Investigations on air quality modeling and measurements at IMK-IFU

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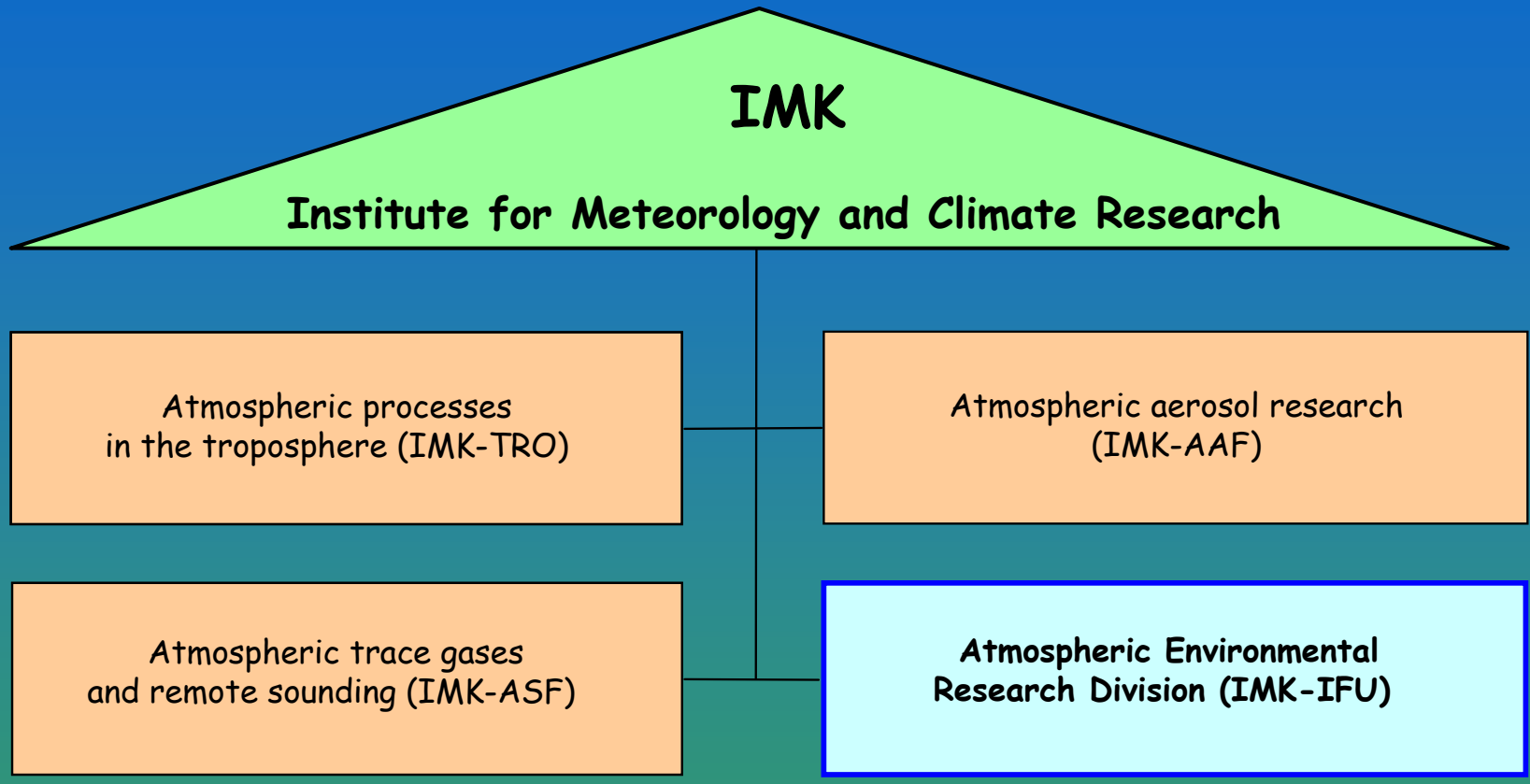
- General introduction
- Introduction working group
- Introduction to the modeling system MCCM
- Short outline about the type of applications
- Examples and results
- Summary / Outlook


IMK
Institute for Meteorology and Climate Research
Atmospheric processes
in the troposphere (IMK-TRO)
Atmospheric aerosol research
(IMK-AAF)
Atmospheric trace gases
and remote sounding (IMK-ASF)
Atmospheric Environmental
Research Division (IMK-IFU)

Institute for Meteorology and Climate Research (IMK)

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Deputy: Priv. Doz. Dr. Klaus Butterbach-Bahl

Working Groups:

- **Ecosystems of Meta-fluxes and Trace Gases**
  Priv. Doz. Dr. Hans Papen
- **Biological Processes of N- and C-Trace Gas Production**
  Priv. Doz. Dr. Jörg-Peter Schnitzler
- **Organismic Interactions and Biodiversity**
  Prof. Dr. Heinz Rennenberg
- **Regionalization of Trace Gas Emissions**
  Priv. Doz. Dr. Klaus Butterbach-Bahl

Department

Atmospheric Trends and Regional Climate Change

Head: Dr. Harald Kunstmann
Deputy: Dr. Ralf Sussmann

Working Groups:

- **Variability and Trends of Atmospheric Parameters**
  Dr. Ralf Sussmann
- **Coupled Model Systems**
  Dr. Rüdiger Grote
- **Climate Change and Terrestrial Hydrology**
  Dr. Harald Kunstmann
- **Air Quality in Metropolitan Areas and Sensitive Regions**
  Dr. Peter Suppan

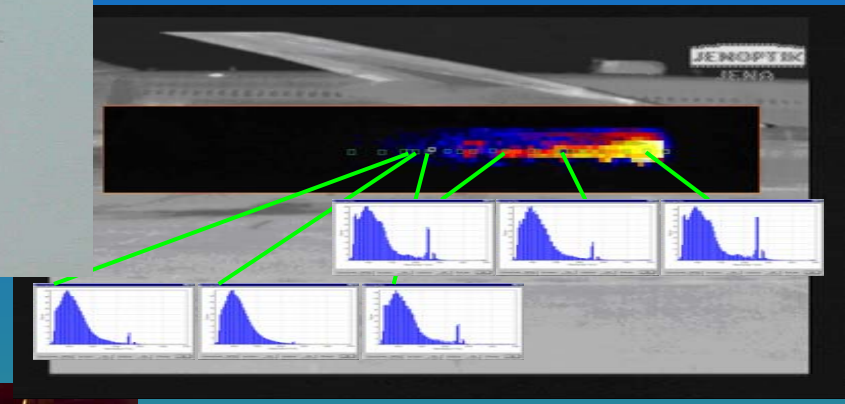
Air Quality in Metropolitan Areas and Sensitive Regions

- Interactions between urban/suburban/rural regions and their feedback mechanism to the air quality
- Impact of regional climate change on air quality
- Developing and validation of innovative measuring techniques for the assessment of the air quality (e.g. Megacities, airports)
- Coupling of models (e.g. MCCM, WRF-Chem, micro scale models)
- Real-time forecast of gas and particle phase pollutants
- Assessment of emission strategies (e.g. source attribution)
- Project "Risk Habitat Megacity" with the topic "Air Quality and Health"; anchor city Santiago de Chile in co-operation with Universidad de Chile

Tools

- Measurements
  - Ultra light aircraft
  - in situ
  - FTIR- Spectroscopy
  - DOAS
  - LIDAR
- Models
  - NEMO (traffic emission modeling)
  - GRAL (emission dispersion in the micro scale)
  - MM5 (meteorological transport model and regional climate model)
  - MCCM (online coupled climate chemistry model)
  - WRF (meteorological transport model and regional climate model)
  - WRF/chem (online coupled chemistry model)
- Methods
  - inverse modeling
  - source attribution
  - source receptor analysis
  - regional-climate simulations
  - remote sensing

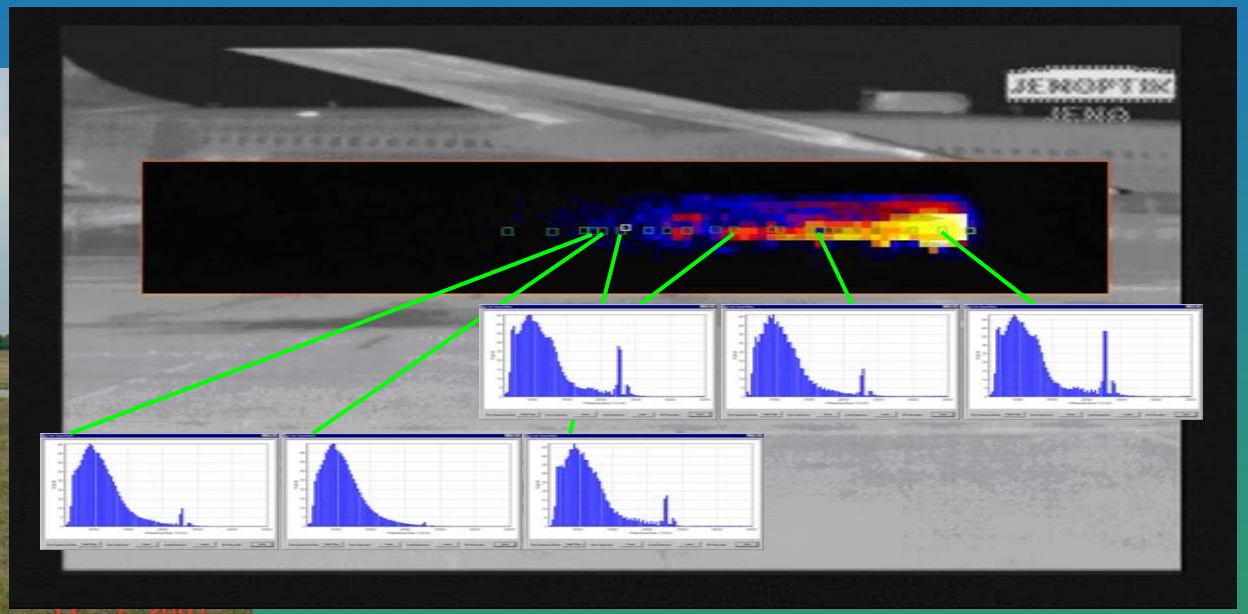
Air Quality Measurements: Platforms



Air Quality Measurements

Infra-red picture and FTIR-spectroscopy signal

- Air craft emissions via different spectra: CO, NO, CO_2
- Dispersion of the emission plume for numerical simulations of the air quality

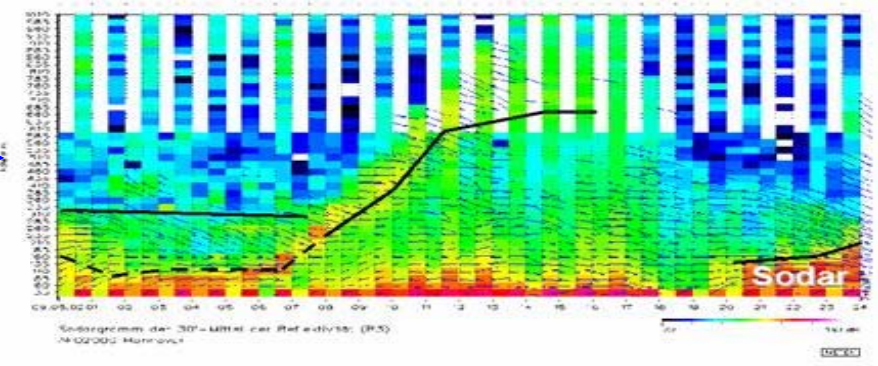


Air Quality Measurements

Comparison of three different MLH retrievals

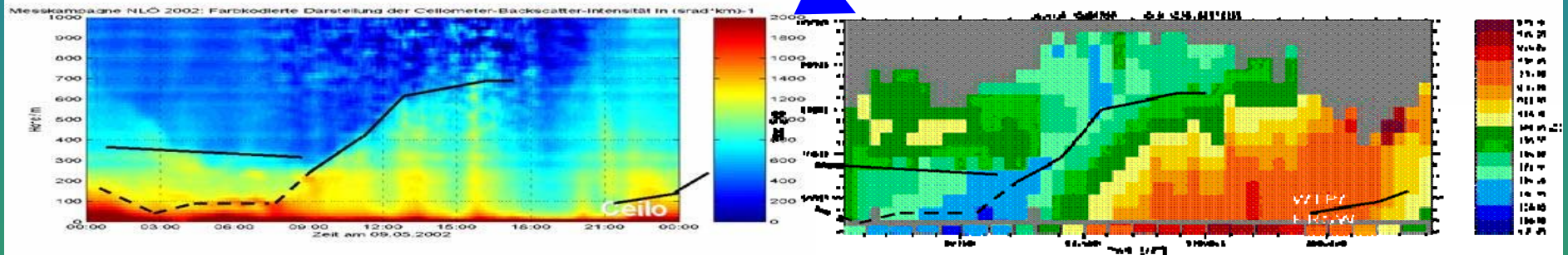
SODAR
acoustic backscatter

Dr. habil. Stefan Emeis
stefan.emeis@imk.fzk.de



CEILOMETER
optical backscatter

RASS
temperature



Emeis, S., Chr. Münkel, S. Vogt, W.J. Müller, K. Schäfer, 2004: Atmospheric boundary-layer structure from simultaneous SODAR, RASS, and ceilometer measurements. Atmos. Environ., 38, 273-286.

Modeling methods

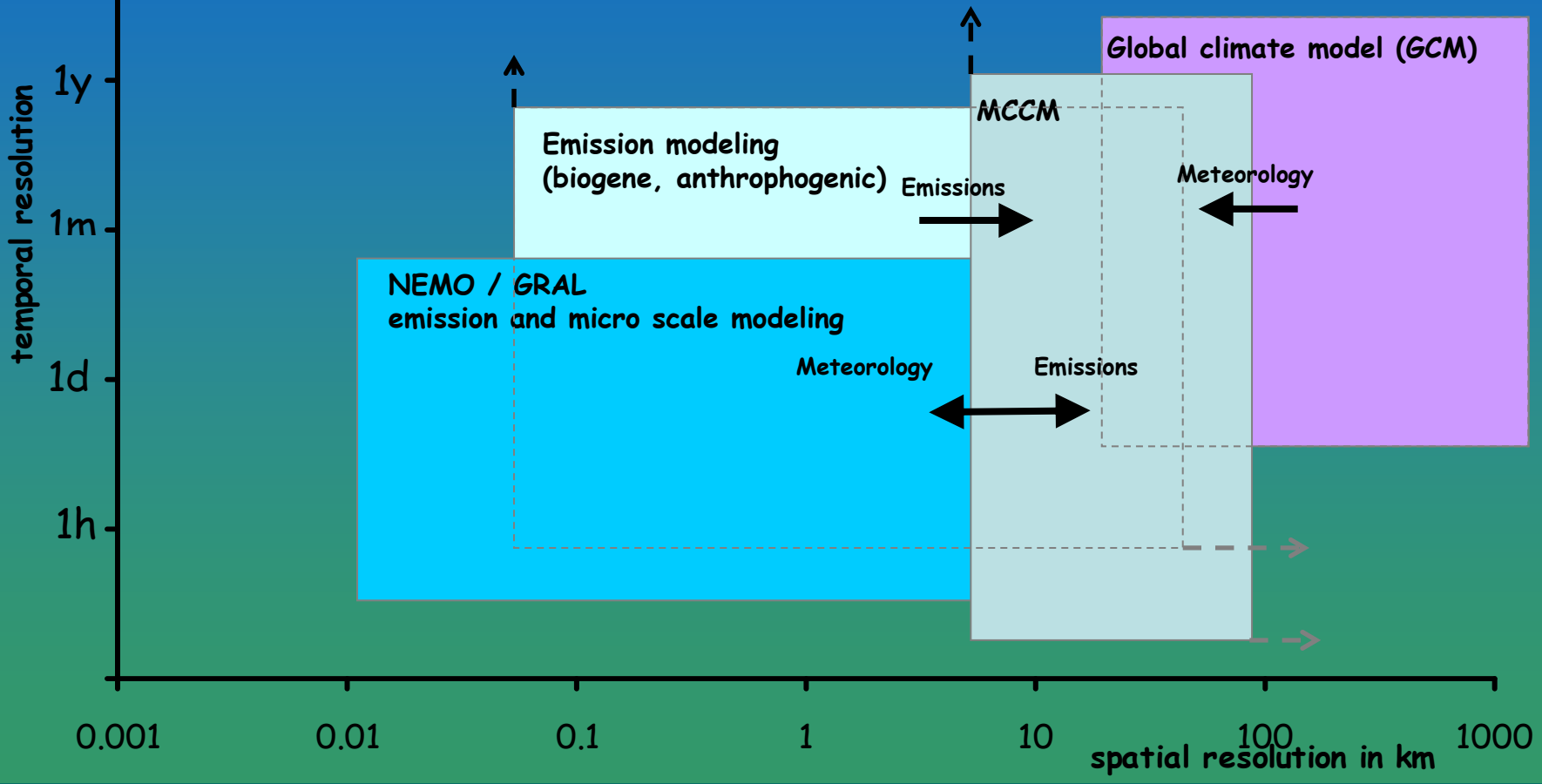
Model Topics

GCM – long term, scenarios

MCCM – long term, nesting, source attribution

NEMO/GRAL – micro scale traffic emissions / dispersion

Modeling network / -coupling IMK-IFU



Online coupled meso scale climate chemistry model

Meteorological part

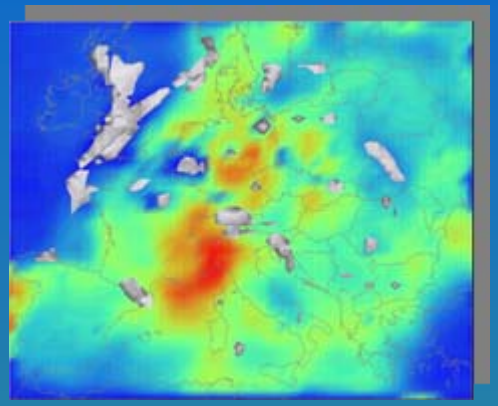
- Based on MM5
- Non-hydrostatic
- Nesting capability
- Soil and snow model

Chemistry part

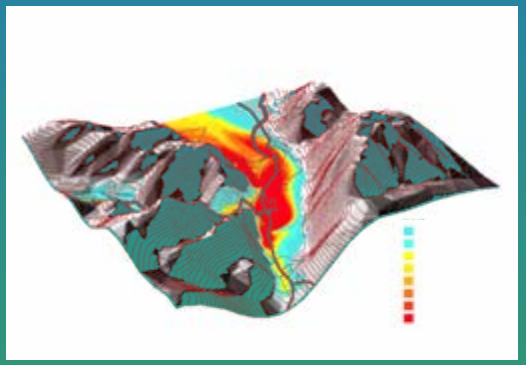
- RADM2 / RACM chemistry
- KPP preprocessor for chemical mechanisms
- Photolysis model
- Aerosol module (MADE/SORGAM)
- Biogenic emission module

Output:
Fields of temperature, humidity, cloud water and ice, rain water, snow, photolysis frequencies, concentrations of chemical compounds in the gas and particle phase, snow height …

Mesoscale-Climate-Chemistry-Model (MCCM)



regional



local

Observations

Orography
Land use
Soil Texture

Anthropogenic
Emissions

Global Weather
forecast models

Global
Climate Models

Analysis

Interpolation

Meteorological
Data Assimilation

Biogenic
Emissions

MCCM (MM5/chem)
Meteorology, Climate, Aerosols,
Air Chemistry, Soil-Vegetation

Runoff / Routing
Model (e.g. WASIM)

Detailed hydrological
Model

Dynamic Vegetation
Model (MOBILE)

Bio-Geo-Chemistry
Model

Micro-scale Model
(e.g. GRAL)

Simulation
of Air Quality

Simulation of
Regional Climate

Air Pollution
Control Strategies

Critical Levels
and Loads

Climate Changes
and Air Quality

Extreme
Events

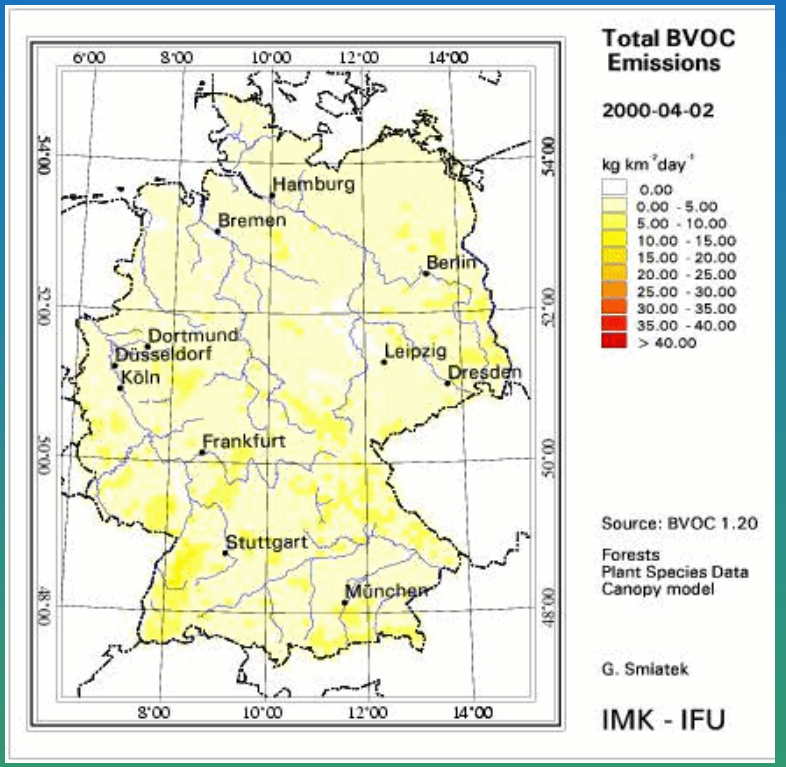
Soil-Vegetation-
Atmosphere
Feedback Effects

Technical Infrastructure

- LINUX-Cluster
  (NEC, 220 AMD Opteron & XEON EMT64 Processors, Infiniband Interconnect)
- HPC Infiniband Storage-Cluster 108 TByte,
  NAS-Storage (Network Appliance) 50 TByte
- Archive: DVD "Juke Box"
  12 Tbyte
- Workstations
  SGI Visualization Workstations
  AMD Opteron Linux Workstations

BVOC data

- Land Cover (CORINE2000, PELCOM, USGS)
- Vegetation
  - Plant specific data (Forests: JRC, Country level)
  - Foliar biomass
  - Leaf Area Index (MODIS)
- Soil (JRC)
- Meteorology 2000 (hourly values)
- Biomass
- Emission Factors



Dr. Gerhard Smiatek
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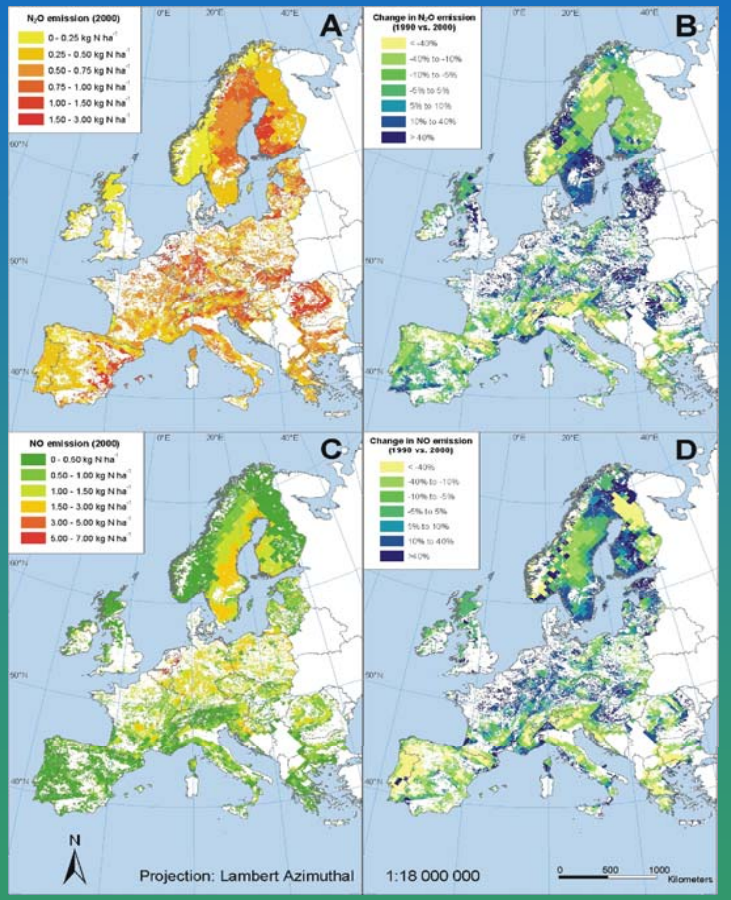
N_2O and NO data

- Regional distribution of annual N_2O and NO emissions from forest soils in Europe (in kg N per ha and yr)

- Relative changes in the N_2O or NO emission strength if meteorological data for the year 2000 were exchanged with those of the year 1990



Source: Kesik et al. (2005)

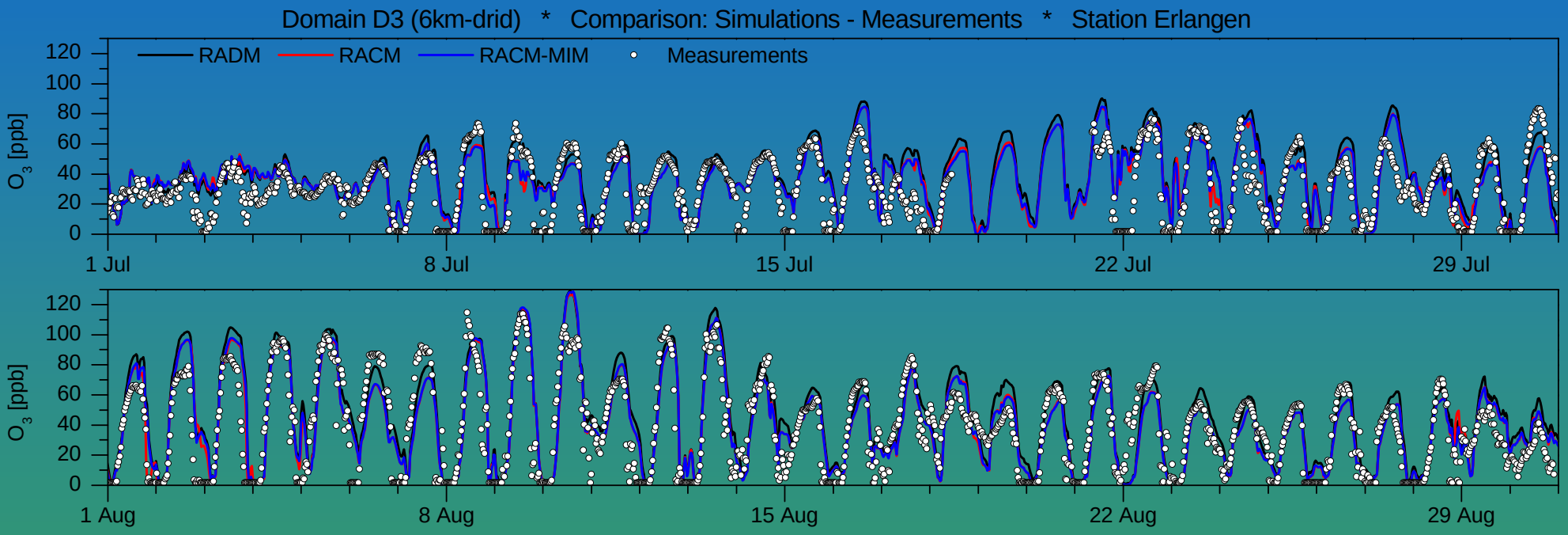
Applications

- Evaluation studies about chemical schemes and numerical methods (→ Bavaria)
- Short time simulations, validation, comparison, strategies and scenarios of air quality studies
  (→ Mexico City, Santiago de Chile, Munich, Augsburg, Berlin)
- Long time simulations with the background on annual thresholds
  (→ Alpine region)
- Operational forecast for O_3 and PM_{10}
  (→ Southern Germany, Bavaria, Southern Austria)
- Climate-chemistry simulations for present and future climate
  (→ Southern Germany, Mexico)

Chemistry Mechanisms

- **RADM2 (Stockwell et al. 1990)**
  63 chemical species, 21 photolysis reactions and 136 chemical reactions of higher order
- **RACM (Stockwell et al. 1997)**
  77 chemical species, 23 photolysis reactions and 214 chemical reactions of higher order
- **RACM-MIM (Geiger et al. 2003)**
  84 chemical species, 23 photolysis reactions and 221 chemical reactions of higher order
  (based on MIM-Isoprene-Mechanism; this mechanism reflects an advanced description of the chemistry of biogenic ozone precursors like isoprene and others

Evaluation Studies – Chemical Mechanisms



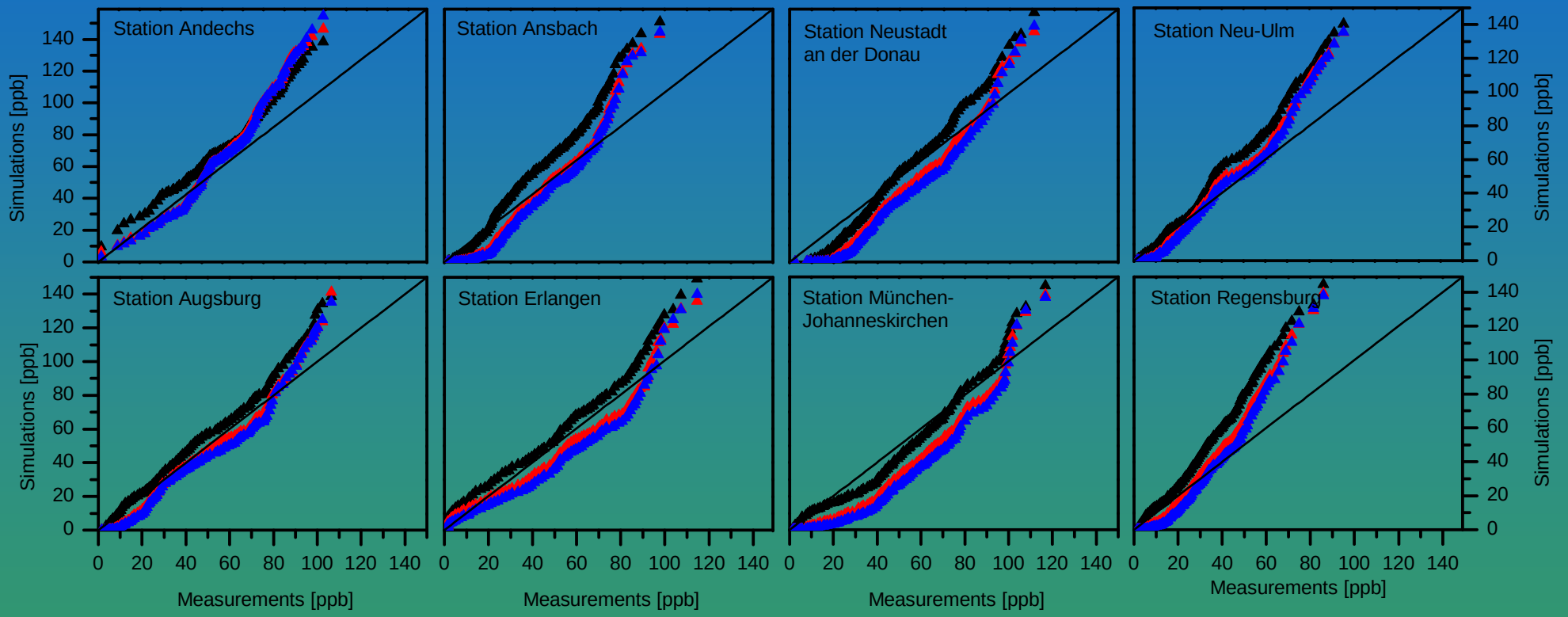
PhD thesis / Edwin Haas 2007

Setup: 54-18-6-2 km grid
2 month period
Southern Germany

Evaluation Studies – Advection Schemes

D3: Quantile-Quantile-Plot

▲ MPDATA ▲ BOTTM ▲ BOTTP

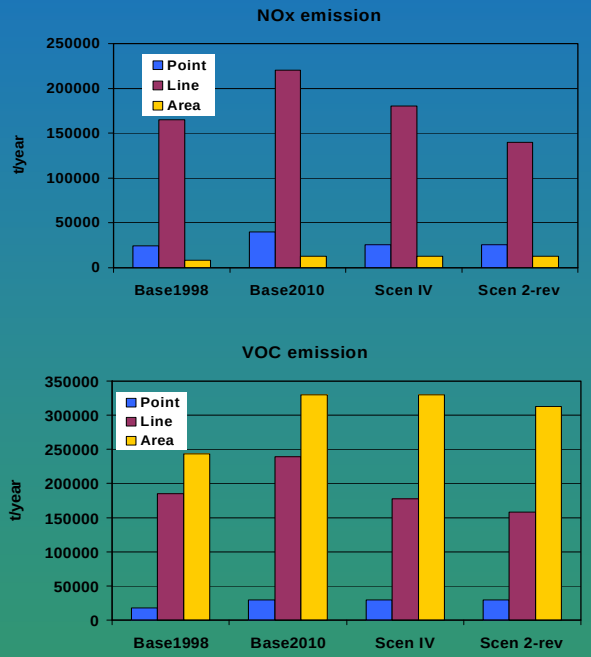


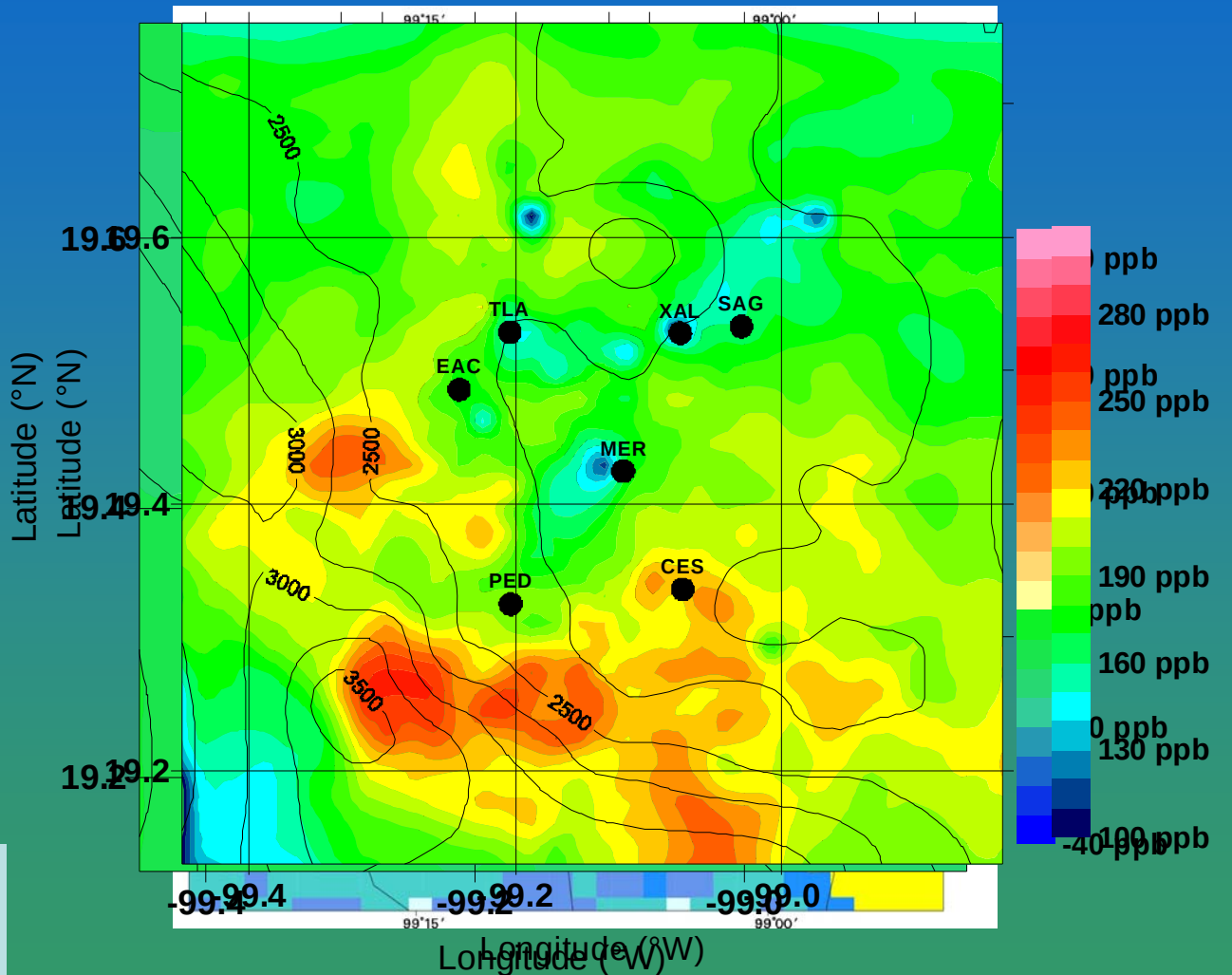
Setup: 54-18-6-2 km grid
10 days period
Southern Germany

PhD thesis / Edwin Haas 2007

Air Quality Studies - Scenarios

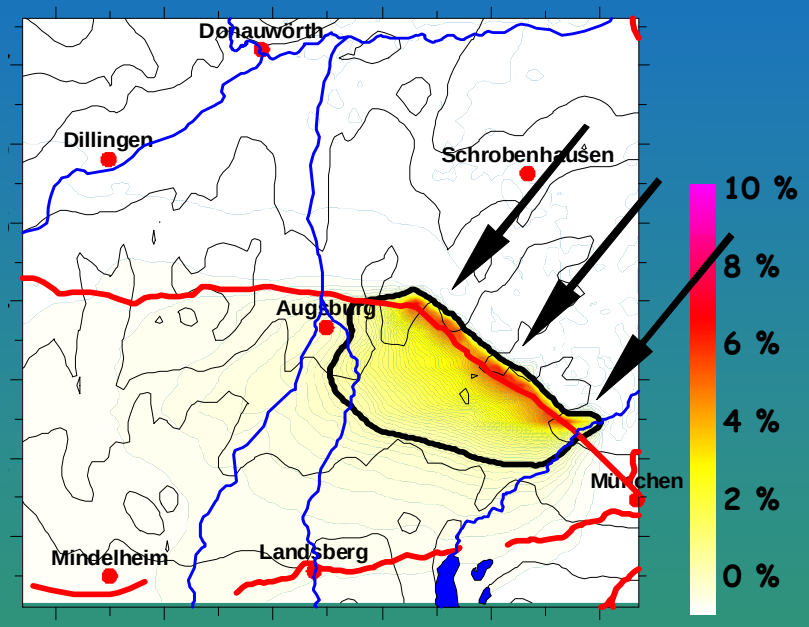
O_3 Concentrations
2010



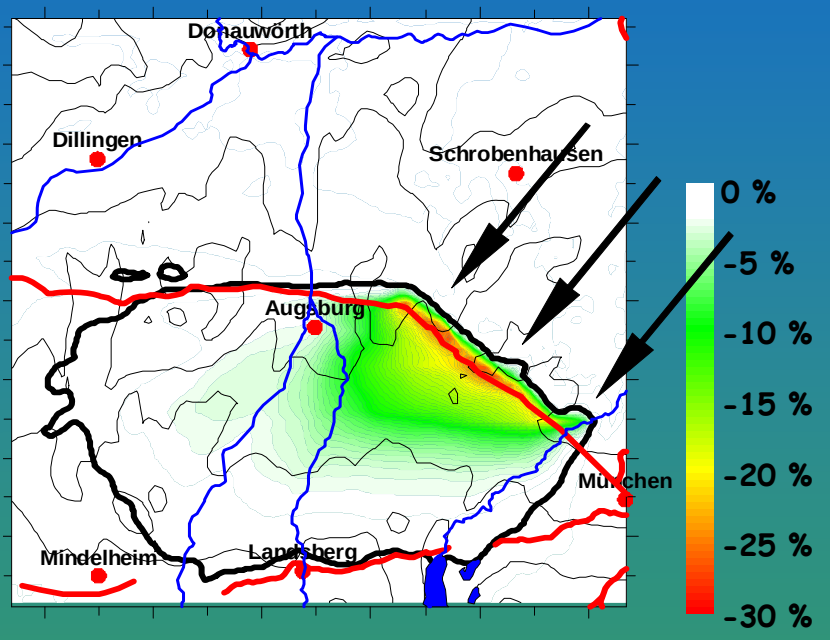


Setup: 18-6-2 km grid
days period
Mexico City

Air Quality Studies – Emission Strategies



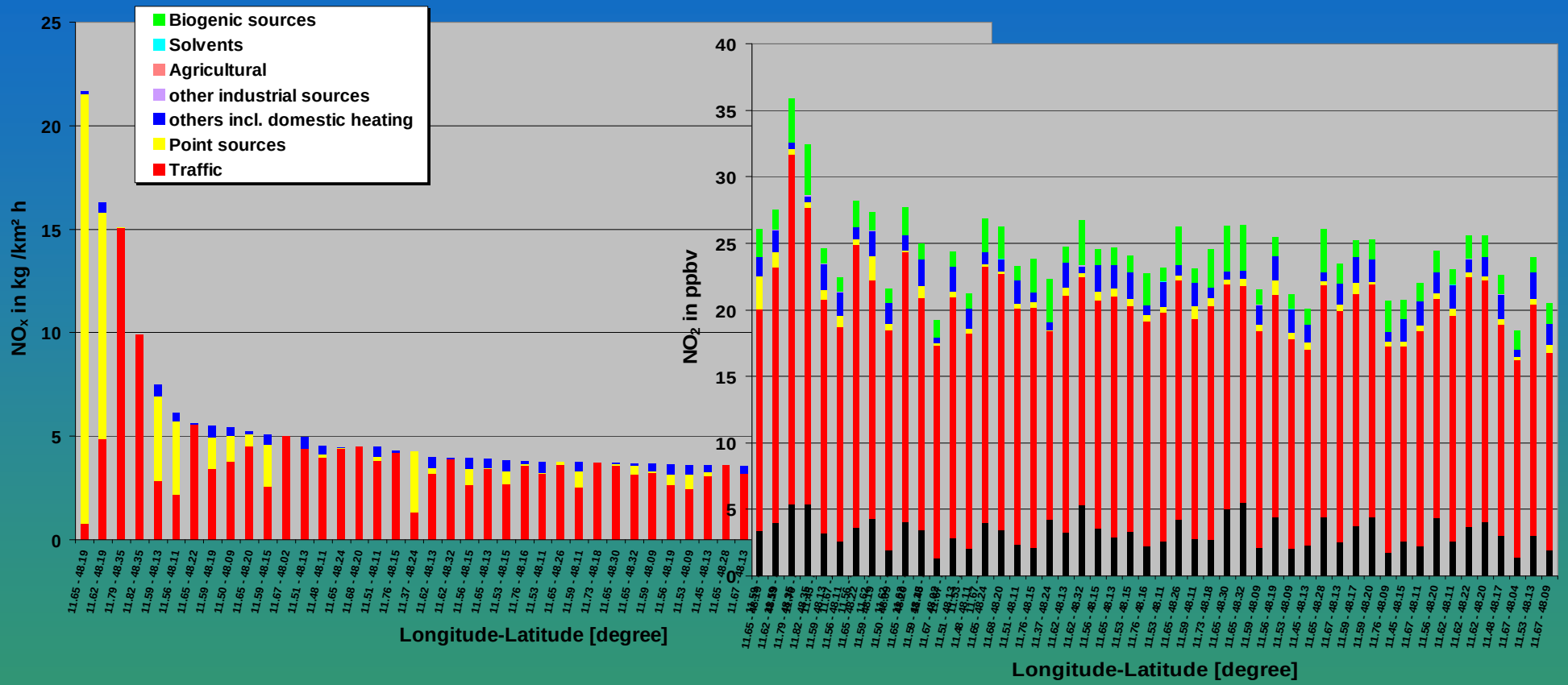
O_3 change



NO_2 change

Setup: 27-9-3-1 km grid
4 days period
Southern Germany

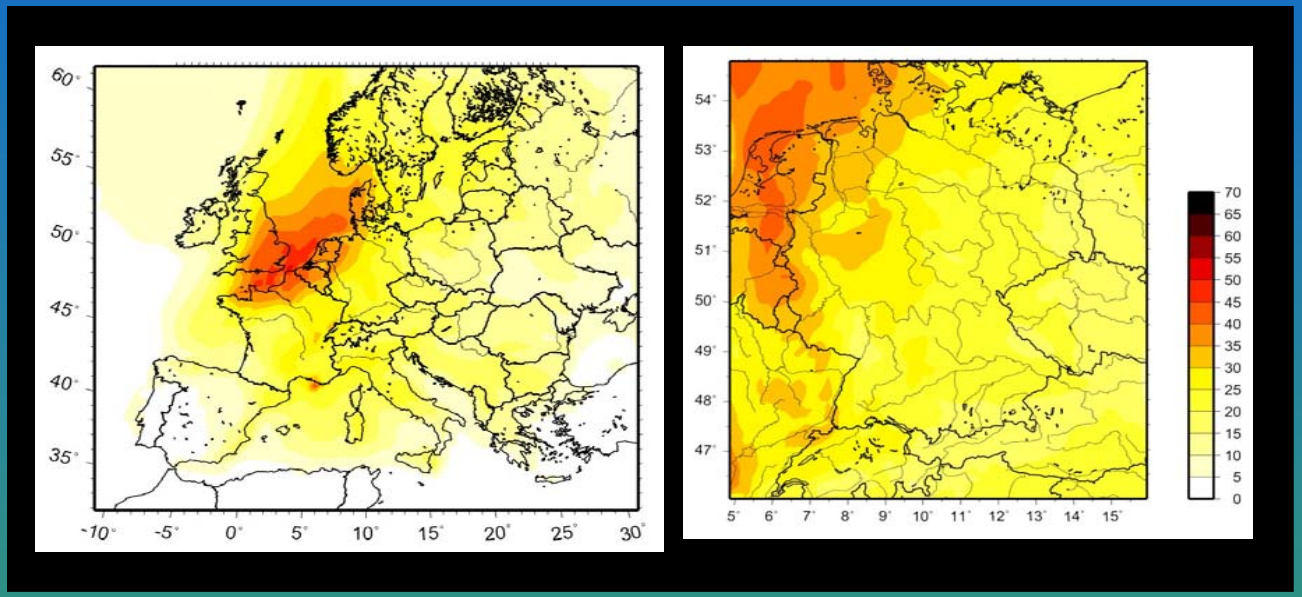
Air Quality Studies - Methodology

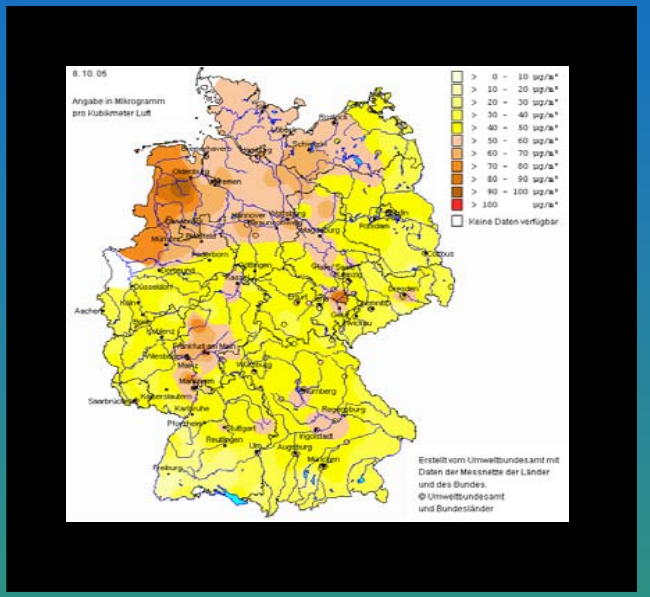


Source-receptor analysis for NO_2 within the conurbation of Munich

Setup: 54-18-6-2 km grid
5 days period
Southern Germany

Operational Forecast e.g. PM_{10}





1 day forecast: 8th Oct. 2005

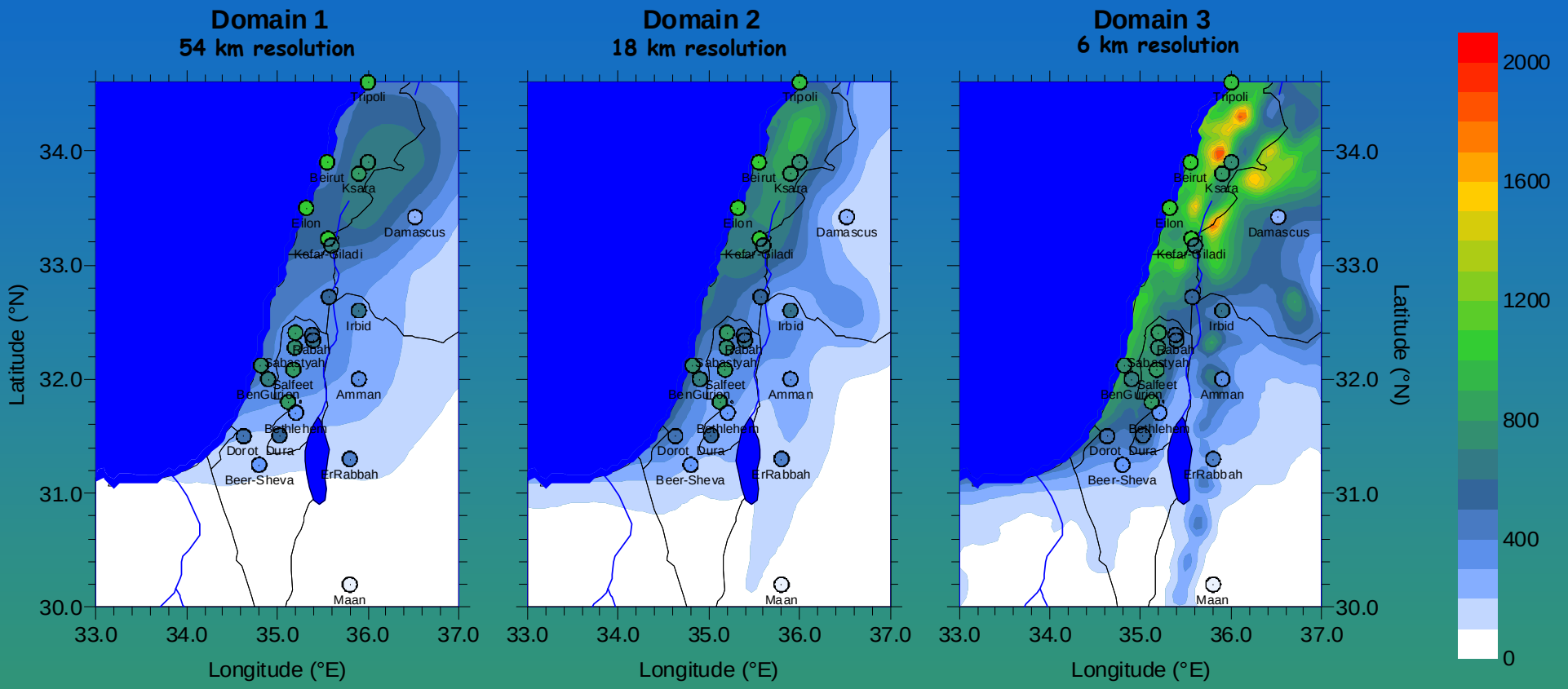
Domain 1: 60 km

Domain 2: 15 km

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

Setup: 60-15 km grid
3 days forecast
Germany

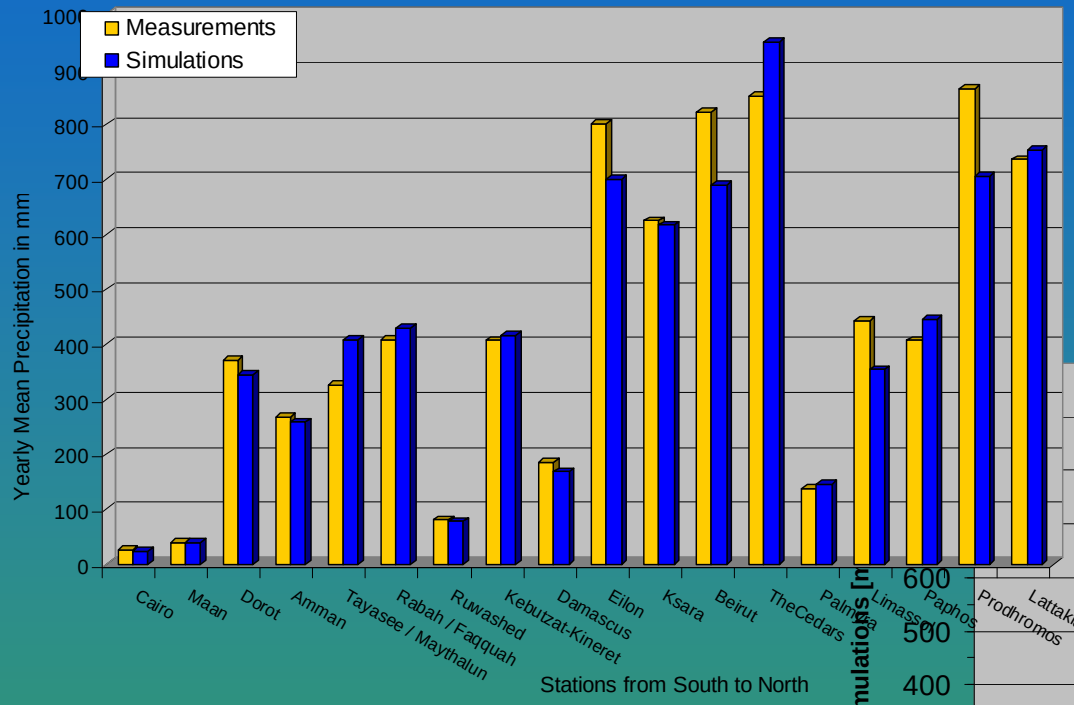
Climate modeling



Yearly Mean Precipitation 1961-1975

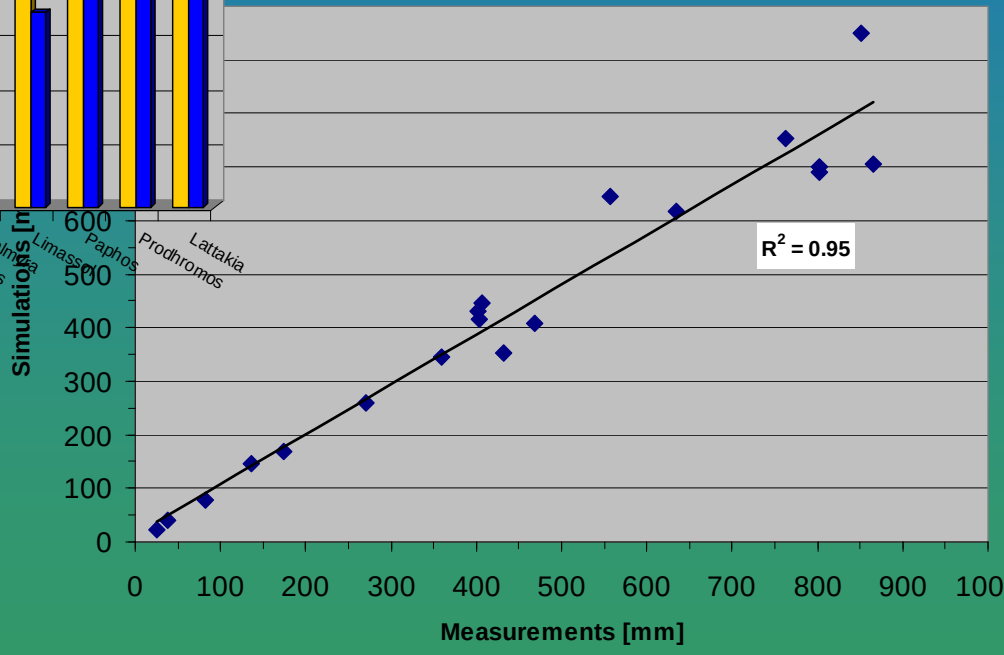
Setup: 54-18-6 km grid
15 years time slices
Near East /Mediteranean

Climate modeling - validation



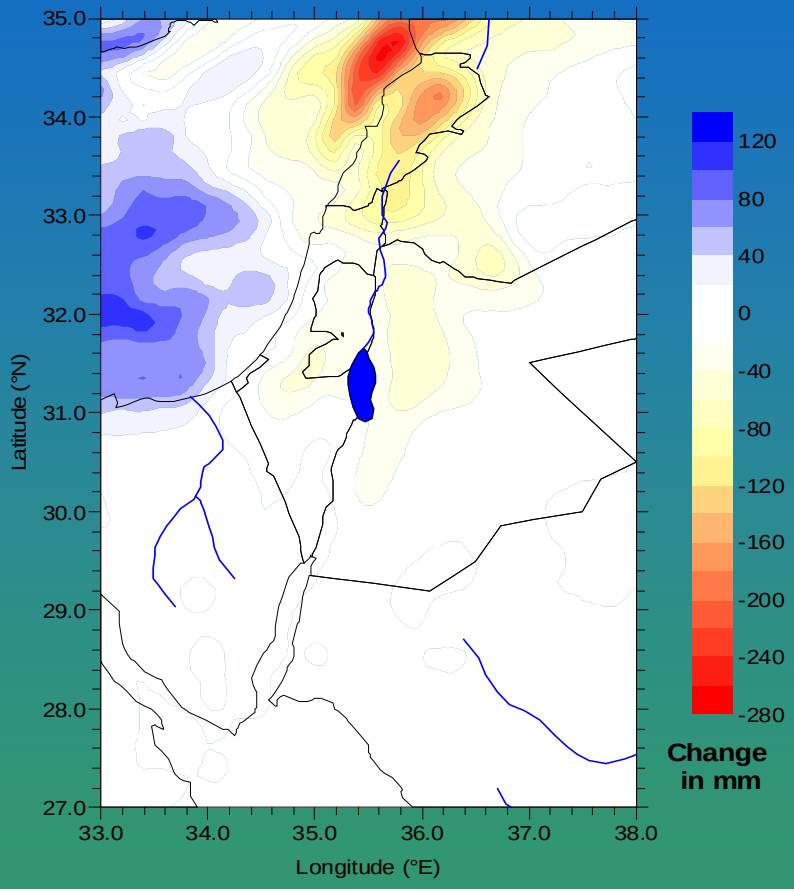
Yearly mean precipitation:

ECHAM4-MM5 Scenario B2
1960-1989
vs. measurement

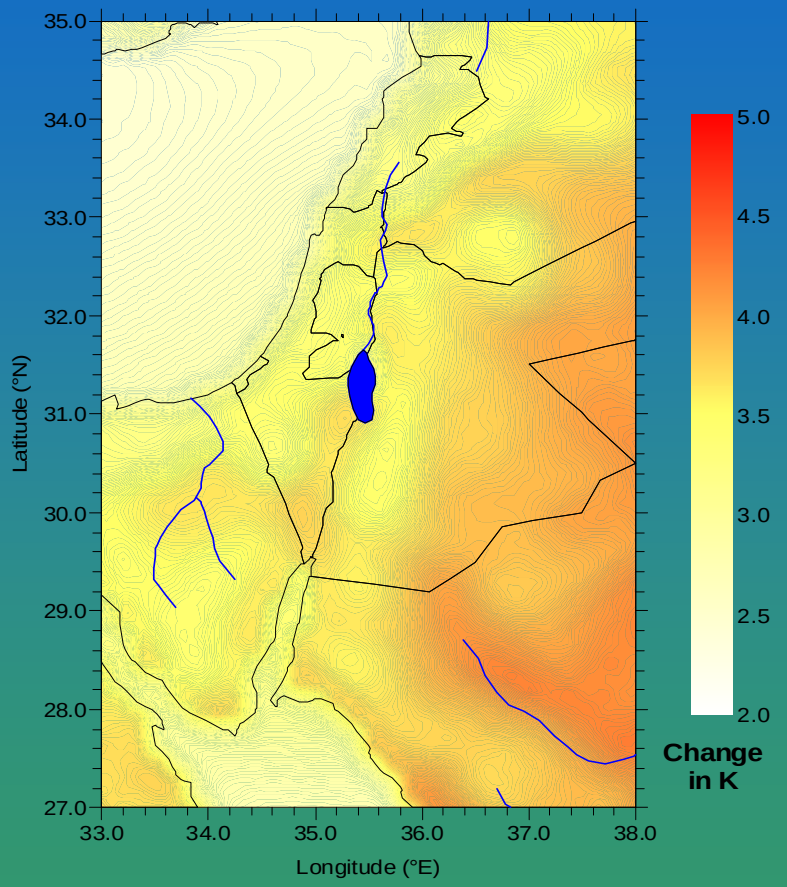


Climate change modeling - future

Rain



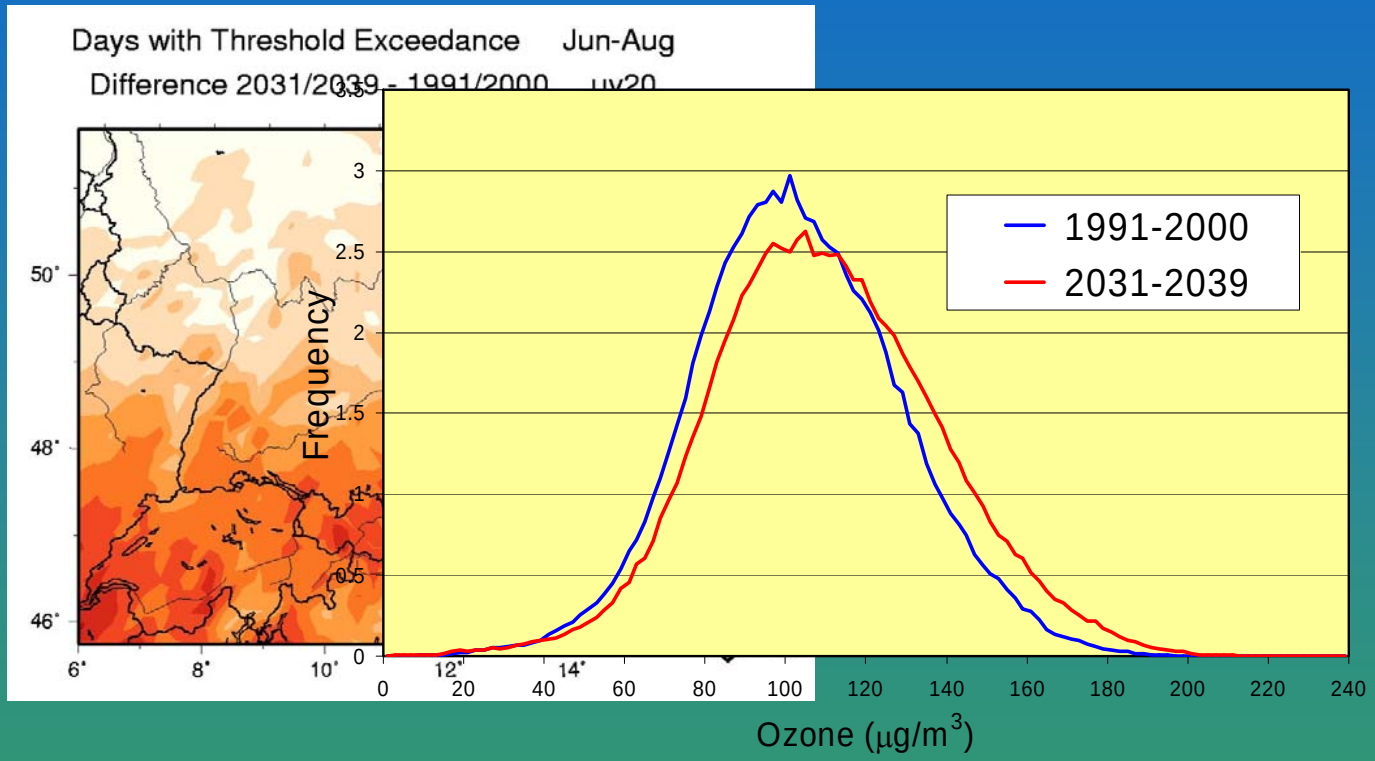
Temperature



Difference of simulated yearly mean values between the future ECHAM4 scenario B2 (2070-2099) and the ECHAM4 control run (1961-1990) based on a grid size of 18km resolution

Setup: 54-18 km grid
30 years time slices
Near East /Mediteranean

Climate-Chemistry Simulations – Air Quality



Threshold exceedances in the future vs distribution of daily O_3 maximum

Setup: 60-20 km grid
2x10 years period
Southern Germany

Summary (I)

- Meso-scale Climate-Chemistry Model (MCCM) ……
  - ✓ based on a well known and validated meteorological model (→ MM5)
  - ✓ performs with validated chemistry mechanisms
  - ✓ short- and long term simulations, assessment of emission strategies, forecast, climate impact assessment
  - ✓ Regional and urban areas (e.g. alpine environments; urbanized conglomerations)

Remarks and Outlook

- Modeling tools are only a part of a integrative description of the air quality
- Models results are only as good as its input data
- Model diversity against community model

- Focus on climate-chemistry simulations with emphasis on urban conglomerations
- Model coupling within the compartments of the bio-, hydro- and atmosphere

Co-operations

- Division of Hydrological & Meteorological Forecasting Bureau of Hydrology Changjiang Water Resources Commission /Ministry of Water Resources Commission, Wuhan

Health Study (Beijing/Leipzig)

- Prof. Pan (Professor and vice director, Dept. of Occupational and Environmental Health Peking University, School of Public Health, "Short-term health effects of fine and ultrafine particle pollution in Beijing, China"

Working group „Air Quality in Metropolitan Areas and Sensitive Regions"

PD Dr. Stefan Emeis
Dr. Renate Forkel
Dipl.-Phys. Herbert Maria Hoffmann
Dipl.-Ing. (FH) Carsten Jahn
Dipl. Ing. Markus Mast
Prof. Dr. Klaus Schäfer
Dr. Peter Suppan
PhD Mathias Türk
Dipl.-Met. Johannes Werhahn

Thank you for your attention