Air Quality and Health

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Overview

- ✓ Introduction

- ✓ Problems and facts

- ✓ Interdisciplinary Research

- ✓ Methodological approach in the field of air quality
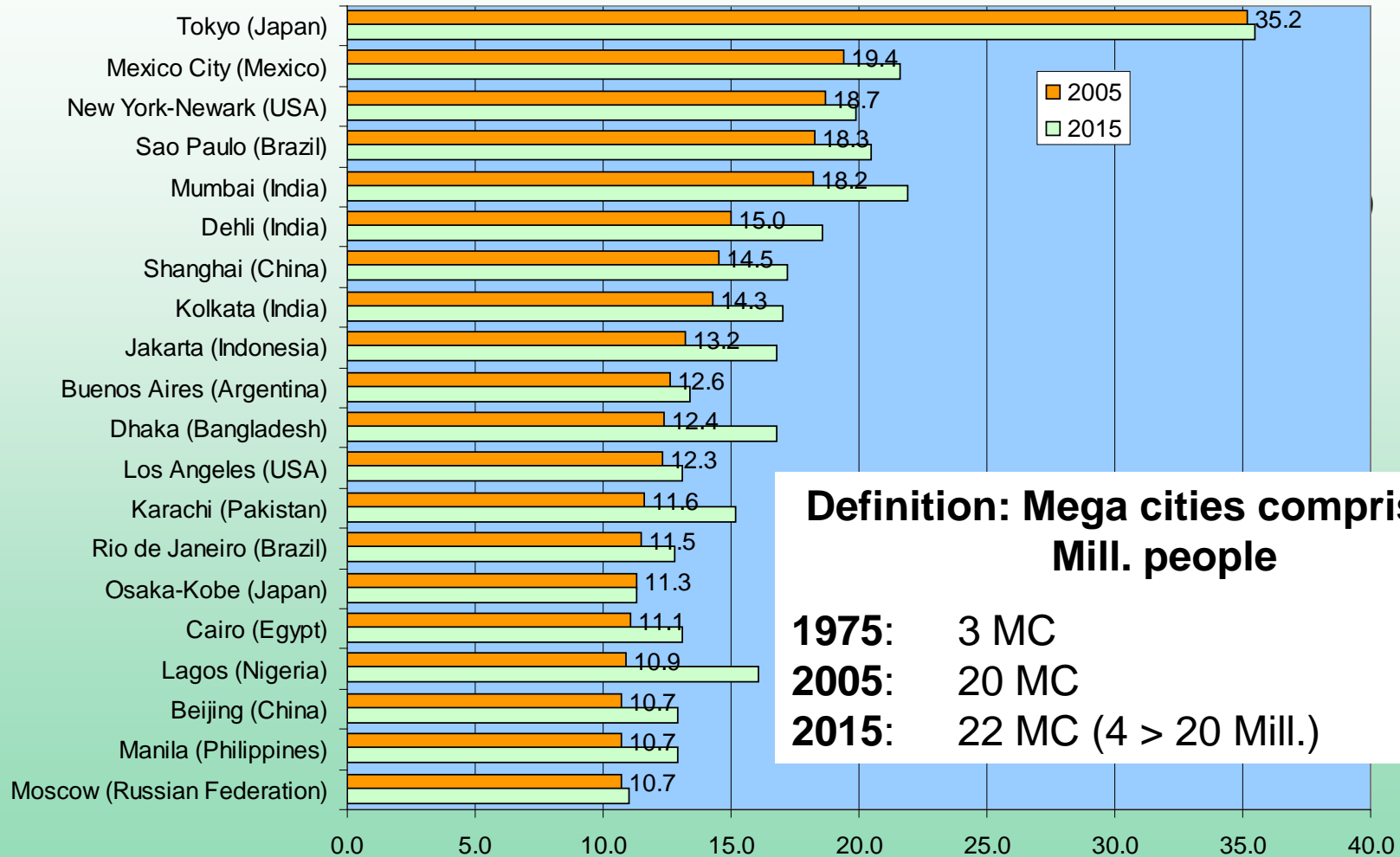
- ✓ Link to human health

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Research Focus

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. urban agglomerations – close cooperation with epidemiologists)**

➢ **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**

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Urban Agglomerations

- In **1974** a UNEP and WHO declaration concerning air pollution was released

- In order to reduce human exposure and health risks in **1992** a EU-report about a more effective planning on energy requirements and transportation was published

- Since **2007** more than 50 % of worlds population live in urban agglomerations

- Urban agglomerations in China increased from 19.6 % to 40.5 % (between 1980-2005)

- Chinas cities increased to 660 (which produce 65.5 % GDP)

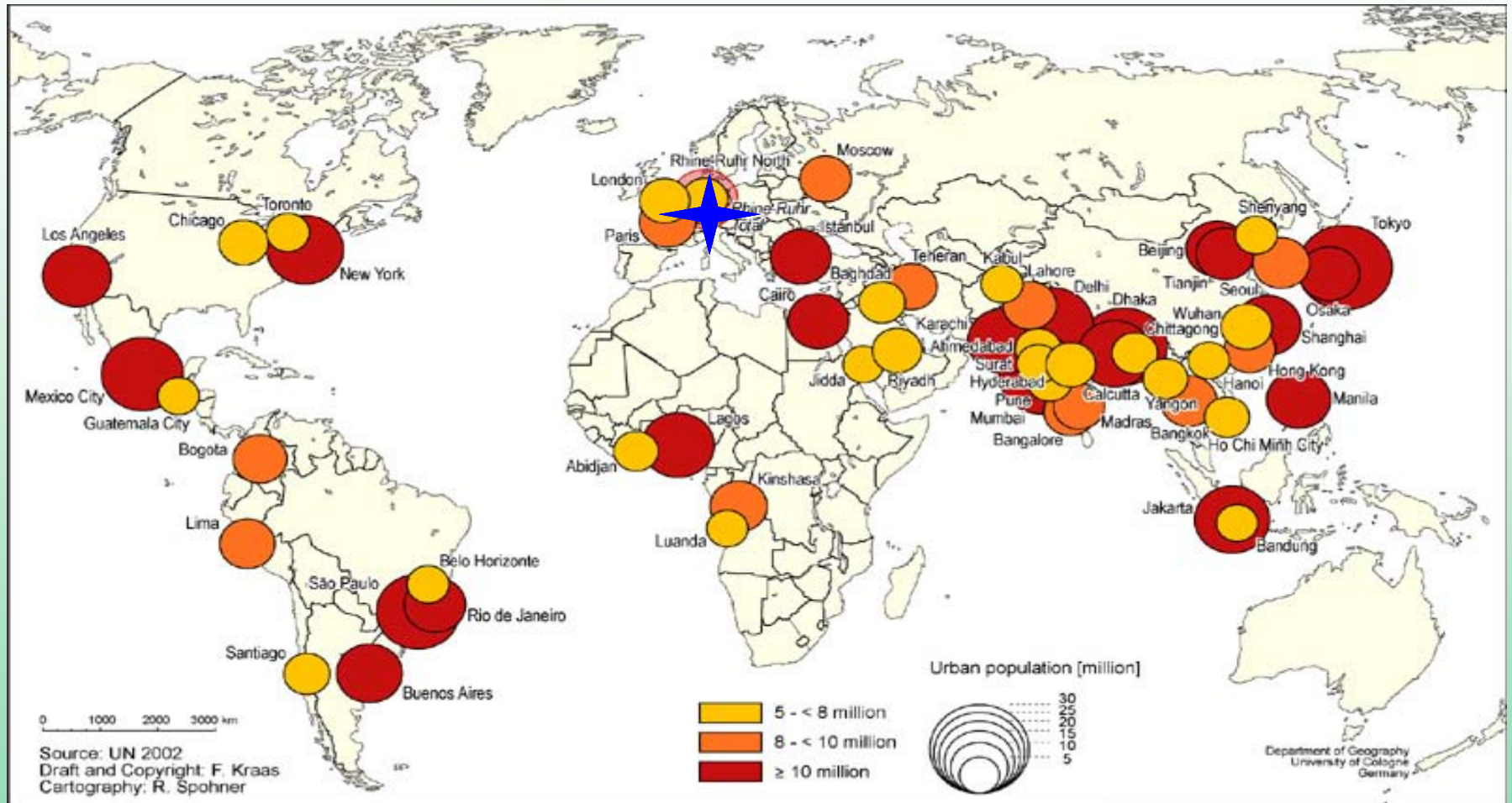- 170 cities have more than 1 Mill. inhabitants

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Mega Cities

Definition: Mega cities comprises 10 Mill. people

1975: 3 MC
2005: 20 MC
2015: 22 MC (4 > 20 Mill.)

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Geographical Situation

Urban population [million]

- 5 - < 8 million
- 8 - < 10 million
- ≥ 10 million

30
25
20
15
10
5

Source: UN 2002
Draft and Copyright: F. Kraas
Cartography: R. Spohner

Department of Geography
University of Cologne
Germany

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Environmental Facts

→ Survey with 500 megacity - „stakeholders"

Air pollution as the most significant environmental challenge, followed by **congestion issues**

but

„The environment matters, but may be sacrificed for growth"

Source: Siemens, 2007

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Health Pyramid

Mortality

Hospital admissions

Emergency room visit

Medication use

Appearance or exacerbation of acute respiratory symptoms
(e.g. low lung function)
and/or cardiovascular diseases

softly, sub clinical effects

Increasing effects severity

Fraction of the whole population

Mortality rates on PM_{10} increase

Region	Percentage change	Reference
Asia	0.49% (0.23-0.76)	HEI, 2004
Europe	0.60% (0.40-0.80)	Katsouyanni, 2001
Latin America	0.61% (0.16-1.07)	PAHO, 2005 [*]
United States	0.21% (0.09-0.33)	Dominici, 2003
Worldwide	0.65% (0.51-0.76)	Stieb, 2002

Source: PAN American Health Organization, 2005

[*] Based on studies in Mexico City, São Paulo, Santiago de Chile

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What to do now?

- The complex chemical interactions of emissions – transmission - air pollution – deposition / exposure needs detailed investigations on the causal chain

- Only interdisciplinary approaches allow a holistic analysis

- But which disciplines are in relation to the air pollution, where we can turn the screw to get a cleaner and healthier air

- …

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➢ Land use

Mexico City

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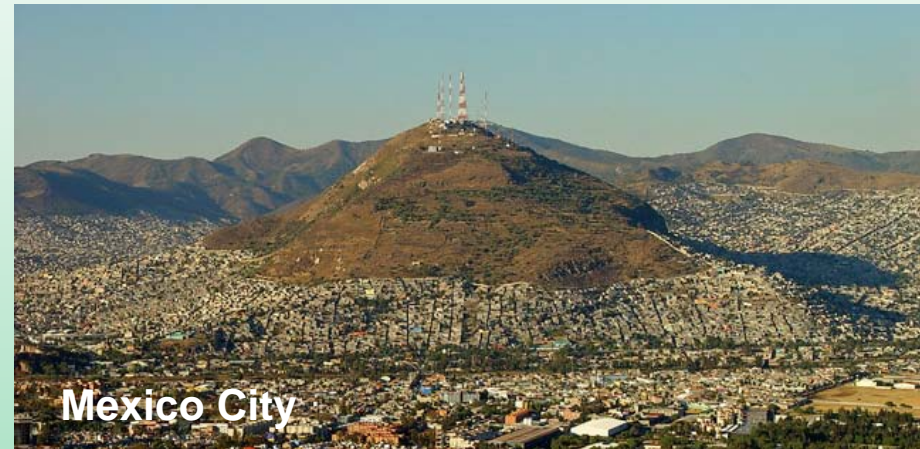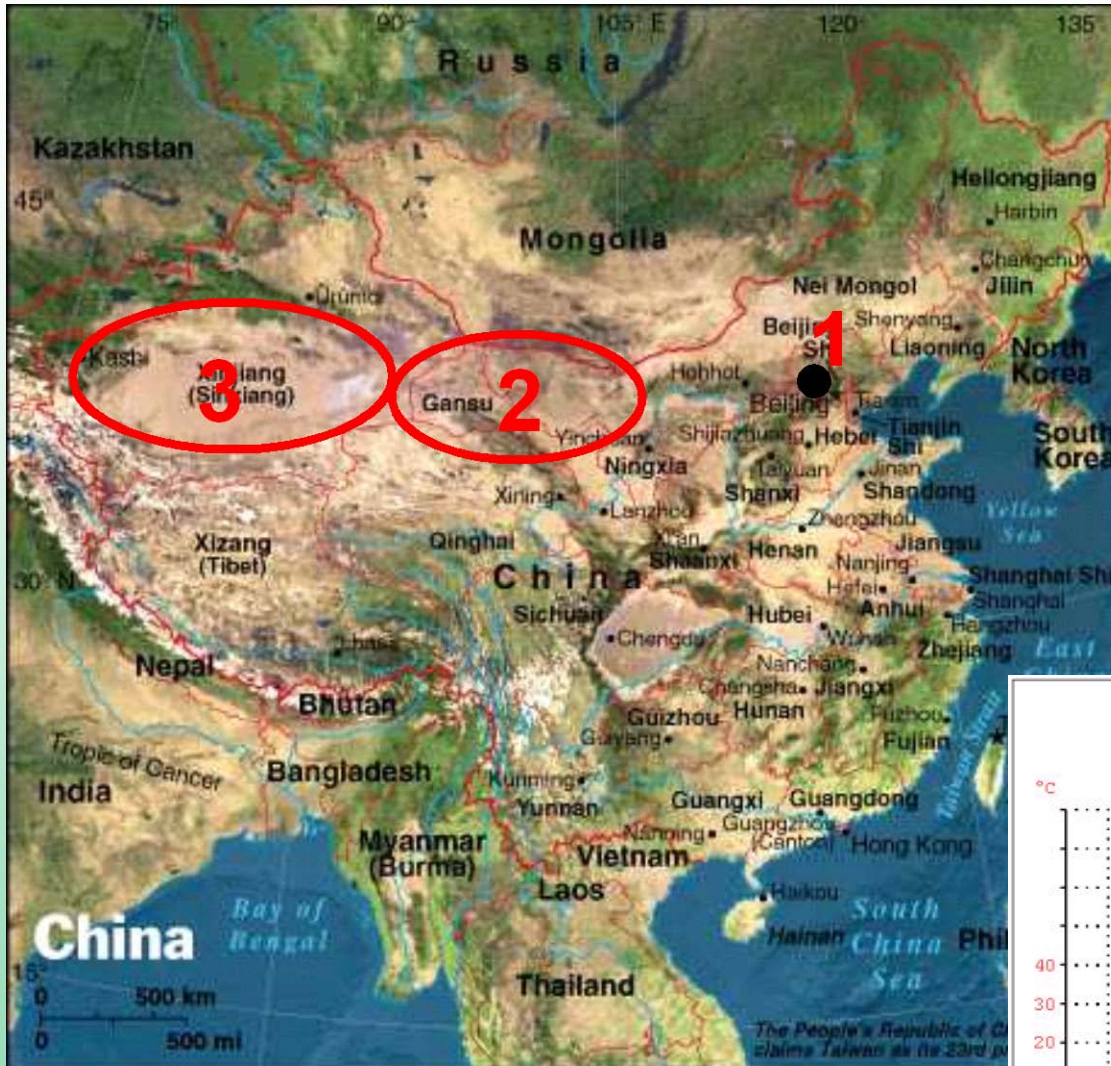
1: Beijing

2: Desert Gobi

3: Desert Takla Makan
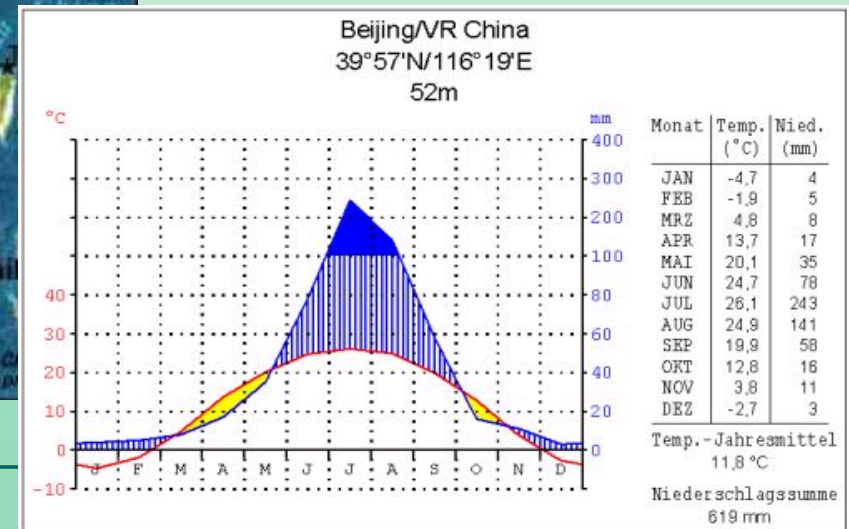
Source: Stefan Norra, University Karlsruhe (IMG)

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Beijing

18.04.2006

Photos by Stefan Norra

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50 µg/m³ · 344 µg/m³ · 2005/01/18 · 2005/01/22
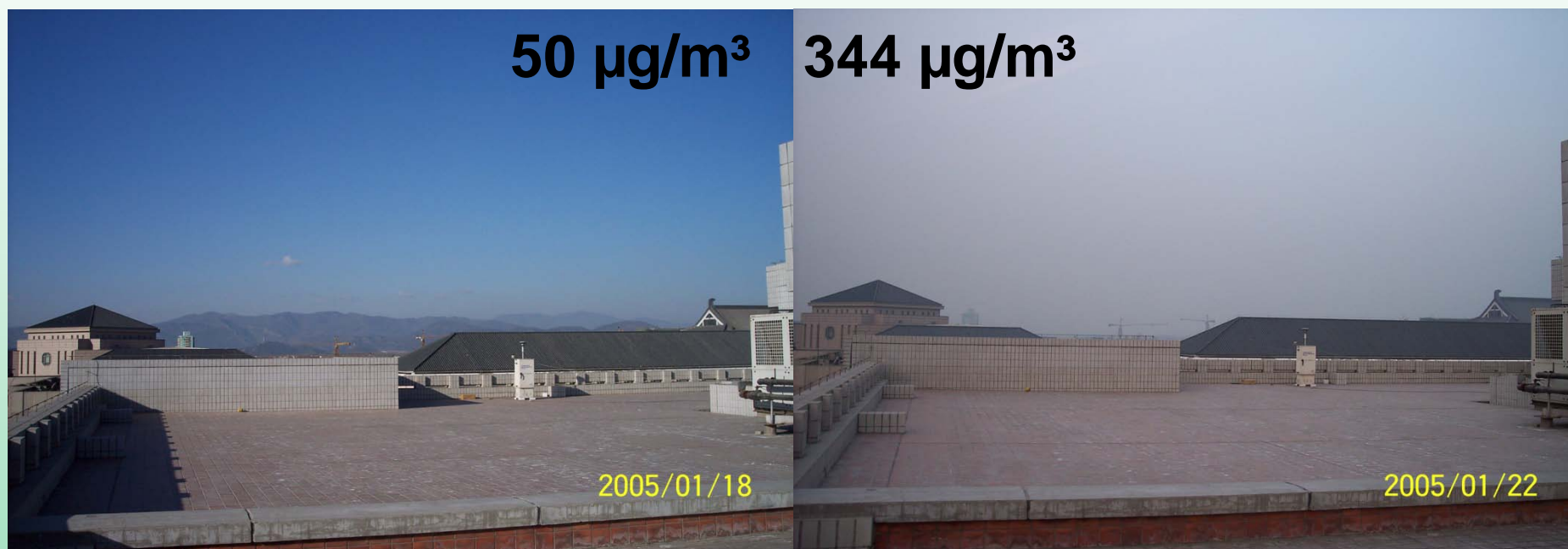
Source: Matthias Tesche, IfT

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31.10.2007

30.10.2007

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Photos by Stefan Norra
Institute of Mineralogy and Geochemistry (IMG)
of the University of Karlsruhe

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Aerosol Pollution

Beijing
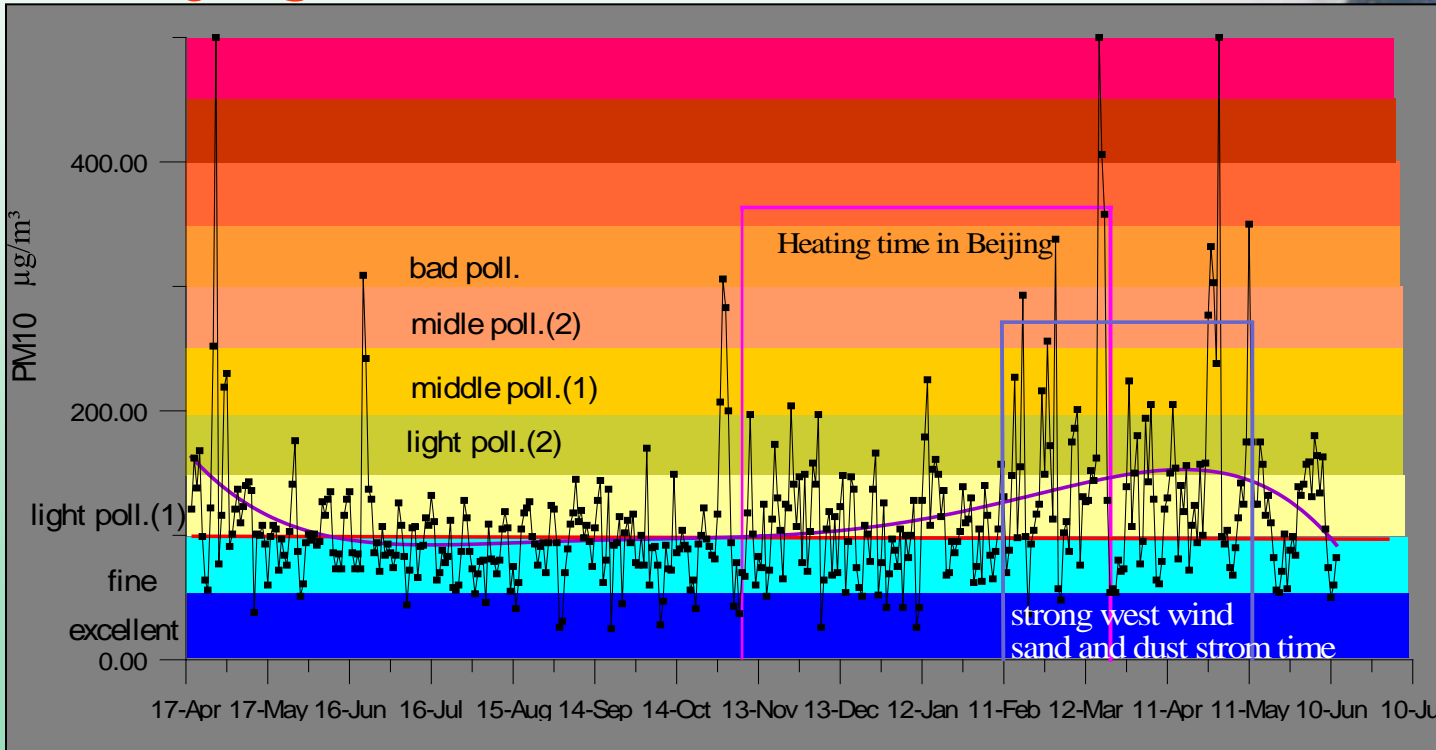
Source: Stefan Norra
Institute of Mineralogy and Geochemistry (IMG) of the University of Karlsruhe

Vertical Measurements

Vertical measurements
- Beijing -
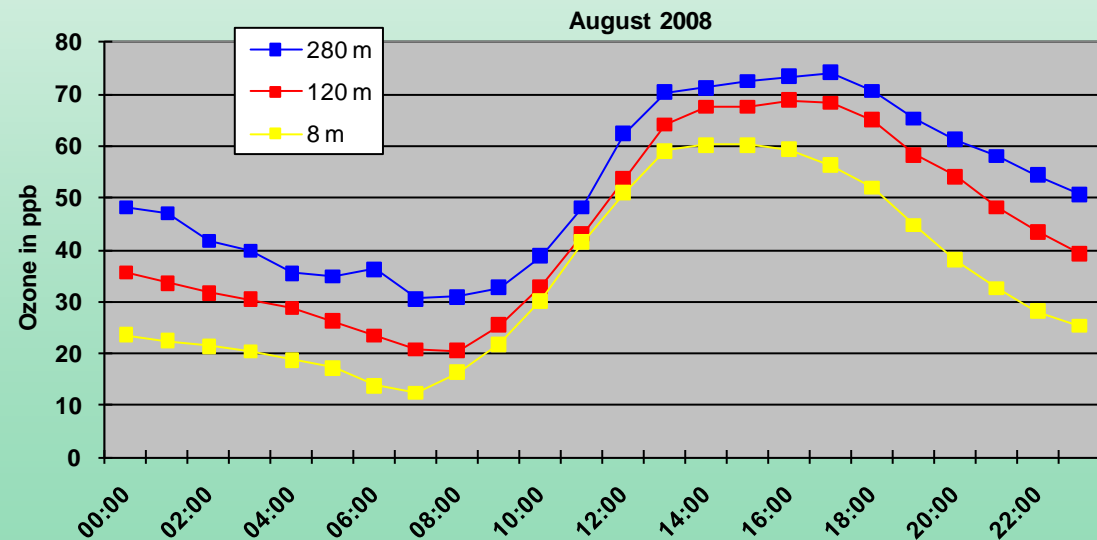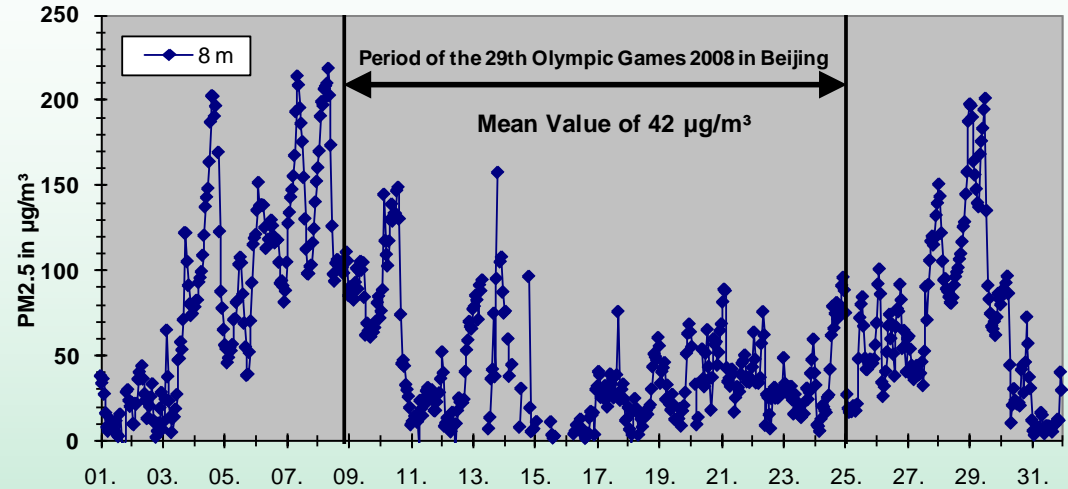
Source: X. Jinyuan (CAS), China

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Land Use Change

	Santiago de Chile 2002	Mexico City 2005
Population	6.061.000	19.410.000
Urbanized area (km²)	641	1800
Population density (p / km²)	9.500	10.800
Population growth (% / y)	~1,32	~1,28

Source: U. Weiland, E. Banzhaf,
A. Ebert, A. Kindler, R. Höfer
(UFZ)

Source:
Poduje 2005 (Santiago de Chile)
APERC 2007 (Mexico City)

Santiago de Chile

Mexico City

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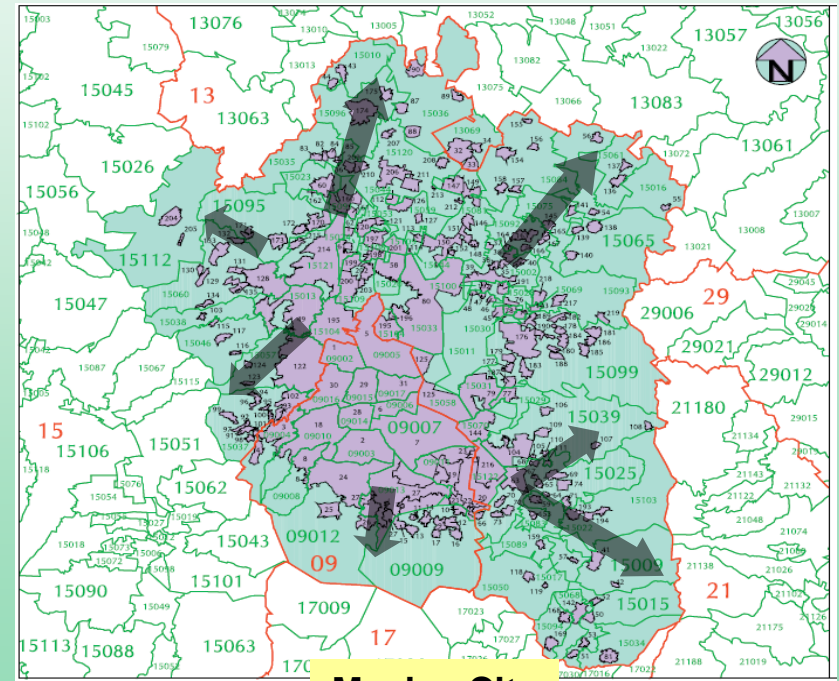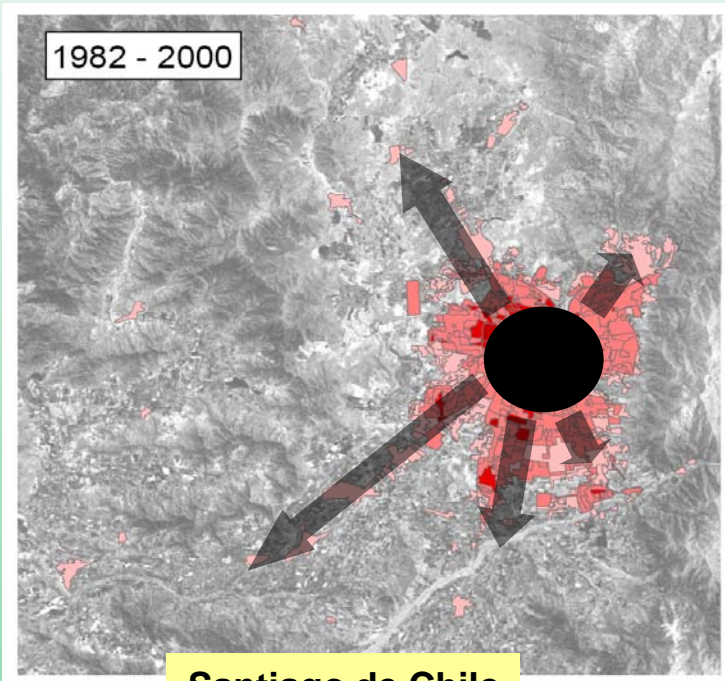
Effect of land use change
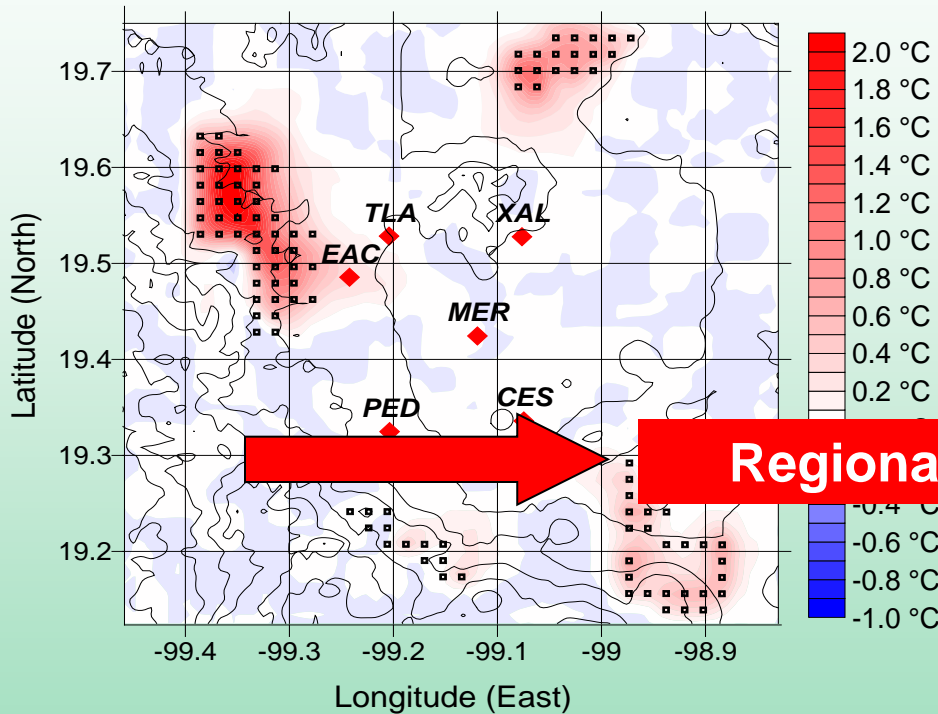
Temperature difference
with and without urban sprawl
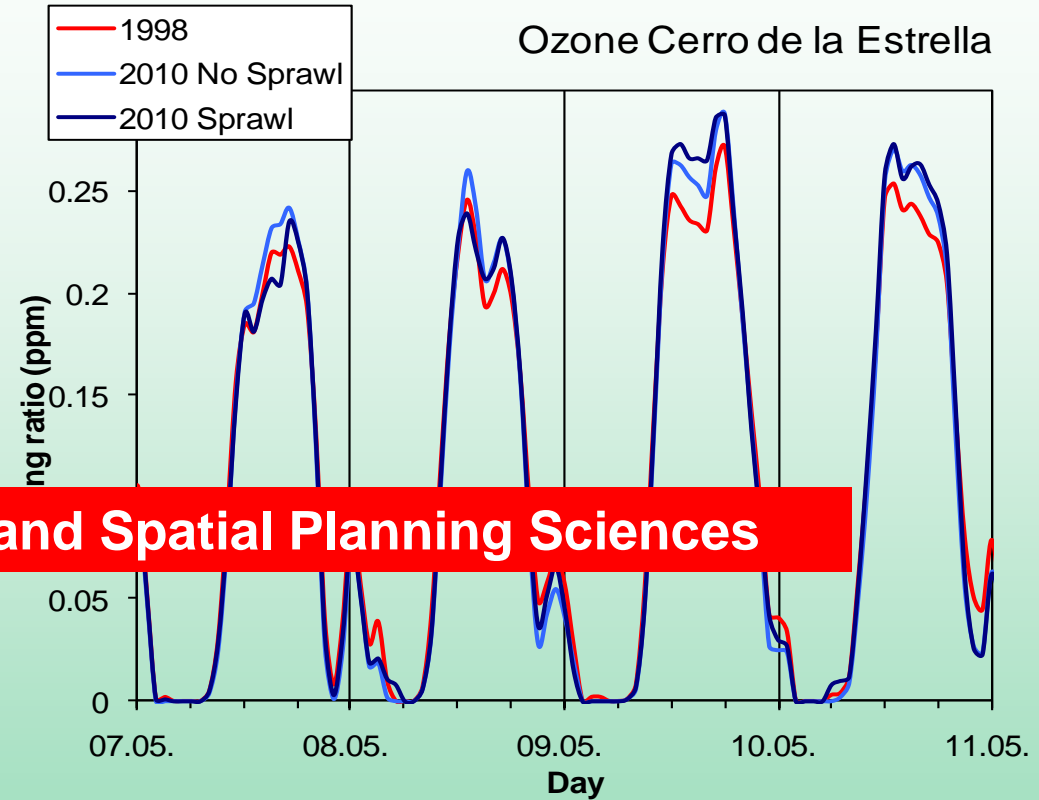
Diurnal variation of ozone concentrations
considering land use change

Regional and Spatial Planning Sciences

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Impact on Air Quality

➢ Land use

➢ Energy

Beijing

Mumbai

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Energy Consumption

Energy consumption by sources

	Industry	Transport	Residential
Beijing	75%	8%	17%
Shanghai	83%	10%	7%
Seoul	38%	25%	37%
Tokyo	41%	37%	22%
Mexico City	38%	44%	18%

Energy Consumption - China
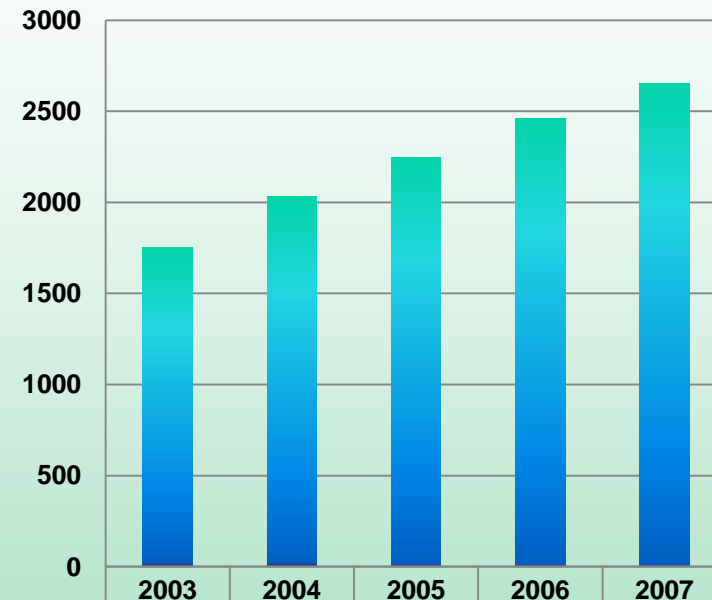
	2003	2004	2005	2006	2007
Total Energy Consumption [1 Mill. Tons CE]	1749.9	2032.227	2246.82	2462.7	2654.8
Growth Rates [%]	15.3	16.1	10.6	9.6	7.8

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Adaptation Strategies

e.g. Mexico City
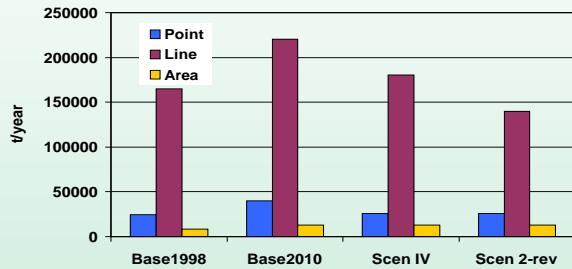
NOx emission
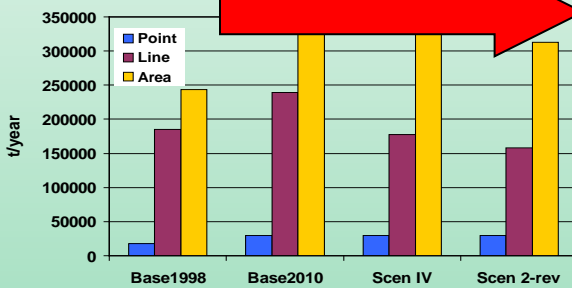
Basic information on present emissions and emissions of reduction measures
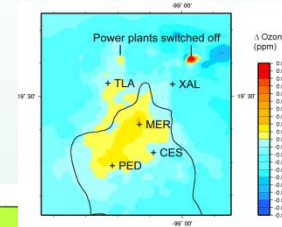
O_3-difference in 2010
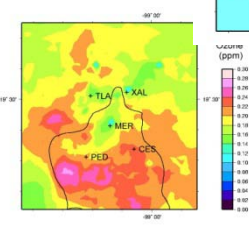
Energy & Technology Assessment Disciplines

O_3-concentrations

NOx Emissions

Land use
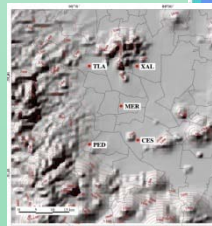
Topography

Source: Working Group "Air Quality"
by R. Forkel (IMK-IFU)

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Impact on Air Quality

➢ Land use

➢ Energy

➢ Mobility

São Paulo

Bogotá

© Mertins

Traffic

Economical background of vehicle ownership
Vehicle purchase max GDP 3000-4000 $
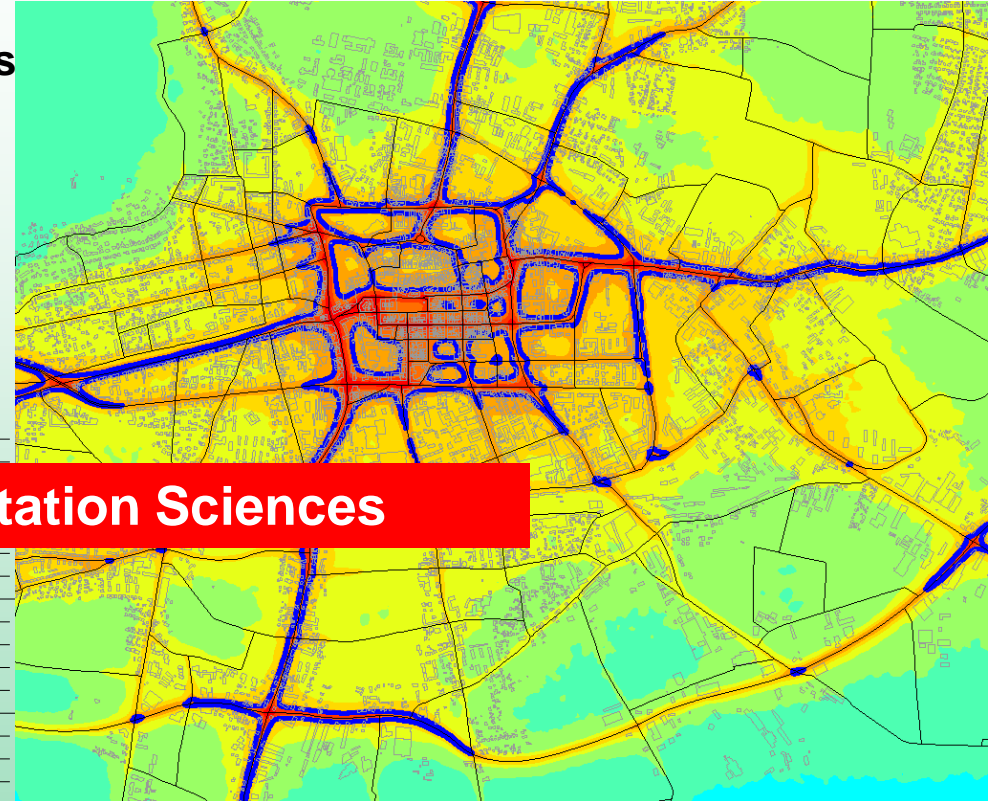
Which will be reached in China in about 20 y

Vehicles per 1000 p

Legend:
- 1996
- 2020

Y-axis: 800, 600, 400, 200, 0

X-axis categories:
- North America (incl. Mexico)
- US only
- Western Europe
- Japan & Australia
- Eastern Europe & Former Soviet Union
- Total industrialized
- Developing Asia incl. China
- Middle East
- Central & South America
- Africa
- Total developing
- WORLD

Source: US Dept.of Energy, 2000
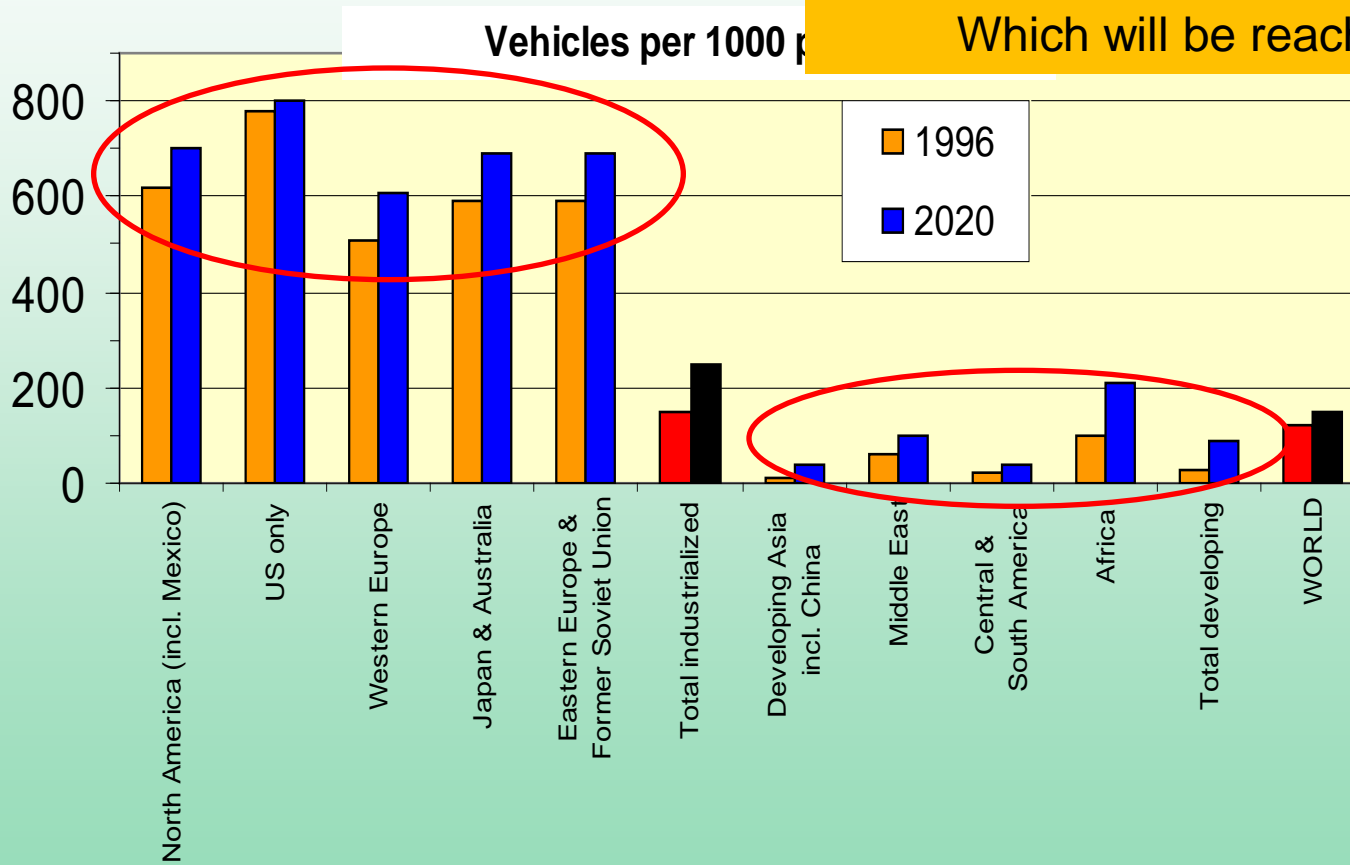
Traffic Volume in 1996 and 2020

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Coupling of Scales

Threshold exceedances

Meso-scale modeling e.g. NO$_2$ with MCCM
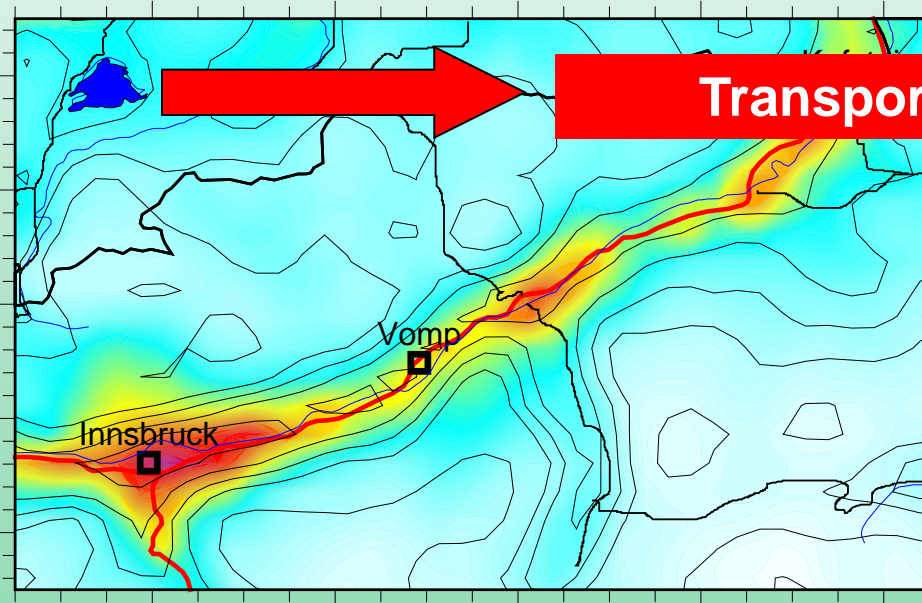
Transportation Sciences

Source: EU-LIFE Project
Klagenfurt Graz Bozen

Micro-scale modelling e.g. NO$_2$ with GRAL

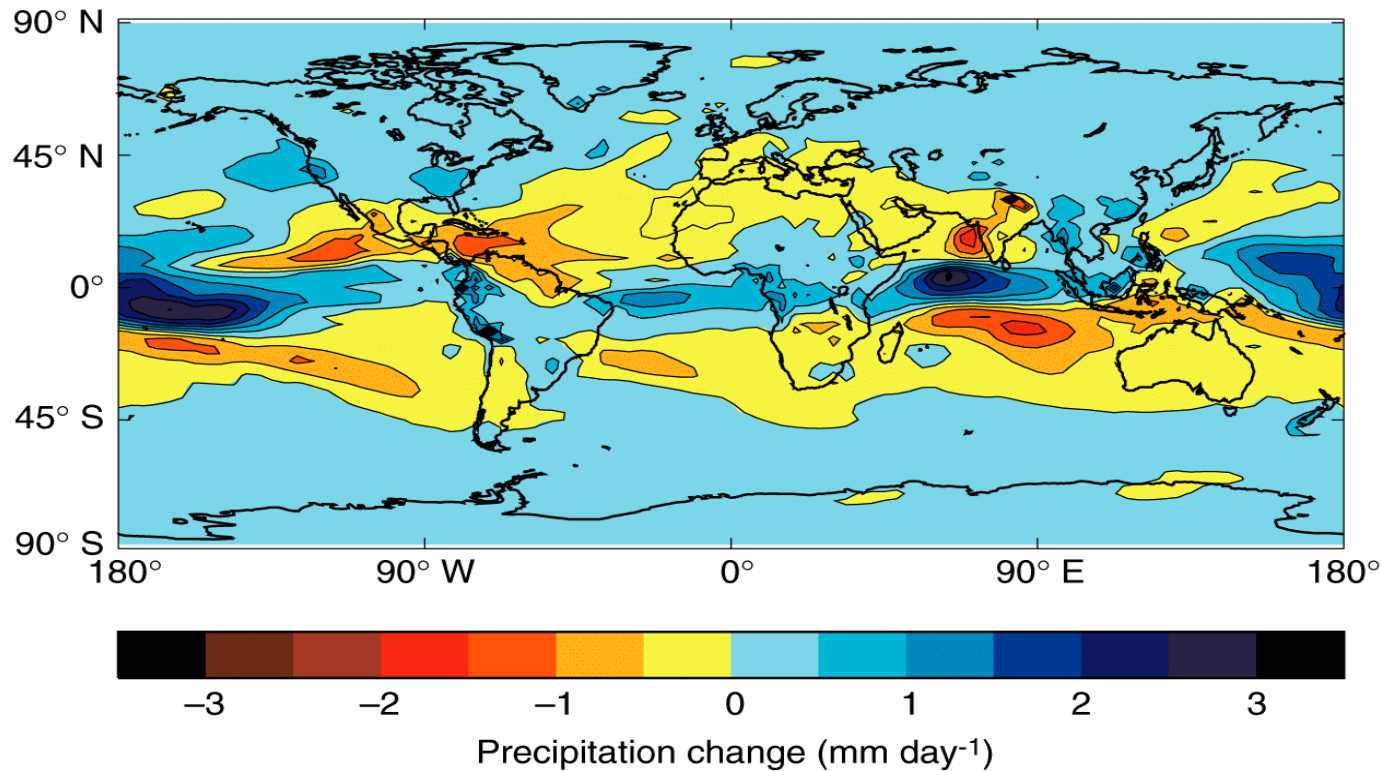**Peter Suppan, Institute for Meteorology and Climate Research (IMK-IFU)**

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Impact on Air Quality
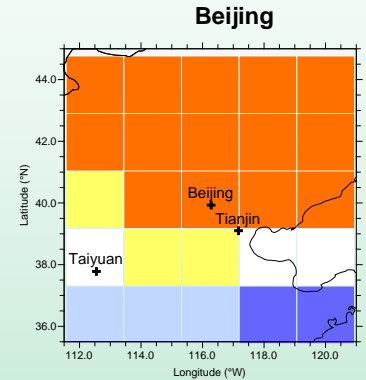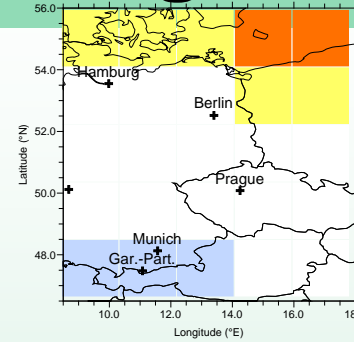
- Land use
- Energy
- Mobility
- Climate Change

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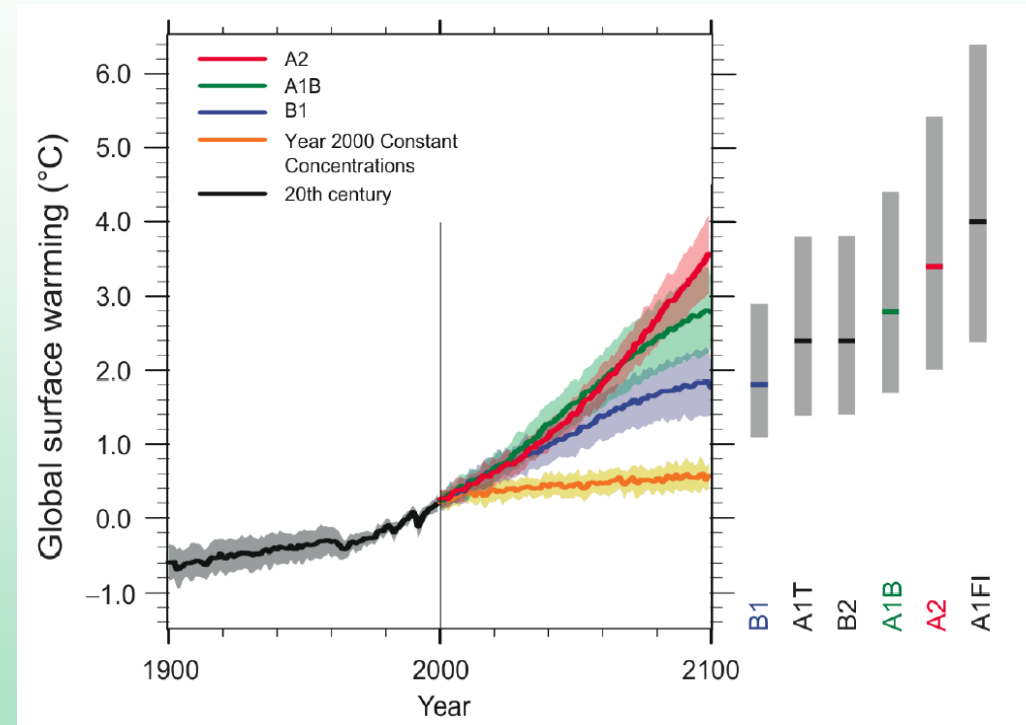
Climate Change

Global Climate Scenarios:
Projected Changes in Annual Precipitation for the 2050s

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Climate Change

Berlin

Bogota

Mexico City

Beijing

Santiago de Chile
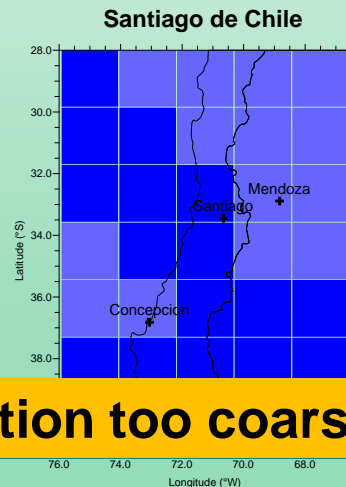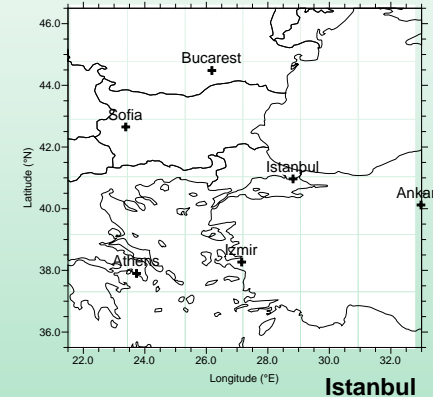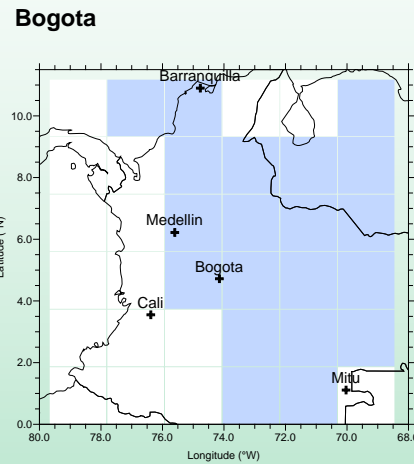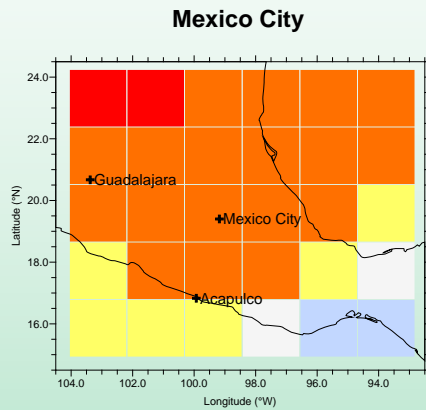
ECHAM5 - A1B scenario
Future (2071-2100) - Present (2001-2030)

Temperature Change in °C

🟥	4.0 to 4.5
🟧	3.5 to 4.0
🟨	3.0 to 3.5
⬜	2.5 to 3.0
	2.0 to 2.5

Istanbul
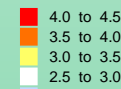
Climate Change
Impact on Urban
Agglomerations

Resolution too coarse for regional impact analysis !

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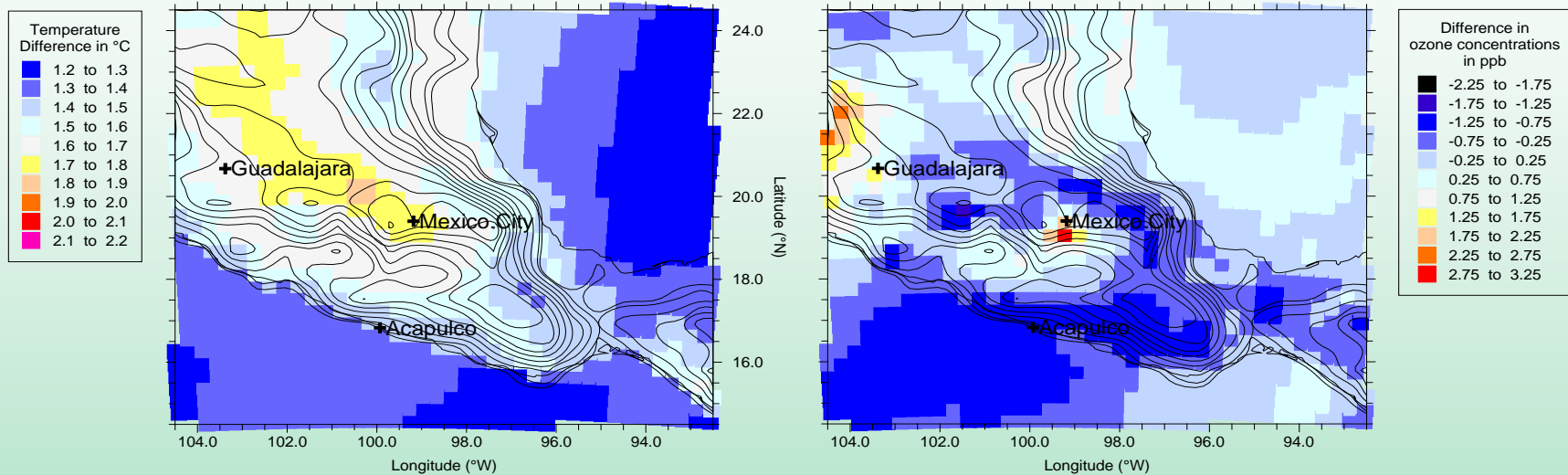
Climate Change

High resolution climate-chemistry simulations
- Mexico -

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Impact on Air Quality

- Land use
- Energy
- Mobility
- Climate Change

- Air Quality
- Health Impact

Integrated Approach

Santiago de Chile

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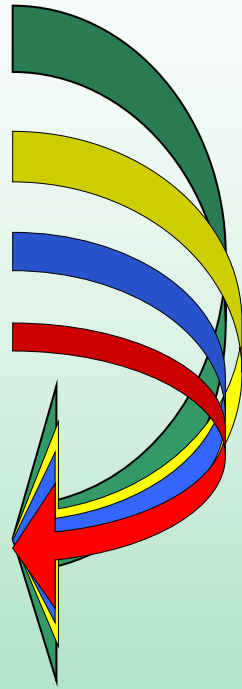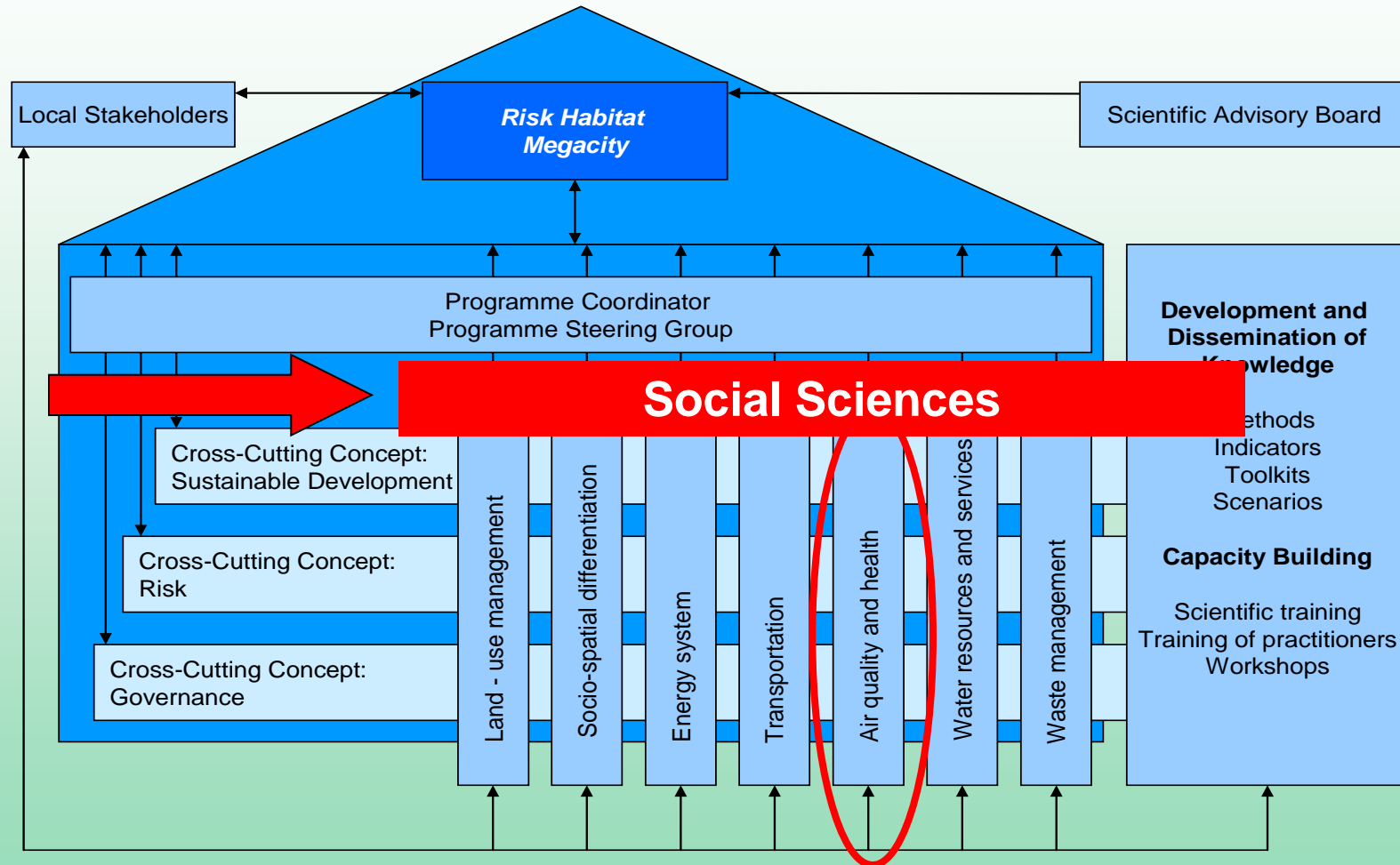
Objectives

➢ Contribute to the specification of sustainable objectives for the future development of mega-cities

➢ Characterize of risks, driving factors and consequences

➢ Design of strategies and instruments for risk management as key tools for a sustainable urban development

➢ Investigate on the regional-urban scale based on interdisciplinary research groups

➢ Develop of a science and experience platform for a technical and science based cooperation

➢ Capacity Building, exchange and transfer of knowledge

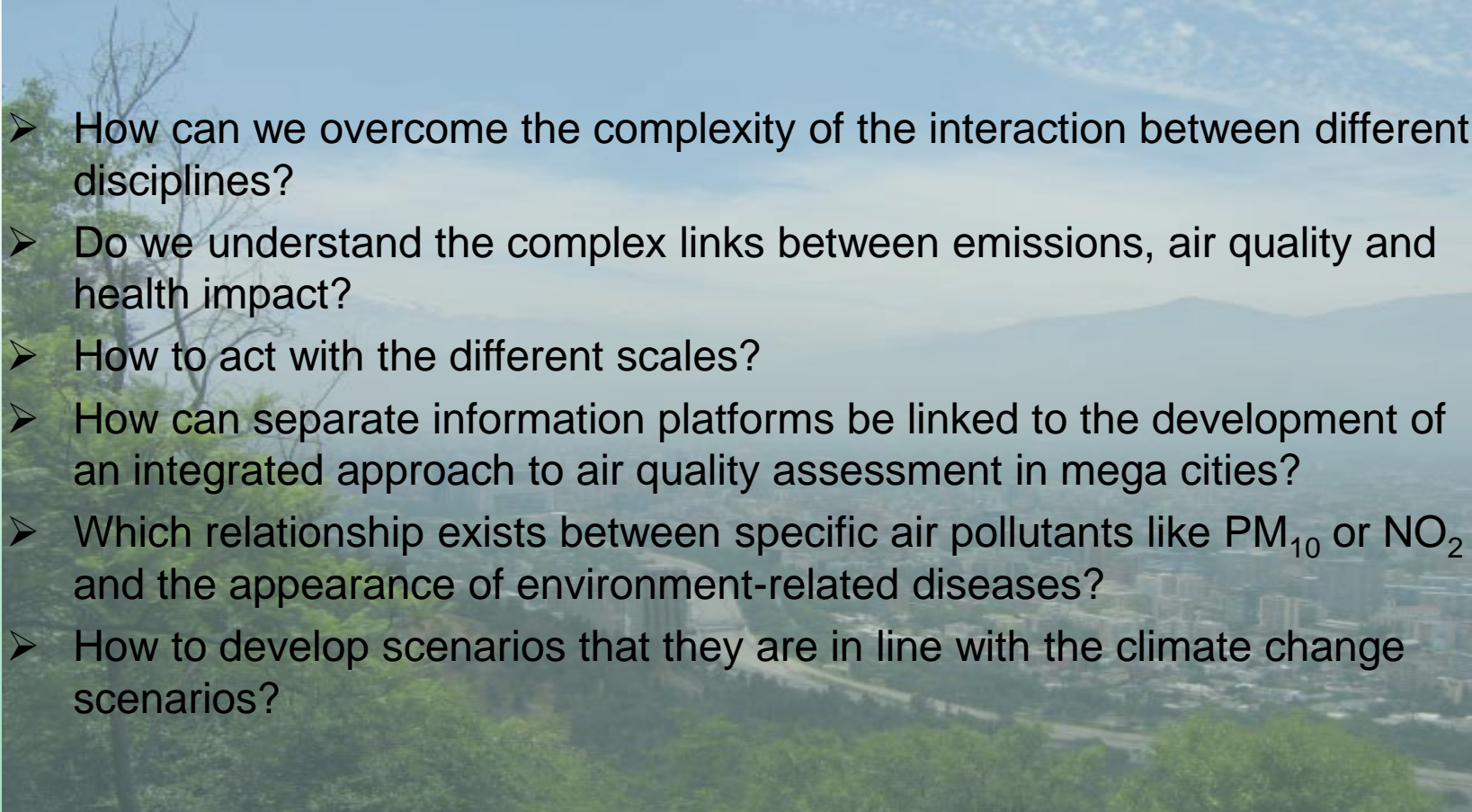**Risk Habitat Megacity**
¿sostenibilidad en riesgo?

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Architecture

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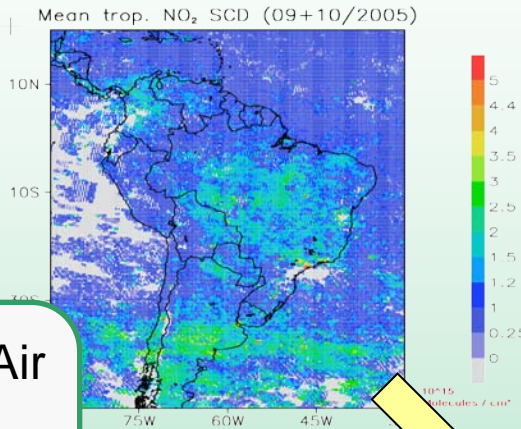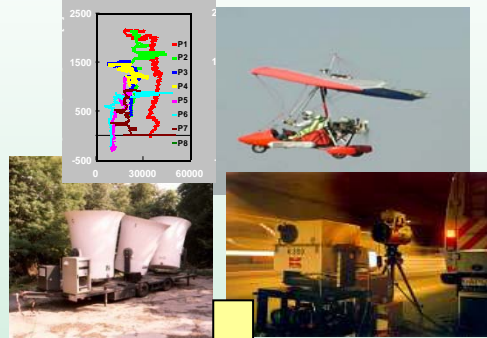Cartagena / Colombia – 16 de Julio de 2009

Research Questions

➢ How can we overcome the complexity of the interaction between different disciplines?

➢ Do we understand the complex links between emissions, air quality and health impact?

➢ How to act with the different scales?

➢ How can separate information platforms be linked to the development of an integrated approach to air quality assessment in mega cities?

➢ Which relationship exists between specific air pollutants like PM_{10} or NO_2 and the appearance of environment-related diseases?

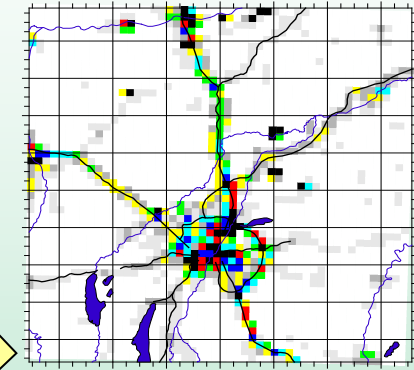➢ How to develop scenarios that they are in line with the climate change scenarios?

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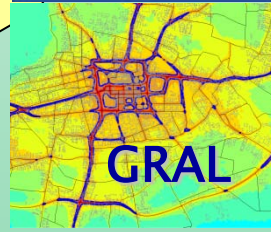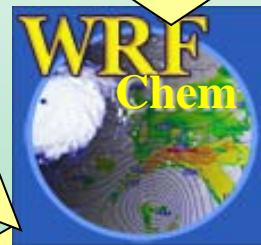# Methodology

Satellite data

Mean trop. NO₂ SCD (09+10/2005)

Measurement data

Emission data

Integrated Air Quality Assessment Studies

WRF Chem

GRAL

Stakeholders: e.g., communities, gov. agencies
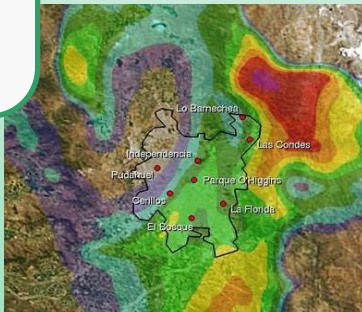
Air quality

science based decision support

Measures

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Measurement Platforms

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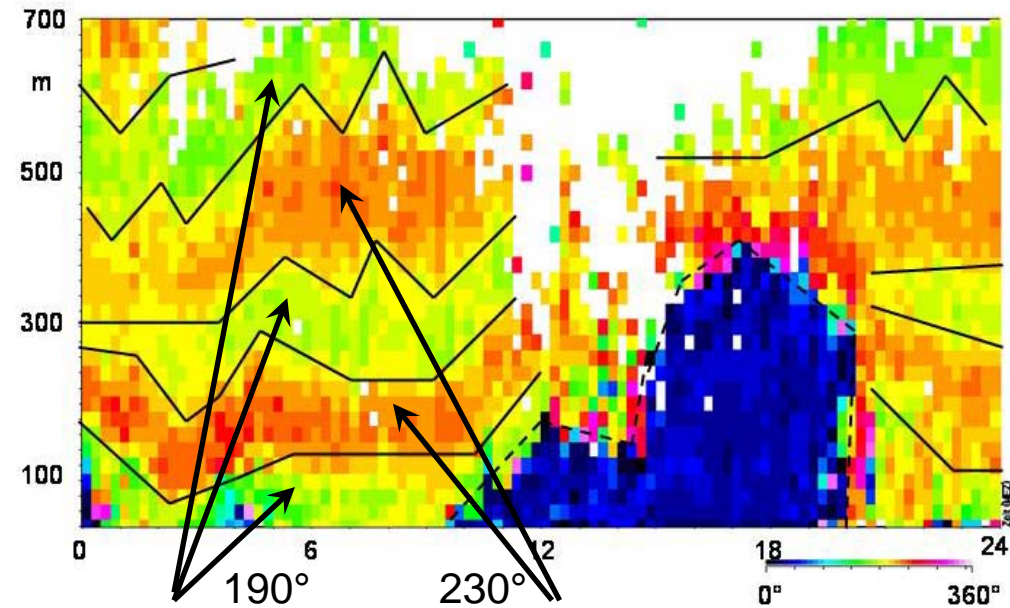
Remote Sensing Techniques

SODAR measurements in the Innvalley - 29 January 2006
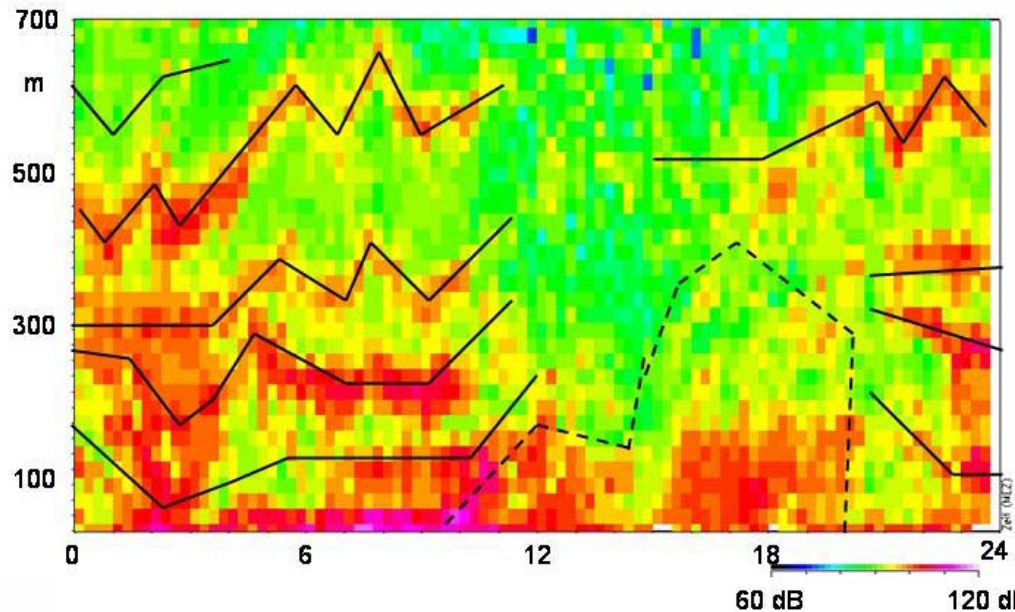
backscatter intensity

wind direction

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UL-Aircraft Measurements

Measurements by a ultra light aircraft around volcano Popocatepetl close to Mexico City (MILAGRO-Experiment)

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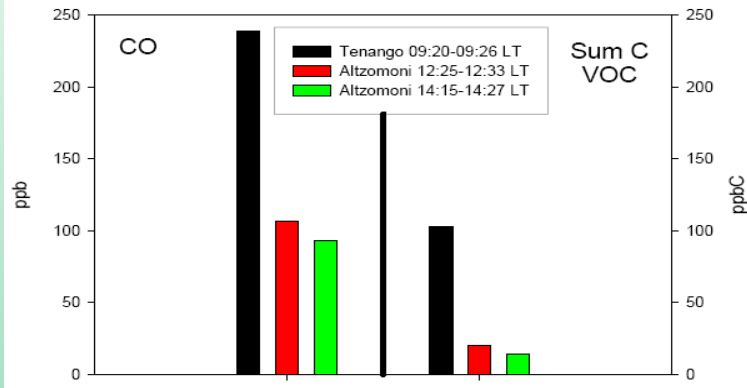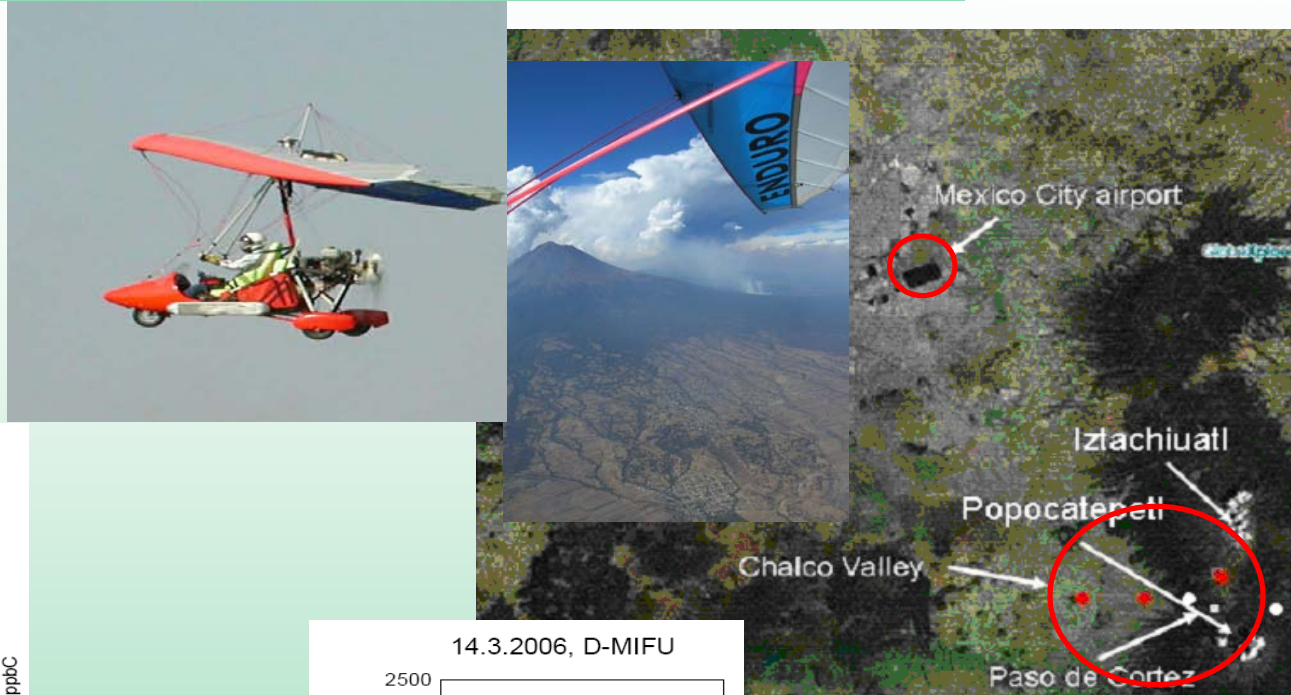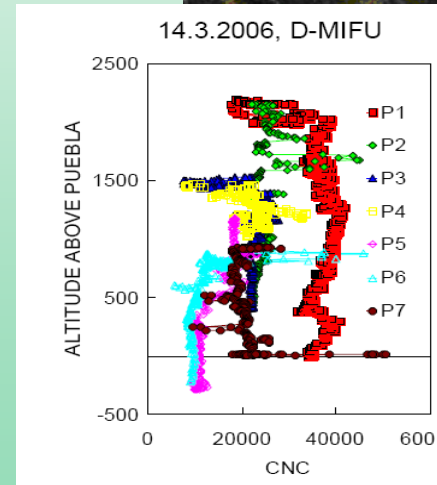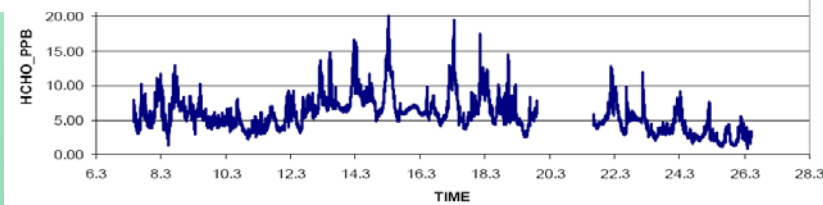
Biogenic Emissions

Biogenic VOC emissions from forests in the vicinity of Mexico City

➢ Updated emission factors for

- Fir (*Abies religiosa*)
- Pine (*Pinus petula*)
- Oak (*Quercus rugosa*)

New Biogenic VOC Emission Inventories in the Mexico City Basin and Expected Differences
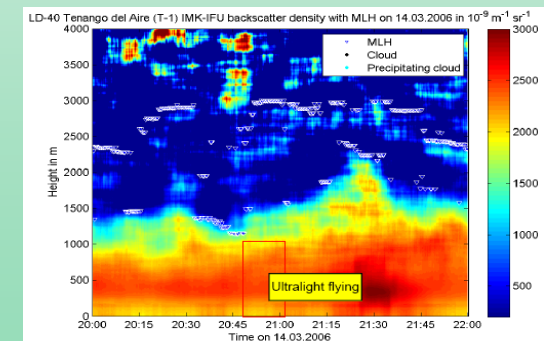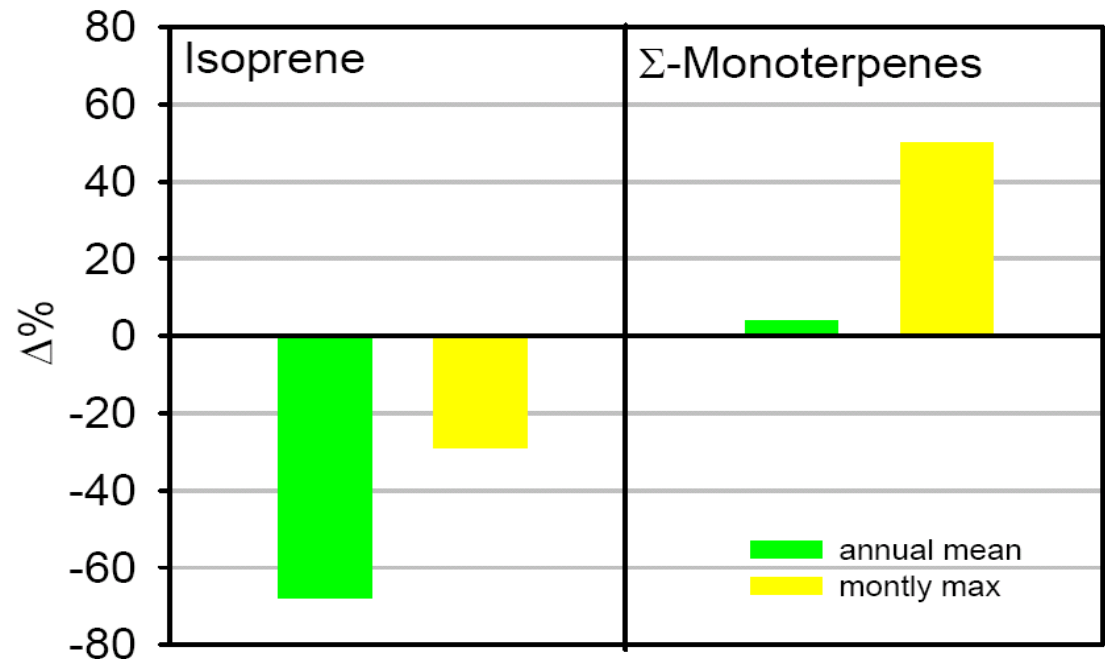
Co-operation Universidad Nacional Autónoma de México (UNAM) and IMK-IFU (MoU)

Source: R. Steinbrecher, IMK-IFU, Germany

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Modelling System

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 or WRF/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

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Simulations

Ozone exposure index
- Santiago de Chile -
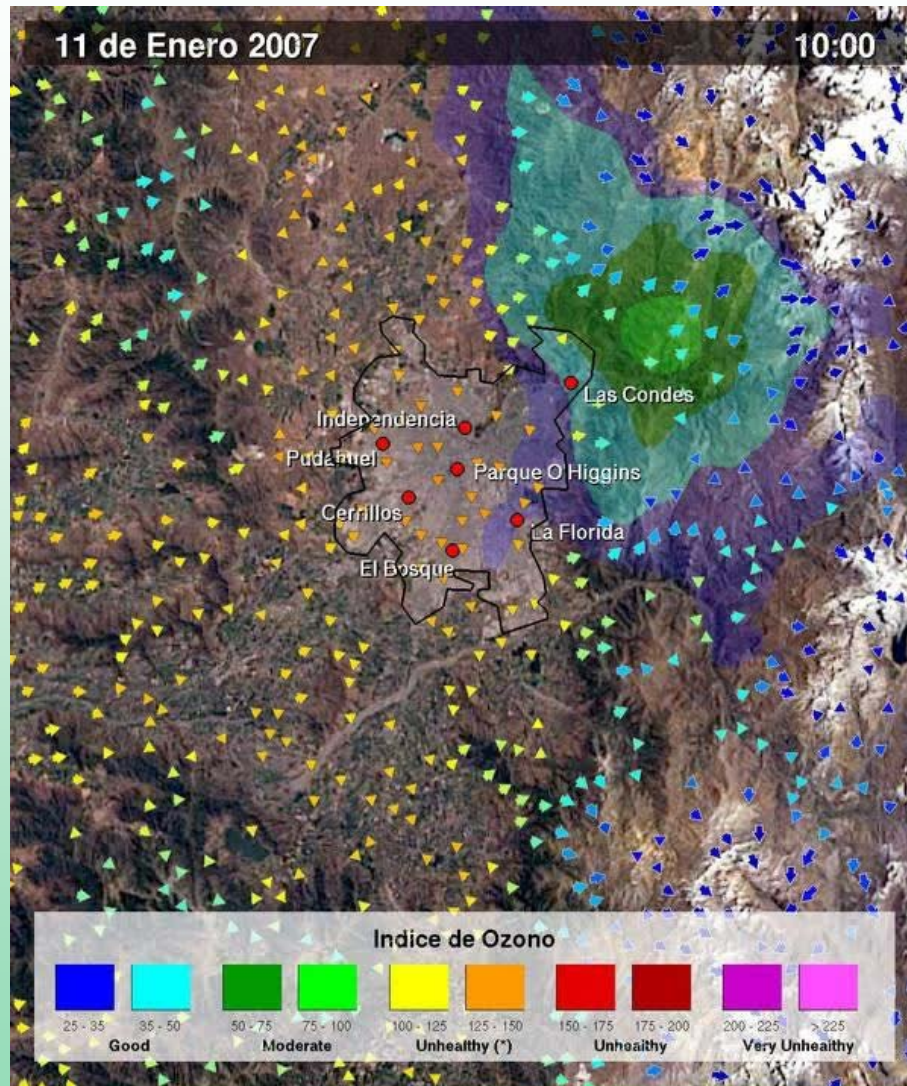
Source:
R. Schmitz (UCH), Chile

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Assessment Studies
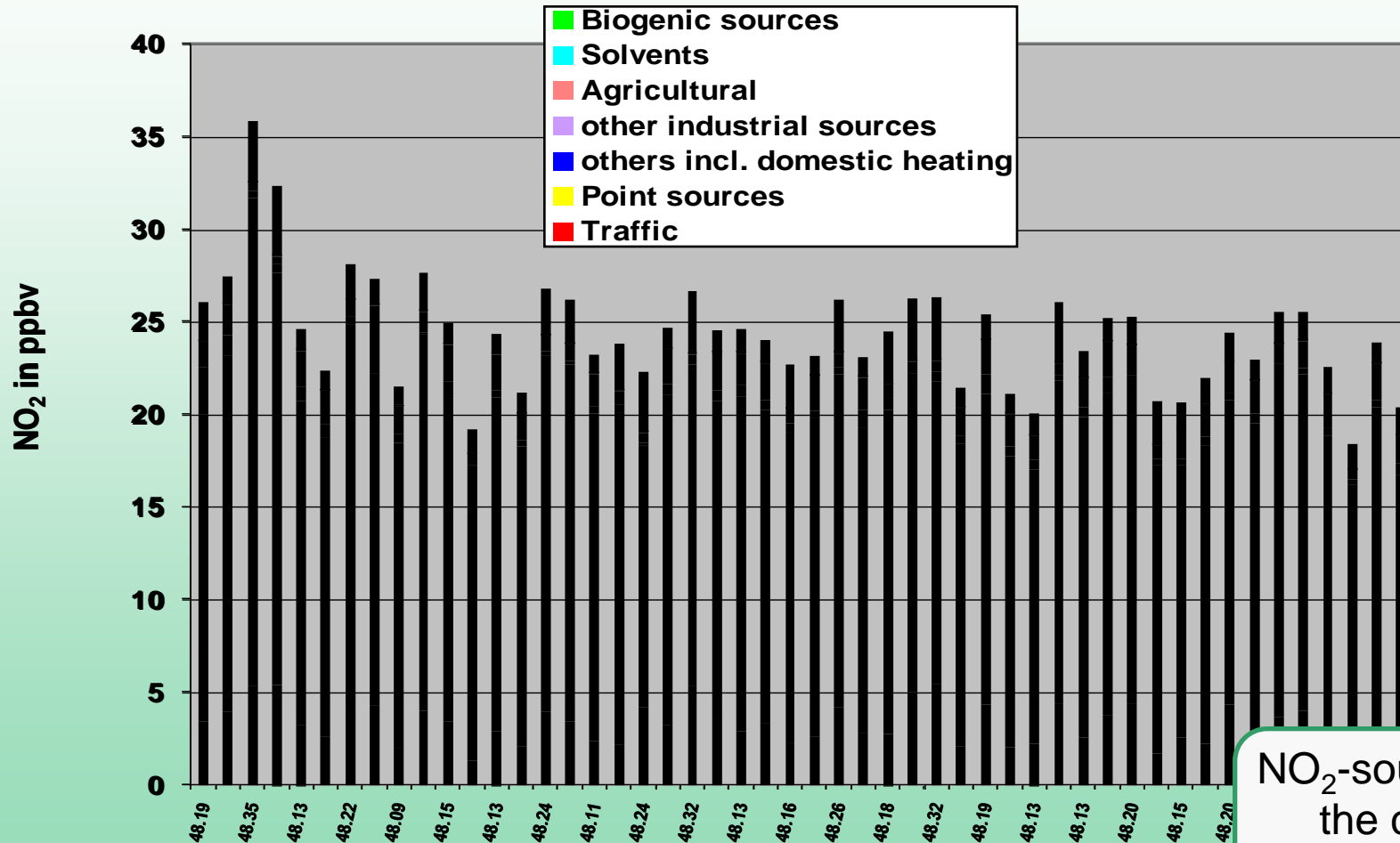
NO$_2$-source attribution in the conurbation of Munich

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Causal Chain

Data

Models

Changes in Air Pollutant concentrations

Population Exposed → **Changes in Human Exposure** ← **Exposure Assessment Models**

Baseline Risk → **Changes in Health Effects** ← **Concentration-Response Functions**

Income → **Social Impacts – Cost / Benefit** ← **Valuation Models**

Good policy flows from good data and from sound analysis

Cifuentes , etal 2005

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Methods in Health Assessment

Data:

- Health insurence data (health care utilisation)

- Air pollution data
  - state/municipal authorities
  - input from remote sensing
  - input from modelling
  - additional measurements (?)

Study design:

- ✓ Transversal
  daily time resolution

- ✓ Longitudinal
  - with respect to subgroups
  - with respect to areas

- ✓ Clinical endpoints
  - respiratory diseases
  - cardiovascular diseases
  - other diseases

Main methods:

- ➤ Regression Models

- ➤ Correlation Analyses

- ➤ Generalized Additive Models (GAM)

Ulrich Franck

Department Human Exposure and Epidemiology

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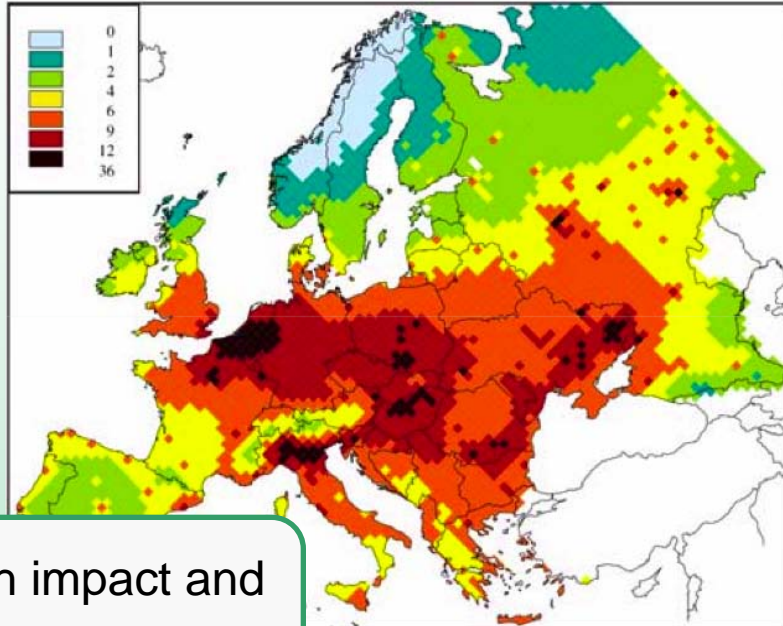
Health Effects

Size dependent health effects of airborne particles
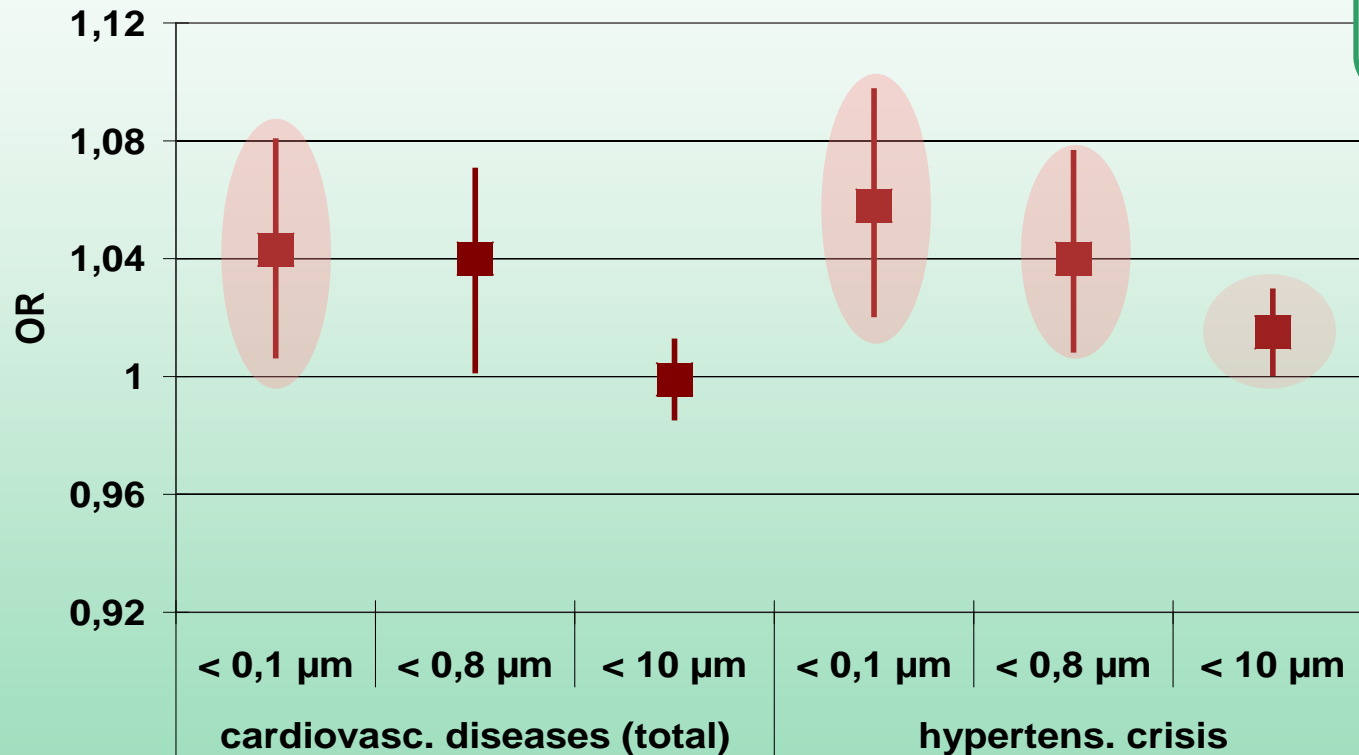
Odeh SF, PhD Thesis 2006
Franck U, Odeh SF, Wiedensohler A,
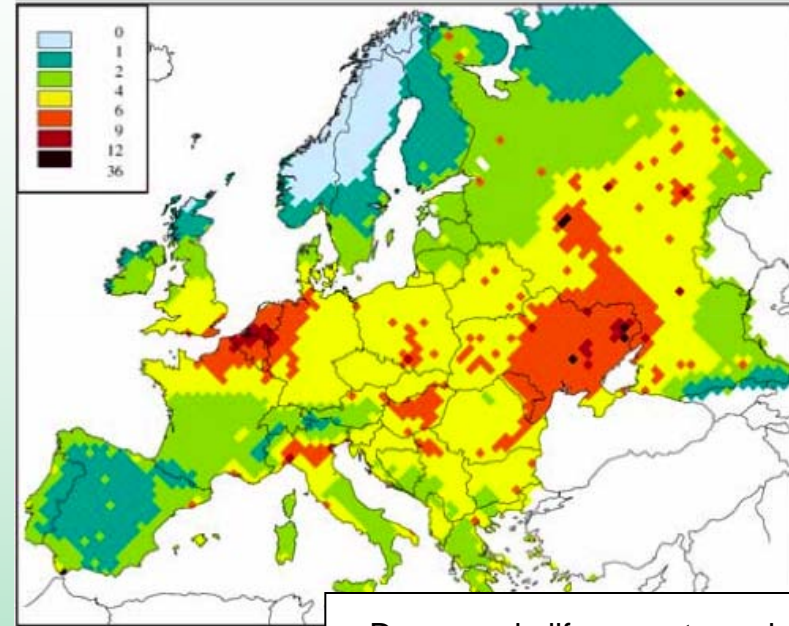Wehner B, Herbarth O et al.2009 subm.

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Health Facts

2000

2020

Health impact and air pollution

Decrease in life expectancy in months due to anthropogenic $PM_{2.5}$

<u>EU-average 2000 vs 2020:</u>
- Life expectancy reduction of 9 months – reduced to 6 months
- Annual loss of 4 Mio. life years – reduced to 2.3 Mio
- Annually 386.000 premature deaths – reduced to 251.000
- Annually 110.000 serious hospital admissions – reduced to 63.000

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Avoidable health effects

Controlled policy aimed strategy to reduce air pollution emissions between 2000 and 2020 in 3 cities of Latin America

- 156 000 deaths
- 4 million asthma attacks
- 300 000 children's medical visits
- 48 000 chronic bronchitis

Economic value between $21 to $165 billion

Source: Bell etal, 2006

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Economical Benefit

Annual average PM$_{10}$ concentrations (µg/m³)

AQG level
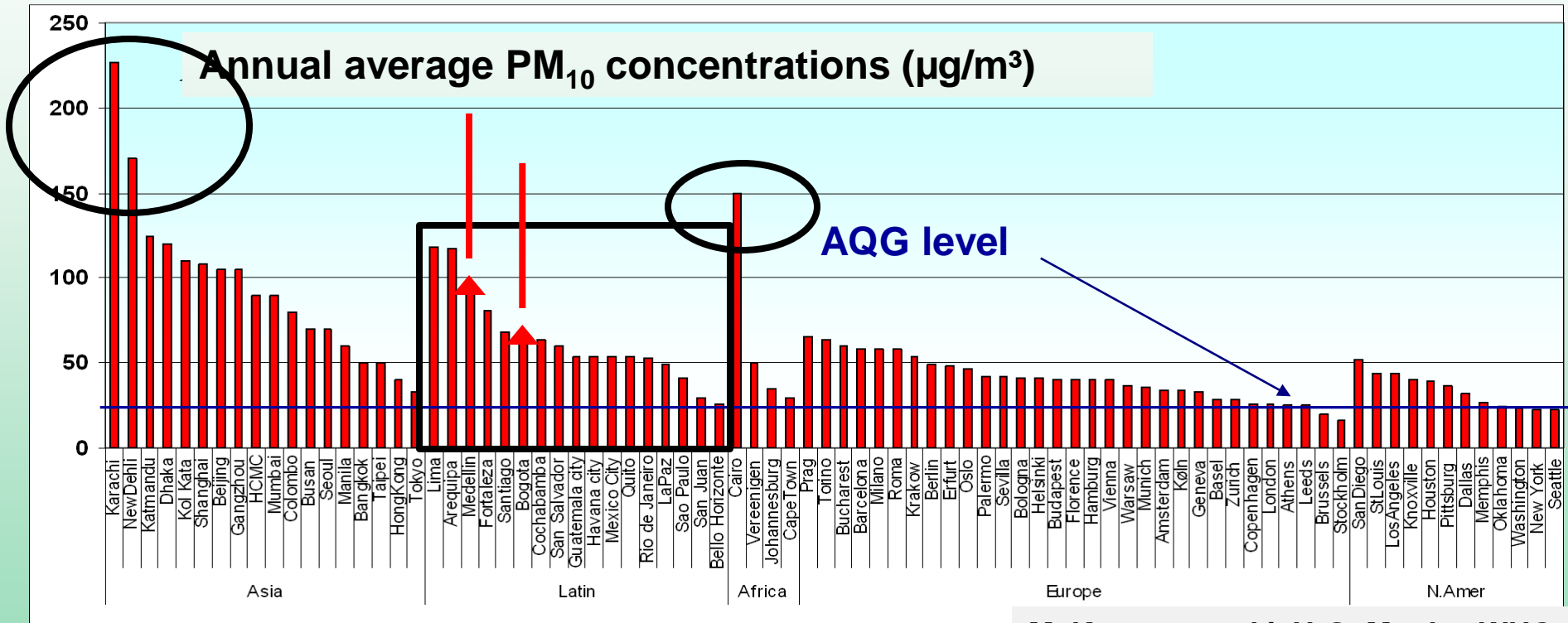
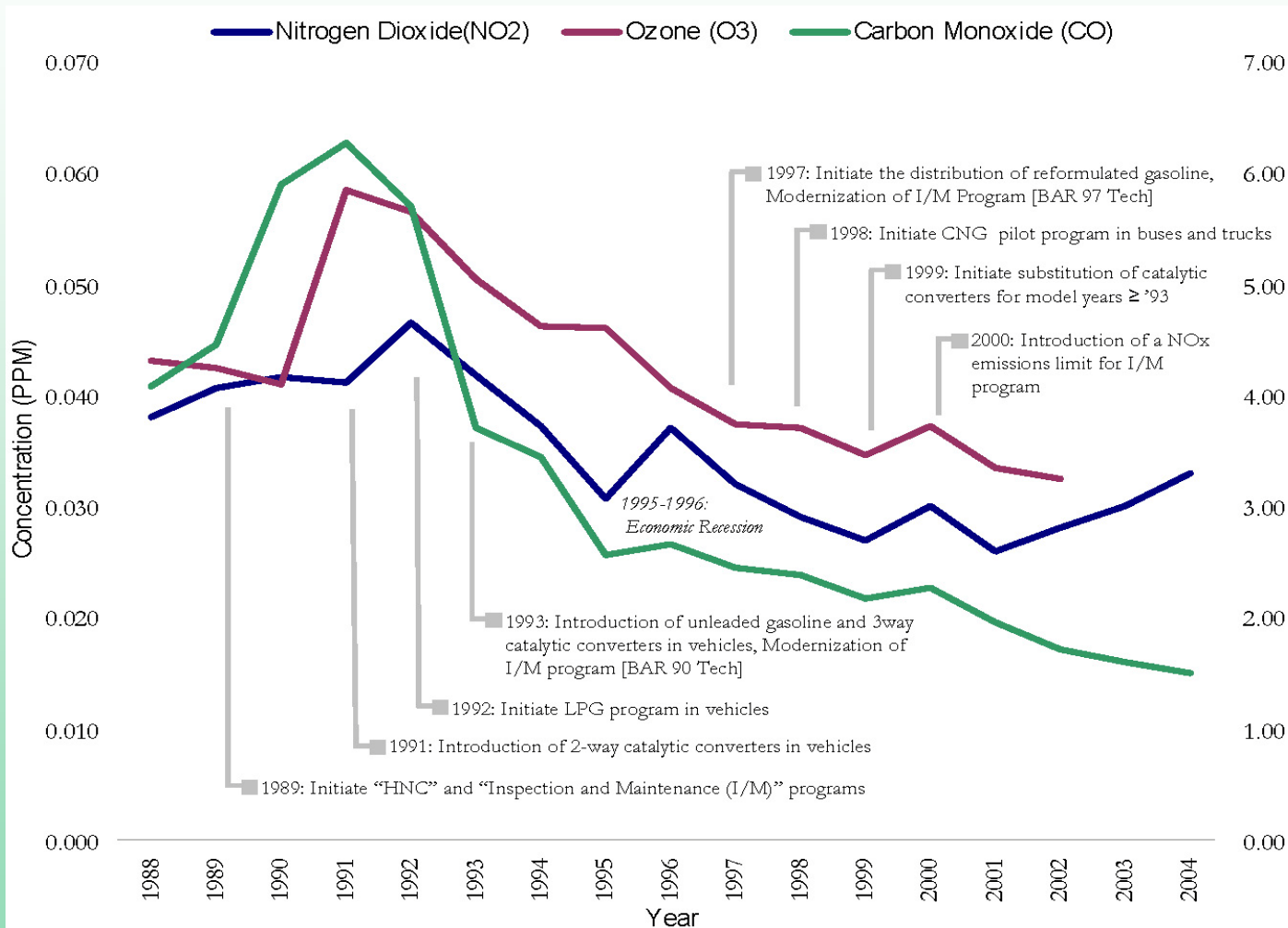M. Krzyzanowski, H-G. Mucke, WHO

Reduction benefit is 10 times higher as for ozone, e.g. Mexico City about $2 Bill.

Molina and Molina, 2002

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Governance & Sustainability

Air Quality management policies, emission control programs and pollutant trends in Mexico City

Source: APERC (2007): Urban Transport Energy Use in the APEC Regions

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Conclusions

➢ Air quality issues need an holistic and interdisciplinary approach

➢ Strong links to

- **Regional and Spatial Planning Sciences**
- **Energy & Technology Assessment Disciplines**
- **Transportation Sciences**
- **Health / Epidemiological Disciplines**
- **Social Sciences**

➢ Link between these fields tackles central problems in mega cities

➢ Complex system of mega cities, needs further process studies in each discipline

➢ Air quality and health impact assessment studies are essential prerequisites for mitigation and adaptation strategies and for reducing e.g.

- environmental risks (air pollution, congestion, waste, ...)
- social risks (spatial segregation, health problems, …)
- costs (healthcare system, transportation, production, ...)

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Co-operations

➢ *Memorandum of Understanding (MoU)* between IMK-IFU and the **Universidad Nacional Autonoma de Mexico (UNAM)** about a cooperation in the fields of research and education *(e.g. Air Quality, Climate Change)*

➢ Establishing of the *International Competence Center for Sustainable Urban Development (ISUD)* in Santiago de Chile *("capacity building"; "multidisciplinary research on Megacities"; "applying knowledge") between* FZK and **Universidad de Chile** in Santiago

➢ *Contract of Cooperation* between the **Institute of Atmospheric Physics (IAP)** of the **Chinese Academy of Sciences (CAS)** and IMK-IFU about "*Monitoring and Modelling of Air Quality at the Megacity, Beijing*"

Santiago de Chile

Bangkok

Shanghai

Mexico City

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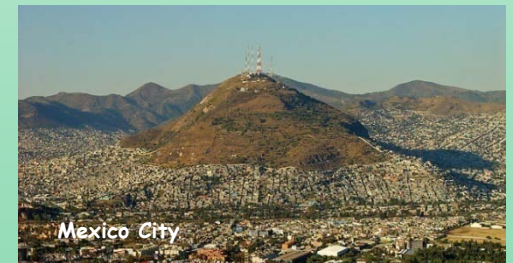
Muchas gracias!

Cooperation Partner

Yuesi Wang, Hong Liao, Xin Jinyuan   *Chinese Academy of Sciences (CAS), Peking*
Jose Agustín García, Gerardo Ruiz   *Universidad Nacional Autonoma de Mexico (UNAM)*
Rainer Schmitz, Ricardo Muñoz   *Universidad de Chile , Santiago de Chile (UdC)*
Michael Hagen   *Fondo Nacional de Salud (FONASA)*
Frank Baier   *Deutsches Luft- und Raumfahrtzentrum (DLR)*
Ulrich Franck   *Helmholtz Zentrum für Umweltforschung (UFZ)*
Annette Peters, Josef Cyrys   *Helmholtz Zentrum München (HMGU)*