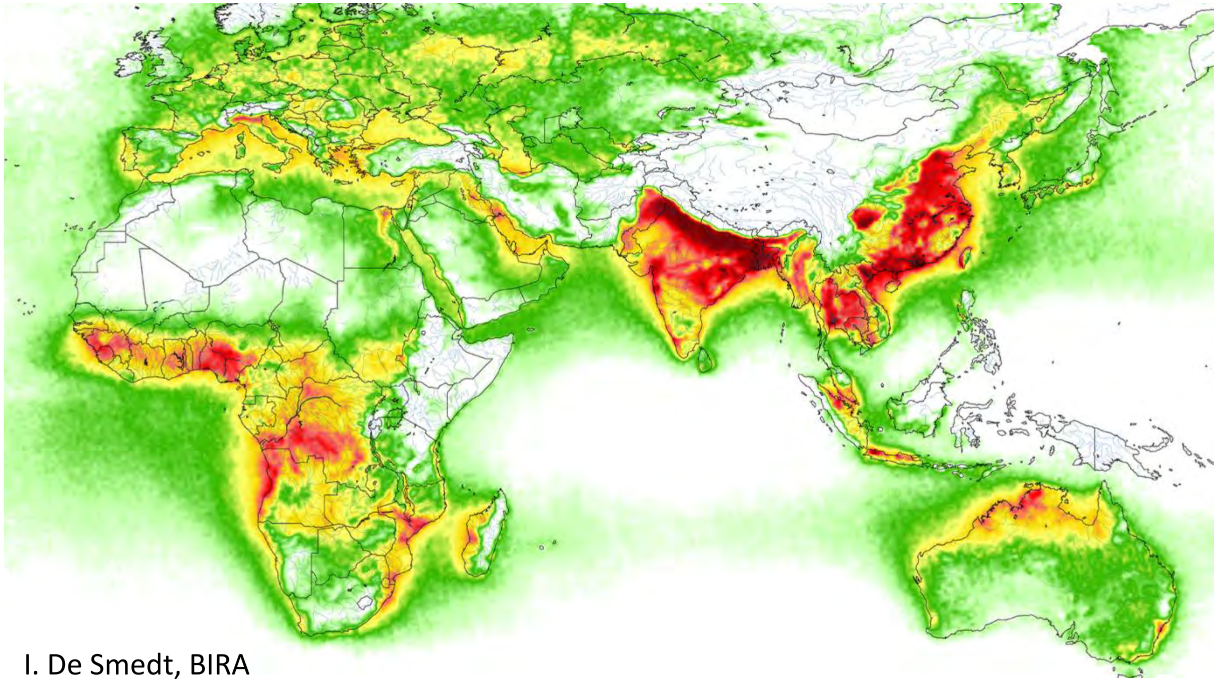


I. De Smedt, BIRA

Global air quality monitoring from space

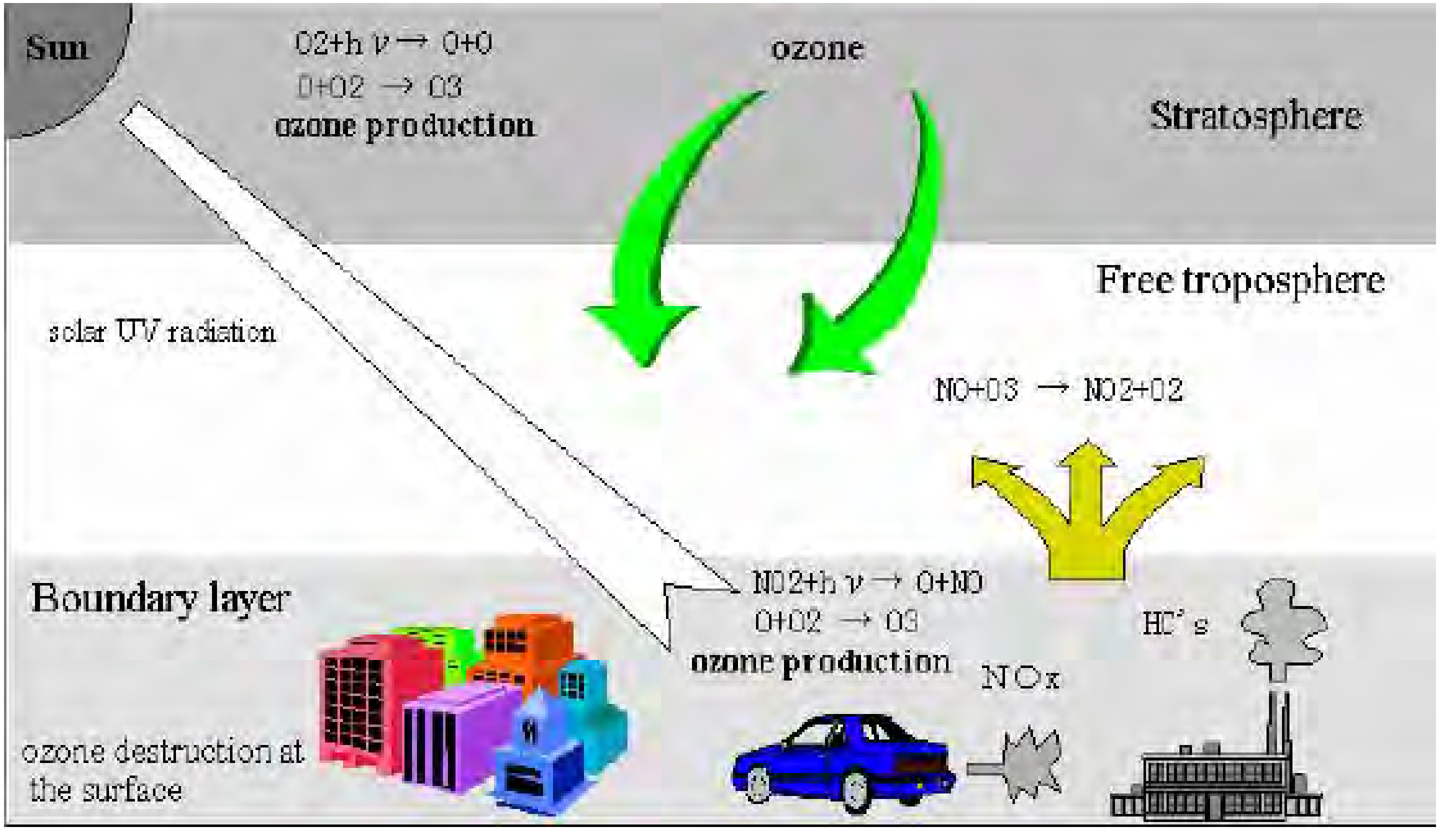
Michel Van Roozendael

Royal Belgian Institute for Space Aeronomy (BIRA-IASB)

Content

- Introduction
- AQ from space – what can be seen?
- Applications
  - Trends
  - Inverse modeling of emissions
  - Long-range transport
  - Volcanic emissions
- Future sensors

Tropospheric ozone



Impacts

- Health
- Ecosystems
- Climate


LIVESCIENCE
NEWS TECH HEALTH PLANET EARTH SPACE

Live Science > Health

Air Pollution Kills More than 3 Million People Globally Every Year

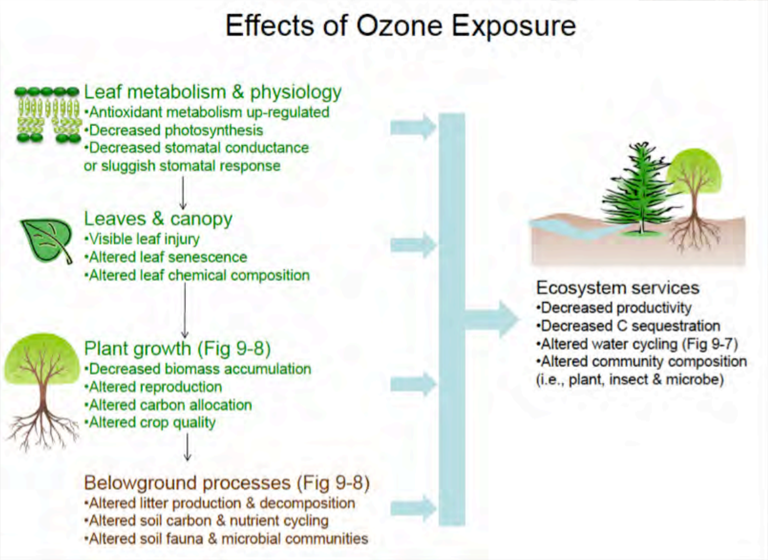
By Charles Q. Choi, Live Science Contributor | September 16, 2015 01:00pm ET

Outdoor air pollution may lead to more than 3 million premature deaths globally per year, according to a new study. About 75 percent of those deaths occur in Asia, the study found.

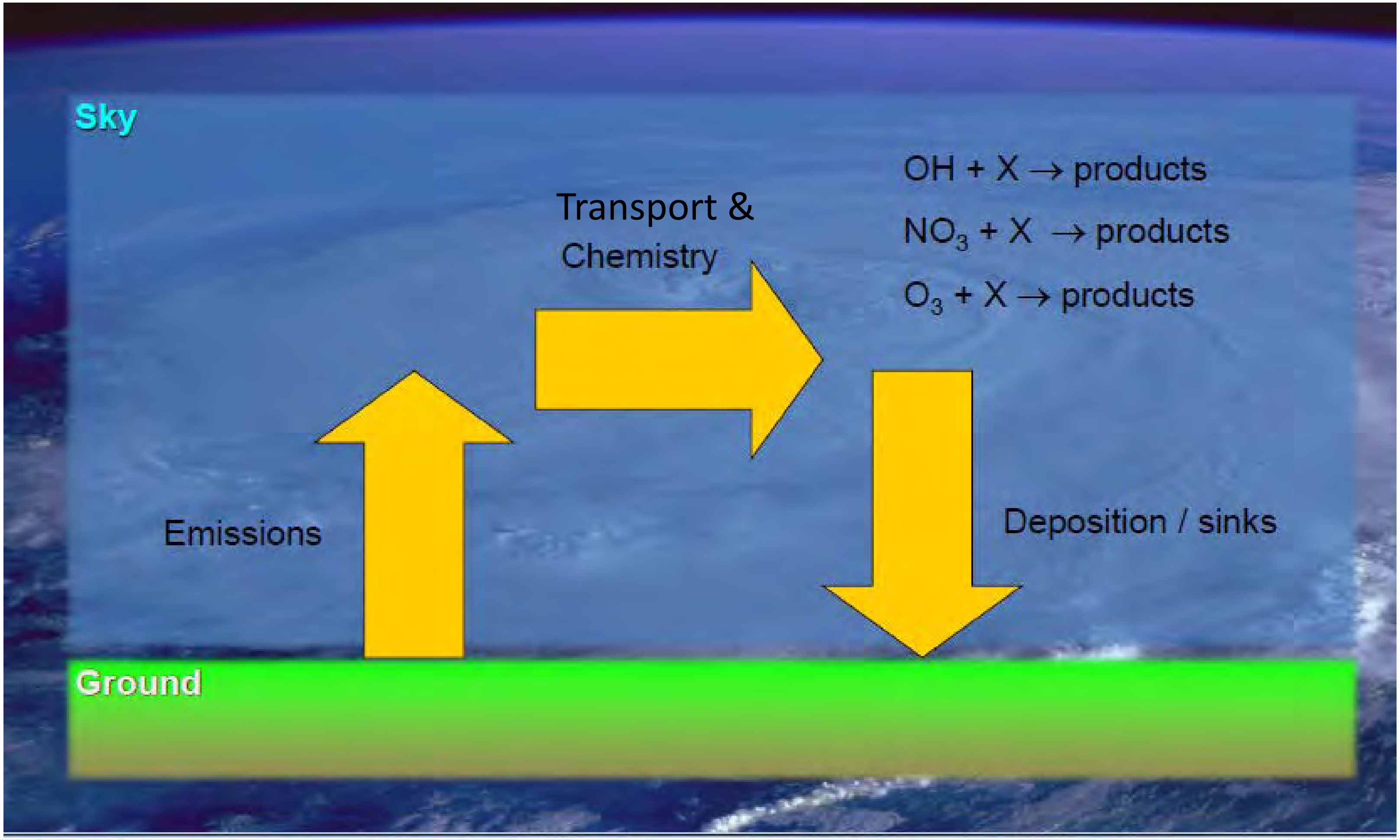
Air pollutants such as ozone and tiny particles of toxins are linked with heart disease, lung disease and other serious afflictions that have long-term ...man health.

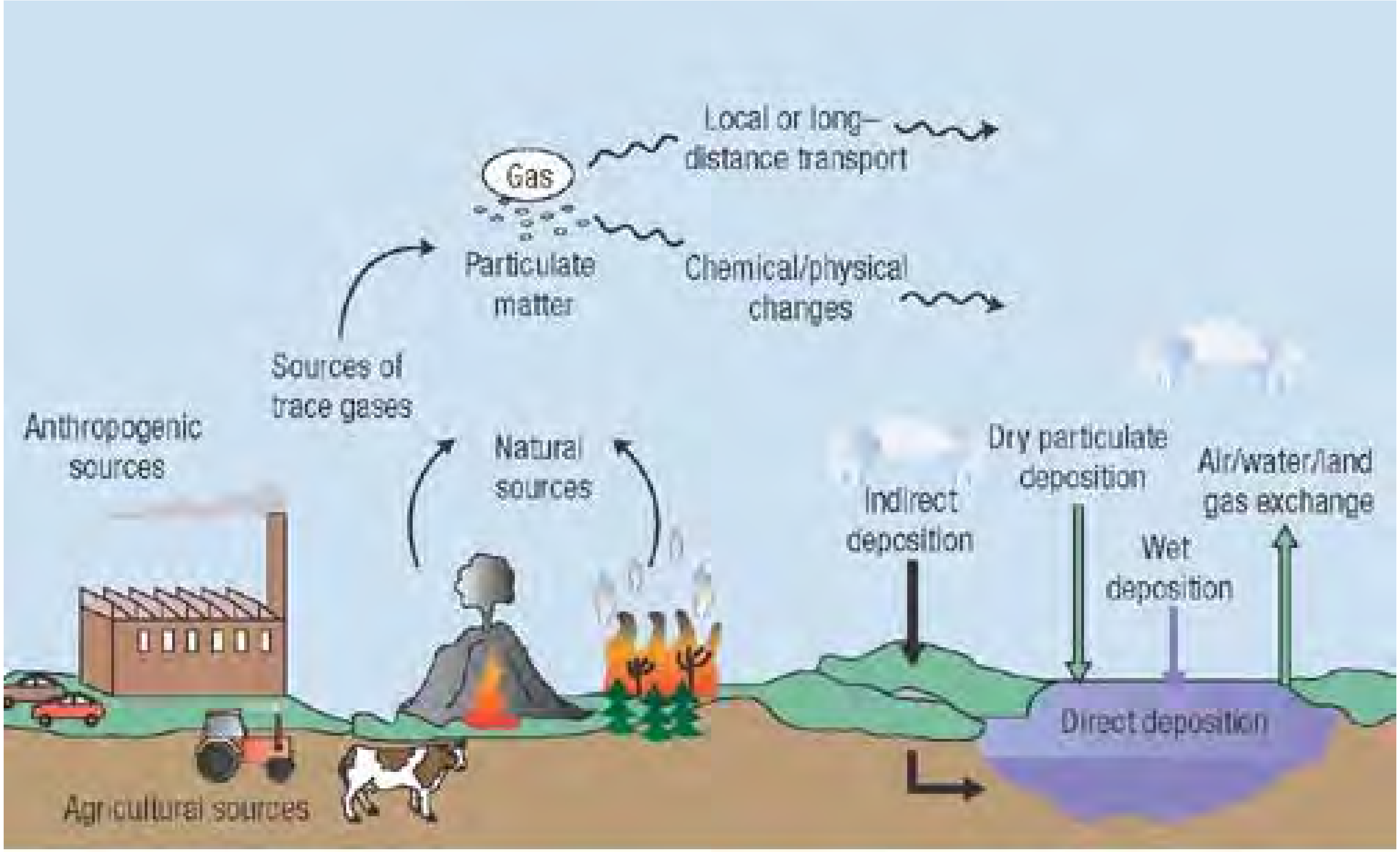
...g's skyline
... Shutterstock.com

...eart attacks are responsible for nearly 75 percent of air ...d mortality," said the lead author of the study, Jos...



Tropospheric chemistry at a glance




Local or long-distance transport
Gas
Particulate matter
Chemical/physical changes
Sources of trace gases
Anthropogenic sources
Natural sources
Agricultural sources
Indirect deposition
Dry particulate deposition
Air/water/land gas exchange
Wet deposition
Direct deposition

Common Components of Air Pollution

- *Sulfur oxides*
- *Particulate matter*
- *Oxidants (ozone)*
- *Carbon monoxide*
- *Hydrocarbons*
- *Nitrogen oxides*
- *Lead*
- *Other heavy metals*

AQ – What can be seen from space?

Nadir UV-Vis sensors

(GOME-2, SCIAMACHY, OMI)

O_3

NO_2

SO_2

HCHO

CHOCHO

Aerosol (absorbing)

Nadir TIR sensors

(IASI, TES, MOPITT)

O_3

CO

SO_2

NH_3

CFC11, CFC12, …

CH_3OH, HCOOH, C_2H_2, C_2H_6,…

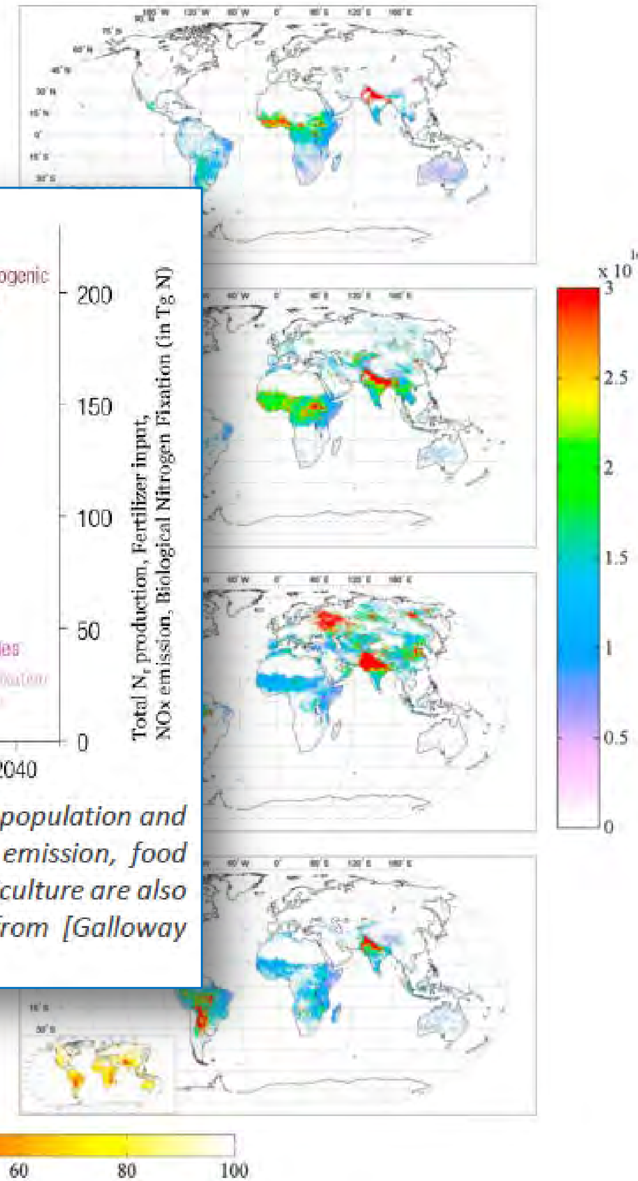
Aerosol

OMI tropospheric NO_2 (2005-2010)

New:

Global NH_3 distributions from IASI

Main source is agriculture (fertilisers)



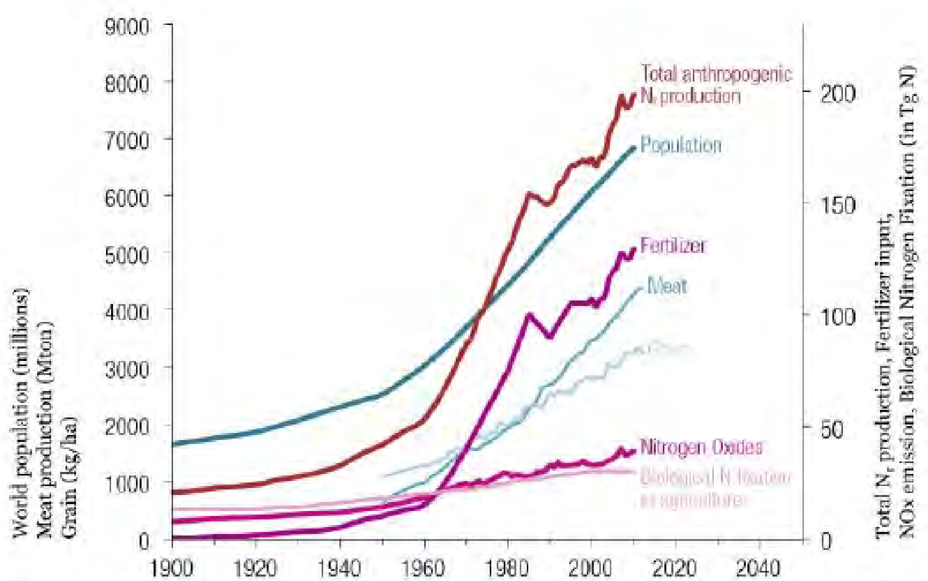
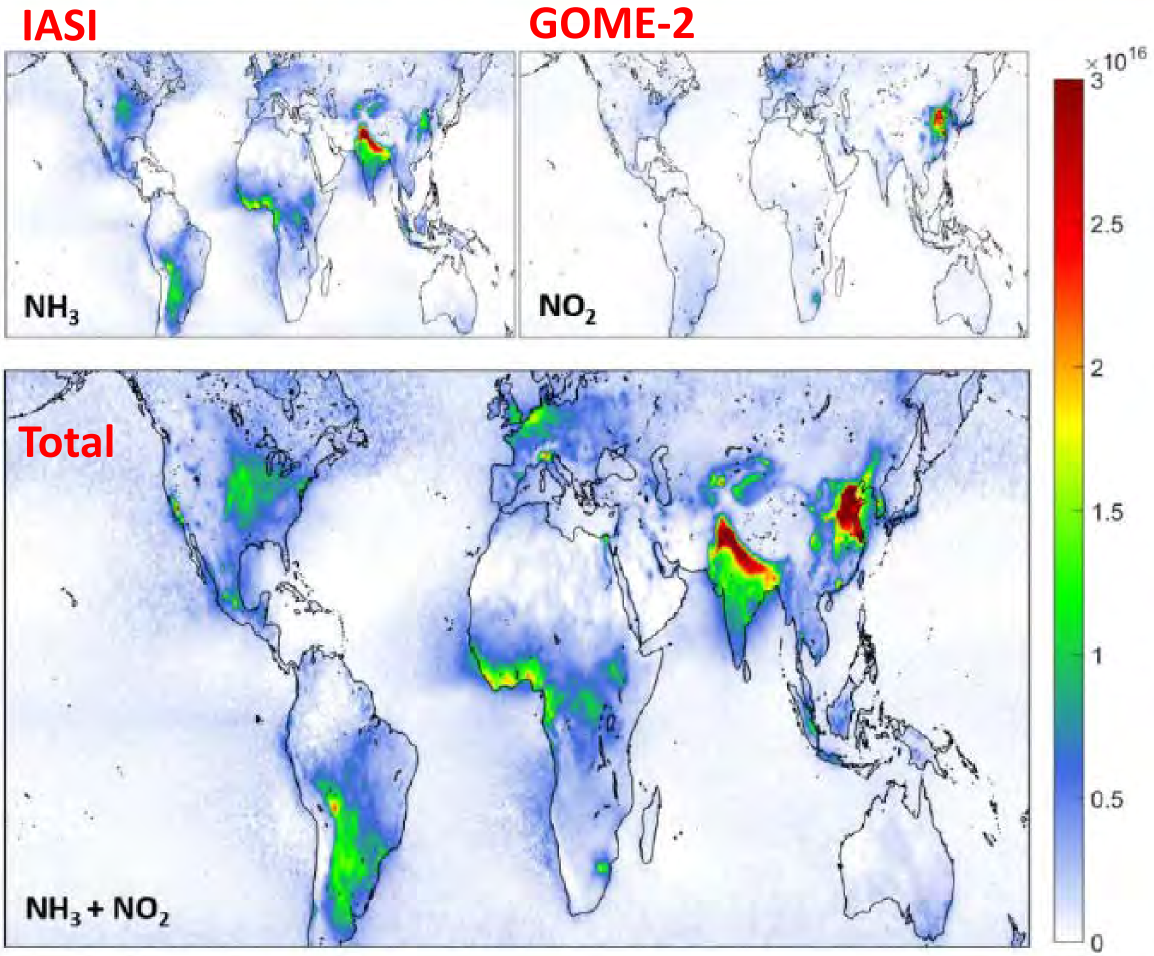


***Figure 3-1**: Global trends between 1900 and 2012 in world population and total anthropogenic Nr production. Fertilizer input, NO_x emission, food production (meat and grain) and biological N fixation in agriculture are also presented. Figure from [Erisman et al., 2015] (adapted from [Galloway et al., 2008, Fowler et al., 2013]).*

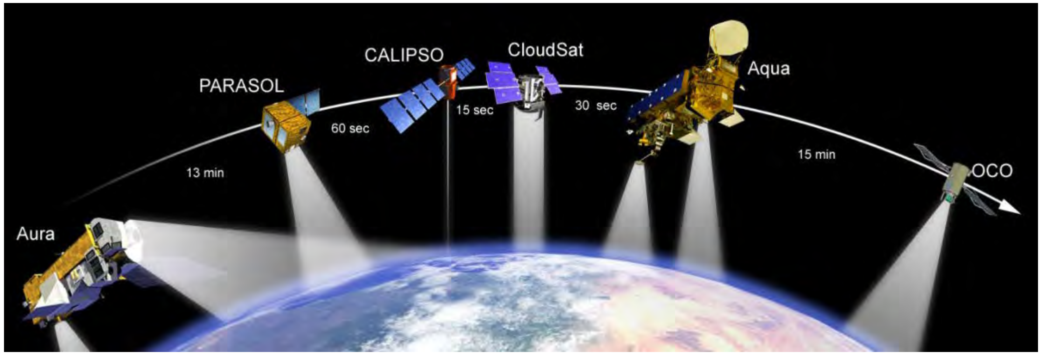
Van Damme et al., GRL, 2015



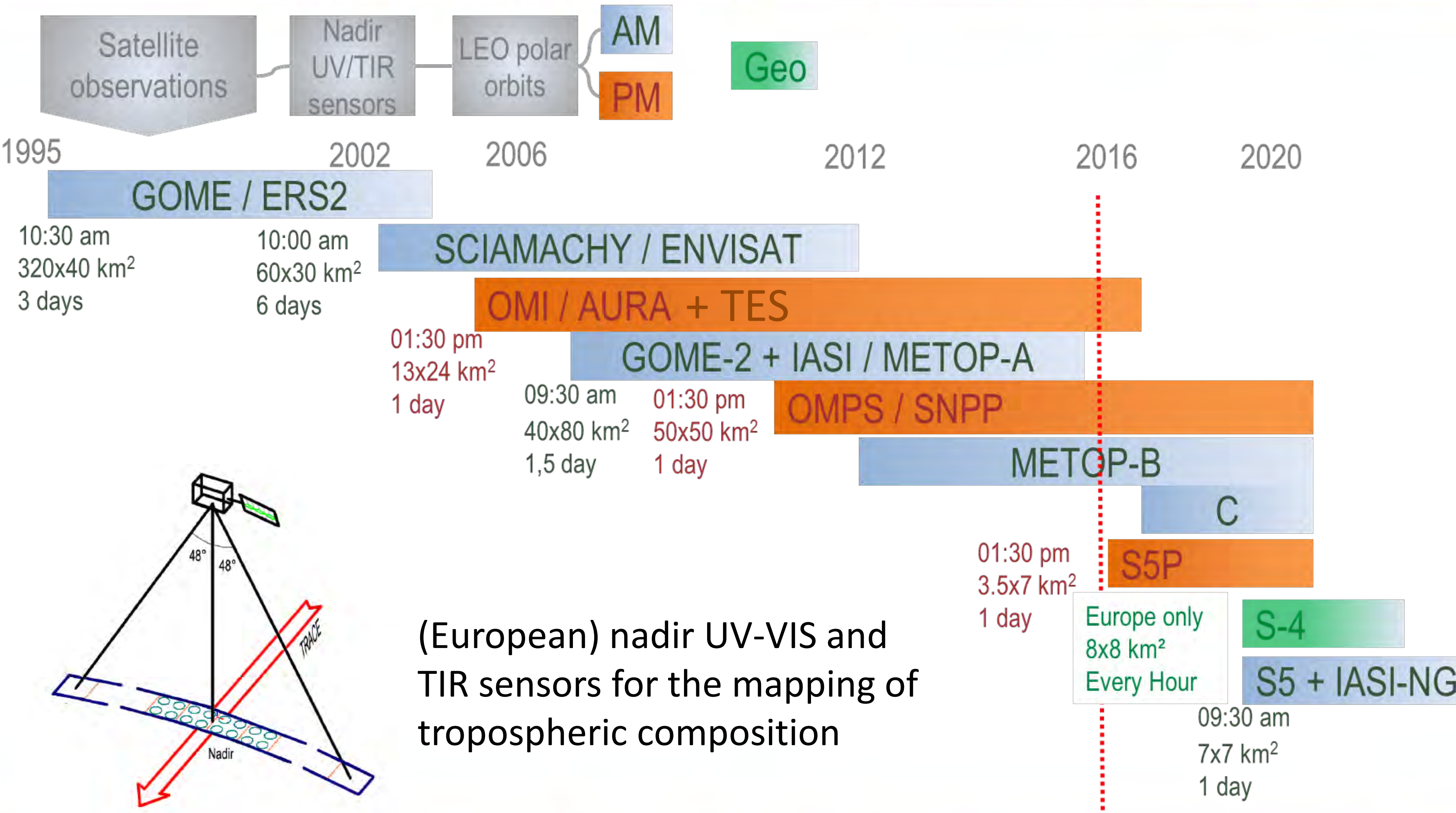
Courtesy: Pierre Coheur and Lieven Clarisse, ULB

Sum of NH_3 and NO_2 columns as an illustration of their collective contribution to the atmospheric Nr.

Strengths and limitations of satellites for AQ



- **Strengths**
  - Global (daily) coverage
  - No restriction on data access (data freely available)
- **Limitations**
  - Limited number of species
  - Coarse horizontal resolution (currently 20x20 km^2 at best)
  - Low sensitivity to surface concentrations (often below detection limit)
  - Low vertical resolution (mostly column measurements)
  - Poor sampling of diurnal changes (LEO)
  - Noise and systematic uncertainties



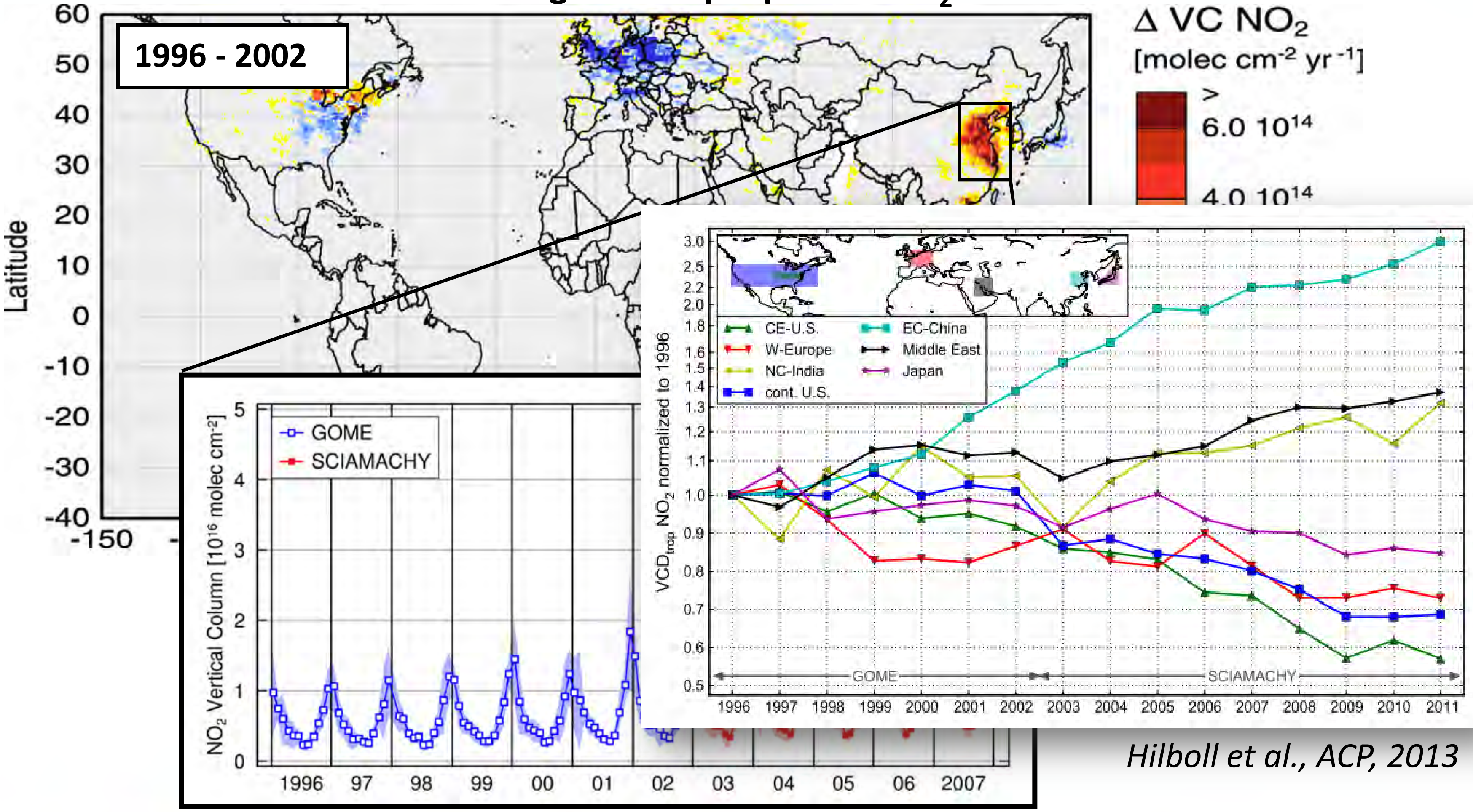
(European) nadir UV-VIS and TIR sensors for the mapping of tropospheric composition

Some applications

1. Long-term trends in pollutants
2. Inverse modelling of emissions
3. Long-range transport of pollutants
4. Volcanic emissions and aviation control

1. Long-term trends

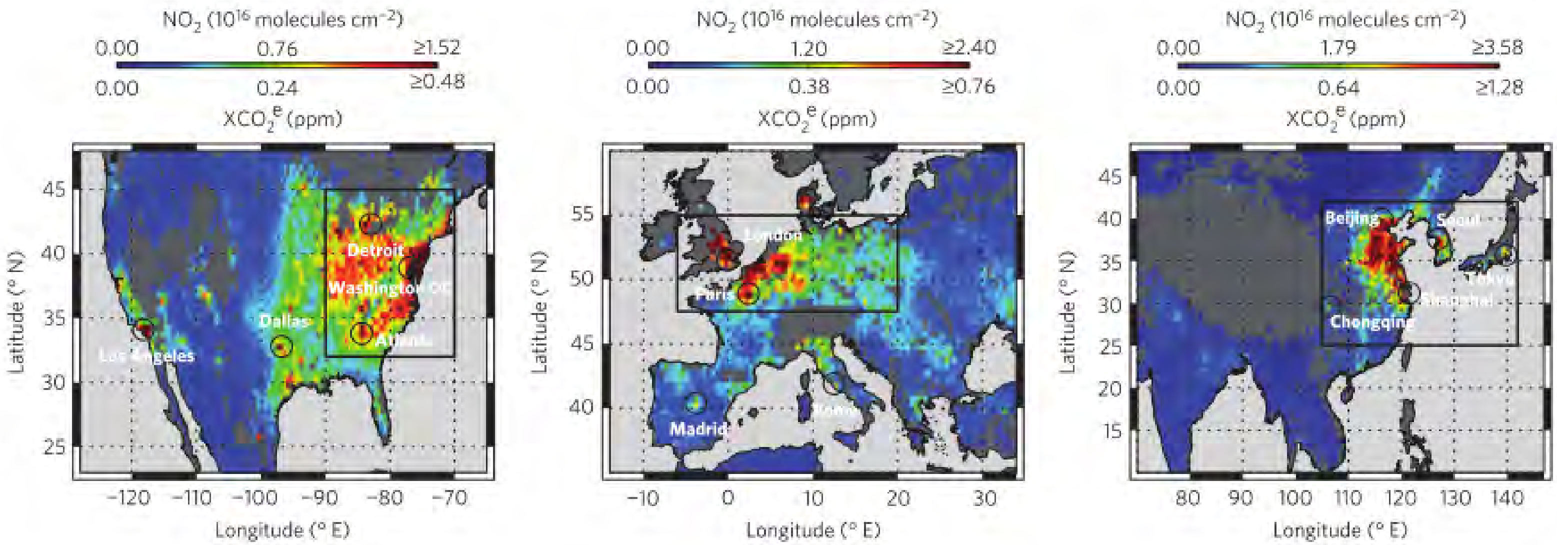
GOME annual changes in tropospheric NO_2



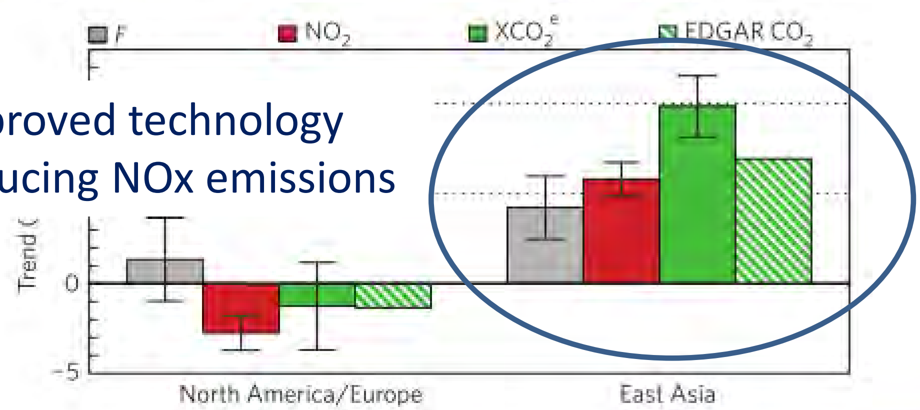
Hilboll et al., ACP, 2013

A. Richter et al., Increase in tropospheric nitrogen dioxide over China observed from space, *Nature*, **437** 2005

Trends of the CO_2-to-NO_x emission ratio

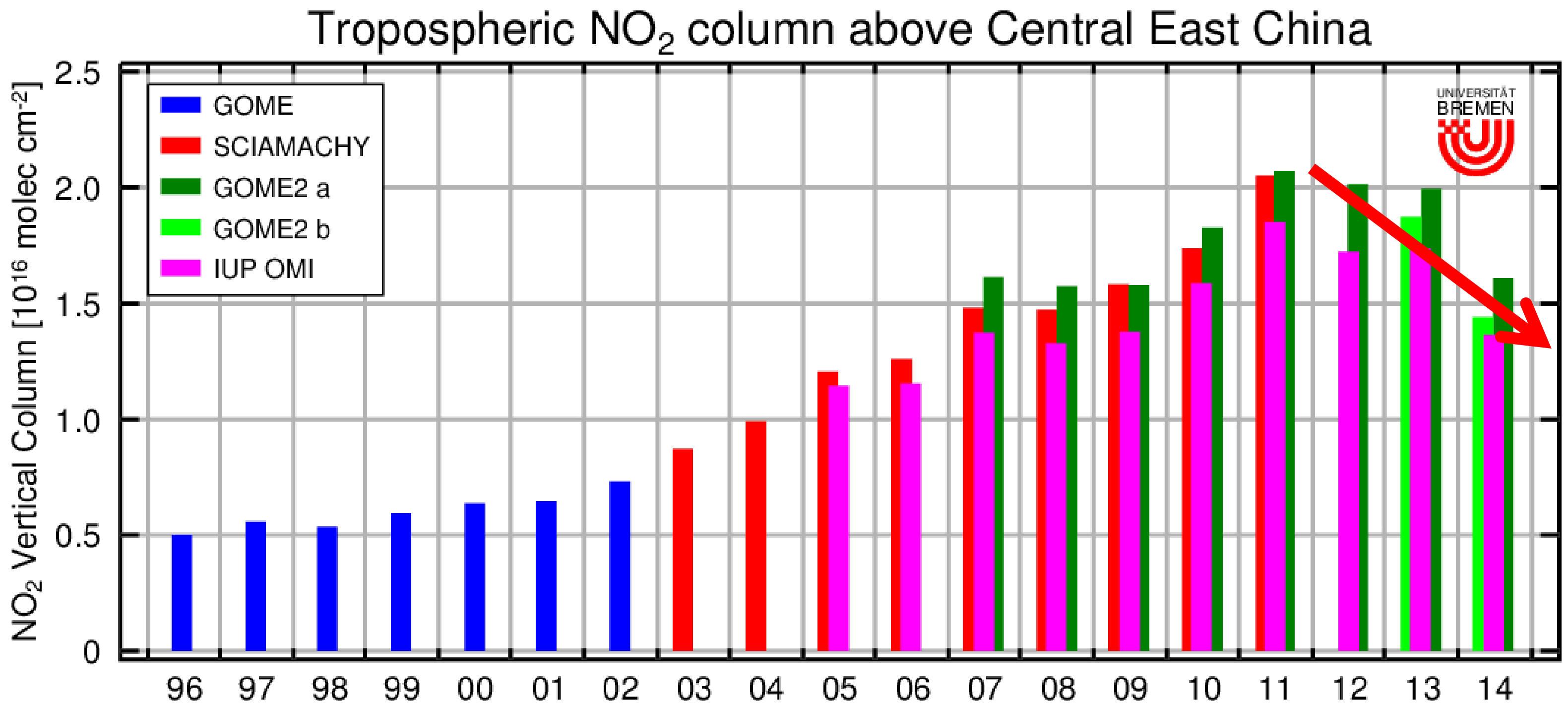


Reuter et al., Nature Geoscience, 2014

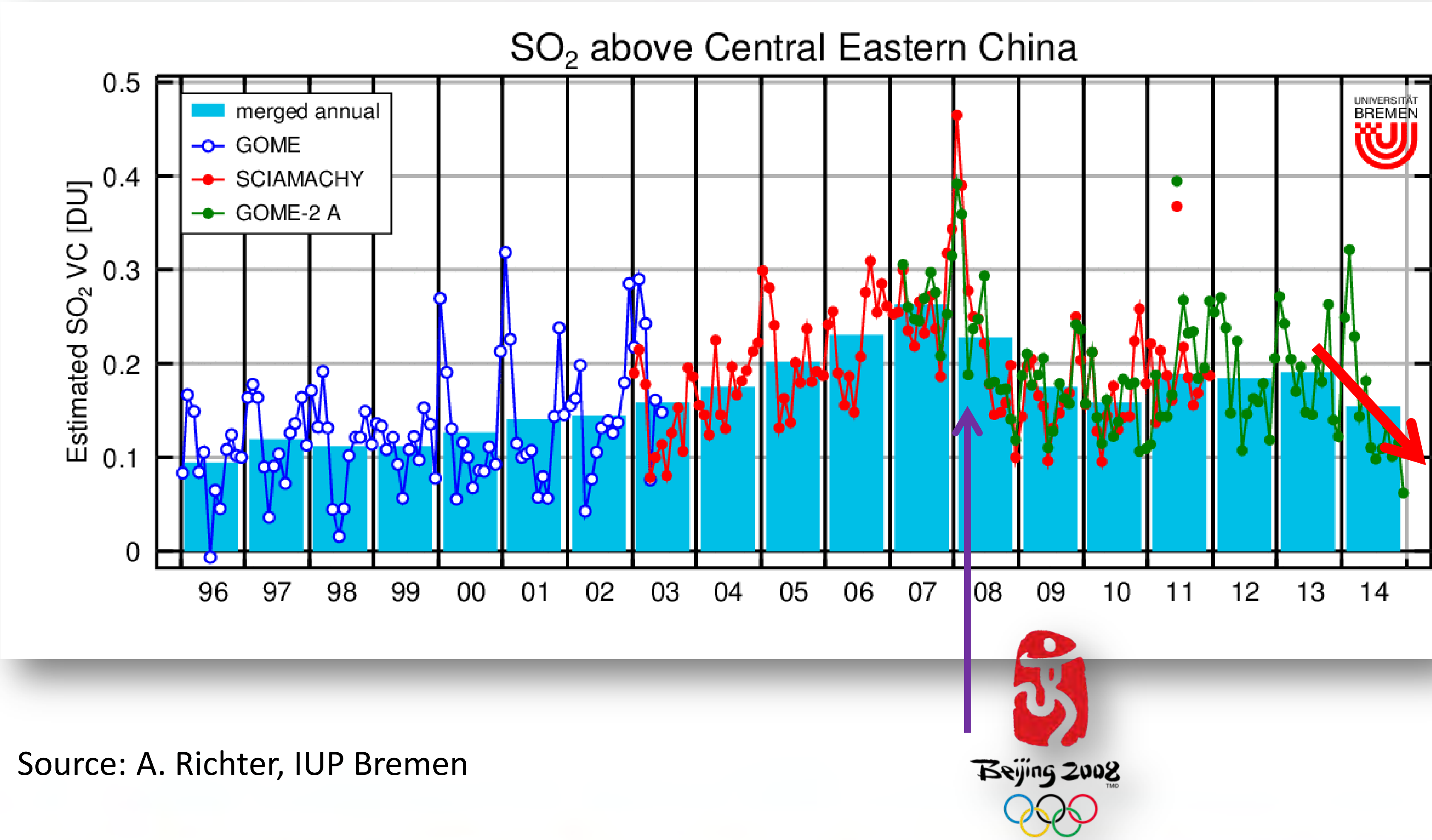


Improved technology reducing NOx emissions

SCIAMACHY

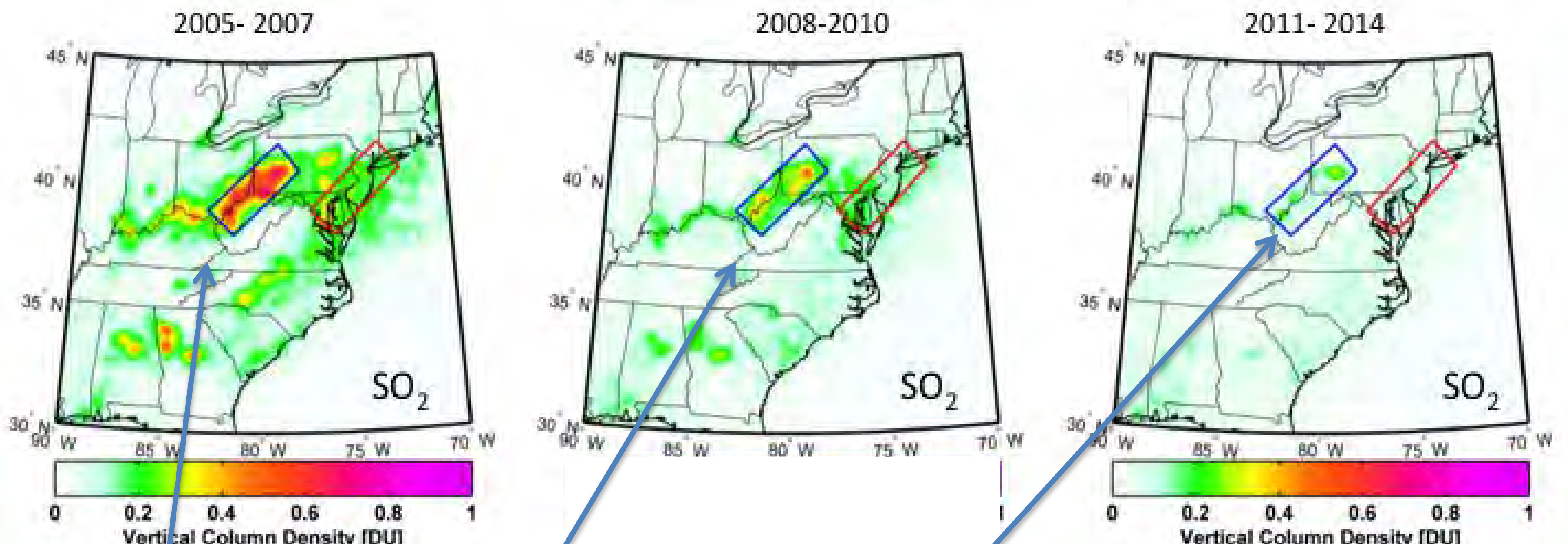


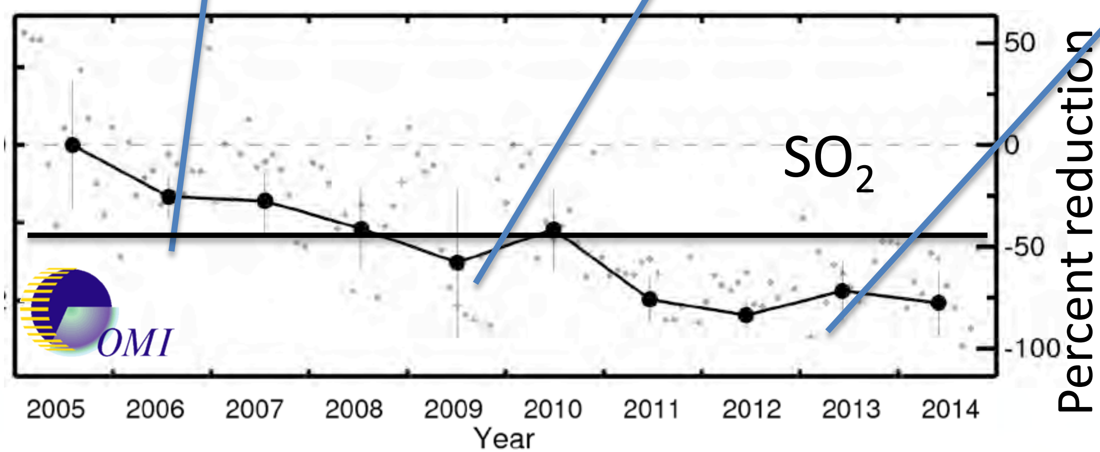
Source: A. Richter, IUP Bremen



Source: A. Richter, IUP Bremen

Large decrease in SO_2 pollution over the US

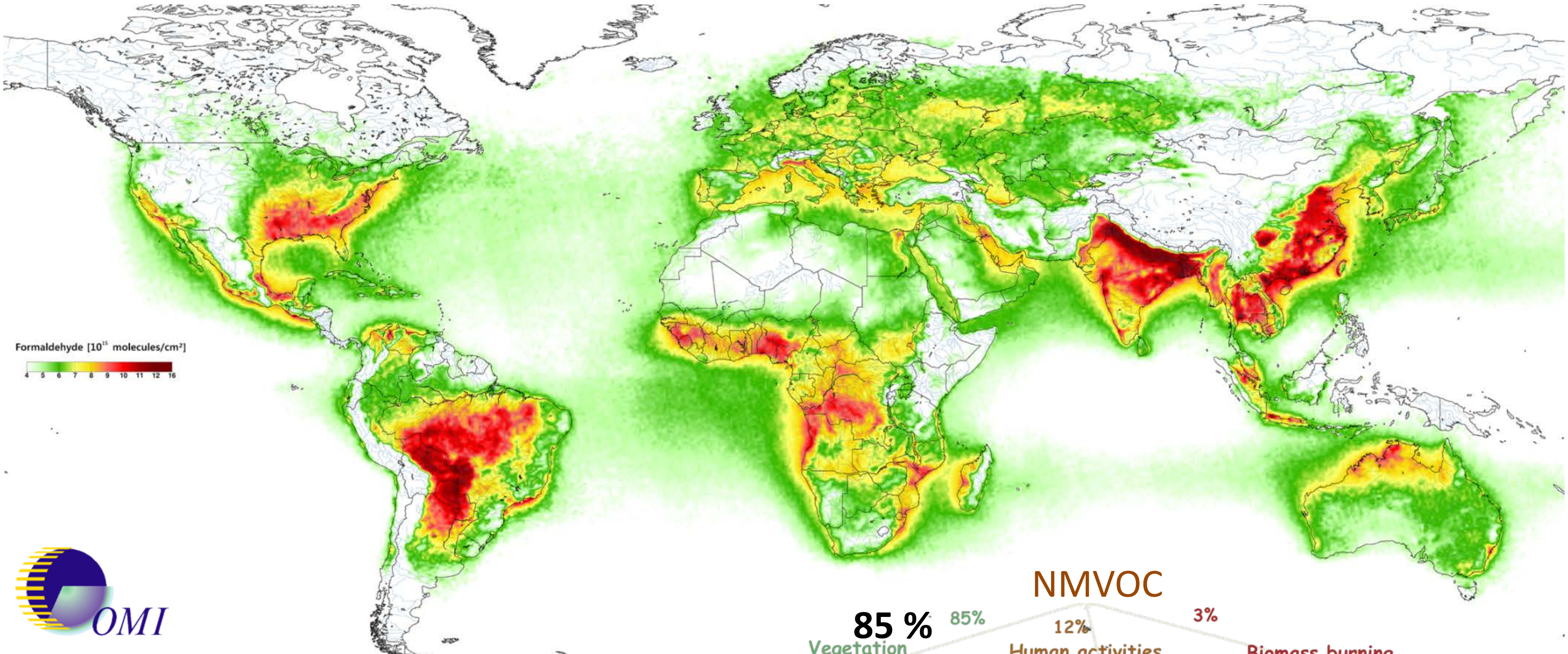




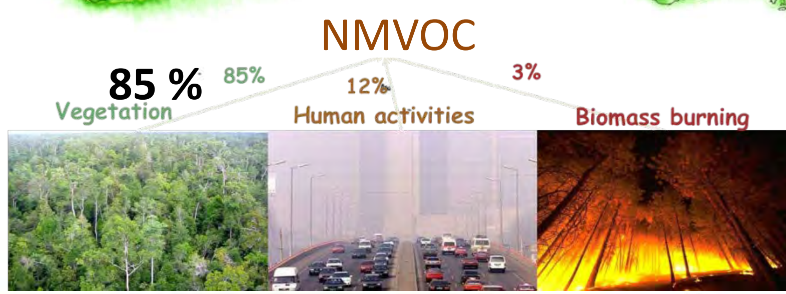
Krotkov et al., ACP OMI special issue

- US Coal-powered Power Plants (PP) generated 34% of nation's electricity in 2015 [Was. Post, Aug1]
- Sulfur content of coal and acidic SO_2 emissions from PPs are largest over Ohio Valley, WVA and PA.
- Since 2005 SO_2 pollution decreased by more than 80%, as a result of retiring old coal-fired PPs, installing Flue Gas Desulfurization devices, and switching to natural gas.
- Follow-up ESA's S5P TROPOMI 2016 – mission will monitor weaker SO_2 emissions during "Clean Power Plan" implementation.

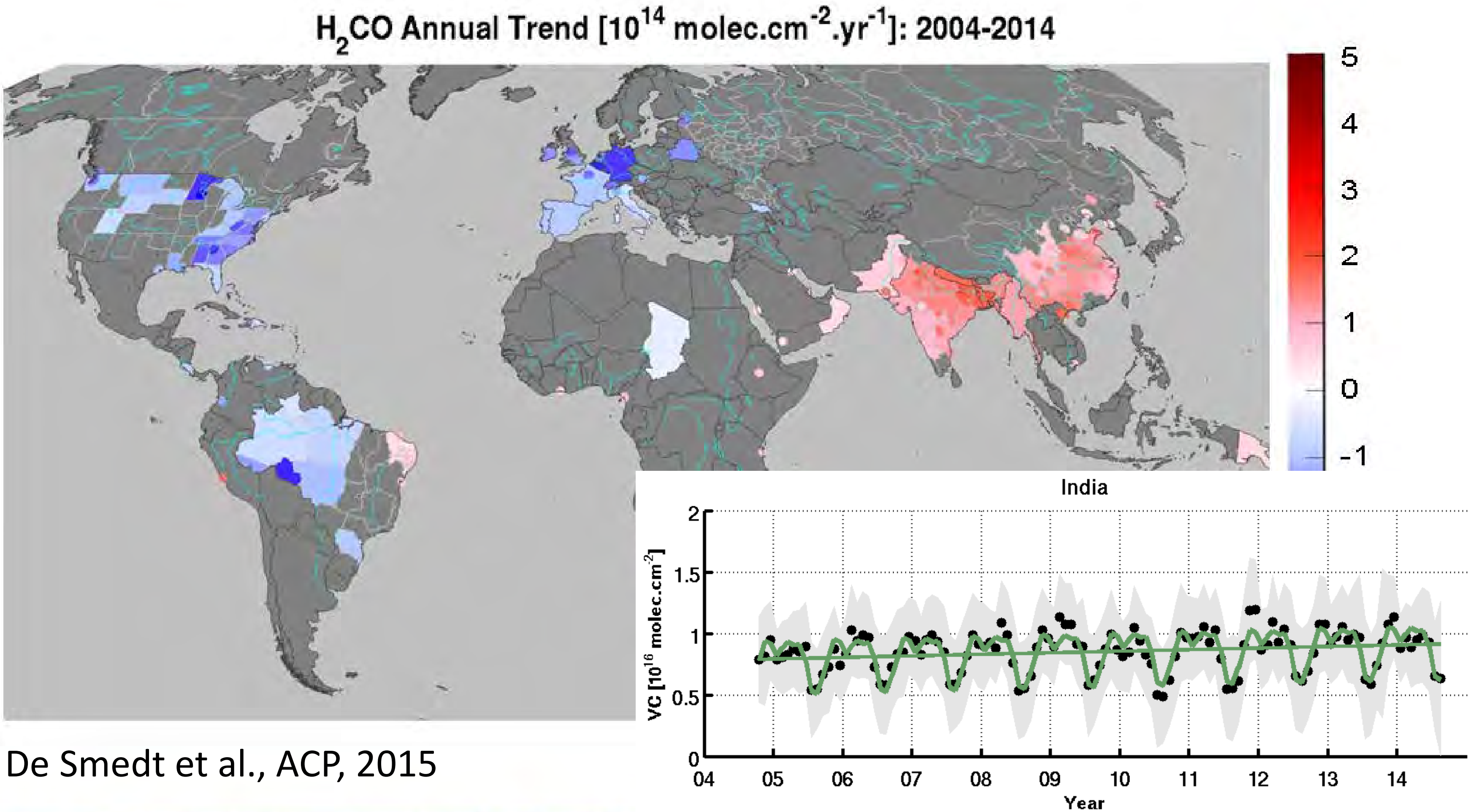
HCHO: a good proxi for NMVOCs



De Smedt et al., ACP, 2015

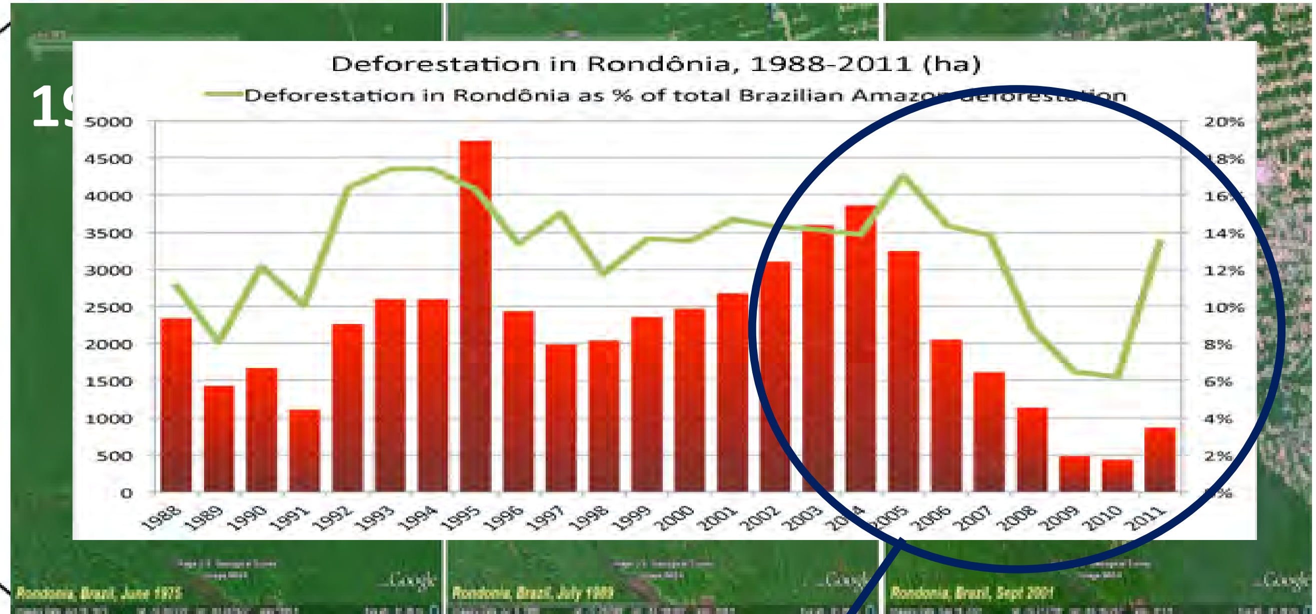


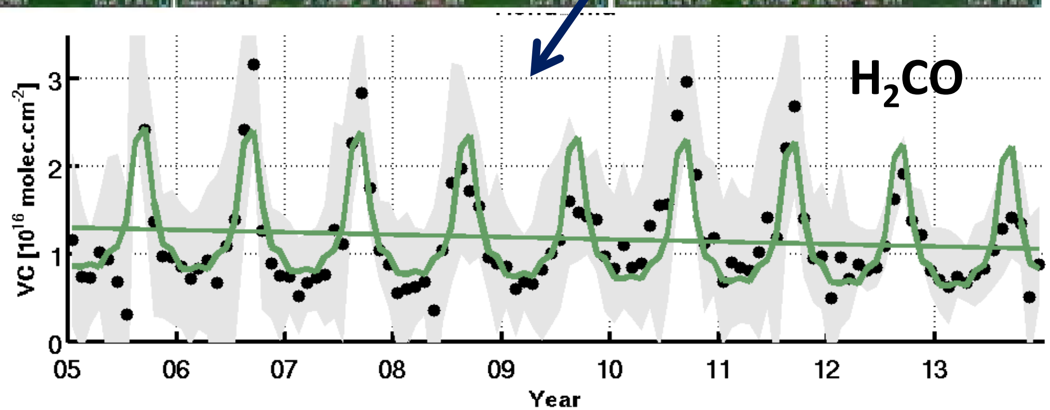
H_2CO trends from OMI 2002-2014



De Smedt et al., ACP, 2015

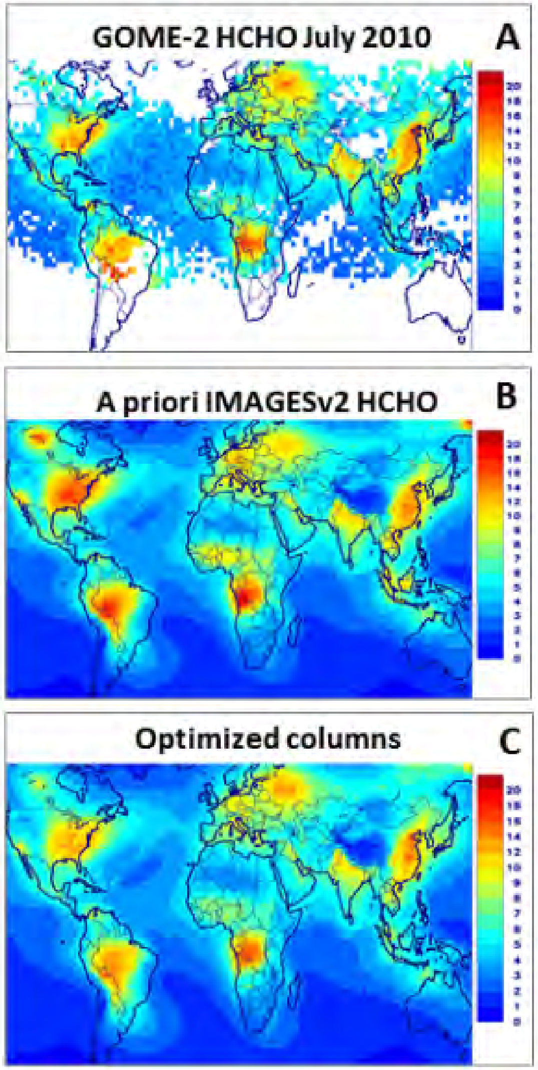
Signature of deforestation in Rondonia (Brazil)

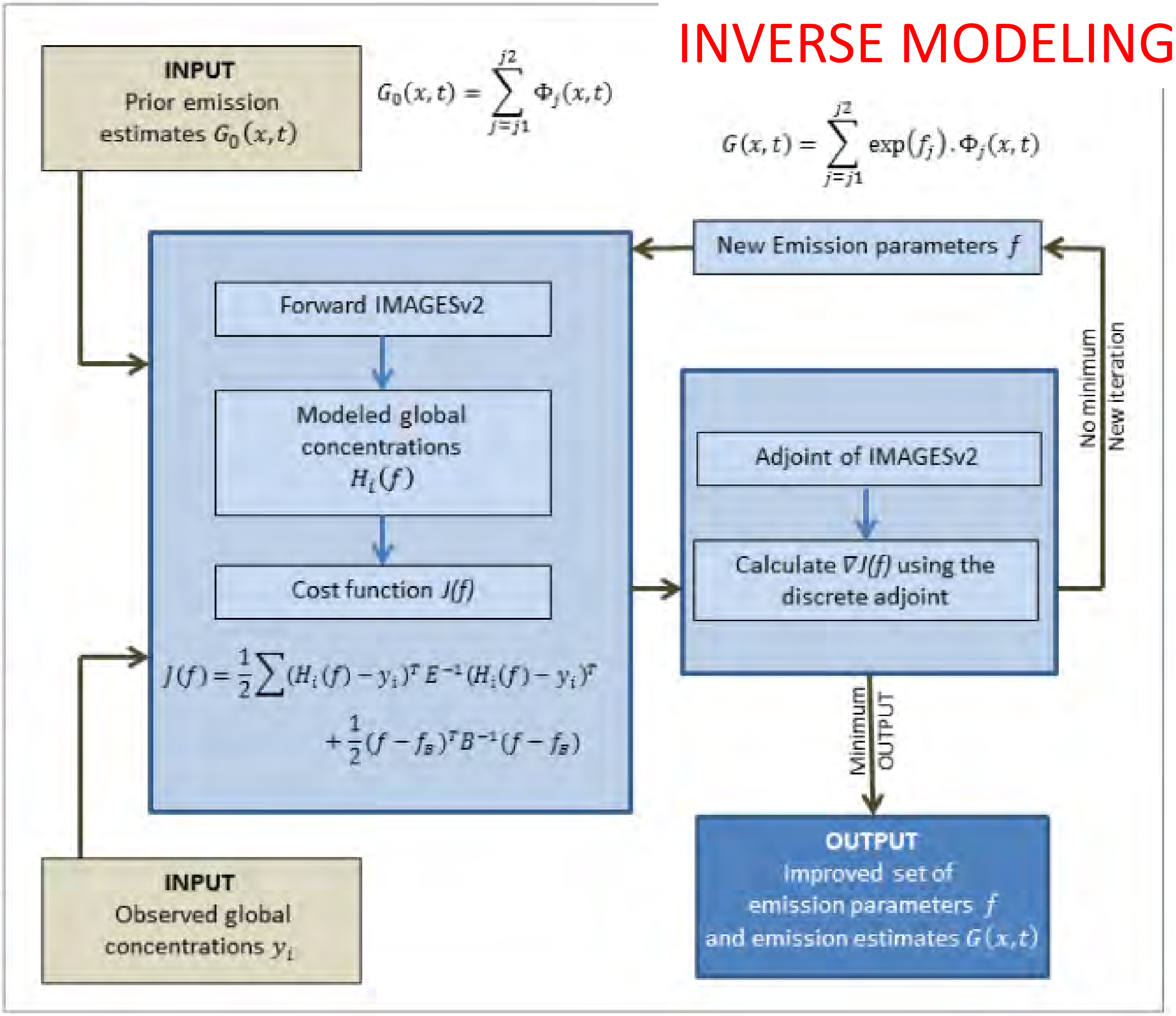




2. Inverse modeling of emission fluxes
(top-down emission inventories)

INVERSE MODELING





Updates in biomass burning VOC emissions based on OMI

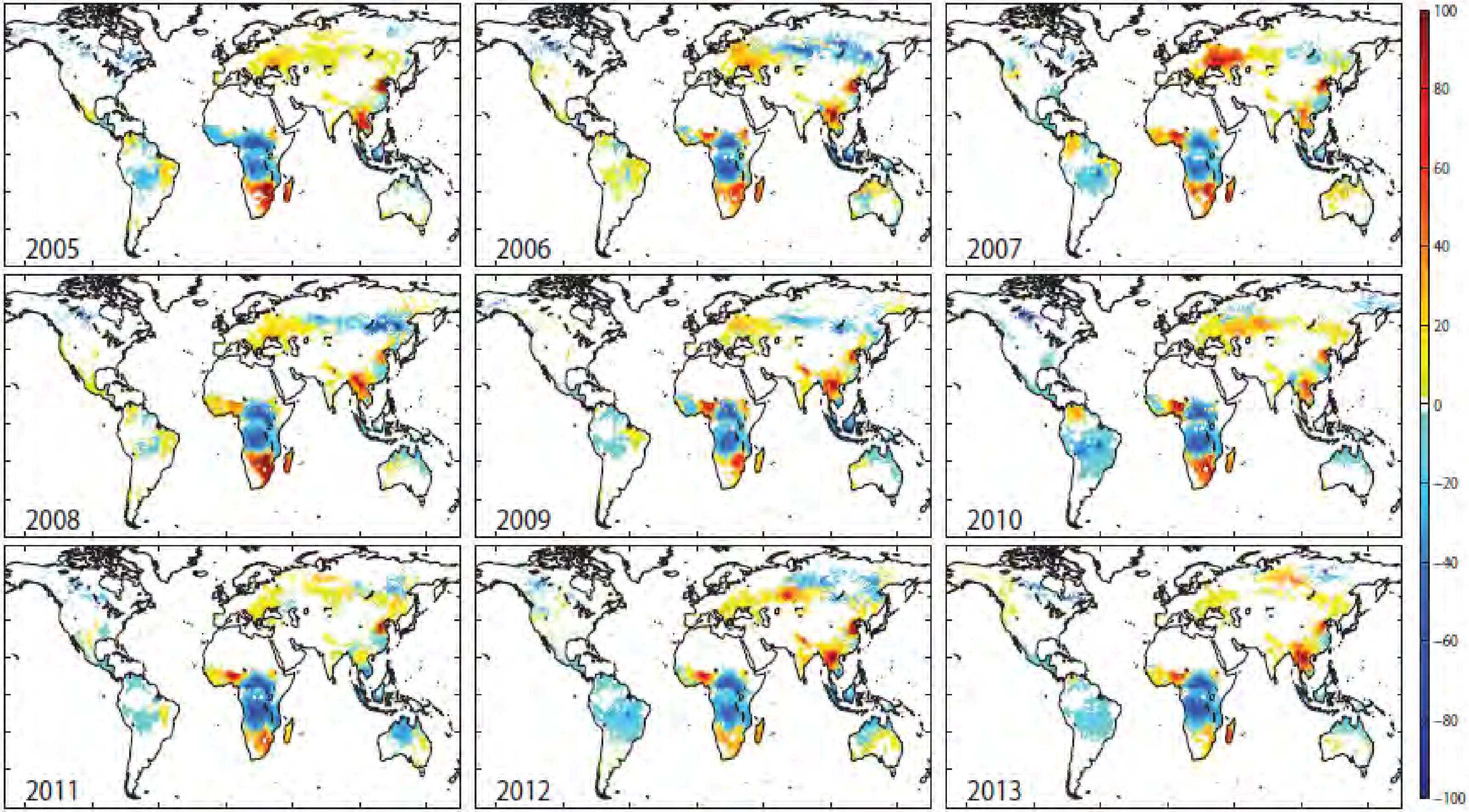


Fig. 5. Updates (percentage change from the a priori) in annually averaged biomass burning emissions suggested by the flux inversion for all years of the study period.

Bauwens et al., ACP, 2016

Updates in isoprene emissions based on OMI

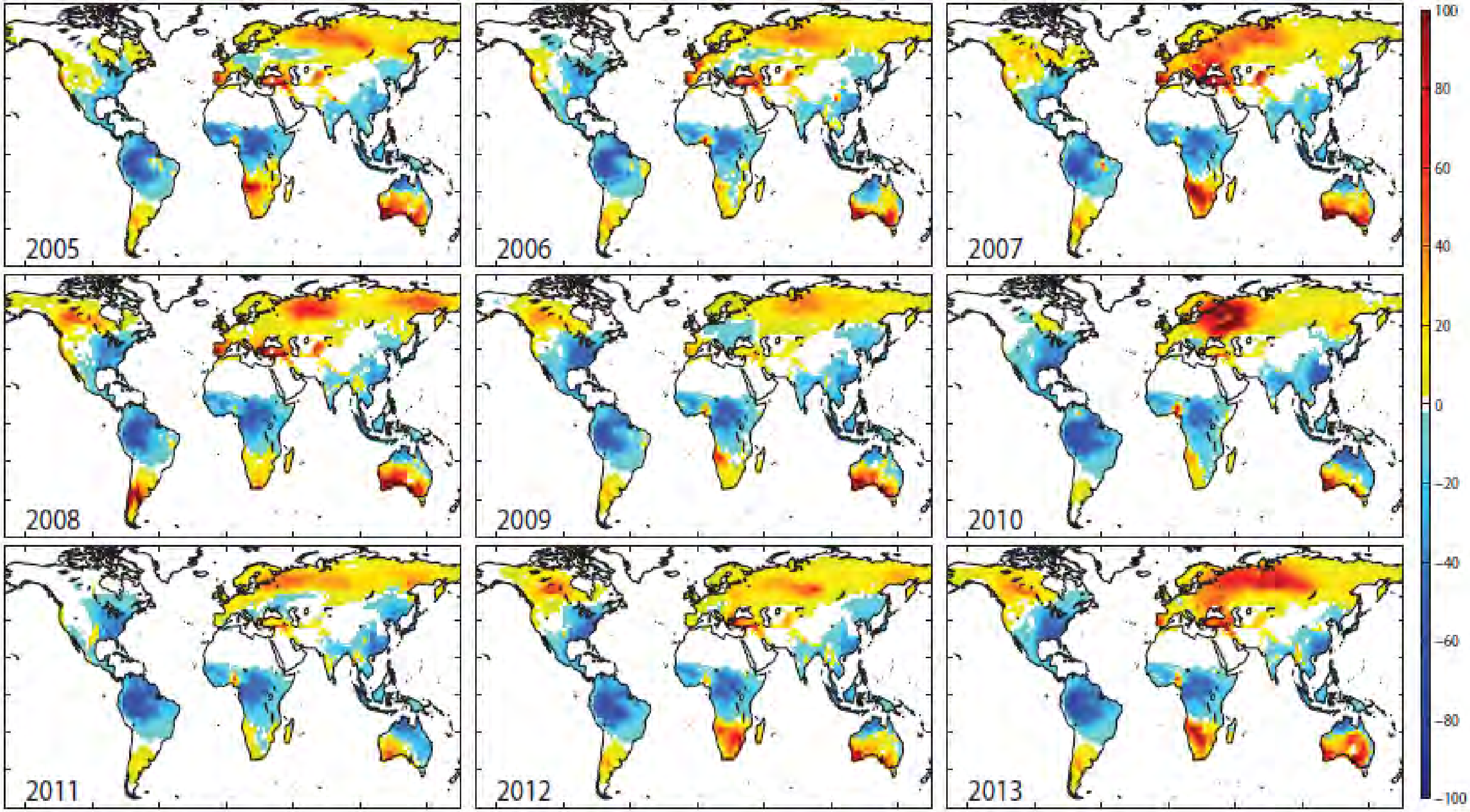
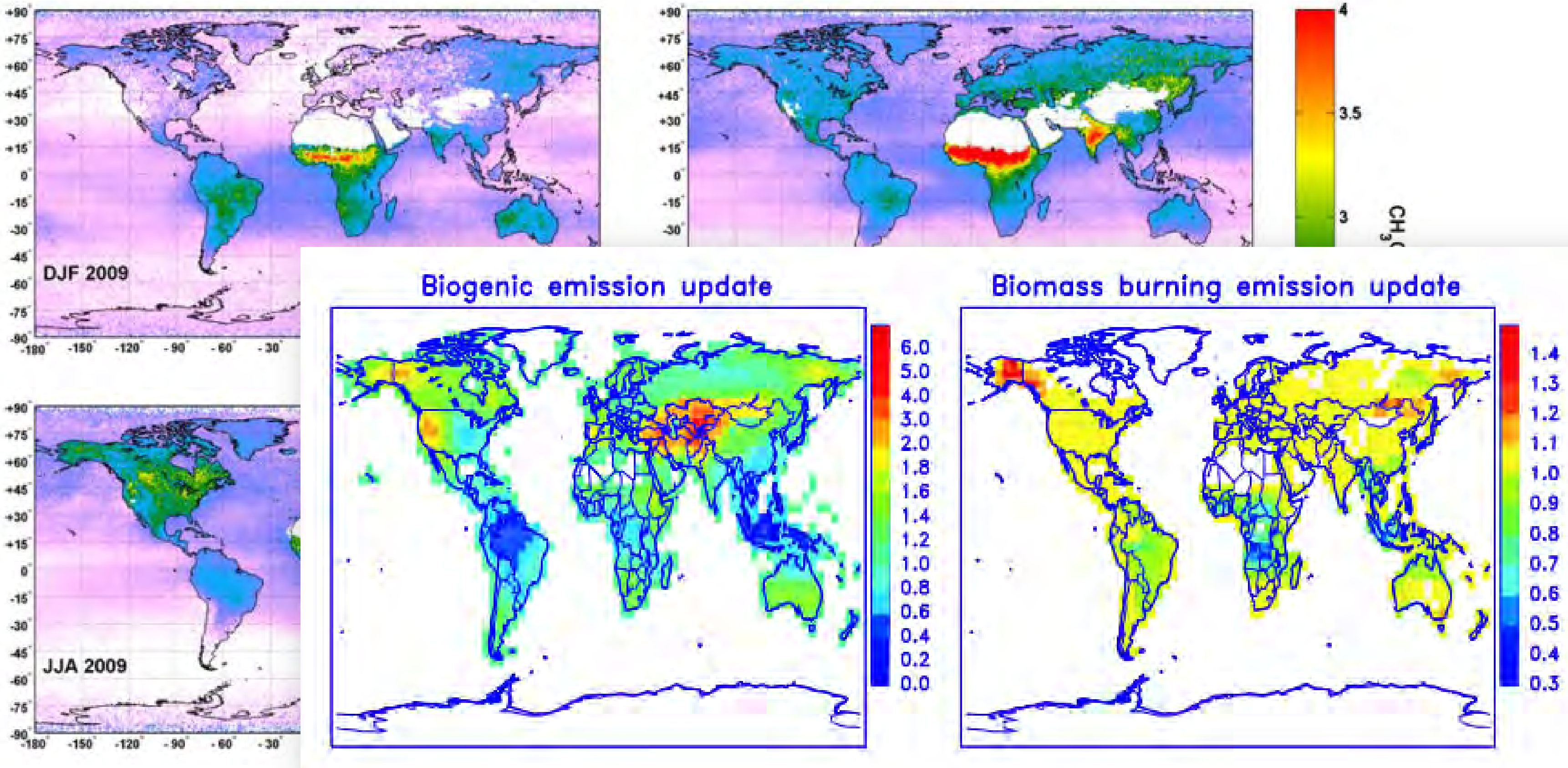


Fig. 6. Updates (percentage change from the a priori) in annually averaged isoprene emissions inferred by the optimization for all years of the study period.

Bauwens et al., ACP, 2016

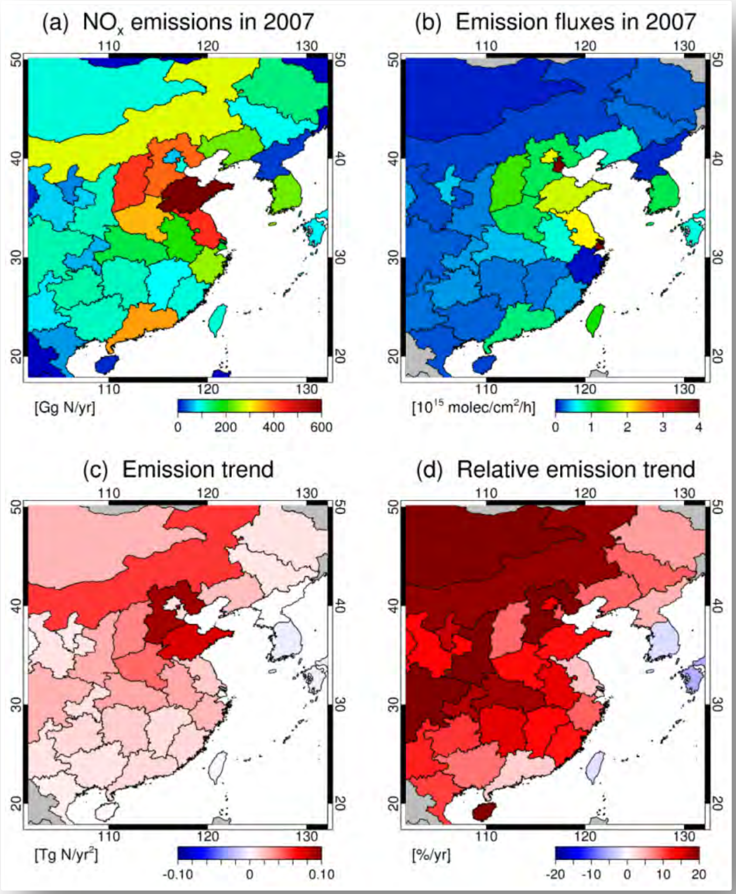
Updates in methanol emissions based on IASI

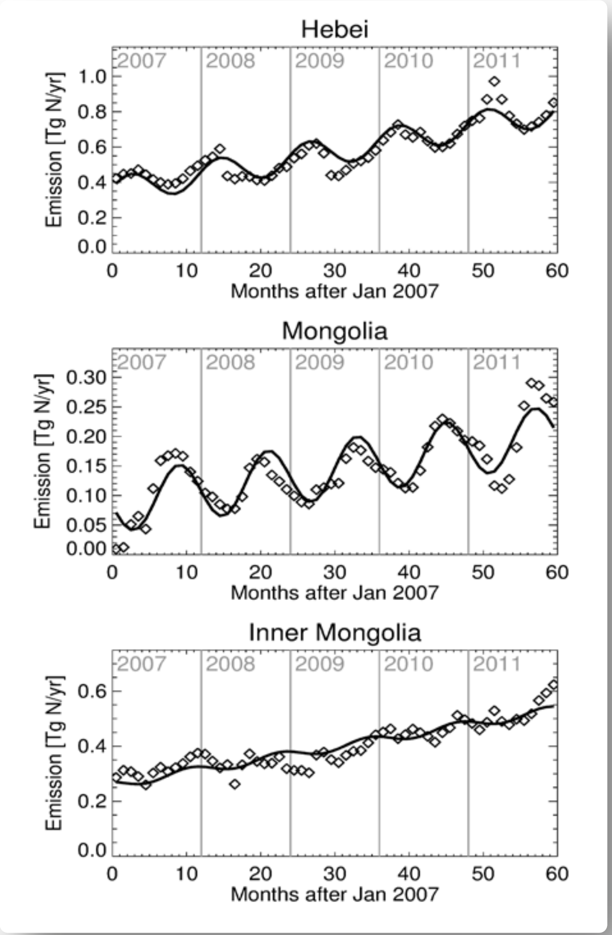


Razavi et al., ACP, 2011

Stavrakou et al., ACP, 2011

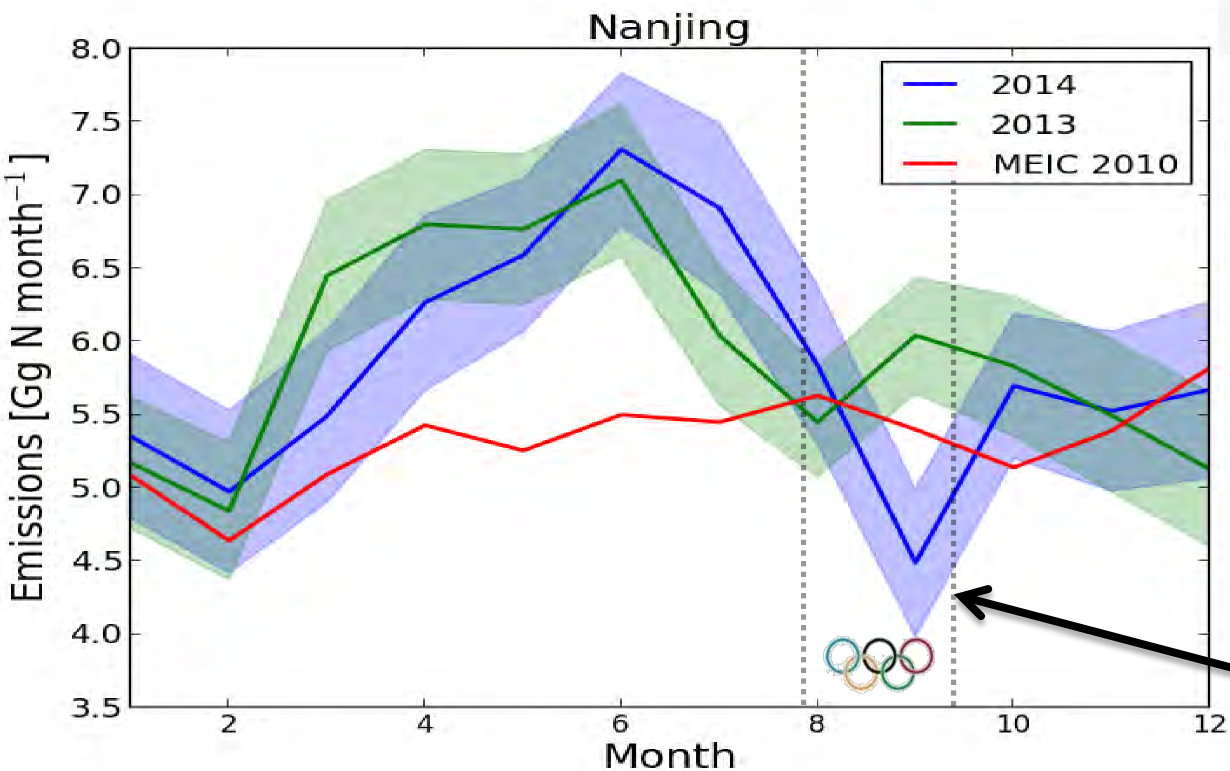
NO_x emission trends in East Asia (DECSO)





Mijling et al., ACP, 2013

NO_x emission estimates by DECSO



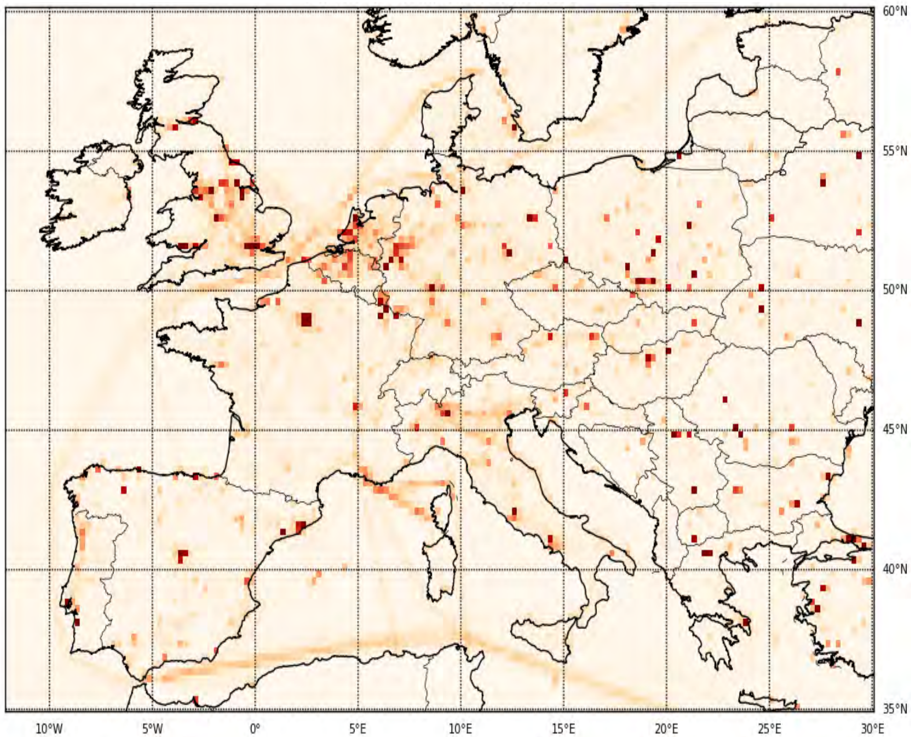
Decrease 25%

The monthly NO_x emission estimates by DECSO in Nanjing for 2013 and 2014, and the monthly NO_x emission of the MEIC inventory of 2010. The shade areas show the natural variability (rms) of the mean NO_x emission estimates from DECSO. *Ding et al., ACP, 2015*

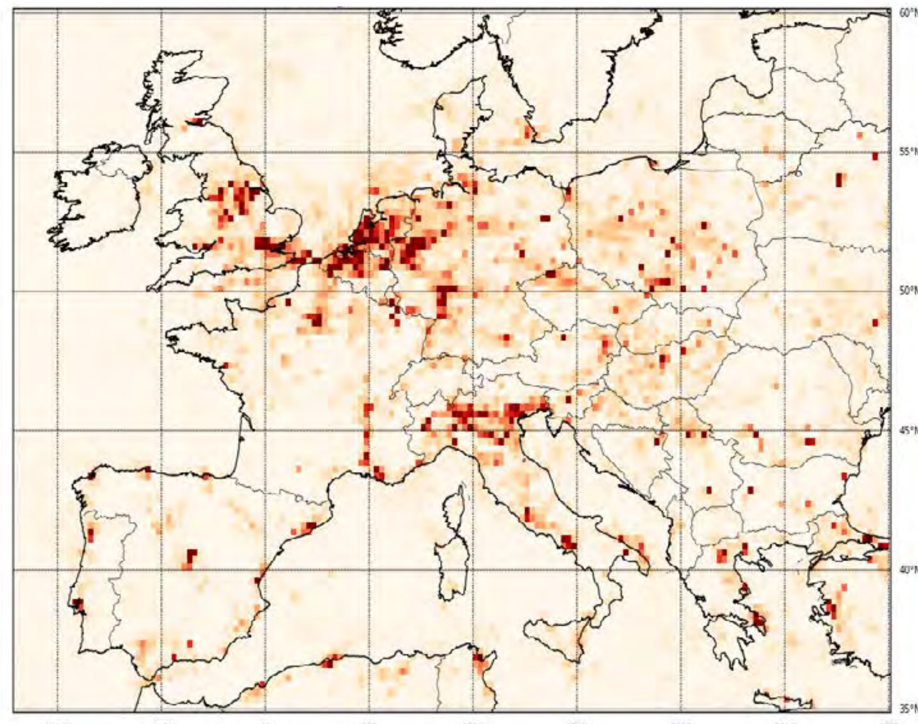
NO_x emissions in Europe

Preliminary!

MACC-II Emissions December 2009

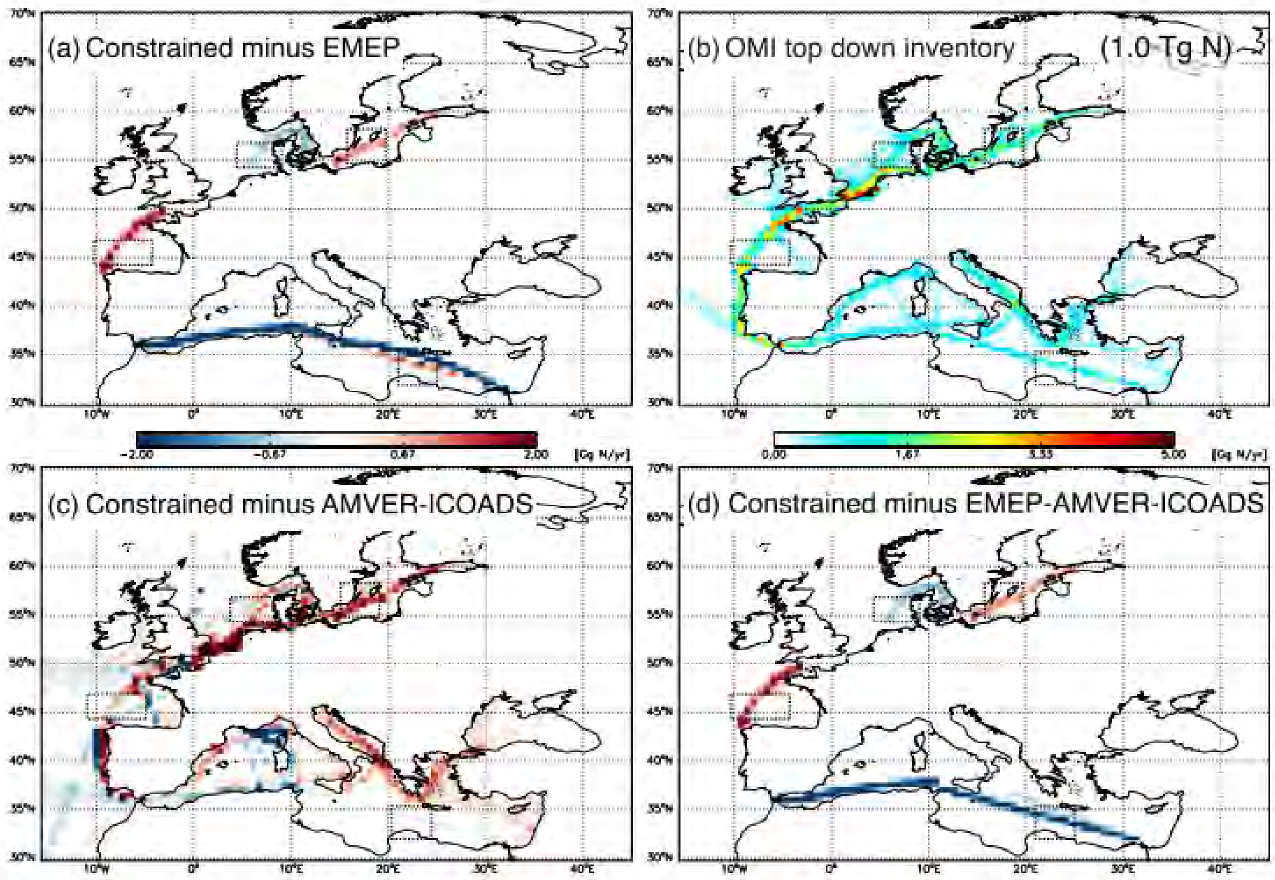


DECSO v3b + OMI, December 2009



Courtesy Mijling and v NO_x emissions in Europe an Der A, KNMI

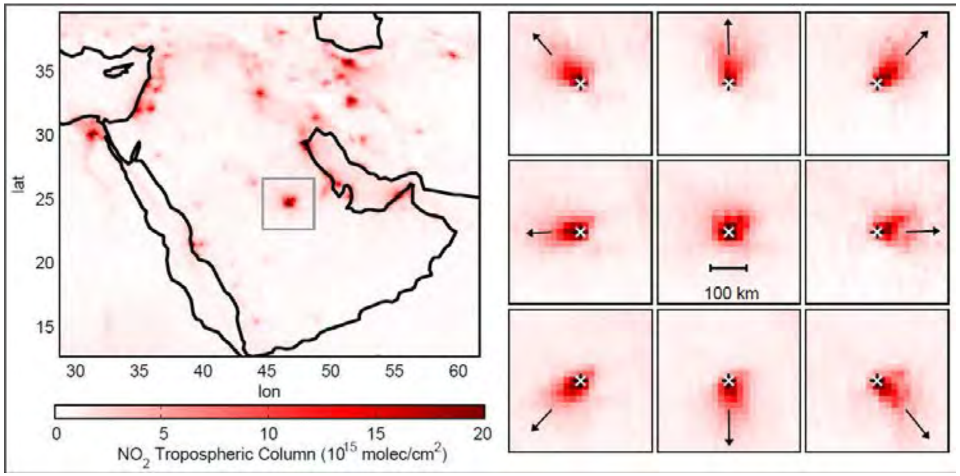
OMI top-down inventory of NO_2 shipping emissions in Europe

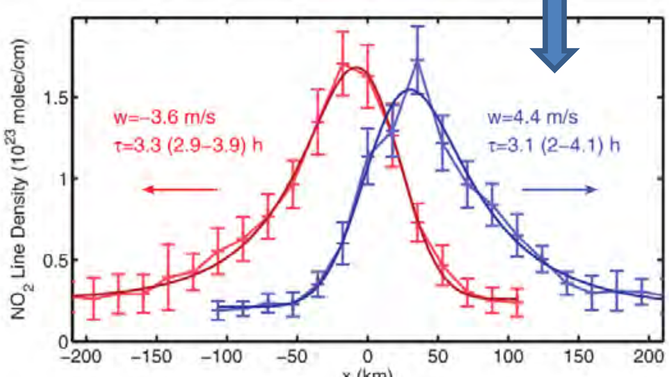


Vinken et al., ACP, 2014

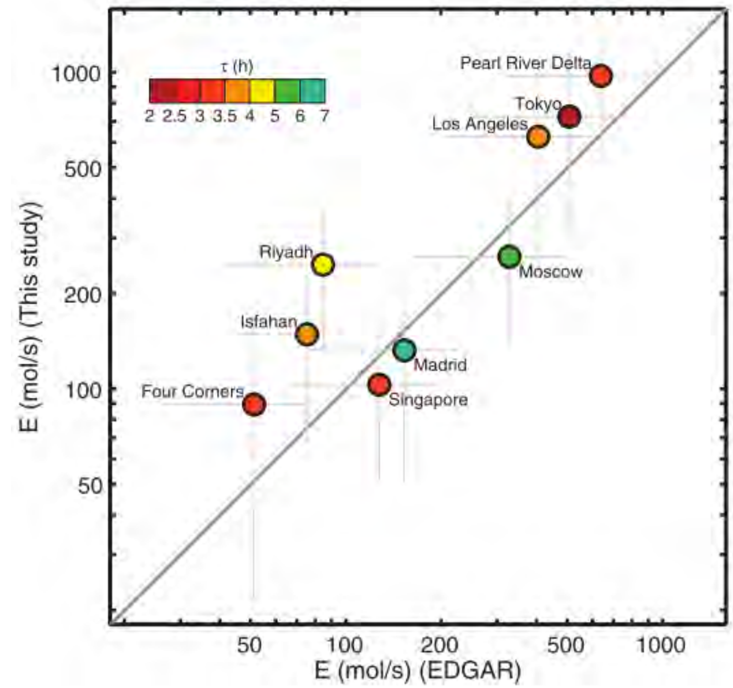
Megacity NO_x emissions and lifetimes based on OMI

Beirle et al., Science, 2011





Downwind evolution of NO_2



Verification of emission inventories (EDGAR)

Home | Data | Gallery | User Workshop | Documents | Links | Contact | Internal

Emissions over Asia

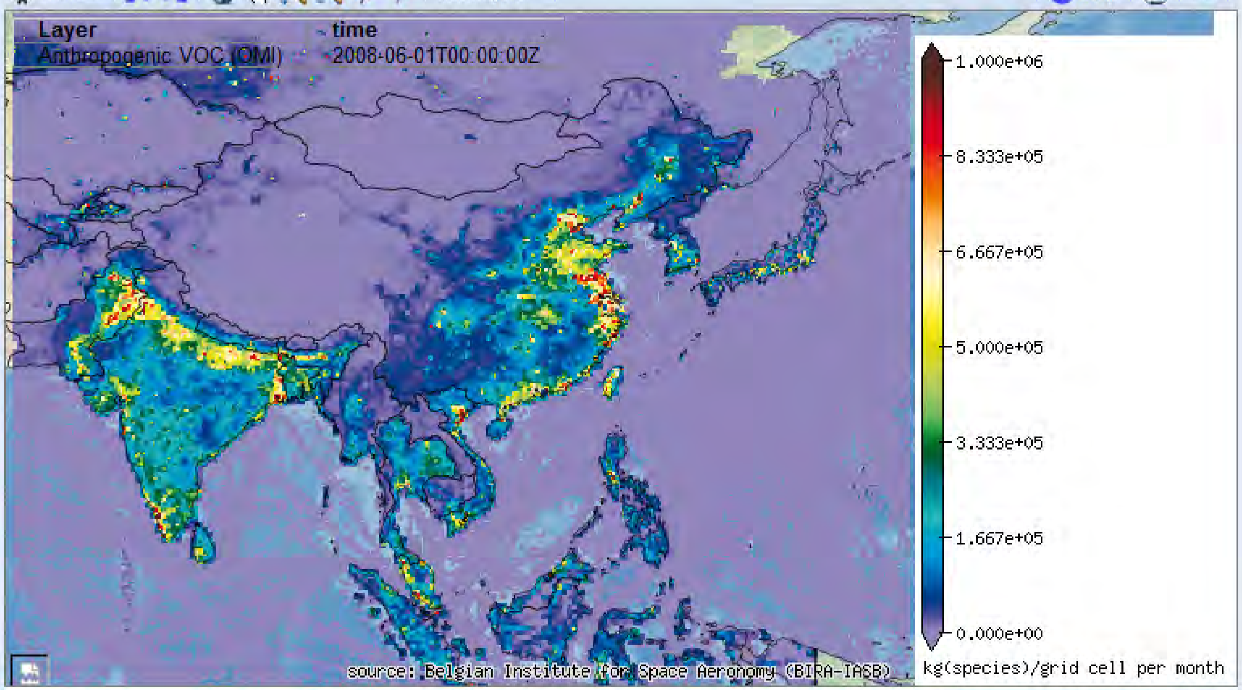
- Anthropogenic VOC emissions over China for June-July-August 2007-2012 are available at 0.25x0.25 degree resolution in NetCdf file format.
- Emissions are derived from source inversion using the adjojnt of the IMAGESv2 global chemistry-transport model (Stavrakou et al., 2009) constrained by tropospheric HCHO column densities from the OMI satellite instrument (De Smedt et al. 2015). HCHO data are publicly available at the TEMIS website.
- The algorithm is described in the Algorithm Theoretical Baseline Document (cf. Section 4.1).

Select species: TNMVOC_OMI : OMI based Anthropogenic VOC emissions - Asia

satellite data at TEMIS

Map

Menu Baselayers Help



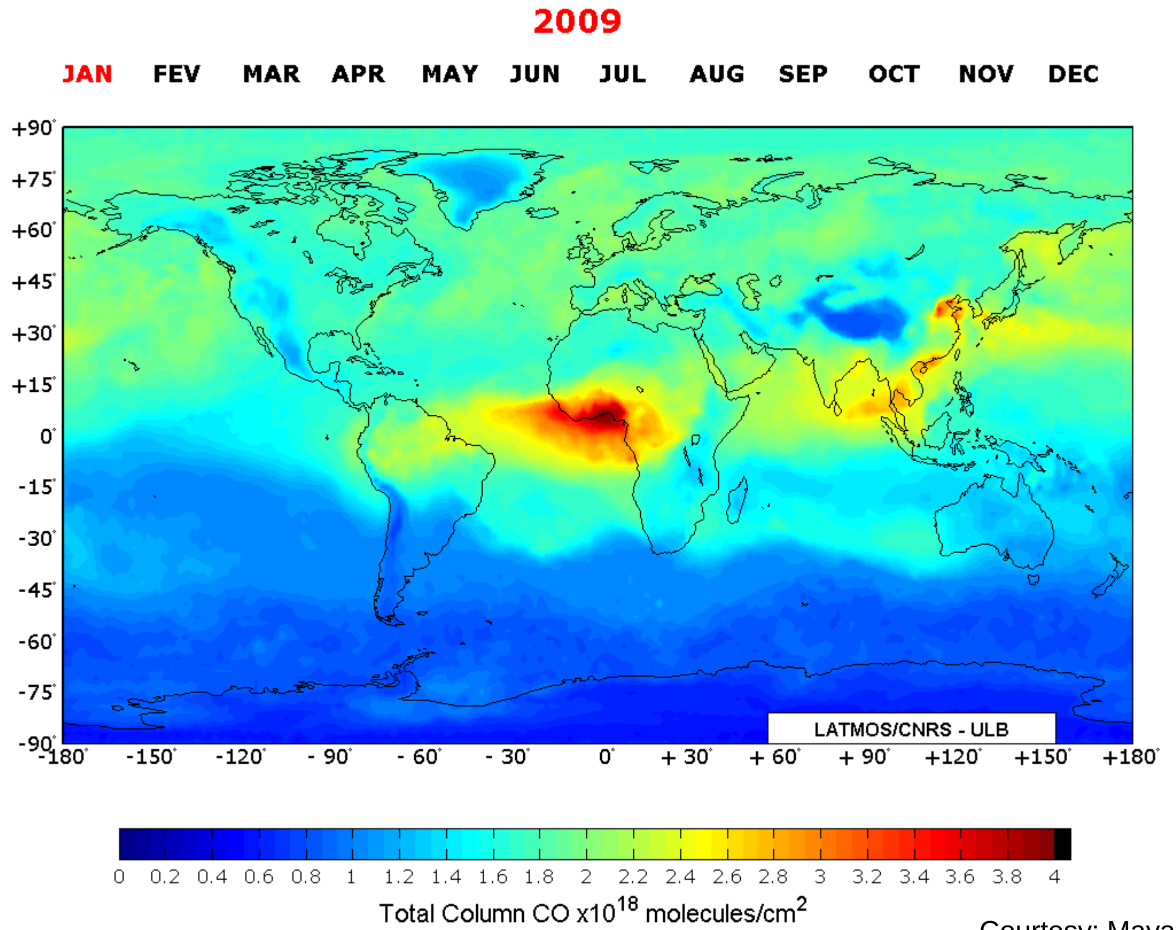
Map type: - Projection: EPSG:4326 Selected layer: 'Anthropogenic VOC (OMI)' Coordinates: (181.97 , 31.9)[181.97,3

GlobEmission Service

DUE project in 2011-2016

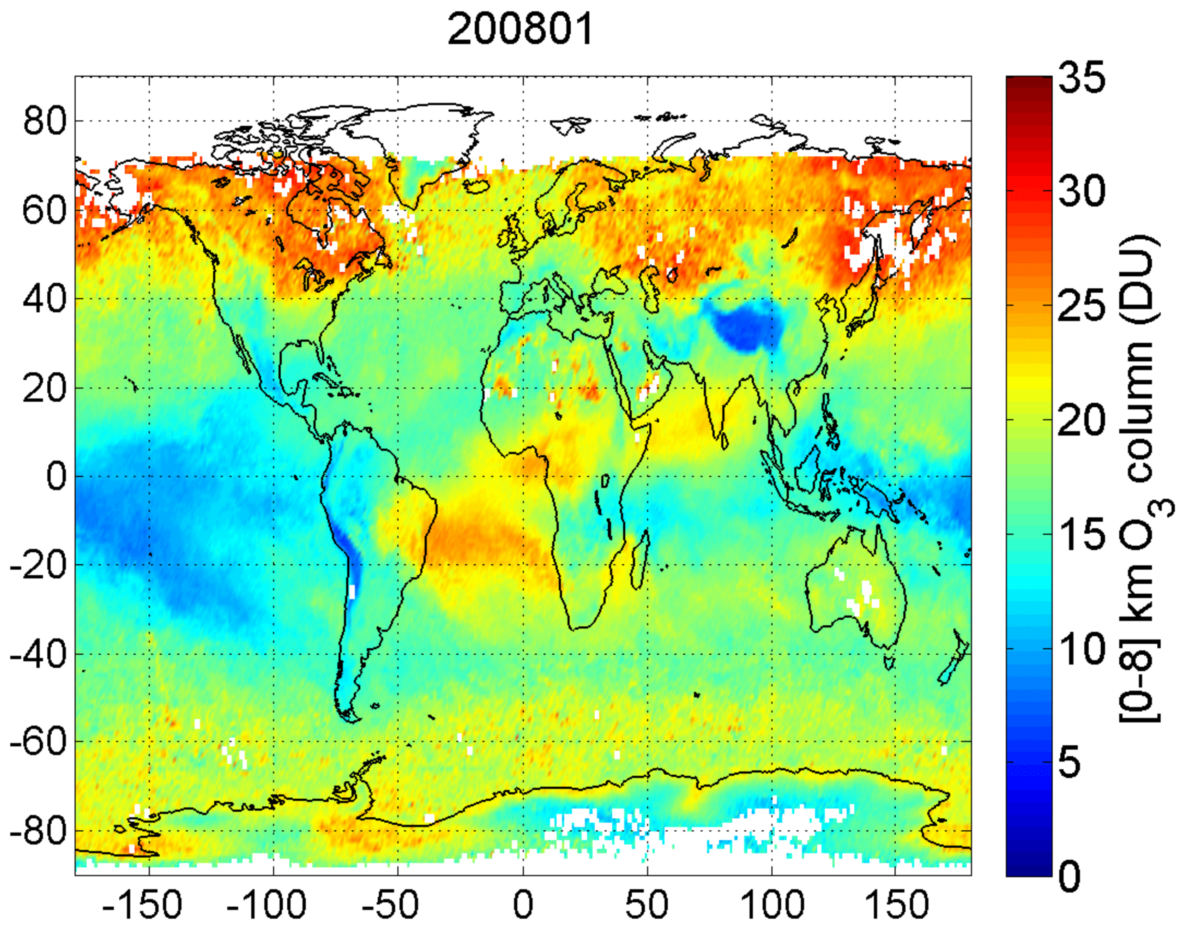
3. Long-range transport

Long-range transport of CO monitored by IASI



Courtesy: Maya George, LATMOS

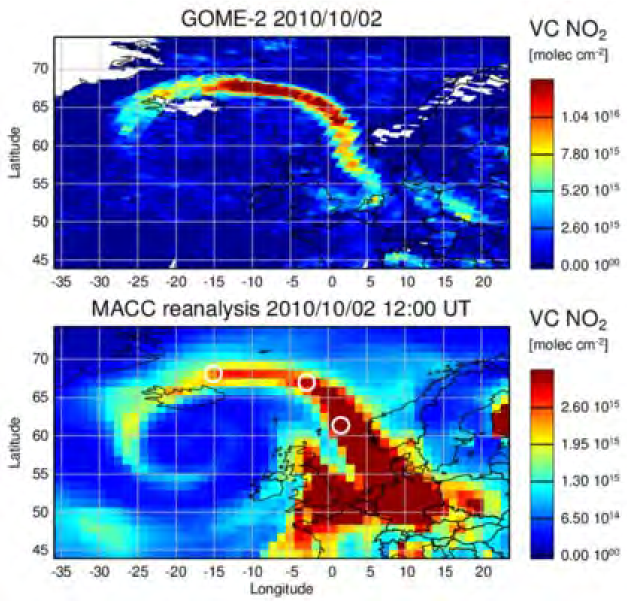
Seasonal variation of IASI tropospheric O_3 over the period 2008-2013



Courtesy Sarah Safieddine, LATMOS

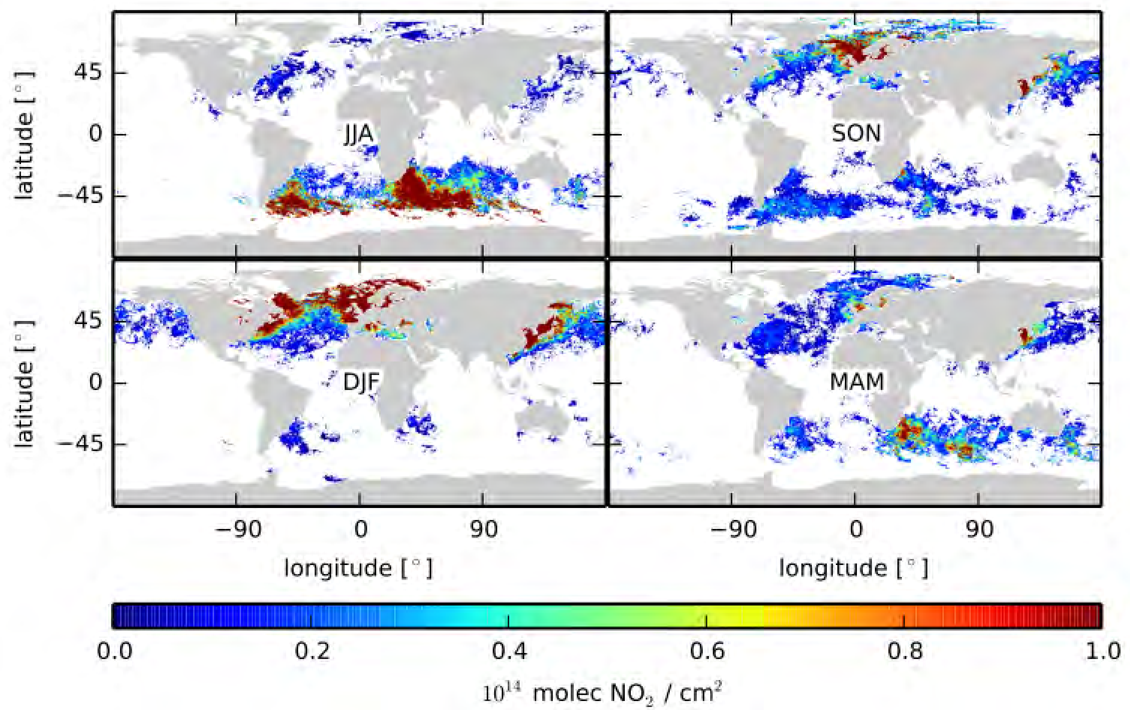
NO_2 long-range transport events in GOME-2 data

‘Above-cloud’ NO_2 columns



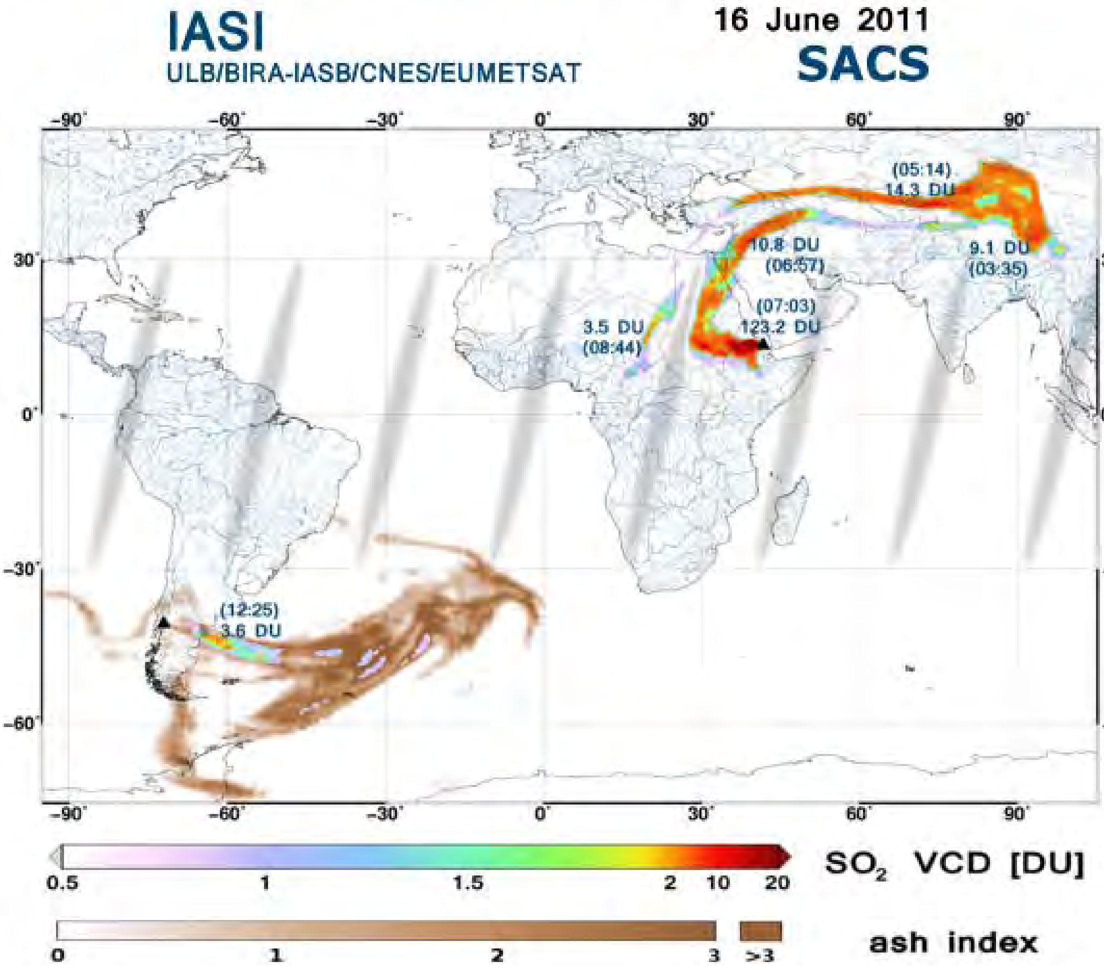
Zien et al., ACP, 2014

Seasonal map of detected long-range transport plume events

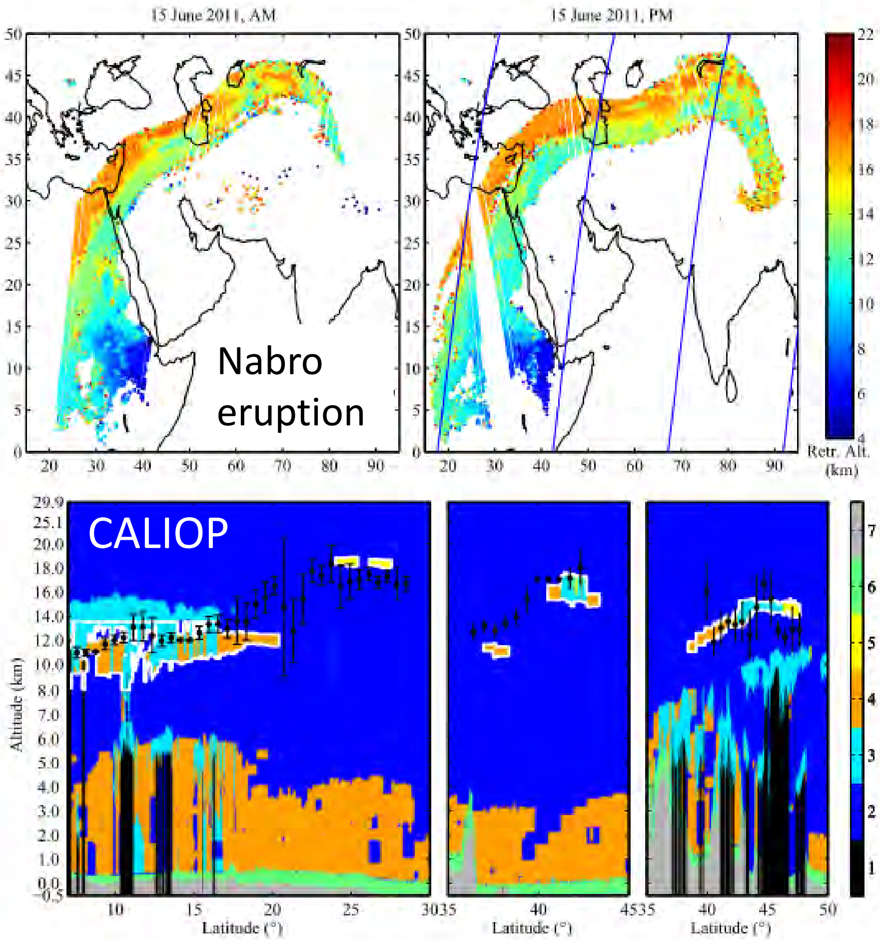


4. Volcanic emissions

Simultaneous eruptions of Nabro and Puyehue

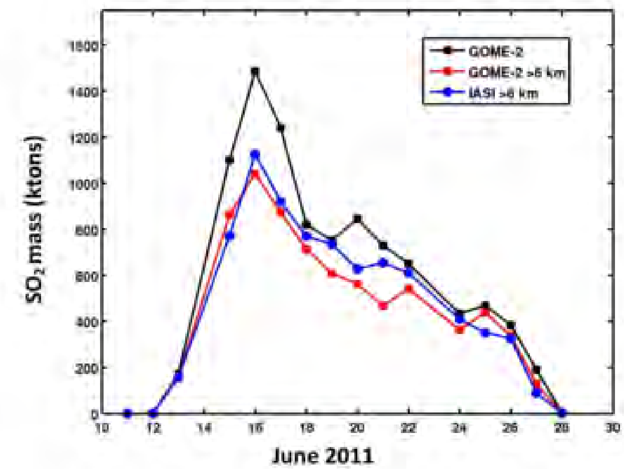


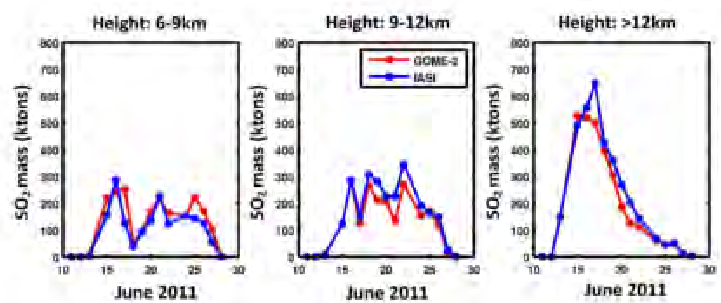
SO_2 plume height detection from IASI



Clarisse et al., ACP, 2014

SO_2 flux from IASI and GOME-2





Theys et al., 2013

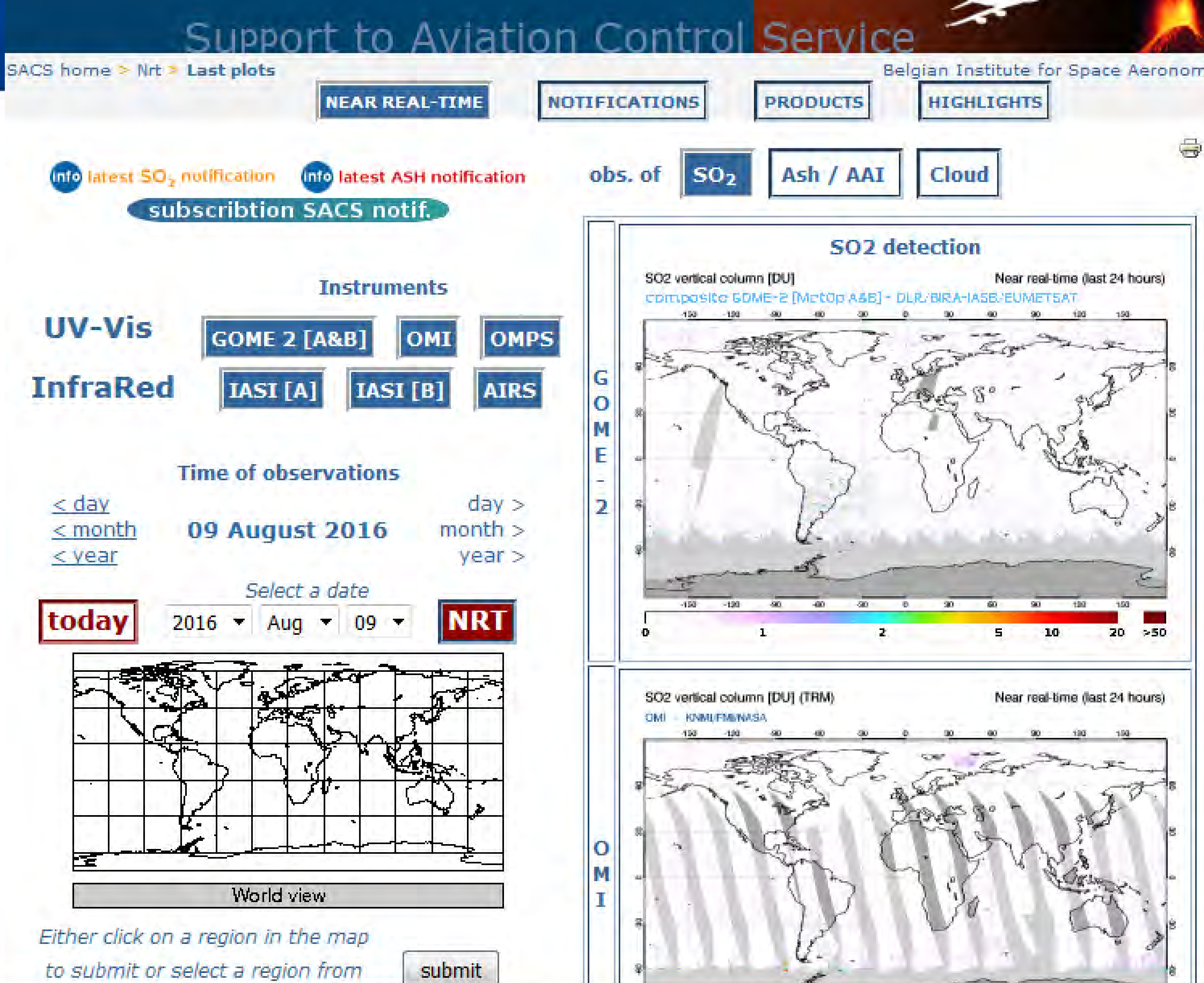
SACS

Support to Aviation Control Service

World Airways DC10 after crossing Mt Pinatubo plume in 1991

Constellation of 6 satellite hyperspectral sensors used to monitor volcanoes

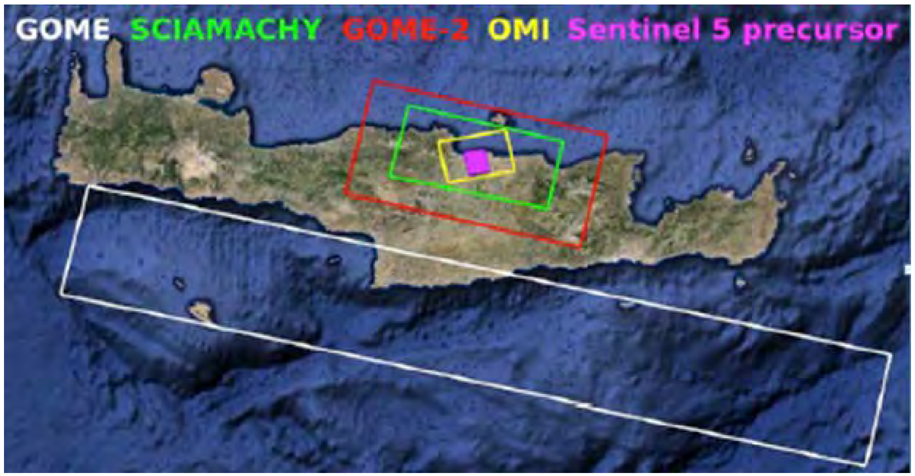
http://sacs.aeronomie.be/



Future sensors will have:

- Improved spatial resolution (7x7 km^2 for TROPOMI/S5-P and similar for other atmospheric Sentinels 4/5)
- Improved S/N ratio → better sensitivity
- Global daily coverage for LEO missions
- Hourly repetition rate for GEO missions (Europe coverage for Sentinel 4)
- Operational processing chains and open data policy (Copernicus)

TROPOMI/S5p : launch in late 2016

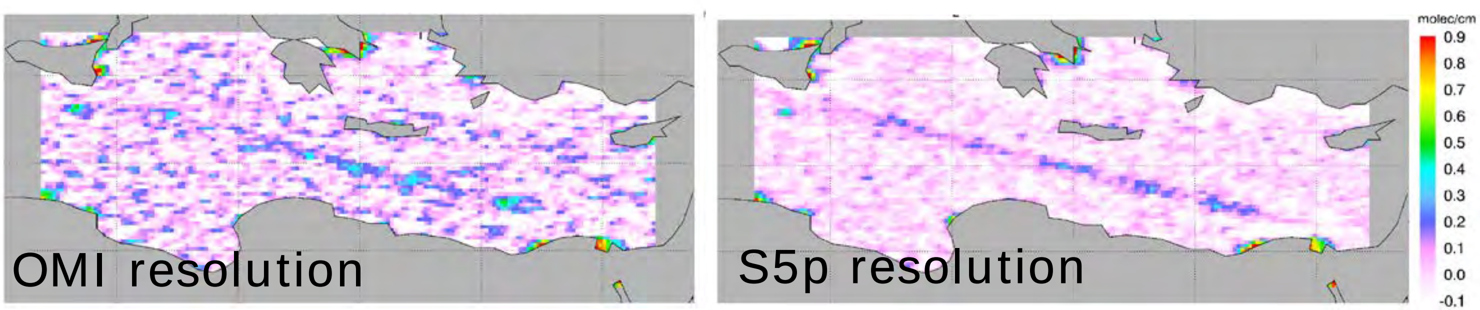


Improved spatial resolution with high S/N ratio will allow for:

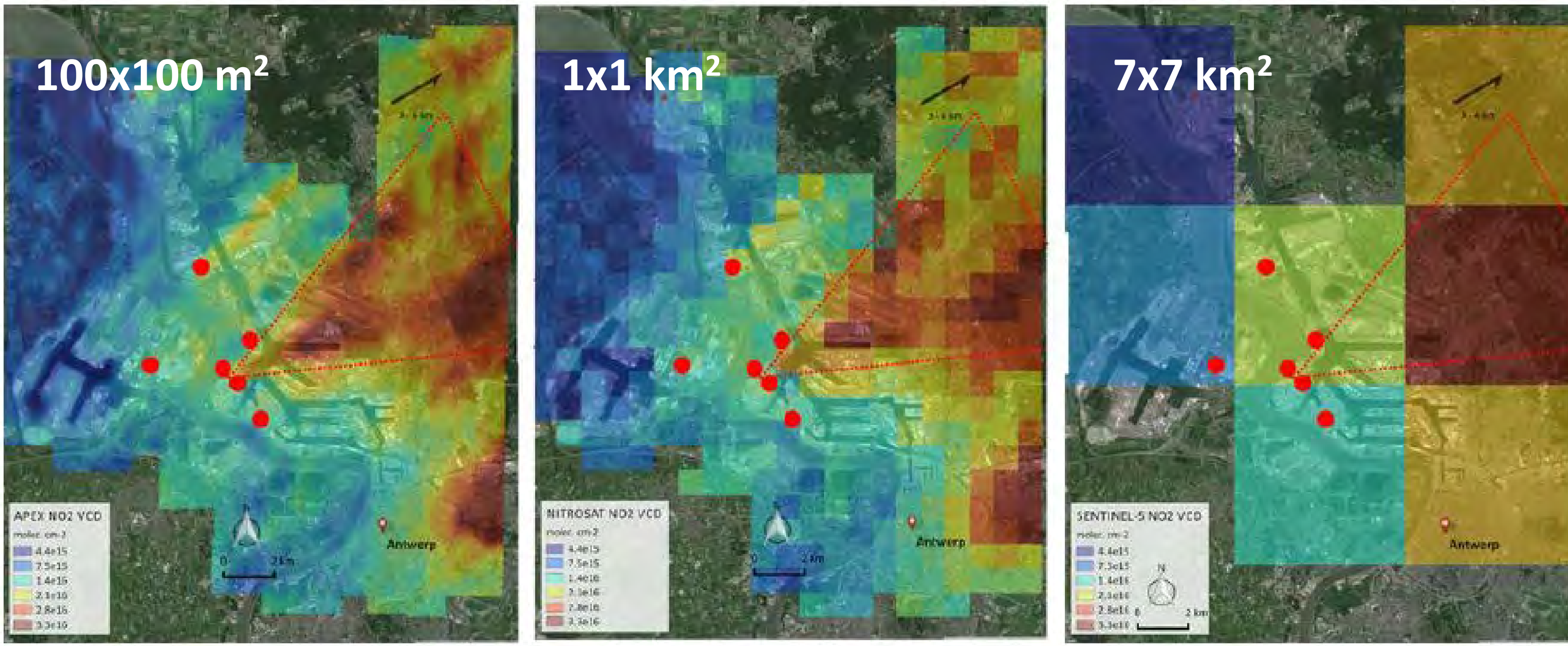
- Identification of more emission sources
- Reach urban scales
- Reduce uncertainties…

Additional SWIR channels -> CO and CH_4

Ship track in monthly mean NO_2 signal



Need for even higher resolution?



Airborne APEX hyperspectral NO_2 columns measured over Antwerp (Courtesy F. Tack). Native resolution is approximately 100x100 m^2. Main sources can still be detected at 1x1 km^2.

Extracted from EE9 Nitrosat Proposal (P. Coheur, ULB)

Thank you for your attention!

Questions?