Tropical upper-tropospheric ozone variability as observed by the Aura Microwave Limb Sounder

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Introduction

- The upper troposphere is an important region for climate as it is here where both water vapor and ozone have their strongest radiative forcing
- Upper tropospheric ozone is controlled by:
  - Rapid vertical transport of (typically but not always ozone-poor) air from the boundary layer e.g., by deep convection
  - Horizontal transport and concurrent chemical evolution of potentially polluted air
  - Influx of ozone-rich air from the stratosphere
- The Microwave Limb Sounder (MLS) on NASA's Aura Spacecraft, launched in July 2004 makes daily global (day and night) profile measurements of:
  - Atmospheric composition from the upper troposphere to ~90 km
  - Upper tropospheric cloud ice water content
  - Temperature, water vapor, and GPH
- Here we present ~4 years of MLS observations of upper tropospheric O_3, CO (a tracer of polluted air) and cloud ice (indicative of convection)

Conclusions / future work

- We have presented a comprehensive survey of the MLS upper tropospheric ozone observations
- Seasonal and interannual variability in upper tropospheric ozone are comparable in magnitude
- Ozone and cloud ice are generally, but not always, anti-correlated
- MLS observations identified as being of cloudy regions show reduced abundances of ozone in the subtropical regions (10° – 30°S/N)
- In future, we plan to concentrate on specific regions / events and study driving factors (convection, transport, pollution etc.) in more detail

Global statistics of MLS v2.2 tropical upper tropospheric ozone

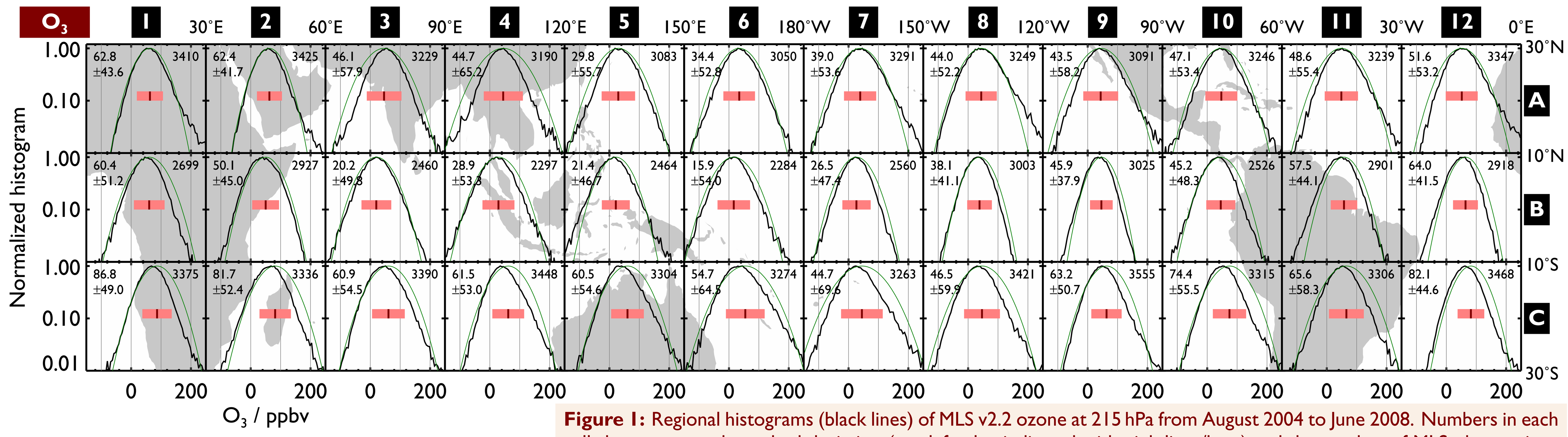

Figure 1: Regional histograms (black lines) of MLS v2.2 ozone at 215 hPa from August 2004 to June 2008. Numbers in each cell show mean and standard deviation (top left, also indicated with pink lines/bars) and the number of MLS observations (top right). Green lines show Gaussians having the same mean and standard deviation.

- Histograms show broadly Gaussian behavior for the MLS upper tropospheric ozone observations
  - Much of this variability will be due to the ~40 ppbv Gaussian noise on individual MLS ozone observations
- Departures, probably indicating influence of stratospheric ozone, are seen in higher latitudes (rows A and C)
  - Particularly in 7A – 9A, also 10A – 12A and 1A
  - Less obvious in the southern latitudes shown
- These departures can reflect both strat./trop. exchange and/or decreases in tropopause altitudes increasing the fraction of stratospheric air reported in the MLS 215 hPa ozone, given the ~2.5 km vertical resolution
- In the tropics, a pronounced minimum in ozone is noted over Indonesia and the Western Pacific (boxes 5B – 7B)
- The largest average values in the tropics are seen over Africa (boxes 1A – 2A and 12A)

Spatio-temporal variability of upper tropospheric ozone and convection

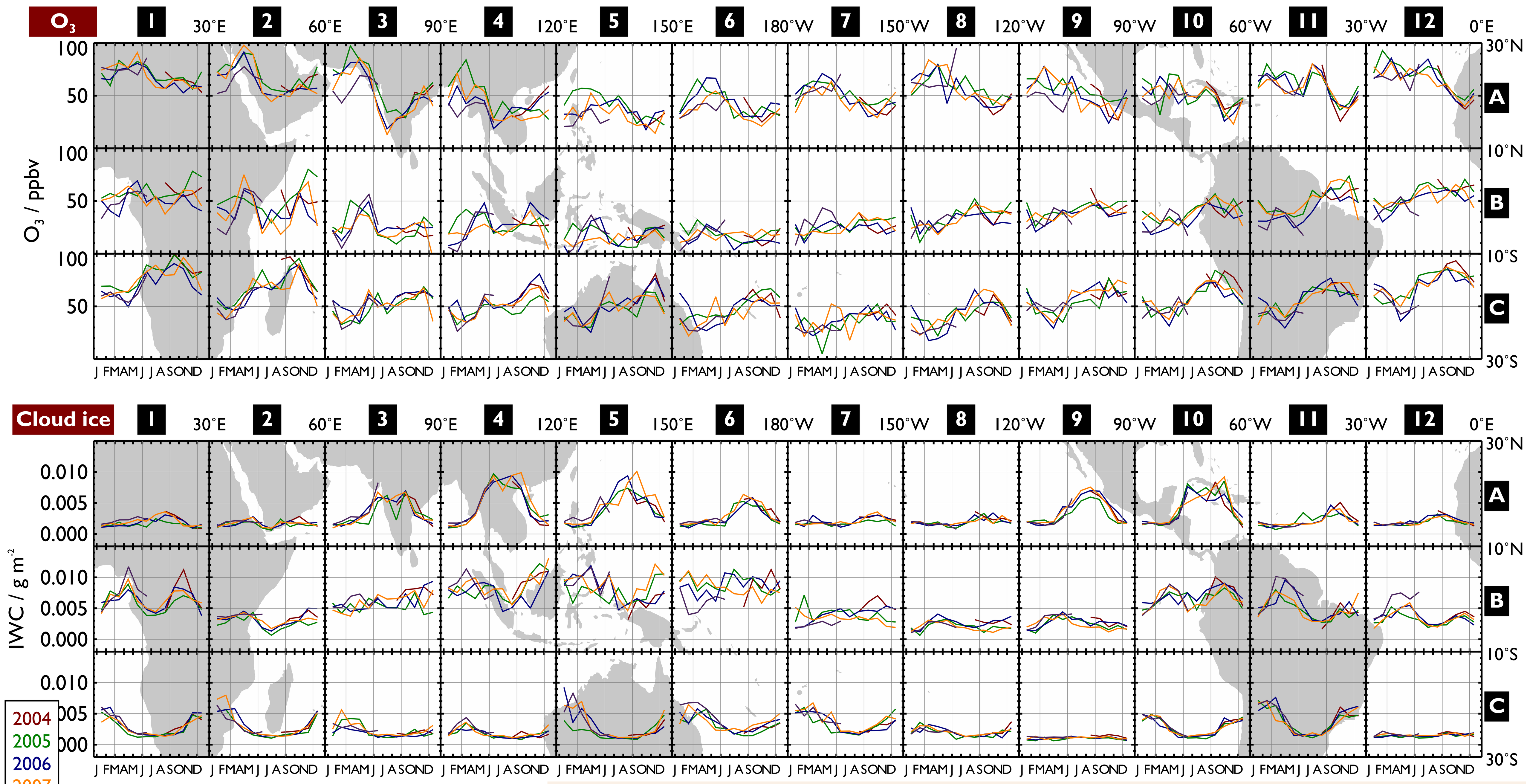

Figure 2: Regional seasonal / annual variations in MLS 215 hPa ozone (top) and cloud ice water content (bottom). Colors indicate years, as shown bottom left.

- Seasonal and interannual variability in upper tropospheric ozone typically have comparable magnitudes, particularly in the 10°S – 10°N regions (row B)
  - Contrast this with cloud ice, where interannual variability is generally smaller than the seasonal variations
- The 10° – 30°N/S regions (rows A and C) show ozone peaking in spring (MAM for row A, SON for row C)
  - Significant anti-correlations with cloud ice are seen, with less ozone observed during strong summertime convection (e.g., regions 3A – 4A, 1C – 2C, 5C, 11C)
- The 10°S – 10°N regions (row B) exhibit a variety of seasonal cycles:
  - Over Africa (1B, 2B), ozone generally peaks slightly during Apr – Jun and again in Oct – Dec, with convection peaking 1 – 2 months earlier
  - Over the Indian ocean (3B – 4B), the Oct – Dec ozone peak is reduced compared to Apr – Jun, with little obvious relationship to cloud ice
  - Little seasonal or interannual variation is seen in the low ozone region over the Pacific
  - Over South America (11B), a strong peak in ozone is seen in Aug – Nov, anti-correlated with cloud ice, which peaks in Mar – May

Cloudy and clear-sky observations of ozone and carbon monoxide

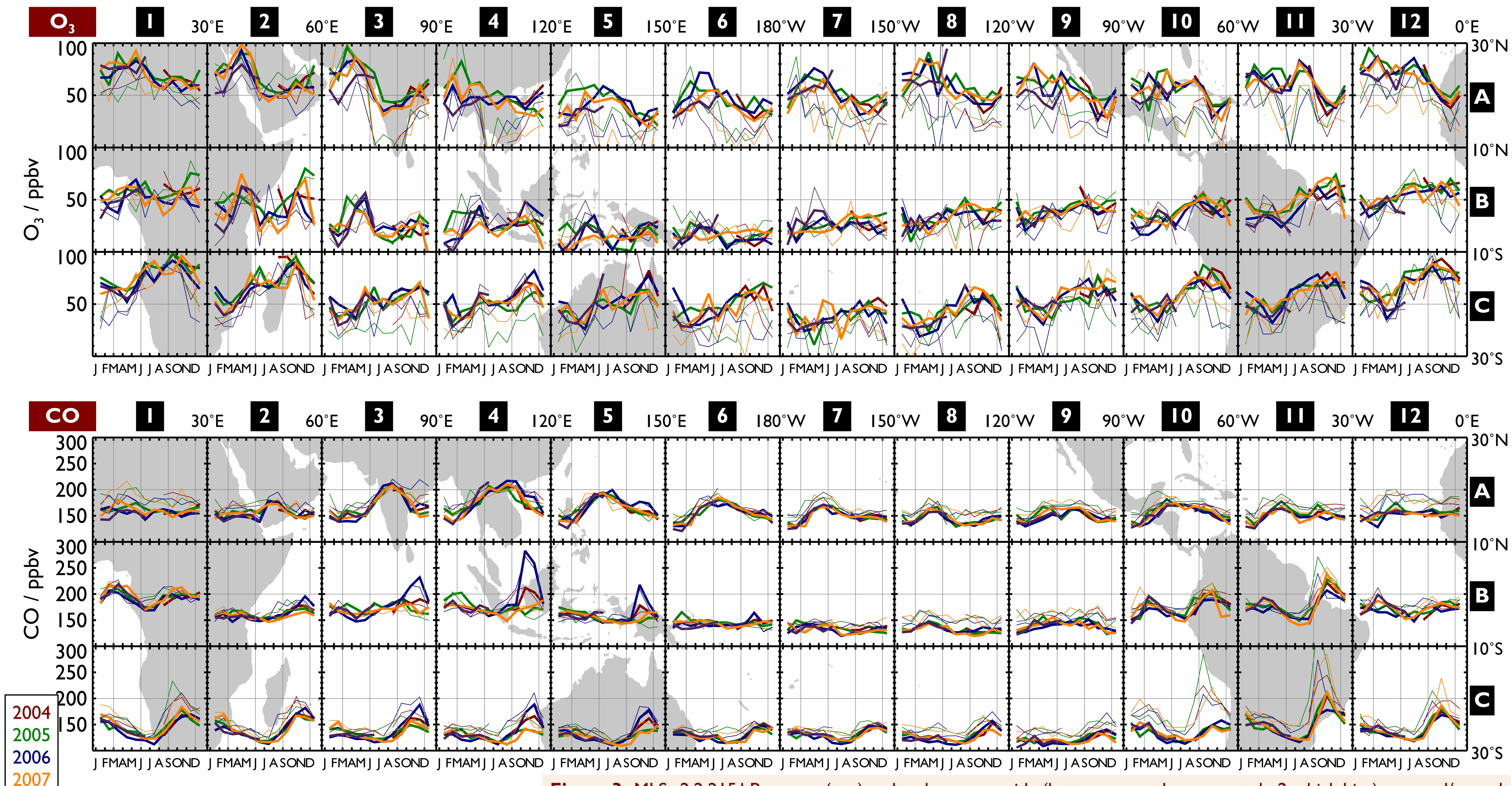

Figure 3: MLS v2.2 215 hPa ozone (top) and carbon monoxide (bottom, note the suspected ~2× high bias) seasonal/annual variations in each region (colors indicate year). Thick lines are for 'clear sky' observations, thin lines are for 'cloudy'.

- Here, MLS observations are separated in to 'cloudy sky' (thin lines, screened cloud ice $> 3\sigma$, see MLS v2.2 data quality document) and 'clear sky' (thick lines, screened cloud ice $<2\sigma$, with points between 2σ and 3σ ignored)
- For regions in rows A and C, cloudy MLS observations tend to be associated with significantly less ozone
  - For example, 10A – 11A, 10C
  - This is consistent with aircraft observations during TC4 (Avery, personal communication, 2008)
- In general, row B regions show less difference between clear and cloudy observations
- Note that the MLS v2.2 algorithms have difficulty accurately retrieving composition in the thickest of clouds, such data have been flagged and ignored
  - Note also that some residual systematic MLS bias between clear and cloudy observations probably remains
  - However, such a bias would be expected to be consistent from region to region
  - The regional variations seen here lend support to these differences reflecting real atmospheric phenomena
- Cloudy observations are typically associated with larger carbon monoxide abundances (note the suspected ~2× high bias in the MLS v2.2 CO product at 215 hPa)
- Note, however, significant regional differences, such as between 11B (which shows significant clear/cloudy differences) and 4B (where little difference is seen)
  - Probably reflecting differences in horizontal transport