Refining Knowledge of the California Current System Through 4D-Var Assimilation of SWOT and Nadir Altimetry

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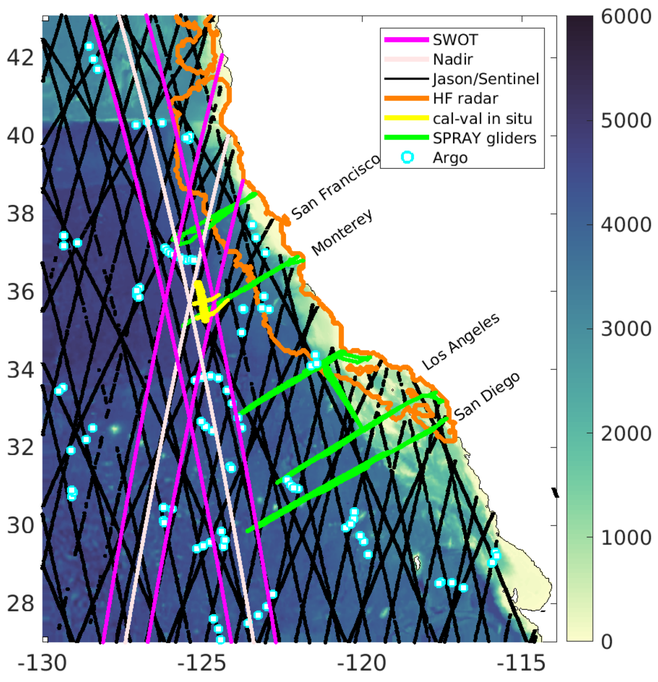
1. What governs variability at scales less than 100 km in the California Curent System (CCS)? To what extent is small-scale flow geostrophic, and how well can these scales be represented in models? To test this, we run a **2-km regional configuration of the MITgcm ocean model and its adjoint**.



- The model is constrained to fit observations by adjusting initial conditions and atmospheric state, while remaining dynamically-consistent within the assimilation window.
- 31-day window (May 1-31, 2023)

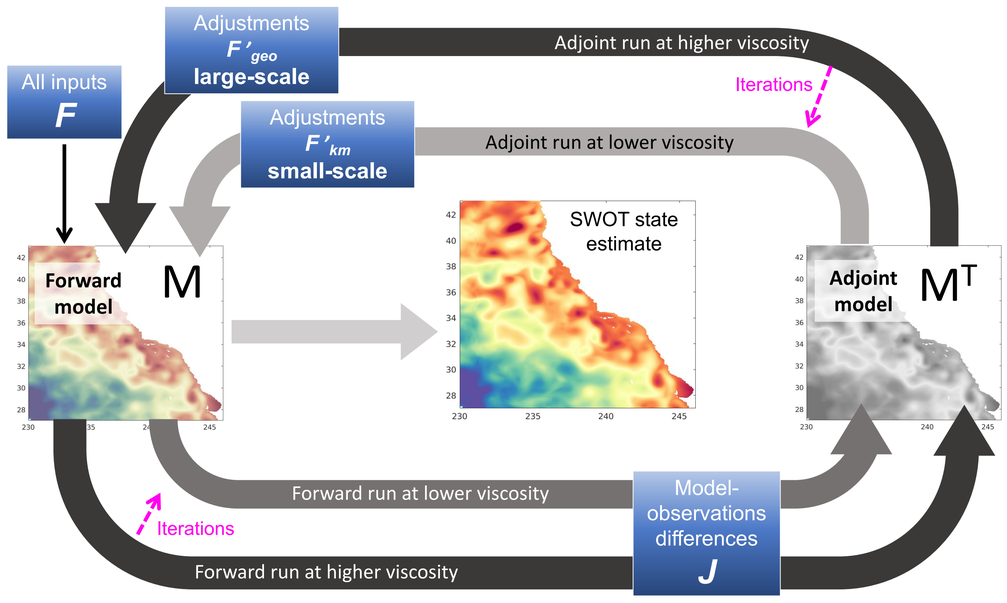
Constraints:

- Global Ocean Observing System (GOOS): nadir altimeters (including Jason/Sentinel 6), OI-SST, Argo & SPRAY glider profiles
- SWOT: L3 1-day repeat
- In situ Cal-Val for independent validation

Controls:

- Atmospheric state: 1-day period, 20 km smoothing scale
- Initial T and S: 10 km horizontal, 10 m vertical smoothing scales

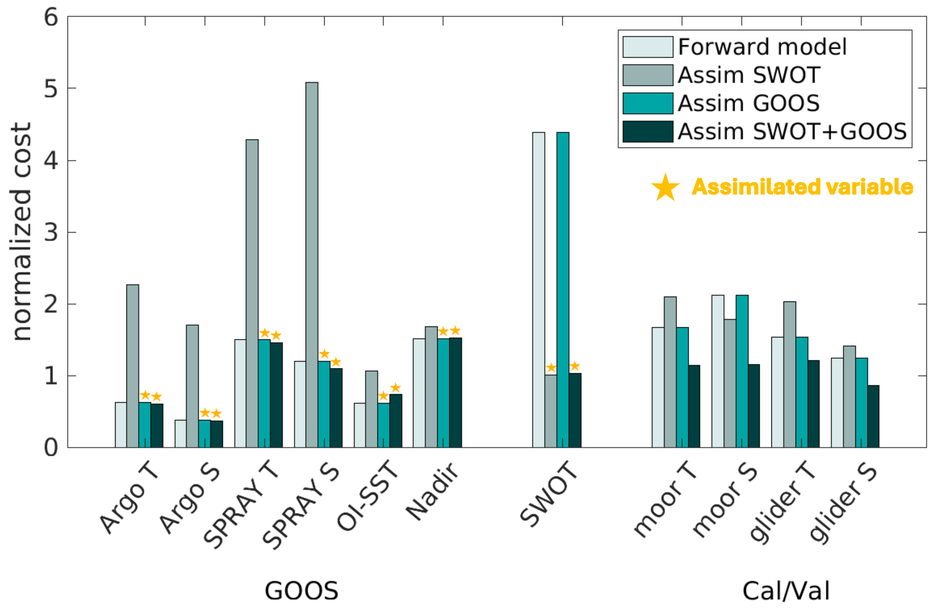
2. The assimilation is run iteratively.
- **Initial steps use high viscosity** to damp small scales and fit balanced motions.
- **Later steps use reduced viscosity** to permit smaller mesoscale and submesoscale features to evolve.



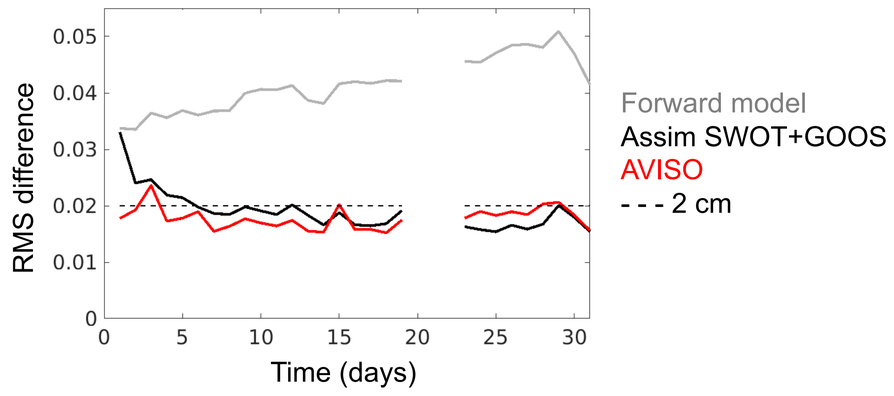
A new cost function package for MITgcm, ObsFit, was created to support use of sparsely sampled data (github.com/averdy/obsfit_mitgcm/)

3. We perform three assimilations with constraints:
- SWOT only,
- GOOS only,
- SWOT+GOOS.

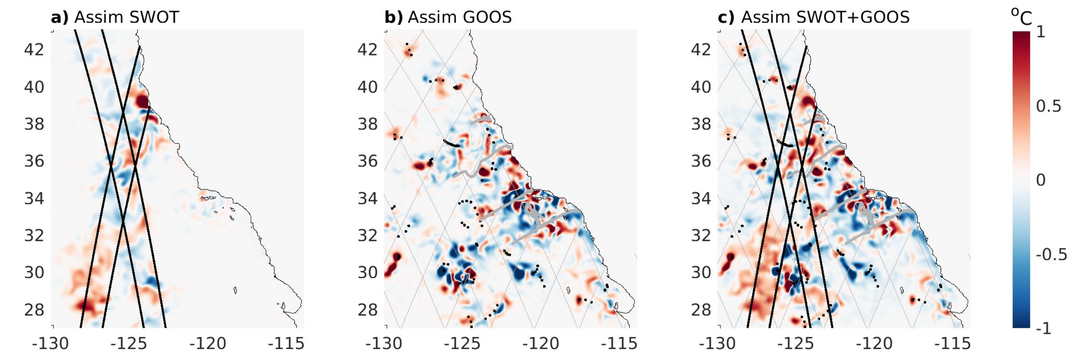
Model-observation **misfits are reduced for assimilated and non-assimilated datasets**.



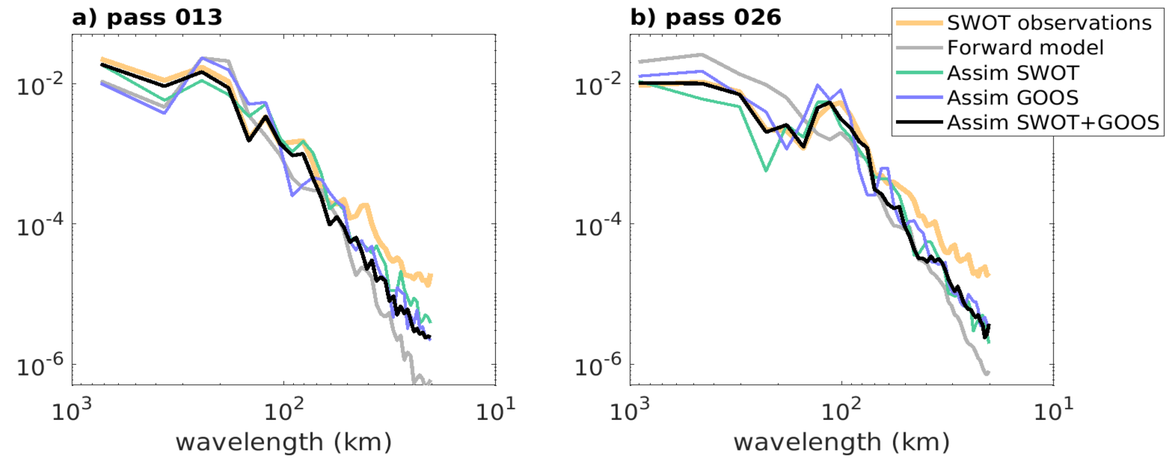
4. The optimized model **fits SWOT data within the assigned 2 cm uncertainty** (mostly), performing similarly to the AVISO product while also simulating the 3D ocean state.



6. The model **adjusts initial and boundary conditions** to best match observations. Here are subsurface changes to 100-m temperature initial conditions.



5. **Wavenumber spectra show that the agreement is good for scales up to 70 km** for the SWOT+GOOS assimilation. Withholding SWOT or GOOS reduces the assimilation skill.



Conclusions

- Using 4D-Var for a 31-day assimilation window, we resolve features with wavelengths as short as 70 km.
- Nadir altimetry and SWOT both provide useful constraints.
- Model fields are consistent with ocean physics.
- Impacts of assimilation propagate horizontally and vertically.

Contact us for a preprint: Verdy et al, to be submitted, JGR-O, 2025

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