DART-CAM at the front lines

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Status

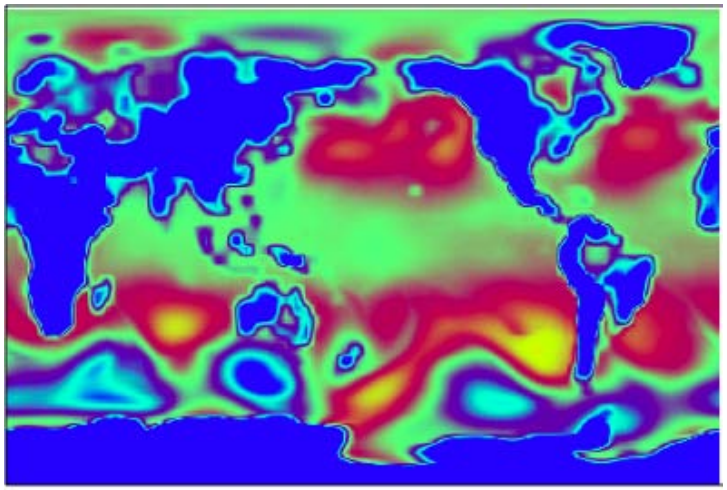
- Track 5 (3.6.32) can be used in data assimilation and short-term forecast mode with the Data Assimilation Research Testbed (DART).
- Released and development CAMs from 3.0 on still work with DART.
- State-of-the-art, data assimilation products are available to assist with CAM model development efforts and modeling studies.
- Thanks to Truesdale for speeding up the implementation and Bailey for help with the ICE restarts with Track 5.

CAM Initial Conditions from DART-CAM

- CAM analysis (ensemble avg) generated every 6 hours.
- On CAM's native grid -> no interpolation or foreign model error to wonder about.
- Analysis error estimate comes for free from ensemble spread; varies with location, time, and field.
- New observations sets frequently incorporated to improve analyses.

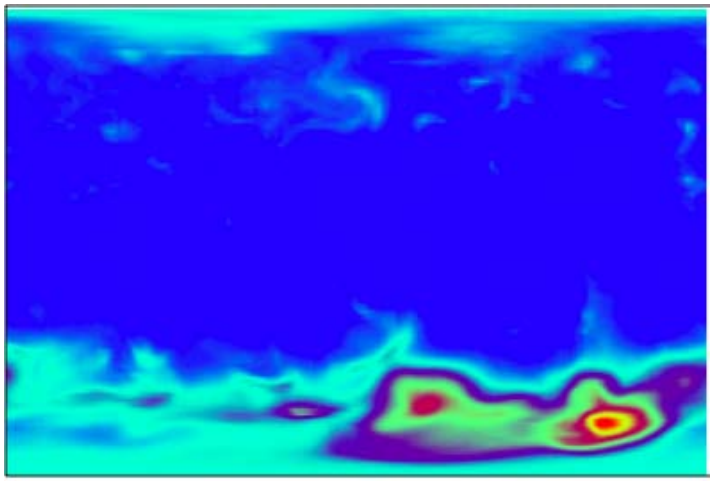
Means (analyses) and Spreads (confidence) 06Z 7/31/07

PS Mean



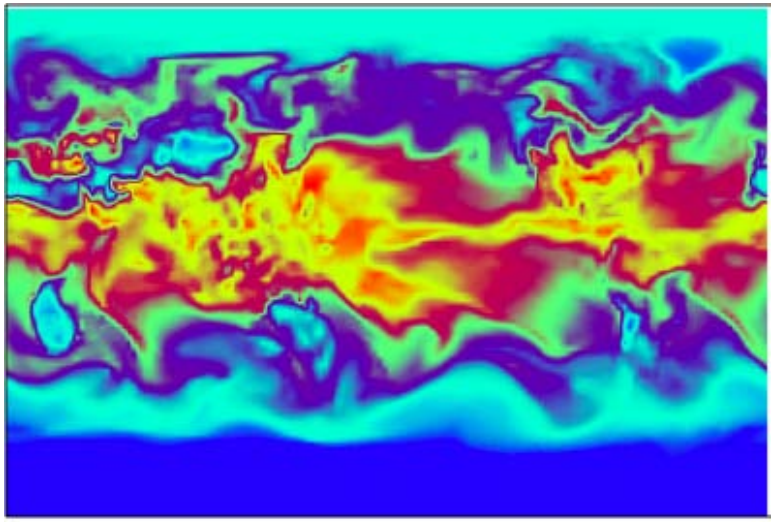
posterior ensemble state
Range of Surface pressure: 97000 to 104469 Pa

PS spread



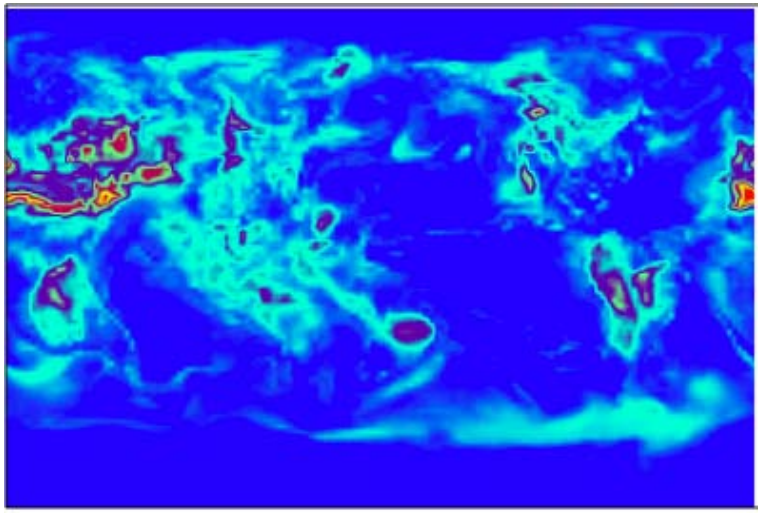
posterior ensemble state
Range of Surface pressure: 34.483 to 1862.57 Pa

Q level=30 Mean



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

Q level=30 spread



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

Analyses used in forecasting studies:

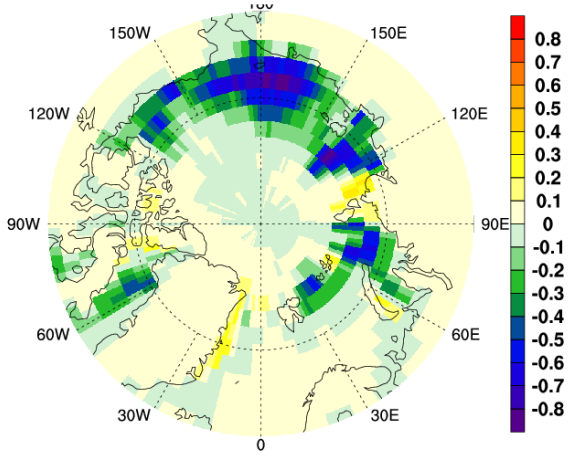
- CAPT(Hannay/Williamson) EPIC boundary layer
- E. Chang; North Pacific cyclogenesis (CAM 3.1 T85)
- Arctic Ice loss studies (Kay)

  - CAM3.5 has an unrealistic built-in feedback between stratus clouds and sea ice because stratus clouds are only diagnosed over open water.
  - CAM4's weak July cloud response to sea ice loss is more consistent with recent observations (Kay and Gettelman, 2009).
  - Both cloud and surface albedo changes alter radiation budgets over newly open water. Due to albedo reductions alone:

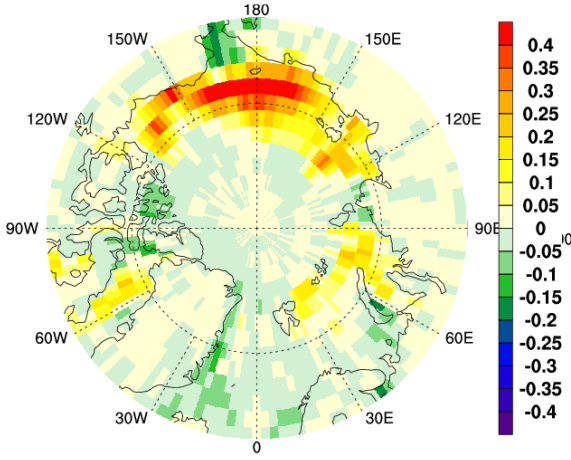
    1) Clouds have a stronger cooling influence (CRF decreases)
    2) Upward SW fluxes decrease (positive ice albedo feedback)
    3) Surface downward SW fluxes decrease (negative multiple scattering feedback)

July Cloud Response to Sea Ice Loss

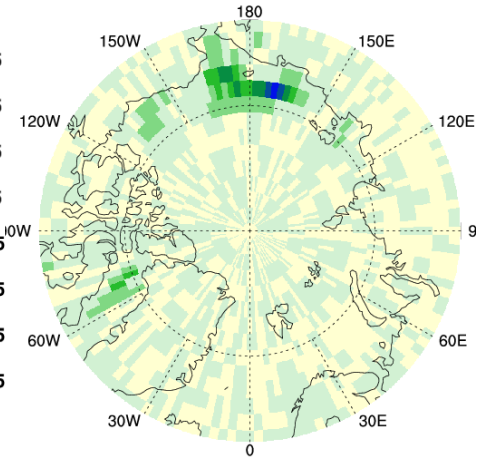
Observed ice fraction loss



CAM3.5 low cloud response



CAM4 low cloud response

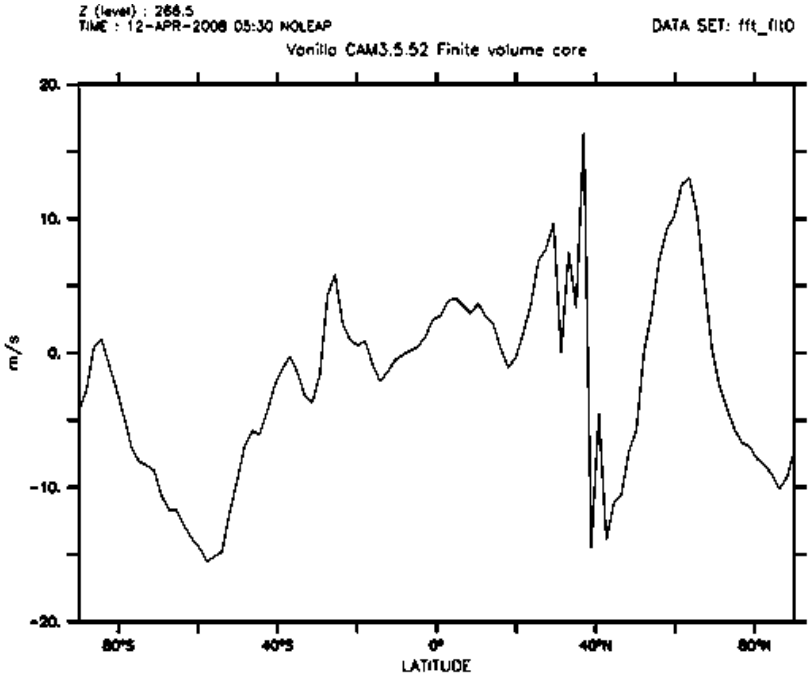


Change in clouds and radiative fluxes (Wm^{-2}) in grid cells with sea ice loss

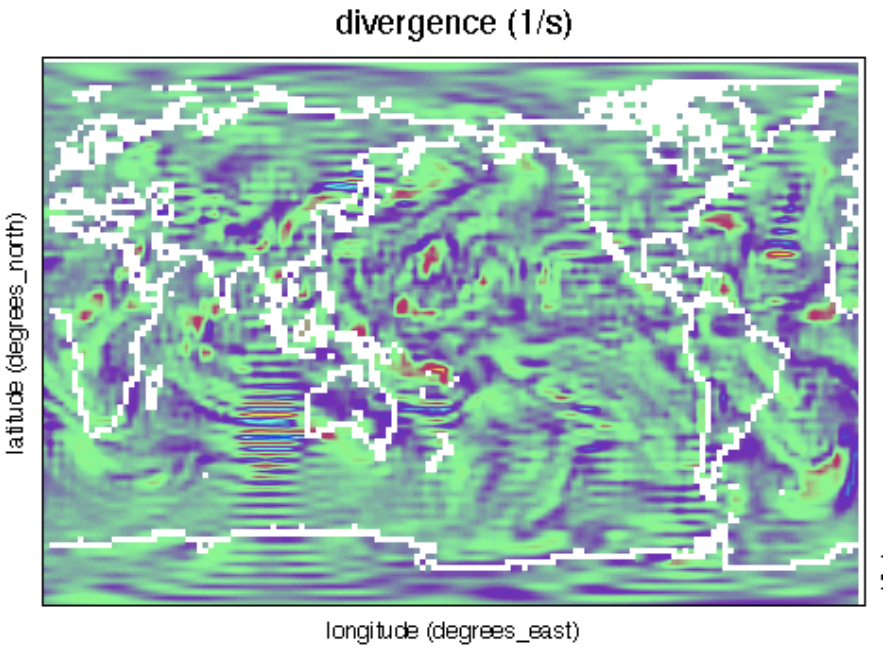
	CAM3.5	CAM4
Low cloud fraction	+16%	-3%
Surface albedo	-13%	-8%
Top of atmosphere CRF	NET -22.7	NET -12.7
Surface CRF	NET -18.9 = SW -25.3 + LW +6.4	NET -11.5 = SW -14.5 +LW +3.1
Surface net radiation	+13.3	+5.1
Surface shortwave fluxes	NET +15.0 = DOWN -23.7 - UP -38.7	NET +9.9 = DOWN -11.3 - UP -21.2

FV core noise

- First noticed in DART-CAM assimilations.
- Seen in free-running FV CAM (all tags), even on the cubed-sphere grid (Lauritzen).
- To be fair; in all discretized models exhibit some numerical noise, but it should be thoroughly evaluated and thoughtfully mitigated.



Meridional wind (V) for free running CAM. Sporadic intermittent noise is especially visible at upper level v winds.



Divergence field in free running CAM at model level 10 (around 200 hPa). Noise visible throughout the run.

New Diagnostics for Model Development

Our goal: accelerate the identification and characterization of model deficiencies by direct comparison with real observations, in order to fix them more efficiently.

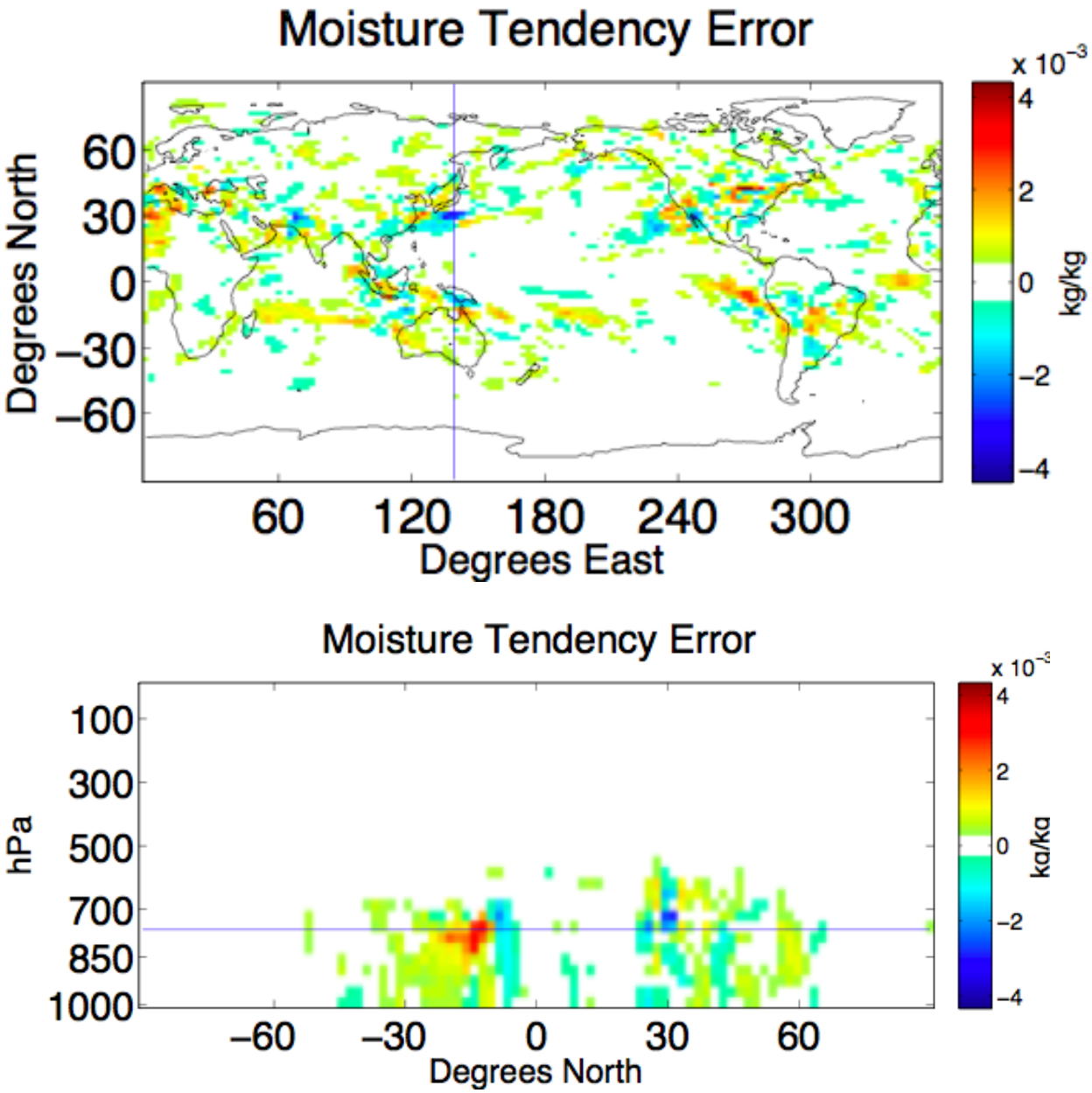
New Tools:

- Tendency Errors
- Biases in state variables at observation locations
- “Sensitivities” of a chosen variable to all state variables

Needed: users/developers with directed questions about model behavior

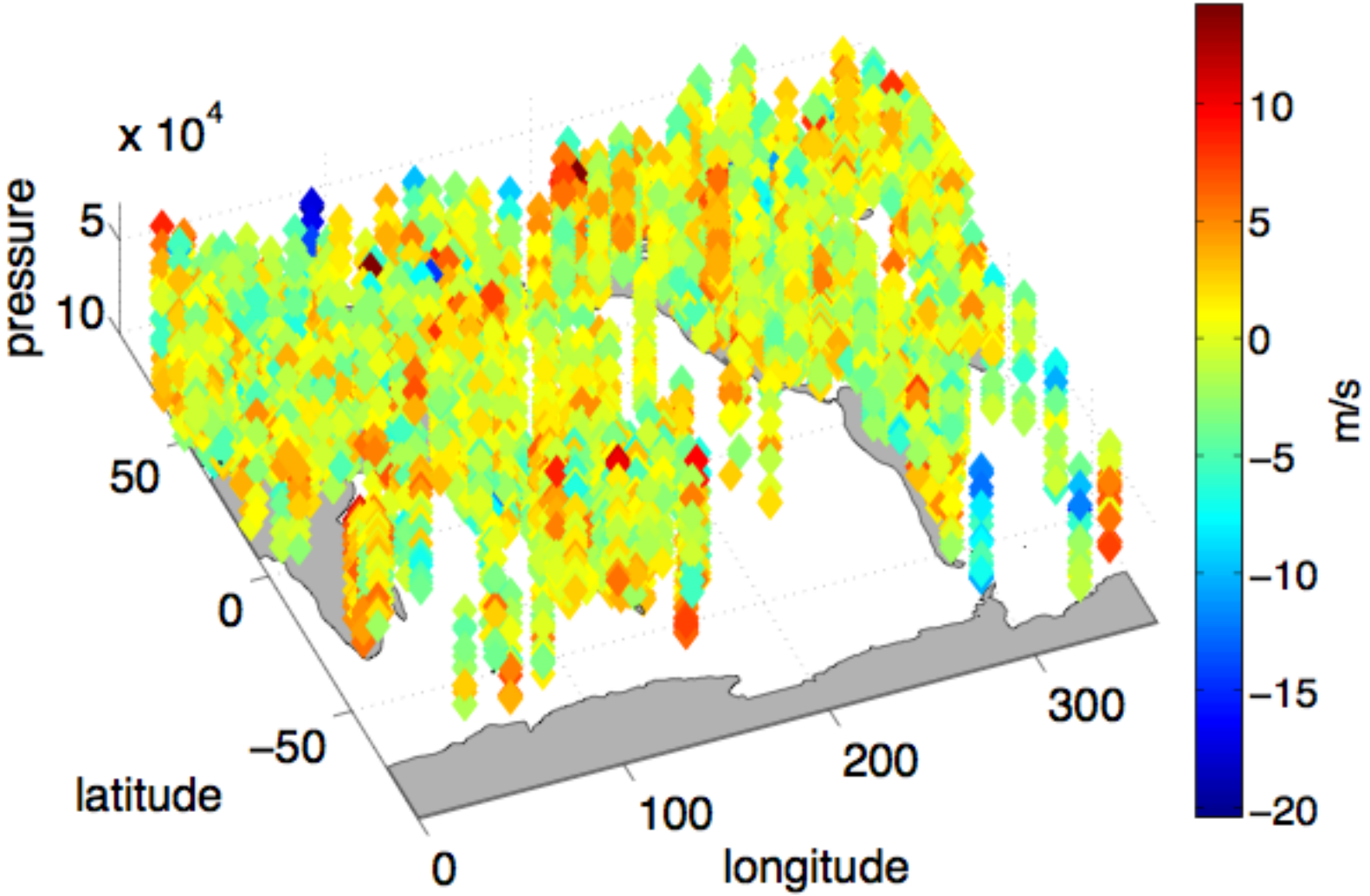
Tendency Errors

DART-CAM can provide time-averaged tendency errors of the state variables over short periods. These have significant correlation with model bias as measured from long climate runs. Shown is a 6-day average of 6-hour Q tendency errors from July 2003. This highlights areas where CAM wants to stray from reality.



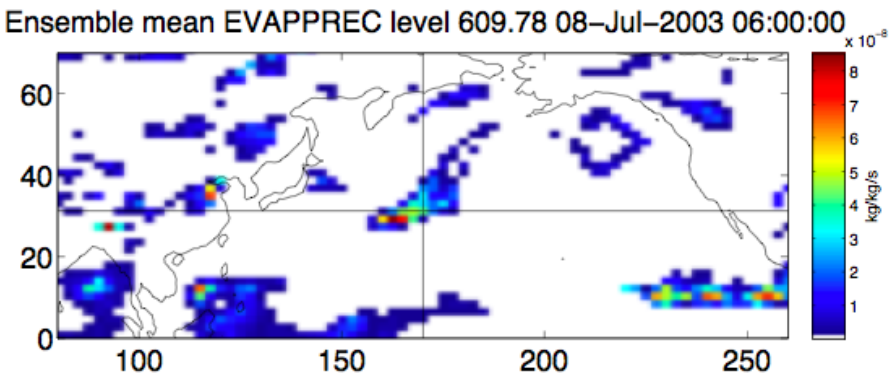
Model Biases at Observation Locations

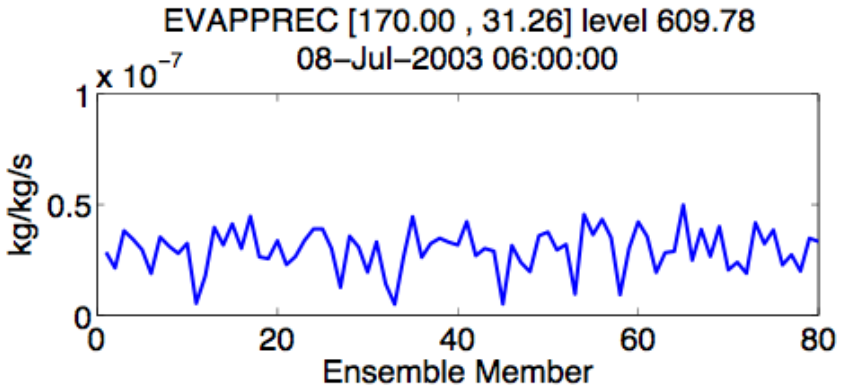
- Matlab script generates the model bias at each obs location, here U at radiosondes.
- Bias can be absolute units, or normalized by the obs value, or the obs error.

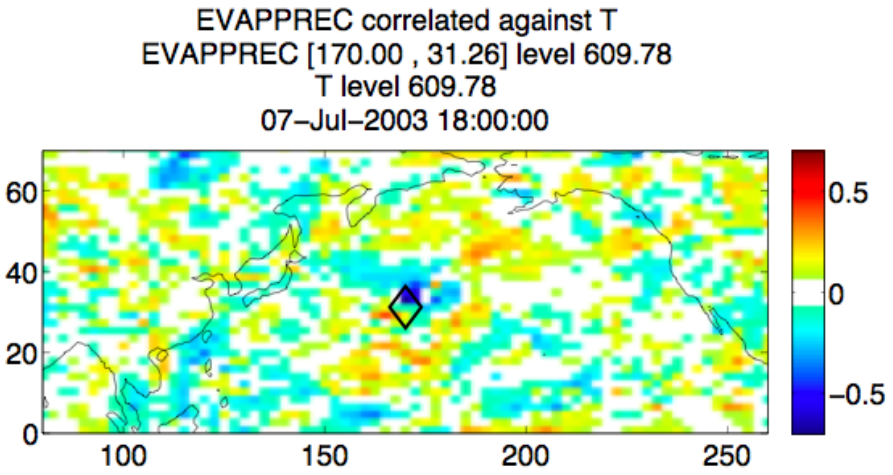


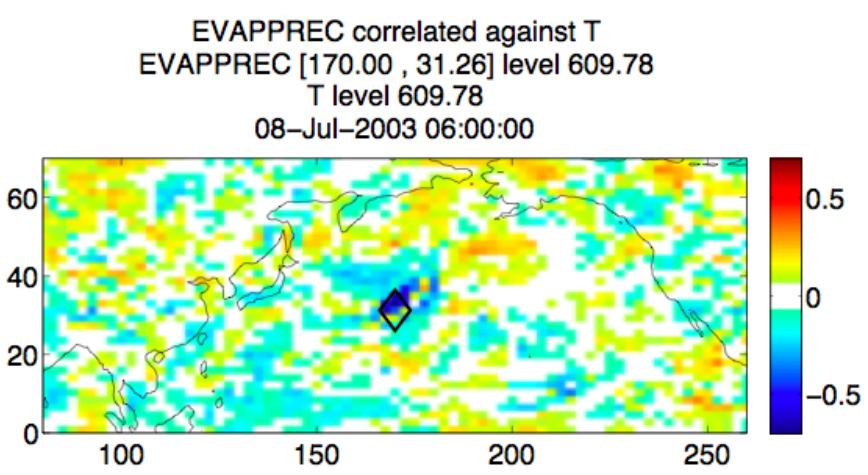
“Sensitivity” of a variable to state vector variables

- Correlation between the 80 ensemble members of EVAPPREC at a point, with the 80 members of T in the whole domain.
- Both taken from the end of a 6 hour forecast; T at earlier times can be chosen to see time evolution of sensitivity.









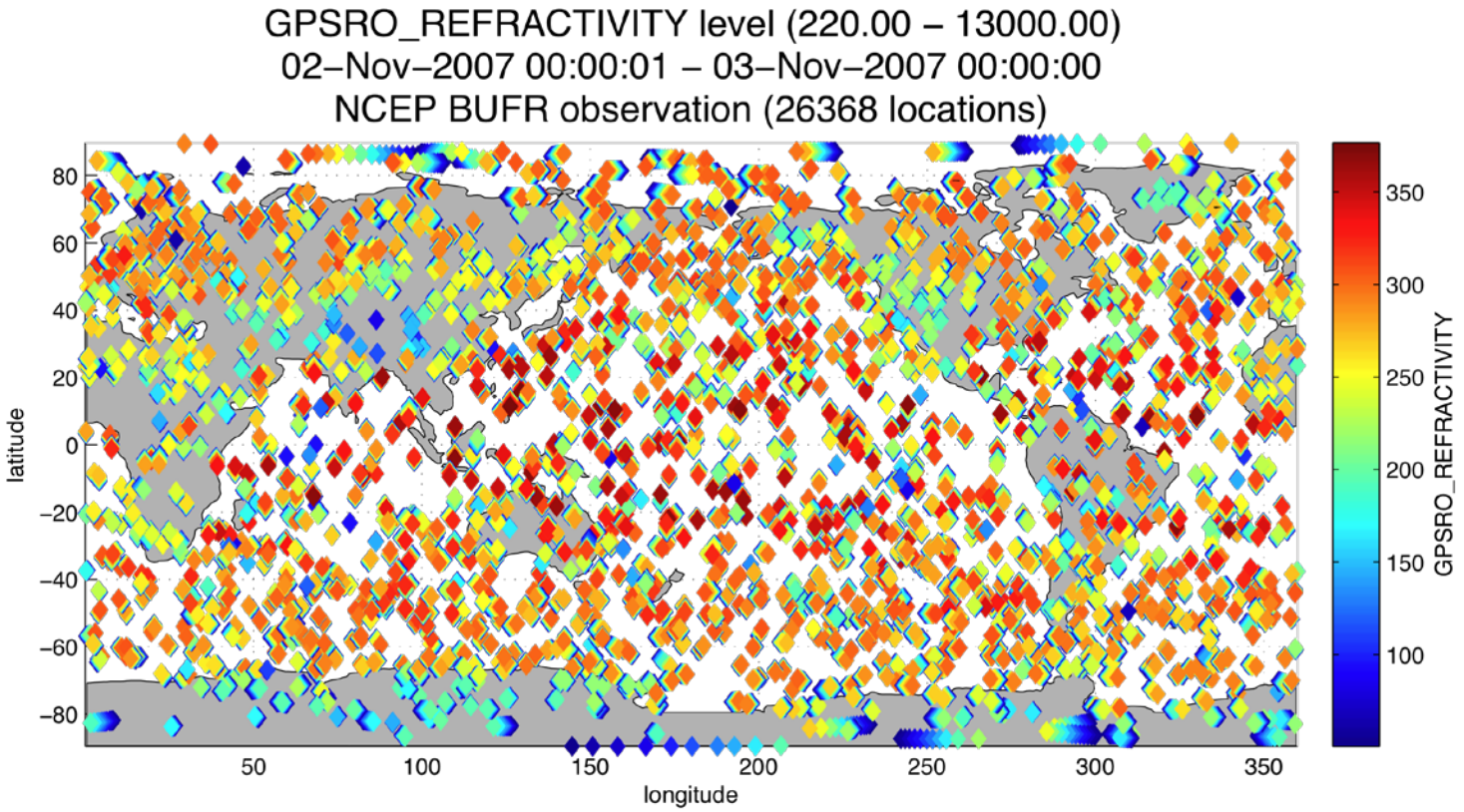
Wrap-up

DART-CAM:

- ✓ provides state-of-the-art, data assimilation products to assist with CAM model development efforts,
- ✓ has helped identify several model deficiencies, leading to timely solutions,
- ✓ analyses can efficiently focus multiple model versions on the same synoptic situation and physical phenomena.

GPS radio occultation refractivity

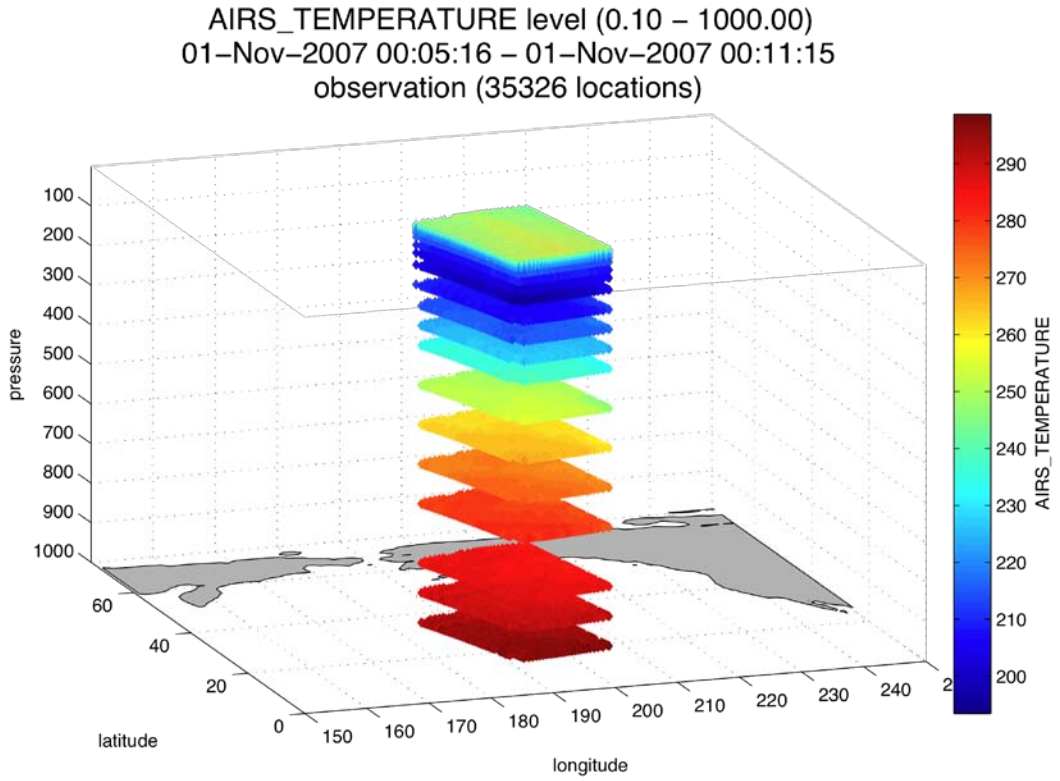
- Atmospheric refractivity is determined, in part, by T and Q
- Distribution is more uniform than radiosondes and aircraft flight paths, so improvements are seen where standard obs aren't.
- But GPS improves analyses even where standard obs *are*: southern hemisphere Q bias improves from .4 to .35 g/kg *at the locations of radiosonde Q obervations*.



Atmospheric Infrared Sounder (AIRS)

- Huge amount of dense data will be thinned for CAM assimilations.
- Retrievals of T & Q, plus green house gases, over gaps in the radiosonde network.
- Value added to existing obs remains to be seen.

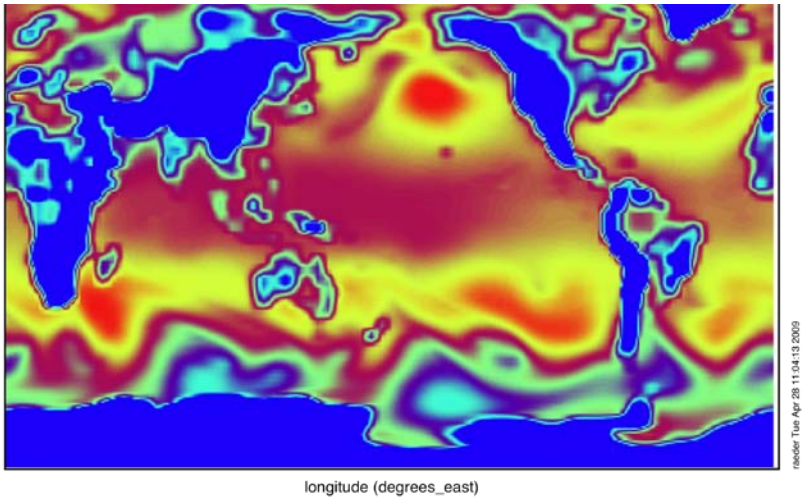
Six minutes' worth of AIRS temperature retrievals



LEFTOVERS

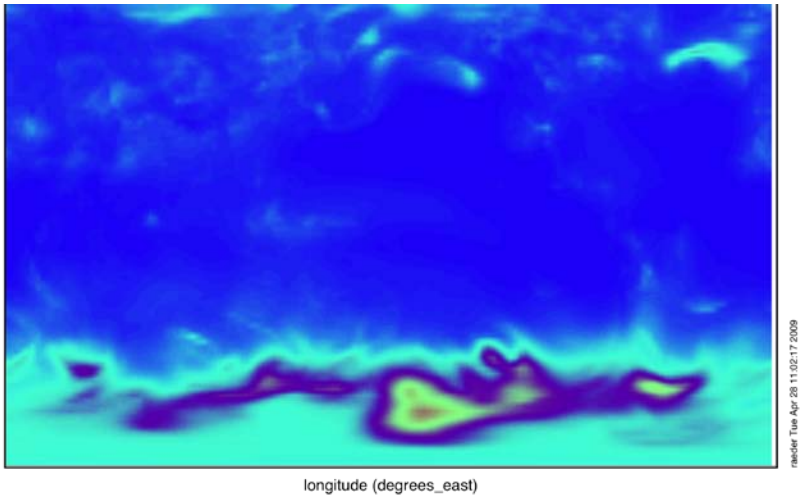
Means (analyses) and Spreads (confidence)

PS Mean



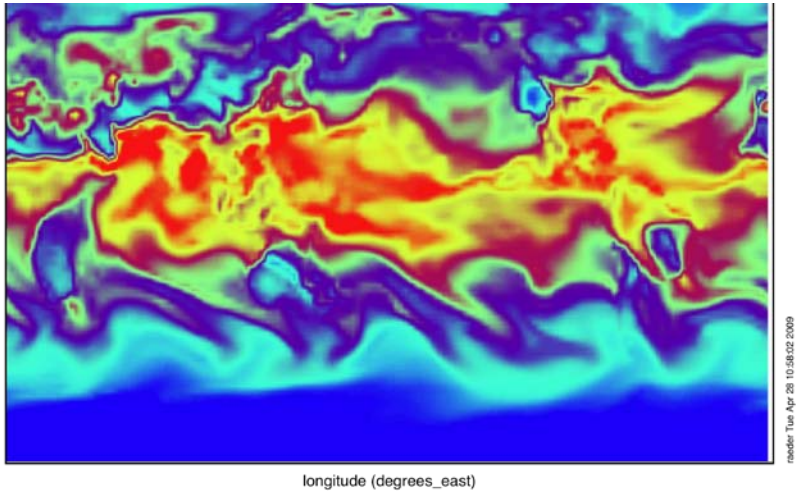
posterior ensemble state
Range of Surface pressure: 95000 to 103424 Pa
Range of longitude: 0 to 357.5 degrees_east

PS spread



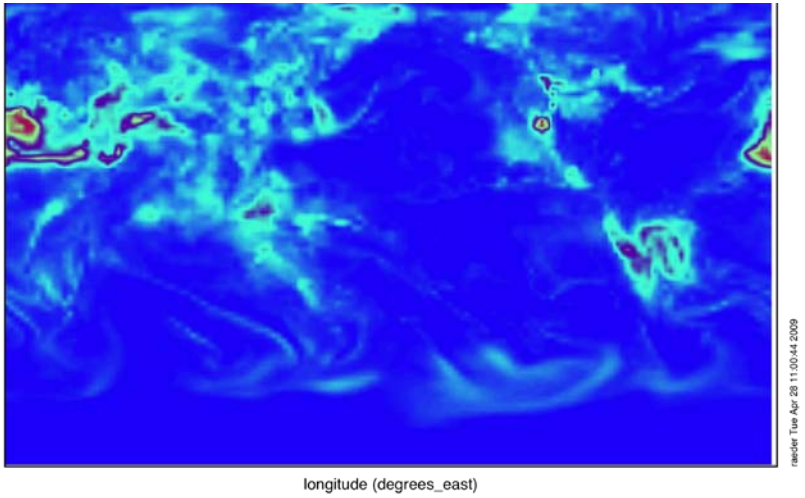
posterior ensemble state
Range of Surface pressure: 0 to 2000 Pa
Range of longitude: 0 to 357.5 degrees_east

Q 992 Mean



posterior ensemble state
Range of Specific humidity: 0 to 0.02 kg/kg
Range of longitude: 0 to 357.5 degrees_east

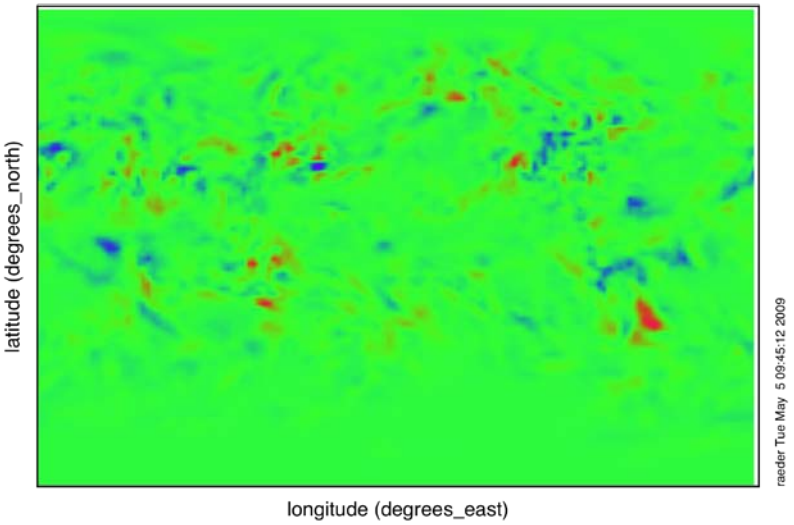
Q 992 spread



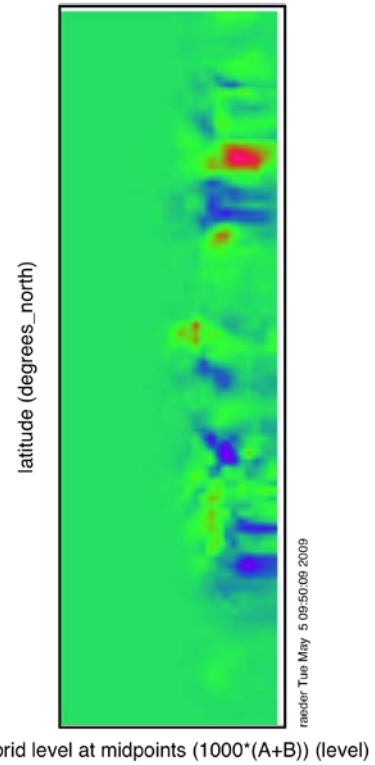
posterior ensemble state
Range of Specific humidity: 0 to 0.01 kg/kg
Range of longitude: 0 to 357.5 degrees_east

Systematic Tendency Errors

- 6-hour forecast – analysis = forecast error
- Averaged over 7/1-7/03
- Q at 610 hPa and lat-level x-section at 170 E

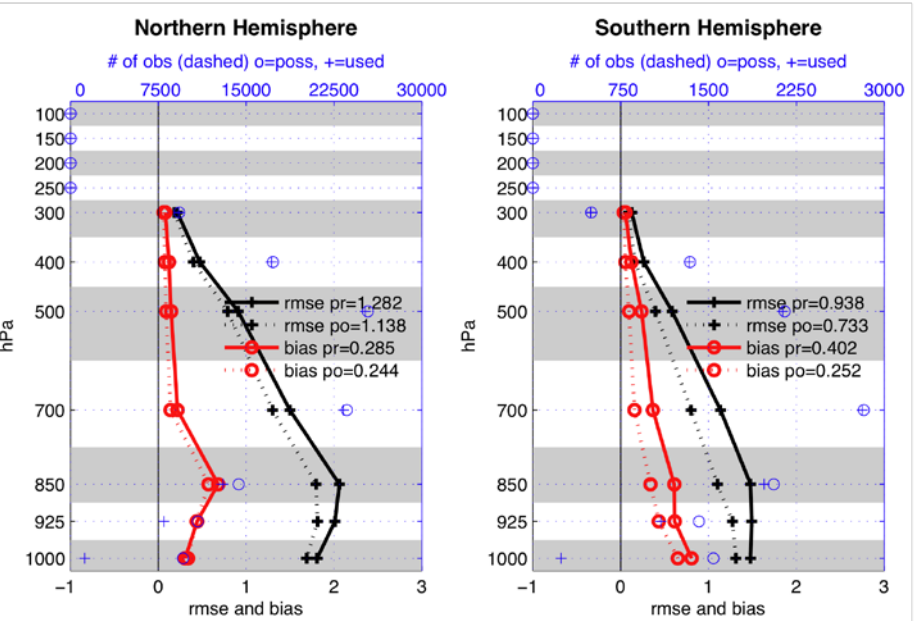


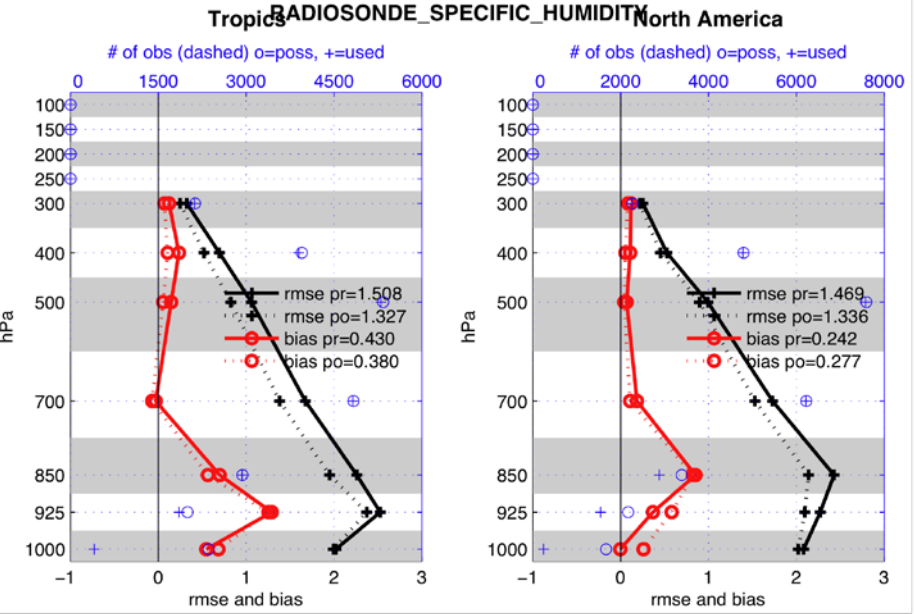
prior ensemble state
Range of Specific humidity: -0.000407941 to 0.000463985 kg/kg
Range of longitude: 0 to 357.5 degrees_east
Range of latitude: -90 to 90 degrees_north
Current time: 147011 days since 1601-01-01 00:00:00
Current ensemble member or copy: 1 nondimensional
Current hybrid level at midpoints (1000*(A+B)): 609.779 level
File CAPT_31-36.nc



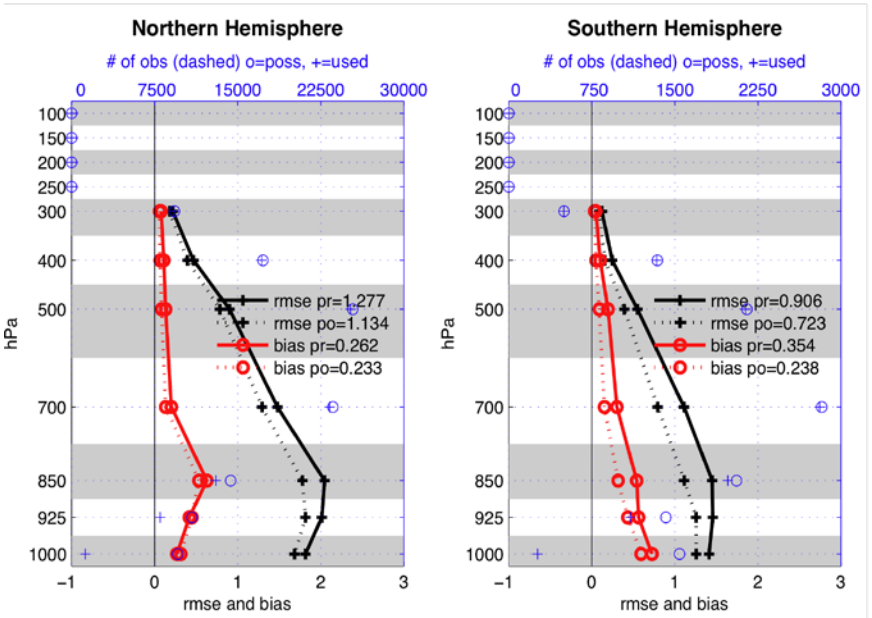
prior ensemble state
Range of Specific humidity: -0.000205359 to 0.000325176 kg/kg
Range of hybrid level at midpoints (1000*(A+B)): 3.64347 to 992.556 level
Range of latitude: -90 to 90 degrees_north
Current time: 147011 days since 1601-01-01 00:00:00
Current ensemble member or copy: 1 nondimensional
Current longitude: 170 degrees_east
File CAPT_31-36.nc

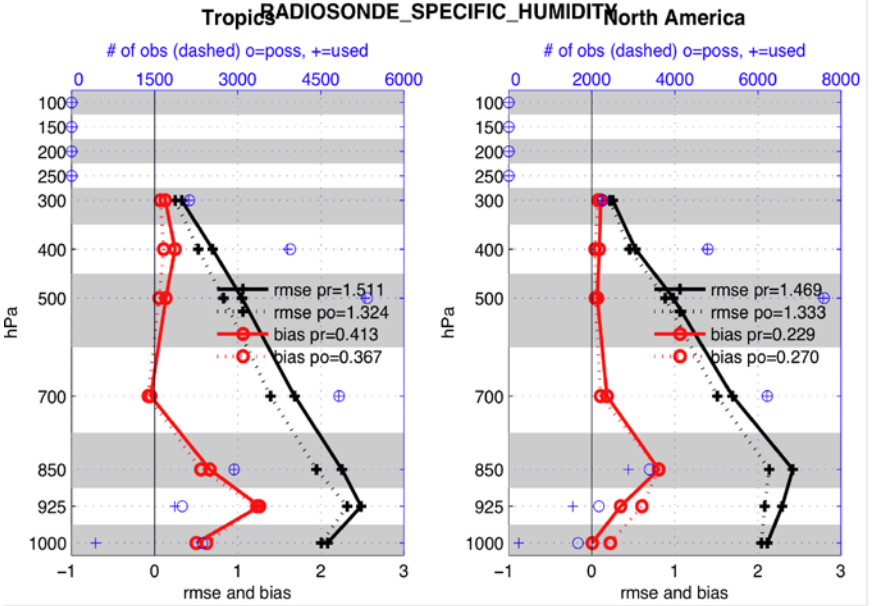
No GPS





with GPS





Observation Space Diagnostics

- Biases and RMS Errors for regions used in standard CAM diagnostics:
  - Pacific: Central Pacific, South of Hawaii, Hawaii, Storm track
  - Tropical: Tropical, Australia, Bay of Bengal, Arabian Sea
  - Zonal: Global, Arctic, Zonal1: 90-70 S, Zonal2: 70-50 S
  - Our standard regions for comparison with earlier studies: N and S Hemis., Tropics, N Amer.
- Example plots for 6/24-7/15 2003.