



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of
Technology

Tropospheric Emission Spectrometer
ARCTAS-CA Preliminary Data
Analysis Meeting - June 30, 2009

Case study during Northern California Wildfires of June 2008 using TES data and RAQMS model results

Greg Osterman Gregory.Osterman@jpl.nasa.gov
Jet Propulsion Laboratory/California Institute of Technology

Brad Pierce

NOAA/NESDIS

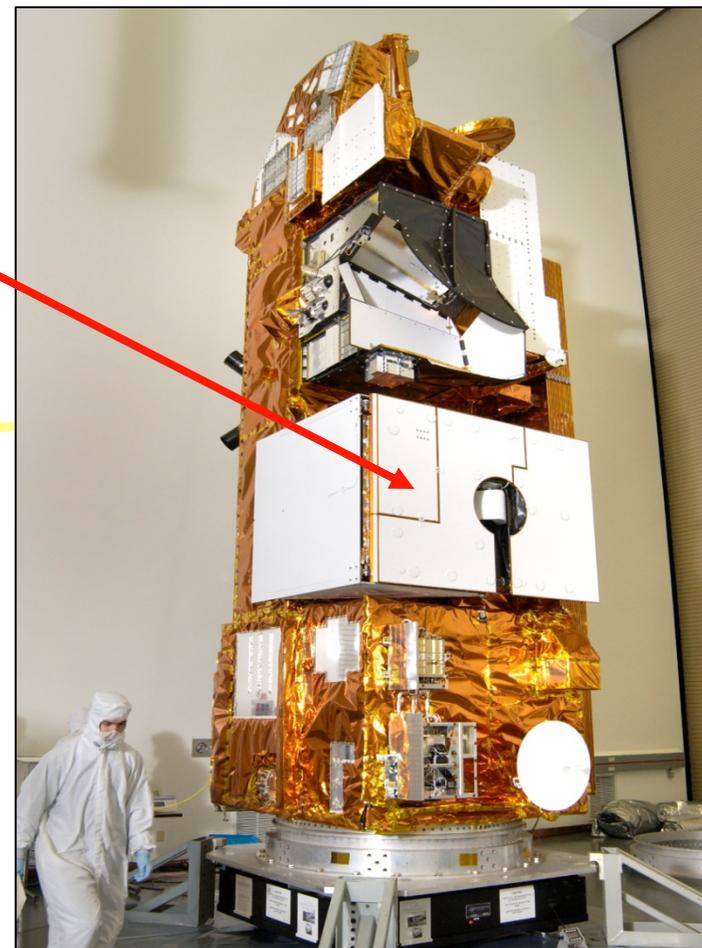
Acknowledgments: DC-8/ARCTAS-CA, ARC-IONS, NOAA/NESDIS, NASA-Langley,
ARB, JPL/TES Collaborators

Tropospheric Emission Spectrometer

TES on EOS-Aura



Launched 2004.07.15

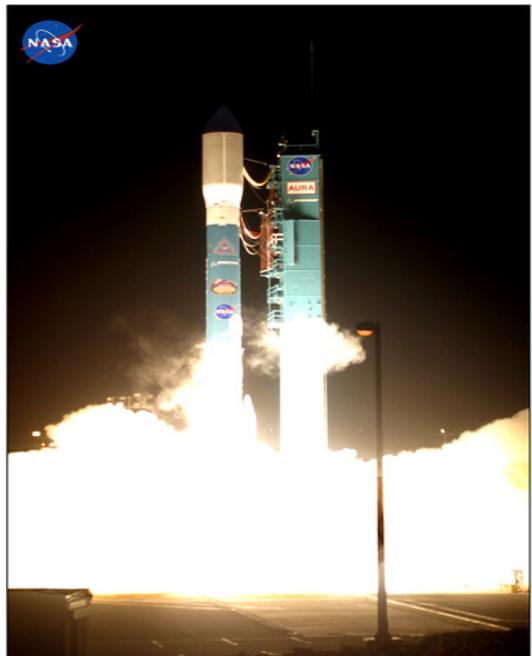


Goleta Air & Space Museum
www.Air-and-Space.com
©2004, Brian Lockett



Tropospheric Emission Spectrometer

TES on EOS-Aura

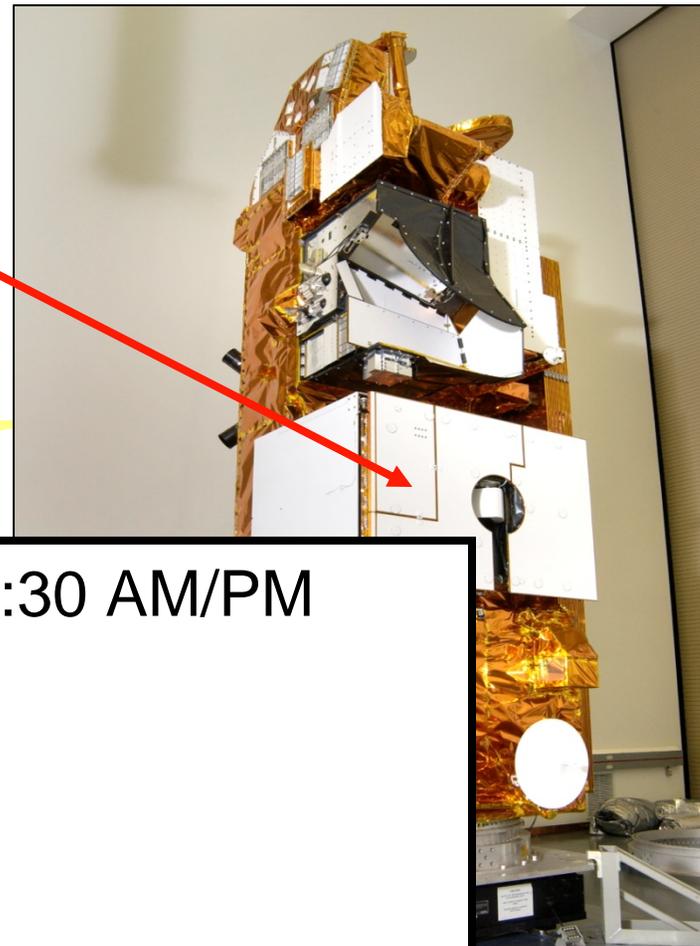


Aura Launch : July 15, 2004
Vandenberg Air Force Base, CA

EOS



Launched 2004.07.15



TES Measures in Nadir Mode (~01:30 AM/PM Local Time):

- Ozone
- Carbon Monoxide
- Water Vapor
- Atmospheric Temperature
- Methane
- Surface Temperature (Sea Surface



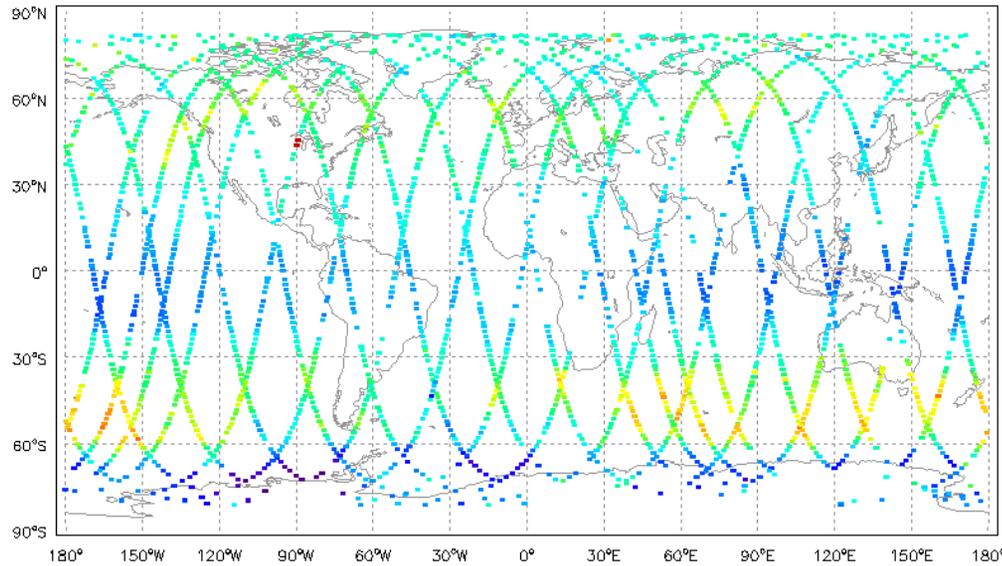


National Aeronautics and Space Administration
 Jet Propulsion Laboratory
 California Institute of Technology

Tropospheric Emission Spectrometer

TES Nadir Coverage

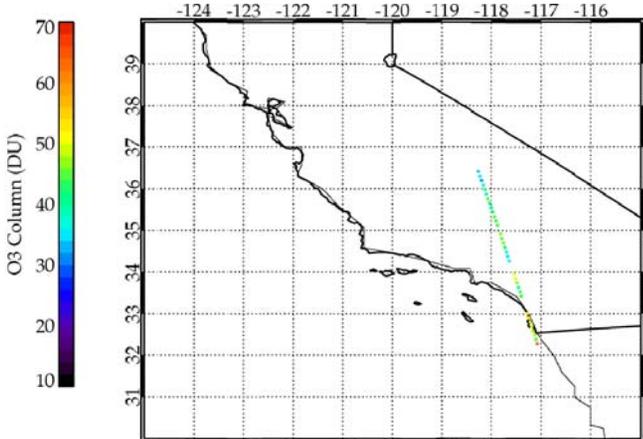
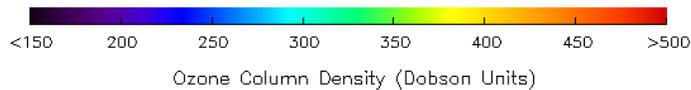
TES Nadir Retrieval: Ozone, Run = 6044, Total Column Density (DU)
 Total Num of Obs = 3318, Num of Valid Retrieval = 2572, Min Val = 182.0 DU, Max Val = 632.1 DU



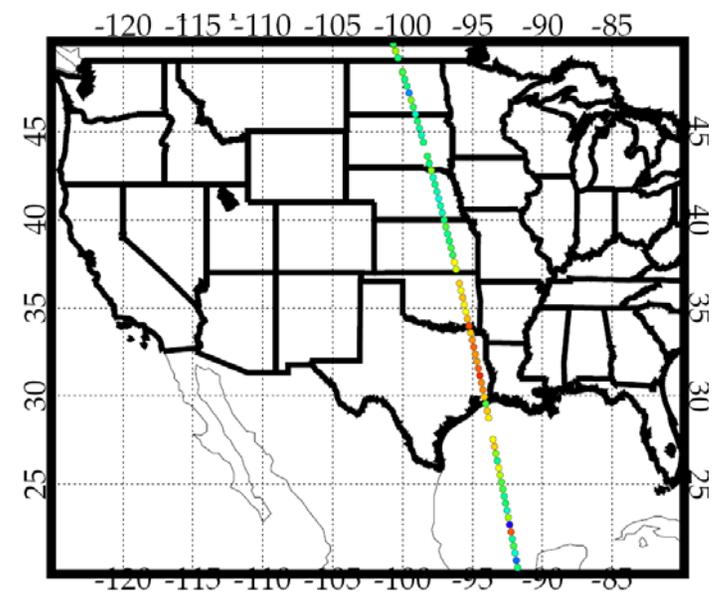
TES Footprint 5 x 8 km

Global Survey footprints
 180 km apart
 Every 2 days... ~767 and counting

Step & Stare footprints
 45 km apart
 Special observation



Transect footprints
 12 km apart
 Special observation



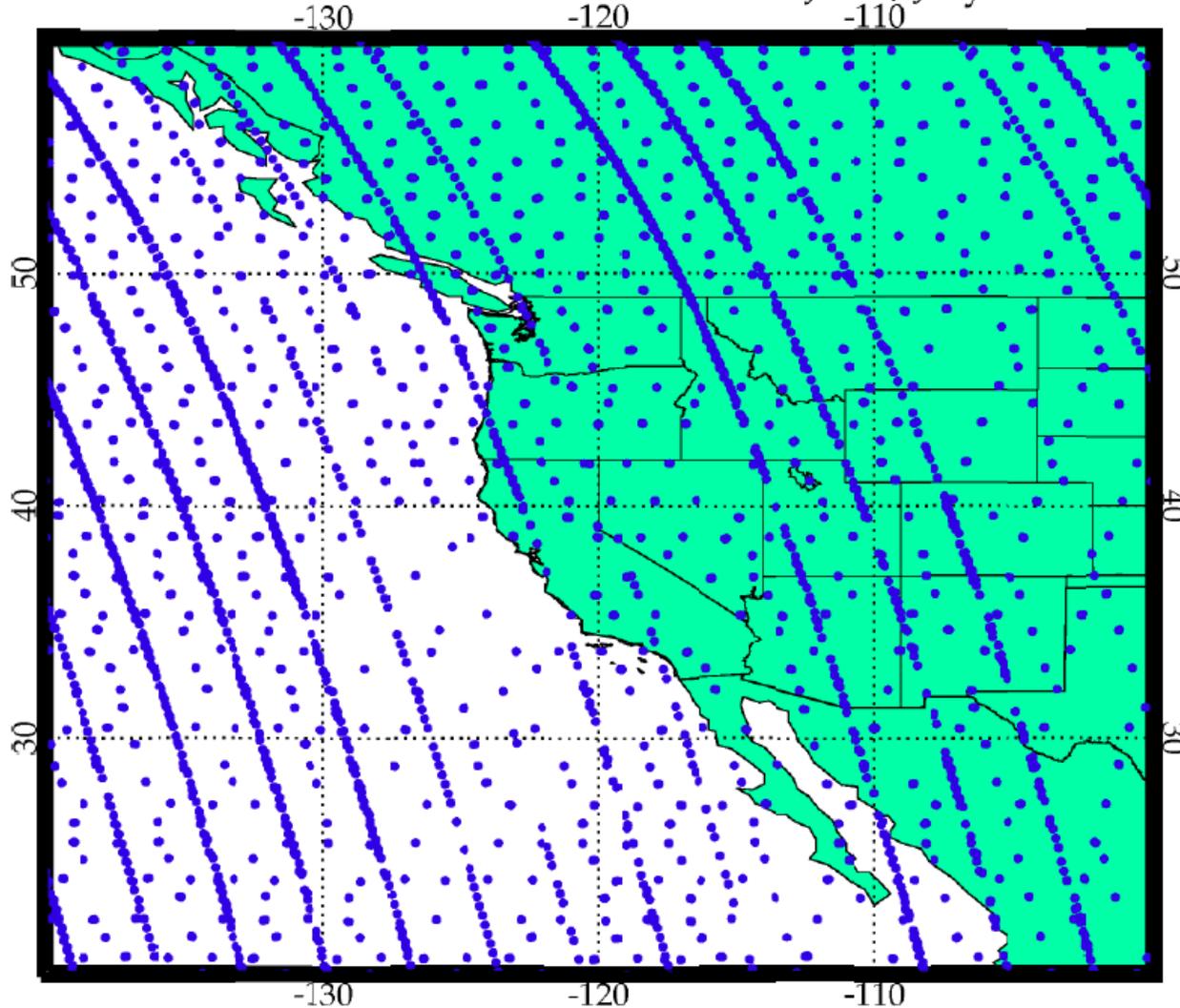


National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of
Technology

Tropospheric Emission Spectrometer

TES Coverage for June & July 2008

Western US Measurement Locations: June/July 2008





Case Study – June 2008 CA Wildfires

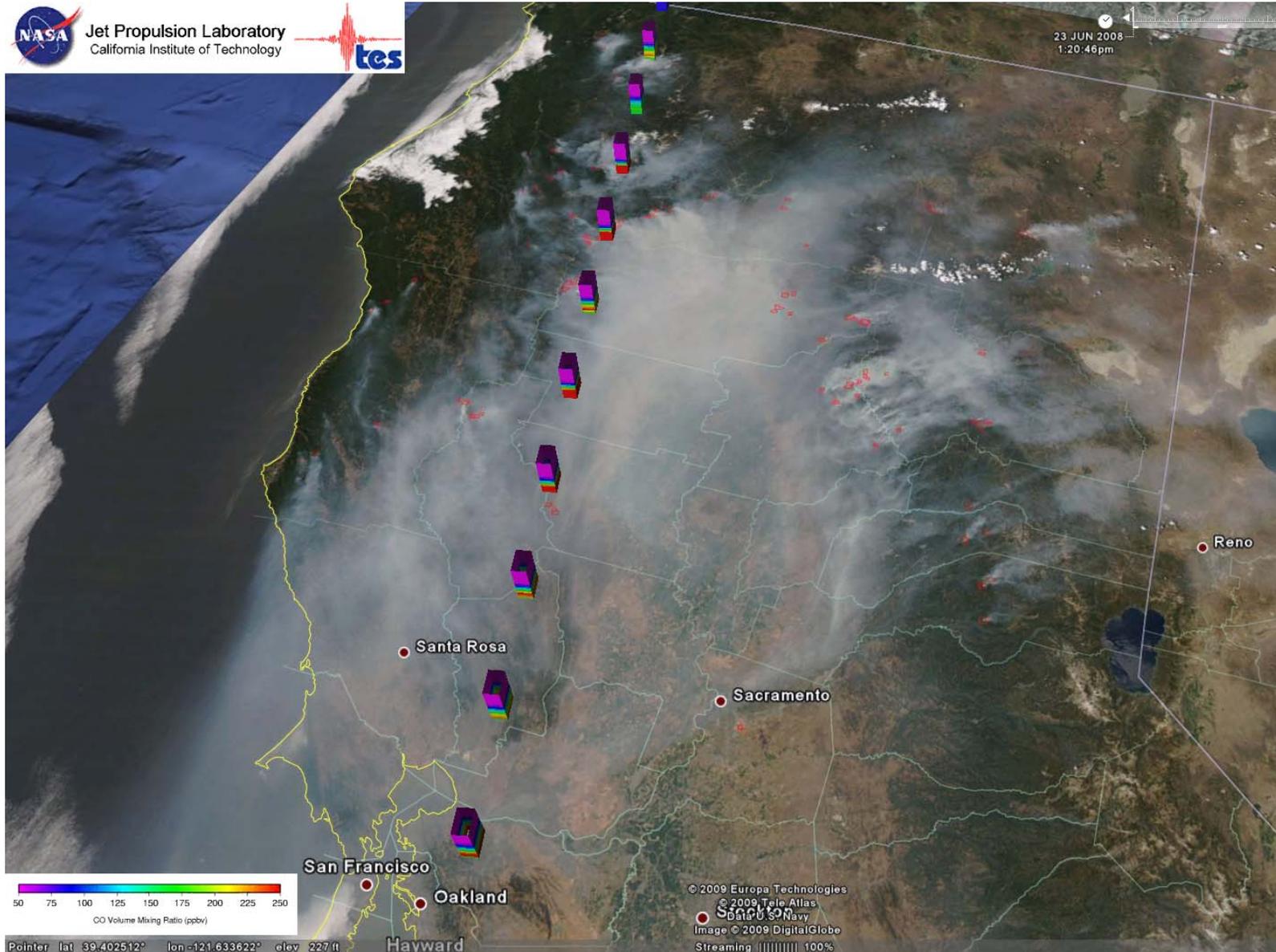
- Particularly dry conditions in Northern/Central CA in 2008
 - Major fires started on May 22, June 6
 - Dry low pressure system moved through on June 20-21 producing lightning that sparked fires
 - Fires burned into August 2008 – 800,000 acres burned
- TES Special Observation caught plume of high CO from CA wildfires on June 23, 2008
 - TES may have sampled plume again on way back into Canada
- DC-8 flew over fires on June 22, 2008
- Ozonesonde data from Trinidad Head, CA
- CALIPSO, AIRS, MODIS
- RAQMS, WRF-Chem
- **Goals:**
 - Study transport and evolution of the CA wildfire plumes
 - Effects of wildfires on CA air quality (Stiller et al., 2008)
 - Analysis similar to those in Pierce et al., 2008, McMillan et al. (under review), Verma et al., 2008



National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Tropospheric Emission Spectrometer

June 23: TES CO, MODIS Image

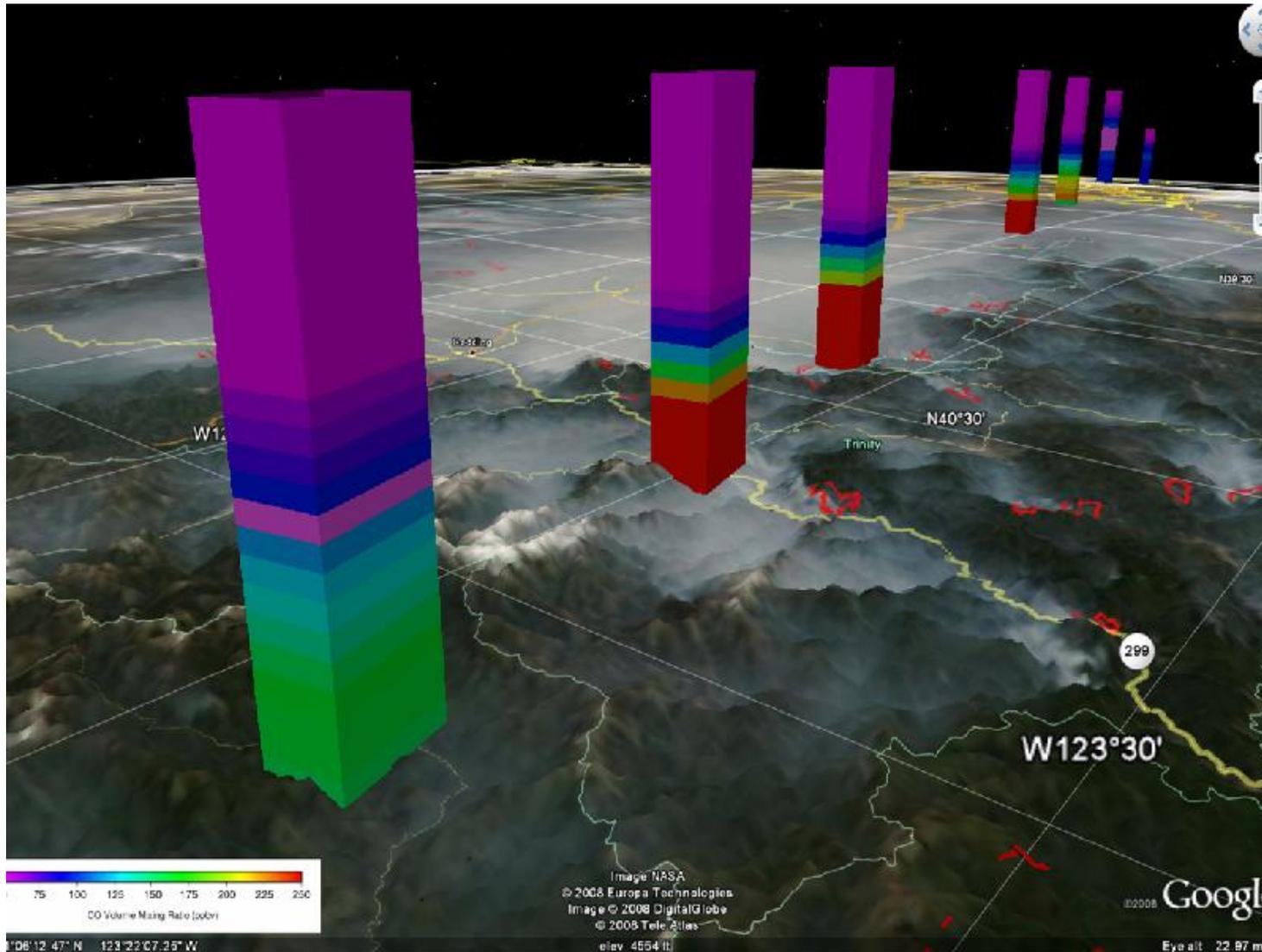


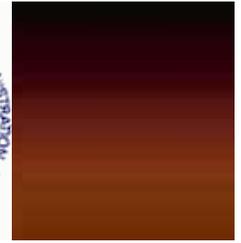
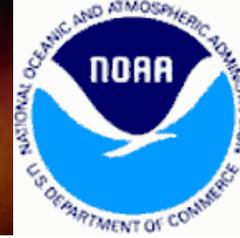


National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Tropospheric Emission Spectrometer

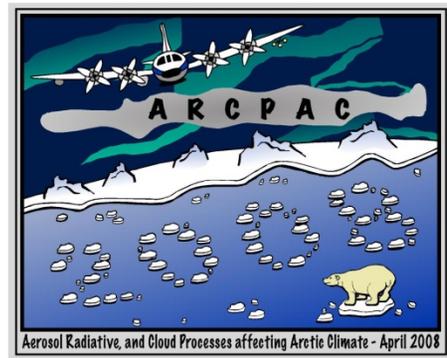
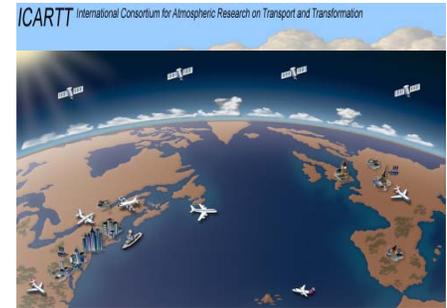
June 23: TES CO, MODIS Image





Real-time Air Quality Modeling System (RAQMS)

- 1) Online global chemical and aerosol assimilation/forecasting system
- 2) University of Wisconsin sigma-theta hybrid coordinate model (UW-Hybrid) dynamical core
- 3) Unified stratosphere/troposphere chemical prediction scheme (LaRC-Combo) developed at NASA LaRC
- 4) Aerosol prediction scheme (GOCART) developed by Mian Chin (NASA GSFC).
- 5) Statistical Digital Filter assimilation system developed by James Stobie (NASA/GSFC)

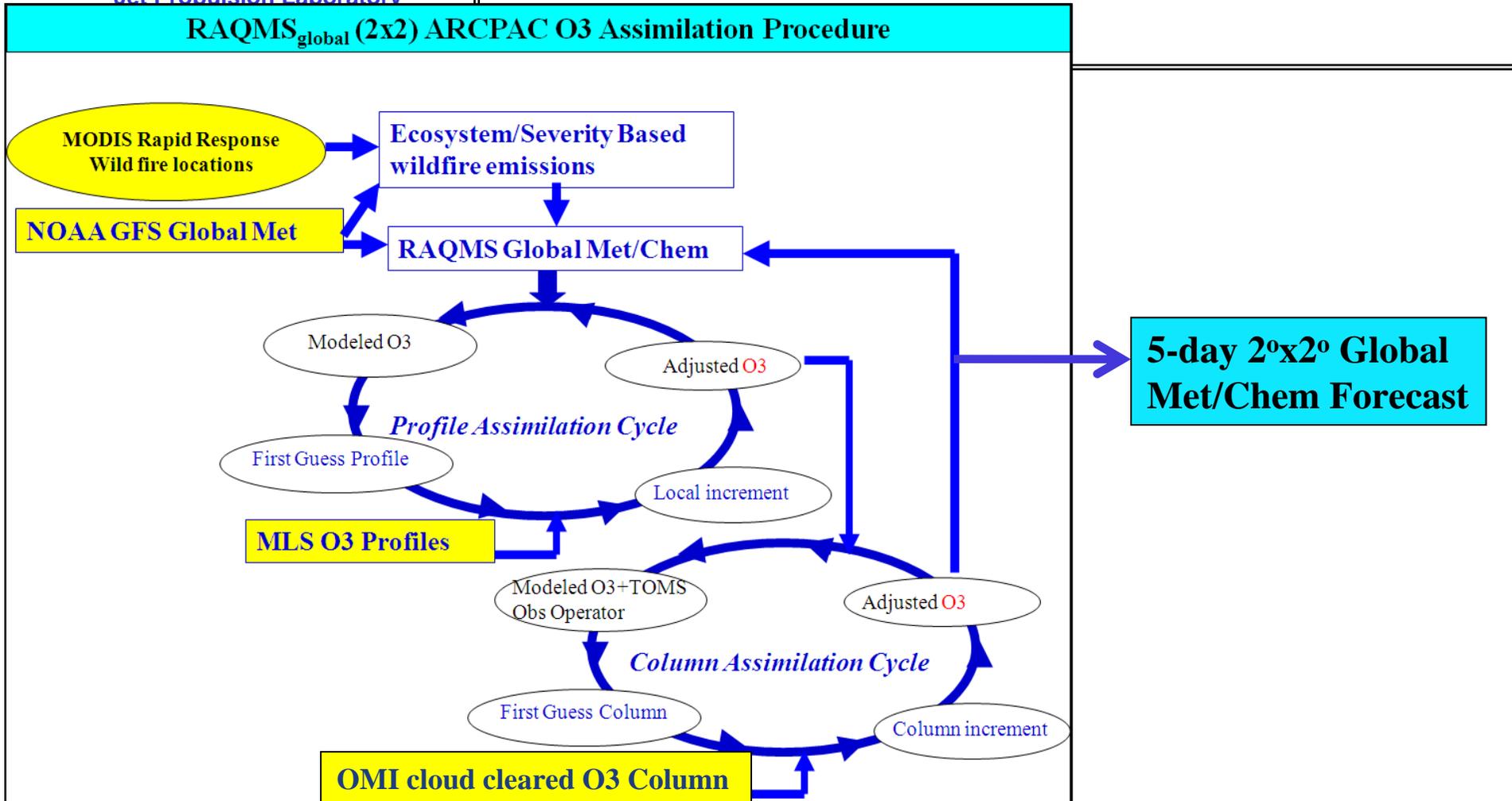


RAQMS has been used to support airborne field missions [Pierce et al, 2003, 2007, 2008], develop capabilities for assimilating satellite trace gas and aerosol retrievals [Fishman et al., 2008, Sunita et al., 2008] and assess the impact of global chemical analyses on regional air quality predictions [Song et al., 2008, Tang et al., 2008]

Will focus on results from the June 2008 NASA/CARB ARCTAS-CA field mission



Tropospheric Emission Spectrometer RAQMS Real-time O₃ Assimilation/Prediction



2x2 degree Global online strat/trop chemistry

Aerosol/photolysis feedback

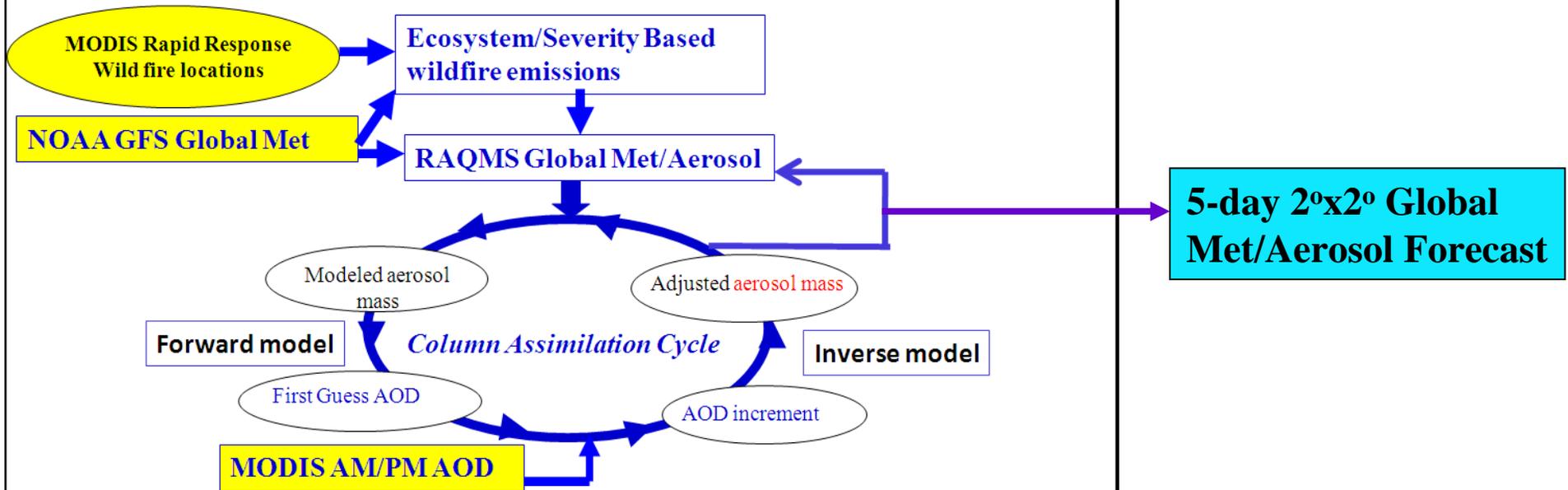
Statistical Digital Filter (SDF) univariate OI assimilation



National Aeronautics and Space Administration
 Jet Propulsion Laboratory
 California Institute of Technology

Tropospheric Emission Spectrometer RAQMS Real-time Aerosol Optical Depth (AOD) Assimilation/Prediction

RAQMS_{global} (2x2) ARCPAC AOD Assimilation Procedure



Forward model:

Compute layer/species extinction based on tabulated extinction coeff and hygroscopic growth Factors

Inverse model:

Distribute total AOD increment across aerosol dry mass based on layer/species extinction accounting for extinction due to hygroscopic growth

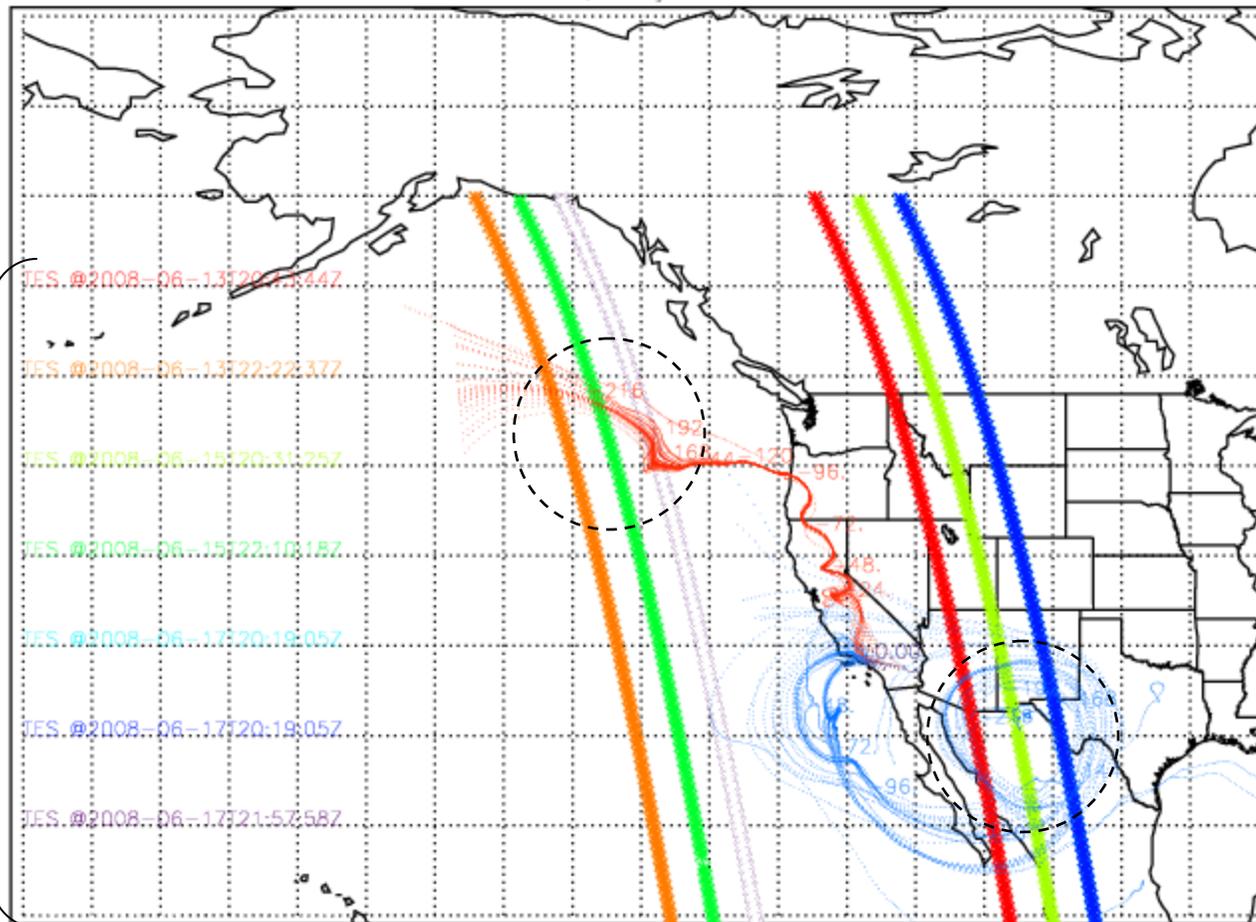
**2x2 degree Global online aerosol (GOCART)
 Statistical Digital Filter (SDF) univariate OI assimilation
 applied to SO₄, Dust, BC, OC (not Sea Salt)**



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of
Te

Tropospheric Emission Spectrometer Lagrangian estimates of background chemistry Los Angeles Basin, CA June 22, 2008

SFC (Red)/850 (Blue) 5-day Backtrajectories
Initialized 2008062200, Los Angeles Basin CA AIRNOW Sites



Near coincident
TES Step&Stare
Observations

RAQMS chemical analyses are used to provide estimates of background composition along ensemble back trajectories that are initialized from surface ozone monitoring stations within the Los Angeles Basin [ala Pierce et al., submitted to TEXAQS Special Issue, 2008]



SFC Lagrangian Evolution

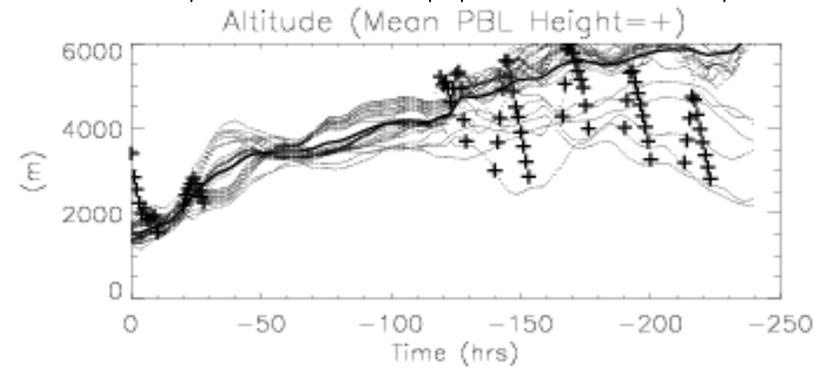
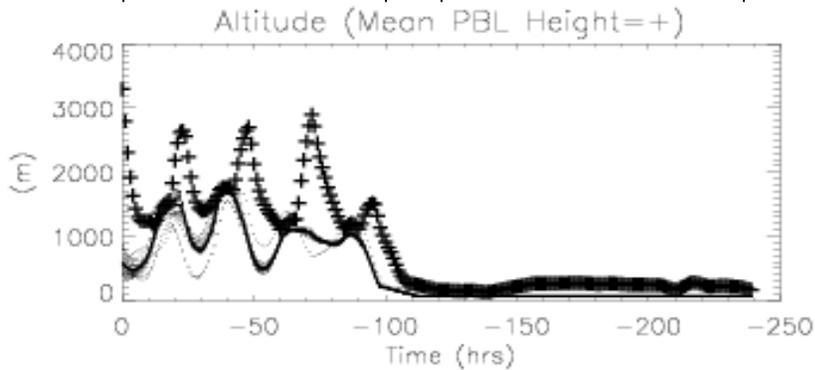
850mb Lagrangian Evolution

Continental BL

Marine BL

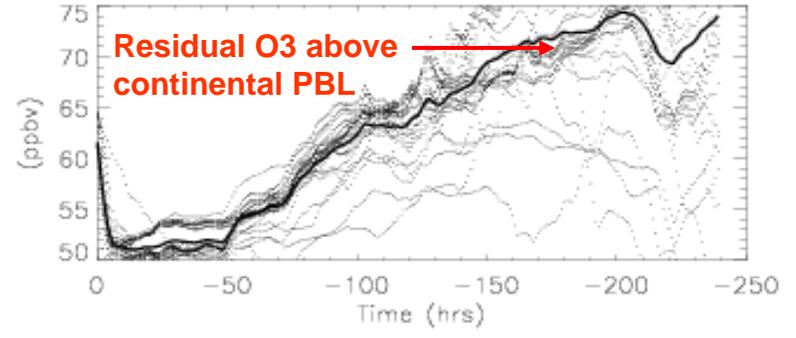
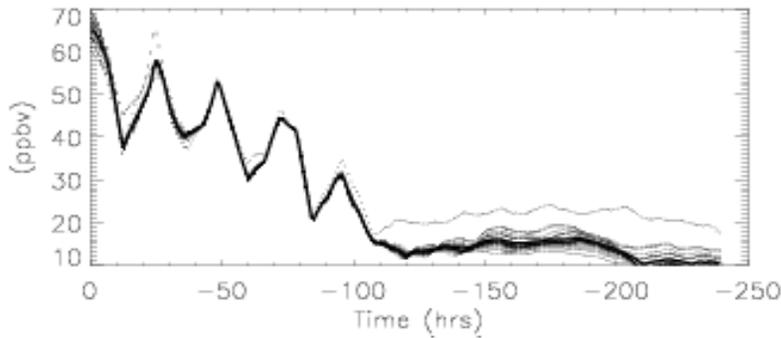
Marine FT

Continental BL/FT



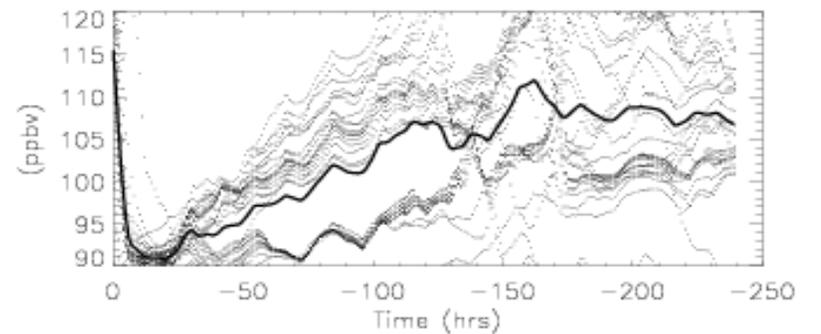
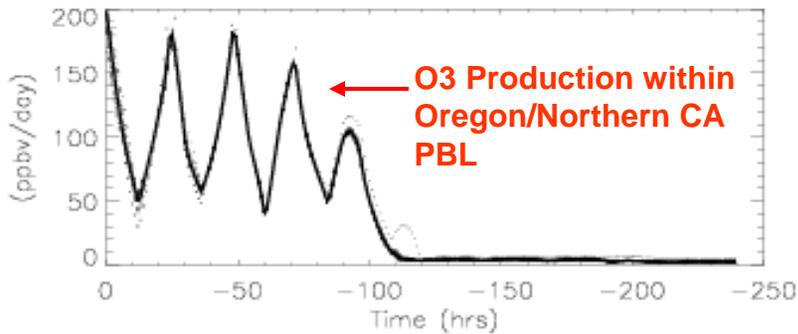
O₃

O₃



O₃ P-L

CO

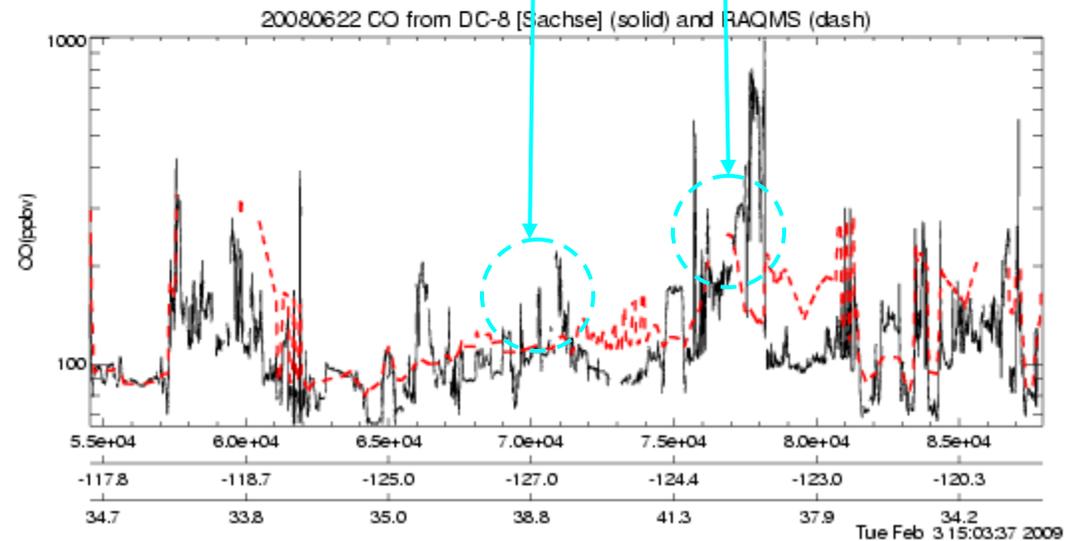
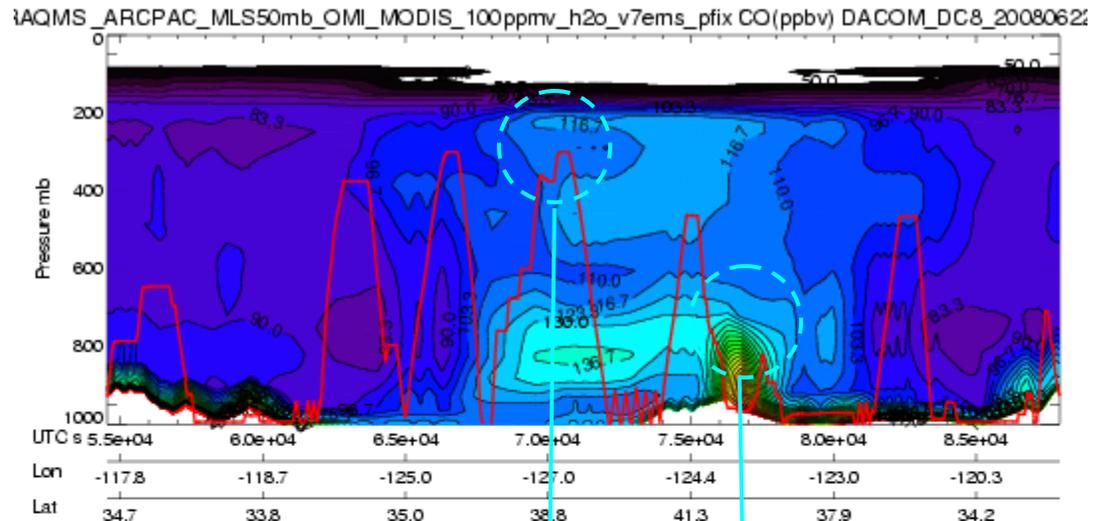
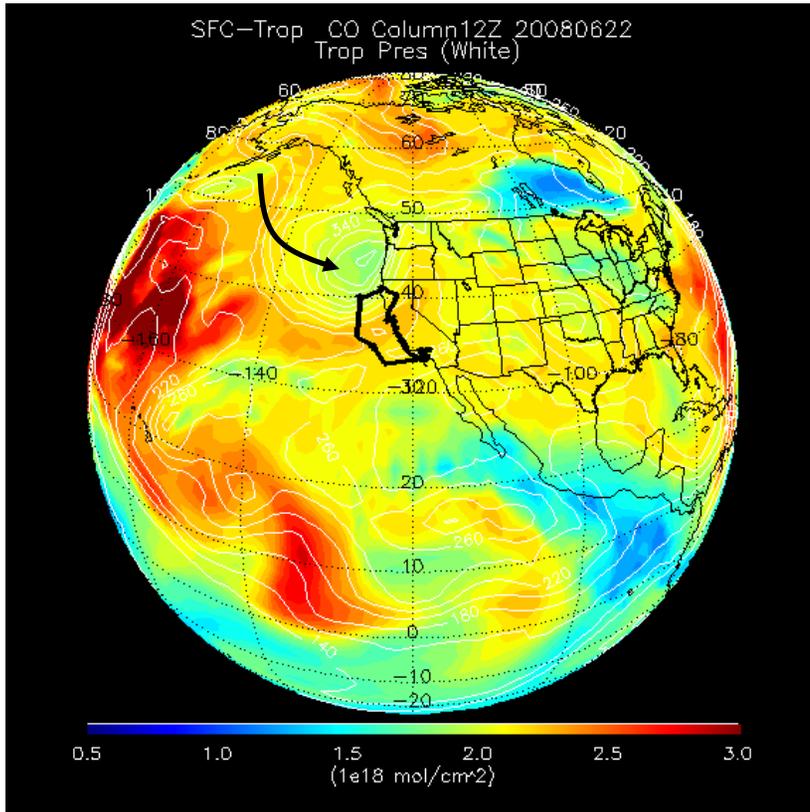




National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Tropospheric Emission Spectrometer

RAQMS vs DC8 CO Measurements ARCTAS-CA Flight 20080622



- RAQMS analysis captures large scale lower tropospheric CO enhancements observed by the DC8.
- RAQMS underestimates CO mixing ratios associated with wildfire plume

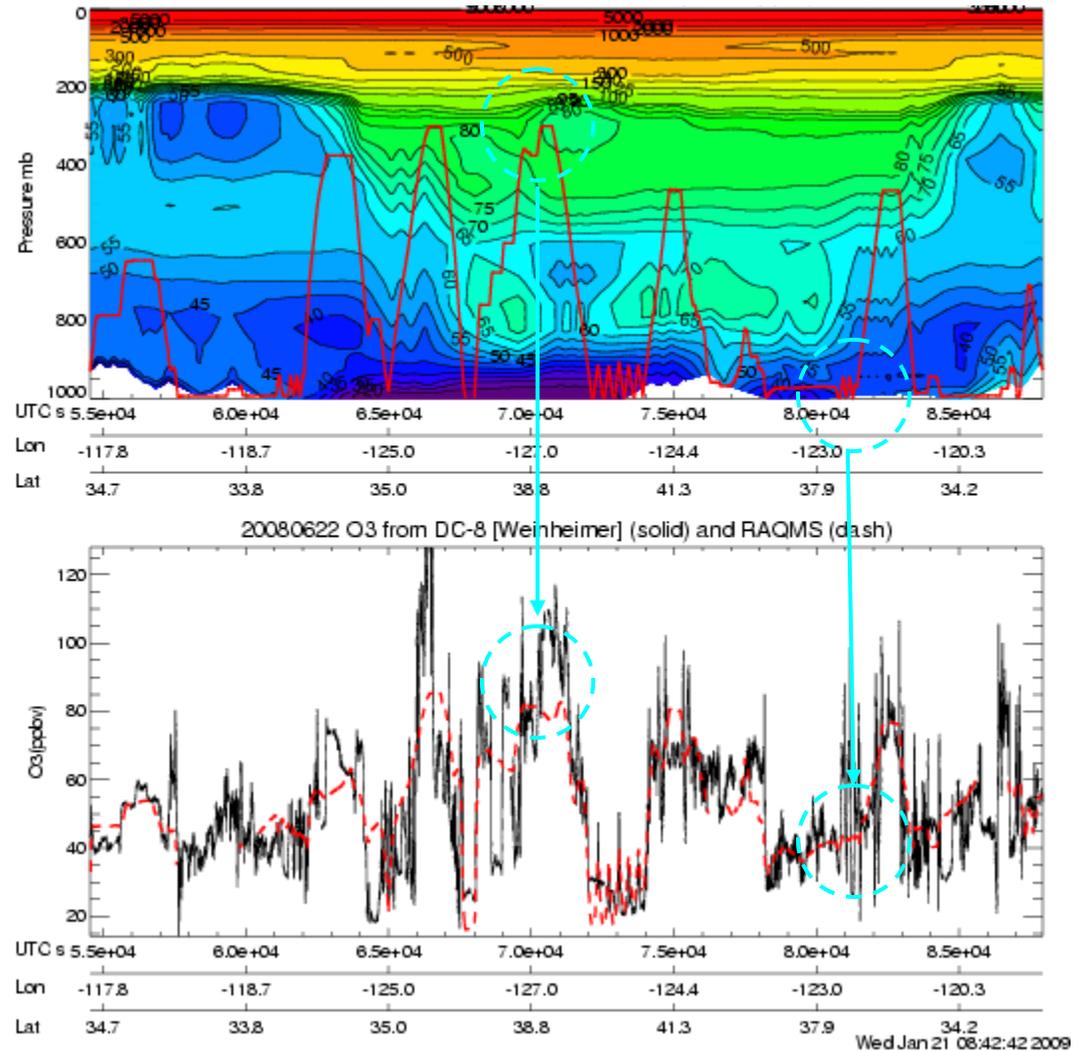
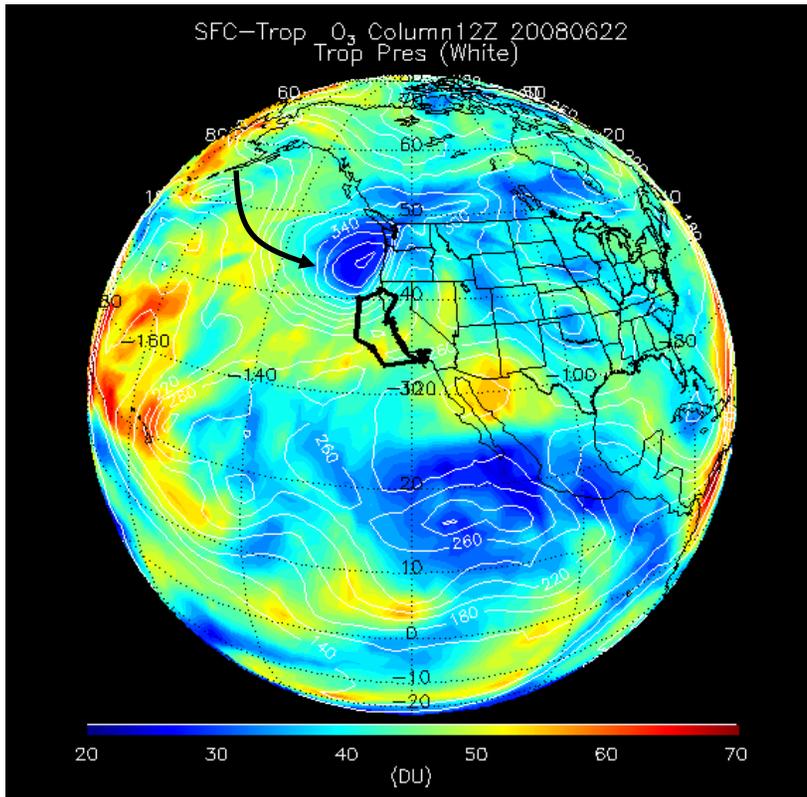
In situ data provided by G. Diskin (NASA/LaRC)



National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Tropospheric Emission Spectrometer

RAQMS vs DC8 O3 Measurements ARCTAS-CA Flight 20080622



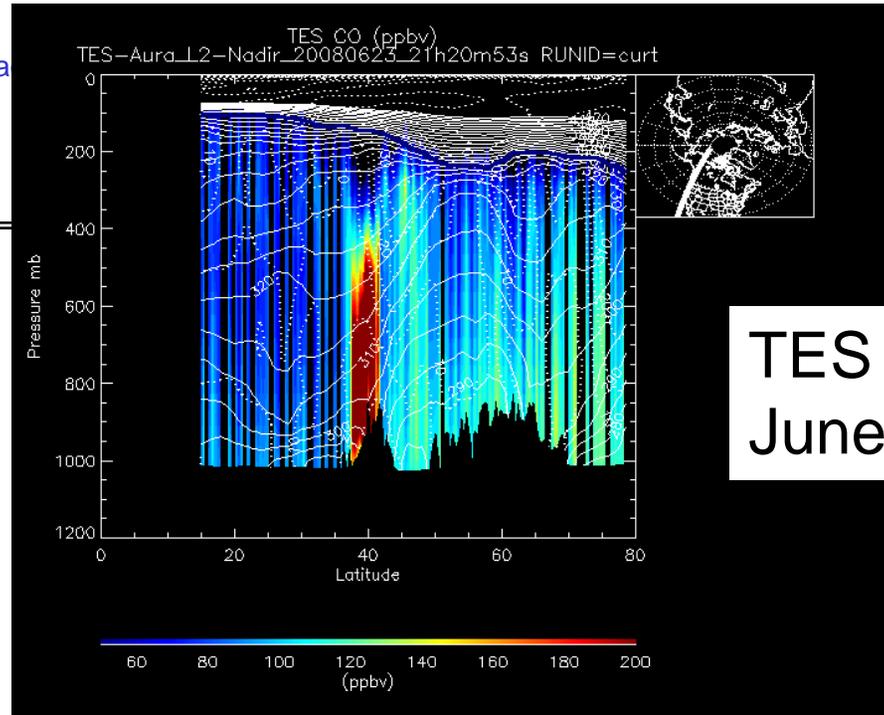
- RAQMS analysis captures large scale upper tropospheric ozone enhancements observed by the DC8.
- RAQMS does not resolve fine scale structure within the PBL

In situ data provided by A. Weinheimer (NCAR)

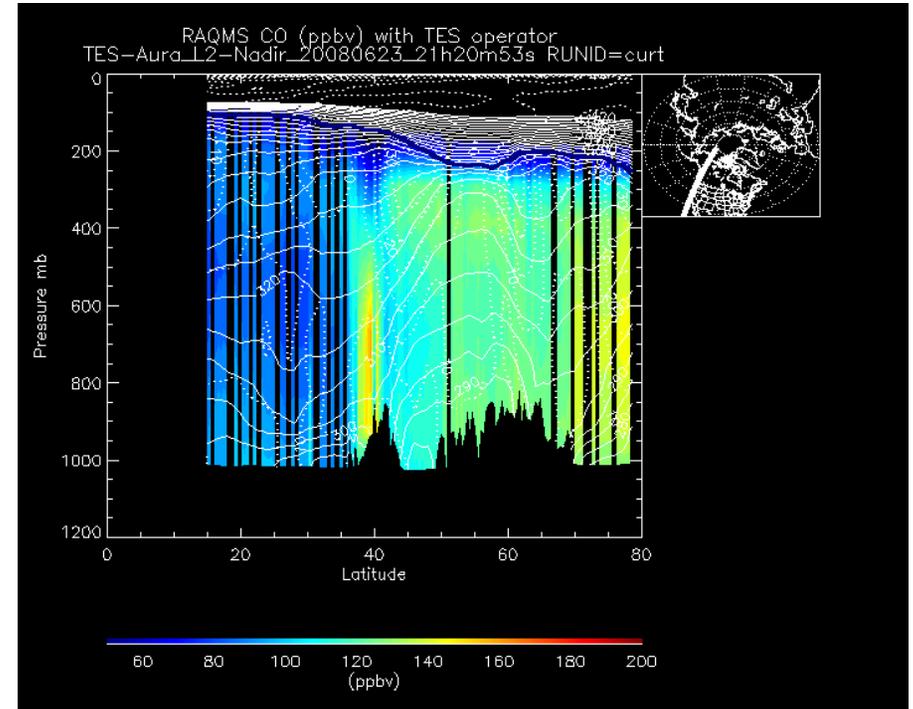
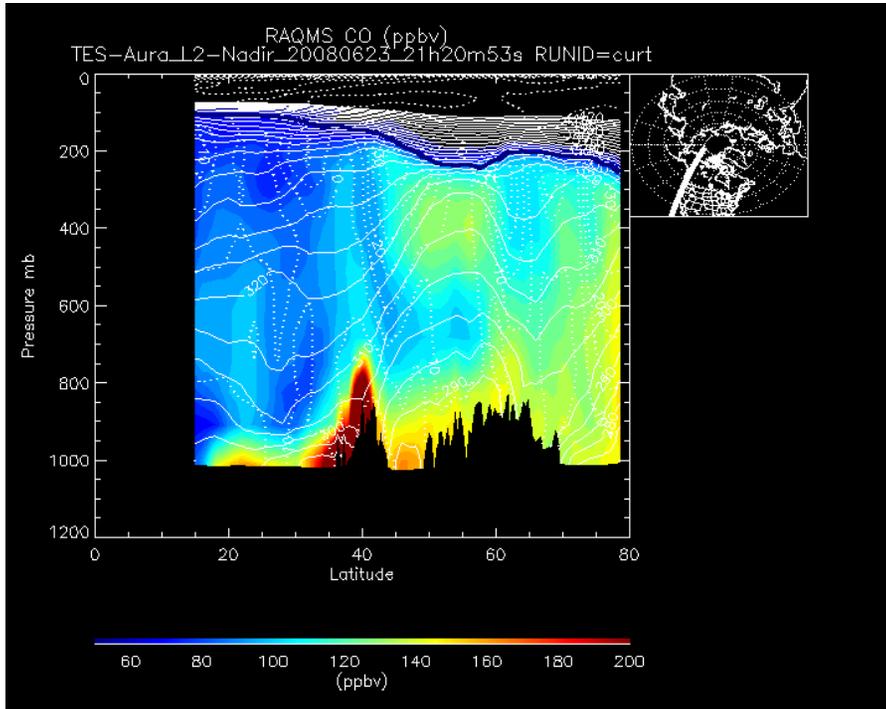


National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Spectrometer



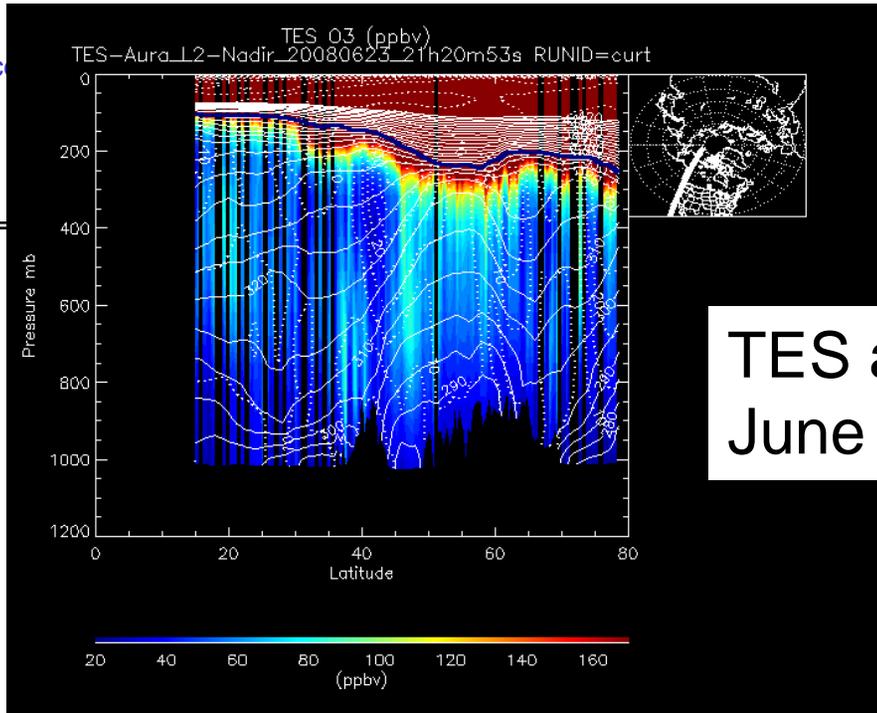
TES and RAQMS CO
June 23, 2008



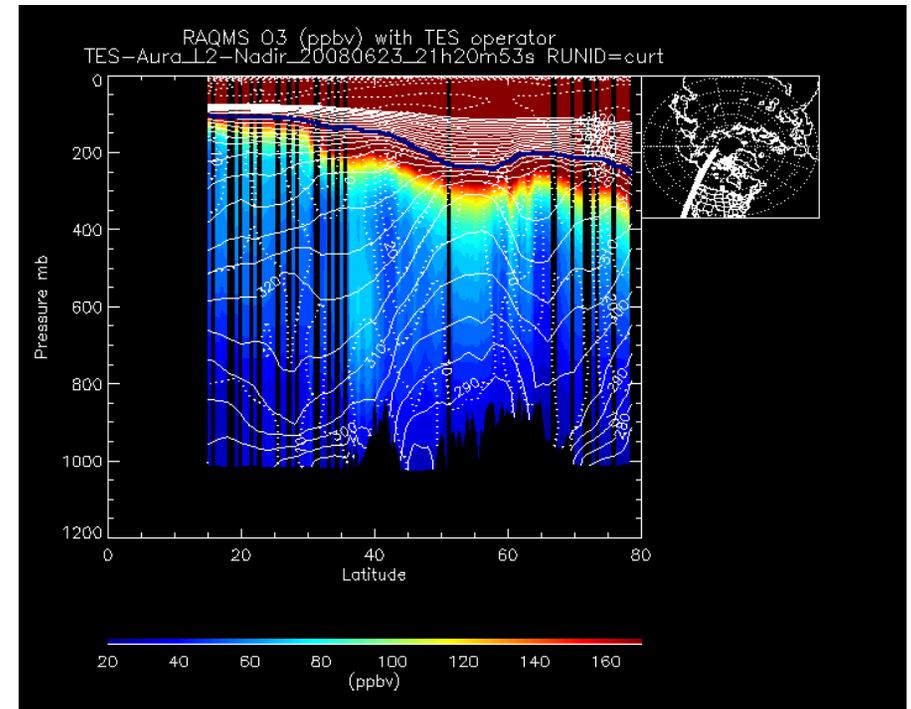
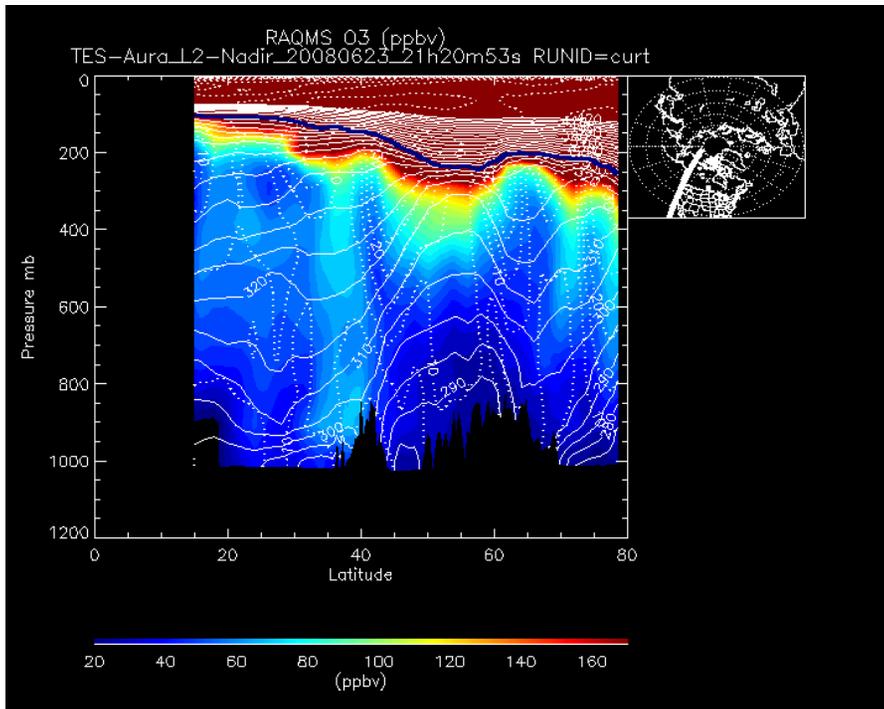


National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Spectrometer



TES and RAQMS O3
June 23, 2008





National Aeronautics and Space Administration
 Jet Propulsion Laboratory
 California Institute of Technology

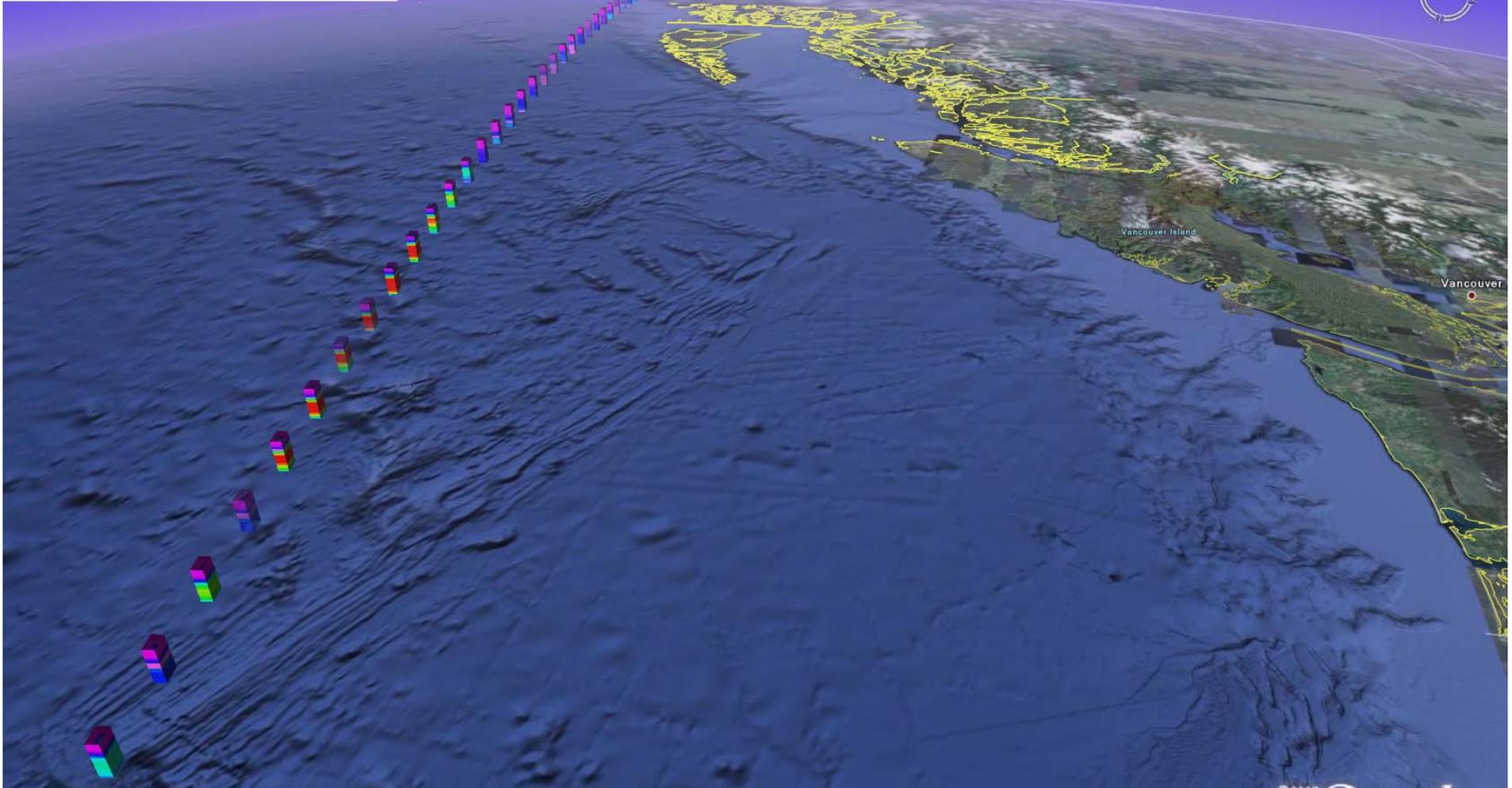
Tropospheric Emission Spectrometer

July 5: TES CO Image



5 JUL 2008 1:45:41pm

5 JUL 2008 2:04:00pm



© 2009 Europa Technologies
 © 2009 Tele Atlas
 Image © 2009 TerraMetrics
 Data SIO, NOAA, U.S. Navy, NGA, GEBCO
 Streaming 100%

© 2007 Google™

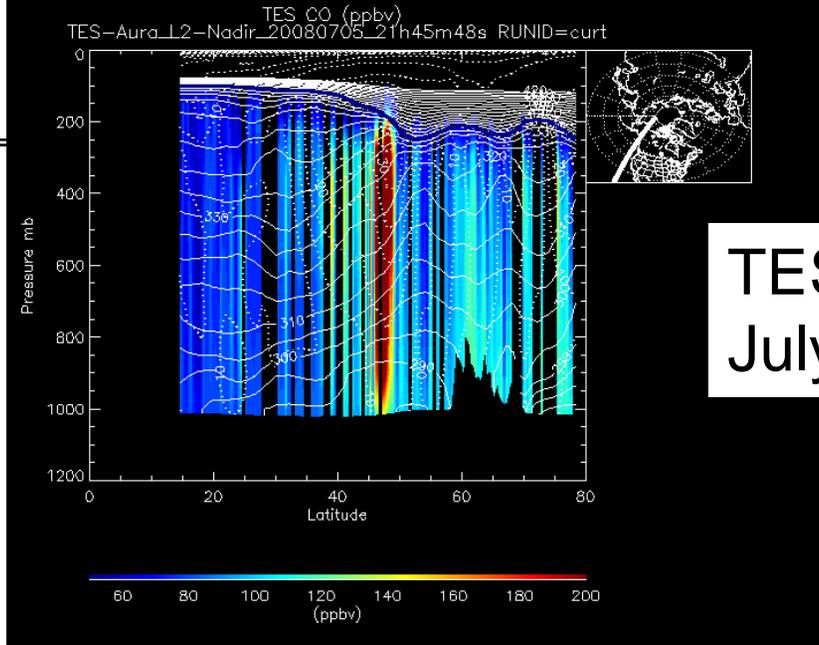
Pointer lat 47.062691° lon -128.436199° elev 0 ft

Eye alt 233.18 mi

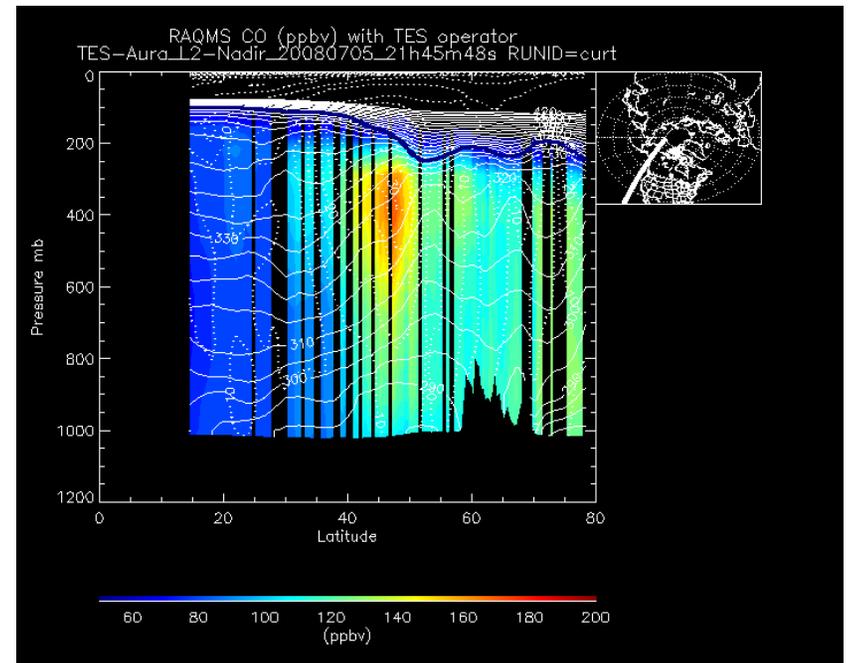
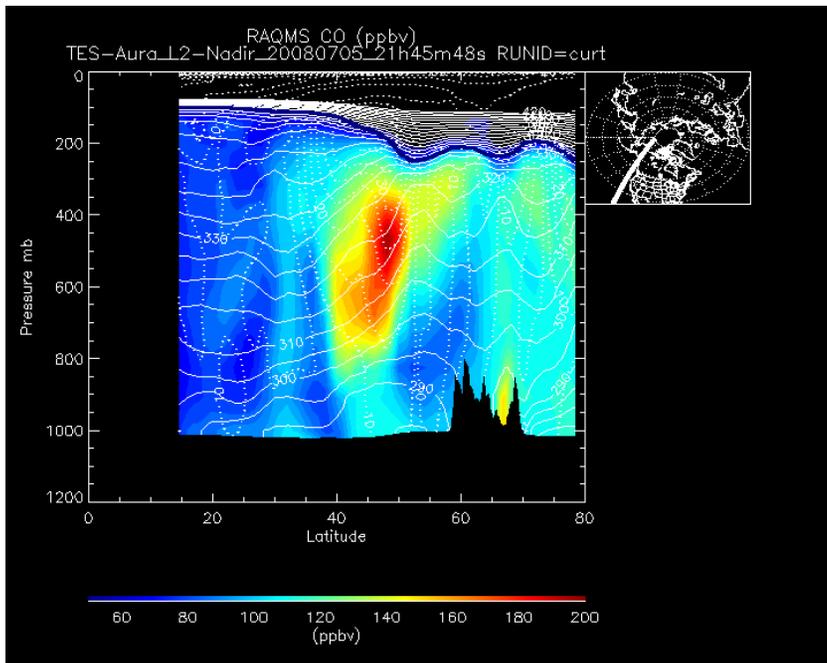


National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of
Technology

Tropospheric Emission Spectrometer



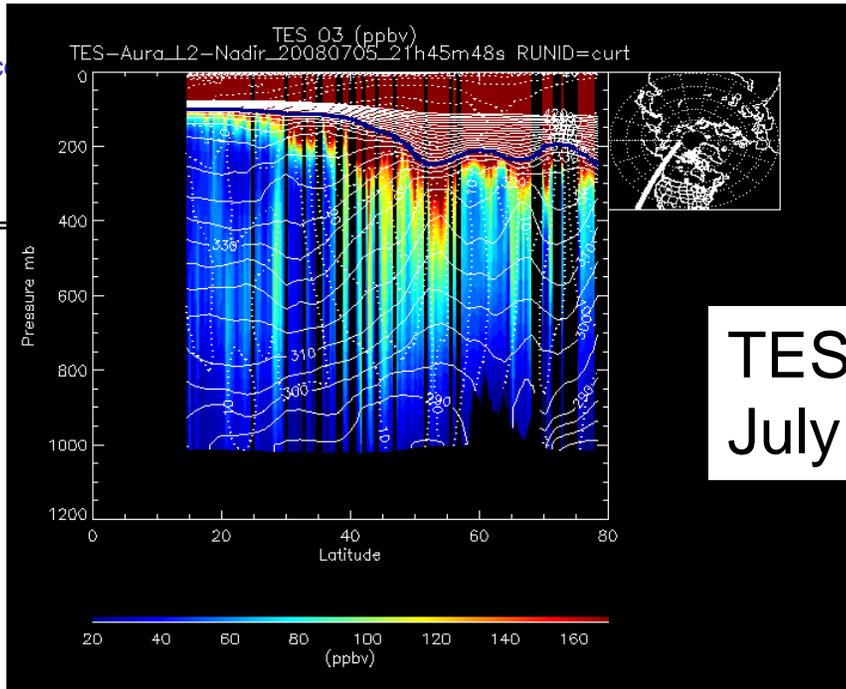
TES and RAQMS CO
July 5, 2008



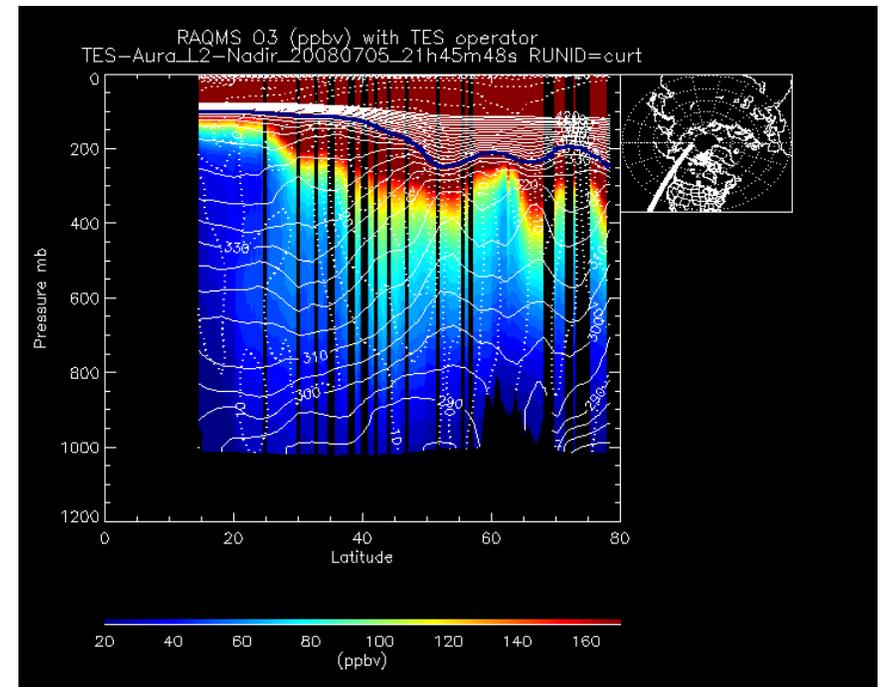
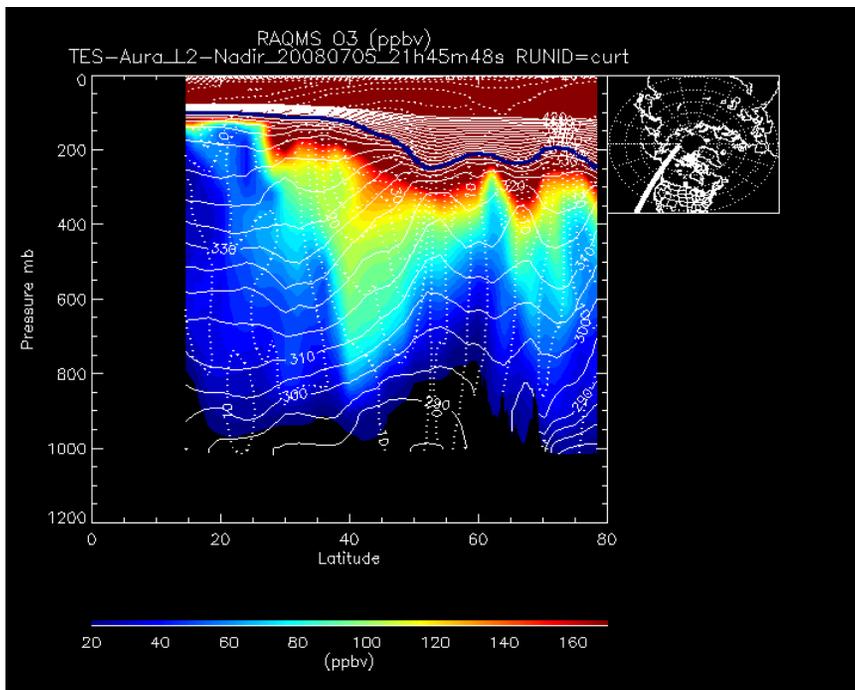


National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

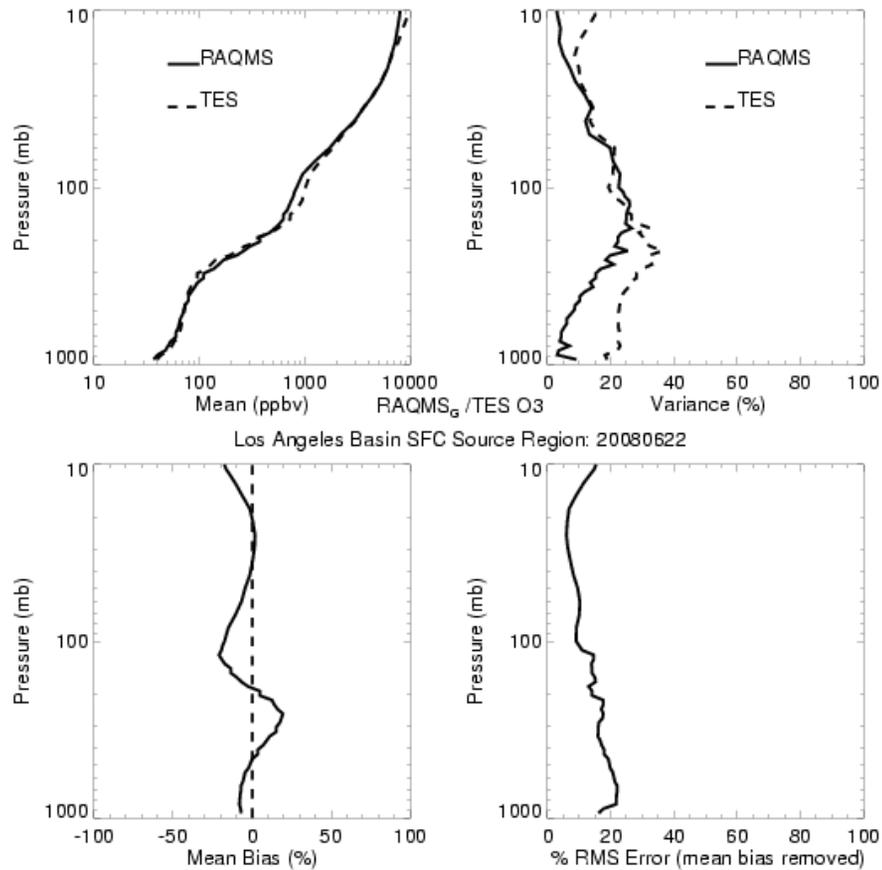
Spectrometer



TES and RAQMS O₃
July 5, 2008

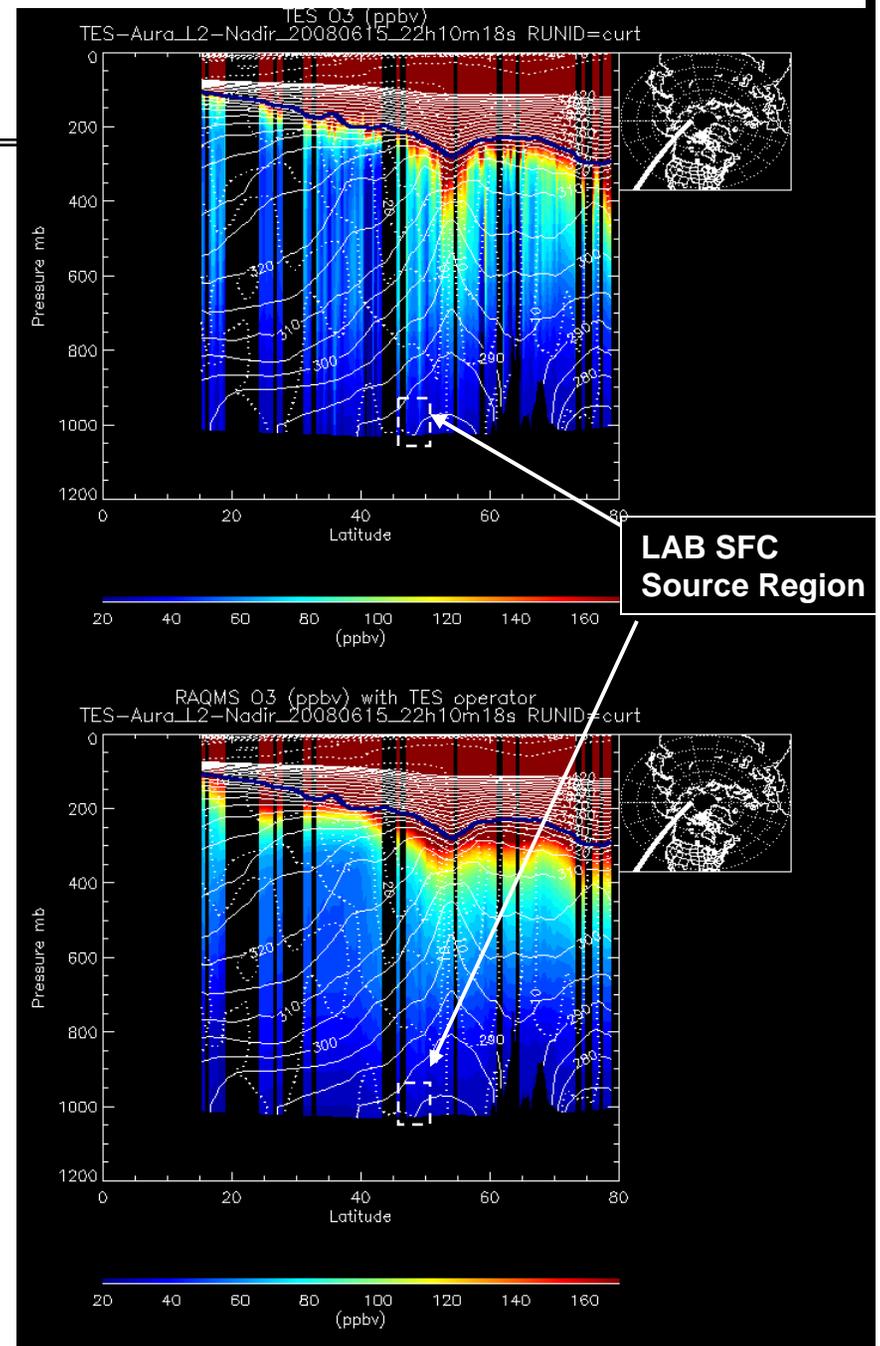


Verification of RAQMS O3 along TES Pacific Step&Stare observations (June 13, 15, 17, 2008)



- RAQMS is in good agreement with TES at LAB SFC Source Region
- TES shows sharper O3 gradients at the tropopause

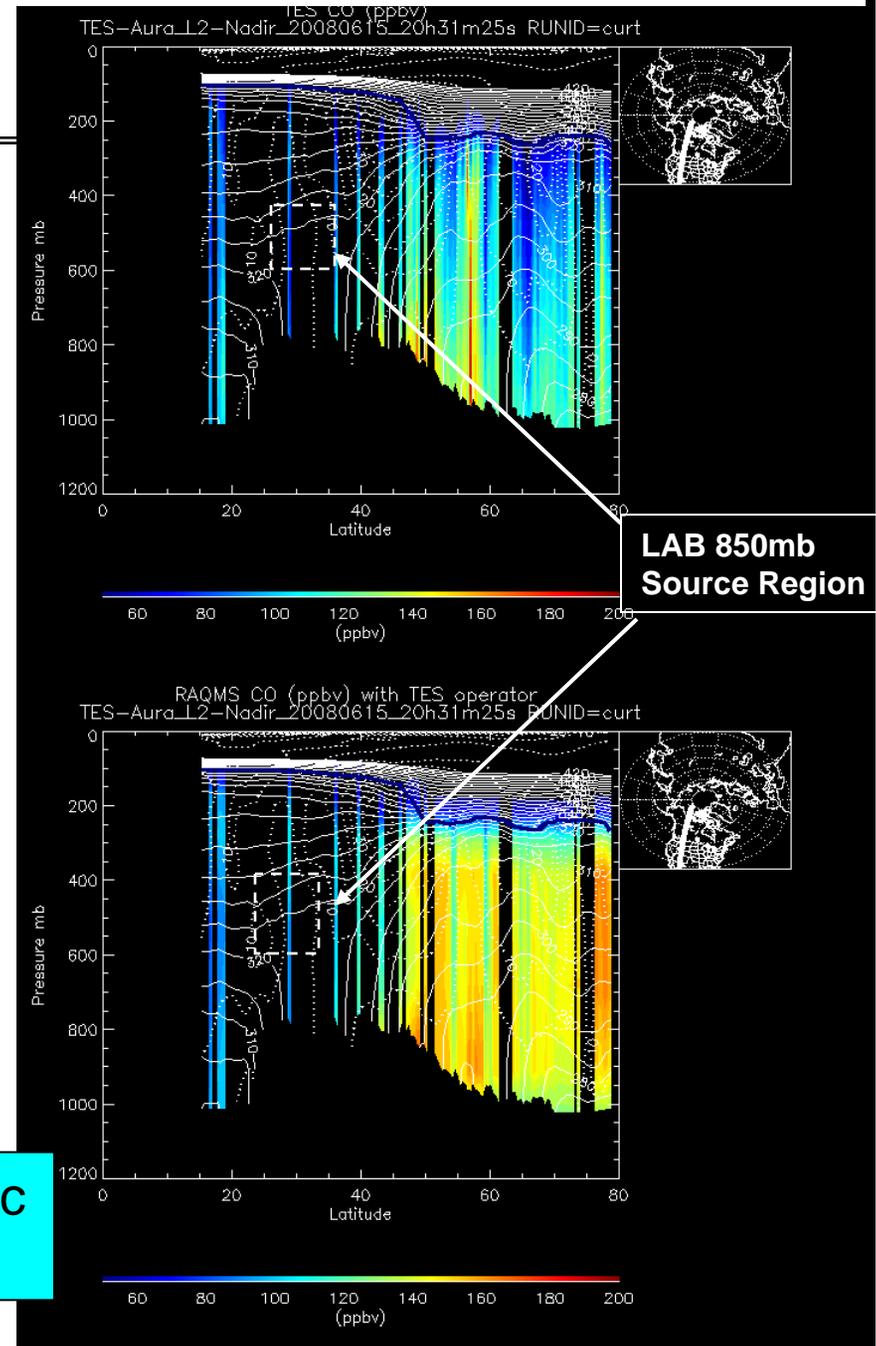
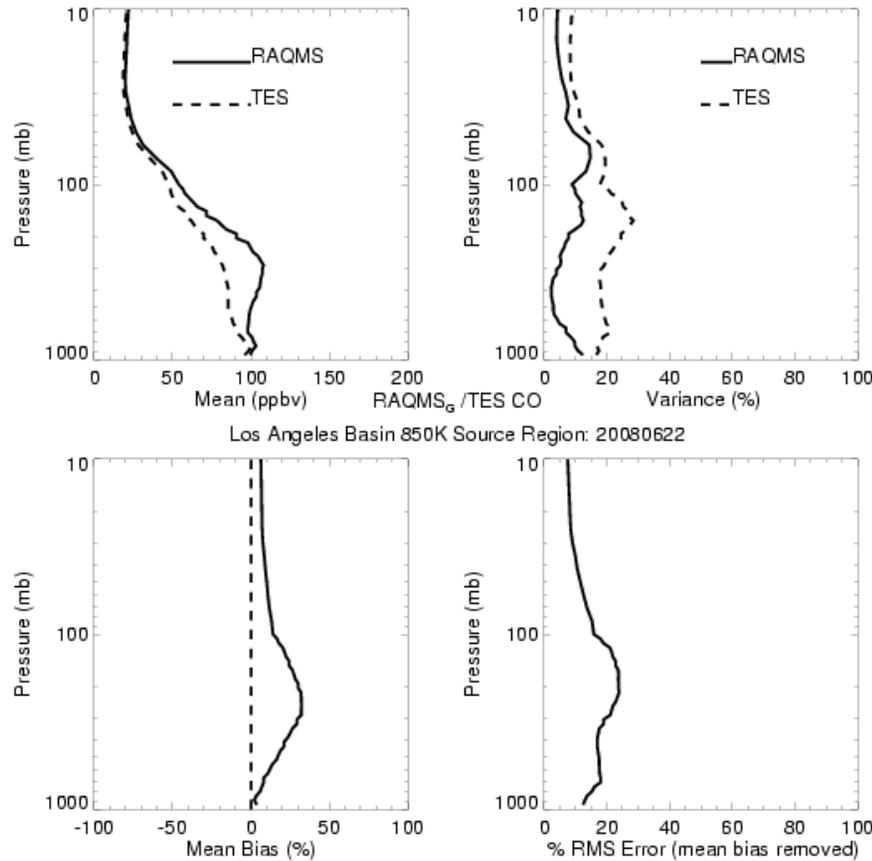
RAQMS vs TES 22Z June 15, 2008





Verification of RAQMS CO along TES Continental Step&Stare observations (June 13, 15, 17, 2008)

RAQMS vs TES 20Z June 15, 2008

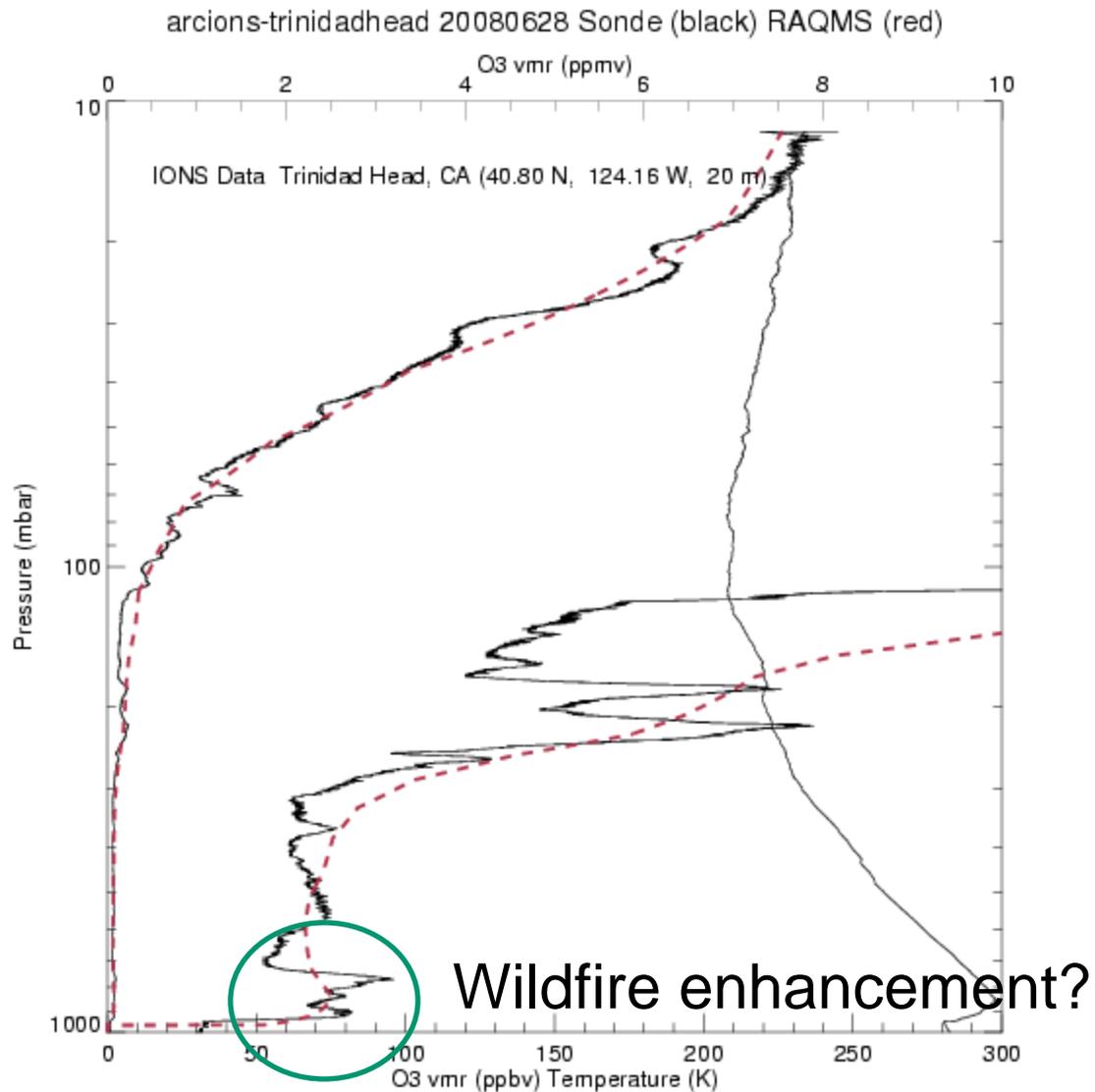


- RAQMS overestimates upper tropospheric CO at LAB 850mb Source Region



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of
Technology

Tropospheric Emission Spectrometer Ozonesonde Measurement from Trinidad Head, CA on June 28, 2009

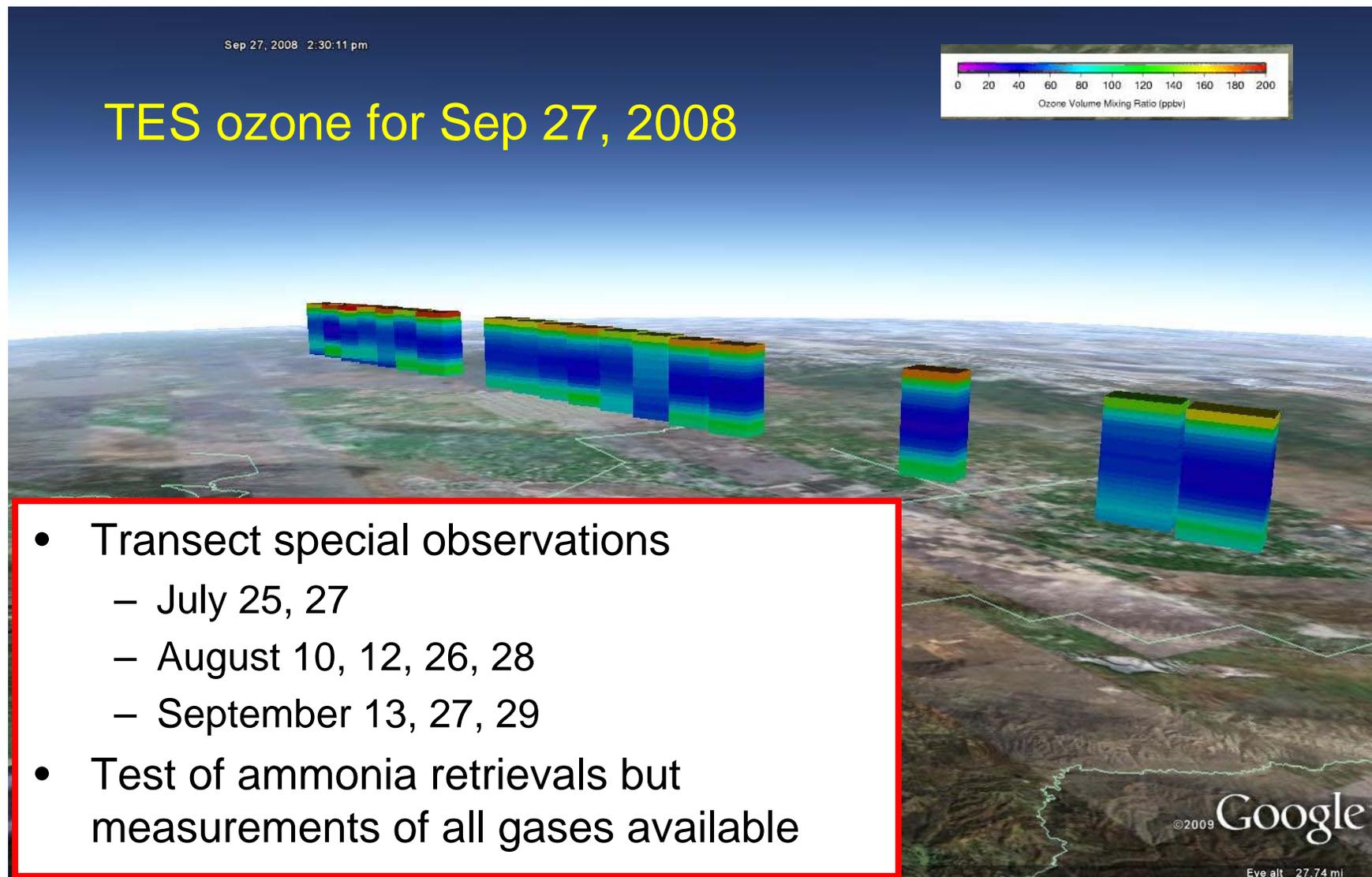




Tropospheric Emission Spectrometer **TES Special Observations in Central Valley in 2008**

Sep 27, 2008 2:30:11 pm

TES ozone for Sep 27, 2008



- Transect special observations
 - July 25, 27
 - August 10, 12, 26, 28
 - September 13, 27, 29
- Test of ammonia retrievals but measurements of all gases available



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of
Technology

Tropospheric Emission Spectrometer

TES Developments/Activities

- Adding carbon dioxide, ammonia and methanol as products (late in 2009)
- Assimilation of (3D, 4D Var) of TES data into GEOS-Chem
- Adjoint capabilities with GEOS-Chem
- Looking at air quality/climate interactions using CMAQ and satellite data
- Working with Texas Commission on Environmental Quality:
 - Provide regional boundary conditions for CAMx modeling efforts as part of SIP update work (using RAQMS and GEOS-Chem)
 - Using satellite data for CAMx model evaluation
- Office of Global Climate and Energy at JPL is developing research areas in regional climate change and water resource management.



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of
Technology

Tropospheric Emission Spectrometer

(Proposed) TES Plans for CalNex 2010

- Support the campaign with special observations
- Near real time processing of TES data for assimilation into RAQMS
- Provide global/regional view of troposphere for analysis/planning in the field.
- Analysis during/after the mission similar to that from TexAQS II (2006)



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
**California Institute of
Technology**

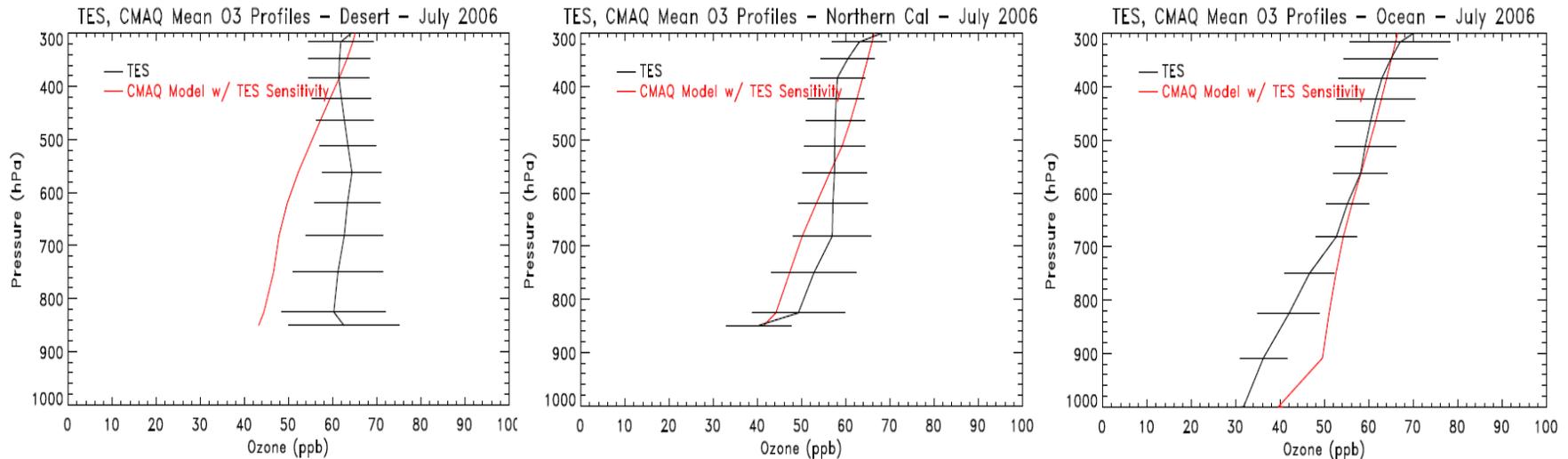
Tropospheric Emission Spectrometer

Extra



Tropospheric Emission Spectrometer

TES Comparisons to CMAQ California – July 2006



- Monthly mean comparisons over a “region”
- TES can provide information about how model is doing in lower and upper free troposphere
- TES spatial coverage is somewhat limited, averaging is necessary for examining a given region



Tropospheric Emission Spectrometer

Assimilation of TES Data into Chemical Transport Models

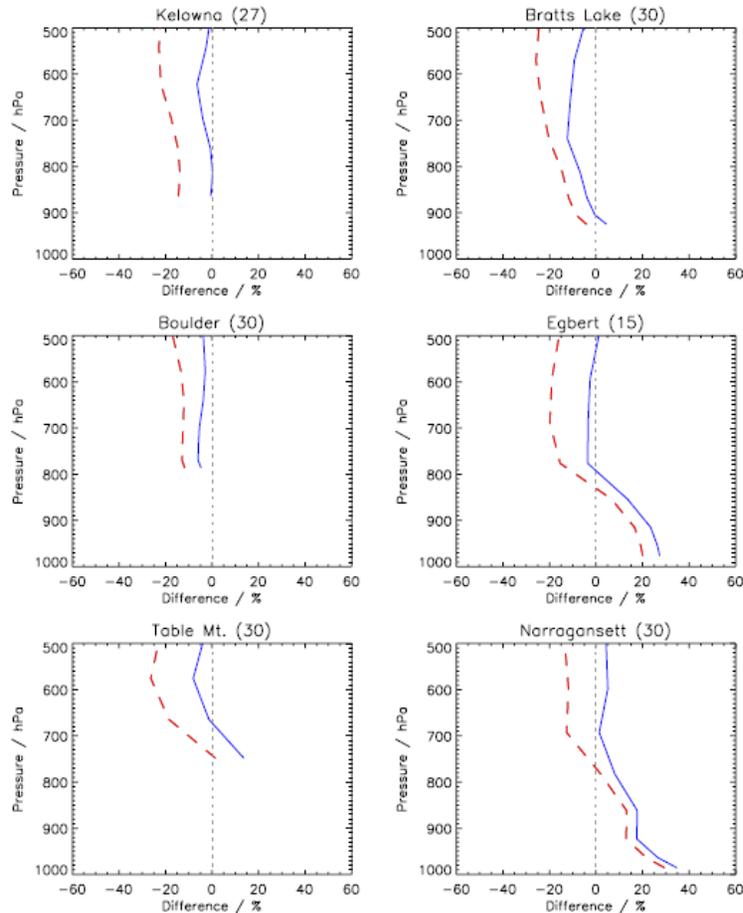


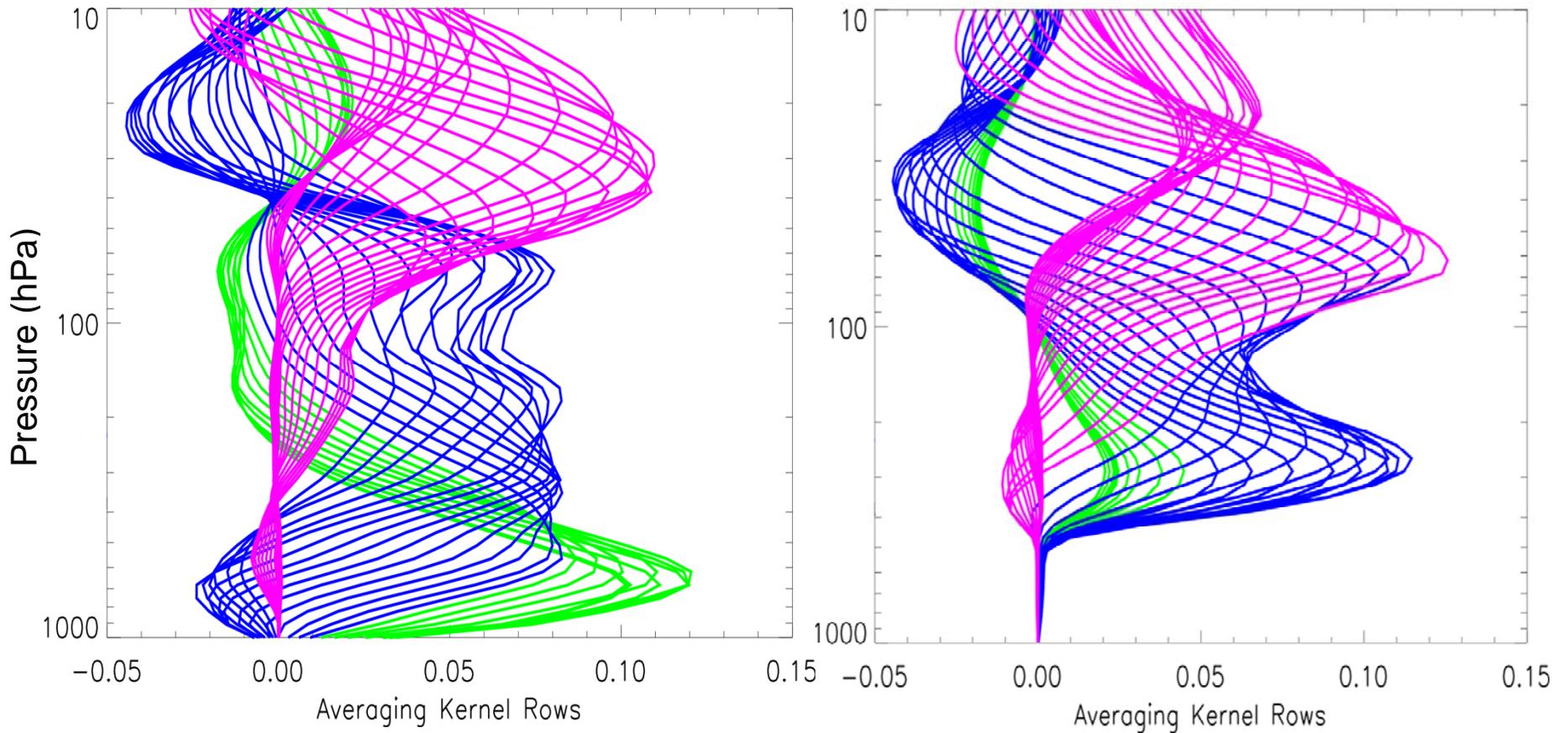
Figure 3. Monthly mean percentage differences between GEOS-Chem, standard simulation (dashed red line) and assimilation (solid blue line), and ozonesonde profiles measured during the IONS-06 measurement campaign for August 2006. The number of ozonesonde profiles available for the comparison are given in brackets for each location.

- Brad Pierce's group has been assimilating TES data into RAQMS
- Mark Parrington & Dylan Jones have been assimilating TES data into GEOS-Chem (GRL – 2009, see left)
- Has led to model improvement in middle and upper troposphere
- TES does not have a near real time data stream



Tropospheric Emission Spectrometer

Averaging Kernels for Ozone



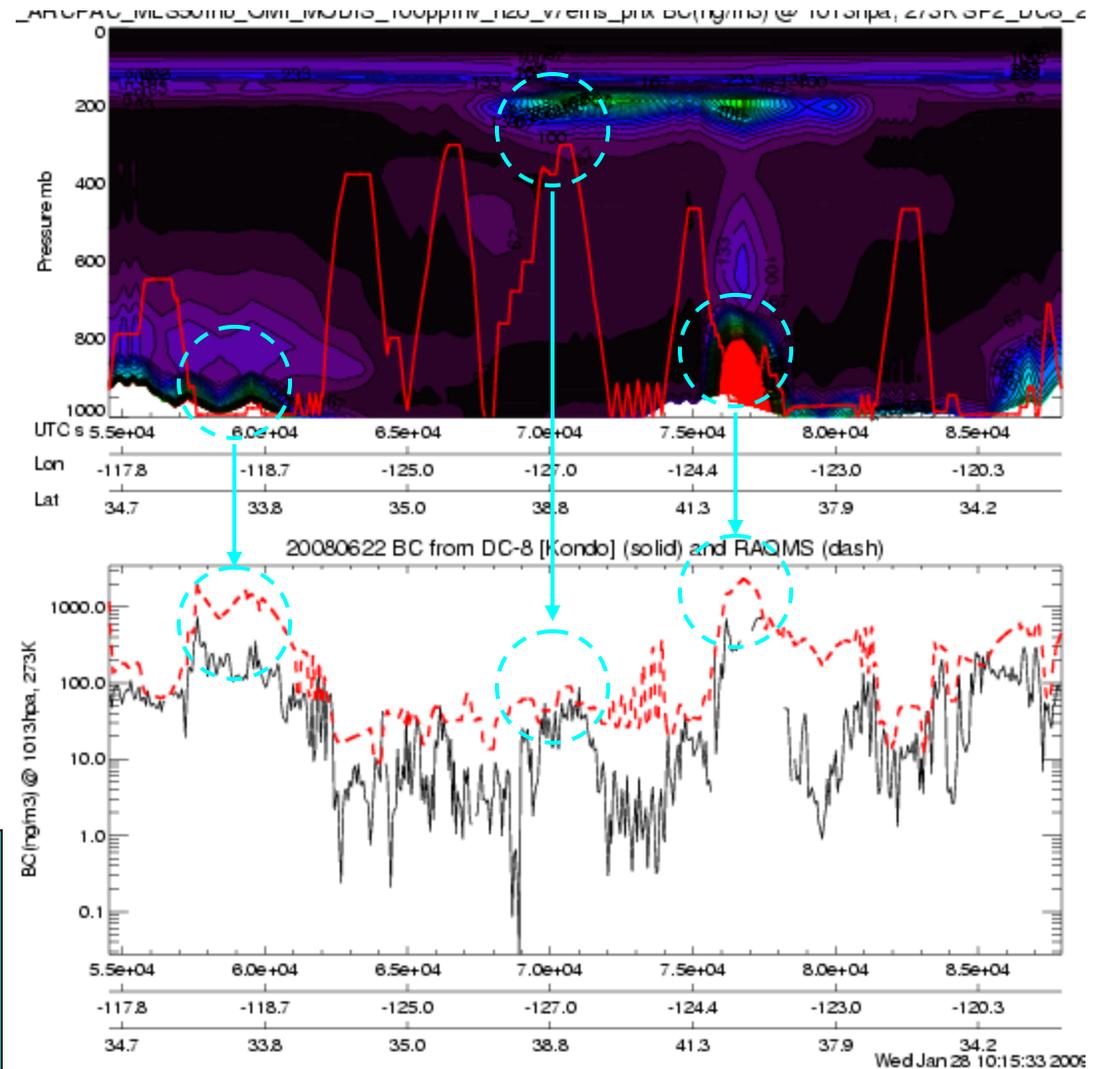
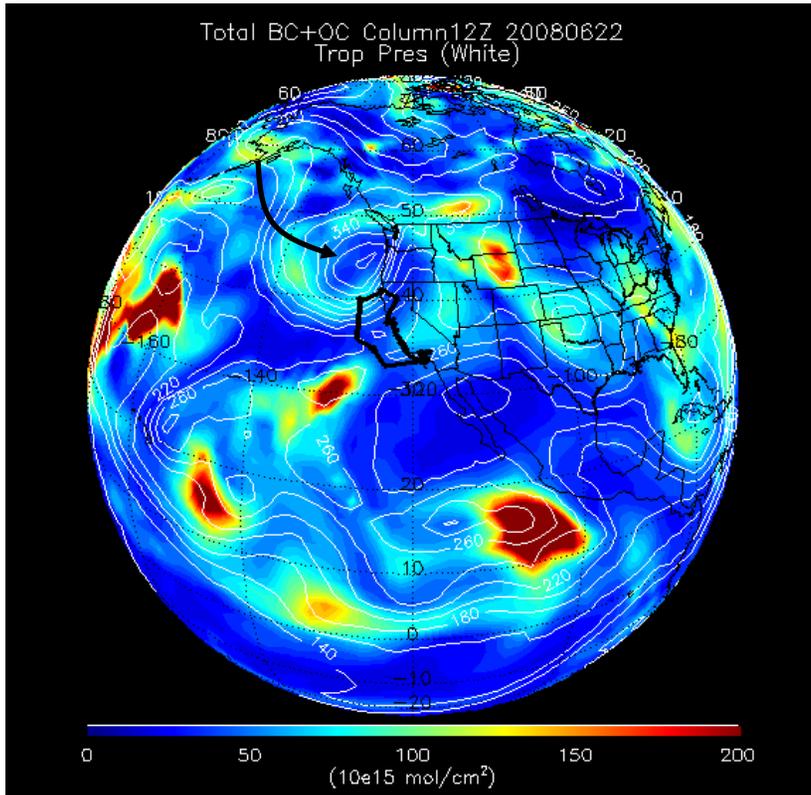
Clear (DOFS = 4.1)

Cloud at 483 hPa (DOFS = 3.0)



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of
Technology

Tropospheric Emission Spectrometer RAQMS Black Carbon vs DC8 SP2 Measurements ARCTAS-CA Flight 20080622



- RAQMS analysis overestimates black carbon aerosol associated with local wildfire activity
- DC8 SP2 measurements support analyzed black carbon aerosol enhancement aloft

In situ data provided by Y. Kondo (Univ Tokyo)

RAQMS

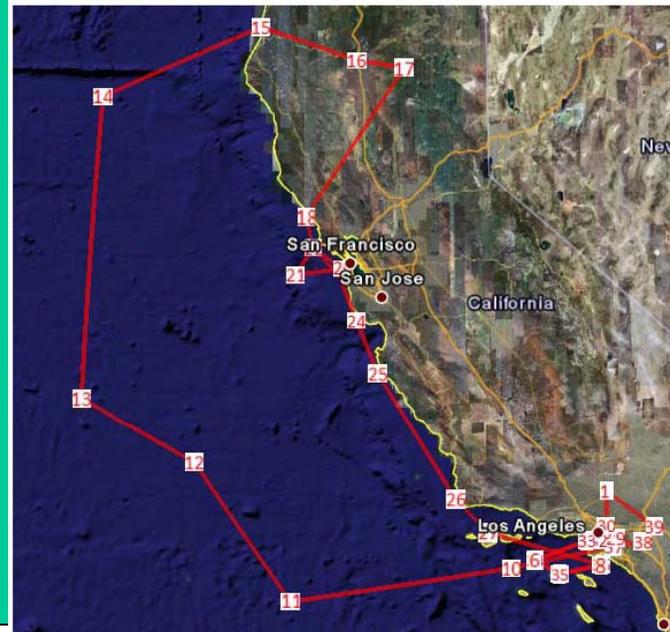
Illustration of CalNex mission Support activities

- Flight Planning (long-range transport focus)
- Data synthesis (linking remote satellite, aircraft and ground-based measurements)



Arctic Research of the Composition of the Troposphere from Aircraft and Satellites- California (ARCTAS-CA)

Final Flight Plan: Boundary Condition Survey Version F 06/22/2008



- Nominal Alt. Ranges:**
- Point 1 through 11:** 0.5 kft over water and 1 kft over land. Arrive 11 at 25 kft.
 - Point 11 through 14:** 0.5 – 30 kft.
 - Point 14 through 15:** 0.5 kft.
 - Point 15 through 18:** 1kft AGL.
 - Point 18 through 40:** 0.5 kft over water and 1 kft over land. Arriving Point 11 at 25 kft.
- Spirals:**
- Point 12: from 0.5 to 30 kft
 - Point 14: from 30 to 0.5 kft
 - Point 15: from 0.5 to 20 kft
 - Point 25: from 0.5 to 20 kft
- Take-Off: 08:00**
Flight Duration: ~9:00.

- ARCTAS-CA was CARB/ NASA collaboration dedicated to California air quality and climate change objectives
- Field campaign during June 15-30, 2008