Pollution over megacity regions from the Tropospheric Emission Spectrometer (TES)

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5. Environment and Climate Change Canada
TES measures AQ around the world

- **July 2004**: TES launched on AURA satellite
- **Main targets**: O$_3$ and CO
- **Other species added**:
  - CH$_4$, CO$_2$, NH$_3$, CH$_3$OH, HCOOH, PAN
- **Global surveys carried out through 2010**
  - Observations ~ 182 km apart
- Also a number of more closely spaced special observations

- **January 2013**: megacity observations start
- **Simultaneous closely spaced observations** of multiple trace gases (~ 12 km apart)
- **Quantify urban pollution production, transformation and export.**

*Cady-Pereira et al., ACP, 2017*
Model summary

**MIROC-Chem**
- Mexico
- Lower resolution: 2.5x2.5 deg
- 2013 forcing fields
- Focus on accurate O$_3$ chemistry modeling
- Limited NH$_3$ emissions
- No separate modeling of HCOOH
- Variable CH$_3$OH

**GEOS-Chem**
- Western Africa
- High resolution: 0.5x0.667 deg
- 2006 forcing fields
- Includes NH$_3$ from
  - biomass burning (GFED4)
  - anthropogenic activity (EDGAR)
  - biofuel and charcoal
  - trash burning
- Only secondary HCOOH production
- Fixed CH$_3$OH
NH$_3$ and HCOOH near Mexico City

TES MAM NH$_3$ transect

TES Seasonal means

TES NH$_3$ peaks to the south, especially in DJF and MAM. TES HCOOH peaks in same region in MAM.

Fire source?

Focus on air quality near the surface:

⇒ will use means of TES data over the first two or three layers above the surface.
Biomass burning in Mexico

Biomass burning is strong over the Yucatan in the NH spring

Mean May GFED C emissions (1997-2010)

CO from AIRS and AOD from MODIS over the TES Mexico City transect also peak during biomass burning season and suggest fires might contribute significantly to pollution in the Mexico City area
Biomass burning in Mexico

Concomitant biomass burning products from TES (methanol, formic acid, ammonia) also point to air quality impacted by biomass burning.

Contrasting days in spring 2013 provide a case study of TES sensitivity.
Possible BB sources

HYSPLIT four day back trajectories

SIMAT stations in the MCMA

Daily means from SIMAT stations
May 9 vs May 25

TES single transects

May 9

May 25

TES and MIROC mean profiles along transect

- O$_3$
- CH$_3$OH
- NH$_3$
- CH$_3$OH
- HCOOH

May 9

May 25
Western Africa has one of the strongest biomass burning seasons (December-March) on Earth.
High pollution in DJF

HYSPLIT 10 day back trajectories

Pollution sources
• Biomass burning
• Petrochemical
• Two-stroke engines
• Generators
• Trash burning
• Traffic

Sea breezes play important role

2015 El Nino may have also been influential

Slow circulation – reduced venting
Seasonal Means

TES 2013-2015

- high values in DJF and MAM
- no gradient in HCOOH
- moderate NH₃ over ocean in DJF and MAM
- weak circulation

GEOS-Chem 2006 1000-700 hPa mean

- higher values in DJF
- sharp ocean/land gradients
A Tale of Two Cities

- Similar O3 and CO levels
- Why is NH$_3$ different?

Beijing

Delhi

O3

NH3

CH3OH

HCOOH


ECLIPSE v5 emissions

NH$_3$

NO$_x$

SO$_2$
OMPS NO$_2$ over Beijing and Delhi

- Much higher NO$_2$ levels in Beijing
- Greater variability between winter and spring
- But current trend is decrease in Beijing and no increase in Delhi
SO₂ over Beijing and Delhi

- Much higher SO₂ levels in Beijing winter
- Some hotspots in Delhi winter and Beijing spring
- Expected trend is decrease in Beijing and increase in Delhi
Global view – $O_3$

Percent of observations above elevated threshold (70 ppmv)

- São Paulo 5.0
- New York City 6.6
- Los Angeles 19.8
- Houston 14.0
- Mexico City 10.7
- Paris 16.2
- Istanbul 12.5
- Delhi 26.3
- Karachi 32.2
- Mumbai 18.0
- Kolkata 16.1
- Dhaka 17.1
- Beijing 21.2
- Tokyo 12.1
- Shenzhen 14.0
- Bangkok 14.0
- Buenos Aires 0.7

(Graphic) G. Grullón/Science;
(Data) JPL TES Science Team
Global view – NH₃

Ammonia levels

Percent of observations above elevated threshold (10 ppmv)

(Graphic) G. Grullón/Science;
(Data) JPL TES Science Team
And now CrIS NH₃

TES (JJA average)  CrIS (July mean)
Summary

• TES has processed data from January 2013 to March 2016 over 19 megacities
• Data are closely spaced (12 km) and are taken approximately every two weeks
• Species measured: O$_3$, CH$_4$, NH$_3$, CH$_3$OH, HCOOH, HDO, PAN, CO$_2$
• Data point to influences of biomass burning and other pollution sources
• Also show different chemistry regimes in different cities
• Ongoing work uses the new AIRS-OMI O3 product to provide context for interpreting the TES megacity measurements
• Data are available on AVDC

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Information content
Mexico City October pollution event

Megacity Pollution: The jointly retrieved TES/OMI near-surface ozone product shows very high ozone (~120 ppb) in Mexico City on a day with stable, stagnant air in the boundary layer.

TES carbon monoxide, methanol, & formic acid (ozone precursors) are also elevated, as is the nitrogen reservoir peroxycetyl nitrate (PAN).
HTAP and TES disagree on source of NH$_3$. JJA Seasonal Means
High NH₃, CH₃OH and HCOOH in July 2013 correlate with higher AOD, but not with CO or O₃
- Early fire season
- But not from fire?
- HCOOH, CH₃OH generated locally over LA
- NH₃ has different source
Western Africa has one of the strongest biomass burning seasons (December-March) on Earth.

High $^{222}\text{Rn}$ in DJF due to stagnant air conditions.
Los Angeles puzzle - 2

High JJA TES peak north of the city
HTAP underestimates NH$_3$ emissions here

TES JJA NH$_3$ transect

TES NH$_3$ and HTAP emissions peak within city