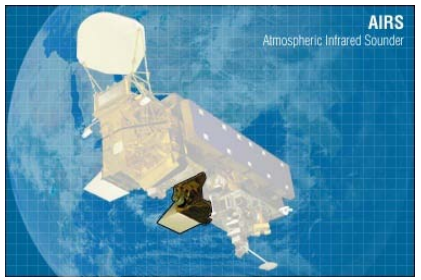
Constraints on GCM Total Water PDF Parameters from AIRS and High-Resolution Models

Andrea Molod, NASA/GMAO

- **Context/Motivation**
- **Define/Justify AIRS-based proxy**
- **Dependance on horizontal resolution from high resolution model**



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Context

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)

Motivation

- Sensitivity of GCM relative humidity, cloud field, cloud forcing to choice and to vertical distribution of total water PDF parameters

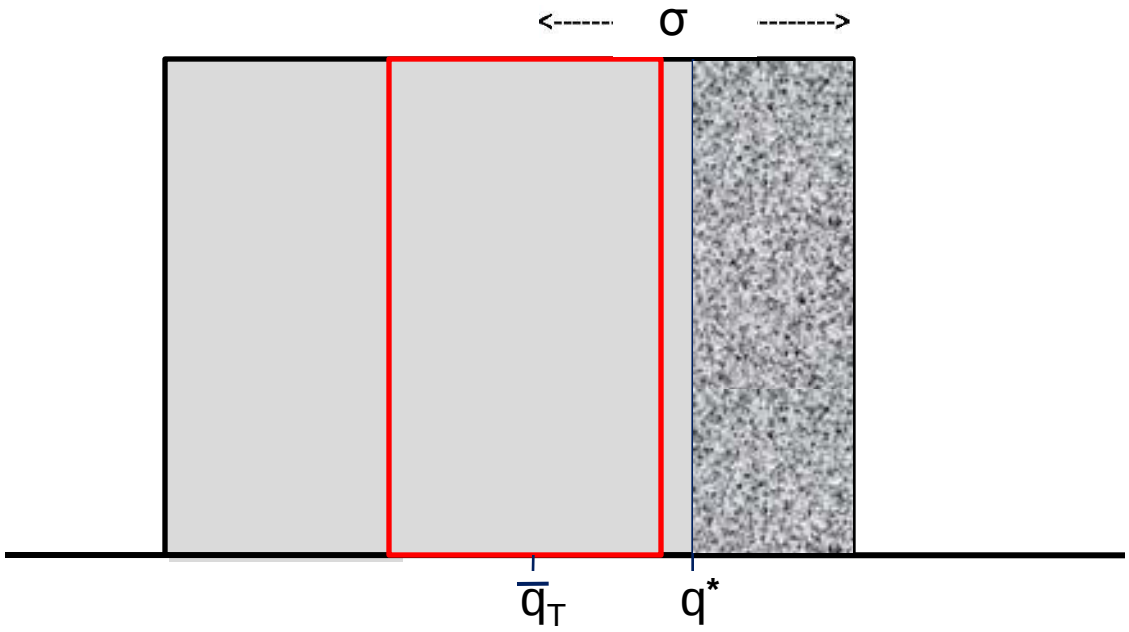
- Choice generally based on behavior of GCM cloud and radiation fields with a given set of parameters (eg., Slingo and Ritter, 1985 ; Neale et al., 2010)

- 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

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



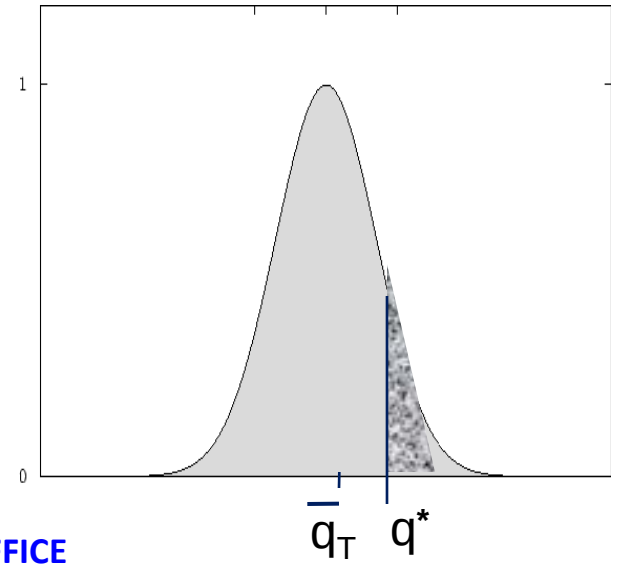
$$C_f = \int_{q^*}^{\inf} P(q_T) dq_T \quad where \quad \int_{-\inf}^{\inf} P(q_T) dq_T = 1$$

$$q_c = \int_{q^*}^{\inf} (q^* - \bar{q_T}) P(q_T) dq_T$$

Larger σ (Wider PDF) – Condensate is shaded area

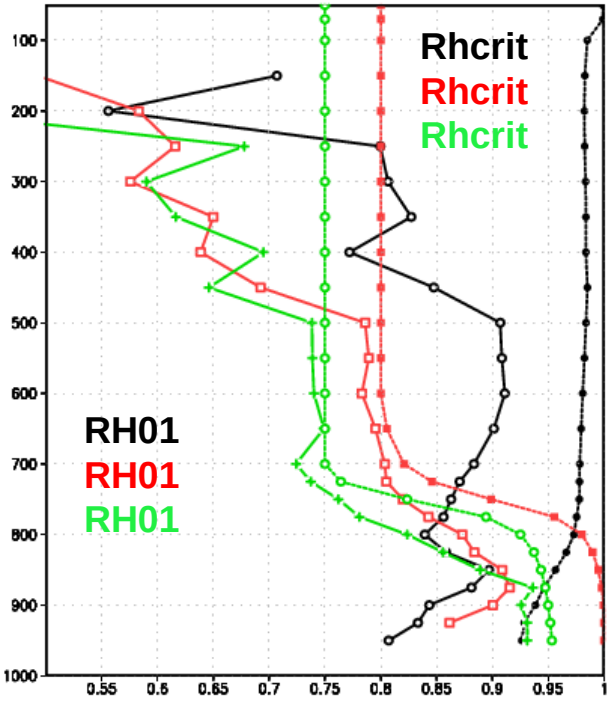
Smaller σ (Narrower PDF) – No condensate/cloud

σ ~ (1-RHc)



"RH01" Diagnostic – Guidance for Critical RH

RH of grid boxes with 0 < Cloud Fraction < 10%



Connection between Rhcrit of GCM and RH01 Diagnostic

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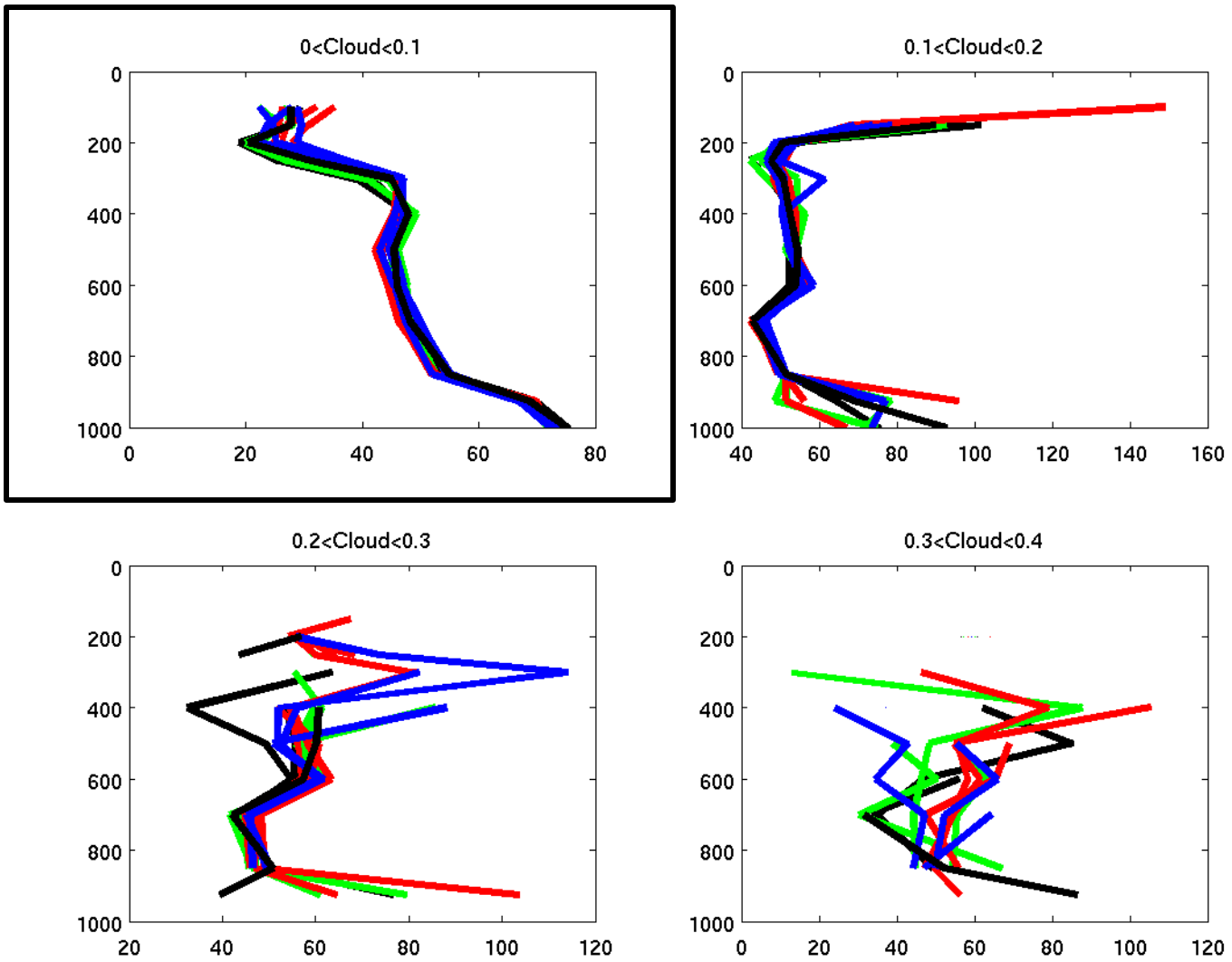
AIRS RH01 Diagnostic

RH01



RH01 from AIRS is computed using monthly mean values of cloud fraction and RH. Impact was found to be small using MERRA RH01 from monthly and 3-hourly fields.

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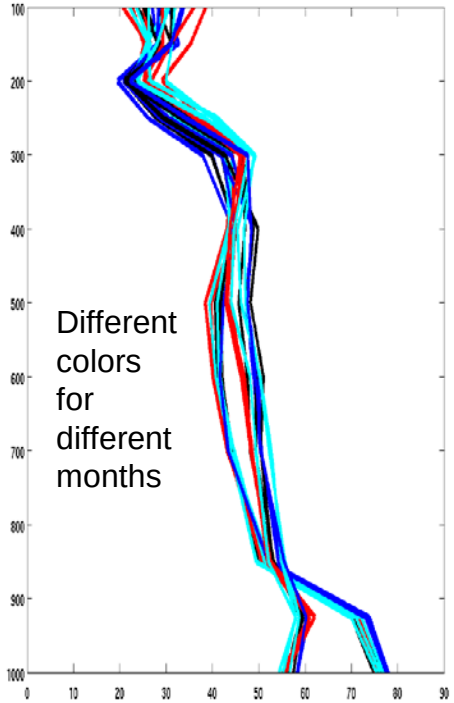
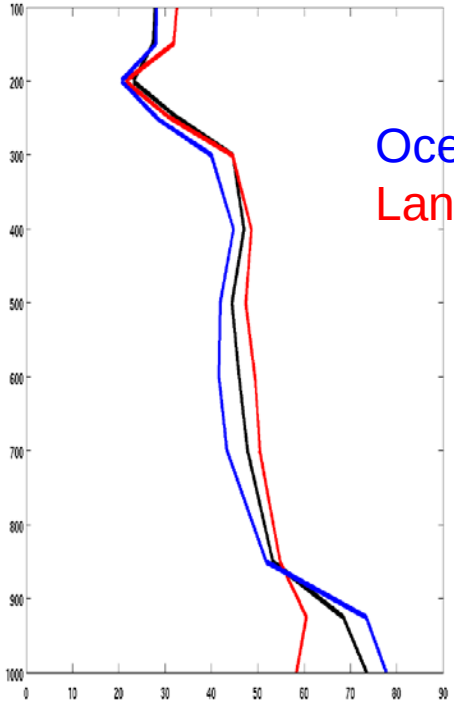
AIRS RH01 Diagnostic

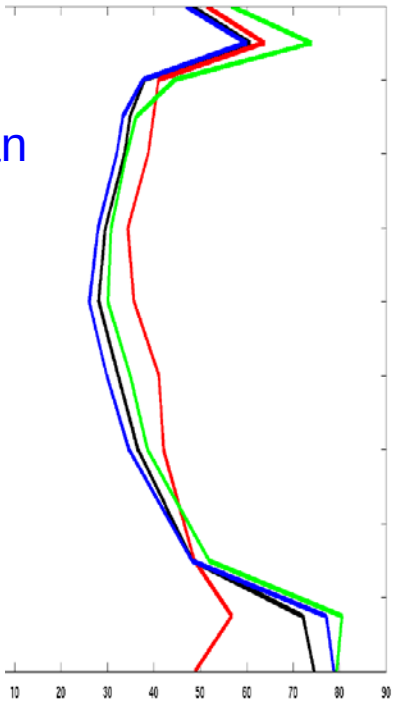
Global – All Months



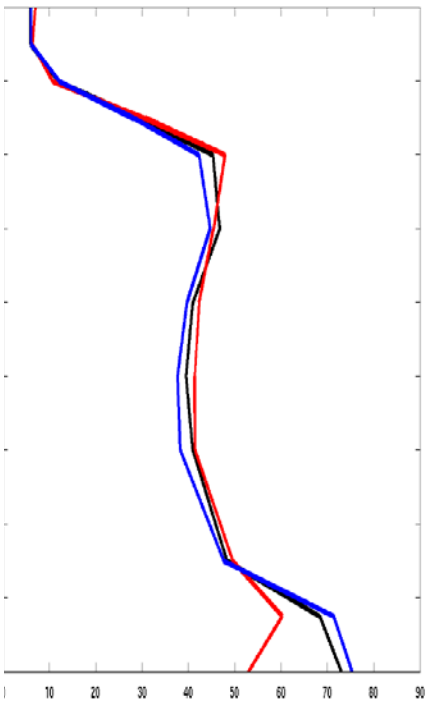
Global



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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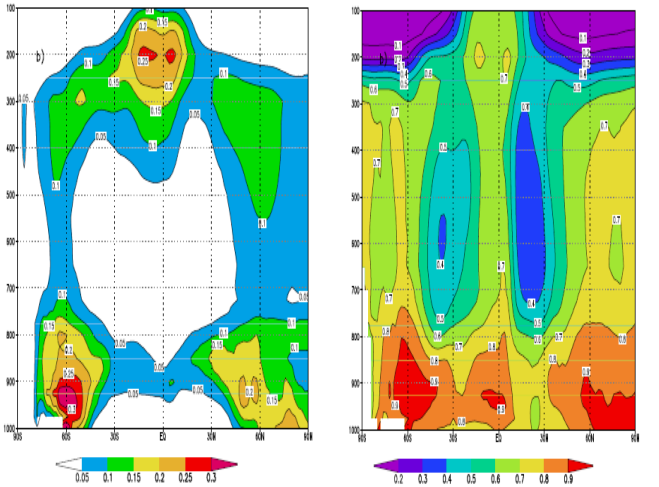
Impact on GCM simulation of AIRS-Guided RHcrit

Cloud Frac

RH



Rhcrit
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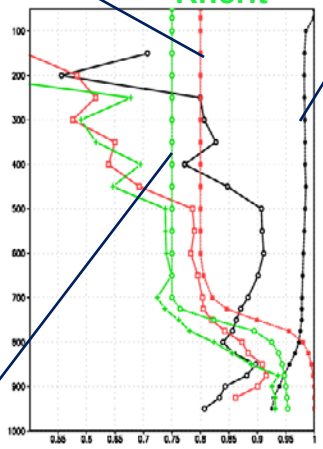
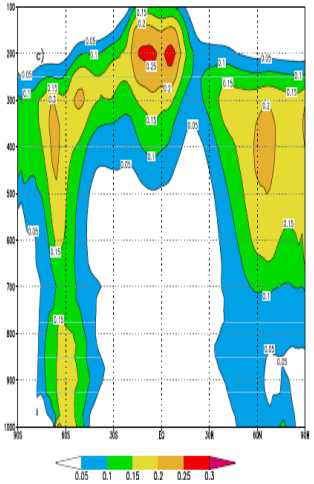
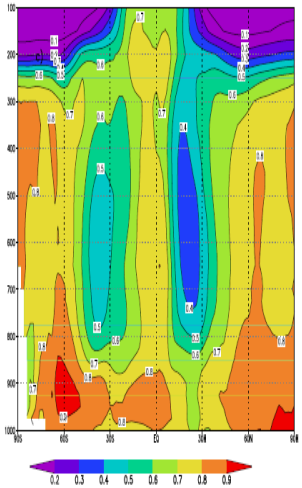


Cloud Frac

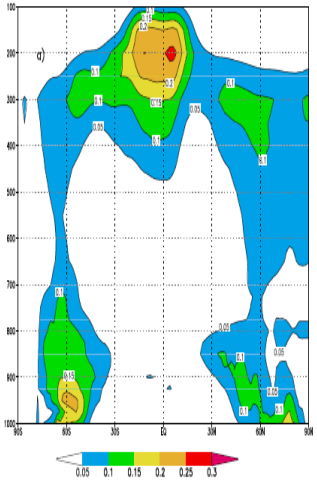
RH

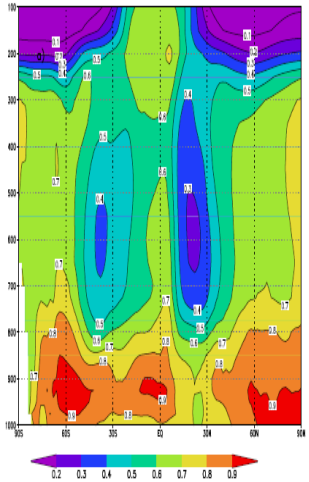




Cloud Frac

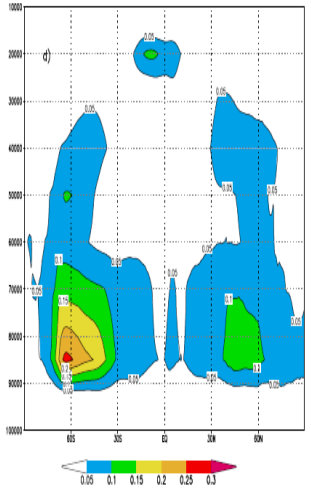
RH

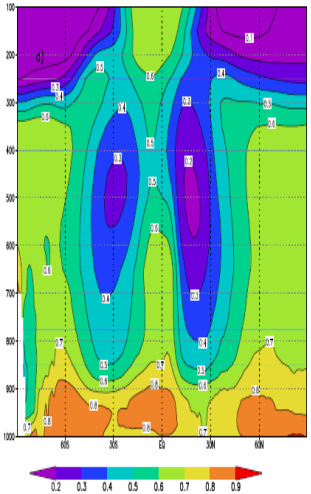




AIRS Cloud Frac

MERRA RH





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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.

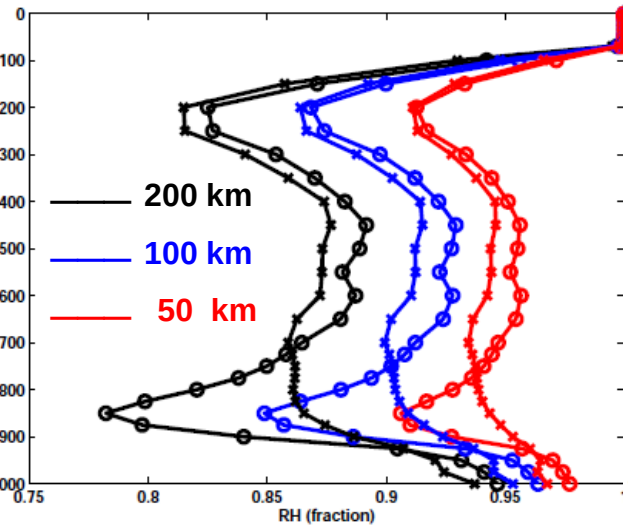
GEOS-5 global model simulation in its cubed sphere grid formulation at approximately 10 km horizontal resolution was used to examine the sub-grid scale variability of total water for several coarser resolution grid sizes.

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 previous slide)

RHcrit Dependance on Horizontal Resolution

Tropics



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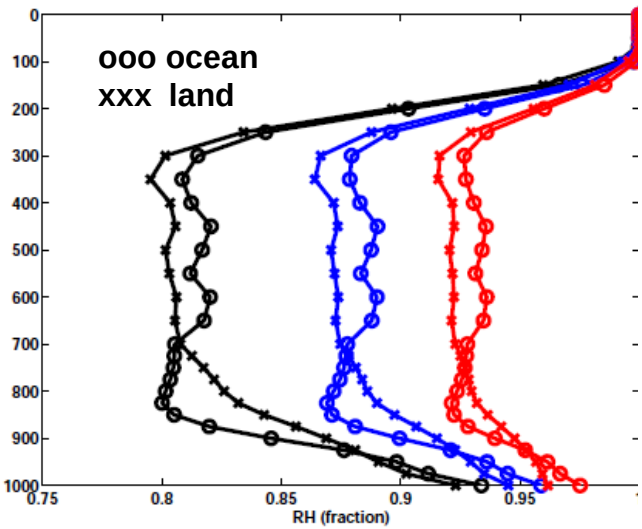
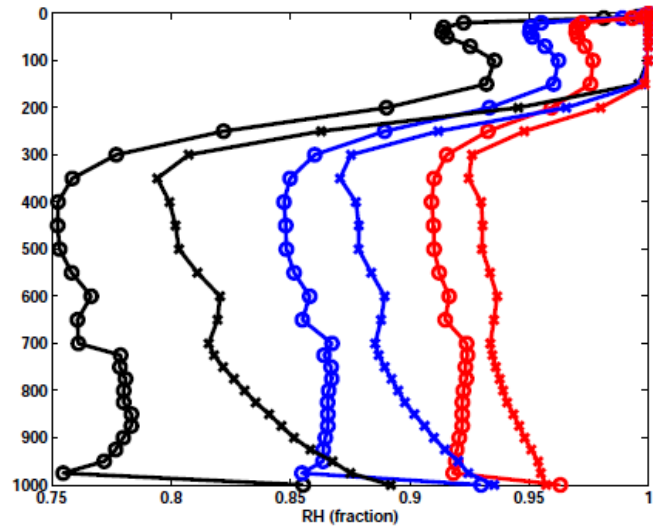


Polar



- 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

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 – RH when the cloud fraction is greater than zero and less than 10%.

- RH01 diagnostic corresponds to Critical RH and AIRS RH01 can be used to inform choice of GCM Critical RH

- Land/Ocean contrast is most important determinant of RH01 structure

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