A Global Climatology of Temperature and Water Vapor Variance Scaling from AIRS

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Motivation and Objectives

- **“Statistical” cloud parameterizations in climate models require knowledge about sub-grid scale variability of T, q, CWC**

  - e.g., *Sommeria and Deardorff* (1977); *Smith* (1990); *Cuijpers and Bechtold* (1995); *Bony and Emanuel* (2001); *Tompkins* (2002); *Teixeira and Hogan* (2002)

  - Statistical moments of PDF ~ Calculate cloud fraction/CWC from supersaturated portion of PDF

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  - Statistical moments of PDF ~ Calculate cloud fraction/CWC from supersaturated portion of PDF
- **A-Train provides new information on vertically-resolved T, q, CWC**
  - **Atmospheric Infrared Sounder (AIRS):** T(z) and q(z) profiles at ~ 45 km horizontal resolution (a couple of FOVs ~ climate model grid resolution)
  - **CloudSat:** IWC(z) and LWC(z) for different cloud types at ~ 1 km horizontal resolution – will not present today

Addressing Small-scale Variability with AIRS

- **Power law scaling of wind, temperature, trace gases, cloud properties**

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Aircraft-derived power law scaling shows mesoscale break (–3 to –5/3)

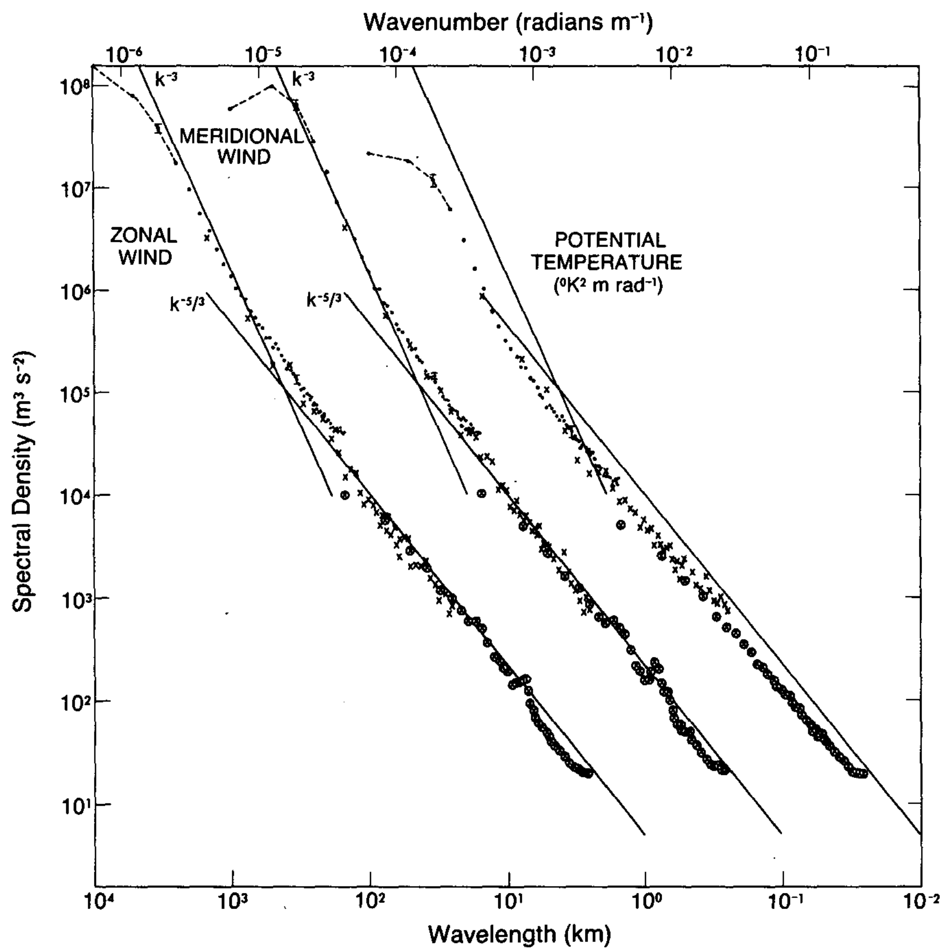

FIG. 3. Variance power spectra of wind and potential temperature near the tropopause from GASP aircraft data. The spectra for meridional wind and temperature are shifted one and two decades to the right, respectively; lines with slopes -3 and $-5/3$ are entered at the same relative coordinates for each variable for comparison.

Nastrom and Gage (1985), JAS

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Water vapor scaling from HIRS shows –5/3 to –2

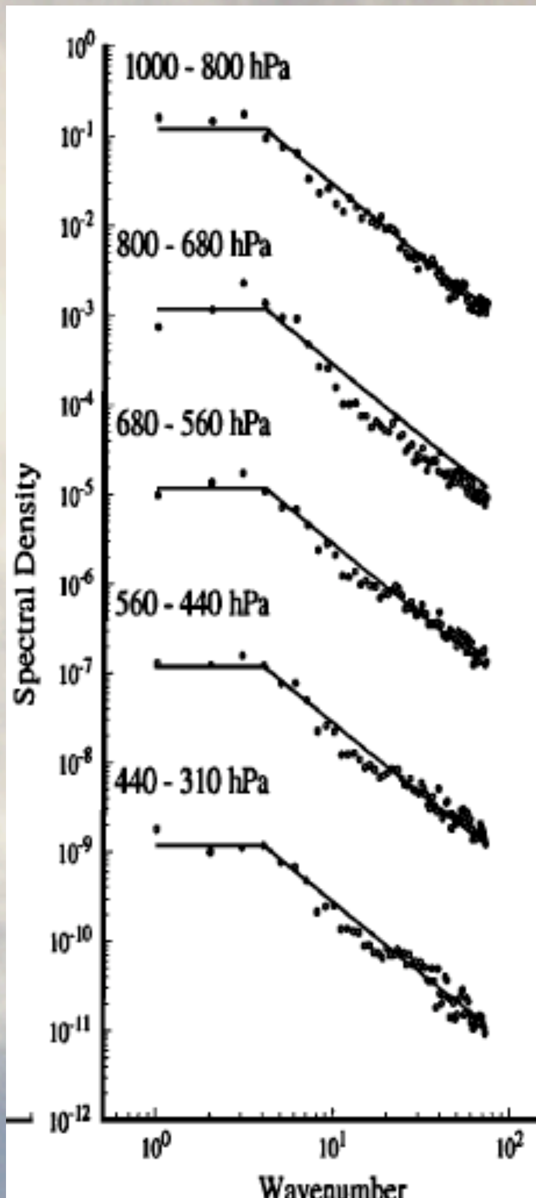

Figure 6. As Figure 4, but for specific humidity. The spectral window function used in the convolution is shown in Figure 7, and the synthetic spectrum consists of a wavenumber independent part followed by (middle) a $m^{-5/3}$ power law or (right) a m^{-3} power law.

Tjemkes and Visser (1994), JGR

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Scaling of LWP in stratocumulus clouds

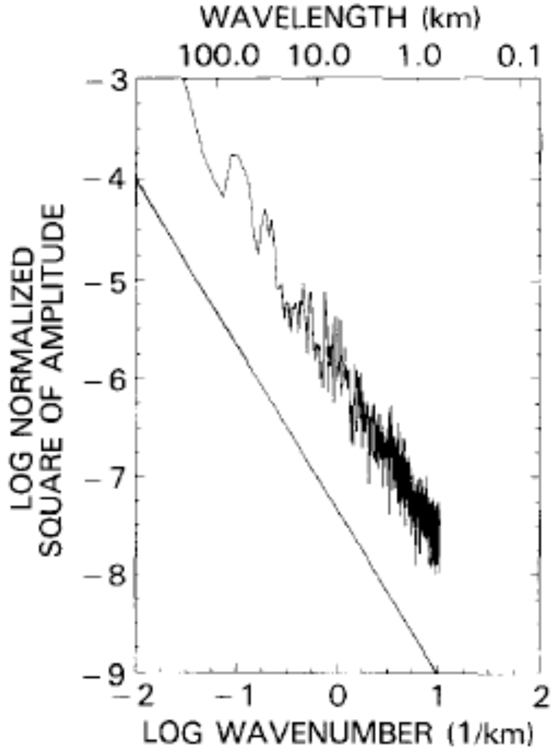

Figure 9. Spectrum of vertically integrated liquid water for 6 days of data similar to Fig. 8, converted from frequency to wavenumber assuming frozen turbulence with a mean 5 m/s advection. The least-square fit gives a 5/3 power-law decrease, suggesting that the liquid water fluctuates with the vertical velocity and may be treated as a passive scalar for the scales shown.

Cahalan and Snider (1989), RSE

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Scaling for MODIS LWP in Stratocumulus Clouds

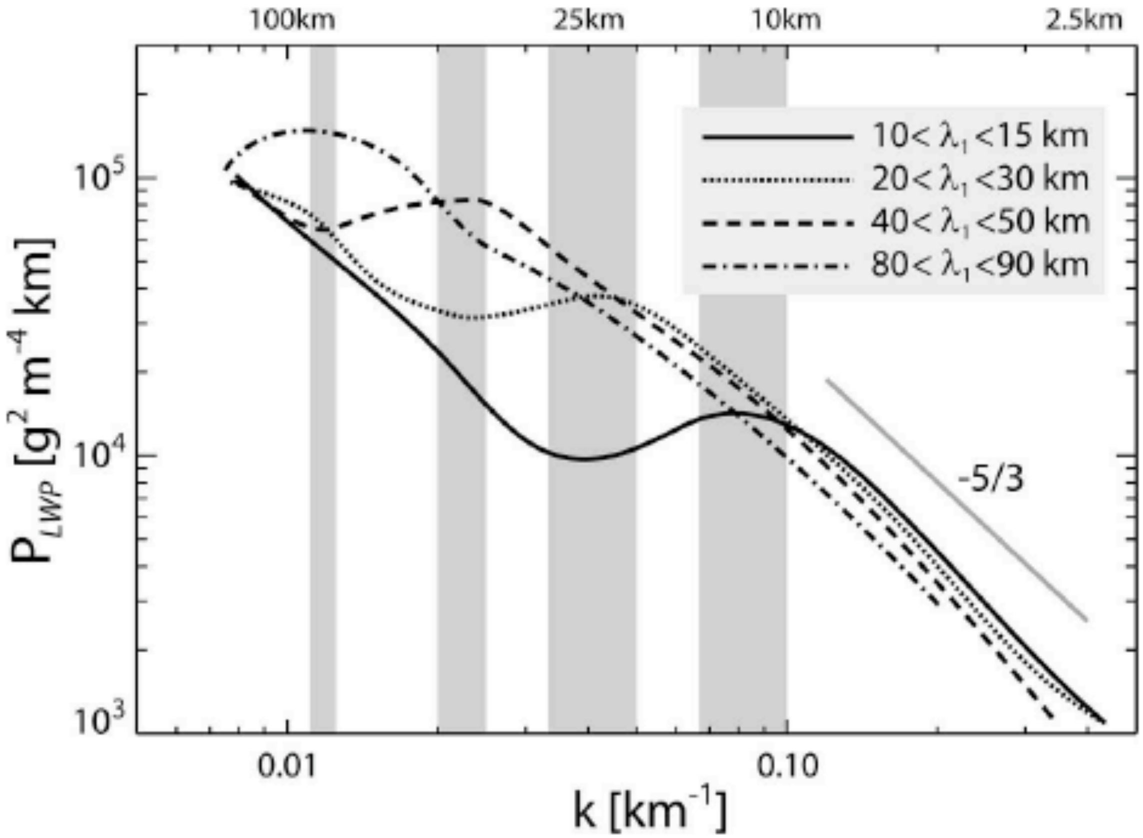

FIG. 10. Averaged power spectra four different ranges of the characteristic cell length scale λ_1. Vertical gray bars indicate extent of λ_1 ranges used for compositing. Data are taken from the NE Pacific region only; composite spectra are almost identical for the SE Pacific data.

Wood and Hartmann (2006), *J. Climate*

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- **How does AIRS-derived T and q compare to previous works?**

Scale-dependence of *T* and *q* variance

- Most previous works derive power spectrum & use slope to derive scaling (e.g., Nastrom and Gage 1986)

Kahn and Teixeira (to be submitted)

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- Scaling derived separately for *T* and *q* in clear and cloudy pixels

- Separate scaling derived from 150–400 and 800–1200 km in 925–200 hPa layers

  - Highlight mesoscale "break" in lieu of higher-order structure functions

- Derive over entire globe from September 2006 to August 2007

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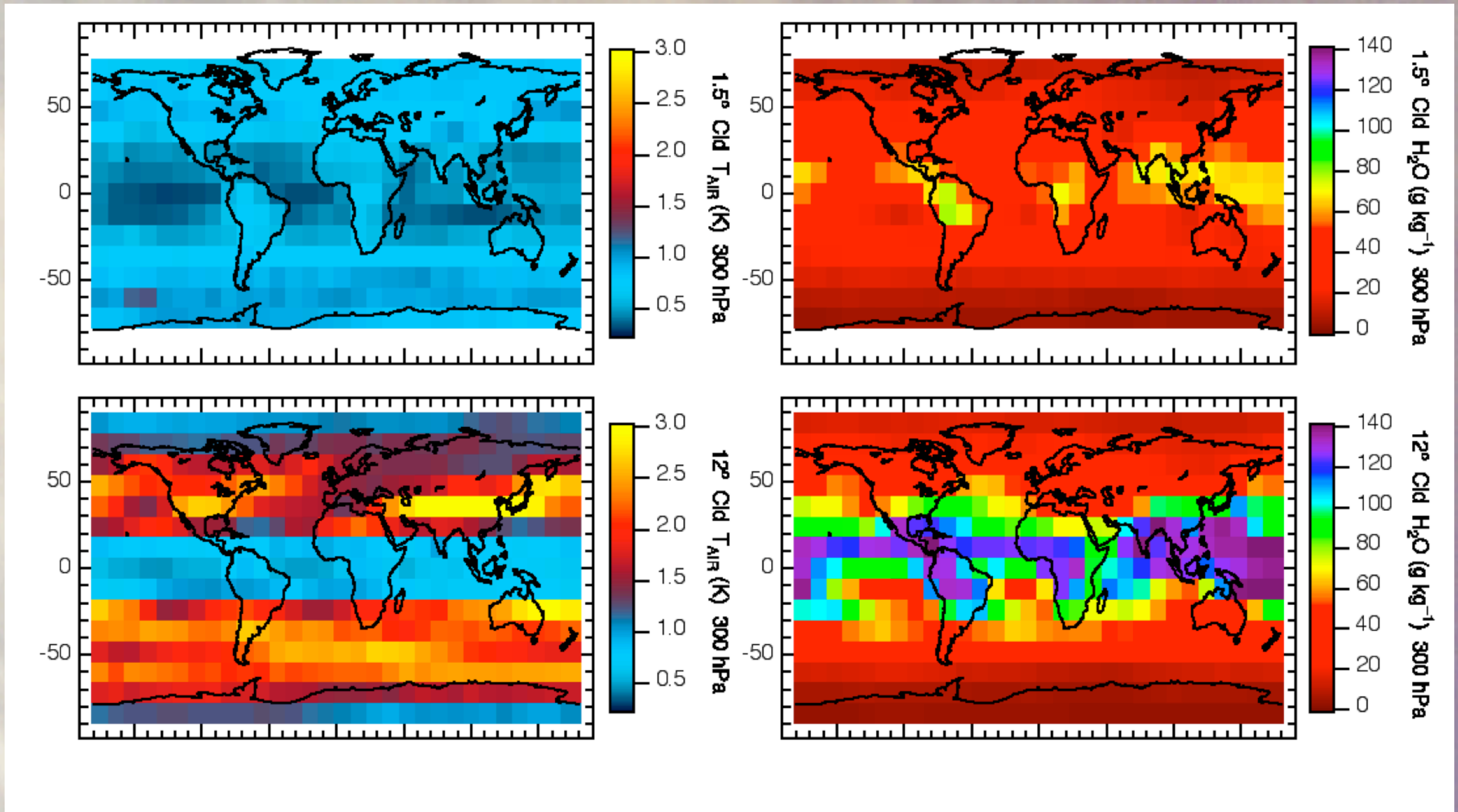

σ_T (left) and σ_q (right) for cloudy scenes in SON 2006. Upper panels show σ_q and σ_T calculated at a grid resolution of 1.5° and then averaged to 12°. Lower panels show σ_q and σ_T calculated for a grid resolution of 12°.

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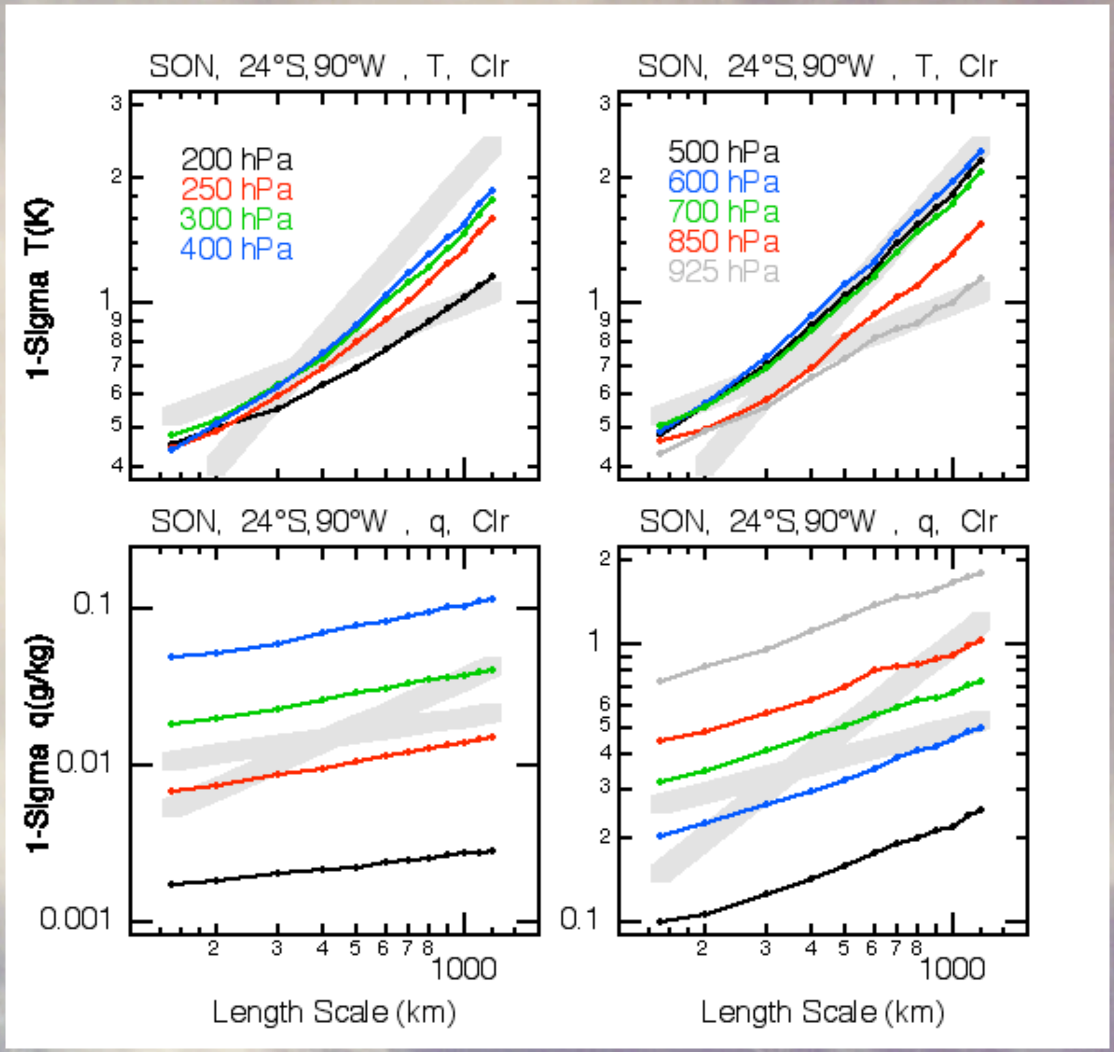
Scaling of *T* and *q* near coast of S. America



Length scale spectra of σ_T (top) and σ_q (bottom) for clear scenes. Gray lines are illustrative spectra for $\alpha = 0.33$ (weaker slope) and $\alpha = 1.0$ (steeper slope).

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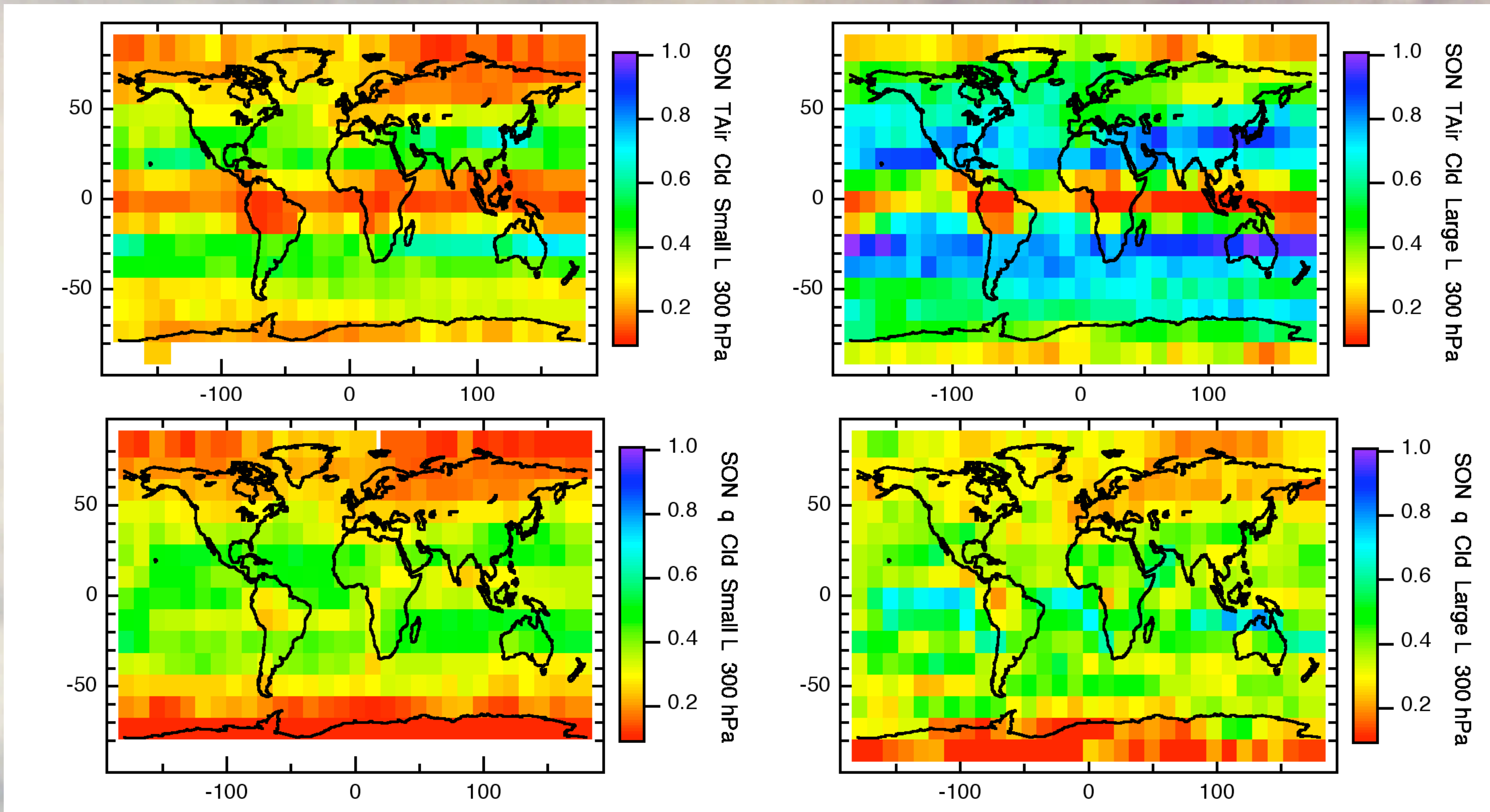
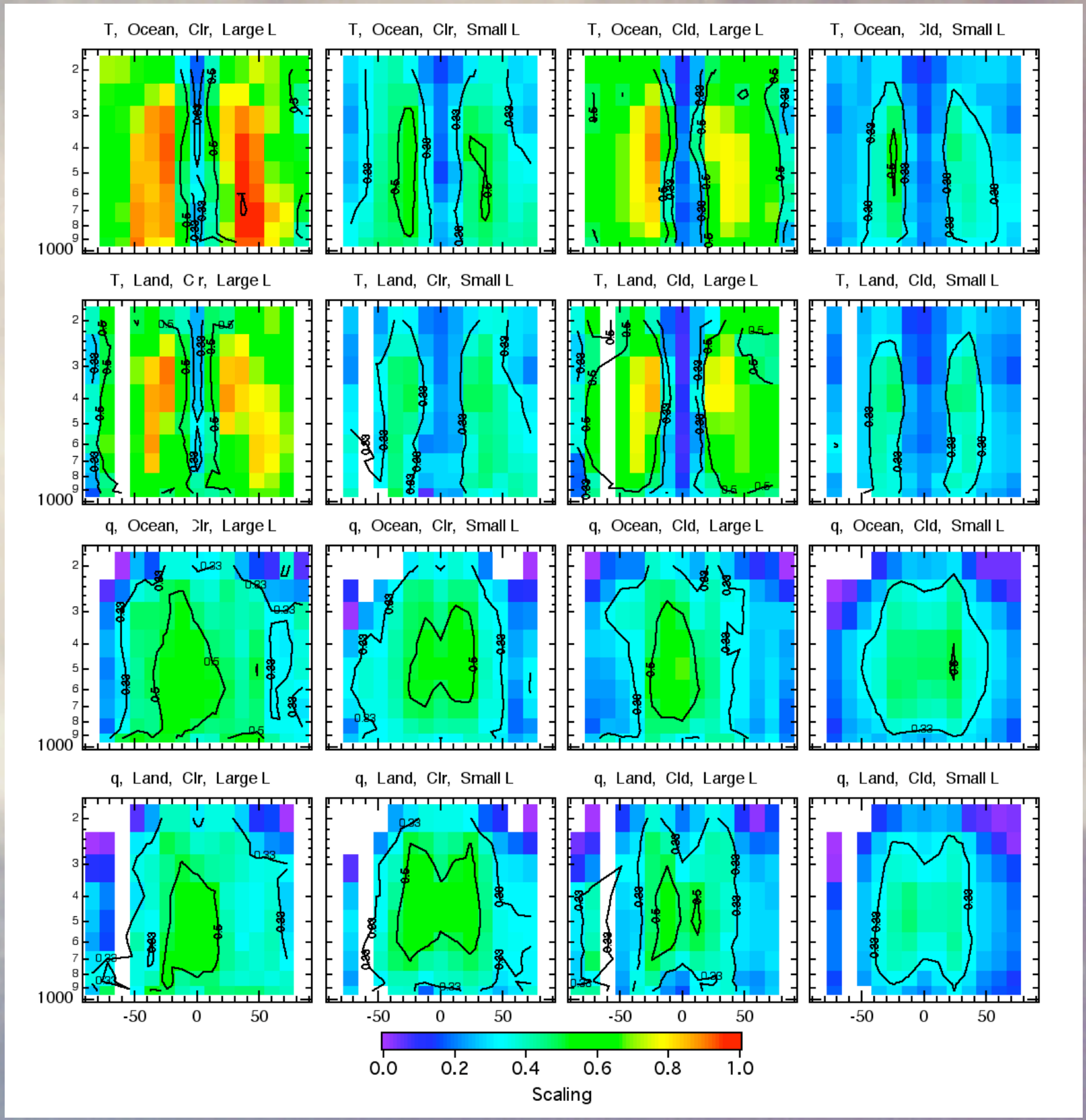
Scaling of "cloudy" *T* and *q* at 300 hPa



Retrieved scaling of *T* and *q* at 300 hPa in "cloudy" conditions for **small** (left) and **long** (right) length scales.

Kahn and Teixeira (to be submitted)

Zonal-averaged Scaling of *T* and *q* During SON 2006



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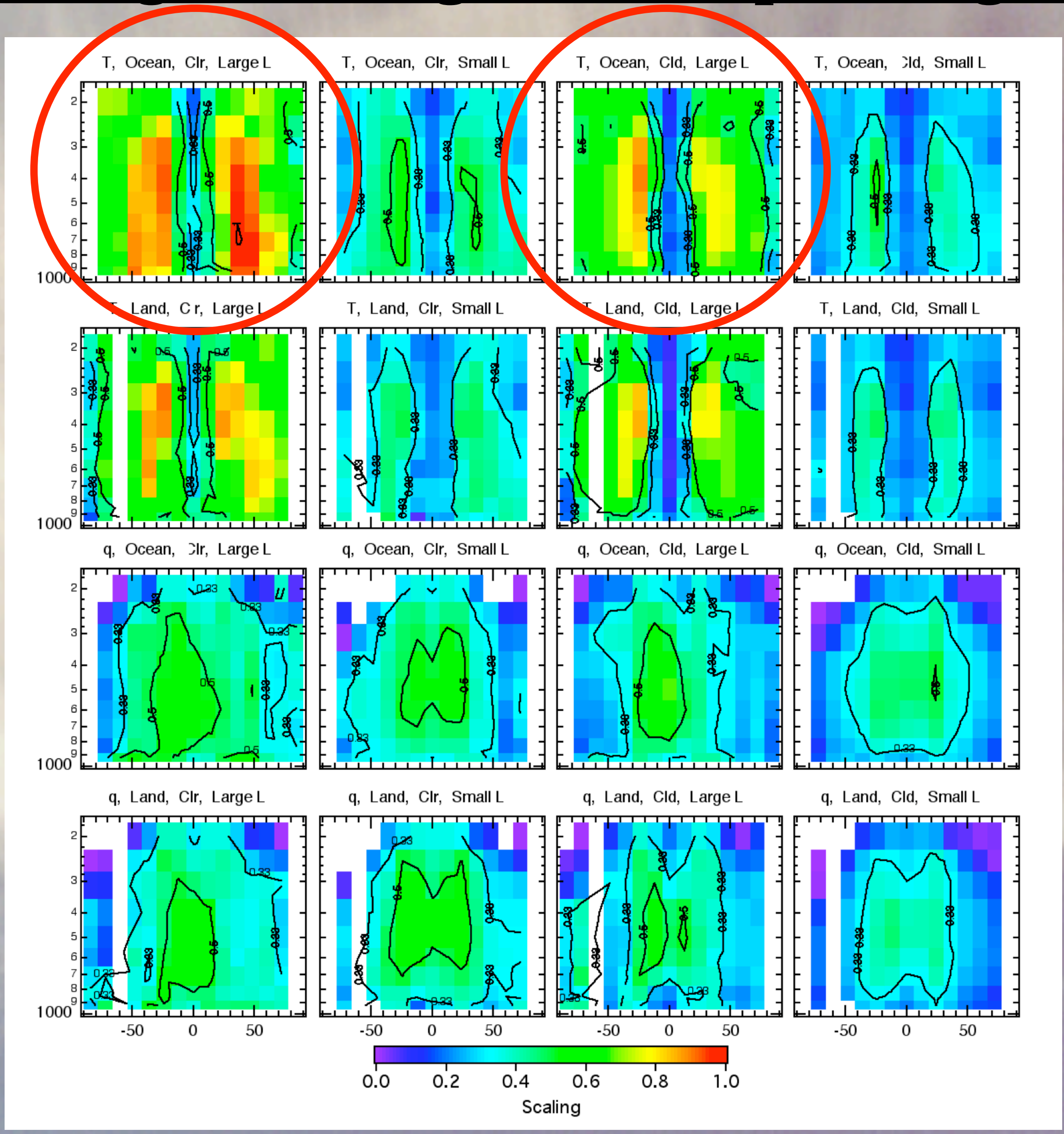

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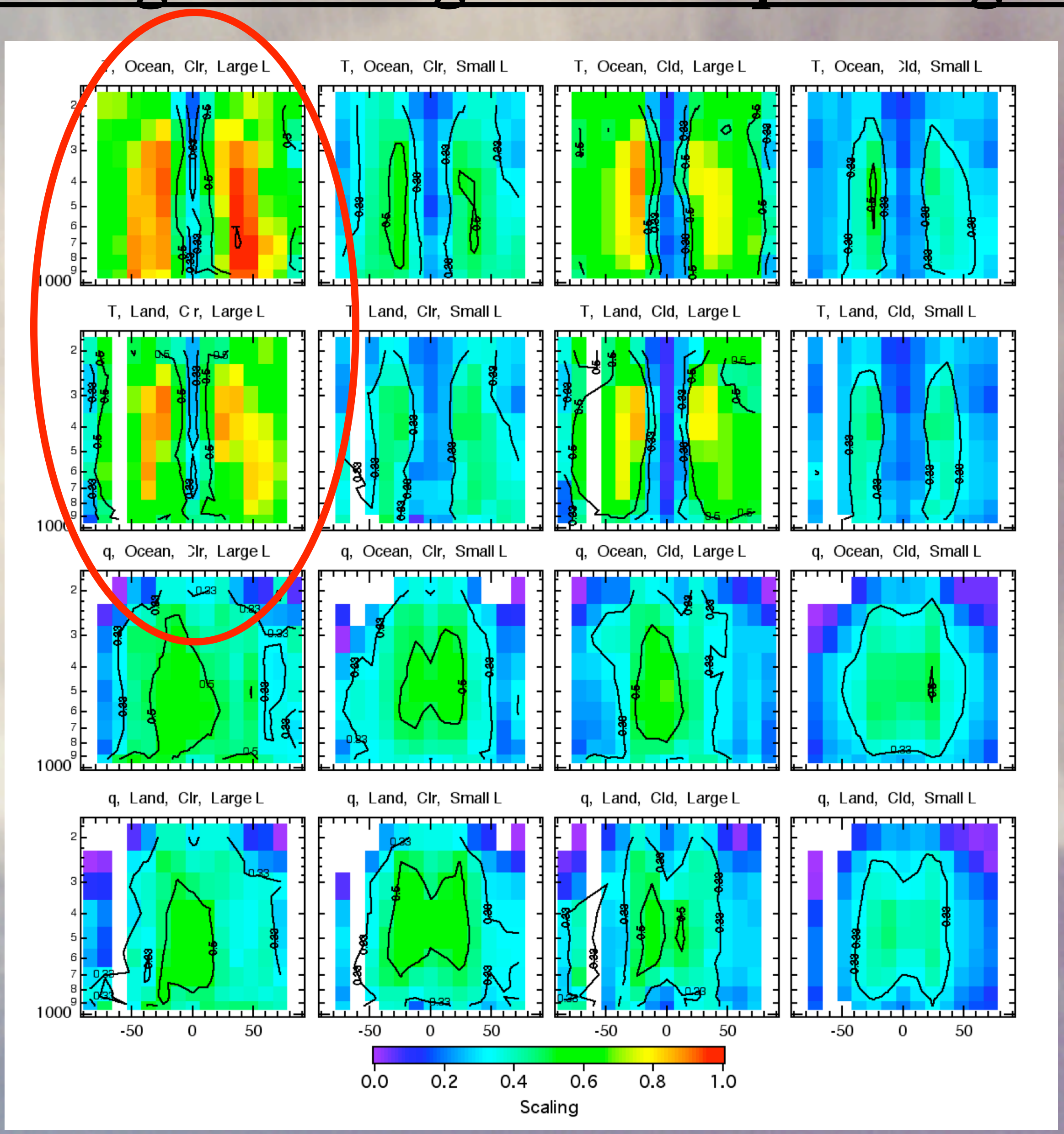

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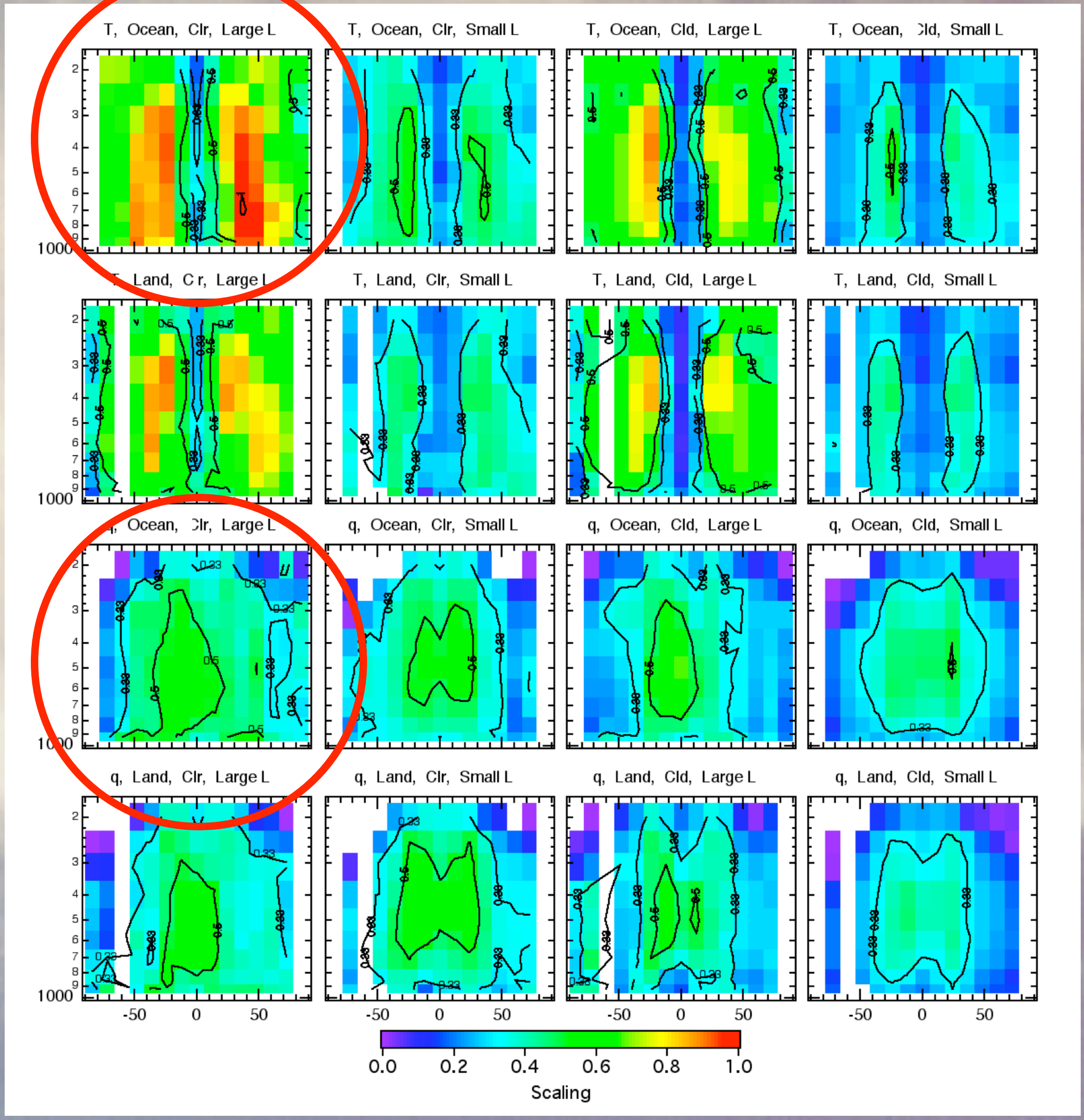

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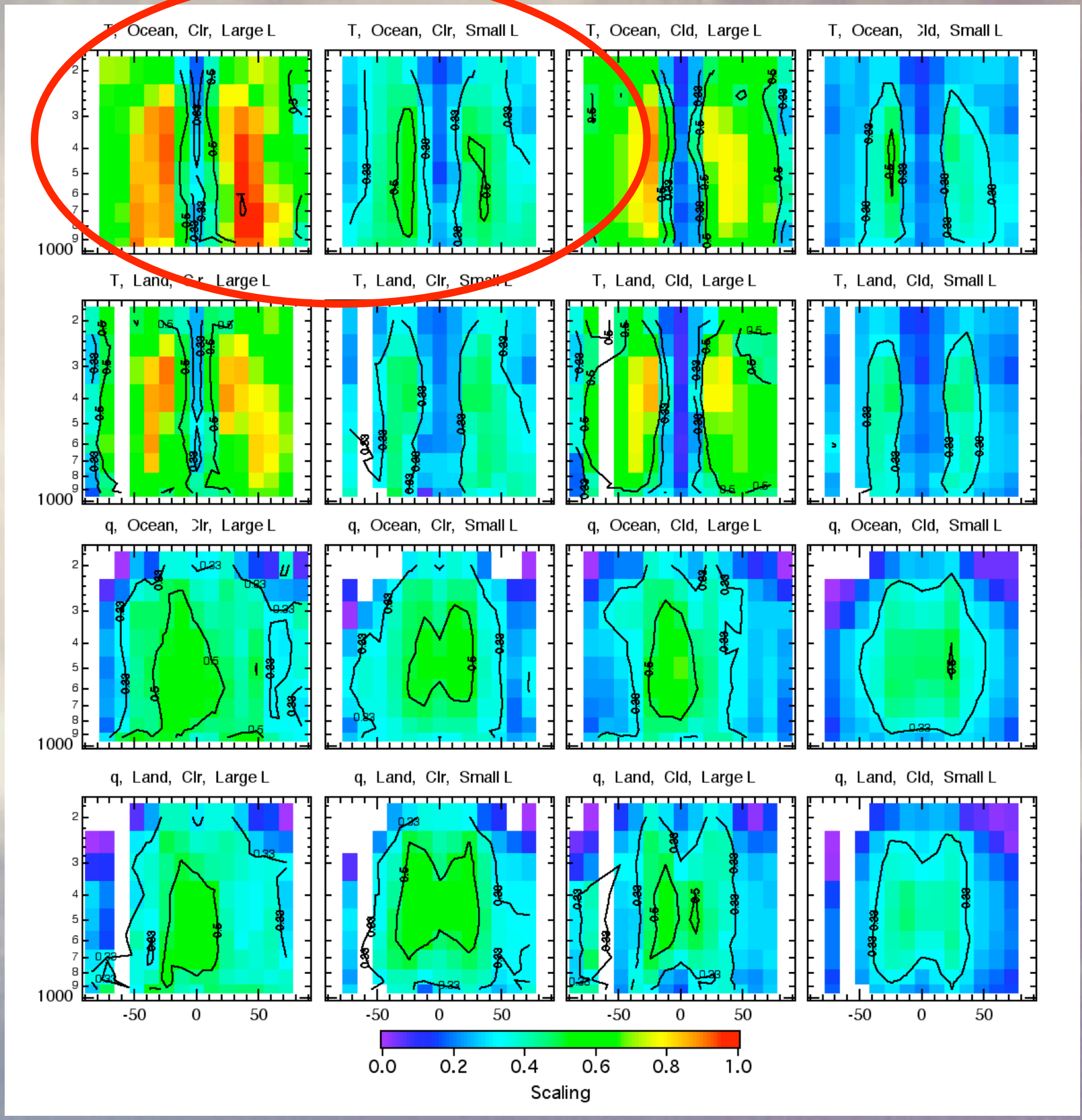


Kahn and Teixeira (to be submitted)

Seasonal variation in *T* scaling

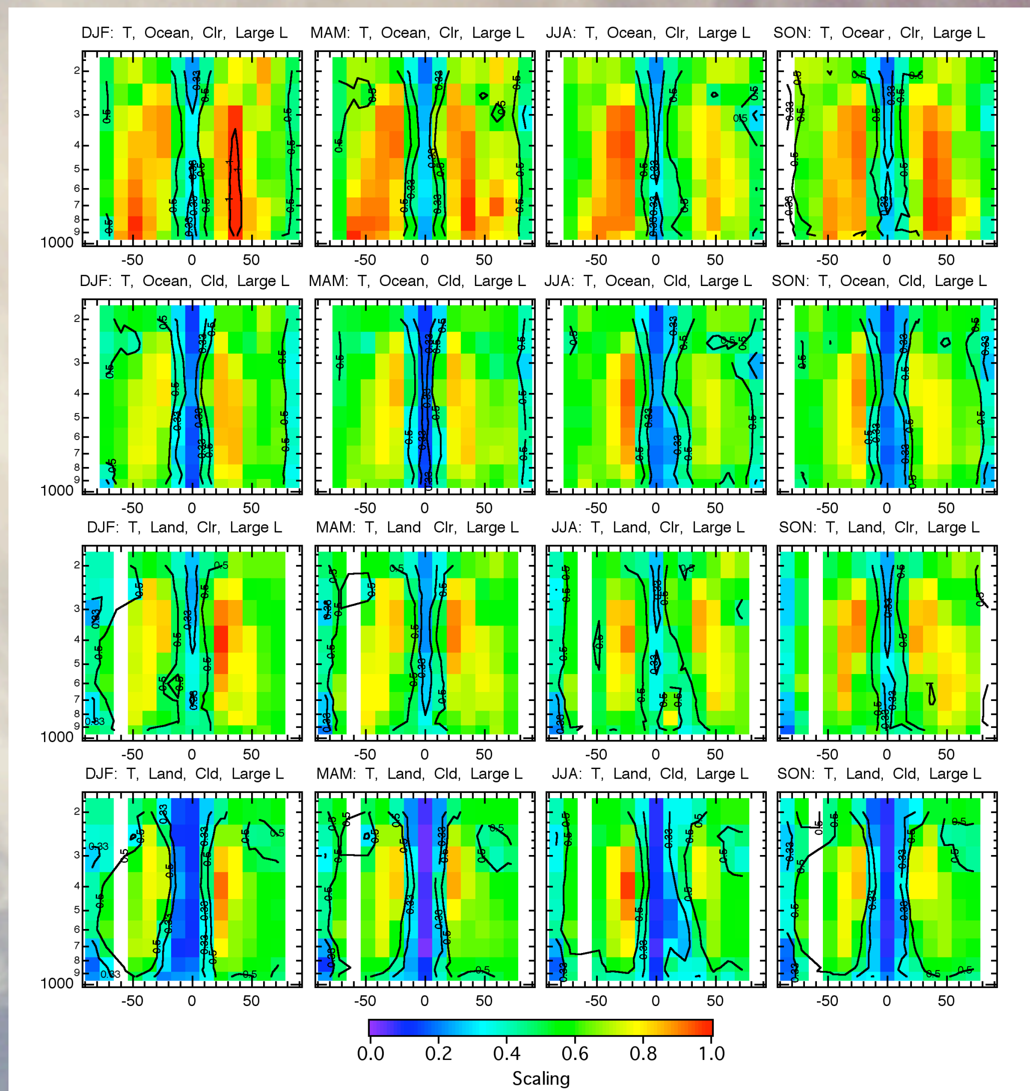
DJF MAM JJA SON

Ocean/ Clear

Ocean/ Cloud

Land/ Clear

Land/ Cloud



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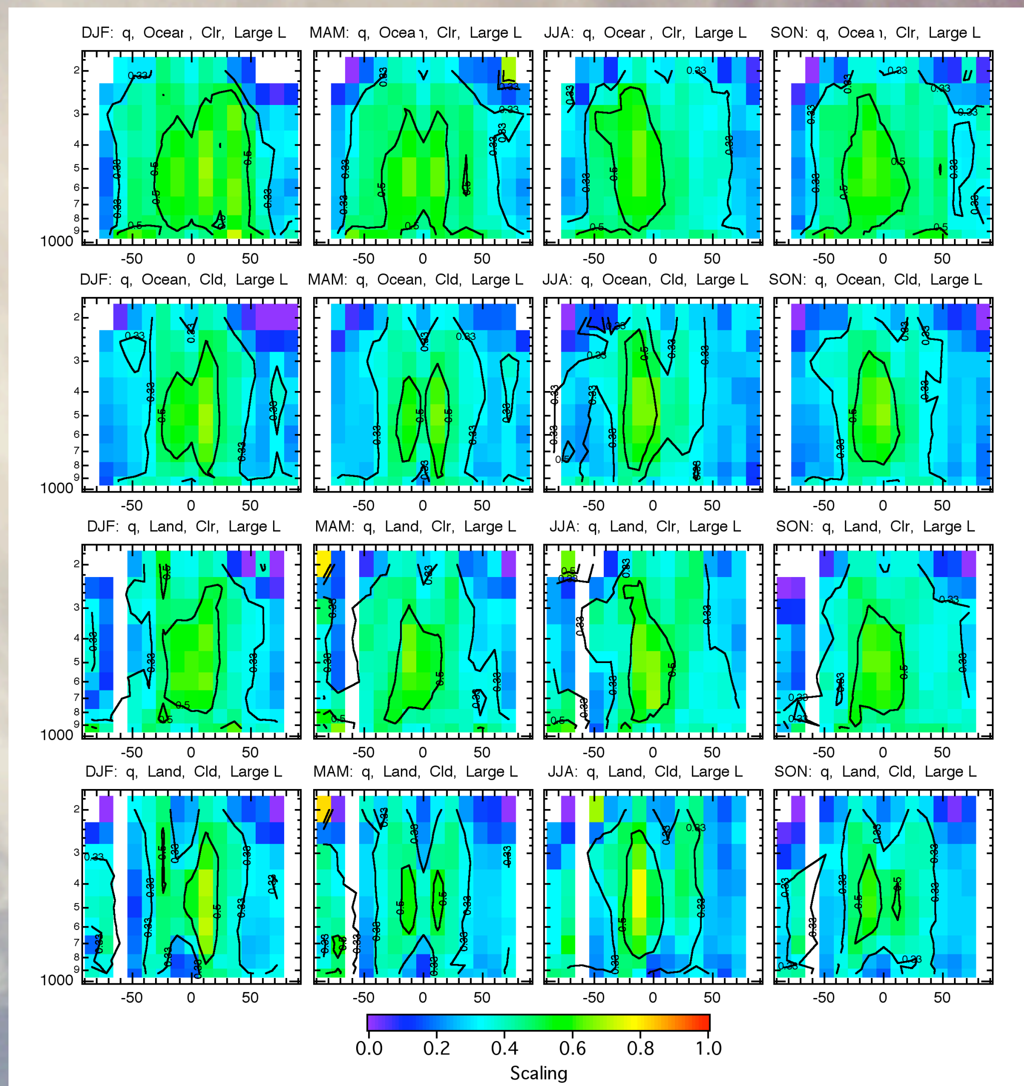

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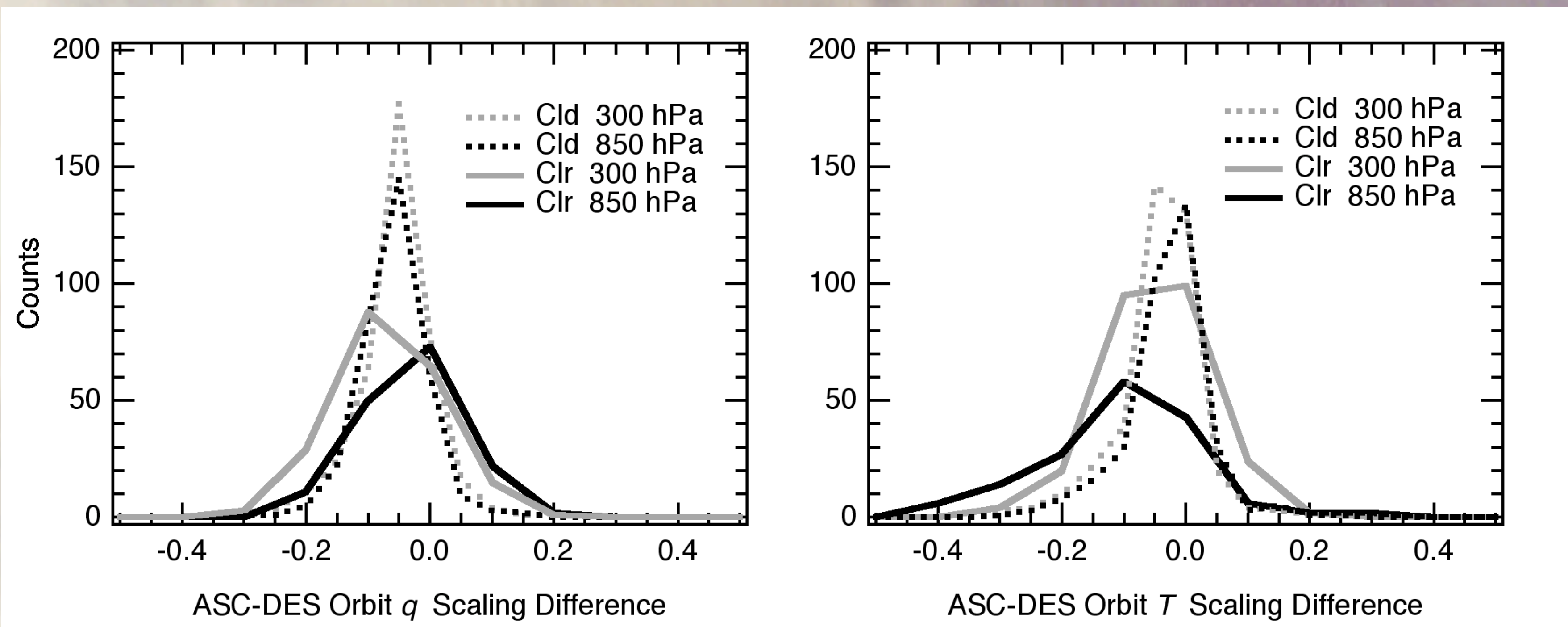
Diurnal cycle in scaling exponents



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Summary and Outlook

- *T* scaling of –3 and –5/3 for 800–1200 and 150–400 km, respectively
    - Weaker in Tropics, Subtropical boundary layer, polar latitudes
- *q* scaling from –5/3 to –2, highest in Tropics/Subtropics
- Significant clear/cloud, land/ocean, seasonal, altitude, regional variations
- Sampling limitations in thicker clouds: help from Microwave sounders?
- Consistency with previous works, more comprehensive view with AIRS
- Extrapolate scaling to smaller scales for parameterizations