Moving ocean prediction skill

G. A. Jacobs[1], J. D'Addezio[2]
[1]University of Southern Mississippi
[2]Naval Research Laboratory

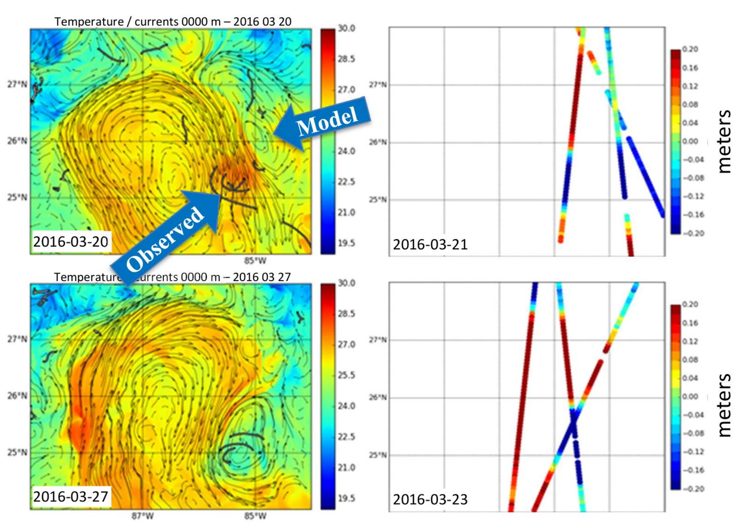
The Global Ocean Data Assimilation Experiment (GODAE) set a goal to predict ocean mesoscale eddy circulation. This goal was achieved by the nadir altimeters from TOPEX / Poseidon through Jason-1. The numerical ocean models were of resolution to represent mesoscale physics, and the satellite observations roughly resolved the eddy features.

Now computers run numerical ocean models representing much smaller scales. Observing systems have advanced with the demonstration of SWOT. We experience patchy dense data. Joined with intensive in-situ campaigns, this occurs horizontally and vertically.

We adapt daily to patchy dense data. Horizontal adaptation was demonstrated during the Sub-Mesoscale Dynamics Experiment (S-MODE) and has been implemented into operational ocean prediction systems. A key component is the daily mapping of resolved scales. Extending vertically separates satellite and in situ observations.

During the SWOT cal/val period, the adaptive scale approach and the prior standard approach were run side-by-side for evaluation. Compared to the in-situ observations, the adaptive approach reduced steric height error variance by more than 50%. Such evolution in observation application carries forward the ability to adapt to changes in the future.

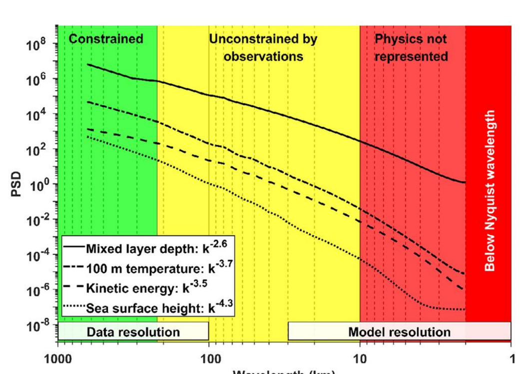
Horizontal resolution



Typical features resolved by nadir altimeter and prediction issues.

During LASER we found eddies smaller than 220 km are often misplaced due to nadir altimeter sampling resolution.

Jacobs, Gregg, Joseph M. D'Addezio, Hans Ngodock, and Innocent Souopgui. "Observation and model resolution implications to ocean prediction." *Ocean Modelling* 159 (2021): 101760.



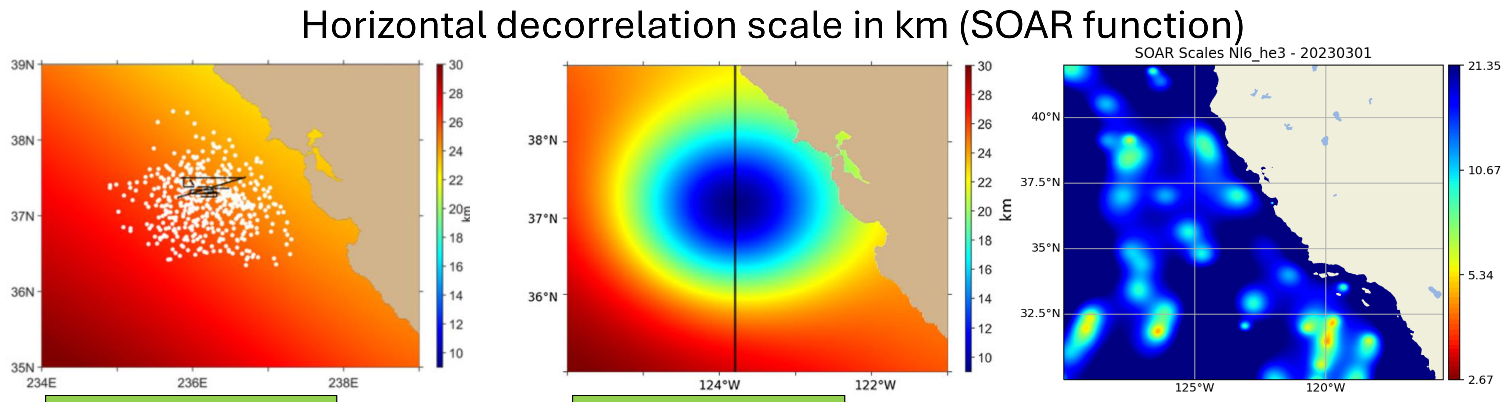
Model PSD extend through a spectrum of resolutions. Regular SSH observations resolve larger features, and the data constrains these in forecast models. Models have skill within constrained scales. Most errors relative to drifters are in smaller scales

Jacobs, Gregg A., Joseph M. D'Addezio, Brent Bartels, and Peter L. Spence. "Constrained scales in ocean forecasting." *Advances in Space Research* 68, no. 2 (2021): 746-761.

Progression through S-MODE adapting horizontal resolved scales

2021	2022	2023
Standard horizontal scales	Adaptive assimilation with time-fixed scale	Time-evolving adaptive assimilation

Horizontal decorrelation scale in km (SOAR function)



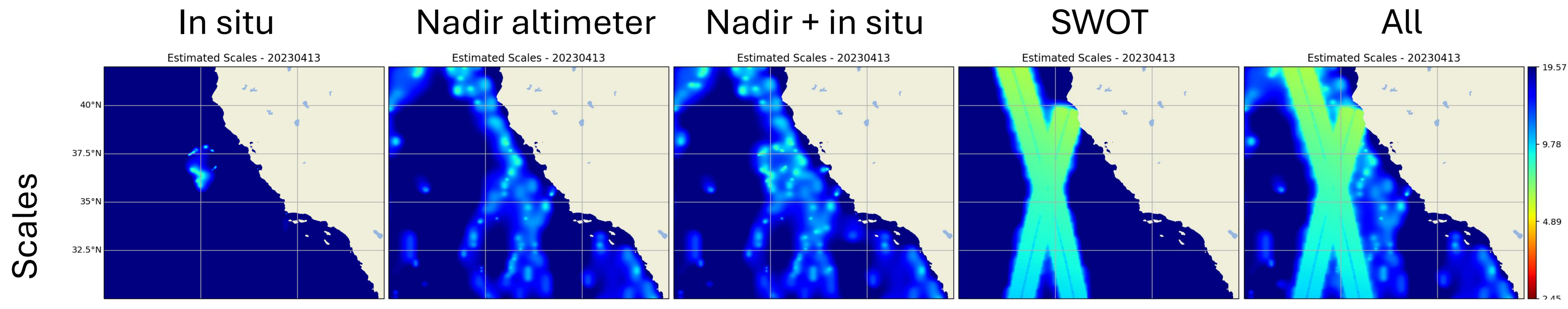
Skill > 220 km scales

Skill > 80 km scales

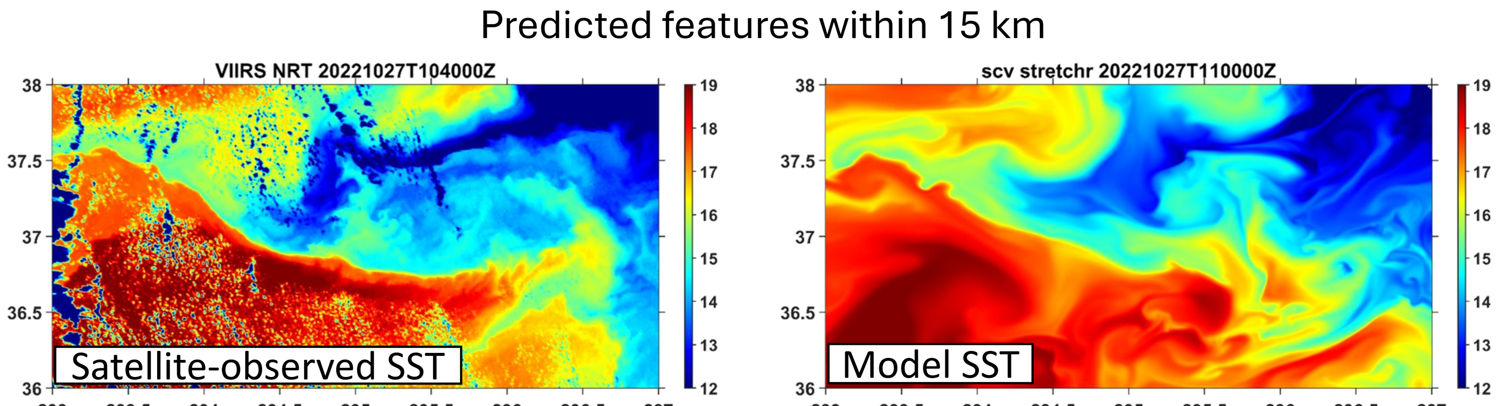
Jacobs, Gregg, Joseph D'Addezio, Brent Bartels, Chris DeHaan, Charlie Barron, Matthew Carrier, Andrey Shcherbina, and Mathieu Dever. "Adapting constrained scales to observation resolution in ocean forecasts." *Ocean Modelling* 186 (2023): 102252.

Daily adaptation during SWOT cal/val

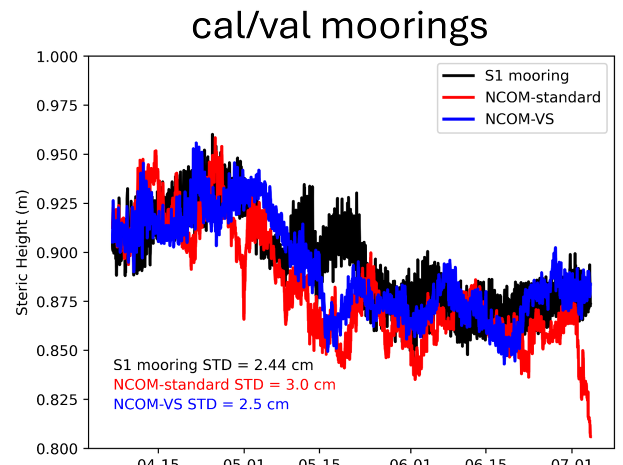
In situ	Nadir altimeter	Nadir + in situ	SWOT	All



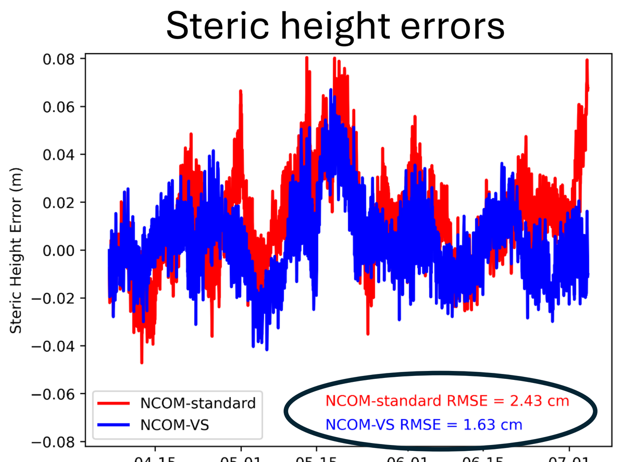
Predicted features within 15 km



Steric height @ SWOT cal/val moorings



Steric height errors

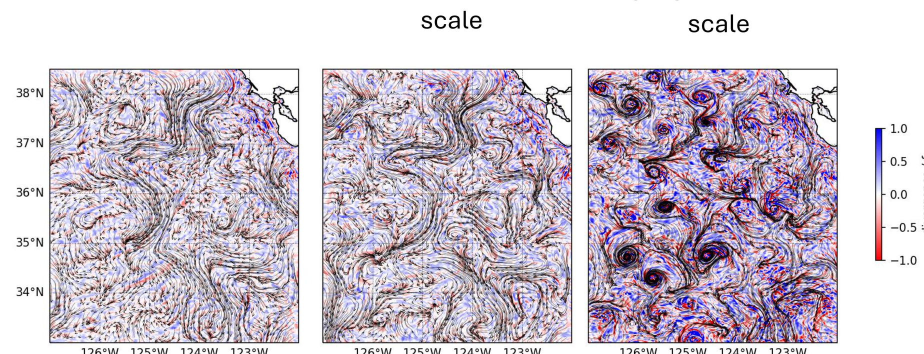


Demonstration during SWOT cal/val shows error variance reduction

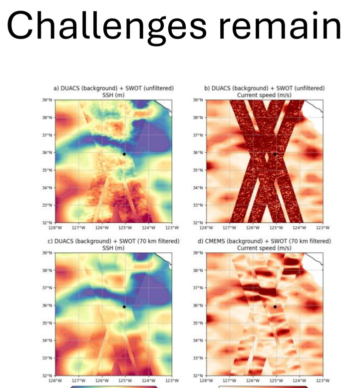
Surface currents
Divergence / f

May 17, 2023

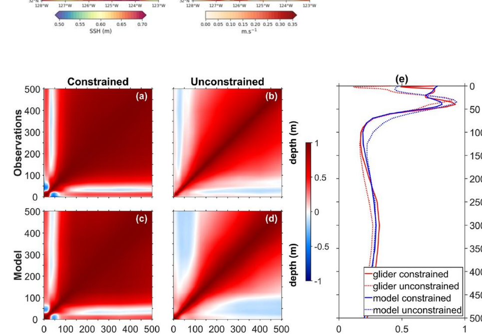
Standard NCODA with SWOT	Adaptive scale NCODA with SWOT 10 km min scale	Adaptive scale NCODA with SWOT 4 km min scale



Challenges remain into the submesoscale



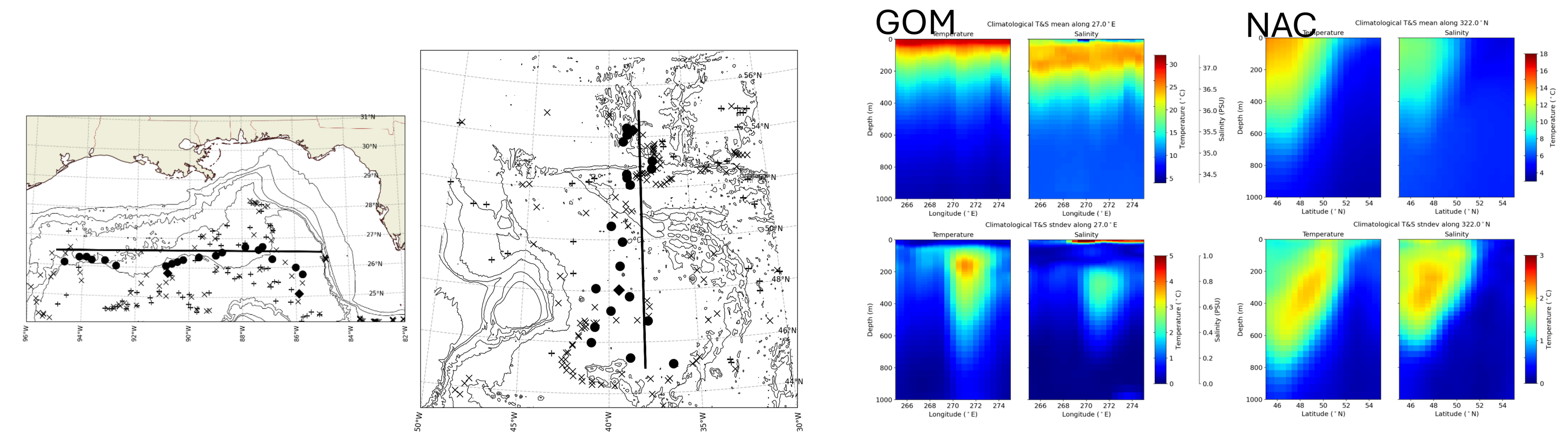
Babette C. Tchonang, Jinbo Wang, Amy F. Waterhouse, Andrew J. Lucas, Caeli Griffin, Matthew R. Archer, Luke Kachelein, Uwe Send, Matthias Lankhorst, Jeffrey Sevadjian and Lee-Lueng Fu
, (2025), SWOT Geostrophic Velocity Validation against in-situ measurements in the California Current, submitted to Earth and Space Science



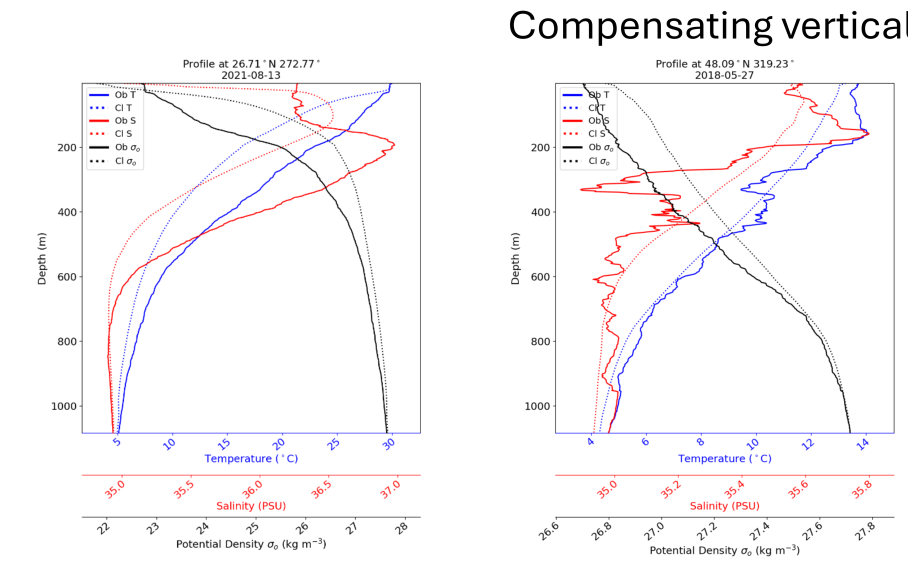
D'Addezio, J.M. and Jacobs, G.A., 2022. Scale-Dependent Ocean Vertical Correlations in the California Current System. *Geophysical Research Letters*, *49*(22), p.e2022GL100184.

Vertical resolution

A tale of two transects



Compensating vertical structure challenges

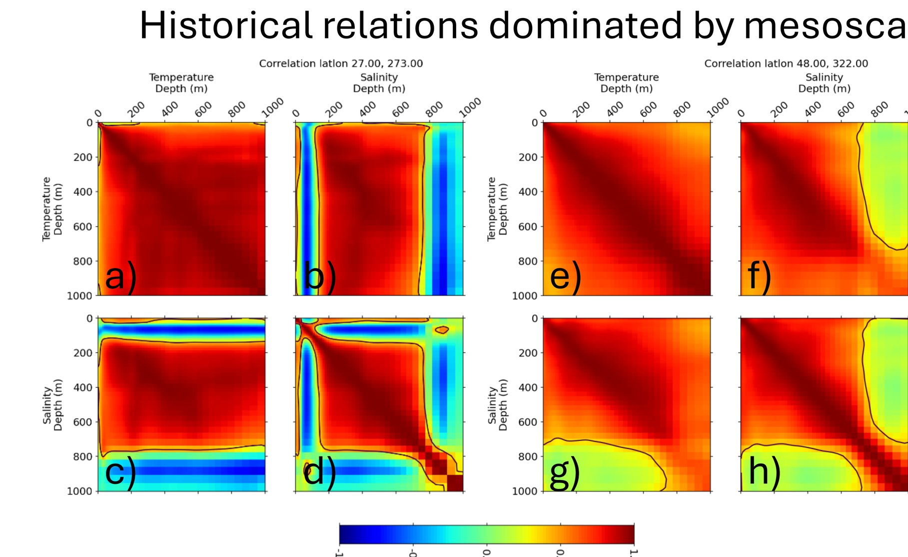


(left) Gulf dominated by relatively large vertical scales in the deviation from climatology
(right) North Atlantic Current containing more variability at smaller vertical scales

The NAC small vertical scale temperature and salinity features compensate one another, which is shown by the lack of these scales in potential density.

Assimilating steric height and profile observations together leads to degradation
We cannot specify one background error to satisfy both simultaneously

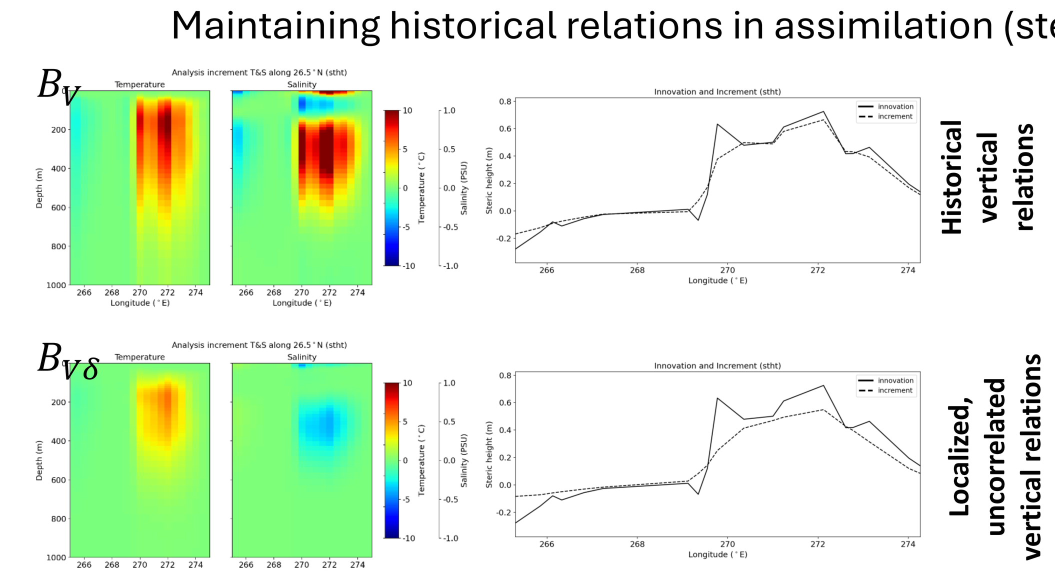
Historical relations dominated by mesoscale features, large vertical scales, compensation



From World Ocean Database 2023

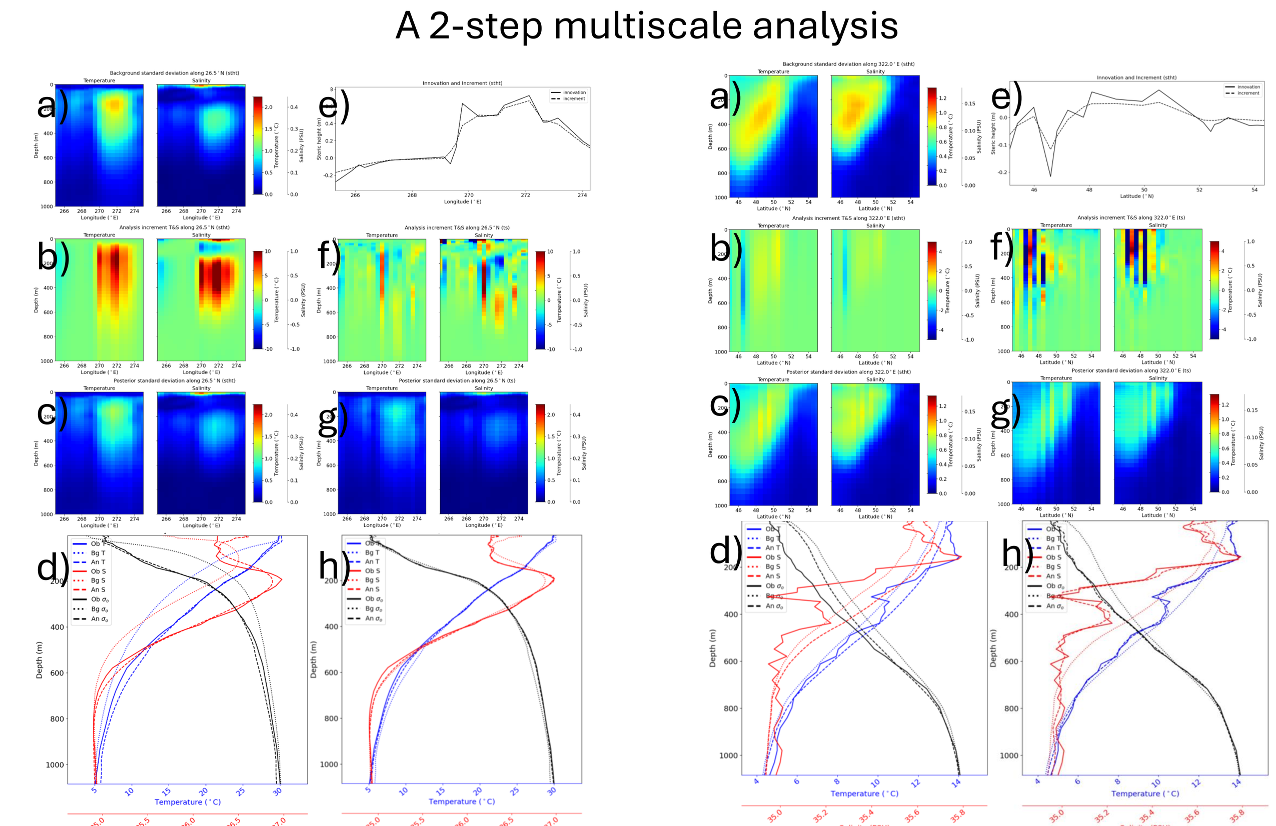
Correlation of temperature and salinity throughout the water column and between the variables. The 4 left panels are for the GOM and the right panels are for the NAC near the profiles above.

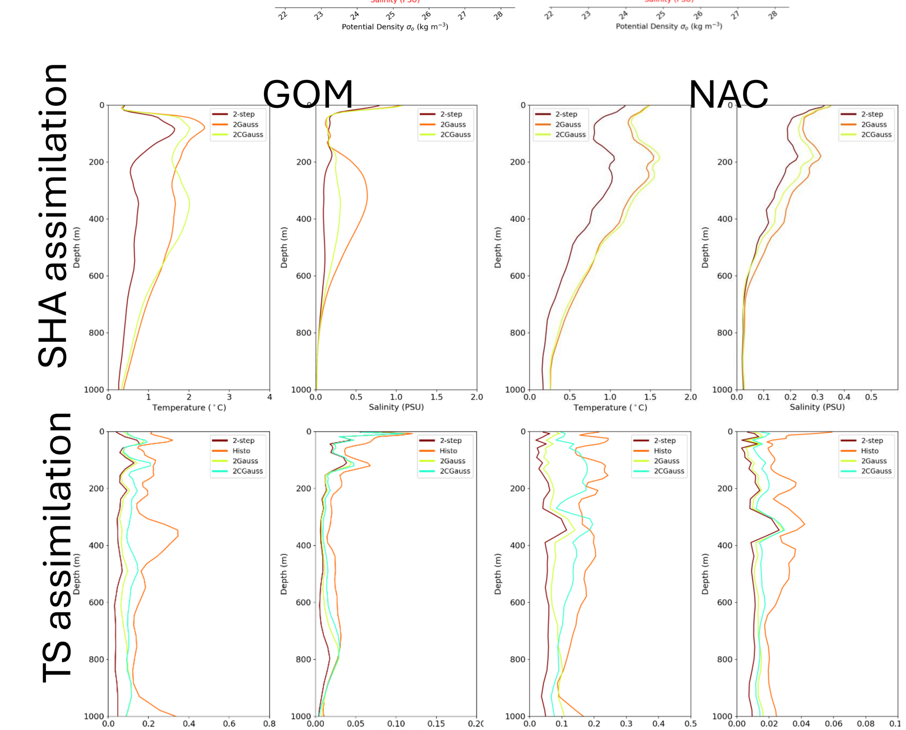
Maintaining historical relations in assimilation (steric height assimilation in the GOM)



Temperature and salinity increments (left, in color) using historical vertical covariance structure (top) and 2-point Gaussian vertical covariance structure B_Vδ (bottom). The innovations and analysis increments for steric height anomaly along the GOM transect are on the right.

A 2-step multiscale analysis





Temperature and salinity RMS errors over all profiles in the transects for the experiments in the GOM (left) and NAC (right). In the multiscale experiment step 1 STHT assimilation (top row), the legend 2-step refers to the resulting errors using B_V. In the multiscale step 2 TS assimilation (bottom row), the legend 2-step refers to the results after assimilating TS.