Assimilation of SWOT One-Day Repeat Data in the California Current System
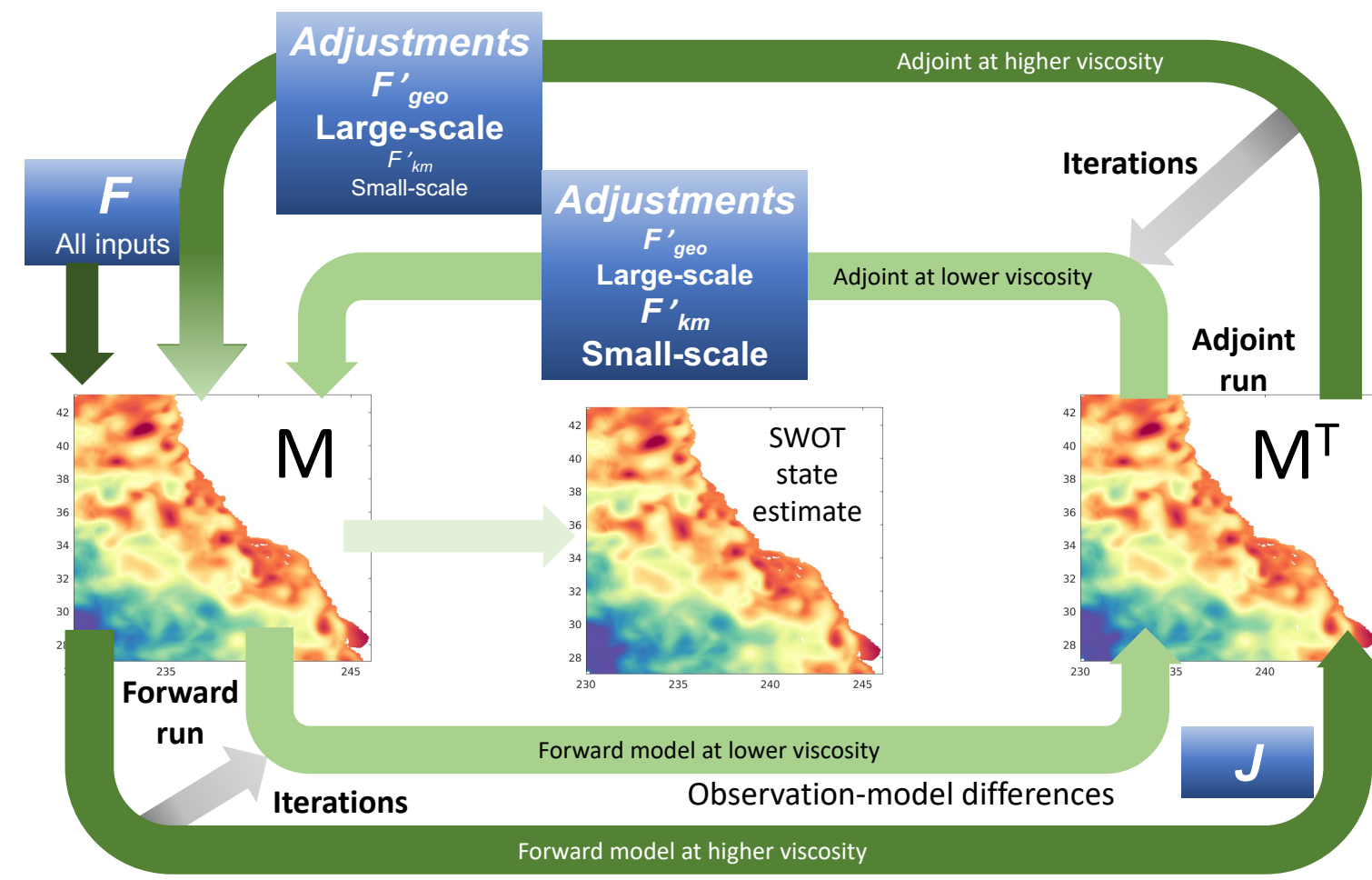
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1. 4dVar Assimilation

SWOT samples about 5% of the global ocean each day. Through 4d-variational data assimilation (4dVar) applied to the MITgcm ocean model, we aim to obtain an optimal combination of observations and ocean physics. The MITgcm-4dVar assimilation system fills spatio-temporal gaps between observations by adjusting atmospheric forcing, initial conditions, and boundary conditions, without disrupting the dynamical consistency with ocean physics.

The SWOT assimilation challenge: SWOT resolves small-scale ageostrophic motions that are nonlinear and potentially incompatible with a linearized adjoint.

Assimilation in a nutshell. In 4dVar, the model is run forward in time, and model—data misfits are computed. The model adjoint effectively runs a linearization of the model backward in time to determine adjustments to forcing + initial & boundary conditions. The process is repeated through multiple iterations. Model parameters (e.g. viscosity) can be refined as the model and data come into agreement over iterations.

2. MITgcm configuration
- 2-km grid spacing and 100 vertical levels.
- 30-day assimilation starting 1 May 2023
- Atmospheric forcing from ERA5.
- Initial and boundary conditions are from the CMEMS Global Ocean Physics Analysis and Forecast.

3. Assimilation Constraints

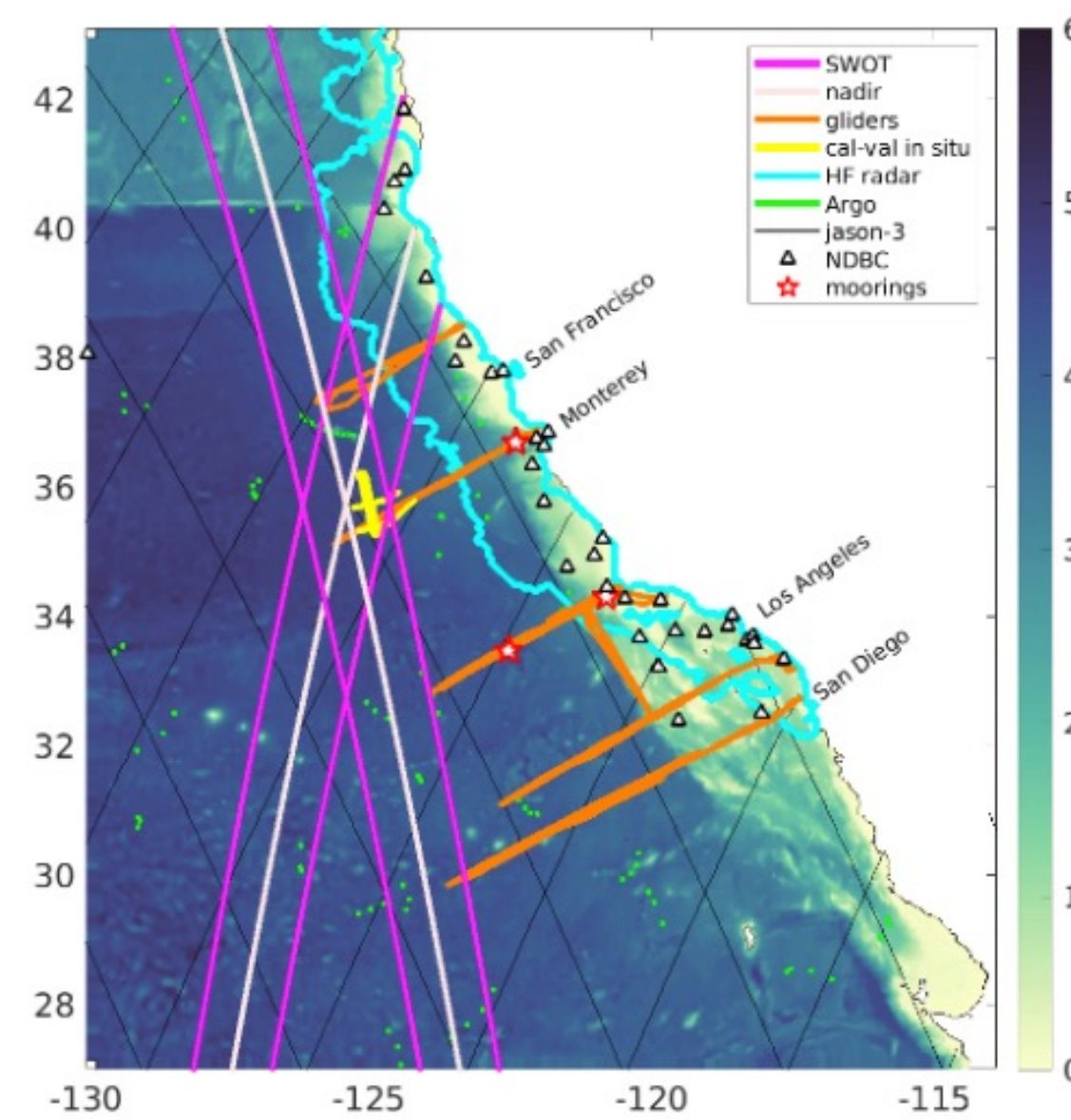GOOS (Global Ocean Observing System)
- Nadir altimeters
- SST
- Argo
- Spray gliders

GOOS + SWOT
- SWOT Level 3 data, subsampled at 10 km resolution

GOOS + SWOT + Cal/Val
- In situ mooring and glider T/S

The model domain spans the California Current System, extending from the Mendocino Escarpment in the north to the Sebastián Vizcaíno Bay in the south. The region encompasses the one-day repeat crossover used for SWOT calibration/validation.


Goal: Implement 4dVar data assimilation at SWOT scales for the post-launch Cal/Val period.

Results:
- Data assimilation brings the model closer to observations.
- Assimilation is unstable at low viscosity.
- Initial iterations at high viscosity can be followed by subsequent iterations with lower viscosity.

4. Misfit to observations decreases with more iterations

GOOS-only assimilation: Normalized cost drops over 8 iterations, both for the assimilated data and for the unassimilated data. (A normalized cost of 1 indicates that misfit is consistent with prescribed error.)
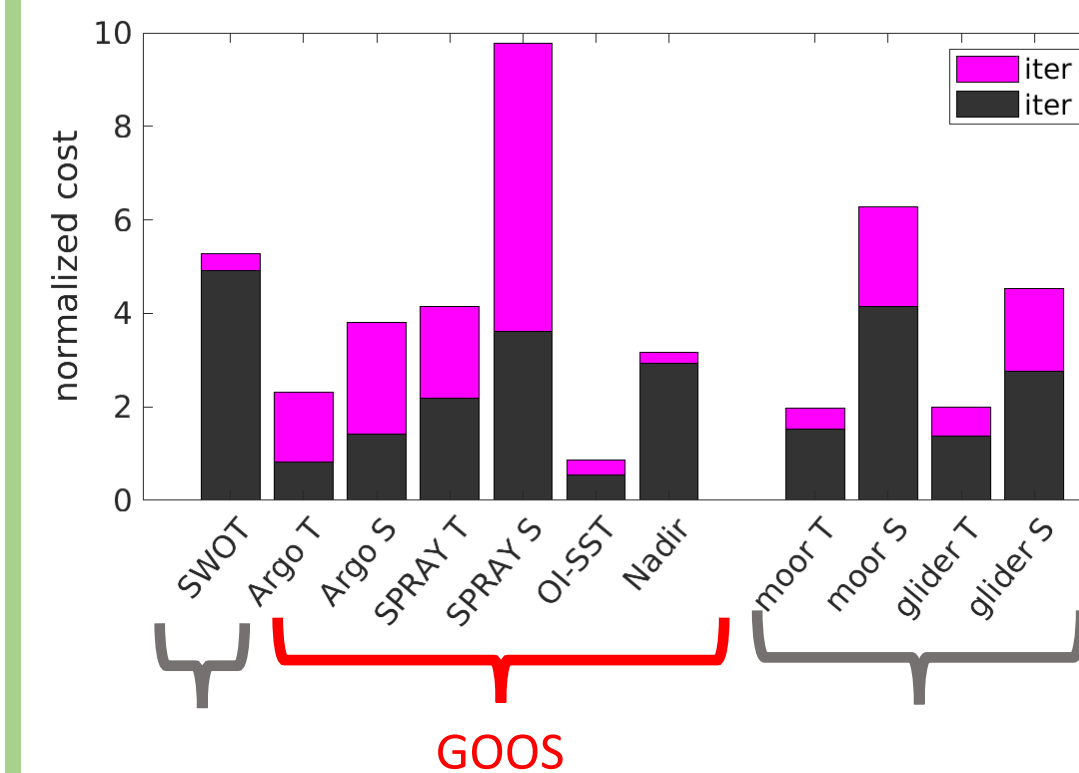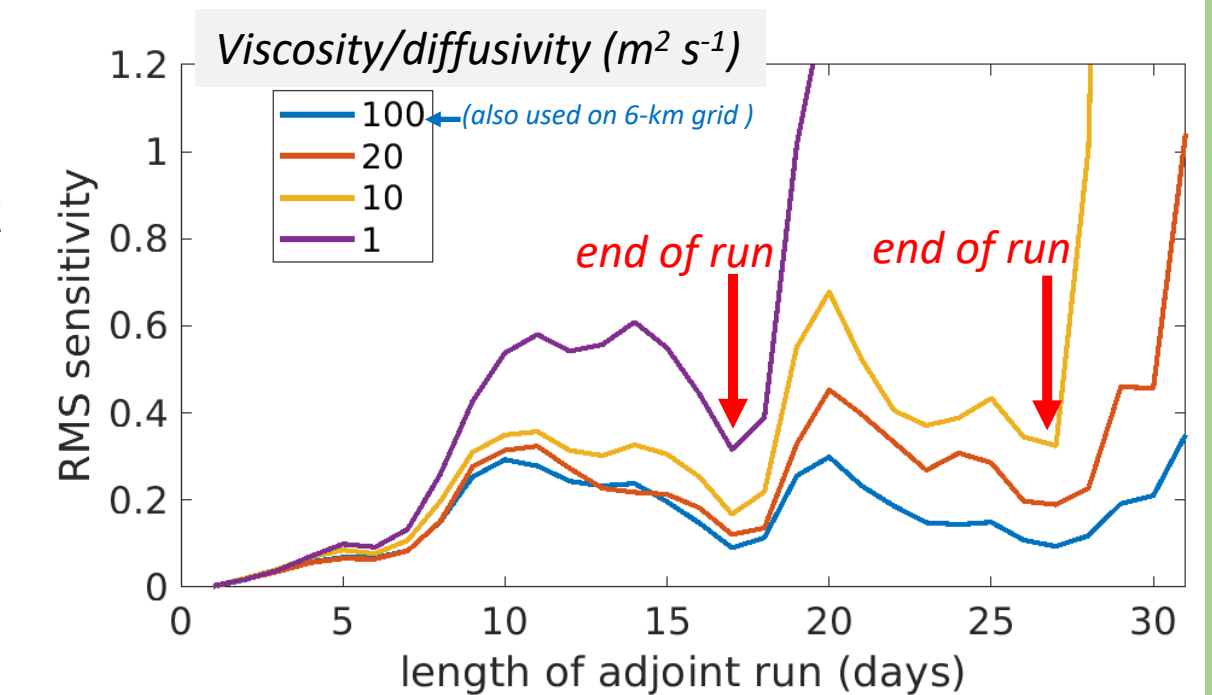

SWOT + GOOS assimilation: Normalized cost drops for assimilated GOOS and SWOT data. Mismatch with unassimilated Cal/Val data reduces more than in GOOS-only assimilation.
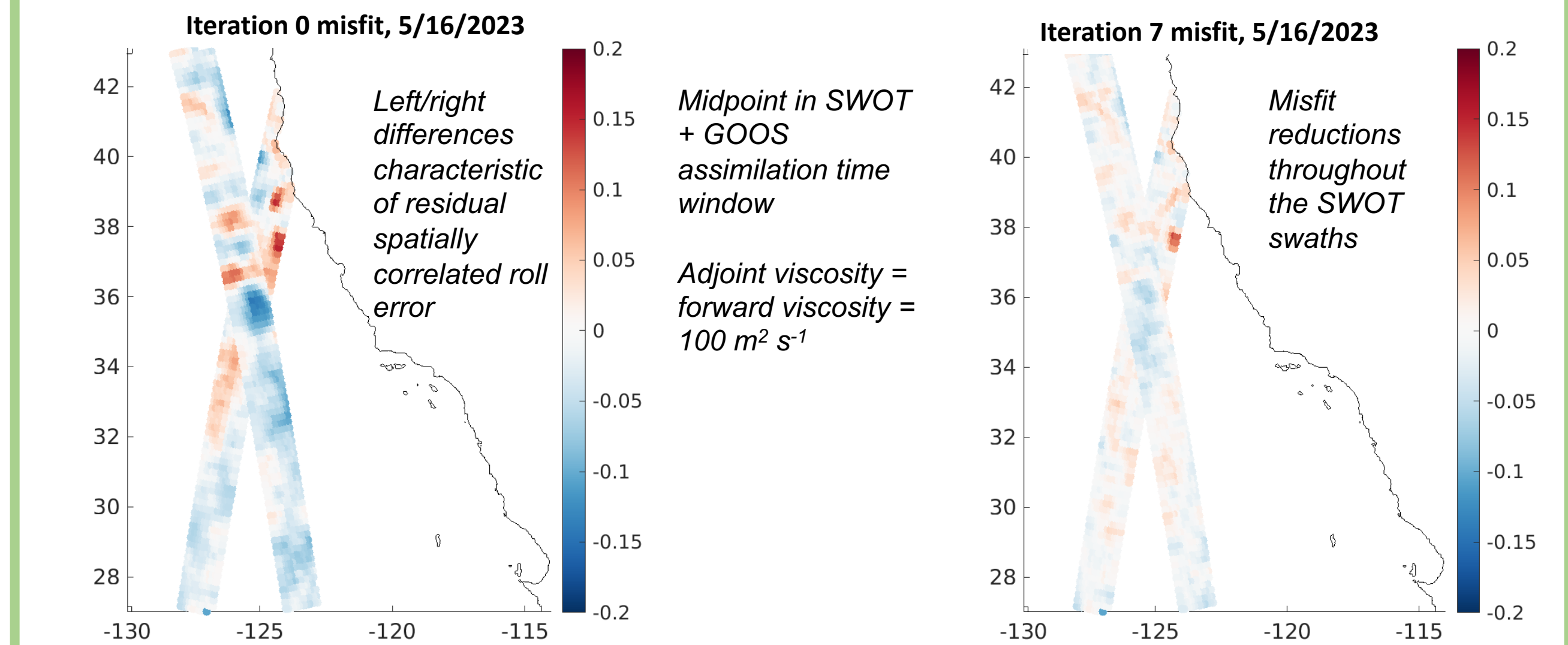

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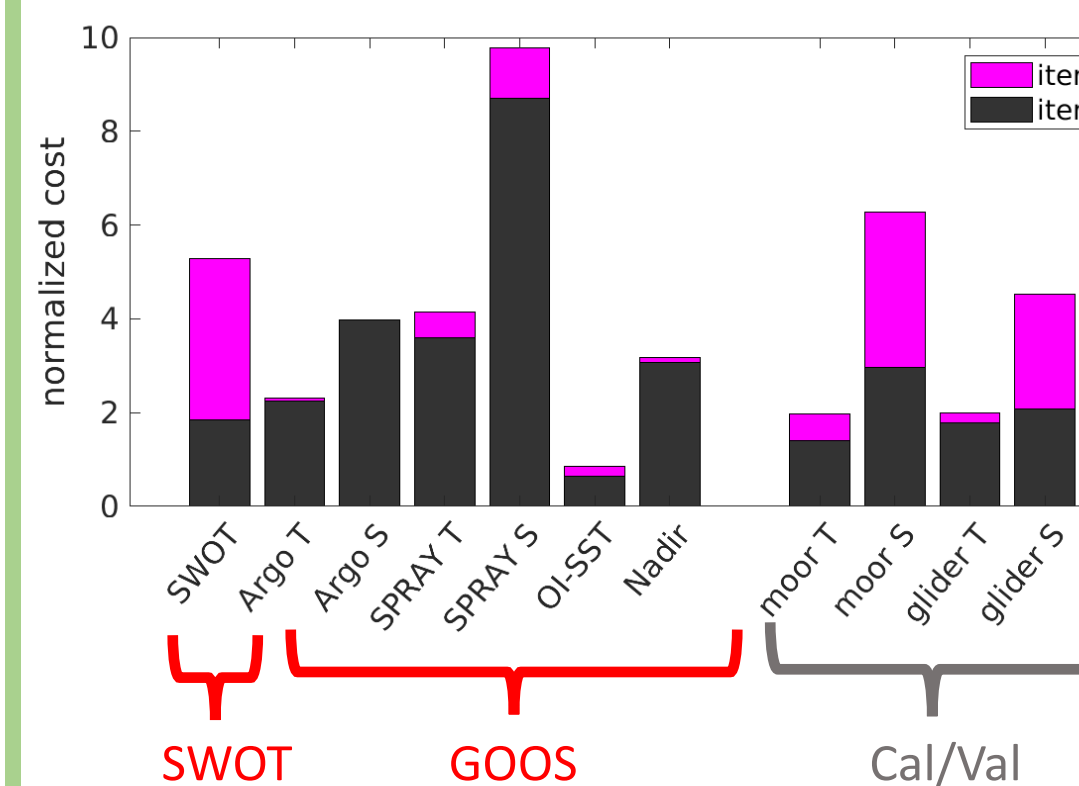
5. Assimilation unstable with low viscosity

To handle SWOT spatial scales, in the California Current System we reduce the assimilation time window to 30 days (compared with 3-month windows used for mesoscale assimilation with a 6-km grid).

Low viscosity is needed to represent high-resolution structure, but at low viscosity, the sensitivity can grow without bound, preventing a 30-day run.

6. Assimilation improves model agreement with SWOT

Left/right differences characteristic of residual spatially correlated roll error

Midpoint in SWOT + GOOS assimilation time window

Adjoint viscosity = forward viscosity = 100 m² s⁻¹

Misfit reductions throughout the SWOT swaths

7. SWOT assimilation changes subsurface

- Temperature initial conditions adjust on SWOT swath.
- Changes largest in top ~150 m.