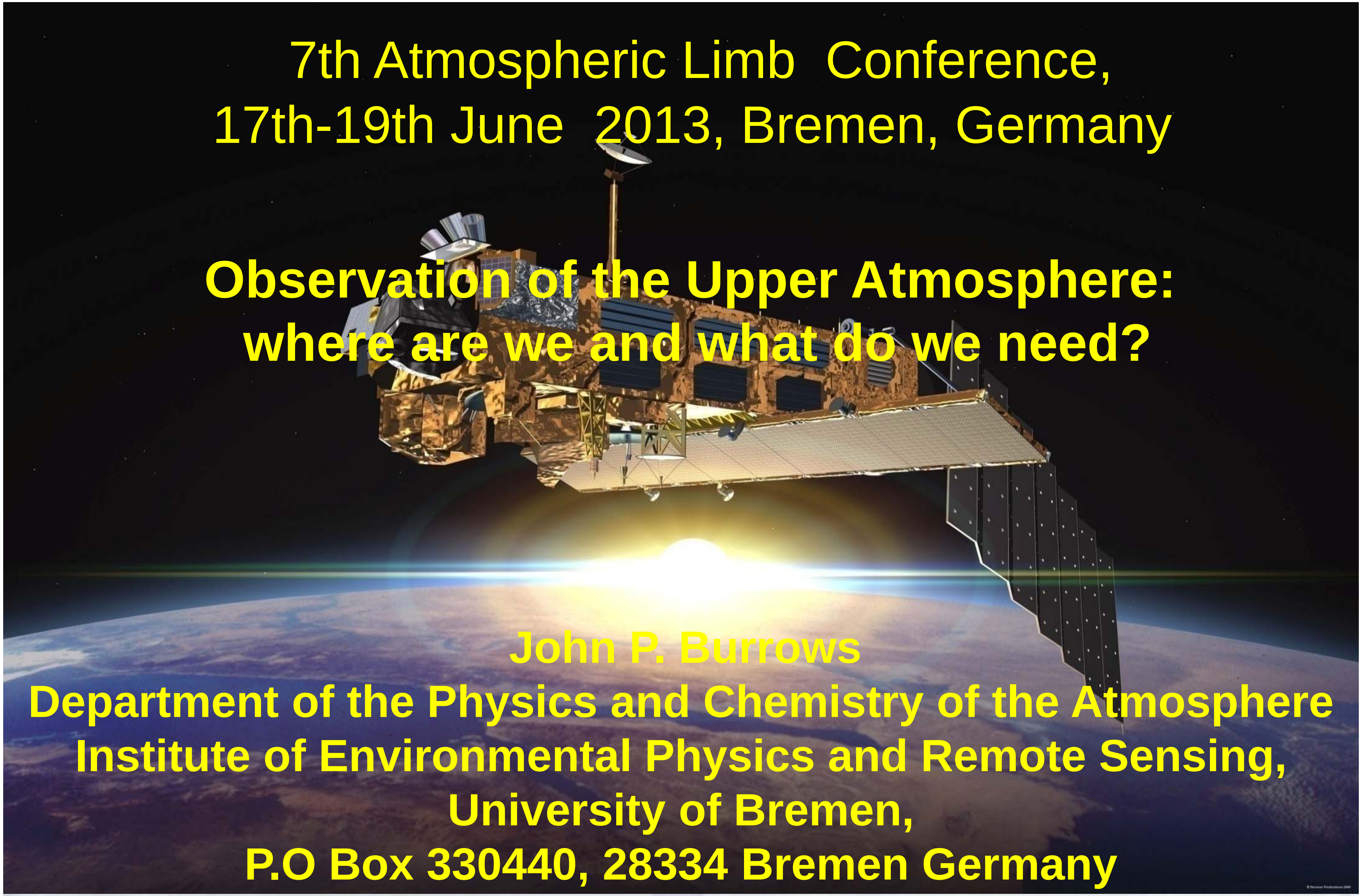


7th Atmospheric Limb Conference,
17th-19th June 2013, Bremen, Germany

Observation of the Upper Atmosphere: where are we and what do we need?

John P. Burrows
Department of the Physics and Chemistry of the Atmosphere
Institute of Environmental Physics and Remote Sensing,
University of Bremen,
P.O Box 330440, 28334 Bremen Germany

Universität Bremen

ACCENT
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK OF EXCELLENCE

Why observe the atmosphere from space?

Conditions in the biosphere and the depend on the interactions of the Sun, the atmosphere, and earth‘s surface and their non linear feedback.

Dramatic changes in population and anthropogenic emissions since 1800!

2 Billion more People since SCIAMACHY proposed - total now over 7 Billion

Anthropocene Mankind is changing the Earth-Atmosphere system → Changes in

- ⇨ **Global transport and transformation of pollution**
- ⇨ **Climate Change - Chemistry climate feedback**
- ⇨ **Global destruction of stratospheric ozone**

⇨ **It is impossible understand or manage what is not measured!!**

⇨ **Environmental/Climate Change requires Global Observations**

⇨ **Evidence base for testing understanding and policymaking.**

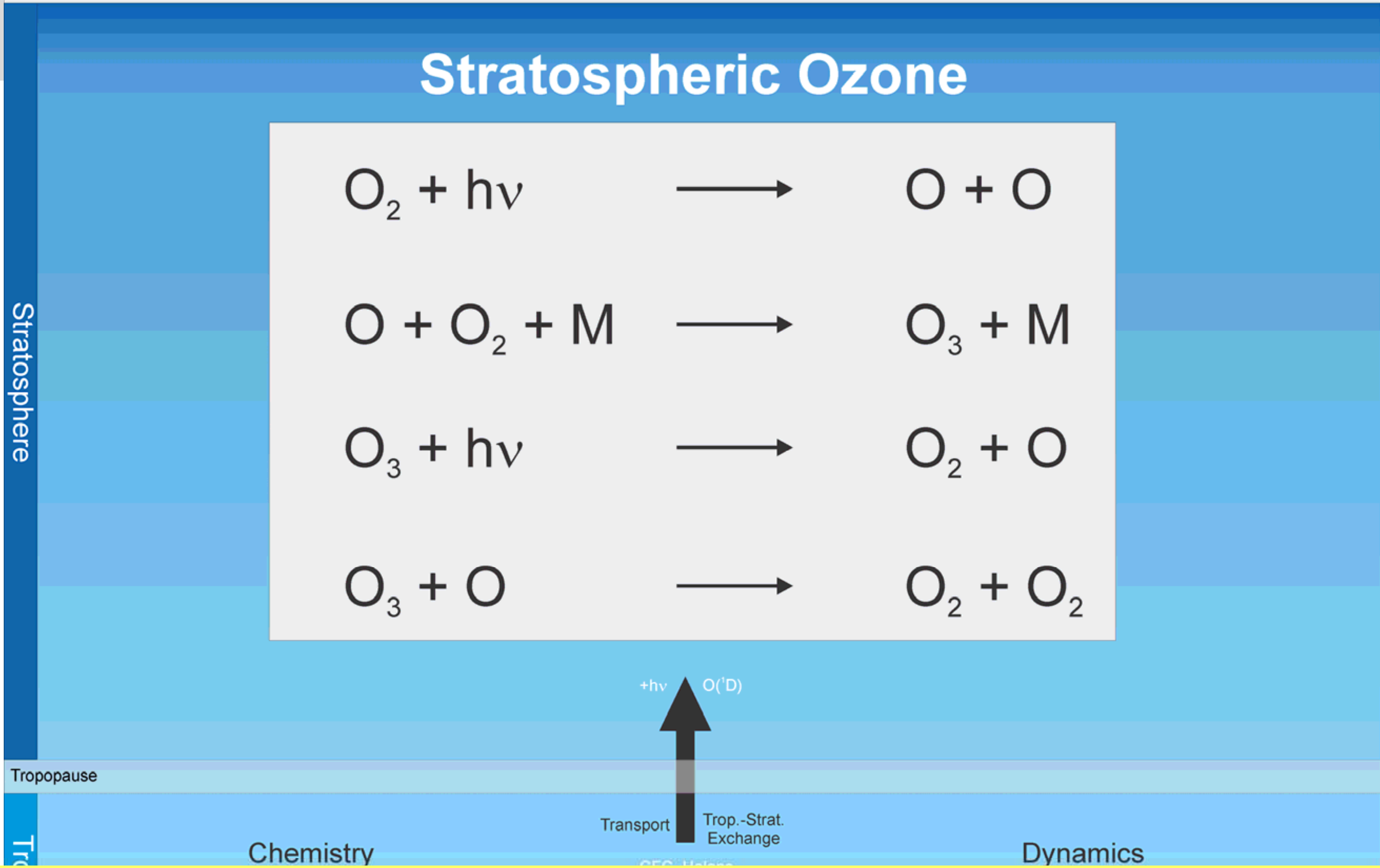
Contents

- *Introduction*
- *SCIAMACHY Limb and Occultaiton*
- *Results*
- *Summary*

Universität Bremen

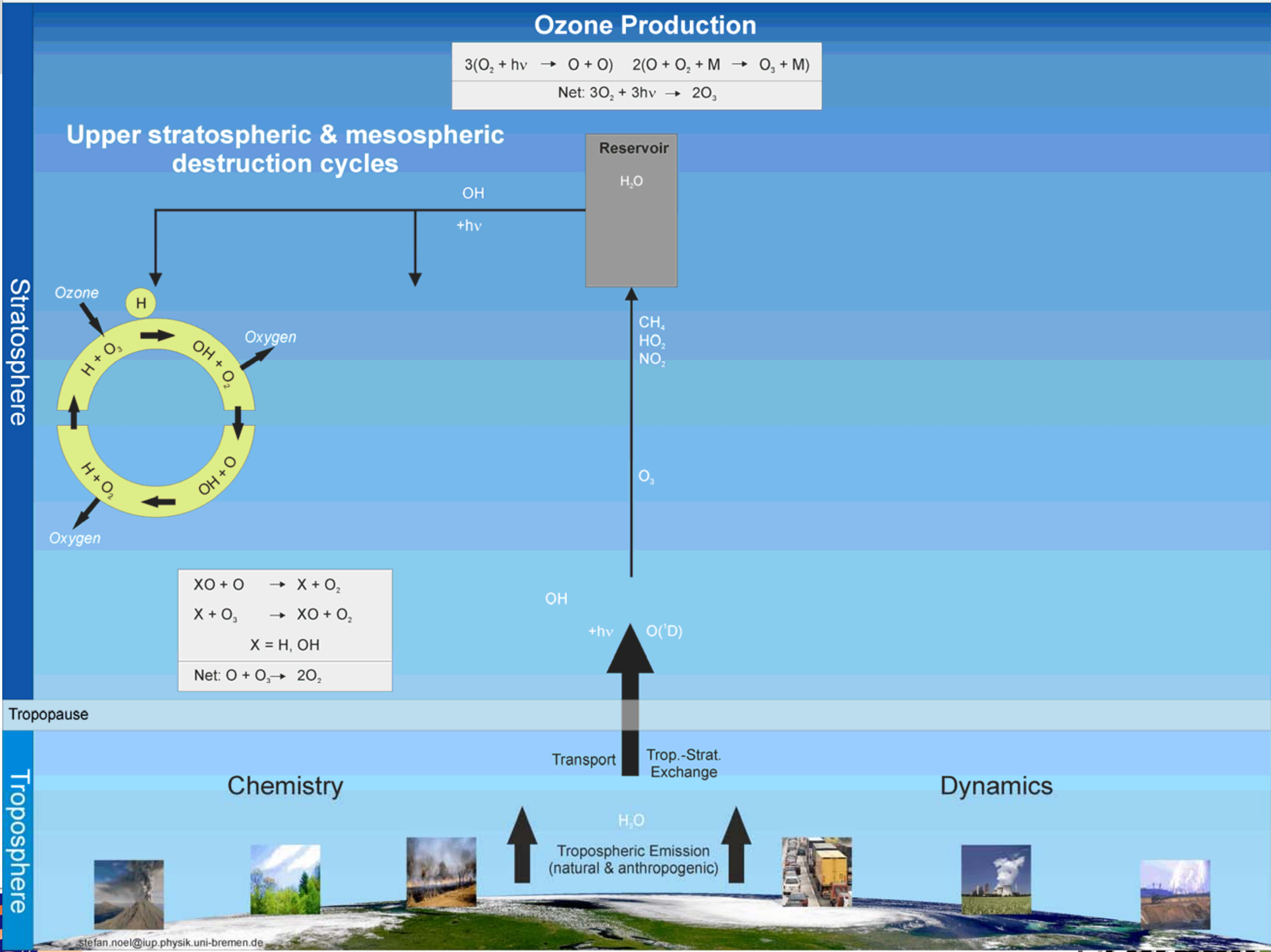
ACCENT
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK OF EXCELLENCE

Ozone Production & Catalytic Destruction



In 1902 the Stratosphere, a temperature inversion above 8-16 km discovered by Leon Philippe Teisserenc de Bort from France and German meteorologist Richard Assmann .
In 1929 Sidney Chapman of Trinity College Cambridge University, explained the observation of Ozone by Dobson Oxford and others. But the reaction $O_3 + O \rightarrow O_2 + O_2$ later discovered to be too slow!

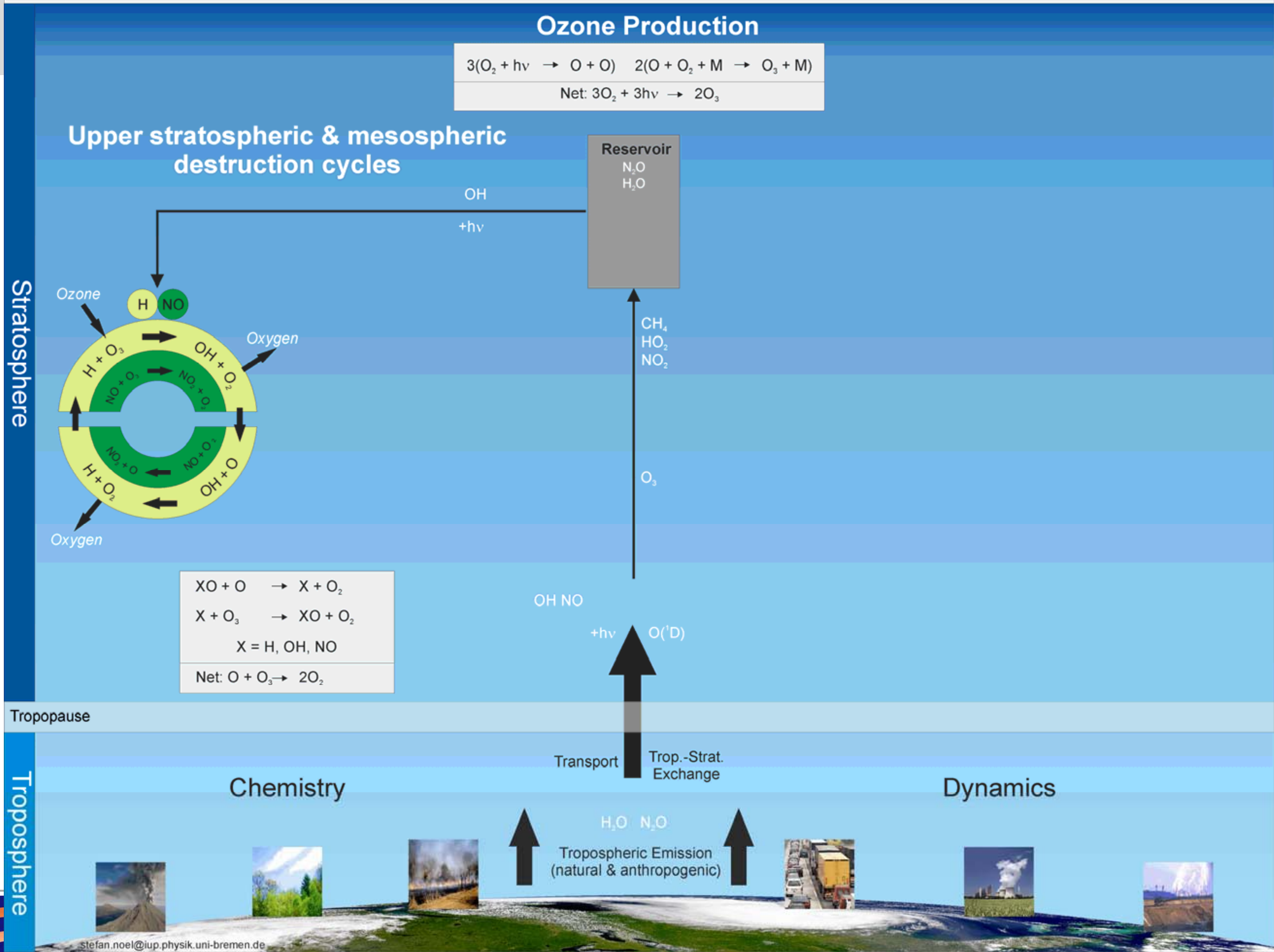
Ozone Production & Catalytic Destruction



SCIAMACHY

CarbonSat Constellation

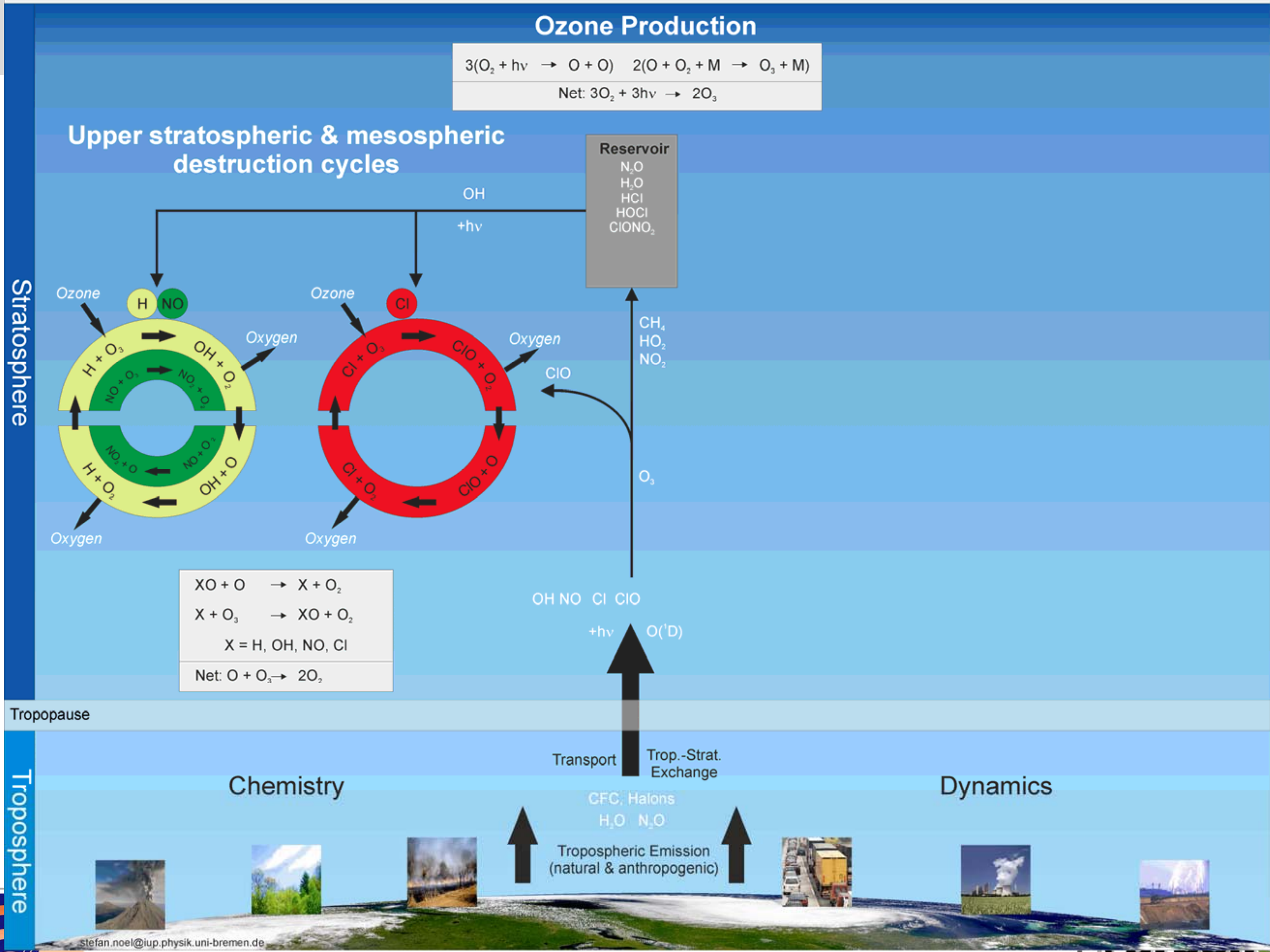
Ozone Production & Catalytic Destruction



SCIAMACHY

CarbonSat Constellation

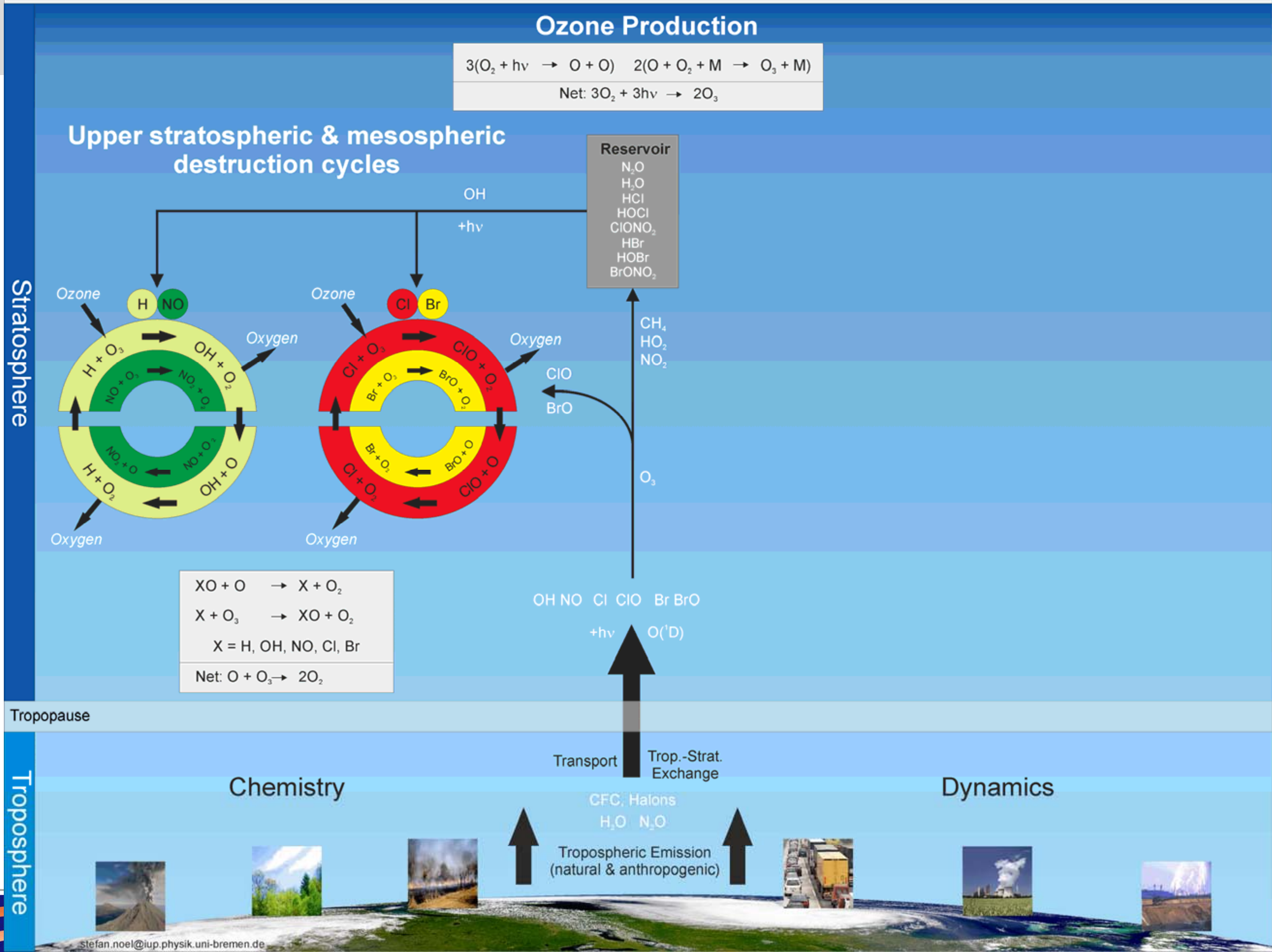
Ozone Production & Catalytic Destruction



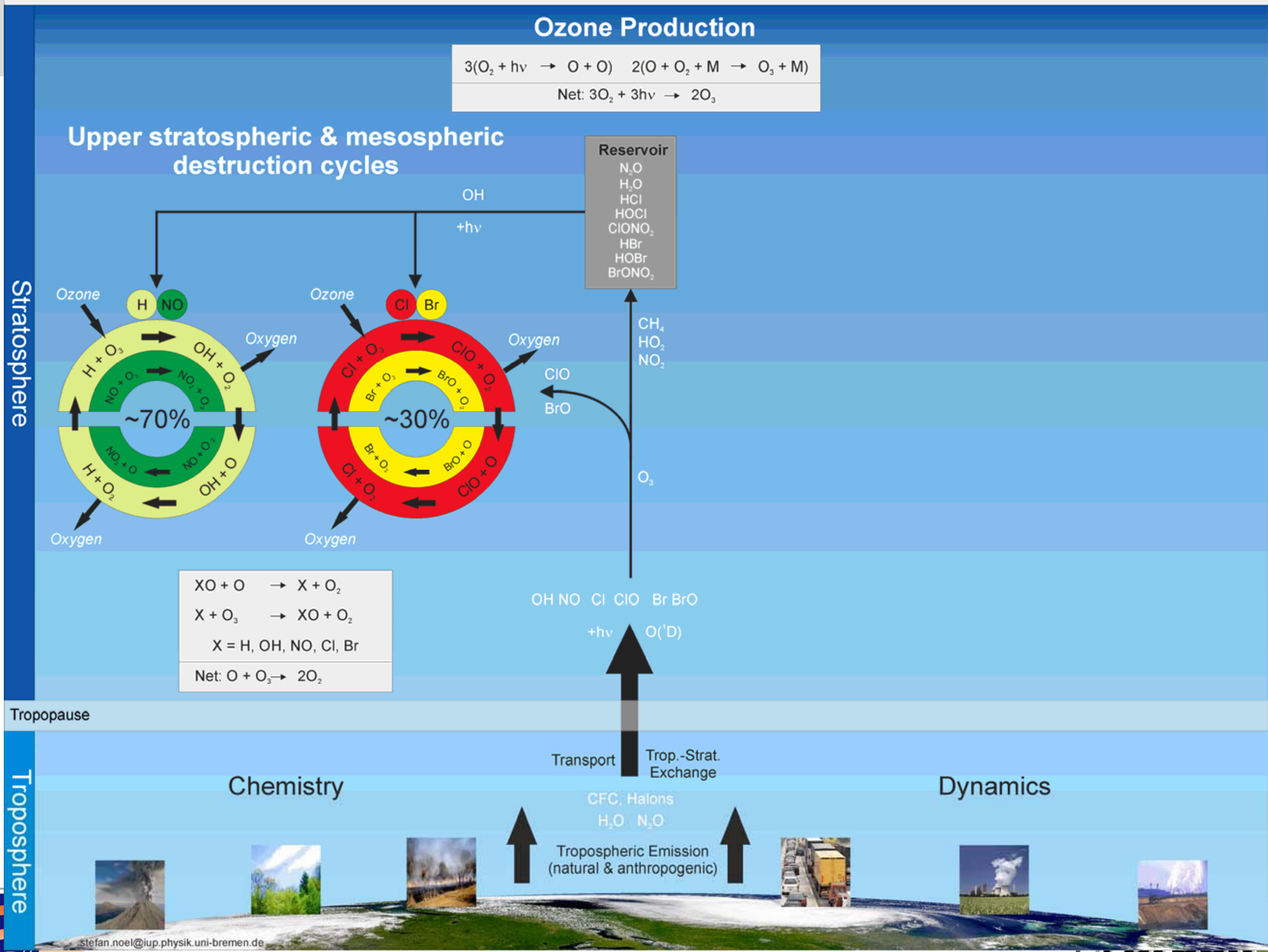
SCIAMACHY

CarbonSat Constellation

Ozone Production & Catalytic Destruction



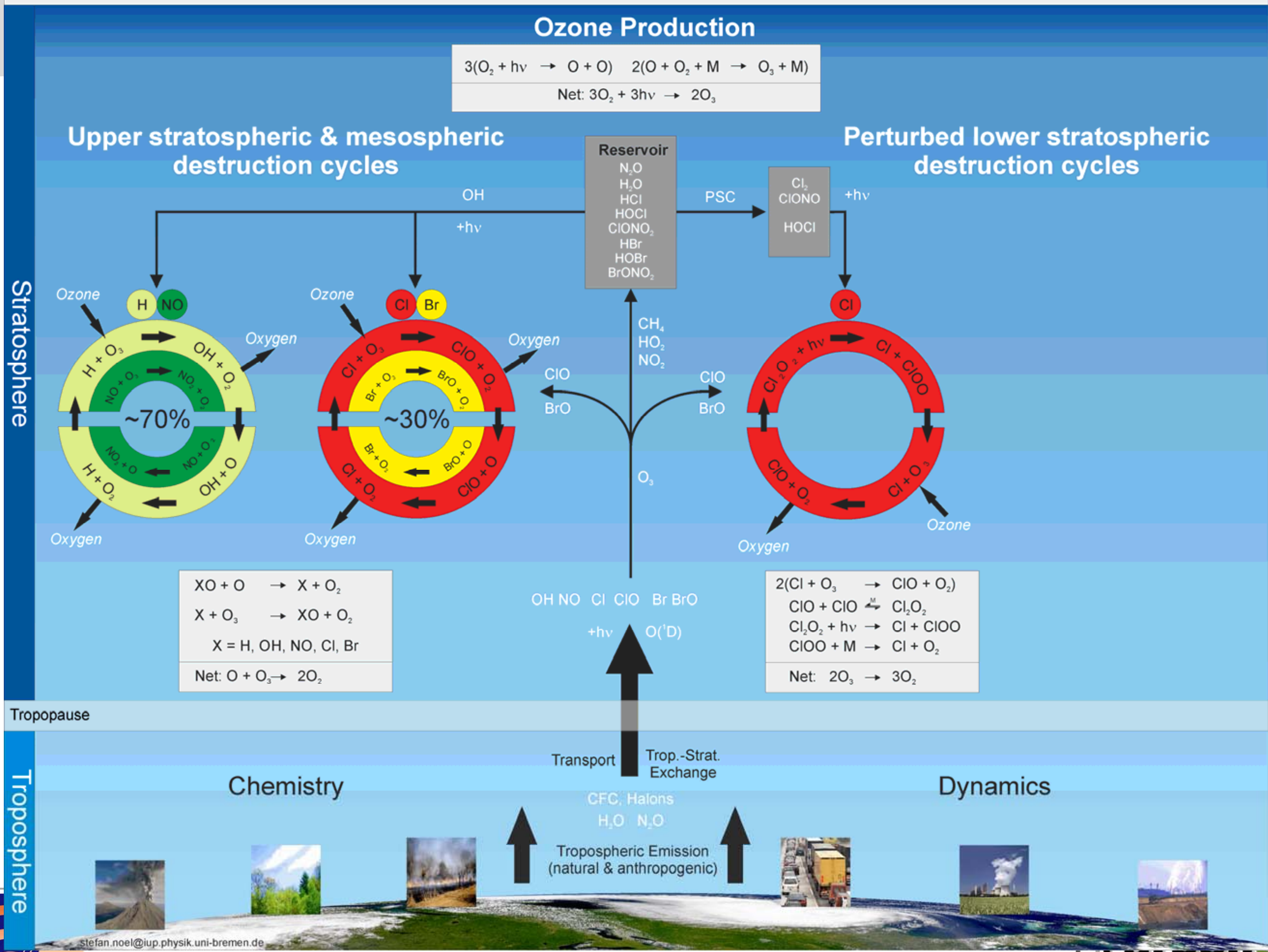
Ozone Production & Catalytic Destruction



SCIAMACHY

CarbonSat Constellation

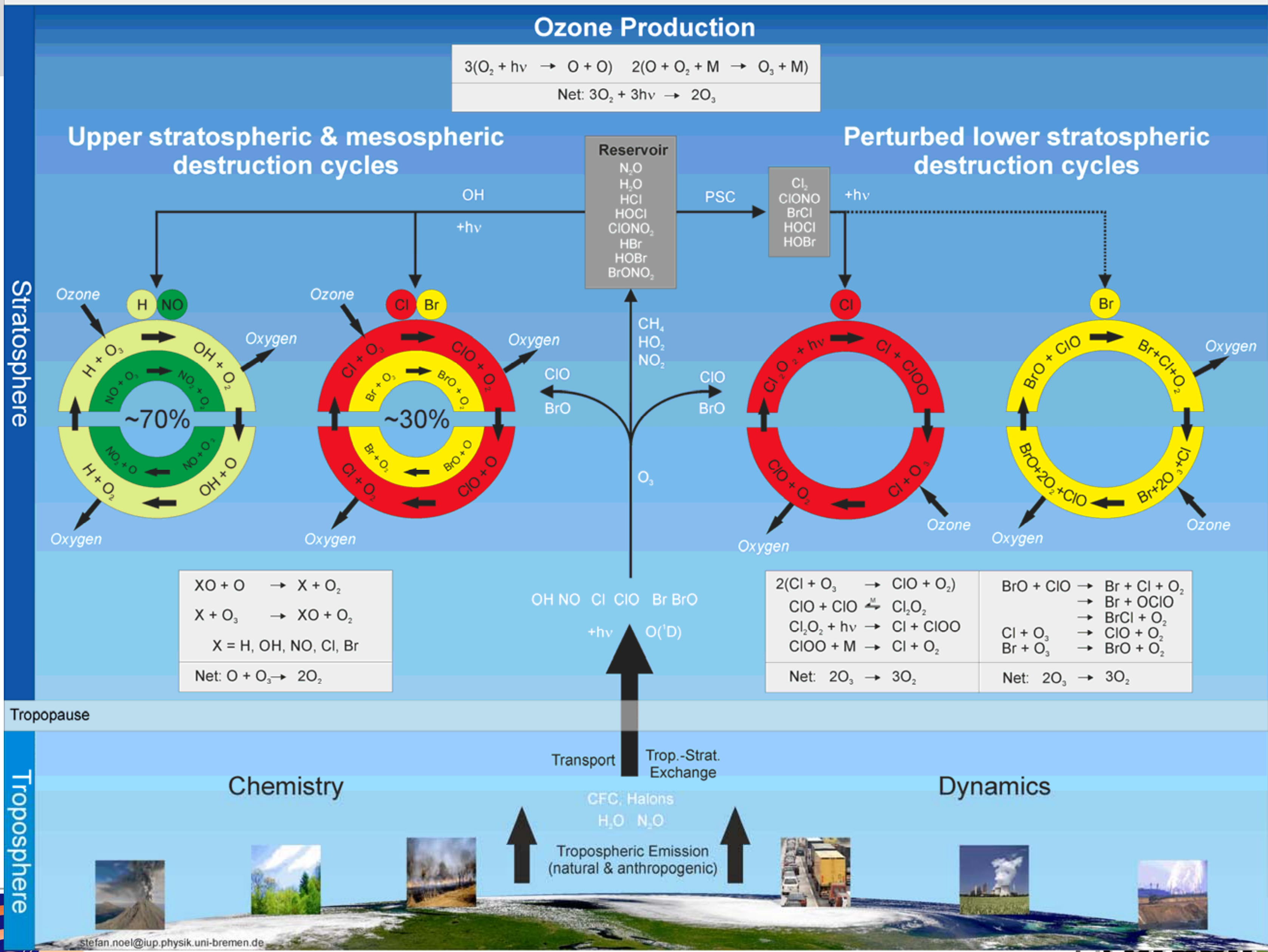
Ozone Production & Catalytic Destruction



SCIAMACHY

CarbonSat Constellation

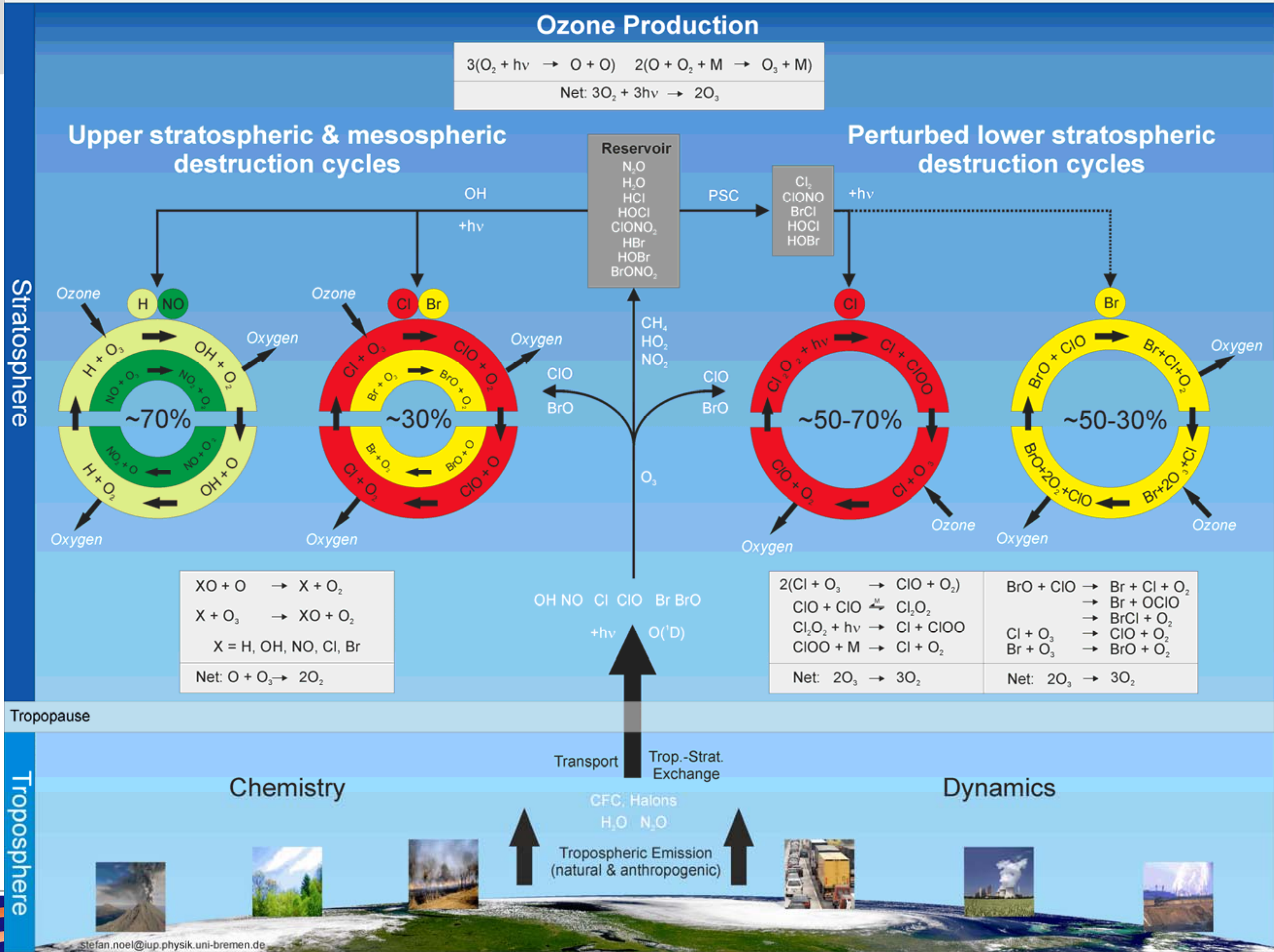
Ozone Production & Catalytic Destruction

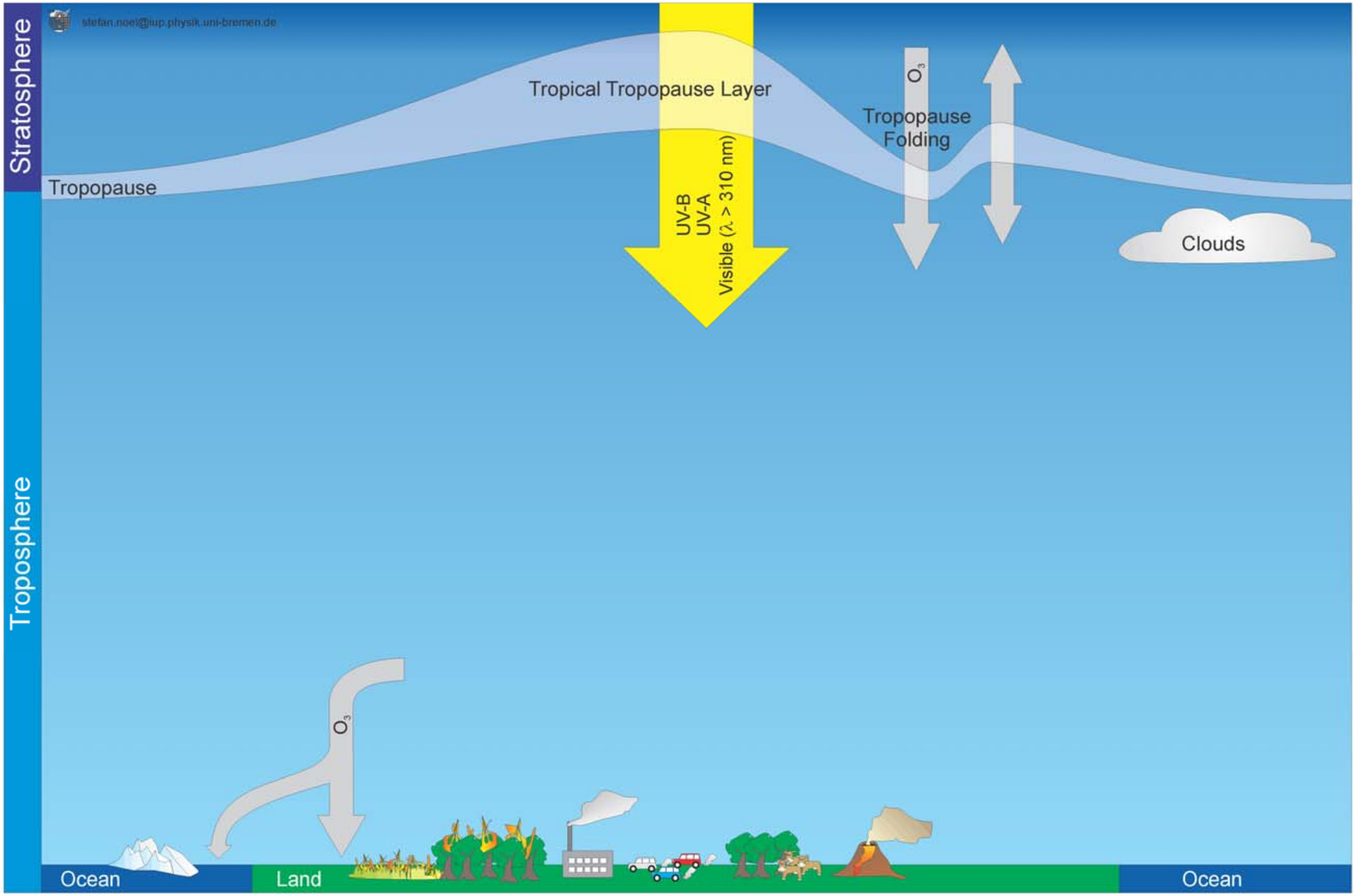


SCIAMACHY

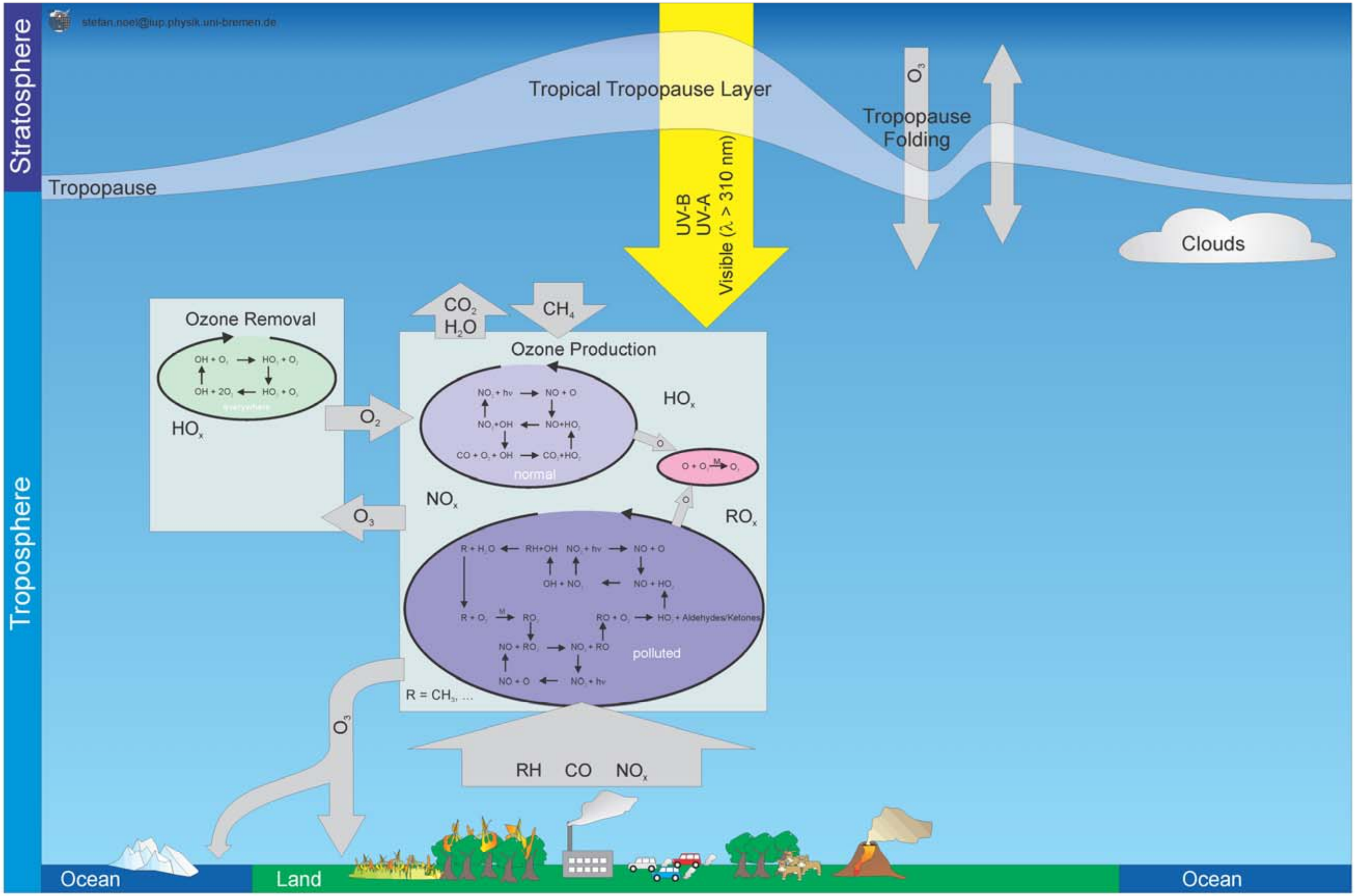
CarbonSat Constellation

Ozone Production & Catalytic Destruction

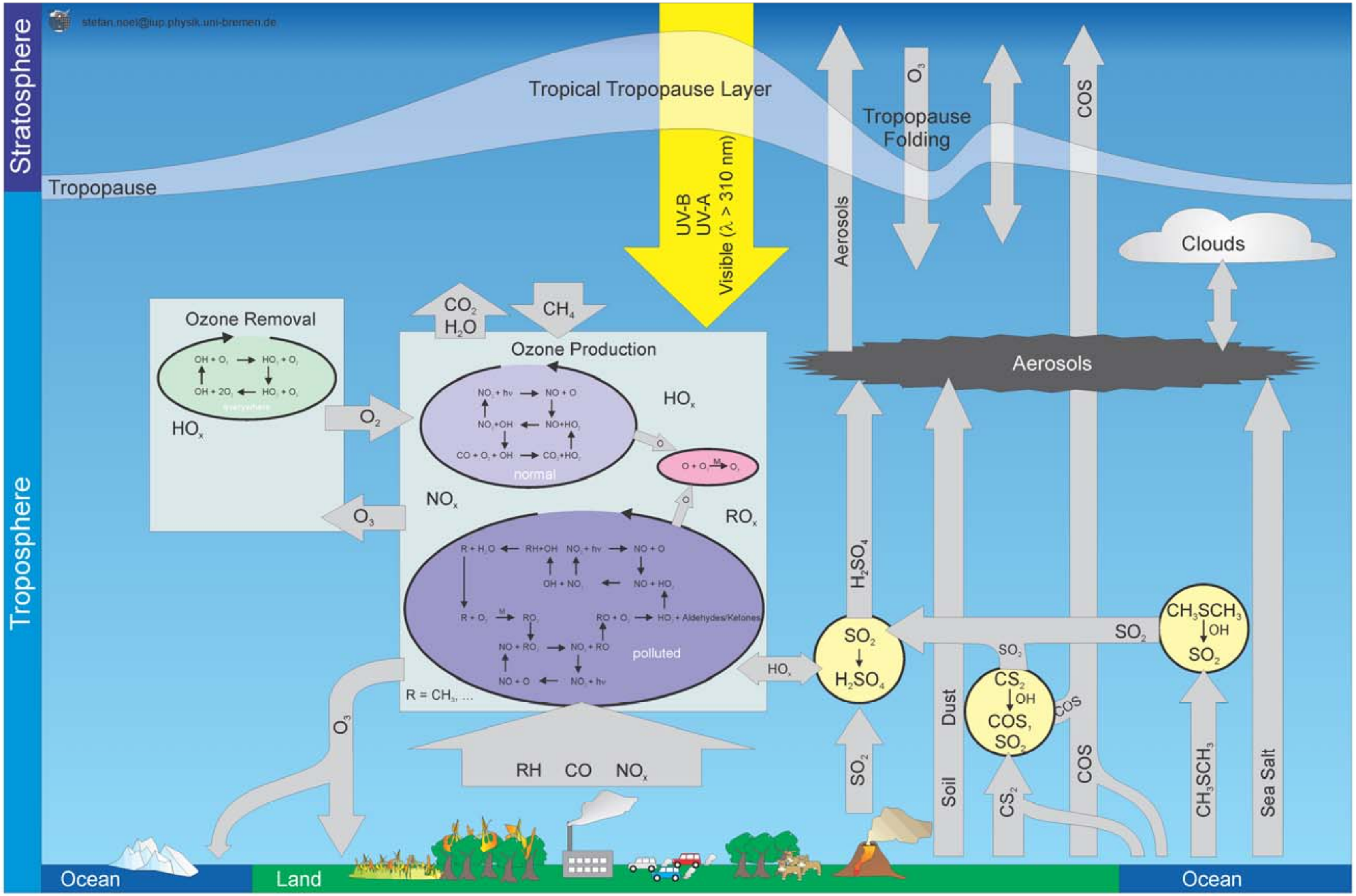




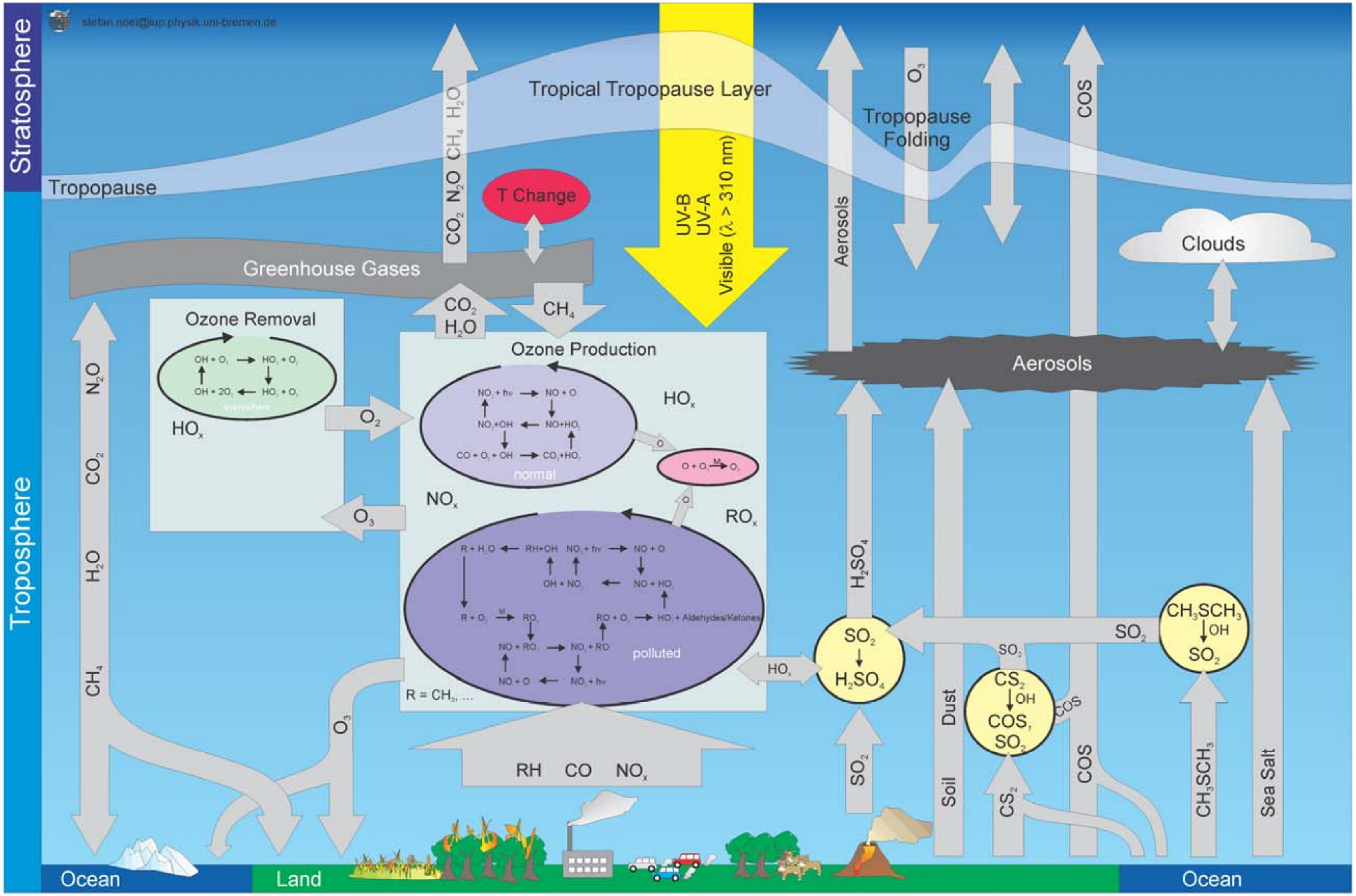
stefan.noel@iup.physik.uni-bremen.de
Stratosphere
Troposphere
Tropical Tropopause Layer
Tropopause
UV-B
UV-A
Visible (λ > 310 nm)
O_3
Tropopause
Folding
Clouds
O_3
Ocean
Land
Ocean



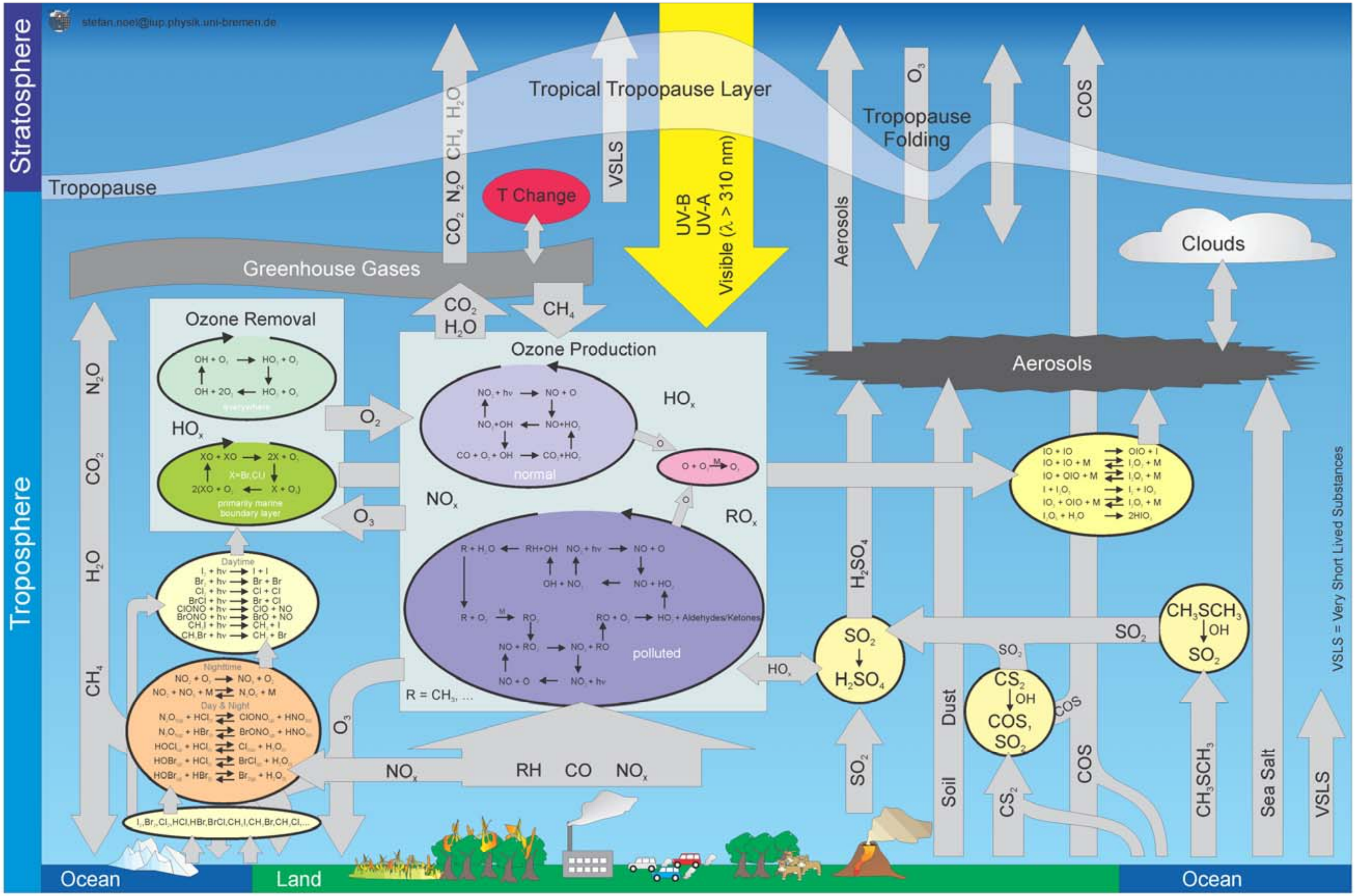
stefan.noel@iup.physik.uni-bremen.de
Stratosphere
Troposphere
Tropical Tropopause Layer
Tropopause
UV-B
UV-A
Visible (λ > 310 nm)
O_3
Tropopause Folding
Clouds
Ozone Removal
HO_x
O_2
O_3
CO_2 H_2O
CH_4
Ozone Production
HO_x
normal
NO_x
RO_x
polluted
R = CH_3, ...
O_3
RH CO NO_x
Ocean
Land
Ocean



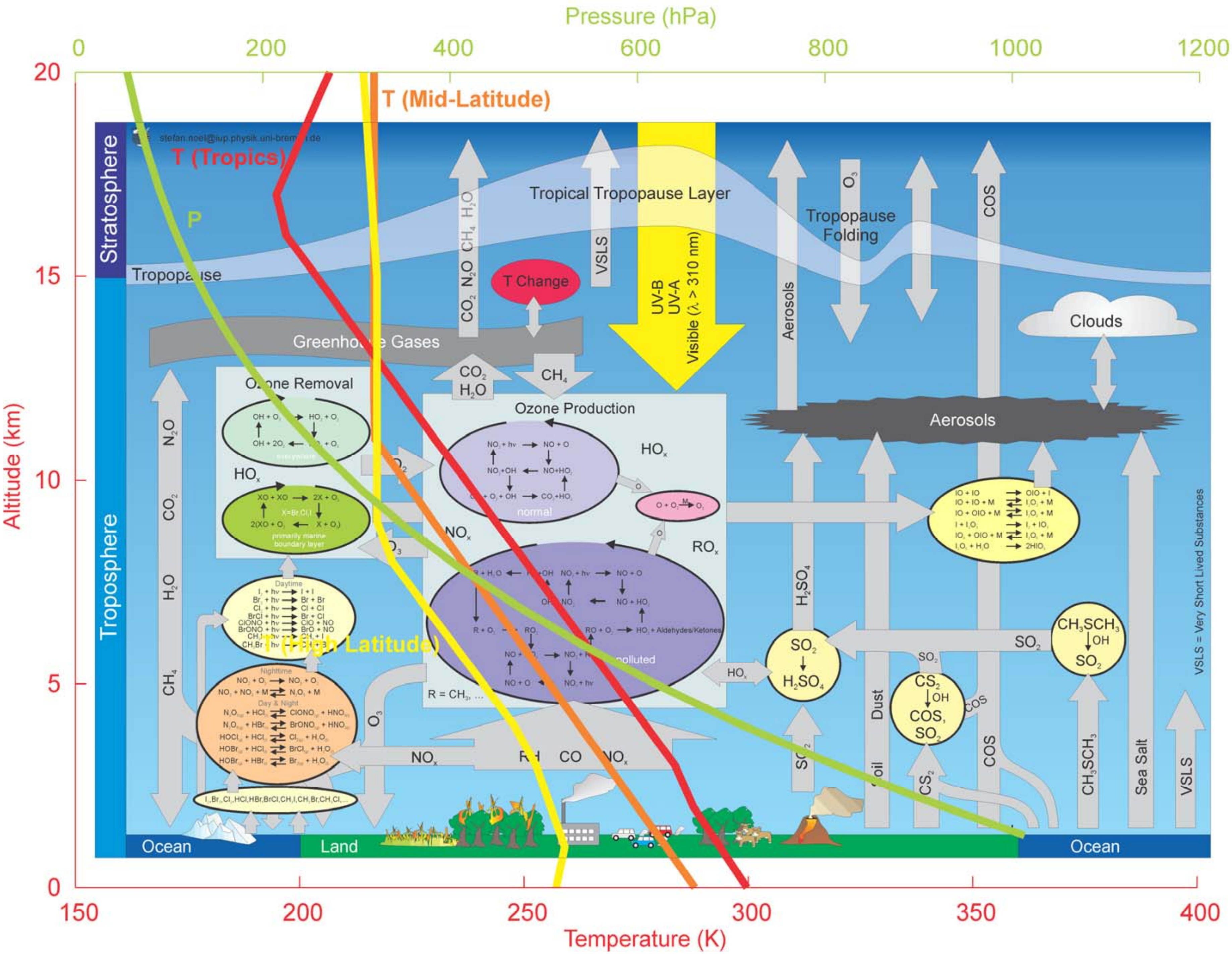
stefan.noel@iup.physik.uni-bremen.de
Stratosphere
Troposphere
Tropical Tropopause Layer
Tropopause
Tropopause Folding
UV-B
UV-A
Visible (λ > 310 nm)
Aerosols
COS
Clouds
Aerosols
Ozone Removal
HOx
O2
O3
CO2 H2O
CH4
Ozone Production
HOx
normal
NOx
ROx
polluted
R = CH3, ...
RH CO NOx
HOx
H2SO4
SO2 → H2SO4
SO2
CS2 OH COS, SO2
CH3SCH3 OH SO2
Dust
Soil
CS2
COS
CH3SCH3
Sea Salt
Ocean
Land
Ocean



Stratosphere
Troposphere
stefan.noel@iup.physik.uni-bremen.de
Tropical Tropopause Layer
Tropopause
Tropopause Folding
T Change
Greenhouse Gases
CO_2 N_2O CH_4 H_2O
UV-B
UV-A
Visible (λ > 310 nm)
Aerosols
O_3
COS
Clouds
Ozone Removal
HO_x
O_2
O_3
CO_2
H_2O
CH_4
Ozone Production
normal
polluted
NO_x
RO_x
R = CH_3, ...
RH CO NO_x
N_2O
CO_2
H_2O
CH_4
H_2SO_4
SO_2
SO_2 → H_2SO_4
CS_2 OH COS, SO_2
CH_3SCH_3 OH SO_2
CH_3SCH_3
CS_2
Dust
Soil
Sea Salt
Ocean
Land
Ocean

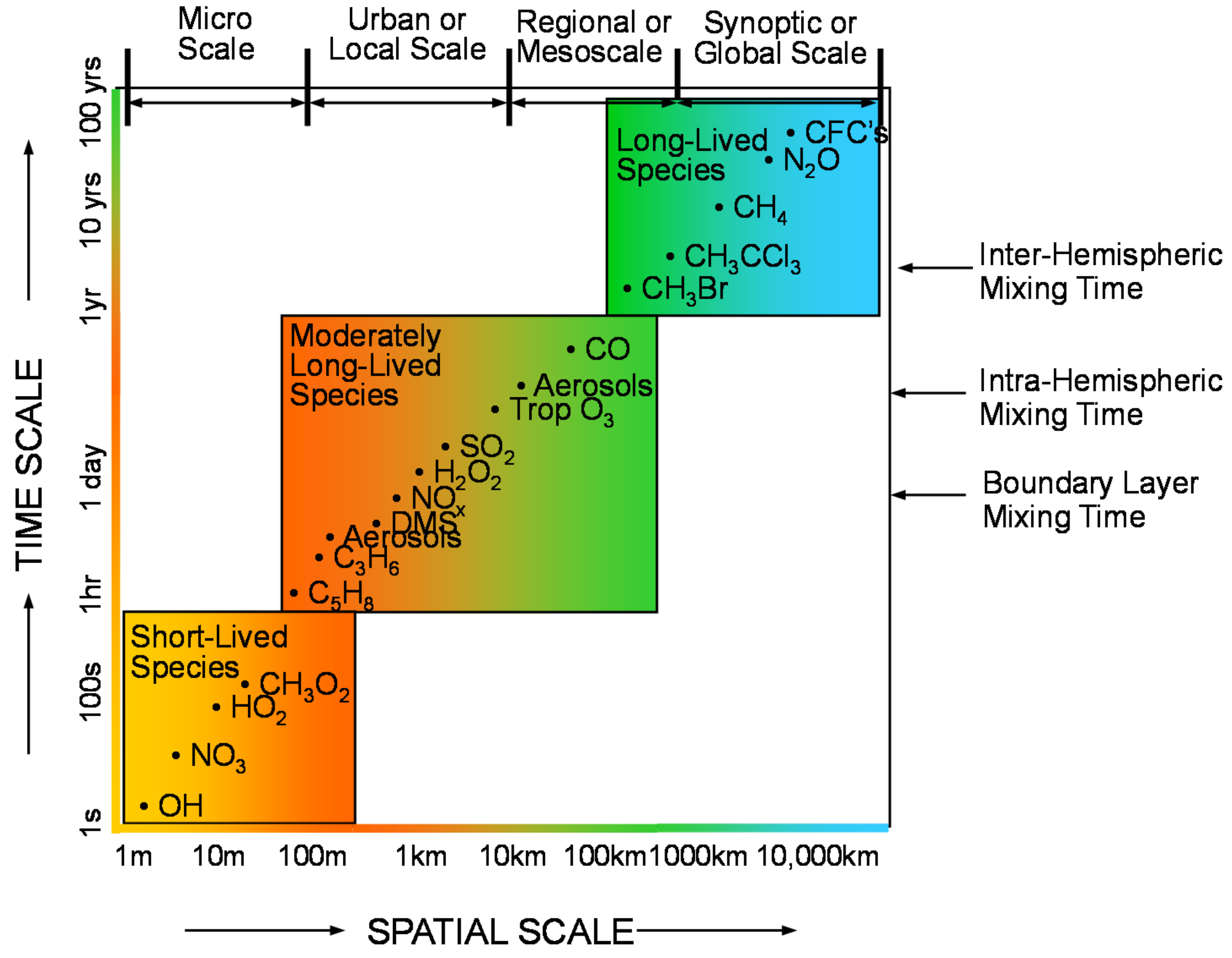


stefan.noel@iup.physik.uni-bremen.de
Stratosphere
Troposphere
Tropopause
Tropical Tropopause Layer
Tropopause Folding
T Change
Greenhouse Gases
CO_2 N_2O CH_4 H_2O
VSLS
UV-B
UV-A
Visible (λ > 310 nm)
Aerosols
O_3
COS
Clouds
CO_2 H_2O
CH_4
Ozone Removal
Ozone Production
HO_x
NO_x
RO_x
O_2
O_3
normal
polluted
R = CH_3, ...
N_2O
CO_2
H_2O
CH_4
Daytime
Nighttime
Day & Night
everywhere
primarily marine boundary layer
RH CO NO_x
NO_x
H_2SO_4
SO_2
SO_2 → H_2SO_4
CS_2 OH COS, SO_2
CH_3SCH_3 OH SO_2
SO_2
Dust
Soil
CS_2
COS
CH_3SCH_3
Sea Salt
VSLS
VSLS = Very Short Lived Substances
Ocean
Land
Ocean

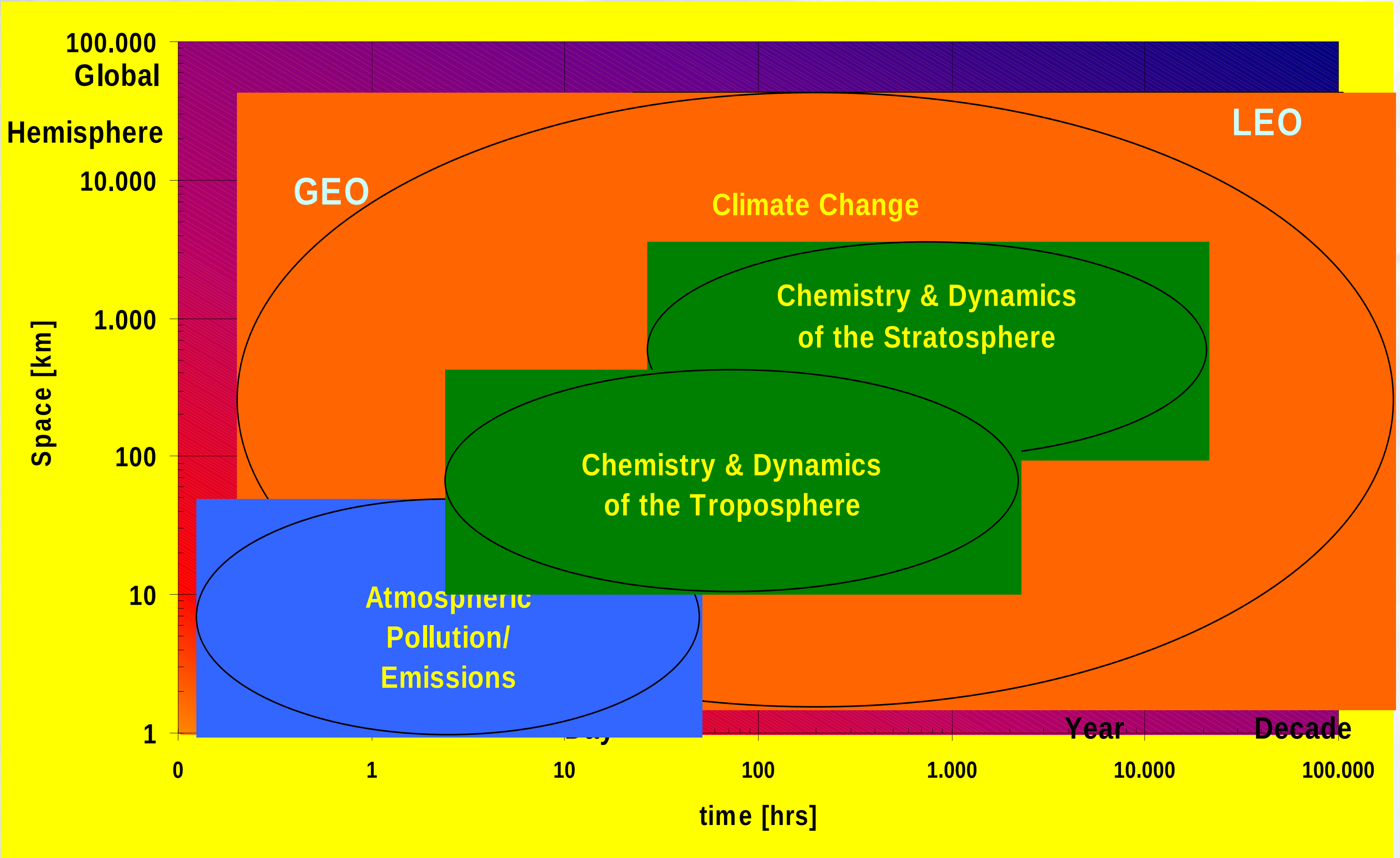


Pressure (hPa)
0
200
400
600
800
1000
1200
20
15
10
5
0
Altitude (km)
150
200
250
300
350
400
Temperature (K)
T (Mid-Latitude)
T (Tropics)
P
T (High Latitude)
stefan.noel@iup.physik.uni-bremen.de
Stratosphere
Troposphere
Tropopause
Tropical Tropopause Layer
Tropopause Folding
T Change
Greenhouse Gases
UV-B
UV-A
Visible (λ > 310 nm)
VSLS
Aerosols
Clouds
Ozone Removal
Ozone Production
HO$_x$
NO$_x$
RO$_x$
normal
polluted
R = CH$_3$, ...
Daytime
Nighttime
Day & Night
primarily marine boundary layer
Dust
Soil
COS
CS_2
SO_2
H_2SO_4
CH_3SCH_3
Sea Salt
CO_2
H_2O
CH_4
N_2O
O_3
RH
CO
Ocean
Land
Ocean
VSLS = Very Short Lived Substances

Spatial and Temporal Scales of Targeted Atmospheric Trace Constituents



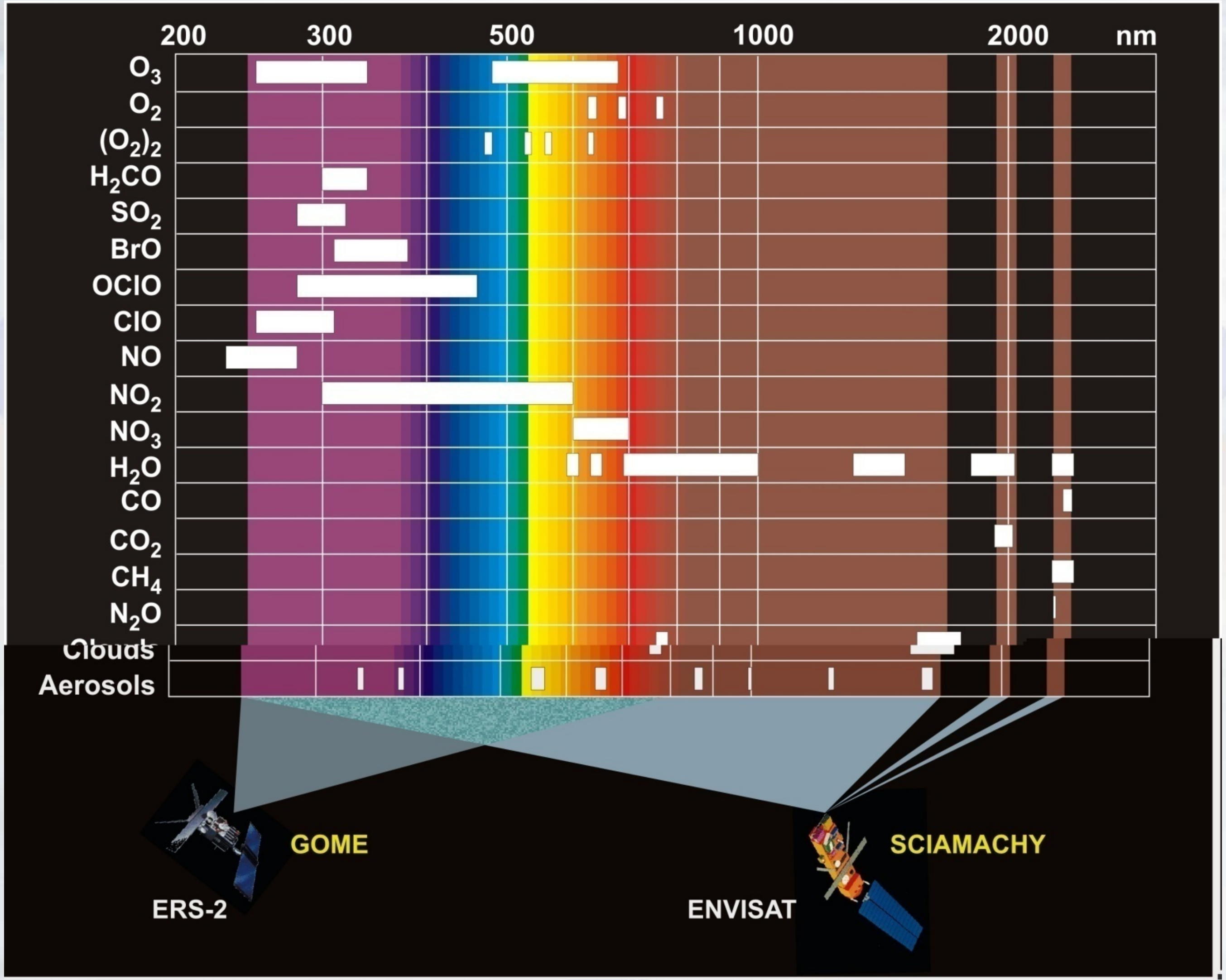
Spatial and Temporal Scales relevant for measurements from LEO and GEO



Universität Bremen

ACCENT
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK OF EXCELLENCE

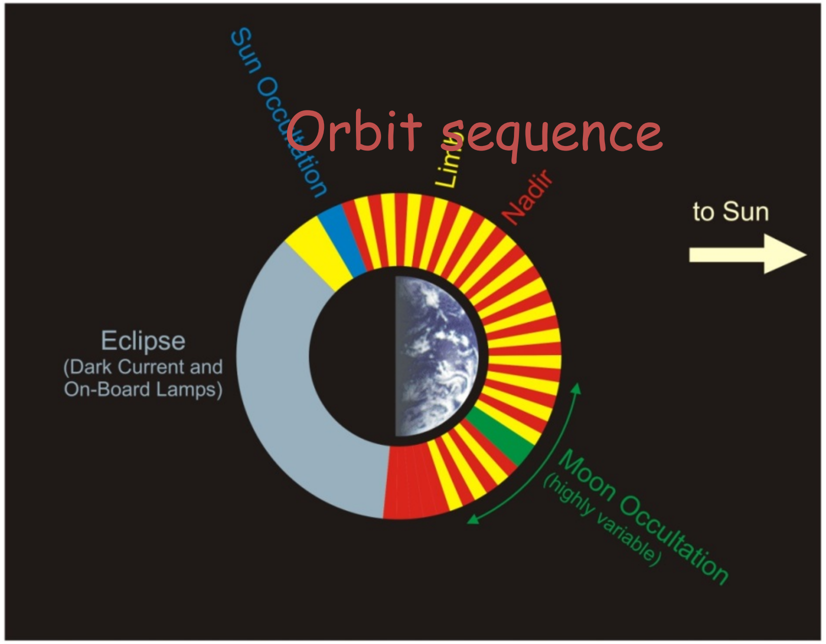
GOME SCIAMACHY: Targets and Spectral Coverage

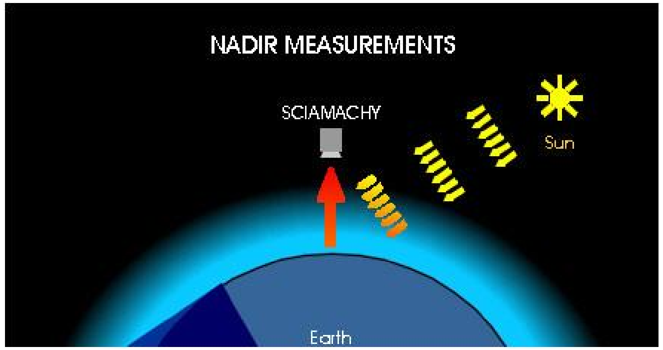


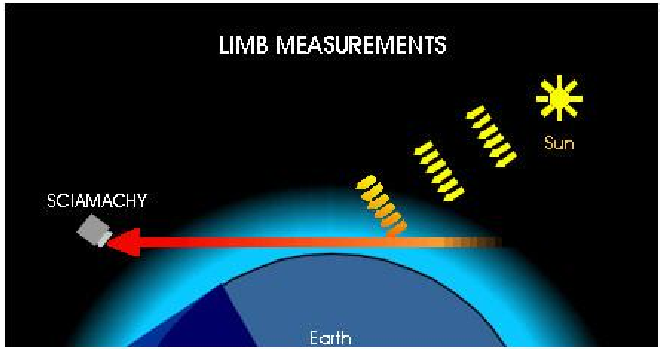
Universität Bremen

ACCENT
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK OF EXCELLENCE

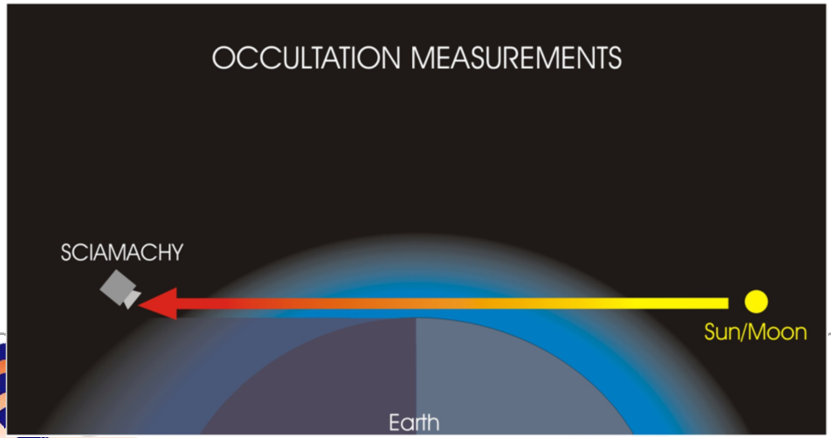
SCIAMACHY: orbit sequence & viewing modes

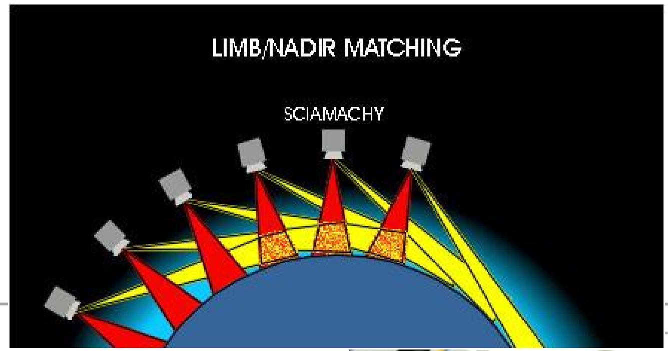






Viewing modes





SCIAMACHY

CarbonSat Constellation

LEO - Low Earth Orbit – Atmospheric Remote Sensing
Relevant History in Europe

1984—1985 platform	MAPS (Mapping of Atmospheric Pollution) proposal for ESA EURECA by Burrows Perner and Crutzen - rejected
1984-1988	Development of SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) concept Burrows et al – hunting light and shadow
1988	Submission of SCIAMACHY to ESA call for POEM Later called Envisat - Burrows et al
1988	Proposal of SCIA-mini to ESA call for ERS-2 – Burrows et al
1989	Selection of SCIAMACHY for ENVISAT
1990	Selection of GOME, a descoped SCIA-mini, for flight on ERS-2
1995	Launch of GOME on ESA ERS-2 20th April
2000	Selection of GOME-2 for Metop series of platforms
2002	Launch of SCIAMACHY on ENVISAT
2004	Launch of Aura with OMI
2006	Launch of Metop A with GOME-2 19th October
2007	EUMESAT Post Metop Committee recommends GOME-2 follow on UVNS
2008	EU GMES agrees to fund Sentinel 5 for Metop Second Generation
2011	ESA decommission ERS-2 and GOME July to September
2012	Loss of Envisat 9th April
2012	Launch of GOME-2 on Metop-B 17th September
2012	Sentinel 5 funding agreed for Metop Second Generation 2020- 2034

SCIAMACHY Phase A Review by ESA

ESA/PB-EO(88)68, 13 December 1988

The Polar Platform Announcement of Opportunity: Results of Evaluation of Instrument Proposals: SCIAMACHY

„The Board agreed that although this was an attractive proposal scientifically, it appeared a little bit over ambitious.“

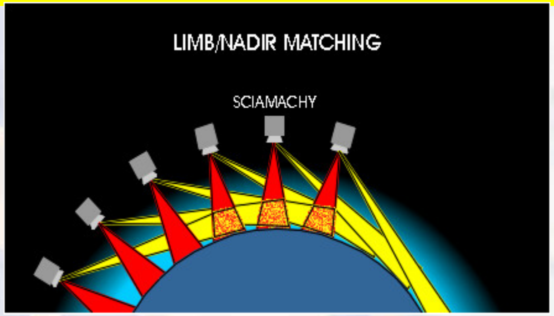
……

SCIAMACHY

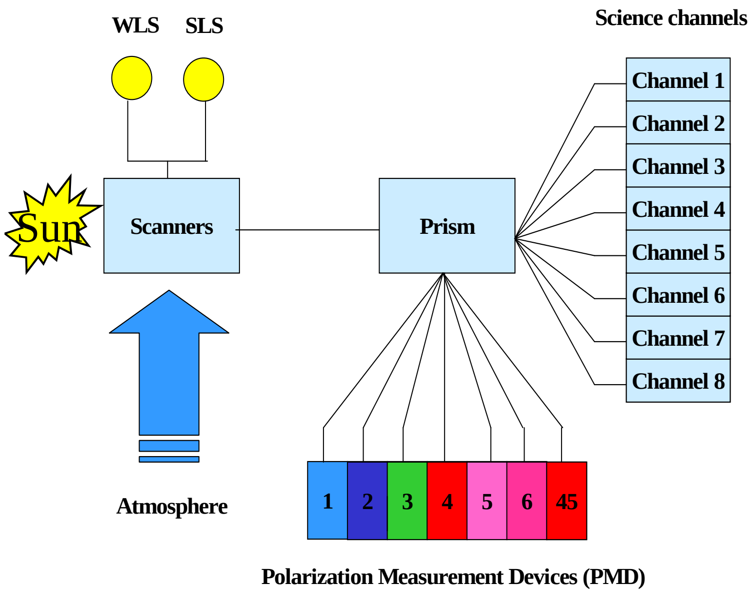
Scanning Imaging Absorption Spectrometer for Atmospheric Chartography

Viewing Geometry

- Nadir
- Limb
- Occultation



Imaging Spectrometer



- Combination of Prism and 8 high resolution channels (each having its own grating)
- Spectral range from 214 to 2380 nm
- Spectral resolution from 0.2 to 1.5 nm
- 7 broadband polarization measurement Devices PMDs
- On-board calibration H/W

Universität Bremen

ACCENT
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK OF EXCELLENCE

Envisat Payload

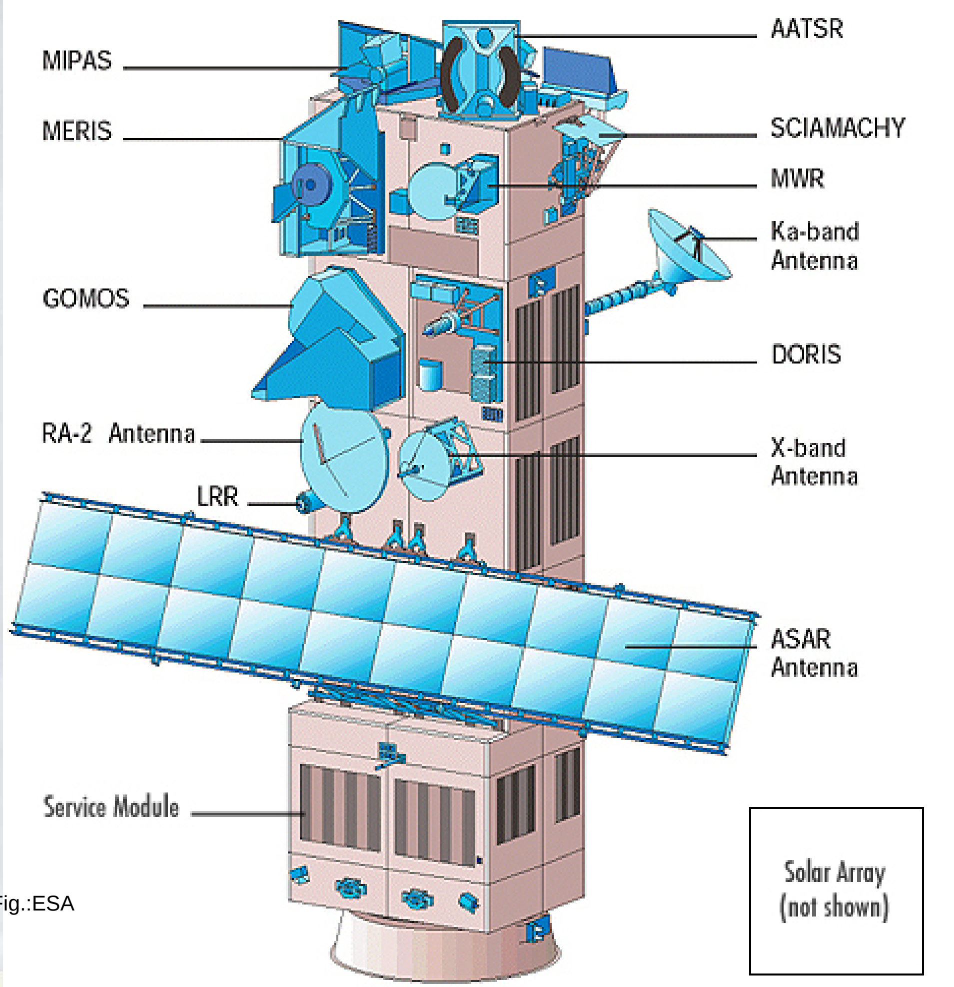


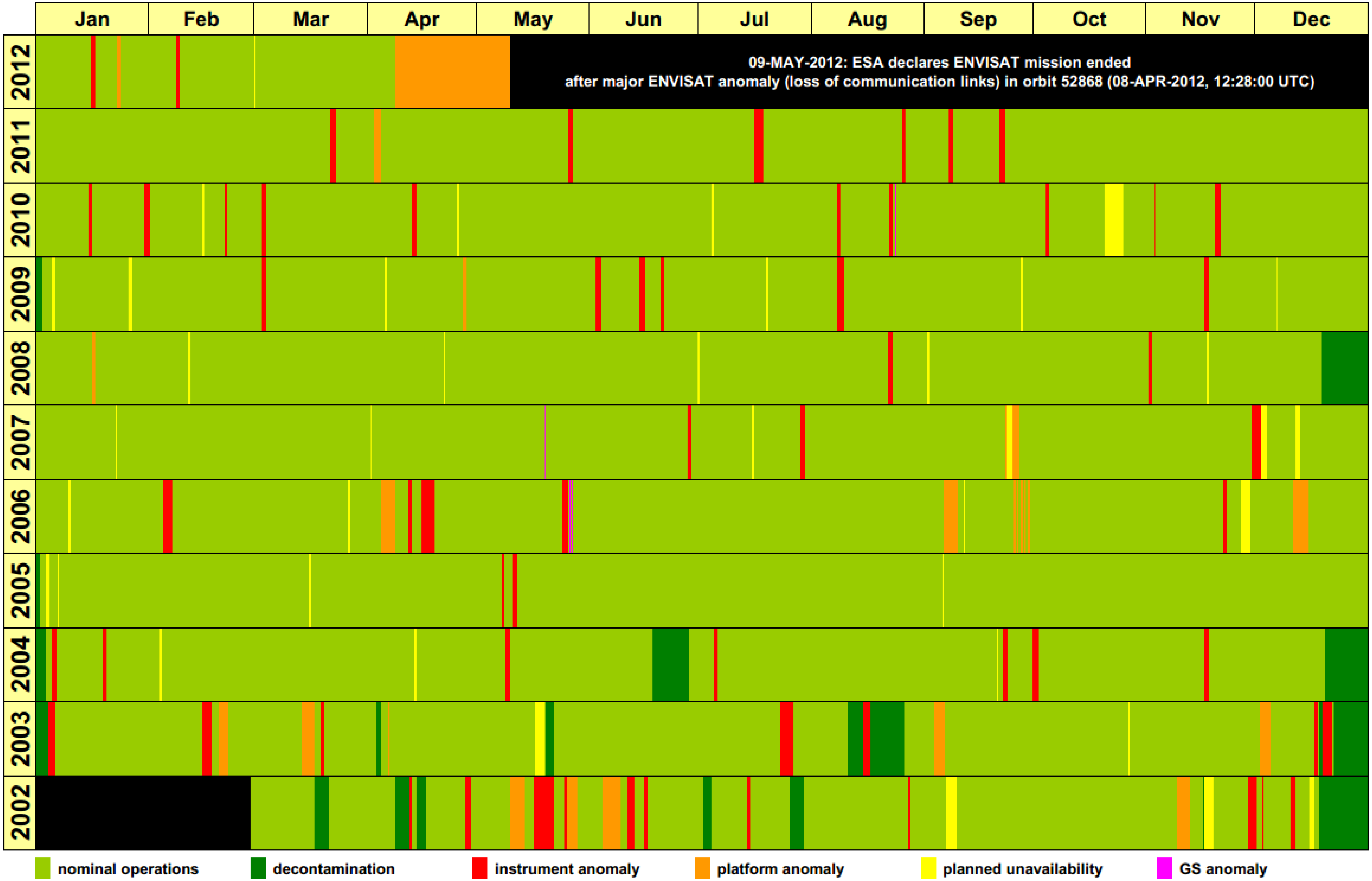
Fig.:ESA

Universität Bremen

ACCENT
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK OF EXCELLENCE

ENVISAT Launch: 1st March 2002, 2:07 CET

SCIAMACHY Routine Operations



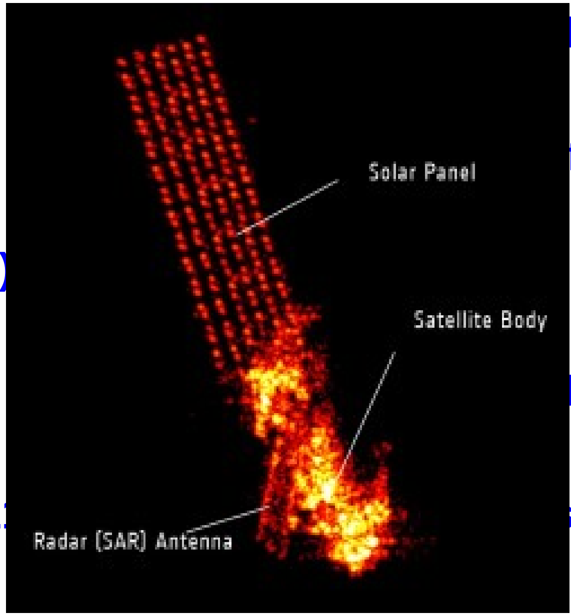
SCIAMACHY: Abridged History 2/3

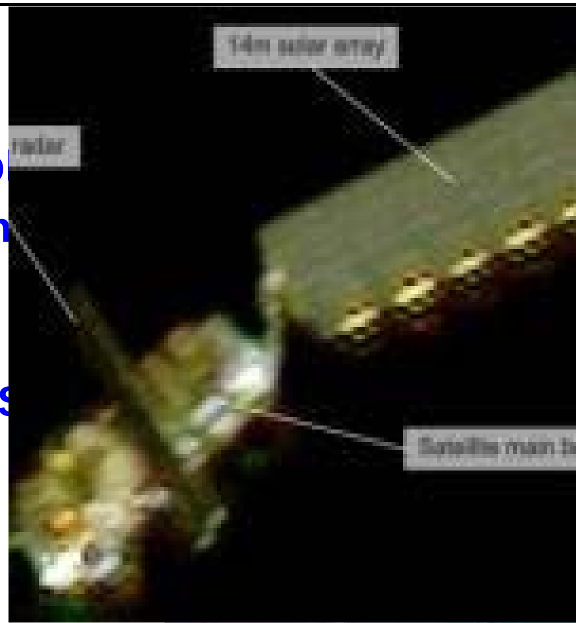
October … h GOME-2 and IASI

2008 … ference approves imp… SAT
heritage) on MTG an… A,
heritage)

2010 … l to and selected by ES… n

July 201… ssion with GOME





8th April 2012 Unexpected Loss of communication with ENVISAT

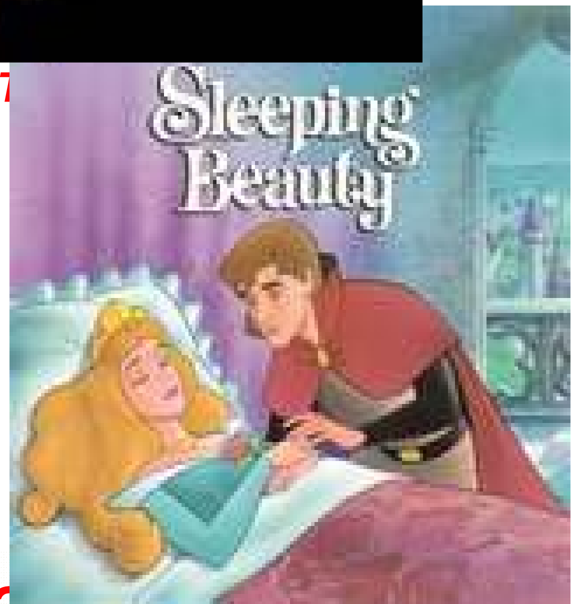
9th May 2012 ESA declared end of ENVISAT operational phase

Loss of Nadir SWIR (CO2 and CH4)

Loss of all vertical profiling using UV Vis NIR SWIR

No European Plans for continuation of occultation limb UV visible NIR or SSI????

WHY NOT?? WHY have these measurements been given no priority??????



Will Envisat like Sleeping beauty wake??

- in orbit for over 100 years!!!

ACE-FTS	Atmospheric Chemistry Experiment – FTS satellite; lifetime: CSA SCISAT-1; 2003 - present species: H_2O, CO_2, CH_4, N_2O, O_3, CO, CFC-11, CFC-12, $ClNO_3$, HCl, HF, HNO_3, NO_2, NO, N_2O_5 and more viewing: O; sounding Tp (upper); spectral region: IR; FTS, contin. spectrum; resolution: OPD 25 cm
ATMOS	Atmospheric Trace Molecule Spectroscopy satellite; lifetime: NASA Spacelab, 1985, ATLAS: 1992, 1993, 1994 re-visit period and equator crossing time: not applicable species: O_3, NO_2, N_2O_5, $ClONO_2$, HCl, HF, CH_4, CFCs viewing: O; sounding Sc, Tc (upper); spectral region: IR; continuous; resolution: 0.01 - 1 cm^{-1}
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization satellite; lifetime: NASA CALIPSO (A TRAIN); 2006 equator crossing time: 13.30, ascending species: aerosol properties: see Table 6.4 viewing: N; sounding Tot; footprint: 330 × 100 m; vert. 30-60 m spectral region: lidar; 532 (polarised), 1064 nm
CLAES	Cryogenic Limb Array Etalon Spectrometer satellite; lifetime: NASA UARS; 1991 - 1993 equator crossing time: asynchronous species: temperature, pressure, O_3, H_2O, CH_4, N_2O, NO, NO_2, N_2O_5, HNO_3, $ClONO_2$, HCl, CFC-11, CFC-12, and aerosol absorption coefficients viewing: L; sounding Sp; spectral channels: IR; 780, 792, 843, 879, 925, 1257, 1605, 1897, 2843 cm^{-1}; resolution: 0.19, 0.25, 0.26, 0.22, 0.22, 0.26, 0.39, 0.47, 0.65 cm^{-1}
GLAS	Geoscience Laser Altimeter System satellite ICESat; viewing: N; sounding altimeter;
GOMOS	Global Ozone Monitoring by Occultation of Stars satellite; lifetime: ESA ENVISAT; 2002 - present equator crossing time: 10:00 species: O_3, NO_2, NO_3, H_2O, O_2 viewing: O; sounding: Tp; Sp, Tot, Me spectral regions: UV/vis; 248 -693 nm, NIR; 750-776 nm, 915-956 nm; resolution: 1.2 nm (UV/vis), 0.2 nm (NIR)
HALOE	Halogen Occultation Experiment satellite; lifetime: NASA UARS; 1991 - 2005 species: CO_2, H_2O, O_3, NO_2, HF, HCl, CH_4, NO viewing: O; sounding Sp, (Tp); spectral region: several channels from 2.45-10.04 µm; resolution: gas correlation radiometer
HIRDLS	The High Resolution Dynamics Limb Sounder satellite; lifetime: NASA AURA, 2004 - 2010 re-visit period: twice a day; equator crossing time: 01.43 species: H_2O, CH_4, N_2O, O_3, CFC-11, CFC-12, $ClONO_2$, NO_2, N_2O_5, HNO_3, T; and cloud properties viewing: L + scan; sounding Sp spectral region: 21 channels from 6.12 to 17.76 µm; resolution: channel dependent
ILAS I, II	Improved Limb Atmospheric Spectrometer satellite; lifetime: I: NASDA ADEOS; 1996 - 1997; II ADEOS II; 1999 species: O_3, NO_2, N_2O, H_2O, CF_2Cl, CH_4, $ClONO_2$, T, P viewing: O; sounding Sp (Tp); footprint: 2 × 2 km (NIR) and 2 × 13 (TIR) spectral region: 753-784 nm (NIR), 6.21-11.77 µm (TIR); resolution: 0.15 nm (NIR), 0.12 µm (TIR)
ISAMS	Improved Stratospheric and Mesospheric Sounder satellite; lifetime: NASA UARS; 1991 - 1992 species: CO_2, H_2O, CO, N_2O, CH_4, NO, NO_2, N_2O_5, HNO_3, O_3 viewing: L + scan ; sounding Sp, Mp; footprint: 2.6 × 13 km spectral region: 605-2257 cm^{-1} (14 Bands); resolution: gas correlation
LIMS	Limb Infrared Monitor of the Stratosphere satellite; lifetime: NASA Nimbus 7; 1978 - 1979 species: CO_2, HNO_3, O_3, H_2O, NO_2 viewing: L+scan; sounding Sp; spectral regions: 637-673, 579-755, 844-917, 926-1141, 1237-1560, 1560-1630 cm^{-1}
LITE	Lidar In-space Technology Experiment satellite Space Shuttle Discovery; lifetime: 9 days species: aerosols, clouds viewing: N; sounding Tot, Np; footprint: 300 m spectral region: 355 nm, 532 nm, 1064 nm;
LRIR	Limb Radiance Inversion Radiometer satellite; lifetime: NASA Nimbus 7 equator crossing time: local noon species: CO_2, O_3 viewing: L; sounding Sp; spectral regions: IR; 14.6-15.9 µm, 14.2-17.3 µm, 8.8 -10.1 µm, 20-25 µm
MAS	Millimeter Wave Atmospheric Sounder satellite; lifetime: Shuttle ATLAS 1, 2 and 3: 1992, 1993, 1994 species: ClO, O_3, H_2O viewing: L + scan; sounding Sp; spectral bands: 60 GHz, 183 GHz, 184 GHz, 204 GHz
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding satellite; lifetime: ESA ENVISAT, 2002 - present re-visit period: 6 days; equator crossing time: 10.00 ascending species: H_2O, CO_2, CH_4, N_2O, O_3, CO, CFC-11, CFC-12, ClO, $ClONO_2$, OClO, HNO_3, C_2H_6, SF_6, NO_2, NO, NH_3, OCS, SO_2 viewing: L; sounding Tc (upper); spectral region: IR; FTS continuous; resolution: OPD: 20 to 8 cm
MLS (UARS)	Microwave Limb Sounder satellite; lifetime: NASA UARS; 1994 - 2001 species: ClO, CH_3CN, H_2O, HNO_3, O_3, SO_2, temp., geopotential height, ice water content, ice water path, relative humidity with respect to ice viewing: L; sounding: Sp; spectral bands, 63 GHz, 183 GHz, 205 GHz
MLS (AURA)	Microwave Limb Sounder satellite; lifetime: NASA (A-TRAIN) AURA; 2004 - present equator crossing time: 13.38 species: BrO, CH_3CN, ClO, CO, H_2O, HCl, HCN, HNO_3, HO_2, HOCl, N_2O, O_3, OH, SO_2, temp., geopotential height, ice water content, ice water path, relative humidity with respect to ice viewing: L; sounding: Sp; spectral bands, 118, 190, 240, 640, 2250 GHz
OSIRIS/IRI	Optical Spectrograph and Infrared Imaging System satellite; lifetime: Swedish ODIN, 2001 - present equator crossing time: 06.00 species: O_3, BrO viewing: L ; sounding Sp; spectral regions: 280-800 nm (OSIRIS); 2 bands, 1.27 µm and 1.53 µm (IRI); resolution: 1 nm (OSIRIS)
POAM-II	Polar Ozone and Aerosol Measurement II satellite; lifetime: SPOT-3, 1993 - 1996 equator crossing time: 10.30 descending species: O_3, H_2O, NO_2, aerosol properties, temperature viewing: O; sounding Sp; orbit: sun-synchronous polar spectral region: UV/vis/NIR; channels, 353.0, 442.0, 448.3, 600.0, 760.8, 780.0, 920.0, 935.5, 1059.0 nm; resolution: 2 to 16 nm
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

Universität Bremen

Data Product – Limb Retrieval Principles

- FURM – FUll Retreival Method / Optimal estimation

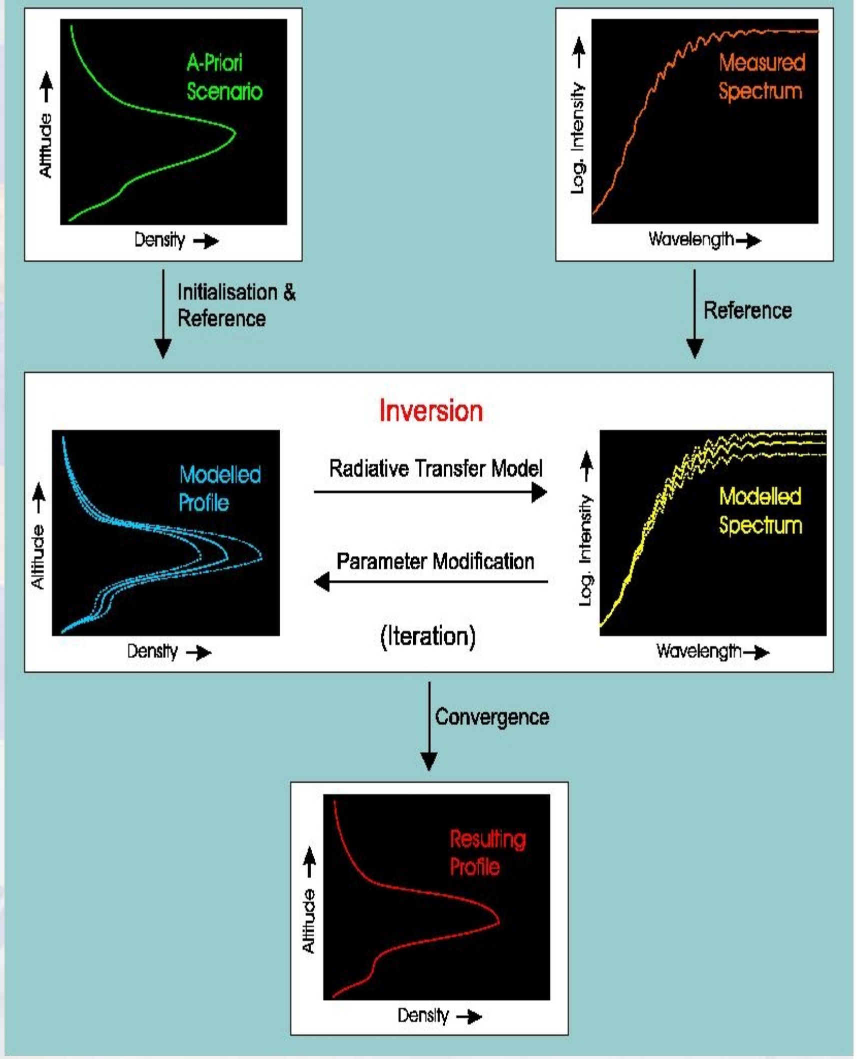
FURM : FUll Retrieval Method

Similarities with inverse modelling

Solar Irradiance, IRmod(λ) + A priori knowledge + radiative transfer model => modelled TOA radiance, Rmod(λ). Reflectance,

$R_{TOA}(\lambda)mod = \pi.Rmod(\lambda)/IRmod(\lambda)$

$R_{TOA}(\lambda)$mod or Rmod(λ) compared with measured observed - iterative adjustment of input until the convergence criteria are achieved



Optimal Estimation

Measurement

$$\hat{\mathbf{x}} = \hat{\mathbf{S}}\left(\mathbf{K}^{\mathrm{T}}\mathbf{S}_y^{-1}\mathbf{y} + \mathbf{S}_\mathrm{a}^{-1}\mathbf{x}_\mathrm{a}\right)$$

RTM

Climatology

$$\hat{\mathbf{S}} = \left(\mathbf{K}^{\mathrm{T}}\mathbf{S}_y^{-1}\mathbf{K} + \mathbf{S}_\mathrm{a}^{-1}\right)^{-1}$$

Instrument modell, measurement errors

$\hat{\mathbf{x}}$: vector of atmospheric parameters, retrieval covariance $\hat{\mathbf{S}}$

$\mathbf{y}$: measurement vector, measurement covariance $\mathbf{S}_y$

$\mathbf{x}_\mathbf{a}$: climatological state vektor, a-priori covariance marix $\mathbf{S}_\mathrm{a}$

$\mathbf{K}$: weighting function, from RTM

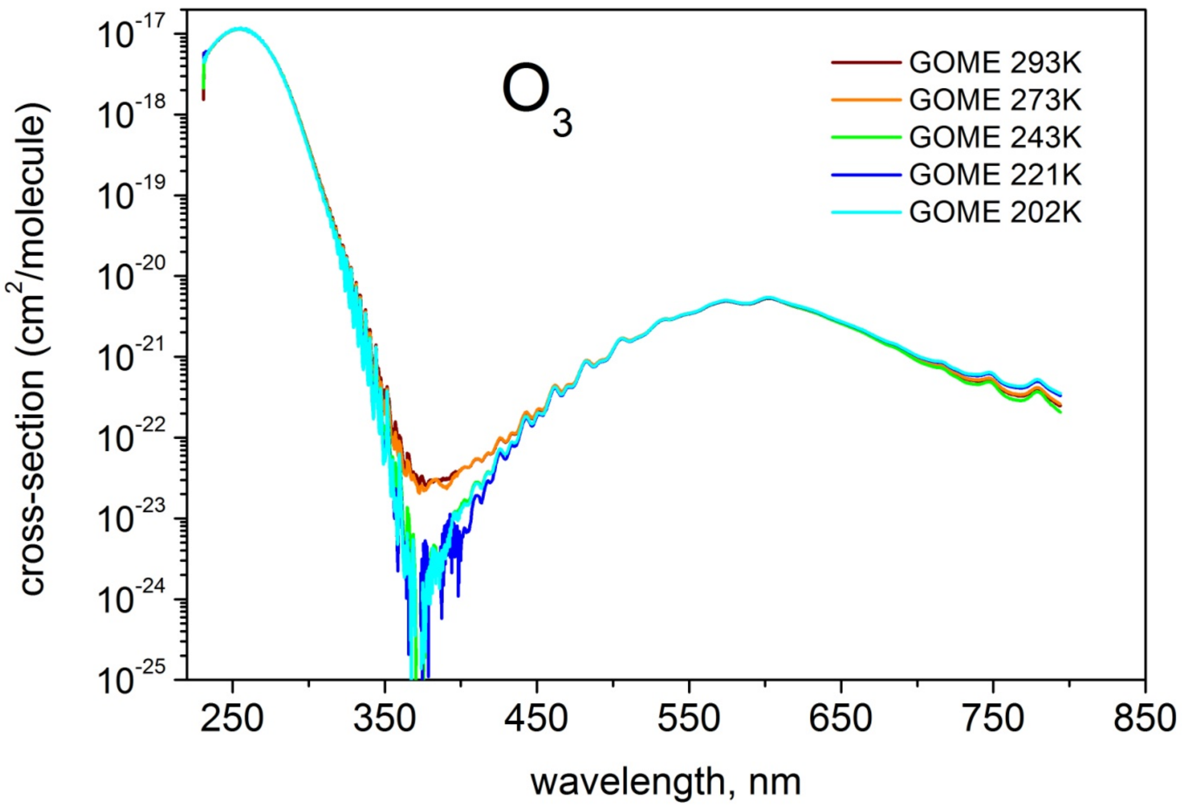
Universität Bremen

ACCENT
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK OF EXCELLENCE

GOME O_3 absorption cross-sections

- **J. P. Burrows, A. Dehn, B. Deters, S. Himmelmann, A. Richter, S. Voigt, and J. Orphal.** *JQSRT*, **61**, 509-517, 1999.

- Spectral range: 231 - 794 nm
- 202, 221, 241, 273, 293 K
- Resolution: wavelength dependent 0.2-0.4 nm



SCIATRAN RTM

GOMETRAN/SCIATRAN

A radiative transfer model for UV/Vis/NIR (240 – 2400 nm)

Products: Radiance, Weighting functions, Air Mass Factors

Spherical RTMs (CDI/CDIPI)

- SCIAMACHY (limb mode)
- Ground-based DOAS (off-axis)
- Aircraft/balloon

Pseudo-spherical RTM

- GOME / SCIAMACHY (near-nadir geometry)
- Ground-based DOAS (near-zenith geometry)

PHOTOST

In pseudo-spherical mode only

- Upwelling flux
- Downwelling flux
- Actinic flux
- Photolysis frequency

Partners in the SCIAMACHY Proje

Universität Bremen

DLR

bmb+f

astrium

OHB SYSTEM
FUCHS GRUPPE

BIRA-
IASB

SRON

Fokker

TNO

esa

SCIAMACHY on Envisat

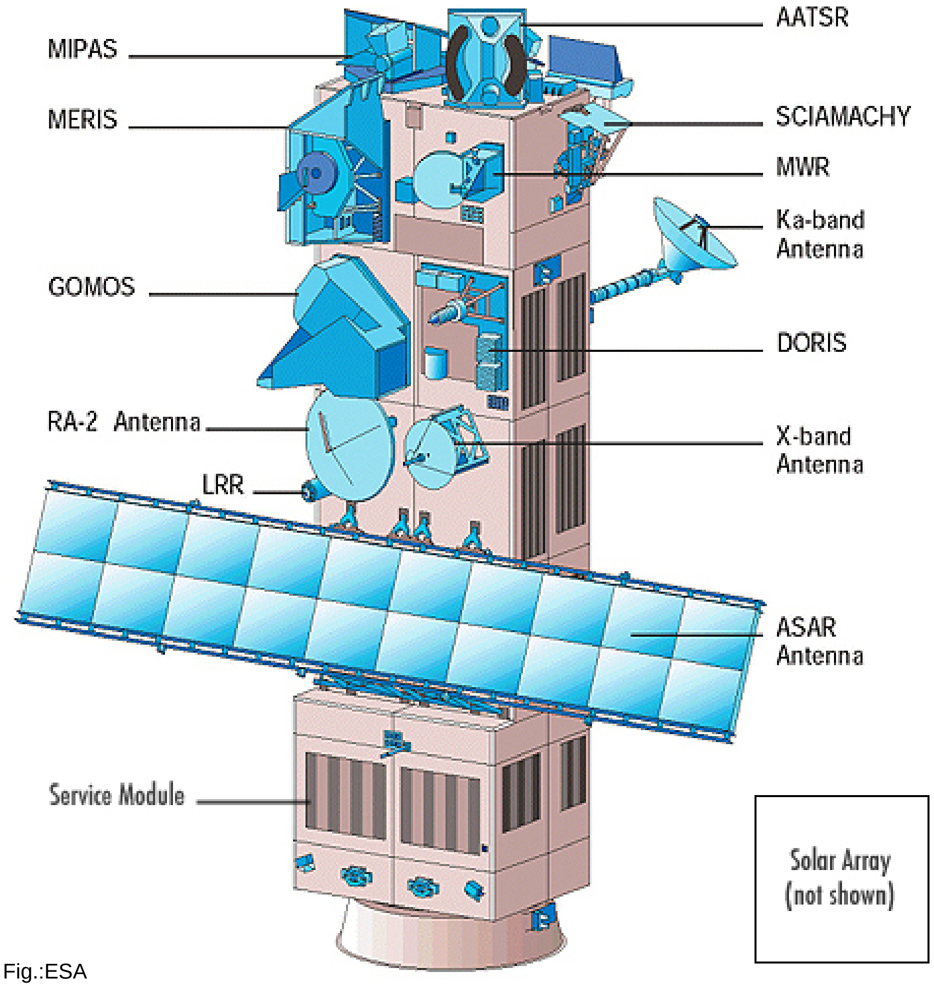
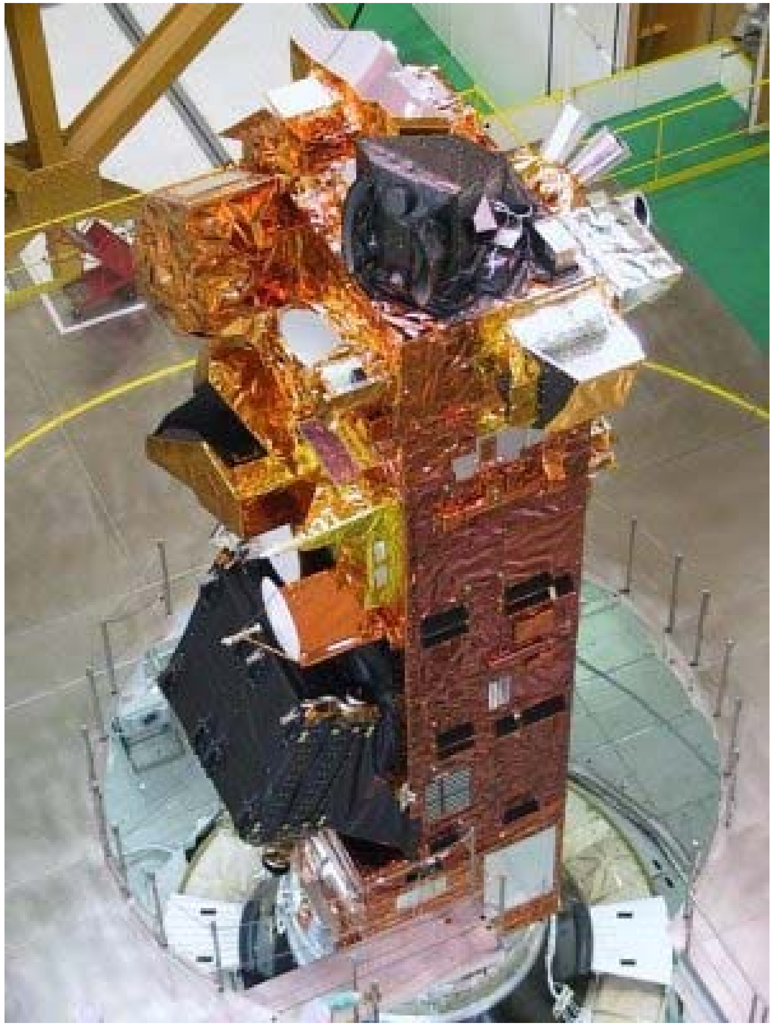


Fig.:ESA



Universität Bremen

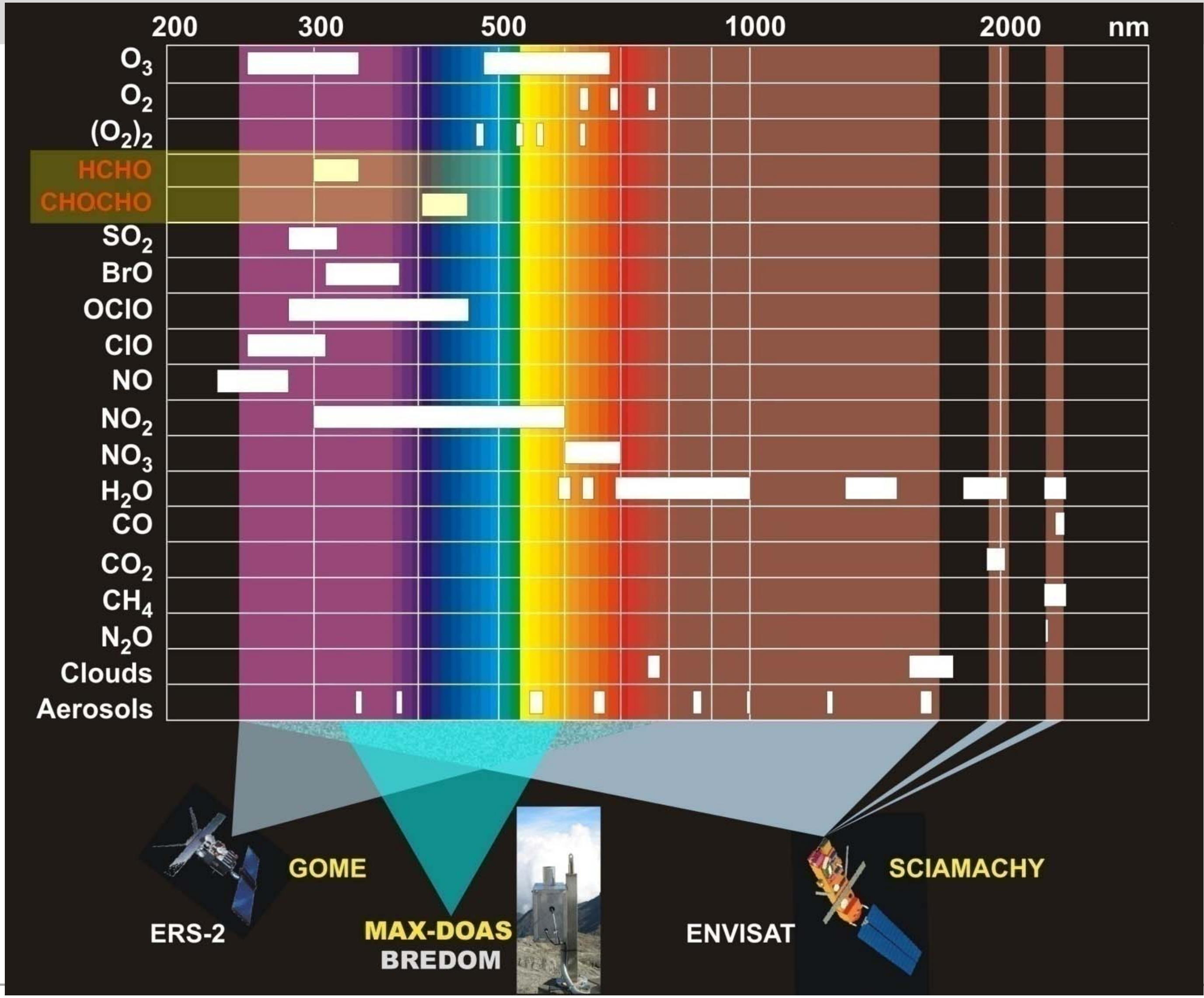
SCIAMACHY

ENVISAT
CARING FOR THE EARTH

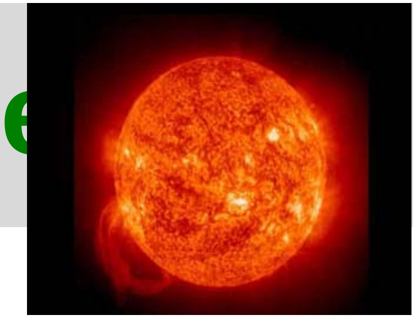
ENVISAT Launch: 1st March 2002, 2:07 CET

Universität Bremen iup ife

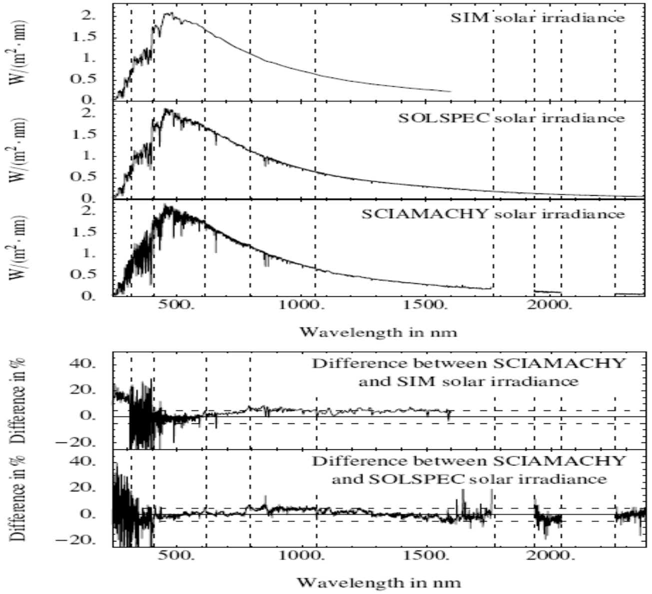
SCIAMACHY: Target Molecules



S1: Solar irradiance Change



SSI comparison SCIA,SIM, and SOLSPEC



Skupin et al., 2005,
see also Pagaran et al., 2011a

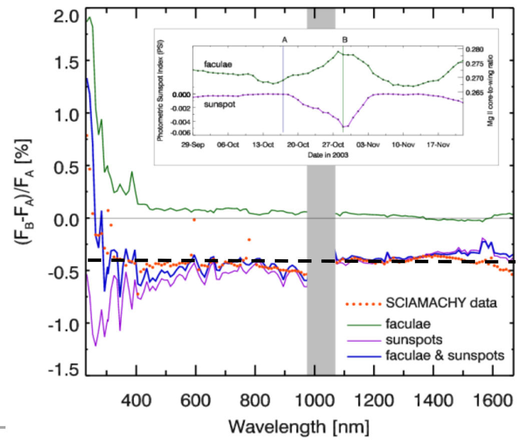
- **SCIAMACHY proxy shows solar cycle variations in ragreement with other models**
- **SCIA MACHY UV solar cycle changes are a factor of four smaller than reported by SIM during SC 23 (Haigh et al., 2010, Pagaran et al., 2011b)**

⑩ **SCIAMACHY solar observations:**

- 214-2400 nm
- Moderateley high spectral resolution (<1.5 nm)
- Daily solar irradiances since August 2002

⑩ **SCIAMACHY science results:**

- Solar proxy time series,
  e.g. Mg II, Ca H and K II (Skupin et al. 2005)
- solar cycle irradiance changes
  using solar proxies fitted to SCIA observations
  (Pagaran et al., 2009)



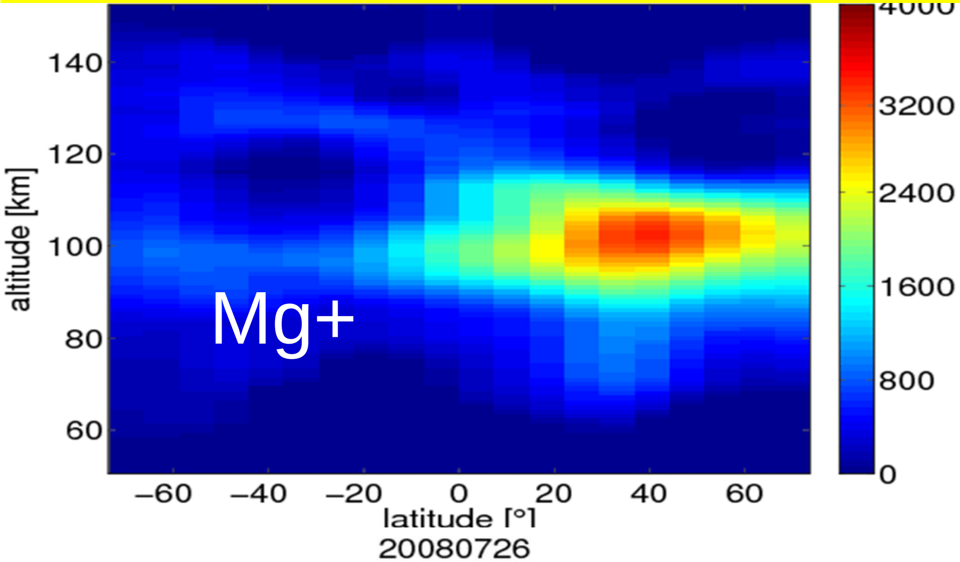
Irradiance chang
during Hallowee
2003 solar storn

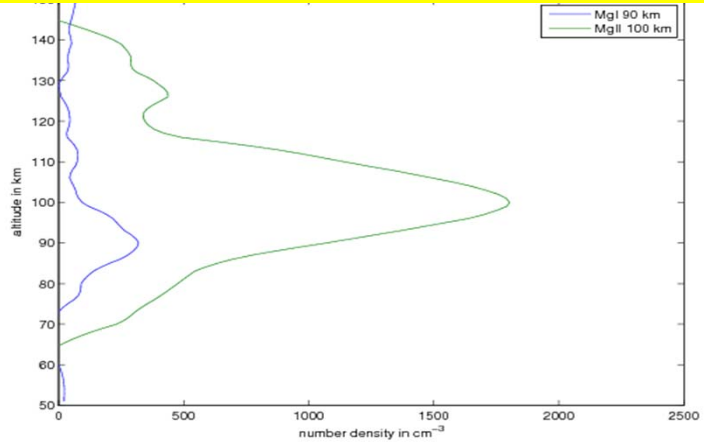
TSI ~ -
0.4%

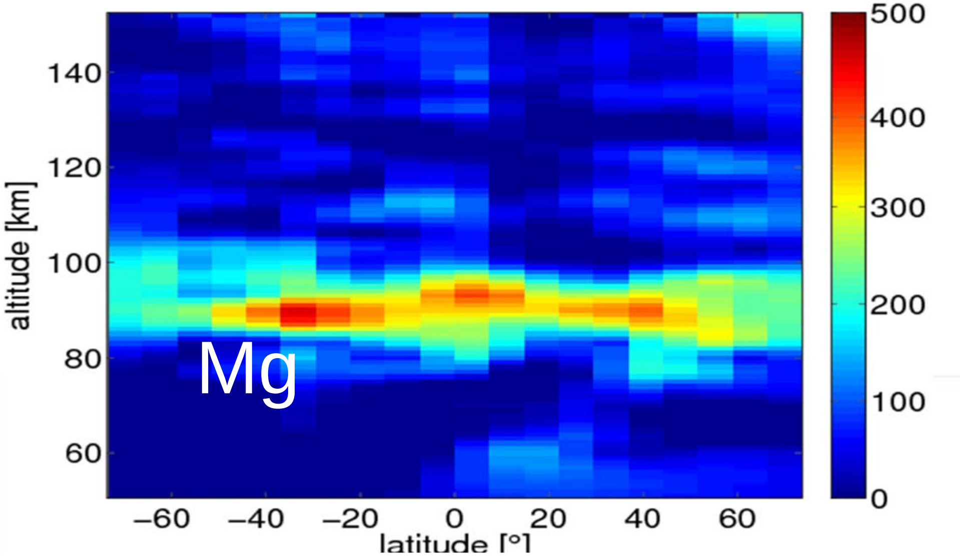
Pagaran et al., 2009

S2: Metal Ions in the upper atmosphere

Mg+ and Mg produced by Ablation of meteorites – source of metal for the upper atmosphere. They retrieved from their Emissions, observed by SCIAMACHY in limb







Mg+: Peak at ~100 km

seasonal cycle with summer Maximum

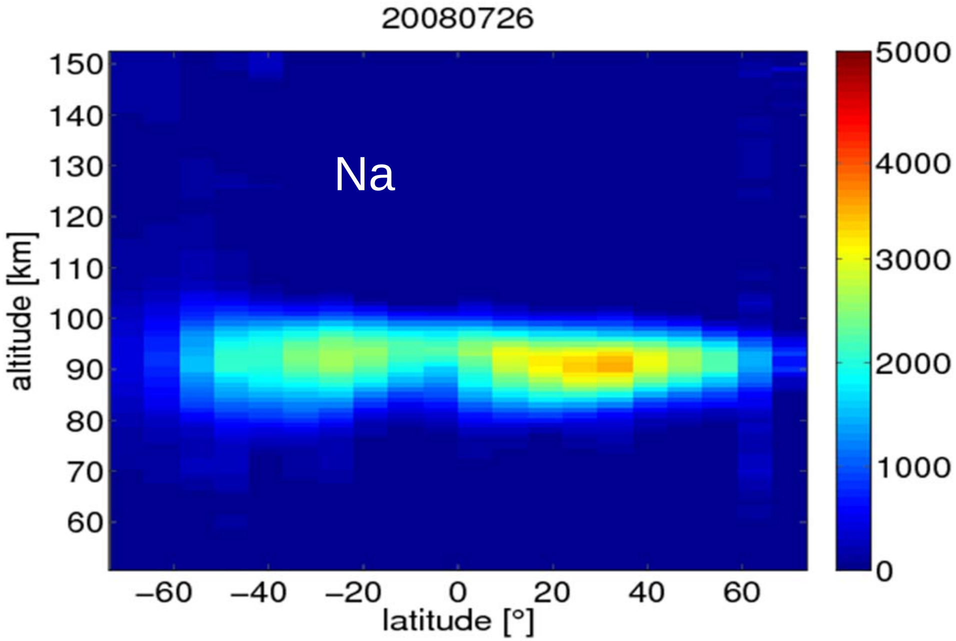
Mg: Peak at ~ 90 km

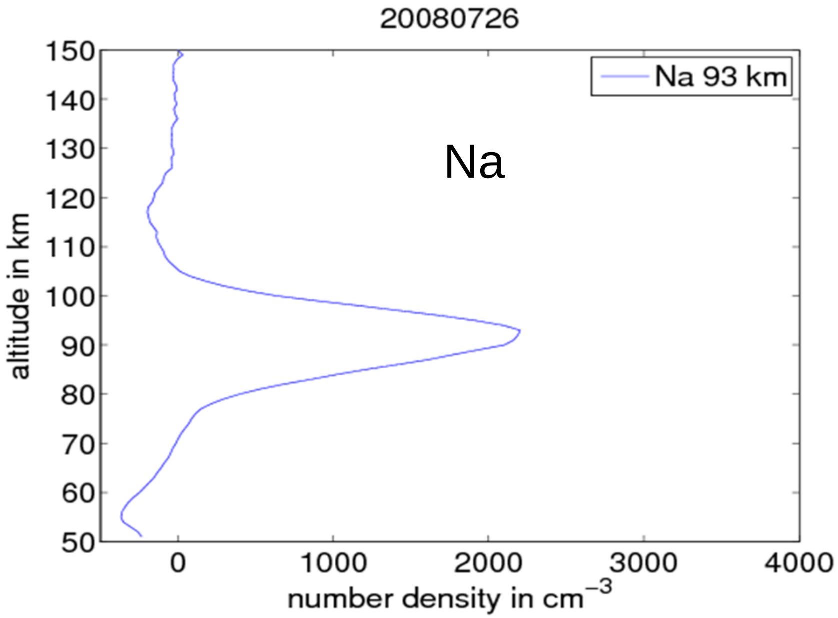
no strong seasonal variation

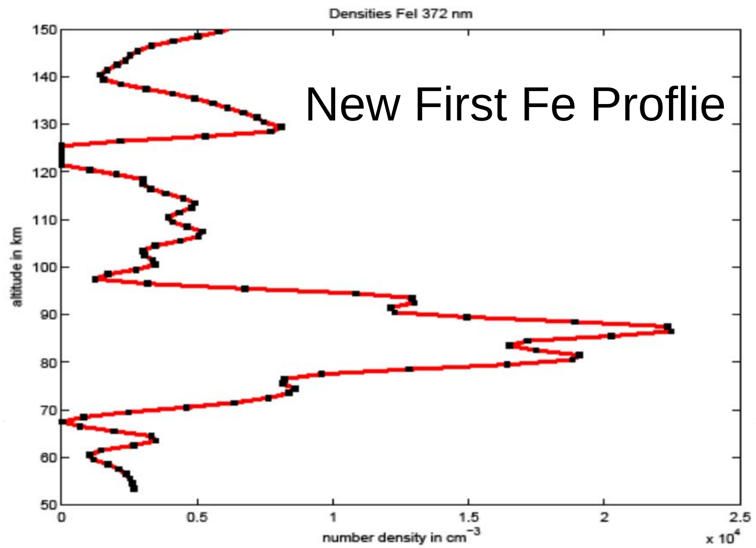
(Values below 75 km for Mg are artifacts from Ring-effect correction)

Na and Fe retrievals from SCIAMACHY

SCIAMACHY

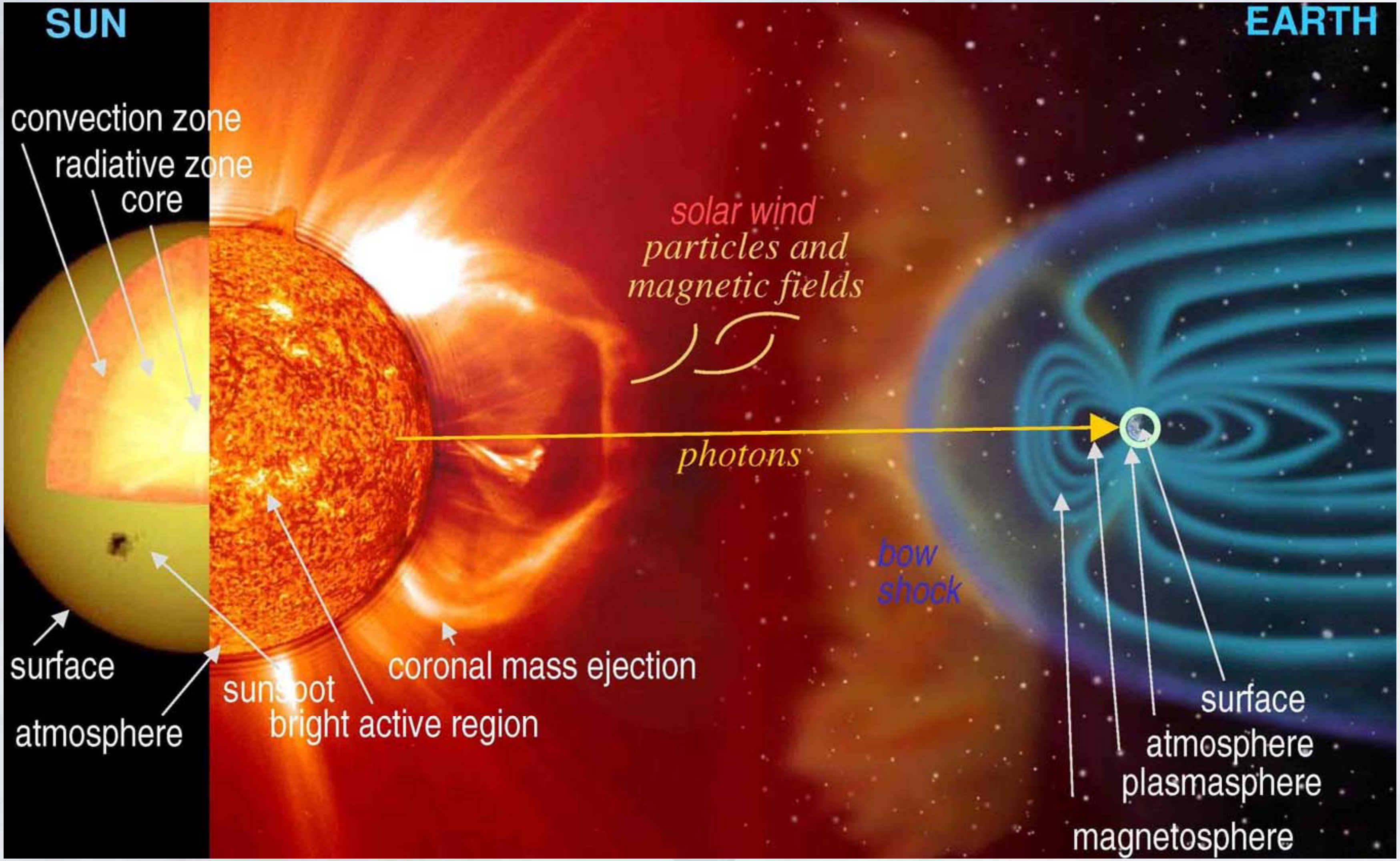




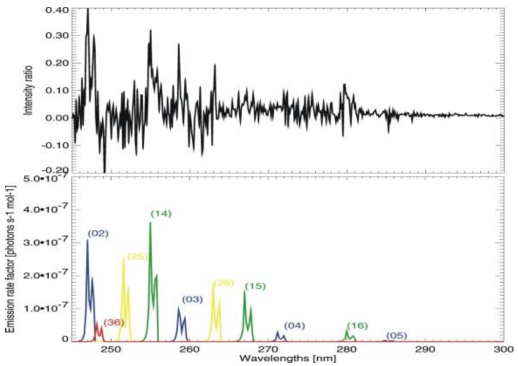


First simultaneous measurements of the input of Mg Mg+, Na, Fe more to come Ca K ++!

Solar-terrestrial: „Space weather“

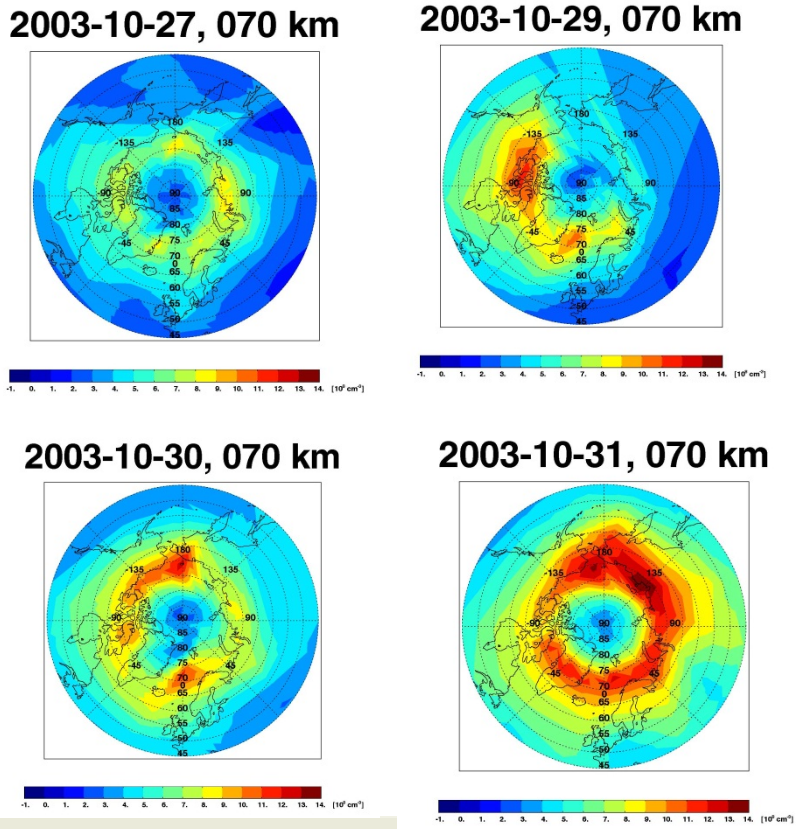


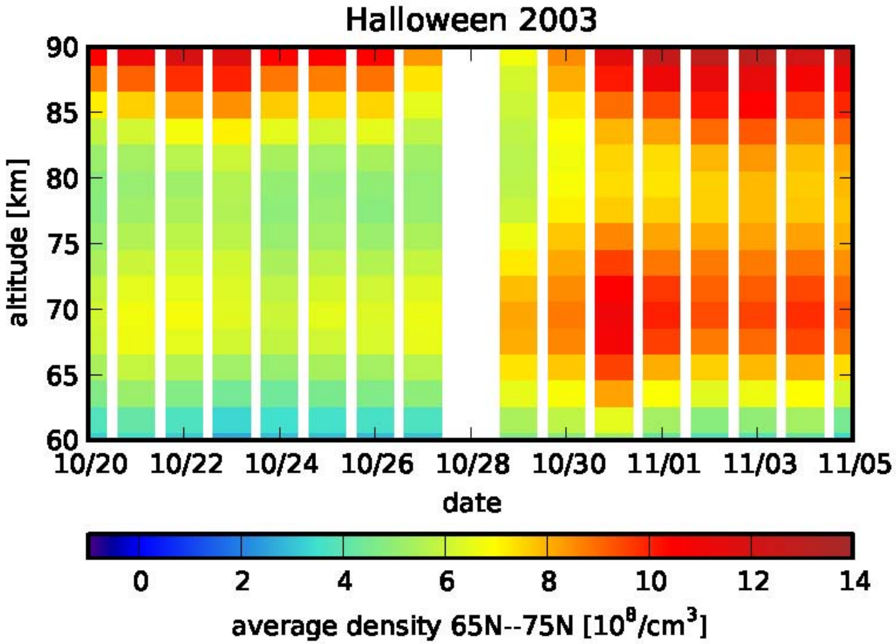
SCIAMACHY: NO Emissions and study of CME during Halloween 2003



Stefan Bender and Miriam Sinnhuber IMK/KIT

NO from SCIAMACHY orbit 798 Northern polar latitudes Limb scan 34 (~100 km) 2002





Universität Bremen

ife

SCIAMACHY

Stratospheric aerosol extinction profiles retrieved from SCIAMACHY limb measurements

Universität Bremen

iup

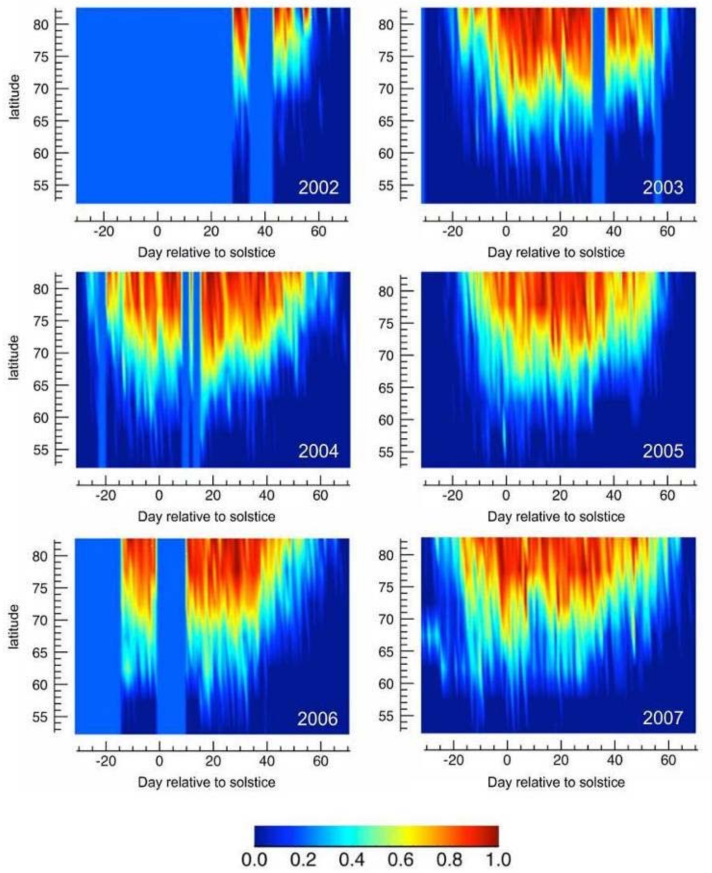
ife

SCIAMACHY

The SCIAMACHY noctilucent cloud (NLC) data set

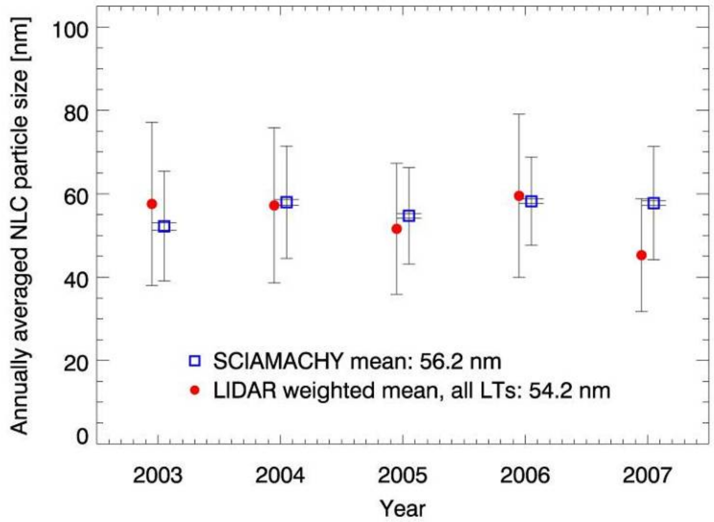
- SCIAMACHY provides daily measurements of NLC occurrence during SH & NH NLC seasons since summer 2002
- NLC particle sizes are retrieved from NLC Angstrom-exponent measurements in the UV spectral range (265 – 300 nm)

NLC occurrence rate



Robert et al., JASTP [2009]

Validation of NLC size retrievals with LIDAR observations above ALOMAR:



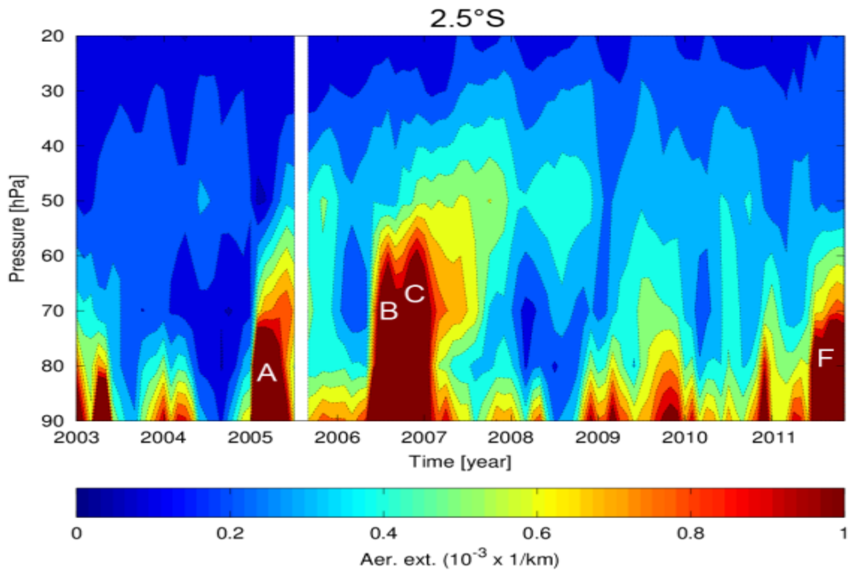
von Savigny et al., Atm. Meas. Tech. [2009]

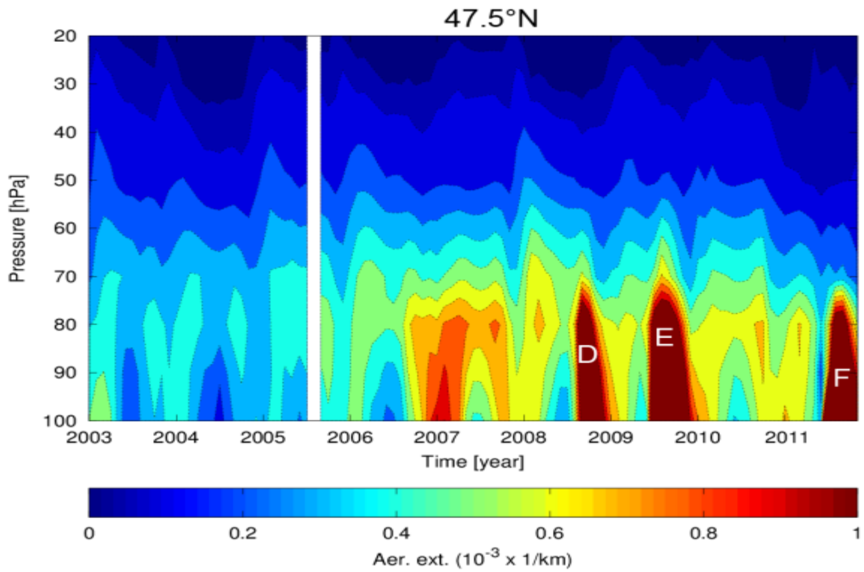
SCIAMACHY NLC measurements allowed:

- First detection of a 27-day solar cycle signature in NLC
- First observation of NLC depletion during a solar proton event (SPE)
- Identification of a QBO signature in SH polar summer mesopause temperature and NLC

SCIAMACHY Stratospheric Aerosol

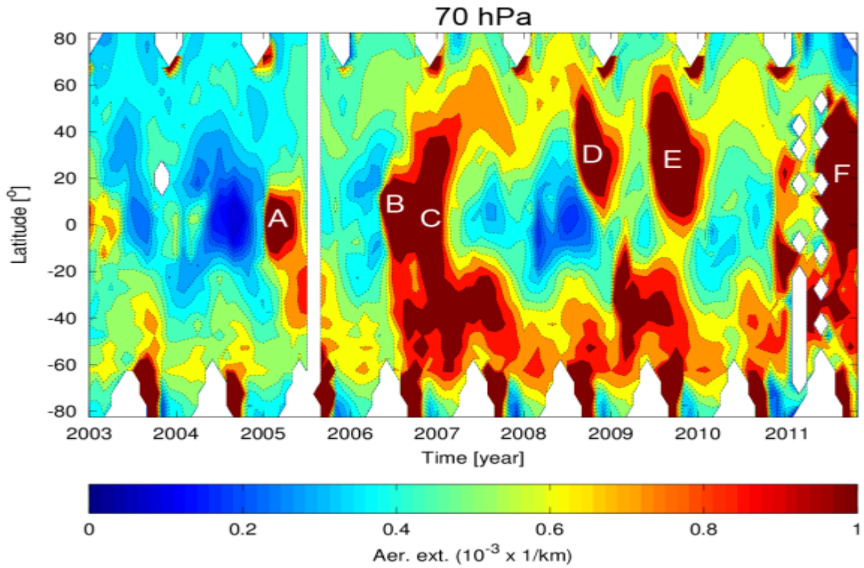
Monthly zonal mean aerosol extinction coefficient at 525 nm 2003 to 2011:





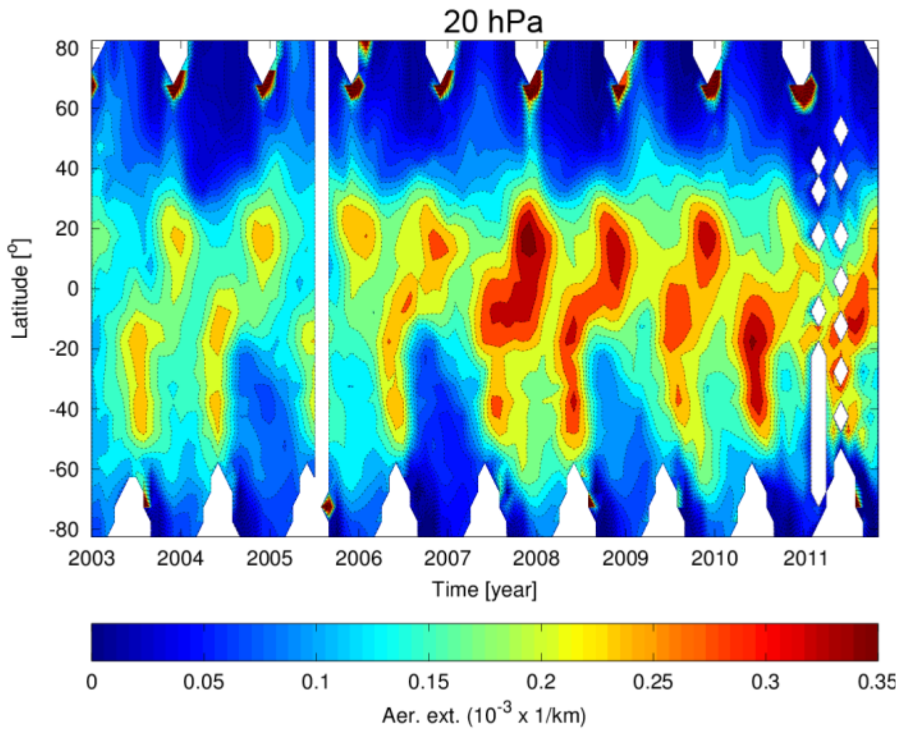
Observed **volcanic eruptions**:

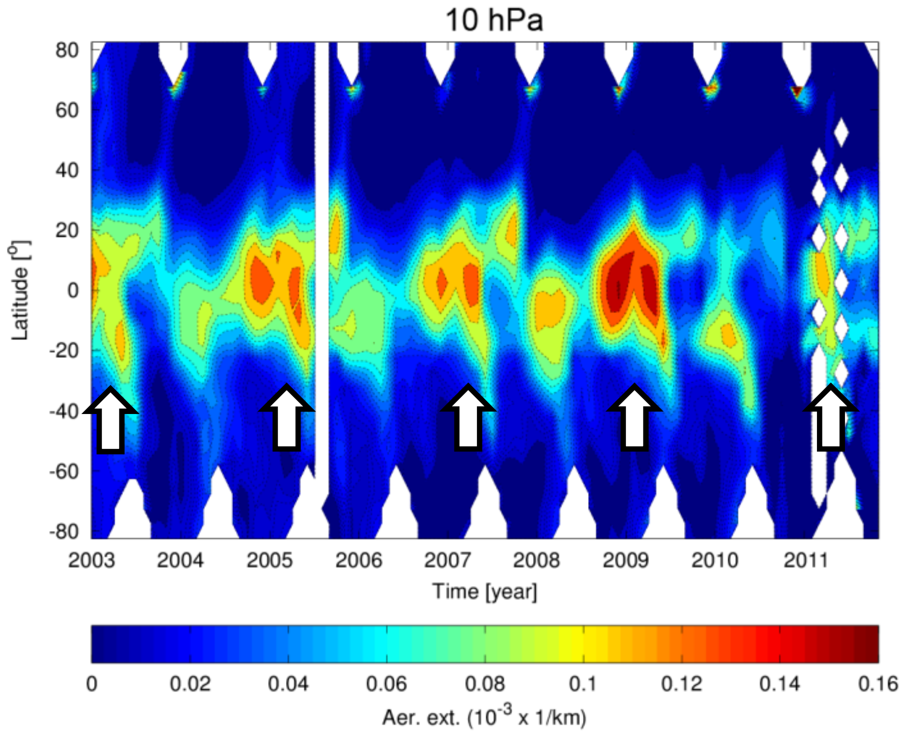
A) Manam (Jan 2005, 4° S)
B) Soufriere Hills (May 2006, 16° N)
C) Tavurvur (Oct 2006, 4° S)
D) Kasatochi (Aug 2008, 52° N)
E) Sarychev Peak (July 2009, 48° N)
F) Nabro (June 2011, 13° N)



SCIAMACHY Aerosol: Monthly zonal mean

Aerosol extinction coefficient at 525 nm for the years 2003 to 2011:





Left panel:
seasonal cycle with a m**aximum** of the **aerosol load in winter**

Right panel:
an apparent **biennial variation,** very likely **a QBO signature** increasing with rising altitude

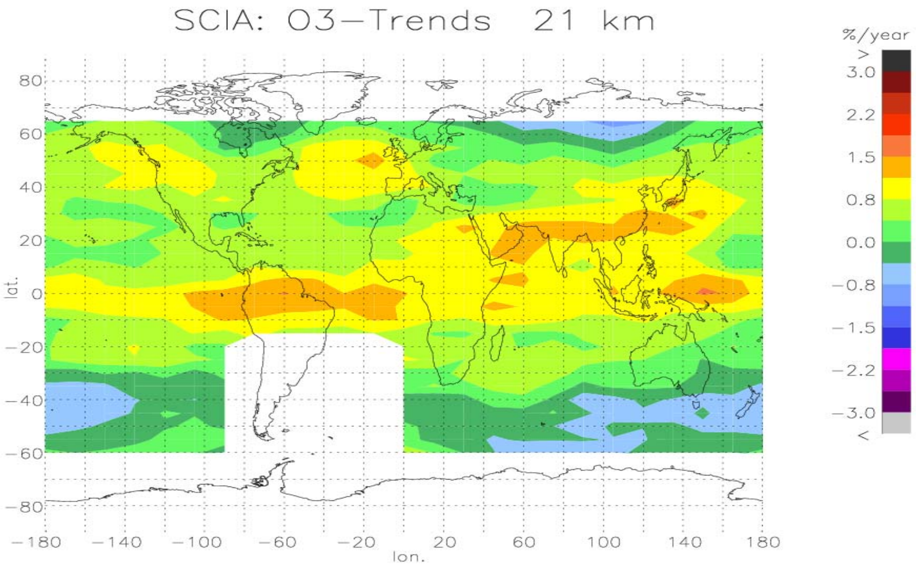
Universität Bremen

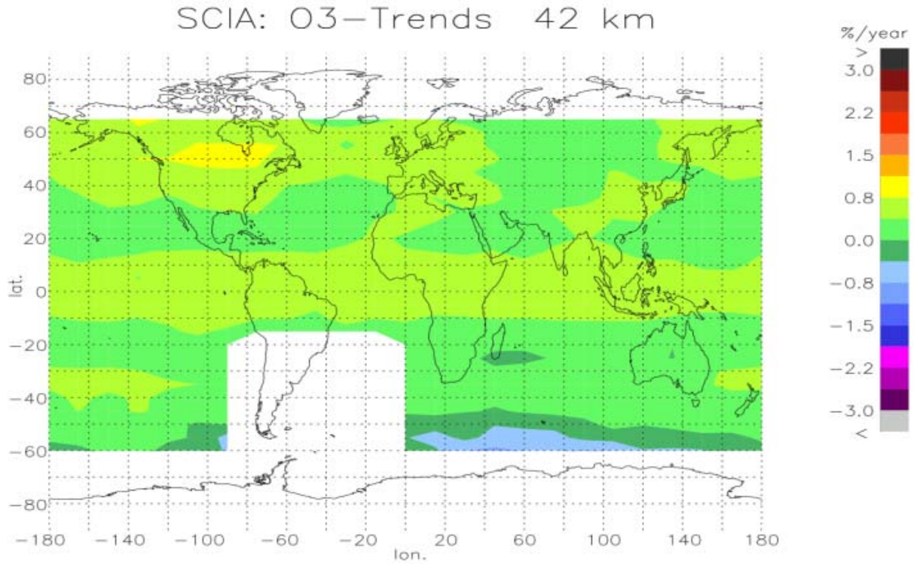
iup

ife

SCIAMACHY

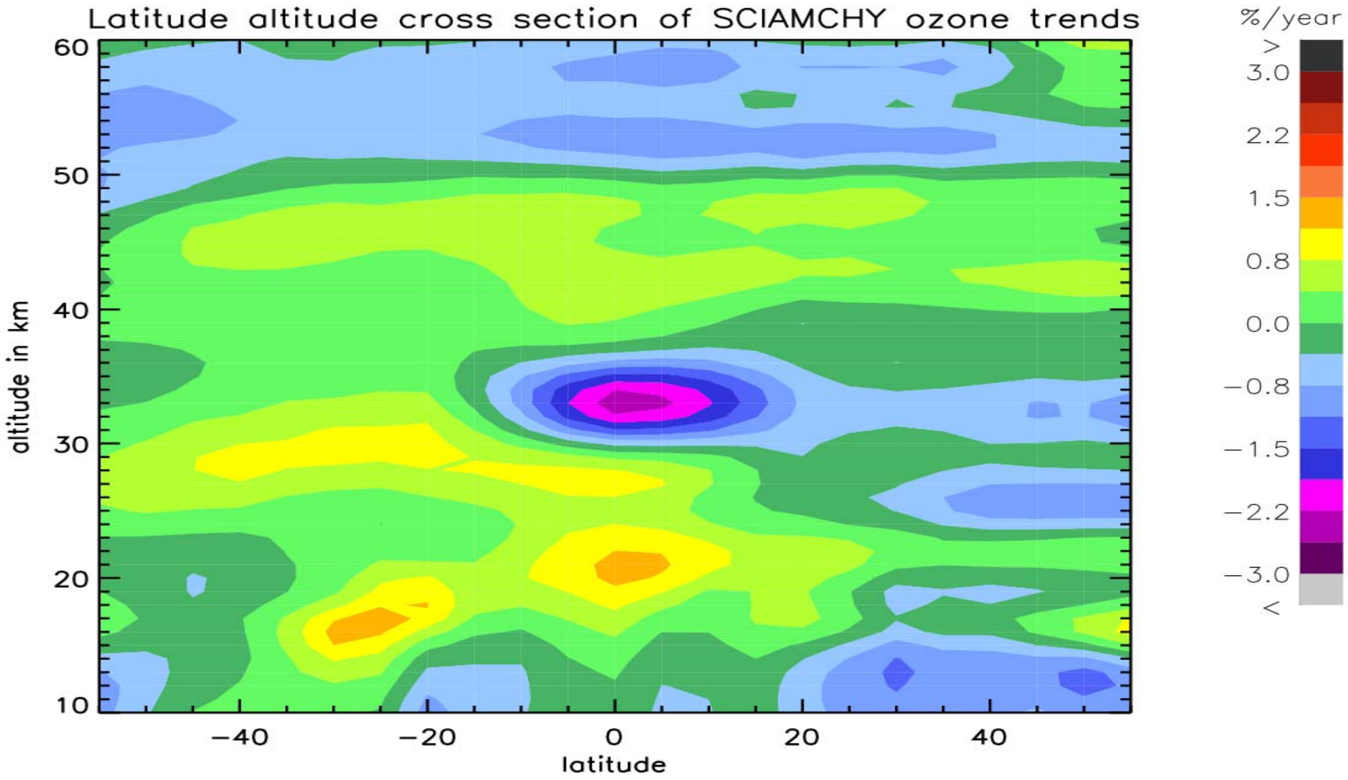
Ozone trend at 21 km and 42 km altitude





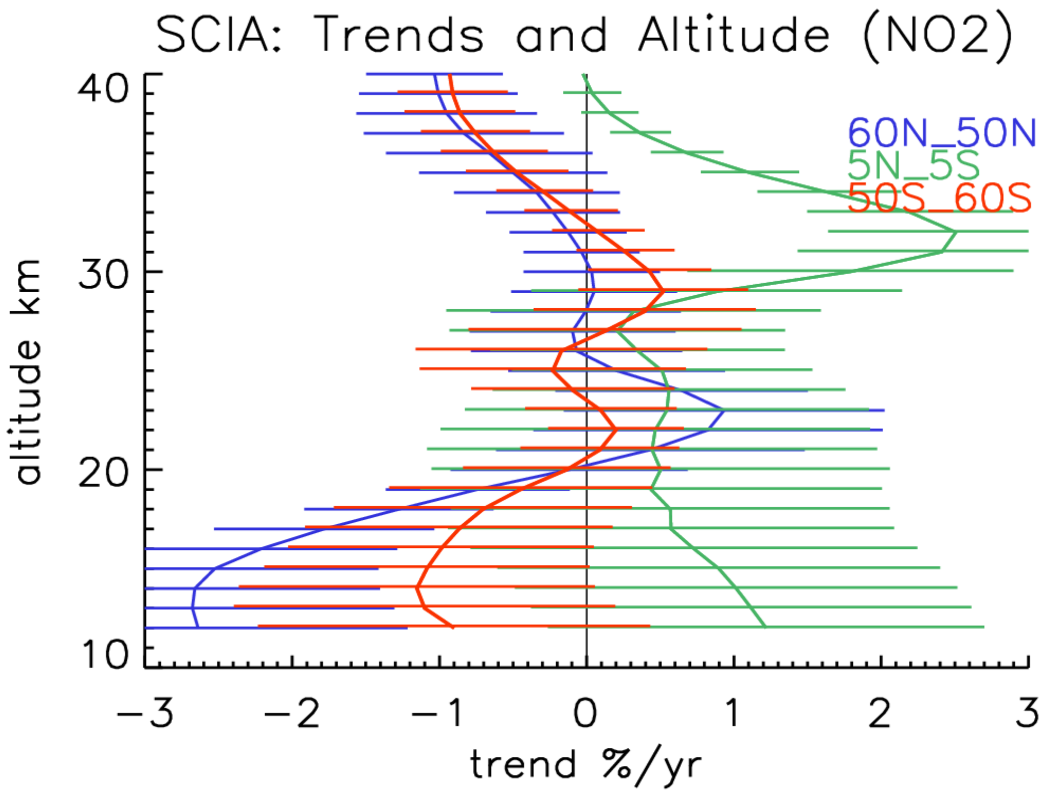
- At 21 km positive trend between 1 – 1.5 % per year in the tropics
- At 42 km moderate positive trends between 0.5-1 % per year in both hemispheres;

Latitude-altitude dependence of ozone trends



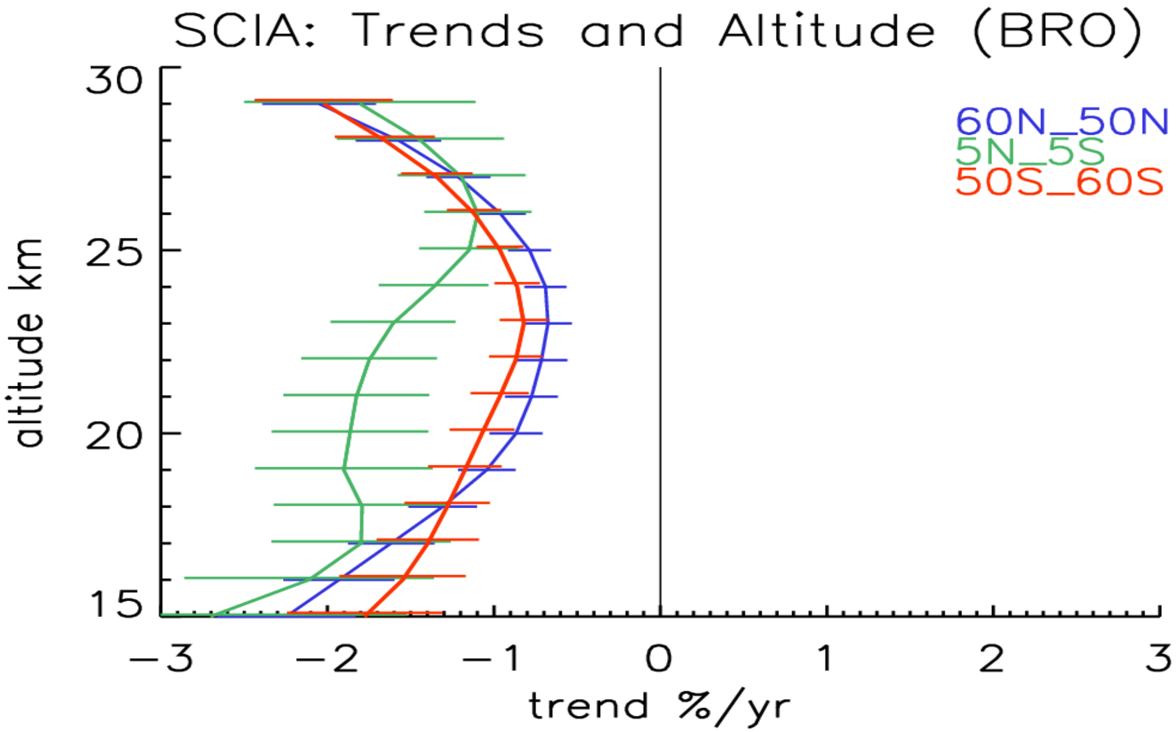
- minimum in the tropical 30-35 km range might be related to NO_X

Vertical Variation of NO_2 trends



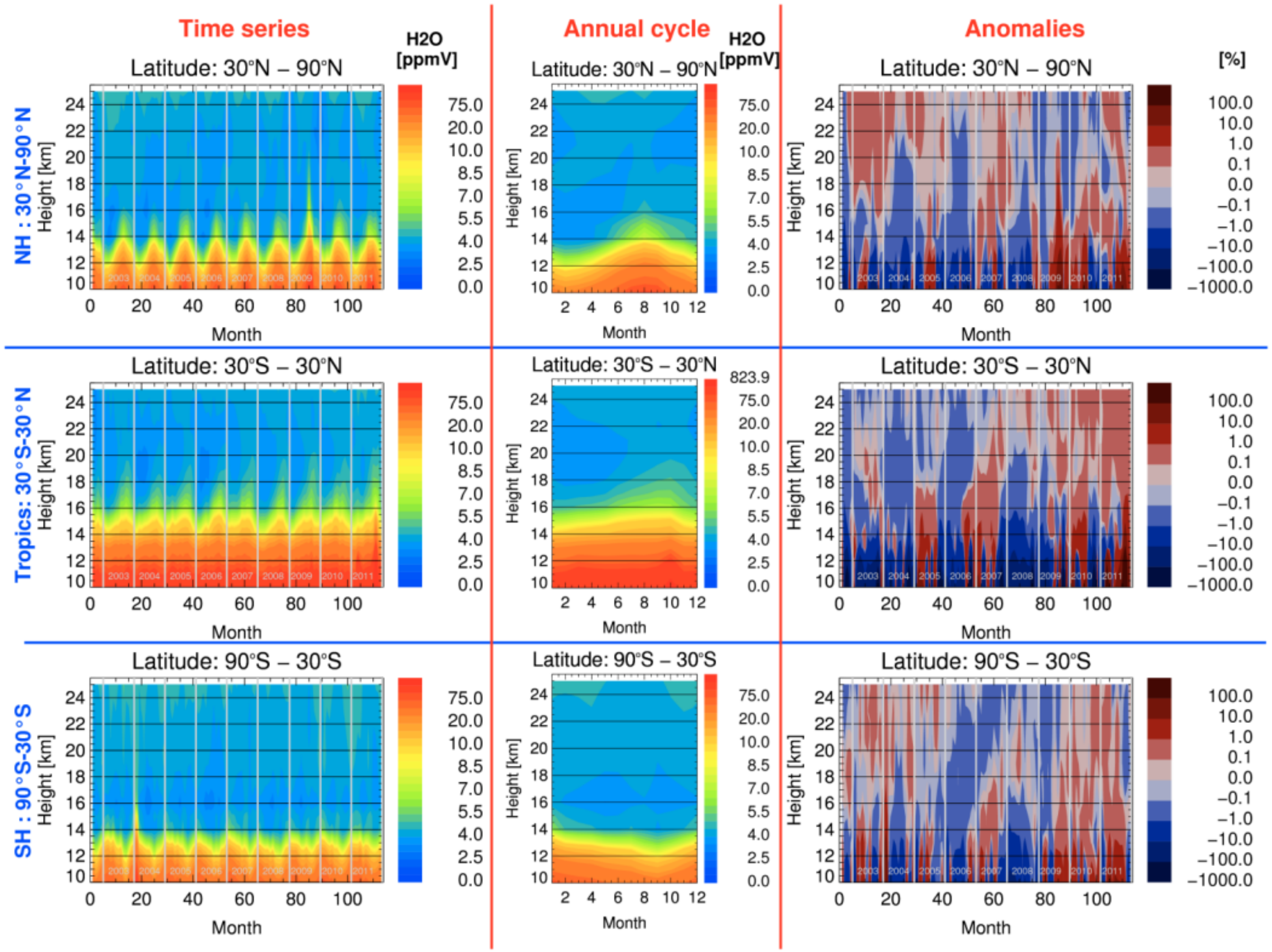
- In the tropics, maximum in the tropical 30 – 35 km range may be related to negative SCIA ozone trends (see slide before)

Vertical variation of BrO trends



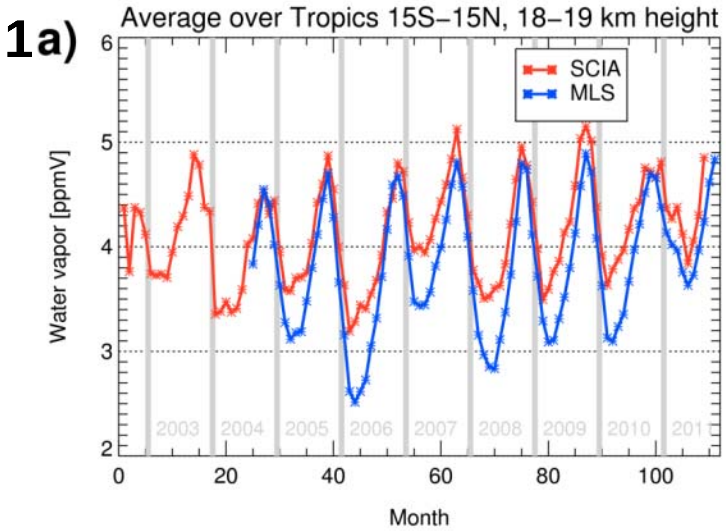
- Trends are clearly negative
- contribution to positive ozone trends in the 15 – 25 km range possible

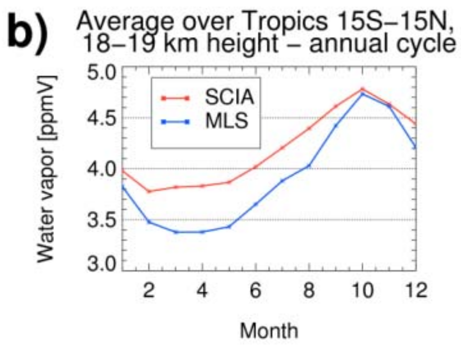
Water vapor from SCIAMACHY Limb measuremments



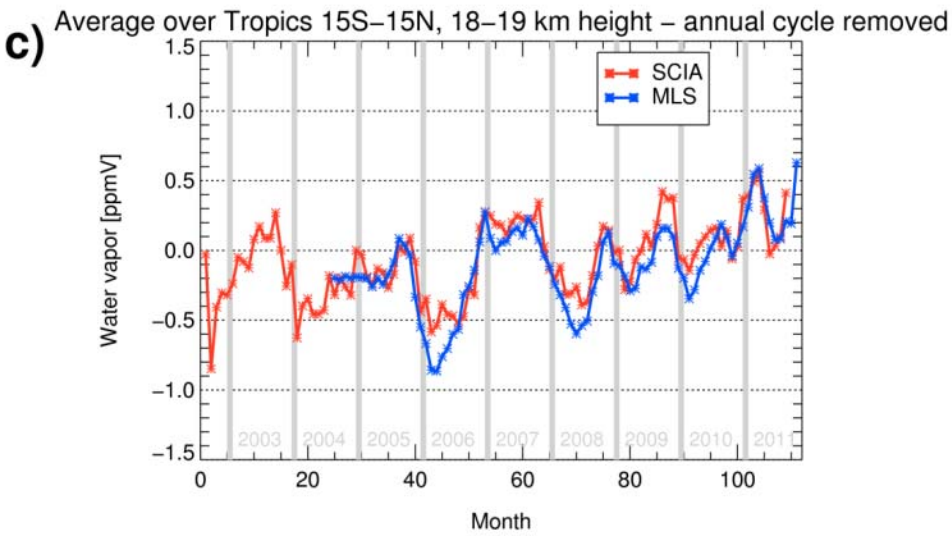
- Water vapor retieved from SCIAMACHy Limb measurements 08/2002 - 12/2011
- Every 8th day
- Monthly, area weighted mean of gridded data
- Retrieved from channel 6, spectral range 1353–1410 nm
- Height range: 11-25 km, covering the UTLS
- Cloud filter: SCODA V19
- Variable aerosol correction
- Rozanov et al., 2011

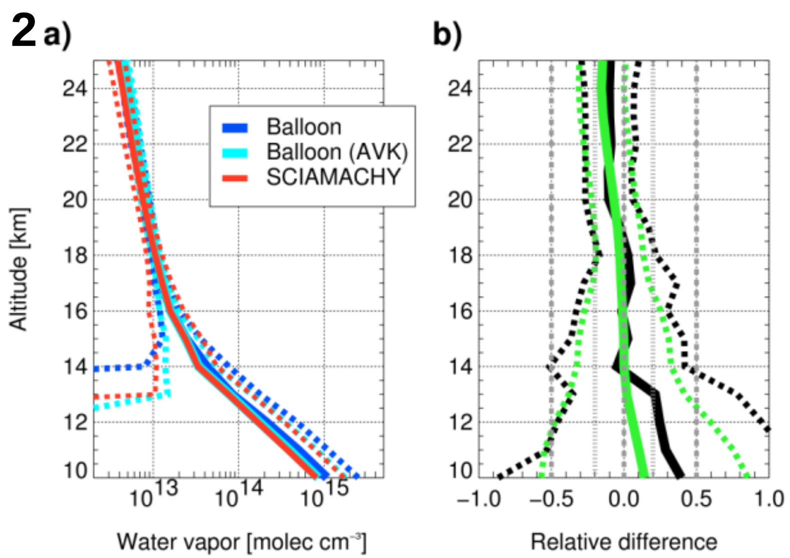
Water vapor from SCIAMACHY Limb measuremments

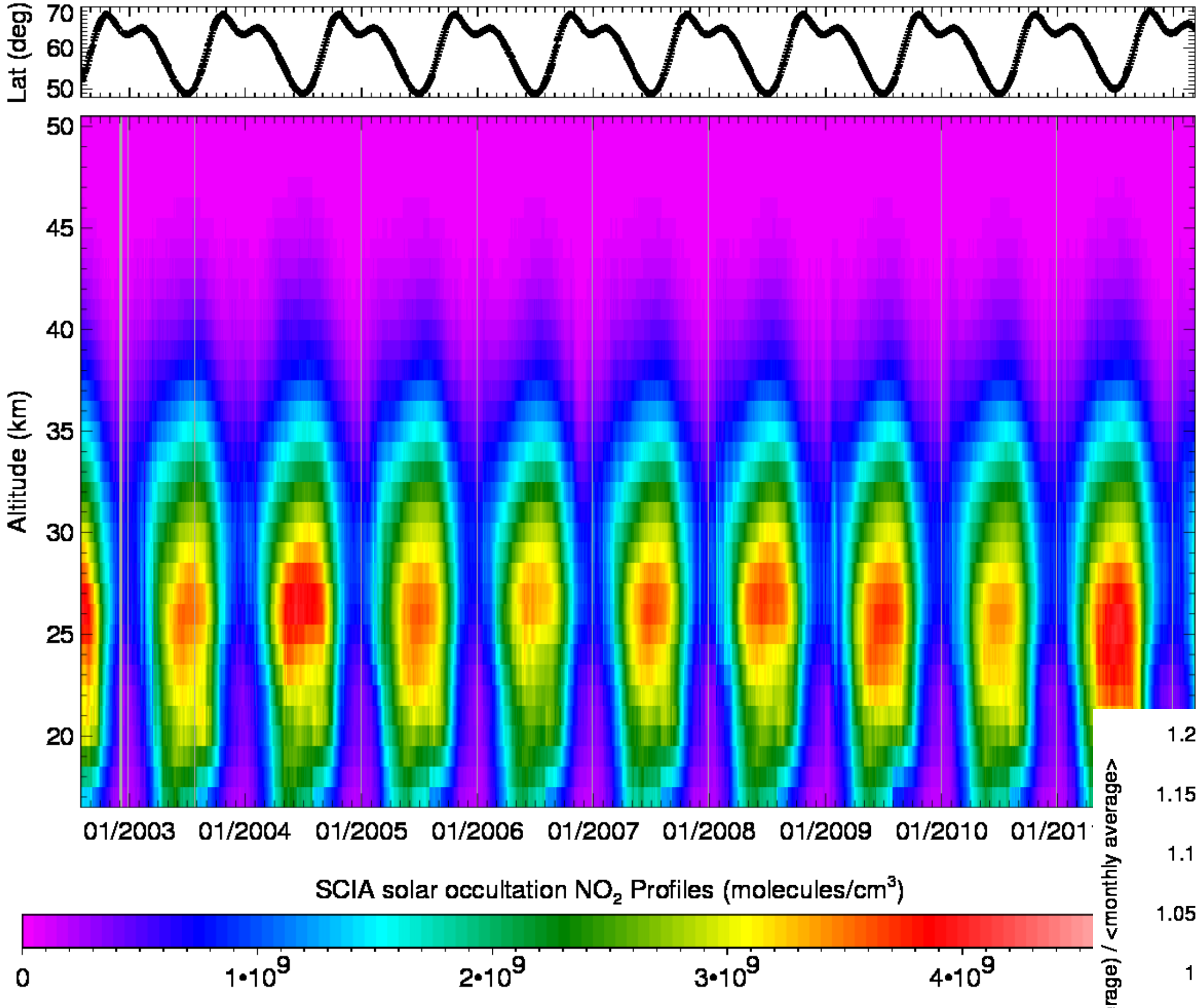




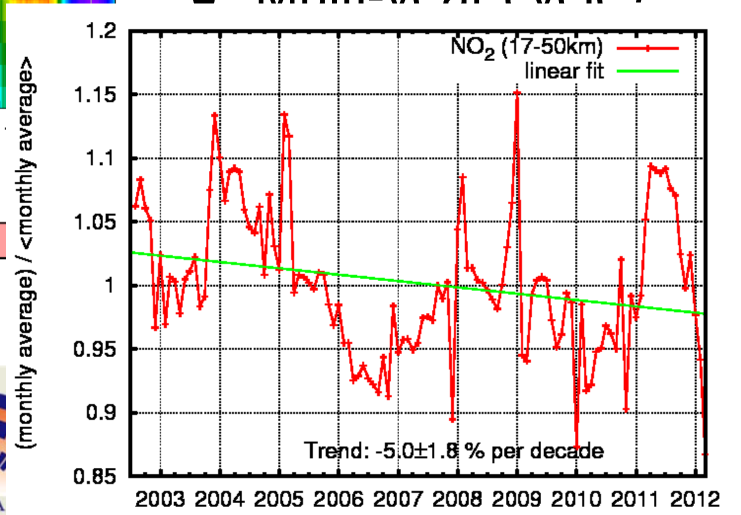
- SCIAMACHY Limb Water vapor agrees well with other data sets, e.g.
  - MLS (1)
  - Balloon borne in situ Cryospheric frost point hygrometer measurements (2)







- Time series of 3-daily means of NO_2 at sunset
- Overall variations driven by season and latitude variation
- Preliminary, simple trend analysis: -5% per decade.
- Multi-year cycle?



Universität Bremen

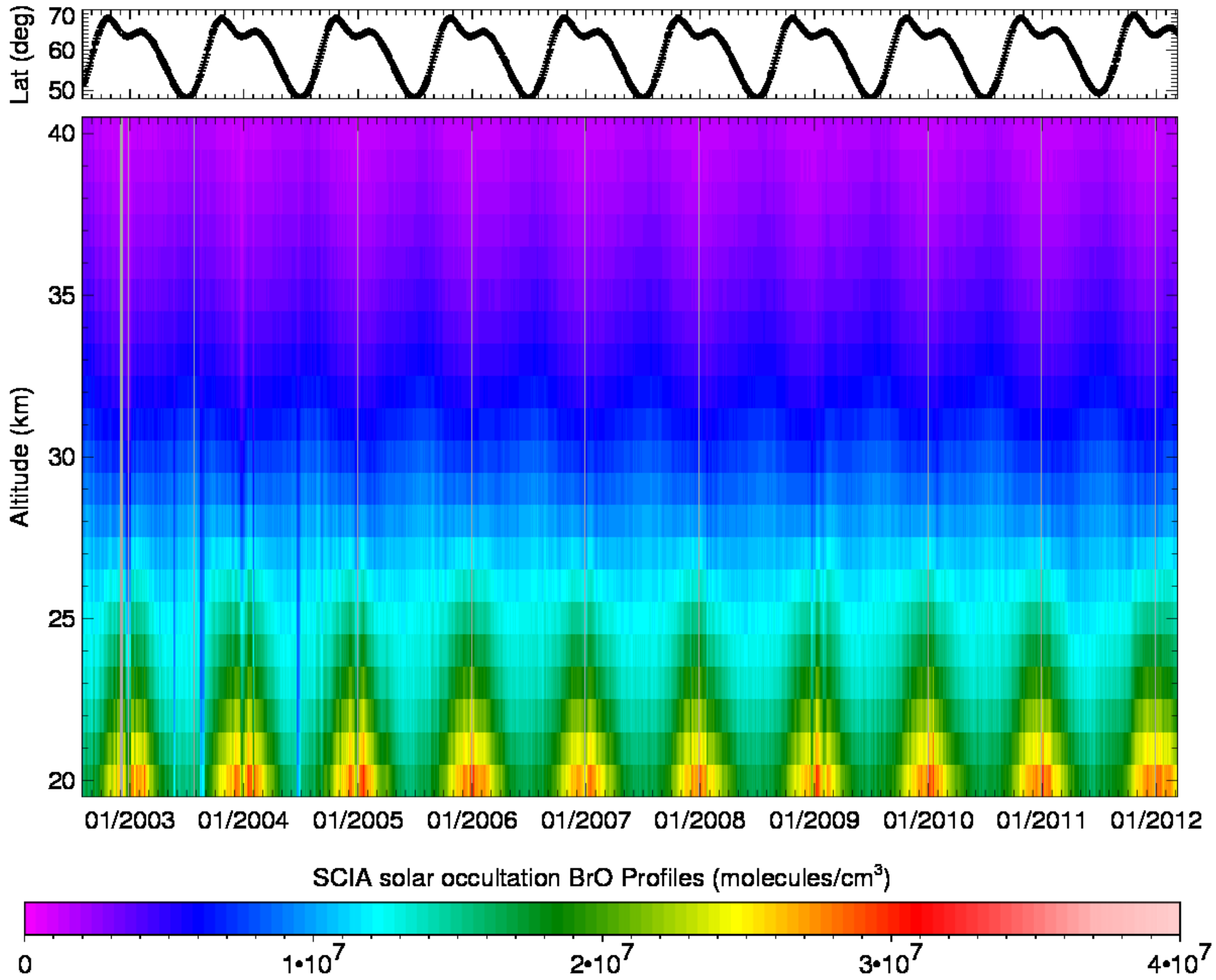
iup

ife

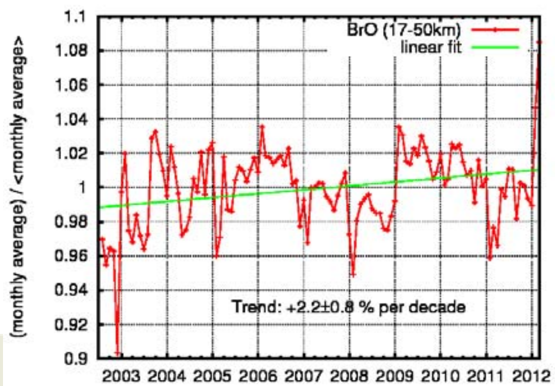
SCIAMA

klaus.bramstedt@iup.phy

SCIAMACHY solar occultation BrO profiles: time series



- Time series of 3-daily means of BrO at sunset
- Overall variations driven by season and latitude variation
- Preliminary, simple trend analysis: +2.2% per decade.



Universität Bremen

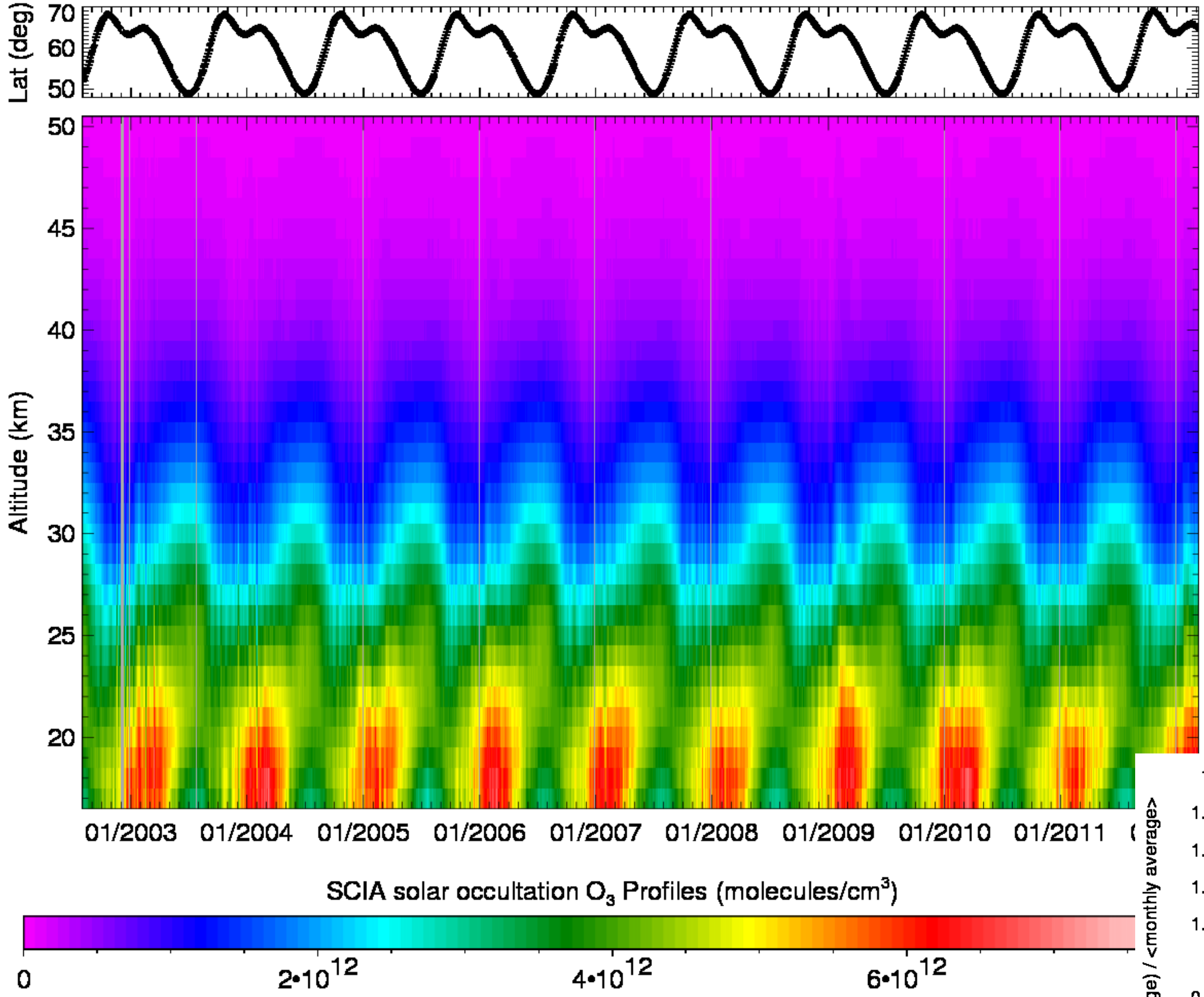
iup

ife

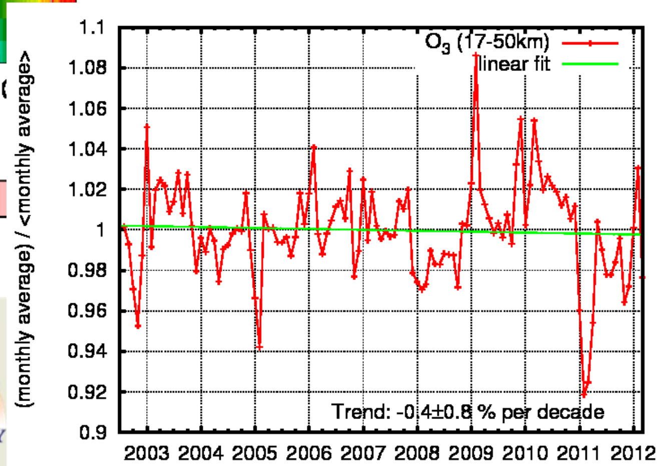
SCIAMACHY

klaus.bramstedt@iup.phy

SCIAMACHY solar occultation O_3 profiles: time series



- Time series of 3-daily means of ozone
- Overall variations driven by season and latitude variation
- Preliminary, simple trend analysis: no significant trend



Universität Bremen

iup

ife

SCIAMACHY

Summary

- SCIAMACHY have demonstrated the capability to retrieve trace constituents from limb / occultaiton measurments from space.
- Ageing fleet of limb instruments
- We need new missions to address the issues of the next phase of the anthropocene.