Insights into tropospheric chemistry: new results utilizing EOS TES, OMI, and MOPITT

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Tropospheric Emission Spectrometer

Tropospheric chemistry is a complex problem!

- Anthropogenic sources
- Natural precursors
- Convection
- Subsidence
- Advection
- Solar radiation

Global TES ozone
Tropospheric Emission Spectrometer

TES Movie

One year of TES CO

One year of TES O₃
The tropical Atlantic "paradox" came from TOMS observations of high ozone column South of the ITCZ but low ozone columns North of the ITCZ over Africa during peak biomass burning season (Thompson et al, 2000).

With greater sensitivity to the lower troposphere, TES observations show elevated concentrations in the lower troposphere over Africa and in the free troposphere over the tropical Atlantic consistent with in-situ data and model predictions.
Ozone Production in Boreal Fire Plumes

Case (a) TES O$_3$/CO 24$^{th}$ July 2006

Case (b) TES O$_3$/CO 24$^{th}$ July 2006

- Based on satellite analysis of observations of CO and ozone from TES in a boreal fire region. Ozone production in these smoke plumes is highly variable. Some plumes show strong ozone enhancement and others show depleted ozone.

- Aerosols have a significant impact on the ozone photochemistry.

(S. Verma et al., 2009)
Tropospheric Emission Spectrometer
TES used to improve predictions of surface ozone

- Assimilation of TES data into the GEOS-CHEM model greatly improves the agreement between GEOS-CHEM and sonde measurements of tropospheric ozone. In the western US, bias reduced by up to 9 ppb.

Parrington et al., JGR, 2009
Recent experiments were conducted to attribute the air pollution of Houston, TX to sources.

Regional ozone production preceded 6 of 9 days with high surface values in Houston.

Source Regions for Houston:
- Midwest/Ohio River
- Chicago

Regional ozone production preceded 7 of 15 days with high surface values in Dallas.

Source regions for Dallas:
- Great Lakes/Southern Canada
- Midwest/Ohio River

Yellow here at 30 deg. latitude is suspected sulfate from Eastern U.S. Here, aloft at 45 deg. latitude, is suspected Canadian fire aerosol. Here also at 45-50 deg. latitude is elevated CO, believed to be from fire.
Retrievals of Ammonia and Methanol

Frequency, cm\(^{-1}\)

Residual, K

CH\(_3\)OH concentration, Beijing

NH\(_3\) concentration, Beijing

San Diego

Residual, K

Longitude, deg

Brightness Temp, K

Residual, K

CH\(_3\)OH concentration, San Diego

NH\(_3\) concentration, San Diego

(Beer et al., 2008)
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Tropospheric Emission Spectrometer

Using and Improving CH$_4$ Product

TES CH$_4$: representative tropospheric VMR

October 2005
October 2006
October 2007

TES RTVMR minus GEOS-Chem 2001 RTVMR field
(after removal of 3.5% high bias from TES and smoothing of difference fields using 2x2 boxcar)

October 2005
October 2005
October 2005

High CH$_4$ over Indonesia in October 2006 associated with increased biomass burning during the El Nino – collaborating with J. Logan (Harvard) and V. Payne (AER) on interpretation
OMI Tropospheric NO$_2$ (average Jan.-June 2006)
In West-Europe, the US and Japan the emissions of SO$_2$ have been reduced strongly. Over China and for certain power plants on the Balkan, OMI is able to detect SO$_2$. Krotkov et al.
OMI Average (2005-2006) SO2 burdens over USA, and China

25.5 million tons of SO2 was emitted by Chinese factories in 2005 up 27% from 2000

Krotkov et al.
Comparing emission inventories with OMI measurements

OMI HCHO
Inversed modelling emission Inventory

Millet et al., 2008
Collocated measurements from space from OMI

October 2005: collection 3

Kurosu, Chance, Harvard; Liou, Bhartia, NASA GSFC
MOPITT Applications I: Improving African CO Emissions*

- Inverse modeling using MOPITT data indicates a longer burning season, reduced amplitude, and interannual variability of the seasonal cycle in northern Africa.
- Inversion improves the fit to independent surface-station measurements by up to 28%.

* Chevallier et al., 'African CO emissions between years 2000 and 2006 as estimated from MOPITT observations'. Biogeosciences, vol. 6, January 2009'
MOPITT Applications II: Exploiting Lower-Trop Sensitivity over Indian Subcontinent*

- MOPITT CO sensitivity at surface strongly dependent on ‘thermal contrast’ between surface and air temperature
- Daytime overpasses of land provide best sensitivity to lower-trop CO

**Sensitivity to Surface-level CO**

MOPITT Applications III: Exploiting Lower-Trop Sensitivity over China and Megacities*

- Demonstrated use of MOPITT CO to identify major populations centers, i.e., patterns of urbanization
- Confirmed importance of thermal contrast conditions as determinant of MOPITT's sensitivity to lower-trop CO

Conclusions

- TES, OMI, and MOPITT on the A-train constellation is providing unprecedented vertically resolved chemical observations of the Earth’s lower atmosphere.
- Over 5(!) years of measurements data are available.
  - For details and links to data go to:
    - http://aura.gsfc.nasa.gov
    - http://terra.gsfc.nasa.gov
Tropospheric Emission Spectrometer

For more info and links to data centers:

tes.jpl.nasa.gov
Global Views of Ozone and Carbon Monoxide from TES

Lower troposphere (750 hPa, about 2.4 km)


### Tropospheric Emission Spectrometer

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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<tbody>
<tr>
<td><strong>Spectrometer Type</strong></td>
<td>Connes'-type 4-port Fourier Transform Spectrometer</td>
</tr>
<tr>
<td><strong>Max. Optical Path Difference</strong></td>
<td>8.45 cm (normal)</td>
</tr>
<tr>
<td></td>
<td>33.8 cm (hi-res); interchangeable</td>
</tr>
<tr>
<td><strong>Scan (integration) Time</strong></td>
<td>4 sec (normal)</td>
</tr>
<tr>
<td></td>
<td>16 sec (hi-res)</td>
</tr>
<tr>
<td><strong>Sampling Metrology</strong></td>
<td>Nd:YAG laser</td>
</tr>
<tr>
<td><strong>Spectral Resolution (unapodized)</strong></td>
<td>0.06 cm(^{-1}) (normal)</td>
</tr>
<tr>
<td></td>
<td>0.015 cm(^{-1}) (hi-res)</td>
</tr>
<tr>
<td><strong>Spectral Coverage</strong></td>
<td>650 to 3050 cm(^{-1}) (3.2 to 15.4 um)</td>
</tr>
<tr>
<td><strong>Detector Arrays</strong></td>
<td>4 (1 x 16) arrays, optically-conjugated, all MCT PV @65K</td>
</tr>
<tr>
<td><strong>Field of Regard</strong></td>
<td>45° cone about nadir; trailing limb or cold space; internal calibration sources</td>
</tr>
<tr>
<td><strong>Pointing Accuracy</strong></td>
<td>75 urad pitch, 750 urad yaw</td>
</tr>
<tr>
<td></td>
<td>1100 urad roll</td>
</tr>
<tr>
<td><strong>Max. Stare Time</strong></td>
<td>208 sec (40 nadir scans)</td>
</tr>
<tr>
<td><strong>Spatial Resolution</strong></td>
<td>0.5 x 5 km (nadir)</td>
</tr>
<tr>
<td></td>
<td>2.3 x 23 km (limb)</td>
</tr>
<tr>
<td><strong>Radiometric Calibration</strong></td>
<td>cavity blackbody (340K)</td>
</tr>
<tr>
<td></td>
<td>+ cold space view</td>
</tr>
<tr>
<td><strong>Detector Array Co-alignment</strong></td>
<td>Internal thin slit calibration source</td>
</tr>
<tr>
<td><strong>Nadir NESR (Noise Equivalent Spectral Radiance)</strong></td>
<td>2B1 filter: 700 nW/cm(^2)/sr/cm(^{-1})</td>
</tr>
<tr>
<td></td>
<td>1B2 filter: 200</td>
</tr>
<tr>
<td></td>
<td>2A1 filter: 150</td>
</tr>
<tr>
<td></td>
<td>1A1 filter: 100</td>
</tr>
<tr>
<td><strong>Nadir NEDT @290K (Noise Equivalent Delta Temperature)</strong></td>
<td>2B1: 1.08 K for 16 detector average</td>
</tr>
<tr>
<td></td>
<td>1B2: 0.36 K for 16 detector average</td>
</tr>
<tr>
<td></td>
<td>2A1: 0.36 K for 16 detector average</td>
</tr>
<tr>
<td></td>
<td>1A1: 2.07 K for 15 detector average</td>
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