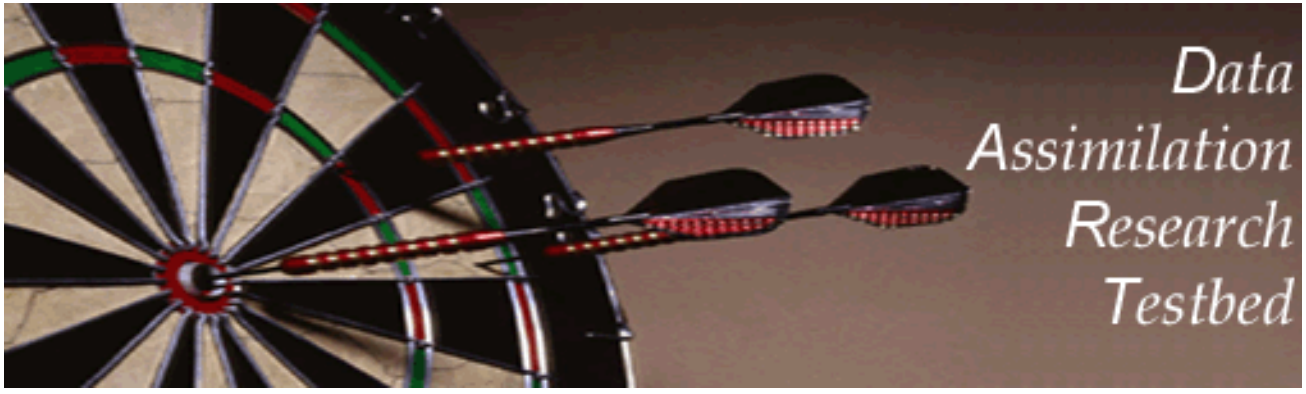
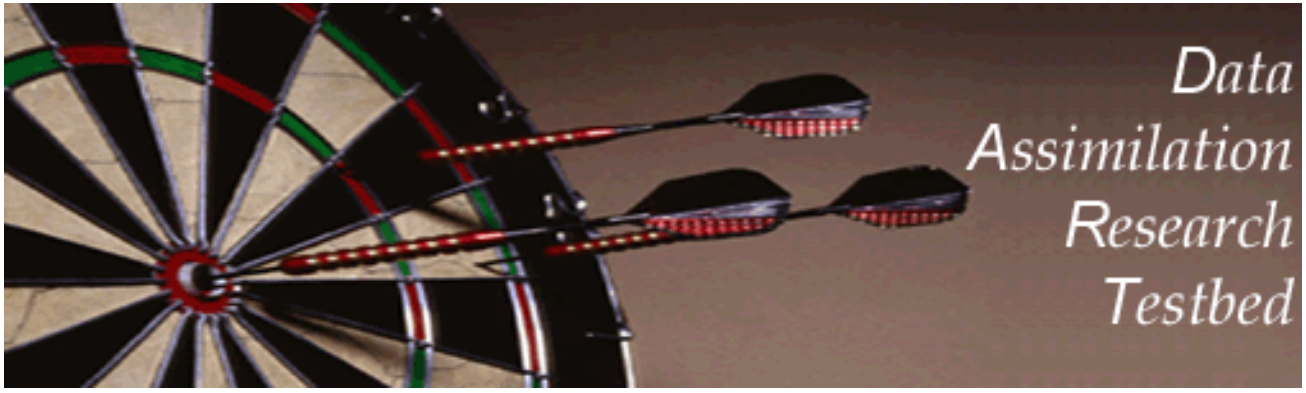
DART:
A Community Tool for Ensemble Data Assimilation Research and Development

Jeffrey Anderson, Nancy Collins, Tim Hoar, Kevin Raeder, Hui Liu
NCAR Data Assimilation Research Section (DAReS)



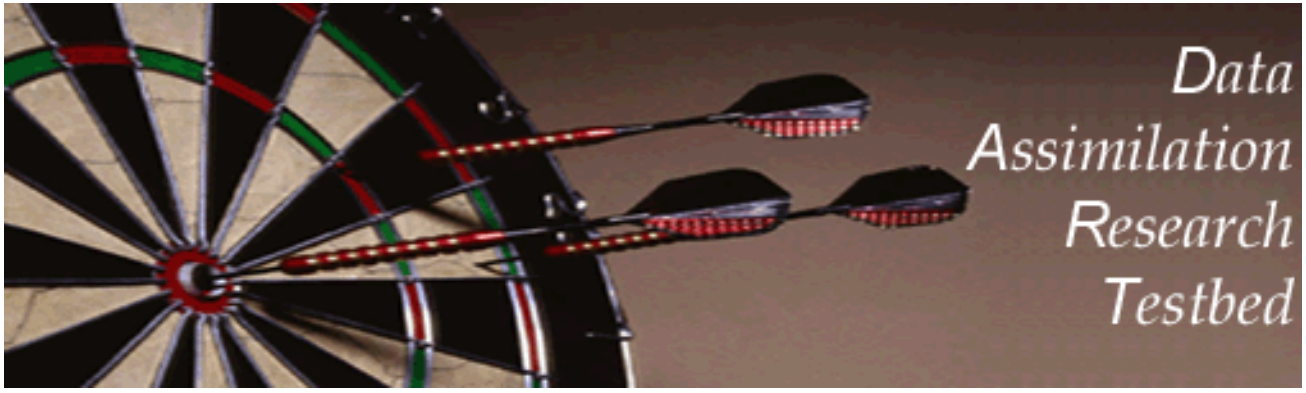
DART features:

1. Wide range of sequential ensemble filter variants.
    a. Deterministic and stochastic square root filters.
    b. Kernel and particle filters (Thursday AM).

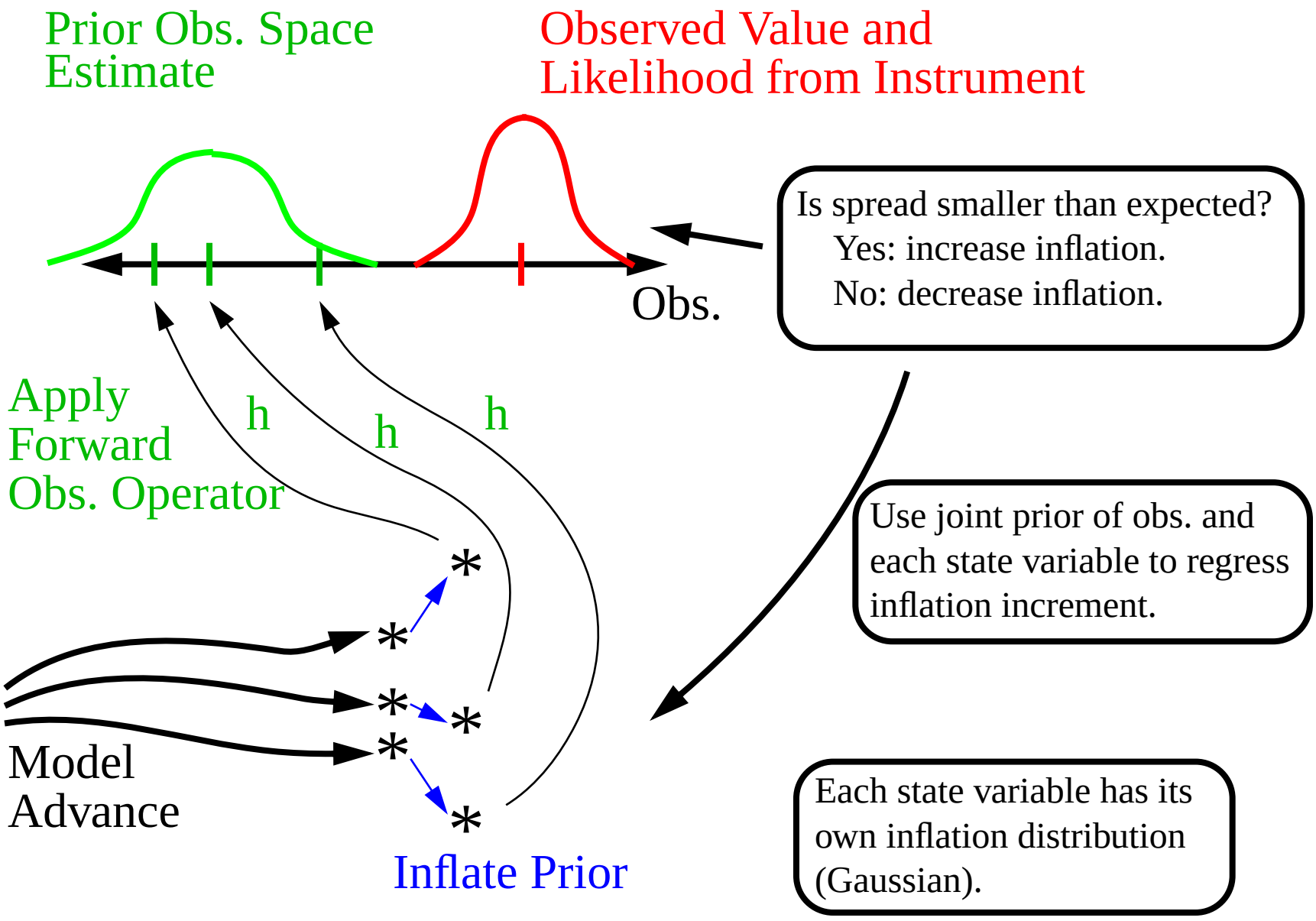


DART features:

2. Advanced hierarchical Bayesian algorithms to minimize tuning:
   Spatially-/temporally-varying adaptive inflation.

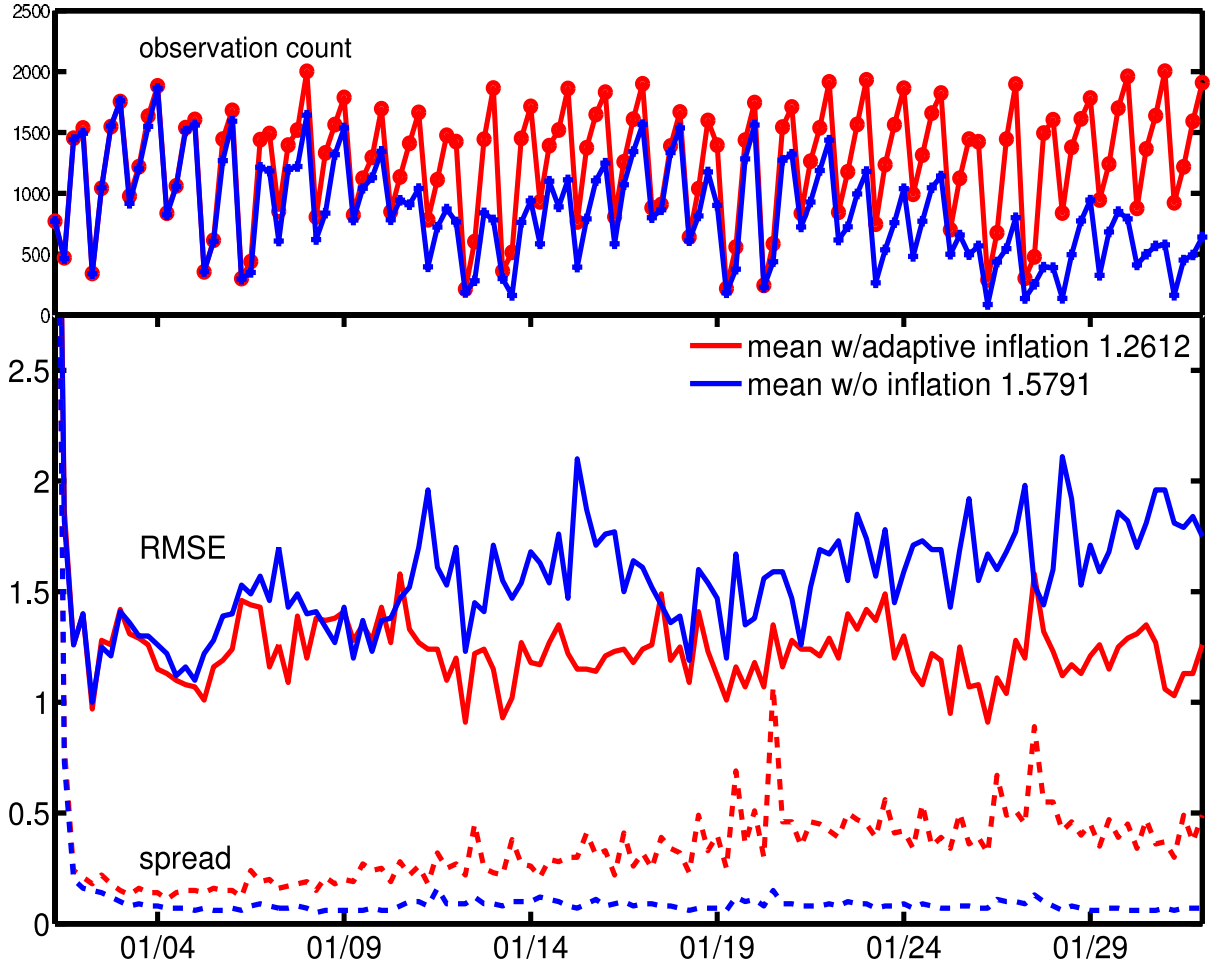


Spatially-varying temporally-adaptive inflation: Hierarchical Bayesian



Adaptive Inflation Applied to DART/CAM January, 2003

Observation Space for 500 hPa North America ACARS Temperatures.



Fewer observations rejected.

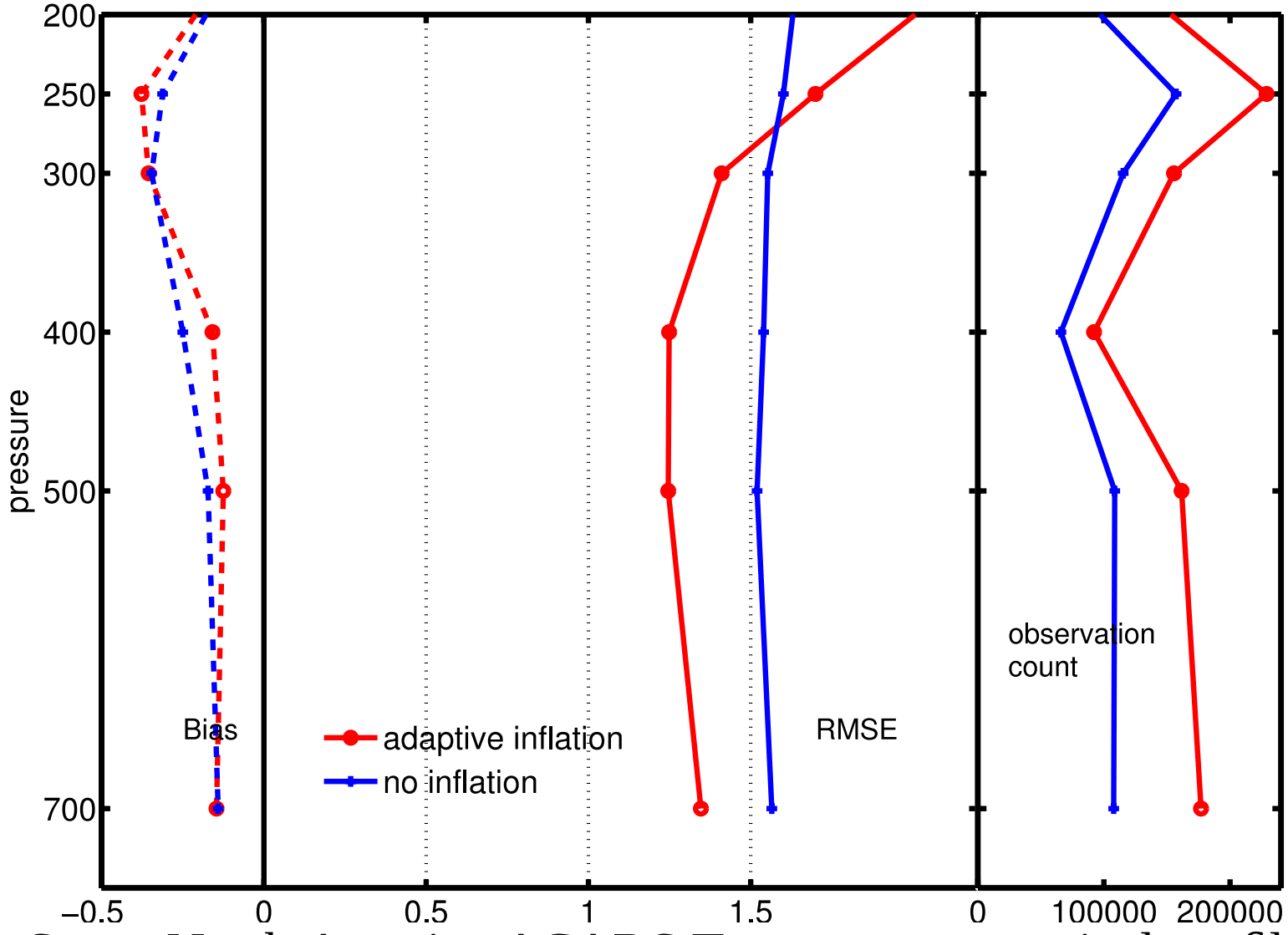
(If prior error is more than 3 times expected, obs. are rejected).

RMS Error is Reduced.

RMS does not increase with time.

Spread is increased.

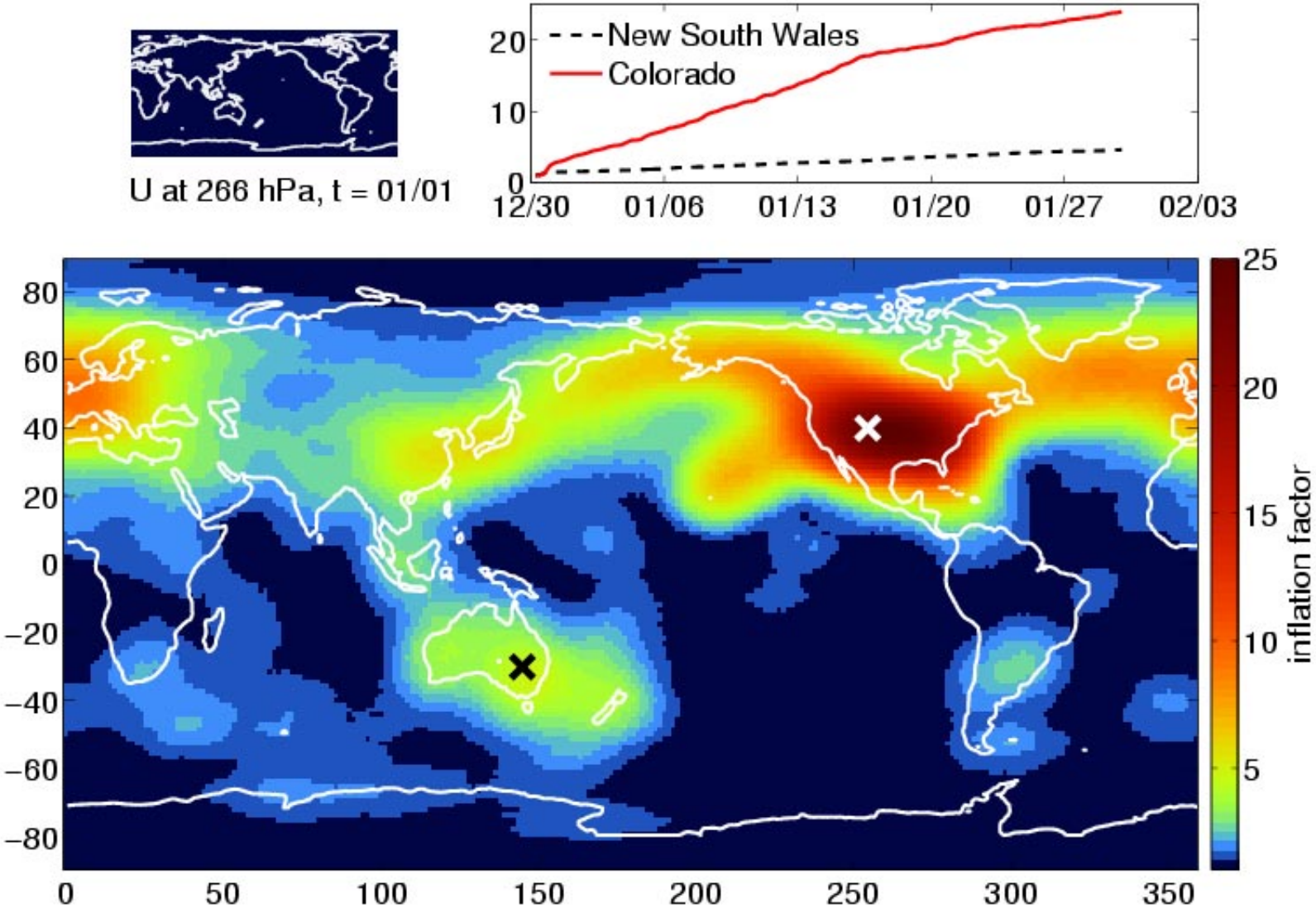
RMS Error Reduced in General: Number of Obs. Rejected Reduced



Obs. Space North America ACARS Temperatures vertical profile.

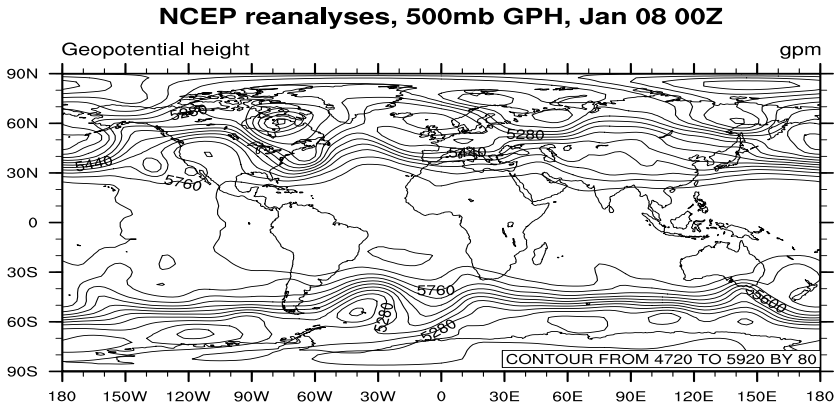
Spatial and Temporal Structure of Adaptive Inflation

Zonal Wind Inflation, 266 hPa

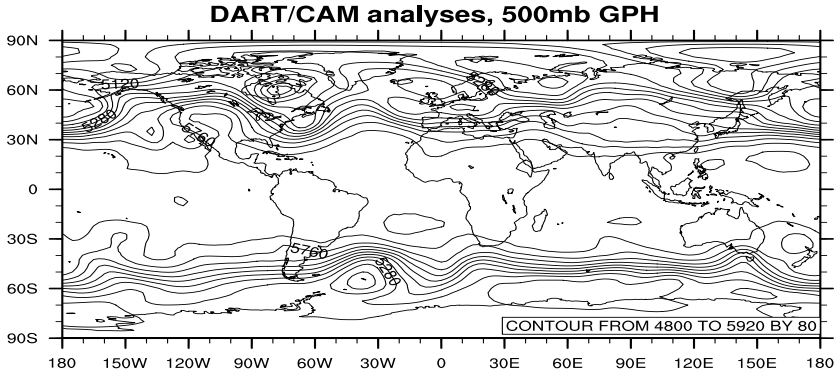


After 7 days.

NCEP

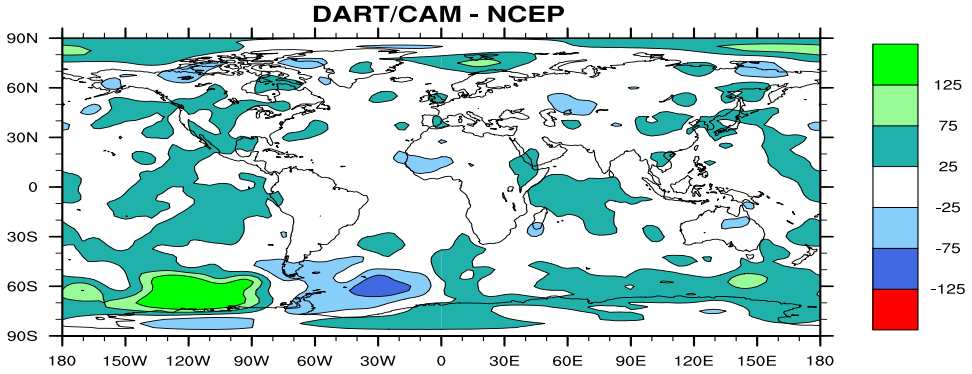


DART/CAM

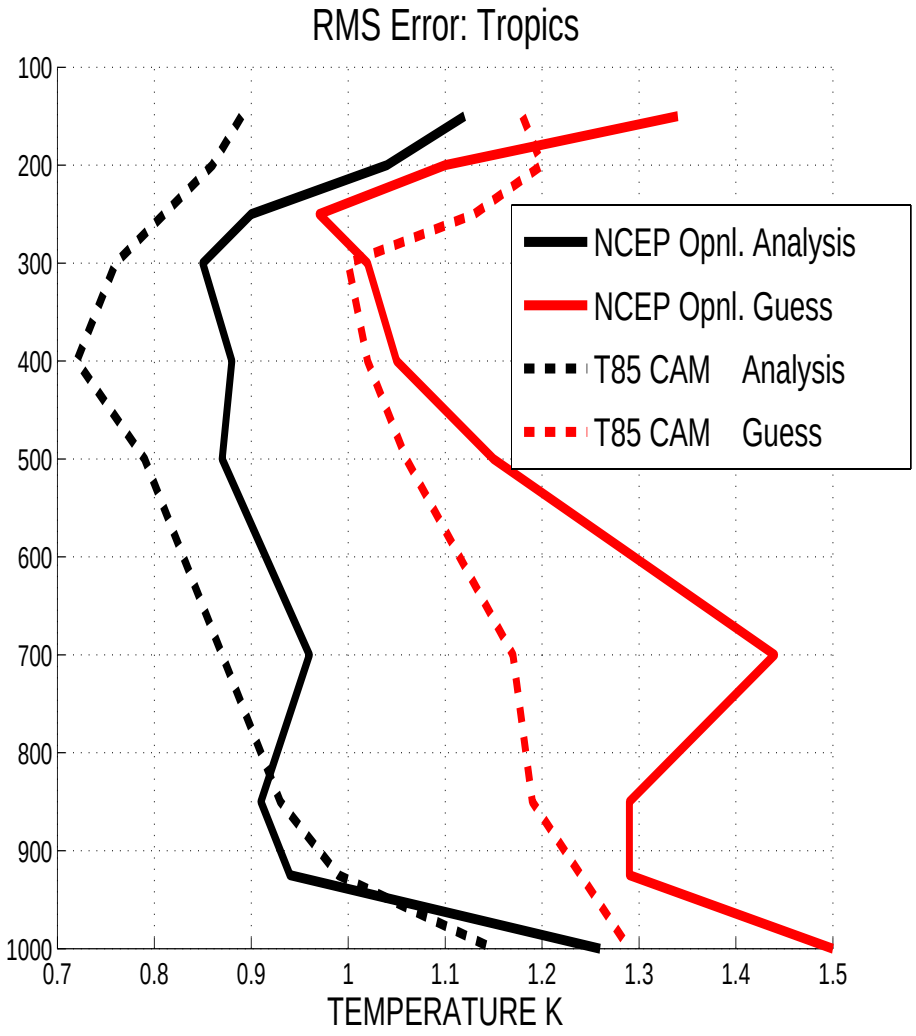


NH converged. SH poorly observed.

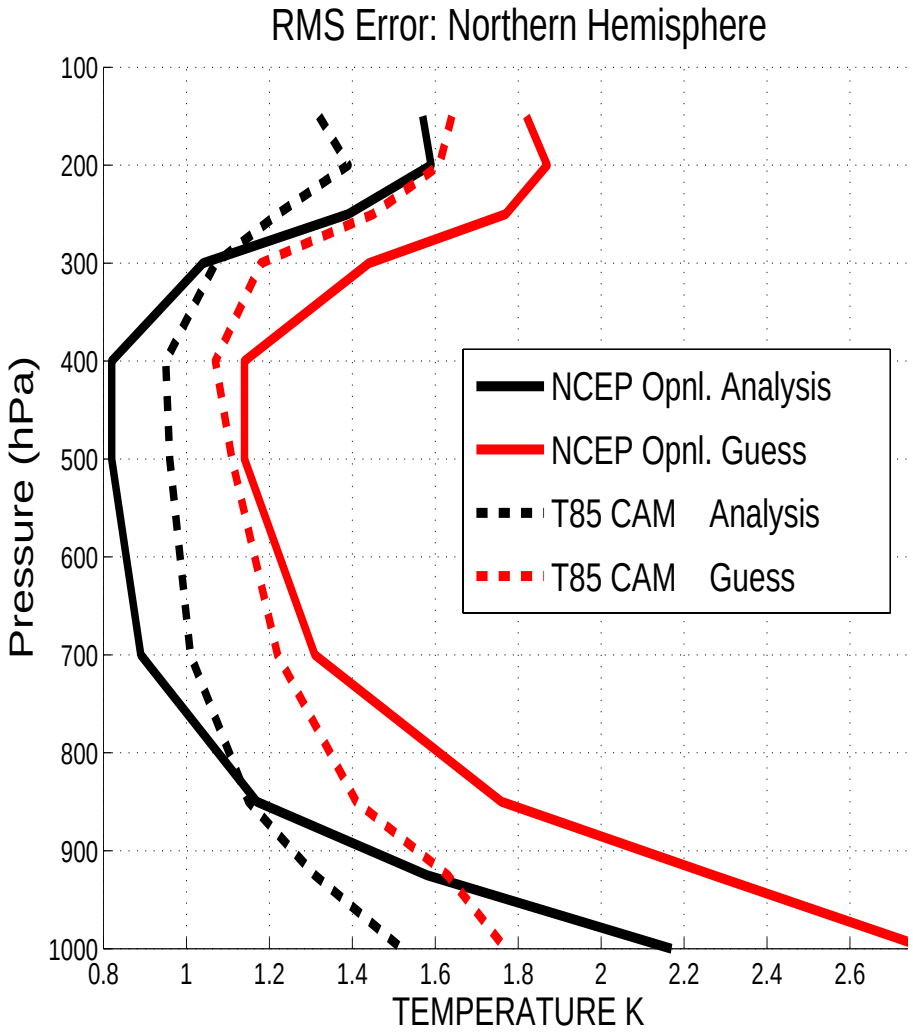
Difference.



6-Hour Forecast and Analysis Observation Space Temperature RMS



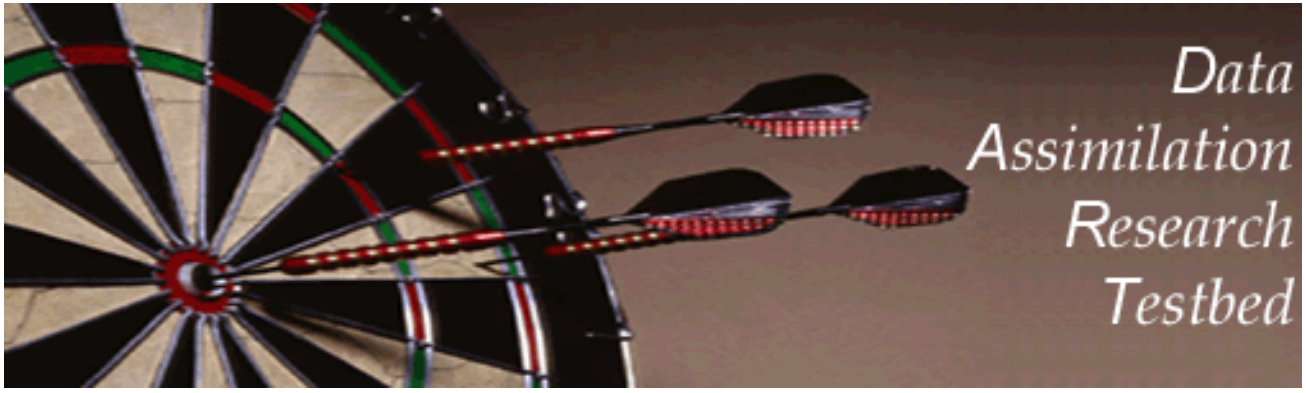
Tropics



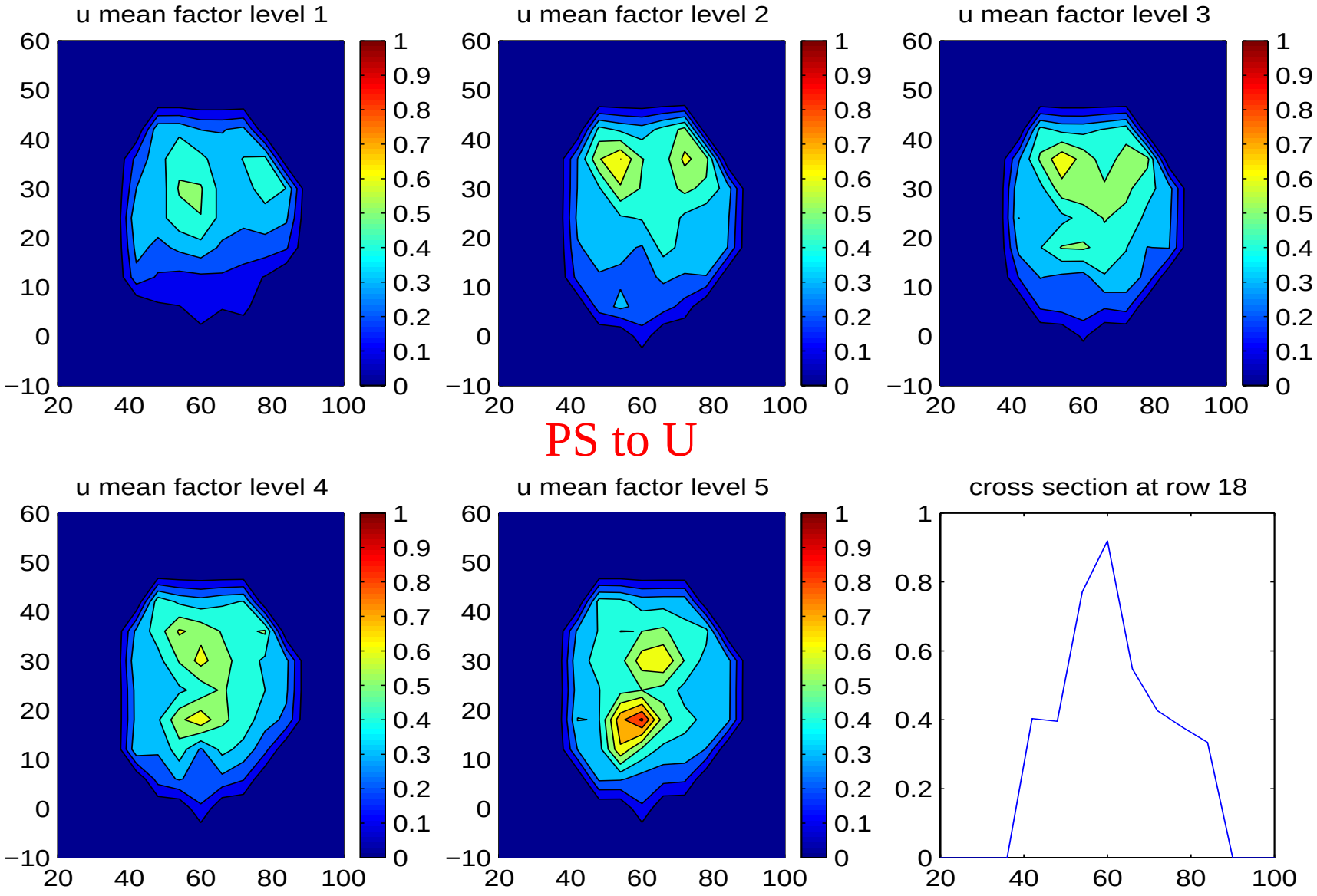
Northern Hemisphere

DART features:

2. Advanced hierarchical Bayesian algorithms to minimize tuning:
   Spatially-/temporally-varying adaptive inflation.
   Hierarchical filters to determine multivariate 4D localization,



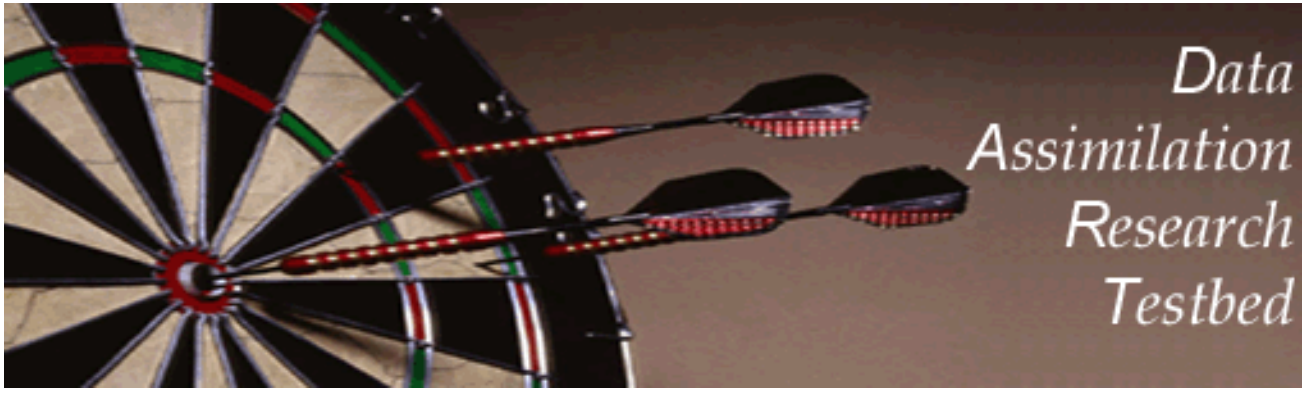
Localization in GCM can be very complex. Surface Pressure Obs. at 20N, 60E



DART PROVIDES ADAPTIVE HELP FOR NON-EXPERT USERS.

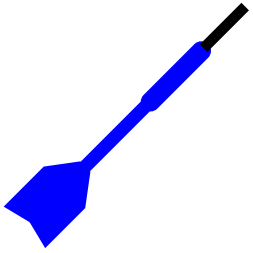
DART features:

2. Advanced hierarchical Bayesian algorithms to minimize tuning:
   - Spatially-/temporally-varying adaptive inflation.
   - Hierarchical filters to determine multivariate 4D localization,
   - Adaptive high-performance observation ‘thinning’.



DART Features:

3. Careful software engineering: easy to apply to any model.
   More than a dozen large geophysical models incorporated.
   Takes 2-4 weeks to implement a new large model.



NWP models in use or development include:

a. WRF
b. GFDL AM2
c. COAMPS
d. NCAR CAM
e. MOM3/4 (GFDL Ocean model)

Mesoscale WRF Surface-Data Assimilation: Spring 2007 Experiments at the National Severe Storms Laboratory

David Dowell
NCAR, Boulder, CO

David Stensrud
NSSL, Norman, OK

Nusrat Yussouf
CIMMS, Norman, OK

Mike Coniglio
NSSL, Norman, OK

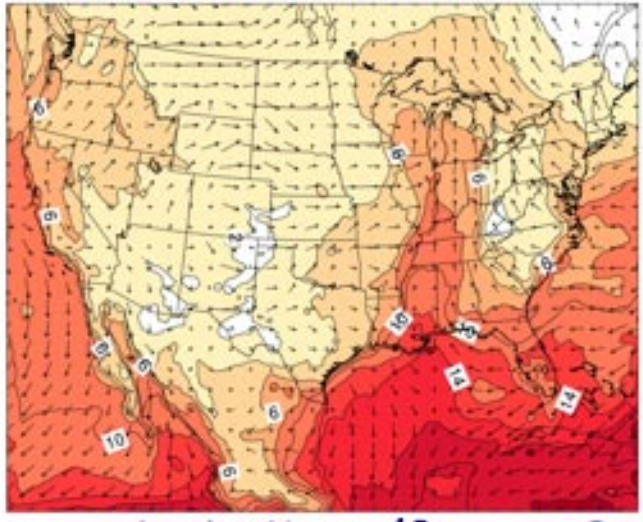
Jeff Anderson
NCAR, Boulder, CO

Chris Snyder
NCAR, Boulder, CO

See Aksoy, Snyder and Dowell, TUESDAY, 9:15 for more.

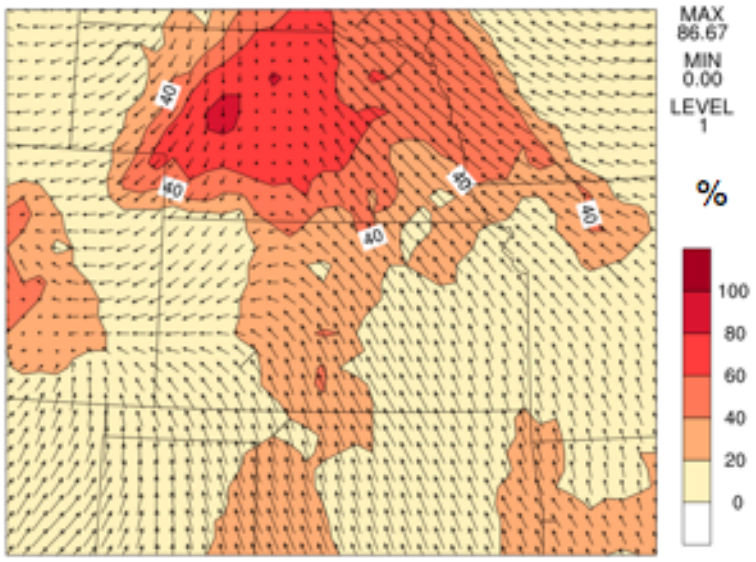
Mesoscale Ensemble Forecasting (WRF-ARW 2.1)

- CONUS grid
  - 30-km horizontal grid spacing, 31 vertical levels
  - Mean initial and boundary conditions from NAM

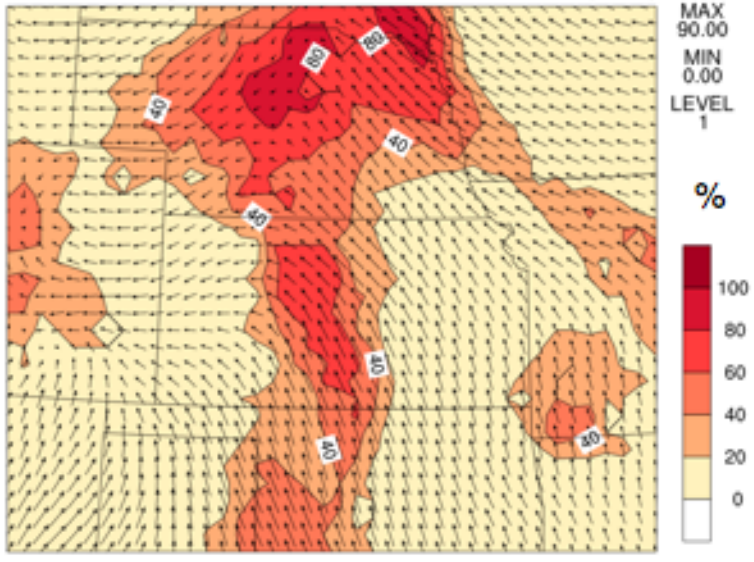


- 30-member ensemble
  - Initial and boundary condition perturbations (from WRF-Var)
  - Parameterization diversity
    - Microphysics: Lin et al. (6 class), WSM (3 class)
    - Shortwave radiation: Dudhia, Goddard
    - PBL: YSU, Mellor-Yamada-Janjic, NCEP GFS
    - Surface layer: MM5 similarity, Eta similarity (Janjic)
    - Cumulus: Kain-Fritsch, Betts-Miller-Janjic, Grell-Devenyi

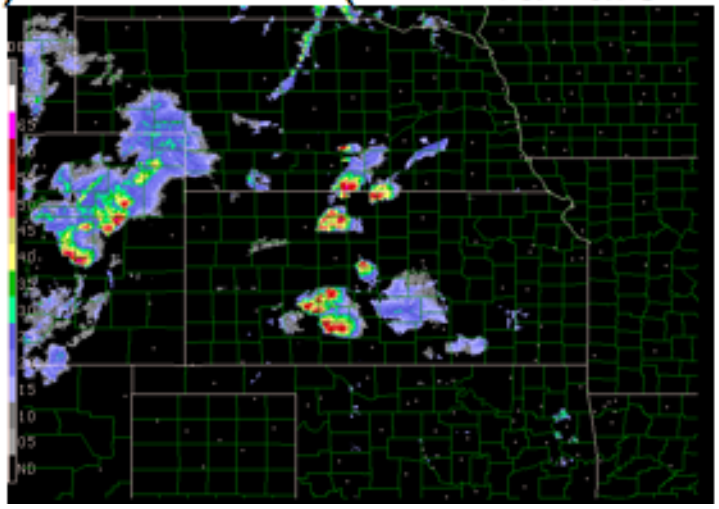
Probability (1-hr convective precip. > 1 mm)
0300 UTC 5 May 2007



9-hr forecast without assimilation
(18Z initialization)

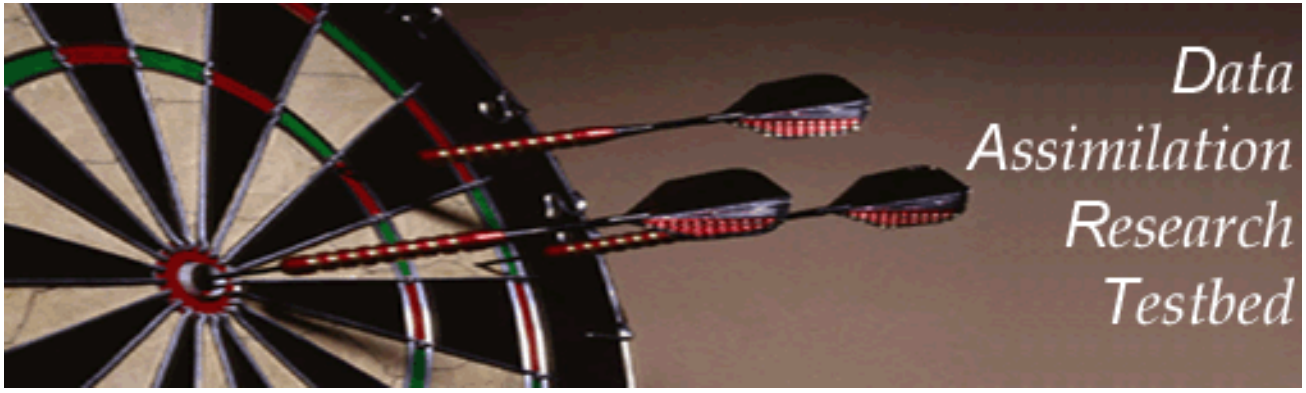


9-hr forecast with assimilation
(12Z initialization + 6 hr assimilation)



DART Features:

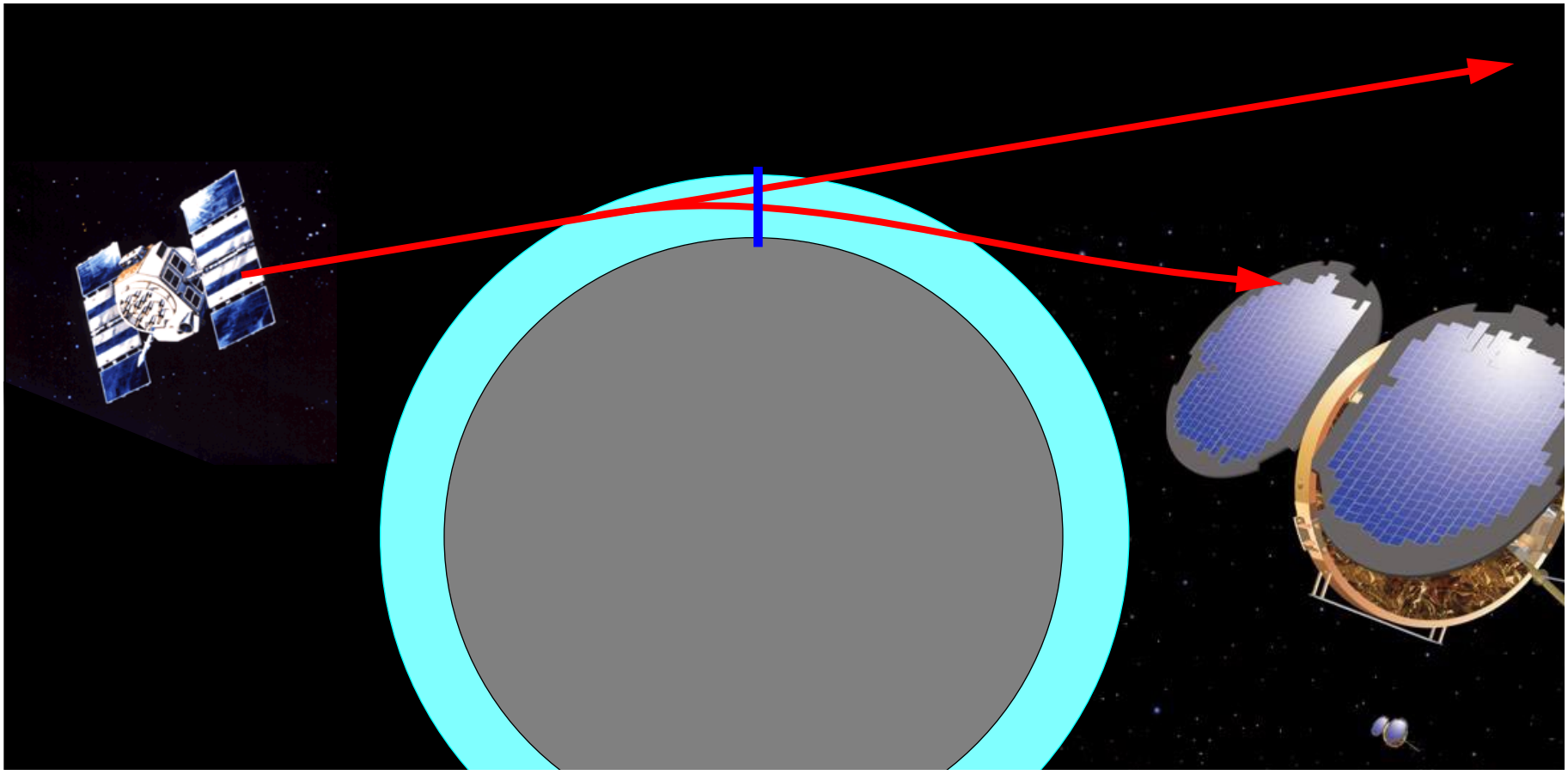
4. New observation forward operators also easy to add.



Assimilating GPS Radio Occultation Observations in WRF

Assimilated as refractivity along beam path.

Complicated function of T, Q, P and ionospheric electric field.

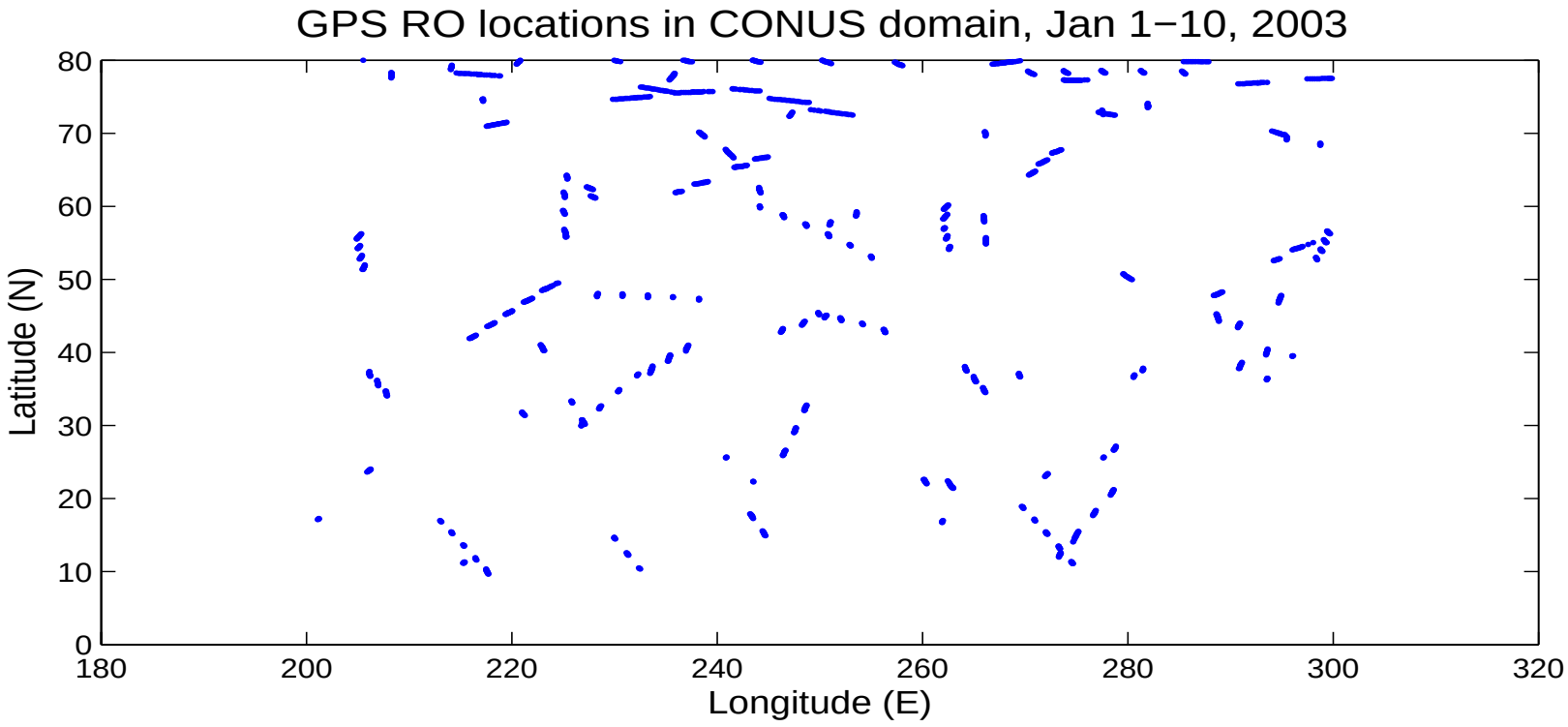


Get a sounding as GPS satellite sets relative to low earth satellite.

Assimilating GPS Radio Occultation Observations in WRF

Weather Research and Forecasting Model.
Regional Weather Prediction model.
Configured for CONUS domain, 50 km grid.

Several hundred profiles available from CHAMP satellite.



Assimilating GPS Radio Occultation Observations in WRF

Evaluating Impact of GPS Observations.

Case 1: Assimilate radiosondes EXCEPT those close to GPS profiles.
Case 2: Also assimilate GPS profiles.

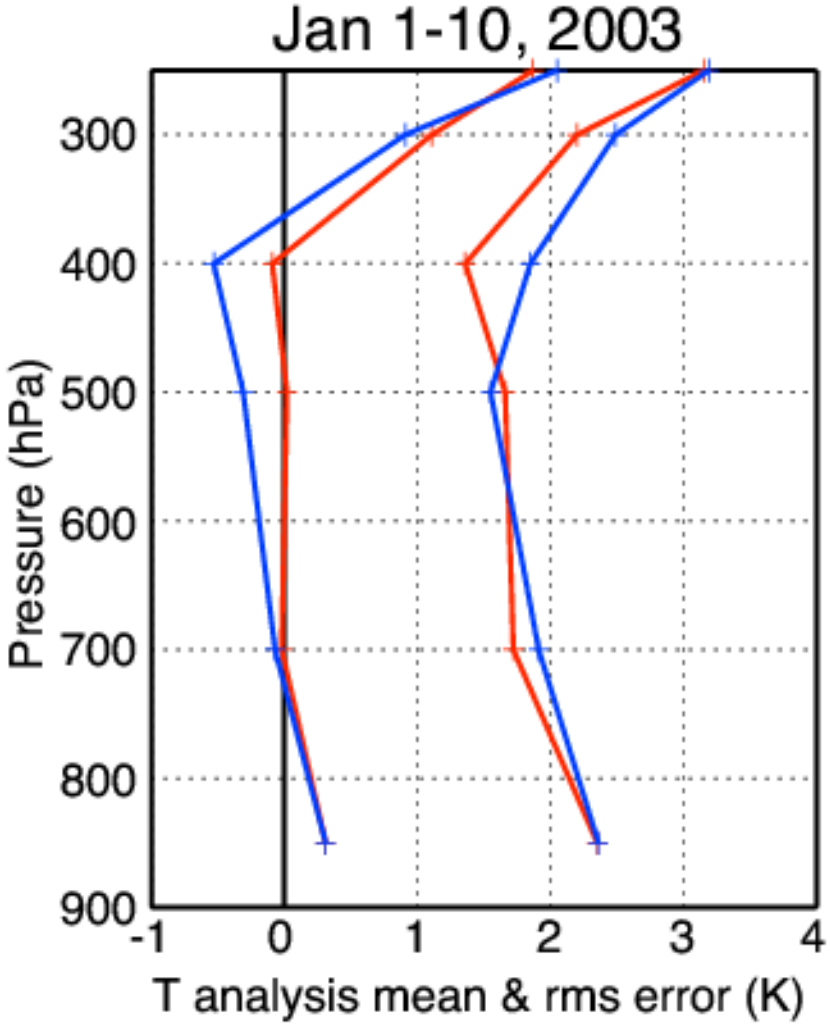
Look at reduction in error from close (unused) radiosonde profiles.

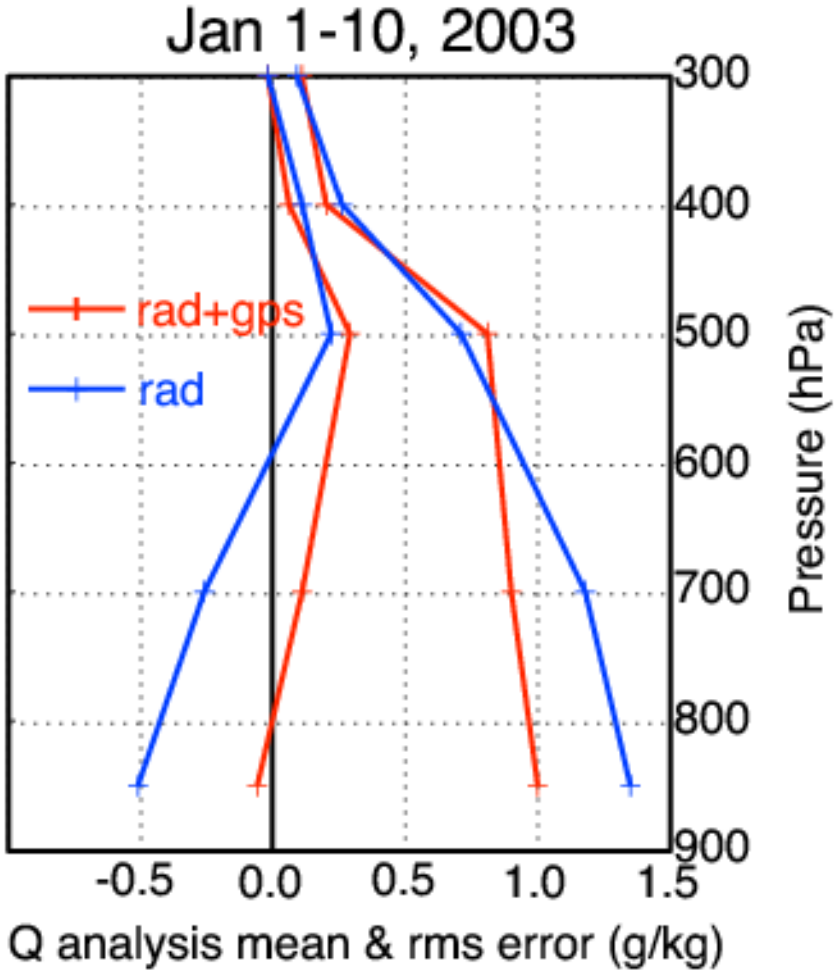
NOTE: Identical code allows assimilation in CAM, GFDL, GFS...

GPS Radio Occultation Impact on T and Q Errors in WRF

Each plot displays bias (left pair) and RMS (right pair).

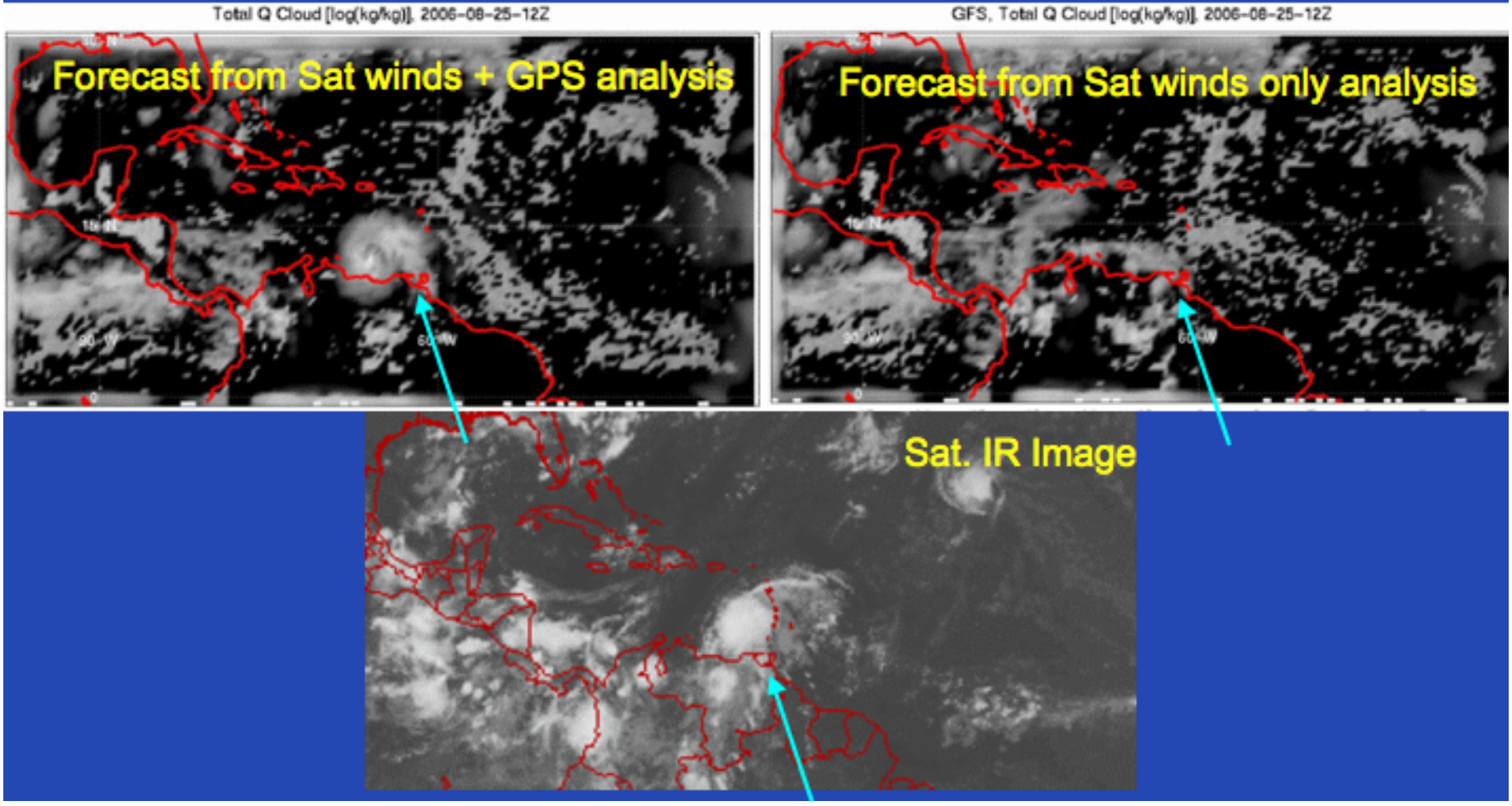
Red curves include GPS: reduced bias and RMS.





54-hour Forecast of Total Cloud Water

2006-08-25-12Z (valid 18 h after TS Ernesto's genesis)



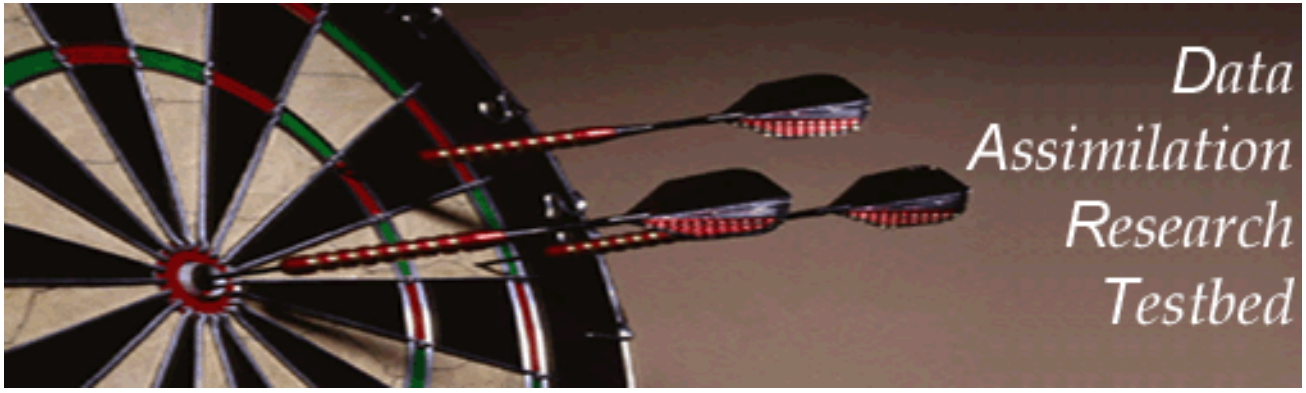
DART Features:

4. New observation forward operators also easy to add.

High-quality analysis of CO in Finite Volume CAM-CHEM model.

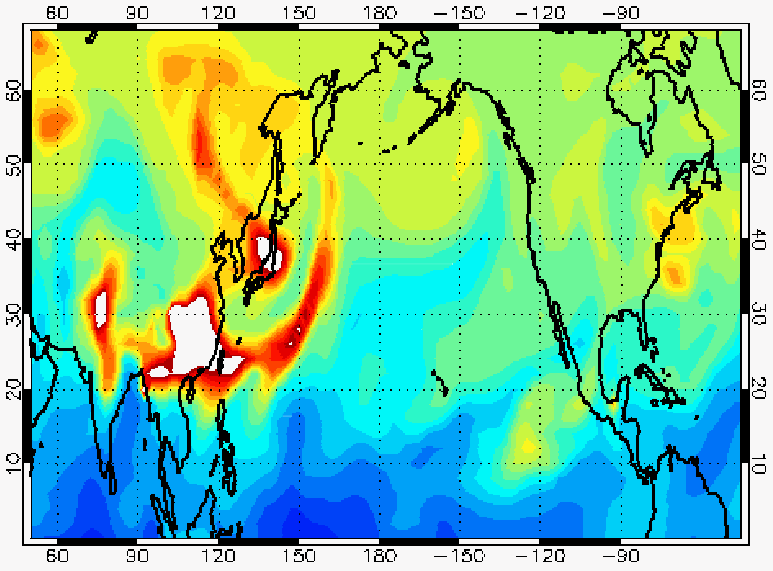
Assimilate standard observations plus MOPITT CO observations.

Work by Ave Arellano and Peter Hess supported by Kevin Raeder.



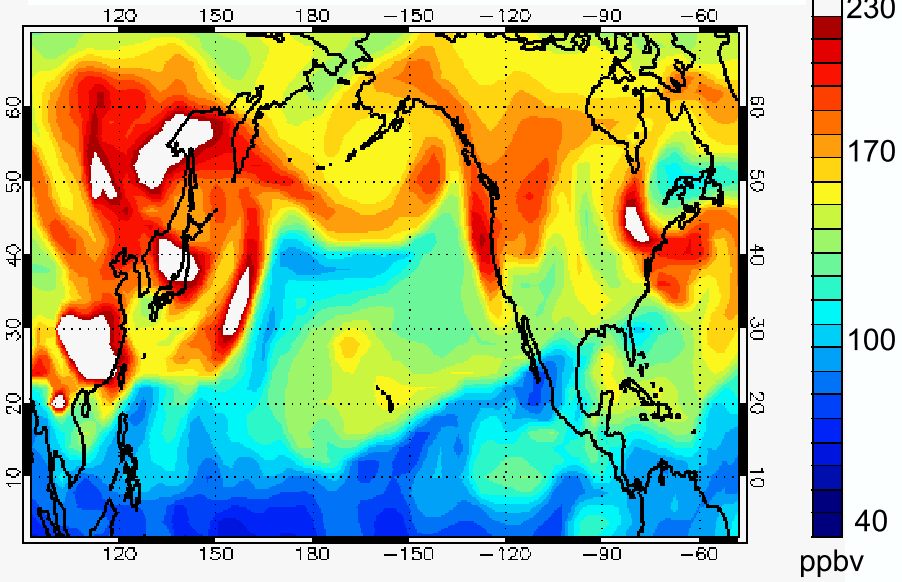
Impact of Assimilation in Modeled CO

No Assimilation @700 hPa 041706 18Z



Assimilating MOPITT CO provides important constraints to regional CO distribution in the troposphere.

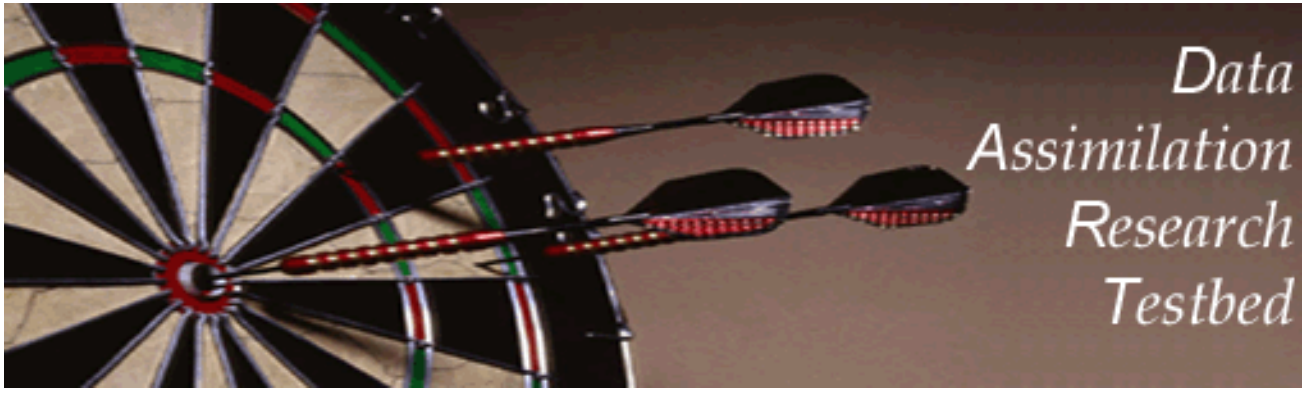
Assimilation @700 hPa 041706 18Z



Suggests the utility of assimilation in providing better initial/boundary conditions to regional CO forecasts.

DART Features:

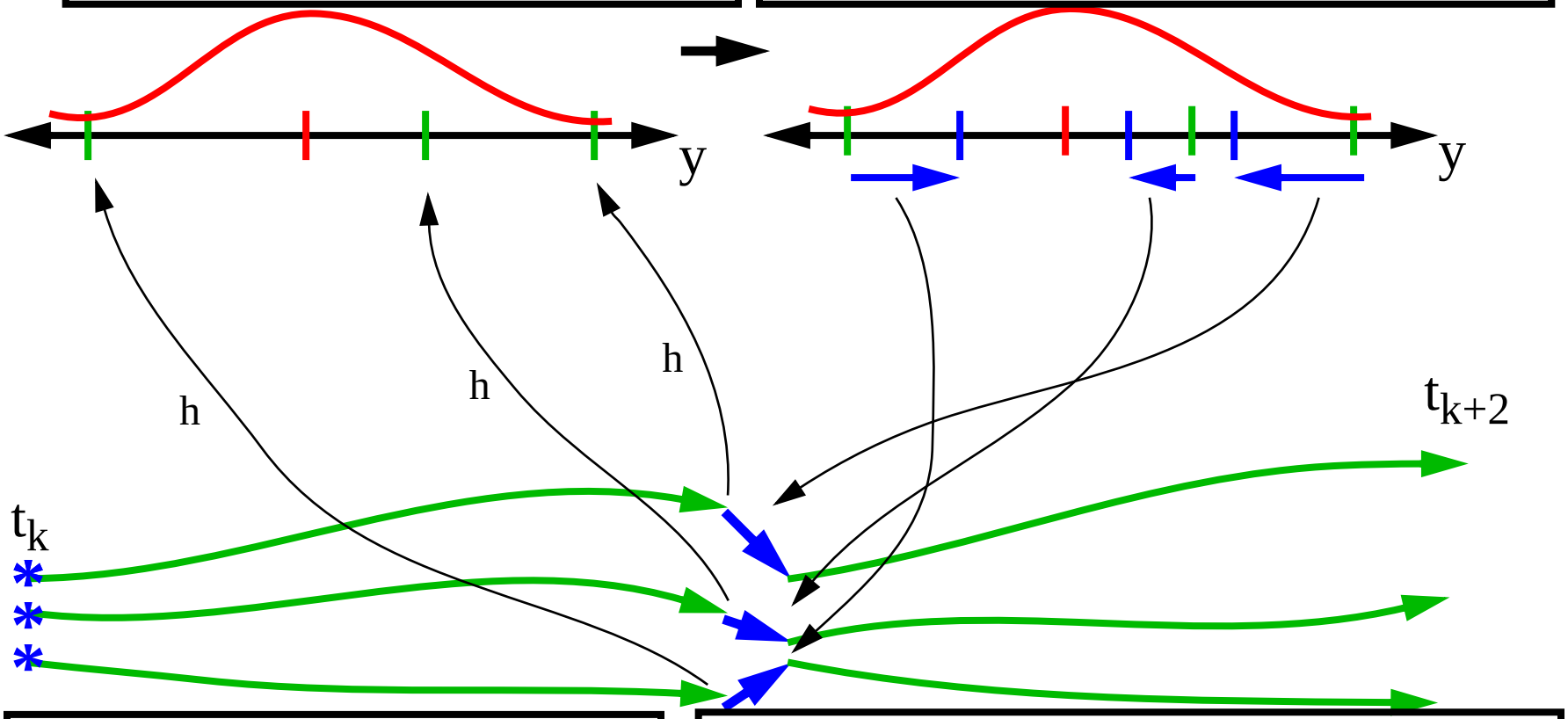
5. Excellent scaling using a generic parallel algorithm.



Speed is of the Essence: A Parallel Sequential Filter.

2. h for each ensemble is independent. All done in parallel.

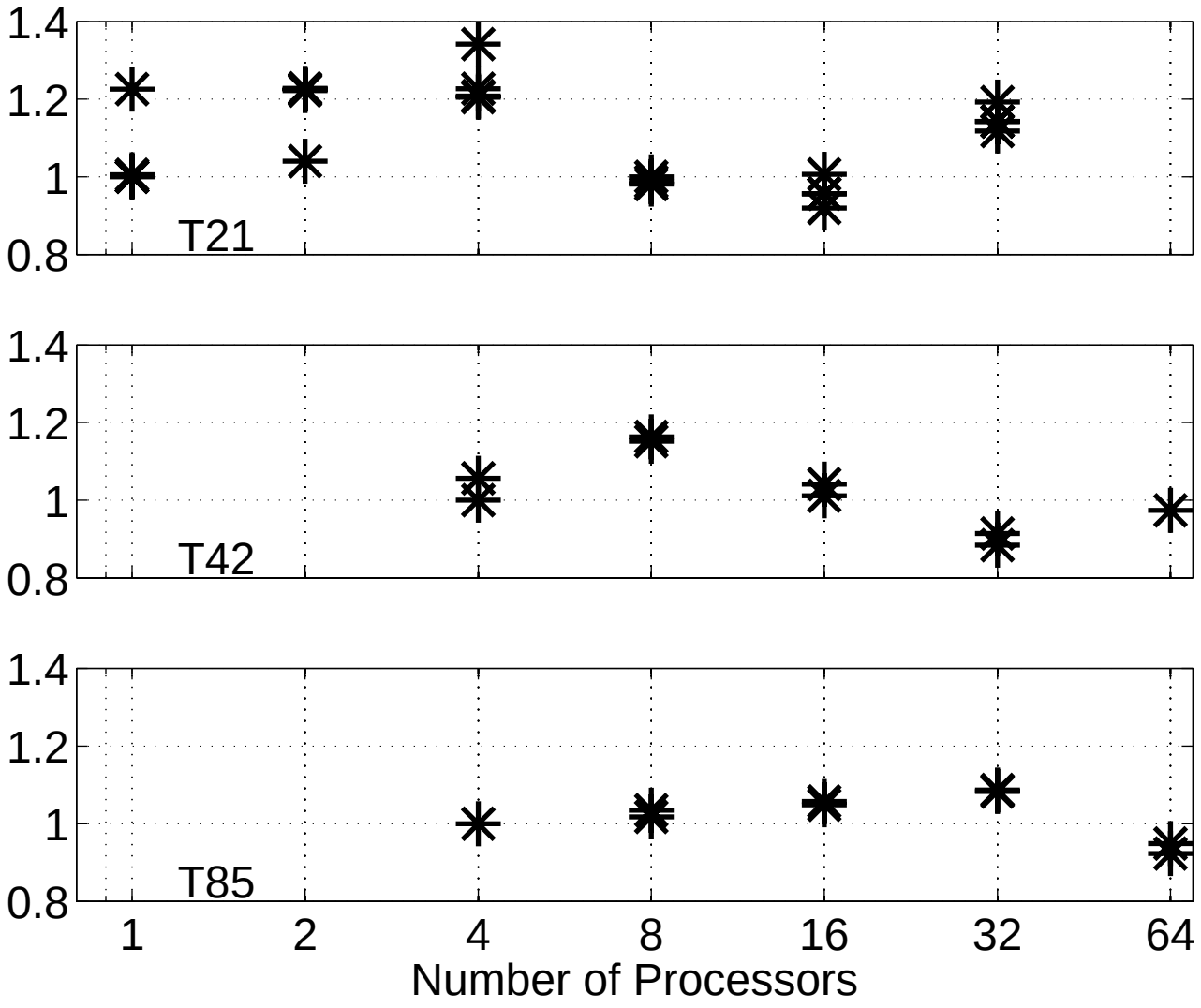
3. Designated process computes increments. Broadcasts increments to all processes.



1. Advances Embarrassingly Parallel. Each is completely independent.

4. State variables randomly assigned to processes. Each process does regression for its state. Completely independent.

Speed is of the Essence: A Parallel Sequential Filter.



Normalized Time for CAM Assimilations (1 is perfect scaling).

DART also includes:

1. Many diagnostic tools,
2. Fixed lag ensemble smoother,
3. Additional sampling error correction algorithms,
4. Detailed tutorial and documentation,
5. Low-/intermediate-order models for education, experimentation.

Check it out at:

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