Atmospheric Physics
UNIVERSITY OF TORONTO

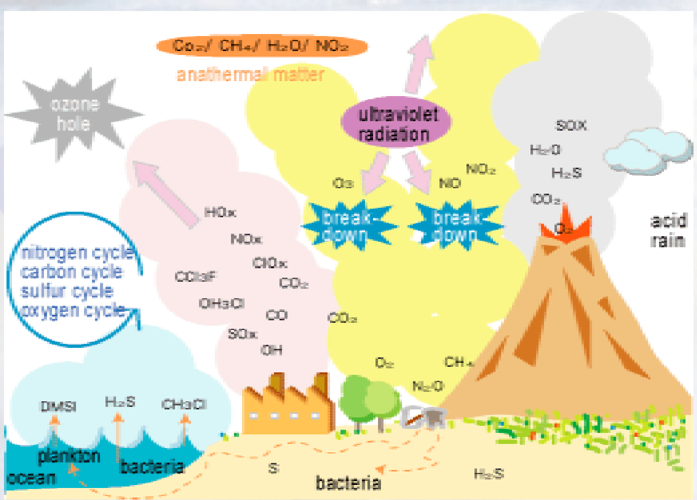
The 2007 Noble Lecture Series

Atmospheric Chemistry and the Remote Sensing of the Global atmosphere March 26-30th 2007.

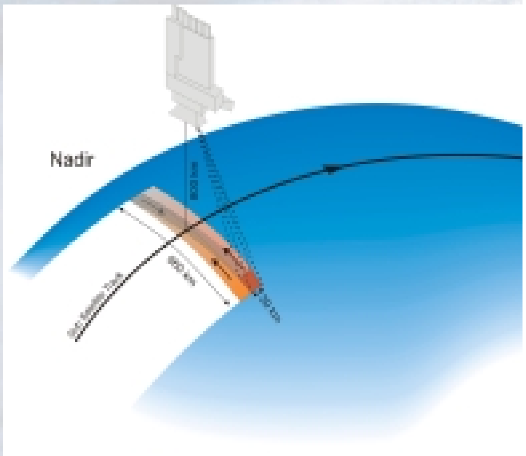
Lecture 4: Results from Nadir Remote Sensing and the Potential Measurement of Atmospheric Composition from Geostationary Orbit – GeoTROPE/GeoSCIA

John P. Burrows
Department of the Physics and Chemistry of the Atmosphere
Institute of Environmental Physics and Remote Sensing
University of Bremen, Bremen, Germany

Atmospheric Composition

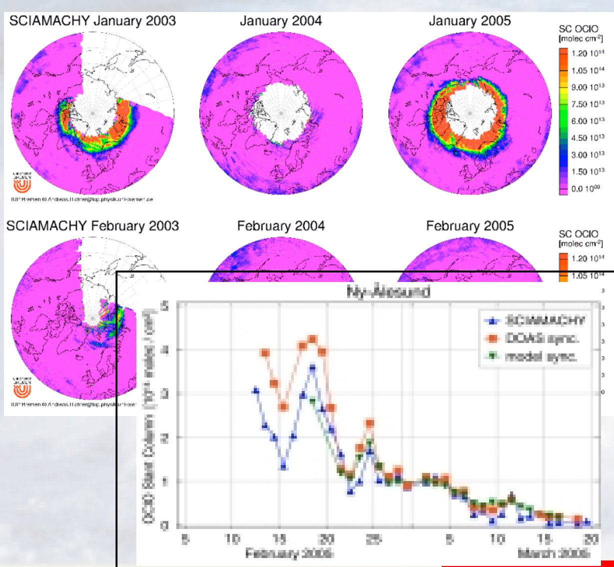


SCIAMACHY: Nadir Viewing Geometry Examples



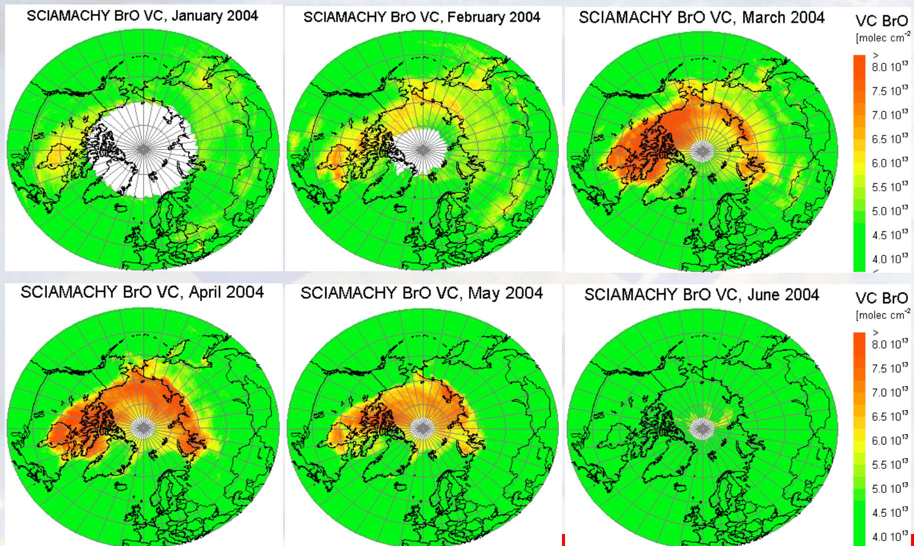
- horizontal resolution in across track:
  - GOME-1 80 and 320 km
    global 1995-2003
    partial 2003- present
  - SCIAMACHY 30-240 km
    global 2002- present
  - GOME-2 40-80 km
  - 960 km swath
- horizontal resolution in along track:
  - GOME 40 km
- Global coverage:
  GOME-1 3 days at the equator
  SCIAMACHY 6 days at the equator
  GOME-2 ~1 day at the equator

Stratospheric OClO measurements



- continuation of GOME time series of stratospheric chlorine monitoring
- good consistency between GOME and SCIAMACHY data
- good agreement with ground-based measurements
- large variability in chlorine activation in the Northern hemisphere depending on vortex stability

SCIAMACHY Arctic 2004



Frost Flowers and Potential Frost Flower Regions

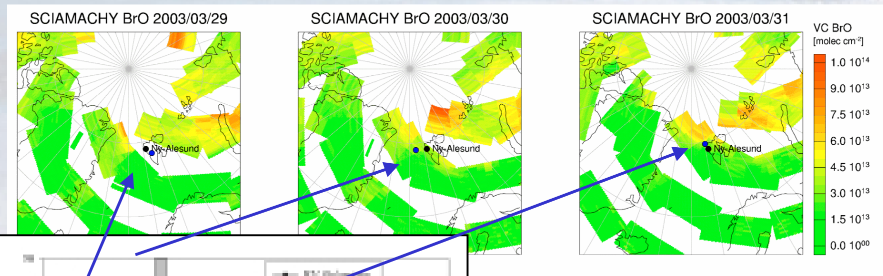
Unique signature identifies frost flowers

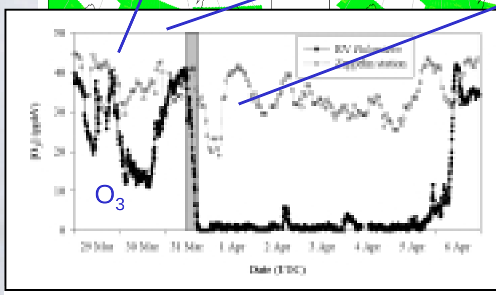
Photograph: Hans-Werner Jacobi AWI

$K = [SO_2^{-4}]/[Na^+] = 0, 25$ constant for seawater

Frost flowers show systematic sulphate depletion ($K < 0.25$)

BrO and Troposheric Ozone and Mercury Depletion

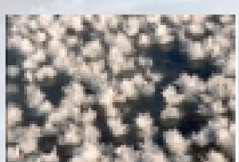


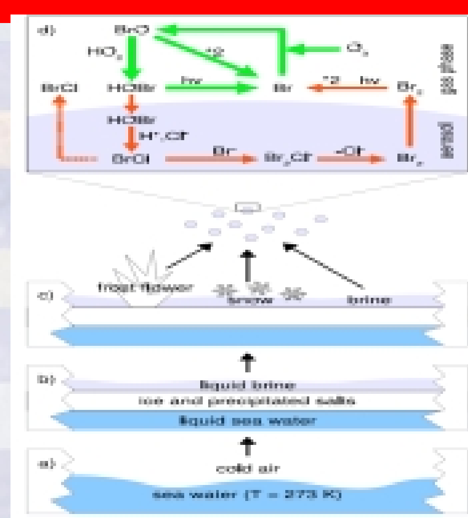


H.-W. Jacobi et al., Observation of a fast ozone loss in the marginal ice zone of the Arctic Ocean , *J. Geophys. Res., in press, 2006*

- observation of rapid O_3 depletion on Cruise of RV Polarstern
- good correlation with BrO fields from SCIAMACHY
- simultaneous observation of frost flowers!!!

Chemistry of Potential Frost Flower Regions





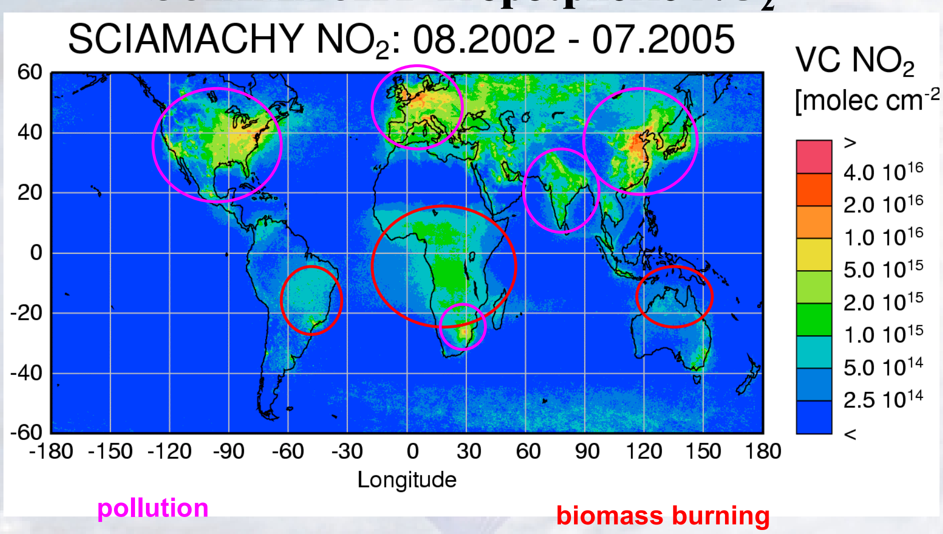
The upper panel shows how the multiphase chemistry in the gas phase and in the aerosol starts the bromine explosion (red arrows) and ozone depletion (green arrows).

R. Sander1, J. Burrows2, and L. Kaleschke ACPd/ACP 2006

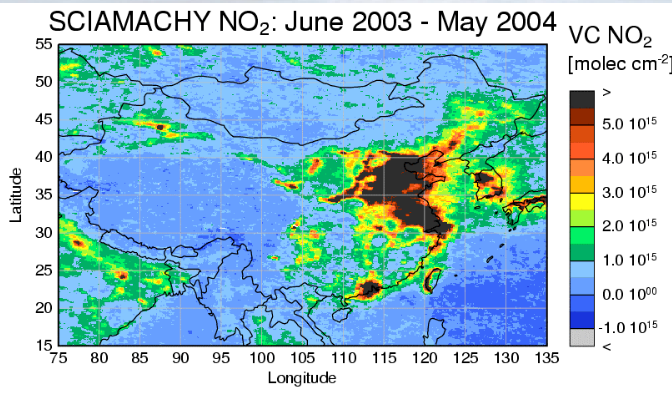
NO_2

Nitrogen Dioxide

SCIAMACHY Tropospheric NO_2



GOME and SCIAMACHY Tropospheric NO_2 - China



GOME:

- **large values**
- **clear signature of swath pattern**

SCIAMACHY:

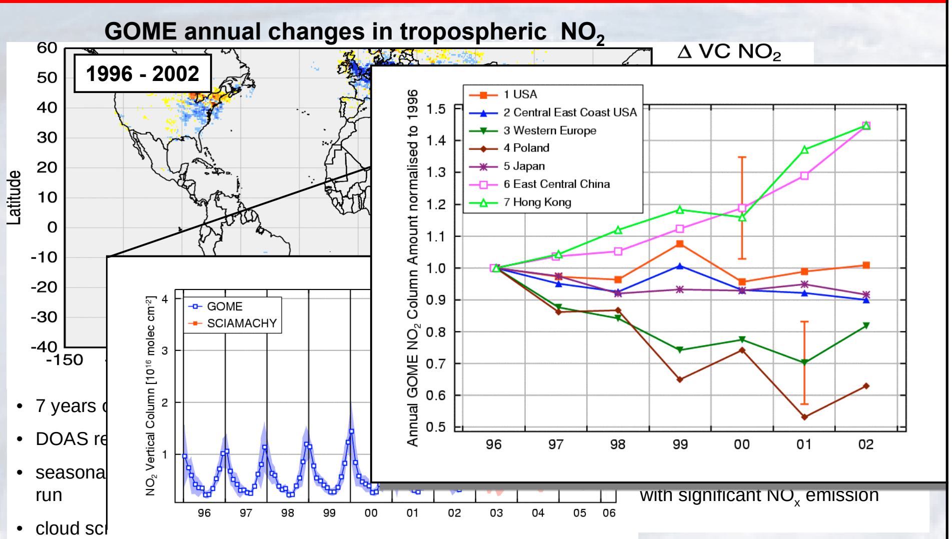
- **even larger columns**
- **much more detail**

- Not the same time period (NO_2 above China is rapidly increasing)

Universität Bremen *ife*

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

Trop. NO_2: Trends Richter et al Nature 2005



- 7 years
- DOAS re
- seasona run
- cloud sc

with significant NO_x emission

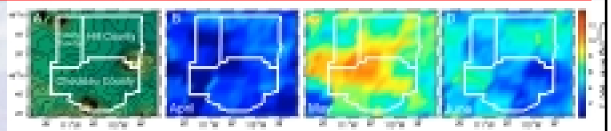
A. Richter et al., Increase in tropospheric nitrogen dioxide over China observed from space, *Nature*, **437** 2005

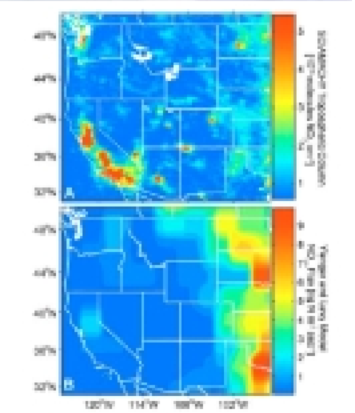
Universität Bremen *ife*

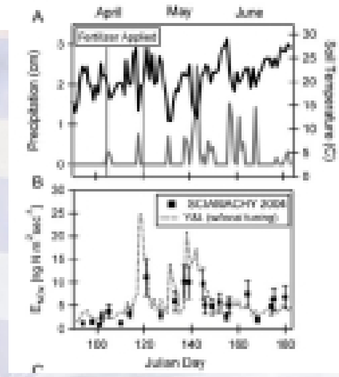
Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

NO_2 from agricultural NO_x emissions (US Montana)

NO_2 columns in spring and estimated Emissions

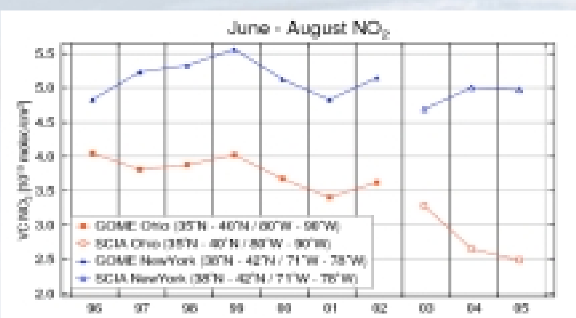


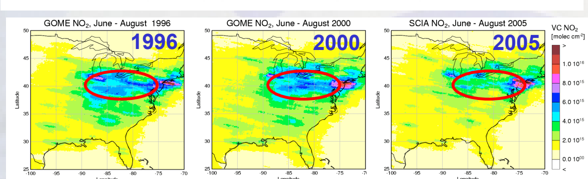




Bertram, et al. GRL 2006

Monitoring Sources/Sinks NO_2: US Power Plant "Denoxification"



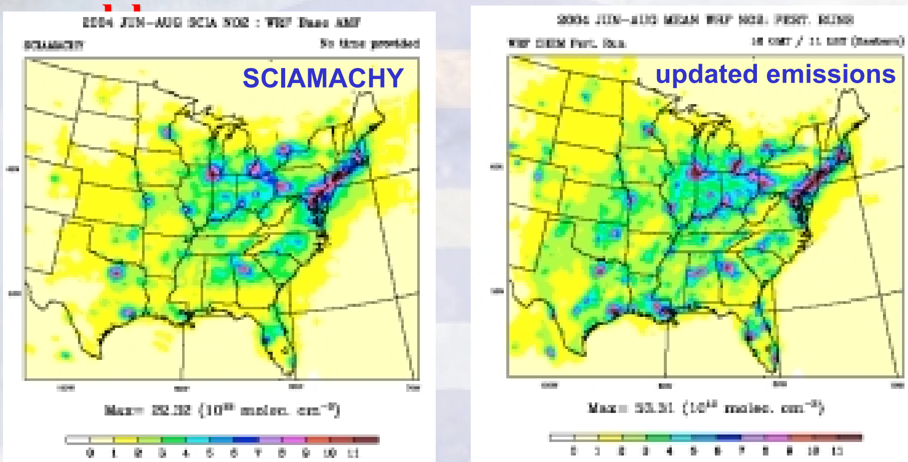


- **GOME NO_2 time-series complex in USA**
- **after 2000, clear decrease (> 30%) in NO_2 in Ohio-valley area**
- **no change in urban areas**
- **size and geographical pattern consistent with model simulations**

S. Kim, A. Heckel et al 2006 NOAA and University of Bremen GRL November 2006

GOME & SCIA NO2: US Power Plant Denoxification

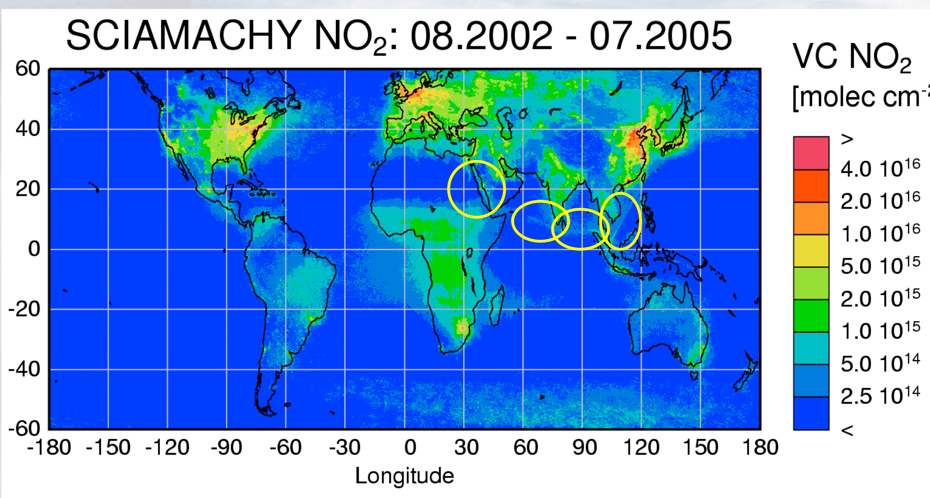
NO_2 columns June-August 2004 – NO2 and WRF



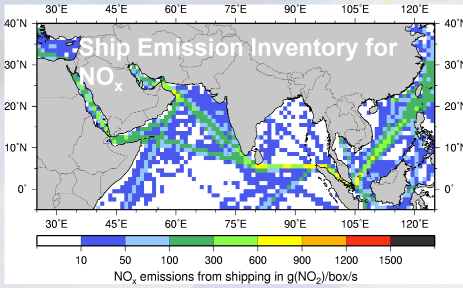
Kim et al GRL 2006

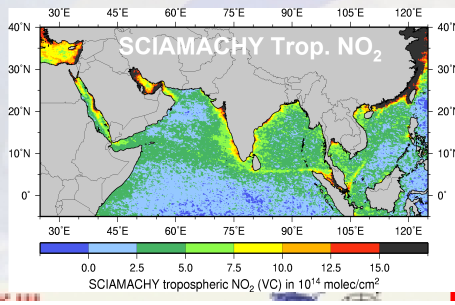
WRF data © Kim, Frost, McKeen, Trainer, NOAA

Can one see the ships tracks?



Emission Inventory for NO_x and NO_2 Satellite Measurements





Emissions along ship routes from inventories

- Global Vessel Traffic Densities from AMVER *(Endresen et al., 2003)*
- Absolute emission scaled to 6.87 Tg(N)yr^{-1} *(Corbett&Köhler, 2003)*
- Global NO_x Inventory (Eyring et al., 2004)

Ship routes seen in SCIA trop. NO2

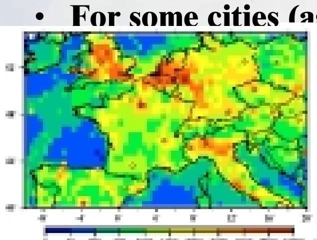
- average August 2002 – April 2004
- moderate cloud filter (30%)
- trop. AMF: albedo 0.04, maritime aerosol
- ship routes clearly visible
- transfer of measured NO_2 and NO_x from emission inventories needs photo-chemical modelling

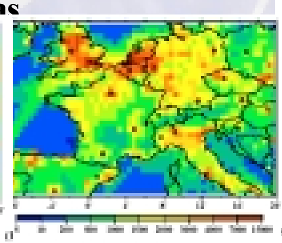
A. Richter et al., Satellite Measurements of NO2 from International Shipping Emissions, *Geophys. Res. Lett.*, **31**, L23110, doi:10.1029/2004GL020822, 2004

Anthropogenic Emission Rates in European Cities

- **Top-Down constrain on anthropogenic emission rates (molecules×cm−2×s −1×1011) averaged for three summer months (June to August) of 2001**
- **Satellite data: GOME ERS-2**
- **Model CHIMERE**
- **A-priori: EMEP data for 2001**
- **For some cities (as**

City	A priori	A posteriori
Barcelona	2.79	1.95 (1.2)
Berlin	2.25	1.56 (1.4)
Bern	0.98	1.01 (1.3)
Birmingham	5.07	4.56 (1.2)
Bratislava	1.09	1.12 (1.3)
Brussels	5.00	4.83 (1.3)
Budapest	2.31	2.16 (1.3)
Cologne	5.64	6.18 (1.4)
Geneva	1.04	1.14 (1.3)
Hague	7.25	6.84 (1.4)
Hamburg	2.33	1.69 (1.3)
Liverpool	3.69	3.37 (1.6)
Ljubljana	1.05	1.14 (1.3)
London	7.76	4.75 (1.4)
Lyon	1.73	1.65 (1.2)
Madrid	2.23	2.73 (1.2)
Marseille	1.93	1.68 (1.2)
Milan	3.13	3.37 (1.2)
Munich	2.03	1.93 (1.2)
Naples	1.98	2.25 (1.1)
Paris	4.68	3.92 (1.3)
Poznan	0.57	0.69 (1.3)
Prague	2.18	2.09 (1.2)
Rome	3.20	3.28 (1.2)
Toulouse	0.86	0.74 (1.3)
Turin	1.41	2.29 (1.3)
Vienna	1.87	1.69 (1.3)
Zagreb	1.15	0.88 (1.3)
Zaragoza	1.41	1.36 (1.5)





Konovalov, et al. 2005

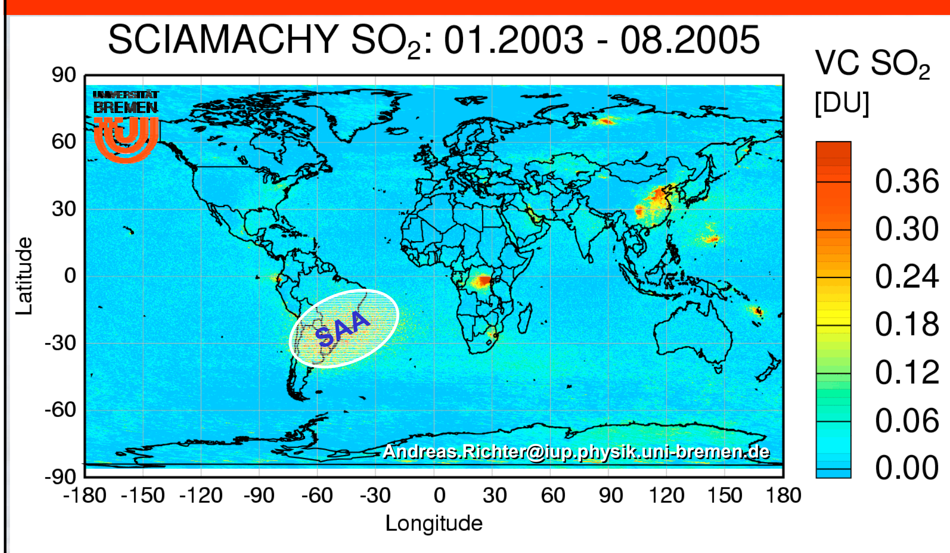
SO_2

Sulfur Dioxide

Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

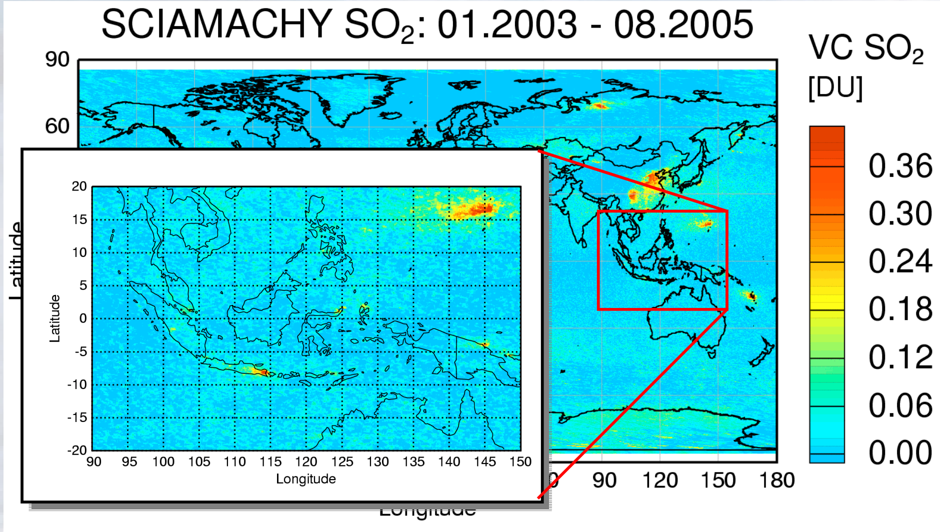
SCIAMACHY SO_2 measurements



Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

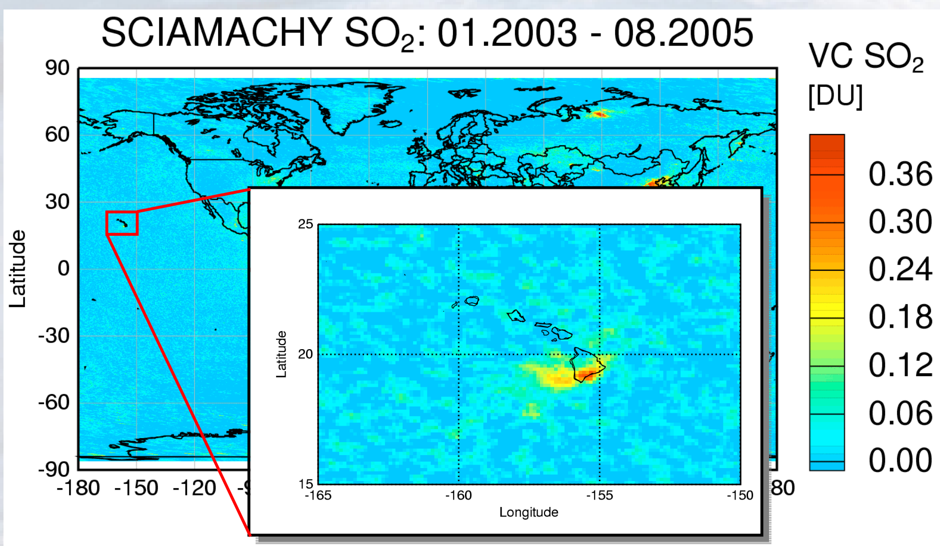
SCIAMACHY SO_2: Volcanic Emissions



Universität Bremen ife

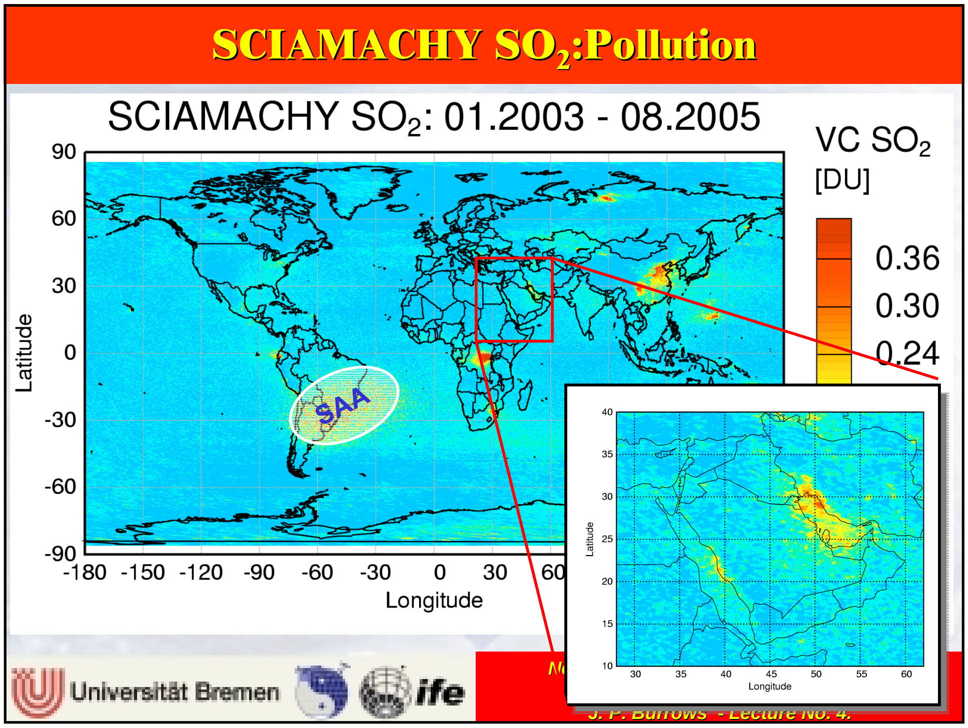
Noble Lectures - University of Toronto,
26-30th March 2007,
J. P. Burrows - Lecture No. 4.

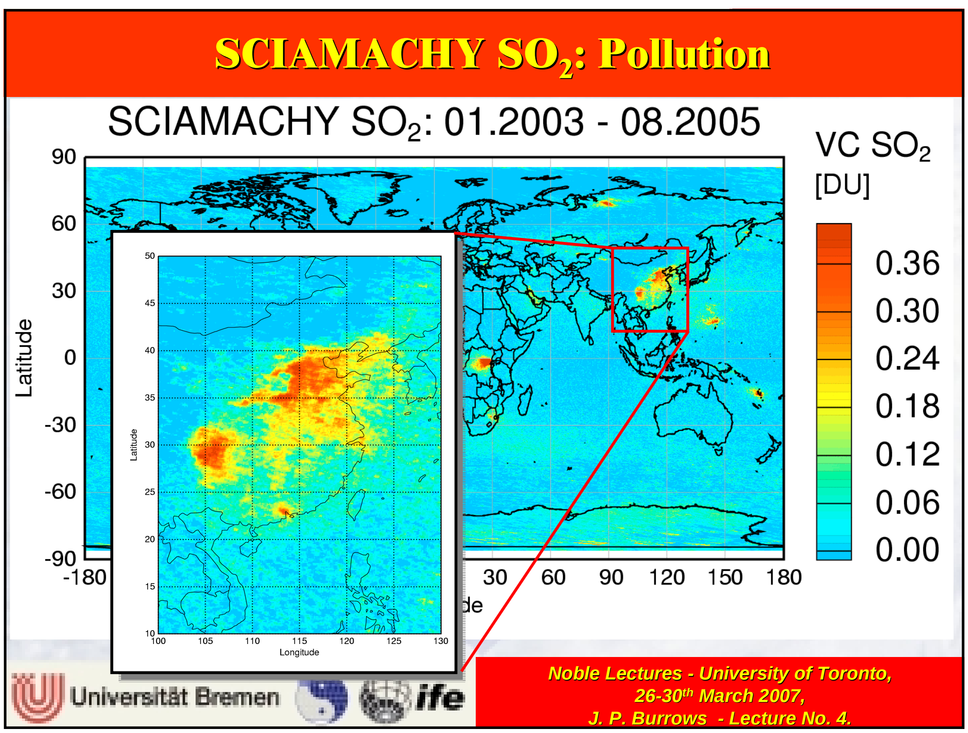
SCIAMACHY SO_2 : Volcanic Emissions



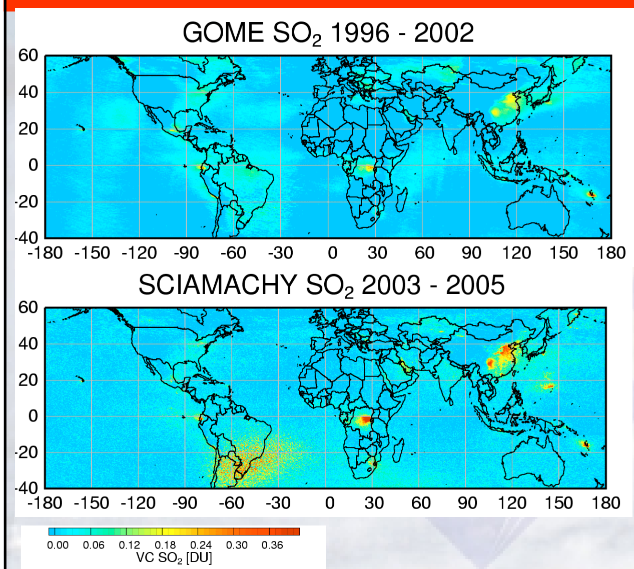
Universität Bremen ife

Noble Lectures - University of Toronto,
26-30th March 2007,
J. P. Burrows - Lecture No. 4.


SCIAMACHY SO_2:Pollution
SCIAMACHY SO_2: 01.2003 - 08.2005
VC SO_2 [DU]
0.36
0.30
0.24
Latitude
90
60
30
0
-30
-60
-90
-180 -150 -120 -90 -60 -30 0 30 60
Longitude
SAA
Universität Bremen
ife
J. P. Burrows - Lecture No. 4.


SCIAMACHY SO_2: Pollution
SCIAMACHY SO_2: 01.2003 - 08.2005
VC SO_2 [DU]
0.36
0.30
0.24
0.18
0.12
0.06
0.00
Latitude
90
60
30
0
-30
-60
-90
-180 30 60 90 120 150 180
Universität Bremen
ife
Noble Lectures - University of Toronto,
26-30th March 2007,
J. P. Burrows - Lecture No. 4.

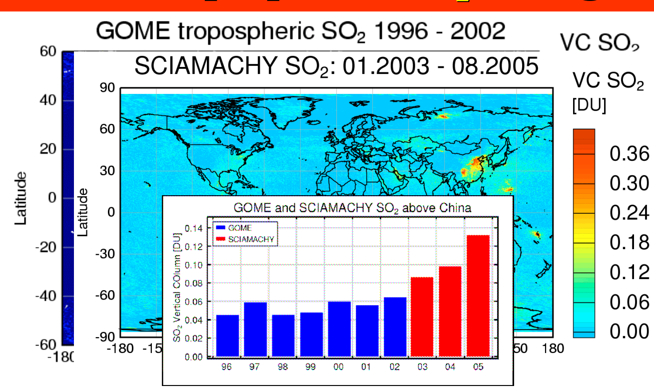
Comparison of GOME and SCIAMACHY SO_2



SCIAMACHY SO_2 has

- **overall similar values**
- **much more detail**
- **higher values over China**
- **slightly reduced columns over Europe and the US?**

Tropospheric SO_2: The global View



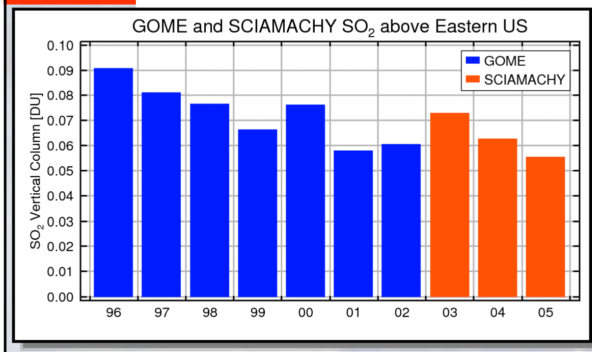
SO_2 sources:

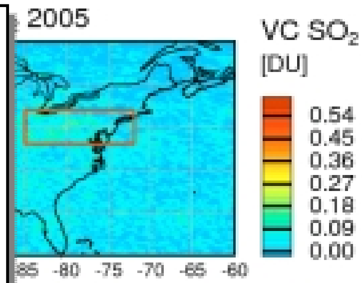
- volcanic eruptions
- coal fired power plants
- coal mine fires
- DMS (small)

Compared to NO_2, SO_2 columns have larger uncertainties:

- low signal (UV)
- small sensitivity to boundary layer
- strong interference by O_3 absorptions

Changes of SO_2 above Eastern US





- indication for a decrease in SO_2 above Eastern US
- high bias in SCIAMACHY measurements?
- this is not yet a quantitative result!

all values still based on "volcanic profile"!

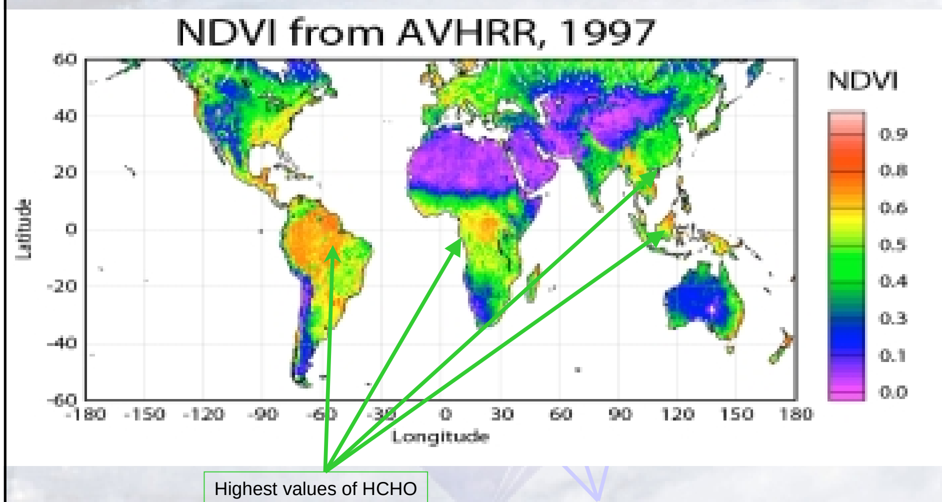
HCHO & CHOCHO

Formaldehyde

and

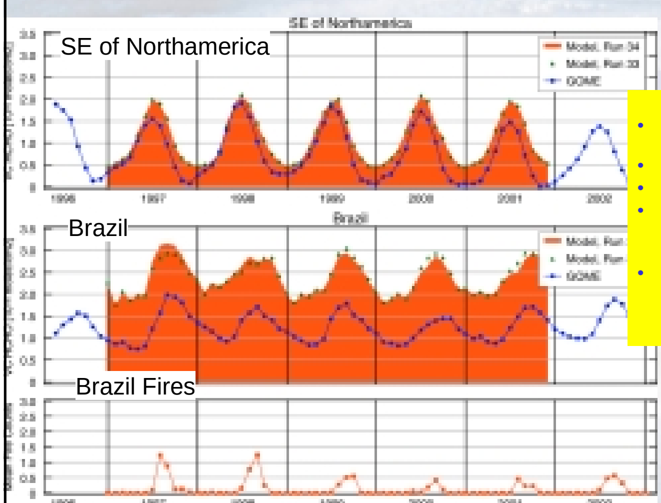
Glyoxal

What are the sources of HCHO?



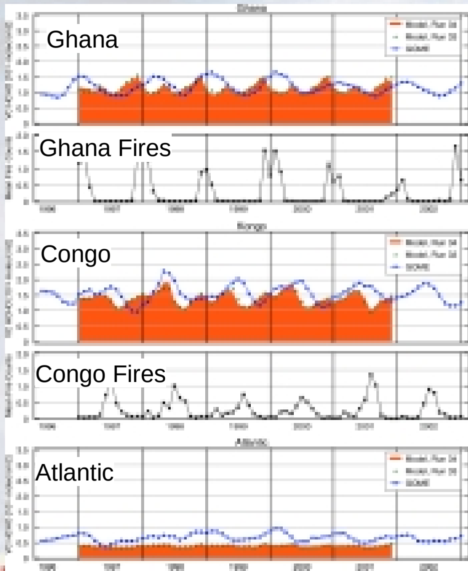
Main Biomass Burning Regions

Evolution of HCHO column amount from GOME



- BIRA Model – EU RETRO Project
- Fire count from ATSR-2 Data
- Good seasonal agreement
- Modelled South America HCHO is too small
- Production of Organic Aerosols from NMHC ↔ Oxidation in the liquid phase ??, Carlton et al., GRL, 2006

Evolution of HCHO column amount from GOME period

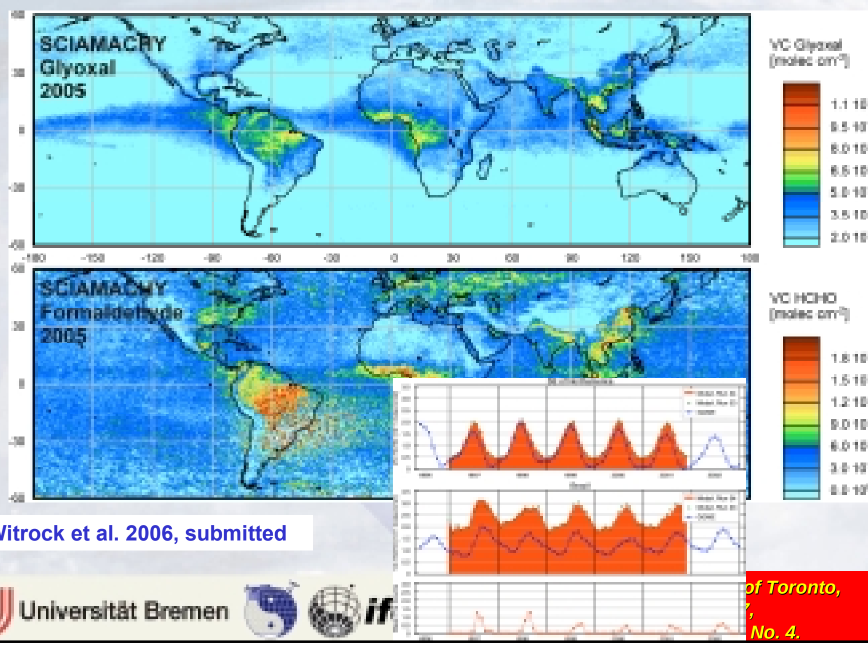


- Poor seasonal response– Problems in the Parameterisation e,g. Biomass Burning?
- Underestimate of model values over water?
- Transport from Biomass Burning less likely
  see fires in Congo

Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

VOC Oxidation Products: Formaldehyde and Glyoxal

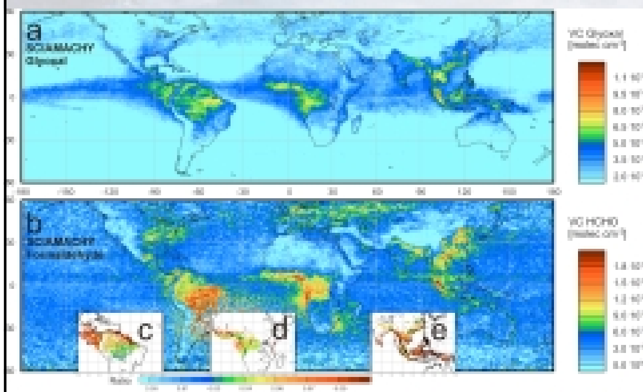


Witrock et al. 2006, submitted

Universität Bremen

of Toronto, ... No. 4.

SCIAMACHY: Glyoxal (CHO.CHO) and HCHO in 2005

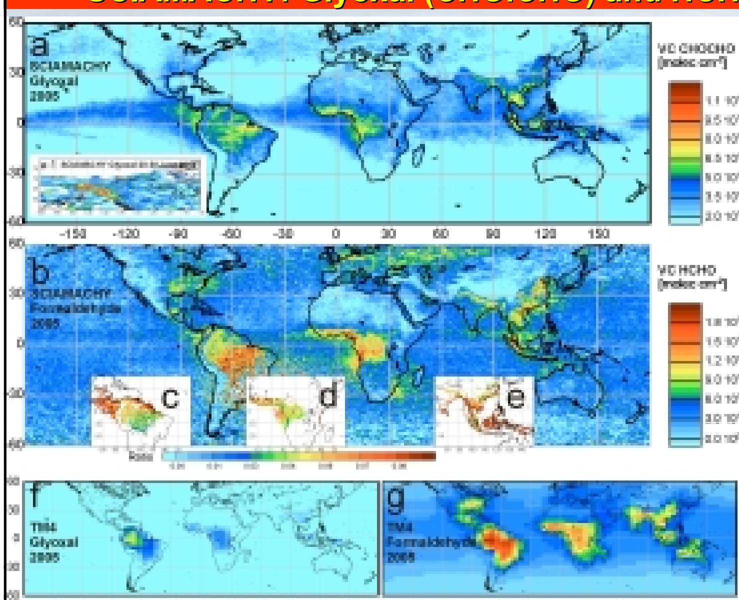


- biogenic emissions dominate simlar to HCHO
- anthropogenic sources and biomass burning can also be identified
- interesting features over water
- broad agreement with model predictions over land

R. Volkammer, P. Spietz, U. Platt and J. P. Burrows, High Resolution Absorption Spectra f CHO.CHO *J. Photochemistry and Photobiology: Chemistry* 2005
F. Wittrock et al., Simultaneous Global observations of Glyoxal and Formaldehyde from space, *Geophys. Res. Lett.*, 2006

=> CHOCHO / HCHO ratio varies and provides valuable information on VOC chemistry

SCIAMACHY: Glyoxal (CHO.CHO) and HCHO in 2005

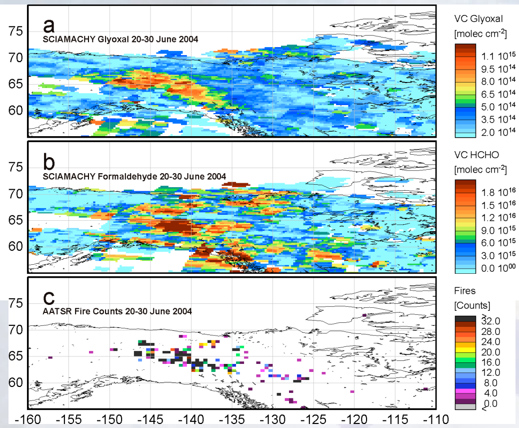


U. Crete TM4 + Chemistry

Additional sources of HCHO and CHO.CHO required over the ocean: Transport of loner lived VOC, release from SOA,

Local Sounce?

SCIAMACHY: CHOCHO and HCHO Asia and from a Fire



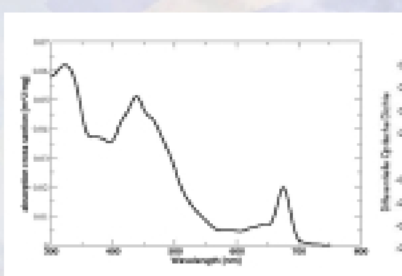
- **biogenic emissions result in large CHO.CHO and HCHO**
- **anthropogenic sources and biomass burning can also be identified**
- **CHOCHO / HCHO ratioscoupled NO2 and O3 yields valuable information on the oxidation of VOC and O3 production**
- **overall broad agreement with model predictions**

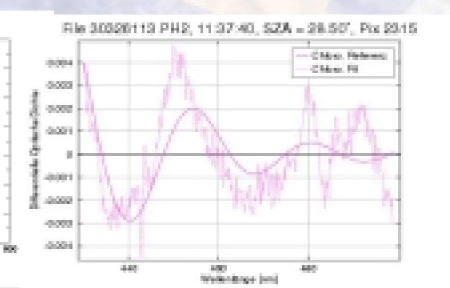
Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

DOAS fitting of chlorophyll

- **DOAS fit from 430 to 500 nm**
- **included in analysis: O_3, NO_2, H_2O (both vapor and liquid), Ring**
- **shows clear differential signal from photosynthetic pigments**
- **Poor fit quality using standard chlorophyll-a cross sections**





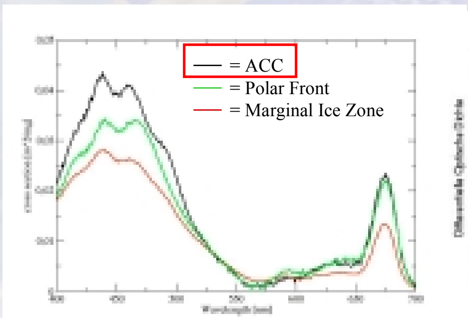
© by Bernd Sierk

Universität Bremen ife

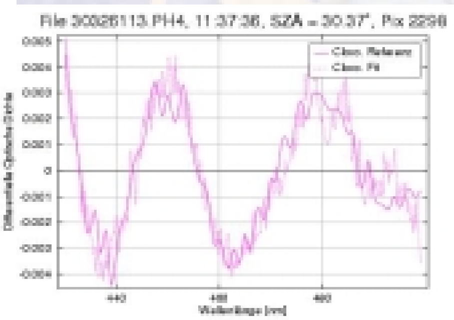
Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

Phytoplankton Absorption from SCIAMACHY

- **DOAS fit at 430 to 500 nm, *in vivo* measured absorption spectrum as reference (A. Bracher, Antarctic Circumpolar Current (ACC) in Southern Ocean)**
  - **Specific absorption varies significantly for biogeochemical provinces (due to different photosynthetic pigment composition)**
  - ***In vivo* reference spectra yield much better fits than chlorophyll-a**



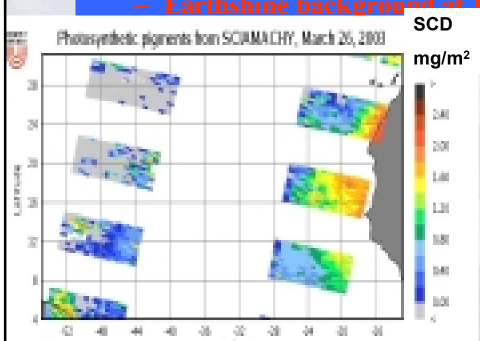
© by Astrid Bracher

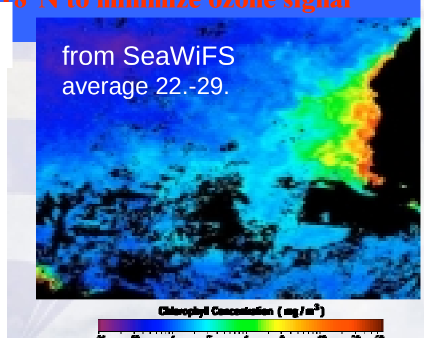


© by Bernd Sierk and Astrid Bracher

Marine photosynthetic pigment concentration

- In the tropical Atlantic on March 26th, 2003
  - Explosive phytoplankton bloom during up-welling event
  - Phytoplankton dominated by dinoflagellates and size class < 20 µm
  - Earthshine background at 18°N to minimize ozone signal



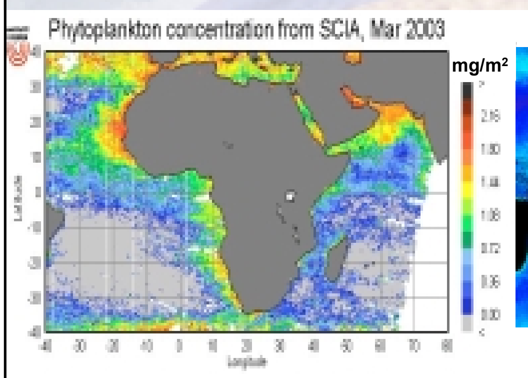


© by Bernd Sierk and Astrid Bracher

(http://seawifs.gsfc.nasa.gov/SEAWIFS.html)

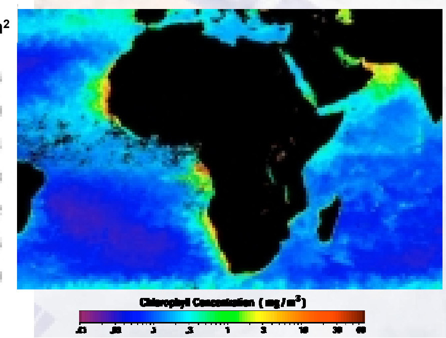
Monthly average of bloom event

- very good qualitative agreement between SCIA and SeaWIFS
- identified structures of elevated concentration mostly identical
- but: rather high concentrations above 30°N in SCIA image
- likely reason: residual ozone/polarisation spectral features



© by Bernd Sierk and Astrid Bracher

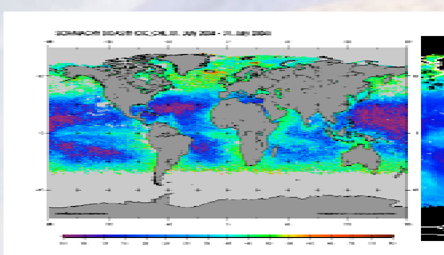
... and SeaWiFS



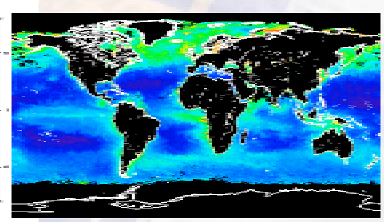
(http://seawifs.gsfc.nasa.gov/SEAWIFS.html)

Improvement by PCA

SCIAMACHY



SeaWIFS



© by Marco Vountas & Tilman Dinter

- large mediterranean chlorophyll values in SCIAMACHY results disappeared
- excellent agreement in all latitudes

Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

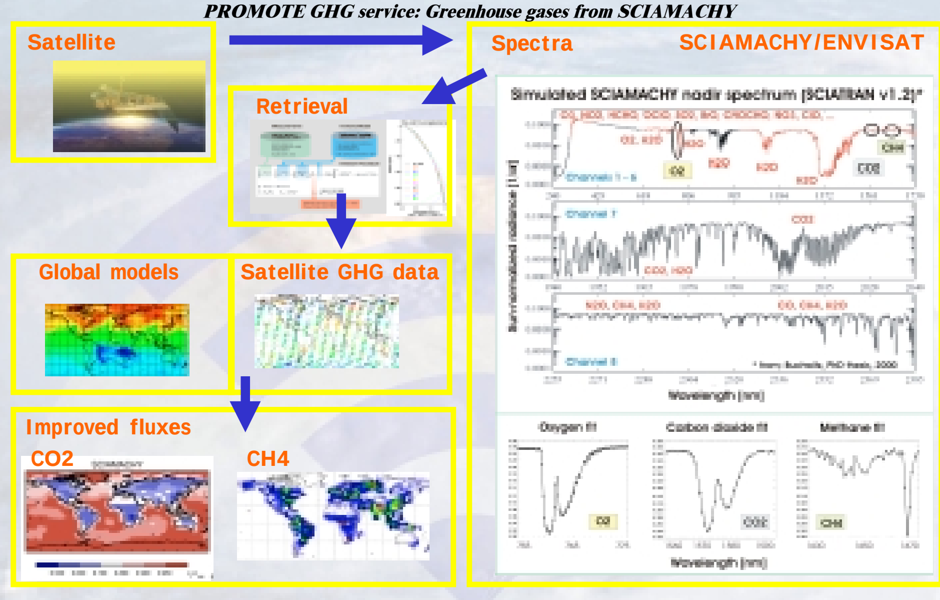
Retrieval of CO, CO2 and CH4

Note the concept of dry column

XCO2= CO2/O2

XCH4=CH2/CO2 or CH4/O2

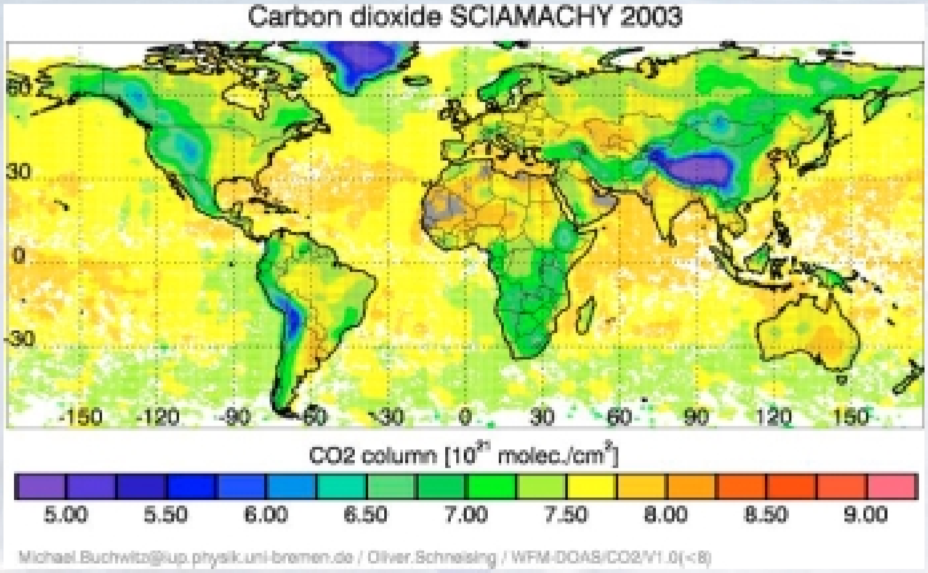
PROMOTE GHG service: Greenhouse gases from SCIAMACHY



Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

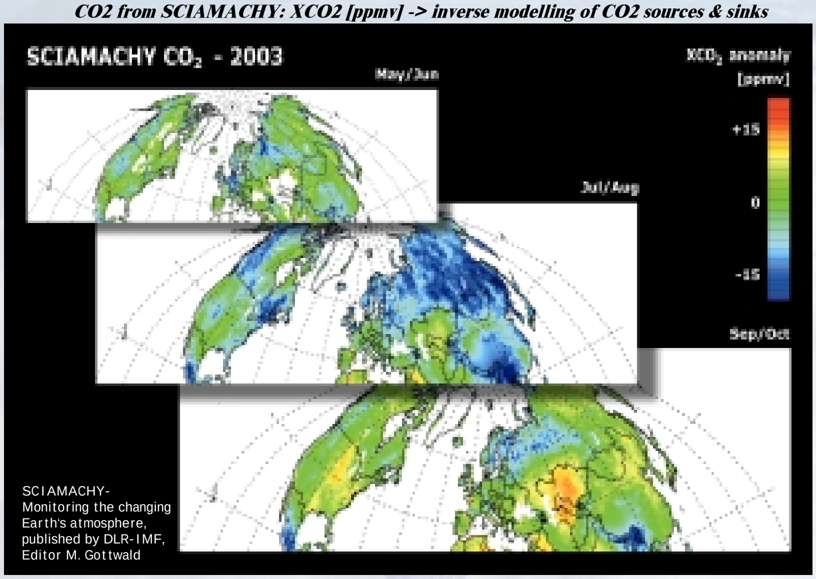
Carbon dioxide from SCIAMACHY: Absolute CO2 columns



Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

CO2 from SCIAMACHY: XCO2 [ppmv] -> inverse modelling of CO2 sources & sinks



WFMD version 0.4: Buchwitz et al., ACP, 2005a, 2005b

Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

Carbon dioxide from SCIAMACHY: Validation with FTS

SCIAMACHY

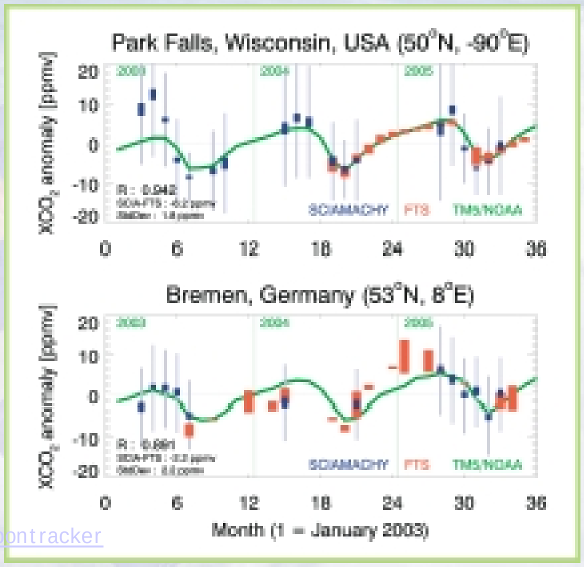
IUP-Bremen / PROMOTE
Buchwitz et al.

FTS

TCCON (Total Carbon Column Observing Network)
Park Falls: Washenfelder et al., 2006
Bremen: Notholt et al.

TM5 model NOAA

W. Peters, P. Tans et al.
http://www.cmdl.noaa.gov/carbontracker



Universität Bremen

Preliminary !

iversity of Toronto,
rch 2007,
J. P. Burrows - Lecture No. 4.

Carbon dioxide from SCIAMACHY: Comparison with TM5/NOAA

SCIAMACHY

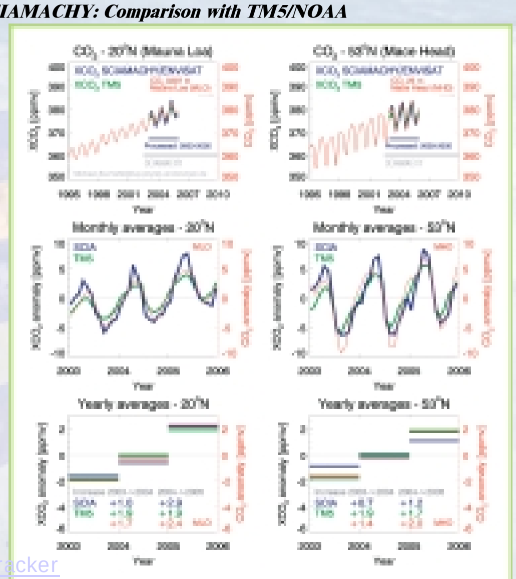
IUP-Bremen / PROMOTE
Buchwitz et al.

CO2 NOAA
flask sampling

T. Conway, P. Tans et al.

TM5 model NOAA

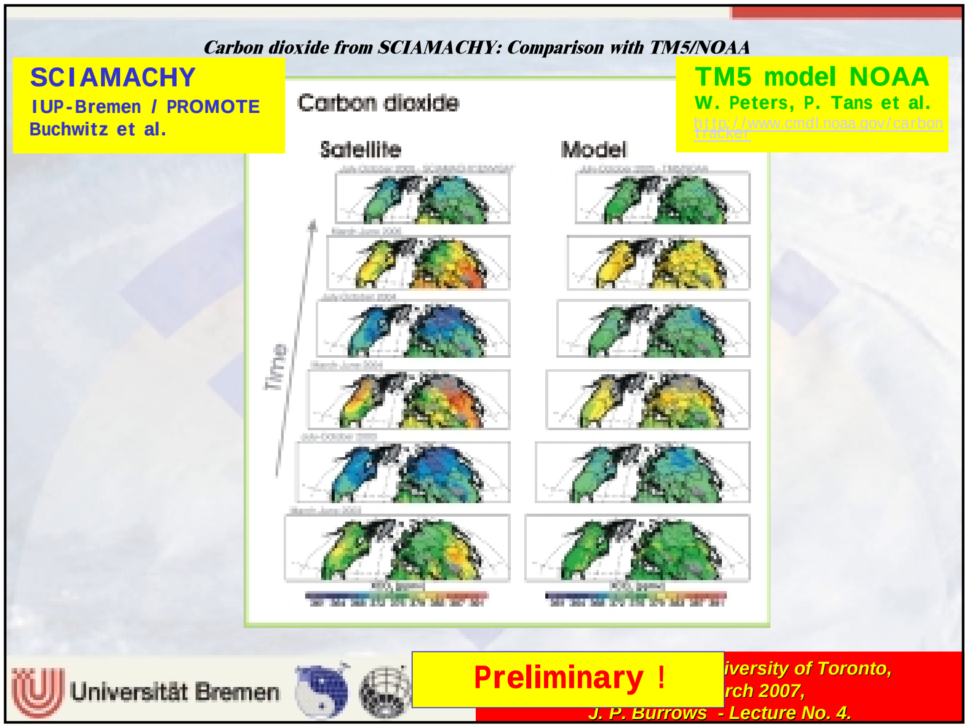
W. Peters, P. Tans et al.
http://www.cmdl.noaa.gov/carbontracker

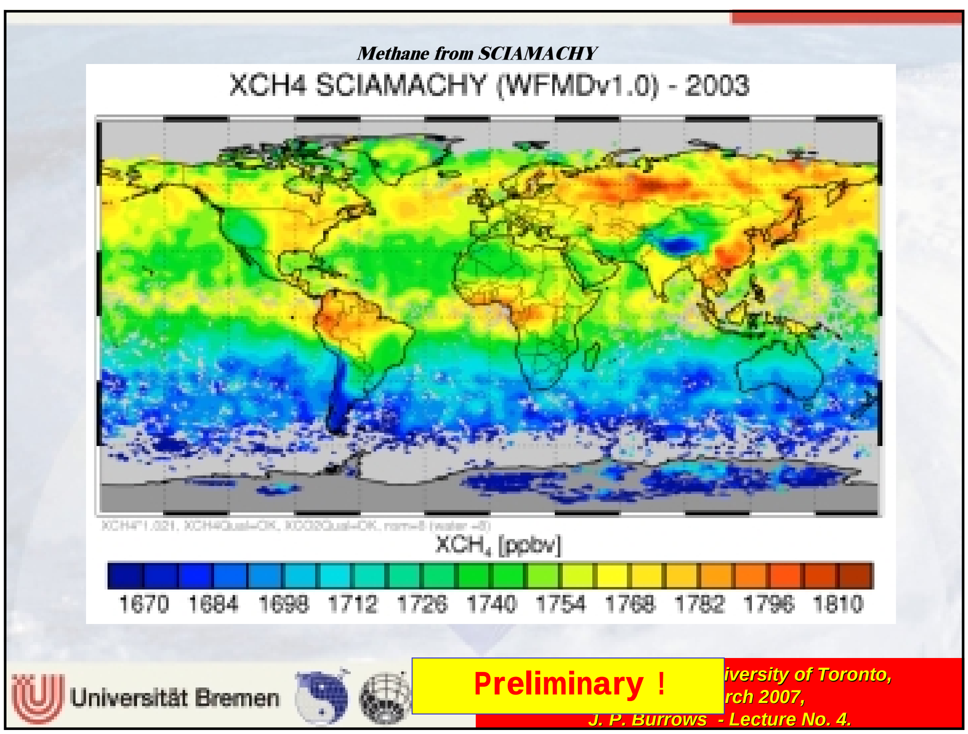


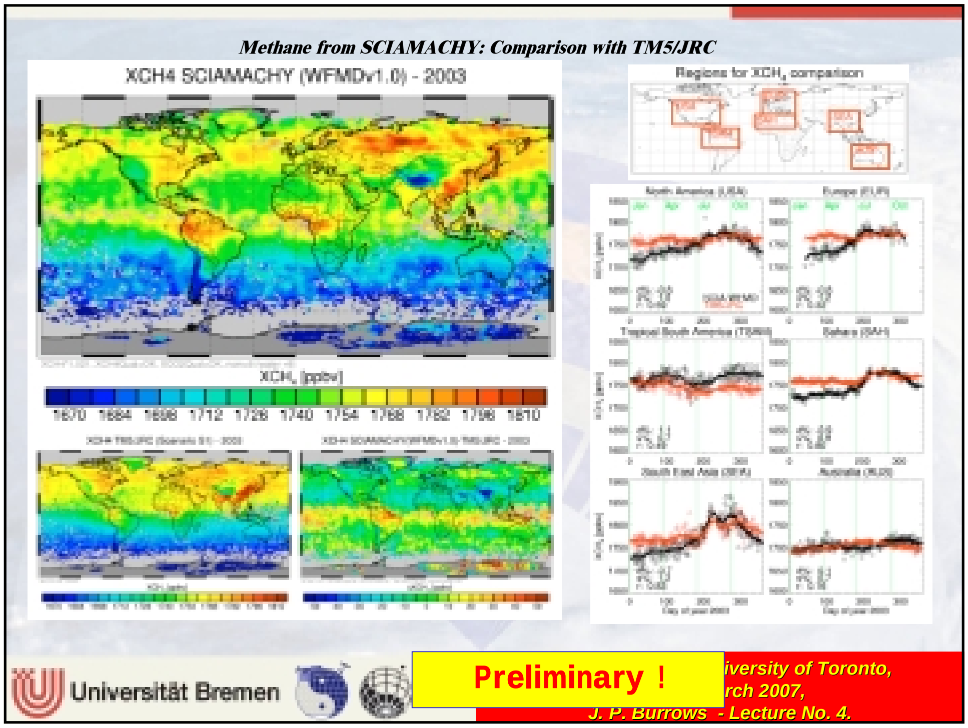
Universität Bremen

Preliminary !

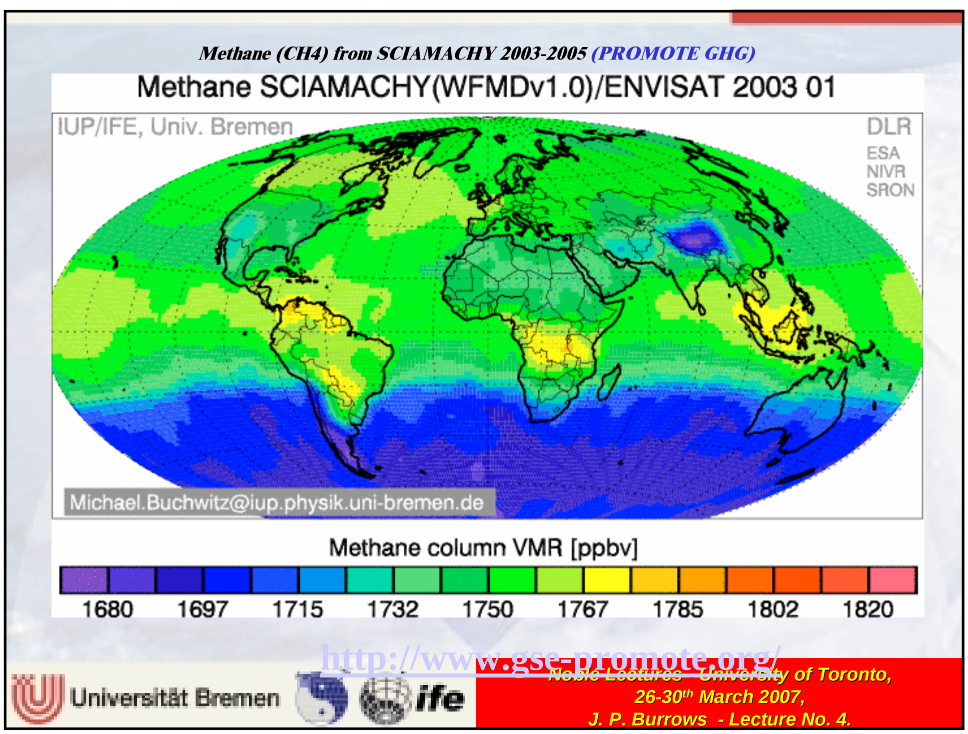
iversity of Toronto,
rch 2007,
J. P. Burrows - Lecture No. 4.


Carbon dioxide from SCIAMACHY: Comparison with TM5/NOAA
SCIAMACHY
IUP-Bremen / PROMOTE
Buchwitz et al.
TM5 model NOAA
W. Peters, P. Tans et al.
Carbon dioxide
Satellite
Model
Time
Universität Bremen
Preliminary !
iversity of Toronto,
rch 2007,
J. P. Burrows - Lecture No. 4.


Methane from SCIAMACHY
XCH4 SCIAMACHY (WFMDv1.0) - 2003
XCH4 [ppbv]
1670 1684 1698 1712 1726 1740 1754 1768 1782 1796 1810
Universität Bremen
Preliminary !
iversity of Toronto,
rch 2007,
J. P. Burrows - Lecture No. 4.

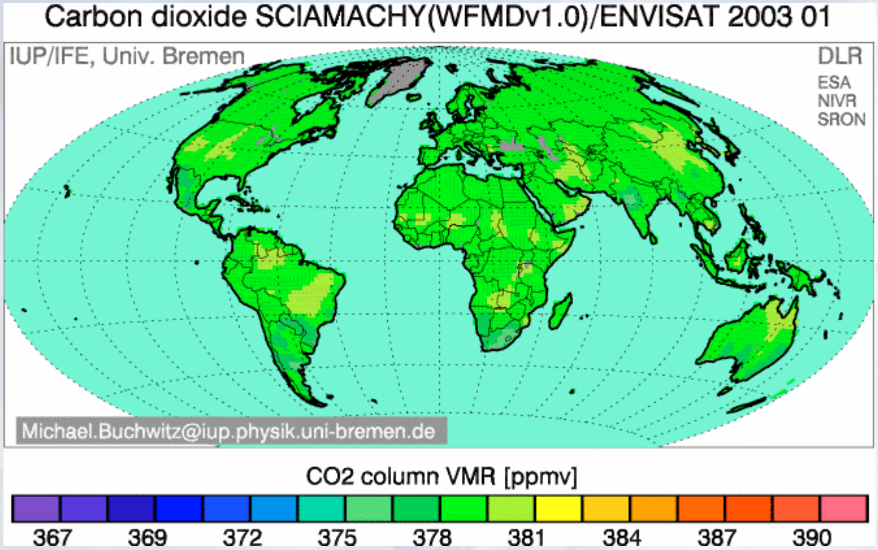


Methane from SCIAMACHY: Comparison with TM5/JRC
XCH4 SCIAMACHY (WFMDv1.0) - 2003
XCH4 [ppbv]
1670 1684 1698 1712 1726 1740 1754 1768 1782 1796 1810
Regions for XCH4 comparison
North America (USA)
Europe (EUR)
Tropical South America (TSAM)
Sahara (SAH)
South East Asia (SEA)
Australia (AUS)
Preliminary !
Universität Bremen
iversity of Toronto,
rch 2007,
J. P. Burrows - Lecture No. 4.



Methane (CH4) from SCIAMACHY 2003-2005 (PROMOTE GHG)
Methane SCIAMACHY(WFMDv1.0)/ENVISAT 2003 01
IUP/IFE, Univ. Bremen
DLR
ESA
NIVR
SRON
Michael.Buchwitz@iup.physik.uni-bremen.de
Methane column VMR [ppbv]
1680 1697 1715 1732 1750 1767 1785 1802 1820
http://www.gse-promote.org/
Noble Lectures - University of Toronto,
26-30th March 2007,
J. P. Burrows - Lecture No. 4.
Universität Bremen
ife

Carbon dioxide (CO2) from SCIAMACHY 2003-2005 (PROMOTE GHG)

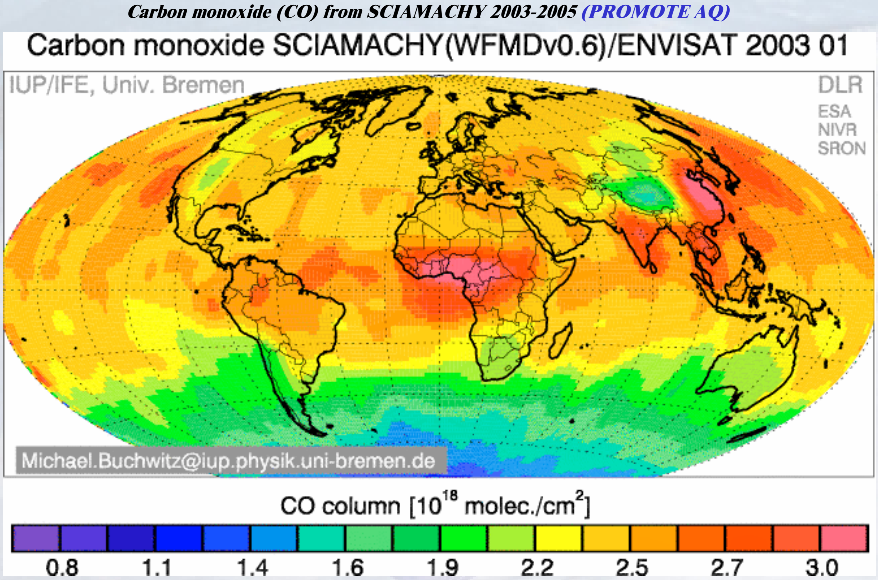


http://www.gse-promote.org/

Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

Carbon monoxide (CO) from SCIAMACHY 2003-2005 (PROMOTE AQ)



http://www.gse-promote.org/

Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

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

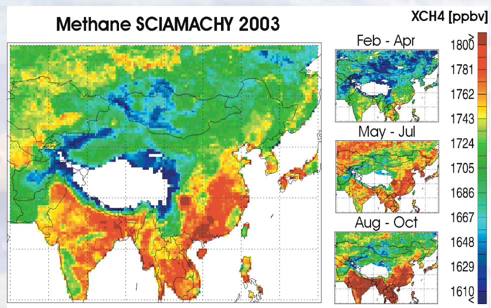
Data products:

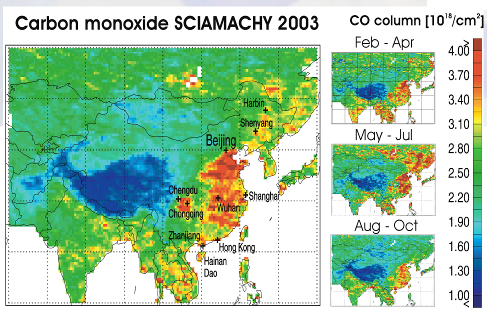
Methane VMR (XCH4 = CH4-column/aircolumn)

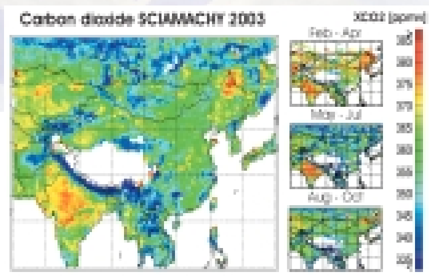
Carbon monoxide column (molecules/cm^2)

Carbon dioxide VMR (XCO2 = CO2-column/aircolumn)

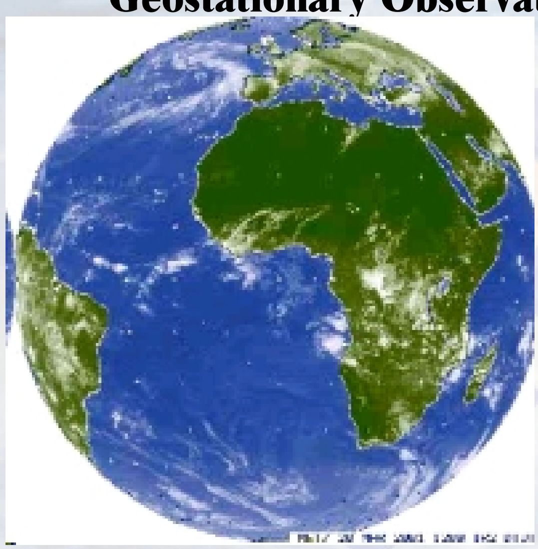
Details latest versions: de Beek et al., ACPD, 2006







Geostationary Observations



- Meteosat
- 0° Longitude
- 20.-23.3.01

Universität Bremen

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

Geostationary Observations

- Meteosat
- 0° Longitude
- 20.-23.3.01

Tropospheric Composition, Dynamics and Air Quality from Space

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

In the 25 years – demonstrated potential

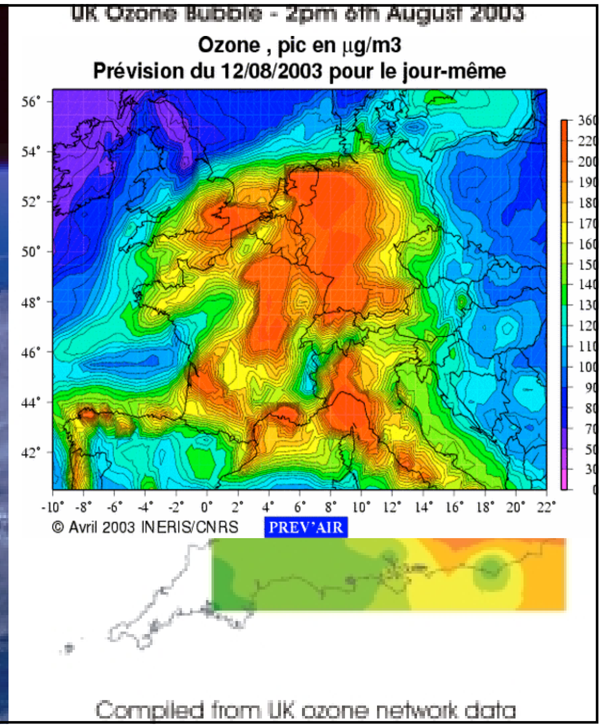
From LEO and some Aerosol products from GEO

Evolving Instrument Technologies and User Needs!

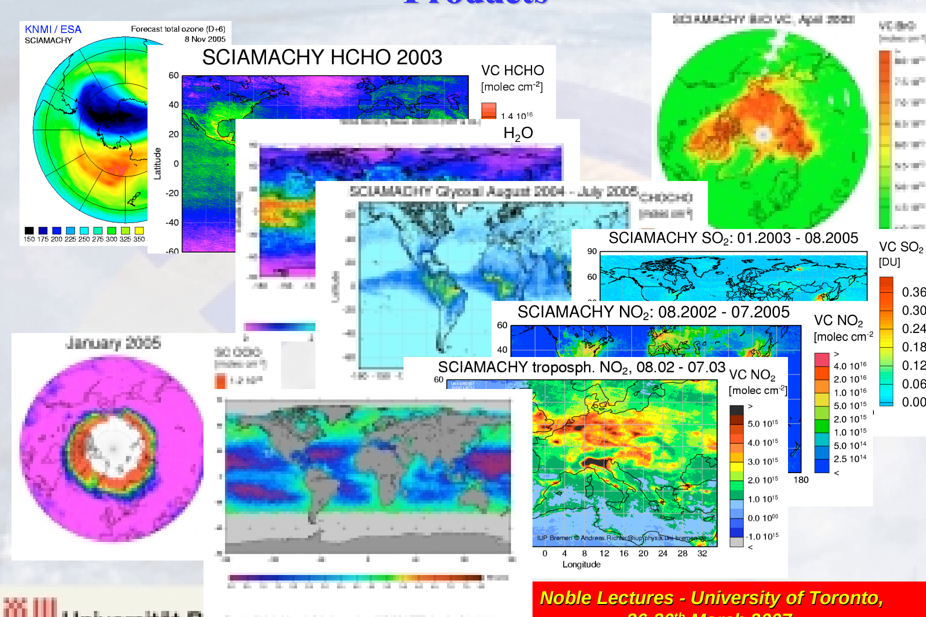
The Troposphere and PBL is complex and sits under the stratosphere and mesosphere!

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/m³ level*
  - *Ozone Information threshold April to August 2003 © EEA 2003*



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



Universität B

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

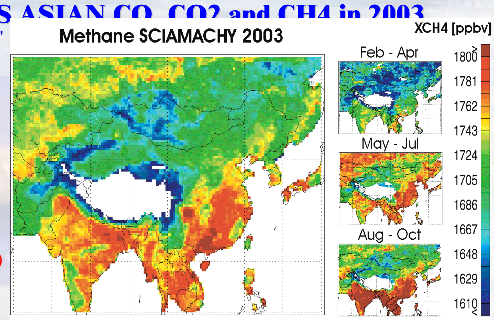
Data products:

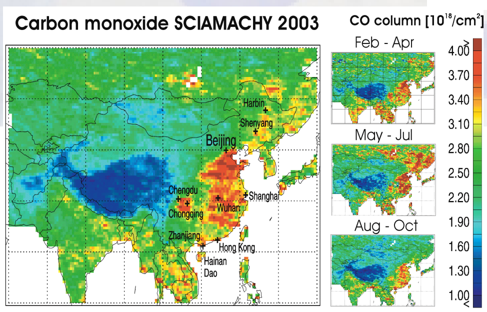
Methane VMR (XCH4 = CH4-column/aircolumn)

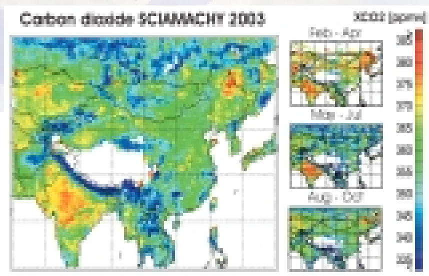
Carbon monoxide column (molecules/cm^2)

Carbon dioxide VMR (XCO2 = CO2-column/aircolumn)

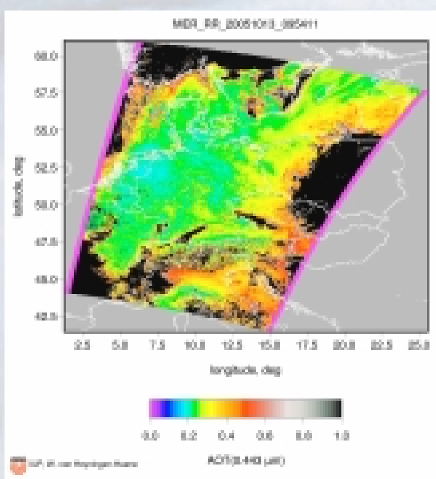
Details latest versions: de Beek et al., ACPD, 2006

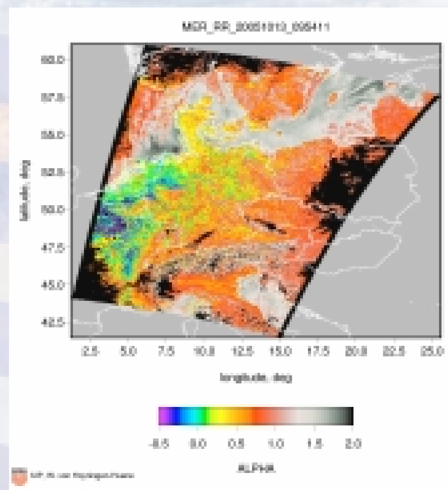




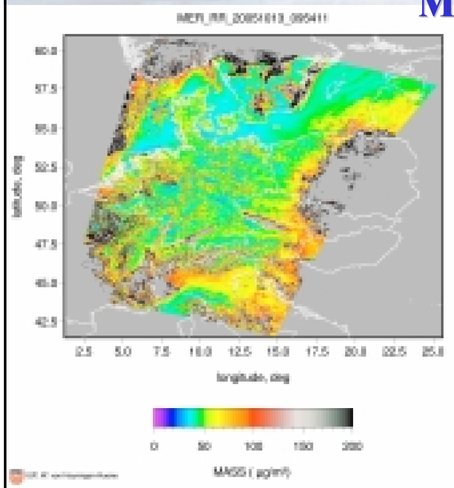


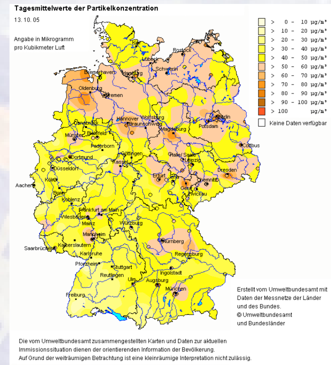
Synergy on ENVISAT MERIS : Simultaneous Data about Aerosols AOT + ALPHA





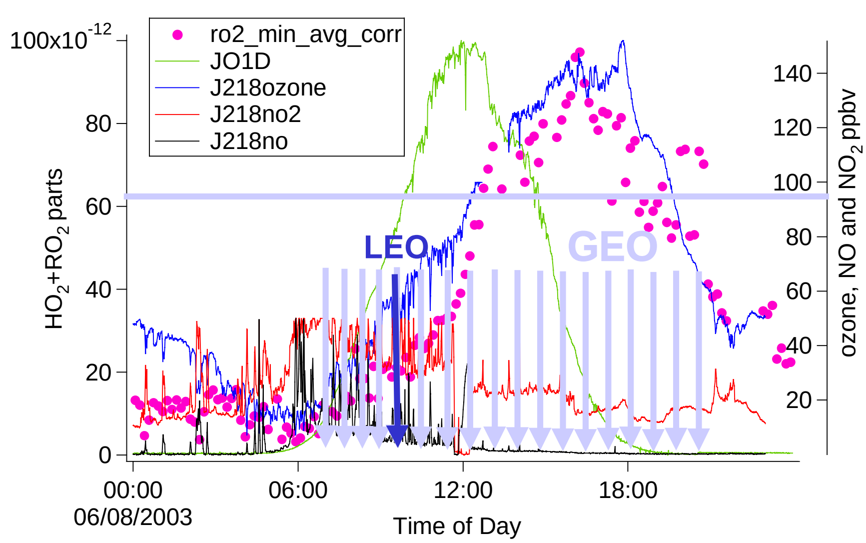
UB - Derived Research Product Particulate Matter





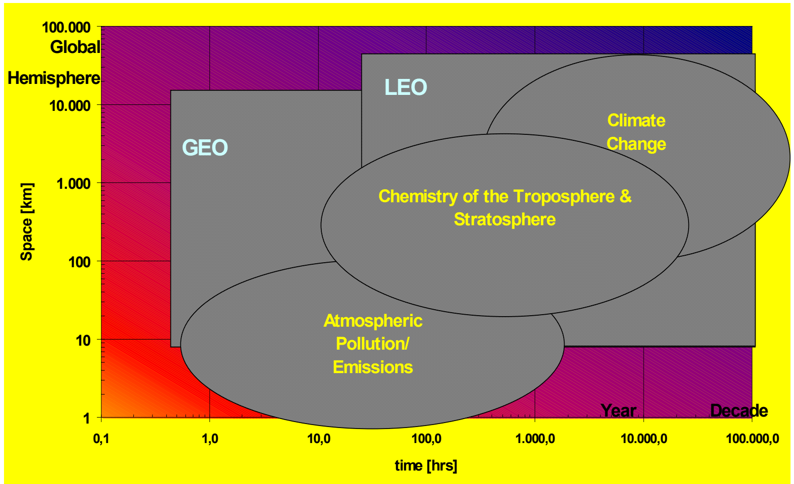
Universität Bremen ife

Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

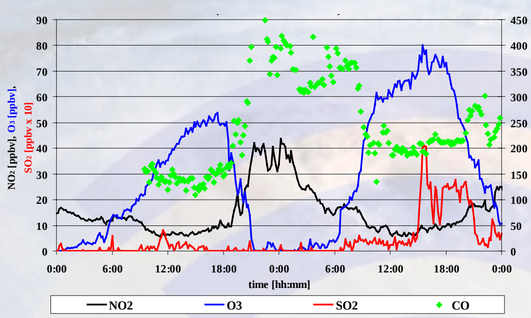


- UK AQ HIGH BAND FOR OZONE

LEO & GEO

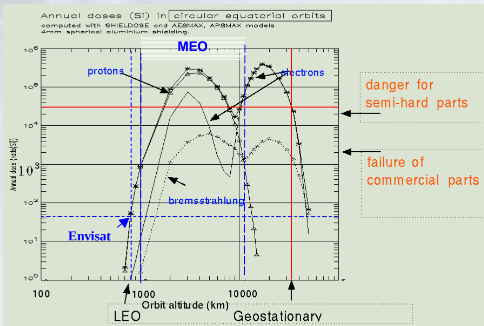


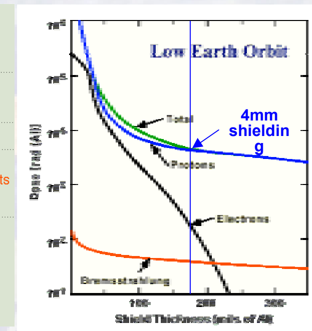
Diurnal Variability of Trace Gases and Constituent



- 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

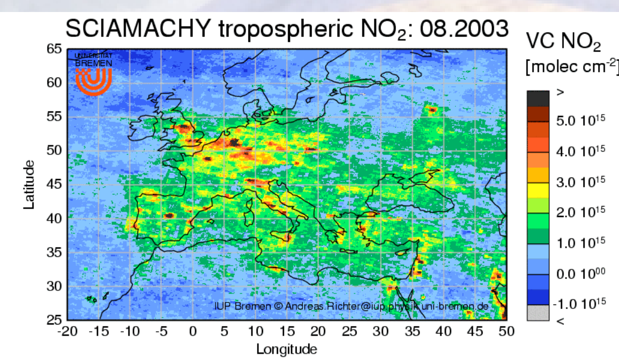


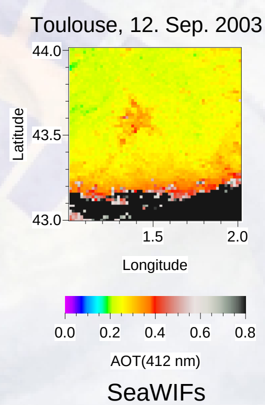


- Most Critical for long lifetime are the high energy photons
- MEO critical w.r.t. high proton radiation dose – electronic problems.
- GEO is a very favourable orbit

© Figure courtesy EADS Astrium

Solar Backscatter Sounding from Geostationary Orbit





European Air Quality Management and Forecast: Concept

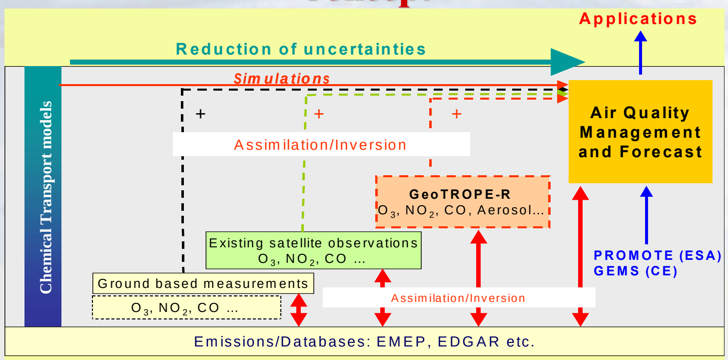
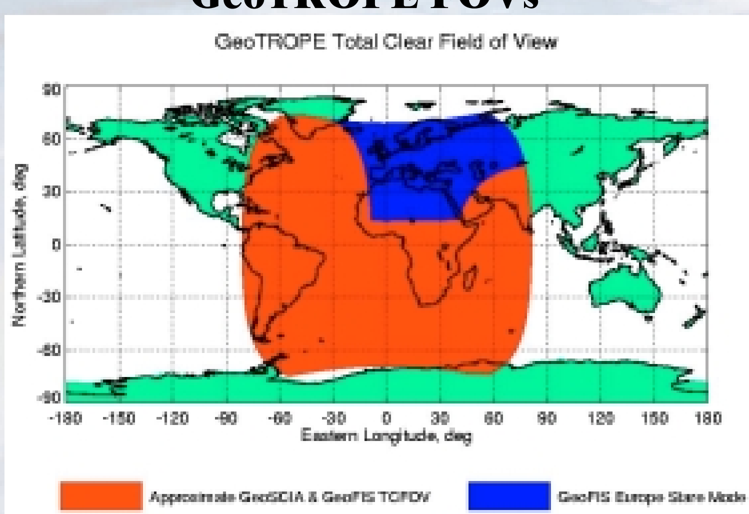


Figure: G. Bergametti, modified by H. Bovensmann).

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.

GeoTROPE FOVs



Universität Bremen ife
Noble Lectures - University of Toronto, 26-30th March 2007, J. P. Burrows - Lecture No. 4.

GeoSCIA @ GeoTROPE

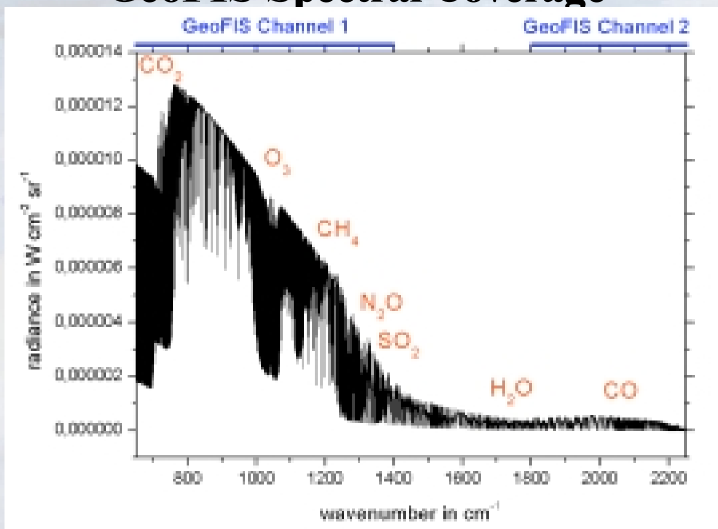
- Imaging spectrometer using 2D CCDs, (GSD: 11.4 x 23 km^2 – 23 x 23 km^2) provided by DLR
- GOME, SCIAMACHY, OMI heritage
- UV-Vis spectral window: 270 nm - 560 nm (O_3(h), NO_2, SO_2, BrO, HCHO, O_4, Aerosol),
- NIR spectral window: 755 nm - 780 nm (mean photon path, cloud cover, cloud top height, cloud optical thickness, aerosol layer scattering height)
- SWIR spectral windows: optimised around 2 µm (CO_2, H_2O) and around 2.35 µm (CO, CH_4, H_2O, Aerosol)
- Polarisation Measurement System PMS to measure polarised and unpolarised radiance (300 – 850 nm) primarily for polarisation correction of the measured upwelling radiance and enhanced Aerosol products
- Tropospheric column information will be derived by residual methods and multi-spectral retrieval

GeoFIS @ GeoTROPE

- Fourier transform infrared spectrometer (GSD: 15 x 15 km^2) provided by CNES
- IASI/METOP heritage
- spectral range from 4.4 µm to 5.6 µm and from 7.1 µm to 15 µm with approx. 0.25 cm^{-1} spectral resolution.
- HgCdTe large focal plane array (LFPA) detectors
- GeoFIS adds during both day and night:
  - Improved tropospheric vertical distributions for O_3, CO, CH_4, H_2O
  - Tropospheric columns of C_2H_2 and C_2H_6
  - Vertical Profiles of H_2O and temperature
- The combination of solar backscatter and thermal

Universität Bremen ife
Noble Lectures - University of Toronto,
26-30th March 2007,
J. P. Burrows - Lecture No. 4.

GeoFIS Spectral Coverage



First Sensitivity Studies

- Goal: Estimate - based on given instrument performance (SNR, spectral parameters etc.) - the mean noise-induced error on geophysical parameters
- Method: Radiative transfer simulation, instrument model and retrieval algorithm („Optimal Estimation“) used to calculate the error on the geophysical parameters
- Method already applied in various sensitivity studies in the MIPAS, GOME, GOME-2 and SCIAMACHY projects

- UV-VIS-NIR: O_3, NO_2, SO_2, HCHO (V. Rozanov, K.U. Eichmann, R. deBeek)
- SWIR: CO, CO_2, CH_4, H_2O (M. Buchwitz, V. Rozanov, K.U. Eichmann)
- Combined GeoFIS - GeoSCIA: O_3, CO, CH_4, H_2O (IFE, IMK)

Universität Bremen ife
Noble Lectures - University of Toronto,
26-30th March 2007,
J. P. Burrows - Lecture No. 4.

GeoSCIA Precisions: Trace Gases

Parameter	Precision Single Measurement	
	Goal	GeoSCIA Estimate
O_3	2 - 10 %	2 TC 5-10 TrC
CO	10 %	10 %
CH_4	1 – 5 %	1 %
NO_2	20 %	5 – 15 %
SO_2	10 [1)] %	10 – 20%
HCHO	20[1),2)] %	10-20 %
BrO	20 %	20 - 30 %
H_2O	2 %	2 %
CO_2	1 %	1 %
Strat. O3 profile	10%	5-10%

GeoSCIA Precisions Cloud/Aerosol

Parameter	Precision Single Measurement	
	Goal	GeoSCIA Estimate
Cloud Top Height	200 -500 m	300 m
Fractional Cloud Cover	0.02 – 0.05	0.05
Aerosol Layer Height	500 m	500 m
Aerosol Optical Depth	0.05 – 0.2	0.1

GeoSCIA/GeoFIS combined retrieval

Species		Vertical layers boundaries		
		0–2 km	2-7 km	7-15 km
O_3 *TIR+SB*		5-10 %	5 %	5 %
	TIR	*28 %*	*13 %*	*6.6 %*
CO *TIR+SB*		10 %	< 10 %	< 10 %
	TIR	*24 %*	*10%*	*6.6 %*
CH_4 *TIR+SB*		2 %	1 %	1 %
	TIR	*7.1 %*	*3 %*	*2.6 %*
H_2O *TIR+SB*		< 1%	< 1%	< 1%
	TIR	*1.2 %*	*1.1 %*	*2.8 %*

Other GEO Concepts

- **GOMAS: Geostationary Observatory for Microwave Atmospheric Sounding (Bizarri et al.): temperature, humidity, ice clouds etc.**
- **GIFTS: Geostationary Imaging FTS: temperature, humidity, O_3, CO**
- **Geostationary Global Pollution Mapper (Fishman et al.)/GeoTRACE: similar to GeoTROPE concept, but no IR FTS**

Summary

- synoptic data is required for monitoring and forecasts of short-term variations of atmospheric composition:
  - Air Pollution, quantification and monitoring of emissions to the troposphere,
  - biomass burning,
  - stratospheric ozone variability (application UV fields),
  - volcanic eruptions.
- Synoptic data sets can be delivered from geostationary observation
- Instrument concepts, based on the heritage from LEO instrumentation are feasible and will yield measurements with the required precisions.
- The combination of solar backscatter with IR emission measurements enhances significantly the precisions in the lower troposphere (0-2 km), which is important to reach the required precision in this layer.
- *Technology and methodo*