Rapid Science Synthesis

Interstate transport of ozone and aerosols: The view from satellites and models

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Principal Findings Data Analysis Workshop – Texas AQS II

June 1, 2007

Jet Propulsion Laboratory
California Institute of Technology

Question H

- **Which areas within Texas adversely affect the air quality of non-attainment areas in Texas?**
- **Which areas outside of Texas adversely affect the air quality of non-attainment areas in Texas?**
  - **Preliminary Finding H1:** *Ozone can be transported into the Dallas area from the Houston area.*
  - **Preliminary Finding H2:** *High ozone concentrations in eastern Texas result from both in-state sources and transport of continental air from the east and northeast.*
  - **Preliminary Finding H3:** *A synthesis of satellite and in situ measurements with photochemical modeling and Lagrangian trajectory analyses provides a quantification of regional influences and distant sources on Houston and Dallas air quality during TexAQS 2006.*
  - **Preliminary Finding H4:** *Ozone transport modeling for the Dallas area shows that local emissions and transport each contributed about equally to the average 8-hr ozone exceedance in 2002.*

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  - **Preliminary Finding H4:** *Ozone transport modeling for the Dallas area shows that local emissions and transport each contributed about equally to the average 8-hr ozone exceedance in 2002.*
- **Required Additional Analysis H2: Synthesize transport information from models, satellites and lidar.**

Preliminary Finding H3

- Update the RAQMS back trajectory analysis
- Which case studies to examine?

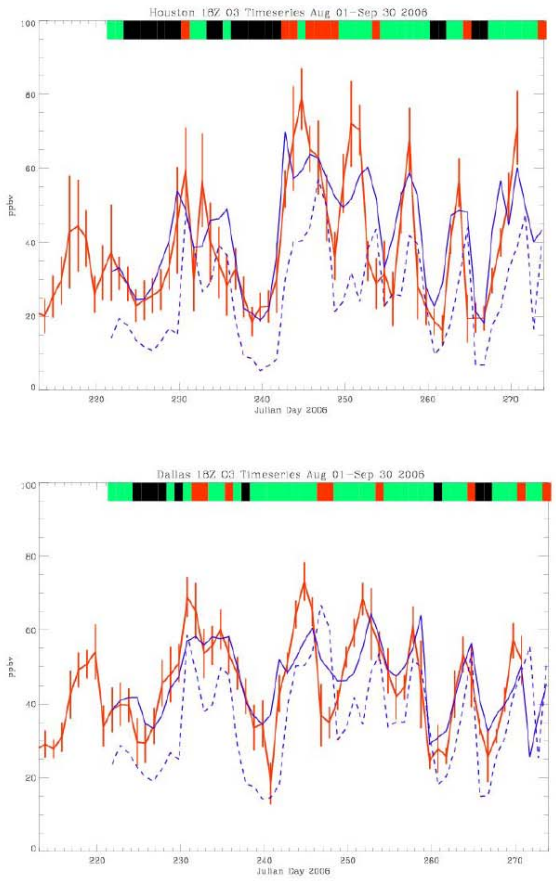


Figure H4. RAQMS back-trajectory analysis of regional influences on Houston/Dallas O_3. Red = Observed mean/variability of surface O_3 in urban area at 18 UTC. Blue = RAQMS predictions, Solid=Predicted O_3 mean (bias corrected), Dashed=Predicted background mean (bias corrected) immediately prior to entering urban area. Color bar along upper part of each time series indicates regional influence classification (analysis Pierce et al. - NASA).

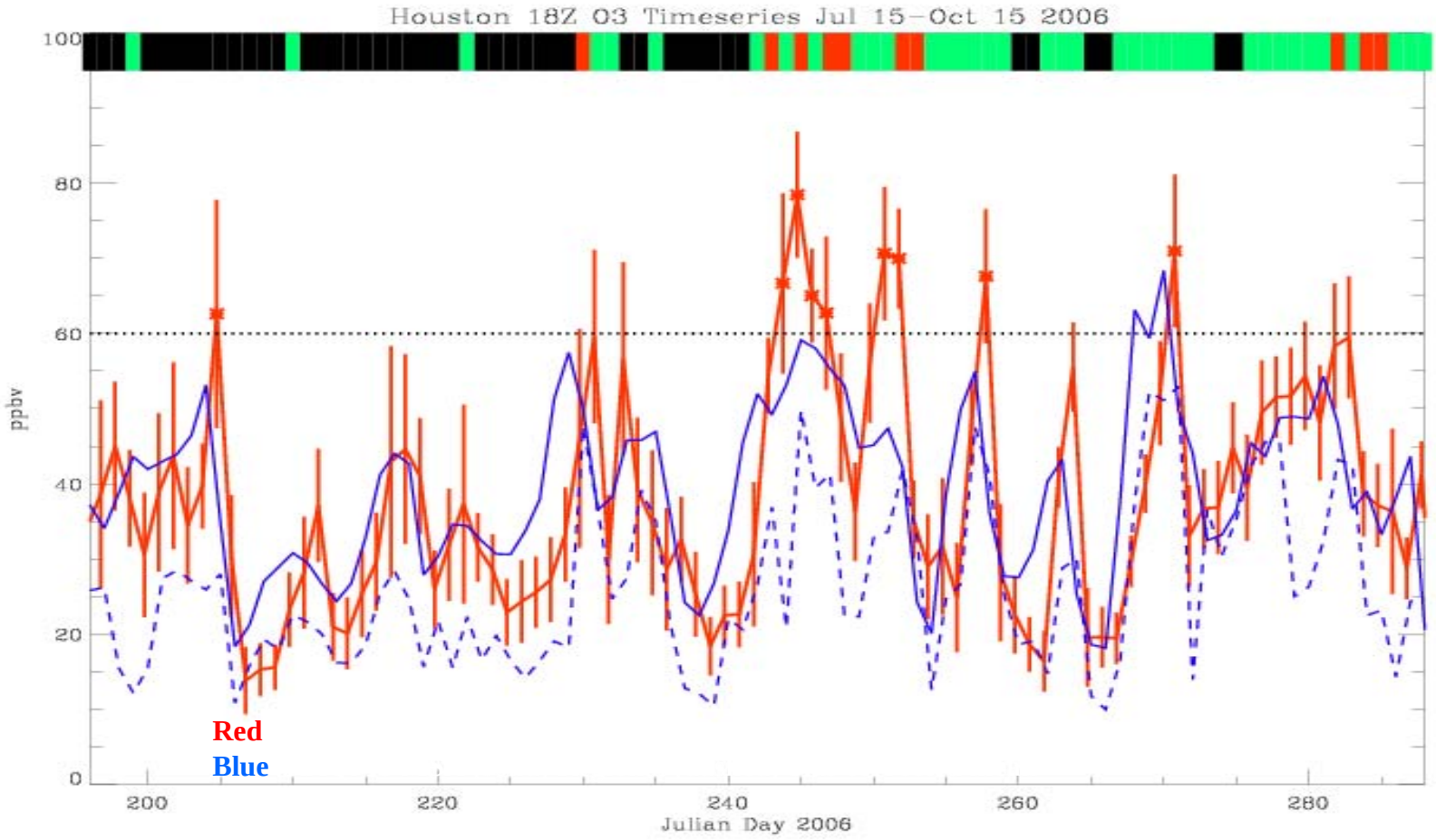
Trajectory Classification

=Net O3 Loss

=5<P-L<10 ppb/day

=P-L>10 ppb/day

Impacts of background ozone production: Houston July 15-October 15, 2006



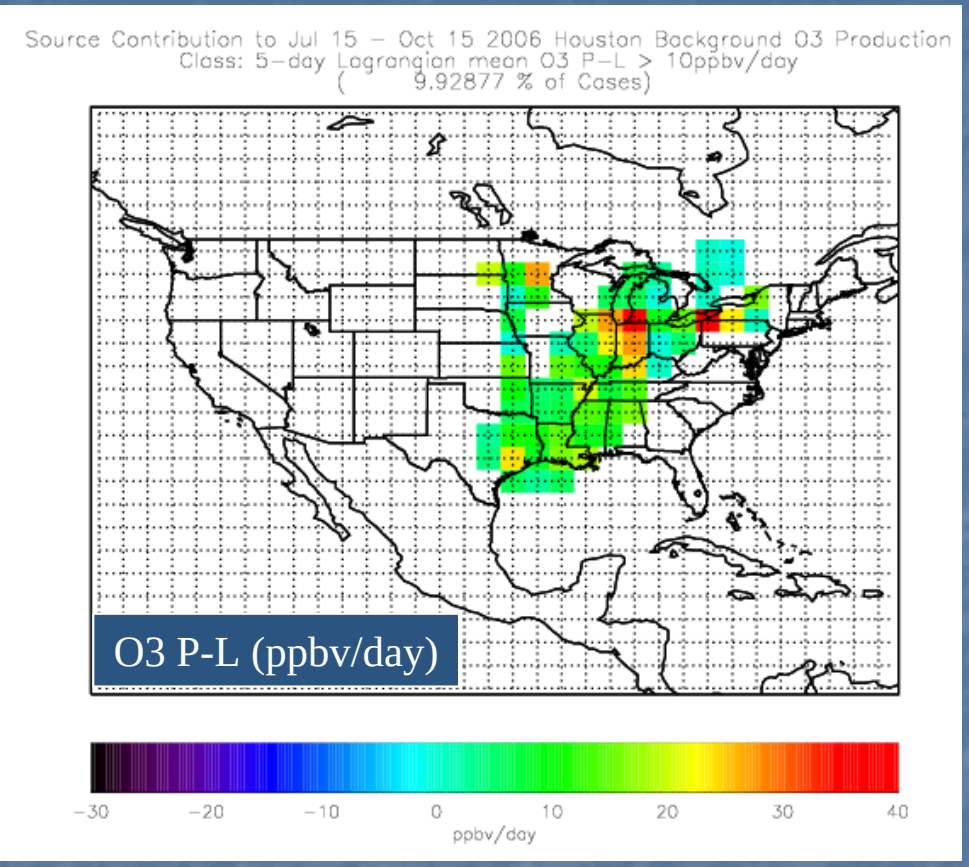
Classifications:

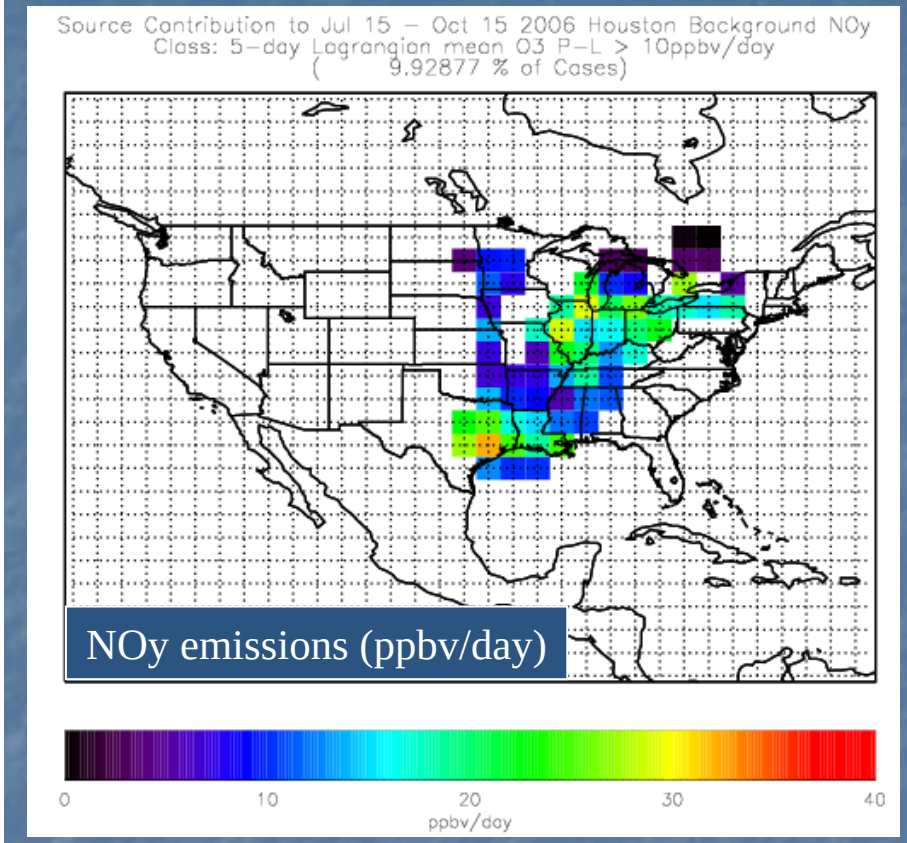
RED=Class1: Enhanced back ground ozone production (ensemble mean 5-day Lagrangian averaged O3 P-L > 10 ppbv/day)

GREEN=Class 2: Moderate back ground ozone production (ensemble mean 5-day Lagrangian averaged O3 P-L > 0 ppbv/day and < 10 ppbv/day).

BLACK=Class 3: Back ground ozone destruction (ensemble mean 5-day Lagrangian averaged O3 P-L < 0 ppbv/day).

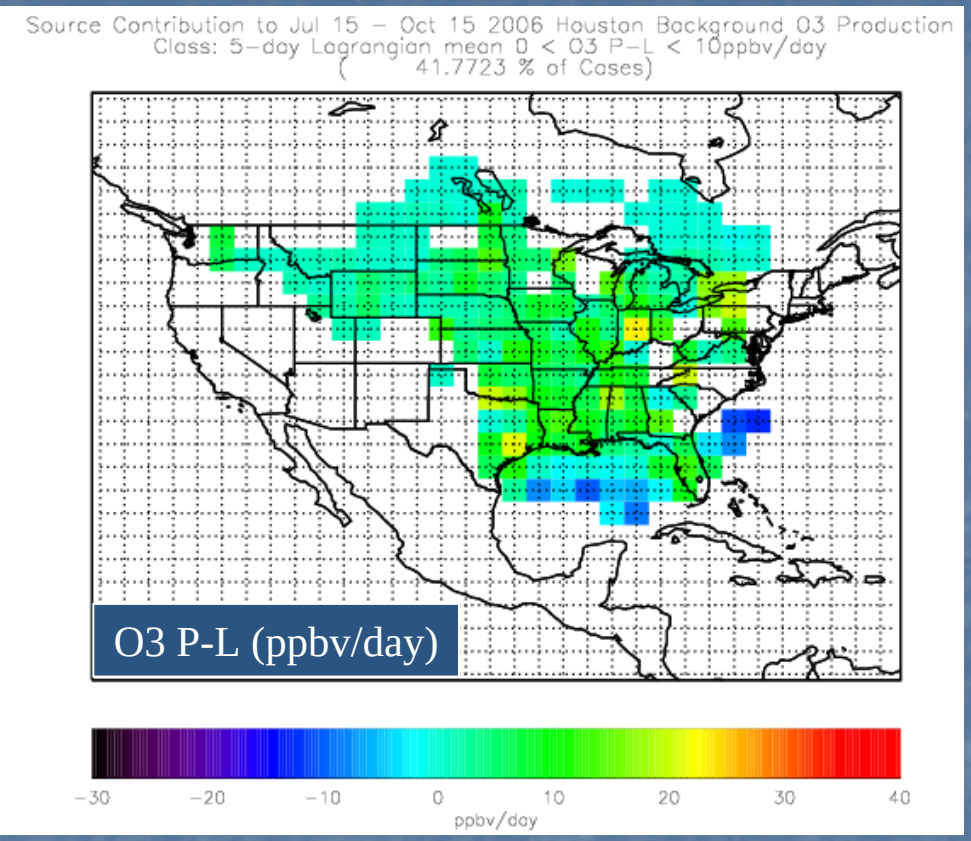
Houston Class 1 Source Contributions July 15-Oct 15, 2006

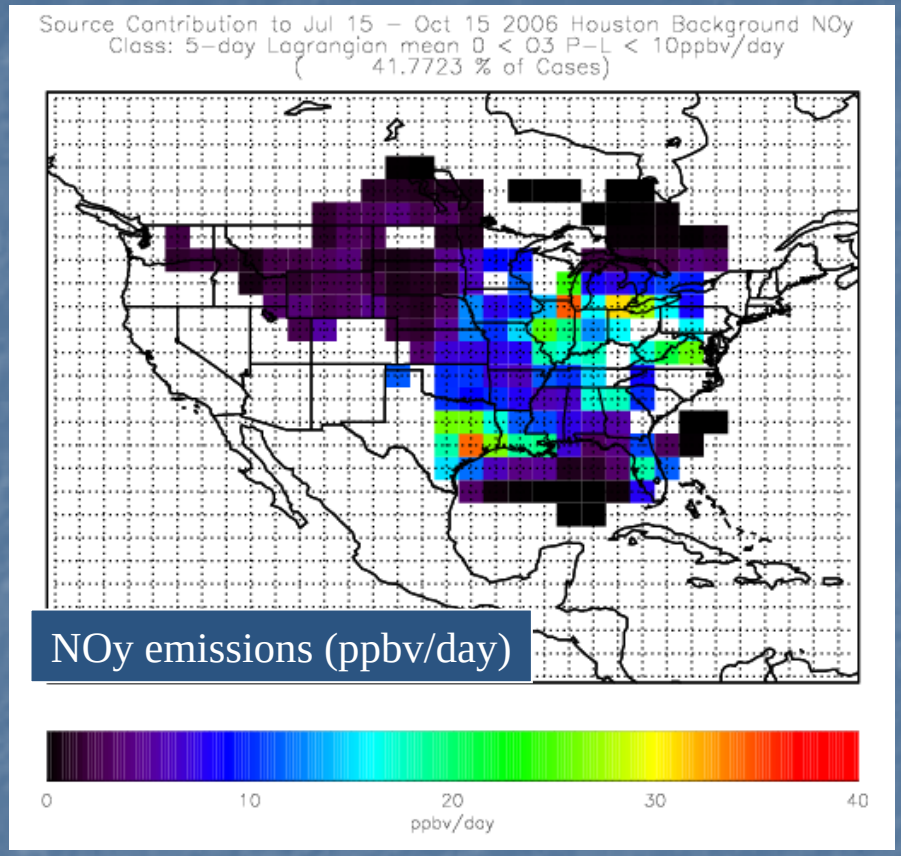




Class 1➔Midwest/Ohio River Valley source with significant O3 P-L (40ppbv/ day) due to NOx sources along the southern Great Lakes.

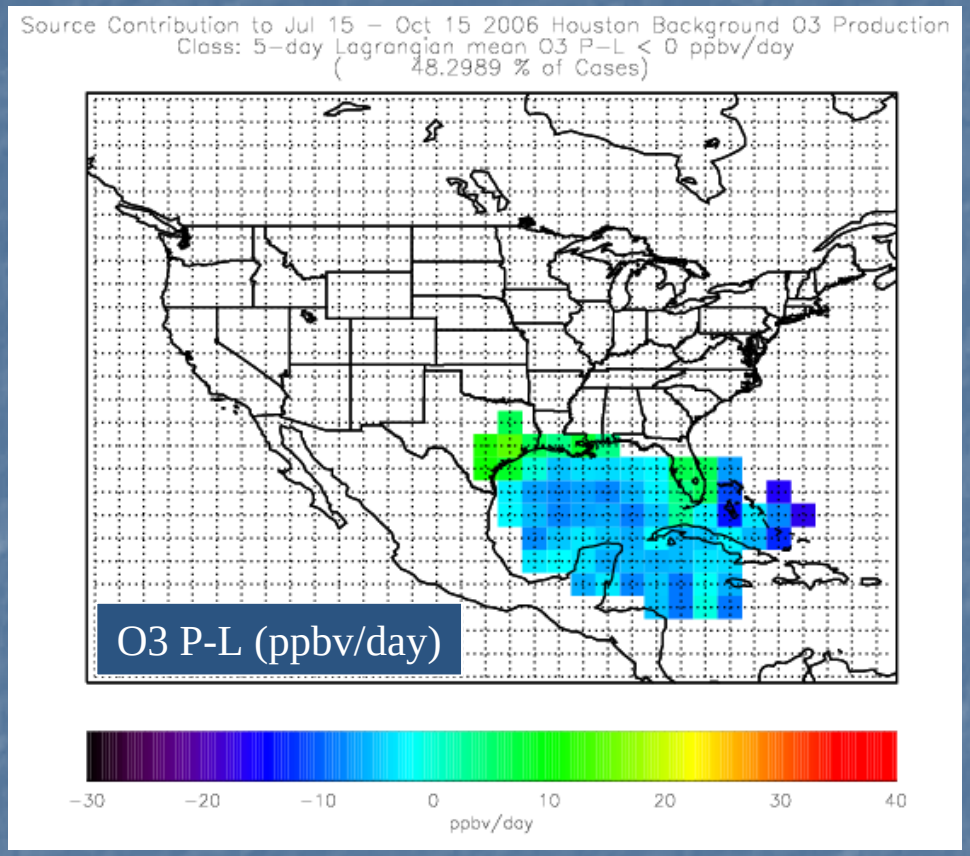
Houston Class 2 Source Contributions July 15-Oct 15, 2006

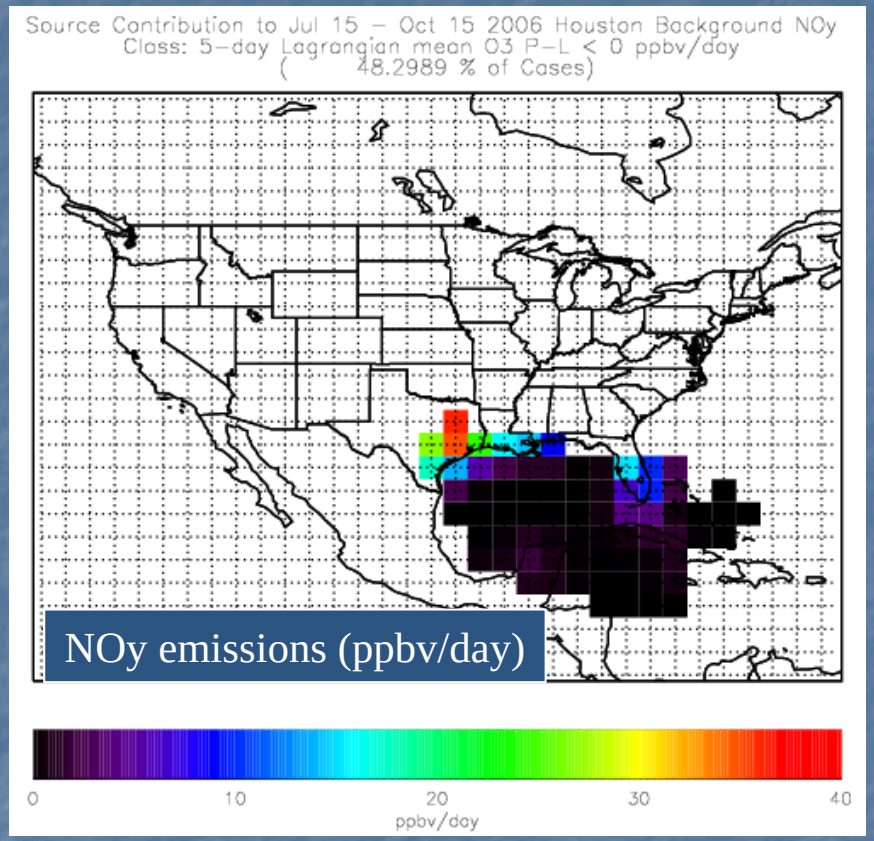




- **Class 2 ➔** Distributed Eastern US sources with moderate (10ppbv/day) O3 P-L due to biomass burning NOx sources in Pacific NW.

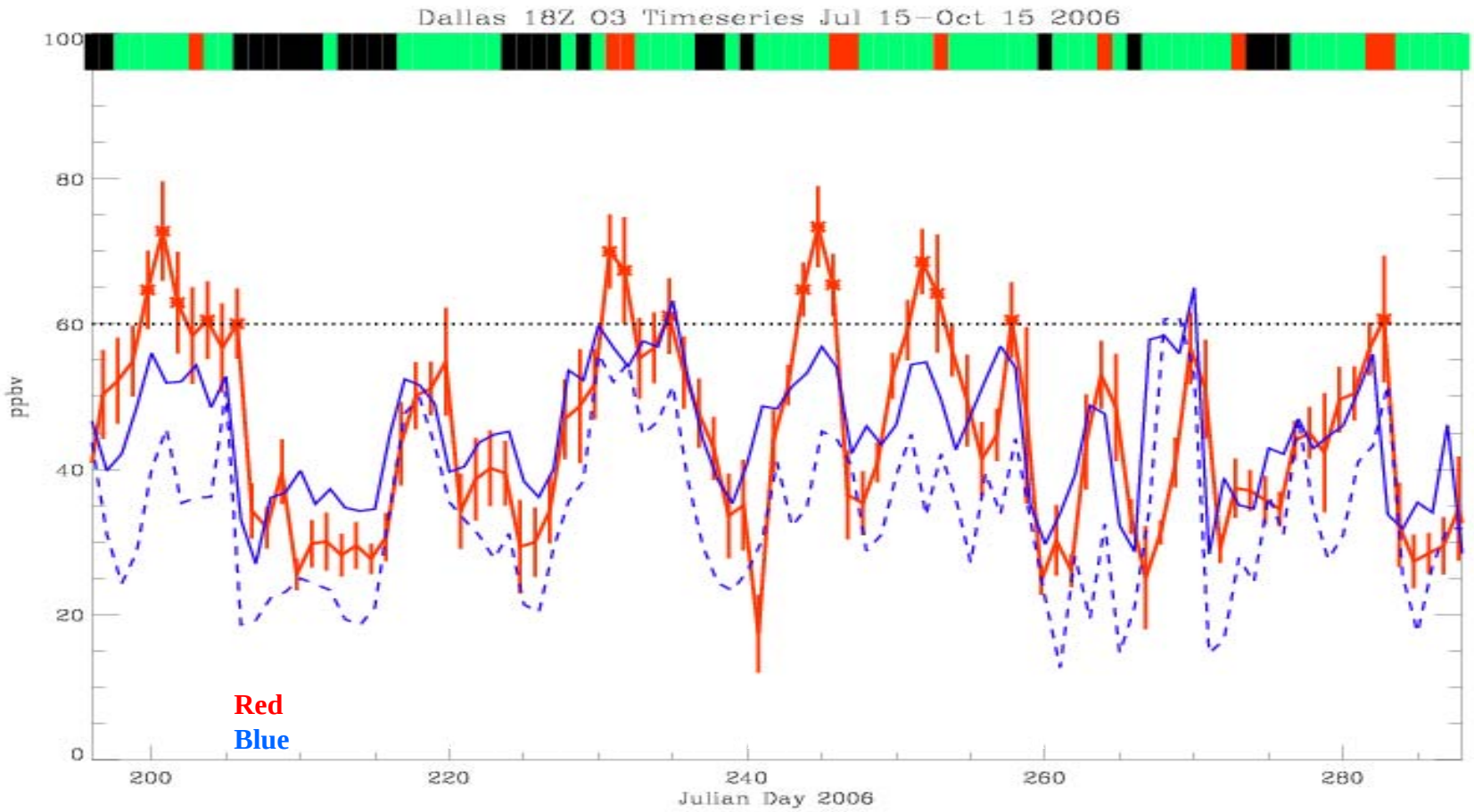
Houston Class 3 Source Contributions July 15-Oct 15, 2006





Class 3➔Net maritime O3 loss over Gulf of Mexico with moderate (10ppbv/day) O3 P-L due to NOx sources in Florida and Louisiana.

Impacts of background ozone production: Dallas July 15-October 15, 2006



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BLACK=Class 3: Back ground ozone destruction (ensemble mean 5-day Lagrangian averaged O3 P-L < 0 ppbv/day).

Summary

Continental US source contributions to daily 18Z mean Houston and Dallas ozone mixing ratios were estimated during July 15-Oct 15, 2006 using Lagrangian approaches.

Three distinct regional influence classifications are developed based on the AIRNow ensemble mean 5-day Lagrangian averaged O3 P-L.

<u>Class 1</u> (Background O3 P-L > 10ppbv/day)
<u>Class 2</u> (Background 0<O3 P-L<10ppbv/day)
<u>Class 3</u> (Background O3 P-L<0ppbv/day)

Class 1 events: 10% (12%) of the Houston (Dallas) back trajectories.
Class 2 events: 42% (60%) of the Houston (Dallas) back trajectories.
Class 3 events: 48% (28%) of the Houston (Dallas) back trajectories.

Periods of enhanced regional ozone production (<u>Class 1</u>) preceed 66% (6 out of 9) and 46% (7 out of 15) of the periods with elevated (Mean >60ppbv) AIRNOW ozone within the Houston and Dallas MSAs respectively.

Satellite Data – Finding H3

- Updates to this figure and description of satellite data
- Concise summary of utility/use of different satellite measurements in Finding H3
- Need to develop a list of action items for updates to descriptions and use of the satellite data
- MISR information

Table H1. Satellite sensors and resulting data products.

NASA Sensor	Product
MODIS - Moderate Resolution Imaging Spectro-radiometer	Aerosol optical depth
CALIPSO - Cloud-Aerosol LIDAR and Infrared Pathfinder Satellite Observation	Aerosol optical depth profile
TES - Tropospheric Emission Spectrometer	Carbon monoxide profile estimate
AIRS - Atmospheric Infrared Sounder	Carbon monoxide

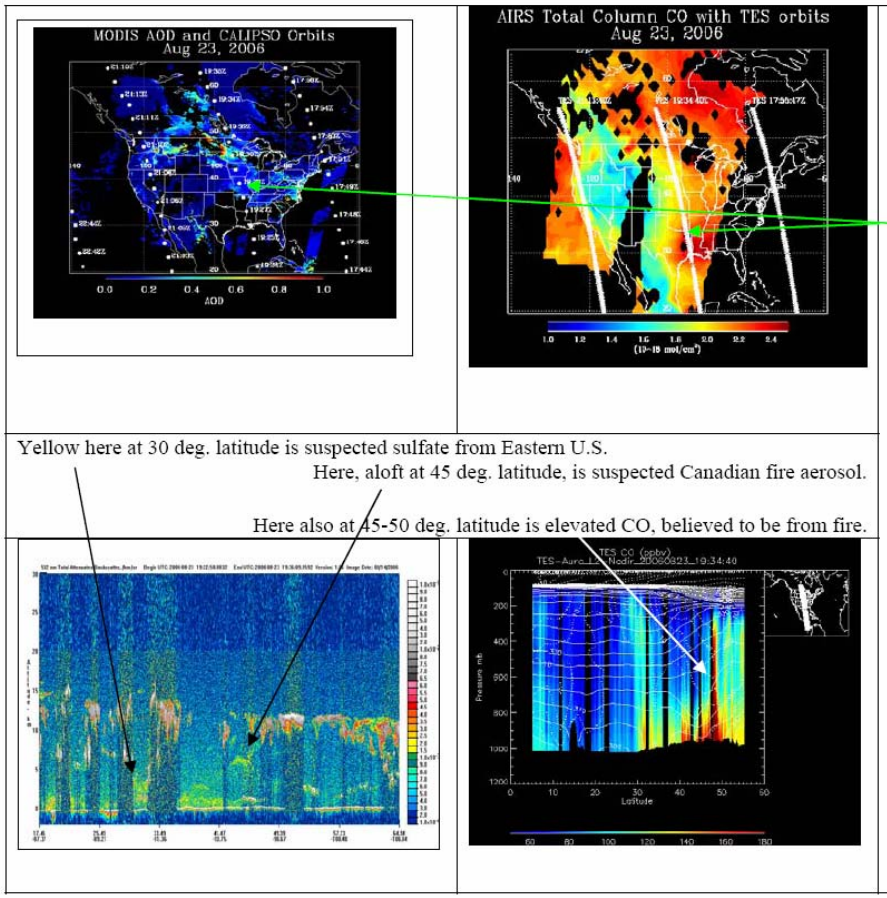


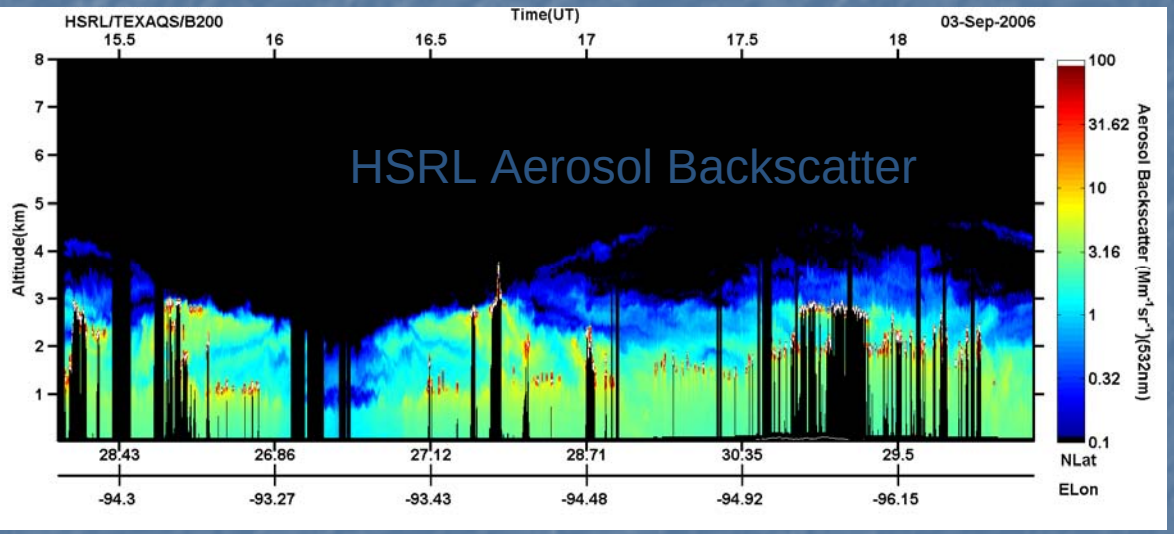
Figure H5. (Top) MODIS and AIRS satellite sensor observations, with CALIPSO and TES orbits given by white lines. Center CALIPSO/TES ground track in two top panels represents 8/23/06 orbit, with color-coding for AOD (left) and CO (right). Bottom two panels show corresponding vertical profiles along the center ground tracks, with x-axis roughly the north-south direction (data from MODIS, AIRS, CALIPSO, and TES teams–NASA).

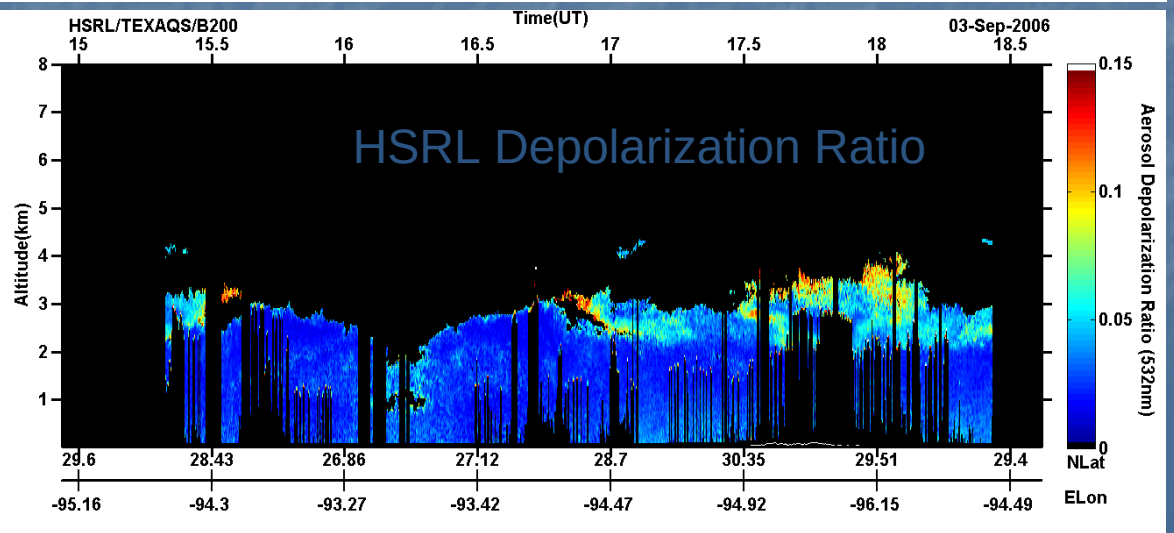
Required Additional Analysis H - Aerosols

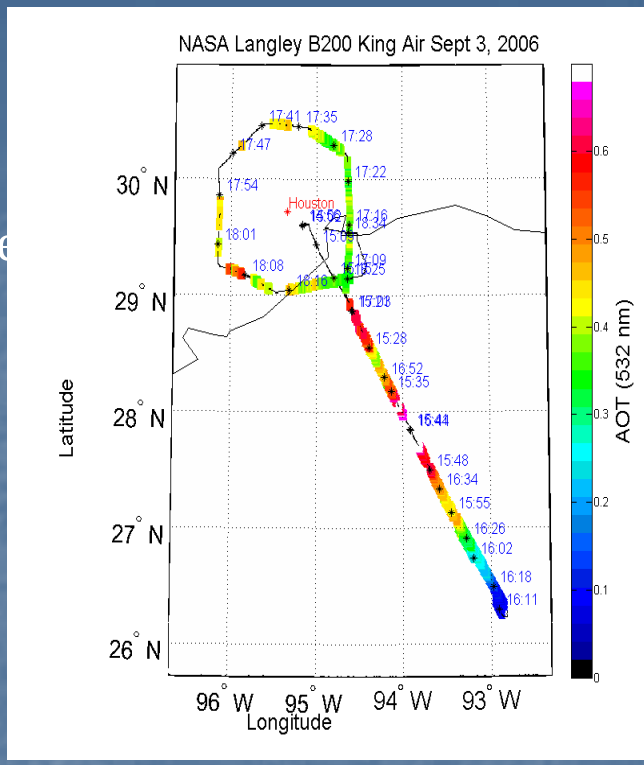
- MODIS AOD, combined with CALIPSO attenuated backscatter measurements, provides a 3-dimensional view of continental scale aerosol transport.
- RAQMS aerosol analyses provide insight into continental aerosol composition and provide link between continental scale satellite, local airborne and surface measurements.
- HSRL aerosol optical measurements provide insight into 3-dimensional SE Texas aerosol composition, validation of CALIPSO attenuated backscatter, and verification of RAQMS analyses.
- Synthesis of these observations and model analyses show the influences of synoptic and hemispheric scale transport processes on speciated aerosol measurements from the TCEQ Deer Park during TEXAQS II.

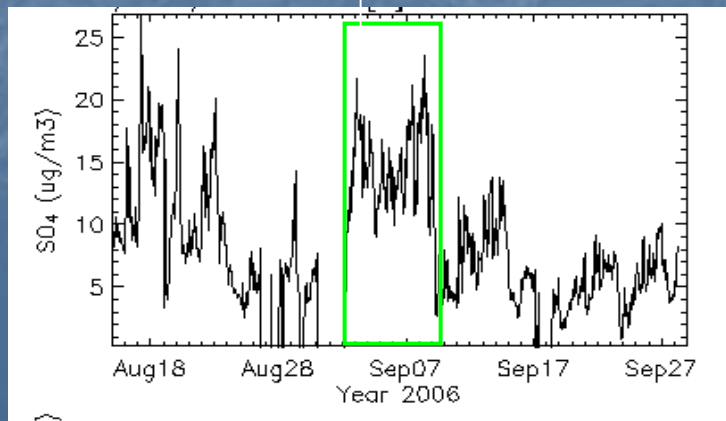
Sulfate Event: Sept. 03, 2006

HSRL Observations show significant >0.5 AOD
With low Depolarization Ratios, consistent with sulfate aerosols

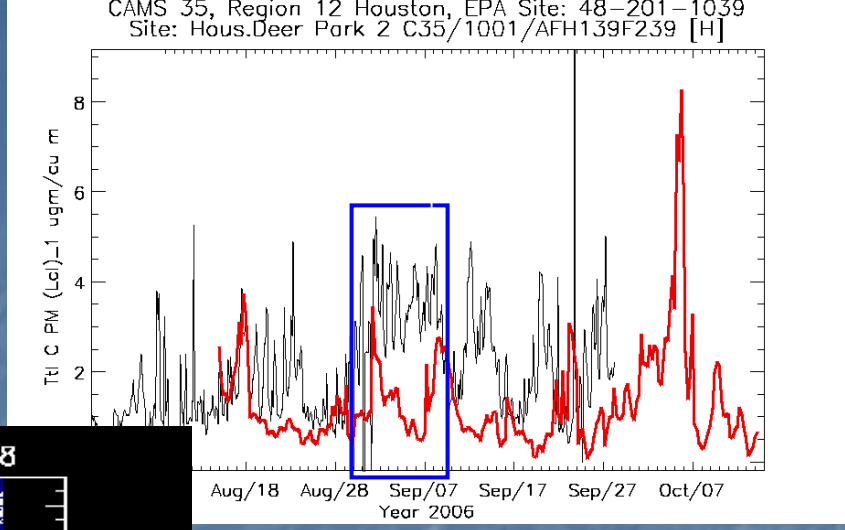


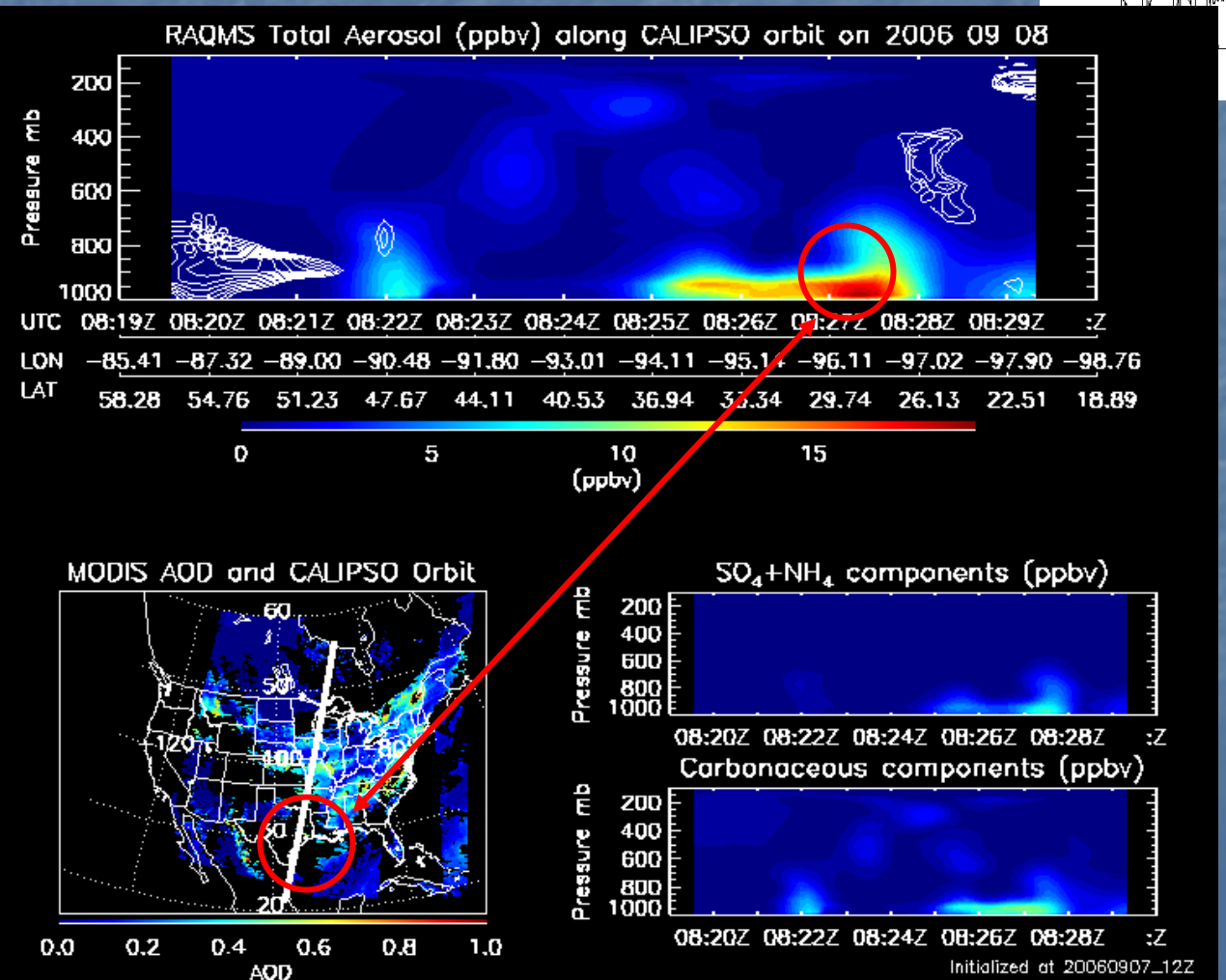






Sulfate/Carbonaceous Event: Sept. 09, 2006





RAQMS underestimates carbonaceous aerosol mass relative to TCEQ measurements.

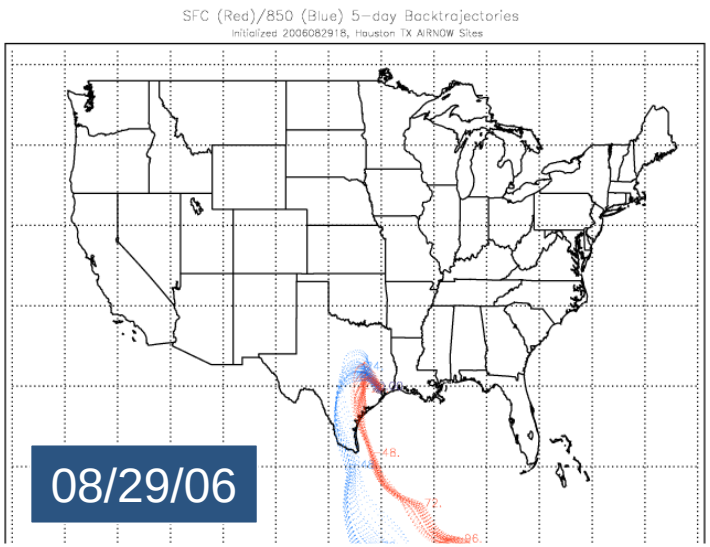
RAQMS aerosol analysis shows carbonaceous dominated aerosols along CALIPSO track near Houston

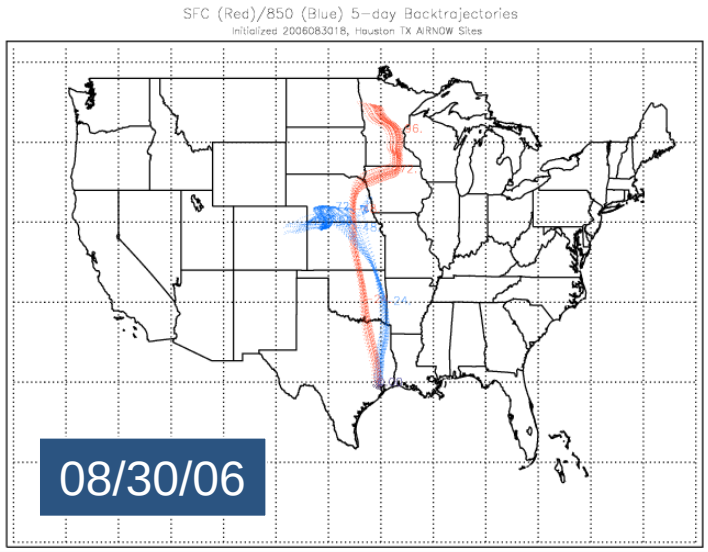
Required Additional Analysis H

- AIRS measurements of O3, CO provide good spatial coverage and vertical information
- TES provides vertical information
- Pick case studies to examine the utility of combining measurements from the two instruments (transport and tropospheric background)
- Incorporate lidar, ozonesonde, tower measurements

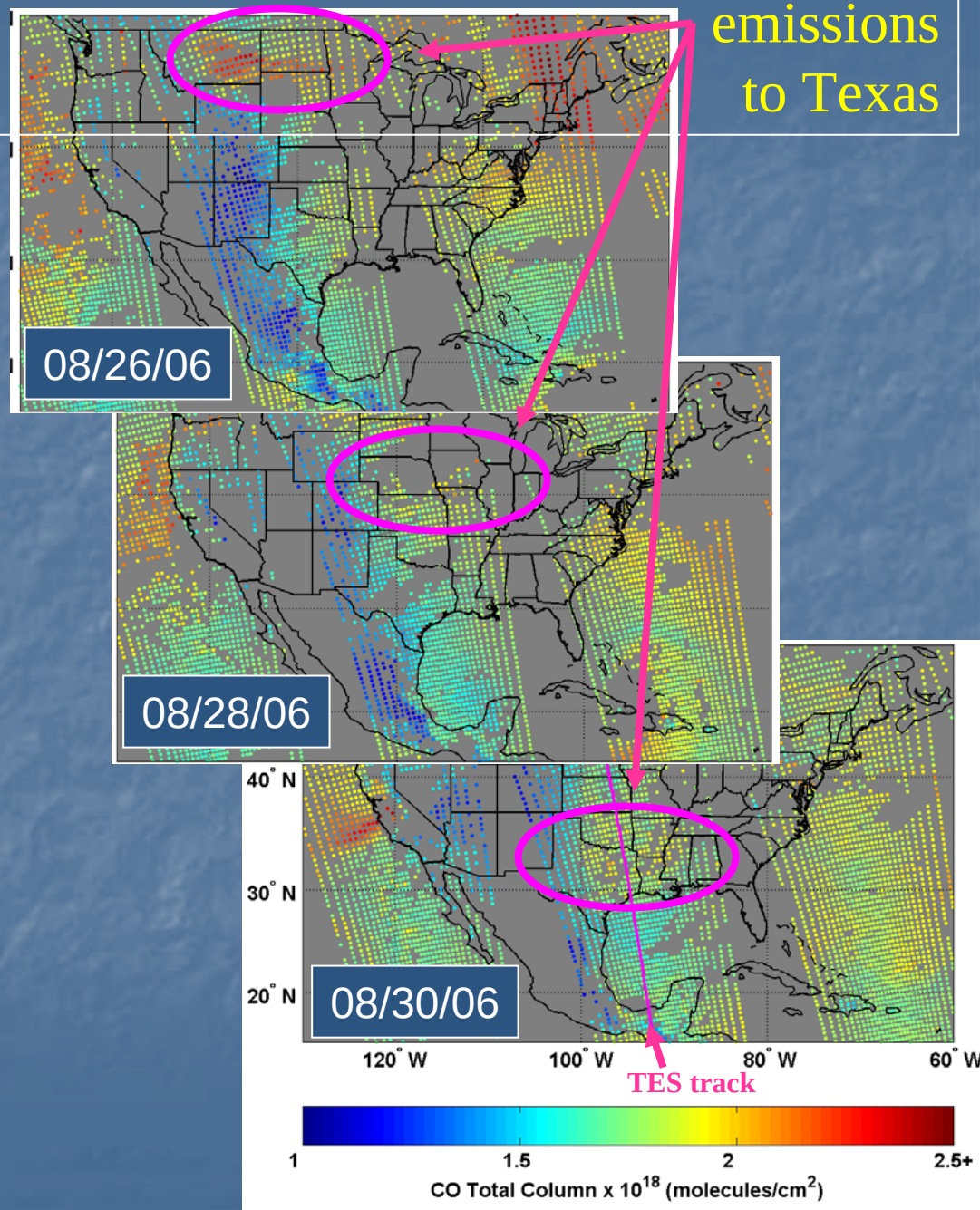
Houston winds shift from marine to continental sources

AIRS Total Column CO tracks fire emissions to Texas





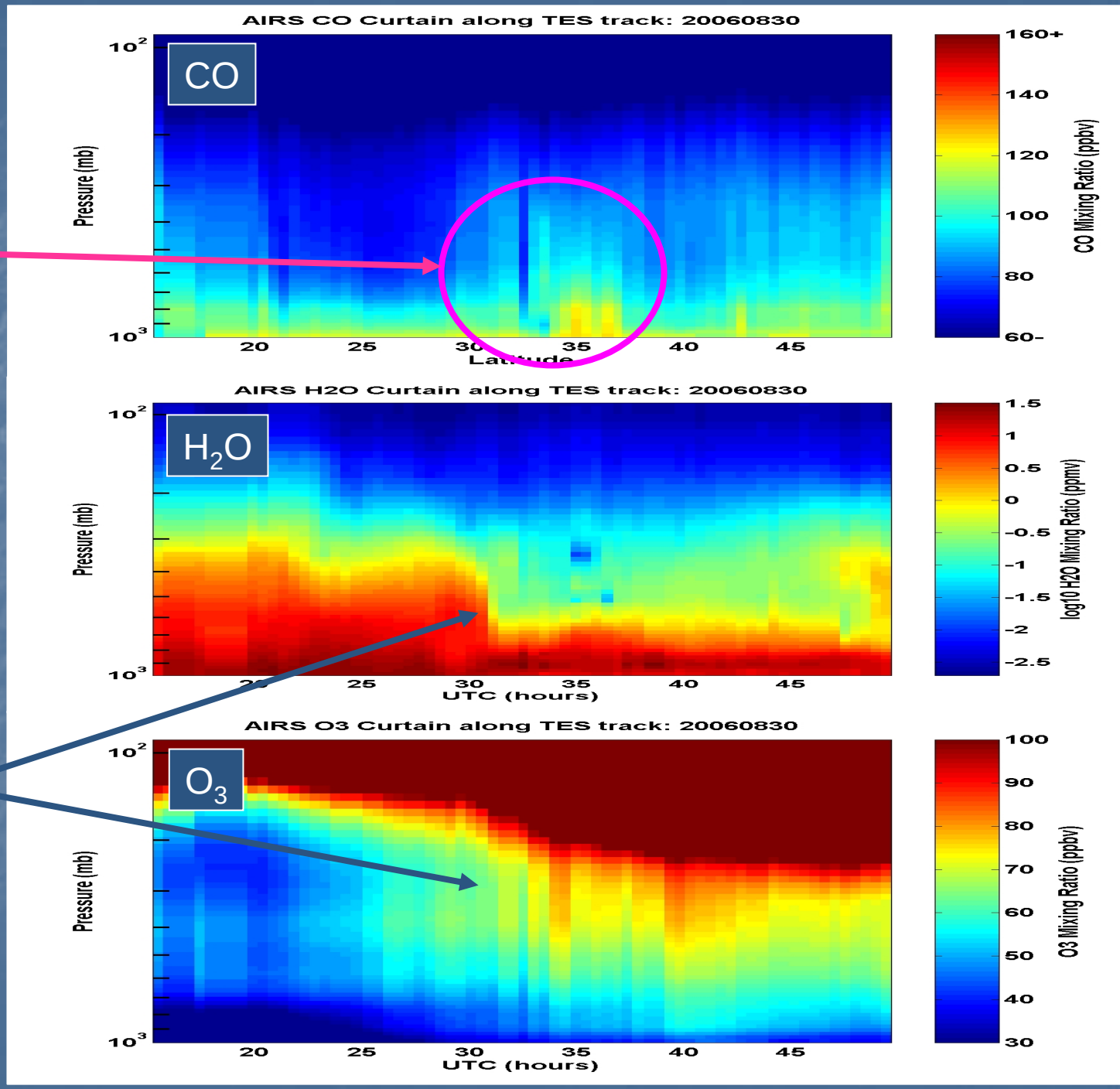
Houston surface and 850mb (1.5 km) 5-day back trajectories



August 30, 2006
AIRS cross-sections
Along TES track

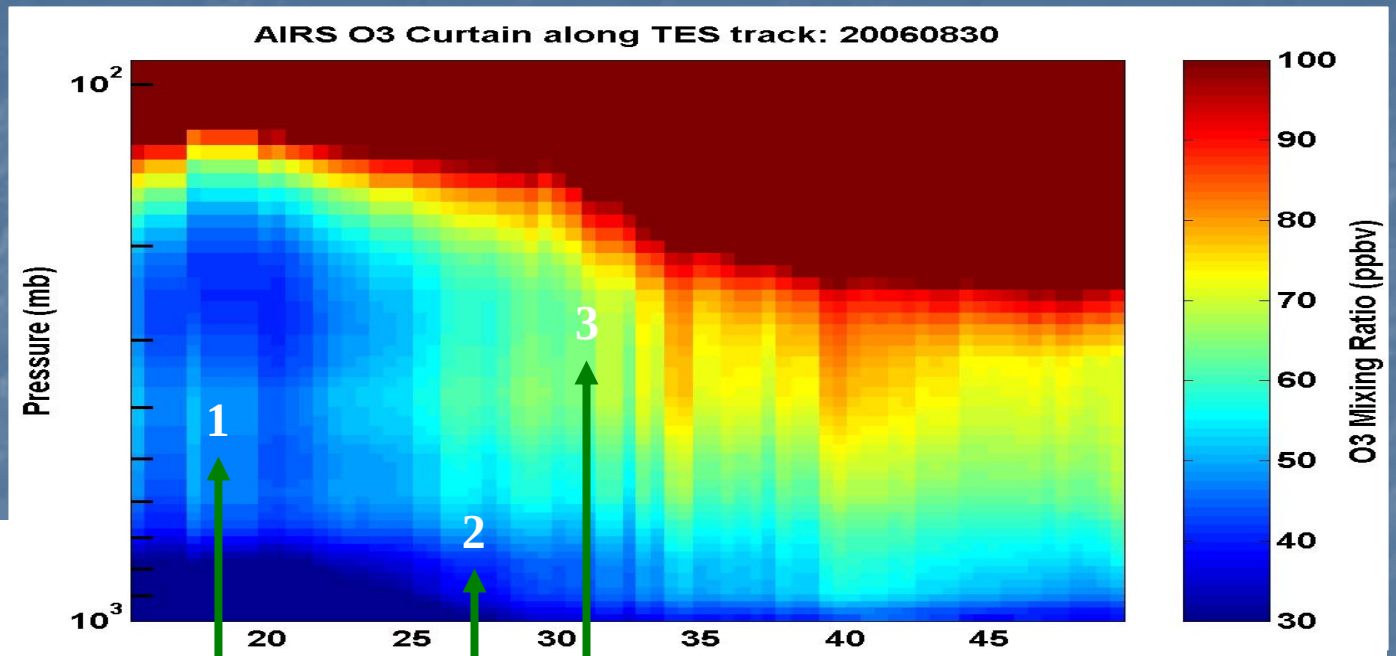
CO enhancement in lower troposphere

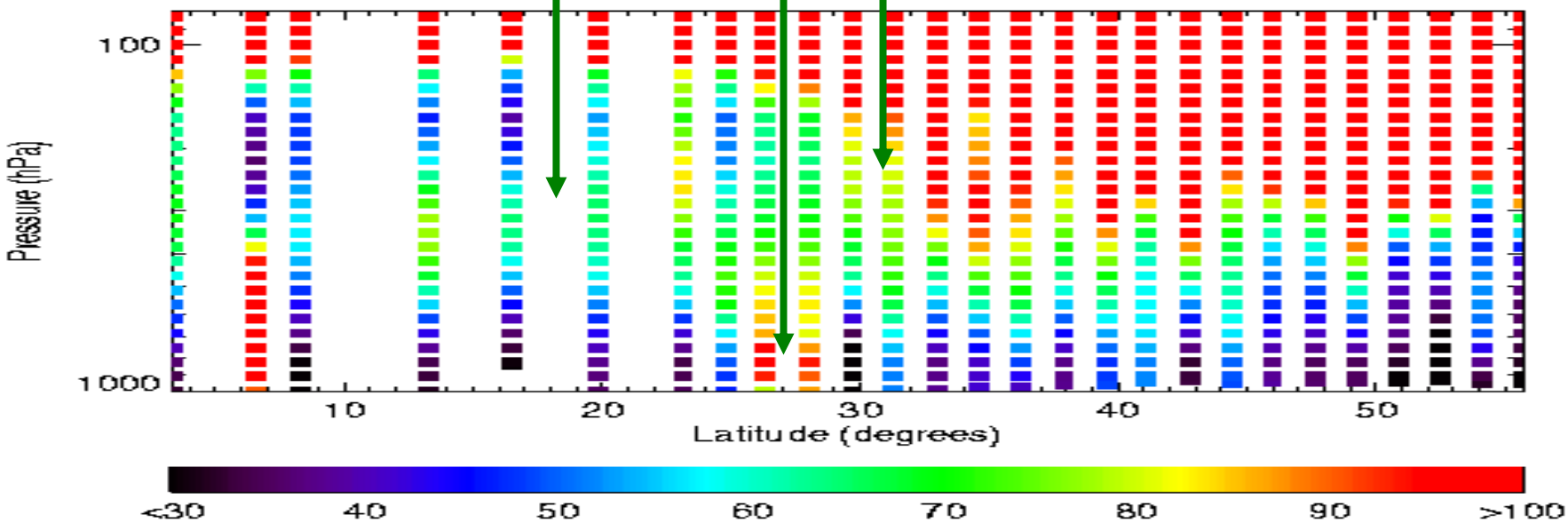
Stratospheric intrusion



AIRS and TES Ozone Cross-sections over Texas on 8/30/06

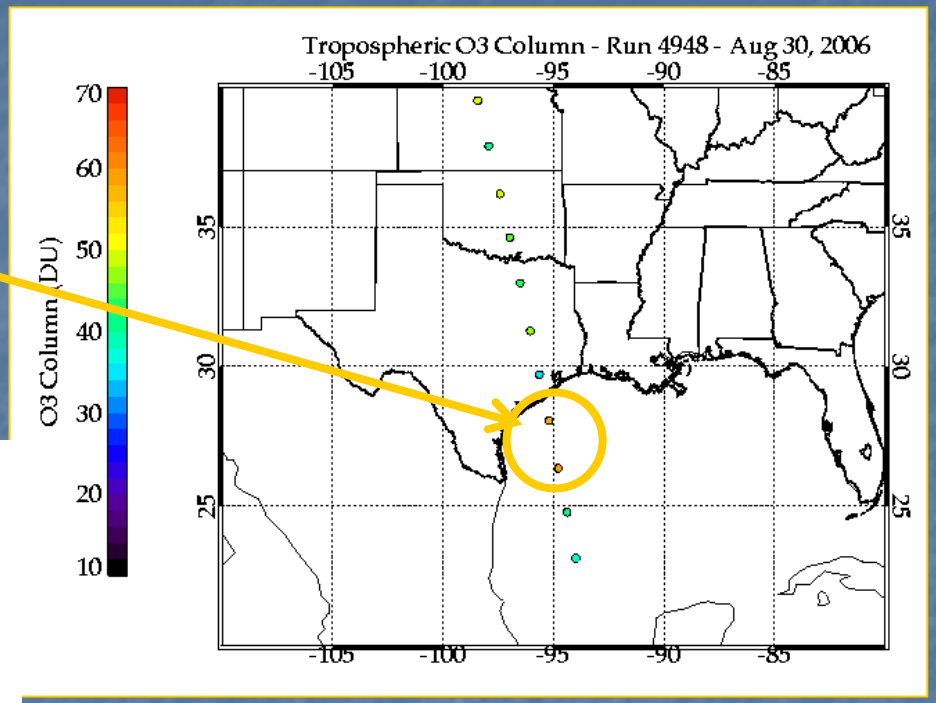
1. Both see a mid-tropospheric enhancement
2. Only TES sees near surface O3
3. Both see a astratospheric intrusion

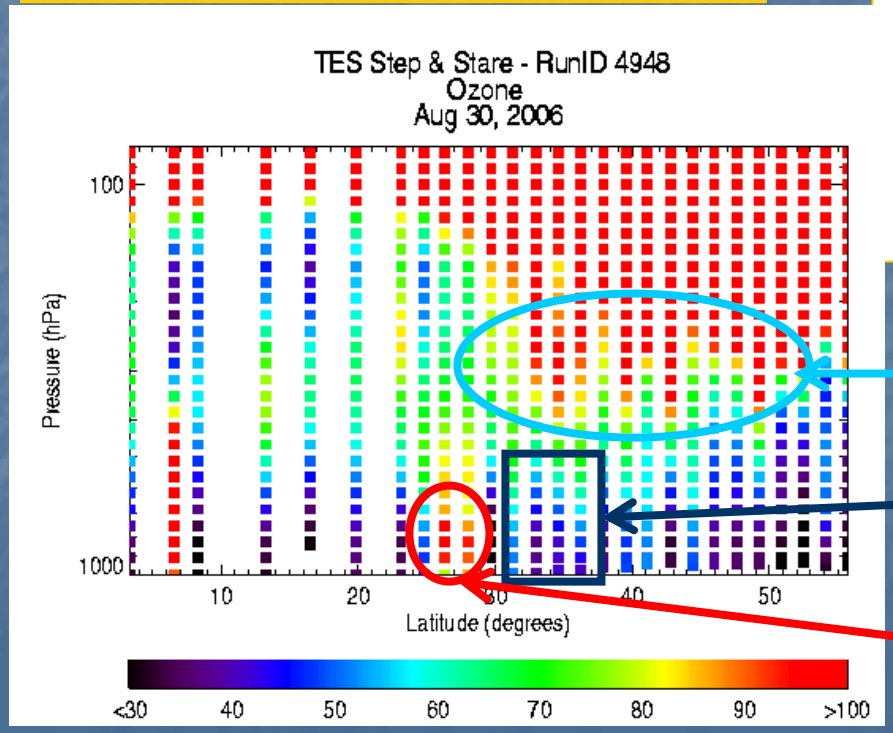




TES Observations – Aug 30, 2006

- TES Global Survey
- High ozone in the troposphere over the Gulf of Mexico seen in Trop Column
- Lower values over East TX





- Enhancement in ozone in middle troposphere over TX, OK, KA
- Low ozone in lower troposphere over East Texas, Central Oklahoma
- High ozone in lower troposphere over the Gulf (still under investigation)

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Extra

Question H

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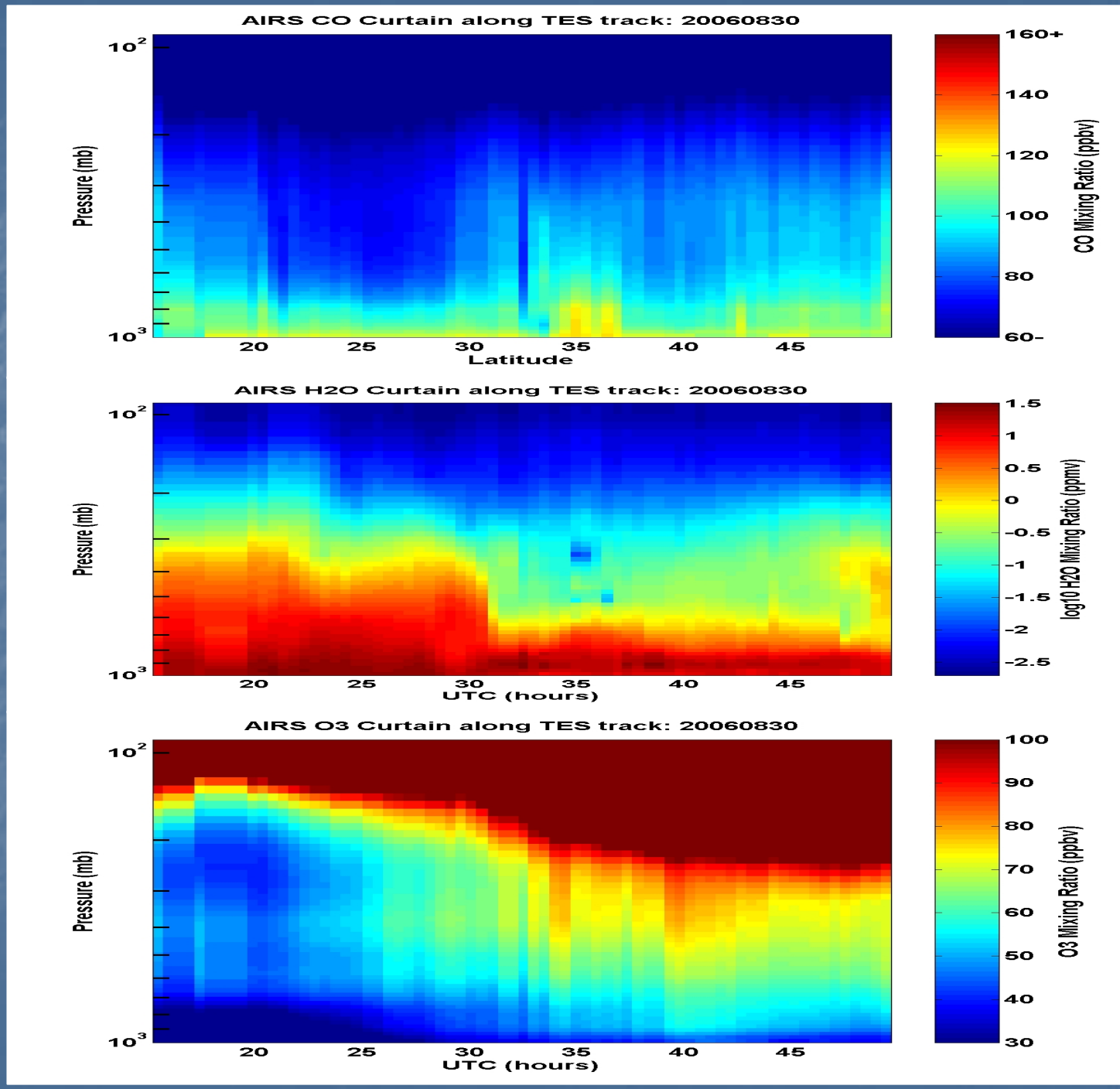
Required Additional Analysis H

1) A synthesis of HSRL lidar aerosol optical measurements, MODIS aerosol optical depths, CALIPSO attenuated backscatter measurements and RAQMS analysis provides insight on the influences of synoptic and hemispheric scale transport processes on speciated aerosol measurements during TexAQS II. In particular, MODIS AOD, combined with CALIPSO attenuated backscatter measurements, provides a 3-dimensional view of continental scale aerosol transport. The RAQMS aerosol analyses provide insight into continental aerosol composition and provide link between continental scale satellite, local airborne and surface measurements. The HSRL aerosol optical measurements provide insight into 3-dimensional SE Texas aerosol composition, validation of CALIPSO attenuated backscatter, and verification of RAQMS analyses.

Required Additional Analysis H

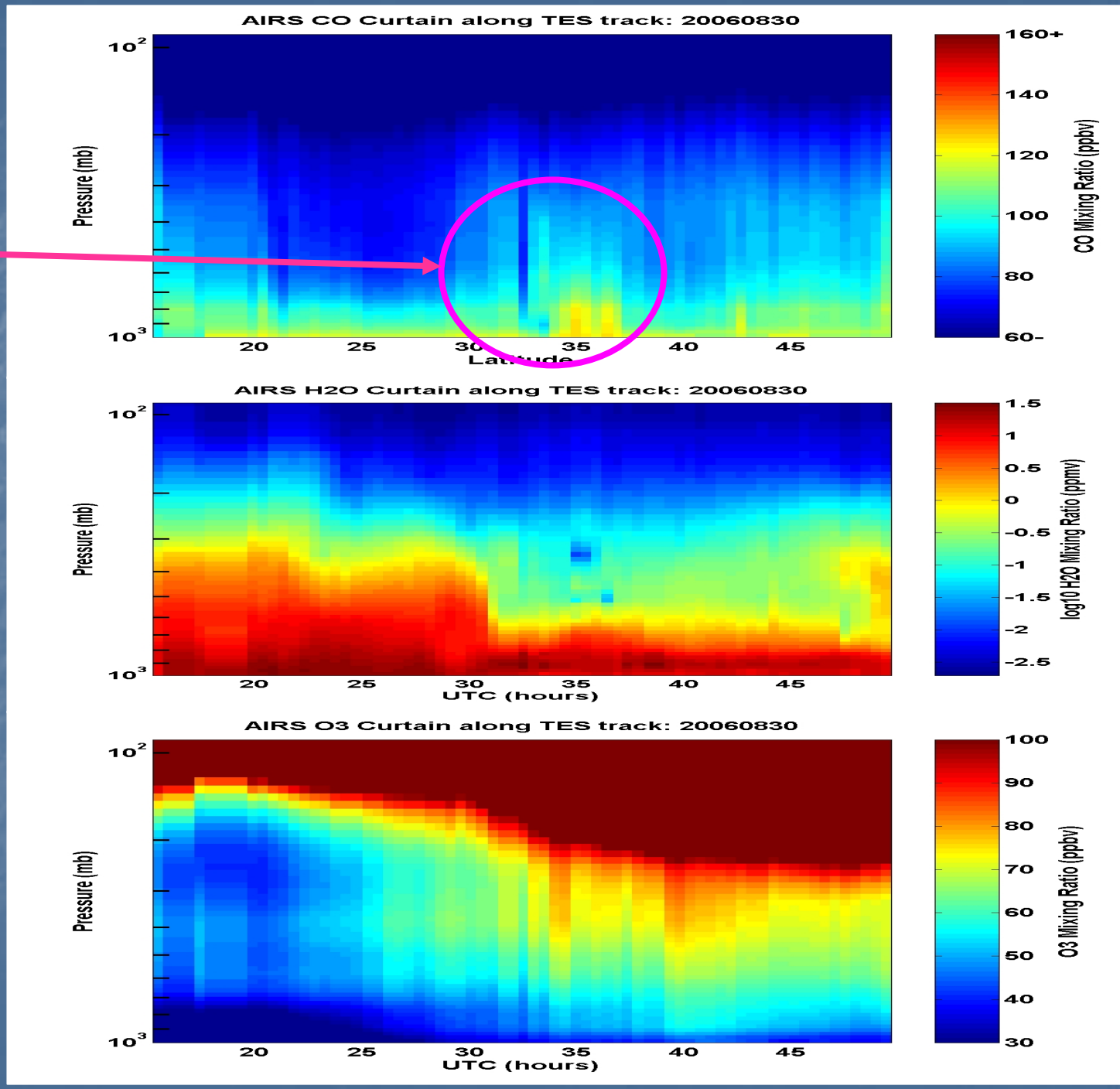
2) **Combining measurements of ozone and carbon monoxide from the TES instrument on the Aura satellite and the AIRS instrument on the Aqua satellite with analysis from the RAQMS model provides insight into the transport of tropospheric air into the Houston area. The TES measurements provide vertical information on the structure of ozone and carbon monoxide in the troposphere. AIRS provides extensive spatial coverage as well as information on the vertical structure of carbon monoxide and ozone. RAQMS lagrangian analysis provides the link to allow insight into the transport history of high ozone events observed over Texas. The satellite data can also provide information on the tropospheric background chemical fields.**

August 30, 2006



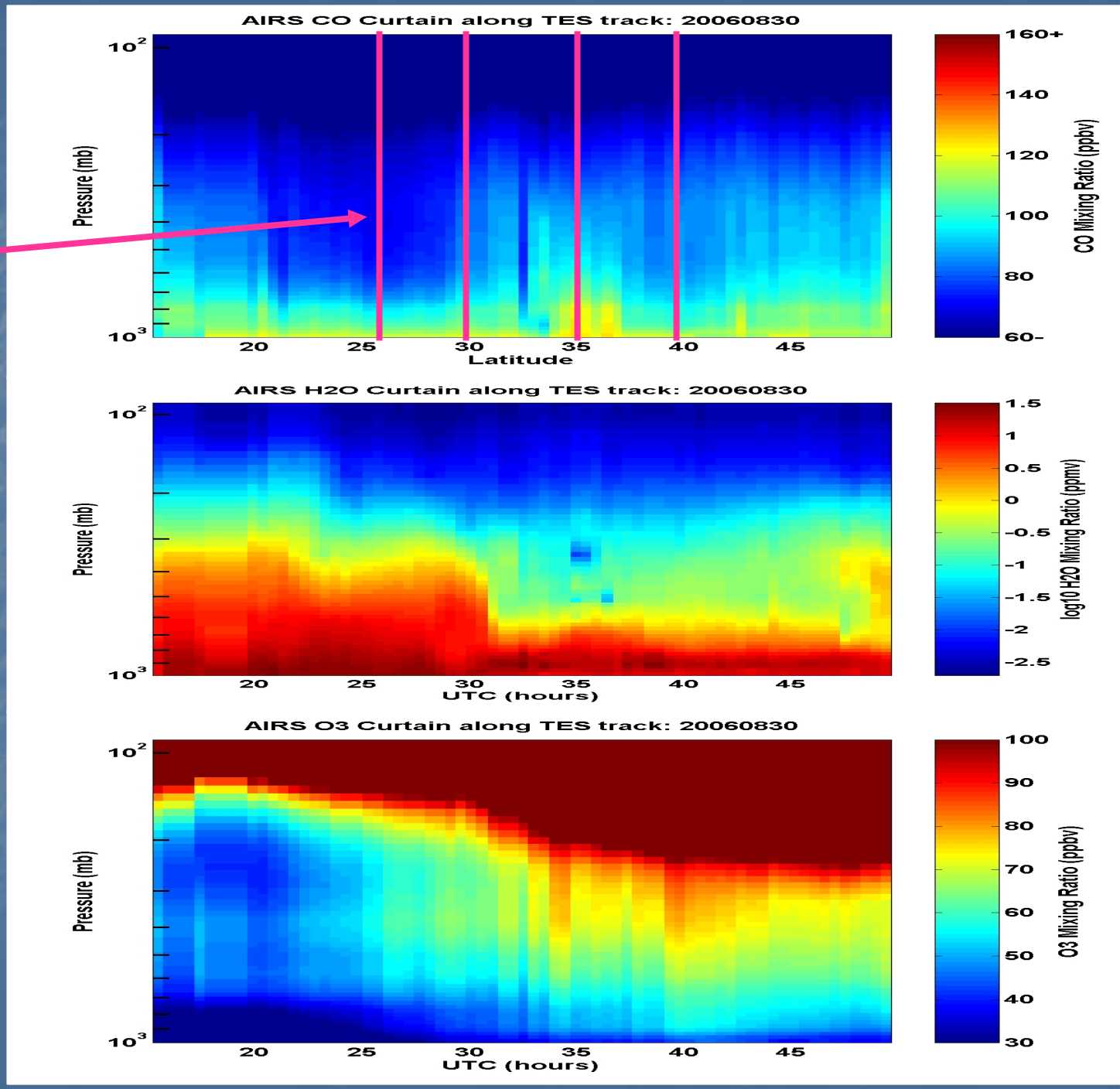
August 30, 2006

CO enhancement
in lower troposphere

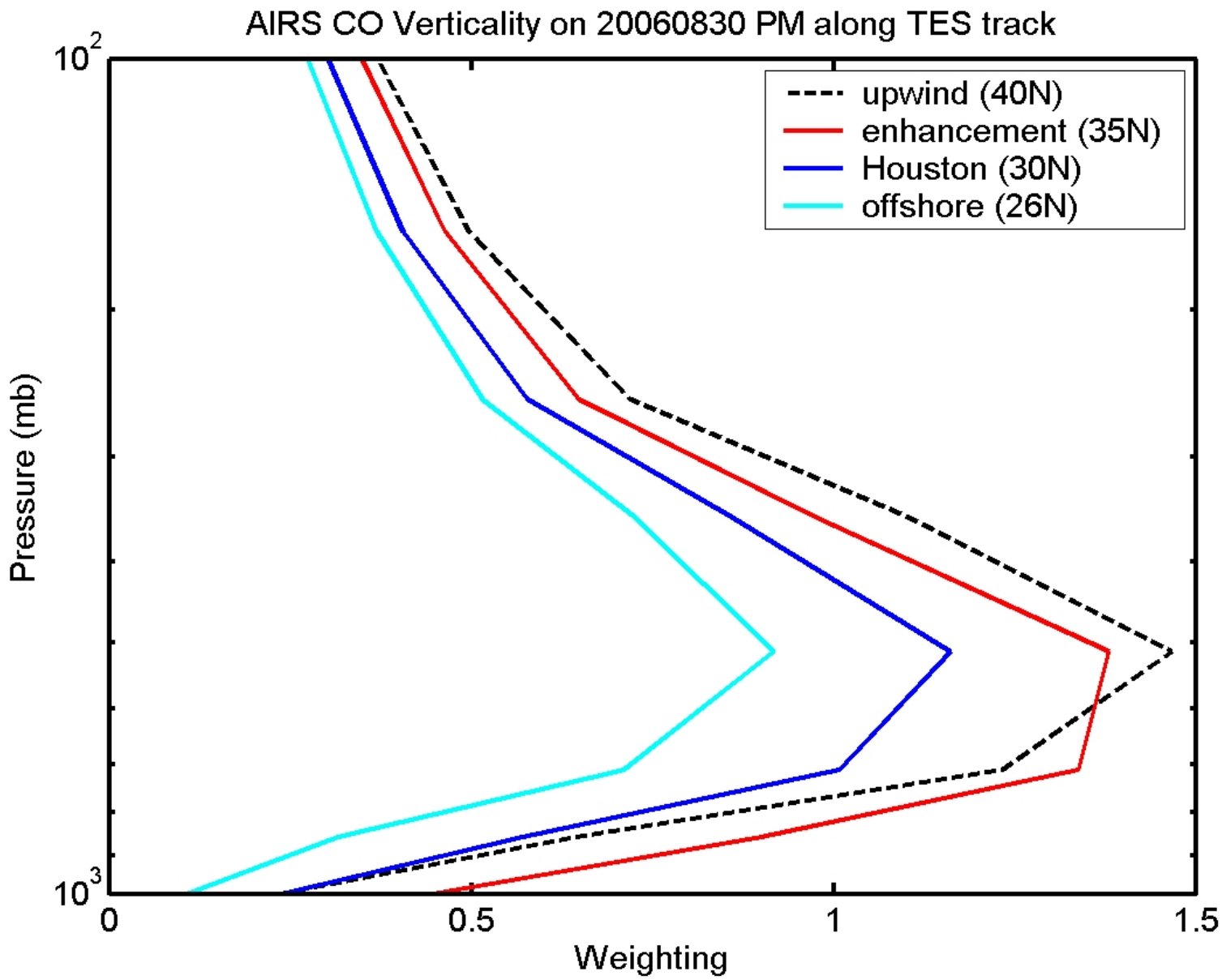


August 30, 2006

CO vertical sensitivity profiles



AIRS CO Column Averaging Kernels



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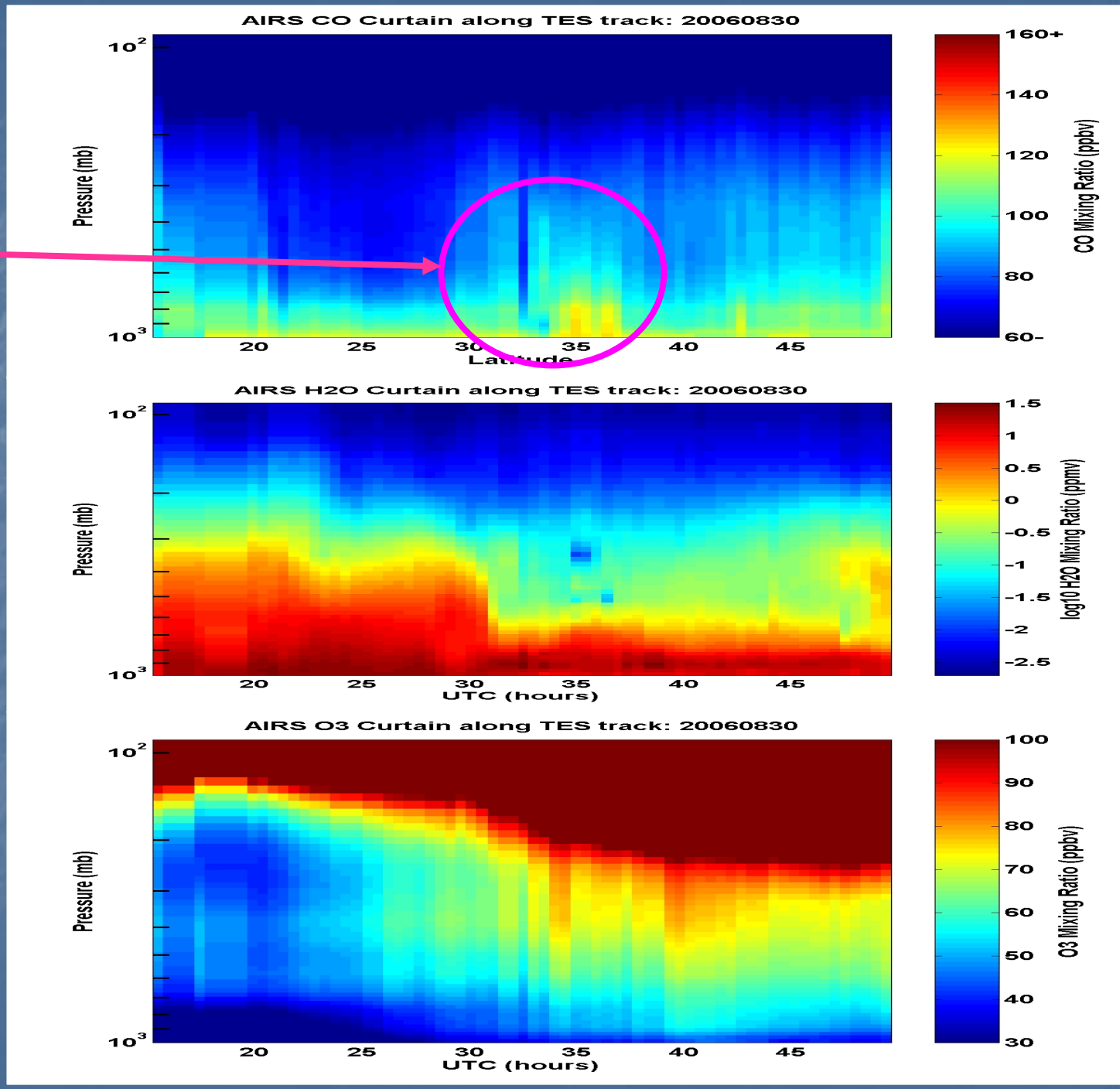

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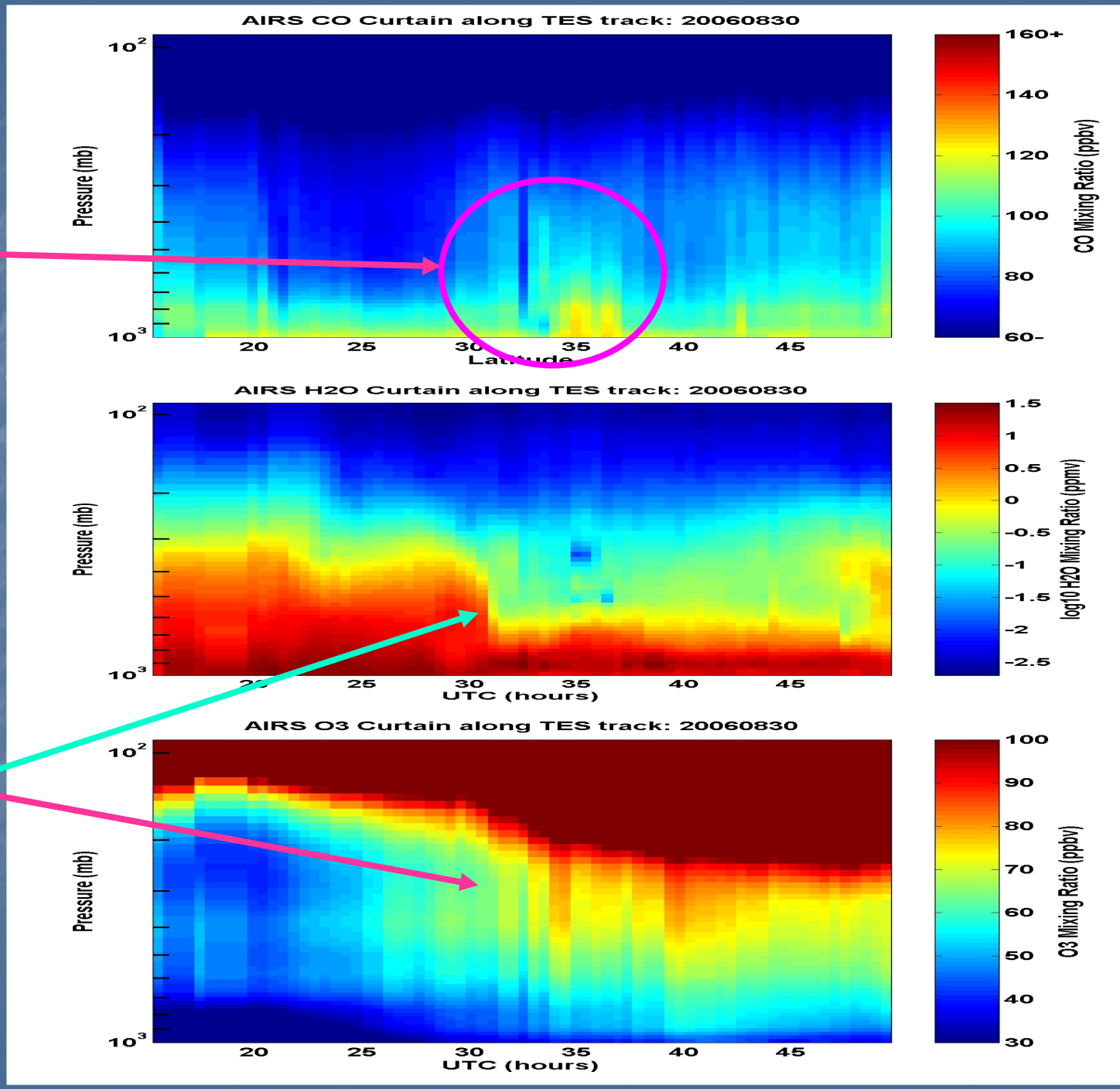
Stratospheric intrusion



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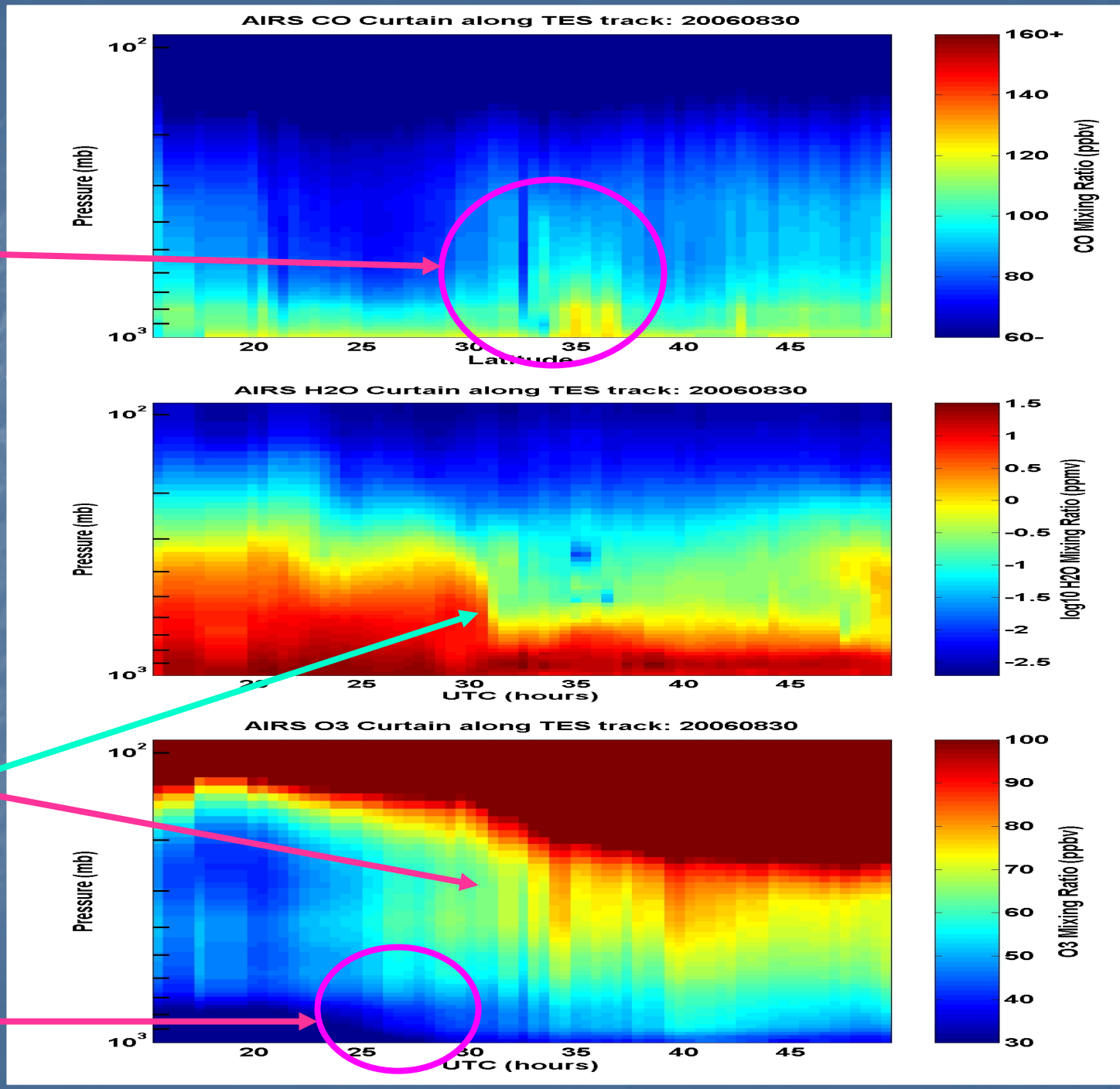
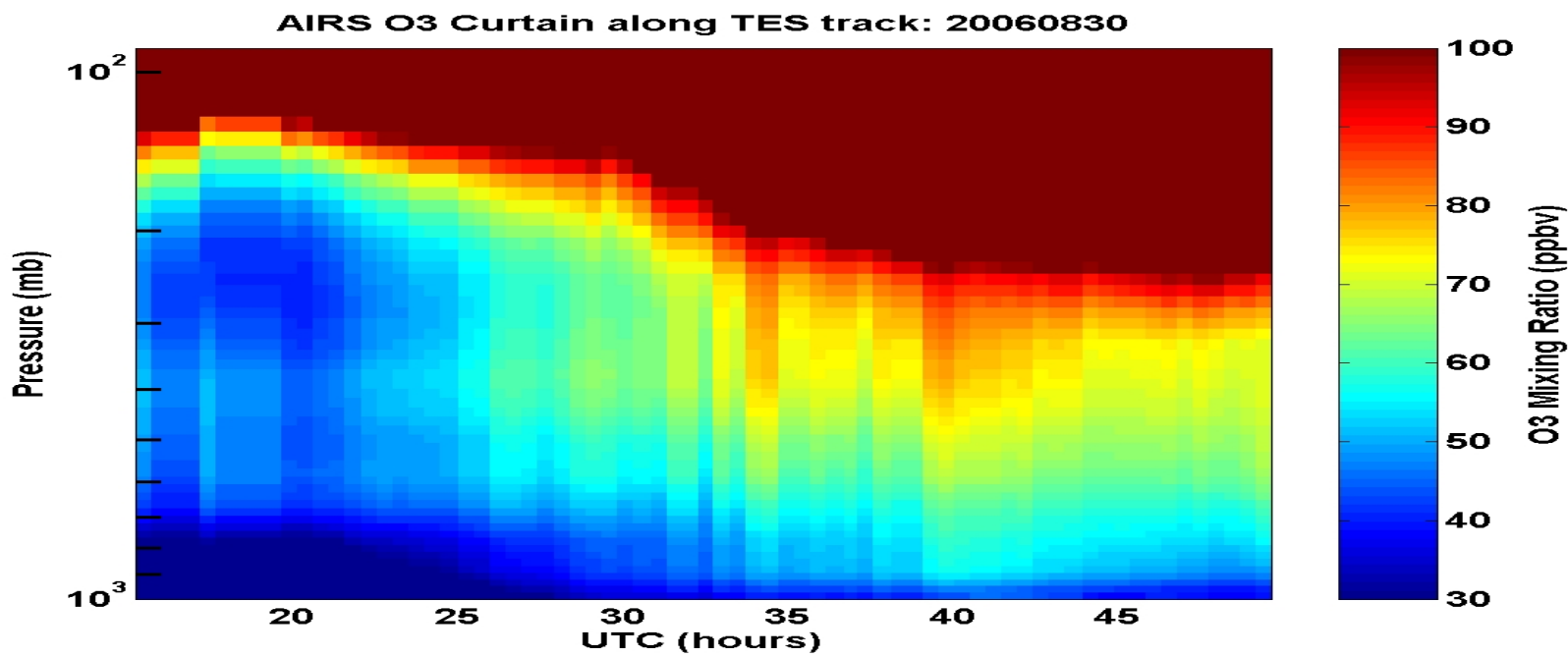
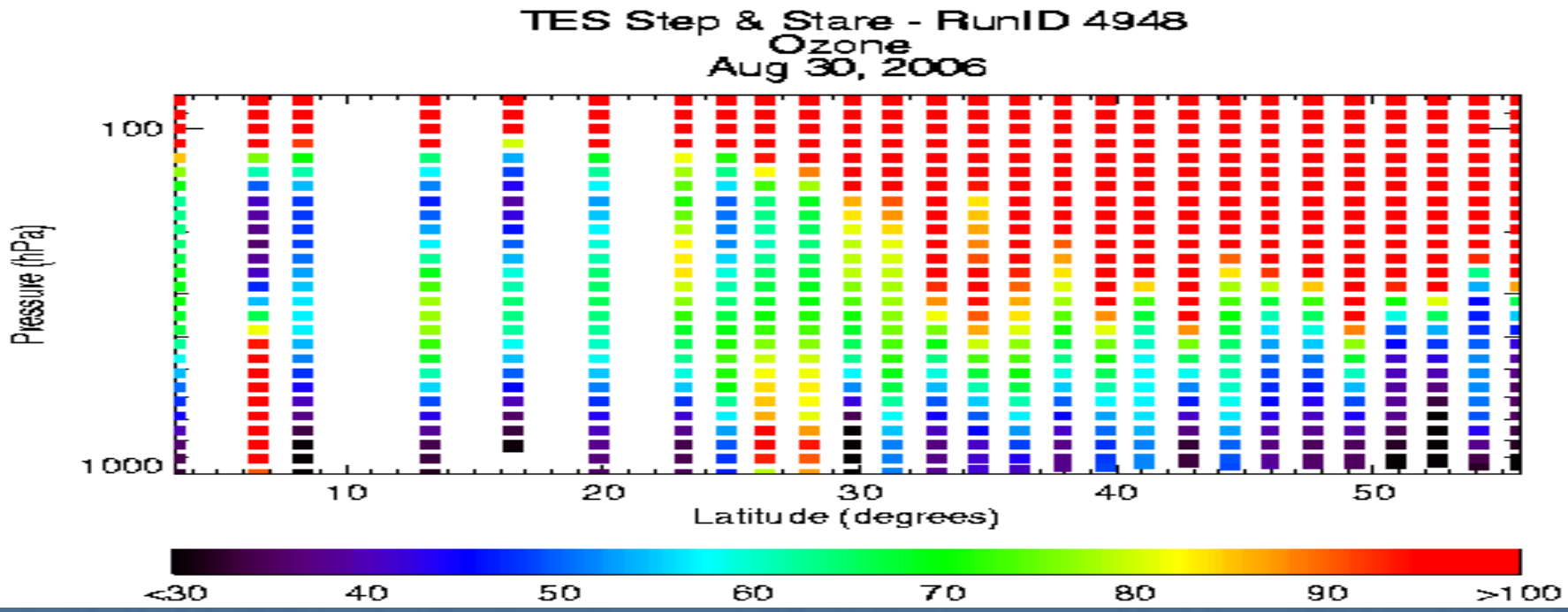
Stratospheric intrusion

AIRS cannot see O3 near surface







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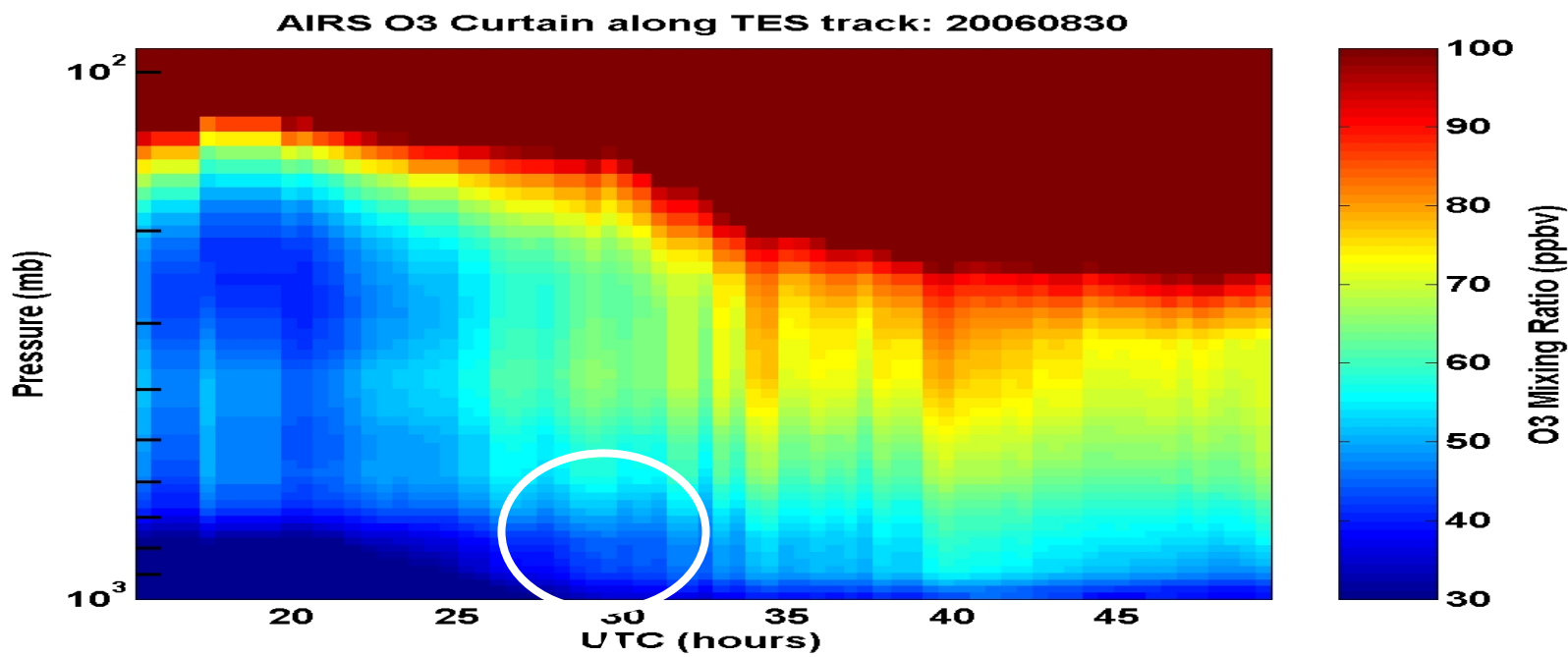

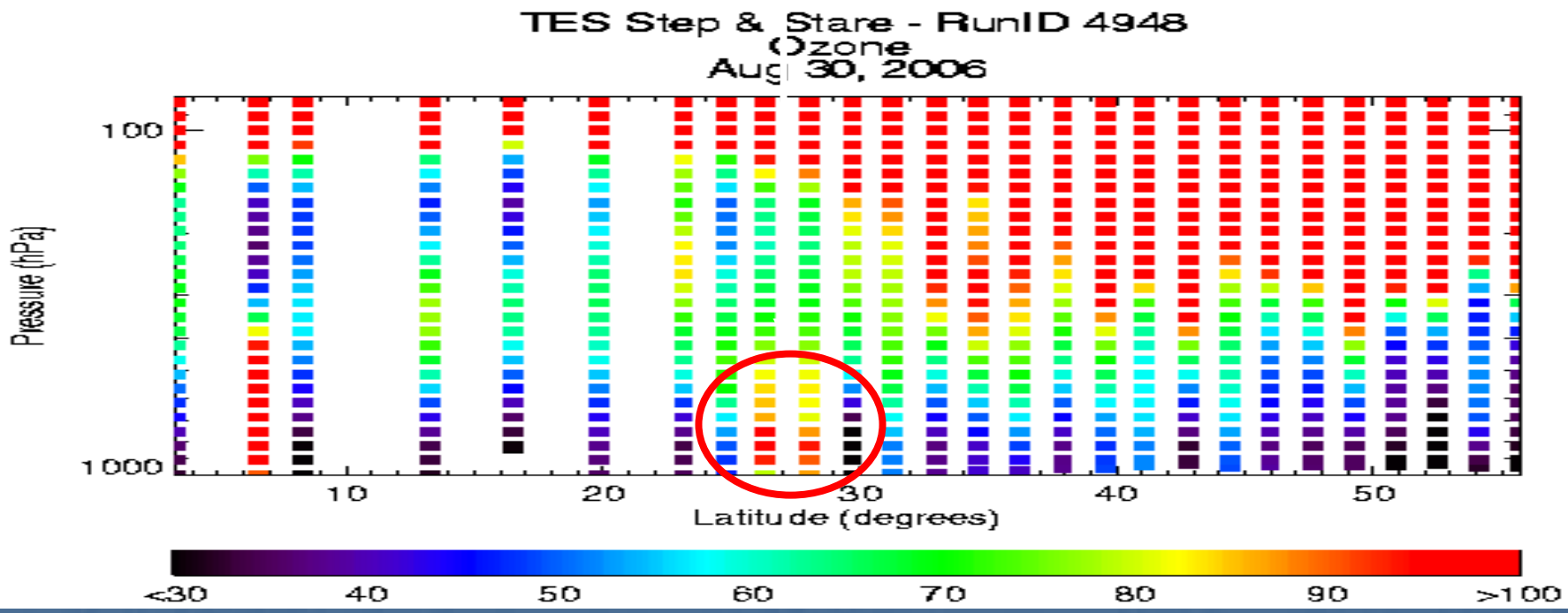

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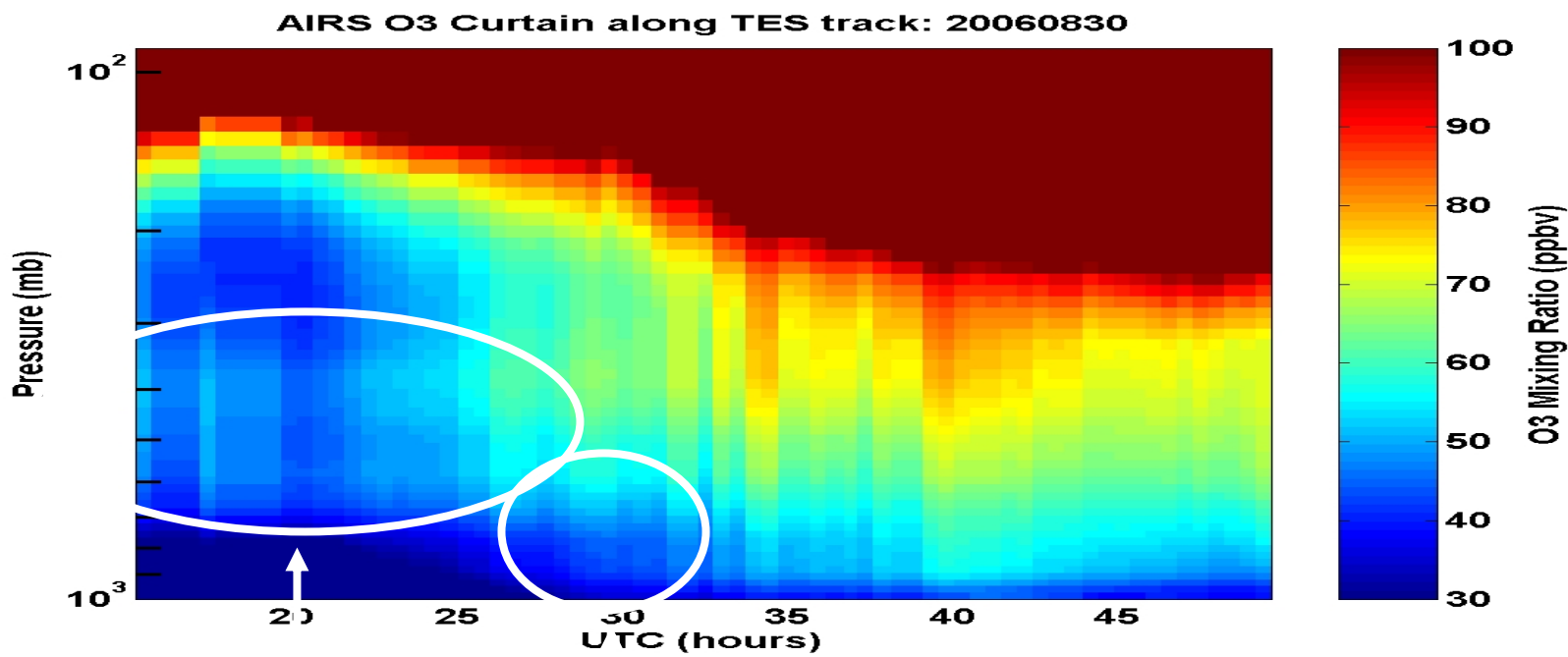

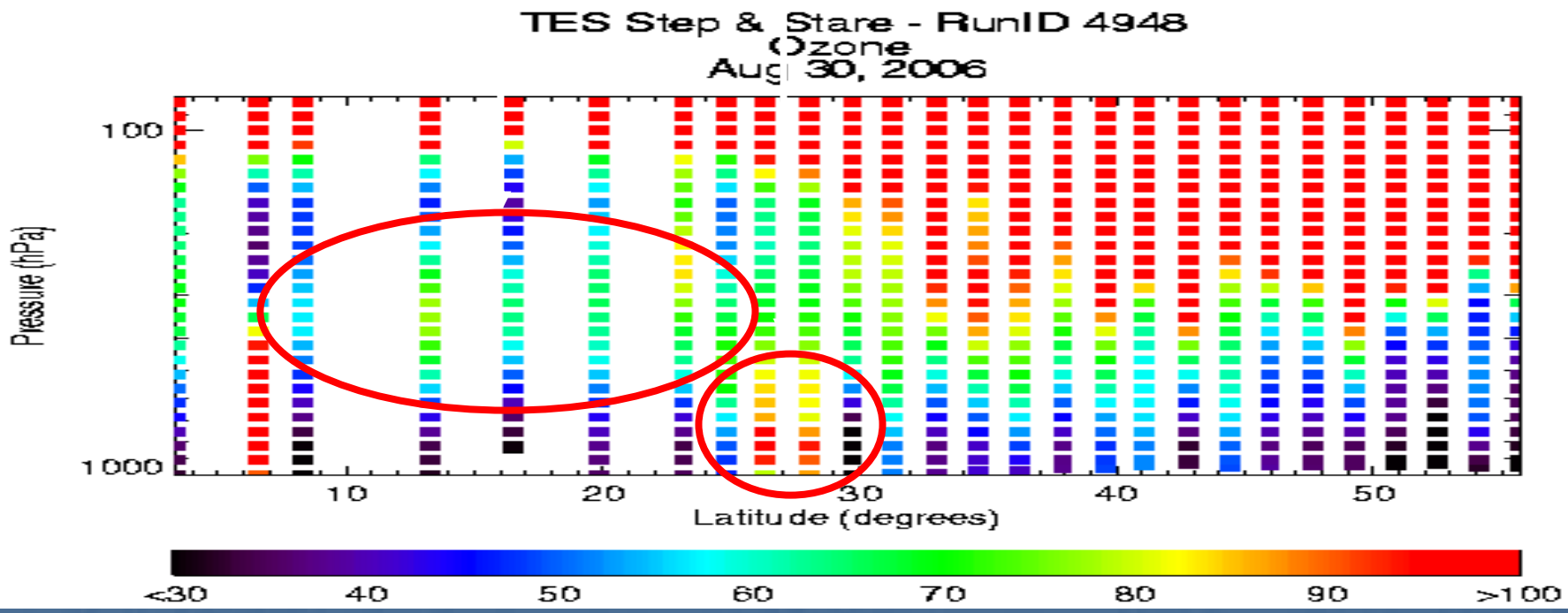

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