CESM-DART

Ocean Data Assimilation

Helen Kershaw
DAReS NCAR

Terminology

DAReS - the group of people
DART - the software we produce

Team

DAReS

Jeff Anderson
Kevin Raeder
Marlee Smith
Brett Raczka
Ben Johnson
Helen Kershaw
Moha Gharamti
Anderson Chauphan

CGD

Dan Amrhein
Alper Altuntas
Brian Dobbins
Jim Edwards

Ensemble Data Assimilation

Ensemble Data Assimilation

Group of model forecasts

Ensemble Data Assimilation

Group of model forecasts

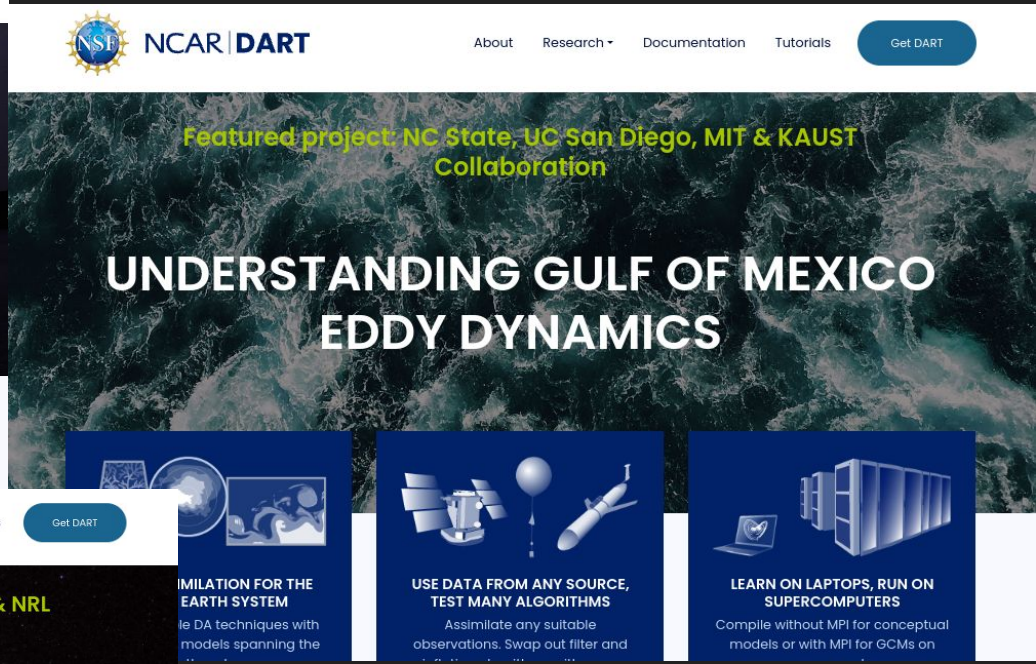
Measurements

Ensemble Data Assimilation

Group of model forecasts

Improved estimate

Measurements



dart.ucar.edu

Existing CESM work

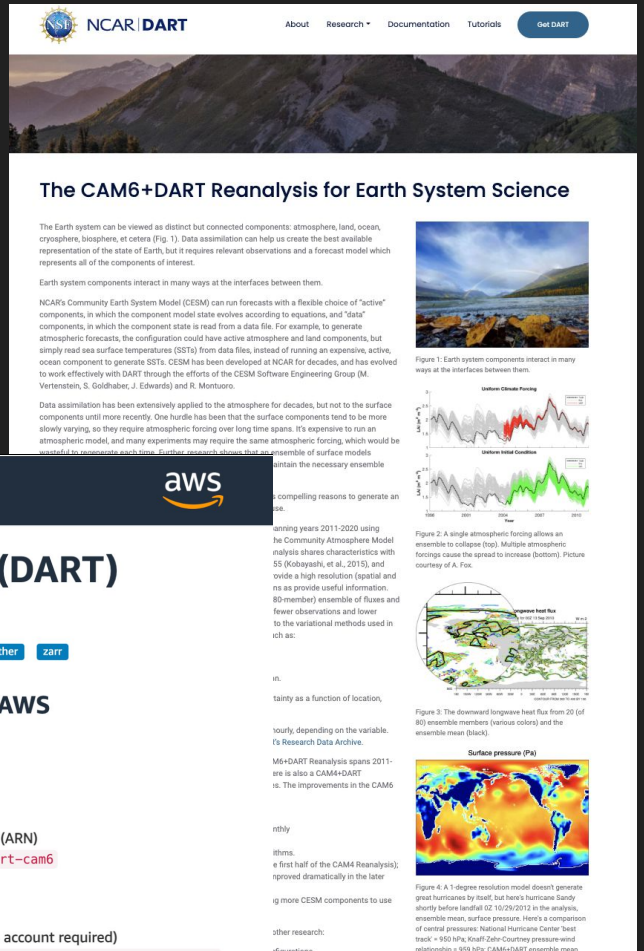
Existing CESM work

2003 DART-CAM2 Breckenridge

Existing CESM work

2003 DART-CAM2 Breckenridge

2021 DART-CAM6 Reanalysis



NCAR | DART

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The CAM6+DART Reanalysis for Earth System Science

The Earth system can be viewed as distinct but connected components: atmosphere, land, ocean, cryosphere, biosphere, et cetera (Fig. 1). Data assimilation can help us create the best available representation of the state of Earth, but it requires relevant observations and a forecast model which represents all of the components of interest.

Earth system components interact in many ways at the interfaces between them.

NCAR's Community Earth System Model (CESM) can run forecasts with a flexible choice of "active" components, in which the component model state evolves according to equations, and "data" components, in which the component state is read from a data file. For example, to generate atmospheric forecasts, the configuration could have active atmosphere and land components, but simply read sea surface temperatures (SSTs) from data files, instead of running an expensive, active, ocean component to generate SSTs. CESM has been developed at NCAR for decades, and has evolved to work effectively with DART through the efforts of the CESM Software Engineering Group (M. Vertenstein, S. Goldhaber, J. Edwards) and R. Montuoro.

Data assimilation has been extensively applied to the atmosphere for decades, but not to the surface components until more recently. One hurdle has been that the surface components tend to be more slowly varying, so they require atmospheric forcing over long time spans. It's expensive to run an atmospheric model, and many experiments may require the same atmospheric forcing, which would be

Figure 1: Earth system components interact in many ways at the interfaces between them.

Figure 2: A single atmospheric forcing allows an ensemble to collapse (top). Multiple atmospheric forcings cause the spread to increase (bottom). Picture courtesy of A. Fox.

Figure 3: The downward longwave heat flux from 20 (of 80) ensemble members (various colors) and the ensemble mean (black).

Surface pressure (Pa)

Figure 4: A 1-degree resolution model doesn't generate great hurricanes by itself, but here's hurricane Sandy shortly before landfall 02 10/29/2012 in the analysis, ensemble mean, surface pressure. Here's a comparison of central pressures: National Hurricane Center 'best track' = 950 hPa; Knaff-Zehr-Courtney pressure-wind

Registry of Open Data on AWS

aws

CAM6 Data Assimilation Research Testbed (DART) Reanalysis: Cloud-Optimized Dataset

atmosphere climate climate model data assimilation forecast geoscience geospatial land meteorological weather zarr

Description

This is a cloud-hosted subset of the CAM6+DART (Community Atmosphere Model version 6 Data Assimilation Research Testbed) Reanalysis dataset. These data products are designed to facilitate a broad variety of research using the NCAR CESM 2.1 (National Center for Atmospheric Research's Community Earth System Model version 2.1), including model evaluation, ensemble hindcasting, data assimilation experiments, and sensitivity studies. They come from an 80 member ensemble reanalysis of the global troposphere and stratosphere using DART and CAM6. The data products represent states of the atmosphere consistent with observations from 2011 through 2019 at 1 degree horizontal resolution and weekly frequency. Each ensemble member is

Resources on AWS

Description
Project data files

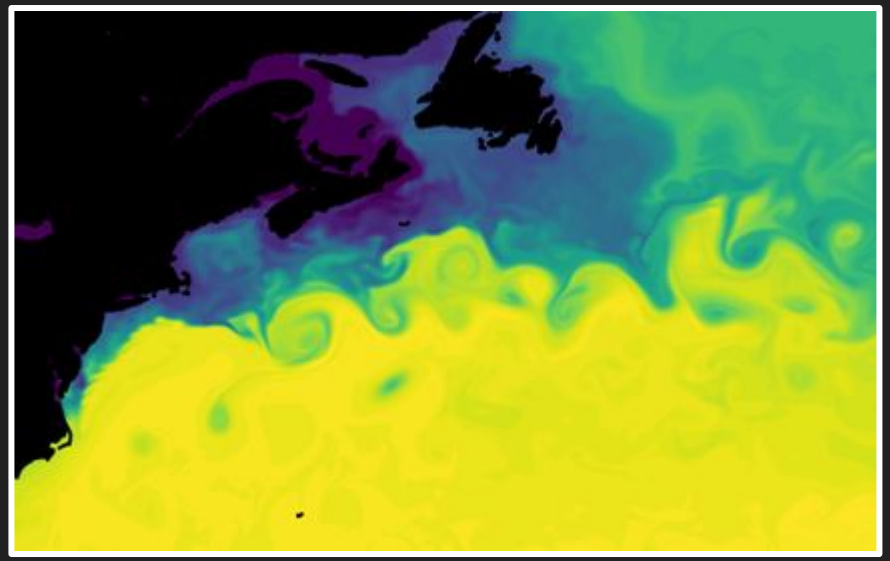
Resource type
S3 Bucket

Amazon Resource Name (ARN)
`arn:aws:s3:::ncar-dart-cam6`

AWS Region
`us-west-2`

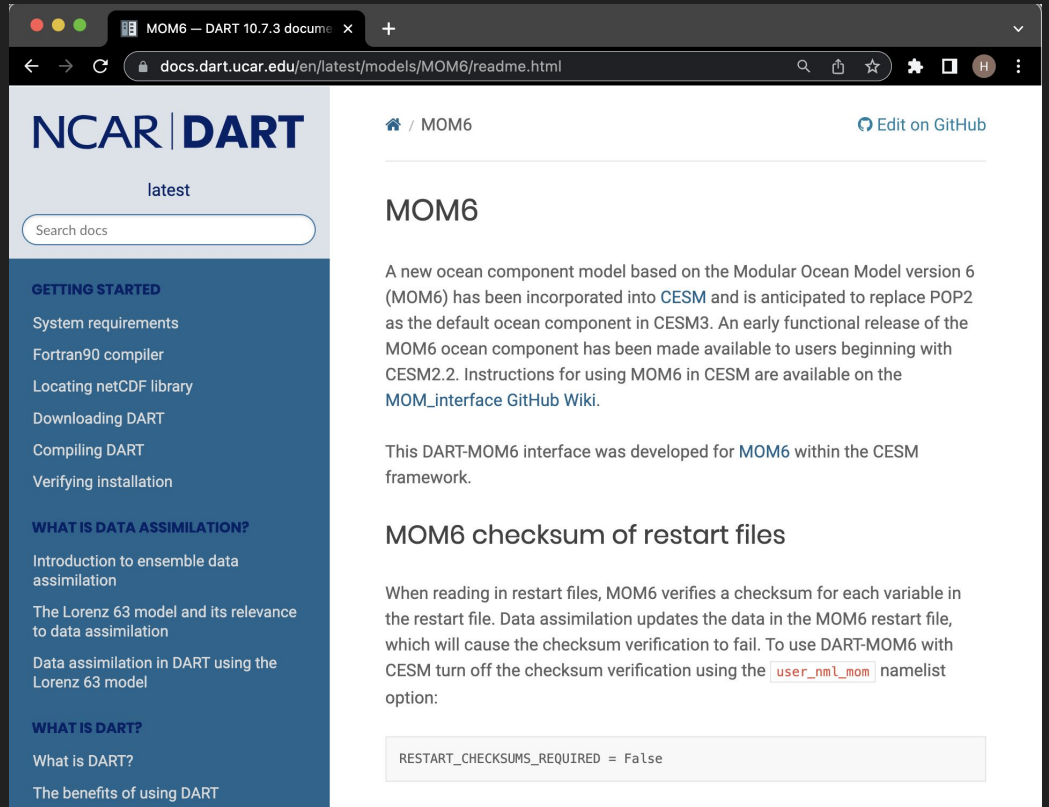
AWS CLI Access (No AWS account required)

POP Accelerated Scientific Discovery

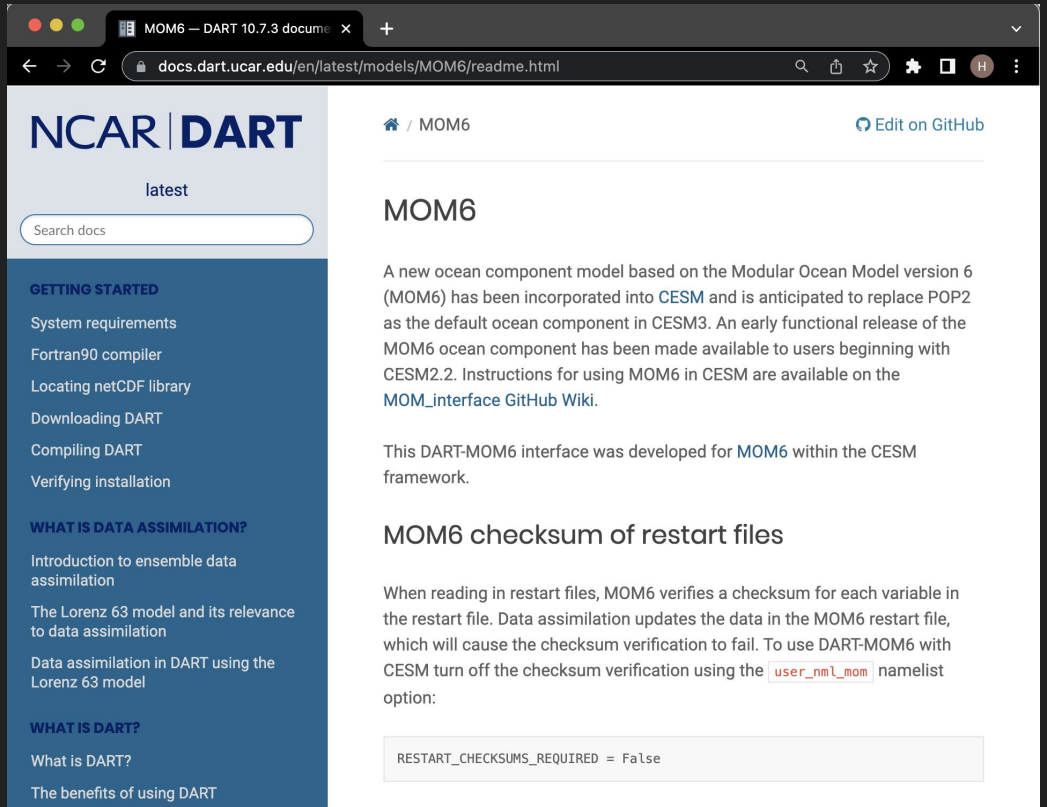


High-resolution ocean DA |
80-member ocean reanalyses spanning 2011-2017 at 1° and 0.1°
Ben Johnson, Moha Gharamti, Anna-Lena Deppenmeier, and Ian Grooms

MOM6 interface



MOM6 interface



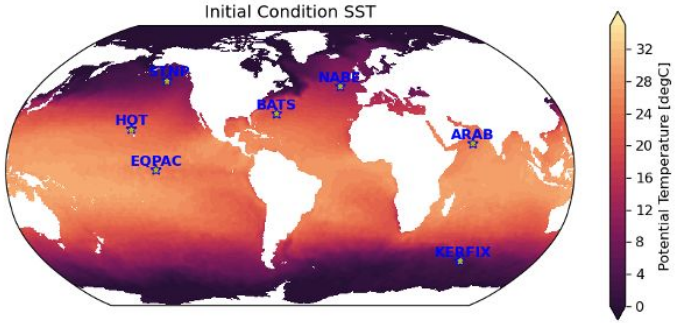
cesm2_3_alpha15a

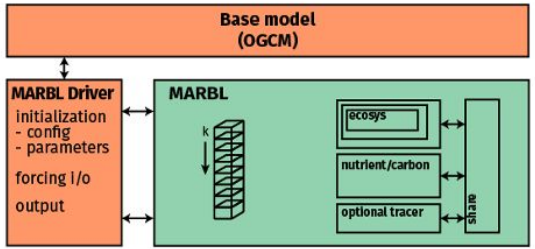
Parameter estimation MARBL

DA and parameter estimation in MARBL-MOM6

Robin Armstrong (SIParCS summer student)

with Mike Levy, Kristen Krumhardt, Helen Kershaw, Alper Altuntas, Keith Lindsay, Moha Gharamti, Matt Long, and Dan Amrhein





Project Goals

Compare 1-D column MOM6/MARBL to data at BATS, HOT, etc.

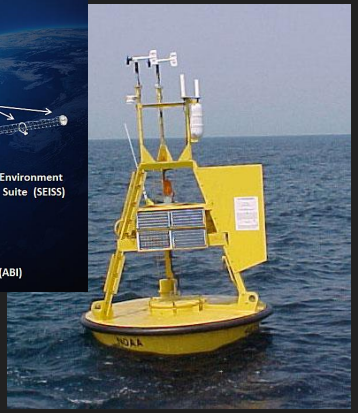
Estimate BGC parameters (nutrient uptake, productivity, predation, …) using the ensemble Kalman filter

Evaluate parameters for global simulations

DART: observations and models

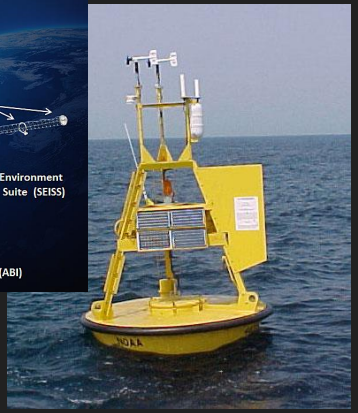
DART: observations and models

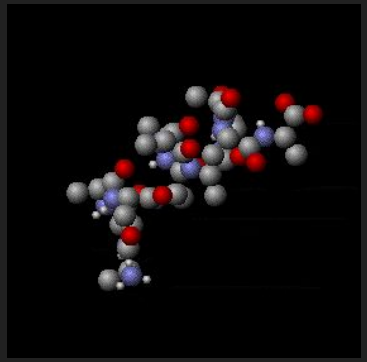
observation



DART: observations and models

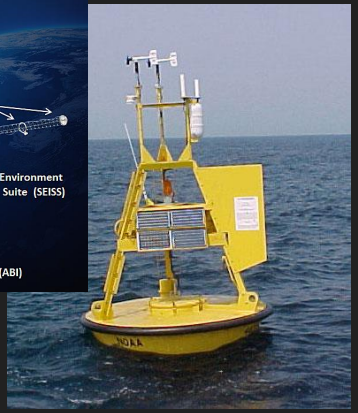
observation



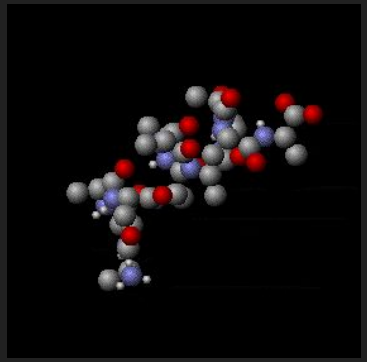


physical quantity

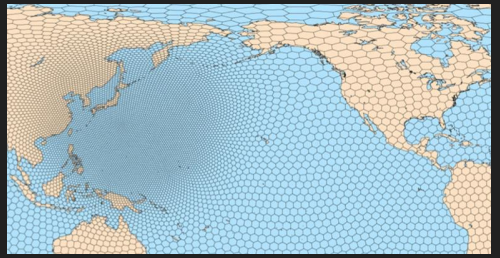
DART: observations and models



observation



physical quantity

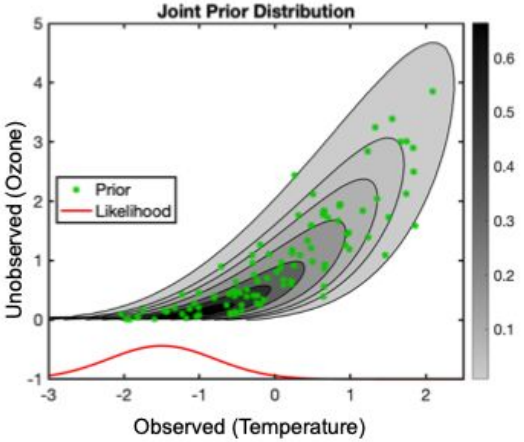


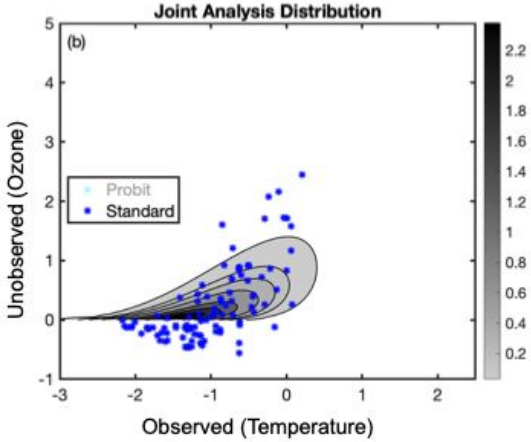
forecast model

Standard EnKF: Challenged by Non-Gaussian and Nonlinear Relations

Prior for normal-gamma distribution with 100 member ensemble.

Posterior ensemble has problems.

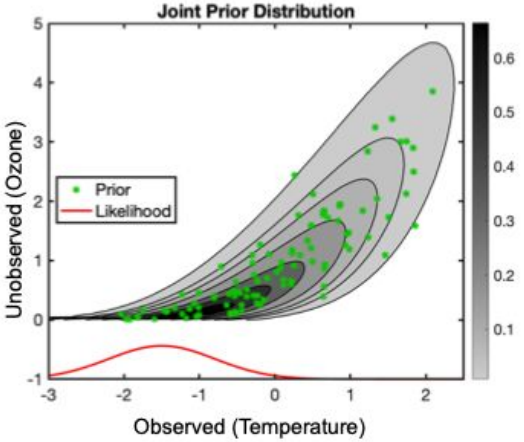




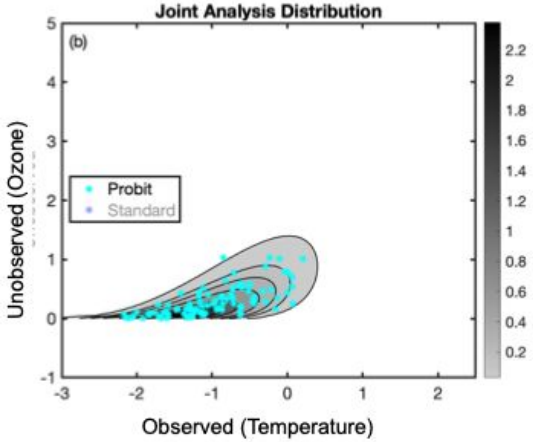
Quantile conserving filters

DART: Novel, General Solutions for Nonlinear, Non-Gaussian Problems

Prior for normal-gamma distribution with 100 member ensemble.



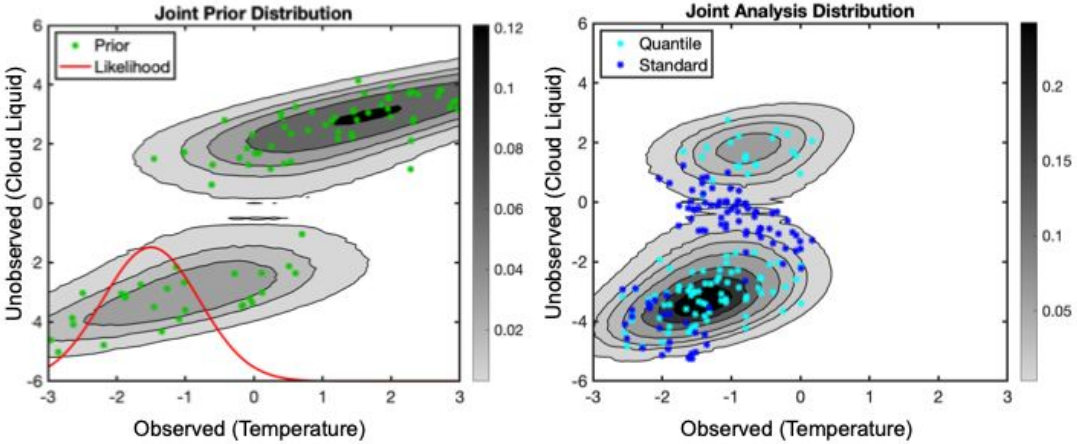
Bounds enforced. Nonlinear aspect respected.



Quantile conserving filters

Example 3: Normal observed, binormal unobserved

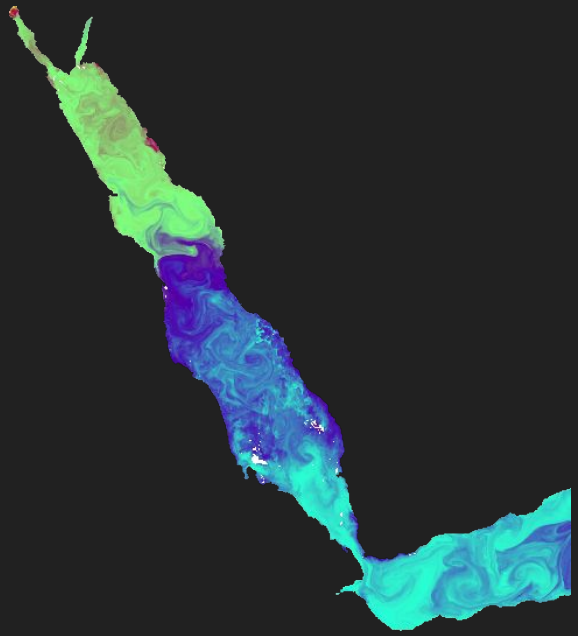
New methods move members from one mode to the other.
Also adjusts ensemble in the modes.
Relevant for initiating convection, for example.



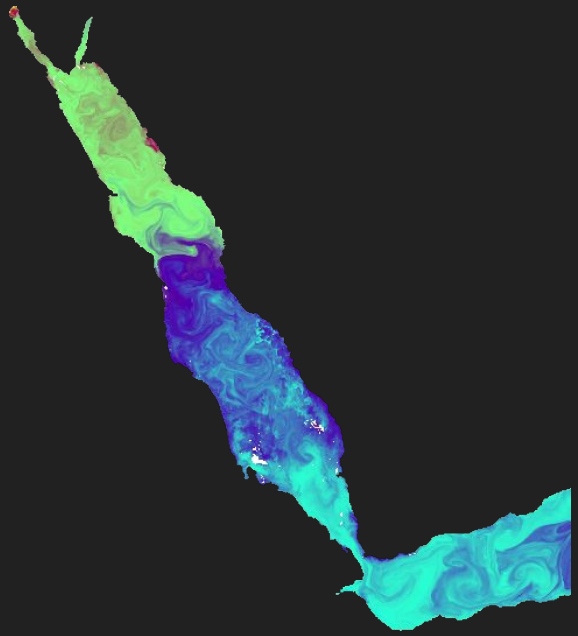
Quantile conserving filters

Workflows

Workflows

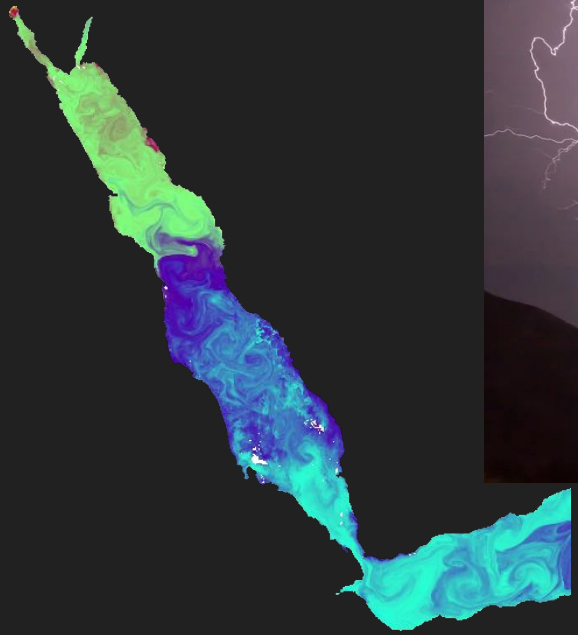


Workflows

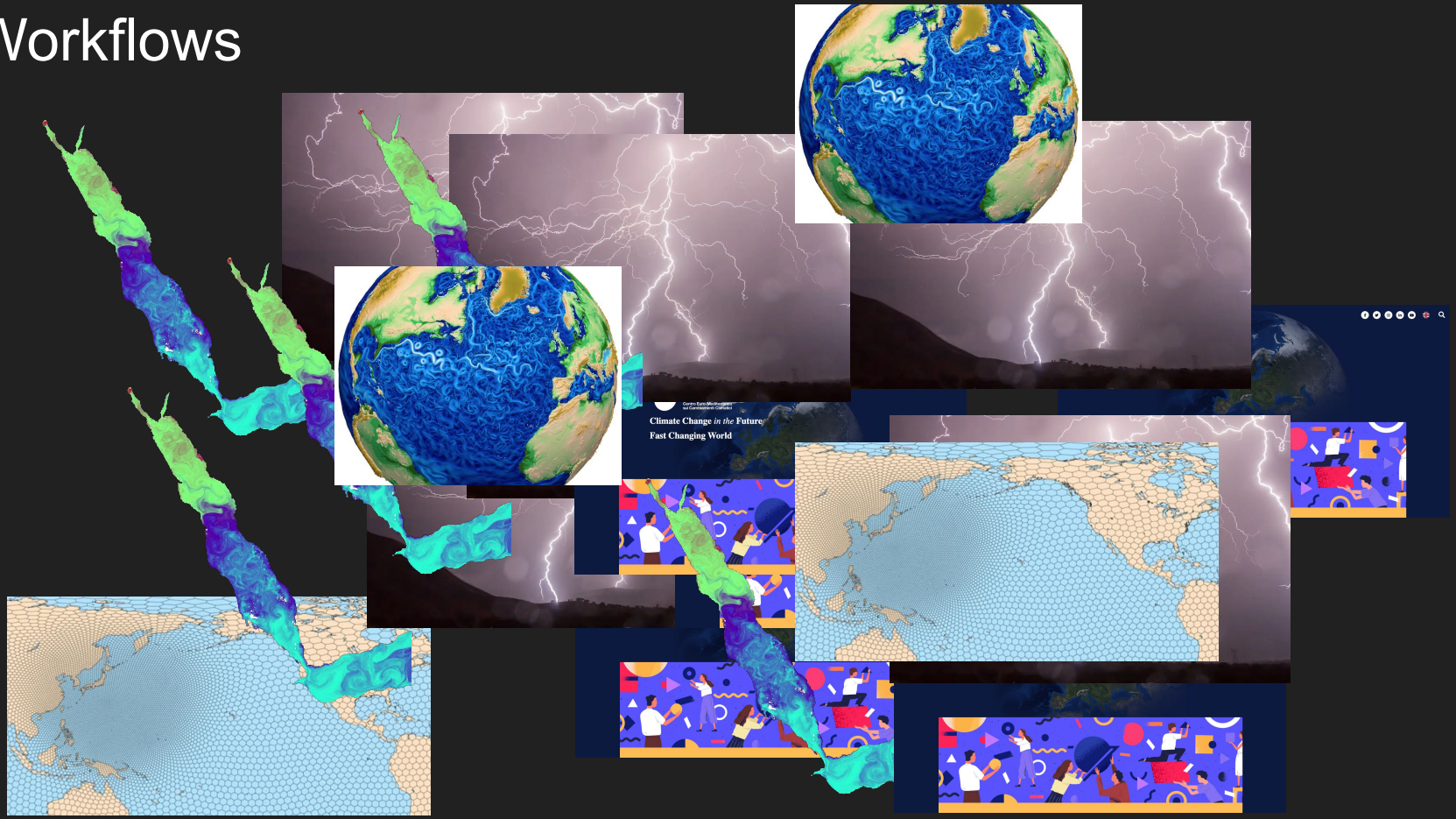



cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici
Climate Change in the Future
Fast Changing World

Workflows



Workflows



Integrate DART with CESM

Key scientific motivation

How can we leverage observational constraints to improve model development and process representation and quantify Earth System Predictability?

DART Compset

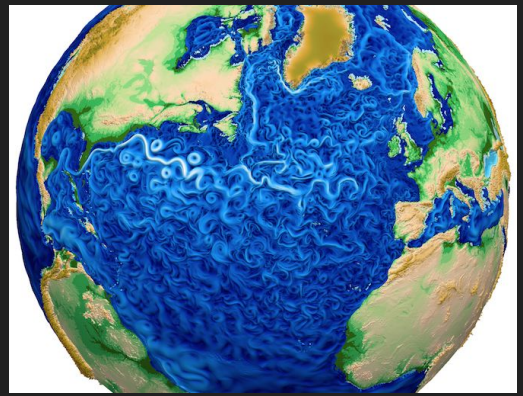
- Leverage major existing capabilities in CESM and the Data Assimilation Research Testbed (DART)
- New community facility for model-data comparison and Earth System DA
- Allow users to run CESM with DA in one or more of ocean, atmosphere, sea ice, and land components
- Leverage CESM's strengths in representing complex coupled processes

What is tricky?

What time is it?

What time is it?

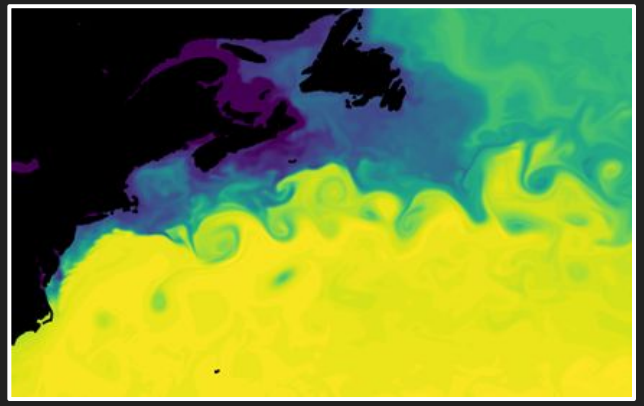
What time is it?



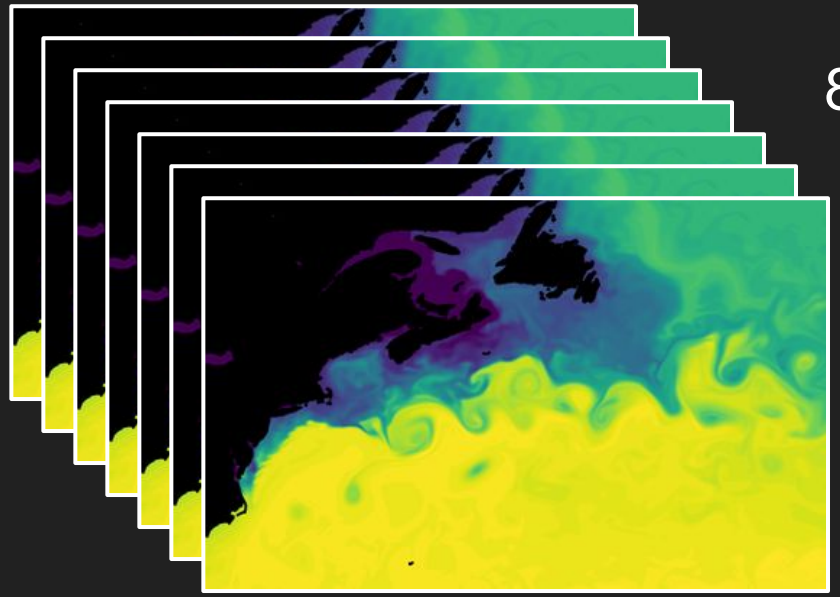
Ensemble

How many?
Ensemble

Ensemble

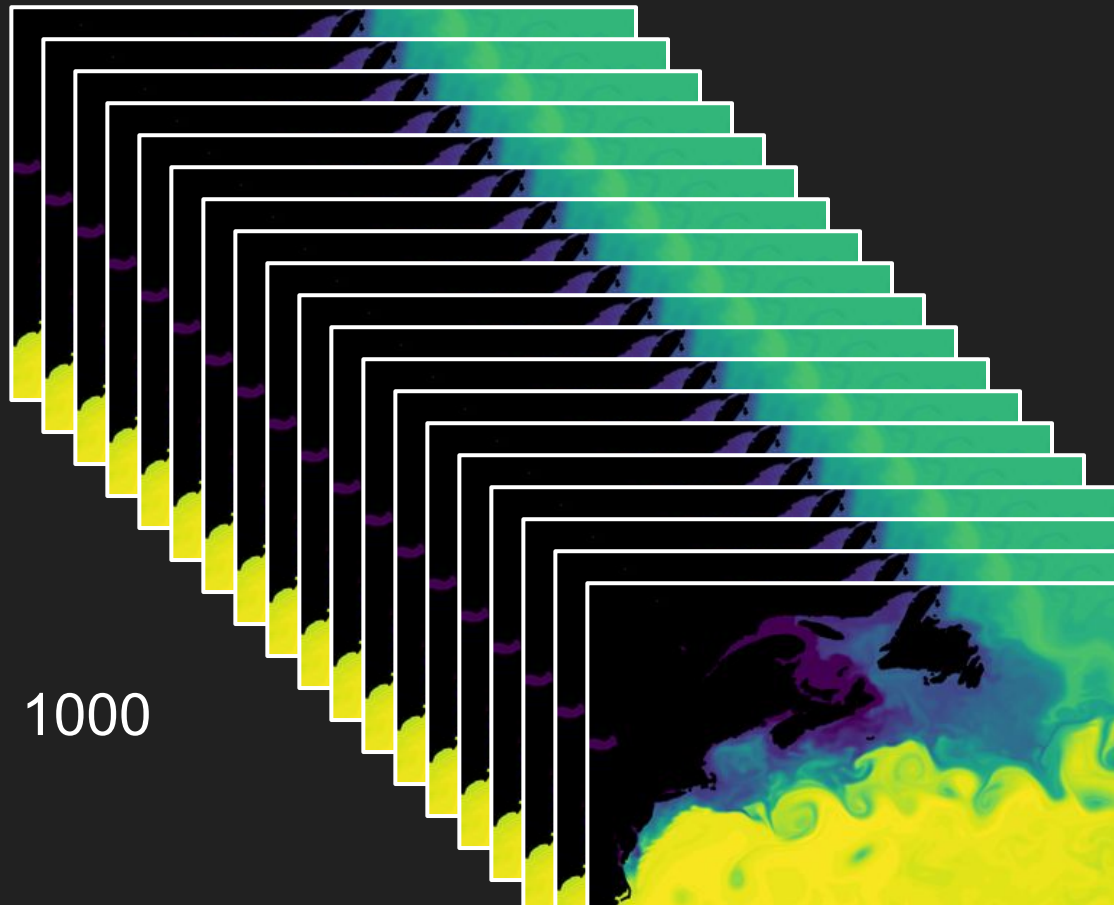


Ensemble



80

Ensemble



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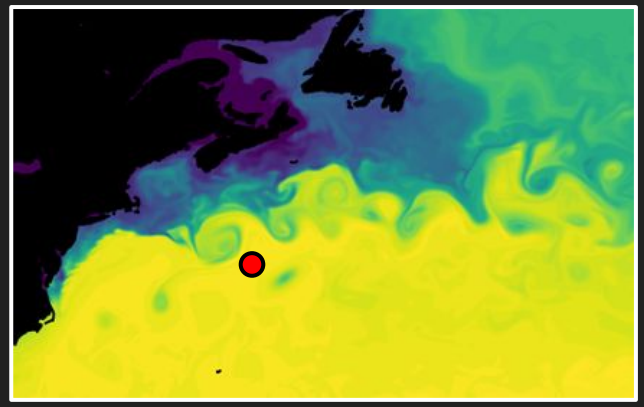
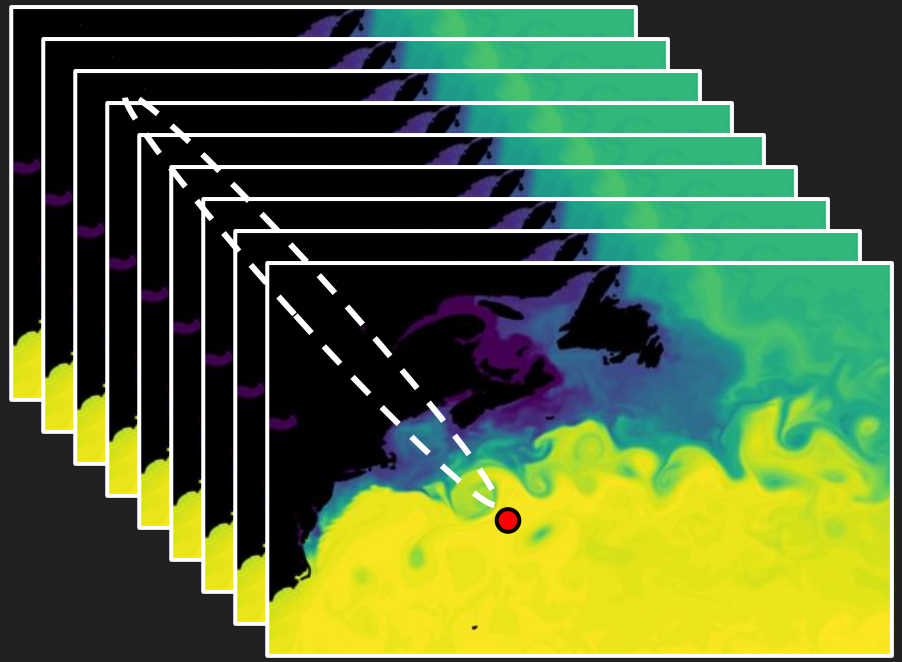
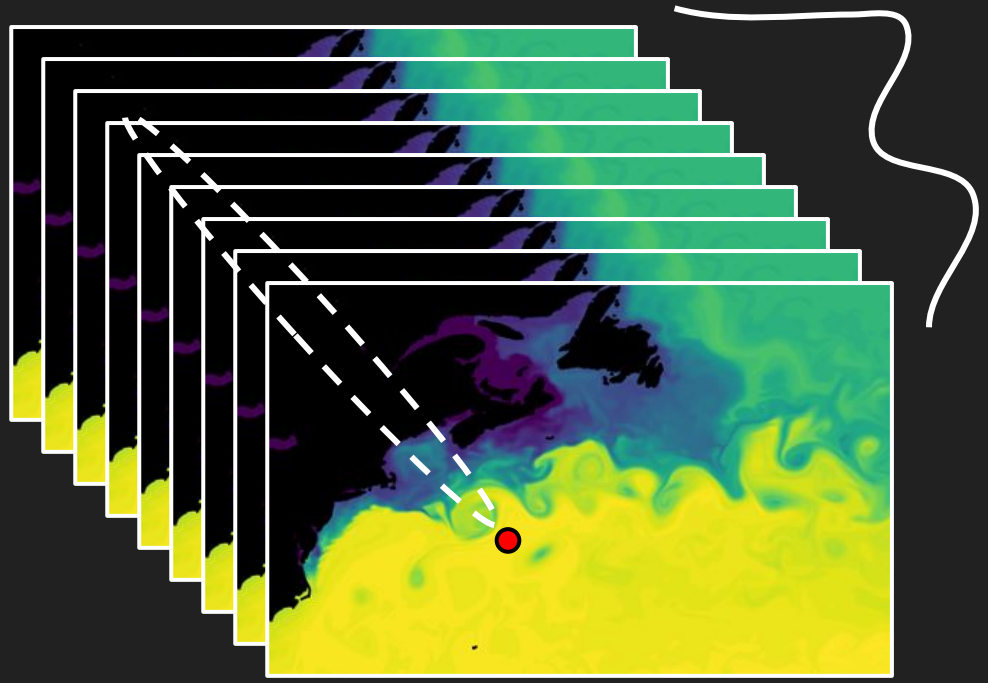
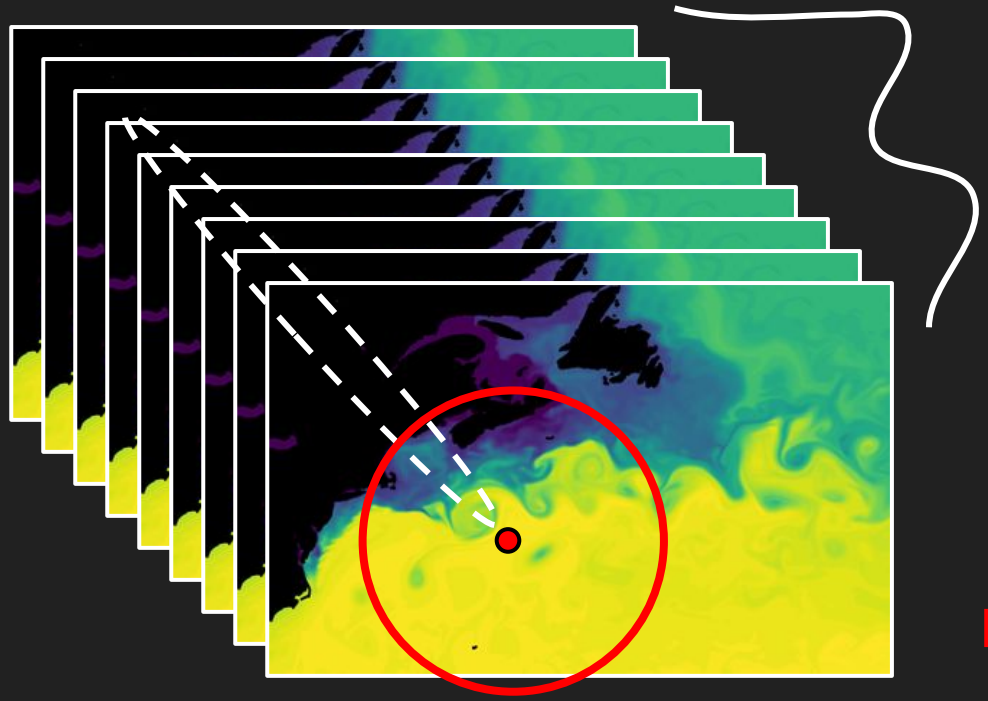






Look across the ensemble



Look across the ensemble

Localize

CESM-DART Compset

CESM-DART Compset

MOM6 multi-instance

MOM6 interface for DART

Alper working on an CIME interface for DART

./manage-externals

Scripting (workflows!) for MOM6

Observations - wealth of existing obs on glade

Join us

Ensemble data assimilation in CESM is the *coolest* computational problem you can work on

Collaborations
CISL Visitor Programs
Student Software Engineering - Job Open
Open Source
Challenging Problems: Faster, Better, Stronger

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hkershaw@ucar.edu