



Royal Netherlands  
Meteorological Institute  
*Ministry of Infrastructure and the  
Environment*

# Latest Algorithm Updates for OMI and S5P/TROPOMI

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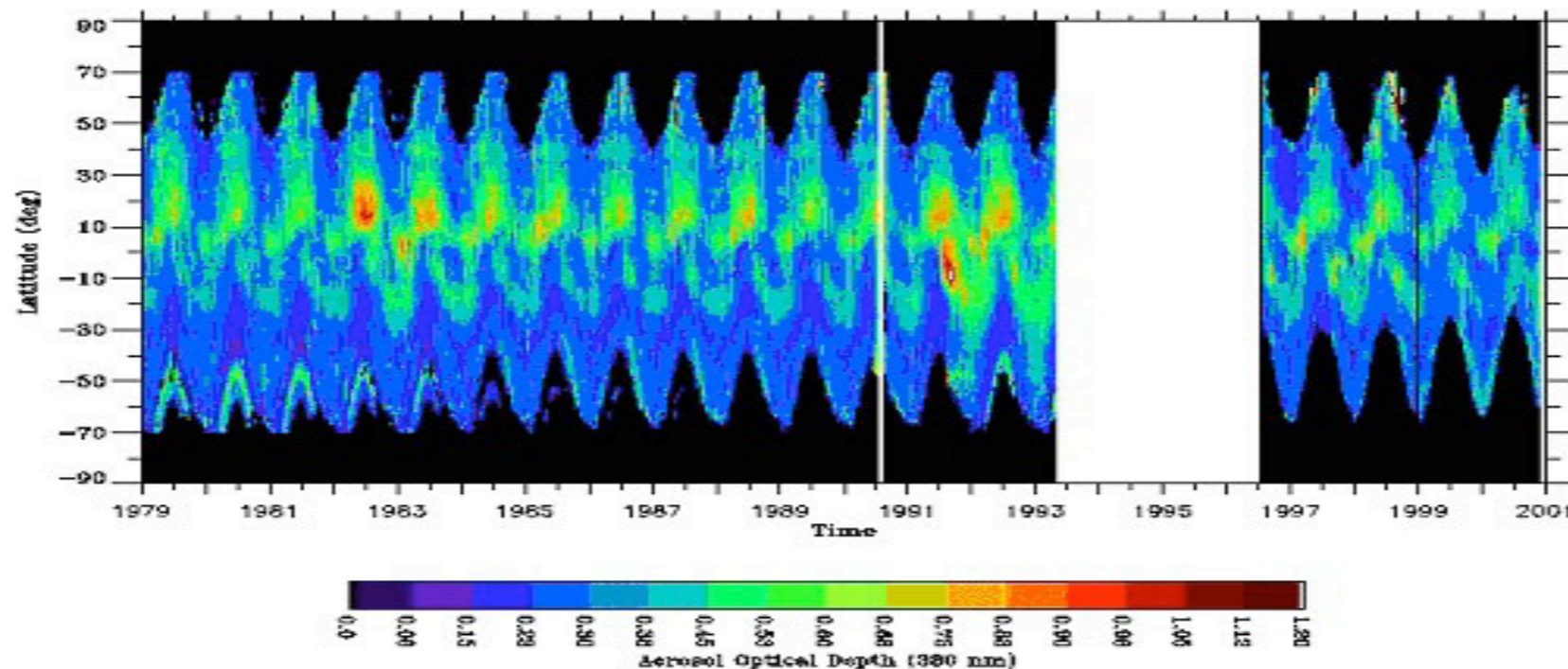
# Outline

- UV Spectrometers: OMI & TROPOMI
- Aerosol Absorbing Index
- Quantitative use of the AAI
- Aerosol Layer Height
- Aerosol and Precursors



# Data Sets from UV satellite instruments

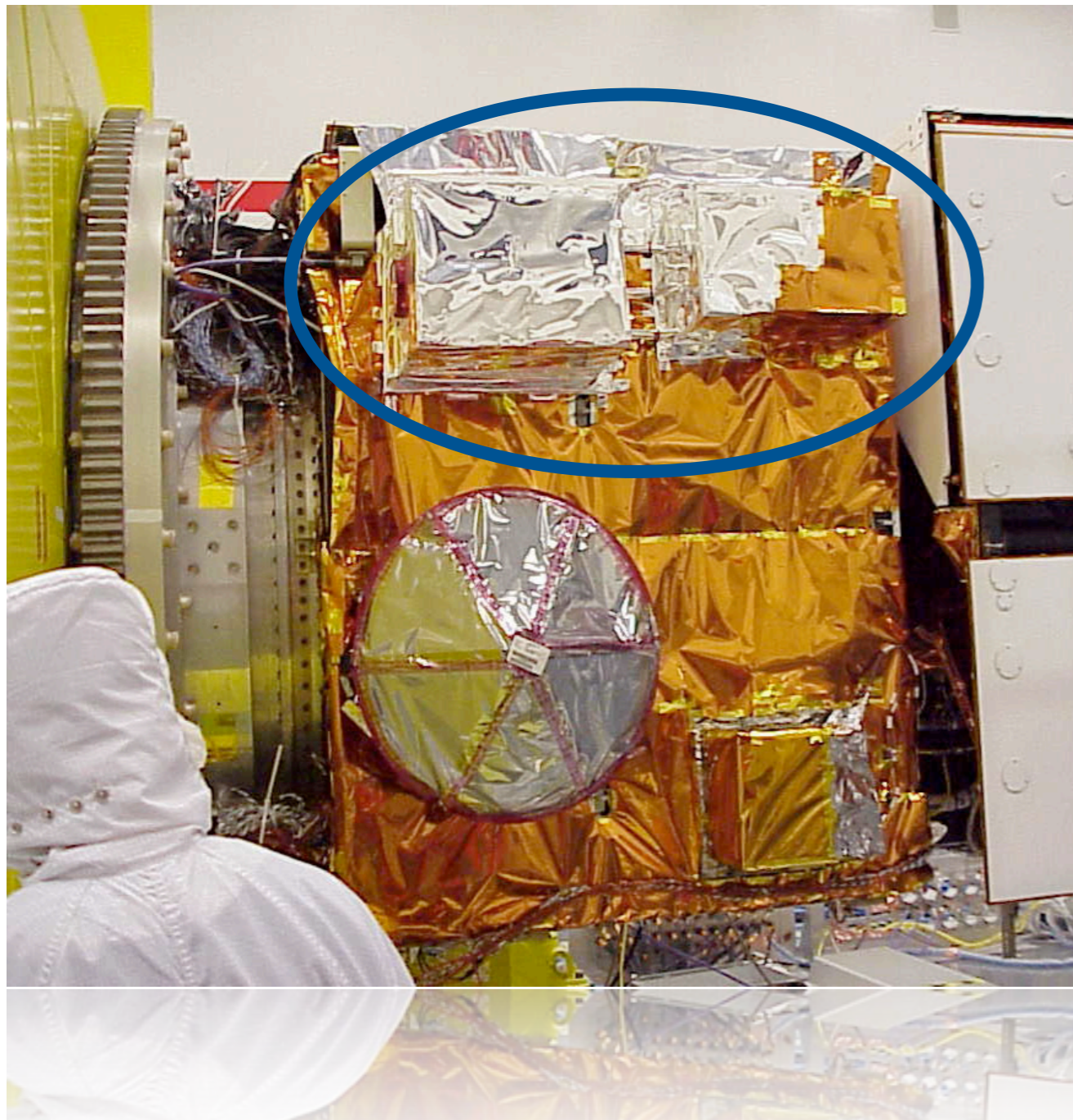
- TOMS on Nimbus+EP: 1978 - 2004
- GOME on ERS-2: 1995 - 2000
- SCIAMACHY on Envisat: 2002 - 2012
- OMI on Aura: 2004 - present
- GOME-2 on Metop: 2007 - present
- OMPS on NPP/NPOESS 2011 - present
  
- TROPOMI on S5 Precursor ~2015 - 2022
- Sentinel 4 UVN on MTG-S ~2019 - 2030
- UVN on Sentinel 5 / Post EPS ~2020 - ~2030



see : Torres et al., JGR, Vol. 103, 17099-17110, 1998  
Torres et al., J. Atm. Sci., Vol. 59, 398-413, 2002



# Ozone Monitoring Instrument



## Ozone Monitoring Instrument

Instrument	Imaging spectrometer
Spectral Range	270 - 500 nm
Spectral Resolution	0.45 - 0.63 nm
Spectral Sampling	0.15 - 0.30 nm
Spatial Resolution	13x24 km <sup>2</sup> (nadir)
Swath Width	2600 km
Mass	65 kg
Size	50 cm × 40 cm × 35 cm
Power	66 W
Data rate	0.8 Mbps (average)
Spacecraft	NASA EOS-Aura
Launch Date	15 July 2004
Orbit	Sun synchronous, 13:30 hr
Altitude	705 km
Agencies	NSO (NIVR), FMI
PI Institutes	KNMI, FMI

*OMI is the Dutch-Finnish contribution to the NASA EOS-Aura Mission and is developed by an international consortium led by Dutch Space and TNO.*

[www.knmi.nl/omi](http://www.knmi.nl/omi)



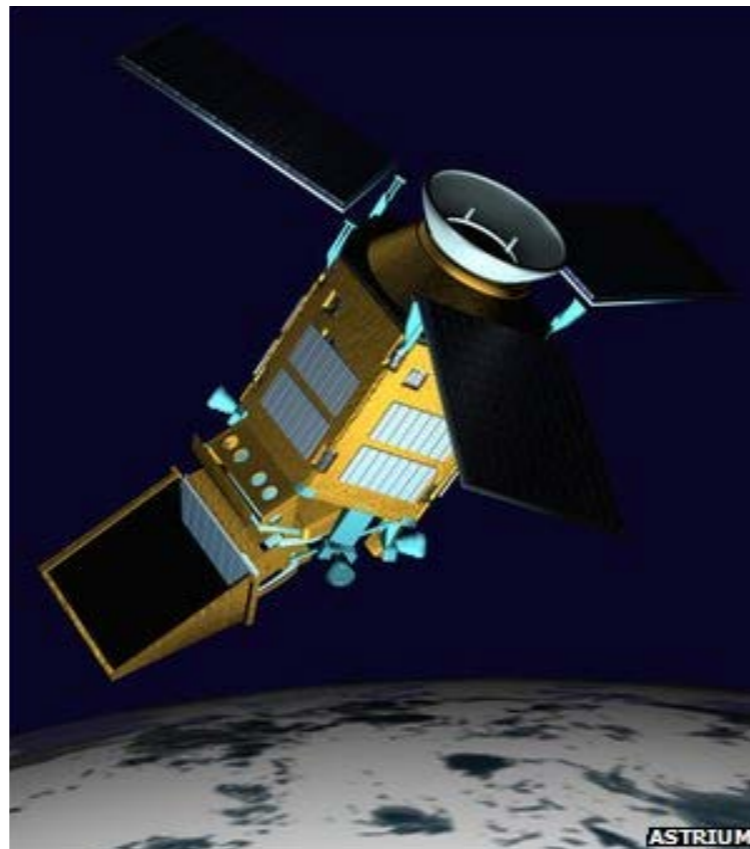
# sentinel-5 precursor

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<sup>2</sup>
- ▶ Global daily coverage at 13:30 local solar time.

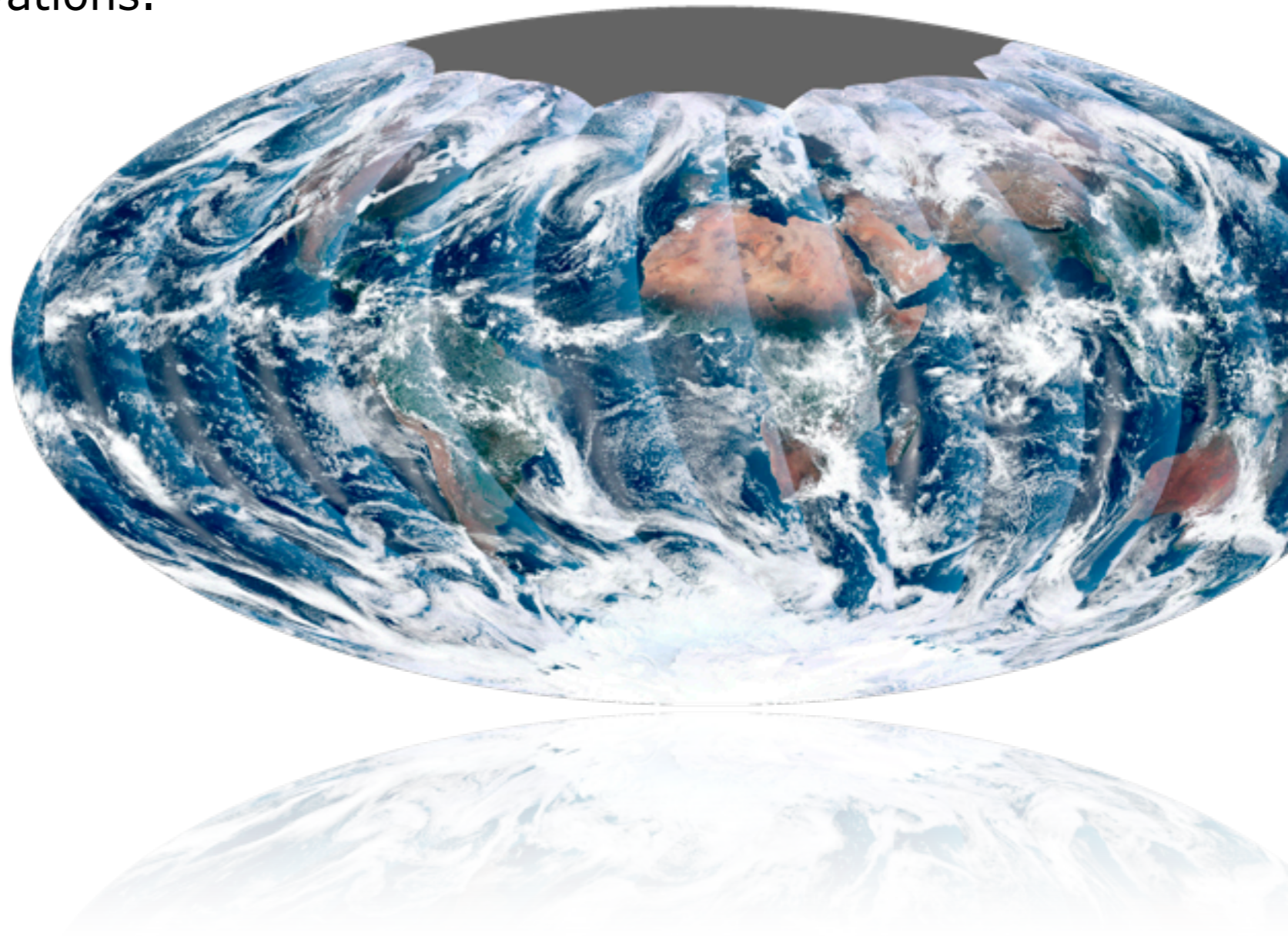


## CONTRIBUTION TO GMES

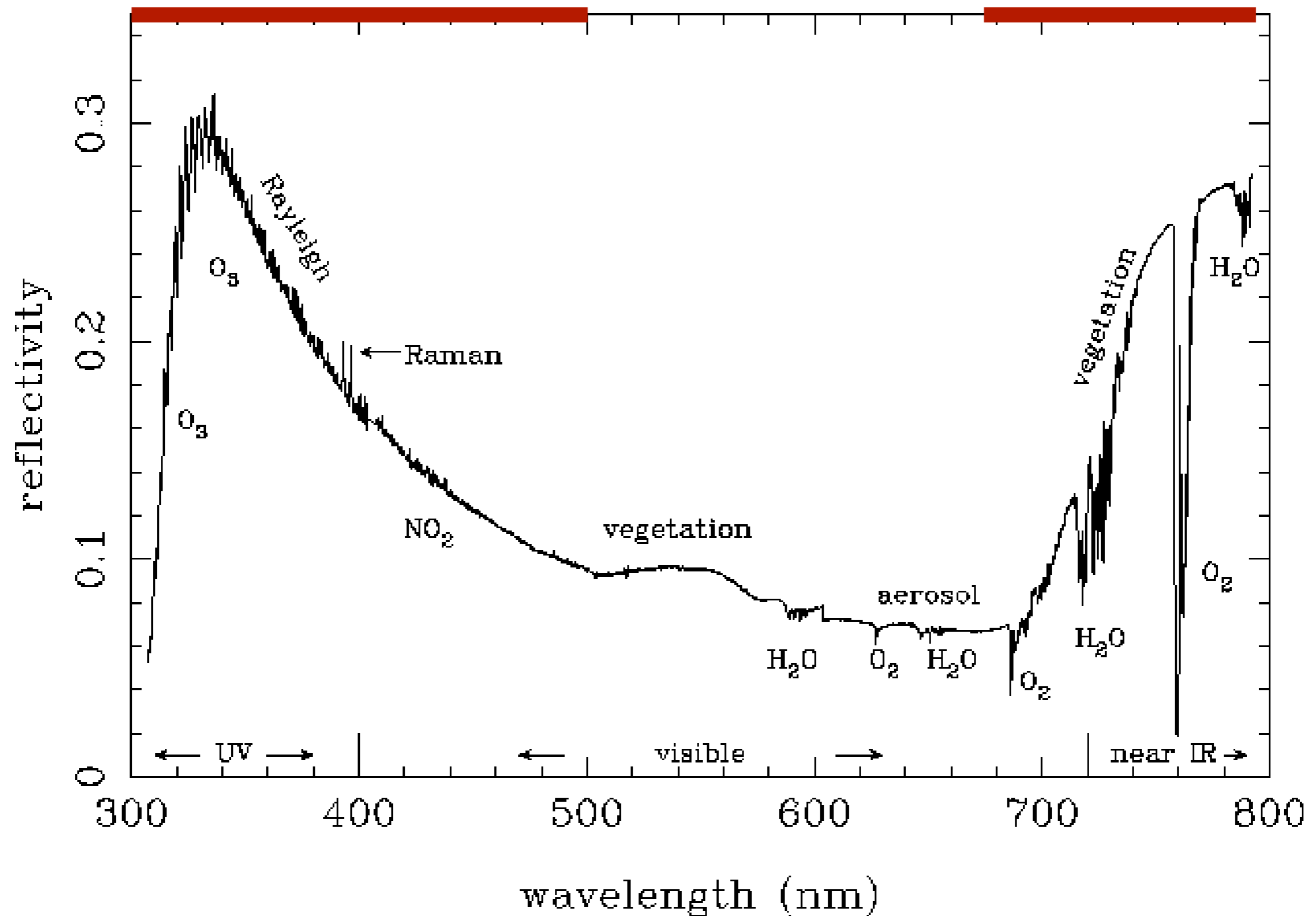
- ▶ Total column  
O<sub>3</sub>, NO<sub>2</sub>, CO, SO<sub>2</sub>, CH<sub>4</sub>,  
CH<sub>2</sub>O, H<sub>2</sub>O, BrO
- ▶ Tropospheric column  
O<sub>3</sub>, NO<sub>2</sub>
- ▶ O<sub>3</sub> profile
- ▶ Aerosol absorbing index,  
type, optical depth

# Suomi-NPP - S5P formation Flying

- S-5P is planned to observe within 5 min. of NPP/JPSS.
- Primary goal is to use VIIRS cloud mask for S-5P methane observations.
- Other opportunities:
  - ▶ TROPOMI-VIIRS cloud and aerosol combined products.
  - ▶ TROPOMI-OMPS-CRIS ozone profiles.
  - ▶ TROPOMI-OMPS inter-calibration.



# Shortwave Spectrum



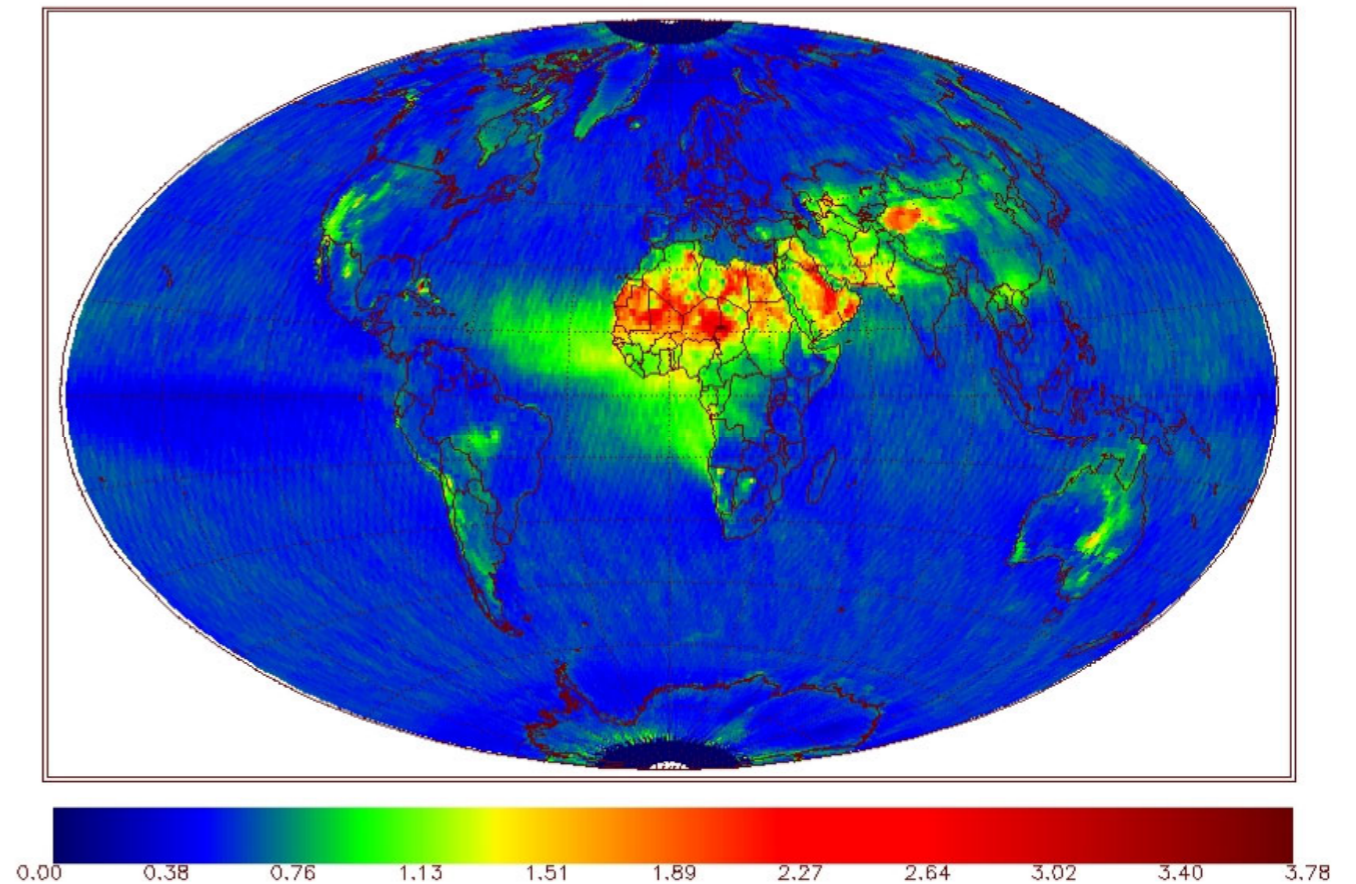
# OMI Aerosol Products

- **OMAERO**

AAI and AOT [350-500 nm]  
*also NRT and VFD processing*

- **OMAERUV**

AAI and AAOT



**OMI AAI, Mean 2007**



# Aerosol Absorbing Index Algorithm

## Input

TOA reflectance at 340 nm and 380 nm

## Algorithm

Compare the measured color of the scene with the color of a clear sky scene (Rayleigh plus surface reflection) having the same reflectance at 380 nm.

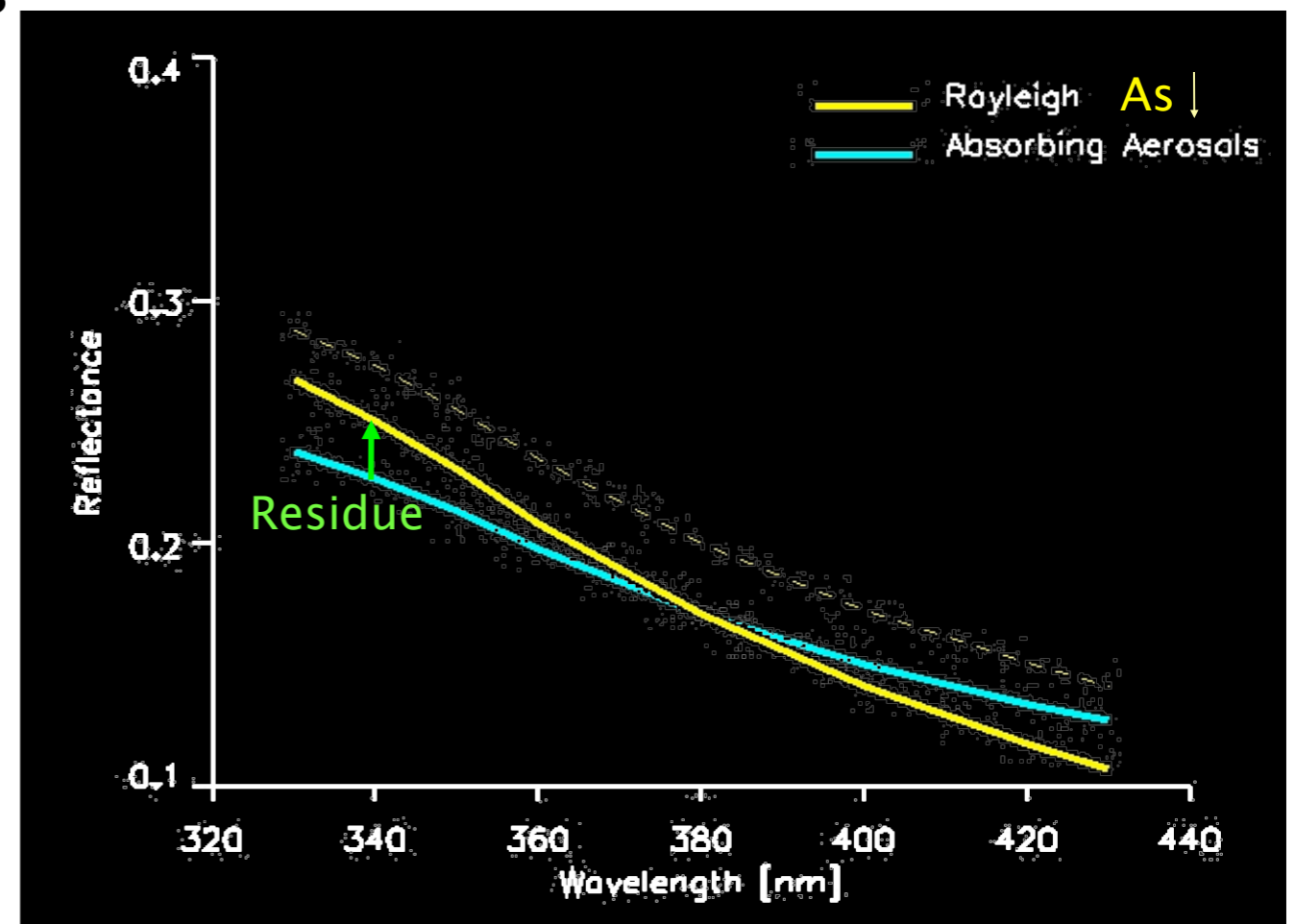
## Output

AAI < 0: no UV absorbing aerosols

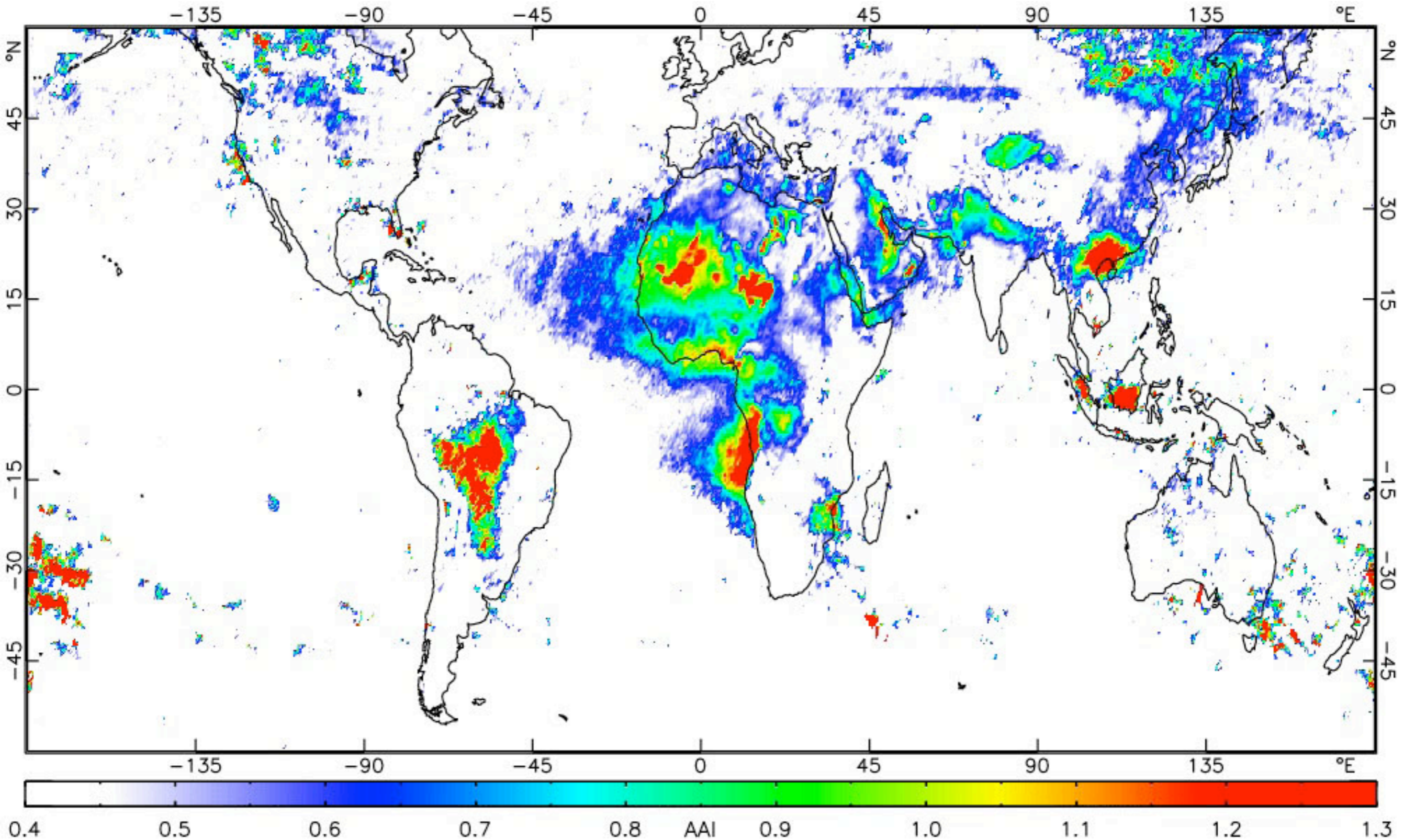
AAI > 0: UV absorbing aerosols

## Dependencies

AAI increases with increasing amount, absorption, and altitude of aerosols.

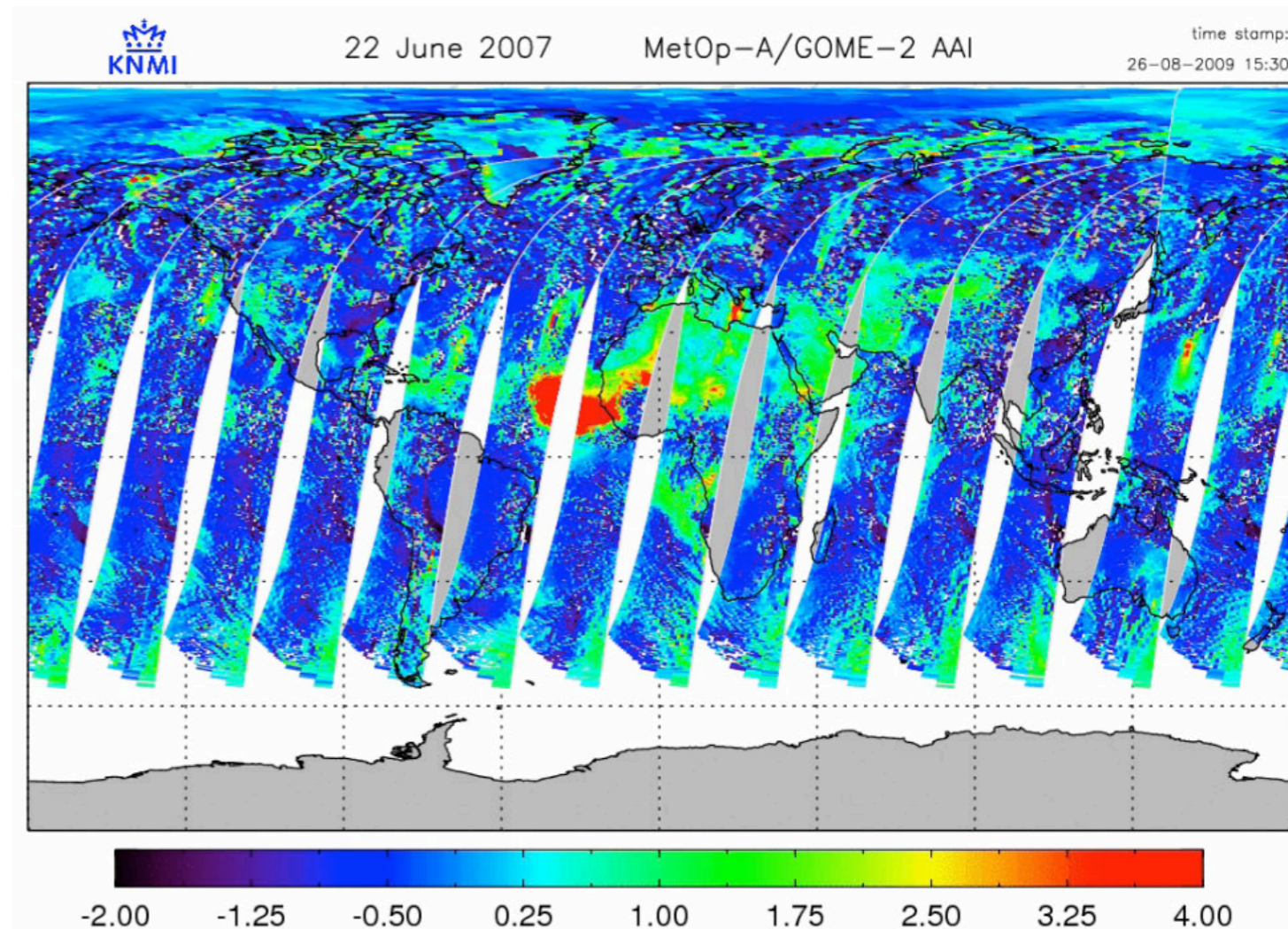


# AAI SCIAMACHY 2002-2012

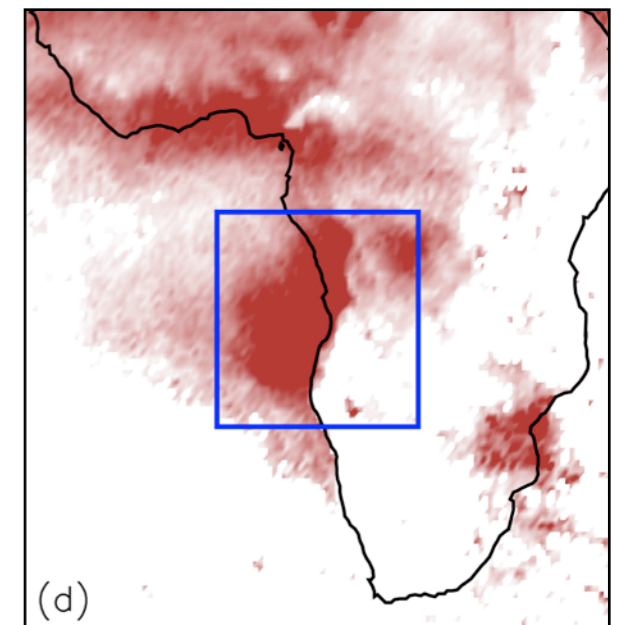
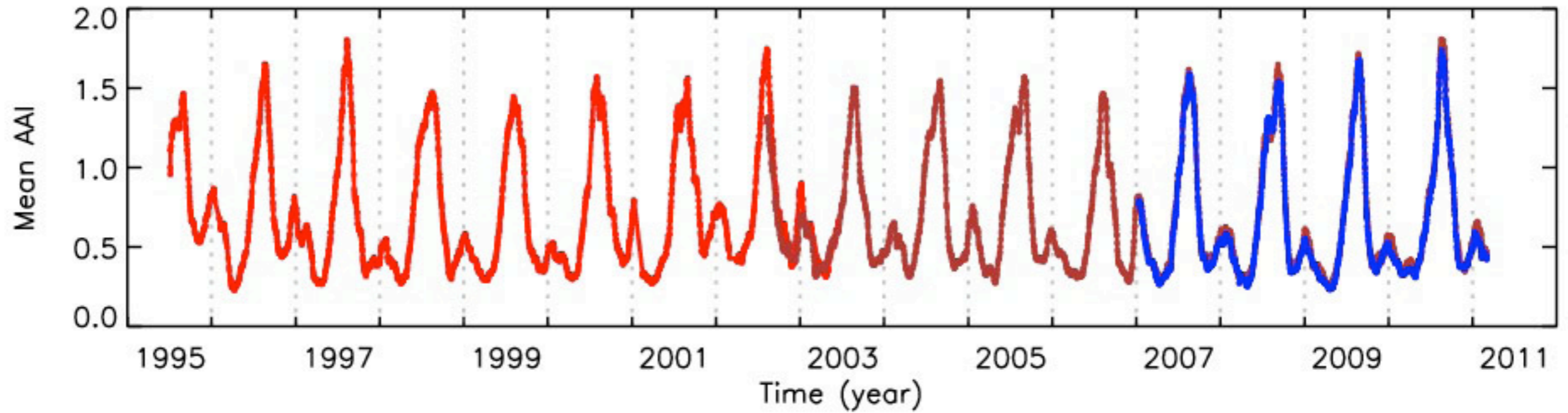


## AAI Data Product

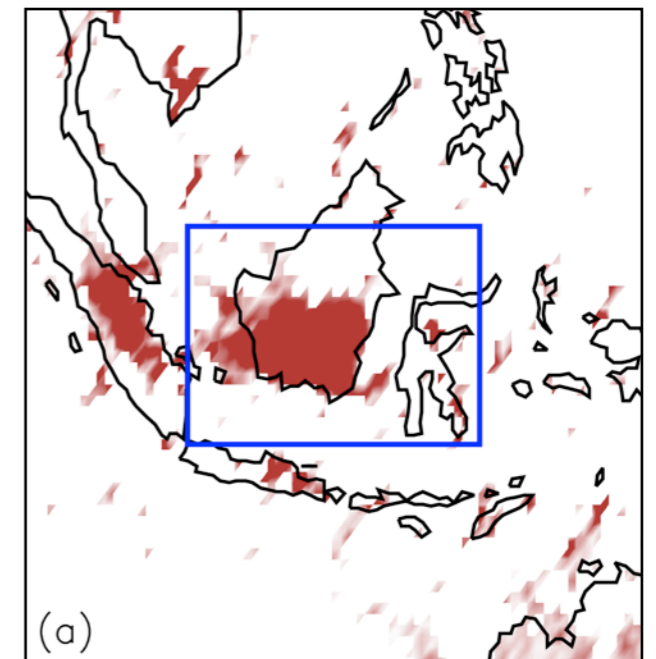
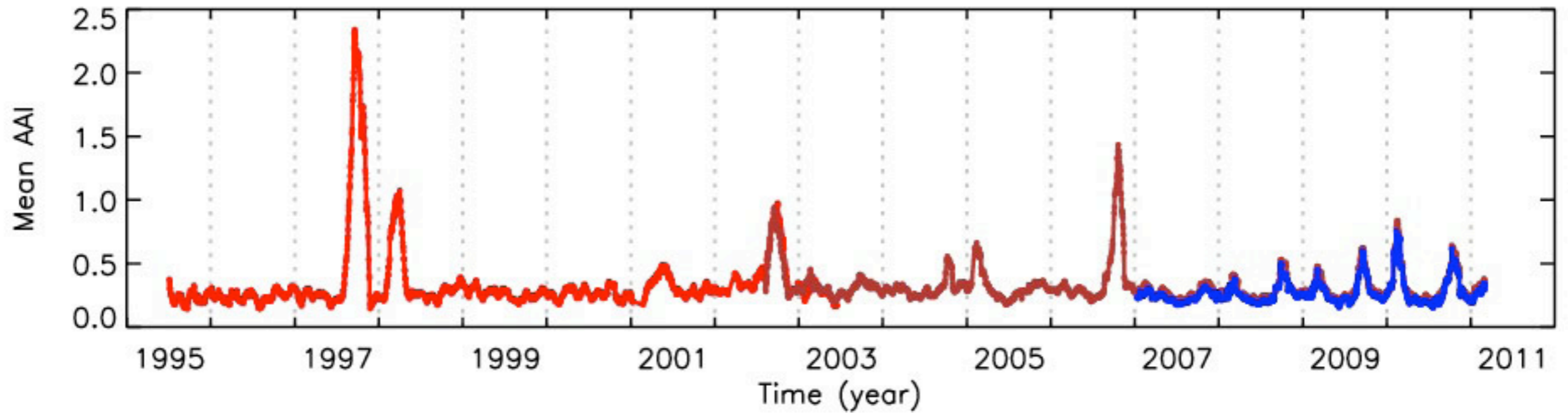
- Sensitive to elevated layers of absorbing aerosols: desert dust volcanic and biomass burning plumes.
- The AAI product allows the detection of absorbing aerosols over all surface types *and over clouds*.
- The algorithm is simple and robust. *No assumptions on aerosol microphysics or composition*
- The aerosol absorbing index is *not a geophysical quantity*.



# Seasonal Variations: West Africa



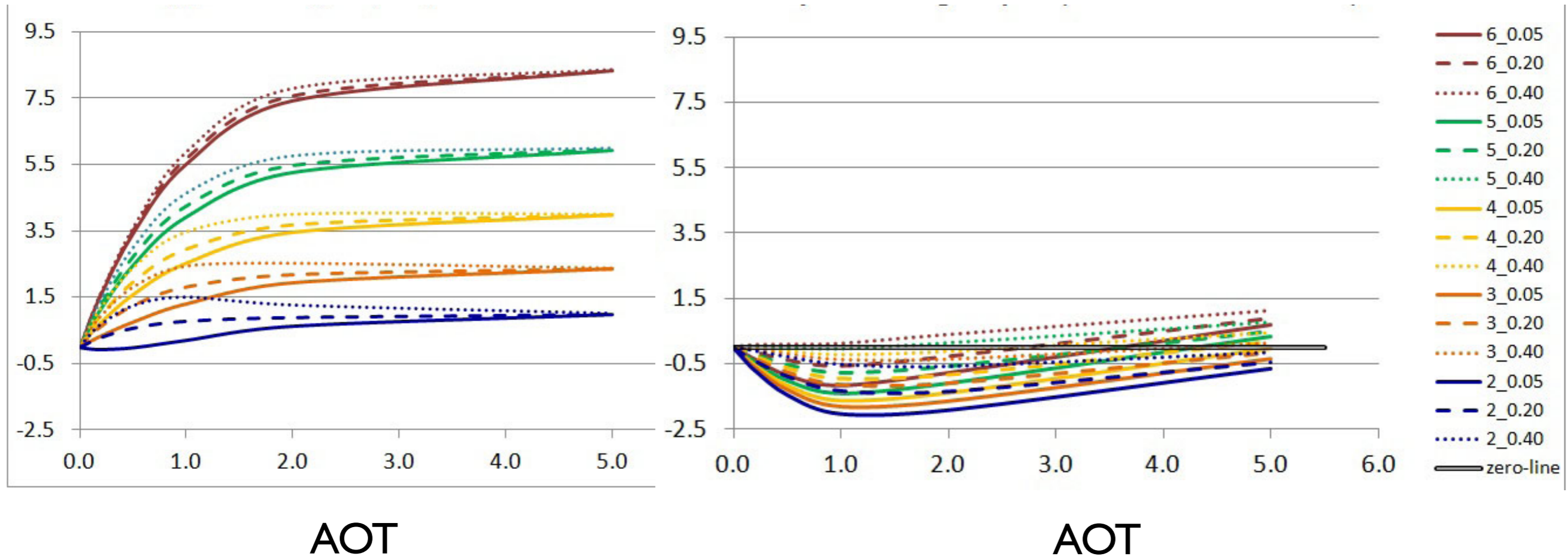
# Episodic Events: Indonesia



# AAI Dependencies

Strongly Absorbing ( $SSA_{500} = 0.80$ )

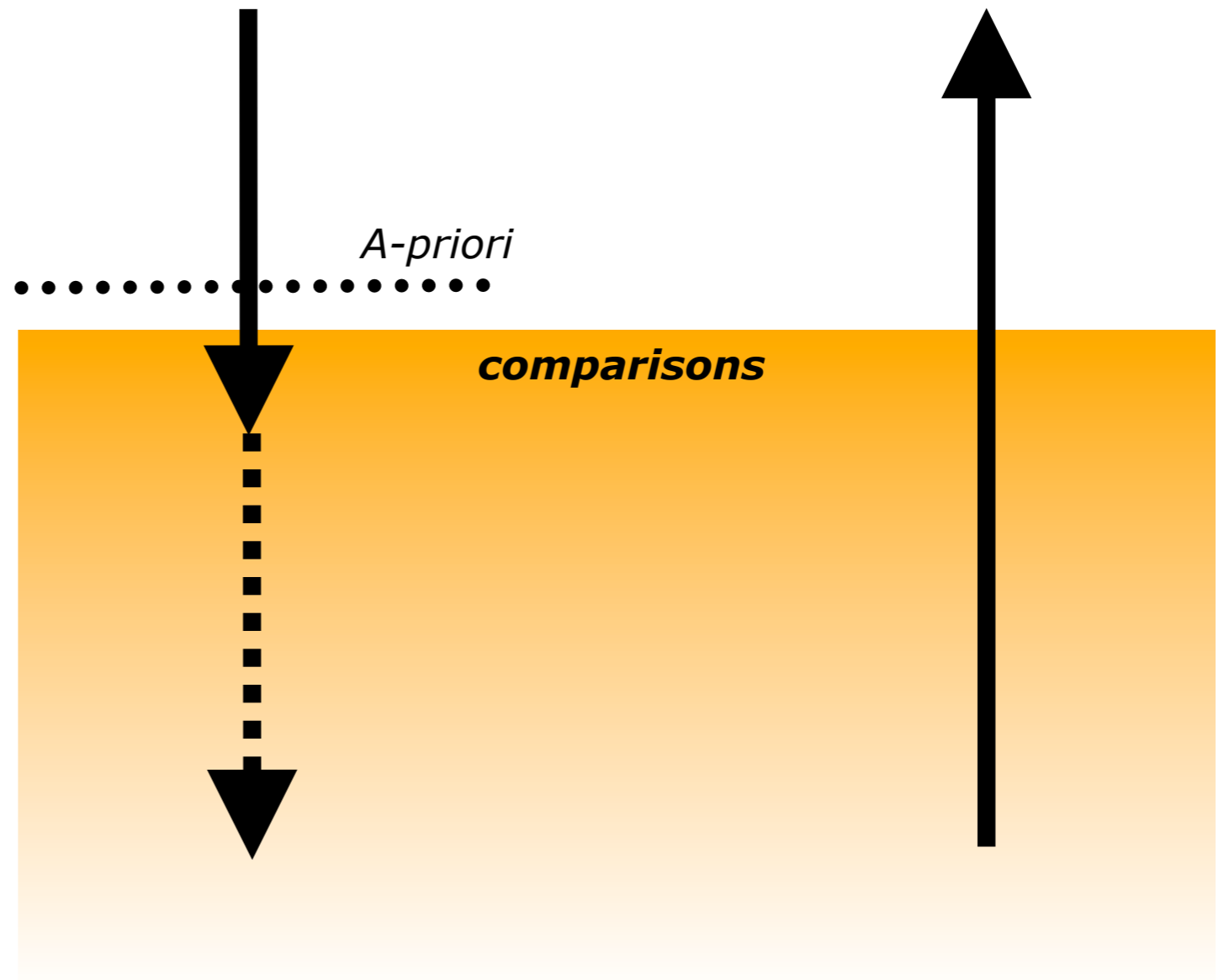
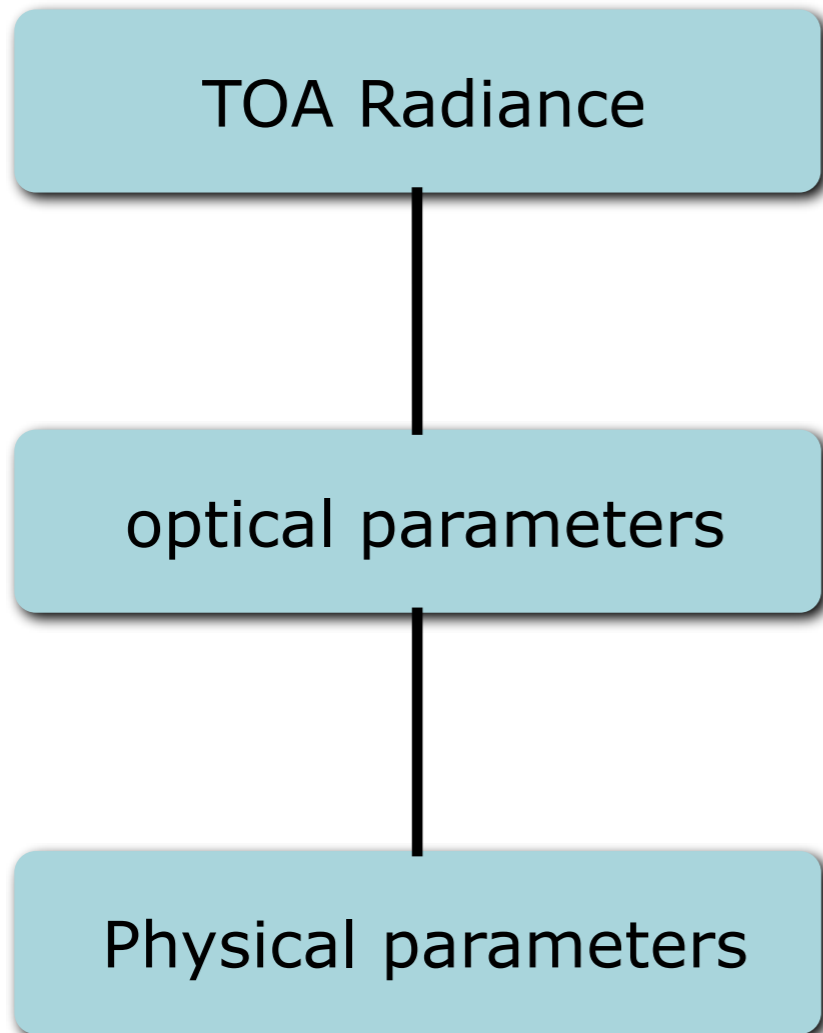
Weakly Absorbing ( $SSA_{500} = 0.98$ )

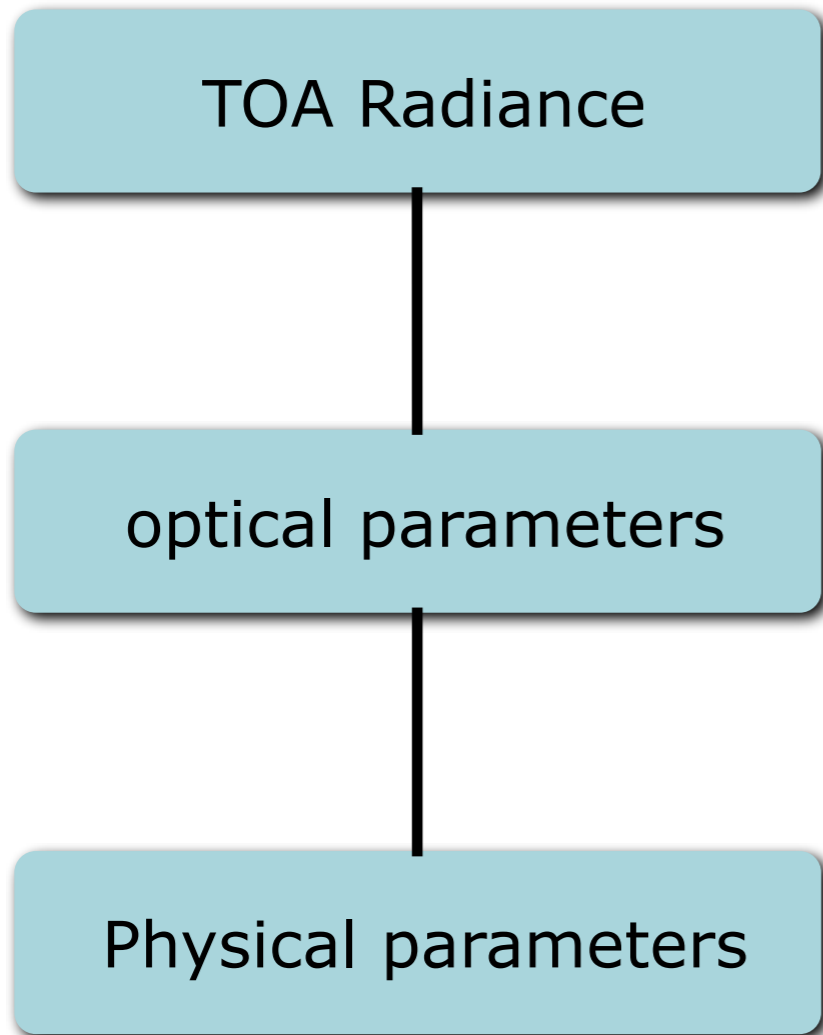




## Satellite Retrievals

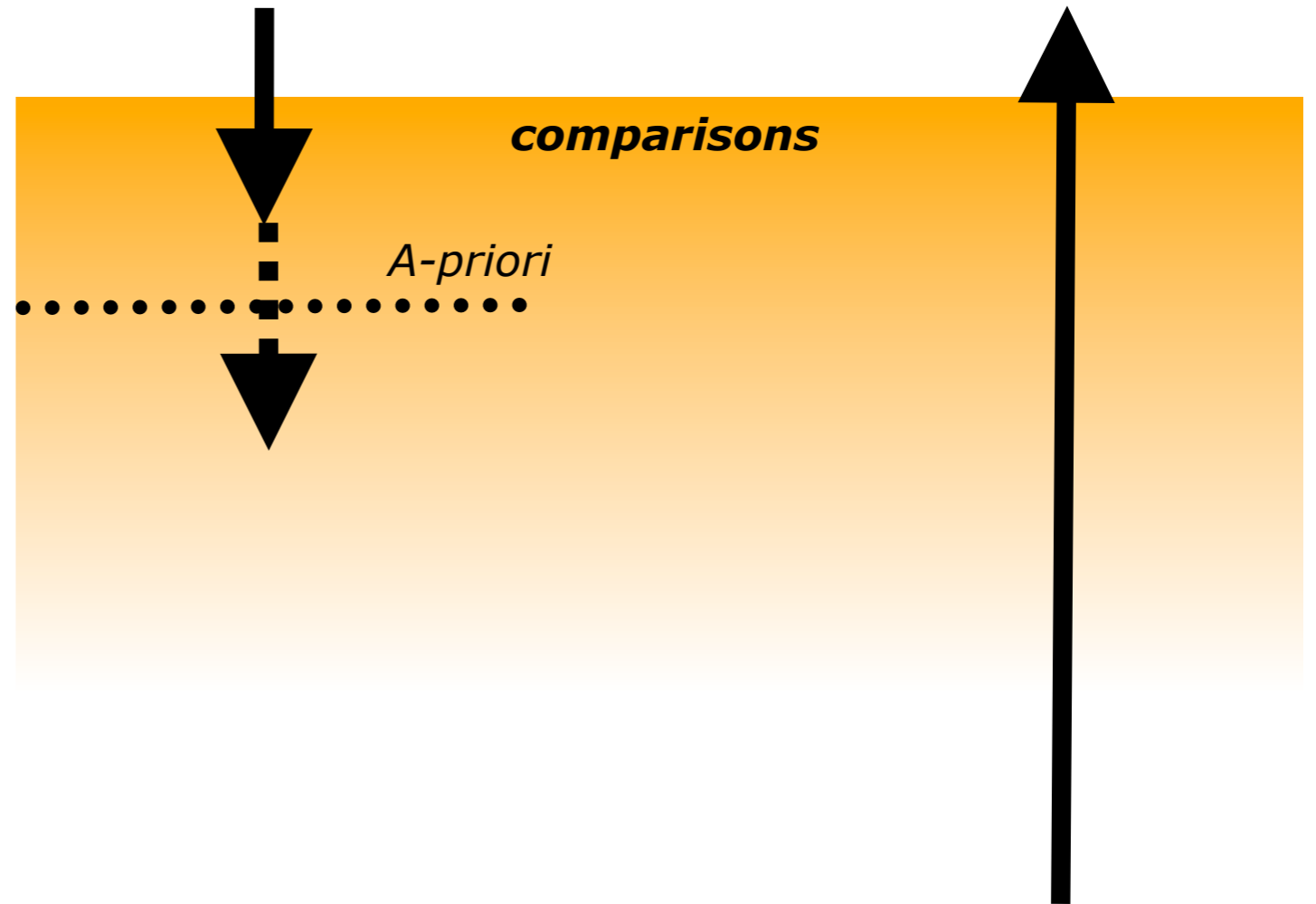
## Models





UV retrievals

Models



***To compare the AAI data with models a AAI simulator is needed***



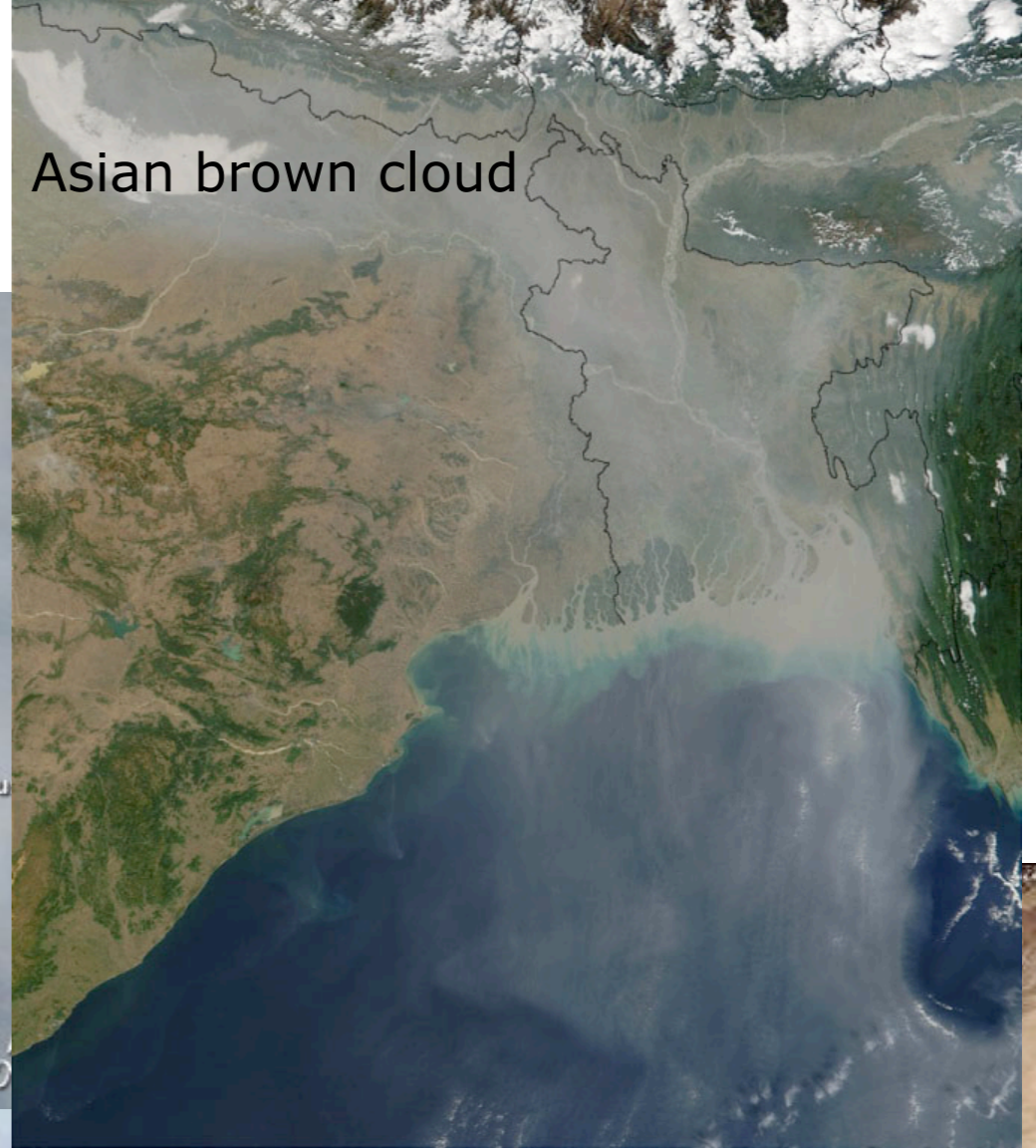
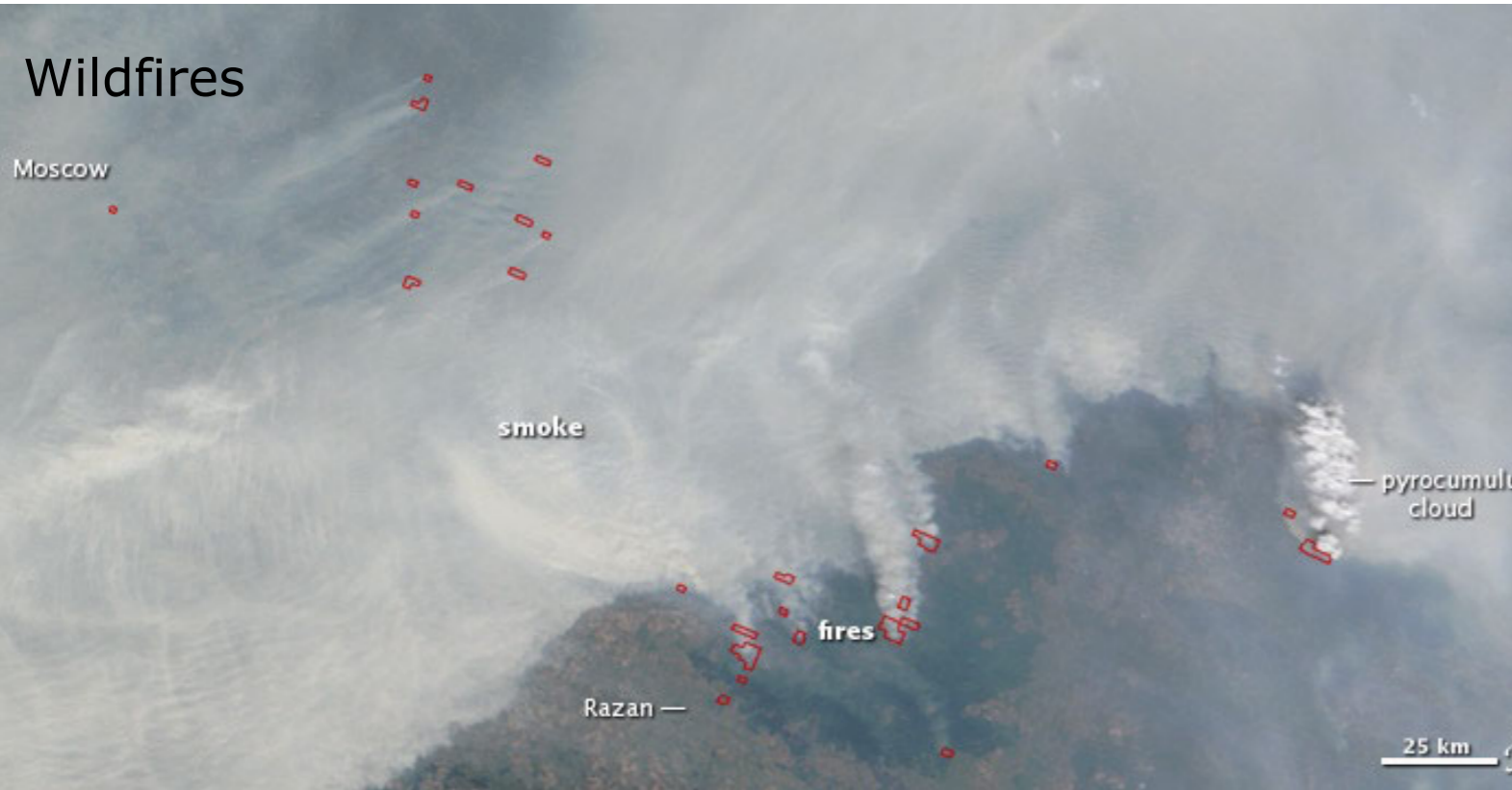
# AAI Fast Simulator

- LUT of AAI as a function of:
  - aerosol type (SSA)
  - aerosol optical depth
  - surface albedo
  - aerosol altitude
  - Sun-satellite geometry
- Provide routines to compute AAI from 3D aerosol model fields



# Elevated aerosol

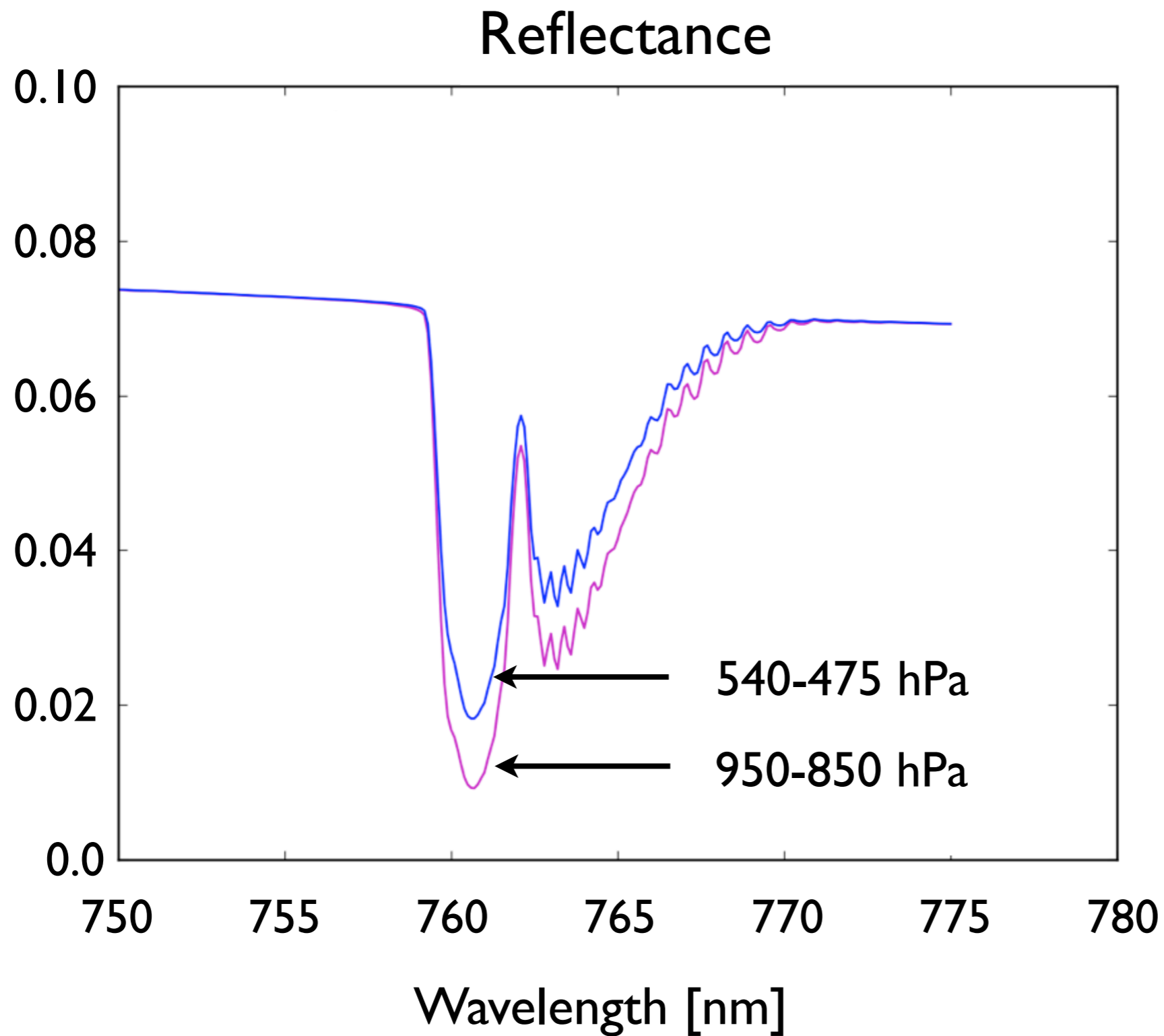
Wildfires



Volcanic eruption



# Height retrieval using O<sub>2</sub> A band

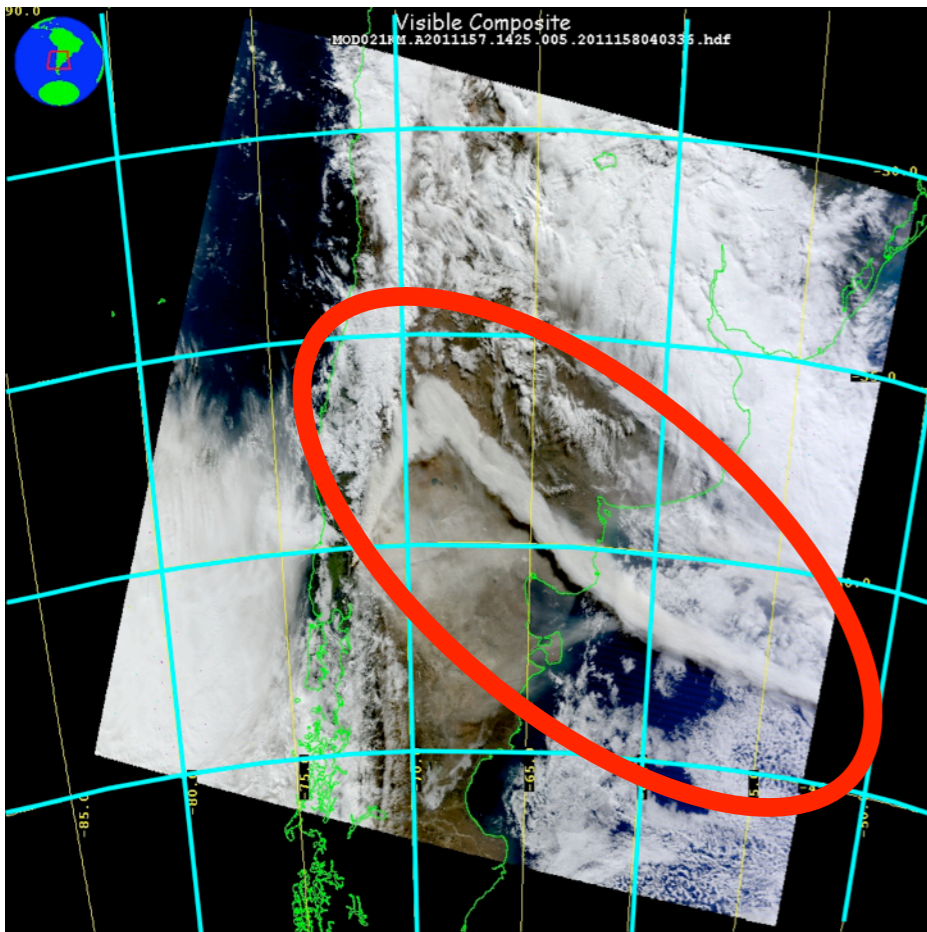


TROPOMI  
spectral  
resolution  
of 0.5 nm

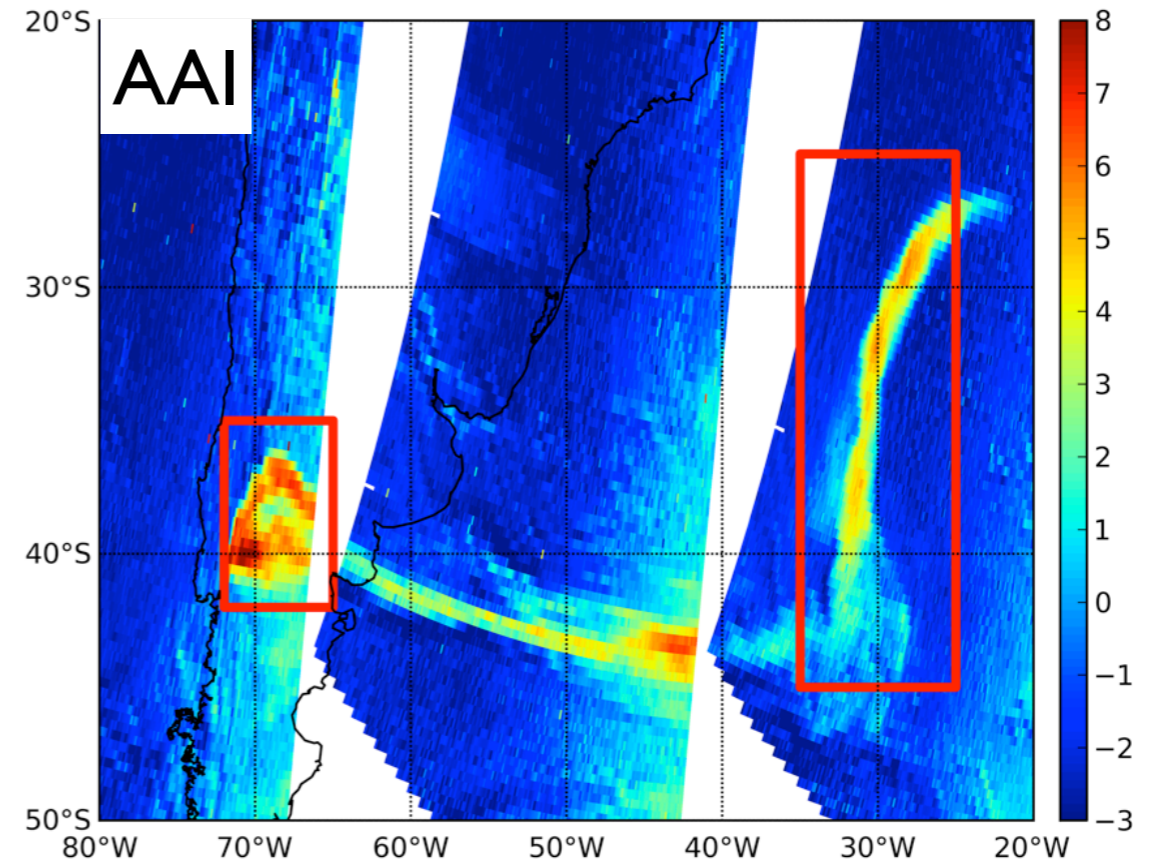
Bram Sanders, KNMI

# FRESCO cloud retrieval algorithm: O<sub>2</sub> A band

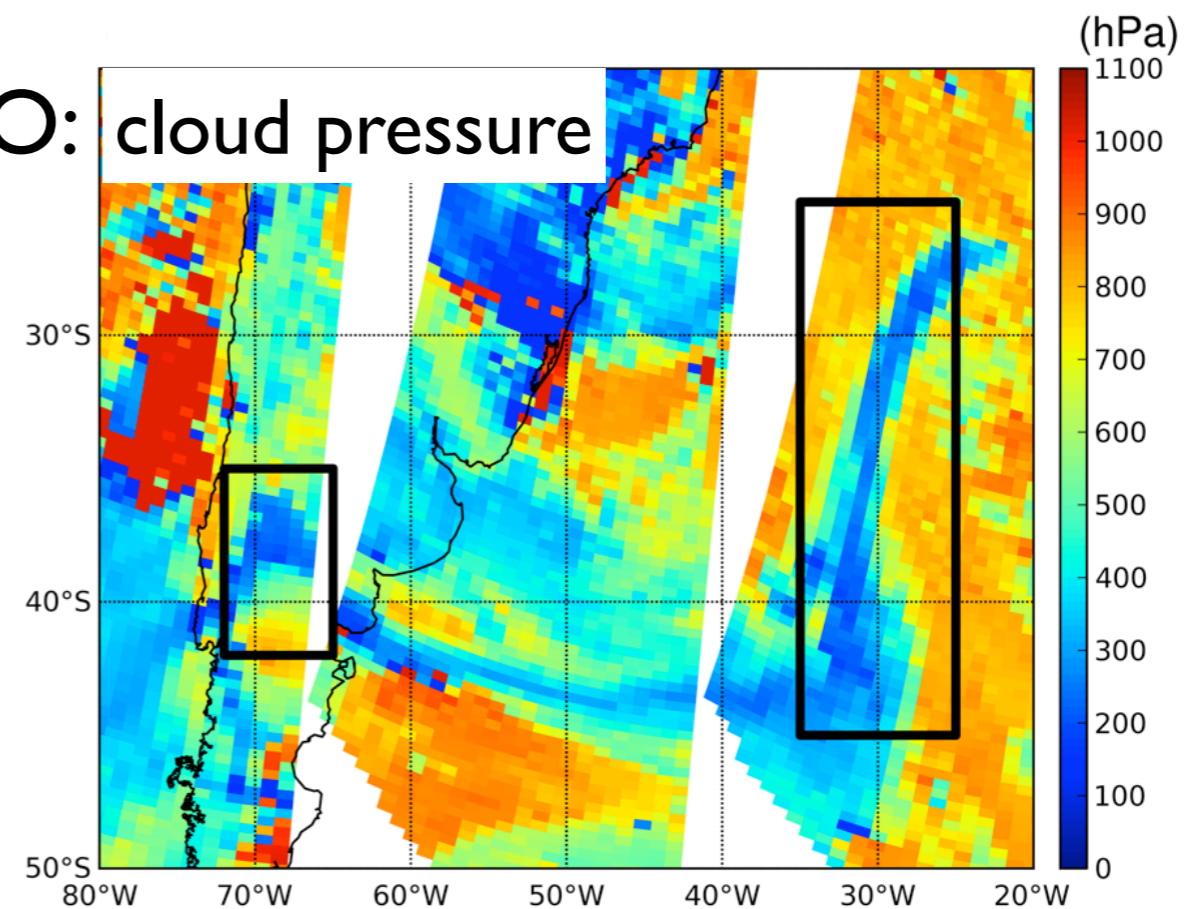
- Volcanic ash plume  
Chile, 6 June, 2011
- GOME-2



*Courtesy: Ping Wang & Olaf Tuinder*



**FRESCO: cloud pressure**

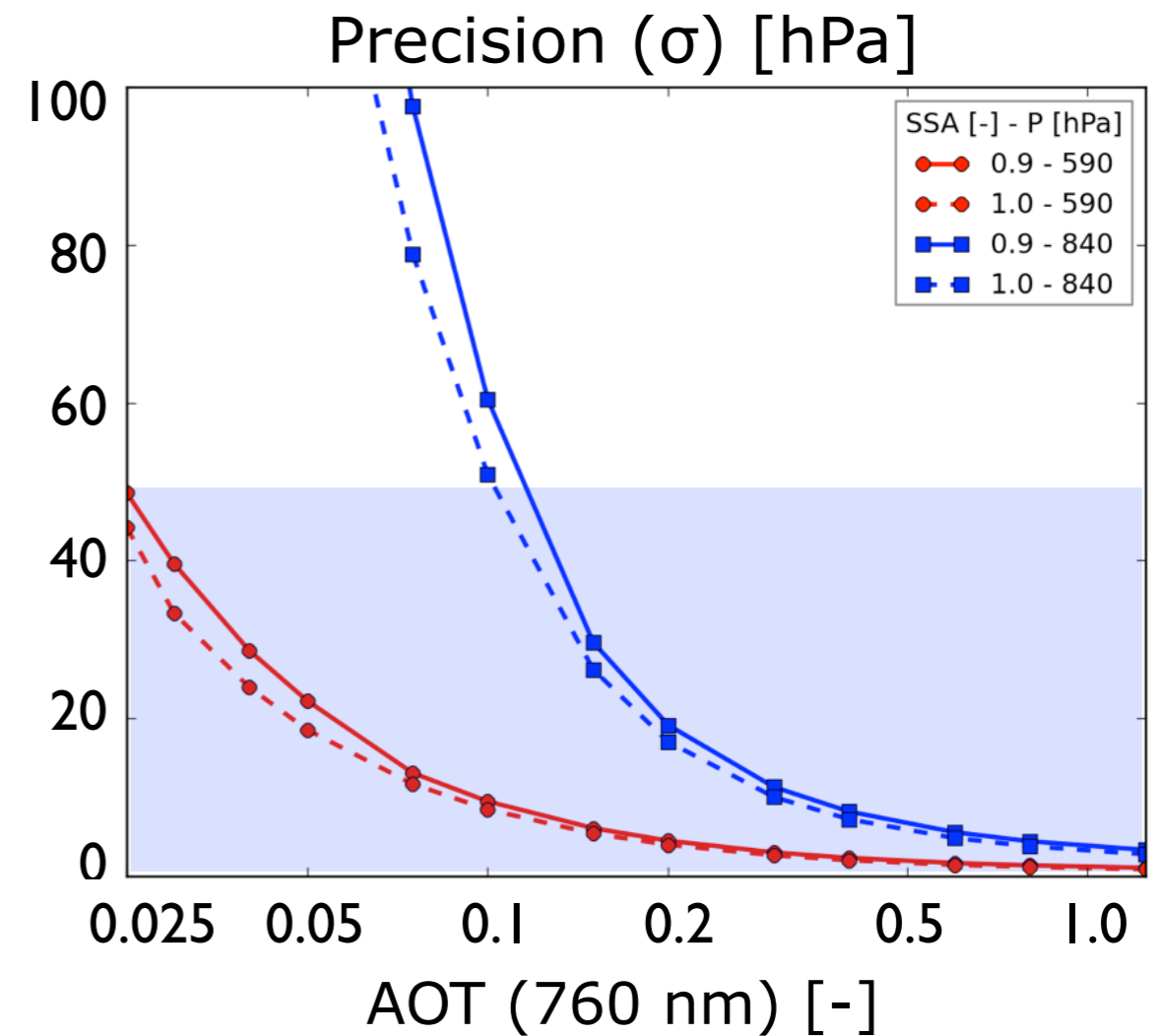
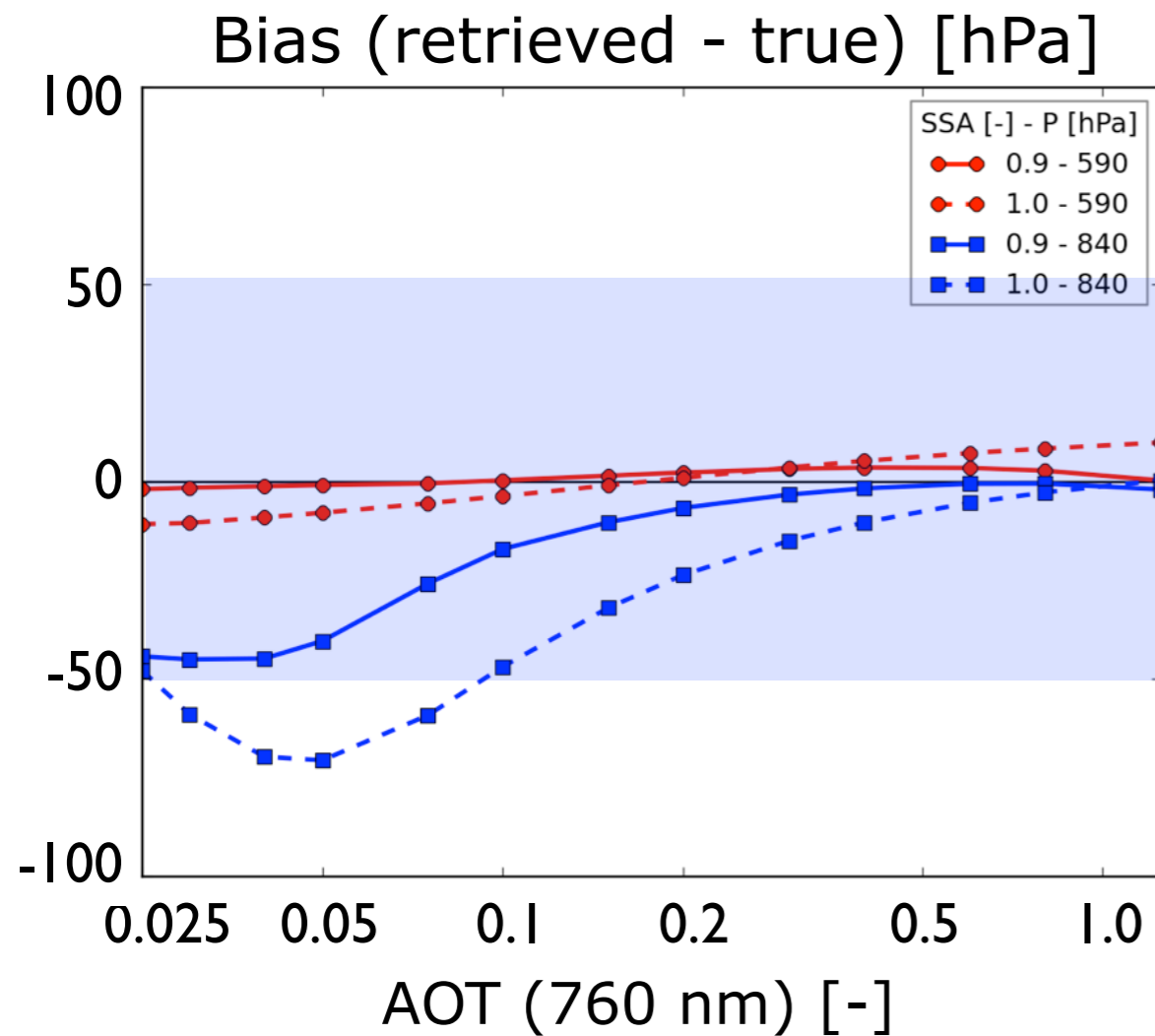


# Operational aerosol height retrieval

- Spectral fit of reflectance at wavelengths ~758-770 nm:  
fit parameters are **ALH**, **AOT**, **A<sub>s</sub>**, ...
- Optimal Estimation: proper error analysis
- Aerosol layer modelled as a layer of particles
- Assumed profile: single layer with fixed pressure thickness

# Error in Single Scattering Albedo

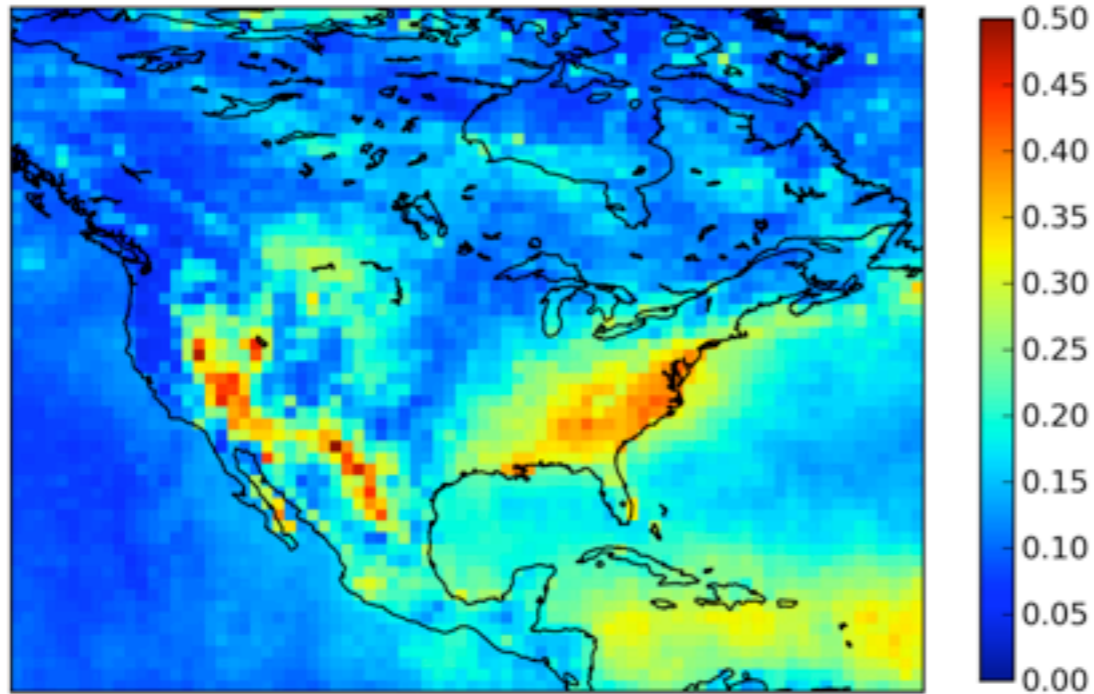
blue: 840 hPa  
red: 590 hPa



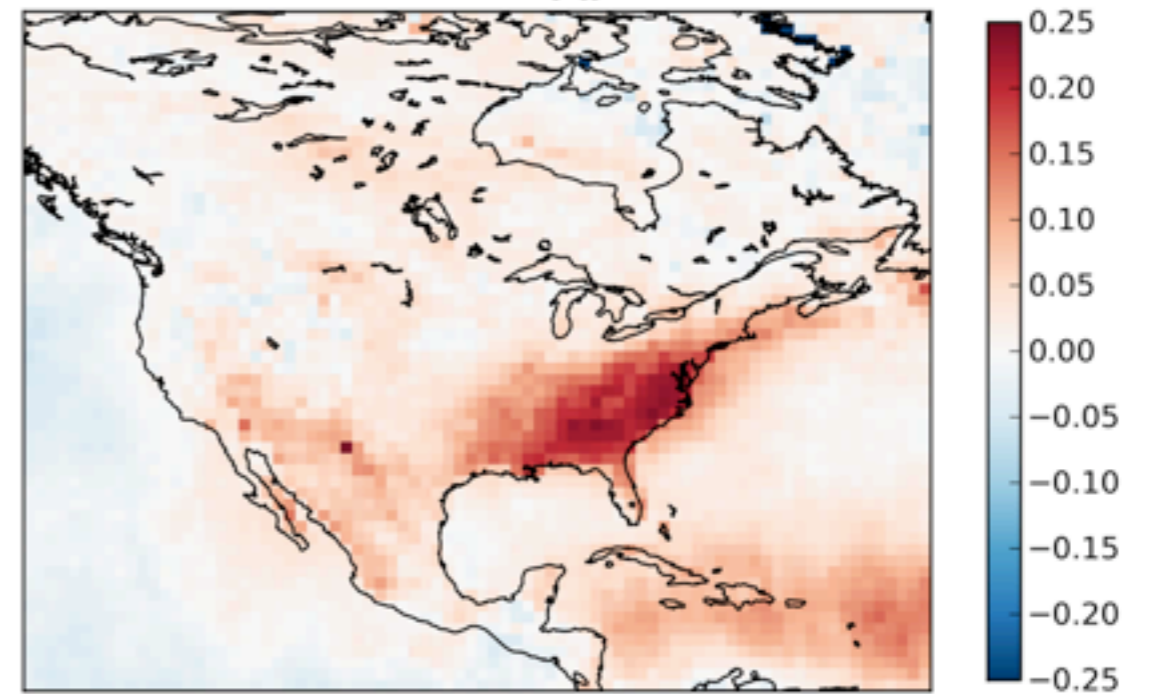
→ For AOT (760 nm) > ~0.1:  
accuracy and precision of retrieved height  
better than 50 hPa (500 m)

# AOT-HCHO: Summer Anomalies

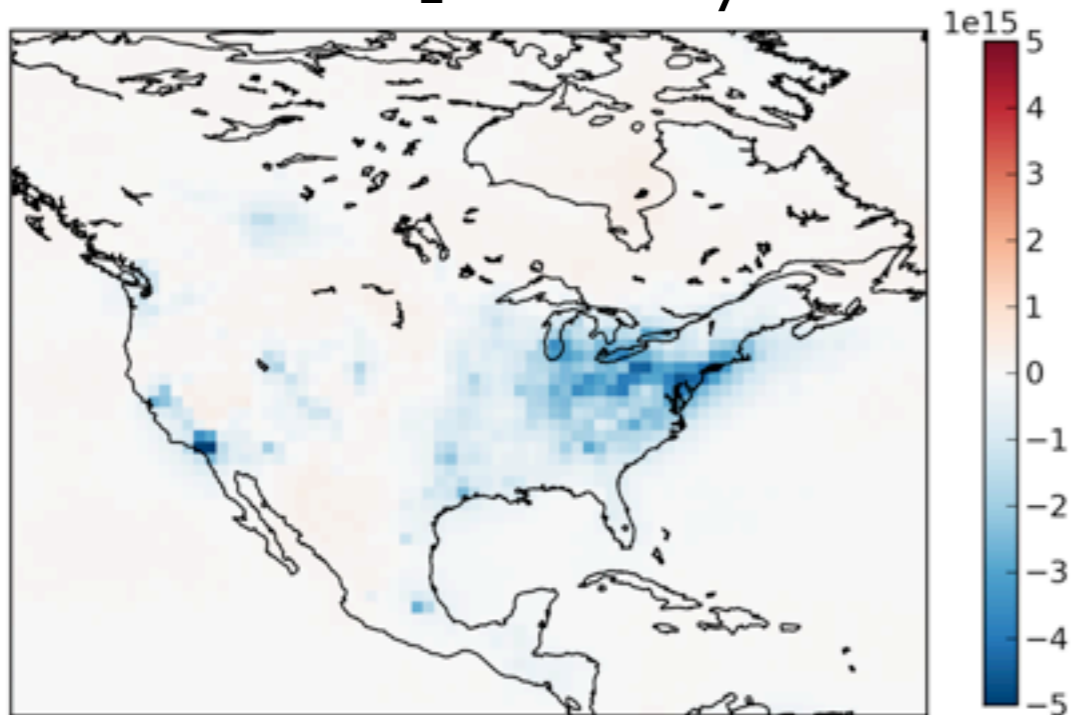
JJA AOT



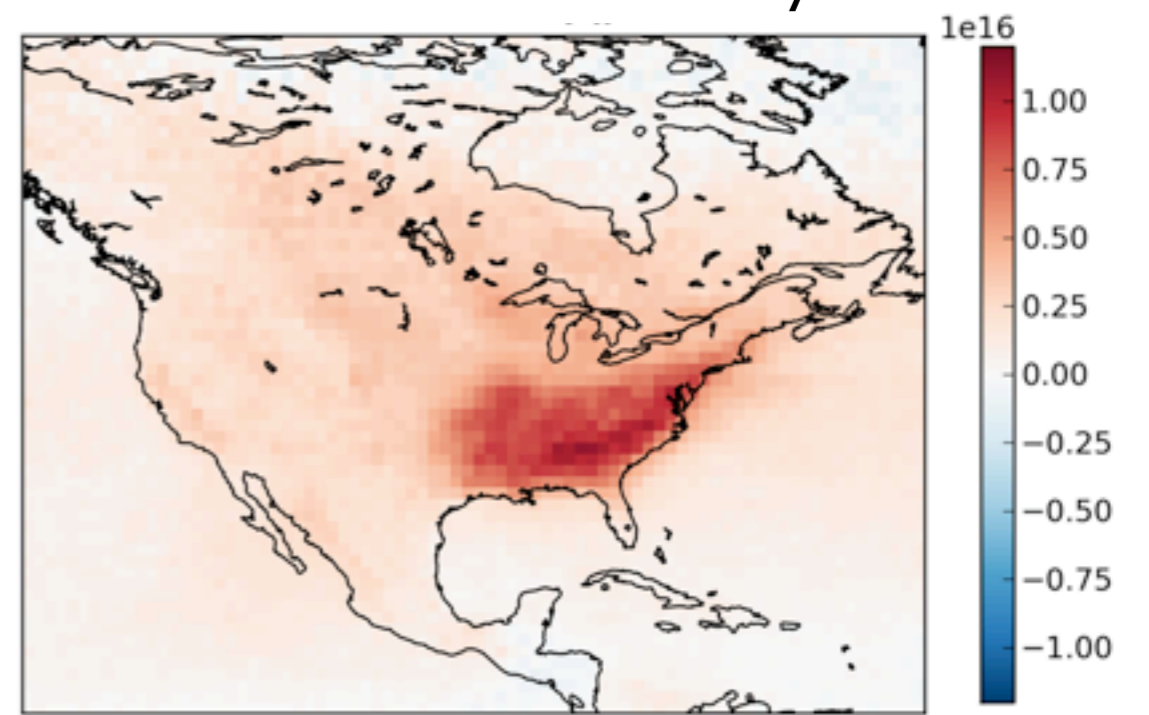
JJA AOT Anomaly



JJA NO<sub>2</sub> Anomaly



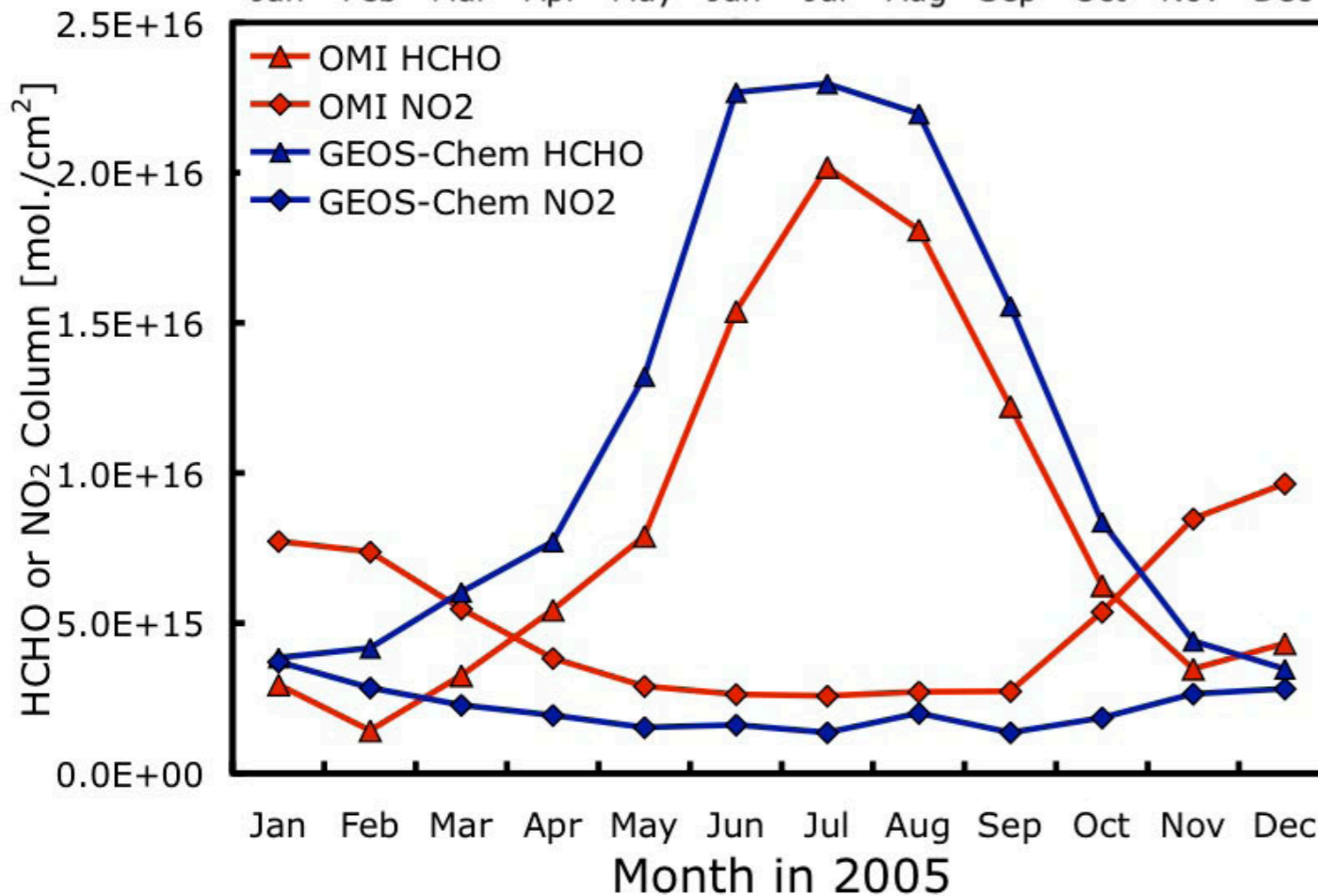
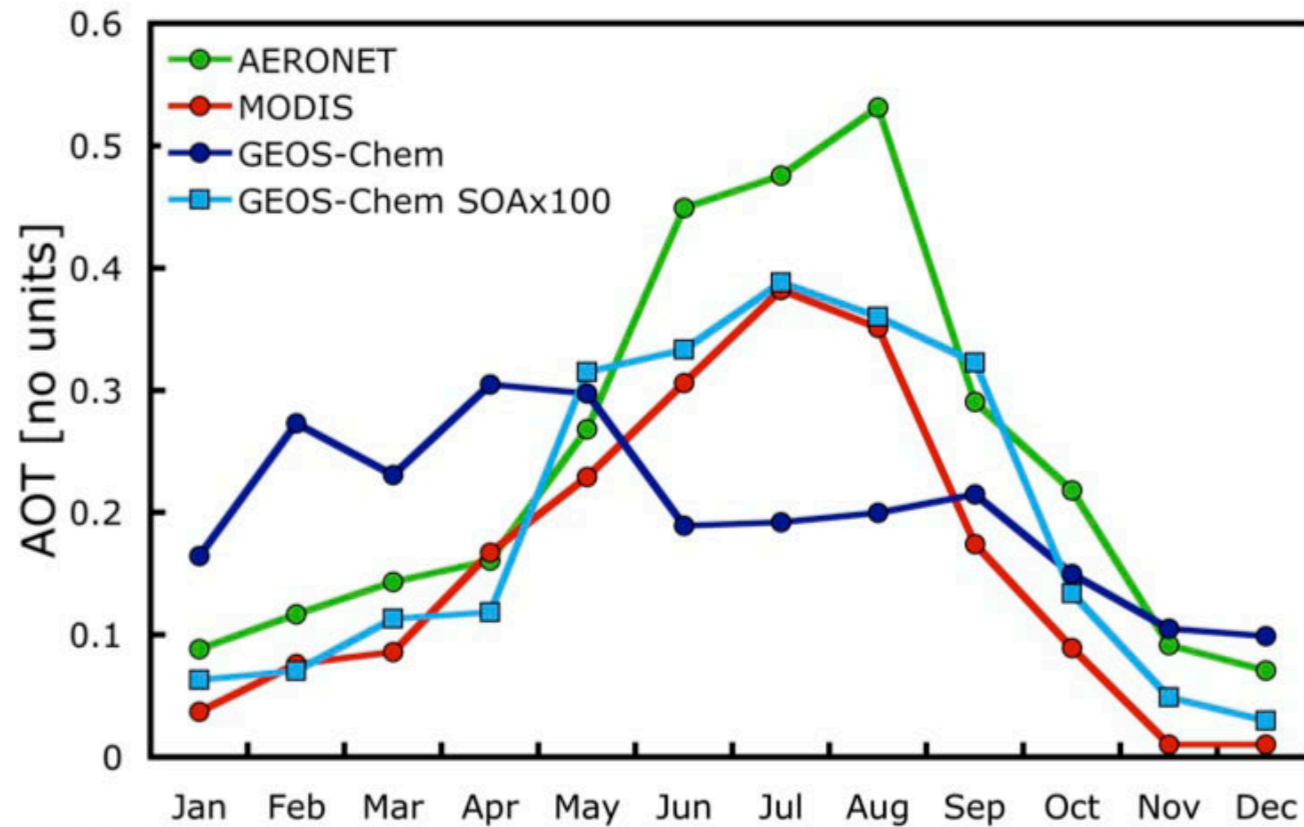
JJA HCHO Anomaly



*Veefkind et al., ACP, 2011*

Years 2005-2007

# SE USA: Seasonal Variations



- Spatial-temporal correlation between AOT and formaldehyde.
- Formaldehyde is produced from biogenic isoprene sources.
- AOT signal of  $\sim 0.2$  than models predict. [e.g. *van Donkelaar et al., AE, 2007*]

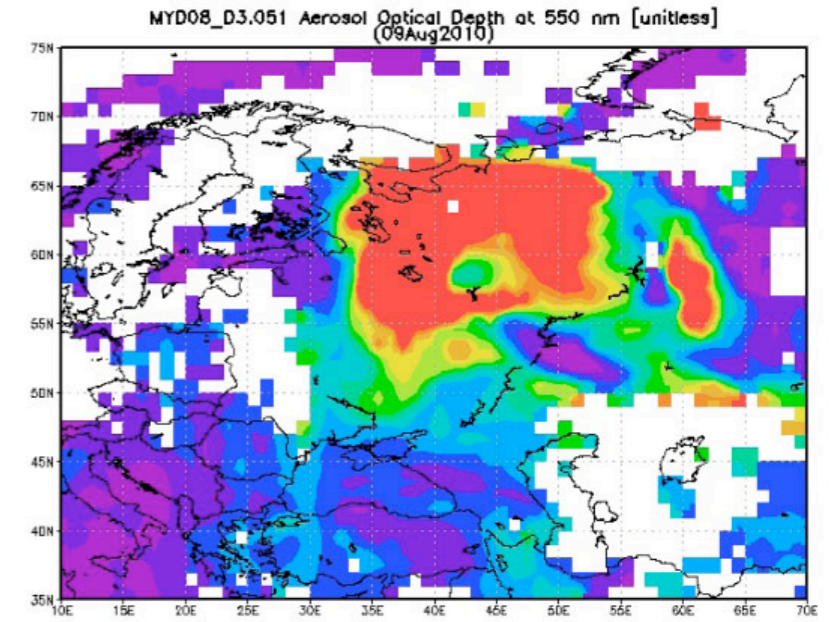
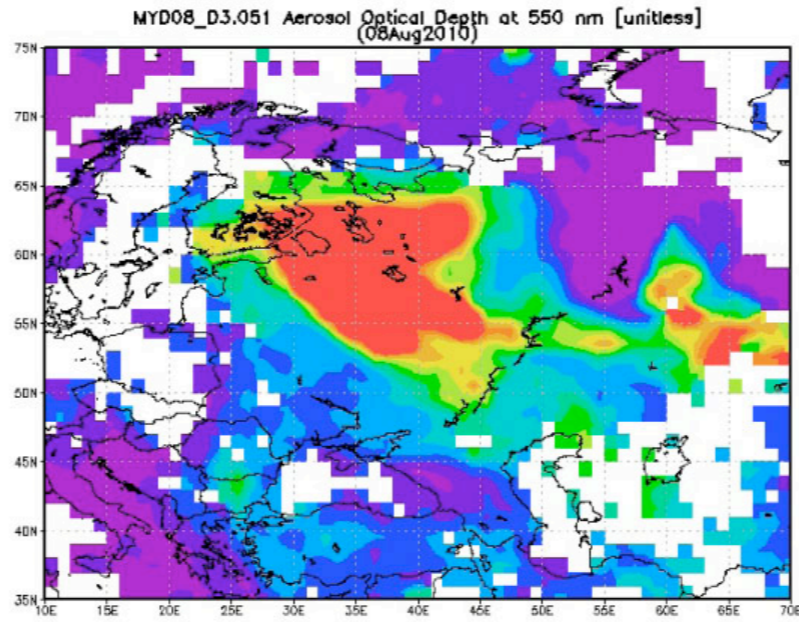
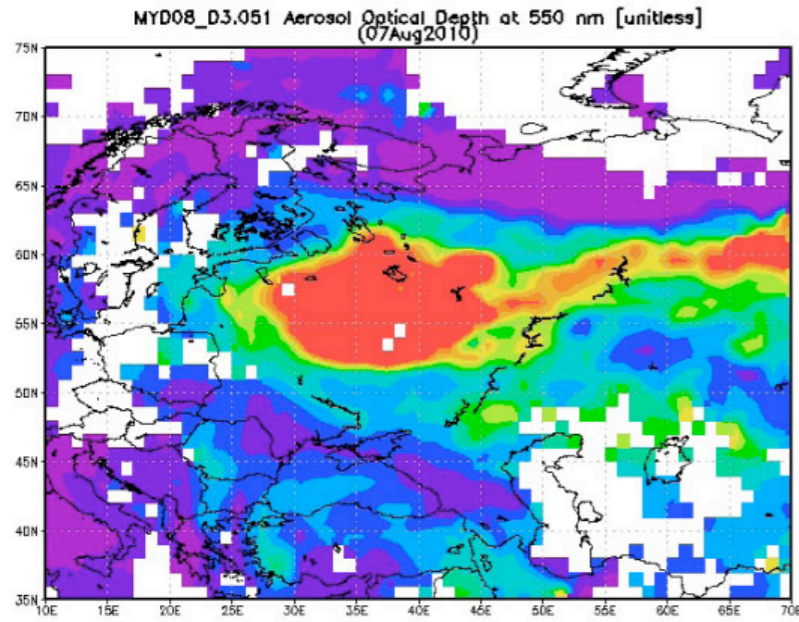


2010-08-07

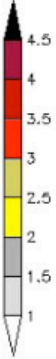
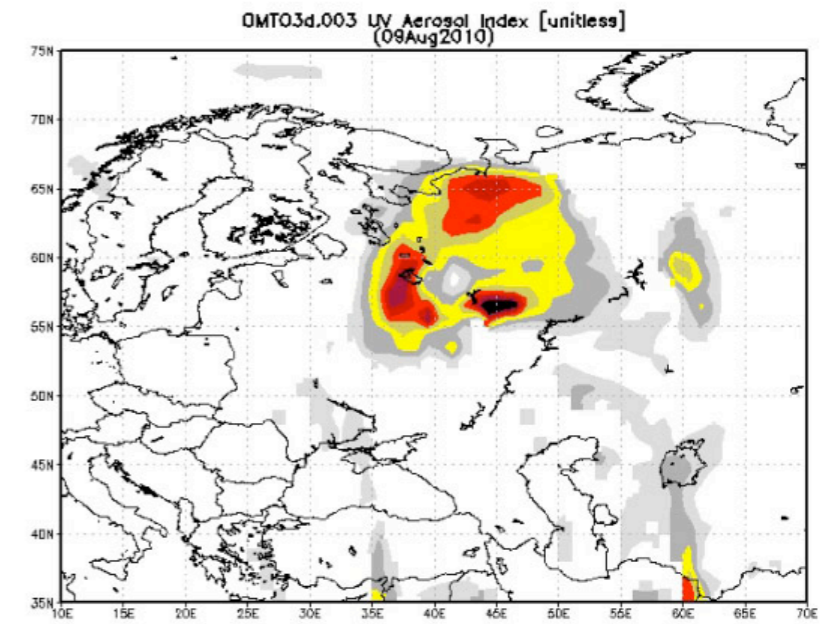
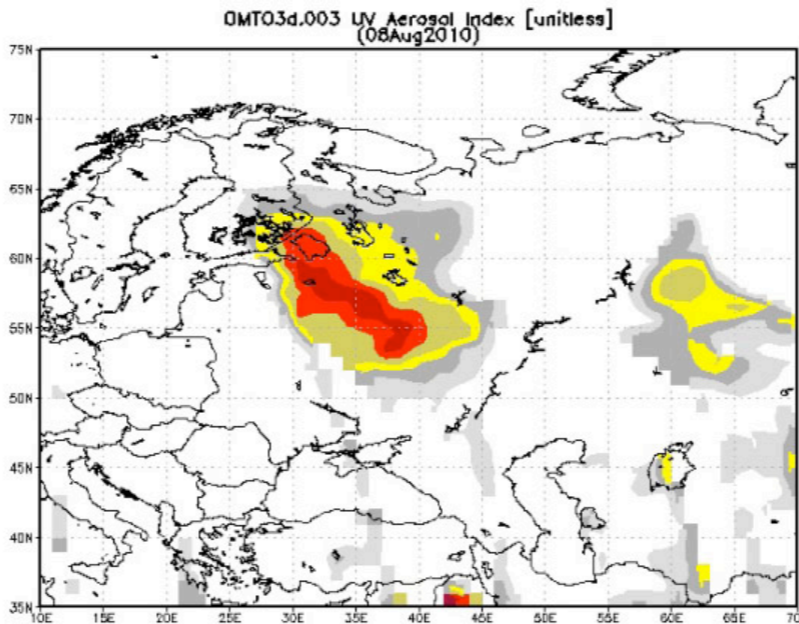
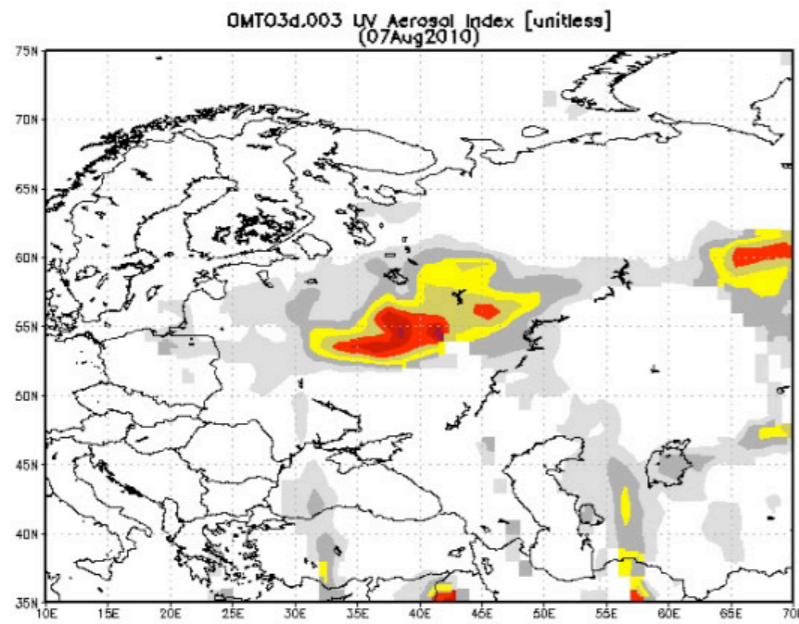
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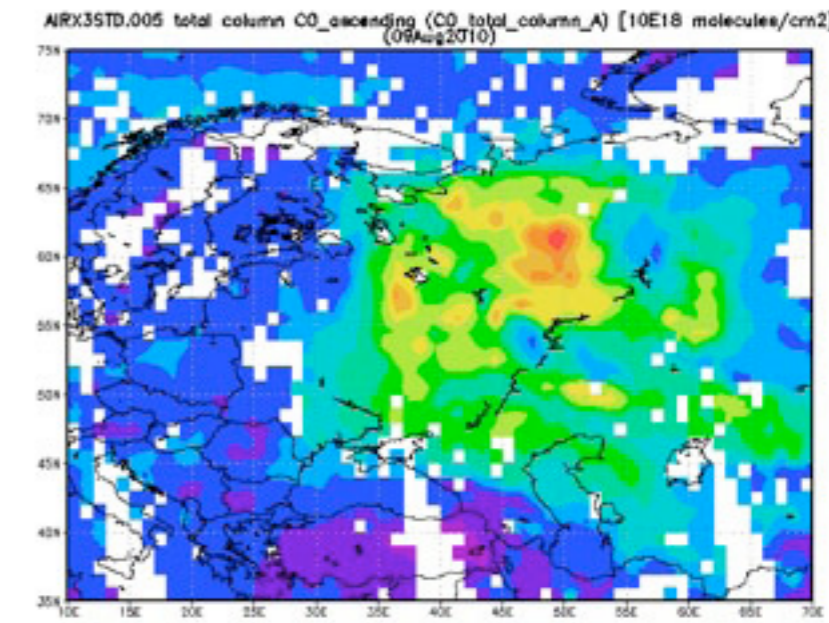
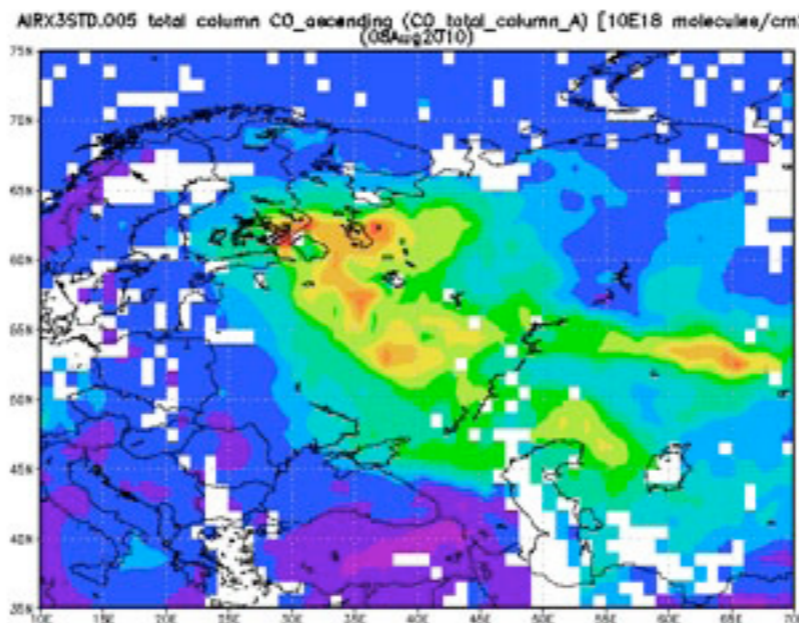
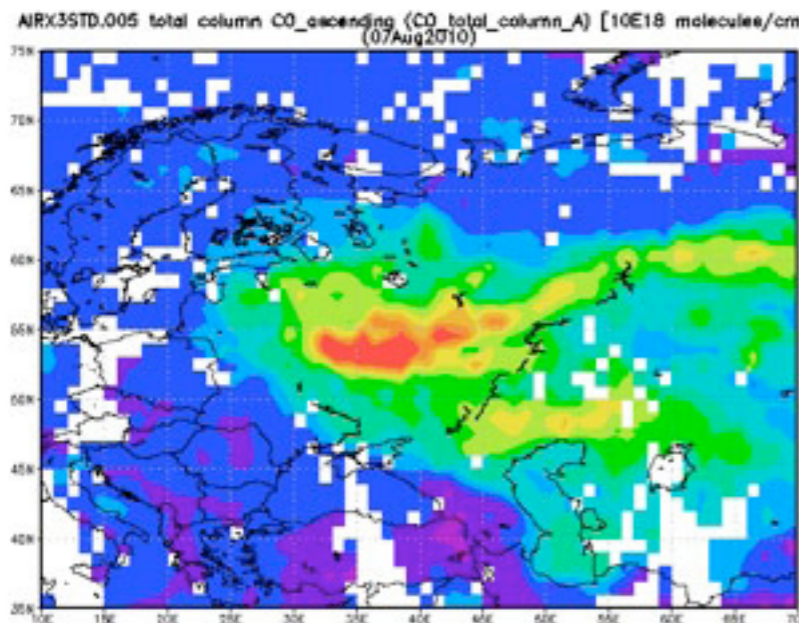
MODIS AOT



OMI AAI



AIRS CO





# Summary



Tropospheric Monitoring Instrument

[veefkind@knmi.nl](mailto:veefkind@knmi.nl)

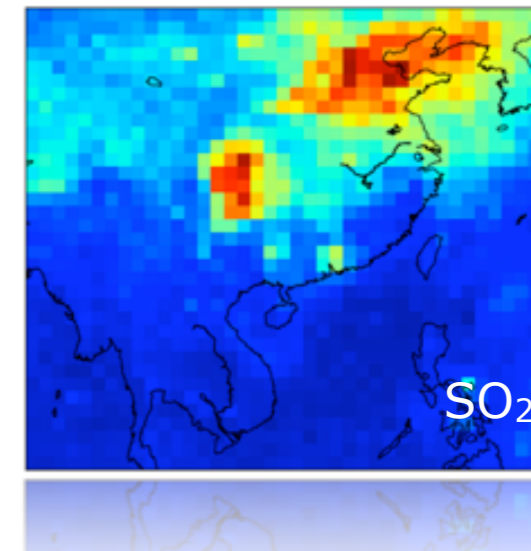
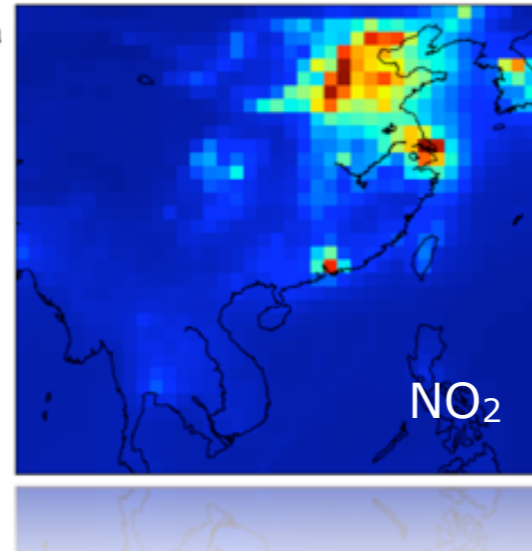
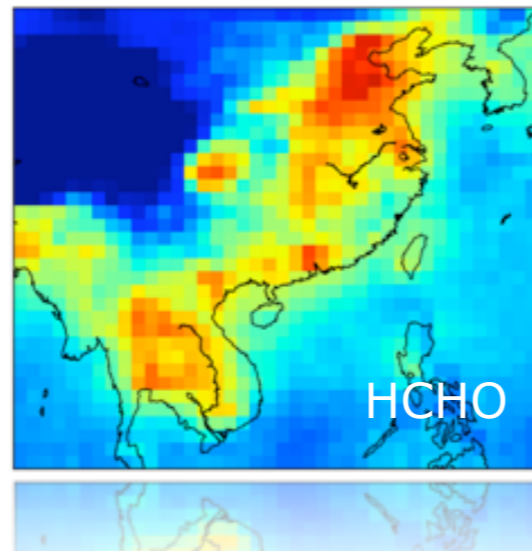
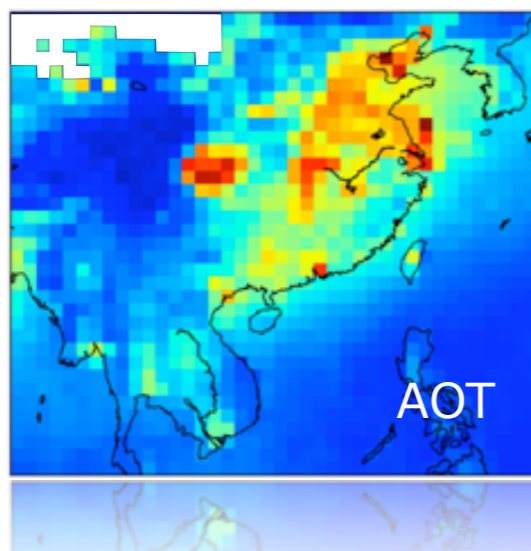
[www.tropomi.eu](http://www.tropomi.eu)

[www.temis.nl](http://www.temis.nl)

[www.knmi.nl/omi](http://www.knmi.nl/omi)

<http://www.esa.int/esaLP>

- There is a long data record of satellite UV-measurements that contains information on absorbing aerosols.
- The AAI is an excellent event detector. The next step is to use the AAI in a quantitative way.
- A new product in development for TROPOMI is the aerosol layer height.
- The combination of trace and aerosol observations contains information on the aerosol type and chemical composition.





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## Remote Sensing of Environment

journal homepage: [www.elsevier.com/locate/rse](http://www.elsevier.com/locate/rse)



### TROPOMI on the ESA Sentinel-5 Precursor: A GMES mission for global observations of the atmospheric composition for climate, air quality and ozone layer applications

J.P. Veefkind<sup>a,g,\*</sup>, I. Aben<sup>b</sup>, K. McMullan<sup>c</sup>, H. Förster<sup>d</sup>, J. de Vries<sup>e</sup>, G. Otter<sup>f</sup>, J. Claas<sup>a</sup>, H.J. Eskes<sup>a</sup>, J.F. de Haan<sup>a</sup>, Q. Kleipool<sup>a</sup>, M. van Weele<sup>a</sup>, O. Hasekamp<sup>b</sup>, R. Hoogeveen<sup>b</sup>, J. Landgraf<sup>b</sup>, R. Snel<sup>b</sup>, P. Tol<sup>b</sup>, P. Ingmann<sup>c</sup>, R. Voors<sup>e</sup>, B. Kruizinga<sup>f</sup>, R. Vink<sup>f</sup>, H. Visser<sup>f</sup>, P.F. Levelt<sup>a,g</sup>

<http://dx.doi.org/10.1016/j.rse.2011.09.027>

# TROPOMI

*TROPOspheric Monitoring Instrument*

[www.tropomi.eu](http://www.tropomi.eu)

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The TROPOspheric Monitoring Instrument (TROPOMI) is a spaceborne nadir viewing spectrometer with bands in the ultraviolet, the visible, the near infrared and the shortwave infrared. TROPOMI is the payload for the ESA/GMES Sentinel 5 Precursor mission, planned for launch in 2014 with 7 years design lifetime. The objective of the mission is to provide high-quality and timely information on the global atmospheric composition for climate and air quality applications. TROPOMI will make daily global observations of key atmospheric constituents, including ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, methane, formaldehyde and aerosol properties. The Sentinel-5 Precursor mission will extend the current data records from OMI (Ozone Monitoring Instrument) on NASA EOS Aura and SCIAMACHY (SCanning Imaging Absorption spectrometer for Atmospheric Cartography) on ESA Envisat and is the link between the current scientific missions and the operational Sentinel-4/-5 missions.

TROPOMI is an initiative from the Netherlands and is developed in cooperation

