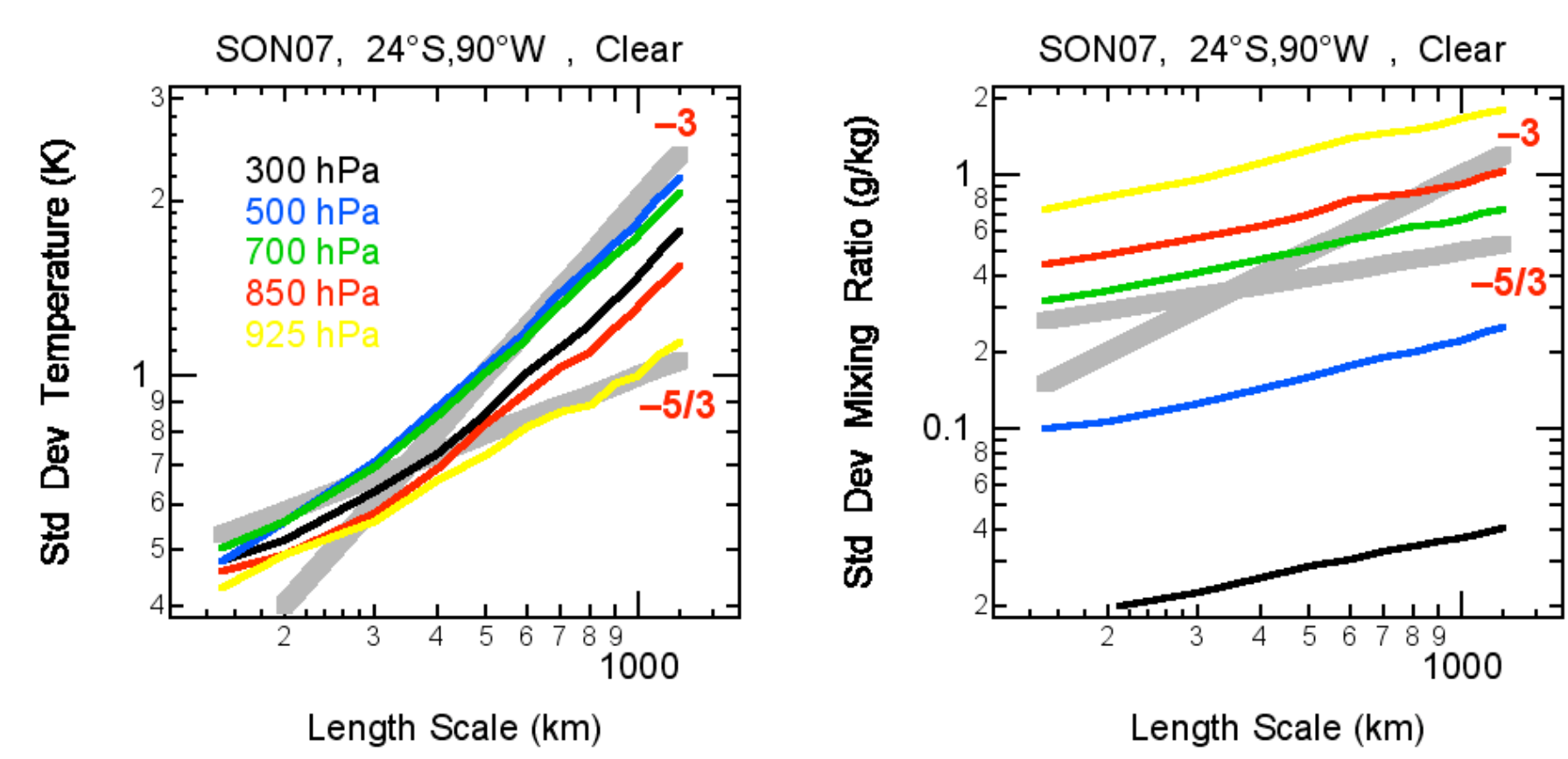


## Multi-moment statistics of cloud and moist conserved variables from the A-train

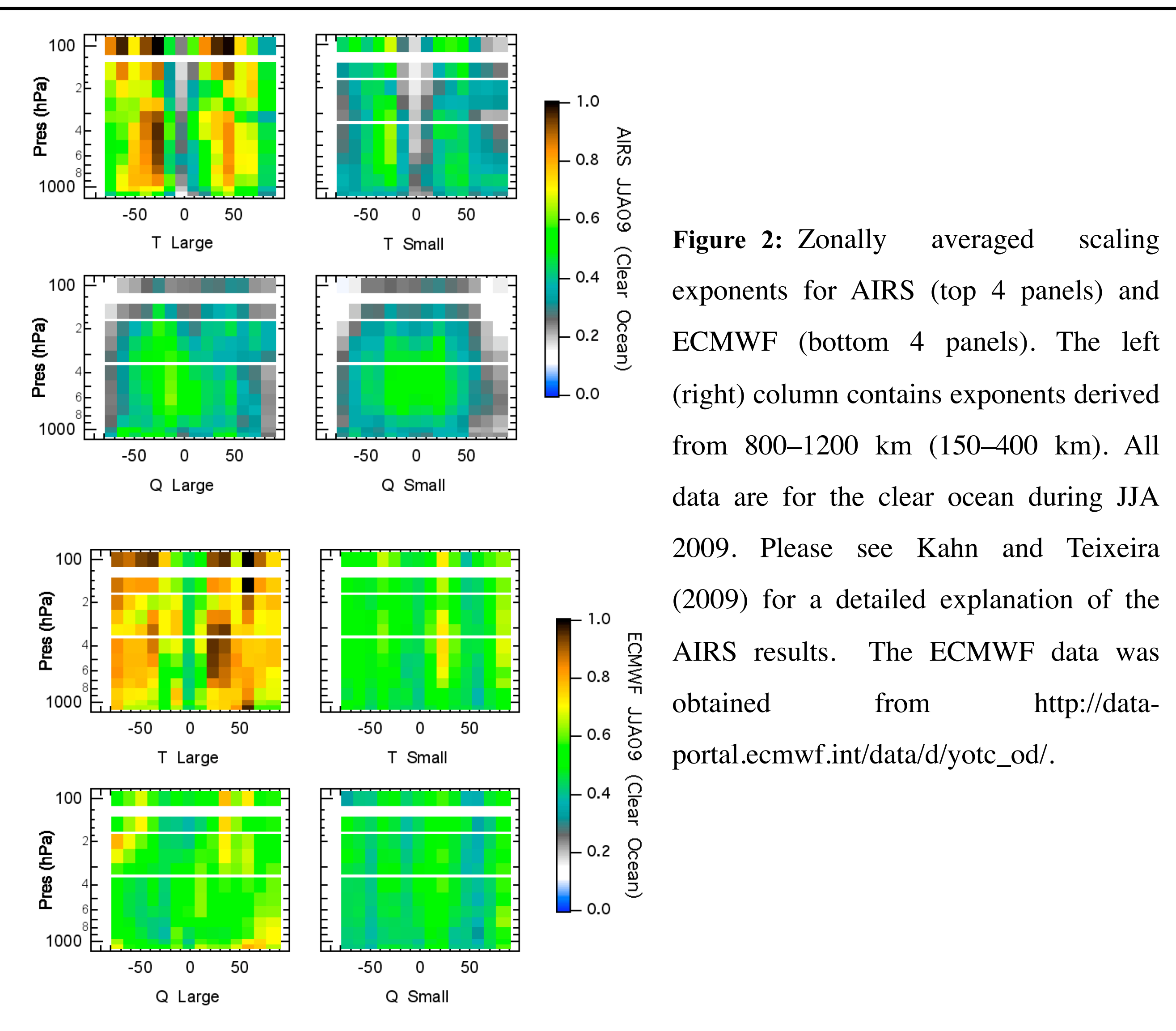
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### ABSTRACT

The simultaneous spatial and temporal vertical profiling of clouds, temperature and water vapor from A-train instruments such as the Atmospheric Infrared Sounder (AIRS) and 94 GHz CloudSat radar, among others, are anticipated to be useful for evaluating and informing subgrid-scale climate model cloud parameterizations. Variance scaling spectra, as well as the variance and skewness of temperature, water vapor and derived moist conserved variables including total water, liquid water potential temperature, and equivalent potential temperature, are shown. This methodology has been extended to the ECMWF model output during YOTC, and similarities and differences between ECMWF and AIRS are highlighted.

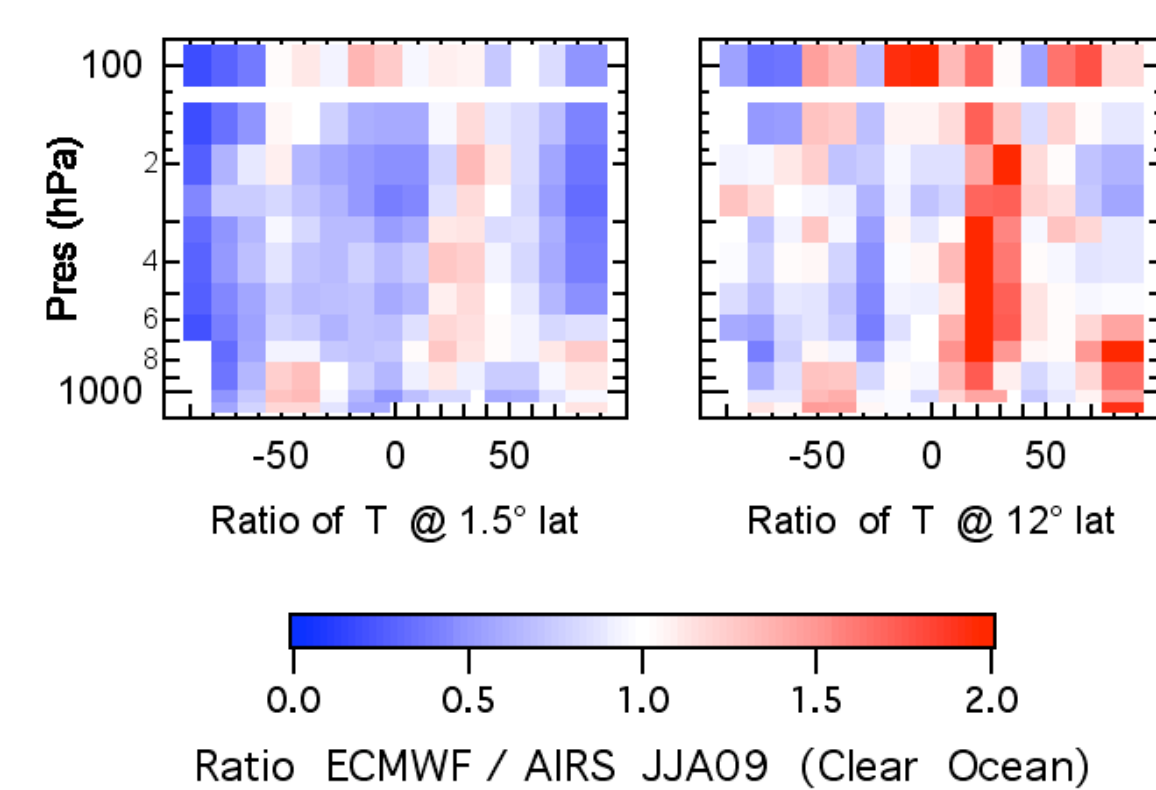


**Figure 1:** AIRS spectra of (left)  $\sigma_T$  and (right)  $\sigma_q$  for clear scenes near the western coast of South America during SON 2006 (248S, 908W) as in Kahn and Teixeira (2009). Also shown in gray are illustrative spectra for  $\alpha = 0.33$  (weaker slope) and for  $\alpha = 1.0$  (steeper slope).

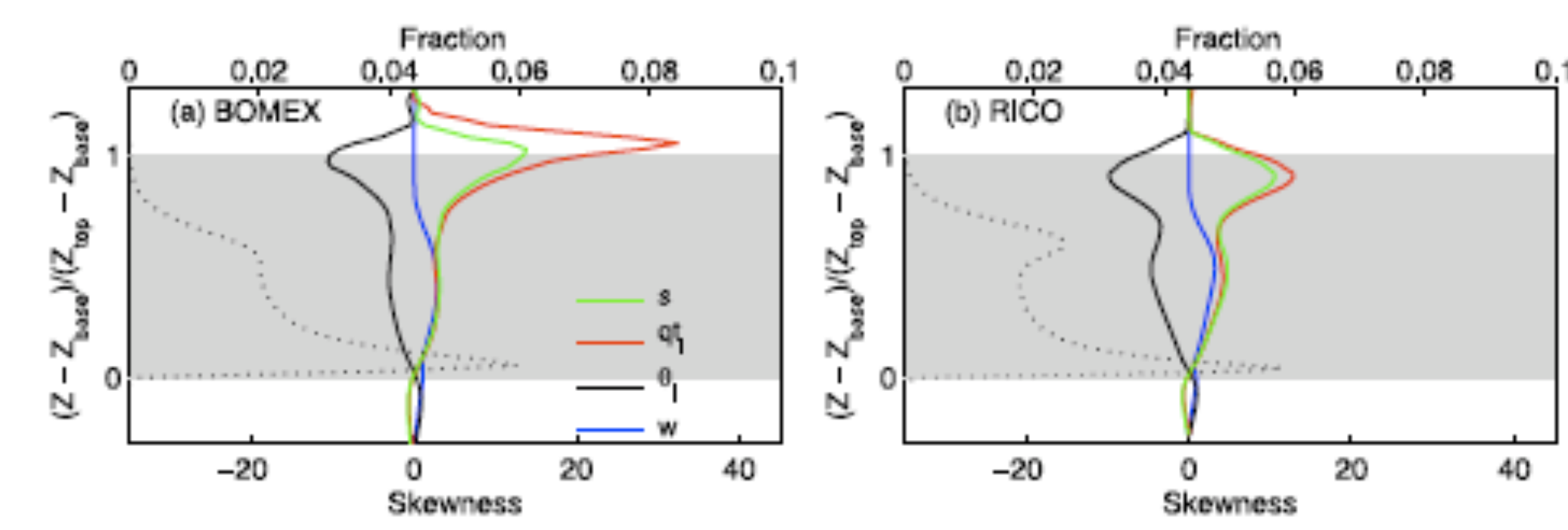


**Figure 2:** Zonally averaged scaling exponents for AIRS (top 4 panels) and ECMWF (bottom 4 panels). The left (right) column contains exponents derived from 800–1200 km (150–400 km). All data are for the clear ocean during JJA 2009. Please see Kahn and Teixeira (2009) for a detailed explanation of the AIRS results. The ECMWF data was obtained from [http://data-portal.ecmwf.int/data/d/yotc\\_od/](http://data-portal.ecmwf.int/data/d/yotc_od/).

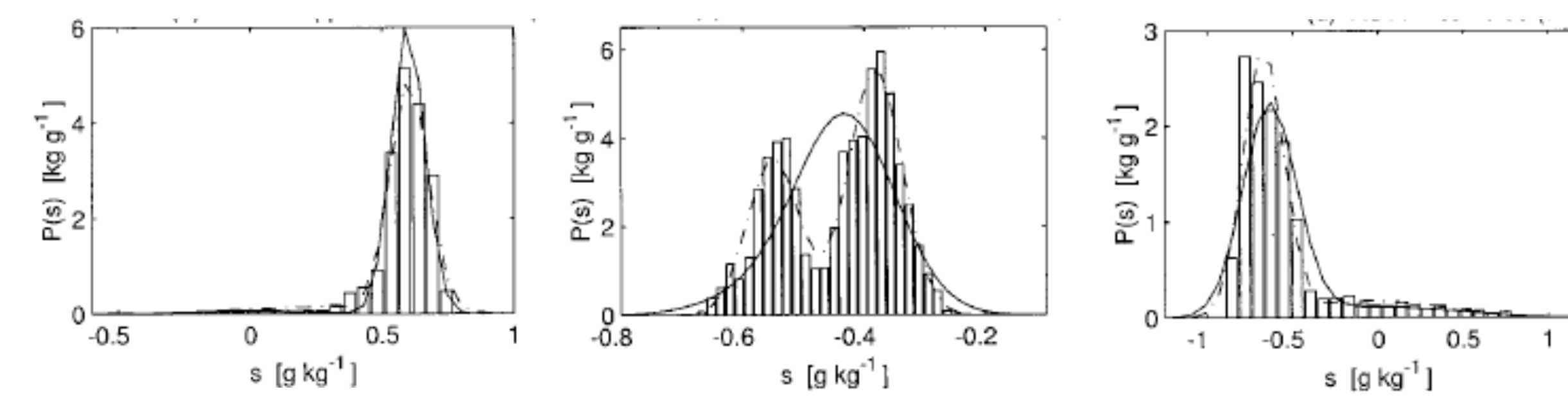
**Figure 3.** Ratio of temperature variance at 1.5° and 12° between ECMWF and AIRS. In Figure 2, the ECMWF exponents show a tendency for higher values than AIRS, and it appears to be largely due to variances that are too small at small scales. This may point to a fundamental parameterization issue in ECMWF. Similar results are observed for water vapor as well (not shown).



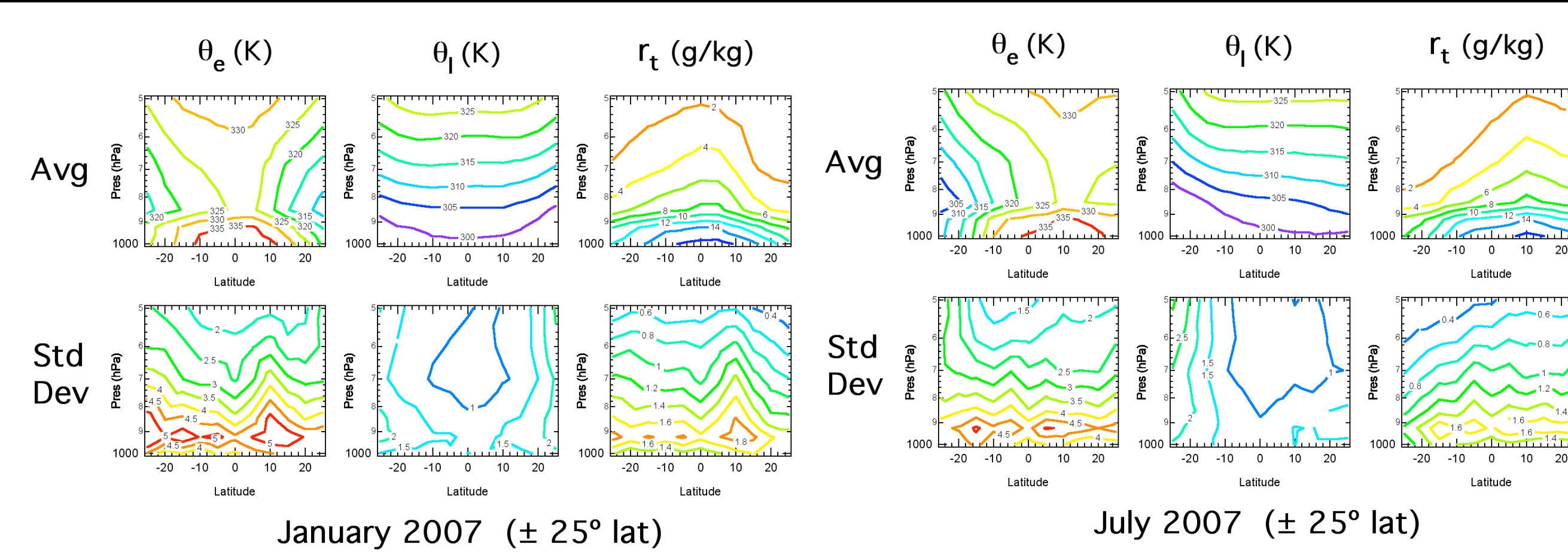
Much of this work is found in Kahn and Teixeira (2009). A global climatology of temperature and water vapor variance scaling from AIRS. *J. Clim.*  
Acknowledgments: A portion of this work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.



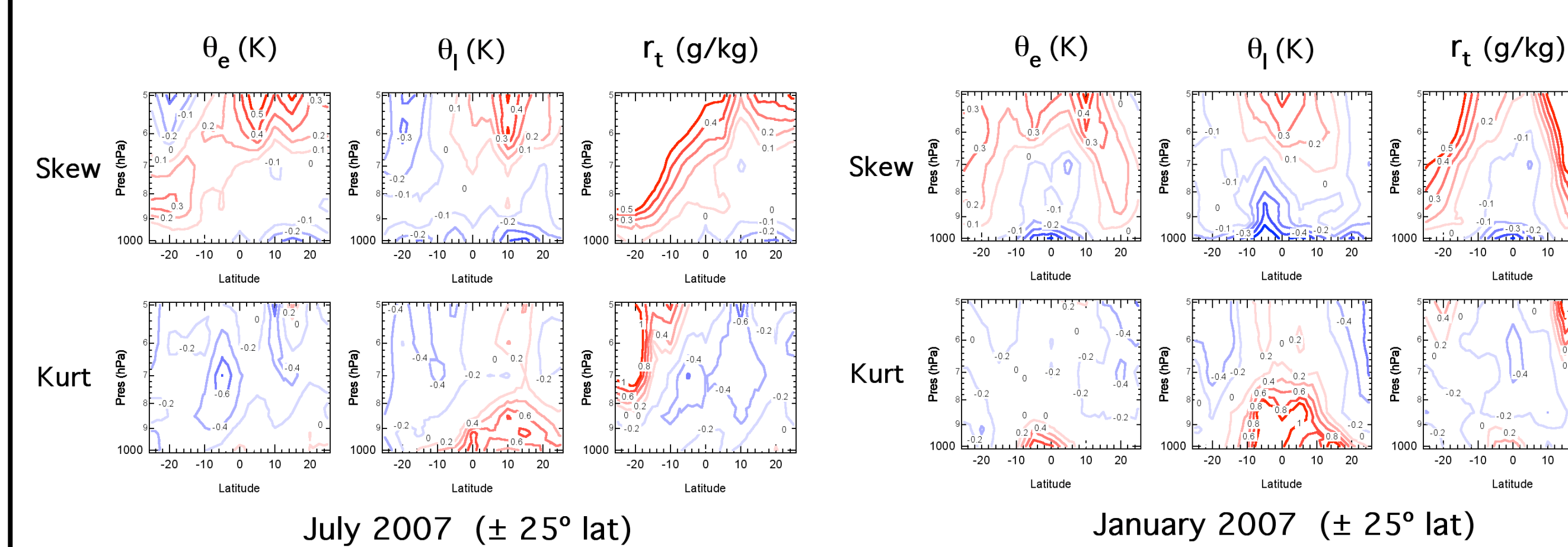
**Figure 4.** Skewness of saturation deficit ( $s$ ), vertical velocity, liquid water potential temperature, and total water ( $q_t$ ) for BOMEX and RICO, two shallow cumulus-oriented field campaigns. All vertical profiles are composited by the base and height of the cloud (gray area). From Zhu and Zuidema (2009), GRL.



**Figure 5.** PDFs of saturation deficit ( $s$ ) for three types of cloud scenes: upper portions of stratocumulus clouds (left); under stratocumulus layers in the sub-cloud layer (middle); cumulus clouds (right). Taken from V. E. Larson et al. (2001), “Small-Scale and Mesoscale Variability of Scalars in Cloudy Boundary Layers: One-Dimensional Probability Density Functions”, *J. Atmos. Sci.* (2001).



**Figure 6.** Average and standard deviations of AIRS/CloudSat-derived equivalent potential temperature, liquid water potential temperature, and total water, for January 2007 (left) and July 2007 (right).



**Figure 7.** Same as Figure 5 except for skewness and kurtosis.

### Summary

- Vertical profiles of temperature and specific humidity from AIRS provide a new height-resolved and global perspective on variance scaling and higher order moments throughout the troposphere
- Combining CloudSat, together with AIRS, yields new information on moist conserved variables such as liquid water potential temperature and total water for shallow cumulus in Tropics and subtropics.
- Statistics of variance scaling and moist conserved variables provide essential information to evaluate sub-grid scales of climate models.