Tropospheric ozone impacts on Eurasian ecosystems and climate forcing

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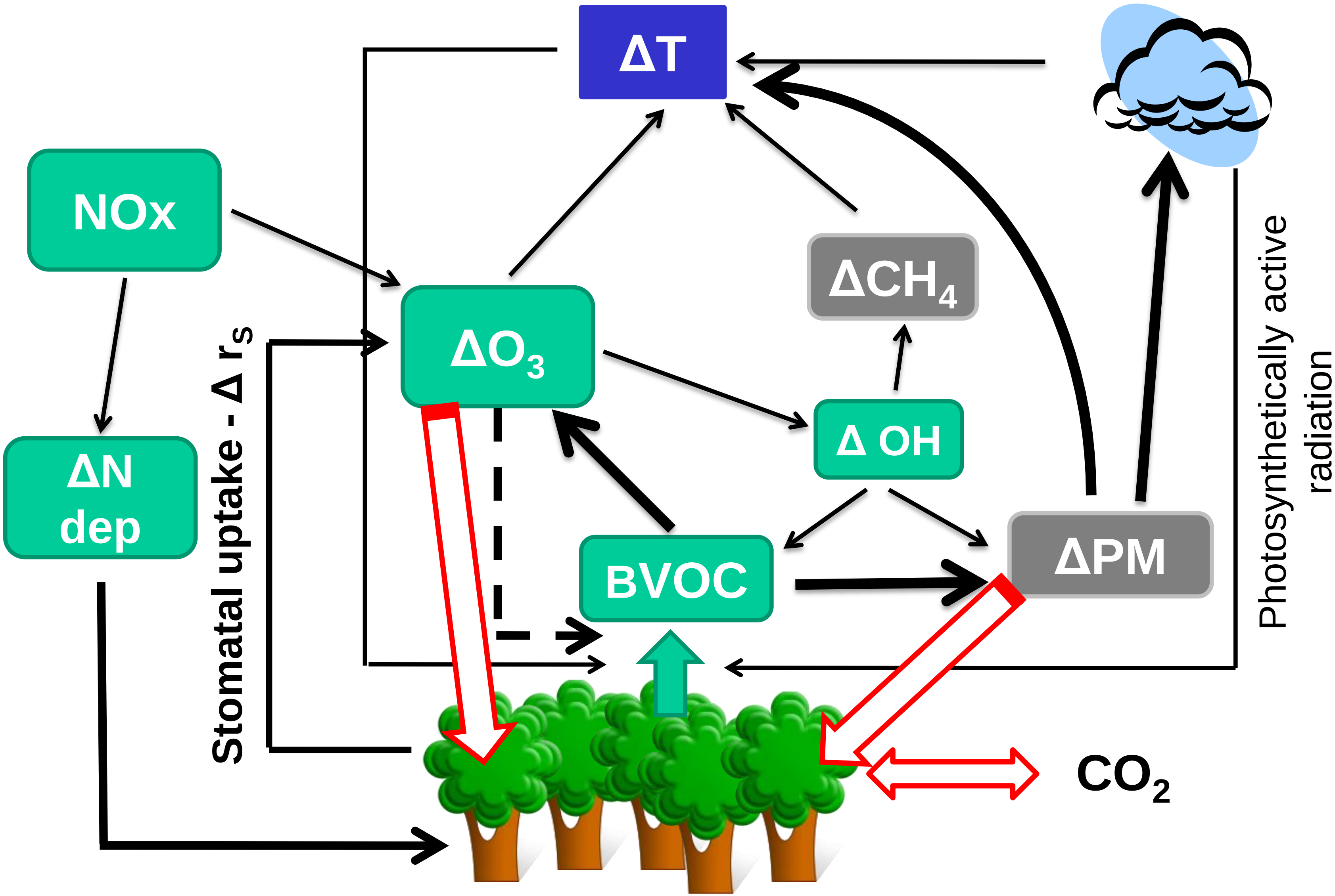
Atmospheric composition and vegetation



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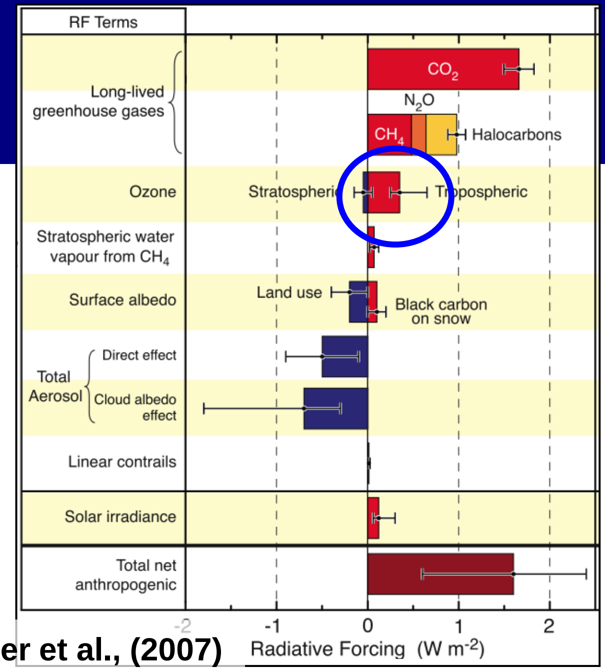
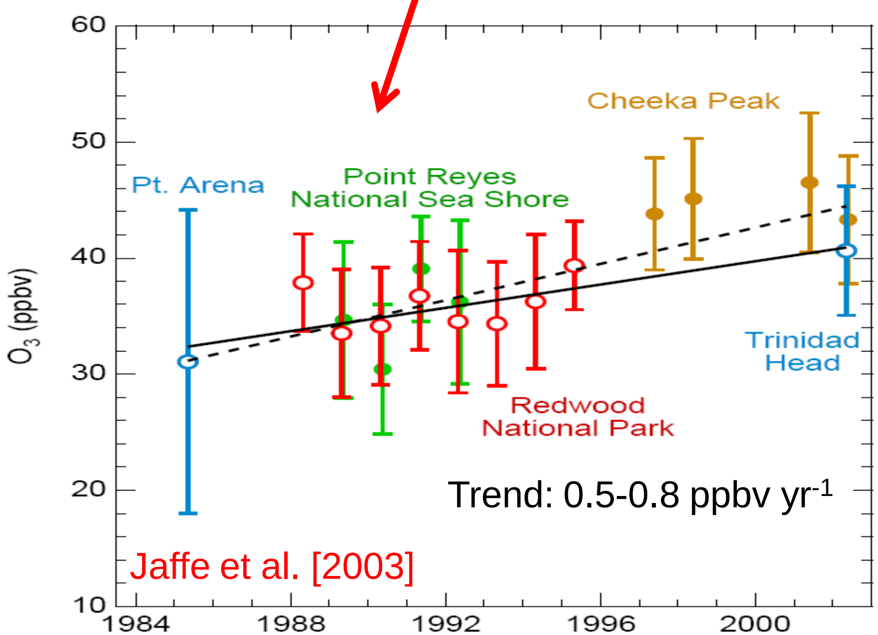
Tropospheric ozone

Ozone is a *secondary* pollutant produced in-situ in troposphere.
- Greenhouse gas
- Strong oxidant – damages health and vegetation
- NOx, CH_4 and CO are controlling precursors for NH background (this is increasing)

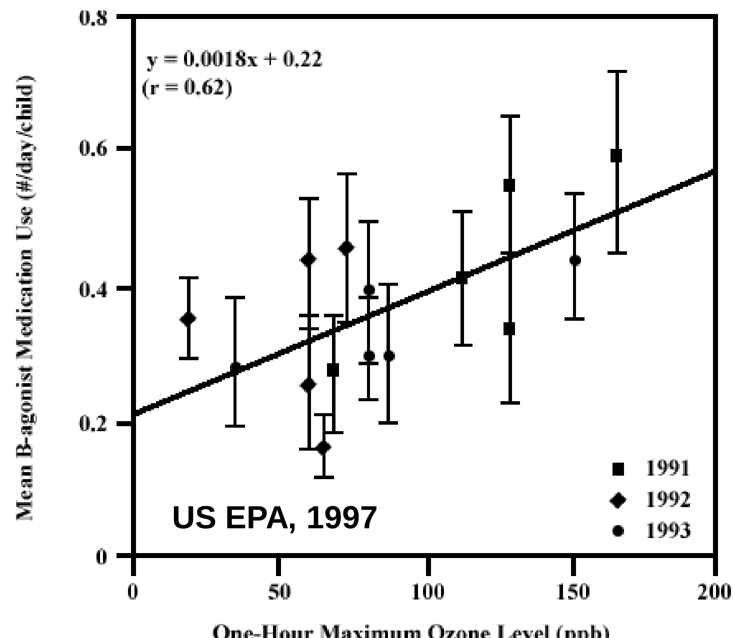


Forster et al., (2007)



Background: concentration that would be present in absence of local anthropogenic emissions

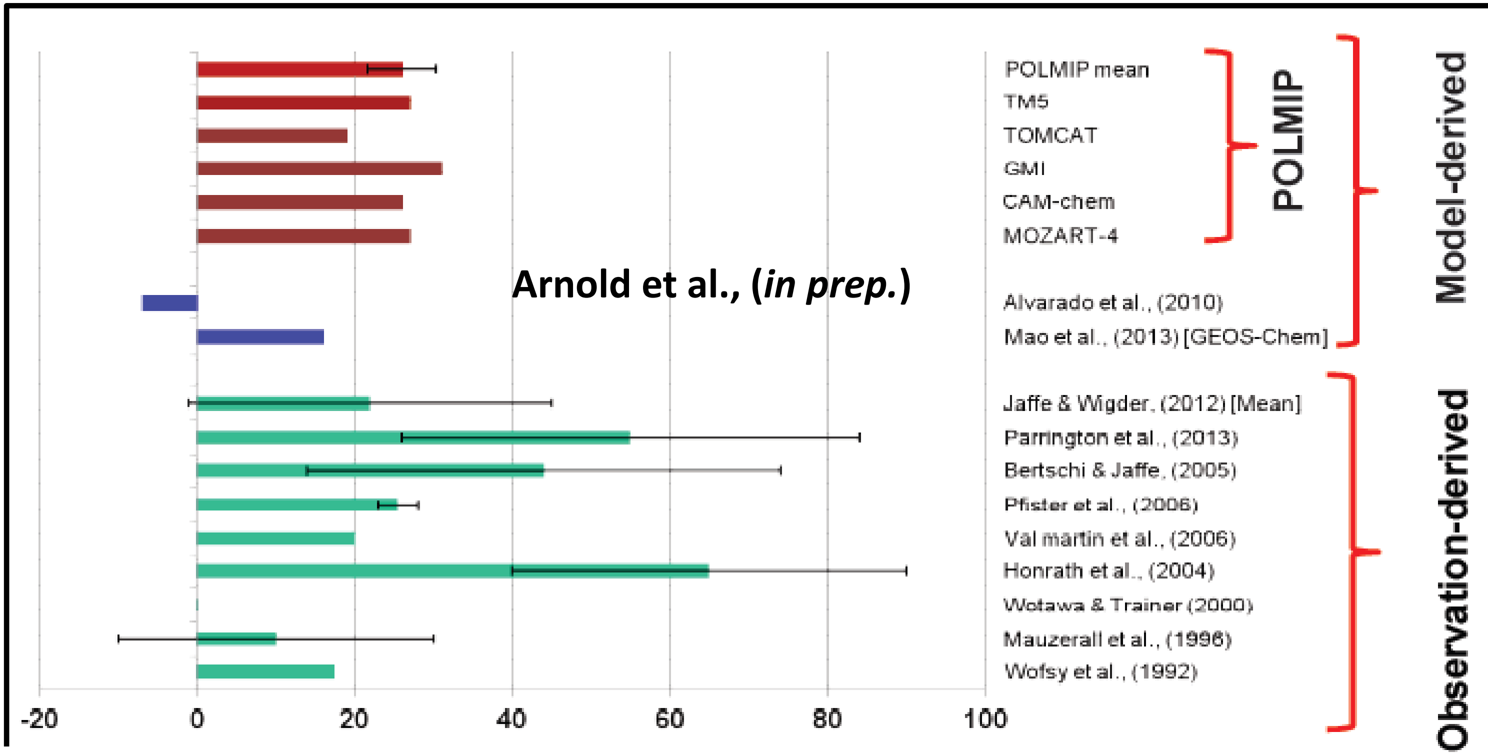
Unscheduled hospital visits for asthma medication increases with ozone



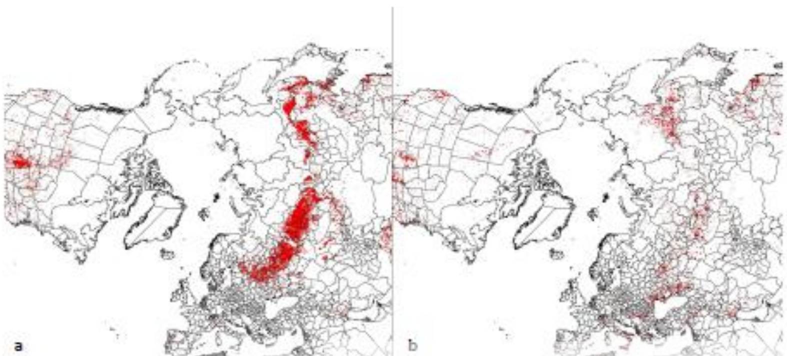
EDS

How important are fires for high latitude ozone?

Observations and models suggest that boreal fire emissions can produce ozone at high latitudes.



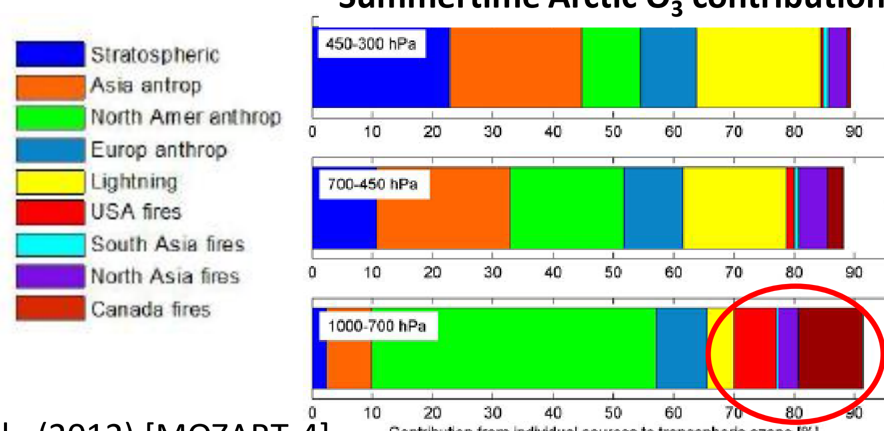
$\Delta O_3 / \Delta CO$ [%] in boreal fire plumes



Hornbrook et al., *ACP*, (2011)

Fig. 4. Plot of the MODIS fire counts in the Northern Hemisphere during (a) April 2008 and (b) June–July 2008.

Summertime Arctic O_3 contributions



Wespes et al., (2012) [MOZART-4]

Modelling tools

CAM-Chem model (CESM 1.1.1) [Lamarque et al., 2012]

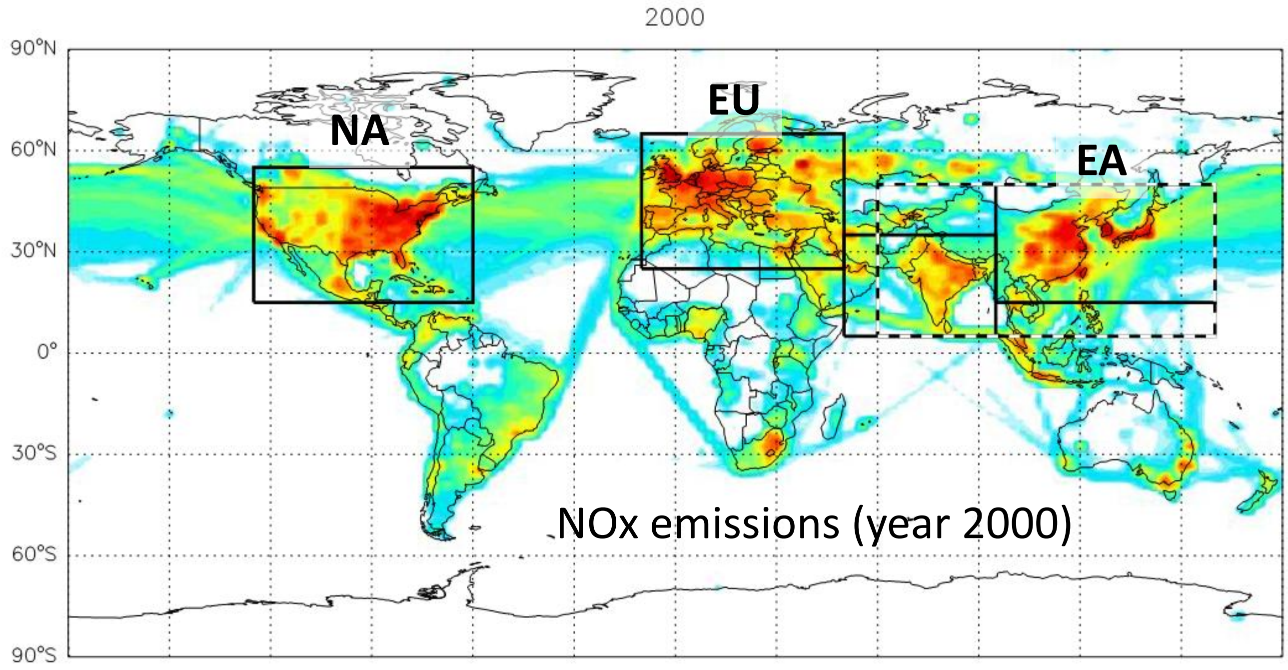
- Year 2010, GEOS-5 specified dynamics.
- MOZART-4 chemistry with NOx source (XNO) / ozone tagging scheme.
- CCMI-Seac4ars (Asia) anthropogenic & FINN fire emissions.
- NOx tagging scheme (Emmons et al., 2012) for anthropogenic & boreal fire emissions.
- Ozone produced from tagged XNO_2 tracked (O3A).

JULES (Joint UK Land Environment Simulator) vegetation model

[Best et al., 2011; Clark et al., 2011].

- Offline meteorology for 2010 and prescribed plant function type (PFT) distribution.
- Ozone damage parameterised as photosynthesis inhibition based on cumulative stomatal ozone uptake (Sitch et al., 2007).
- 5 experiments with different surface ozone fields.
- Calculate change in productivity attributable to tagged ozone from each source of NOx.

Ozone 'tagging'



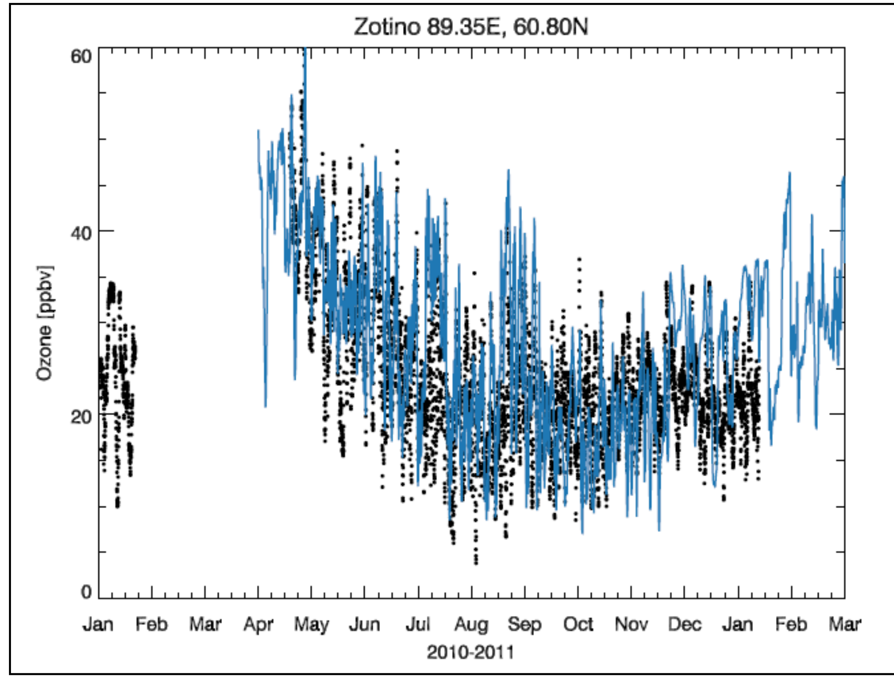
Ozone produced in the troposphere from NOx pollution (road transport, power generation, fires):

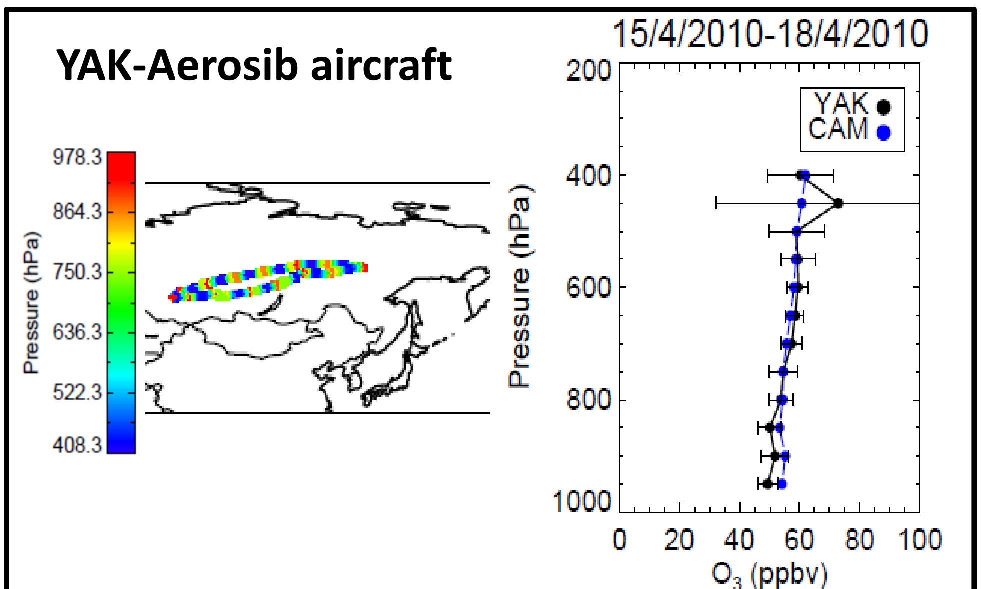
NO_2 + sunlight → NO + O

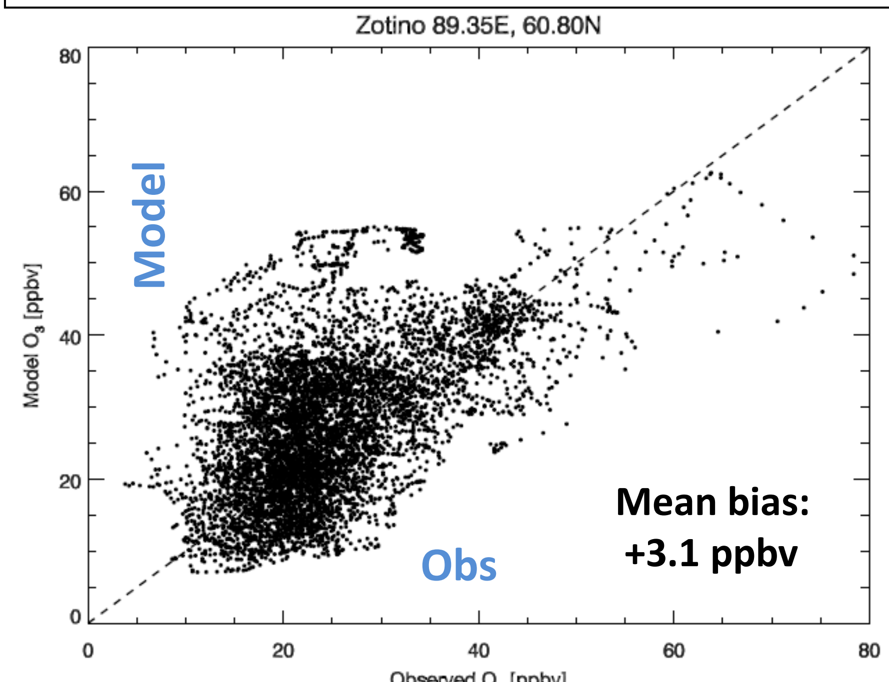
$O + O_2 \rightarrow O_3$

Tagging allows us to follow ozone in the model that is produced from NOx emissions in a given region → break down total ozone at given location into its constituent sources.

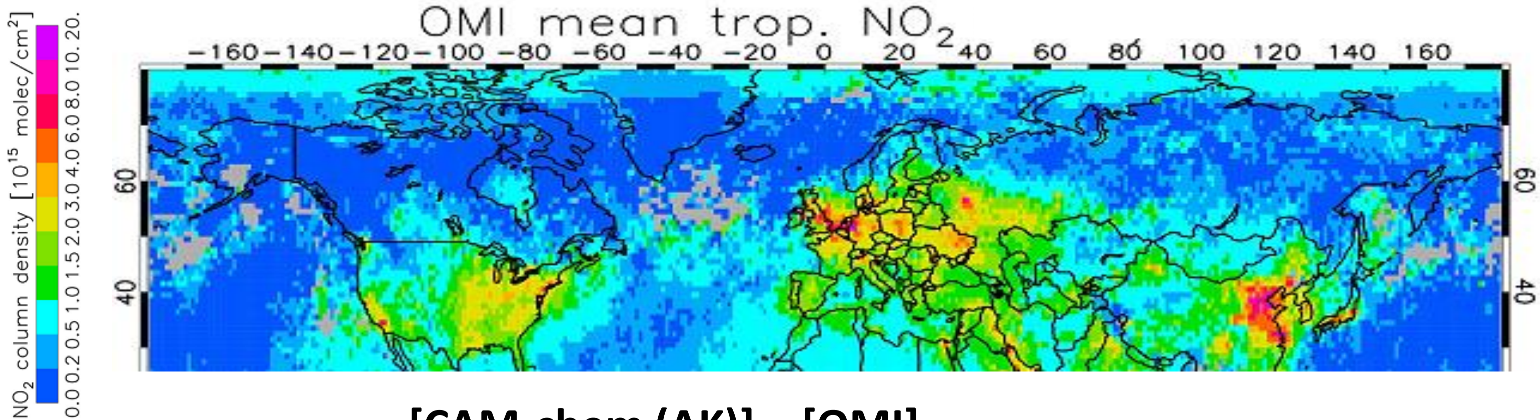
Model O_3 evaluation over Eurasia



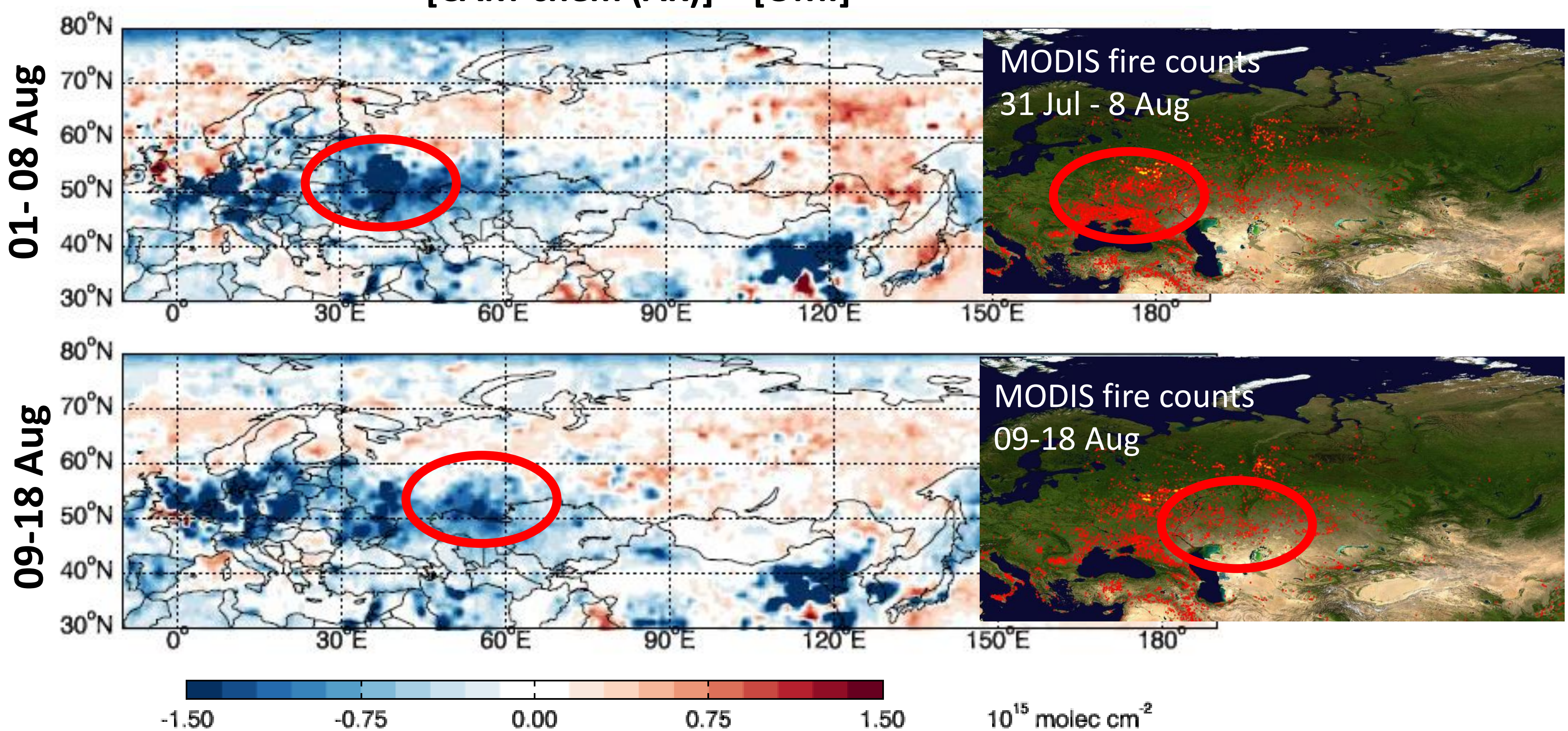




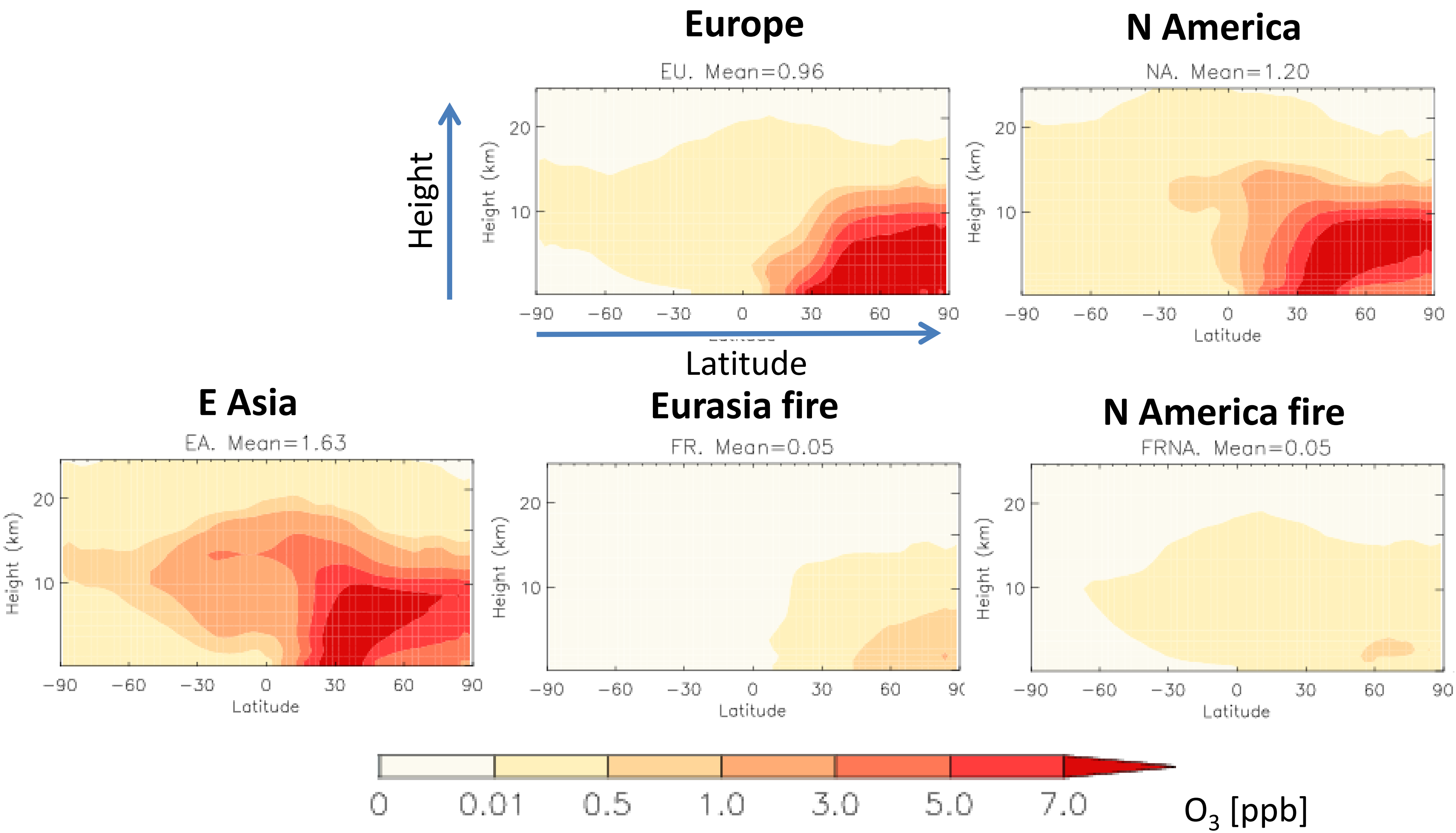
Fire emissions and ozone precursors (OMI satellite)



[CAM-chem (AK)] – [OMI]

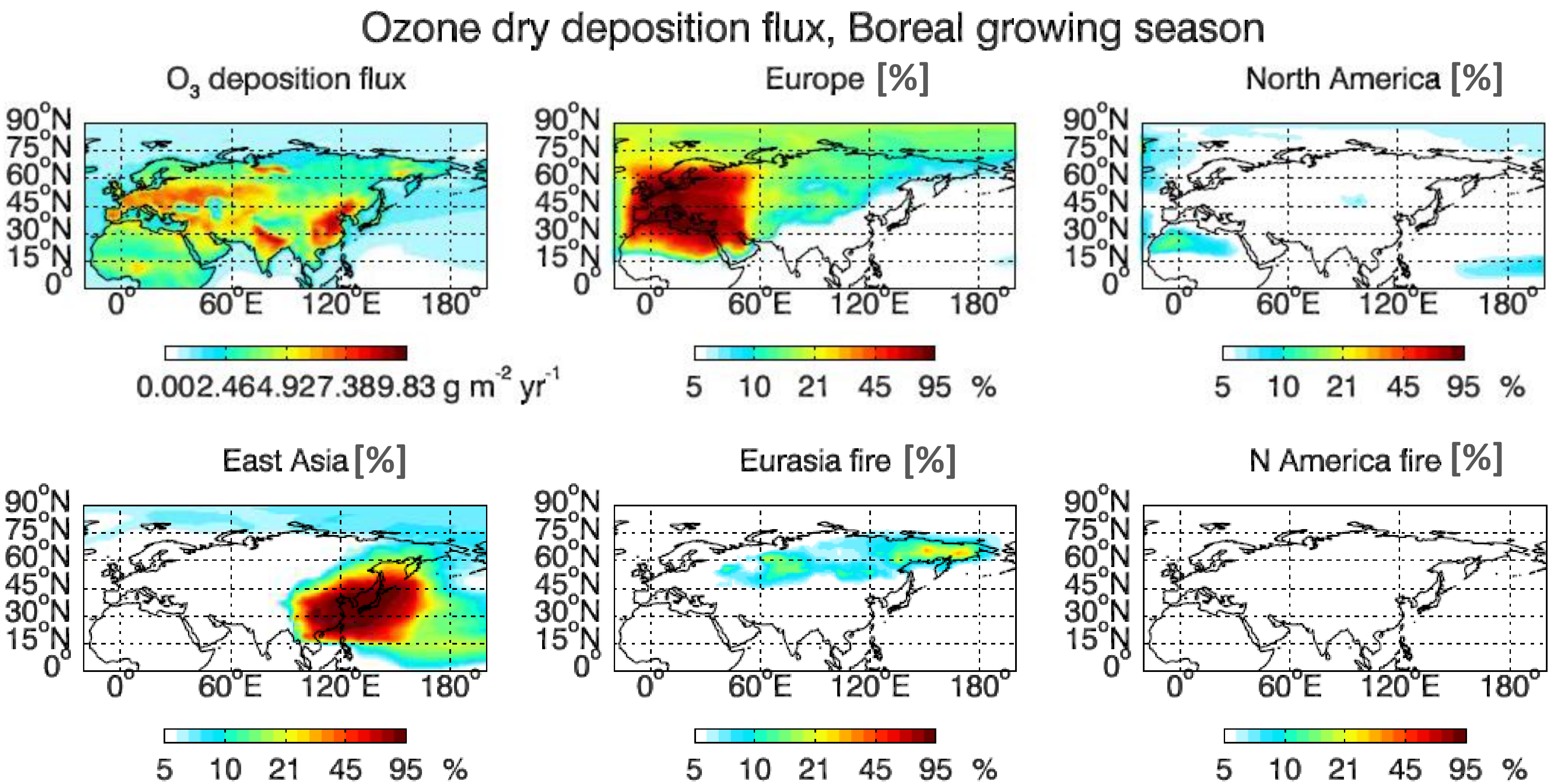


Where do different NOx sources lead to ozone production?



Familiar 'stacked' source contributions at high latitudes. Absolute fire O_3 contributions are small compared with anthropogenic impacts.

Source contributions to ozone deposition flux

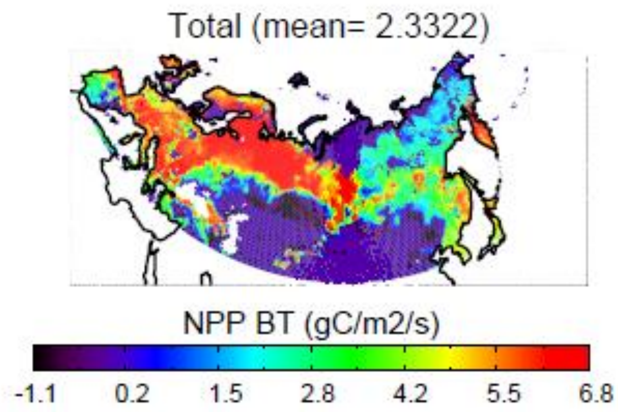


Fires contribute to ~10-40% of ozone uptake at surface over a wide area of Siberia.

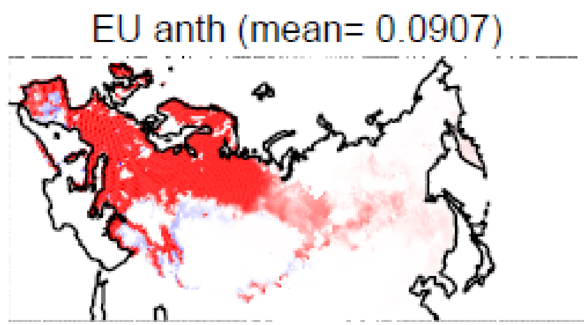
Source contributions to ozone-induced Eurasian ecosystem damage

5 PFTs: **broadleaf tree**, needleleaf tree, C3 grass, C4 grass, shrub

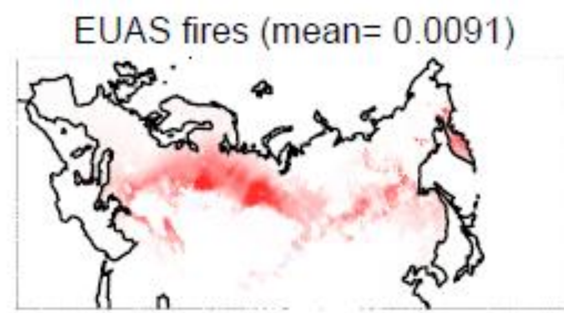
July NPP with total O_3

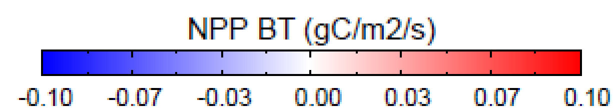


ΔNPP (minus Europe O_3)

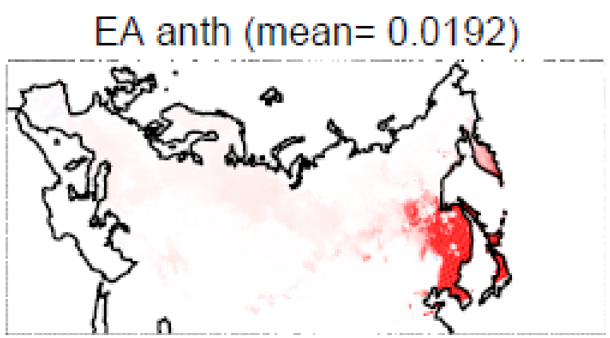


ΔNPP (minus Eurasia fire O_3)

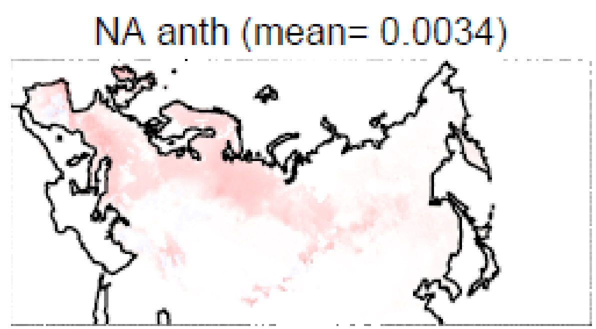




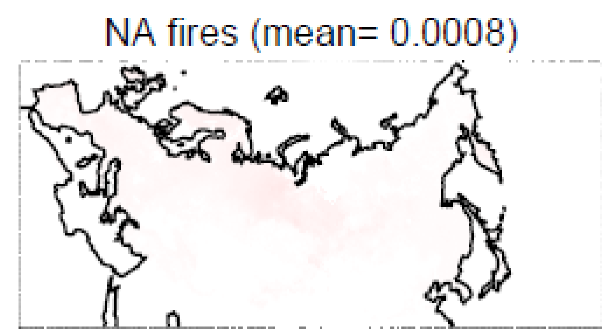
ΔNPP (minus E Asia O_3)

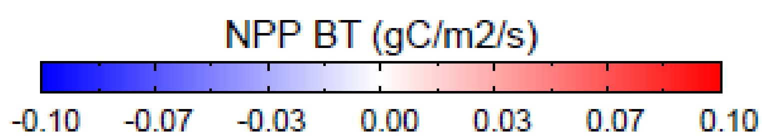


ΔNPP (minus N America O_3)

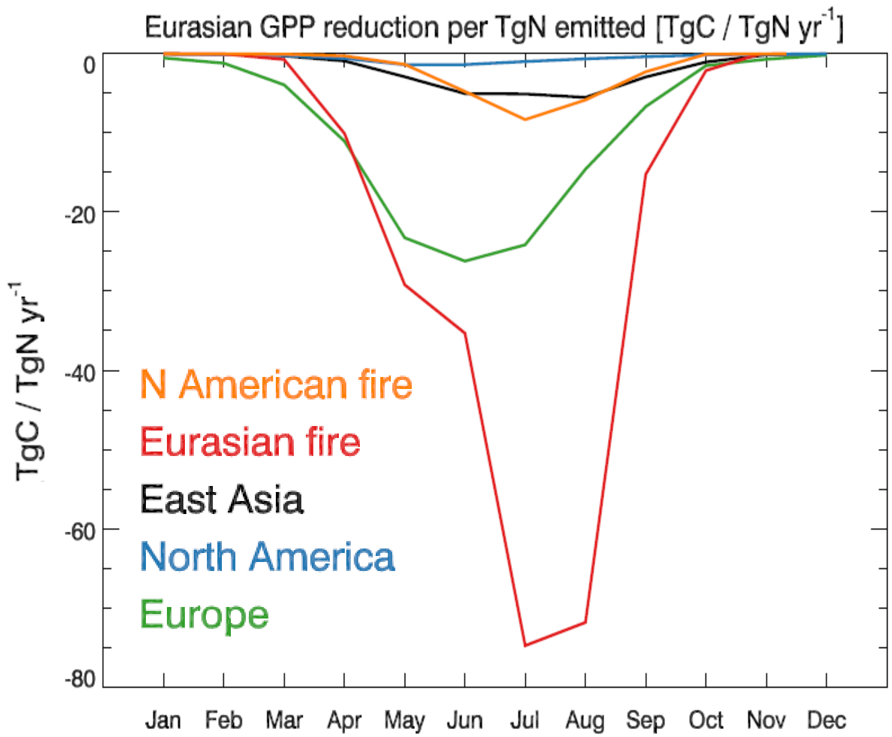


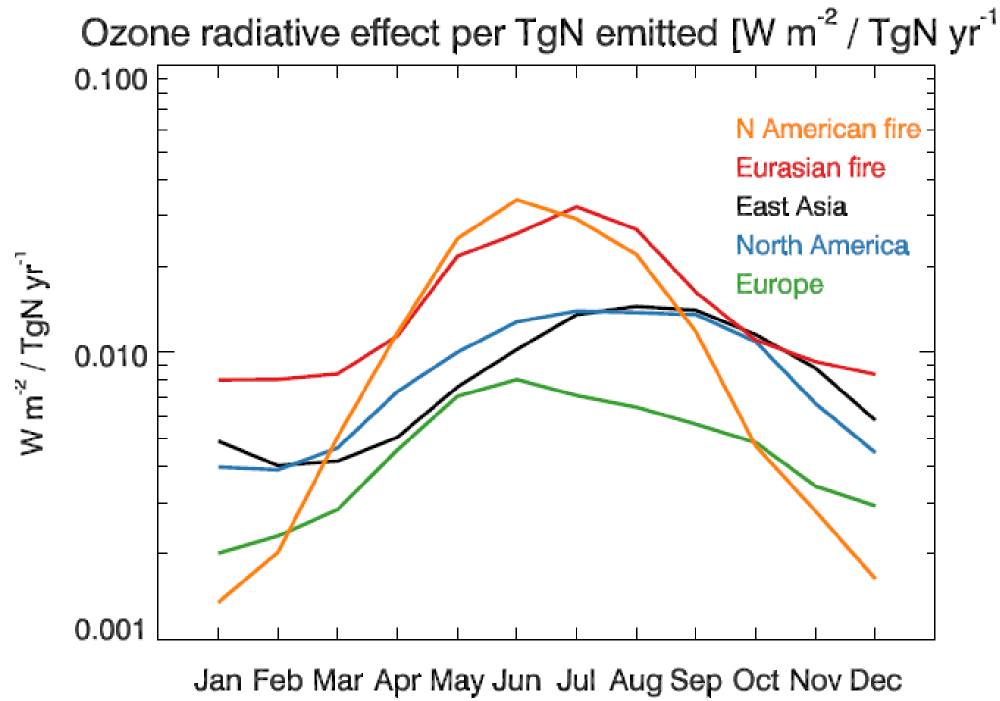
ΔNPP (minus N America fire O_3)





Ecosystem damage and climate forcing efficiency of NOx emission sources





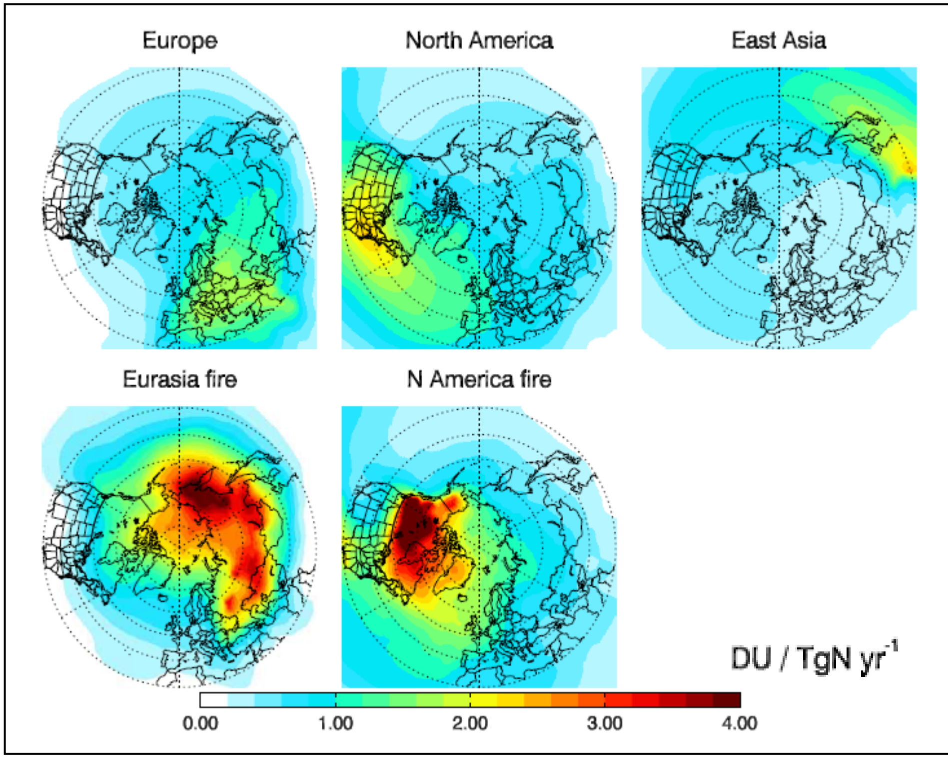
JULES simulations with vegetation ozone damage. Reductions in Eurasian GPP due to 'tagged' ozone from each region.

Ozone tagging mechanism from anthropogenic and boreal fire NOx emission regions + offline radiative transfer model.

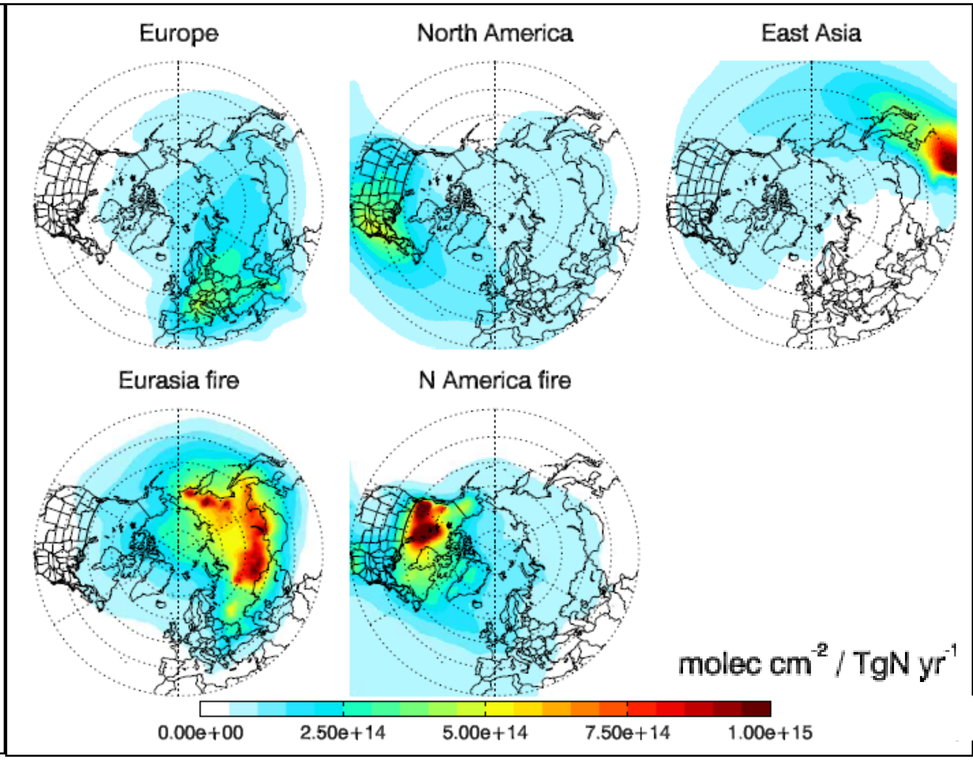
NOx emissions from Eurasian fires result in the largest ozone radiative efficiency and Eurasian GPP loss efficiency per kg NOx emitted.

Efficiency of ozone production from fire emissions

Tagged O_3 column per regional NOx emission



Tagged AN column per regional NOx emission



Per kg emitted, NOx emissions from Eurasian fires are *most efficient* producers of high latitude tropospheric O_3 and key precursor species (PAN).

This is likely explained by (a) the seasonality and (b) the (organic) chemical composition of fire emissions.

Summary

- Ozone damage impact from European man-made emissions spreads north-eastwards into Russian high latitudes.

- Fires dominate NPP ozone loss in remote Siberian forest.

- Dominant meteorology means that E Asian emissions are less important for Eurasian vegetation damage.

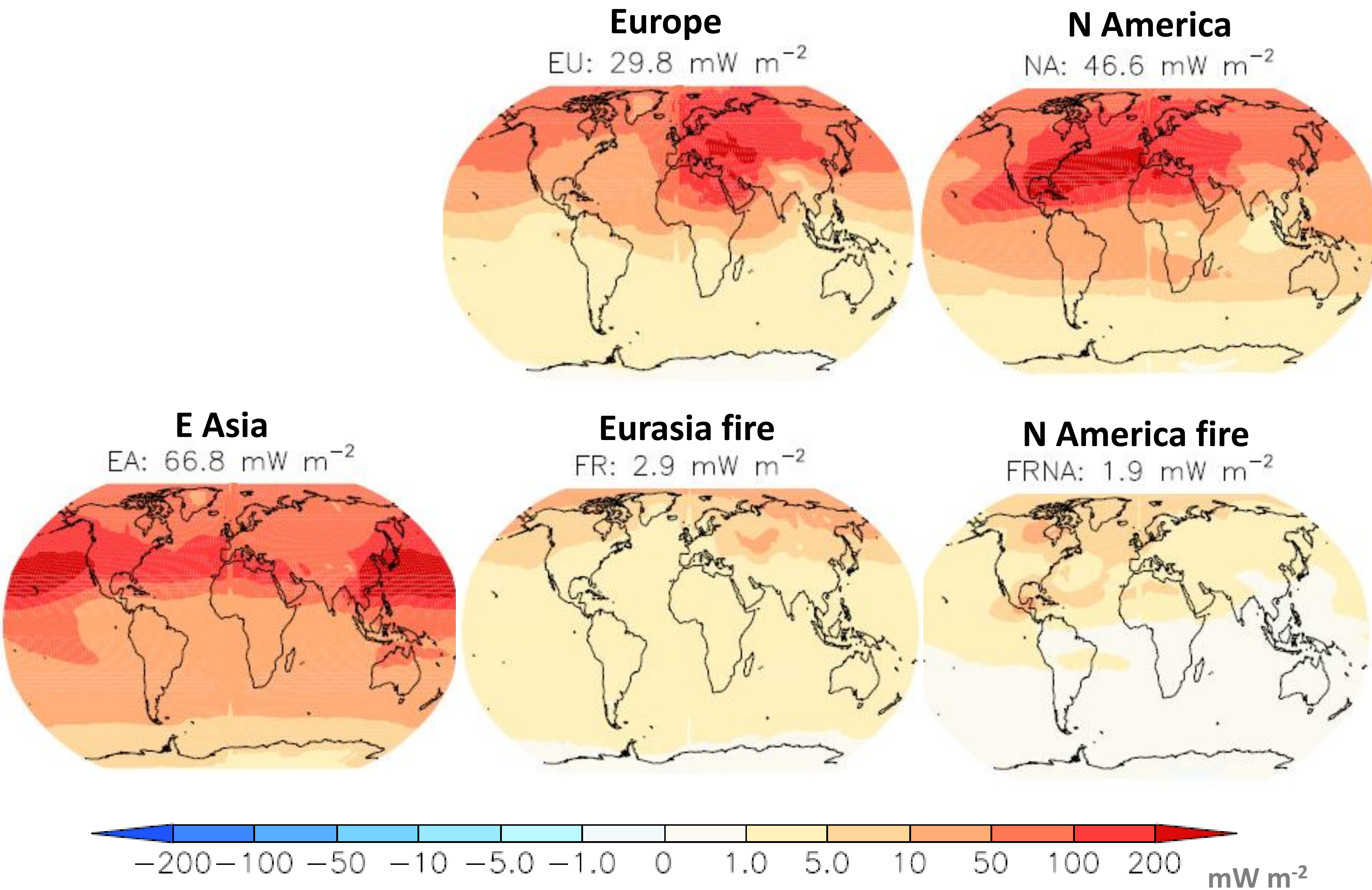
- Ozone produced from Eurasian fire emissions results in the largest Eurasian ecosystem GPP reduction per NOx emitted. Europe is the dominant anthropogenic source.

- Ozone radiative effect from Eurasian fires is small compared with anthropogenic sources, however per molecule of NOx emitted, it is dominant.

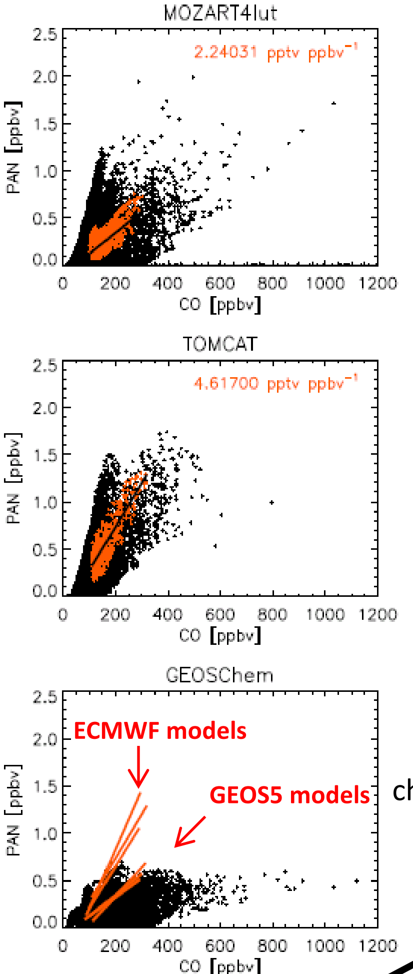
- FINN fire emissions appear to underestimate NO_2 in large Moscow fires of 2010.

Acknowledgements:
- UK Natural Environment Research Council (NE/H020241/1).
- NCAR Advanced Study Programme and NCAR Atmospheric Chemistry Division.

Radiative effects of tagged regional ozone



Perspectives from POLMIP (Polarcat Model Intercomparison)

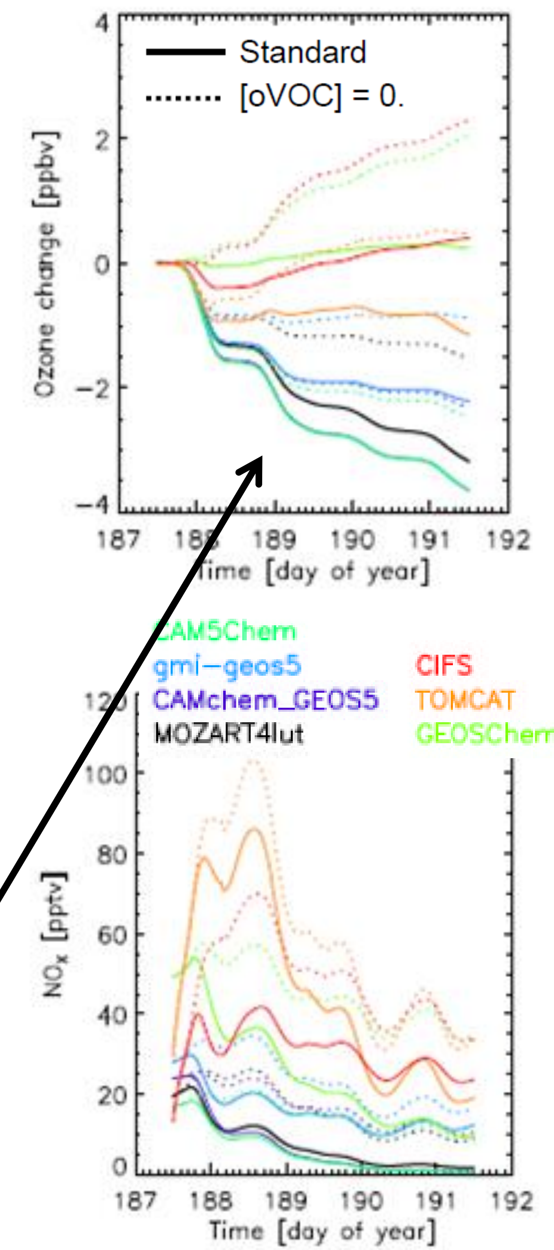


Same chemistry

Model	ΔPAN / ΔCO in fire air masses
CAM-Chem	2.02 pptv ppbv^{-1}
MOZART-4	2.24 pptv ppbv^{-1}
GMI	3.02 pptv ppbv^{-1}
TM5	4.44 pptv ppbv^{-1}
TOMCAT	4.62 pptv ppbv^{-1}
CIFS	6.28 pptv ppbv^{-1}

GEOS5

ECMWF



PAN enhancement in Arctic sensitive to driving met data → different vertical transport efficiencies.

POLMIP plume model study

- Ozone production in Arctic fire plume highly dependent on model oVOC abundances.

Arnold et al., (*in prep.*)