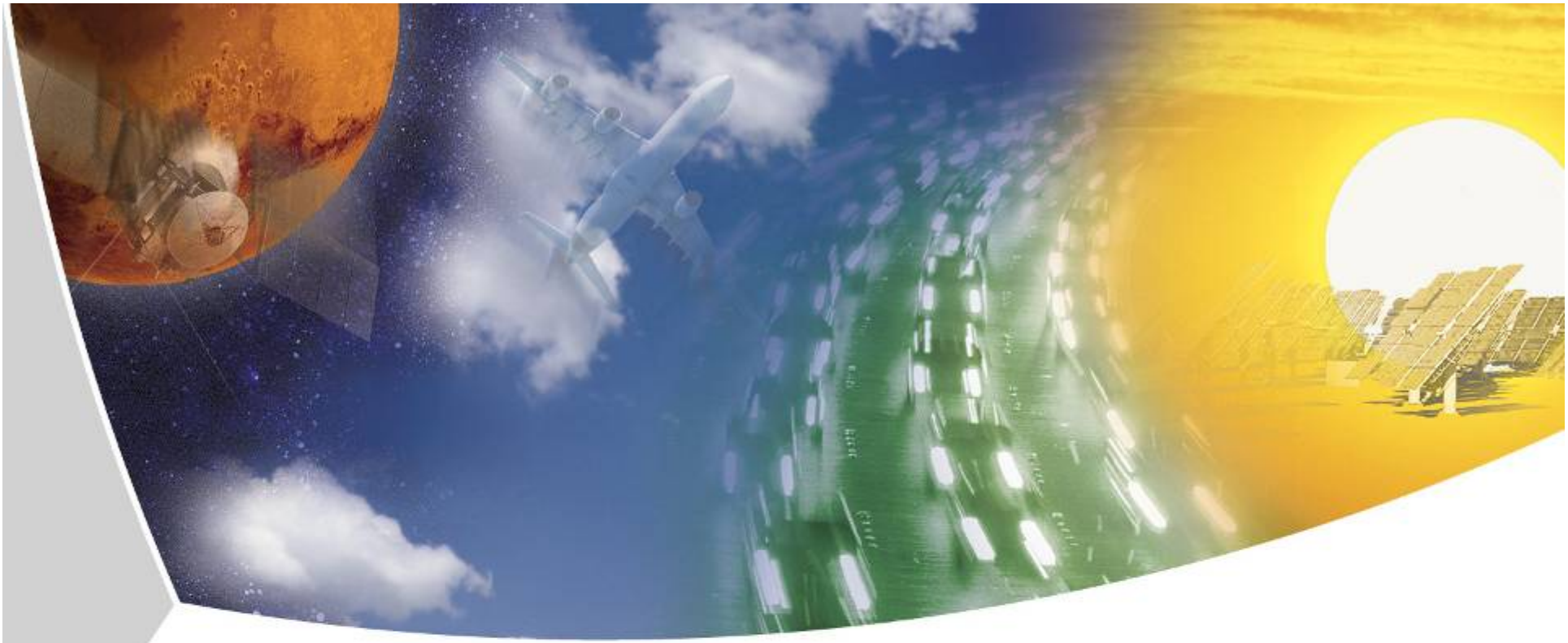


Estimation of NO_2 amounts emitted from the Portuguese wildfires in 2005: A synergistic use of observations by imaging and atmospheric instruments and chemistry-transport models

Julian Meyer-Arnek, Pieter Valks, Thilo Erbertseder, Marianela Fader

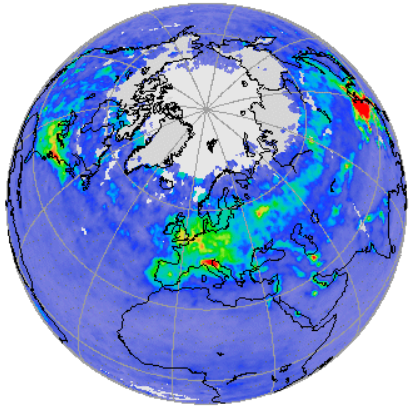
Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Overview

- Why care about tropospheric NO_2?
- NO_2 profile in the atmosphere
- Retrieval of tropospheric NO_2 vertical column densities (VCD)
- Spatial and temporal distribution of tropospheric NO_2 VCD over Europe
- Case study:

  Portuguese wildfires during August 2005 and biogenic emissions of soils during September 2005

Tropospheric NO_2…



- leads to hemisphere wide increase of tropospheric ozone
- supports acidification
- is toxic.

For the air quality service of the
GMES Service Element PROMOTE
tropospheric NO_2 vertical column densities (VCD) from
SCIAMACHY (GOME-2) are retrieved operationally.

PROMOTE

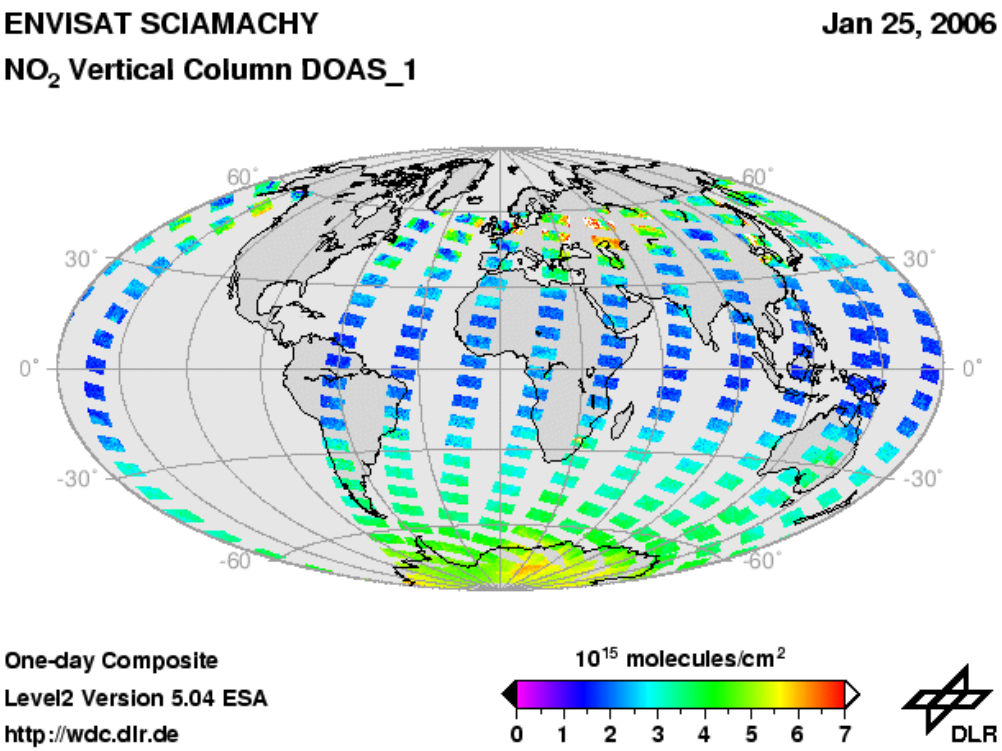
Tropospheric NO_2

NO_2 is equally distributed in the troposphere and the stratosphere.

Satellite-Measurement:

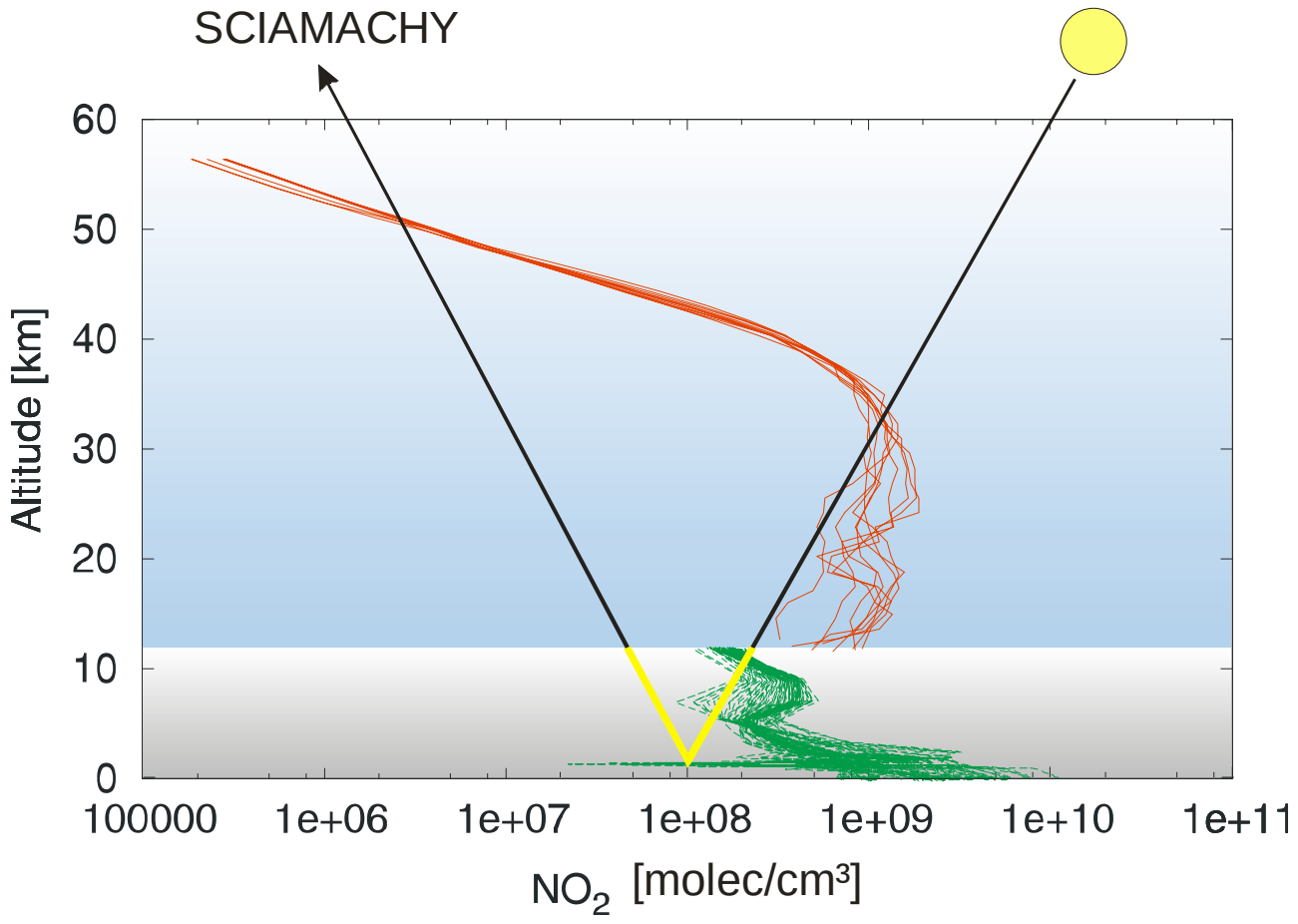
Integral of both contributions

→ Necessity to seperate both contributions



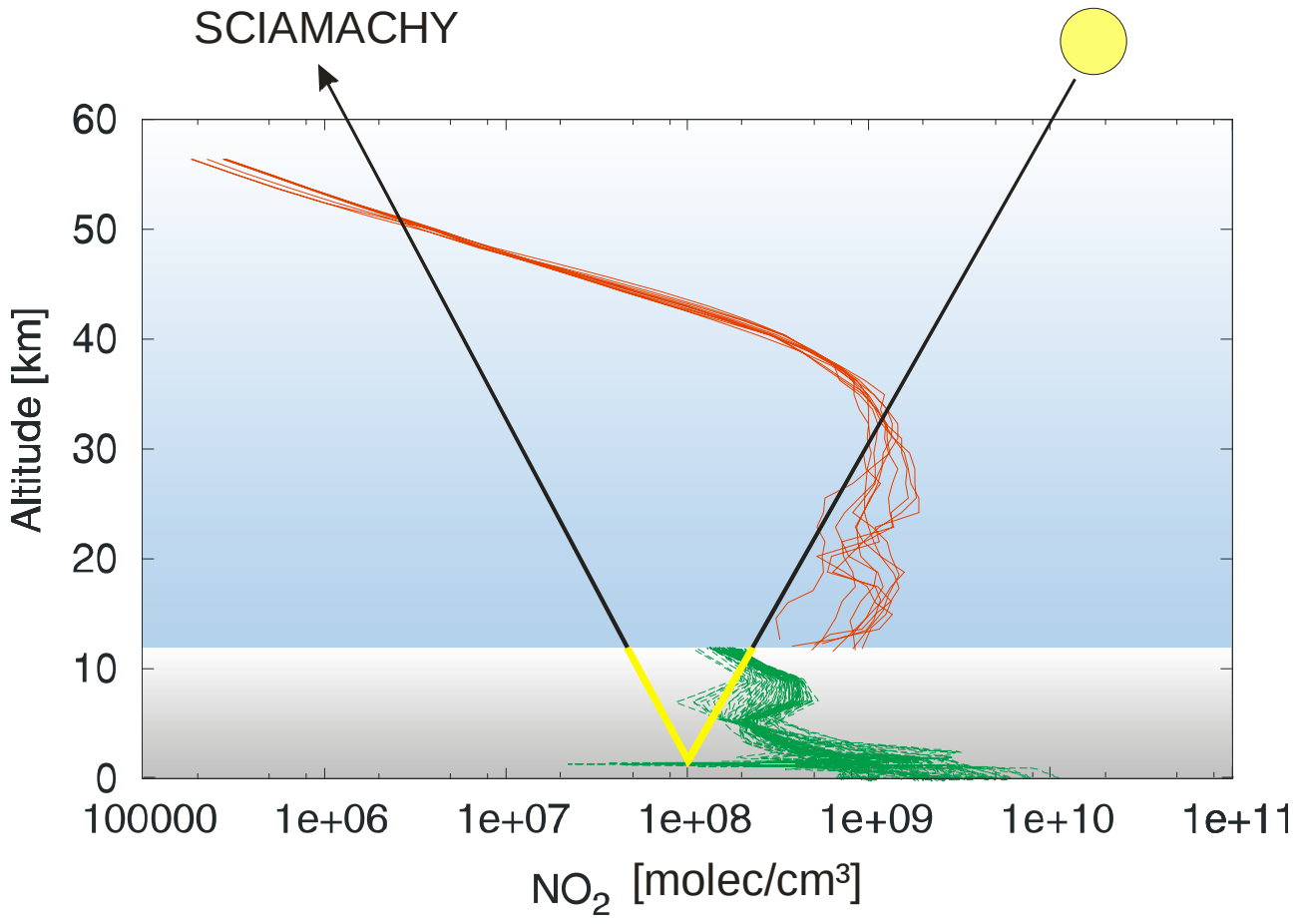
NO_2 in the atmosphere

NO_2 is equally distributed in the troposphere and the stratosphere.



NO_2 in the atmosphere

- Maximum at 30 km, second maximum near the ground (polluted situation)



NO_2 in the atmosphere

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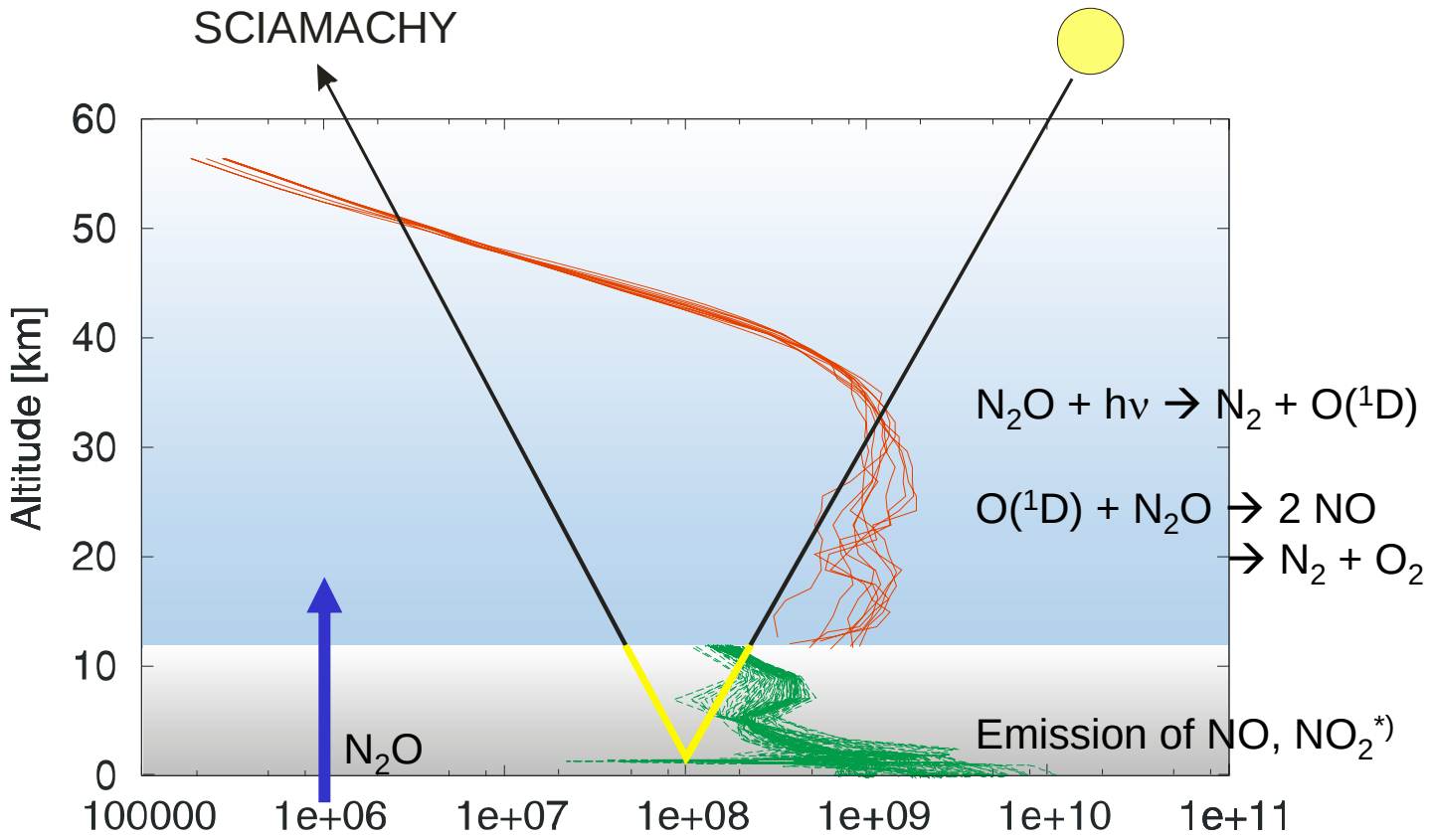
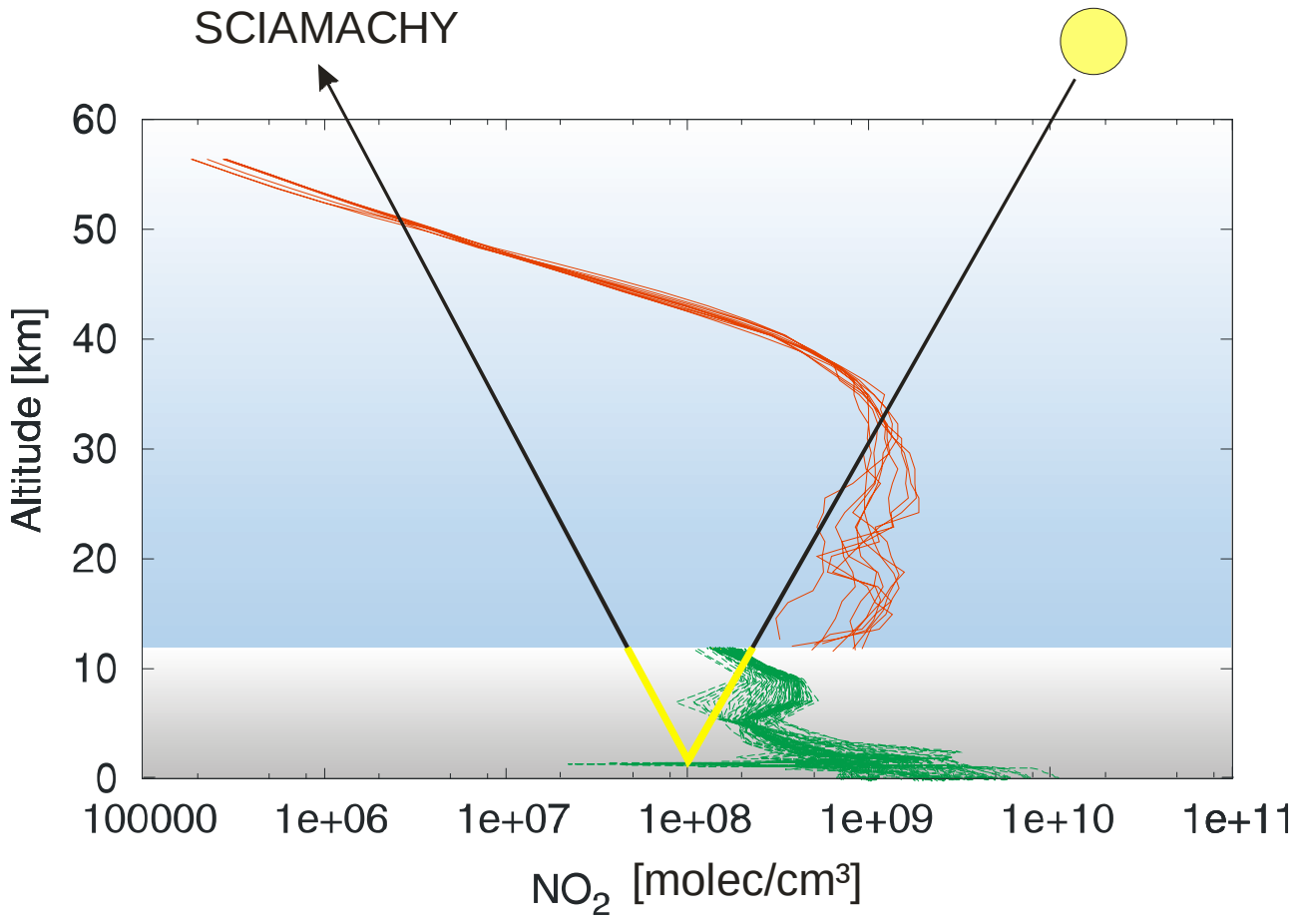


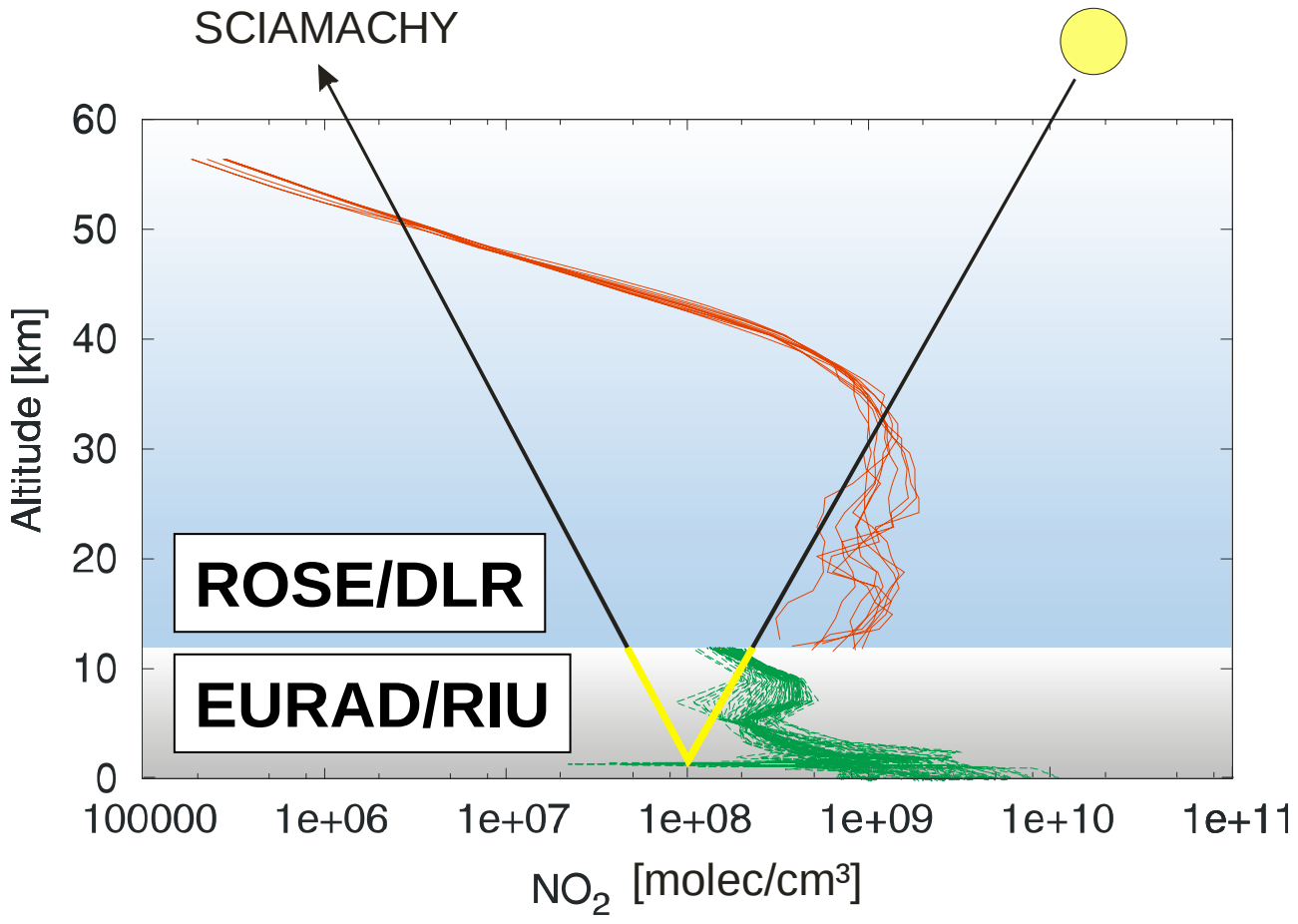
*) Primary emission: NO_2 / NO_x = 10%

NO_2 in the atmosphere

→ Necessity to seperate stratospheric and tropospheric contribution.



NO_2 in the atmosphere

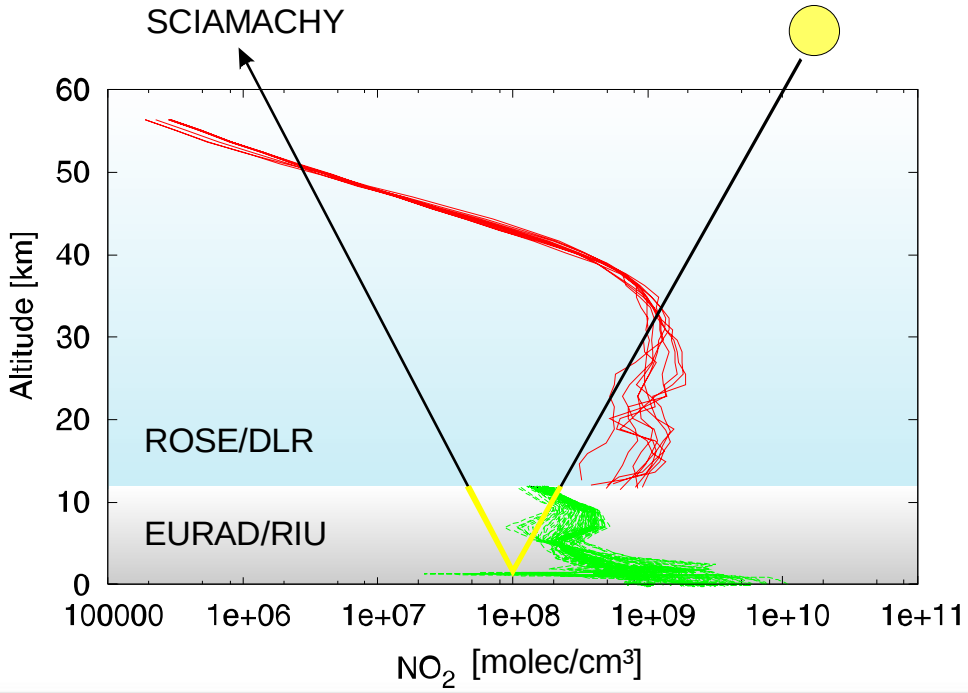


Tropospheric NO_2: Slant column

- Slant column (SC_{TOTAL}) retrieved from SCIAMACHY measurement
- Stratospheric slant column (SC_{STRAT}) derived from ROSE/DLR[1)].

  $SC_{STRAT} = VC_{STRAT,\ ROSE} * AMF_{GEOMETRIC}$
- Tropospheric slant column:

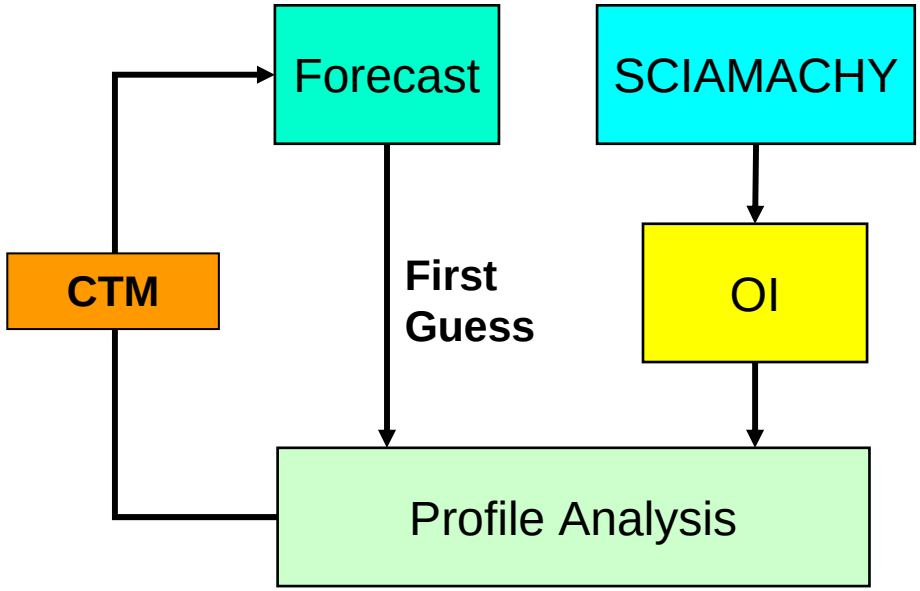
  $SC_{TROP} = SC_{TOTAL} - SC_{STRAT}$



[1)] Miss time
model ⇔ SCIAMACHY meas.
less than 1 hour

Stratospheric NO_2: ROSE/DLR

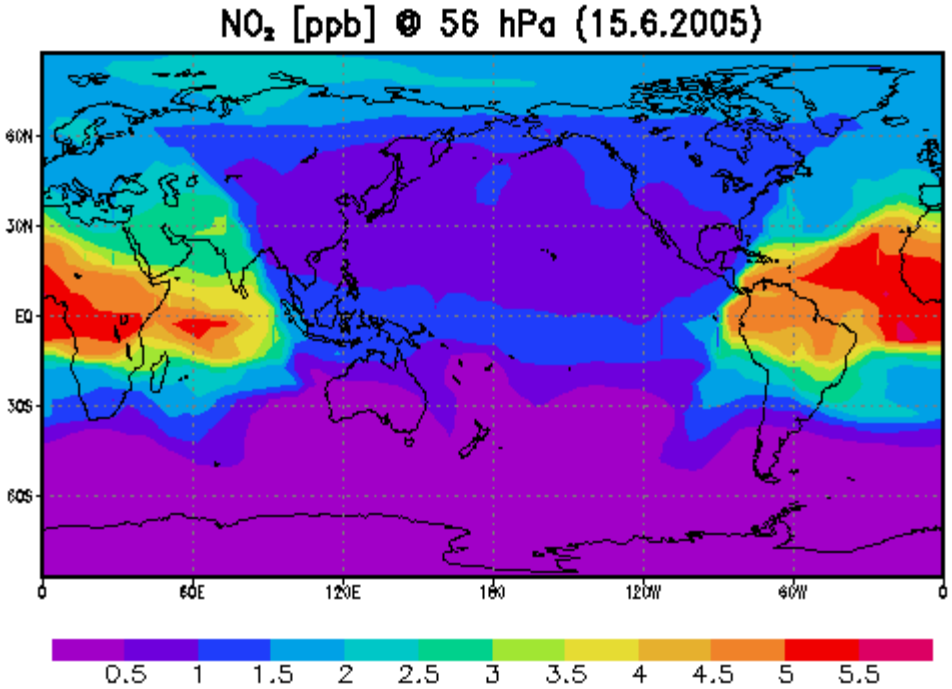
Assimilation of SCIAMACHY ozone by optimal interpolation (OI).



CTM = Chemistry-Transport-Model ROSE/DLR v2.7

Resolution	Horizontal 5.6° x 5.0° lat-lon, vertical 1.3 km
Grid	Spherical grid on pressure levels
Transport	Semi-Lagrange, ECMWF/GME
Chemistry	120 homogenous, 7 heterogeneous reactions (family conc)

ROSE/DLR: Stratospheric NO_2



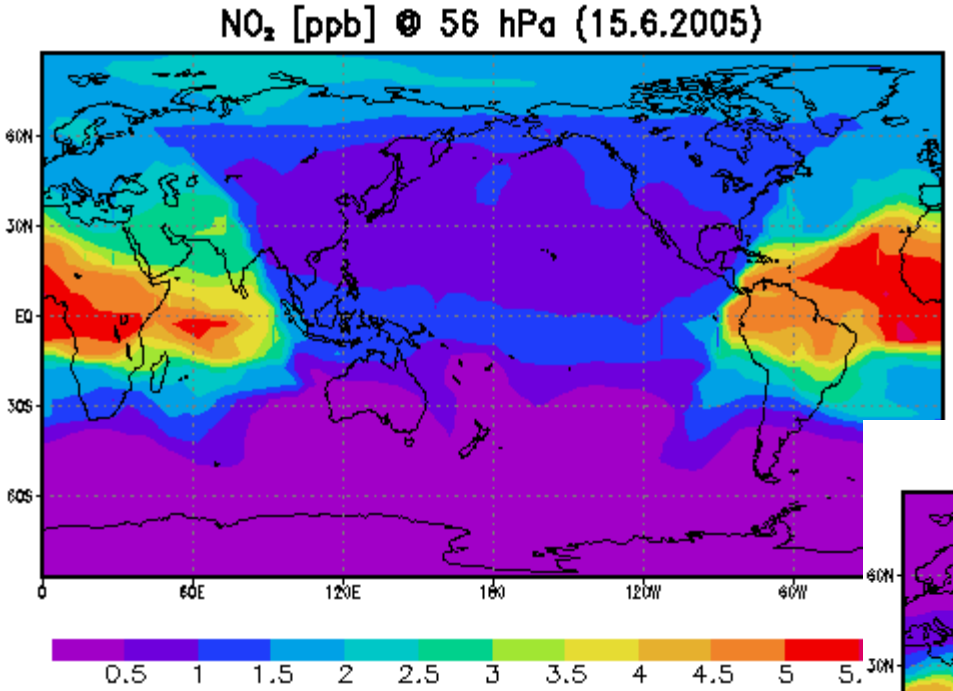
ROSE/DLR 2.7
Chemistry transport model

Rose, K. and G. Brasseur, 1989
Baier et al., 2005

Diurnal cycle:

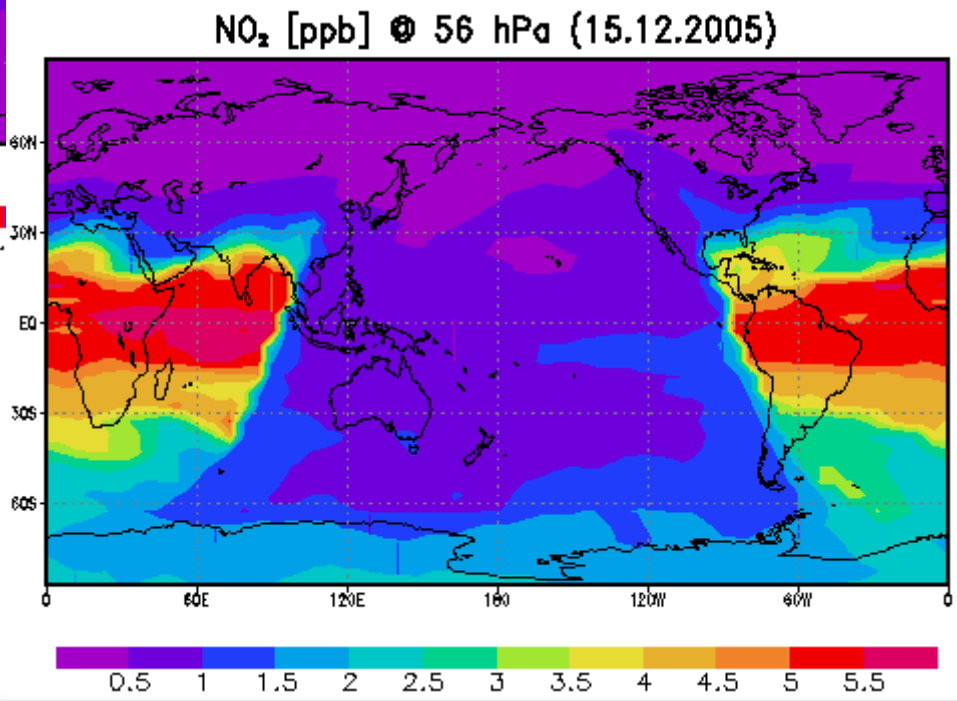
Conversion of NO_y, NO_2 → NO.

ROSE/DLR: Stratospheric NO_2



ROSE/DLR 2.7
Chemistry transport model

Rose, K. and G. Brasseur, 1989
Baier et al., 2005



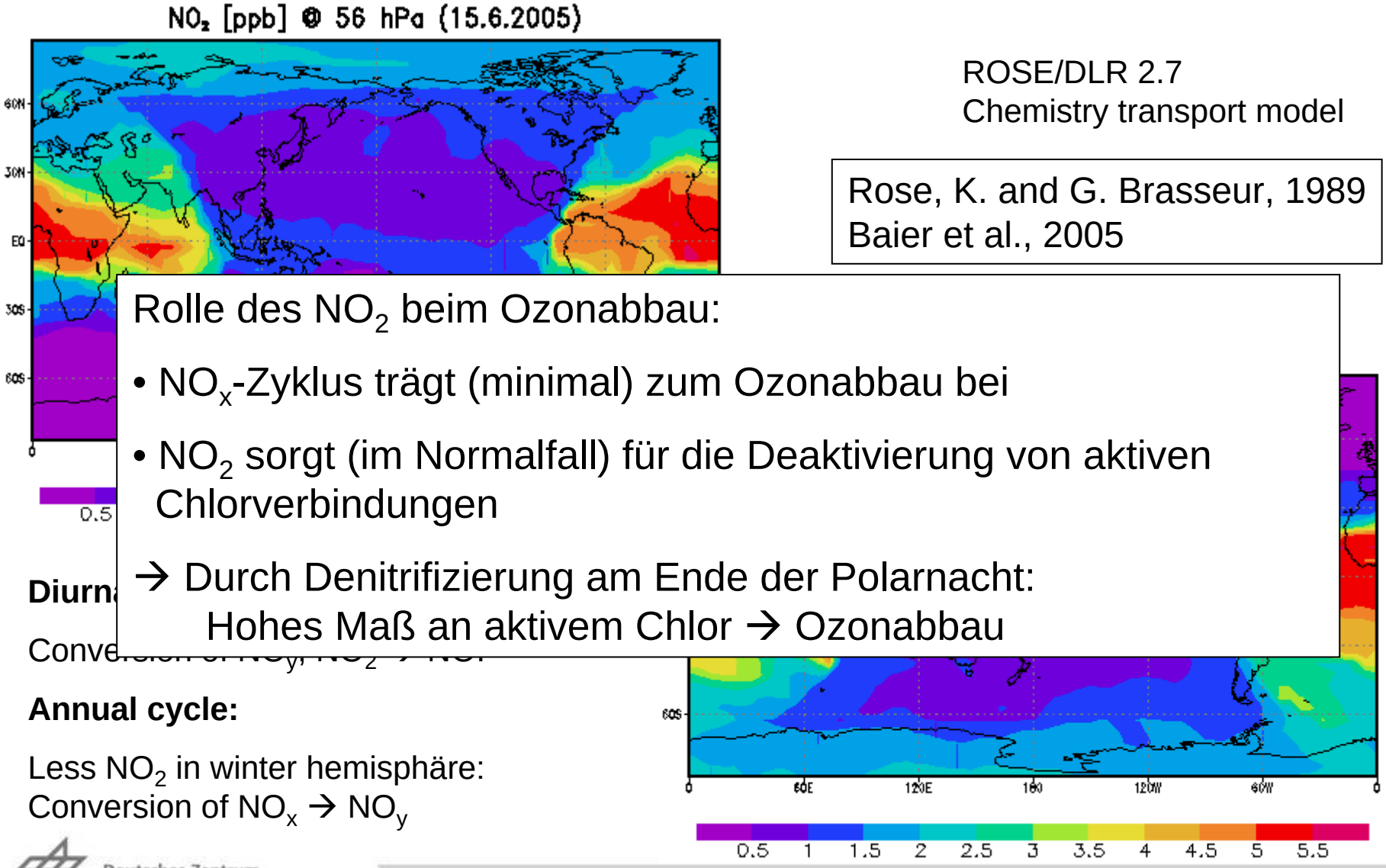
Diurnal cycle:

Conversion of NO_y, NO_2 → NO.

Annual cycle:

Less NO_2 in winter hemisphäre:
Conversion of NO_x → NO_y

ROSE/DLR: Stratospheric NO_2



ROSE/DLR 2.7
Chemistry transport model

Rose, K. and G. Brasseur, 1989
Baier et al., 2005

Rolle des NO_2 beim Ozonabbau:

- NO_x-Zyklus trägt (minimal) zum Ozonabbau bei
- NO_2 sorgt (im Normalfall) für die Deaktivierung von aktiven Chlorverbindungen

→ Durch Denitrifizierung am Ende der Polarnacht:
Hohes Maß an aktivem Chlor → Ozonabbau

Diurn

Conve

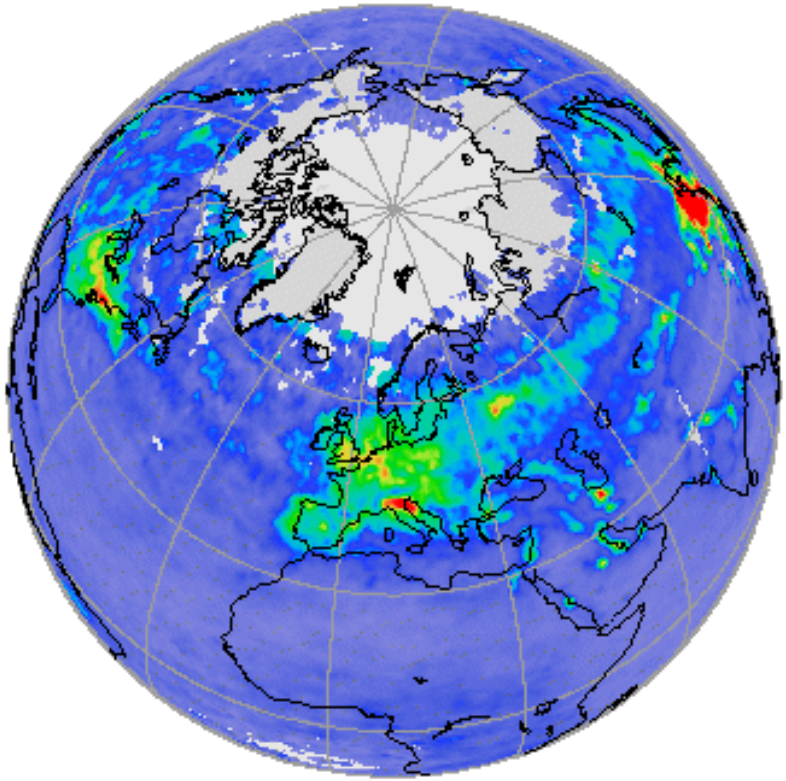
Annual cycle:

Less NO_2 in winter hemisphäre:
Conversion of NO_x → NO_y

Tropospheric NO_2: Slant column

ENVISAT SCIAMACHY **Nov+Dec 2005**

Tropospheric NO_2 Slant Column



Mean

Lv 4 Version 0.1 / Lv2 Version 5.04 ESA

http://wdc.dlr.de

10^{15} molecules/cm^2

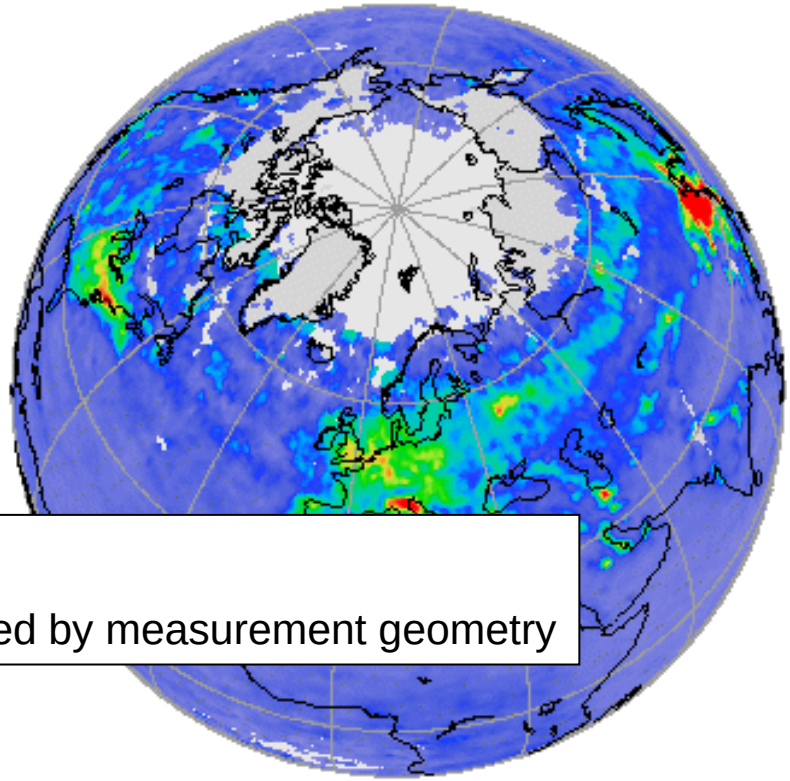
0 1 2 3 4 5 6 7 8 9 10 11

DLR

Tropospheric NO_2: Slant column

ENVISAT SCIAMACHY **Nov+Dec 2005**

Tropospheric NO_2 Slant Column



Problem:

SC_{TROP} is influenced by measurement geometry

Mean

Lv 4 Version 0.1 / Lv2 Version 5.04 ESA

http://wdc.dlr.de

10^{15} molecules/cm^2

0 1 2 3 4 5 6 7 8 9 10 11

DLR

Tropospheric NO_2: Vertical column

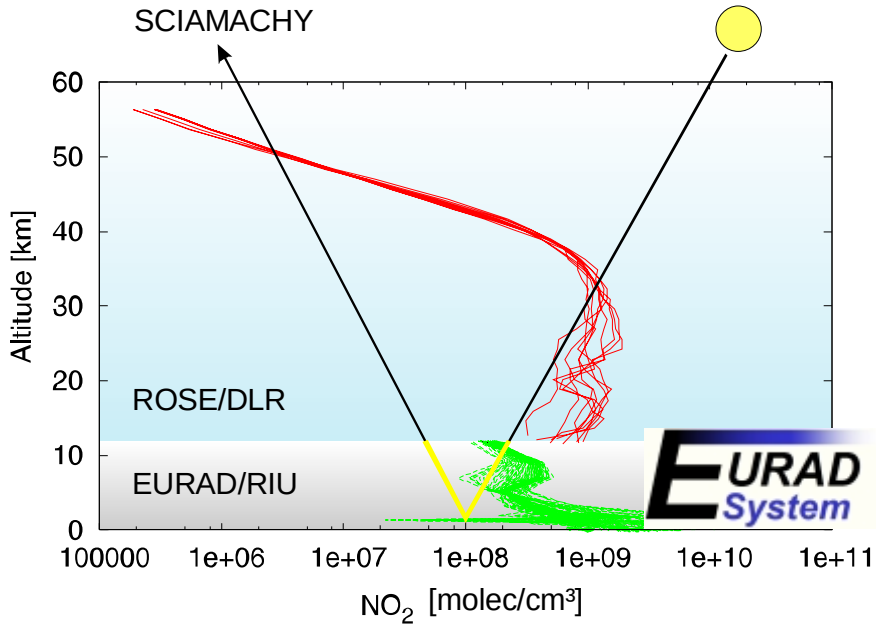
- tropospheric slant column:

$$SC_{TROP} = SC_{TOTAL} - SC_{STRAT}$$

- tropospheric vertical column:

$$VC_{TROP} = SC_{TROP} / AMF_{TROP}$$

where $$AMF_{TROP} = \frac{\int AMF(z) \cdot c(z) dz}{\int c(z) dz}$$



AMF(z) depends on the altitude *z*, viewing geometry (μ, μ_0), albedo (*a*), height of the reflecting surface (cloud top height) (altitude resolved air mass factor approach)

→ AMF_{TROP} considers tropospheric NO_2 profile shape.

Palmer et al., 2001

EURAD/RIU

The **EUR**opean **A**ir Pollution **D**ispersion (**EURAD**) model system simulates the

physical, chemical and dynamical processes

which control

emission, production, transport and deposition

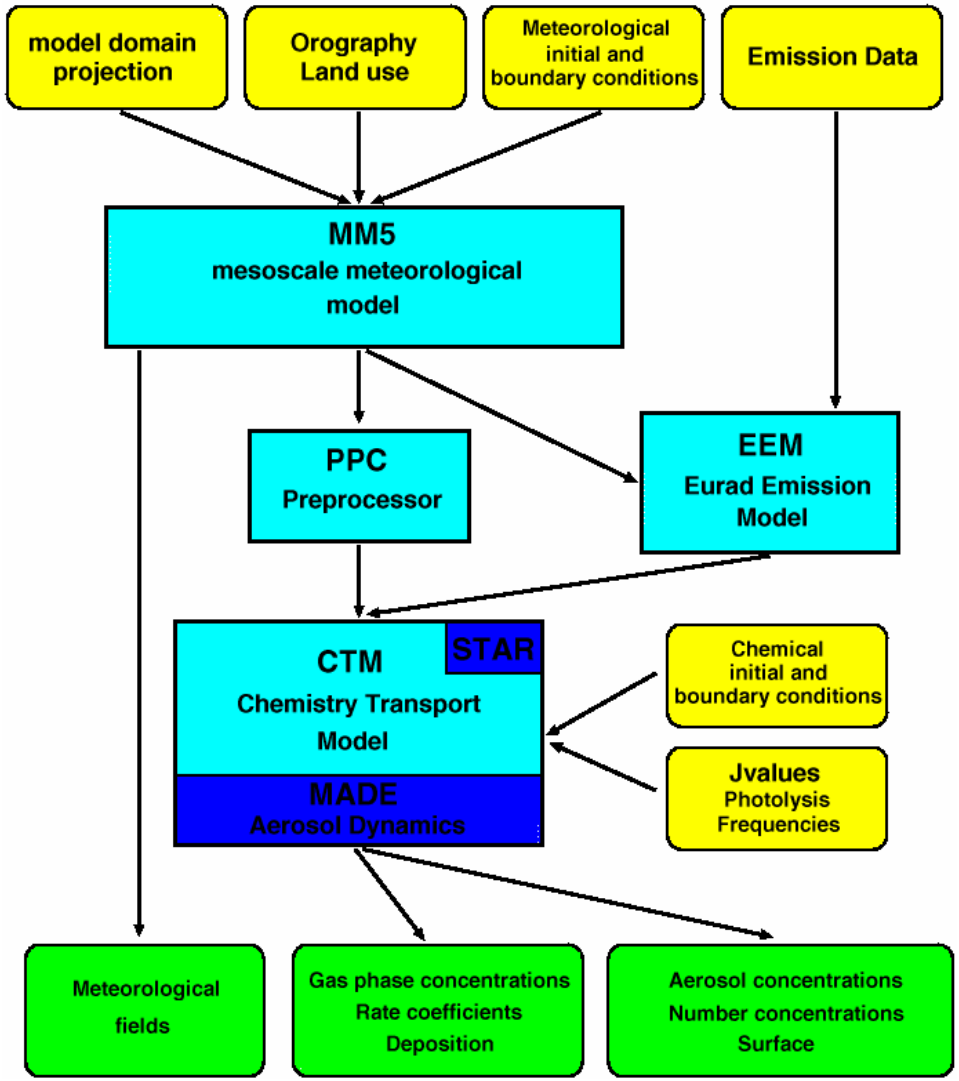
of atmospheric trace species in the troposphere.

→**EURAD** provides forecasts of concentrations of considered trace species for different domains in the troposphere.

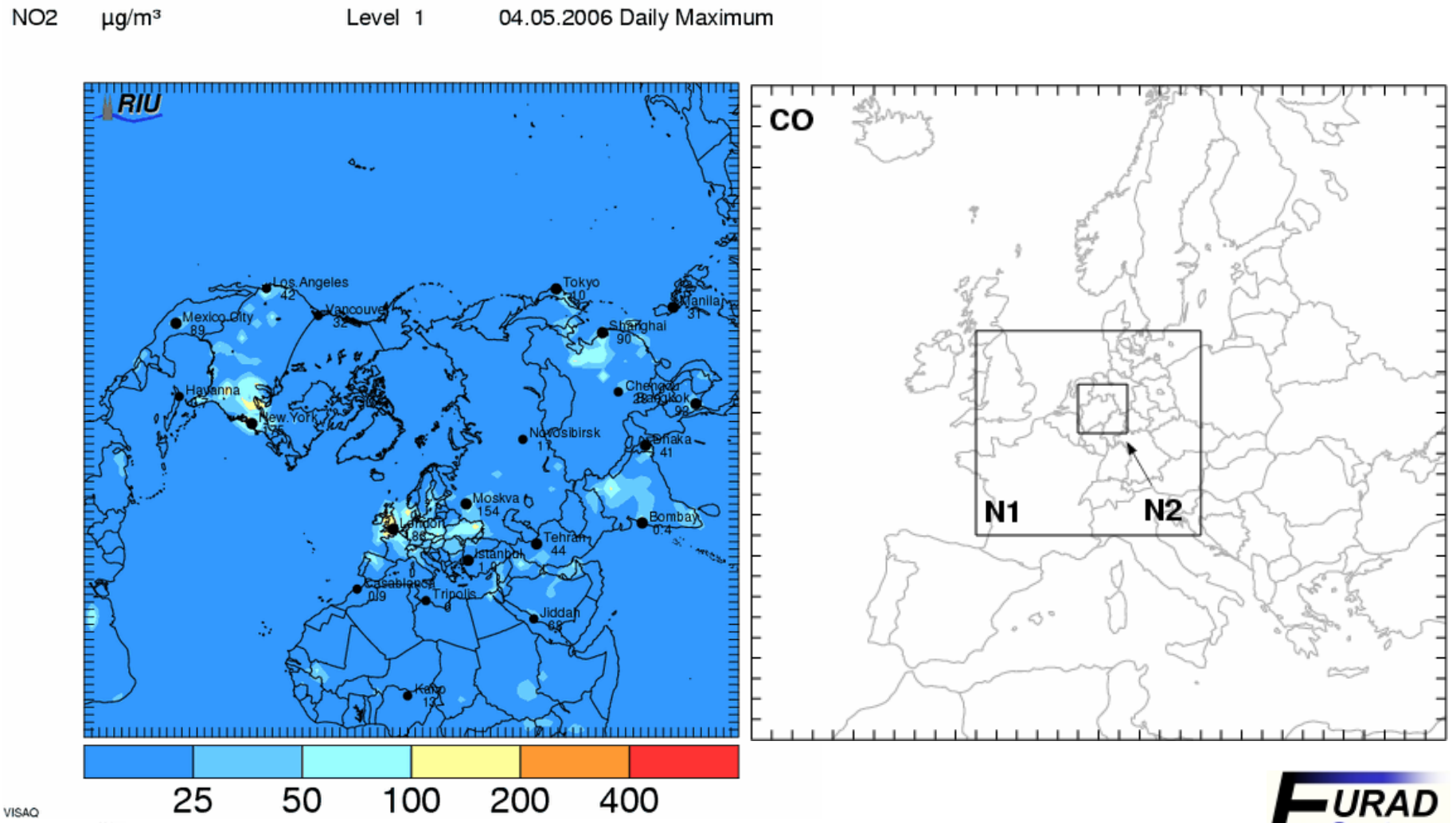
At DFD the air quality forecast system EURAD/RIU is run operationally.

Jacobs et al., 1995
Jacobs et al., 2001

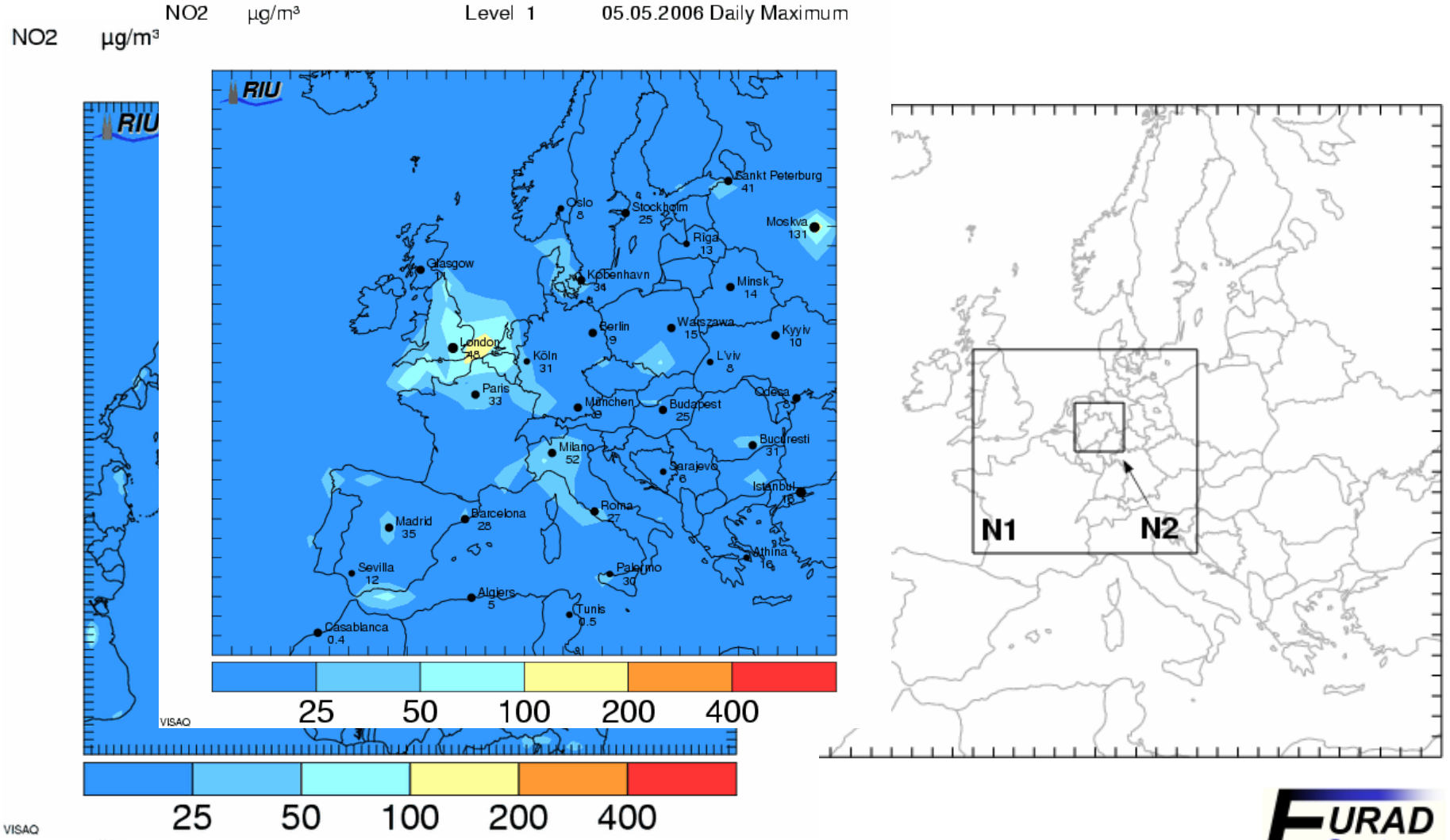
EURAD/RIU: Model setup



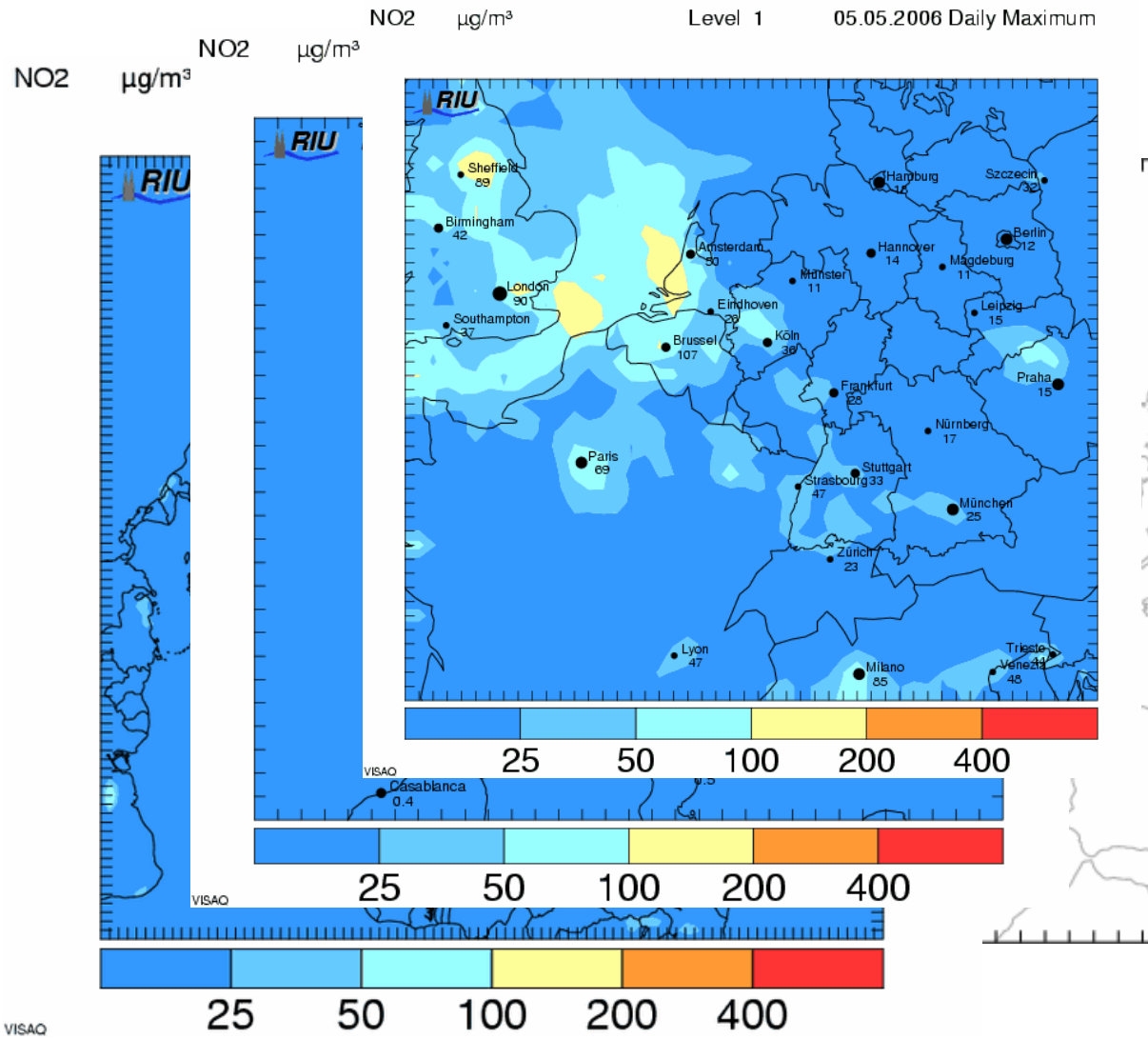
EURAD/RIU: Nested simulations

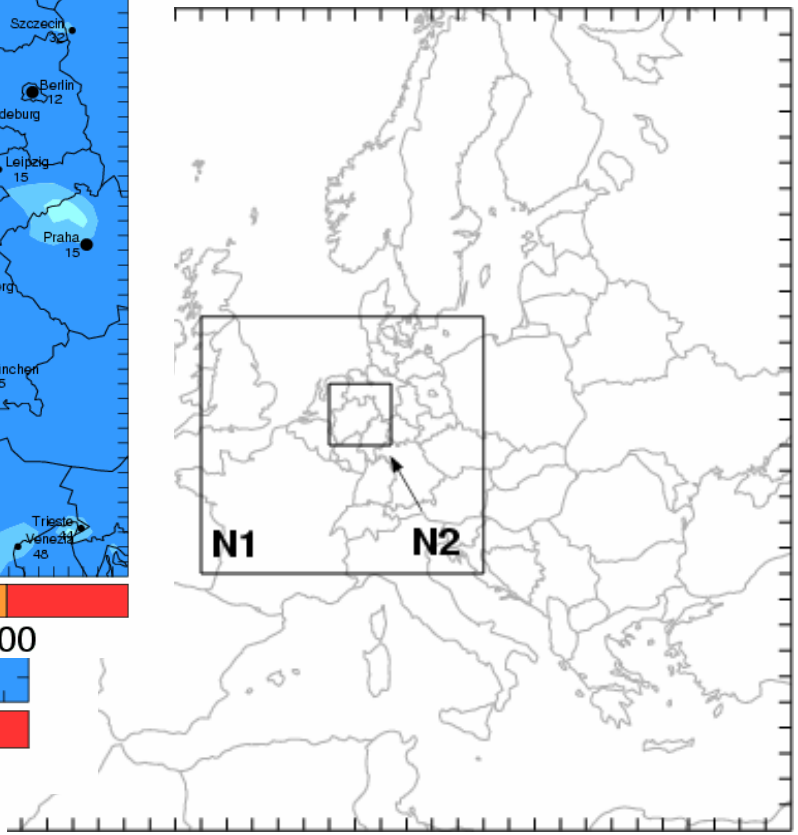


EURAD/RIU: Nested simulations



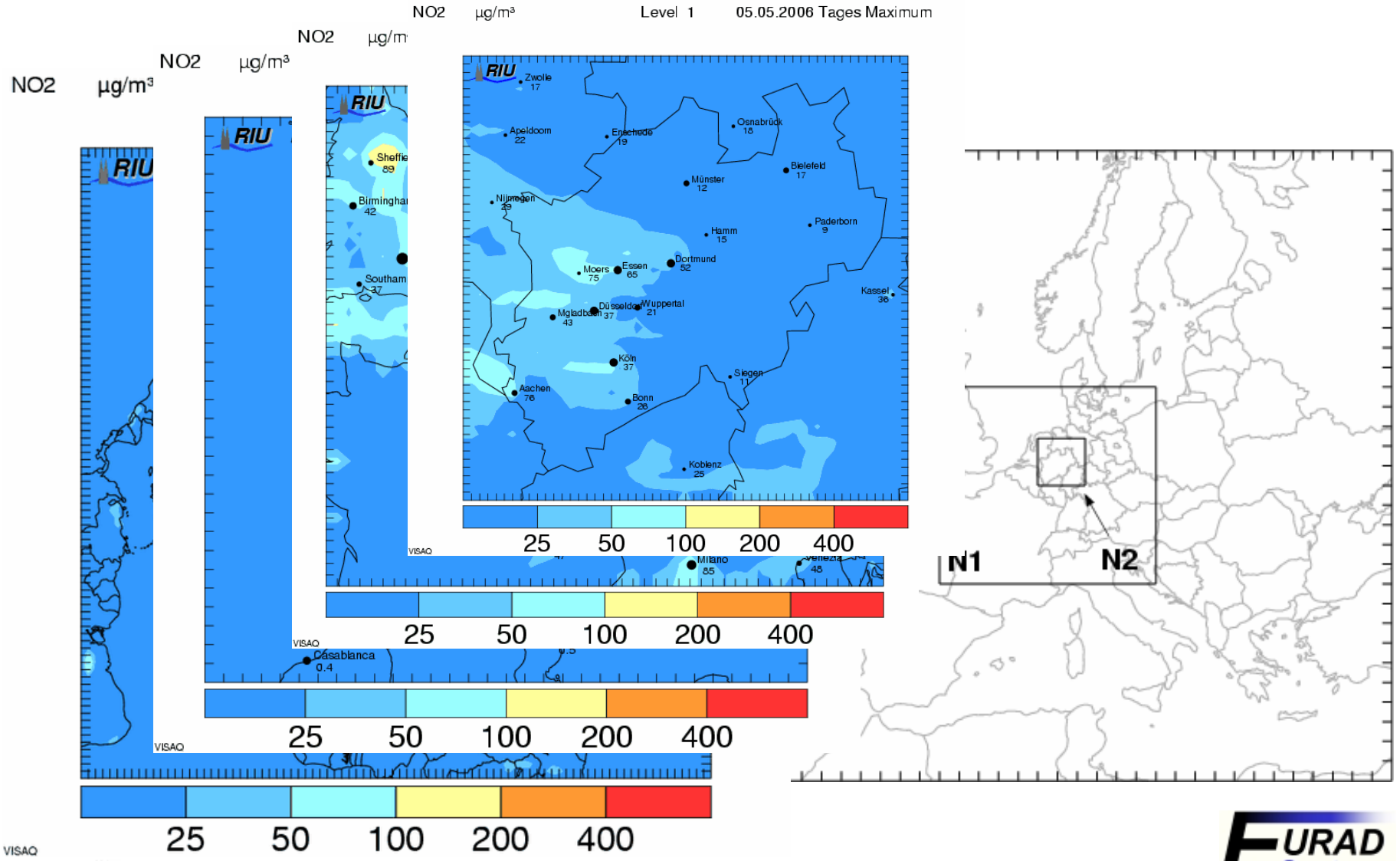
EURAD/RIU: Nested simulations



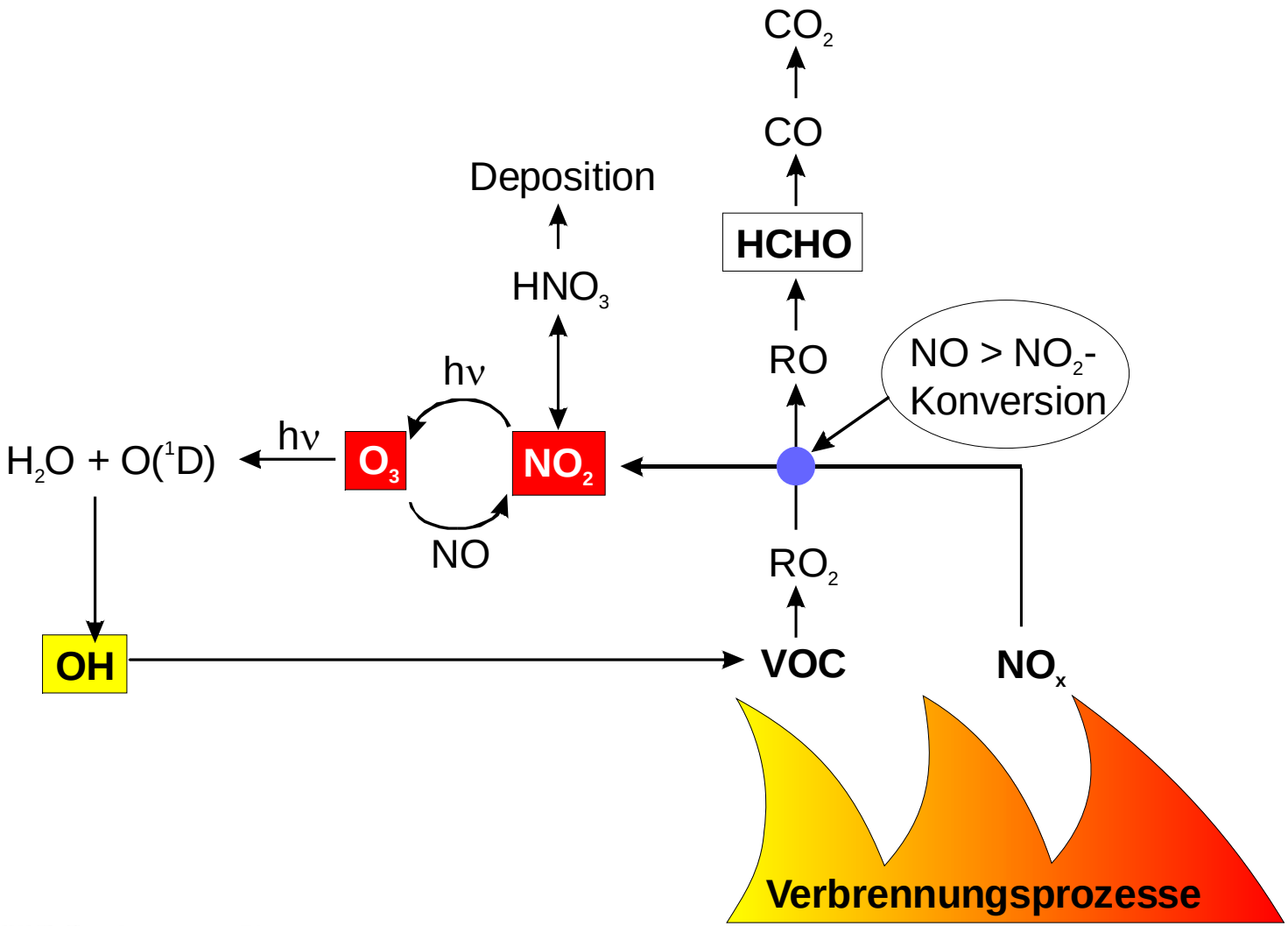


EURAD System

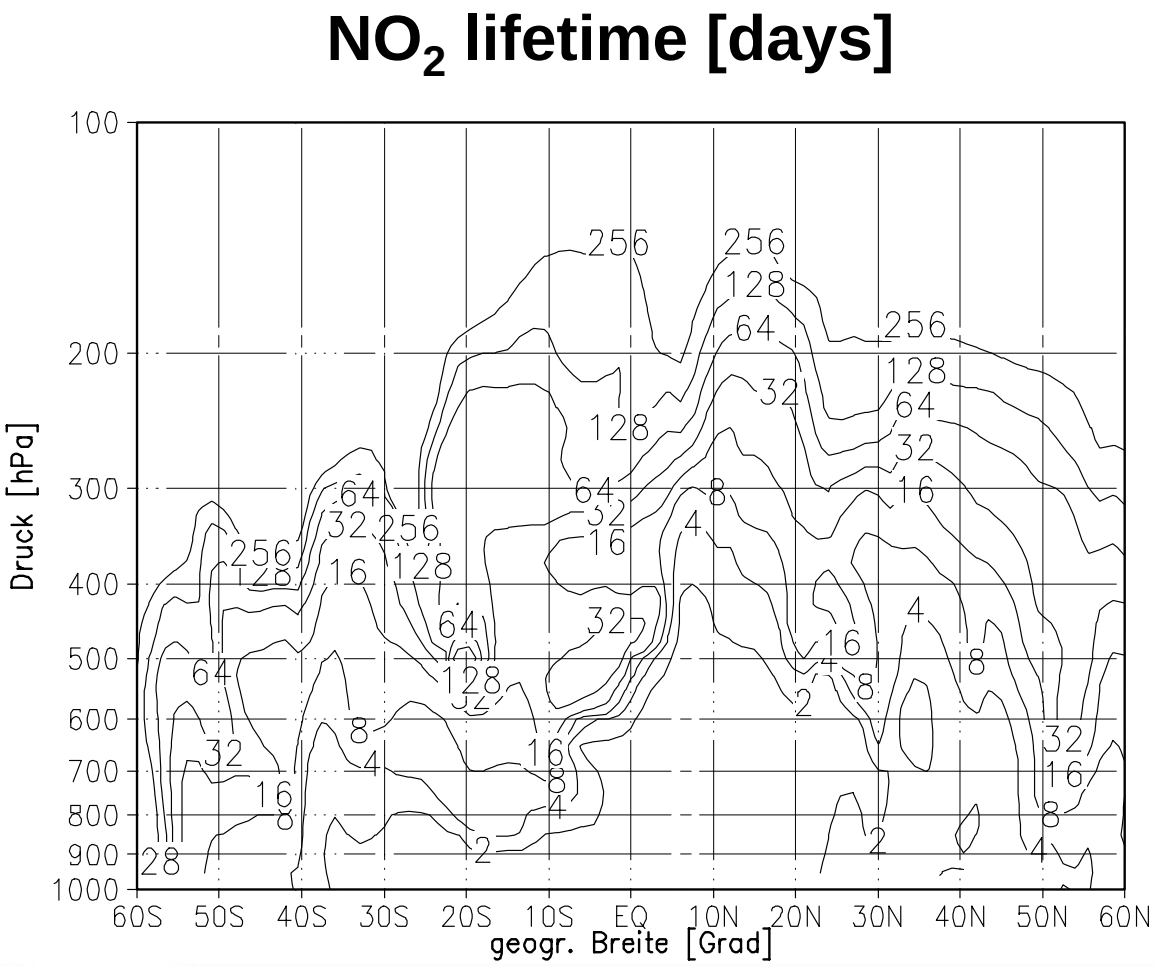
EURAD/RIU: Nested simulations



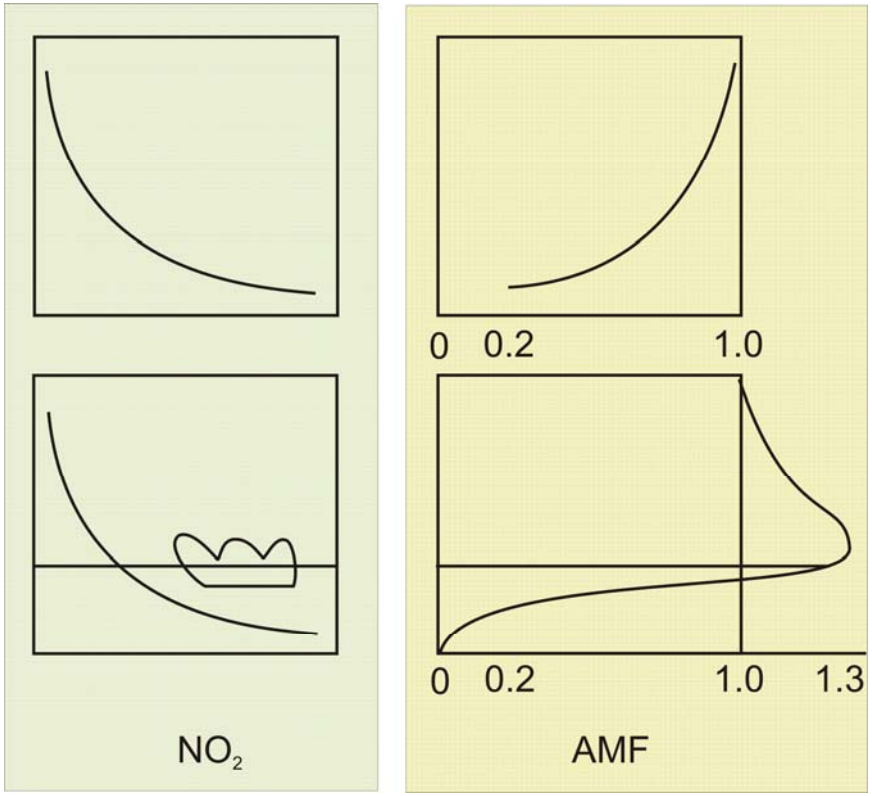
Tropospheric NO_2



Tropospheric NO_2



Tropospheric NO_2: Consider cloudiness



$w = w\ (cf,\ p_{surf},\ p_{cloud},\ \mu,\ \mu_0,\ \sigma,\ a)$

$AMF_{TROP}(z) = w * AMF_{cloud} + (1\text{-}w) * AMF_{clean}$

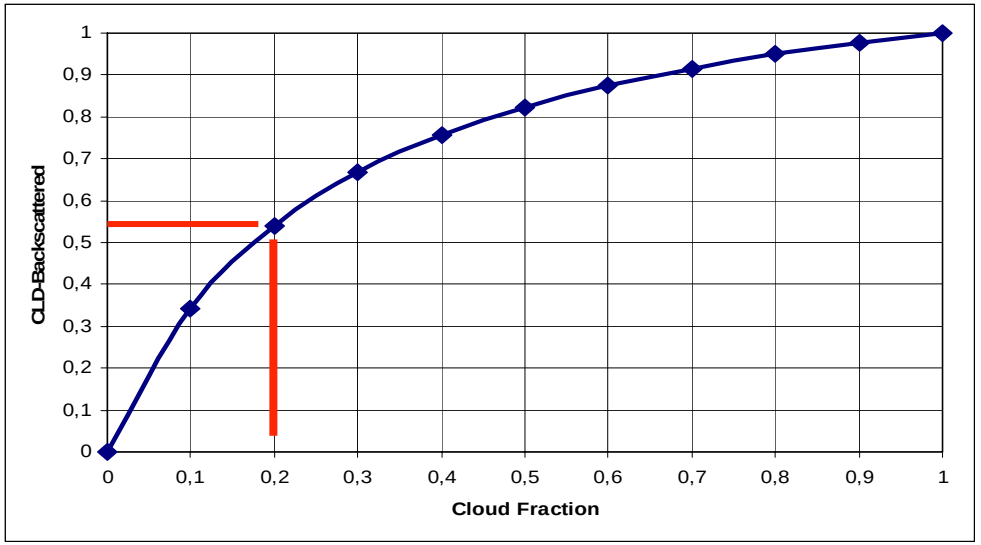
AMF(z): LIDORT

R. J. D. Spurr et al., 2001.
R. J. D. Spurr et al., 2002.

Cloud fraction and cloud top height
→ Apply OCRA and SACURA

Tropospheric NO_2: Clouds

Backscattered radiance as a function of cloud fraction



Cloud fraction of 20%: 50% of the backscattered radiance originates from the cloud top.

→ Maximum allowed cloud fraction: 20%

Sources of tropospheric NO_2

Anthropogenic sources (Tg N / year)	
Fossil fuel combustion including aircraft	**21.9**
Biomass burning including biofuel combustion	**7.7**
Industrial processes	**1.5**
Aircraft	**0.5**
Mineral fertilizer use, direct emission	**0.4**
Atmospheric deposition	**0.3**

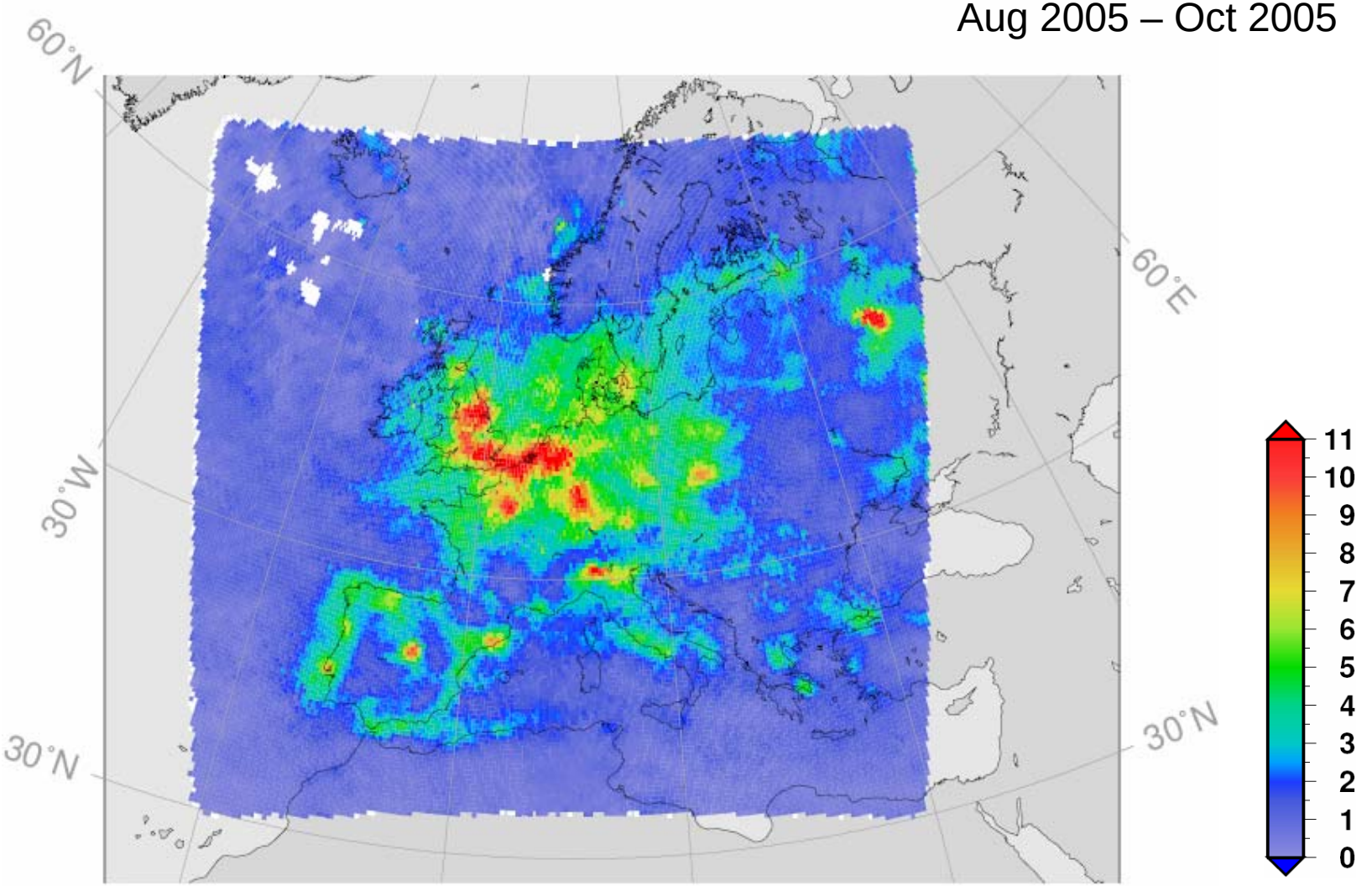
Natural sources (Tg N / year)	
Soils under natural veg.	**13.0**
Lightning	**12.2**
Excreta of wild animals	**0.1**
Tropospheric chemistry	**0.9**
Transport from stratosphere	**0.1**

Total: 59.0

Food and Agricultural Organisation,
Global estimates of gaseous emissions of NH3, NO and N2O from agricultural land, Rome, 2001 and references therein

Summer composite, NO_2 VCD

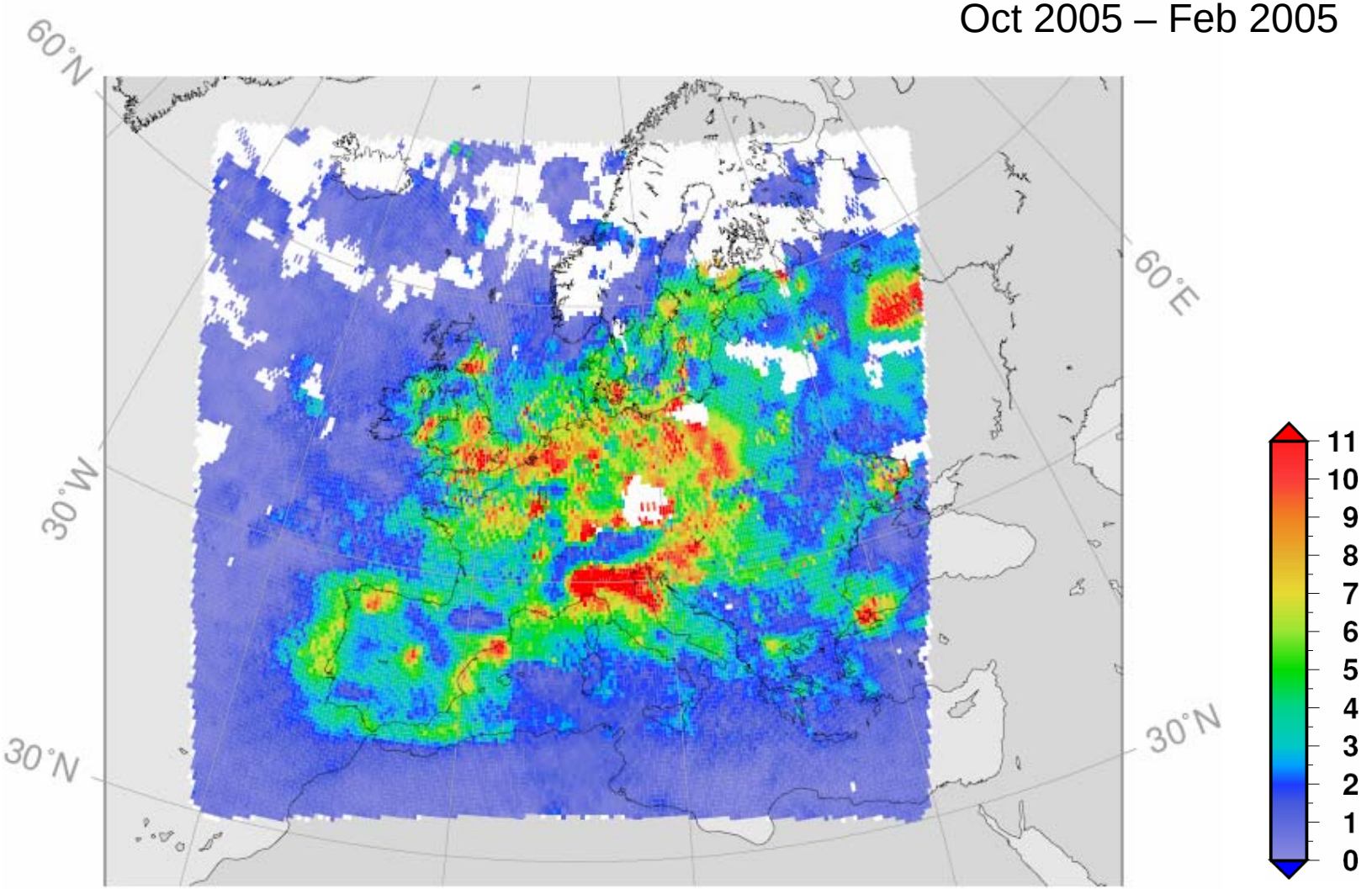
Aug 2005 – Oct 2005



* 10^{15} molecules cm^{-2}

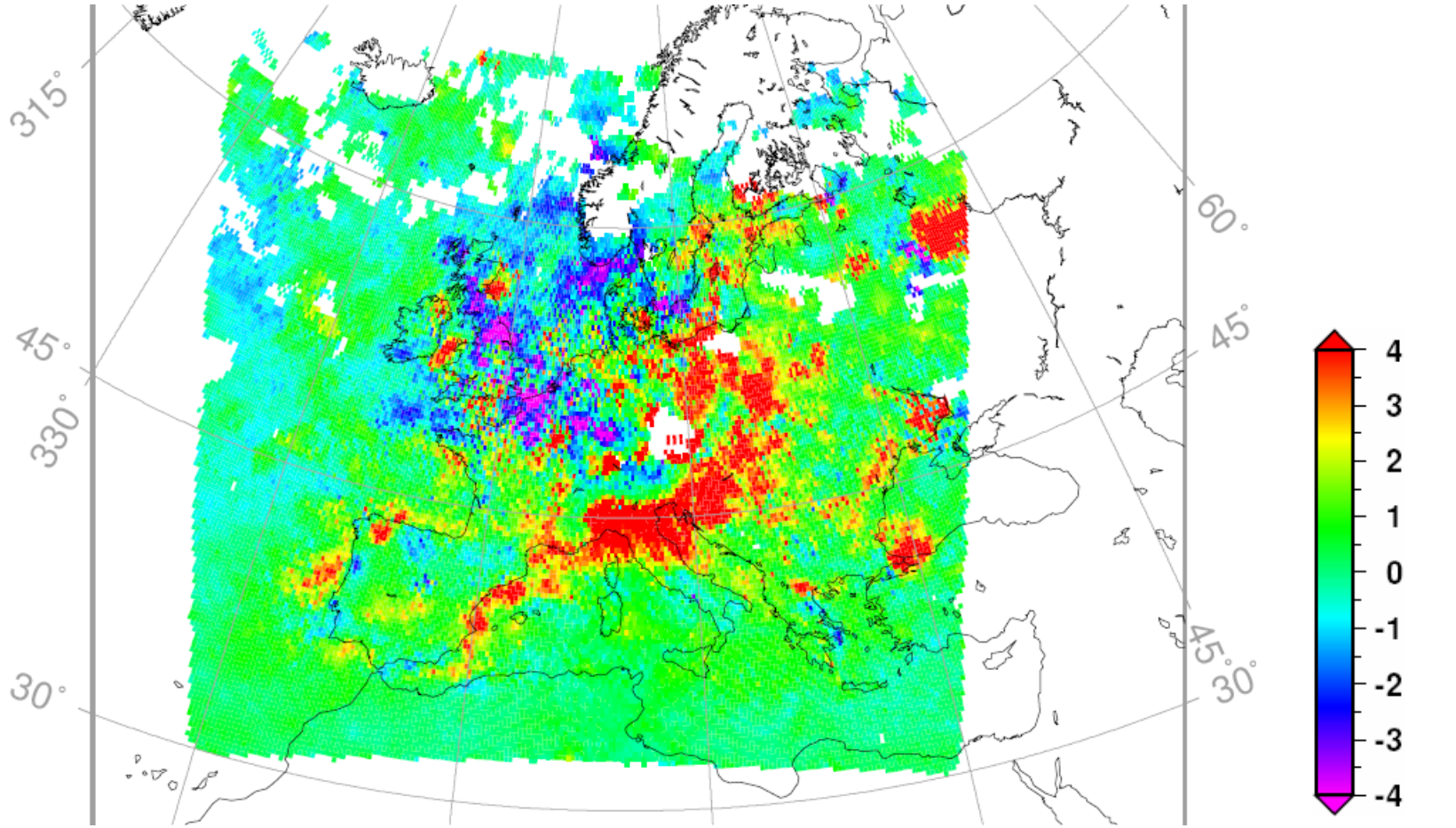
Winter composite, NO_2 VCD

Oct 2005 – Feb 2005



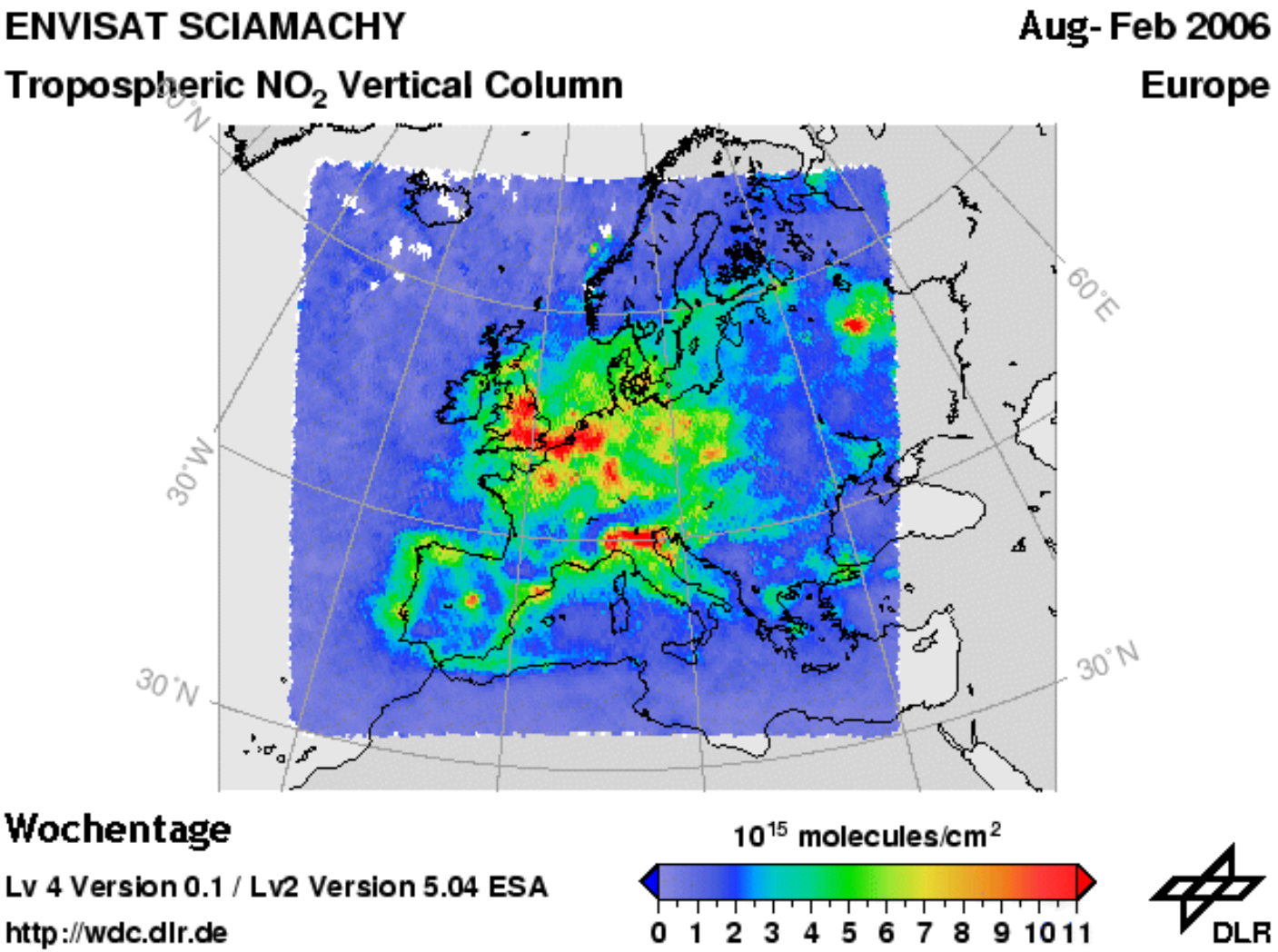
* 10^{15} molecules cm^{-2}

Difference between summer and winter composite



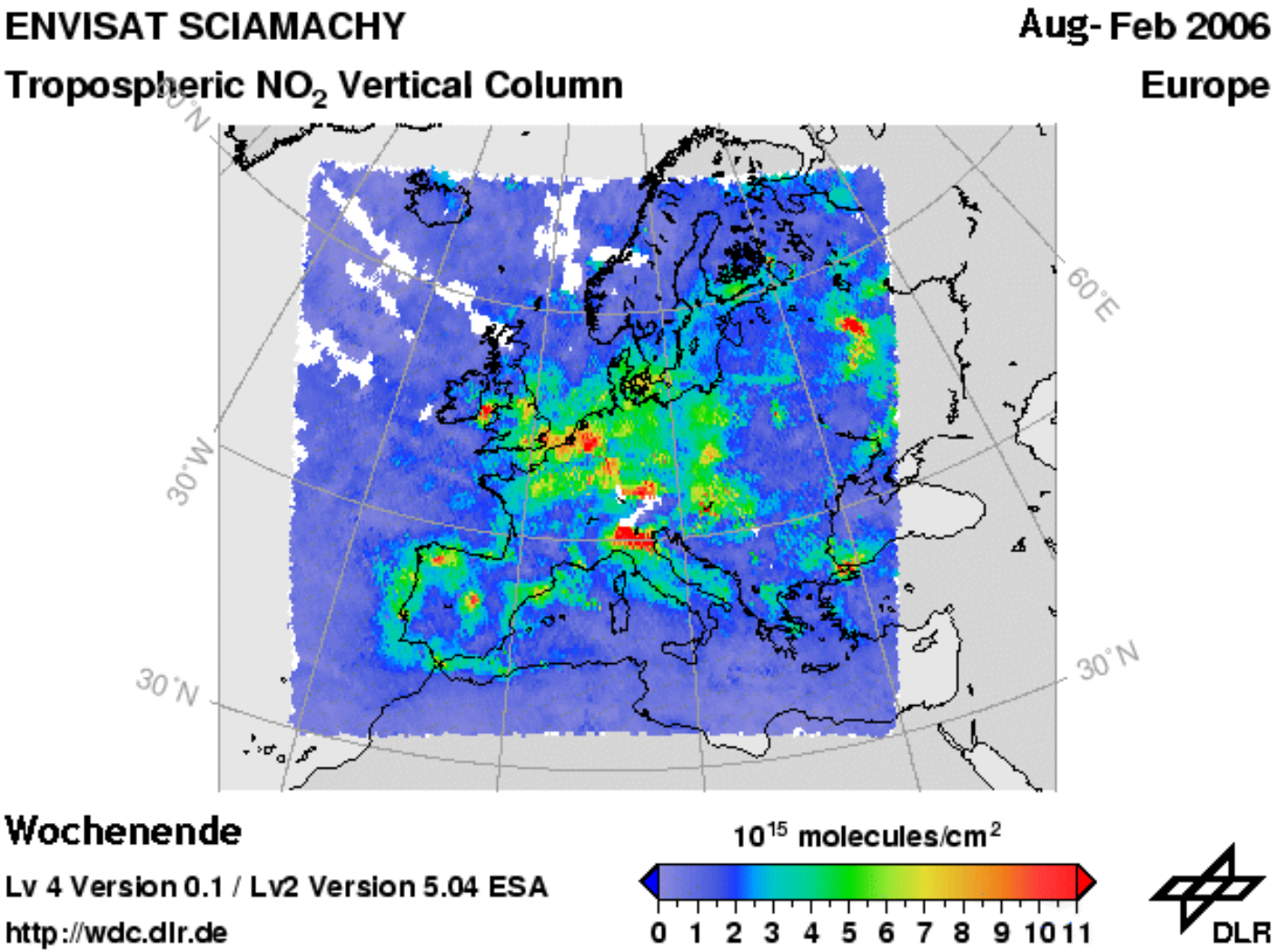
* 10^{15} molecules cm^{-2}

Tropospheric NO_2: Weekdays (Mo-Fr)



Quelle: Eigene Darstellung

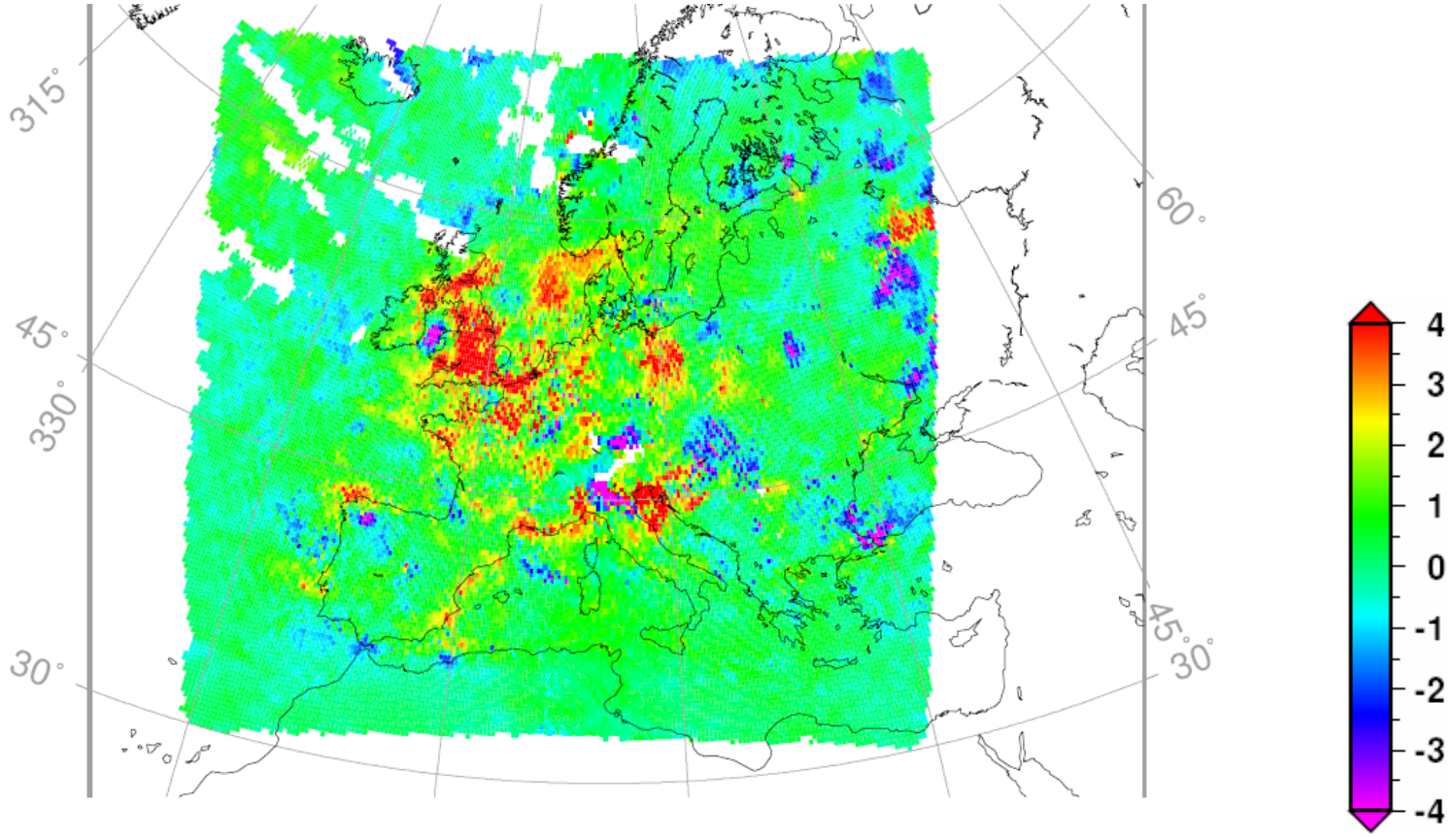
Tropospheric NO_2: Weekend (Sa+So)



Quelle: Eigene Darstellung

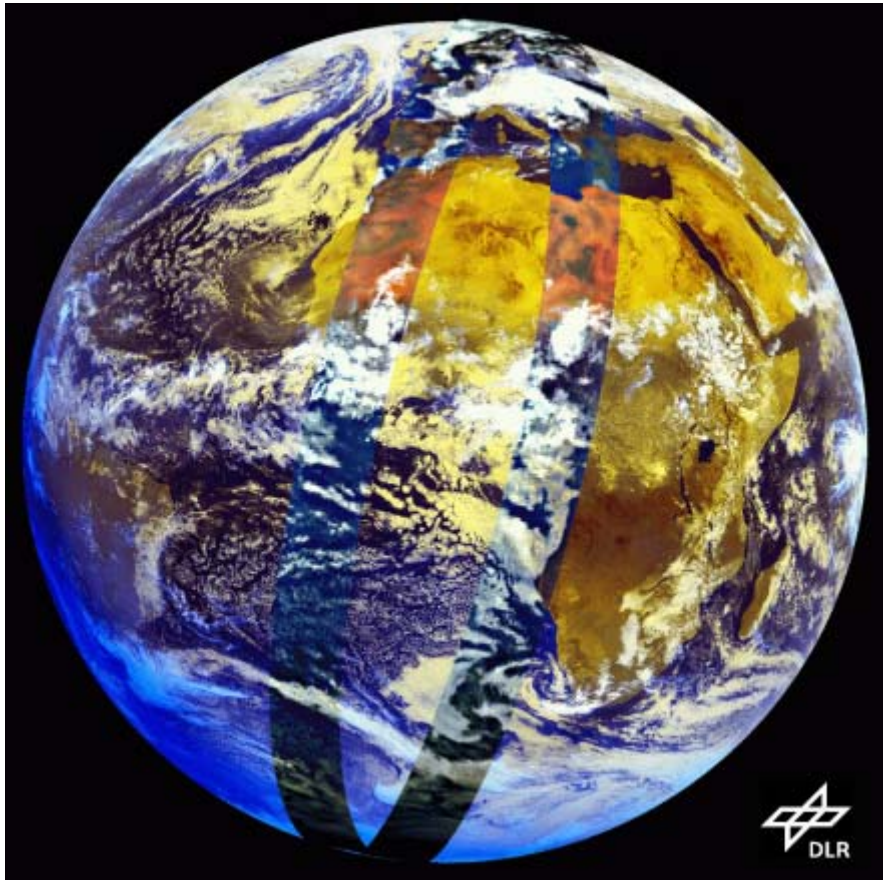
Week (Mo-Fr) - Weekend (Sa+So)

Aug 2005 - Feb 2006



Troposphärisches NO_2: Wolkenbedeckung

Optical Cloud Recognition Algorithm (OCRA)

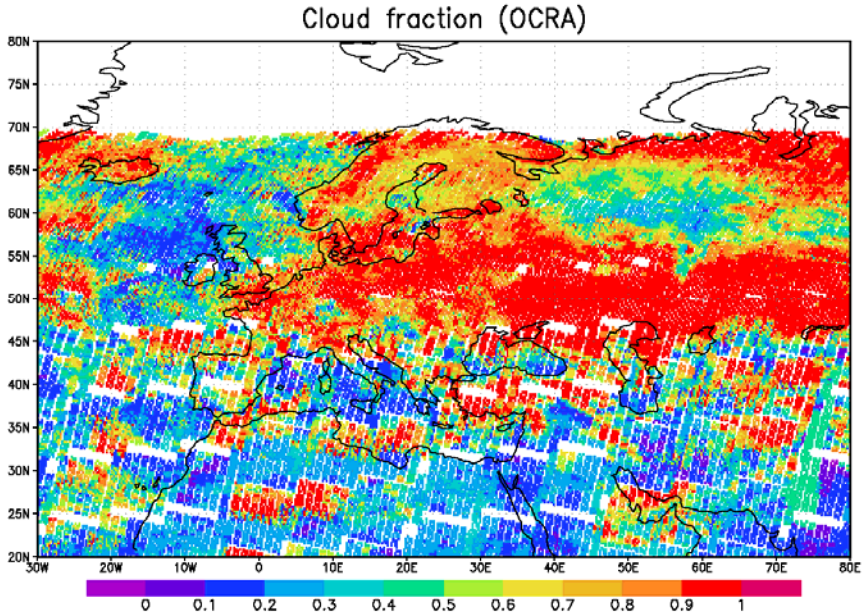


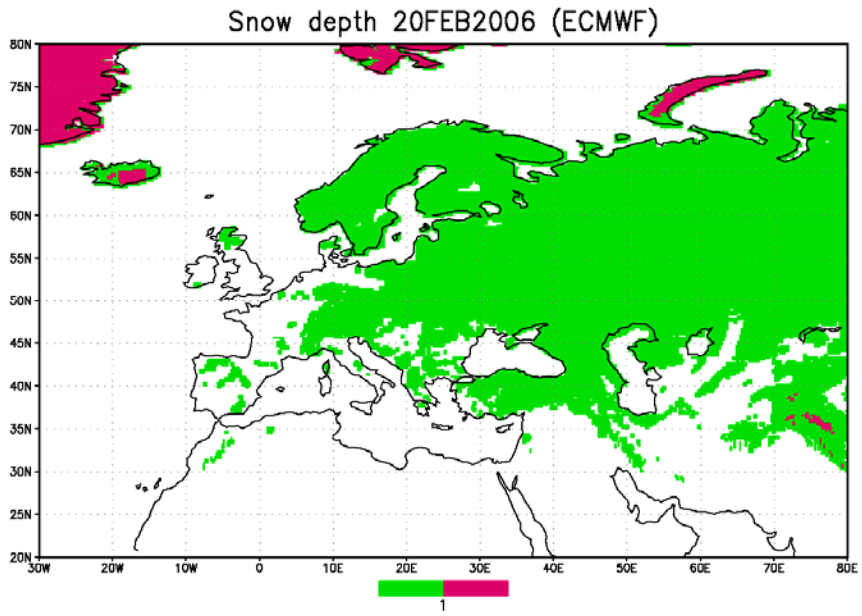
Meteosat 7 ⇔ OCRA (GOME)

Diego Loyola (DLR-IMF)

Troposphärisches NO_2: Wolkenbedeckung

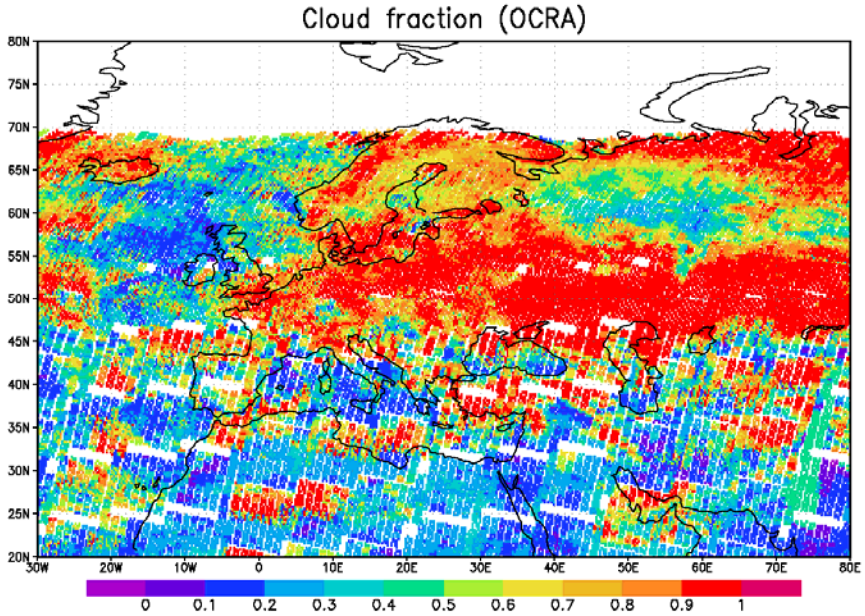
Problem: Wolkenretrieval (OCRA) unterscheidet Wolke und Schnee nicht

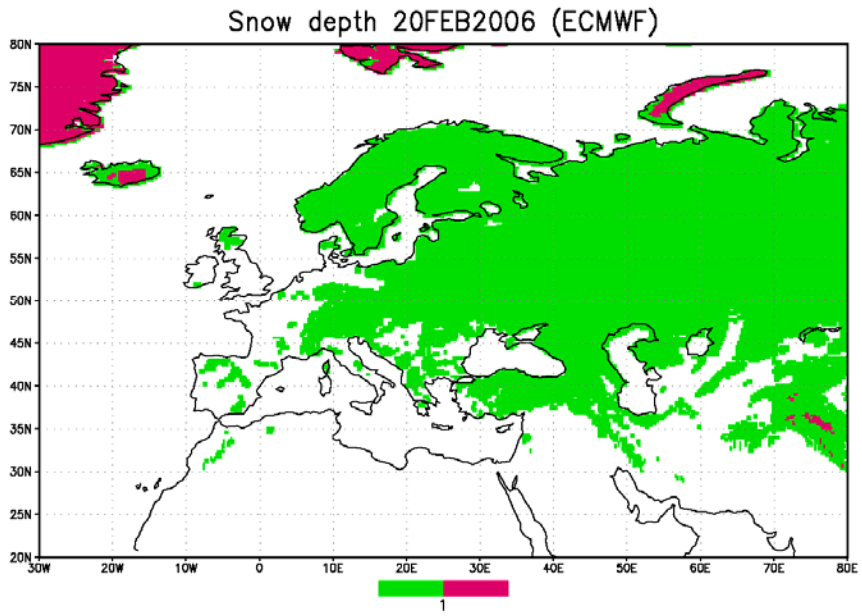




Troposphärisches NO_2: Wolkenbedeckung

Problem: Wolkenretrieval (OCRA) unterscheidet Wolke und Schnee nicht

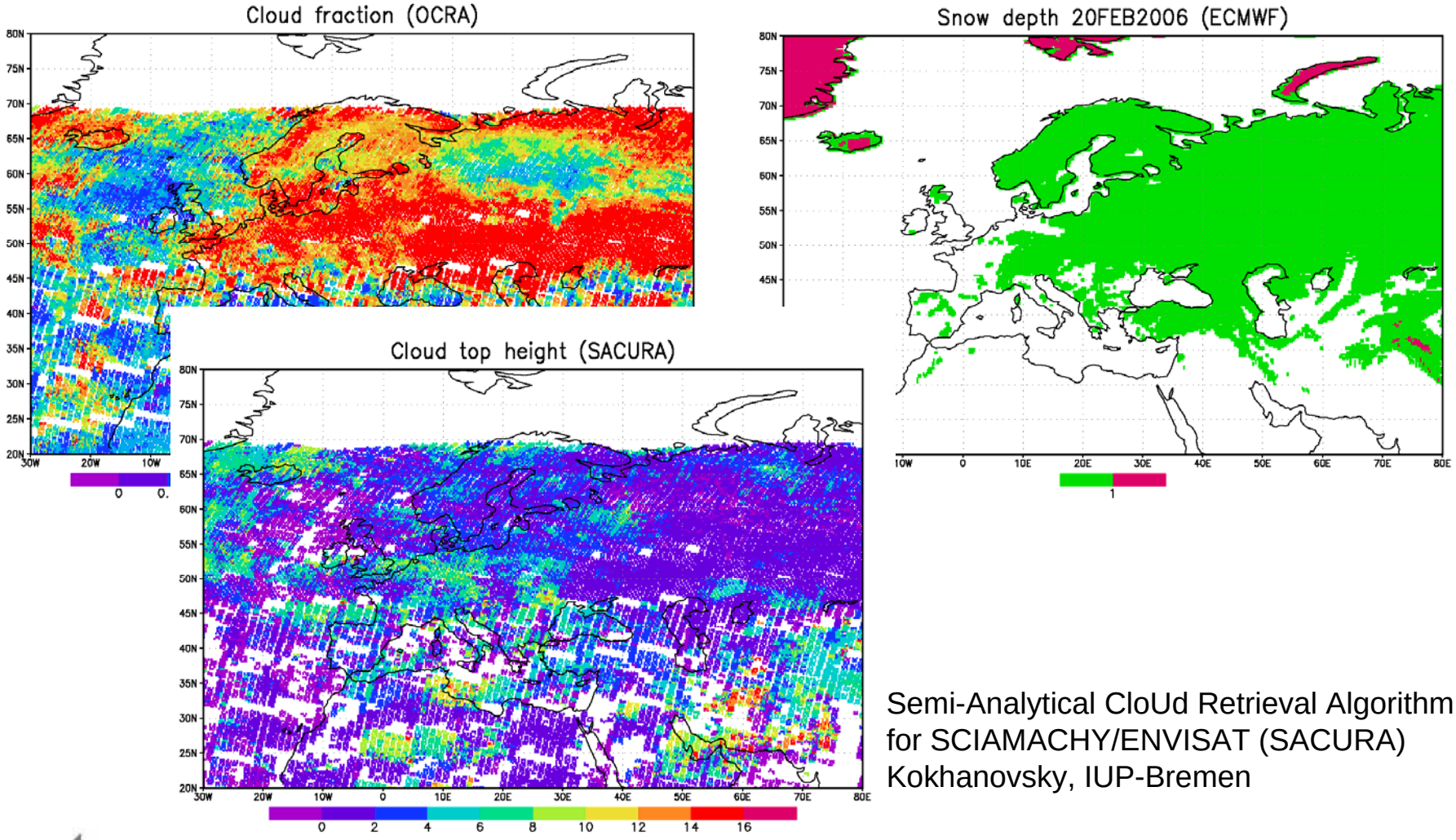




Weiteres Problem: ESA-Wolkenhöhe aus ISCCP-Klimatologie
(ISCCP: Internat. Cloud climatology project)

Troposphärisches NO_2: Wolkenbedeckung

Problem: Wolkenretrieval (OCRA) unterscheidet Wolke und Schnee nicht



Semi-Analytical CloUd Retrieval Algorithm for SCIAMACHY/ENVISAT (SACURA)
Kokhanovsky, IUP-Bremen

Troposphärisches NO_2: Grenzwerte

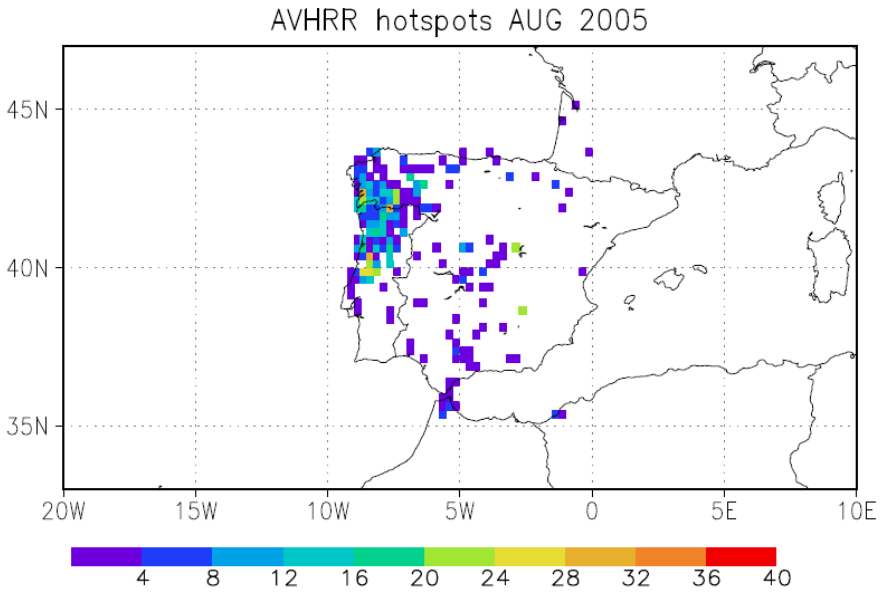
Exposition	Grenzwert (WHO)
1 Stunde	200 µg / m3 (0.11 ppm)
Jahresmittelwert	40 ... 50 µg/m3 (0.021 ... 0.026 ppm)

Überschreiten der Grenzwerte in Europa ist eher selten.

Aber: NO_2 ist wichtige Vorläufersubstanz für Ozon und weitere Substanzen, die z. B. sauren Regen begünstigen.

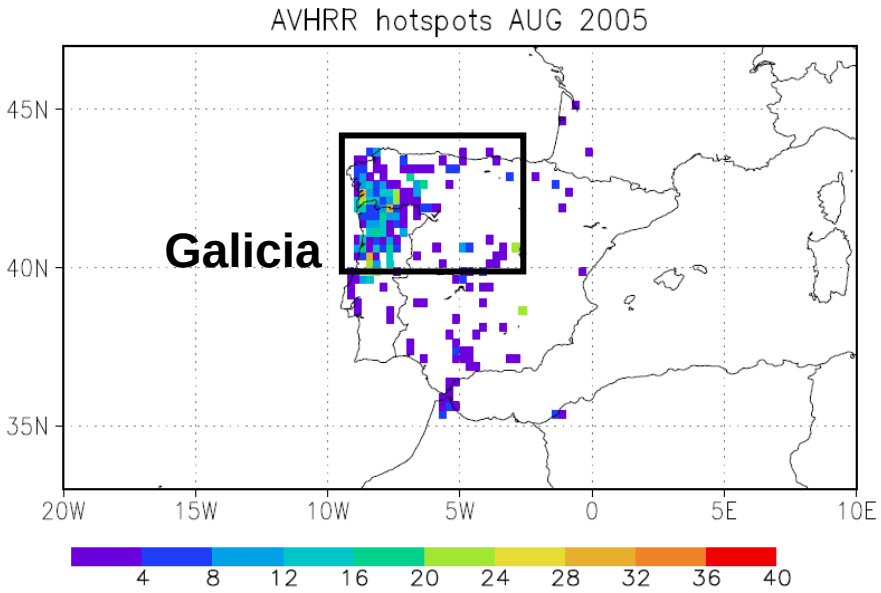
Gefahr: Änderung von Techniken (→ Dieselmotoren)

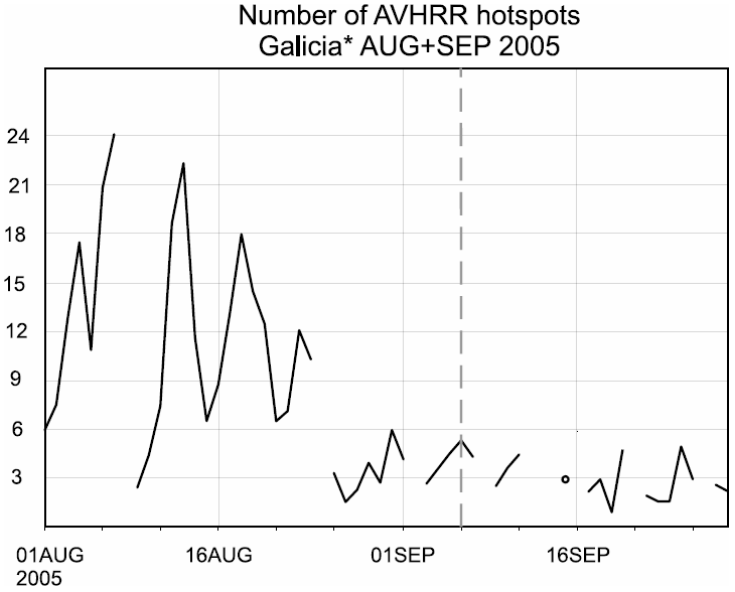
Portuguese wildfires / biogenic emissions



Hotspots derived from AVRHH at DLR-DFD (G. Gesell)

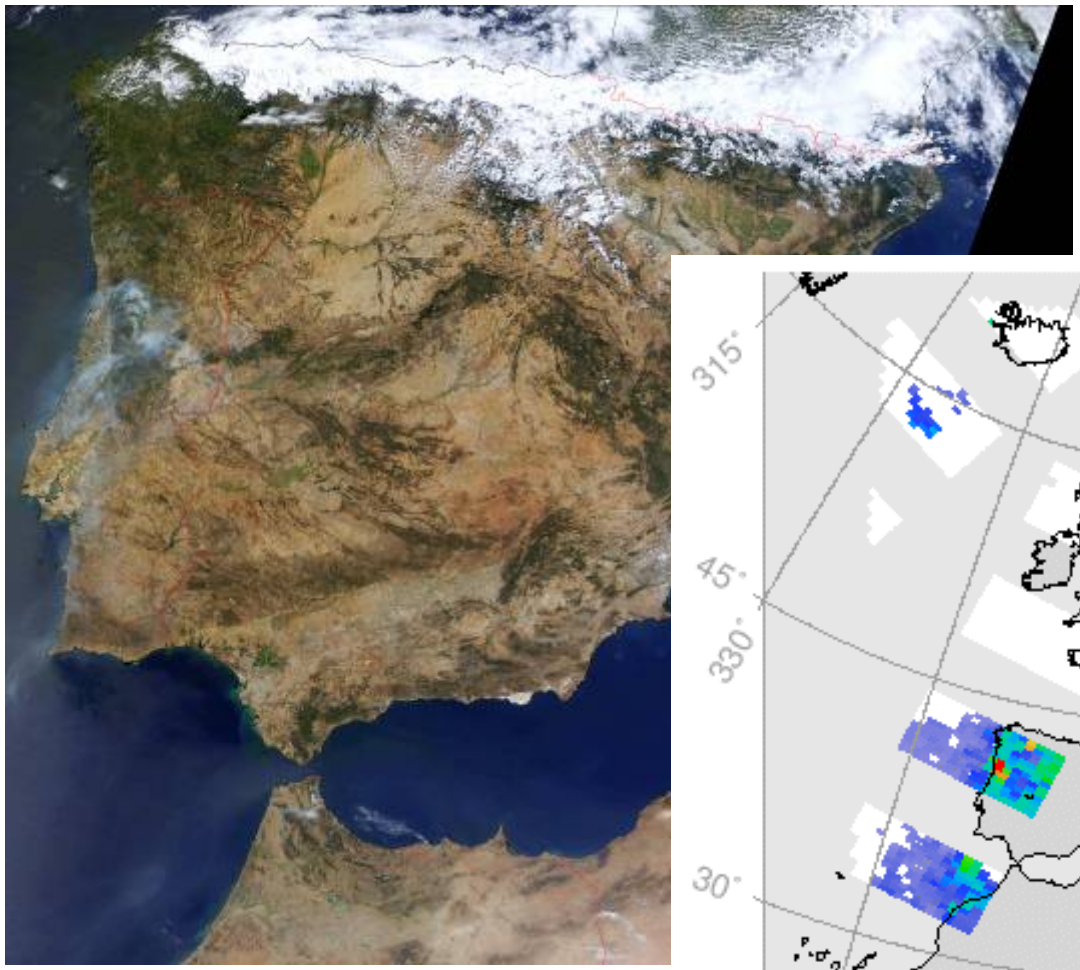
Portuguese wildfires / biogenic emissions





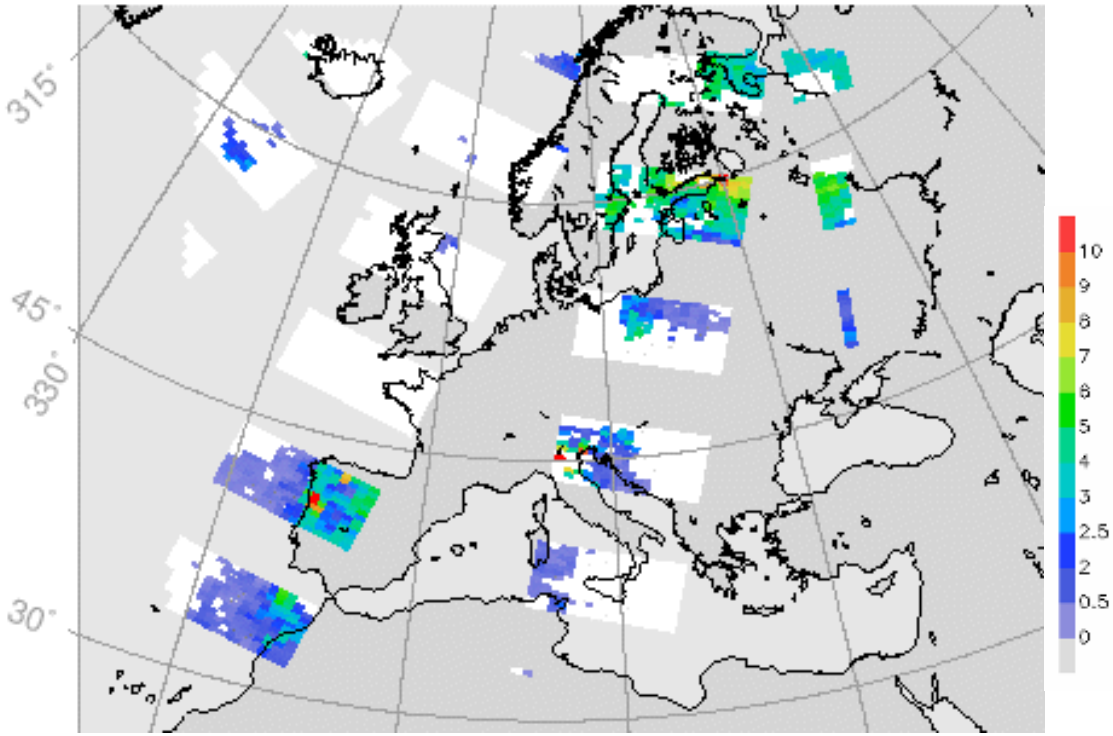
Hotspots derived from AVRHH at DLR-DFD (G. Gesell)

Portuguese wildfires / biogenic emissions



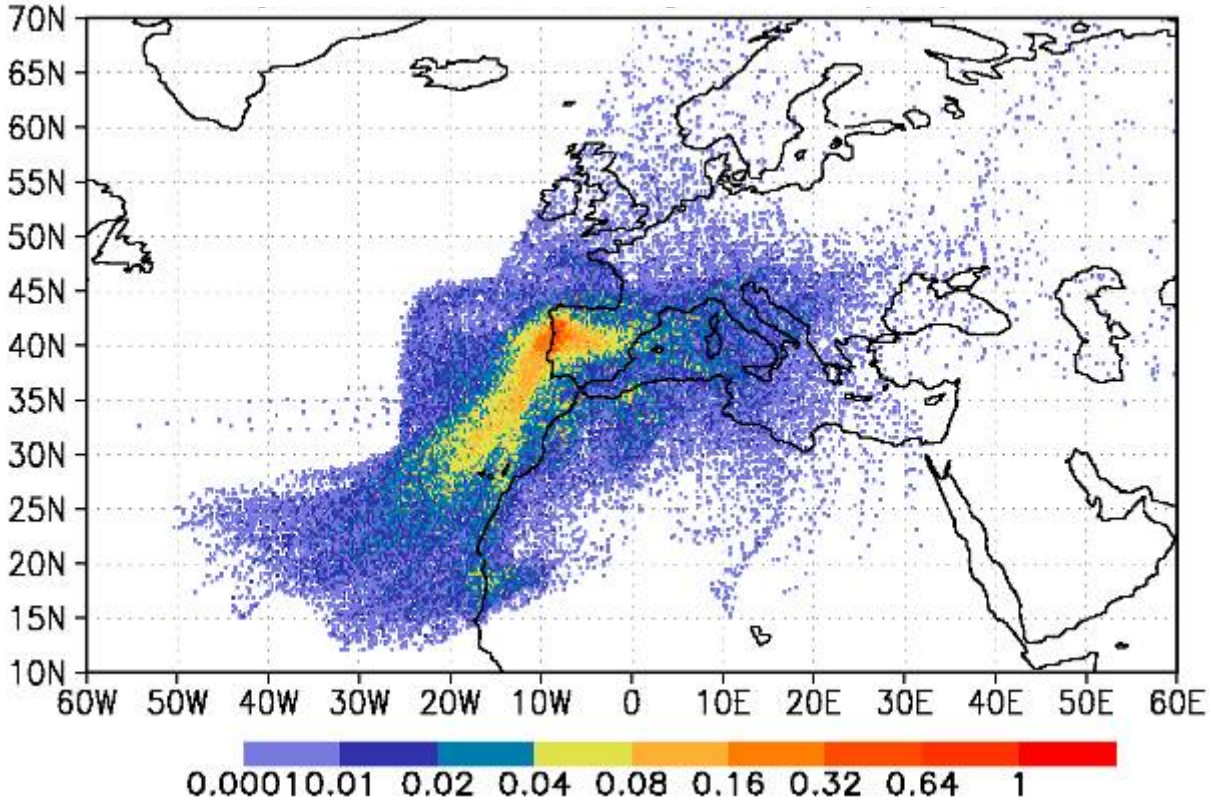
MODIS: 23.8.2005

SCIAMACHY trop. NO_2 VCD
[10^{15} molec cm^{-2}]
24.8.2005



Portuguese wildfires / biogenic emissions

Trajectory density Portuguese fires 08/2005
(based on ECMWF analysis data)

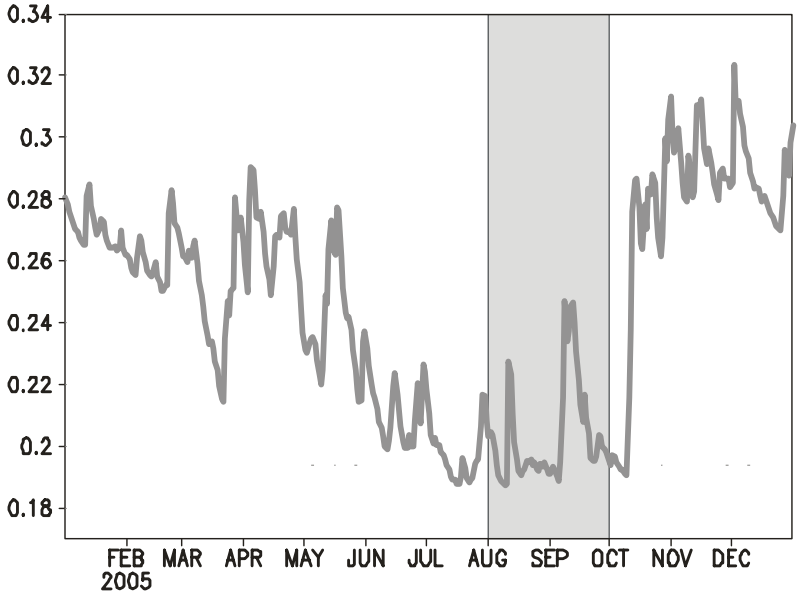


Trajectory density calculated using Traj.x, Meyer-Arnek et al., 2005

Portuguese wildfires / biogenic emissions

Pulses of biogenic NOx emission are observed in tropical regimes following the first rain on dry soils (e. g. Jaegle et al., 2004).

Soil water content [m^3/m^3], Galicia from ECMWF



Portuguese wildfires / biogenic emissions

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Soil water content [m³/m³], Galicia
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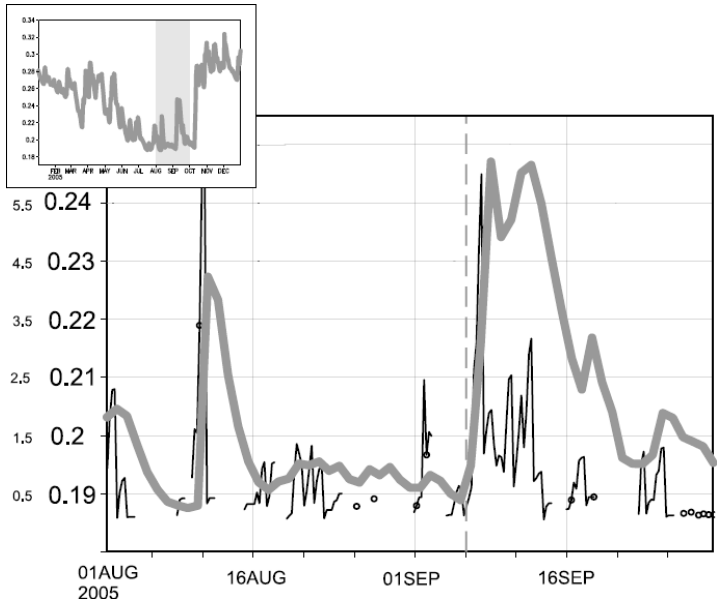
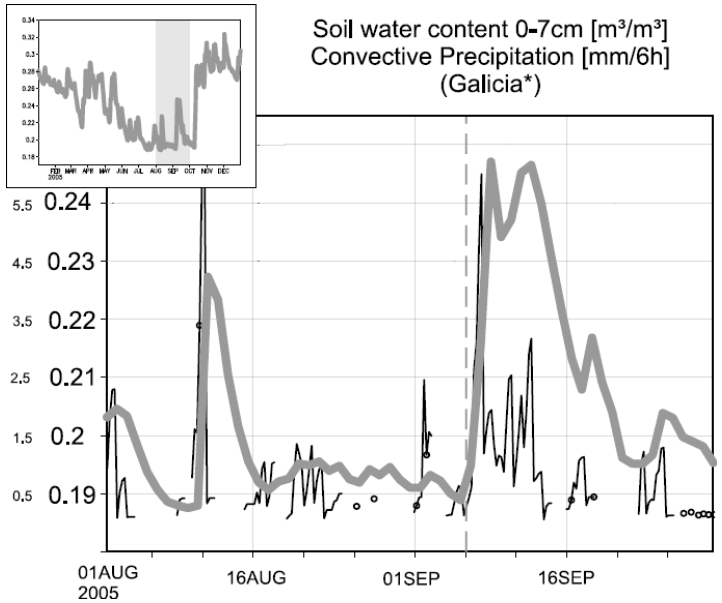


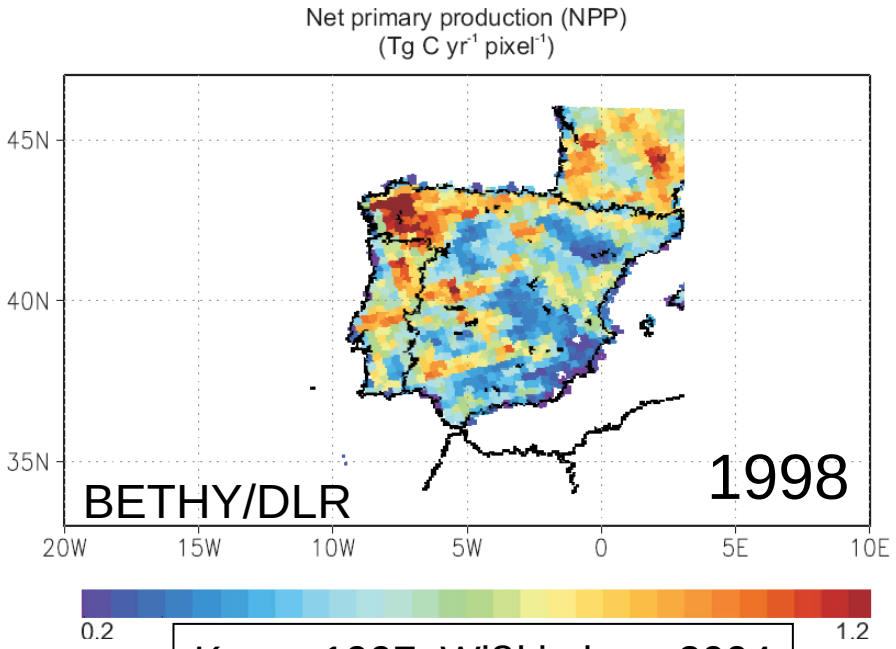
Portuguese wildfires / biogenic emissions

BETHY/DLR (**B**iosphere **E**nergy **T**ransfer **H**ydrolog**Y** model)

→simulations of net primary production (NPP) over Europe

(based on meteorological data (from ECMWF) and surface parametres as landcover classification and LAI time series)





Knorr, 1997, Wißkirchen, 2004

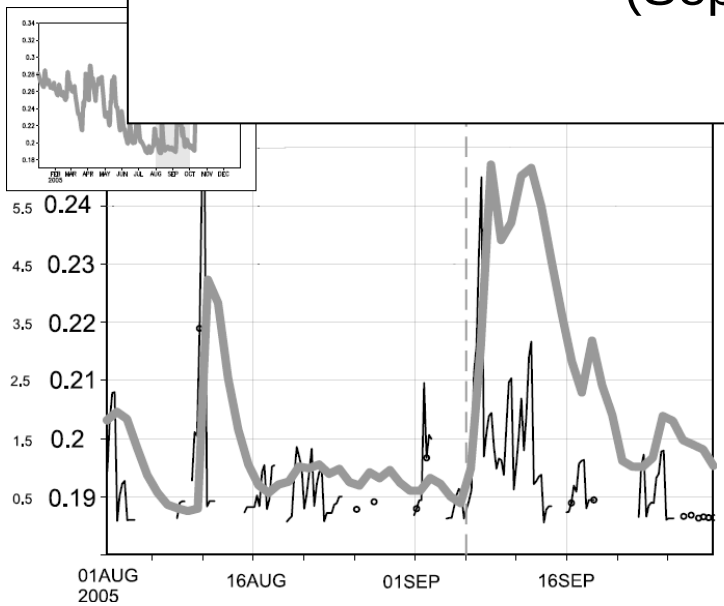
Portuguese wildfires / biogenic emissions

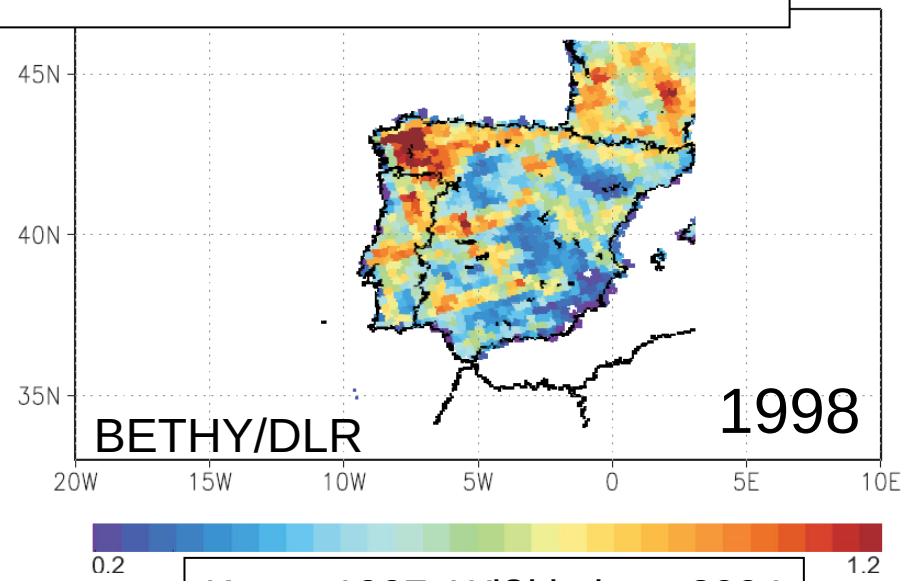
BETHY/DLR (**B**iosphere **E**nergy **T**ransfer **H**ydrolog**Y** model)

→sim

Northwestern parts of the Iberian Peninsula:

Dense vegetation + first rain after dry conditions (September 2005)

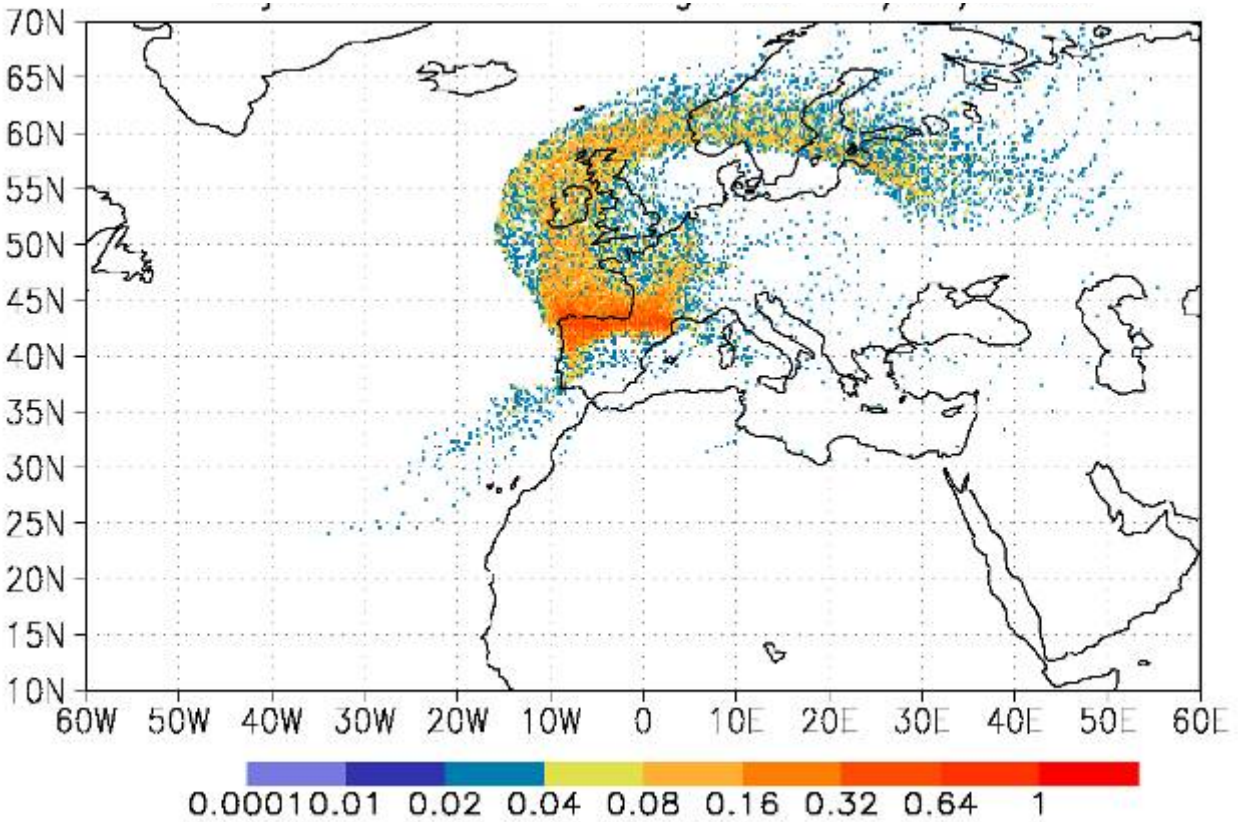




Knorr, 1997, Wißkirchen, 2004

Portuguese wildfires / biogenic emissions

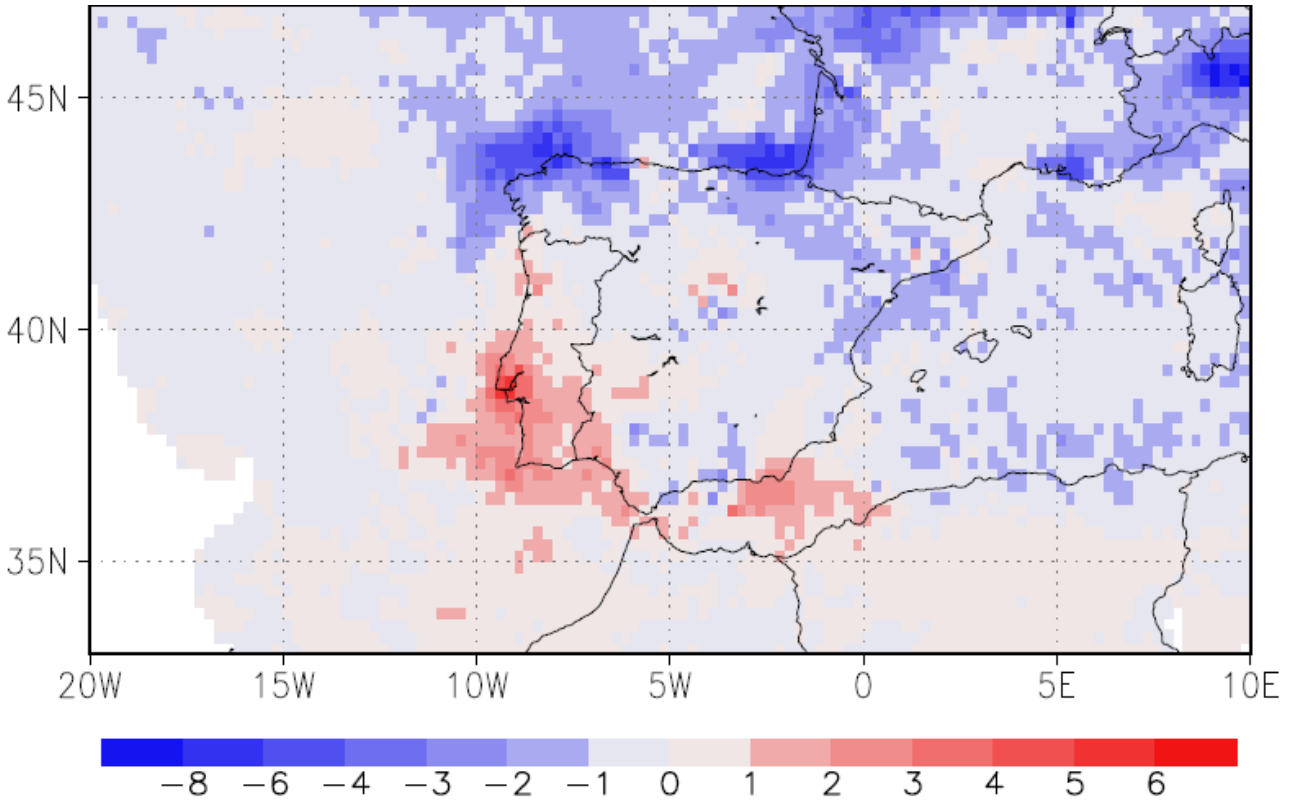
Trajectory density 09/2005
(based on ECMWF analysis data)



Trajectory density calculated using Traj.x, Meyer-Arnek et al., 2005

Portuguese wildfires / biogenic emissions

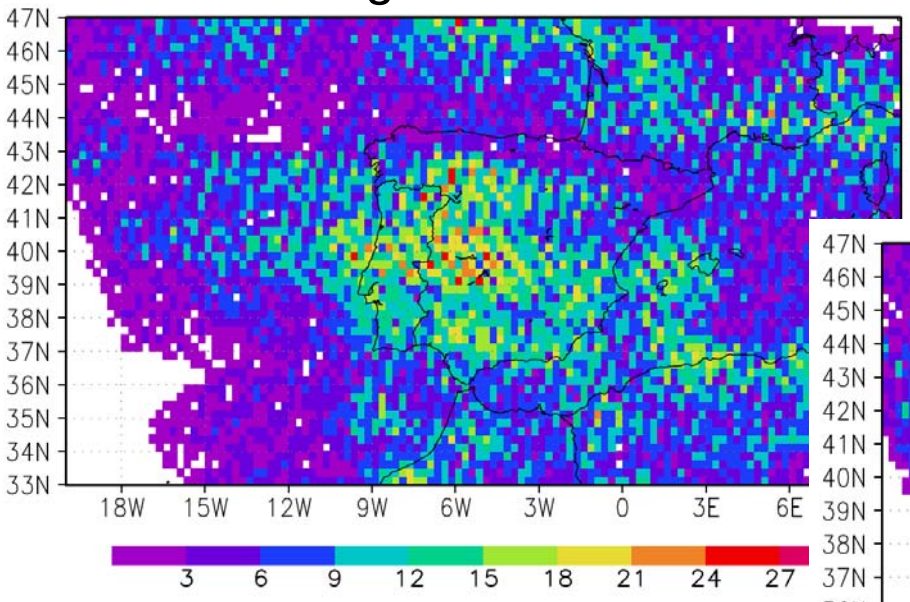
Comparison of August and September 2005 composite
Troposph. NO_2 VCD [10^{15} molec cm²]



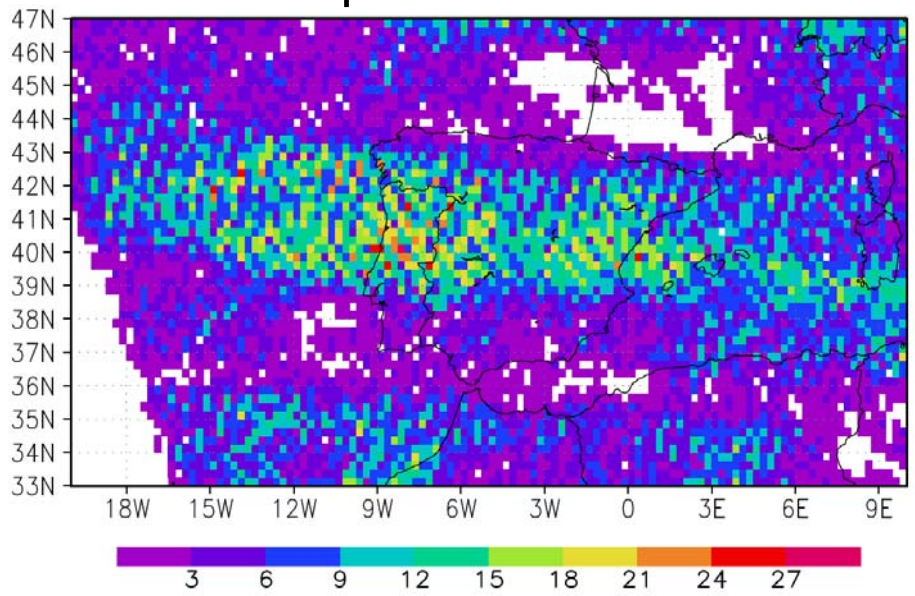
Portuguese wildfires / biogenic emissions

Number of successful SCIAMACHY measurements

August 2005

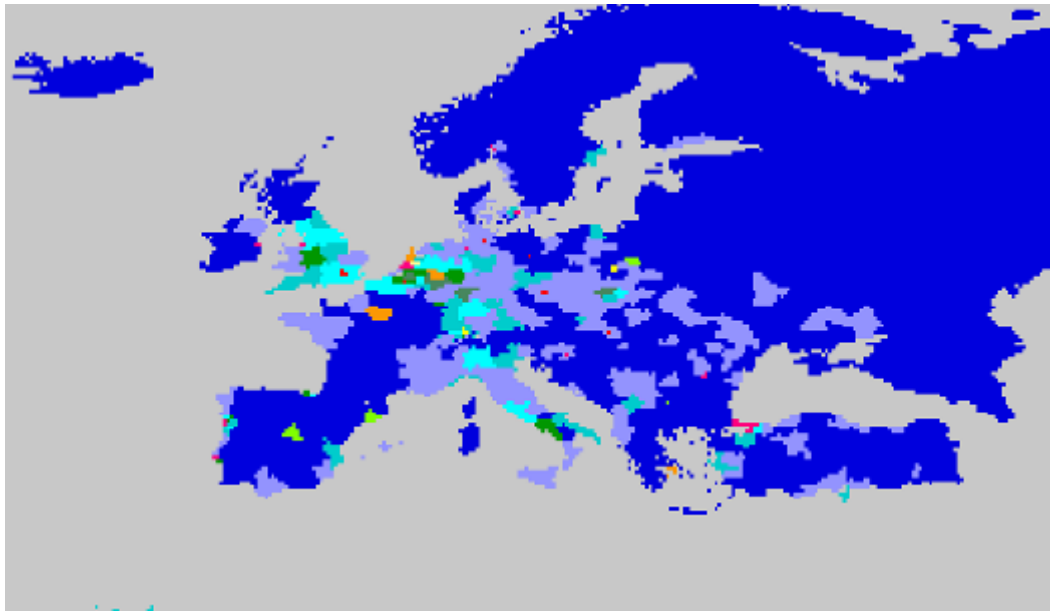


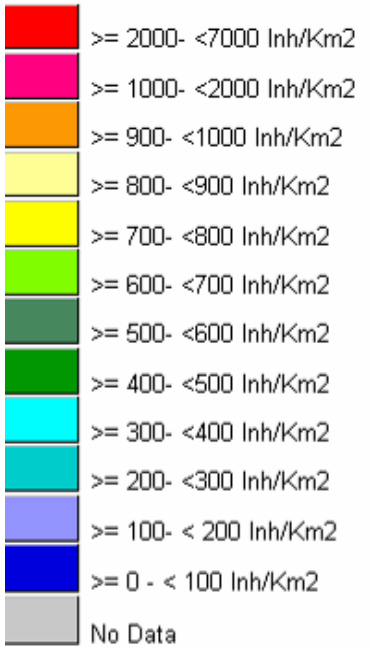
September 2005



Portuguese wildfires / biogenic emissions

Population density (Europe, 2004)





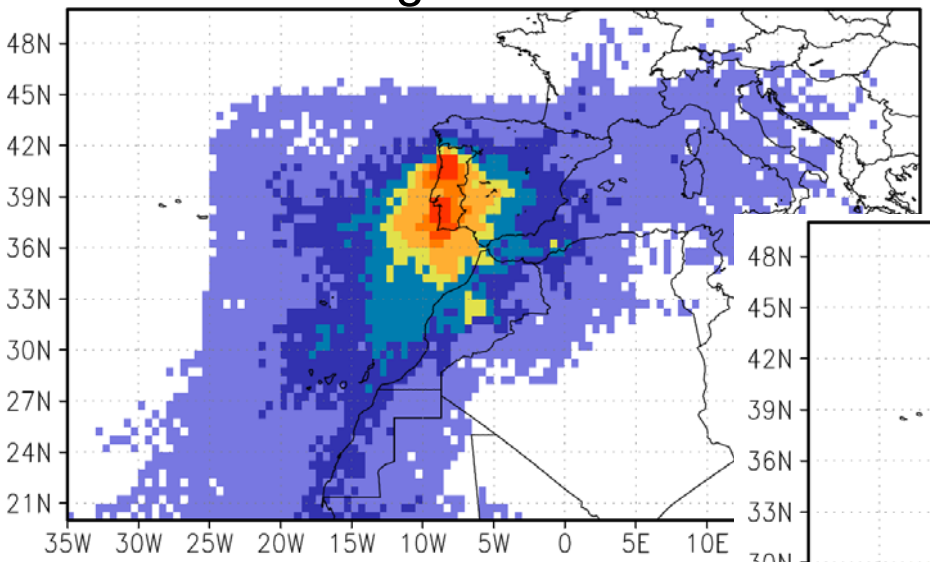
Europe regional demographics of 200 aggregated regions of Europe.

→ Iberian Pensinsula relatively sparsely populated (except for Lisboa, Porto)

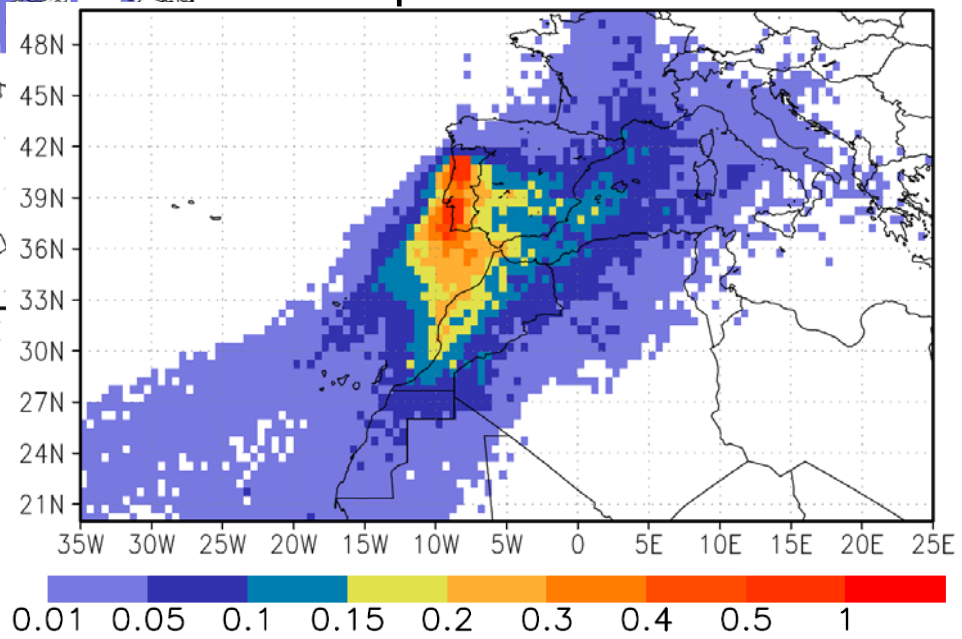
Portuguese wildfires / biogenic emissions

Transport of emissions from Lisboa and Porto:
Trajectory density (Traj.x)

August 2005

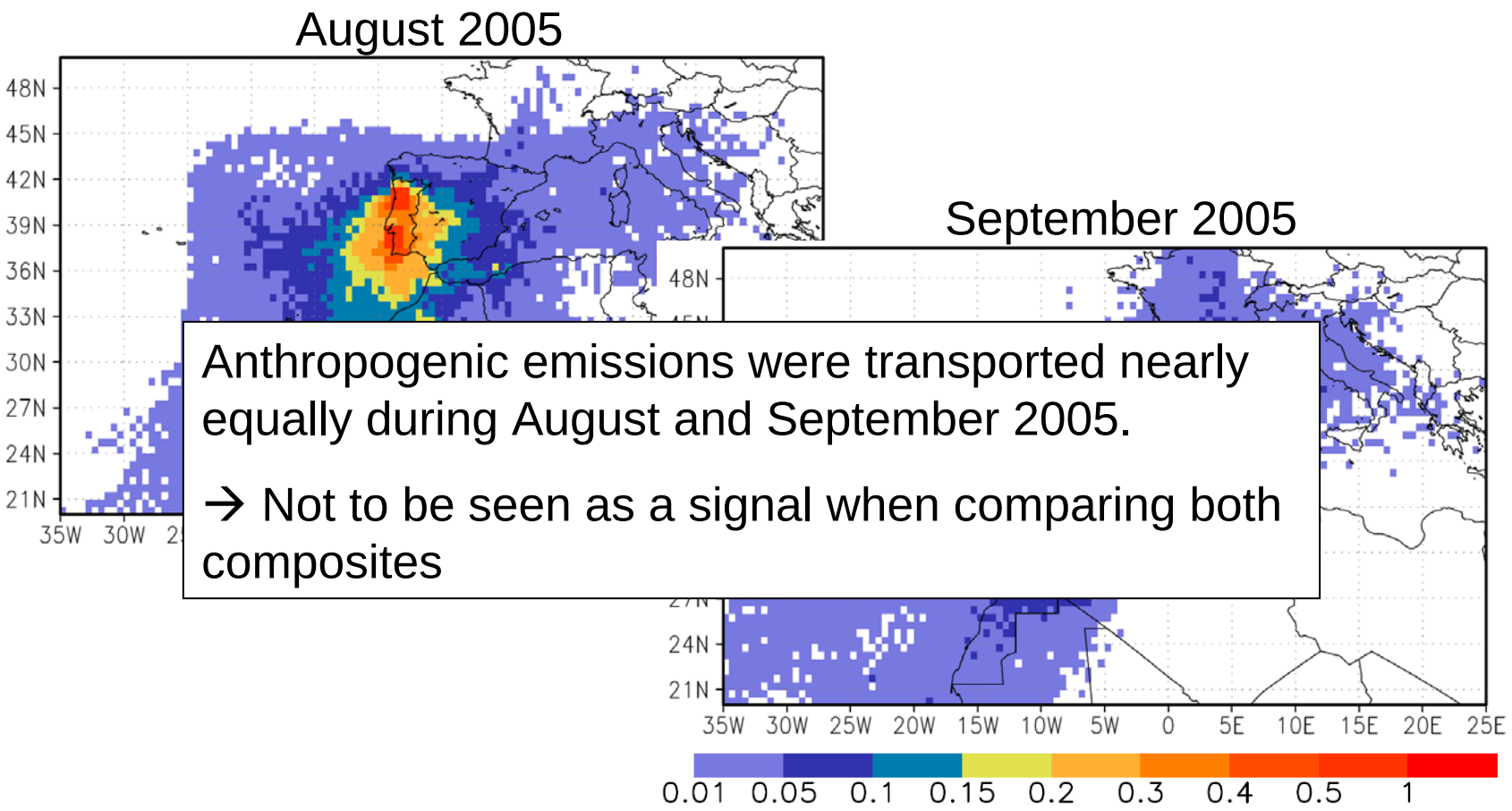


September 2005



Portuguese wildfires / biogenic emissions

Transport of emissions from Lisboa and Porto:
Trajectory density (Traj.x)



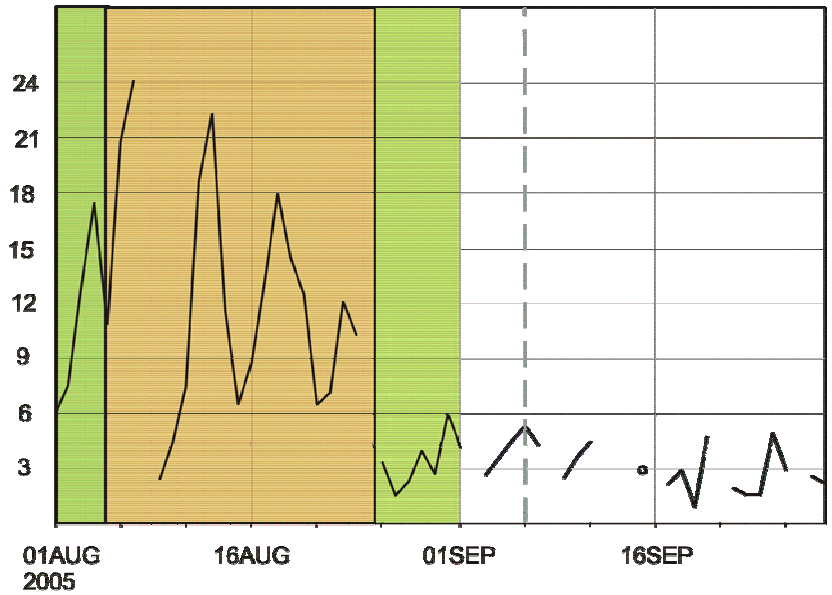
Anthropogenic emissions were transported nearly equally during August and September 2005.

→ Not to be seen as a signal when comparing both composites

Portuguese wildfires / biogenic emissions

Absorption by aerosols?

Number of AVHRR hotspots



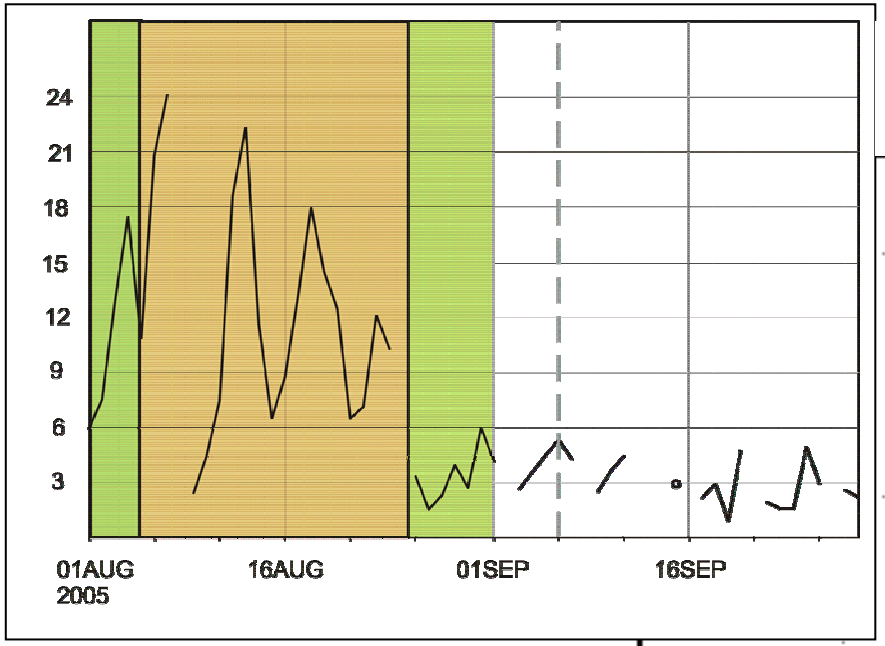
[5.-24.8.] --

[1-4.8.+25-31.8.]

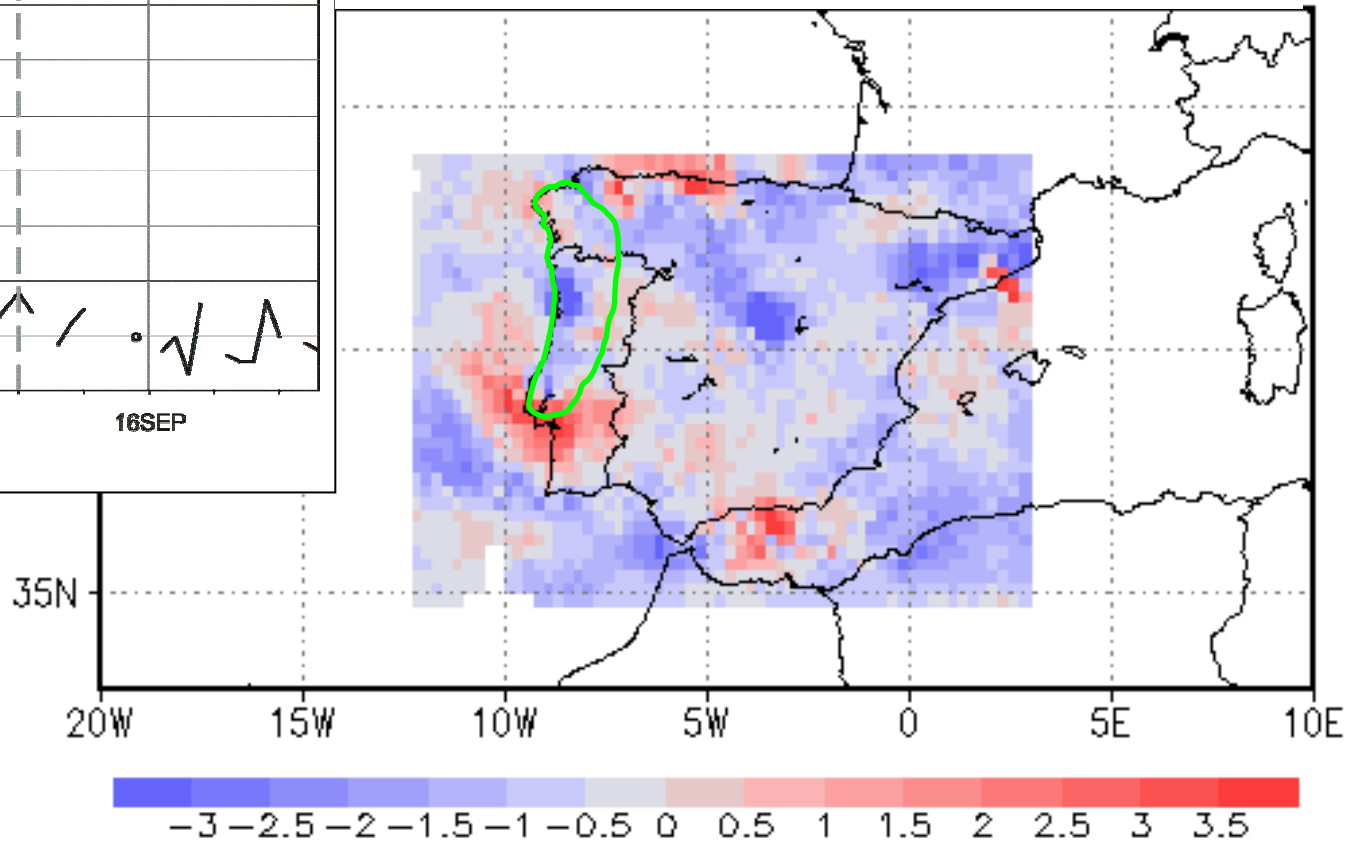
Portuguese wildfires / biogenic emissions

Absorption by aerosols?

Number of AVHRR hotspots



Tropospheric NO_2 VCD anomaly
[10^{15} molec cm^2]



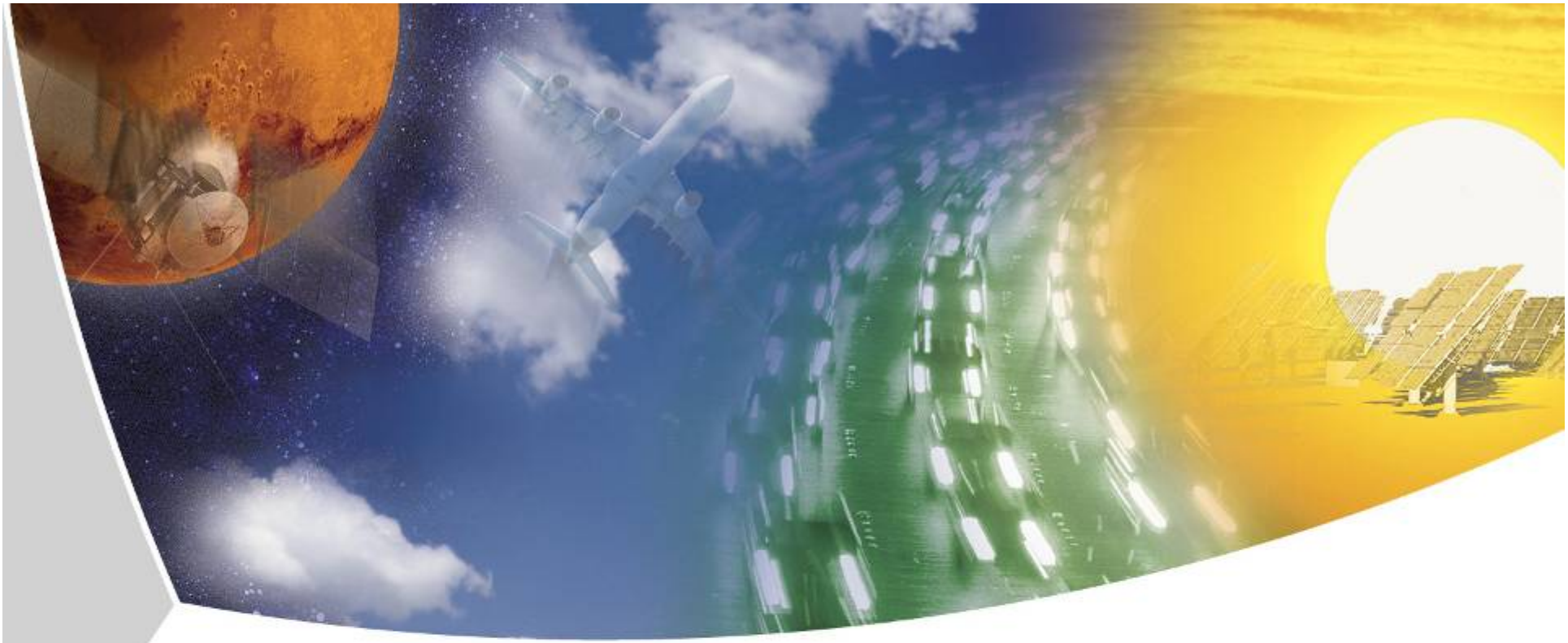
[5.-24.8.] --

[1-4.8.+25-31.8.]

Conclusions

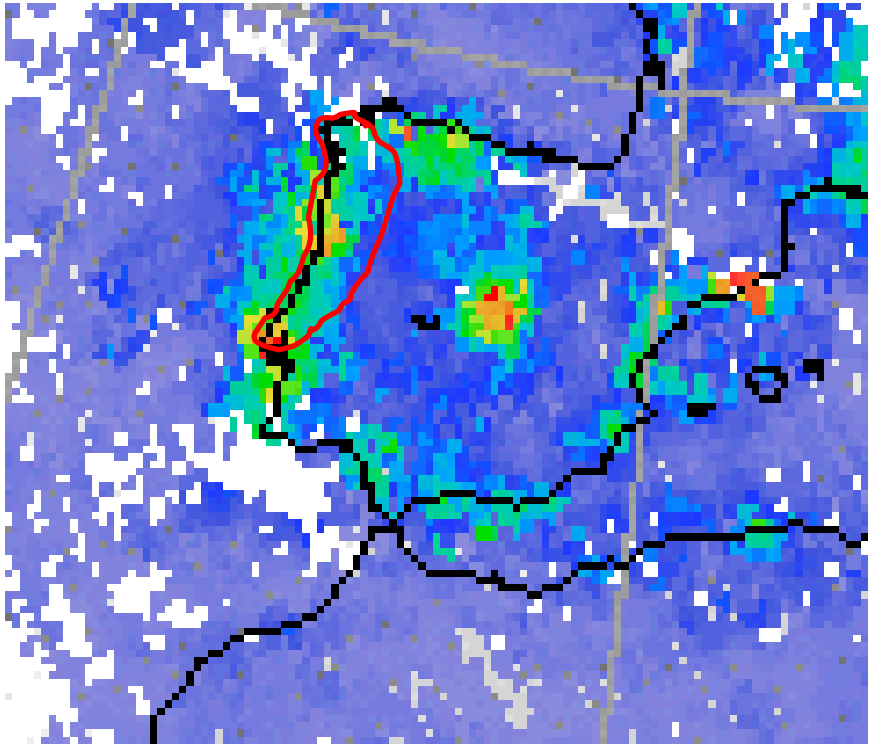
- **Case study Portuguese wildfires / biogenic emission**
  - Measurement statistics:
    Small number of successful measurements
    (especially in the area of interest)
  - Measurements likely to be influenced by aerosol absorption
  - Signal from biomass burning / biogenic emission cannot be clearly determined

- **Composites of tropospheric NO_2 (Summer, Winter)**
  - Qualitatively: Good agreement with expected results
  - Quantitatively:
    Reasonable results (when compared to IUP-Bremen or EURAD/RIU troposph. NO_2 VCD)
  - Seasonal cycle of tropospheric NO_2:
    Compliant to EURAD/RIU model results



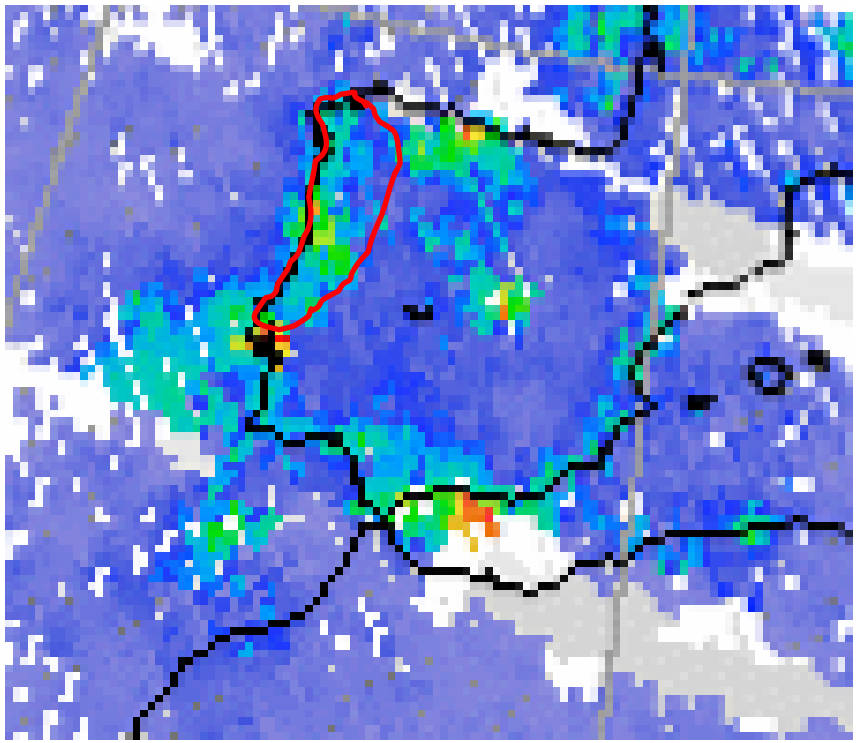
Thank you for your attention!

4.3. Waldbrände im August 2005

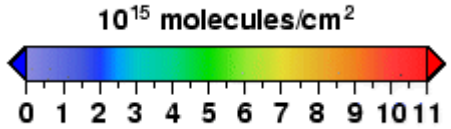


TNO2-VC: 1.8.-12.8.

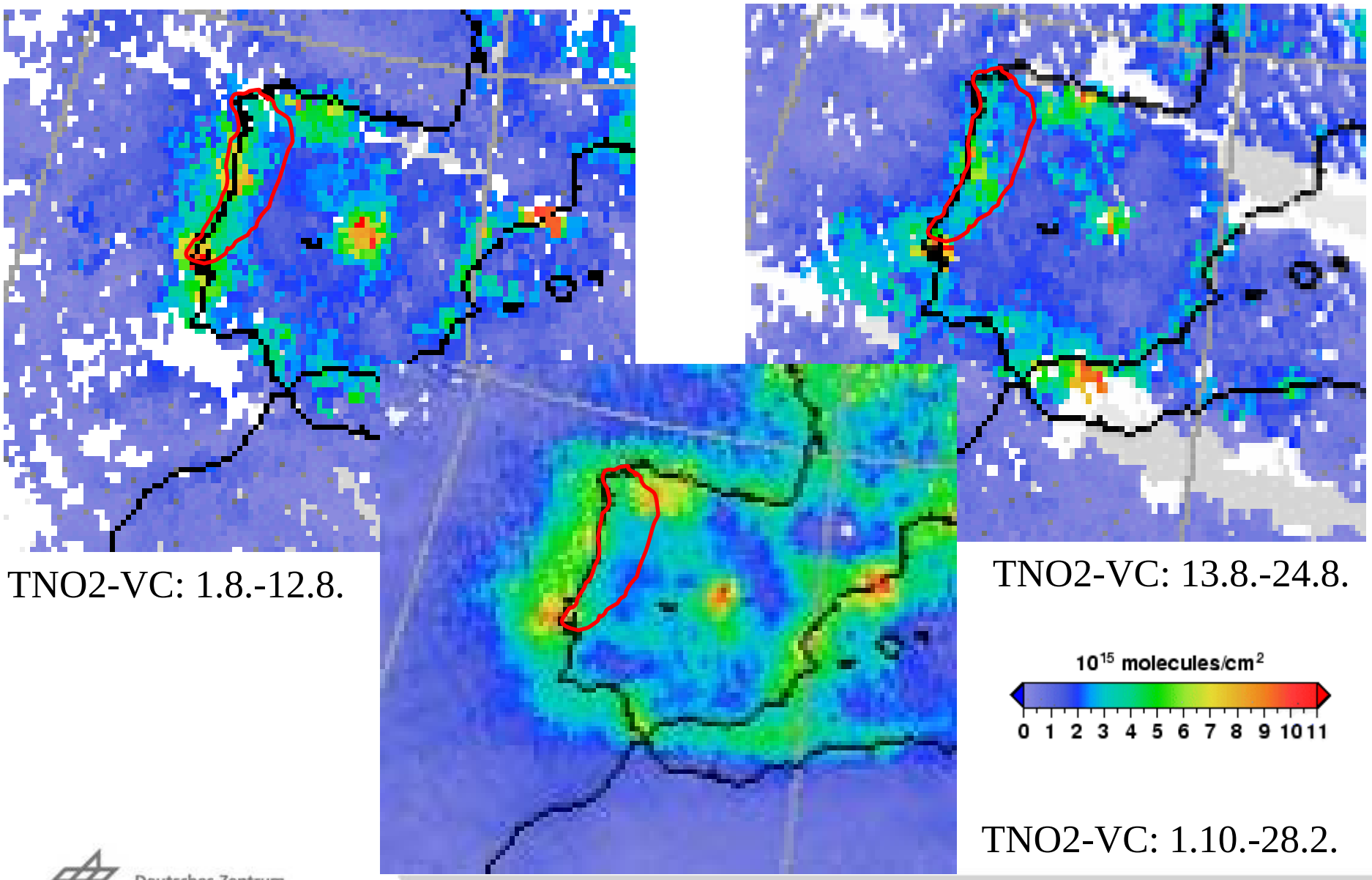
Quelle: Eigene Darstellung



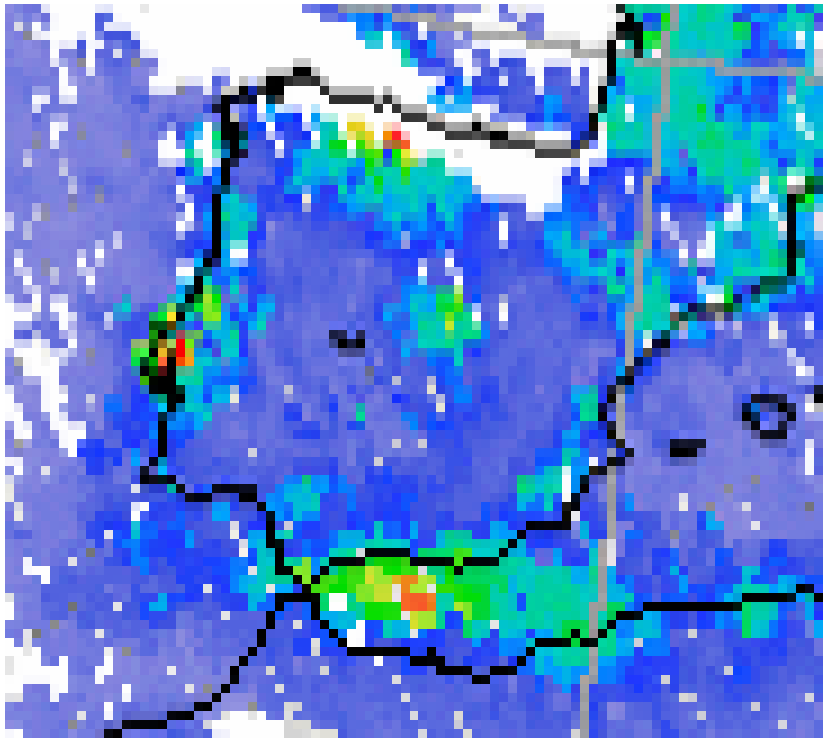
TNO2-VC: 13.8.-24.8.

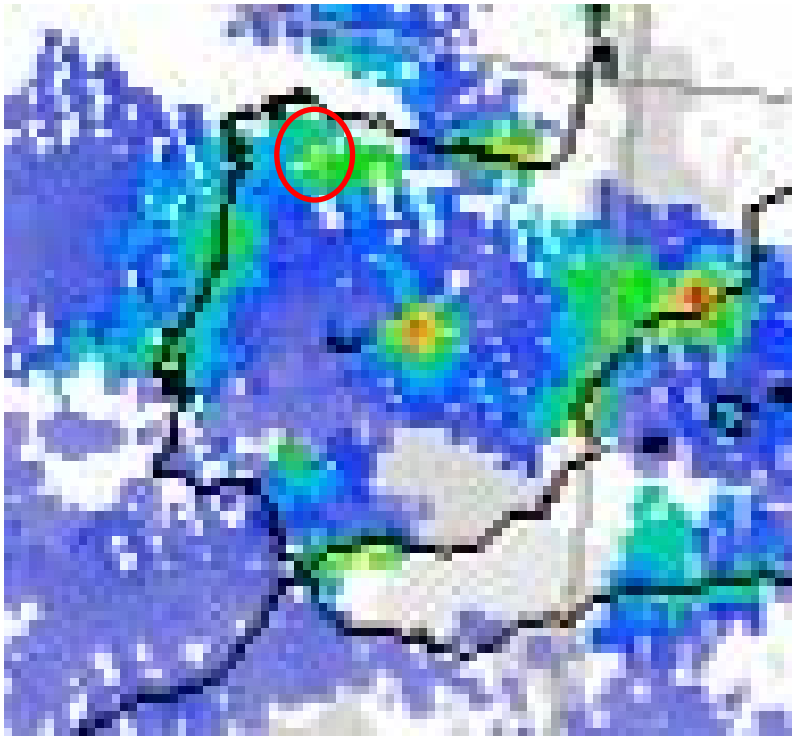


4.3. Waldbrände im August 2005



4.4. Biogene Emissionen im September 2005





Quelle: Eigene Darstellung

TNO2-VC: 1.9.-5.9.

TNO2-VC: 5.9.-15.9.