Peroxyacetyl Nitrate (PAN) from TES: A new view into ozone chemistry

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ARCTAS Science Team

ROSES Aura Science Team funding

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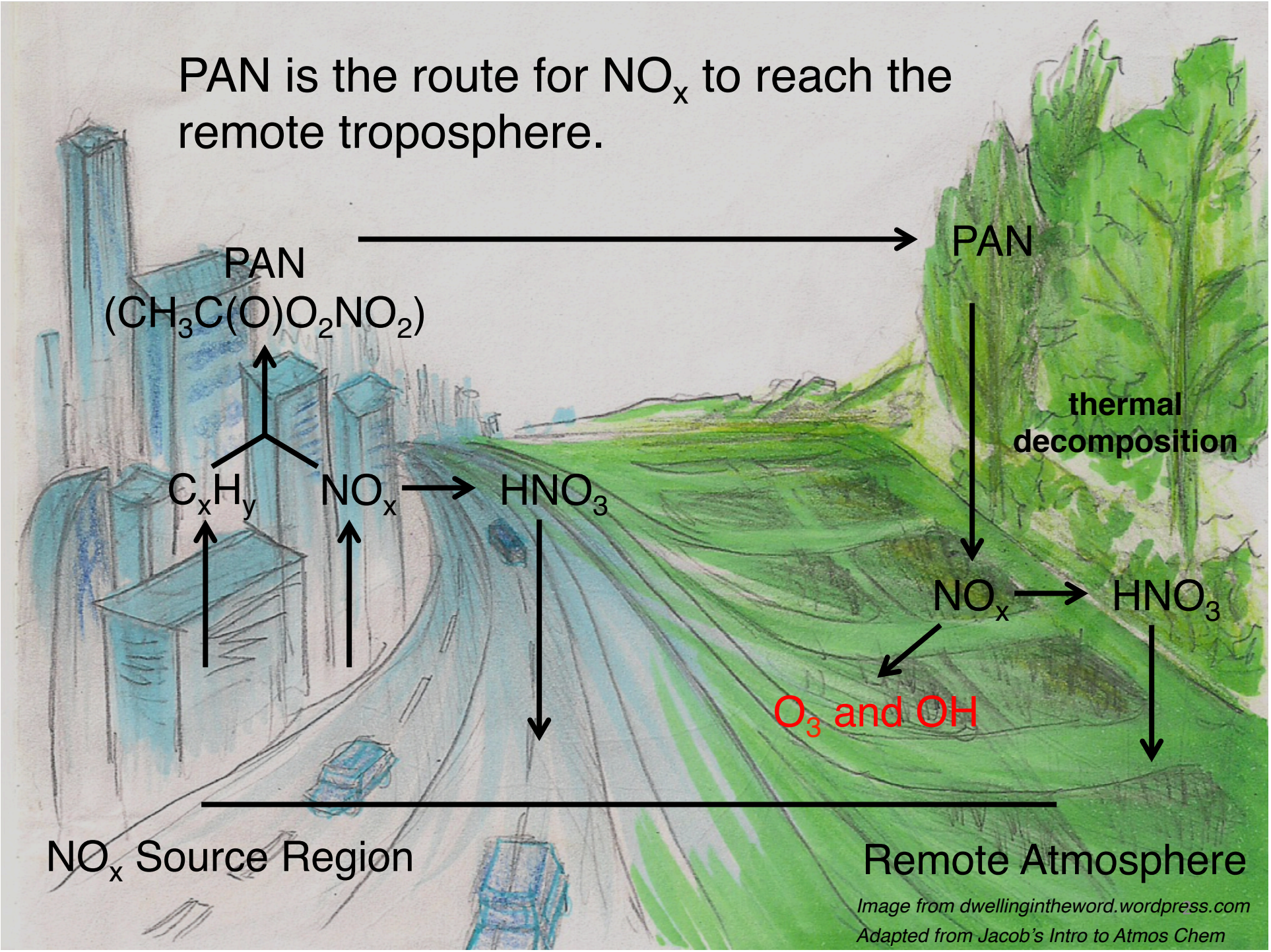
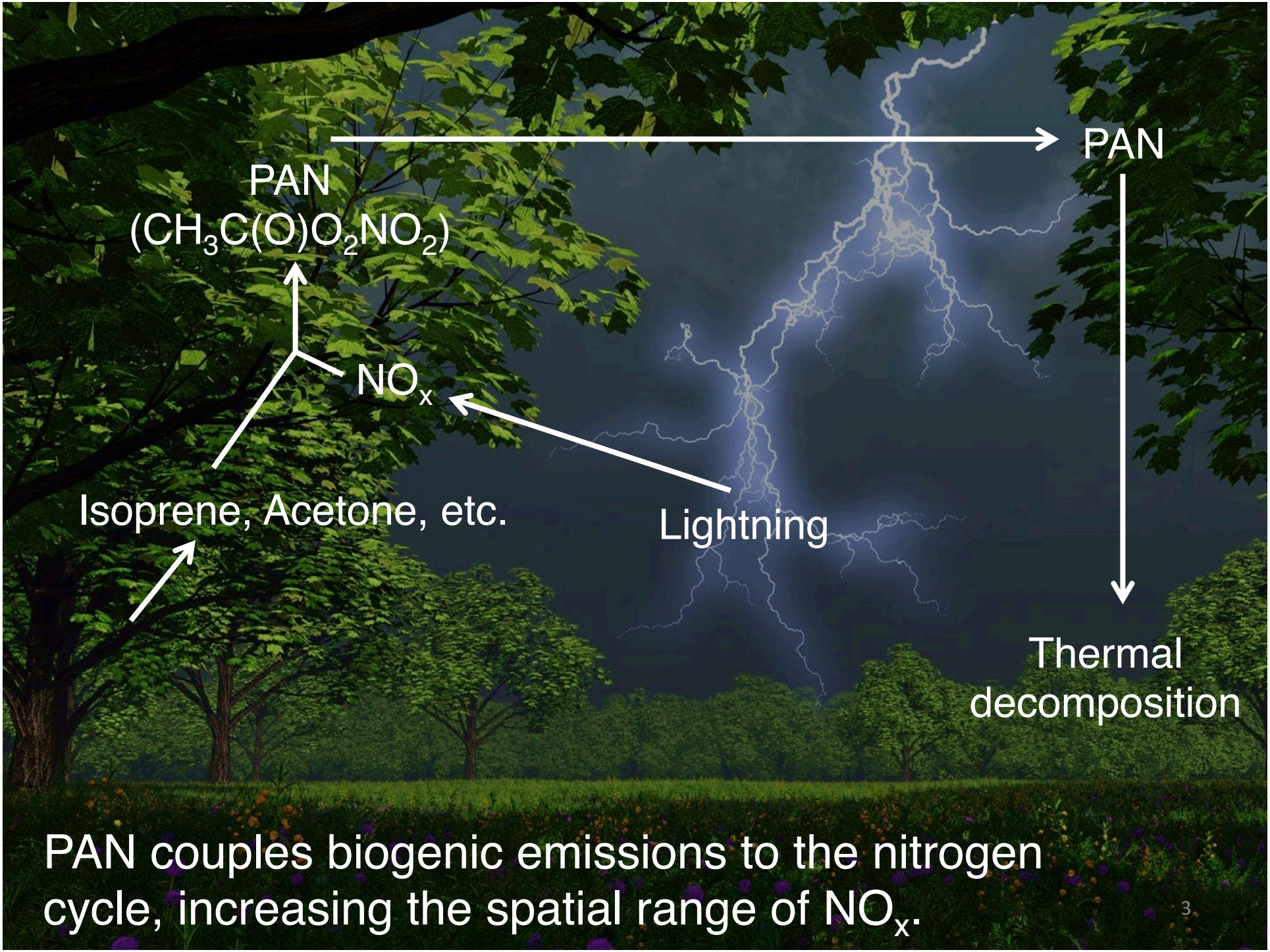


Image from dwellingintheword.wordpress.com

Adapted from Jacob's Intro to Atmos Chem



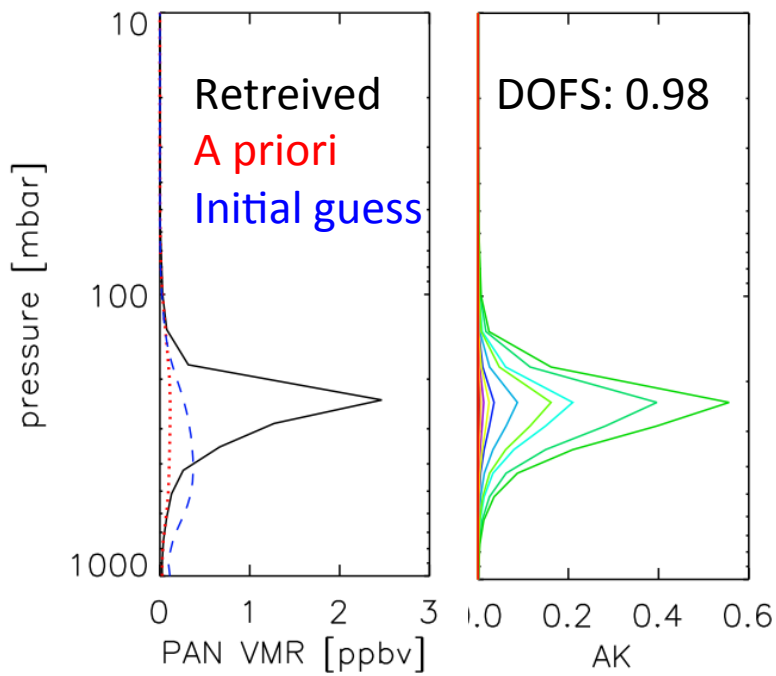
PAN couples biogenic emissions to the nitrogen cycle, increasing the spatial range of NO_x.

PAN extends the air quality impacts of fires.

Photos of High Park Fire from CNN

TES PAN sensitivity

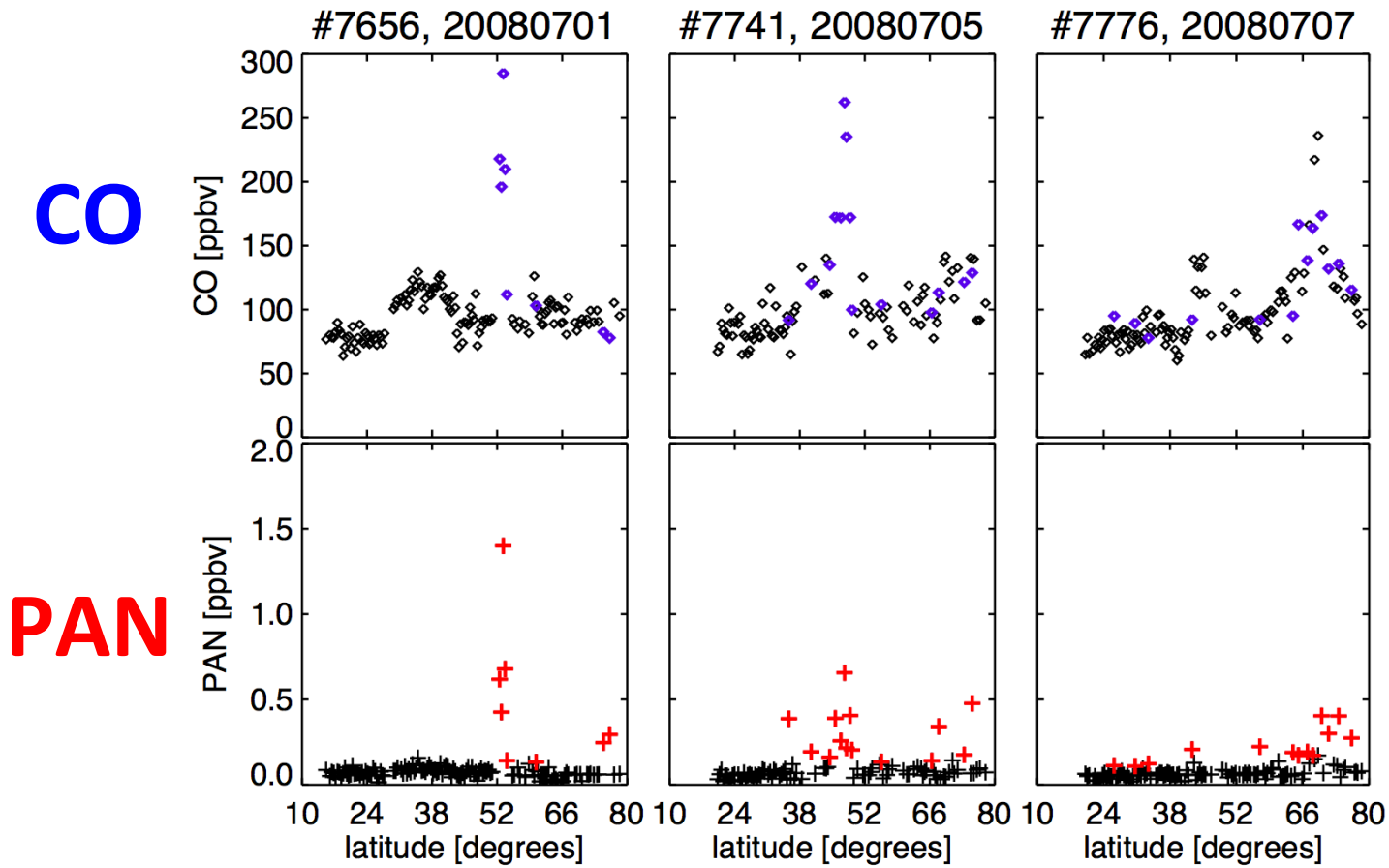
- **Sensitivity:**
  - Mainly mid-upper troposphere
  - **DOFS < 1.0**
- Limit of detectability:
  - Individual TES footprint
    - ~0.2 ppbv
    - **TES only sees elevated PAN**
  - Future:
    - **Could be reduced by co-addition of spectra**
- **Estimated errors: 30-50 %**



TES observation of PAN in a boreal fire plume (July 2008)

First detection of PAN in TES spectra: **Alvarado et al., Atmosphere [2011]**
Algorithm description in **Payne et al., AMTD [2014]**
PAN included in the TES v07 product release

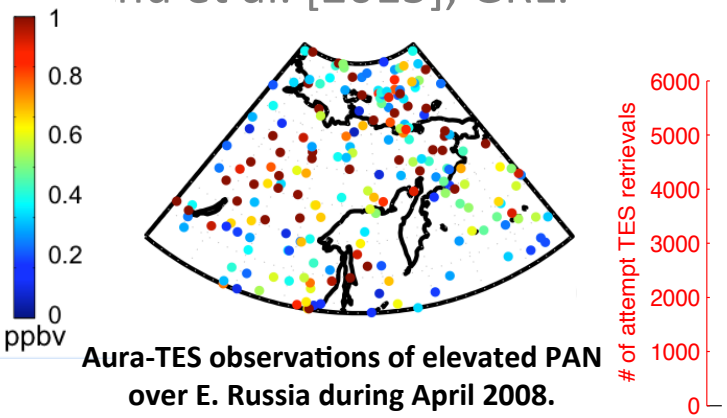
PAN in boreal fire plumes



- **From Payne et al., [2014]**
- **Examples of elevated CO and PAN in boreal burning plumes**
- **On TES special obs. made during the July 2008 phase of the ARCTAS campaign.**
- **Colored points show the cases where the DOFS was greater than 0.6 for the PAN retrieval.**

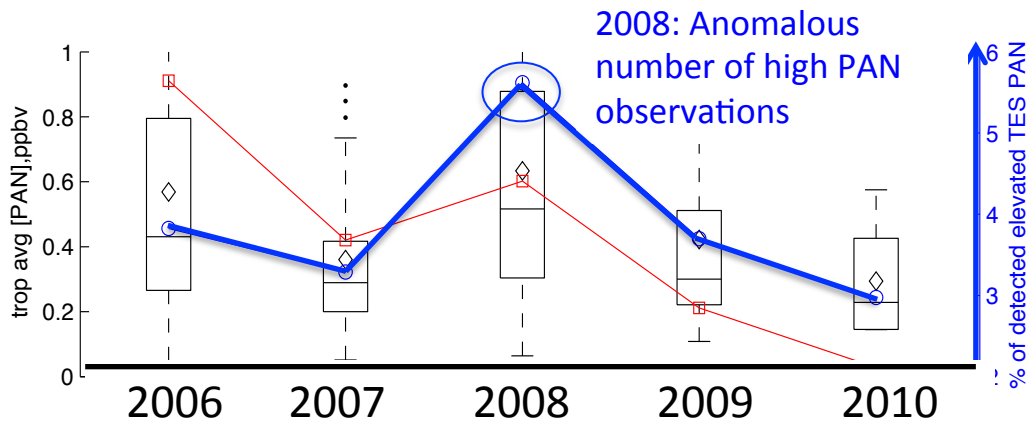
Springtime fires: Interannual variability in PAN over Northern Eurasia

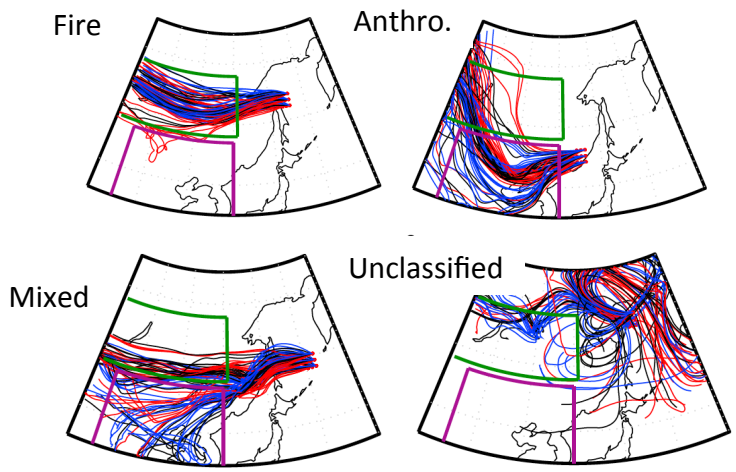
- Zhu et al. [2015], GRL:



Aura-TES observations of elevated PAN over E. Russia during April 2008.

Interannual variability in Aura-TES PAN over E. Russia in April.





Example HYSPLIT back-trajectories from TES elevated PAN observations.

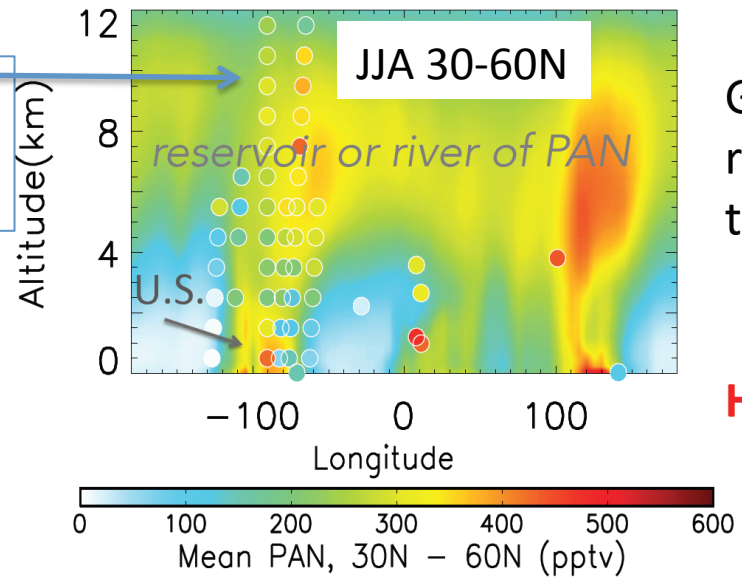
% of TES elevated PAN obs in each category for April 2008

Source category	% obs in category
Fire	**42**
Anthropogenic	9
Mixed fire/anthro.	2
Unclassified	21
Polar circulation	26

Fires in summer

see poster by Fischer et al.

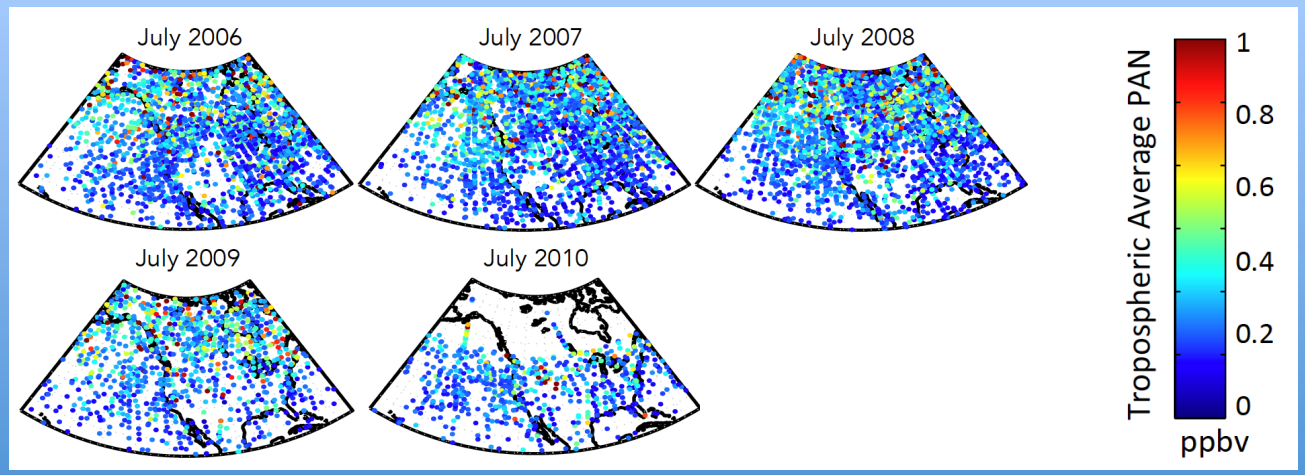
Filled circles represent aircraft data



GEOS-Chem predicts a reservoir of PAN in the mid-troposphere during summer.

How do fires contribute?

TES provides observations over multiple years



PAN from lightning

Example orbit track below shows PAN contributions from both fires and lightning.

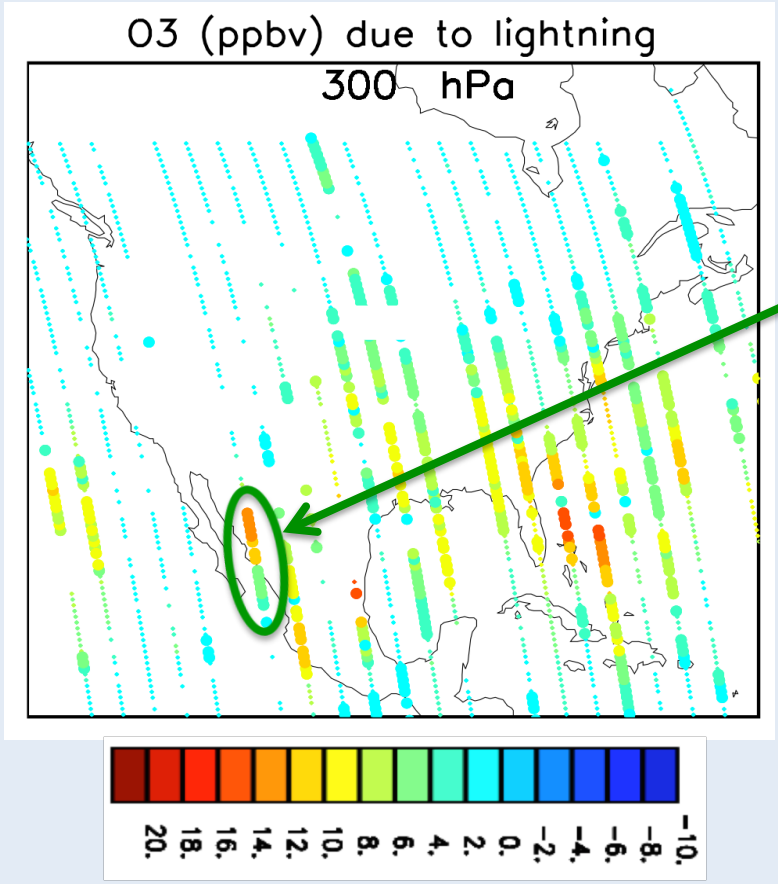
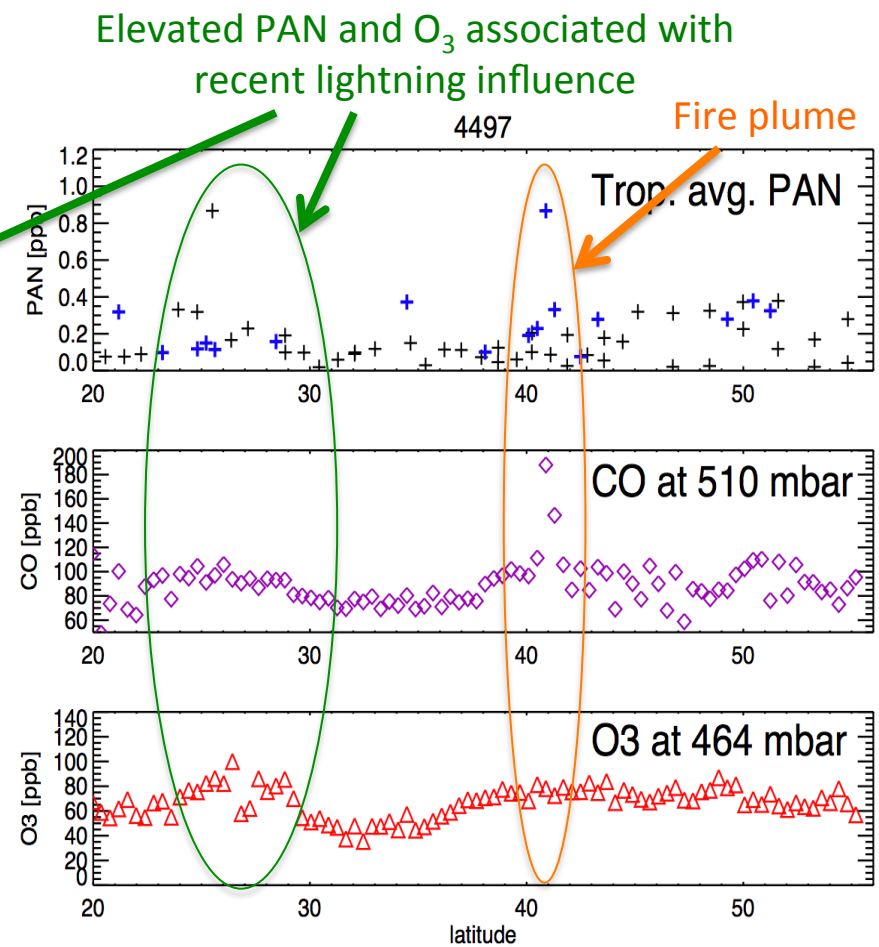


Figure from Jourdain et al. [2010] showing GEOS-Chem estimates of O_3 enhancement due to lightning for TES footprints between 4th and 18th July 2006.

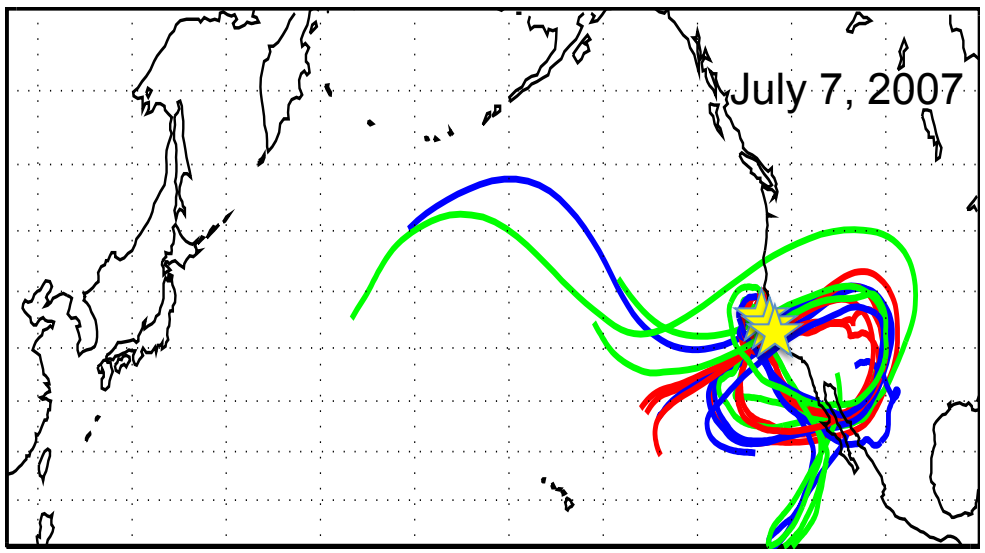
Large circles show cases recently influenced by lightning.



Influence from multiple sources

- See poster by Liye (Juliet) Zhu et al.

(a) US West Coast Recirculation

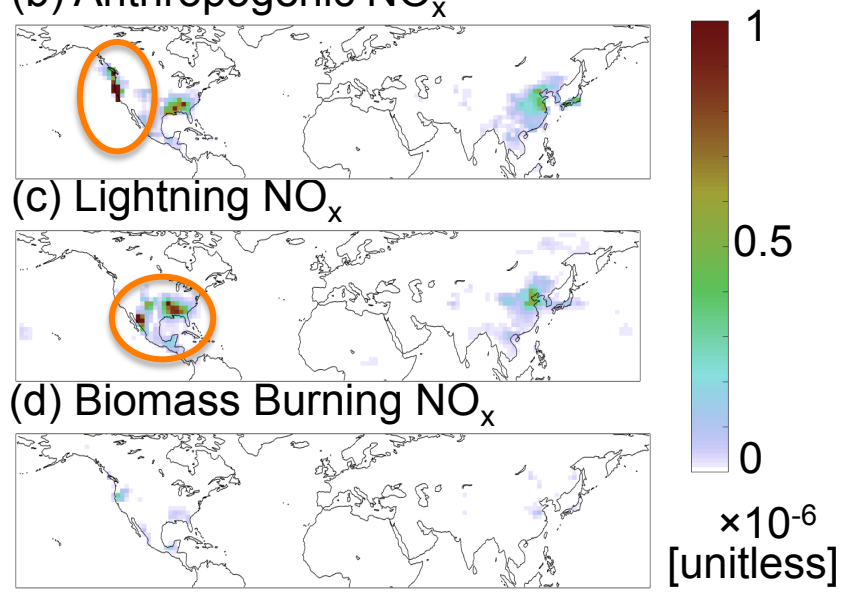


HYSPLIT back-trajectories

(b) Anthropogenic NO_x

(c) Lightning NO_x

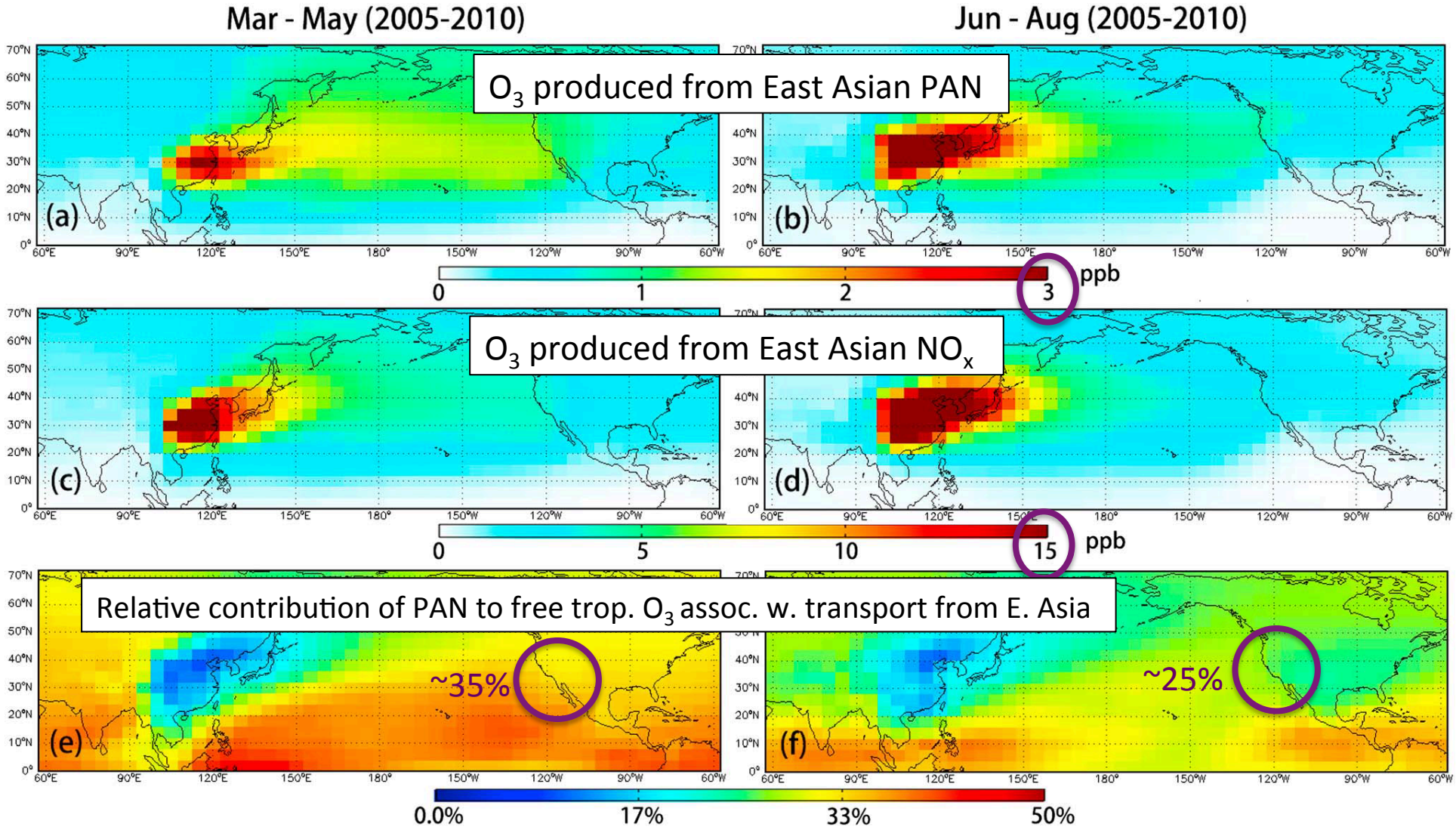
(d) Biomass Burning NO_x



Sensitivity to NO_x emissions
(calculated using GEOS-Chem adjoint)

Contribution of PAN to long-range O_3 transport

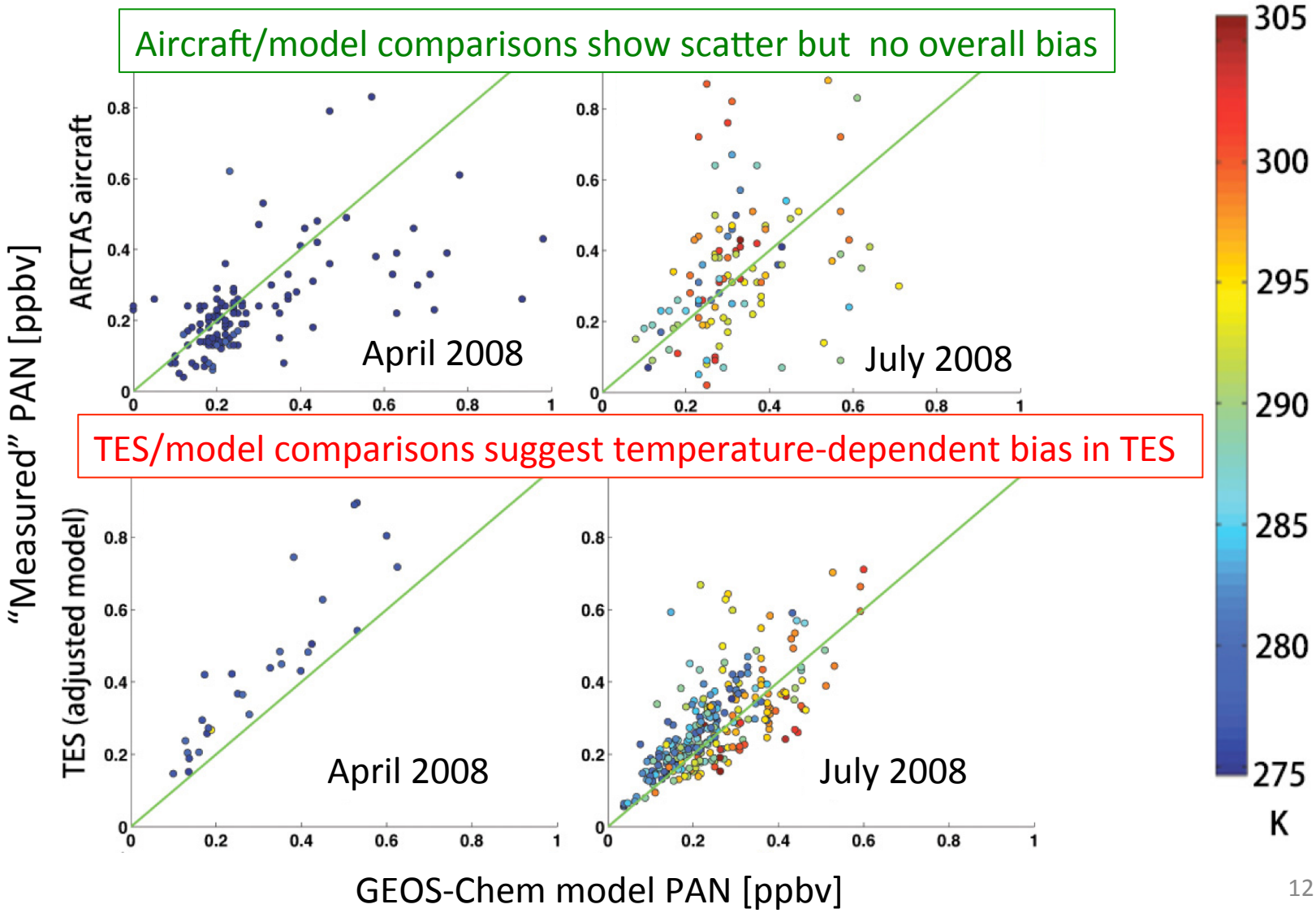
Jiang et al. [2016], JGR



Comparison to ARCTAS aircraft measurements

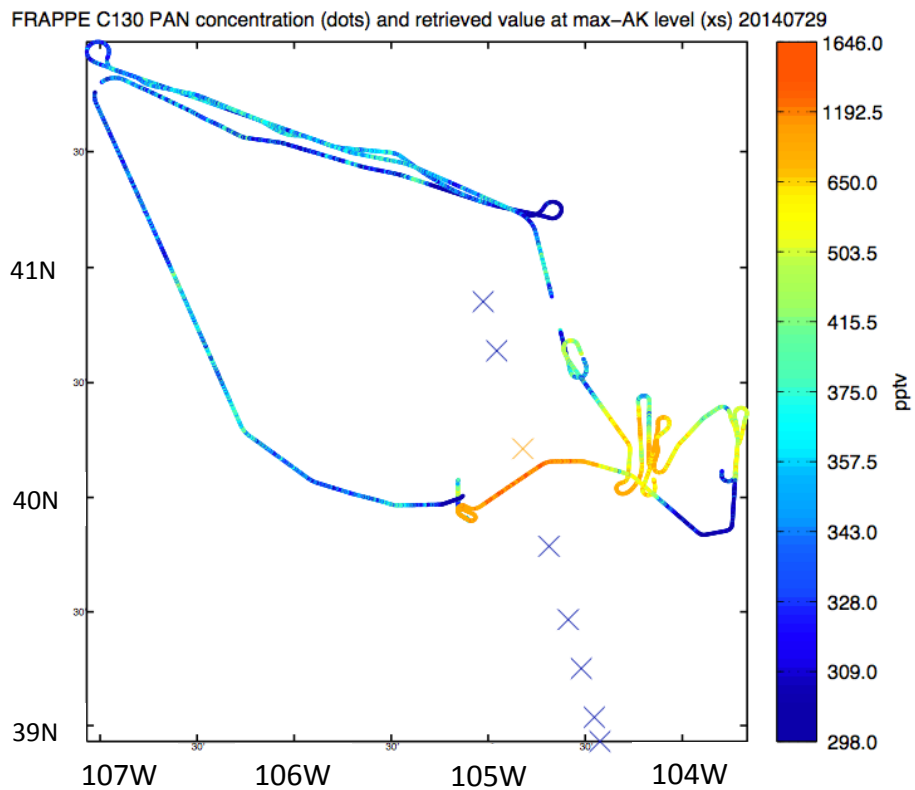
No direct TES/aircraft coincidences during ARCTAS – use GEOS-Chem as a transfer standard

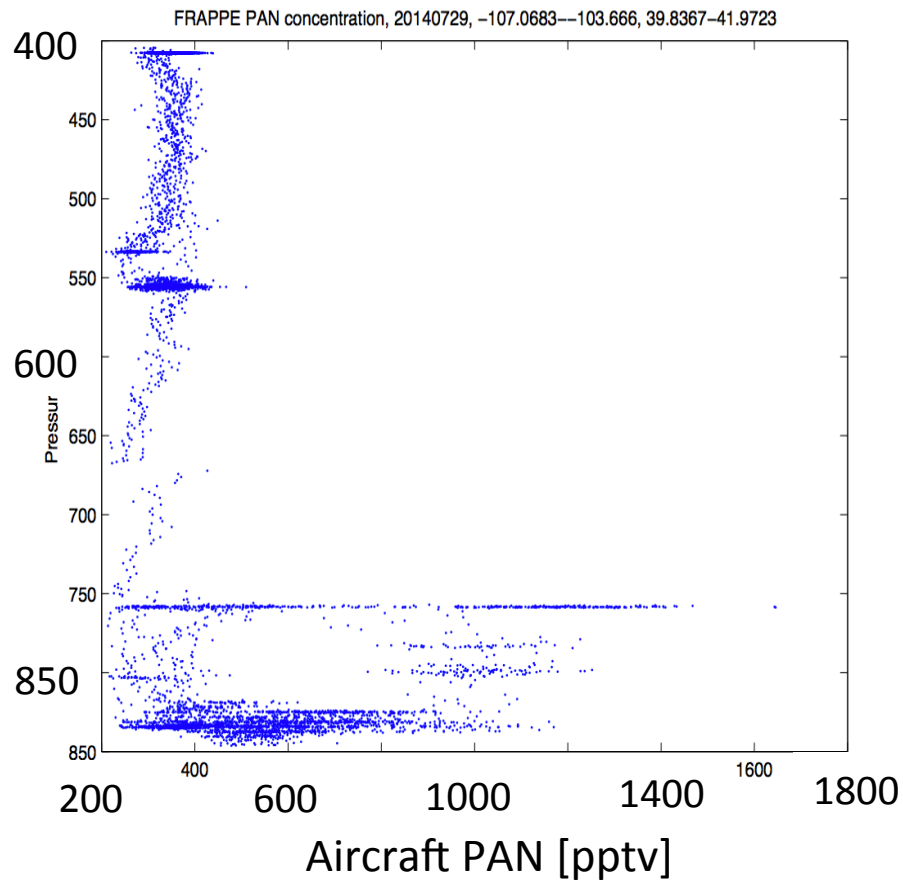
Jiang et al. [2016], JGR



TES observations during FRAPPE

Example: 29th July 2014

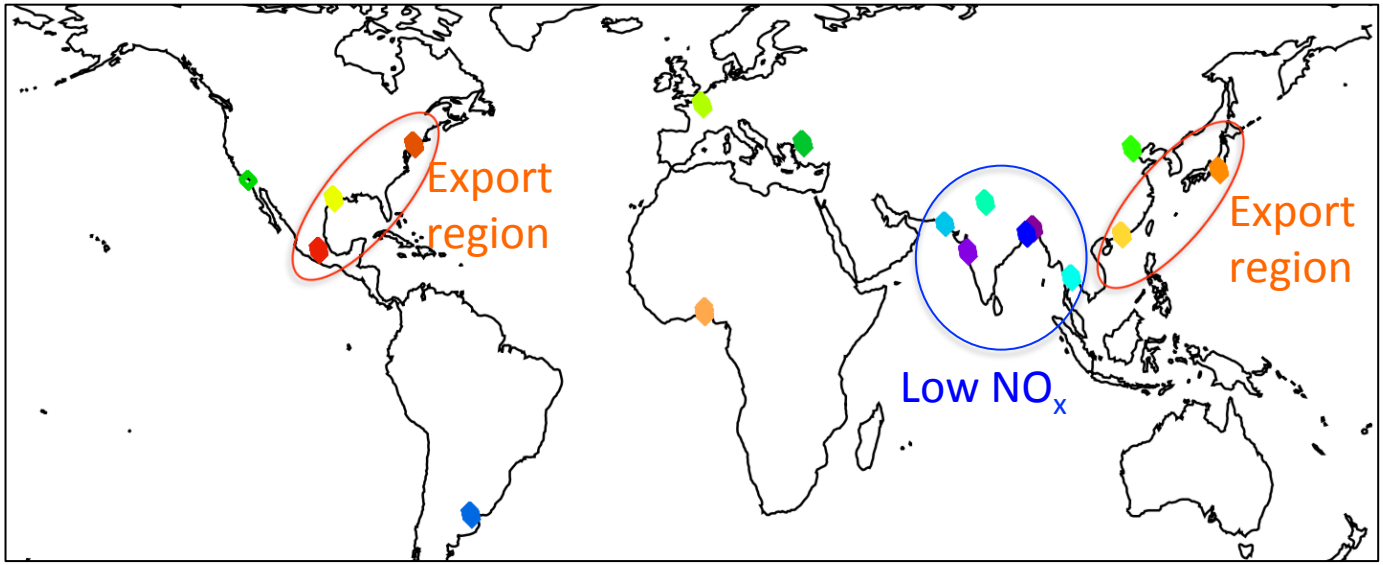




FRAPPE aircraft measurements: Lisa Kaser and Frank Flokke (NCAR)

PAN in TES megacity observations (2013-2016)

Megacities ranked by fraction of high PAN observations (red=high, blue=low)



TES PAN observations influenced by:

- Local sources (anthropogenic/biomass burning/lightning)
- Vertical transport/convection
- Long-range transport

Summary/Conclusions

- PAN plays an important role in determining the global distribution of ozone
- We show examples of PAN associated with fires, anthropogenic emissions and lightning
- TES PAN product included in the R14 (V007) release
- Limited validation so far
  - Suggests TES PAN biased high for cold regions
- See posters for more PAN results:
  - Zhu et al.
  - Fischer et al.

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- Zhu et al. (2016, in prep): PAN in the Eastern Pacific Free Troposphere: A Satellite View of the Sources, Seasonality, Interannual Variability and Timeline for Trend Detection

- Fischer et al. (2016, in prep): Summertime free tropospheric PAN over the US as observed by TES and simulated by GEOS-Chem

Back-up slides

PAN: Expected Distribution

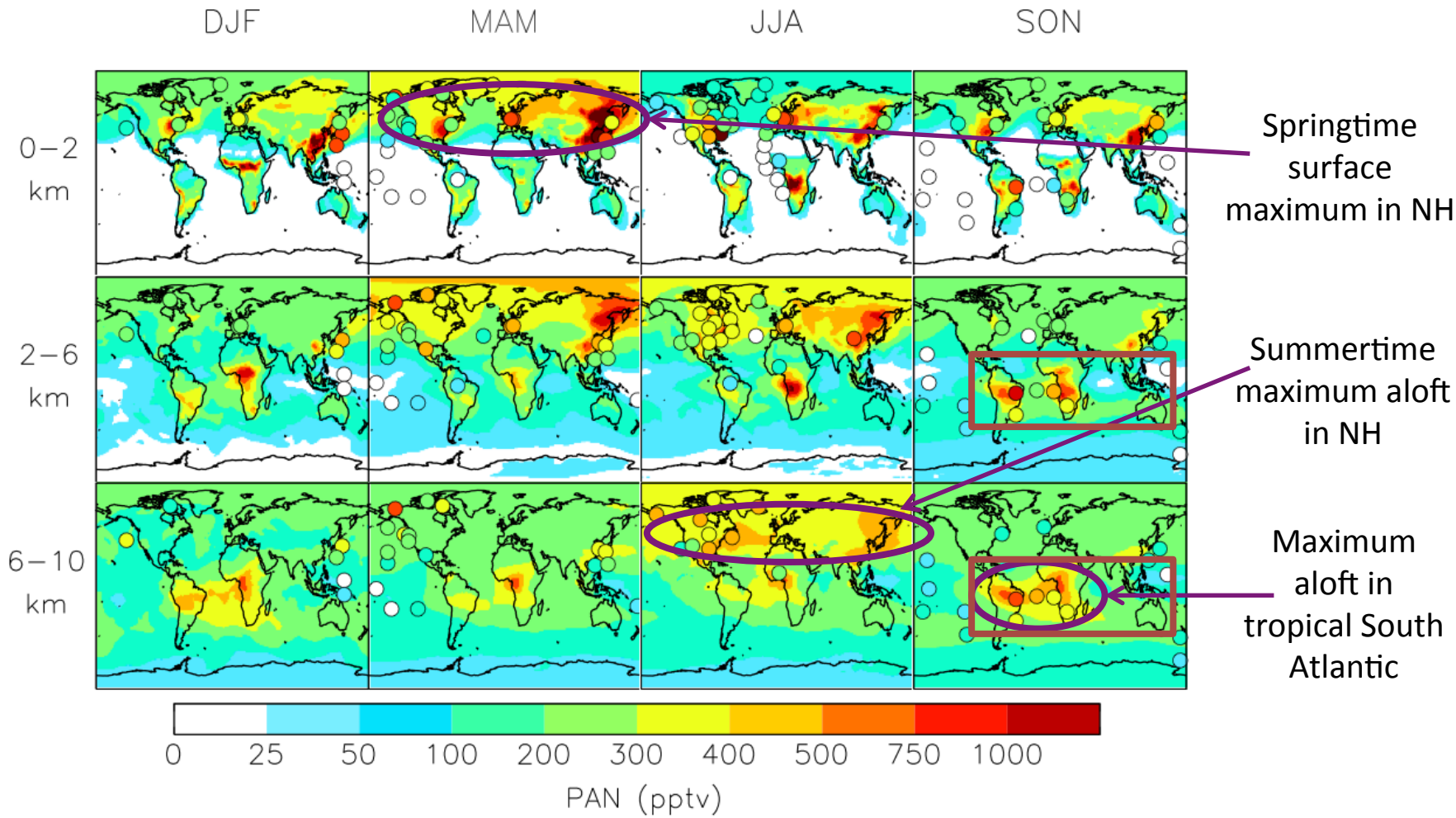

Figure from **Fischer et al., 2014** shows GEO-Chem PAN fields (for 2008).
Colored circles represent in situ measurements from aircraft campaigns (all years).