EU ACCENT Plus Workshop 15-16th May 2013

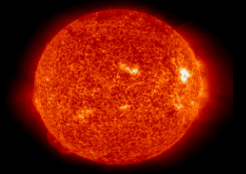
Regional atmospheric chemistry and climate: Emerging trends'
during 6-7 May at IPRL

Pollution studied by REmote Sensing of Conurbations/megacities and Retrieved from observations made by Instrumentation on space BasEd platforms - PRESCRIBE

John P. Burrows[1,2] and Andreas Richter

1 Institute of Environmental Physics
University of Bremen, Bremen, Germany
2 Natural Environment Research Council: Centre for Ecology and Hydrology, Wallingford, Oxfordshire, U.K.

The Institute of Environmental Physics – Institute of Remote Sensing – IUP-UB University of Bremen



IUP-UB comprises four research departments:

- **Physics and Chemistry of the Atmosphere (Prof. Dr. John P. Burrows)**
- **Remote Sensing (Prof. Dr. Justus Notholt)**
- **Physical Oceanography (Prof. Monika Rheine)**
- **Terrestrial Environmental Phocis (Dr. Helmut Fischer)**

Overarching Goal: Earth System Systems by means of Physical Methods

IUP-UB is a partner of the DFG(German Research Foundation) Marum Excellence Cluster at the Universlty of Bremen

University of Bremen
marum
Center for Marine Environmental Sciences

Universität Bremen*

*EXZELLENT.

IUP-UB Organisation: http://www.iup.uni-bremen.de/

Executive Board of the IUP-UB:
Directors: J. P. Burrows, J. Notholt and M. Rhein + P. Lemke (AWI)

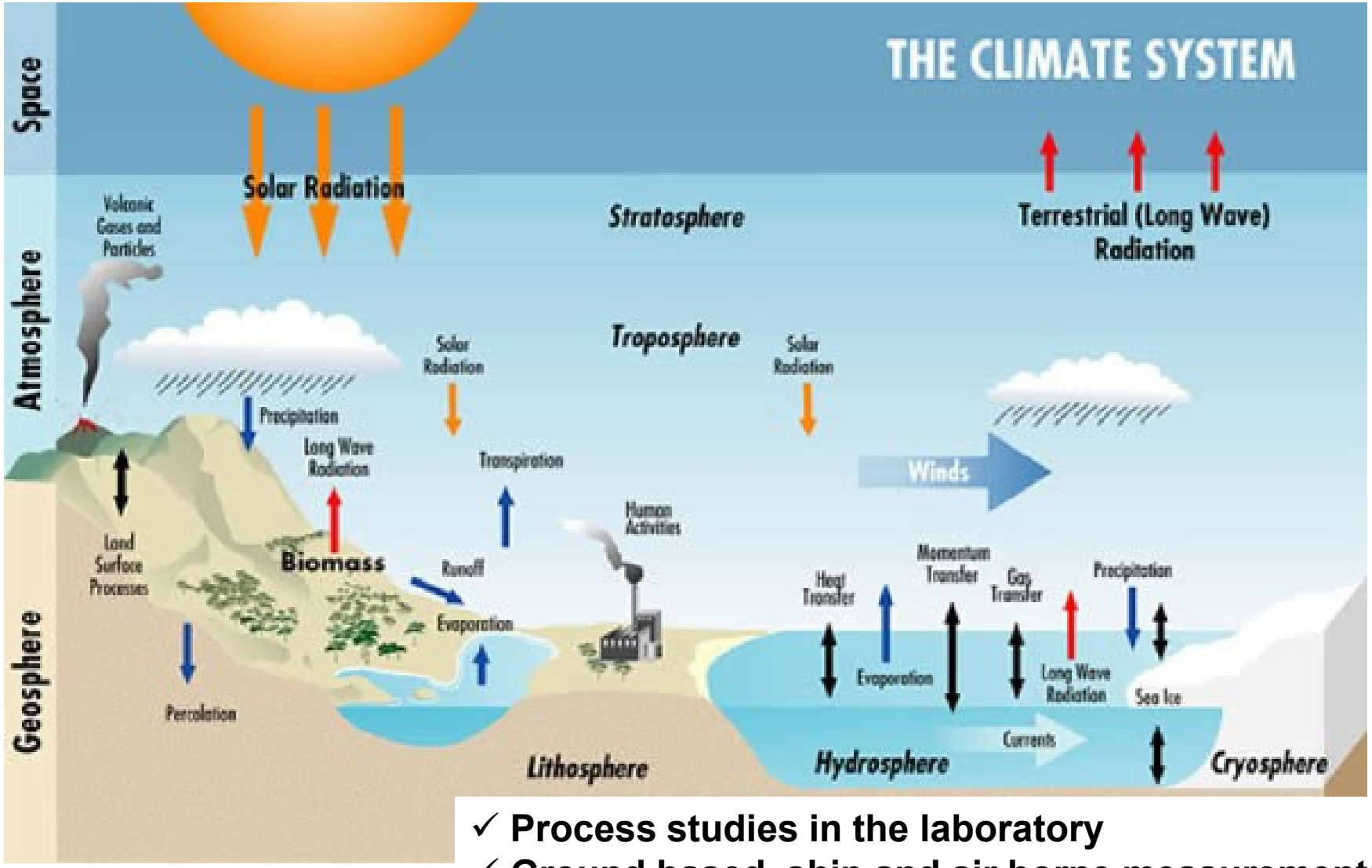
Physics and Chemistry of the Atmosphere	Remote Sensing	**Physical Oceanography**	**Terrestrial Environmental Physics**
Professor J. P. Burrows	Professor J. Notholt	Professor M. Rhein	Dr. H. Fischer
5 Senior Researchers	2 Senior Researchers	2 Senior Researchers	
+ Professor A. Bracher (AWI-IUP)			
Staff: ~75	Staff: ~ 30	Staff: ~ 20	Staff: ~10

IUP-UB Academic Courses :

International M. Sc. Environmental Physics – 50 students
B.A. Physics, M.A. Physics – Optional Environmental Physics courses
Professor Dr. Annette Ladstätter-Weissenmayer + Professors , Senior Scientists and 2 administrative staff.
Students selected from abroad have their tuition fees waivered
htttp://www.pep.uni-bremen.de/

Remote Sensing Book : http://www.iup.uni-bremen.de/materials/remsensingbook/
e-learning Module: http://www.iup.uni-bremen.de/deu/lehre/elearning/index.html/

The Earth System and its Climate

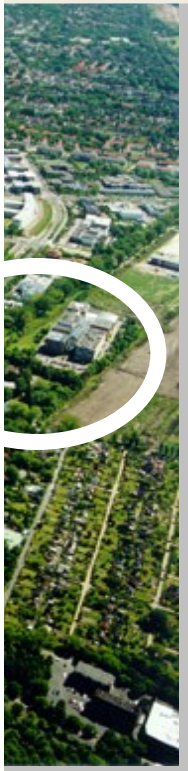


- ✓ Process studies in the laboratory
- ✓ Ground based, ship and air borne measurements
- ✓ Space based Instrumentation – Remote Sensing
- ✓ Modelling for interpretation and to improve prediction

Institute of Environmental Physics, University of Bremen

J. P. Burrows - 1992 to present

Klaus Künzi and Wolfgang Peether, 1992 to 2000/ 2004

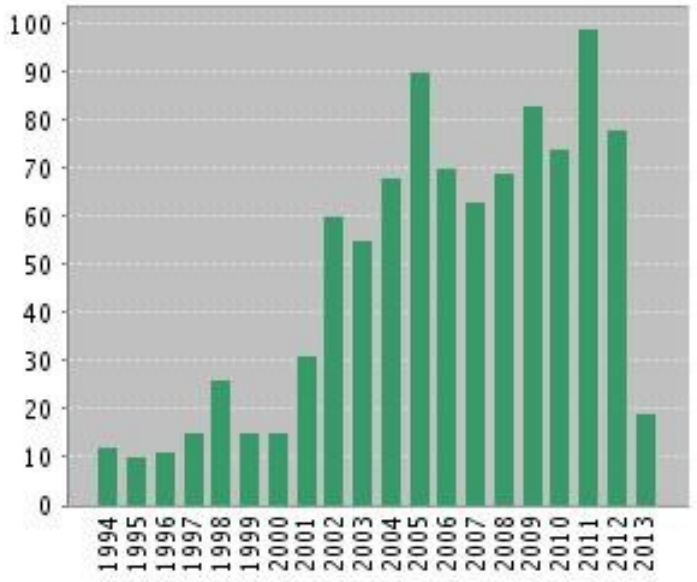


SCIAMACHY

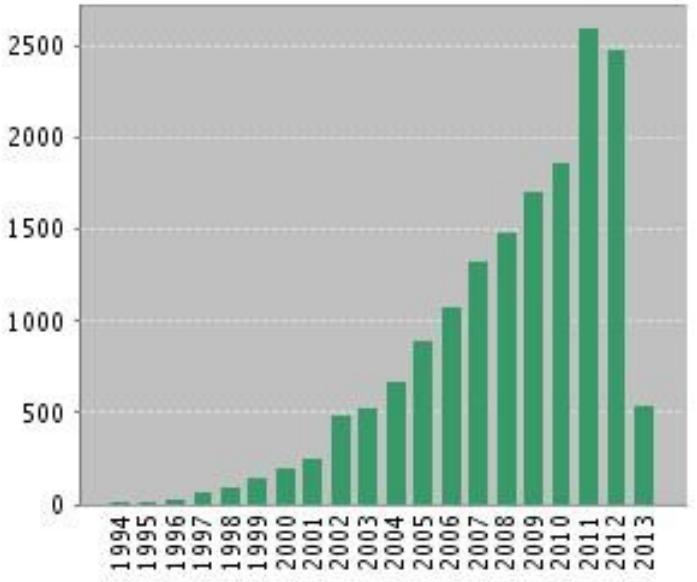
CarbonSat Constellation

IUP Research Output - Results

Publications per Year



Citations per year



ISI Web of Knowledge Analysis Ist January 1993 to 1st May 2013:

h-index:	**56**
Average Citations per Item:	**17**
Results found:	973
Sum of the Times Cited:	16566
Sum of Times Cited without self-citations:	12909
Citing Articles:	8222
Citing Articles without self-citations:	7479

ACCENT *Plus*
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK

ACCENT PLUS is an EU Framework 7 Project

http://www.accent-network.org/

ACCENT-Plus (Atmospheric Composition Change: the European Network – Policy Support and Science) is a coordination Action financed by the European Commission within FP7. It builds on the successful efforts of the Network of Excellence ACCENT which over the past six years has brought together the atmospheric science community engaged in global change and air pollution studies. The integrating activities within the ACCENT Network have produced a stronger, more cohesive community and have facilitated the engagement of a new generation of scientists who have started their career in the collaborative environment promoted by ACCENT.

1) THE ACCENT Plus CHALLENGE

Fragmentation of research efforts, lack of a shared scientific vision and insufficient availability of research tools, shared databases, etc., is a major limitation for the understanding of atmospheric composition change over Europe under a changing climate, and the consequent inadequate transfer of prospects to the decision makers for future policies. The ACCENT-Plus project builds on the successful efforts of the NoE ACCENT which has brought together the atmospheric science community engaged in global change and air pollution studies. ACCENT Plus aims at extending the breath of the previous ACCENT phase to reach out to the policy community, facilitating the transfer of research results into policy/decision making.

ACCENT PLUS is an EU Framework 7 Project
http://www.accent-network.org/

ACCENT Plus PROJECT OBJECTIVES

The overarching question that ACCENT-Plus aims answering is: “How can Europe control the composition of its atmosphere under a changing climate?” A prerequisite to achieve this goal is to maintain the coordination and integration of the European science community in the field of atmospheric composition change and tostrengthen the outreach from the science domain into the policy arena and, where possible, to wider global decision making activities, by producing integrated assessment and synthesis and connecting science and policy making by transferring to the decision makers the important links between air quality and climate change and the prospects and benefits of co-control policies. ACCENT-Plus also aims at preserving and enhancing the excellence of European global change and air quality research within the European Research Area context.

ACCENT PLUS is an EU Framework 7 Project
http://www.accent-network.org/

ACCENT Plus PROJECT Team

1	(Coordinator) Consiglio Nazionale delle Ricerche	CNR-ISAC Italy
2	Centre National de la Recherche Scientifique	CNRS France
3	Climate Service Centre	GKSS Germany
4	University of Bremen	IUP.UB Germany
5	Weizmann Institute of Science	WEIZMANN Israel
6	Università di Urbino “Carlo Bo”	UNIURB Italy
7	Paul Scherrer Institut	PSI Switzerland
8	National Environment Research Council	NERC UK
9	University of Leicester	ULEIC UK

ACCENT Plus

EU ACCENT PLUS and ICACGP Workshop on "Pollution studied by REmote Sensing of Conurbations/megacities and Retrieved from observations made by Instrumentation on space BasEd platforms – PRESCRIBE 15 -16th may 2013"

Objectives of PRESCRIBE

1) Assess the current achievements and capability of remotes sensing of large agglomerations and their emission from space and our interpretative capability

2) Identify gaps in the observational strategy and interpretative/modelling capability

3) Make recommendations for the way forward

DELIVERABLE – Workshop report
We would like to publish at the most appropriate place.

ACCENT Plus
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK

EU ACCENT PLUS and ICACGP Workshop on

"Pollution studied by REmote Sensing of Conurbations/megacities and Retrieved from observations made by Instrumentation on space BasEd platforms - PRESCRIBE"

Draft Agenda

Day 1, 15th May 2013

09:00 – 09:30	Arrival, Registration, Coffee
09:30 – 10:00	Opening, Welcome and Introduction
10:00 – 10:30	Overarching Objectives of the Workshop - Presentation (John P. Burrows) - Formation of the two working groups - Discussion
10:30 – 11:00	Coffee Break
	Block 1: Status of Current Space Based Research on Atmospheric Composition of Conurbations / Megacities
11:00 – 11:20	**J. Drummond:** Insights from Long Term Measurements of CO from Space
11:20 – 11:40	**A. Boynard:** How able is IASI for tracking pollution?
11:40 – 12:00	**G. de Leeuw:** Aerosol retrieval using satellite data
12:00 – 12:20	**Y. Xue:** Multi-scale AOD Retrieval from Satellite Data for Beijing Air Pollution Study
12:20 – 12:40	**M. Vrekoussis:** On the impact of the economic recession on urban air quality: Trends in air pollution levels
12:40 – 13:00	**P. Valks:** GOME-2 observations of air quality in Chinese Megacities
13:00 – 14:00	Lunch Break
	Block 1 continued
14:00 – 14:20	**U. Platt:** Ground truth for flux measurements from Urban Areas
14:20 – 14:40	**P. Schneider:** A global SCIAMACHY-based trend analysis of tropospheric NO2 over megacities
14:40 – 15:00	**A. Hillboll**: Changes in tropospheric NO2 over megacities: A multi-instrument approach
15:00 – 15:20	**S. Beirle:** From columns to emissions - how much a-priori do we need?
15:20 – 15:40	**T. Wagner:** Estimating megacity trace gas emissions using satellite observations of tropospheric species and wind fields
15:40 – 16:00	Coffee Break
	Block 2: Perspectives for future Space Based Research on Megacities
16:00 – 16:20	**R. Cohen:** A Space Based Perspective on Urban Emissions and Photochemistry: Winds, Spatial Resolution and perspectives on Future progress
16:20 – 16:40	**R. Leigh:** Remote sensing of NO2: Integrating slant column measurements into operational air quality management systems.
16:40 – 17:00	**J.P. Veefkind:** TROPOMI on the Sentinel 5 Precursor: global urban-scale monitoring of air quality and climate
17:00 – 17:20	**H. Bovensmann:** Hourly geostationary observations of key constituents to constrain air pollution and tropospheric chemistry at the Urban scale: GMES Sentinel-4
17:20 – 17:40	**M. Buchwitz:** Carbon gases (CO2, CO) over anthropogenic source regions: From SCIAMACHY to CarbonSat
17:40 – 18:30	**Wrap-up session, Day 1** Teaming of the Break out Working Groups:
20:00	Dinner

Day 2, 16th May 2013

	Block 3: Use of Remote Sensing for Megacity Observations coupled with Models
08:20 – 08:40	**M. Gauss:** Use of satellite observations in EMEP modelling
08:40 – 09:00	**M. Kanakidou:** Synergistic use of chemistry-transport modelling and satellite observations for air pollution control.
09:00 – 09:20	**B. Mijling:** Fast emission estimates in China and South Africa constrained by satellite observations
09:20 – 09:40	**T. Stavrakou:** Addressing the role of major chemical uncertainties on top-down NOx and VOC emission estimates
09:40 – 10:00	**I. Konovalov:**Using satellite NO_2 measurements to infer multiannual changes in CO_2 emissions in China
10:00 – 10:30	Discussion
10:30 – 11.00	Coffee Break
11:00 – 12:30	**Block 4: Working Groups** - **A Requirements for evolution of Instrumentation** - **B Requirements for Modelling and Inversion**
12:30 – 13:30	Lunch Break
13:30 – 14:30	**Block 4 continued**
14:30 – 15:00	Presentation from working groups
15:00 – 15:15	Coffee Break
15:15 – 16:00	Planning of the review Assignment of writing tasks
16:00	End of meeting

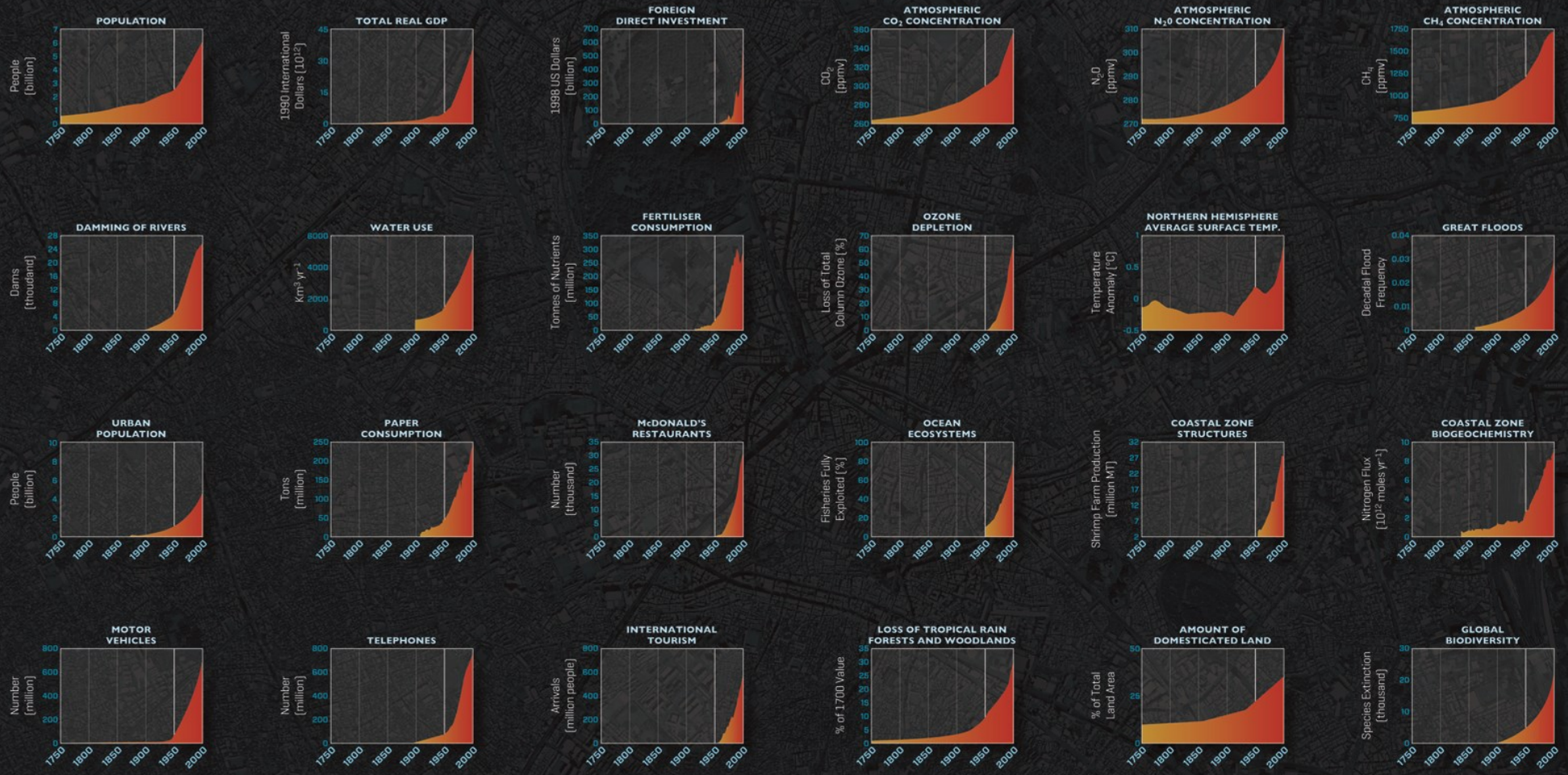
THE **ANTHROPOCENE**

The Anthropocene defines Earth's most recent geologic time period as being human-influenced, or anthropogenic, based on overwhelming global evidence that atmospheric, geologic, hydrologic, biospheric and other earth system processes are now altered by humans.

The line corresponding to 1950 highlights the **Great Acceleration**, the post-World War II worldwide industrialization, techno-scientific development, nuclear arms race, population explosion and rapid economic growth.

These graphs were compiled in a publication of the **International Geosphere-Biosphere Programme** (IGBP).

GLOBAIA



SOURCE: igbp.net | Steffen et al., 2005, Global Change and the Earth System, Springer, pp. 132-133

Why observe the atmosphere from space?

Conditions in the Biosphere depend on 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

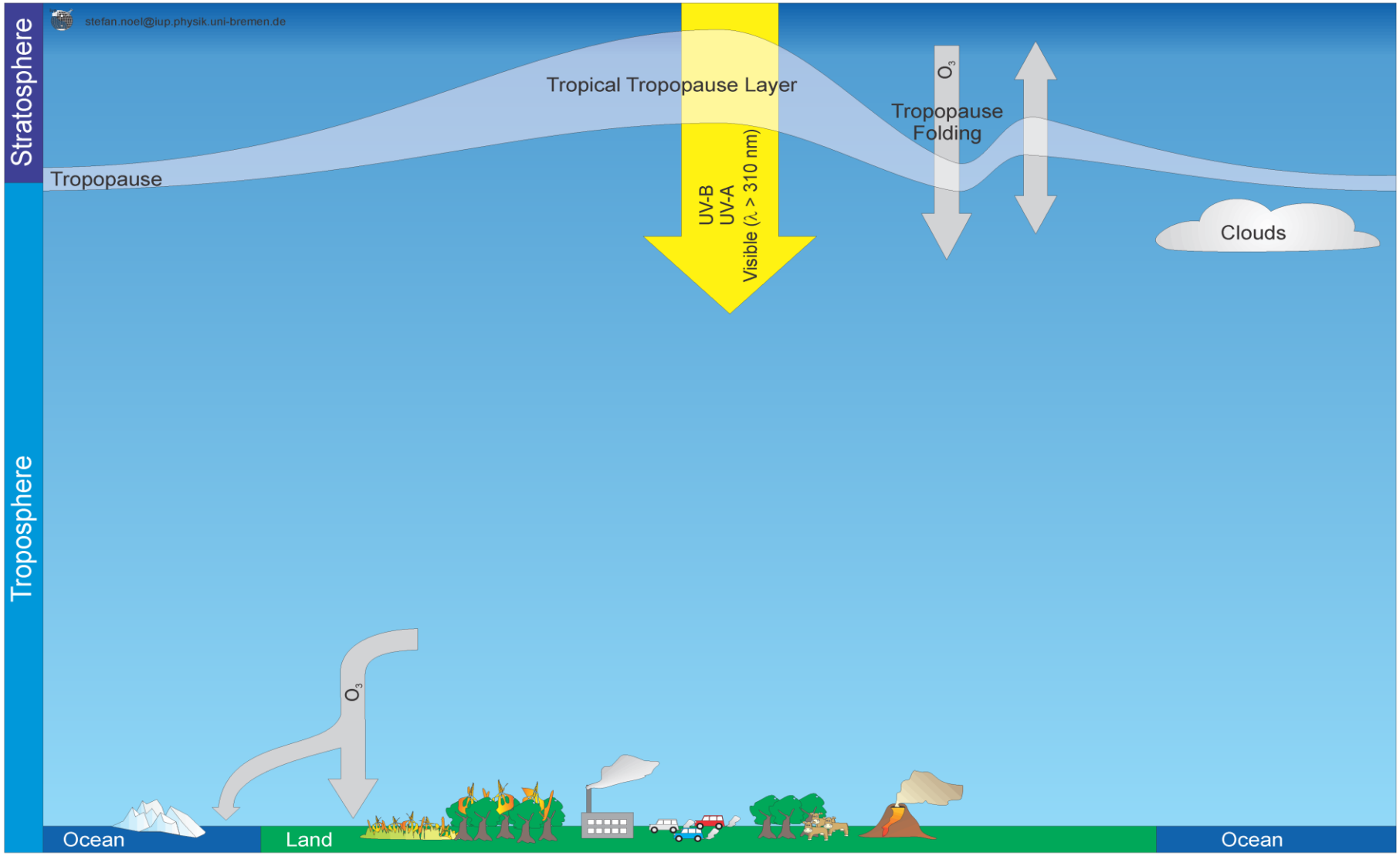
⇨ Climate Change - Chemistry climate feedback

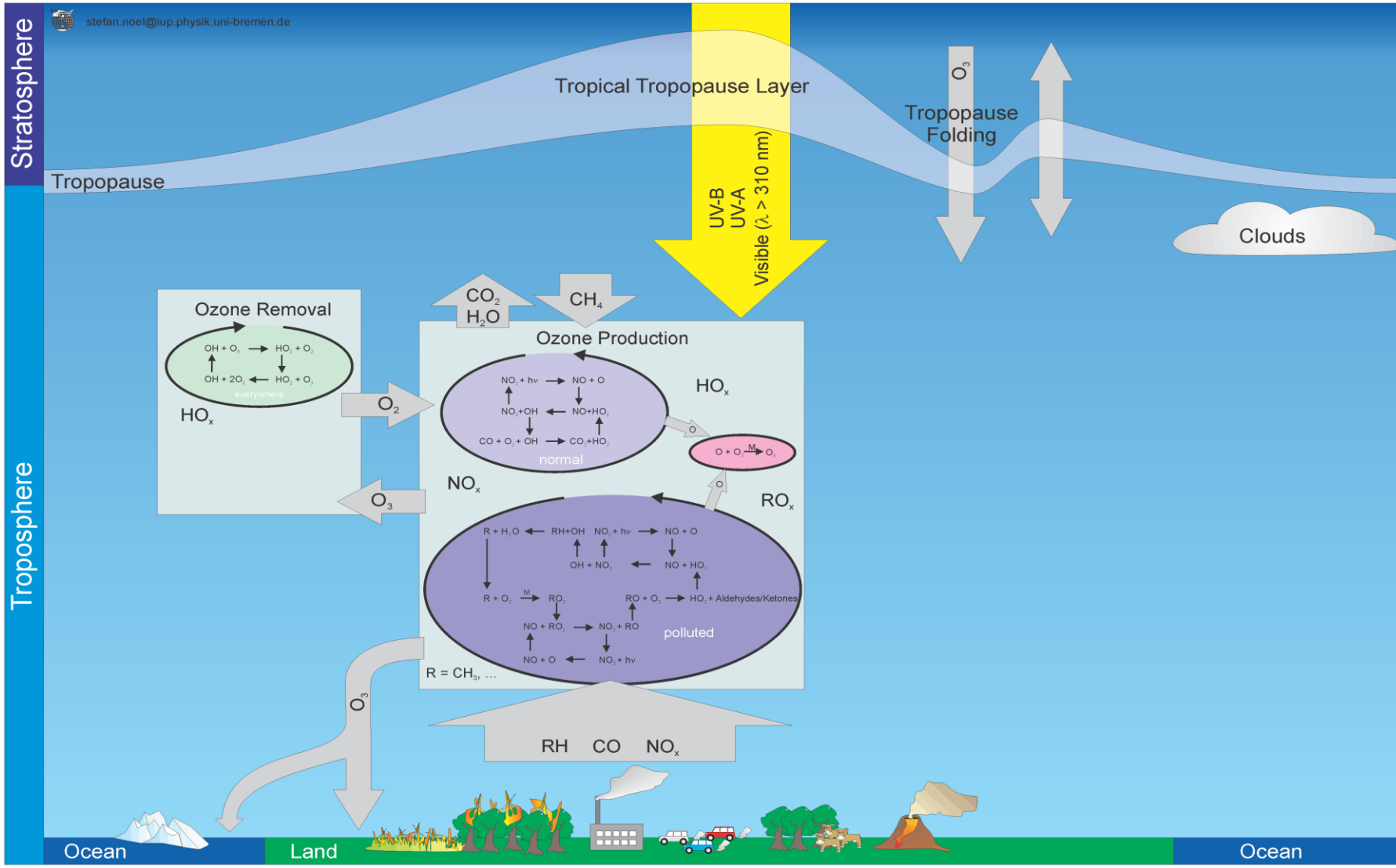
⇨ Global destruction of stratospheric ozone

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

⇨ Environmental/Climate Change requires Global Observations

⇨ Evidence base for testing understanding and policymaking


stefan.noel@iup.physik.uni-bremen.de
Stratosphere
Troposphere
Tropical Tropopause Layer
Tropopause
UV-B
UV-A
Visible (λ > 310 nm)
O3
Tropopause
Folding
Clouds
O3
Ocean
Land
Ocean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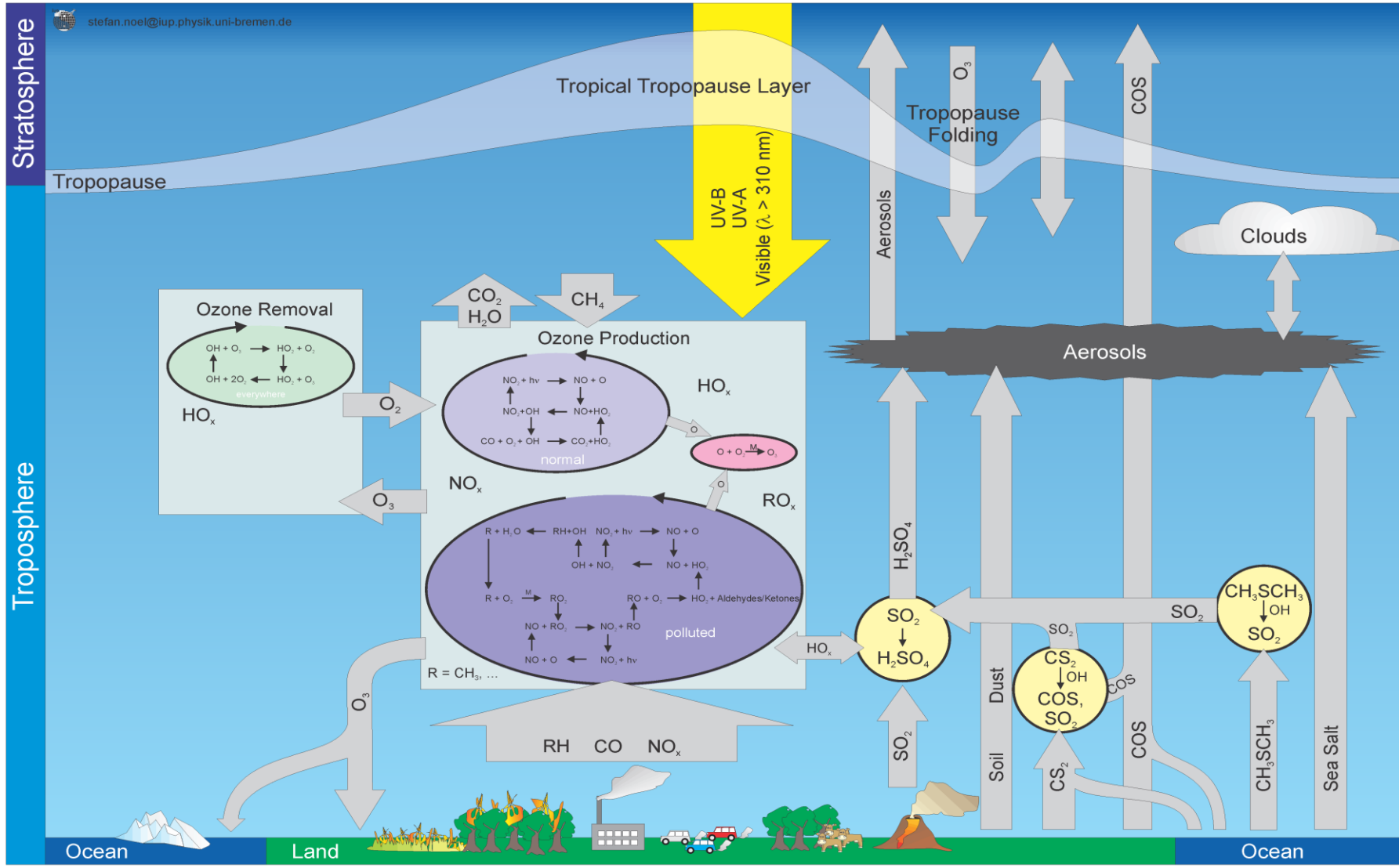
Tropopause
Tropopause Folding
O_3
UV-B
UV-A
Visible (λ > 310 nm)
Clouds
Ozone Removal
HO_x
everywhere
O_2
CO_2
H_2O
CH_4
Ozone Production
HO_x
normal
NO_x
RO_x
O_3
polluted
R = CH_3, ...
O_3
RH CO NO_x
Ocean
Land
Ocean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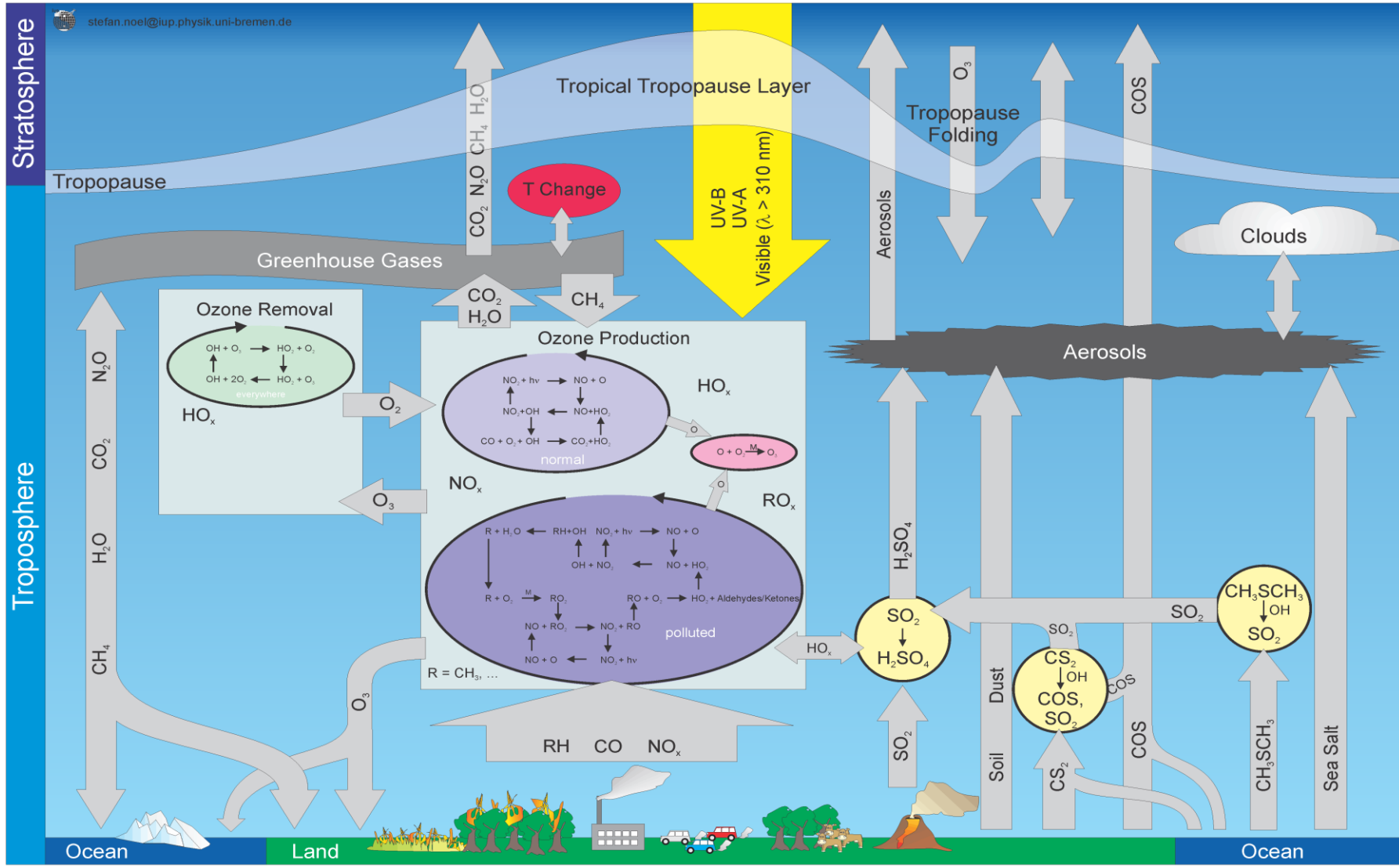
O3
COS
Aerosols
Clouds
Aerosols
Ozone Removal
OH + O3 → HO2 + O2
OH + 2O2 ← HO2 + O3
everywhere
HOx
O2
CO2
H2O
CH4
Ozone Production
NO2 + hv → NO + O
NO2+OH ← NO+HO2
CO + O2 + OH → CO2+HO2
normal
HOx
O + O2 → O3
NOx
O3
ROx
R + H2O ← RH+OH NO2 + hv → NO + O
OH + NO2 ← NO + HO2
R + O2 → RO2
RO + O2 → HO2 + Aldehydes/Ketones
NO + RO2 → NO2 + RO
NO + O ← NO2 + hv
polluted
R = CH3, ...
HOx
H2SO4
SO2
H2SO4
SO2
SO2
CH3SCH3
OH
SO2
CS2
OH
COS, SO2
COS
Dust
Soil
CS2
COS
CH3SCH3
Sea Salt
O3
RH CO NOx
SO2
Ocean
Land
Ocean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HO_x
NO_x
RO_x
normal
polluted
R = CH_3, ...
RH CO NO_x
N_2O
CO_2
H_2O
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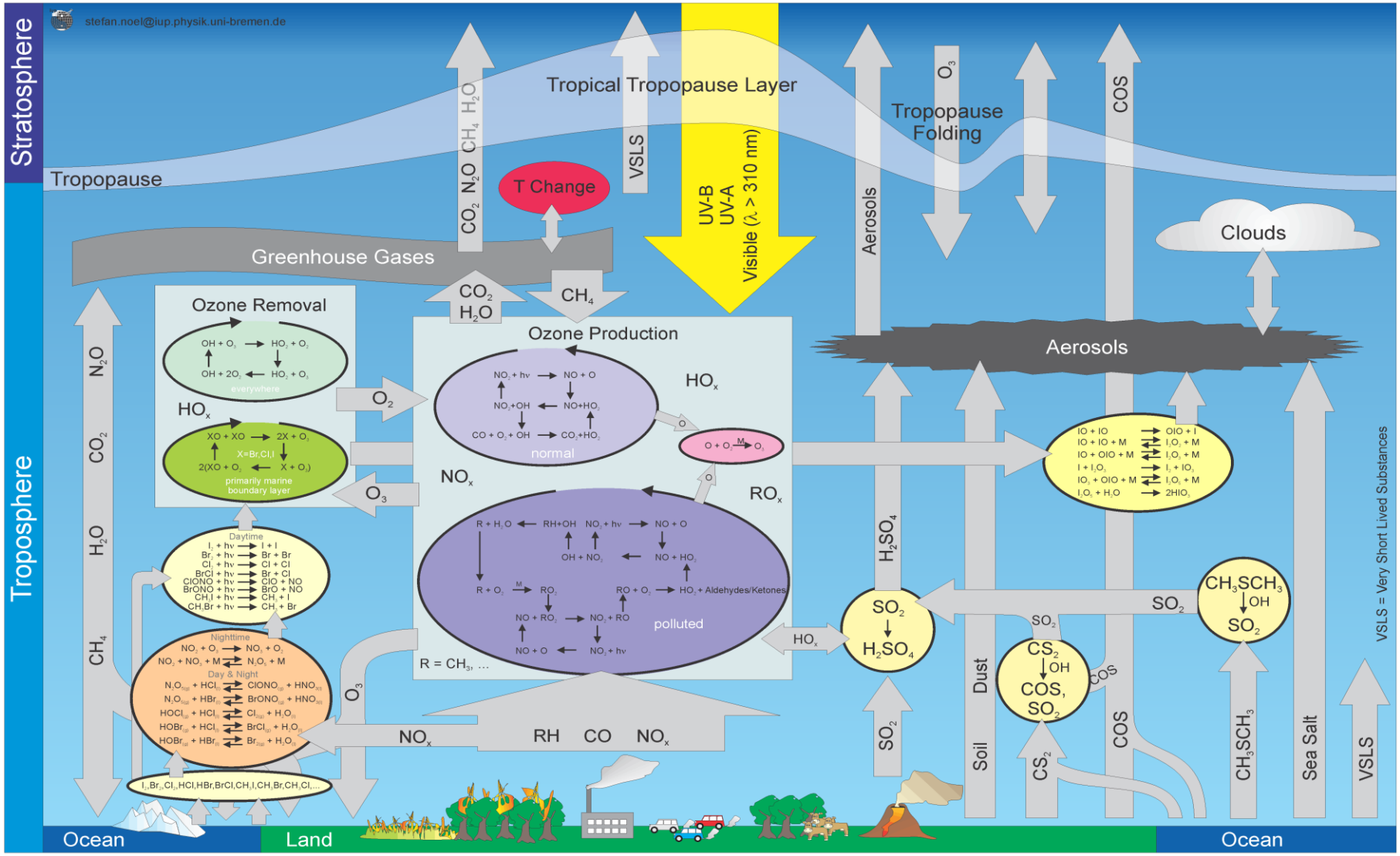
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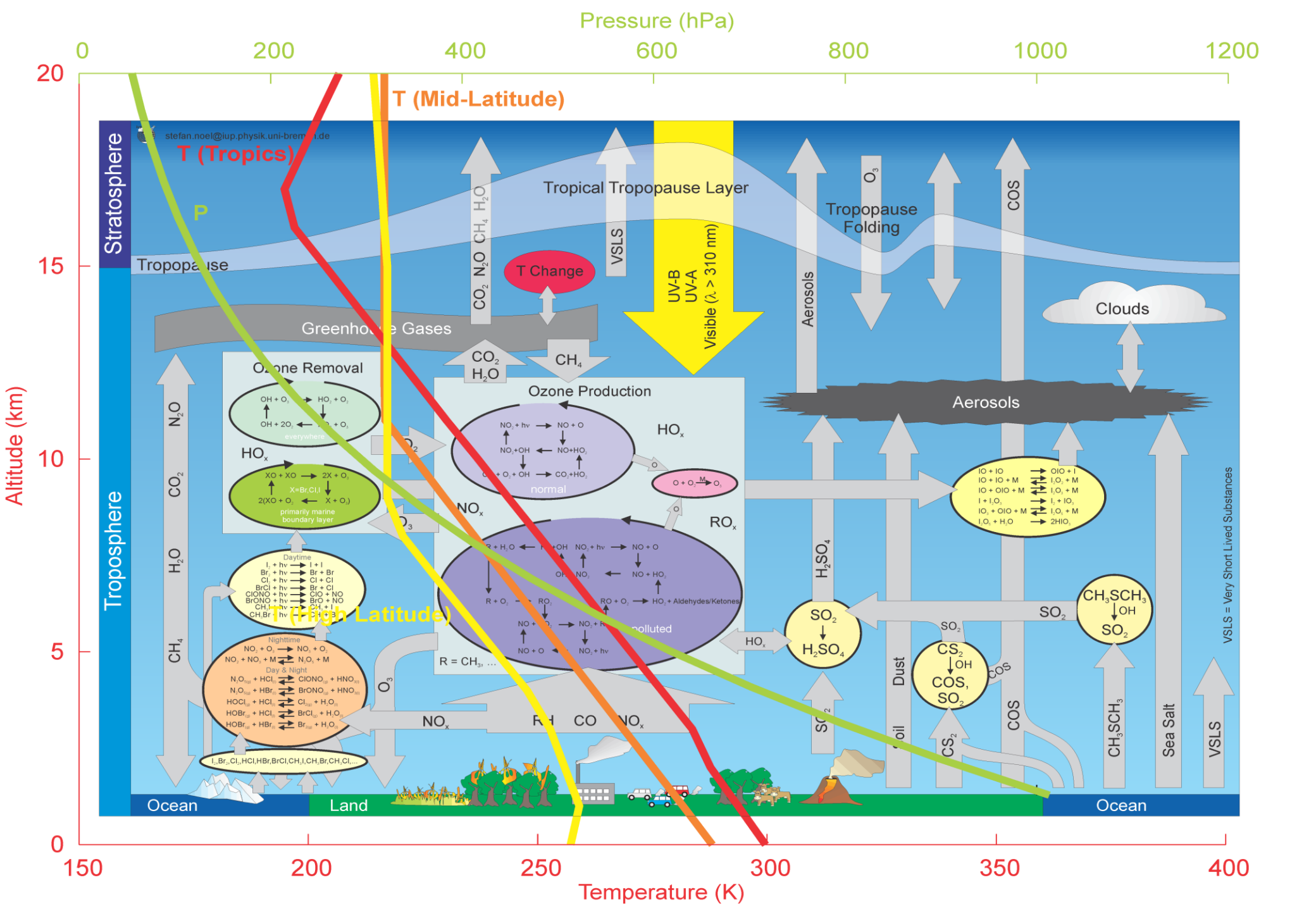
VSLS
UV-B
UV-A
Visible (λ > 310 nm)
O_3
COS
Aerosols
Clouds
Greenhouse Gases
CO_2 H_2O
CH_4
Ozone Removal
Ozone Production
HO_x
NO_x
RO_x
O_2
O_3
normal
polluted
primarily marine boundary layer
everywhere
R = CH_3, ...
N_2O
CO_2
H_2O
CH_4
Daytime
Nighttime
Day & Night
I_2,Br_2,Cl_2,HCl,HBr,BrCl,CH_3I,CH_2Br_2,CH_2Cl_2,...
H_2SO_4
SO_2
SO_2 → H_2SO_4
CH_3SCH_3 → OH → SO_2
CS_2 → OH → COS, SO_2
Dust
Soil
Sea Salt
CH_3SCH_3
CS_2
COS
VSLS
VSLS = Very Short Lived Substances
RH
CO
Ocean
Land
Ocean


Pressure (hPa)
0
200
400
600
800
1000
1200
Altitude (km)
20
15
10
5
0
Temperature (K)
150
200
250
300
350
400
T (Mid-Latitude)
T (Tropics)
P
Stratosphere
Troposphere
Tropopause
Tropical Tropopause Layer
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VSLS = Very Short Lived Substances
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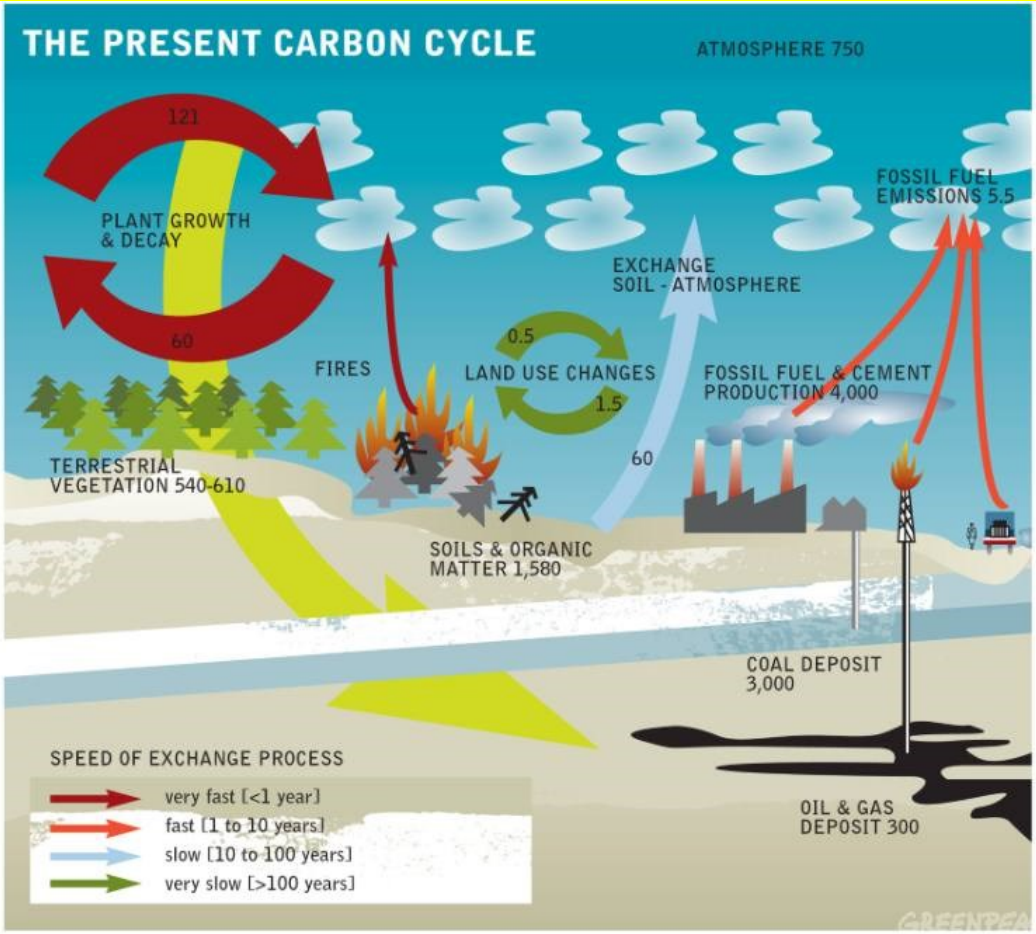
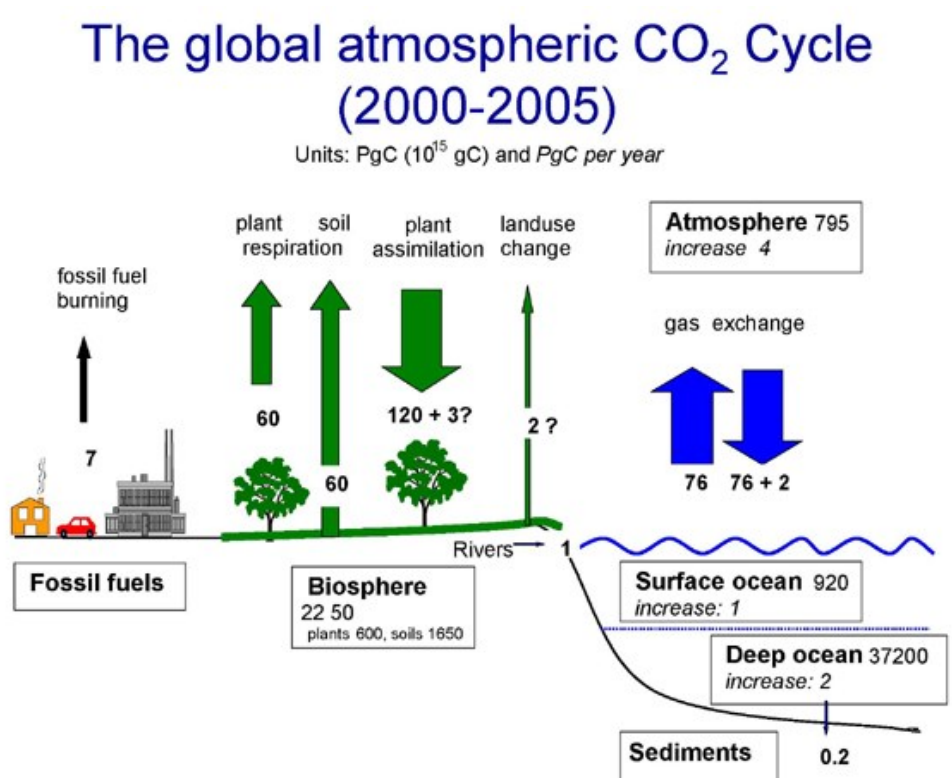
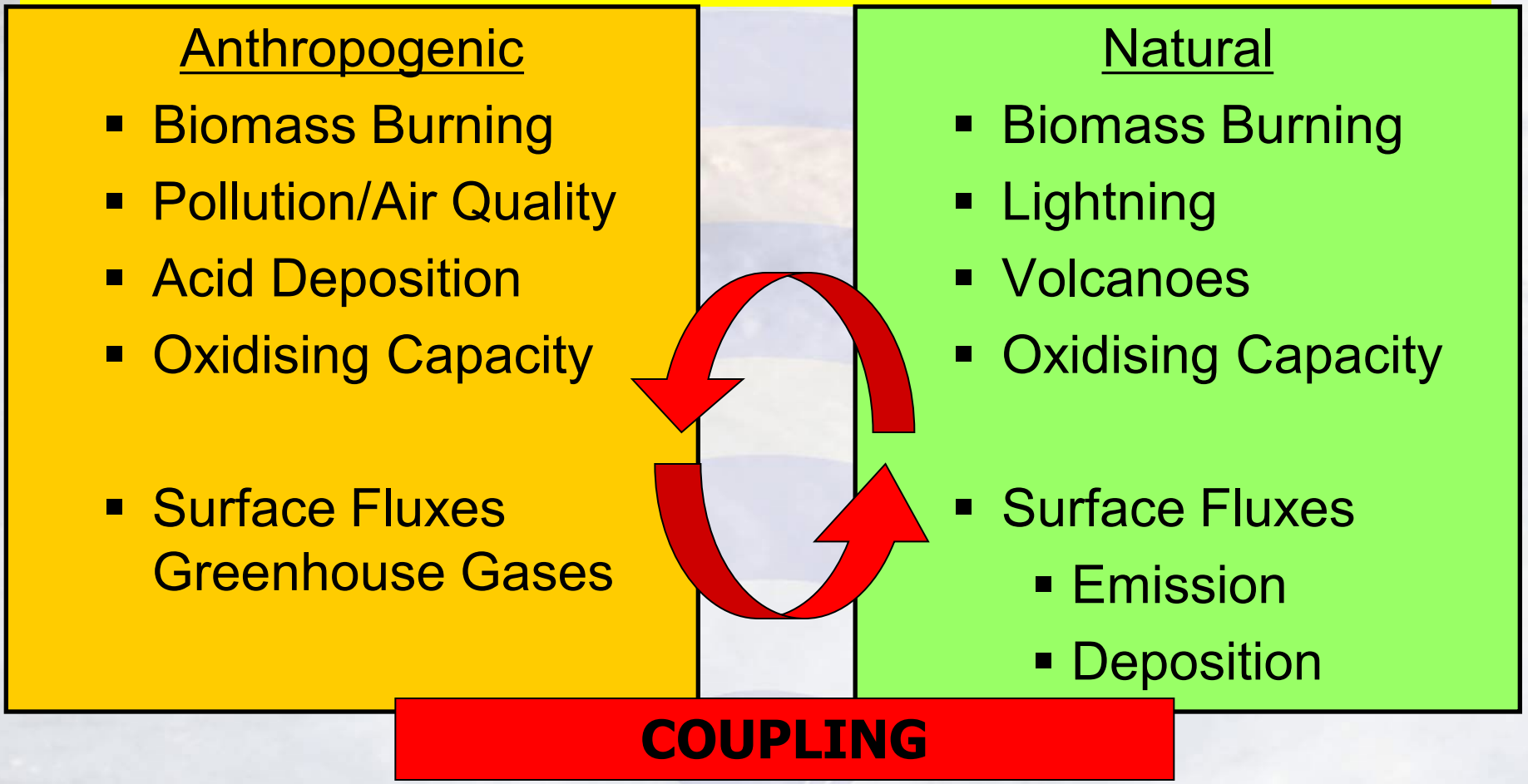
Ocean

Climate Change and The Carbon Cycle

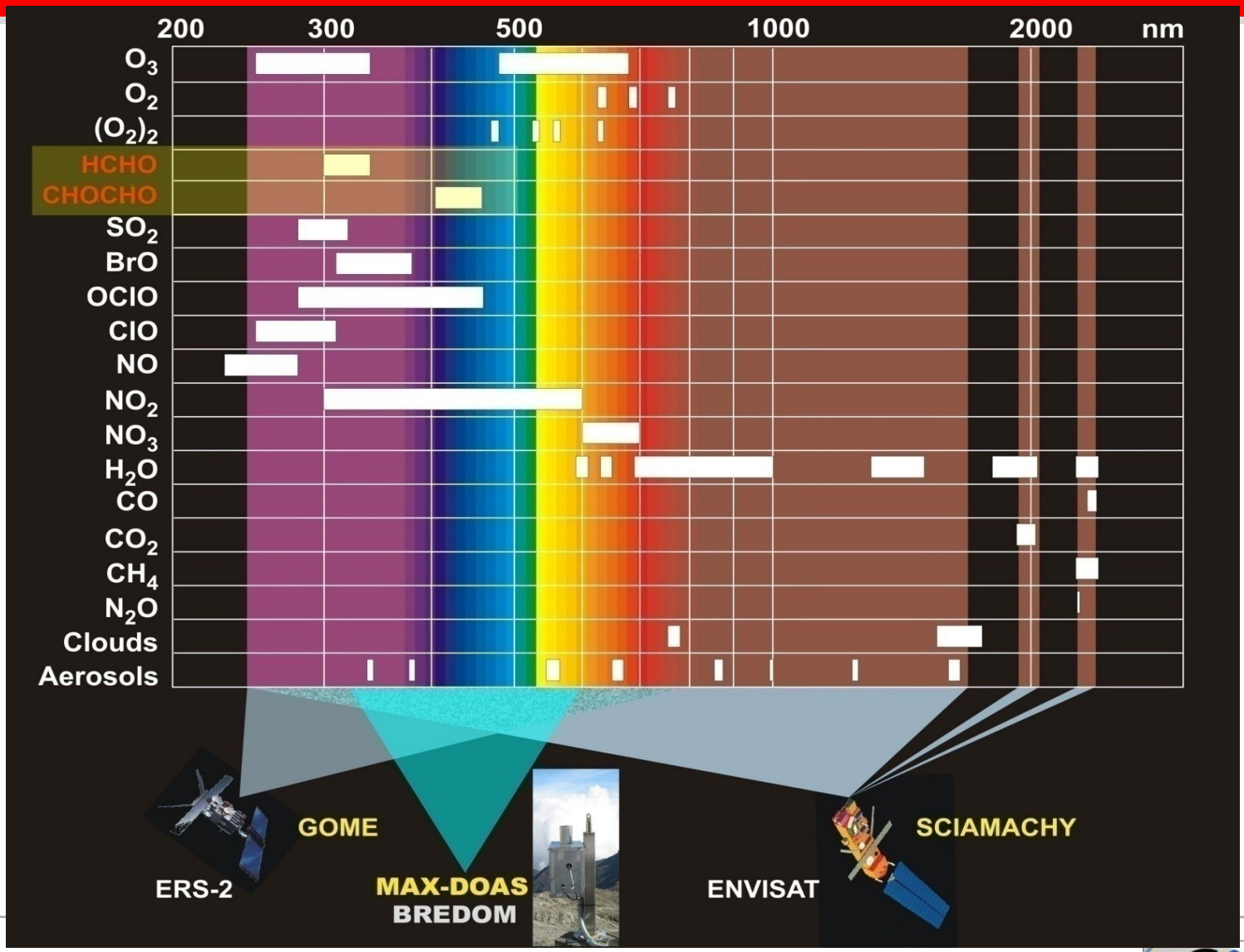




Anthropogenic vs. Natural ?



SCIAMACHY: Target Molecules + Parameters



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

1984—1985	MAPS (Mapping of Atmospheric Pollution) proposal for ESA EURECA platform 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

Geostationary Measurement of Trace gases: relevant European history and development

1997 IGAC Conference Toronto, Canada, discussions with Jack Fishman and Arlin Krueger: GeoTropSAT an VULCAN concept

1997 Development of GeoSCIA Concept , targeting SCIA trace gases

1998 Proposal of GeoSCIA UV-VIS-NIR to ESA Earth Explorer Mission EEM-1 IUP – UB led team Burrows et al.

2000 Proposal of GeoSCIA++ UV-VIS-NIR-SWIR-TIR/Lightning/fire to ESA EEM-2 IUP – UB led team Burrows et al.

2002 Proposal of GeoTROPE UV-VIS-NIR-SWIR-TIR to ESA EEM-3 IUP – UB led team Burrows et al.

2003 Proposal of GeoSCIA^{light} UV-VIS (-NIR) to DLR national call IUP – UB led team Burrows et al. – Regional

2005 Proposal of GeoTROPE^{Regional} UV-VIS-NIR + TIR to ESA EEM-3 IUP – UB led team Burrows et al. – Regional

Geostationary Measurement of Trace gases: relevant European history and development

2005 EUMETSAT Meteosat Third Generation advisory Committee recommend UVS Instrument for MTGStudy (EUMETSAT Phase 0)

2006 UVS Instrument for Study (EUMETSAT Phase 0)

2007 EU GMES Working Group 4 recommend GeoSCIA like UVN

2007 GMES Sentinel 4 UVN Study (ESA Phase 0)

2008 ESA/EUGMES/EUMETSAT Decision to fly S4 UVN on METEOSAT Third Generation two instruments planned for 2018 to 2032 flies with IRS, an FTIR yielding H_2O, CO, O_3.. on MTG B – Combination similar to GeoTROPE-R

2009 EU GMES Sentinel 4 UVN (ESA Phase A)

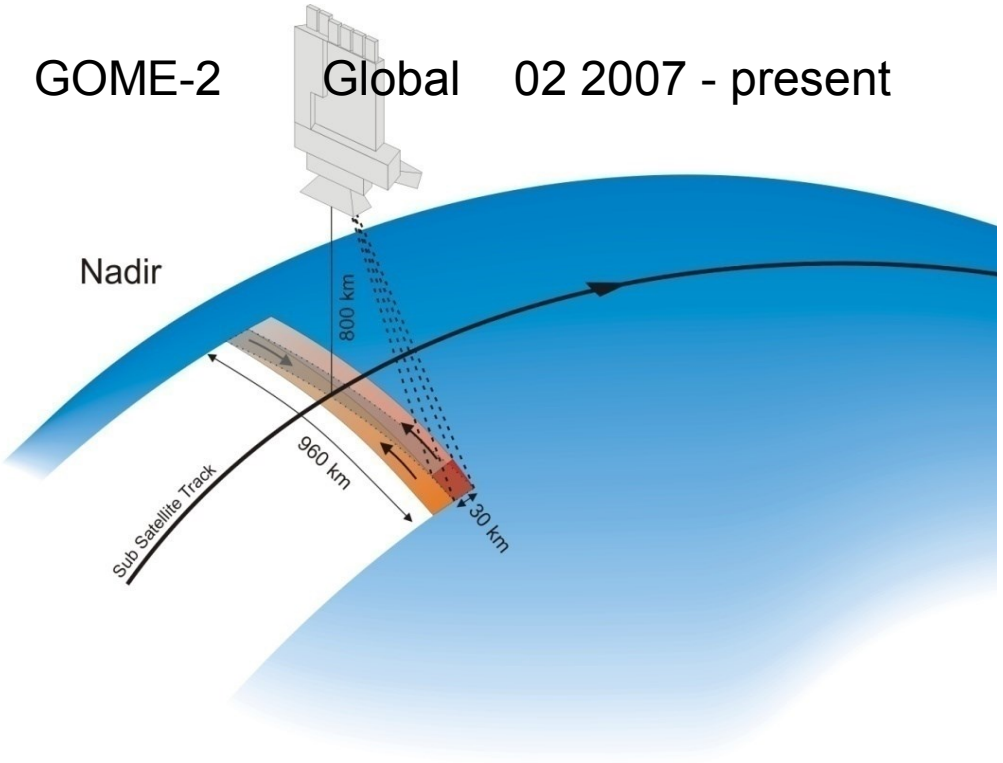
2011 Phase B2/C/D for S4 initiated by ESA

2012 The MTG series comprises four imaging and two sounding satellites.

The MTG-I imaging satellites will carry the Flexible Combined Imager (FCI) and the Lightning Imager. The MTG-S sounding satellites will carry an Infrared Sounder (IRS) and an Ultraviolet Visible Near-Infrared spectrometer, which will be provided by ESA as the GMES Sentinel-4 mission. The primary objective of the GMES Sentinel-4 mission will be to support air quality monitoring and forecasting over Europe, in full synergy with the IRS sounder.; now entering phase B. 2018 to 2032.

Legacy Data Sets : 1995 - present
Nadir Viewing Geometry

GOME	Global	07 1995 - 06 2003
	Regional	07 2003 - 07 2011
SCIAMACHY	Global	08 2002 - 04 2012
GOME-2	Global	02 2007 - present



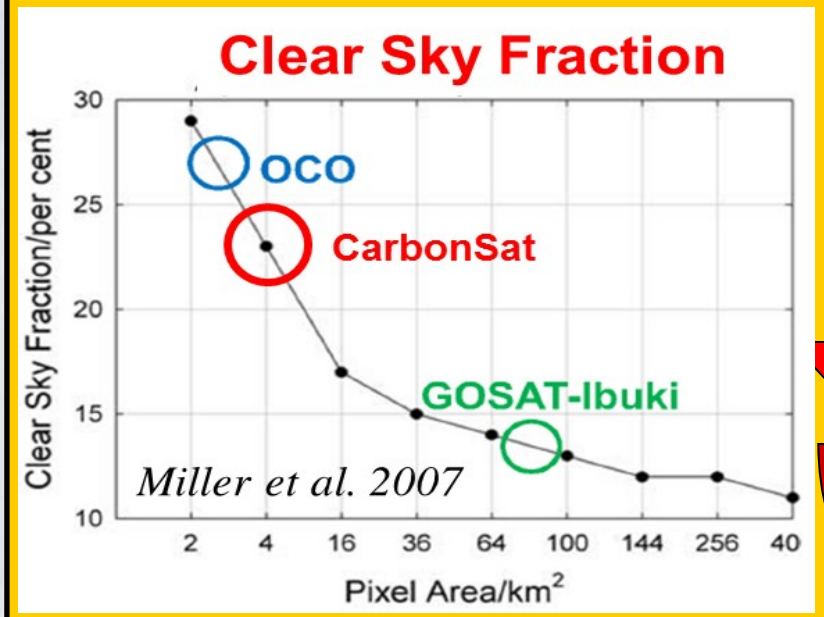
- horizontal resolution in across track:
  - GOME 80 and 320 km
    global 1995-2003
    partial 2003- present
  - SCIAMACHY 30-240 km
    global 2002- present
  - GOME-2 40-80 km
- horizontal resolution in along track:
  - GOME-1 and -2 40 km
  - SCIAMACHY 30 km
- Global coverage:
  GOME-1 - swath 960 km - 3 days at the equator 10:30 am crossing time
  SCIAMACHY - swath 960 km 6 - days at the equator 10:00 crossing time
  GOME-2 – swath 1950 km
  ~1 day at the equator – crossing time 09:30 am

SCIAMACHY

CarbonSat Constellation

Two main issues ?

Cloud free



Spatial Scales dynamics and chemistry

- Biomass Burning
- Lightning 1-5 km^2
- Volcanoes 0.5 km^2
- Oxidising Capacity

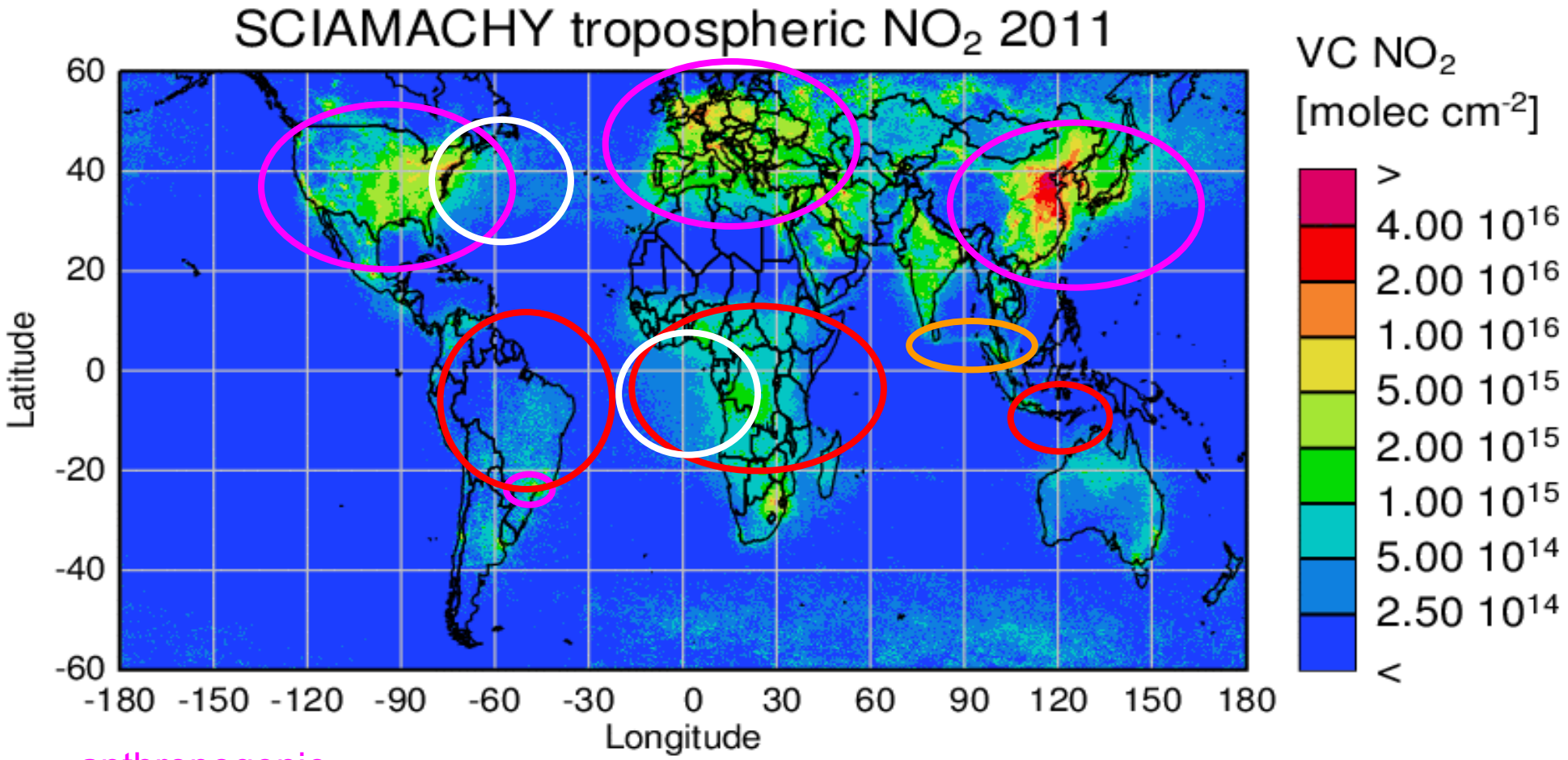
and tropospheric processing m^2 to global

- Surface Fluxes
  - Emission chimney 1m^2 upwards
  - Deposition

COUPLING

Universität Bremen ife

Tropospheric NO_2 and Sources?



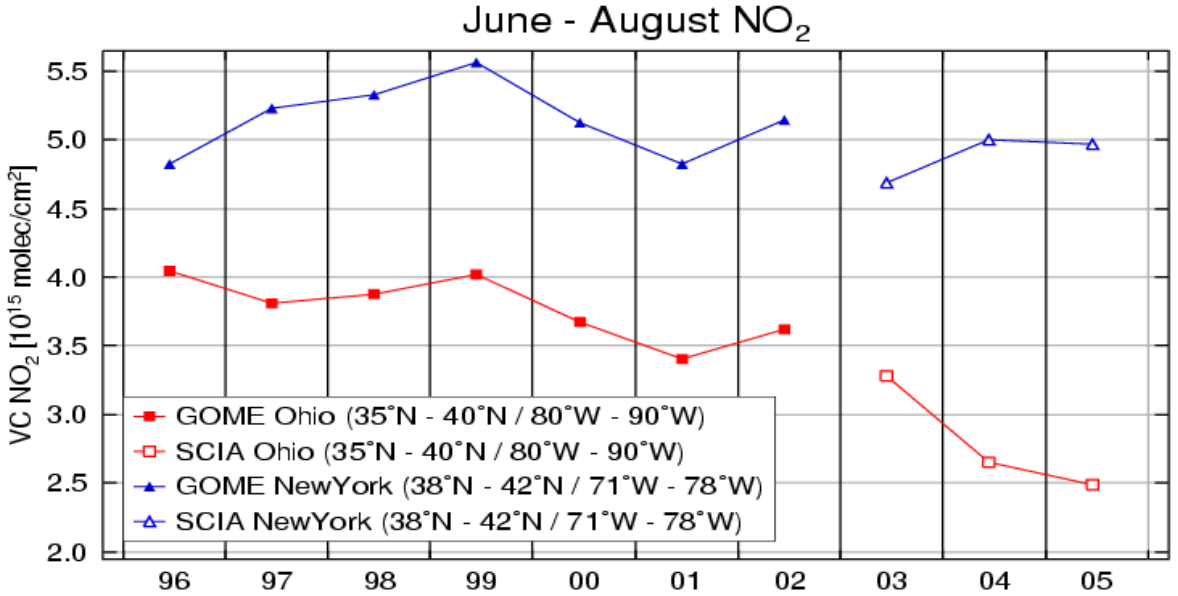
anthropogenic pollution

biomass burning

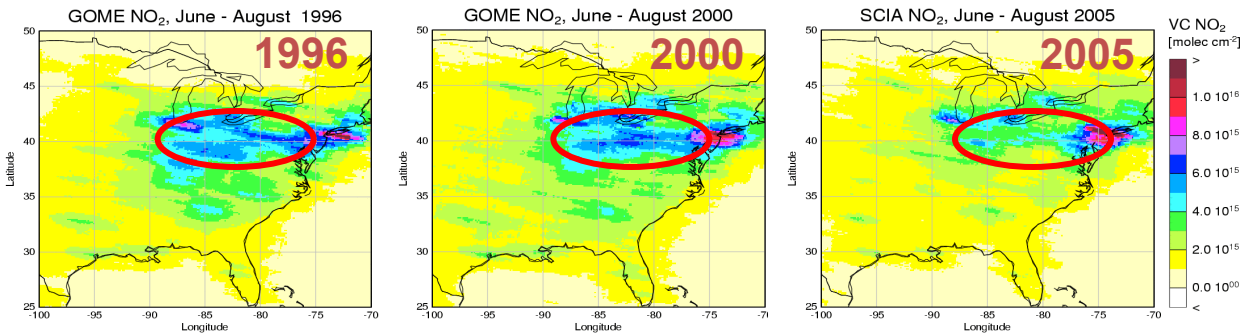
ships

transport

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



- GOME NO_2 time-series
- after 2000, clear decrea
- no change in urban are
- size and geographical

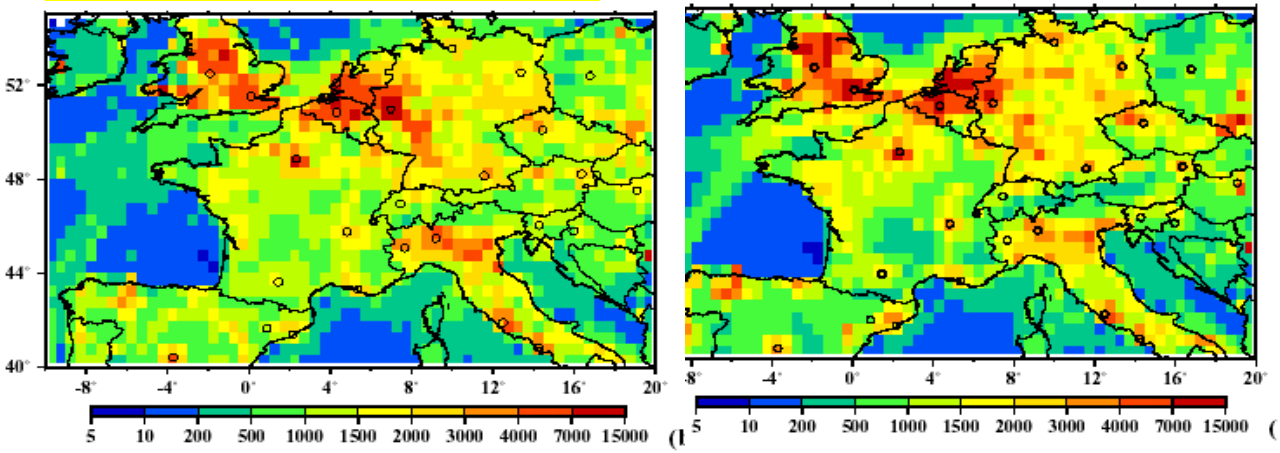


S. Kim, A. Heckel et al 2006 NOAA and University of Bremen GRL November 2006

NO2 Emission Rates in European Cities

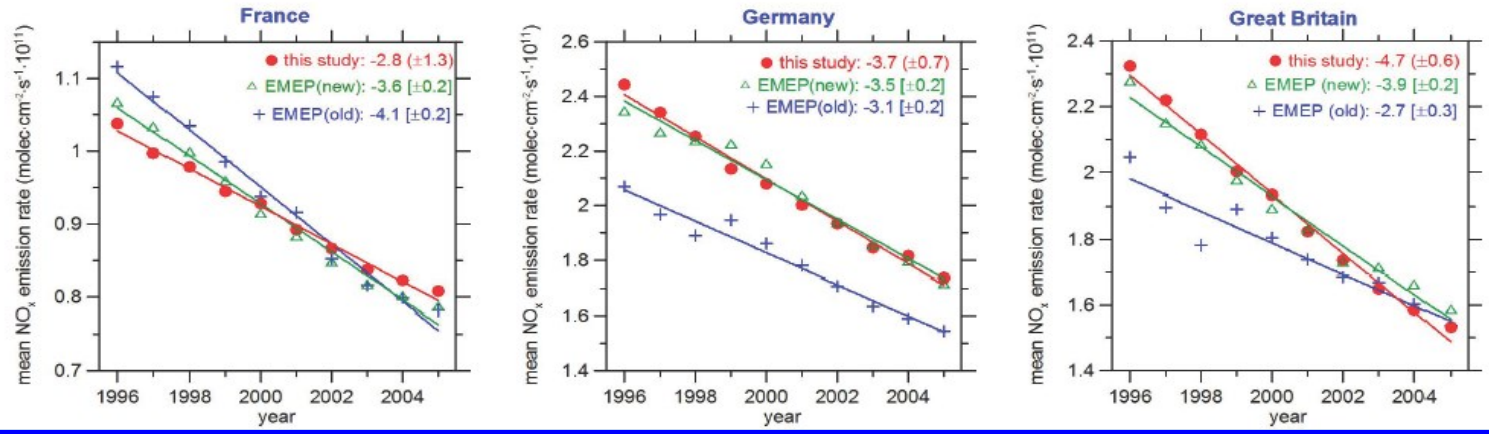
- Top-Down constraint on anthropogenic emis
- Satellite data: GOME and SCIAMACHY
- Model CHIMERE
- A-priori: EMEP data for 2001
- For some cities (as Cologne),neighbouring c
- A posteriori < a priori

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, 2007

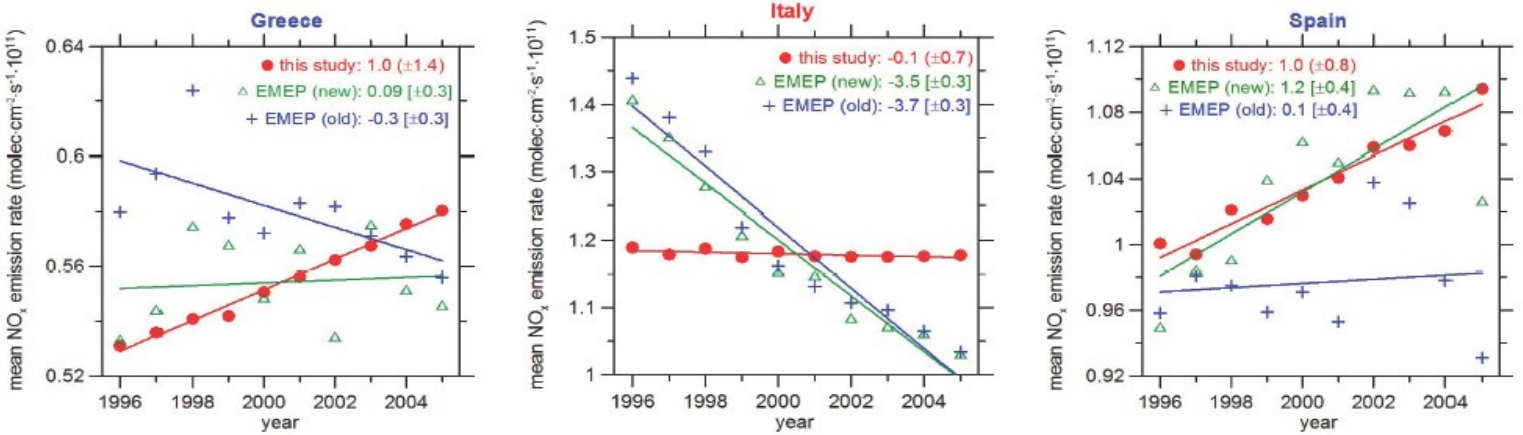
NO_2 Change in Europe



GOME and SCIAMACHY data over Europe + CHIMERE

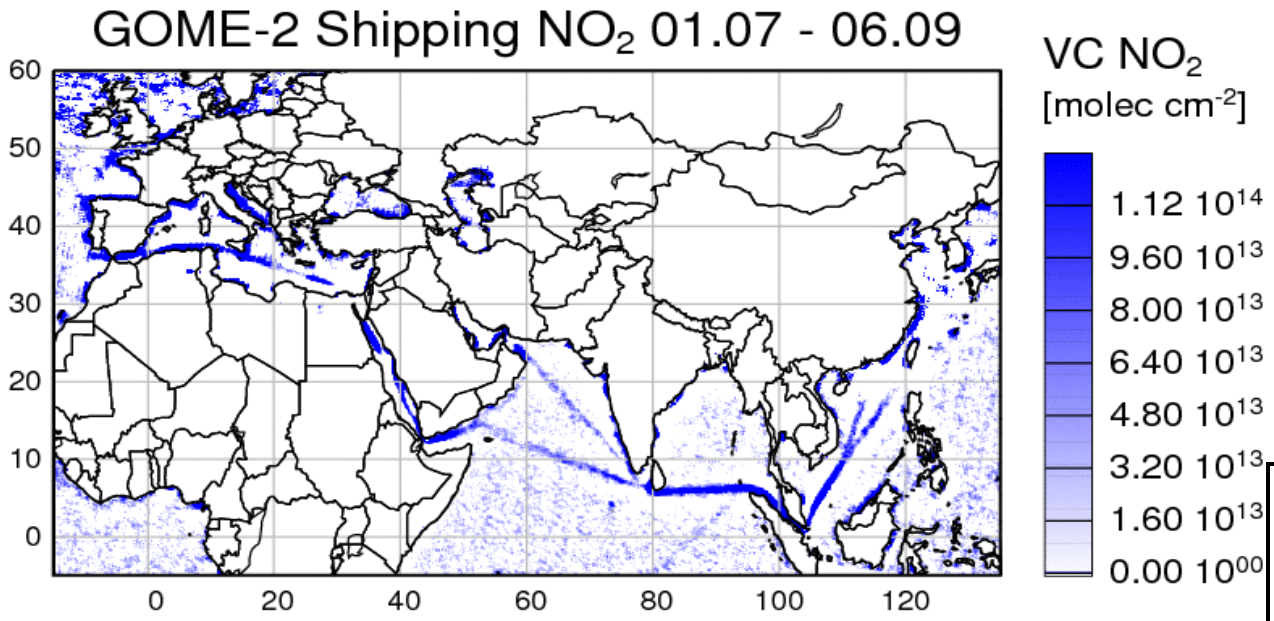
Comparison to two versions of EMEP emissions

Excellent agreement with latest EMEP in NE, disagreement in SE.

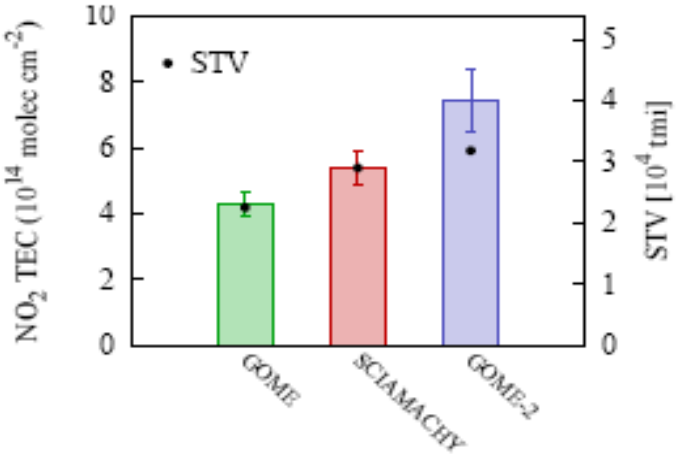


Konovalov, I.et al., Satellite measurement based estimates of decadal changes in European nitrogen oxides emissions, Atmos. Chem. Phys. Discuss., 8, 2013-2059, 2008

Shipping NO_2 data



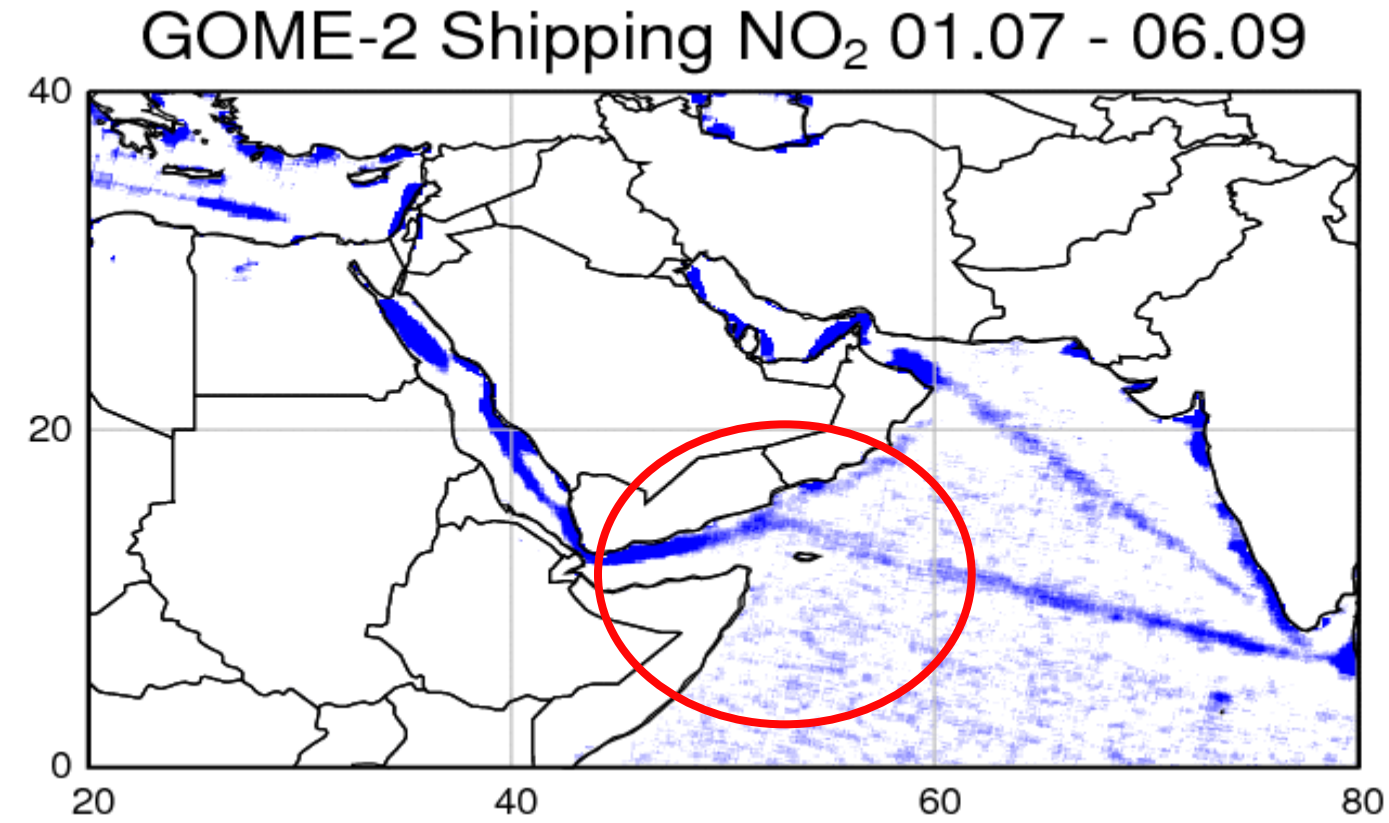
- Large fitting window GOME-2 NO_2 retrievals have very low nc
- Very clear shipping signals



Franke et al., Atmos. Chem. Phys. Discuss., 8, 15997–16025, 2008

Shipping NO_2 in GOME-2 data

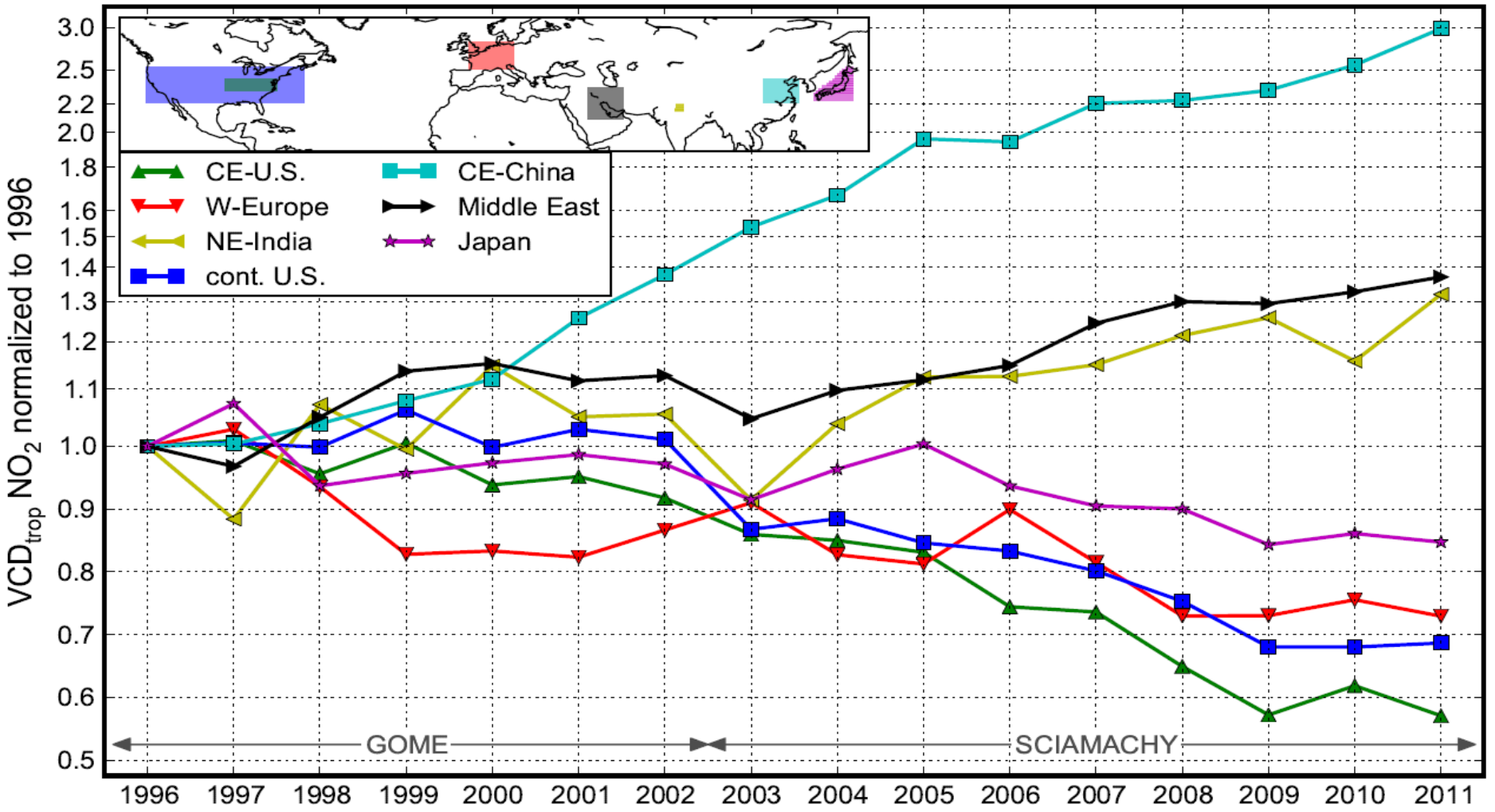
- Pattern of shipping NO_2 close to Somalia has changed in 2007
- Probably as an attempt to evade pirates



SCIAMACHY

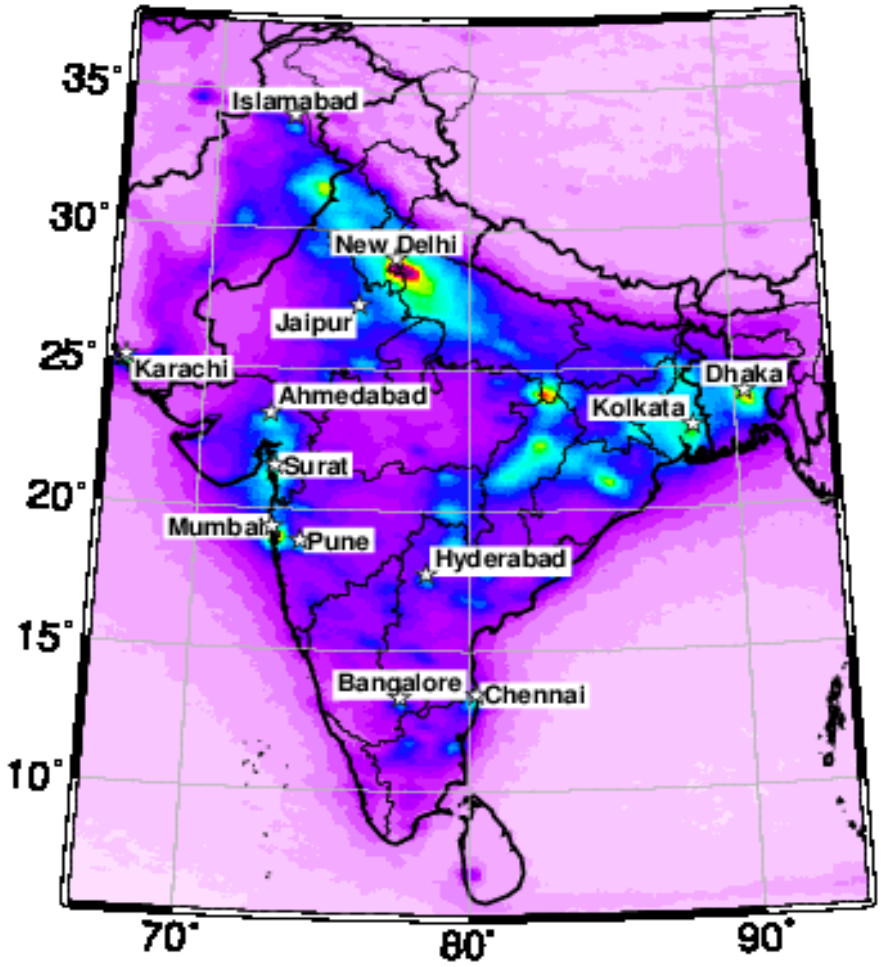
CarbonSat Constellation

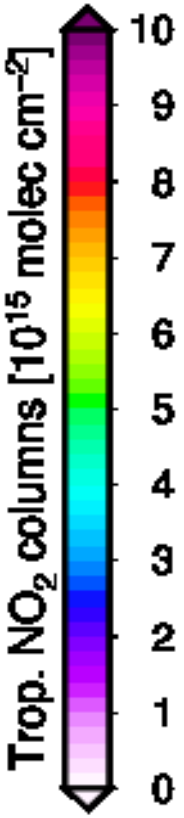
NO_2 Changes over Regions Hilboll et al., 2012/2013



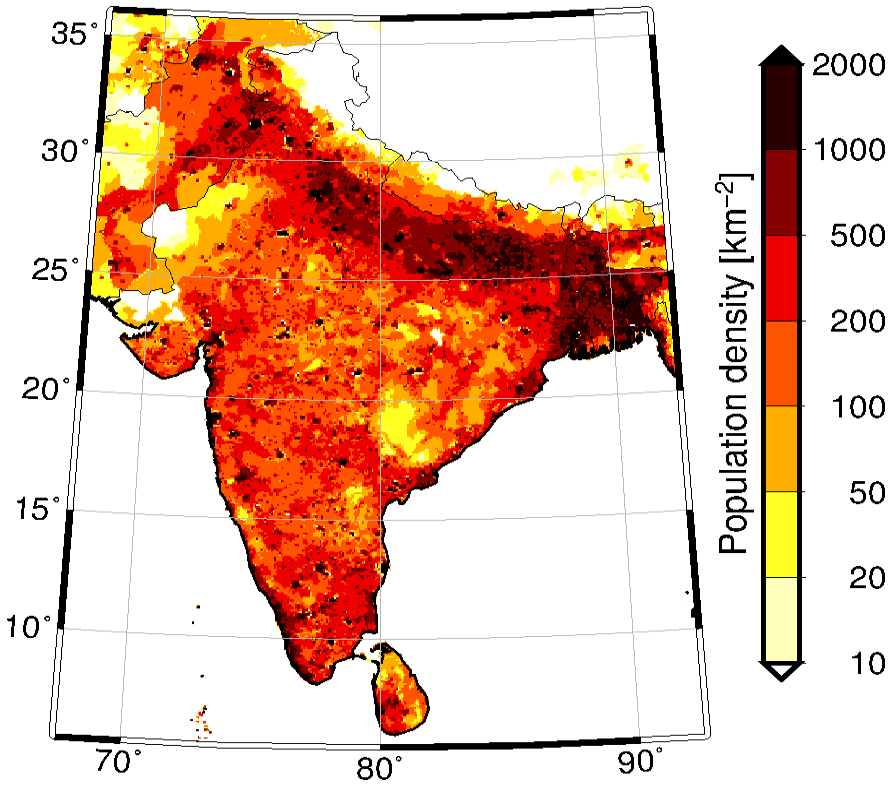
Hilboll, A., Richter, A., and Burrows, J. P.: Long-term changes of tropospheric NO2 over megacities derived from multiple satellite instruments, Atmos. Chem. Phys., 13, 4145-4169, doi:10.5194/acp-13-4145-2013, 2013.

Tropospheric NO_2 column over Indian Subcontinent observed from space: SCIAMACHY (2003-2011)

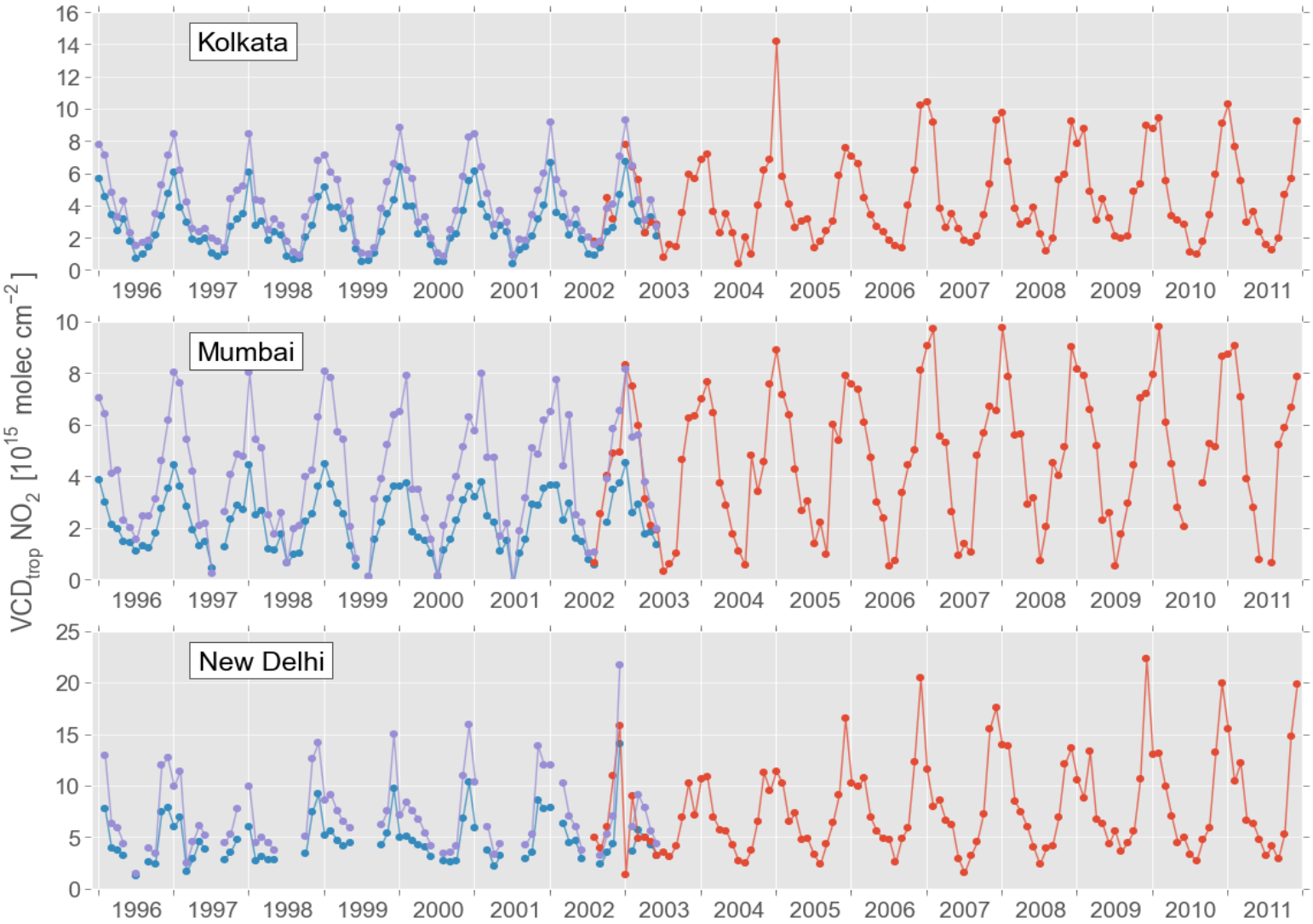




Centres of Population are clearly visible

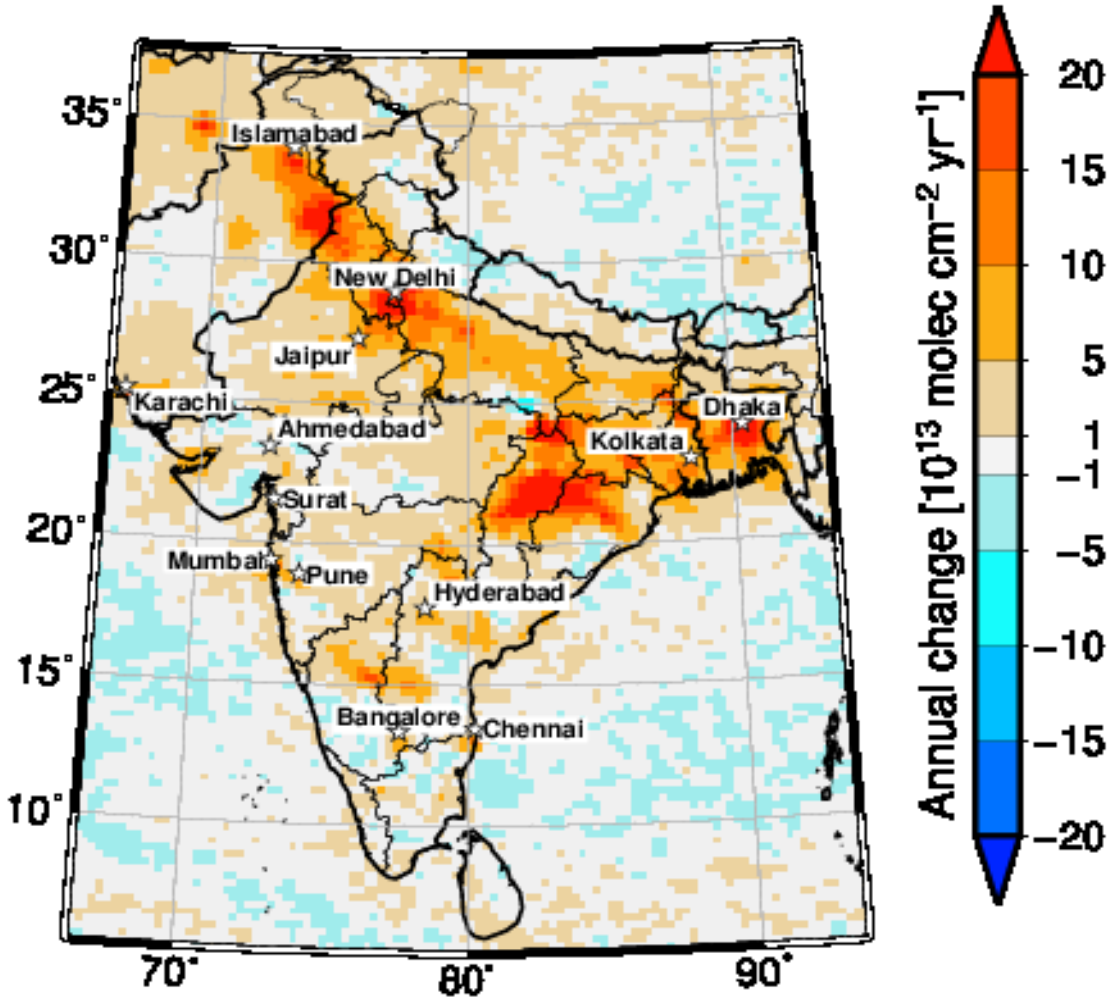


Timeseries over Megacities



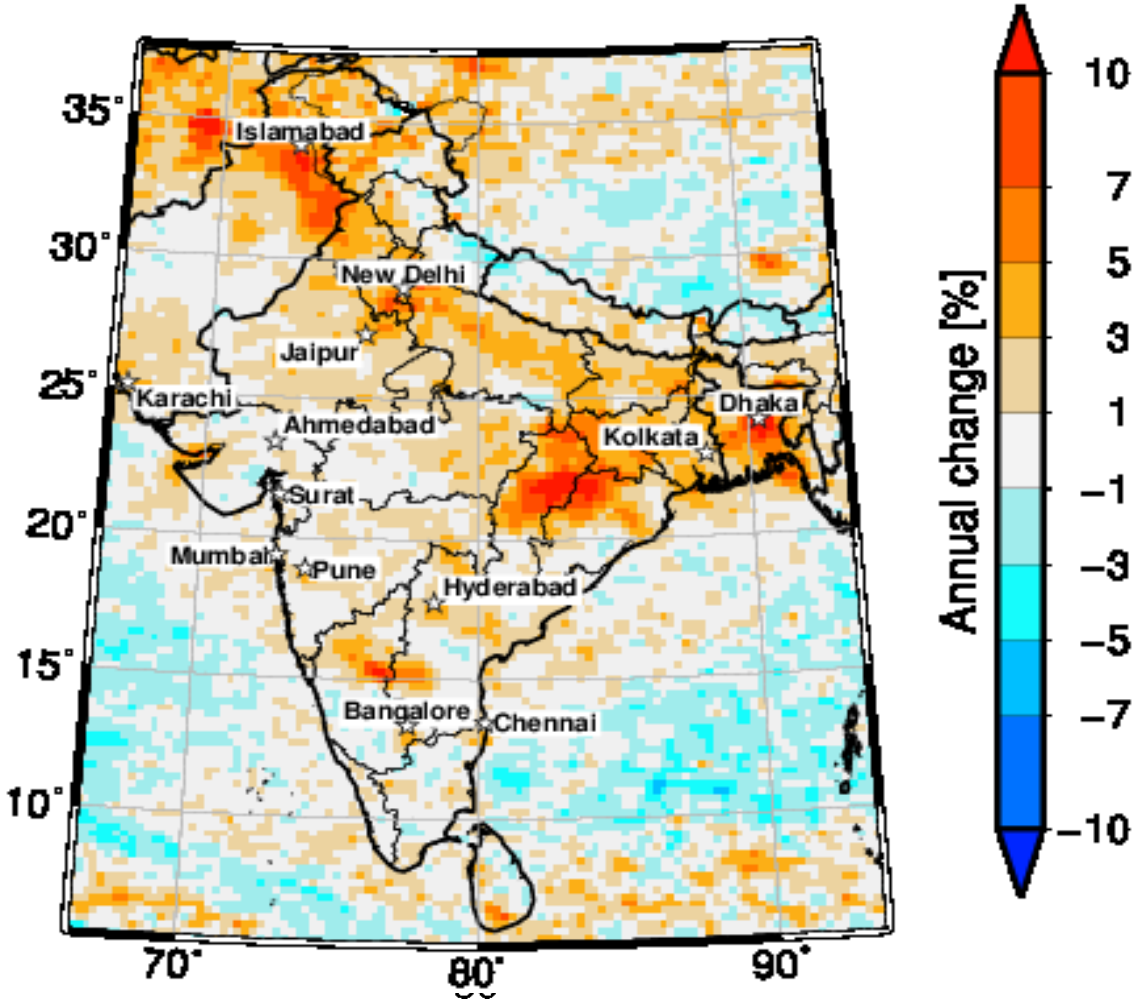
- Strong seasonality (heating, sunlight)
- Instruments are different

Tropospheric NO_2 column over the Indian Subcontinent is increasing strongly



- Tropopsheric NO_2 strongly increases in major centres of population
- Attributed to fossil fuel, domestic heating and cooking and related
- Strongest relative increase is in Odisha and Chhattisgarh
- Attributed to heavy industry + electricity

Tropospheric NO_2 over India is strongly increasing in populated regions



Strong increases in conurbations and other centres of population

Drummond Burrows Psychological Phasing of Satellite Remote Sensing from Space.

1st Phase – Proposal Disbelief – It is impossible not worth doing anyway

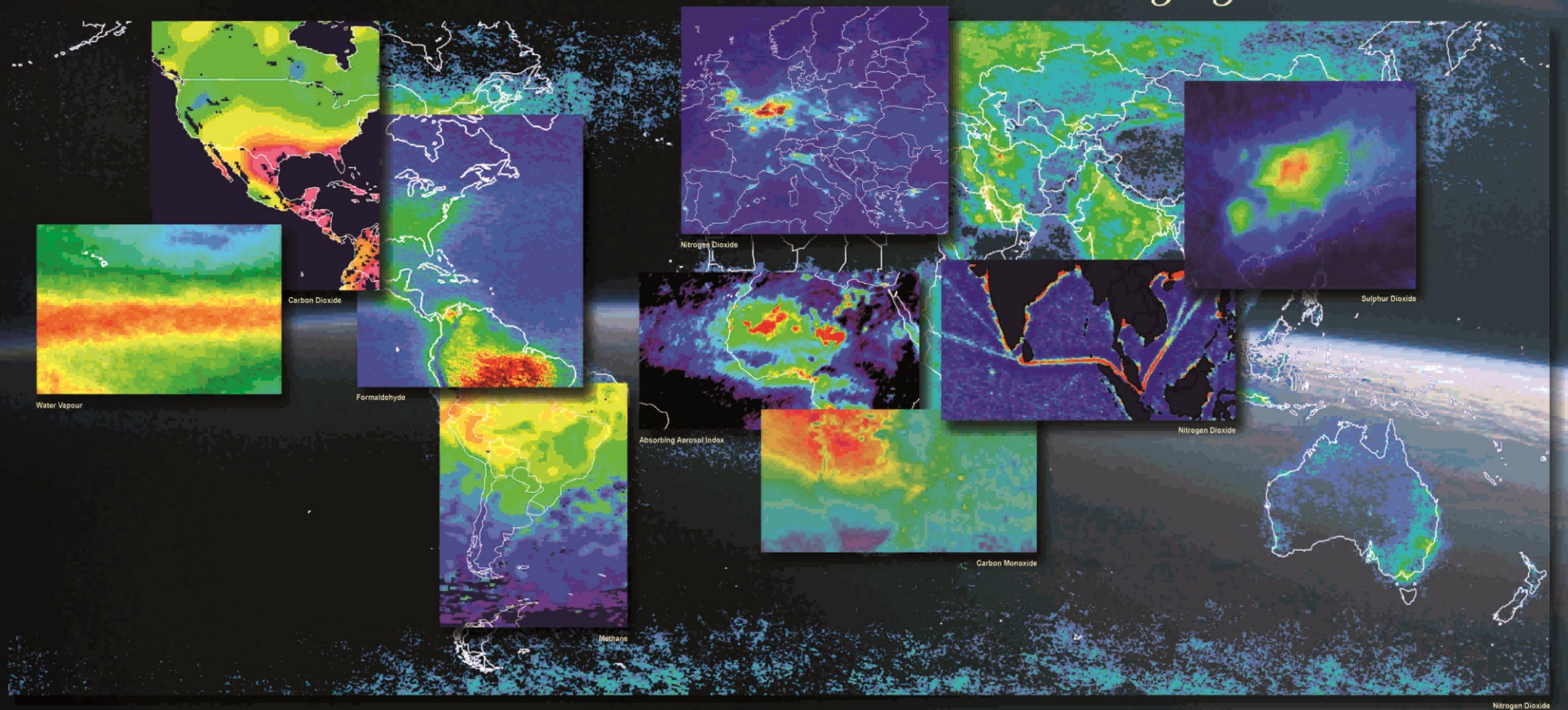
2nd Phase – Pre-flight Acquiescence – well as we have to do something, industry needs projects, your team could help but the concept has to be descoped etc.

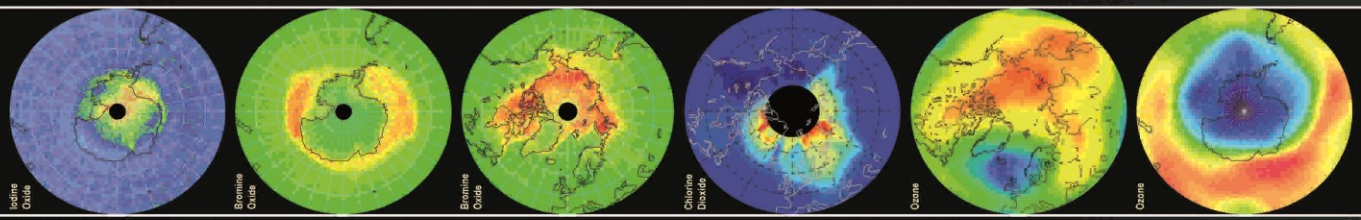
3rd Phase – Critical Acclaim Post-Launch and In-Flight - How come it does not work better, poor resolution and sampling, how come it cost so much, could you not do better etc.!

SCIAMACHY

SCIAMACHY 2002-2012

hunting light and shadows





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Images: DLR, IUP-IFE University of Bremen, SRON, KNMI, IASB-BIRA, MPI for Chemistry, ESA, NASA