Constraints on GCM Total Water PDF Parameters from AIRS and High-Resolution Models

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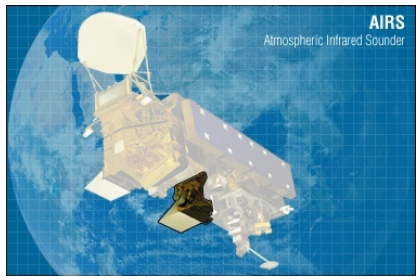
- Context/Motivation
- AIRS-based proxy
- Dependance on horizontal resolution from high resolution model
- Results from GCM and DAS experiments



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Context and Motivation

An assumption about the sub-grid scale distribution of total water must be made as part of GCM description of condensation/freezing and evaporation/sublimation processes in clouds. Current and recent GCMs assume:

- Uniform Distribution: Condense/Freeze when grid box RH > 100%
  Evaporation/Sublimation may proceed up to RH=100%

- 'Top Hat', Triangular: Two-parameter distributions with thresholds beyond which no condensation/freezing occurs. Parameters are mean and width. Relationship between width and 'Critical RH' is straightforward. (Most GCMs use this - Neale et al., 2010, Schmidt et al., 2006, Collins et al., 2008)

- Gaussian, other 2-parameter distributions, Beta, Generalized Extreme Value, assymmetric triangular, other distributions with more parameters (Norris, 2010)

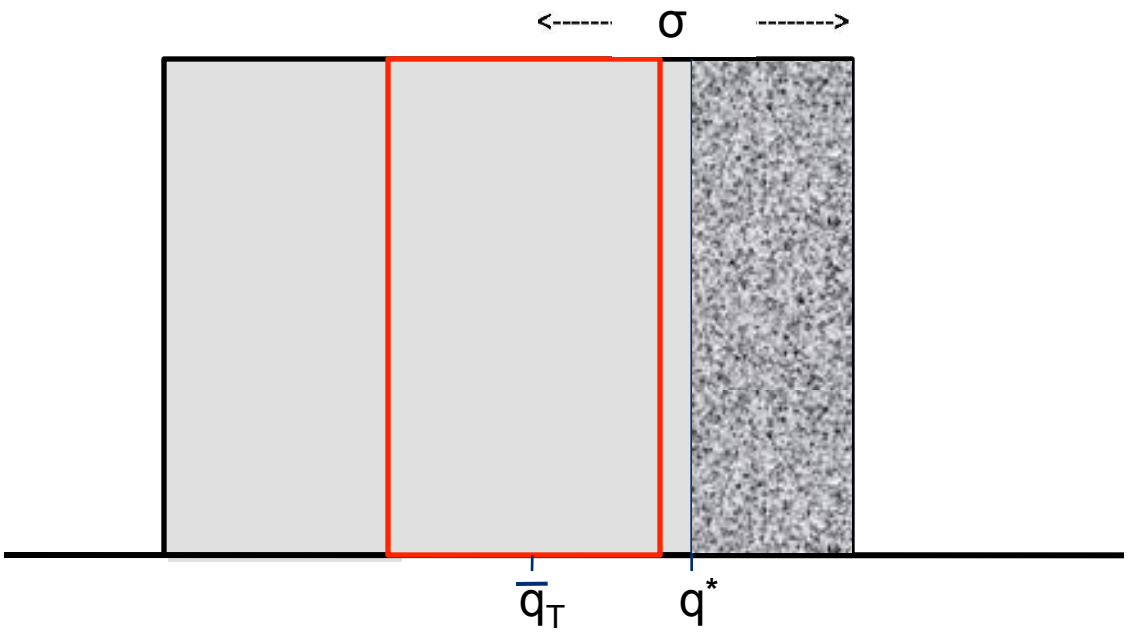
- Prognostic parameters (Tompkins 2002)

GCM relative humidity, cloud field and cloud forcing are highly sensitive to the choice and to vertical distribution of total water PDF parameters. The choice is generally based on behavior of GCM cloud and radiation fields with a given set of parameters (eg., Slingo and Ritter, 1985 ; Neale et al., 2010). CRM results have also been used to guide choice (eg., Tomkins, 2002 ; Zhu and Zuidema, 2009)

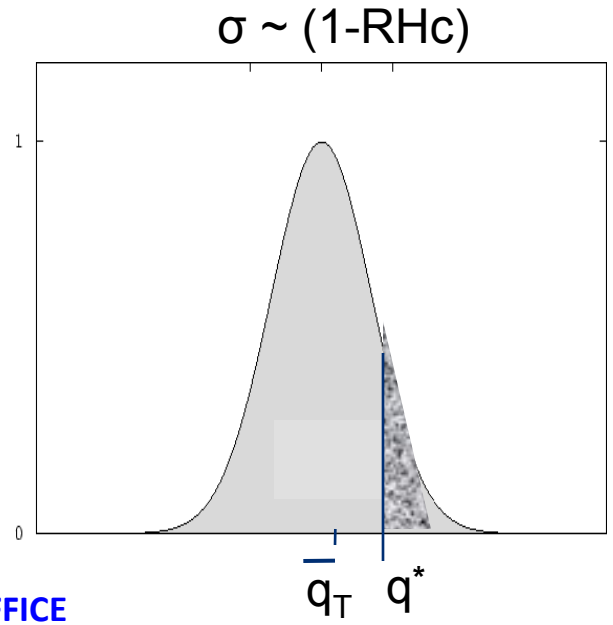
The quality of the latest generation of satellite observations allows their use to guide/ inform the choice of total water PDF (MODIS: no profile info ; AIRS: use proxy)

Total water PDF parameters, relationship to critical relative humidity

$$q^* \leq \bar{q_T} + \sigma q^* \quad \rightarrow \quad \frac{q_T}{q^*} = 1 - \sigma \quad \rightarrow \quad RH_{crit} \equiv 1 - \sigma$$

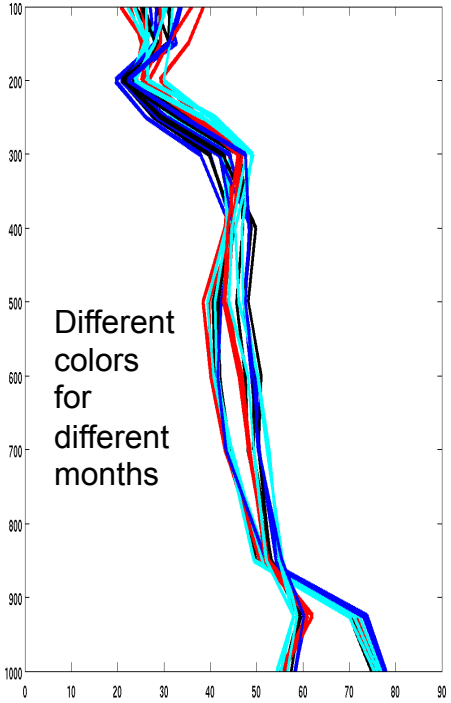


Larger σ (Wider PDF) – Condensate is shaded area
Smaller σ (Narrower PDF) – No condensate/cloud

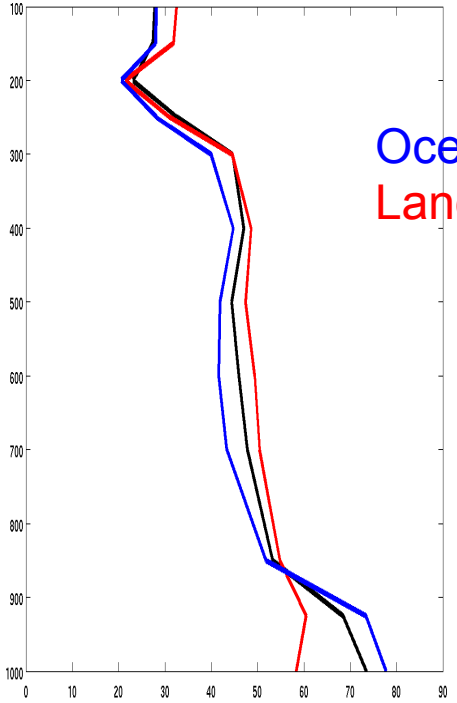


AIRS RH01 Diagnostic (RH when $0<C_f<0.1$)

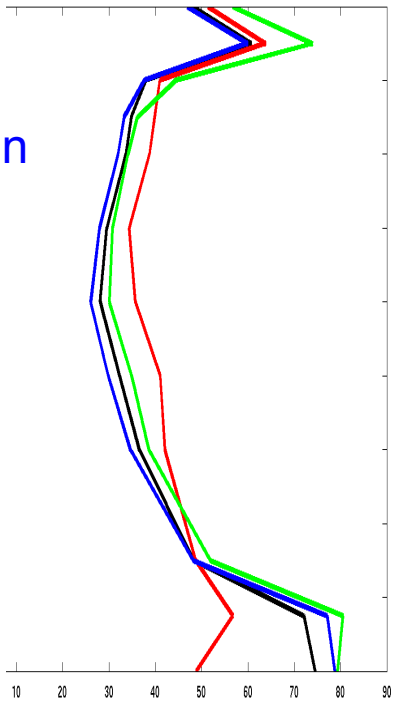
Global – All Months



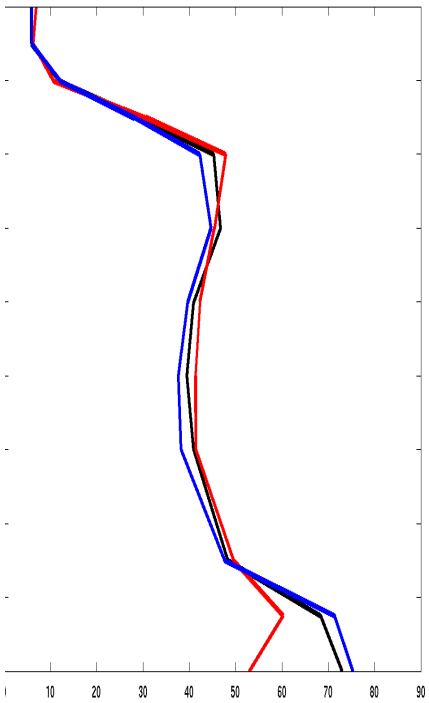
Global



Tropics



Extratropics



- Profiles show small RH01 aloft (wider PDF), large nearer surface (narrower PDF).
  [Resembles RHcrit values used in GCMs by tuning to radiative fluxes]

- Land Ocean contrast is more important than seasonality or latitude

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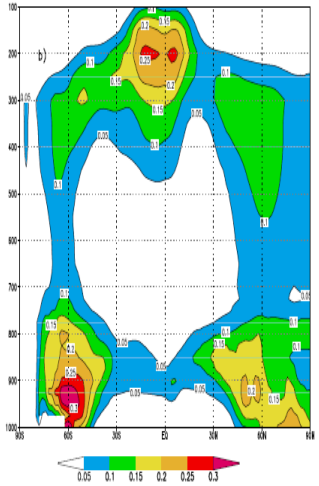
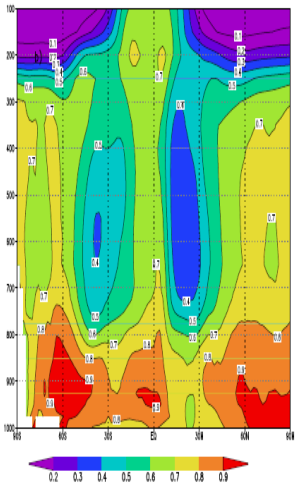
Impact on GCM simulation of AIRS-Guided RHcrit

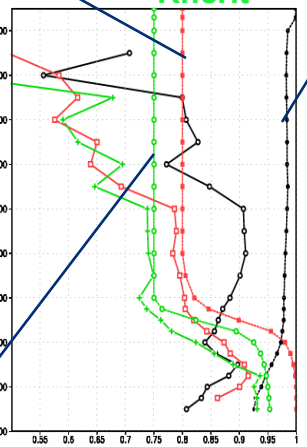
Cloud Frac



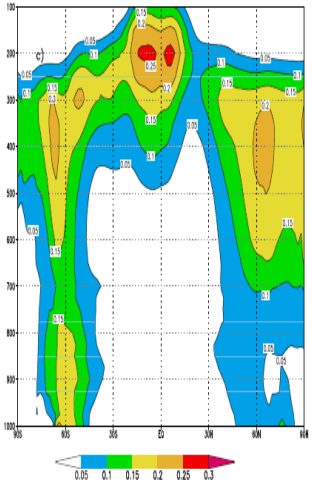
RH



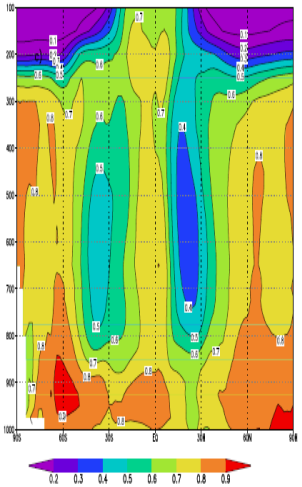
Rhcrit
Rhcrit
Rhcrit



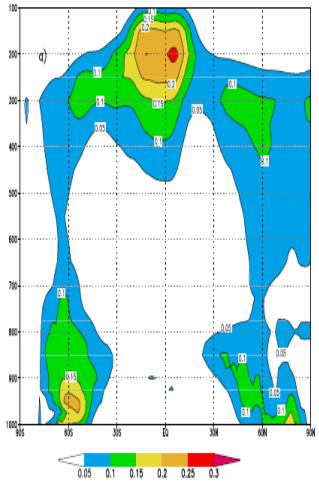
Cloud Frac



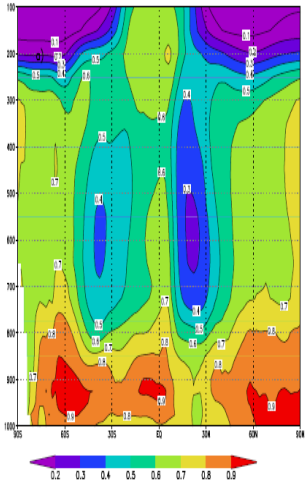
RH



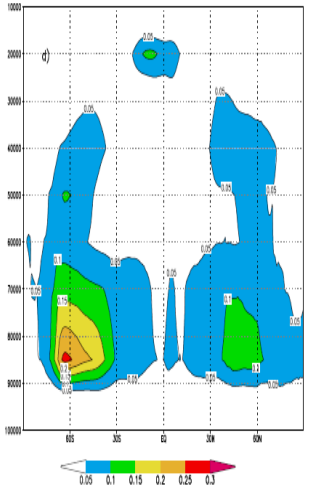
Cloud Frac



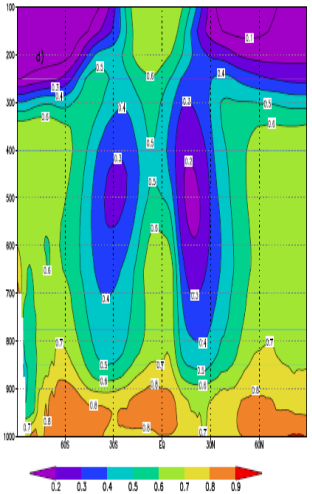
RH



AIRS Cloud Frac



MERRA RH



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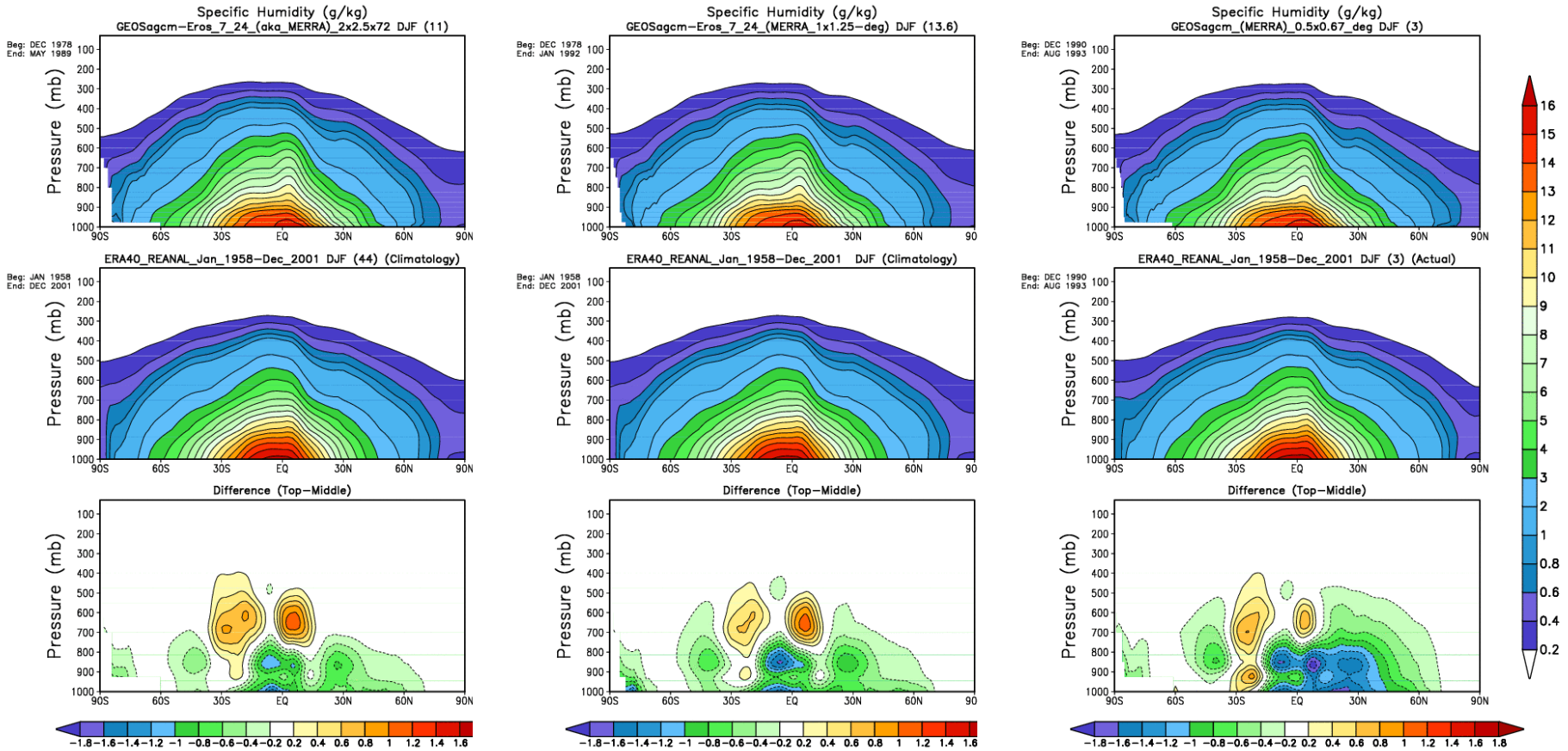
Dependance of Humidity on Horizontal Resolution

GEOS-5 AGCM "Eros" Generation (used for MERRA)



2° x 2.5°

1° x 1°

0.5° x 0.67°

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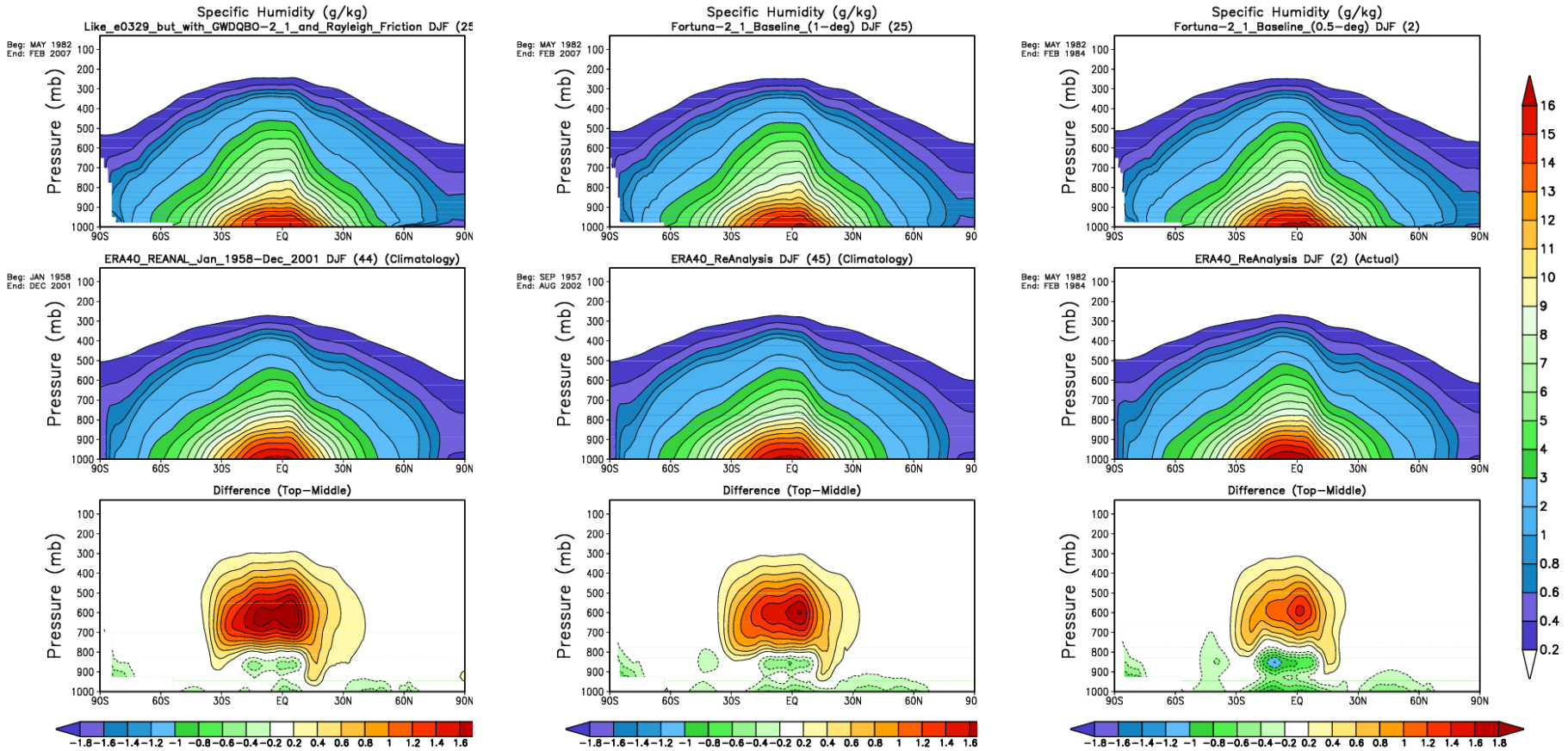
Dependance of Humidity on Horizontal Resolution

GEOS-5 AGCM early "Fortuna" Generation



2° x 2.5°

1° x 1°

0.5° x 0.67°

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RHcrit Dependance on Horizontal Resolution

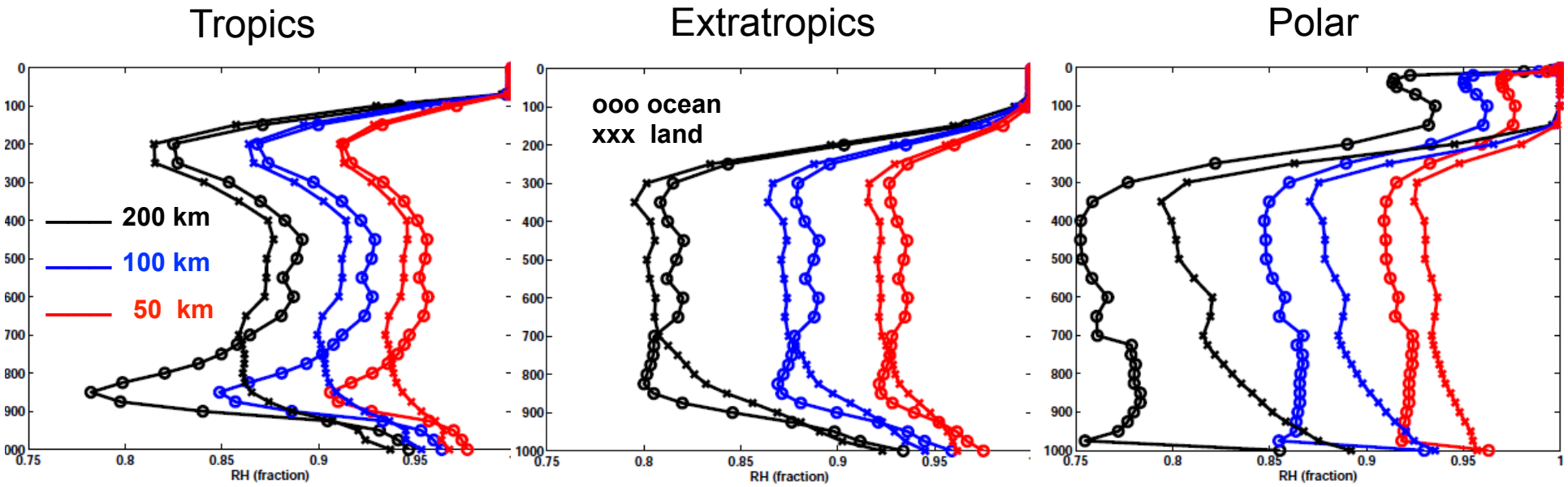
Intuition suggests that subgrid scale variability of total water would depend on grid size, and in particular decrease as the grid size decreases. This would imply that RHc estimates increase as grid size decreases.

GEOS-5 global model simulation in its cubed sphere grid formulation at approximately 10 km horizontal resolution was used to examine the sub-grid scale variability of total water for several coarser resolution grid sizes.

Subgrid scale variance of total water within 200km, 100km, and 50 km regions was computed using the 10 km model output fields. RHc profiles were calculated assuming that the width of the PDF is twice the subgrid scale standard deviation.

Note: RHcrit specified in the model used for this simulation has minimum near surface, values near 1. aloft (RHcrit black profile from a previous slide)

RHcrit Dependance on Horizontal Resolution

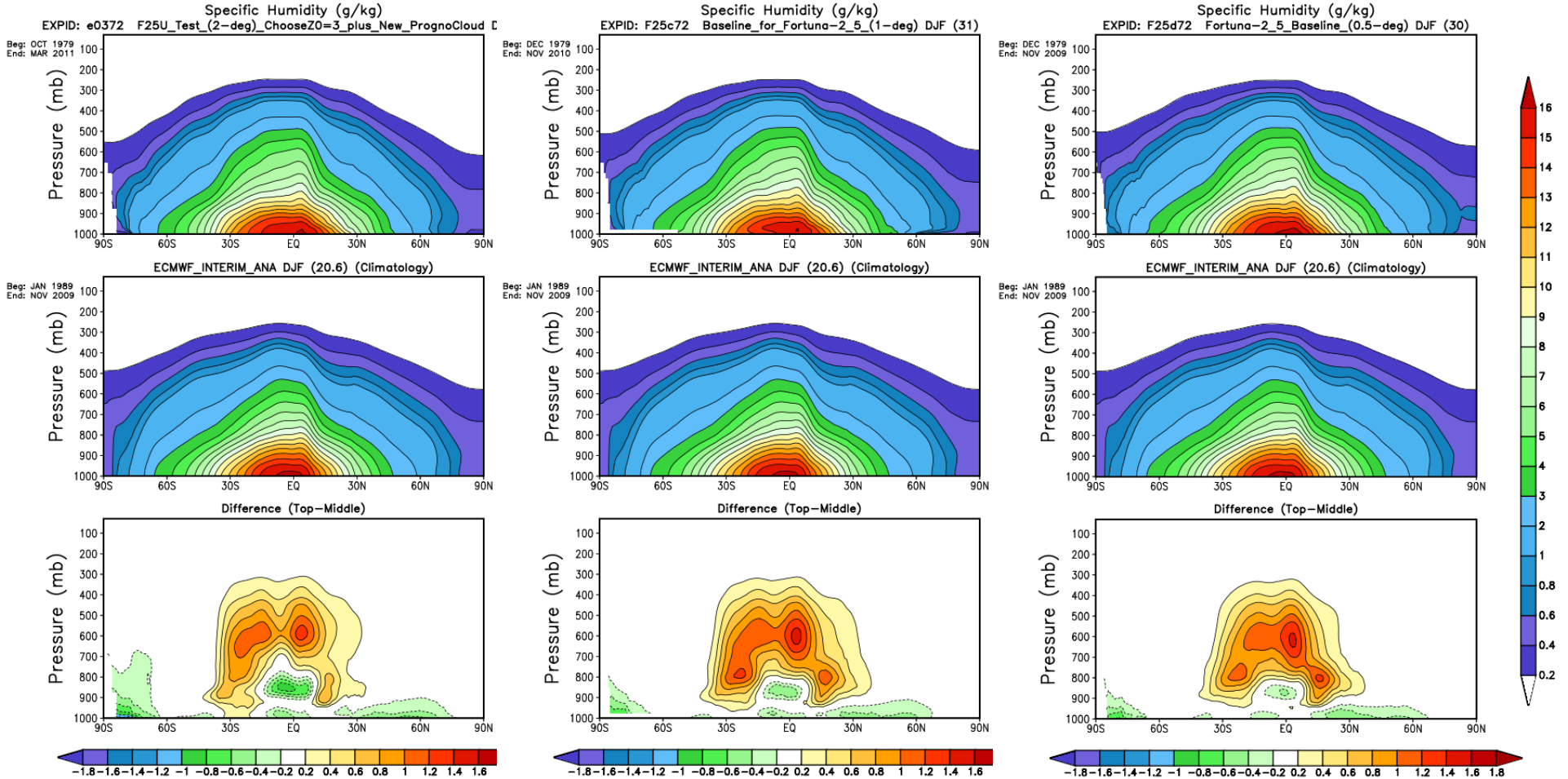


- General vertical profile of the critical relative humidity is unchanged as the grid resolution changes, for all regions and underlying surfaces, and shifts to higher values with smaller grid size.

- Vertical structure similar to the vertical structure from AIRS RH01

Dependance of Humidity on Horizontal Resolution

GEOS-5 AGCM "Fortuna-2_5" (used for all AR5)



2° x 2.5° | 1° x 1° | 0.5° x 0.67°

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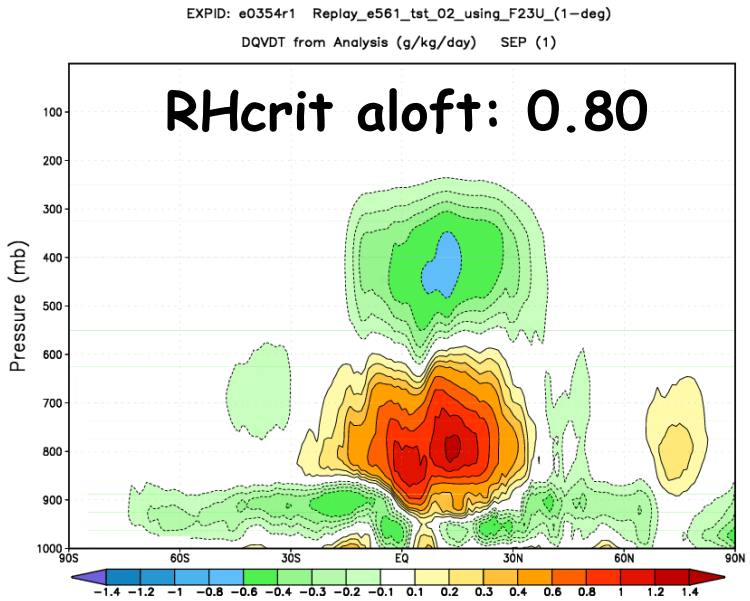
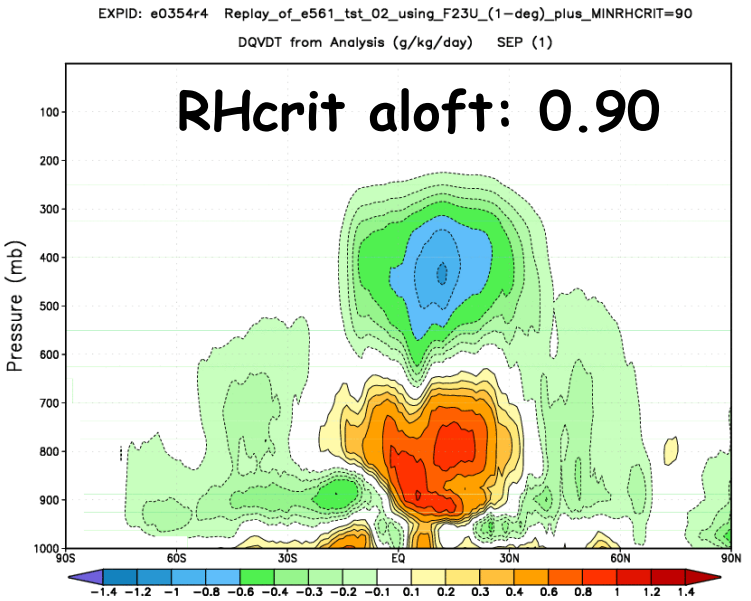
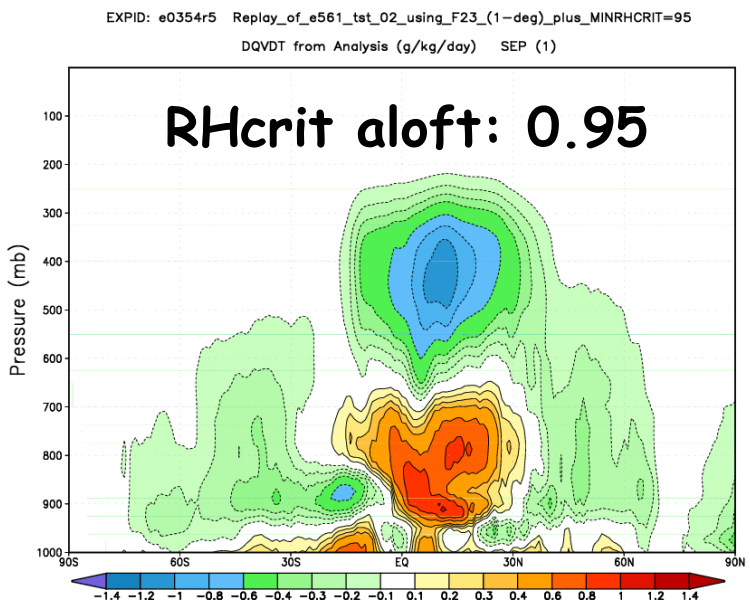
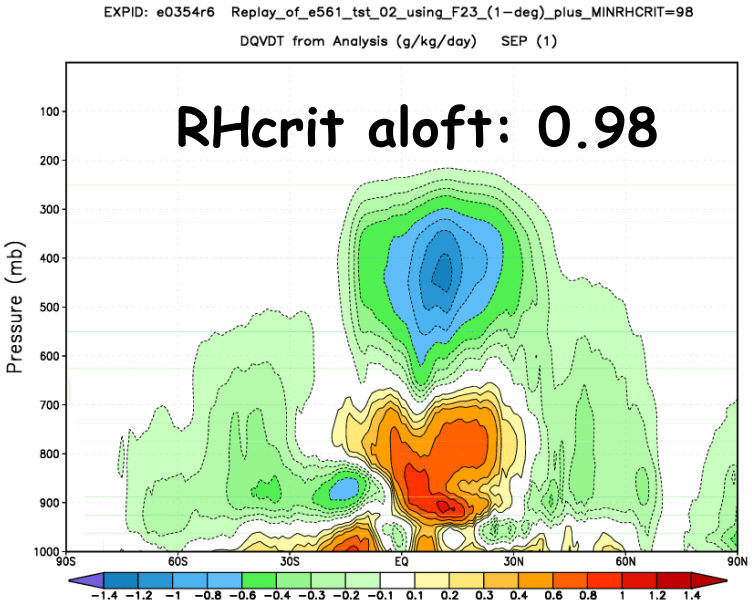
RHcrit for Data Assimilation – Analysis Increments

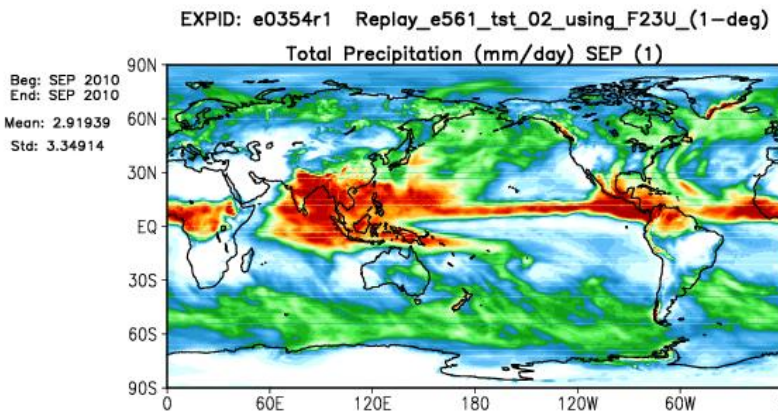




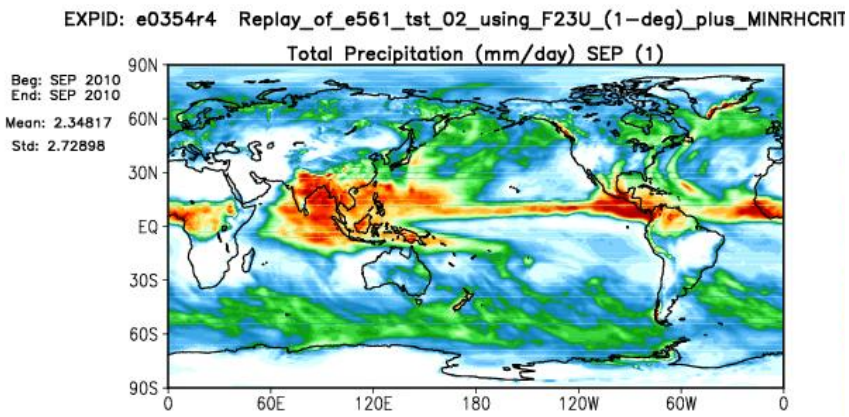




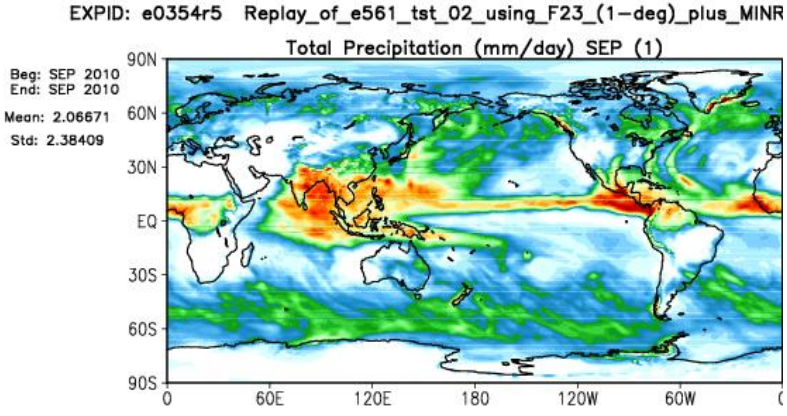
RHcrit for Data Assimilation – 1° "Replay"



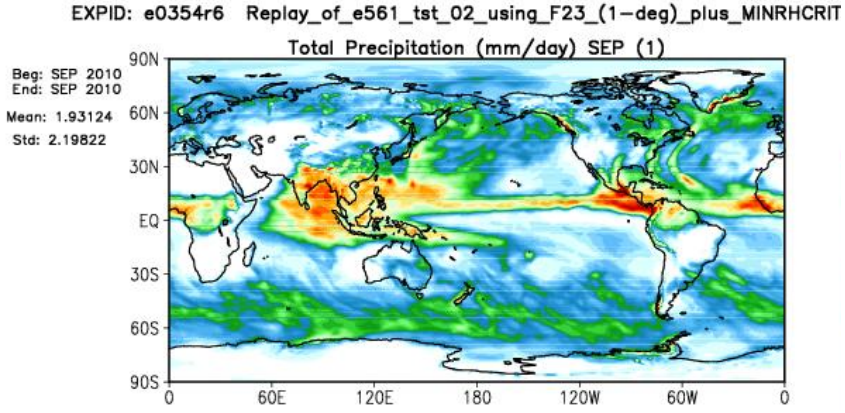
RHcrit aloft: 0.80



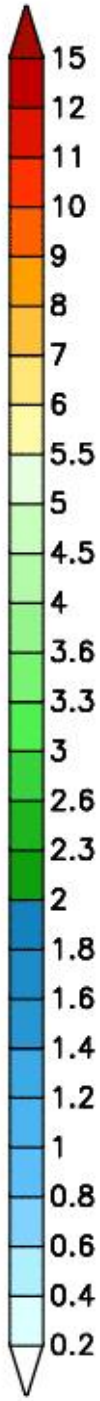
RHcrit aloft: 0.90



RHcrit aloft: 0.95



RHcrit aloft: 0.98



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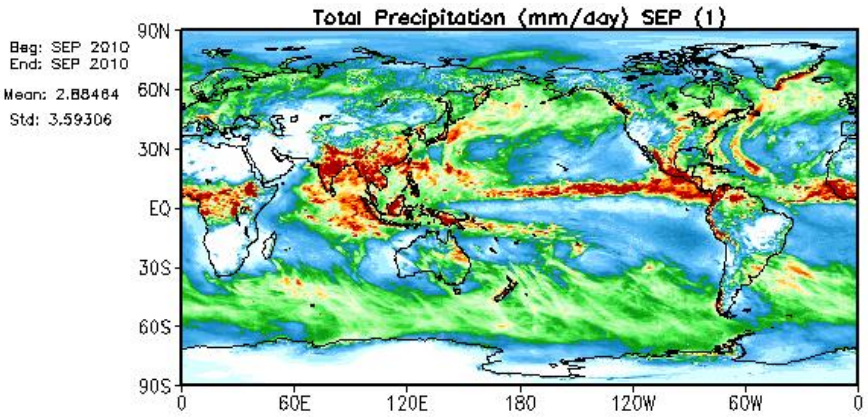
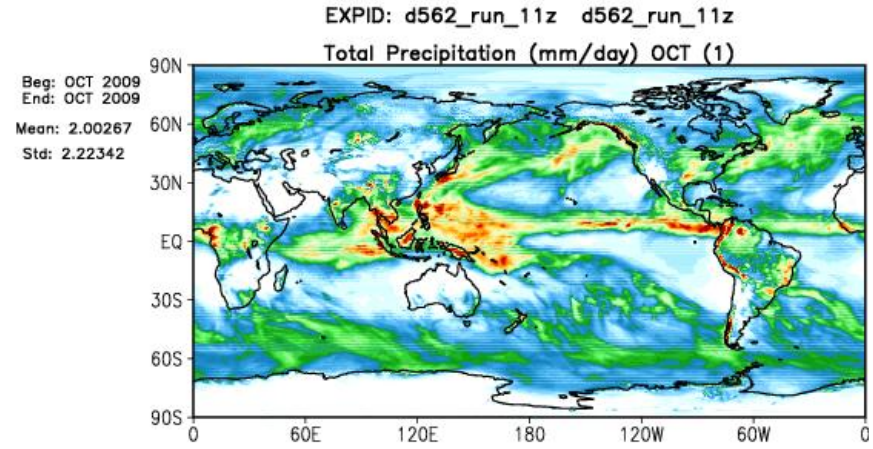
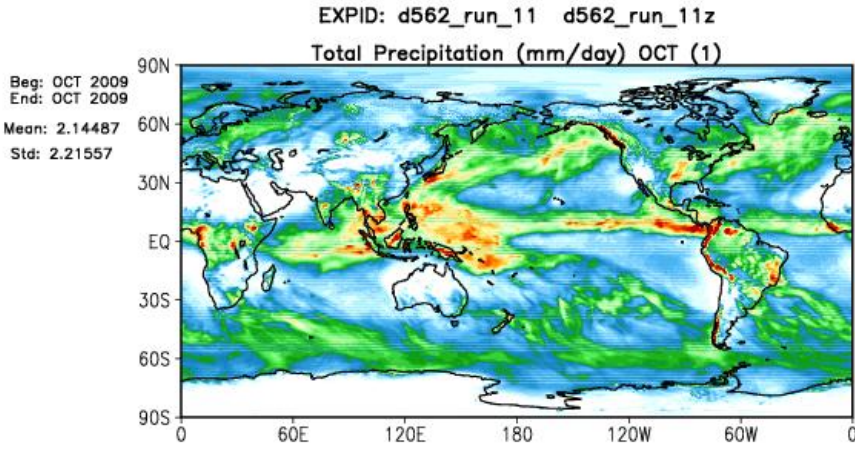
RHcrit for Data Assimilation – 0.5°



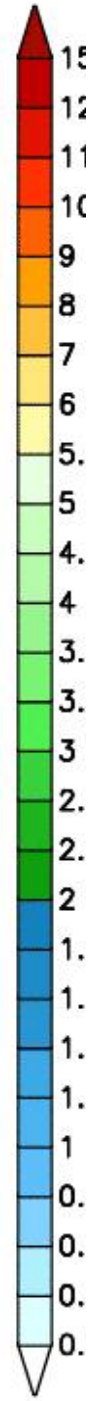
RHcrit aloft: 0.80



RHcrit aloft: 0.95



RHcrit aloft: 0.98



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Summary

- GCM climate is sensitive to prescribed with of total water PDF/Critical RH

- AIRS monthly mean cloud amount and relative humidity fields were used to compute the "RH01" diagnostic – a proxy to inform the choice of GCM Critical RH profile.

- Results from 10 km model simulation using GEOS-5 show that RHcrit should increase with increasing resolution

- Implementing resolution-dependant RHcrit eliminates change of simulated RH with resolution and reduces RH bias at higher resolutions.

- Resolution-dependant RHcrit is important in data assimilation mode. It reduces analysis increments in tropical lower atmosphere and reduces excessive precipitation problem at higher resolution.

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GEOS-5 AGCM "Nature Run"

- Cubed Sphere grid ~10 km global resolution
- 2 years: May 2005 - August 2007
- Interactive aerosol (GOCART)

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