POLMIP

The POLARCAT Model Intercomparison Project (POLMIP) aims to exploit the large number of observations collected in the Arctic troposphere as part of International Polar Year in 2008, to evaluate 10 state-of-the-art atmospheric chemical transport models.

Louisa Emmons, Simone Tilmes (NCAR) – MOZART-4, CAM-chem
Steve Arnold, Sarah Monks (Univ. of Leeds) – TOMCAT
Kathy Law, Solene Turquety, Jennie Thomas, Idir Bouarar (IPSL, Univ. Pierre et Marie Curie, Paris) – LMDZ, WRF-chem
Bryan Duncan, S. Steenrod, S. Strode (NASA Goddard) – GMI
Vincent Huijnen (KNMI) – TM5
Johannes Flemming (ECMWF) – C-IFS
Jingqiu Mao (GFDL) – GEOS-Chem

Model	Resolution	Meteorology	Chemistry
TOMCAT	2.8°x2.8°, 31 levels	ECMWF ERA-oper.	trop: 82 species
MOZART-4	1.9°x2.5°, 56 levels	GEOS-5	trop: 103 species, bulk aerosols; photolysis options: FTUV: online; LUT: lookup table
CAM4-chem	1.9°x2.5°, 56 levels	GEOS-5	MOZART-4, bulk aerosols
CAM5-chem	1.9°x2.5°, 56 levels	GEOS-5	MOZART-4, modal aerosols
LMDZ-INCA	1.9°x3.75°, 19 levels	ECMWF	trop: 89 species
C-IFS	T159 (~1°), 60 levels	ECMWF	trop: CB05, strat: linear. O3 (Cariolle)
TM5	2°x3°, 60 levels	ECMWF	trop: CB05
NASA GMI	2°x2.5°, 72 levels	GEOS-5	strat&trop (154 species), GOCART aer.
GEOS-Chem	2°x2.5°, 47 levels	GEOS-5	trop: ~100 species
WRF-Chem	100, 50, 25 km	NCEP GFS	MOZART-GOCART

Emissions – Same for all models:

Anthropogenic: Streets' ARCTAS-v1.2

Fires: FINN-v1

Biogenic, Ocean, etc: MACCity

*GEOS-chem used slightly different anthro emissions and includes increased HO_2 aerosol uptake [Mao et al., ACPD, 2012]

Output:

Monthly for all of 2008

Hourly for Spring & Summer for comparison with field campaigns

Focus on gas-phase chemistry

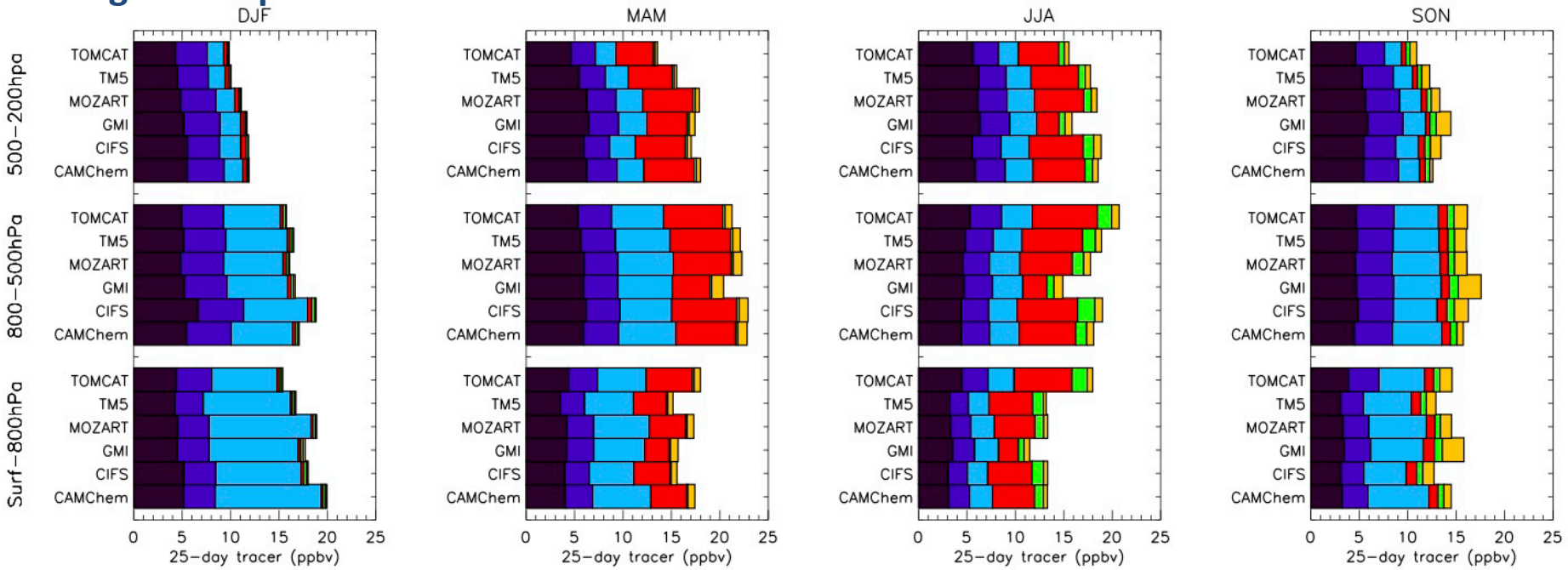
Artificial tracers – 25-day lifetime, based on CO anthro and fire emissions

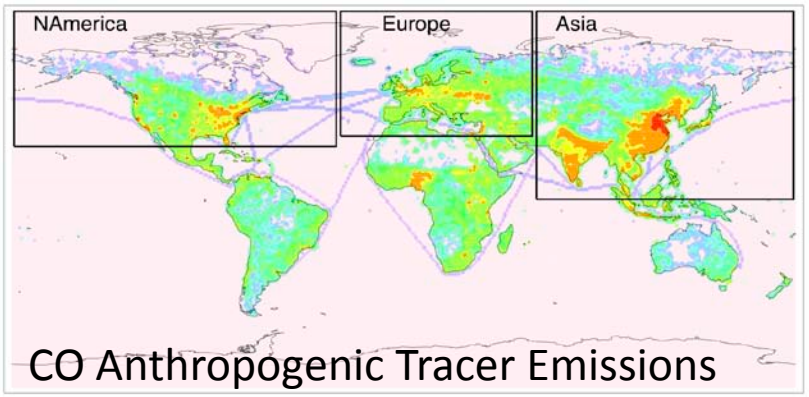
Artificial 25-day tracers with CO emissions from 3 regions

Allow comparison of purely dynamics between the models, without chemistry

ANTHRO - Asia
N. America
Europe
FIRE - Asia
N. America
Europe

Averages over poleward of 66N





CO Anthropogenic Tracer Emissions

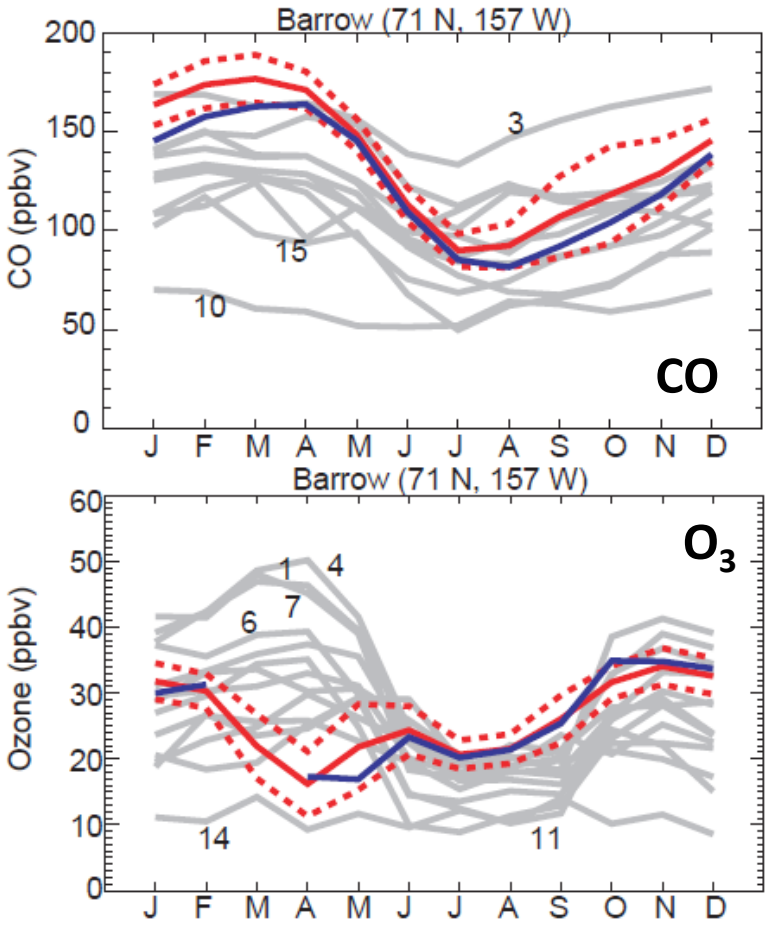
All models show same general patterns:

- 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

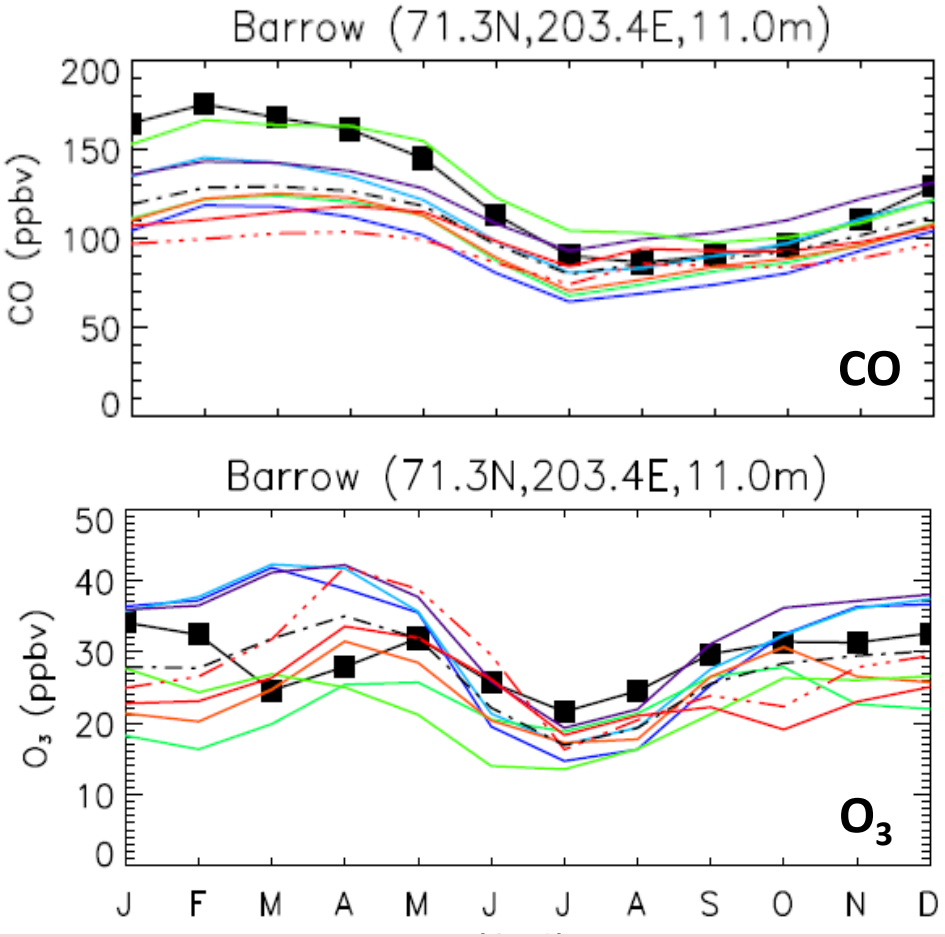
Largest differences between models in fire tracers

Sarah Monks, in preparation

HTAP Models [Shindell et al., 2008]



POLMIP Models



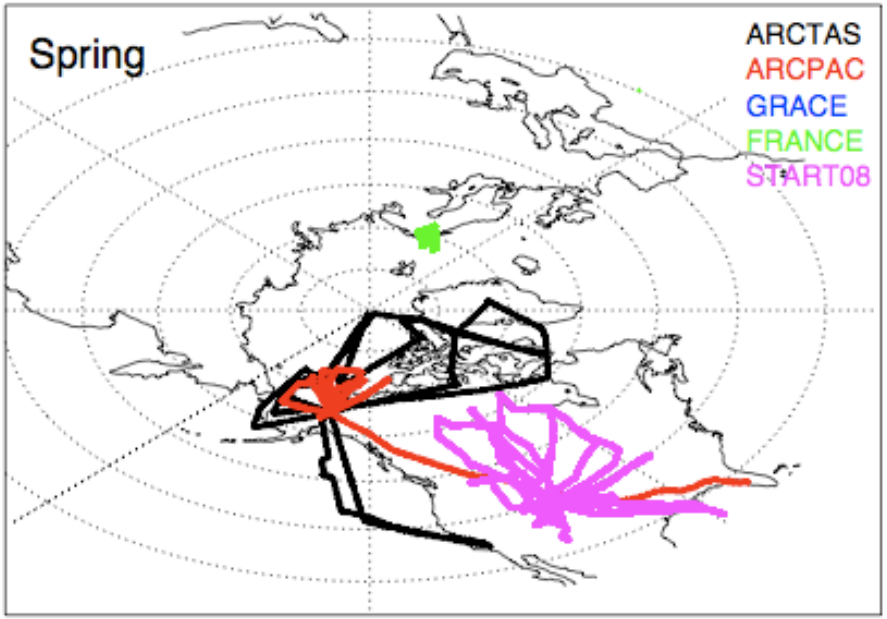
The HTAP models, with various emissions, had difficulty reproducing Arctic observations; POLMIP models which all use the same emissions, show smaller differences, but still show deficiencies.

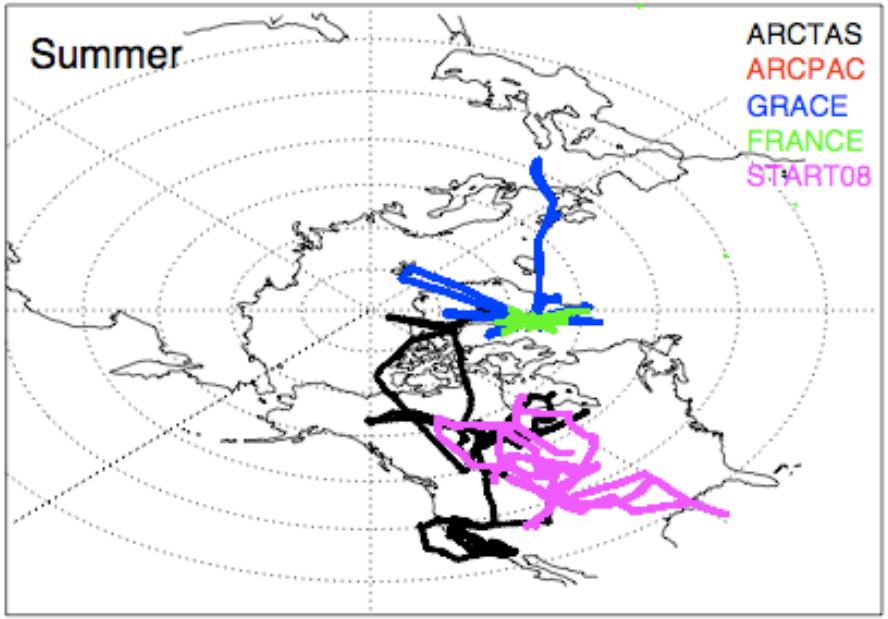
POLARCAT Experiments
April-July 2008

Spring:
- NASA – ARCTAS (Alaska)
- NOAA – ARCPAC (Alaska)
- POLARCAT-France (Sweden)

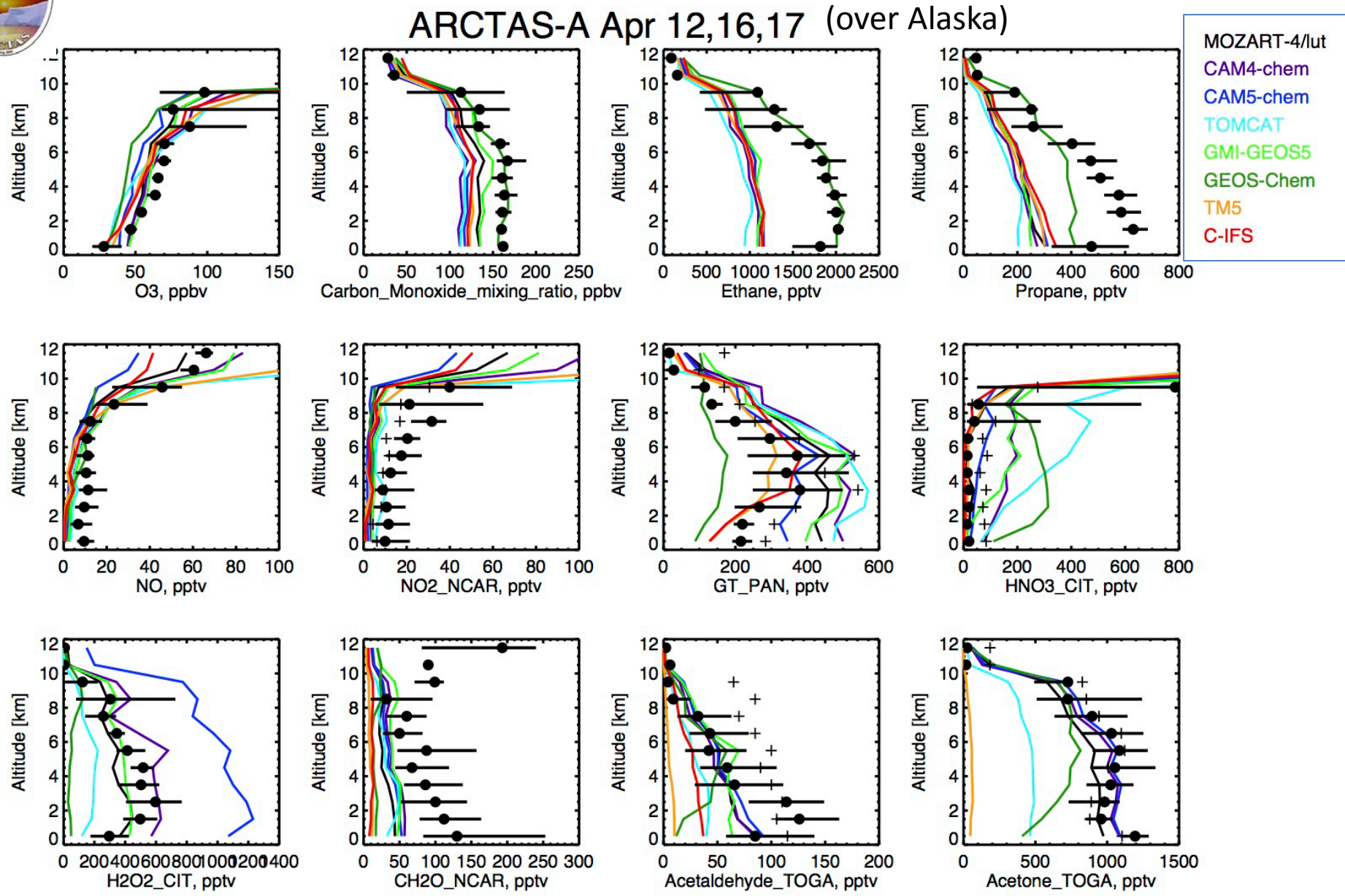
{May-June: START08 (NCAR-GV, N.Amer.)}

Summer:
- NASA – ARCTAS (Canada)
- DLR – GRACE (Greenland)
- POLARCAT-France (Greenland)



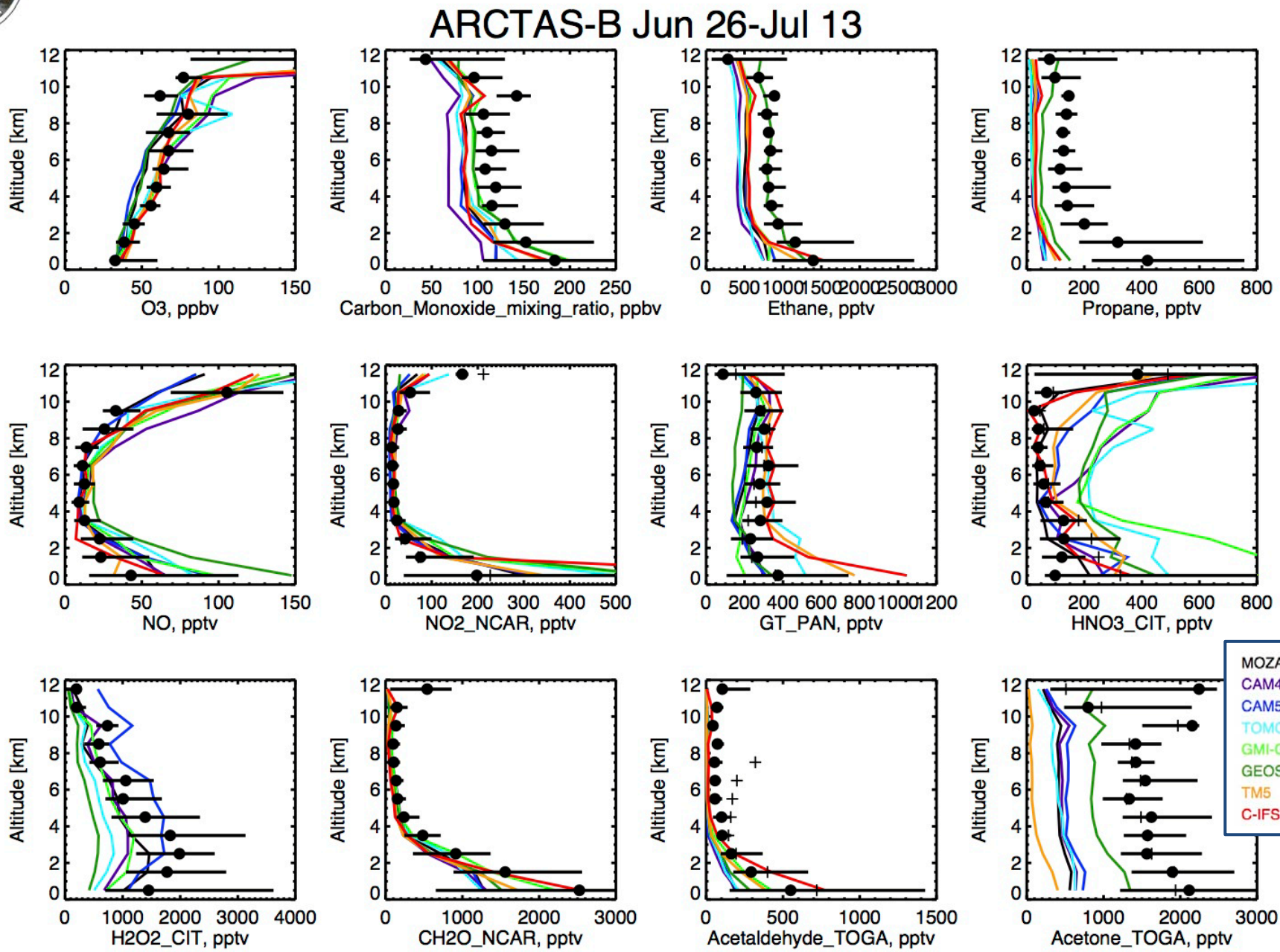


Comparison to DC-8 obs – all models interpolated to flight tracks, then binned by alt.

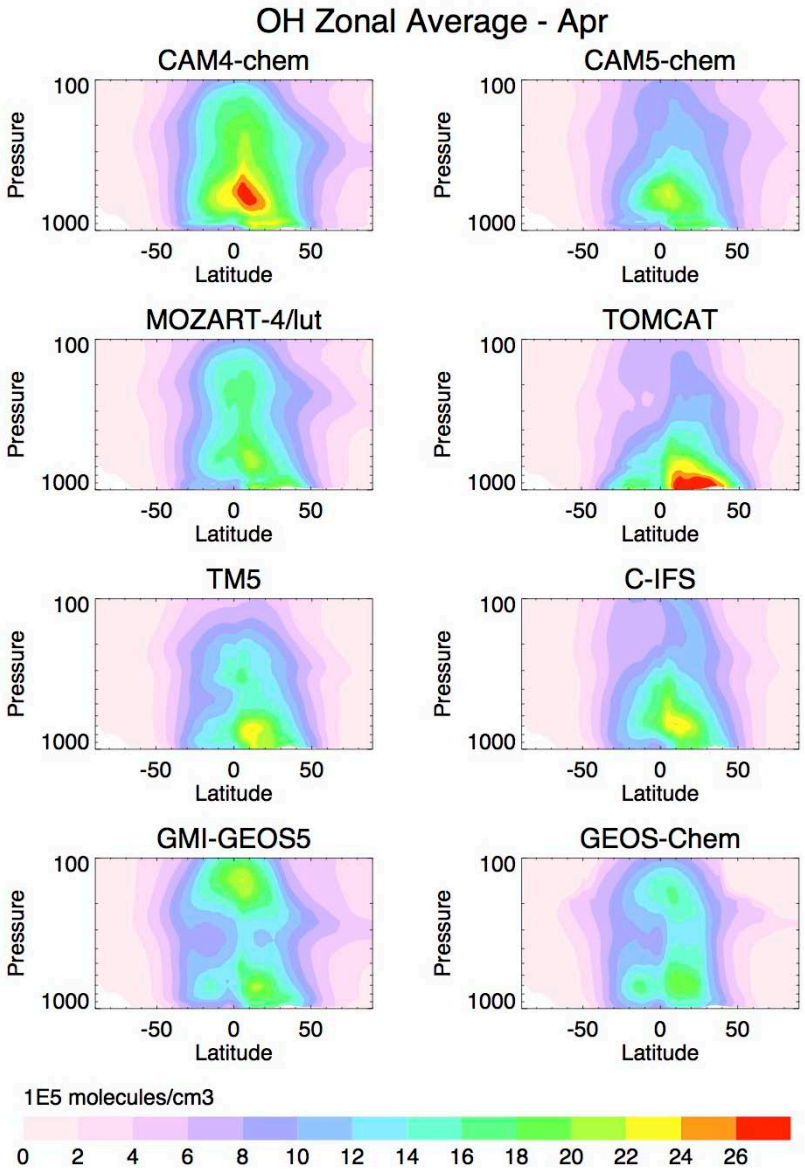


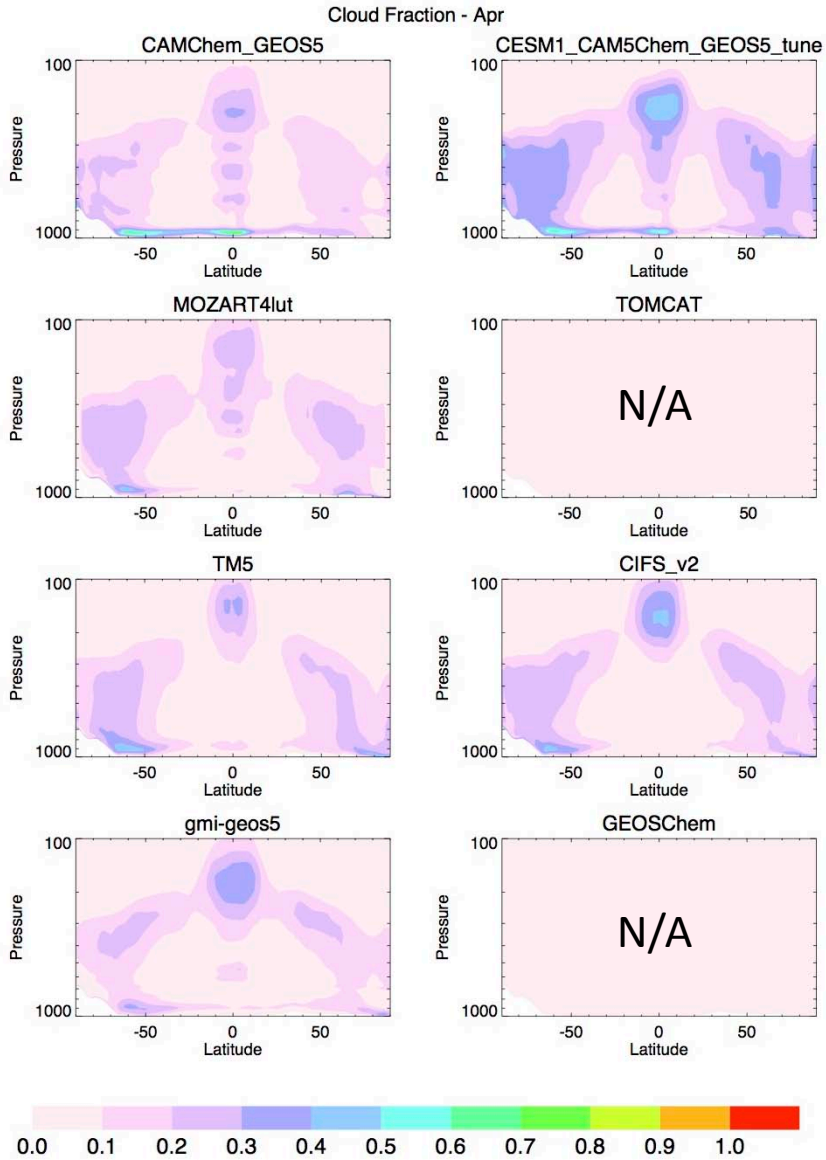
Large differences in model CO indicate model chemistry and OH differences

DC-8 flights over Canada and the Arctic
– some flights focused on fires in Saskatchewan

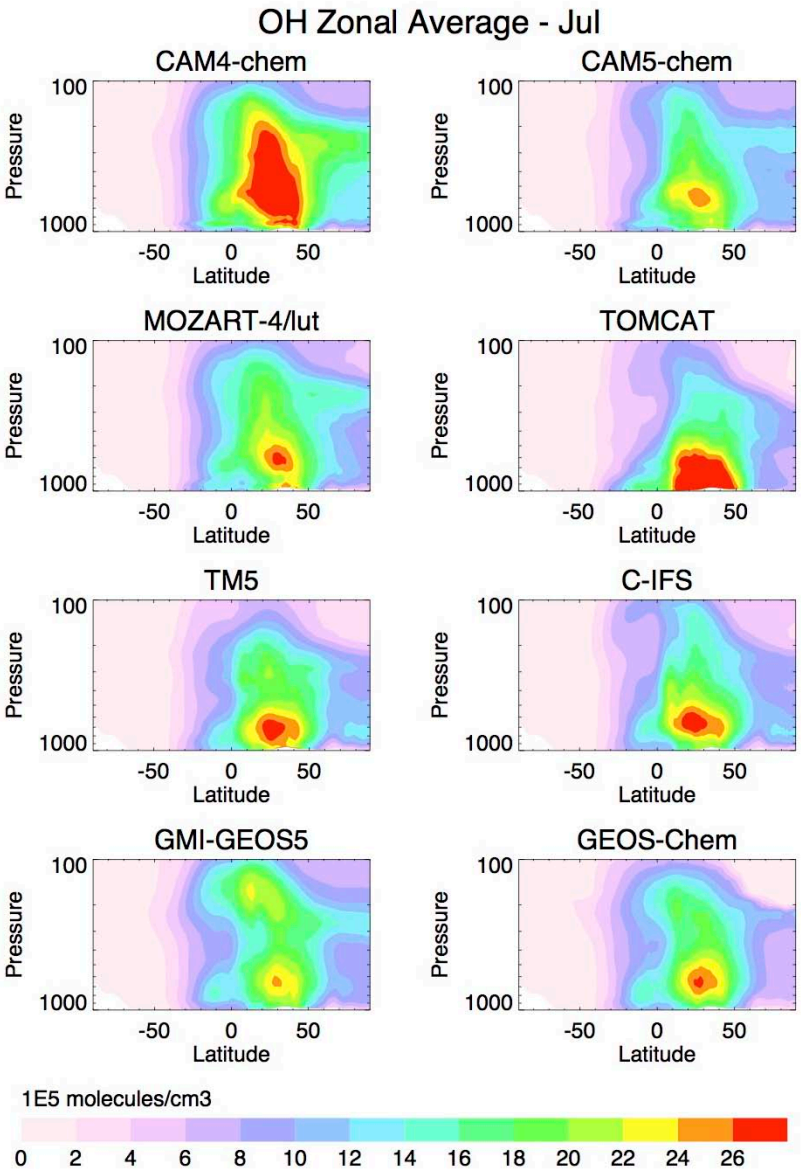


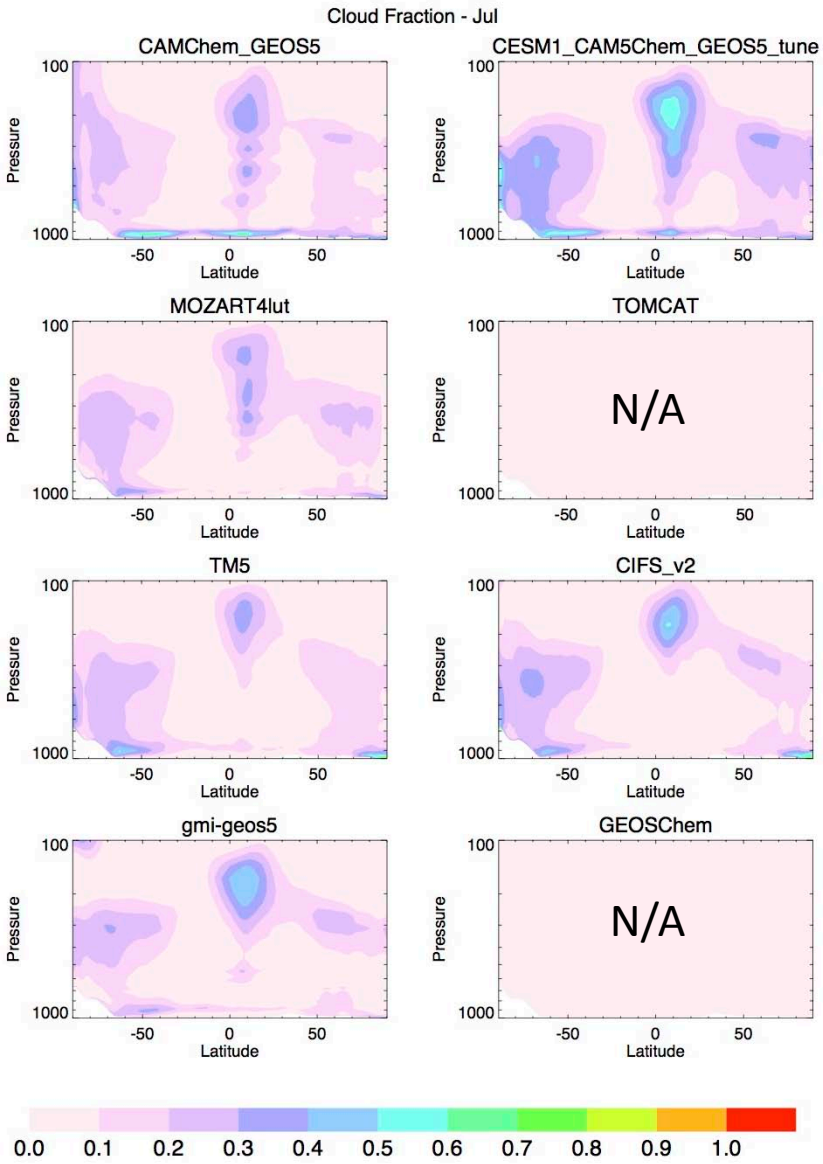
POLMIP models – OH and Cloud zonal averages – monthly mean - April





POLMIP models – OH and Cloud zonal averages – monthly mean - July





Photolysis Rates

Photolysis rates differ significantly between models

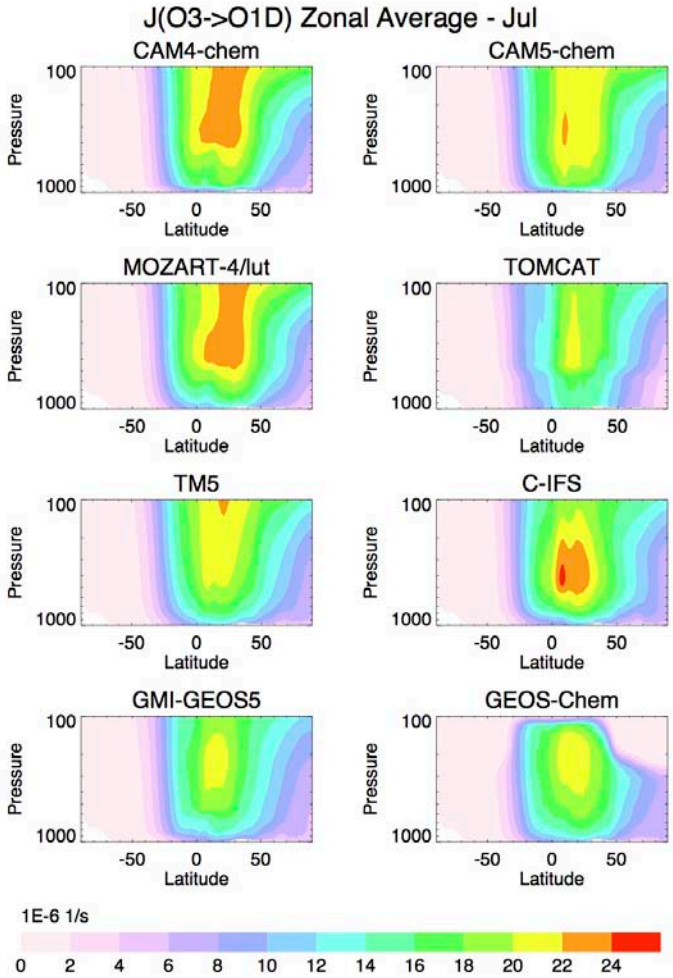
The differences in photolysis rates are probably the main source of variations in OH and O_3

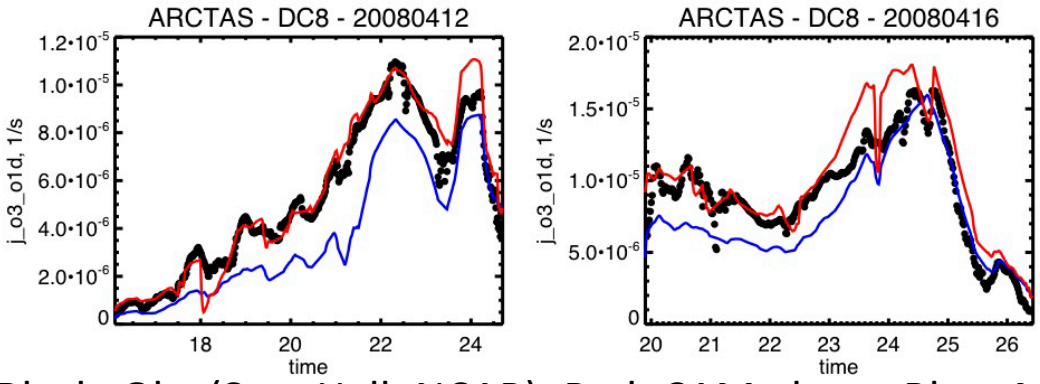
For example:

$J(O_3 \rightarrow O^1D)$ & $O^1D + H_2O \rightarrow 2\ OH$, is a principal term for ozone loss, as well as OH production

$J(H_2O_2) \rightarrow 2\ OH$ is another key OH source

Differences in the cloud distributions between models is a key factor in the photolysis differences





Photolysis rates, based on actinic flux observations made on the NASA DC-8 can be used for model evaluation

… if hourly Js are output!

Black: Obs (Sam Hall, NCAR); Red: CAM-chem; Blue: MOZART-4/FTUV

Ozone Budget

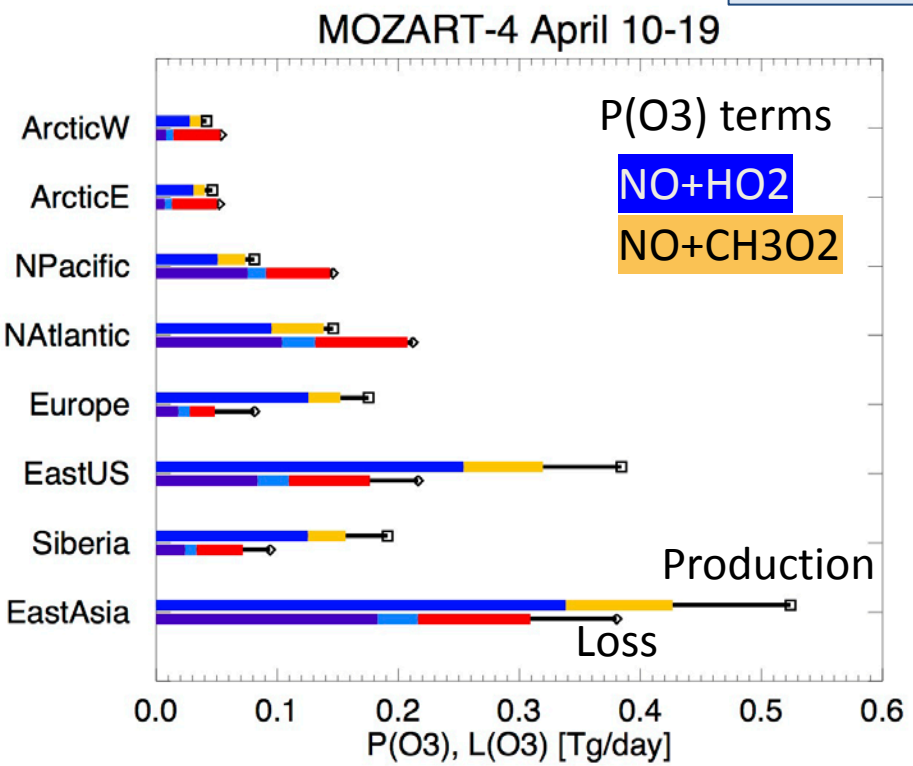
The individual tropospheric ozone production and loss rate terms have been saved from a MOZART-4 simulation.

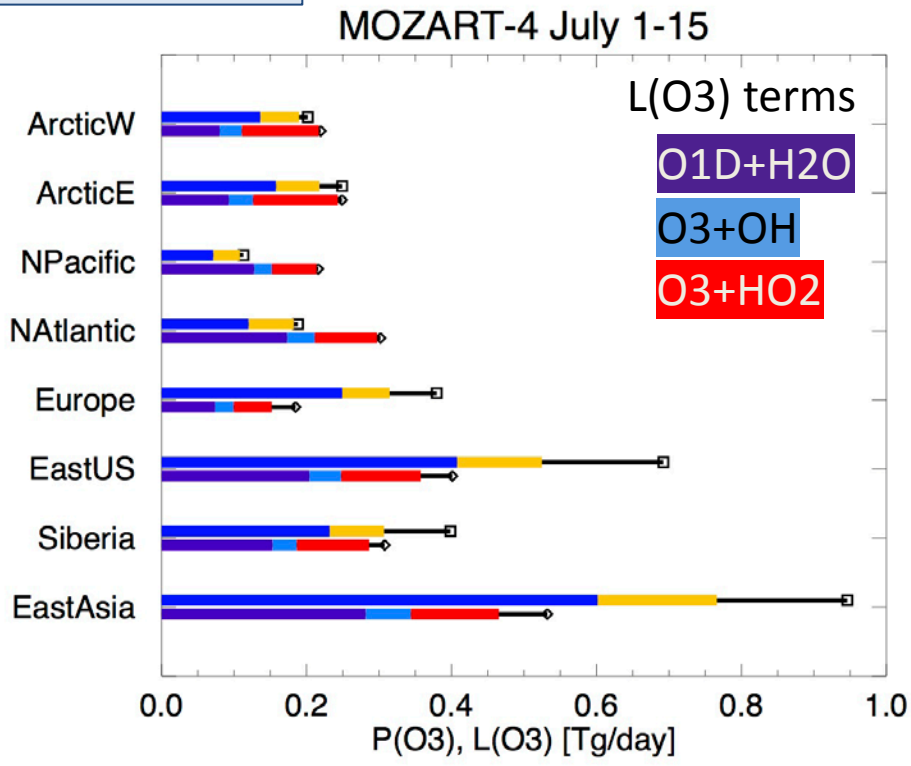
In both April and July, the most active ozone chemistry is in East Asia and the eastern US.

The Siberia region contains primarily fire emissions (little anthropogenic) yet shows significant ozone production.

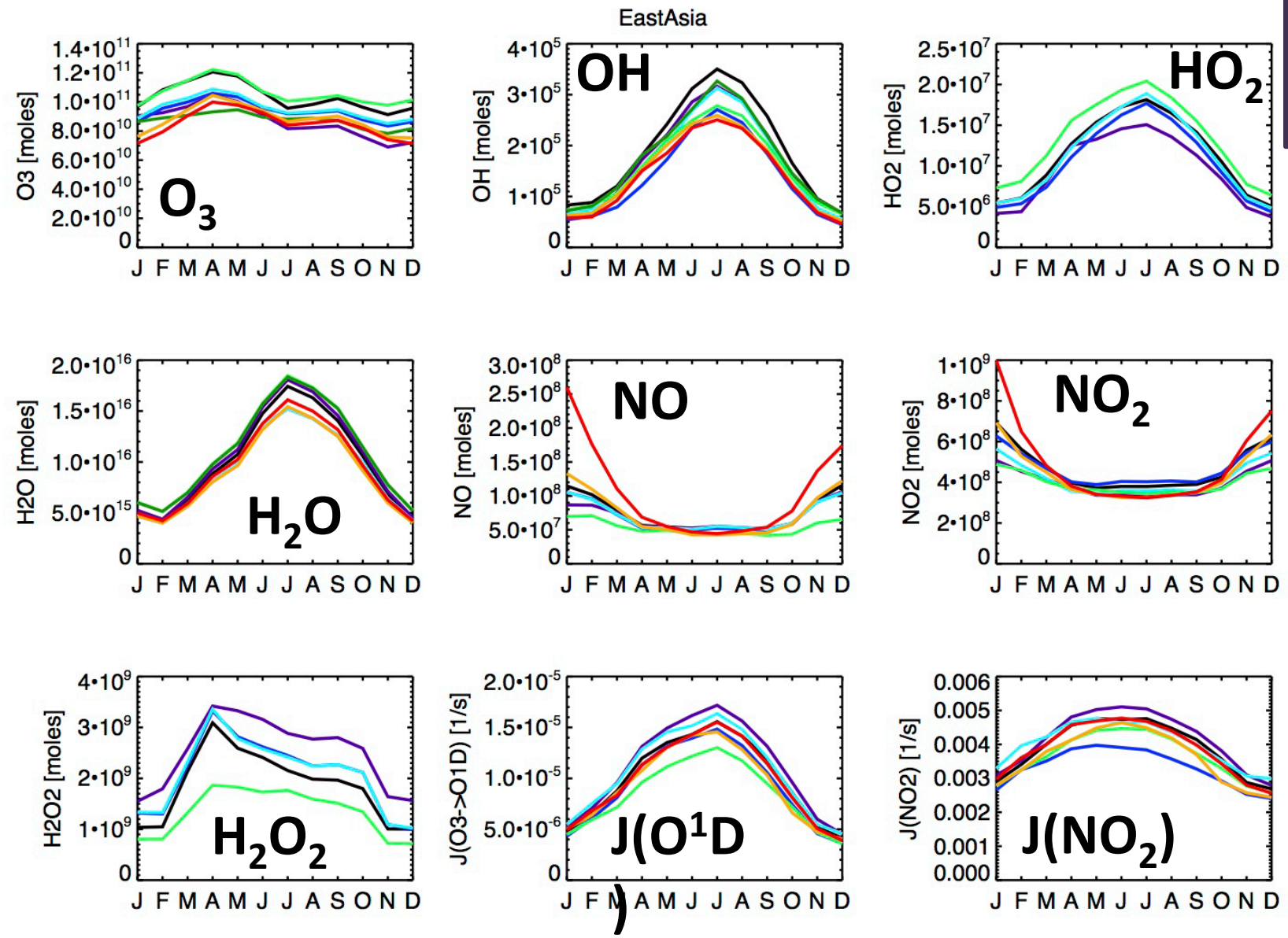
Over the Arctic and ocean regions there is greater loss than production.

Surface – 300 hPa totals



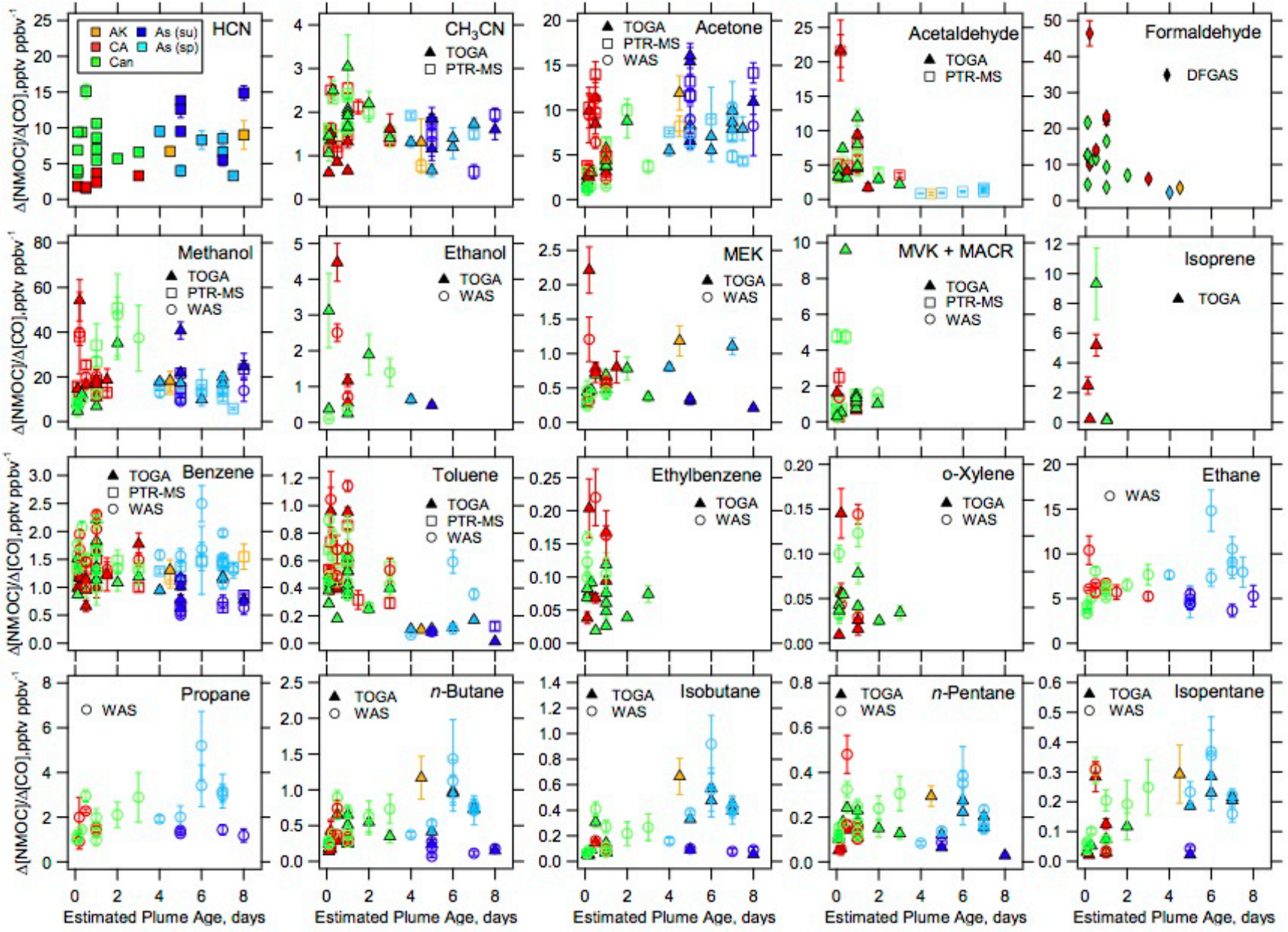


Tropospheric Burden - East Asia (20-45N, 104-130E)

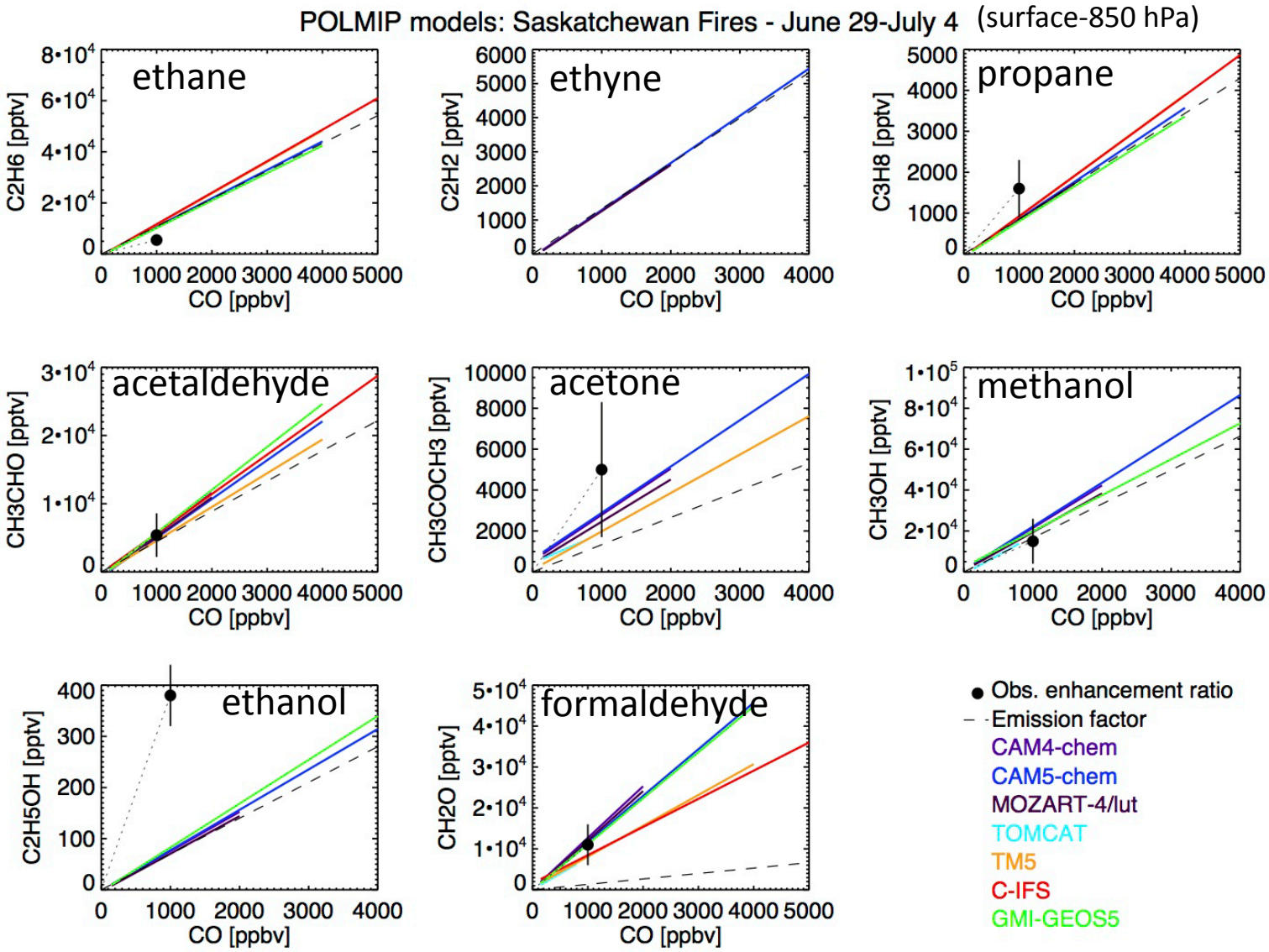


Significant differences between models in OH, HO_2, ozone precursors over major source regions

Fire Emissions - Observed Enhancement Ratios from ARCTAS DC-8 observations [Hornbrook, Apel, et al., ACP, 2011]

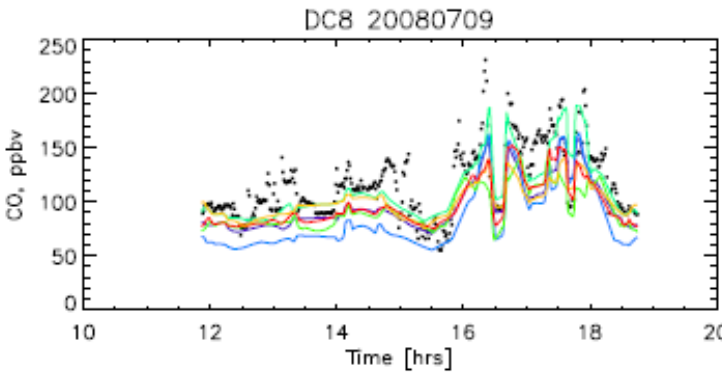


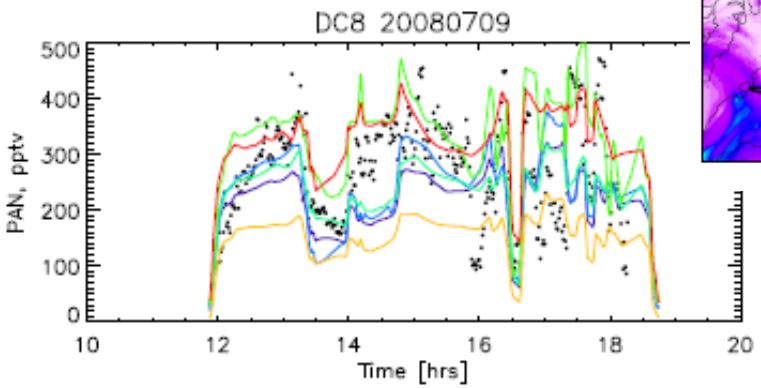
Fire Emissions – Modeled VOC/CO correlations compared to emissions and observations

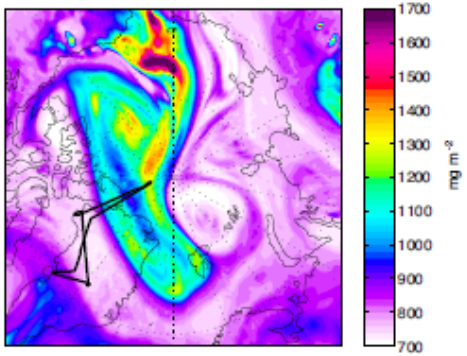


Modeled ratios match emissions for NMHCs, but not species also produced chemically
C2H6 fire emissions slightly high, propane too low, ethanol much too low
Modeled acetone low – due to chemistry or emissions? or both?

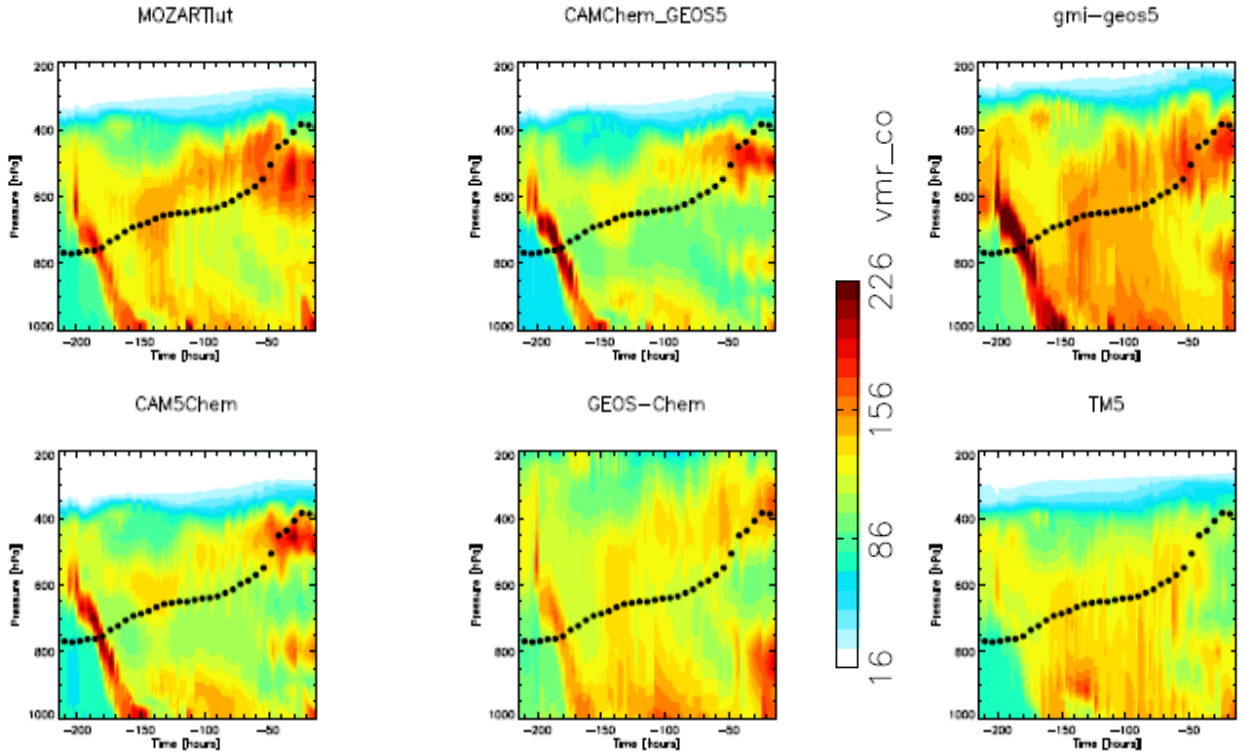
Asian plume (anthro+fire) sampled by DC-8 July 9

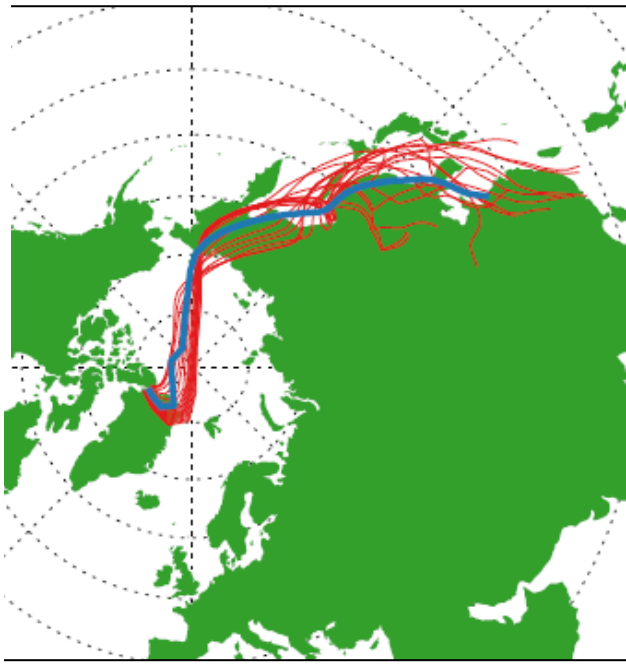






Model CO profiles sampled along mean plume trajectory.





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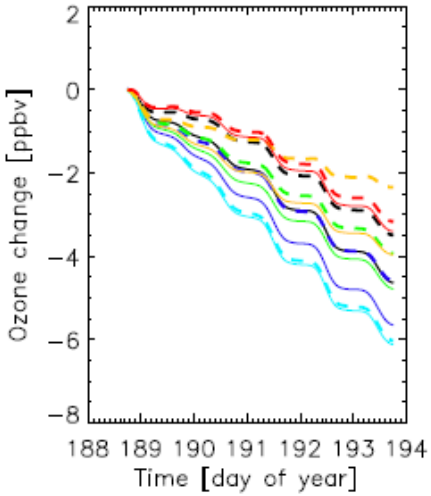
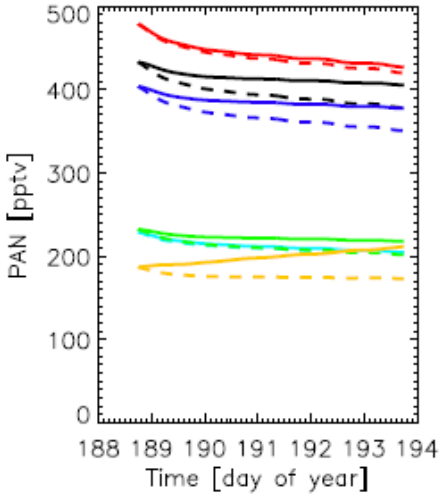
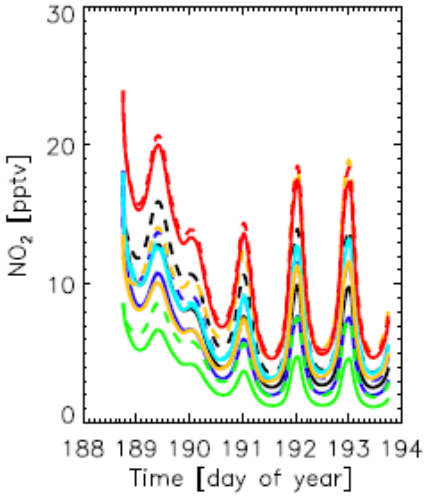
Lagrangian model initialised 18UT 7 July

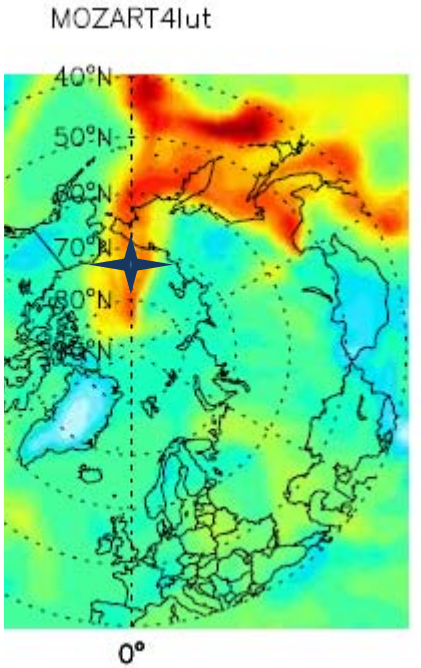
TM5
GEOSChem
CAM5Chem
gmi−geos5
CAMchem_GEOS5
MOZART4lut

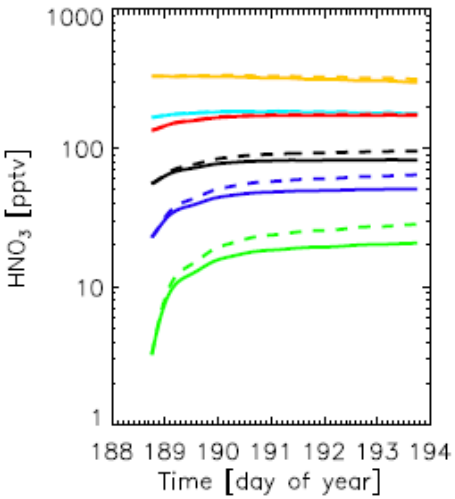
5-day CiTTyCAT Lagrangian box model simulations initialised with POLMIP model concentrations.

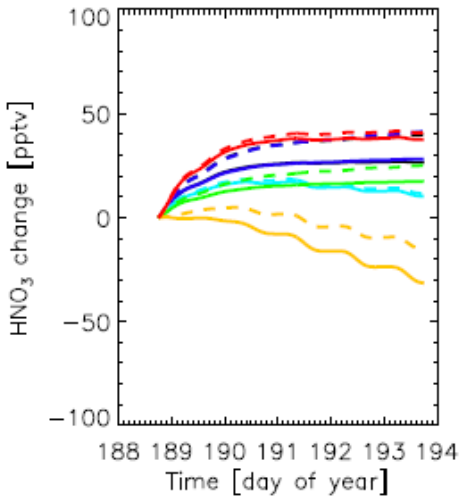


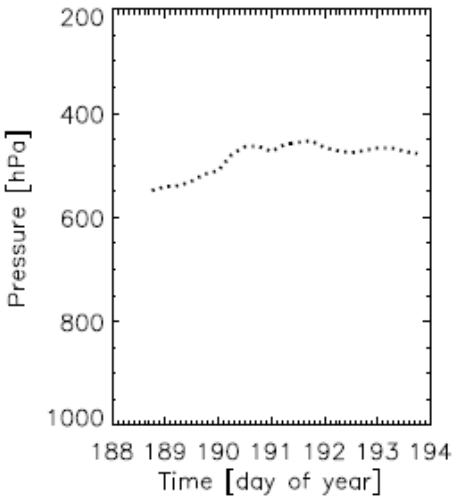












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Summary & Conclusions

- Transport of mid-latitude sources into Arctic is broadly consistent between models.
- Models vary widely in their simulation of ozone precursors in the Arctic – esp. for NOy and oVOC species.
- Differences in ozone production and loss in Arctic between models is controlled by NOy partitioning and oVOC chemistry.
- Model differences in OH are likely due primarily to differences in photolysis rates, which are affected by model-simulated clouds and their treatment in the photolysis schemes.
- Hydrocarbon oxidation schemes in models impact the OH budget, as well.

Model evaluations need to include comparisons of ozone precursors, as well as ozone.

Multi-model assessments such as these can lead to valuable insights in model performance, but require a large number of parameters to be provided by each model group.