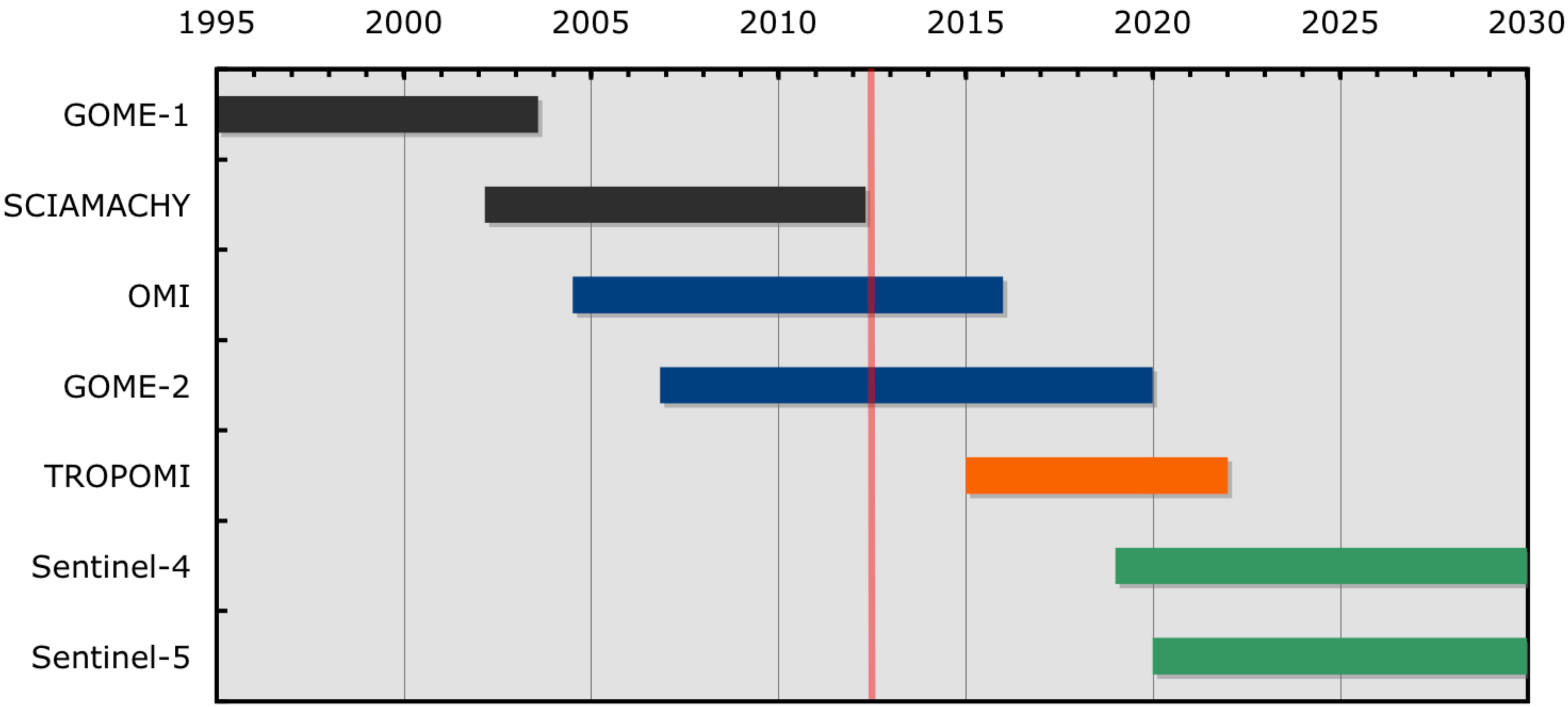
Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

Aerosol measurements by spectral instrumentation

Pieternel Levelt, Pepijn Veefkind, and Piet Stammes

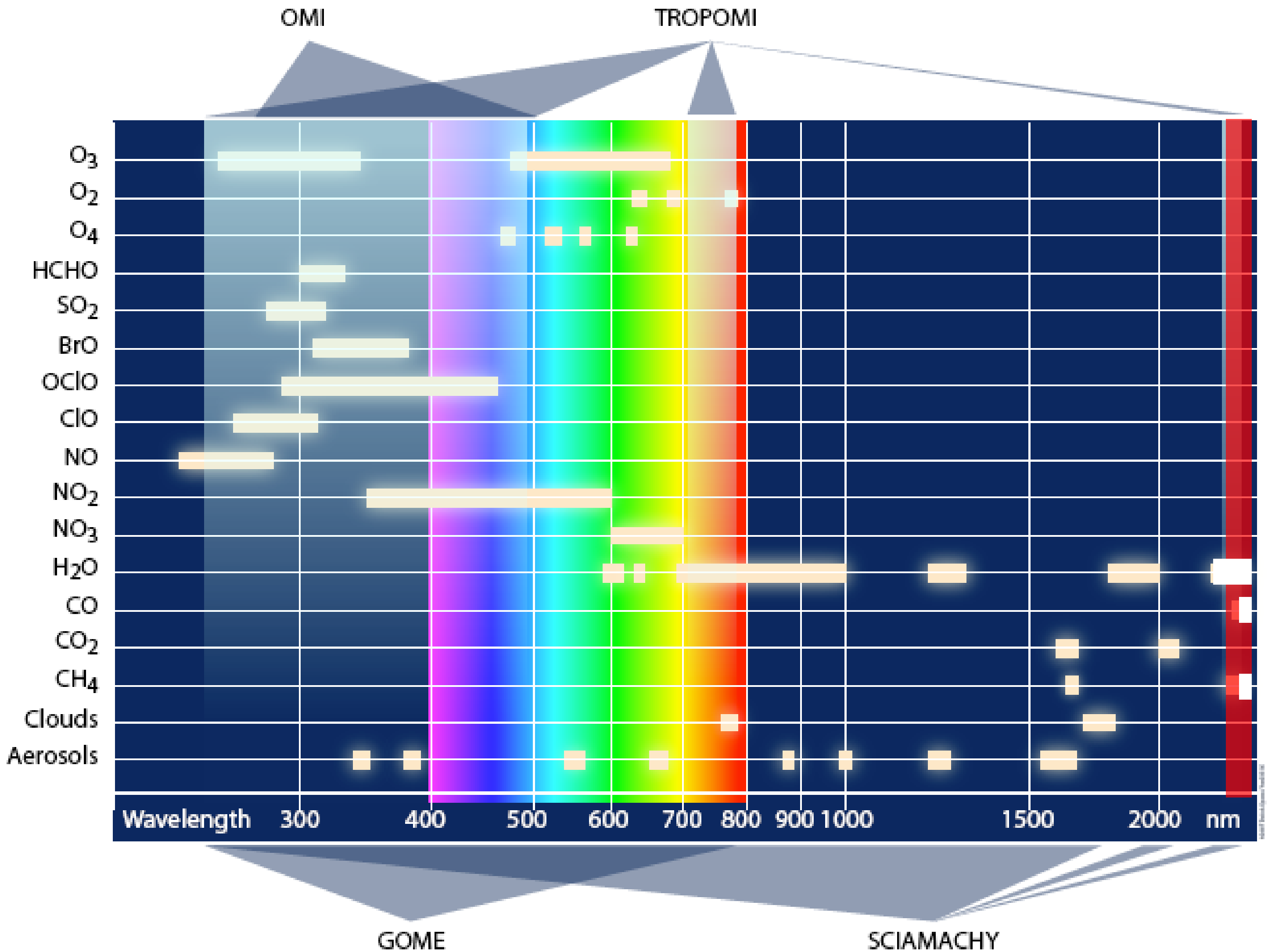
Prof. dr. Pieternel F. Levelt
Head Climate Observations KNMI
Professor at TU Delft (Climate Centre)
Principal Investigator OMI

Solar Backscatter satellite instruments measuring atmospheric composition



KNMI is Principal Investigator of OMI and TROPOMI
TROPOMI will fly on ESA's sentinel 5p

wavelength range and products



Ozone Monitoring Instrument OMI

- UV and VIS backscatter instrument (270 - 500 nm)

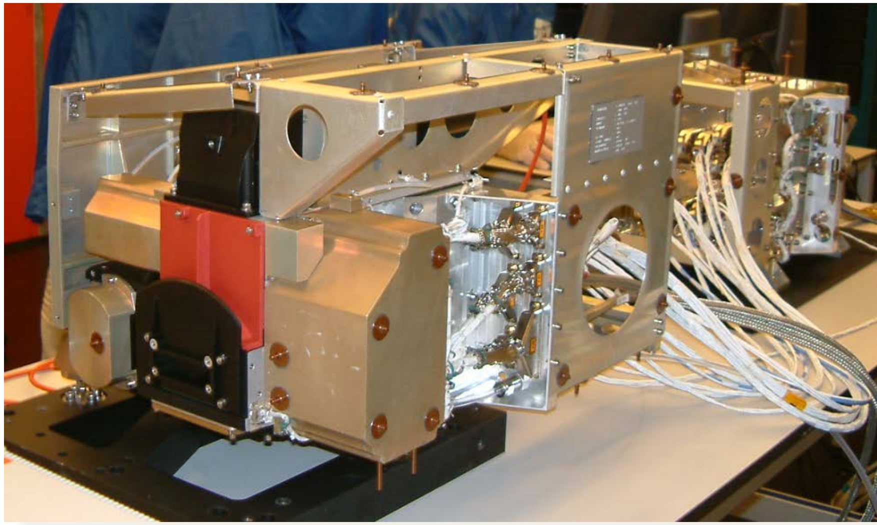
- Wide swath telescope yields daily global maps (2600 km)

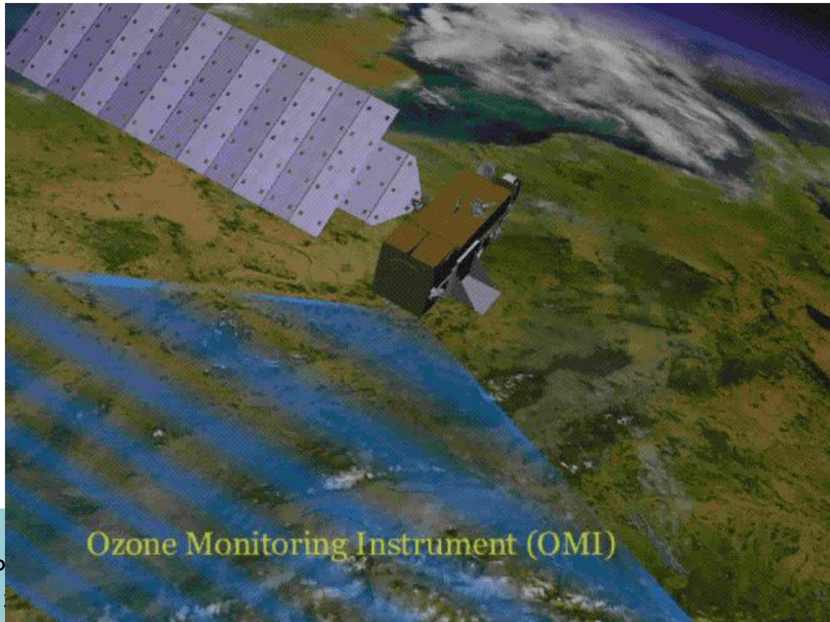
- Urban scale resolution is best ever for air quality measurements from space

(13 x 24 km^2)

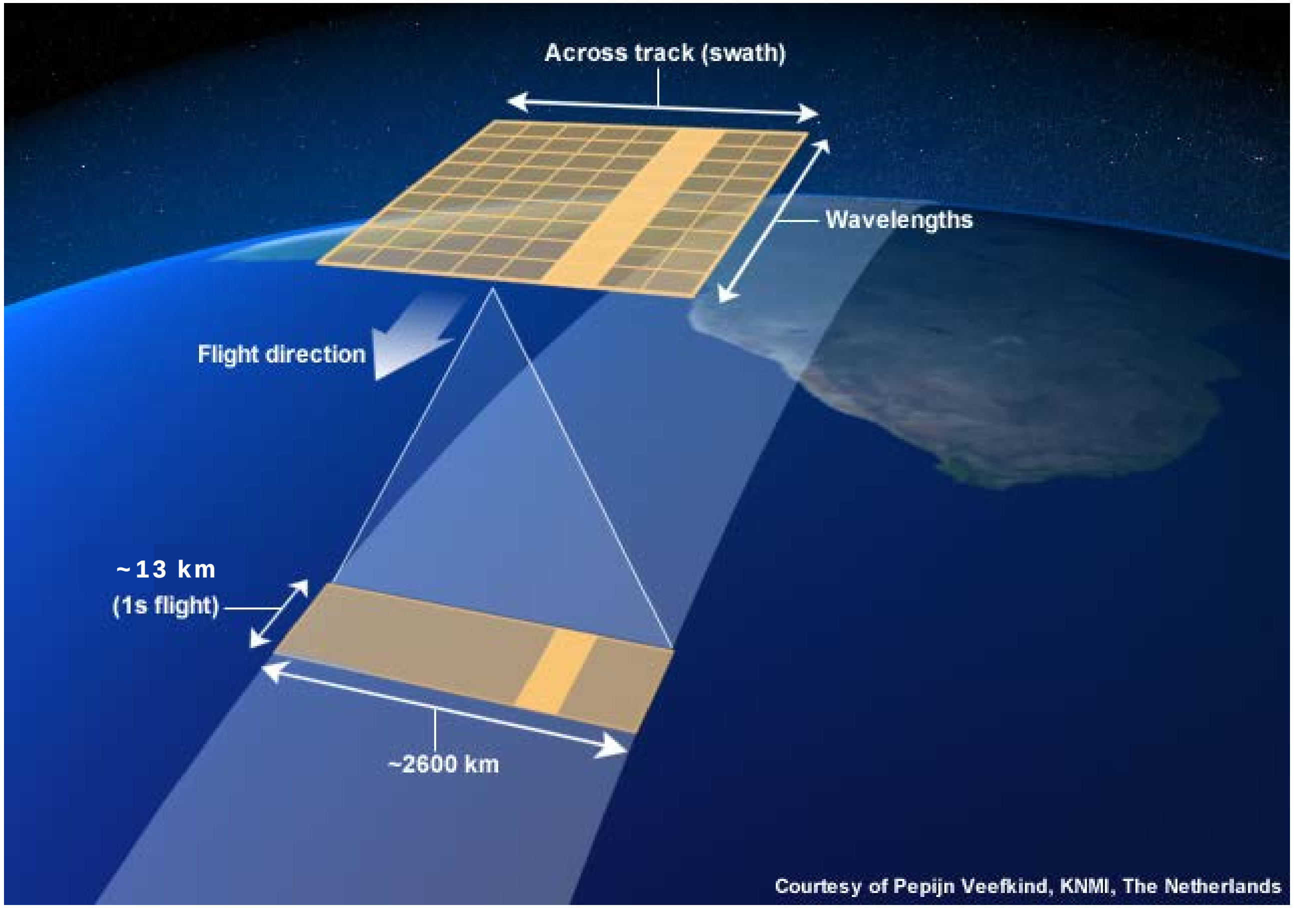
Dutch-Finnish instrument launched at NASA's EOS-Aura in July 2004

Heritage: GOME, SCIAMACHY, GOMOS and TOMS





The technical heart of the OMI instrument



sentinel-5 precursor

COPERNICUS/GMES ATMOSPHERE MISSION IN POLAR ORBIT

The ESA Sentinel-5 Precursor (S-5P) is a pre-operational mission focussing on global observations of the atmospheric composition for air quality and climate.

The TROPOspheric Monitoring Instrument (**TROPOMI**) is the payload of the S-5P mission and is jointly developed by The Netherlands and ESA.

The planned launch date for S-5P is 2015 with a 7 year design lifetime.

TROPOMI

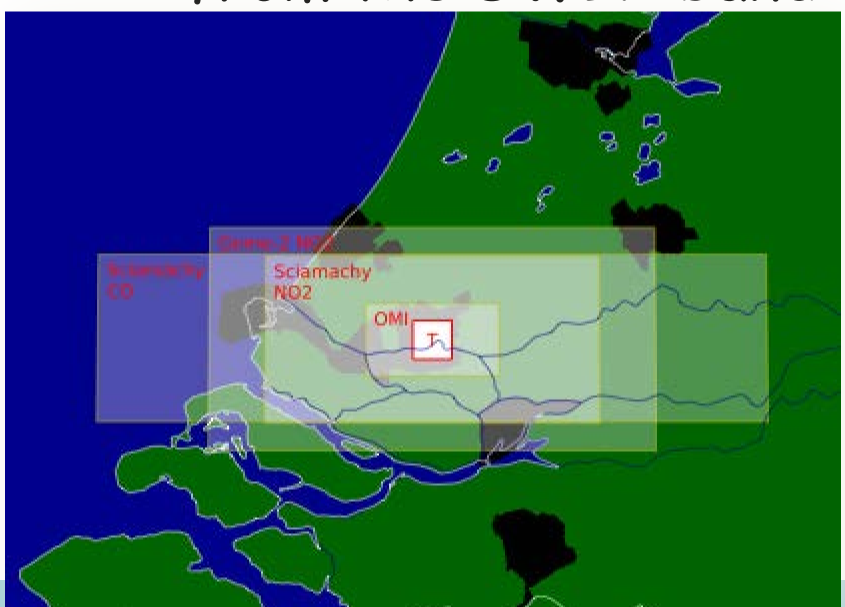
- UV-VIS-NIR-SWIR nadir view grating spectrometer.
- Spectral range: 270-500, 675-775, 2305-2385 nm
- Spectral Resolution: 0.25-1.1 nm
- Spatial Resolution: $7x7km^2$
- Global daily coverage at 13:30 local solar time.

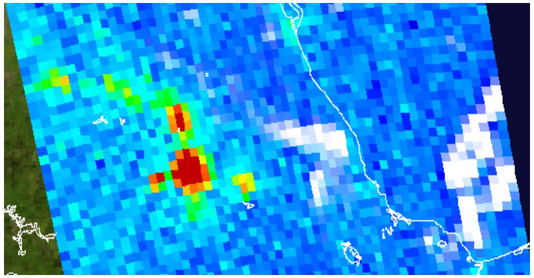
CONTRIBUTION TO GMES

- Total column O_3, NO_2, CO, SO_2, CH_4, CH_2O, H_2O, BrO
- Tropospheric column O_3, NO_2
- O_3 profile
- Aerosol absorbing index, type, optical depth

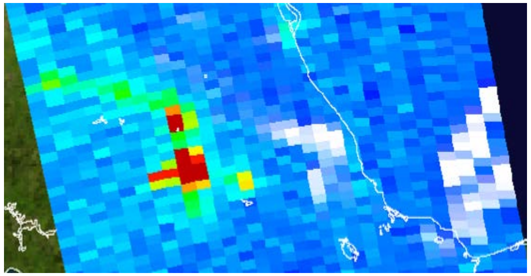
From OMI to TROPOMI: unprecedented spatial resolution

- 6x **higher spatial resolution** 7x7 km^2 vs. 13x24 km^2
- 1-5x **higher signal-to-noise**
- **better cloud information** from the oxygen A band
- **CO and CH_4 observations** from the SWIR band

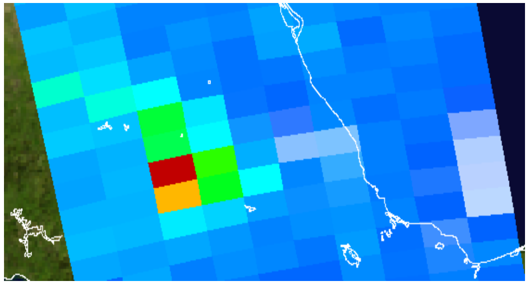




OMI Zoom 12x13 km^2

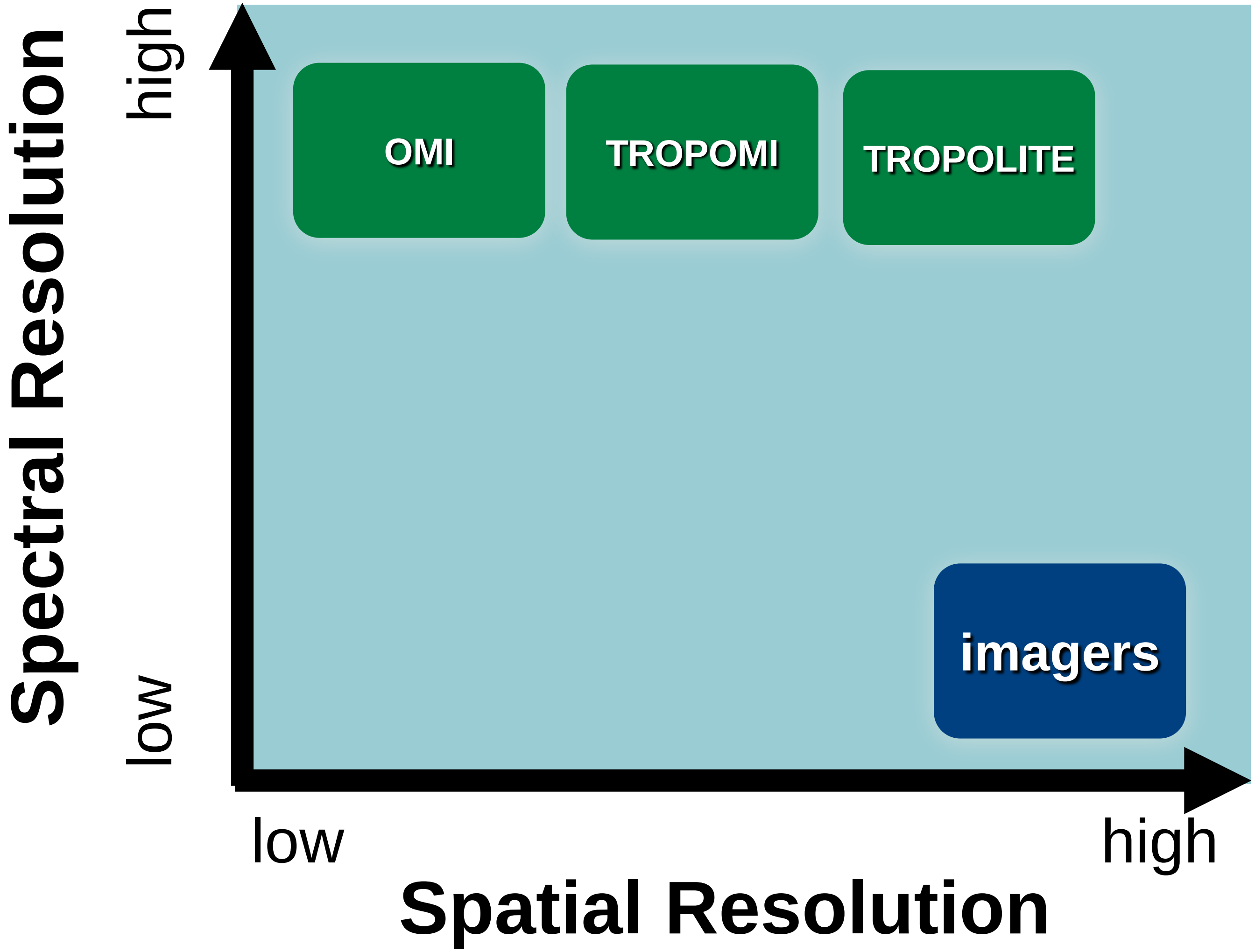


OMI 24x13 km^2



Approx. GOME-2 72x39 km^2

New developments: TROPOLITE: 2 x 2 km^2 and daily global coverage



Satellite aerosol retrievals at KNMI

Absorbing aerosol index (AAI)
GOME, SCIAMACHY, GOME-2 A+B and OMI
(De Graaf et al., JGR, 2006; Tilstra et al., JGR, 2012) - *www.temis.nl*

Aerosol layer height from O2 A-band
GOME, SCIAMACHY, GOME-2 A+B
(Wang et al., ACP, 2012; Sanders and De Haan, AMT, 2013)

Aerosol direct radiative effect from SCIAMACHY
(De Graaf et al., JGR, 2012)

AOD from OMI *(Torres/Braak/Veihelmann)*

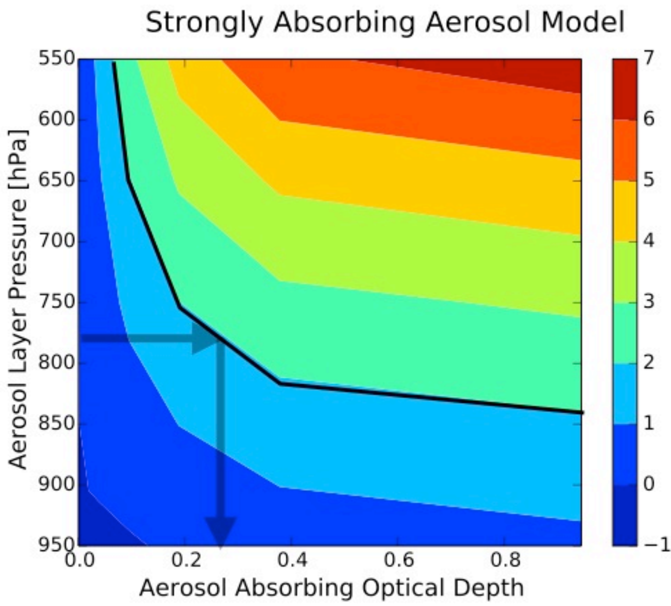
TROPOMI: AAI, aerosol layer height and AAOD(future)

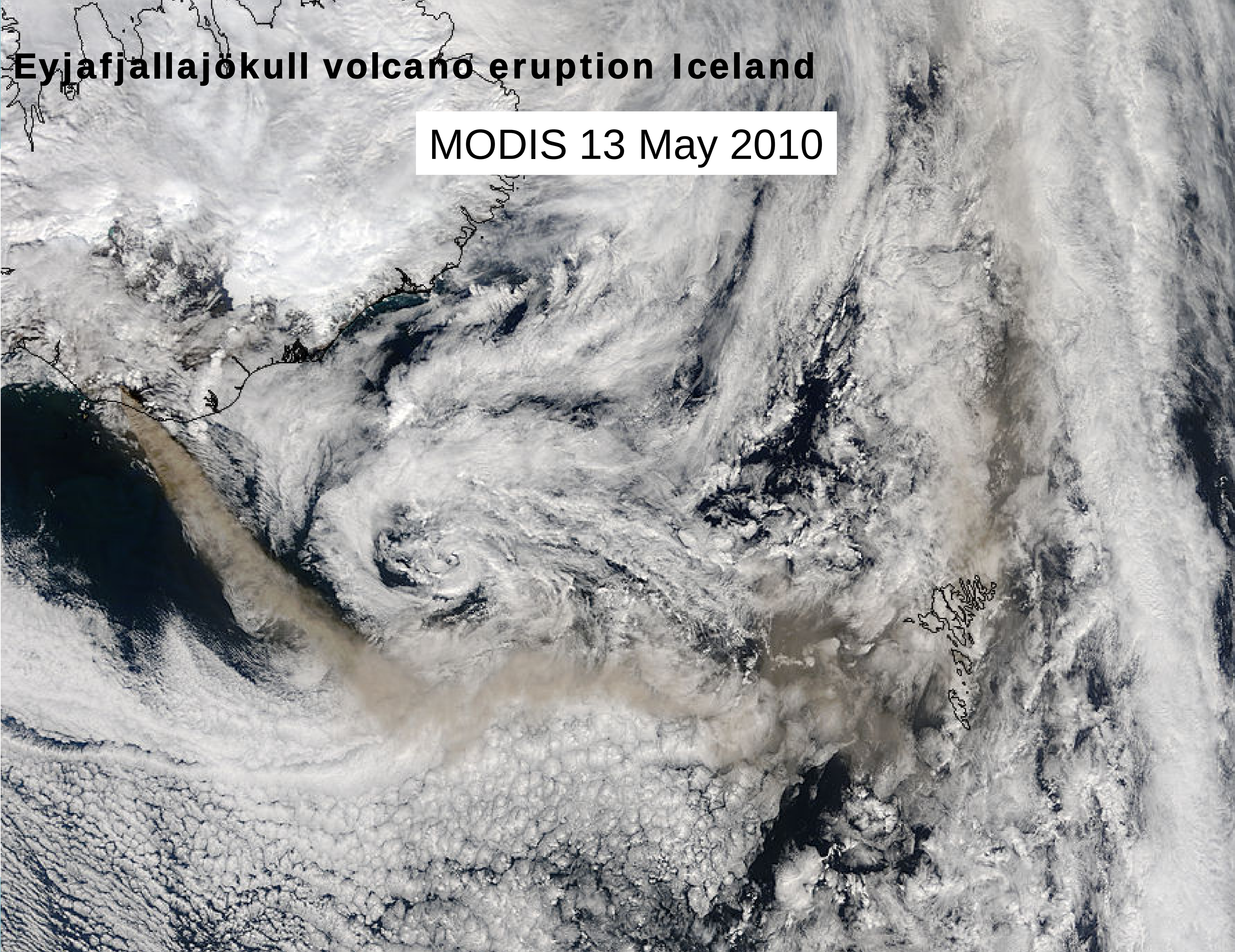
Special features of UVVIS spectral instrumentation:

•Spectral instruments in the UV are sensitive for absorbing aerosols, even above clouds (AAI)

•It is more difficult to calculate AOT and SSA, than AAI, since these products are severely compromised by clouds.

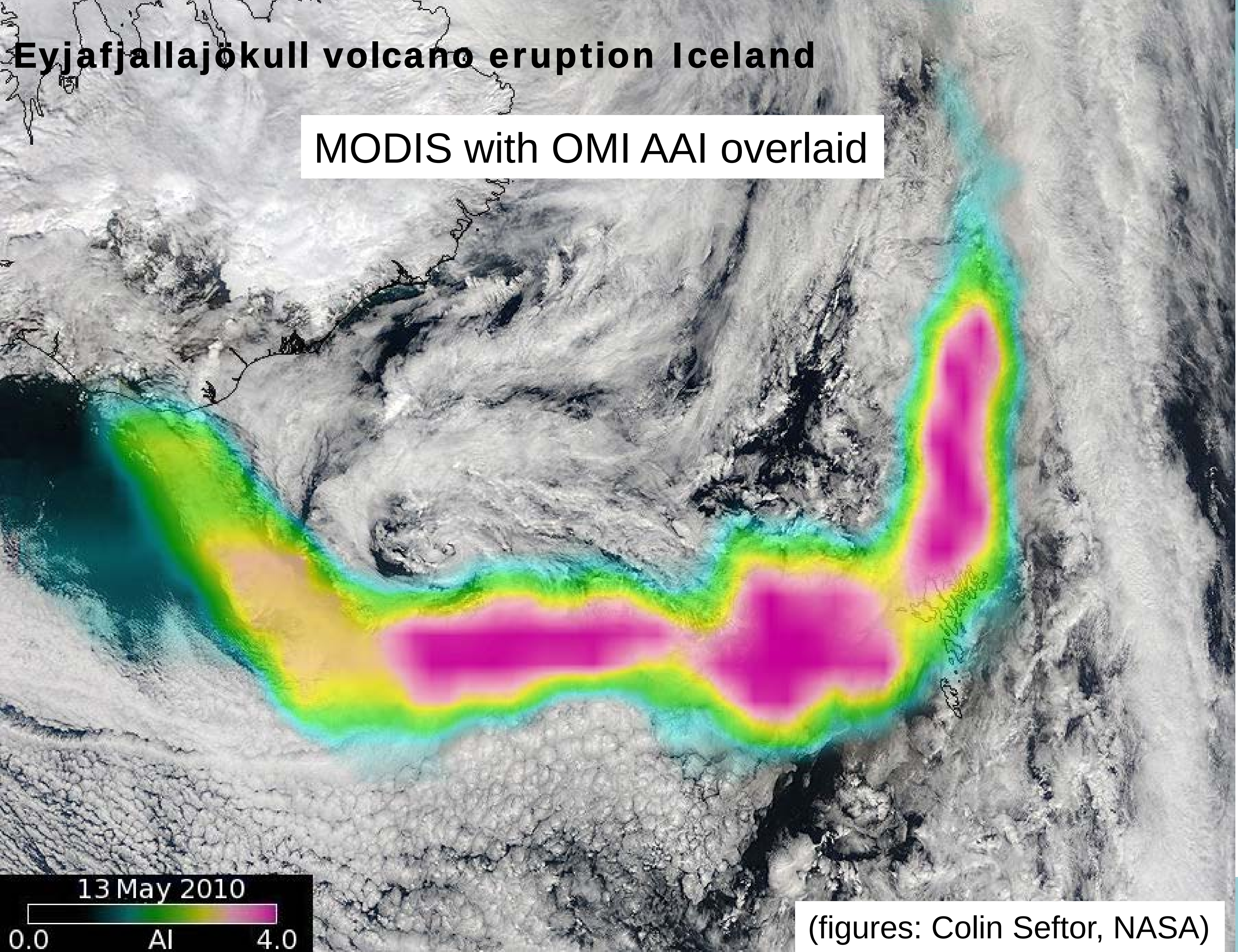
•AAOD product: also information on aerosol height is needed



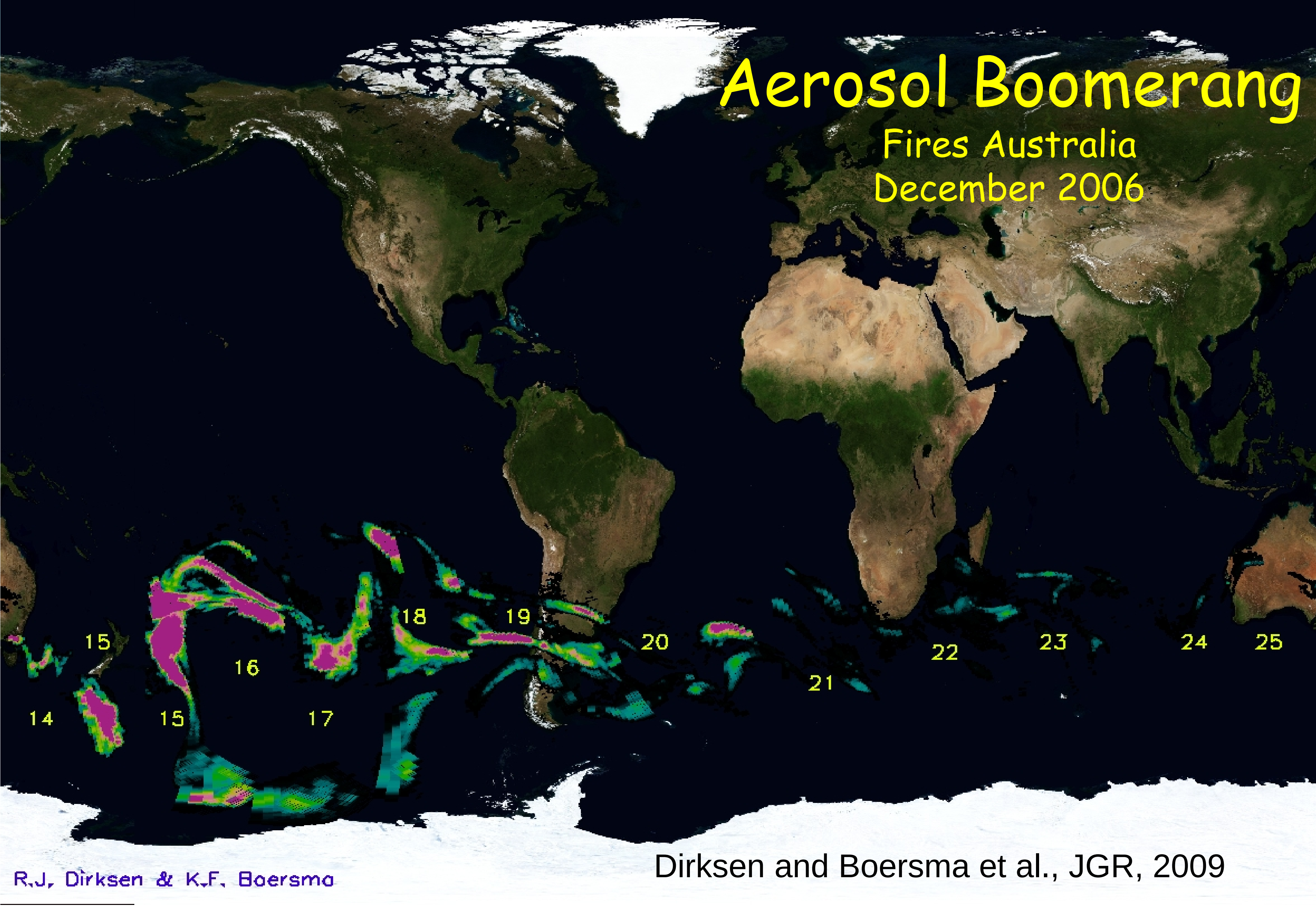

Eyjafjallajökull volcano eruption Iceland
MODIS 13 May 2010

Eyjafjallajökull volcano eruption Iceland

MODIS with OMI AAI overlaid

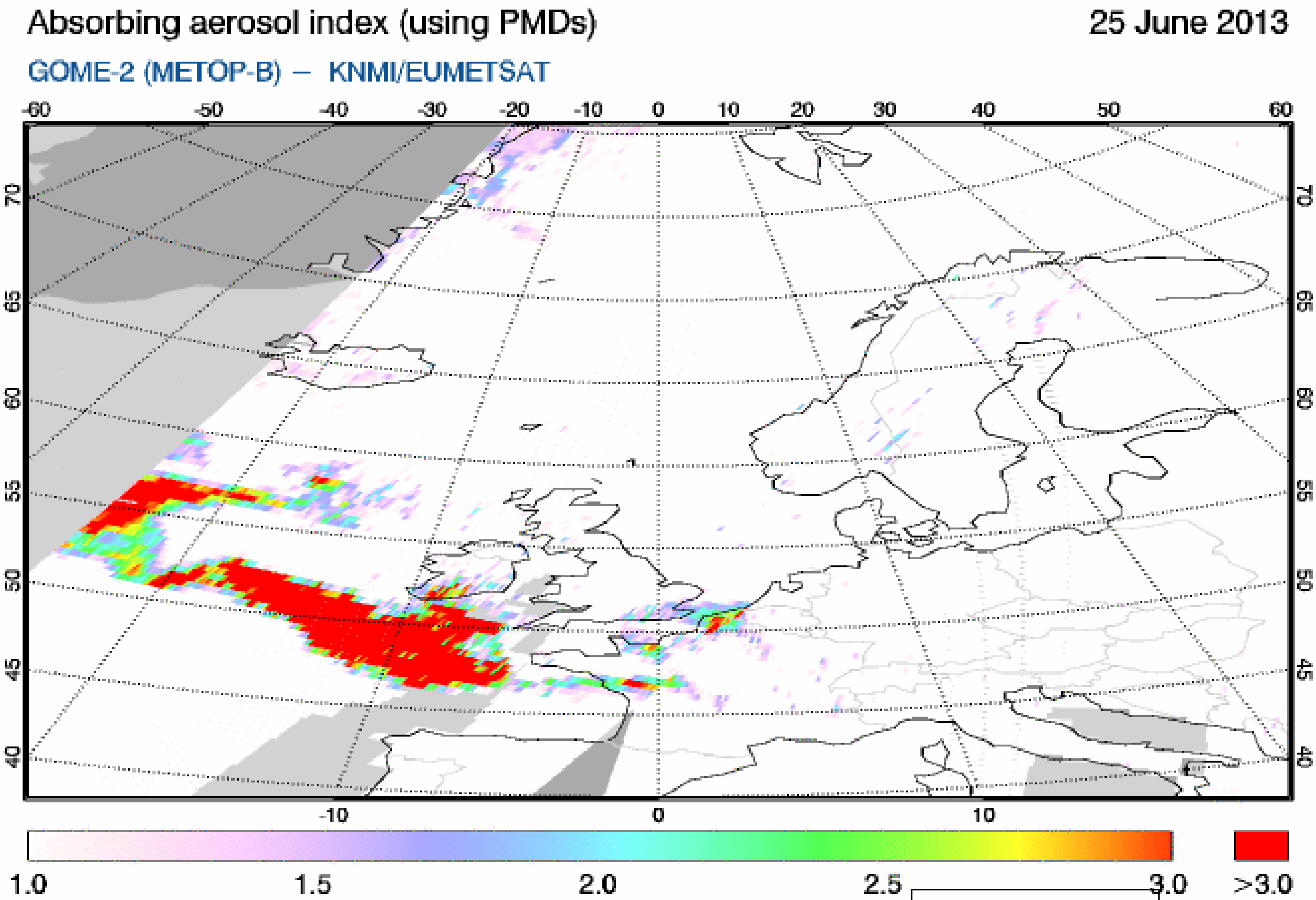


(figures: Colin Seftor, NASA)



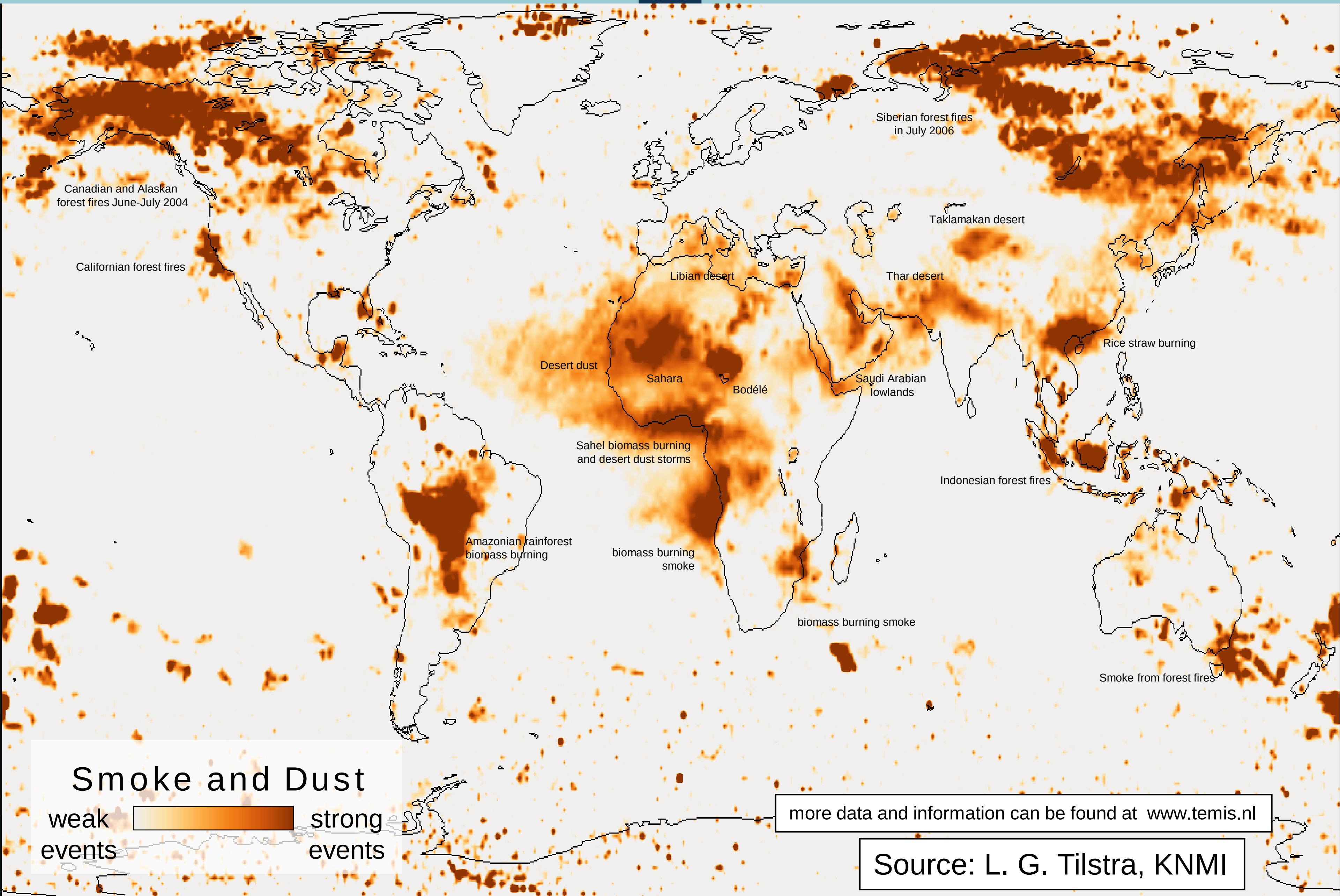
Dirksen and Boersma et al., JGR, 2009

AAI for event monitoring: Smoke from N-American wildfires



www.temis.nl

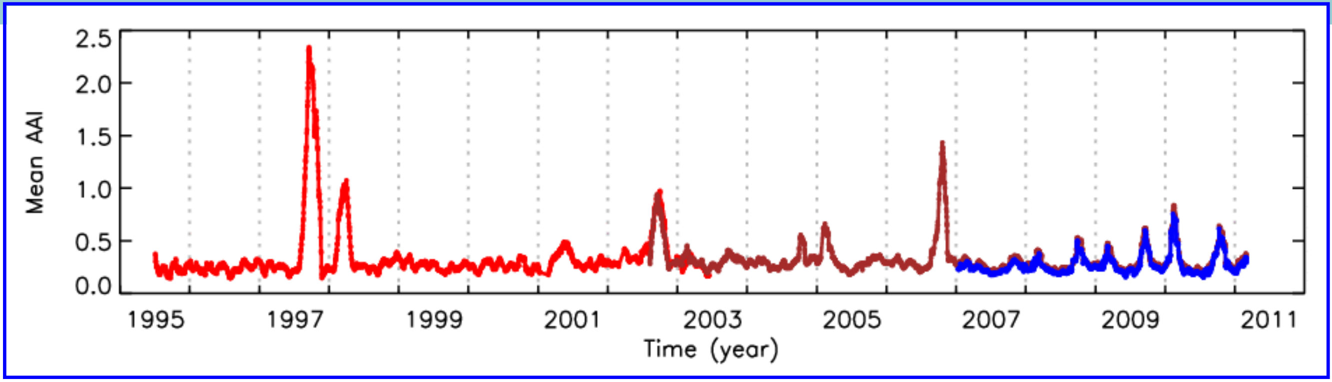
Absorbing aerosols 2002 - 2010 from SCIAMACHY



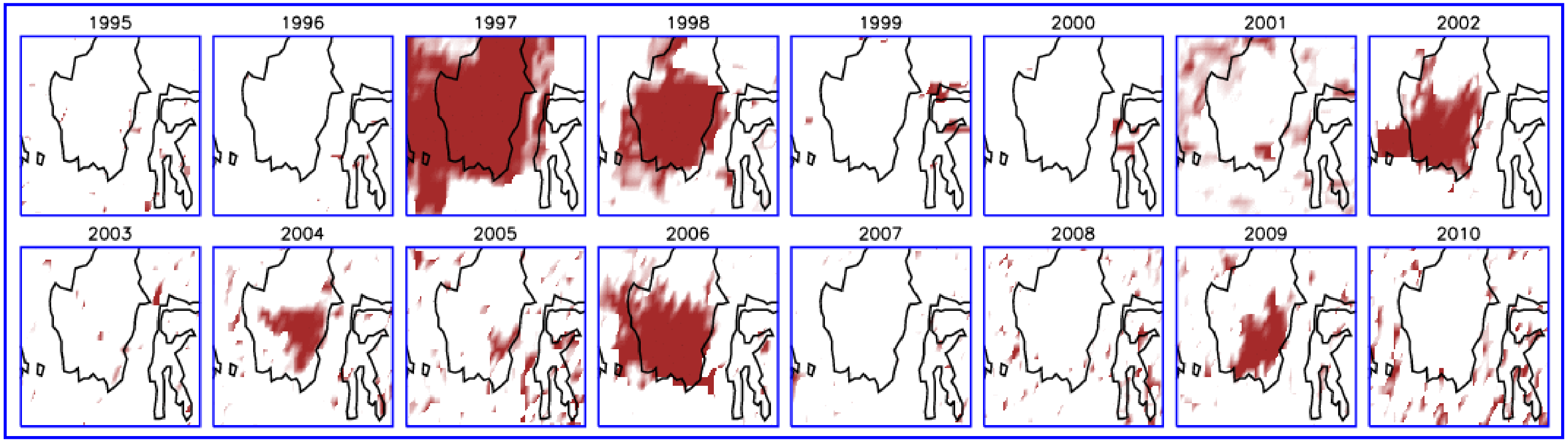
more data and information can be found at www.temis.nl

Source: L. G. Tilstra, KNMI

Smoke over Borneo from AAI, 1995 -2010



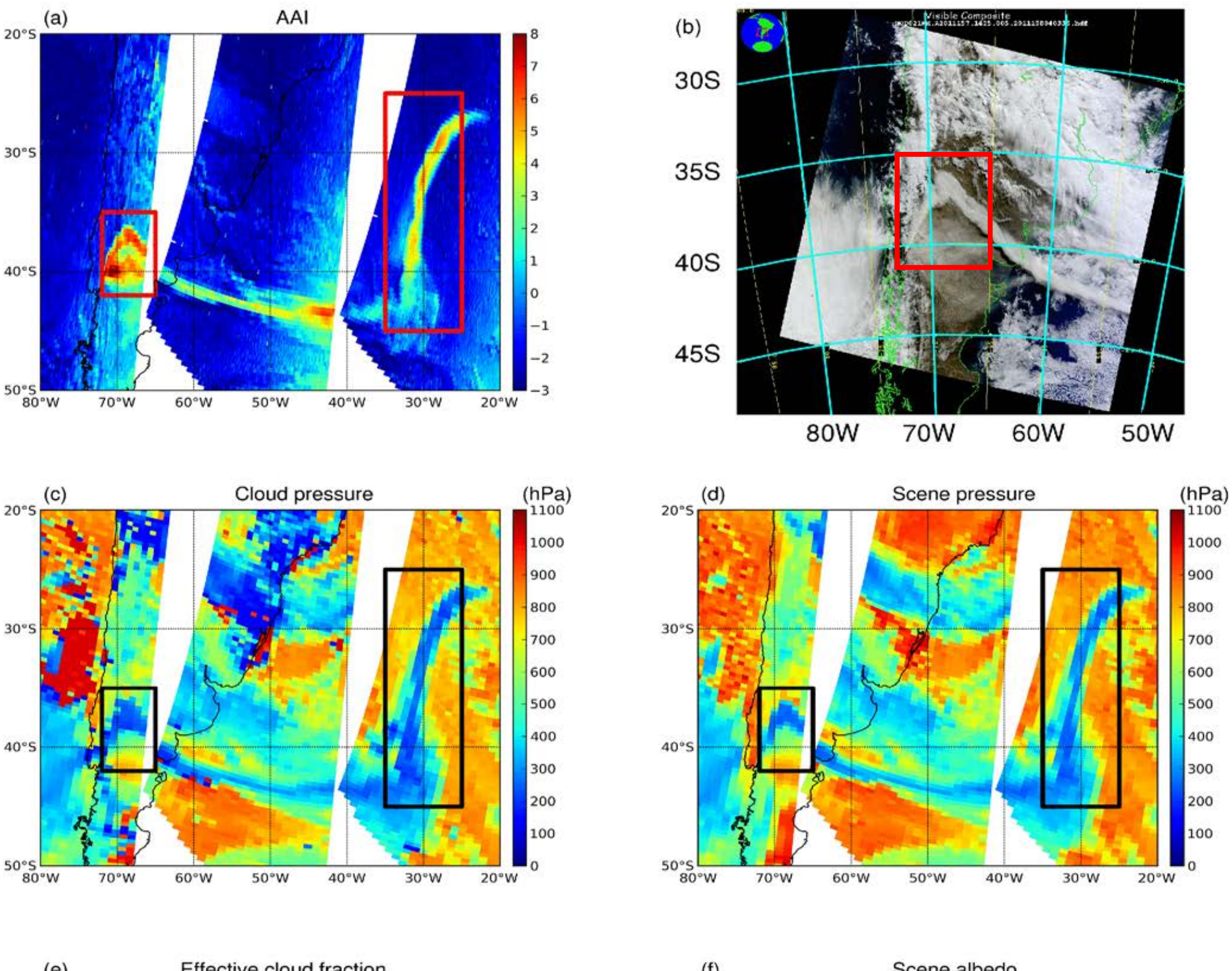
1997/1998 El Niño: drought caused many forest fires; 120.000 km^2 forest burned.



Satellite data sources: GOME, SCIAMACHY, GOME-2

Figure: L.G. Tilstra, KNMI

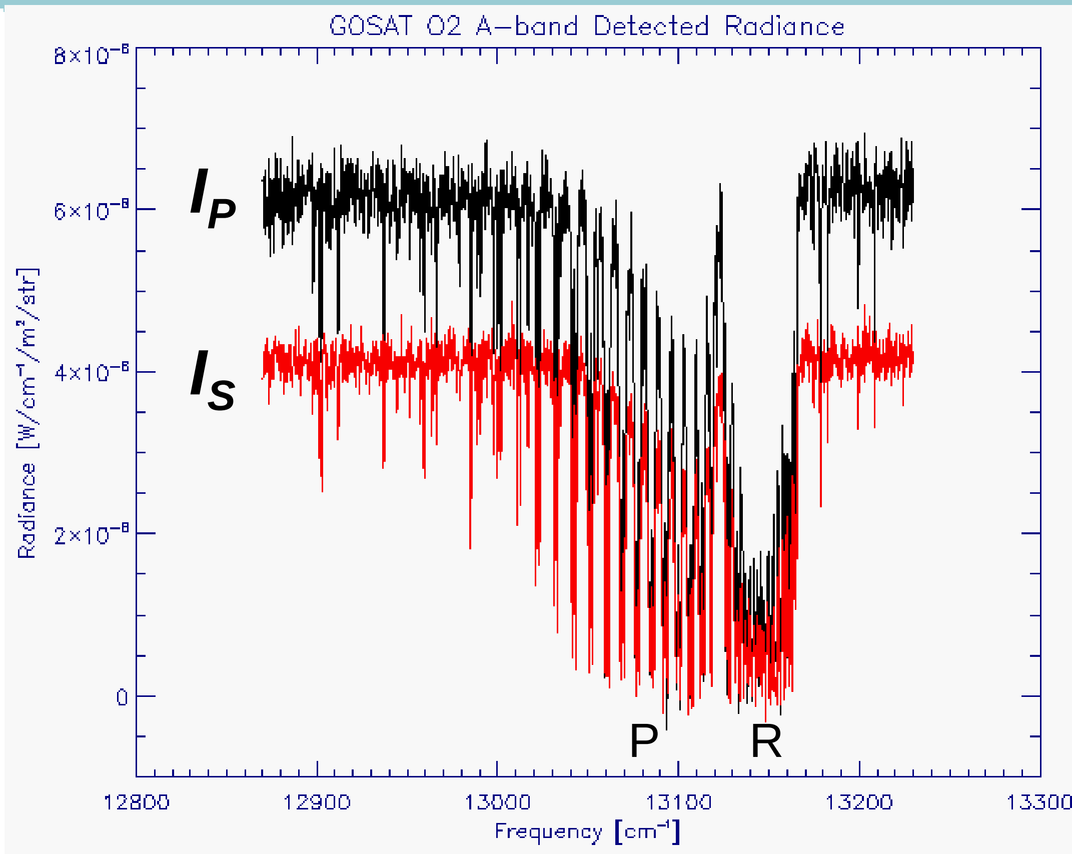
Aerosol Height using O_2A band: Puyehue volcano (Chile), 6 June 2011



Aerosol layer height with FRESCO O_2A band algorithm

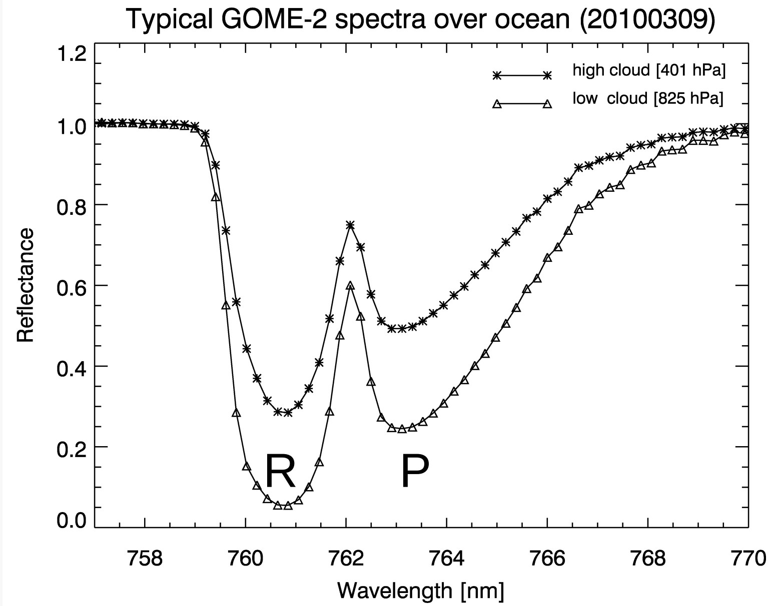
Wang et al., ACP, 2012

GOSAT O_2 A-band measurement



0.015 nm resolution

For comparison GOME-2 O_2 A-band

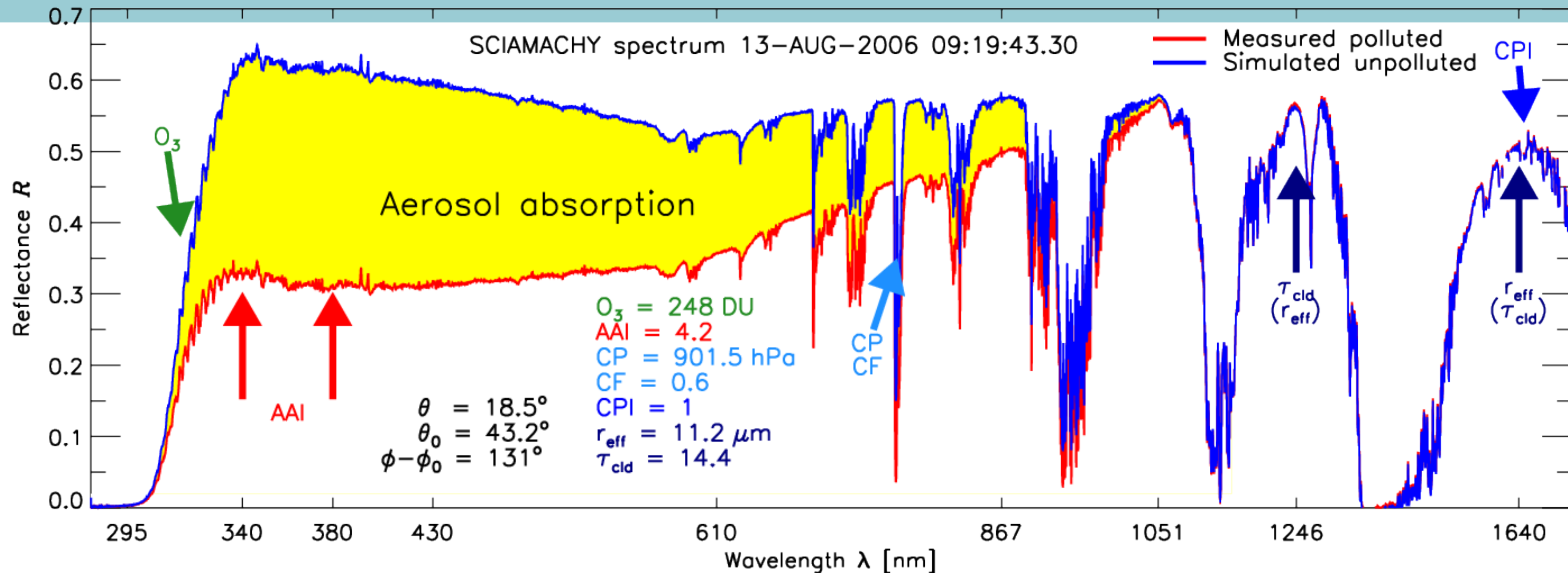


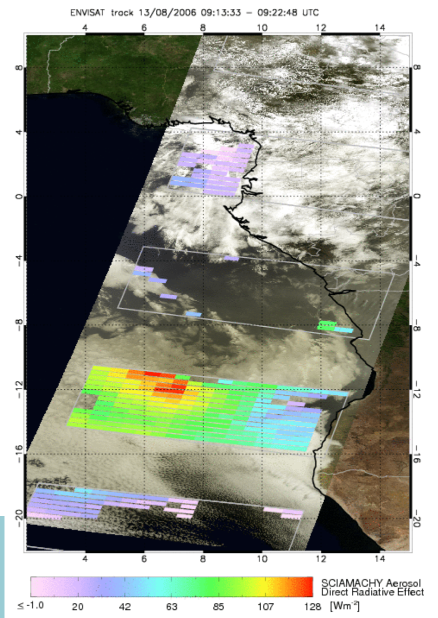
0.5 nm resolution
similar to TROPOMI

Number of spectral points in O_2 A-band: ~1800

Sentinel 4: 0.12 nm resolution

Spectral absorption of aerosols over clouds measured by SCIAMACHY





Direct measurement of spectral absorption of aerosols over clouds from UV to SWIR.

Biomass burning aerosols over marine clouds can cause absorption of up to 100 W/m2.

Important: combination of UV, VIS & SWIR reflectances.

De Graaf et al., JGR, 2012.

Future instrumentation (1)

- **Expected** to be available:
  - VIIRS and Metimage: continuation MODIS
  - 3MI on METOP SG: continuation POLDER; start of operational monitoring of aerosol AOT, SSA, size, etc.
  - OMI, TROPOMI, sentinel 4 and 5: AAI and aerosol height
  - ADM, Earthcare: lidar
- **New:** GEO role: sentinel 3, sentinel 4.

Aerosol products from sentinel 3 are however not yet supported

Future instrumentation (2)

- In future **new instrument** developments needed:

  - TROPILITE (OMI/TROPOMI with 2x2 km2)
  - New ways to measure polarisation (The Netherlands) and many angles
    - Follow on Polder type of instrumentation
    - New measurements for aerosol-cloud interaction by measuring the rainbow (TUD, Levelt, Veefkind)
  - Operational Lidar like Calipso

New development ideas – might be useful for the ToR

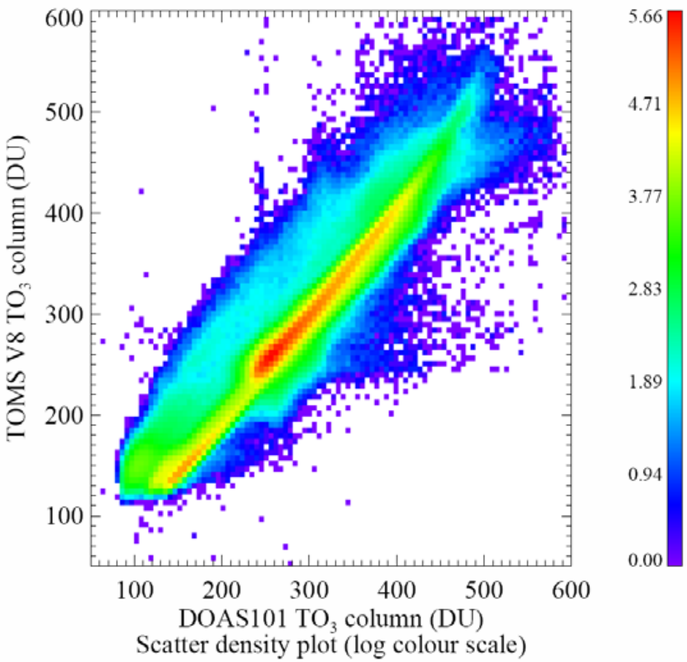
•Need for standardisation algorithms, start e.g. with MODIS AOT and apply this for all comparable instruments like VIIRS, MetImage

•Standardisation of aerosol models used as starting point in the retrievals.

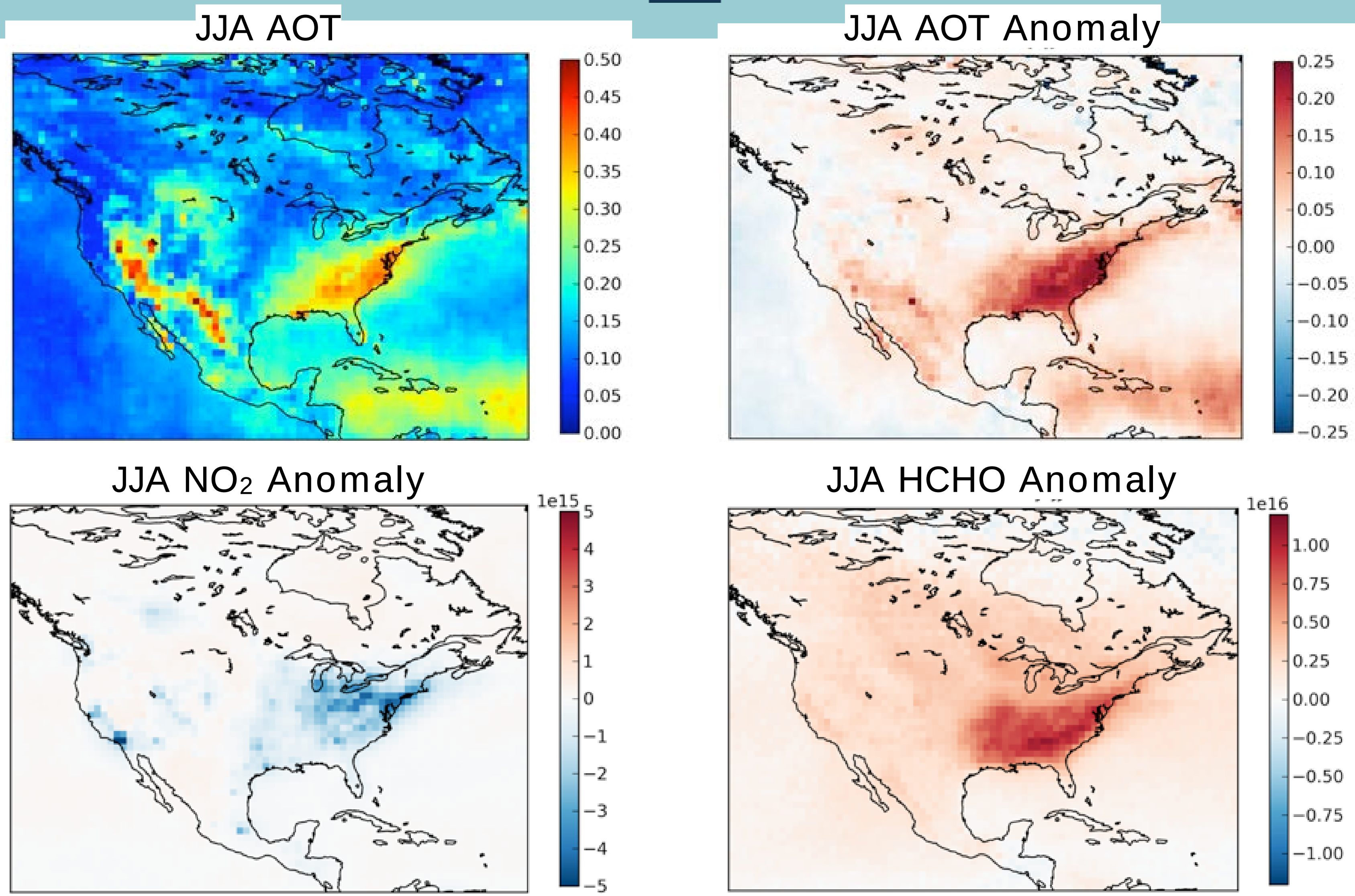
•Simulators: built simulators in models for easy comparison with measurements.

•Assessment of aerosols and their precursor gases (NOx, SO2, HCHO, Ammonia, ...)

•AAOT black carbon
(David Fahey paper, JGR, 2013)



Secondary aerosol formation from space: AOT-HCHO: Summer Anomalies



Veefkind et al., ACP, 2011

Years 2005-2007

Users

- Air quality community (EU MACC)
- Climate community
- Rerouting aviation (VAACs)
- Assimilation of aerosols for atmospheric corrections (e.g. for land applications)

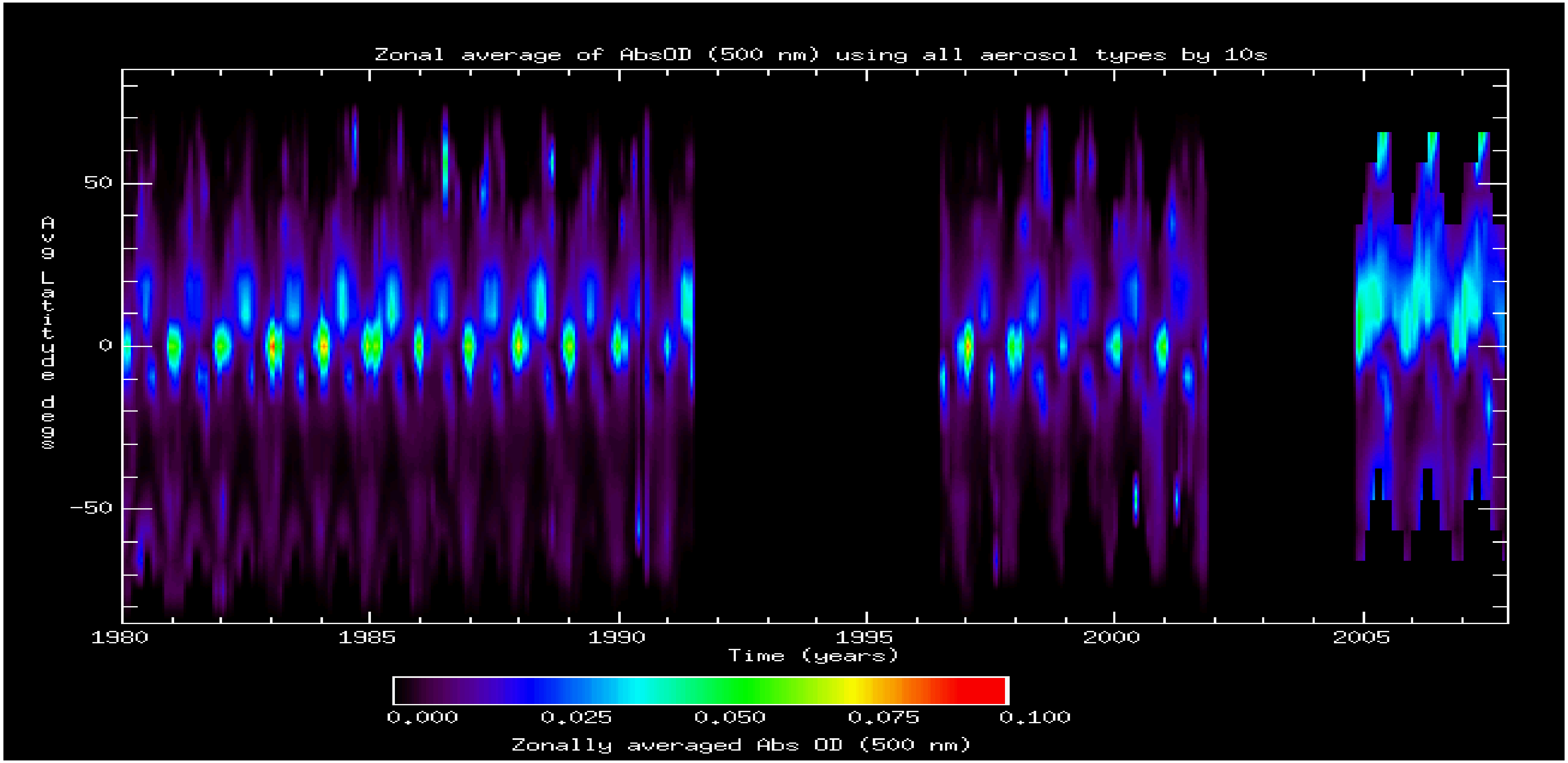
Thank you for your attention!

backup

Nodig

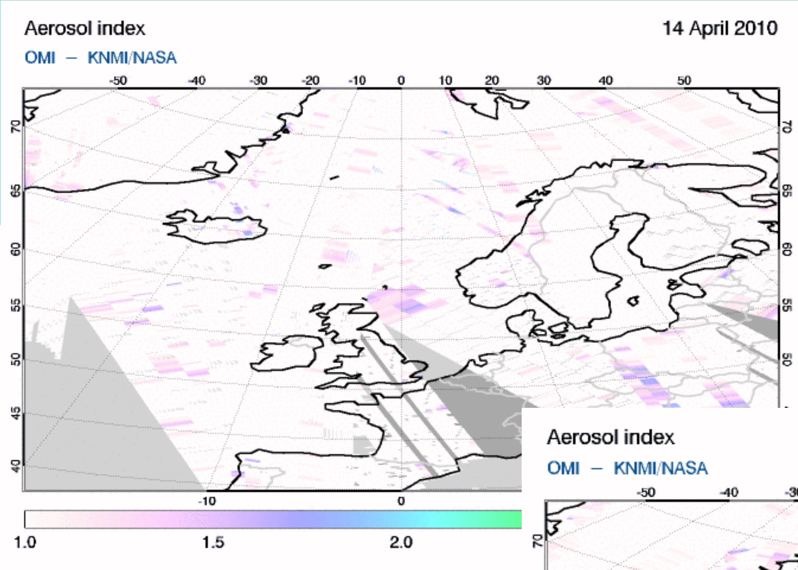
- Aerosol boomerang
- O2A band plaatje van resultaat! Niet retrieval
- Uitleg absorbing aerosols – AAI plaatje van Kopenhagen
- Andere plaatjes Piet kan ik niet volgen
- SPEX : noemen, ook ons eigen project noemen?
- David Fahey boodschap

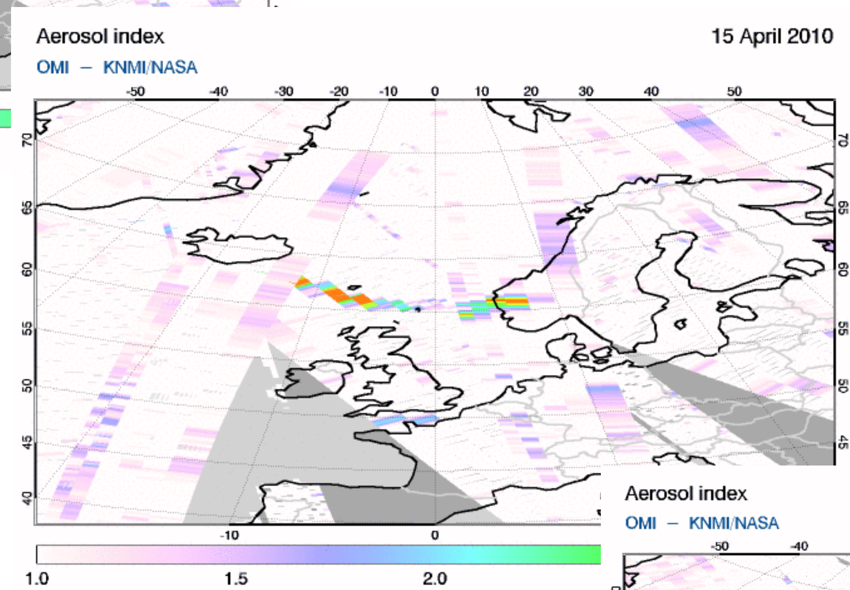
Combined TOMS-OMI Record on Aerosol Absorption (Preliminary Results)

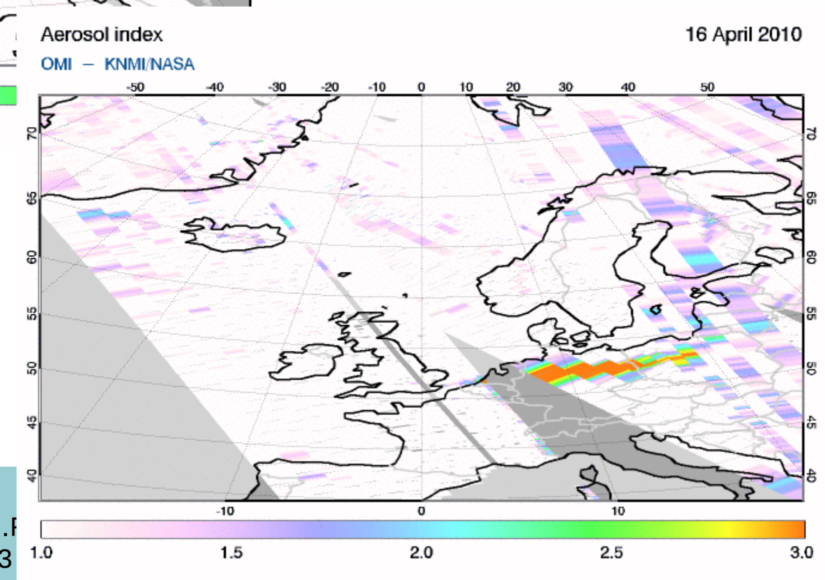


Larger OMI values are the result of algorithmic differences.
TOMS record will be re-processed using OMI algorithm

OMI AAI 14 – 16 April







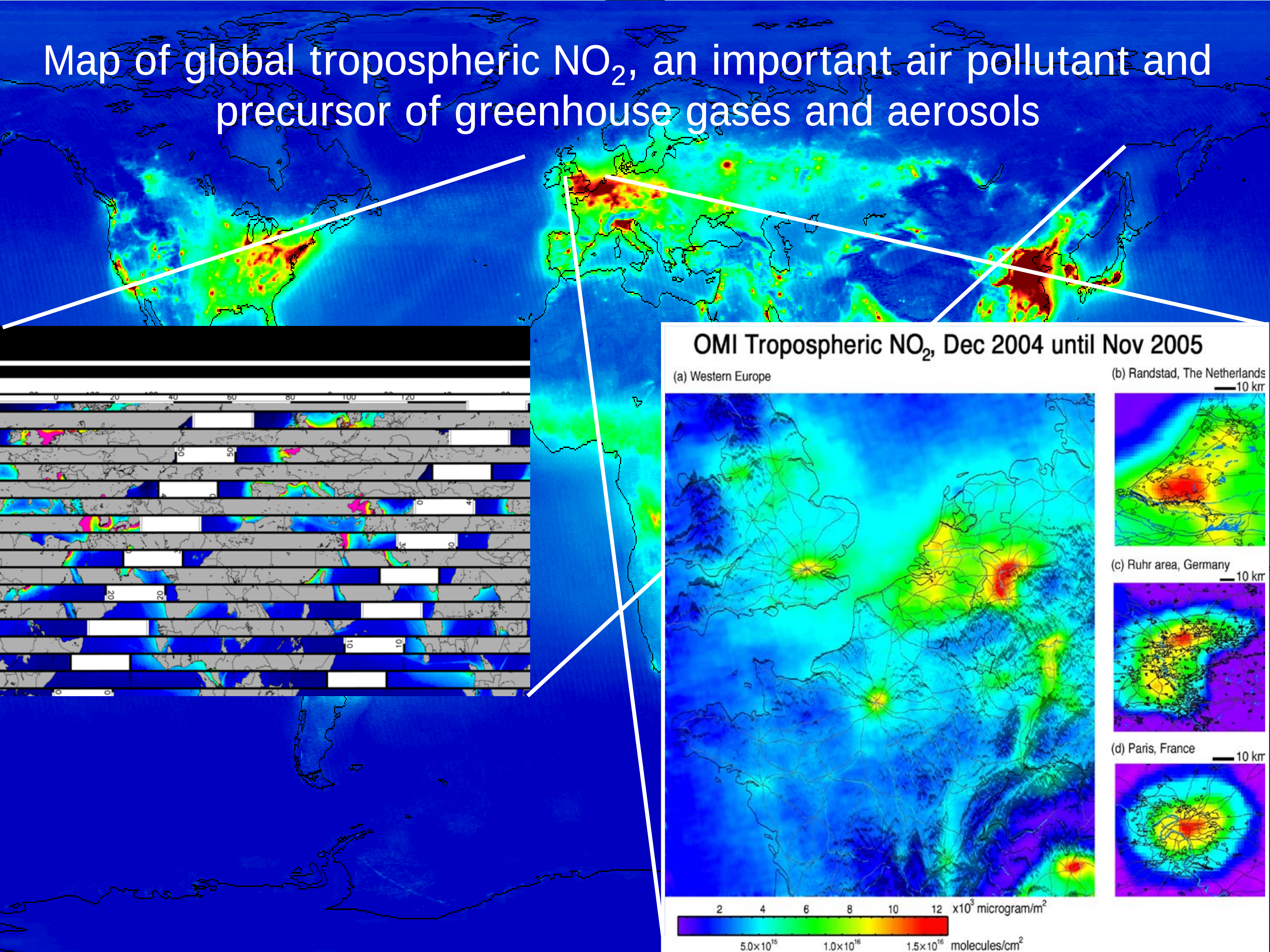
Overview volcanic eruption

In December 2006 southeastern Australia suffered from severe forest fires. Using the OMI instrument we observed how a smoke plume released by these fires on 14 December rapidly crossed the Pacific and reached southern America only five days later. After passing south America the plume continued its journey over the Atlantic and the Indian Ocean to return to home base on 25 December, making it the first-time observation of rapid around-the-world transport in the extra-tropical southern hemisphere.

Dirksen, R. J., K. Folkert Boersma, J. de Laat, P. Stammes, G. R. van der Werf, M. Val Martin, and H. M. Kelder (2009),

An aerosol boomerang: Rapid around-the-world transport of smoke from the December 2006 Australian forest fires observed from

space, J. Geophys. Res., 114, D21201, doi:10.1029/2009JD012360.


Map of global tropospheric NO_2, an important air pollutant and precursor of greenhouse gases and aerosols
OMI Tropospheric NO_2, Dec 2004 until Nov 2005
(a) Western Europe
(b) Randstad, The Netherlands
10 km
(c) Ruhr area, Germany
10 km
(d) Paris, France
10 km
2 4 6 8 10 12 $\times 10^3$ microgram/m^2
5.0×10^{15} 1.0×10^{16} 1.5×10^{16} molecules/cm^2