Aura Validation and Science Objectives for TC4

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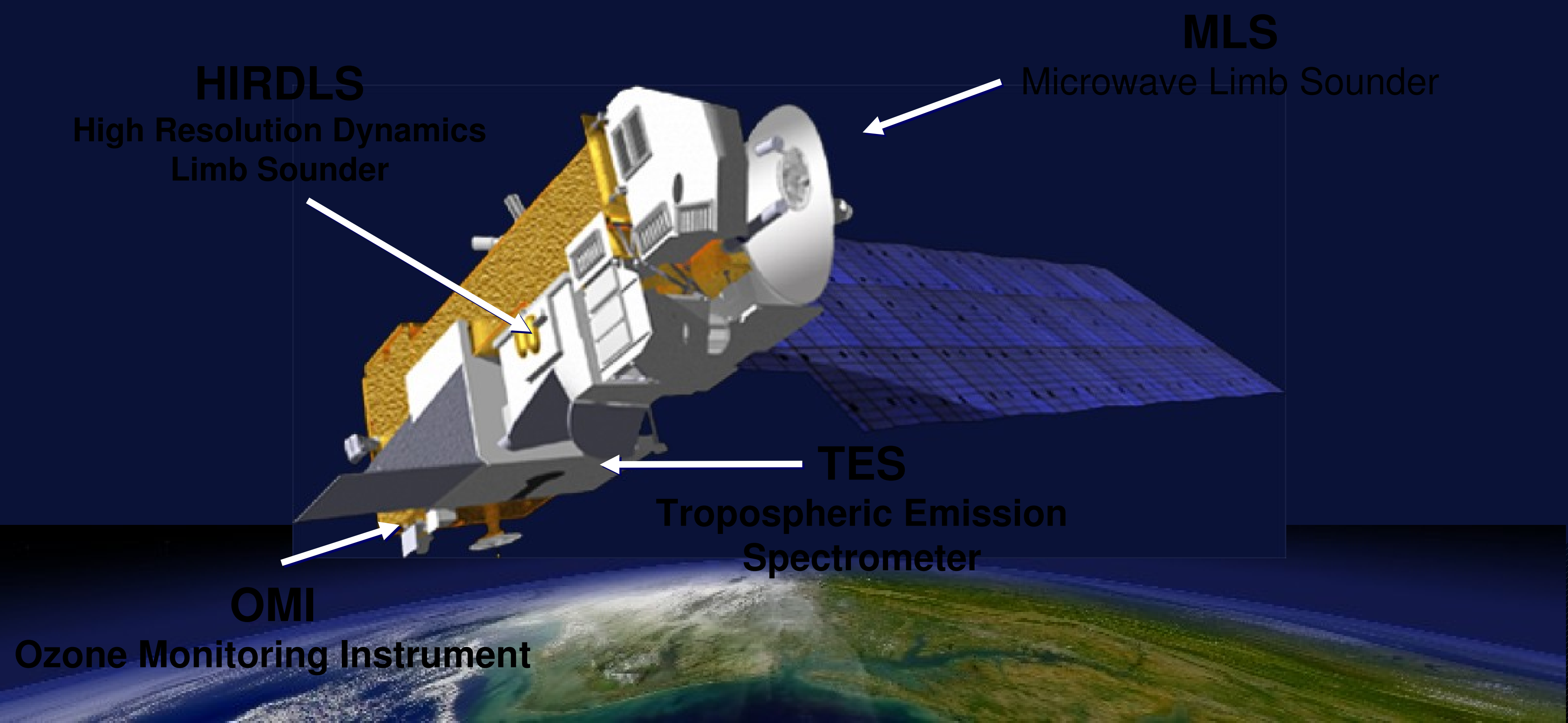
and Aura PI's

EOS AURA

- Orbit: Polar: 705 km, sun-synchronous, 98° inclination, ascending 1:45 PM equator crossing time.
- Launched VAFB, July 15, 2004
- AURA follows AQUA in the same orbit by 15 minutes.
- Six Year Spacecraft Life



MLS Validation Priorities

Priorities for MLS (aircraft measurements and flight tracks) during TC4

Profile information along the MLS sub-orbital track is desired (as in previous campaigns)

H_2O, Relative Humidity, Temperature (500 - 50 hPa)

H_2O:
- UT/LS H2O profiles along with frostpoint sondes versus the satellite data
- also address horizontal variability of diffs (MLS vs AIRS) [not done during CR-AVE]

→ H_2O DC-8 lidar measurements viewed as a key measurement capability for TC4 would be good to cover 200 hPa (close to DC-8 top alt.) to 400 hPa (for MLS)

Temperature: Mainly for inferring relative humidity; also to check horizontal variability.

LASE + in situ instruments

Cloud Information (coincident along-track 'curtain' sampling)

- **Note that this was not done (well) during CR-AVE → high priority**

(a) remote sampling of thick clouds via aircraft microwave and radar, along MLS track.
Compare to MLS IWC & slant IWP data (240 GHz [V-pol], 640 GHz [V-pol], 190 GHz [H-pol])

(b) *in situ* sampling of thick clouds from ~ 5 km to cloud top.
Get information along MLS track for particle size distribution (30 to 500 µm) & shape

- Will need to try to deal with MLS vs CloudSat footprint offsets [horizontal offset ~ 90 km]

ER-2 µwave radiometers
ER-2 CPL

'57 in situ particles

CO and O_3 (500 - 50 hPa)

If get (or predict) pollution or biomass burning-related variations near Costa Rica:

- **Validation of some stronger variations (CO especially) would be very good, if can fly close to pollution plumes.**
- Also useful: aircraft ozone columns (from CAFS – level/stacked flights) for comparison

'57/DC-8 in situ O3, CO
DC8 ozone lidars
CAFS , sondes

Lower priority

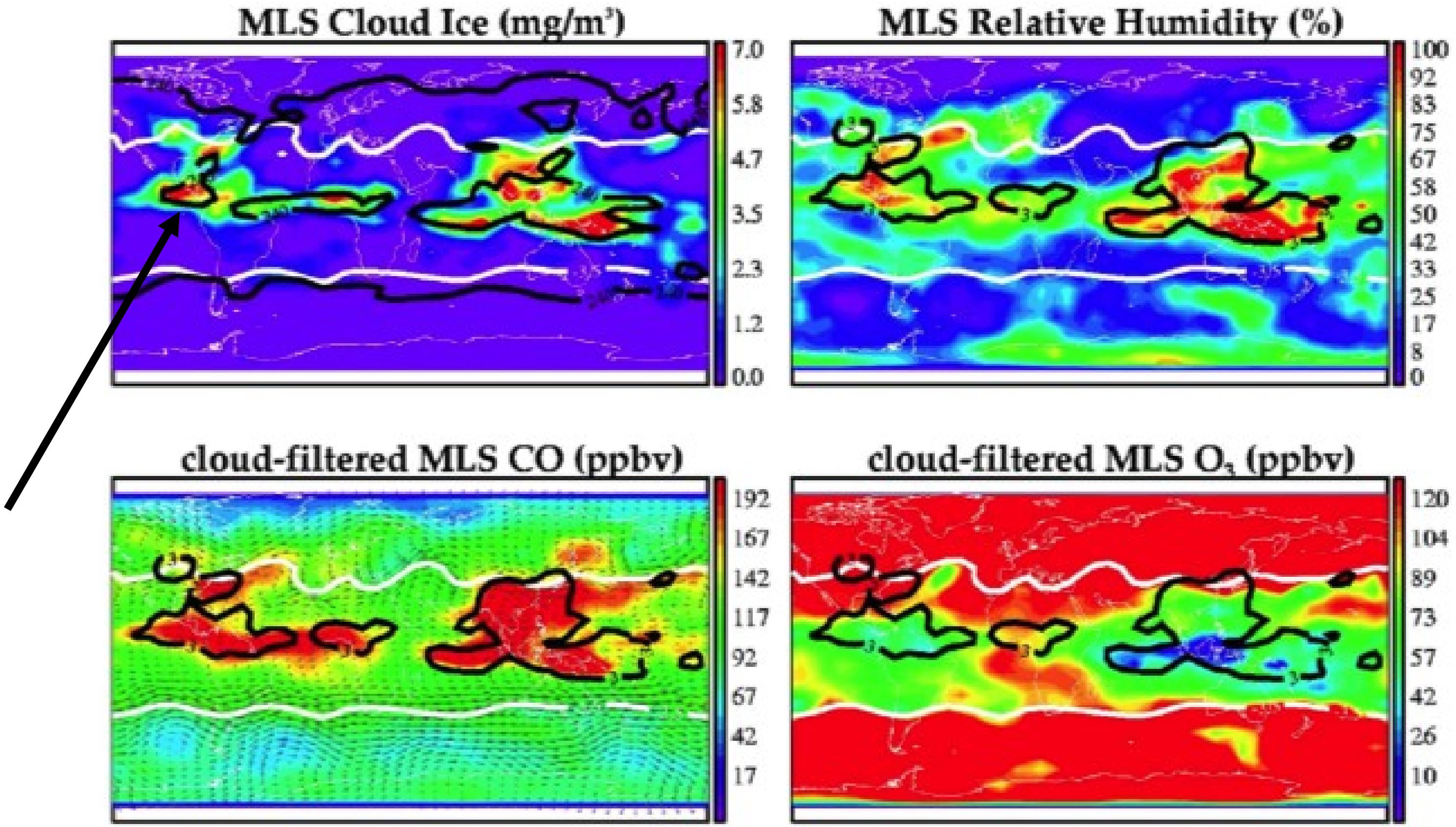
Profiles of UT/LS HCl, HNO_3, N_2O

MLS

Sample MLS measurements (for 215 hPa)

for 11-17 June 2006 (~ 1 year before planned TC4 campaign from Costa Rica)

Weekly-averaged maps show cloud/convective activity [top left (+ OLR overlays)] and enhanced CO, relative humidity near central America.



MLS Validation Details

MLS measurements of clouds (background information)

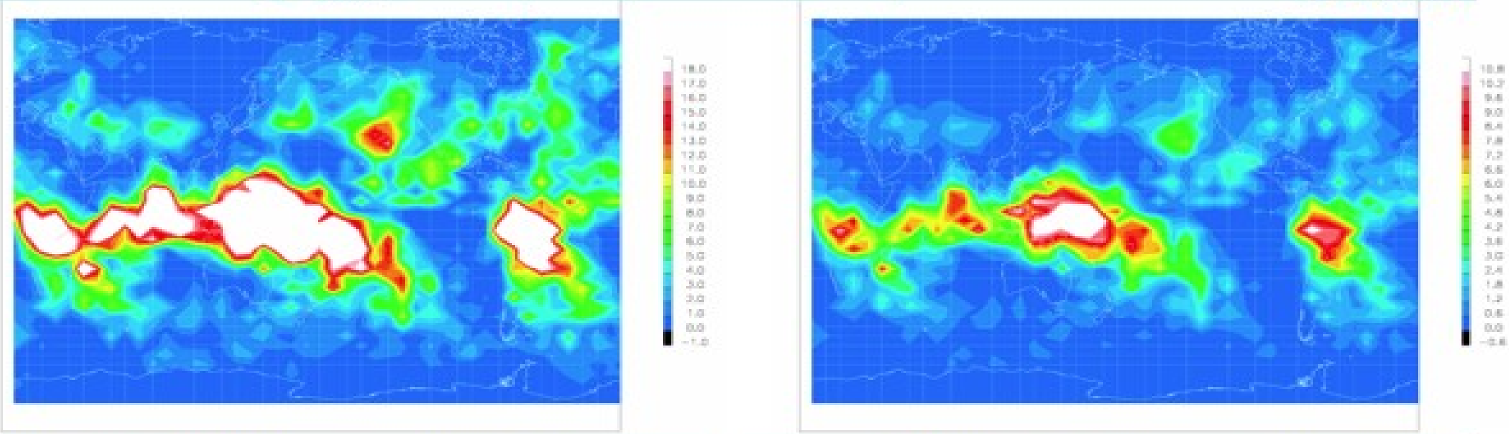
In the upper troposphere (and besides H_2O, CO, and O_3),
MLS measures ice water content (IWC) and ice water path (IWP) for 'thick clouds'.

► Would like to do some statistical comparisons of IWC and slant IWP from MLS versus aircraft remote data from microwave radiometer and radar. *In situ* information on particle size distribution (30 to 500 μm) and shape is also desired (→ interpretation & constraints for IWC & IWP data).

► MLS ice cloud info comes from 240 GHz as well as 640 GHz (better sensitivity to smaller ice particles)

- MLS IWC (240 GHz standard V1.51 product) is recommended for P < 215 hPa
- MLS 240 GHz IWP (planned new V2 product) is a measure of the cloud ice column above ~ 6 km
- MLS 640 GHz IWP (planned new V2 product) is a measure of the cloud ice column above ~ 10 km
  [not above 6 km because of stronger attenuation - impact of water vapor continuum and clouds]

240 GHz $IWP_{z > 6\ km}$ (example for Jan. 05) 640 GHz $IWP_{z > 10\ km}$



MLS IWP (240 GHz) precision for monthly mean is 3.5 g/m^2, and 28 g/m^2 for single tangent point view.
MLS IWP (640 GHz) precision for monthly mean is 1.8 g/m^2, and 15 g/m^2 for single tangent point view.

TES Objectives for Costa Rica TC4 mission (2007)

- Nitric acid:
  - High altitude aircraft HNO_3 measurements are the best way to validate TES upper tropospheric HNO_3 retrievals, and one of the highest priorities for TES validation. [will run limb mode?]
- HDO:
  - It is critical to obtain aircraft measurements of HDO at 700-750 hPa, where TES is most sensitive to this species. This is one of the highest priorities for TES validation. DC-8
- Ozone:
  - Lidar profiles of ozone under different atmospheric conditions during long, level DC-8 flight legs along Aura orbit track.
  - CAFS measurements of ozone both above and, if possible below the aircraft.
  - *In situ* aircraft profiles of ozone along the Aura orbit track.
  - Ozonesonde profiles coordinated with TES special observations.
- Carbon Monoxide:
  - Similar to ozone, getting *in situ* tropospheric profiles under a variety of atmospheric conditions along the Aura flight track will be very useful for validation of TES measurements.DC-8 WB57
- Water Vapor:
  - If possible, measurements from a water vapor lidar could be very beneficial to TES.
  - Additional balloon and aircraft measurements of water vapor in the upper troposphere. [lidars, in situ, sondes]
- Clouds:
  - Cloud top heights over thick, uniform cloud are desirable to validate TES cloud products.
  - A second priority is cloud top pressure over uniform, thin clouds.
- L1B Radiances:
  - Cloud-free coincidences between S-HIS and TES will still be useful to TES for monitoring L1B calibration.

TES: First Global Observations of HDO/H_2O ratio - A Tracer of the Global Hydrological Process

Water isotopes trace the history of an air parcel.

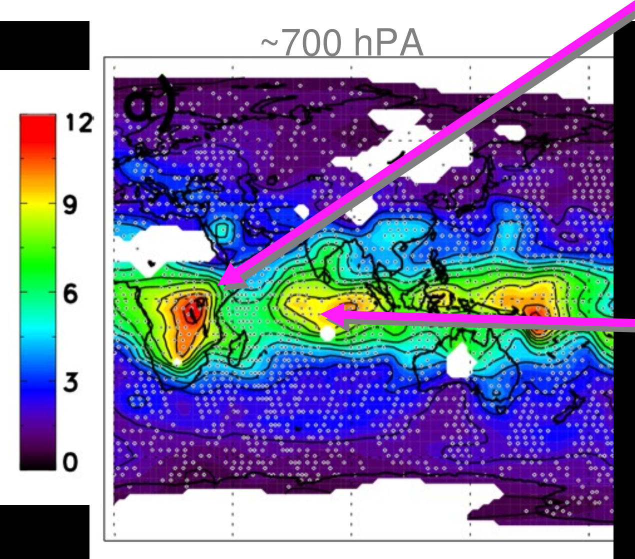
Lighter isotopes preferentially evaporate and heavier isotopes preferentially condense thus more condensation leads to more net isotope depletion.

The TES measurements show that in the tropics, re-evaporation of precipitation is an important process controlling cloud formation. Up to 70% of precipitation is re-evaporated into the cloud.

High H_2O and HDO/H_2O ratio over land indicates strong evapo-transpiration as the water vapor source

Worden et al., Nature 2007

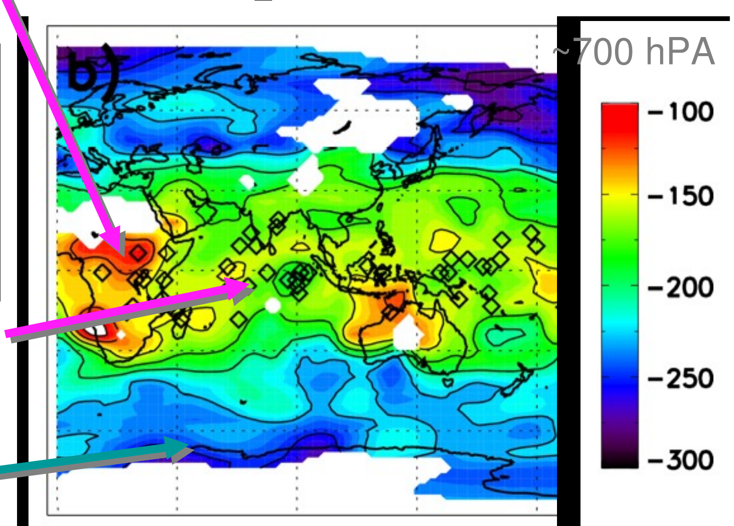
H_2O (10^3ppmv)



Relatively Low HDO/H_2O ratio with high H_2O indicates re-evaporation of precipitation in tropical cloud systems

Lower HDO/H_2O ratio with latitude due to condensation along with poleward transport

HDO/H_2O (delta-D)



HIRDLS Measurement Priorities for TC-4

1. CLOUDS/Aerosol – This remains the top priority for HIRDLS because relatively few cloud opportunities existed during the CR-AVE campaign, and because of a known HIRDLS height registration issue.

   Remote: Location and altitude of thin (&SV) cirrus layers, cumulus anvil blow-off, opaque cloud tops and aerosol layers.

   In-Situ: Location and characterization of aerosols and ice particles, including size distribution and composition.
   Background aerosol size distribution (in part, as radiance correction verification).

2. Species vertical profiles - In order of priority: H_2O, CH_4, F11, F12, N_2O, Temperature (& CO_2 if possible), HNO_3 and O_3 to as high an altitude as possible.

Costa Rica TC4 June ’07 – OMI Validation Opportunities

Objective #1: To validate / understand differences in cloud heights determined by the various cloud algorithms (IR, O2A, Raman, O2-O2)

Measurement requirements: physical cloud top height, physical cloud thickness, physical cloud fraction, identification of single and multi-layer clouds, cloud particle characterization, cloud brightness

Objective #2: To understand effect of clouds on OMI TOMS and DOAS total ozone retrievals

Measurement requirements: ozone above, within and below clouds of various type and structure

Objective #3: To obtain tropospheric columns and profiles of trace gases and aerosols

Measurement requirements: O3, NO2, H2CO, SO2 and aerosols columns and vertical profiles in the troposphere [cover all flight altitudes possible including dipping the boundary layer], aerosols type, size, chemical composition and distributions analysis

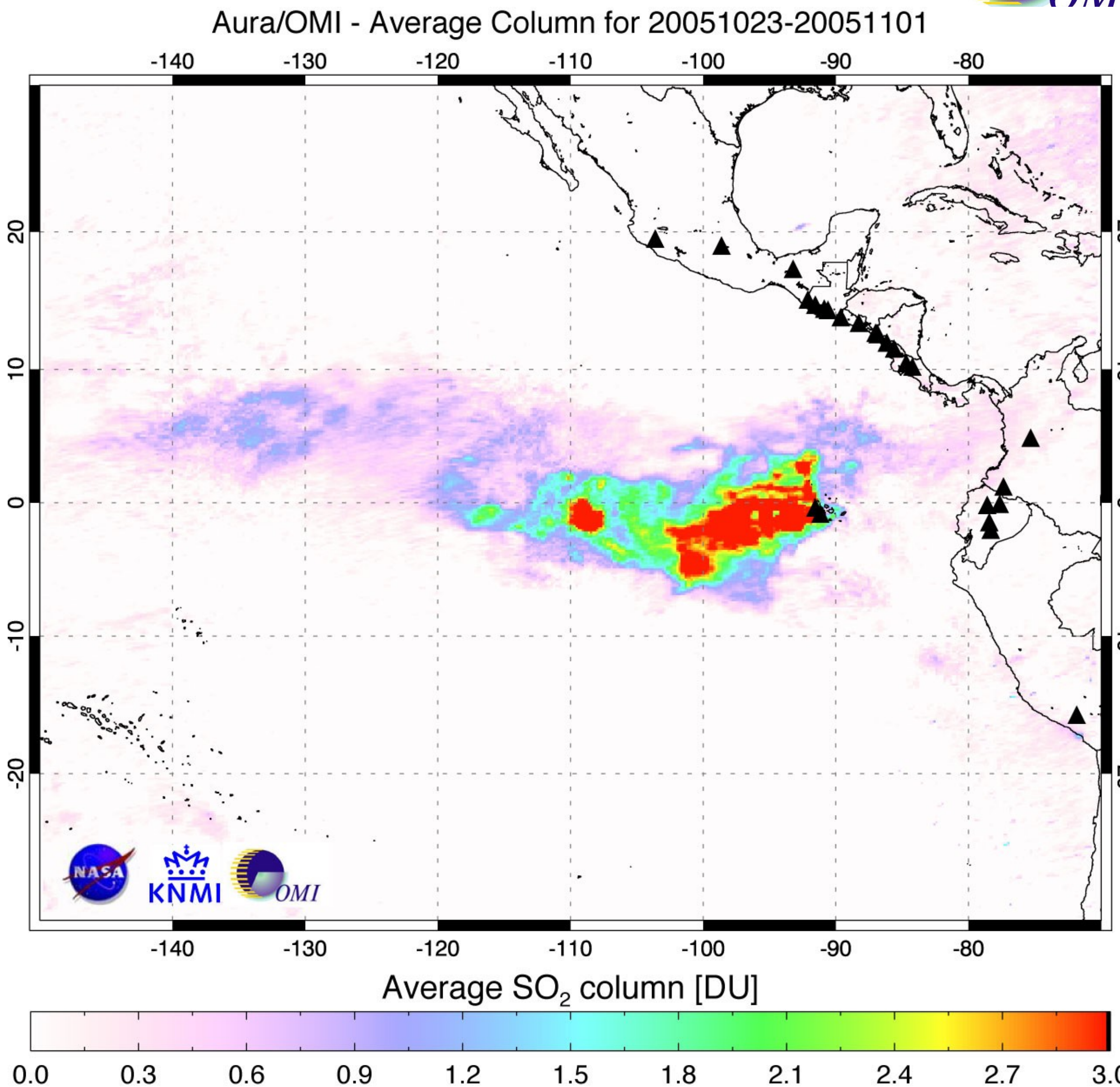
Objective #4: Assessment of lightning generated NO2 budget

Measurement requirements: NO2 remote and in-situ sensor, lightning information, NO2 profiles needed in cloud-outflow region and in below-cloud source region (see Objective #3)

Objective #5: Validating OMI SO2 observations of volcanic degassing

Measurement requirements: SO2 remote and in-situ sensor Aircraft instruments: in-situ SO2 sensor on DC-8, remote DOAS instruments, special interest in areas subject to volcanic degassing and volcanic eruptions.

Costa Rica TC4 June ’07 – OMI Science Opportunities



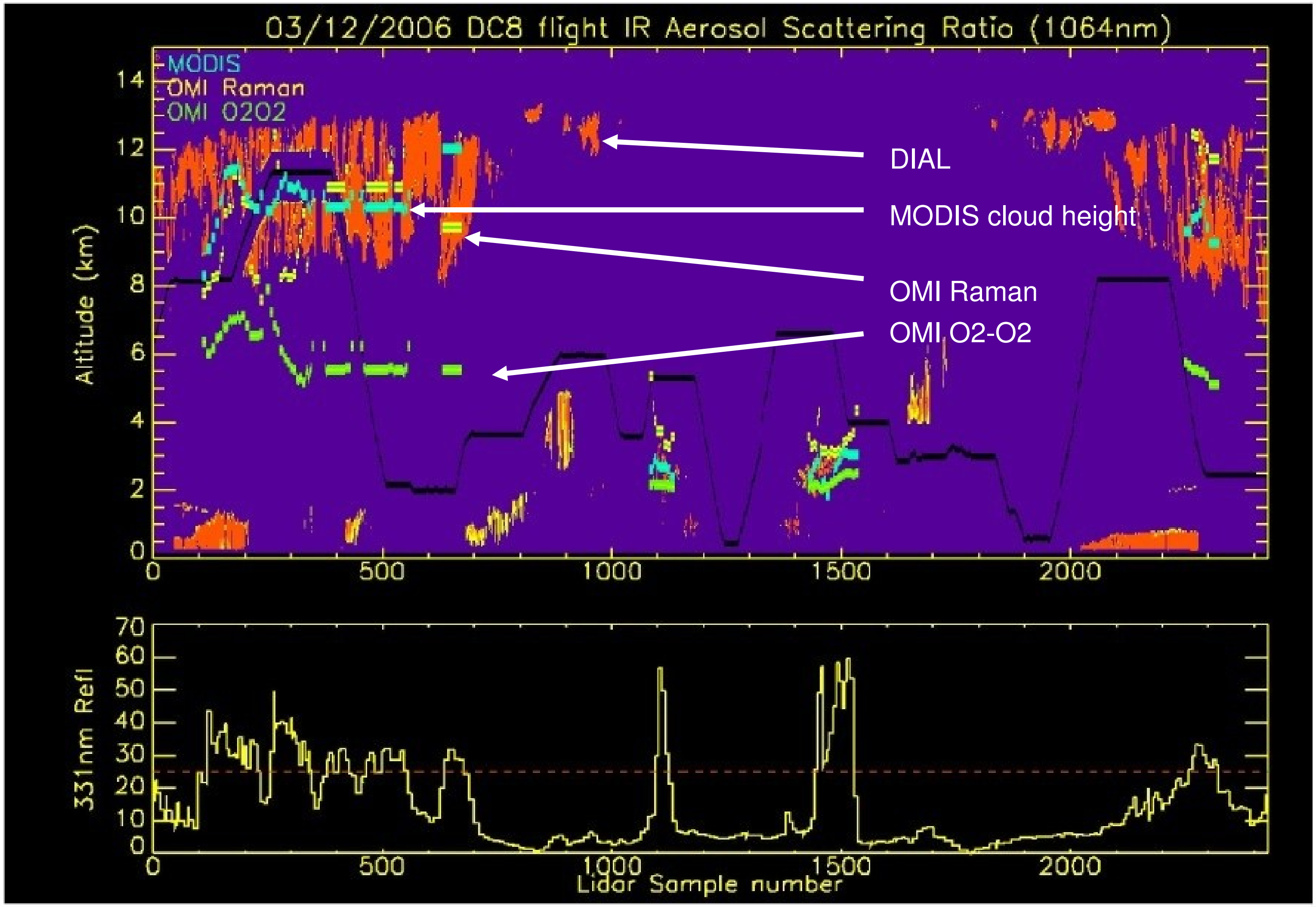
Tropospheric SO2 from volcanoes observed by OMI

http://earthobservatory.nasa.gov/NaturalHazards/Archive/Nov2005/galapagos_omi_2005305_lrg.jpg

Science Issues

- What is the height of a cloud?
- Ozone in clouds and at cloud tops
- CO and convective transport
- NO_2 and lightning

OMI Lidar Cloud Height Comparison during Intex- B



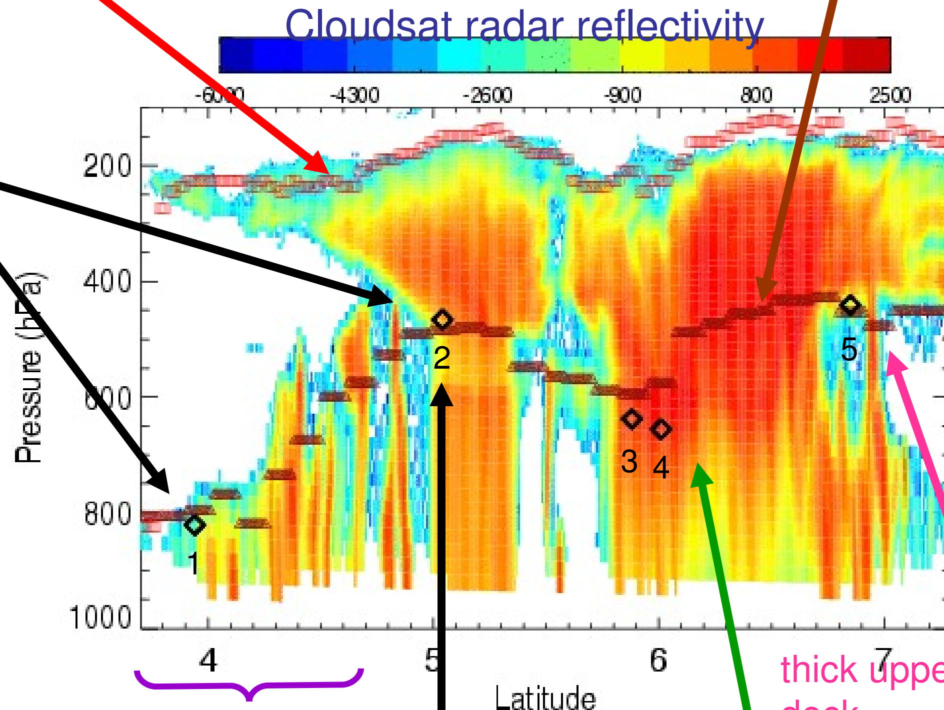
What do clouds look like to OMI?
(Important question for trace-gas retrievals)
Cloudsat (A-train) helps us to answer

MODIS: sensitive to cloud-top
(not appropriate for UV-VIS trace-gas
retrievals)

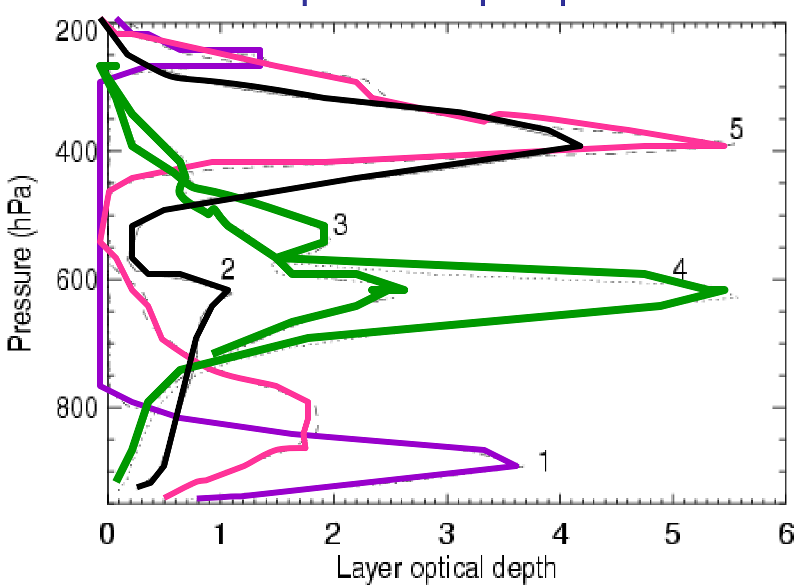
OMI effective cloud pressure from Raman
scattering: UV/visible light penetrates deeper

OMI simulated from Cloudsat

Cloudsat radar reflectivity



Cloudsat optical depth profiles



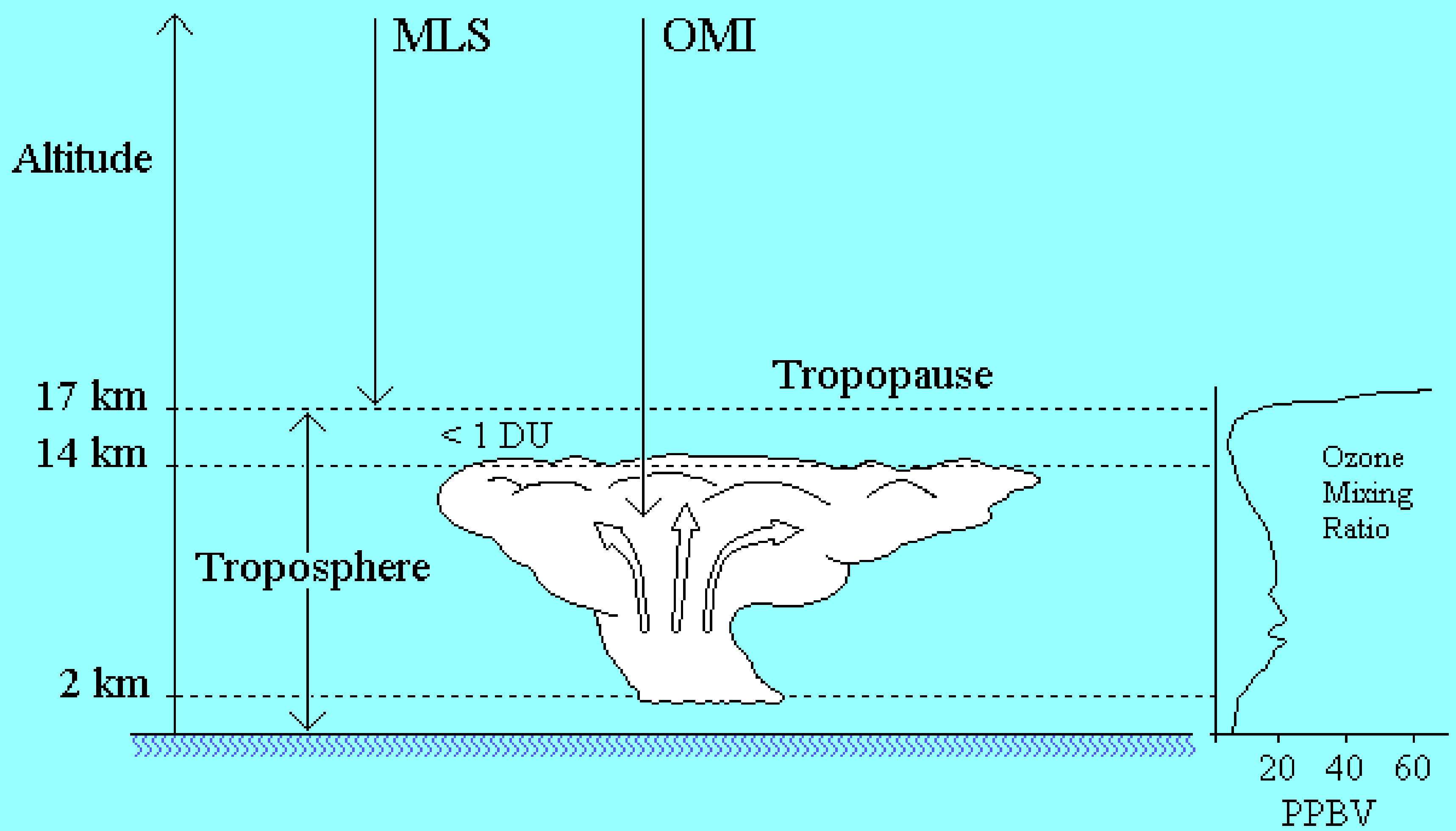
thick upper
deck

Optical depth
peaks in ice
portion of cloud

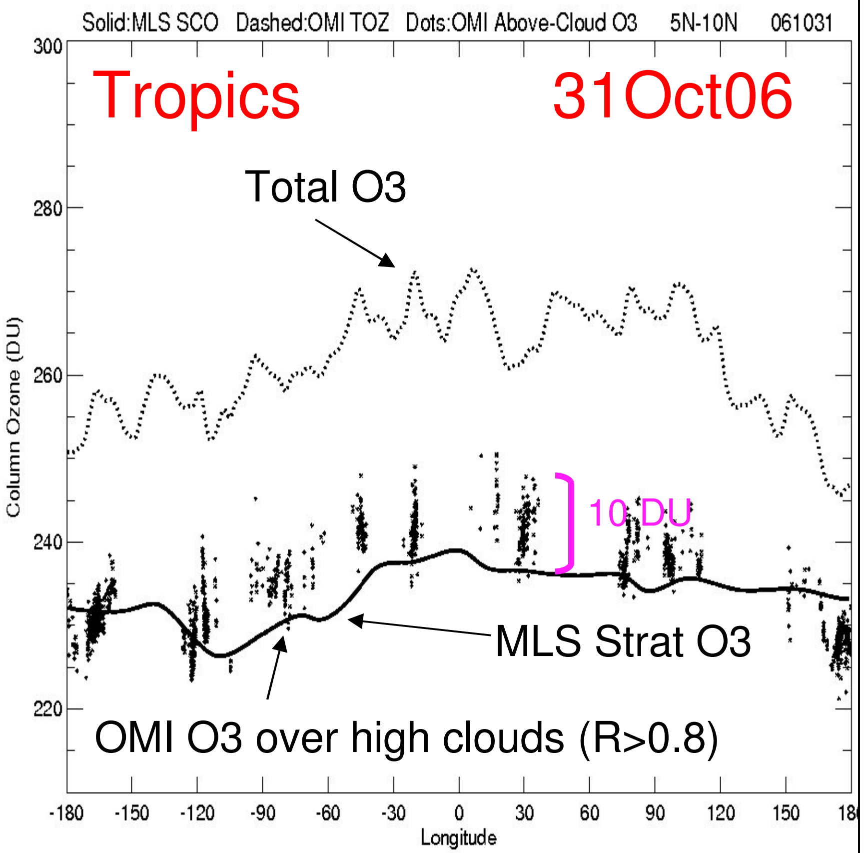
Optical depth peaks in
liquid water portion of
cloud

2 cloud decks: thin upper deck-
OMI retrieves pressure of lower deck

Stratospheric Ozone Measured by Aura OMI and MLS



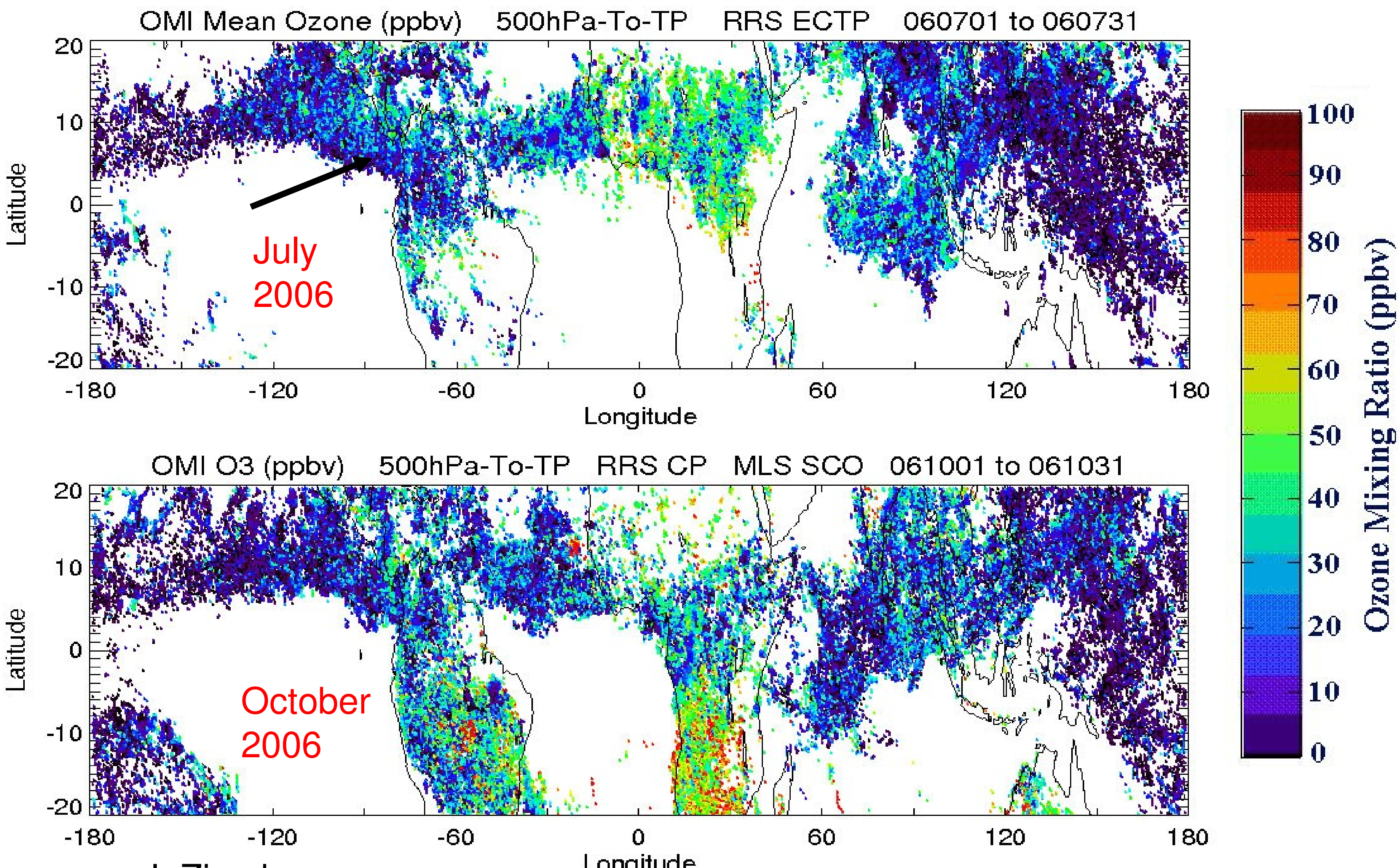
Total Column O_3 and Above-Cloud Column O_3



J. Ziemke

The mystery here is that OMI should see into the clouds.The clouds aren't mirrors…
So why do some of the points show "0" ozone?

Aura OMI/MLS Upper Tropospheric Ozone (500 hPa to Tropopause) from Cloud Slicing



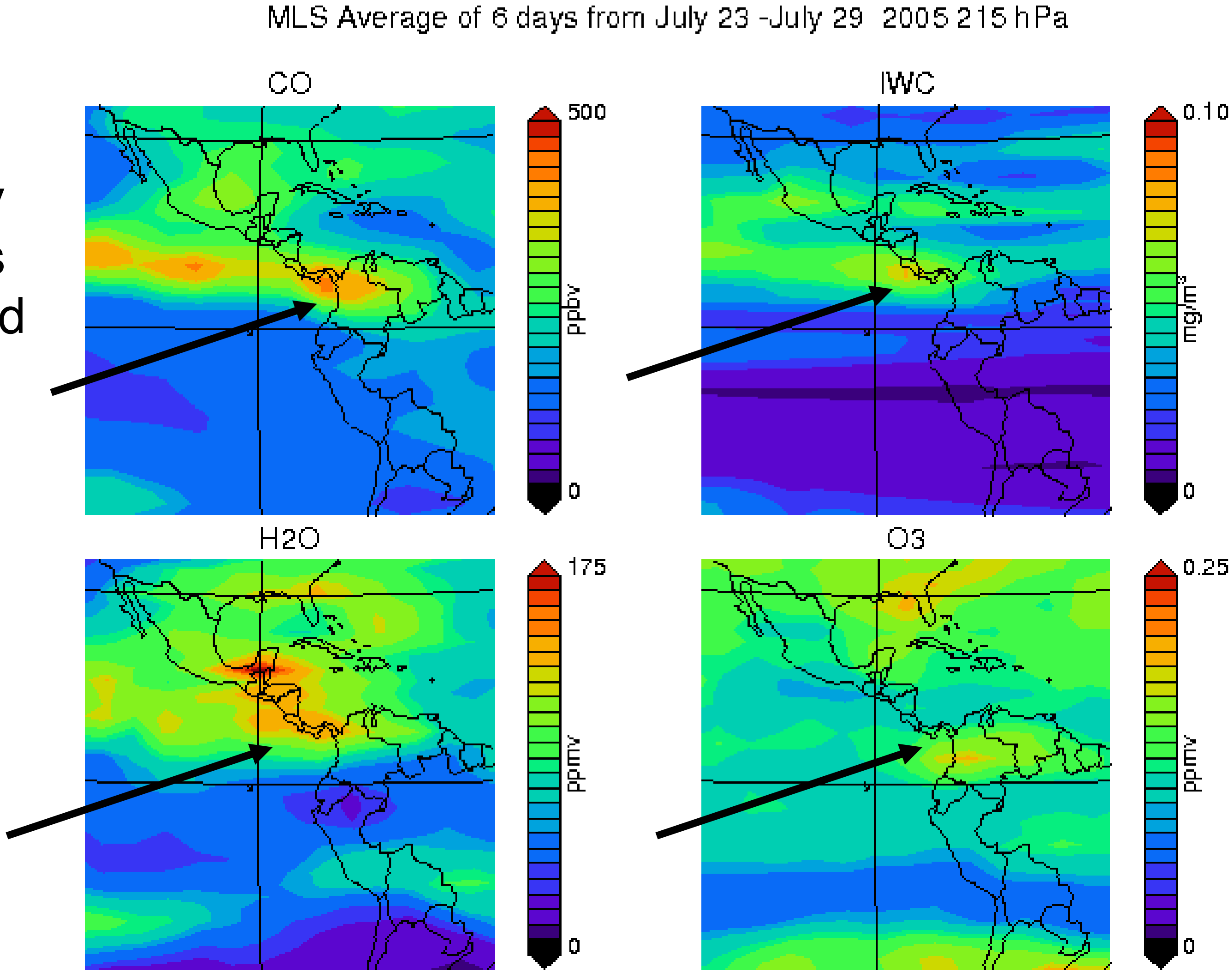
J. Ziemke

CO and Convective Cloud Transport

MLS 215 hPa (~10 km, 345K)

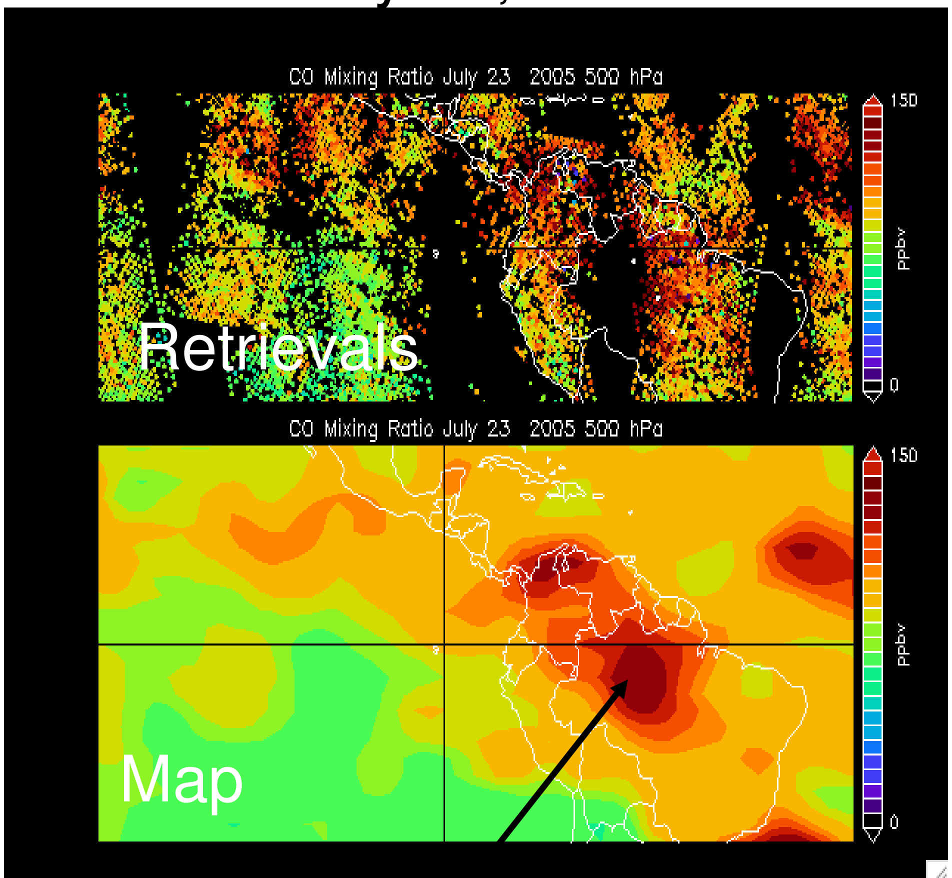
CO levels ~350 ppbv but MLS is high biased

Convective moistening

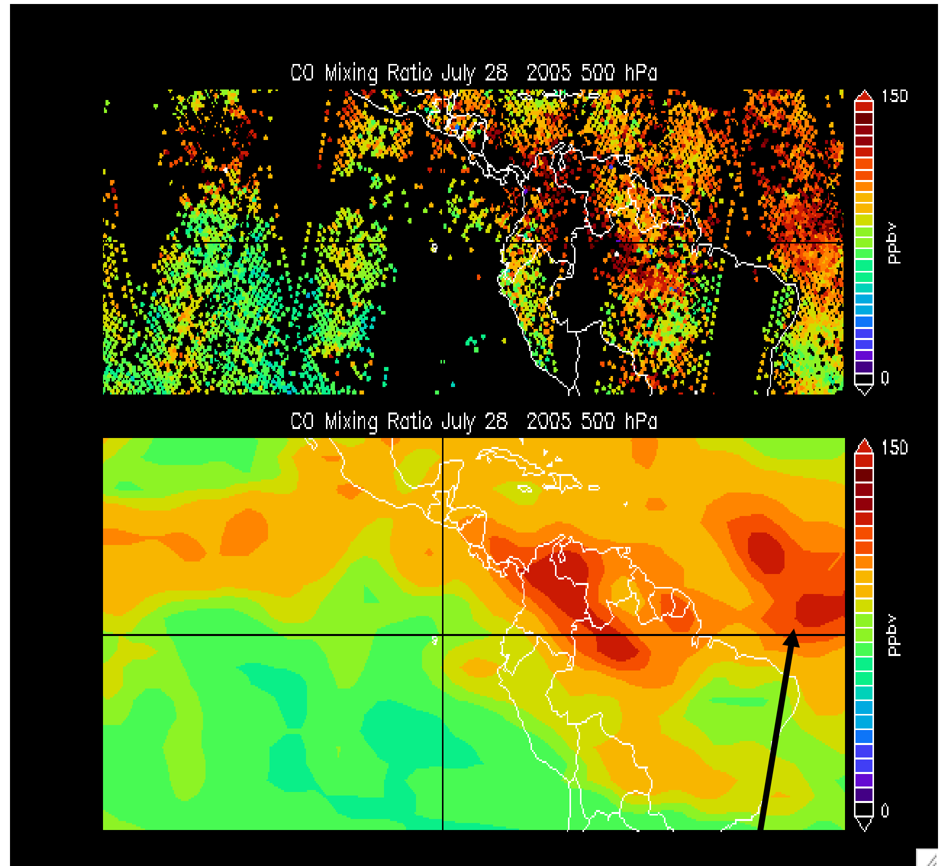


AIRS CO 500 hPa

July 23, 2005



July 28, 2005



Brazil Burning

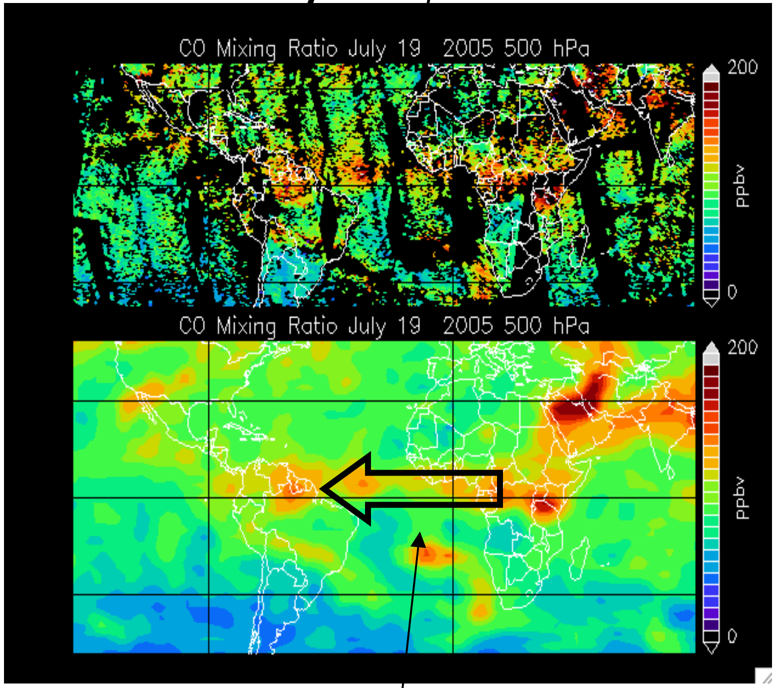
Enhanced CO is available for convective transport

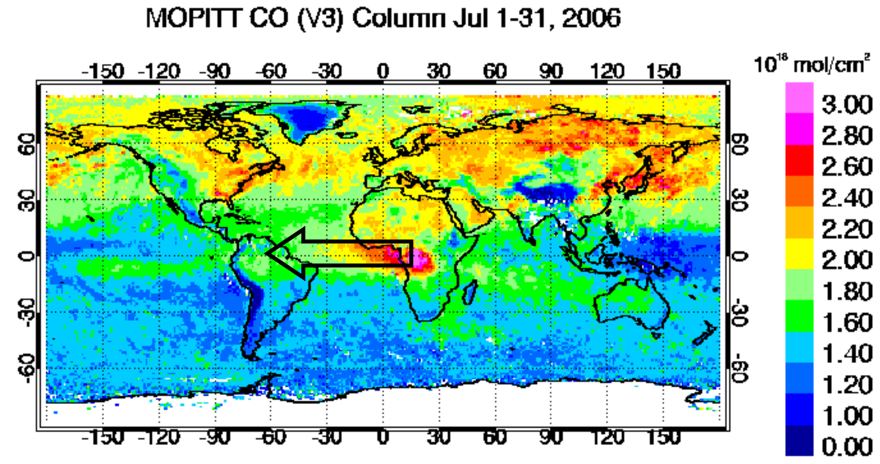
African Plume

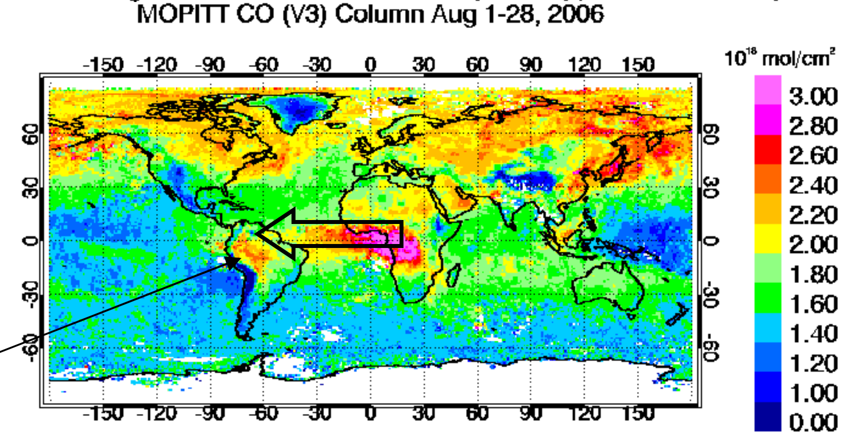
Joanna Joiner

Plumes from Africa vs Brazil

July 19, 2005



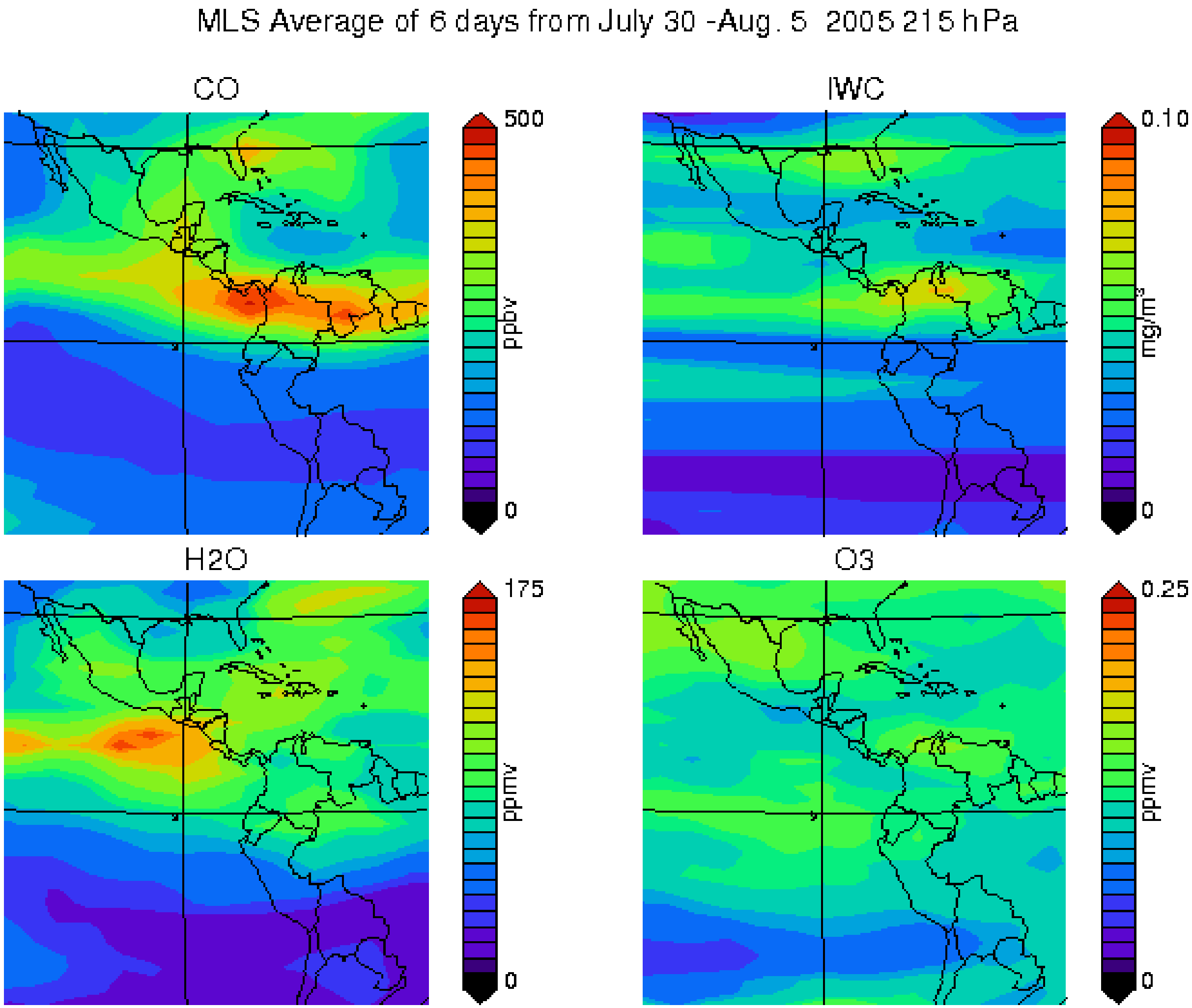




Burning in Brazil

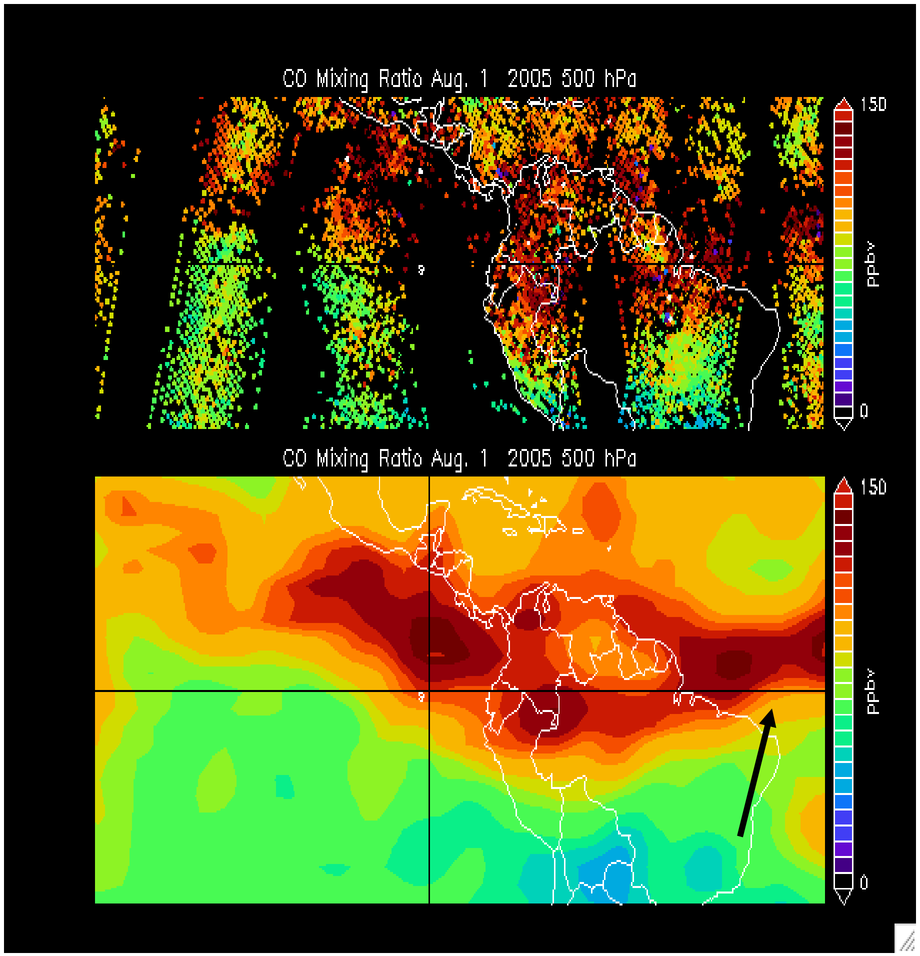
African Plume

Early Aug.

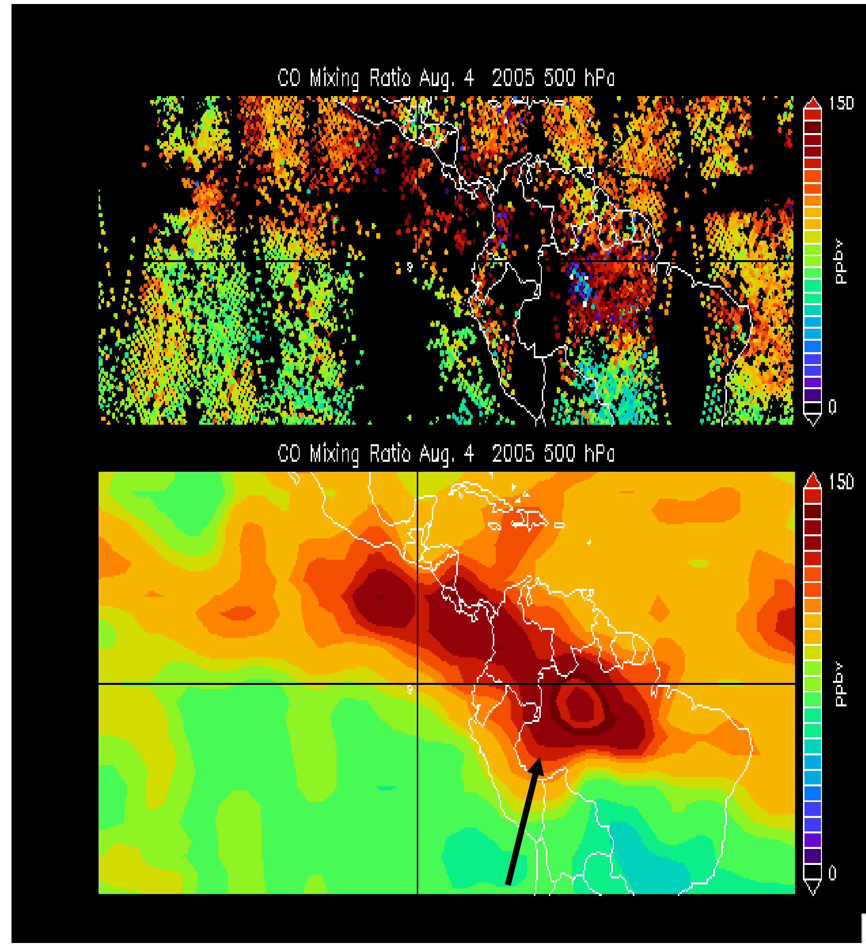

MLS Average of 6 days from July 30 -Aug. 5 2005 215 hPa
CO
500
ppbv
0
IWC
0.10
mg/m3
0
H2O
175
ppmv
0
O3
0.25
ppmv
0

AIRS CO

Aug 1, 2005

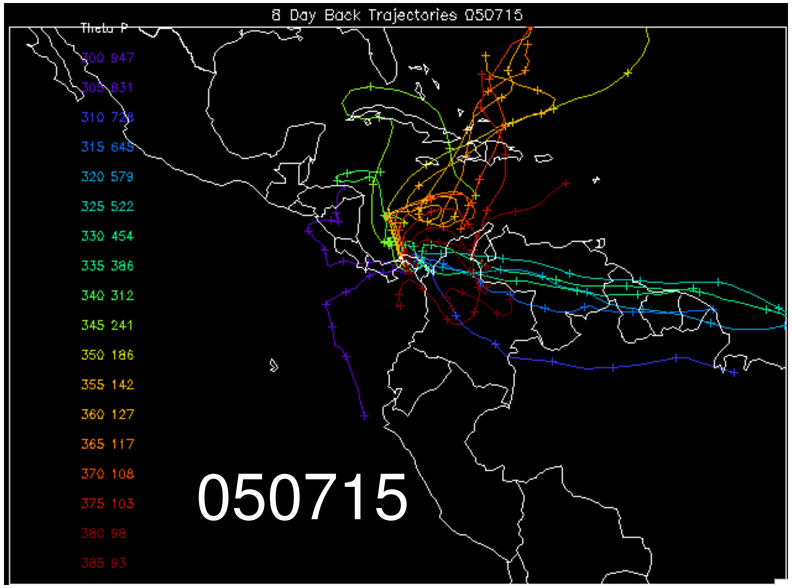


Aug 4, 2005



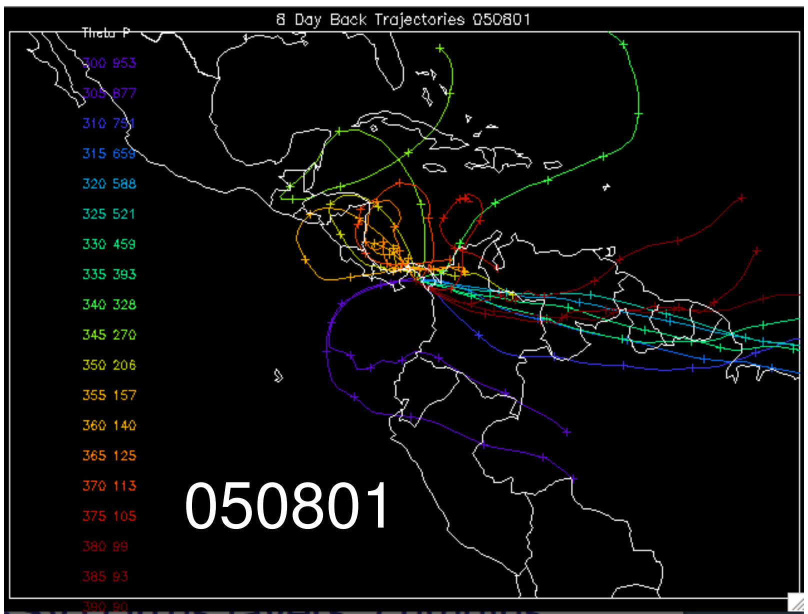
Joanna Joiner

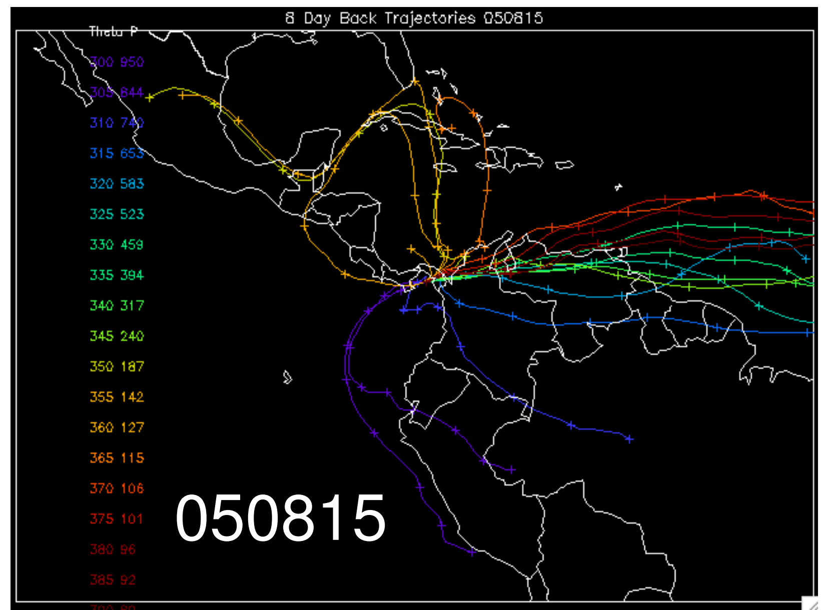
Where does the air come from?



8 day back trajectories:

- Air near ~600 - 300 hPa is coming from the South Atlantic
- Low altitude air comes from the south east burning regions (Aug.)
- Higher altitude air wanders in from the north east - east

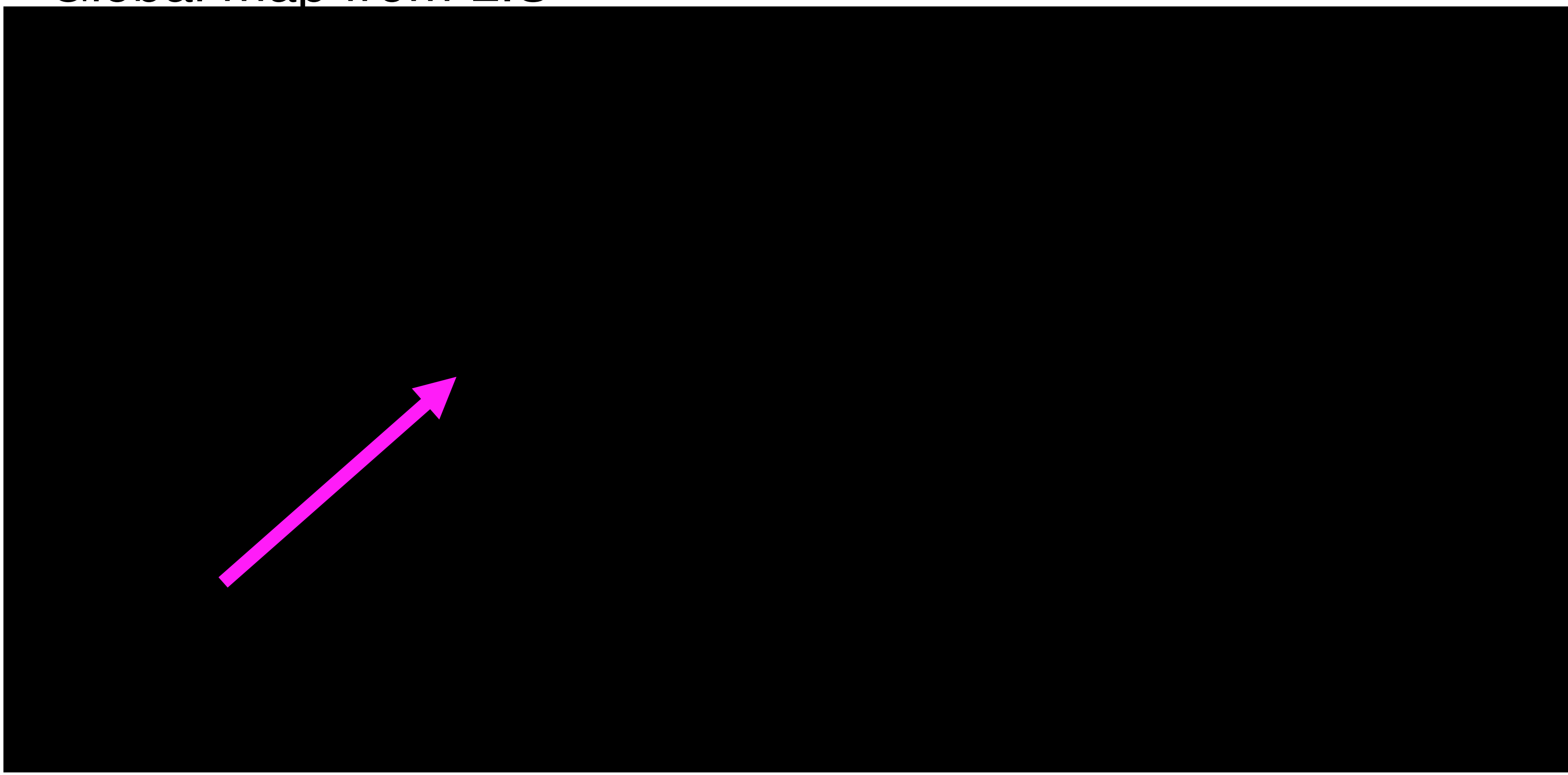




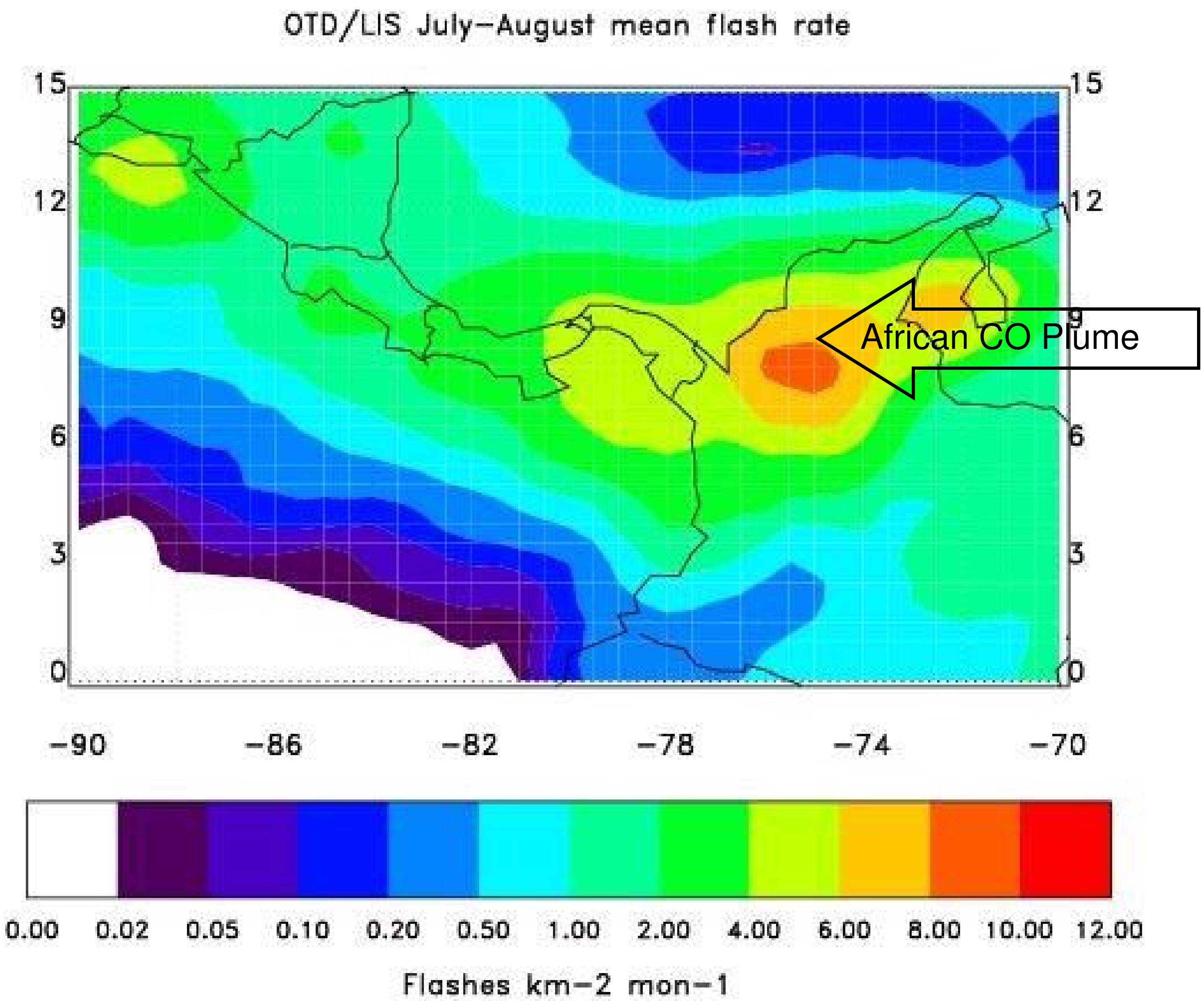
NO_2 and Lightning

Lightning

Global map from LIS

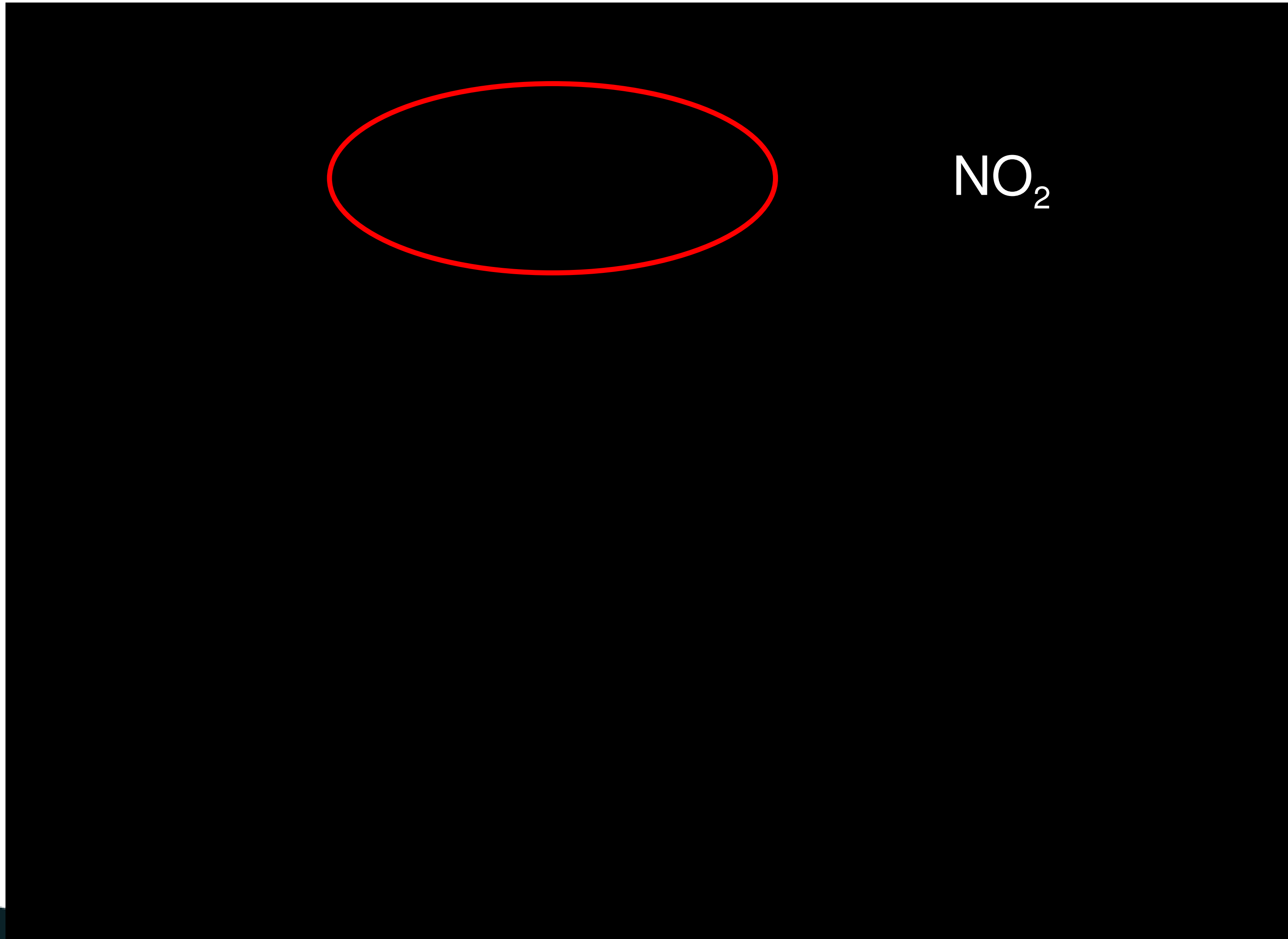


Flashes/km²/year



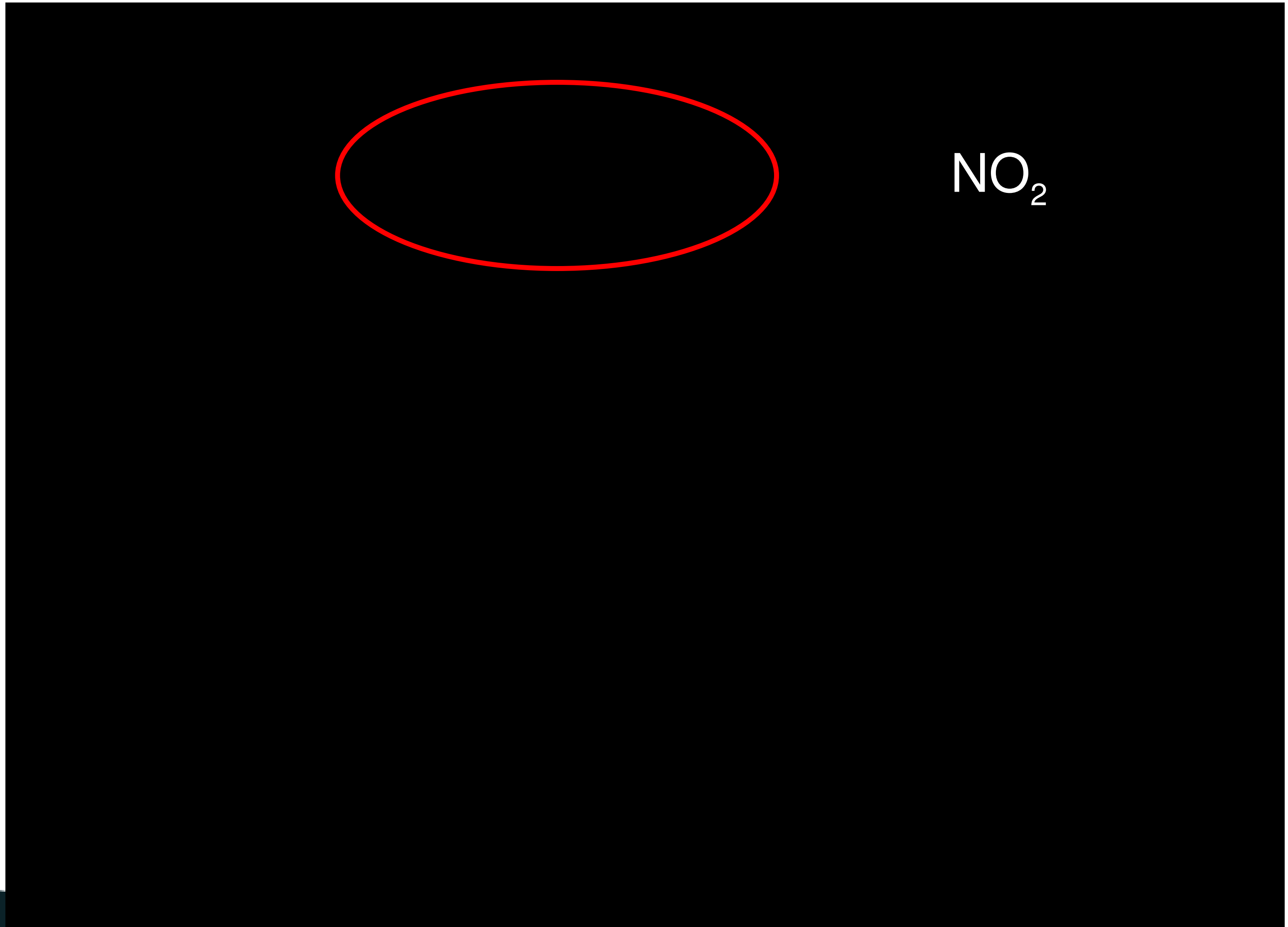
OTD/LIS July–August mean flash rate
15
12
9
6
3
0
−90
−86
−82
−78
−74
−70
African CO Plume
0.00
0.02
0.05
0.10
0.20
0.50
1.00
2.00
4.00
6.00
8.00
10.00
12.00
Flashes km−2 mon−1

Costa Rica TC4 July ’05 – OMI Science Opportunities



Monthly mean tropospheric NO2 from OMI – Note the ITCZ

Costa Rica TC4 Aug ’05 – OMI Science Opportunities



Monthly mean tropospheric NO2 from OMI – Note the ITCZ

Some Science Questions for Aura + TC4 observations

- Can CO be used as a surrogate for pumping air from the mid-troposphere to the upper troposphere through convection - is this consistent with UT/LS observations from MLS?
- Does the convection over Colombia “wash” the African plume?
- Can we understand the lack of ozone above (and inside) some clouds as inferred from OMI?
- Is the NO_2 amount consistent with distribution of lightning in the region?