# Using CloudSat and MLS data to study convection and deposition of surface pollution in the upper troposphere

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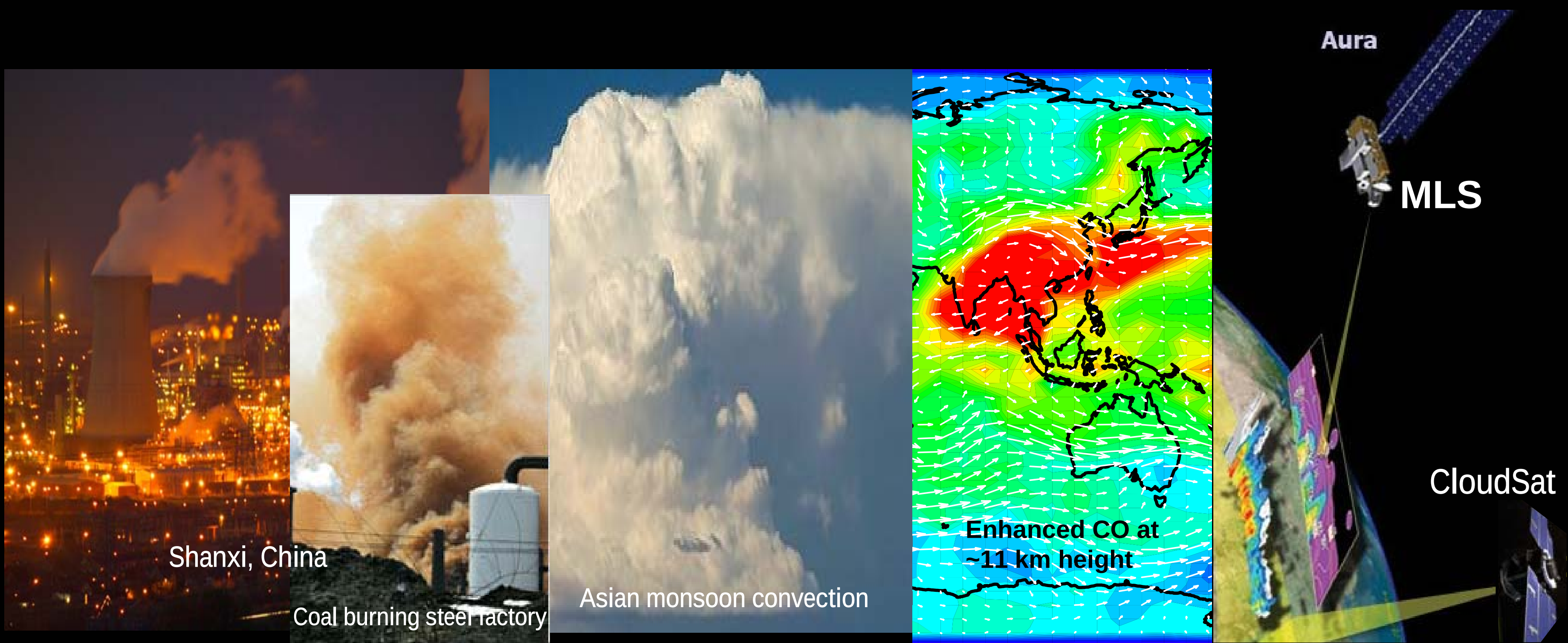
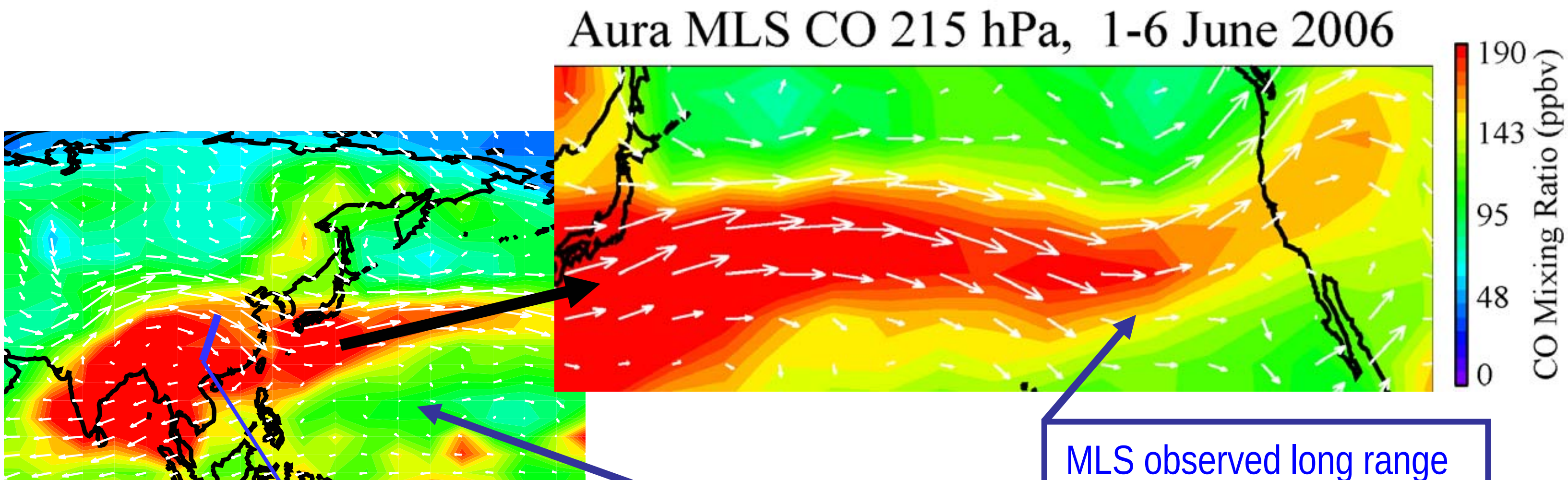
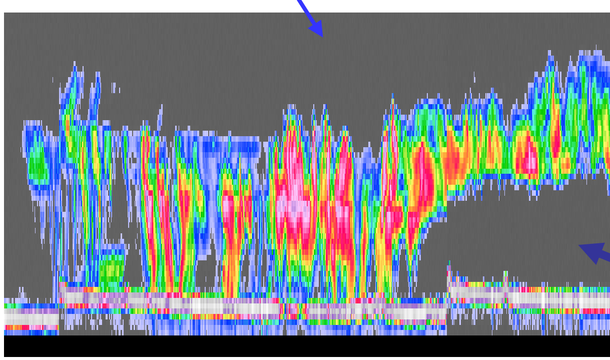


# Why we care?

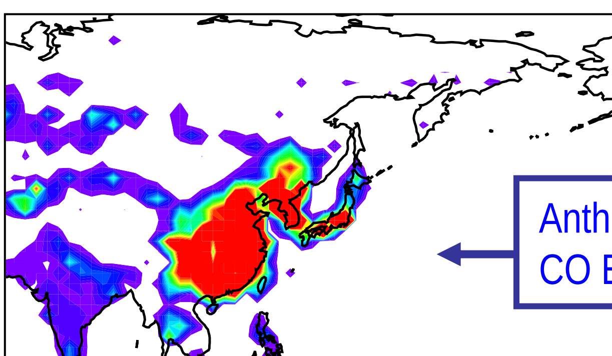



MLS observed long range transport of CO at 215 hPa

MLS observed upper tropospheric CO enhancement



CloudSat observed convection event over Asian continent



Anthropogenic CO Emission

**Deep convection transports surface pollution, including anthropogenic emissions, into the upper troposphere, where it can be transported inter-continentally, affecting global air quality, upper tropospheric and lower stratospheric com-position, and global climate.**

# Objectives

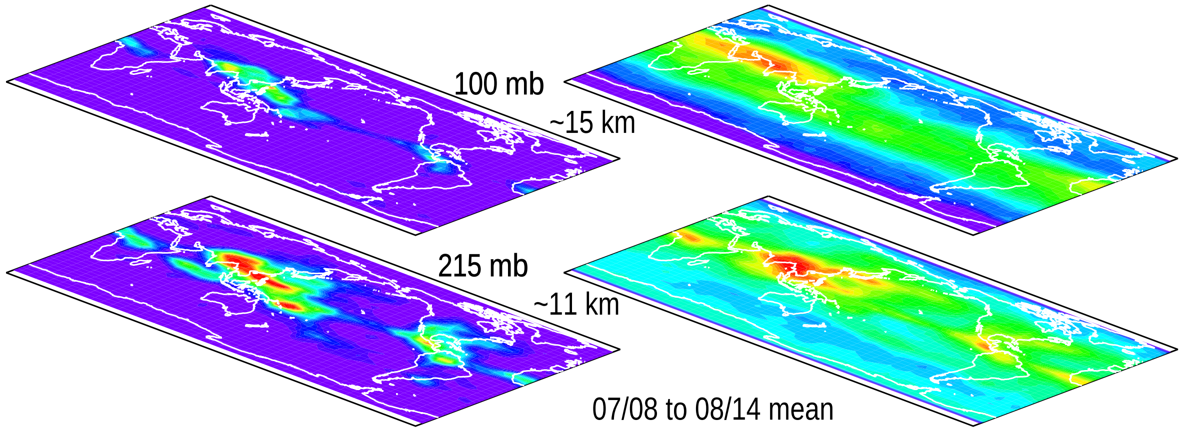
- **This is an exploratory study of how CloudSat and MLS data may be used together for understanding of**
  - Deposition of anthropogenic and bio-mass burning pollution (CO, in particular) into the upper troposphere by convection.
  - How CloudSat data, especially the cloud measurements at lower altitudes than seen by MLS, can be used in addition to MLS data to gain needed information for vertical transport of surface pollution.
- **Due to the limitations of the datasets** (coarse temporal resolution and the ~200 km separation between the CloudSat and MLS orbits)**, we focus on studying the bulk properties of convective influence on the upper tropospheric CO averaged over certain regions in space and time**
  - Use 2006 Asian monsoon event as a sample case
  - Use monthly mean data (8 July - 14 August) with 8° (longitude) $\times$ 4° (latitude) horizontal grids.

# Brief description of CloudSat and MLS data

## MLS IWC and CO data

V1.5 currently available (08.2004-02.2007); V2.2 will soon be available in early 2007. **Pressure levels**: 68, 83, 100, 121, 147, 178, 215, 261 mb. **Resolution**: ~3.5 km vertical; ~200 km along track.

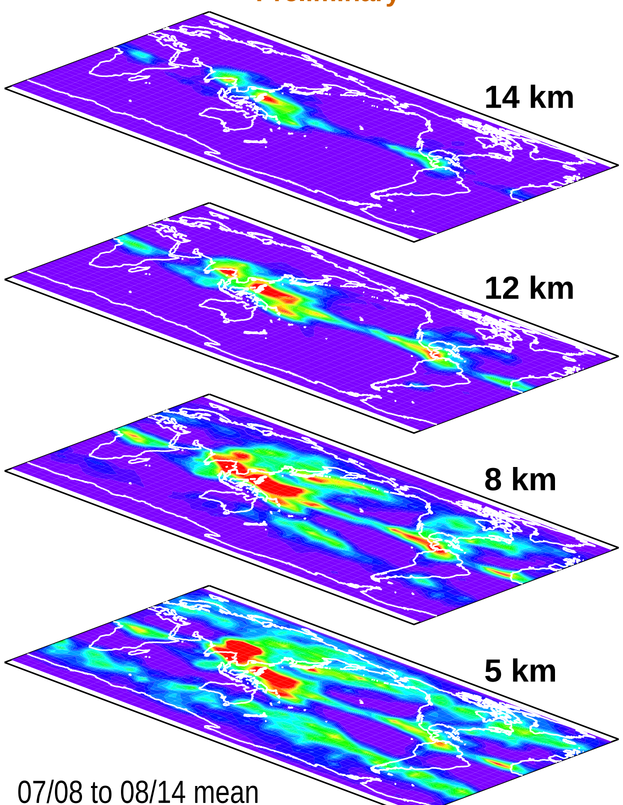
MLS IWC (mg/m$^3$) MLS CO (ppbv)




07/08 to 08/14 mean

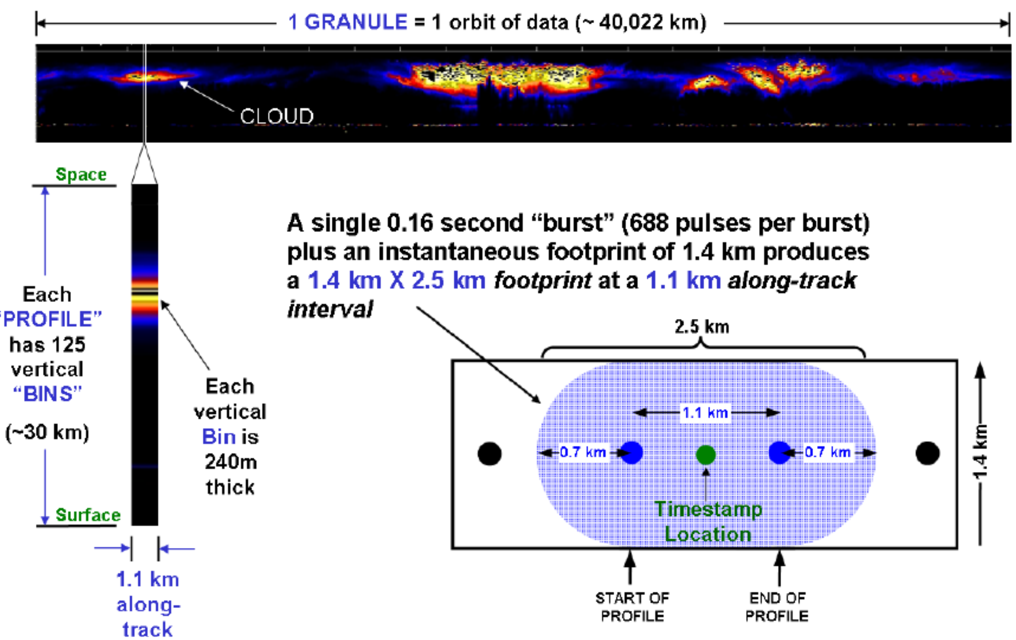
CloudSat IWC (mg/m$^3$)

Preliminary




07/08 to 08/14 mean

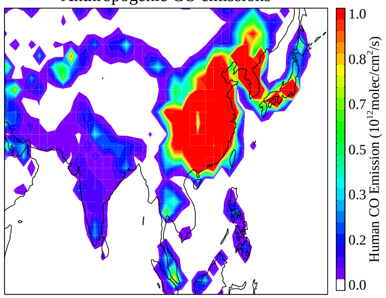
## CloudSat IWC and LWC data



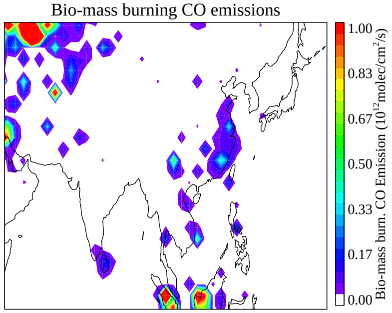
# CloudSat and MLS observations of Asian Monsoon

## CO Emissions

Anthropogenic CO emissions




Bio-mass burning CO emissions

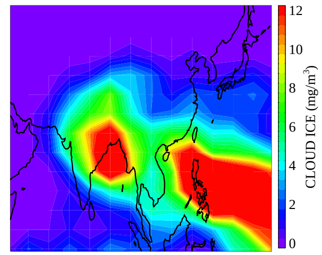



During the Asian summer monsoon season, major surface emission sources are anthropogenic. Bio-mass emissions are minor due to heavy precipitation associated with monsoon circulation.

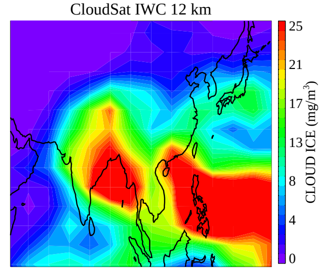
## CloudSat **IWC**

Preliminary

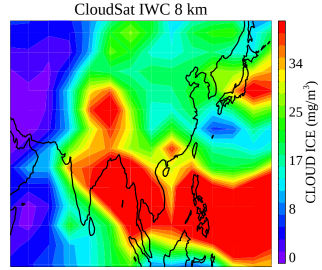
CloudSat IWC 14 km



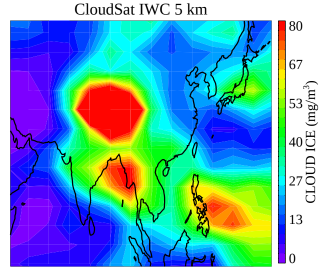

CloudSat IWC 12 km




CloudSat IWC 8 km

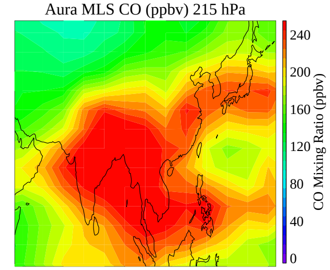



CloudSat IWC 5 km

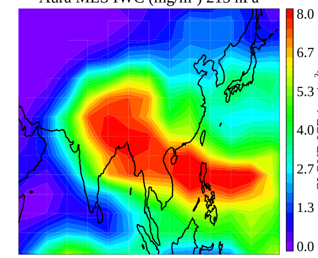



## MLS CO ~11 km MLS IWC

Aura MLS CO (ppbv) 215 hPa



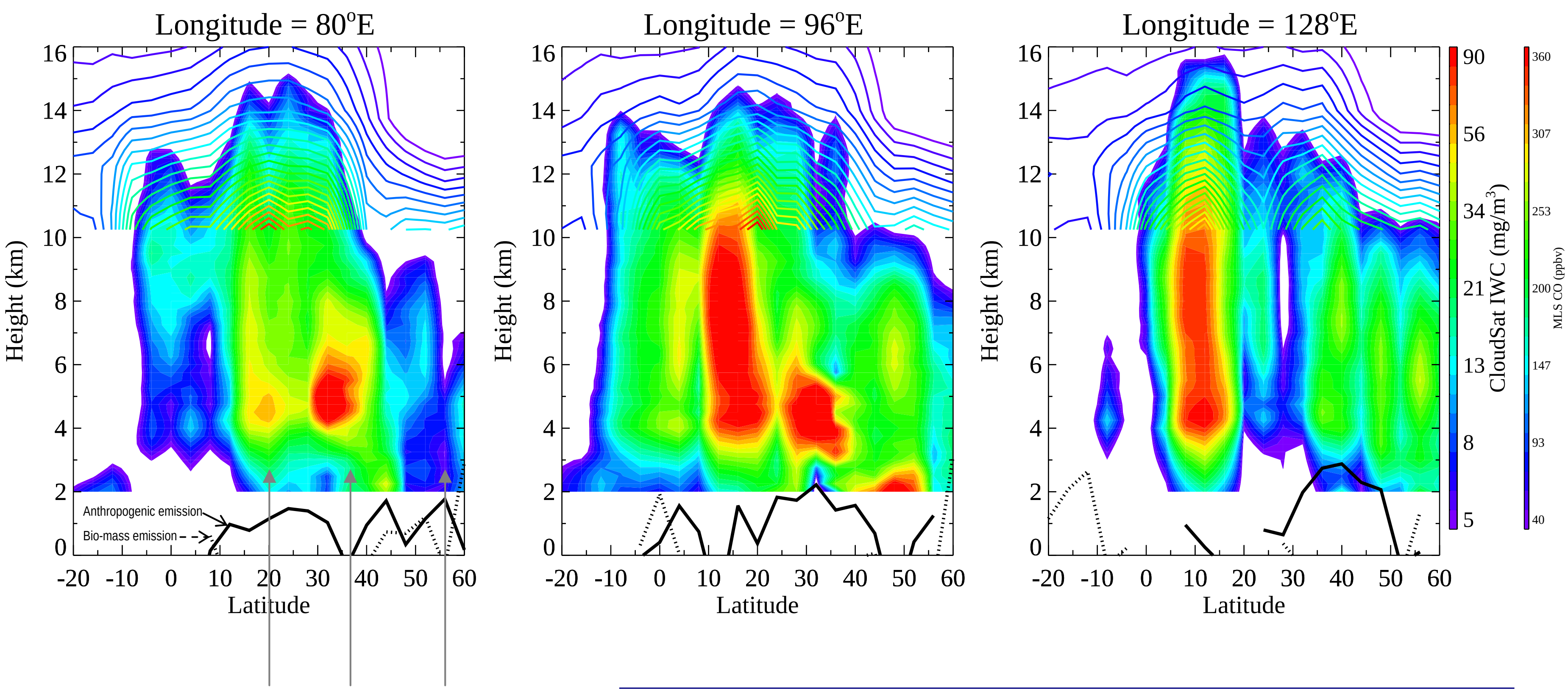

Aura MLS IWC (mg/m$^3$) 215 hPa




- MLS observations show enhanced CO & IWC in the upper troposphere.
- CloudSat measurements also show variation of convective cloud system in the mid- and lower troposphere.

►CloudSat provides needed high resolution measurements in the mid- and lower troposphere, which could help answer the question: **"How is the surface emitted CO deposited into the upper troposphere?"**

# How do convection and surface emission influence UT CO?




IWP ~1443 EMI ~ 0.1 $CO_{147}$~142 $CO_{215}$~281

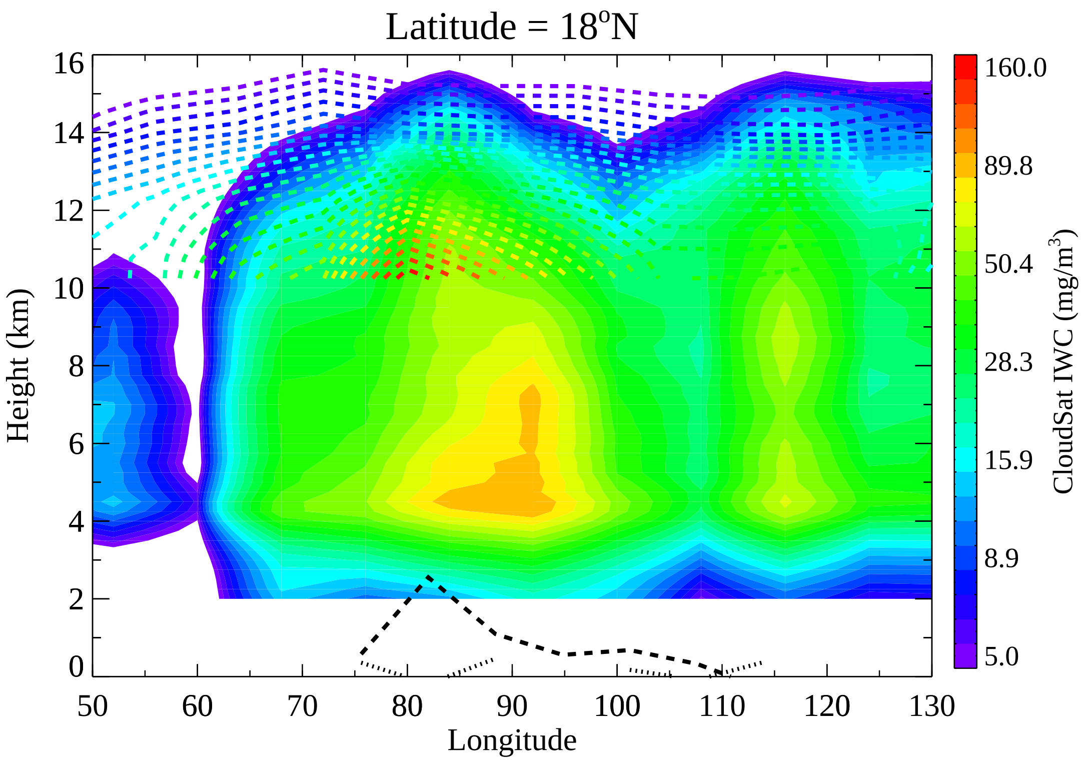
IWP ~1448 EMI ~0.01 $CO_{147}$~99 $CO_{215}$~192

IWP ~154 EMI ~0.2 $CO_{147}$~0 $CO_{215}$~98

**About MLS CO:** Current V1.5 MLS CO have high biases of a factor ~2 at 215 hPa, and ~50% at 147 hPa. The overall CO morphology shows reasonable agreement with other data sources and models.

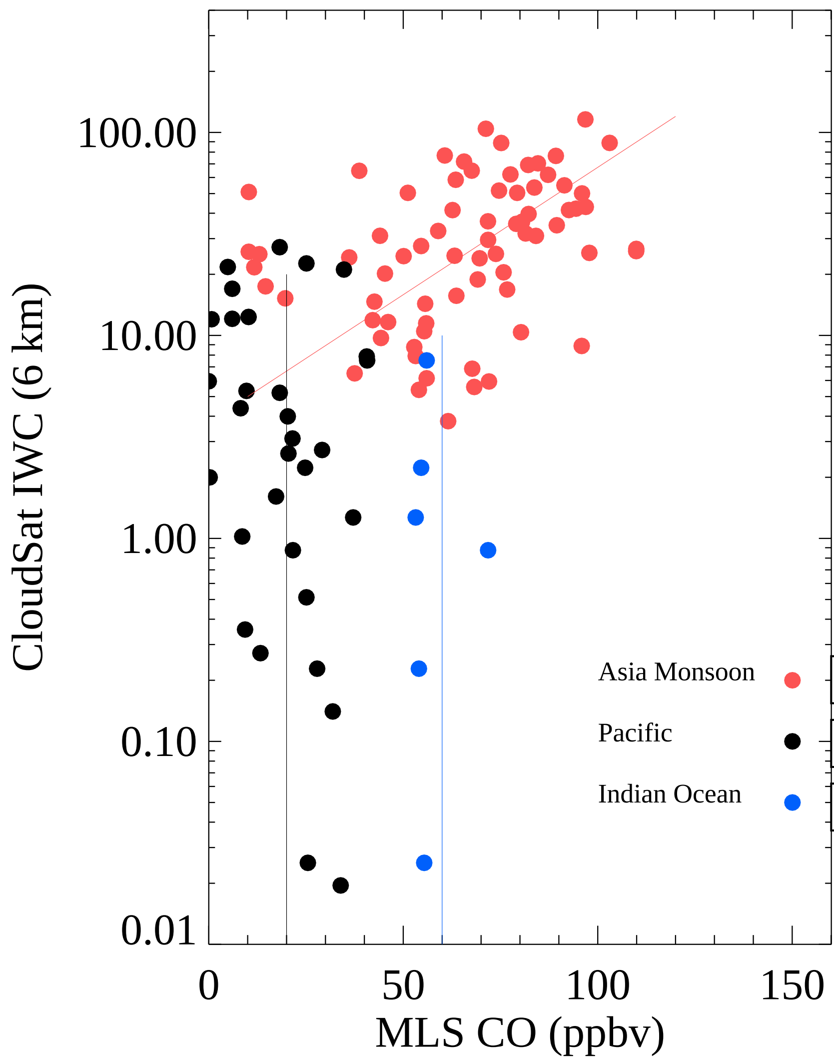
To have CO in the upper troposphere, both the strength of convection and the strength of surface emission are important factors. The strength of convection may be measured by the total amount of CloudSat observed moist condensates in an air column.

# How can CloudSat IWC provide more information than MLS IWC alone?




In this example, the two IWC peaks at upper troposphere level are similar, but one is associated with high CO, the other is not. CloudSat data provide information about convection strength in the mid- and lower troposphere which may account for the difference in CO, although this example is complicated by the non-uniform surface emissions. Cases with similar emissions but different convection strengths may be observed when more CloudSat data become available.

# CloudSat data can help identifying different convection/transport regimes

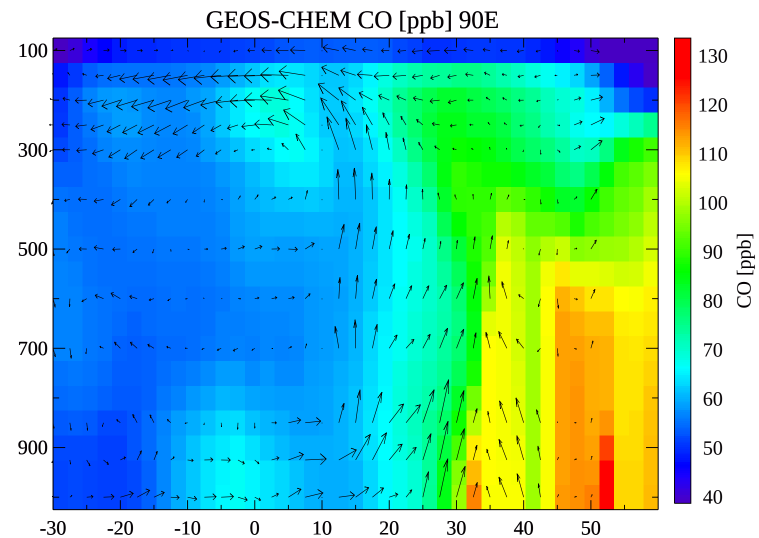



Convective deposition of surface emission

No emission, weak horizontal transport

No emission, strong upper trop transport

Scatter plots of CloudSat 6-km IWC versus MLS 147 hPa CO (8 July to 14 August 2006).




A cross-section of GEOS-CHEM simulation illustrates upper level transport of CO.

- MLS measured high CO mixing ratios may come from:
  - Convective deposition of surface emission;
  - Convective lifting of lower level transported CO;
  - Upper level transport.
- MLS observed low CO level indicates:
  - No surface emission and no lower level CO;
  - No convection and no upper level transport

**CloudSat data can help studying these different cases.**

# Future work

• Combine CloudSat and MLS observations together to provide the statistical characteristics of convective deposition of surface pollutants into the upper troposphere, including occurrence frequency, seasonality and geographical distributions, etc.

• Perform budget analysis of cloud condensates (as measured by CloudSat) and upper tropospheric CO (as measured by MLS). Aided by other analyses data and model results, obtain an estimate of convective mass flux and the turnover time of upper tropospheric polluted air.

❖ Note caveats of such analysis due to coarse temporal resolution and current large separation between the CloudSat and MLS orbits. Large-scale averages over certain regions in space and time are required.

# Summary

- CloudSat provides information about convection in the mid- and lower troposphere, which is useful to connect MLS upper tropospheric CO observations to surface emission sources.

- During the 2006 Asian summer monsoon, it is found that the upper tropospheric CO loading (observed by MLS) is influenced both by the strength of deep convection as indicated by the IWP loading (observed by CloudSat) and by the amount of surface anthropogenic emission.

- CloudSat and MLS data can be used together to identify different regimes for upper tropospheric CO variations. Quantitative estimates of convective deposition may be achieved in the future.