On Aerosol-CO Relationship, and Aerosol Effect on Ice Cloud Particle Size

— Analyses from Aura MLS and Aqua MODIS Observations —

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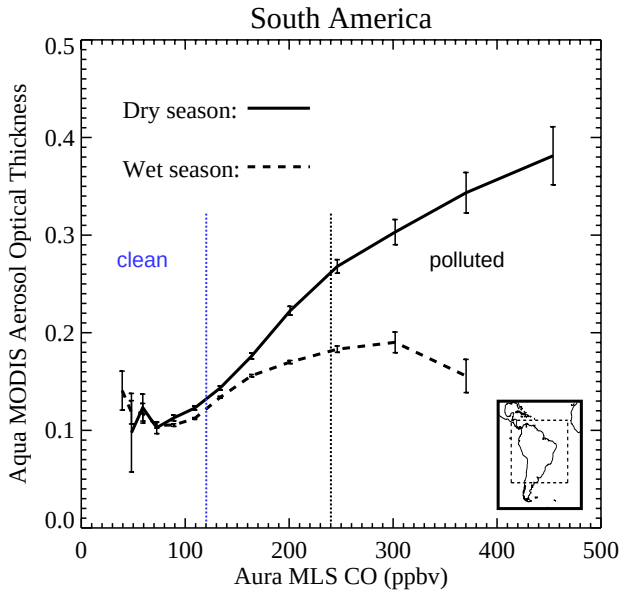
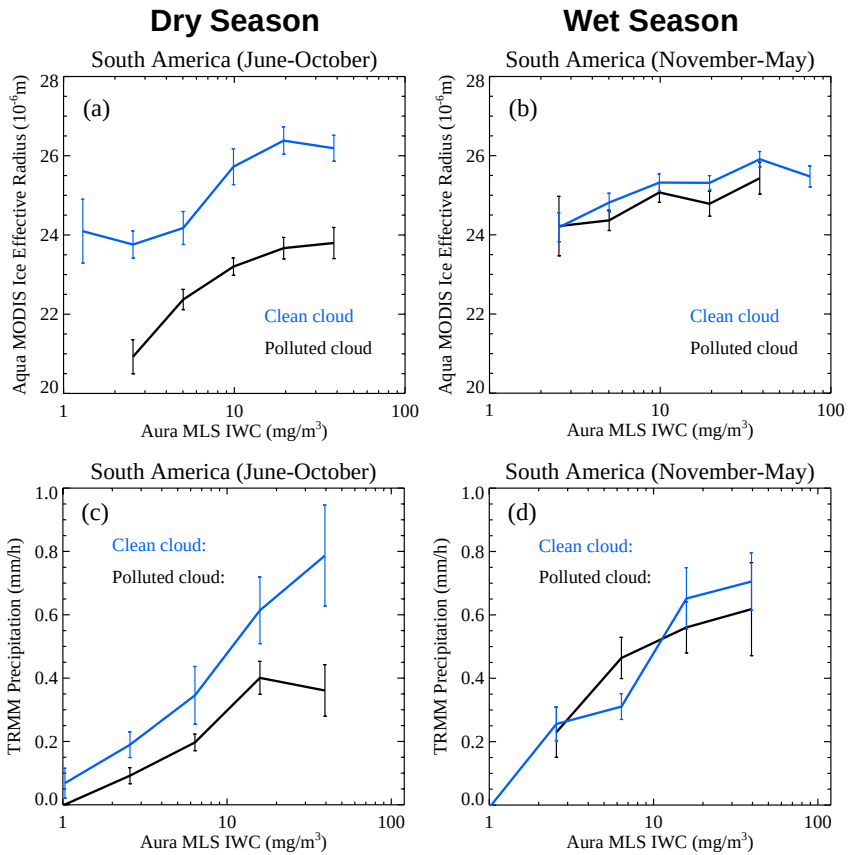
Review: findings from a previous work



Top: Aqua MODIS AOT versus Aura MLS CO (215hPa)

Right: Ice cloud r_e and associated precipitation, for polluted & clean clouds, sorted by collocated IWC

– *Jiang, Su and Schoeberl et al.* [2008]

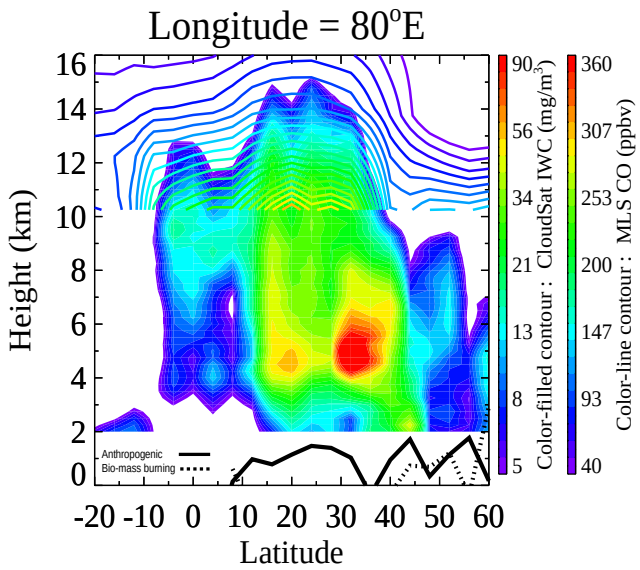


- A positive correction between MLS CO and MODIS AOT during dry season (Jun-Oct) in South America
- MLS CO is used as a proxy for aerosol in cloudy regions
- During the dry season, for the same IWC amount (i.e. convection strength), the polluted clouds have smaller effective radii and are associated with weaker precipitation
- During the wet season (Nov-May), the polluted clouds defined by the CO amount show little differences in cloud particle size and precipitation from the clean clouds.

Remaining question (1)

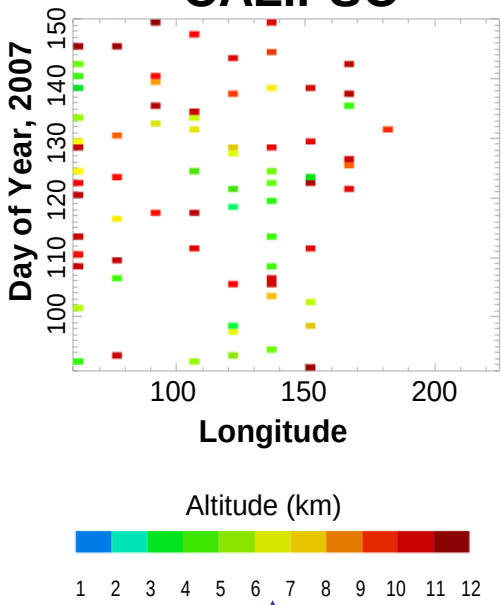
1. **MLS CO is measured in the upper troposphere (UT). However, MODIS AOT is a columnar quantity which does not tell the height of aerosols, which may locate in the lower troposphere**

CloudSat + MLS



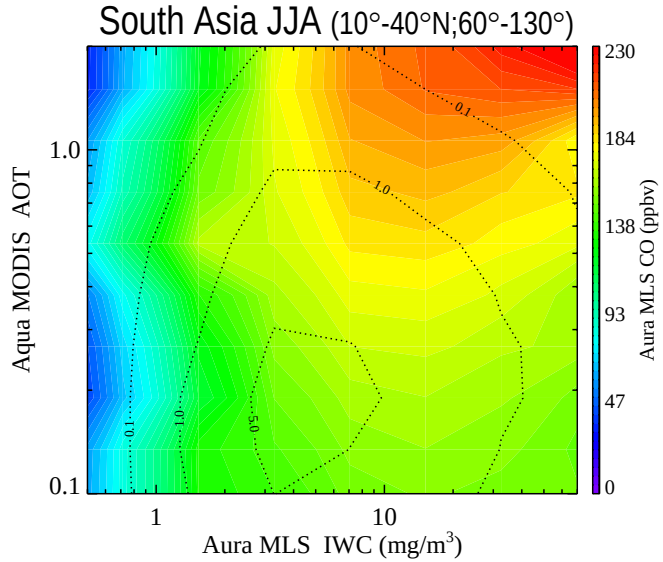
Evidence of convective up lift of CO to UT

CALIPSO



Evidence of aerosols in the UT

MODIS + MLS

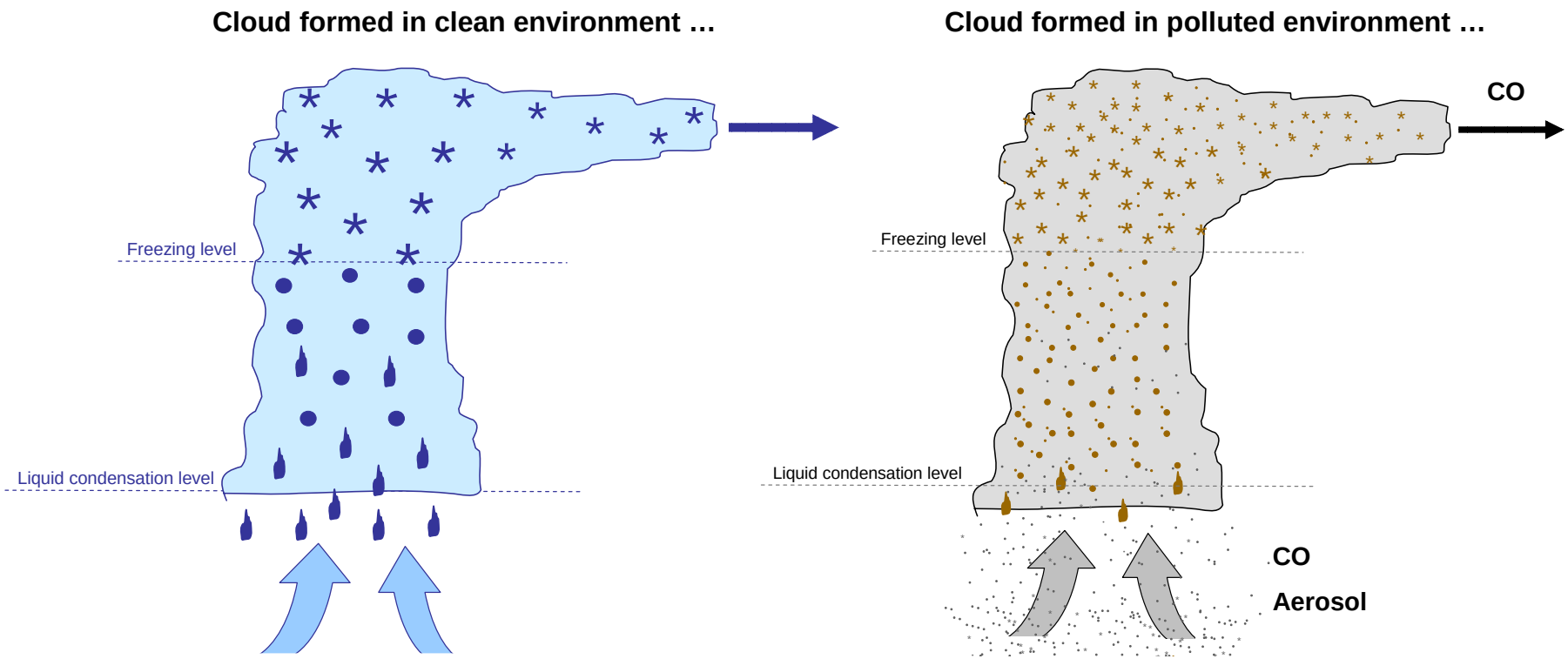


Observed CO, AOT, and IWC relationship

Combined observational evidences from A-Train (MLS, CloudSat, CALIPSO & MODIS) do show that:

- UT CO is related to convective uplifting of surface pollution,
- Aerosol pollutants can exist in UT (~10-15 km)
- There are cases of high aerosol collocating with high CO in convective clouds.

What about if AOT do remain in lower troposphere?

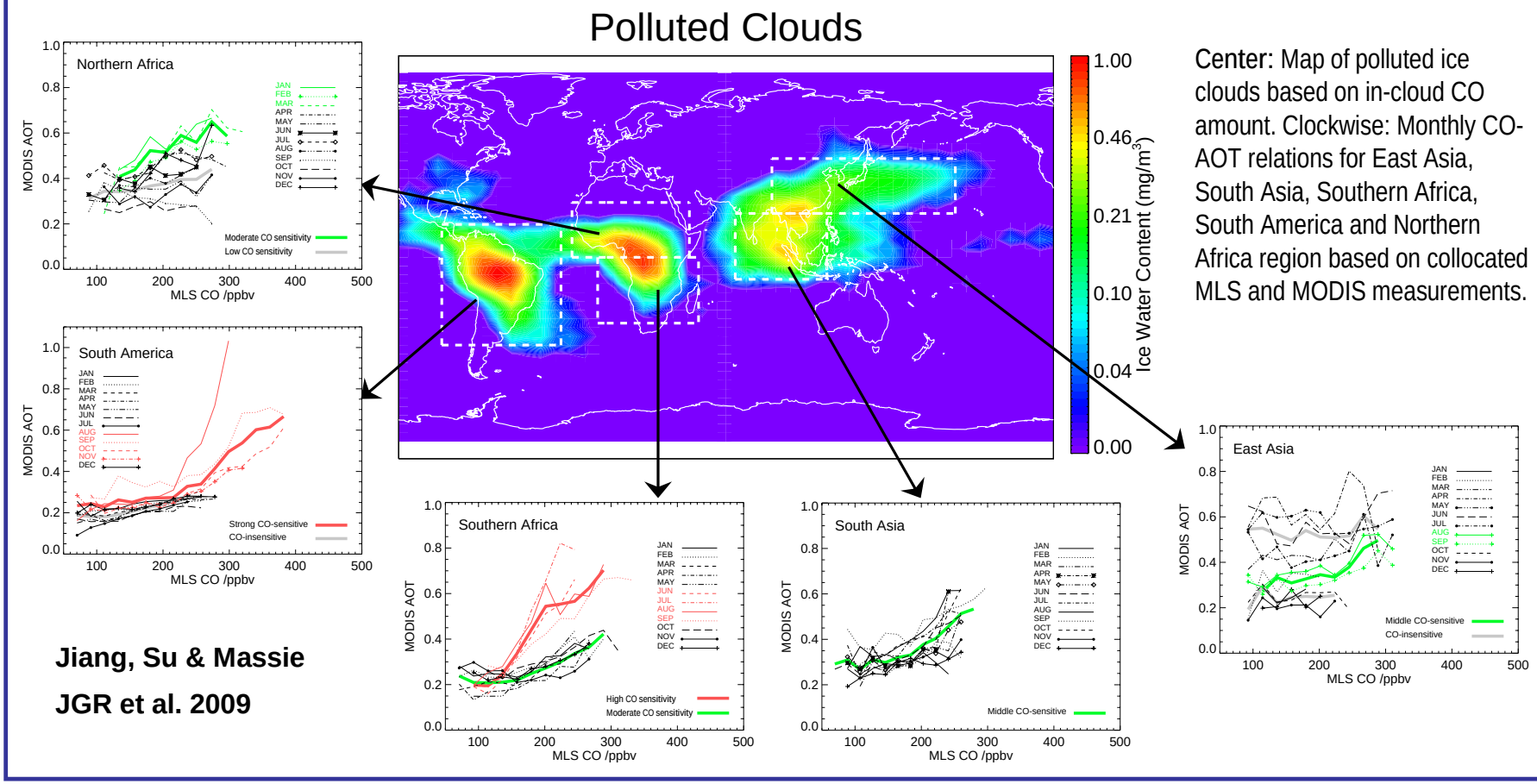


Another possibility is that aerosol can influence ice clouds even it remains at low altitude: When clouds are formed through convection in a region with aerosol pollution, aerosols could reduce the cloud particle sizes near the cloud base and the smaller liquid particles lofted above the freezing level to form ice clouds would bear the signature of aerosol effect [*Sherwood*, 2002].

Remaining question (2)

2. **Besides South America, what are the relationships between aerosol and CO in different regions and seasons, and how good is CO as an aerosol proxy in each of these regions and seasons?**

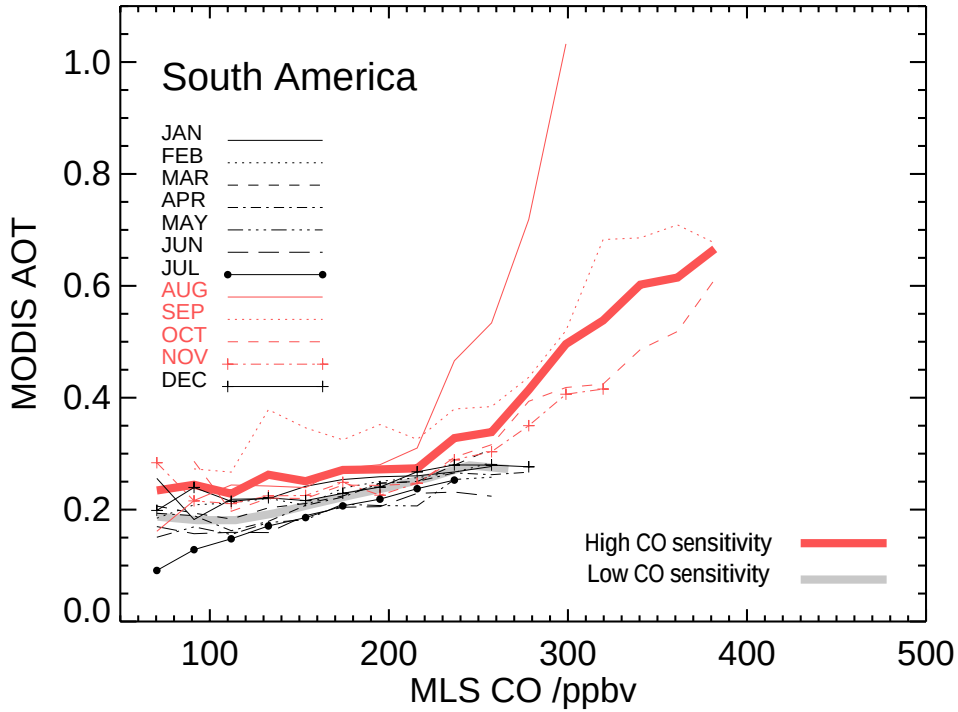
When and where MLS CO can be used as aerosol proxy?



Jiang, Su and Massie et al. [2009] examines the relation between the UT CO and AOT in different regions and seasons, to address when and where MLS CO at 215 hPa could be used as a proxy for AOT.

Monthly AOT- CO relationships – South America (SAM)

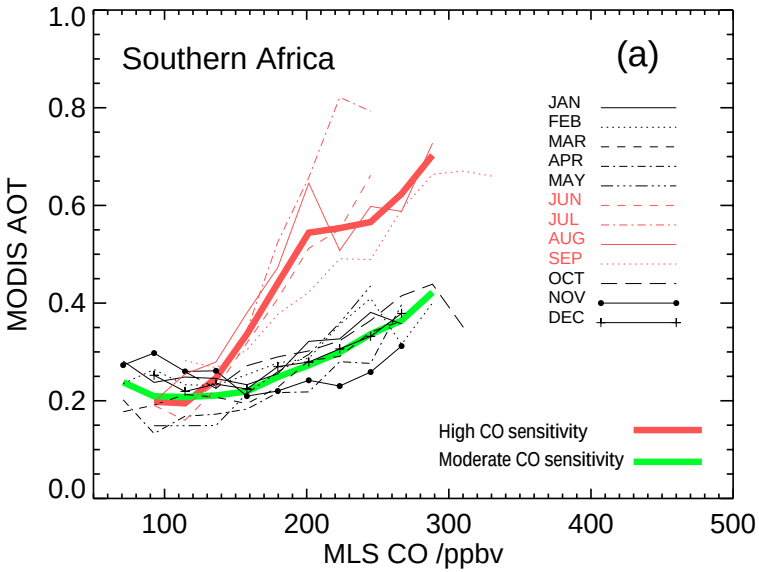
Figure 2 from *Jiang, Su and Massie et al. JGR in press* [2009]

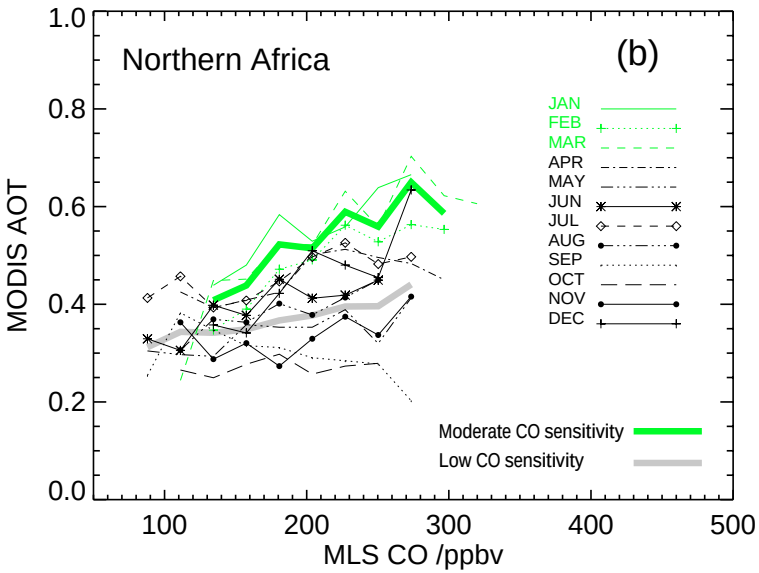


- **High AOT to CO sensitivity** (or shortened as high sensitivity): Aug-Nov.
  The AOT difference for the polluted and clean clouds is > 0.2
- **Low AOT to CO sensitivity** (or shortened as low sensitivity): Dec-Jul.
  The AOT difference for the polluted and clean clouds is < ~0.1

The plot is made in cloudy regions with MLS IWC $\geq$ 2 mg/m^3. The MODIS AOT are collocated with MLS CO by averaging the data in boxes of 3° along the track and 1° across the track centered on the MLS measurement locations. Since the MODIS measurement has much higher horizontal resolution, we found that within the 3°×1° boxes, the AOT data are available in about 40% of the MLS data with IWC $\geq$ 2 mg/m^3

Monthly AOT-CO relationships – Southern & Northern Africa

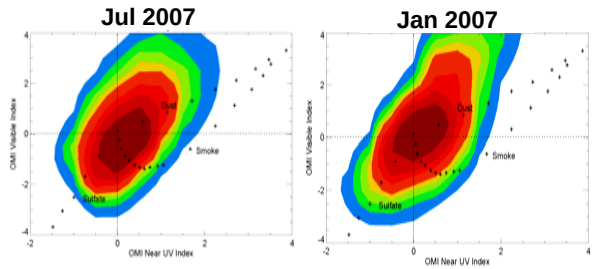




Southern Africa (SAF)

- High sensitivity: Jun-Sep
- **Moderate sensitivity**: Oct-May. The AOT difference is within 0.1 and 0.2 between clean and polluted clouds.

Preliminary analysis of aerosol type using OMI data



Northern Africa (NAF)

- Moderate sensitivity: Jan-Mar
- Low sensitivity: Apr-Dec

NAF has more dust type aerosols, of which CO is not a good proxy

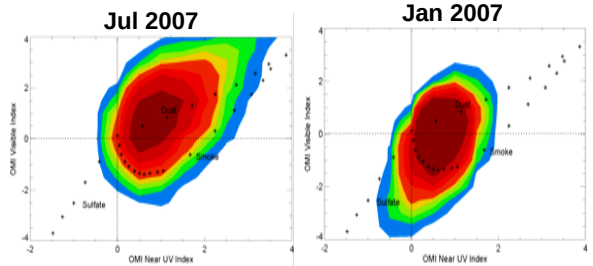
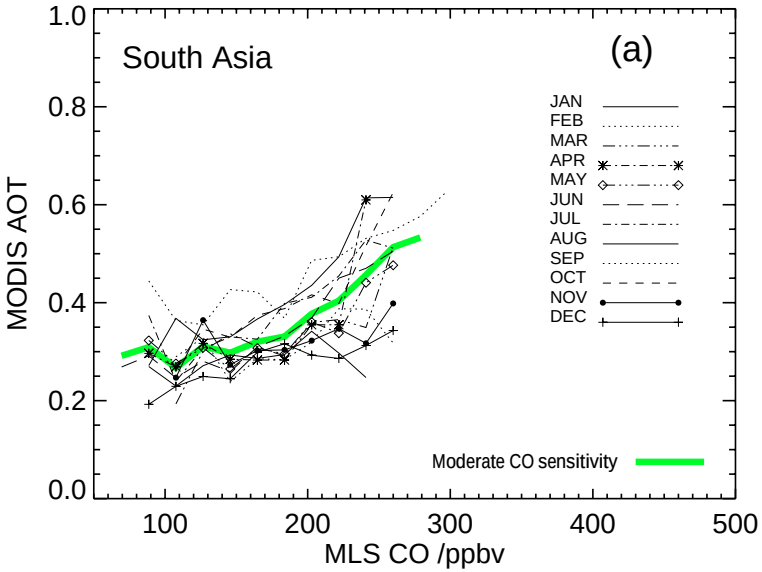


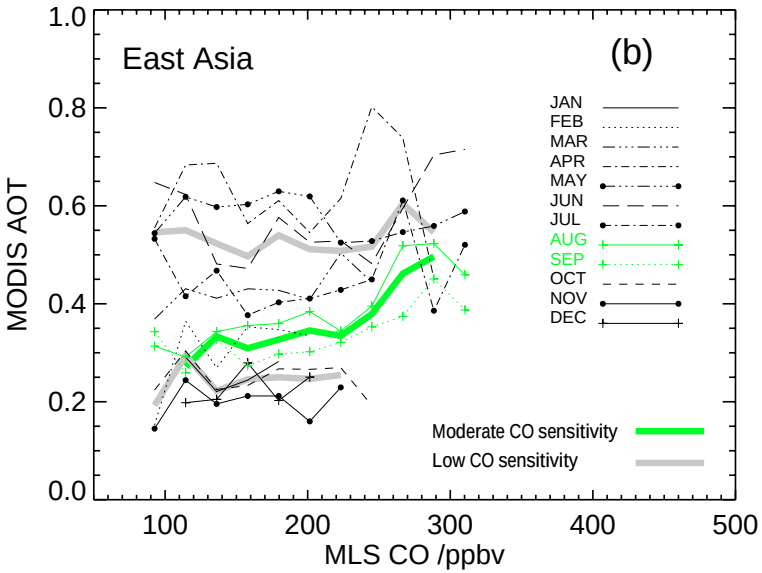
Figure 3 from *Jiang, Su and Massie et al. JGR in press* [2009]

Monthly AOT-CO relationships – South & East Asia



South Asia (SAS)

- Moderate sensitivity: all year around



East Asia (EAS)

- Moderate sensitivity: Aug-Sep
- Low sensitivity: Oct-Dec (low AOT); Jan-Jul (high AOT, mainly Dust)

Preliminary analysis of aerosol type analysis using OMI data

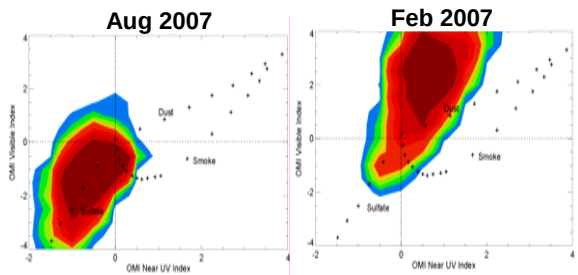
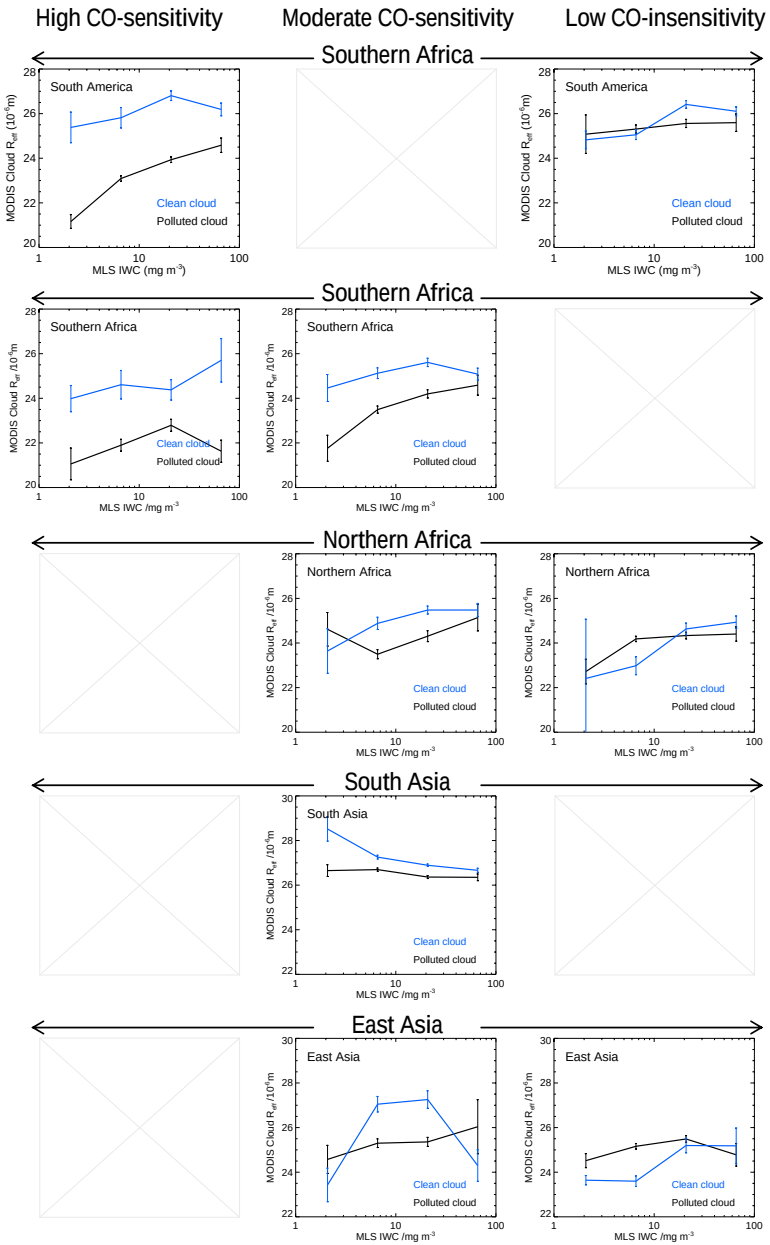


Figure 4 from *Jiang, Su and Massie et al. JGR in press* [2009]

Aerosol influence on ice cloud particle size



- High and Moderate sensitivity: smaller particle size for the polluted clouds than the clean clouds
- Low sensitivity: no clear or no significant difference in particle size between the polluted and clean clouds

Separating clean and polluted clouds		**AOT sensitivity to CO**		
Clean	Polluted	High	Moderate	Low
CO <110 ppbv	CO > 220 ppbv	$\delta > 0.2$	$\delta \sim 0.1$-0.2	$\delta < 0.1$

CO is a good aerosol proxy

CO is an OK aerosol proxy

CO can no be used as an aerosol proxy

Figure 5 from *Jiang, Su and Massie et al. JGR in press* [2009]

Conclusions

1. **Three categories are found for the AOT and CO relations:**
   - **High Sensitivity:** the AOT difference between the CO-polluted clouds and the clean clouds > 0.2.
   - **Moderate Sensitivity:** the AOT difference between the CO-polluted clouds and the clean clouds within 0.1 and 0.2.
   - **Low Sensitivity:** the AOT difference between the CO-polluted clouds and the clean clouds < ~0.1.
2. **During the high and moderate sensitivity periods, the CO-polluted clouds have smaller particle size than the clean clouds; during the low sensitivity periods, no significant difference is observed between the CO-polluted clouds and clean cloud.**
3. **Near-simultaneous and collocated A-Train measurements are important for studies of aerosol-cloud interactions.**

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3. **Near-simultaneous and collocated A-Train measurements are important for studies of aerosol-cloud interactions.**

Fly ACE and GACM in a close time-frame will greatly, greatly enhance the scientific return of climate studies, process analyses, model evaluations, and studies of aerosol-cloud interactions, etc.