Atmospheric Pollution Measurements from Space: The GeoSCIA (Geostationary Scanning Imaging Absorption spectroMeter for Atmospheric ChartographY) and GeoTROPE (Geostationary Tropospheric Explorer)

J.P. Burrows, H. Bovensmann, S. Noel
Institute of Environmental Physics and Remote Sensing, University of Bremen, Germany
P. Monks, *University of Leicester, UK*
J.-M. Flaud and J. Orphal, G. Bergametti, *LISA, Créteil, France*
A. Goede, *KNMI, The Netherlands*
B. Buchmann, *EMPA, Switzerland*
K. Tørseth *EMEP/NILU, Norway*

Tropospheric Composition, Dynamics and Air Quality from Space

The final frontier for the Remote Sensing Community (Holy Grail?)

In the 25 years – demonstrated potential

From LEO and some Aerosol products from GEO

Evolving Instrument Technologies and User Needs!

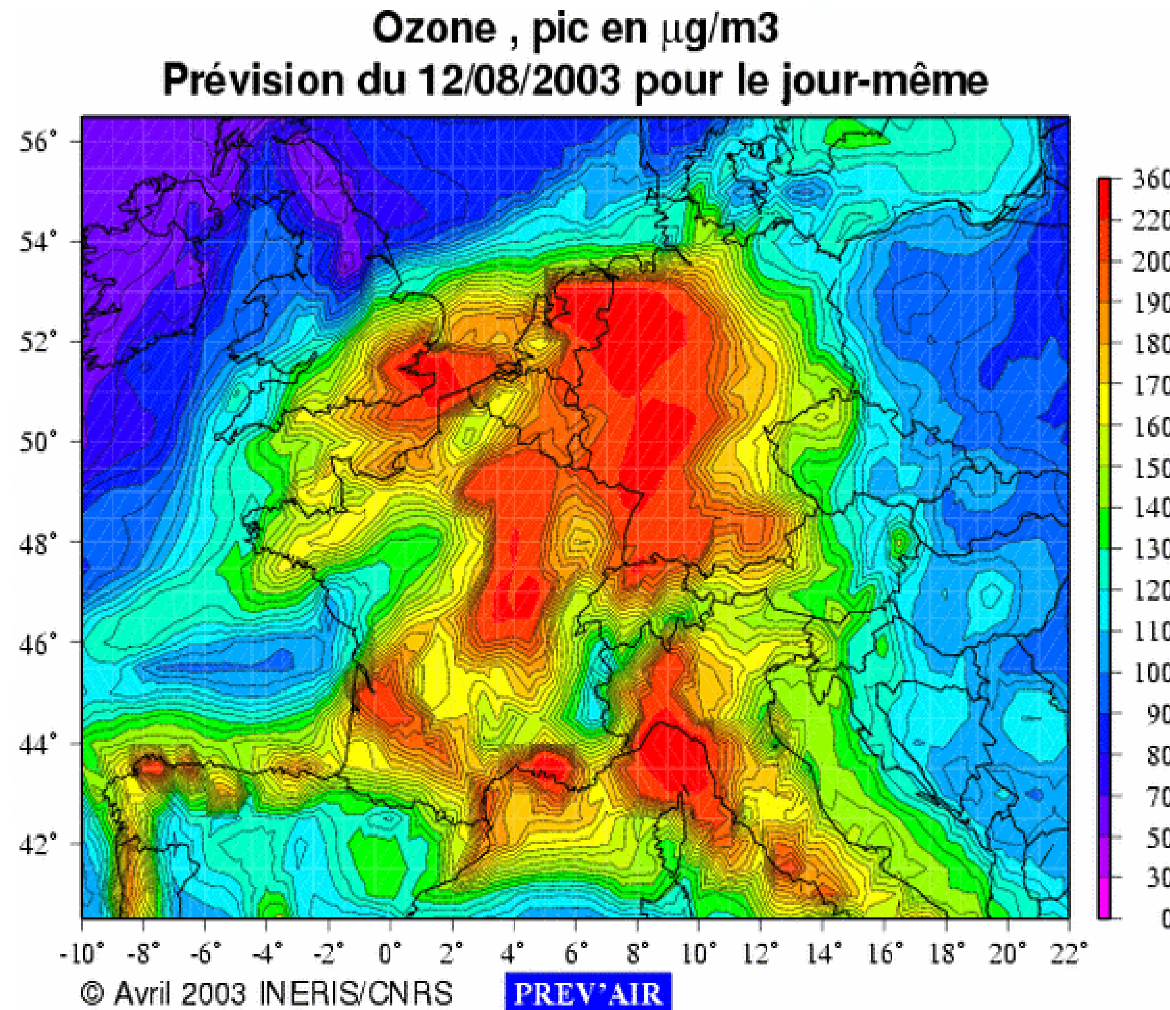
The Troposphere and PBL is complex and sits under the stratosphere and mesosphere!

Recognition of the need for Synergetic Use of Platforms/Instrument/Retrieval Techniques

• 2003 summer *heatwave*

- *In the UK, 2000 excess deaths during heatwave*
- *700 may have been attributable to high levels of ozone and PM10*
- *20-40% of all U.K. deaths*
- *Over Europe estimates are between 22,000-44,000 excess deaths*
- *Exceedance of the 180 mg/m^3 level*
- *Ozone Information threshold April to August 2003 © EEA 2003*

UK Ozone Bubble - 2pm 6th August 2003

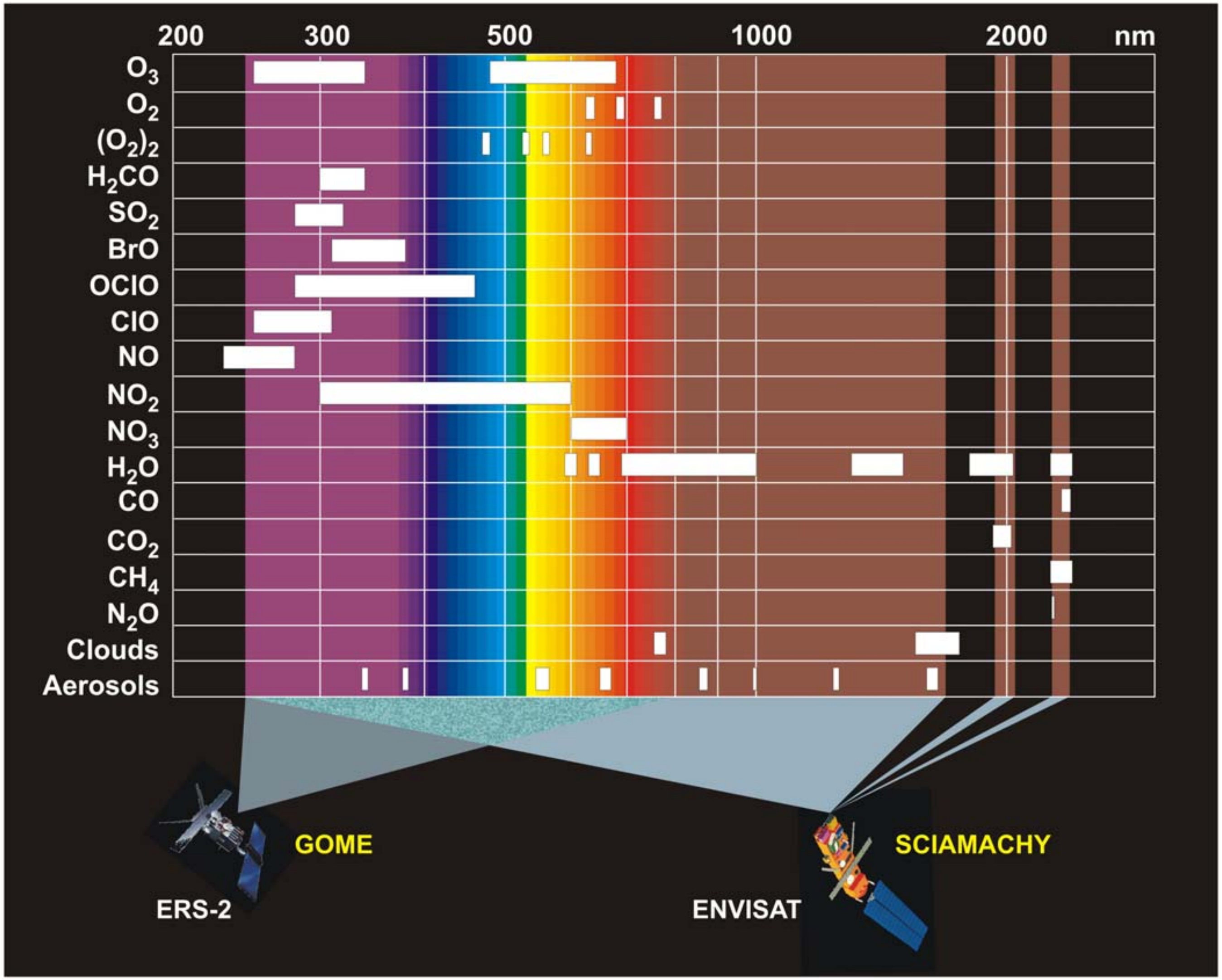


Compiled from UK ozone network data

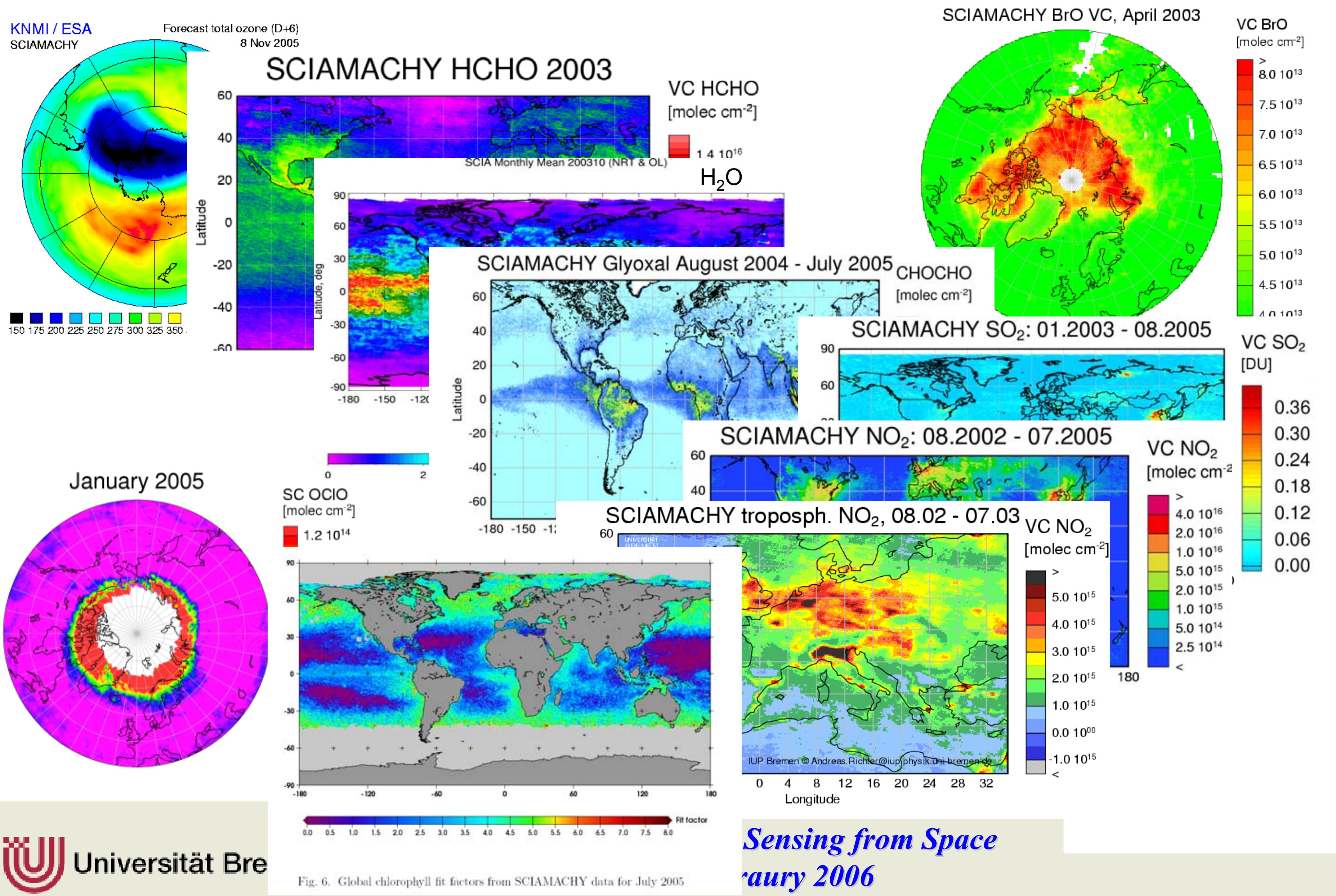
SCIAMACHY - GOME - GeoTROPE

03-1985	MAP (Measurement of Atmospheric Pollution) proposal idea to ESA for EURECA *not selected*
05-1985	Stratospheric Ozone hole observed by Farman et al (Nature).
1985 – 1988	Submission of the *SCIAMACHY proposal,* supported by Germany to ESA for the Polar Platform, now ENVISAT.
1988	Proposal of SCIA-mini for ERS-2
1989	Descope of *SCIA-mini to GOME (Global Ozone Monitoring Experiment)*
1989 – 2002	*Selection, Design and Development of SCIAMACHY as German/Dutch/Belgian contribution to ENVISAT*
20.04.1995	Launch of ERS-2 with GOME
1997-1998	Development of GeoSCIA Cncept
12.1998	Proposal of GeoSCIA to ESA – recommended for further study
1997-2000	Selection of GOME-2 for the EUMETSAT operational series Metop.
2000	GeoSCIA++ Idea for ESA Earth Explorer
2000-2001	Development of GeoFIS
01.2002	Proposal of *GeoTROPE(GeoSCIA+GeoFIS) Geostationary TROPospheric Explorer* to ESA for EEOM-2 recommended for further study -
28.02.2002	Launch of ENVISAT with SCIAMACHY on board.
12.2003	Proposal GeoSCIA-Lite – small sat for national EO programme Germany
15.08.2005	Proposal GeoTROPE-R for the ESA Earth Explorer

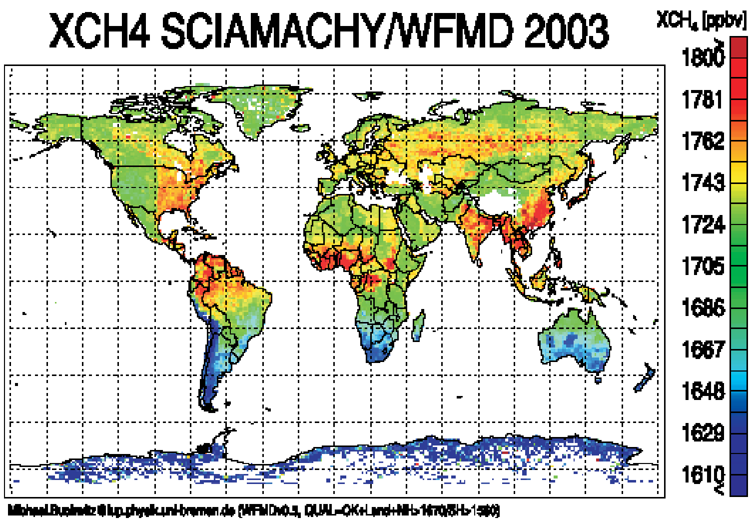
GOME SCIAMACHY Targets and Spectral Coverage

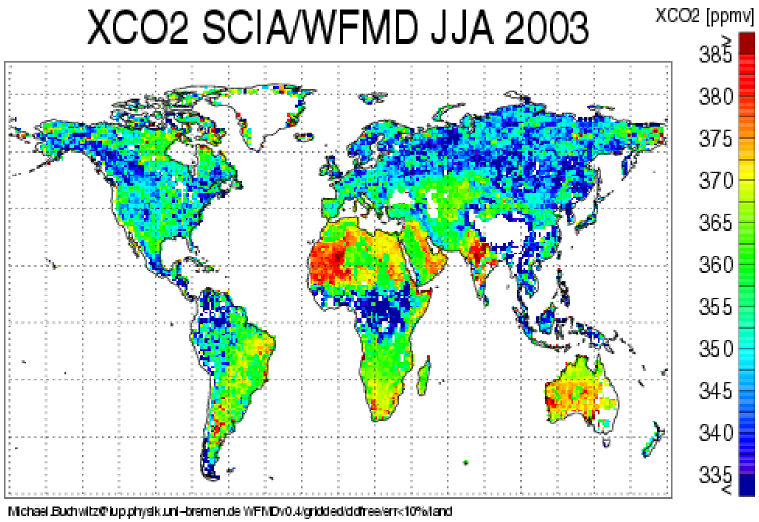


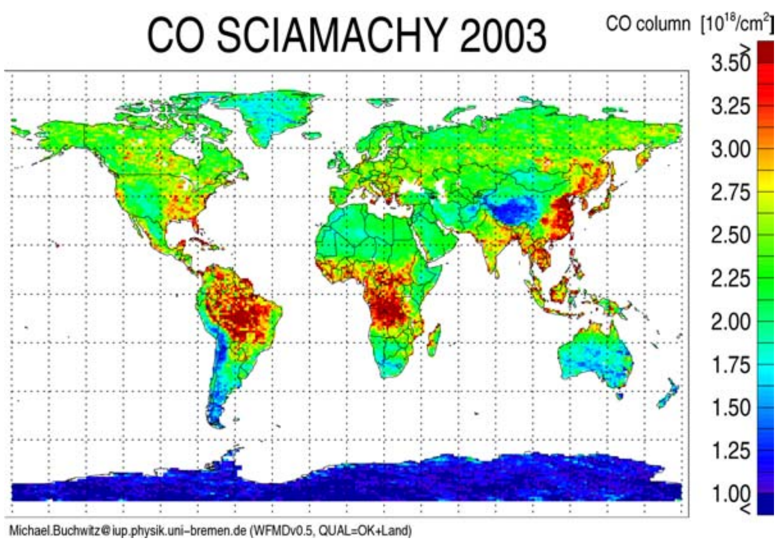
SCIAMACHY - Nadir - UV/Vis/NIR DOAS Data Products



SCIAMACHY - Nadir - SWIR WFDOAS Data Products







SCIAMACHY SWIR WFDOAS ASIAN CO, CO2 and CH4 in 2003

Four data products: Vertical columns of CH_4, CO, CO_2, and O_2 from SCIAMACHY nadir observations using appropriate spectral windows in the near-infrared

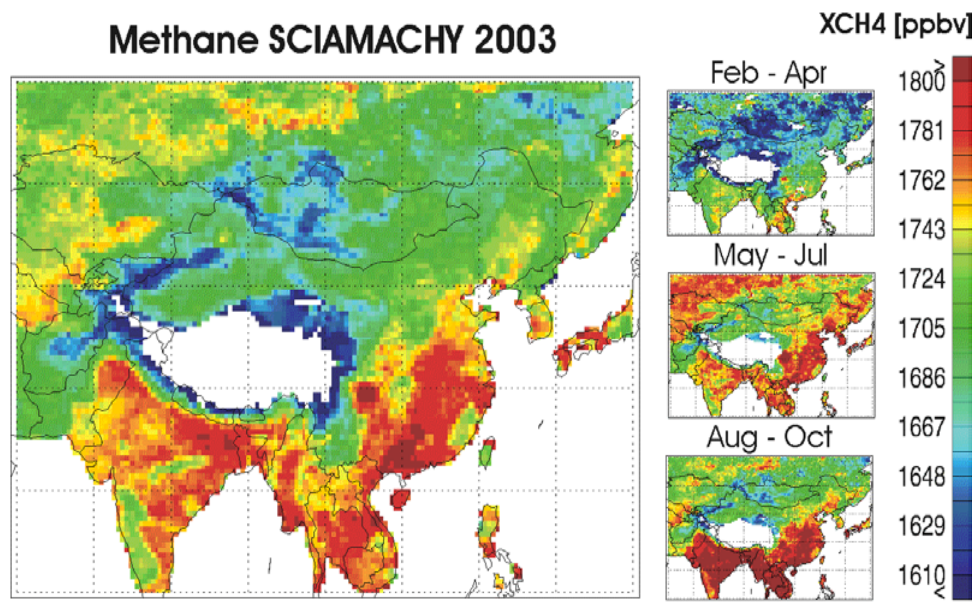
Data products:

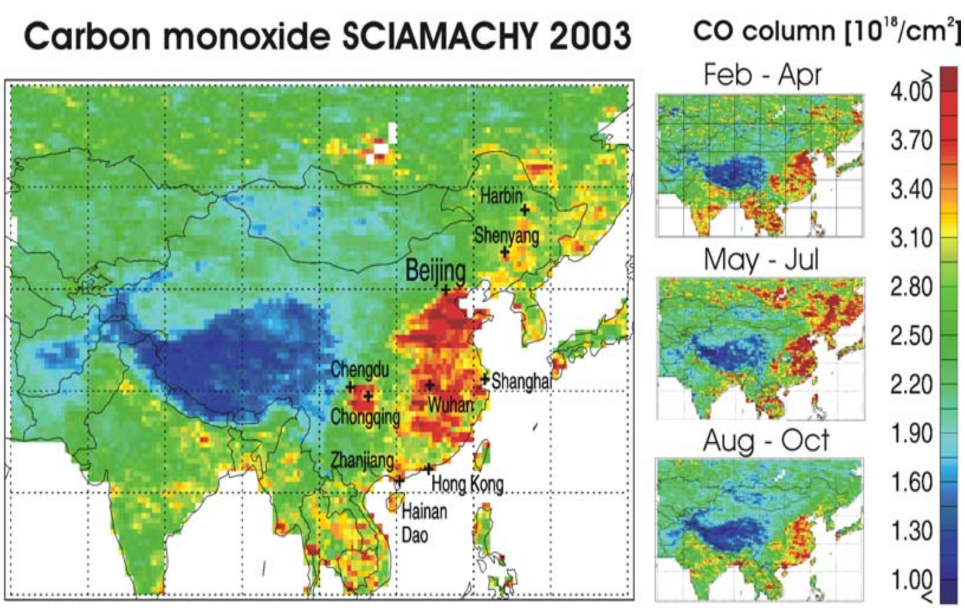
Methane VMR (XCH_4 = CH_4-column/aircolumn)

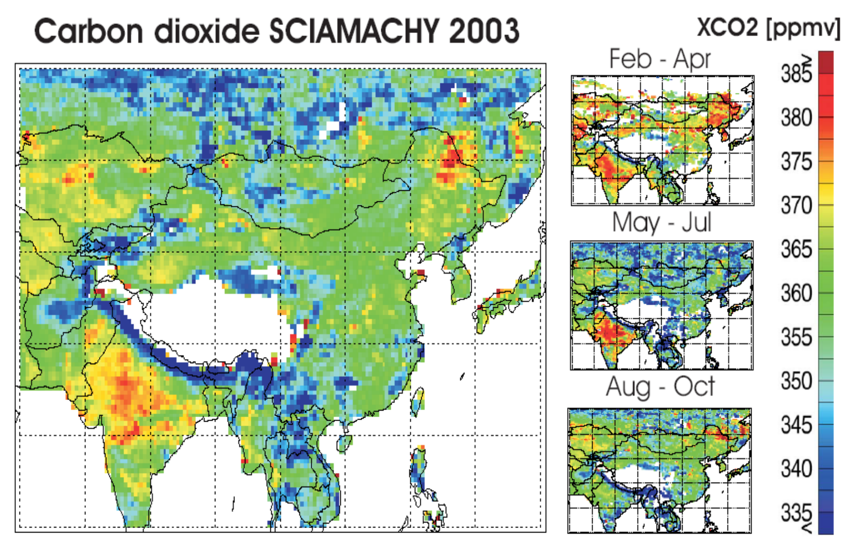
Carbon monoxide column (molecules/cm^2)

Carbon dioxide VMR (XCO_2 = CO_2-column/aircolumn)

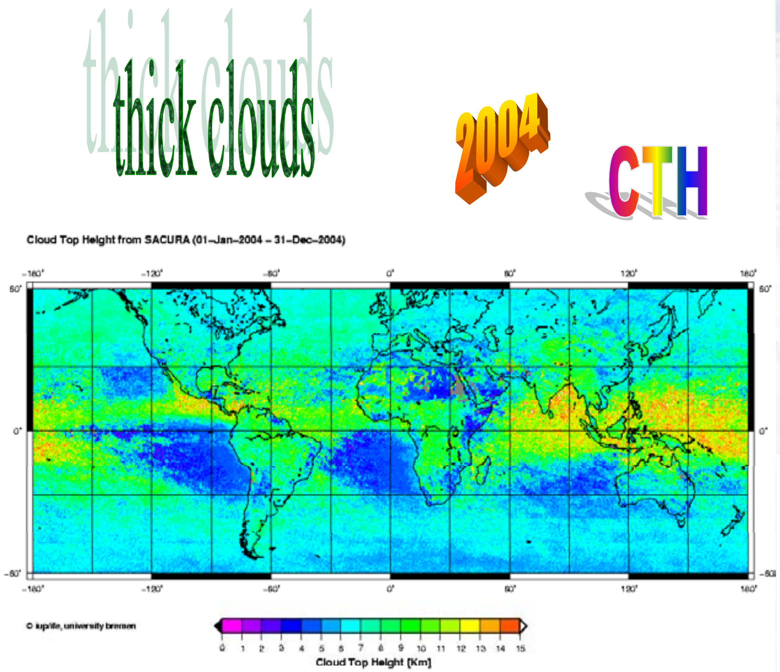
Details latest versions: de Beek et al., ACPD, 2006







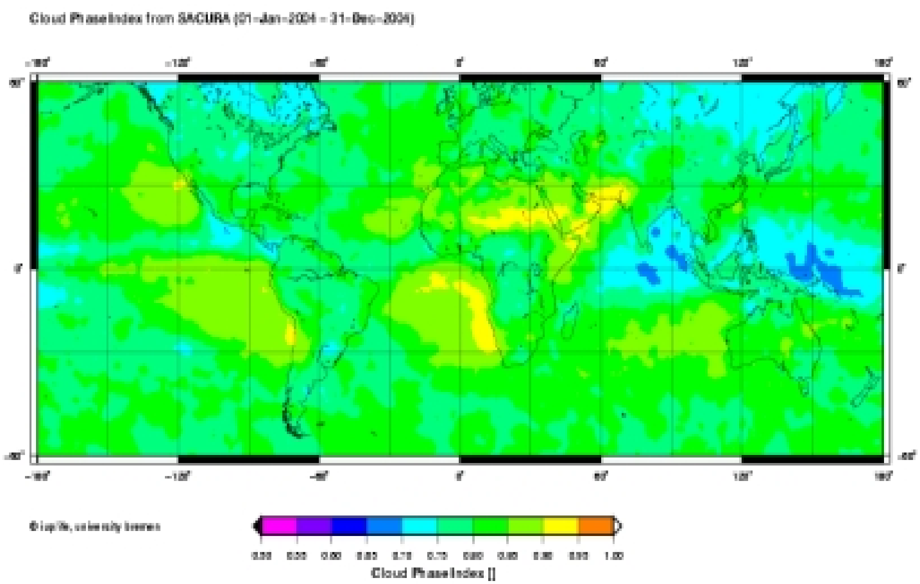
SCIAMACHY Some Cloud Products in 2004



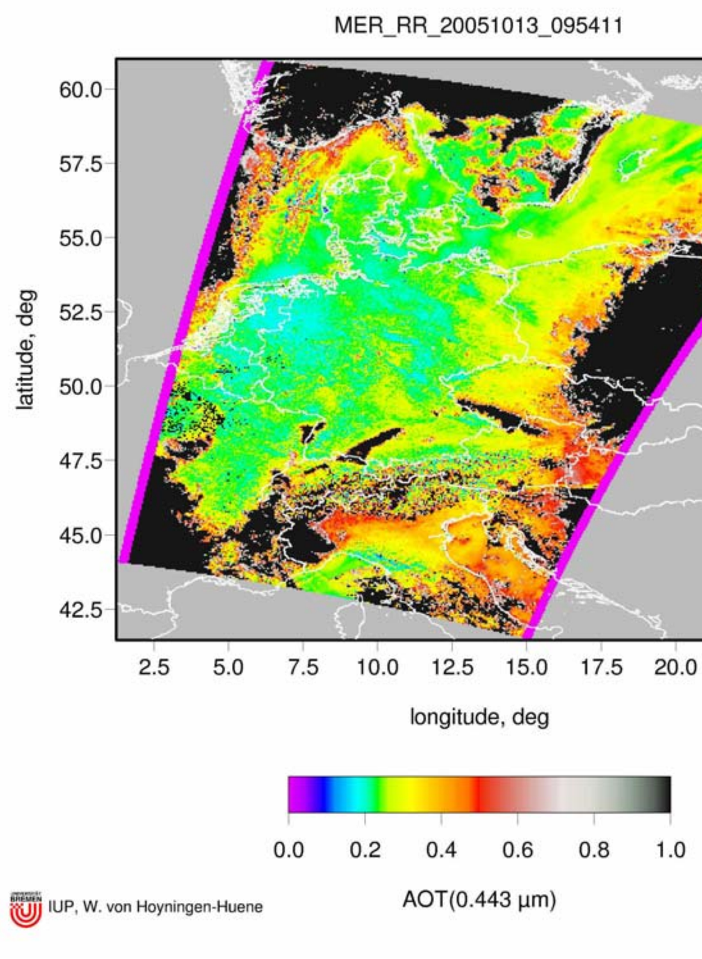
Using O2 Absorption from SCIAMACHY nadir observations using appropriate spectral windows in the near-infrared

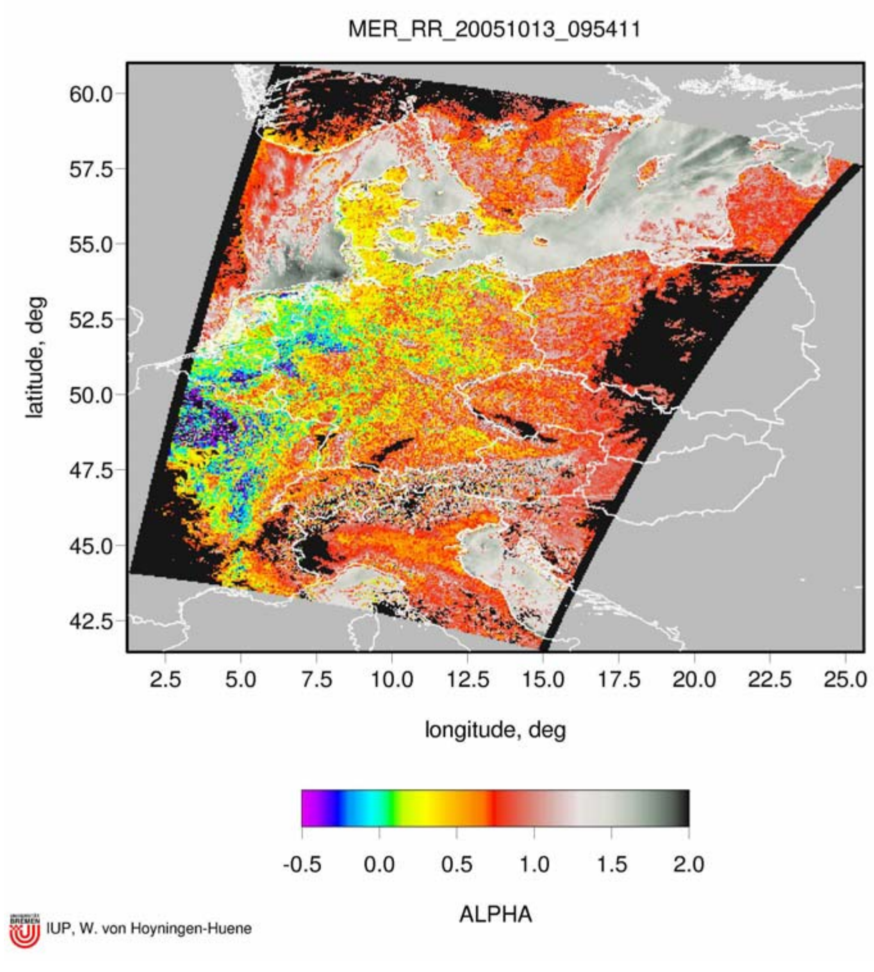
Cloud Products - SACURA

- Cloud Top Height
- Cloud optical

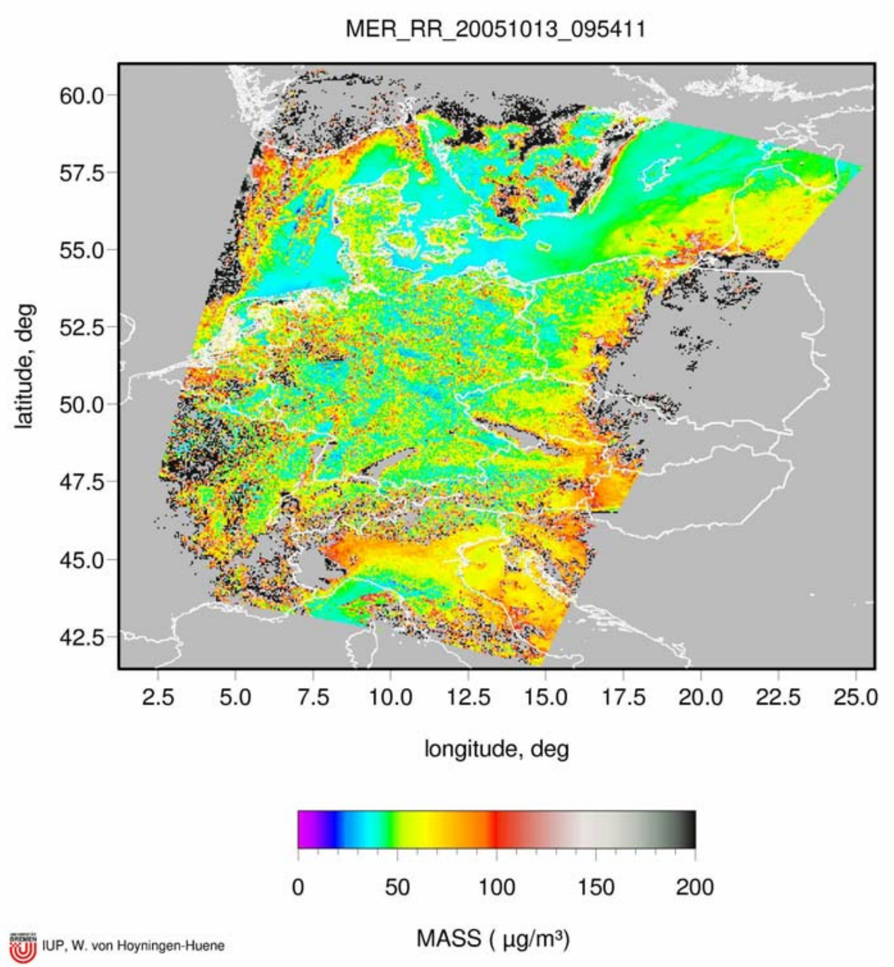


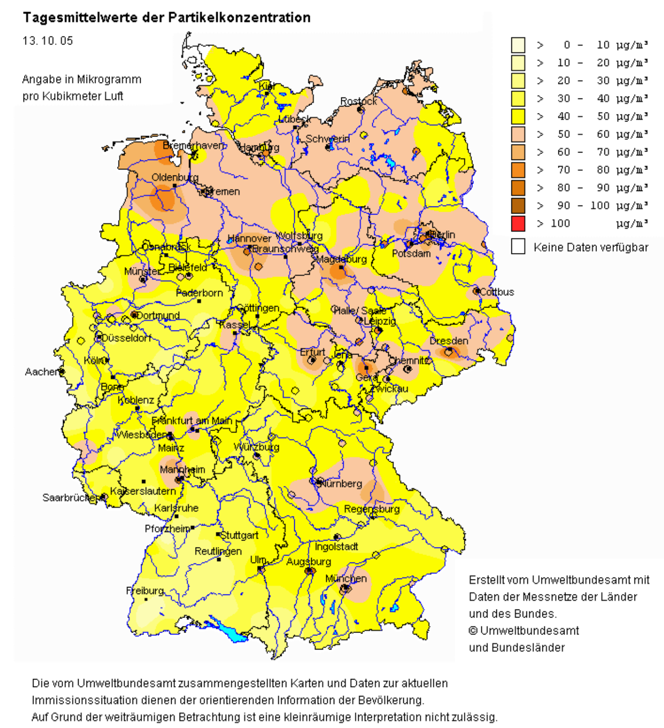
Synergy on ENVISAT MERIS : Simultaneous Data about Aerosols AOT + ALPHA



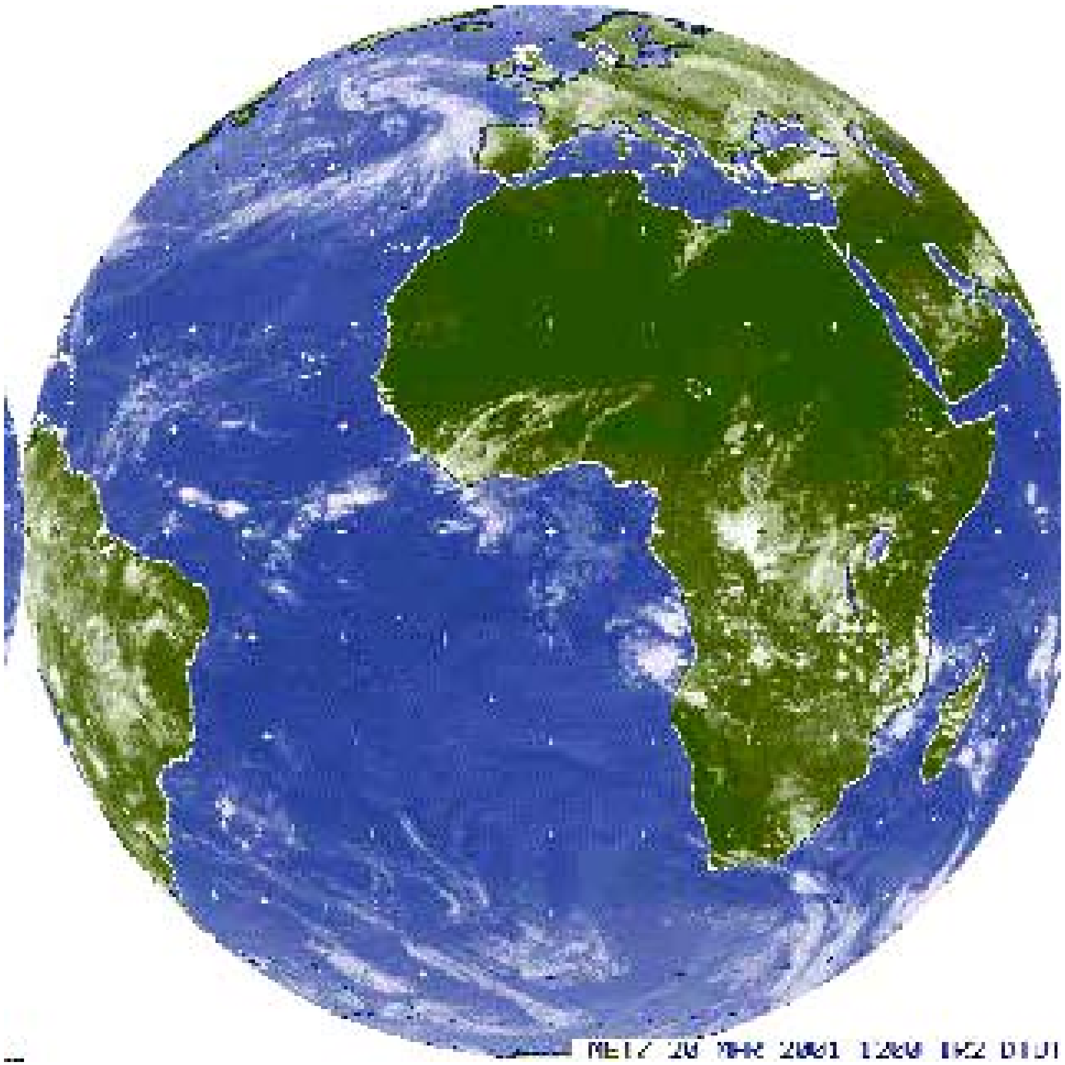


UB - Derived Research Product Particulate Matter

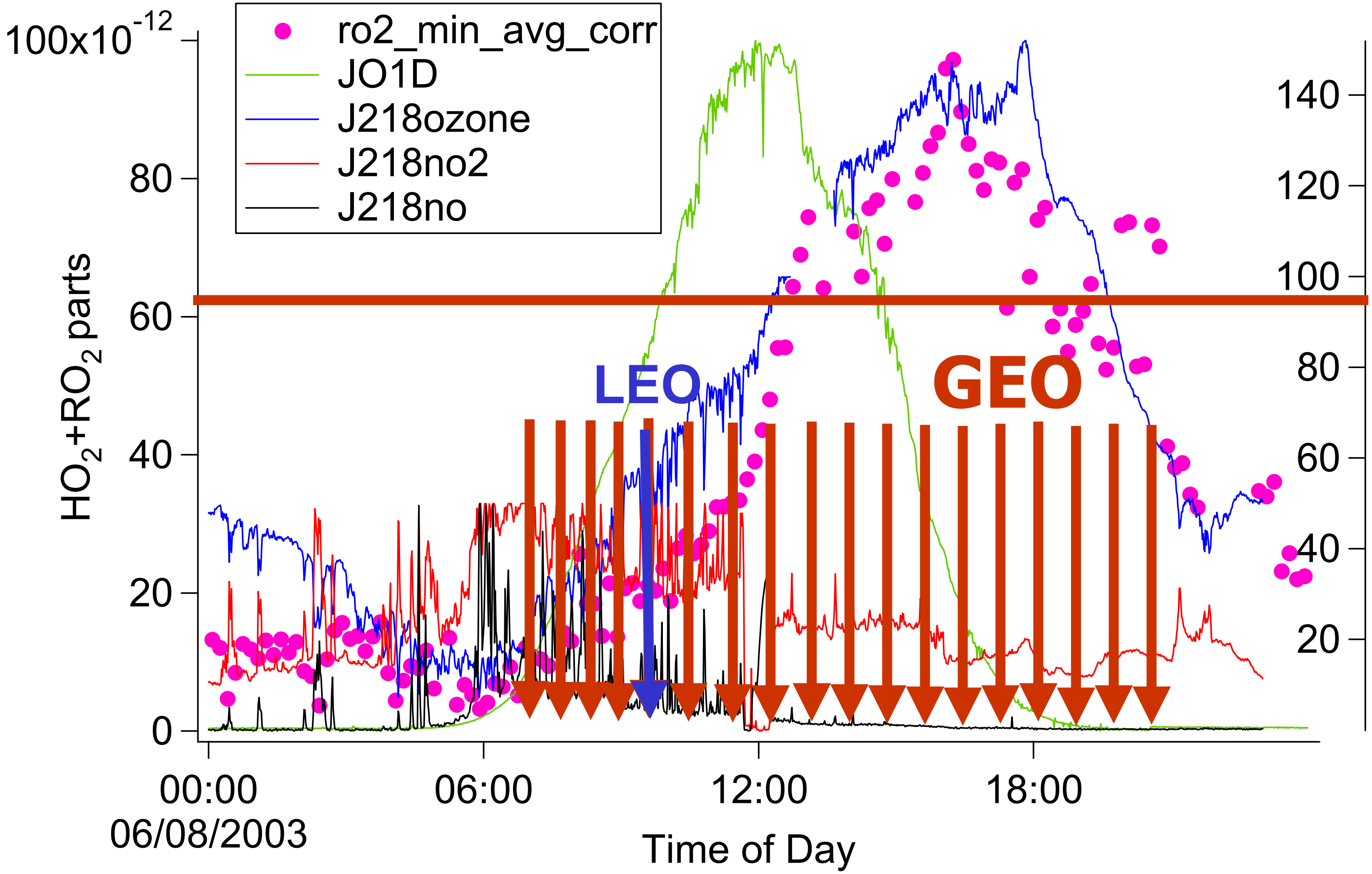




Geostationary Observations

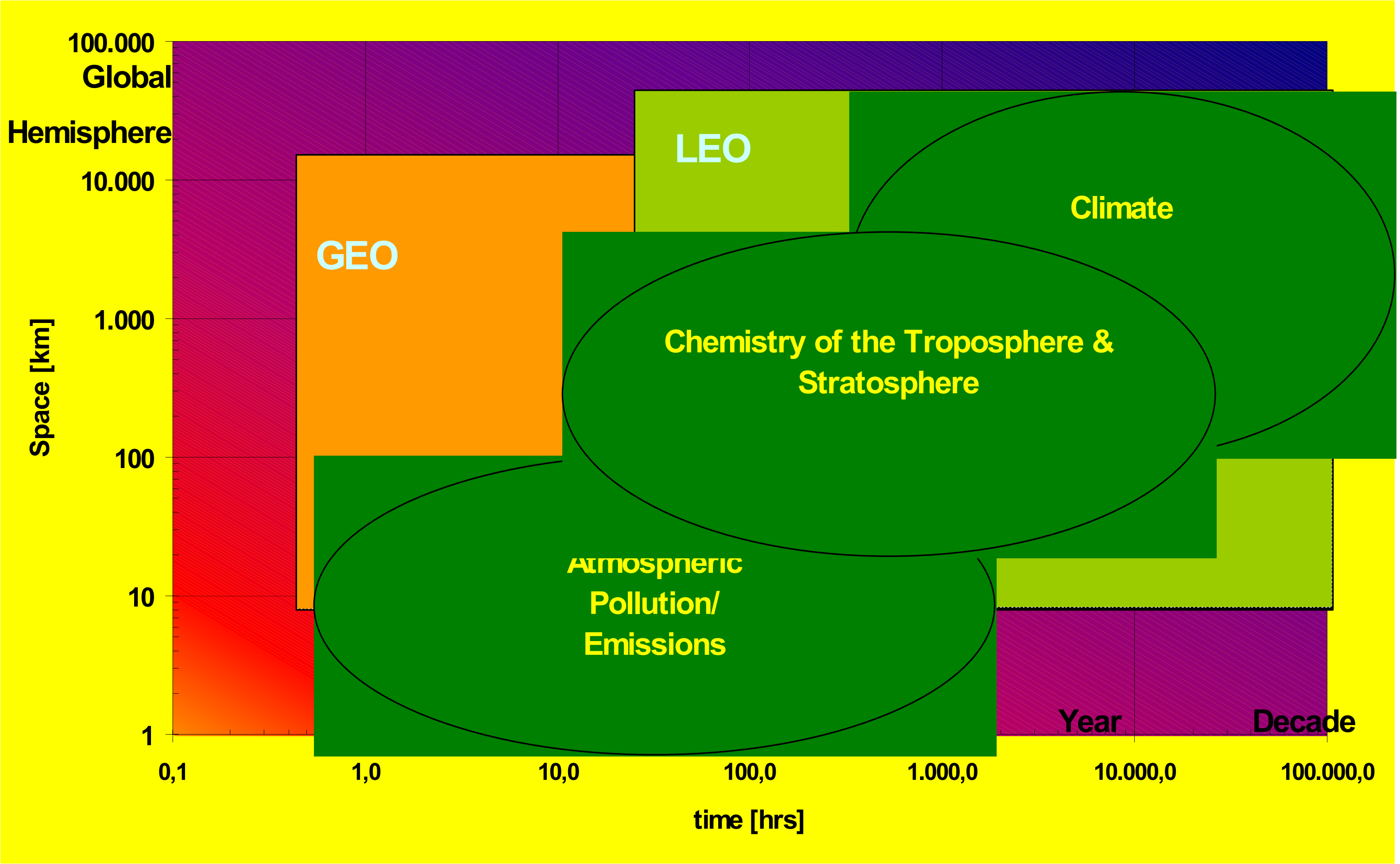


- Meteosat
- 0° Longitude
- 20.-23.3.01



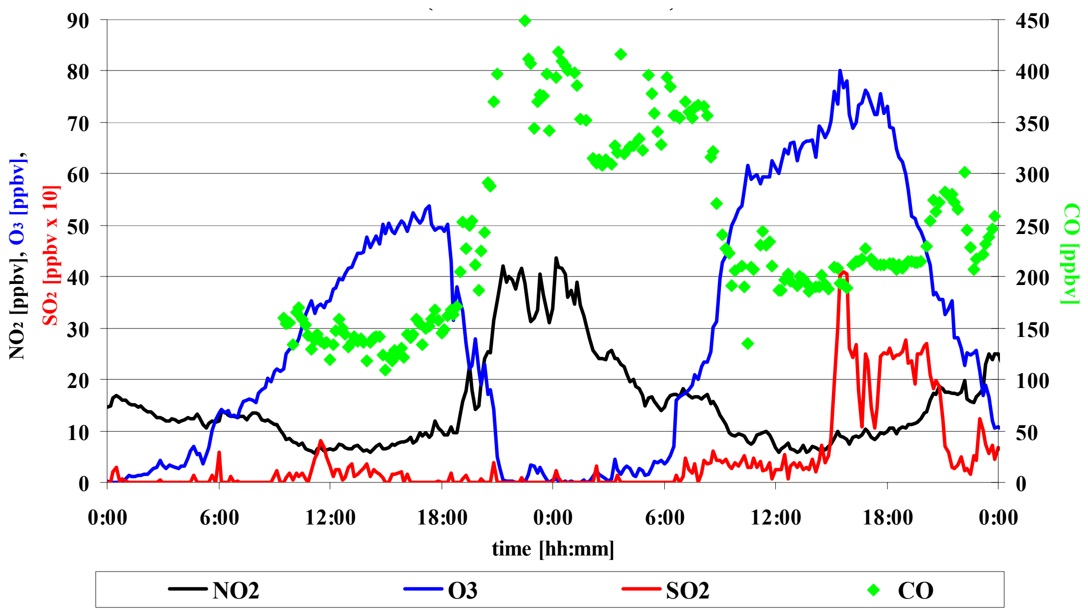
- UK AQ HIGH BAND FOR OZONE

LEO & GEO



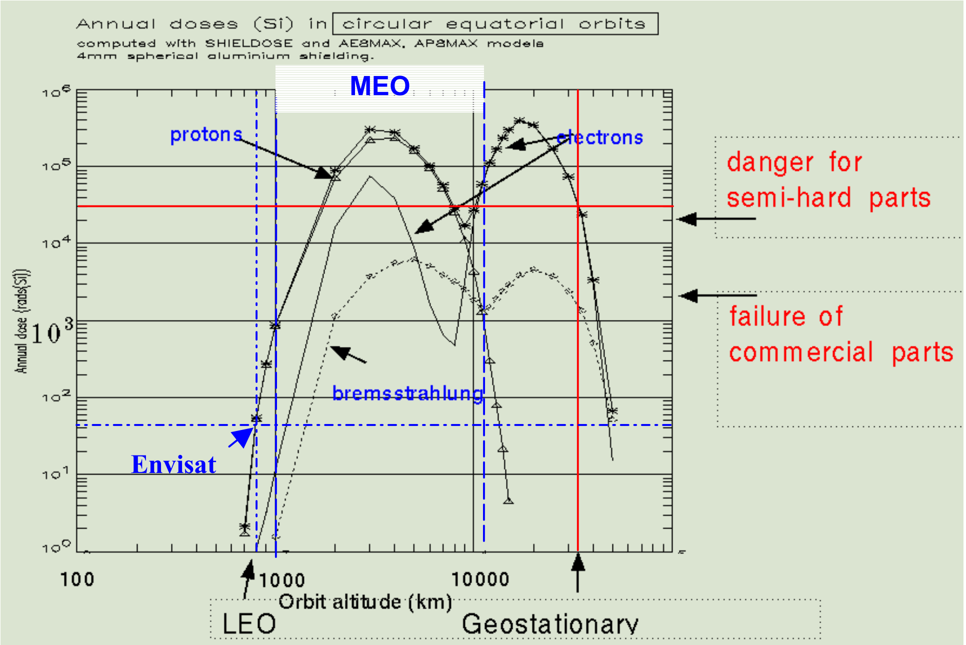
100.000
Global
Hemisphere
10.000
1.000
100
10
1
Space [km]
LEO
GEO
Climate
Chemistry of the Troposphere & Stratosphere
Atmospheric Pollution/ Emissions
Year
Decade
0,1
1,0
10,0
100,0
1.000,0
10.000,0
100.000,0
time [hrs]

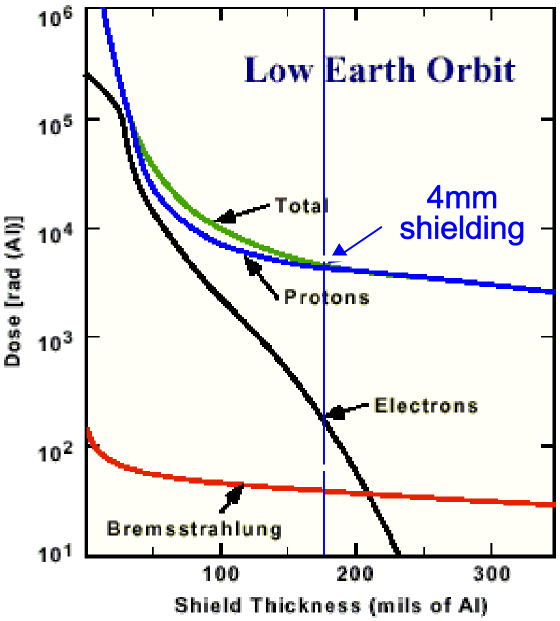
Diurnal Variability of Trace Gases and Constituents



- The Troposphere from is currently significantly undersampled in space and time by existing and planned LEO (Low Earth Orbit) Missions
- The spatial and temporal sampling of LEO data is indadequate for Air Quality and tropospheric chemical temporal applications.
- GEO offers the required temporal sampling and the spatial coverage.
- Combination of GEO and LEO yields the optimal global system – see IGACO proposal.

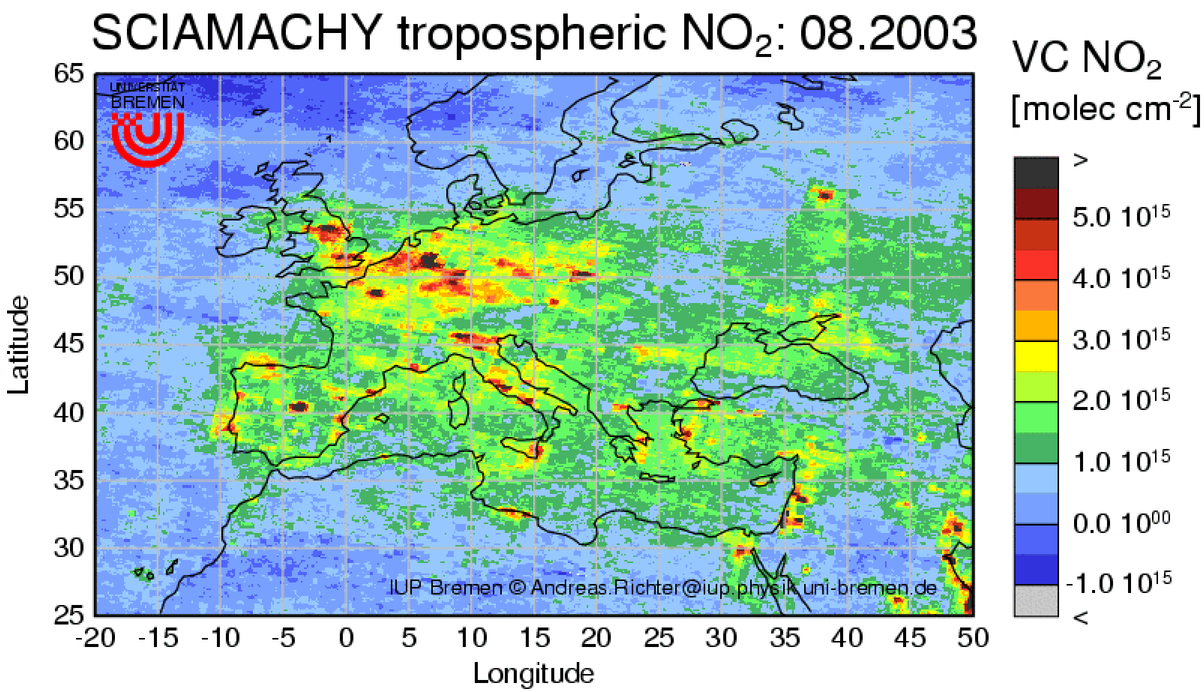
Mission Relevant Aspects: Radiation Environment

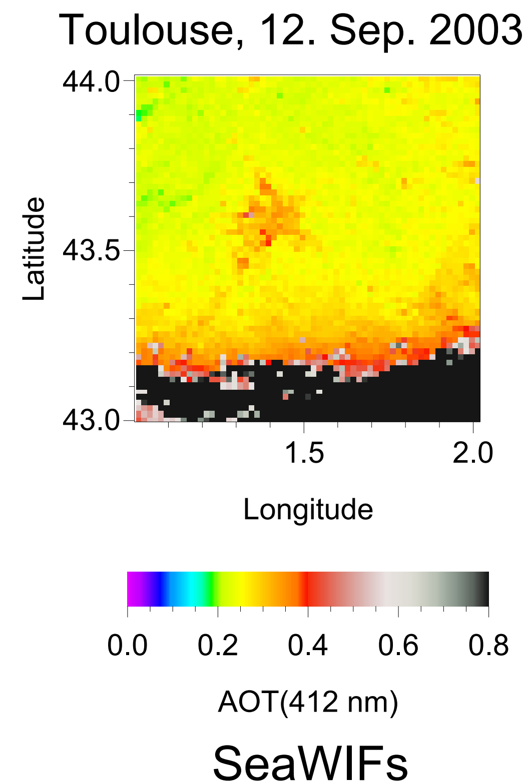




- Most Critical for long lifetime are the high energy photons
- MEO critical w.r.t. high proton radiation dose – electronic problems.
- GEO is a very favourable orbit

Solar Backscatter Sounding from Geostationary Orbit





European Air Quality Management and Forecast: Concept

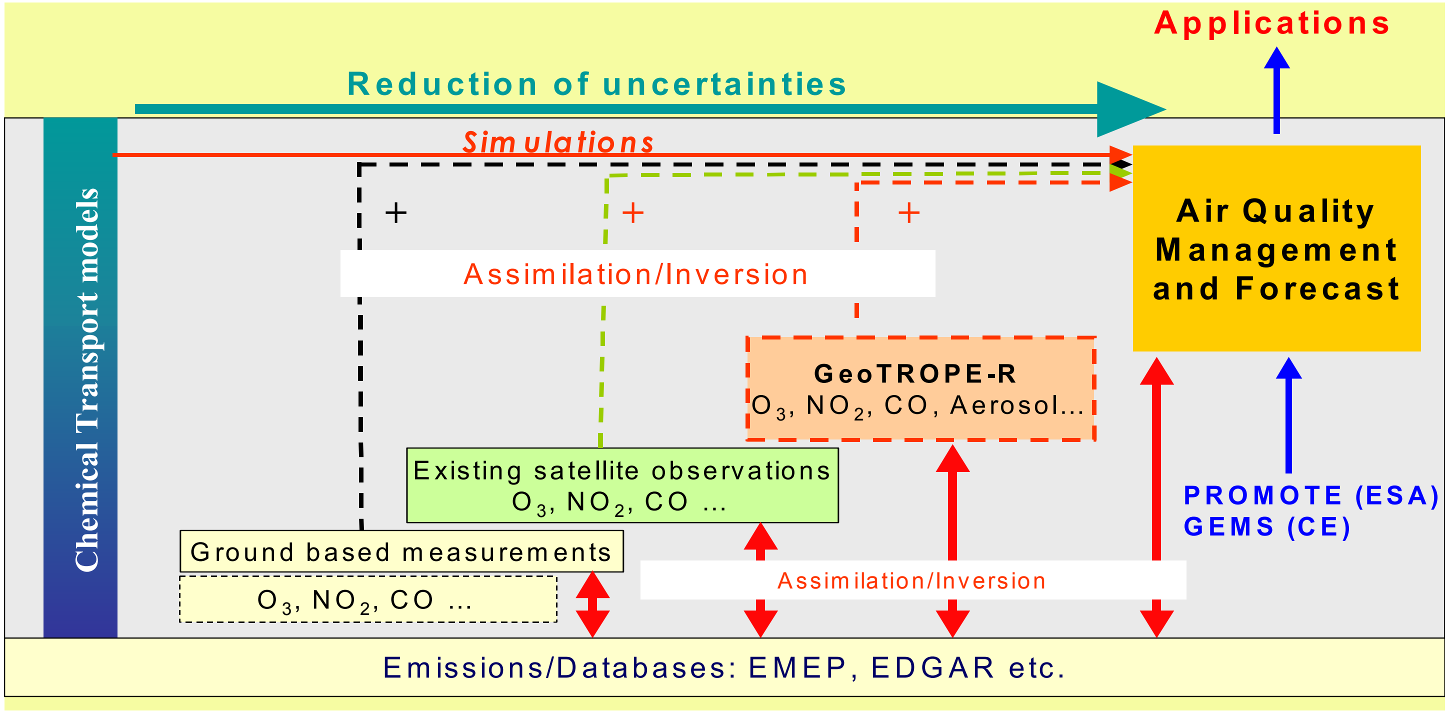


Figure: G. Bergametti, modified by H. Bovensmann).

GeoTROPE-R is complementary to MetOp and MSG/MTG.
It meets the requirement for AQ by providing day-by-day, near real-time, hourly and contiguous city scale resolution data of aerosol and relevant trace gases over Europe.

Objectives

The primary scientific objective of the GeoTROPE-R is:

- **To improve our understanding, monitoring and forecasting of tropospheric composition and air quality through synoptic measurements of changing tropospheric composition**

The secondary scientific and user objectives of GeoTROPE-R are to enhance:

- Local and regional pollution emission inventories
- Measurements of trans-boundary transport of pollutants
- Quantification of air pollutant fluxes within Europe, imported into and exported from the European area
- Differentiation between anthropogenic and natural sources of pollutants
- Understanding of chemical transformation in convective systems
- UV radiation monitoring and forecasting

Relevant Requirement References

- **IGBP/IGOS-IGACO (Integrated Global Observation Strategy -Integrated Global Atmospheric Chemistry Observations) Theme Report (2004)**
- **GEOSS (Global Earth Observation System of Systems) Initiative, esp. User Requirement and Outreach Document (2004)**
- **GMES (Global Monitoring for Environment and Security) Strategy Report(s) (EC/ESA Initiative, 2004)**
- **EUMETSAT Observation Requirements Now Casting and Very Short Range Forecasting 2015-2025 (2003)**
- **WMO-GAW strategy for Integrating satellite and ground based (2001)**

Relevant User Groups

- **In comparison to 2002, the number of user groups has grown by the activities within the following projects and initiatives:**
  - ACCENT
  - PROMOTE
  - GEMS
  - TEMIS
  - CAPACITY
  - GEOSS (Global Earth Observation System of Systems)
  - IGBP/IGOS-IGACO (Integrated Global Observation Strategy -Integrated Global Atmospheric Chemistry Observations) Theme Report (2004)

Requirements for Regional Tropospheric Research

- Requirements asking for high temporal resolution/sampling are mostly linked to the application area "Operational Air Quality Forecast and Monitoring".
- Main characteristics is the combination of high horizontal resolution (< 10 km x 10 km) with high temporal resolution (< hourly) for tropospheric distributions of atmospheric parameters (O_3, CO, NO_2, SO_2, HCHO, other OVOC, PM etc.) with sensitivity to lowest troposphere.
- Threshold area to be covered is Europe - Target area is the maximum 1/3 disc aviable to GEO but this makes for significantly more expensive and heavier instruments.
- Measurements from Geostationary Orbit (GEO) offer a very attractive approach to the observation of the high tropospheric variability from space.
- Christoph Hueglin (EMPA) at TEMIS workshop Jan. 2005: „Application of space-borne data would boost with increased spatial and temporal data coverage (i.e. geostationary satellite)“

Summary of Requirements

Parameter	Application Area		Spectral Range		Uncertainty	Horizontal Resolution	Vertical Resolution	Revisit Time
	AQ	Climate	UVV-SWIR	TIR		[km]	Troposphere [km]	[hours]
O_3	X		X	X	10 – 25 %	5 – 20	1-3 - TrC	0.5 - 2
NO_2	X		X		10 – 30 % (1.3e15mol/cm^2)	5 – 20	1-3 - TrC	0.5 – 2
CO	X		X	X	20 – 25 %	5 – 20	1-3 - TrC	0.5 – 2
SO_2	X		X		20 – 50% (1.3e15mol/cm^2)	5 – 20	1-3 - TrC	0.5 – 2
HCHO	X		X		20 – 50% (1.3e15mol/cm^2)	5 – 20	1-3 - TrC	0.5 – 2
Aerosol Optical Depth	X	X	X		0.05	5 – 20	-	0.5 – 2
Aerosol Type	X		X		< 10% mis-assignments	5 – 20	-	0.5 – 2
H_2O	X	X	X	X	10 – 20 %	5 – 20	1-3- TrC	0.5 – 2
HNO_3	X			X	20 % (1.3e15mol/cm^2)	5 – 20	1-3 – TrC	0.5 – 2
N_2O_5 (night)	X			X	20 – 50% (1.3e15mol/cm^2)	5 – 20	1-3 - TrC	0.5 – 2
PAN	X			X	20 % (1.3e15mol/cm^2)	5 – 20	1-3 - TrC	0.5 - 2
Organic Nitrates (B3-S only)	X			X	30 %	5 – 20	PBL only	0.5 - 2

Applications are asking for sensitivity of measurements including the PBL

Orbit Comparison (focus trace gas sounding)

Orbit	LEO	LEO	MEO	GEO
	sun-snyc.	non sun-sync.		
Height [km]	600 - 800	600 - 800	1.000 - 20.000	36.000
Orbits/Day	14	14	2 - 6	1
Spatial Coverage	global	near global (no high lat. coverage)	global	full disk
Temporal Coverage [hrs]	12 - 24	2 - 48, highly variable and not continously	2 - 4	0.5 - 2 continously
Illumination Conditions	constant illumination	highly variable	smooth variation	smooth variation
EO Example	ERS-2, ENVISAT	TRMM	GPS	GOES, METEOSAT
Others	allows compact instrument design	changing illumination has severe impact on satellite design (power etc.)	high radiation dose (protons)	instrument aperture larger, partly compensated by longer integration times

- Especially if no full global coverage is required like for regional- continental tropospheric composition studies, geostationary observations are most efficient to address a revisit time requirement of 0.5- 2 hours continously.

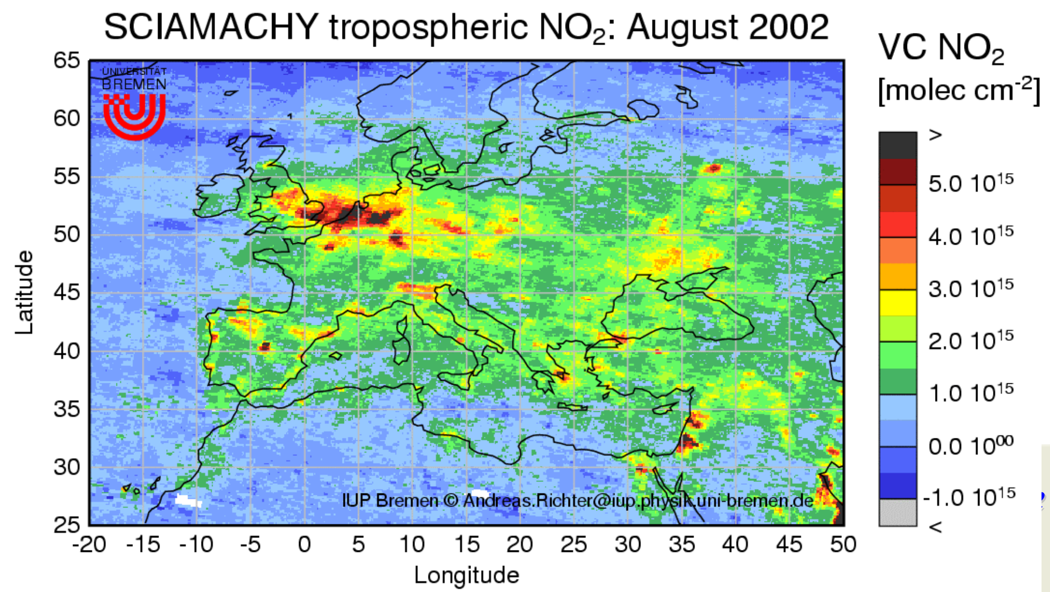
Geostationary Benefits

➢ GEO optimal for closing the gap between the different spatial (regional to hemispheric/global) and temporal scales (short term to long term) by synoptic hourly or better view of a complete hemisphere

➢ Diurnal variation and variability of parameters observable

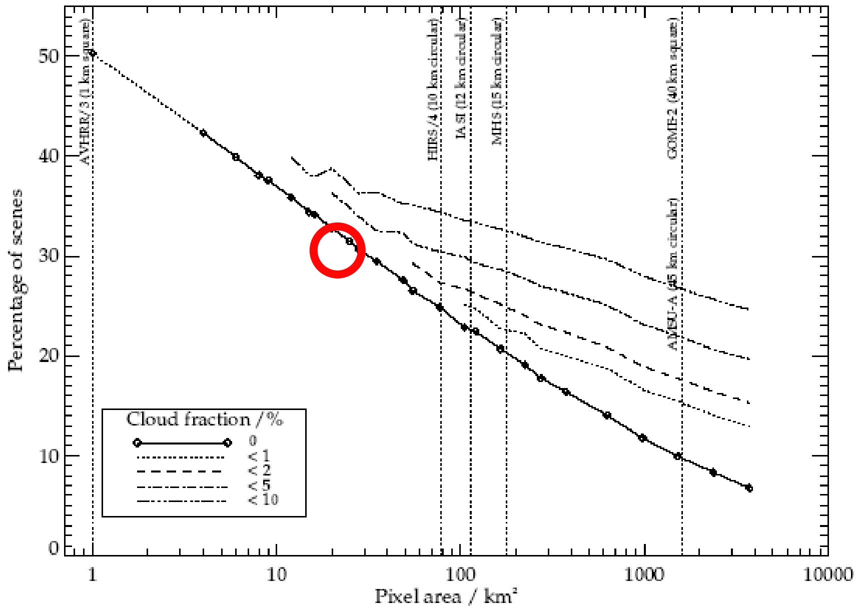
➢ GEO optimal for monitoring, now- and fore-casting of short-term variations of atmospheric composition:

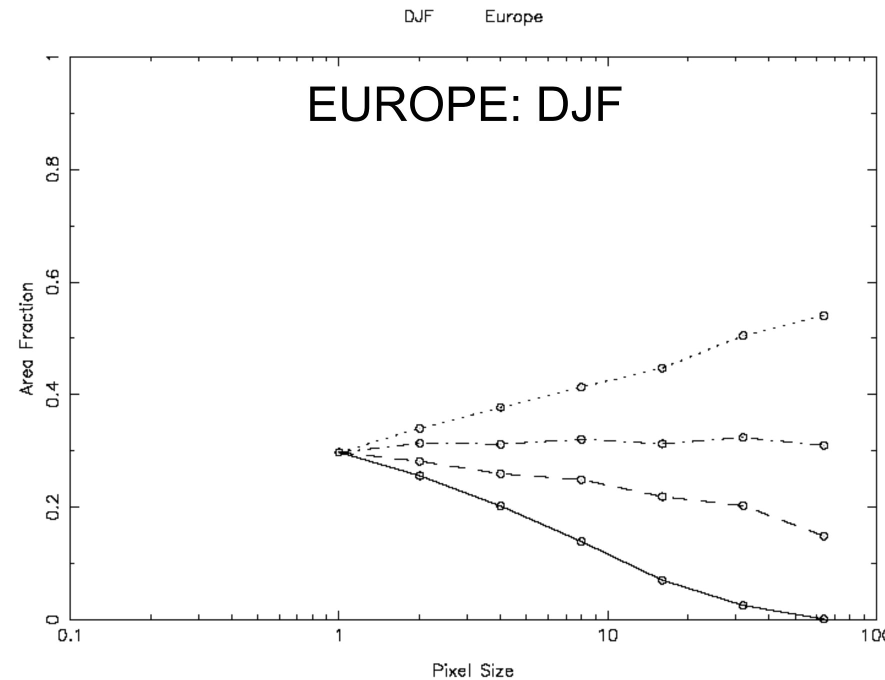
- air quality management (monitoring, forecast, health)
- emissions to the troposphere (anthropogenic, natural),



Universität

Impact of Clouds





- LEO (Kerridge et al., ACOR FR)
- ATSR-2/ERS-2,
- 1.5 km x 2 km
- 1 day global average

- GEO (Tjemkes et. Al. 2005)
- MVIRI/METEOSAT
- 4.8 km x 4.8 km (= 1 Pixel=23 km^2)
- Selected regions, seasonal averages

Cloud free measurements per day and geolocation

LEO

Instrument	Orbit	Swath	Dx	area	Fraction of c
	Descending Node Crossing	km	km x km	km2	CF=0.0
GOME-2 (2006 - 2020)	09:30	1900	40 x 80	3200	0,07
OMPS Nadir NPP (2007- 2012)	10:30	2800	50 x 50	2500	0,08
OMPS Nadir NPOESS (2012- 2017+)	13:30	2800	50 x 50	2500	0,08
CAPACITY UV_VIS Nadir_LEO	15:30	2600	10 x 10	100	0,23
METOP and NPP/NPOESS					**0,15**
METOP, NPP/NPOESS + LEO UV-Vis Nadir					**0,38**

GEO

Tjemkes et al. 2005, Europe (MVIRI Data 4.8 x 4.8 km2) Fig. 3.4		**5 km x 5 km**	**15 km x 15 km**
DJF, 7 measurements during daylight hour	cloud free area fraction	0,3	0,2
	number of cloud free measurement/day	**2,1**	**1,4**
MAM, 10 measurements during daylight hour	cloud free area fraction	0,5	0,4
	number of cloud free measurement/day	**5,0**	**4,0**
JJA, 13 measurements during daylight hours	cloud free area fraction	0,6	0,5
	number of cloud free measurement/day	**7,8**	**6,5**
SON, 10 measurements during daylight hours	cloud free area fraction	0,4	0,3
	number of cloud free measurement/day	**4,2**	**3,0**
Seasonal Average	number of cloud free measurement/day	**4,8**	**3,7**

Conclusions on Cloud Impact

- An instrument with 5 x 5 km^2 (SSP) in GEO will deliver over Europe on average approx. 2 (winter) to 8 (summer), (seasonal average: 5) cloud free observations per day <u>per covered geolocation</u>, based on MVIRI cloud statistics.
- An instrument with 15 x 15 km^2 (SSP) in GEO will deliver over Europe on average approx. 1.5 (winter) to 6.5 (summer), (seasonal average: 3.5) cloud free observations per day <u>per covered geolocation</u>, based on MVIRI cloud statistics.
- A LEO constellation (METOP+NPP/NPOESS+OMI/NewUV-Vis) will give on average approx. 0.4 cloud free observations per day per <u>covered geolocation</u> (0.15 for METOP +NPP), based on ATSR-2 cloud statistics.

Note: this analysis estimates the amount of cloud free observations w.r.t. to the covered scene, not w.r.t. the number of cloud free observations in a given horizontal cell.

Heritage and Related Studies Solar Backscatter

- TOMS on various NASA platforms,
- GOME on ERS-2
  - Demonstrates quantitative determination of trop. column distributions of **O_3, NO_2, SO_2, HCHO, H_2O** from solar backscatter measurements
- SCIAMACHY on ENVISAT
  - Demonstrates quantitative determination of trop. column distributions of **CO, CH_4 and CO_2** from solar backscatter measurements
  - Demonstrates value of improved spatial resolution (30 x 30/60 km2)
- OMI on AURA
  - Demonstrates the use of 2-dimensional CCDs and polarisation scrambler for solar backscatter trace gas applications
- GOME-2/METOP
  - Polarisation measurement system to characterise **aerosol** (Hasekamp et al.)
- GeoSCIA
  - Studies on requirements and instrument concepts (UK, D, ESA)
- MTG-UVS
  - Studies on requirements and instrument concepts (see contribution S. Tjemkes, EUMETSAT)

Heritage and Related Studies thermal IR

Satellite projects for Nadir-observations of the atmosphere in the thermal infrared (TIR), about 500-3000 cm^{-1} (3-20 μm) relevant to this part of Work Package 3100 are:

1) Interferometric Monitor of Greenhouse Gases (IMG), NASDA

2) Tropospheric Emission Spectrometer (TES), NASA

3) Infrared Atmospheric Sounding Interferometer (IASI), ESA-EUMETSAT

4) Meteosat Third Generation Infrared Sounder, ESA-EUMETSAT

5) Geostationary Fourier Transform Spectrometer (GIFTS), NASA

6) Geostationary Fourier Imaging Spectrometer (GeoFIS), CNRS-LISA, IMK

Survey of European GEO Concepts – UV/Vis/SWIR

Instrument Parameter	GeoSCIA EEOM 2002	MTG-UVS	GeoSCIA-R
Spatial Coverage	Full disk N-S: +- 69.7° E/W: +- 60°	N-S: 18° E-W: 6°	30° - 65°N with 3.4° 20°W – 40 °E with 7.6° option: full disk
Temporal Coverage	30 min.	30 min. 6° NS x 6° EW in 10 min	60 min.
Horizontal Sampling SSP	11.5 km x 23 km	6 km x 6 km	5 km x 5 km
Spectral Ranges(resolution)	270 – 560 (0.5 – 1) nm 755 – 780 (0.08) nm 2015 – 2035 (0.07) nm 2352 – 2372 (0.07) nm	290 – 360 (0.4) nm 420 – 440 (0.4) nm 772 – 770 (0.06) nm + 2 imaging channels	290 – 490 (0.5 – 1) nm (option: 755 – 780 (< 0.25) nm)
Spectral Sampling	3 – 4	3-6	3
Polarisation Measurements	Yes, 300 – 850 nm	Option, 310-335 nm	Yes, 300 – 100nm
Number of FPAs	8	3-5	5
T detector	UV-VIS-NIR : 220 – 260 K SWIR 110 K	UV-VIS-NIR: 220 – 260 K	UV-VIS(-NIR) : 220 – 290 K
Mass	155 kg	150 kg	< 100 kg
Data Rate	30 Mbps	15 – 20 Mbps	> 6 Mbps
Other	Scientific mission	Operational mission	Scientific mission

- Status: Summer 2005
- MTG Update see talk S. Tjemkes

Survey of European GEO Concepts - IR

Instrument Parameter	GeoFIS EEOM 2002	MTG-IRS	GeoFIS-R
Spatial Coverage	N-S: 6.1° E/W: 7.6°	Full Disk - N-S: 18° x E-W: 6°	30° - 65° N with 3.4° 20°W – 40°E (@40°N) with 7.6°
Temporal Coverage	30 min.	30 min. full disk 10 min. 18° x 6°	60 min.
Horizontal Sampling SSP	15 km x 15 km	3 km x 3 km 6 km x 6 km	15 km x 15 km
Spectral Ranges	4.4 – 5.6 µm 7.1 – 15.4 µm	4 - 15 µm	4.55-4.76 µm, 8.33- 10.26 µm
Spectral Resolution	0.25 cm^{-1}	0.5 cm^{-1}… 2.45 cm^{-1}	0.25 cm^{-1}
Number of FPAs	2	4	2
Lowest T detector	60 – 80 K	50 K	90 K
Mass	180 kg	300 kg	120 kg
Data Rate	20 Mbps	360 - 500 Mbps (FTS)	300 Mbps
Other	Scientific mission	Operational mission	Scientific mission

- Status: Summer 2005
- MTG Update see talk S. Tjemkes

GeoTROPE-R Mission

- GeoSCIA-R Instrument
  - Focus: O_3, NO_2, HCHO, SO_2, Aerosol, Clouds
  - Imaging Spectrometer:
    - 290 nm – 490 nm, optionally 755-780 nm using 2D CCDs
    - Spectral resolution 0.25 – 1 nm
    - Polarisation Measurements: 300 – 1000 nm, 2 – 20 nm spectral resolution
- GeoFIS-R Instrument
  - Focus: O_3, CO, PAN
  - Imaging FTIR:
    - 4.55 – 4.76 µm, 8.33 – 10.26 µm
    - Spectral resolution 0.25 cm-1
- 3-axis stabilised platform
- Launch into GEO
- Mission duration 3 years minimum, 5 years goal

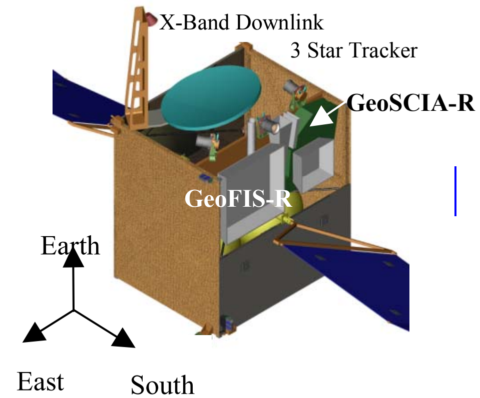
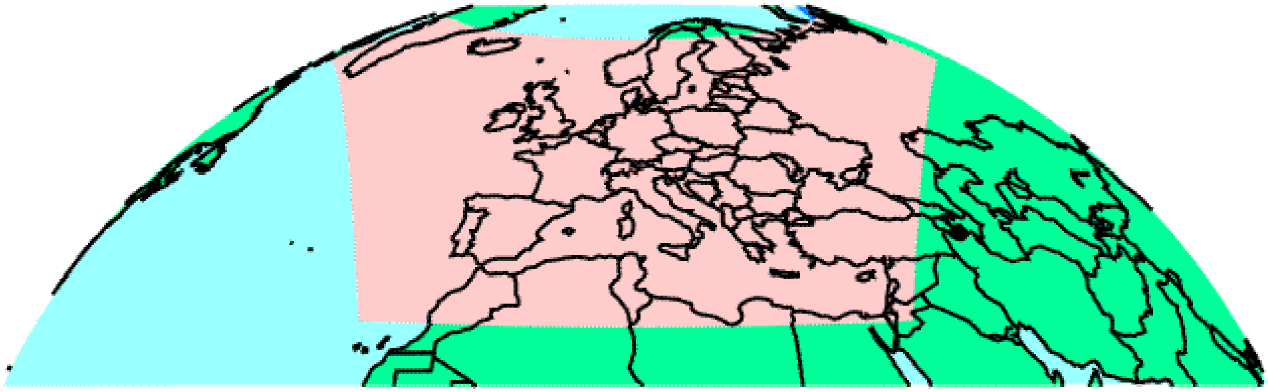


Figure 1 GeoTROPE-R satellite in-orbit configuration.

Coverage & Resolution

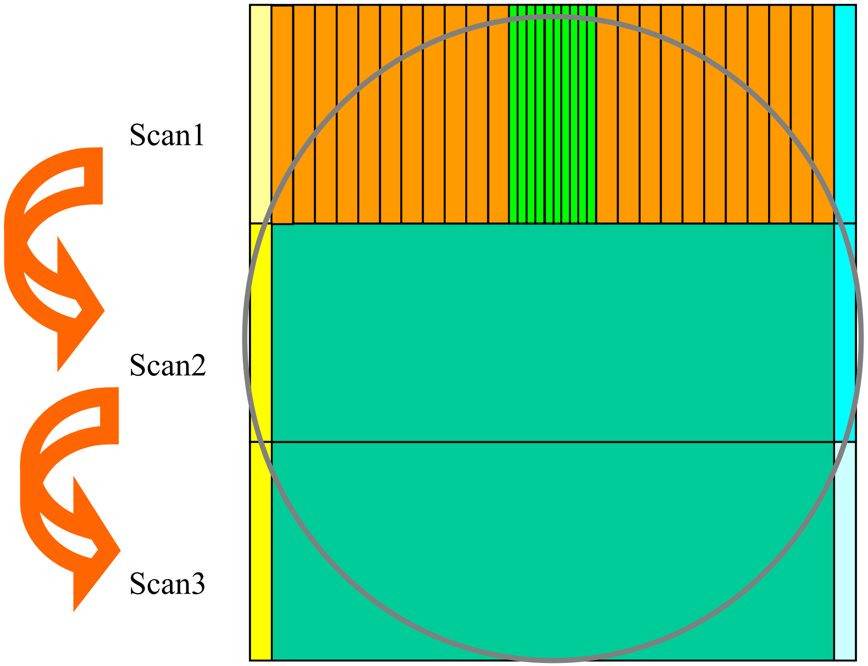
- Coverage & Resolution
  - Focus on Europe and surrounding regions (about 20°W - 40°E , 30°N - 65°N)
  - FOV can be positioned all over the disk
  -



  - Spatial resolution:
    - GeoSCIA-R: 5km x 5km @ SSP
    - GeoFIS-R: 15km x 15 km @ SSP
  - Temporal resolution: 30 - 60 min

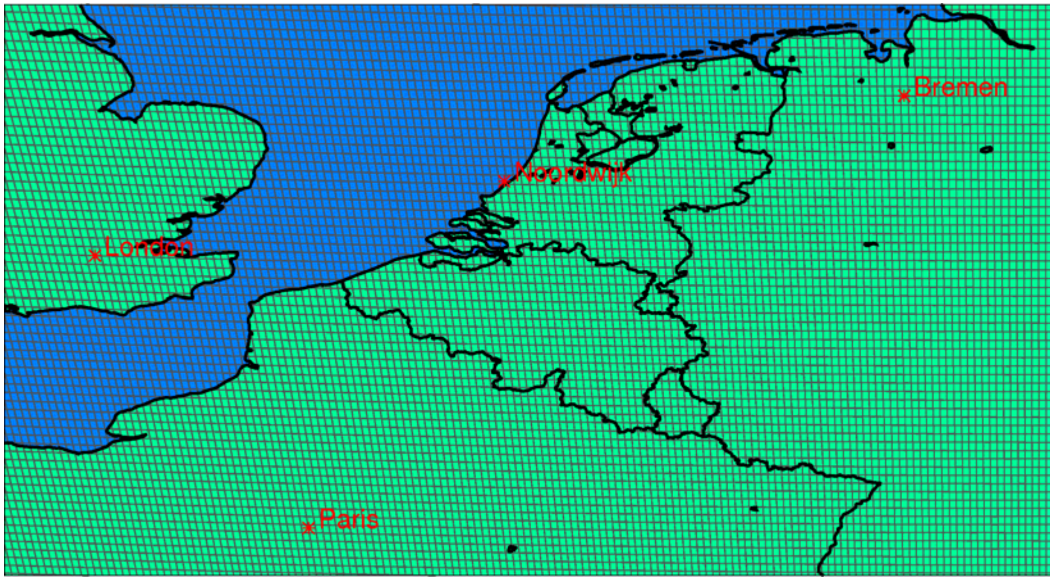
Spatial Sampling Options

- Fine resolution
  - Industrial emissions
  - Regional transport
- Coarse resolution
  - Natural emissions
  - Continental transport



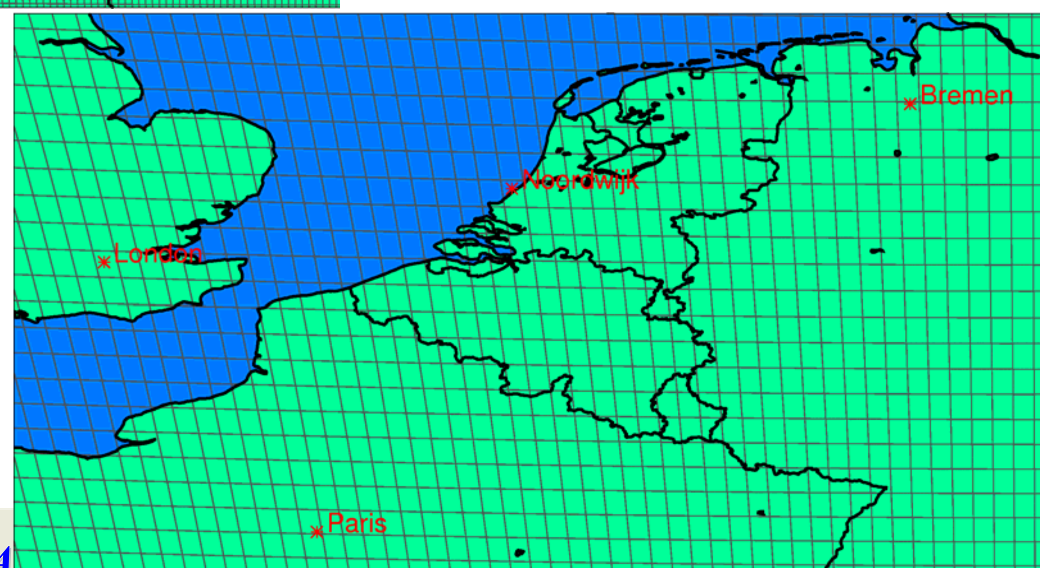
Not to scale

Spatial Resolution over Europe



GeoSCIA-R
horizontal sampling
over Western Europe
(5 km x 5 km at SSP)

GeoFIS-R
horizontal sampling over
Western Europe
(15 km x 15 km at SSP)

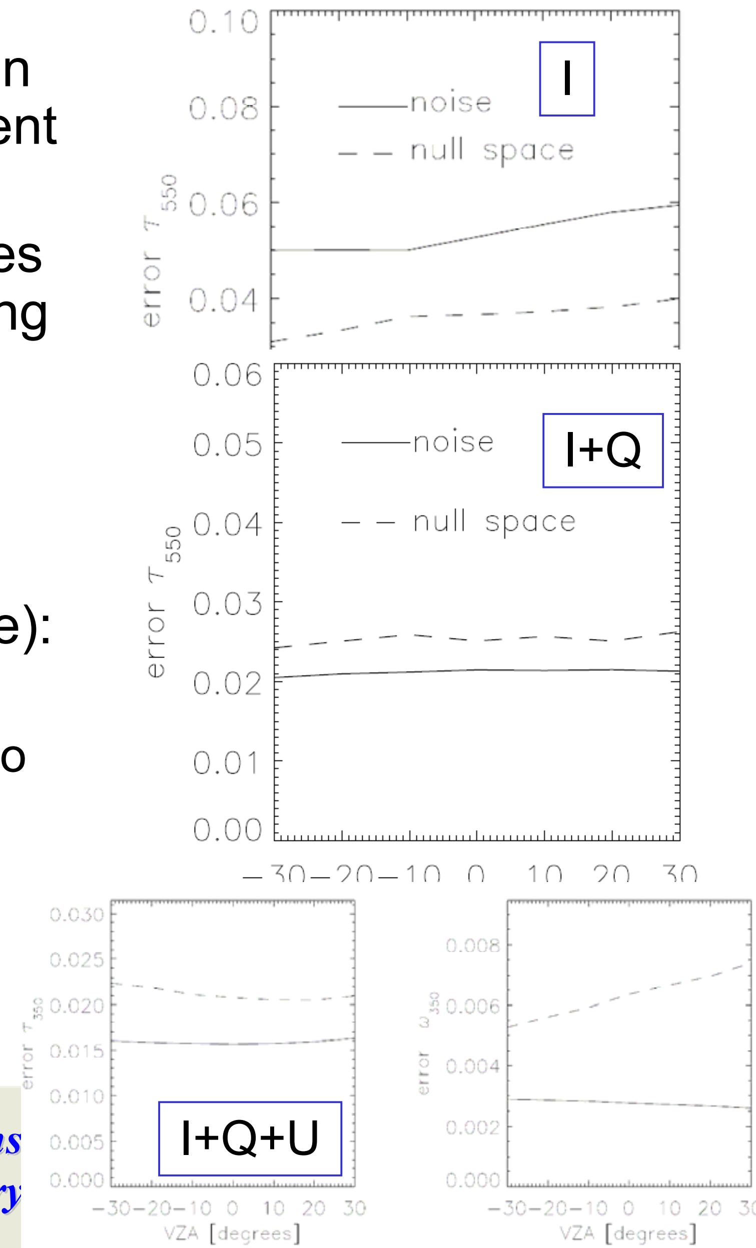


Can polarisation improve on aerosol from GEO?

- Investigated by O.Hasekamp, SRON
- Intensity: 350 – 550 nm (w.r.t. albedo), spectral resolution 10 nm
- Polarisation (Q, U): 350 – 1000 nm, spectral resolution 10 nm
- SNR: 500
- bi-modal (fine and coarse) aerosol model (here industrial aerosol) with 5 free parameters per mode: effective radius, effective variance, aerosol column, real/imaginary part of refractive index
- Albedo: vegetation
- Two SZA (45°, 50°) are used simultaneously (5° < 1 hour)
- Investigated: Degrees of Freedom for Signal (DFS), AOT @ 350 nm and 550 nm, SSA @ 350 nm

Polarisation can improve on aerosol from GEO!

- Measurements of I and Q results in error on AOT well below (@ 550 nm) the requirement (0.05), DFS=6-7.
- Measurements of I, Q and U further reduces the error on AOT (roughly factor 2), resulting in AOT @ 350 nm also be within 0.05, DFS=7.
- DFS > 5 should allow for fine and coarse mode discrimination
- Instrument Specification (GOME-2 heritage):
    - FOV: as trace gases
    - IFOV: 5 km x 5 km SSP, with the goal to have 5 km x 5 km over Europe
    - Polarisation:I, Q, U
    - 350 – 1000 nm,
    - spectral resolution 10 nm
    - SNR: 500



UV-SWIR/IR Nadir Sounding Combined Retrieval

Species		Vertical layers boundaries		
		0–2 km	2-7 km	7-15 km
O_3		**5 %**	**< 5 %**	**< 5 %**
	IR	*28 %*	*13 %*	*6.6 %*
	UV/Vis	*10%*	*6 %*	*13 %*
CO		**10 %**	**< 10 %**	**< 10 %**
	IR	*24 %*	*10%*	*10 %*
	SWIR		*Total column < 10%*	
CH_4		**2 %**	**1 %**	**1 %**
	IR	*7.1 %*	*3 %*	*2.6 %*
	SWIR	*13 %*	*12 %*	*18 %*
H_2O		**< 1%**	**< 1%**	**< 1%**
	IR	*1.2 %*	*1.1 %*	*2.8 %*
	SWIR	*5 %*	*5%*	*30%*

- **Combined retrieval on solar backscatter and IR emission provides:**
  - **maximum vertical resolution and**
  - **enhanced precisions in the lower troposphere (0-2 km), which is important to reach the required precision in this layer.**
- **METOP (IASI/GOME-2) and EOS-AURA (TES/OMI) data analysis will verify this theoretical prediction.**

Comparison to User Requirements

Parameter		Uncertainty	Horizontal Resolution (@Europe)	Vertical Resolution Troposphere	Revisit Time
			[km]	[km]	[hours]
O_3	**Req.**	**10 – 25 %**	**5 – 20**	**1-3 - TrC**	**0.5 - 2**
	Solar	10 – 20%	5-10	TrC	1
	TIR	10 – 20 %	15 – 25	5 – 6	1
	Comb.*	< 10	15 – 25	2/5-6	1
NO_2	**Req.**	**10 – 30 %**	**5 – 20**	**1-3 - TrC**	**0.5 – 2**
	Solar	20 - 30 %	5-10	TrC	1
CO	**Req.**	**20 – 25 %**	**5 – 20**	**1-3 - TrC**	**0.5 – 2**
	Solar	10 – 20 %	5-10	TrC	1
	TIR	10 –20 %	15 – 25	5-6	1
	Comb.*	< 10 %	15 – 25	2/5-6	1
SO_2	**Req.**	**20- 50%**	**5 – 20**	**1-3 - TrC**	**0.5 – 2**
	Solar	30-40 %	5-10	TrC	1
HCHO	**Req.**	**20-50%**	**5 – 20**	**1-3 - TrC**	**0.5 – 2**
	Solar	30-40 %	5-10	TrC	1
Aerosol Optical Depth	**Req.**	**0.05**	**5 – 20**	**-**	**0.5 – 2**
	Solar	< 0.05	5-10	-	1
Aerosol Type	**Req.**	**< 10% mis-assignments**	**5 – 20**	**-**	**0.5 – 2**
	Solar	TBD	5-10	-	1

Parameter		Uncertainty	Horizontal Resolution (@Europe)	Vertical Resolution Troposphere	Revisit Time
			[km]	[km]	[hours]
H_2O	**Req.**	**10 – 20 %**	**5 – 20**	**1-3- TrC**	**0.5 – 2**
	Solar	10 %	5-10	TrC	1
	TIR	1-2%	15 – 25	2 - 3	1
HNO_3	**Req.**	**20 %**	**5 – 20**	**1-3 – TrC**	**0.5 – 2**
	TIR	(Note 1)	15 – 25	TrC	1
N_2O_5 (night)	**Req.**	**20 – 50%**	**5 – 20**	**1-3 - TrC**	**0.5 – 2**
	TIR	(Note 1)	15 – 25	TrC	1
PAN	**Req.**	**20 %**	**5 – 20**	**1-3 - TrC**	**0.5 - 2**
	TIR	30%	15 – 25	TrC	1
Organic Nitrates (B3-S)	**Req.**	**30 %**	**5 – 20**	**PBL only**	**0.5 - 2**
	TIR	(Note 1)	15 – 25	TrC	1

(Note 1): Uncertainties for HNO3, N2O5 (night) and Organic Nitrates need further studies to be established.

Conclusion 1/2

The user requirements for Air Quality Applications are best served by a **combined solar backscatter and TIR sounding mission in GEO**

- one hour sampling and at 5 km x 5 km SSP (solar backscatter, TIR: 15 km x 15 km)
- Solar backscatter will provide total and tropospheric columns of O_3, NO_2, SO_2, HCHO, CO as well as data on aerosol (AOT etc.)
- Solar backscatter polarimetry allow aerosol type characterisation
- TIR will provide O_3 and CO profiles, tropospheric columns of C_2H_6 and PAN during day and night and has potential to provide HNO_3, N_2O_5 (night) and Organic Nitrates (see poster J.M. Flaud)
- Combined Solar Backscatter – TIR sounding: height resolved O_3 and CO with enhanced sensitivity to lowest troposphere,

Conclusions 2/2

- The GeoTROPE-R mission will improve our understanding, monitoring and forecasting through synoptic measurements of changing tropospheric composition
- It will provide
  - total and tropospheric column amounts of O_3, CO, NO_2, SO_2, HCHO, and PAN
  - tropospheric height resolved information of O_3 and CO
  - aerosol optical thickness, effective radius, and single scattering albedo via polarimetric measurements from GEO
  - cloud cover, cloud top height, and optical thickness

  on city - regional – continental scale, and on an hourly basis.

The proposed mission can serve as a demonstrator for operational missions (MTG, GMES Sentinel)

Additional Material

GeoTROPE-R

The Geostationary Tropospheric Pollution Explorer - **R**egional

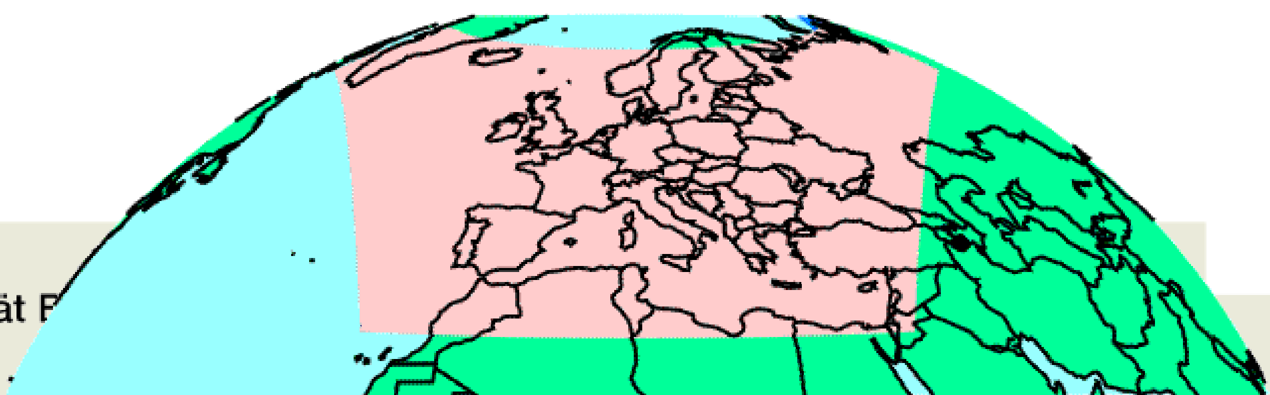
Proposal submitted to ESA in response to the Call for Earth Explorer Core Missions in 2005

by

John P. Burrows

Heinrich Bovensmann

Institute for Environmental Physics and Remote Sensing (IUP/IFE), University Bremen



Teaming (1)

Proposal Preparation Team

•*CNRS-LISA***,** G. Bergametti, J.-M. Flaud, J. Orphal, M. Beekmann (F); *EMEP/NILU***,** K. Tørseth (N); *EMPA***,** B. Buchmann (CH); *IMK-FZK* H. Fischer, F. Friedl-Vallon, H. Oelhaf, G. P. Stiller, T. von Clarmann, T. Steck (D); *KNMI,* A.P.H. Goede (NL); *Univ. Bremen,* H. Bovensmann, S. Noël, J. P. Burrows (D); *Univ. Leicester***,** P.S. Monks, G.K. Corlett , D.J. Llewellyn-Jones, J. J. Remedios (UK)

•Technical support from *CNES* and the following industries within various studies funded by ESA, EUMETSAT and DLR is acknowledged: *Astrium (UK,D), OHB-System AG*, *SIRA Ltd., TNO-TPD*.

GeoFIS-R Instrument Team

•*CNRS-LISA*, J.-M. Flaud (Lead-I.), G. Bergametti, J. Orphal (F); *CNRS*, Laboratoire d'Aérologie, P. Ricaud, B. Barret (F); *CNRS*, Service d'Aéronomie, C. Clerbaux (F); *Hampton University,* William L. Smith (USA); *DLR-IMF,* M. Birk, A. von Bargen, F. Schreier (D); *IFAC-CNR*, B. Carli, P. Raspollini, L. Palchetti (I); *IMK-FZK,* H. Fischer, F. Friedl-Vallon, H. Oelhaf, G. P. Stiller, T. von Clarmann, T. Steck (D); *JPL*, C. E. Miller (USA); *NASA LARC*, C. P. Rinsland (USA); *NCAR*, D. P. Edwards (USA); *Univ. Bologna*, M. Carlotti, M. Ridolfi (I); *Univ. Bremen*, M. Weber, J. P. Burrows, (D); *Univ. Leicester*, J. Remedios (UK)

GeoSCIA-R Instrument Team

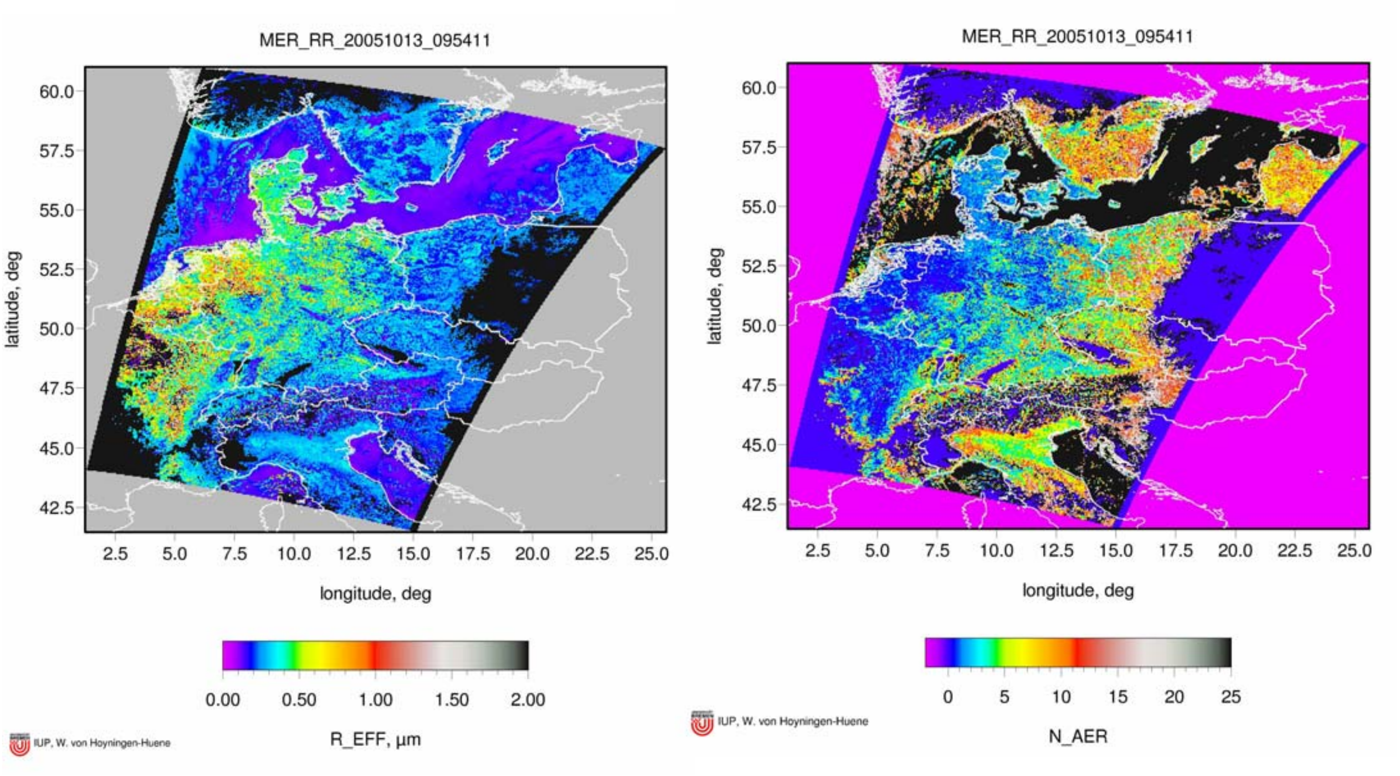
•*Univ. Bremen*, H. Bovensmann (Lead-I.), A. Richter, S. Noël, J. P. Burrows (D); *Univ. Leicester*, P. S. Monks, G. Corlett (UK); *BIRA-IASB*, C. Muller, M. van Roozendal (B); *CNRS-LISA*, J.-M. Flaud, J. Orphal (F); *DLR-IMF,* T. Trautmann, A. von Bargen, M. Gottwald, D. Loyola, S. Slijkhuis, P. Valks (D); *ISAC-CNR*, A. Petrioli (I); *Italian Space Agency*, R. Guzzi (I); *KNMI*, A.P.H. Goede (NL); *NASA LARC*, C. Rinsland (USA); *TNO-FEL*, G. de Leeuw (NL); *SRON*, O. Hasekamp, R.T. Jongma (NL); *Univ. Clermont-Ferrand,* O. Jourdan (F); *Univ. Zurich*, J. Nieke (CH)

Teaming (2)

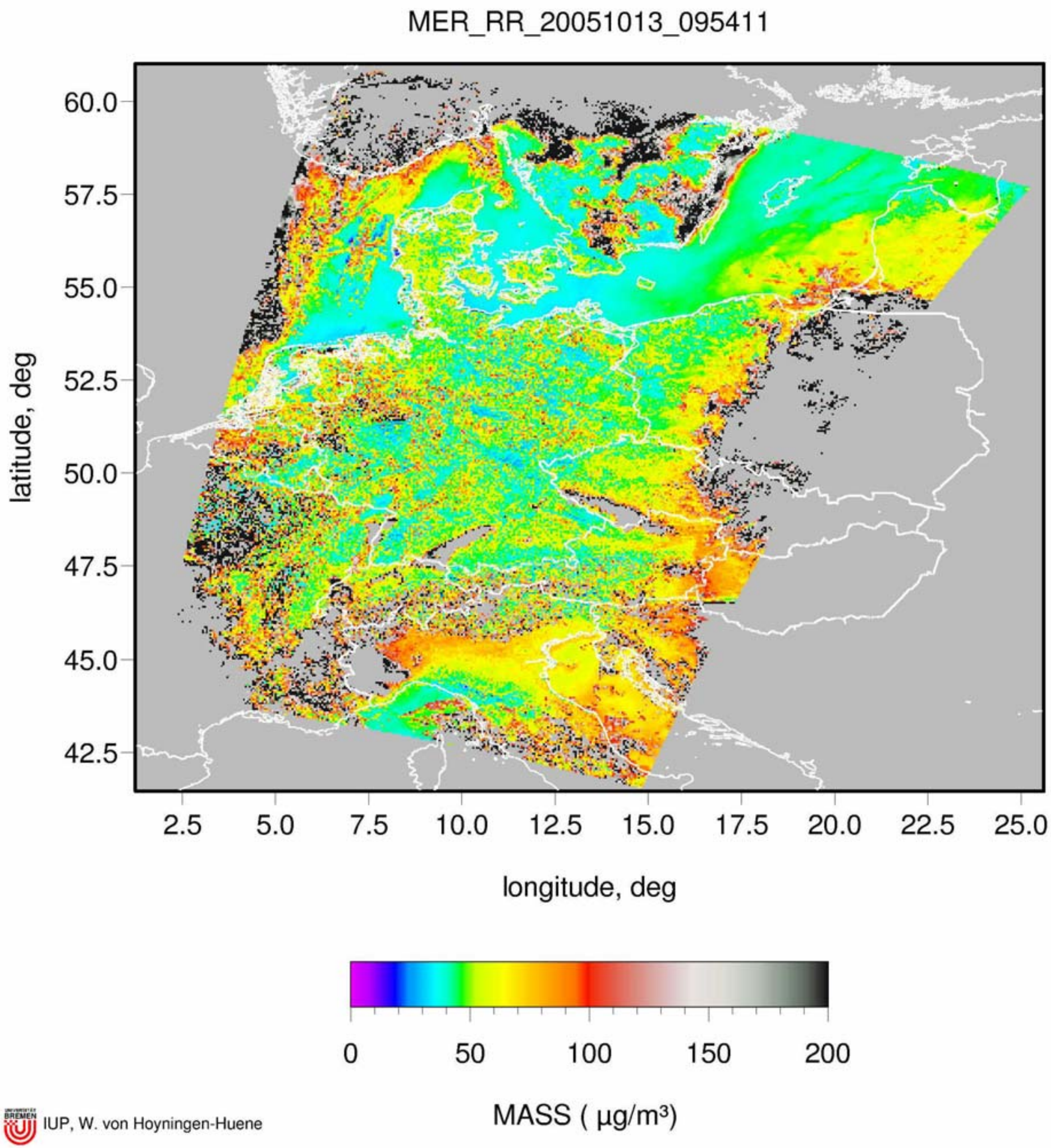
GeoTROPE-R Validation, Data Usage, Assimilation and Modelling Group

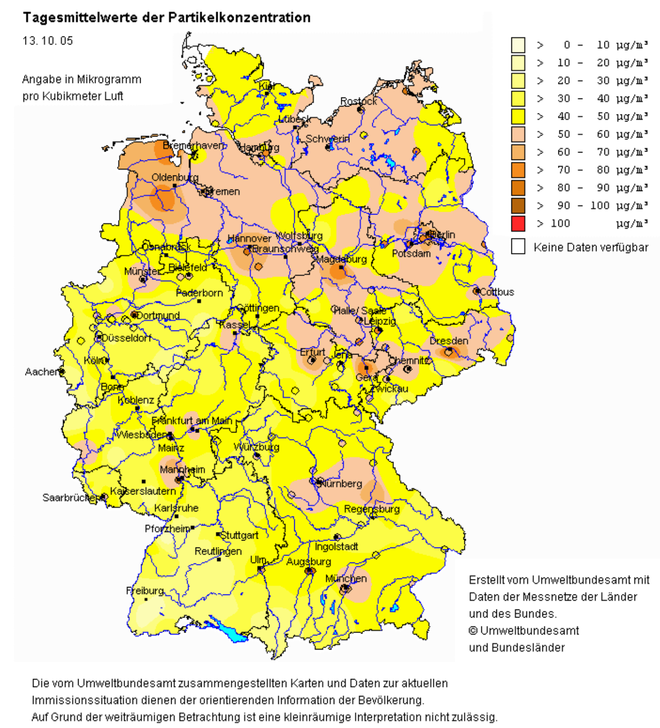
•*ADEME*, C. Elichegaray, N. Poisson (F); *AirParif*, P. Lameloise (F); *BIRA-IASB*, M. de Maziere, J.-F. Muller, C. Muller (B); *CNRM/Meteo-France*, V.H. Peuch, A. Dufour (F); *CNRS*, Laboratoire d'Aérologie, P. Ricaud, B. Barret (F); *CNRS, Service d'Aéronomie*, C. Clerbaux (F); *CNRS-LISA*, M. Beekmann (F); *CNRS-LMD*, R. Vautard, L. Menut, (F); *DLR-DFD*, M. Bittner, Th. Holzer-Popp (D); *DLR-IMF* T. Trautmann, A. von Bargen, M. Birk, A. Doicu, M. Gottwald, D. Loyola, F. Schreier, G. Schwarz, S. Slijkhuis, P. Valks (D); *DLR-IPA*, U. Schumann (D); *DWD*, H. Claude, W. Thomas (D); *EMEP/NILU*, K. Tørseth (N); *EMPA*, B. Buchmann, Daniel Schaub (CH); *ETH Zurich*, U. Lohmann (CH); *IMK-FZK*, T. von Clarmann, T. Steck (D); *INERIS*, L. Rouil, C. Honoré, F. Meleux (F); *ISAC-CNR*, A. Petrioli (I); *Italian Space Agency*, R. Guzzi (I); *KNMI*, A.P.H. Goede, R. van Oss, A. Piters, (NL); *MPI for Chemistry*, J. Lelieveld (D); *MPI for Meteorology*, O. Stein, G. Brasseur (D); *National Environmental Research Institute*, M. Hvidberg (DK); *NCAR*, D. P. Edwards (USA); *Service d'Aéronomie/IPSL*, C. Granier (F); *TNO-FEL*, G. de Leeuw (NL); *UK Metoffice*, D. Rodgers, (UK); *Umweltbundesamt*, R. Höller (A); *Univ. Athens*, C. Zerefos (G); *Univ. Cambridge*, N. H. Savage, J. A. Pyle (UK); *Univ. Clermont-Ferrand,* O. Jourdan (F); *Univ. Cologne*, H. Elbern (D); *Univ. Crete*, M. Kanakidou (G); *Univ. Frankfurt*, U. Schmidt (D); *Univ. Hamburg*, D. Stammer (D); *Univ. Heidelberg*, U. Platt (D); *Univ. Liège*, E. Mahieu, R. Zander (B); *Univ. Oxford*., A. Dudhia (UK); *Univ. Zurich*, J. Nieke (CH); *WMO*, L. Barrie (CH); *ZSW*, A. Kaifel (D)

Eff. Radius + Number Concentration



Particulate Matter





from Space
06

IUP, W. von Hoyningen-Huene

Validation

First comparison of

PM retrieved from BAER AOT, 13. Oct. 2005

PM10, daily averages, UBA, 13. Oct. 2005