Microwave Remote Sounding of Atmospheric Composition

Section on MLS observations of upper tropospheric composition and convection for GSFC talk

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Tropospheric ozone is an important greenhouse gas with strong geographical and temporal variability (e.g., compared to CO$_2$ and CH$_4$ which are well mixed).

It is in the upper troposphere where ozone’s impact on climate is greatest.

Many factors control the abundance of upper tropospheric ozone:

- Transport of ozone-rich air from the lower stratosphere (‘stratosphere-troposphere-exchange’) can act to increase ozone.
- Rapid uplift (e.g., by convection) of air from the lower troposphere generally (but not universally) acts to decrease ozone.
- Ozone can be increased by formation from ‘precursor species’ downwind of sources (or of convection).
Larger abundances and variabilities in the subtropics (Nb/Sb) than the tropics (Na/Sa)
The ‘wave one’ feature is evident (less $O_3$ in the Pacific sector)

The signature is a little more pronounced in the southern than the northern subtropics.
The subtropics exhibit moderate seasonal cycles in ozone

- In the subtropics, we see moderate seasonal cycles in ozone, with more \( \text{O}_3 \) in winter/spring than summer/fall.
- The northern subtropical springtime \( \text{O}_3 \) maximum is weaker in the Eastern (5Nb) than the Western Pacific (8Nb), as found by (e.g.,) Waugh and Polvani 2000.
- However, in many parts of the subtropics interannual variability can be as strong as the seasonal cycle.
Abundances over land are high in spring and early summer

Interannual variability is high during these months also

Values are consistently lower later in the year, and much more repeatable

Over India, the ozone abundances plummet during summer
  - This reflects the strong convective uplift of comparatively clean air by deep convection
  - We’ll return to this issue later

Over the western Pacific, ozone abundances are much lower and the seasonal cycle is much reduced
Tropical O$_3$ seasonal cycles are weak, esp. over oceans

- Some seasonal variations seen over land
  - e.g., 11Sa, 1Sa (upper)
- But over the Pacific, seasonal variations are virtually non-existent
  - e.g., 6Sa (lower left)
- Also, there is an interesting ‘double peak’ structure seen over tropical east Africa (2Sa)
  - Peaks in both March/April and November/December
Cloud Ice (i.e., convection) variations

— 215 hPa Cloud ice (Atlantic)

As previously reported, convection is strongest over land.
Seasonal cycles over Africa are quite repeatable, while convection over the Indian Ocean (and, to some extent, South America) shows more interannual variability.
The passage of the ITCZ is seen in the seasonal cycle

Interannual variations in convection are strong over Indonesia, Polynesia etc.
Cloud Ice (i.e., convection) variations

Ozone / convection relationships

Strong convection generally associated with reduced O$_3$...

- In some regions (e.g., India, 3Nb, left), strong convection can significantly reduce ozone abundances.
- However, the absence of convection does not imply increased ozone.
- The western Pacific shows low ozone in spring, implying weak influx of stratospheric air in this region.
The strong seasonal cycle in convection over Amazonia (11Sa, right) is significantly anticorrelated with $O_3$. However, a similar (opposite phase for opposite hemisphere) cycle in convection over Central America (10Na, left) is, if anything, weakly correlated with $O_3$. The Sep/Oct $O_3$ maximum in this region is thought to be related to lightning NO$_x$ and precursor emissions from biomass burning.
CO shows much more repeatable seasonal cycles than O₃

In general upper tropospheric CO is a ‘dot product’ between emissions and convection.
- While seasonal cycles are largely repeatable, there are notable exceptions (e.g., over Indonesia)
- Signs of long-range pollution transport from Asia across the Pacific (4Nb – 7Nb)
Strong CO events don’t significantly affect $O_3$

- The 2006 El Niño brought dramatic increases in biomass burning over Indonesia (blue, left)
  - The $O_3$ during this period is mildly enhanced
- An unusual enhancement in CO over South America (green, right) in 2005 shows no significant impact on $O_3$
- However, a comparable enhancement in CO in October 2010 is associated with significantly increased $O_3$
Signatures of industrial vs. biomass burning pollution

- Over India (3Nb) the seasonal cycles in CO and IWC coincide. Here, the lofted pollution is more representative of industrial emissions than biomass burning.
- Over South America (11Sa), the CO enhancement leads the IWC peak by several months. The peak in S. American CO coincides with the peak in biomass burning emissions. Once the convection really sets in, the associated precipitation suppresses biomass burning.
Conclusions and further work

Conclusions

- Interannual variations in tropical upper tropospheric ozone are, in many regions, as strong as the seasonal variations.
- Seasonal variations in convection and carbon monoxide are much more repeatable (with notable exceptions).
- Convection often acts to decrease upper tropospheric ozone, but examples of increased ozone are seen.
- These MLS observations can provide information for validating the depiction of the upper troposphere in chemistry transport models, and, in a climatological sense, chemistry climate models.

Further work

- Compare these observations to models and identify where model improvements are needed.
- Use the models to better understand processes driving these variations, and identify implications for radiative forcing etc.