Hyperspectral Infrared Water Vapor Radiance Assimilation

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and many others.

Water Vapor Radiance Assimilation

- Problems
  - Innovations do not have a normal distribution
    - Use q, log(q) or pseudo RH
    - All have +/-
  - Multivariate problem
    - T and q are both unknown
  - Non-linearity
- Symptoms
  - Increased penalty
  - Decreased convergence
  - Unstable moisture field
    - Supersaturation
    - Negative moisture
    - Precipitation spin down

GSI Software Modifications

- Q < 1.0e-7, reset to 1.0e-7 before each outer loop and analysis output
  - Minimal impact
- Q > = 1.0e-7 for CRTM vice 1.0e-6
  - Minimal impact
- Supersaturation is reset to saturation during initial read (to properly compute heights), before each outer loop, and analysis output.
  - Substantial impact
  - ** REVIEW RH BACKGROUND ERROR **
  - Adjust factqmax and factqmin to slow production of negative and supersaturated Q.
  - Adjust conventional observation errors

CIMSS

GSI Software Modifications

- Stratospheric components of the AIRS and IASI water vapor jacobians may need to be adjusted based on model top and vertical resolution.
  - Weak water vapor lines in surface and CO2 channels.
  - Near absorption lines in water vapor region.
- Needs to be tuned for each model
  - Model generated supersaturation
  - Background Error and factqmax/factqmin will degrade convergence.
  - Will need to re-compute bias corrections for any water vapor radiances being used.

Factqmax and factqmin are inflation terms which add to the cost function when negative water vapor or supersaturation occur in the inner loops.

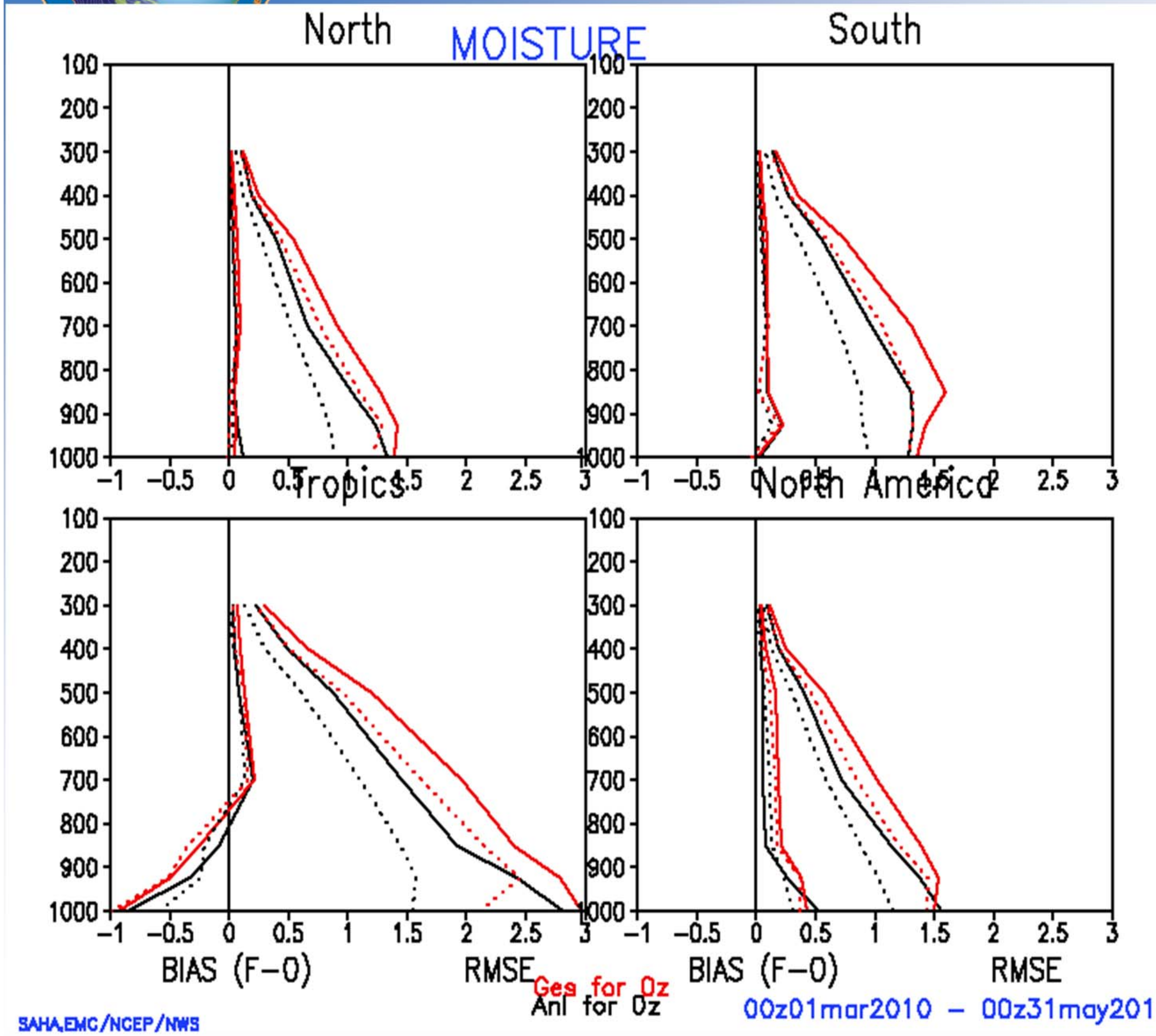
Water Vapor Radiances

- Use the gross error check to limit the response for all water vapor channels.
  - Adjusted gross error check 4.5 -> 0.9 [K] (AIRS and IASI)
  - Adjusted gross error check 4.5 -> 1.5 [K] (HIRS and GOES)
  - Adjusted gross error check 6.0 -> 3.0 [K] (MW sensors)
- Assumes clear sky conditions.
- Adjusted assimilation weights closer to the noise equivalent delta temperature (nedt).
- 233 total, 68 water vapor IASI channels
  - 53 tropospheric (off-line)
  - 31 stratospheric (on-line)
- 121 total, 38 water vapor AIRS channels
  - 29 tropospheric (off-line)
  - 9 stratospheric (on-line)
- All HIRS, GOES, AMSU-B and MHS water vapor channels are used.

Effects

- Less observations per channel used wrt using the original gross error check.
  - ~70% reduction initially
  - ~20% reduction in final analysis
- Most observations pass QC on second outer loop
  - Better temperature profile (?)
- Water vapor channels now have similar characteristics to temperature channels
  - Convergence improved
  - Penalty improved
- Smaller initial changes to the moisture field, greater changes over time
  - Each assimilation cycle changes are about an order of magnitude less than the model values
- Most changes occurring in the mid- and upper Troposphere

Vertical RMS fit to Raobs



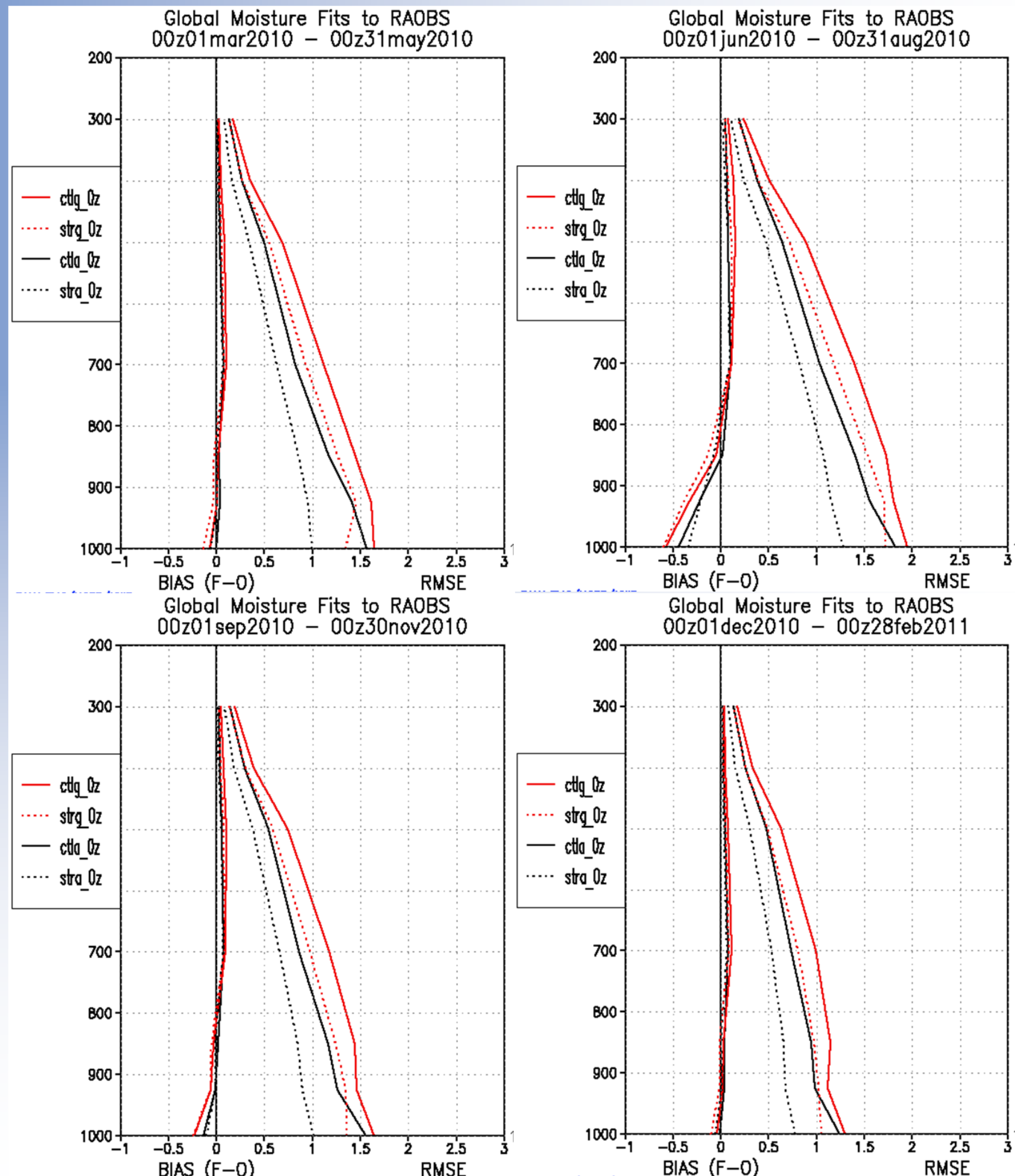
Solid Lines = control
Dashed Lines = experiment

Red = Background
Black = Analysis

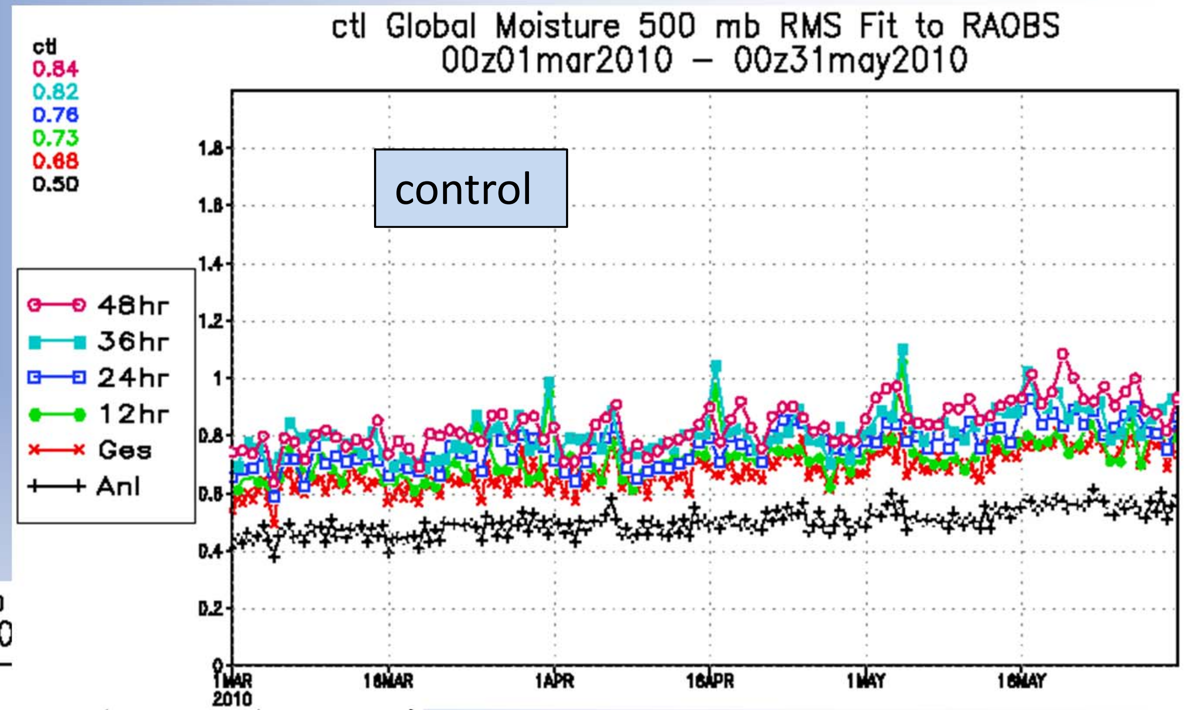
Consistent improvements with respect to rawinsaondes are realized in all four seasons

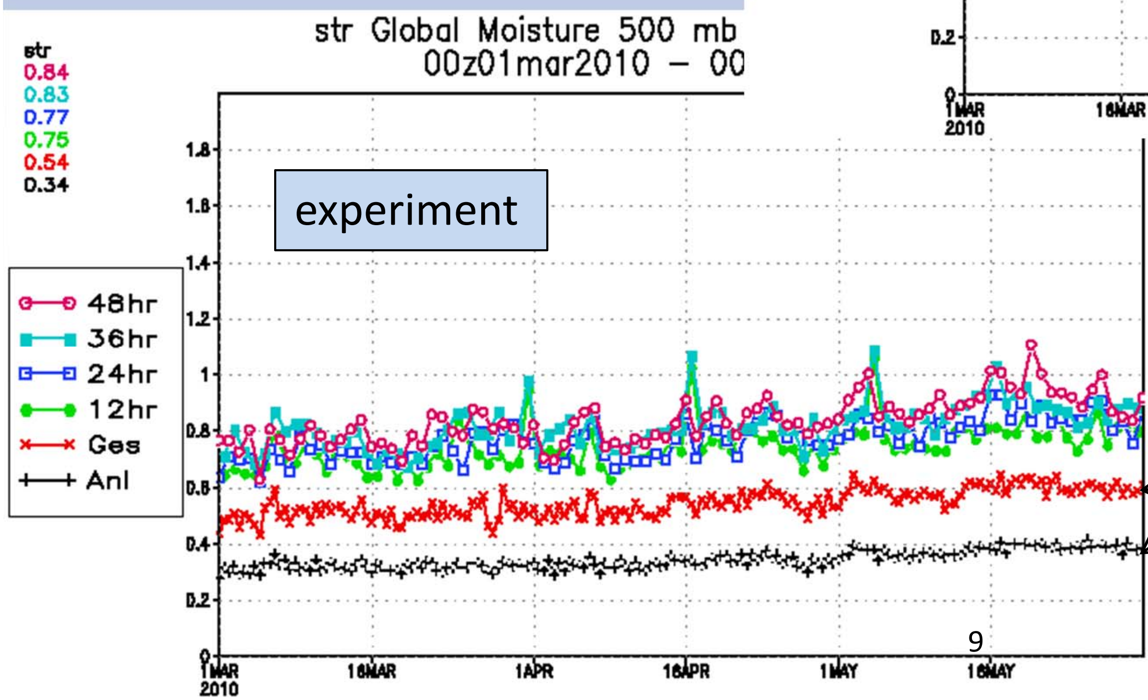
Solid Lines = control
Dashed Lines = experiment

Red = Background
Black = Analysis



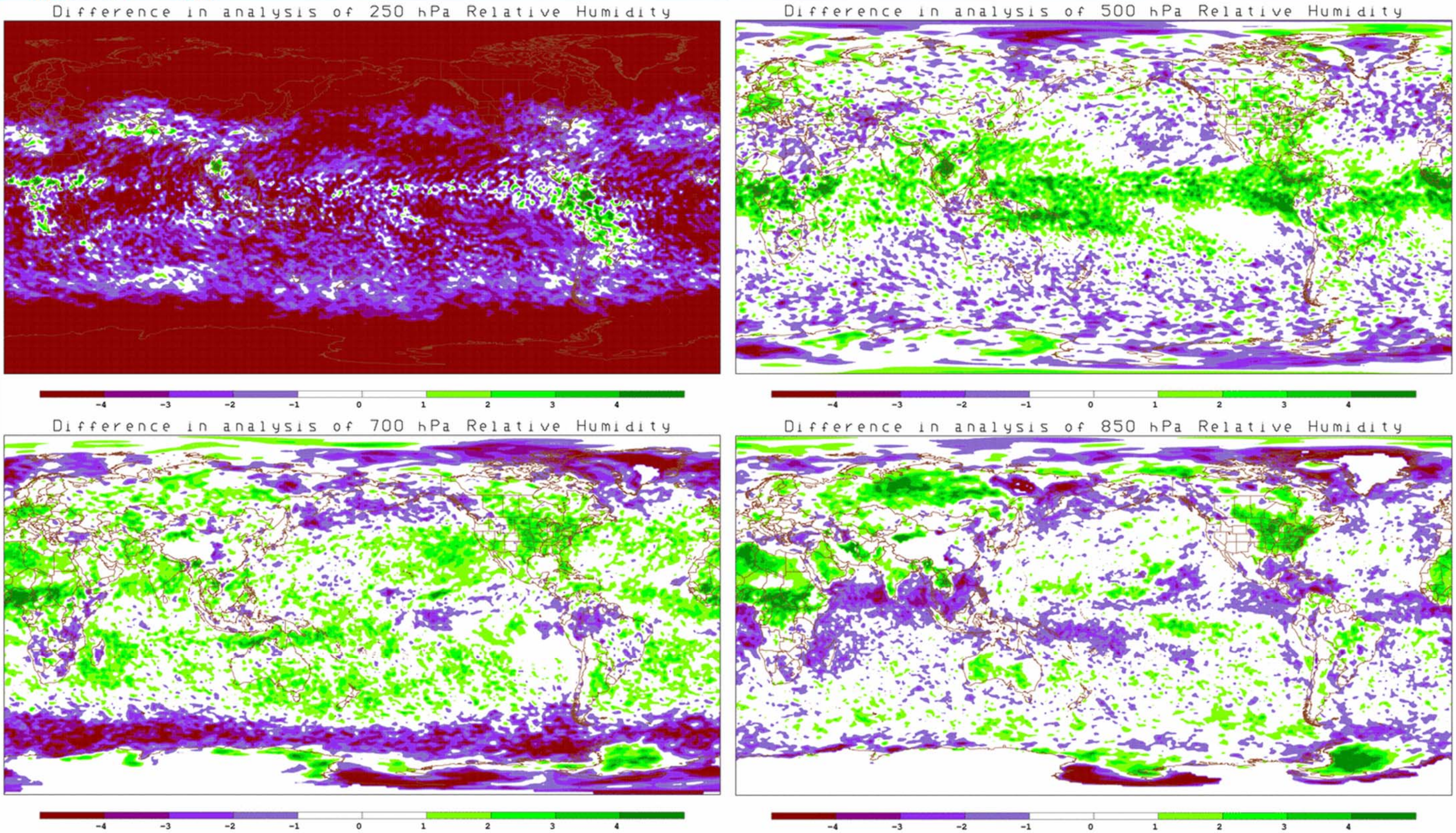
500 hPa Time series of RMS fit to RAOBS





Improvements in the analysis and 6 hour forecast

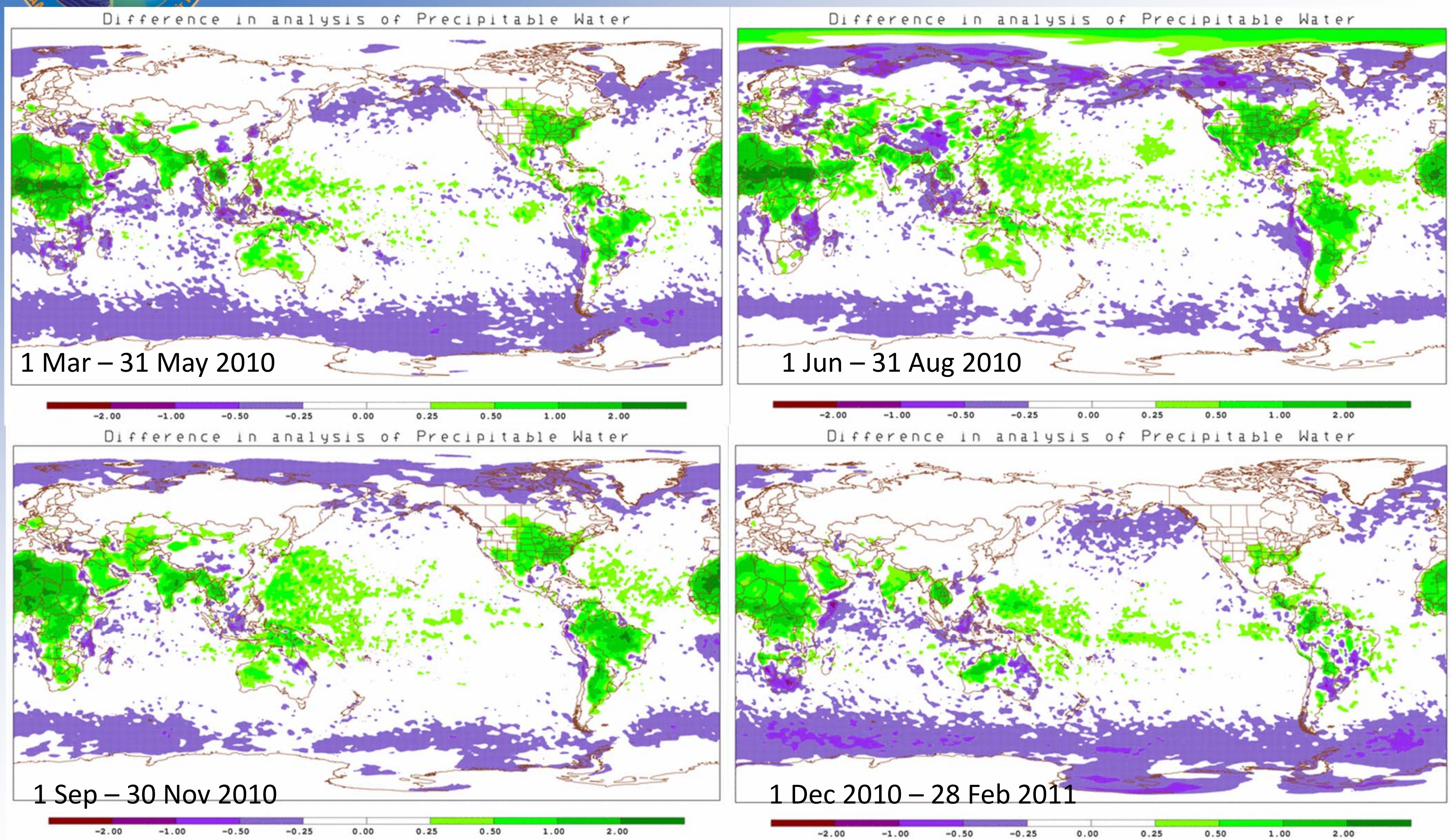
Analysis Differences of Relative Humidity at selected levels



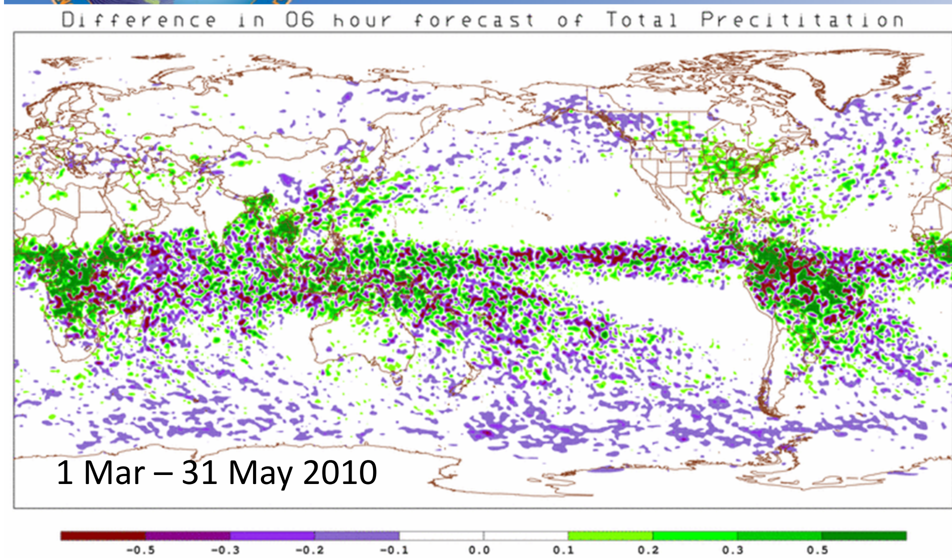
1 Mar – 31 May 2010

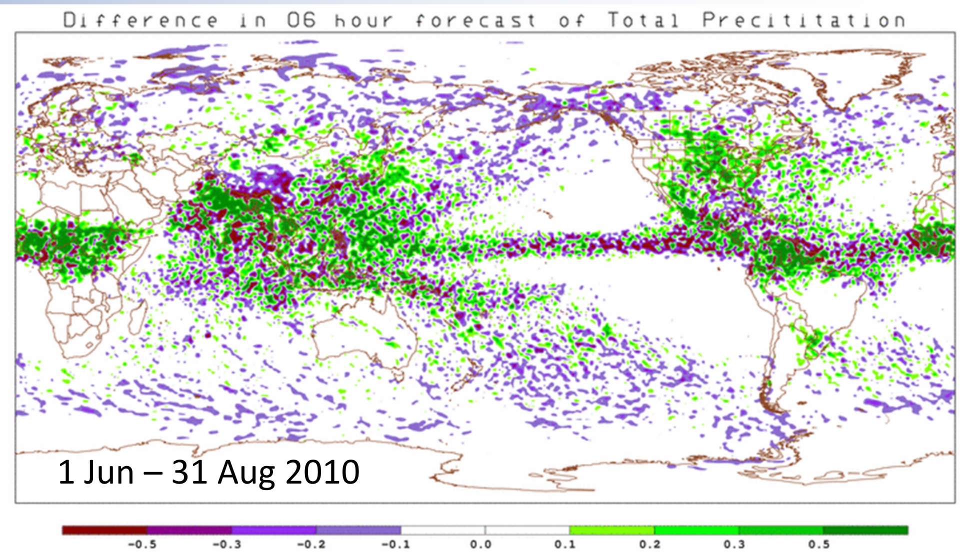
Experiment
Red < Green >

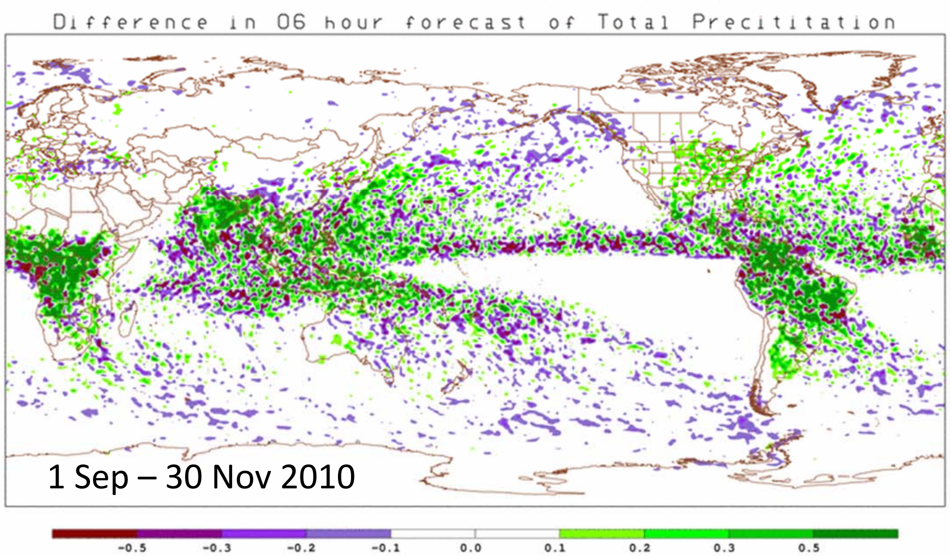
Analysis Differences of Precipitable Water

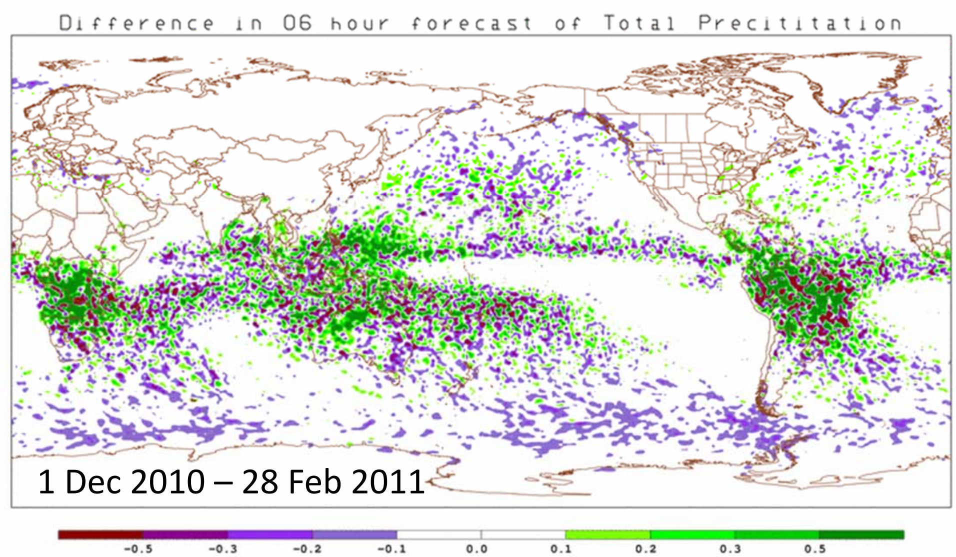


6 hour accumulated precipitation differences for each season









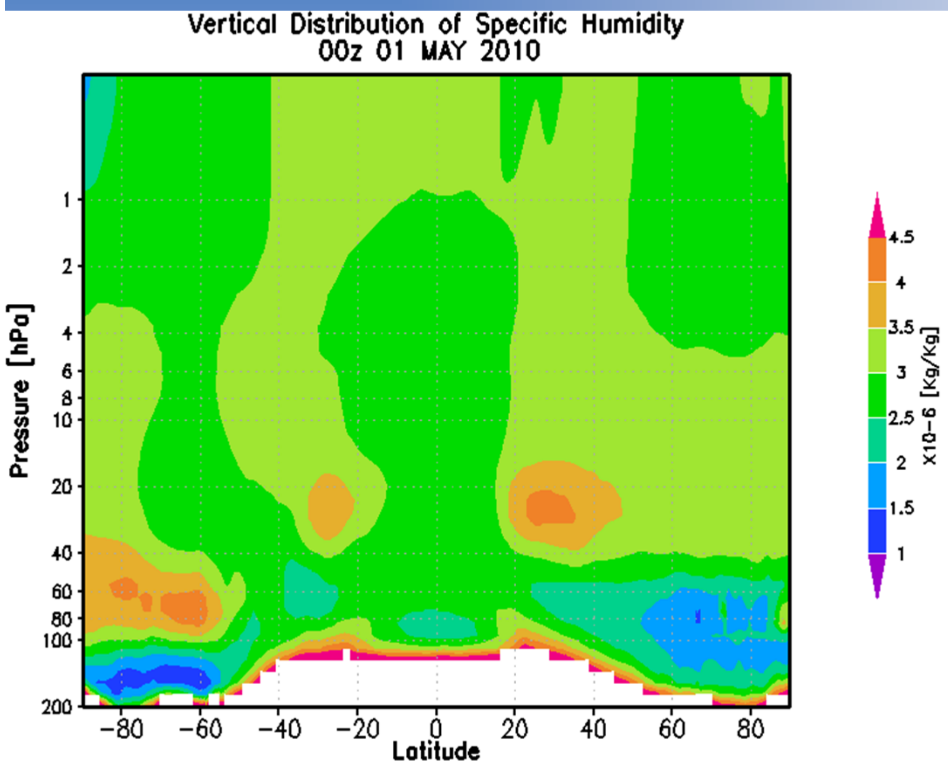
Summary

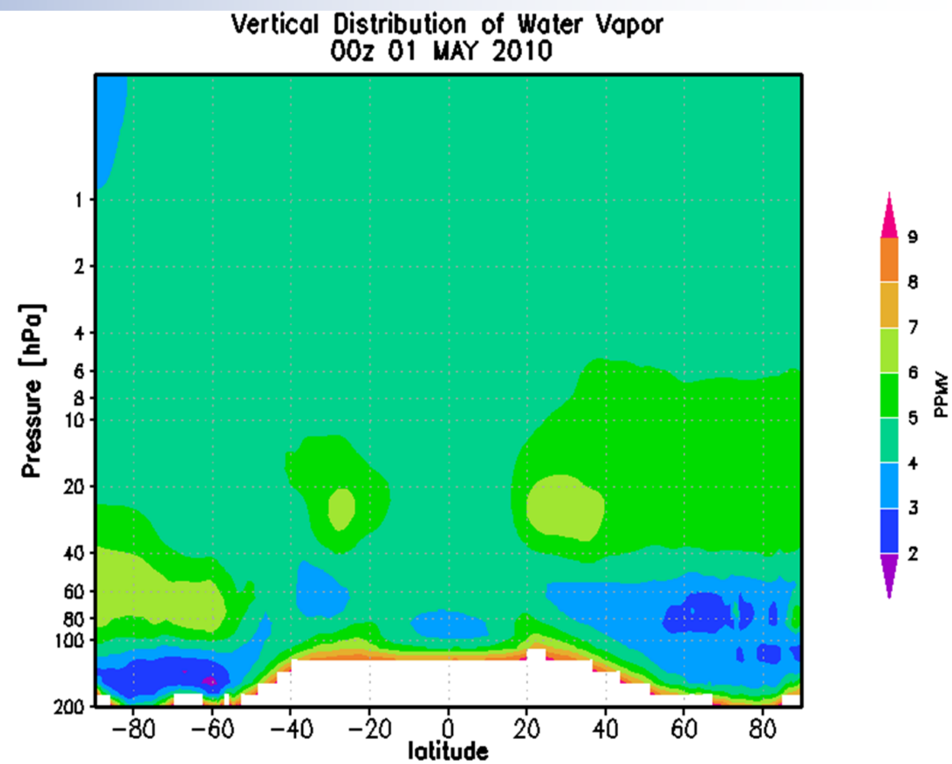
- Water vapor statistics show
  - Improvements with respect to rawinsondes are noted in the analysis and 6 hour forecast.
  - Upper troposphere is dryer.
  - Tropics have marginally higher PW
  - Polar regions are generally dryer.
  - Rainfall differences are noted up to 12 hours in all four seasons
  - Other seasons statistics are similar
- Non water vapor statistics are mostly neutral (not shown)
  - Anomaly correlations.
  - Wind, temperature, etc. fits to observations.

Stratosphere Water Vapor Assimilation Overview

- Using infrared radiances to “estimate” stratospheric moisture.
- These are moisture ESTIMATES
  - Observations are not available
  - Derived from jacobian tails
  - Uses a nudging approach
- 3 Sources of information
  - IASI (dominant)
  - AIRS
  - GPS-RO

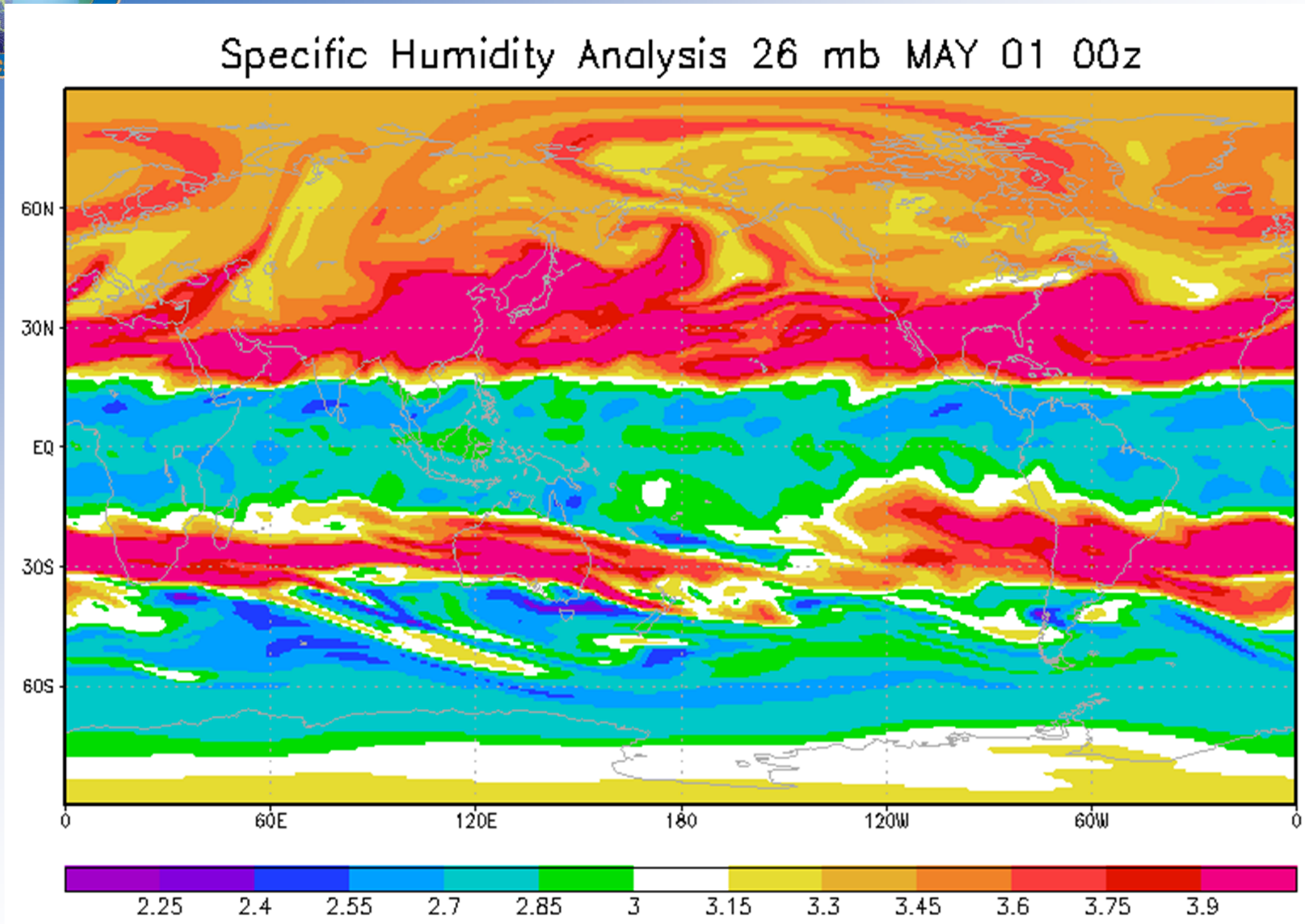
Vertical Distribution of Water Vapor





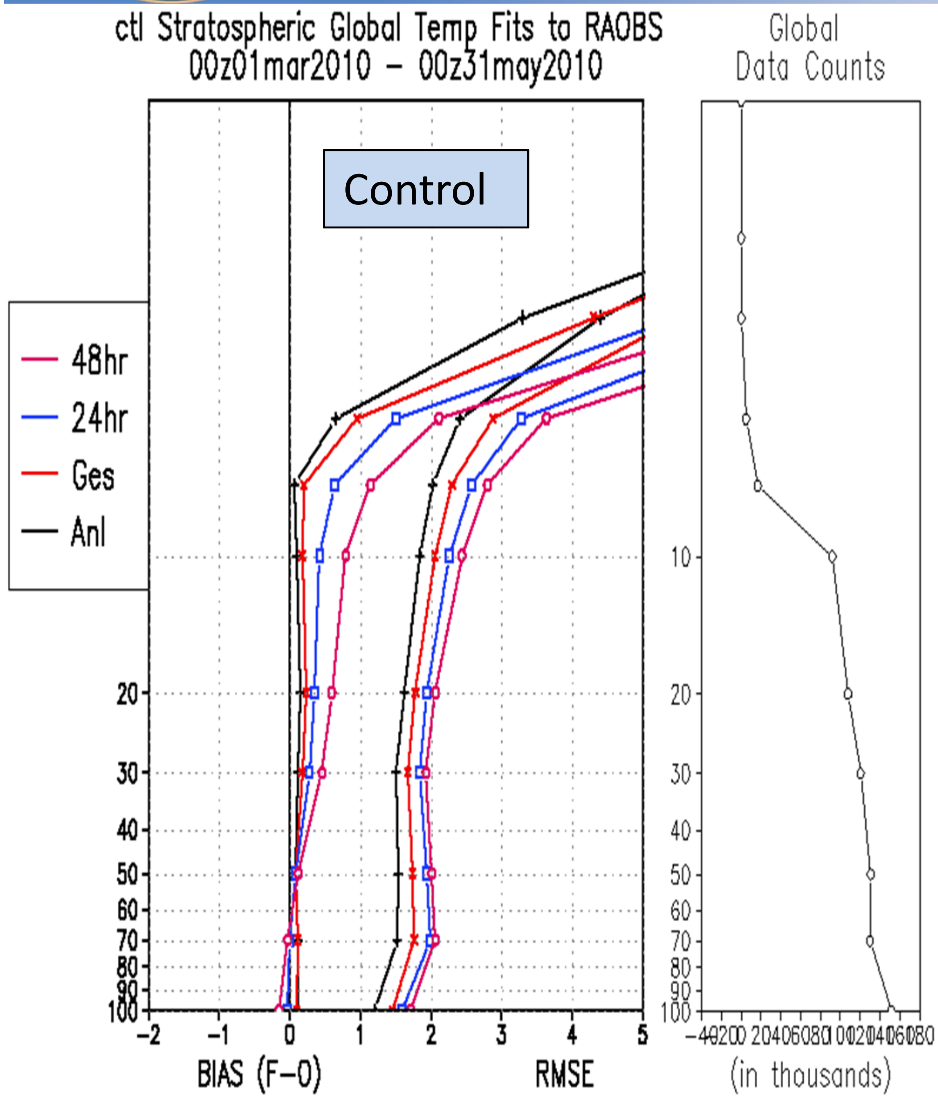
Standard longitudinal average (not ln(q))
Single assimilation cycle .

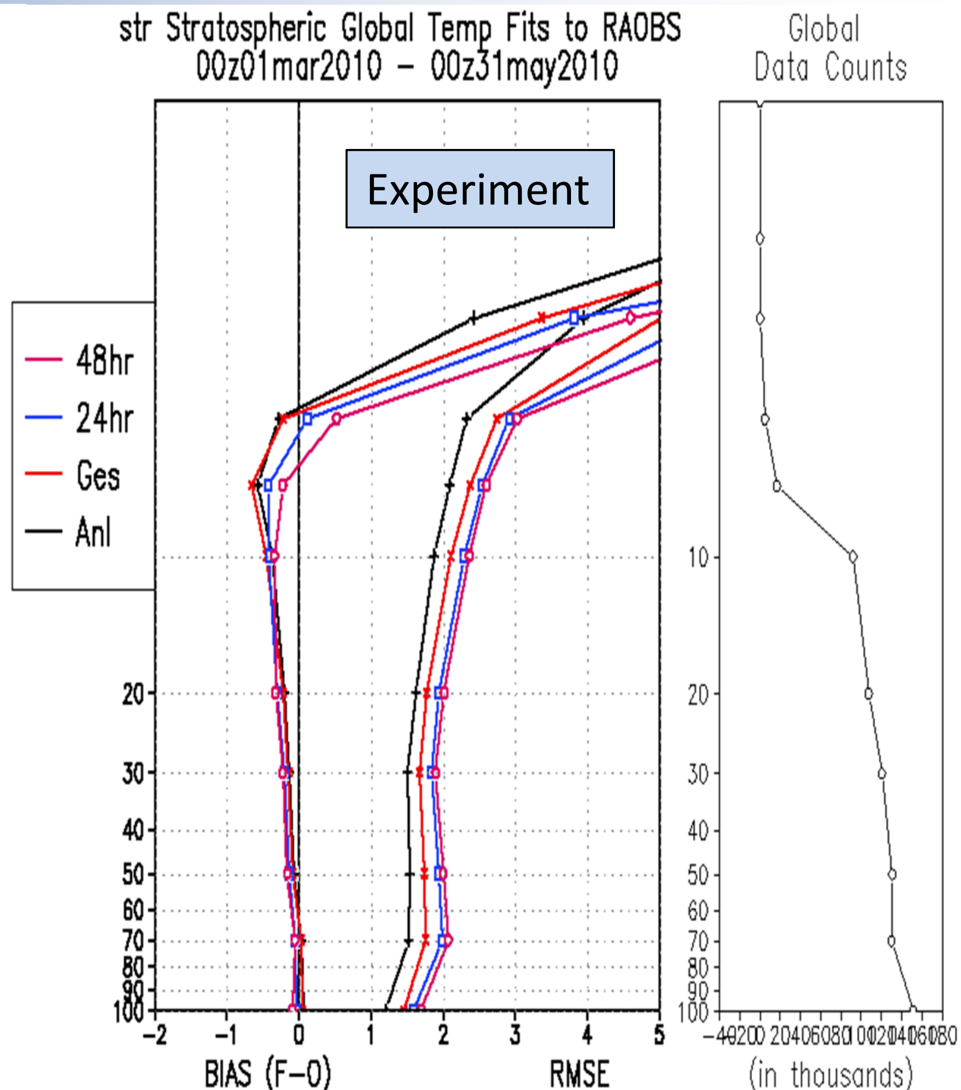
Horizontal Distribution of Water Vapor



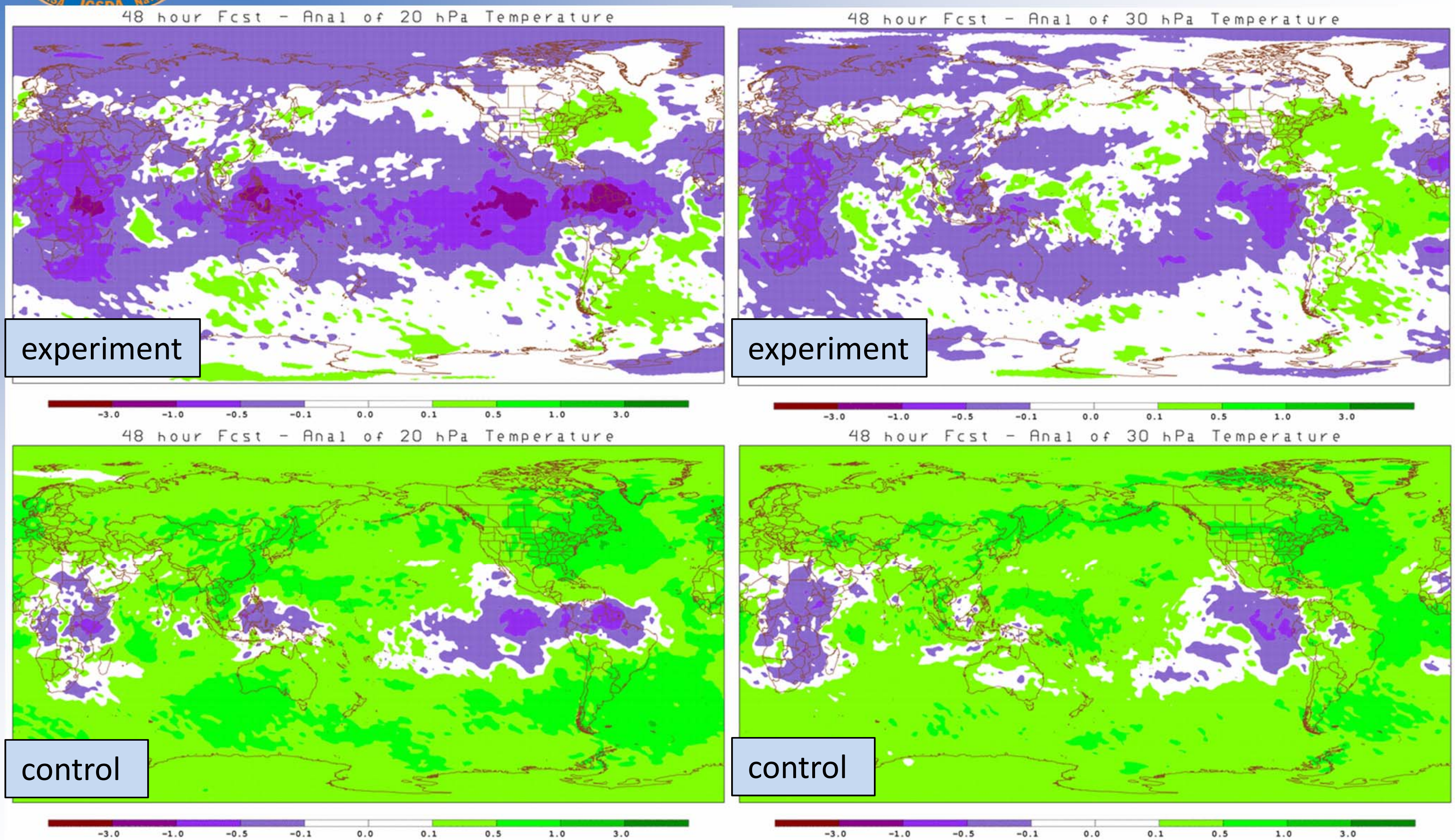
Colors are x10^{-6} [Kg/Kg]

Analysis and forecast stratosphere temperature fits to rawinsondes for March-April-May 2010





Stratosphere Forecast Temperature drift comparison (Forecast – Analysis) at 20 and 30 hPa



March-April-May 2010

Summary

- Using hyperspectral IR radiances, it is possible to generate reasonable estimates of specific humidity in the stratosphere.
- Qualitative stratospheric water vapor analysis with other sensors show:
  - Equal to slightly wetter with respect to HALOE.
  - Dryer with respect to SAGE II, Aura MLS, and MIPAS.
- Stratosphere water vapor assimilation requires a long spinup time
  - 2+ months after being initialized to > 3.0e-6 [Kg/Kg]
- Rawinsonde comparisons suggest:
  - A slightly cooler stratospheric temperature (cold bias).
  - A reduced stratospheric temperature drift with time.
- Stratospheric temperature comparisons with its own analysis are improved through 48 hours.