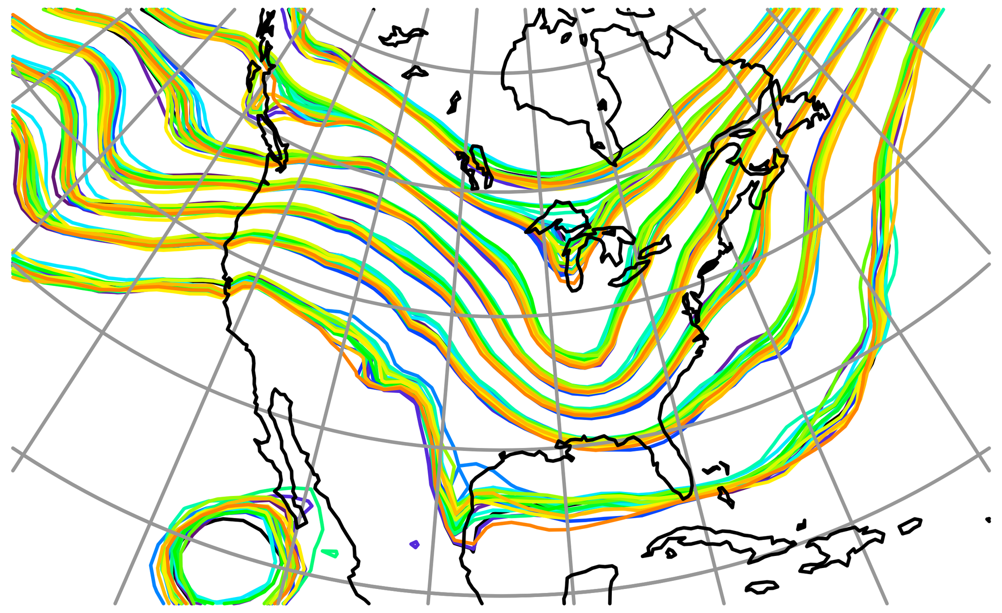

New Developments in the Data Assimilation Research Testbed

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1. The Kodiak Release

The Data Assimilation Research Testbed (DART) "Kodiak" release became available in July 2011 and includes more than 20 major feature enhancements, support for 24 models, support for (at least) 14 observation formats, expanded documentation and diagnostic tools, and 12 new utilities.

Major feature enhancements: • Inflation Damping, • Sampling Error Correction, • Adaptive Localization, • new diagnostics, . . .

Models include (models in blue are under development):

CAM	Community Atmosphere Model,
WRF	Weather Research & Forecasting Model,
POP	Parallel Ocean Program,
NCOMMAS	NSSL COllaborative Model for Multiscale Atmospheric Simulation,
COAMPS	Coupled Ocean/Atmosphere Mesoscale Prediction System,
NOGAPS	Navy Operational Global Atmospheric Prediction System,
AM2	GFDL Global Atmosphere Model,
TIEgcm	Thermosphere Ionosphere Electrodynamics gcm,
Global/Planet WRF	ask about Mars,
CLM	Community Land Model,
MPAS (atmosphere)	Model for Prediction Across Scales,
MPAS (ocean)	Model for Prediction Across Scales,
COSMO-Model	Consortium for Small-Scale Modelling,
GITM	Global Ionosphere Thermosphere Model

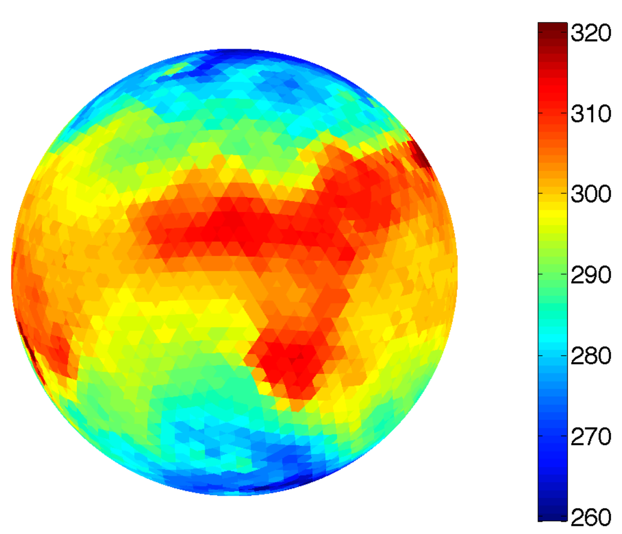


Figure 1: *Support for arbitrary grids is being extended. This is an MPAS field from a DART diagnostic file.*

2. DART: Assimilation Schematic

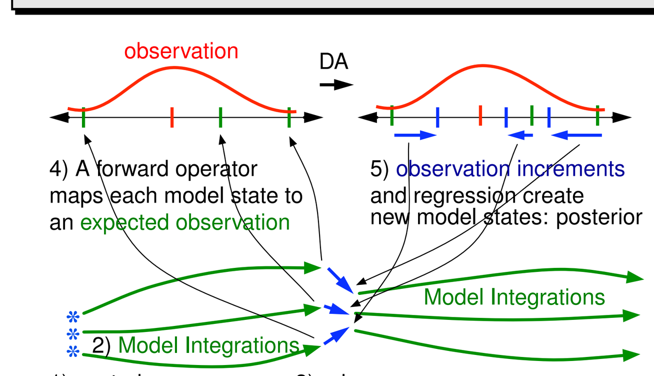
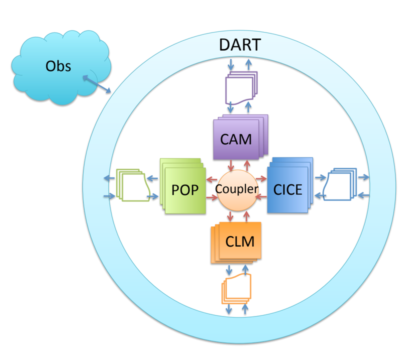


Figure 2: *Illustration for a toy ensemble size of 3.*



Development efforts are underway to provide much tighter, more efficient use of the Community Earth System Model (CESM) "multi-instance" capability.

3. Global Atmosphere Assimilation

CAM and DART assimilated all the observations that were used in the NCEP/NCAR Reanalysis to produce a global, 6-hourly, 80-member ensemble reanalysis for 1998 through 2010 — with plans to continue. The dataset is ideal for research that would benefit from an ensemble of equally-likely atmospheric states that are consistent with observations.

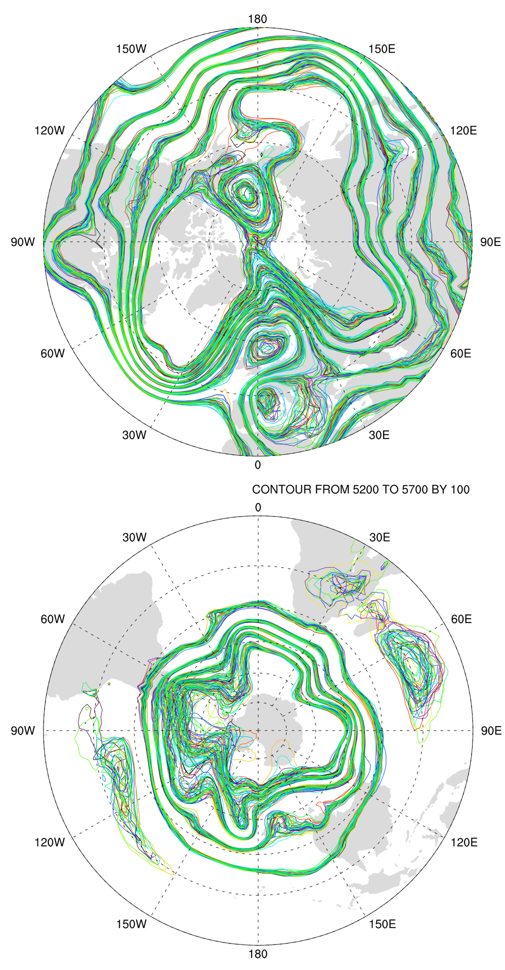


Figure 3: *Contours of the 500hPa geopotential height in 40 of the 80 CAM members for 6 hour forecasts valid 12:00 UTC 17 February 2003 (top) and 06:00 UTC 1 July 2001 (bottom). All of the model states are consistent with the observations, the ensemble captures the uncertainty.*

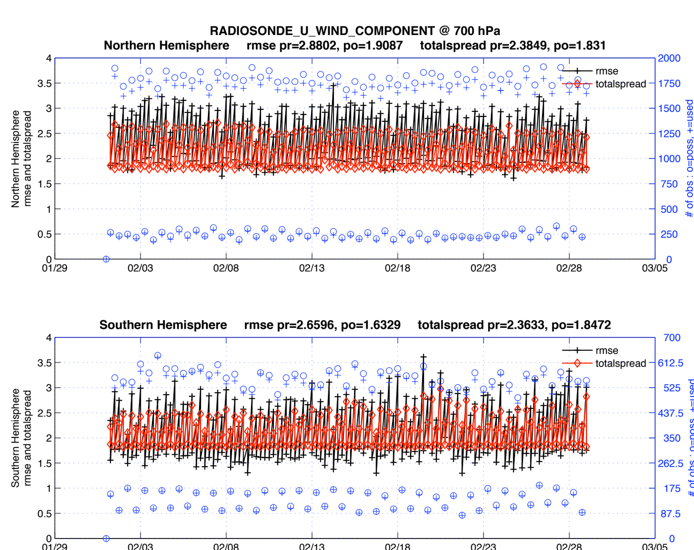


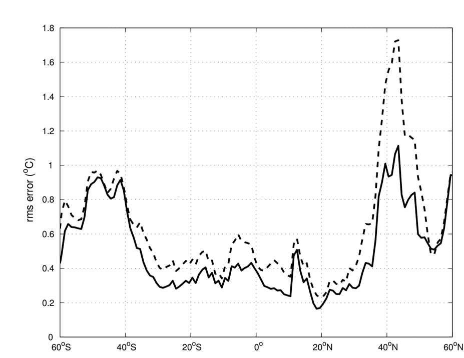
Figure 4: *The RMSE and totalspread of the 6 hour forecasts of the U winds compared to radiosonde observations for the month of February, 2003 ≈ 5 years into the assimilation. The RMSE is not expected to be smaller than the totalspread — this assimilation is performing very close to optimally.*

Assimilation Details

- 80 ensemble members of CAM Version 4
- (1.9° x 2.5°) 96 latitudes, 144 longitudes, 26 levels
- variables influenced by the assimilation: surface pressure, temperature, horizontal winds, specific humidity, cloud liquid, and cloud ice
- assimilation performed every 6 hours starting 1 Dec 1997
- globally, about 100,000 observations every 6 hours
- all members are forced by the same ocean analyses
- adaptive inflation used to maintain ensemble spread

4. Global Ocean Assimilation

The CESM interfaces for the Parallel Ocean Program (POP) and the Community Land Model (CLM) support multiple instances, allowing data assimilation experiments to exploit unique atmospheric forcing for each POP or CLM model instance. A multi-year DART ocean assimilation has been completed and provides valuable insight into the successes and challenges of oceanic data assimilation.



Assimilating subsurface temperature and salinity reduces the RMS difference between the time-mean SST and the time-mean Hurrell SST over the same time period.

Figure 5: *RMS difference (as a function of latitude) between the time average (2000-2005) Hurrell SST and the SST from the DART/POP EAKF assimilation ("Assim") over the same time period (solid black). Dashed line is the RMS difference between Hurrell SST and a wind-forced ocean simulation with no assimilation ("NoAssim").*

The time-mean SST from 2000-2005 has more realistic western boundary currents in both basins as shown in Figure 6. The assimilation of data moves the SST field in a direction that reduces the mismatch between the wind-forced ocean SST and the observed satellite/in situ SST.

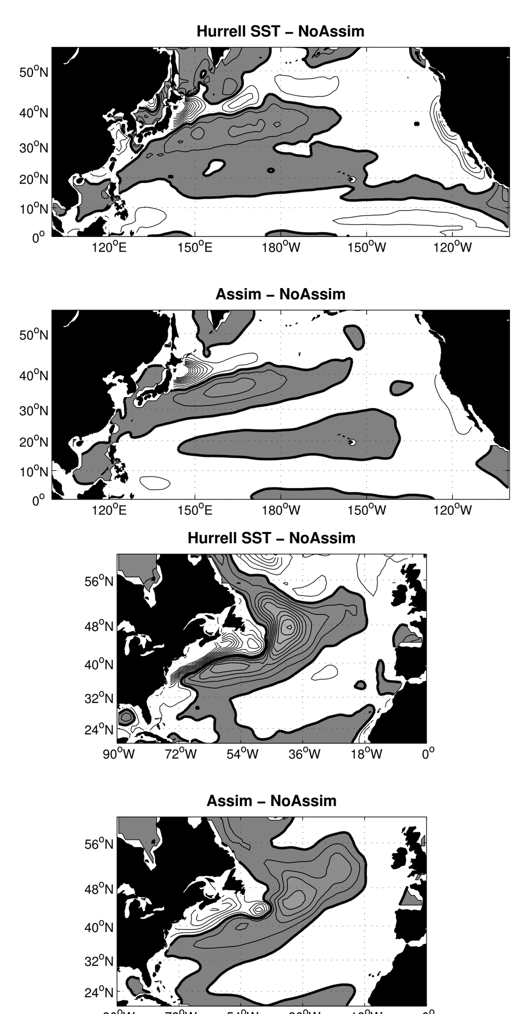


Figure 6: *Difference between the Hurrell SST (time average from 2000-2005) and the NoAssim SST and difference between the Assim SST and the NoAssim SST. Zero contour indicated in bold, with gray shading over positive contours. Contour intervals are $0.5^\circ C$.*

Assimilation Details

- 1 degree grid with displaced pole, 60 levels (POP gx1v6)
- 48 members initially drawn from a model climatology
- prescribed sea ice concentration
- assimilate every midnight starting 3 January 1998
- use all temperature and salinity obs in the World Ocean Database in a +/- 12 hour window
- atmospheric forcing for each POP member comes from a unique CAM ensemble member analysis (*i.e. from Section 3*)

5. Real-time WRF Assimilation/Forecasting for Field Campaign Support

The WRF-DART system was run real-time in a continuous cycling mode for a 47-day period during the NH spring of 2011 in support of the *Deep Convective Clouds and Chemistry* experiment test phase and the *Storm Prediction Center Hazardous Weather Testbed*. This provided a 50-member ensemble mesoscale (15 km dh) analysis every six hours, with one member analysis selected daily at 00Z to provide initial and boundary conditions for a cloud-resolving (3 km dh) 48-hr forecast over the eastern 2/3 CONUS. Analysis of real-time system performance identified significant model bias which limited forecast skill. Subsequent improvements in the analysis system physics suite led to marked improvements in forecasts.

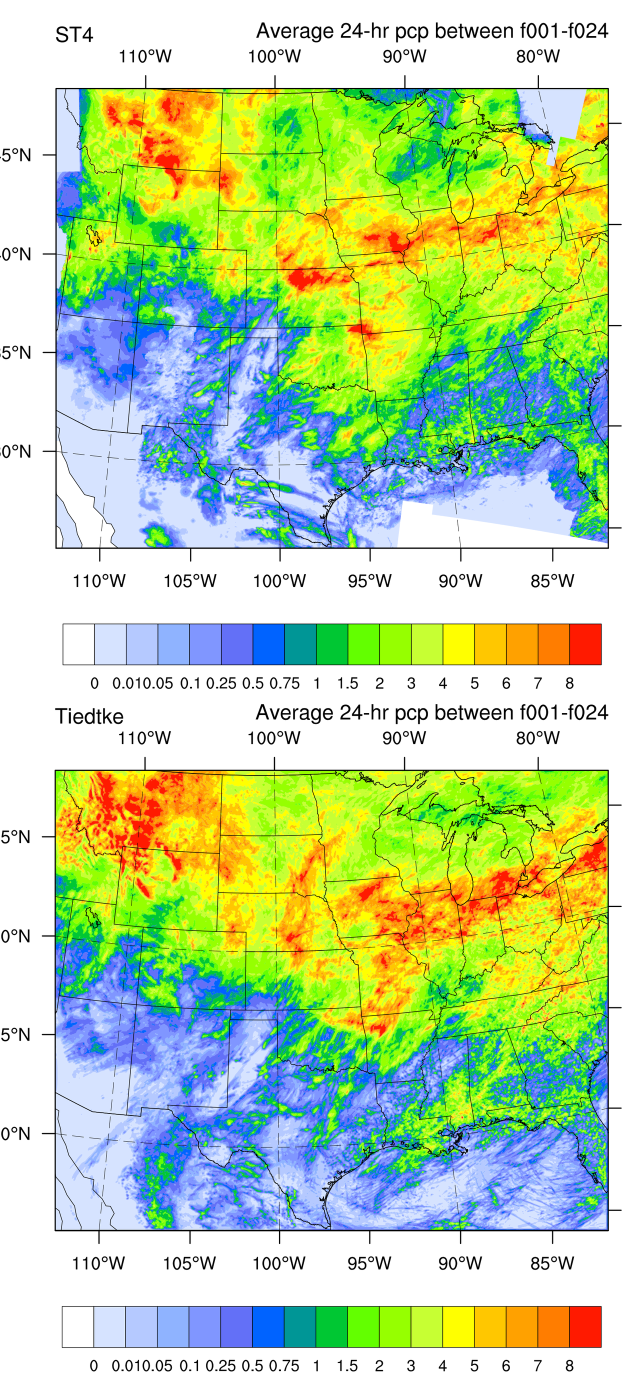


Figure 7: *30-day average 24-hour mean accumulated precipitation from NCEP Stage 4 (top) and from cloud-resolving forecasts using initial and boundary conditions from the physics adjusted cycled WRF-DART analysis (bottom) for the period 13 May - 12 June 2011.*

The general climatology is captured well, although forecasts from the WRF-DART analysis tend to over-predict accumulated precipitation. A positive bias is particularly notable at higher rain rate thresholds. Sources of this precipitation bias are still under investigation.

6. Tropical Cyclone Retrospective Forecasting

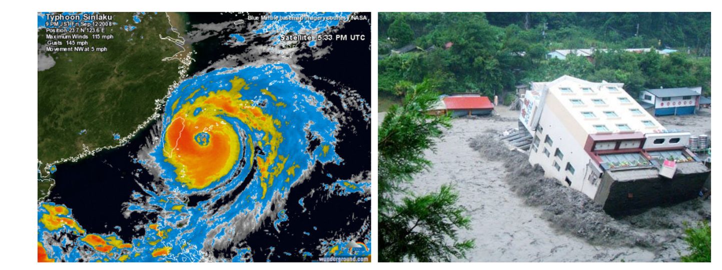


Figure 8: *Tropical Cyclone Sinlaku (left) and damage to the Kimei Hot Springs Hotel in Lushan, Taiwan on 9 Sep 2008 (right).*

The impacts of integrated satellite observations including Atmospheric Motion Vectors (AMVs), Atmospheric Infrared Sounders (AIRS) temperature and water vapor soundings, and Advanced Microwave Scanning Radiometer (AMSR) microwave total precipitable water (TPW) observations on analyses and forecasts of Tropical Cyclone *Sinlaku* (2008) are investigated. The assimilations are done with a 27km resolution WRF model over the Western Pacific for 8-14 Sep 2008 in a 6-hourly analysis cycle. A moving 9km nest grid with feedback to the 27km grid is used in the 6-hour ensemble forecasts when the TC is present.

CTRL run: Radiosondes, conventional AMVs from Japan Meteorological Agency (JMA) extracted from NCEP/GFS dataset, aircraft data, station and ship surface pressure data, Joint Typhoon Warning Center (JTWC) advisory TC positions.

SAT run: Additionally, the CIMSS processed rapid-scan AMVs, AIRS T/Q soundings and AMSR MW TPW data.

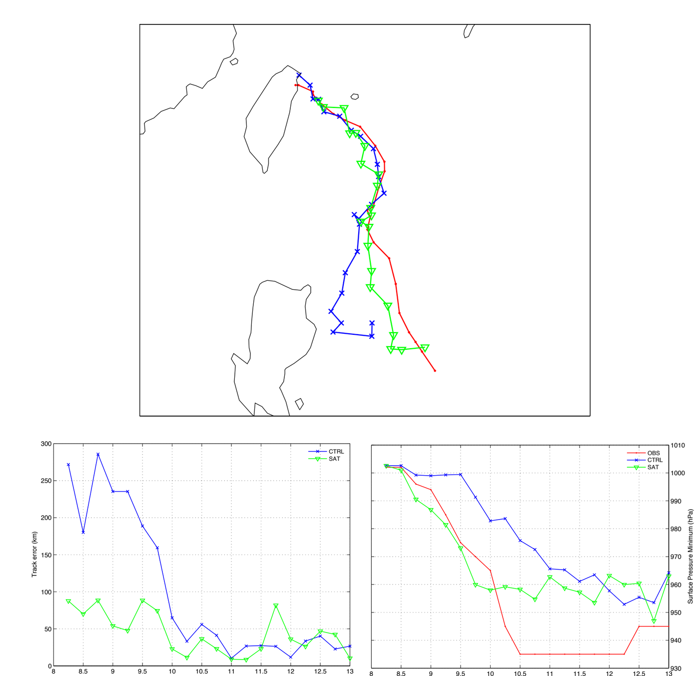


Figure 9: *The track, track errors, and intensity of the control analyses (CTRL run – in blue) and the analyses using all of the new satellite observation types (SAT run – in green) for Tropical Cyclone Sinlaku 00UTC 8-13 Sep 2008. The observed track and intensity are shown in red.*

The results suggest that the use of all satellite observation types improves the initial track and intensification compared with the control analyses.

P.S. Parts of Taichung County in central Taiwan recorded more than 1600 mm of rainfall during the passage of *Sinlaku*. **That's 5.25 feet!** Boulder, CO averages about 1.25 feet of total moisture per *year*.

7. Observation-Space Diagnostics

The performance of the assimilation is assessed by comparing the short-term forecast state to the observations about to be assimilated; a metric that is not dependent on a third party analysis. DART has a wide range of observation-space diagnostic tools to evaluate the performance of the assimilation.

DART has many more diagnostics than those shown here (Figure 4, Figure 10); rank histograms, 3D plots of the observation locations color-coded to the observation value/QC value/rmse/bias/spread/rejected observations, mapping tools, . . .

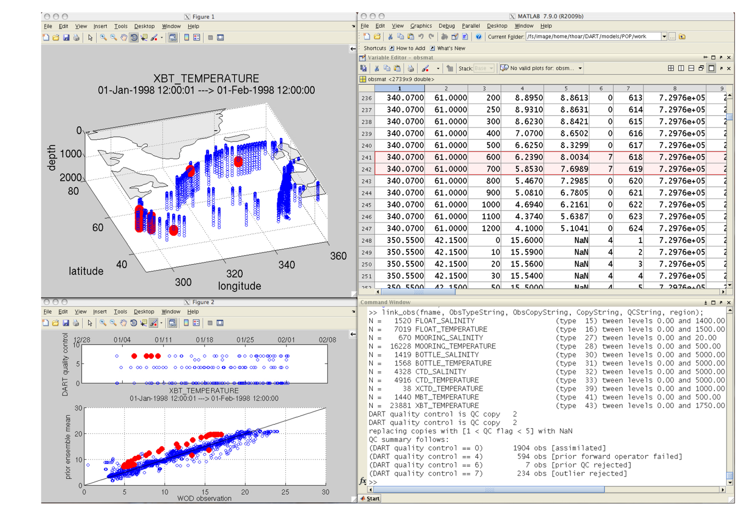
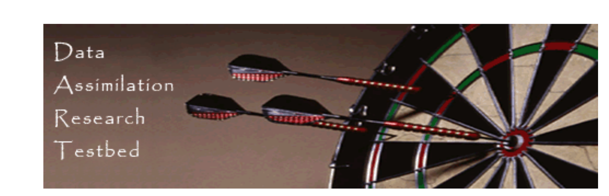


Figure 10: *DART's diagnostic tools make it easy to explore what observations are being rejected . . . and why. This is an example of some XBT observations in the North Atlantic. The information in the plots is linked — selecting observations in one view highlights them in all the views.*

8. Further Information

http://www.image.ucar.edu/DAReS/DART has information about how to download DART from our subversion server, a full DART tutorial (included with the distribution), and how to contact us.



9. References

J. Anderson, T. Hoar, K. Raeder, H. Liu, N. Collins, R. Torn, and A. Arellano, 2009: *The Data Assimilation Research Testbed: A Community Data Assimilation Facility.* *BAMS* **90** No. 9 pp. 1283–1296

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