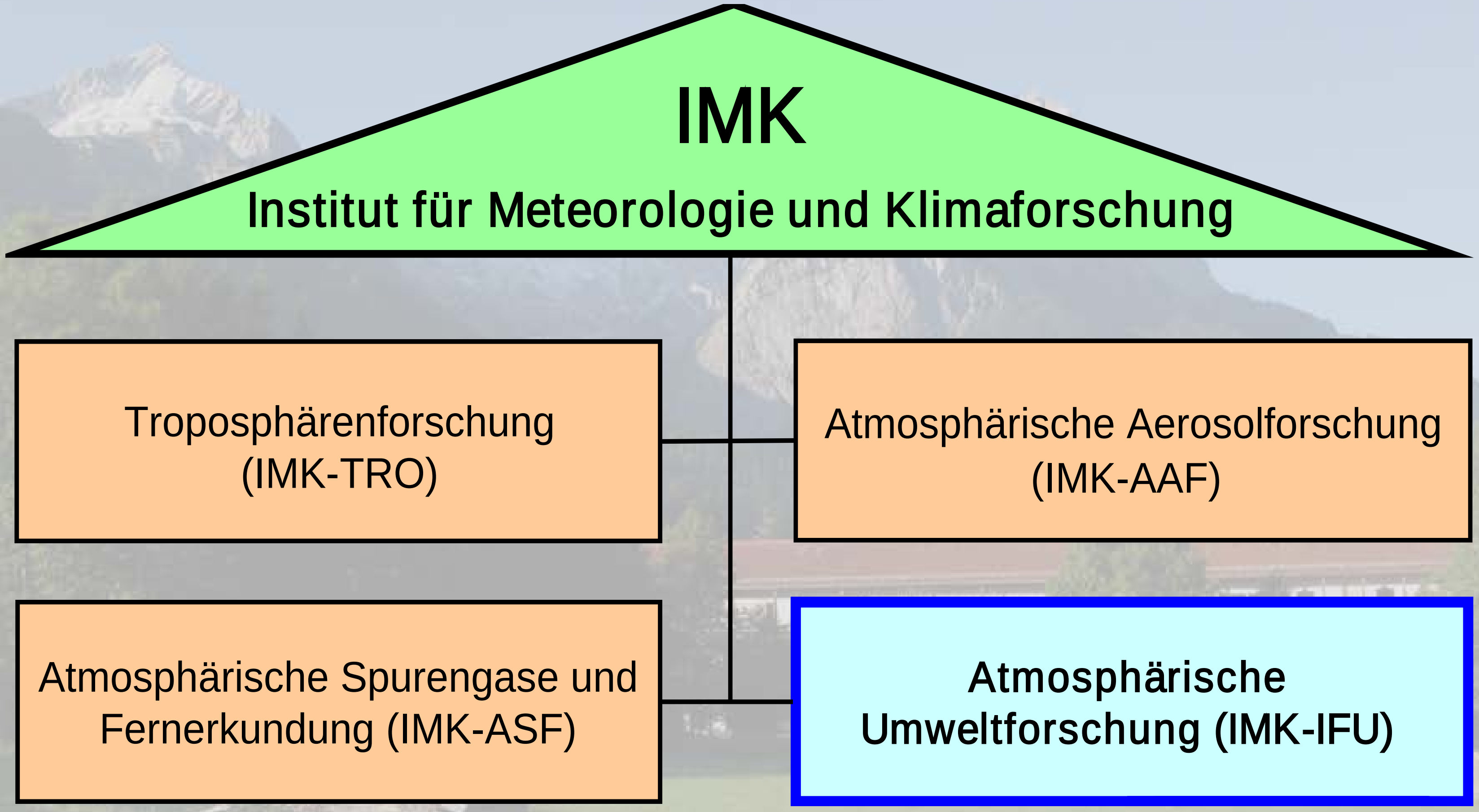
Atmosphärische Umweltforschung

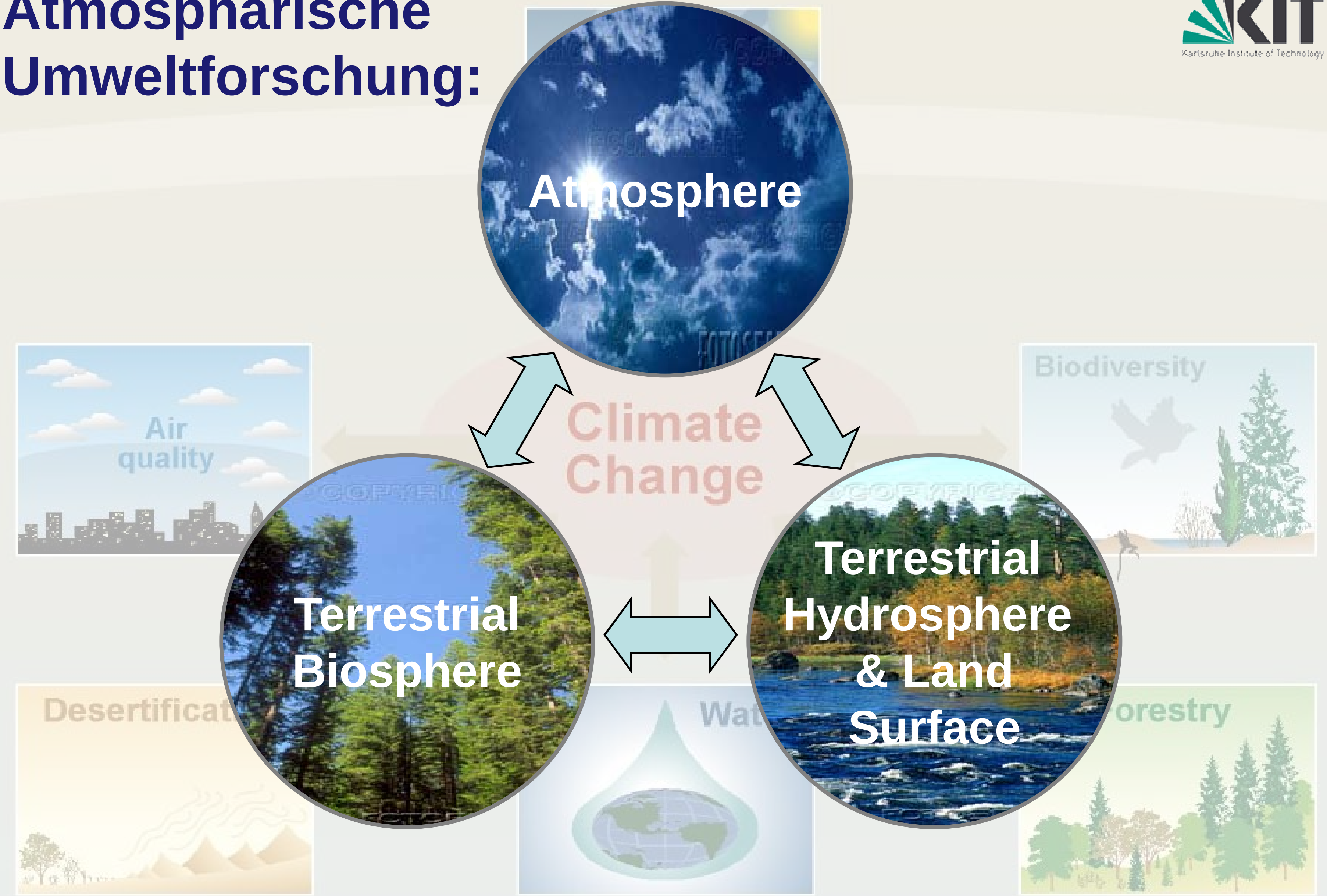
KIT
Karlsruhe Institute of Technology

Institut für Meteorologie und Klimaforschung IMK-IFU
Forschungszentrum Karlsruhe

Organisation des IMK



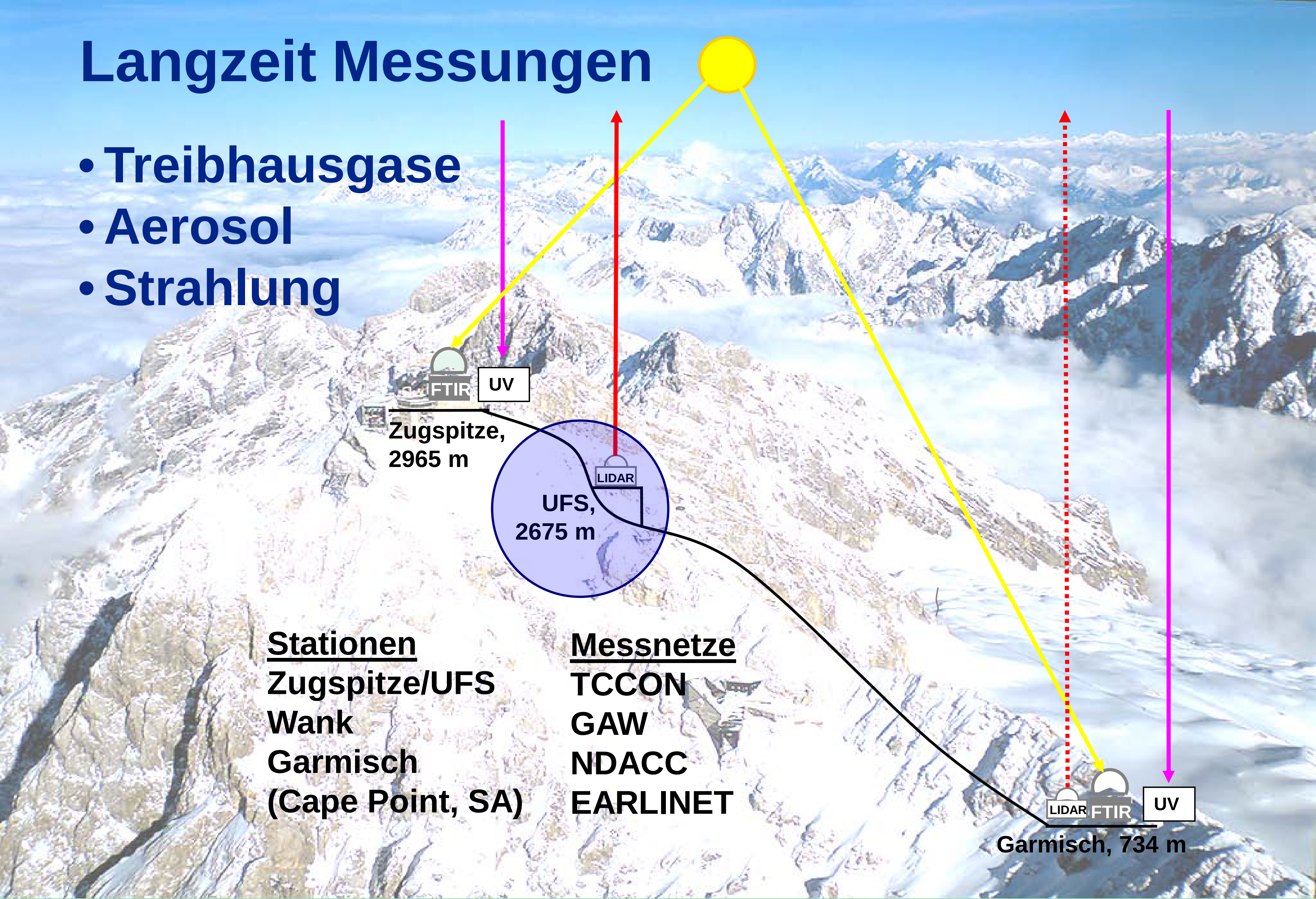
Atmosphärische Umweltforschung:



(source: IPCC 2001, WG1 Report, Summary)

Langzeit Messungen

- Treibhausgase
- Aerosol
- Strahlung

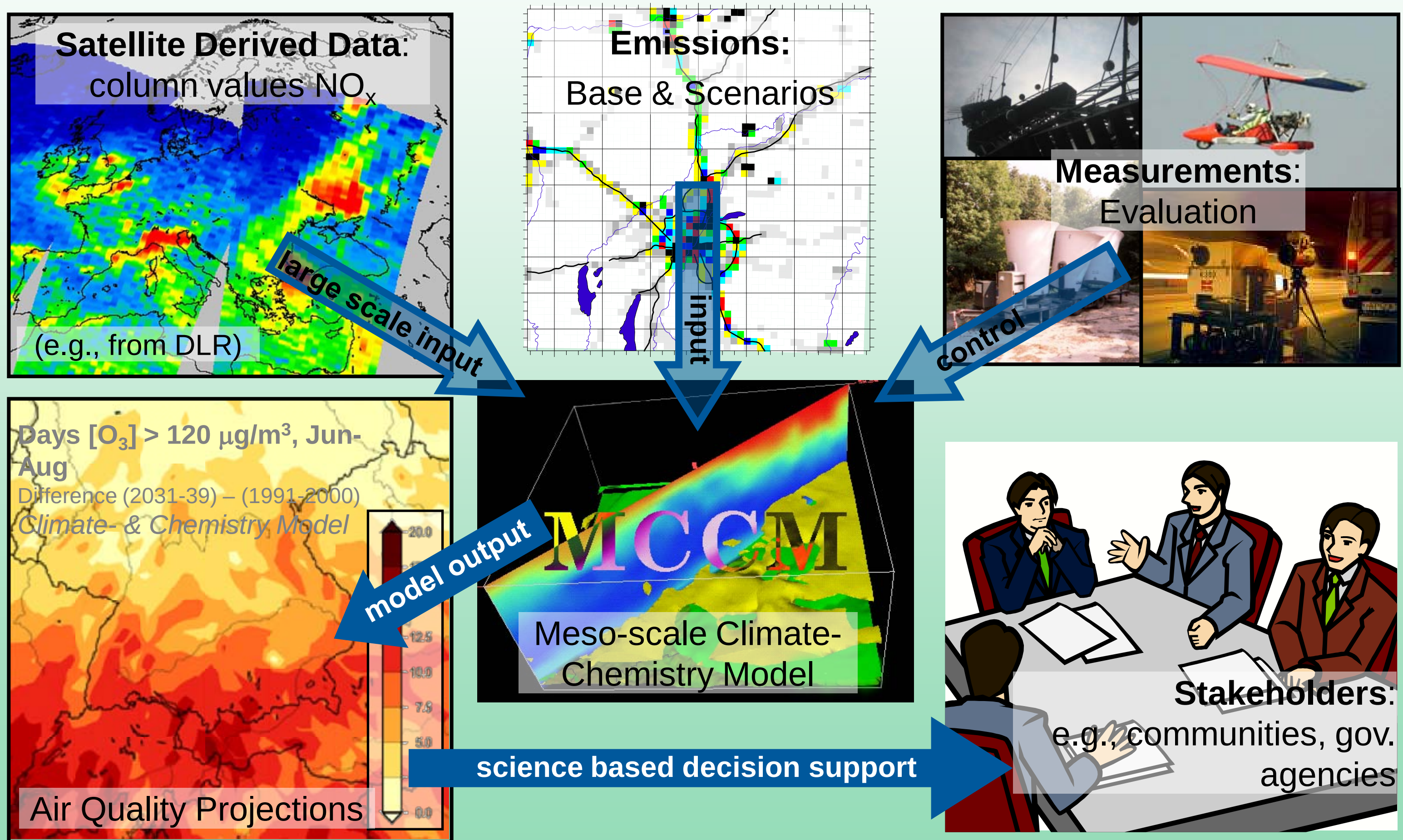


Stationen
Zugspitze/UFS
Wank
Garmisch
(Cape Point, SA)

Messnetze
TCCON
GAW
NDACC
EARLINET

Impact of regional climate change on urban-rural interactions

Coupled Mesoscale Climate Chemistry Model (MCCM): **integration of models & observations for air quality mitigation decision support**

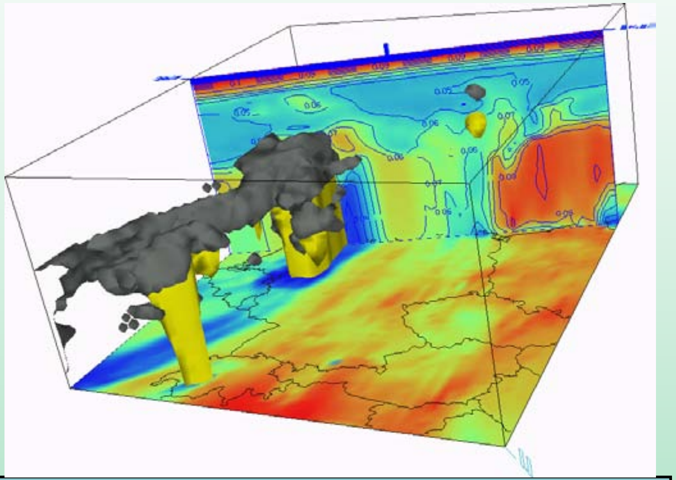


Regional coupled meteorology-chemistry simulations

Models: MCCM(based on MM5) , WRF/chem

Main features

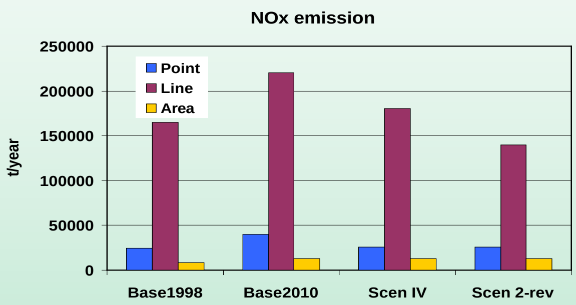
- **Online coupled** gas phase chemistry and aerosol module
- **Nesting capability**
- Non-hydrostatic

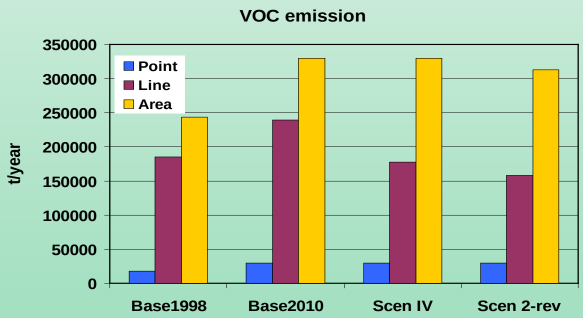


Applications

- Episodes and sensitivity, and scenario studies
- Real time meteorological and air quality simulations
- Regional coupled climate-chemistry simulations

Emission scenario simulations for Mexico City

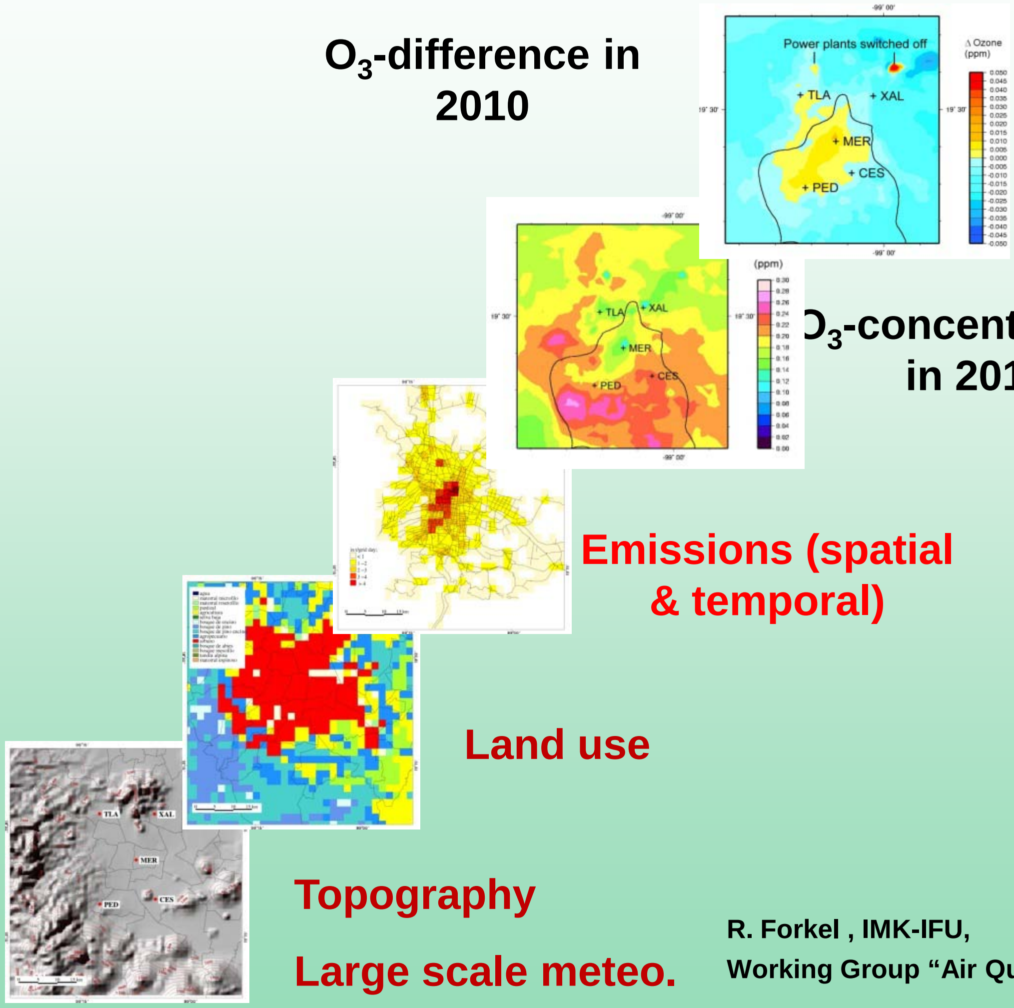




Basic information on present emissions and emissions of reduction measures

O_3-difference in 2010

O_3-concentrations in 2010



Emissions (spatial & temporal)

Land use

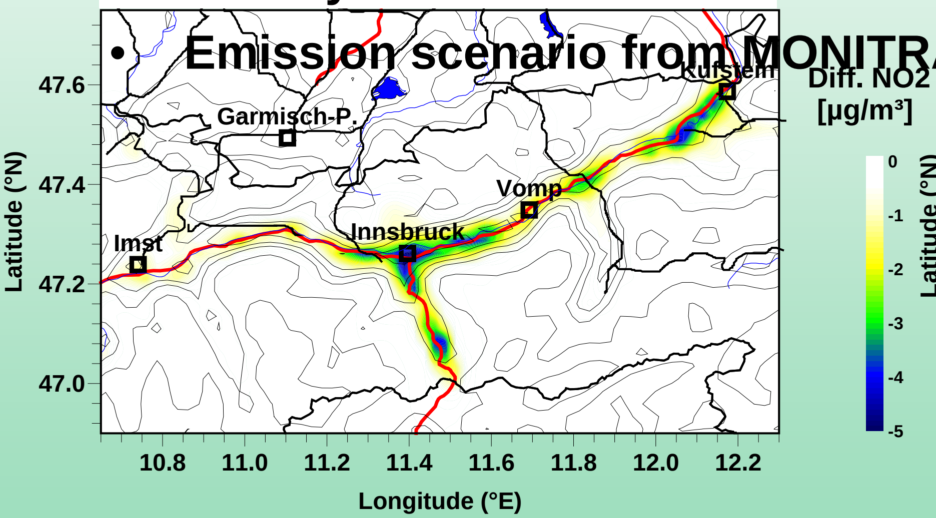
Topography

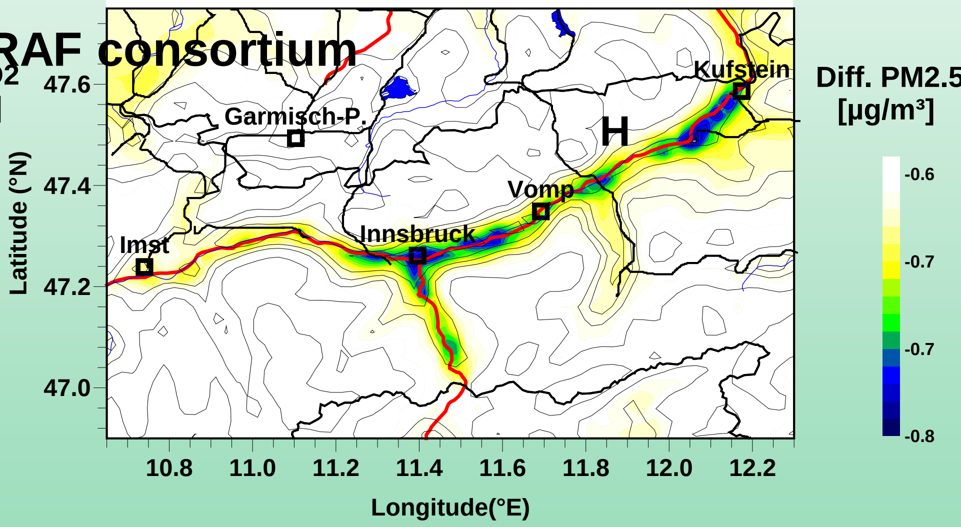
Large scale meteo.

R. Forkel , IMK-IFU,
Working Group "Air Quality"

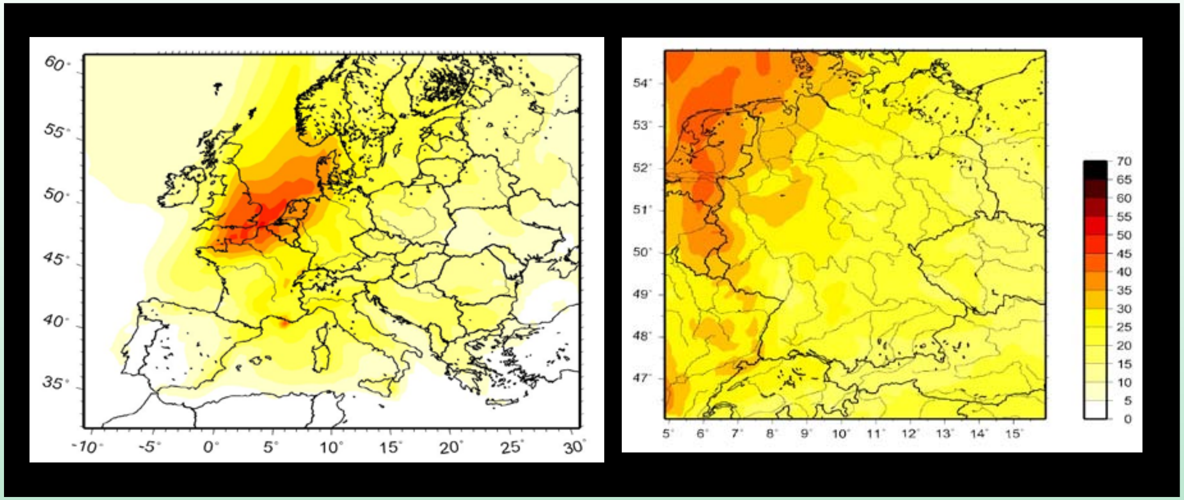
Emission scenario studies for an Alpine valley

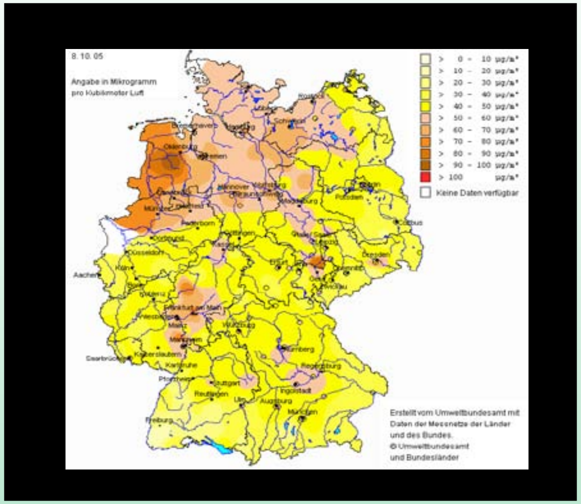
- Continuous simulation of the year 2004 with MCCM
- Three nested domains with horizontal resolution 60 km, 12 km, and 2.4 km
- Meteorological boundary conditions for Domain1 from NCEP reanalysis
- Emission scenario from MONITRAF consortium





Real time forecast e.g. PM_{10}





1 day forecast: 8th Oct. 2005

Domain 1: 60 km

Domain 2: 15 km

Measurements: 8th Oct. 2005 (Source: UBA)

Setup: MCCM, 60-15 km grid (Europe and Germany)
3 days forecast
Emissions: IER Stuttgart, global meteorology: GFS

Measurement techniques and methodologies for investigating air pollution situations

Klaus Schäfer, Stefan Emeis, Peter Suppan

IMK-IFU, Forschungszentrum Karlsruhe GmbH, Garmisch-Partenkirchen

Problems and objectives

Methodology: remote sensing, inverse modelling and model validation

Influence of mixing layer height upon air quality

Relations between optical depth and particle concentrations

Concept of ICAROS platform

Up scaling of flux measurements

Discussions, conclusions and outlook

Problems

A lot of measures for
- emission reduction (health protection) and
- efficient energy consumption (climate protection)

in the traffic and industrial sector realised

NO_2/NO_x ratio in ambient air continuously increasing

High amount of ultra-fine dust is background

How to reduce NO_2 and PM_{10} in a sustainable way?

Are the threshold values enough for health protection?

Solutions

Observation of air pollution processes by application of the available remote sensing methods

Interaction between urban areas and its surroundings

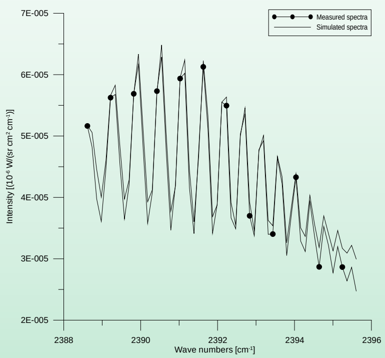
Determination of emission source strengths for modelling: Gaps; Hot spots

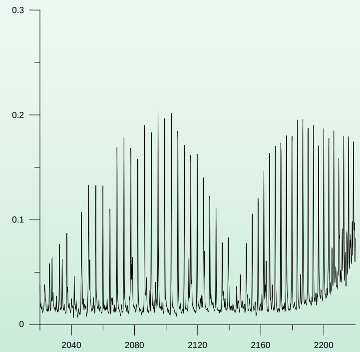
Validation of air quality modelling:
Validation strategies; Data requirements

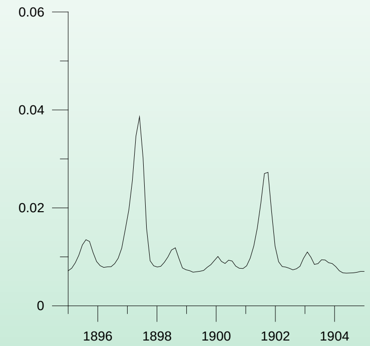
Basics for improvement of air quality in urban conglomerations

Methodology

In situ techniques for NO, NO_2, CO, O_3, THC, PM_{10}, $PM_{2.5}$







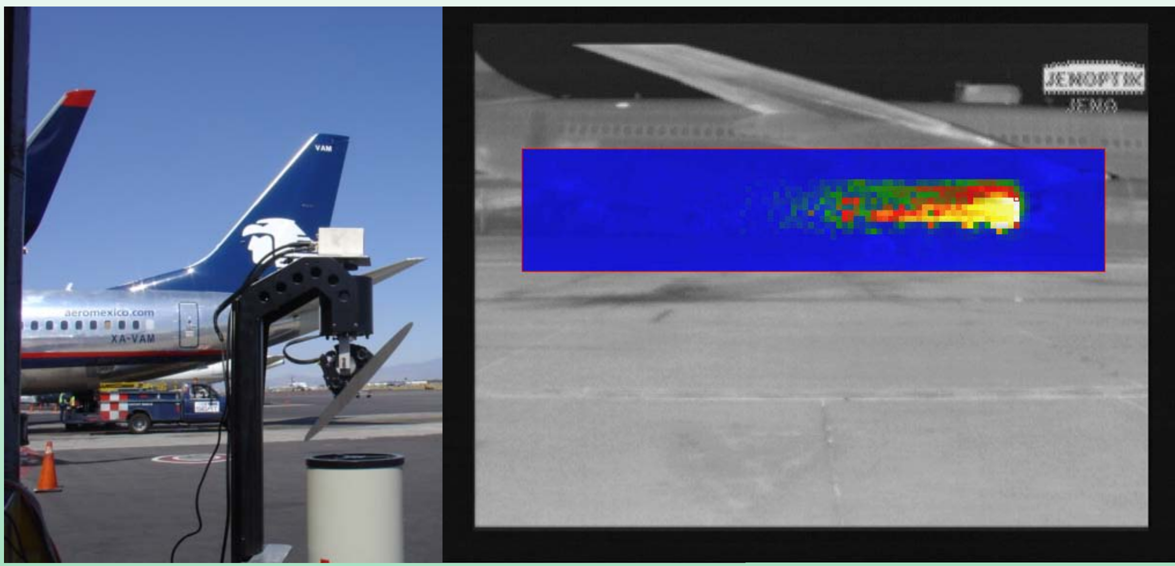
Path-averaging optical remote sensing techniques

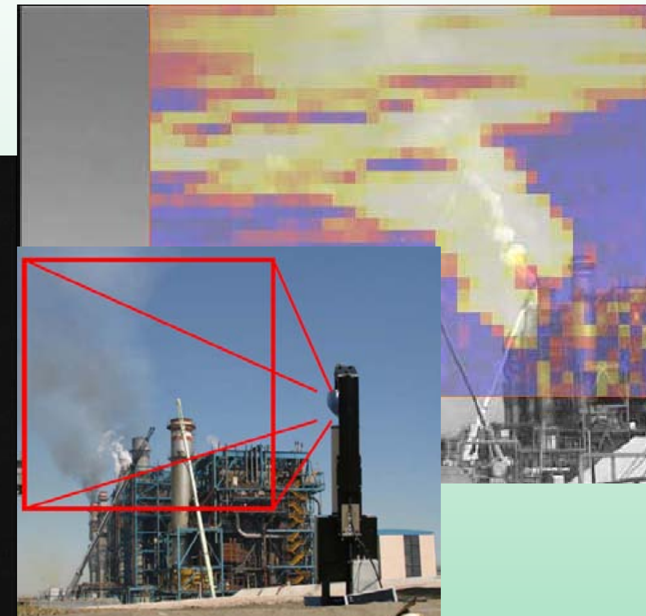
- FTIR emission spectrometry of hot exhausts (CO, NO, CO_2; NO_2 below detection limit)
- FTIR absorption spectrometry (CO, CO_2, CH_4, N_2O)
- DOAS (NO, NO_2, O_3, NH_3, BTX, HCHO)

Karlsruhe Institute of Technology

Improvement of measurement technique for detection of emission indices: Scanning Infrared Gas Imaging System

Application together with UNAM





Flores-Jardines, Edgar: Turbine exhausts monitoring with Fourier Transform Infrared emission spectroscopy. Dissertation zur Erlangung des Doktorgrades der Naturwissenschaften / Caracterización de las emisiones de turbinas de avión usando espectroscopía FTIR pasiva con un sistema de visualización (Dr. rer. nat.), Centro de Ciencias de la Atmosfera, Universidad Nacional Autonoma de Mexico, Mexico City, 2007

Calibration method

Instrumental line shape determination in MAPS: Checking the correct optical alignment of FTS

Average emission index *EI* of a molecule *X* in g/kg kerosene:

$$EI(X) = EI(CO_2) \times \frac{M(X)}{M(CO_2)} \times \frac{Q(X)}{Q(CO_2)}$$

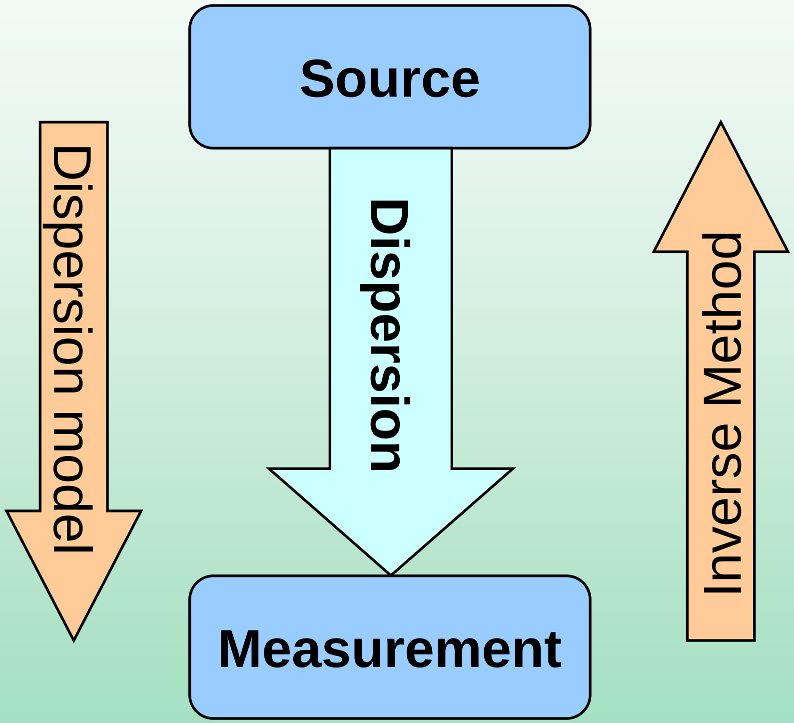
M: molecular weight

Q: concentrations (mixing ratios, column densities etc.)

Theoretical emission index of CO_2: 3,159 g/kg

EI (NO_x) = EI (46/30 NO + NO_2)

Inverse dispersion modelling



Bayesian statistics to solve the inverse problem: hourly averaged concentration measurements

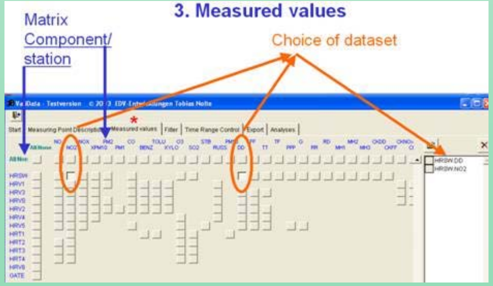
All kinds of emissions at a heterogeneous area source

Traffic is highly variable

Dispersion matrix by modelling with the Lagrangian model Austal2000

Schürmann, Gregor: Inverse Ausbreitungsmodellierung zur Emissionsratenbestimmung heterogener Flächenquellen. Dissertation zur Erlangung des Doktorgrades der Naturwissenschaften (Dr. rer. nat.) der Fakultät für Angewandte Informatik, Universität Augsburg, 2006; Prüfung 12.07.2007.

Model validation
Data base and pre-analyses tool



- Air monitoring data
- Meteorological data
- Intensive operating phases
- Location of sites
- Description
- Time

Schäfer, K., Emeis, S., Hoffmann, H., Jahn, C., Müller, W., Heits, B., Haase, D., Drunkenmölle, W.-D., Bächlin, W., Schlünzen, H., Leitl, B., Pascheke, F., Schatzmann, M.: Field measurements within a quarter of a city including a street canyon to produce a validation data set. International Journal of Environment and Pollution, 25, 1/2/3/4 (2005), 201-216.

Relationship between atmospheric optical depth and particle concentration

Ground-based measurements

- Daily mean measurements of PM_{10}, $PM_{2.5}$ and PM_1 at rural and urban background sites
- AOD from ground-based sun-photometer measurements around 560 nm at rural and urban background sites
- MLH from SODAR and ceilometer

Correlation with linear regression: $PM = a\,\beta_{ext} = a\,AOD / MLH$

a: mass extinction efficiency

Schäfer, K., Harbusch, A., Emeis, S., Koepke, P., Wiegner, M.: Correlation of aerosol mass near the ground with aerosol optical depth during two seasons in Munich. Atmospheric Environment, (2008).

Alföldy, B., Osán, J., Tóth, Z., Török, S., Harbusch, A., Jahn, C., Emeis, S., Schäfer, K.: Aerosol optical depth, aerosol composition and air pollution during summer and winter conditions in Budapest. Science of the Total Environment 383, 1-3 (2007), 141-163.

General characteristics of the ICAROS platform

High spatial resolution satellite imageries in regions of 100 km x 100 km (SPOT, Landsat: resolution 30 m x 30 m):

- images in the green spectral range
- one image recorded under very clear atmospheric
- one image of the same geographical area recorded during different pollution levels

Information about aerosols, particle diameter 0.2 - 1.0 µm

Soulakellis, N.A., Sifakis, N.I., Tombrou, M., Sarigiannis, D., Schäfer, K.: Estimation and mapping of aerosol optical thickness over the city of Brescia – Italy using diachronic and multiangle SPOT 1, SPOT 2 and SPOT 4 imagery. Geocarto International, 19, 4 (2004), 57-66.

Outlook

Joint interpretation of the integrated measurements for air quality model validations

Joint analyses of air quality simulations at different scales

Application of remote sensing techniques and inverse dispersion modelling for improvement of emission inventories

Up-scaling and down-scaling of fluxes near the surface:

- Determination of fluxes at the scale of emission inventories
- Influence of emissions upon ambient air in the higher scale

Air pollution by particulate matter - a challenge for megacities; the example of Beijing

Klaus Schäfer, Peter Suppan

Institute of Meteorology and Climate Research, Atmospheric Environmental Research Division, Forschungszentrum Karlsruhe, Garmisch-Partenkirchen

Joachim Vogt

Institute of Regional Science, University of Karlsruhe

Stefan Norra

Institute of Mineralogy and Geochemistry, University of Karlsruhe

Scientific question

Which regional meteorological situations (transport and exchange conditions) and which emission processes cause in Beijing high particulate matter (PM) exposures?

In particular these are the questions:

How much the local wind systems influence the PM load?

How much the mixing layer height (MLH) influences the PM exposure?

Are there secondary circulation systems and heat island effects which influence the exchange between the metropolitan region and the surroundings?

Tasks

Analyses of height depending particulate loads

• Measurements of MLH and PM parameters by ceilometers (IMK-IFU, Vaisala)

• Measurements of particle size distributions and concentrations (IMG)

• Analyses of PM2.5 actively and TSP passively at CRAES and CAS/Beijing (IMG)

•Meteorological monitoring and measurements of meteorological parameters at the 300-m-mast by Chinese partners and with the Zeppelin by IRS (IMG) 70 km south of Beijing at CAS station to determine the transport and exchange conditions

• Study of particulate load on the basis of sun-photometer measurements by Chinese partners (CAS)

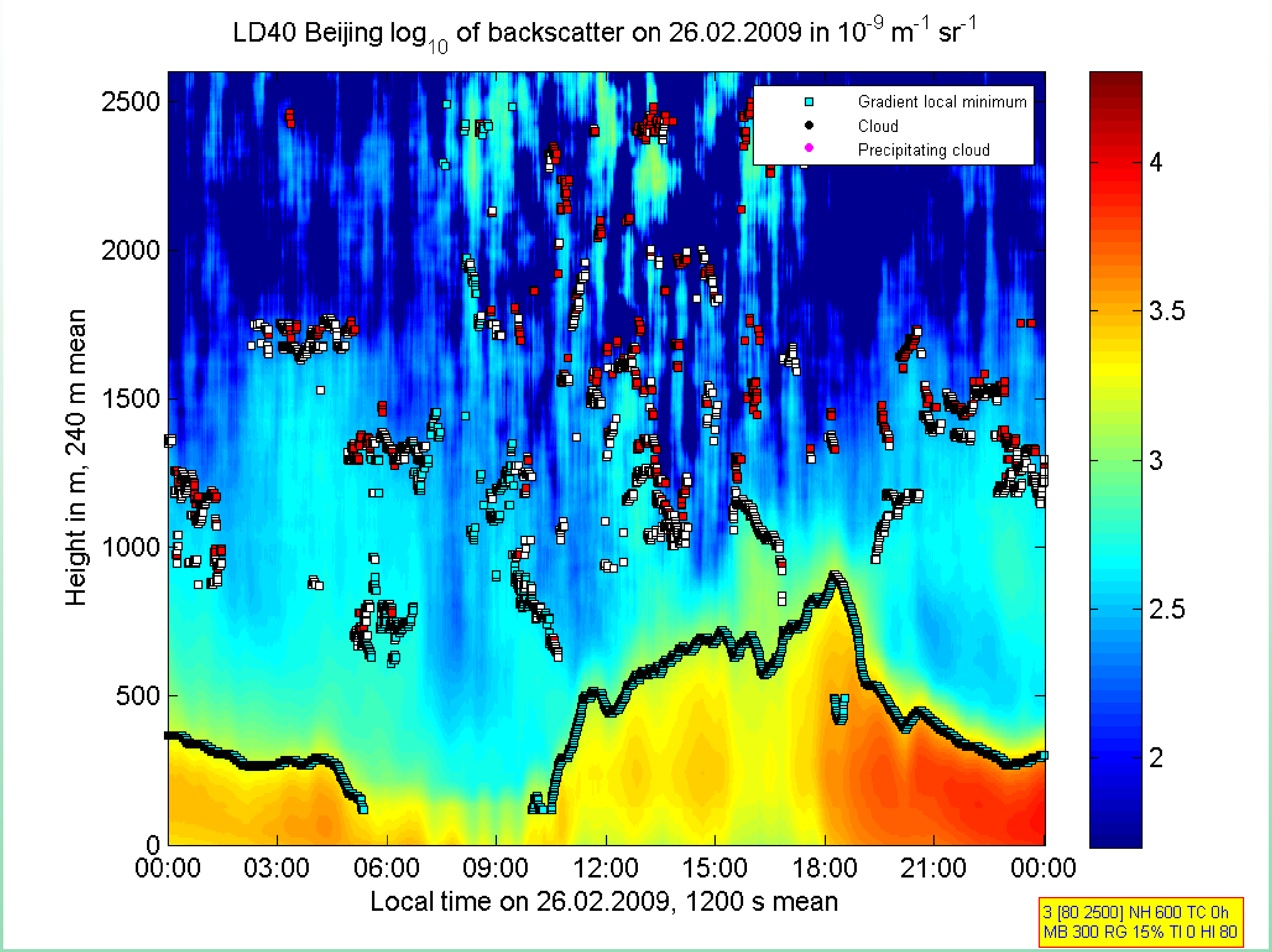
• Analyses of weather conditions for high PM pollution (IMK-IFU with Chinese partners)

Location of the Measurement systems

- Ceilometer and particle samplers/spectrometers at the 300-m-mast
- Ascents of weather zeppelin 70 km south of Beijing

Co-operations with Chinese partners

- Meteorological monitoring data
- Air pollution data (PM, gases) from monitoring network
- Weather maps
- Meteorological and air pollution data from the 300-m-mast
- Sun-photometer data
- Emission inventory for modelling



LD40 Beijing log10 of backscatter on 26.02.2009 in 10-9 m-1 sr-1
Gradient local minimum
Cloud
Precipitating cloud
Height in m, 240 m mean
Local time on 26.02.2009, 1200 s mean
0
500
1000
1500
2000
2500
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
2
2.5
3
3.5
4
3 [80 2500] NH 600 TC 0h
MB 300 RG 15% TI 0 HI 80

Discussion and conclusions

Development of a Super Site Beijing: Integration of 300-m-mast, ceilometers, passive DOAS, active DOAS, passive/solar FTIR, radiometers (AERONET), SODAR, in situ

- Vertical column densities of NO_2, SO_2, O_3 and CO as well as GHG
- Near-surface horizontal column densities of NO_2, NO, SO_2, O_3 and CO
- Altitude profiles of aerosol backscatter intensities near 1 µm: continuous aerosol and MLH information
- Near-surface concentrations, column densities and MLH
- Wind profiles for transport investigations
- Determination of relation between near surface PM concentrations and AERONET atmospheric optical depth with MLH measurements
- Spectral resolved atmospheric radiation in the UV/vis: information about optical characteristics of aerosols as well as particle diameters and composition

Measurement systems

•Layering of the lower atmosphere and mixing layer heights: ceilometers (IMK-IFU), 300 m measurement mast (IAP, IMG, IRS)

•Vertical profile of meteorological data: 300 m mast (IAP)

•Path-averaged concentrations of air pollutants NO, NO_2 (SO_2, O_3, BTX, NH_3, HCHO are possible) near and above the motorway: DOAS (with three retroreflectors, up to about 150 m distance to the emitter/receiver-unit, system is changing automatically from path to path) (IMK-IFU)

Inter-comparisons

Comparison of air pollutant measurements by the DOAS and a monitoring station nearby: NO, NO_2