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

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Overview

- ✓ Problems and Facts
- ✓ Interdisciplinary Research
- ✓ Regional Climate Change Modeling
- ✓ Human Health Impact
- ✓ Conclusions

Some urban facts (I)

- 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
- India is different: by 2030 40% of the country's total projected population (590 million) will live in cities
- Urban agglomerations in China increased from 19.6 % to 40.5 % (between 1980-2005)

Some urban facts (II)

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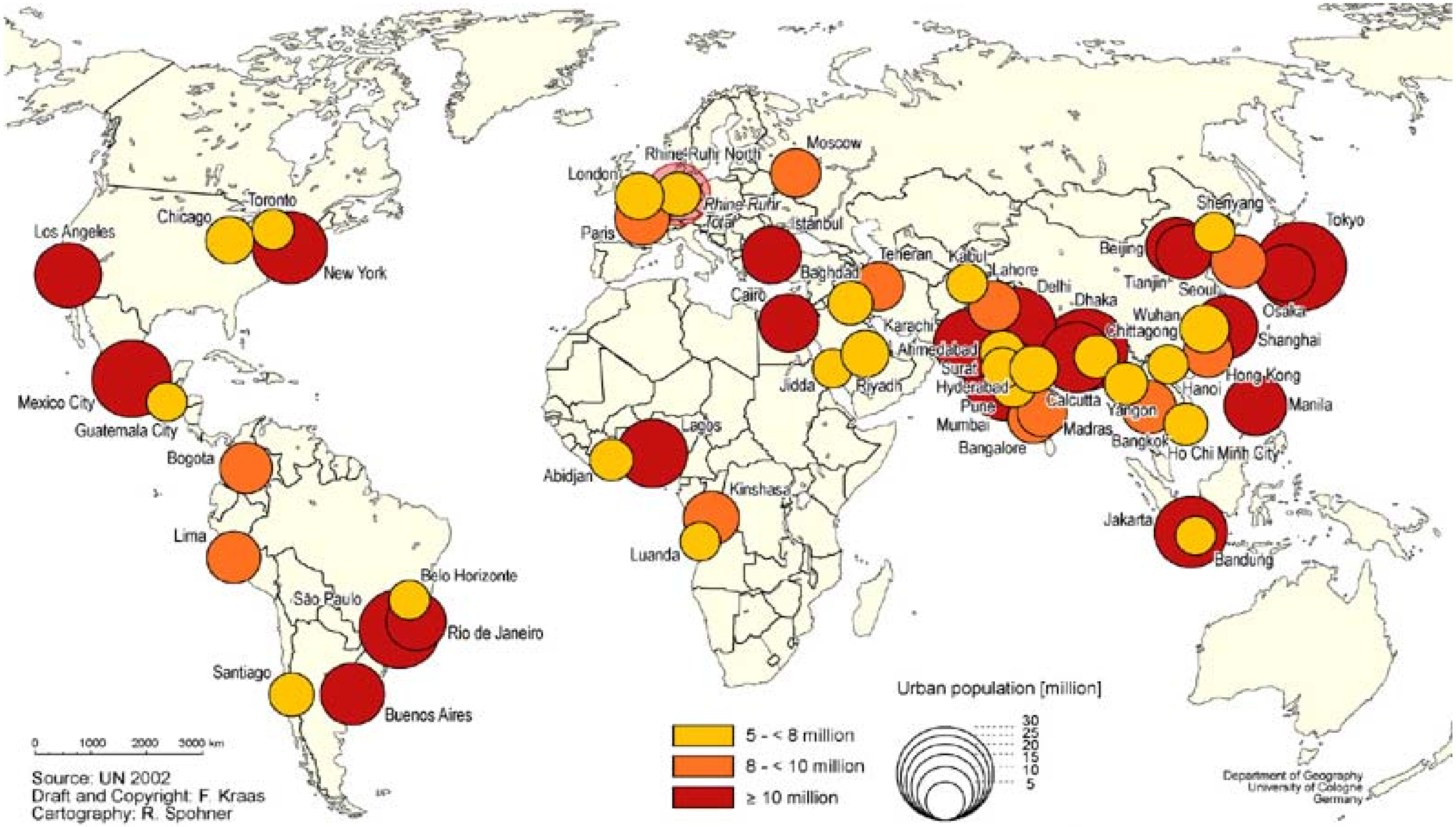
- Chinas cities produce about 65 % of the GDP
- Indian cities will account for nearly 58% of the GDP in 2008 and 70% in 2030
- 170 cities in China have more than 1 Mill. inhabitants
- In 2030 India will have 68 "million-plus" cities, 13 "four million-plus" cities and six megacities of over 10 million population (McKinsey)
- Peak vehicular densities are likely to reach as high as 330 vehicles per lane kilometers. At such densities, an average journey may take up to five hours in peak morning traffic. (Source: McKinsey report)
- Per capita water supply could drop from 105 litres currently to 65 in 2030

Geographical Situation



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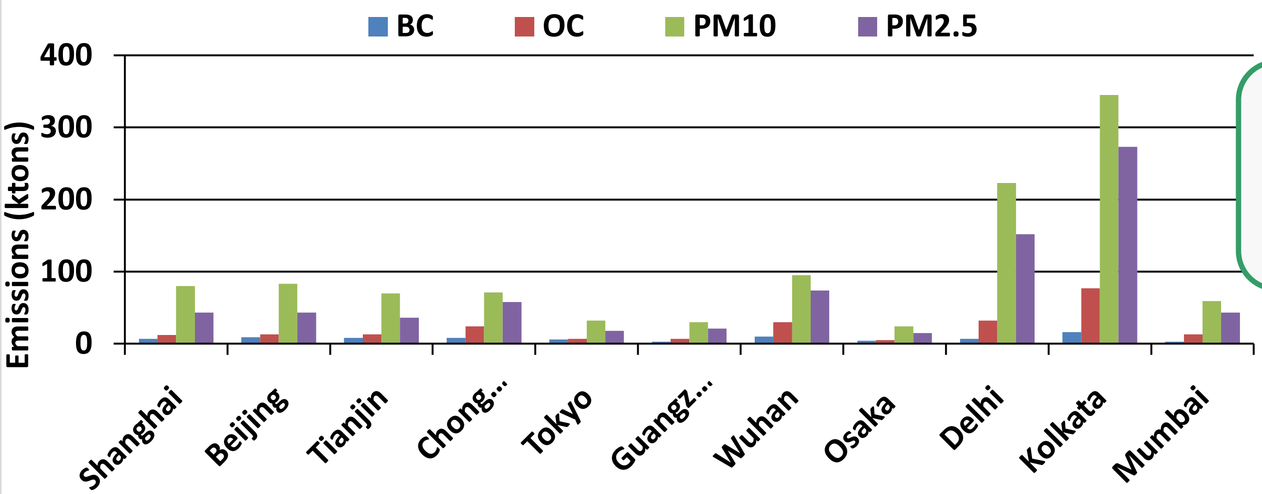
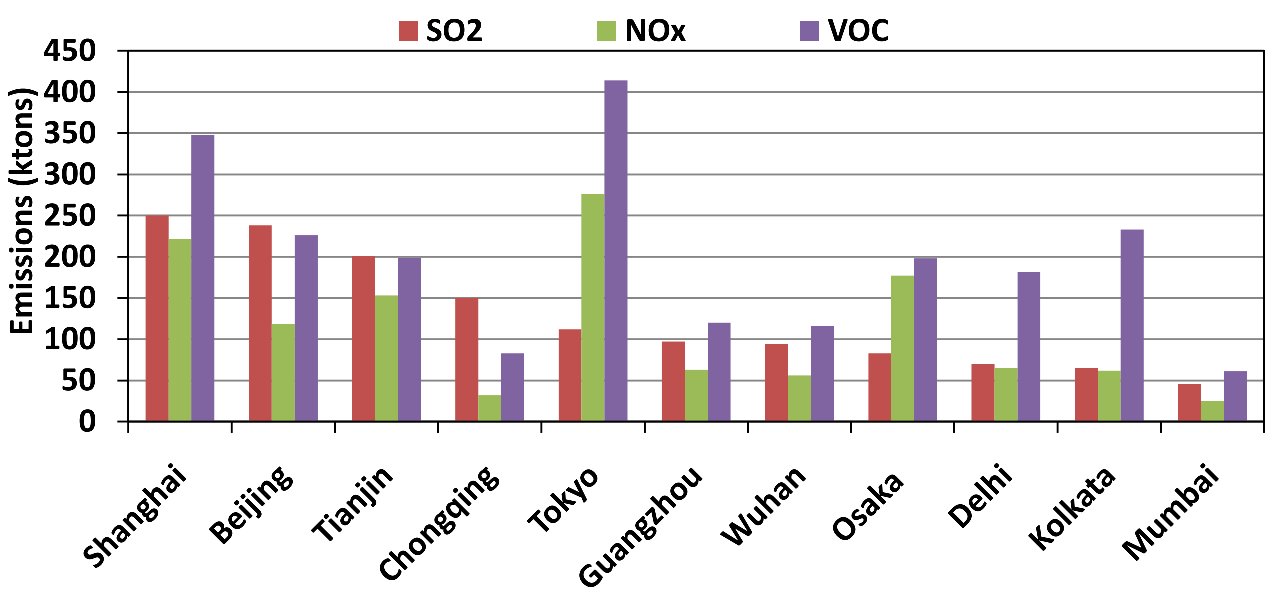
Anthropogenic Emissions



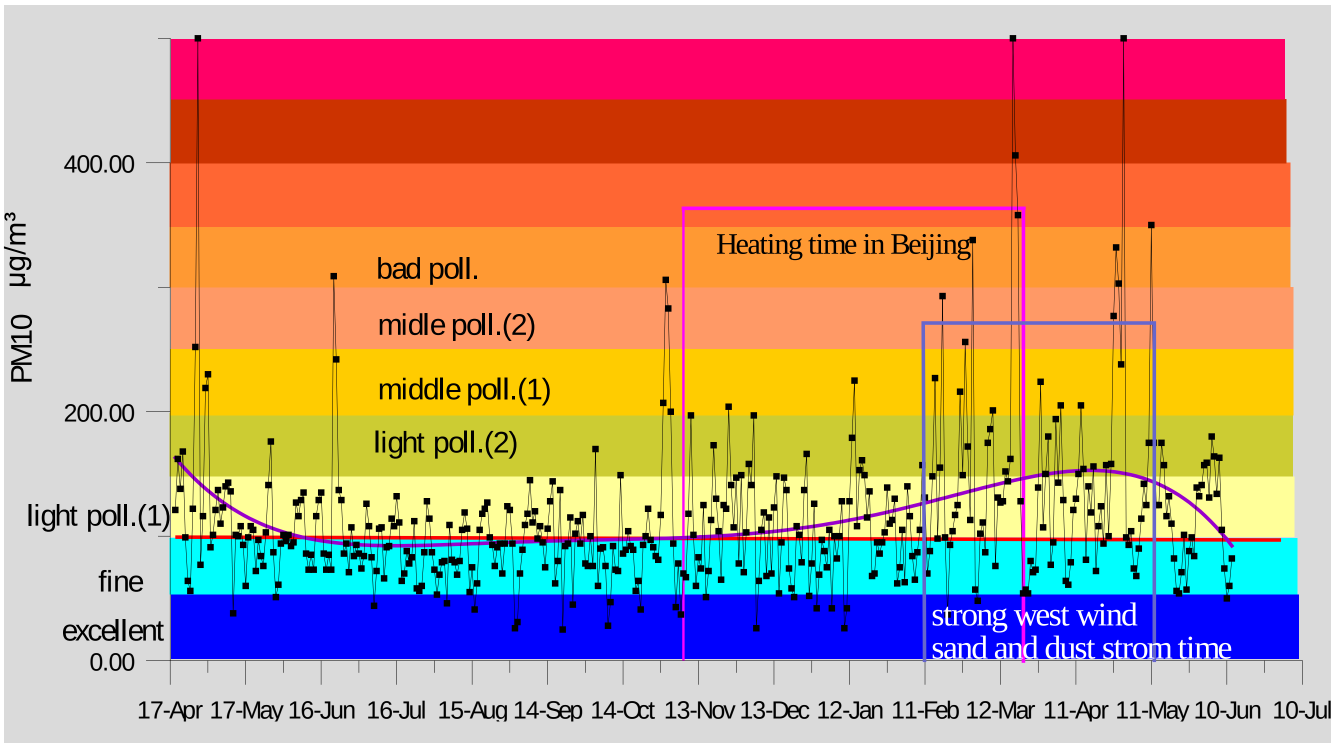
Emissions from megacities of China, Japan, India (2000)

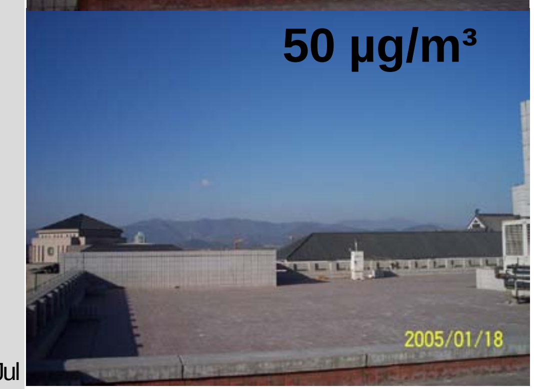


Guttikunda et al. Impact of Asian megacity emissions on regional air quality during Spring 2001

Aerosol Pollution

Beijing





Pictures: Matthias Tesche, IfT

Stefan Norra
Institute of Mineralogy and Geochemistry (IMG) of KIT

Atmospheric Brown Clouds (ABC)

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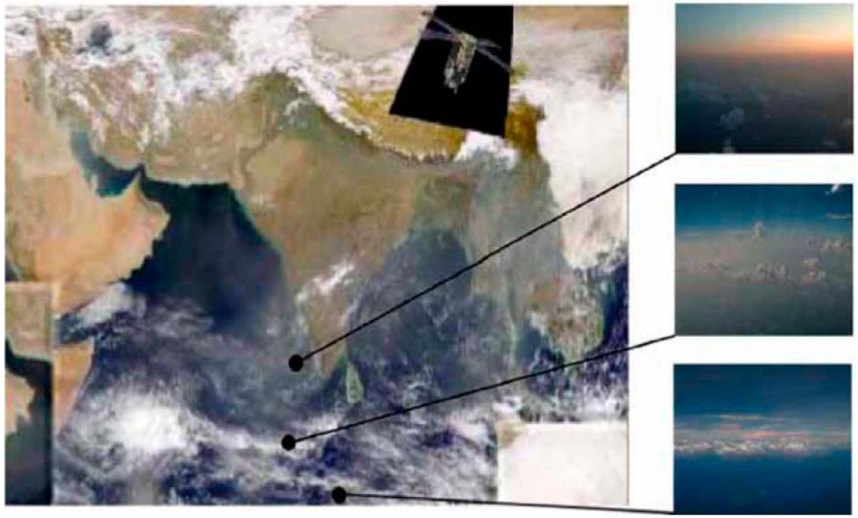
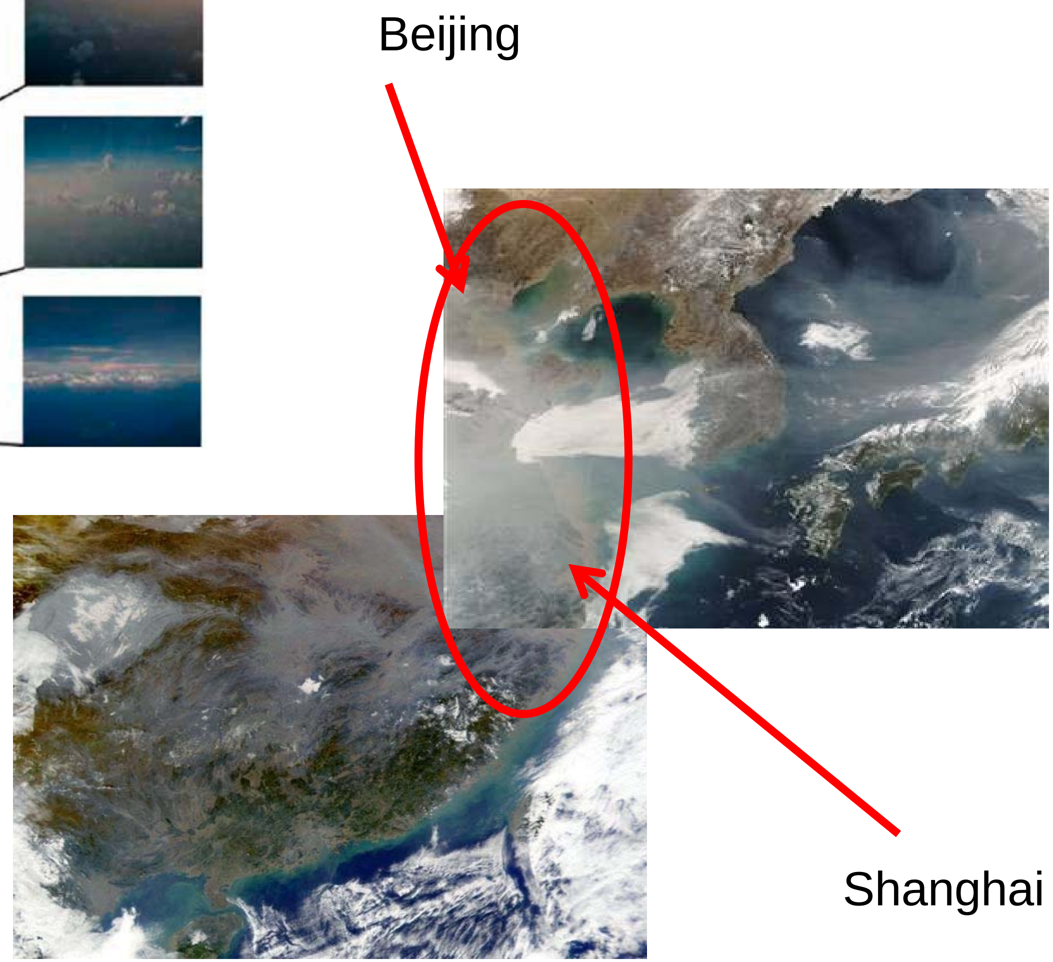
- Around 13 megacities have been identified as ABC hotpots: **Bangkok, Beijing, Cairo, Dhaka, Karachi, Kolkata, Lagos, Mumbai, New Delhi, Seoul, Shanghai, Shenzhen and Tehran**
- Soot levels are 10% of the total mass of anthropogenic particles
- Overall effect of ABCs is to make 'hot spot' cities darker or dimmer (10-25 %)
- For India as a whole, the dimming trend has been running at about 2% per decade between 1960 and 2000 - more than doubling between 1980 and 2004
- In China the observed dimming trend from 1950s to 1990s was about 3-4% per decade, with larger trends after 1970s
- ABCs masking the impact of Climate Change

- Atmospheric Brown Clouds. Regional Assessment Report with Focus on Asia. UNEP
- Science Daily, Dirty Brown Clouds Impact Glaciers, Agriculture and the Monsoon. (Nov. 16, 2008). http://www.sciencedaily.com/releases/2008/11/081114191911.htm

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

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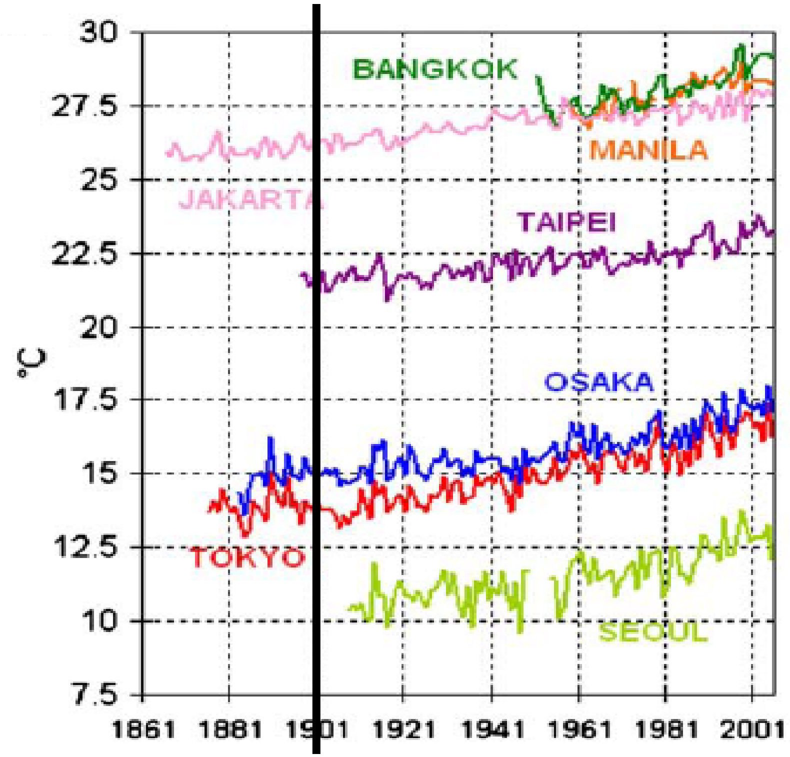
Variation in Annual Mean Temperature

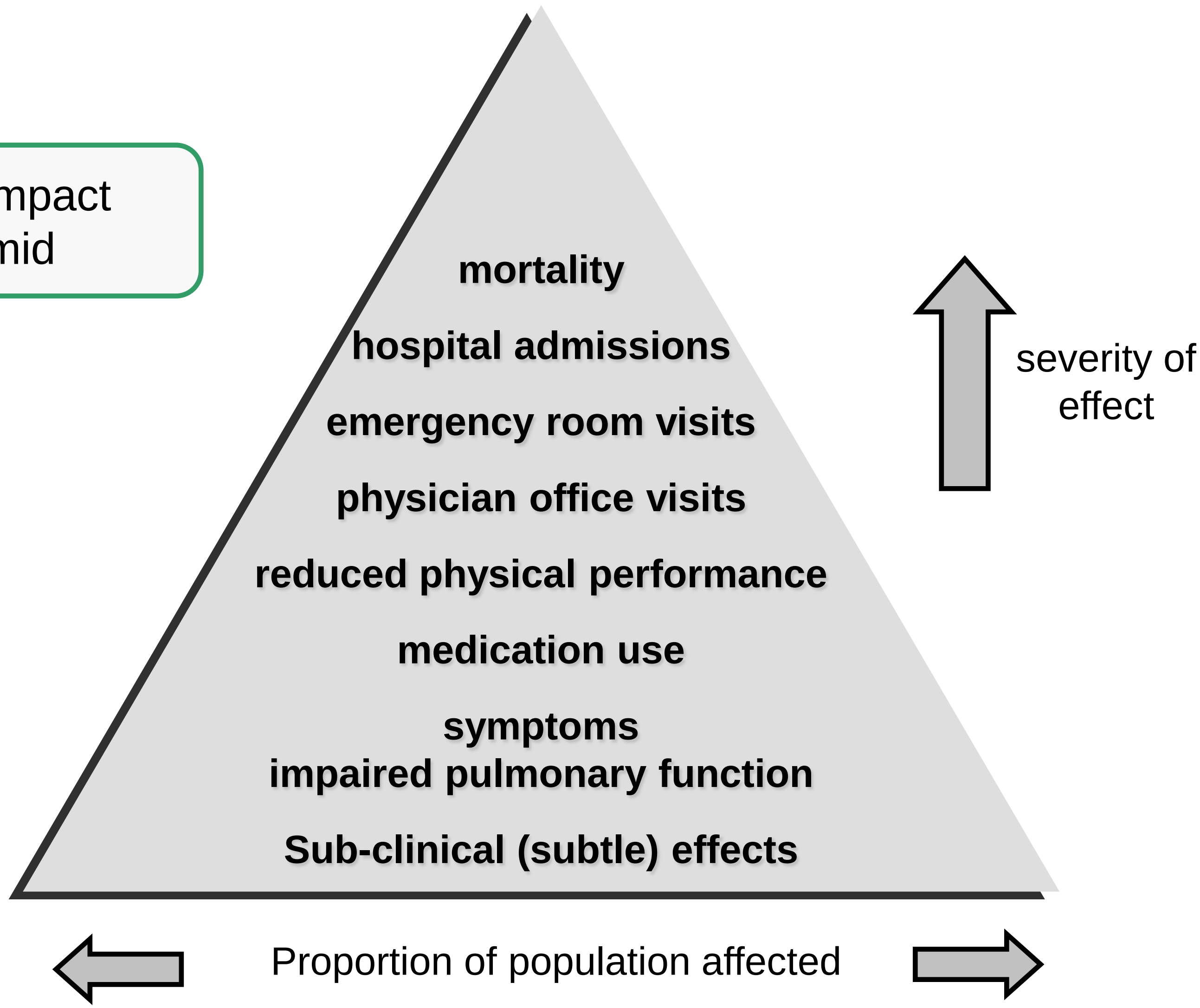


Trend of observational temperature data obtained on urban sites

Source: Kataoka et al., 2009. Urban warming trends in several large Asian cities over the last 100 years. Science of the Total Environment, 407, 3112-3119

Driving Force: Health Impact

Health Impact Pyramid



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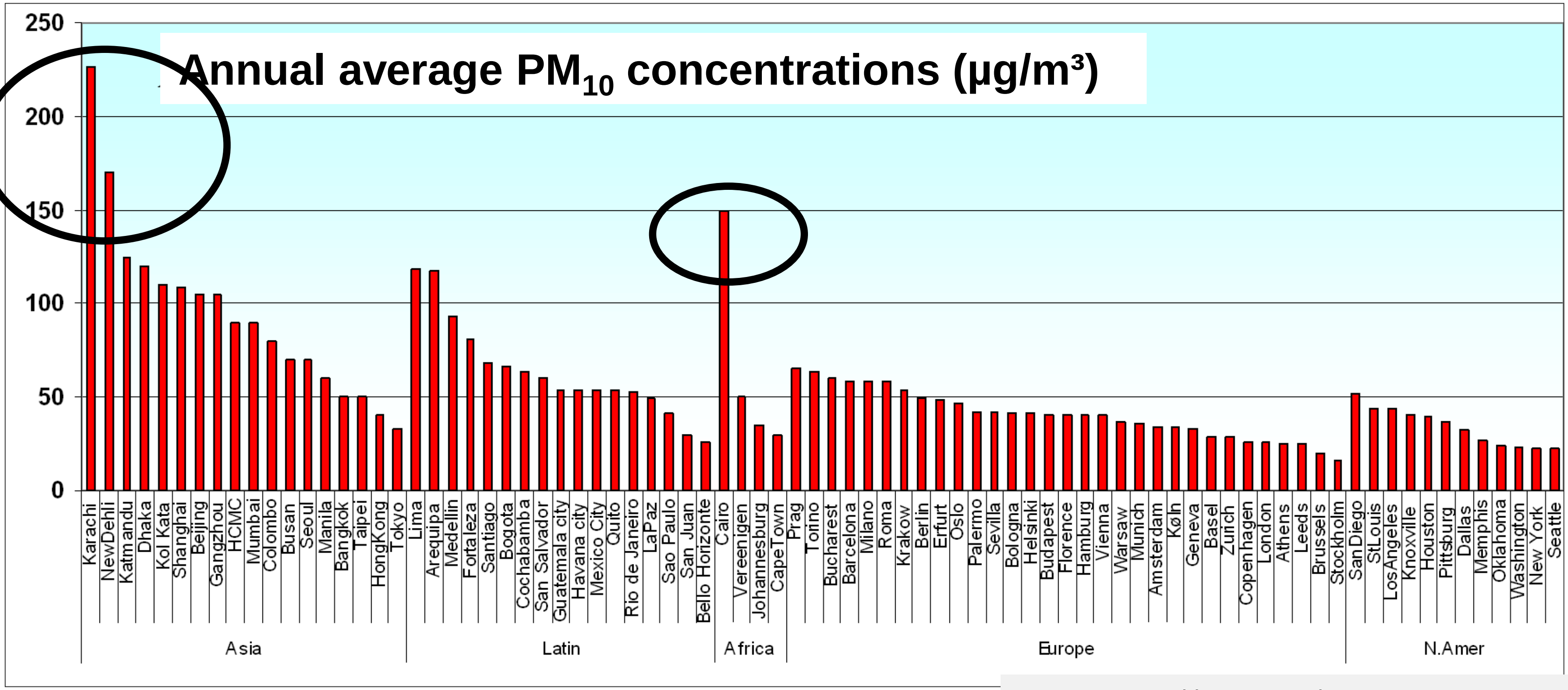
Mortality rates on PM_{10} increase

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



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

Meteorology / Climate: Impact

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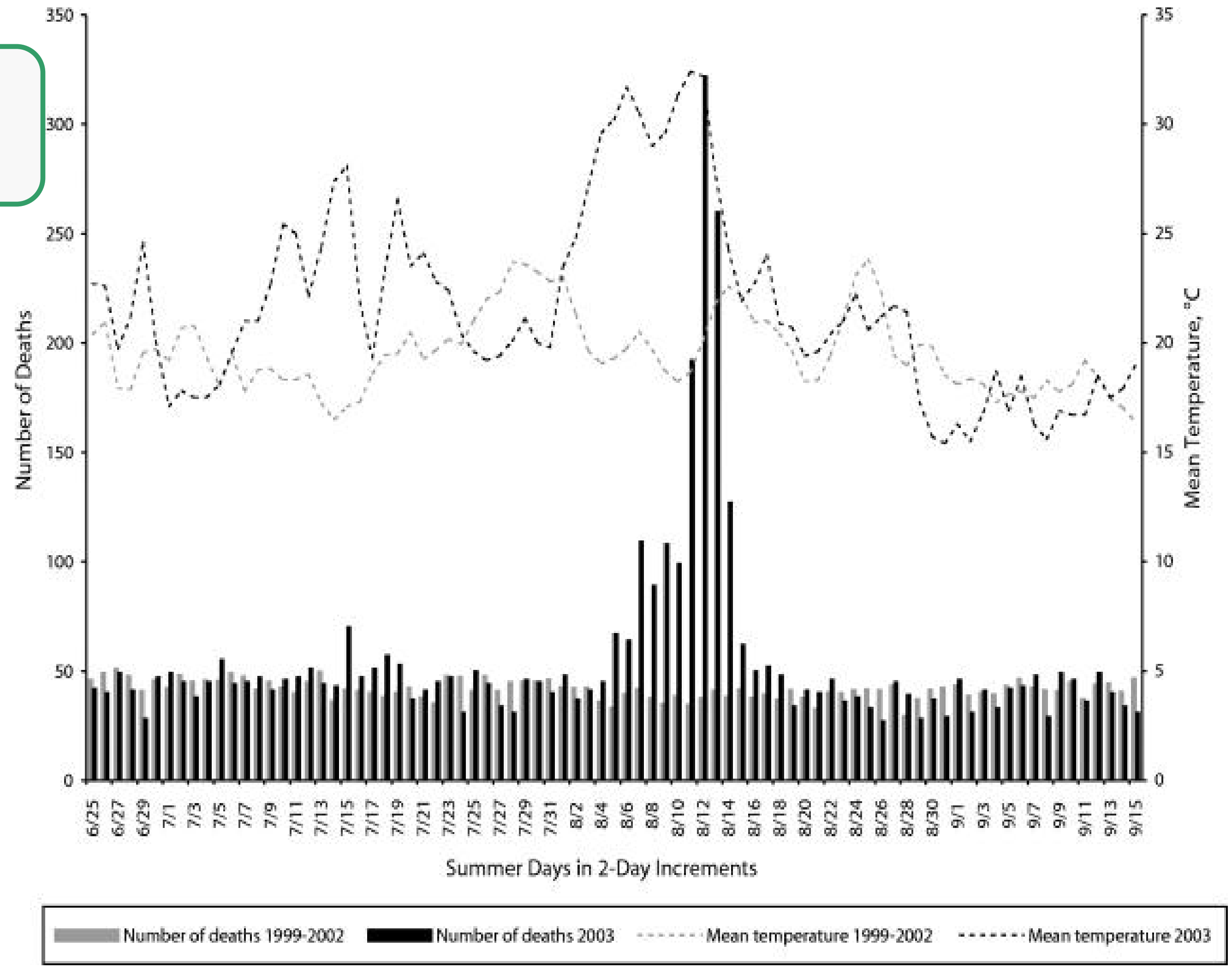
Heat waves and mortality

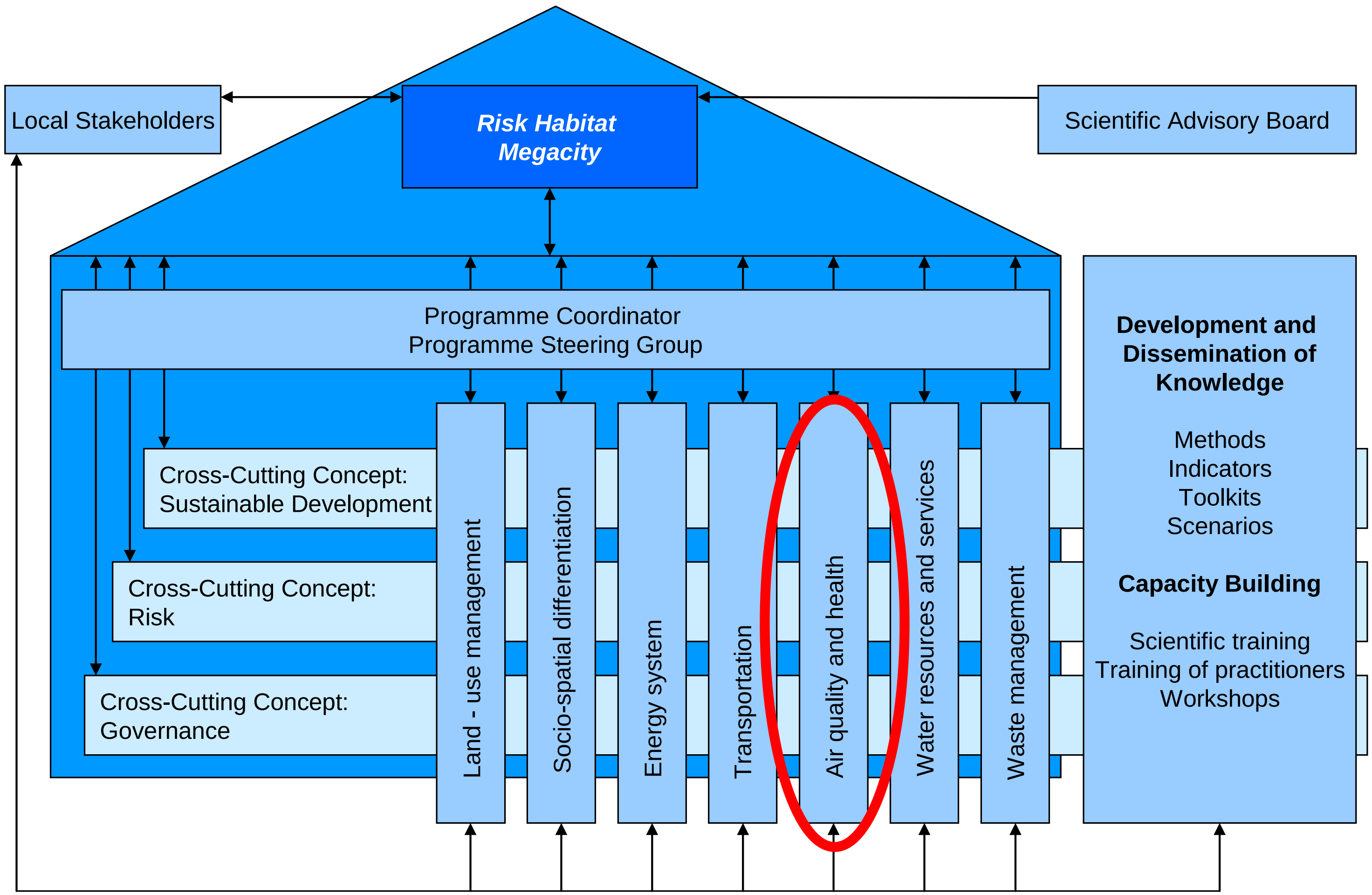


Vandentorren et al. 2004

Research needs…..

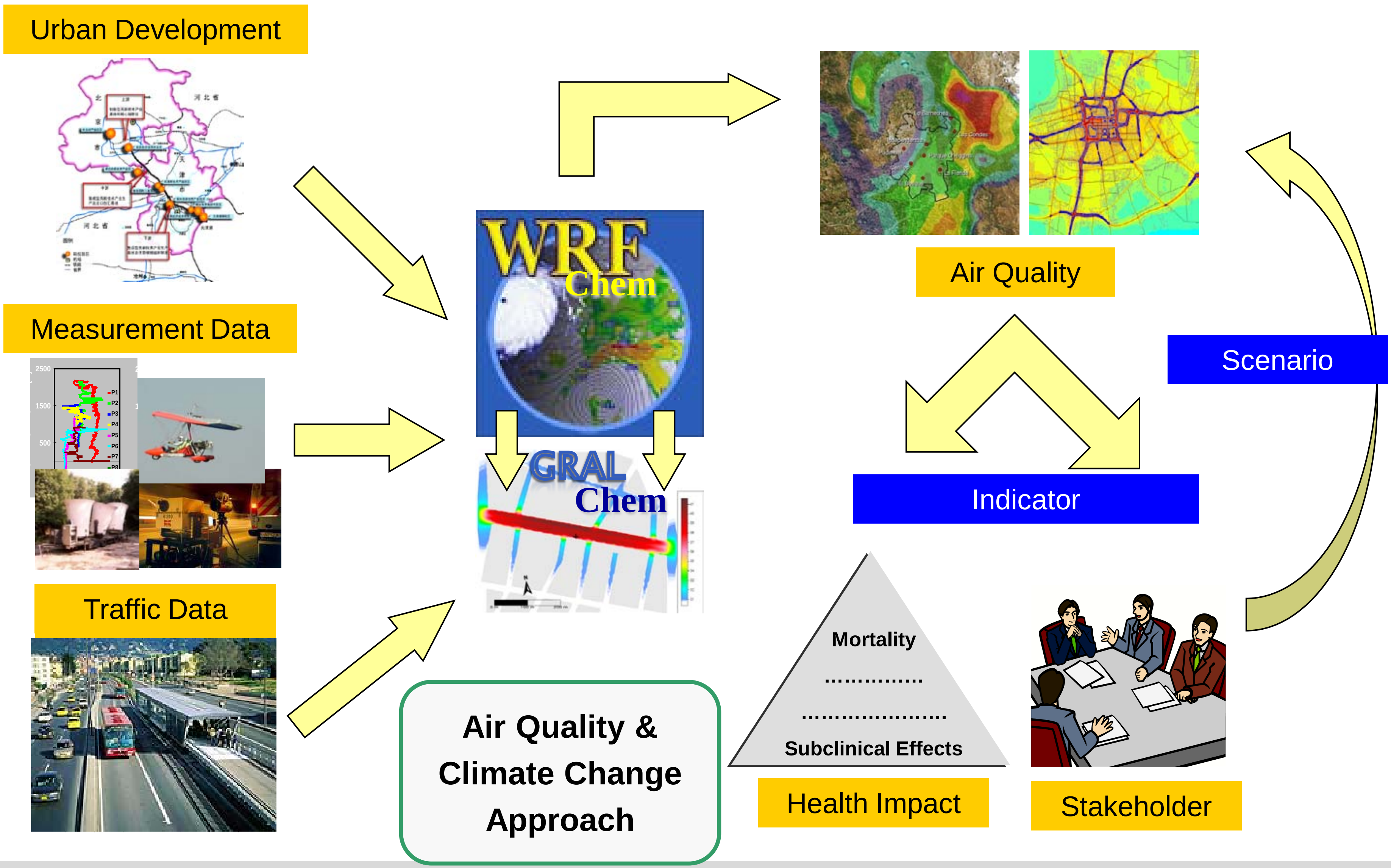
- The complex chemical interactions of emissions – transmission - air pollution – deposition / exposure needs detailed investigations on the causal chain, e.g.
  - Source apportionment
  - Particle interaction / composition
  - Deposition rates / accumulation
  - (real) Exposure
- Climate Change Impact on these topics
- Only interdisciplinary approaches allow a holistic analysis
- ….

Research Project



Risk Habitat Megacity
¿sostenibilidad en riesgo?

Integrated Approach



Impact on Air Quality

- Land use

Natural Land Use Change (Impact)

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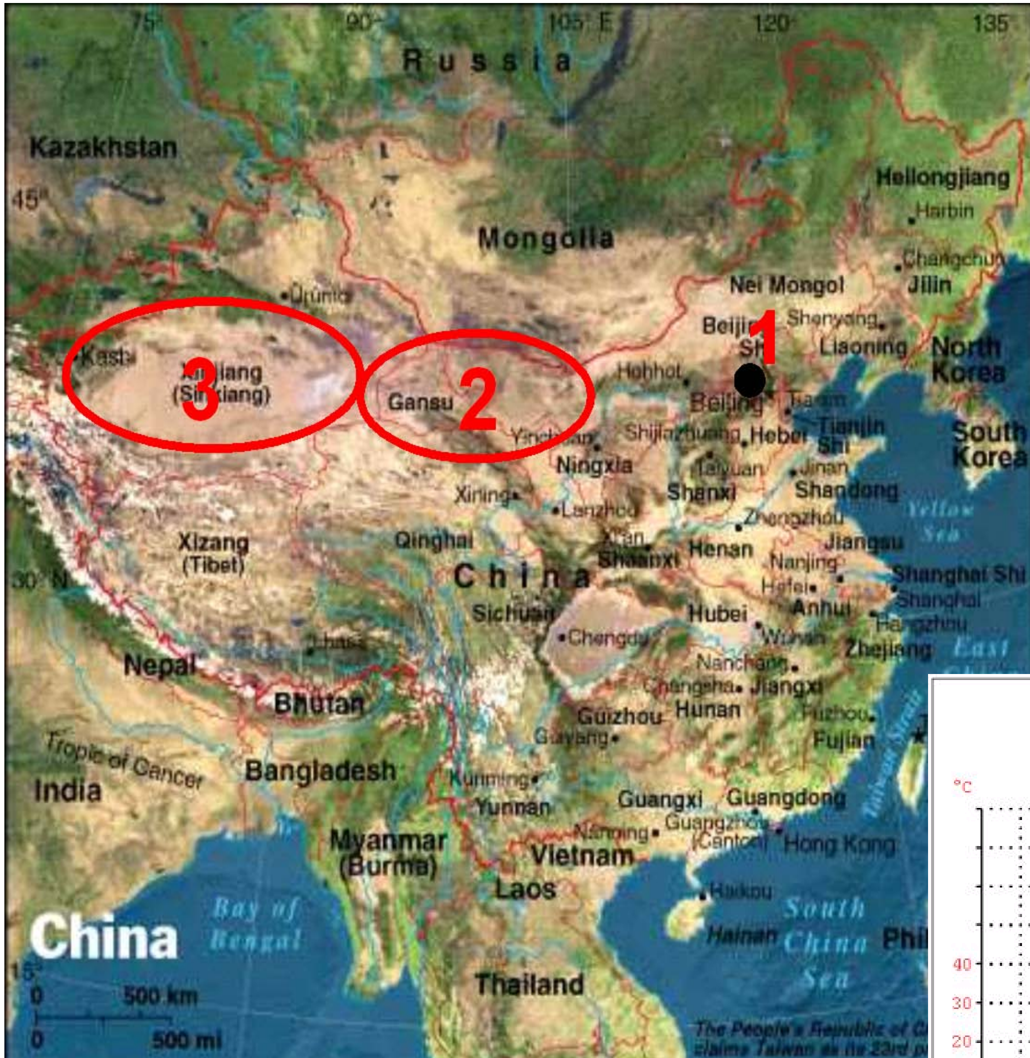
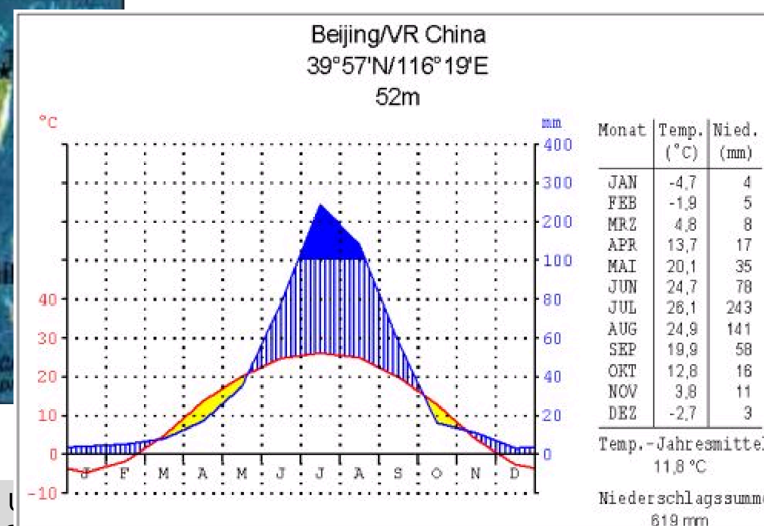


Source: Stefan Norra, University Karlsruhe (IMG)

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



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Dust Storms

Beijing

18.04.2006

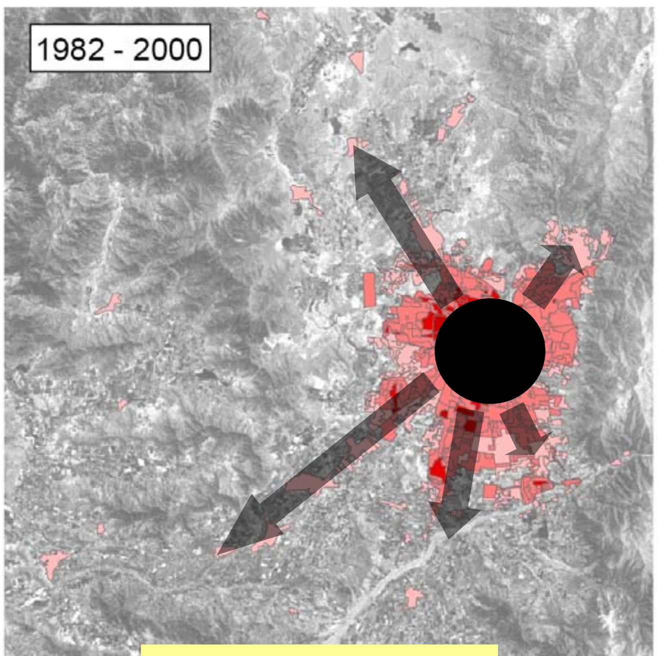
Photos by Stefan Norra

Land Use Change

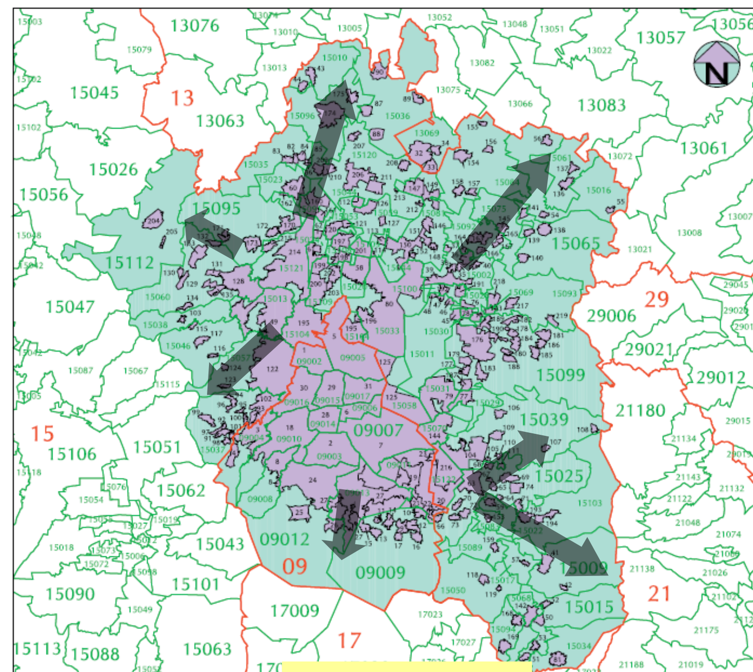
	Santiago de Chile 2002	Mexico City 2005
Population	6.061.000	19.410.000
Urbanized area (km²)	641	1800
Population density (p / km²)	9.500	10.800
Population growth (% / y)	~1,32	~1,28

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

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

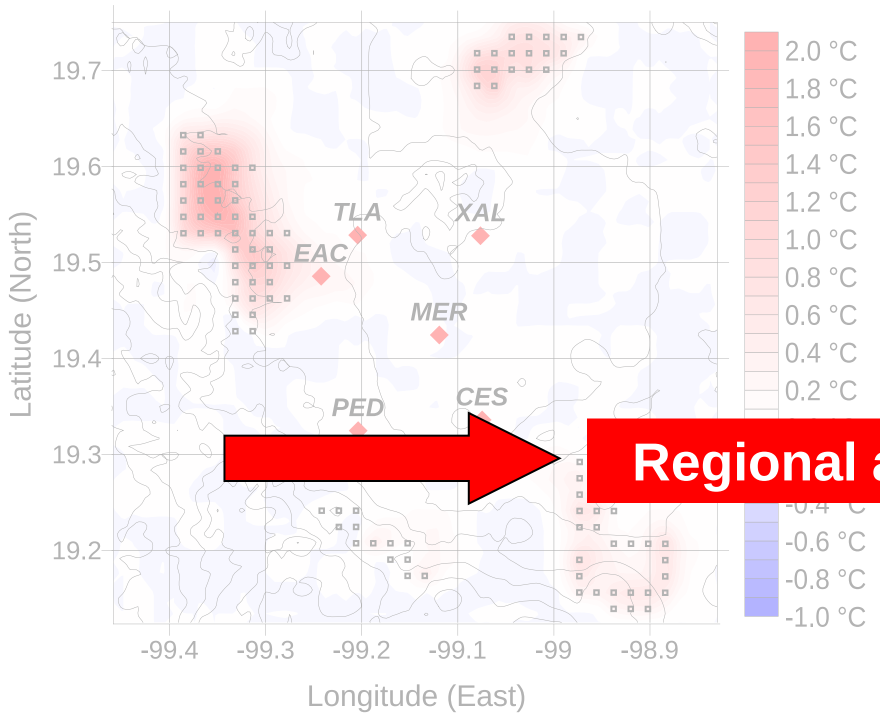


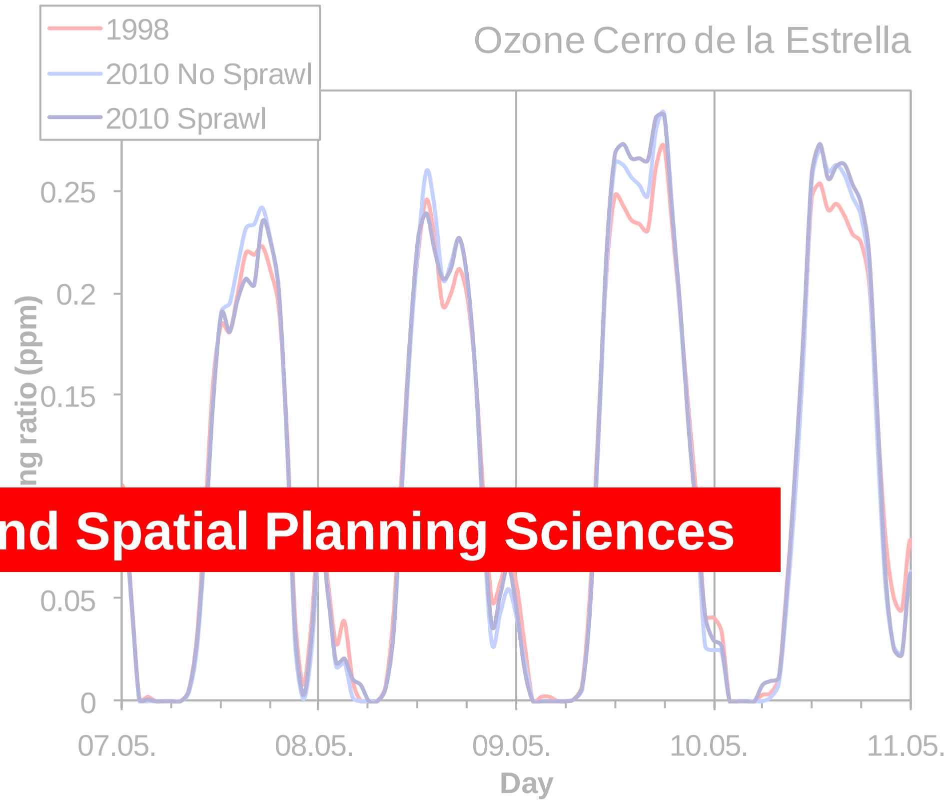
Santiago de Chile



Mexico City

Effect of land use change





Regional and Spatial Planning Sciences

Temperature difference
with and without urban sprawl

Diurnal variation of ozone concentrations
considering land use change

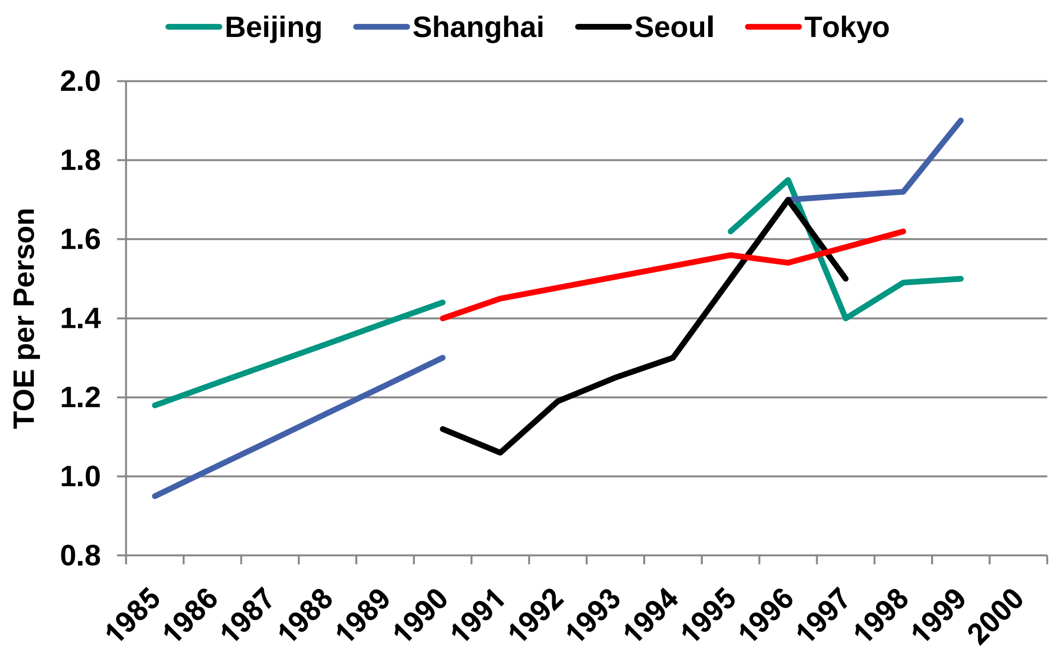
Renate Forkel (IMK-IFU)

Impact on Air Quality

- Land use
- Energy

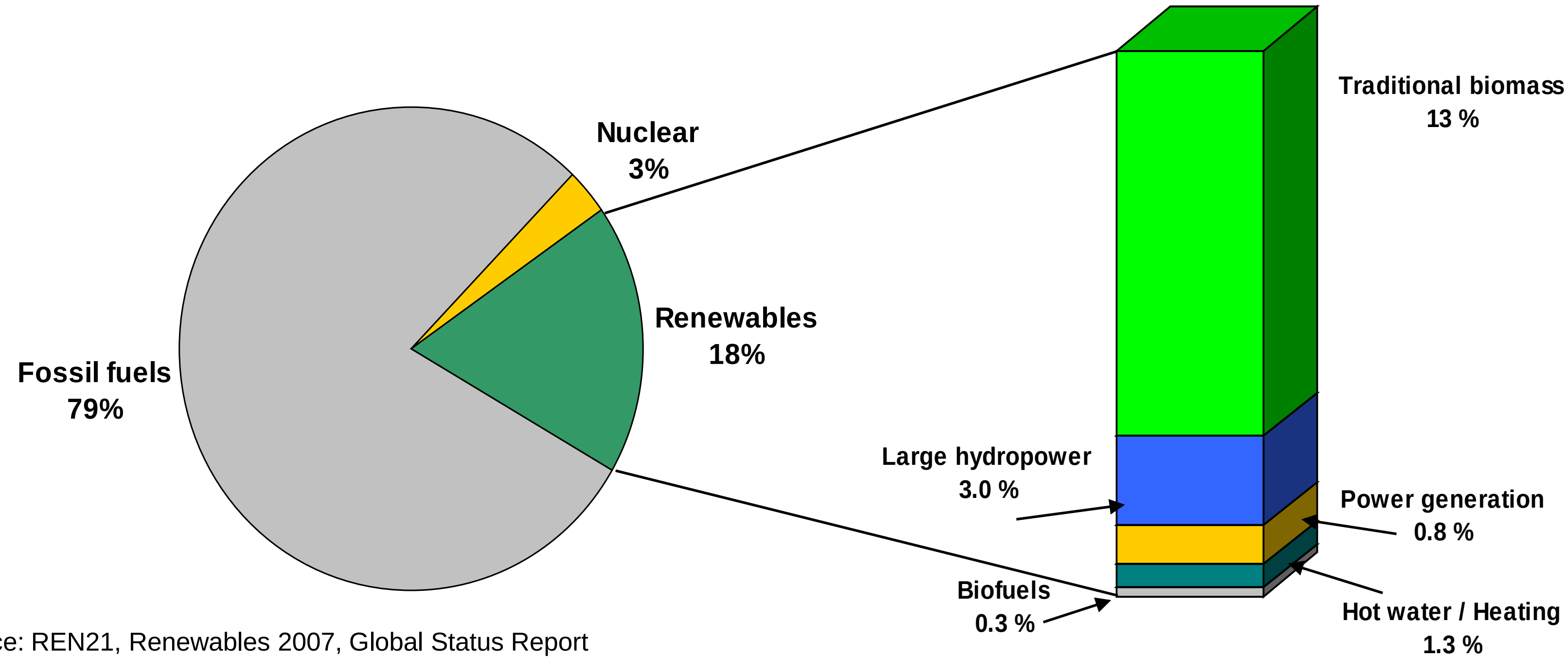
Urban energy distribution

	Industry	Transport	Residential	Commercial
Beijing	62%	8%	17%	13%
Shanghai	80%	10%	7%	3%
Seoul	18%	25%	37%	20%
Tokyo	11%	37%	22%	30%



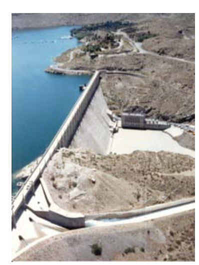
Source: APERC 2007, Shobhakar Dhakal (2004). Urban Energy Use and Greenhouse Gas Emissions in East Asian Mega-cities

Global final energy consumption



Source: REN21, Renewables 2007, Global Status Report



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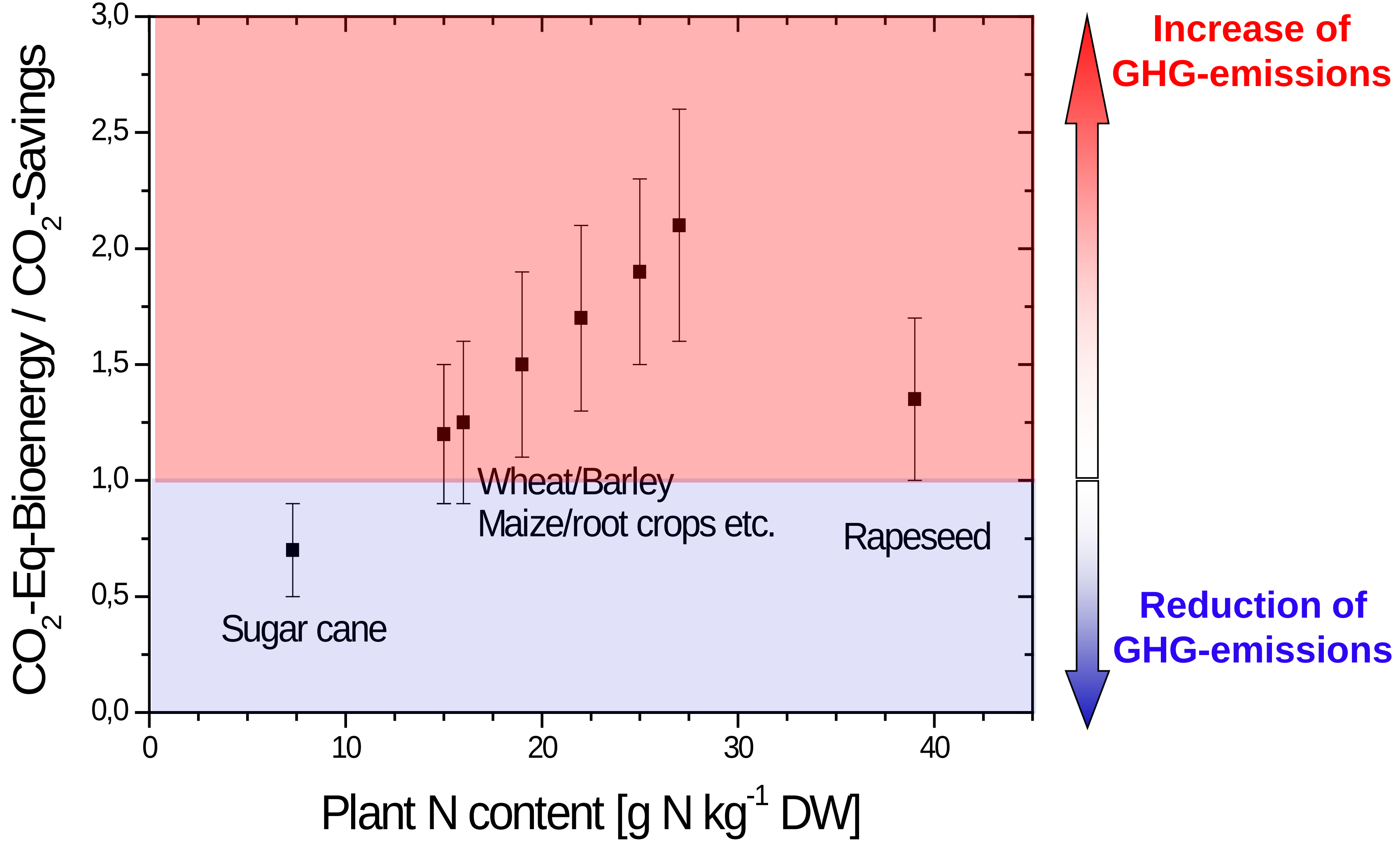
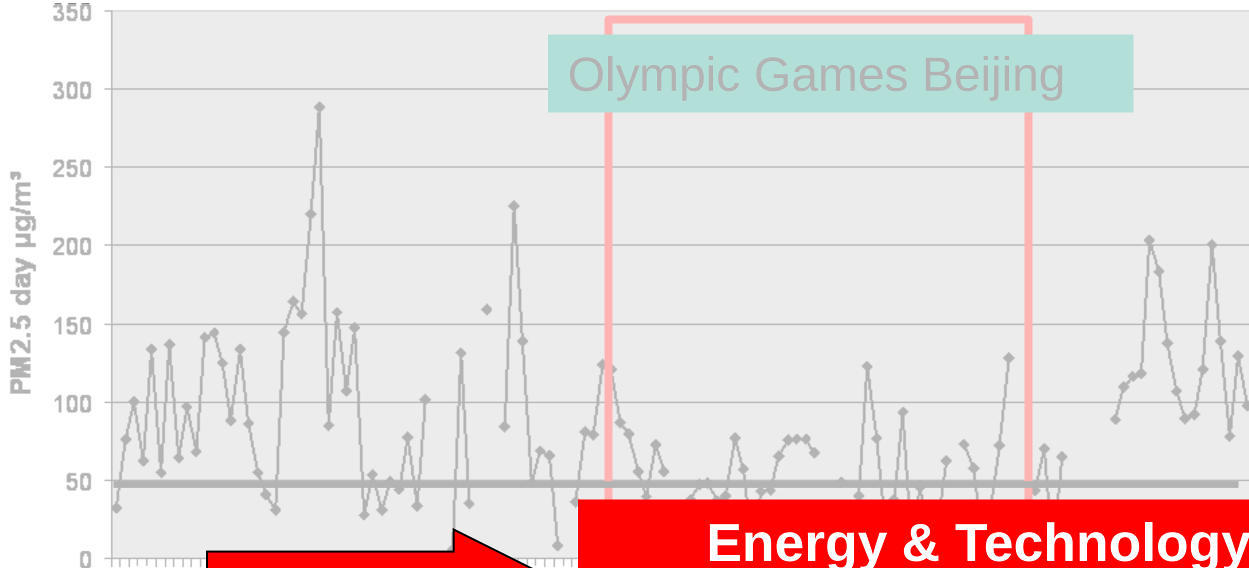
Bioenergy from N⁺Plants



Crutzen et al., 2008

Emission Reduction Strategies



Energy & Technology Assessment Disciplines

Time Period:
15.10.2007 – 01.02.2009

Stefan Norra
Institute of Mineralogy and Geochemistry (IMG) of 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

Source: US Dept.of Energy, 2000

Traffic Volume in 1996 and 2020

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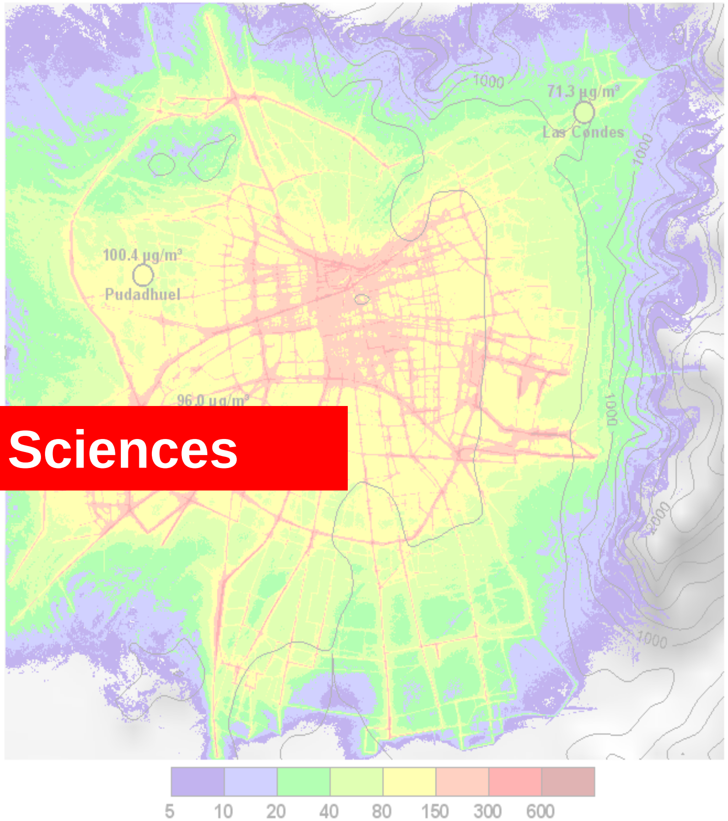
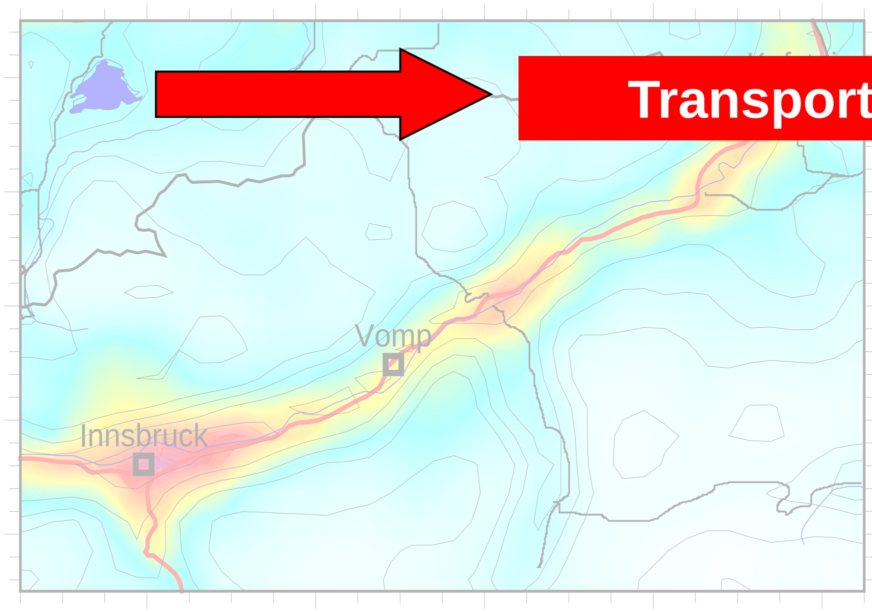
Coupling of Scales

Santiago de Chile
NOx µg/m³ yearly mean



Meso-scale modeling
e.g. NO_2 with MCCM

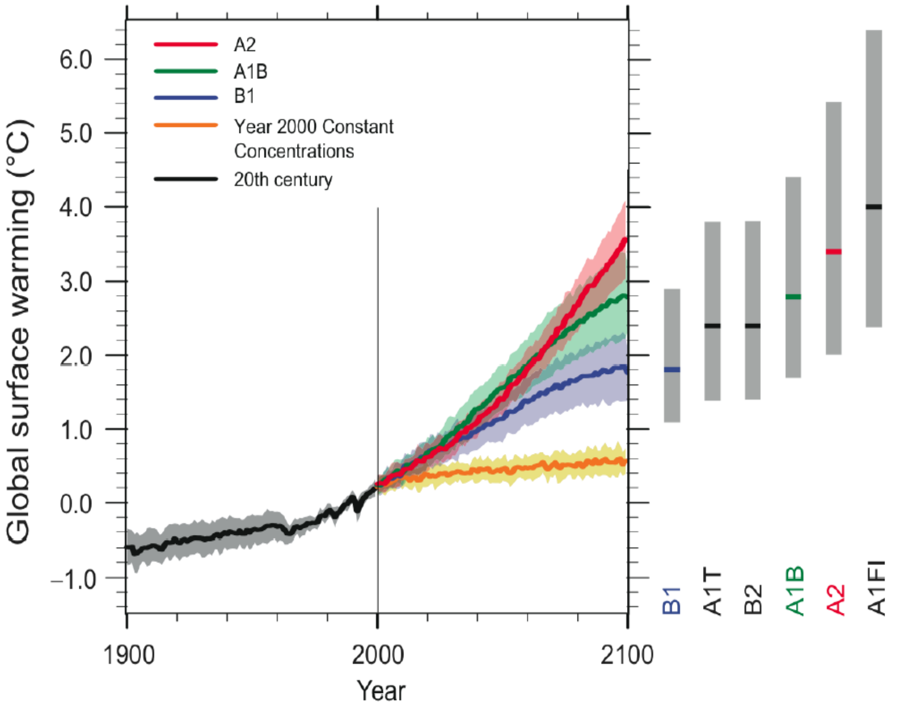


Transportation Sciences

Micro-scale modelling
e.g. NO_x with GRAL

Impact on Air Quality

- Land use
- Energy
- Mobility
- Climate Change



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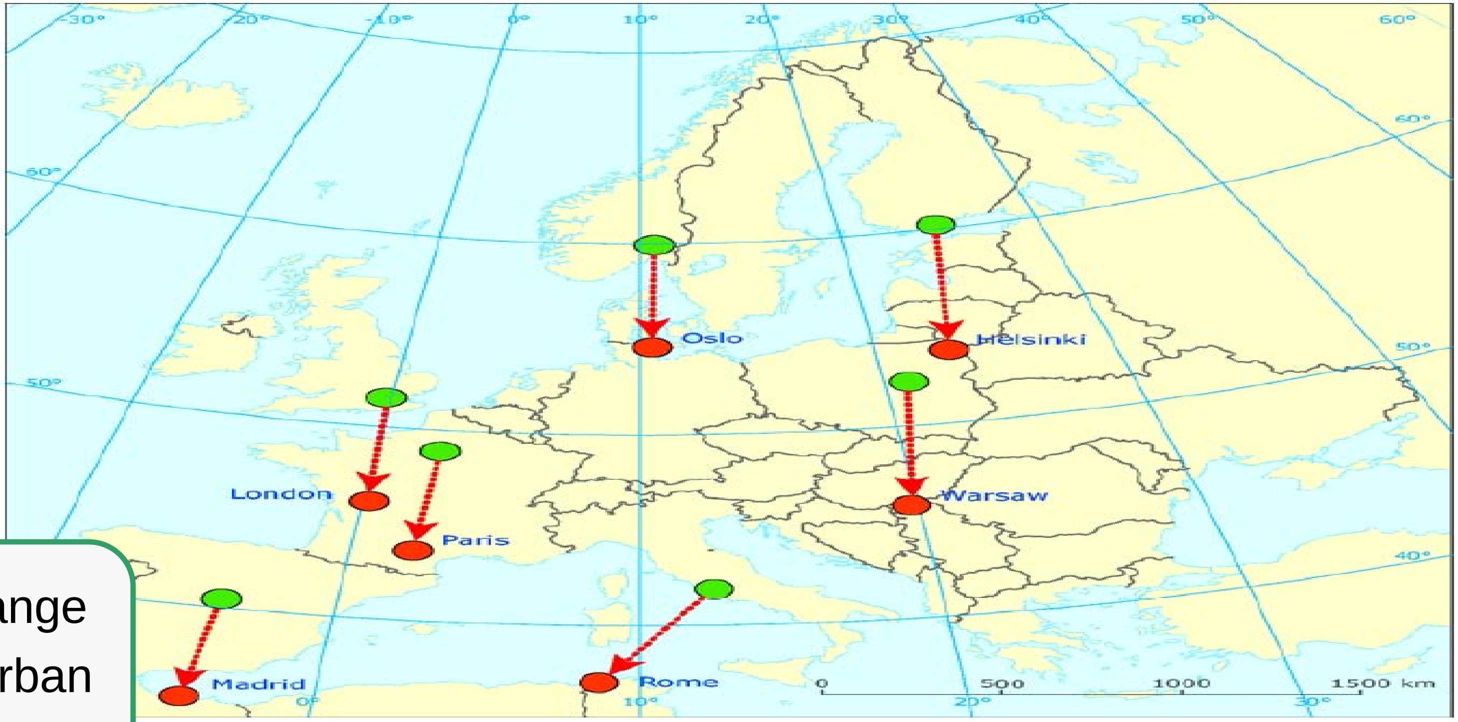
Consequences of Climate Change

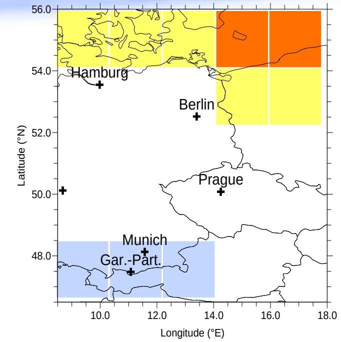


Climate Change Impact on Urban Agglomerations

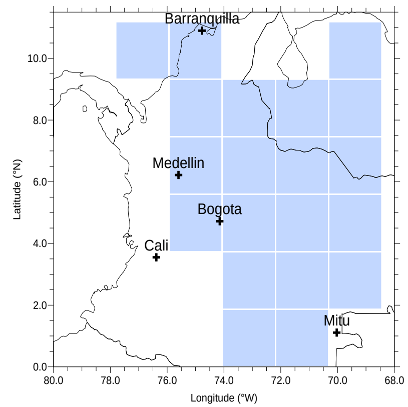
Kamal-Chaoui, Lamia and Alexis Robert (eds.) (2009), “Competitive Cities and Climate Change”, OECD. Regional Development Working Papers N° 2, 2009, OECD publishing.

Climate Change

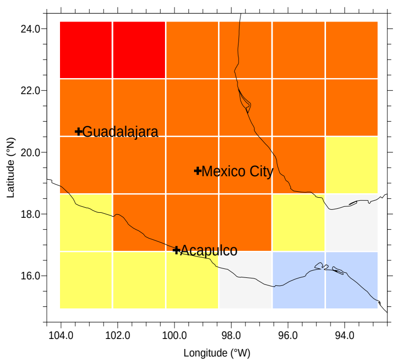
Berlin



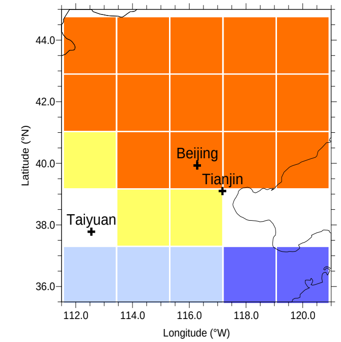
Bogota

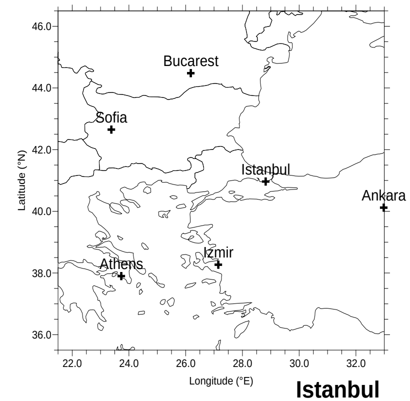


Mexico City



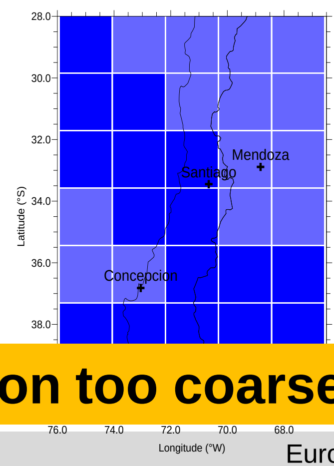
Beijing





Istanbul

Santiago de Chile



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

Temperature Change in °C

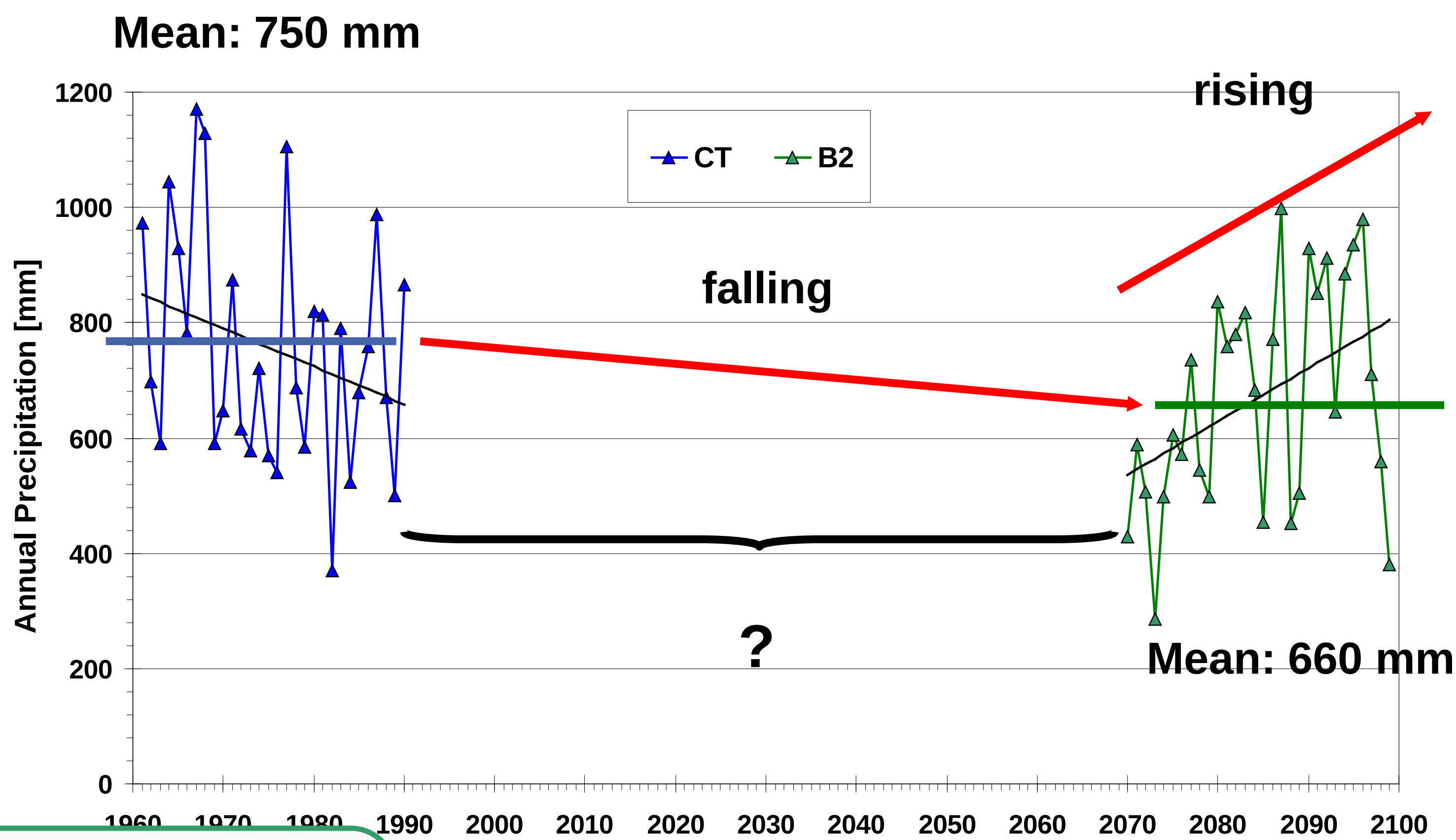
- 4.0 to 4.5
- 3.5 to 4.0
- 3.0 to 3.5
- 2.5 to 3.0

Climate Change Impact on Urban Agglomerations

Resolution too coarse for regional impact analysis !

Peter Suppan
Bhola R. Gurjar

Regional Climate Simulations



Problem of comparing time slices: long term trends - short time trends

Solution: transient simulations

Dynamical Downscaling

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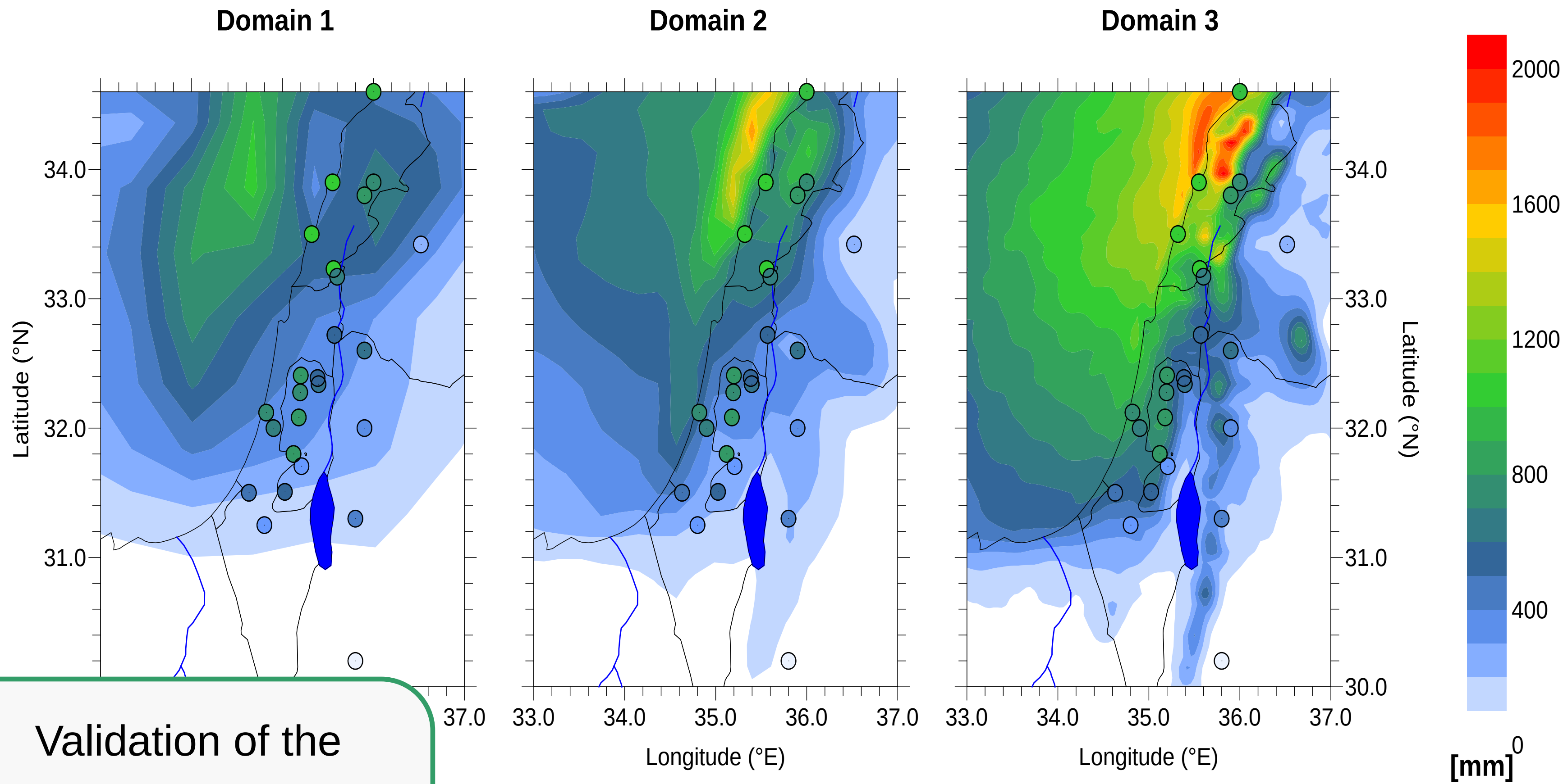

Yearly Mean Precipitation 1961-1975

Validation of the simulation results by comparing simulated observed precipitation

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Regional Climate Change Impact

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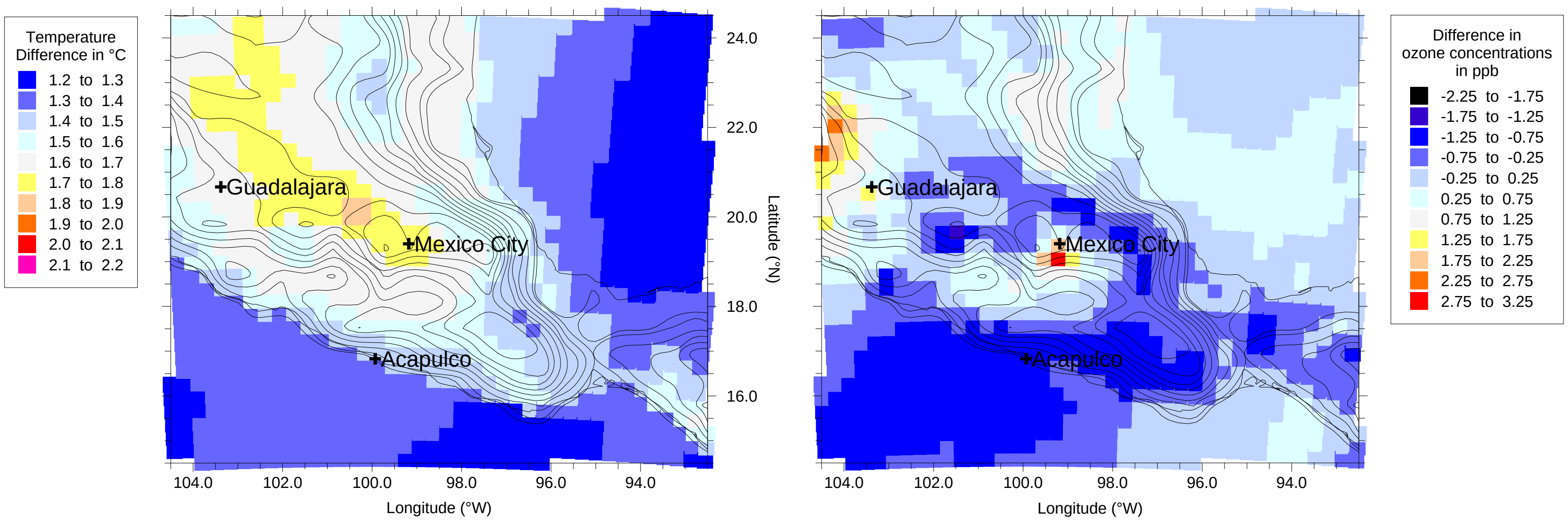

High resolution climate-chemistry simulations
- Mexico -

Renate Forkel (IMK-IFU)

Regional Climate Change Impact

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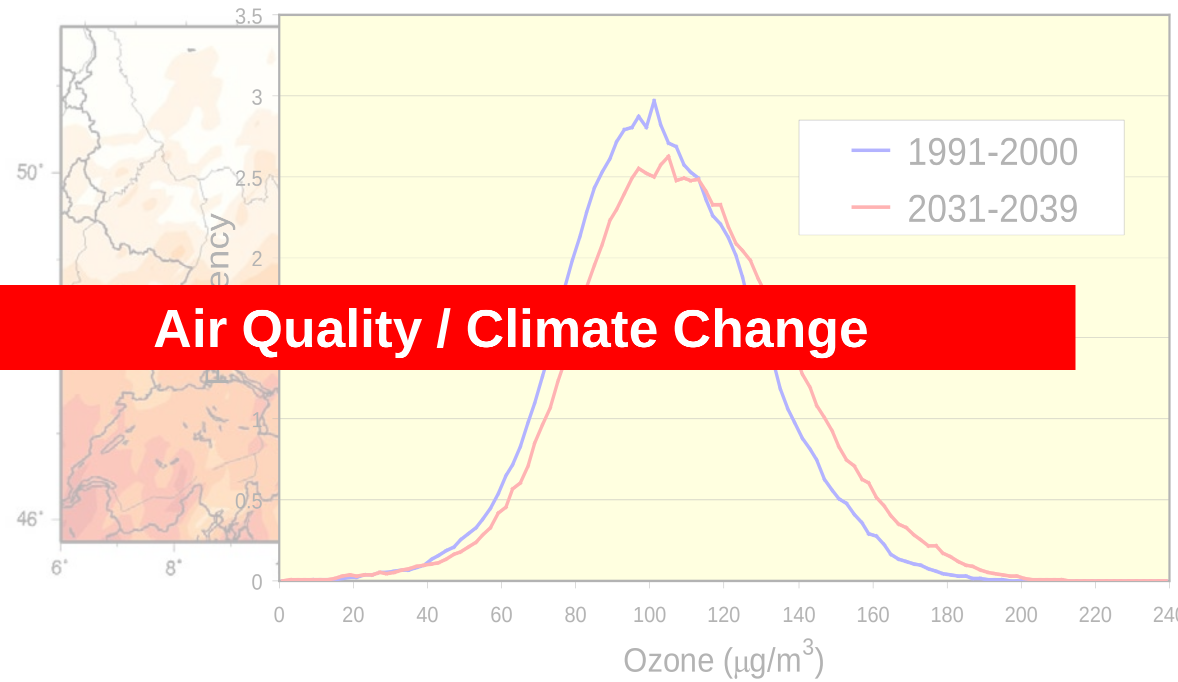

Air Quality / Climate Change

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

Peter Suppan
Bhola R. Gurjar

Temperature and Health Impact

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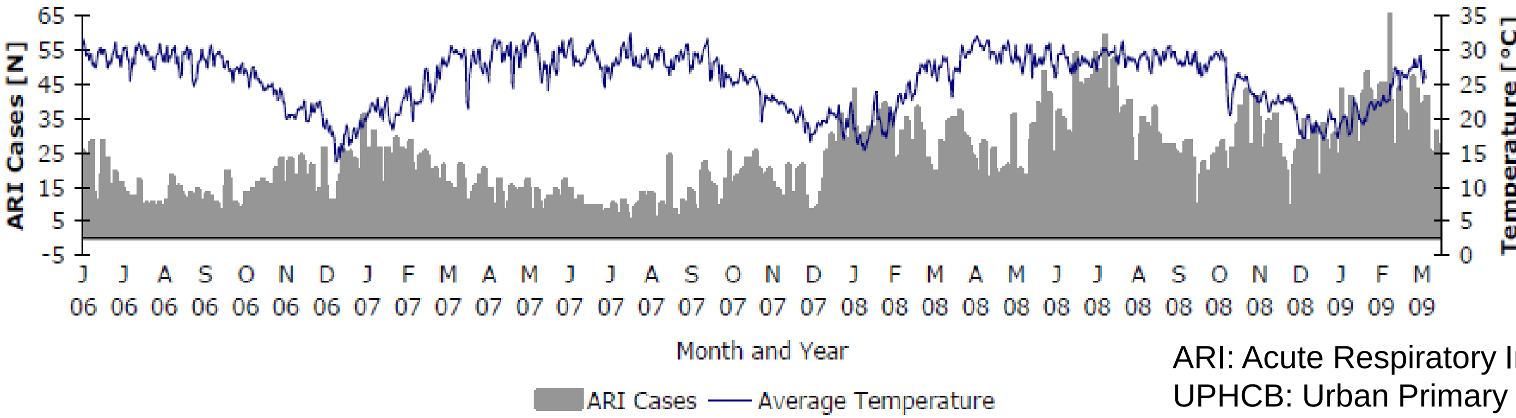
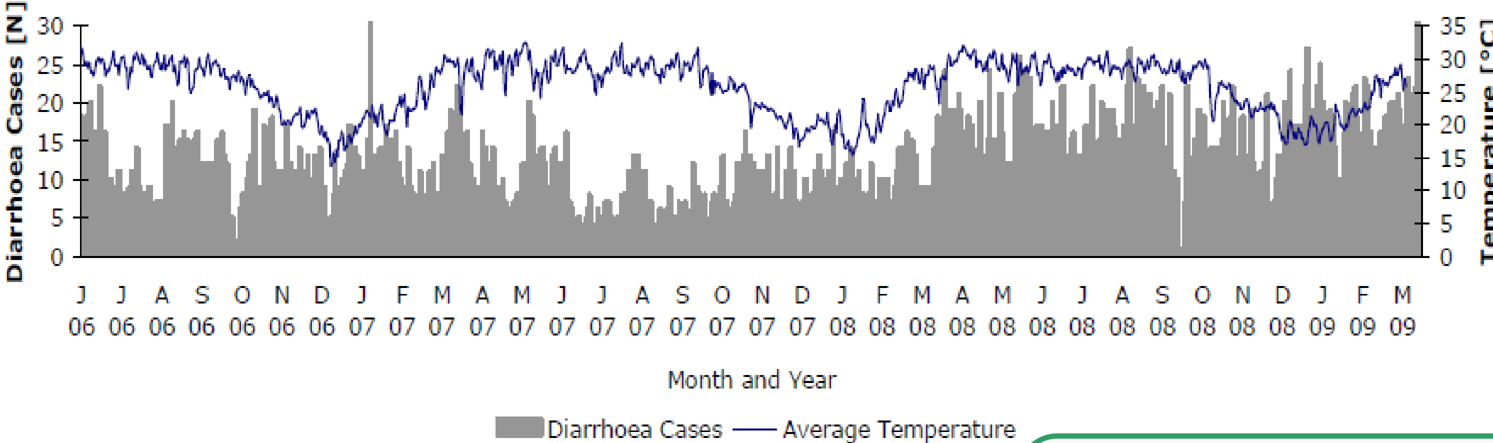


ARI: Acute Respiratory Infection;
UPHCB: Urban Primary Health Care Project



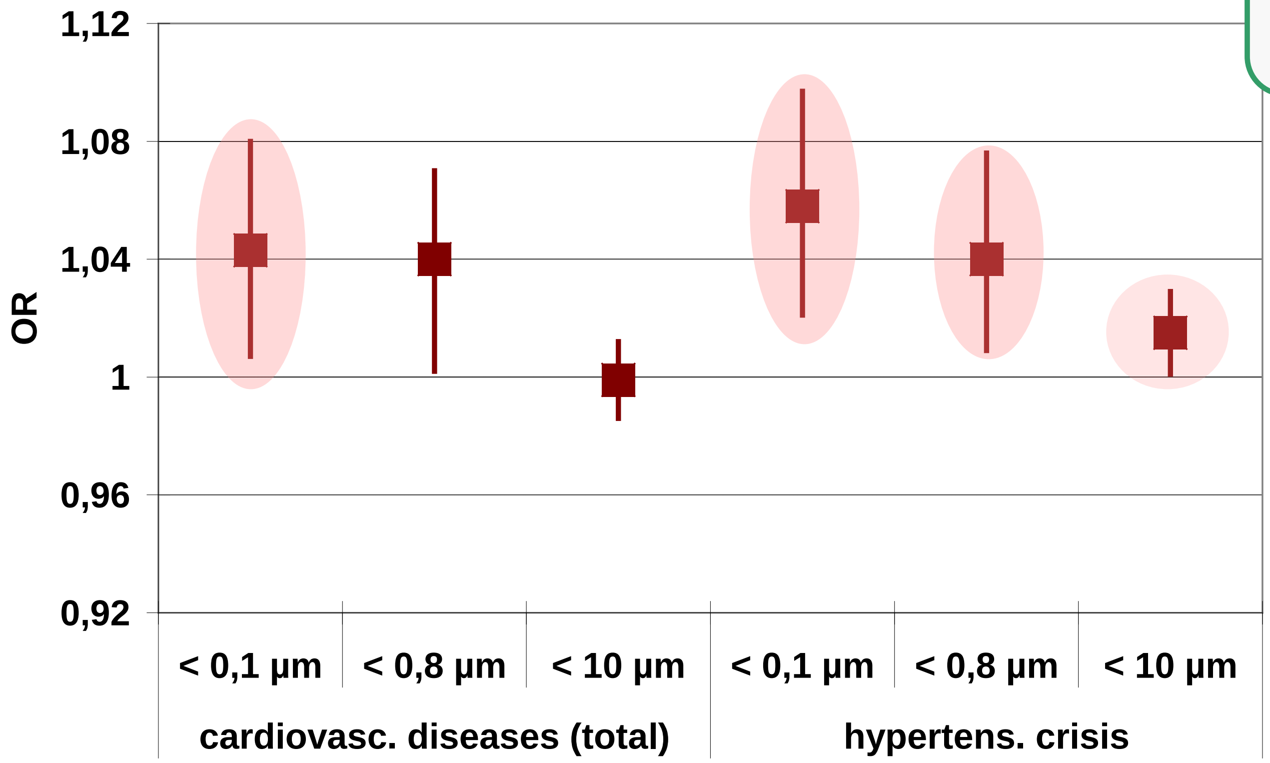
Temporal Distribution of ARI cases and Diarrhea cases between July 2006 and March 2009

Burkart and Endlicher. Bio-meteorological and air pollution conditions in the Megacity of **Dhaka**, Bangladesh and their effects on public Health of urban poor population groups. The seventh International Conference on Urban Climate, 29 June - 3 July 2009, Yokohama, Japan.

Health Effects

Karlsruhe Institute of Technology

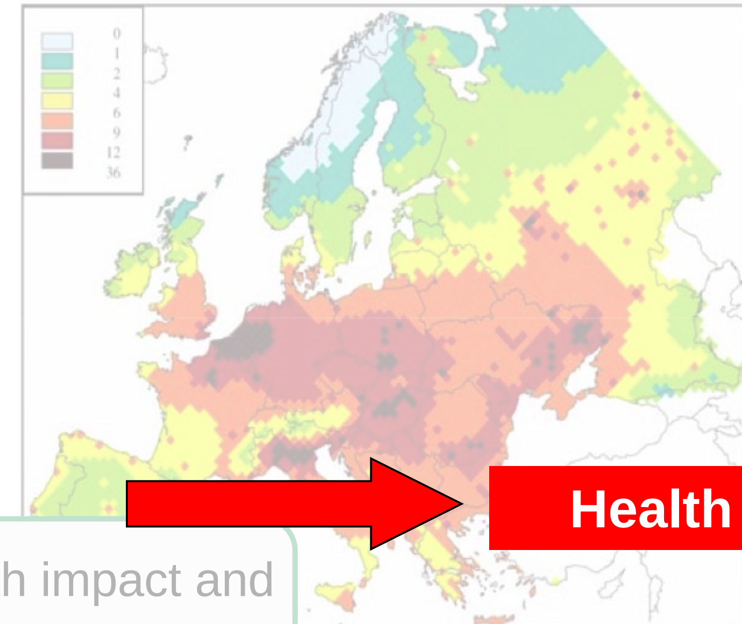
Size dependent health effects of airborne particles



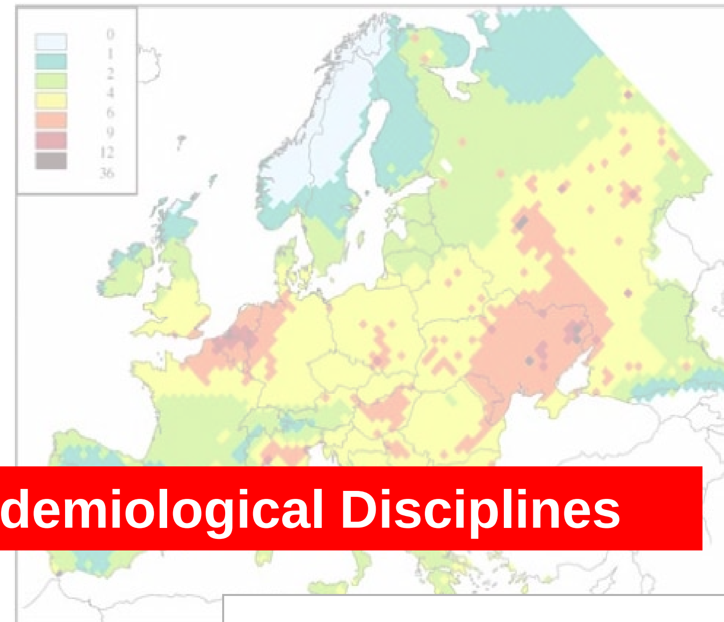
Odeh SF, PhD Thesis 2006
Franck U, Odeh SF, Wiedensohler A, Wehner B, Herbarth O, et al.2009

Health Impact

2000



2020



Health / Epidemiological Disciplines

Health impact and air pollution

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

EU-average 2000 vs 2020:

- 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

Source: CAFÉ (Clean Air for Europe), 2005
by support of Alexandra Schneider (HMGU)

Conclusions

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

Thank you for your attention

Cooperation Partner

Stefan Norra	*Institute of Mineralogy and Geochemistry (IMG) of KIT, Karlsruhe*
Yuesi Wang, Hong Liao, Xin Jinyuan	*Chinese Academy of Sciences (CAS), Beijing*
Longyi Shao	*Chinese University of Mining and Technology (CUMTB), Beijing*
Jose Agustín García, Gerardo Ruiz	*Universidad Nacional Autonoma de Mexico (UNAM)*
Rainer Schmitz, Ricardo Muñoz	*Universidad de Chile, Santiago de Chile (UdC)*
Ulrich Franck	*Helmholtz Zentrum für Umweltforschung (UFZ)*
Annette Peters, Josef Cyrys	*Helmholtz Zentrum München (HMGU)*