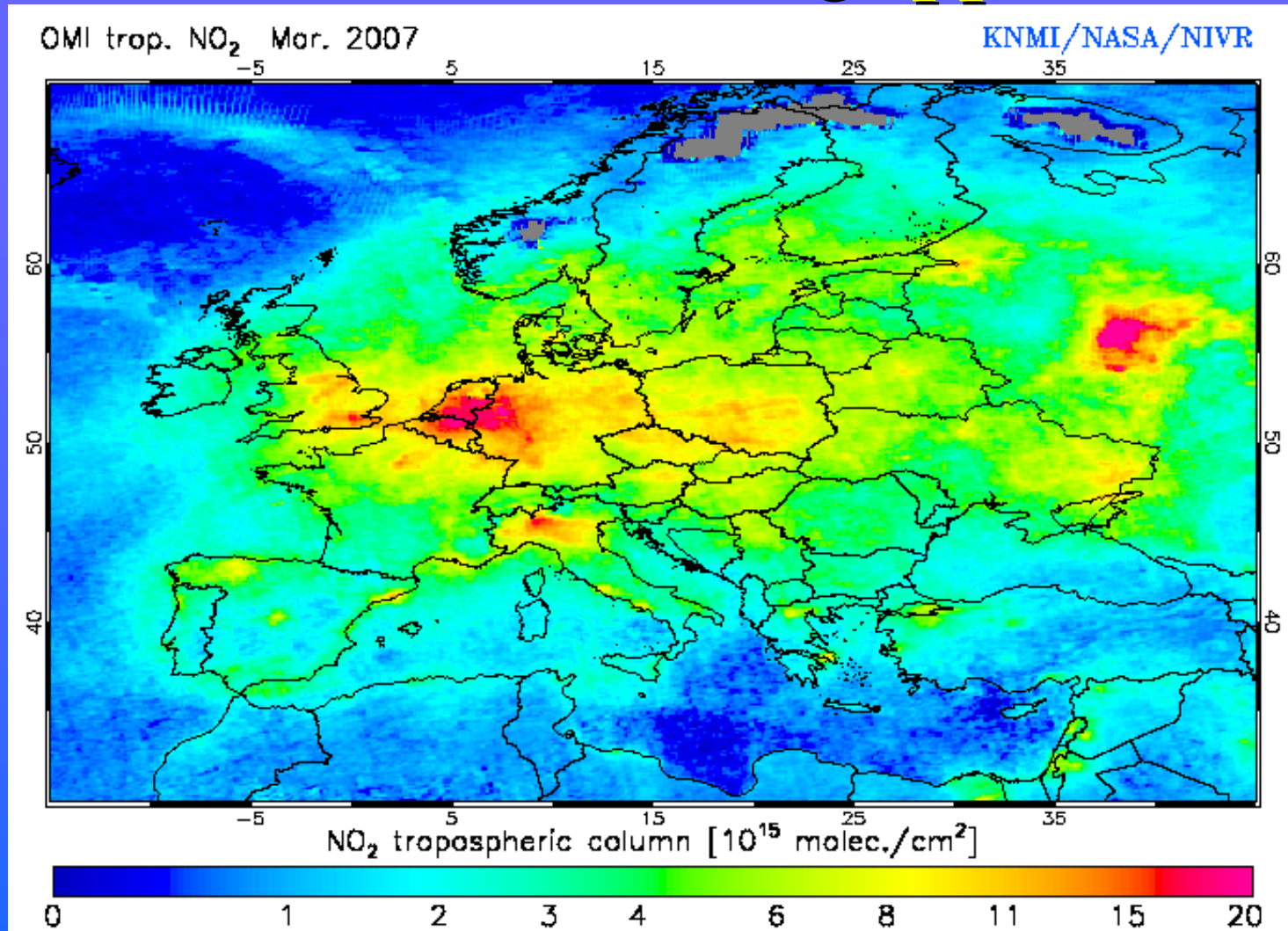


# OMI Products for AQ applications



**Pieter Levelt (KNMI) and P.K. Bhartia (NASA GSFC),  
June 18-20, 2007, NASA AQ Meeting, Washington DC**

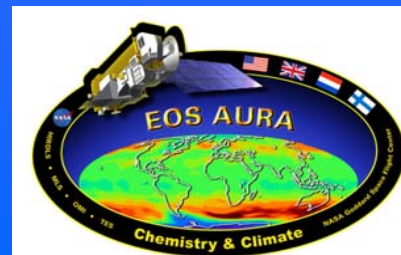
# Royal Netherlands Meteorological Institute

## KNMI



- Weather prediction
- Climate Research (OMI)
- Infrastructure

450 employees



# International OMI Team

## International OMI Science team

- PI (KNMI): P.F. Levelt
- dep.PI (KNMI): J.P. Veefkind
- co-PI (FMI) J.Tamminen
- US ST Leader (NASA GSFC): P.K. Bhartia
- .... And about 60 - 80 scientists

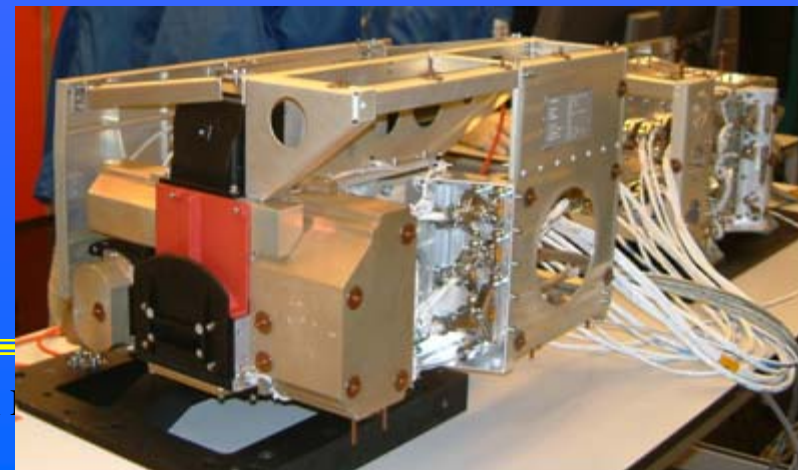
## Industry

- Dutch: DS, TNO-TPD, SRON
- Finnish: VTT, Patria
- USA: Northrop GES USA

## Dutch, Finnish and US Space Agencies

- NIVR, FMI and NASA

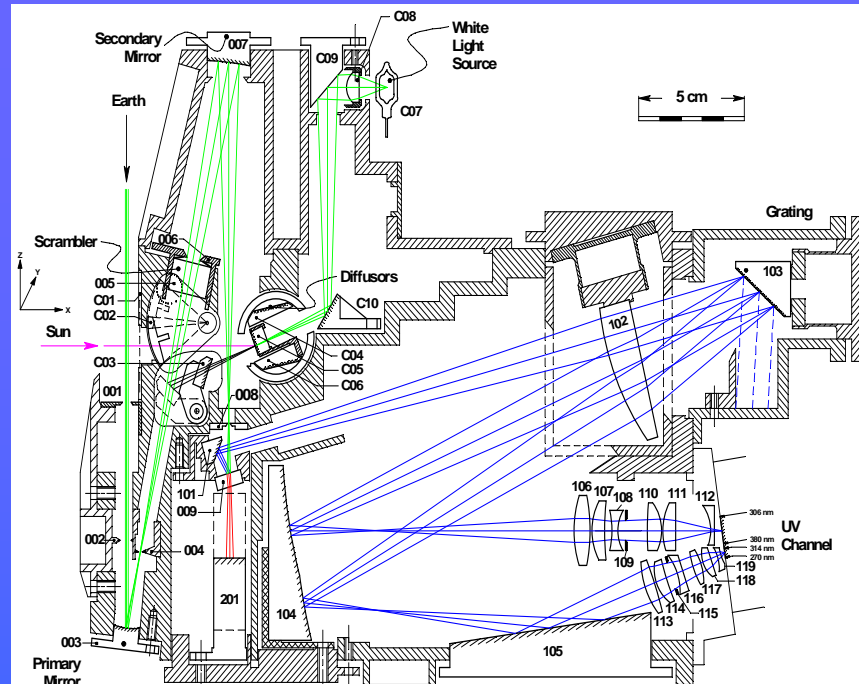
OMI is a Dutch-Finnish Instrument on the NASA spacecraft EOS-Aura



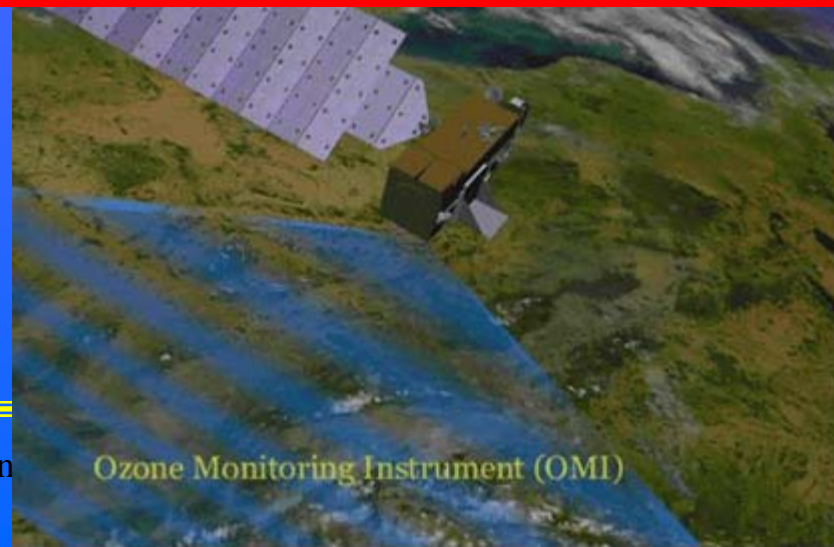
# Ozone Monitoring Instrument OMI

- 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<sup>2</sup>)

Heritage: GOME, SCIAMACHY, GOMOS and TOMS



*IEEE Aura Special Issue, May 2006  
on AURA instruments, algorithms and first results*



Ozone Monitoring Instrument (OMI)



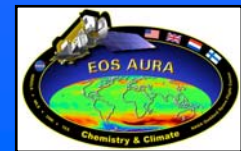
# Status of OMI Data Products

| Product                                  | Provisional release | Validated Stage 1 release<br>(Public) | Algorithm originator |
|--|---------------------|---------------------------------------|----------------------|
| - Level 1B                               | Released            | August 2007 (collection-3)            | KNMI                 |
| - Total Column Ozone (TOMS)              | Released            | Released                              | NASA GSFC            |
| - Total Column Ozone (DOAS)              | Released            | Released                              | KNMI                 |
| - Aerosol (UV and multi- $\lambda$ )     | Released            | Released                              | NASA GSFC & KNMI     |
| - NO <sub>2</sub> total and trop. column | Released            | Released                              | KNMI & NASA GSFC     |
| - Cloud Height (O2-O2)                   | Released            | Released                              | KNMI                 |
| - Cloud Height (Raman)                   | Released            | Released                              | NASA GSFC            |
| - Surface UVB                            | Released            | Released                              | FMI & NASA GSFC      |
| - HCHO                                   | Released            | Released                              | Harvard              |
| - SO <sub>2</sub>                        | Released            | Released                              | NASA GSFC            |
| - BrO                                    | Released            | Released                              | Harvard              |
| - OCIO                                   | Released            | Released                              | Harvard              |
| - O <sub>3</sub> Profile                 | Released            | Fall 2007 (collection-3)              | KNMI                 |



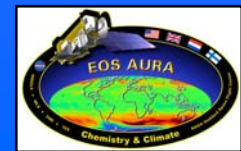
NASA AQ Meeting, June 18-20, 2007, Washington DC

Dr. P.F. Levelt, KNMI



# Status of OMI Data Products

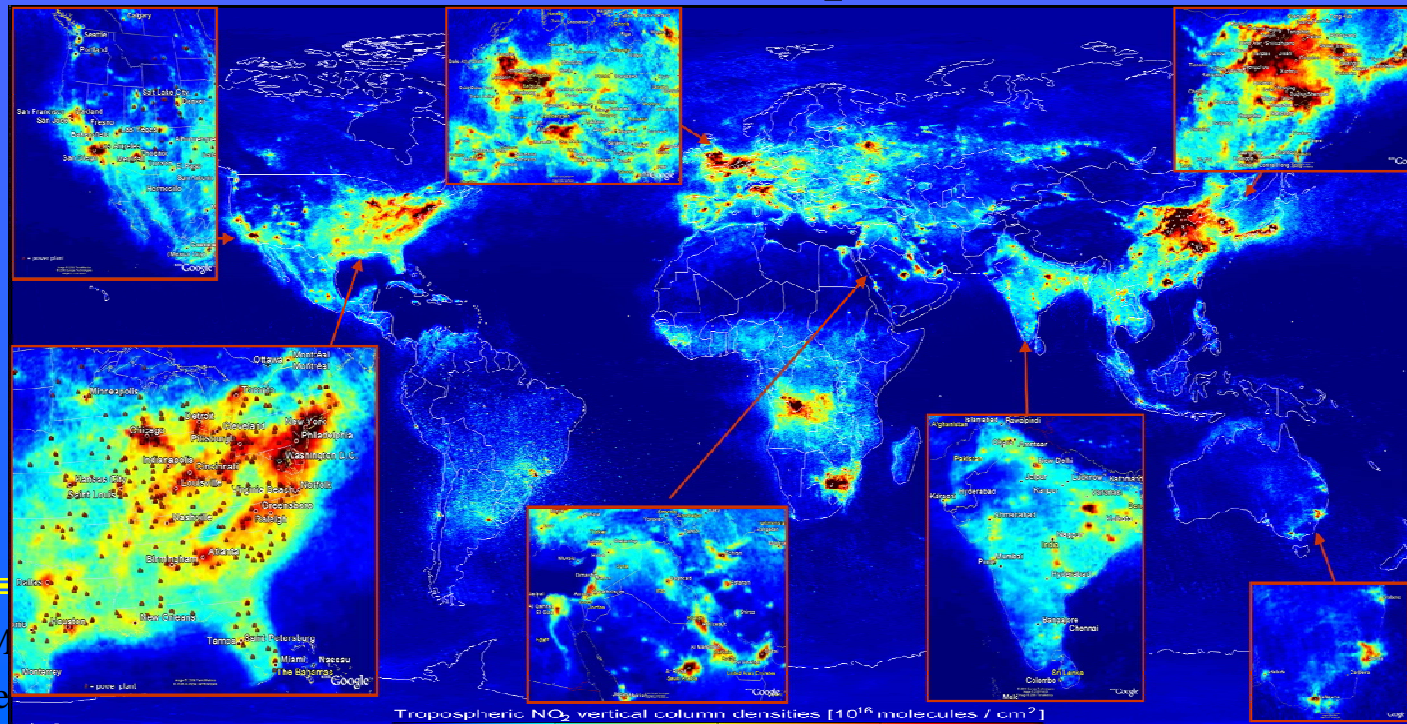
| Product | Provisional release  | Validated Stage 1 release | Algorithm originator |
|---------|--|---------------------------|----------------------|
| - Le    | Off line data: NASA GSFC DISC<br>( <a href="http://acdisc.gsfc.nasa.gov">http://acdisc.gsfc.nasa.gov</a> ) |                           |                      |
| - To    | NRT data: TEMIS website ( <a href="http://www.temis.nl">http://www.temis.nl</a> )                          |                           |                      |
| - To    | VFD data : Very Fast Delivery ( <a href="http://omivfd.fmi.fi">http://omivfd.fmi.fi</a> )                  |                           |                      |
| - Ac    | AVDC Aura Validation Centre ( <a href="http://avdc.gsfc.nasa.gov">http://avdc.gsfc.nasa.gov</a> )          |                           |                      |
| - NC    |  |                           |                      |
| - Cl    |  |                           |                      |
| - Cl    | <b>Product description: IEEE Aura Special Issue March 2006 &amp; read "read-me" files</b>                  |                           |                      |
| - Su    |  |                           |                      |
| - Ho    |  |                           |                      |
| - SC    |  |                           |                      |
| - Br    | <b>Validation: JGR Aura Validation Special Issue 2007</b>  |                           |                      |
| - OC    |  |                           |                      |
| - O     | <b>Please contact OMI PI team!</b>   |                           |                      |



# Available products from OMI for AQ

- NO<sub>2</sub> (NRT and off-line)
- Aerosol Index : Smoke and Dust transport
  - Correlation with visibility for desert dust

## OMI Tropospheric NO<sub>2</sub> (average Jan.-June 2006) NASA GSFC/KNMI off-line product



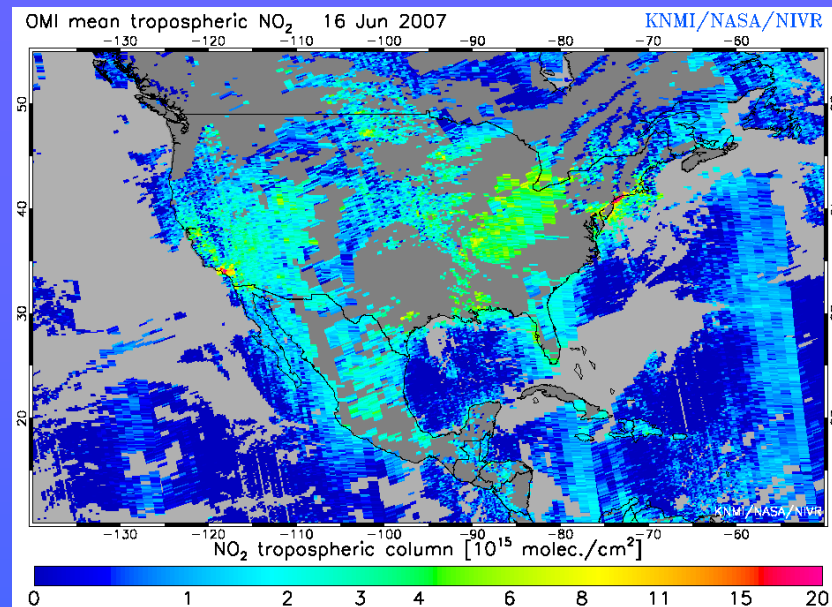
*Courtesy of  
J. Gleason, NASA-  
GSFC,  
and  
J.P. Veefkind, KNMI*



NASA AQ M  
Dr. P.F. Levelt

# First ever Near Real Time global, daily, urban scale measurements on NO<sub>2</sub> from space!

Saturday 16 June 2007



Monday 18 June 2007

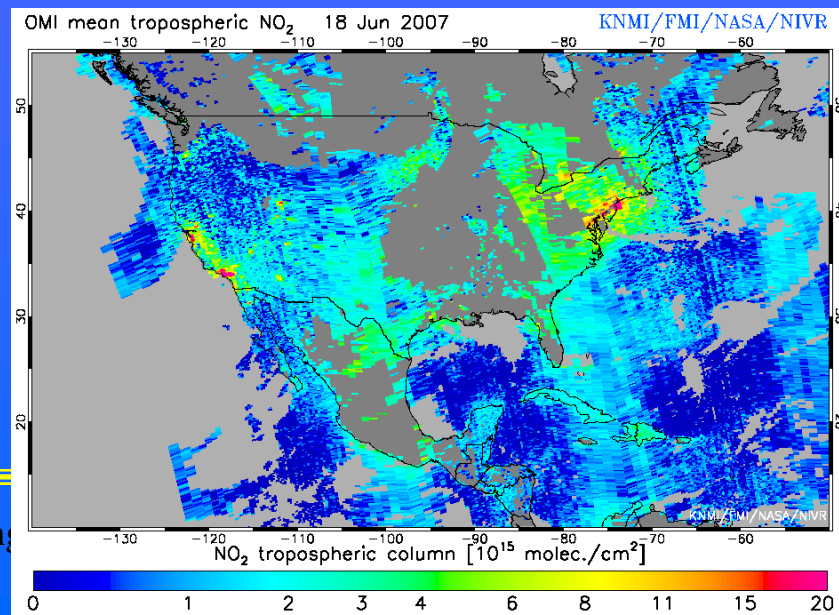
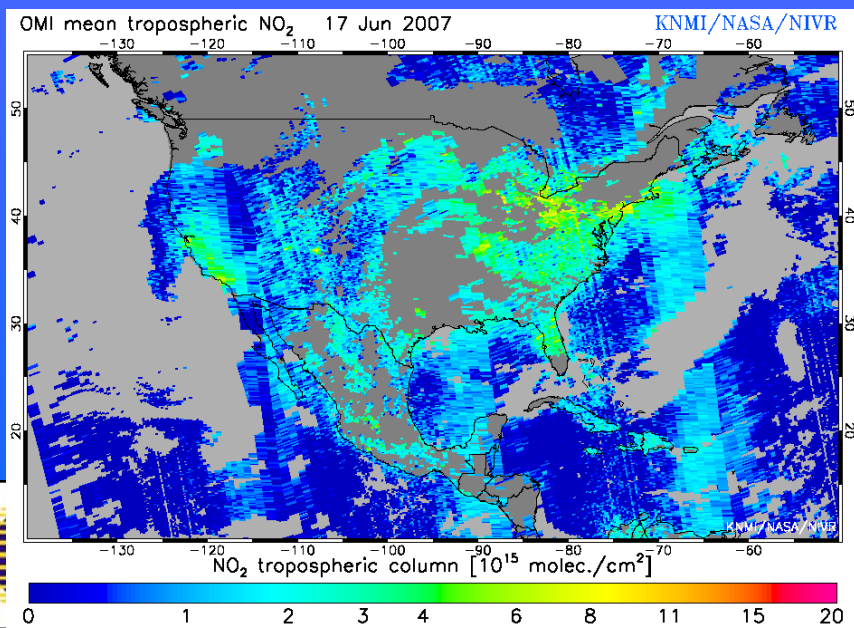
(KNMI NO<sub>2</sub> NRT product)

<http://www.temis.nl/>

<http://www.knmi.nl/omi>

Boersma et al., accepted in ACP

Sunday 17 June 2007

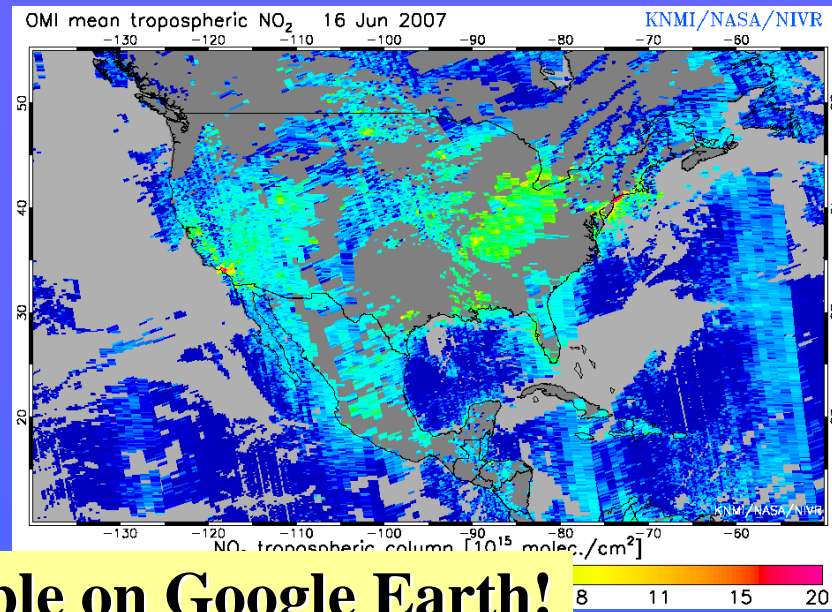


Washing



# First ever Near Real Time global, daily, urban scale measurements on NO<sub>2</sub> from space!

Saturday 16 June 2007



(KNMI NO<sub>2</sub> NRT product)

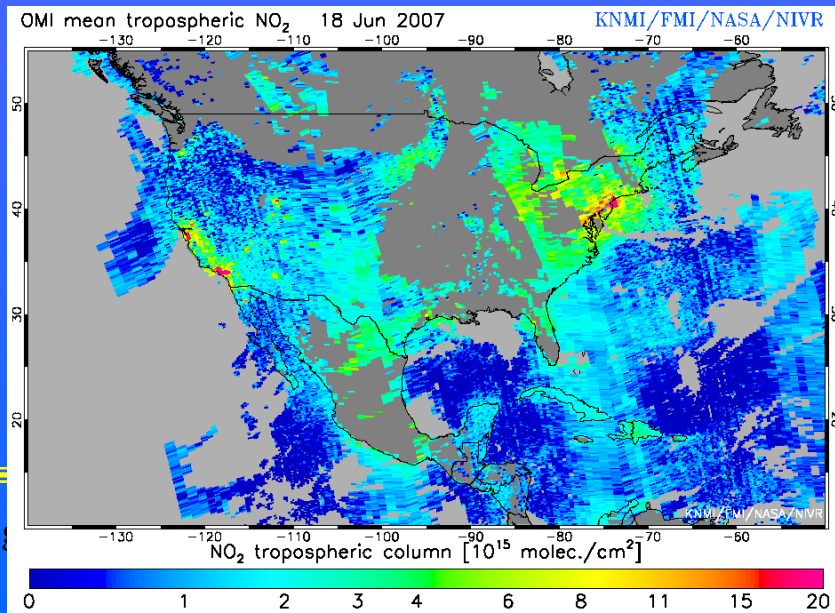
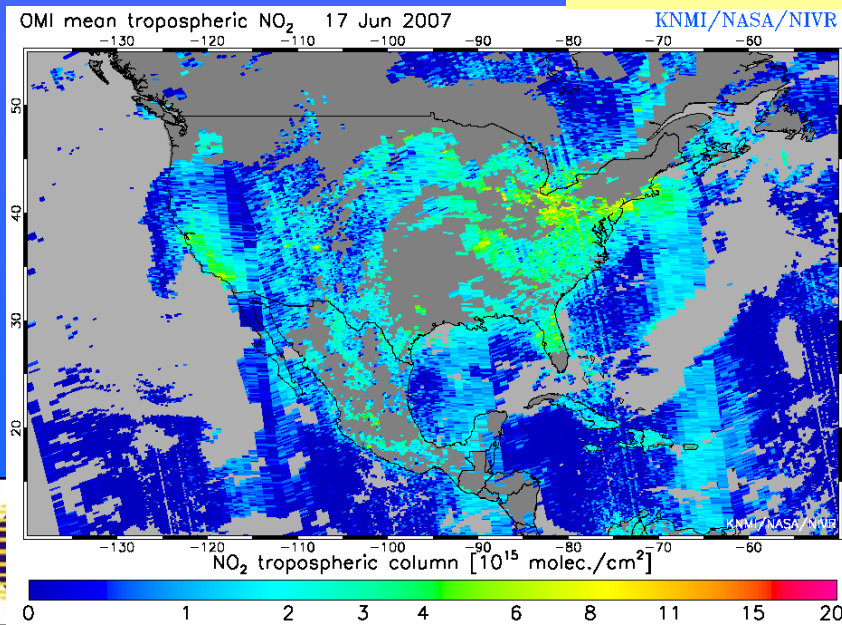
<http://www.temis.nl/>

<http://www.knmi.nl/omi>

Boersma et al., accepted in ACP

Sunday 17 June 2007

Now also available on Google Earth!



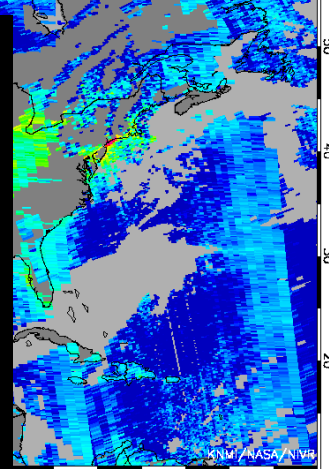
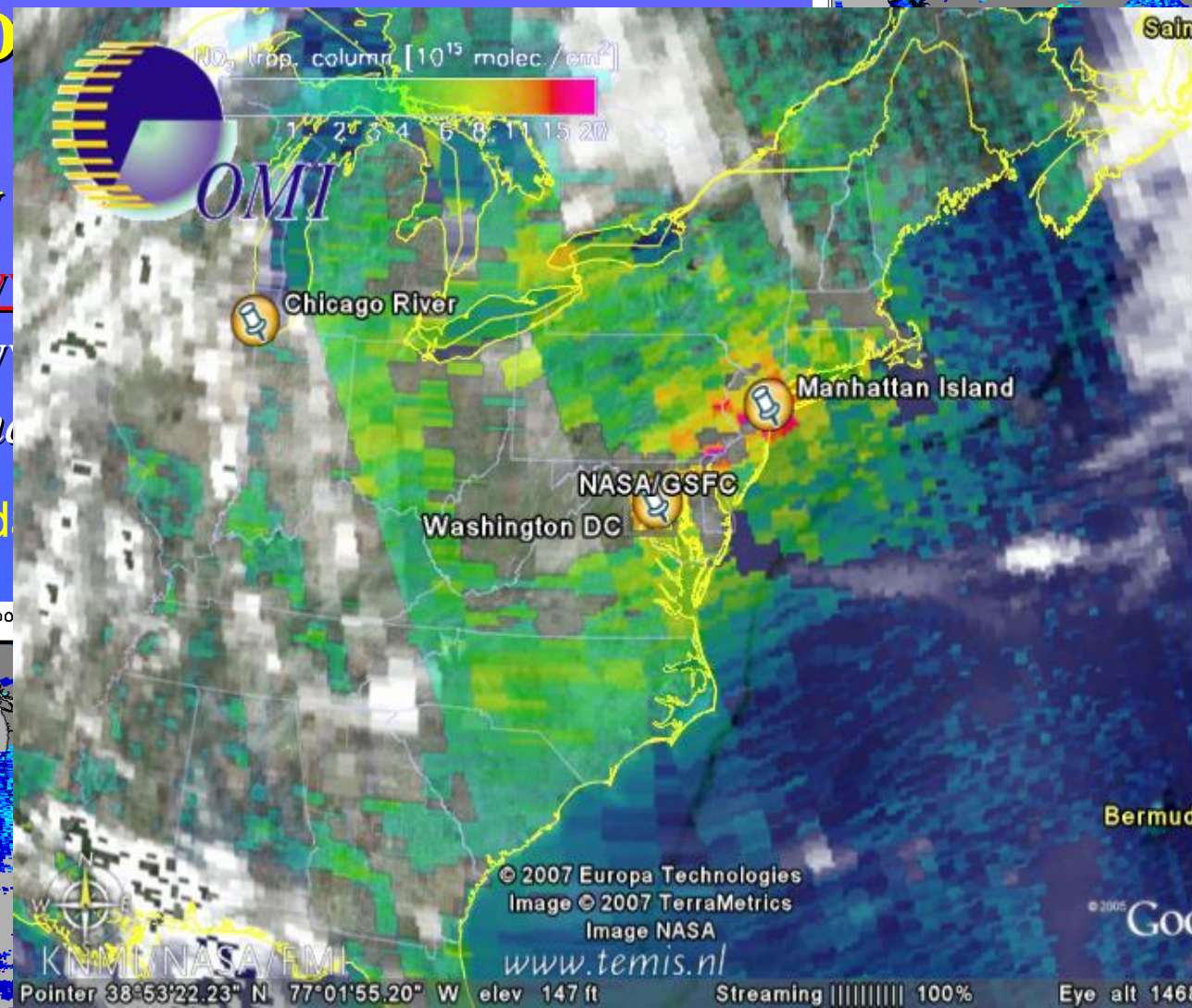
Washing

# First ever Near Real Time global, daily, urban scale measurements on NO<sub>2</sub>

Saturday 16 June 2007

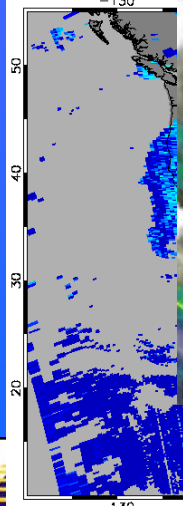
(KNMI  
<http://www.temis.nl>  
<http://www.boersma.nl>  
Sund

OMI mean tropospheric NO<sub>2</sub> 16 Jun 2007 KNMI/NASA/NIVR



molec./cm<sup>2</sup> 70 60 8 11 15 20

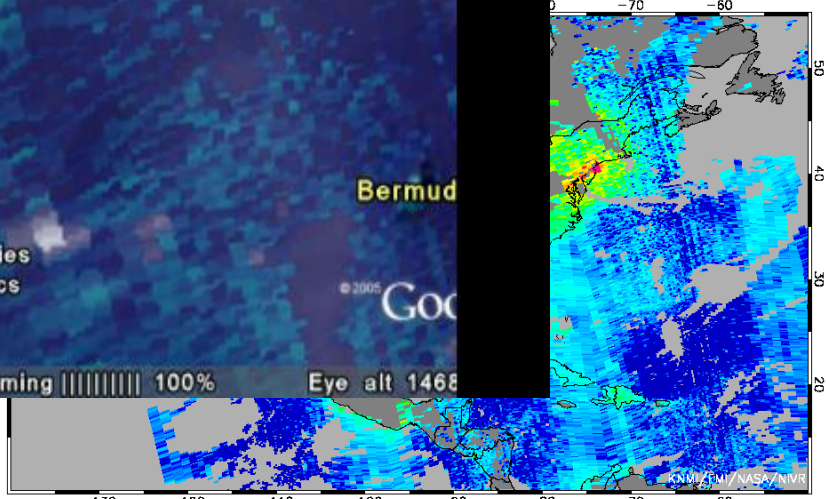
OMI mean tropo



NO<sub>2</sub> tropospheric column [10<sup>15</sup> molec./cm<sup>2</sup>]



KNMI/FMI/NASA/NIVR

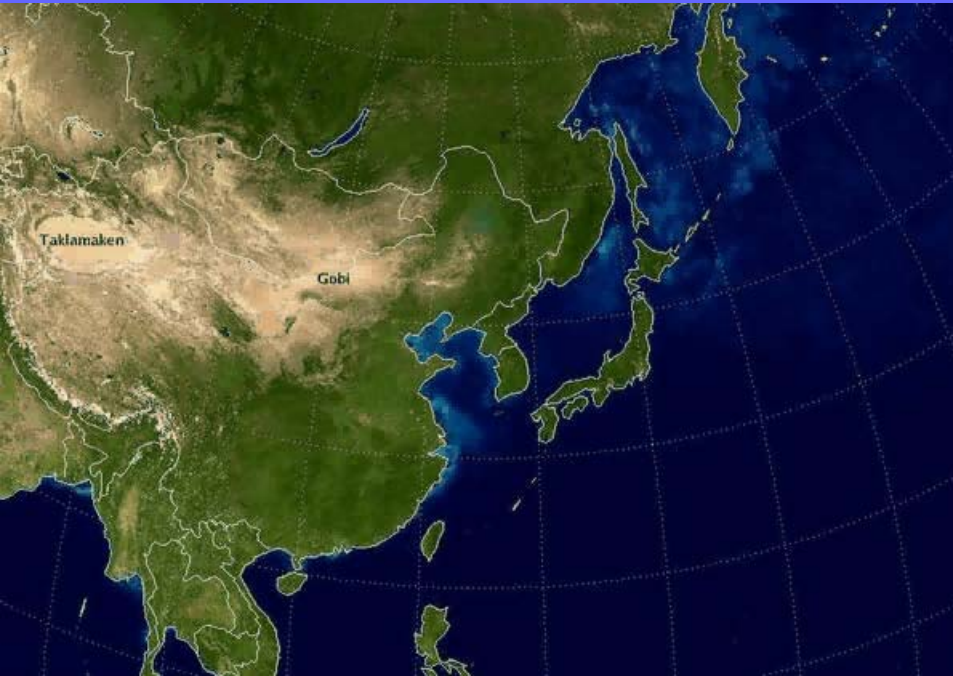


NO<sub>2</sub> tropospheric column [10<sup>15</sup> molec./cm<sup>2</sup>]



Washing

# Available OMI products for AQ: Aerosols

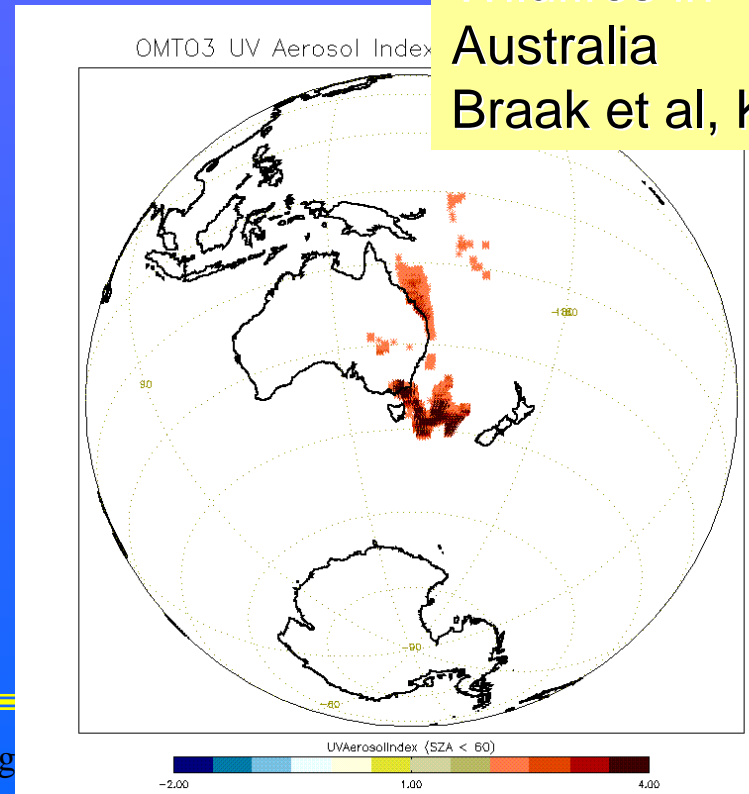


*Torres, Bhartia, NASA GSFC, ATMOS*

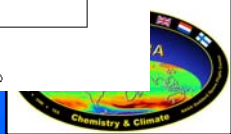
Aerosol detection above clouds:  
OMI Aerosol Index (color scale)  
OMI reflectivity (gray scale)

*With OMI measurements in the UV desert dust and biomass burning plumes can be traced over large distances.*

Wildfires in Australia  
Braak et al, KNMI



Aerosol detection above land and ocean.



# Potential products from OMI for AQ

- Tropospheric Ozone
- SO<sub>2</sub>
- Aerosol SSA and AOT
- HCHO

KNMI OMI O<sub>3</sub> profile retrieval  
De Haan and Veeffkind

**Schoeberl et al.**  
**Submitted to**  
**JGR special issue**



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NASA AQ Meeting, June 18-20, 2007, Washington DC

Dr. P.F. Levelt, KNMI

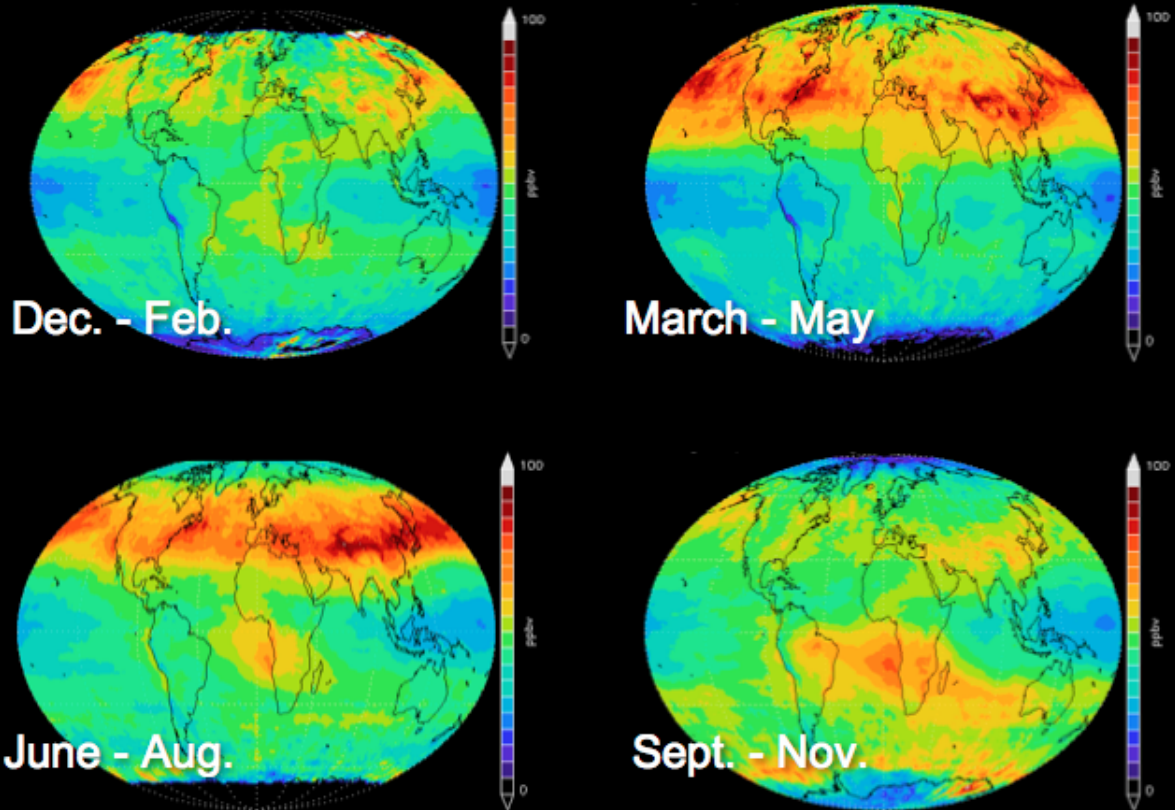


# Potential products from OMI for AQ

- Tropospheric Ozone
- SO<sub>2</sub>
- Aerosol SSA and AOT
- HCHO

**Schoeberl et al.**  
**Submitted to**  
**JGR special issue**

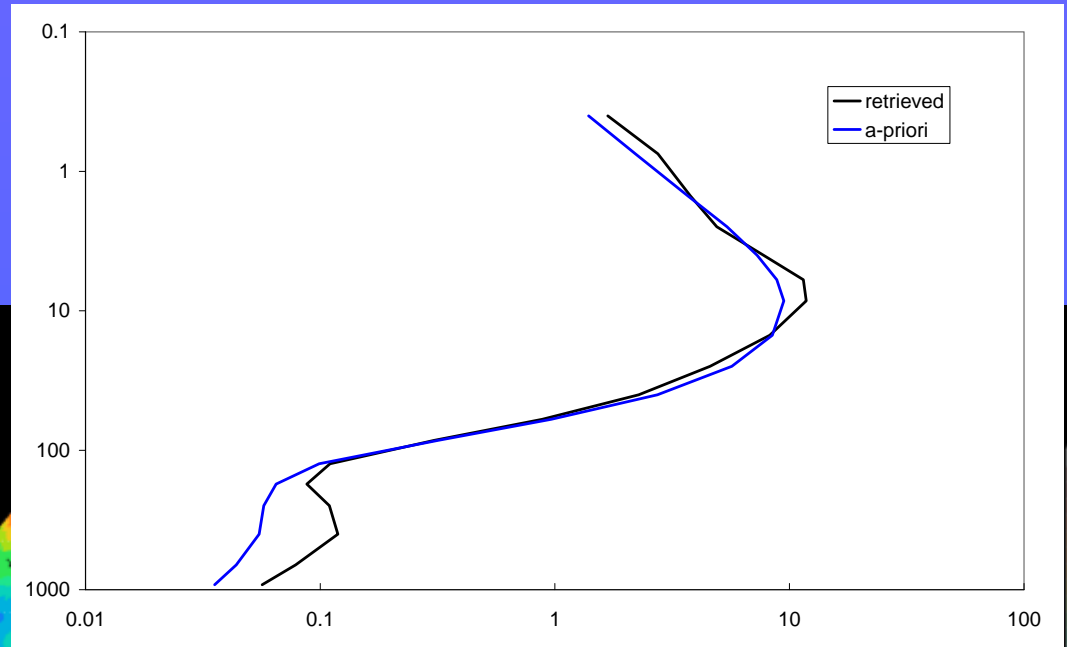
## Seasonal TOR Mixing Ratio



# Potential products from OMI for AQ

- Tropospheric Ozone
- SO<sub>2</sub>
- Aerosol SSA and AOT
- HCHO

**Schoeberl et al.**  
**Submitted to**  
**JGR special issue**



Dec. - Feb.

March - May

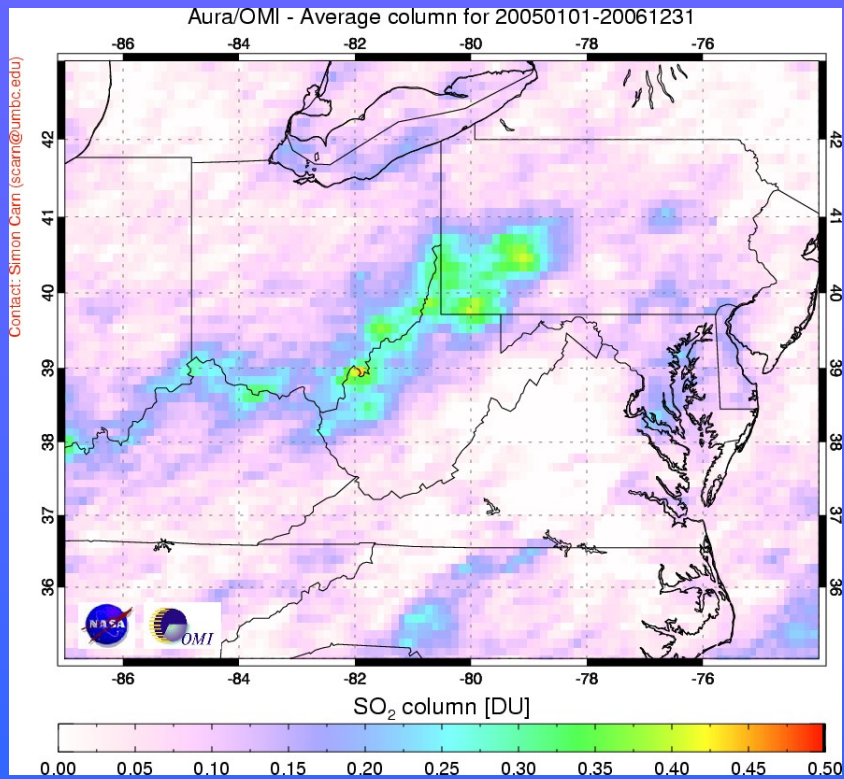
June - Aug.

Sept. - Nov.

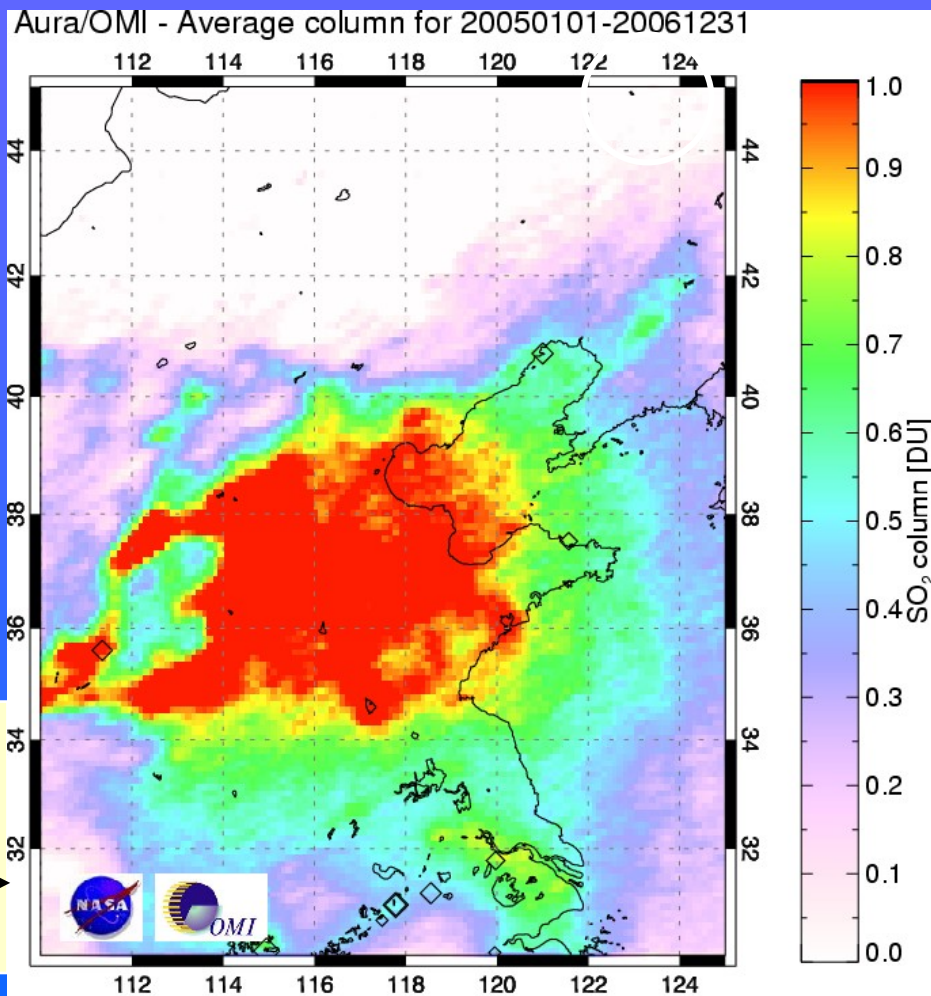


# Potential products:

## Average (2005-2006) SO<sub>2</sub> burdens over USA, and China



← Ohio valley PPs



25.5 million tons of SO<sub>2</sub> was emitted  
by Chinese factories in 2005  
up 27% from 2000

*Krotkov et al.*

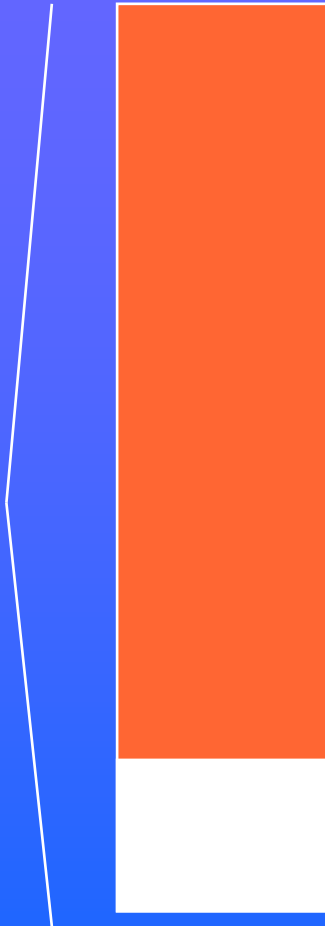
NASA AQ Meeting, June 18-20, 2007,  
Dr. P.F. Levelt, KNMI

Contact: Simon Carn (scarn@umbc.edu)



# Aerosol optical depth (AOT) and single scattering albedo (SSA)

Extinction  
= AOD  
= AOT



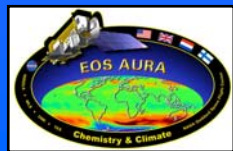
$$\text{Extinction} * \text{ssa} = \text{SAOT}$$

**Extinction = scattering + absorption**

**SSA : aerosol type**

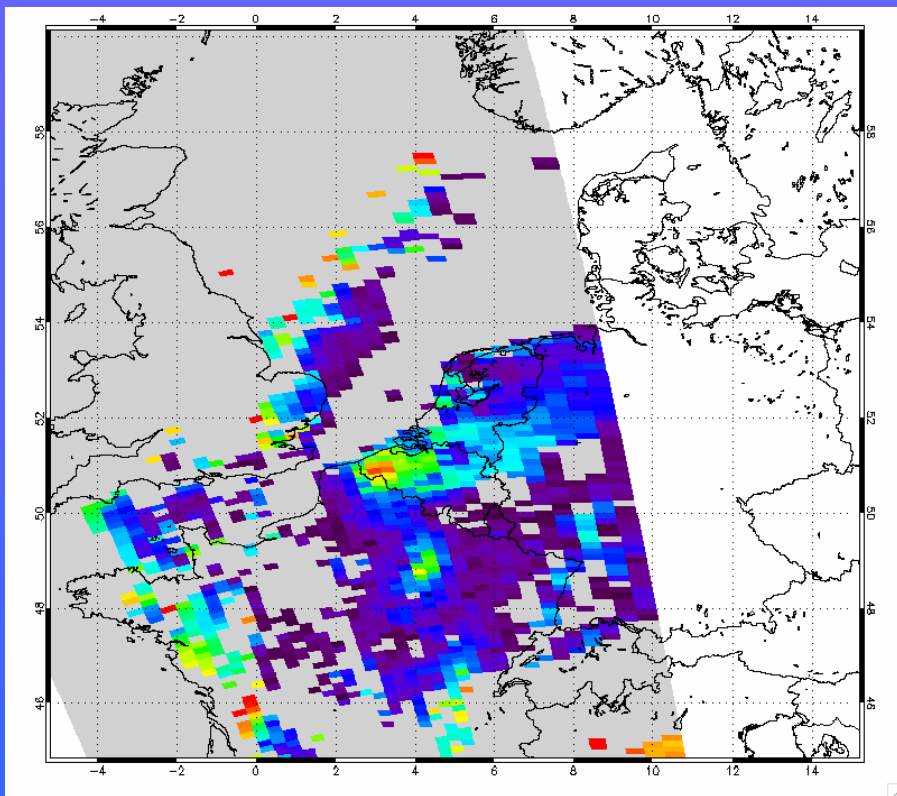
**AAOT: is a measure for aerosol absorption**

$$\text{Extinction} * (1-\text{ssa}) = \text{AAOT}$$





# Potential OMI products for AQ: AOT and SSA

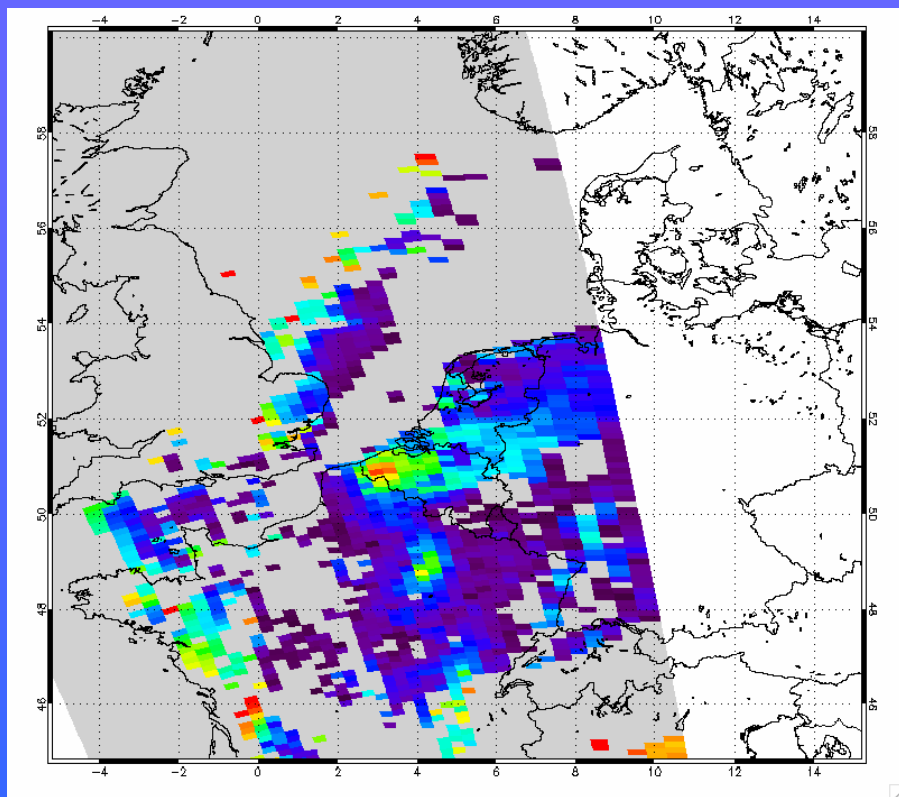


OMI unique feature: measures in the UV: this gives information on the SSA (due to interaction between aerosol absorption and spectral dependence of the Rayleigh scattering):

- Potential to distinguish between absorbing and non-absorbing aerosols

Multiwavelength algorithm KNMI (Veefkind, Veihelmann *et al.*):  
Distinguish between absorbing and non-abs. aerosols: biomass burning, dust, industrial aerosols

# Potential OMI products for AQ: AOT and SSA



Using the **full spectral information**, potential to distinguish:

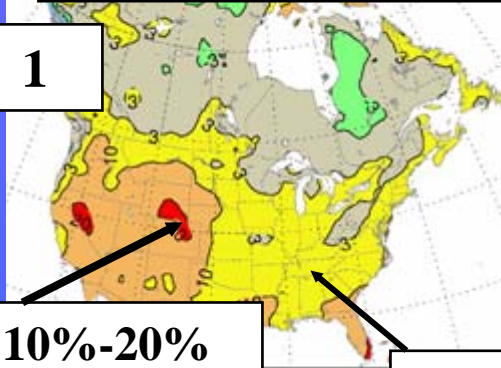
- Different types of carbonaceous aerosols (secondary organic and black carbon) (biomass burning and industrial pollution)
- Different types of dust from different deserts

Multiwavelength algorithm KNMI  
(*Veefkind, Veihelmann et al.*):  
Distinguish between absorbing  
and non-abs. aerosols: biomass  
burning, dust, industrial aerosols

# Why is aerosol UV absorption important ?

Satellite (TOMS/OMI)  
overestimation of surface  
UV irradiance

1



+ 10%-20%

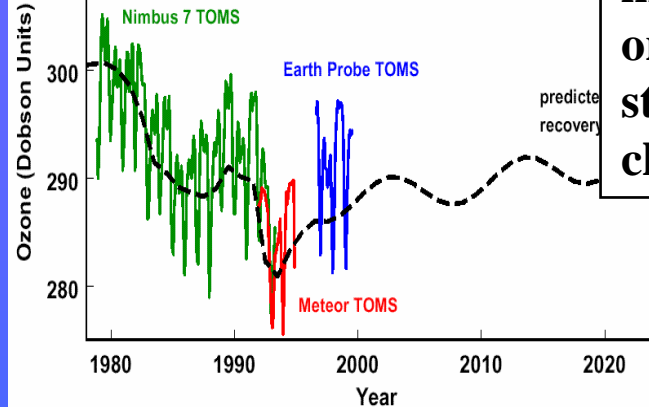
+ 0 - 10%

3) Aerosol effects on photochemical  
smog production: aerosol scattering  
increases photolysis rates; while  
aerosol absorption decreases it:

Change in boundary layer ozone mixing ratios as a  
result of direct aerosol forcing

2

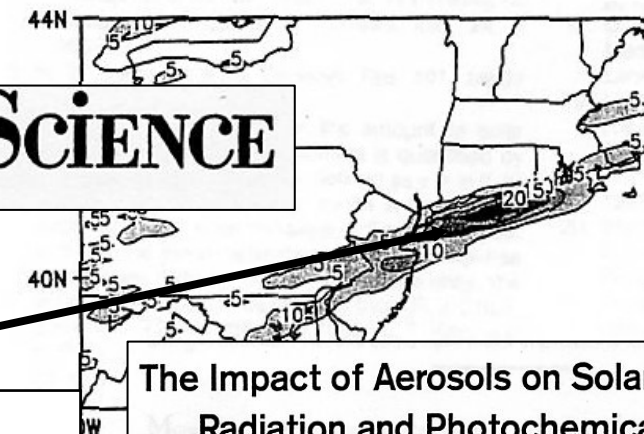
Global Average Ozone



Aerosol “dimming”  
effects on UV trends  
may enhance reduce,  
or reverse effects of  
stratospheric O<sub>3</sub>  
change

3

SCIENCE



The Impact of Aerosols on Solar Ultraviolet  
Radiation and Photochemical Smog

R. R. Dickerson,\* S. Kondragunta, G. Stenchikov,  
K. L. Civerolo, B. G. Doddridge, and B. N. Holben



# Single scattering albedo of pollution aerosols may be considerably smaller at UV than visible wavelengths

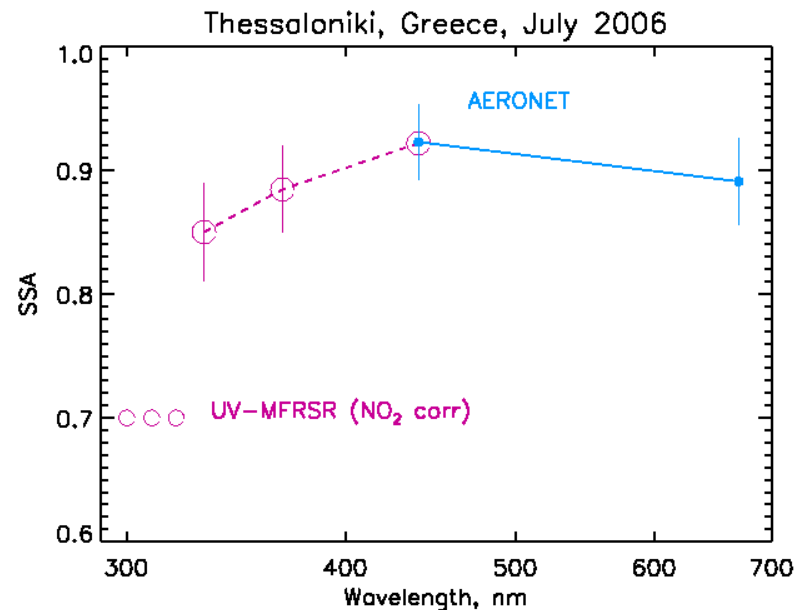
- Secondary organic aerosols?
  - Increased optical depth and ssa at visible wavelengths
  - Absorption at UV wavelengths
  - Composition is largely unknown

## Large effects on

- Biologically active UV at surface, calculation of UV Index
- Photolysis rates in PBL

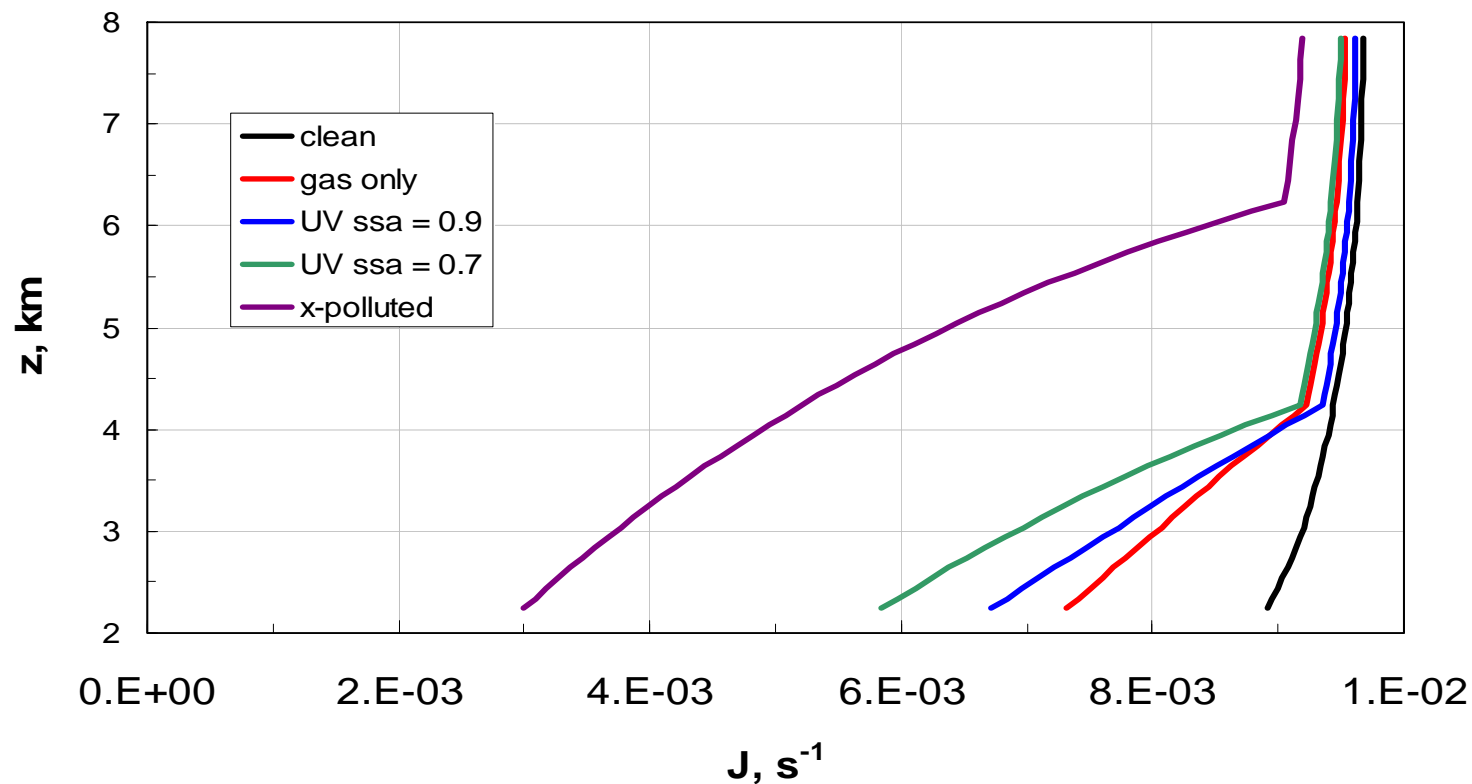
*New preliminary results from*

*Krotkov et al, NASA GSFC*



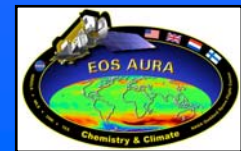
# $\text{NO}_2 + h\nu (\lambda < 420 \text{ nm}) \rightarrow \text{NO} + \text{O}(^3\text{P})$

## Megacity experiment 2006 (Mexico city, Milagro campaign)



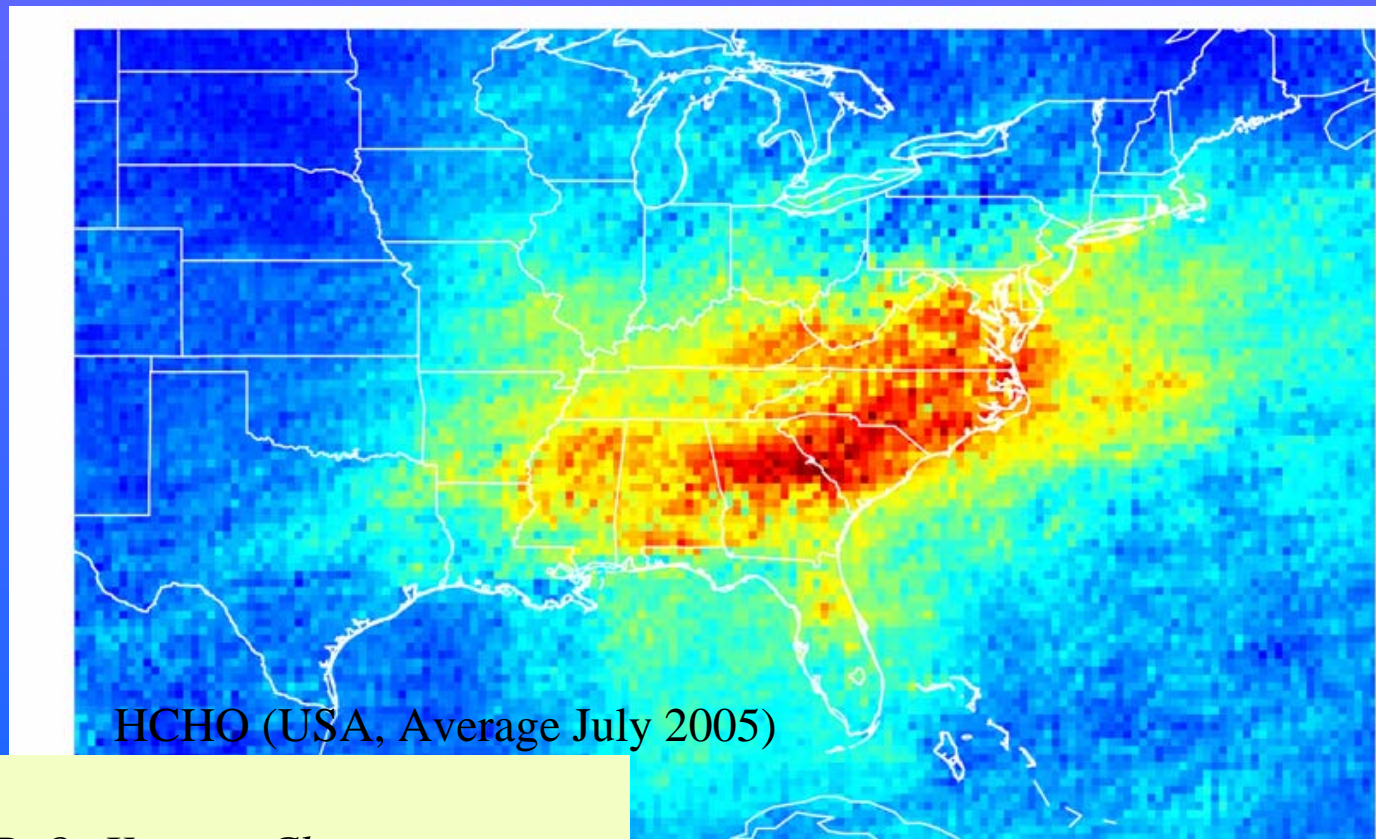
NASA AQ Meeting, June 18-20, 2007, Washington DC

Dr. P.F. Levelt, KNMI



# Emission inventories

- SO<sub>2</sub>
- HCHO
- NO<sub>2</sub> - diurnal cycle

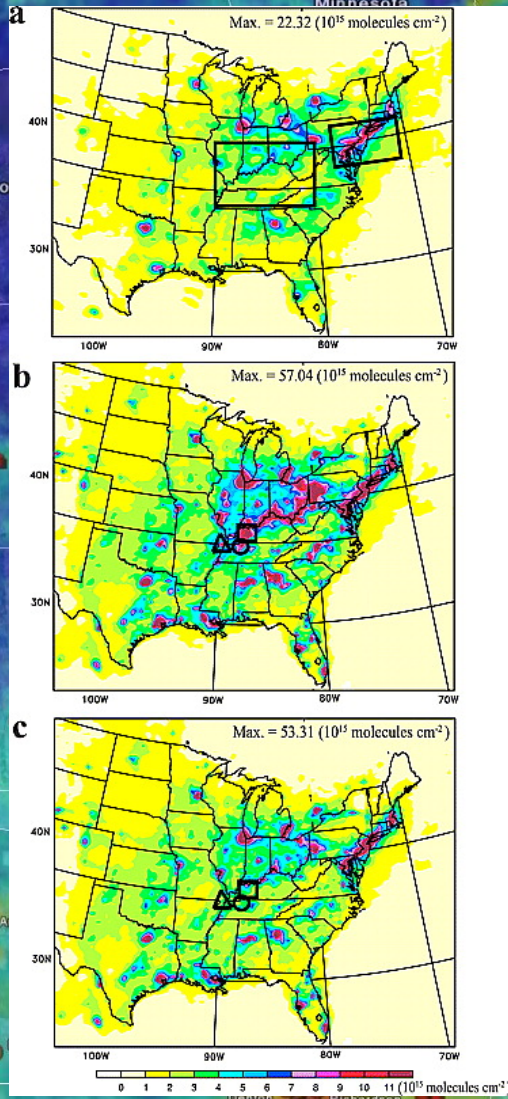


HCHO (USA, Average July 2005)



Courtesy:  
CHO-CHO, HCHO and BrO: Kurosu, Chance,  
(Harvard)

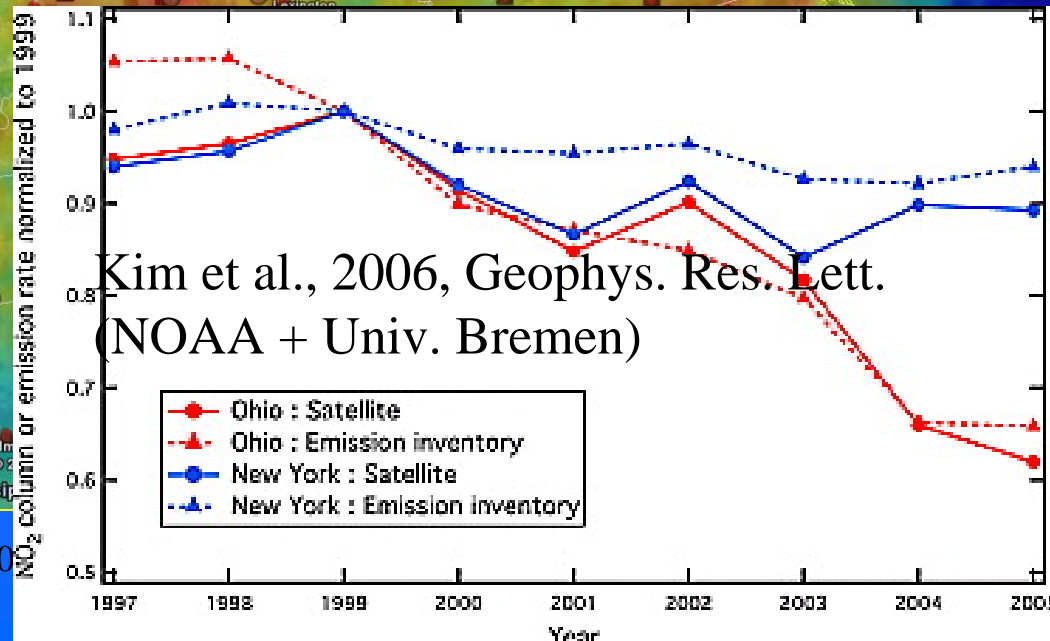
# Monitoring NO<sub>2</sub> emissions in the US



SCIA

Reference emissions

Updated emissions



Kim et al., 2006, Geophys. Res. Lett.  
(NOAA + Univ. Bremen)

10 15 20 25 30

Contact: Sin

**Rovinari, Turceni,  
Craiova PP, Romania**

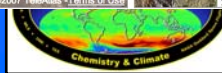
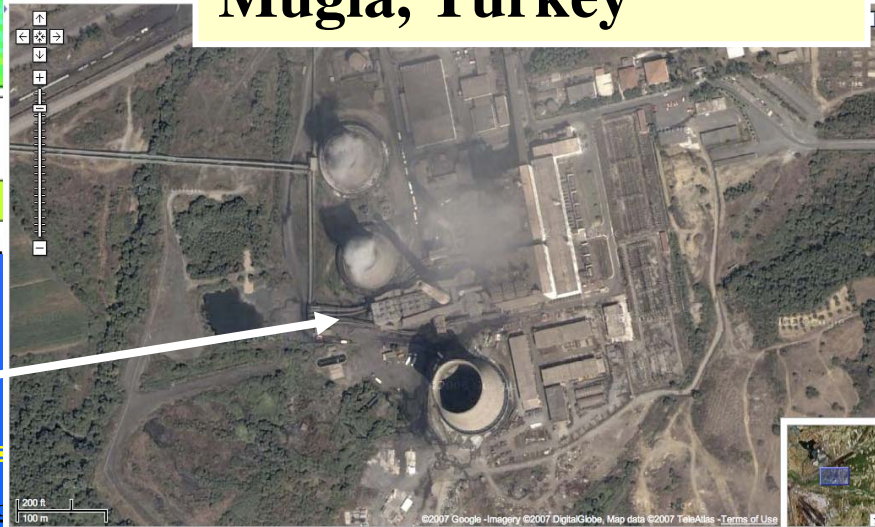
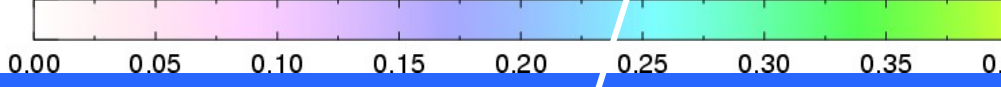
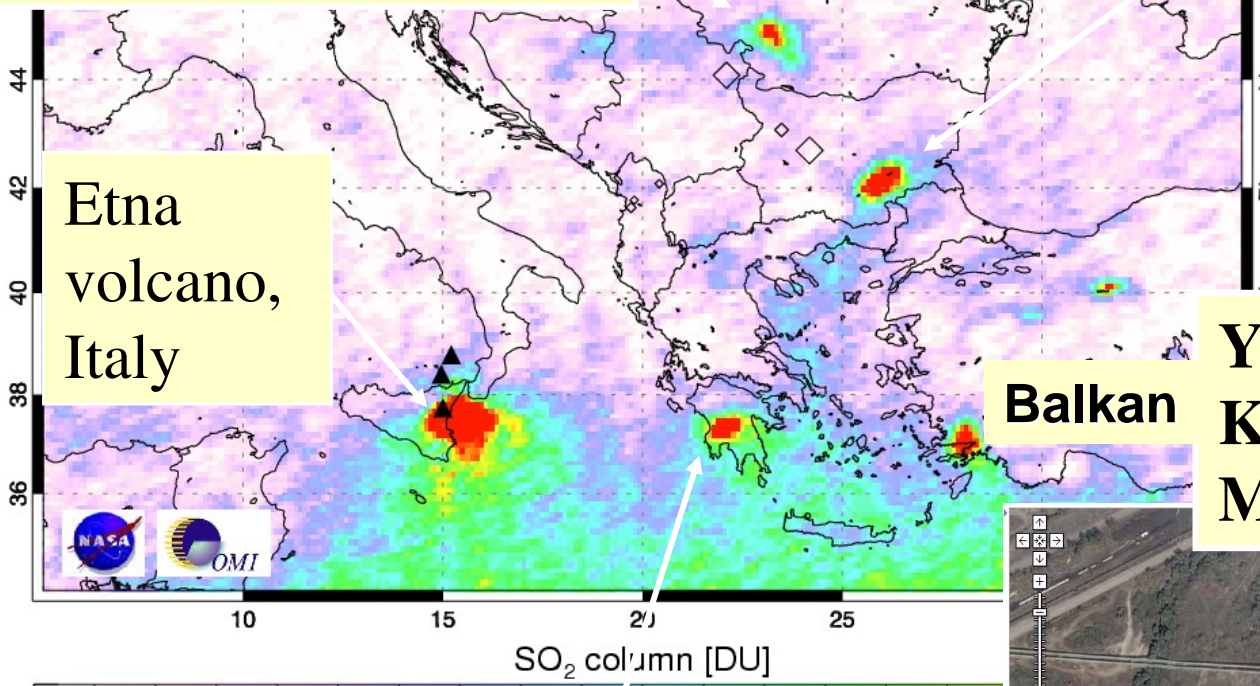
**Maritza Iztok PP,  
Bulgaria**

**Etna  
volcano,  
Italy**

**Yatagan, Yenikoy,  
Kernerkoj complex in  
Mugla, Turkey**

**Balkan**

**Megalopolis  
PP in Arkadia,  
Greece**





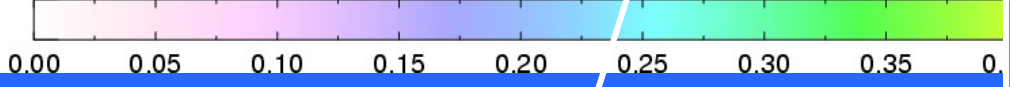
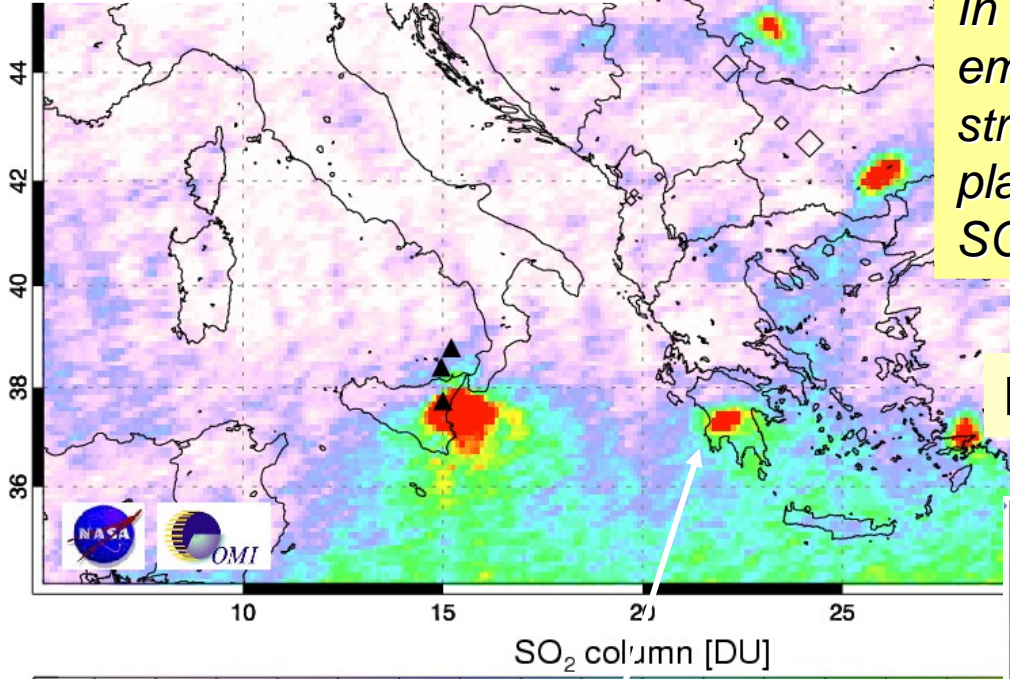
10 15 20 25 30

Contact: Sin

**Rovinari, Turceni,  
Craiova PP, Romania**

**Maritza Iztok PP,  
Bulgaria**

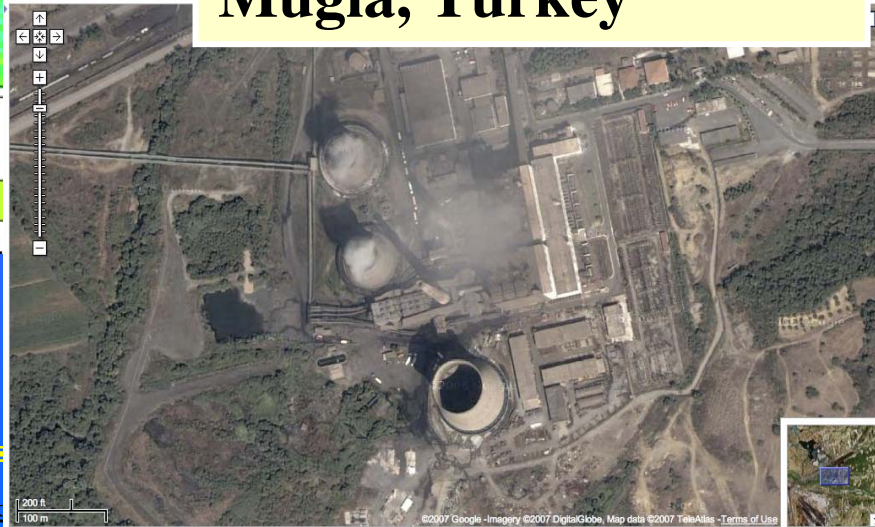
*In West-Europe, the US and Japan the emissions of SO<sub>2</sub> have been reduced strongly. Over China and for certain power plants on the Balkan, OMI is able to detect SO<sub>2</sub>. Krotkov et al.*



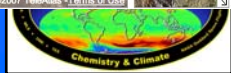
**Balkan**

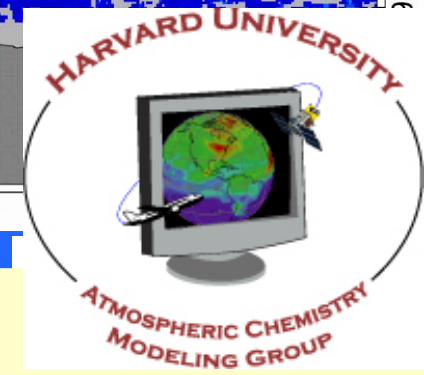
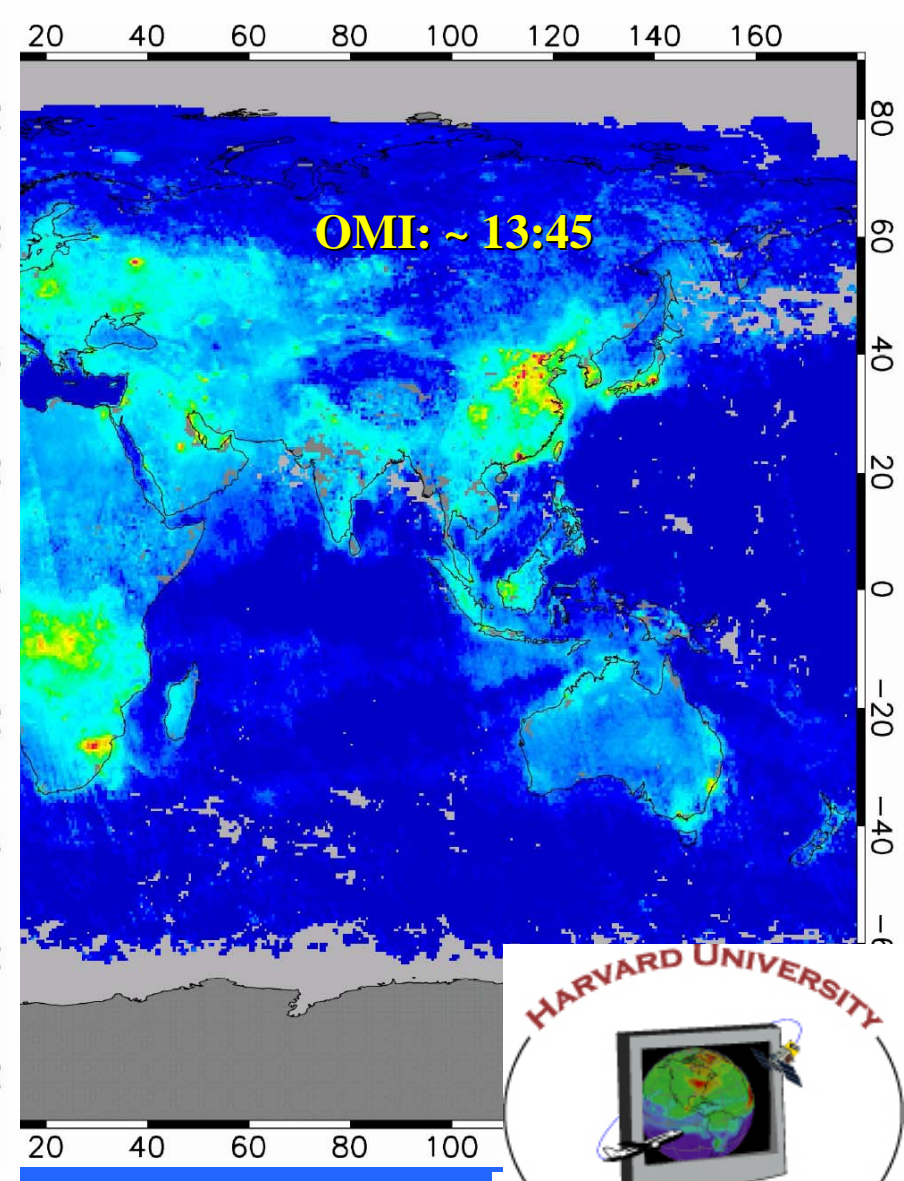
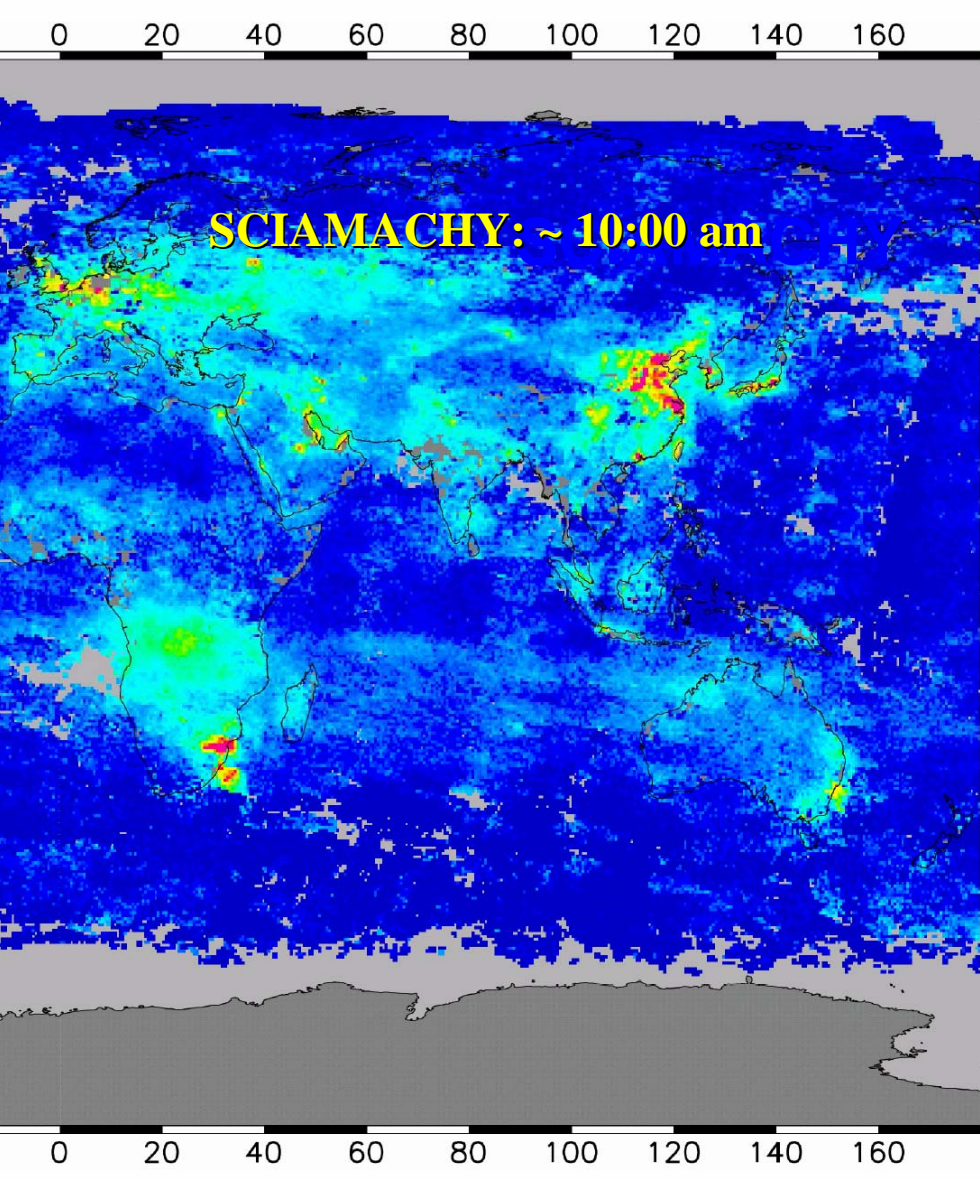
**Yatagan, Yenikoy,  
Kernerkoy complex in  
Mugla, Turkey**

**Megalopolis  
PP in Arkadia,  
Greece**



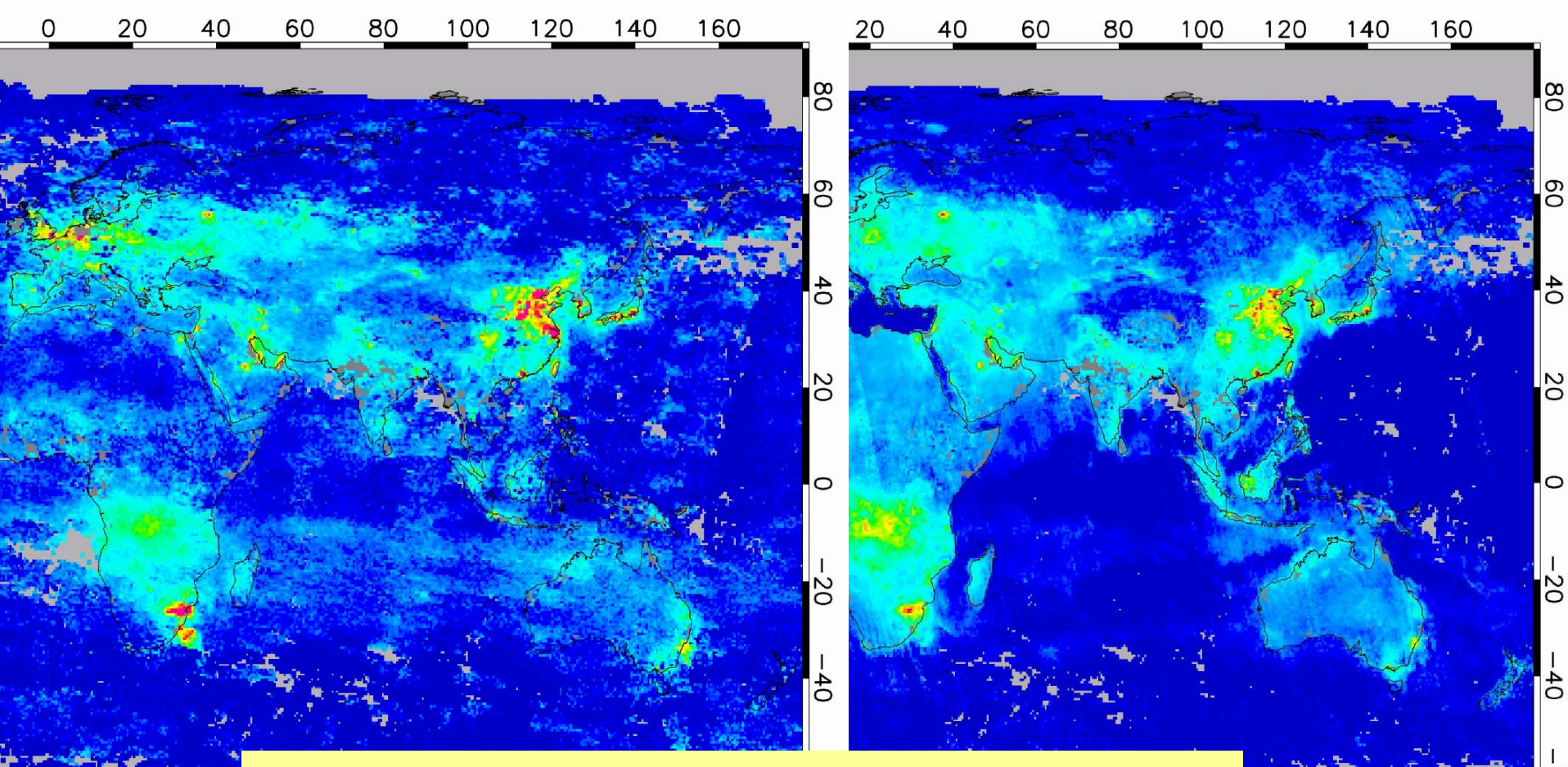
NASA A...  
Dr. P.F. ... 7, Washing



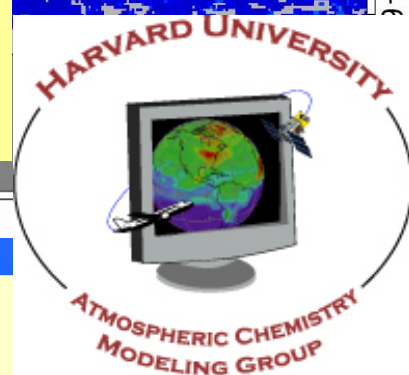


# Concurrent measurements of tropospheric NO<sub>2</sub> from OMI and SCIAMACHY

*Folkert Boersma, Daniel Jacob, Henk Eskes, Rob Pinder, Jun Wang, and Ronald van der A*



**First ever Diurnal variation from satellites  
using KNMI's trop. NO<sub>2</sub> NRT product**



**Concurrent measurements of  
tropospheric NO<sub>2</sub> from OMI and SCIAMACHY**

*Folkert Boersma, Daniel Jacob, Henk Eskes, Rob Pinder, Jun Wang, and Ronald van der A*

# Conclusions

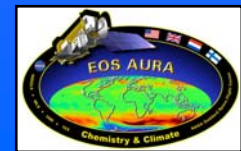
OMI data well suited for AQ applications

## Available OMI AQ Products:

- First ever daily NRT data on tropospheric NO<sub>2</sub> with unprecedented spatial resolution ([www.temis.nl](http://www.temis.nl): now on Google Earth!)
- OMI's UV measurements enable:
  - unique feature to detect aerosols above clouds (AI)
  - detect dust and smoke aerosols

## Potential OMI AQ products include

- tropospheric ozone (several methods are being developed)
- SO<sub>2</sub>
- HCHO
- unique feature to measure ssa (~aerosol type)
- detect secondary organic aerosols (?)
- Diurnal variation emission data bases (SCIA/OMI/GOME-2)

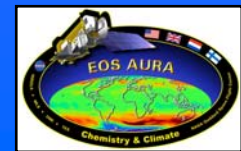


# BACKUP

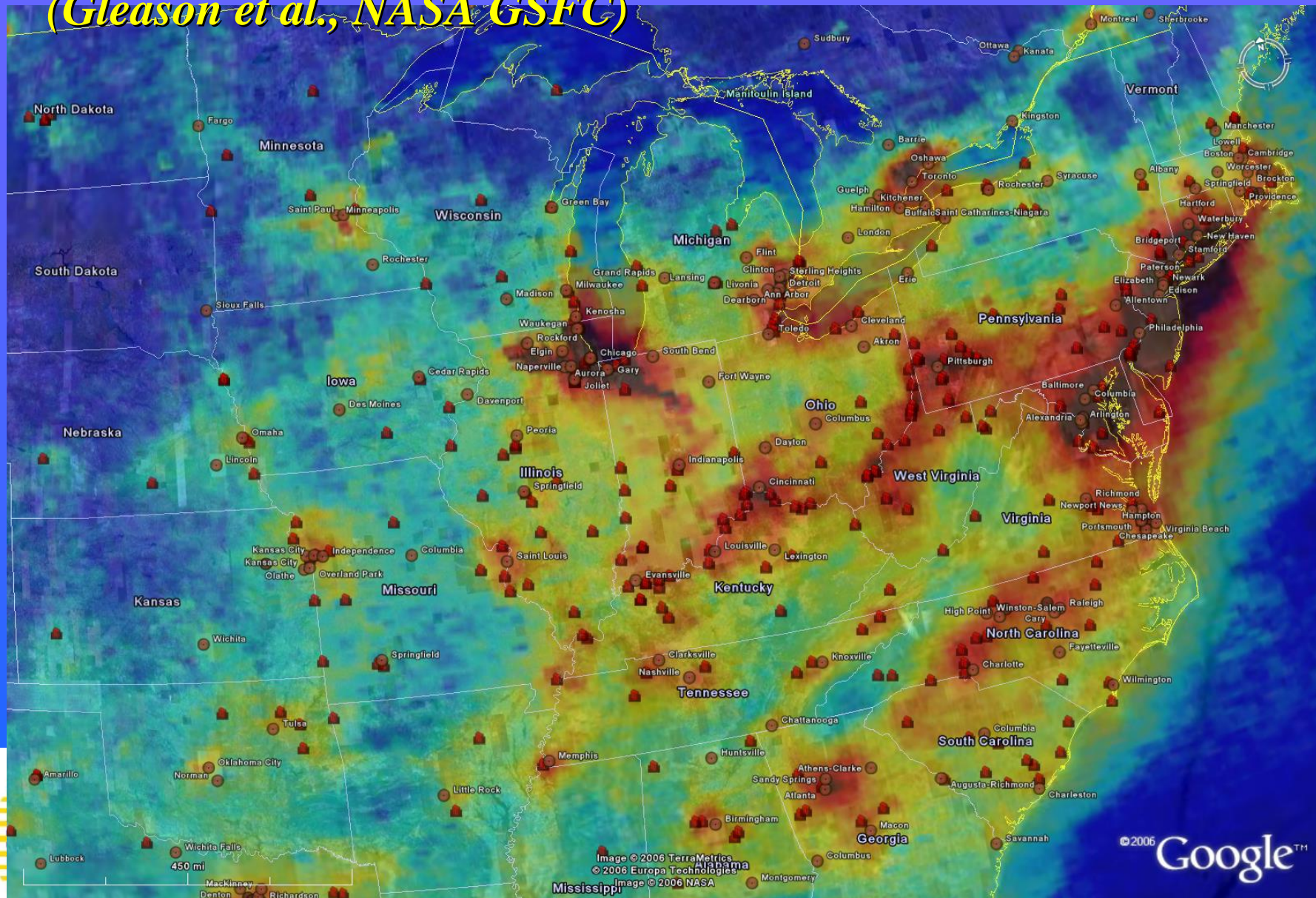


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# Available products NO<sub>2</sub>: OMI NO<sub>2</sub>, Eastern US + Cities + Power Plants (Gleason et al., NASA GSFC)

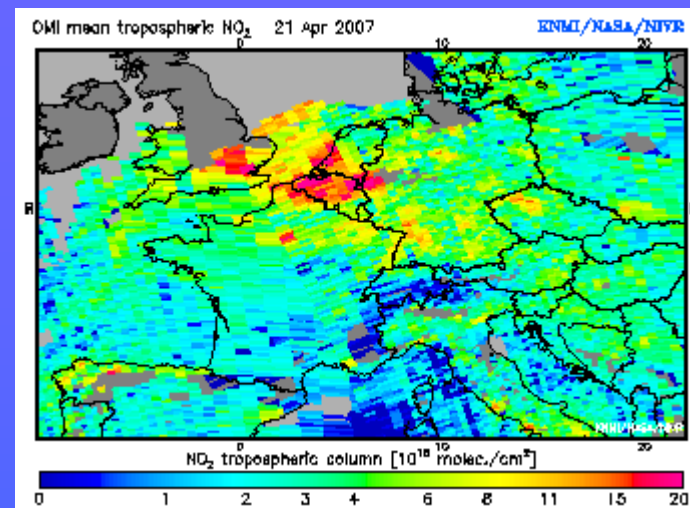


# Thanks to OMI Science Team !

|   |   |  |  |
|---|---|--|--|
| PK Bhartia  | US OMI Team Leader,<br>TOMS Ozone algorithm | Pieter Levelt  | OMI-Principal Investigator   |
| Richard McPeters                                  | Co-Lead OMI Validation<br>WG                | Pepijn Veefkind                                      | Deputy PI, DOAS Ozone &<br>Cloud O2-O2 Algorithm                           |
| Kelly Chance<br>Thomas Kurosu                     | HCHO, BrO, OCIO and<br>CHOCHO algorithms    | Jacques Claas  | Lead Operations & ODPS<br>Dataprocessing                                   |
| James Gleason<br>Eric Bucsela<br>Ed Celarier      | NO2 algorithm                               | Marcel Dobber<br>Quintus Kleipool<br>Nico Rozemeijer | Lead OMI Calibration   |
| Marghi Hopkins                                    | Lead Data processing                        | Mark Kroon   | Co-Lead OMI Validation WG  |
| Glen Jaross                                       | Instrument calibration                      | Remco Braak  | OMI aerosol validation   |
| Joanna Joiner                                     | Cloud RRS algorithm                         | Johan de Haan  | Ozone profile algorithm  |
| Nick Krotkov<br>Simon Carn<br>Alexander Vassilkov | SO2 and UV algorithms                       | Mirna van Hoek<br>René Noordhoek<br>Maarten Sneep    | OMI operations<br>OMI scientific secretary<br>OMI Cloud product validation |
| George Mount                                      | Instrument calibration                      | Ben Veihelmann                                       | Aerosol multi-wavelength alg.  |
| Mike Newchurch                                    | Ozone validation                            | Tim Vlemmix  | GLOBE aerosol project  |
| Paul Newman                                       | Long term ozone trend                       | Hester Volten  | OMI NO2 Validation   |
| Stanley Sander                                    | NO2 validation                              | Henk Eskes   | OMI key ST member  |
| Richard Stolarski                                 | Long term ozone trend                       | Folkert Boersma                                      | OMI key ST member  |
| Omar Torres                                       | Aerosol algorithm                           | Piet Stammes   | OMI key ST member  |
| Jerry Ziemke                                      | Trop. Ozone algorithm                       | Hennie Kelder  | OMI key ST member  |
| Johanna Tamminen                                  | Finnish co-PI                               | Ilse Aben  | OMI key ST member  |
| Aapo Tanskanen                                    | Surface UV irradiance                       | Claus Zehner   | OMI key ST member  |
| Seppo Hassinen                                    | OMI VFD products                            | Frank Dentener                                       | OMI key ST member  |
| Gerrit de Leeuw                                   | OMI key ST member                           | Ulrich Platt   | OMI key ST member  |
| Paul Simon  | OMI key ST member                           | Didier Hauglustaine                                  | OMI key ST member  |

# First ever Near Real Time global, daily, urban scale measurements on NO<sub>2</sub> from space!

Saturday 21 April 2007



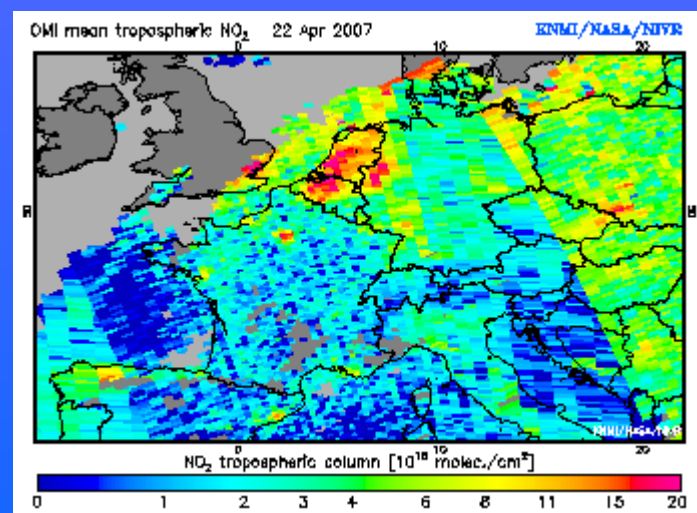
(KNMI NO<sub>2</sub> NRT product)

<http://www.temis.nl/>

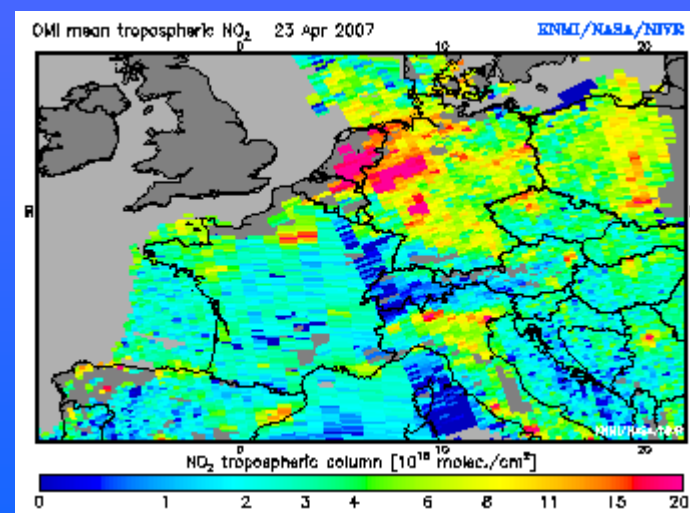
<http://www.knmi.nl/omi>

*Boersma et al., accepted in ACP*

Sunday 22 April 2007



Monday 23 April 2007



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