YAK-AEROSIB: continental scale aircraft measurements of trace gases gases above Siberia

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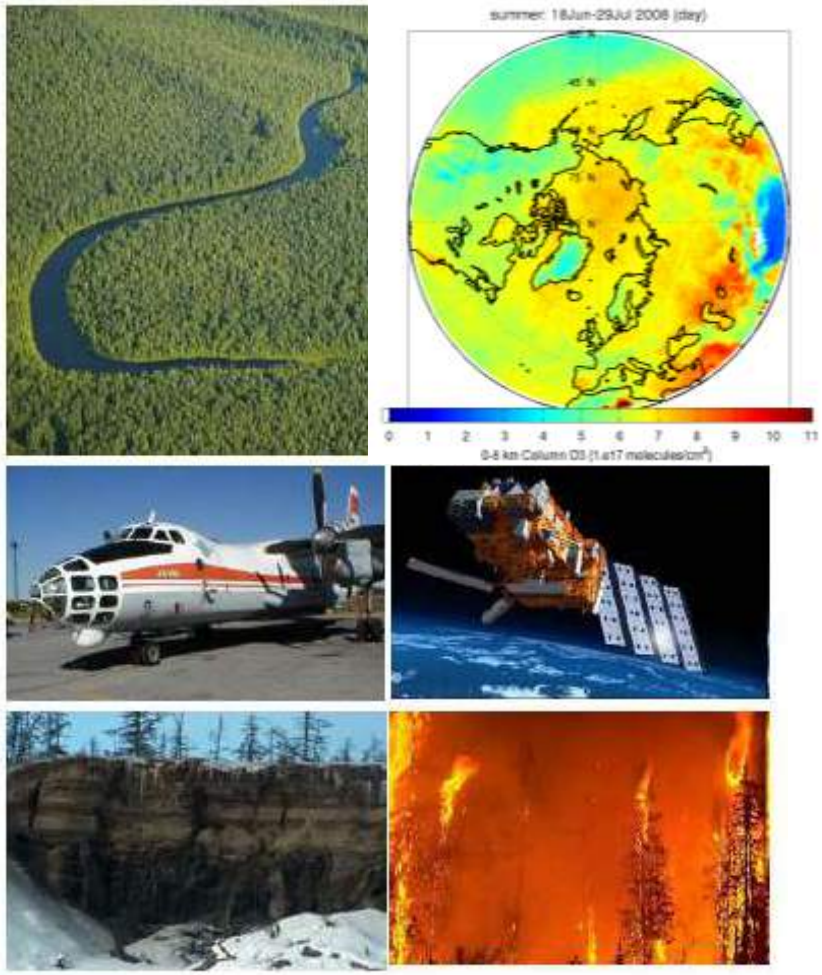
MOZAIC Meeting, Toulouse, 13-15 May 2014

Airborne measurements bring new data

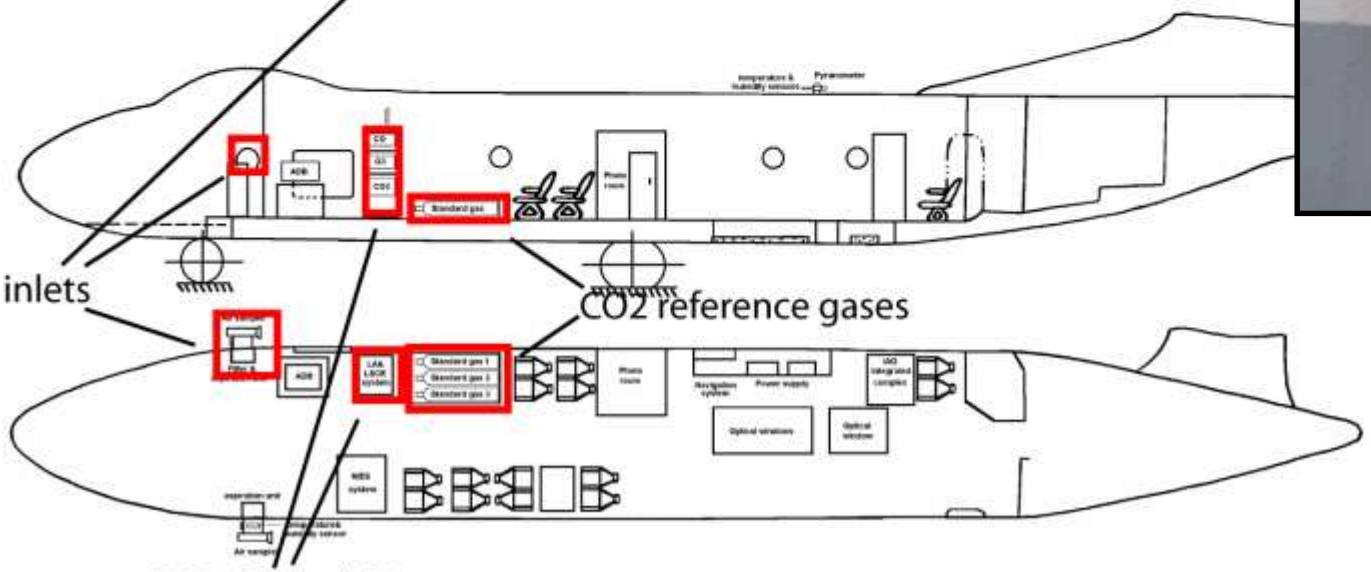
- Observe short lived **pollutants** (CO, O3, BC, fine particles) and discriminate local vs remote emissions to characterize long range transport across Eurasia.
- Validate **atmospheric models**, land flux models and **space-borne instruments** over Siberia, a vast under-documented region
- Characterize local sources, esp. **forest fires**, and their impact on regional air quality and in the Arctic.
- Better constrain the **sources and sinks of GHG** (CO2, CH4) in Siberia under a changing climate.
- Quantify the atmospheric impact of **CH4** emissions over the major natural (**wetlands**, **permafrost**) and anthropogenic sources



Past milestones of the YAK-AEROSIB collaboration

- 2003: Creation of the first « GDRI »
- January 2006: First test flight
- April 2006: first campaign
- 2008: first Fr-Ru joint paper
- 2008: International Polar Year: POLARCAT
- June 2011: creation of the new structure (LIA):
  - France: LSCE, LATMOS, Laboratoire d'Aérologie
  - Russia: Institute for Atmospheric Optics -SB-RAS
- July 2013: 8th campaign

Aircraft: AN-30



YAK-AEROSIB

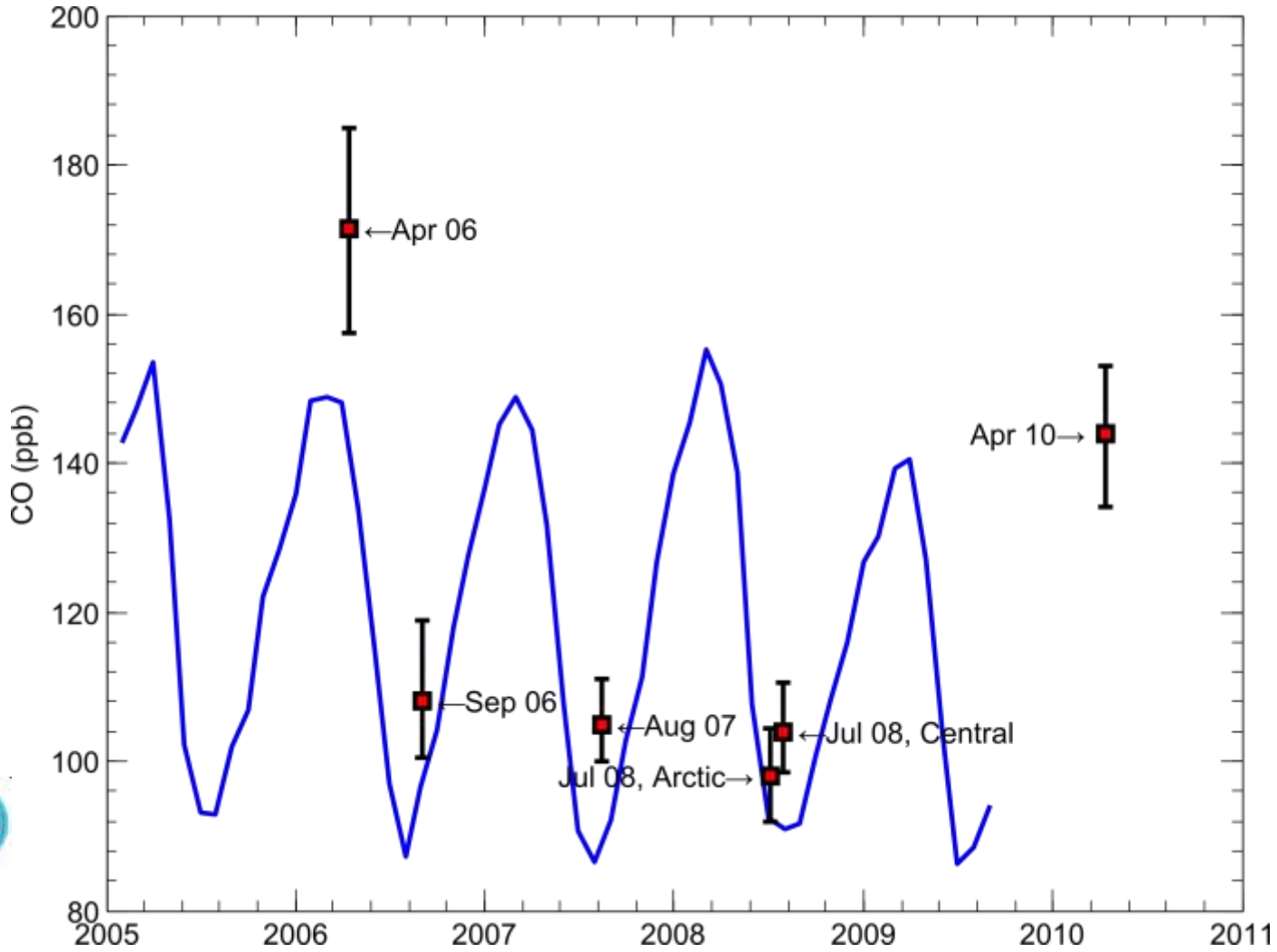
Aircraft: Tu-134

Russian team


PICARRO

CO statistics vs. Hemispheric background

- YAK always higher than MHD bg: transport of European & other emissions
- Apr 2010 relatively clean (more air from the Arctic, less from Europe and China)



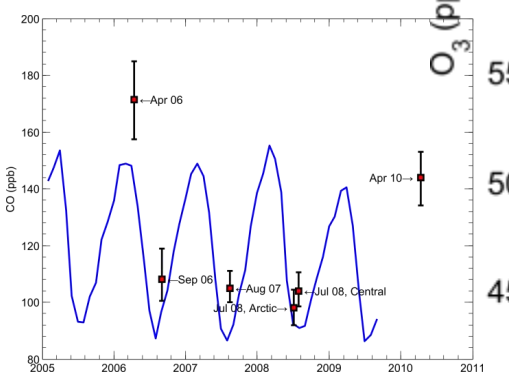
YAK: median+IQR

MHD: Agage

WMO WDCGG

O_3 statistics in context

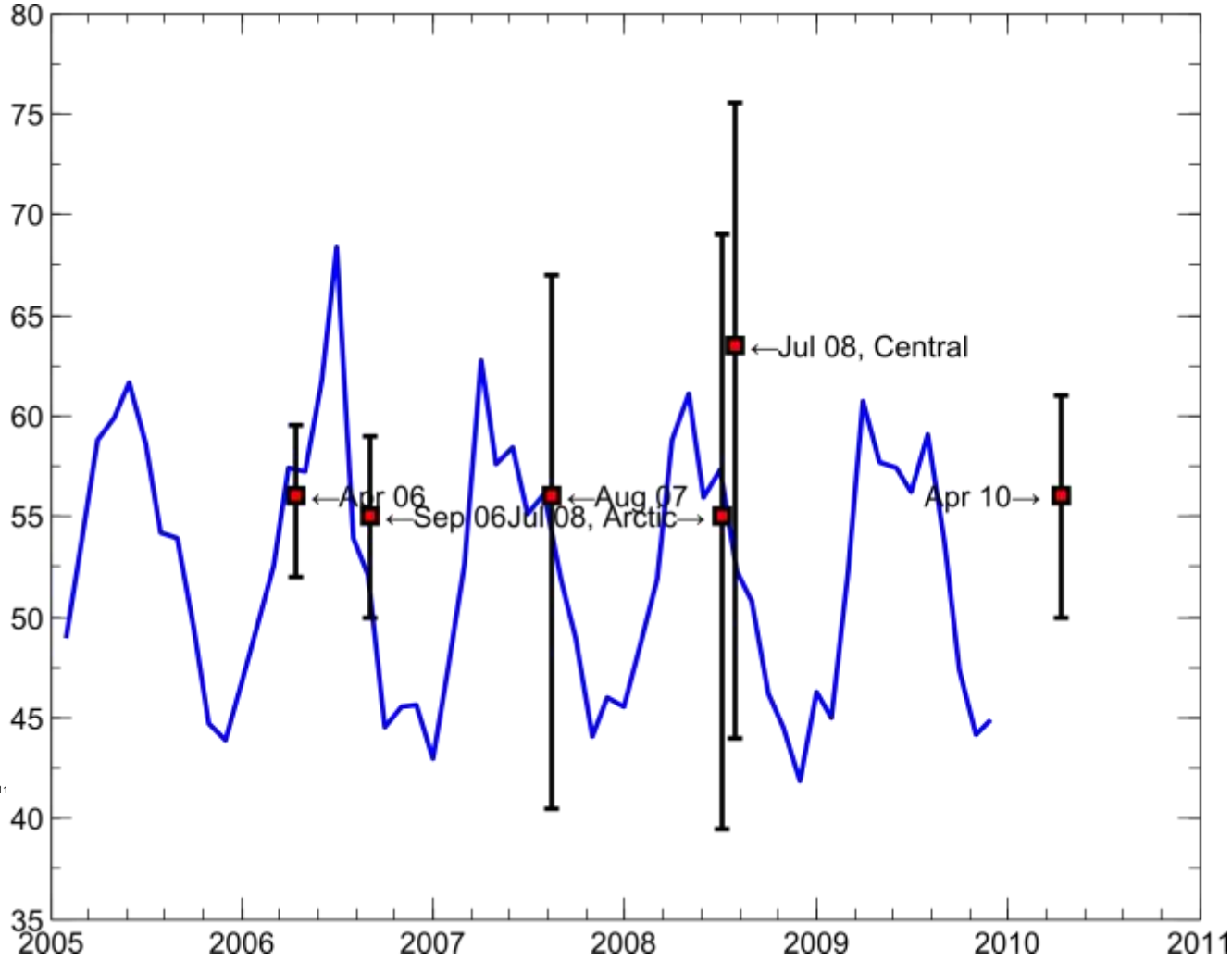
- High variability
- Reduced variability because of smaller vertical gradient compared to summer
- JFJ 3500m



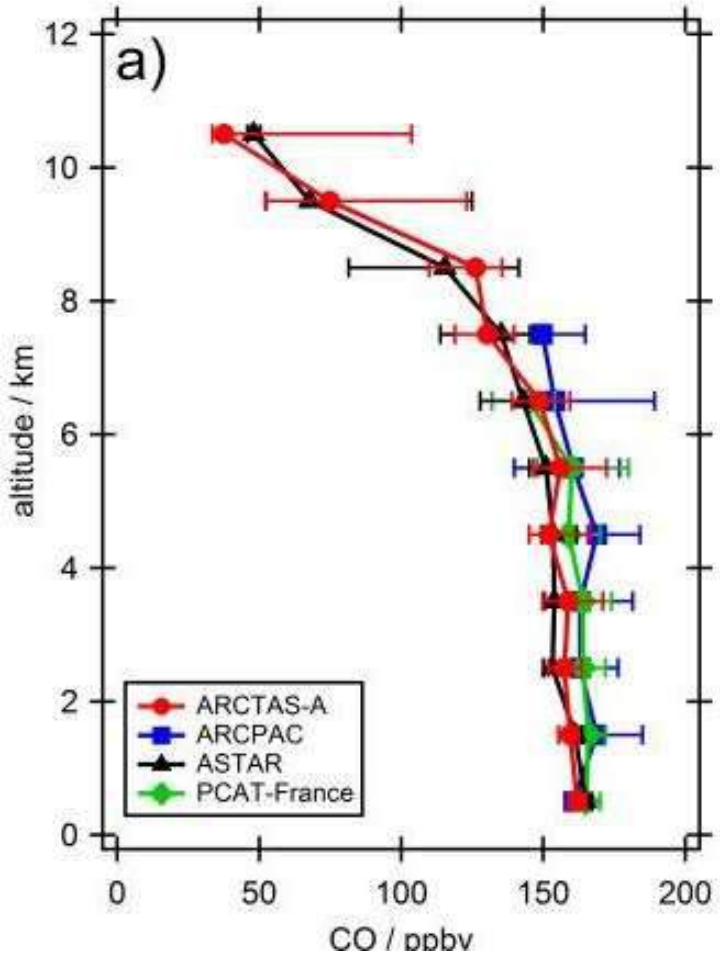
YAK: median+IQR

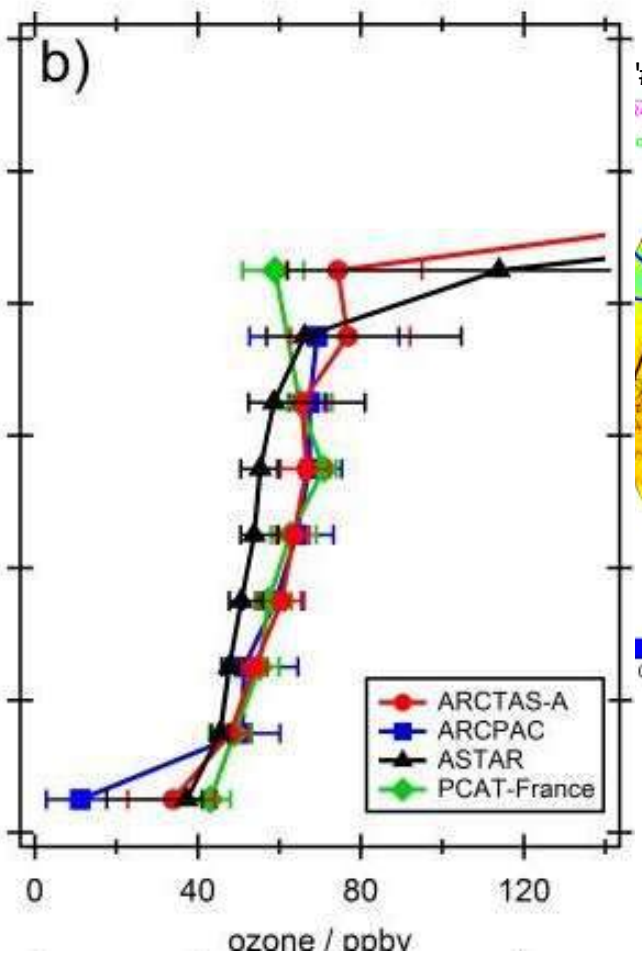
JFJ: EMPA

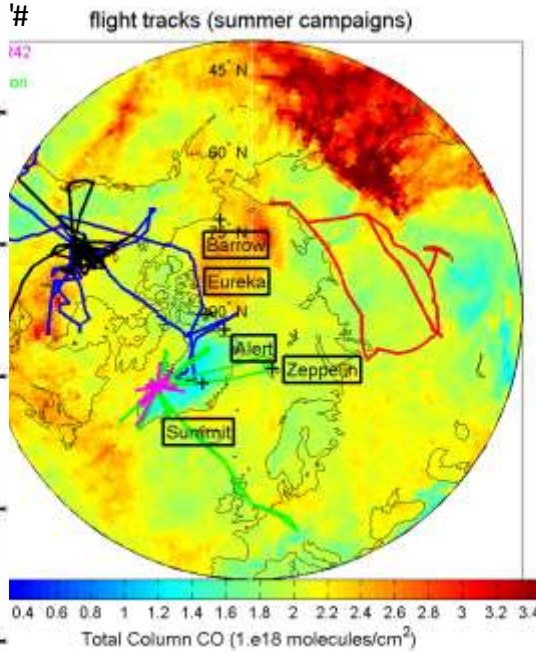
WMO WDCGG



Summer 2010 aircraft measurements across the Arctic

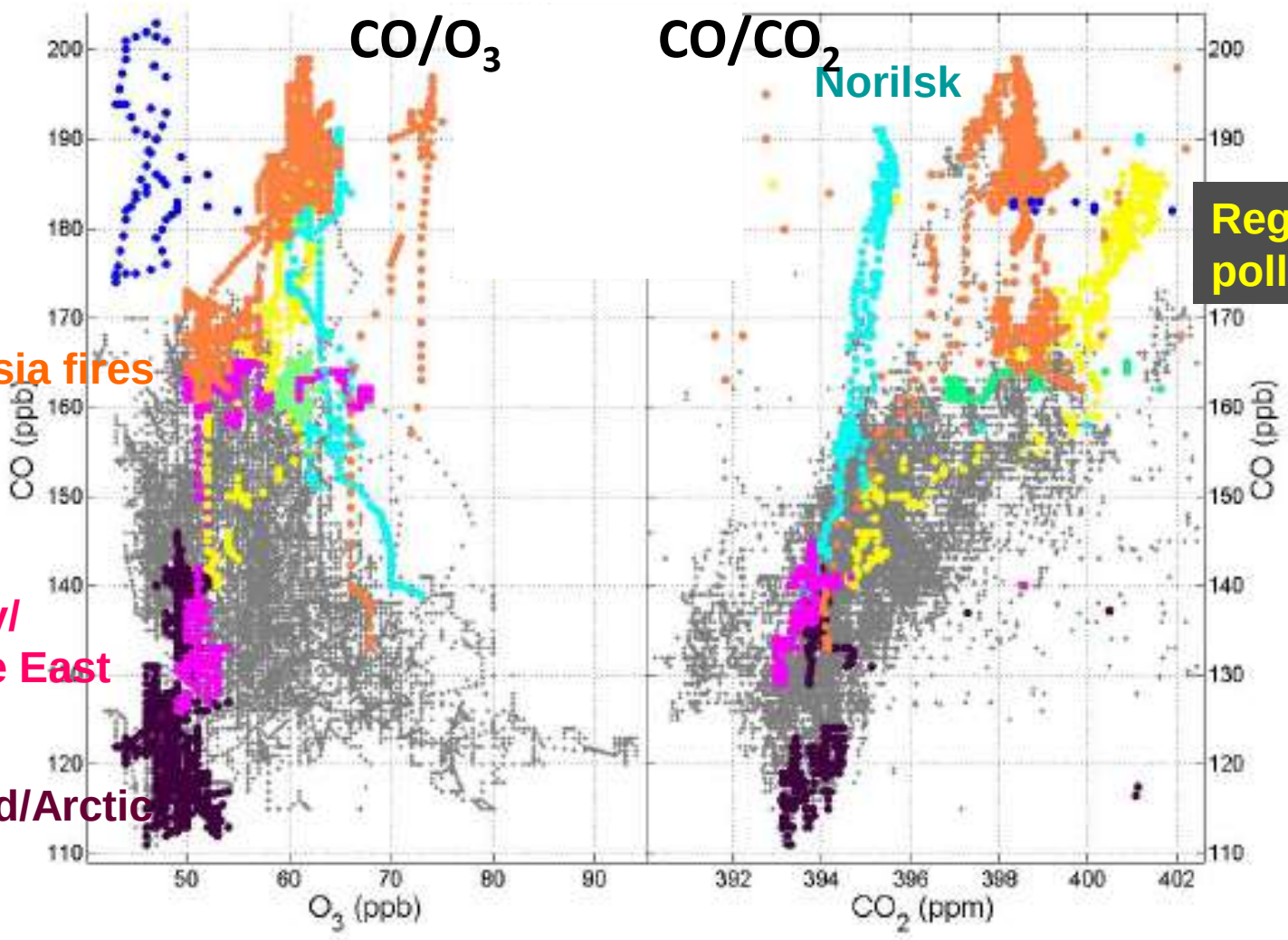






K Law et al., BAMS, in press

Diverse pollution origin over Siberia
Case of the 2010 spring campaign

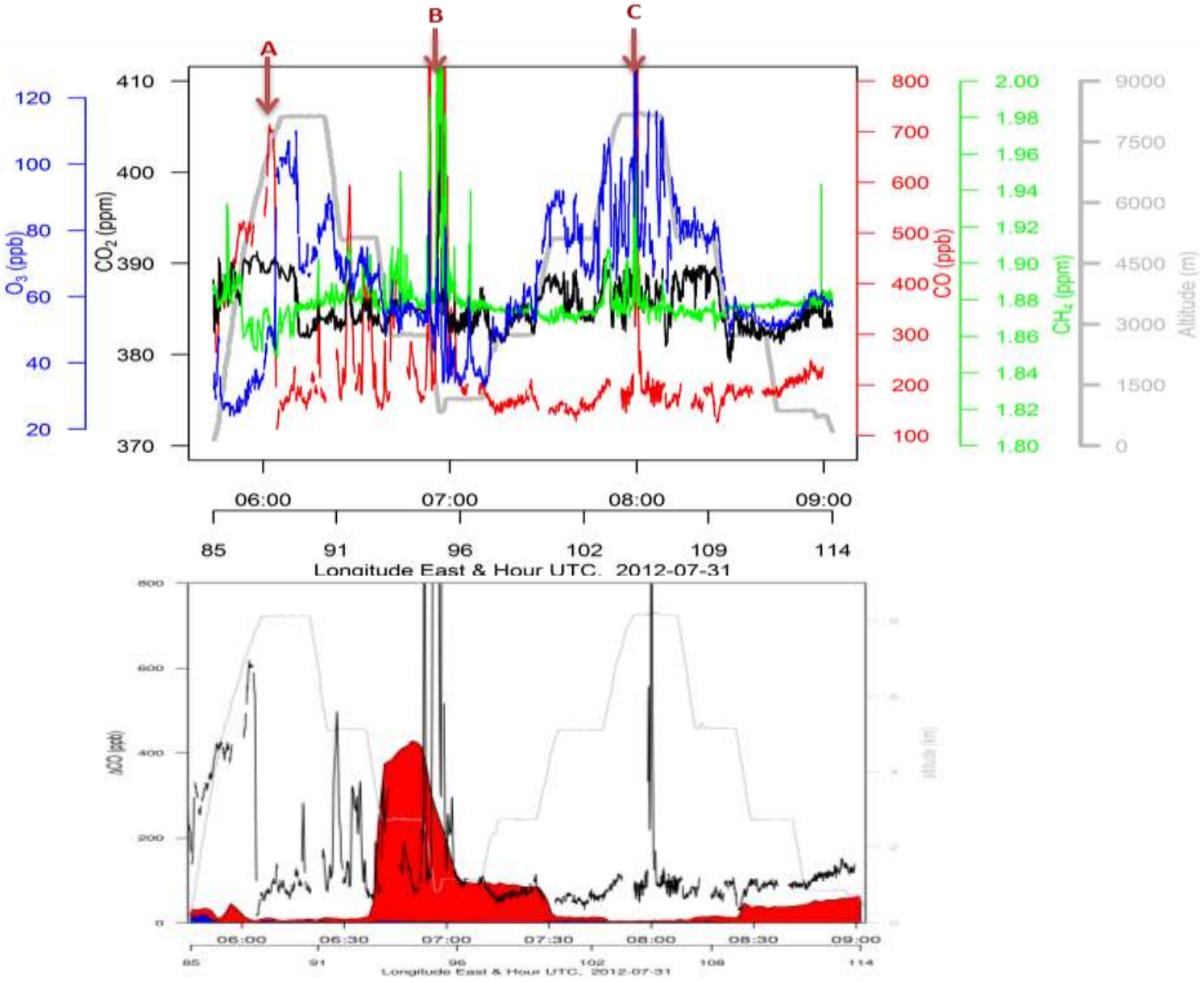


Plume identification using FLEXPART 10 days backward plume

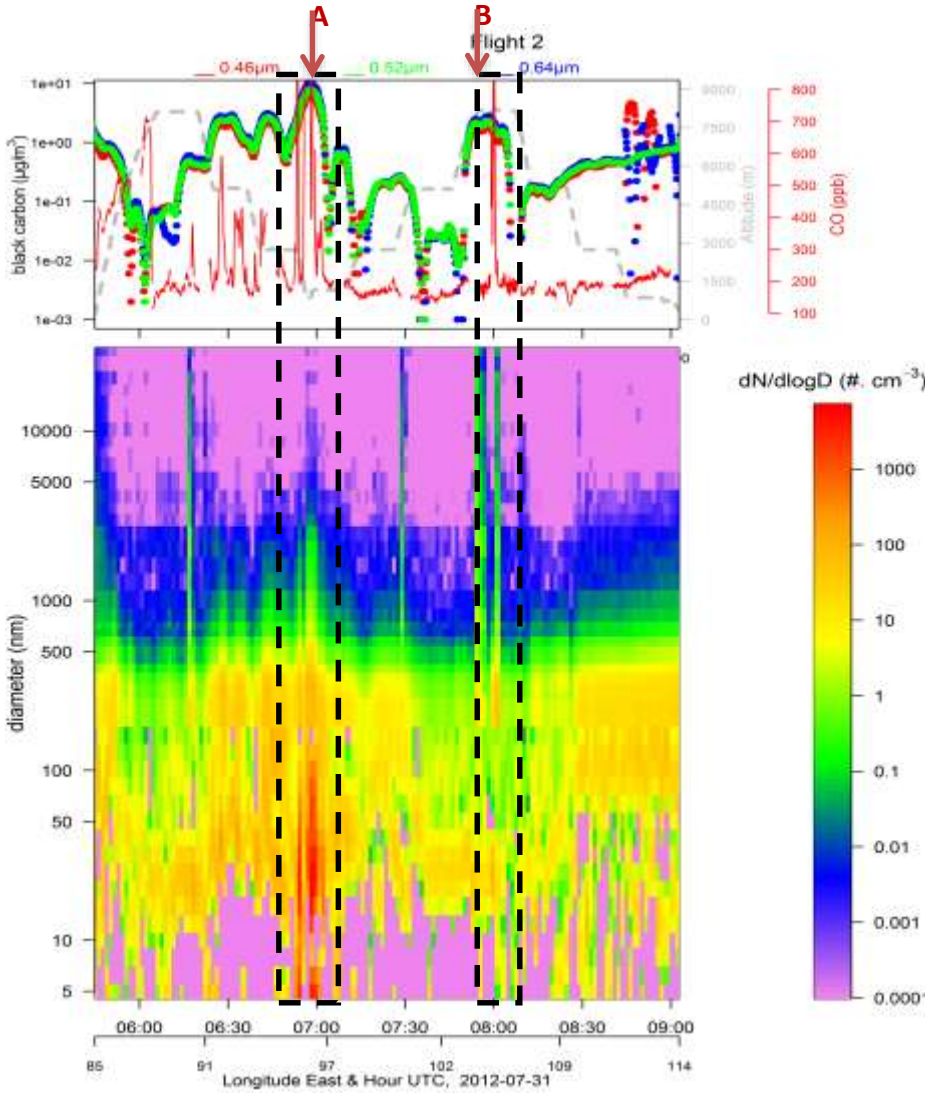
A. Berchet et al., Tellus B, 2013

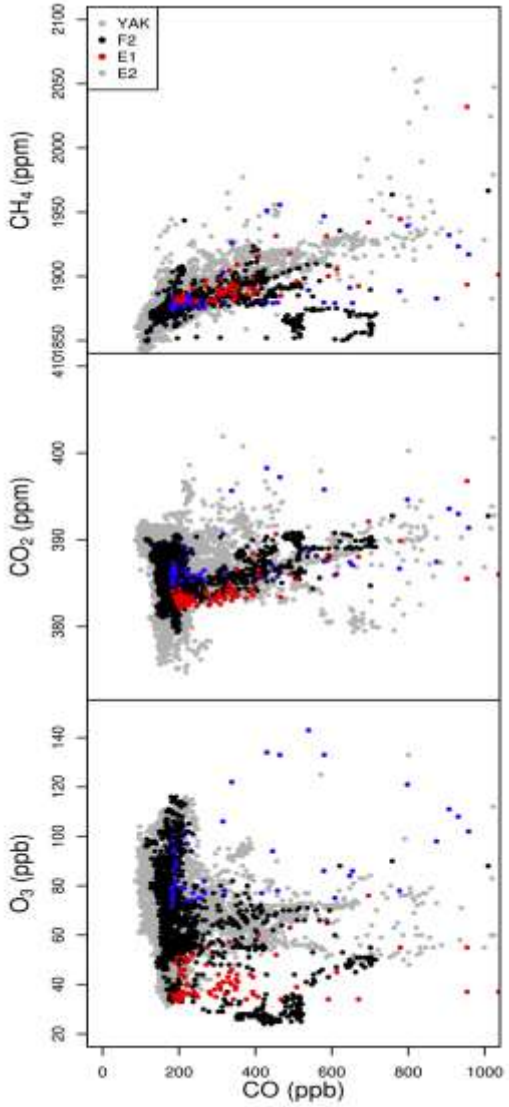

Summer 2012 wildfires

July 2012, Flight 2



High aerosols and CO on July 2012, fire-dominated Flight 2





Previous examples of strong fire emissions…

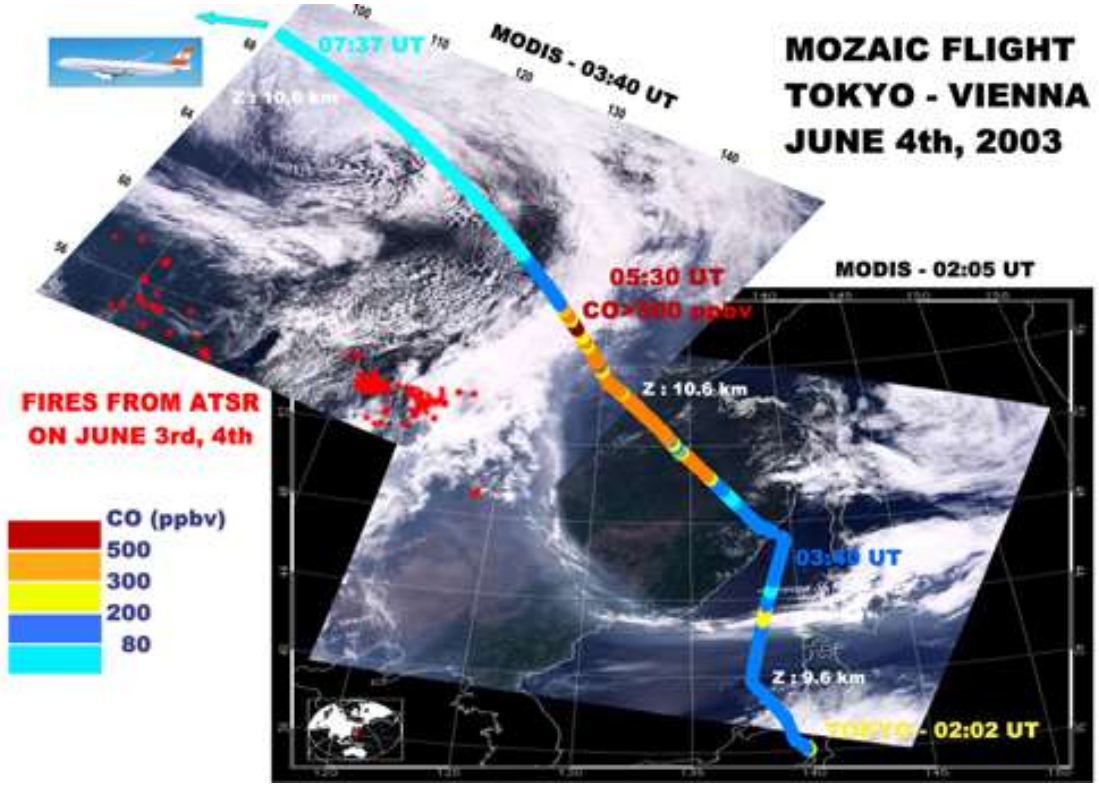
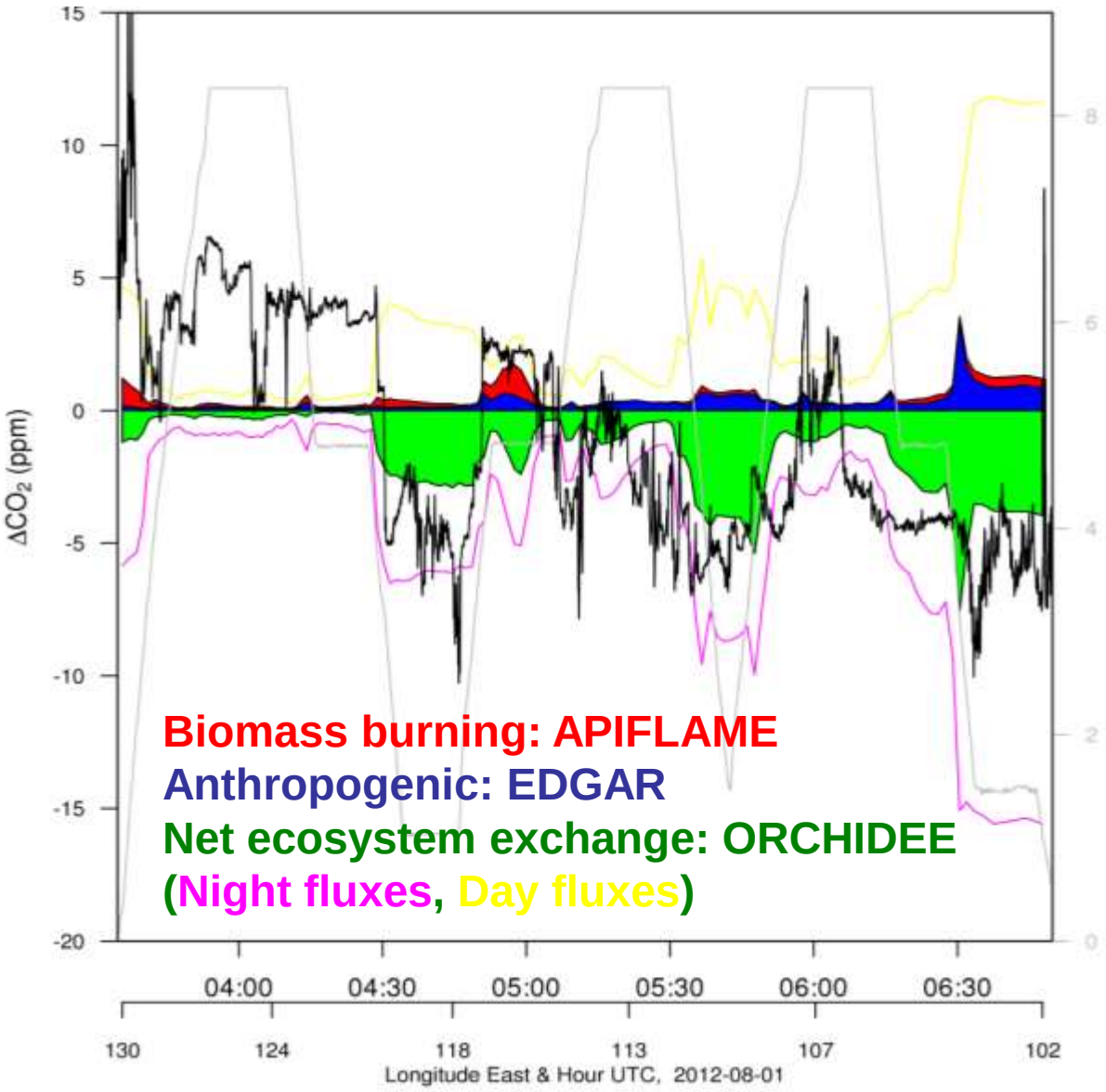


Figure 3. MOZAIC flight track color-coded with CO concentration (ppbv) from Tokyo to Vienna on June 4th, 2003, plotted over a composite of two MODIS satellite

Nedelec et al., GRL, 2005

Simulated CO_2 in Flight 2, July 2012

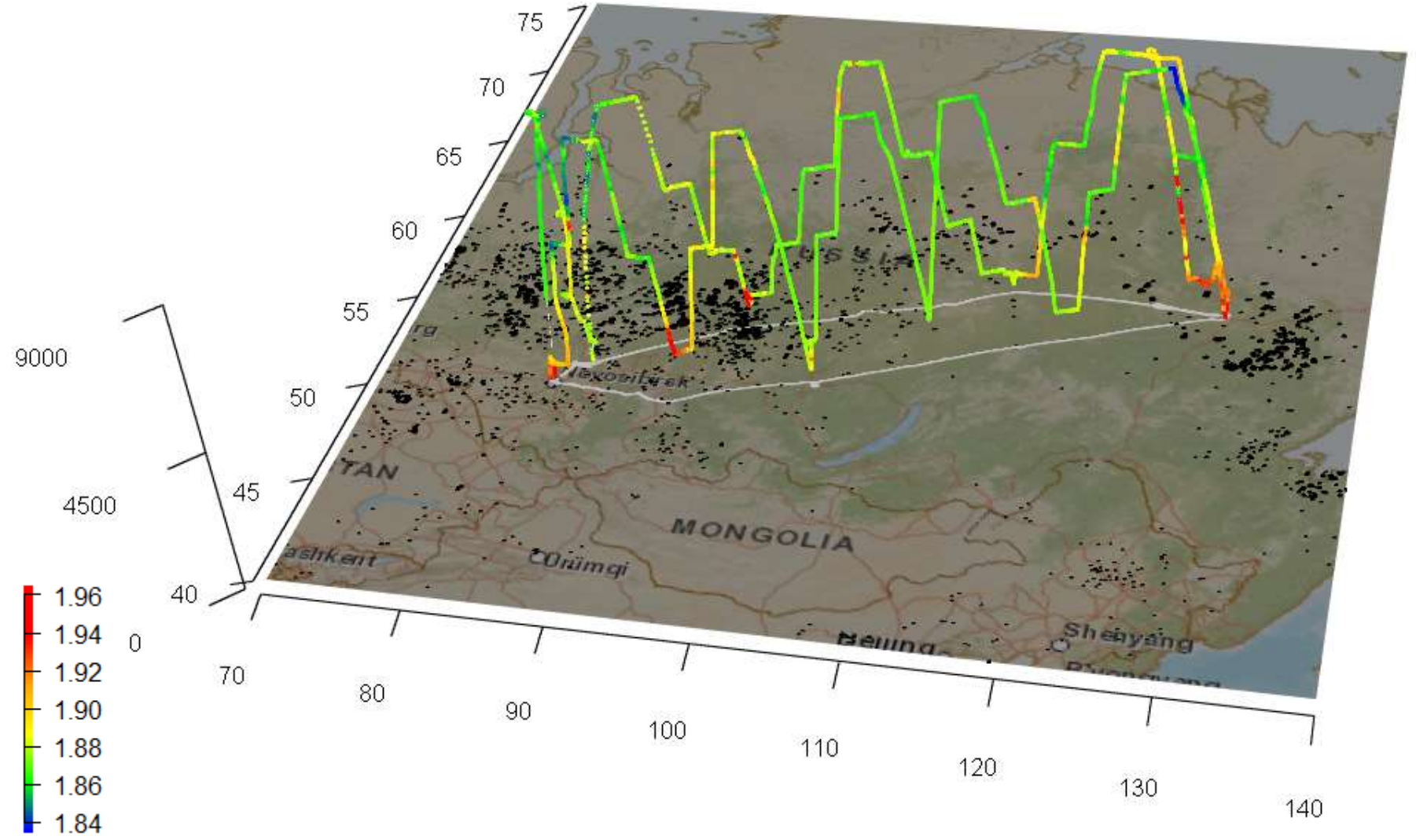


FLEXPART simulation over 10 days

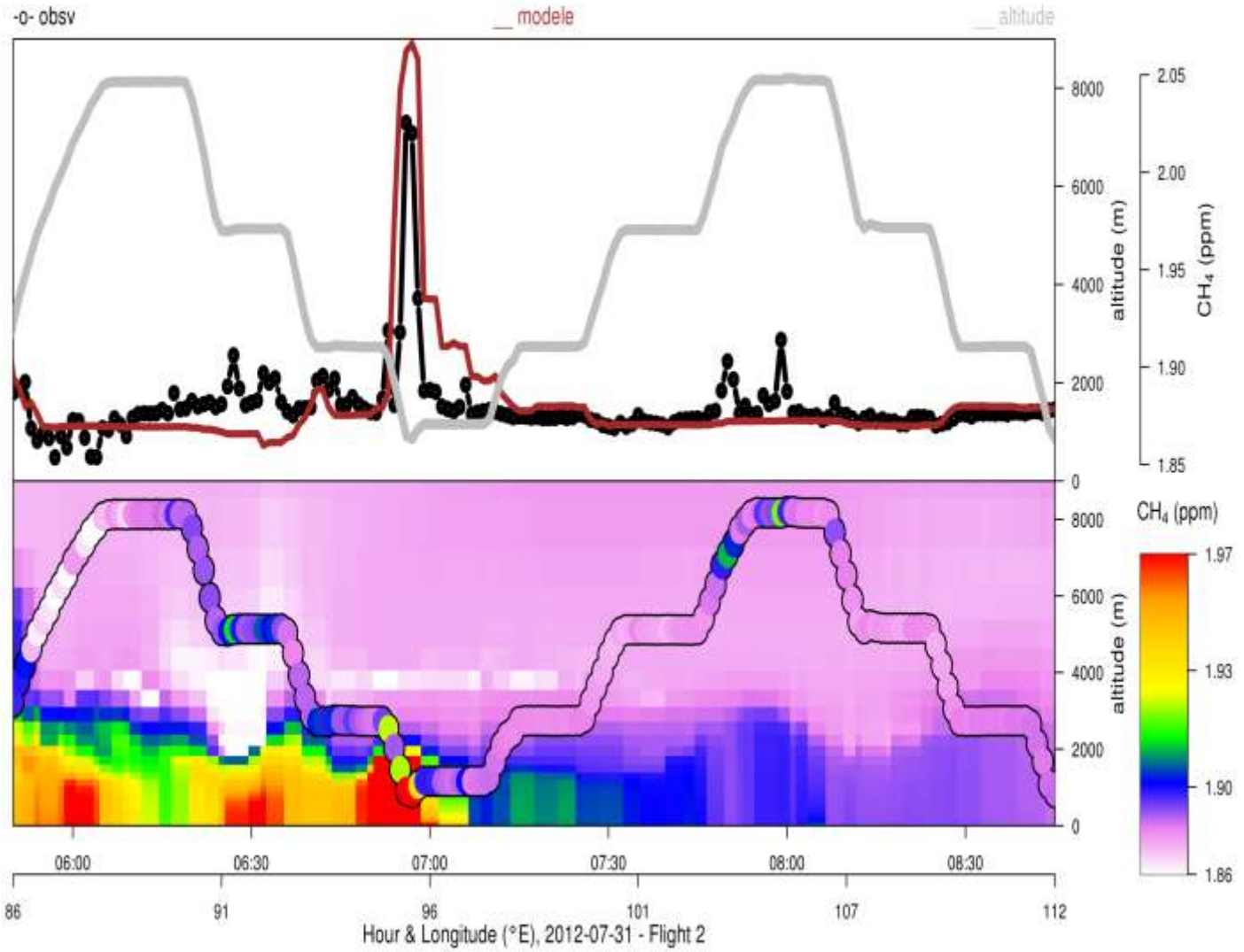
NEE attenuates fire signal

Impact on total emitted carbon, emission factor estimation

CH4 over Siberia, july-august 2012



Revising fire emissions for CH4 over Siberia

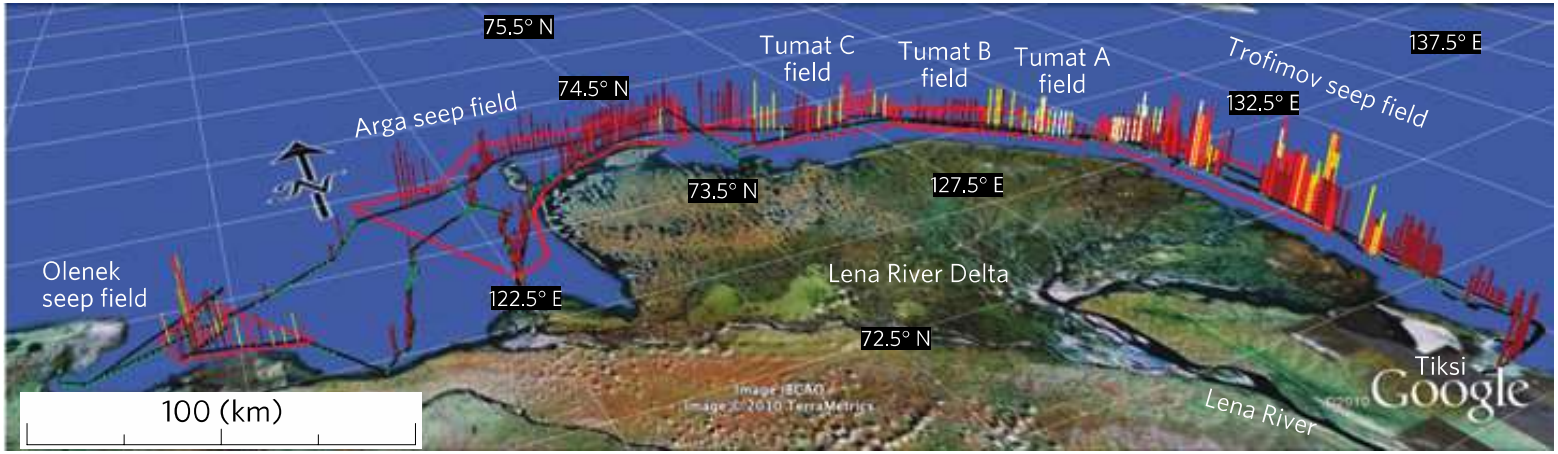


E. Arzoumanian

Emissions: APIFLAME, S. Turquety, LMD

Future plans

Shakhova et al., Nature Geosci. 2013



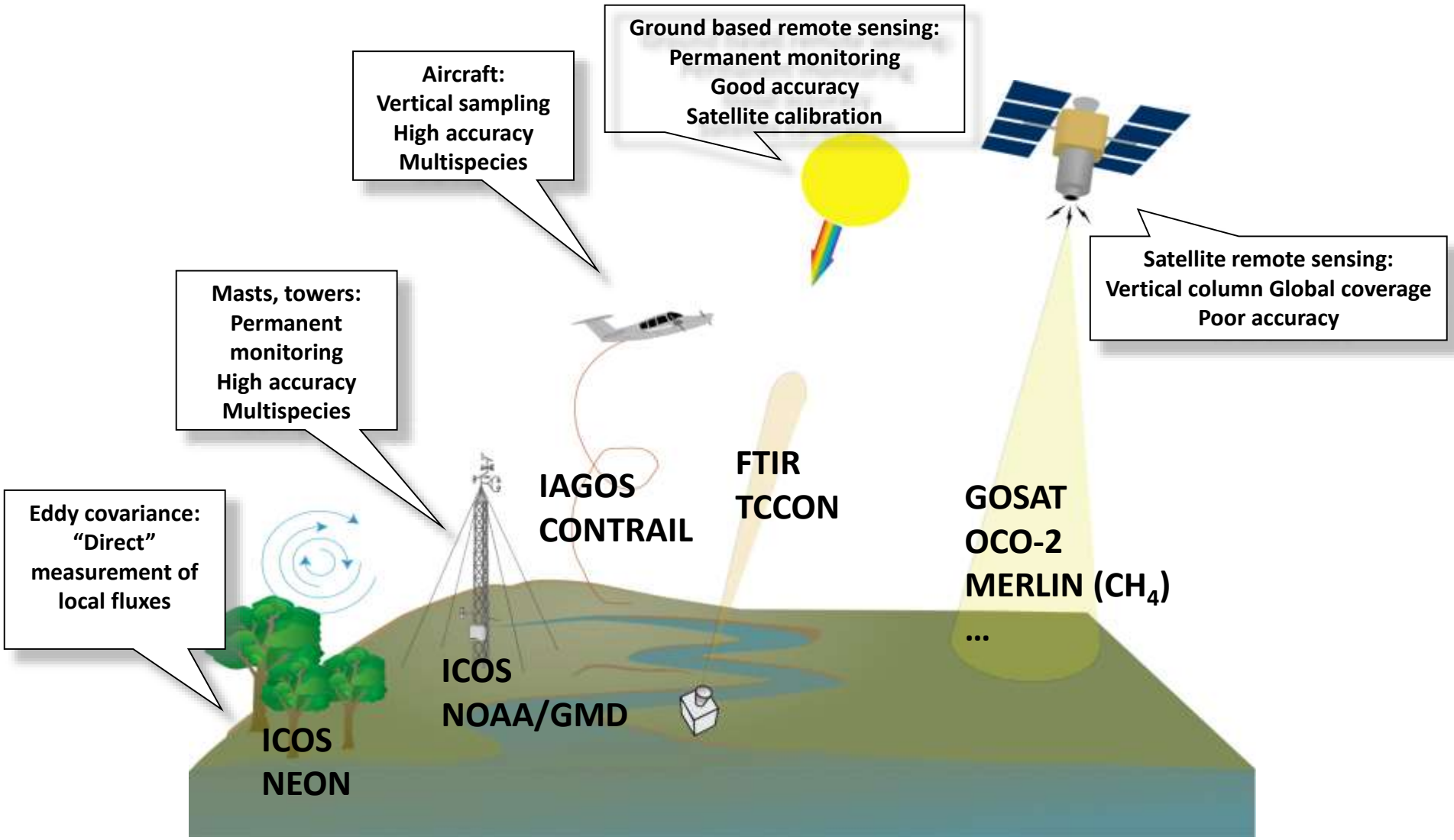
Seep density class
($\times 10^2$ km^{-2})

200–400
100–199
50–99
25–49
15–24
<15
0

Seep intensity class

1 2 3 4

Atmospheric observations

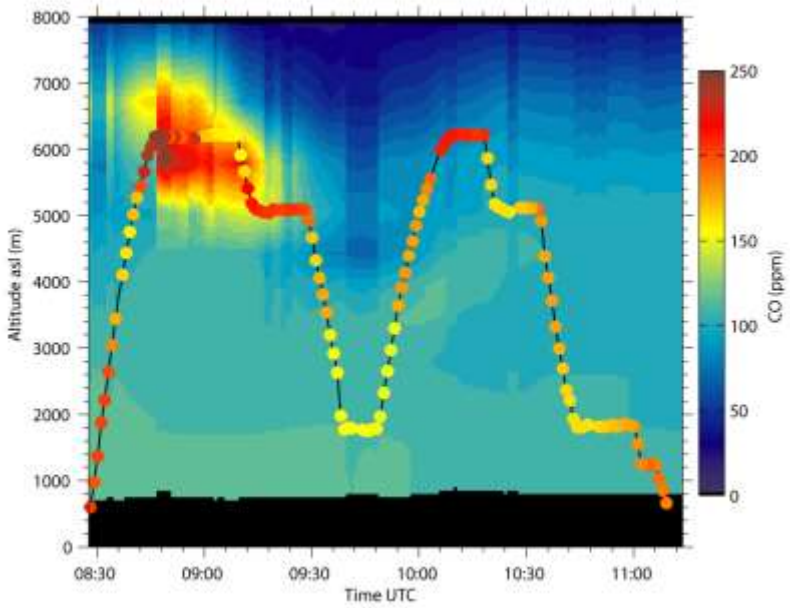


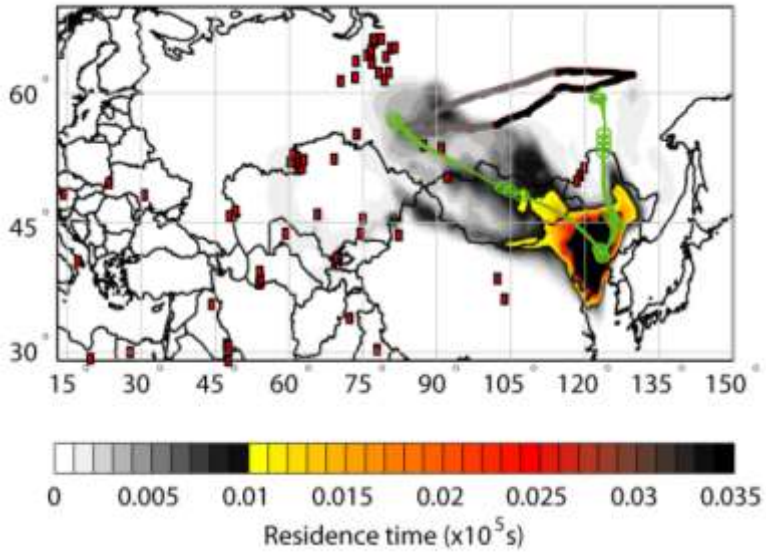
Thank you for your attention

Thanks to

- CNRS-INSU, MESR, ANR, RFBR, SB-RAS, CEA, Generali, for funding this research
- Jean-Luc Teffo and others at the CNRS international affairs and CNRS Moscow bureau for making this project possible at all

Long range transport of pollutant in the free troposphere from China to the Arctic through Siberia



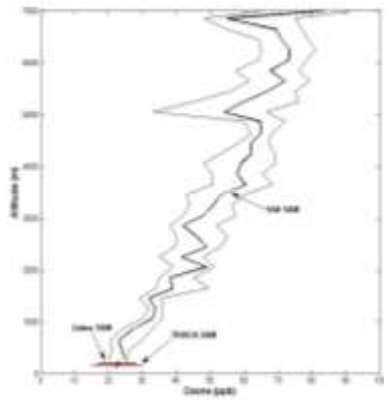


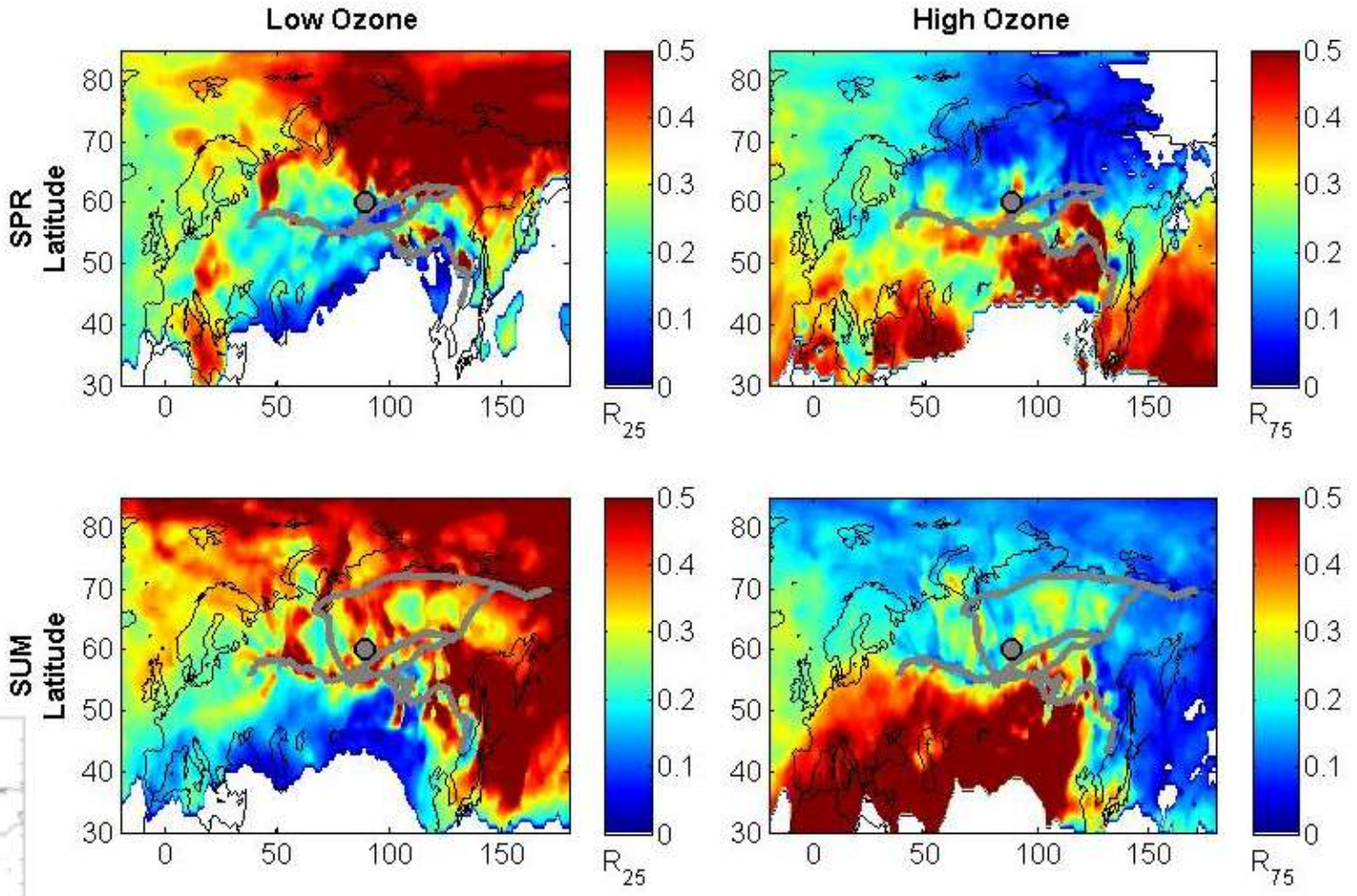
- The Siberian air shed is thought to be **clean air** affected only by minor regional emissions (but also Norilsk)
- Here we discovered large **enhancement of pollutants** (CO, aerosols) and GHG (CO2) over Siberia that could not be traced to regional pollution
- A suite of atmospheric models pointed to **emissions from NE China**, further confirmed by CO/CO2 ratio analysis, a tracer of (fossil fuel) combustion efficiency that differs between China, Russia and europe

J.-D. Paris et al., *Tellus B*, *60* (4), 551-568, 2008.

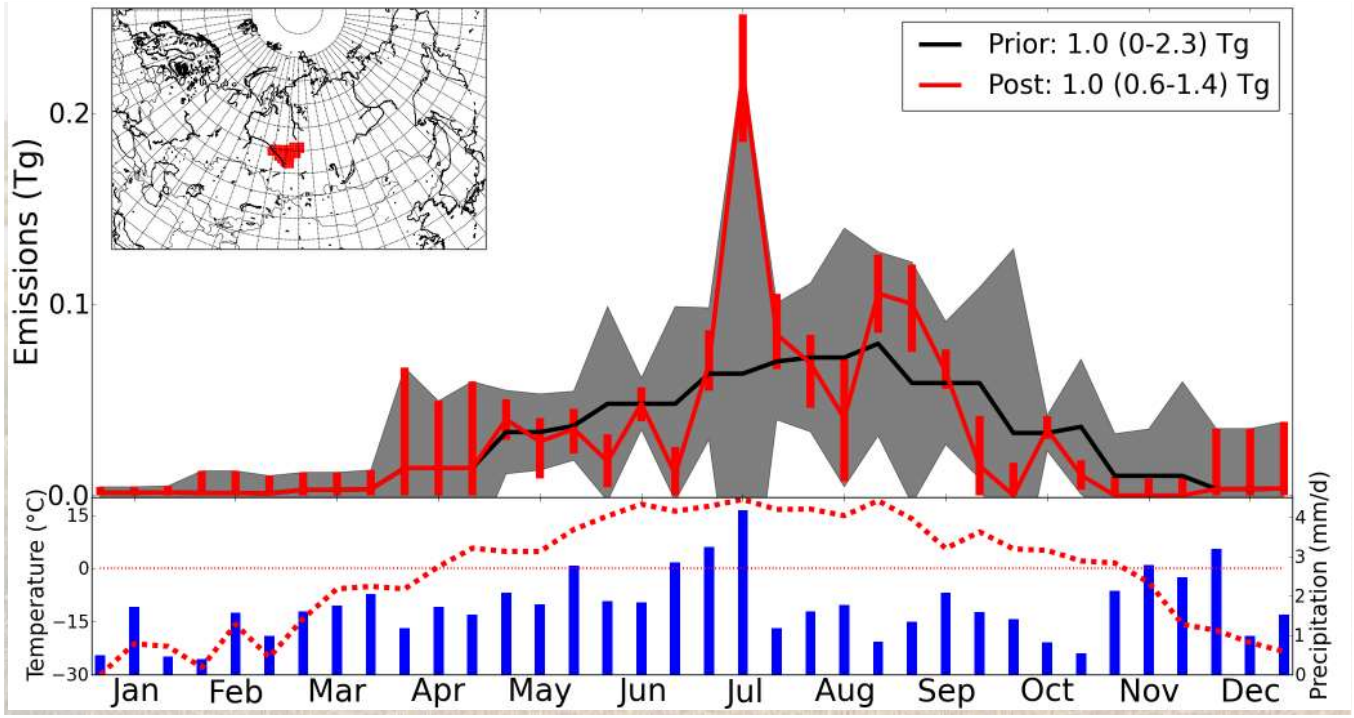
J.-D. Paris et al., *Bull. Amer. Meteorol. Soc.*, 2010, 625-641

Low surface O_3 in Siberia: Large scale deposition or Arctic chemistry?





Engvall-Stjernberg et al., Tellus B, 2012


Prior: 1.0 (0-2.3) Tg
Post: 1.0 (0.6-1.4) Tg
Emissions (Tg)
0.2
0.1
0.0
Temperature (°C)
15
0
−15
−30
Precipitation (mm/d)
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

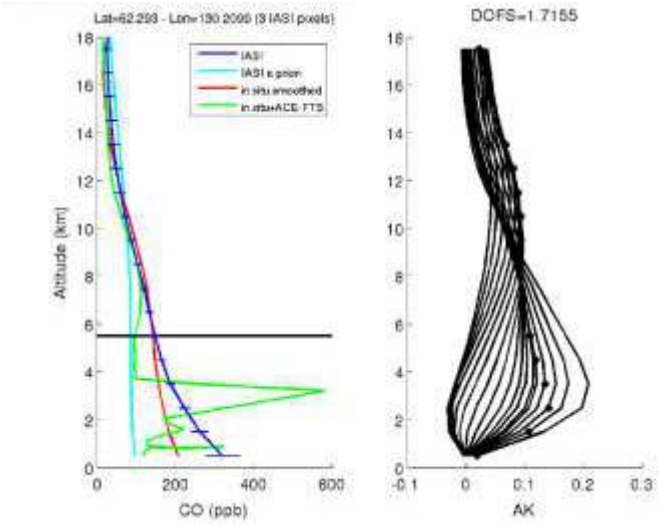
Stanislav Lvovsky / Flickr

Orders of magnitude, TgCH4/yr

- Anthropogenic sources (global) 273-409
- Wetlands (global) 140-280
- Hydrates (global) 1-10
- Permafrost 0-1
  - (Kirschke et al 2013)
- Anthropogenic Russia: 26
  - (Dolman et al. 2012)
- East Siberian Arctic Shelf: storm+bubble 17
  - (Shakhova et al., 2013)
- West Siberian wetlands : 1-6
  - (Kim et al., 2011)
- Thermokarst lakes: 3.8
- Northern wetlands: 6-60
  - (Walter et al., 2006)

IASI CO vs. aircraft data: a combined view on smoke transport to the Arctic

- **In IPY/POLARCAT biomass burning plumes transport has been observed from Siberia and Kazakhstan across the North Pole to North America.**
- **Biomass burning plumes can be used as a contrasted signal to validate spaceborne IASI measurements of pollutants (CO).**
- **Retrieval are well correlated to in situ profiles, but rather over land in summer and sea-ice in spring.**



M. Pommier et al., 2010, *Atmos Chem Phys,*

J.D. Paris et al., 2009, *Atmos Chem Phys*