Convective transport of surface pollution

Preliminary analyses from "A-Train" satellites

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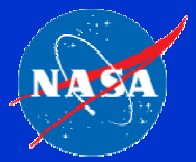
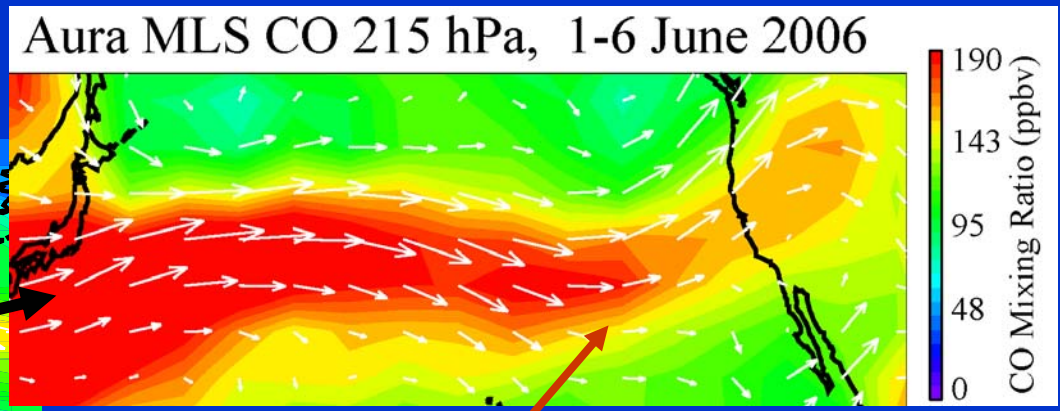
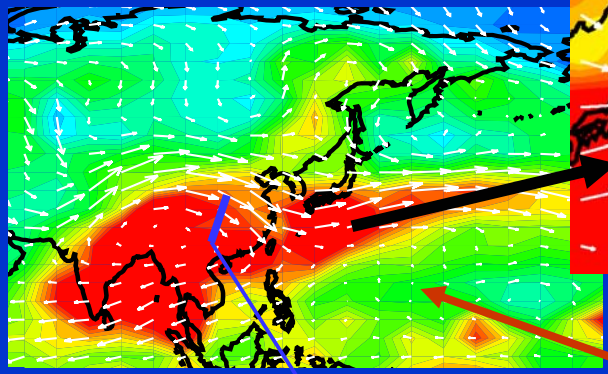


JPL

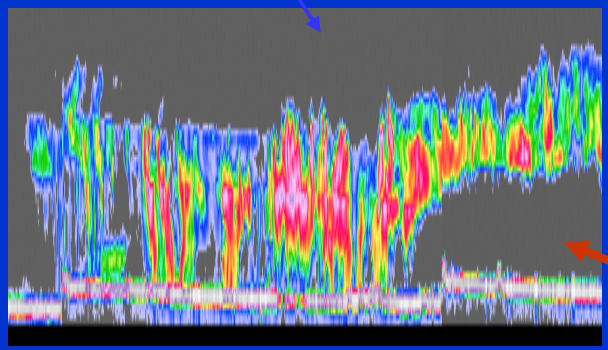
Objective



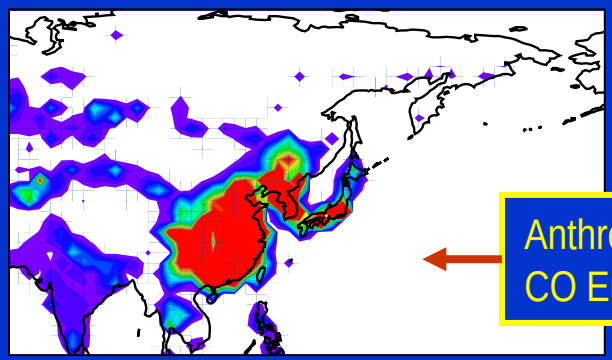


MLS observed upper tropospheric CO enhancement

MLS observed long range transport of CO at 215 hPa



CloudSat observed convection event over Asian continent



Anthropogenic CO Emission

The goal is to use combined multi-satellite observations to study how boundary layer pollutions transport vertically and globally, and how they affect air quality and climate.

Approach

(1) "Track Approach": (Focus of this talk)

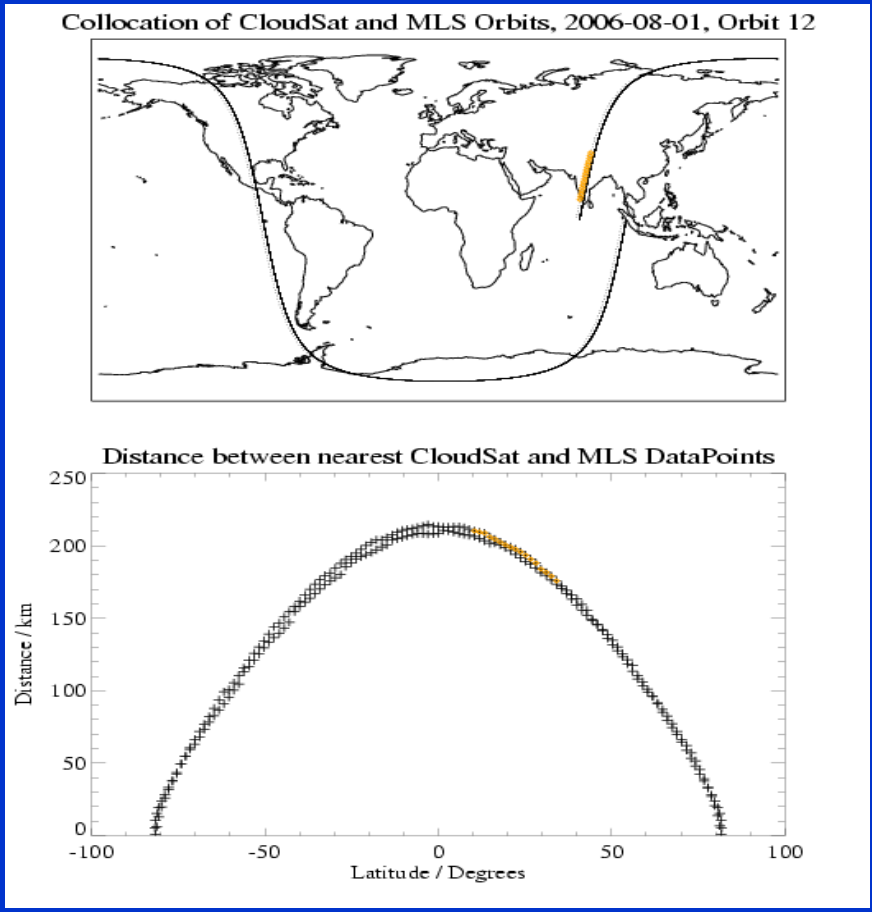
- Analyze data along the A-Train tracks to study nearly-simultaneous measurements of pollutants and clouds, and to find signature of altered cloud properties by pollutants/aerosols.
- The track approach can be applied to any satellite datasets in the A-Train family. Model data can also be interpolated onto the satellite tracks.

(2) "Gridded Approach":

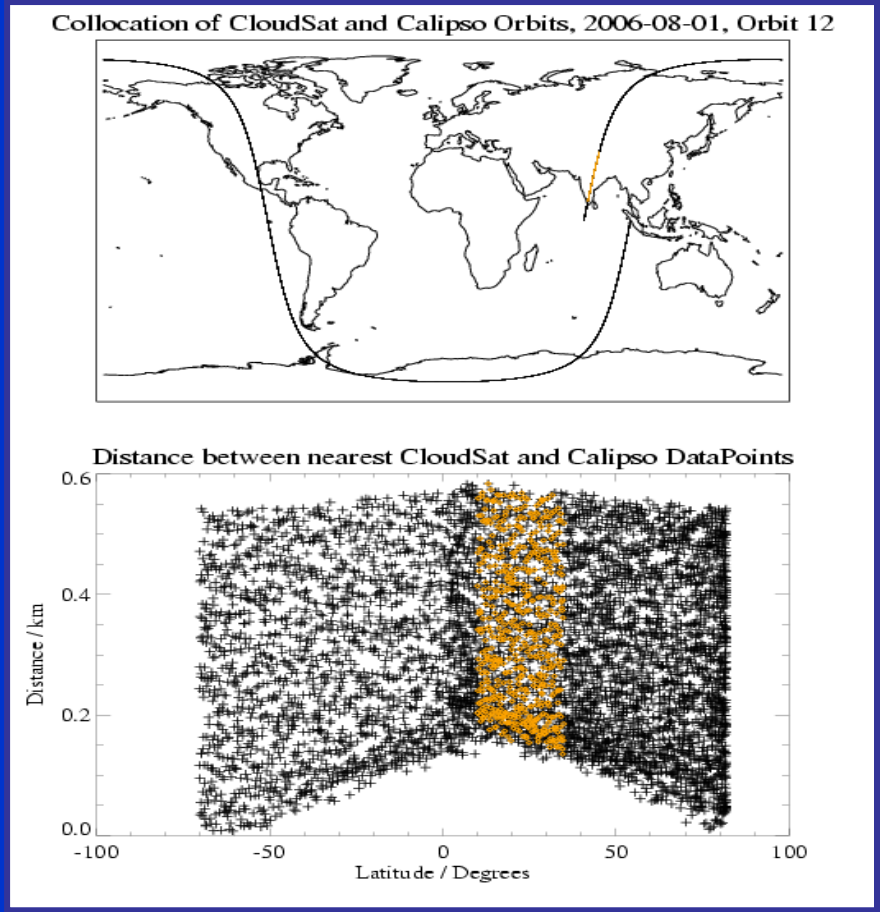
- Due to the limitations of the datasets (coarse temporal resolution and large separation between the orbits), this approach focuses on studying the bulk properties of cloud, aerosol and other tracers averaged over certain space and time.
- The gridded approach is convenient for model-data comparison studies.

Collocation between the “A-Train” Tracks

Aura and CloudSat Orbits



CloudSat and CALIPSO Orbits

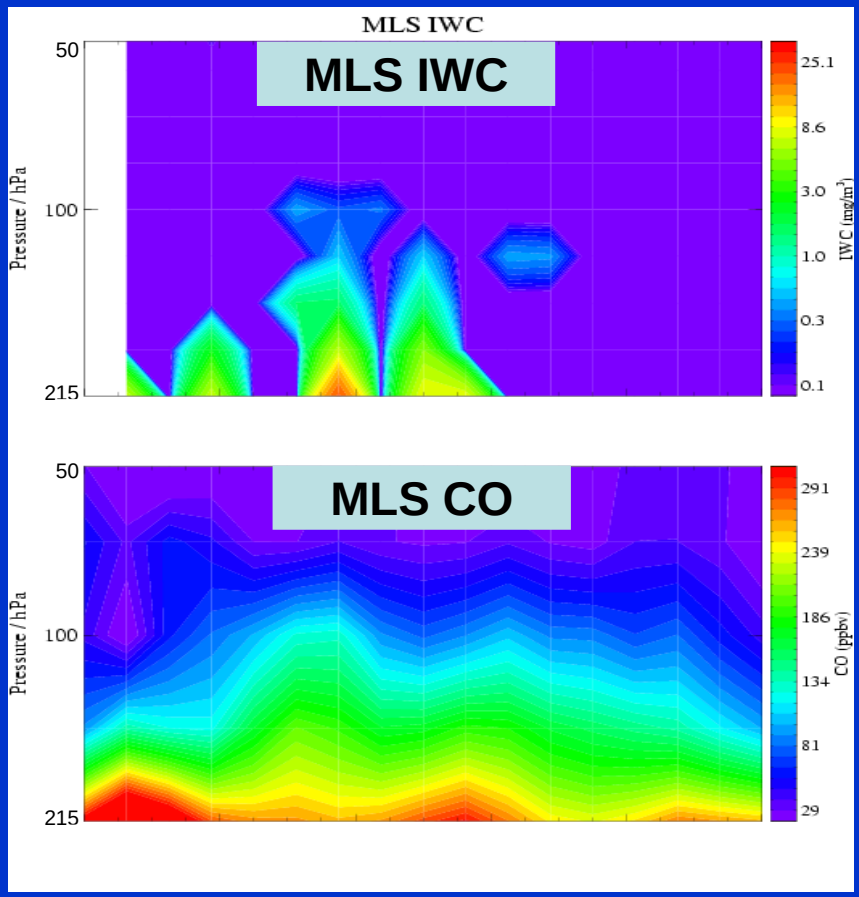


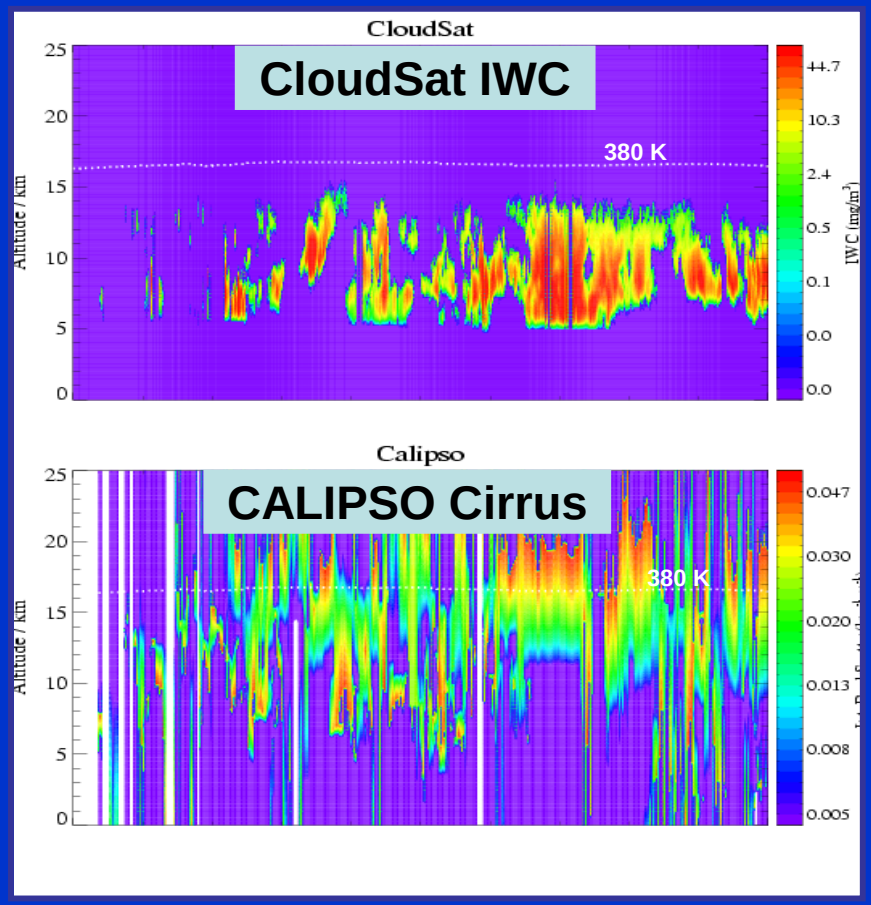
Left panels: collocation between CloudSat and Aura orbits and distance between the nearest data points. There is ~200km separation between the two orbits near the tropics.

Right panel: collocation between CloudSat and CALIPSO orbits. The maximum separation between the two orbits is typically less than a few kms throughout the globe.

The section of orbit that marked in **red** color will be used for curtain plots shown in next page)

Collocated “curtain” plots along the “A-Train” tracks





Left panels: Curtain plots of Aura MLS measured cloud Ice Water Content (IWC) and CO mixing ration along a section of orbit over India. (*MLS v2.2 data are used*).

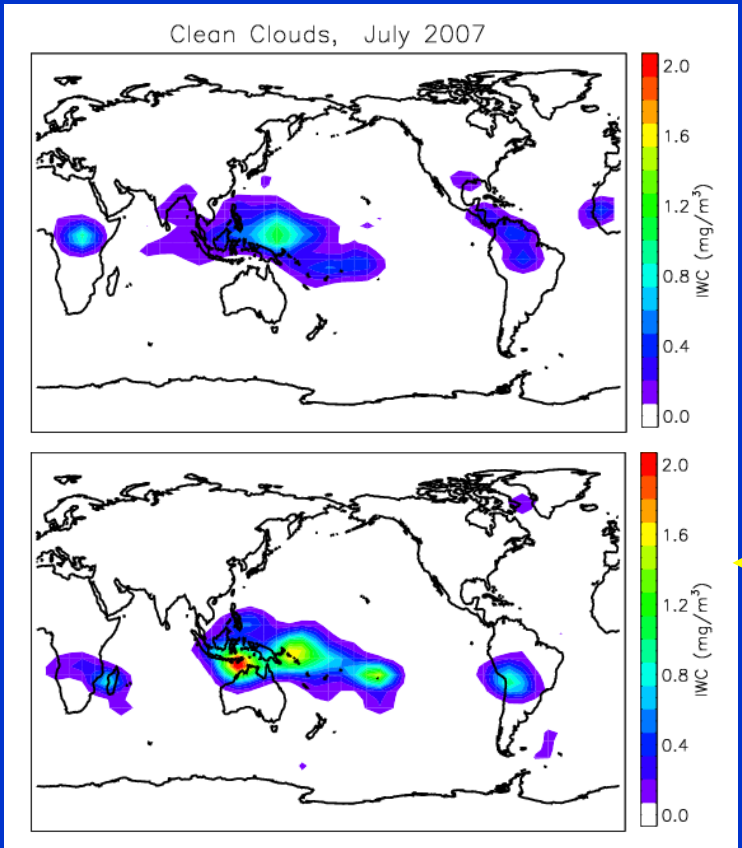
Right panel: Curtain plots of CloudSat measured IWC (v3) and CALIPSO cirrus backscatter (v1.1) along a section of orbit over India. CALIPSO measures thin cirrus at higher altitudes.

(N.B. The white strips in CALIPSO data are gaps with “missing or bad-data”. The data quality screen/control is challenging.)

Separating Clear and Polluted Clouds using MLS data

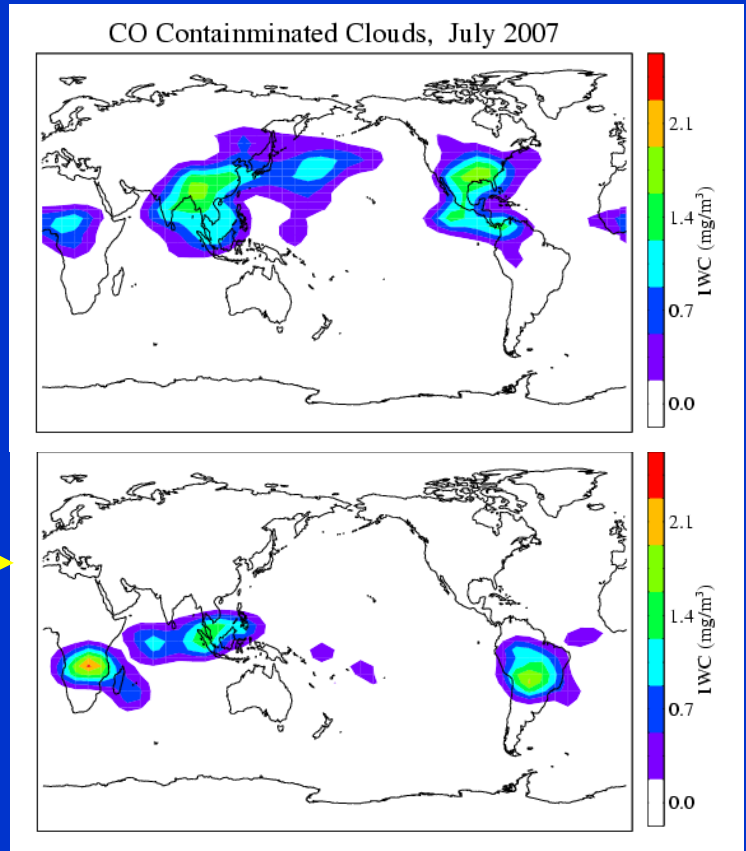
Clean Clouds

Polluted Clouds



July 2007

January 2007

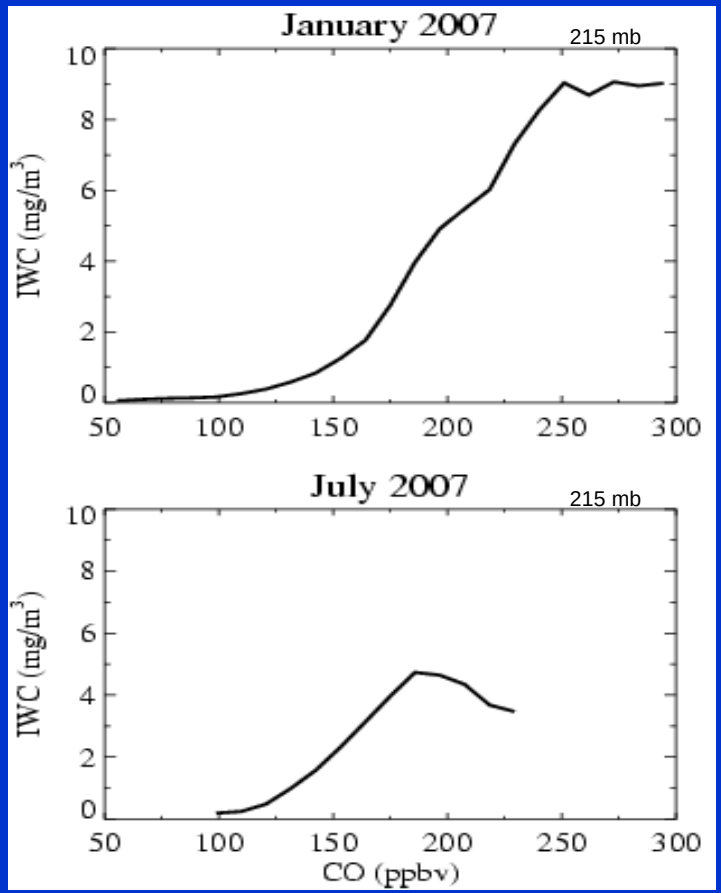


MLS CO data are used to classify ice clouds in the UT as “clean” or “polluted”. We define a polluted cloud using coincident CO measurements greater than a certain background value (e.g. at 215 hPa, the criterion is >100ppbv for polluted clouds and <60ppbv for clean clouds).

(*MLS v2.2 CO and IWC data are used*).

CO, cloud, and precipitation relations

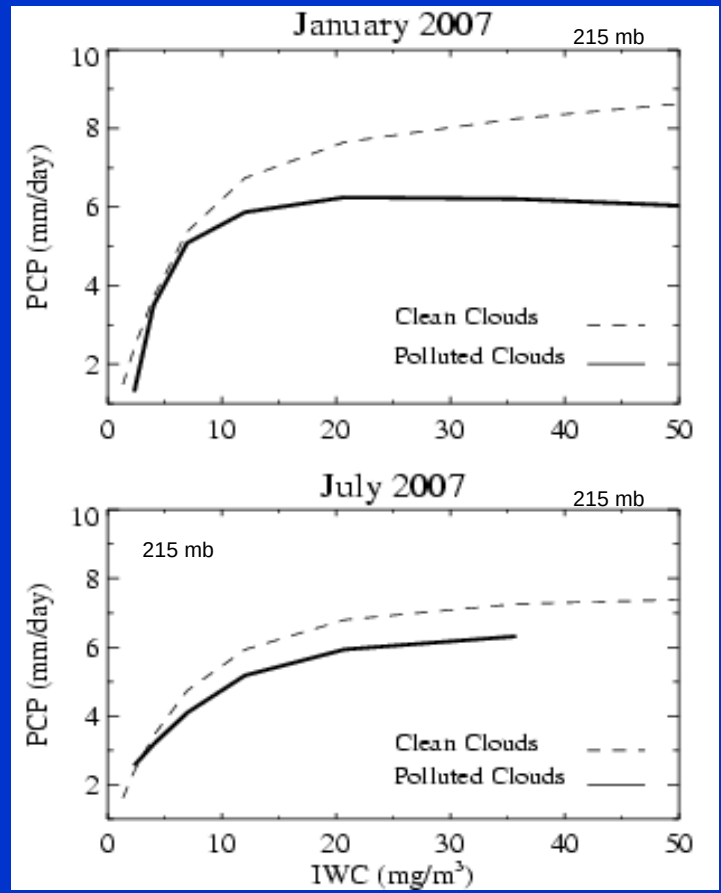
IWC versus CO



Jan 2007

Jul 2007

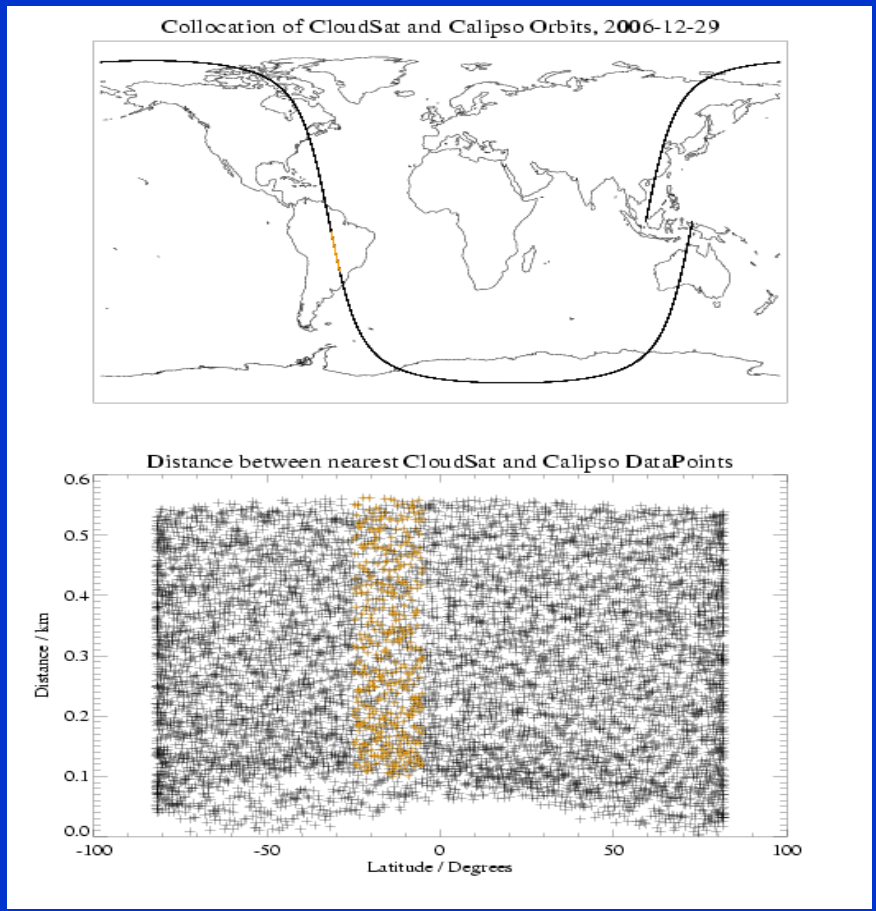
Precipitation versus IWC

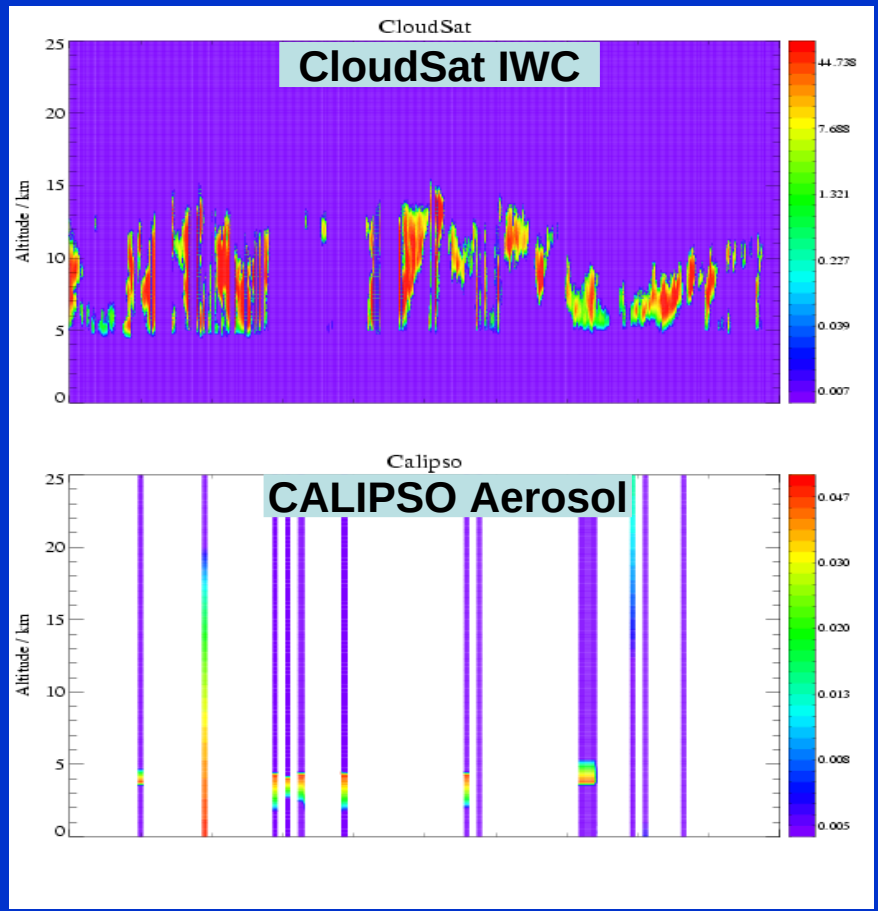


There is a generally positive relation between CO and ice cloud amount in the upper-troposphere, reflecting convective transport of surface pollution.

Cloud ice and precipitation (NCEP) are positively correlated. The “polluted” ice clouds are associated with less rainfall than “clean” clouds.

Identify aerosol contaminated clouds using CALIPSO and CloudSat data





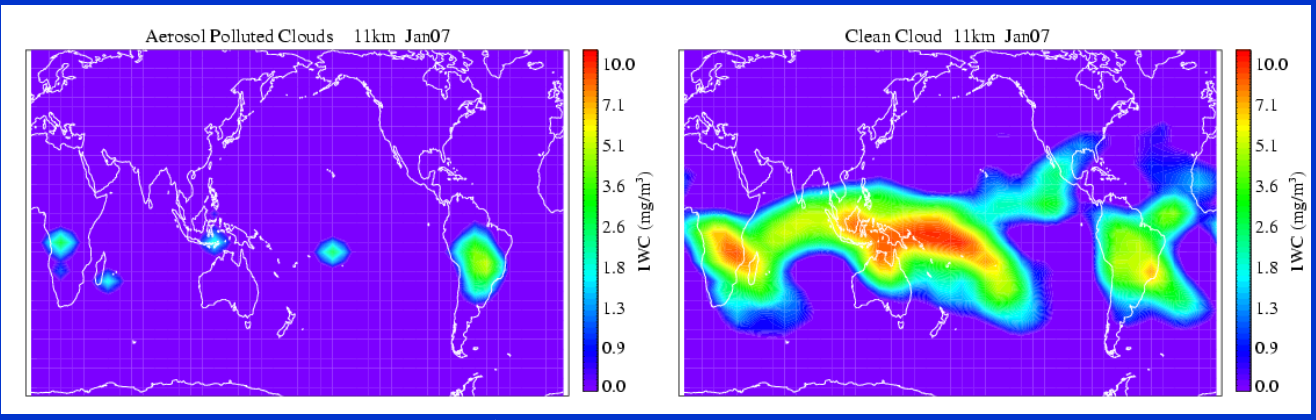
Curtain plots of CloudSat measured IWC (v3) and CALIPSO aerosol backscatter (v1.1) along a section of orbit over South America as shown by the left panel (marked in **red**). Most aerosols are located at lower troposphere; however, convection can lift aerosols associated with strong emission source such as bio-mass burning to high altitudes.

(N.B. The white strips in CALIPSO data are gaps with "missing or bad-data". The data quality screen/control is challenging.)

Aerosol contaminated Clouds

Aerosol contaminated ice clouds

Aerosol free ice clouds

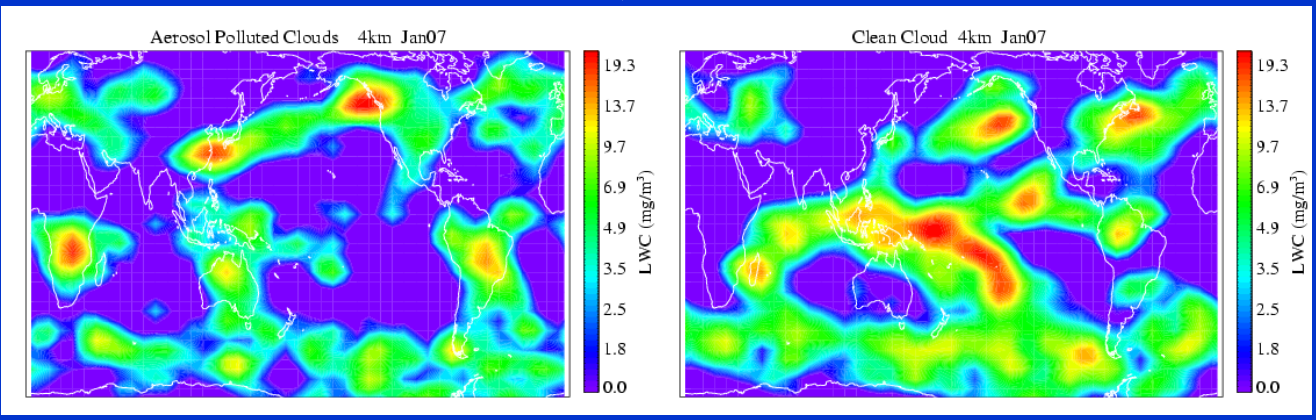


11 km, Jan 07

4 km, Jan 07

Aerosol contaminated liquid clouds

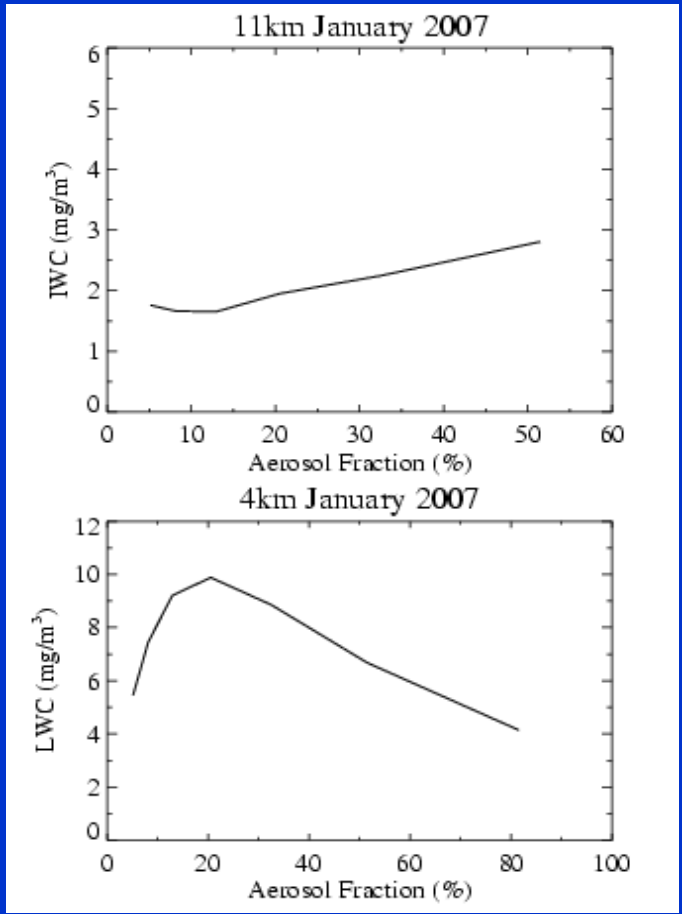
Aerosol free liquid clouds



- Aerosols can be found to collocate with warm liquid clouds. For UT ice clouds, only ~5% are mixed with aerosols.
- Aerosol-contaminated ice clouds are concentrated over land over South America and Africa. East China and North America west coast have 2 maxima of aerosol-contaminated liquid clouds.
- Oceanic clouds are mostly aerosol free, except that the liquid clouds in equatorial Atlantic are mixed with aerosols.

Aerosol, cloud, and precipitation

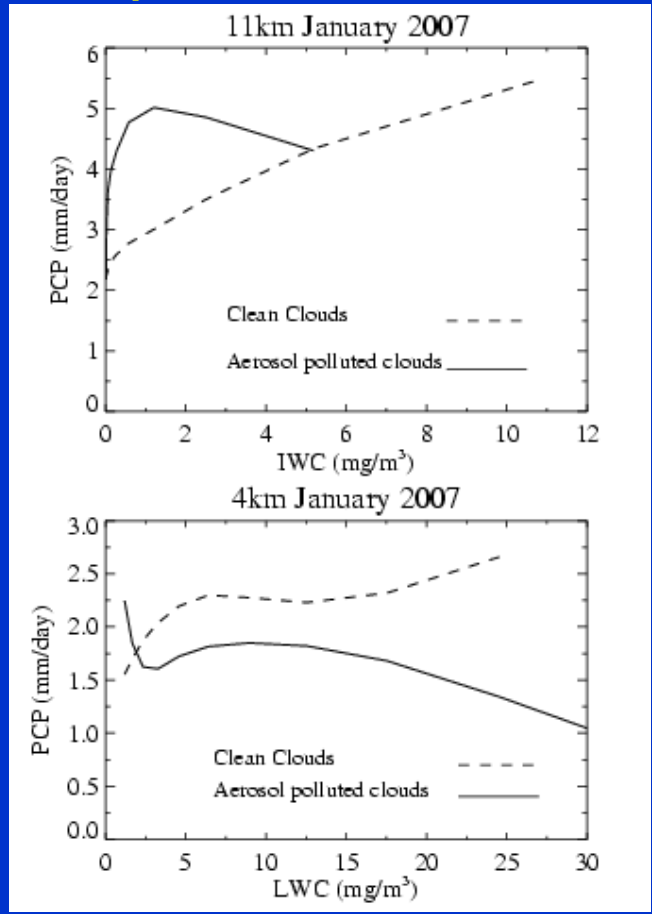
IWC/LWC versus Aerosol



Ice Cloud → 11km

Liquid Cloud → 4km

Precipitation versus IWC/LWC



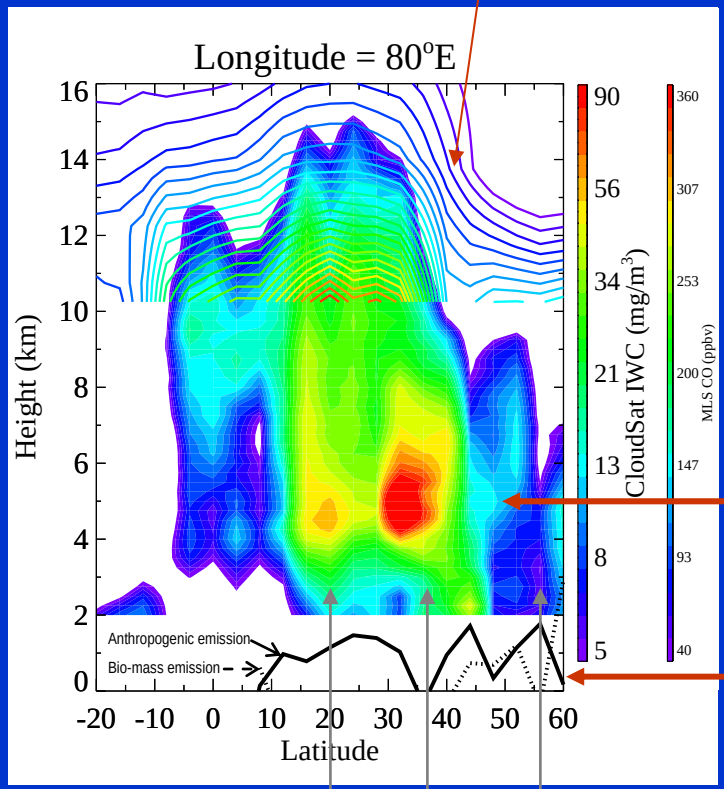
The relation between cloud amount and aerosol loading is complex. In the UT, the cirrus ice increases with the aerosol fraction. At lower altitude, liquid clouds first increase then decrease with aerosol loading.

For “clean” clouds (ice and liquid), increasing cloud amount usually is associated with larger precipitation. The aerosol-contaminated clouds, especially those with large LWC are associated with less precipitation than aerosol-free clouds.

Gridded Approach: comparing data and model for signatures of convective deposition of surface pollution

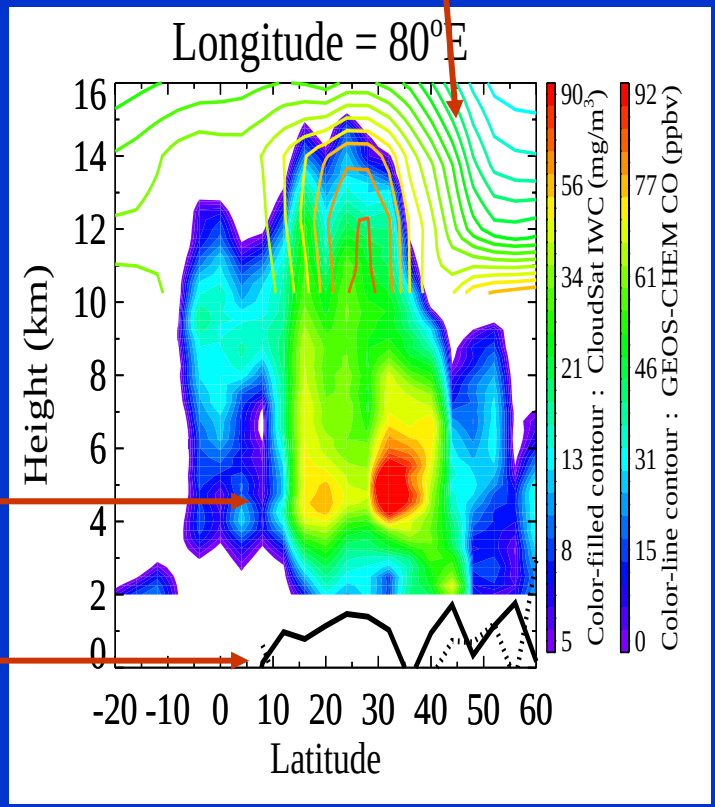
MLS CO

GEOS-CHEM CO



CloudSat IWC

Surface emission



IWP ~1443	IWP ~1448	IWP ~154
EMI ~ 0.1	EMI ~0.01	EMI ~0.2
CO_{147}~142	CO_{147}~99	CO_{147}~0
CO_{215}~281	CO_{215}~192	CO_{215}~98

A-Train data, CloudSat and MLS in this example, could be used to evaluate model performance.

(*See Jiang et al. poster for more examples of gridded approach*)

Summary and Discussion

- A-Train data (Aura-MLS, CloudSat, CALIPSO) are used to investigate convective deposition of boundary layer pollution (CO and aerosols) into the mid- and upper troposphere, and how they interact with clouds.

- We use both “track” approach focusing on the near-simultaneous measurements of pollutants and clouds, and “gridded” approach focusing on the bulk properties cloud, aerosol and other tracers averaged over certain areas and time.

- We use MLS CO data to classify ice cirrus clouds as “clean” or “polluted” and CALIPSO aerosol data to identify liquid and ice clouds that are contaminated by aerosols. Preliminary analyses show “clean” clouds are usually positively correlated with precipitation. “Polluted” clouds are associated with less precipitation than “clean” clouds. The “aerosol contaminated” clouds show more complex relations with precipitation, and the relations vary with altitude.

- Future work will including analyses of collocated cloud particle size information from MODIS data. We will also perform model simulations and model-data comparisons.

Acknowledgements

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