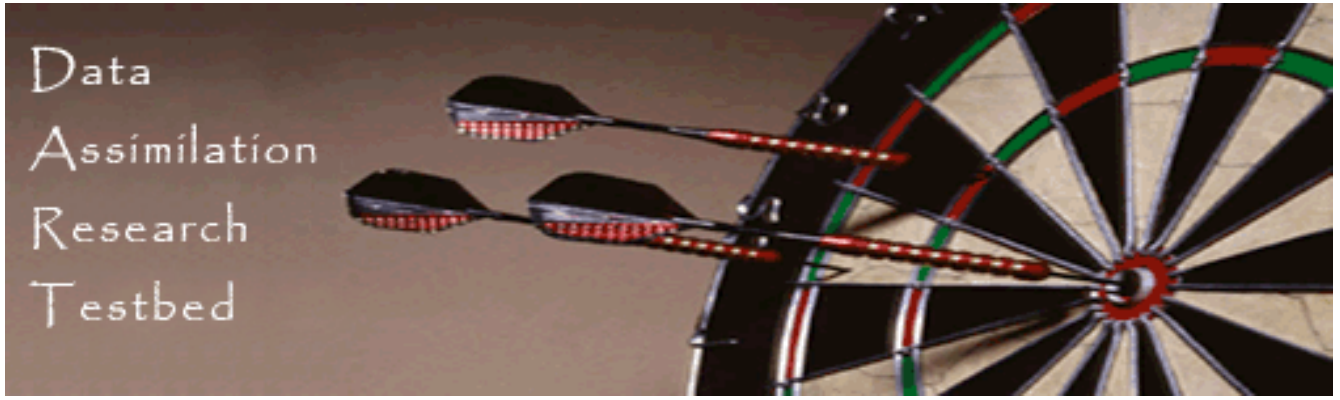
Ensemble Data Assimilation for POP

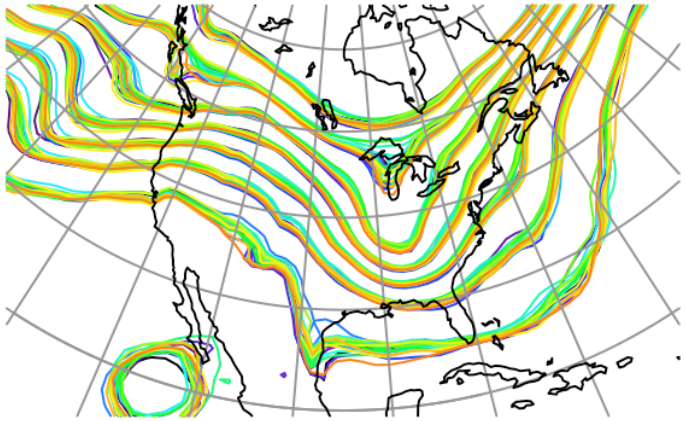


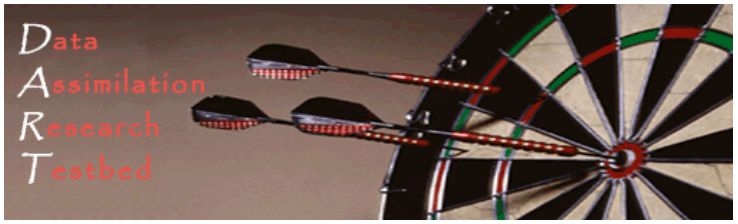
Tim Hoar, Nancy Collins, and Jeffrey Anderson
NCAR Institute for Math Applied to Geophysics
Data Assimilation Research Section

What is Data Assimilation?

Observations combined with a Model forecast…

…to produce an analysis
(best possible estimate).





DART is:

Public domain software for Data Assimilation

- Well-tested, portable, extensible, free!

Models

- Toy to HUGE

Observations

- Real, synthetic, novel

An extensive Tutorial

- With examples, exercises, explanations

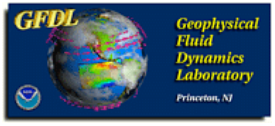
People: The DAReS Team

used at -

UNIVERSITY OF WASHINGTON

CIRES

THE UNIVERSITY OF UTAH



PENNSTATE

JPL
Jet Propulsion Laboratory
California Institute of Technology

and many more.

...

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Ensemble Filter for Large Geophysical Models

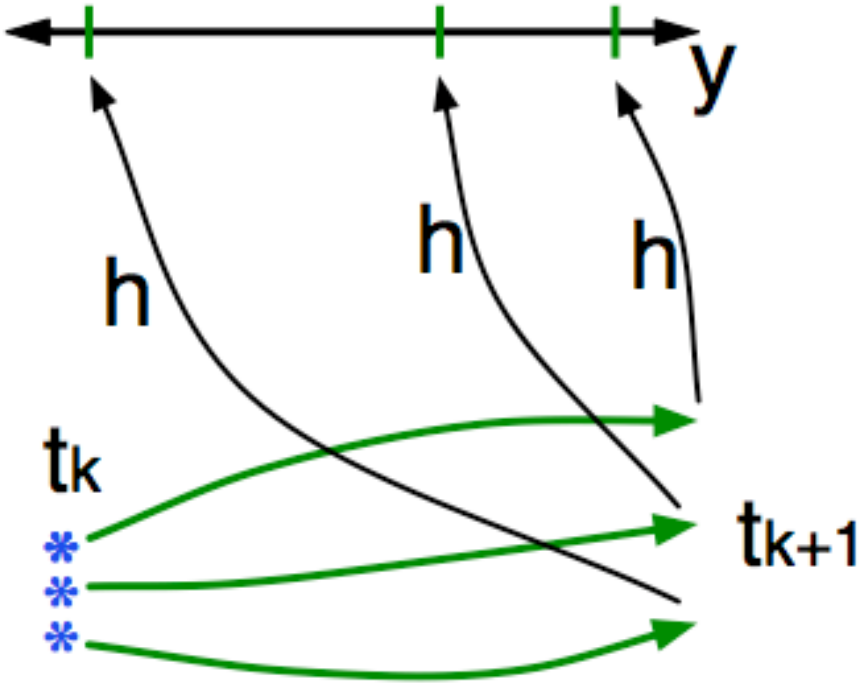
1. Use model to advance ensemble (3 members here) to time at which next observation becomes available.

Ensemble state estimate after using previous observation (analysis)

Ensemble state at time of next observation (prior)

Ensemble Filter for Large Geophysical Models

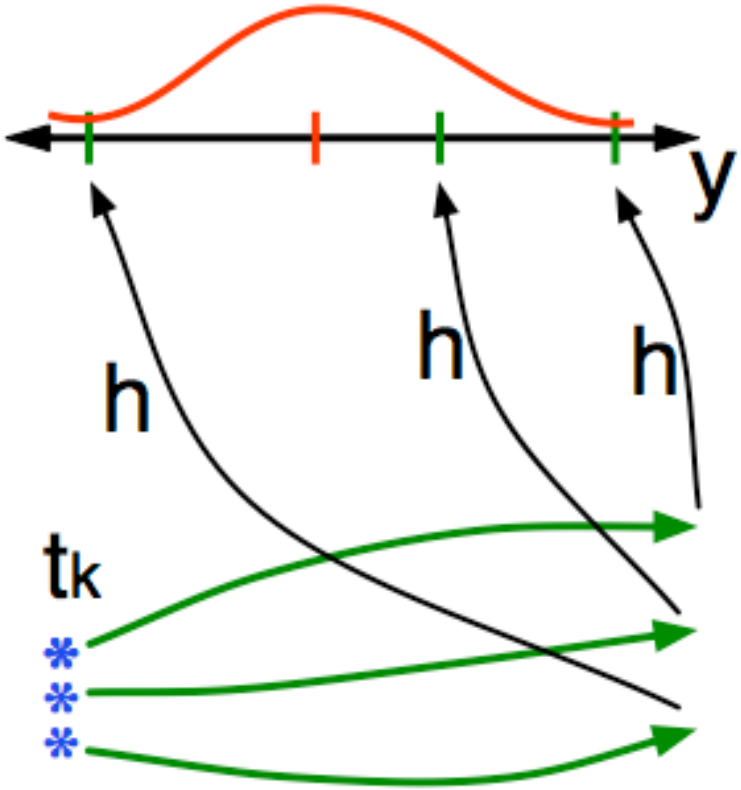
2. Get prior ensemble sample of observation, y = h(x), by applying forward operator **h** to each ensemble member.



Theory: observations from instruments with uncorrelated errors can be done sequentially.

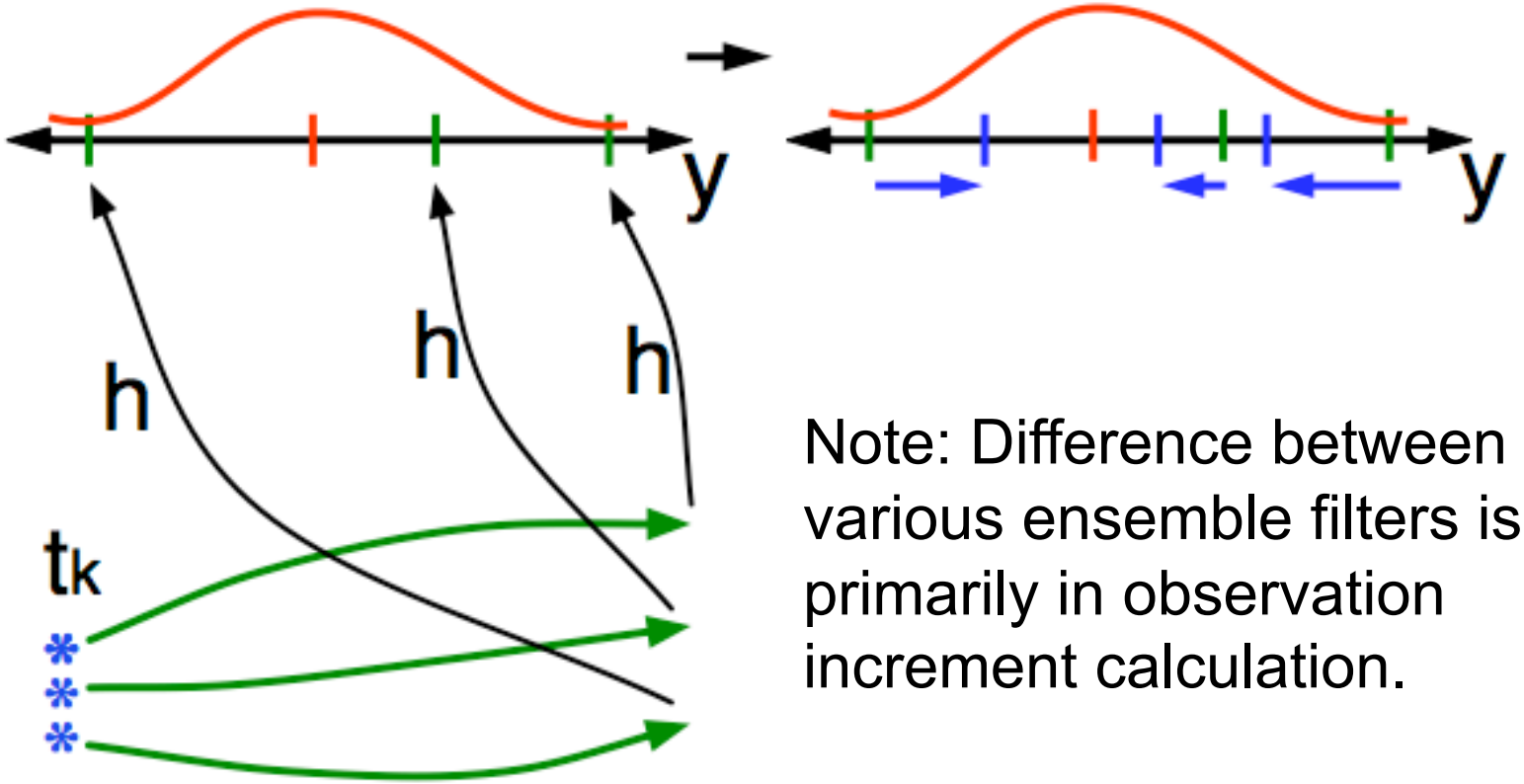
Ensemble Filter for Large Geophysical Models

3. Get observed value and observational error distribution from observing system.



Ensemble Filter for Large Geophysical Models

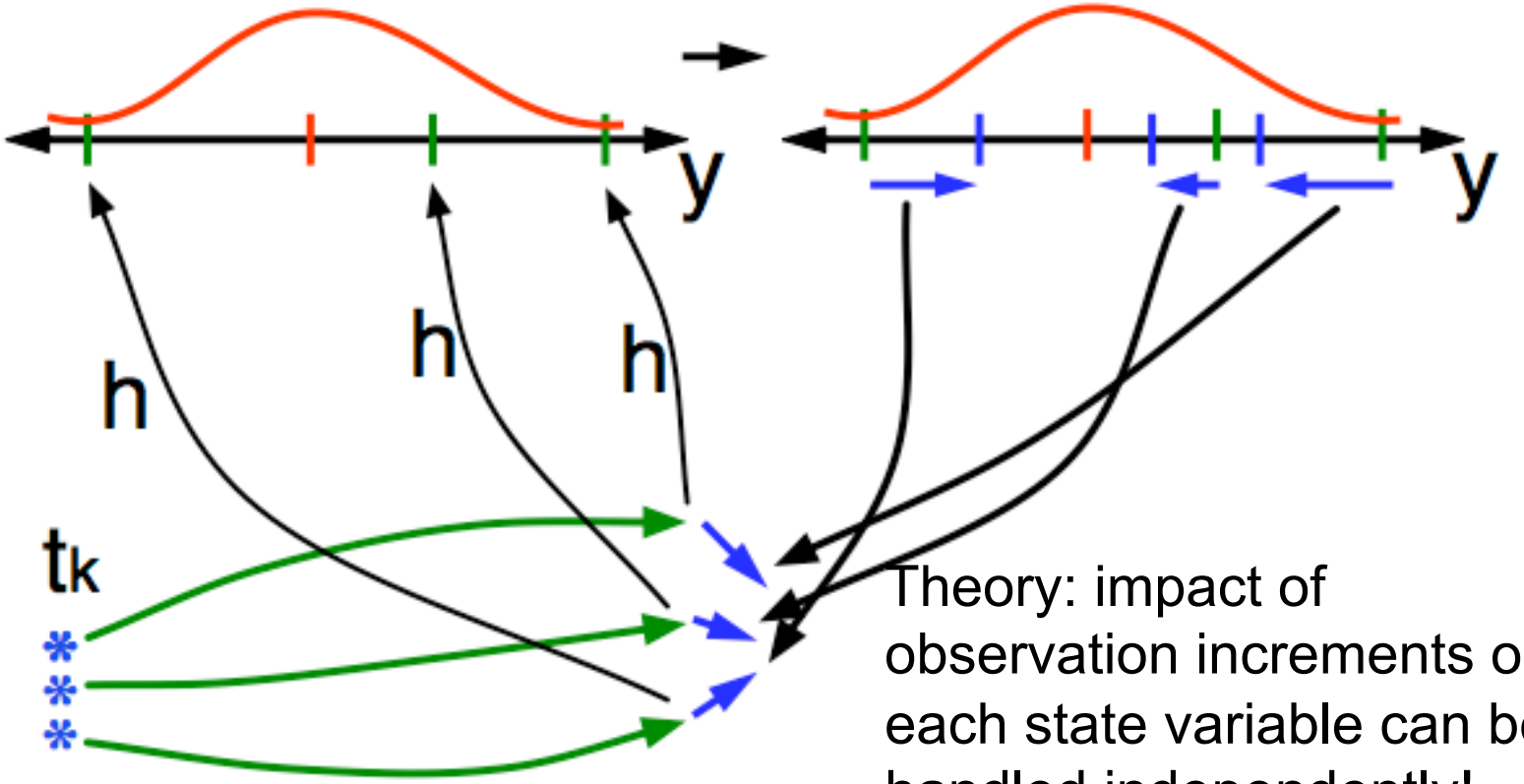
4. Find the increments for the prior observation ensemble (this is a scalar problem for uncorrelated observation errors).



Note: Difference between various ensemble filters is primarily in observation increment calculation.

Ensemble Filter for Large Geophysical Models

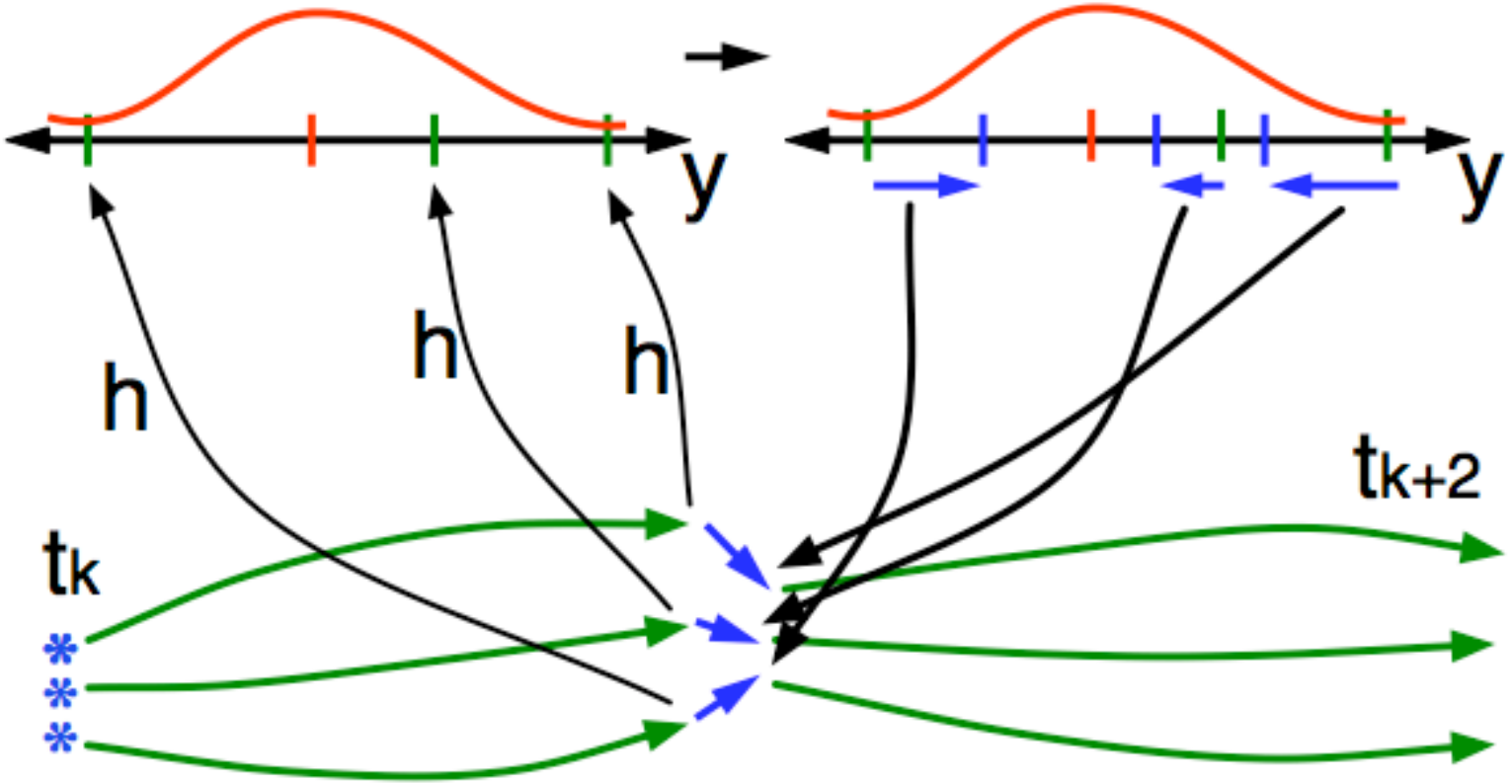
5. Use ensemble samples of **y** and each state variable to linearly regress observation increments onto state variable increments.



Theory: impact of observation increments on each state variable can be handled independently!

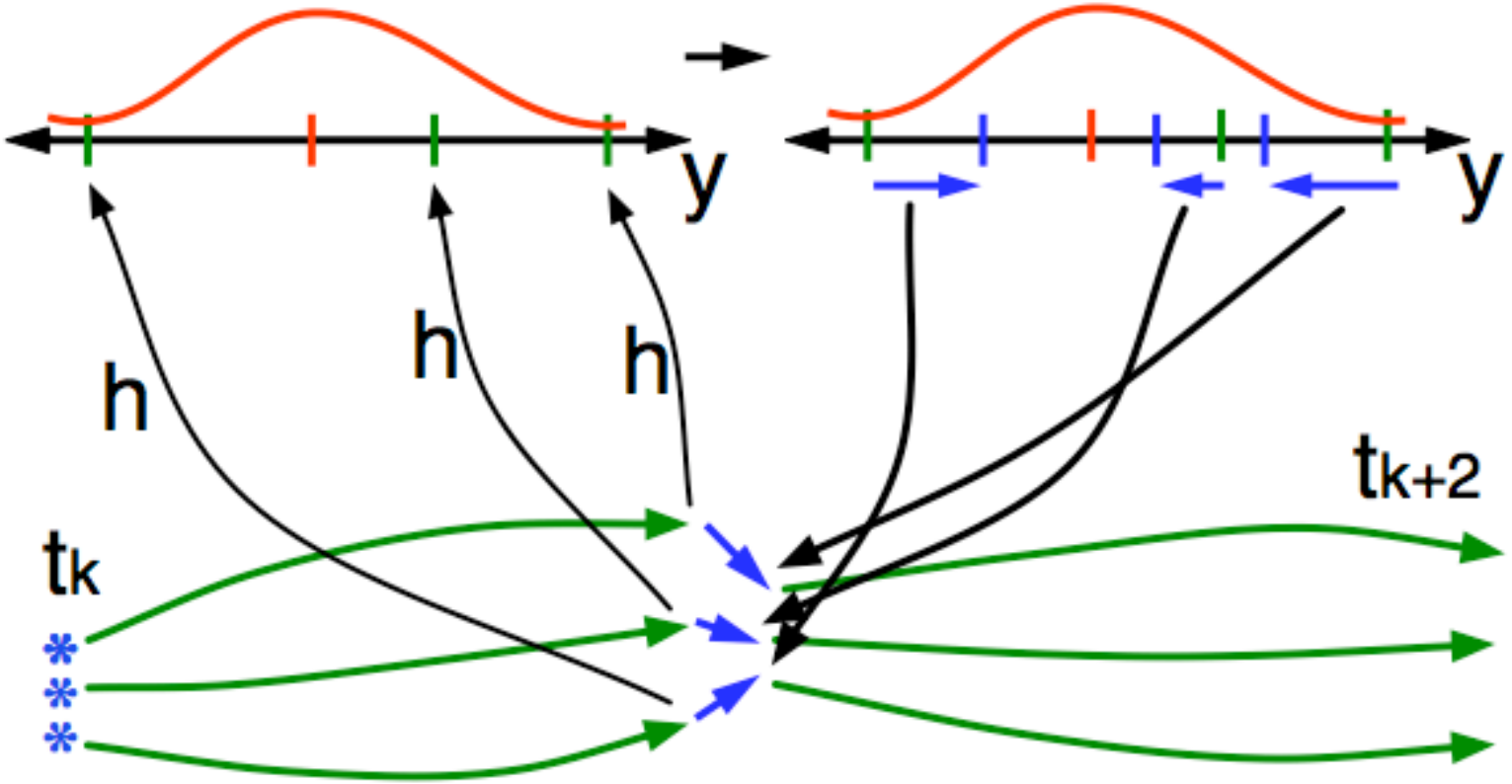
Ensemble Filter for Large Geophysical Models

6. When all ensemble members for each state variable are updated, there is a new analysis. Integrate to time of next observation …



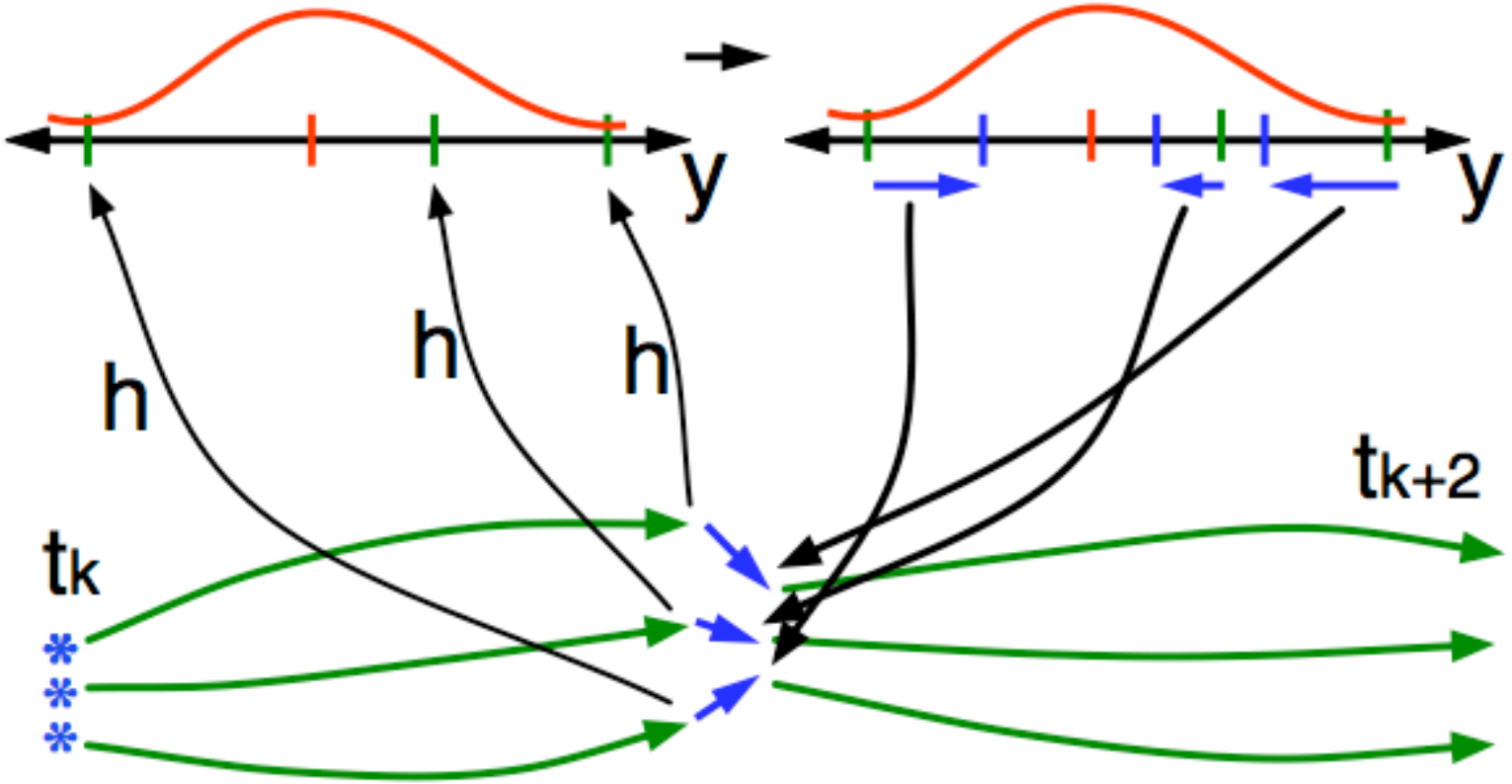
Ensemble Filter for Large Geophysical Models

To work with POP, DART just needs:
1. A way to make model forecasts (done by CGD);



Ensemble Filter for Large Geophysical Models

To work with POP, DART just needs:
1. A way to make model forecasts (CGD, PetaApps);
2. Forward operators, h. Interpolation (DAReS).



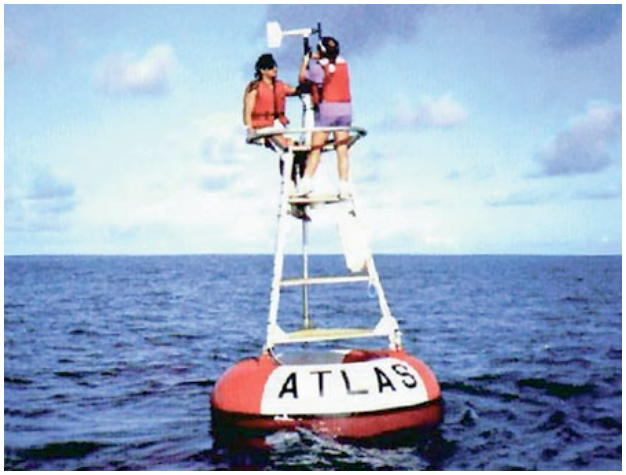
DART/POP Assimilation Experiments

1. POP 1 degree displaced pole;
2. 23 Ensemble members;
3. All 23 oceans forced by same observed atmosphere;
4. Start from ‘climatological ensemble’;
5. Assimilate all available observations once a day;
6. Use all observations in +/- 12 hour window;
7. January 1998 through December 1999.

Observations for 1998-1999

Temperature and salinity from World Ocean Database 2005.

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



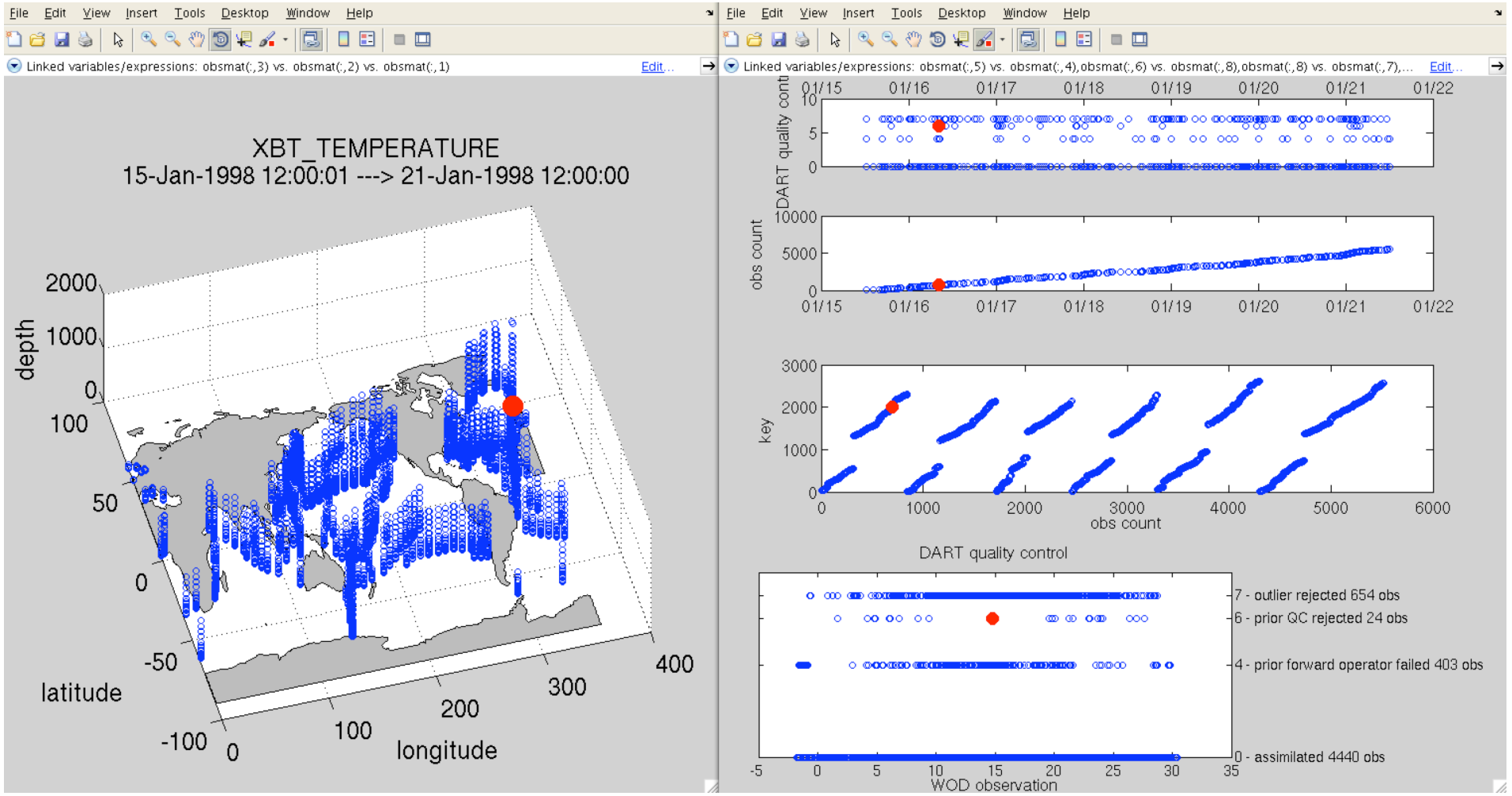
Observations for 1998-1999

Temperature observation error standard deviation 0.5 K;
Salinity observation error standard deviation 0.5 msu.

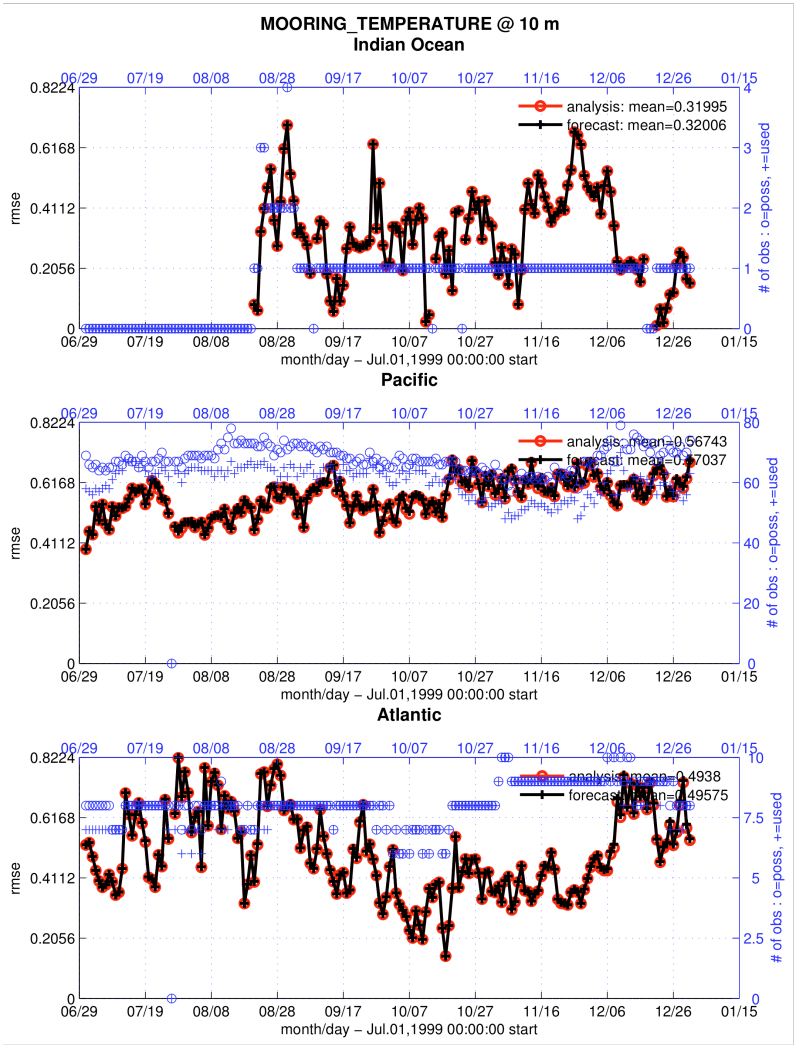
System is also ready to assimilate:

- Currents;
- Sea surface height.

Observation Visualization Tools



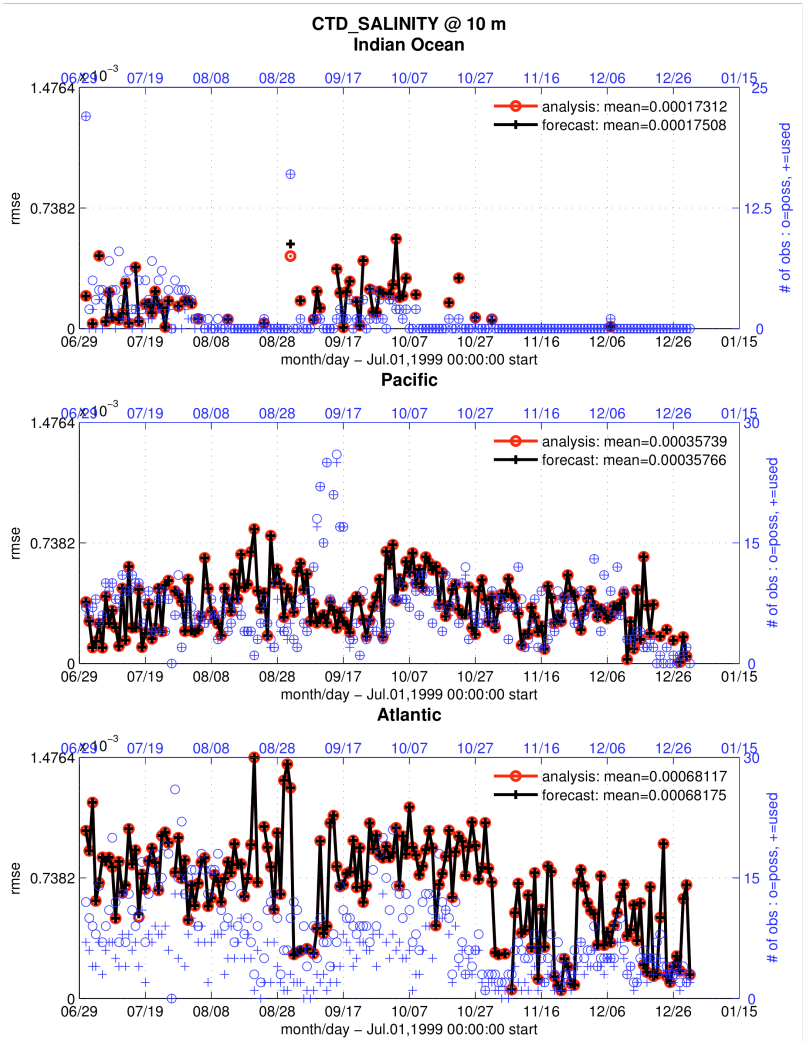
Observation Space Diagnostics (July-Dec. 1999)



10m Mooring Temperature

1. Ensemble mean analysis difference from obs.
2. Ensemble mean 1-day forecast difference from obs.
3. Blue circle is # of obs.
4. Blue + is # assimilated.
5. Obs. are rejected if they are too far from ensemble mean (3 standard deviations here).

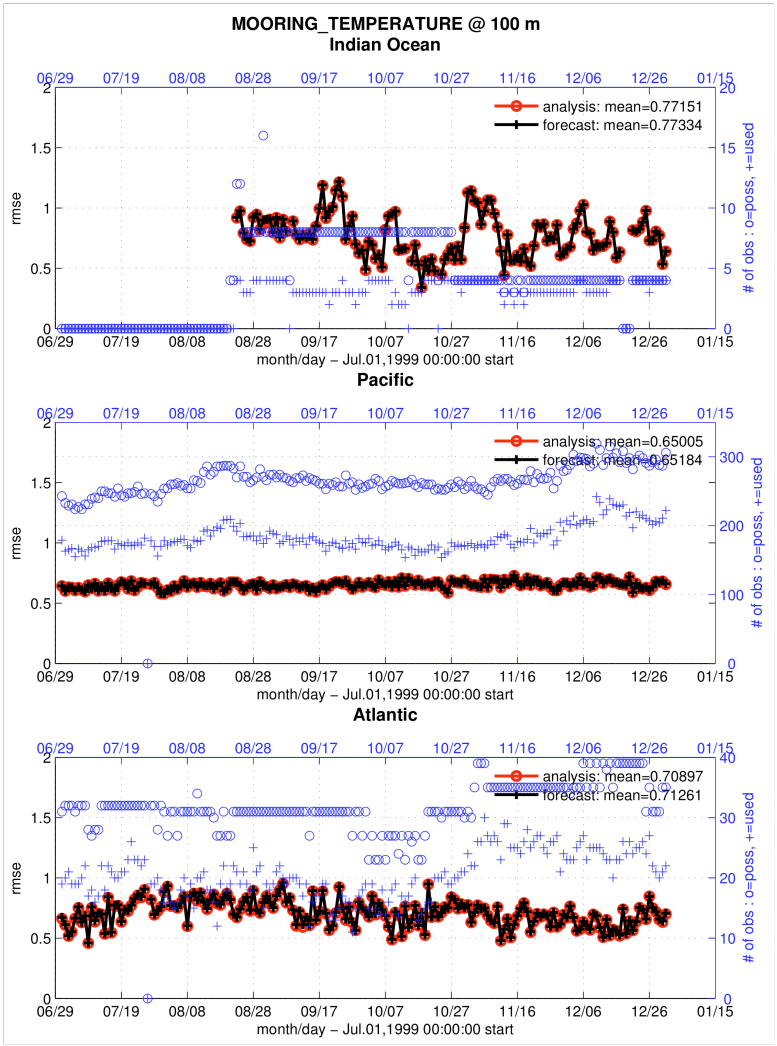
Observation Space Diagnostics (July-Dec. 1999)



10m CTD Salinity

1. Ensemble mean analysis difference from obs.
2. Ensemble mean 1-day forecast difference from obs.
3. Blue circle is # of obs.
4. Blue + is # assimilated.
5. Obs. are rejected if they are too far from ensemble mean (3 standard deviations here).

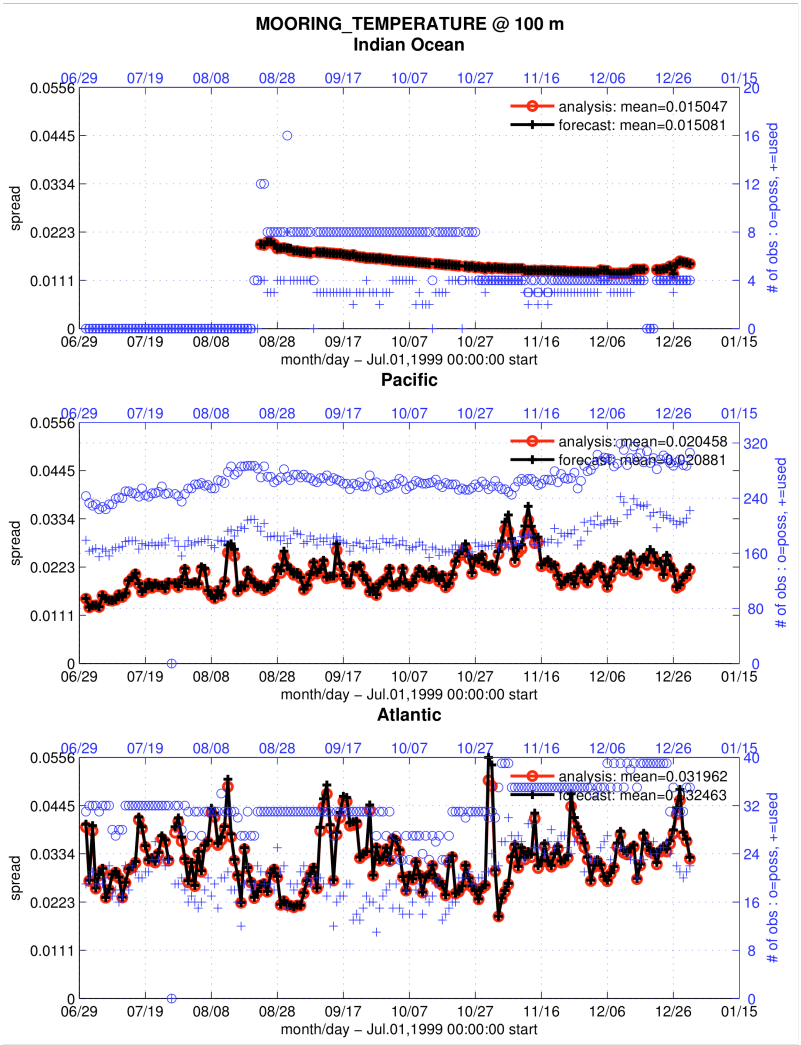
Observation Space Diagnostics (July-Dec. 1999)



100m Mooring Temperature

1. Blue circle is # of obs.
2. Blue + is # assimilated.
3. Obs. are rejected if they are too far from ensemble mean (3 standard deviations here).
4. About 1/3 of obs. rejected.
5. Model bias in thermocline?

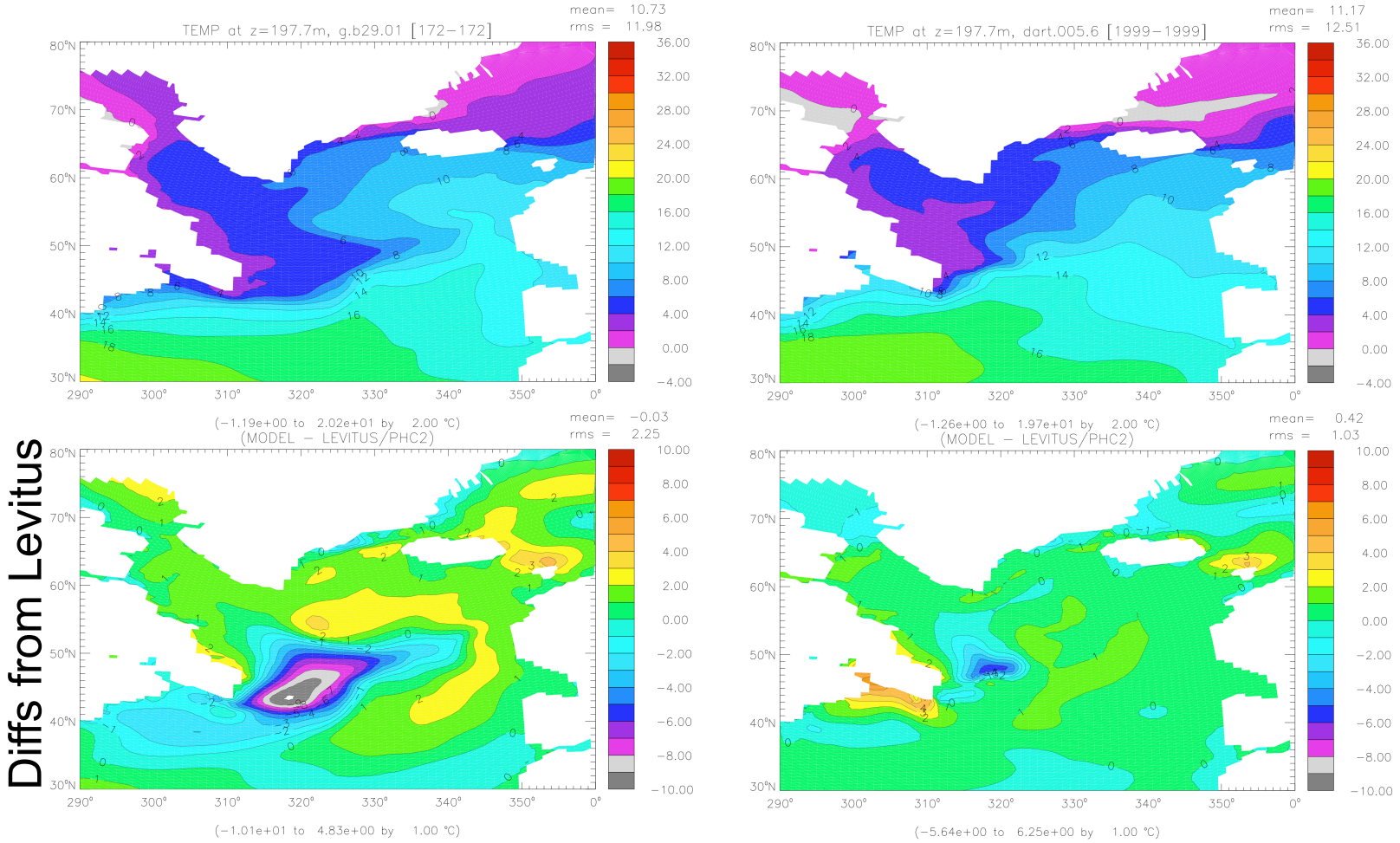
Observation Space Diagnostics: Ensemble Spread



100m Mooring Temperature

1. Spread is way too small (trust me, we know);
2. Model bias makes this even worse;
3. Using single atmospheric forcing is part of the problem;
4. Automatic spread correction tools in DART won't work with POP (yet).

Physical Space Preview: 200m Temperature Means



POP Free Run

DART

Next Step

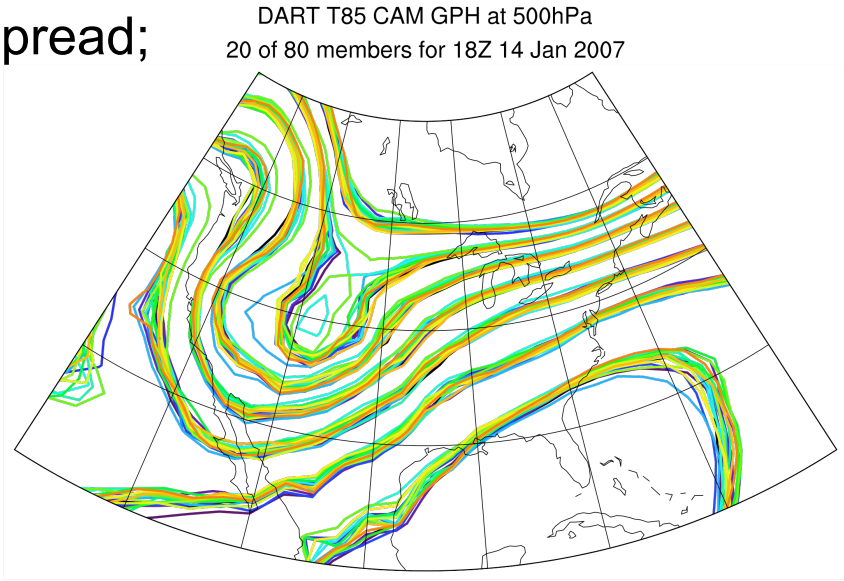
1. Force each ensemble member with a different member from an atmospheric ensemble reanalysis;

2. DART can produce reanalyses with CAM, GFDL's AM2, or NCEP GFS;

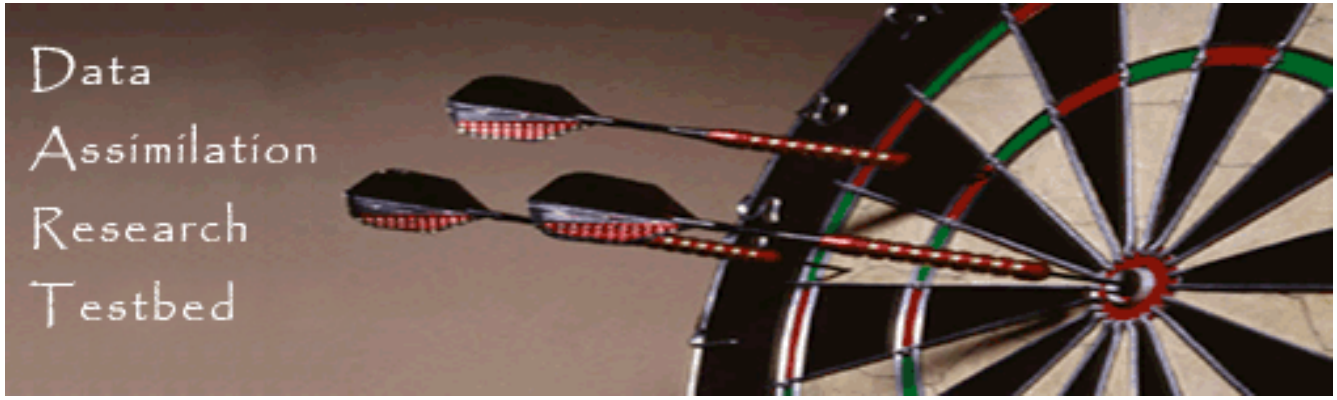
3. Should give some additional spread;

4. Plan to test for 2006-07.

5. May try larger ensemble.



Learn about ensemble assimilation and DART tools at:



http://www.image.ucar.edu/DAReS/DART/