Ozone production in pollution plumes transported to the Arctic

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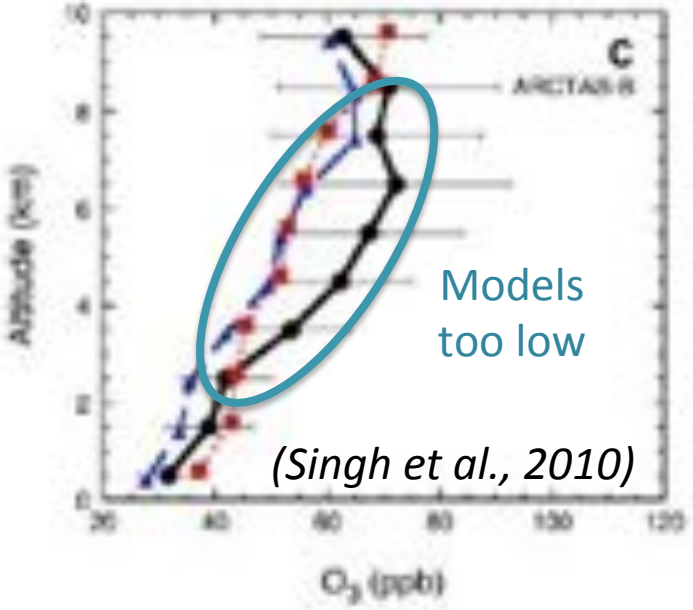
POLARCAT: Long-range transport of pollutants to the Arctic

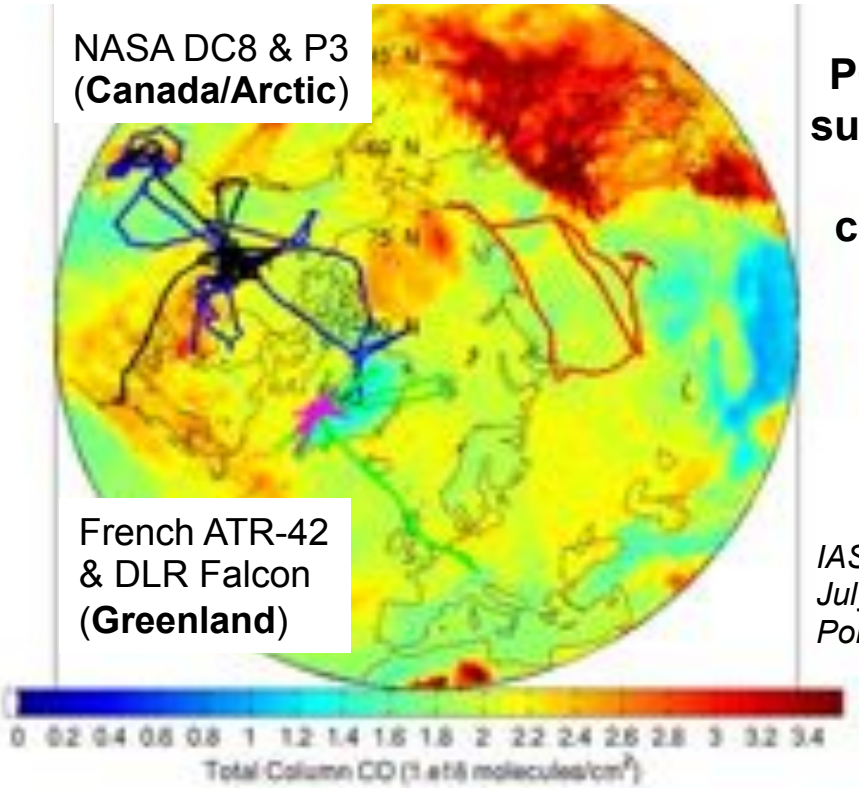
- Multiple aircraft campaigns spring/summer 2008
- Arctic ozone budget – how much O_3 from mid-latitudes, formed (destroyed) during transport or from UTLS?

GEOS-Chem/MOZART vs ARCTAS-B aircraft data (DC8, summer 2008)



NASA DC8 & P3 (**Canada/Arctic**)

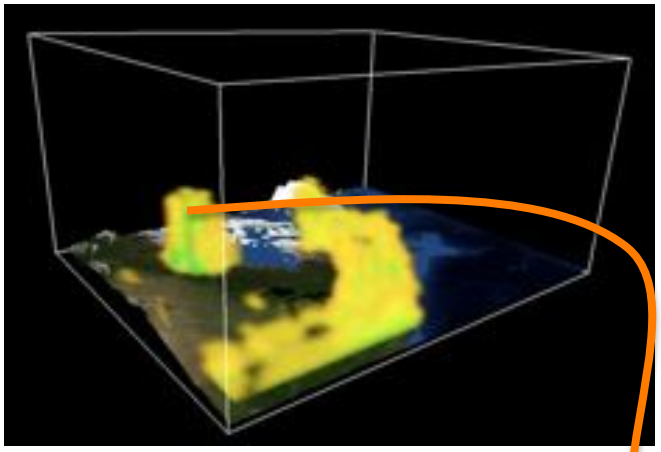
French ATR-42 & DLR Falcon (**Greenland**)



POLARCAT summer 2008 aircraft campaigns

IASI CO columns July 2008 Pommier et al. (2010)

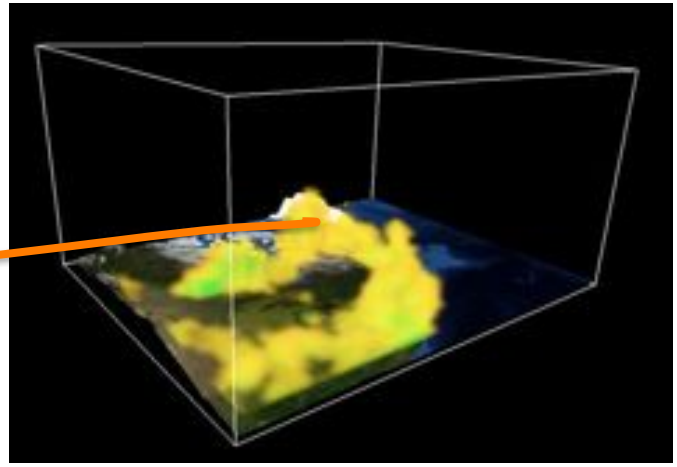
Using POLARCAT aircraft measurements to understand long range transport & chemistry



Use emissions with 3D chemistry and meteorology to predict measurements in fresh plumes and plumes after long range transport

fresh emissions
- **Chemical composition**
- **Injection height**

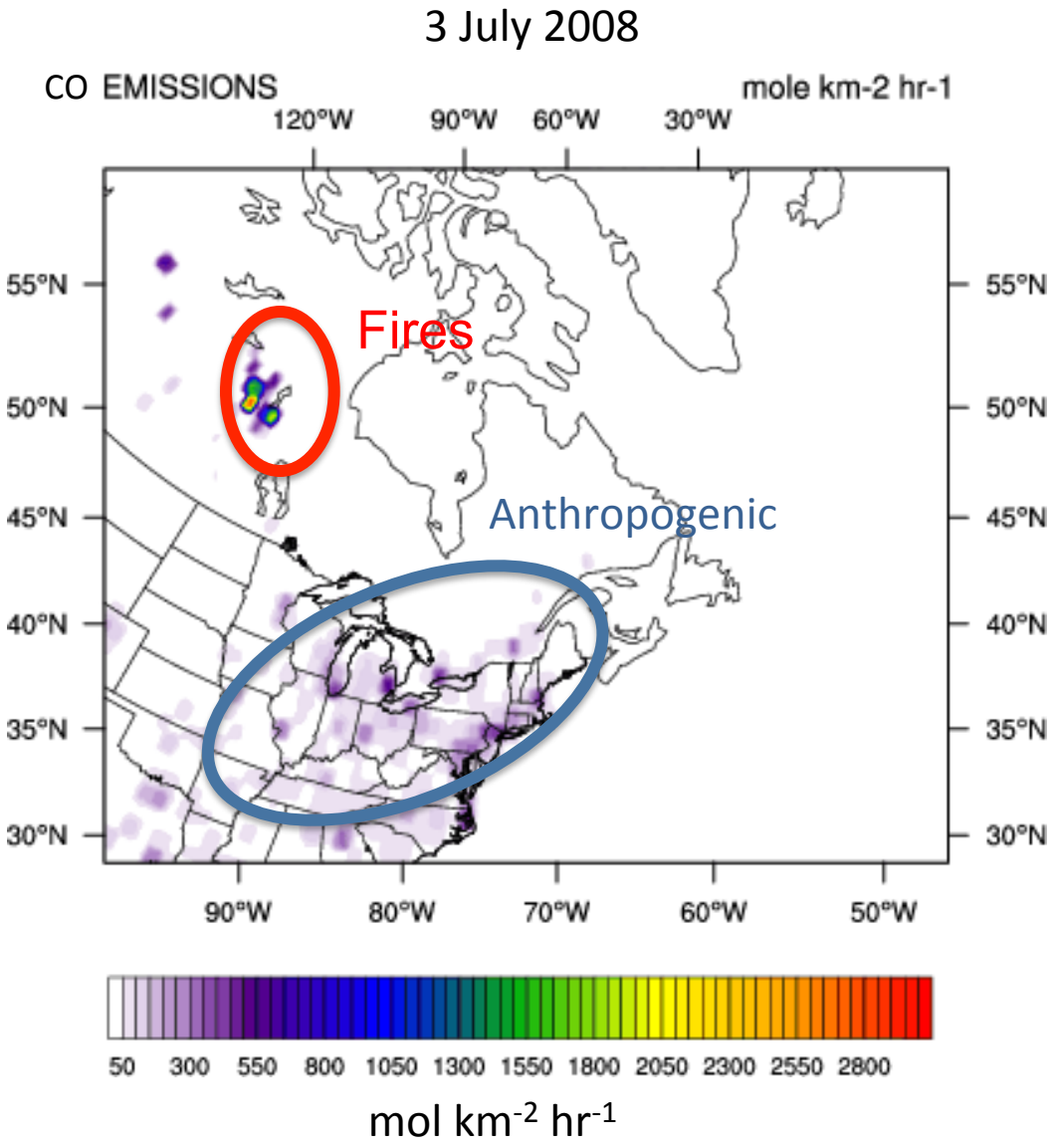
transport & chemistry



predicted chemical composition and spatial extent of pollution plumes

Key issue: model resolution vs. plume spatial extent

WRF-Chem model setup and simulations



Case study:
28 June 2008 – 8 July 2008

35 km x 35 km, 27 vertical levels

POLMIP emissions

- **Daily Anthropogenic emissions** 2008 inventory for ARCTAS (D. Streets)
- **Daily Fire emissions** from FINN-v1 (Wiedinmyer et al., Geosci. Model Devel., 2011) + online plume rise model (Freitas et al., ACP, 2007)

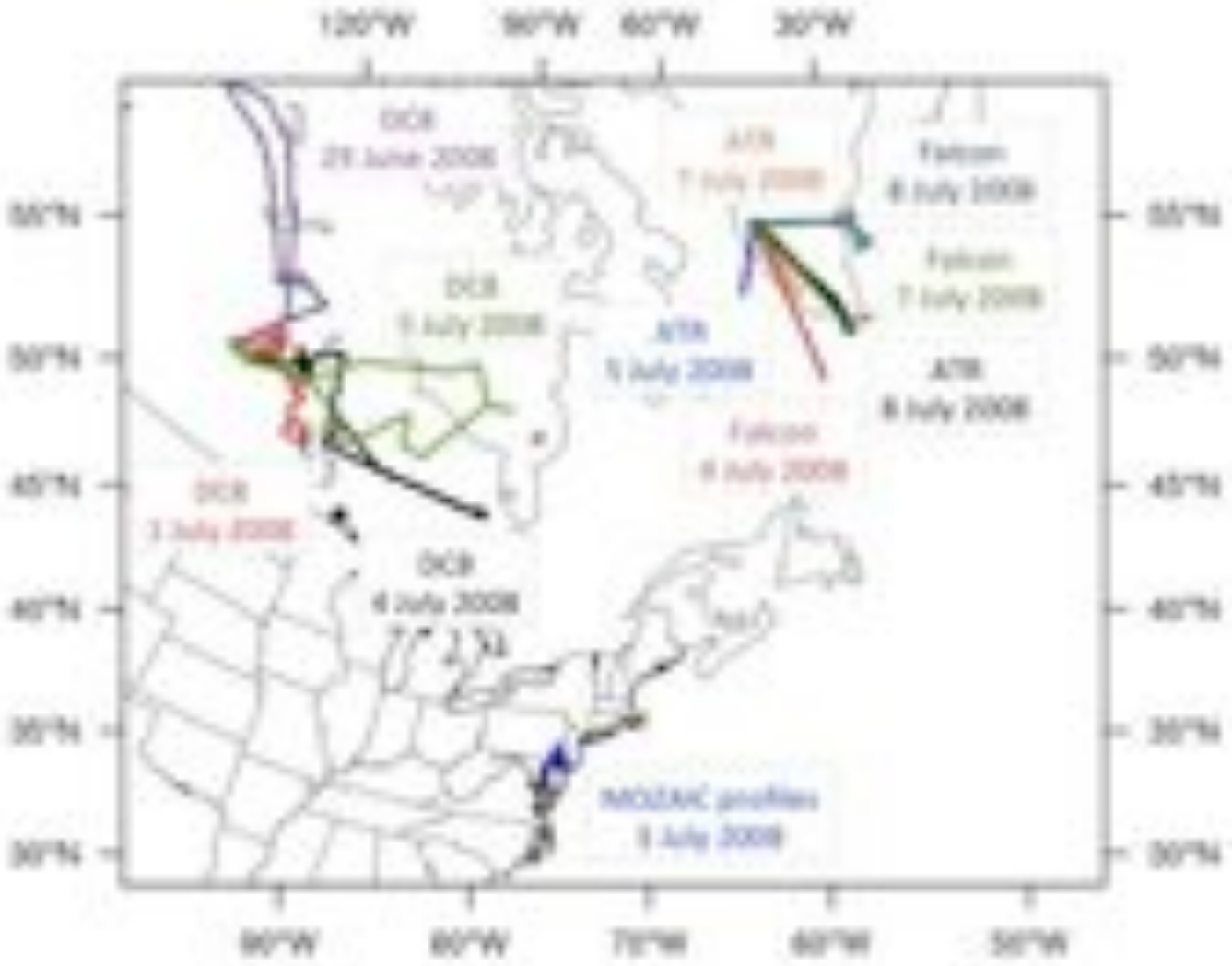
Initial & boundary conditions from MOZART4 for chemistry & GFS for meteorology + nudging (6hr)

MOZART gas phase chemistry & GOCART aerosol scheme

Runs:

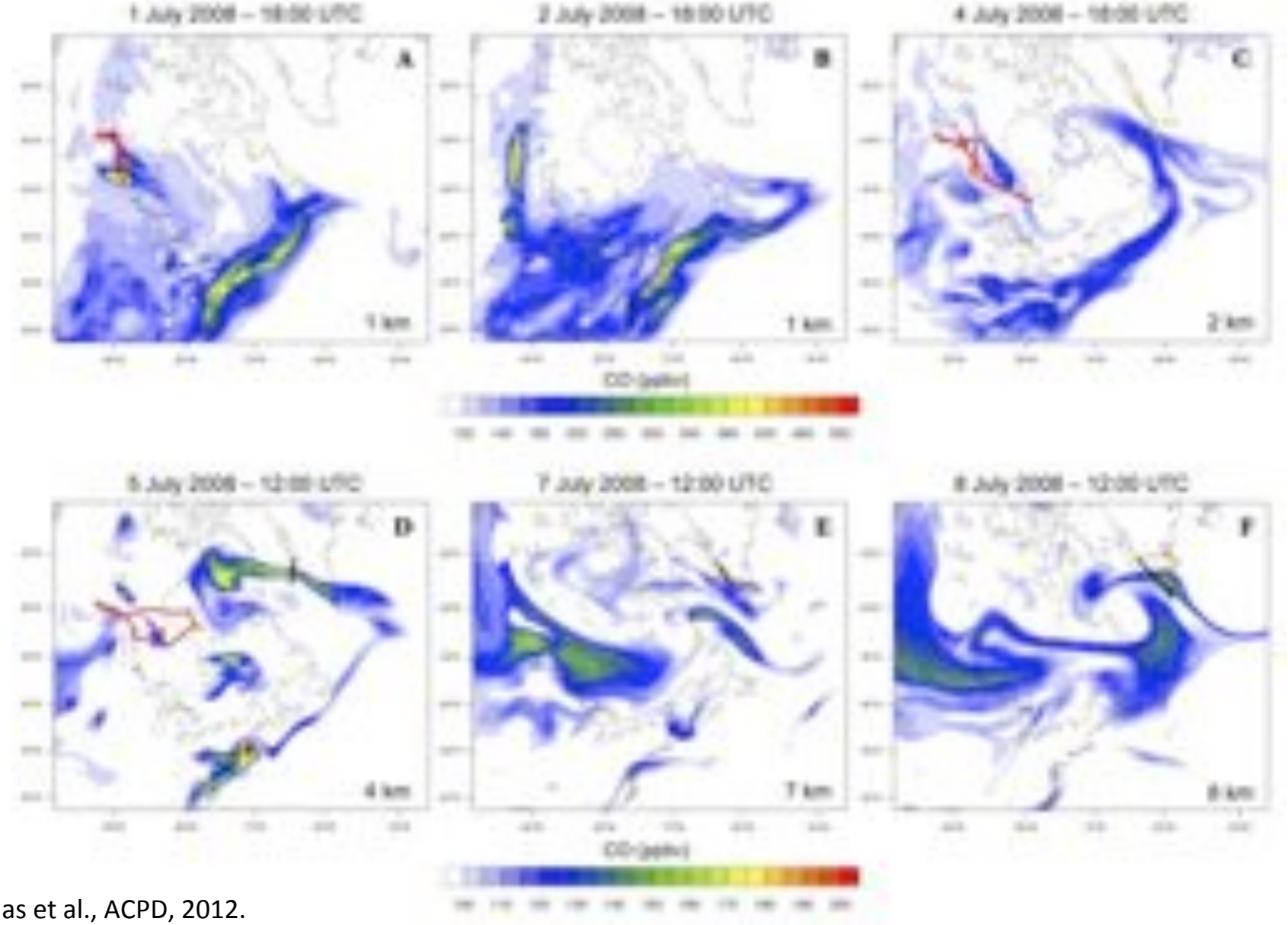
- Base case (all emissions included)
- No anthropogenic emissions
- No fire emissions

POLARCAT flights used for evaluating model results



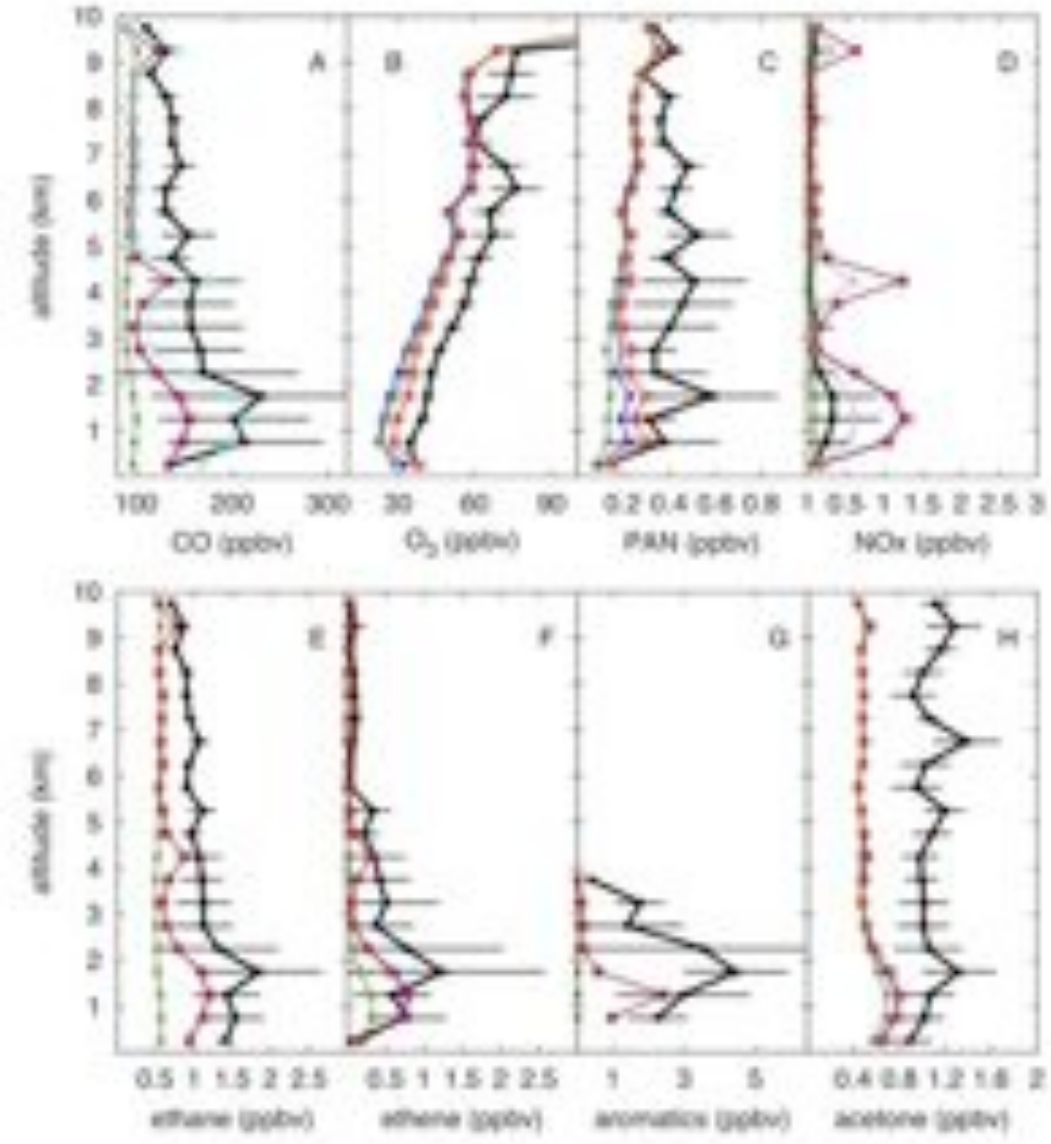
Thomas et al., ACPD, 2012.

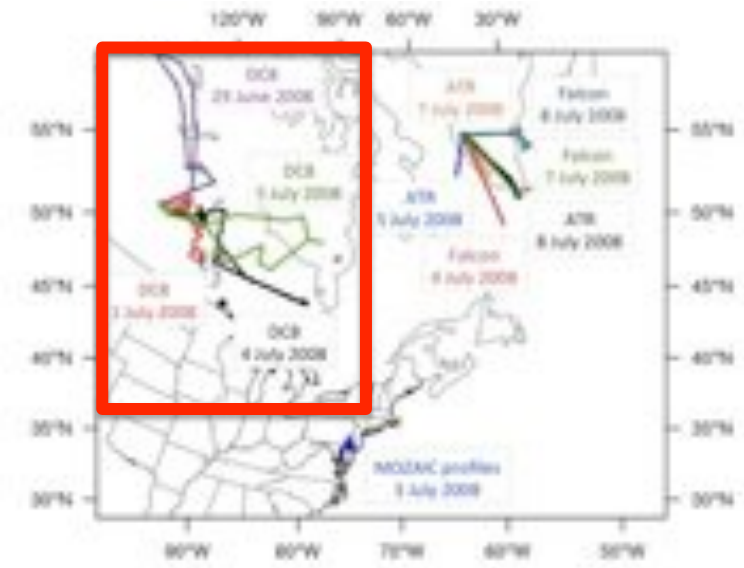
Example pollution plumes – fresh emissions and uplift



Thomas et al., ACPD, 2012.

Comparison – fresh fire plumes in Canada





Measurements

Base model run

noAnthro emissions run

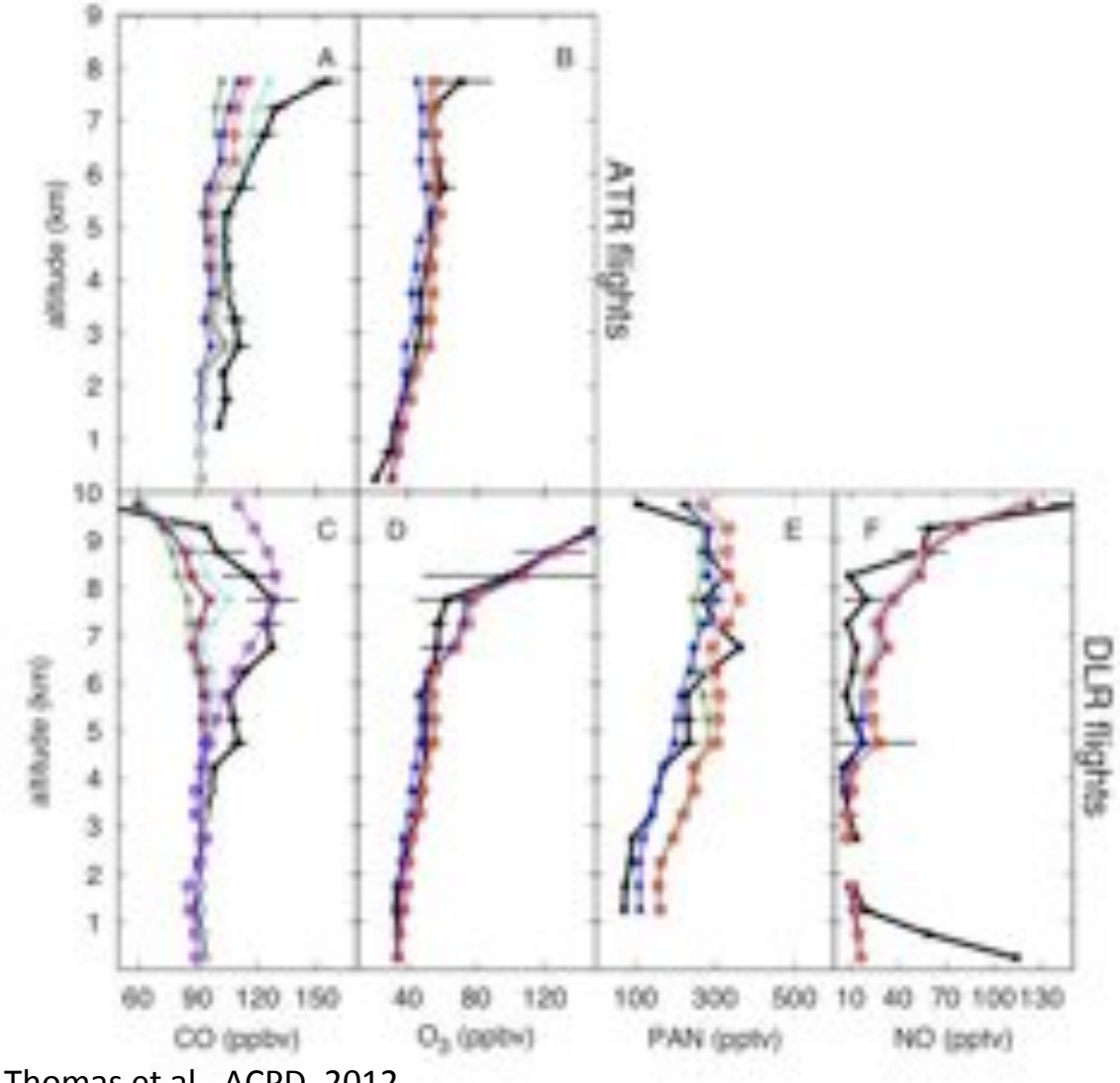
noFire emissions run

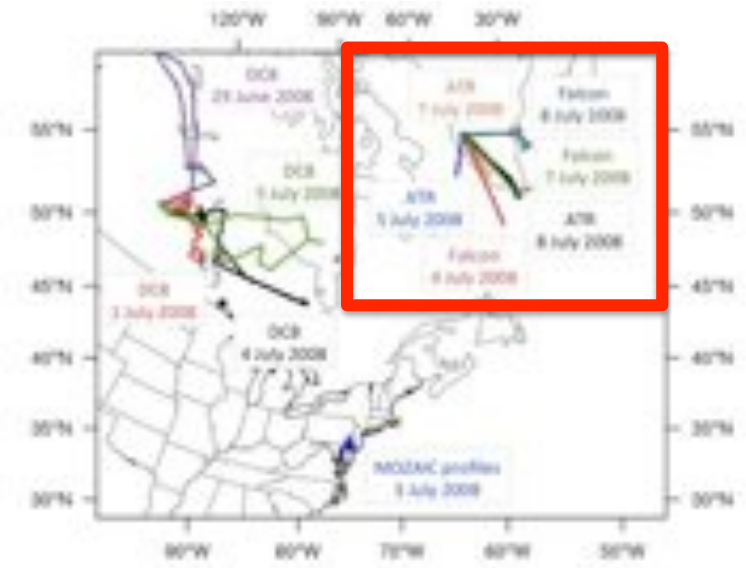
2x CO emissions from fires

½ NOx emissions from fires

Thomas et al., ACPD, 2012.

Comparison – aged plumes measured after long range transport (southern Greenland)





Measurements

Base model run

noAnthro emissions run

noFire emissions run

2x CO emissions from fires

½ NOx emissions from fires

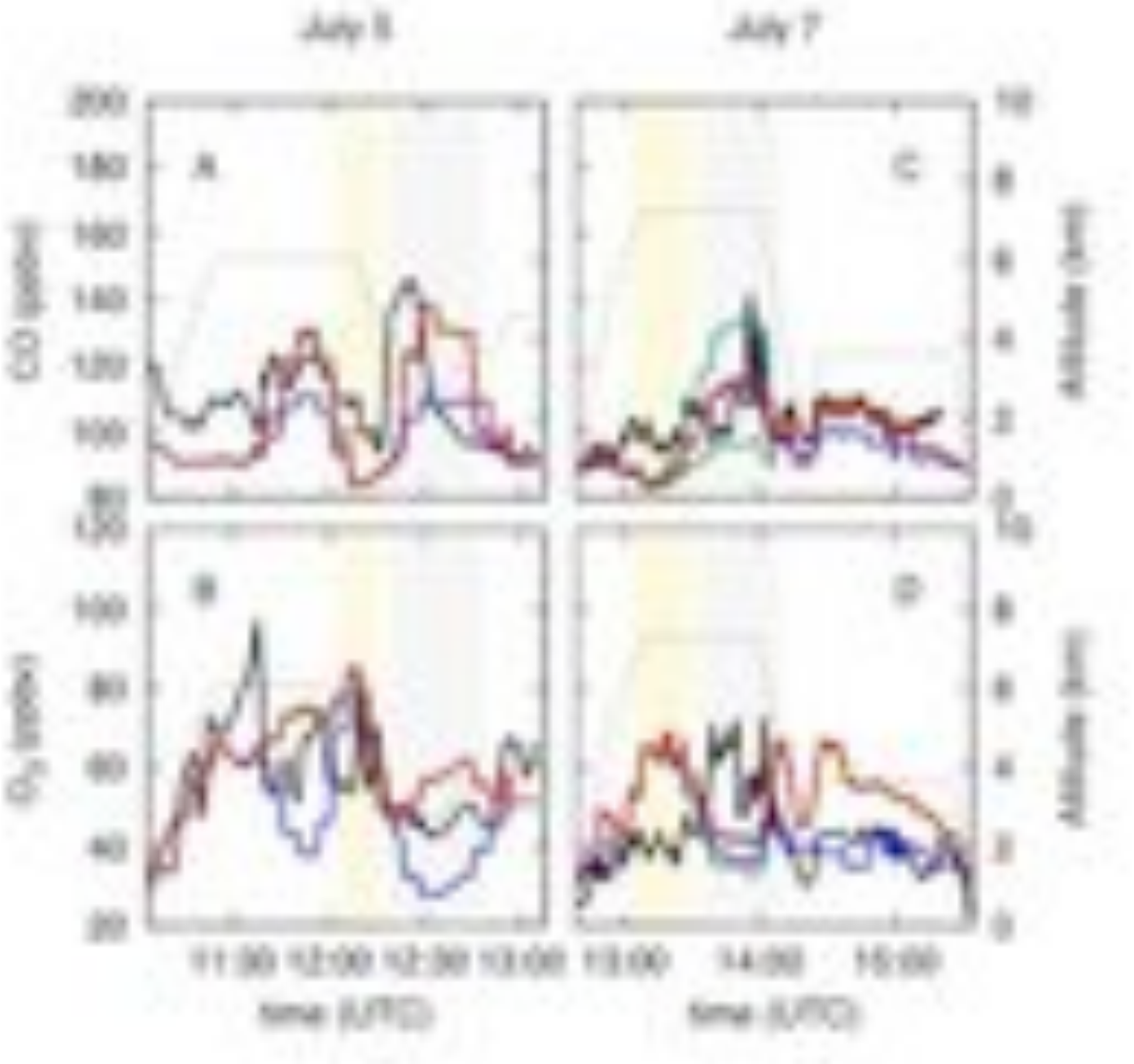
CO profile near flight track

Thomas et al., ACPD, 2012.

Measurements of individual aged plumes – onboard the ATR-42 over S. Greenland

stratospheric airmass

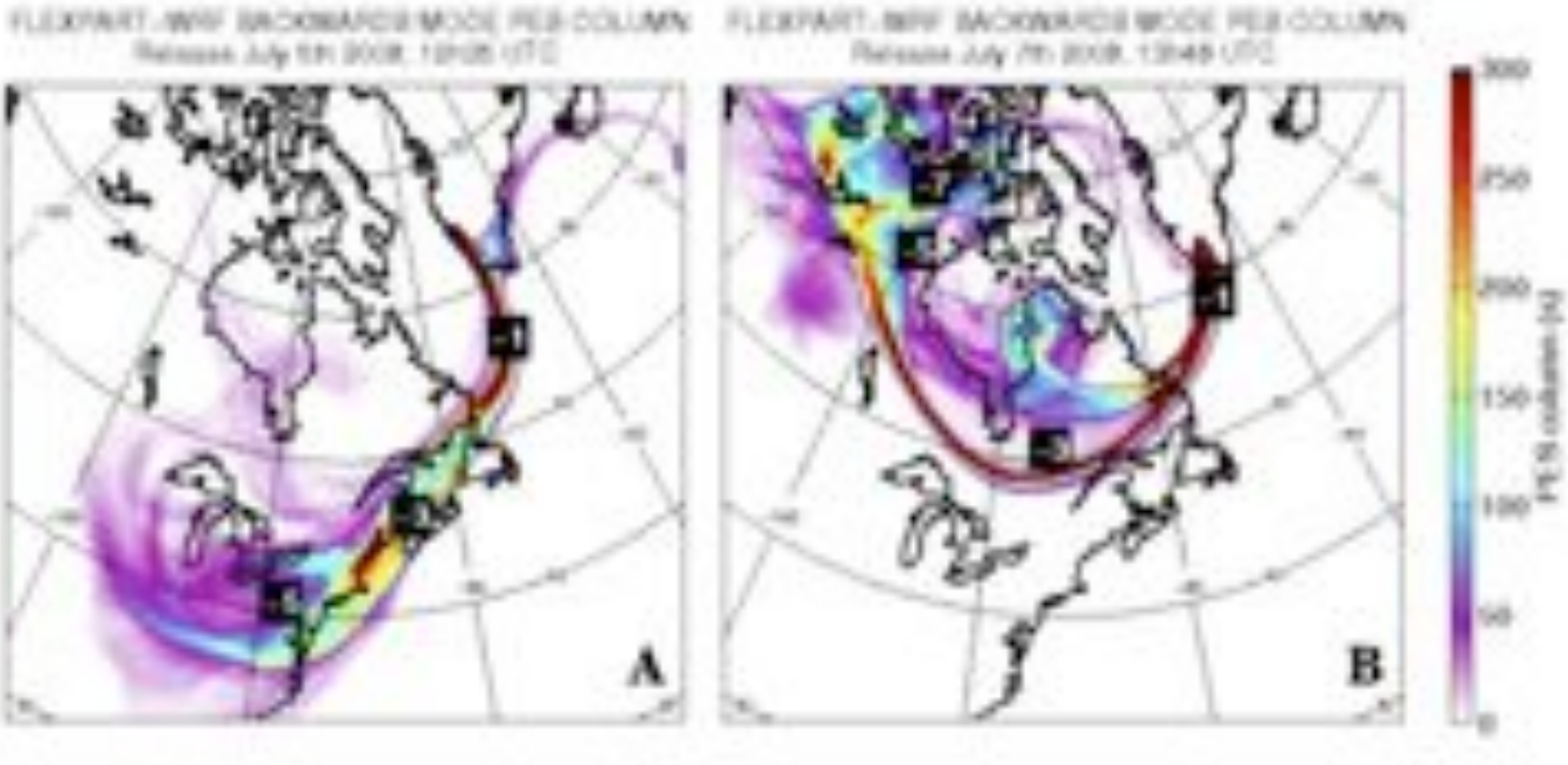
pollution plume



Measurements
Base model run
noFire emissions run
noAnthro emissions run
2x fire CO emissions

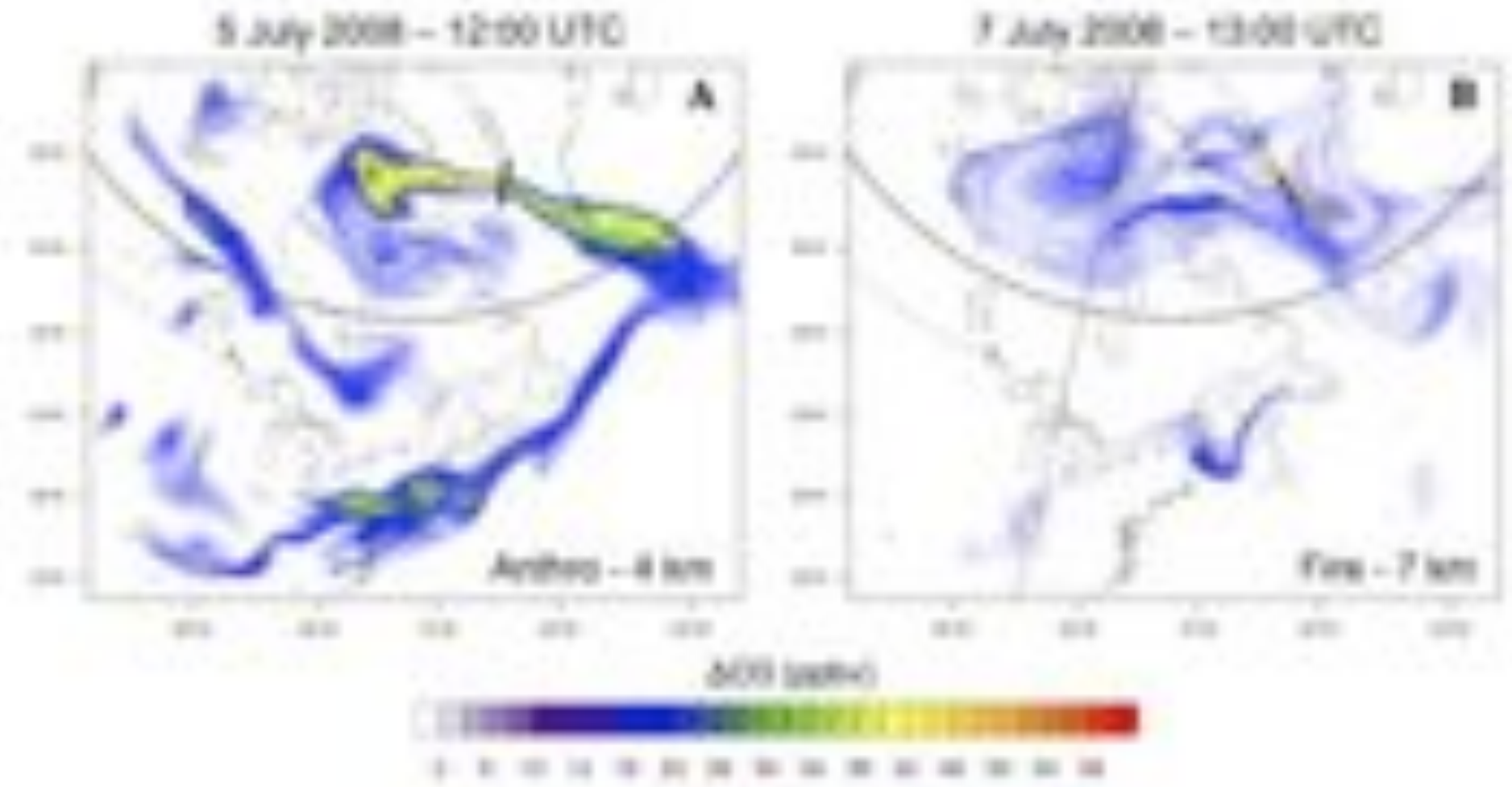
Thomas et al., ACPD, 2012.

FLEXPART-WRF used to identify air mass origins
5 July Plume (Anthropogenic) and 7 July Plume (BB)



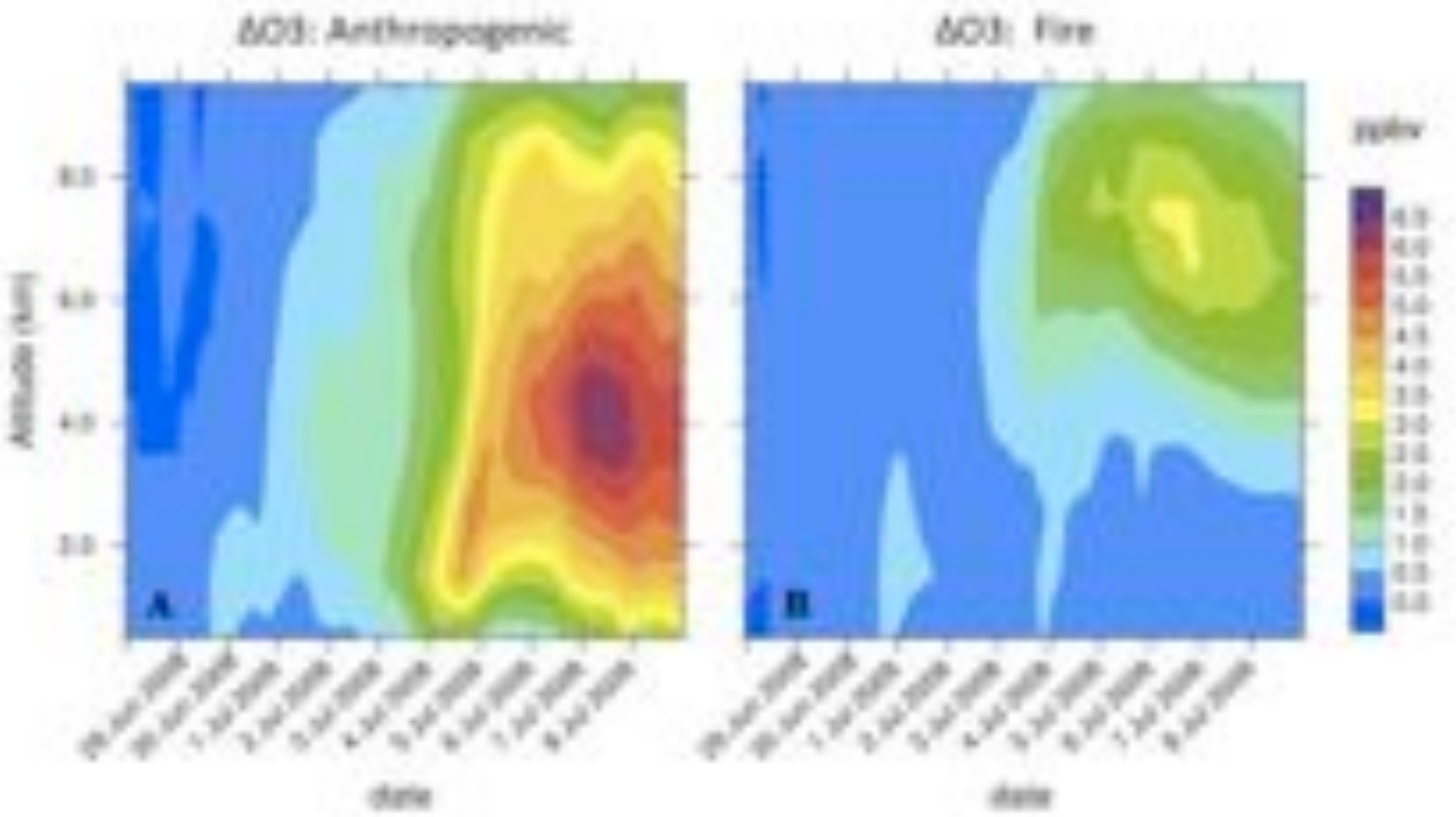
Thomas et al., ACPD, 2012.

Increase in ozone due to anthropogenic (left) and fire (right) emissions



Thomas et al., ACPD, 2012.

Quantifying the increase in ozone due to anthropogenic and fire pollution & chemistry (north of 55 °N)



Thomas et al., ACPD, 2012.

Summary & conclusions

- Fresh and aged plumes correctly represented in the model
- The ozone produced due to anthropogenic and BB emissions has been quantified
- Air mass origin has been identified using FLEXPART-WRF PES
- Sensitivity to increased CO and decreased NOx emissions from fires has been studied
- Future work: focus on aerosol processes during long range transport to the Arctic

Aircraft Campaign – July 2012

Jennie L. Thomas, Kathy Law, Claire Granier,
Jean-Christophe Raut,
Louis Marelle (LATMOS)

Hans Schlager, Anke Roiger, ACCESS Campaign team (DLR)

Ivar Isaksen, Stig Dalsoren (CICERO)

ACCESS
Arctic Climate Change
Economy and Society

ACCESS aircraft campaign 2012

- DLR Falcon base: Andoya (Norway)
- Time period: 9th-27th July 2012
- 13 local flights performed in order to study Arctic pollution sources

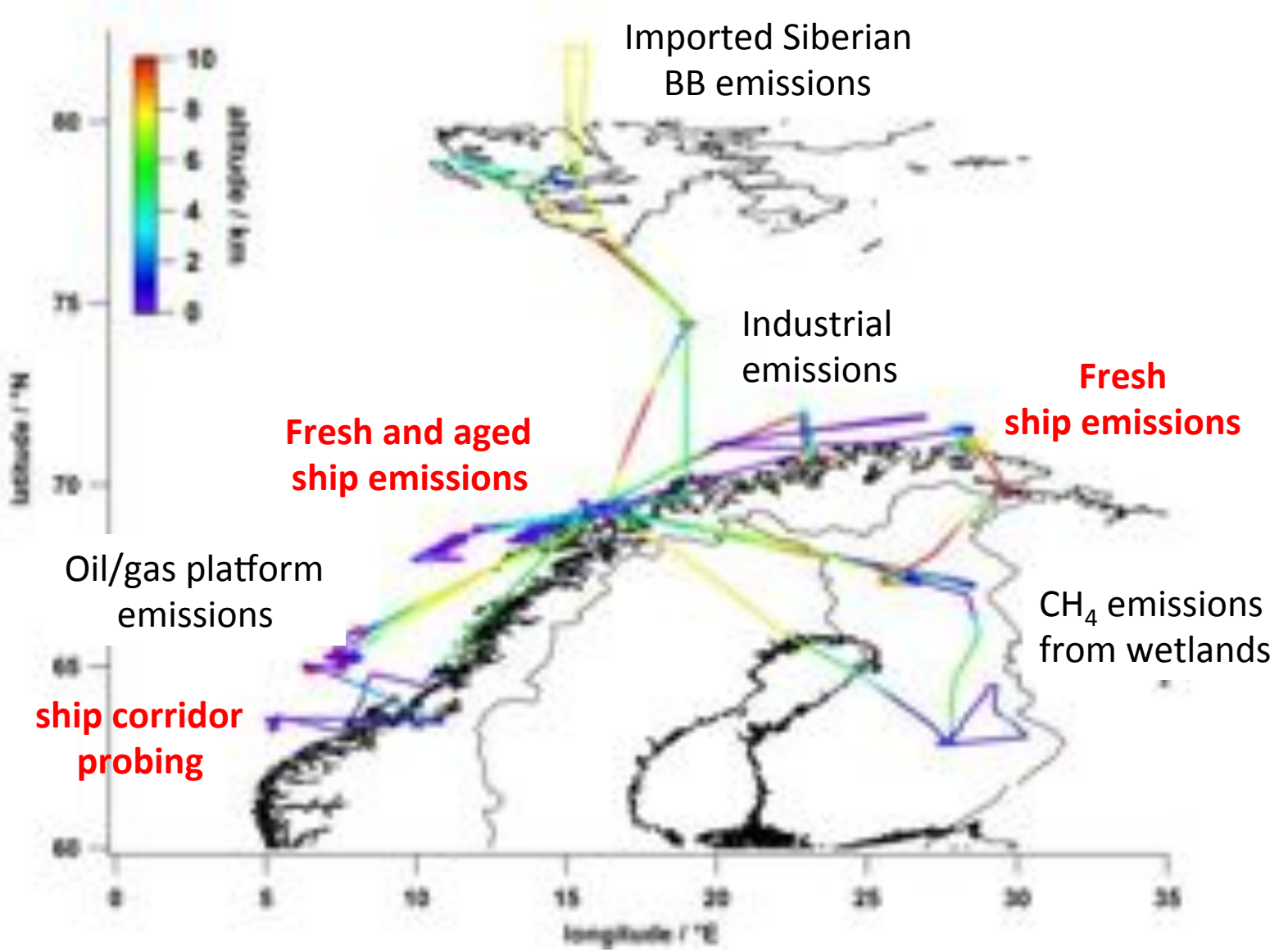
ACCESS
Arctic Climate Change
Economy and Society

DLR

ACCESS campaign 2012 – flight overview

Date	Flight Objectives
11 July	F#1 Single ship plume study „Wilson Leer“ (and „Costa Delizioso“)
12 July	F#2 Single ship plume study „Wilson Nanjing“
13 July	F#3 Sampling of Kola Peninsula Plume
16 July	F#4 Low-level survey over southern Finland
17 July	F#5+6 Sampling of Siberian BB plume
19 July	F#7 Ship corridor probing F#8 Sampling of different oil/gas facility plumes
20 July	F#9 Single plume study at „Heidrun“ platform
22 July	F#10+11 Low-level survey over N/S Finland
25 July	F#12 Sampling of fresh ship emissions F#13 Vertical profile for Sodankylä FTS

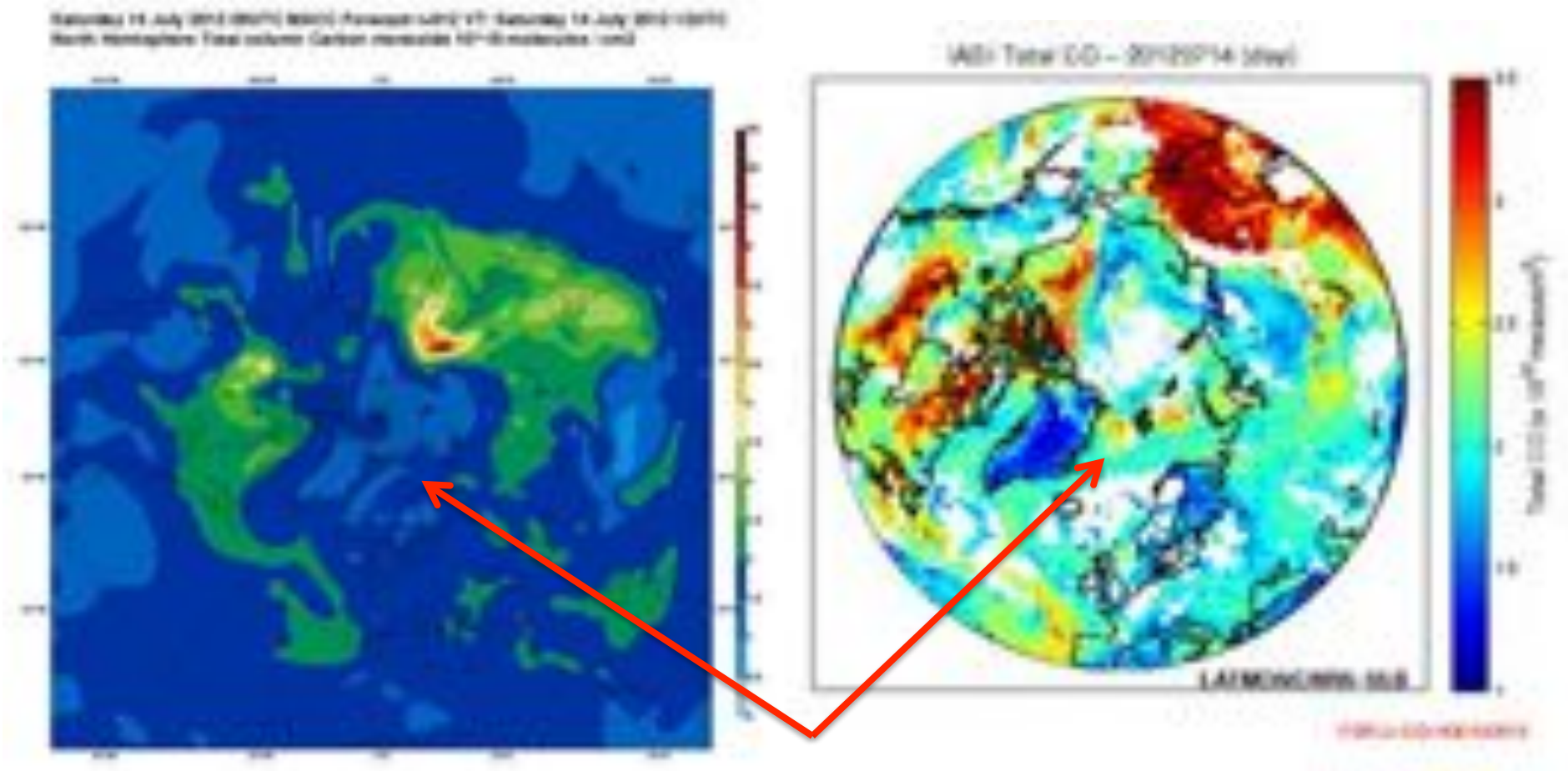
ACCESS campaign 2012 – flight overview



Total column CO: IASI vs MACC Forecast

14 July MACC 12z

14 July



Different scales!

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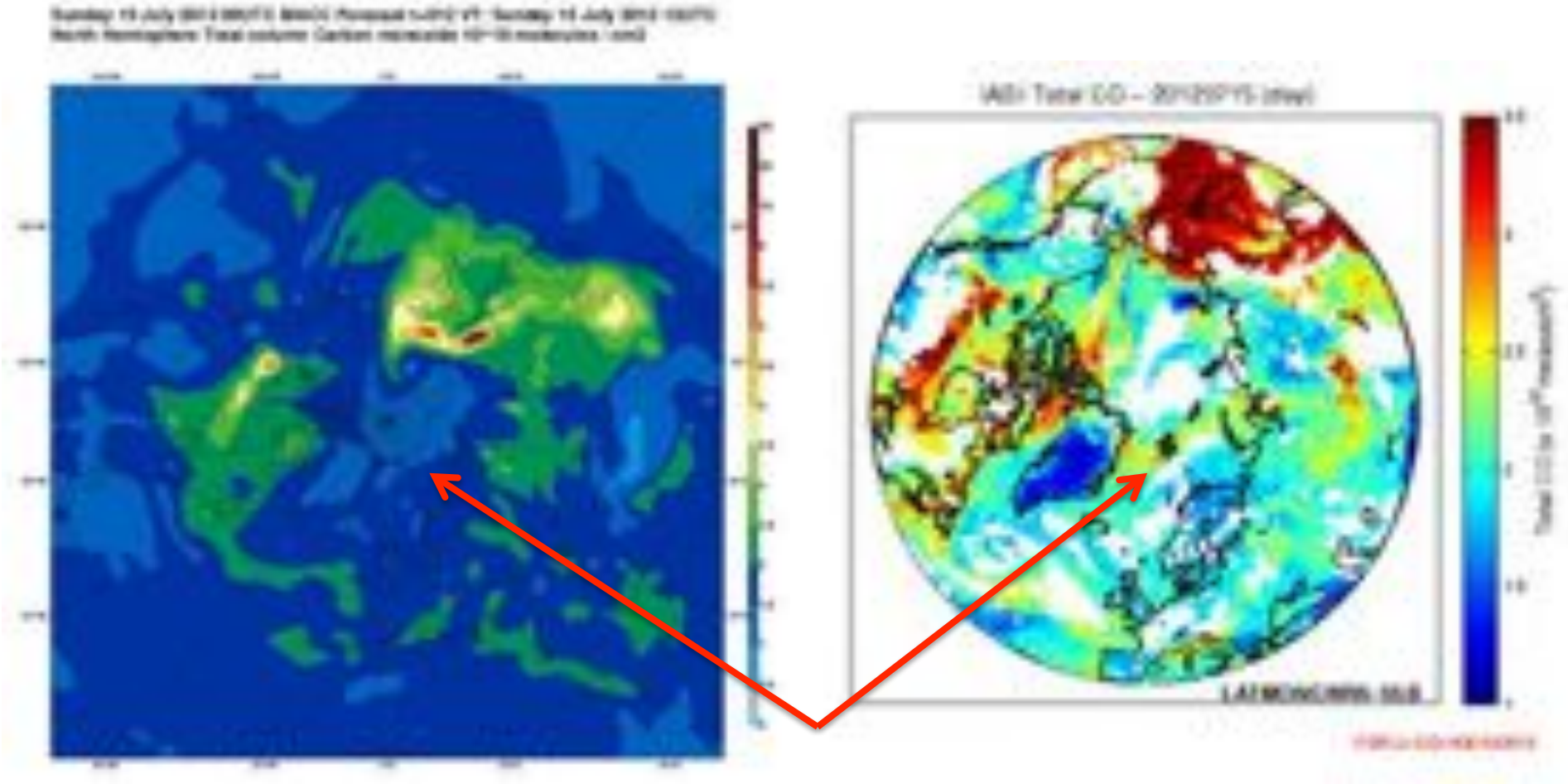

Different scales!

A multi-model evaluation of processes controlling spring and summer tropospheric ozone in the Arctic: The POLARCAT Model Intercomparison Project (POLMIP)

L. K. Emmons[1], S. R. Arnold[2], K. S. Law[3],
S. Turquety[4], S. A. Monks[2], S. Tilmes[1], B. Duncan[5],
Jennie L. Thomas[3], I. Bouarar[3], J. Mao[6],
J. Flemming[7], V. Huijnen[8], S. Steenrod[5], S. Strode[5]

(1) Atmospheric Chemistry Division, NCAR, Boulder, CO, USA
(2) Institute for Climate and Atmospheric Science, School of Earth and Environment, University of Leeds, UK
(3) LATMOS-IPSL, Univ. Pierre et Marie Curie, Paris, France
(4) Laboratoire de Meteorologie Dynamique, IPSL, Univ. Pierre et Marie Curie, Paris, France
(5) Atmospheric Chemistry & Dynamics Laboratory, NASA Goddard, Greenbelt, MD, USA
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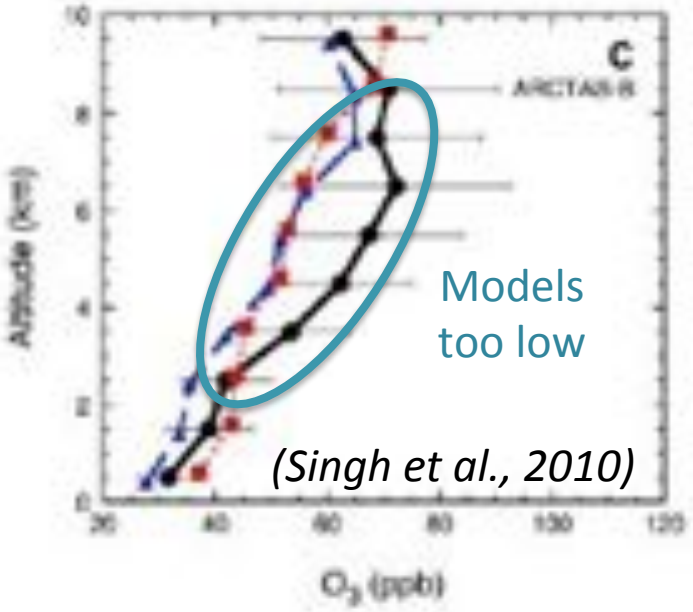
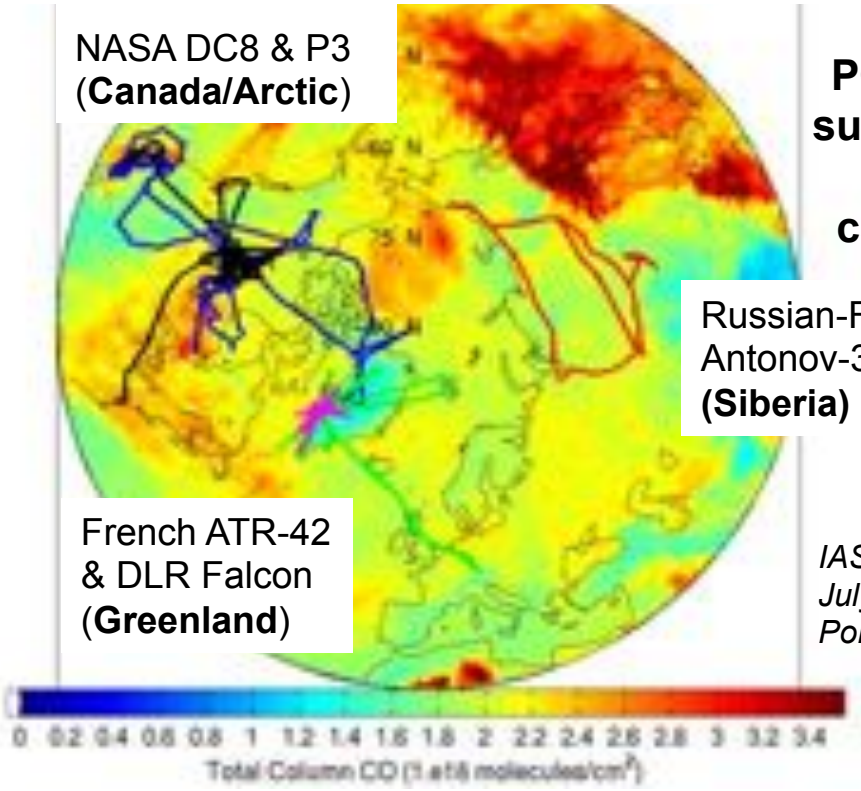


NASA DC8 & P3 (**Canada/Arctic**)

Russian-French Antonov-30 **(Siberia)**

French ATR-42 & DLR Falcon (**Greenland**)



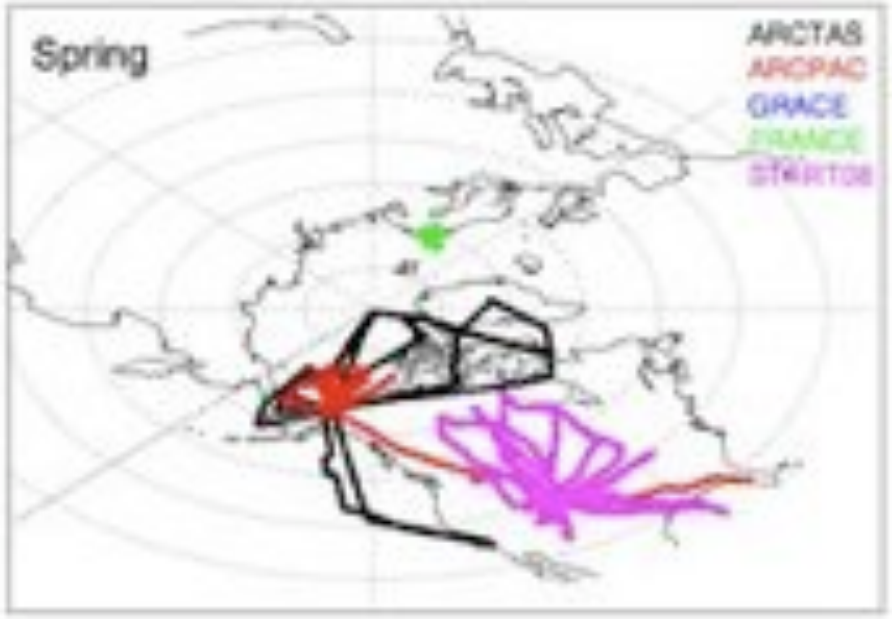
POLARCAT summer 2008 aircraft campaigns

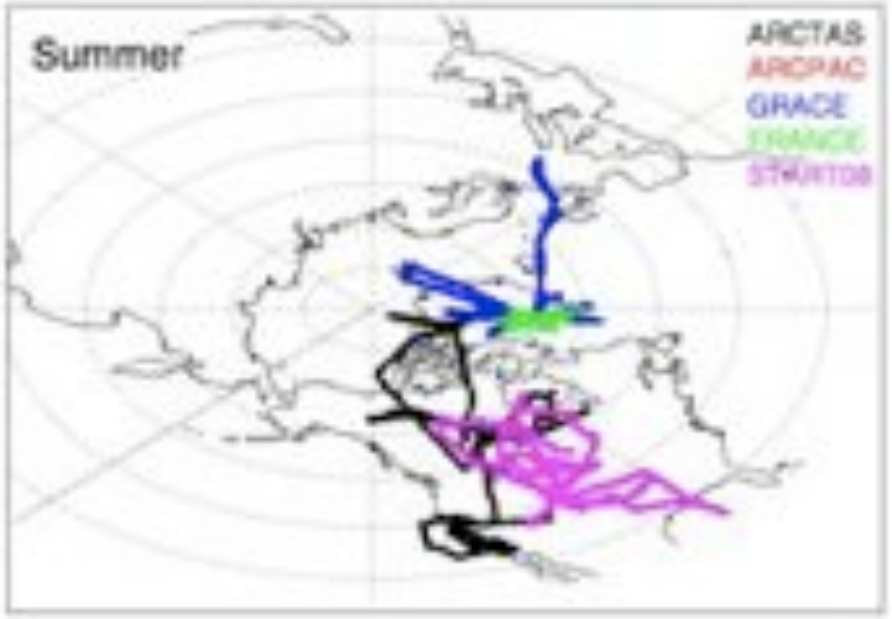
IASI CO columns July 2008 Pommier et al. (2010)

POLARCAT Aircraft Experiments
April-July 2008

NASA - ARCTAS
NOAA - ARCPAC
DLR - GRACE
POLARCAT-France



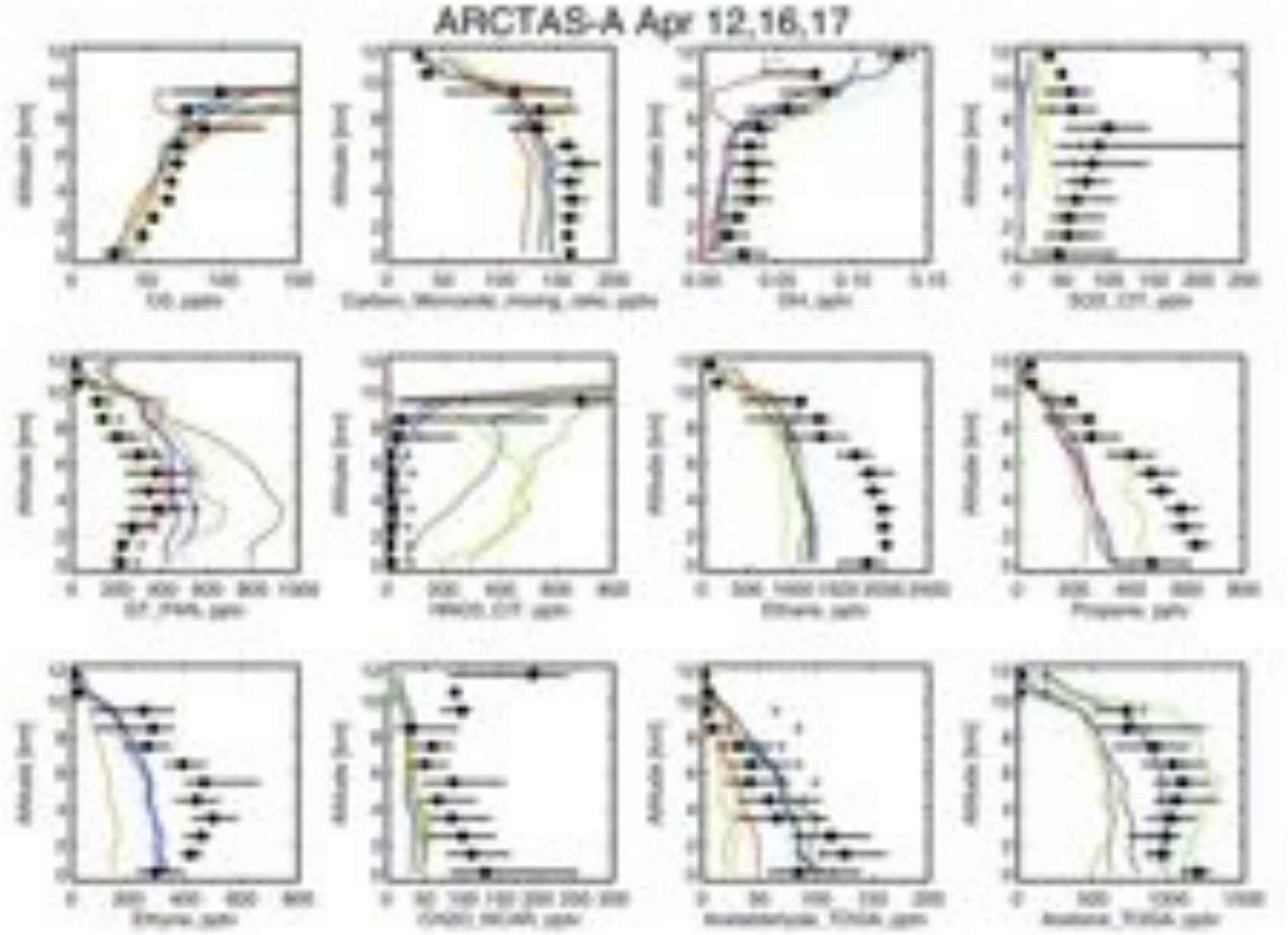


Models

Emissions: Anthropogenic: Streets' ARCTAS-v1.2; Fires: FINN-v1; Other: MACCity

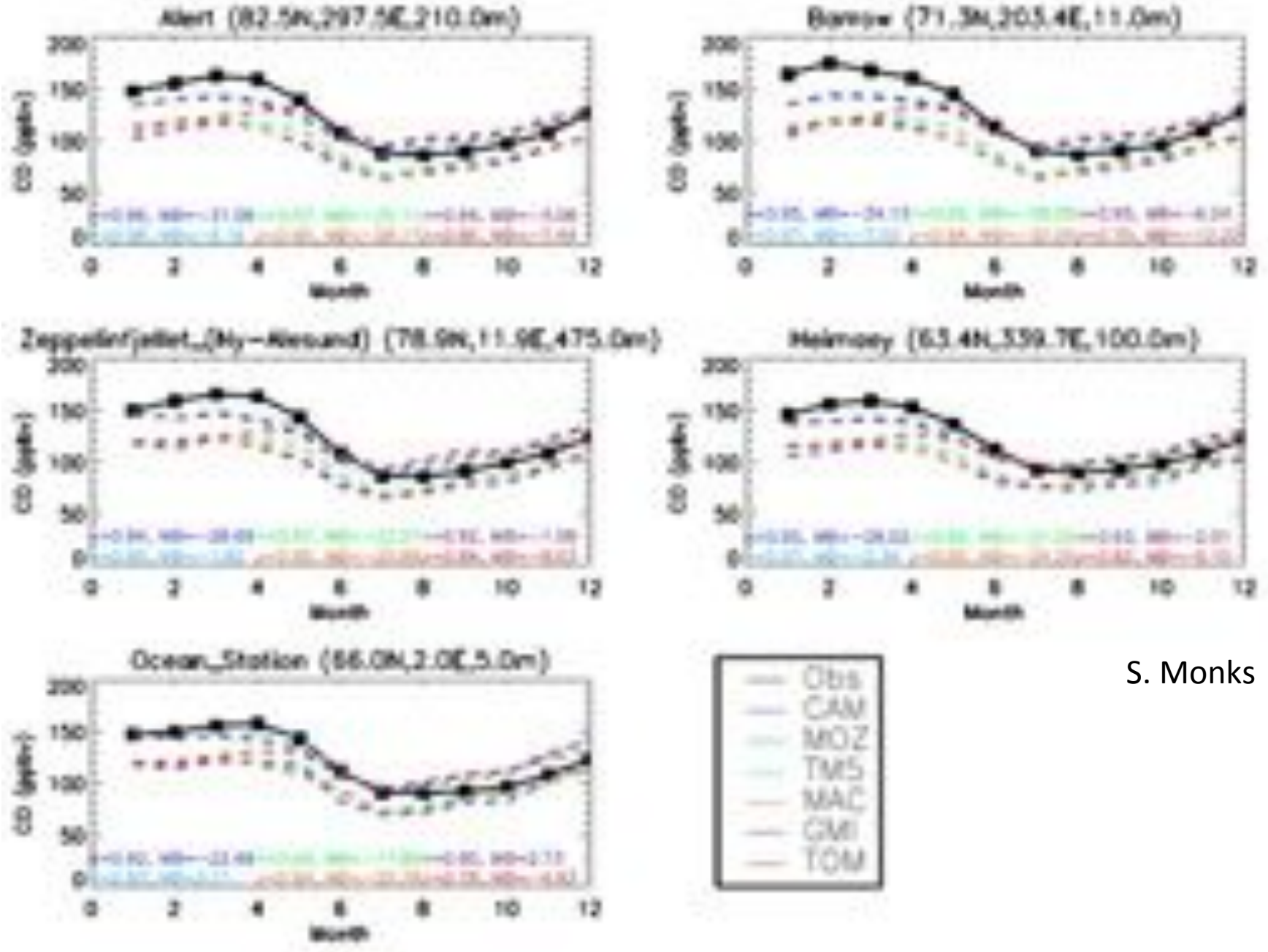
Model	Resolution	Meteorology	Chemistry
TOMCAT	2.8°x2.8°, 31 levels	ECMWF ERA-oper.	trop: 82 species
MOZART-4	1.9°x2.5°, 56 levels	GEOS-5	trop: 103 species
CAM-chem	1.9°x2.5°, 56 levels	GEOS-5	MOZART-4
LMDZ-INCA	1.9°x3.75°, 19 levels	ECMWF	trop: 89 species
C-IFS	T159 (~1°), 60 levels	ECMWF	trop: CB05, strat: linear. O3 (Cariolle)
TM5	2°x3°, 60 levels	ECMWF	trop: CB05
NASA GMI	2°x2.5°, 70 levels	GEOS-5	strat+trop (123 species)
GEOS-Chem	2°x2.5°, 47 levels	GEOS-5	trop: ~100 species
WRF-Chem	70, 35, 17.5 km		MOZART-GOCART

Preliminary comparison: spring 2008 aircraft data



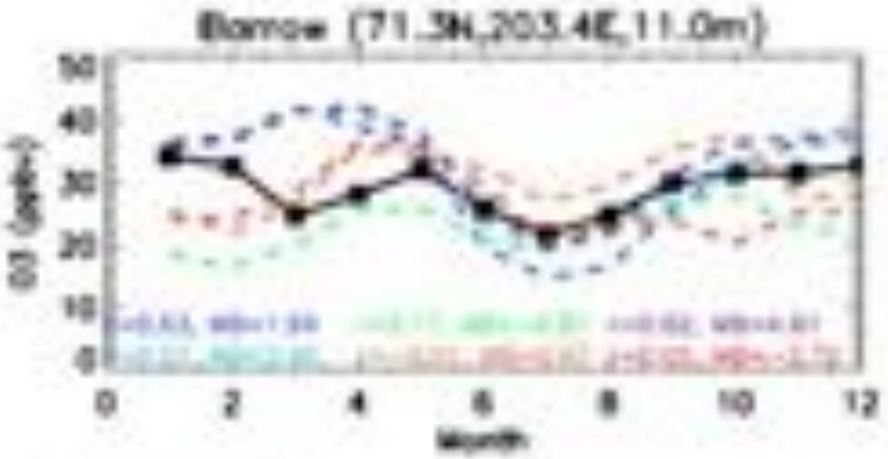
L. Emmons

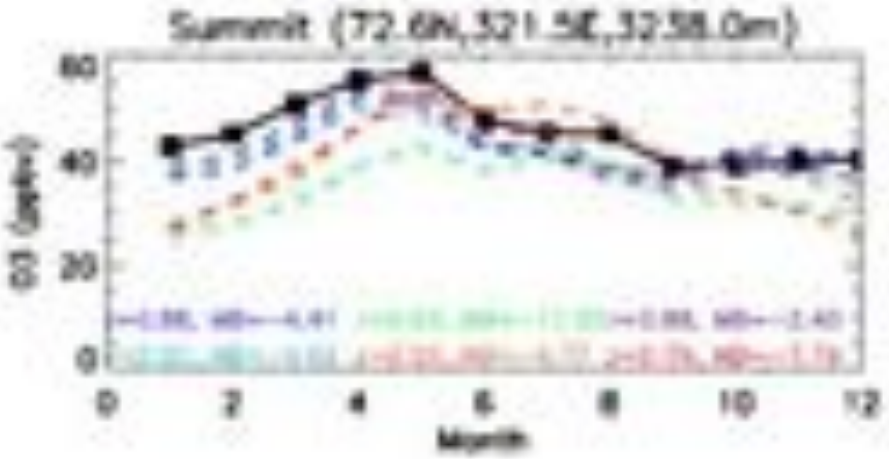
Surface CO compared to Arctic Station data



S. Monks

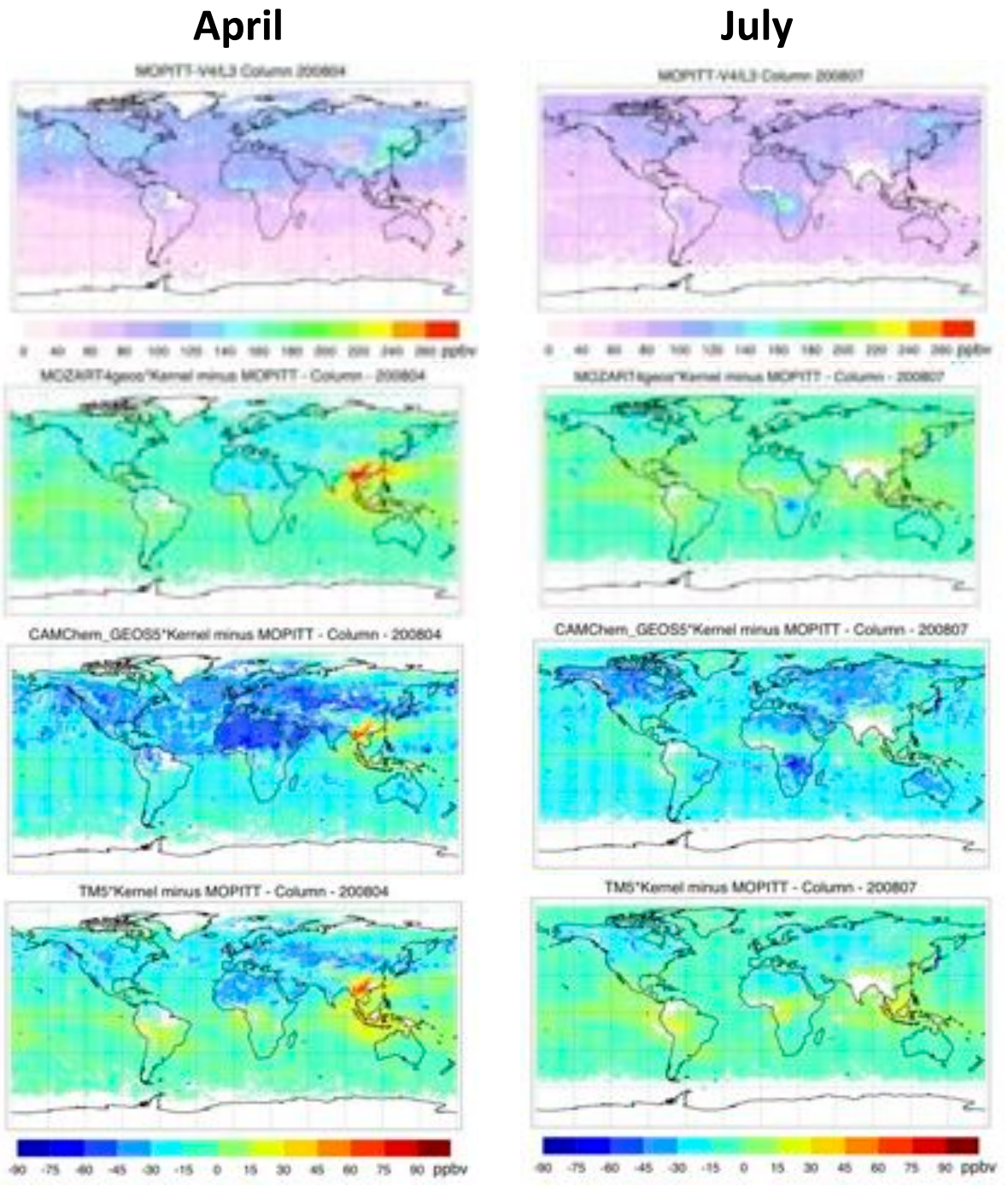
Surface ozone compared to Arctic Station data





S. Monks

Comparisons to MOPITT CO



L. Emmons

POLMIP Summary

- Models are being evaluated in the Arctic using POLARCAT data
- POLMIP will aim to understand the cause of the variability between models in the Arctic and the ability of models to predict the composition of the Arctic troposphere
- The correlation of model-observation differences with air mass origin will be used to identify poorly modeled transport processes
- Models vary in their simulation of ozone precursors in the Arctic
- Differences in chemistry are likely explained by differences in transport, efficiency of NO_y export, photolysis, and chemistry