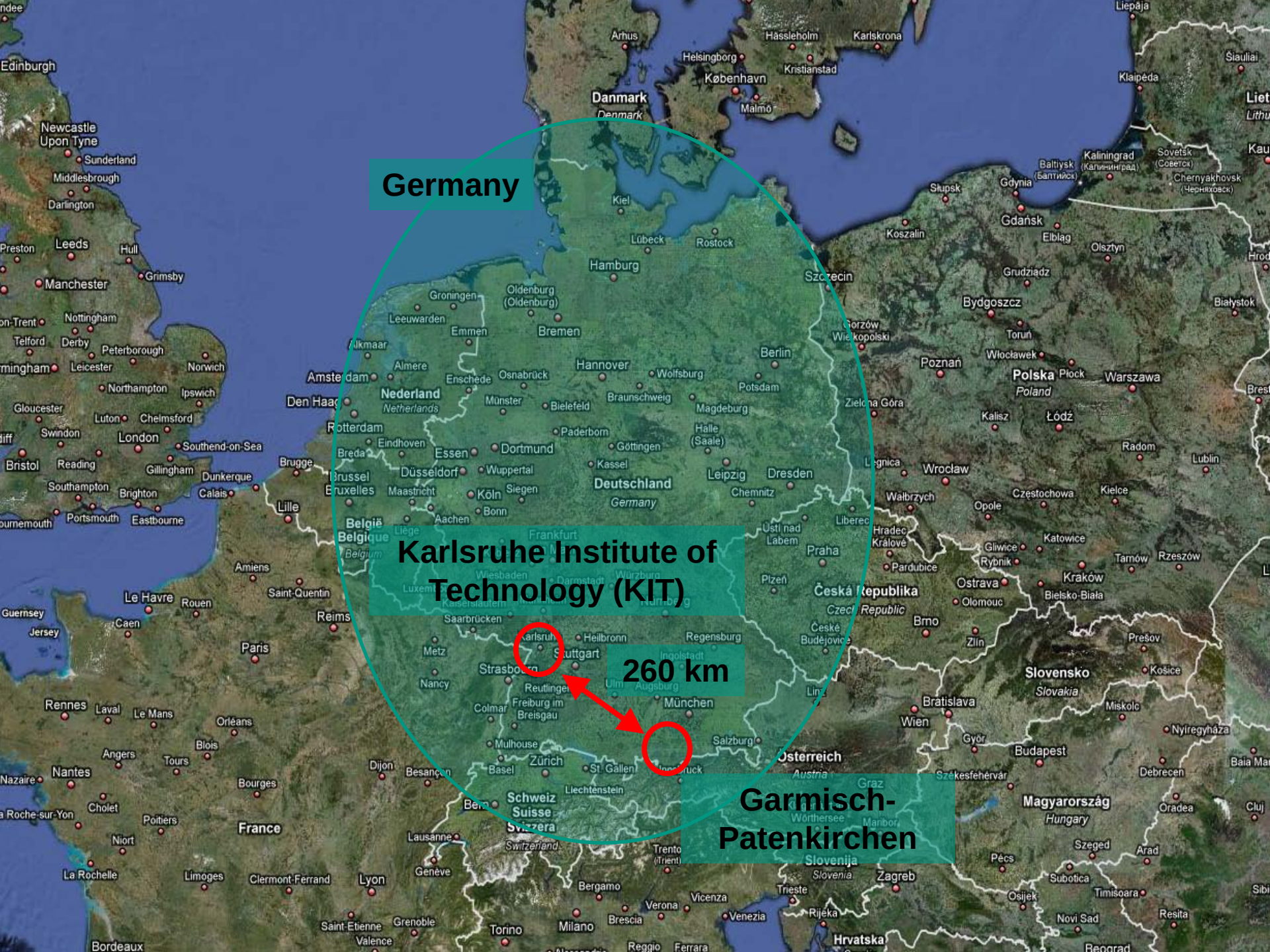
Climate change and air pollution:
A challenge for multidisciplinary research in megacities

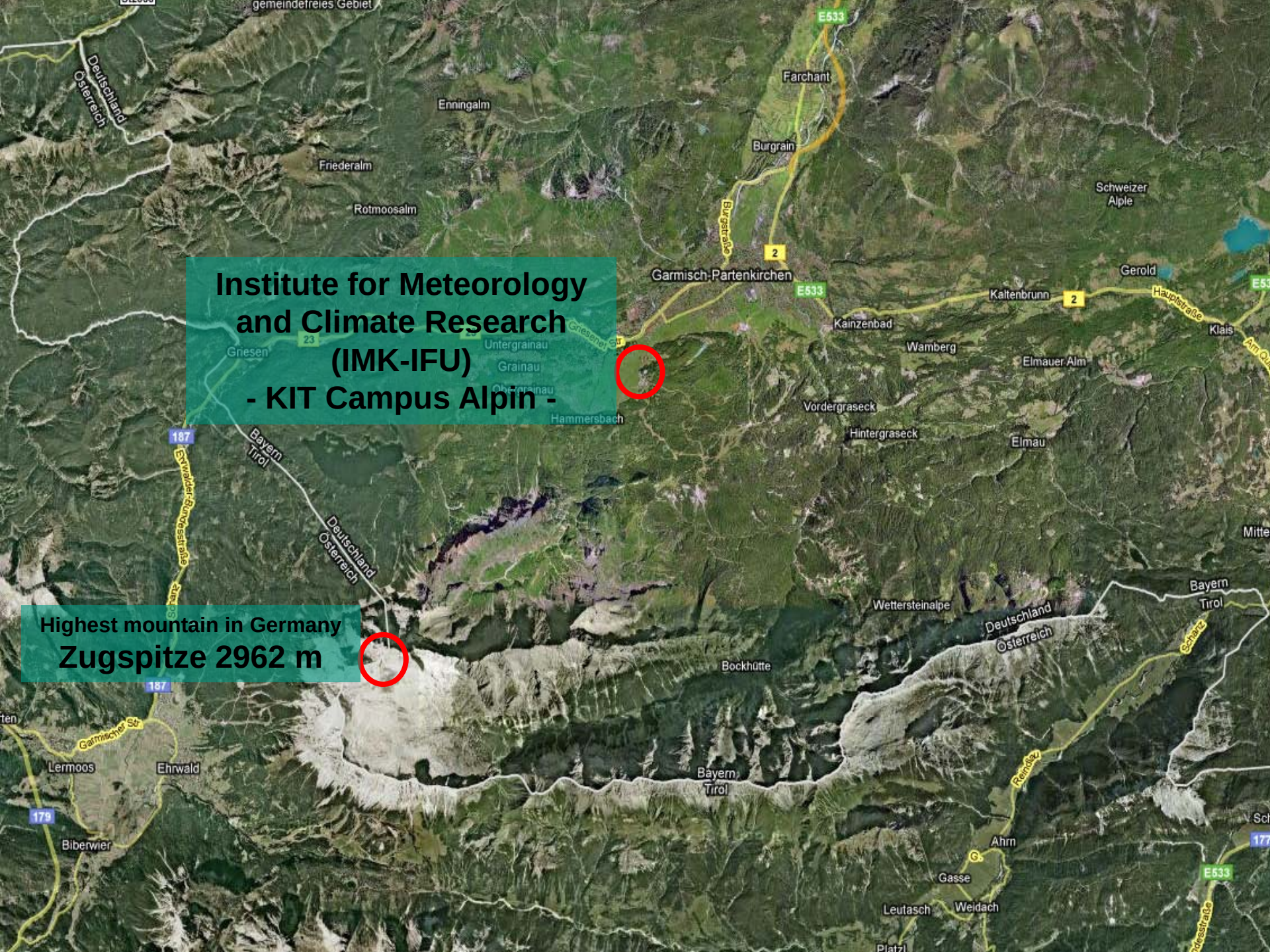
Peter Suppan

Institute for Meteorology and Climate Research (IMK-IFU), Karlsruhe Institute of Technology (KIT),
Campus Alpine, Germany

Overview

- *Where I come from*
- Facts and Problems
- Methodological Approach
- Results
- Conclusions

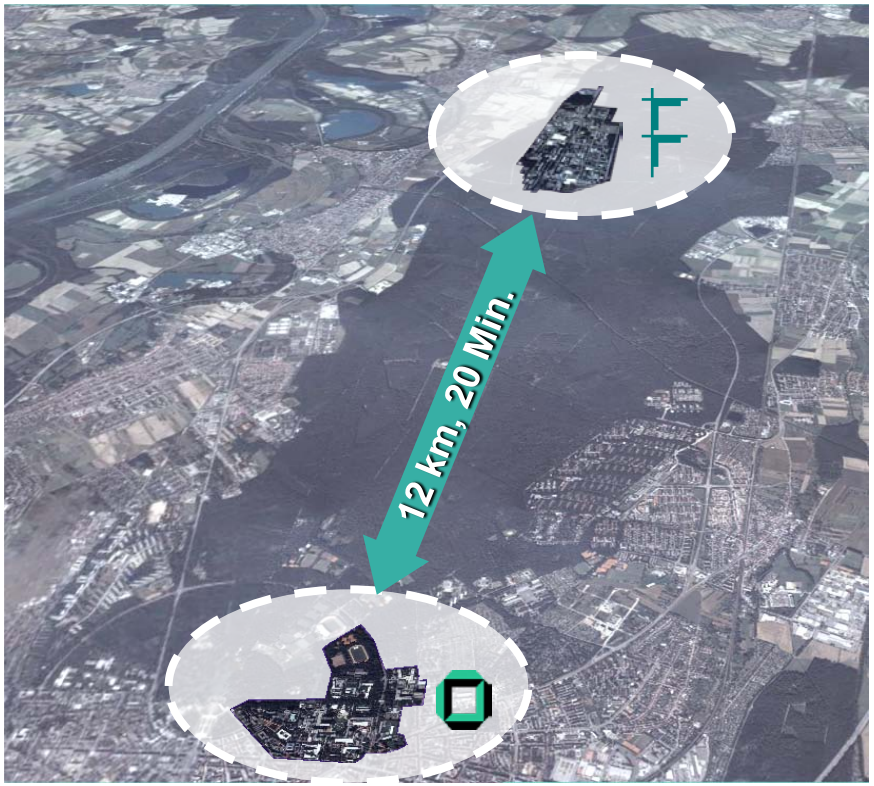

Germany
Karlsruhe Institute of Technology (KIT)
260 km
Garmisch-Patenkirchen


Institute for Meteorology and Climate Research (IMK-IFU)
- KIT Campus Alpin -
Highest mountain in Germany
Zugspitze 2962 m
gemeindefreies Gebiet
Deutschland
Österreich
Enningalm
Farchant
Burgrain
Friederalm
Rotmoosalm
Schweizer Alpe
Garmisch-Partenkirchen
Gerold
Kaltenbrunn
Kainzenbad
Klais
Griesen
Untergrainau
Grainau
Wamberg
Elmauer Alm
Vordergraseck
Hammersbach
Hintergraseck
Elmau
Bayern
Tirol
Wettersteinalpe
Bockhütte
Lermoos
Ehrwald
Biberwier
Ahrn
Gasse
Leutasch
Weidach
Platzl

Research Network

Unique Situation in Karlsruhe:

- Close cooperation of the University and Forschungszentrum since 15 years
- 26 professors are working at both the University and Forschungszentrum
- Close proximity, comparable size, overlapping topics

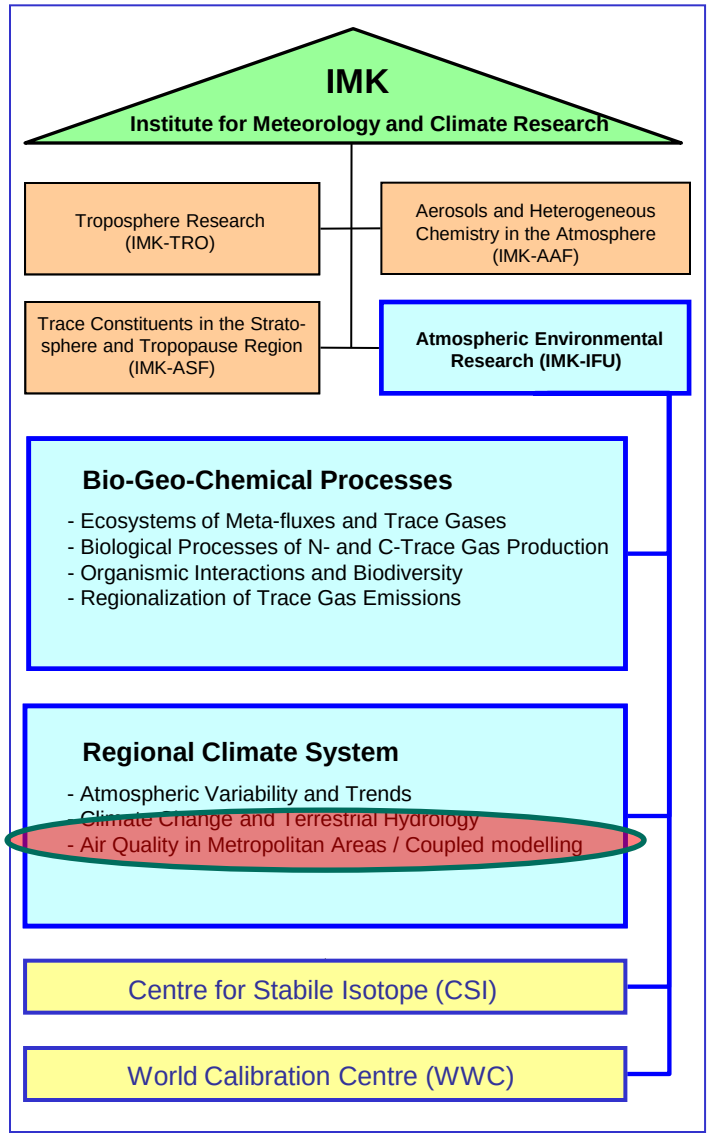


KIT

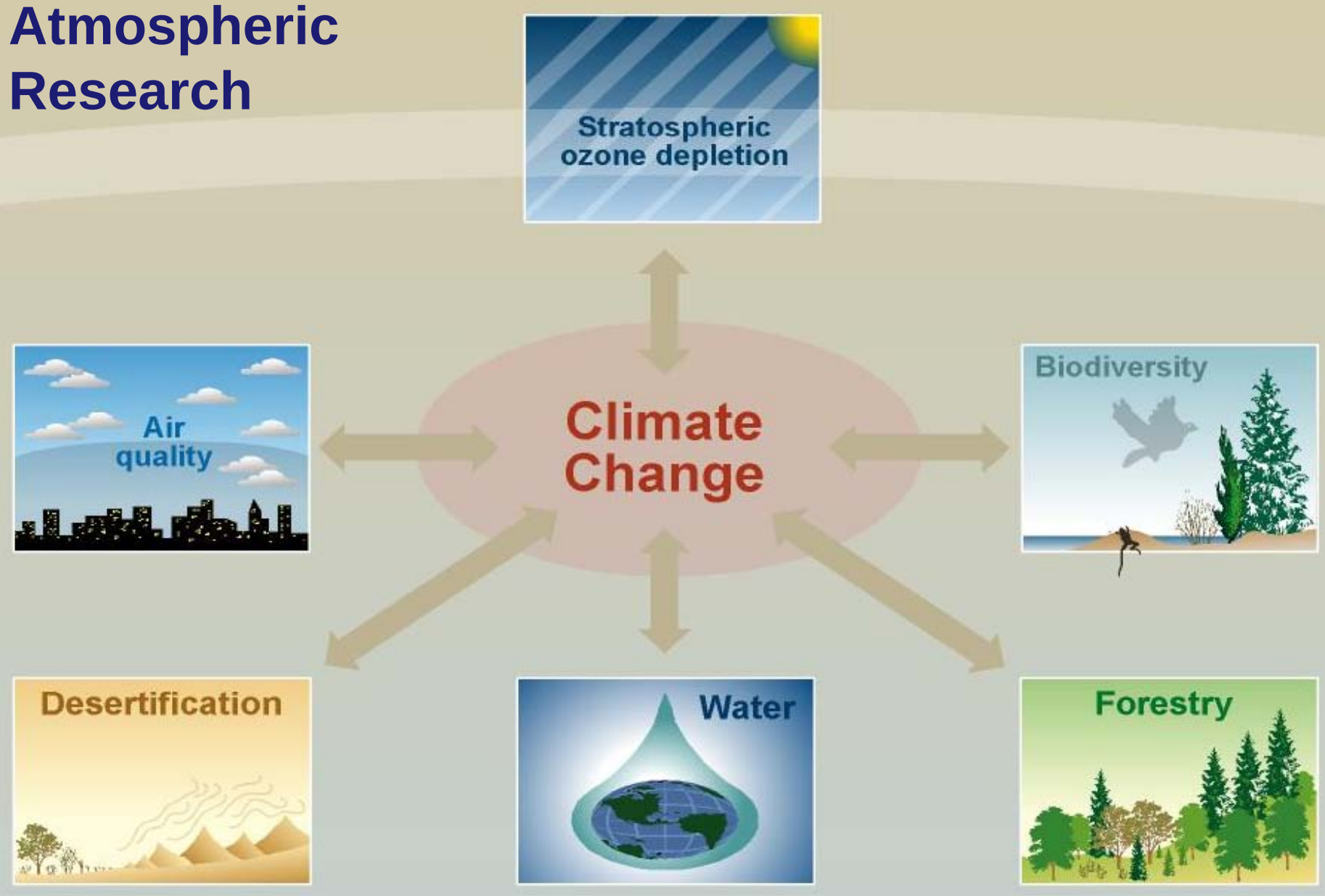
Forschungszentrum Karlsruhe GmbH		University of Karlsruhe (TH)	
10	Programs	11	Faculties
31	Institutes	118	Institutes
3690	Employees	4269	Employees
408 Mio €	Budget	18353	Students
		299 Mio €	Budget

Natural and Engineering Sciences

Institute

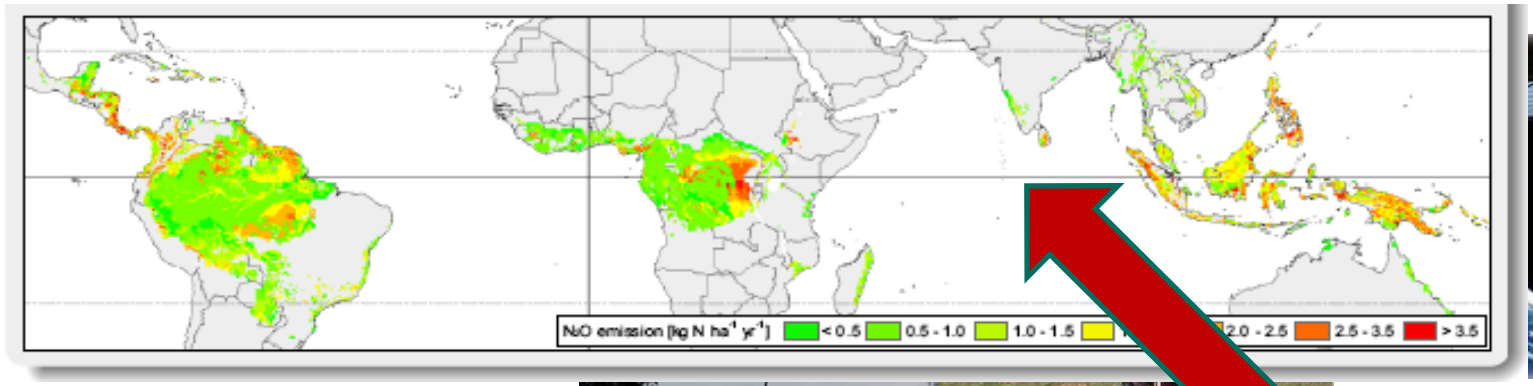

IMK
Institute for Meteorology and Climate Research
Troposphere Research (IMK-TRO)
Aerosols and Heterogeneous Chemistry in the Atmosphere (IMK-AAF)
Trace Constituents in the Strato-sphere and Tropopause Region (IMK-ASF)
Atmospheric Environmental Research (IMK-IFU)
Bio-Geo-Chemical Processes
- Ecosystems of Meta-fluxes and Trace Gases
- Biological Processes of N- and C-Trace Gas Production
- Organismic Interactions and Biodiversity
- Regionalization of Trace Gas Emissions
Regional Climate System
- Atmospheric Variability and Trends
- Climate Change and Terrestrial Hydrology
- Air Quality in Metropolitan Areas / Coupled modelling
Centre for Stabile Isotope (CSI)
World Calibration Centre (WWC)

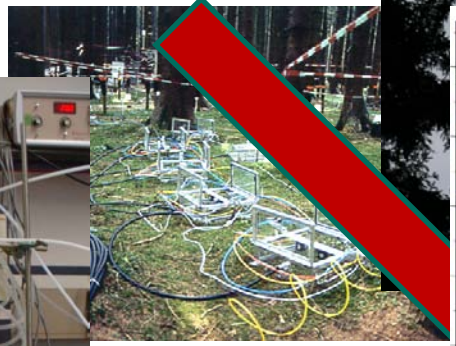
Atmospheric Research

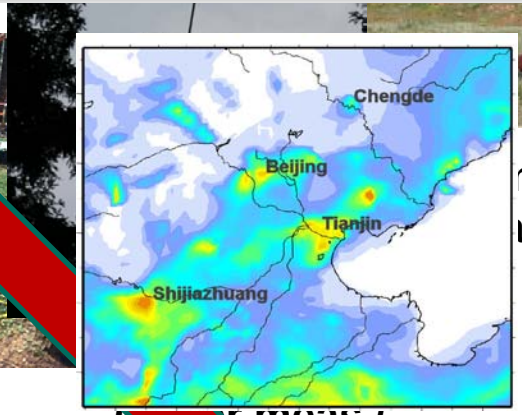


(source: IPCC 2001, WG1 Report, Summary

The Challenge





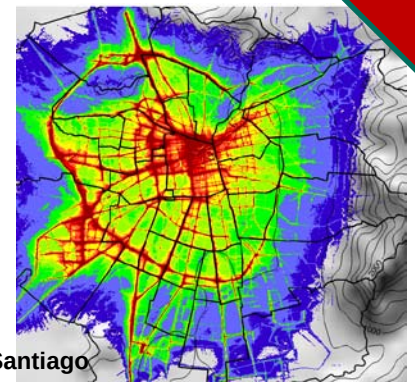


global scale
mote sensing)

nal scale
ft meas.)

plot scale
(chamber meas.)

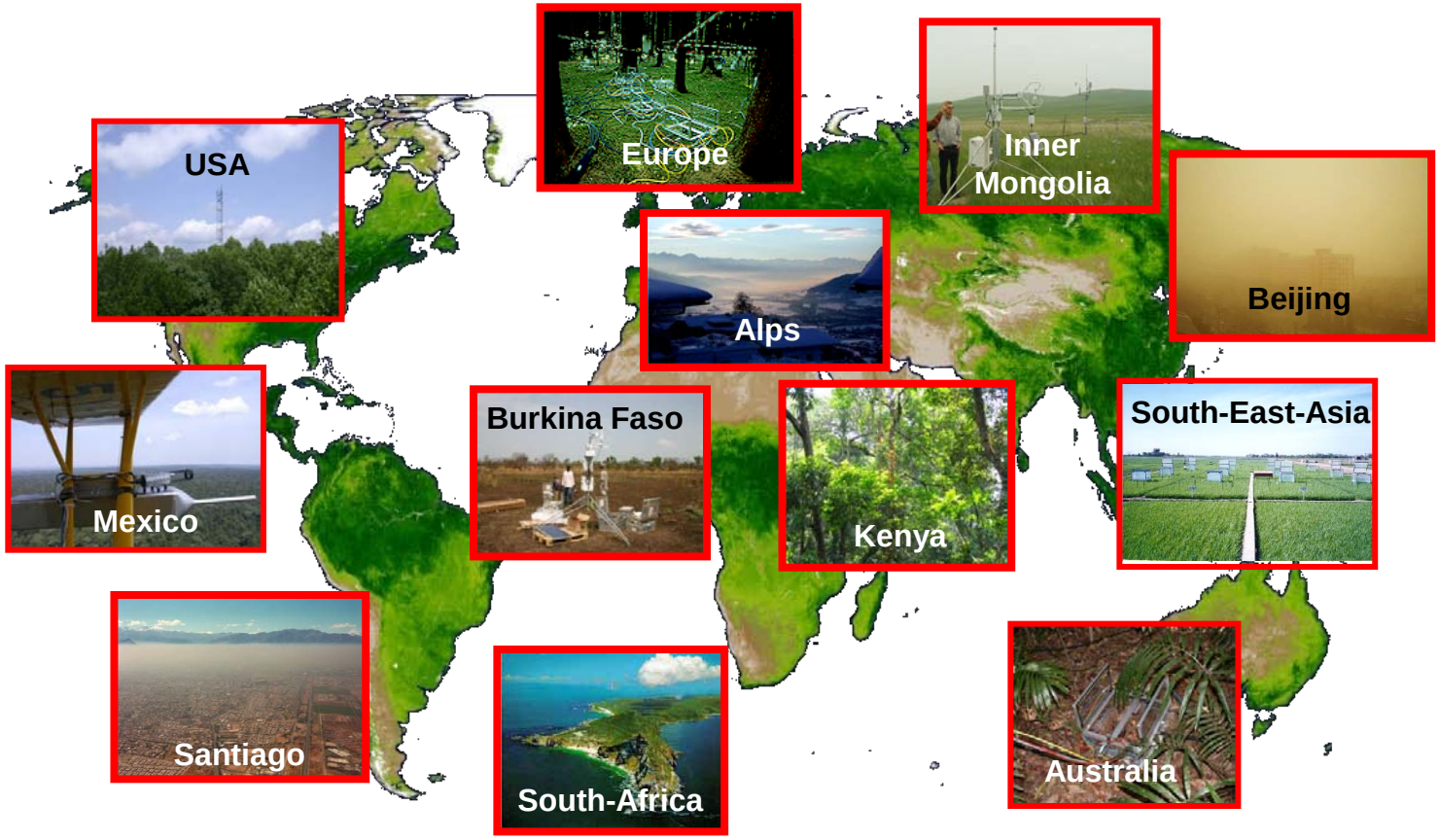
meas./
nsing)



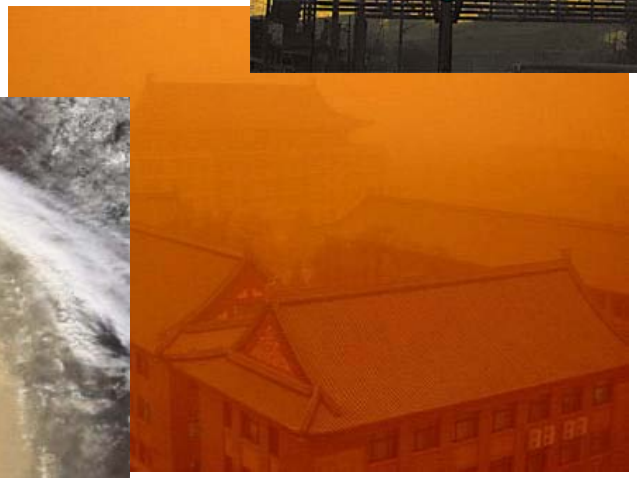
…from measurements to modeling
…from the micro to the macro scale and vice versa

(laboratory meas.)

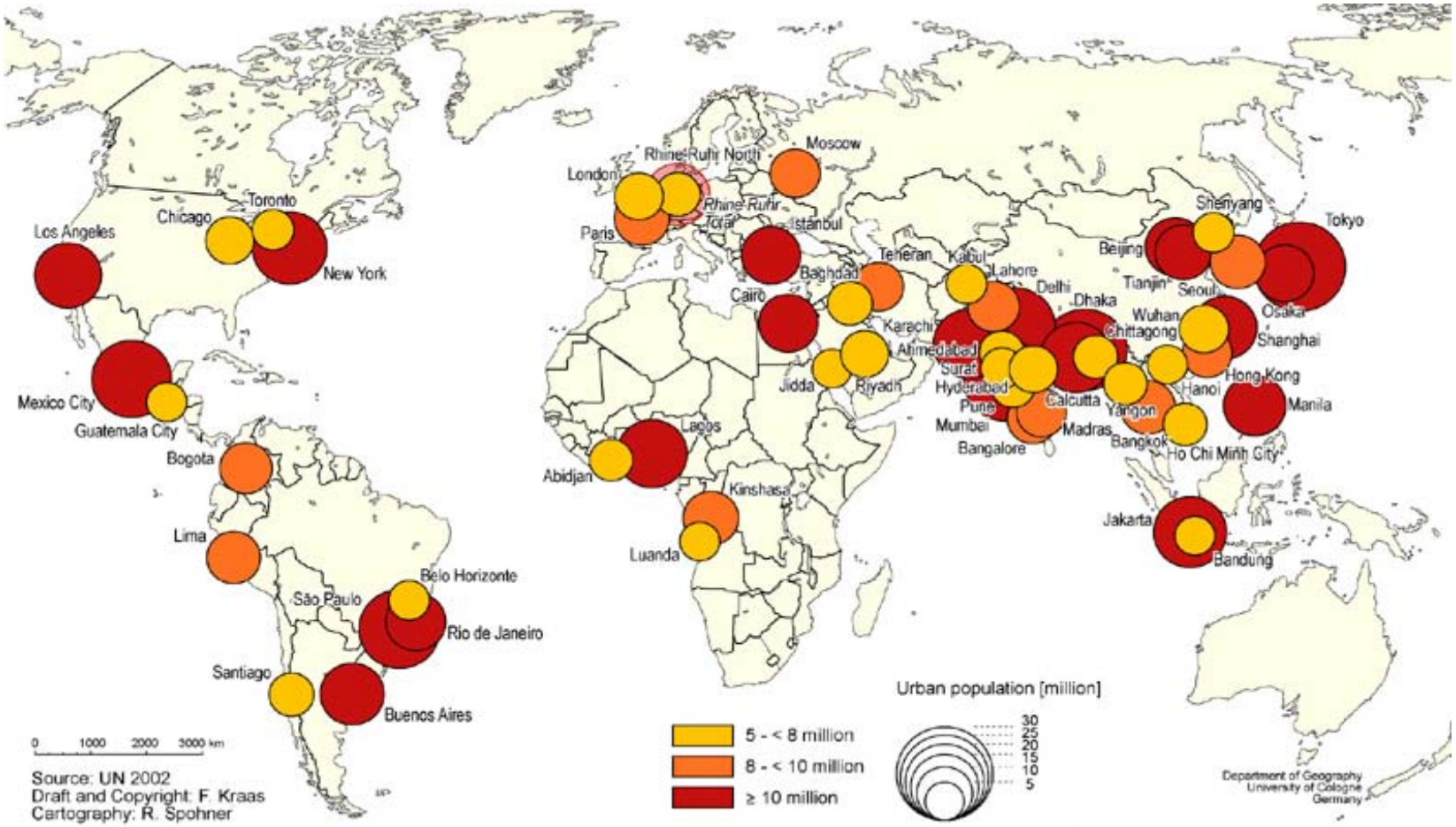
IMK-IFU Investigations



Facts and Problems

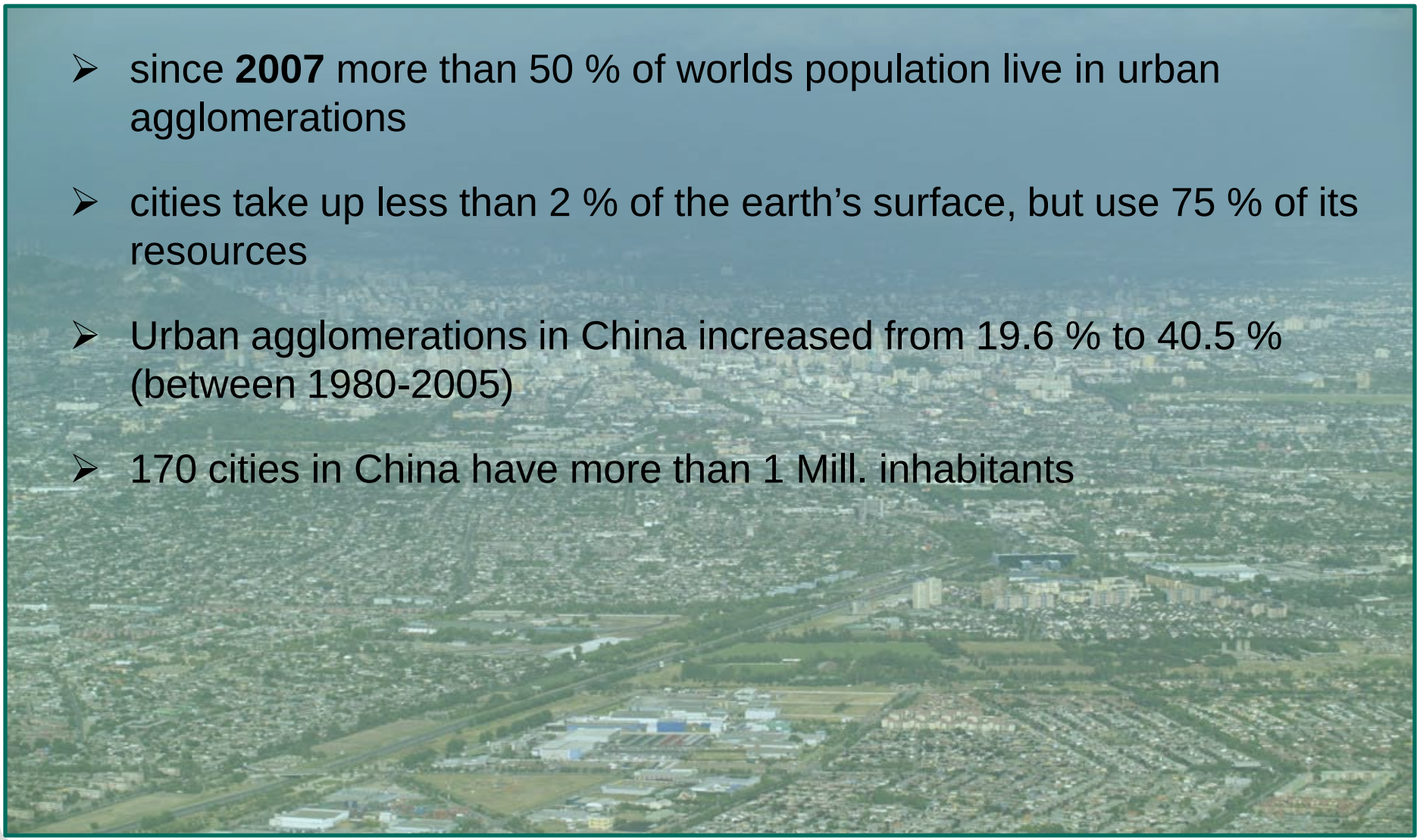


Geographical Situation



Some urban facts (I)

- since **2007** more than 50 % of worlds population live in urban agglomerations
- cities take up less than 2 % of the earth's surface, but use 75 % of its resources
- Urban agglomerations in China increased from 19.6 % to 40.5 % (between 1980-2005)
- 170 cities in China have more than 1 Mill. inhabitants



Urban settlements - spaces of opportunities and risks (I)

Opportunities

- engines of global economic growth
- contribute over the average to the national output
  - Bangkok or Sao Paulo are home to about 10 – 15% of the national population but contribute more than 40% to the GDP
- provision of education is better in large agglomerations
- financial strength likewise opens opportunities for diversification in culture, arts and science along with technological innovation
- potential of cost-effective and ecologically-oriented way
  - concentration of people potentially reduces the per-capita demand for occupied land, the cost of providing treated water or collecting solid and liquid waste

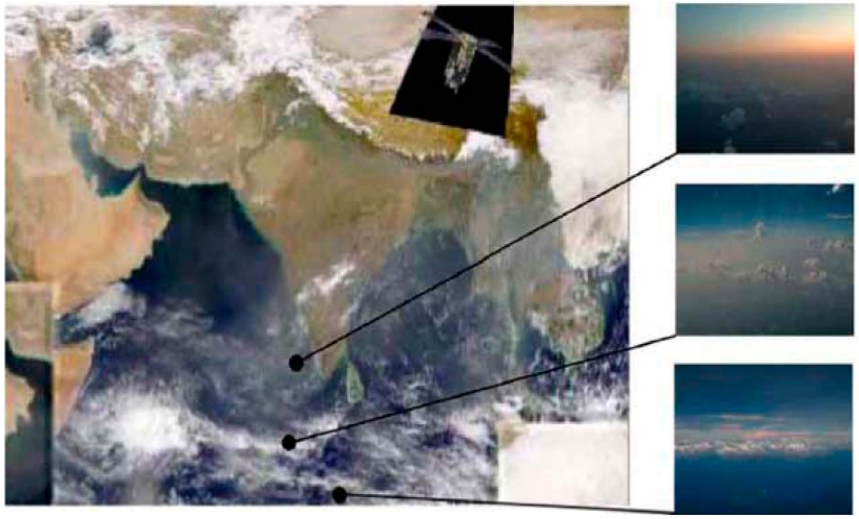
Urban settlements - spaces of opportunities and risks (II)

Risks

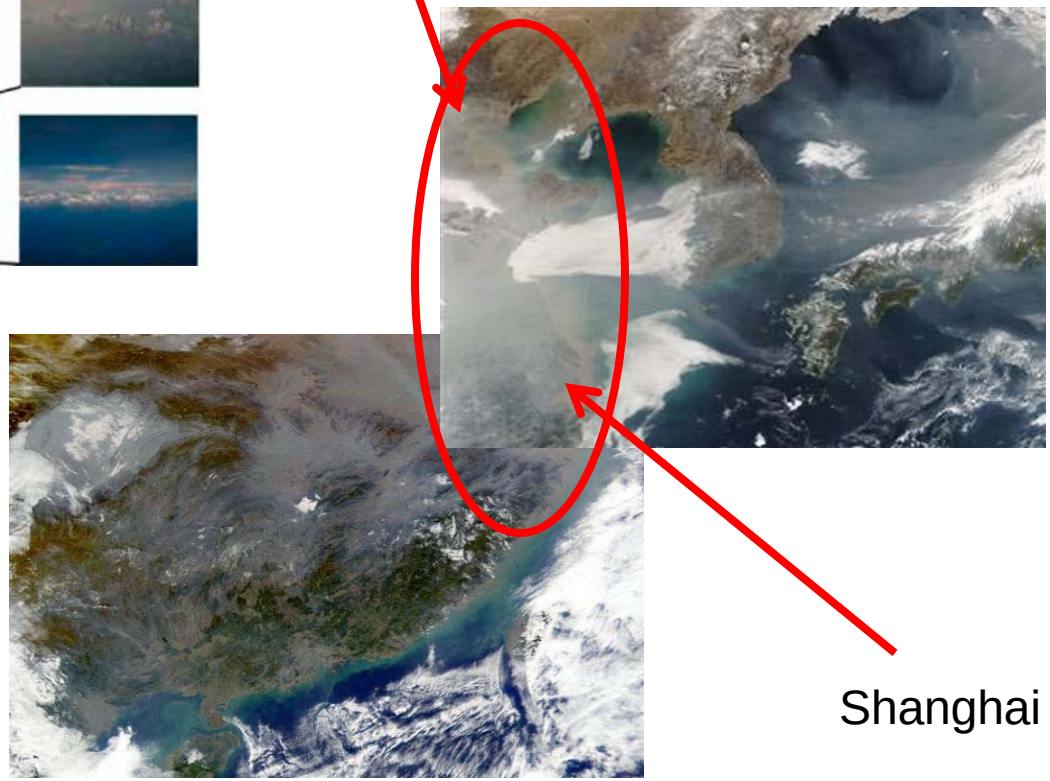
- Natural risks
  - earthquakes, floods, and landslides *(75 % of the world's population lives in areas that were affected at least once by an earthquake, a tropical cyclone, floods, or drought between 1980 and 2000)*
- Man-made (environmental and technological) risks
  - land-use change → flood risks
  - uncontrolled waste disposal → health risks
  - emissions → health risks

Traffic – Air Pollution – Health Impact **← Climate Change**

Atmospheric Brown Clouds (ABC)



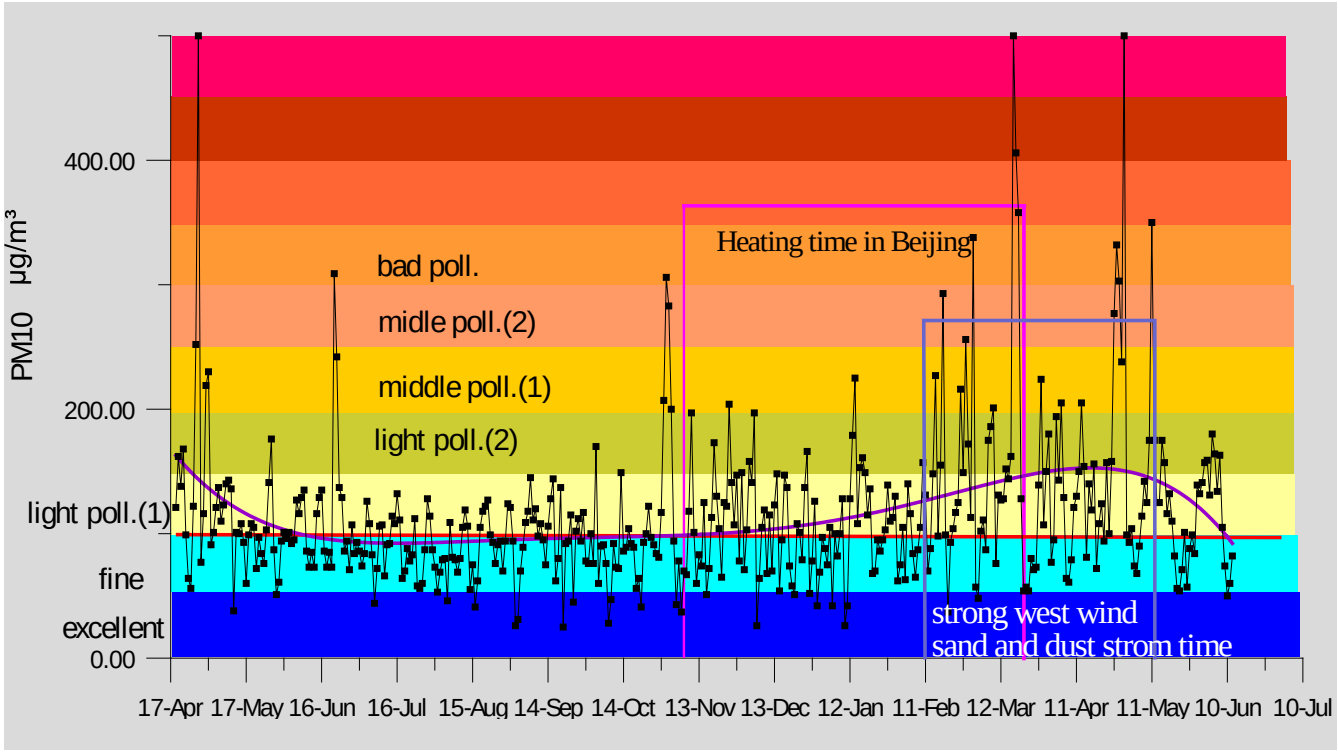
Source: Peringe Grennfelt. Air pollution & Climate Change. Two sides of the same coin. Chapter 9. ISBN 978-91-620-1278-6

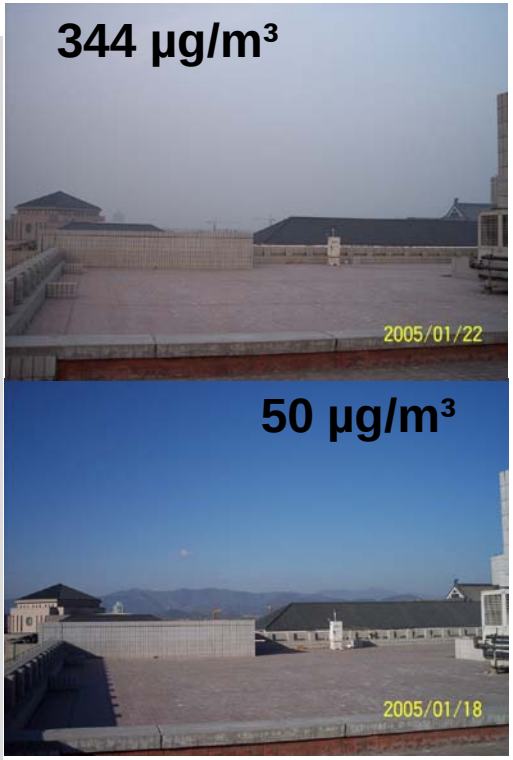


NASA/GODDARD / NYT

Aerosol Pollution

Beijing



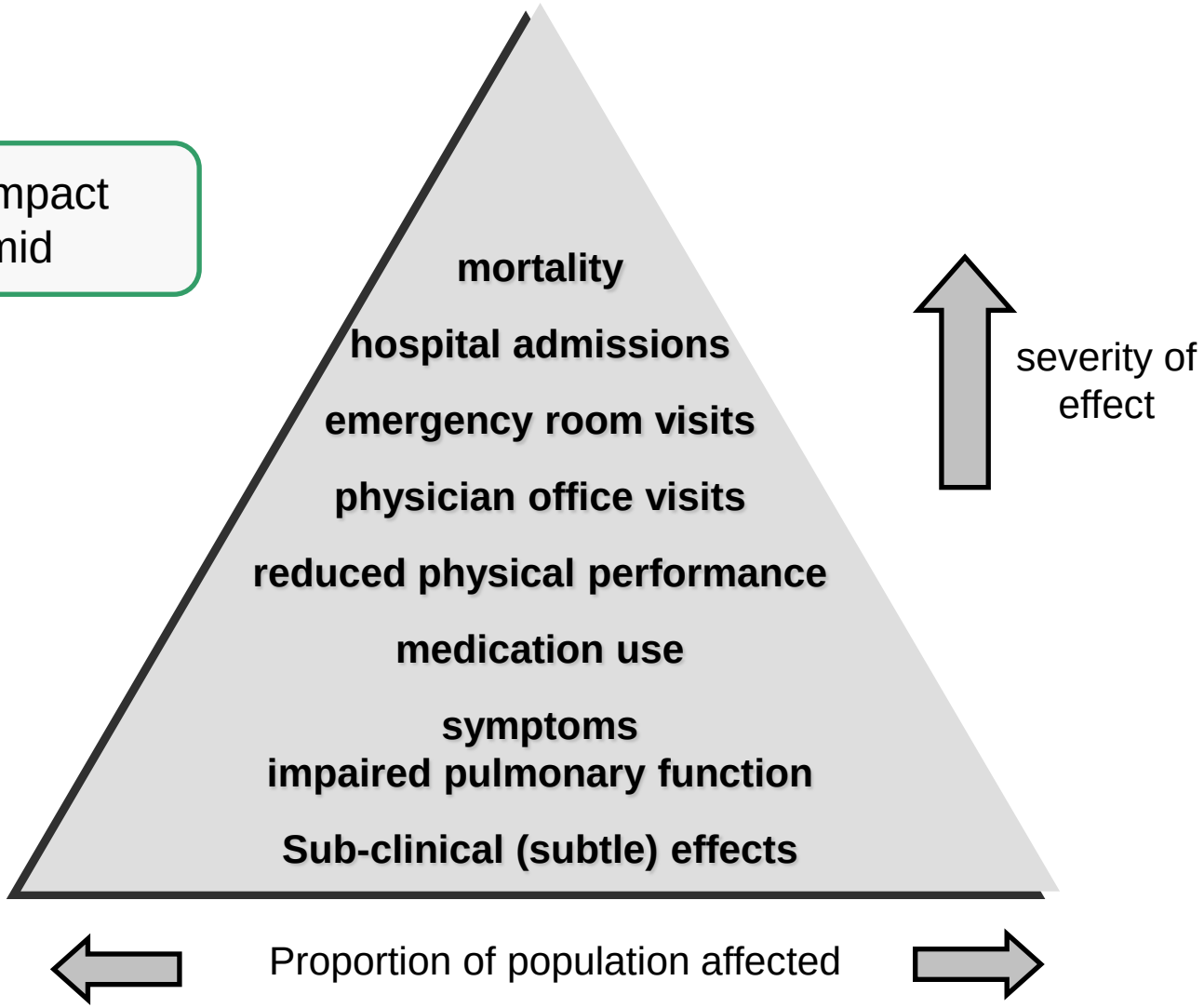


Pictures: Matthias Tesche, IfT

Source: Stefan Norra, KIT

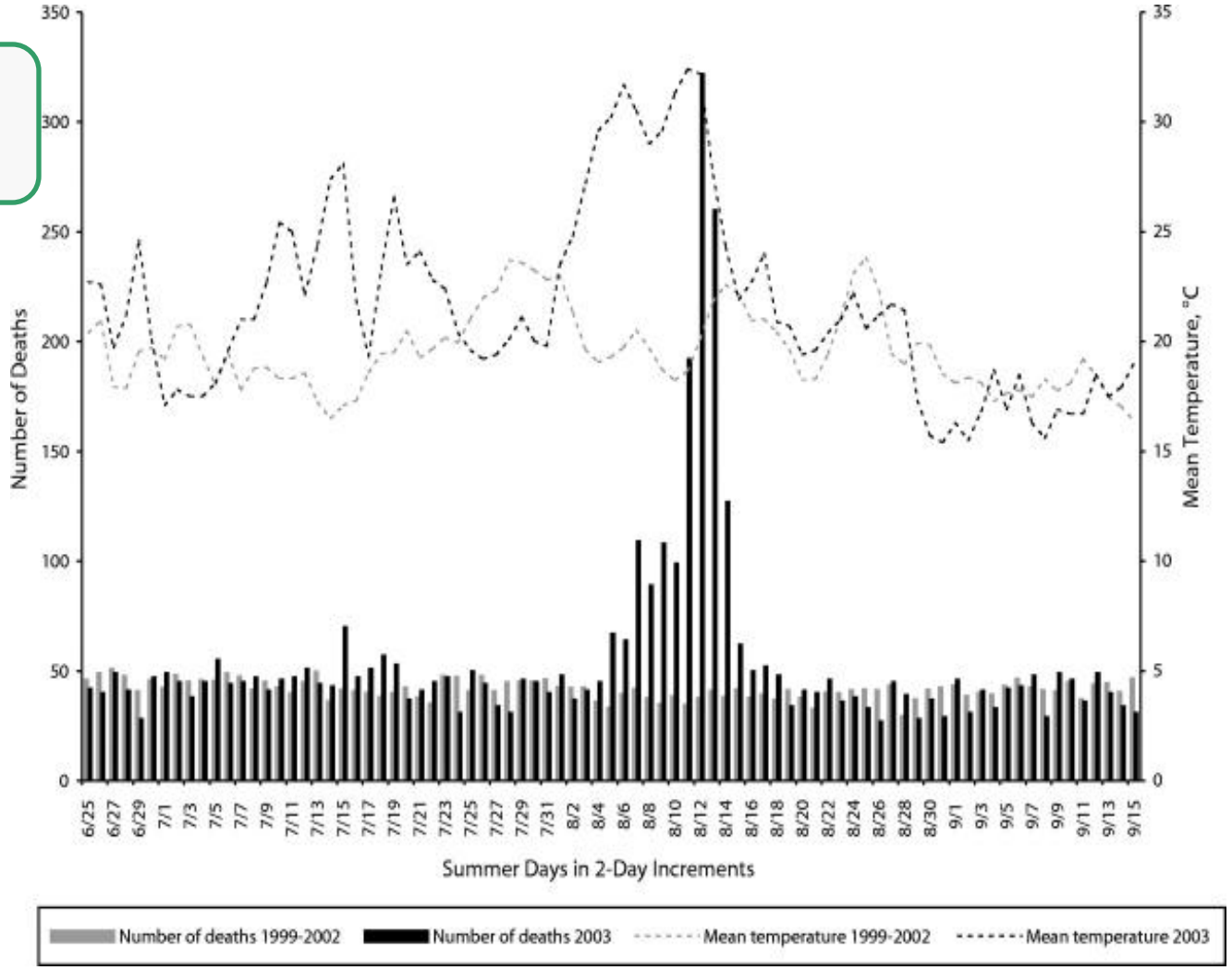
Driving Force: Health Impact

Health Impact Pyramid



Meteorology / Climate: Impact

Heat waves and mortality



Source: Vandentorren et al. 2004

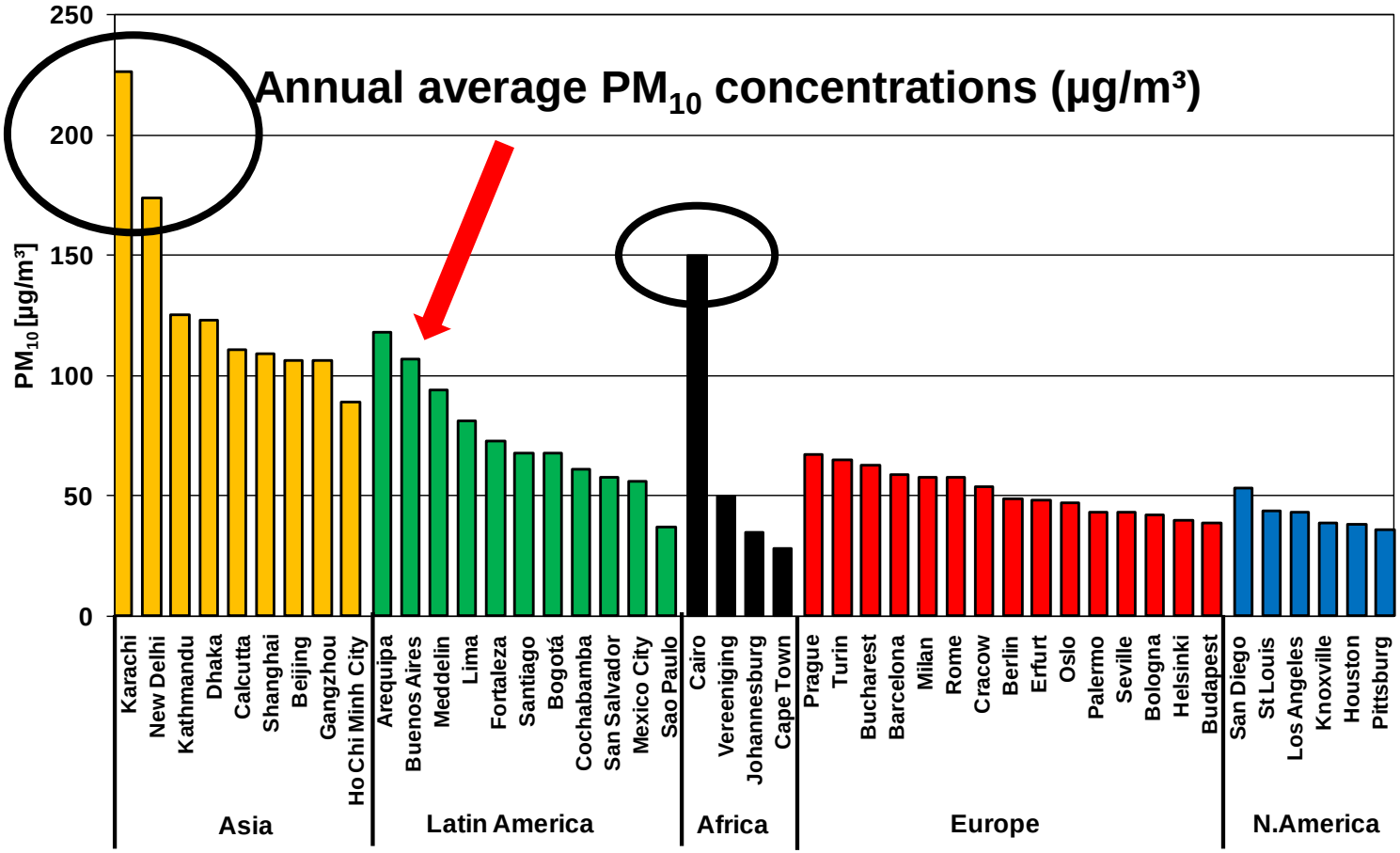
Mortality rates on PM_{10} increase

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

PAN American Health Organization, 2005

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

Economical Benefit



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

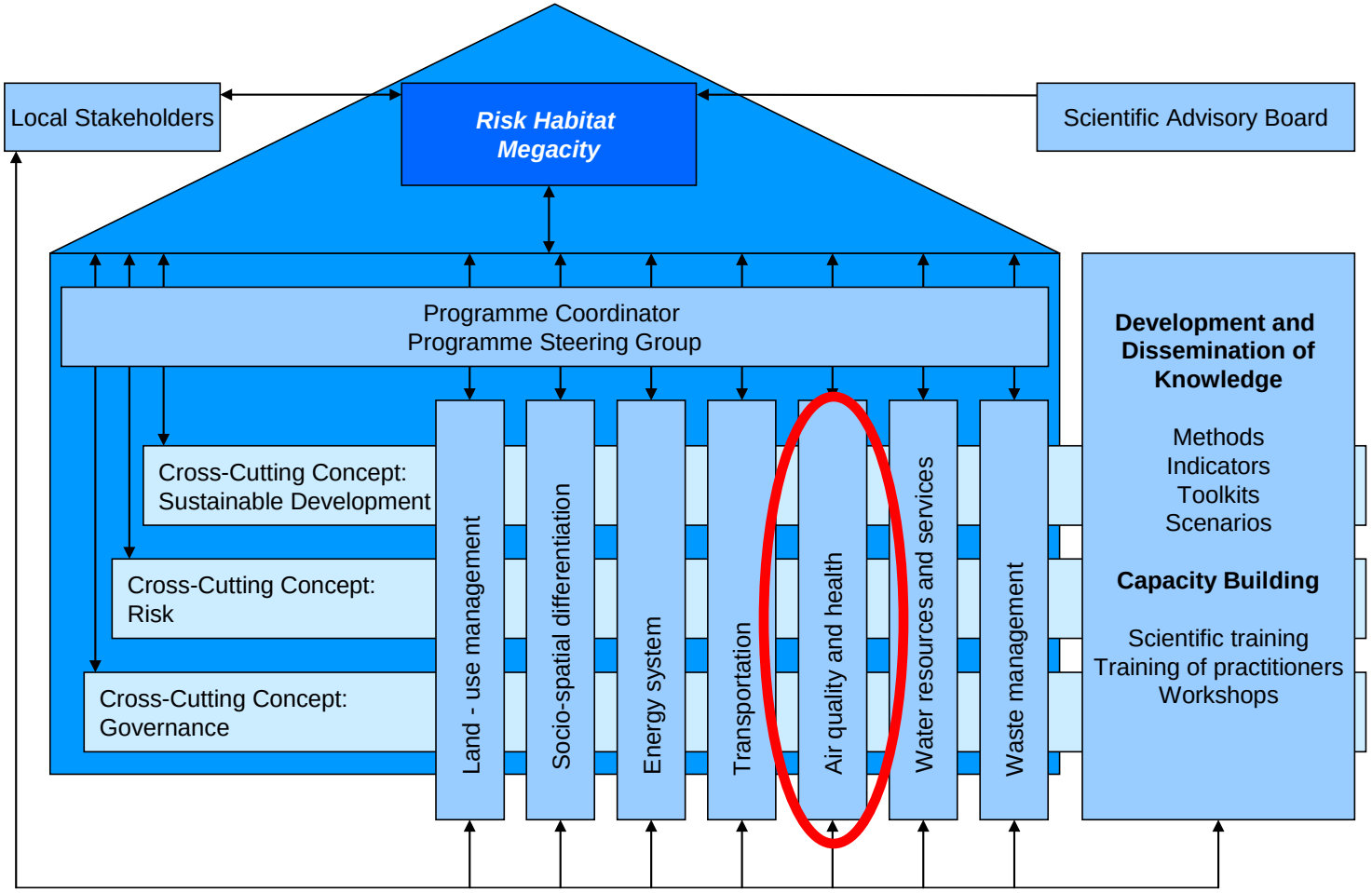
M. Krzyzanowski & H-G. Mucke, WHO
update by Jordan et al, CEPAL

Molina and Molina, 2002

Research needs…..

- **The complex chemical interactions of emission – transmission - air pollution - deposition / exposure need detailed investigations on the causal chain, e.g.**
  - **Source apportionment**
  - **Particle interaction / composition**
  - **Deposition rates / accumulation**
  - **(real) Exposure**
- **Circulation patterns → Regional-Urban interactions**
- **Climate Change Impact on these topics**
- **Only multidisciplinary approaches allow a holistic analysis**
- **….**

Research Project

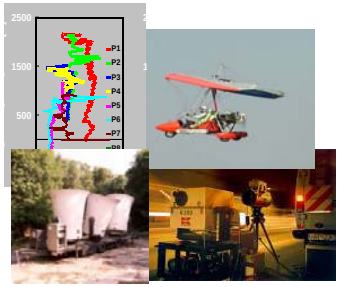


Risk Habitat Megacity
¿sostenibilidad en riesgo?

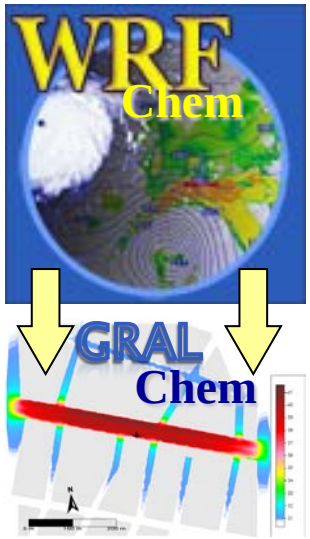
Integrated Approach

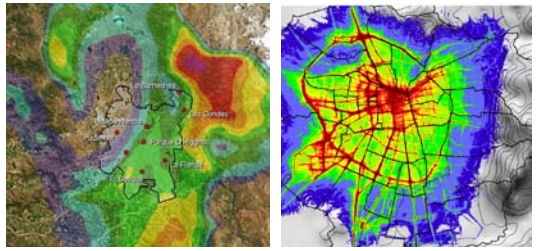
Urban Development

Measurement Data



Traffic Data

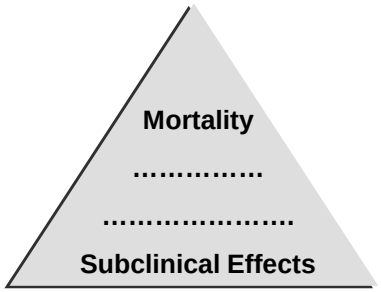




Air Quality

Scenario

Indicator



Health Impact

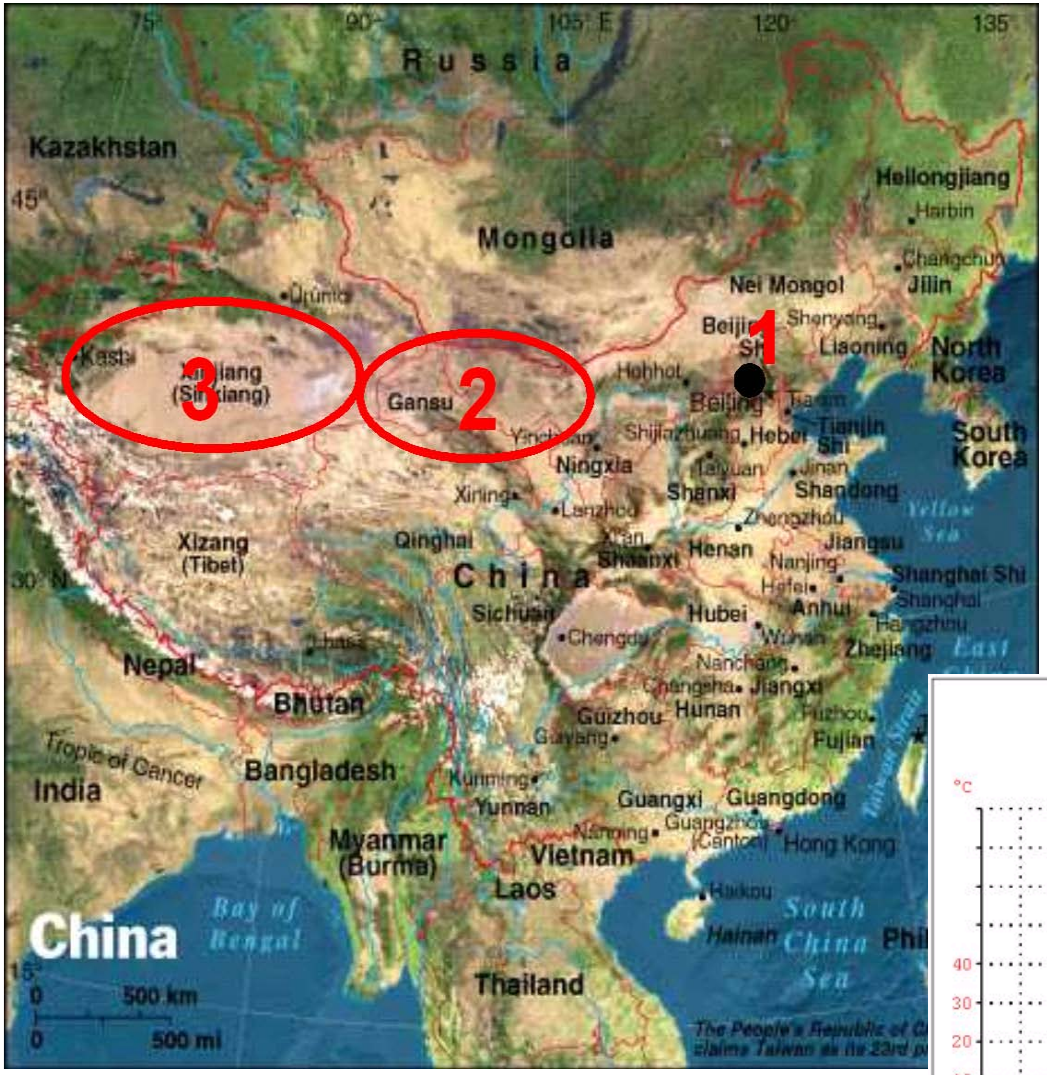
Stakeholder

Air Quality & Climate Change Approach

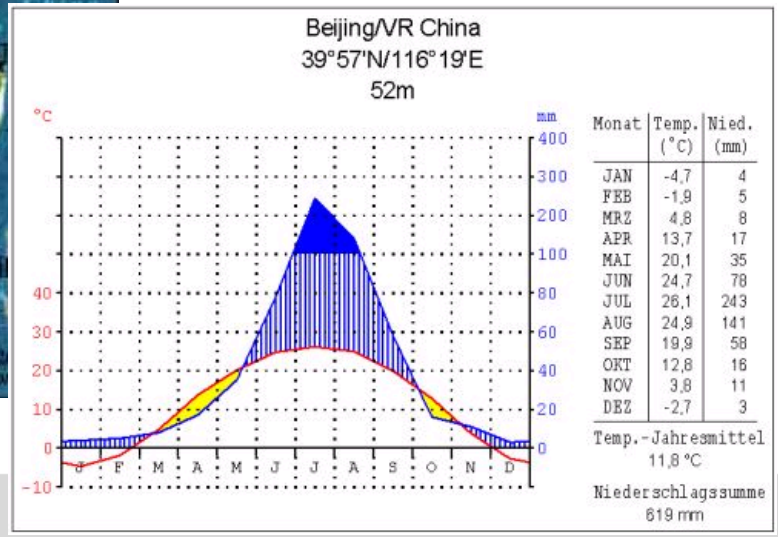
Impact on Air Quality

- Land use

Natural Land Use Change (Impact)



1: Beijing
2: Desert Gobi
3: Desert Takla Makan



Monat	Temp. (°C)	Nied. (mm)
JAN	-4,7	4
FEB	-1,9	5
MRZ	4,8	8
APR	13,7	17
MAI	20,1	35
JUN	24,7	78
JUL	26,1	243
AUG	24,9	141
SEP	19,9	58
OKT	12,8	16
NOV	3,8	11
DEZ	-2,7	3

Temp.-Jahresmittel 11,8 °C

Niederschlagssumme 619 mm

Source: Stefan Norra, KIT

Dust Storms

Beijing

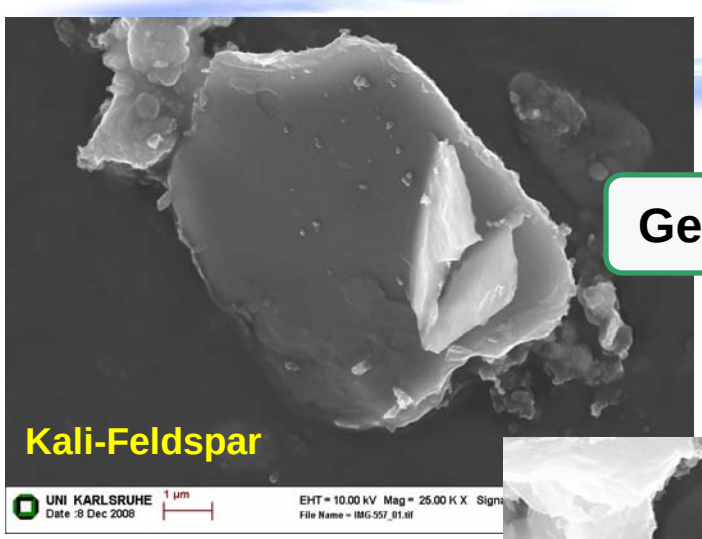
18.04.2006

Photos by Stefan Norra

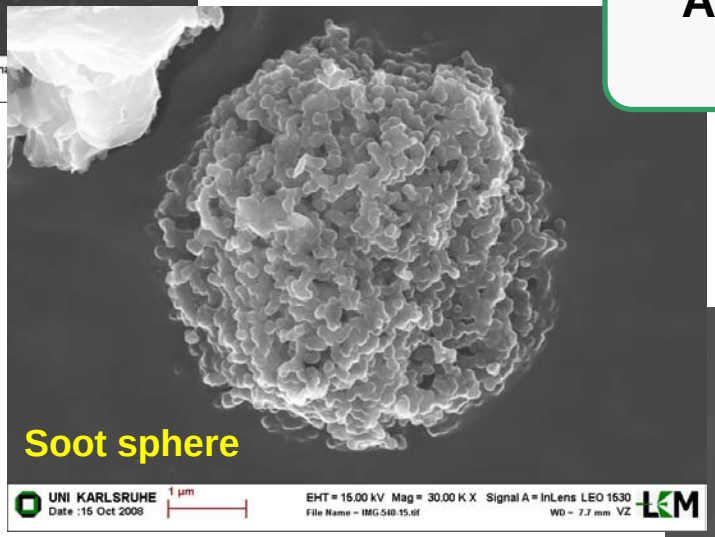
SEM Images

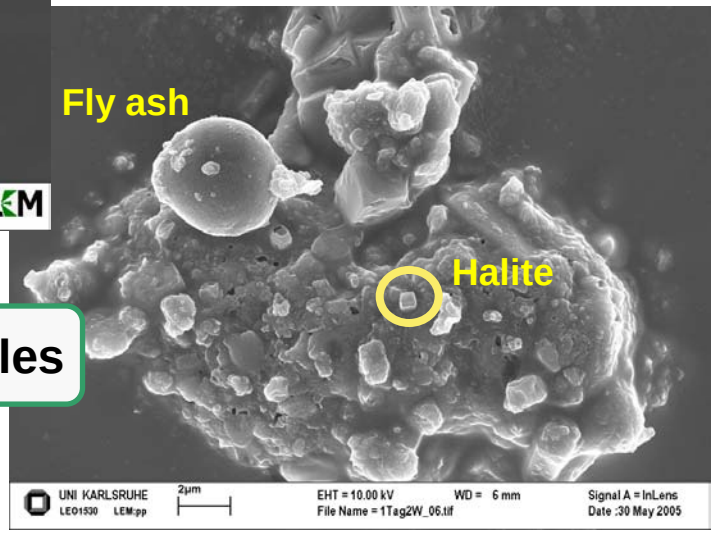
Karlsruhe Institute of Technology

Geogenic particles



Anthropogenic particles





Connected particles

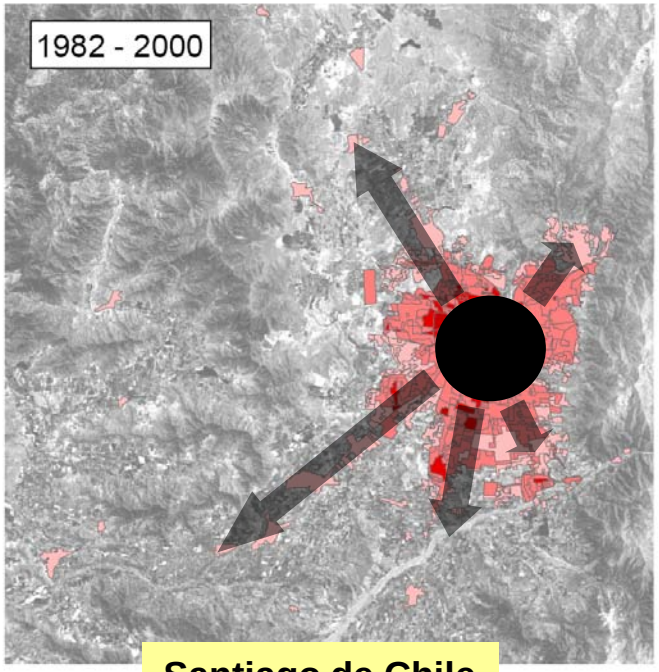
Source: Stefan Norra, KIT

Land Use Change

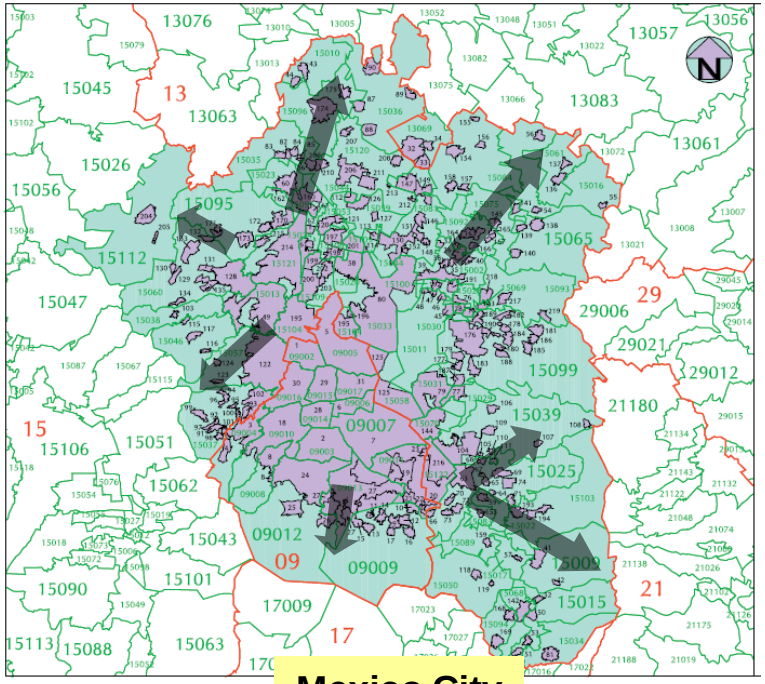
	Santiago de Chile 2002	Mexico City 2005
Population	6.061.000	19.410.000
Urbanized area (km²)	641	1800
Population density (p / km²)	9.500	10.800
Population growth (% / y)	~1,32	~1,28

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

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

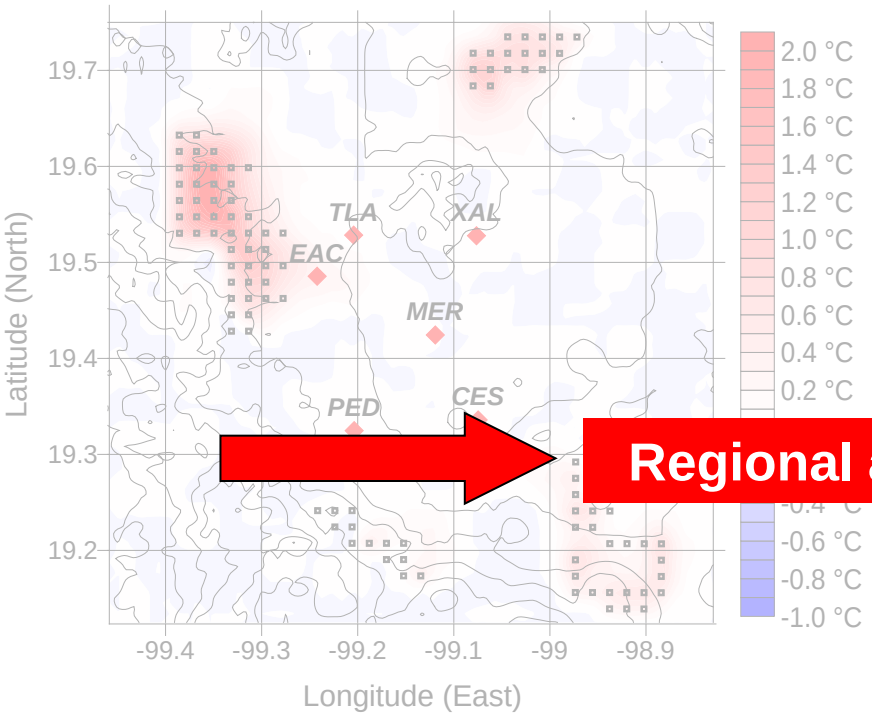


Santiago de Chile

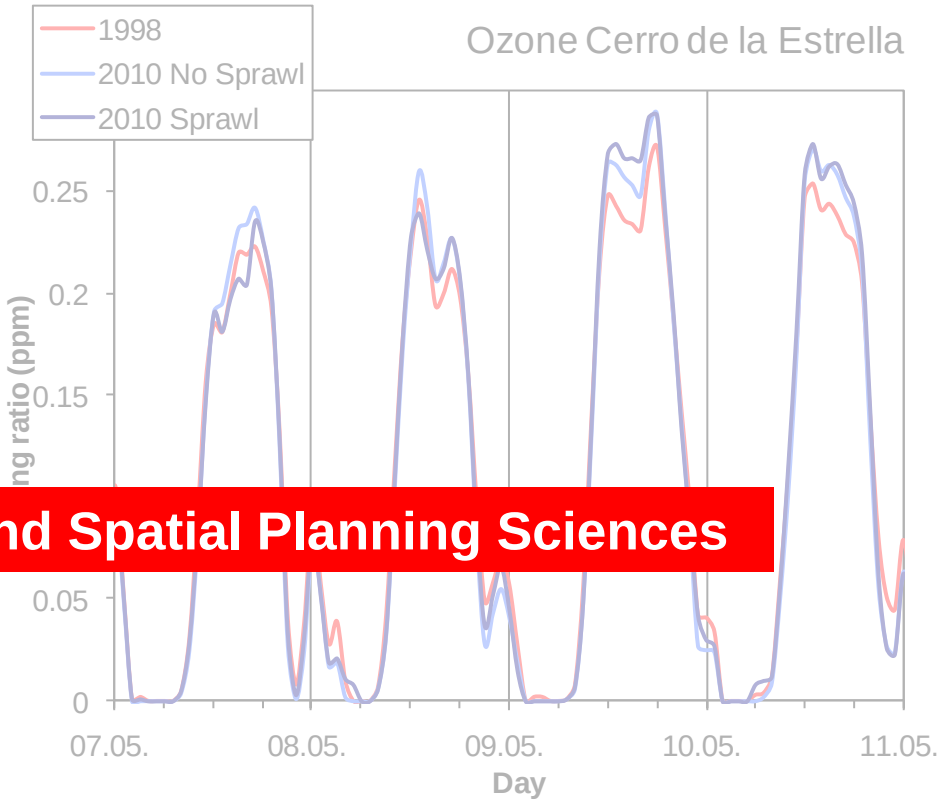


Mexico City

Effect of land use change



Temperature difference
with and without urban sprawl



Diurnal variation of ozone concentrations
considering land use change

Source: Renate Forkel (IMK-IFU)

Regional and Spatial Planning Sciences

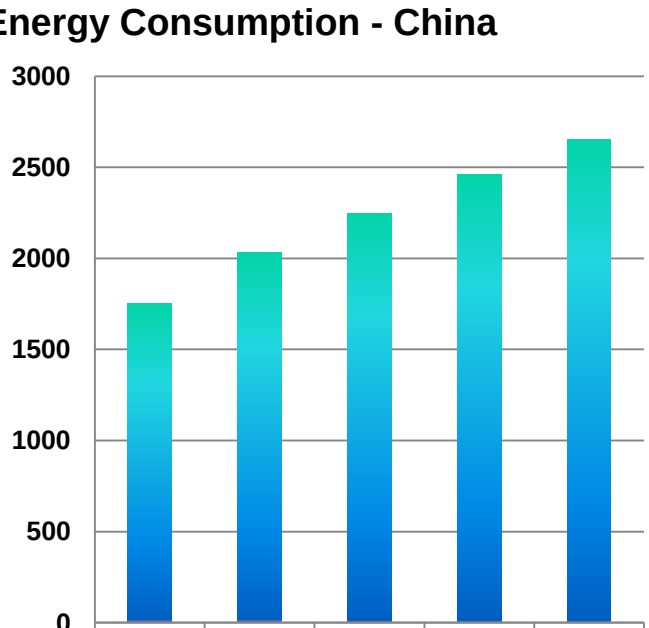
Impact on Air Quality

- Land use
- Energy

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%

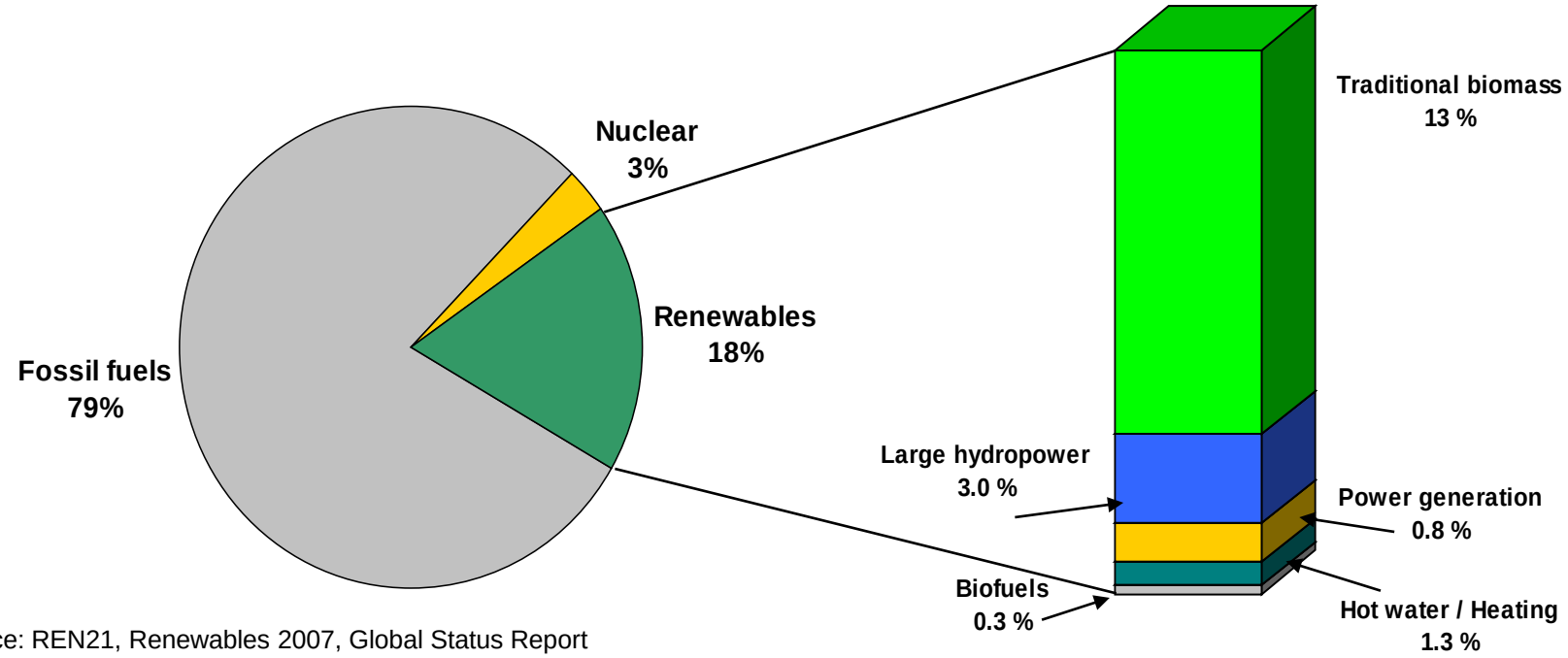


	2003	2004	2005	2006	2007
Total Energy Consumption [1 Mill. Tons CE]	1749.9	2032.227	2246.82	2462.7	2654.8
Growth Rates [%]	15.3	16.1	10.6	9.6	7.8

Source: APERC 2007, Shobhakar Dhakal (2004). Urban Energy Use and Greenhouse Gas Emissions in East Asian Megacities

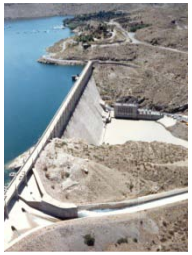
Source: China Statistical Abstract 2009

Global final energy consumption

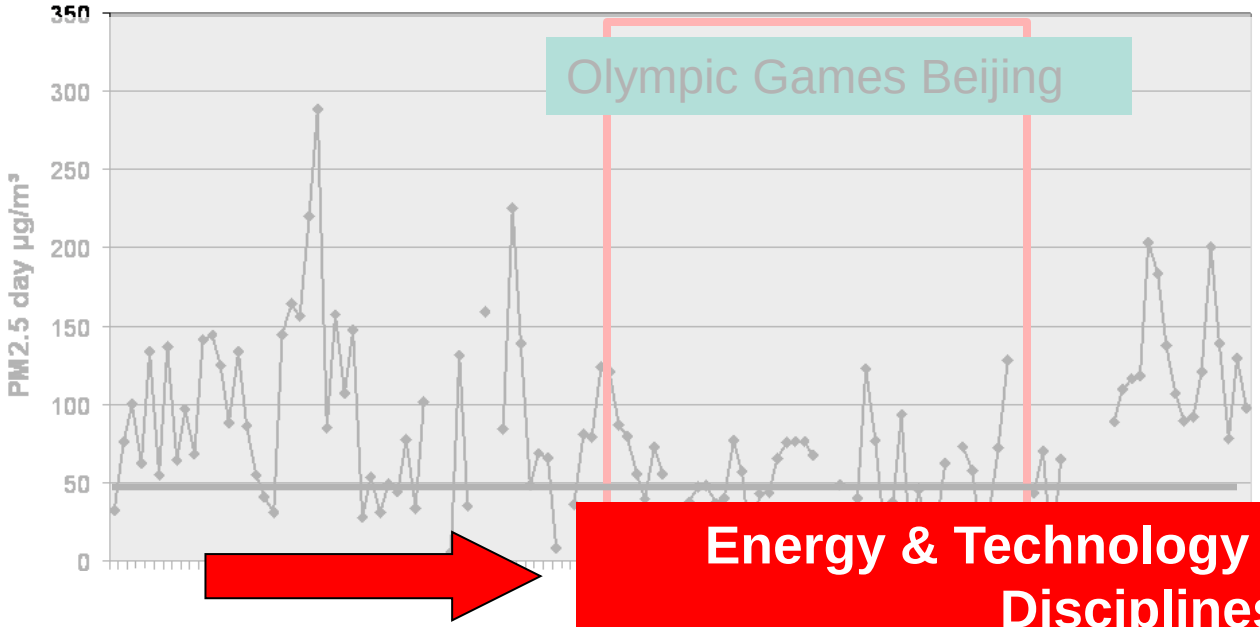


Source: REN21, Renewables 2007, Global Status Report



Emission Reduction Strategies



Energy & Technology Assessment Disciplines

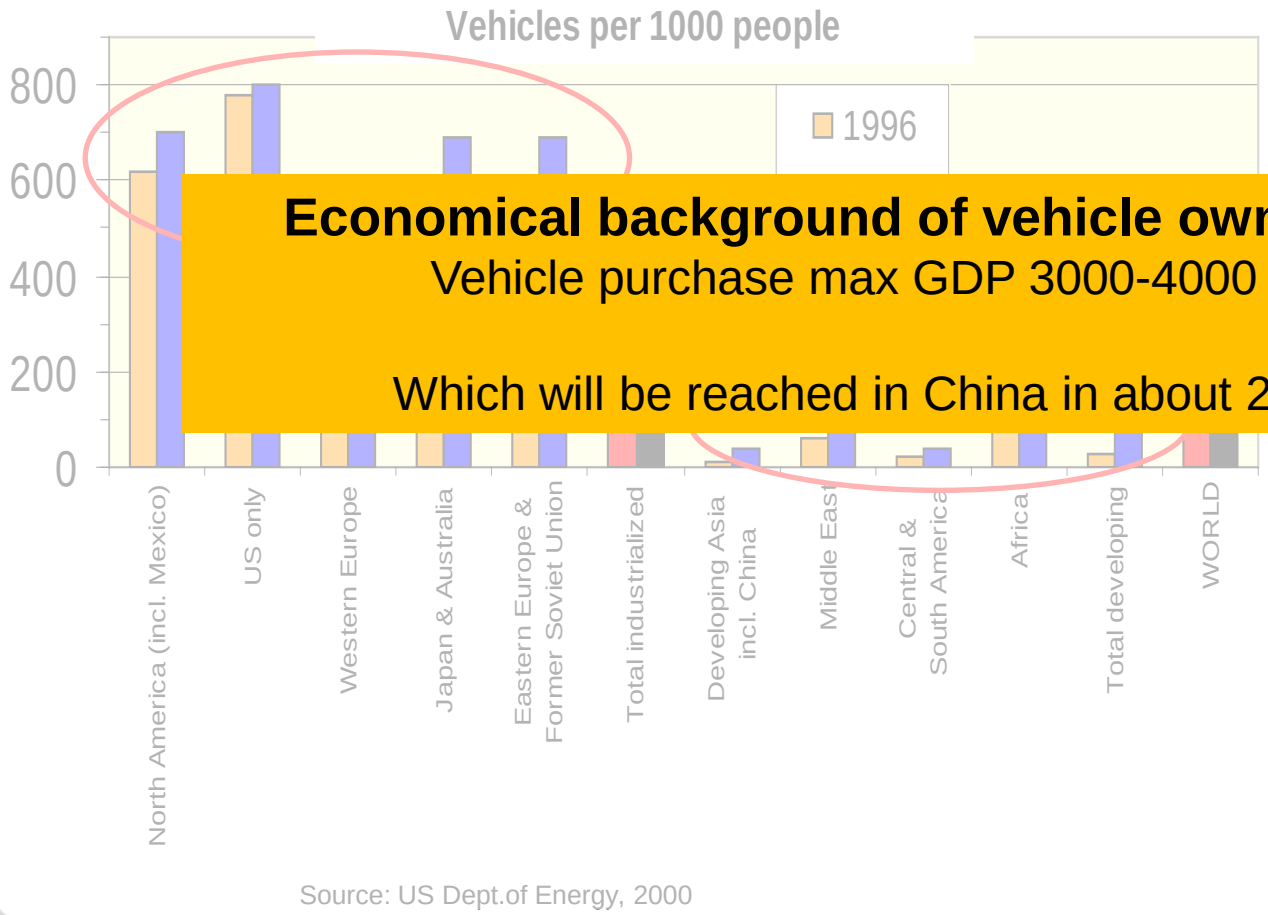
Time Period:
15.10.2007 – 01.02.2009

Source: Stefan Norra, KIT

Impact on Air Quality

- Land use
- Energy
- Mobility

Traffic



Economical background of vehicle ownership

Vehicle purchase max GDP 3000-4000 $

Which will be reached in China in about 20 y

Traffic Volume in 1996 and 2020

Source: US Dept.of Energy, 2000

Measurements

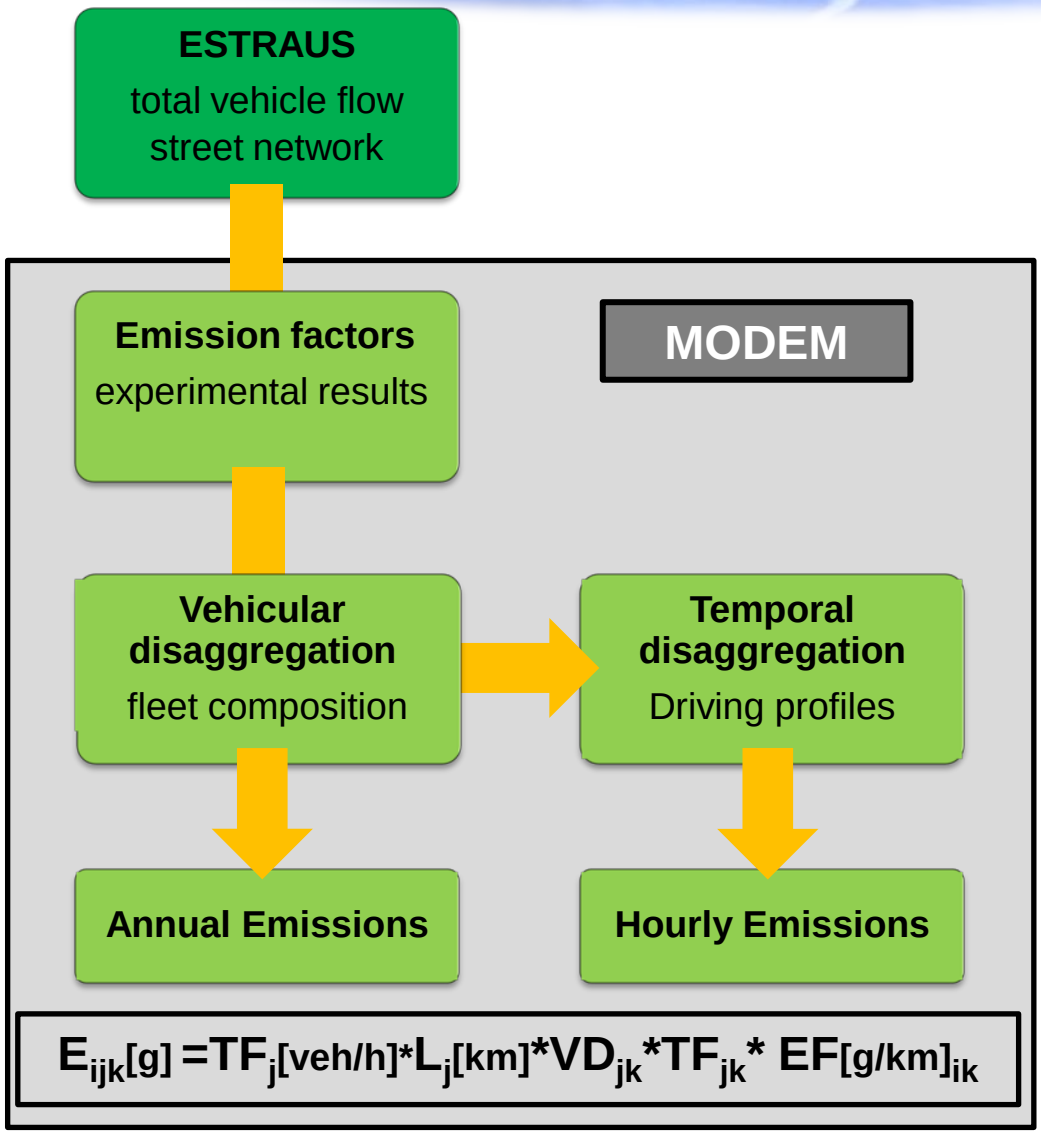
Measurement sites: LAPC tower, ceilometer, DOAS

Optical remote sensing:
Ceilometer
Vaisala LD40
wave length: 855 nm
range: 4000 m
Resolution: 15 m

Particle concentrations ($PM_{2.5}$) on 8 m and 80 m altitude at 325 m LAPC tower

Source: Klaus Schäfer, IMK-IFU

Traffic & Emission Modelling: Santiago



61 vehicle categories

Buses licitados Diesel convencional
Buses licitados Diesel tipo 1
Buses licitados Diesel tipo 2
Buses licitados Diesel tipo 3
Buses licitados DIesel tipo 3 Articulando
Buses licitados Diesel tipo 2 con filtro
Buses licitados Diesel tipo 3 con filtro
Buses Interurbanos Diesel convencional
Buses Interurbanos Diesel tipo 1
Buses Alimentador Diesel tipo 2
Buses Alimentador Diesel tipo 3
Buses Alimentador Diesel tipo 3 con filtro
.....

5 categories of emissions

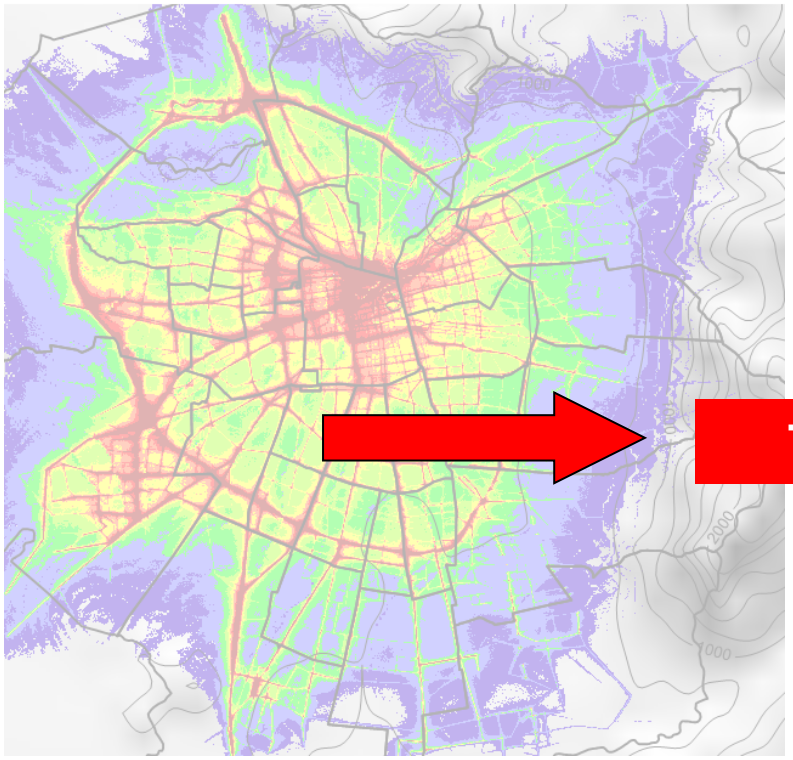
cold emissions
hot emissions
evaporation
resuspension (→ abrasion tyres, abrasion brakes)

6 emission pollutants

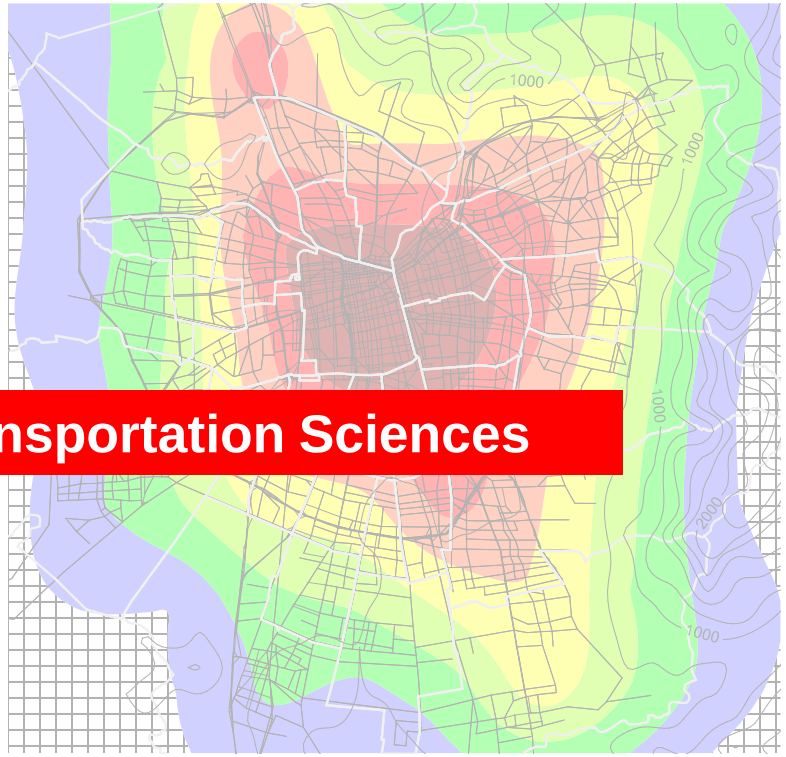
PM10
SO2
NOx
HC
CO
CO2
[Gasoline consumption]

Input data for the simulation of traffic emissions

Coupling of Scales



Transportation Sciences

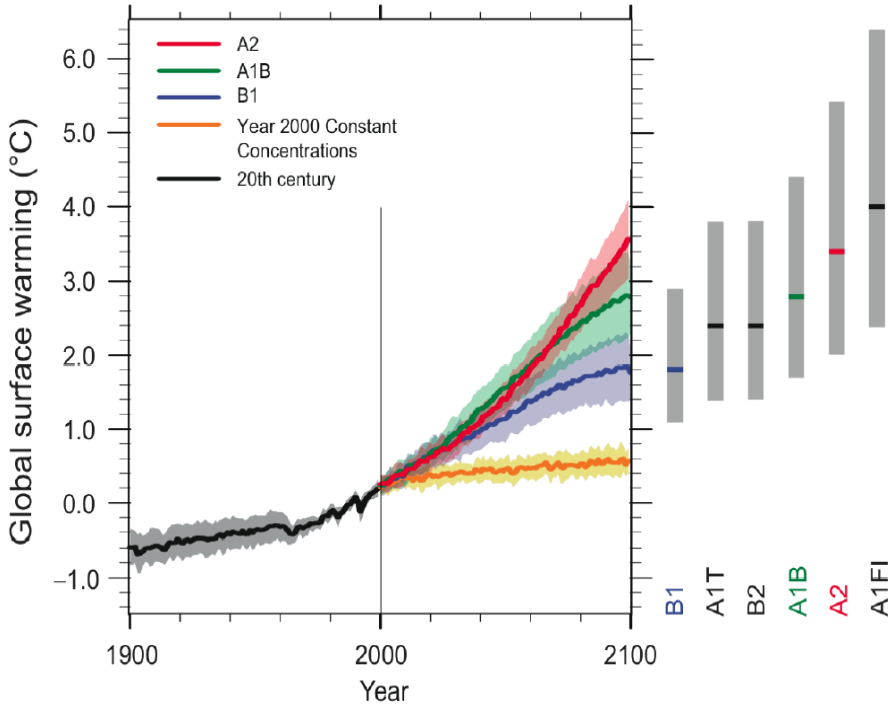


Micro-scale modelling
e.g. NO_x with GRAL

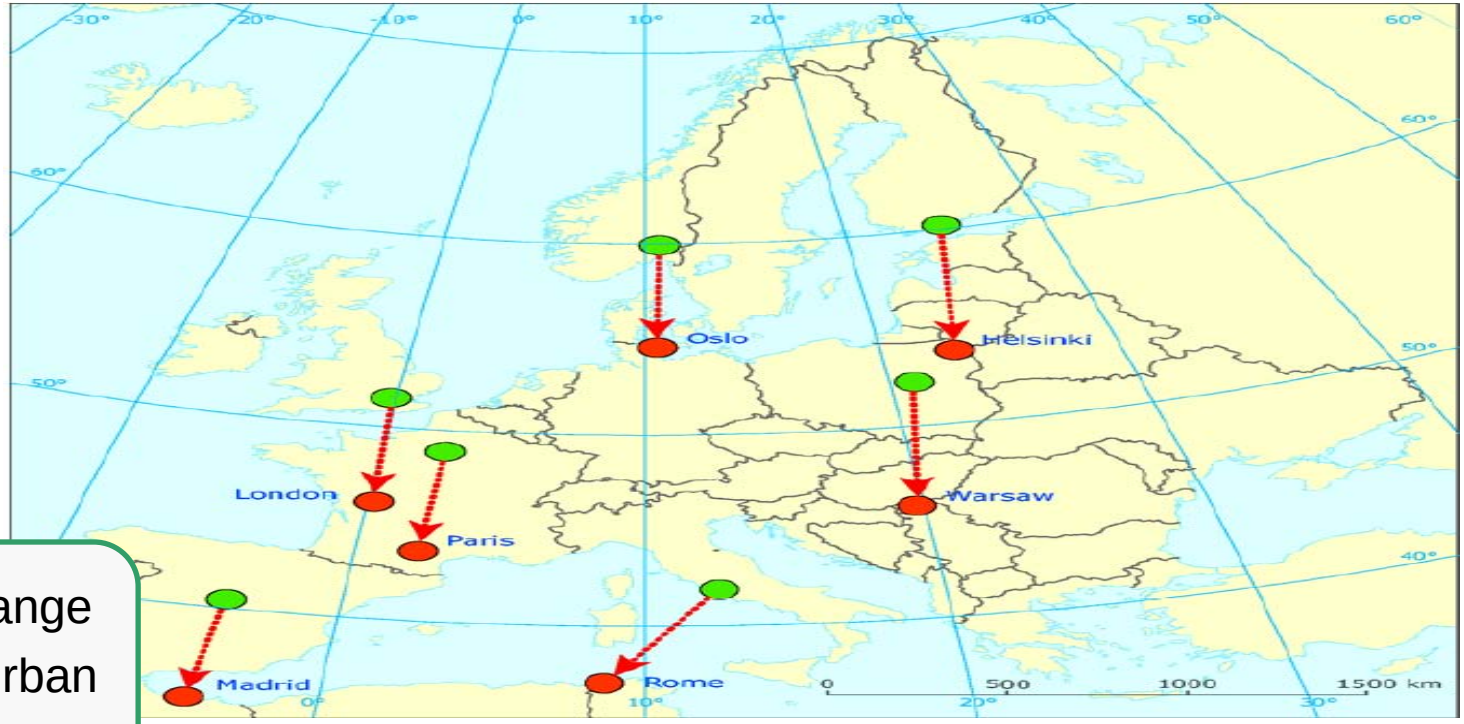
Meso-scale modeling e.g.
NO_2 with WRF/chem

Impact on Air Quality

- Land use
- Energy
- Mobility
- Climate Change



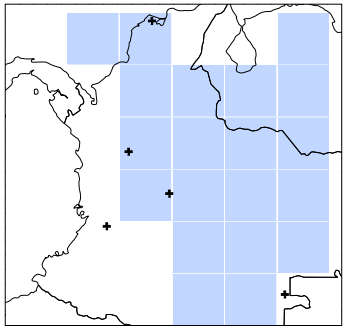
Consequences of Climate Change



Climate Change Impact on Urban Agglomerations

Kamal-Chaoui, Lamia and Alexis Robert (eds.) (2009), “Competitive Cities and Climate Change”, OECD. Regional Development Working Papers N° 2, 2009, OECD publishing.

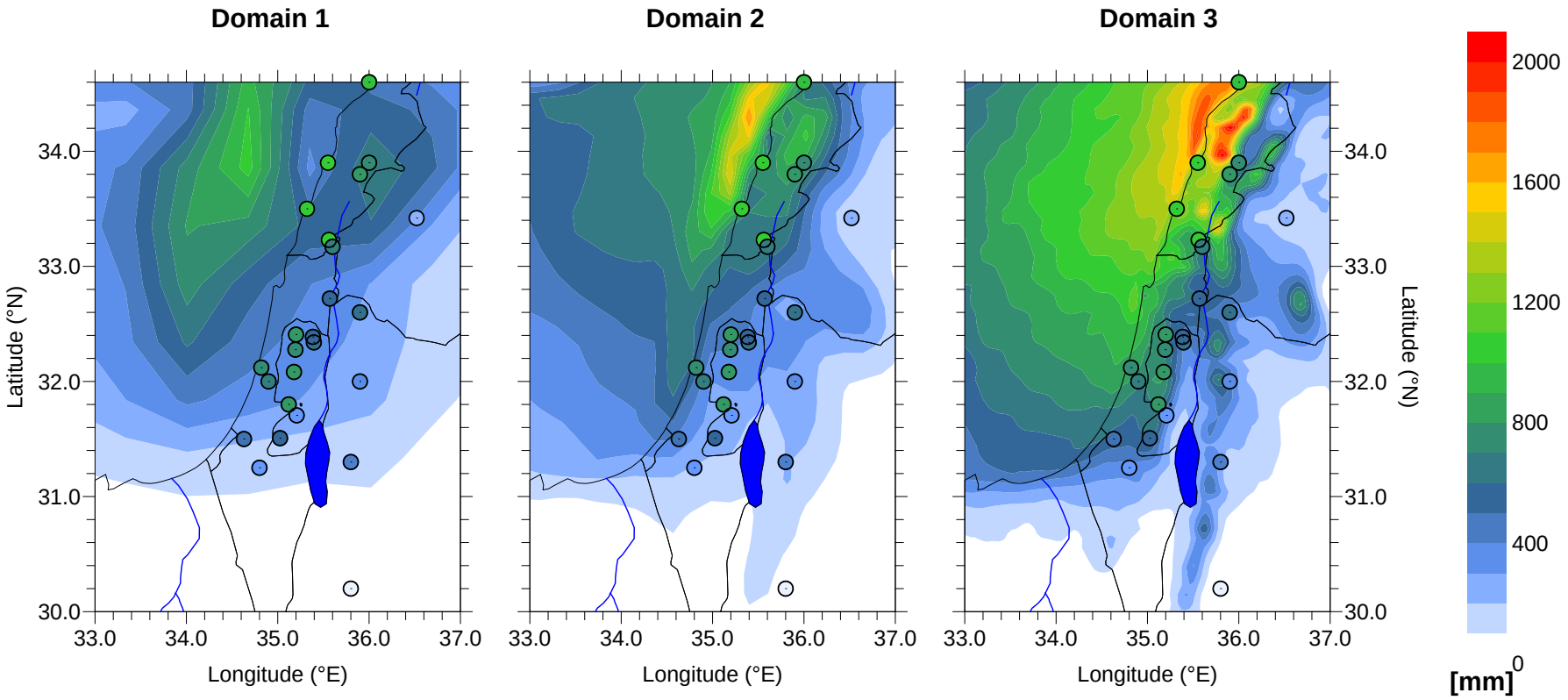
Climate Change



Climate Change
Impact on Urban
Agglomerations

Resolution too coarse for regional impact analysis !

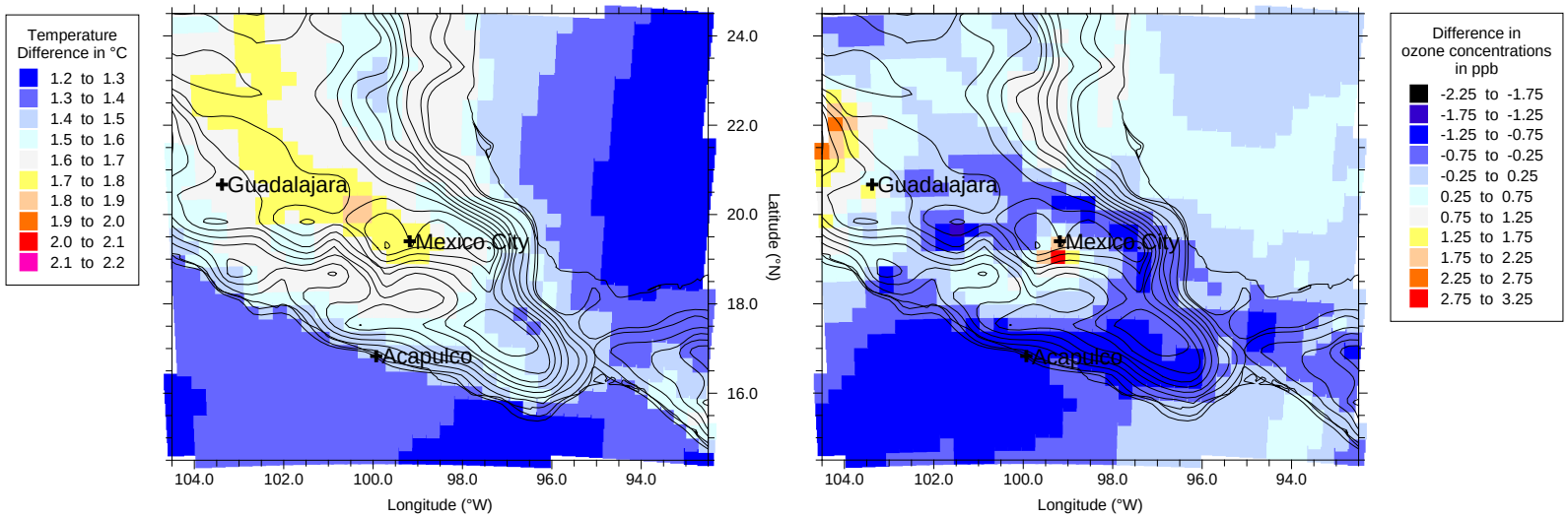
Dynamical Downscaling



Yearly Mean Precipitation 1961-1975

Validation of the simulation results by comparing simulated observed precipitation

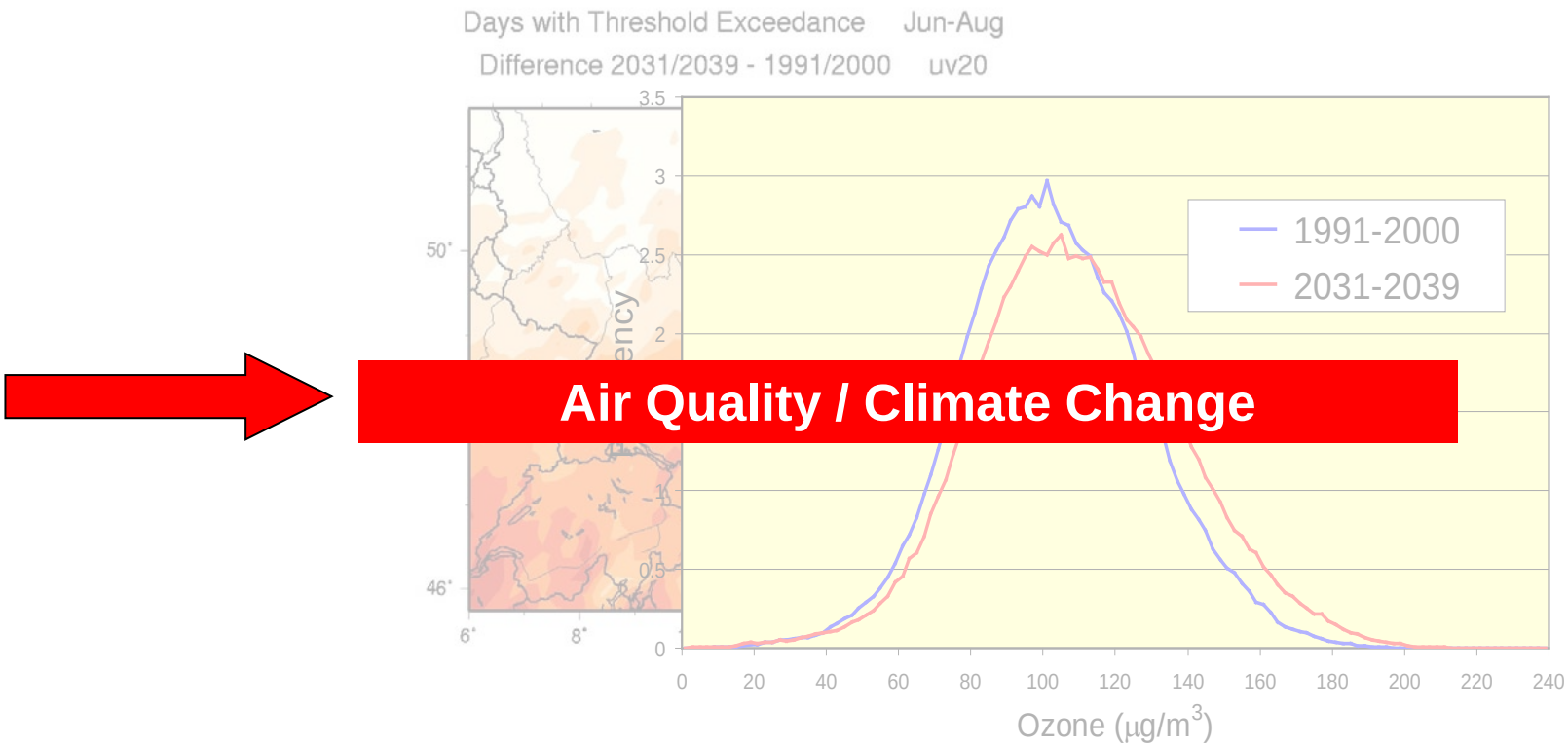
Regional Climate Change Impact



High resolution climate-chemistry simulations
- Mexico -

Source: Renate Forkel (IMK-IFU)

Regional Climate Change Impact



Air Quality / Climate Change

Threshold exceedances in the future

Distribution of daily O_3 maximum

Source: R. Forkel (IMK-IFU)

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

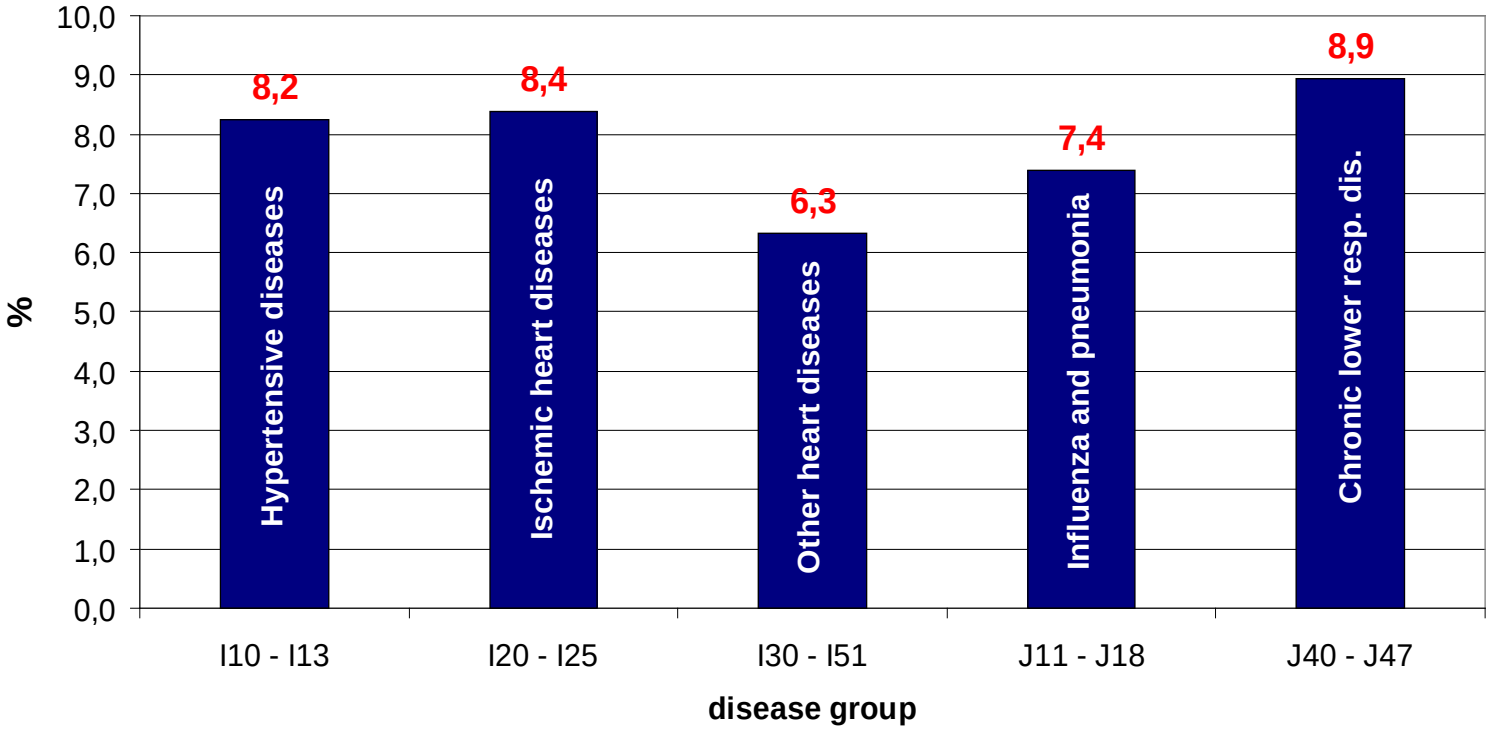
Impact on Air Quality

- Land use
- Energy
- Mobility
- Climate Change

- Air Quality
- **Health Impact**

Integrated Approach

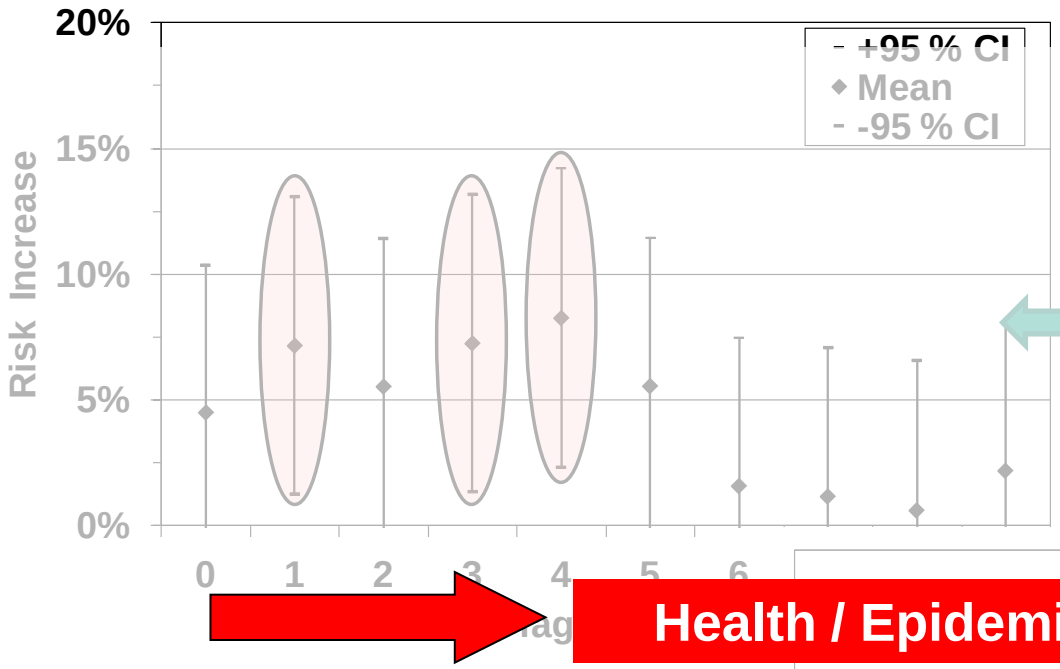
Adverse Health Effects: Santiago



Source: Ulrich Franck, UFZ

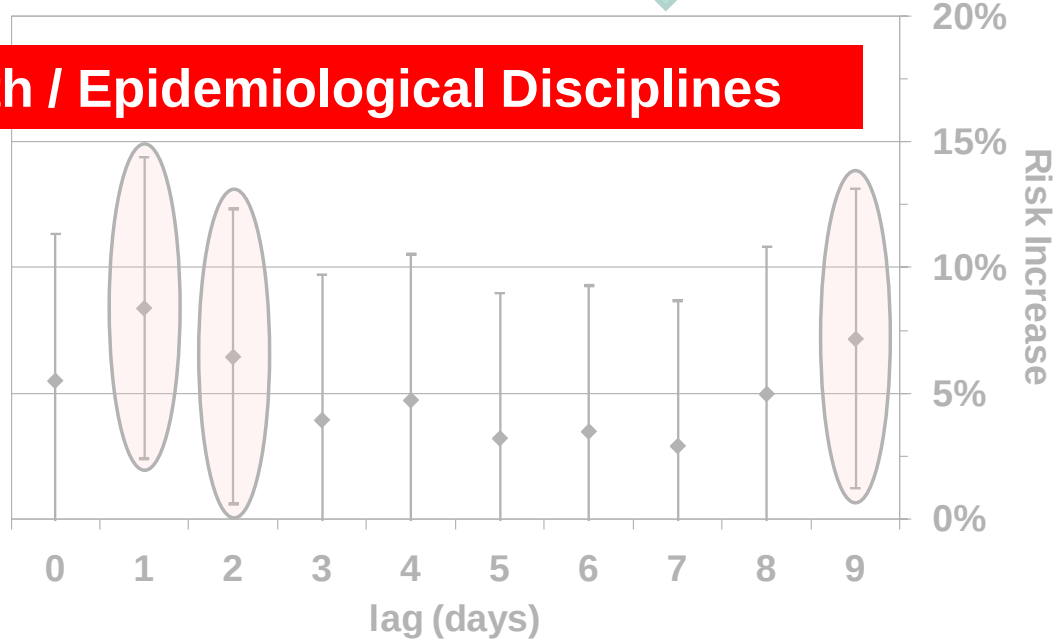
Maximum Mortality Risks per 10 µg/m³ PM_{10}

Adverse health effects of PM_{10} in 2006



Lagged risk increase per 10 µg/m³ PM10 for hypertensive (left) and ischemic heart diseases (below).

Health / Epidemiological Disciplines



Source: Ulrich Franck, UFZ

Conclusions

- Air quality & Climate Change issues need an holistic and multidisciplinary 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, climate change impact, congestion, waste, ...)
  - social risks (spatial segregation, health problems, …)
  - costs (healthcare system, transportation, production, ...)

Muchas Gracias por su atención

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