The Data Assimilation Research Testbed (DART)

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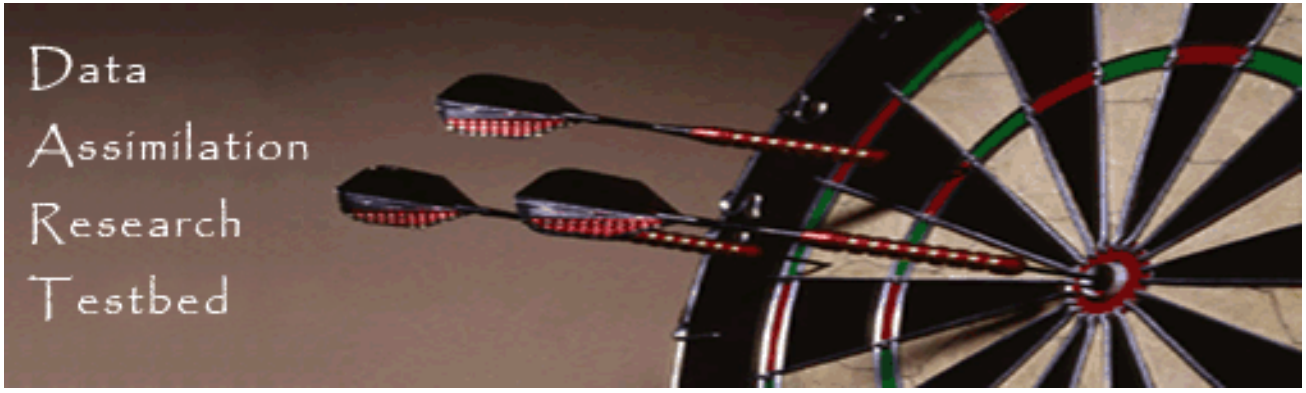
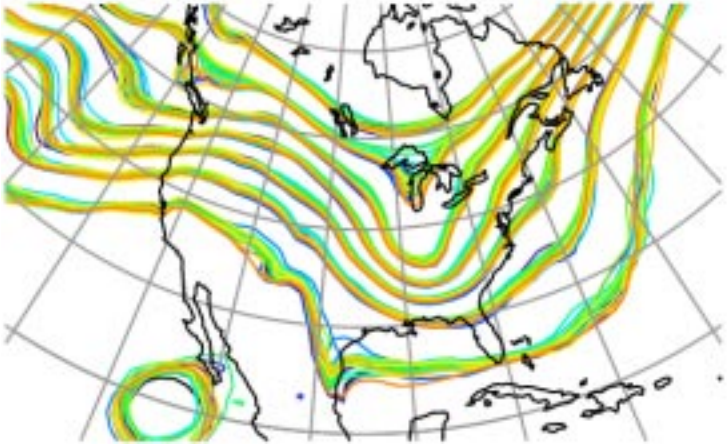




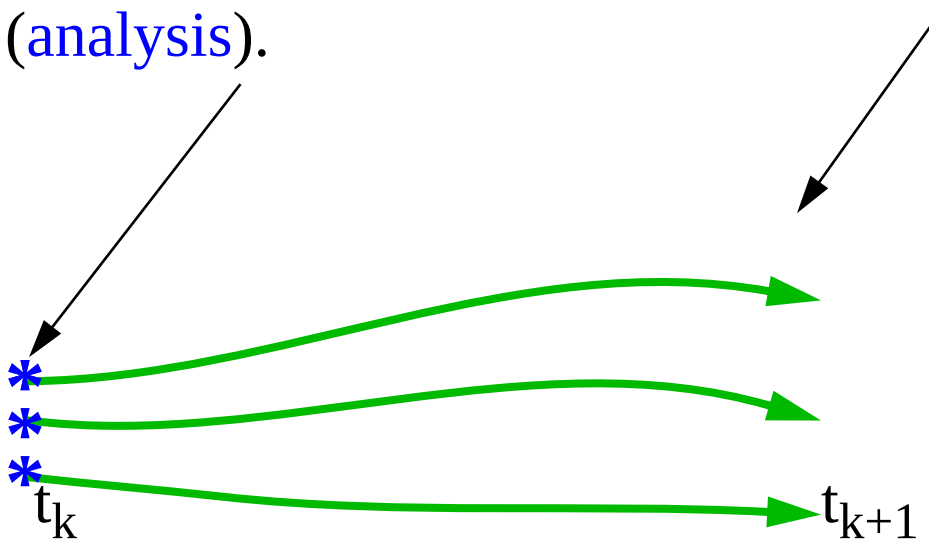
DART is a public domain ensemble assimilation facility.

Ensemble Filter Overview.

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

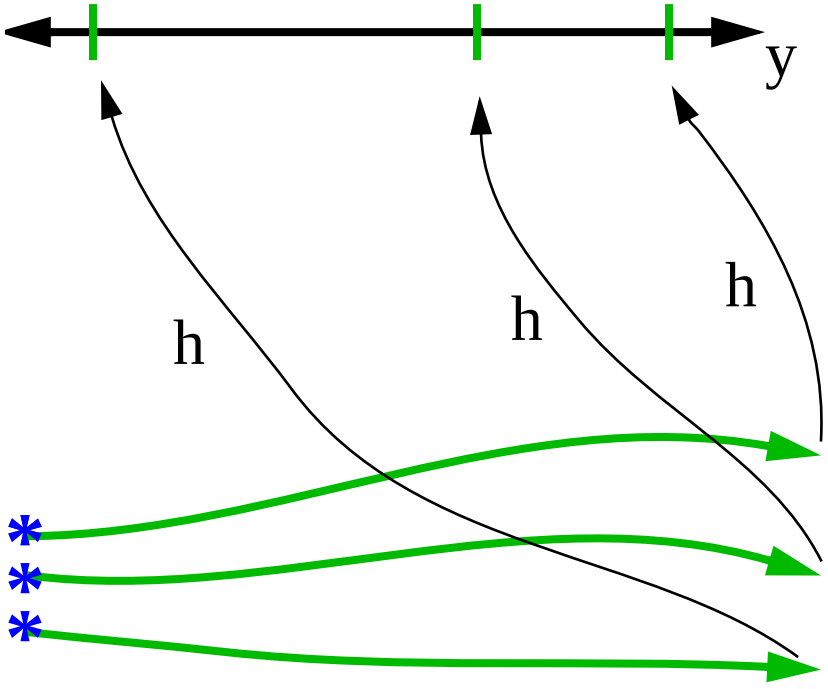
Ensemble state estimate after using previous observation (analysis).

Ensemble state at time of next observation (prior).



Ensemble Filter Overview.

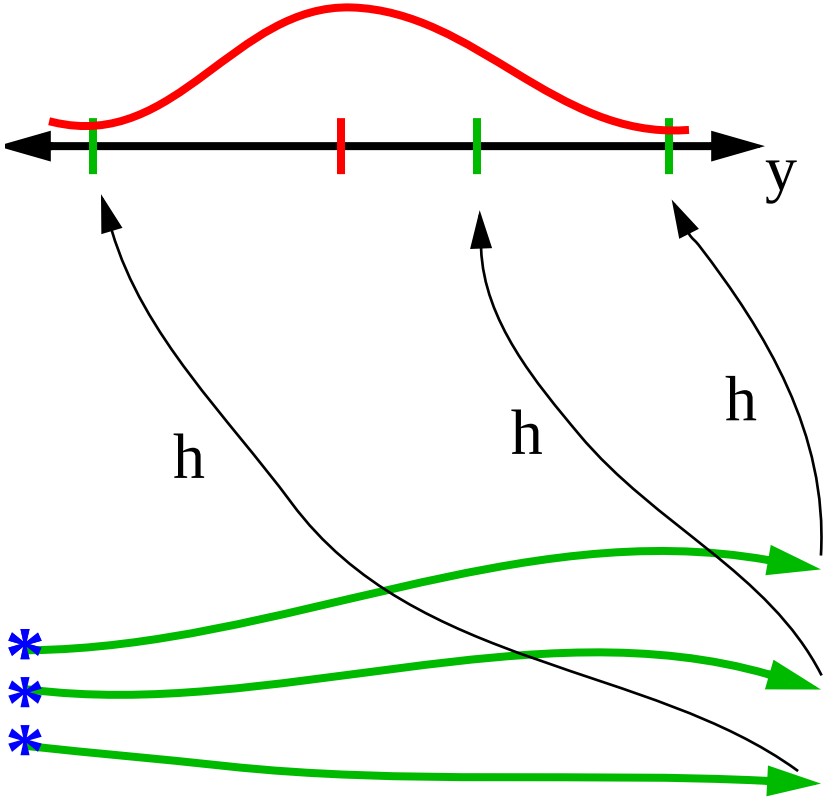
2. Get prior ensemble sample of observation, y=h(x), by applying forward operator h to each ensemble member.



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

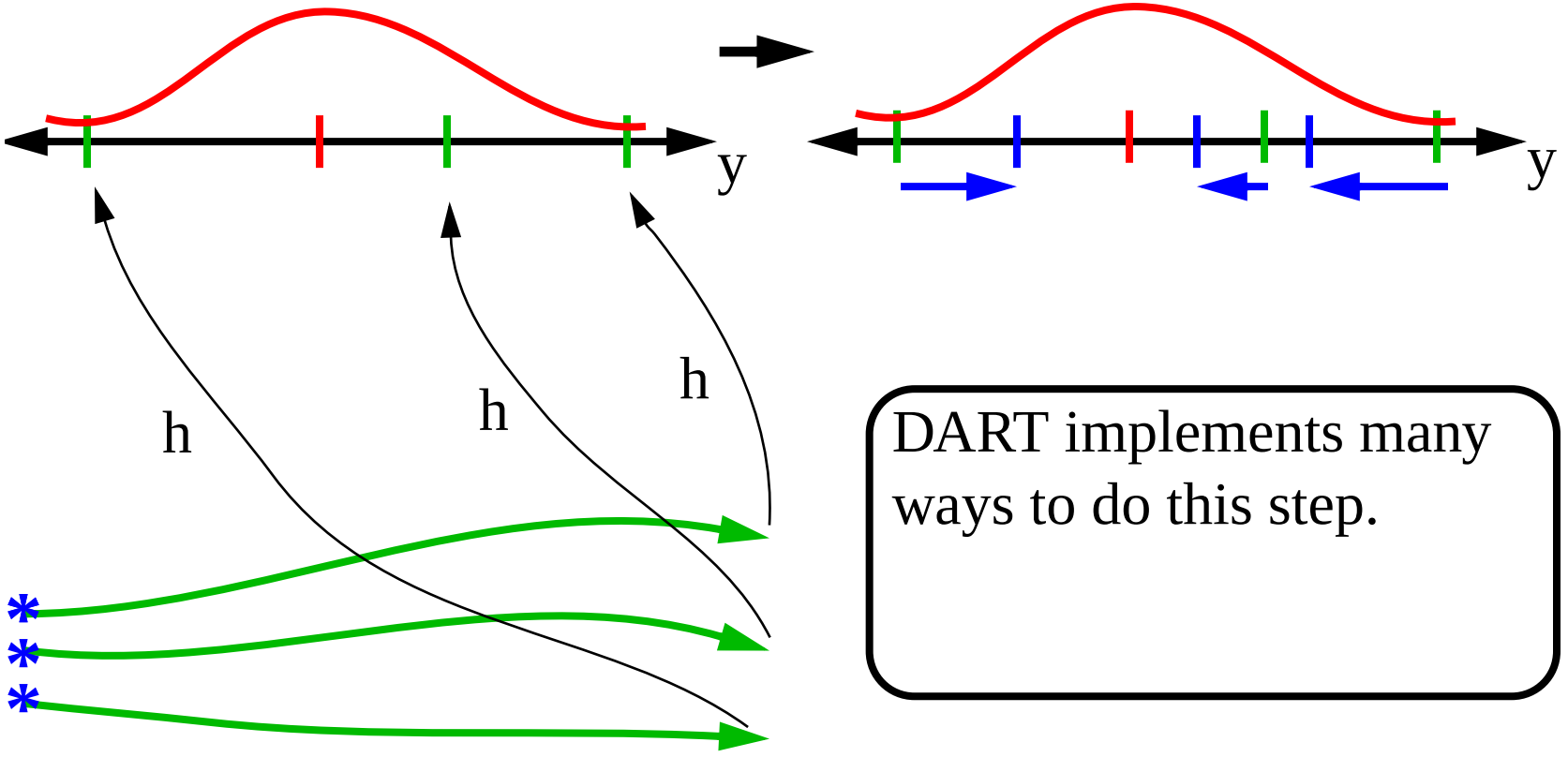
Ensemble Filter Overview.

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



Ensemble Filter Overview.

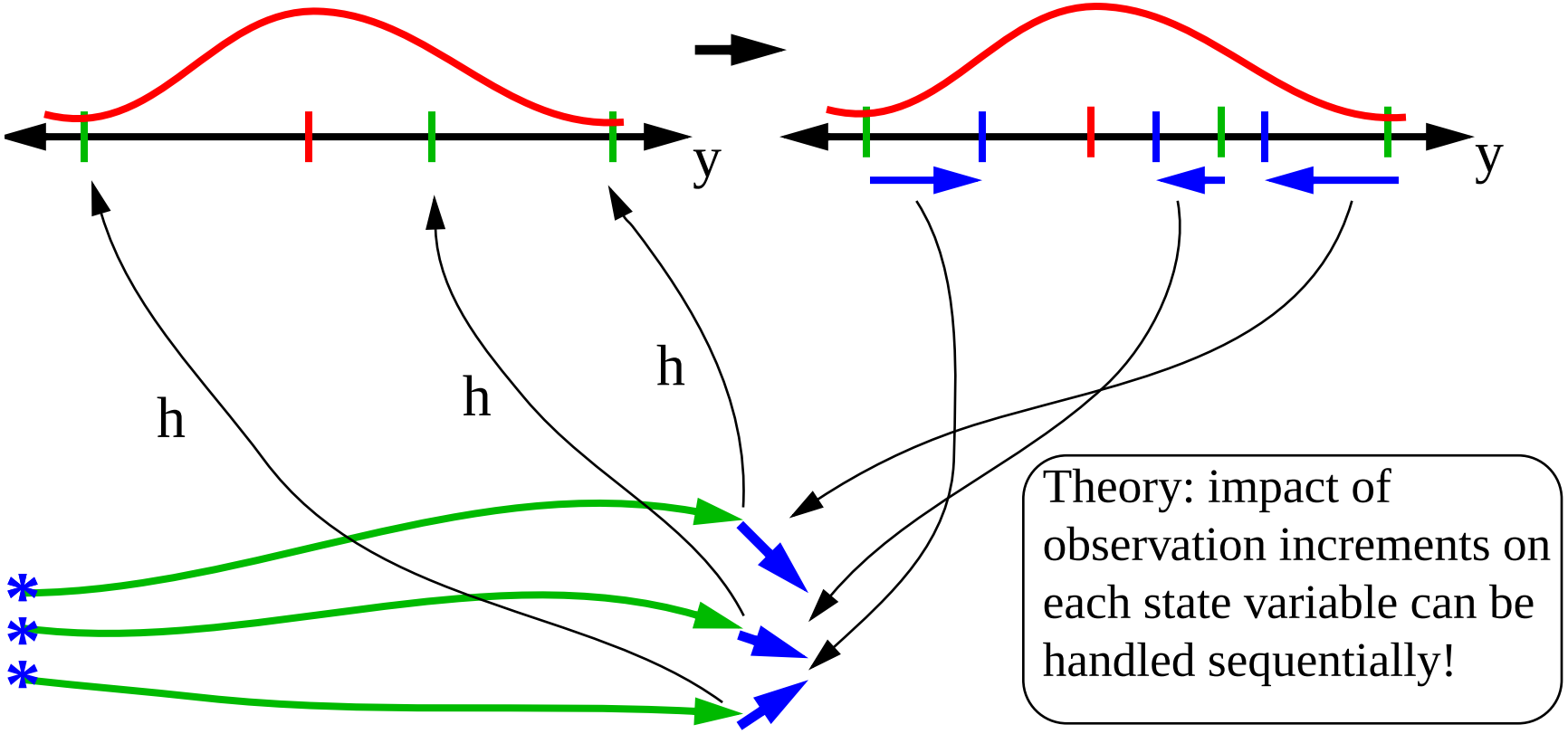
4. Find increment for each prior observation ensemble (this is a scalar problem for uncorrelated observation errors).



DART implements many ways to do this step.

Ensemble Filter Overview.

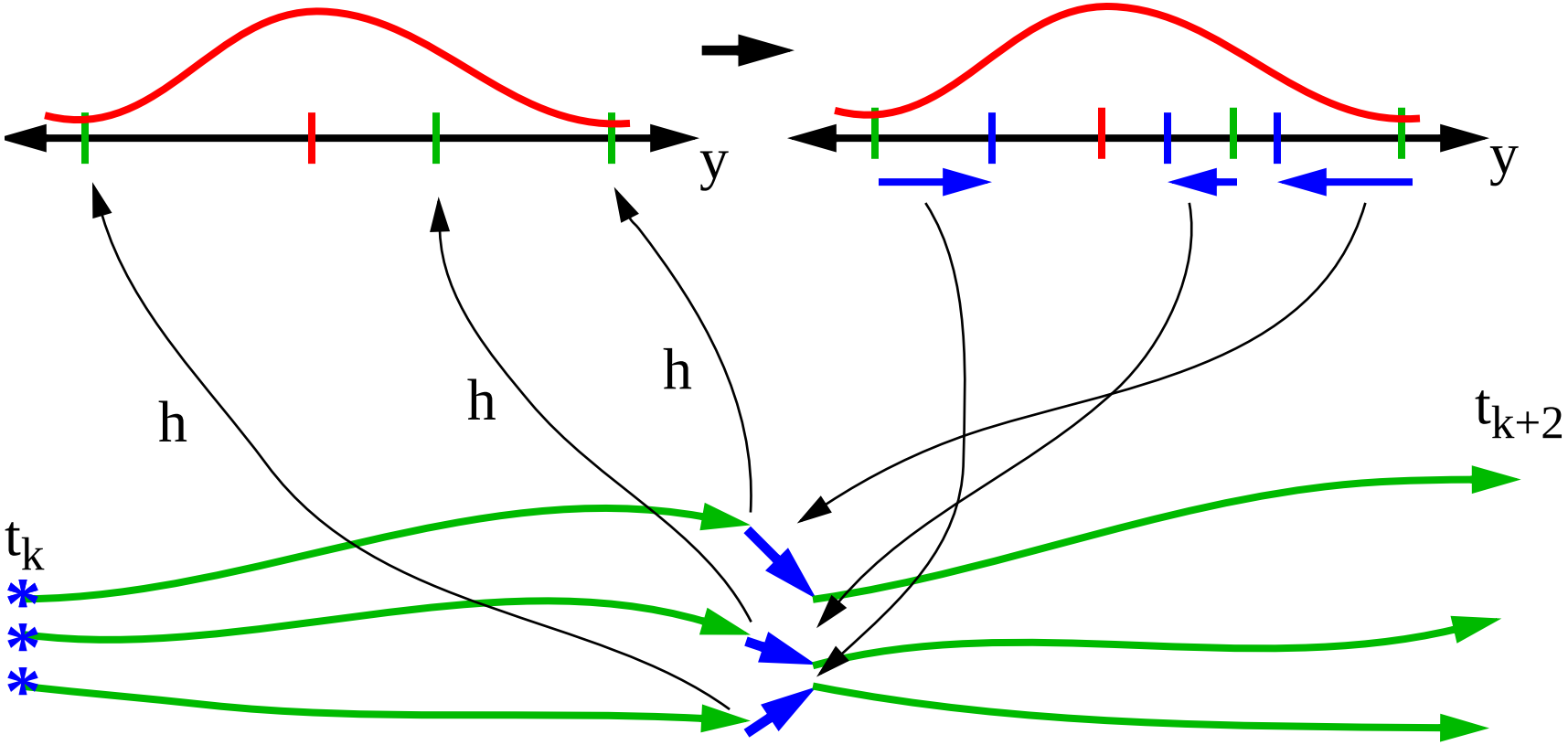
5. Use ensemble samples of y and each state variable to linearly regress observation increments onto state variable increments.



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

Ensemble Filter Overview.

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



Important Features of Ensemble Filters

1. Fully multivariate: all observations impact all related state variables.
   Tracer observations impact tracer and meteorological state.
   Meteorological observations impact tracer state, too.

2. Tracers are modeled and assimilated ‘on-line’.

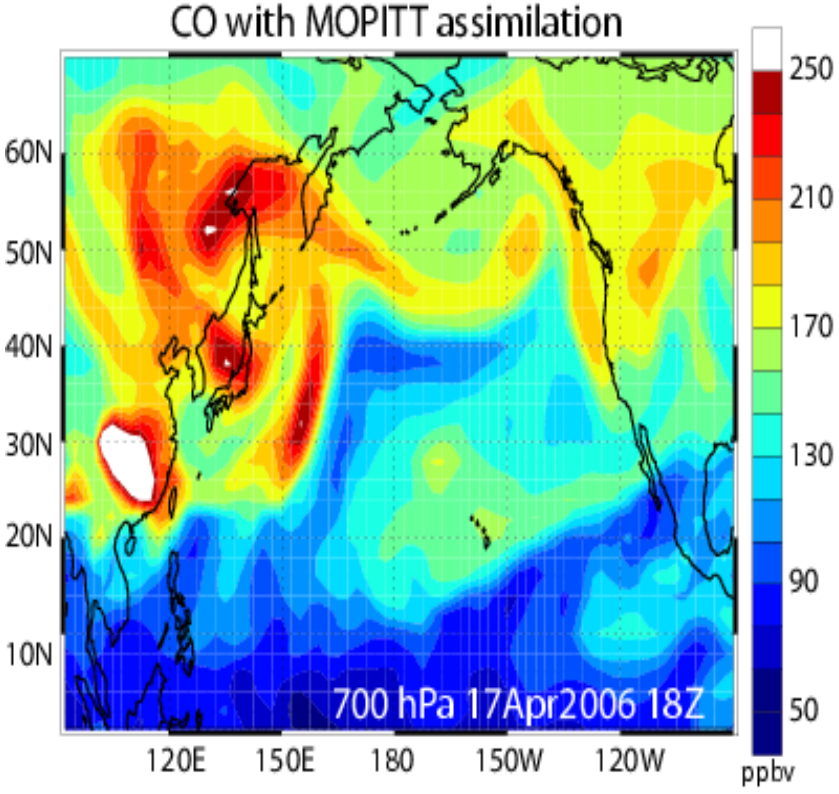
3. Complex forward operators (e.g. radiances) can be used.

It's Easy to Add New Models (Tracers) to DART

Uses set of well-defined interfaces.

Adding tracer to large model can be trivial.

Can add new tracer to CAM (global climate model) at runtime.



DART CAM/CHEM assimilation (Ave)

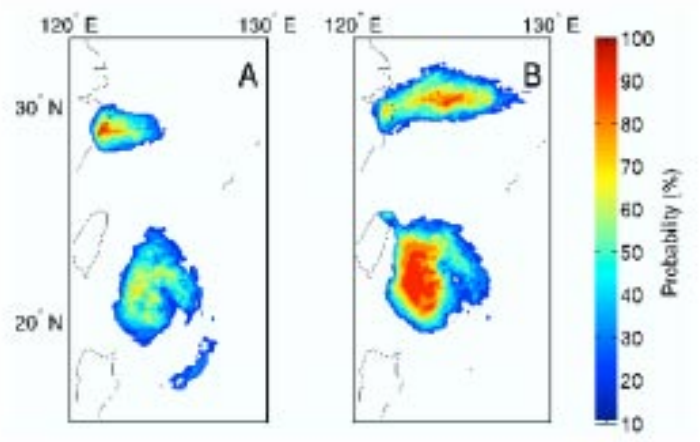
Some DART Compliant Geophysical Models:

1. CAM, CAM/CHEM.
2. WRF.
3. GFDL AM2.
4. NCEP GFS (old version).
5. MIT Ocean Model.
6. Navy COAMPS Atmosphere.
7. ROSE middle atmosphere with chemistry.

It's Easy to Add New Observations, too.

Requires only forward operator: maps state to expected observation.
No linear tangents or adjoints.

Small amount of additional coding in well-defined framework.



Impact of assimilating GPS radio occultation soundings on WRF ensemble forecasts of probability of heavy precipitation over Taiwan for typhoon Shanshan.

Some DART Observation Types:

1.T, winds, moisture from radiosondes, ACARS.
2. Satellite drift winds.
3. Doppler radar velocity, reflectivity.
4. GPS radio occultation refractivity.
5. Ground-based GPS.
6. Scatterometer winds.
7. Retrievals from orbiting radiometers.
8. Development underway for radiances.

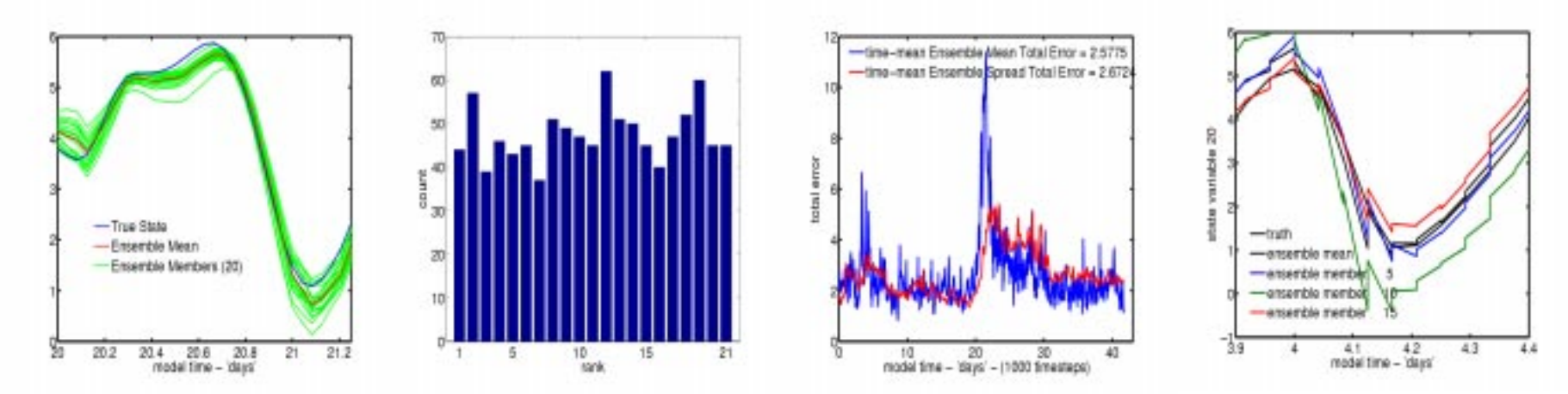
What's in DART?

1. Variety of ensemble filter flavors:
   EnKF (perturbed obs.); EAKF (deterministic square root);
   Nongaussian; Kernel.

2. Comprehensive tutorial and example models.

3. Diagnostic output in netCDF and custom observation format.

4. Diagnostic visualization tools (used for all figures here).



DART Has Additional Algorithms for Enhanced Performance

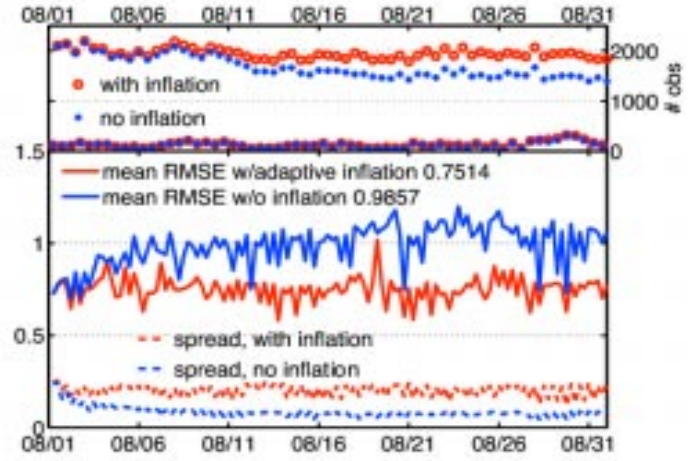
These are especially helpful for using small (~20) ensembles.

1. Adaptive inflation;
   Corrects for model and filter errors by increasing variance.

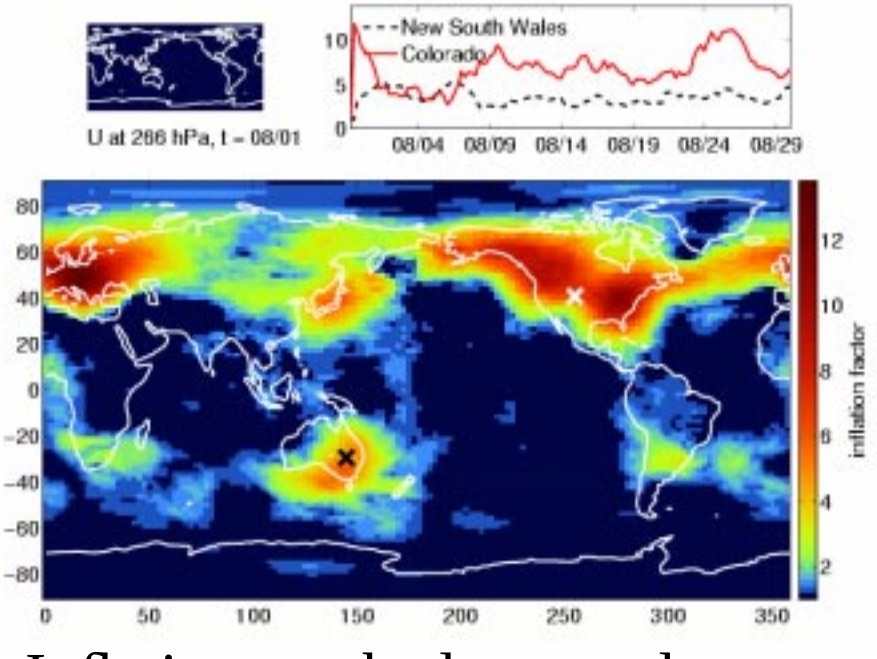
2. Hierarchical filter / adaptive localization;
   Reduces filter sampling error,
   Detects noise in observation/state relation and reduces weight.

3. Adaptive thinning of dense observations;
   Increased efficiency and reduced filter sampling error.

Adaptive Inflation



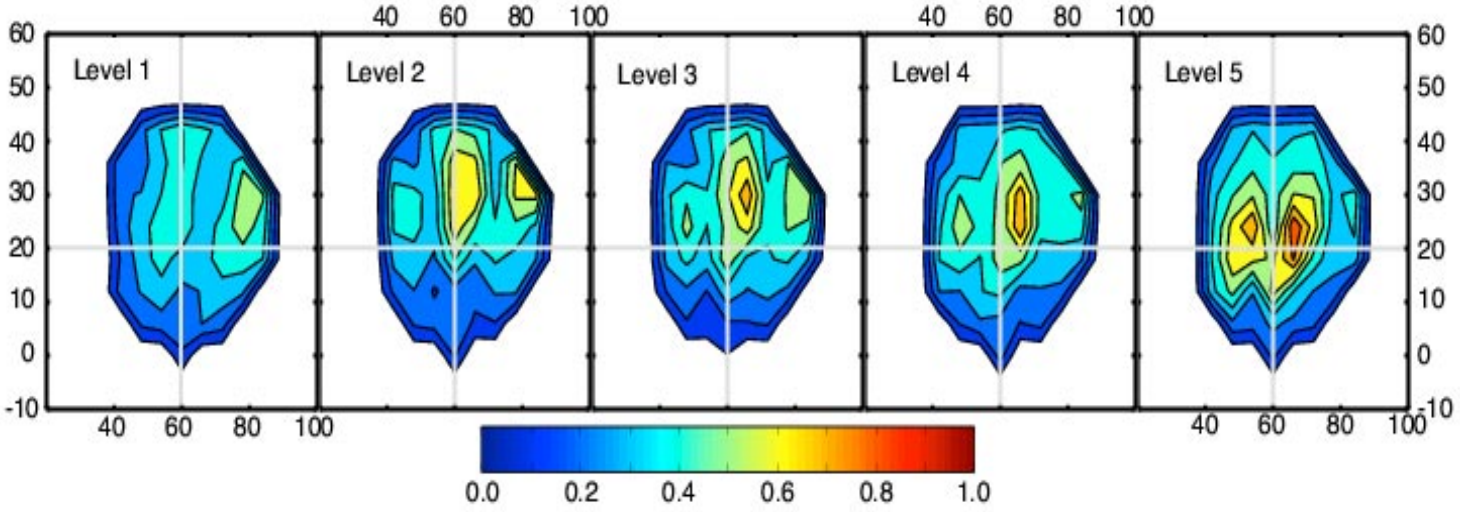
Adaptive inflation in CAM improves forecast fit to radiosonde T observations, increases spread to more appropriate levels, reduces number of observations rejected.



Inflation can be large and spatially-varying: depends on model and observation distribution.

Hierarchical Filter / Adaptive Localization

Most effective localization can be complicated.
Appropriate values may not be known *a priori* for tracers.
DART has tools to help estimate localization.



Computed localization for surface pressure observation impacting v wind in GFDL AM2 GCM.

DART Runs on Many Compilers / Platforms

Platforms:

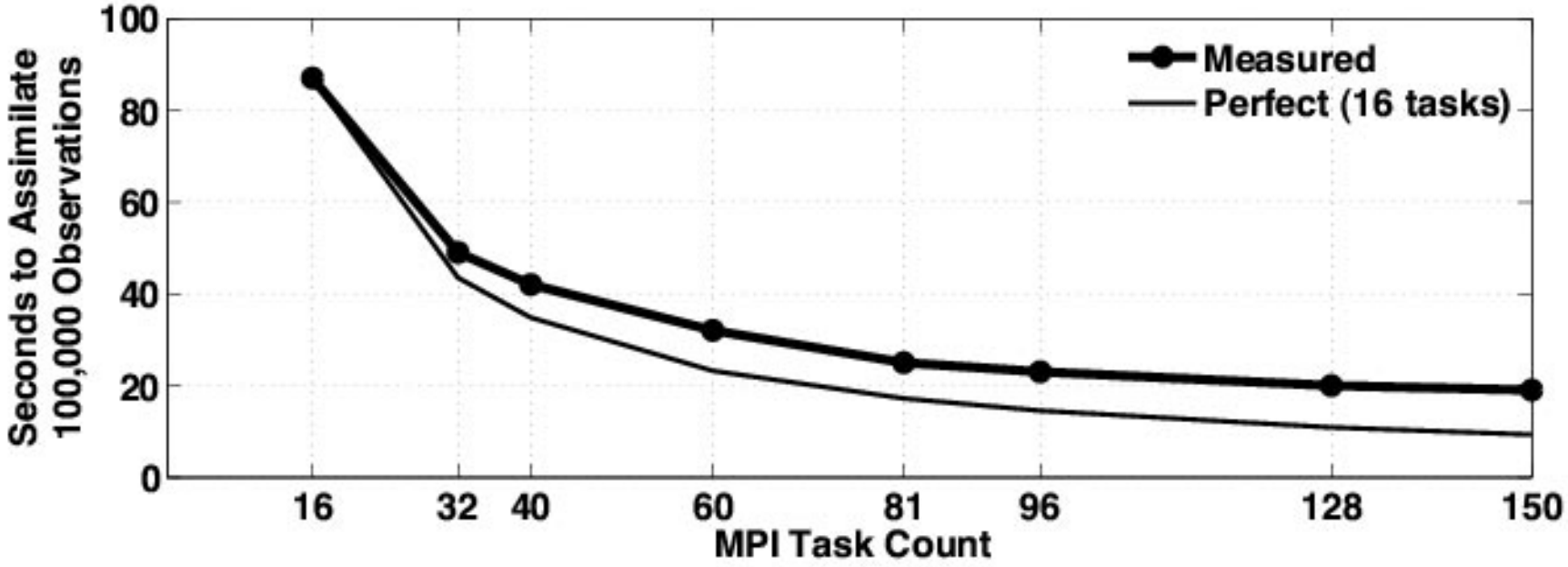
IBM Power6 and Power5 supercomputers,
SGI Altix supercomputers,
Linux clusters (many types),
Apple Mac PowerPC, Apple Mac Intel,
Windows (cgywin).

Compilers:

Intel ifort (Linux, Mac Intel, SGI altix),
Absoft f90 (Mac PowerPC/Intel),
PGI pgf90 (Linux, Mac PowerPC/Intel),
gfortran (Linux, Mac PowerPC/Intel, cgywin),
g95 (Linux, Mac PowerPC),
IBM xlf (IBM Power 5/6),
PathScale pathf90 (Linux),
Lahey lf95 (Linux).

DART Parallel Algorithms

Generic parallel scaling.
Works out-of-the-box on parallel architectures noted above.



Scaling of DART/CAM assimilation (not including model advance) on NCAR's Bluefire. For this model scales well past 96 processes.

DART User Support

The DART team supports high-impact applications like:

WRF, CAM, CAM/CHEM and WRF/CHEM.

Chris Snyder's MMM group also supports DART/WRF.

Want to try it out?

DART software, documentation, and model interfaces available at:

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