OMI history talk

Pieternel Levelt

27 August 2019, Aura meeting, Pasadena, USA

William T. Pecora Award 2018
OMI international science team

History

- How did OMI came about???
- OMI main instrument developments
- OMI main scientific achievements
- OMI lessons learned
- Photo’s !!!!

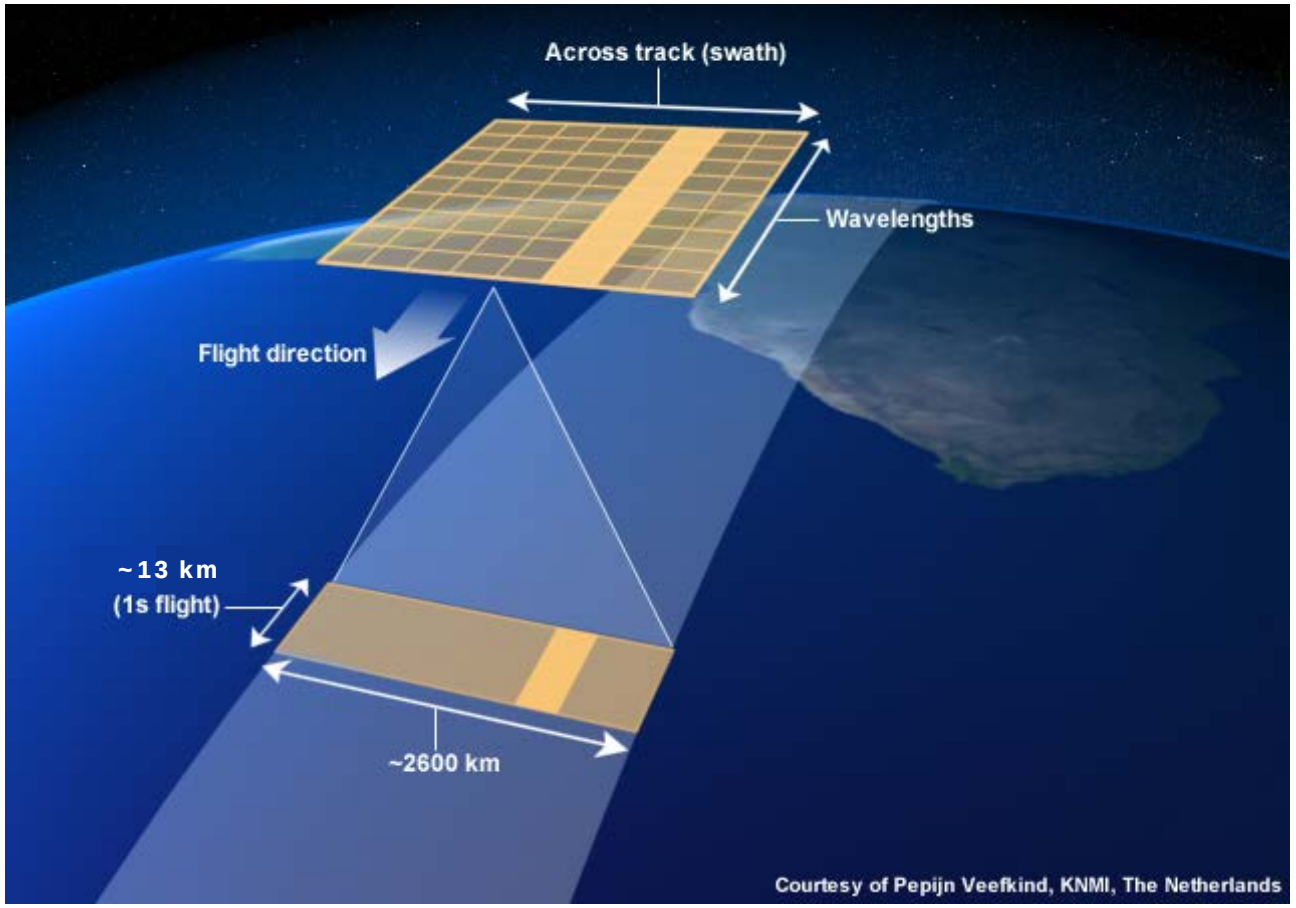
My familie at the Launch event at KNMI

Ozone Monitoring Instrument OMI

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

- UV and VIS backscatter instrument (270 - 500 nm)
- Wide swath telescope yields daily global maps (2600 km)
- First instrument with urban scale resolution of air quality measurements from space (13 x 24 km^2)
- Dutch-Finnish instrument launched at NASA's EOS-Aura in July 2004

The technical heart of the OMI instrument



OMI's instrument highlights

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- Use of 2D detector & unique optical design

  → Daily global coverage & urban scale resolution

  → Is now the basis for every satellite instrument designed after OMI

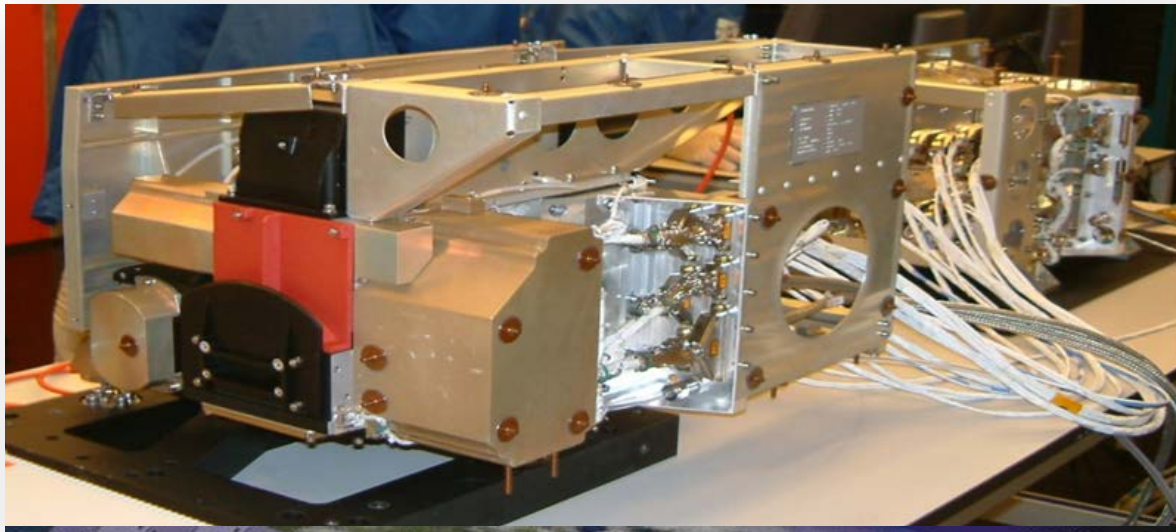
  → Combined the best of the spatial and spectral capabilities in USA and European instruments (TOMS-GOME)

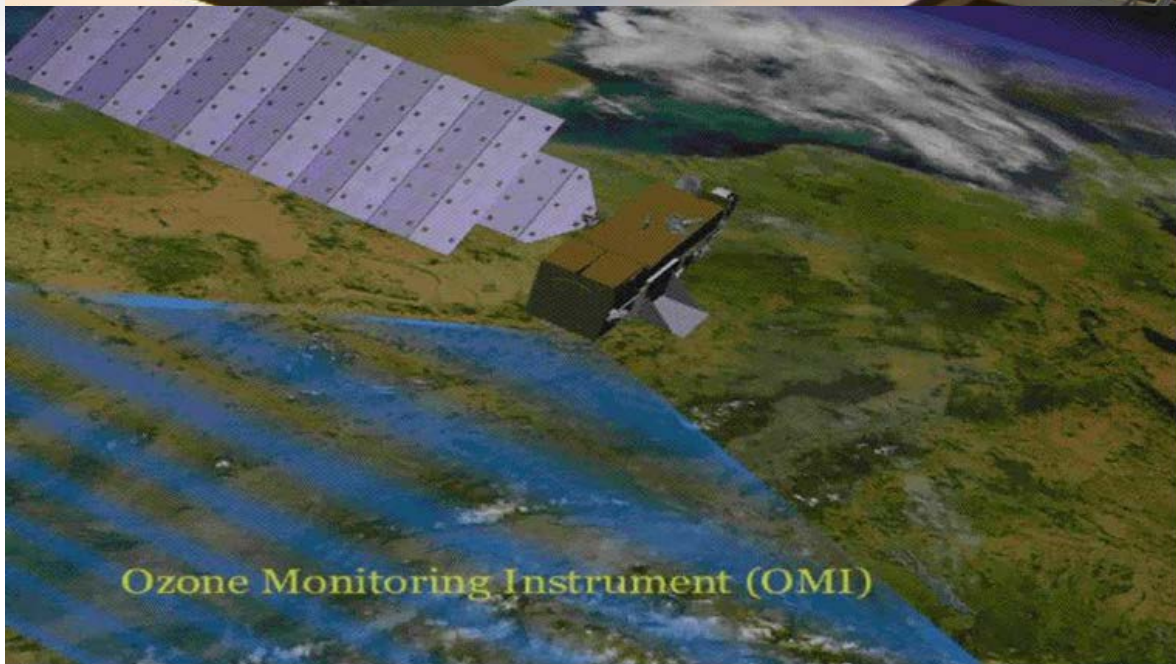
- OMI is optically extremely stable:

  → 3 % (UV1) and 2% (UV2 and VIS) degradation since launch

  → most stable UV/VIS instrument ever

  → long term trending & climate





OMI Science Questions

Ozone layer, Air Quality and Climate Change

- Is the ozone layer recovering as expected ?

- What are the sources of aerosols and trace gases that affect global air quality and how are they transported?

- What are the roles of tropospheric ozone and aerosols in climate change ?

- What are the causes of surface UV-B change?

How did it all start

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How did OMI start

- Who did the first step?
  - Airbus or NASA
  - QuickTOMS or GOME-2

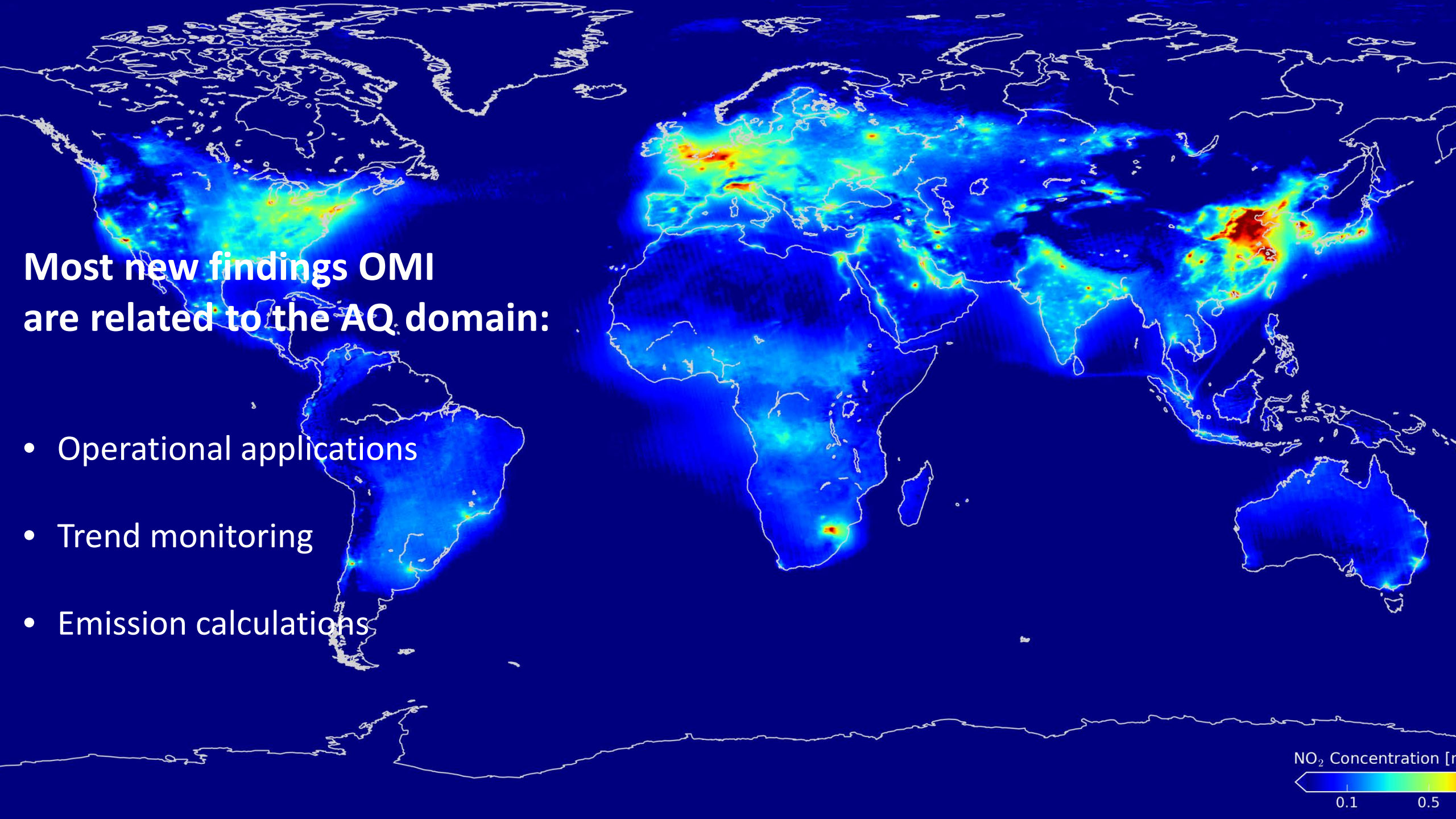
- How KNMI got involved
  - OMI on METOP – 1996
  - Invitation for Aura meetings in Washington DC and Boulder (July and August 1997)
  - January 1998 visit PK and Ernie to KNMI
  - April 1, 1998 – OMI accepted on Aura: is this a joke?
  - OMI PI ship decision end of June 1998
  - Pregnancy leave July – Early November 1998, PDR in December 1998

How did OMI start

- How the Finnish got involved
  - GOMOS-2 detector – Finnish industry
  - FMI double role

- Requirements
  - PK's view versus Pieternel's view
  - PK:

  'KNMI to lead the world in this field'



Most new findings OMI are related to the AQ domain:

- Operational applications
- Trend monitoring
- Emission calculations

Air quality on a daily basis:
Smog in Europe measured by OMI, March 2014

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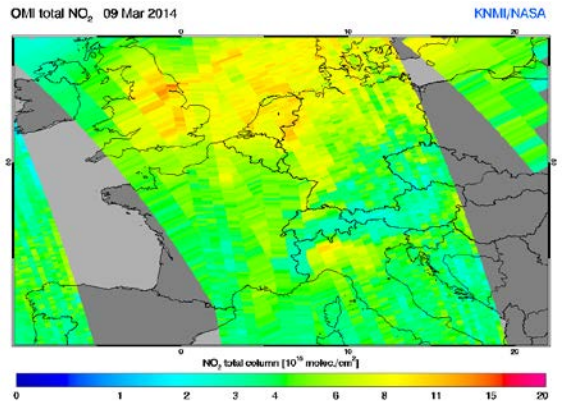
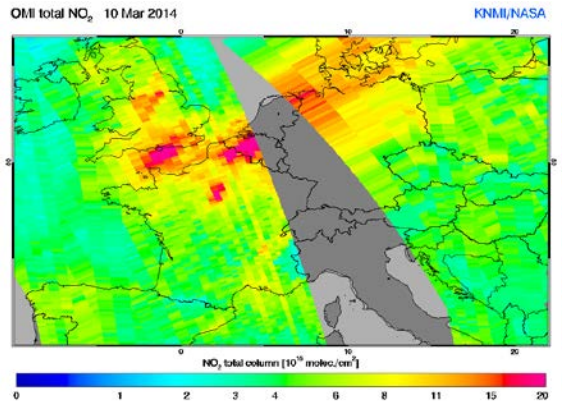
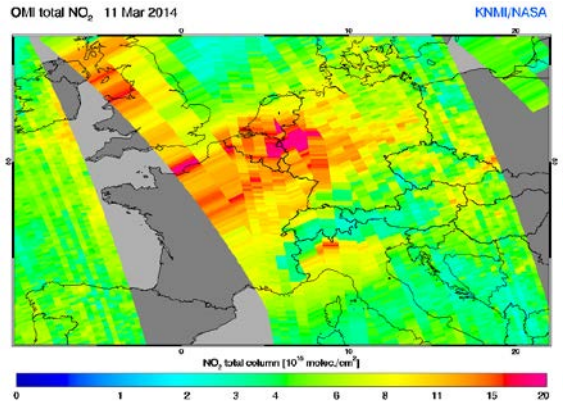


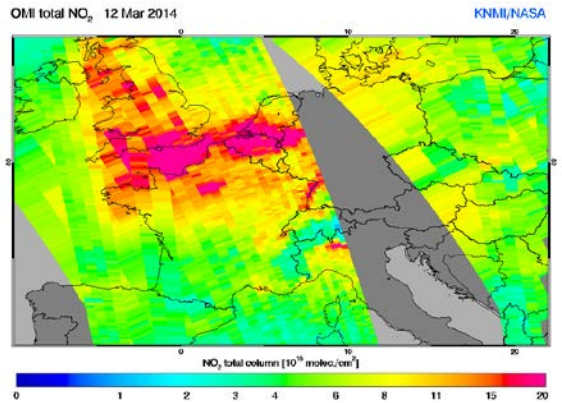
9 March



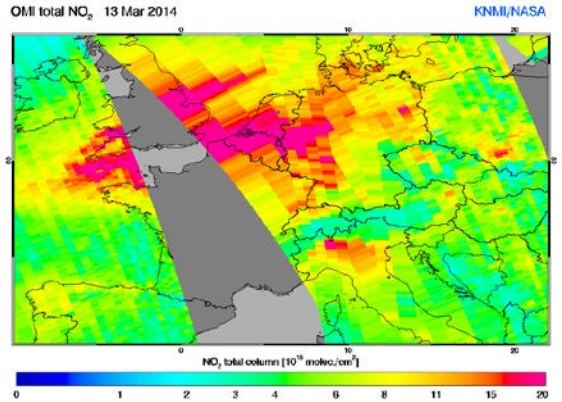
10 March



11 March



12 March



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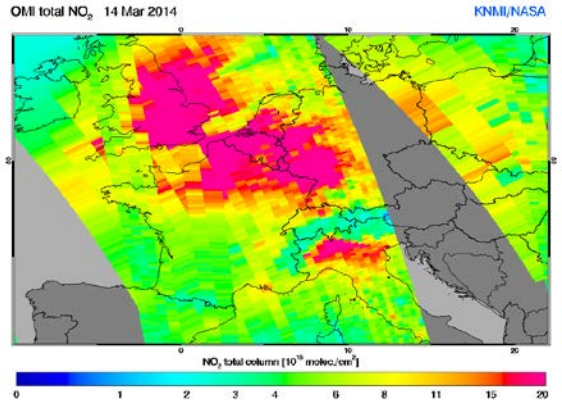
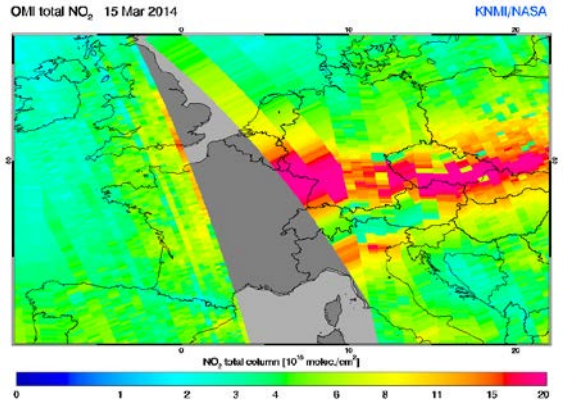
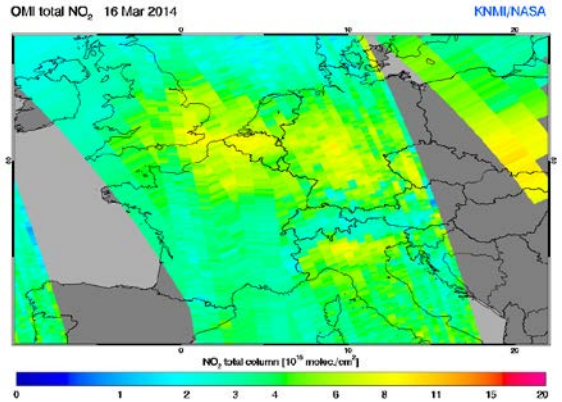


14 March

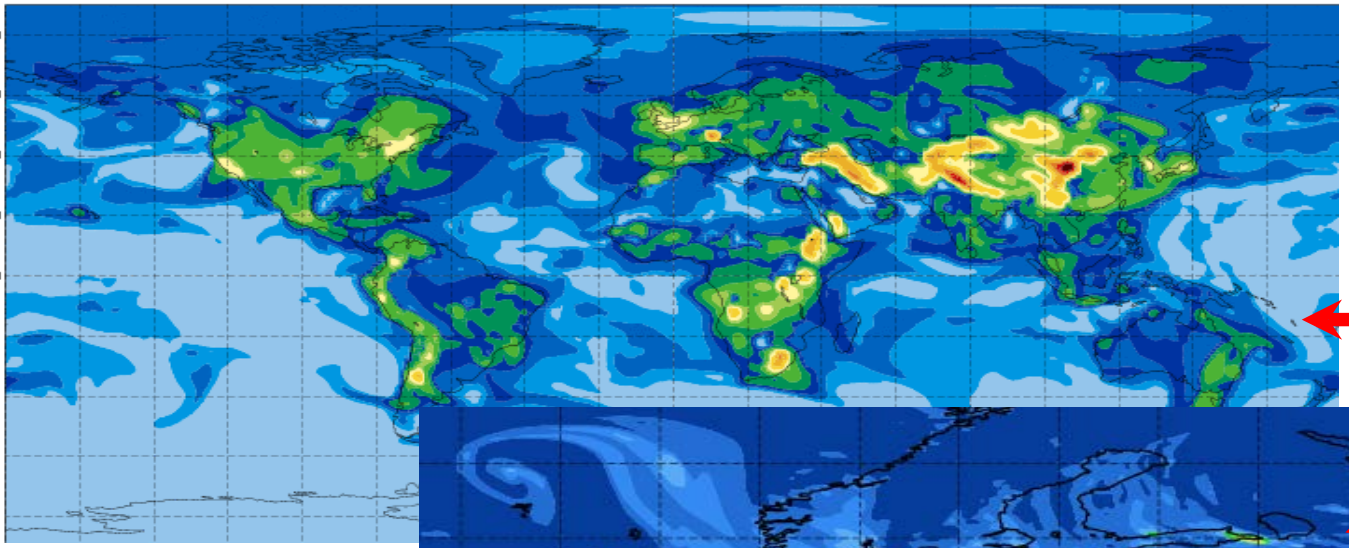


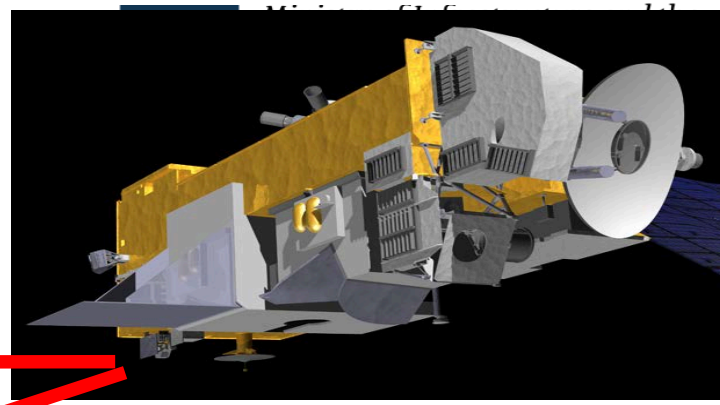
15 March



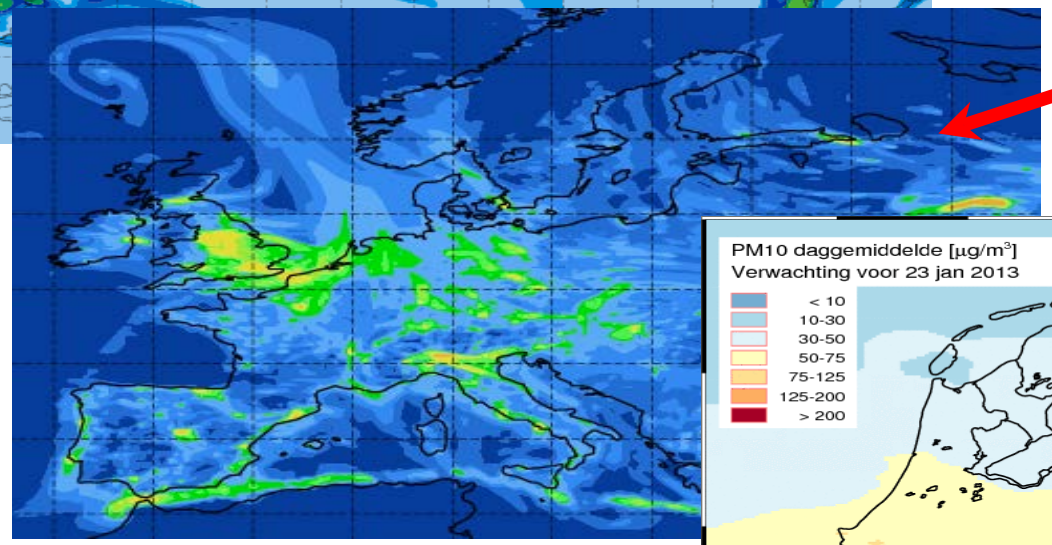
16 March

Copernicus Atmosphere: Air Quality product chain

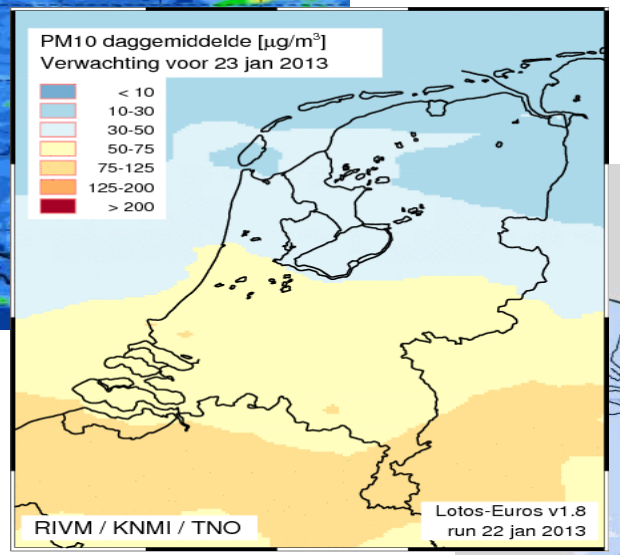




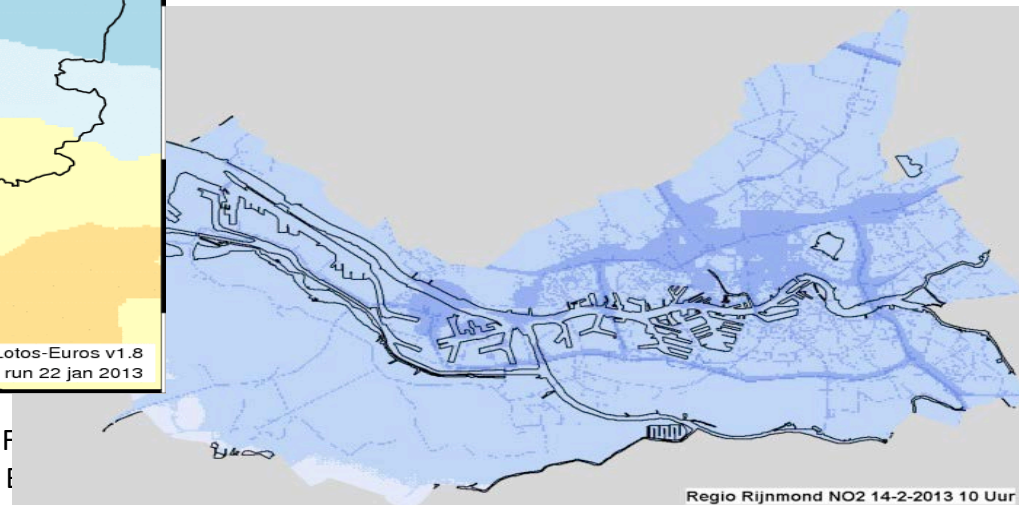
OMI NRT contributions



National forecasts:
Nesting in MACC regional



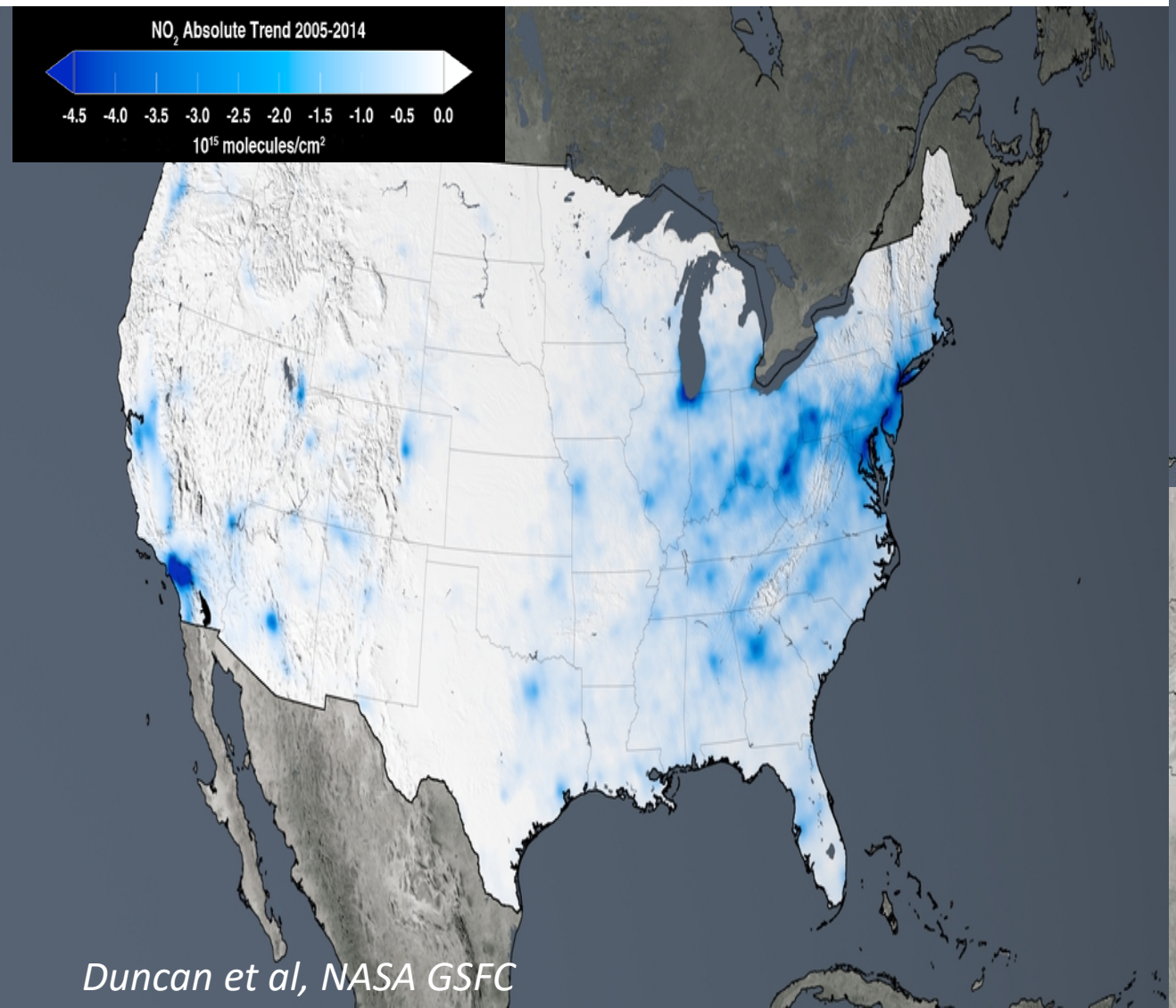
Couple to
city-scale models

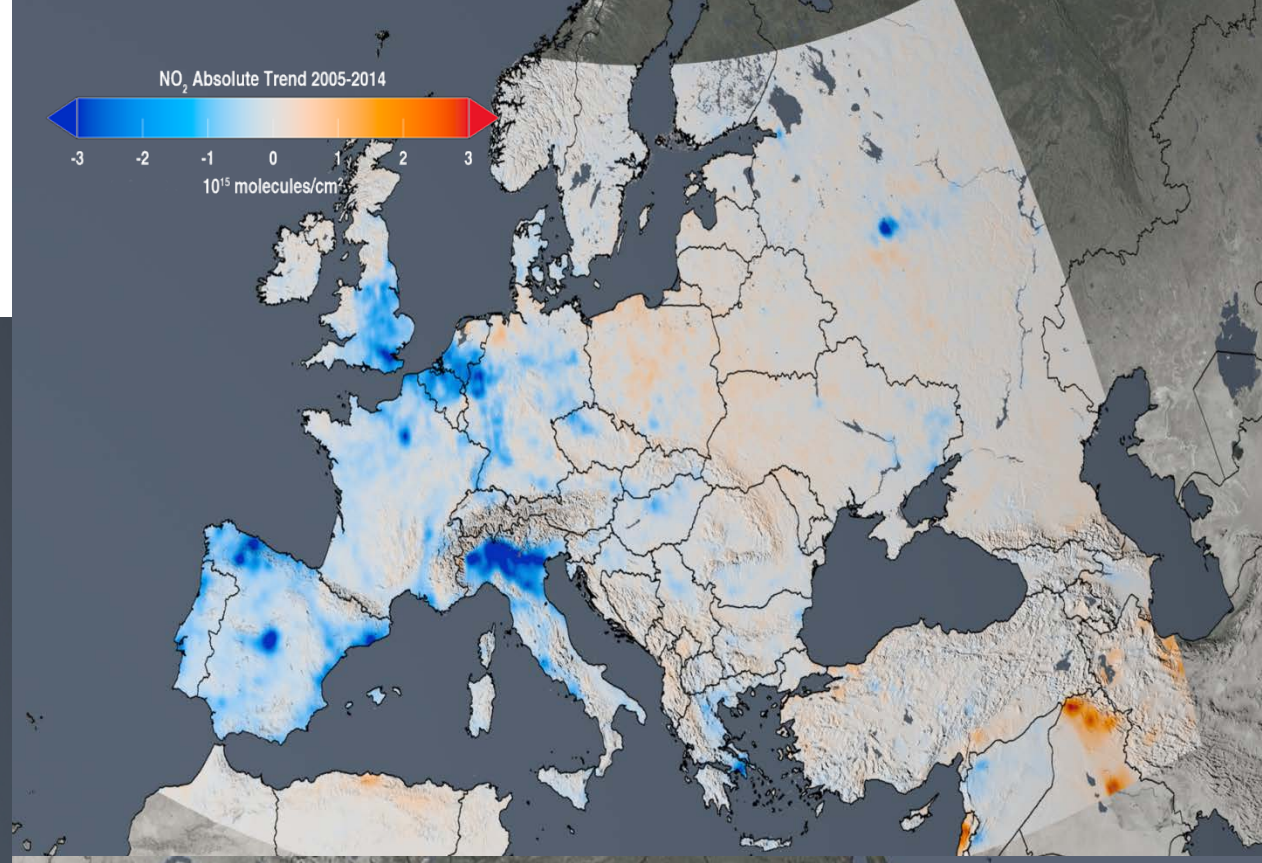


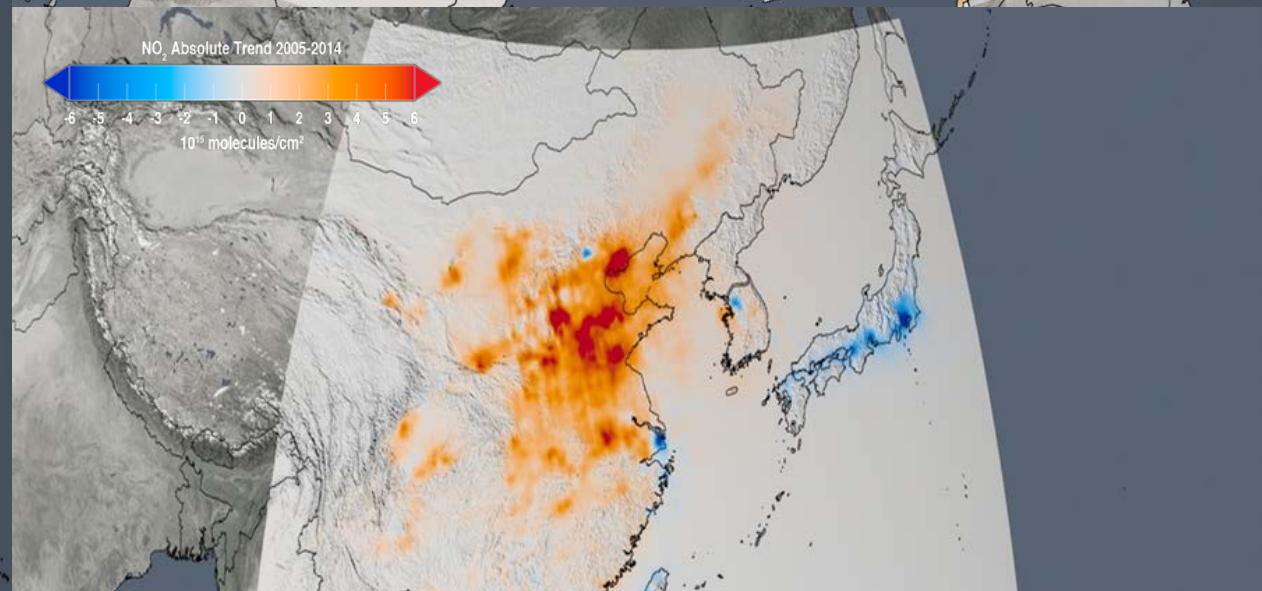
Use of
MACC-global analyses as
boundary conditions for
MACC-Europe

Prof. dr. P.F
KNMI, De B

OMI: 2005 compared to 2014 (NASA/KNMI)







Duncan et al, NASA GSFC

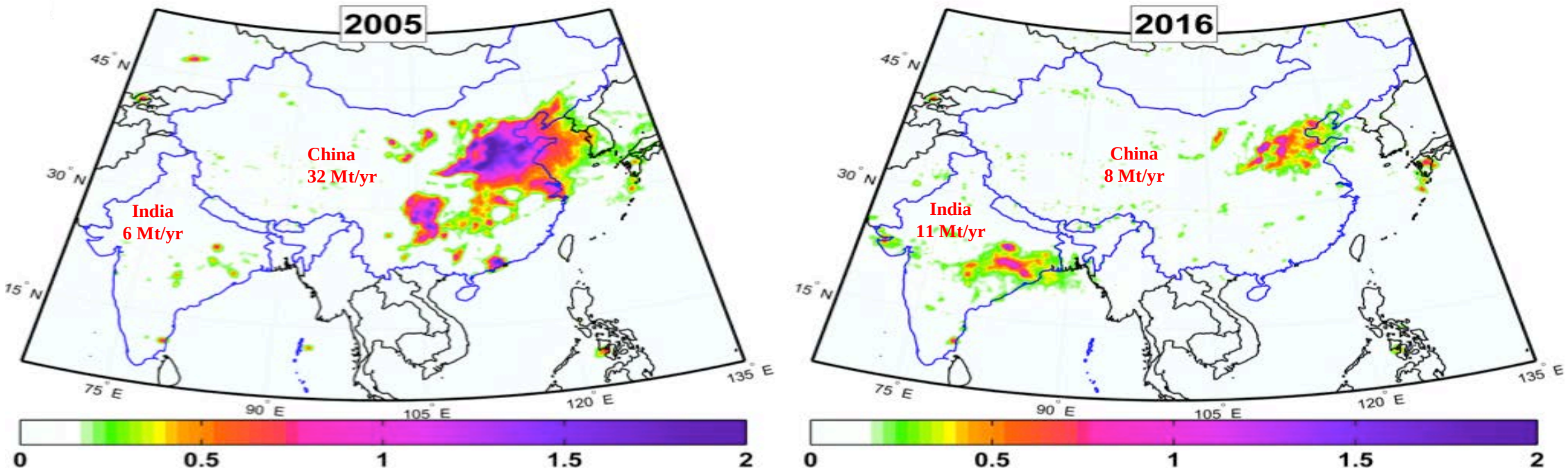
India Overtaking China as the Top Emitter of SO_2 Pollution

Can Li (Code 614, NASA/GSFC, UMD/ESSIC), Chris McLinden, Vitali Fioletov, Nickolay Krotkov, Simon Carn, Joanna Joiner, David Streets, Hao He, Xinrong Ren, Zhanqing Li, Russell Dickerson

ECCC, MTU, DOE/ANL, UMD/AOSC, NOAA/ARL

Annual Mean SO_2 Column Amounts *(DU)*

(with Aura OMI-based SO_2 emissions estimates)



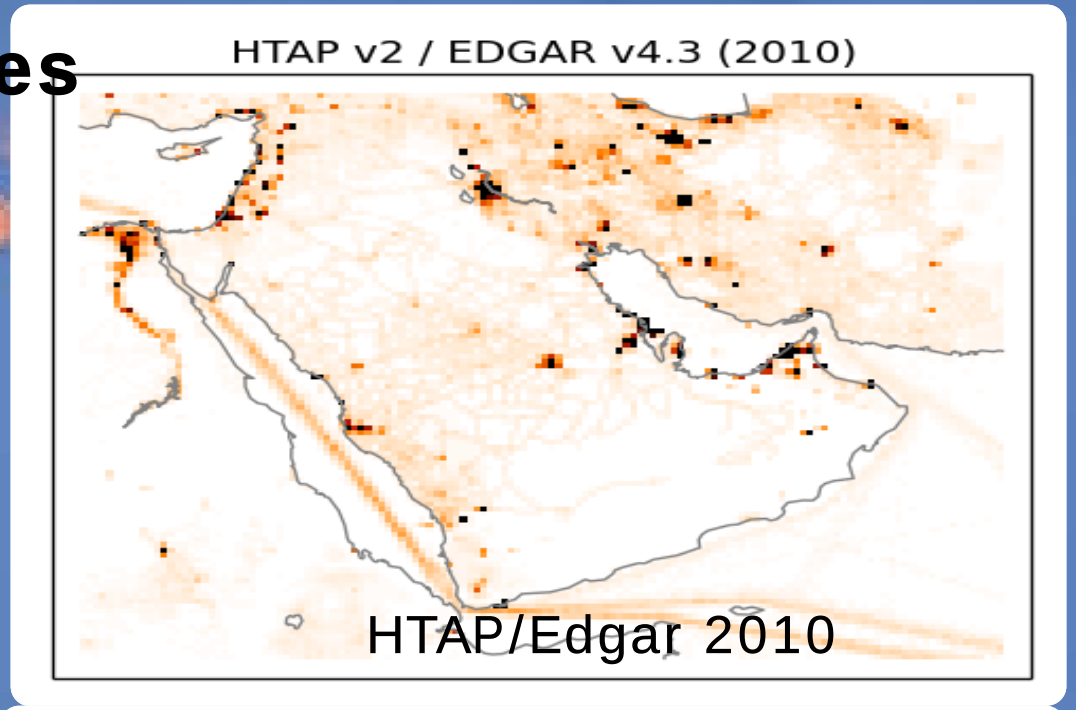
(Dobson Units; 1 DU = 2.69×10^{16} molecules/cm^2)

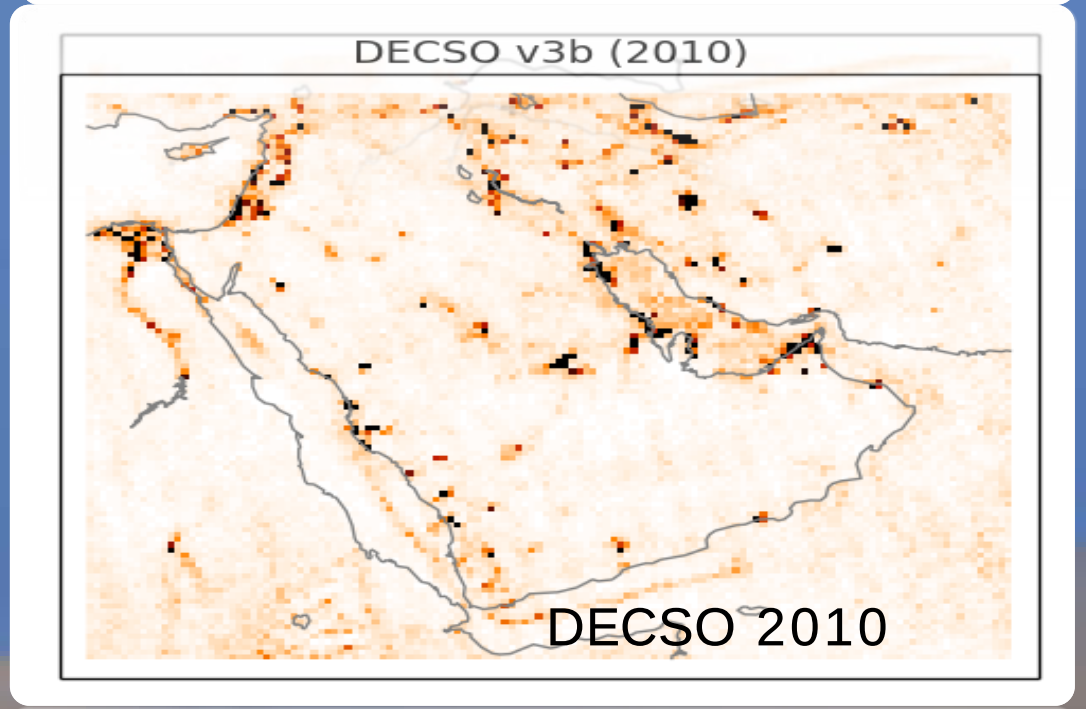
- **Anthropogenic SO_2** (mainly from coal burning): a major pollutant contributing to the severe haze in China and India.
- **Global satellite data record** of SO_2 pollution: produced by GSFC-based OMI Science Team, 13-year and ongoing.
- **OMI-based estimates** of SO_2 emissions: India is becoming the top emitter of anthropogenic SO_2 in the world, an unexpected development.
- **Coal consumption**: up by 100% in India and by 50% in China, effective control of SO_2 in China and continued lack of control in India.
- **Policy implications**: need to reduce other pollutants in China, and need to take action in India.

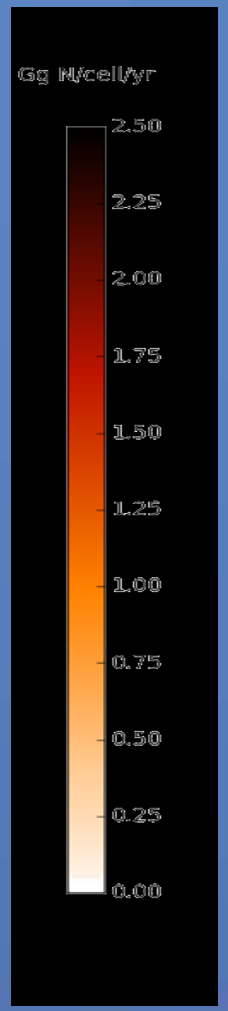
Li et al., *Scientific Reports*, 7, 14304, DOI:10.1038/s41598-017-14639-8, 2017.

Coverage: UMD and NASA Press Releases, Media Outlets including BBC World Service, Economic Times, Xinhua News, Quartz, Hindustan Times etc.

Top-down emission estimates based on satellite data





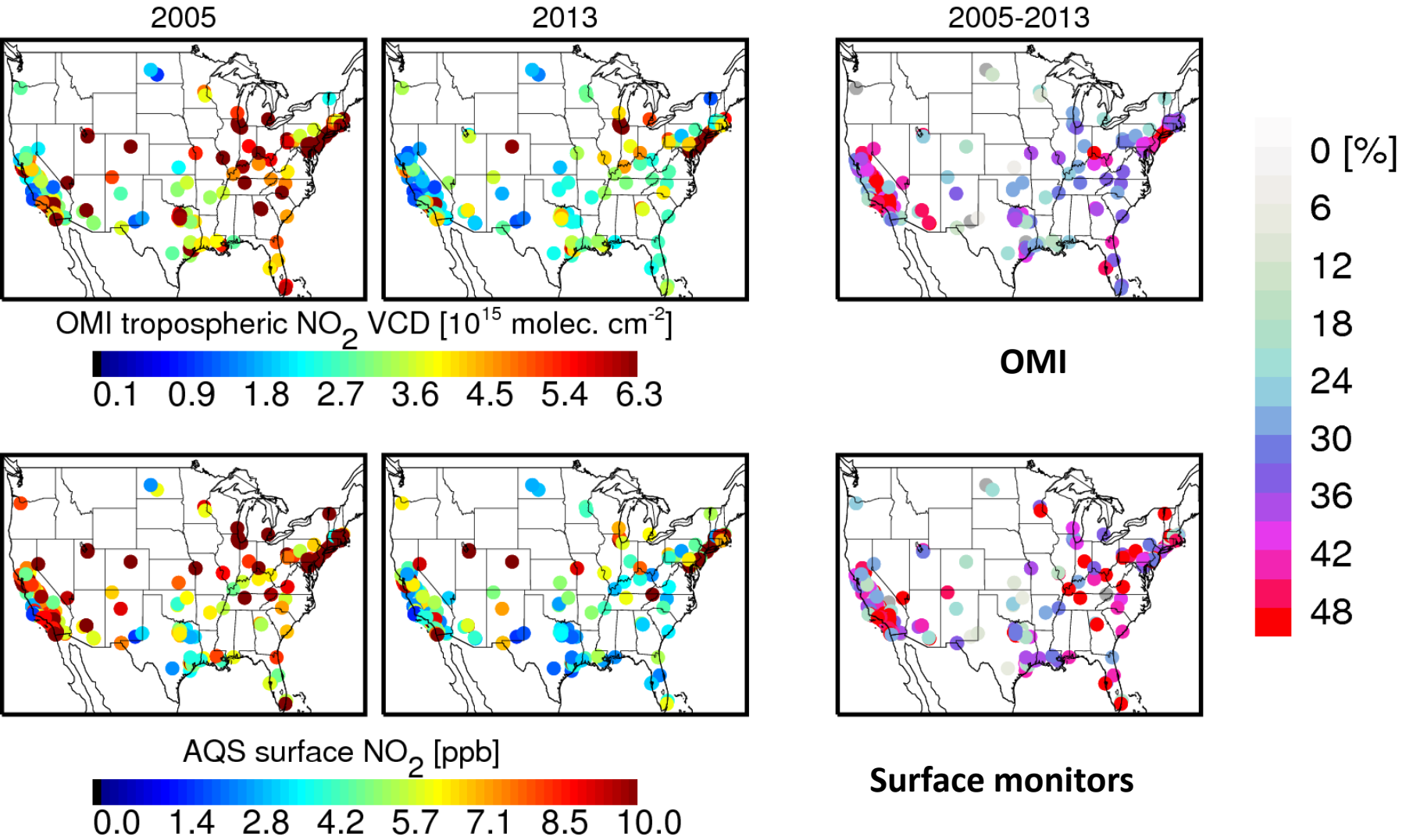


Daily emission estimates constrained by satellites: DECSO algorithm from KNMI

Bas Mijling , Ronald van der A
KNMI

How do OMI NO2 trends compare with surface measurements?

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment



Agreement remarkable:

(1) column vs. surface values;
(2) area average vs. point measurements;
(3) surface monitors measure NO_2 and some fraction of HNO_3, PAN, Alkyl nitrate

Lamsal et al., 2015

OMI Data Benefiting The Health Community

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

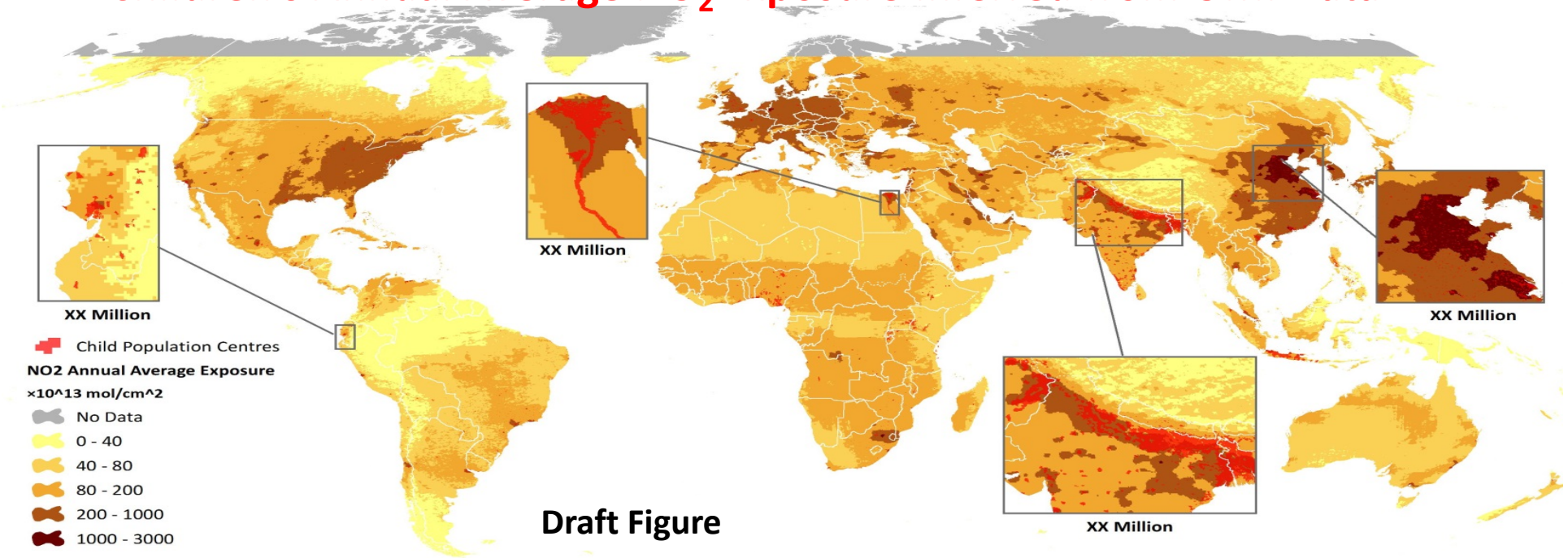
Cover of a similar report on climate change.

Report not available yet.

UNICEF Report: "The impact of air quality on children"

- Lok Lamsal sent them inferred surface OMI NO_2 data – NO_2 is well correlated with mortality and morbidity.
- Randall Martin's group (Dalhousie U.) sent inferred surface $PM_{2.5}$ data (from AOD data) – the most important pollutant for mortality and morbidity.

Children's Annual Average NO_2 Exposure Inferred from OMI Data



Draft Figure

OMI entering the climate domain

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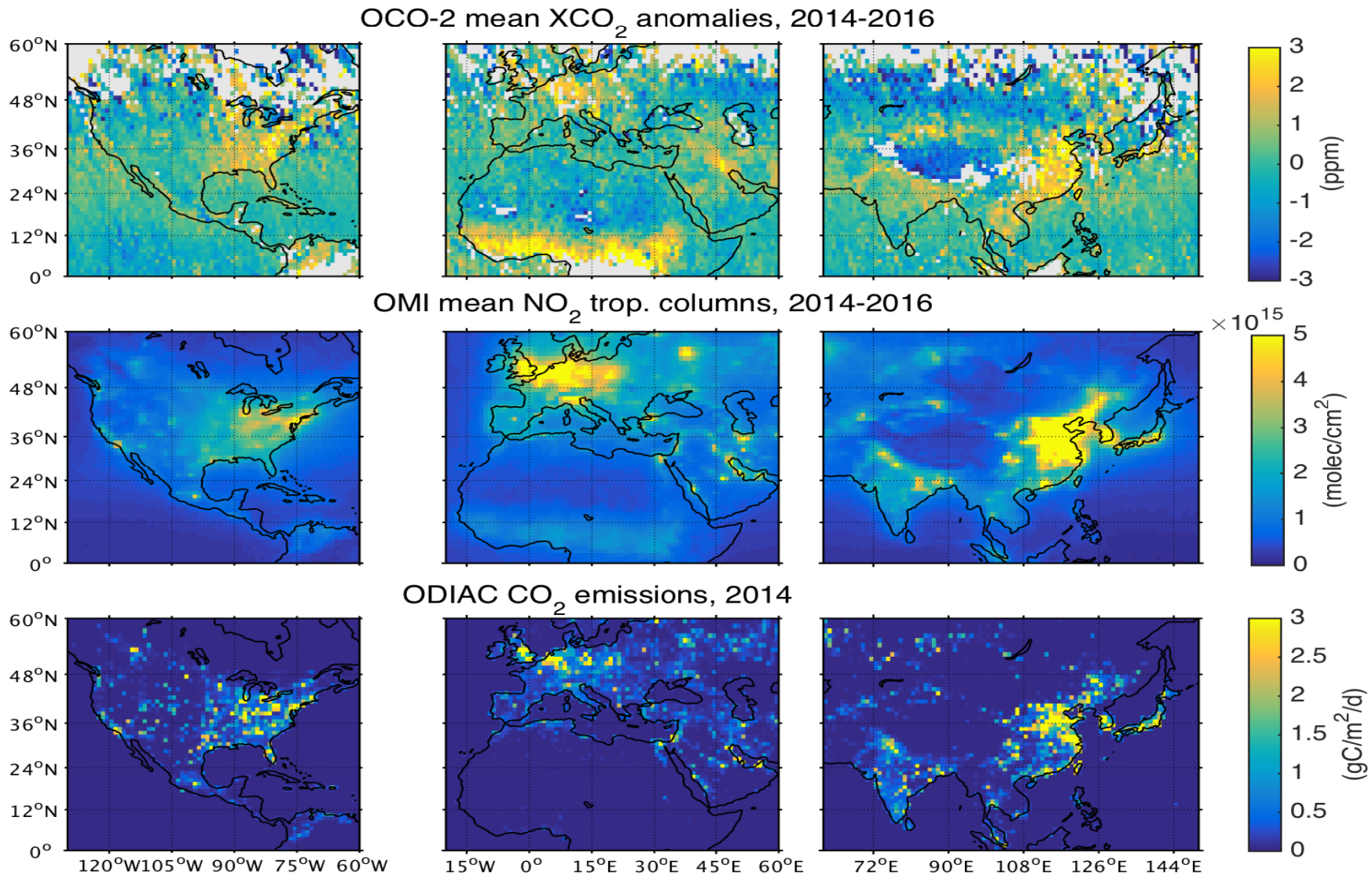
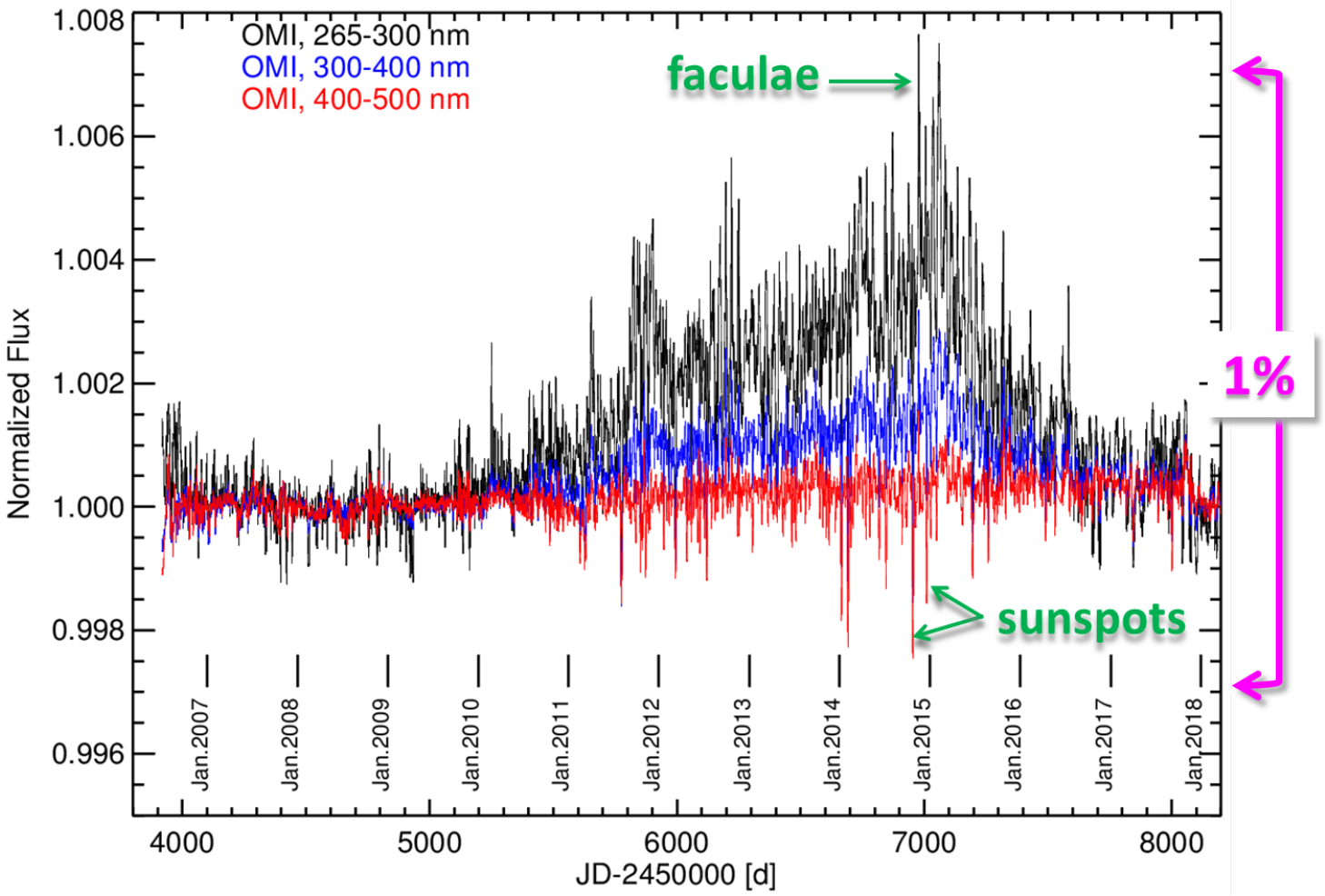


- First direct observation of anthropogenic CO_2 from OCO-2
- Synergy between OCO-2 CO_2 and OMI NO_2 data is used as a first step towards anthropogenic CO_2 identification
- CO2 anomalies are obtained deseasonalising and detrending the OCO-2 data

REFERENCE: Hakkarainen, J., et al.: Direct space-based observations of anthropogenic CO_2 emission areas from OCO-2, Geophys. Res. Lett., in review, 2016.

OMI Solar Spectral Irradiance (SSI)

- OMI's unprecedented stability and characterization has made it a standard for UV/Vis SSI measurements
- OMI SSI data set (2006-2018) now covers full range of solar cycle 24
- Short-term solar variability (bright faculae, dark sunspots) clearly seen with high precision
- Long-term accuracy (0.1% in UV, 0.05% in visible)
- OMI data being used to validate SSI models (e.g. NRLSSI2)



Marchenko et al., *Earth and Space Science, in review.*

OMI's Lessons learned

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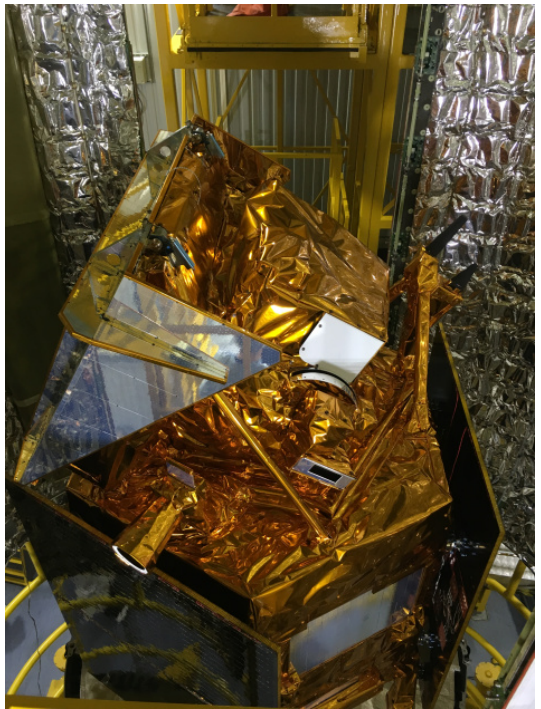
Ministry of Infrastructure and the Environment

- Scientists and engineers should work together
- For a cross-Atlantic combined international science team, such as OMI, at start 2 to 3 face-to-face meetings a year are essential to built trust and confidence between the teams and their leaders
- Level 0-1b/ calibration (on-ground and in-flight) should be a 1 team approach
- Balancing requirements – they are not always black and white
- Outgassing an optical spectrometer instrument after launch for a month , and being the last instrument to cool down on the spacecraft, is essential to limit the risk on contamination
- Straylight, spectral features and other complicated optical effects are a hell of a job to capture, get rid of, or get corrected. However their requirements can never be dropped to limit costs or annoying discussions.
- International Team co-operation is fun! and leads to innovation (algorithms amd science!)
- Do not use MLI in the neighborhood of an entrance slit!!!! (Row anomaly)



Aura Meetings in the USA

OMI Science Team Meetings at KNMI

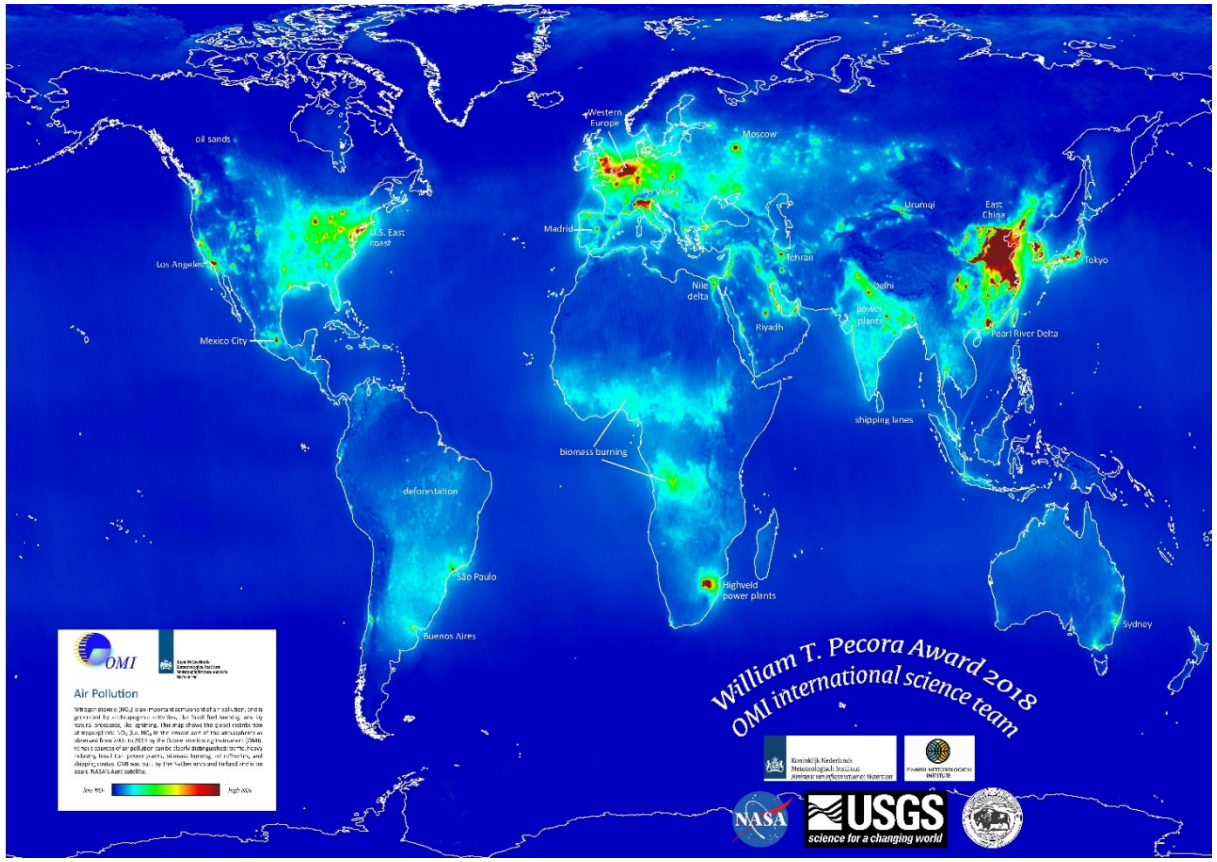
Very serious PI

Toys for boys

The Prince of the house of Orange
of The Netherlands

OMI team receives USGS/NASA 2018 Pecora award

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

- **OMI team (**Dutch, Finnish, and American scientists) won for "15+ years of sustained team innovation and international collaboration to produce daily global satellite data that revolutionized urban air quality and health research."

OMI 2005-2014 tropospheric column NO_2 shows pollution emitted from fossil fuel combustion