# New Ocean, Atmosphere, Land, and Sea Ice Reanalyses from CESM1 (CAM5)

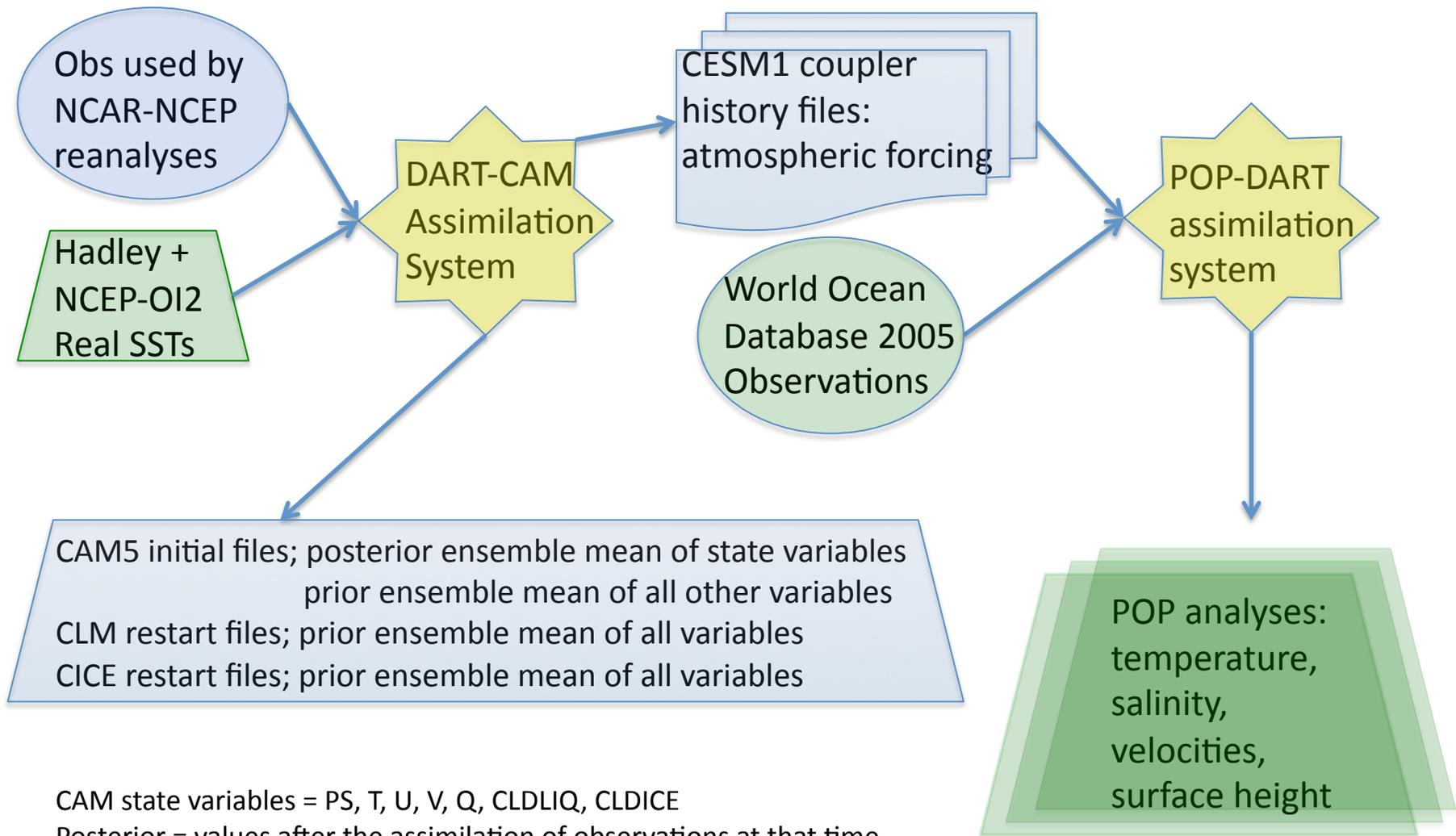Kevin Raeder[§], Tim Hoar[§], Nancy Collins[§], Jeff Anderson[§]
Steve Yeager[¶],  Gokhan Danabasoglu[¶]

[§] NCAR/CISL/IMAGe/Data Assimilation Research Section
[¶] NCAR/NESL/CGD/Oceanography

# Reanalyses from a Mostly Coupled Ocean-Atmosphere System

Obs used by NCAR-NCEP reanalyses

Hadley + NCEP-OI2 Real SSTs

DART-CAM Assimilation System

CESM1 coupler history files: atmospheric forcing

World Ocean Database 2005 Observations

POP-DART assimilation system

CAM5 initial files; posterior ensemble mean of state variables
prior ensemble mean of all other variables
CLM restart files; prior ensemble mean of all variables
CICE restart files; prior ensemble mean of all variables

POP analyses: temperature, salinity, velocities, surface height

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

Data Assimilation Research Testbed

# CAM & DART

CAM =  ~CAM5, FV core, "2-degree", real SSTs.

DART = Data Assimilation Research Testbed, an ensemble Kalman filter data assimilation system.

Assimilate observations used in operational forecasting:

→ U, V, and T from radiosondes, ACARS, and aircraft,

→ U and V from satellite wind scatterometers, every 6 hours

This system is competitive with operational  weather centers' data assimilation systems.

# CAM/CLM/CICE Analyses,
# Packaged as Initial Conditions

➢ Easy to use initial conditions for CAM forecast studies.

➢ Analyses generated every 6 hours, (ensemble avg AND/OR, ensemble of model states at the same time for ensemble forecasts).

➢ On models' native grids -> no interpolation or foreign model error to wonder about.

➢ CAM's PS, T, US, VS, Q, CLDLIQ, and CLDICE are analyses after assimilation of observations at each time.

➢ Remaining CAM fields plus CLM and CICE fields are ensemble averages of the 6 hour forecast fields (before each assimilation).

➢ Analysis error estimate comes for free from ensemble spread; varies  with location, time, and field.

➢ 1998-1999 currently available.   Plan to extend through the present.

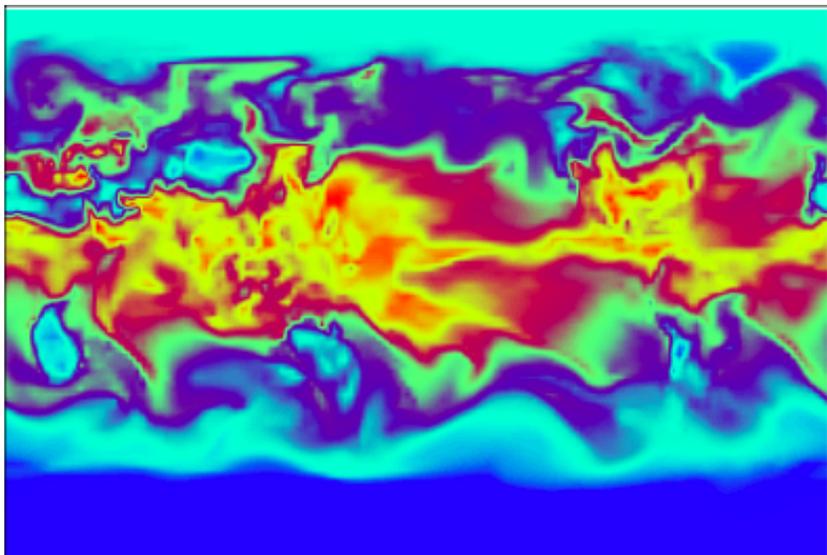# Means (analyses) and Spreads (confidence) 06Z 7/31/07

PS Mean
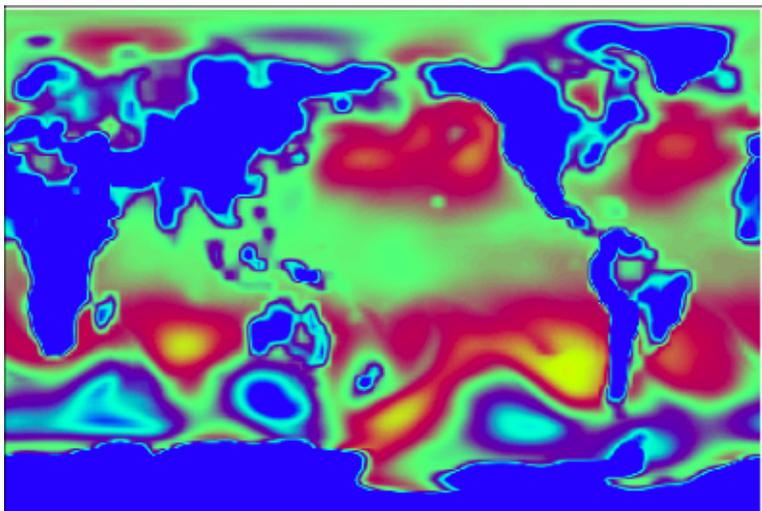
PS spread



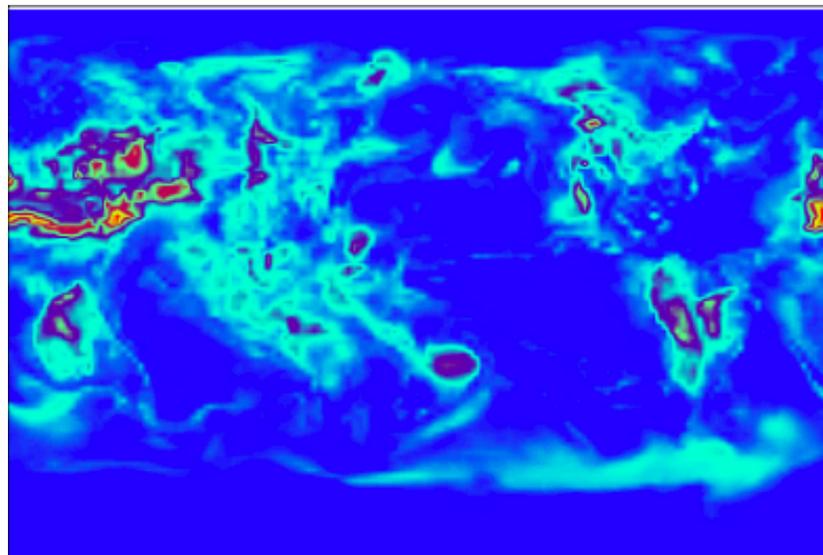posterior ensemble state
Range of Surface pressure: 97000 to 104469 Pa
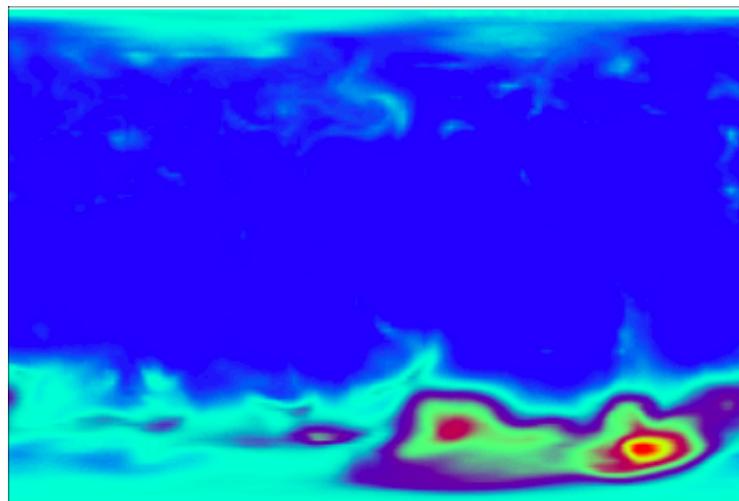
posterior ensemble state
Range of Surface pressure: 34.483 to 1862.57 Pa

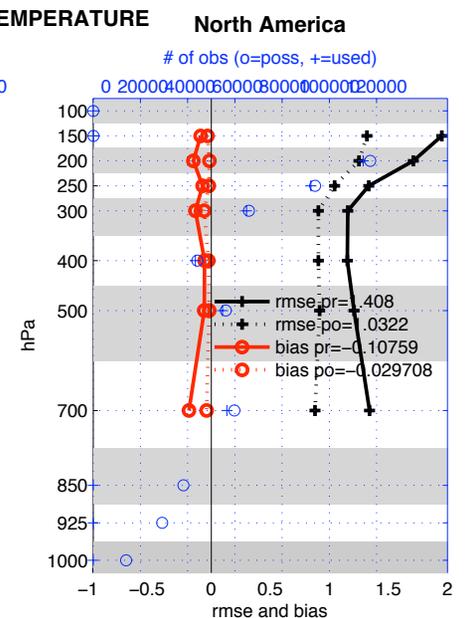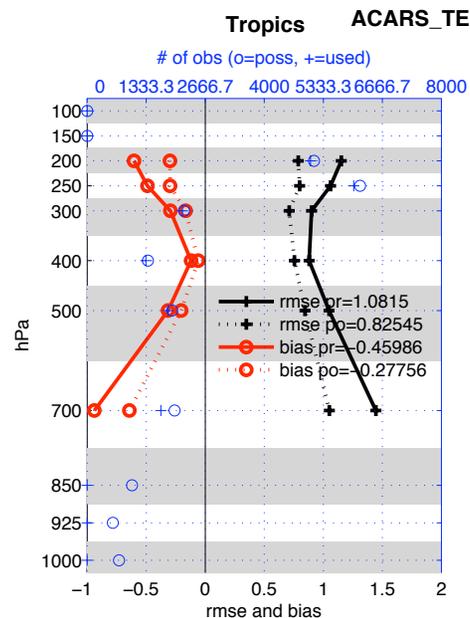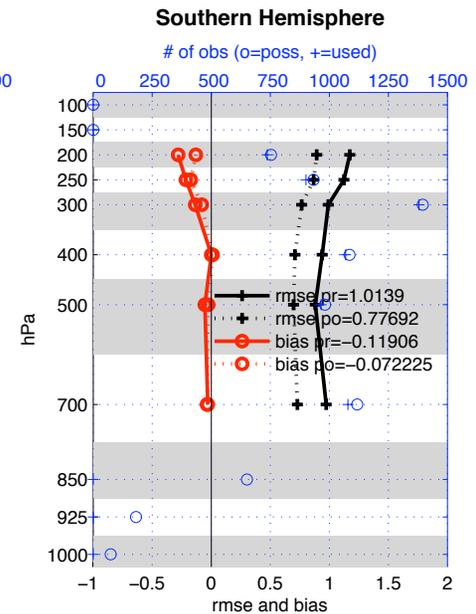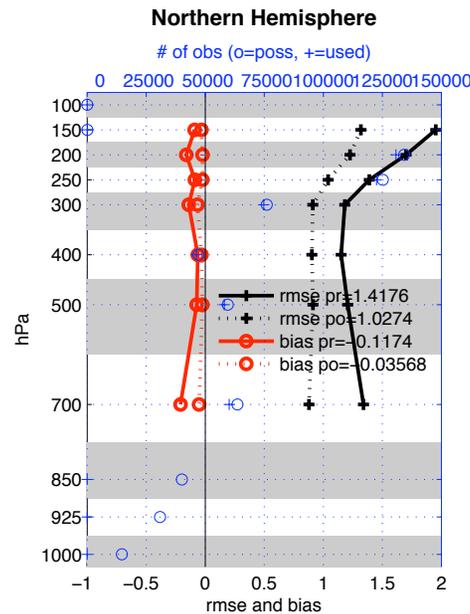Q level=30 Mean

Q level=30 spread



posterior ensemble state
Range of Specific humidity: 6.61214e-06 to 0.0217079 kg/kg

posterior ensemble state
Range of Specific humidity: 2.05892e-05 to 0.00680974 kg/kg

# Comparison of DART-CAM Analyses Against Observations

➤ Example compares against just T measurements from aircraft in several regions for Jan 1999.

➤ Prior (6-hour forecast) profiles are the best measuring stick; less overfitting (see solid lines).

➤ Posterior bias and rmse are smaller than prior, since assimilation pulls model state towards observations.

➤ # of obs used (✚) is very close to # of obs available (〇); healthy assimilation.



Northern Hemisphere

rmse pr=1.4176
rmse po=1.0274
bias pr=-0.1174
bias po=-0.03568

Southern Hemisphere

rmse pr=1.0139
rmse po=0.77692
bias pr=-0.11906
bias po=-0.072225

Tropics — ACARS_TEMPERATURE — North America

rmse pr=1.0815
rmse po=0.82545
bias pr=-0.45986
bias po=-0.27756

rmse pr=1.408
rmse po=1.0322
bias pr=-0.10759
bias po=-0.029708

# POP-DART Assimilation Characteristics

1. POP 1-degree displaced pole;
2. 48 Ensemble members;
3. Each ocean forced by a different CAM atmosphere;
4. Start from 'climatological' ocean ensemble;
5. Start from the 'converged' ensemble of atmospheric analyses;
6. Use all observations in midnight +/- 12 hour window;
7. Assimilate them once per day;
8. January 1998 through August 1999 (done) and on to the present;
9. To be used as initial conditions for IPCC decadal predictions.

# Physical Space Detail: SST Anomaly from HadOI-SST
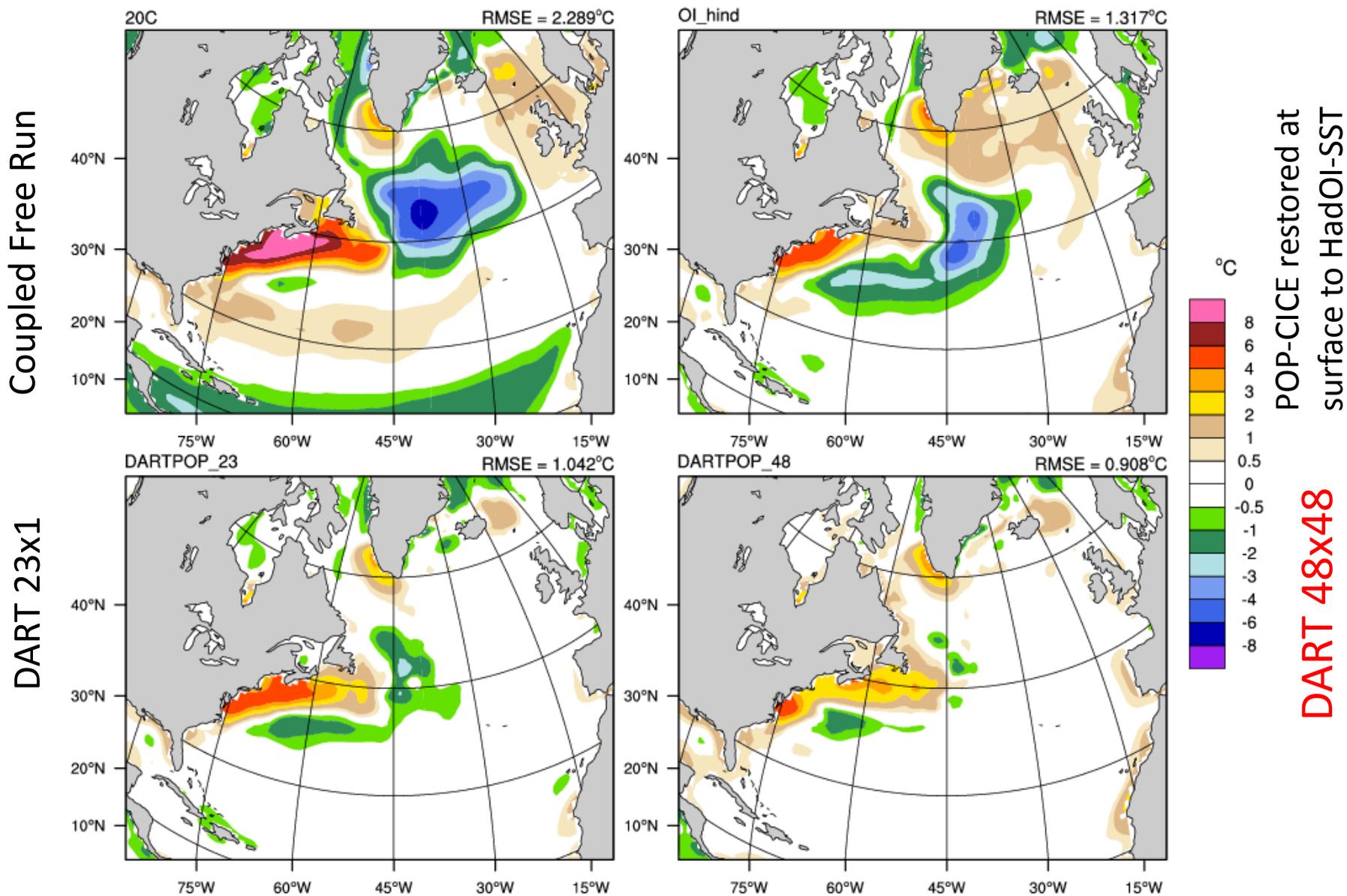
# Example Uses for Analyses

① Initial conditions for forecasts requiring actual synoptic conditions:
Jen Kay; atmospheric influence on record arctic ice loss in 2007

> Kay, J.E., K. Raeder, A. Gettelman, and J. Anderson:The boundary layer response to recent Arctic sea ice loss and implications for high-latitude climate feedbacks, Journal of Climate (pending minor revisions, June 2010)

Chang; North Pacific extra-tropical cyclone development

IPCC; initial conditions for coupled model, decadal predictions

② Facilitates statistical analysis of models and the atmosphere, e.g.
Zagar: nonlinear normal mode analysis of analysis increments tropical waves

> N. Žagar, J. Tribbia, J. L. Anderson, K. Raeder and D. T. Kleist 2009. Diagnosis of systematic analysis increments by using normal modes. *Q. J. R. Meteorol. Soc.* **136**

③ Helps identify model deficiencies:

Peter Lauritzen:  improved damping of numerical noise using a $\nabla^4$ operator

> Anderson, J. L., T. Hoar, K. Raeder, H. Liu, N. Collins, R. Torn, A. F. Arellano, Jr., 2009: The Data Assimilation Research Testbed: A community data assimilation facility. Bull. Amer. Meteor. Soc., 90, 1283-1296

Kay: improvement of shallow cumulus parameterization

④ Ensemble Kalman Filter Data Assimilation  in general has additional applications in model and instrument evaluation.