The Use of the Data Assimilation Research Testbed for Initializing and Evaluating IPCC Decadal Forecasts.

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Thanks to the NSF Climate Simulation Lab at NCAR for providing computer time.

The National Center for Atmospheric Research is sponsored by the National Science Foundation.

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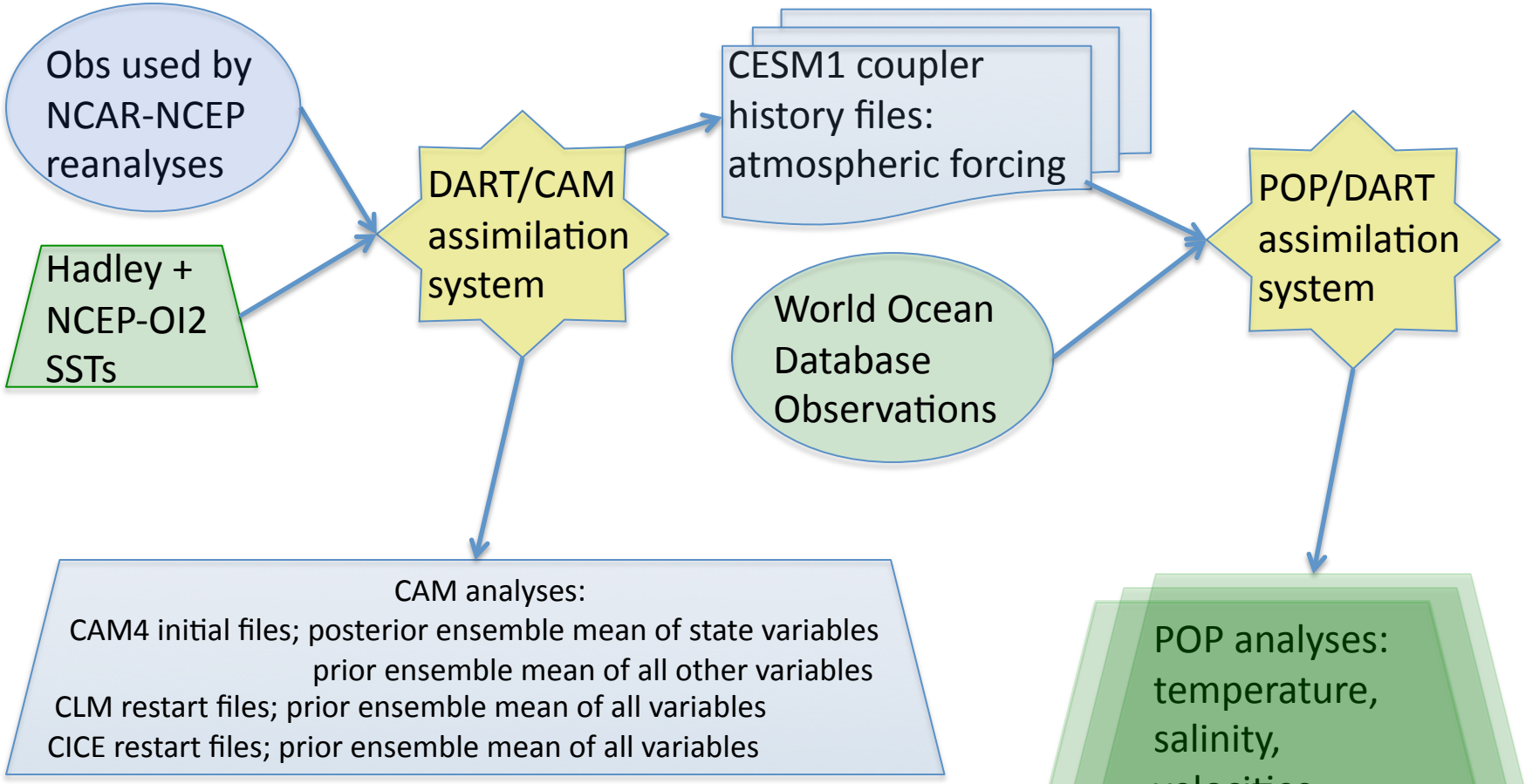
Outline

- Loosely coupled ocean-atmosphere data assimilation.
- Comparing model forecasts to observations (and analyses).
  - Ocean; conventional + surprising, but sparse
  - Atmosphere; old standbys and exciting newcomers
  - Tools for exploration
- Other uses of analyses and short forecasts.
  - Comparison with model output in model space
  - Initial conditions for forecasts
  - Identification of model formulation errors

A Loosely Coupled, Ocean-Atmosphere, Data Assimilation System

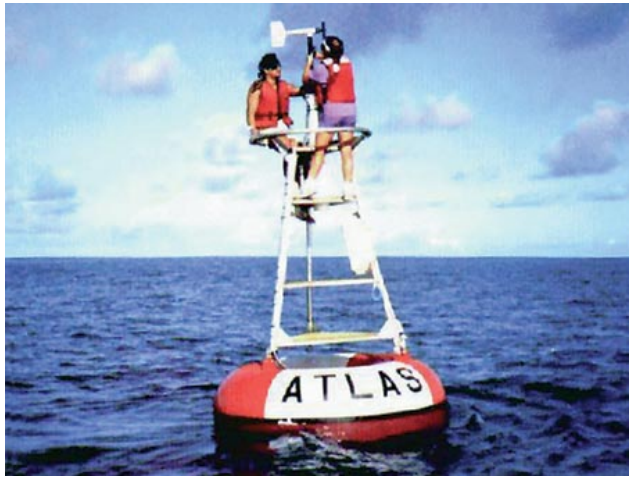


CAM state variables = PS, T, U, V, Q, CLDLIQ, CLDICE
Prior = values before assimilation (but after a short forecast)
Posterior = values after the assimilation of observations at that time

Observations for 1998-1999

Temperature and salinity from World Ocean Database.

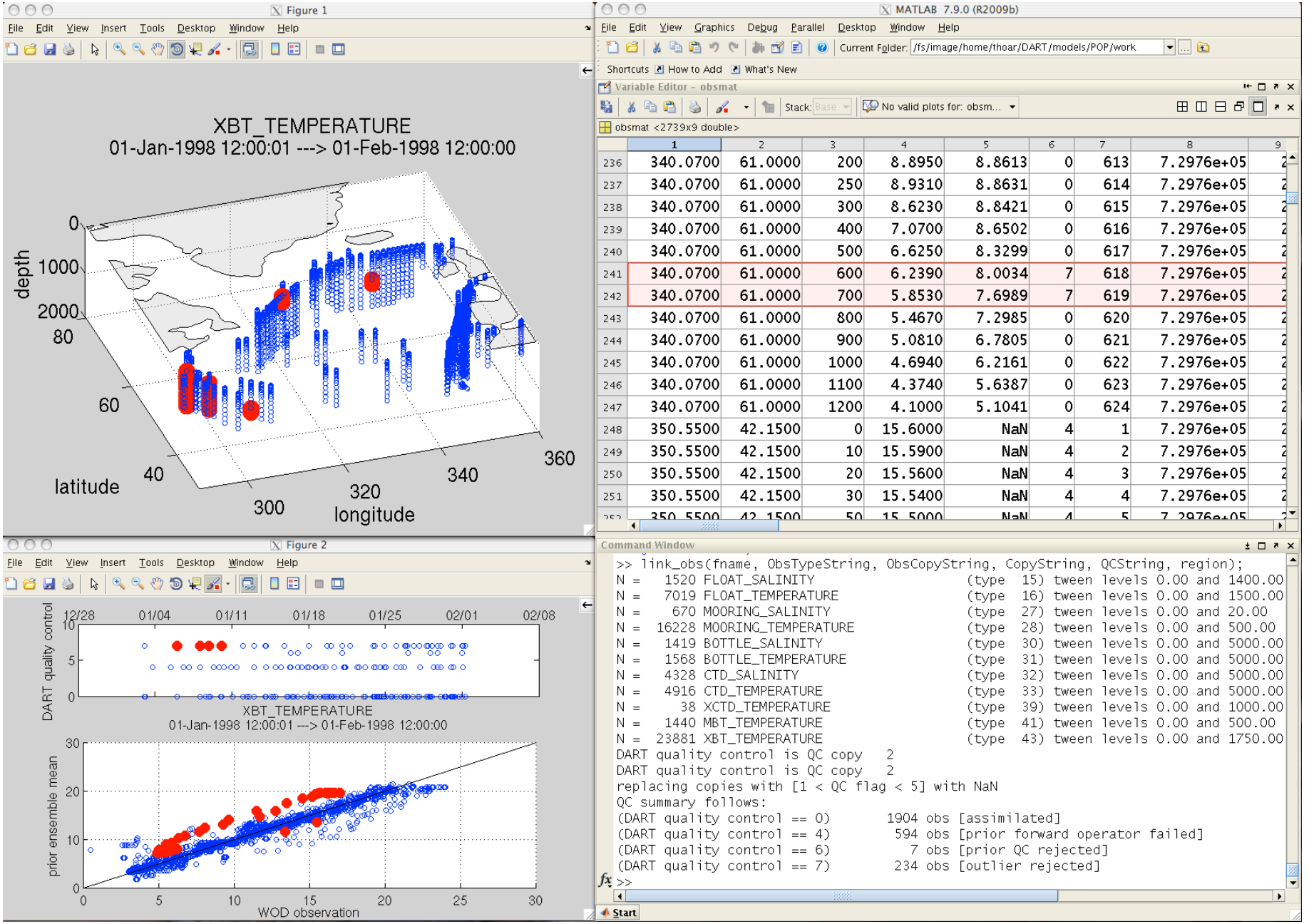
FLOAT_SALINITY	68200
FLOAT_TEMPERATURE	395032
DRIFTER_TEMPERATURE	33963
MOORING_SALINITY	27476
MOORING_TEMPERATURE	623967
BOTTLE_SALINITY	79855
BOTTLE_TEMPERATURE	81488
CTD_SALINITY	328812
CTD_TEMPERATURE	368715
STD_SALINITY	674
STD_TEMPERATURE	677
XCTD_SALINITY	3328
XCTD_TEMPERATURE	5790
MBT_TEMPERATURE	58206
XBT_TEMPERATURE	1093330
APB_TEMPERATURE	580111



Autonomous Pinniped

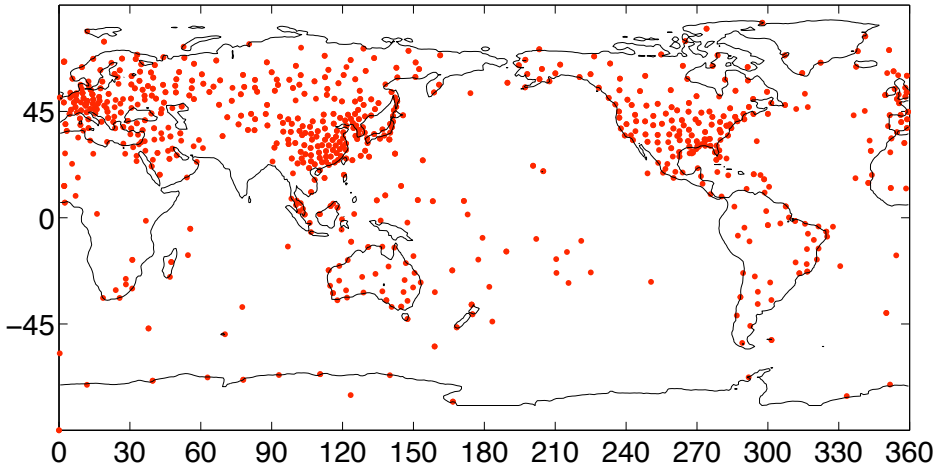
Observations of ocean currents are also available.

Exploring in Observation Space: MATLAB linked windows

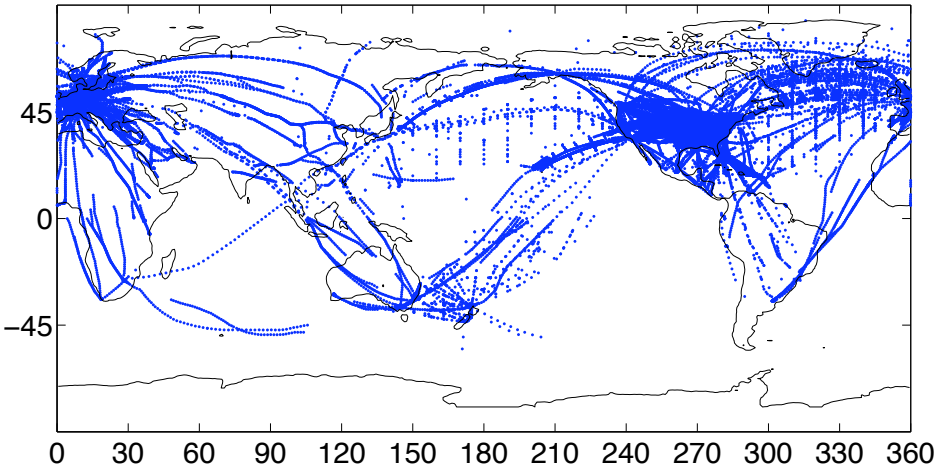


Typical Daily Atmospheric Observation Set Coverages (e.g. 12/6/2006)

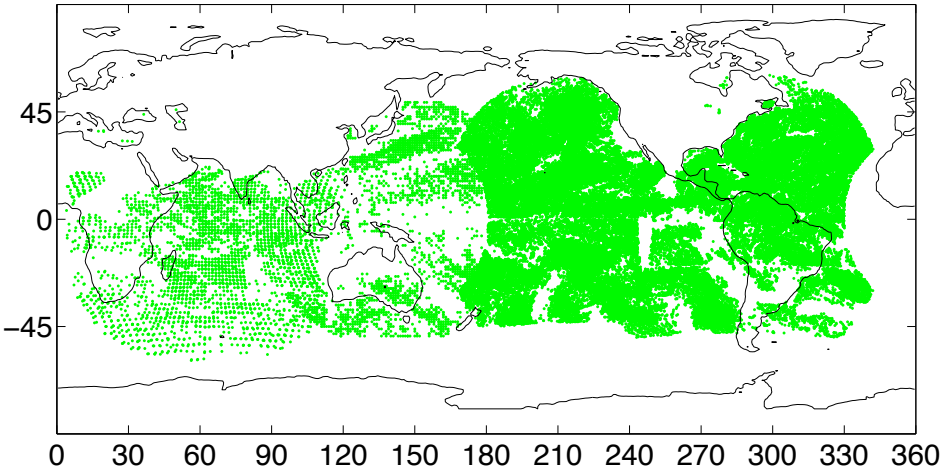
Radiosonde



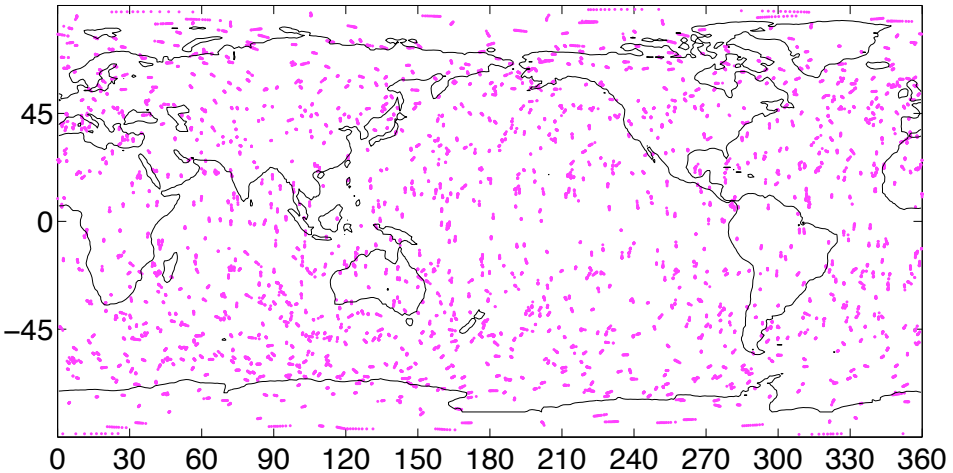
ACARS/Aircraft



Satellite drift winds



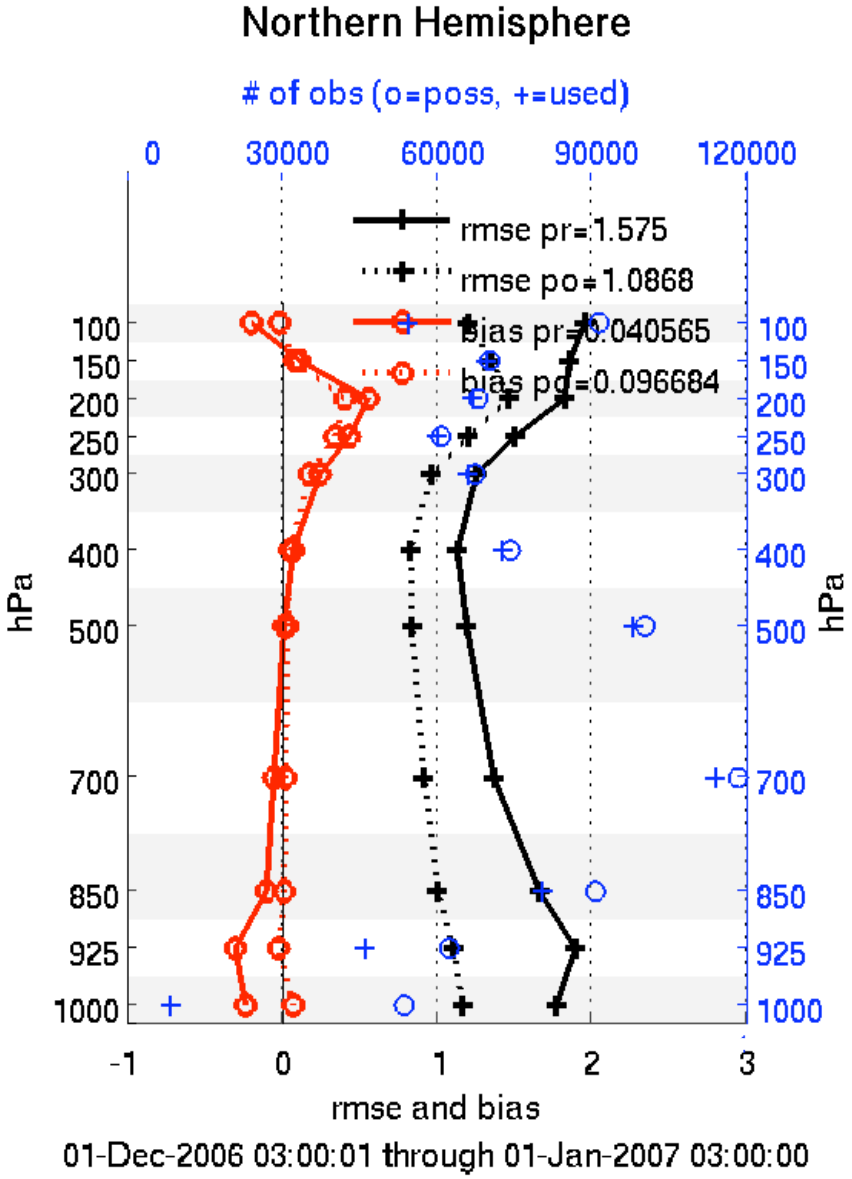
GPS radio occultation



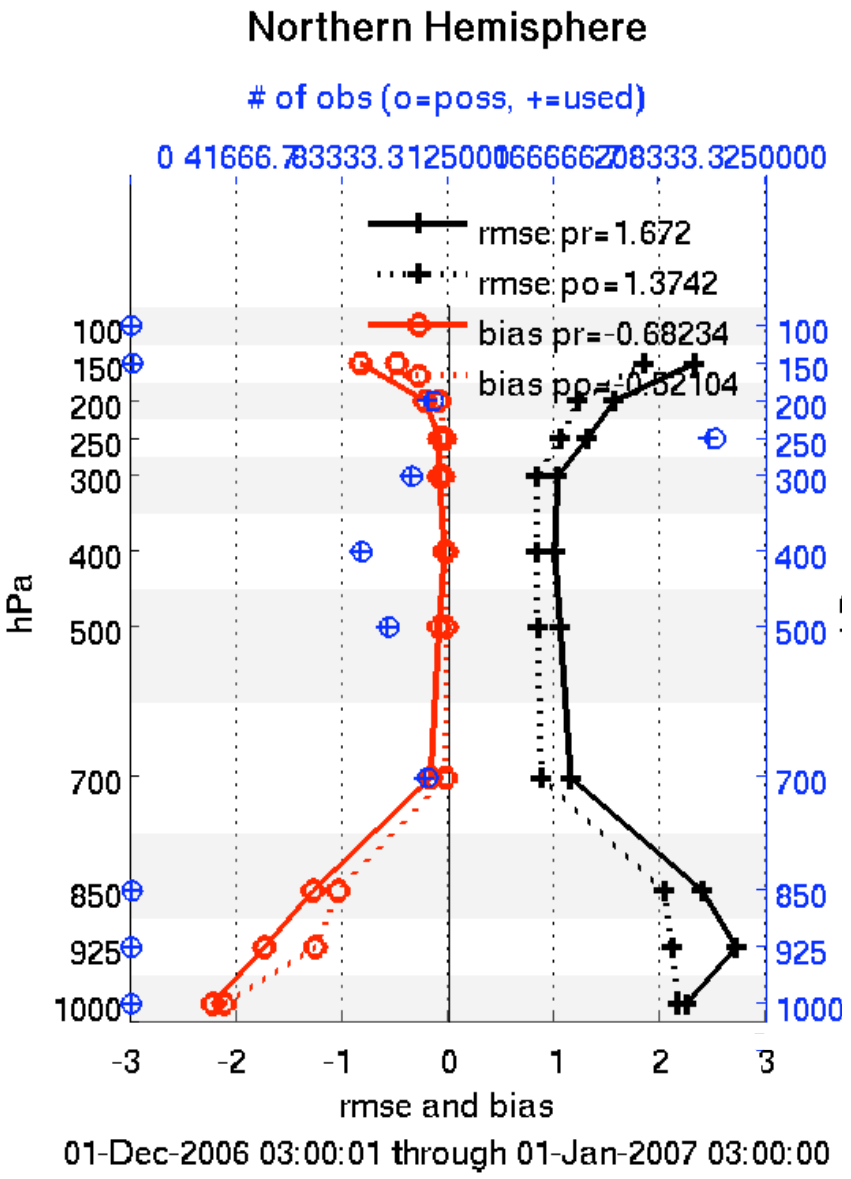
Observations of moisture and pressure are also available.

Exploring in Observation Space: **Bias**, RMS Error, and Obs Count

Radiosonde Temperature



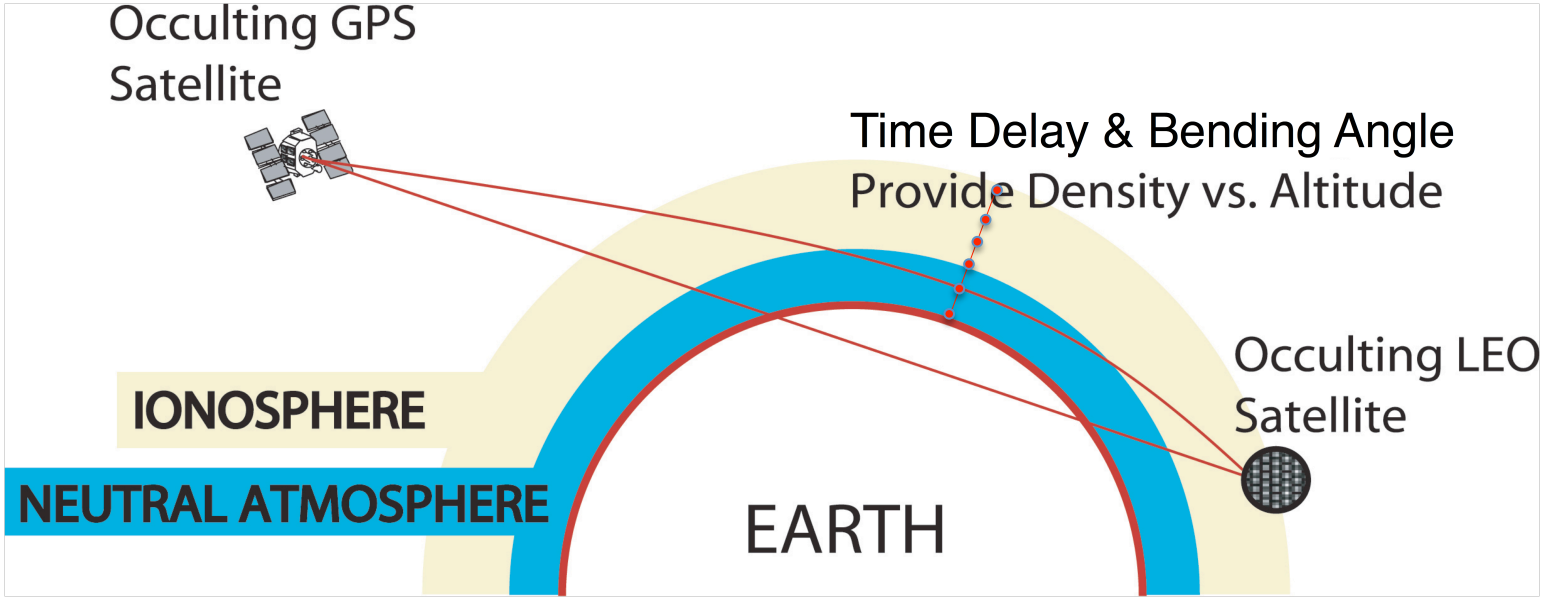
Aircraft Temperature



GPS occultation forward operators

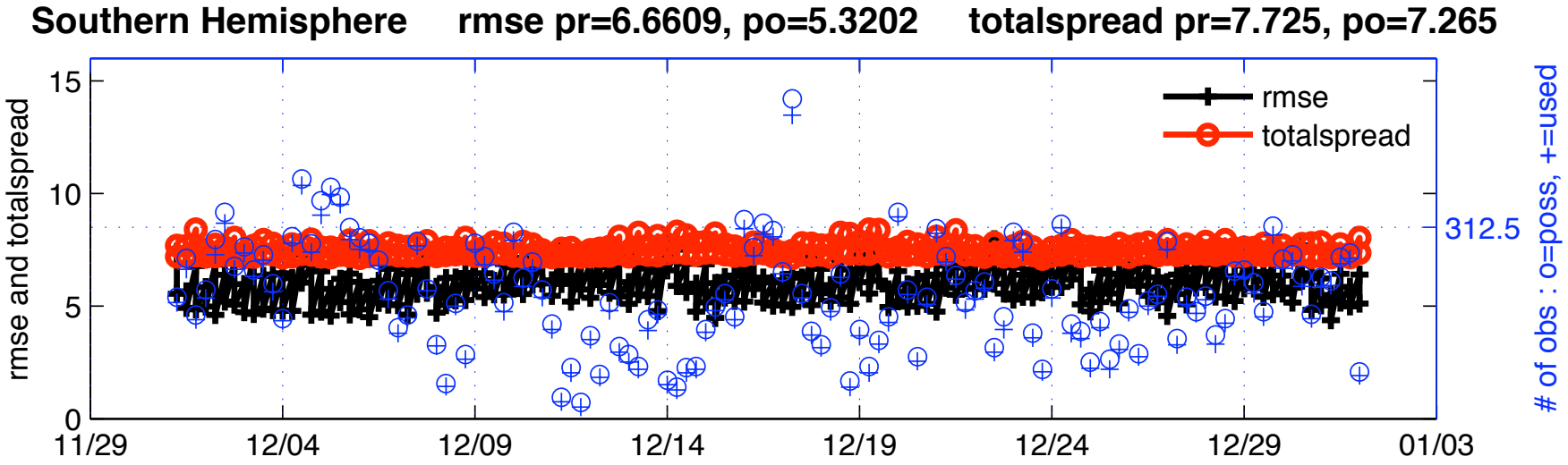
Local refractivity:

- Interpolate model pressure, temperature and moisture to tangent point.
- Calculate density, then atmospheric refractivity.
- Compare refractivity from COSMIC DAAC.
- Max of 15 tangent points below 13 km per profile.

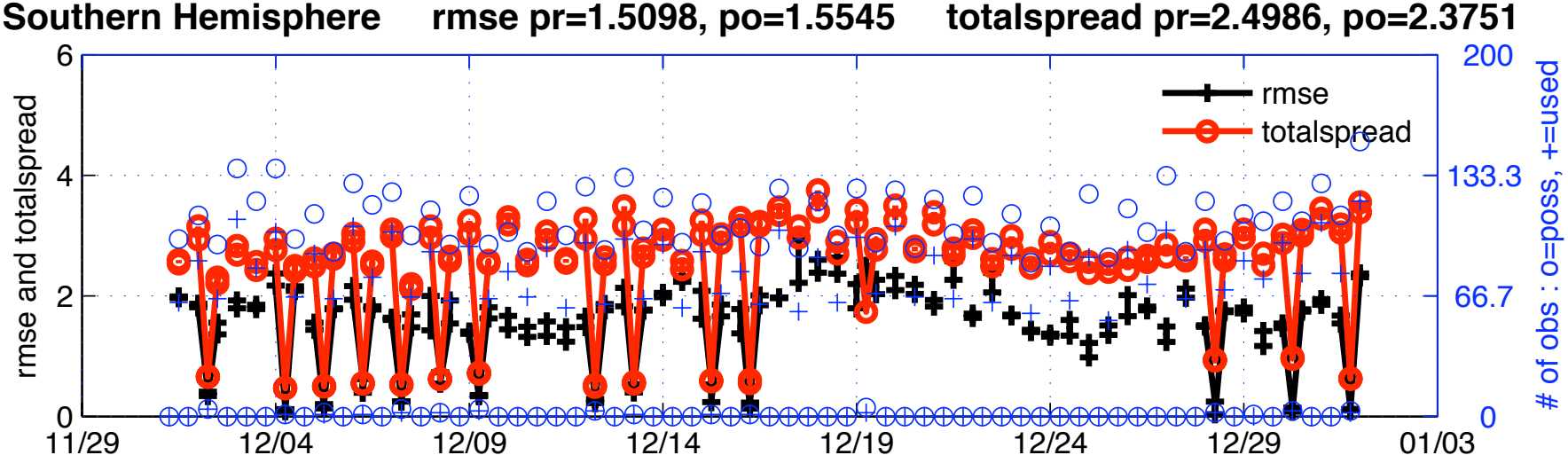


Exploring in Observation Space: Time series of RMS Error, **Total Spread** and Obs Count

GPS Radio Occultation Refractivity ~1000m

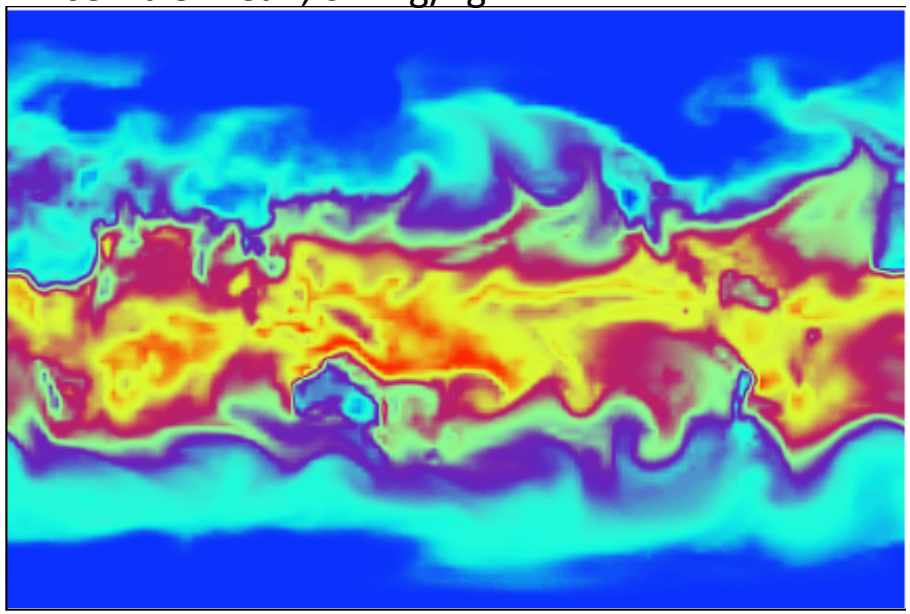


Radiosonde Specific Humidity ~925 hPa

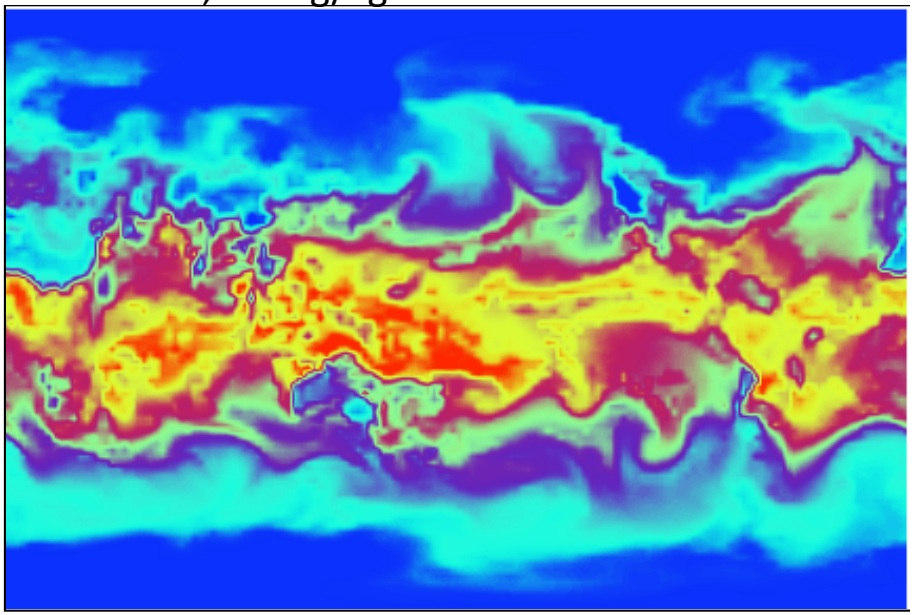


DART-CAM Specific Humidity Analyses (and more) @ 992 hPa

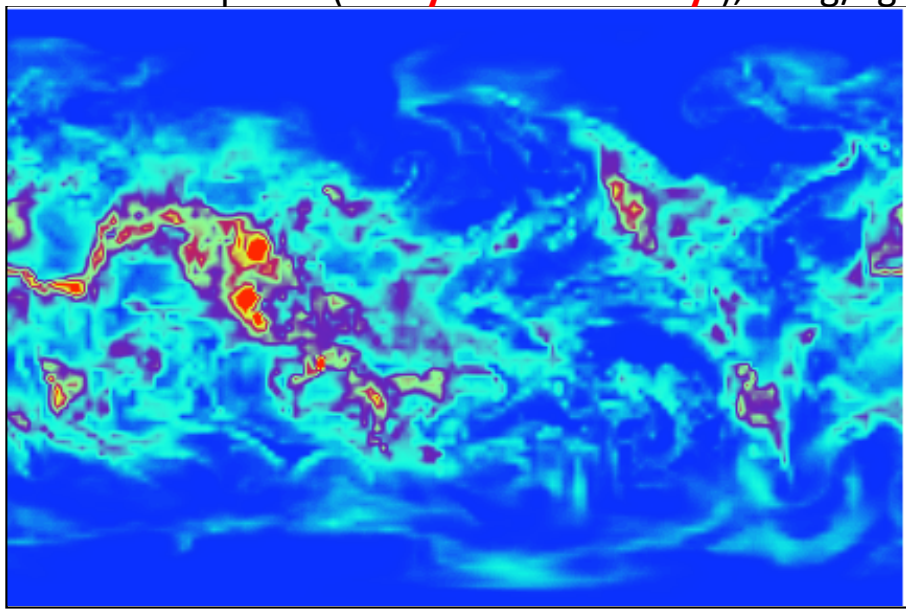
Ensemble Mean, 0-21 g/kg



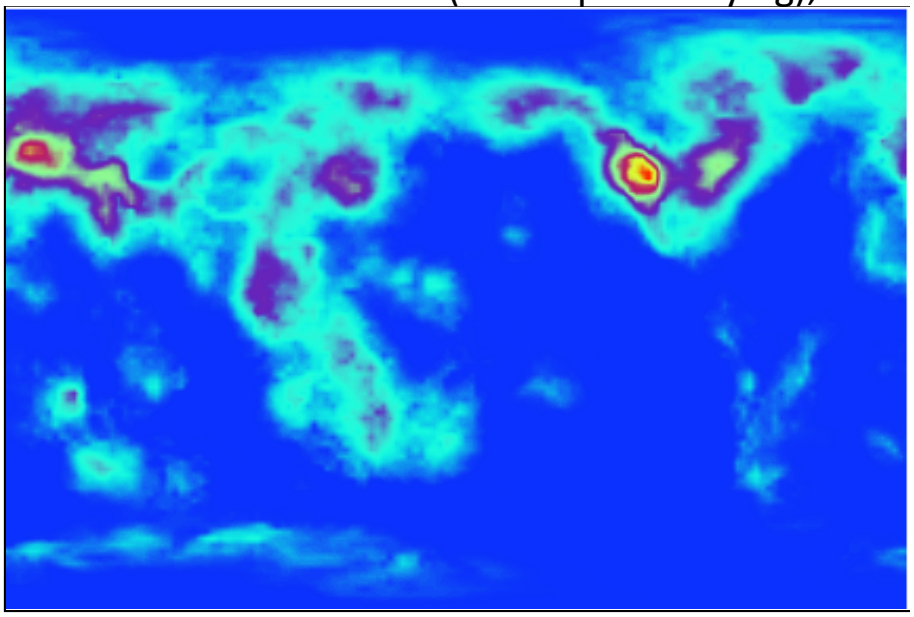
Member 1, 0-21 g/kg



Ensemble Spread (**Analysis Uncertainty!**), 0-4 g/kg



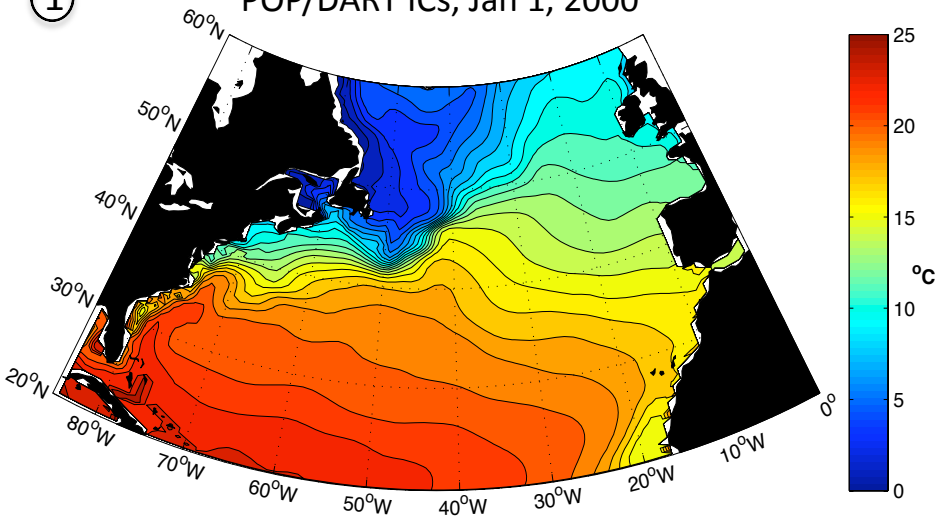
Prior Ensemble Inflation (time+space varying), 0-7



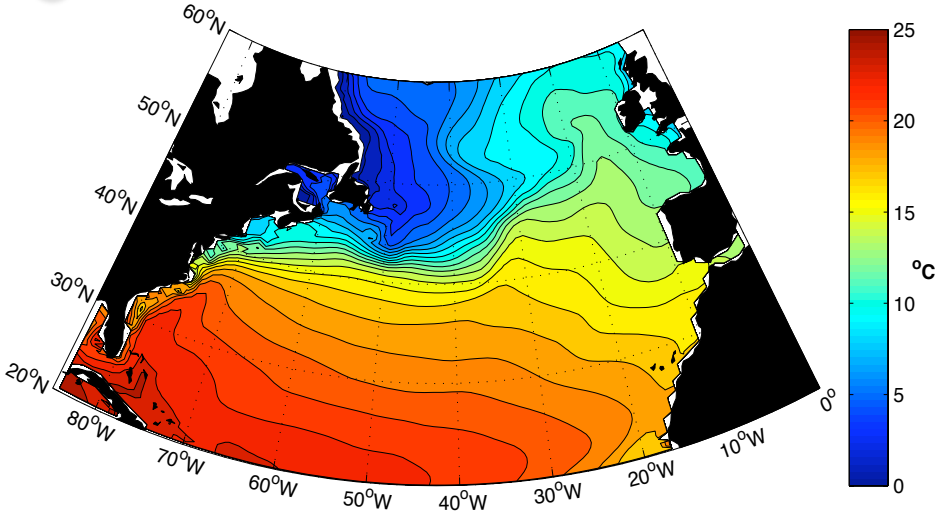
CCSM4 (POP+CAM4) Decadal Prediction Initial Conditions

Figures and analysis thanks to Alicia Karspeck

① POP/DART ICs, Jan 1, 2000



② ICs from hindcast, Jan 1, 2000



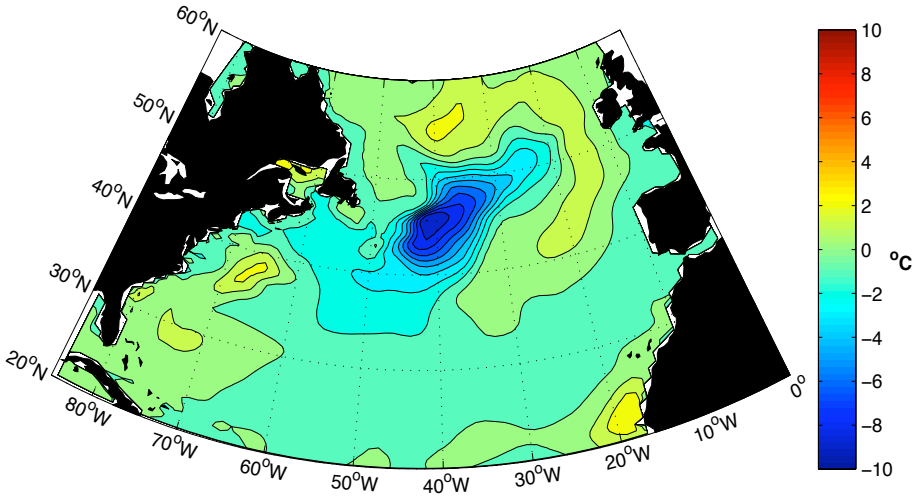
① Analysis (avg T in top 250m of N. Atlantic) from POP/DART assimilation.

② ICs from a hindcast forced by CORE2 historical surface fluxes.

③ Difference of 2 from 1:

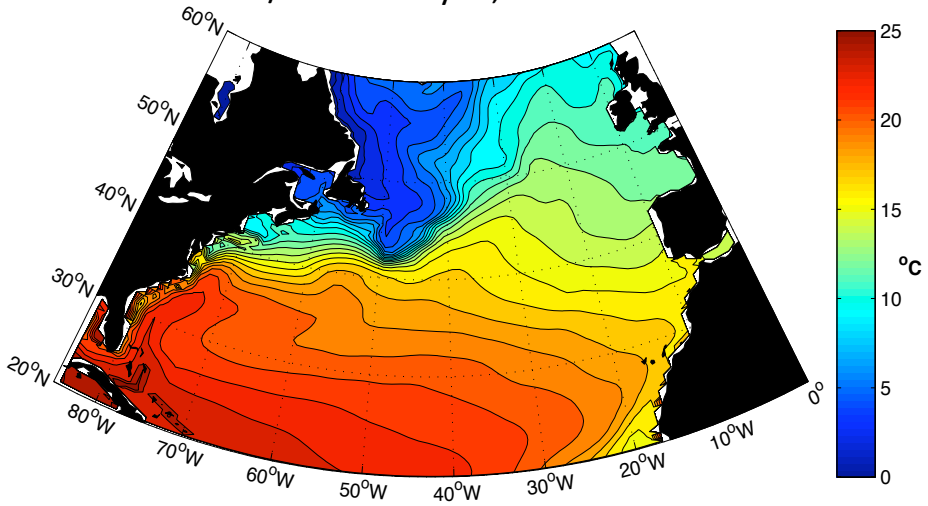
- Gulfstream fails to turn north @ 45W
- Gulfstream too broad off east coast
- North Atlantic drift eastward and southward is too weak

③ Hindcast error, Jan 1, 2000

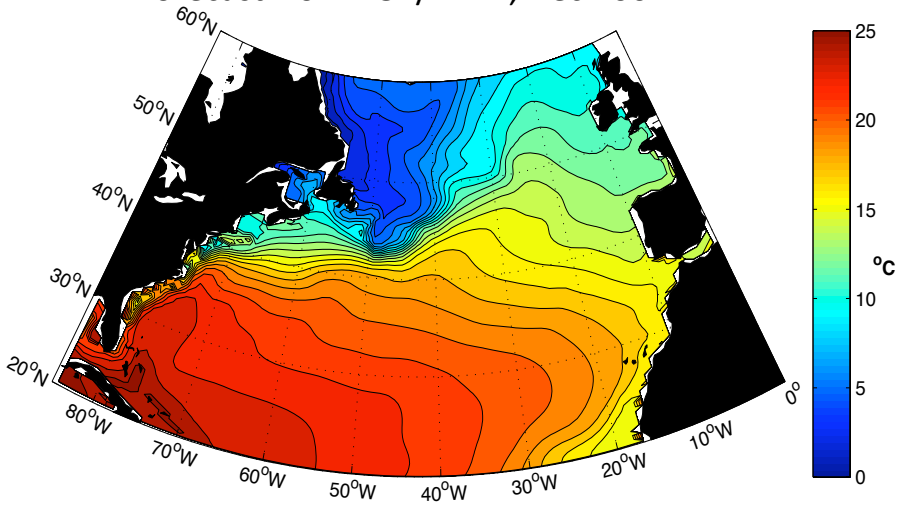


2 Year Lead Forecast; Monthly Means

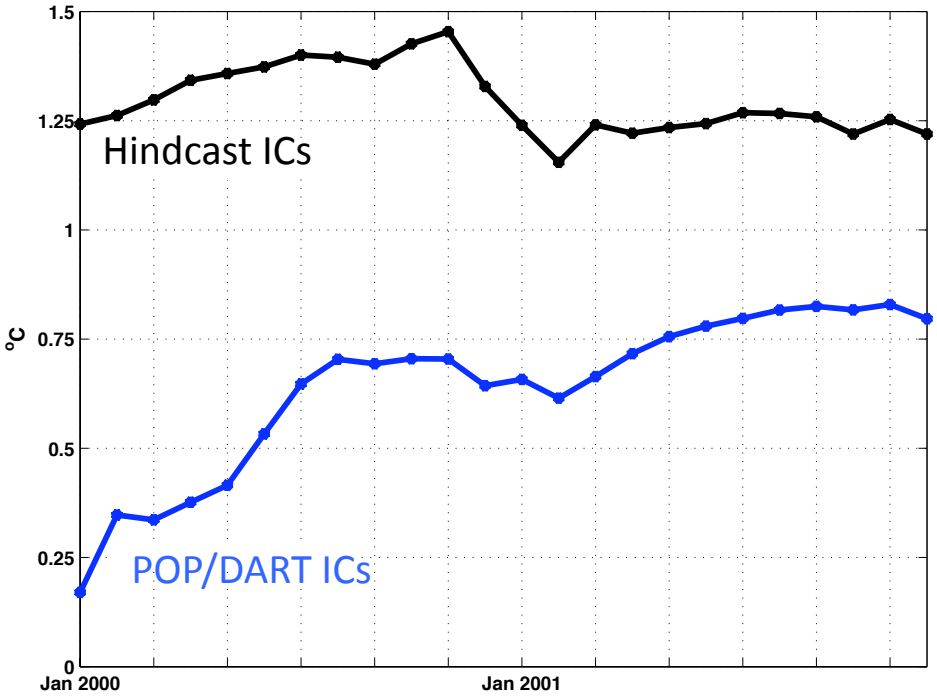
POP/DART analysis, Dec 2001



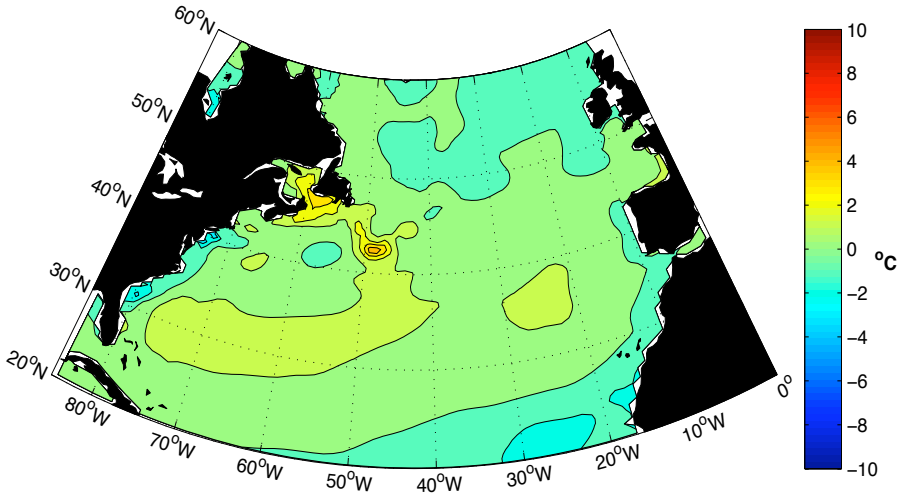
Forecast from POP/DART, Dec 2001



Area weighted RMS forecast error of average 250m T



POP/DART forecast error, Dec 2001

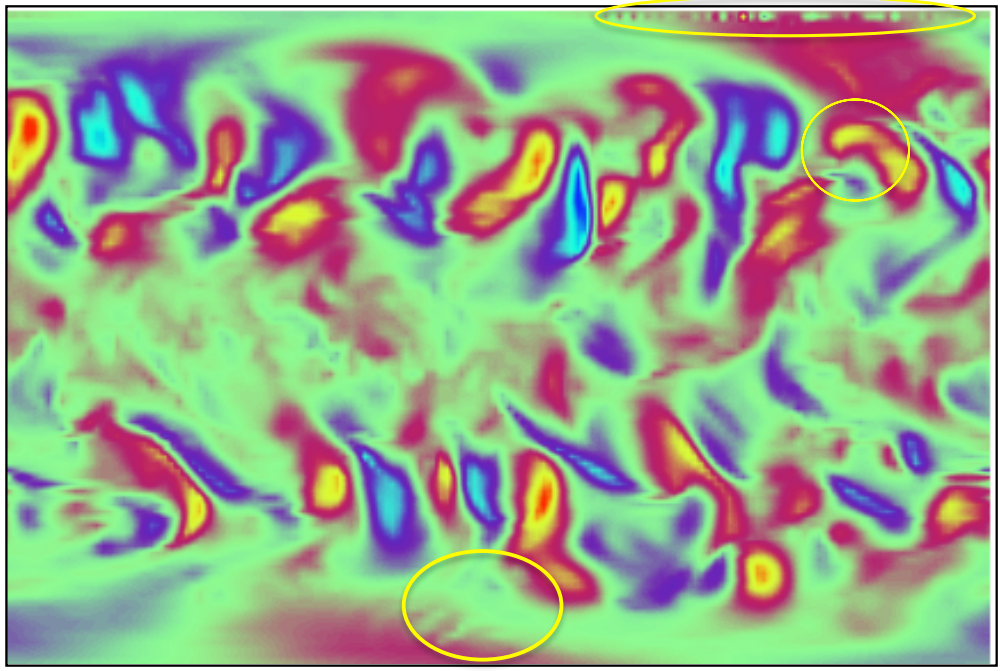


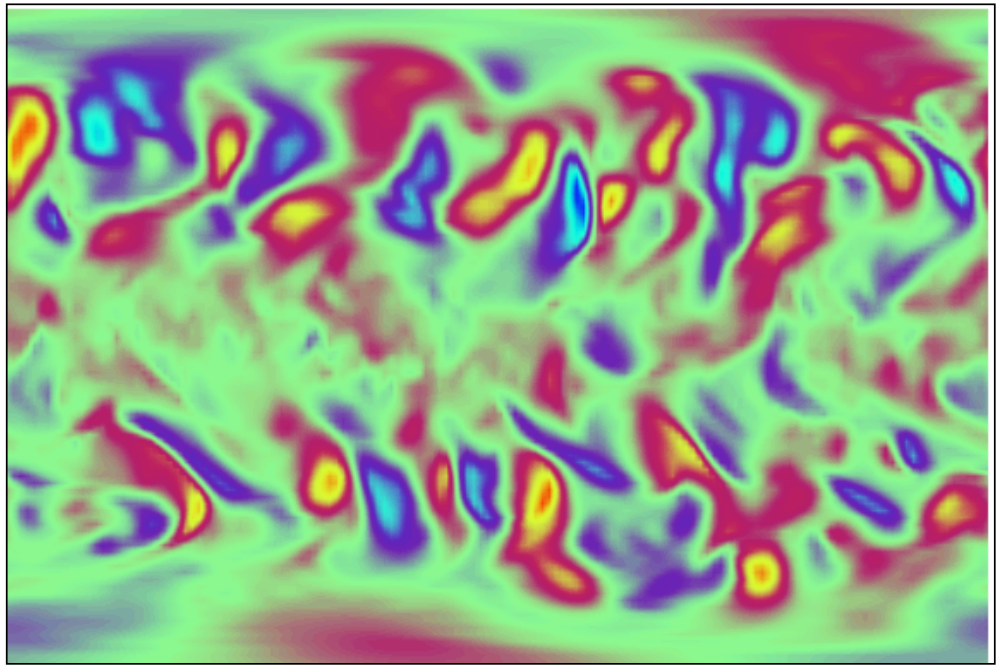
Benefit of improved ICs lasts at least 2 years.

Other results imply benefit to at least 5 years.

Improving Climate AGCMs with Data Assimilation

- 6-hour forecasts from analysis ICs.
- Instantaneous meridional velocity (VS).
- Default (CESM 1.0) damping; 2 dy and 2 dx noise O(several m/s).
- Masked by time averaging or regridding.
- ∇^4 damping (Peter Lauritzen); reduced noise; not perfect.





Examination of climate model output in a data assimilation framework helps identify model deficiencies.

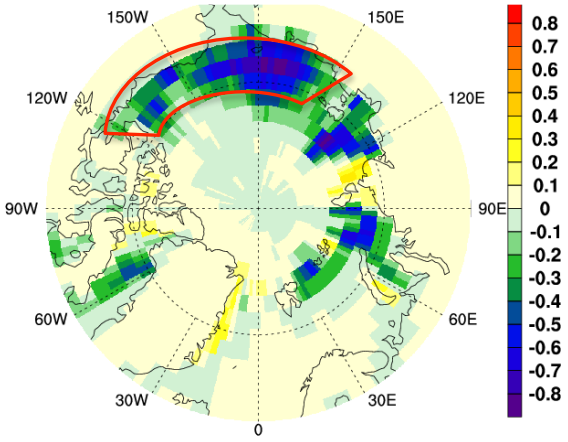
CAM4's cloud response to sea ice loss; July 2006 to 2007

24-hour forecasts started from DART/CAM analyses identified erroneous cloud response to disappearing sea ice.

Jen Kay found that low clouds were only diagnosed over open water, not ice, and the low cloud scheme should have required a well mixed boundary layer.

Short forecasts with a climate model from analyses, compared against observations, point to model improvements.

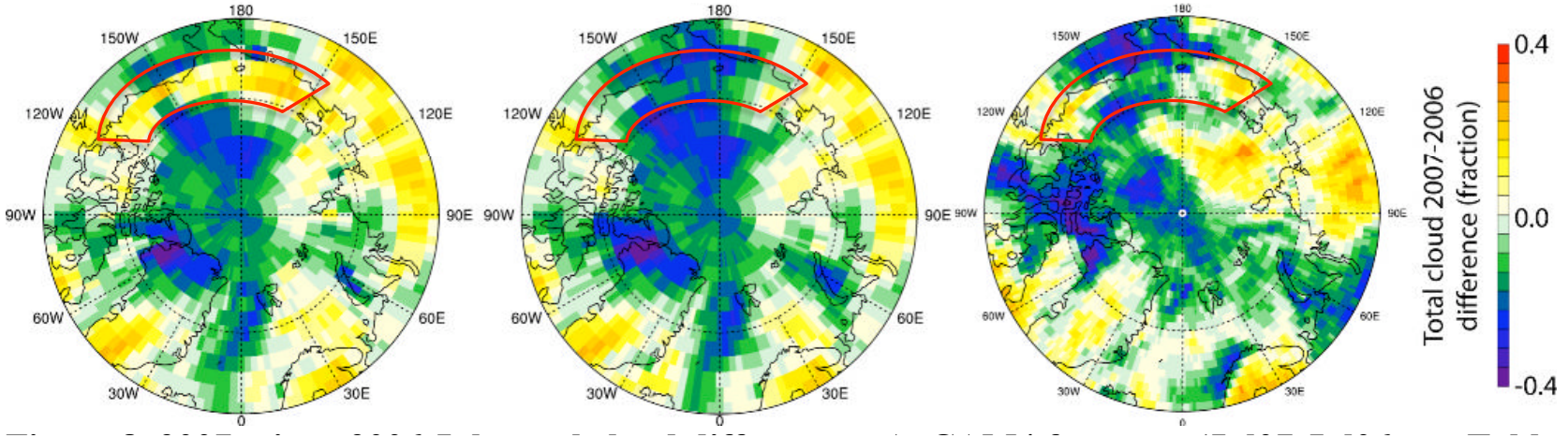
Observed ice fraction loss



July CAM4 Forecasts

July CAM4 Forecasts with CLDST_MIXBL

July Observed



Data Assimilation; not just for experts anymore

- DART has been engineered to minimize the effort to incorporate new models.
- Full complexity models have been interfaced to DART in less than a week.
- Many geophysical models already included: CAM (several versions), POP (CESM1), MITgcm_ocean, AM2, COAMPS, ROSE, WRF, NOGAPS, NCOMMAS.
- New observation sets can be incorporated with similar ease.
- Model interfaces are independent from observation interfaces, so that any model can assimilate any relevant observations without additional coding.

Summary

DART provides a flexible, convenient, rigorous environment for:

- Identifying model deficiencies and biases relative to real observations, both in model space and in observation space;
- Generating analyses for use as forecast initial conditions and for evaluating forecasts;
- Evaluating the forecasting skill of models.

Learn more at www.image.ucar.edu/DAReS/DART

Contact us at dart@ucar.edu

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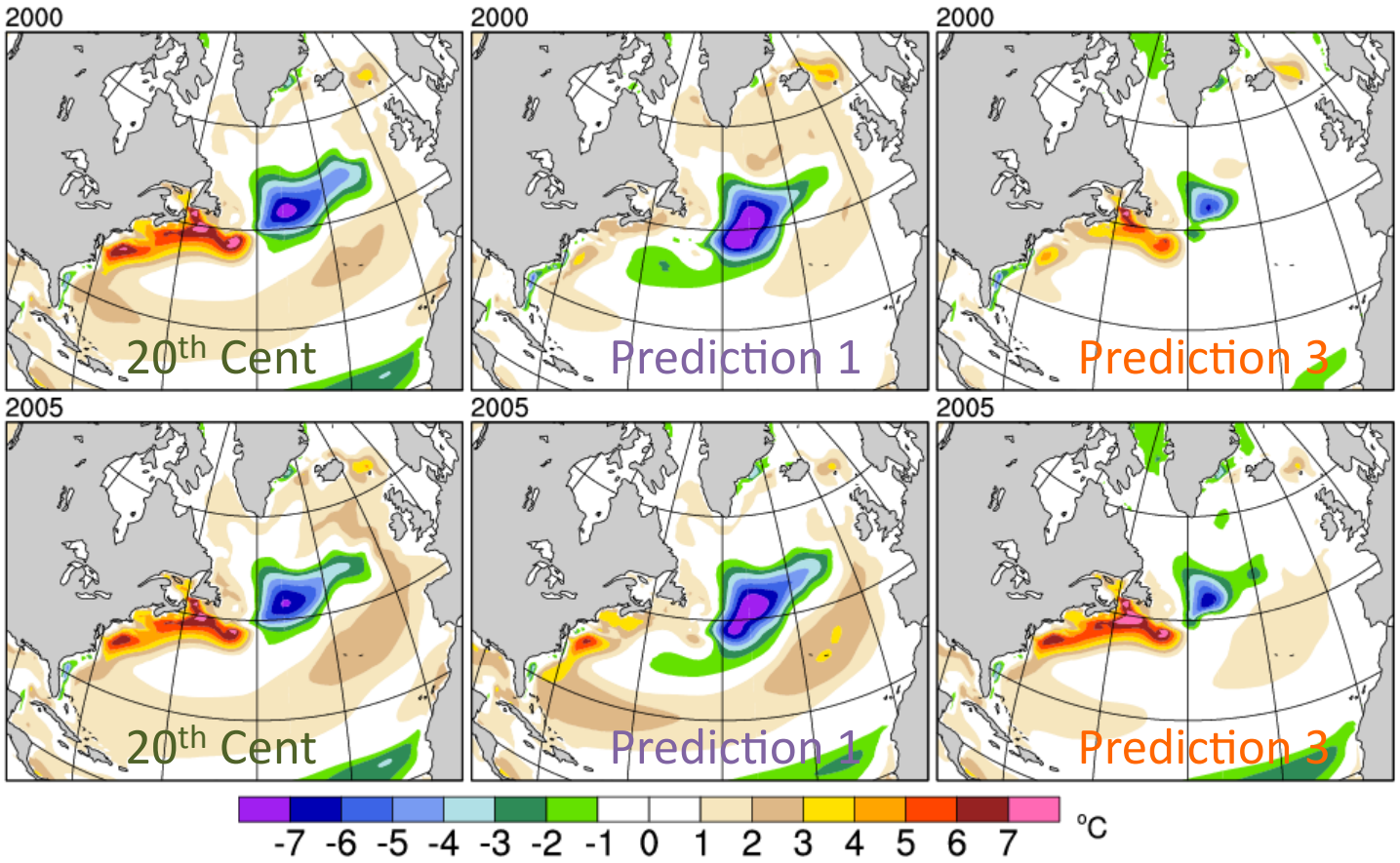
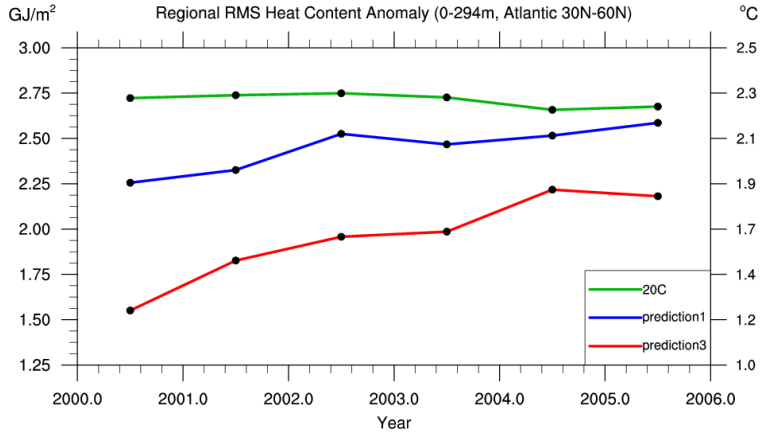
Mean Temperature Bias (0-294m)



2000

2005

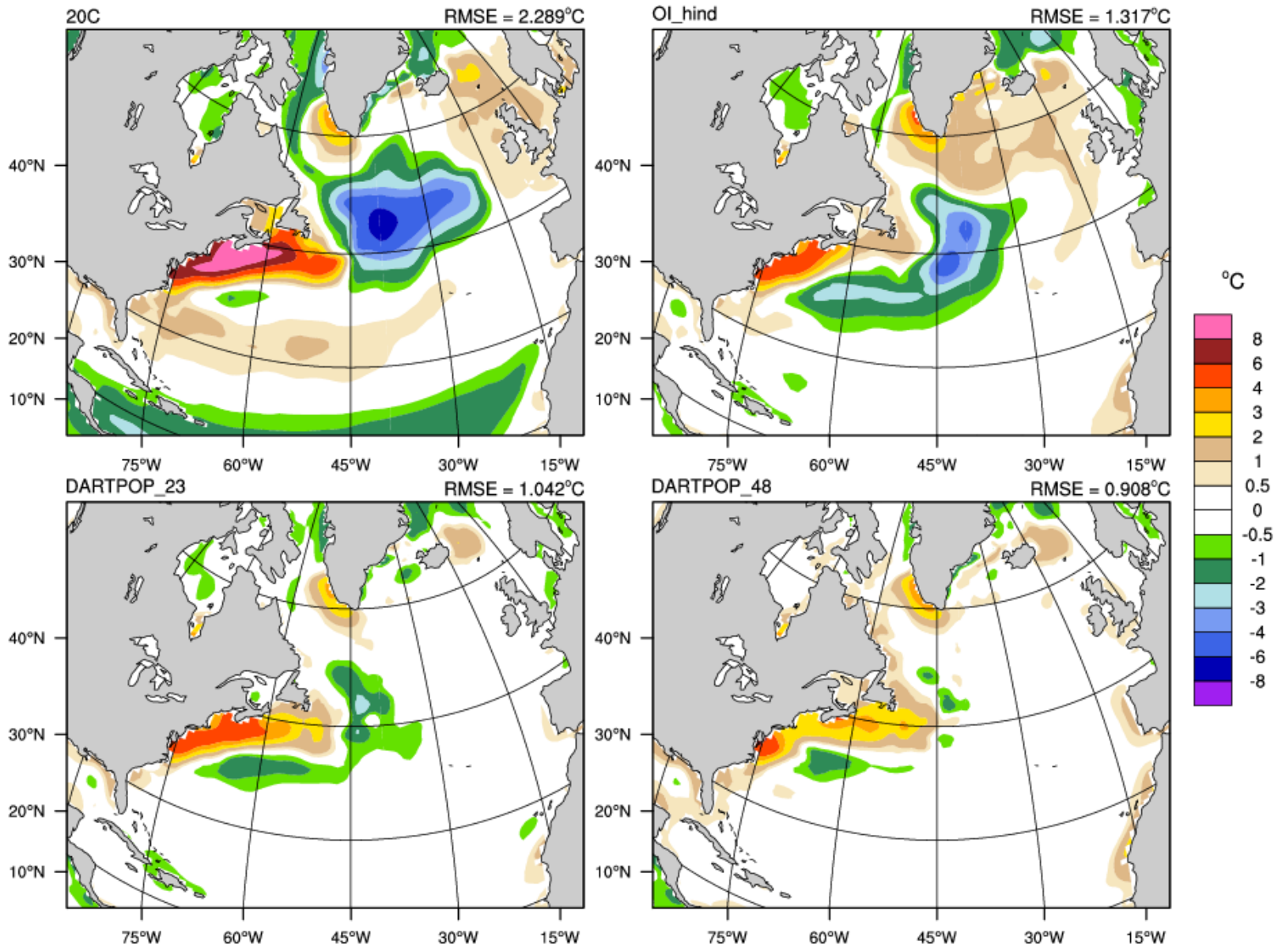
However, prediction tests show that upper ocean bias reduction persists for 5+ years, especially with data assimilation initialization (red).



Physical Space Detail: SST Anomaly from HadOI-SST

Coupled Free Run

DART 23x1



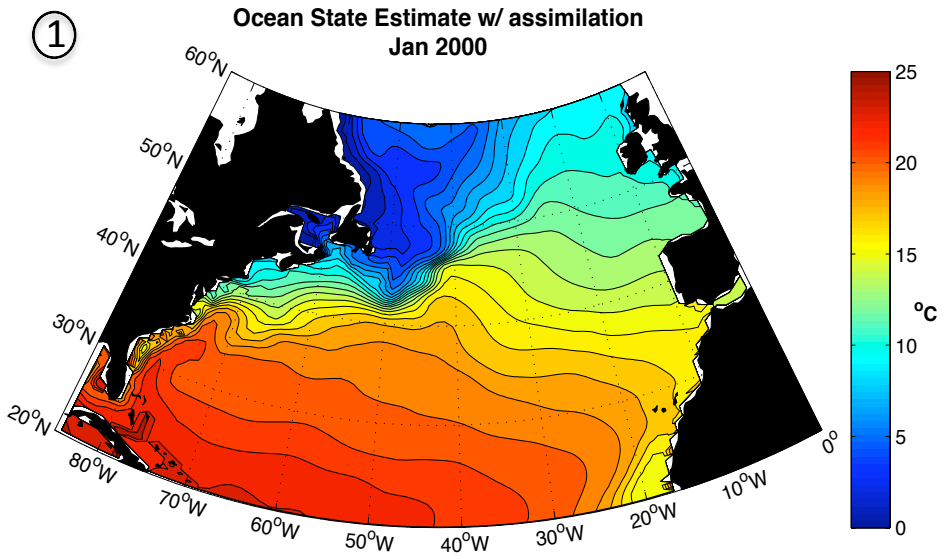
POP-CICE restored at surface to HadOI-SST

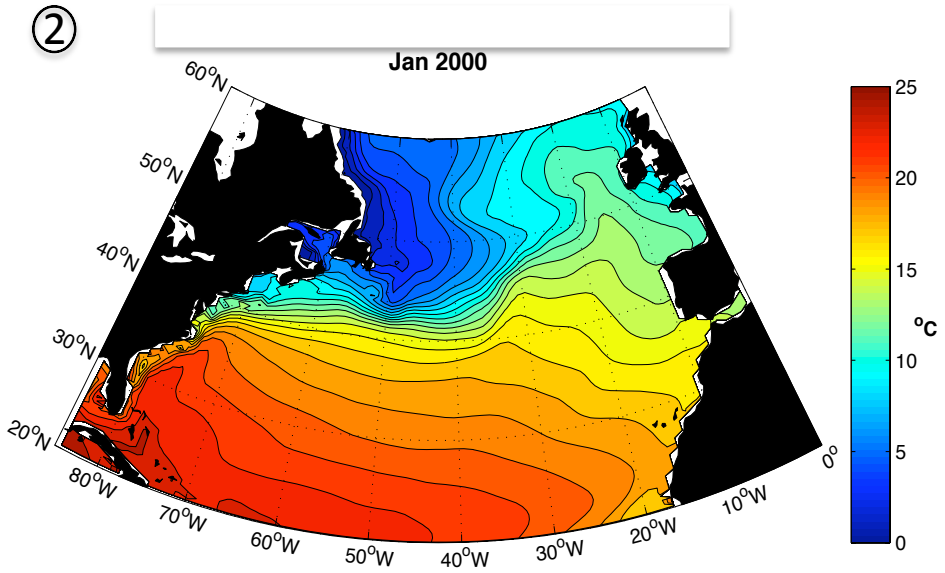
DART 48x48

CCSM4 (POP+CAM4) Decadal Prediction Initial Conditions

POP/DART analysis

Figures and analysis thanks to Alicia Karspeck





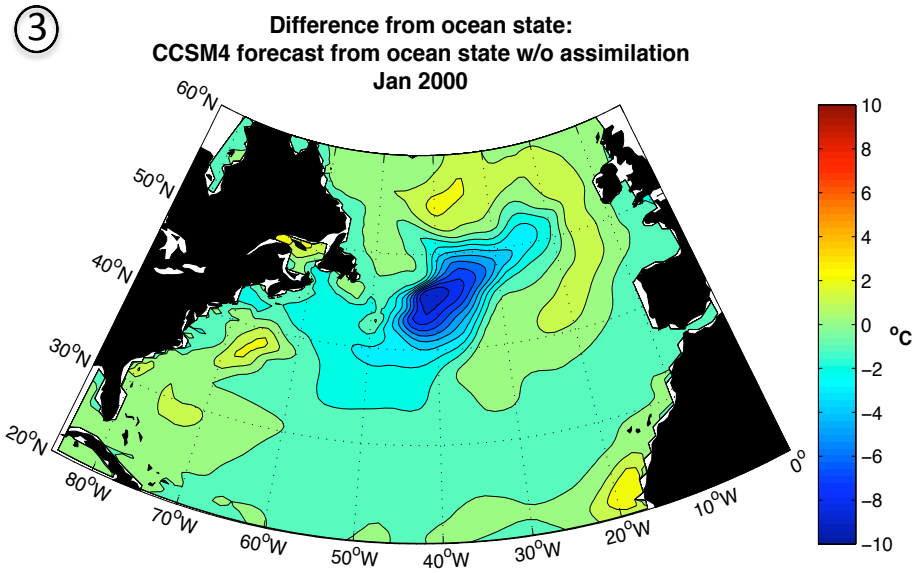


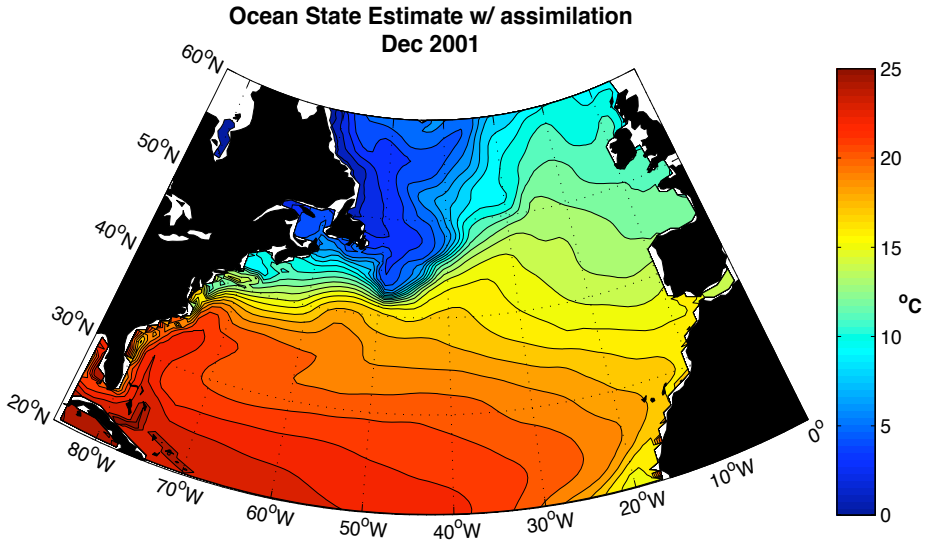
Illustration: average T in top 250m of N Atlantic from:

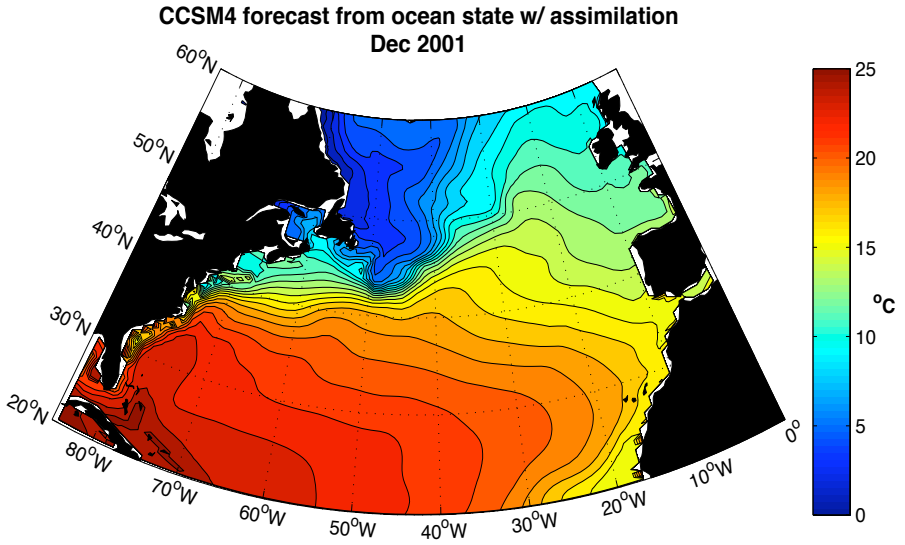
① POP/DART analysis (used as ICs for "POP/DART" forecast),

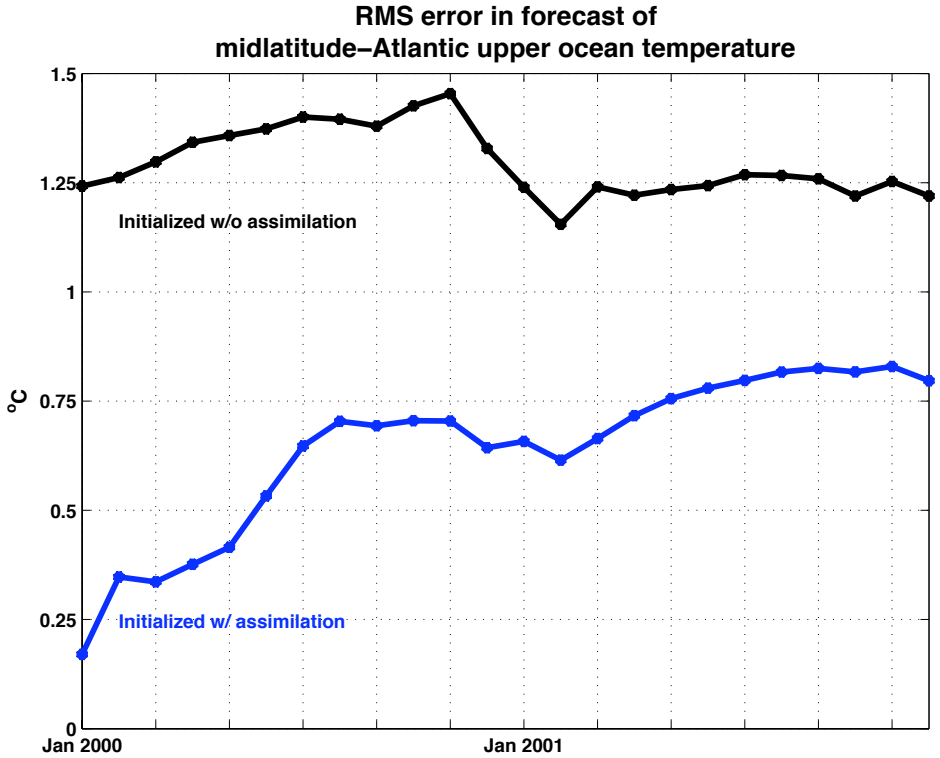
② ICs from a "hindcast" forced by CORE2 historical surface fluxes,

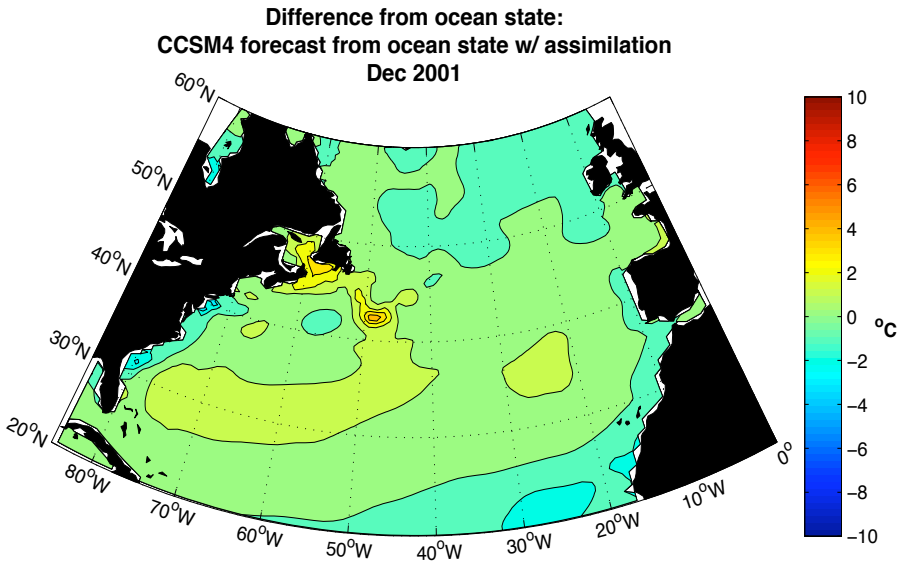
③ Difference of 2 from 1.

Year 2 forecasts (to be continued…)









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