

Atmospheric Chemistry in the Earth System

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Joint IGAC/SPARC Meeting Kyoto
2009



Talk Outline

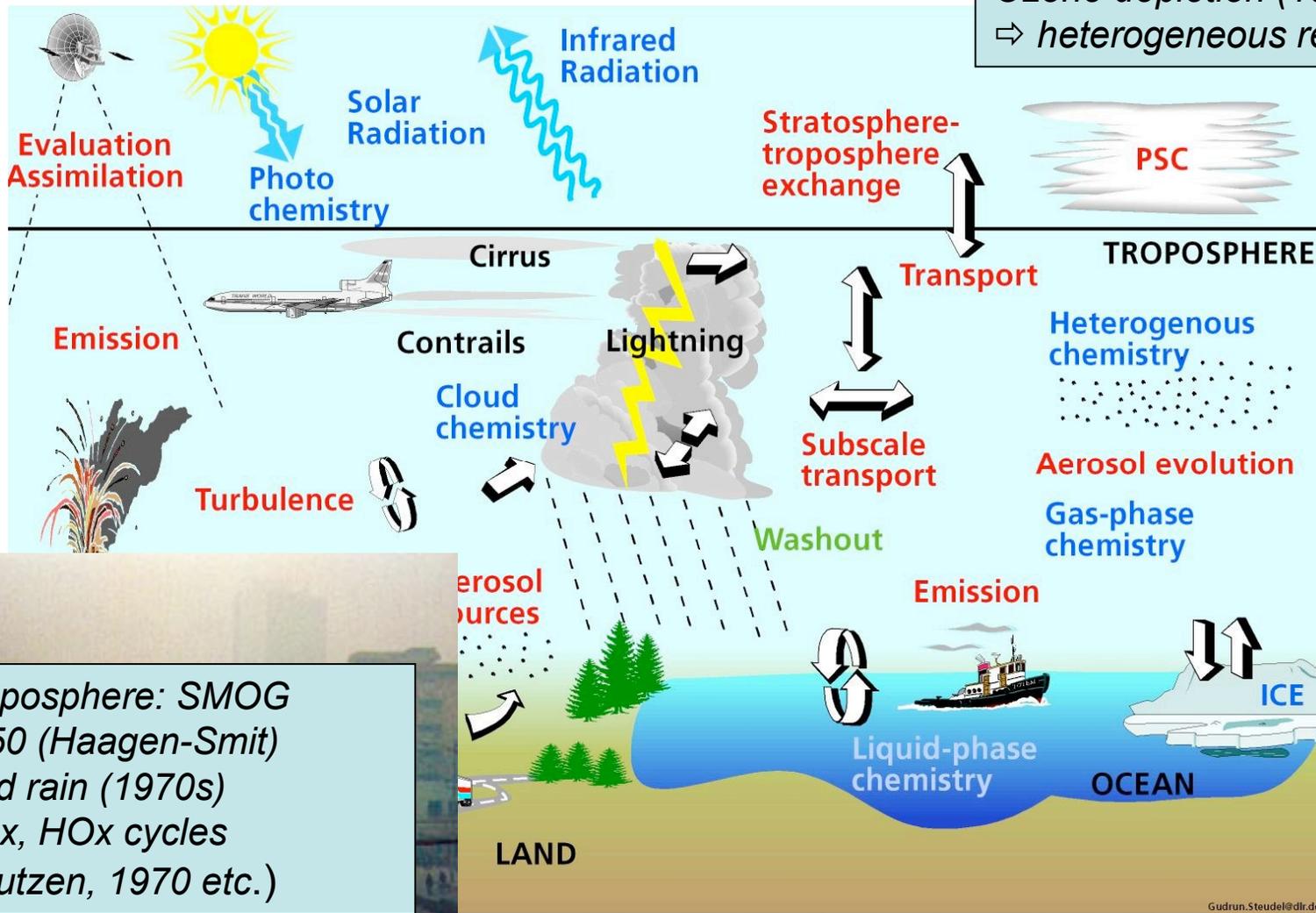
- **Atmospheric chemistry in the Earth system - perspectives from on-going and new IGAC activities**
- **Highlighting some links between troposphere and stratosphere**
- **Future directions - moving towards “One Atmosphere”**

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Atmospheric Chemistry has moved along way since

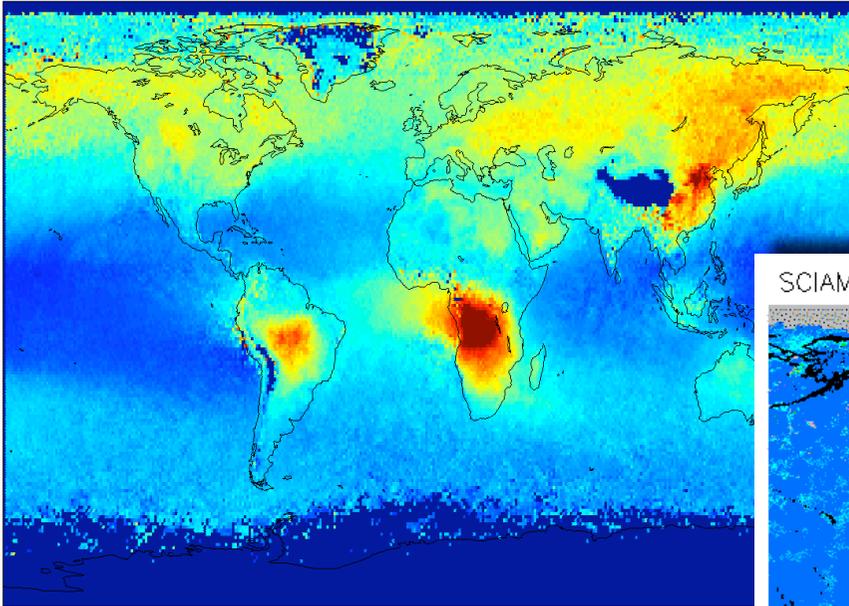
Stratospheric ozone:
 Chapman (1930)
 Chlorine cycles (1970s)
 Ozone depletion (1980s)
 ⇒ heterogeneous reactions



Troposphere: SMOG
 1950 (Haagen-Smit)
 Acid rain (1970s)
 NO_x, HO_x cycles
 (Crutzen, 1970 etc.)

Local Pollution is Global

July-August-September

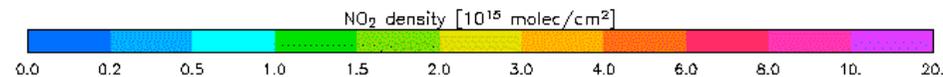
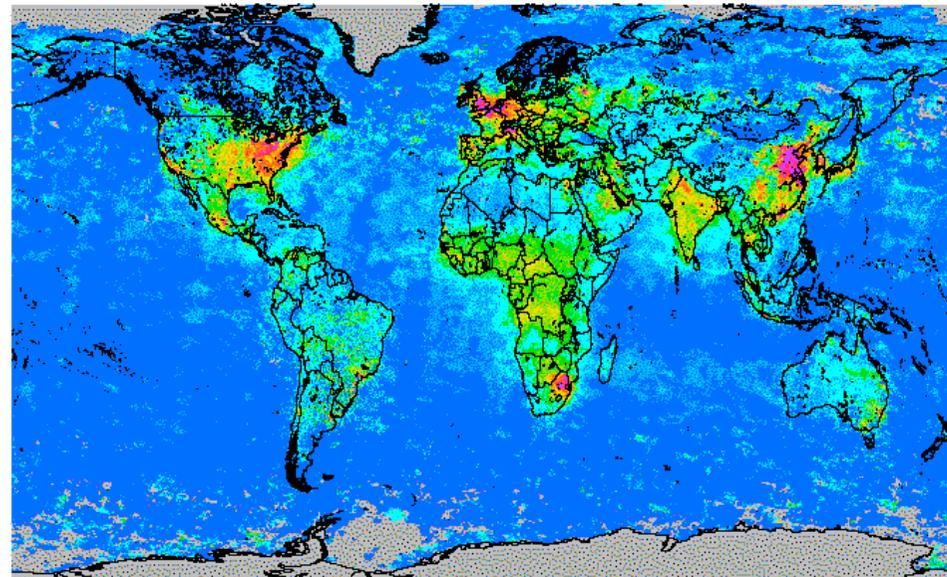


CO from MOPITT

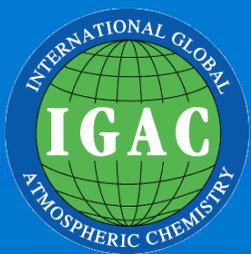
NO₂ from SCIAMACHY

SCIAMACHY mean tropospheric NO₂ 2003

KNMI/IASB/ESA

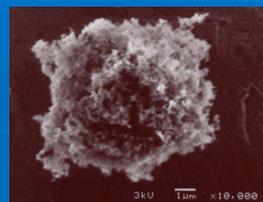


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Pollution : important interactions with biosphere, oceans, stratosphere & impacts on climate

nano-scale



particles & trace gases

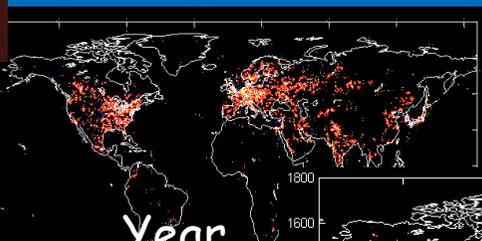


clouds

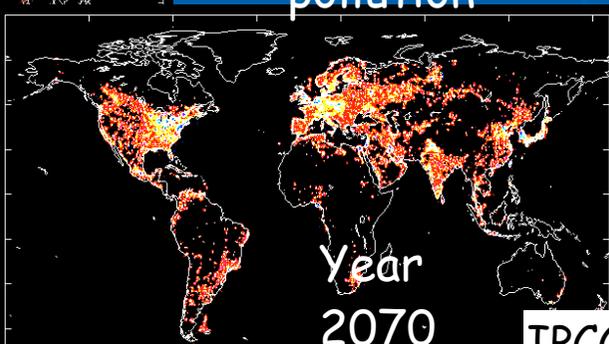
macro-scale



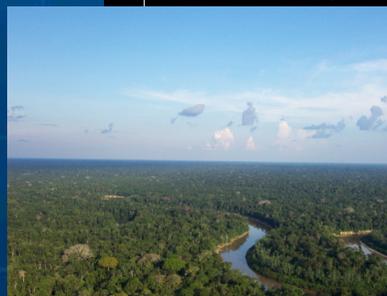
emissions



Year 2000



Year 2070



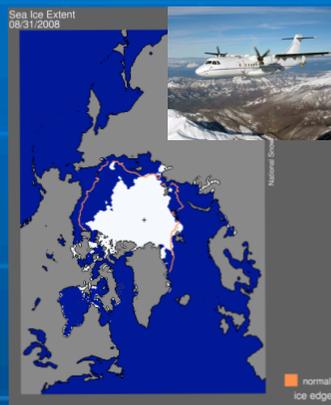
biosphere

local



pollution

regional



long-range transport

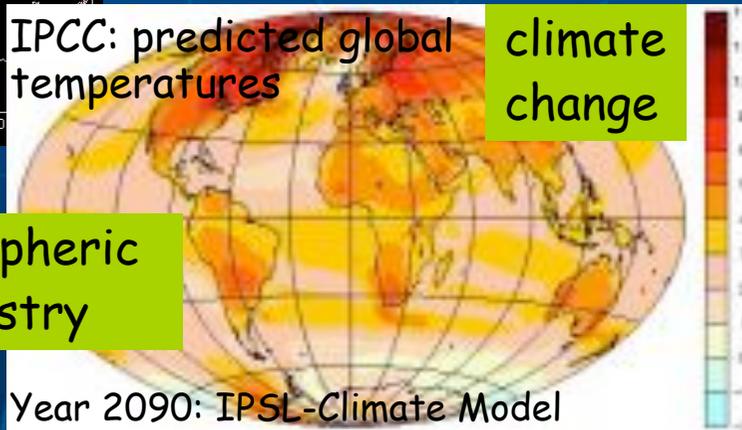
global

IPCC: predicted global temperatures

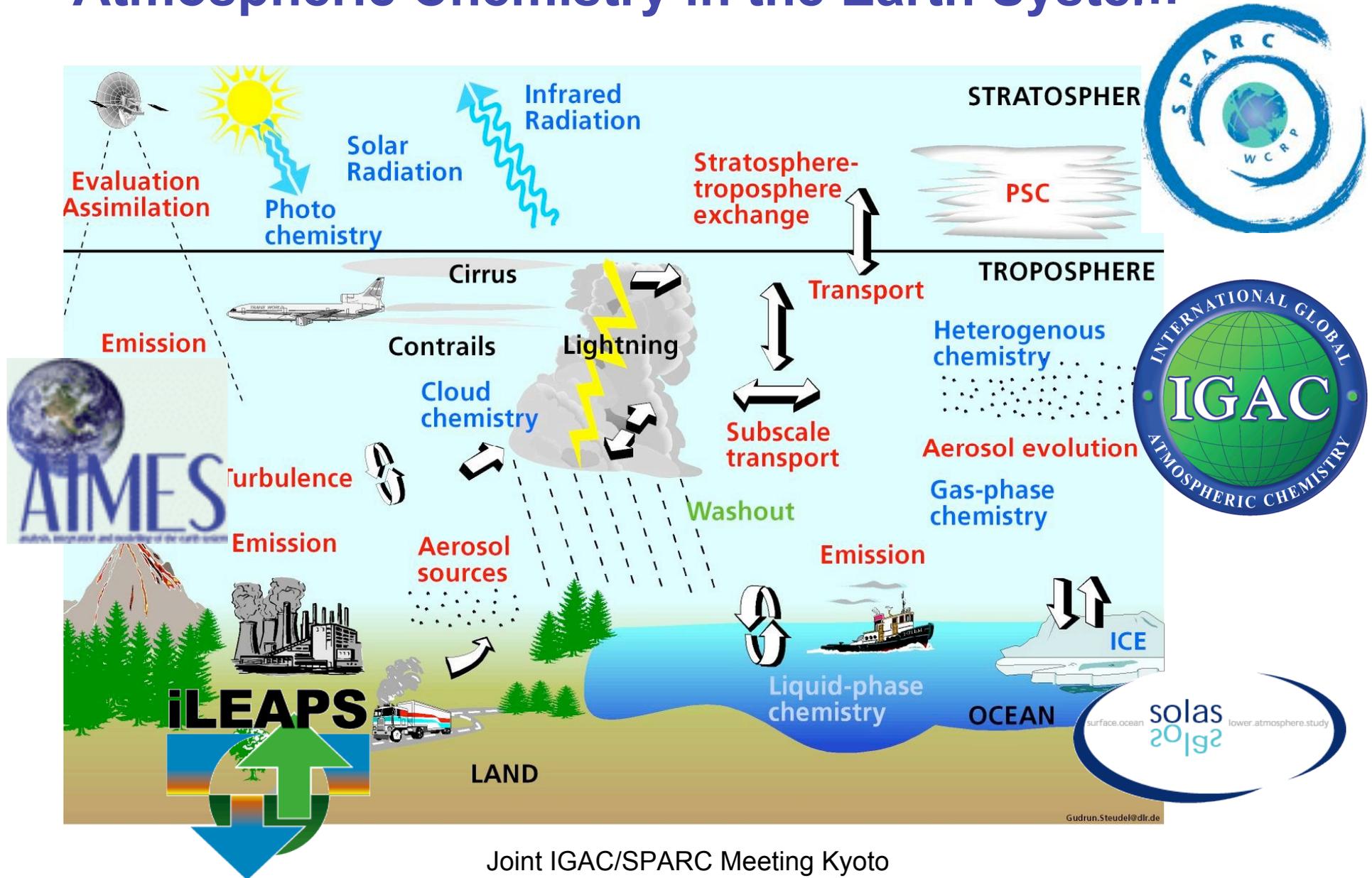
climate change

atmospheric chemistry

Year 2090: IPSL-Climate Model



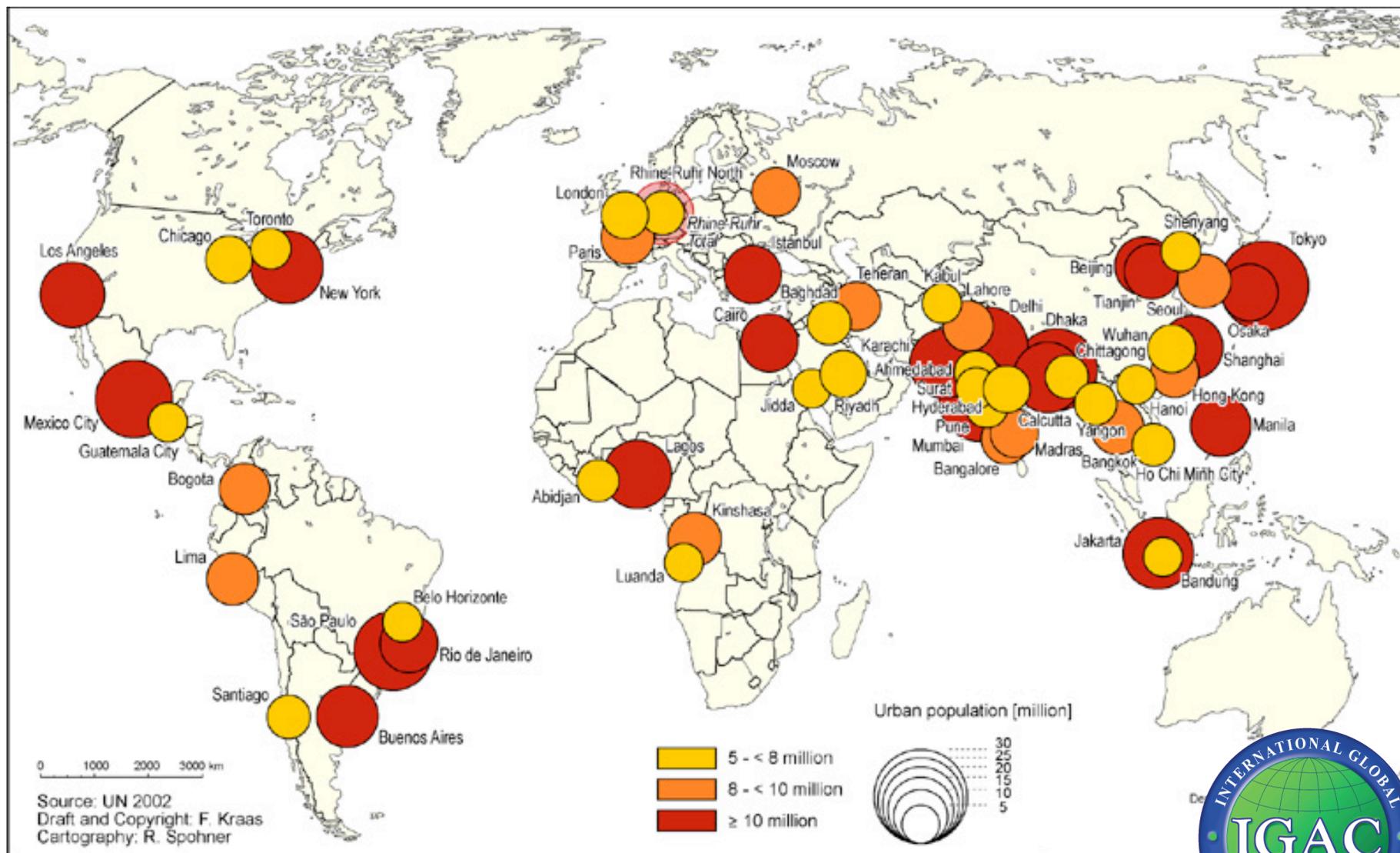
Atmospheric Chemistry in the Earth System



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Gudrun.Steudel@dlr.de

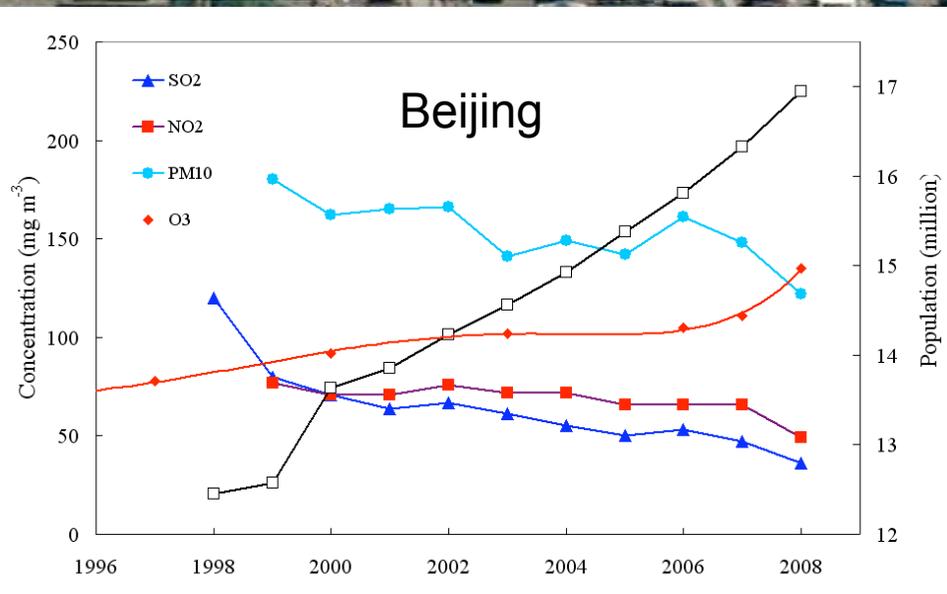
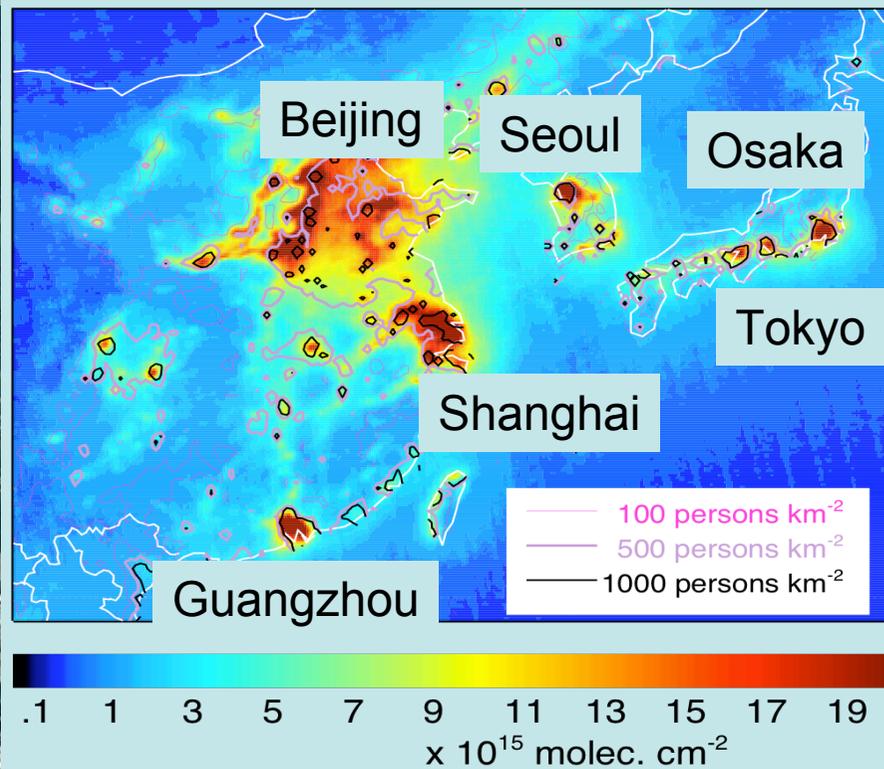
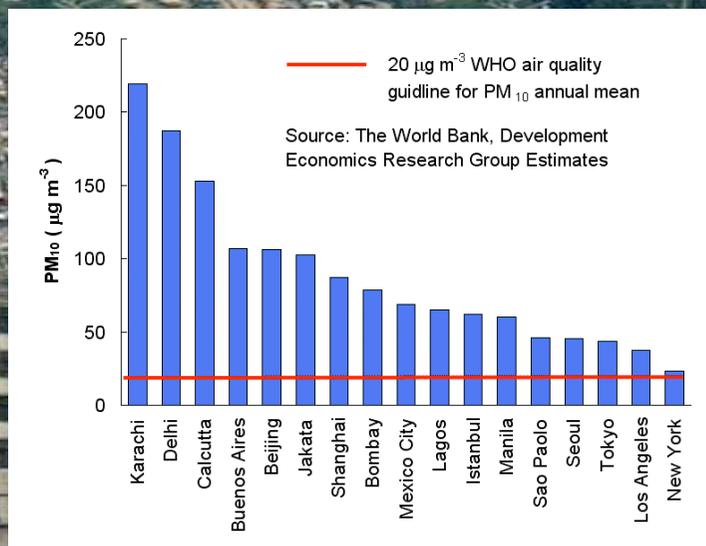
Local Pollution ⇒ Megacities ⇒ Impacts ⇒ IGAC Megacities Assessment



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Megacities-Asia (IGAC task) - rapidly increasing urban population - high pollution levels



NO₂ column - Randal Martin

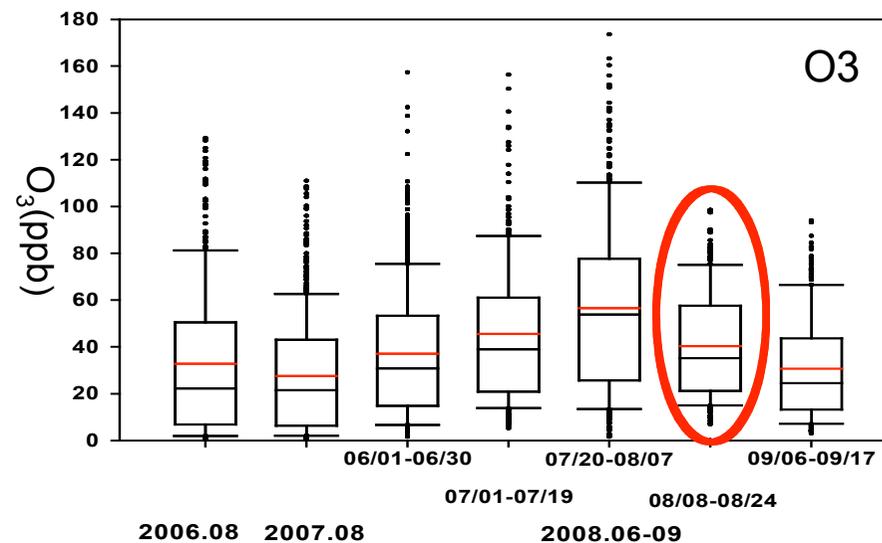
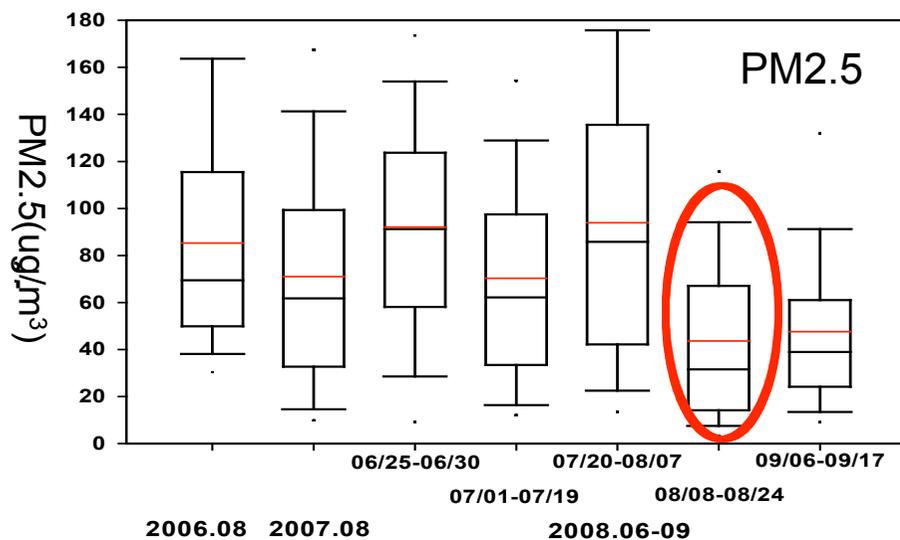
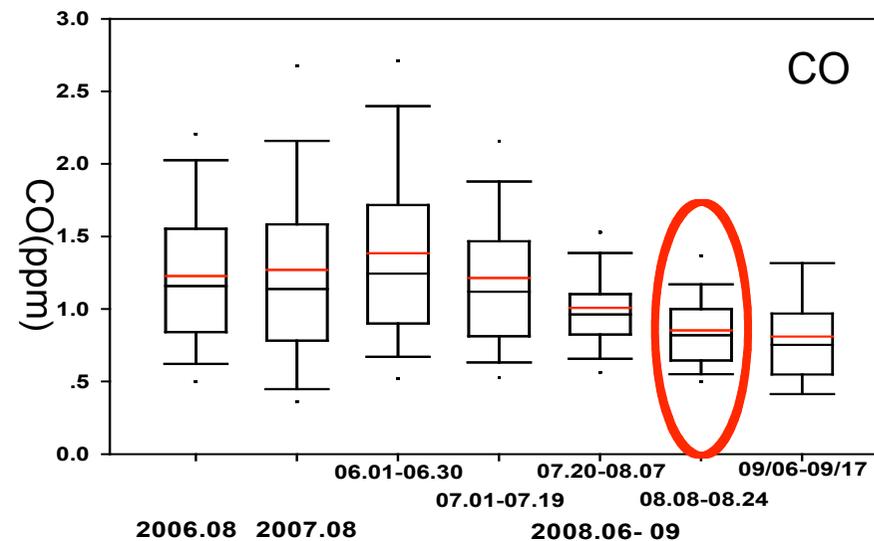
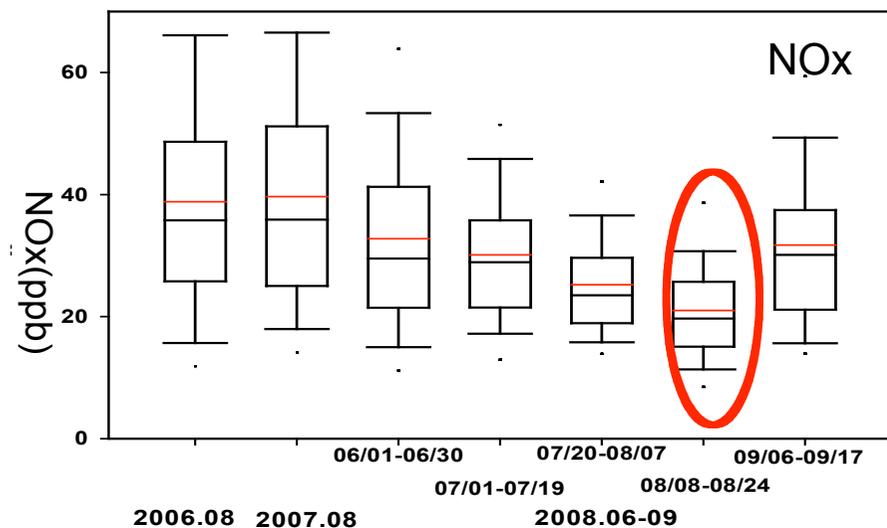
Parrish and Zhu, 2009



Example: CAREBEIJING-2008



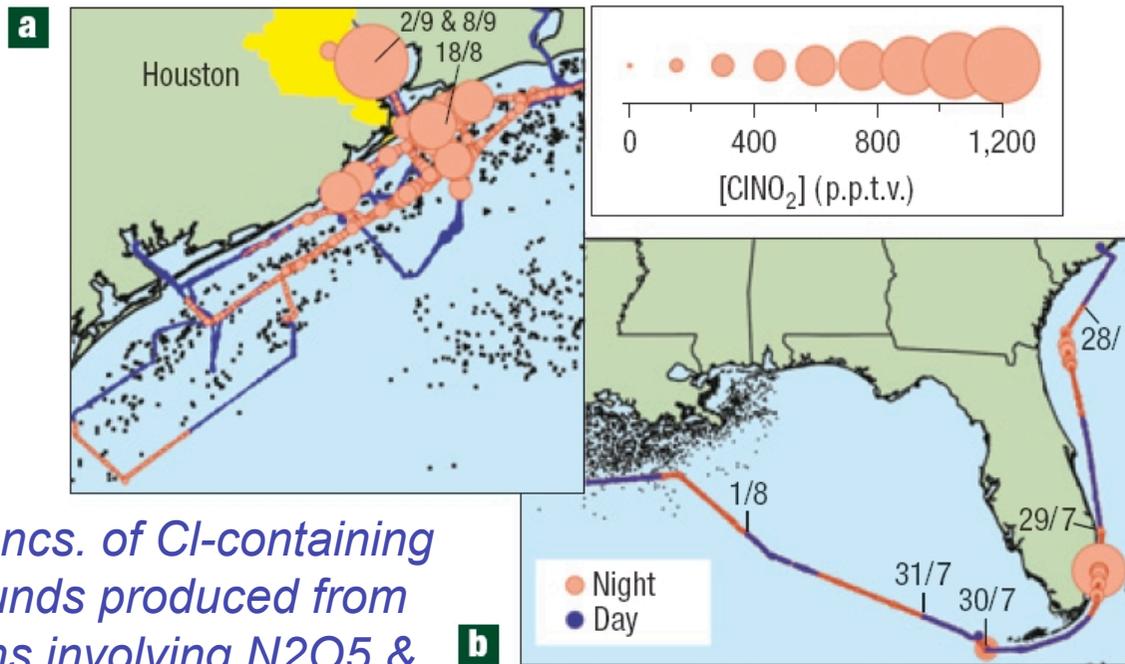
High pollution levels - reduced during Olympics (Aug. 08)



2009

Courtesy Tong Zhu

Megacity pollution interacts with marine environment



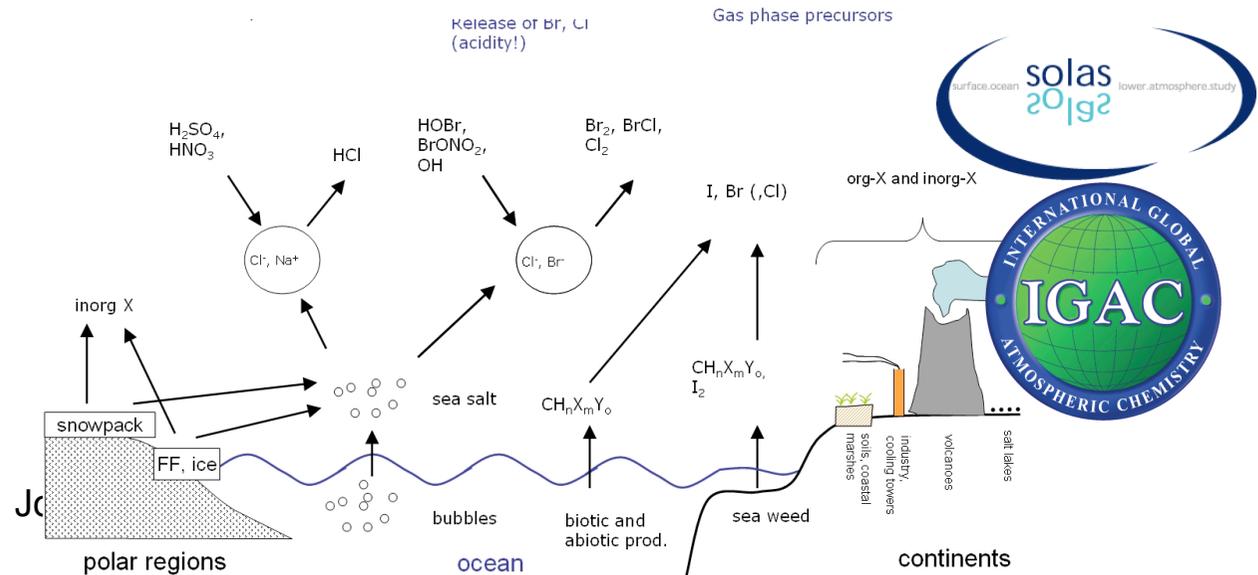
High concs. of Cl-containing compounds produced from reactions involving N_2O_5 & particles (Osthoff et al., 2008)

⇒ O_3 production in polluted marine environments

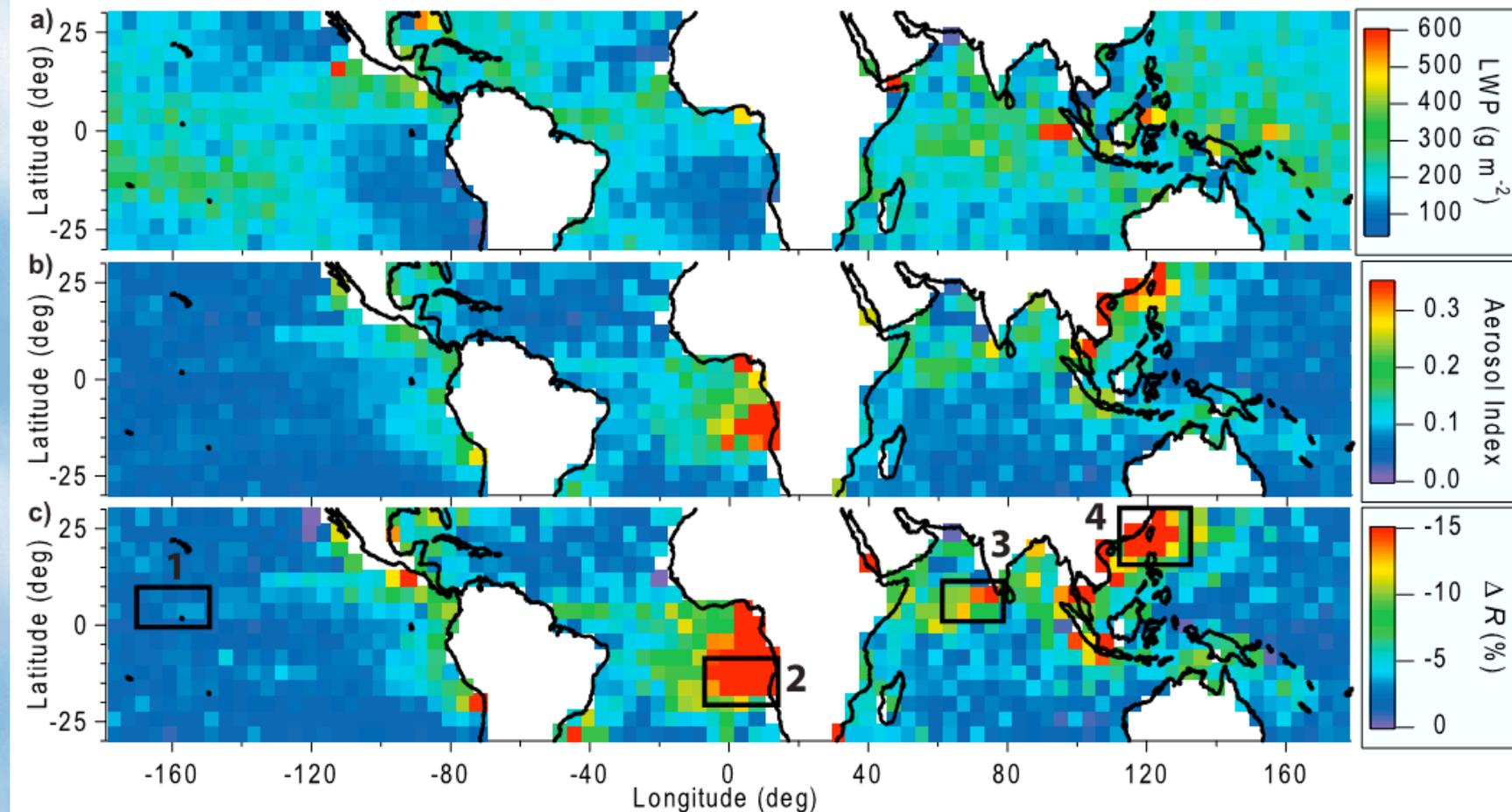
NEW Megacities in Coastal Zone (IGBP fast-track initiative)

Example: Halogen chemistry in the troposphere (HitT) (IGAC-SOLAS) -

Link to stratospheric kinetic studies

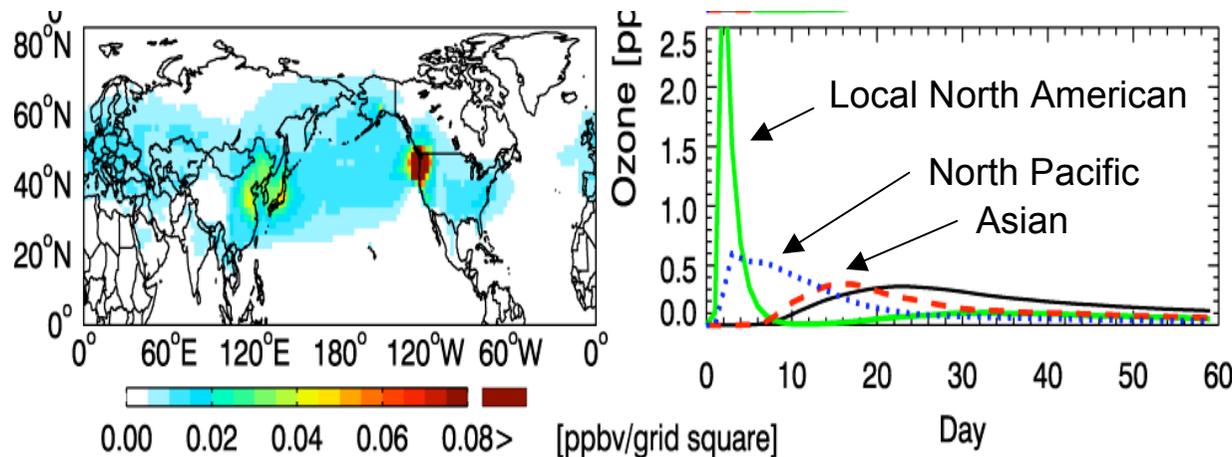


Aerosols, Clouds, Precipitation and Climate (ACPC) - new joint project iLEAPS/IGAC/GEWEX



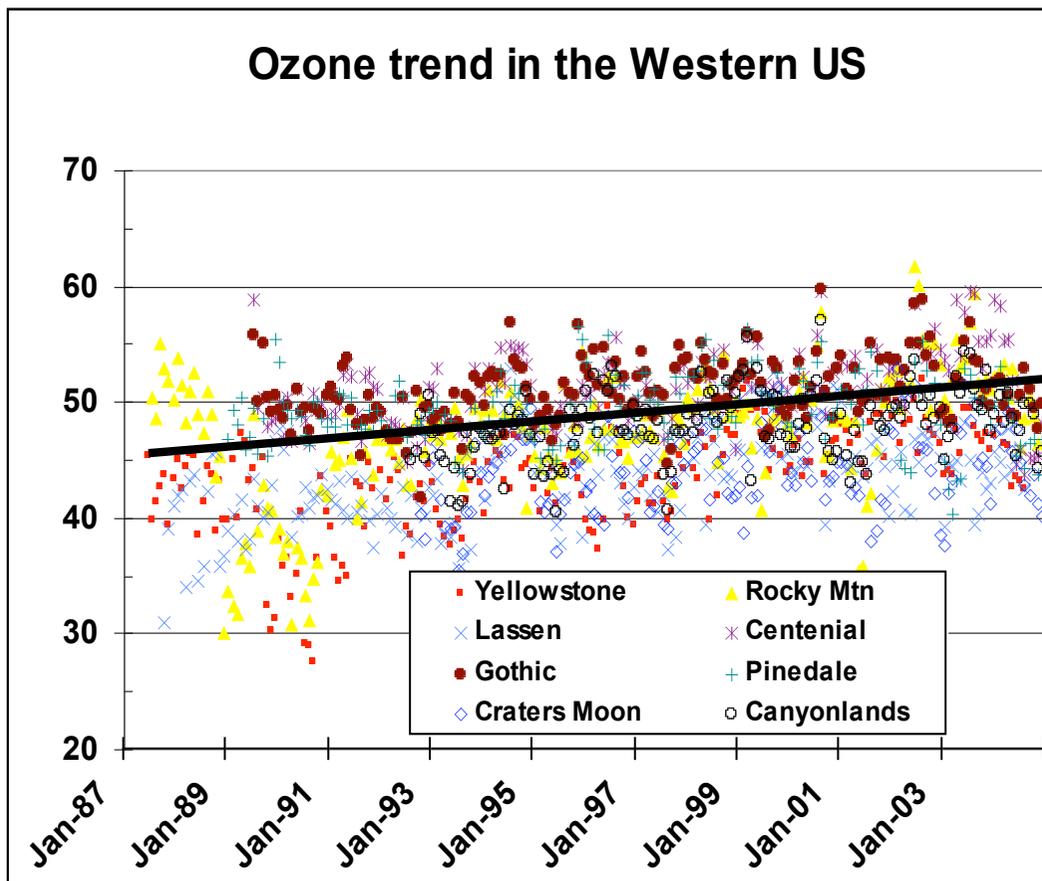
Global distribution of the 2007 annual averages of (a) AMSR-E LWP, (b) MODIS aerosol index (AI), and (c) % change in precipitation rate (ΔR) for the AI variability within a given 4x4 pixel. Measurements pertain only to precipitating cloud cases. The strongest ΔR are in boxes 2, 3, and 4.

Long-range transport of pollution - impacts downwind surface air quality



*Example:
Source regions
affecting O₃
concentrations at
Trinidad Head
(GEOSCHEM model),
Henze et al., 2007*

Ozone trend in the Western US

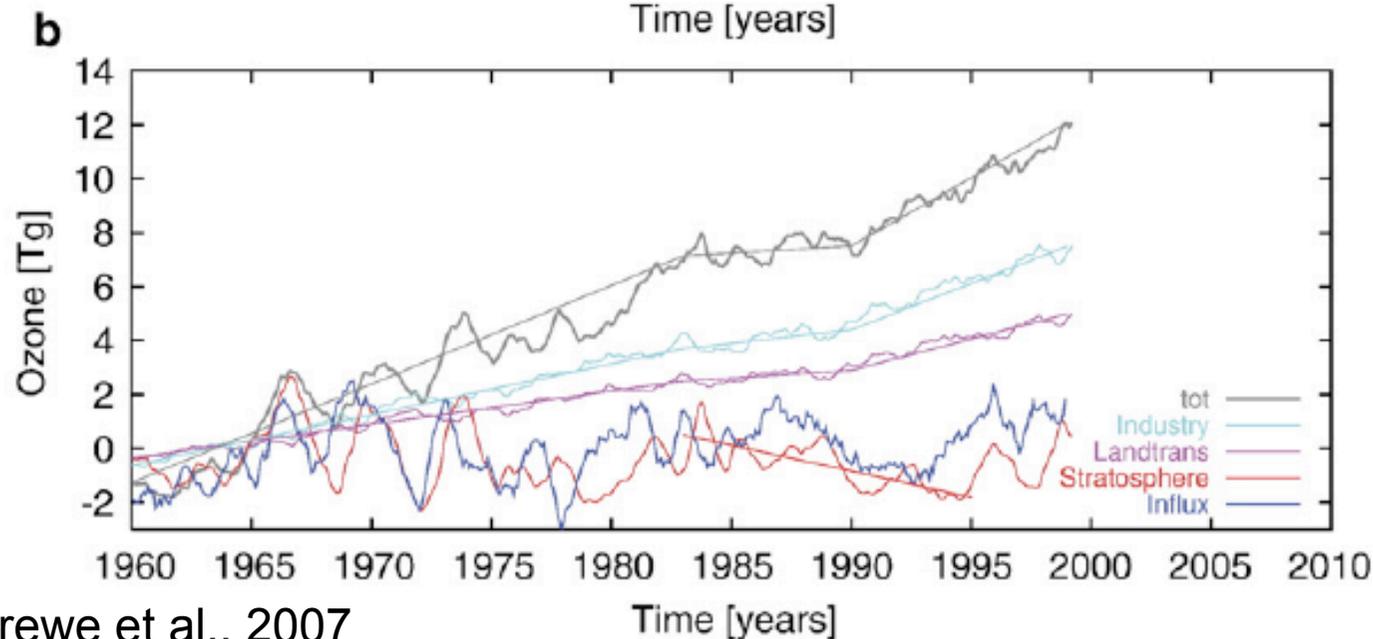
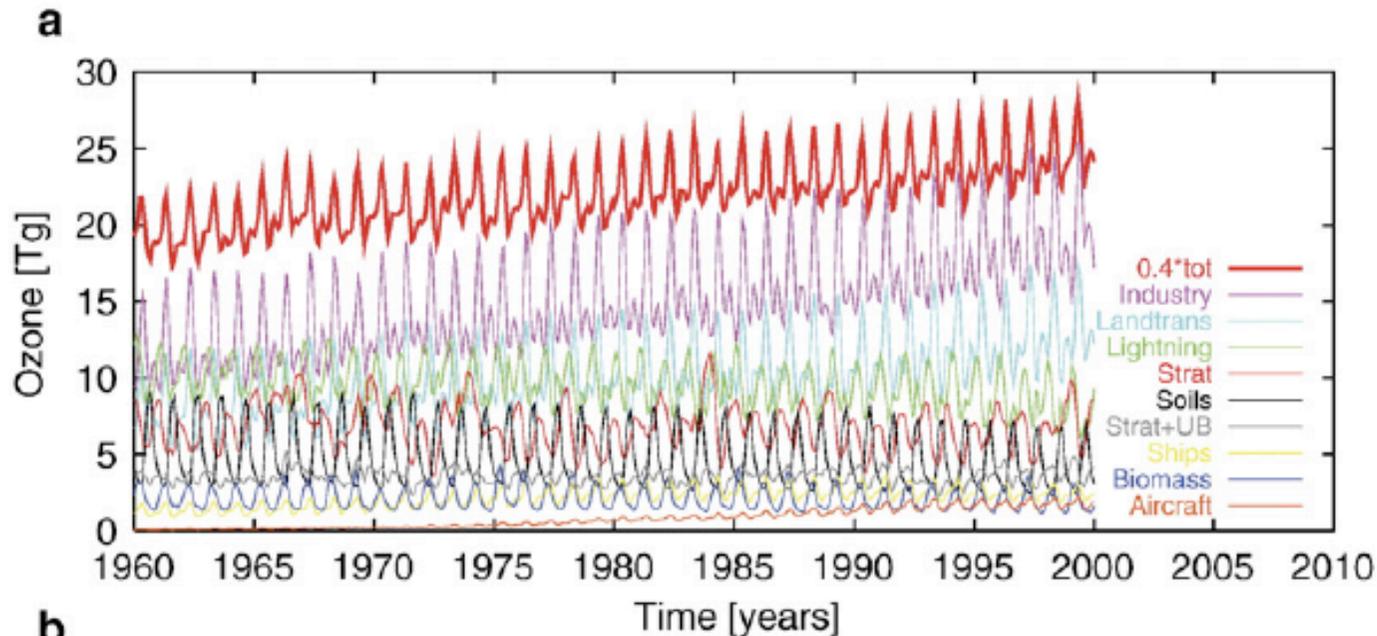


Jaffe &
Ray, 2008

*Background O₃
trends - increasing at
some locations (e.g.
western US) -
implications for air
quality control
legislation.....*

*BUT, not well
quantified - Task
Force on
Hemispheric
Transport of Air
Pollutants (HTAP)*

Atmospheric composition trends (troposphere) are along way from being understood and models from reproducing them

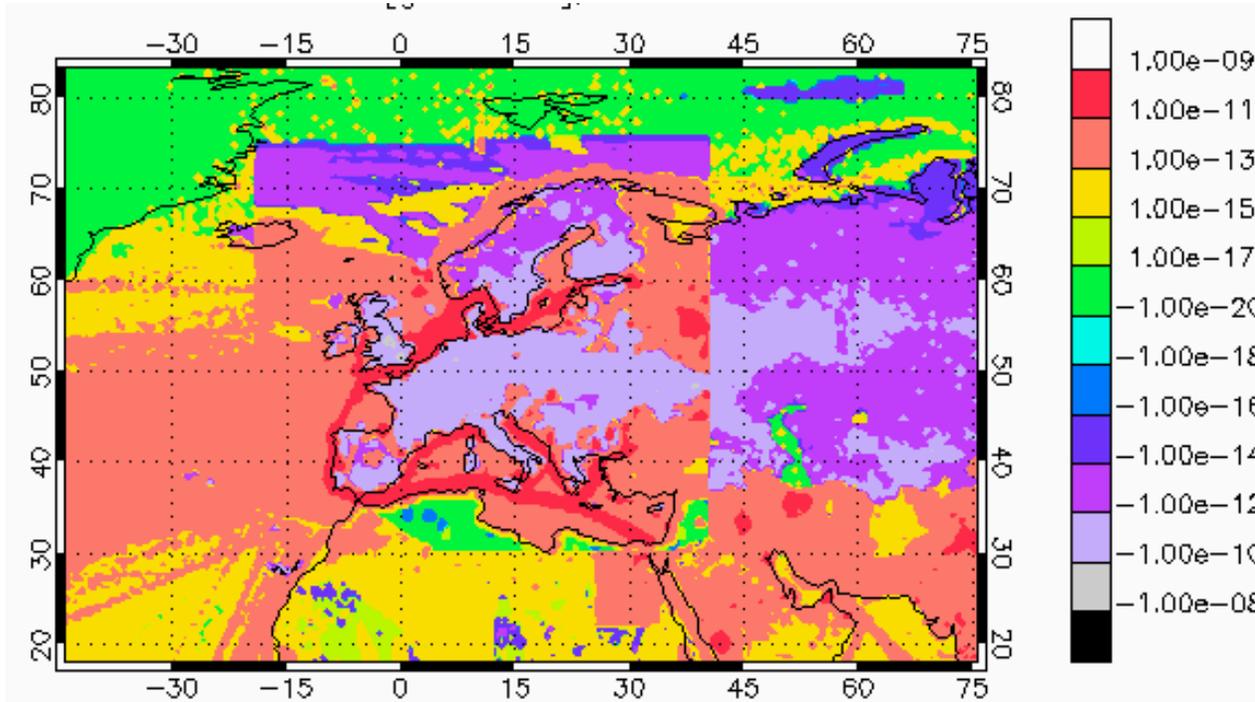


Atmospheric
Chemistry &
Climate
(IGAC/SPARC)

20-year hindcast

Troposphere-
stratosphere
models versus
data

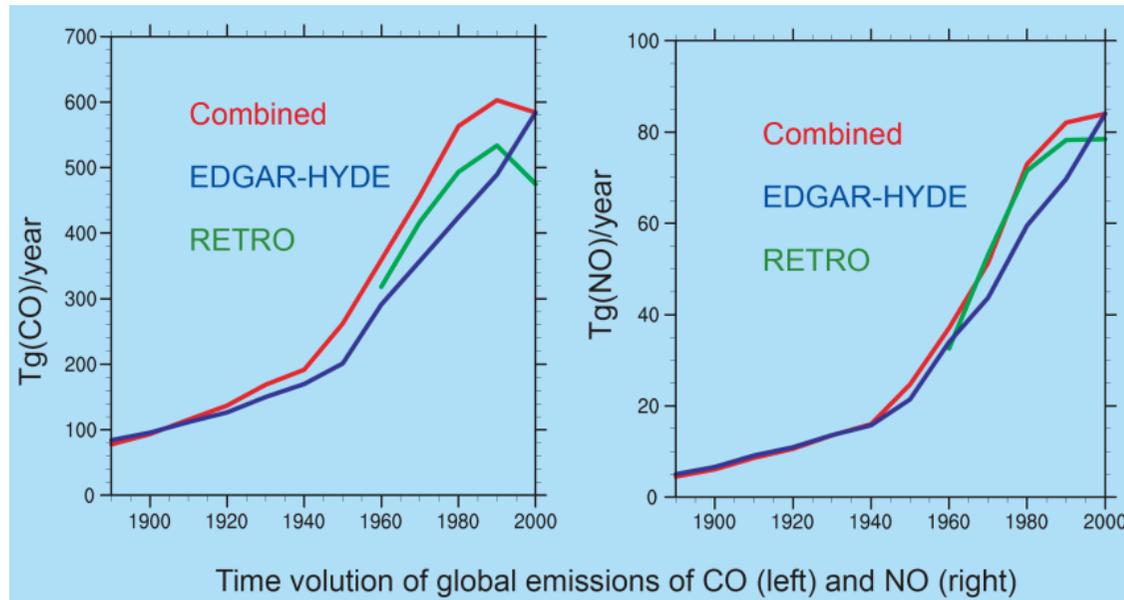
Emissions - many uncertainties still.....



Regional vs global

Difference in NOx emissions from 1998 to 2006:

- global IPCC emissions
- regional EMEP emissions for Europe



Past (up to 2000) & future emissions defined for AR5

courtesy Claire Granier/GEIA
EU MACC/CITYZEN projects

Uncertainties in O₃ radiative forcing

- Results from IPCC AR4 models - GHGs plus strat. O₃ (Gauss et al., 2006)
- Strat. vs trop. model differences (1850 to 2000)

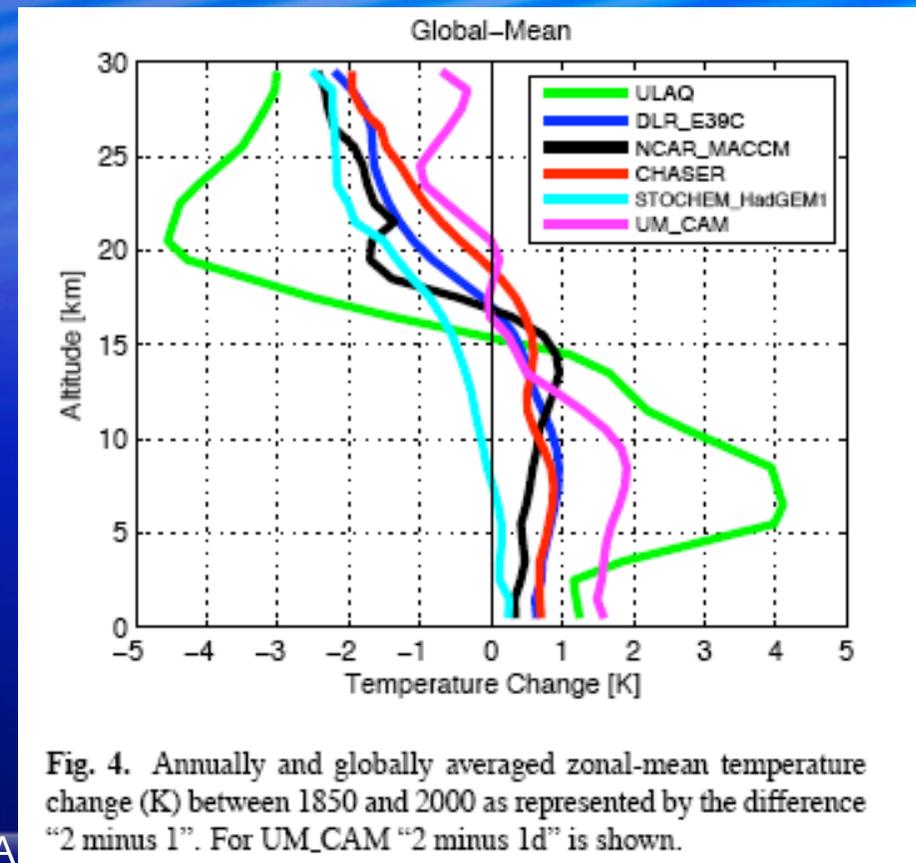
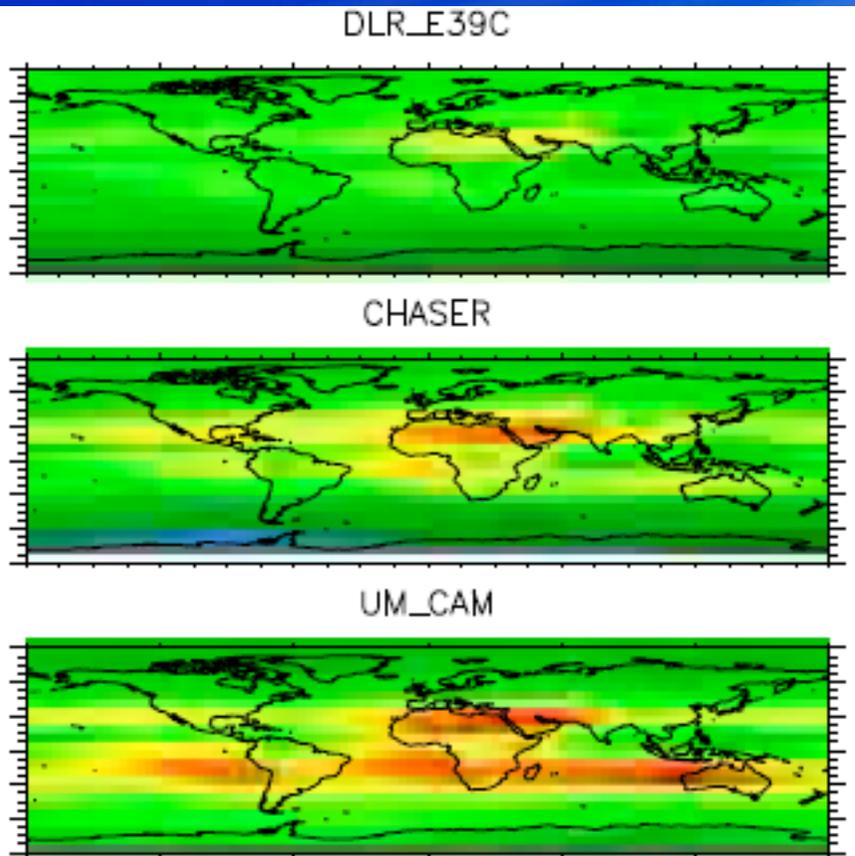
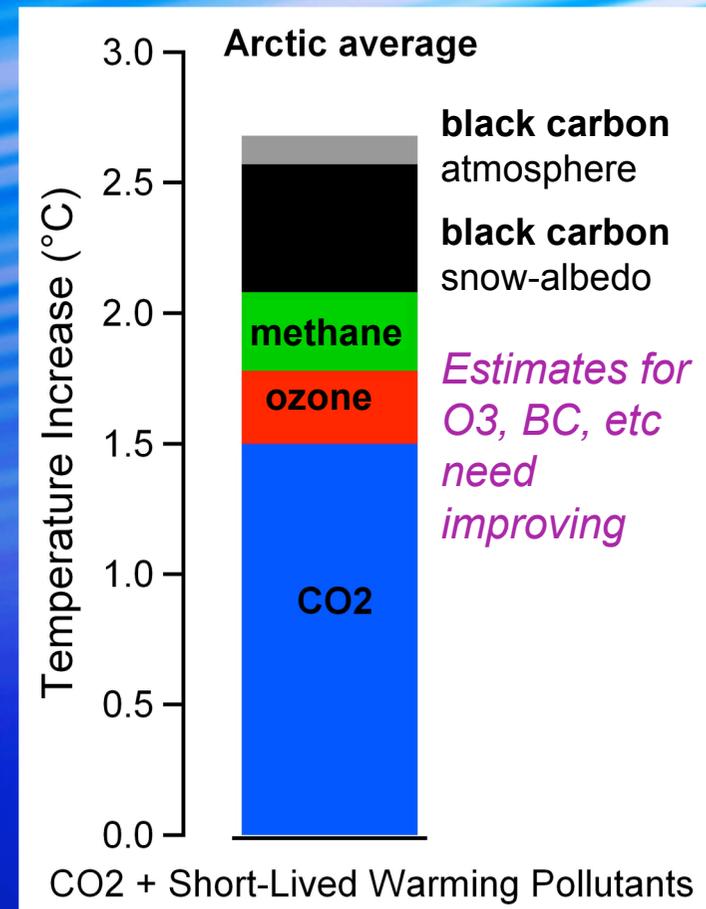
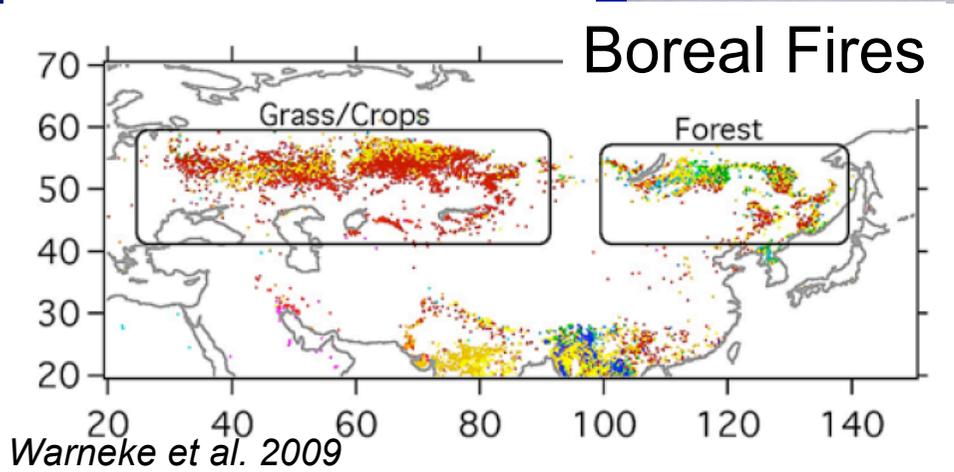
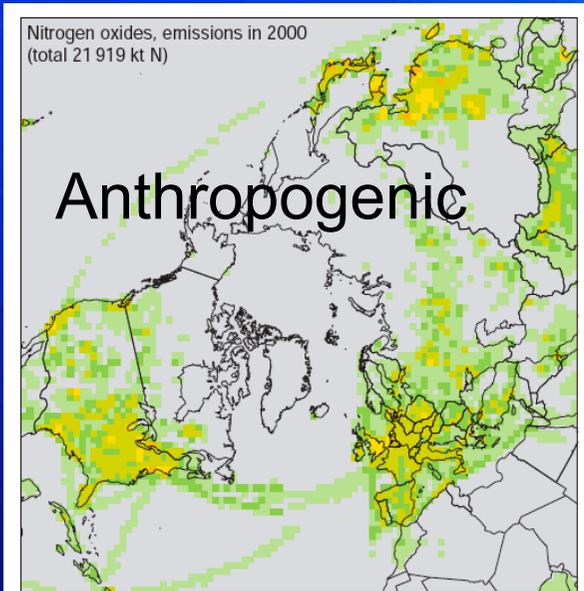


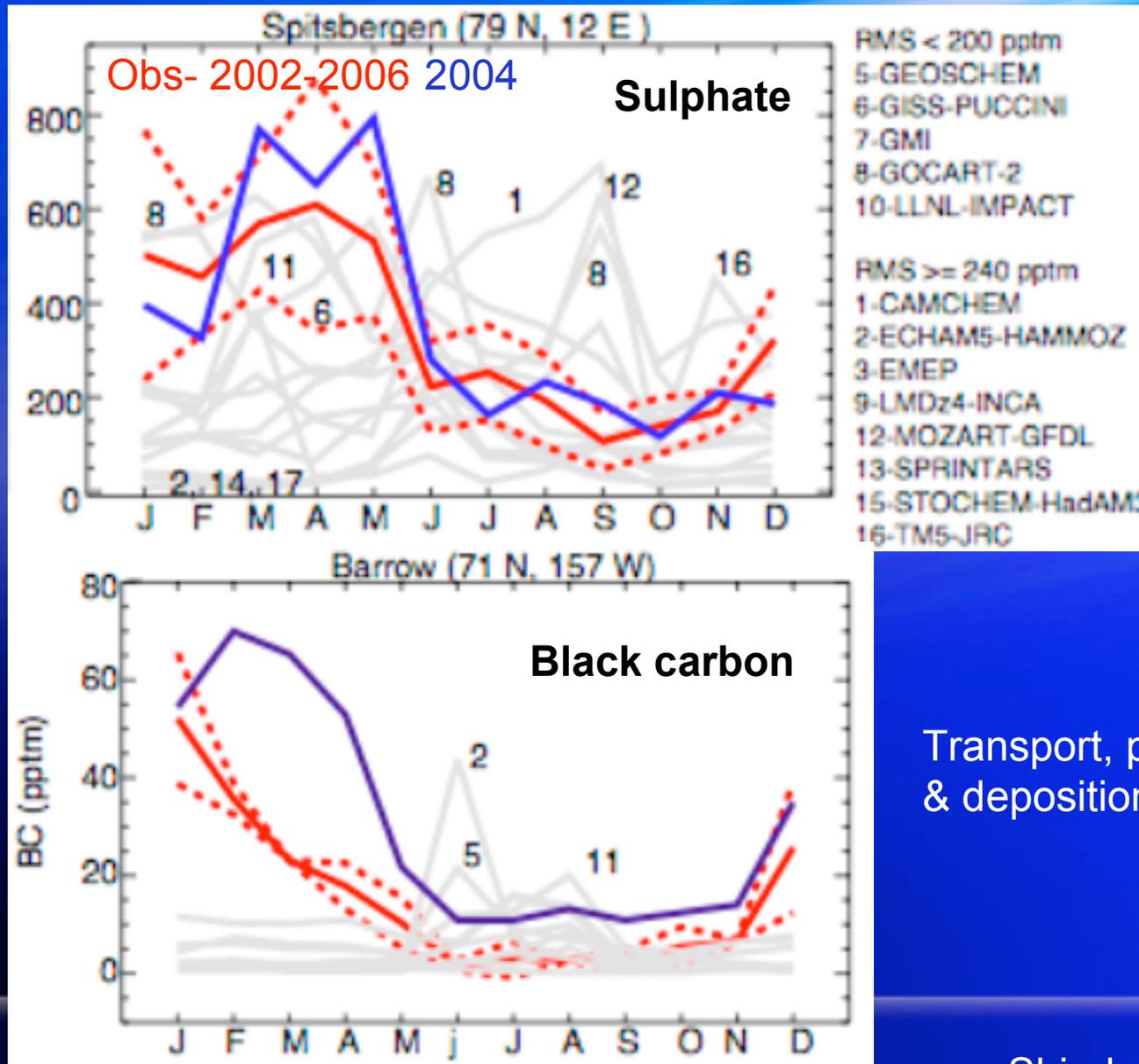
Fig. 4. Annually and globally averaged zonal-mean temperature change (K) between 1850 and 2000 as represented by the difference "2 minus 1". For UM_CAM "2 minus 1d" is shown.

Key Issue: better estimates for impacts of short-lived pollutants on climate - Arctic



Annually averaged surface air temperature increase due to CO₂ + short-lived pollutants (lifetimes of weeks to years)

Arctic: Models have problems reproducing seasonal cycles (aerosols & trace gases)



Transport, processing
& deposition (wet + dry)

POLARCAT Field Campaigns 2008



Ground-sites

NASA ARCTAS/DOE ISDAC



NOAA ARCPAC



Yakutsk



Franco/Russian YAK TROICA - Train



ASTAR / DLR-GRACE

Longyearbyen

Norilsk

POLARCAT-France

POLARCAT-France



Kangerlussuaq

NOAA-ICEALOT



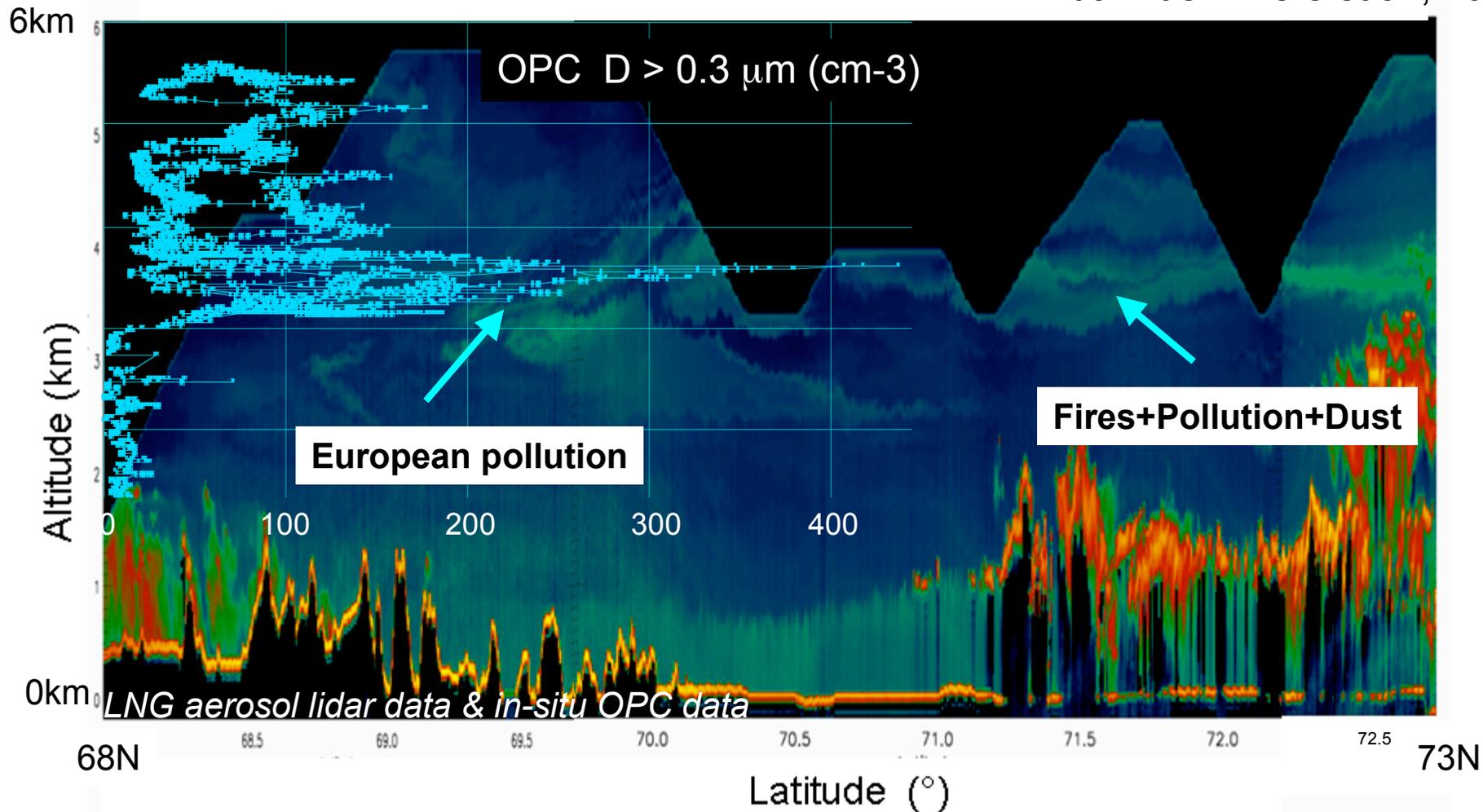
Kiruna



POLARCAT-spring: pollution over northern Sweden/Arctic Ocean

ATR-42 Flight: 11 April 2008

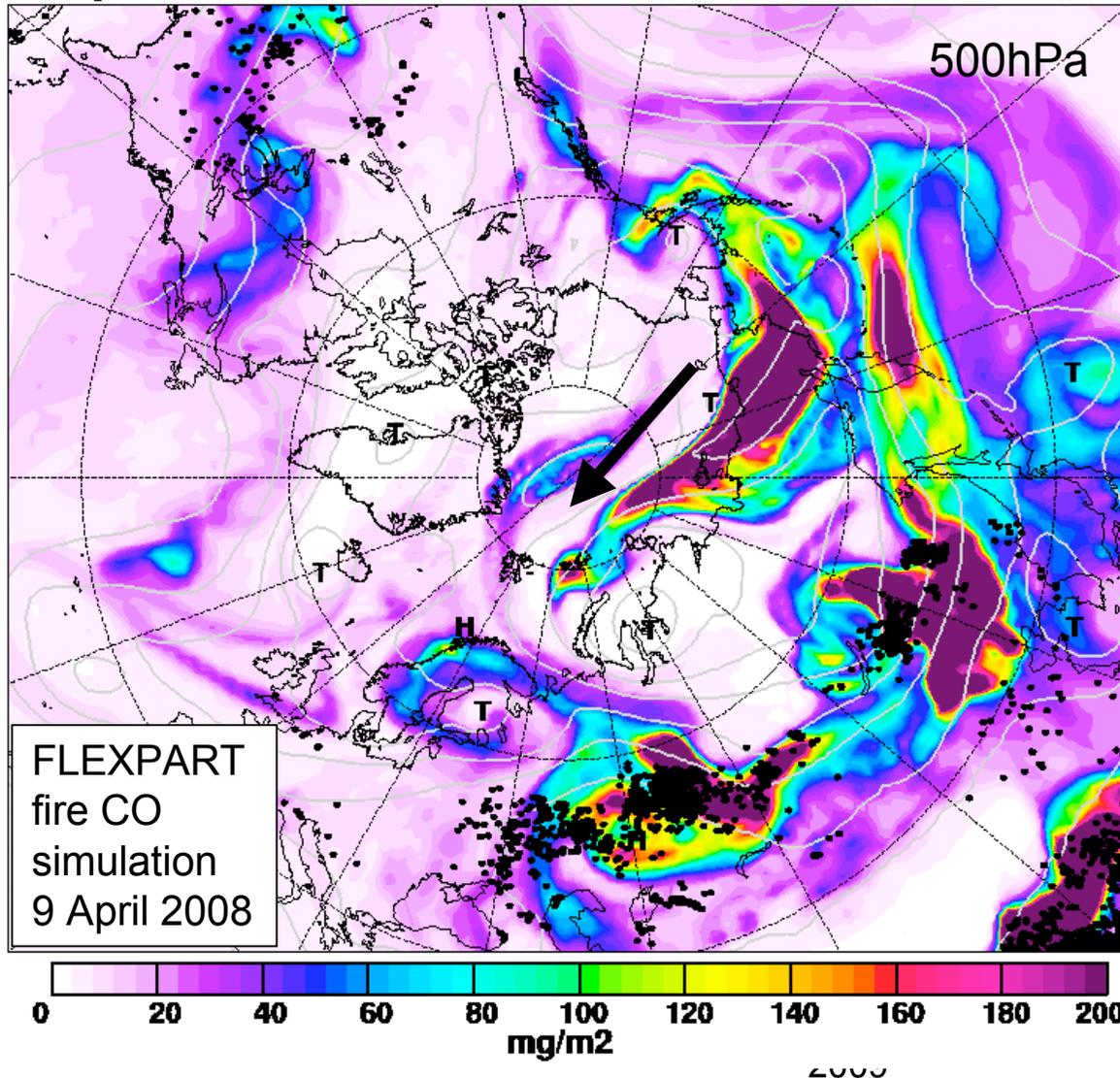
Adam de Villiers et al., 2009



Aerosol plumes : Siberian fires + Asian pollution + mineral dust and European pollution
Study of aerosol evolution during transport (radiative properties, CALIPSO)

POLARCAT-spring: Transport of pollution to Arctic

Total column of BB-CO and 500 hPa geopotential
Analysis @ 20080408.180000 Actual @ 20080409.120000



April 2008

Early boreal fires (Siberia) and agricultural fires (eastern Europe)

Plus Asian pollution/mineral dust (UT)

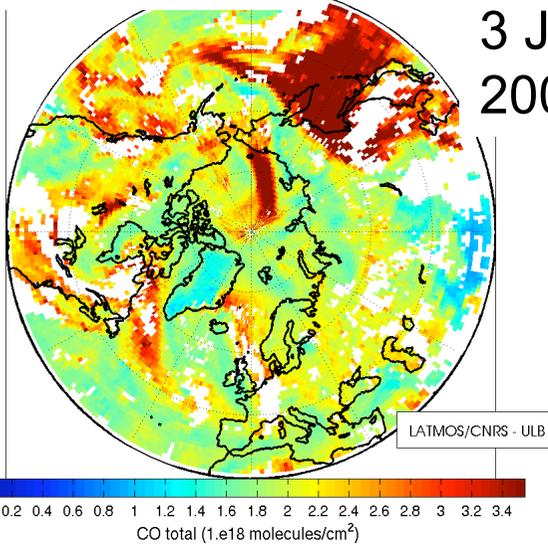
High concentrations of aerosols and trace gases (CO)

Impact on radiative forcing in Arctic?

POLARCAT-summer: Siberian boreal fire plumes (YAK) + Asian pollution transported across Arctic

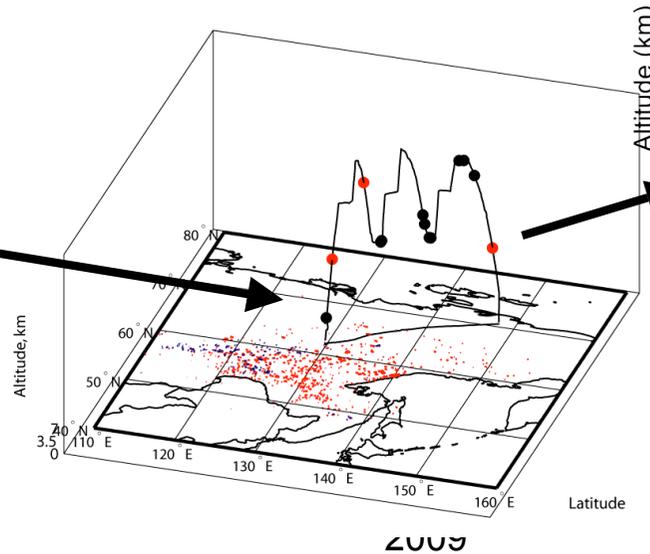
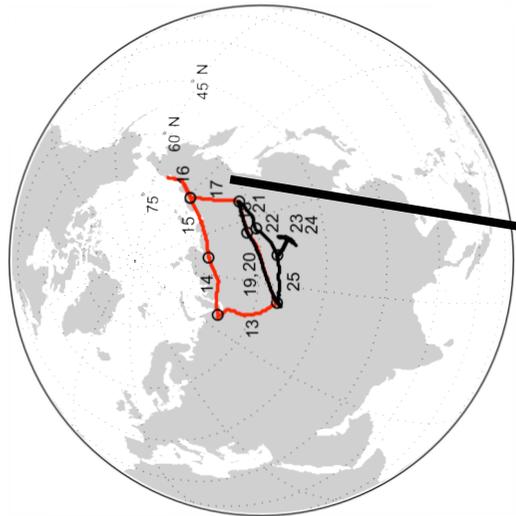
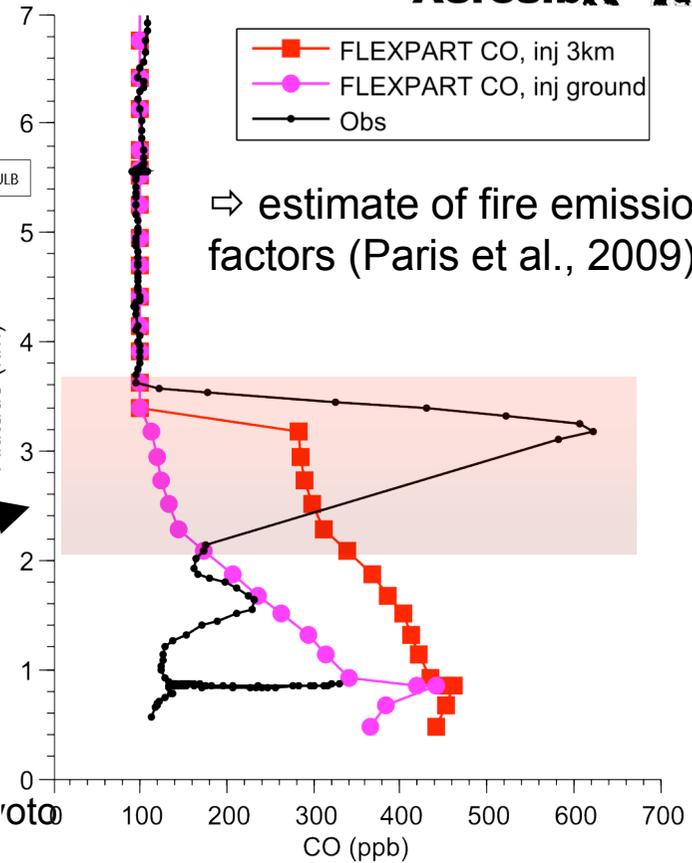
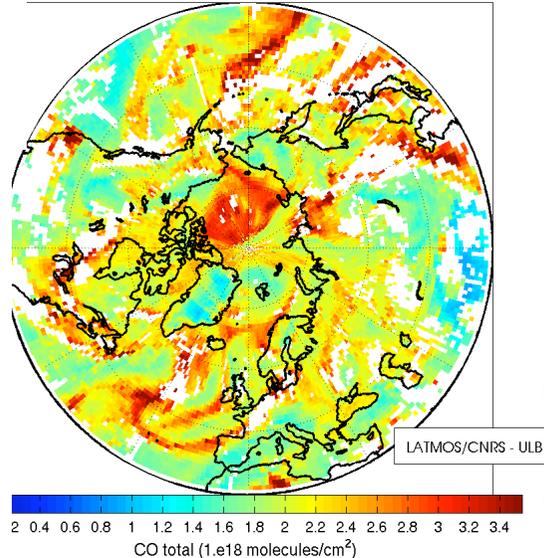
IASI CO data 703

3 July
2008



day IASI CO 20080711

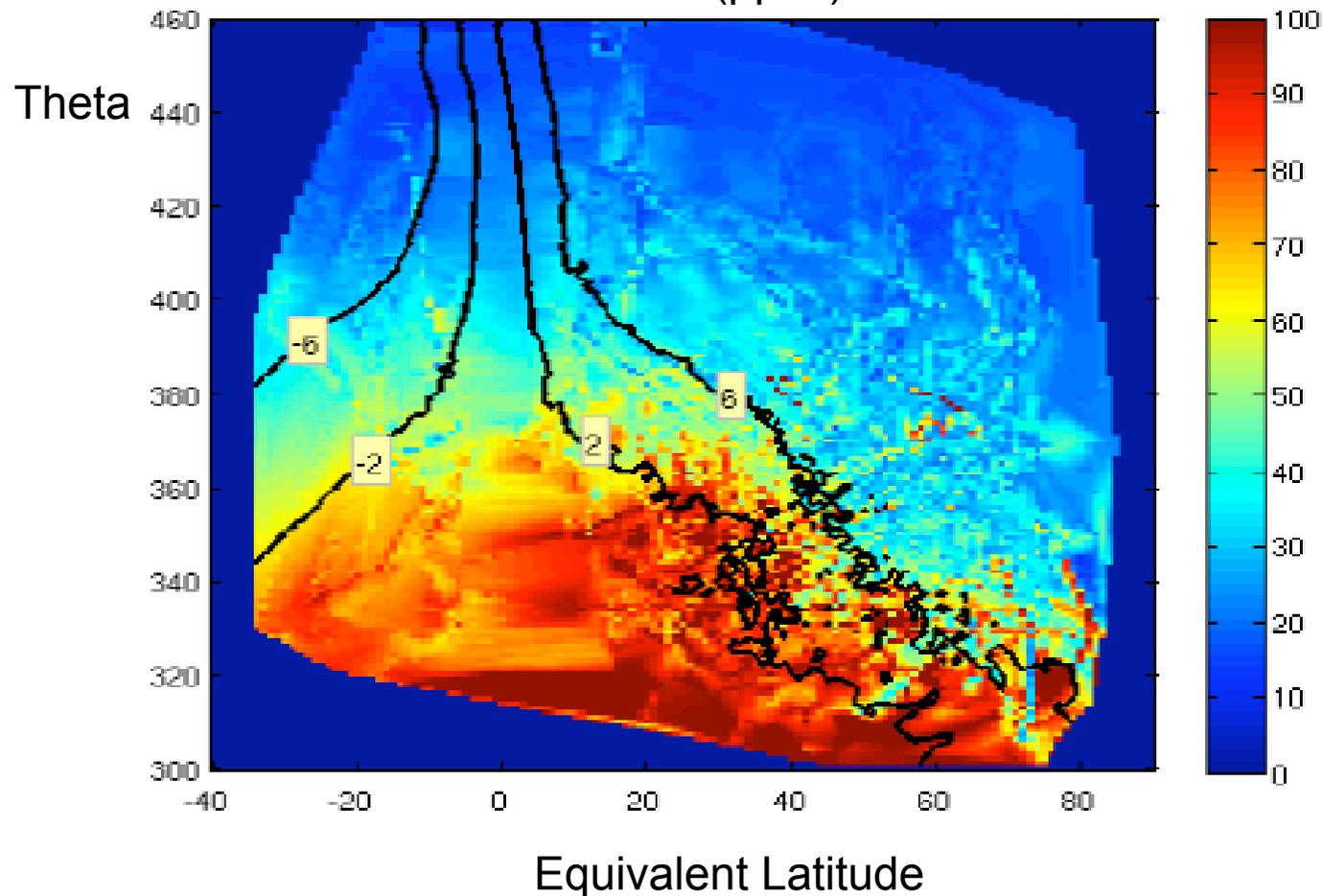
11 July 2008



2009

Aircraft data composites from many airborne campaigns - mixed extra-tropical tropopause region

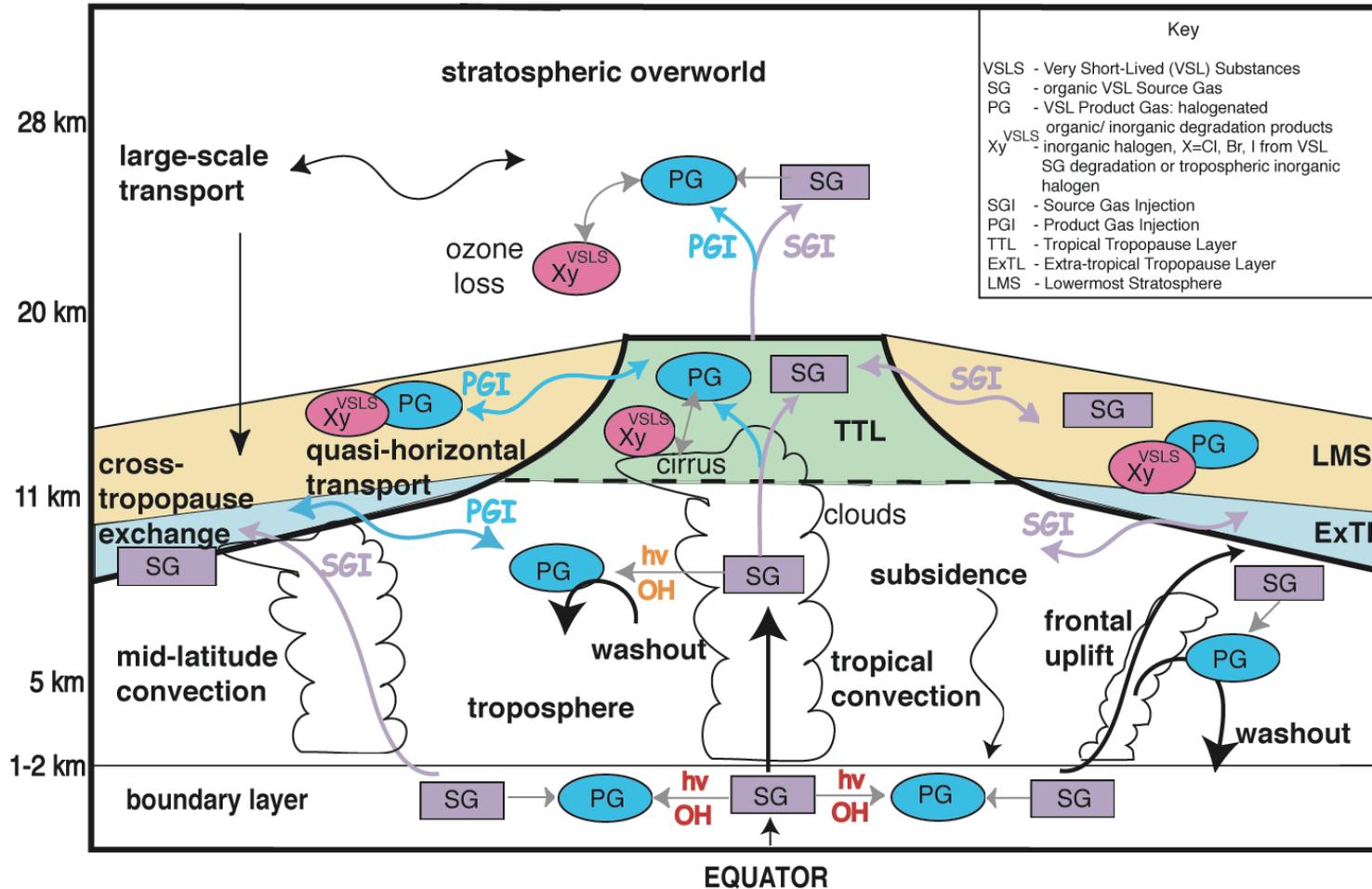
CO concentrations (ppbv) - all seasons



Pisso et al., 2009

Full circle: strong coupling between troposphere & stratosphere

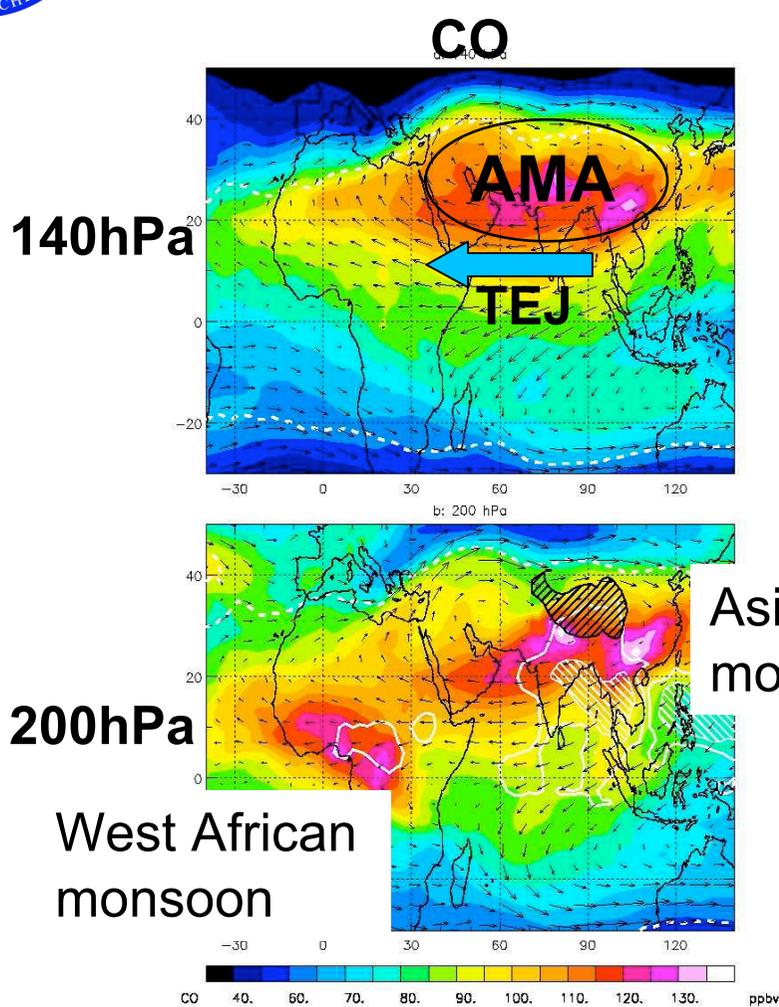
Chemical and Dynamical Processes Affecting VSLs



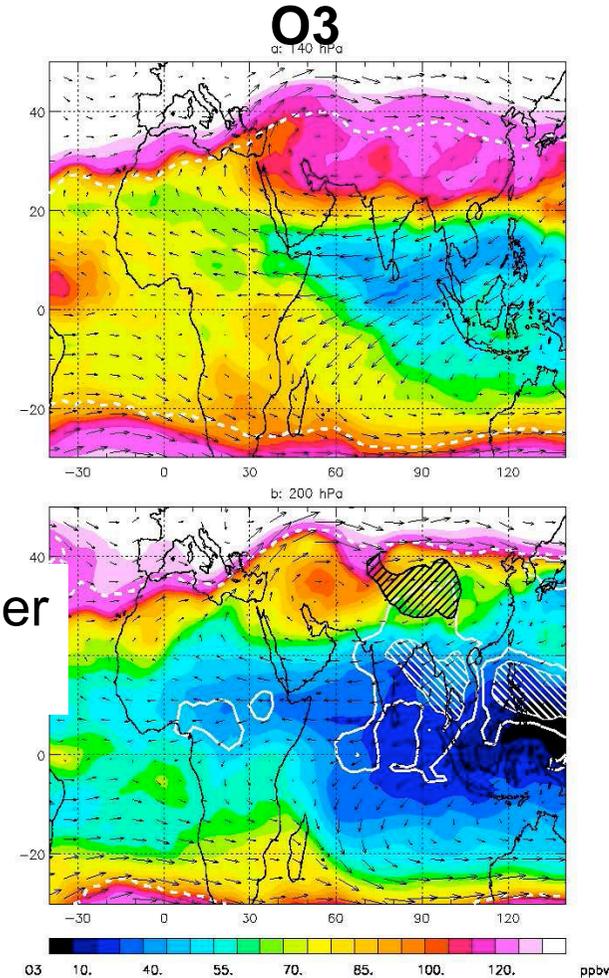
From WMO, 2006



Asian pollution - convective uplift & transport to Africa via Asian monsoon anticyclone (AMA) in mid/upper TTL during summer monsoon 2006



Asian summer monsoon



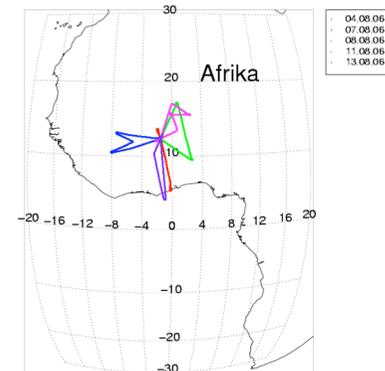
MOCAGE CTM + assimilated MLS CO & O3 data (Barret et al., 2008)



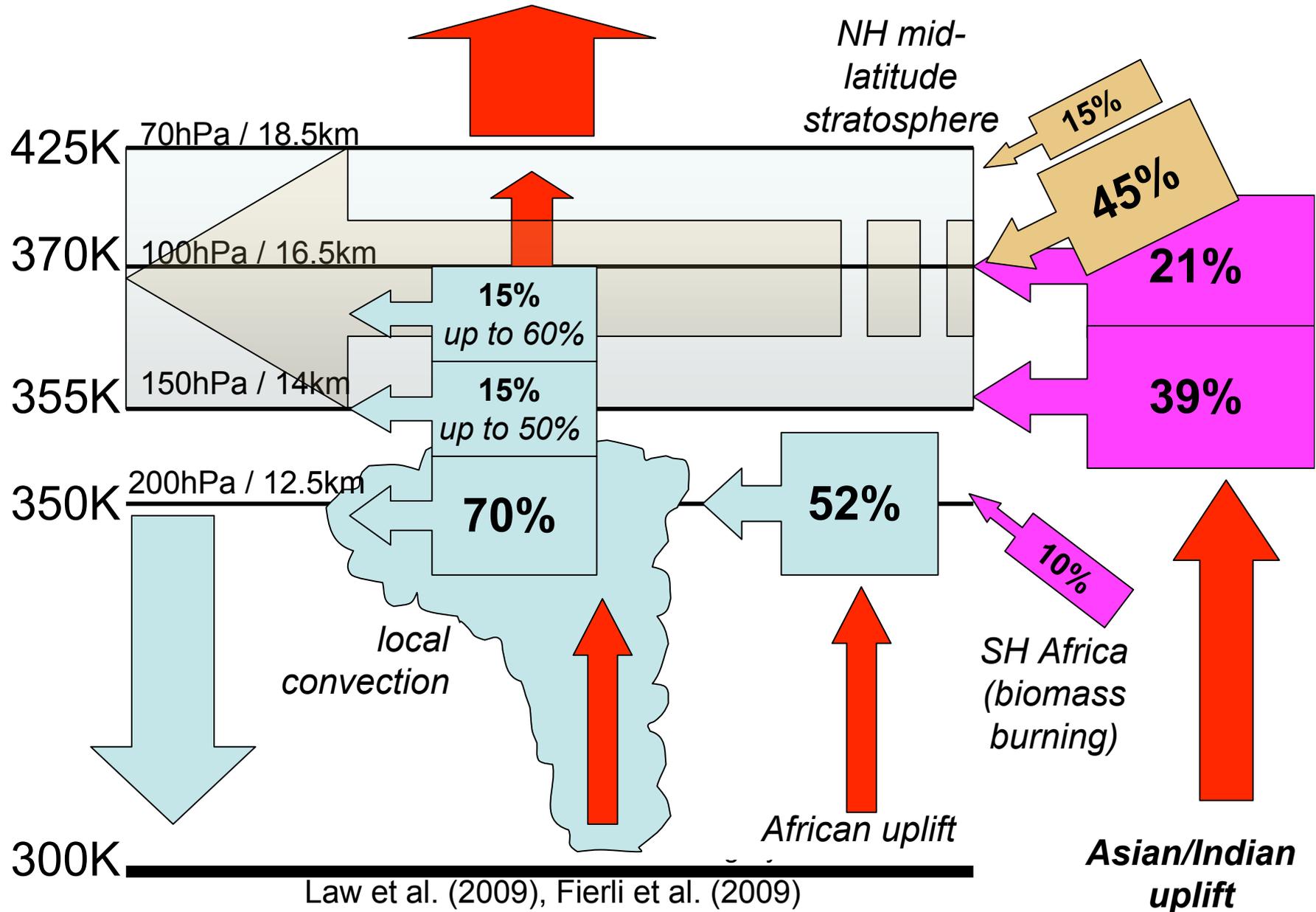
AMMA-SCOUT M55 Geophysica Airborne Campaign August 2006 - summer monsoon

1. Transport of trace gases and aerosols into the upper troposphere & stratosphere (ozone depletion)
2. Chemical composition in tropical tropopause layer (12-20km) - important for radiative forcing (H_2O , O_3 , CO_2) & climate change

Cairo et al., 2009, Real et al., 2009, Borrmann et al., 2009, Schiller et al., 2009, Homan et al., 2009, Law et al., 2009, Fierli et al., 2009a, Fierli et al., 2009b



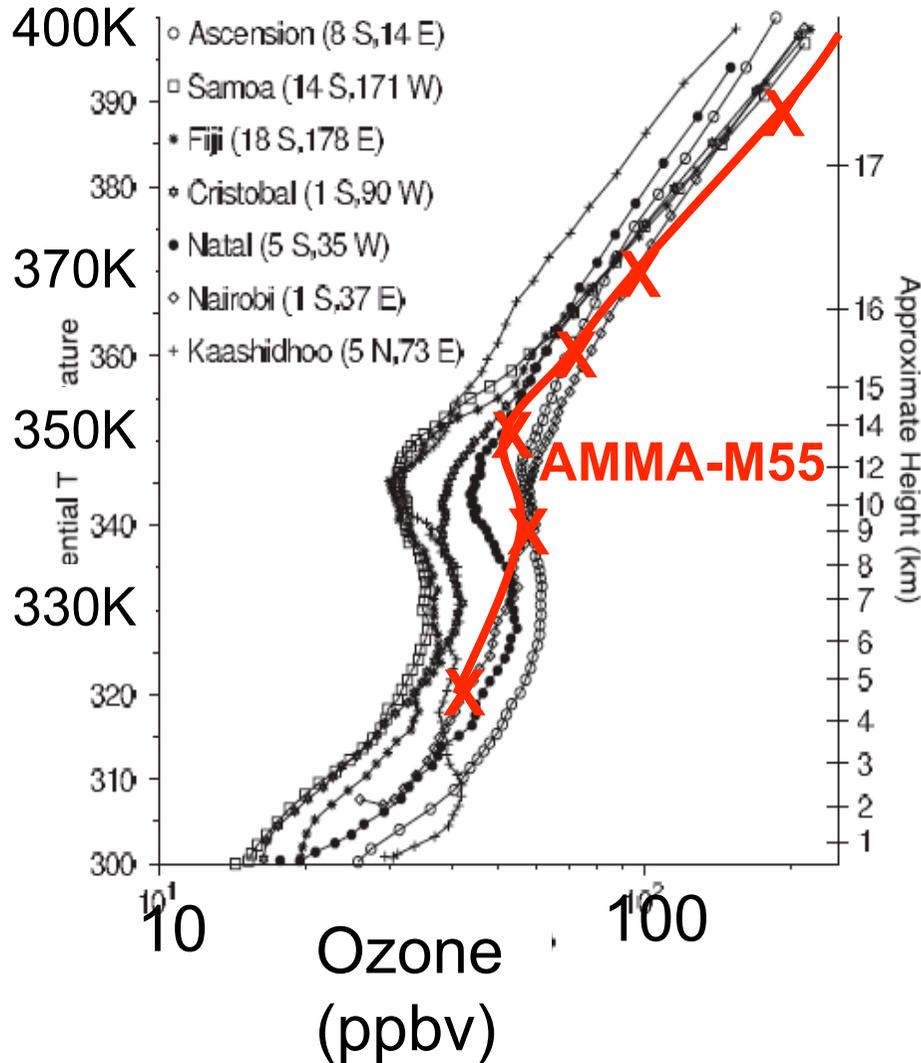
TTL air mass origins (AMMA-SCOUT) M55-Geophysica campaign - August 2006



Ozone Profiles: West Africa vs tropical sondes



SHADOZ data (Folkins et al., 2002)



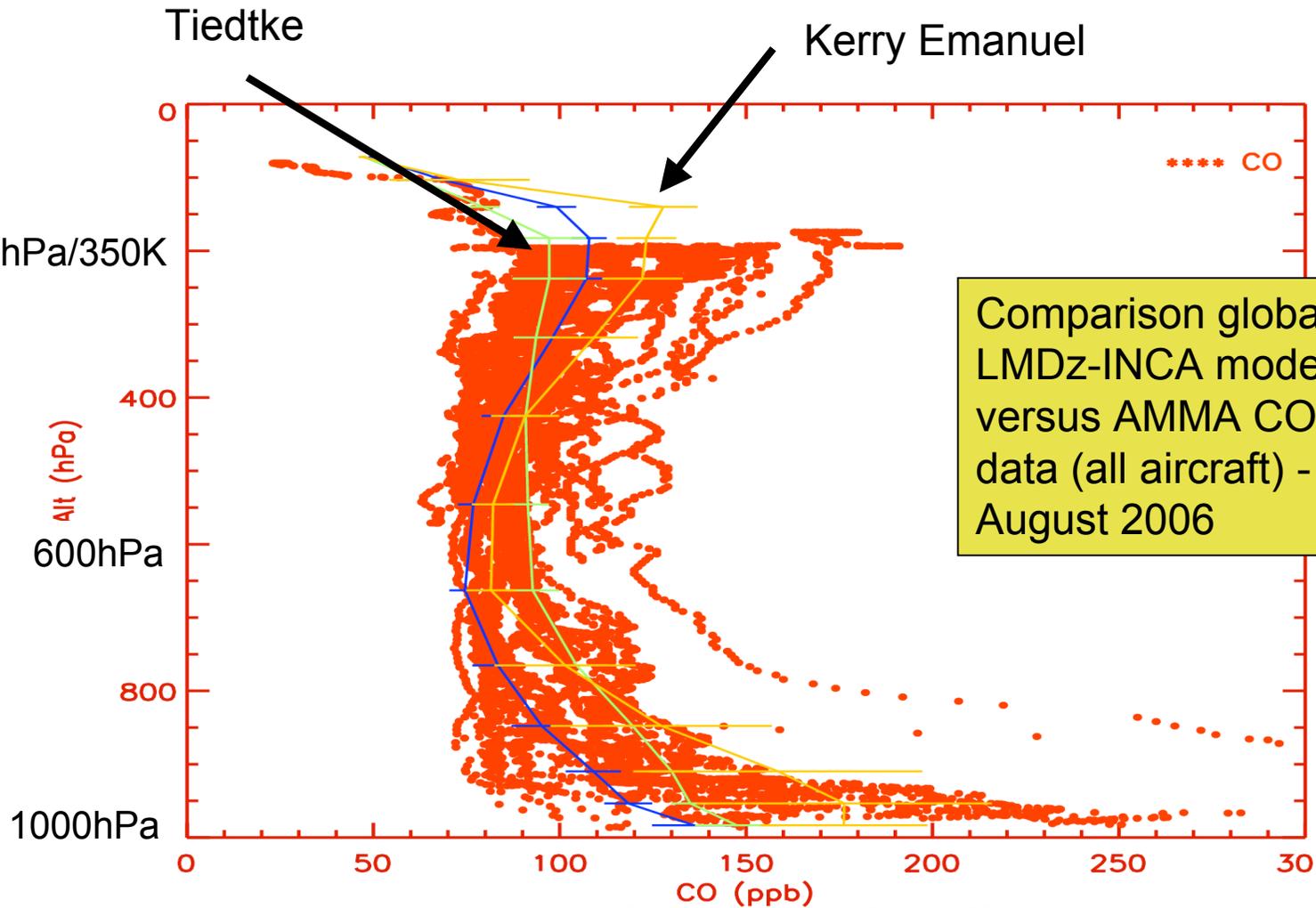
Long-range transport from Asia bringing air with higher O₃

Super-imposed on local convective signature (O₃-poor plus production from LiNO_x and BB - up to 355K)

NH mid-lat (strat.) source > 370K



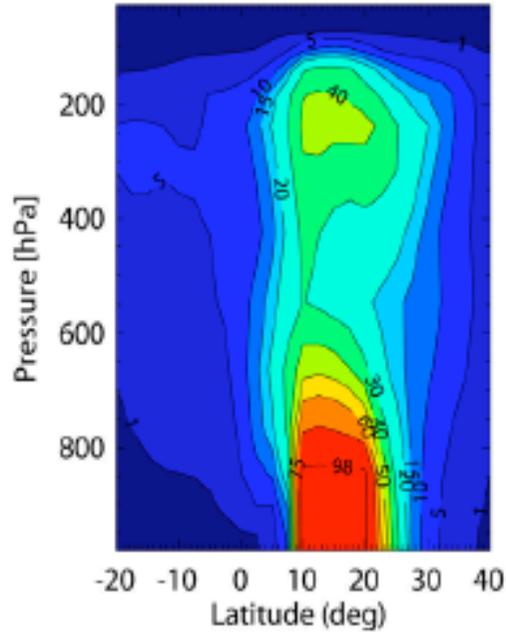
Convective transport - further model evaluation needed



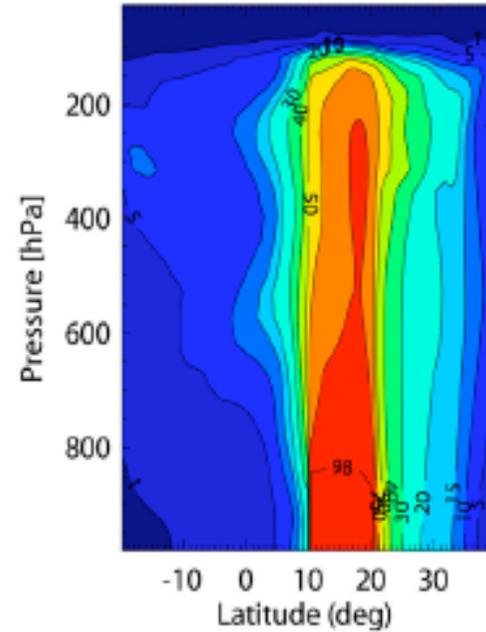
Data courtesy of DLR, M55, B146, French Falcon-20 teams - Bouarar et al., in prep.



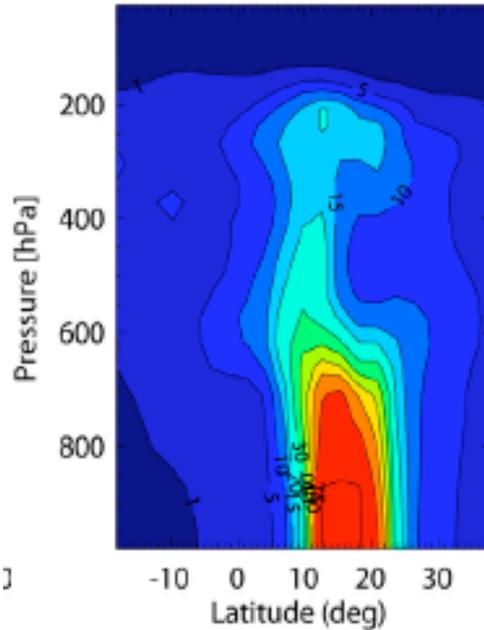
LMDZ AUG



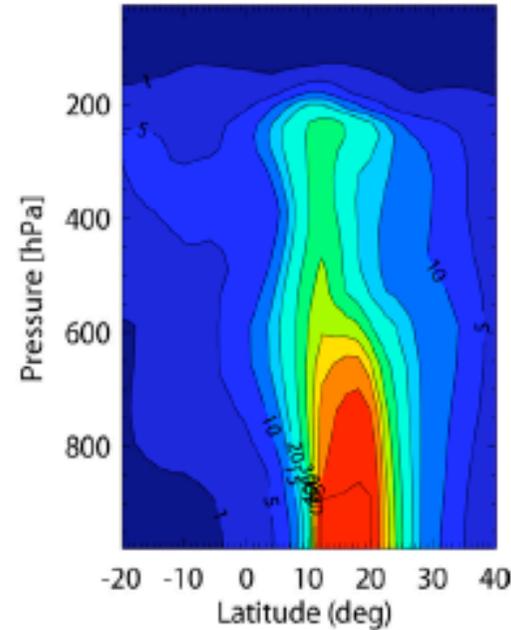
MOCAGE AUG



p-TOMCAT AUG



TM4 AUG

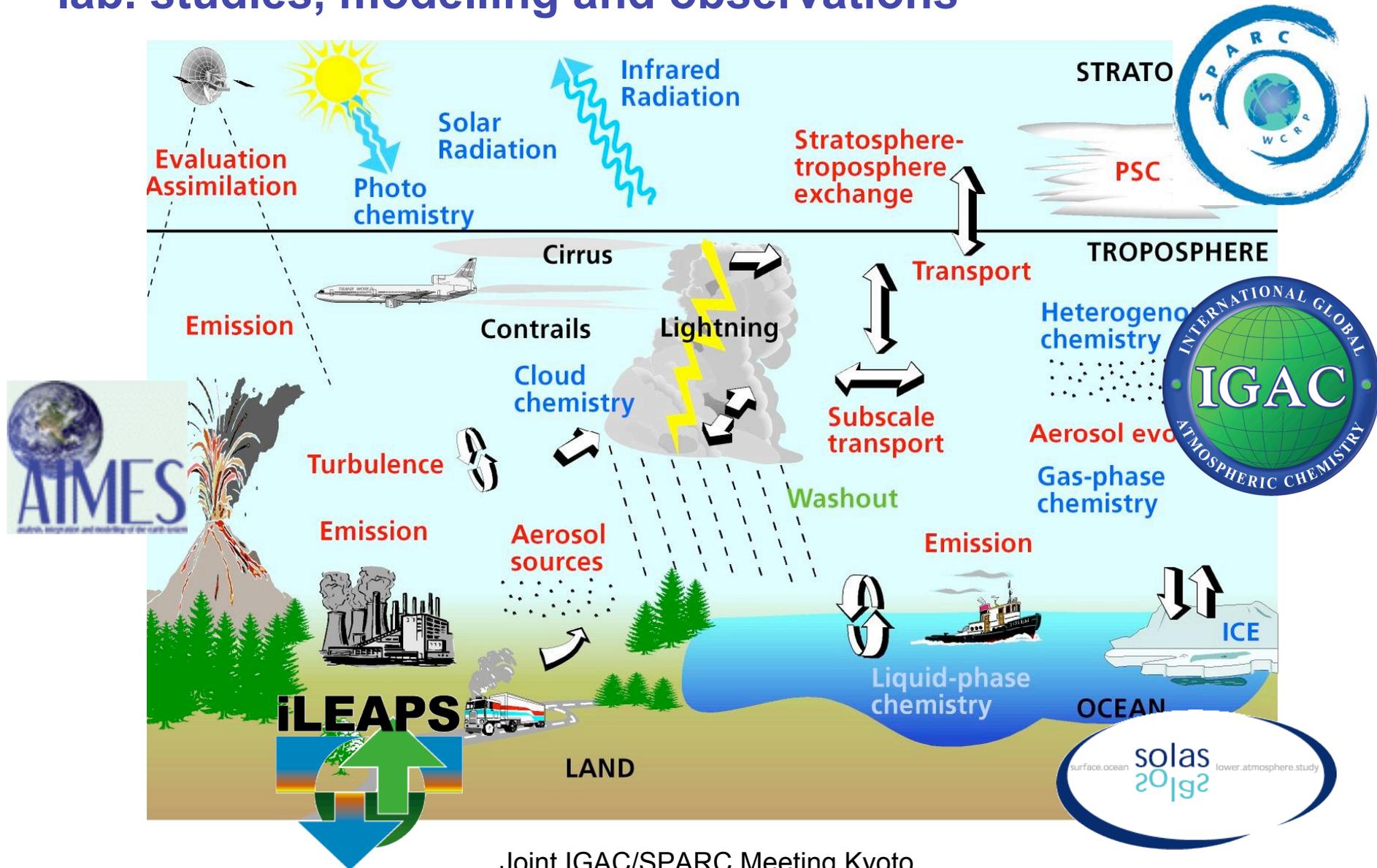


AMMA chemical model comparison - tracers & trace gases

⇒ AC&C transport activity

Williams et al. (2009)

Strong links between regions especially related to lab. studies, modelling and observations



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Atmospheric Chemistry in the Earth's System

Move towards cross-programme coordination:

- **Fundamental science** (lab, models, observations)
- **Monitoring and prediction of atmospheric composition change** (for mitigation & adaptation)



Atmospheric Chemistry in the Earth's System

Move towards ...

- Coordinated research programmes addressing **societal needs (climate, air quality, food, water, etc.)**
 - **Cross-cutting across boundaries** (strat-trop, chem-bio-dynamics)
- ⇒ **“One Atmosphere”** approach



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