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

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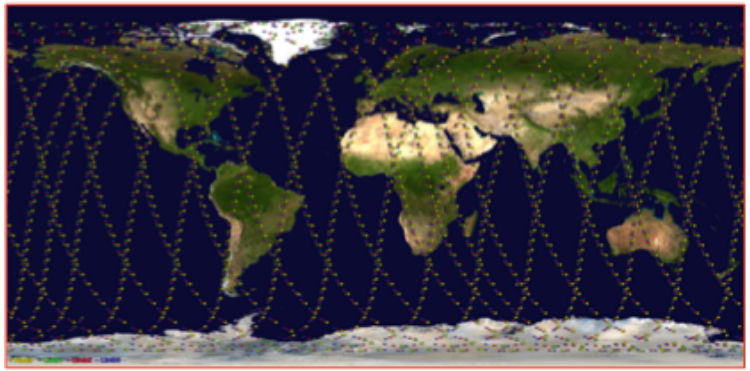
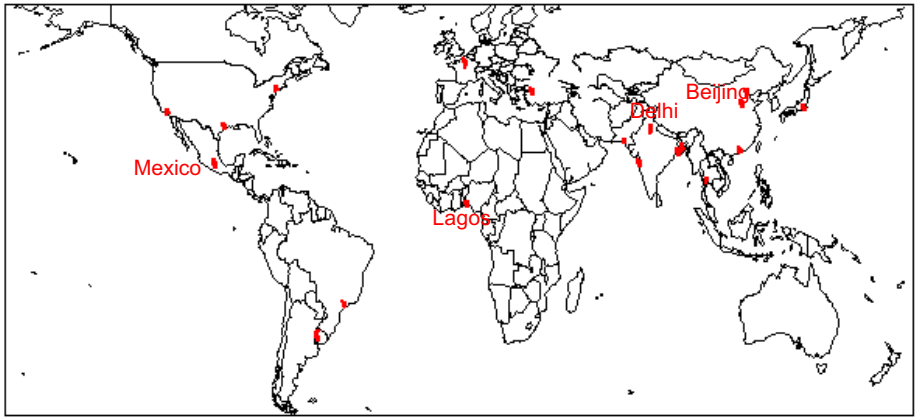
3. Harvard University
4. Colorado State University
5. Environment and Climate Change Canada

# TES measures AQ around the world

- **July 2004**: TES launched on AURA satellite
- Main targets: $O_3$ and CO
- Other species added:
  - $CH_4$, $CO_2$, $NH_3$, $CH_3OH$, 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**

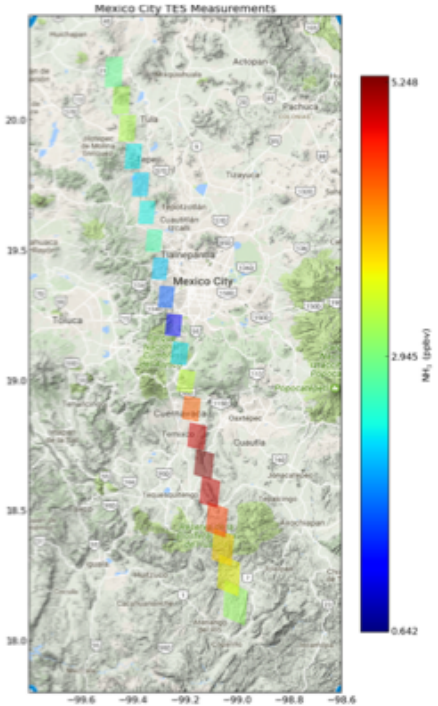
- **Mexico**
- **Lower resolution: 2.5x2.5 deg**
- **2013 forcing fields**
- **Focus on accurate $O_3$ chemistry modeling**
- **Limited $NH_3$ emissions**
- **No separate modeling of HCOOH**
- **Variable $CH_3OH$**

**GEOS-Chem**

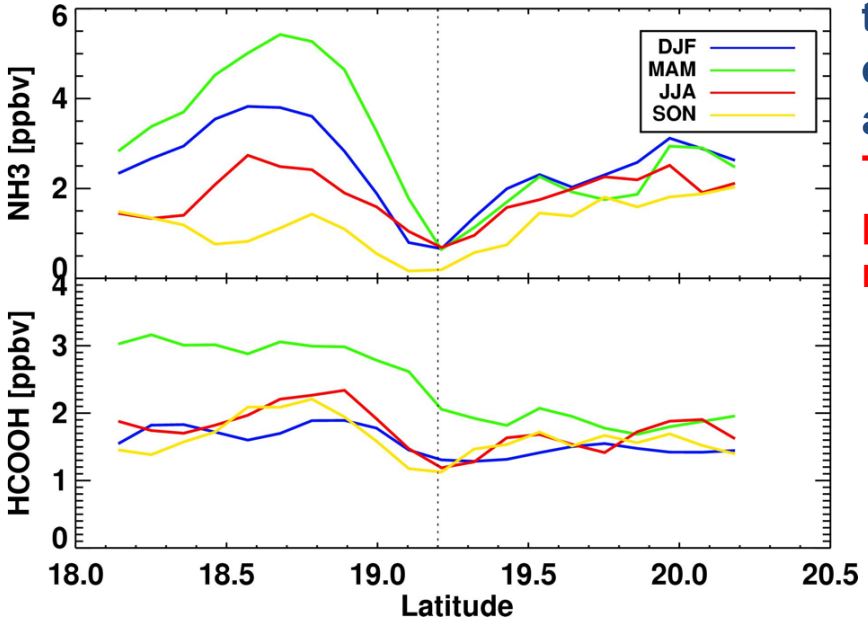
- **Western Africa**
- **High resolution: 0.5x0.667 deg**
- **2006 forcing fields**
- **Includes $NH_3$ from**
  - biomass burning (GFED4)
  - anthropogenic activity (EDGAR)
  - biofuel and charcoal
  - trash burning
- **Only secondary HCOOH production**
- **Fixed $CH_3OH$**

# $NH_3$ 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**

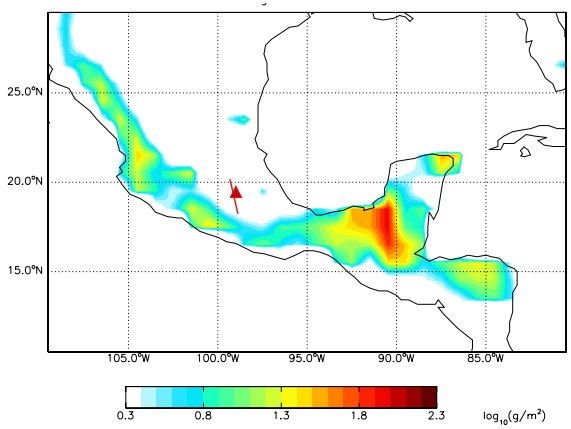
**Fire source?**

**Focus on air quality near the surface:**

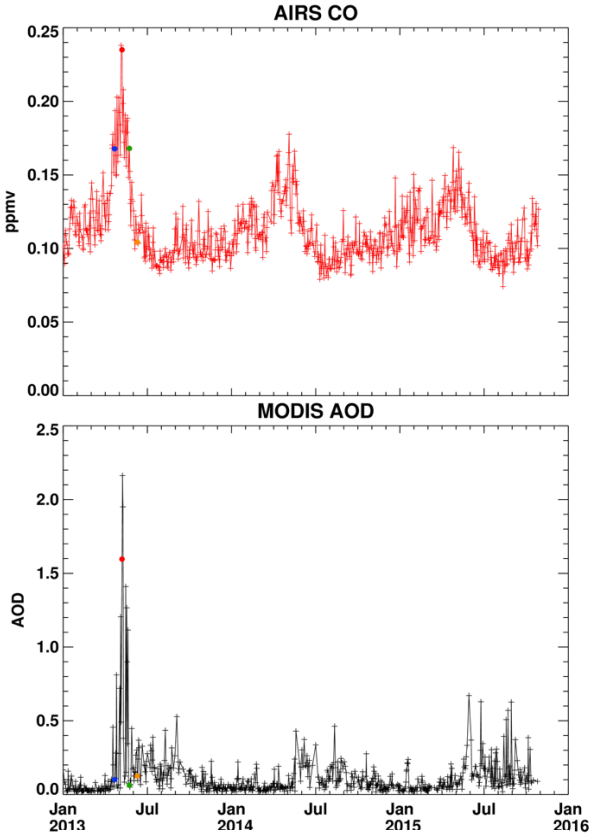
➔ **will use means of TES data over the first two or three layers above the surface**

# Biomass burning in Mexico

**Biomass burning is strong over the Yucatan in the NH spring**




**Mean May GFED C emissions (1997-2010)**



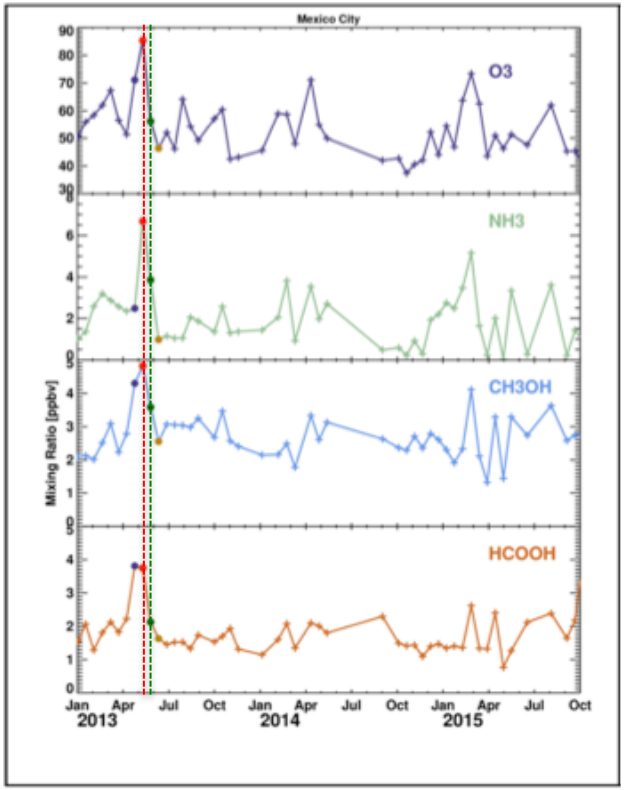

**CO from AIRS and AOD from MODIS over the TES Mexico City transect also peak during biomass burning season and suggest fires might contribute significantly to pollution in the Mexico City area**

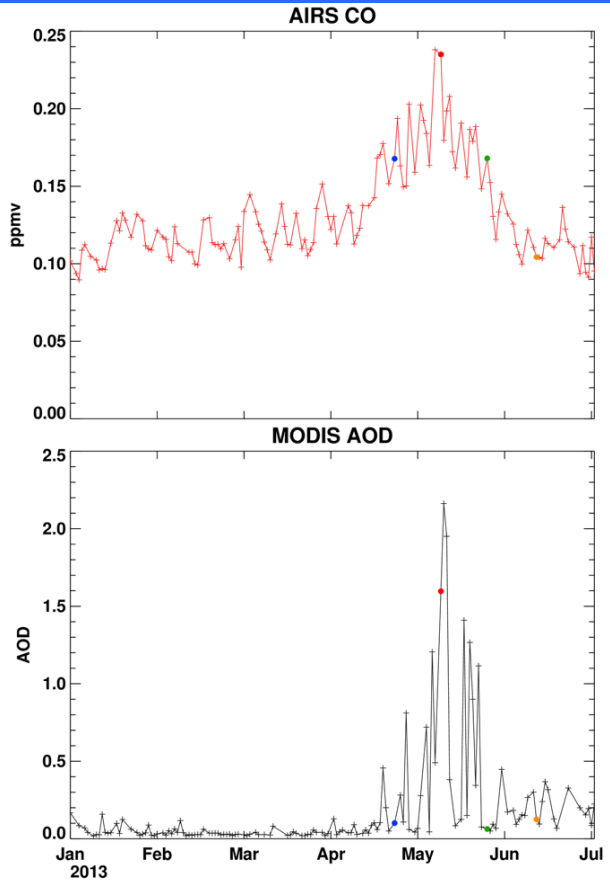
# Biomass burning in Mexico

## TES transect means

May 9

May 25

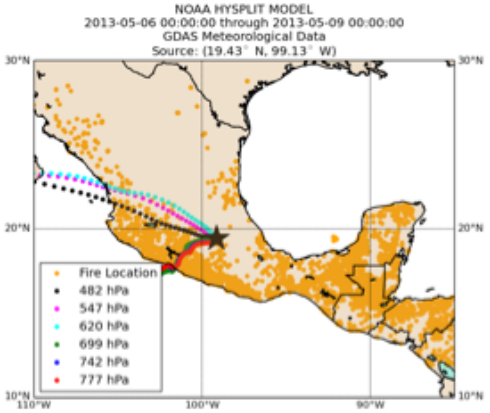


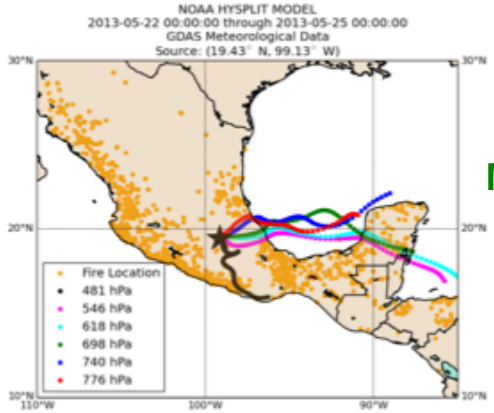

- **Concomitant biomass burning products from TES (methanol, formic acid, ammonia) also point to air quality impacted by biomass burning**
- **Contrasting days in spring 2013 provide a case study of TES sensitivity**

# Possible BB sources

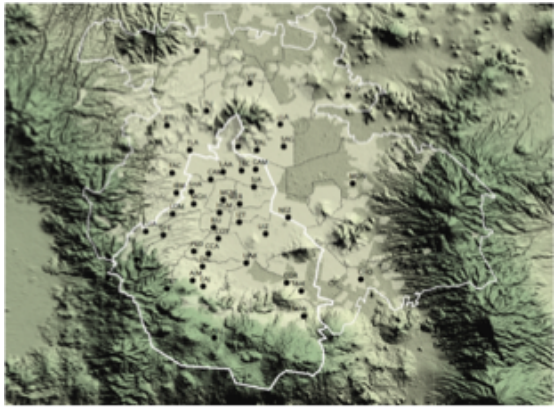
## HYSPLIT four day back trajectories



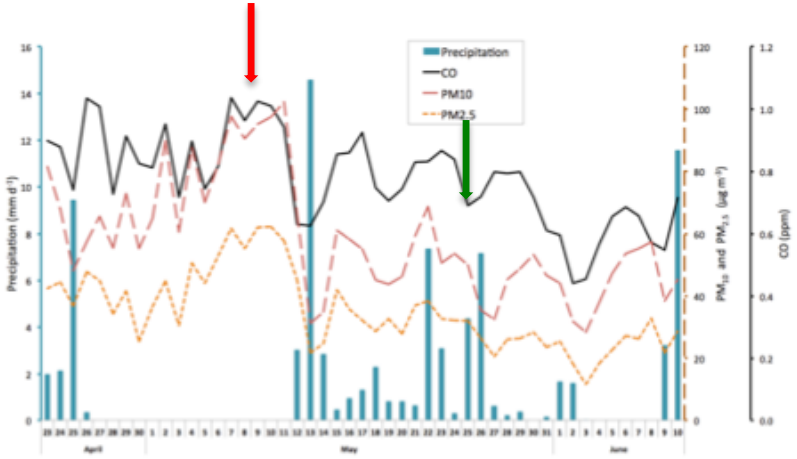

May 9




May 25



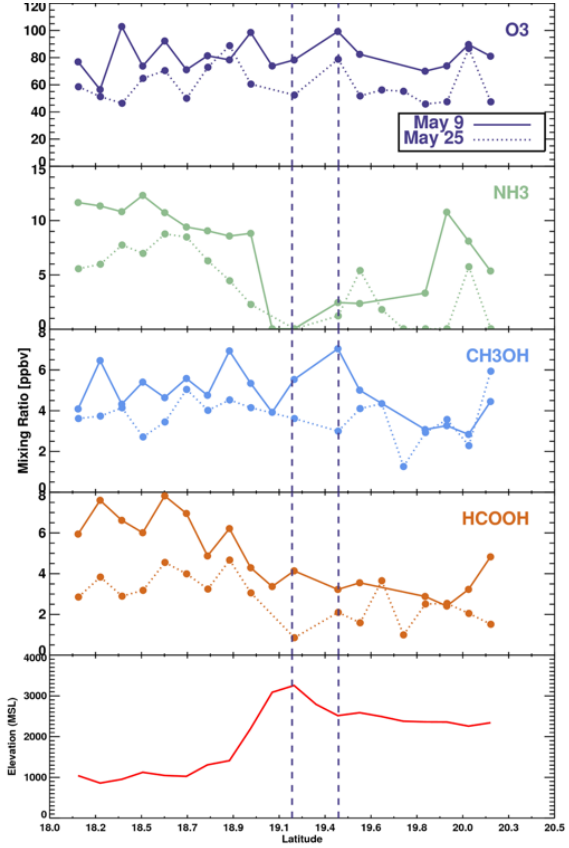
SIMAT stations in the MCMA




Daily means from SIMAT stations

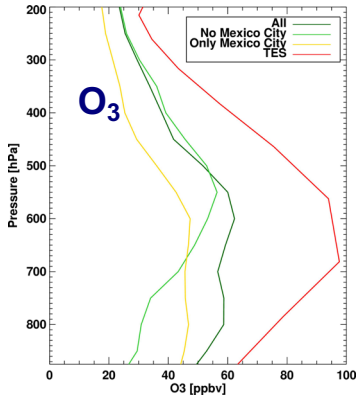
# May 9 vs May 25

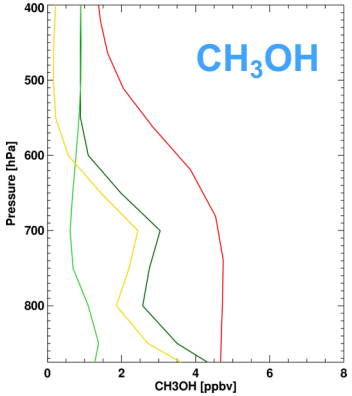
## TES single transects



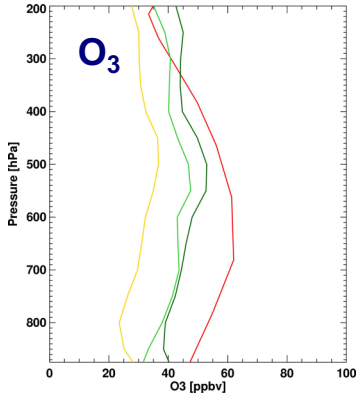

## TES and MIROC mean profiles along transect

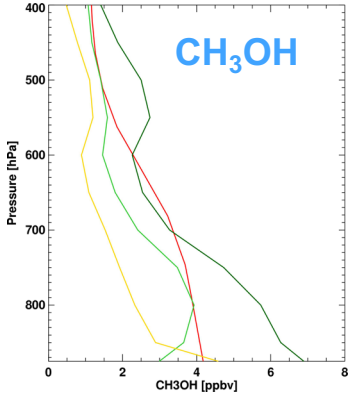
May 9



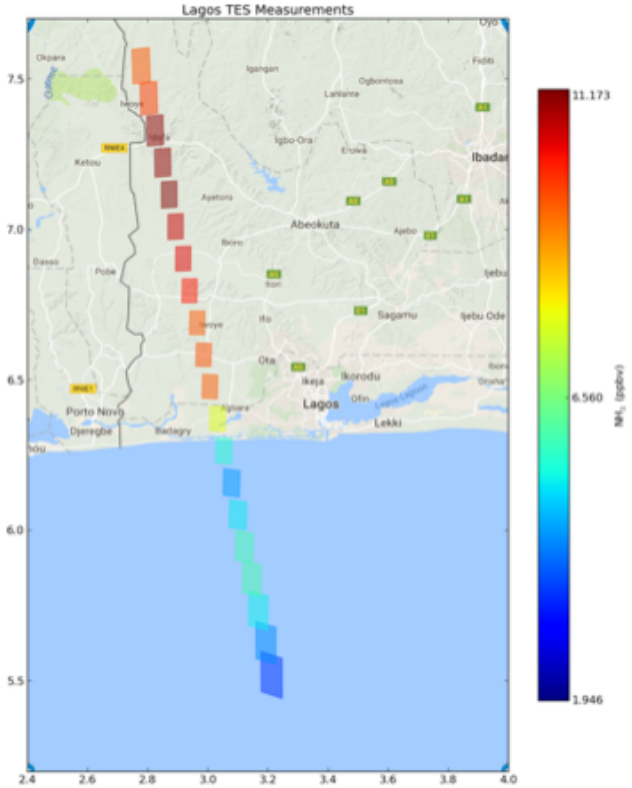



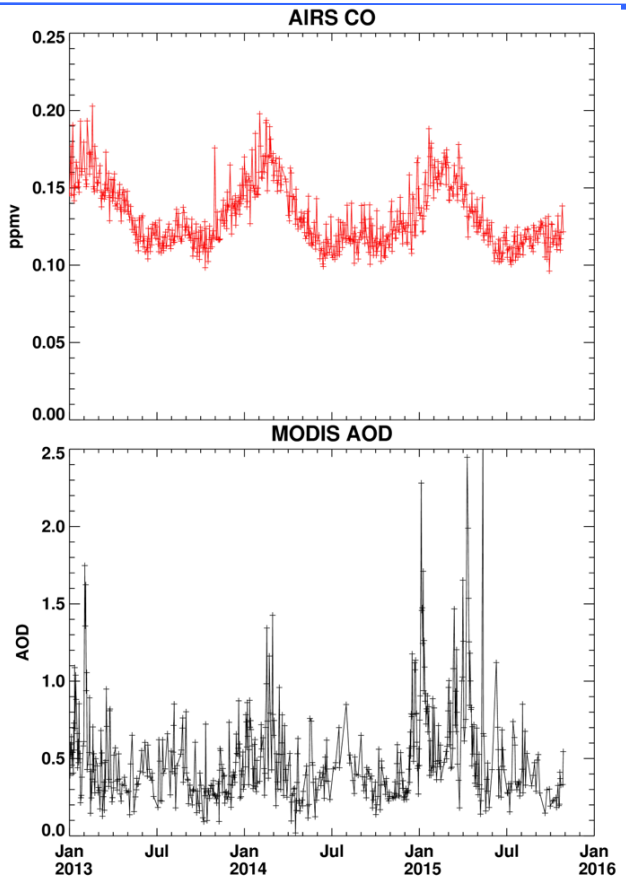

May 25



# Western Africa- Lagos

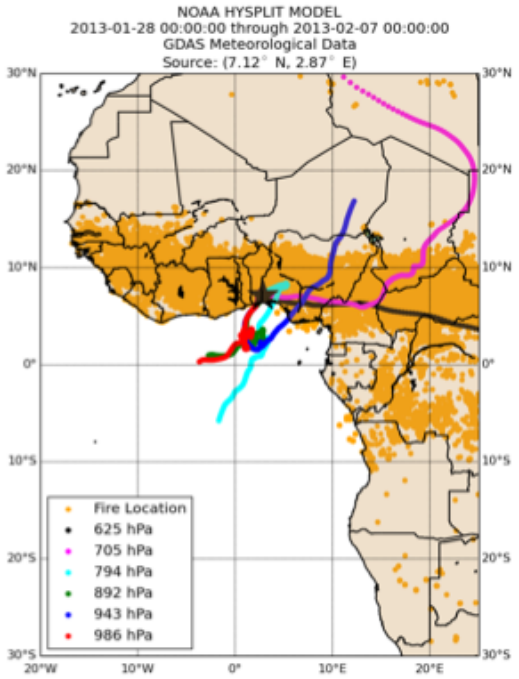



**Western Africa has one of the strongest biomass burning seasons (December-March) on Earth**

# High pollution in DJF

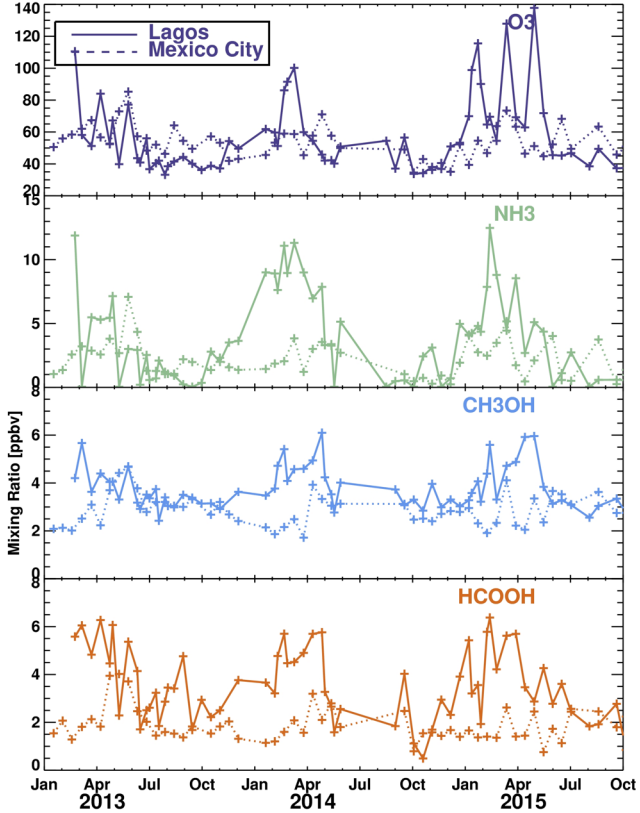
## HYSPLIT 10 day back trajectories




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

**Sea breezes play important role**

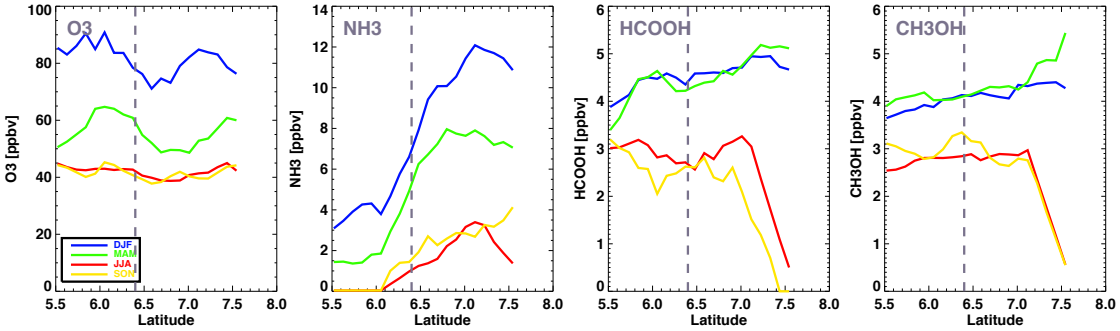
**2015 El Nino may have also been influential**



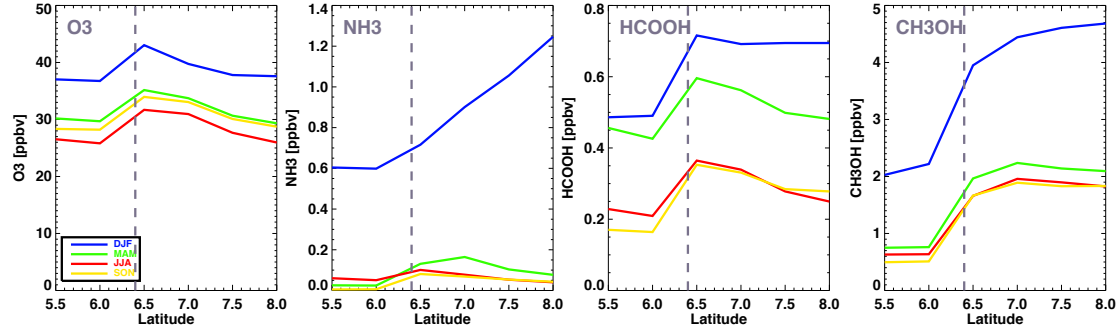

**Slow circulation – reduced venting**

# Seasonal Means

**TES 2013-2015**




**GEOS-Chem 2006 1000-700 hPa mean**




**TES:**

- high values in DJF and MAM
- no gradient in HCOOH
- moderate $NH_3$ over ocean in DJF and MAM
- ➔ weak circulation

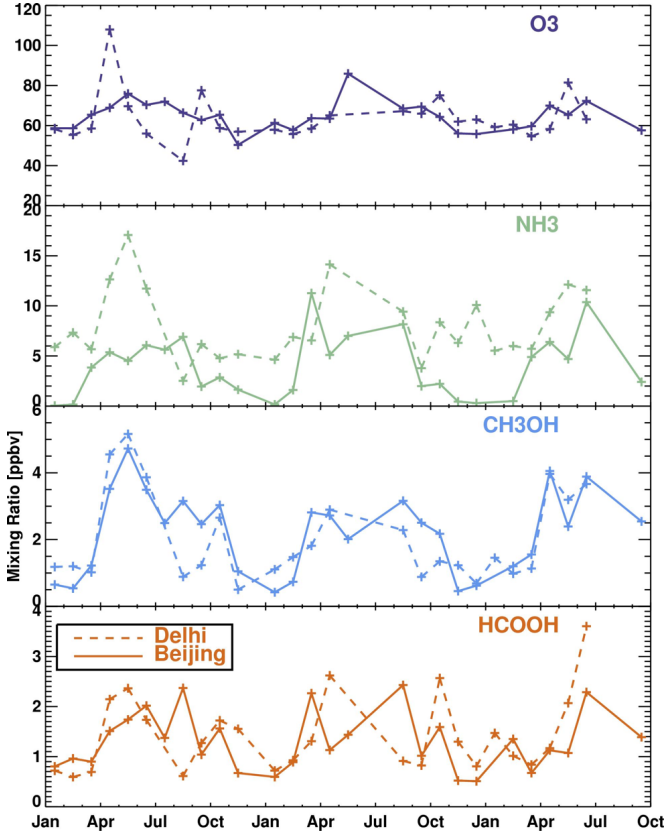
**GC:**

- higher values in DJF
- sharp ocean/land gradients

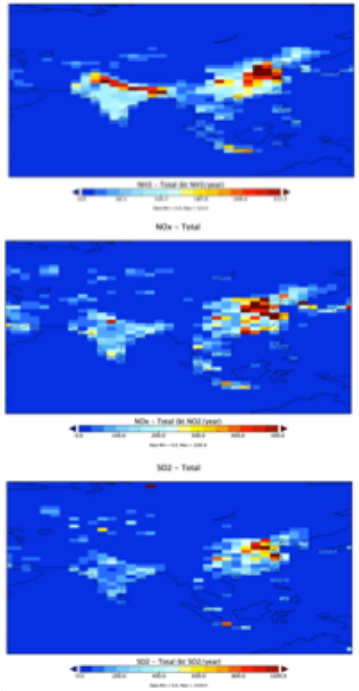
# A Tale of Two Cities

**Beijing**

**Delhi**




- Similar **O3 and CO** levels
- Why is **$NH_3$** different?



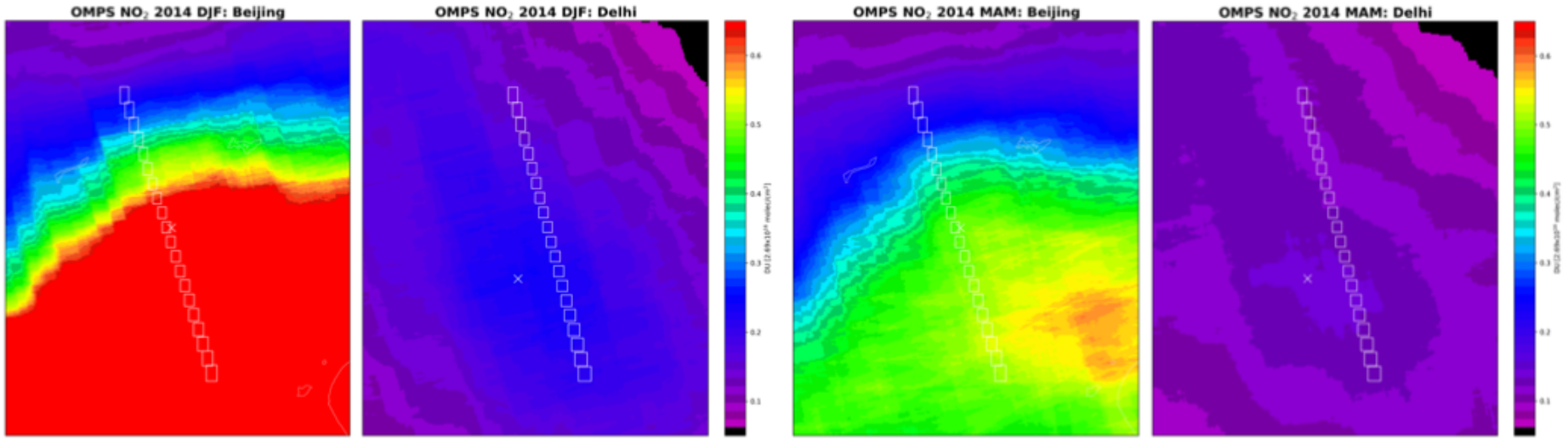
**$NH_3$**

**$NO_x$**

**$SO_2$**

ECLIPSE v5 emissions

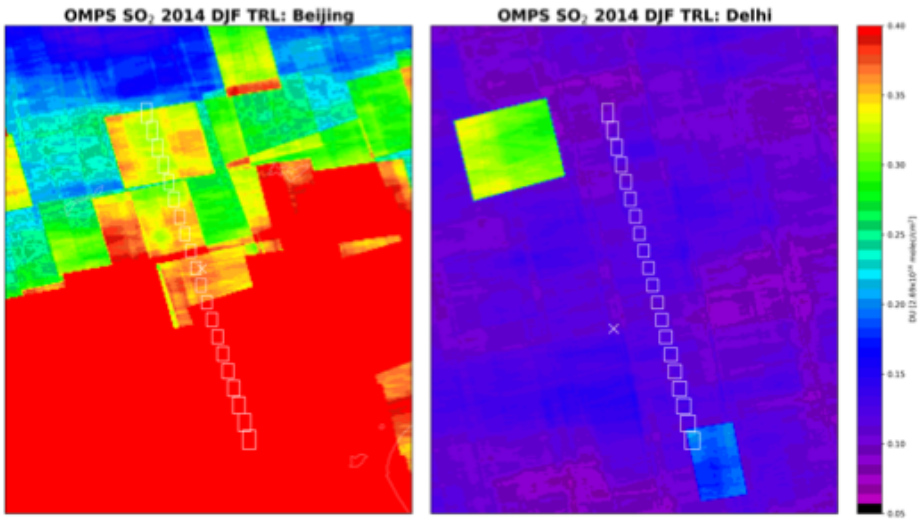
# OMPS $NO_2$ over Beijing and Delhi



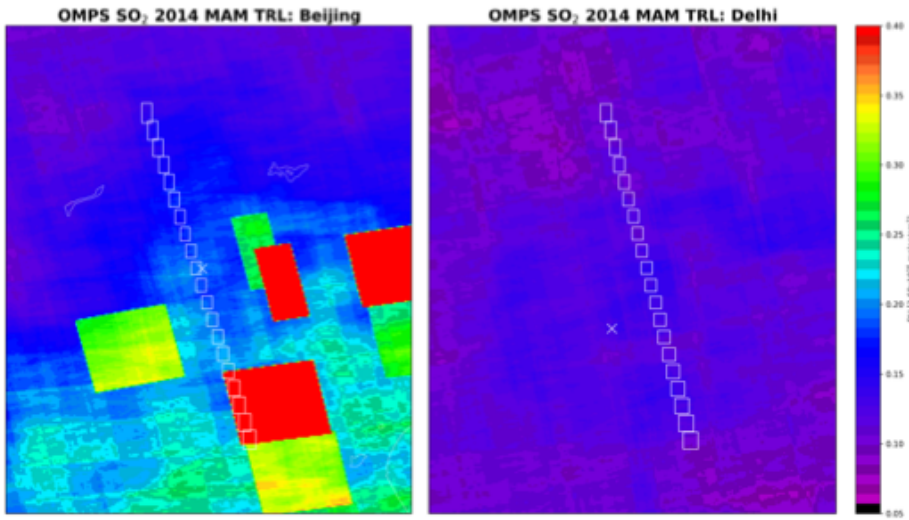

**DJF** **MAM**

- 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

# $SO_2$ over Beijing and Delhi



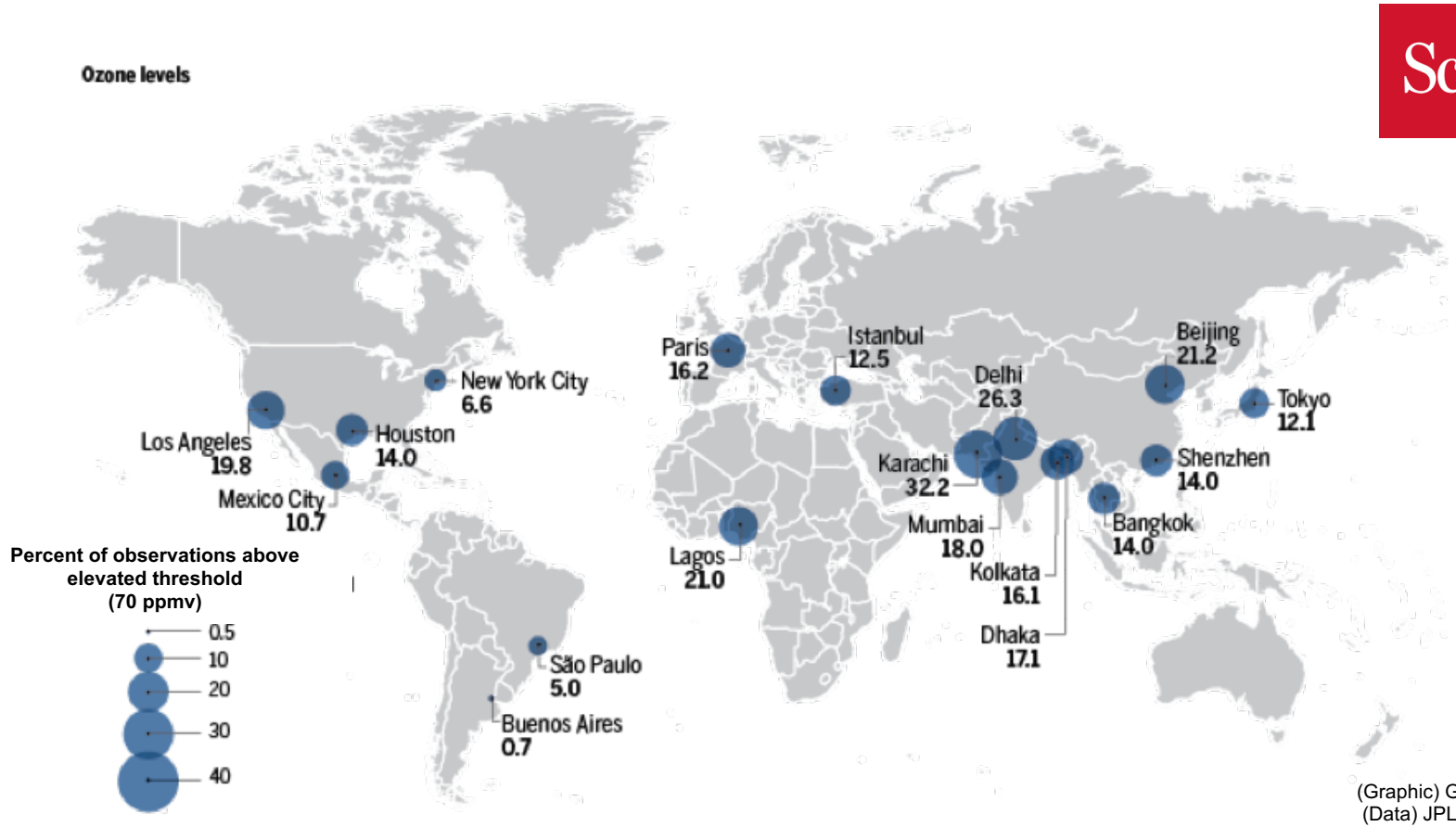

DJF




MAM

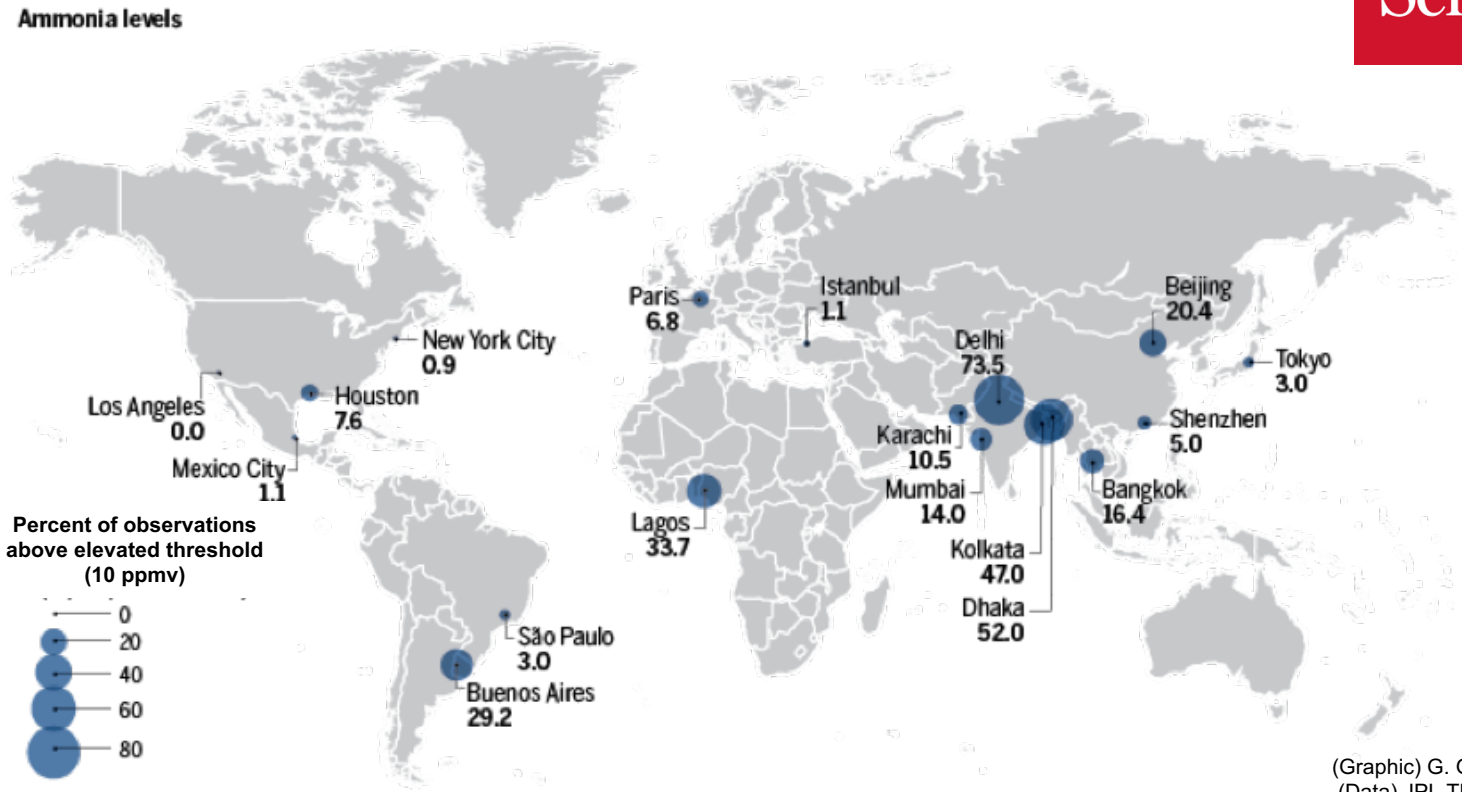
- Much higher $SO_2$ levels in Beijing winter
- Some hotspots in Delhi winter and Beijing spring
- Expected trend is decrease in Beijing and increase in Delhi

# Global view – $O_3$




(Graphic) G. Grullón/Science;
(Data) JPL TES Science Team

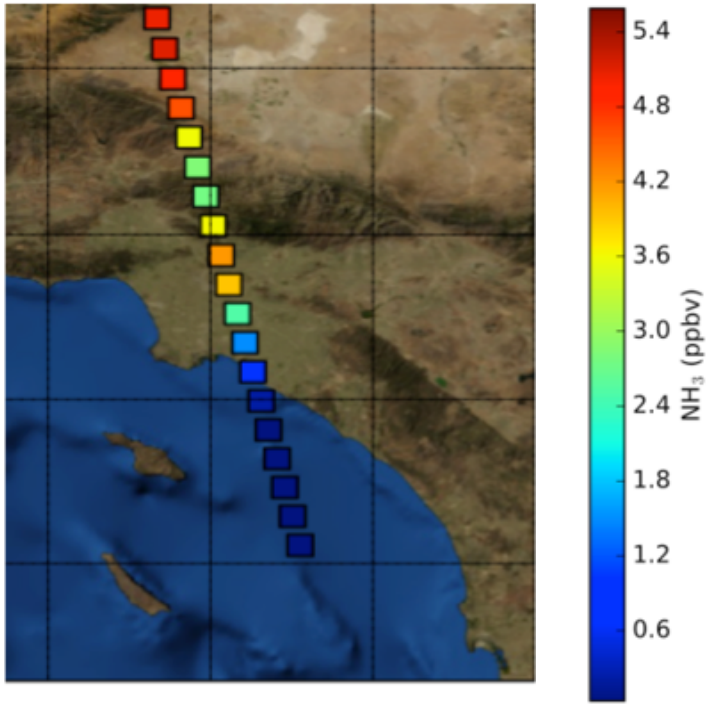
# Global view – $NH_3$



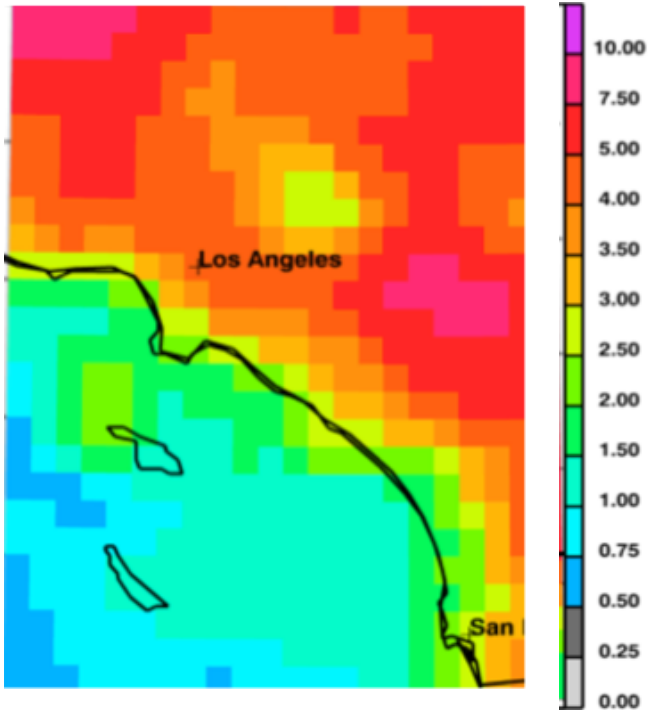

(Graphic) G. Grullón/Science;
(Data) JPL TES Science Team

# And now CrIS $NH_3$

TES (JJA average)




CrIS (July mean)

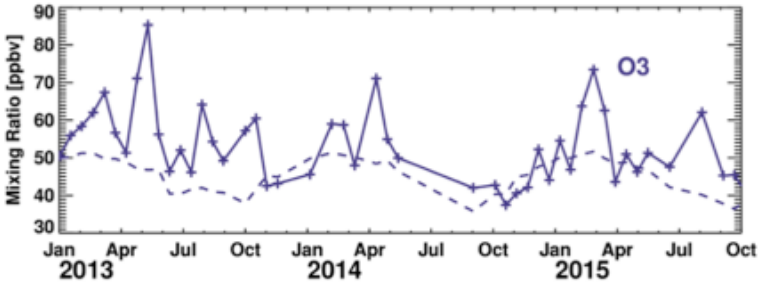


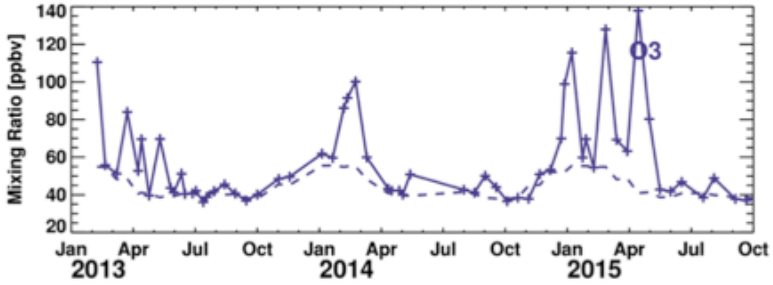
# Summary

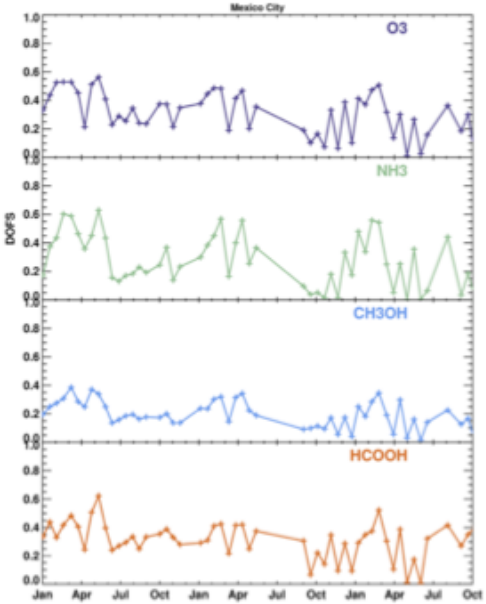
- TES has processed data from January 2013 to March 2016 over 19 megacities
- Data are closely spaced (12 km) and are taken approximately every two weeks
- Species measured: $O_3$, $CH_4$, $NH_3$, $CH_3OH$, HCOOH, HDO, PAN, $CO_2$
- Data point to influences of biomass burning and other pollution sources
- 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

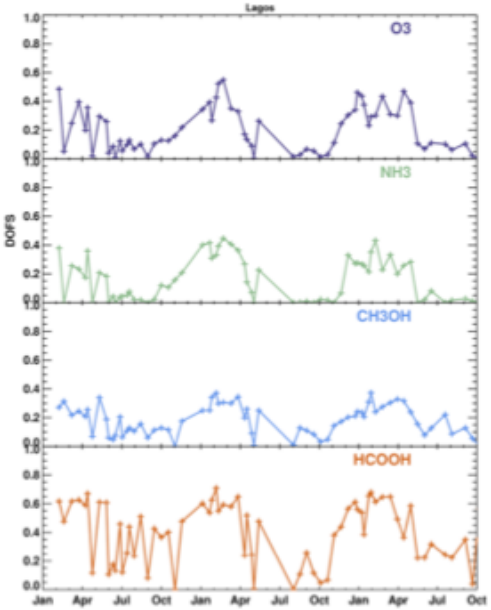
| City | Lat | Lon |
|---|---|---|
| Bangkok | 13.6383 | 100.304 |
| Beijing | 39.8543 | 116.386 |
| Buenos Aires | -34.7112 | -58.9112 |
| Delhi | 28.957 | 77.4496 |
| Dhaka | 23.6374 | 90.1974 |
| Houston | 29.7203 | -95.2691 |
| Istanbul | 40.9605 | 29.1336 |
| Karachi | 24.6877 | 66.7348 |
| Kolkata | 22.5168 | 88.4081 |
| Lagos | 6.57795 | 3.25456 |
| Los Angeles | 34.0724 | -118.146 |
| MexicoCity | 19.1627 | -99.2384 |
| Mumbai | 18.8821 | 72.8437 |
| New York City | 40.7045 | -73.9673 |
| Paris | 48.8499 | 2.37268 |
| Sao Paulo | -23.5372 | -46.6846 |
| Shenzhen | 22.3653 | 113.674 |
| Tokyo | 35.5149 | 139.425 |

# Information content

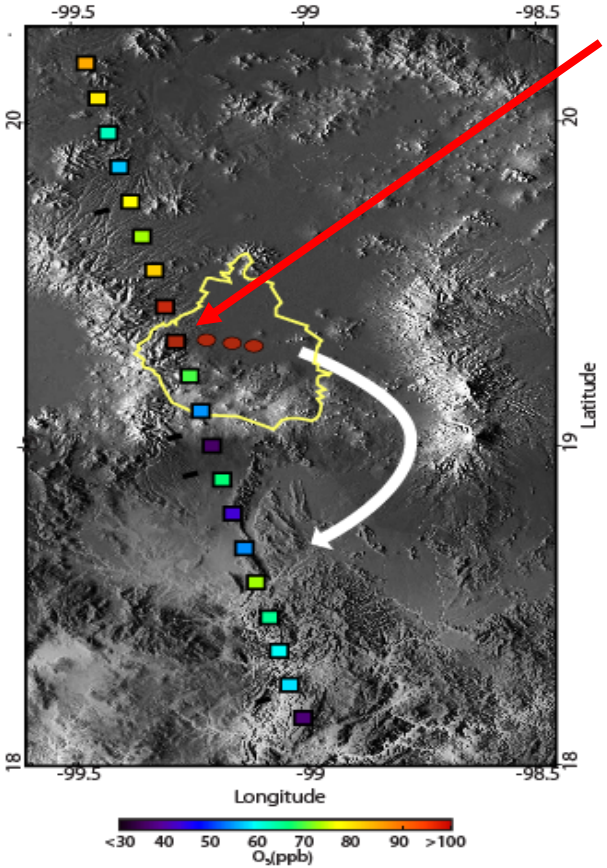


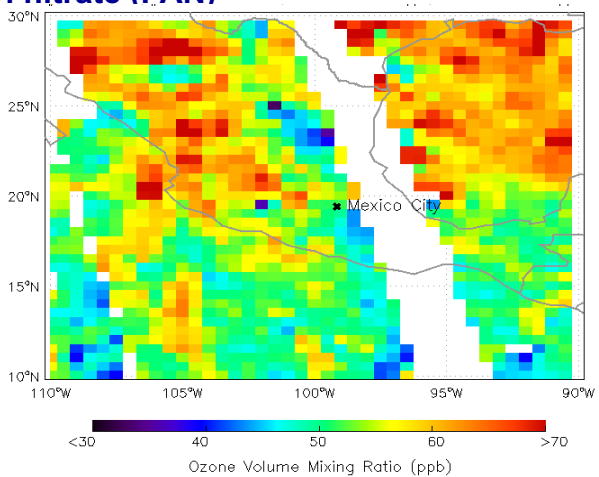
# Mexico City October pollution event

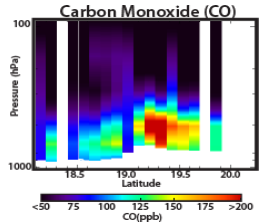


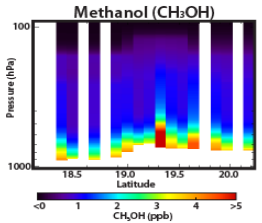

**Megacity Pollution:** The jointly retrieved TES/OMI near-surface ozone product shows very high ozone (~120 ppb) in Mexico City on a day with stable, stagnant air in the boundary layer.

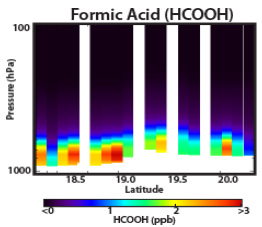
TES carbon monoxide, methanol, & formic acid (ozone precursors) are also elevated, as is the nitrogen reservoir peroxyacetyl nitrate (PAN)

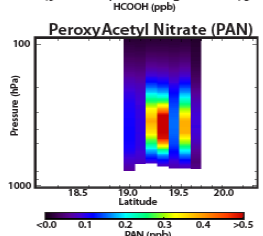
AIRS-OMI $O_3$



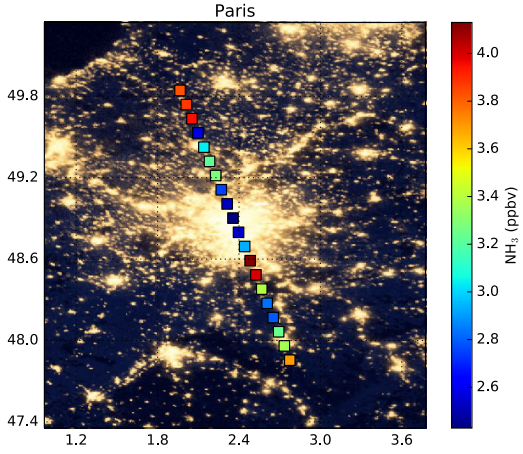



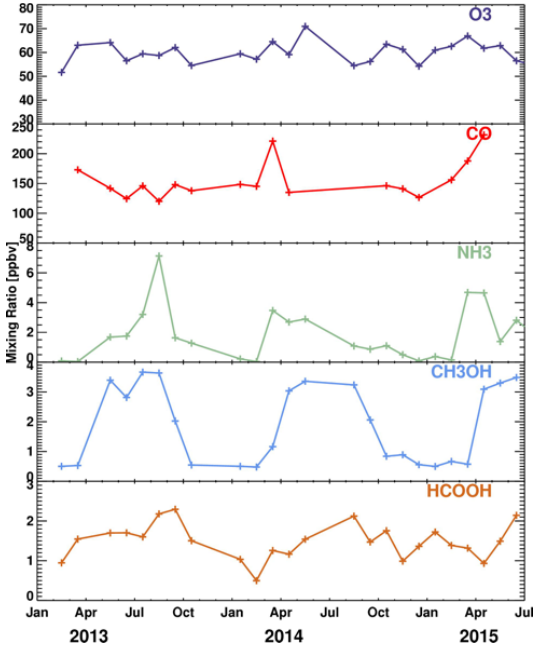



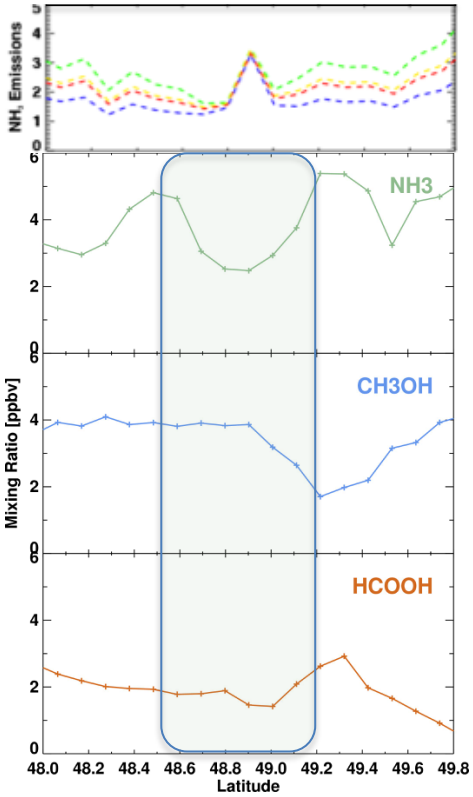



# Paris



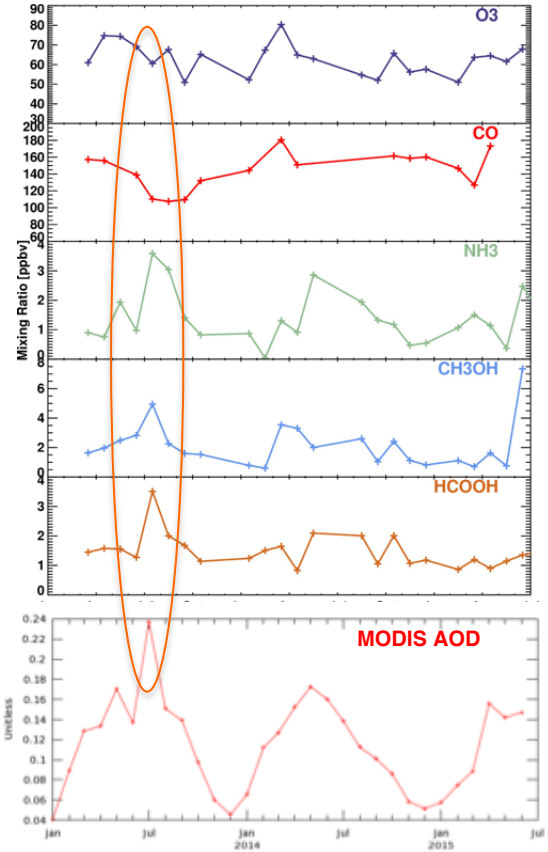




JJA Seasonal Means

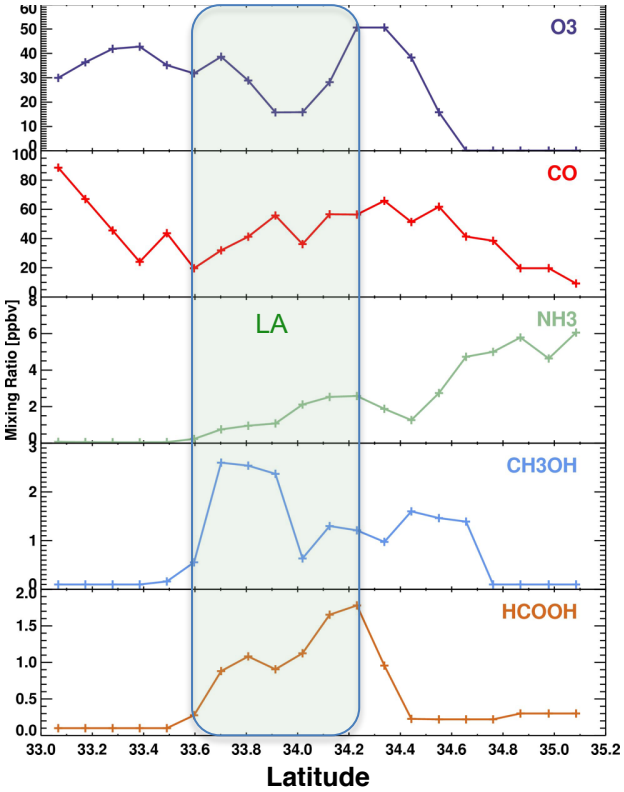
HTAP and TES disagree on source of $NH_3$

# Los Angeles puzzle - 1



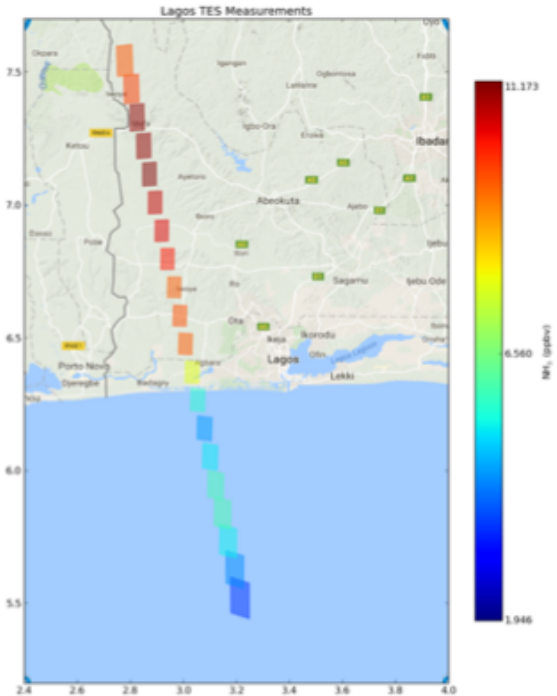

**High $NH_3$, $CH_3OH$ and HCOOH in July 2013 correlate with higher AOD, but not with CO or $O_3$**

- Early fire season
- But not from fire?
- HCOOH, $CH_3OH$ generated locally over LA
- $NH_3$ has different source

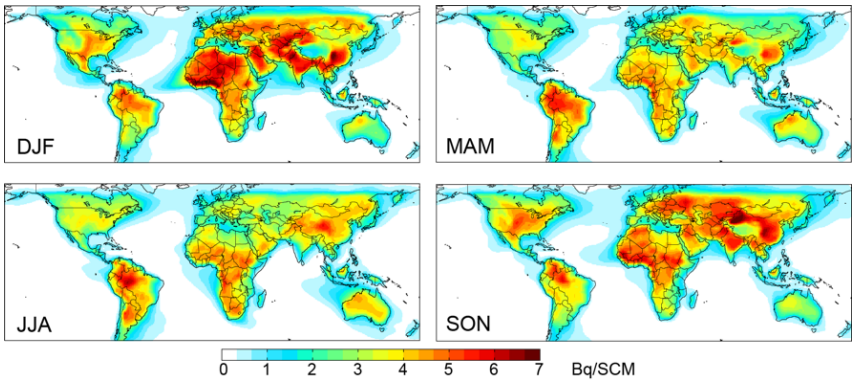



August 2013

# Western Africa- Lagos

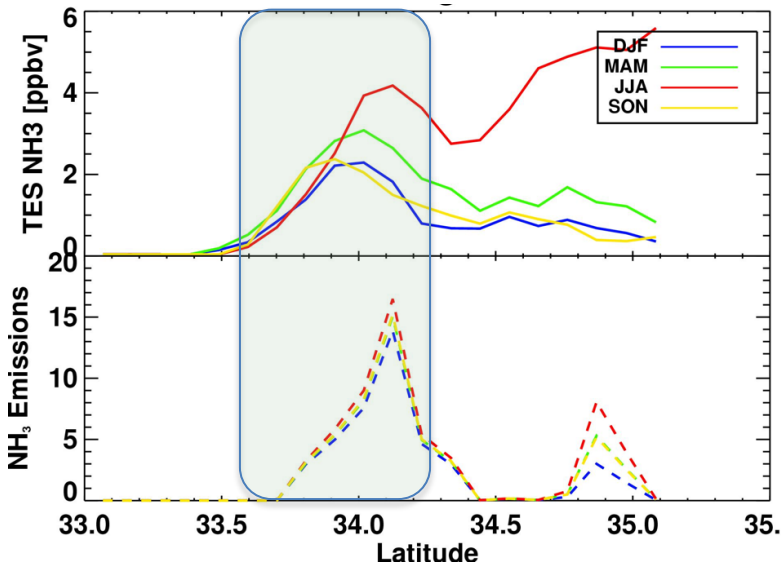



**Western Africa has one of the strongest biomass burning seasons (December-March) on Earth**




**High $^{222}$Rn in DJF due to stagnant air conditions**

# Los Angeles puzzle - 2




**TES $NH_3$ and HTAP emissions peak within city**

**High JJA TES peak north of the city**

**→ HTAP underestimates $NH_3$ emissions here**

**TES JJA $NH_3$transect**