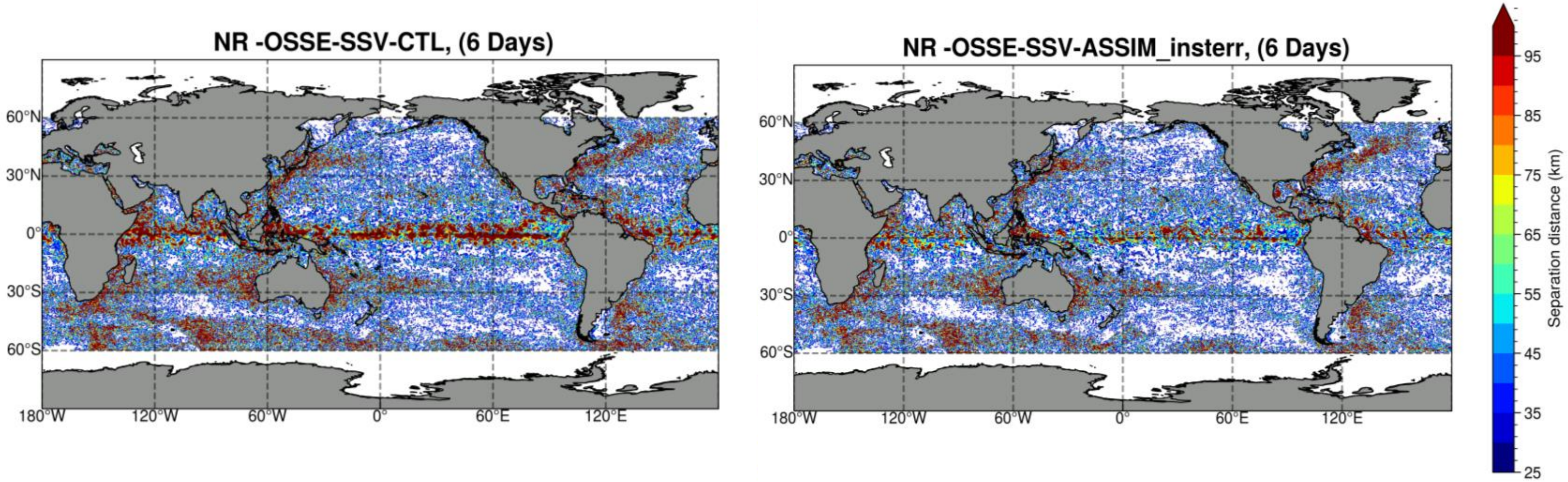


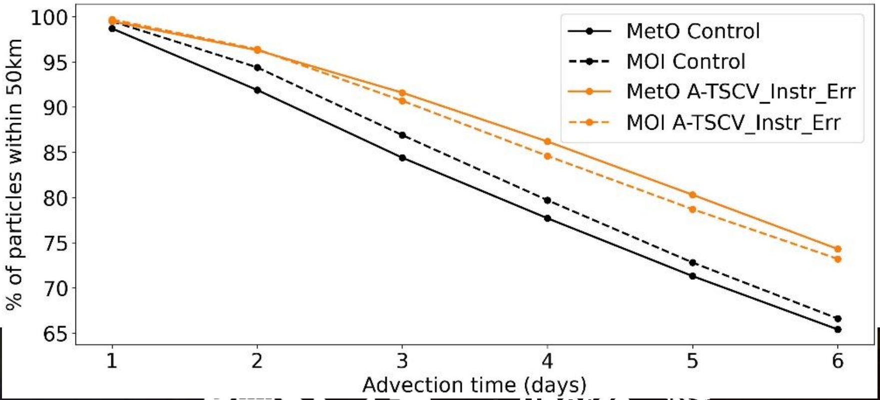
Conclusion: In both MetOffice and Mercator Ocean global ¼° systems,

- Surface velocities are improved in all dynamical regions, especially the Equator, with an improvement maintained in forecasts,
- The different covariance/DA scheme imply very different impact on T,S,SSH, and velocities at depth, with some degrations at depth.

Papers following the A-TSCV project:

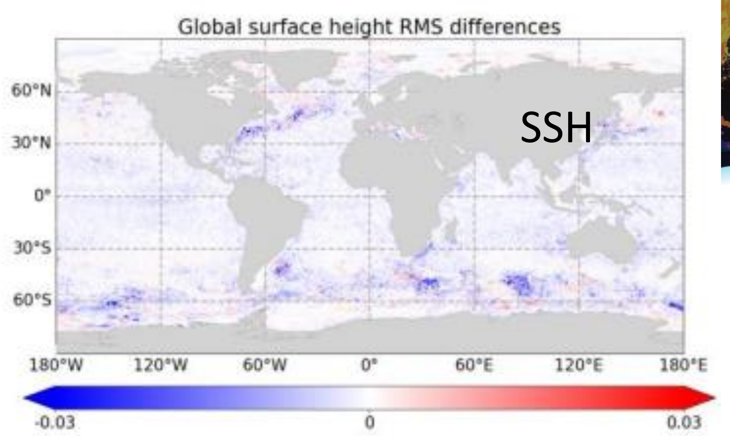
- Waters, J. et al. Assessing the potential impact of assimilating total surface current velocities in the Met Office's global ocean forecasting system
- Mirouze, I. et al. Impact of assimilating satellite surface velocity observations in the Mercator Ocean International analysis and forecasting global 1/4°system
- Waters, J et al. The observation impact of simulated Total Surface Current Velocities on operational ocean forecasting and requirements for future satellite missions.





Global OSSEs with ODYSEA at MOi: first results

- **Nature Run**: NEMO3.1 free global simulation at 1/12° with 50 levels, 3h IFS forcing
- **ODYSEA OSSE setup**: NEMO4.2 global ¼° system, 1h ERA 5, 75 levels, SST, T, S, SLA from 5 altimeter missions, SIC +/- Odysea L2C u,v, ODYSEA observation error including mapping, instrument and representativity.

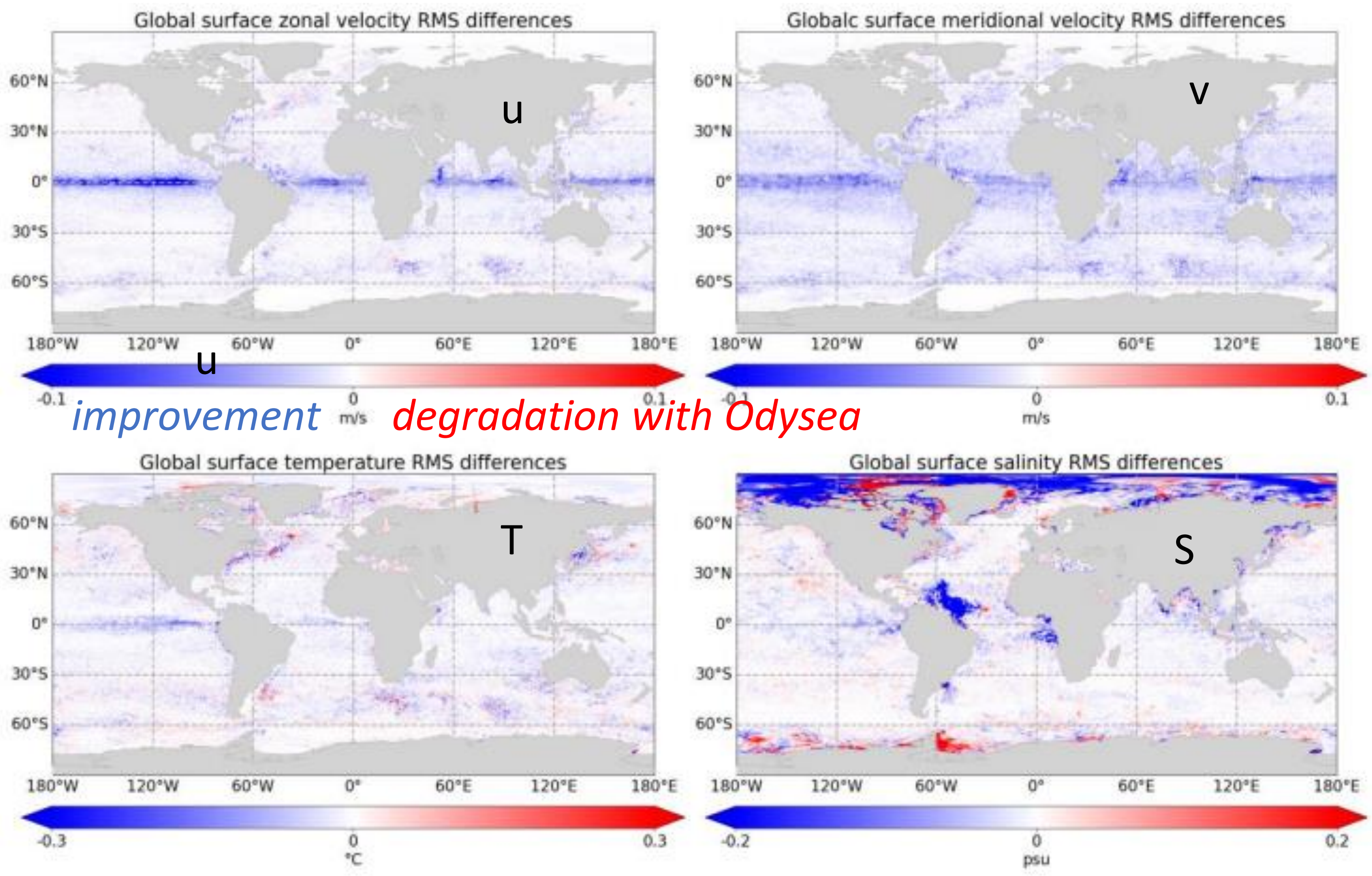


- **ODYSEA observations and errors** with the JPL simulator + ODL: mapping error (Ur to Ugrid) + random error with a wind and swath position dependency.

Significant improvement on:

- ✓ Velocities, especially at the equator, and globally for the meridional component,
- ✓ retained in the forecast :1.5/2 day gain for u/v
- ✓ SSS in river outflow regions,
- ✓ SSH in the WBC and ACC.

RMS(error_Odysea) - RMS(error_Control)
Error = OSSE – NR from Feb to Dec 2009



Global OSSEs with ODYSEA at MOi: first results

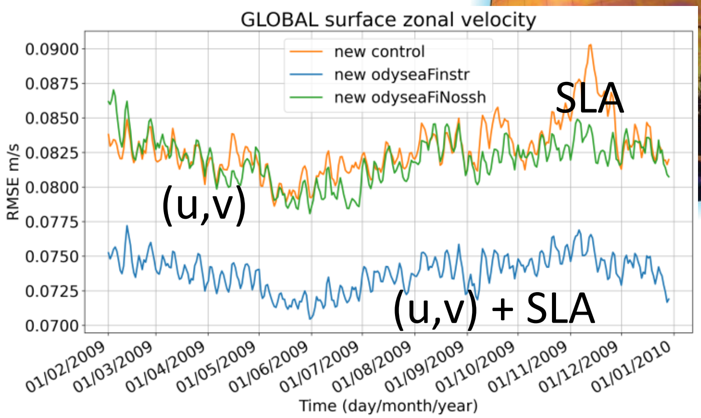
Sensitivity experiments:

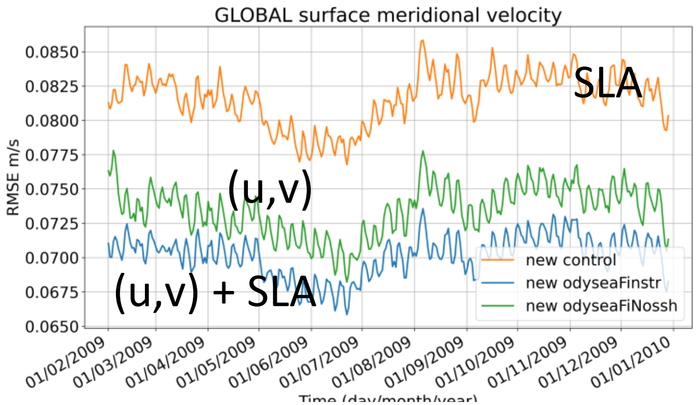
- Complementarity to altimetry in constraining surface current: especially in the tropics and for meridional current.
- Sensitivity to orbit
- Sensitivity to instrument error level specified for the observations

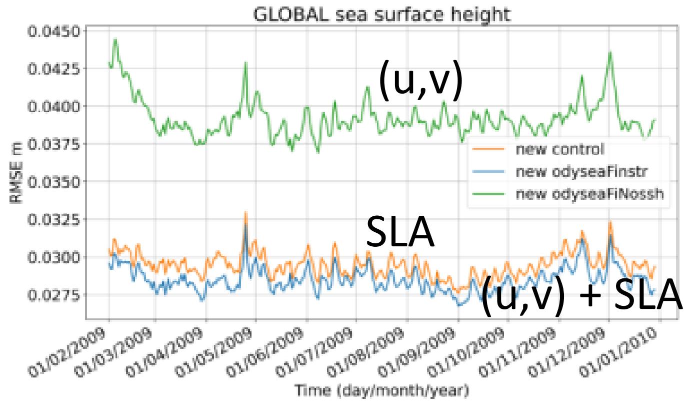
Planned diagnostics:

- Regional diagnostics
- Lagrangian diagnostics (particle dispersion),
- Climate indicator and Ocean extreme,
- Decomposition of velocity component

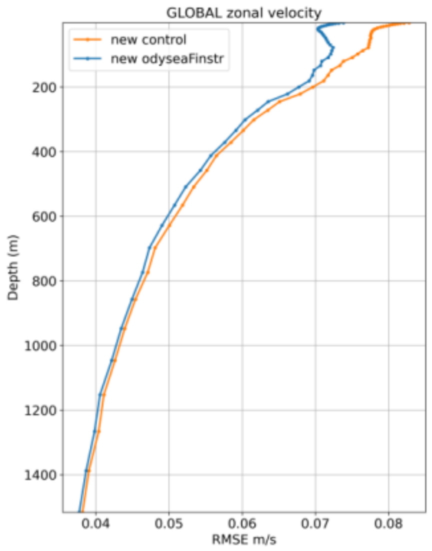
Ongoing analysis
Preliminary results !

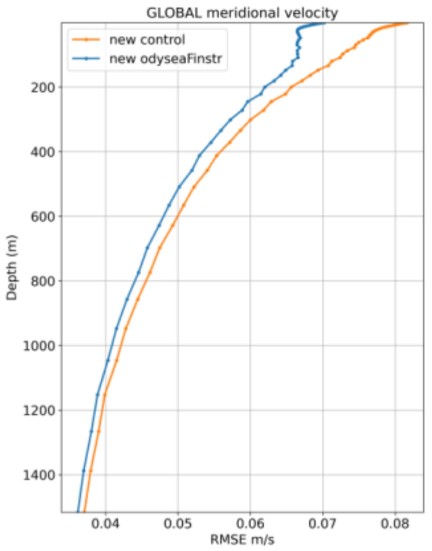






Global RMS error for OSSE_Odysea and OSSE_Control for u and v
Error = OSSE – NR





Regional OSSEs at NRL

Torres H, Wineteer A, Klein P, Lee T, Wang J, Rodriguez E, Menemenlis D, Zhang H. Anticipated Capabilities of the ODYSEA Wind and Current Mission Concept to Estimate Wind Work at the Air–Sea Interface. *Remote Sensing*. 2023; 15(13):3337. https://doi.org/10.3390/rs15133337

Nature Run: Navy Coastal Ocean Model (NCOM) **<u>Gulf of Mexico</u>** run at 1 km with 50 vertical layers (July through December 2020) with assimilation using NCODA system of SSHA, SST, T and S in situ profiles.

ODYSEA OSSE setup: perturbed IC from NR, inclusion of ODYSEA velocity simulated observations

ODYSEA simulated current observations and errors with the ODYSEA simulator

u and v errors: based on wind speed from NR, increased under low wind speeds, with a swath location dependency + wind, swath and land masks.

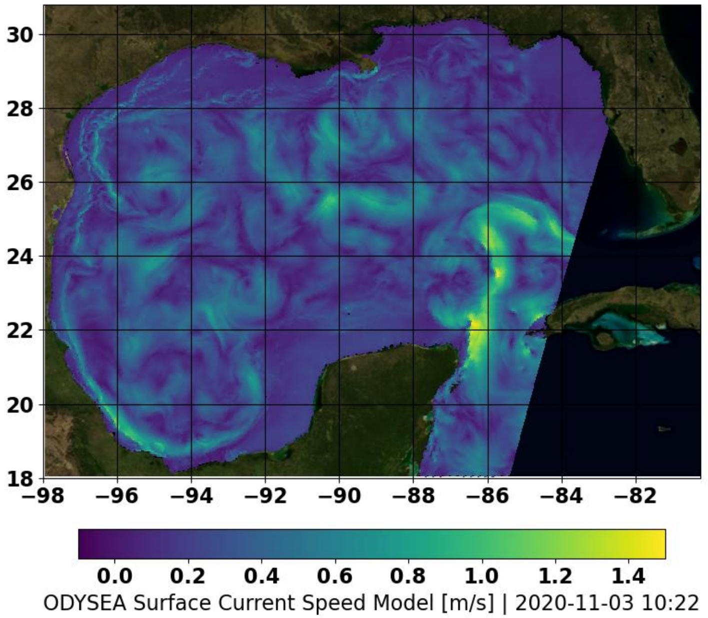
Today status:

- ✓ complete Nature Run
- ✓ Data assimilation system that includes velocity DA
- ✓ Simulated ODYSEA observations

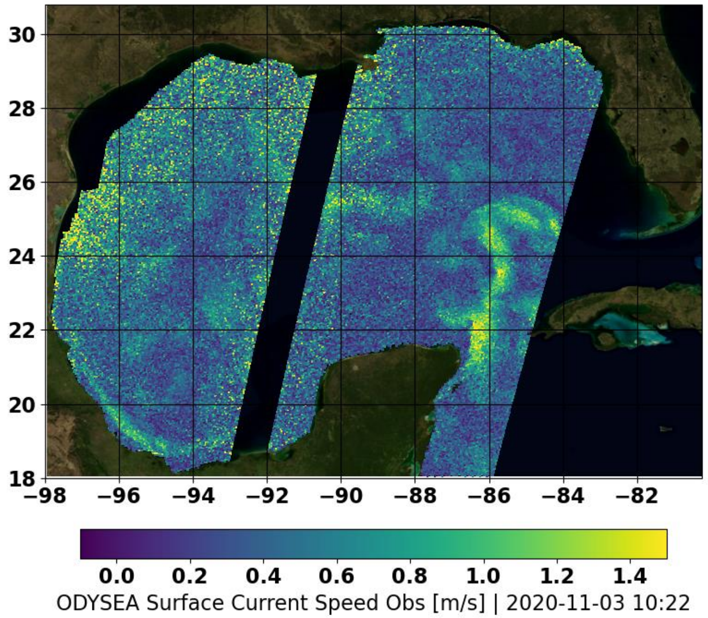
➢ Ready to run assimilative runs with and without ODYSEA velocity!

J. May, G. Jacobs courtesy

Model speed (Nature Run)



ODYSEA observed speed (masked)



Ocean Predict

Challenges and perspectives for assimilation of TSCV

- Improved covariance especially the **vertical covariance** (« localization ») in the MOi system
- High density of observation compared to the model effective resolution: **thinning to superobing**
- How to take into account the **correlated error?**
- How to deal with sub daily variability (**NIO**, …)?
  - Filtering or control, with scale separation, specific tuning for the IAU (as MetOffice for IAU)?

- Assimilation of **radial velocity** components to limit interpolation error
- Assimilation of component as **vector** with correlated error in the DA

- Ensure the **coherency between wind and current in an ocean only system**:
  - through a direct linear relationship or inclusion of wind in the state In (control?) vector

Assimilation of wind and current in a coupled ocean/atmosphere/wave system

Impact of BGC

Ocean Predict

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ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Thank you!

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