Effects of Backscatter Parameterization in MOM6 on Global Ensemble-Based Data Assimilation

Kate Boden and Ian Grooms

Ocean Model Working Group

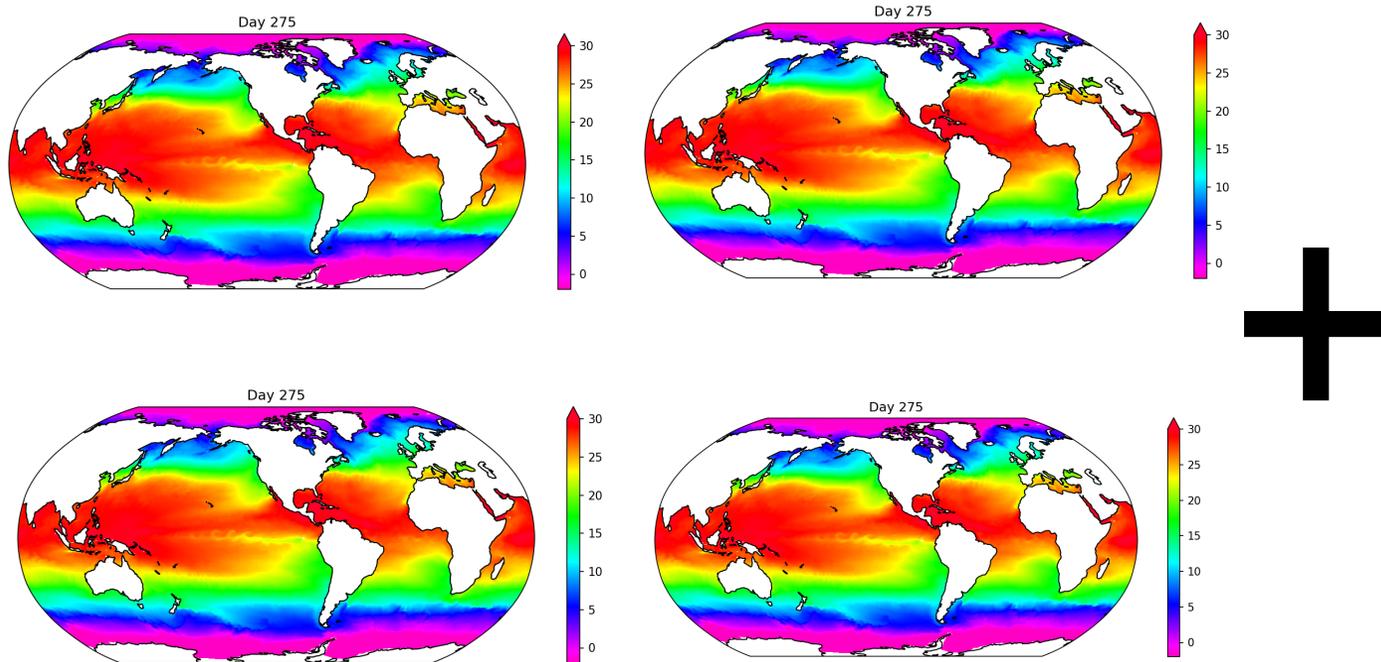NCAR Feb 6th 2026

Motivation: Why Data Assimilation?

The Goal: Accurately initialize models to improve sub-seasonal to decadal predictions.
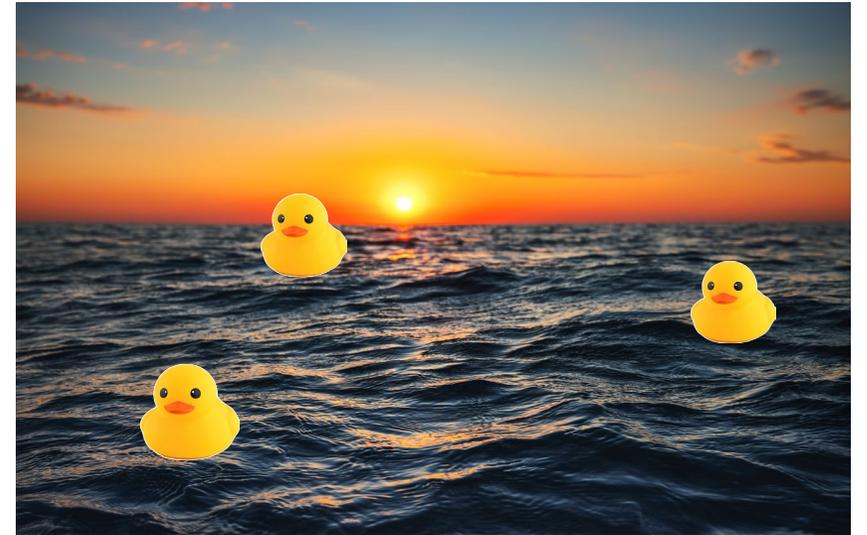
The approach: Use data assimilation to contrains the initial state by incorporating real observations.
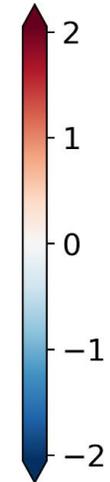
Ensemble-Based Data Assimilation
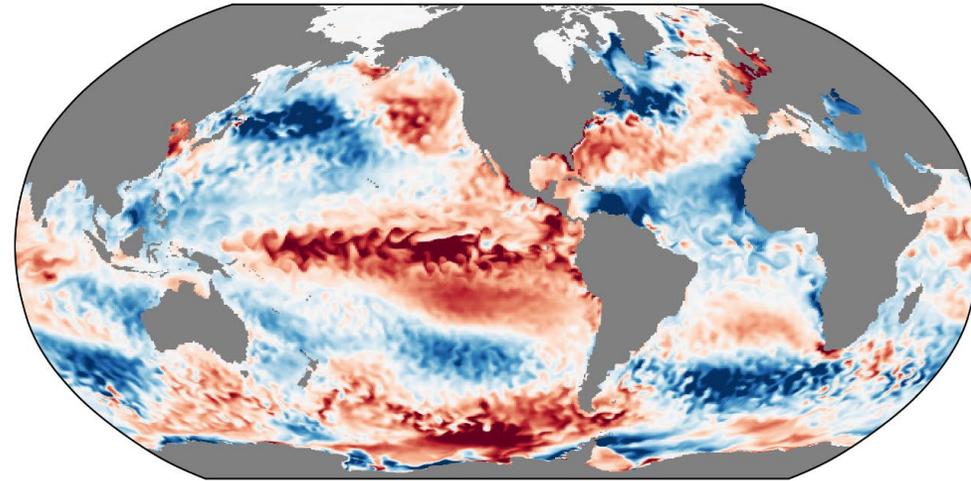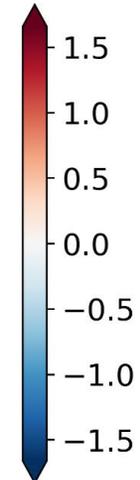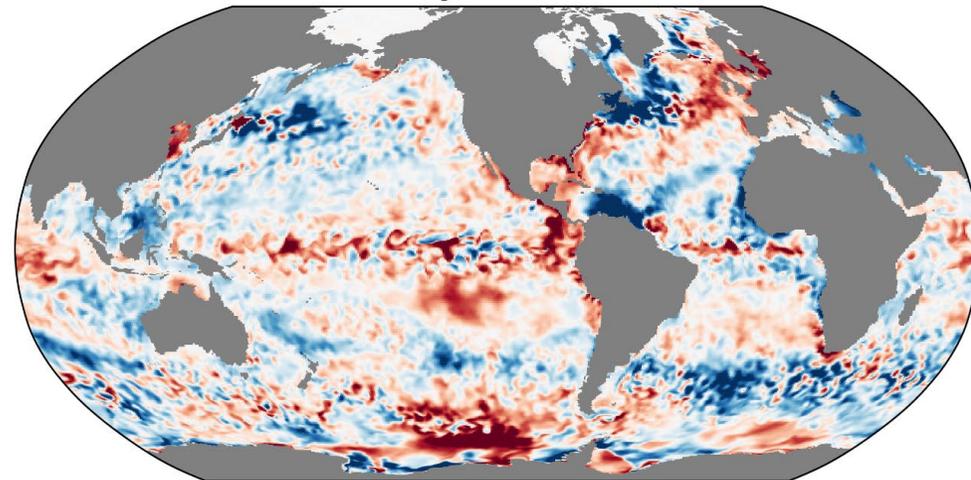
Forecast ensemble

Observing system

Combine imperfect dynamical forecast with imperfect observations for an improved estimate of the state (SST)

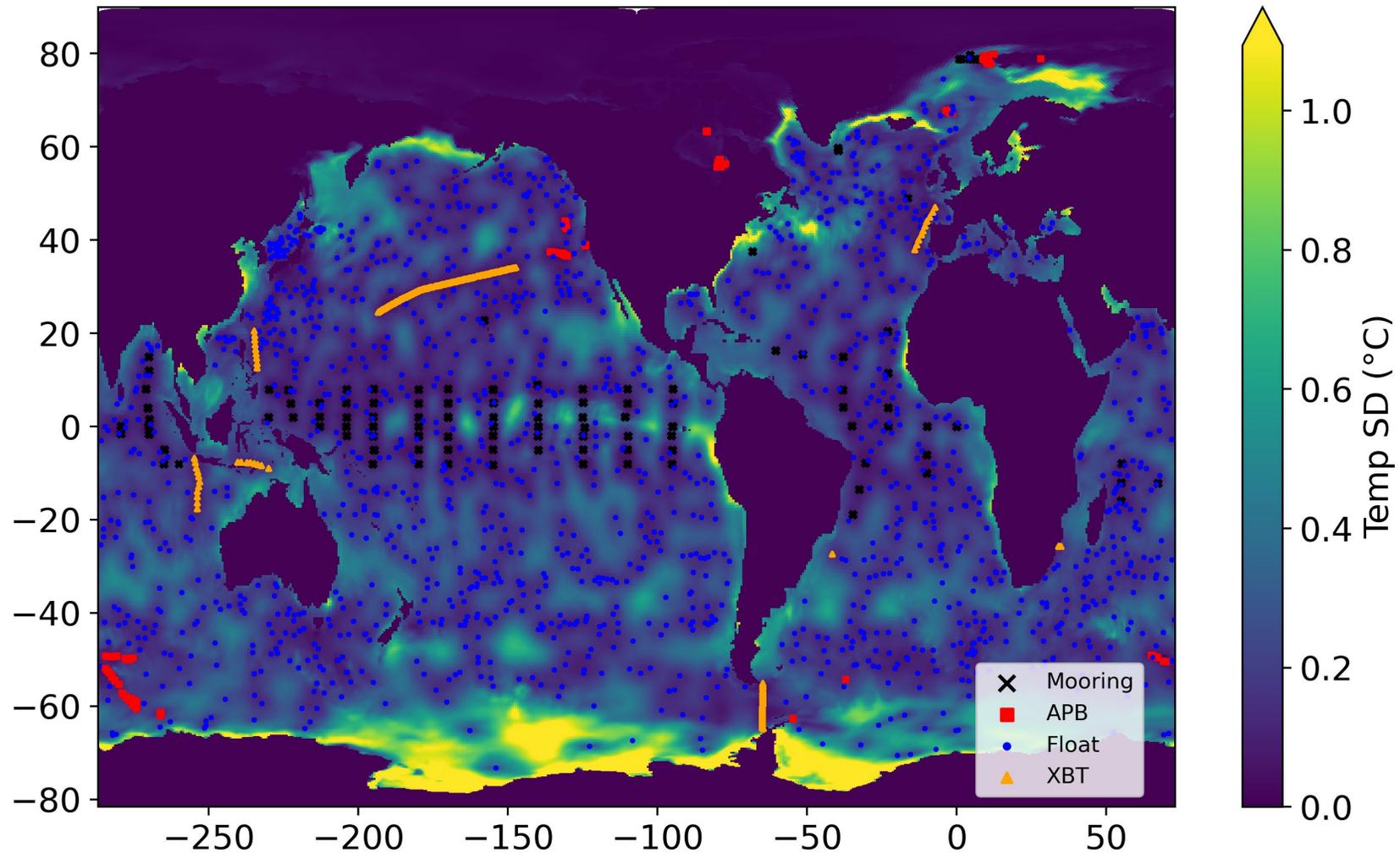# Data Assimilation Improves SST Estimate
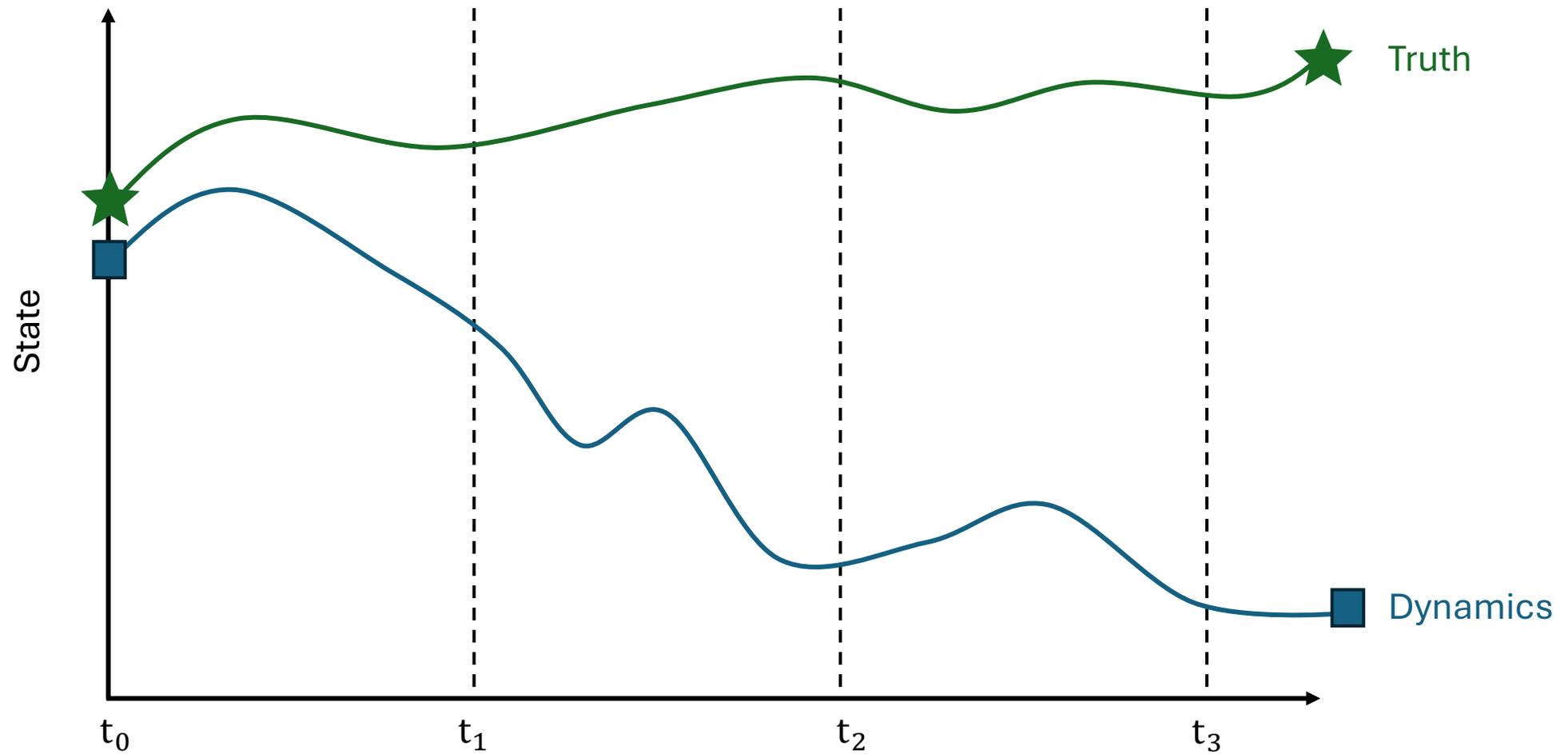

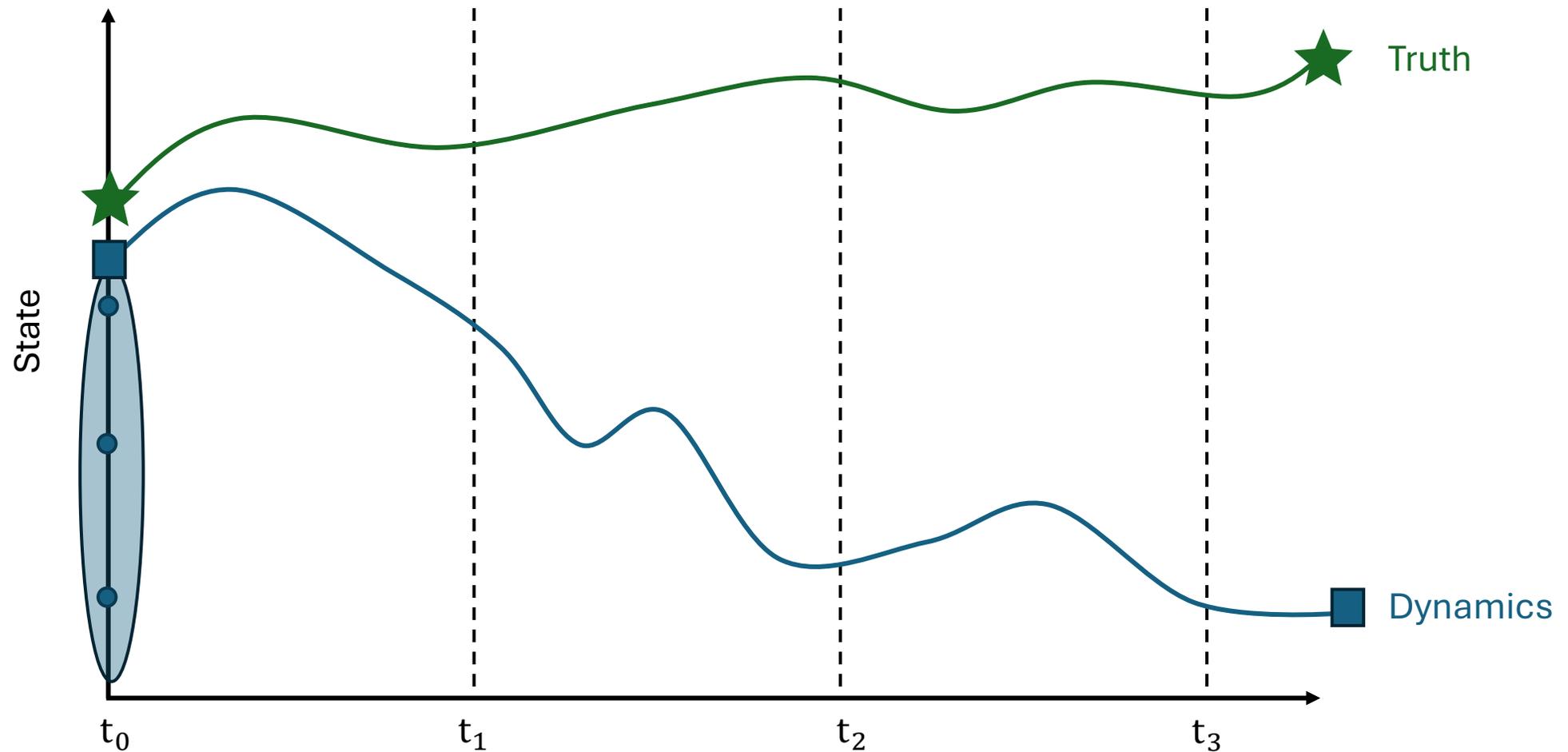
Forecast - Truth

Analysis - Truth

Reduced Uncertainty in SST Around Observations

Well Behaved EnKF

Well Behaved EnKF

Well Behaved EnKF

Well Behaved EnKF

Well Behaved EnKF

Well Behaved EnKF

Well Behaved EnKF

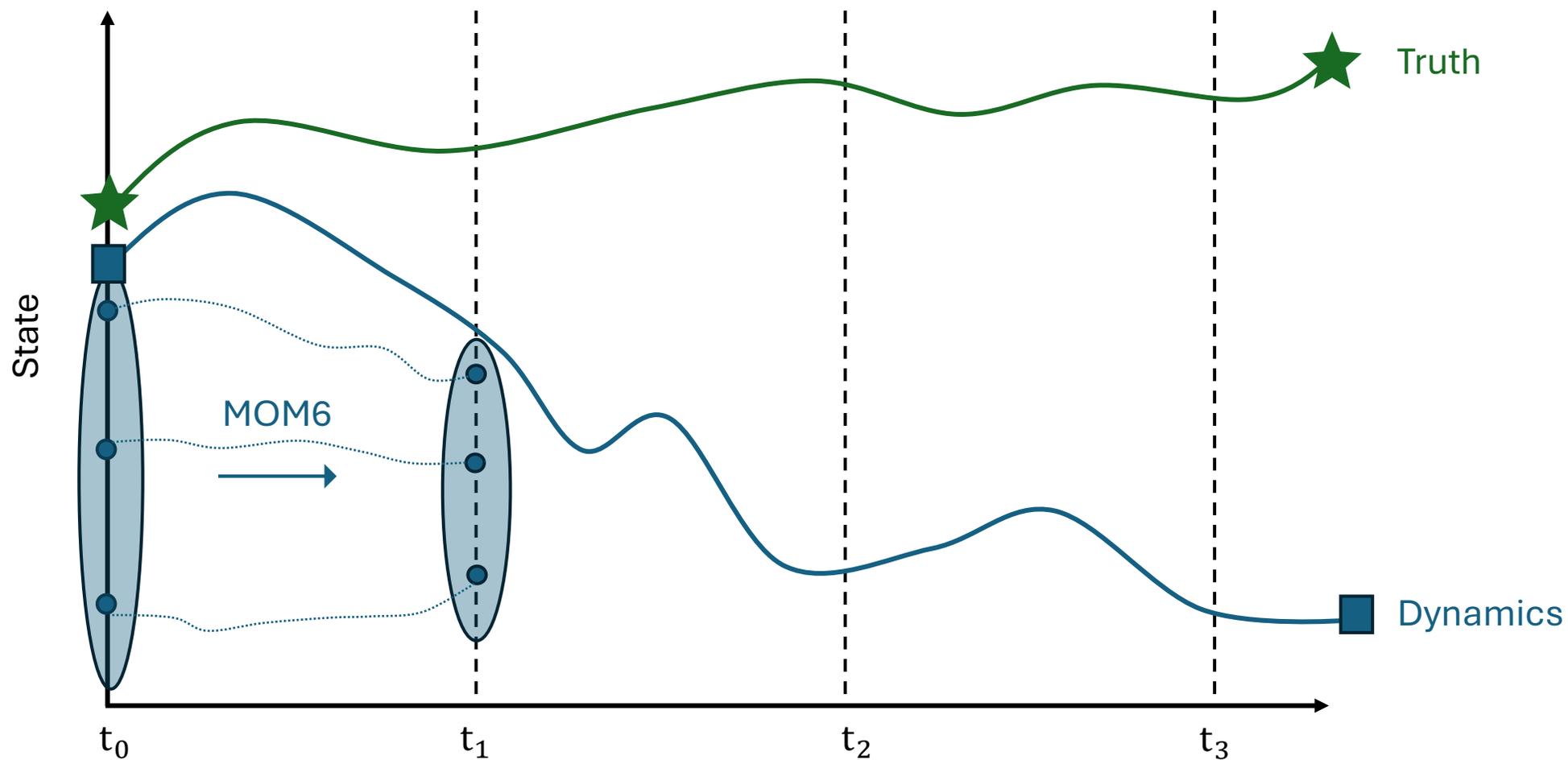# Well Behaved EnKF

Well Behaved EnKF

Well Behaved EnKF

Well Behaved EnKF

Well Behaved EnKF

$$\Delta \text{State} \propto \frac{\text{Var}_{\text{forecast}}}{\text{Var}_{\text{forecast}} + \text{Var}_{\text{obs}}}$$
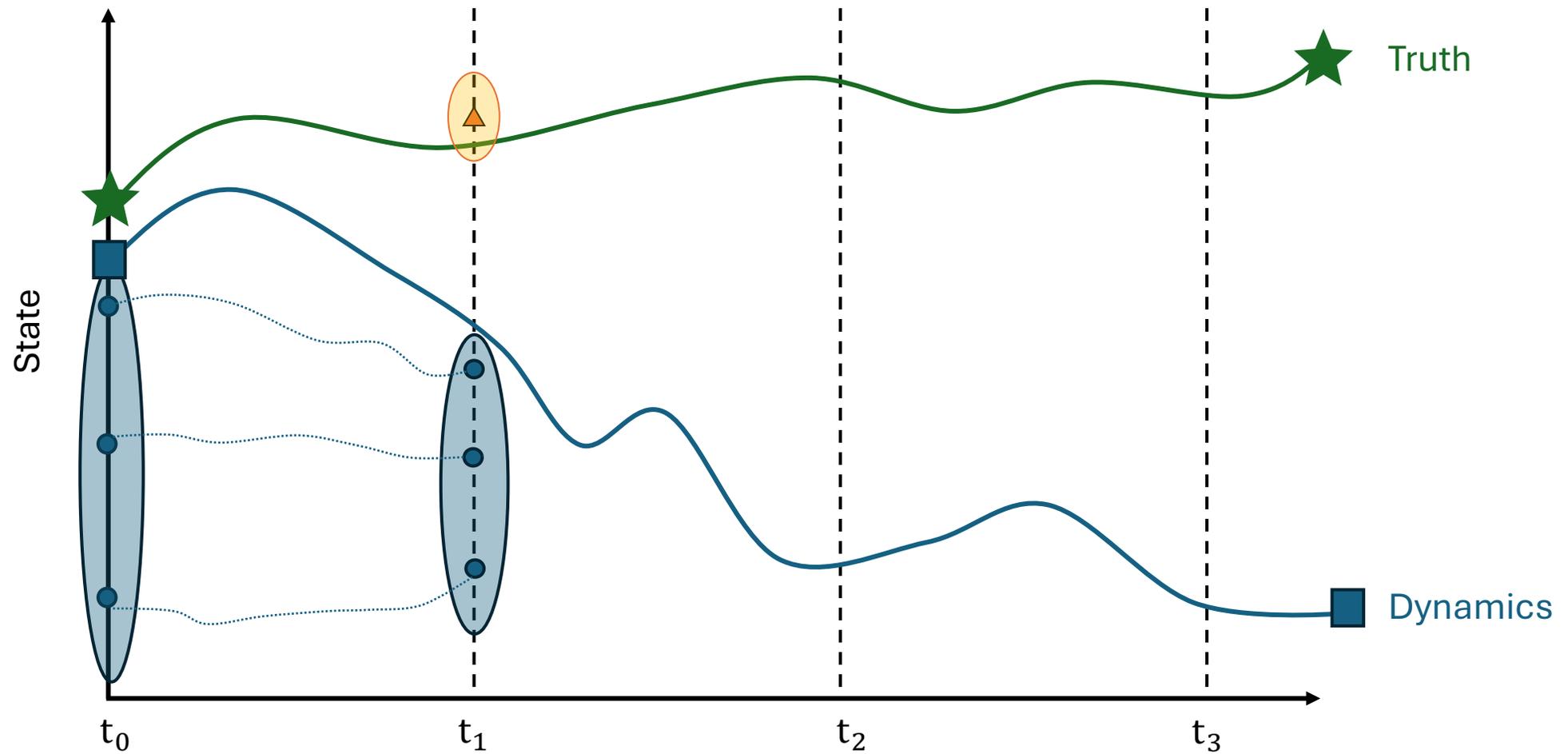
○ Analysis

● Forecast

▲ Observation

Truth

DA Free Dynamics

State

t_0 t_1 t_2 t_3
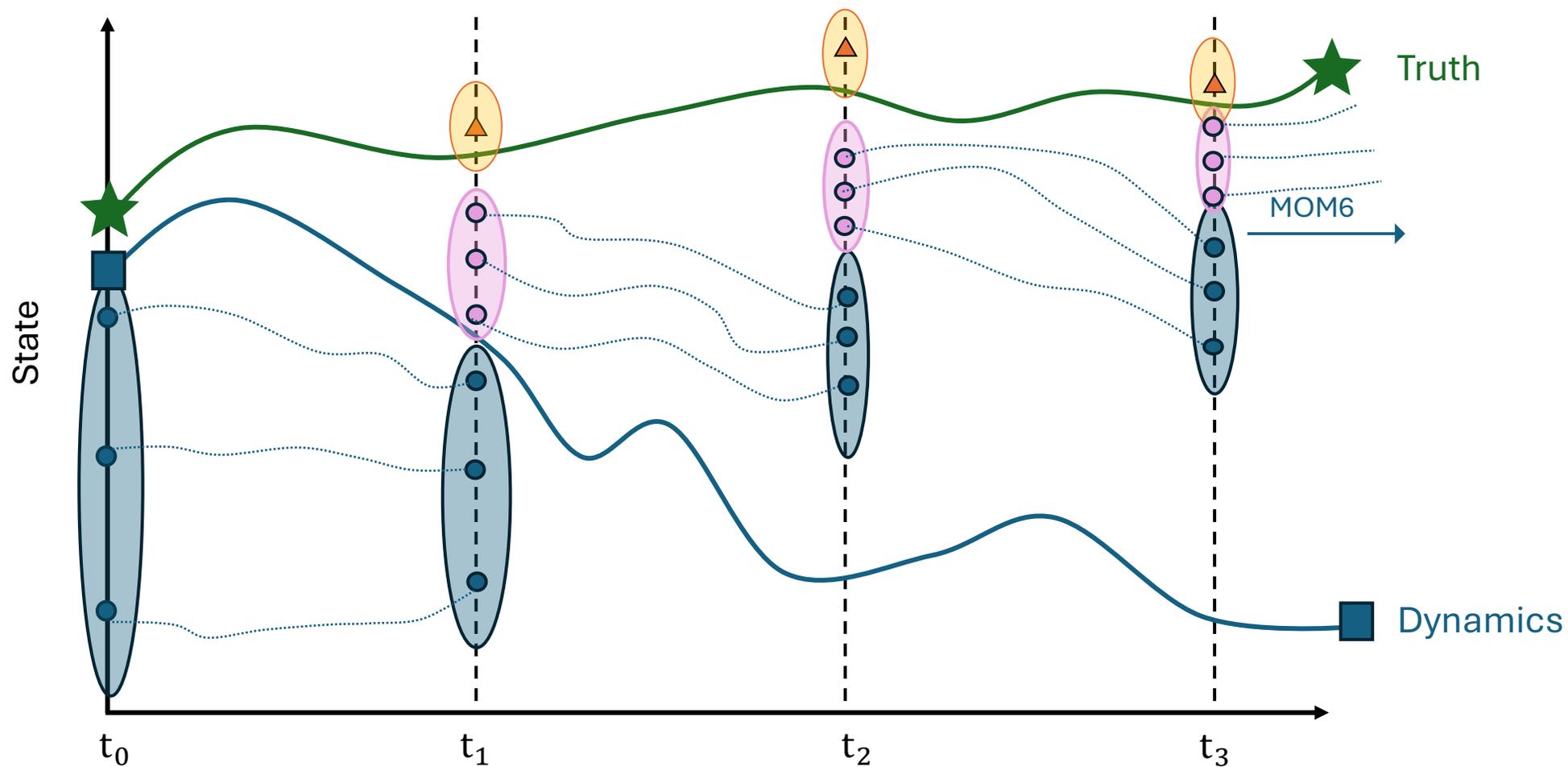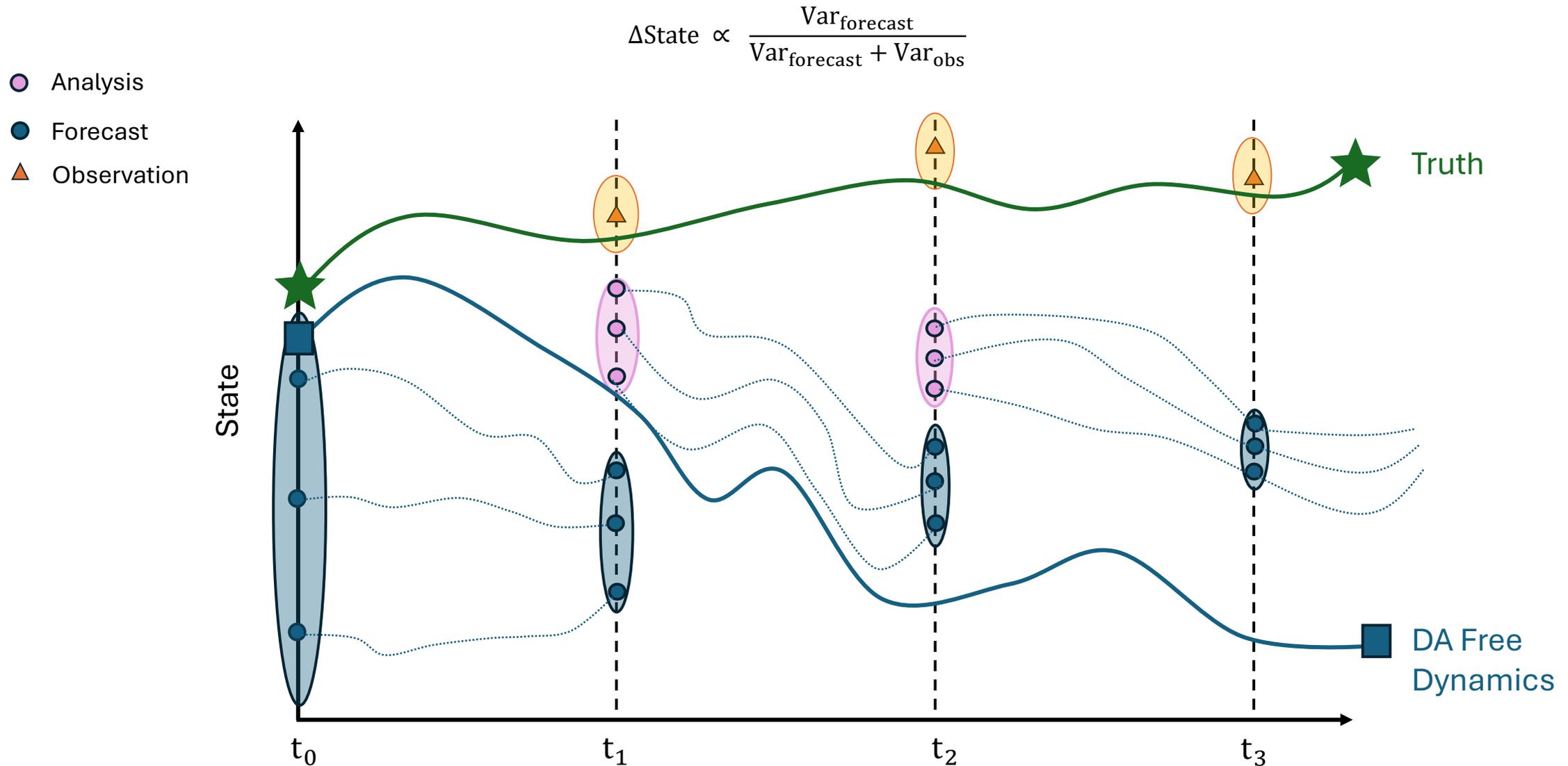
DA Fix: Adaptive Inflation

$$(y - \bar{x})^2 \gg \sigma_y^2 + \sigma_x^2$$

01-10

03-11
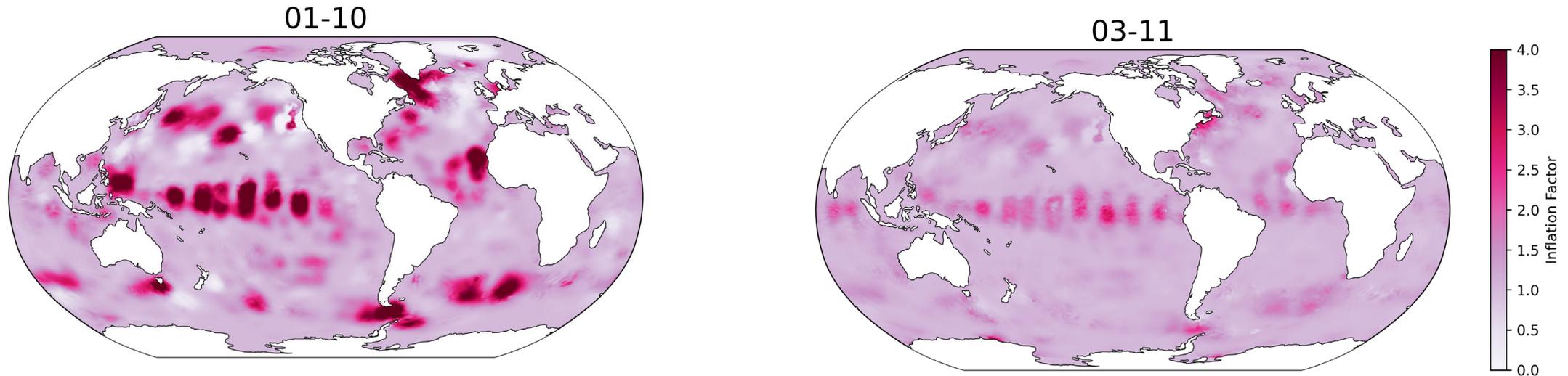
Model bias: The difference in the ensemble mean and the observation is not explained by the combined variance

Two months of DA (assimilating every 5 days) has reduced the bias, the difference in the ensemble mean and the observation can be explained by the variance, inflation factor goes down.

19

Underlying Issue: Lack of Model Variability

- **Inflation addresses a fundamental limitation of coarse-resolution models:** insufficient variability due to unresolved processes such as mesoscale eddies.

- **MOM6 includes a backscatter parameterization** designed to represent the impact of mesoscale eddies and other unresolved phenomena on resolvable scales.

- **Directly increasing model variability** could therefore improve not only the model dynamics but also the performance of data assimilation.

Research Question

To what extent can the physically based backscatter parameterizations within MOM6 reduce or replace the need for covariance inflation in ensemble data assimilation?

Model Fix: Backscatter Parameterization

There are 3 backscatter parameterization in MOM6 that are on by default

1. Stochastic GM + E

2. Stochastic Equation of State

3. Deterministic Leith + E

SST standard deviation for observations
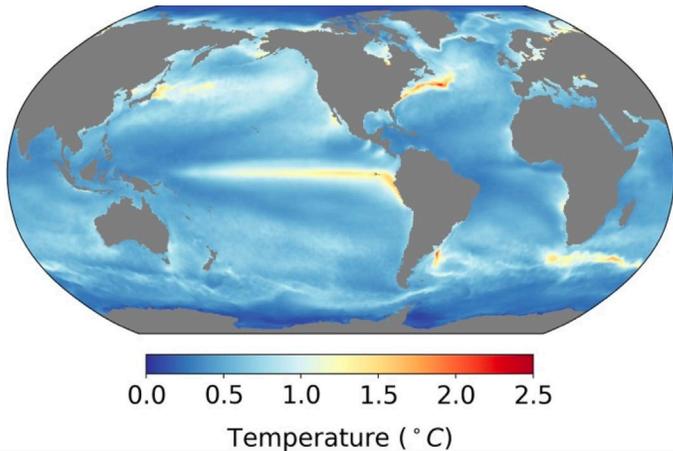
Control−Observations

Backscatter − Control

*Figure adapted from Grooms et al 2025
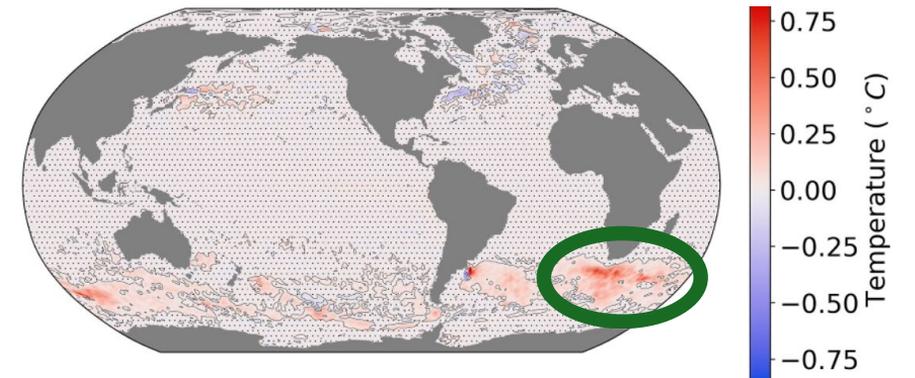
MOM6 + DART Configuration

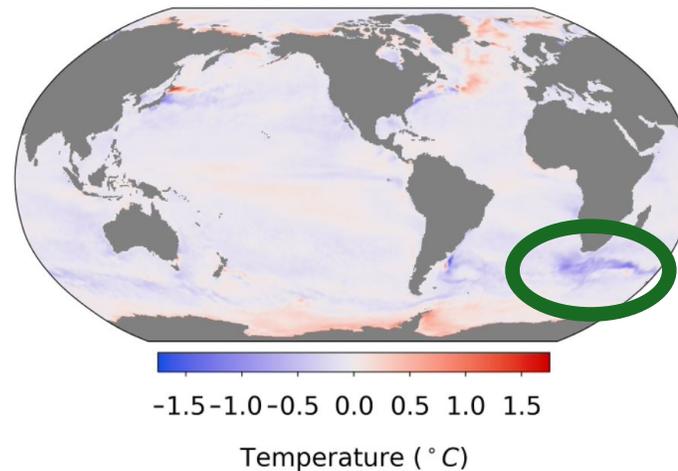| MOM6	Nominal 2/3° — G case
Vertical layers	75, z*
Ensemble size	40
Assimilation Frequency	Every 5 days
Observations Types	Salinity and Temperature
Number of Observations per DA cycle	~ 250, 000
Update variables	u,v, S,T
Horizontal localization	R ~ 2,000 km
Inflation	Adaptive (prior only)

Experiments

With the configuration from the previous slide, run each of the following experiments for 1 full year- 2011.

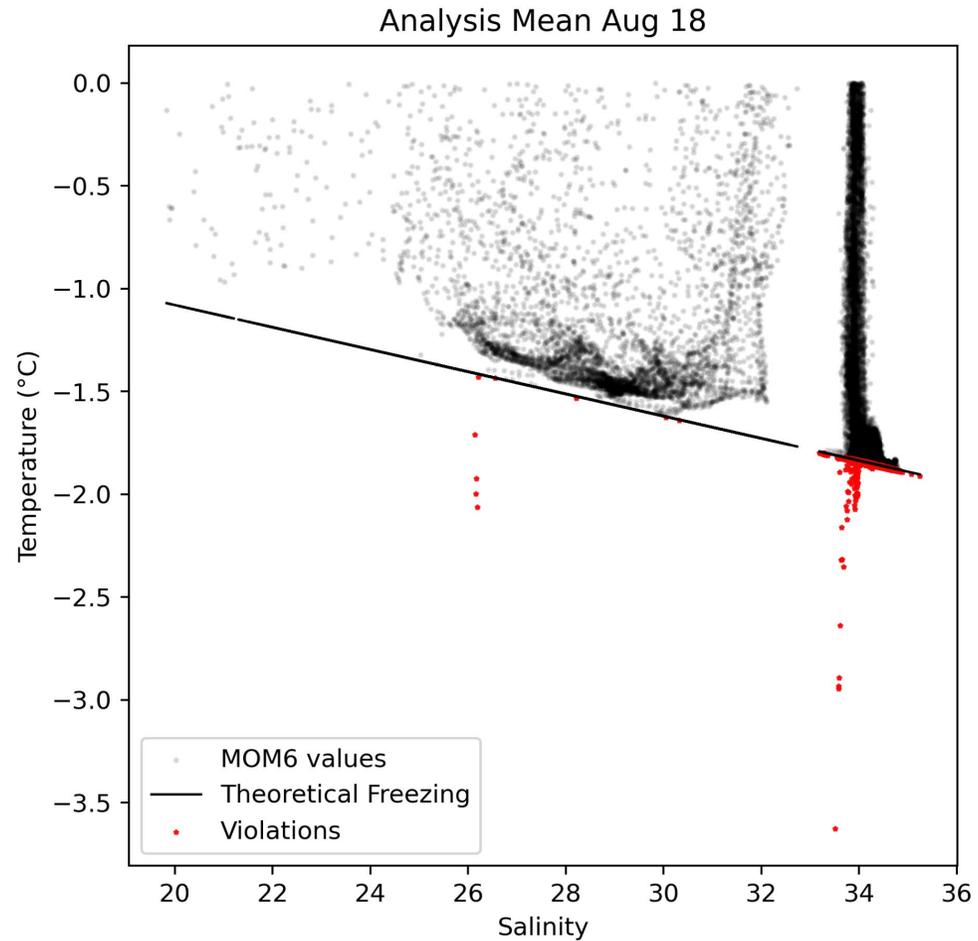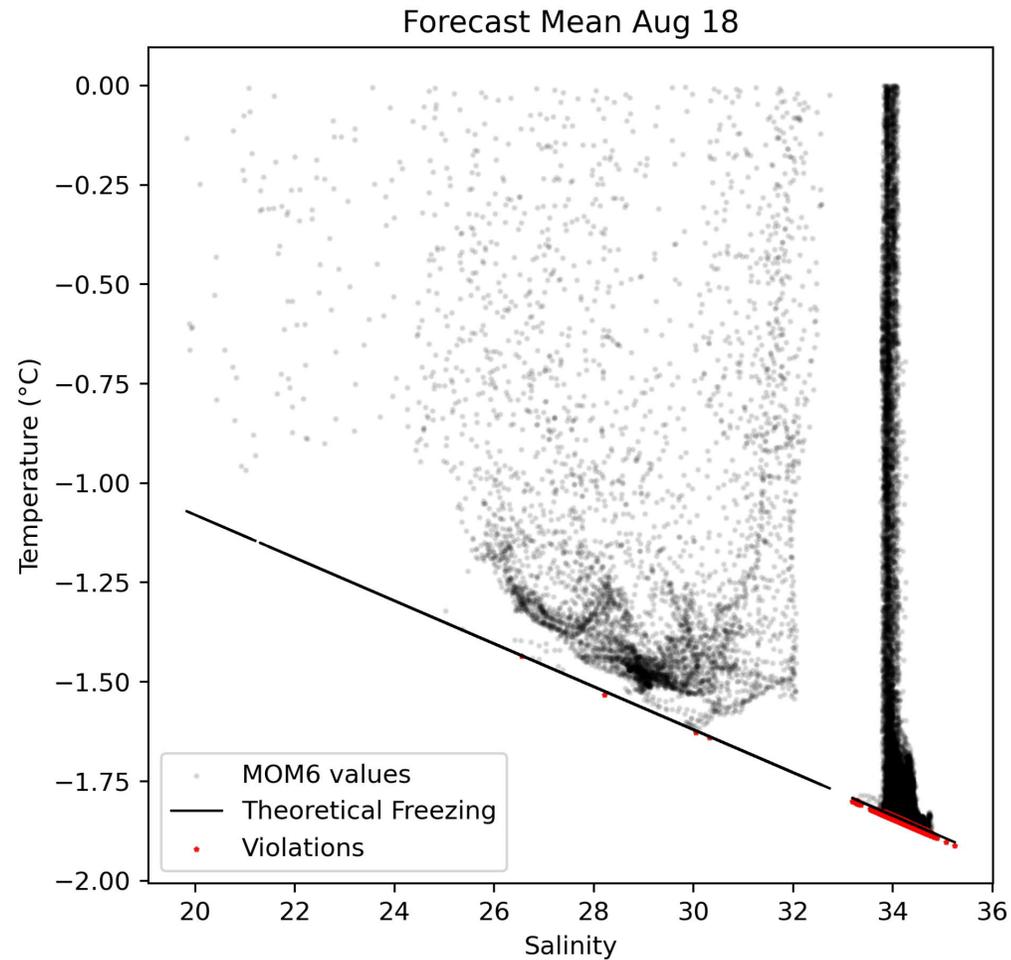| Experiment	Observation Source	MOM6 Configuration
1	Control	Control
2	Control	Backscatter
3	Backscatter	Contol
4	Backscatter	Backscatter

Ocean-Ice Issues

Non-physical DART temperature increments lead to thermodynamic instabilities in CICE

Ocean-Ice "Fix"

Post process the restart files using a linear approximation to the freezing temperature based on salinity

$$T_{freeze} \geq -0.054 \cdot S + epsilon$$

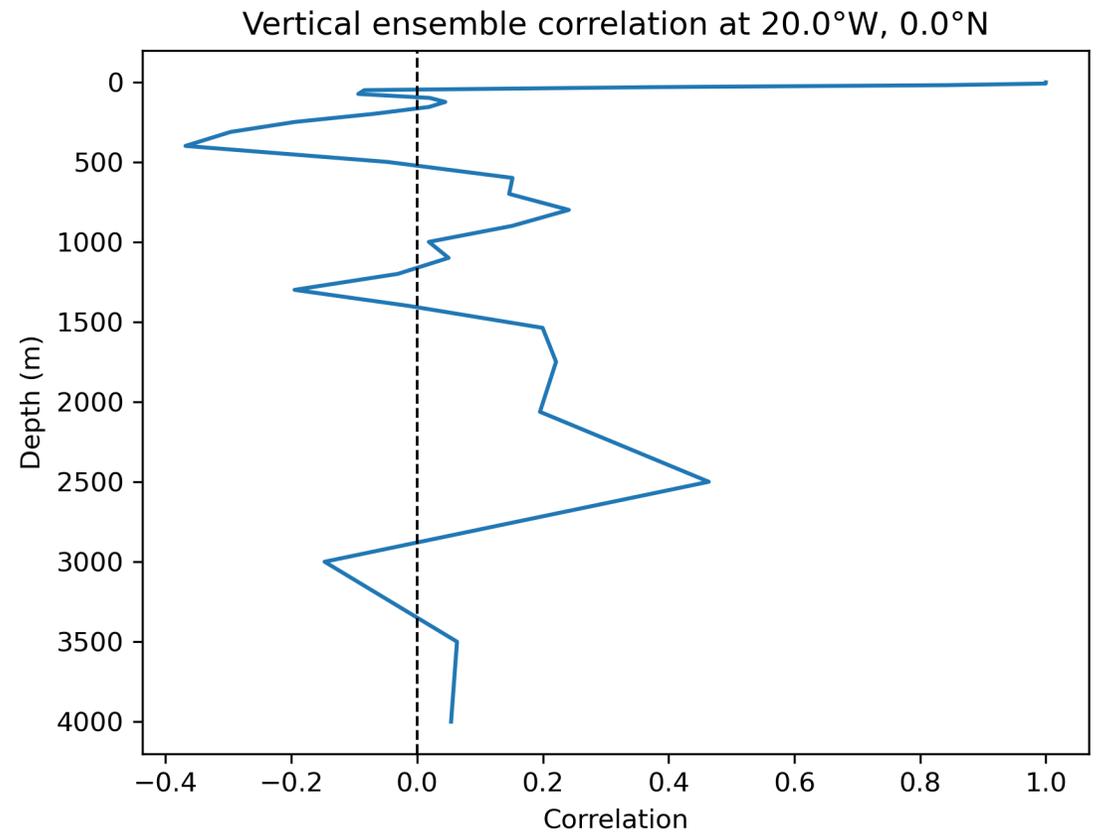Future work to be done here managing the DA increments in the ocean and how they influence ice thermodynamics
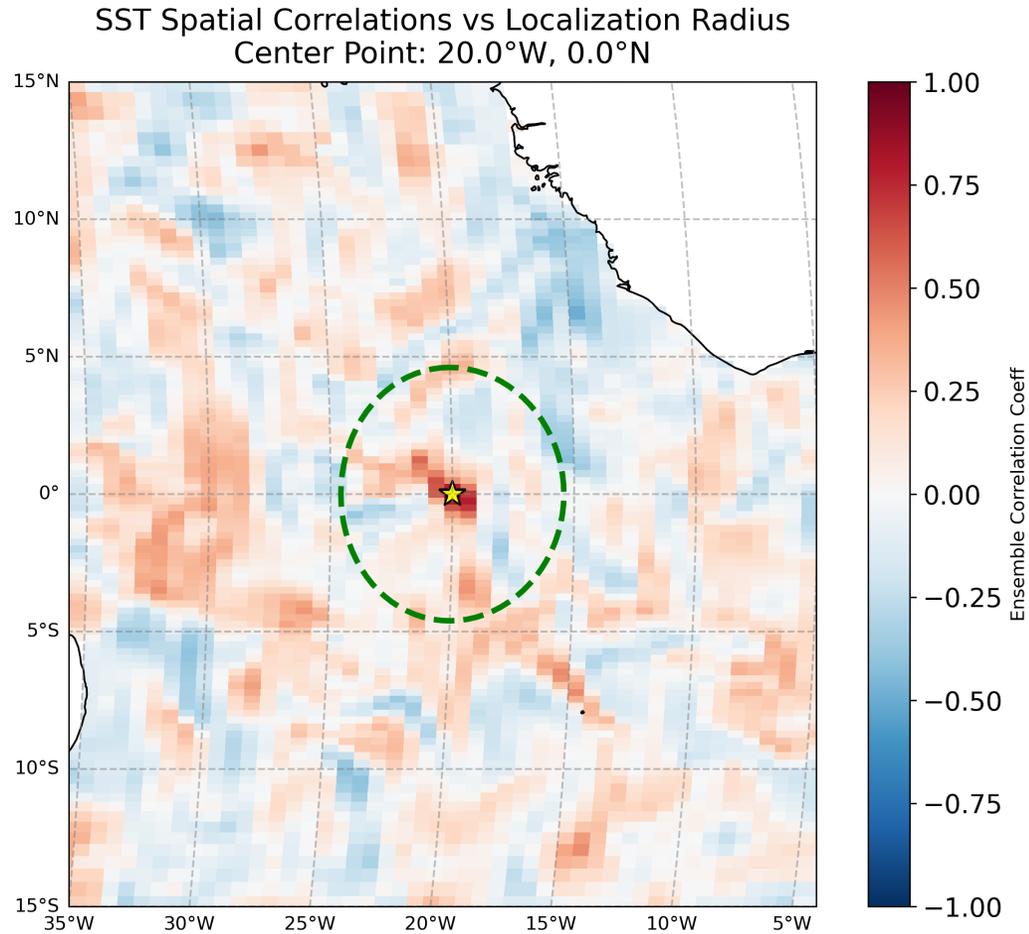
Results: Assimilating control observations
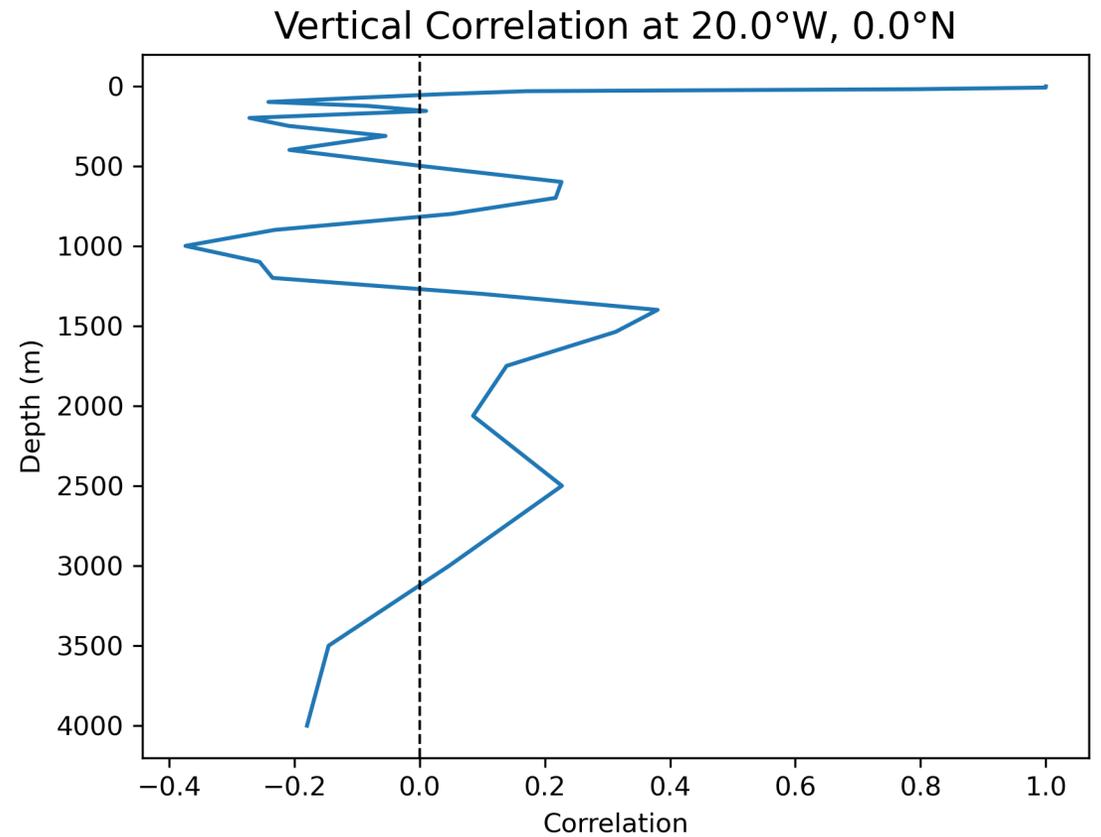
MOM6 Control   MOM6 Backscatter Package

Backscatter correlation structure

SST Spatial Correlations vs Localization Radius
Center Point: 20.0°W, 0.0°N

Vertical ensemble correlation at 20.0°W, 0.0°N

Control correlation structure

SST Spatial Correlations vs Localization Radius
Center Point: 20.0°W, 0.0°N

Vertical Correlation at 20.0°W, 0.0°N
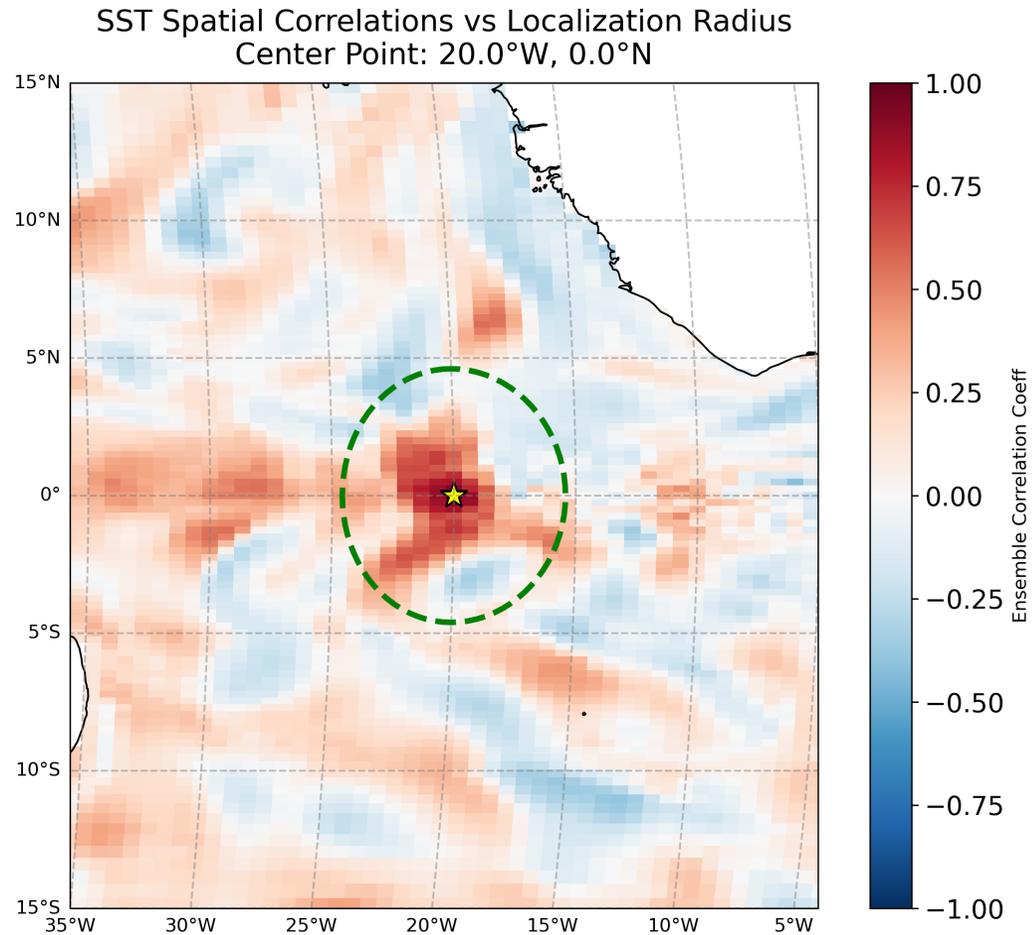
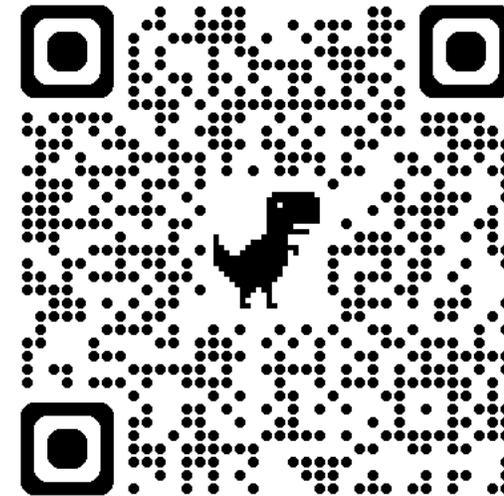# MOM6-DART Working Notes and Resources

Notes and documentation on

1. MOM6 + DART case setup and runs
2. DART input configurations
3. Tips for viewing results
4. Restarting a failed case
5. Ongoing updates

https://kateboden.github.io/mom6_dart_notes/

Thank You!

NCAR | DART

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- Moha Gharamti
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- Kevin Raeder
- Molly Wieringa