Microwave Remote Sounding of Atmospheric Composition

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

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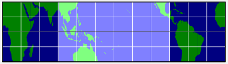
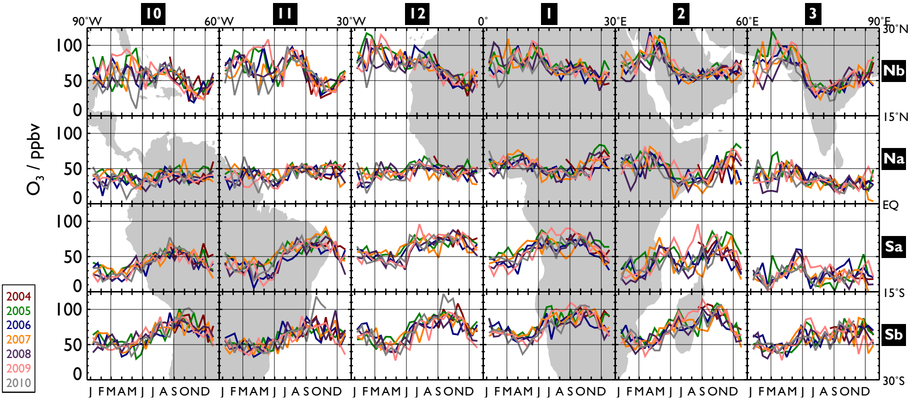
Introduction – observations of low upper trop. O_3

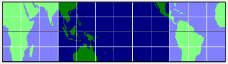
- Tropospheric ozone is an important greenhouse gas with strong geographical and temporal variability (e.g., compared to CO_2 and CH_4 which are well mixed)
- It is in the upper troposphere where ozone's impact on climate is greatest
- Many factors control the abundance of upper tropospheric ozone
  - 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)



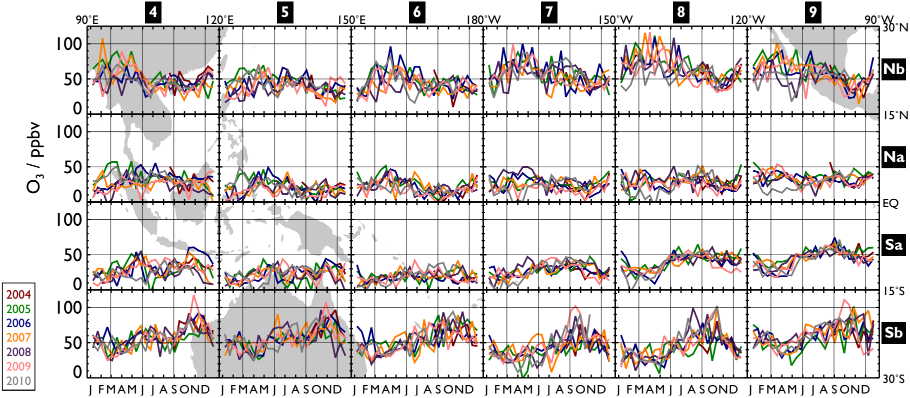
— 215 hPa Ozone (Atlantic)



- Larger abundances and variabilities in the subtropics (Nb/Sb) than the tropics (Na/Sa)

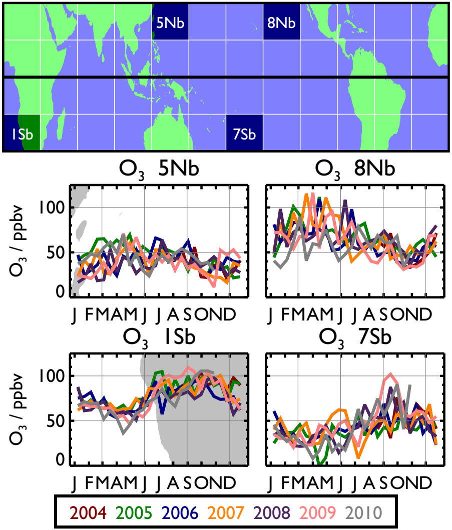


— 215 hPa Ozone (Pacific)

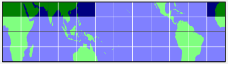


- The 'wave one' feature is evident (less O_3 in the Pacific sector)
- The signature is a little more pronounced in the southern than the northern subtropics

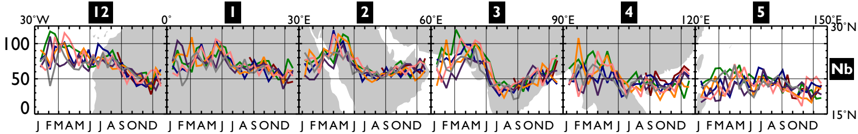
The subtropics exhibit moderate seasonal cycles in ozone



- In the subtropics, we see moderate seasonal cycles in ozone, with more O_3 in winter/spring than summer/fall
- The northern subtropical springtime 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

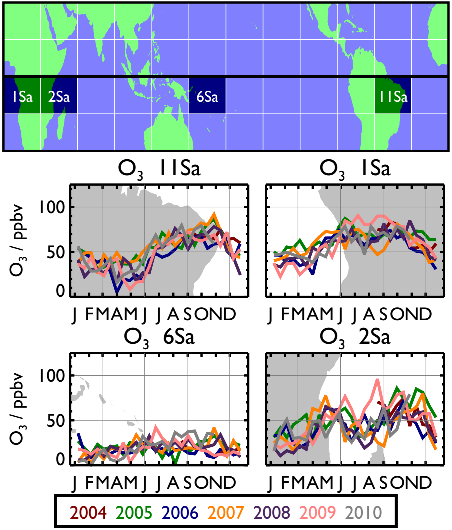


Variations over North Africa / India

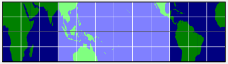


- Abundances over land are high in spring and early summer
- Interannual variability is high during these months also
- Values are consistently lower later in the year, and much more repeatable
- Over India, the ozone abundances plummet during summer
  - This reflects the strong convective uplift of 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

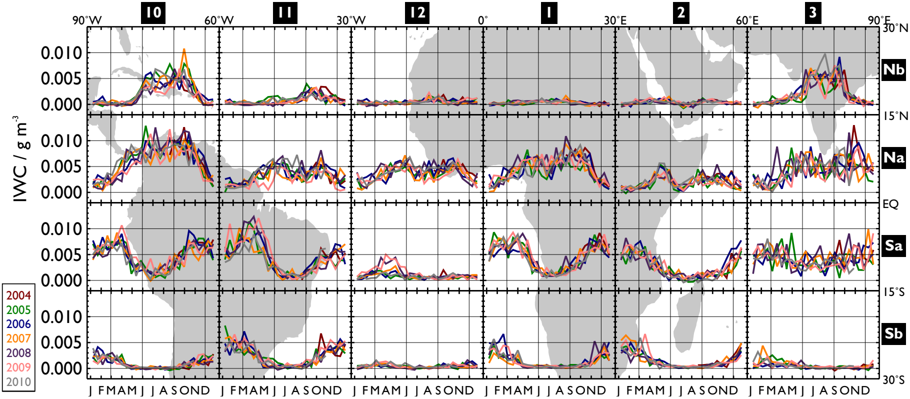
Tropical O_3 seasonal cycles are weak, esp. over oceans



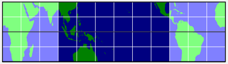
- Some seasonal variations seen over land
    - e.g., 11Sa, 1Sa (upper)
- But over the Pacific, seasonal variations are virtually non-existent
    - e.g., 6Sa (lower left)
- Also, there is an interesting ‘double peak’ structure seen over tropical east Africa (2Sa)
    - Peaks in both March/April and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



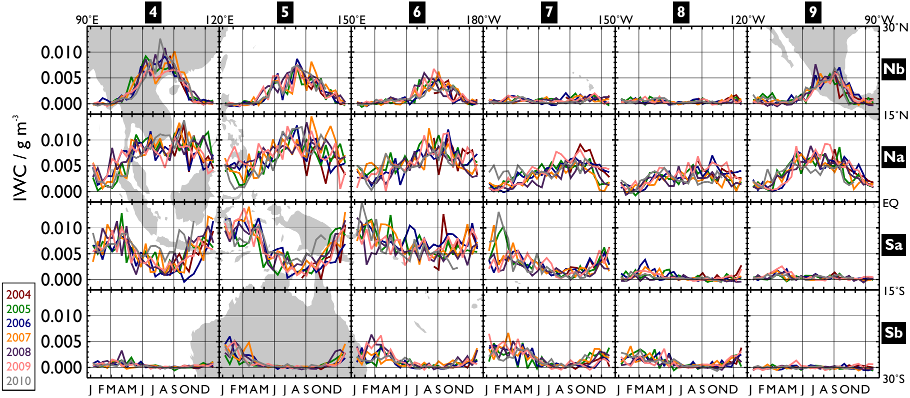
— 215 hPa Cloud ice (Atlantic)



- 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

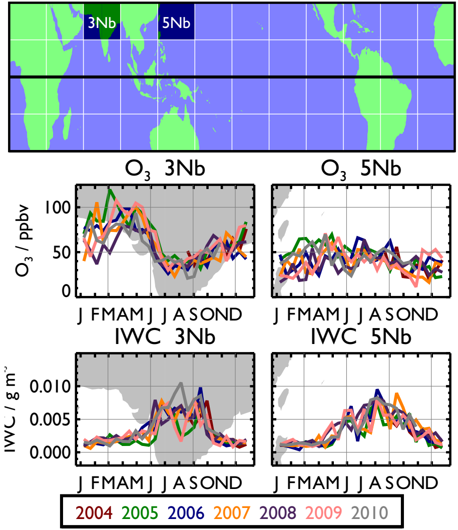


— 215 hPa Cloud ice (Pacific)



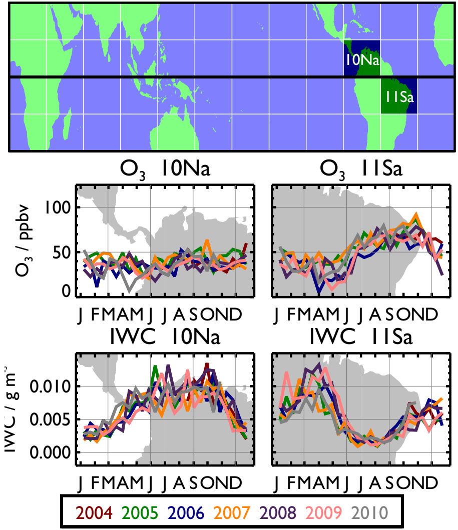
- The passage of the ITCZ is seen in the seasonal cycle
- Interannual variations in convection are strong over Indonesia, Polynesia etc.

Strong convection generally associated with reduced O_3...

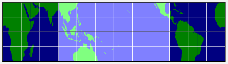


- In some regions (e.g., India, 3Nb, left), strong convection can significantly reduce ozone abundances
- However, the absence of convection does not imply increased ozone
- The western Pacific shows low ozone in spring, implying weak influx of stratospheric air in this region

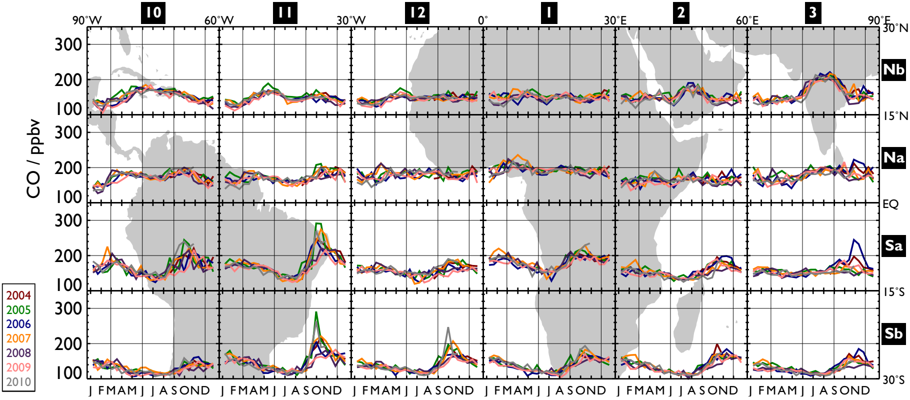
. . . but not in all cases



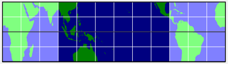
- The strong seasonal cycle in convection over Amazonia (11Sa, right) is significantly anticorrelated with O_3
- However, a similar (opposite phase for opposite hemisphere) cycle in convection over Central America (10Na, left) is, if anything, weakly correlated with O_3
  - The Sep/Oct O_3 maximum in this region is thought to be related to lightning NO_x and precursor emissions from biomass burning



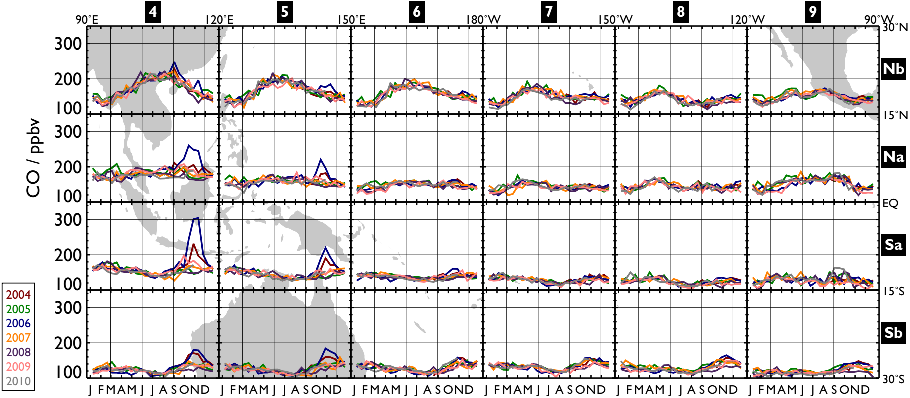
— 215 hPa Carbon monoxide (Atlantic)



- CO shows much more repeatable seasonal cycles than O_3
- In general upper tropospheric CO is a 'dot product' between emissions and convection.

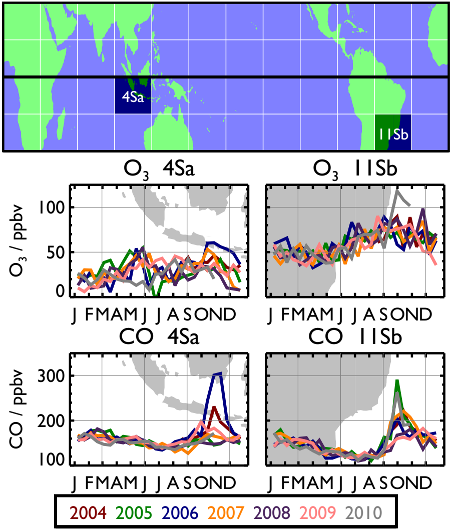


— 215 hPa Carbon monoxide (Pacific)



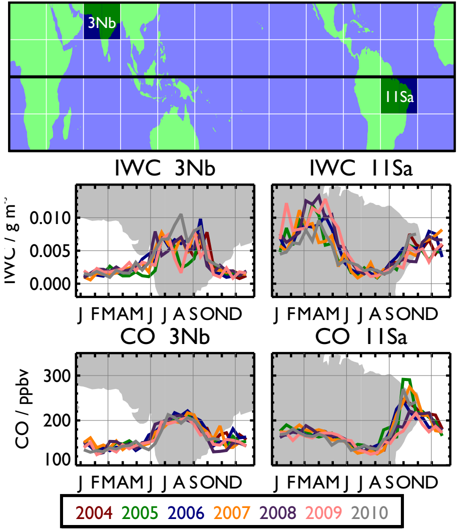
- While seasonal cycles are largely repeatable, there are notable exceptions (e.g., over Indonesia)
- Signs of long-range pollution transport from Asia across the Pacifc (4Nb – 7Nb)

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.