Assessing the impact of the assimilation of SWOT observations in a global high-resolution analysis and forecasting system: OSSEs analysis

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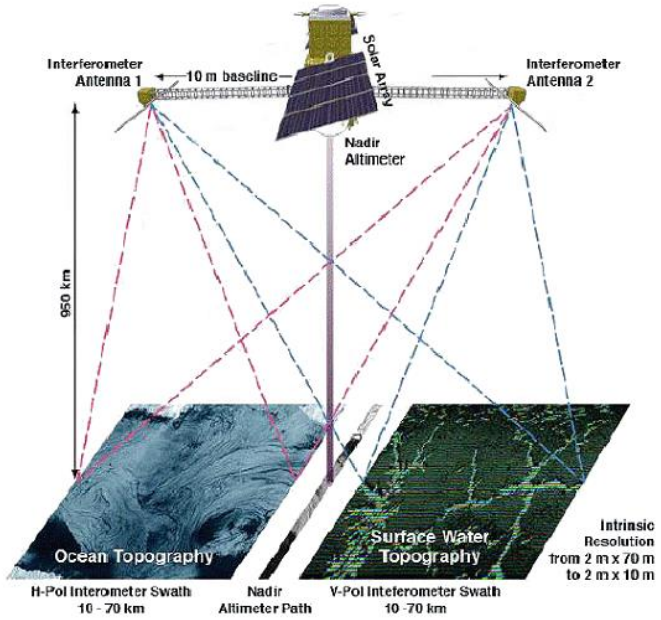
Introduction: SWOT

- **Conventional Nadir altimetry:** Representation of wavelengths > 200 km only
- **SWOT** will provide a much finer view of the mesoscale range (~15-100 km wavelength)
  - Fine enough to represent the mesoscale and submesoscale variability of the ocean (Wang et al., 2019)



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What improvements in mesoscale ocean analysis and forecasting can be expected by assimilating SWOT observations?

Introduction: SWOT

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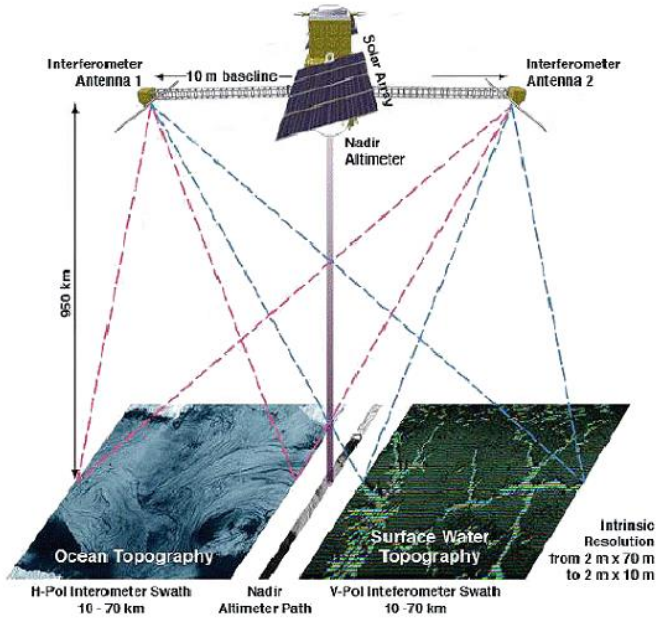

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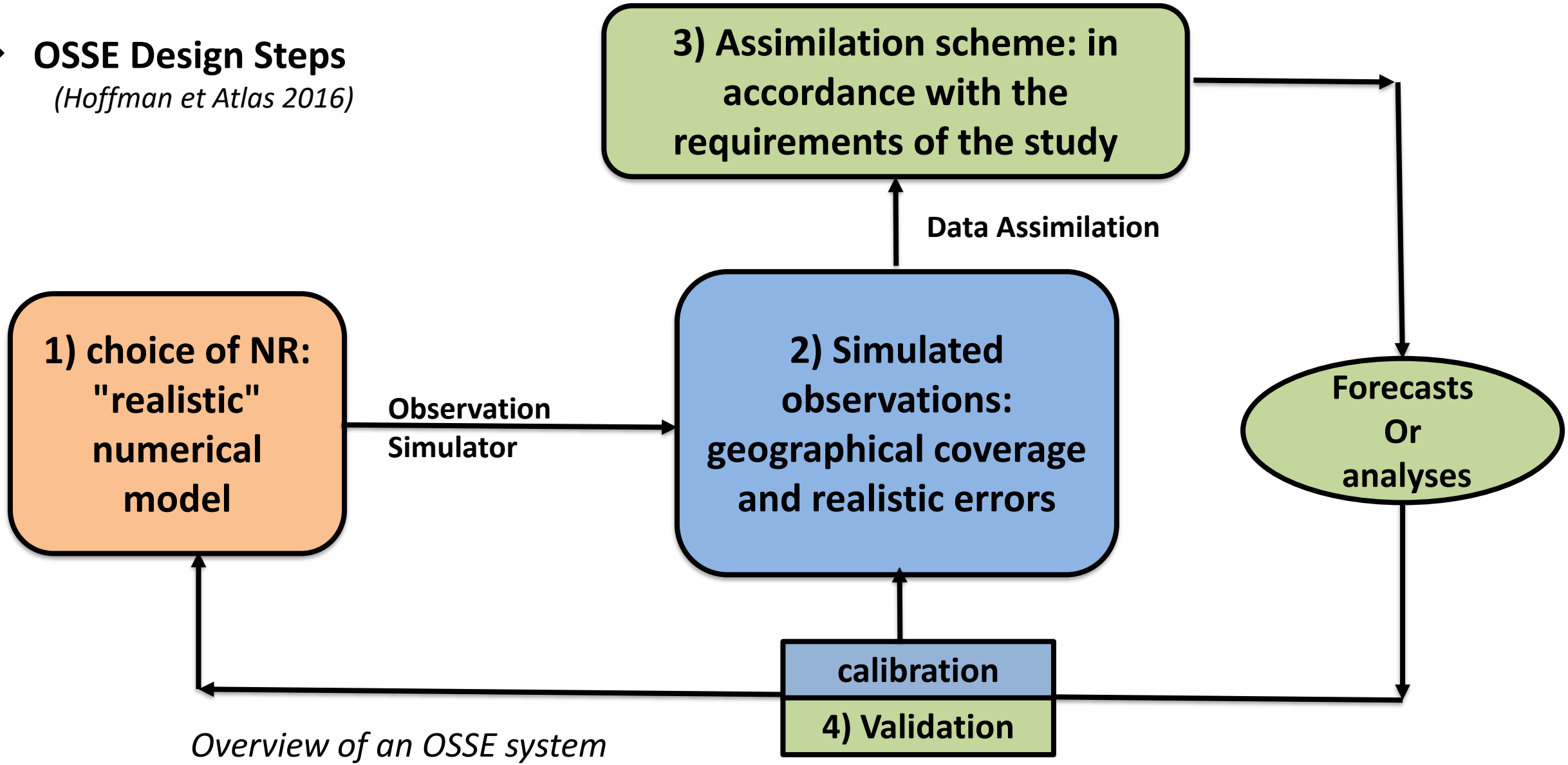
What improvements in mesoscale ocean analysis and forecasting can be expected by assimilating SWOT observations?

In order to answer this question, we conducted for the first time a set of Observing System Simulating Experiments (OSSEs) in a global 1/12° data assimilation system.

Introduction: OSSEs

❖ **OSSE Design Steps**

(Hoffman et Atlas 2016)



Overview of an OSSE system

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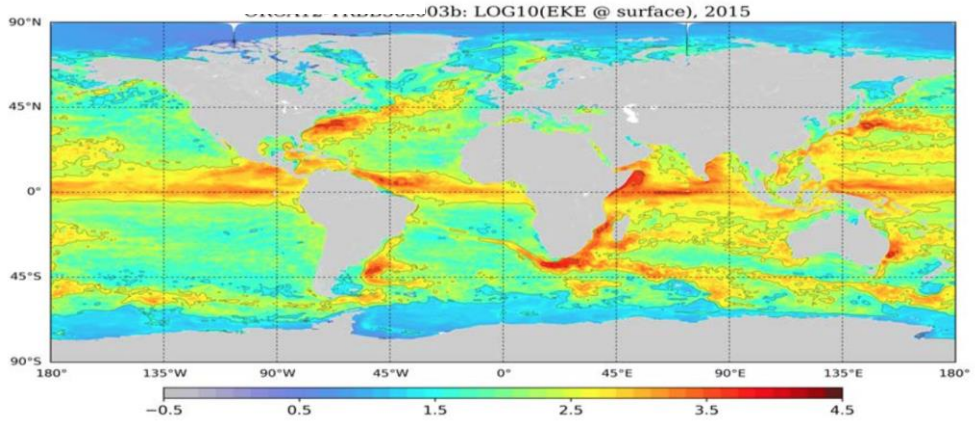
Design of the global OSSE system

Step 1: Simulate NR and FR (≠ oceanic state).

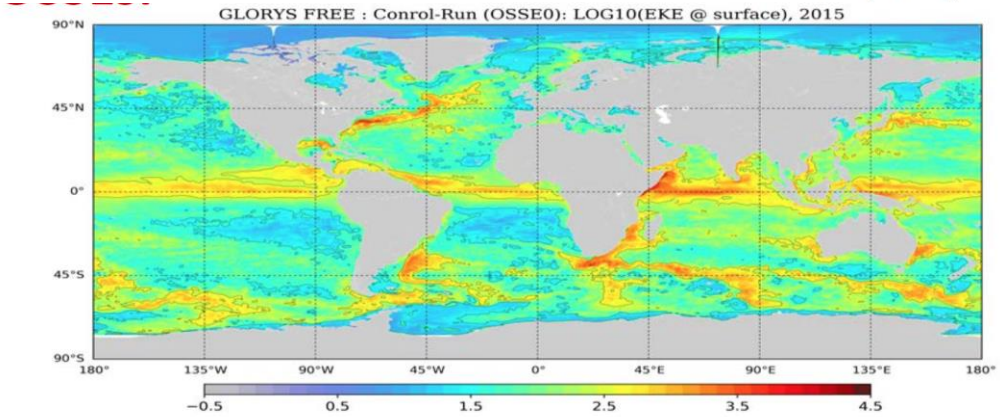
Nature Run (NR)

EKE (2015)



Free Run (FR): OSSE0

EKE (2015)



Step 2: Generate synthetic obs

NR: synthetic observations

- **In-situ: position /date = obs. CORA4 of Coriolis**
- **SST: 1/10° daily card L3**

Satellite observations:

- 3 Nadir: Jason3, Sentinel 3A et 3B➔ 3cm error
- SWOT ➔ KaRIn noise (JPL' simulator, 7km X 7km)

Step 3: Assimilate the obs in the FR

OSSE1 (3Nadir),
OSSE2 (SWOT), OSSE3 (SWOT + 3Nadir)

Step 4: Compare to NR

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Design of the global OSSE system

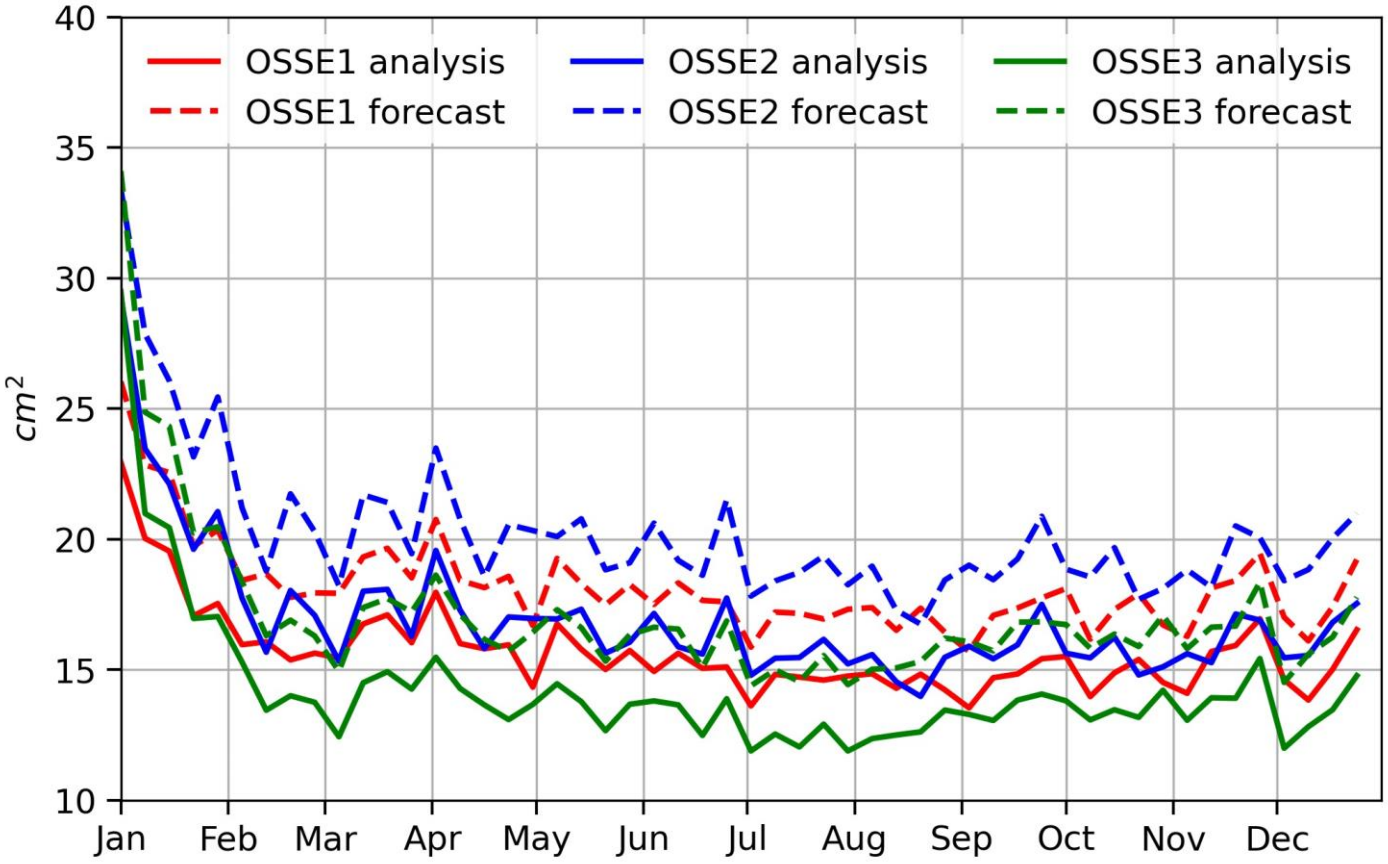
- **Natural Run** (NR): free run 1/12 degree model (Real Ocean)
- **OSSE0 (Free Run (FR))**: free run GLORYS 1/12 degree model (different config. than NR)
- **OSSE1**: run assimilating NR as observed by 3 Nadir altimeters
- **OSSE2**: run assimilating NR as observed by SWOT
- **OSSE3**: run assimilating NR as observed by SWOT + 3 Nadir

All OSSE experiments have assimilated the same type of in-situ and SST observations

Results: Impact on SSH (Sea Surface Height)

OSSE1 ➔ 3 Nadir
OSSE2 ➔ SWOT
OSSE3 ➔ SWOT + 3 Nadir

SSH error variance (NR- OSSEs)



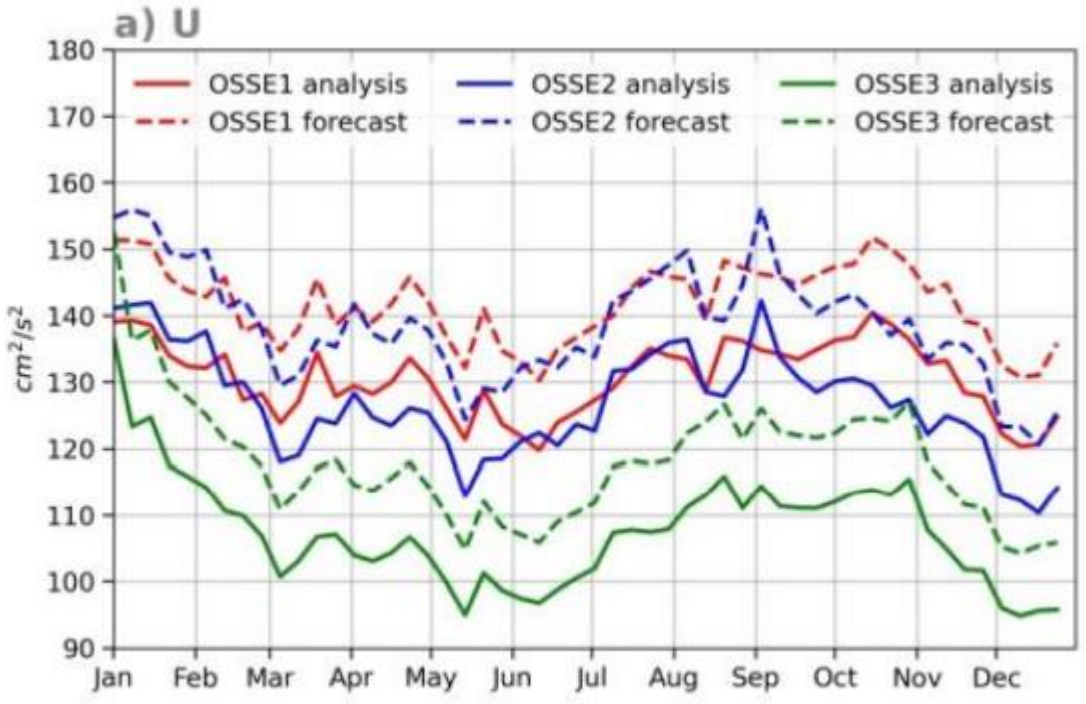
- ✓ Forecast error ---- > analysis error ——
- ✓ **OSSE1** ~= **OSSE2** ➔ **15 cm2**
- ✓ **OSSE3** = **11cm2** ➔ **reduction of 4 cm2** compared to **OSSE1** et **OSSE2**.

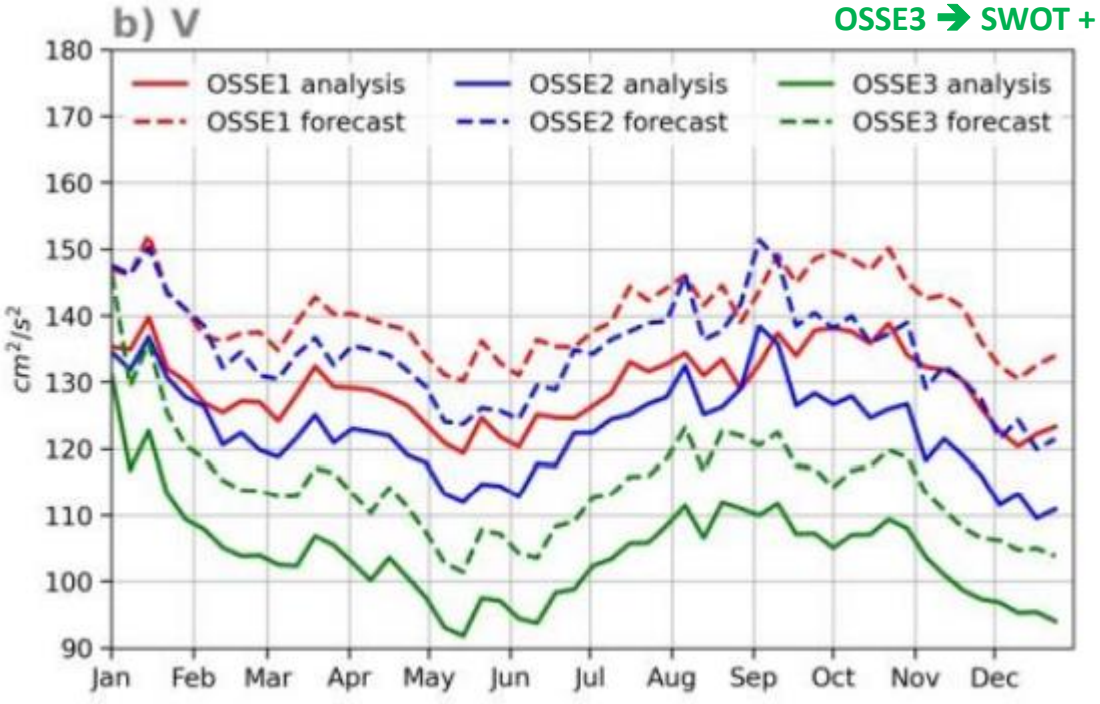
Adding SWOT observations to those of three nadir altimeters reduces the global error variance of the SSH in the analyses and forecasts by about 30%.

Results: Impact on zonal (U) and meridional (V) velocities

U and V error variance (NR- OSSEs)

OSSE1 → 3 Nadir
OSSE2 → SWOT
OSSE3 → SWOT + 3 Nadir





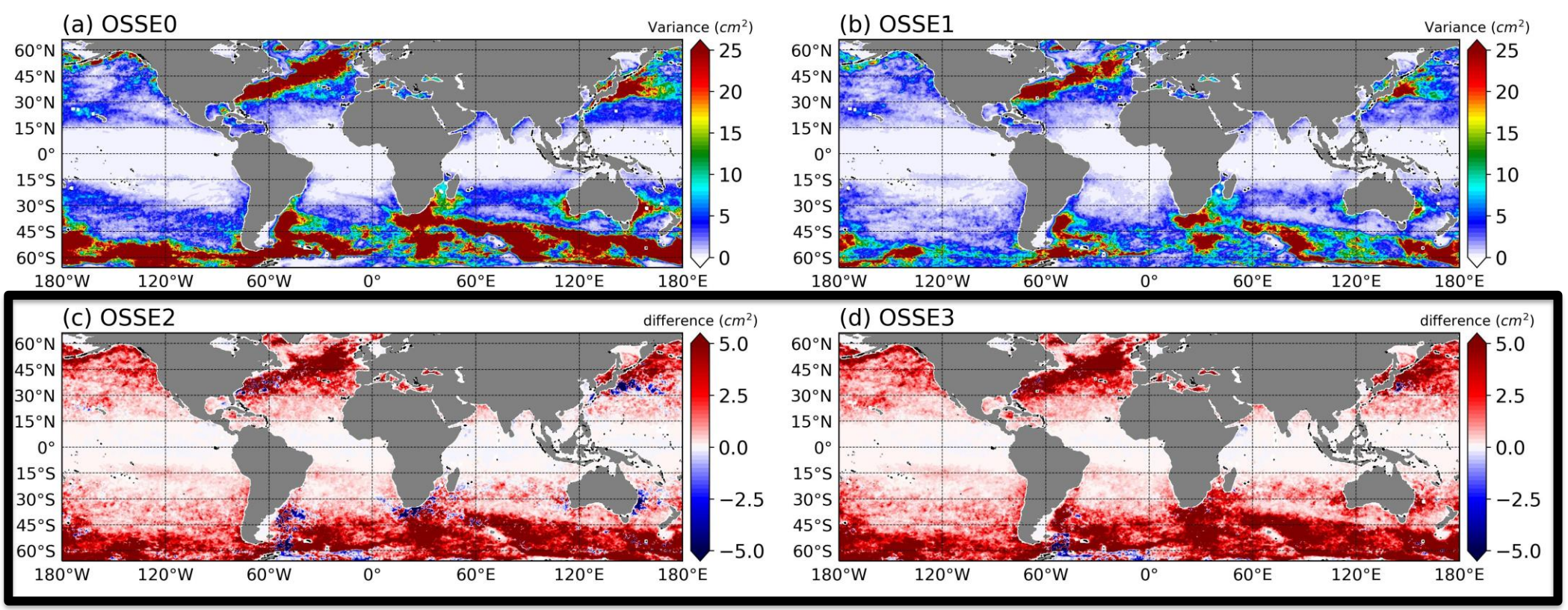
- ✓ Forecast error ---- > analysis error ——
- ✓ **OSSE2 =** 136 cm2/s2 → reduction of 5 cm2/s2 compared to **OSSE1**
- ✓ **OSSE3 = 115cm2/s2 →reduction of** 26 (21) cm2/s2 compared to **OSSE1 (OSSE2)**

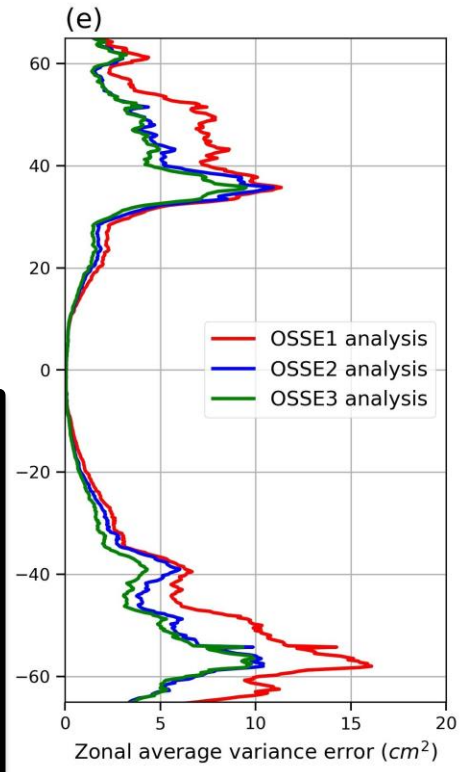
Adding SWOT observations to those of three nadir altimeters reduces the global error variance of U and V in the analyses and forecasts by about 20%.

Results: Impact on SSH filtered at 200 km

SSH error variance: OSSE0 and 1
Difference: Var Error OSSE1 - Var Error OSSE2 and 3

✓ Equatorial band ➔ signal < 200 km is weak
✓ High latitude ➔ space-time coverage of SWOT is denser





By excluding equatorial and tropical regions (+/- 20°), OSSE3 reduces the global error of OSSE1 in the analyses by about 40%.

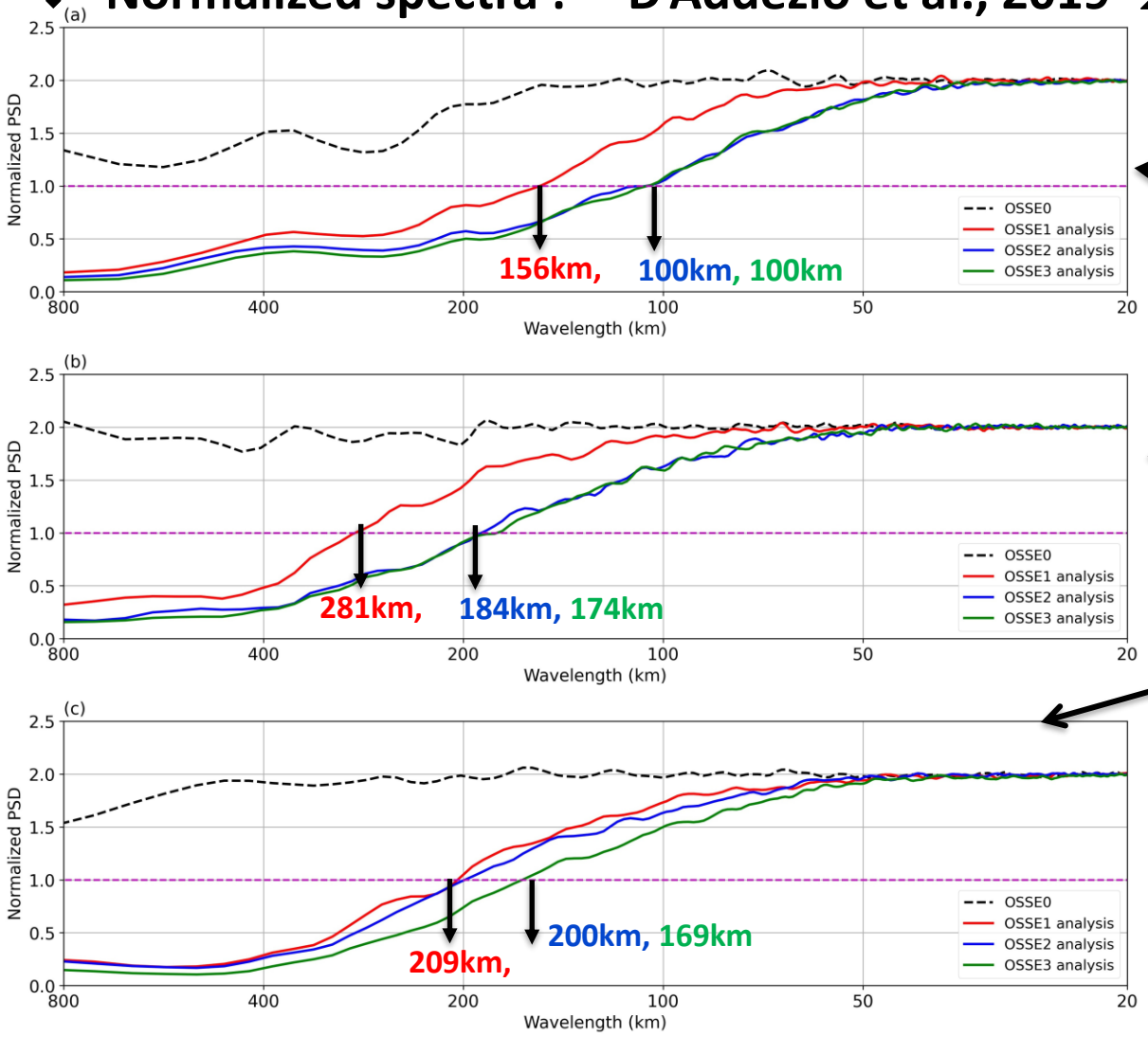
OSSE1 ➔ 3 Nadir
OSSE2 ➔ SWOT
OSSE3 ➔ SWOT + 3 Nadir

Results: spectral analysis

❖ **Normalized spectra : D'Addezio et al., 2019 ➔** $\alpha = \frac{\varepsilon_{OSSE_k}}{\langle \gamma_{NR}, \gamma_{OSSE_k} \rangle}$

ε_{OSSE_k} ➔ Error spectrum (NR – OSSE)

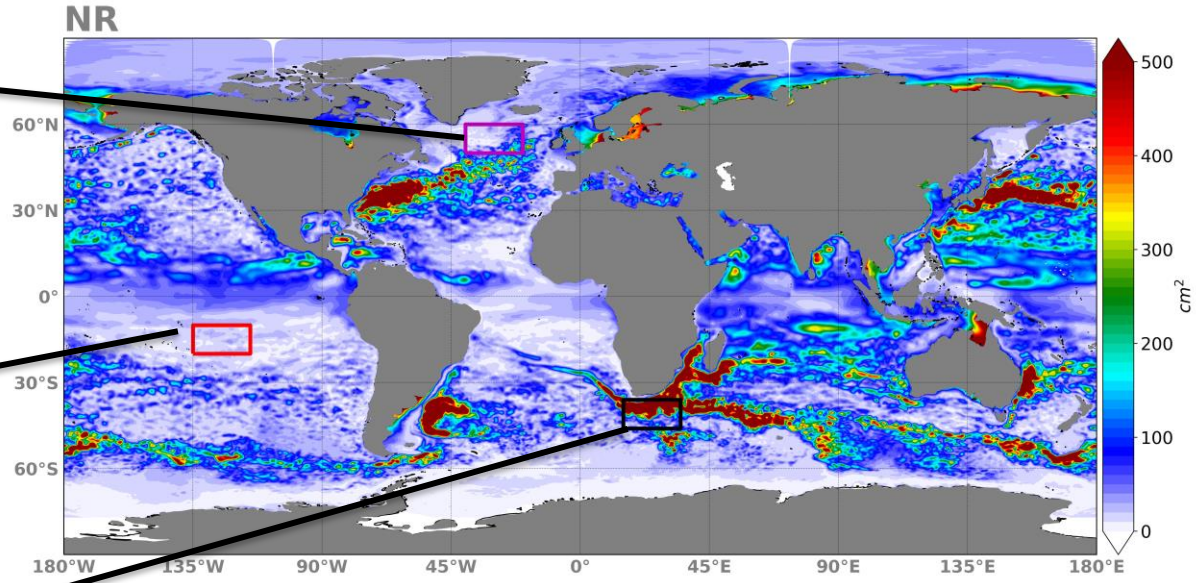
$\langle \gamma_{NR}, \gamma_{OSSE_k} \rangle$ ➔ Average spectrum of NR and OSSE



OSSE1 ➔ 3 Nadir

OSSE2 ➔ SWOT

OSSE3 ➔ SWOT + 3 Nadir



OSSE3:

- ✓ Smallest error in all 3 regions
- ✓ Crosses the normalized value of 1 at smaller wavelengths than other OSSEs
- ✓ 200 km - 50 km ➔ improvement of more than 40% compared to the OSSE1.

Conclusion

- ✓ **SWOT observations**: significant improvement in the quality of ocean analyses and forecasts
- ✓ **Impact of SWOT observations**: Very different depending on the geographical area.
- ✓ **SWOT + 3 Nadirs**: global reduction in SSH and U errors by ~30% and ~20% compared to 3 nadirs.
- ✓ **Spatial scales < 200 km**: global reduction of SSH error by ~40% outside tropical regions compared to 3 Nadirs
- ✓ More important improvements at high latitudes where SWOT space-time coverage is denser

Constraining smaller spatial scales (wavelengths below 100 km) remains challenging as they are also associated with small time scales.

SWOT data could be readily assimilated in the Mercator Ocean and Copernicus Marine Service global high-resolution analysis and forecasting system with a positive impact at all latitudes and excellent performances.

Two papers concerning this work have been plublished in Frontiers

Tchonang et al, 2021: Results

frontiers in Marine Science

ORIGINAL RESEARCH
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Assessing the Impact of the Assimilation of SWOT Observations in a Global High-Resolution Analysis and Forecasting System – Part 2: Results

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Feel free to dive in

Benkiran et al. 2021: Methods

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Assessing the Impact of the Assimilation of SWOT Observations in a Global High-Resolution Analysis and Forecasting System Part 1: Methods

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