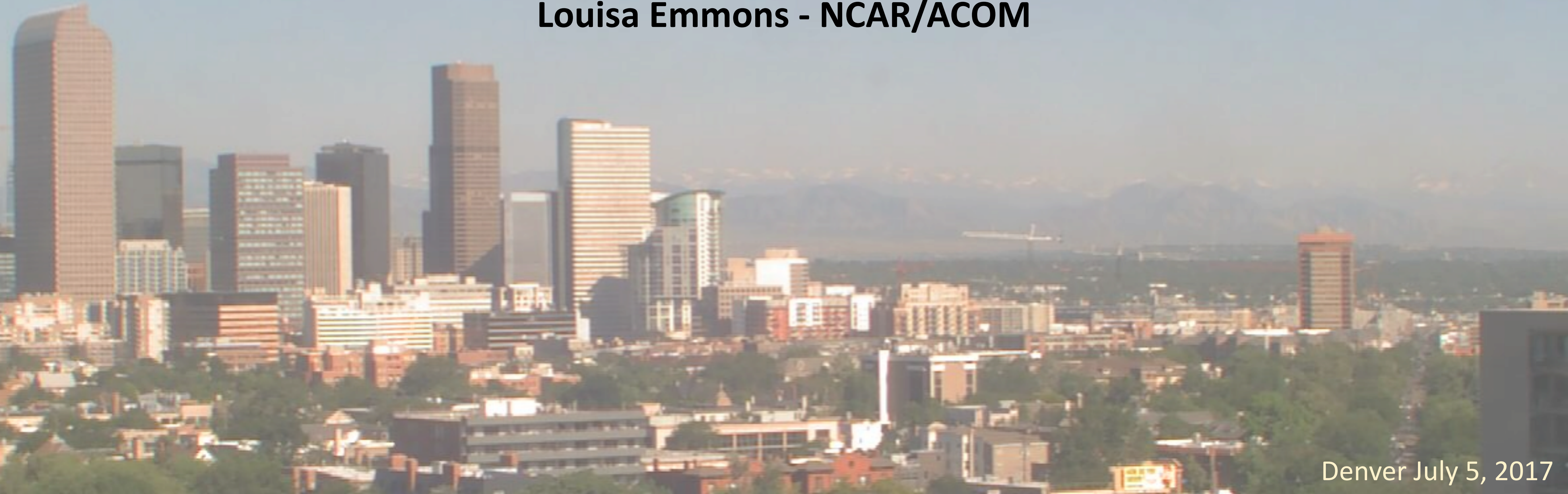
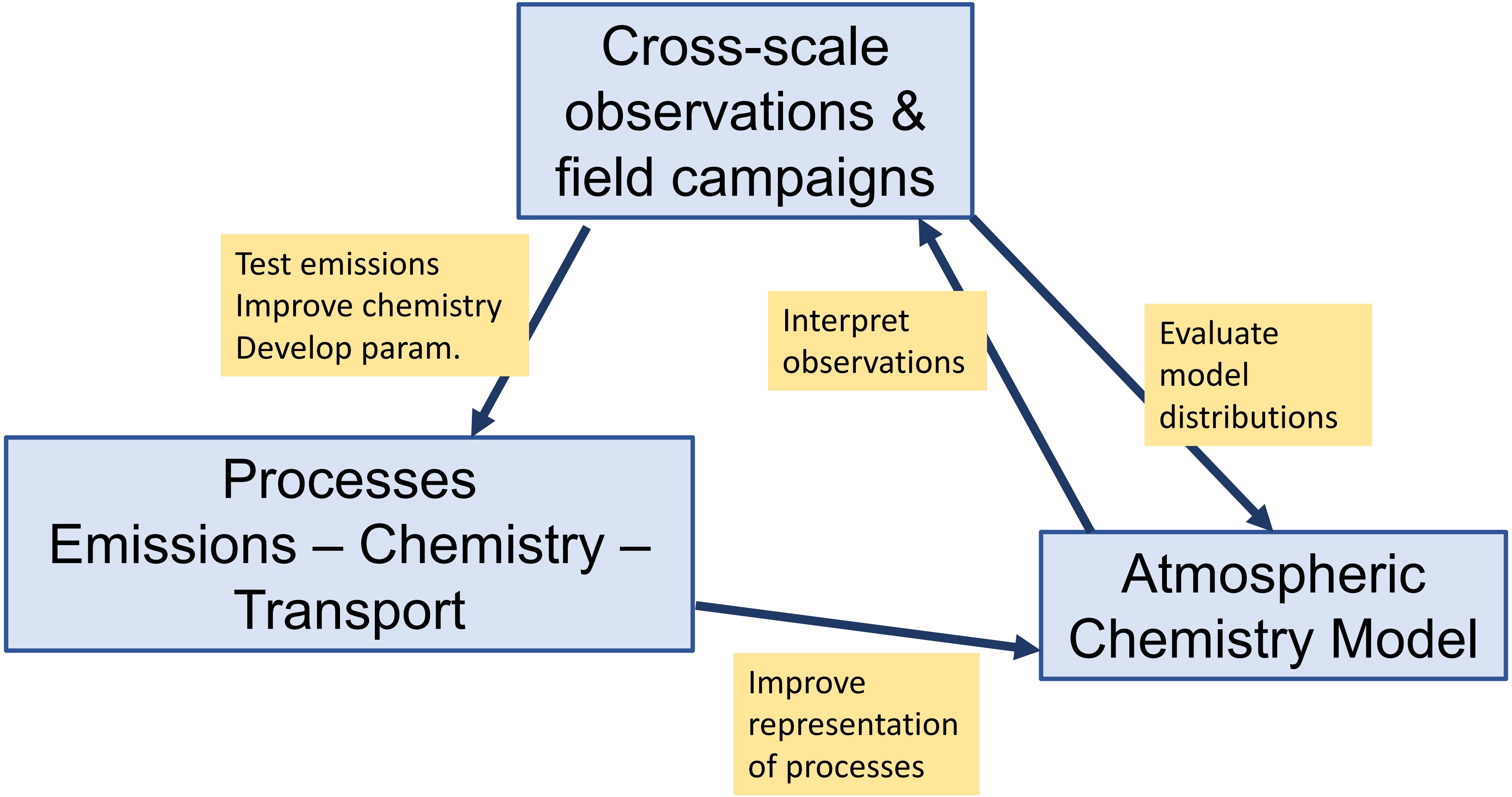
Evaluating 3D models with aircraft observations

and using models to interpret observations

Louisa Emmons - NCAR/ACOM



Denver July 5, 2017

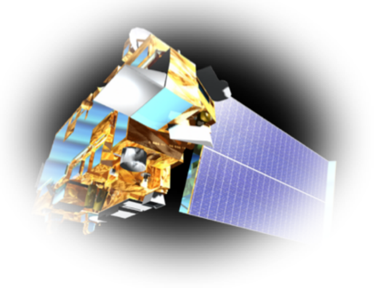

Cross-scale observations & field campaigns
Test emissions
Improve chemistry
Develop param.
Interpret observations
Evaluate model distributions
Processes
Emissions – Chemistry – Transport
Atmospheric Chemistry Model
Improve representation of processes

Aircraft field campaigns in air quality research

Aircraft field measurements deliver:

- High resolution 3-D picture of tracer distributions and the state of the atmosphere
  - Air mass evolution
  - Vertical profiles to provide link with satellite and other remote sensing data
- Large payloads can include measurements of primary and secondary pollutants, including intermediates
- A key tool for model evaluation
  - Evaluate emissions
  - Identify source contributions
  - Measure chemistry and physical transformations
- Aircraft data can be used for ground monitor evaluation
  - Provide validation for existing ground monitoring network
  - Provide input for optimal monitor placement

Aircraft field campaigns in air quality research



Aircraft field measurements do NOT deliver:

- Long term monitoring
  - Typically weak statistics
- Smaller point source characterization
  - Require simultaneous ground measurements
- Measurements very close to the ground (in populated areas and complex terrain)

  However, missed approaches can help with this in select areas

Satellites and long-term ground sites complement aircraft campaigns

Comparing models with observations - 1

- Average observations over a region (hope/assume fairly uniform, representative) and compare to model averaged over same region

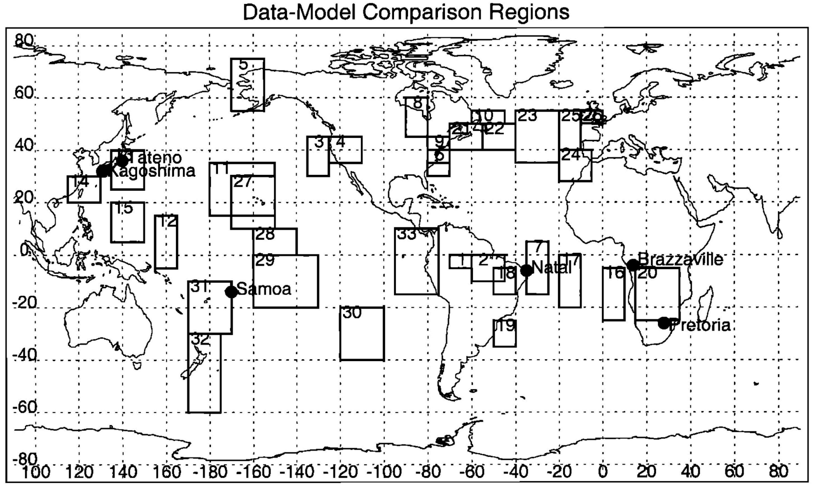


Figure 1. Map showing regions for which vertical profiles were compared. Regions are identified in Table 3. Circles show locations of ozonesondes (discussed in section 4.1).

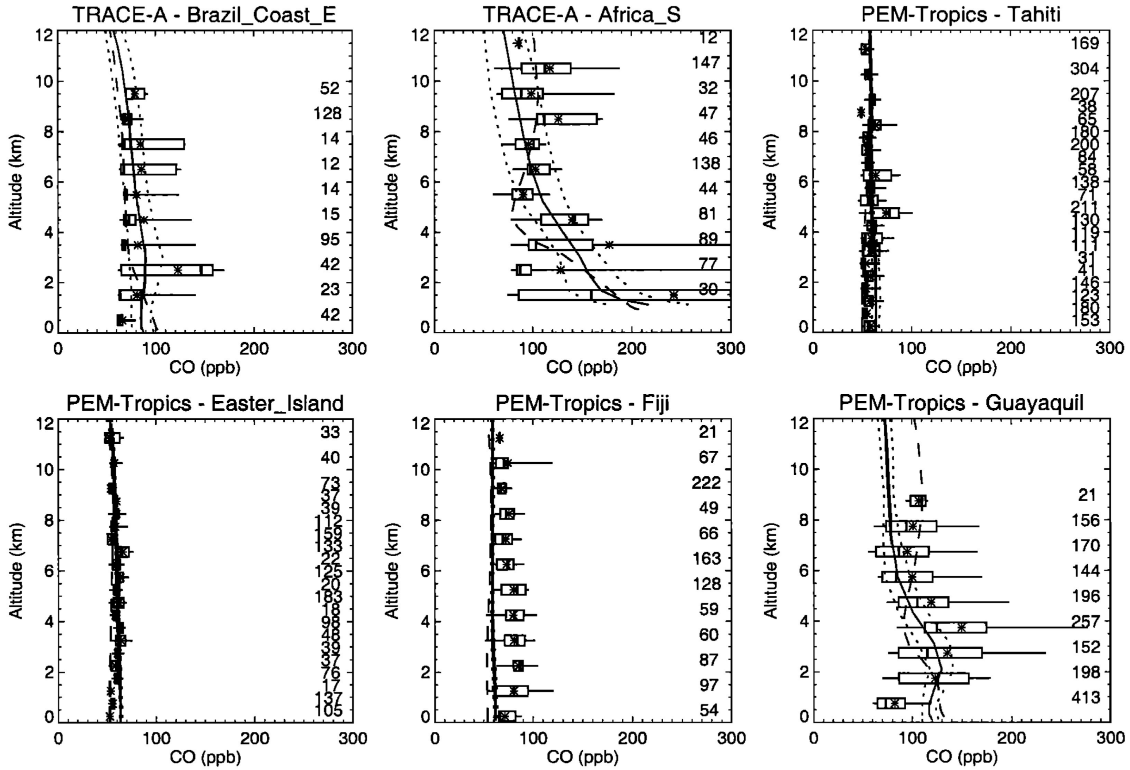


Figure 9. CO profiles for regions influenced by biomass burning.

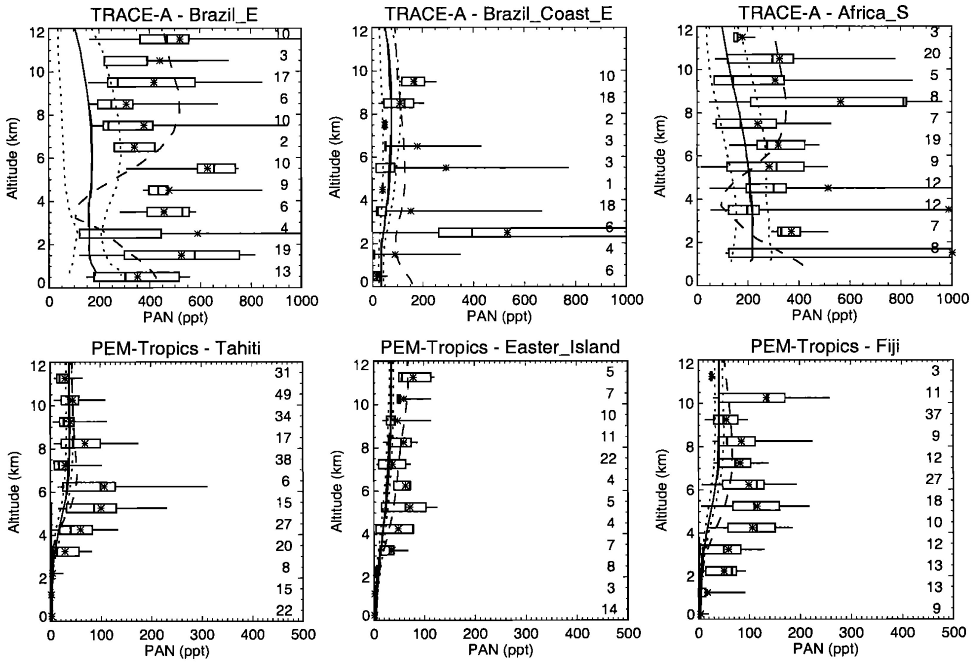
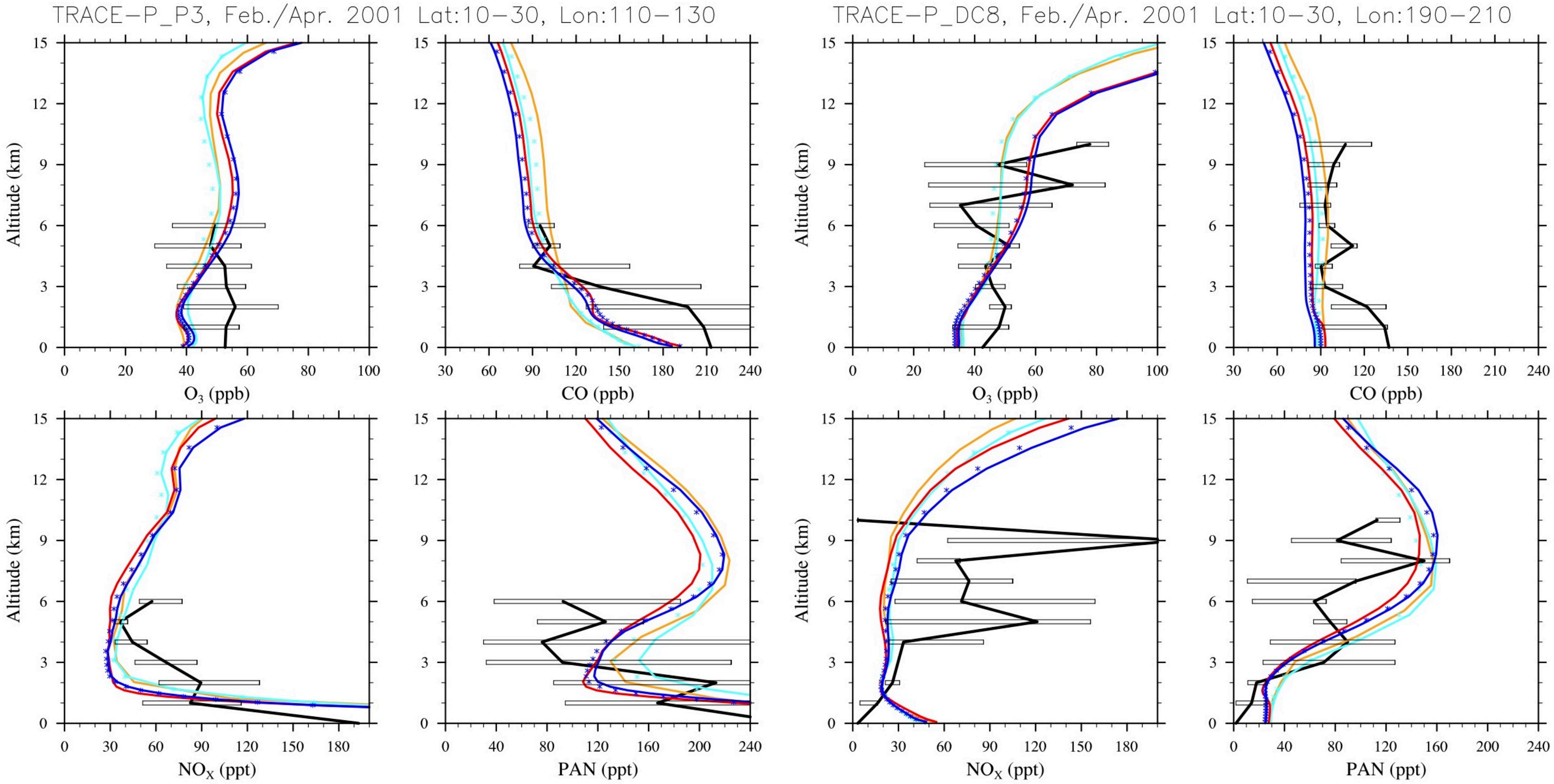


Figure 11. PAN profiles for regions influenced by biomass burning.

Emmons et al., JGR, 2000

Regional averages still used

- Standard CAM-chem evaluation diagnostics



Tilmes et al., GMD, 2015

Comparing models with observations - 2

- Average observations to model grid

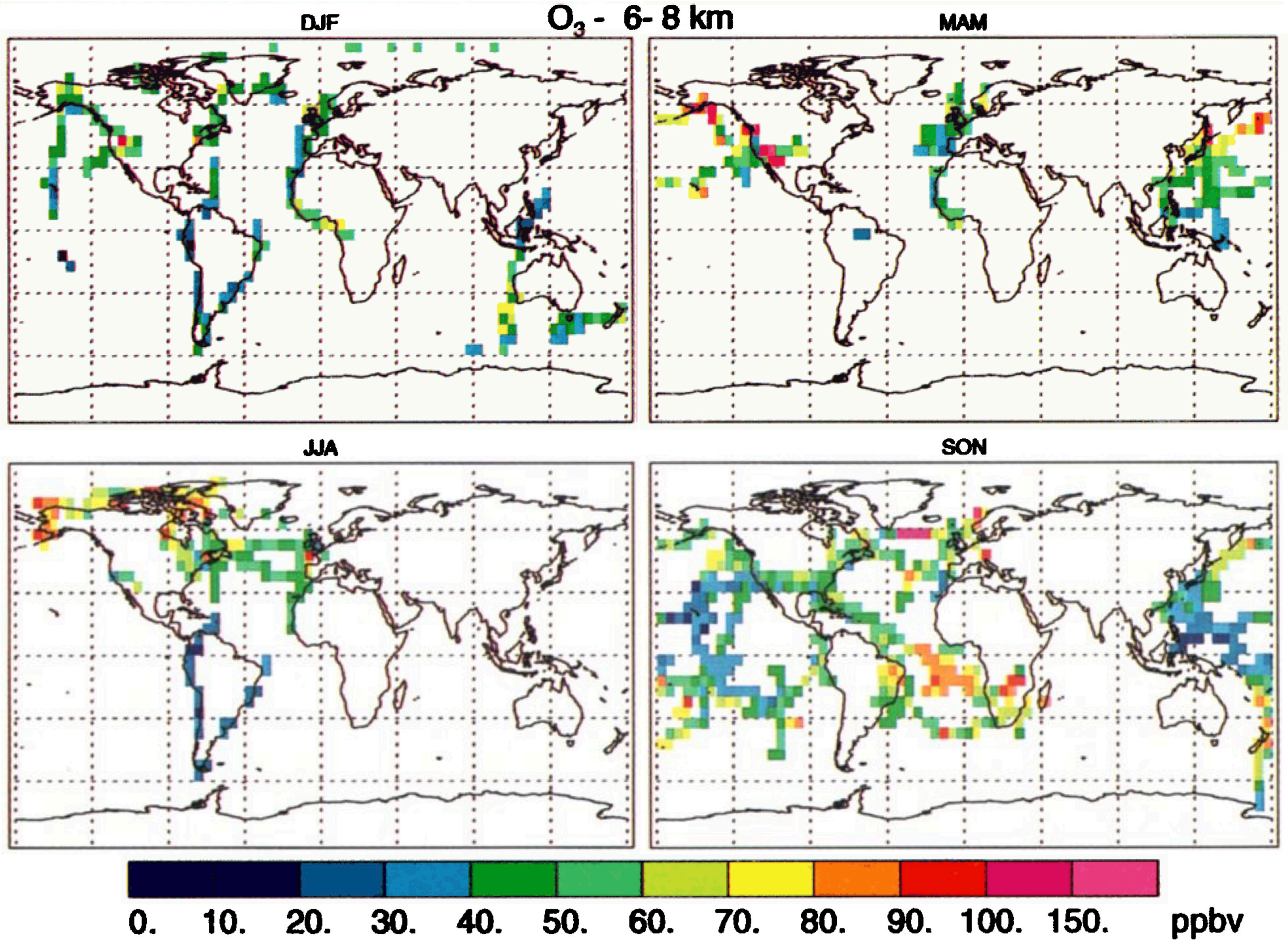


Plate 1. O_3 data composites for 2–4 km (top four panels) and 6–8 km (bottom four panels). The observations are sorted into four seasons.

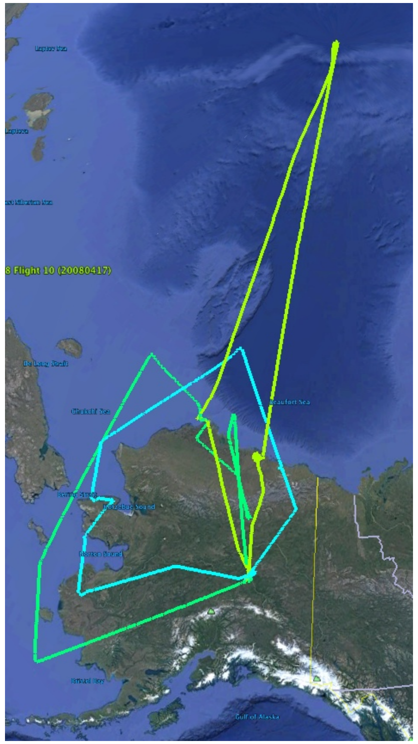
Gridding observations is really only reasonable if the observations are representative of the whole box:

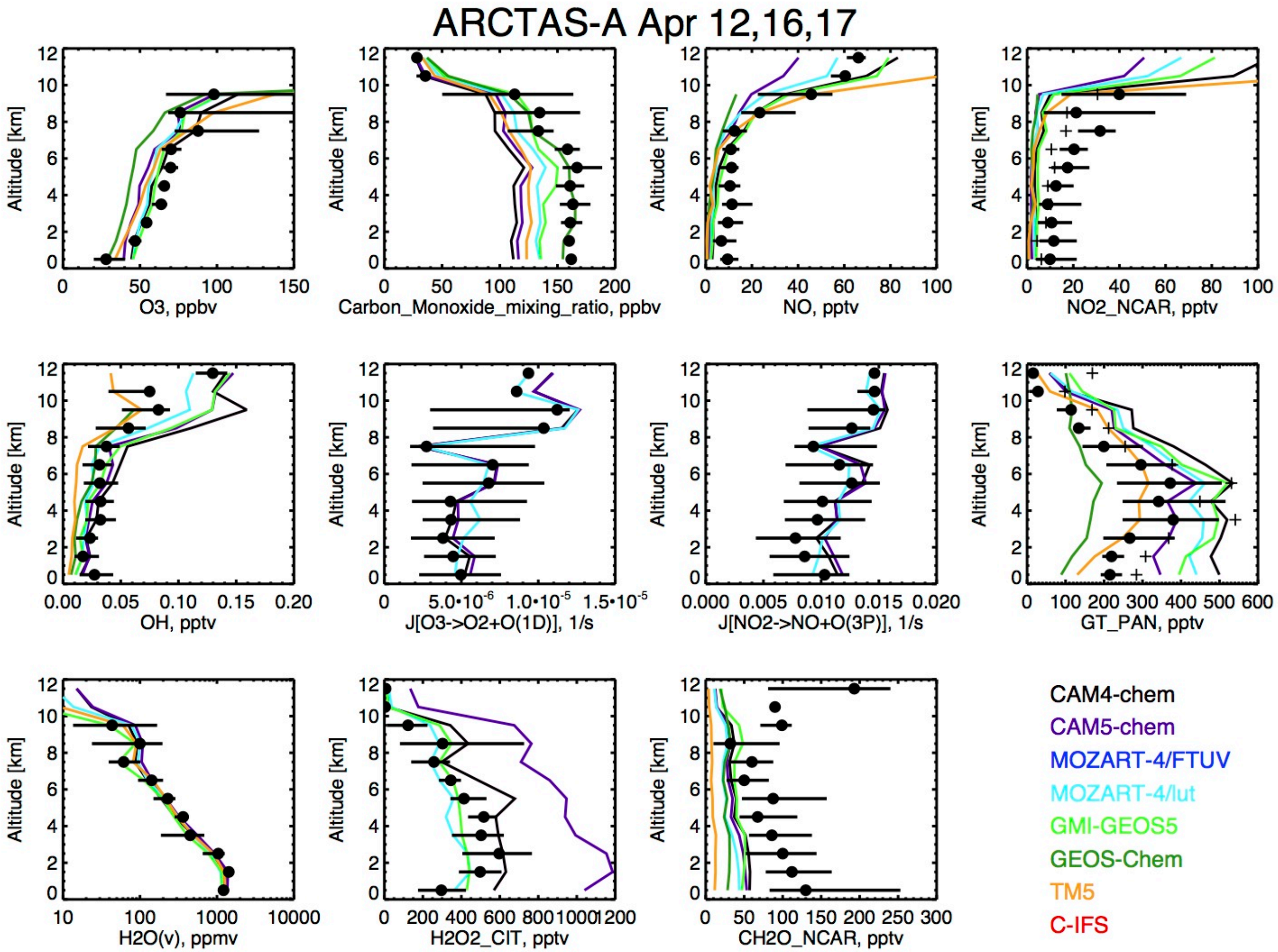
- Full coverage of box
- Representative sample of a uniform distribution

Emmons et al., JGR, 2000

Comparing models with observations - 3

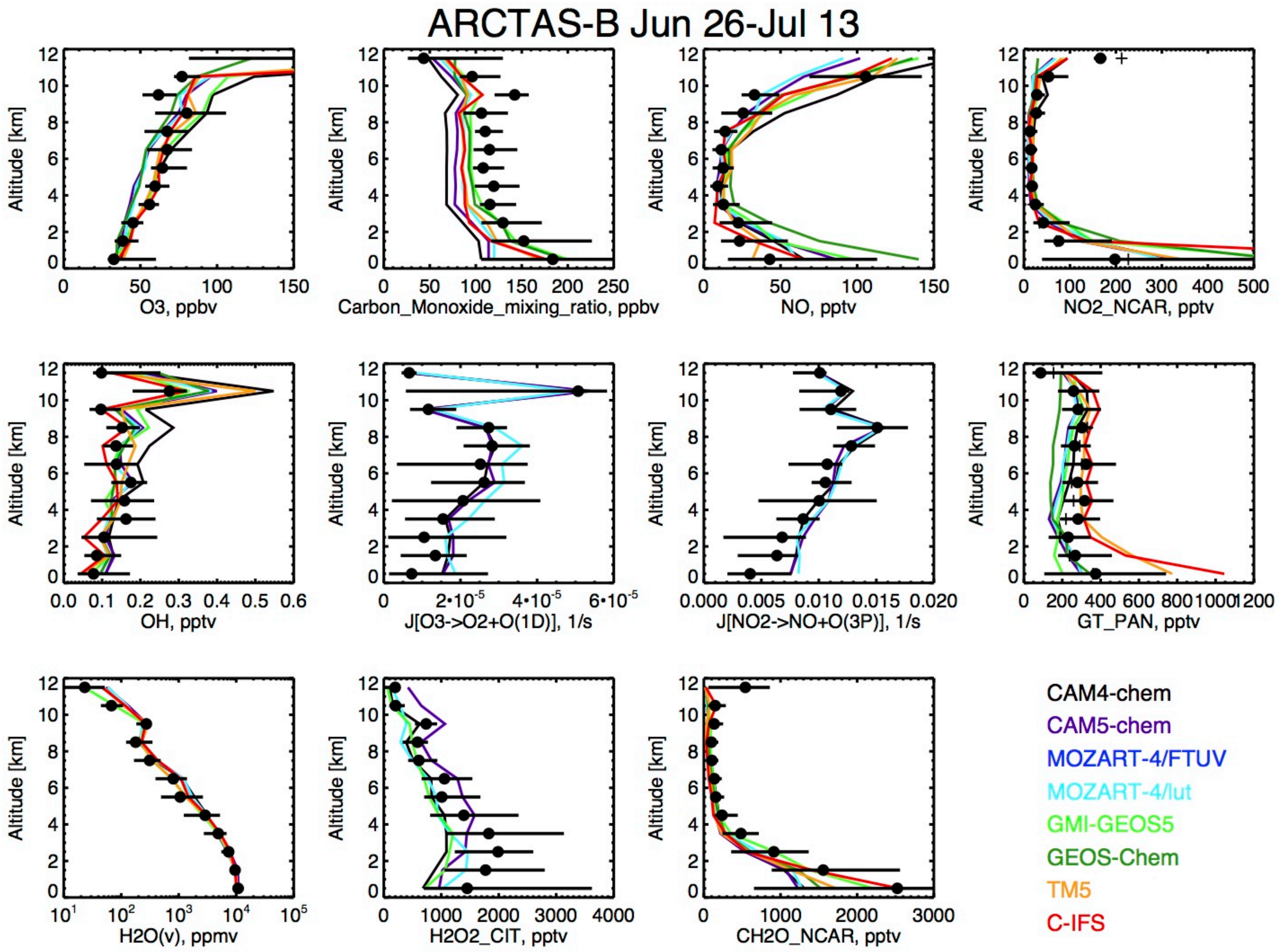
- Interpolate models (horizontal, vertical, time) to flight tracks





And then bin both observations and model-along-flight-tracks by altitude

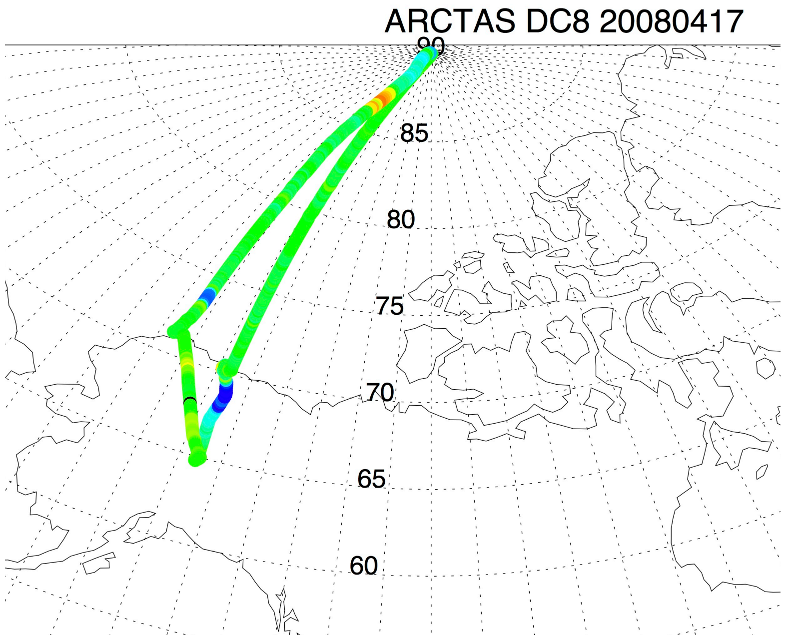
Still need to choose small regions and short times to make meaningful comparisons

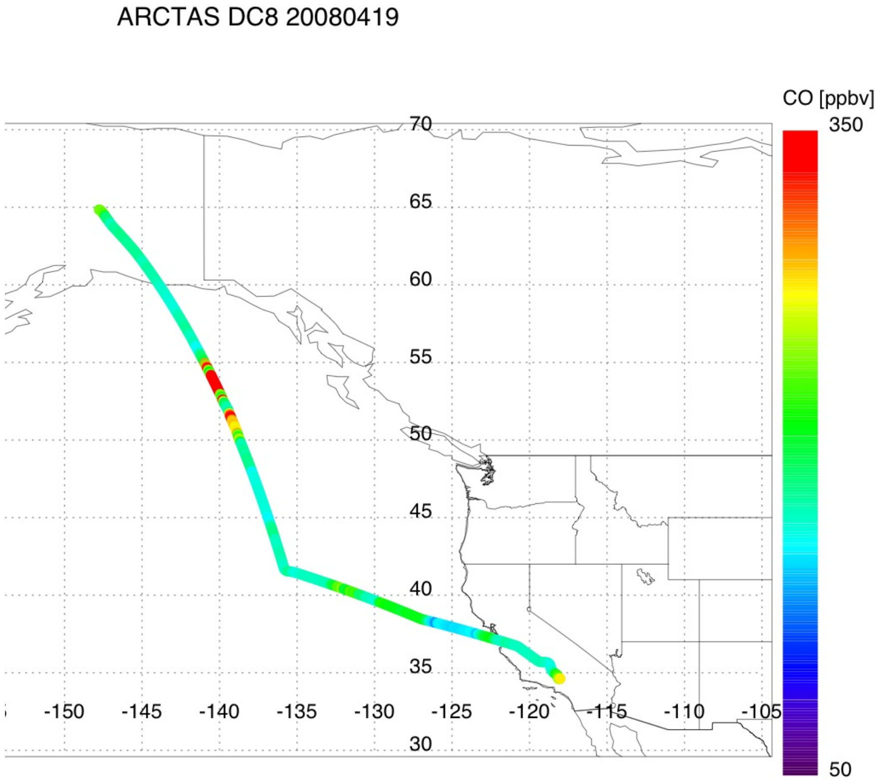


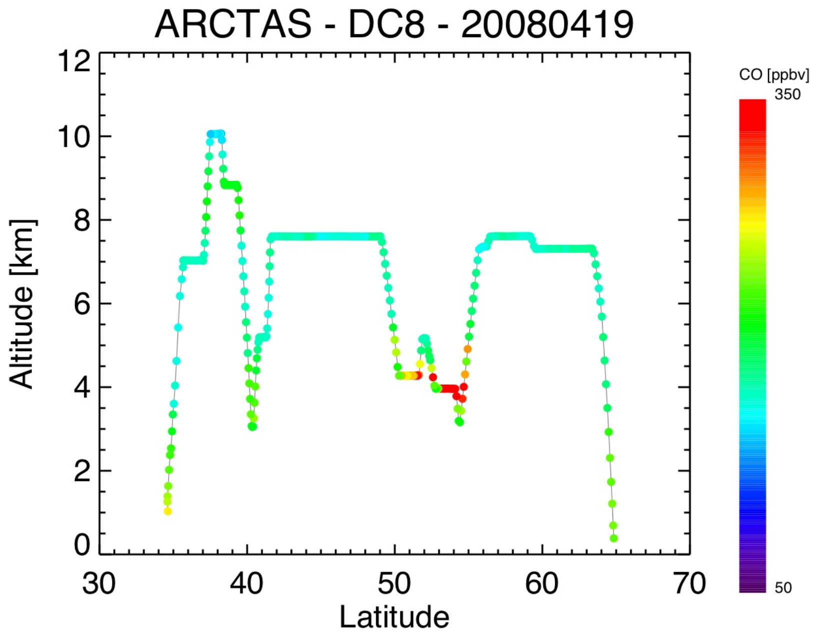
In Summer, DC-8 flights over Canada and the Arctic sampled local fires in Saskatchewan, as well as remote fires in Asia.

Plumes

- Very challenging to use isolated observed plumes for direct model evaluation
- Model resolution (horiz.&vert.) dilutes plume
- Model transport may have plume at different altitude

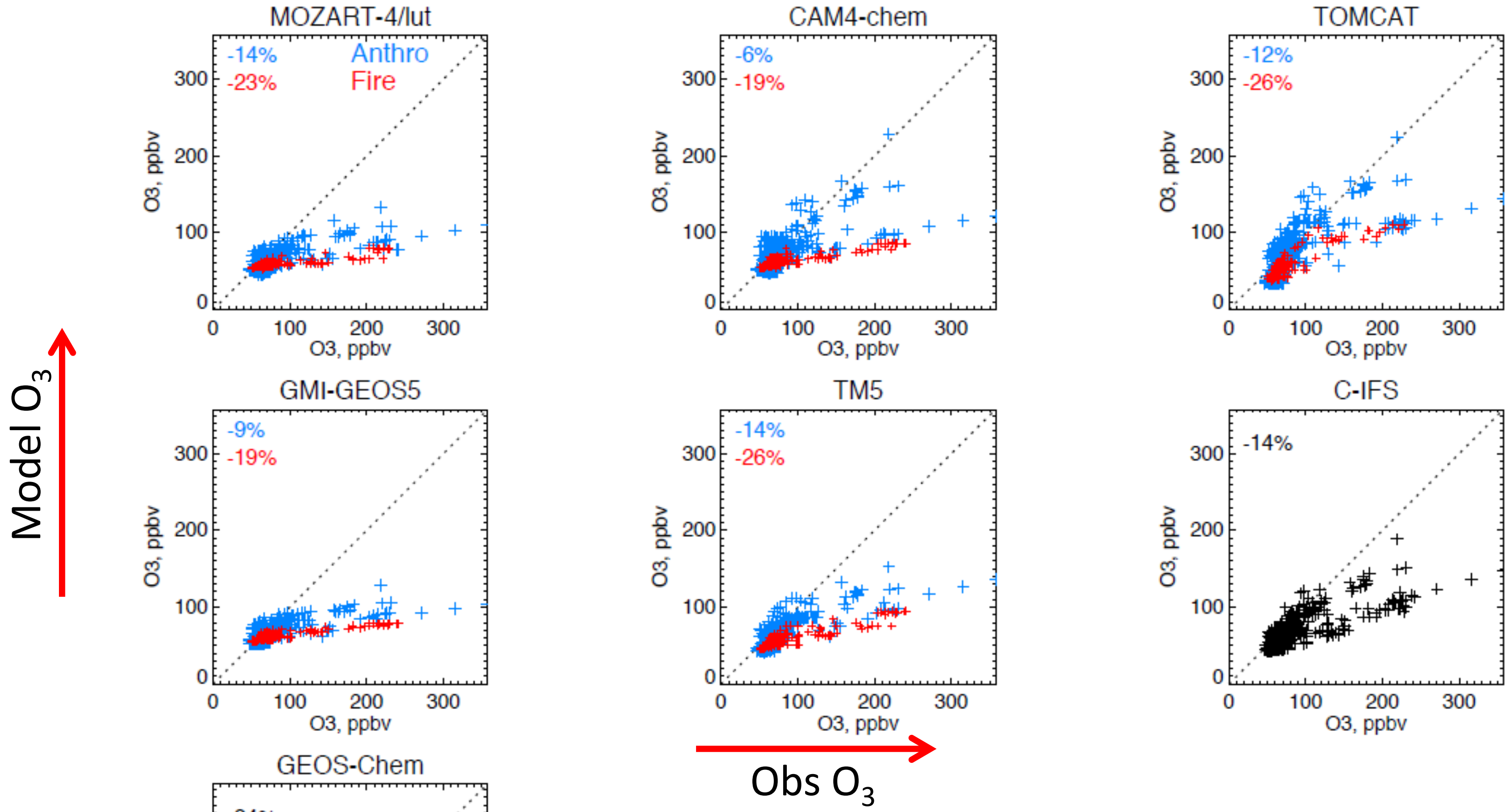


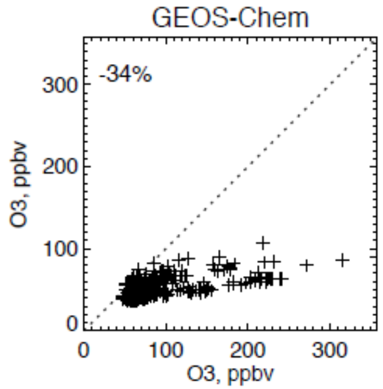




Model vs observed ozone for fire-dominated period

ARCTAS DC-8 observations over Alaska April 2008





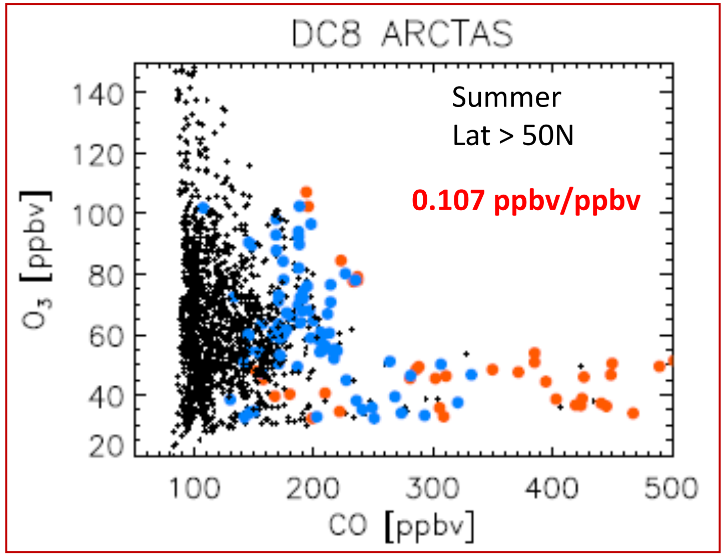
25-d lifetime model source tracers allow us to separately evaluate models in air most influenced by fires.

ARCTAS-A DC-8 Apr 12,16,17 (3-9km, >50N)

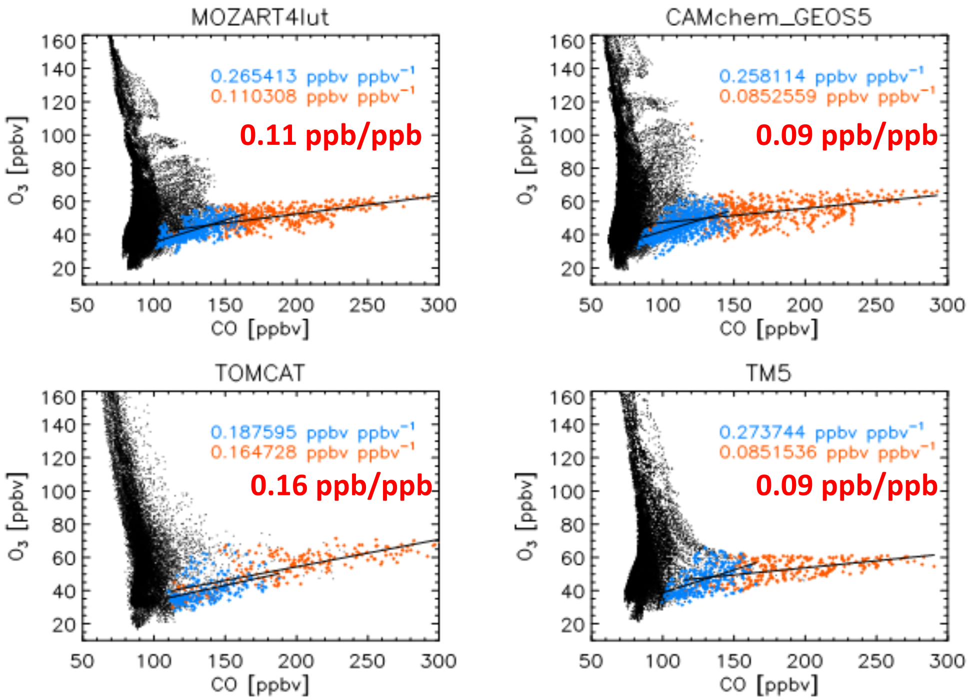
Model ΔO_3 / ΔCO relationships (July)

25-d lifetime model source tracers allow us to separately evaluate models in air most influenced by fires.

Observations



Models



Models show positive ΔO_3 / ΔCO slopes in fire-dominated air, increasing with age since emission.

All model points north of 66N

Colored points show **fresh** and **aged** air where

fire tracer > 70% total tracer

Arnold et al., ACP, 2015

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PAN vs CO – great variety among models

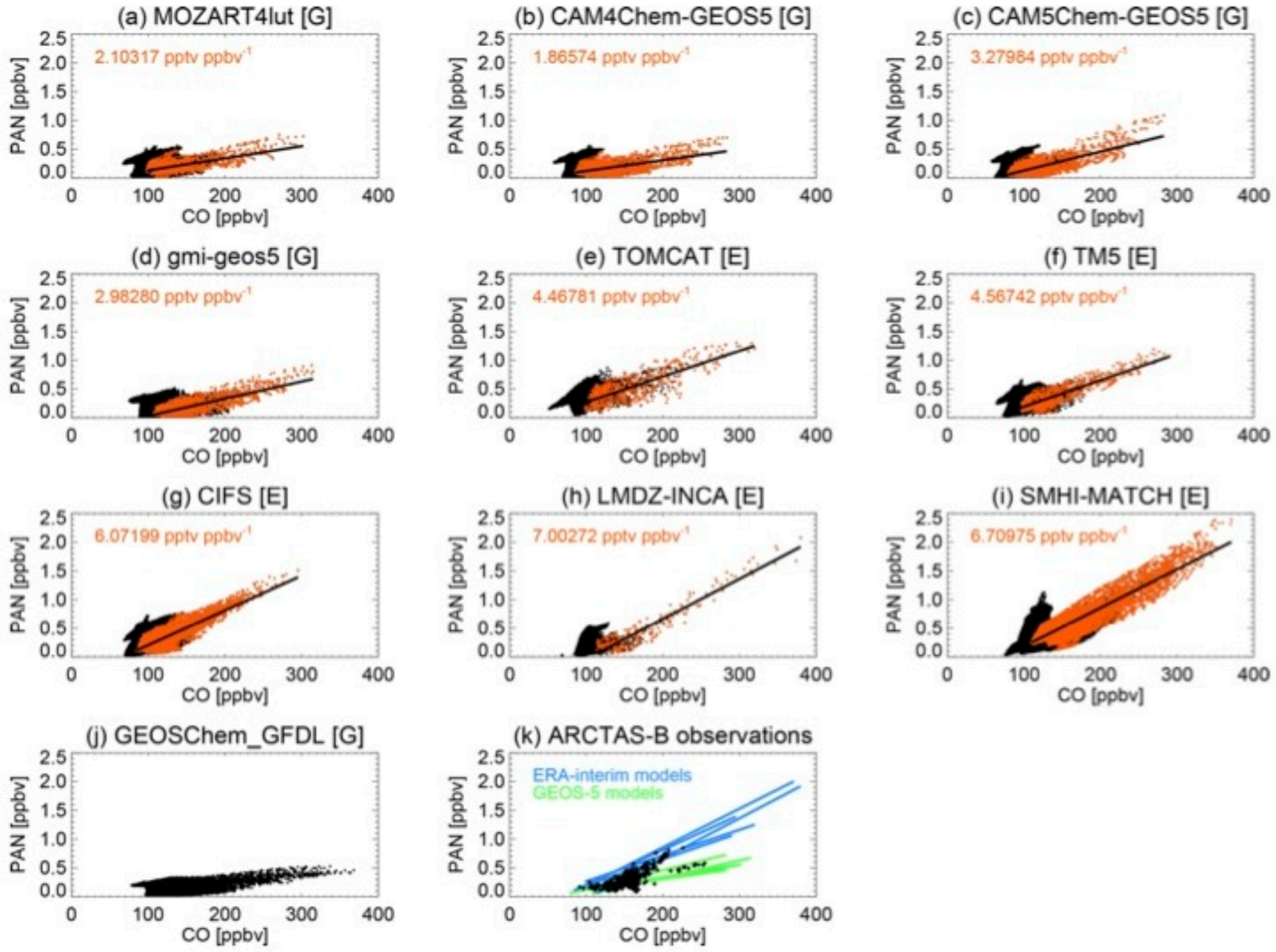
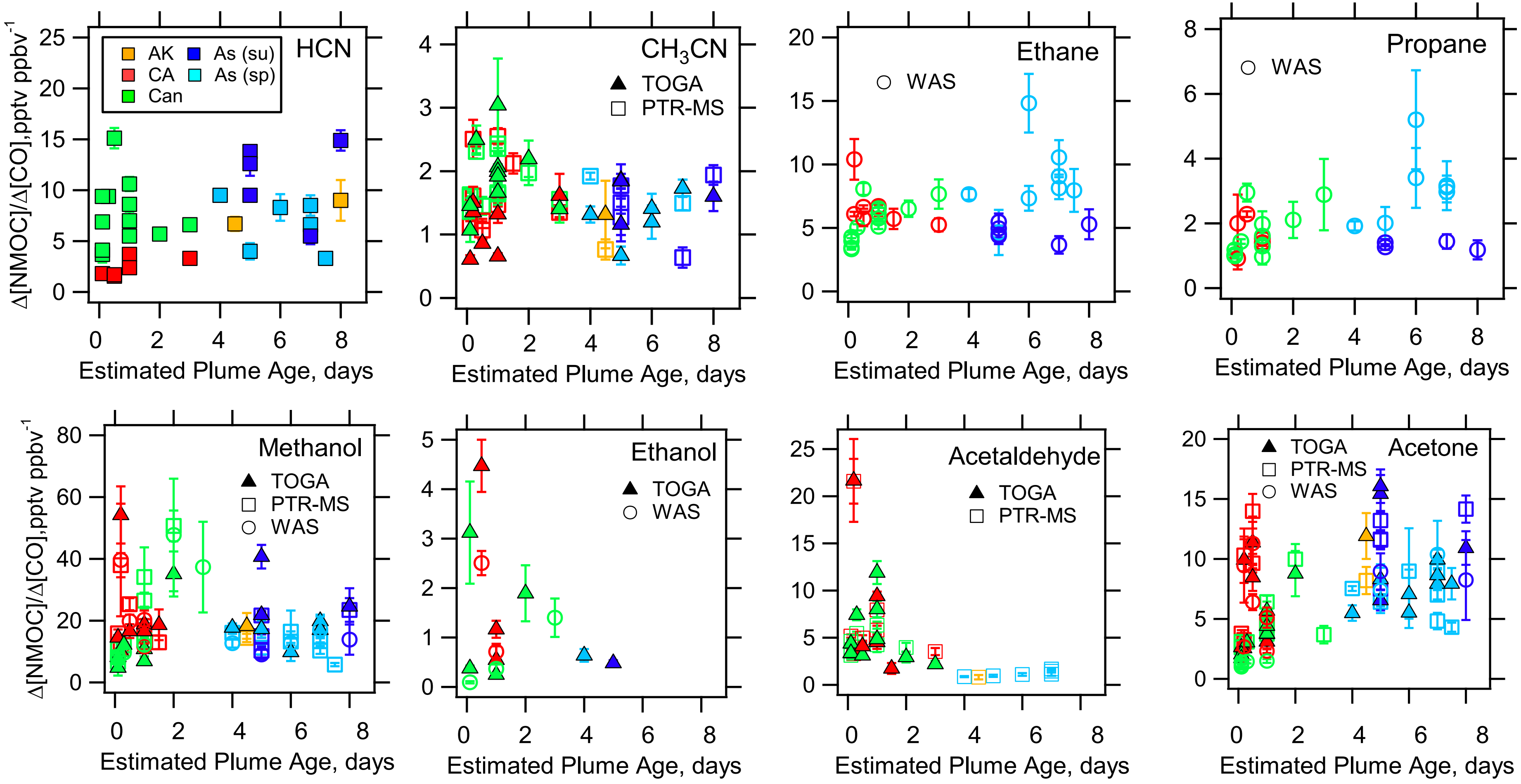


Figure 7. July 2008 PAN/CO relationships for POLMIP models coloured by fire influence.

Arnold et al., ACP, 2015

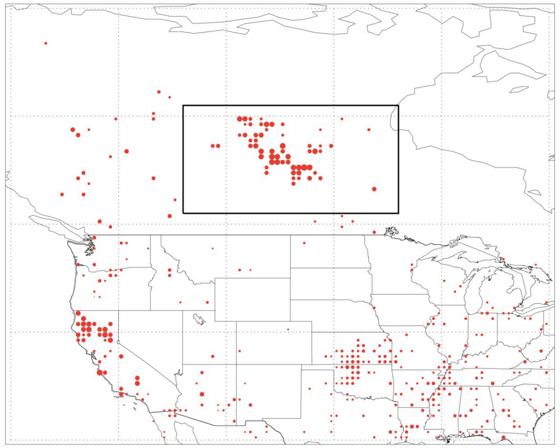
Enhancement Ratios from ARCTAS observations in fire plumes

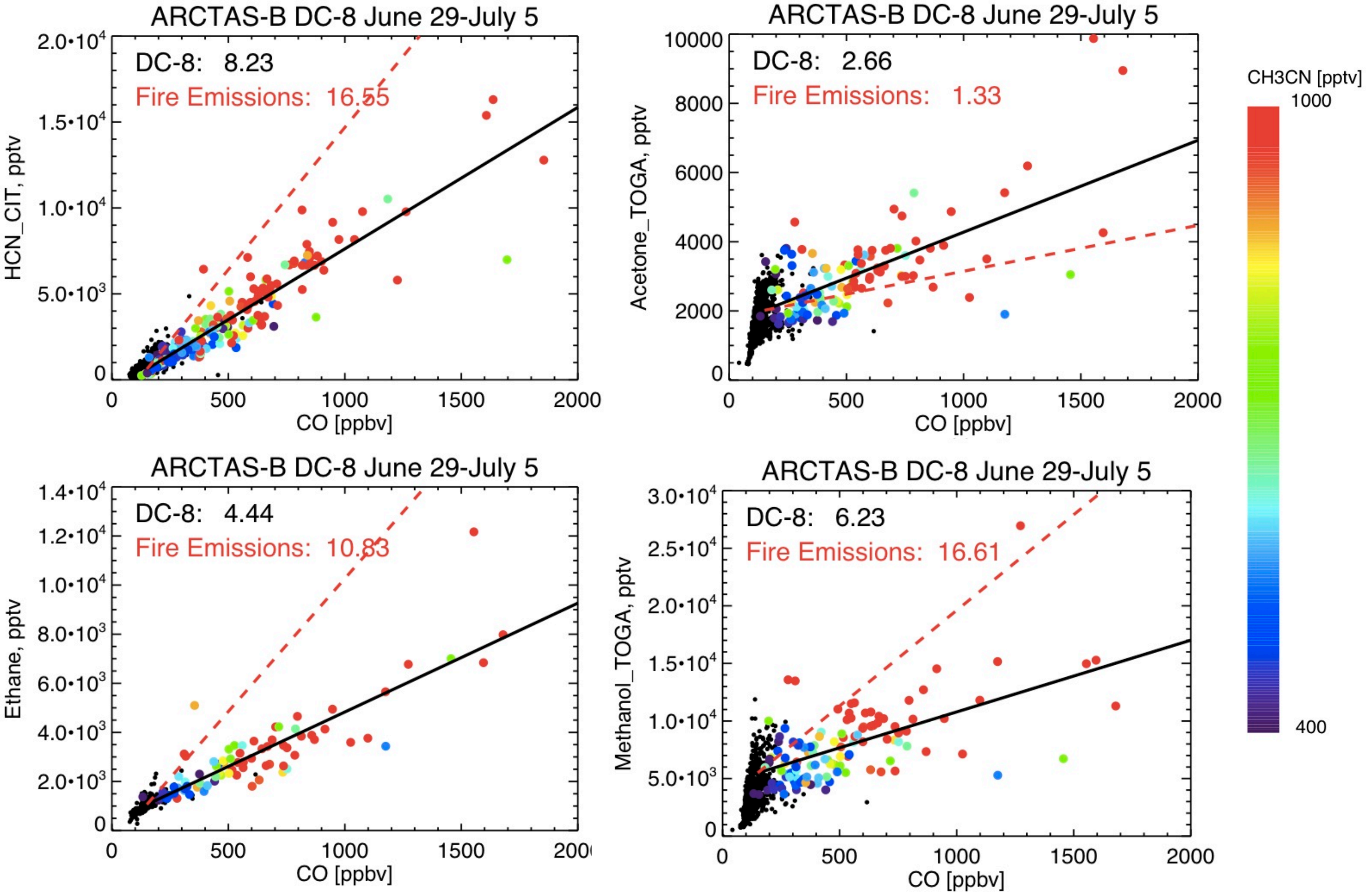


Observed fire plumes sorted by origin and age
Long-lived HCs have constant ratios with age

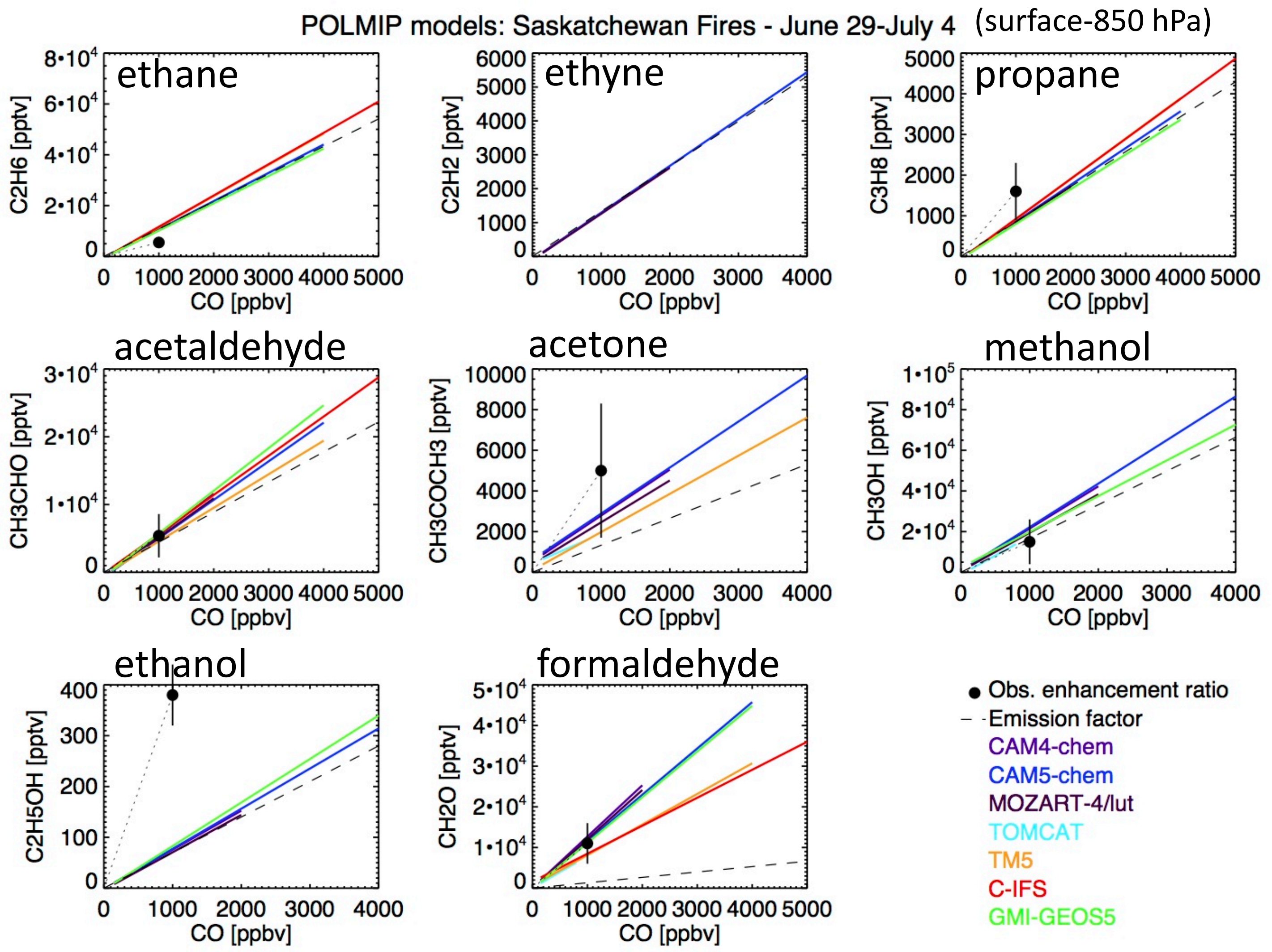
Hornbrook et al., ACP, 2011

Compare ARCTAS VOC/CO correlations to Emission Ratios





Modeled VOC/CO correlations compared to fire emissions and observations



Modeled ratios match emissions for NMHCs, but not species also produced chemically

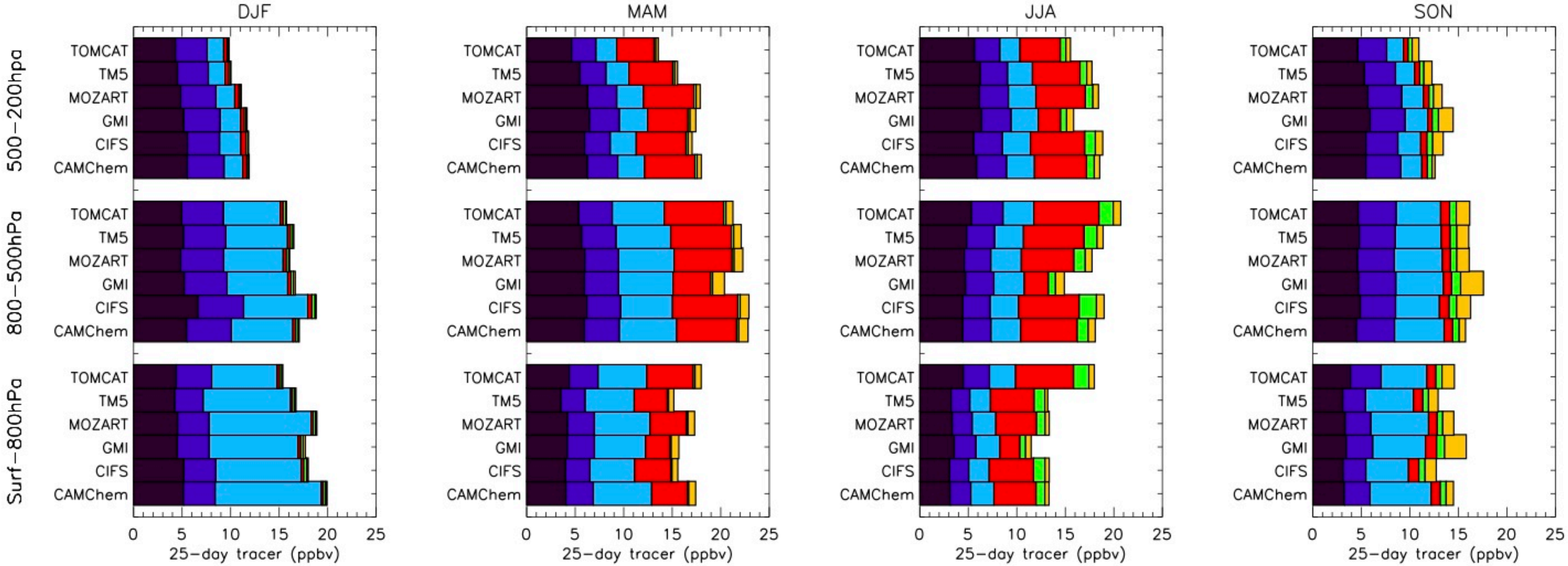
C_2H_6 fire emissions slightly high, propane too low, ethanol much too low

Modeled acetone low – due to chemistry or emissions? or both?

POLMIP: Artificial 25-day tracers with CO emissions from 3 regions

Allow comparison of purely dynamics between the models, without chemistry

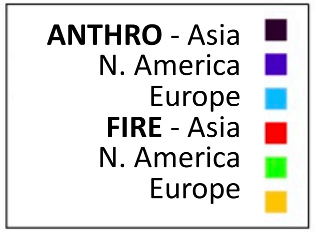
Averages over 66-90°N, for each season, over 3 altitude bands



All models show same general patterns:

- Anthro emissions dominate in winter
- Asia fires significant in spring and summer
- Europe anthro is major source in DJF lower trop
- In summer Asia is largest anthro source in UT

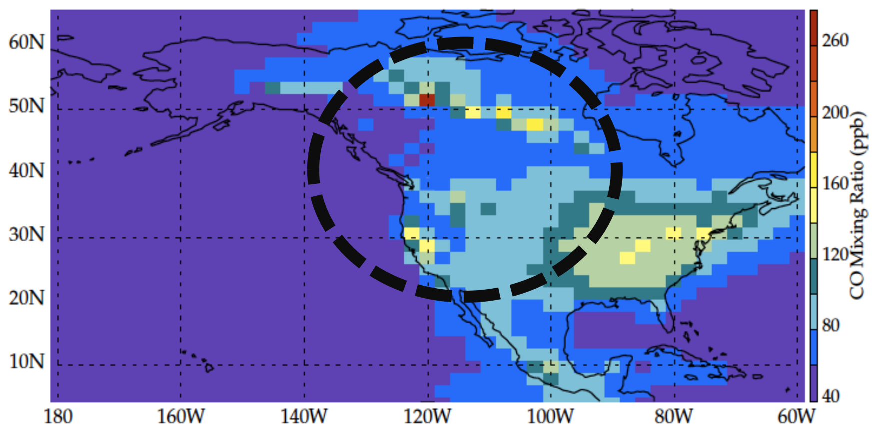
Largest differences between models in fire tracers



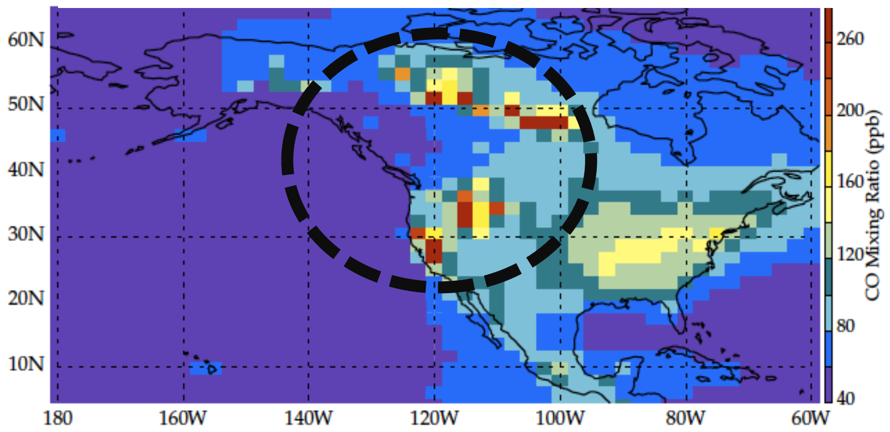
Sarah Monks, ACP, 2015

CAM-chem (FINN & QFED) Aug 2013

CAM-chem CO (FINN)

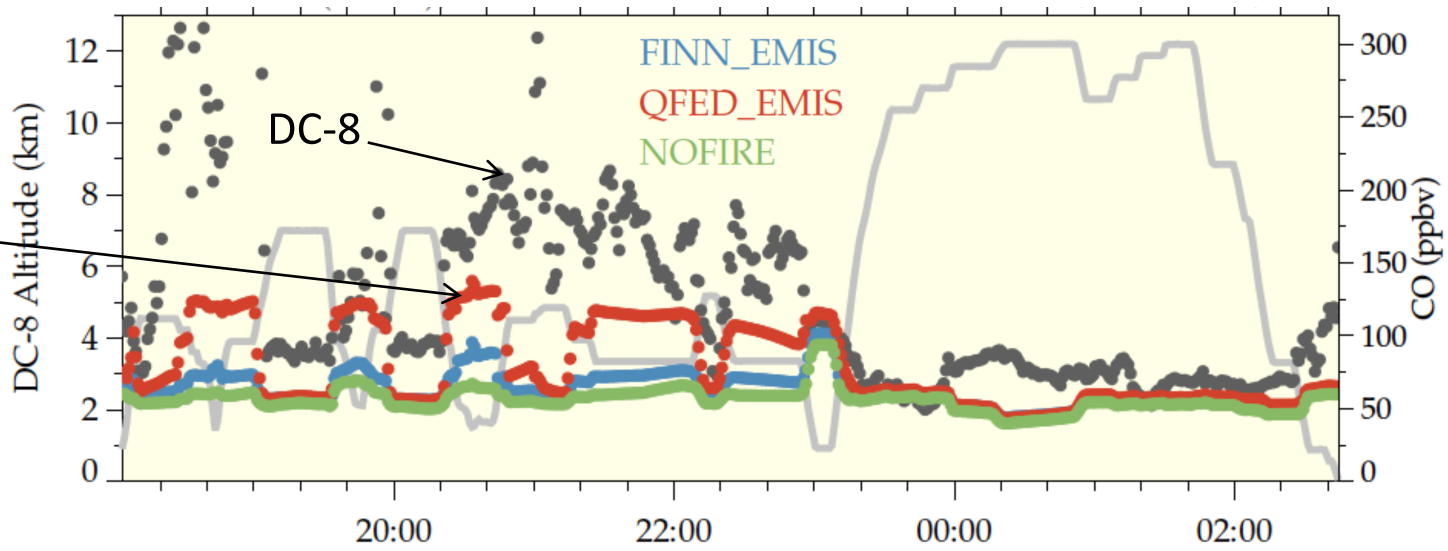


CAM-chem CO (QFED)



CAM-chem simulations with 2 fire emissions inventories (QFED>FINN)

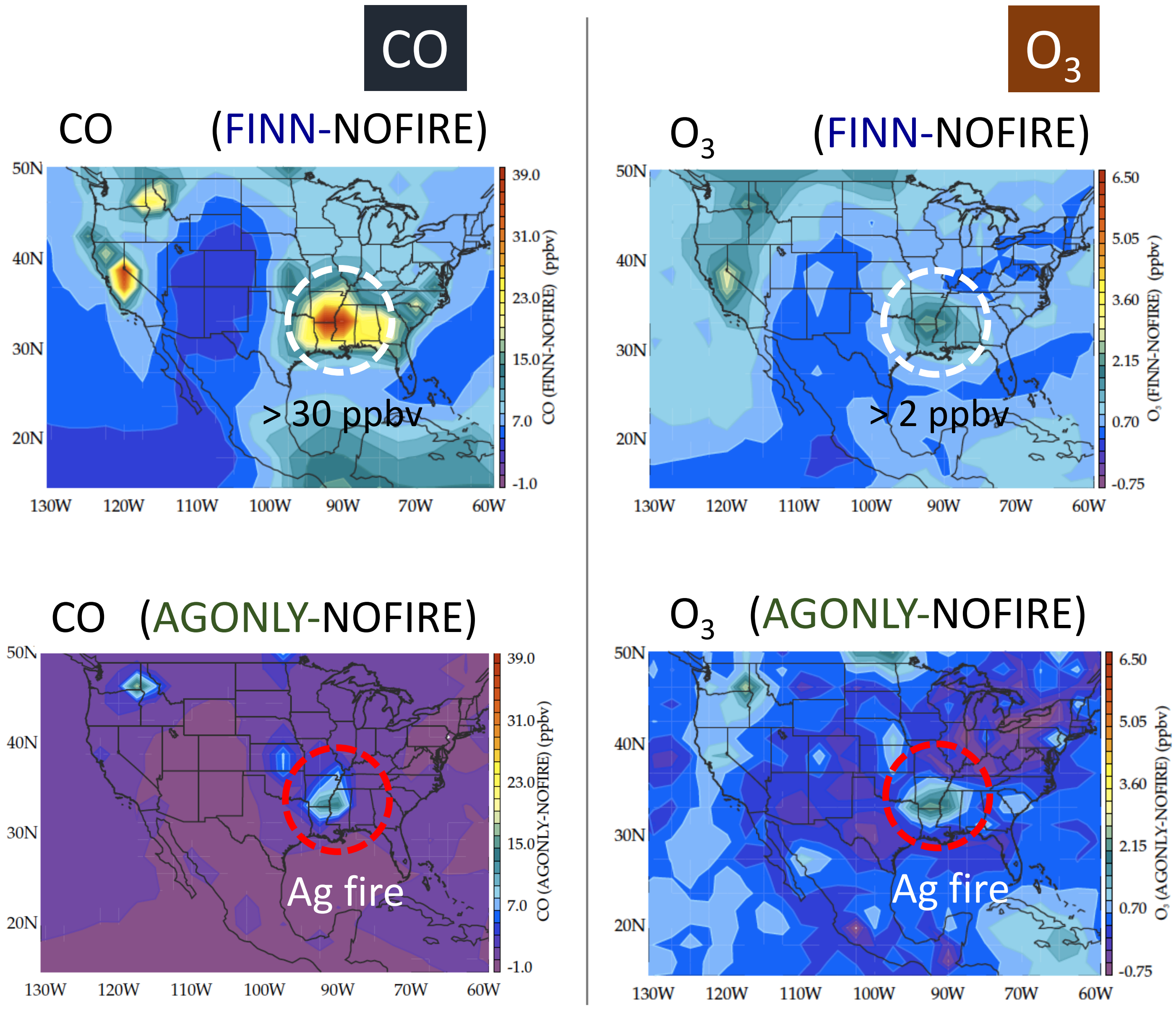
SEAC4RS (DC-8)/CAM-chem CO (Aug 27, Rim Fire)



Both emissions underestimate CO observations in CAM-chem

CAM-chem (FINNv1.5 & AG fire) – Sep 2013

Model experiments valuable for estimating source contributions (e.g., Agricultural fires)



Sep 2013
(surface)

Consider during breakout sessions

- Which science questions can be addressed with existing aircraft data? and in combination with models?
- What are the limitations of existing data that can be improved in future field campaigns (sampling strategies, compounds measured, …)?
- Other issues … ???