Karlsruhe Institute of Technology

KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

Panorama Actual de las Ciencias Atmosféricas 2015

Atmospheric Sciences in Urban Regions

Peter Suppan

Karlsruhe Institute of Technology (KIT), Institute of Meteorology and Climate Research (IMK-IFU), Campus Alpin, Garmisch-Partenkirchen, Germany

Overview

- Introduction
- Driving Forces
- Source Apportionment - regional
- Source Apportionment - local
- Urban Heat Island
- Future Challenges

Urban Settlements

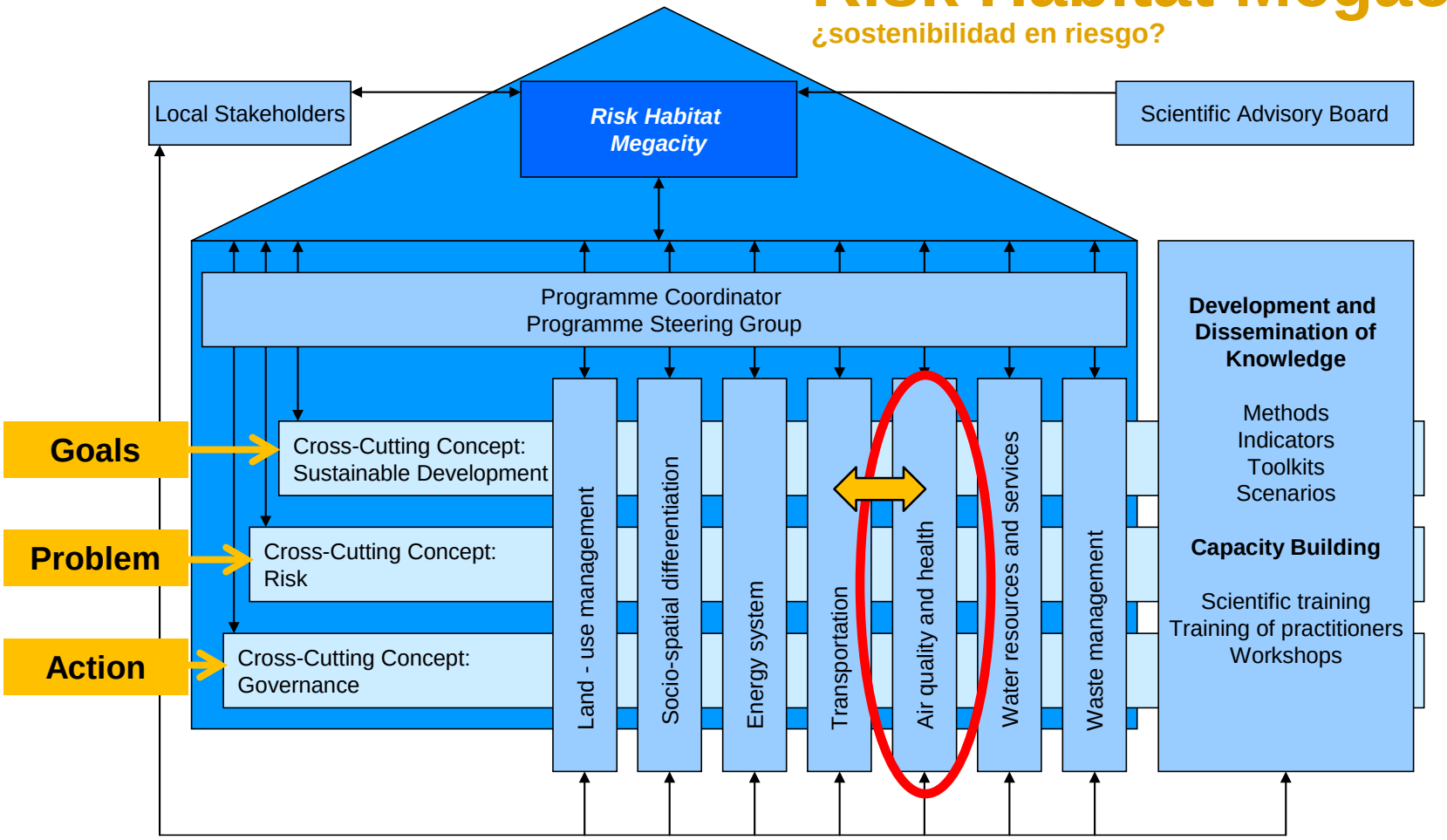
- In 1900 about **3 %** of the worlds population lived in cities; **33 %** in the 50s - since 2007 more than **50 %**; and 3 out of 5 in 2030
- **15 %** of the urban population live in Mega-Cities (>10 Mill.)
- Urban emissions have a significant impact on global greenhouse emissions (**5-10 %**, Butler et al. 2012)
- About **75 %** of the material flow is realized in cities
- Urban emissions have a severe impact on air quality and regional climate (Hodzic et al. 2010, Kanakidou et al. 2012, Parrish & Zhu 2009)
- Climate change have/will have a strong impact on urban agglomerations (e.g. heat island effect) and related processes
- Air pollution levels in urban areas depend not only on local emissions but also on regional emissions (e.g. BVOC, Papiez et al. 2009)

- Quality of life (→ health-related; atmosphere, water, biosphere, soil)
- Climate change (→ extreme weather)
- Demographic change (→ adaptation needs)
- Mobility (→ general mobility; modal split)
- Management of natural and anthropogenic risks (→ flooding; mudslides)
- Increasingly scarce resources (→ construction material)
- Sustainable development (→ city planning and construction)

What we have learned from …

Risk Habitat Megacity

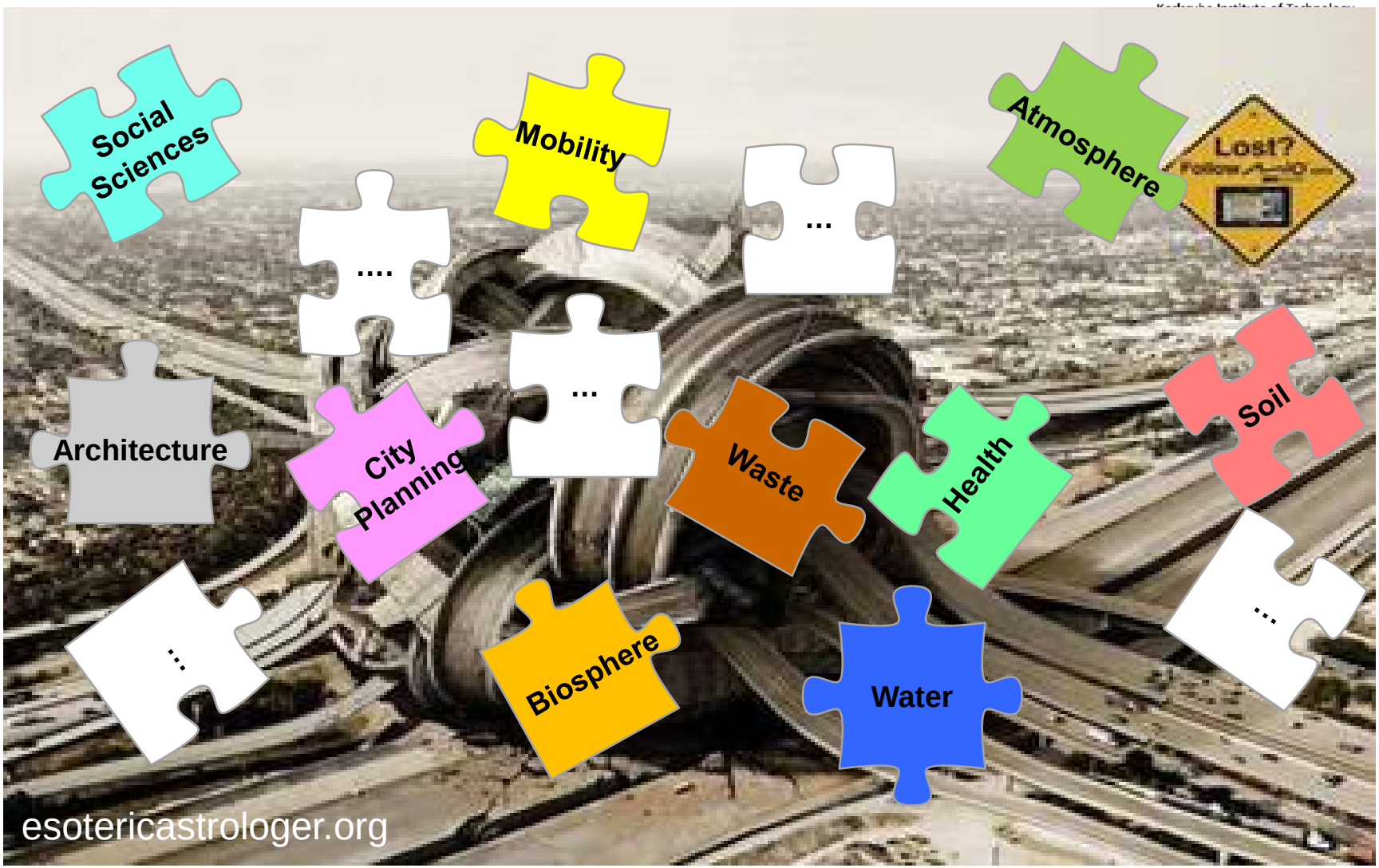
¿sostenibilidad en riesgo?



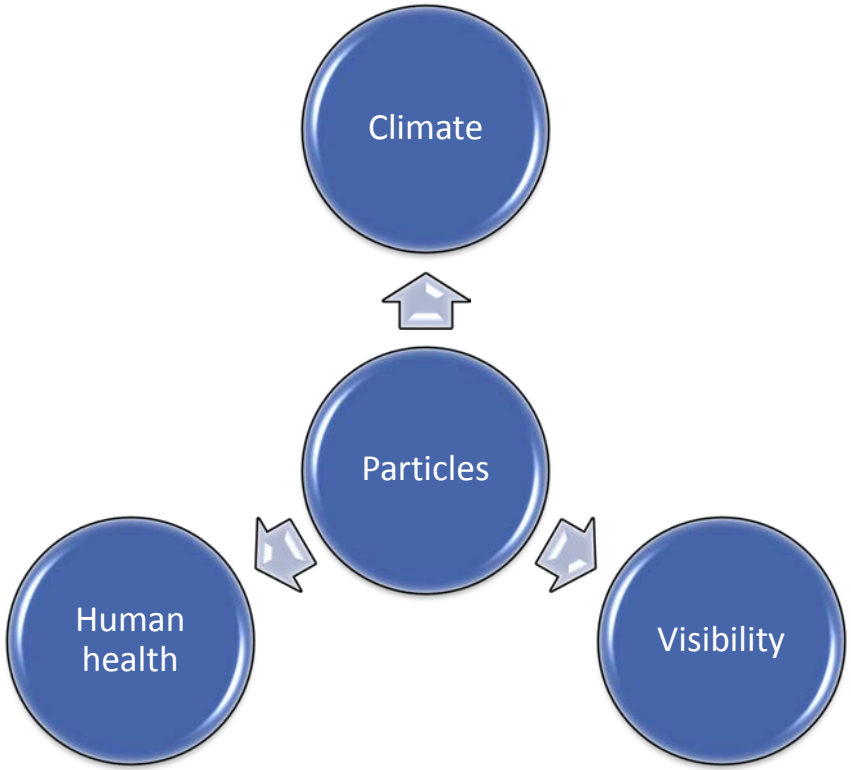
http://www.ufz.de/risk-habitat-megacity/index.php?de=15003

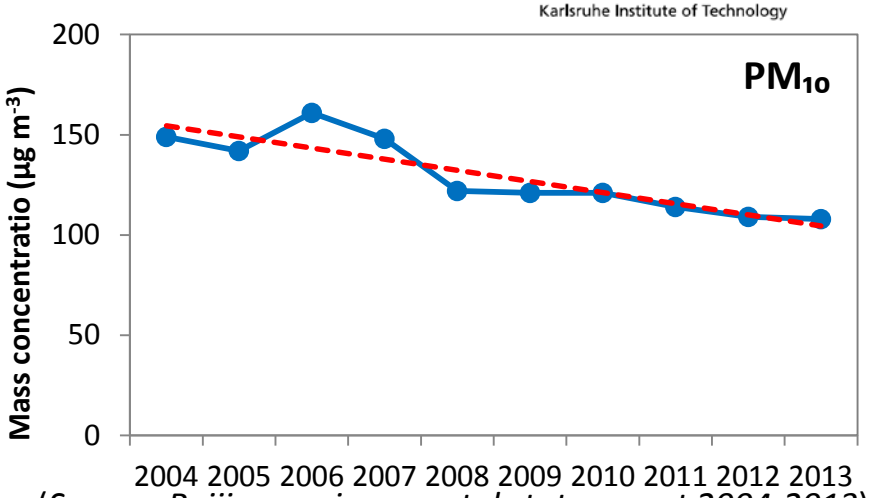
City of Tomorrow

Complex System

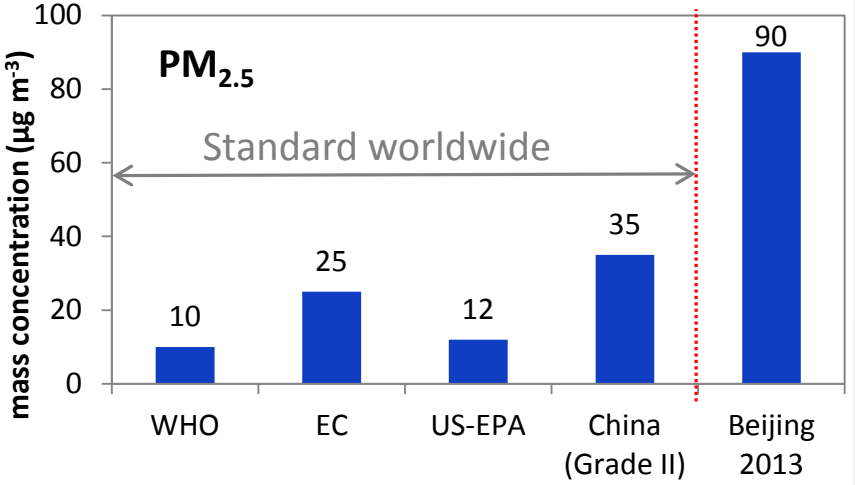


Background: Example Beijing





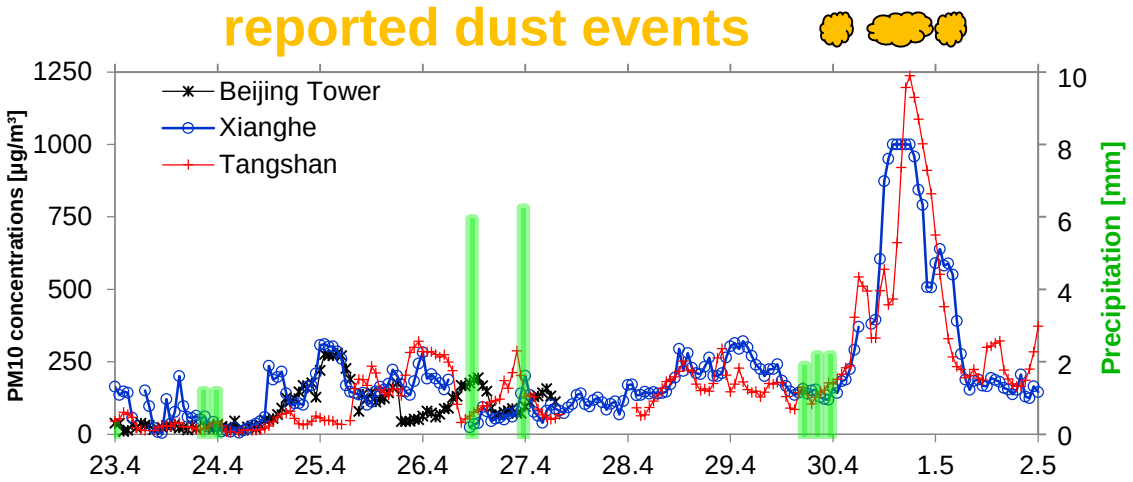
(*Source: Beijing environmental state report 2004-2013*)



Source: Dr. Rongrong Shen

- Annual PM_{10} ↓ but $PM_{2.5}$ still high level

Source Apportionment: Regional Investigations



PhD Thesis Stephanie Schrader, 2014:
Assessment of the impact of mineral dust on air quality in Northern China by using COSMO-ART model in conjunction with satellite and ground-based data

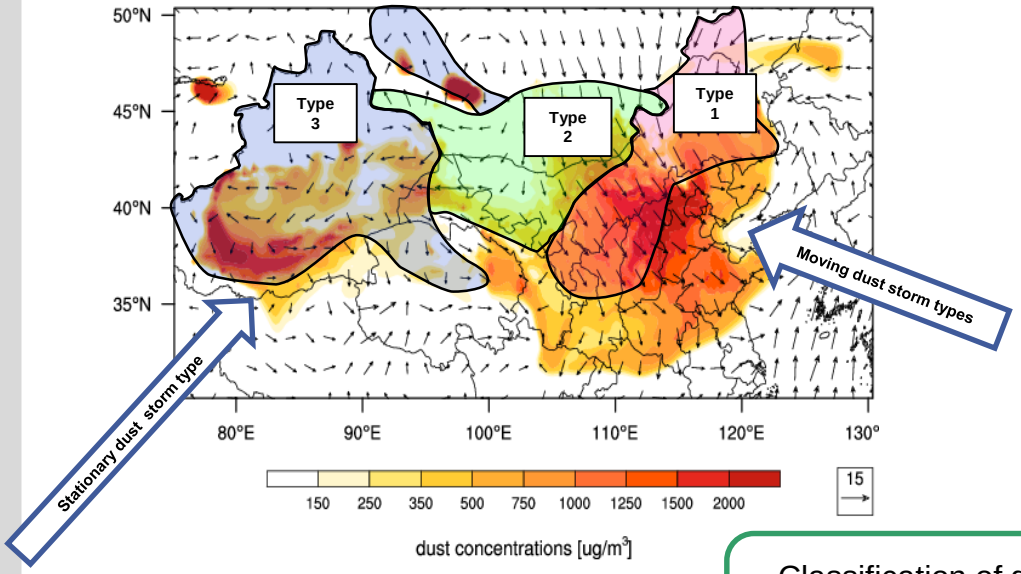
Aim: Investigation of the impact of natural and anthropogenic gases and aerosols on the state of the atmosphere on regional to continental scales

- **Meteorology:** COSMO weather forecast model of the German Weather Service
- **Gases & Aerosols:** simulation in ART (developed at KIT) of 80 gaseous species, 5 anthropogenic aerosol modes, mineral dust, sea salt and pollen
- **Feedbacks:** meteorology, aerosols, gas phase, dynamics, clouds

Source Apportionment: Local Impact at Beijing

Photos by Stefan Norra

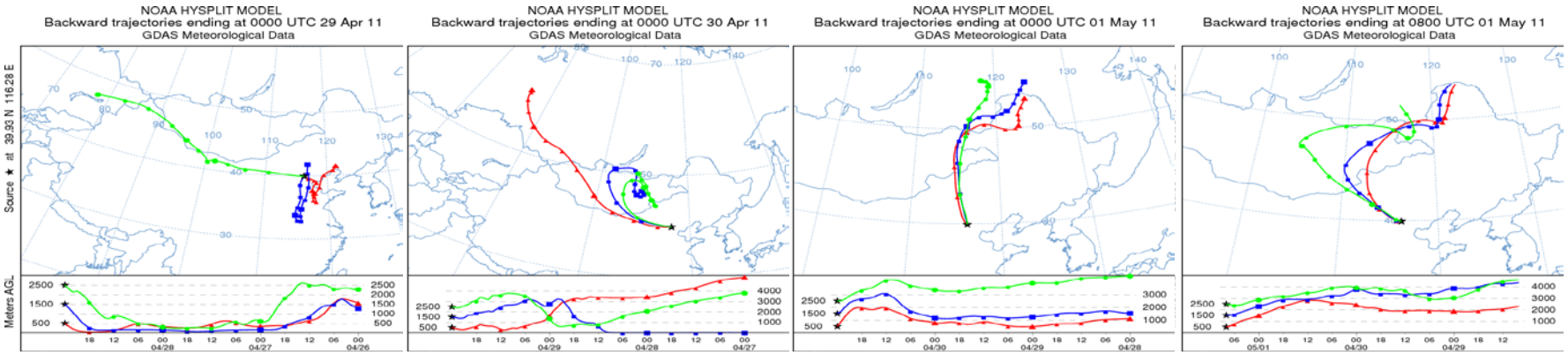
Source Apportionment: Regional Identification



- Analysis on $PM_{2.5}$ and PM_{10} source attribution
- Impact of geogenic / anthropogenic emissions on local/regional air quality
- COSMO-ART can now be used for mineral dust forecast in China

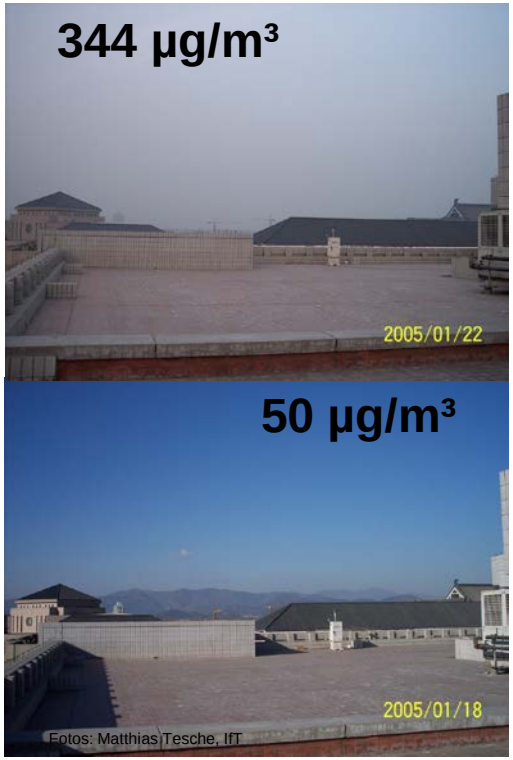
Classification of dust source types for dust event impact studies

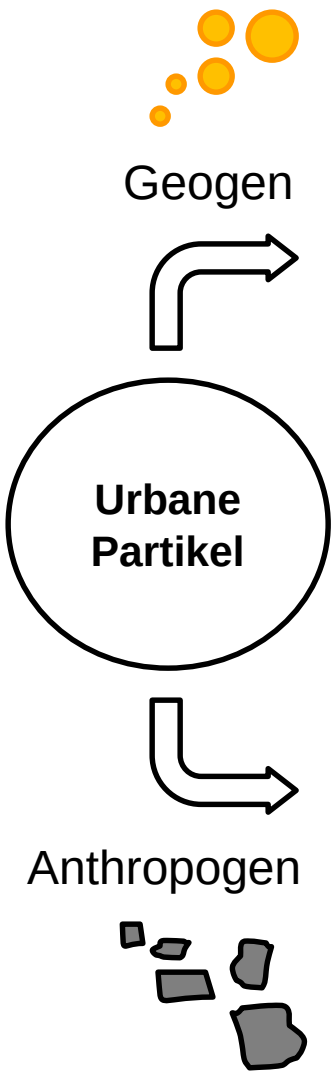
PhD Thesis Stephanie Schrader, 2014



Hysplit backward trajectories for 72 hours starting at Beijing during April 29th to May 1nd

Source Apportionment: Local Investigations





Zhang, Y.-L., Schnelle-Kreis, J., Abbaszade, G., Zimmermann, R., Zotter, P., Shen, R.-R., Schaefer, K., Shao, L., Prévôt, A.S.H., Szidat, S.: **Source apportionment of elemental carbon in Beijing, China: insights from radiocarbon and organic marker measurements**. Environ. Sci. Technol., 49 (14), 8408–8415, 2015; doi: 10.1021/acs.est.5b01944

Source Apportionment: Methodology

CUGB: PM sampling 2010.06.21 – 2011.06.20

IAP: PM sampling 2013.04.10 – 2013.06.08

ZBAA: Weather station

Source Apportionment: Analysis

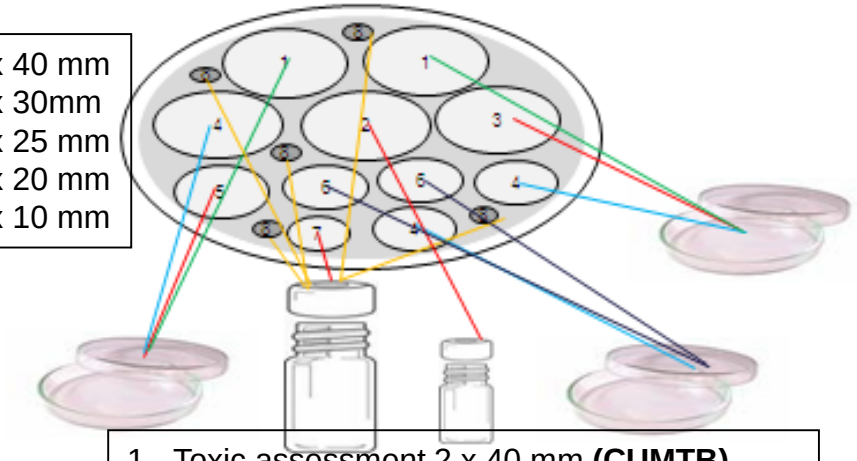
Karlsruhe Institute of Technology

Sample A

Organic composition

GC-MS, EC/OC/ WSOC, stable isotopes, toxic-testing

5 x 40 mm
1 x 30mm
4 x 25 mm
1 x 20 mm
5 x 10 mm



1 - Toxic assessment 2 x 40 mm **(CUMTB)**
2 - Organic 40 mm **(HMGU)**
3 - IRMS 40 mm **(IMK-IFU)**
4 - Spare 40 mm + 2 x 25 mm
5 - Toxic assessment 30 mm **(U. Cardiff)**
6 - EC/OC WSOC 2 x 25 mm **(U. Rostock)**
7 - Isotope extraction 20 mm **(IMK-IFU)**
8 - EC/OC 5 x 10 mm **(U. Rostock)**

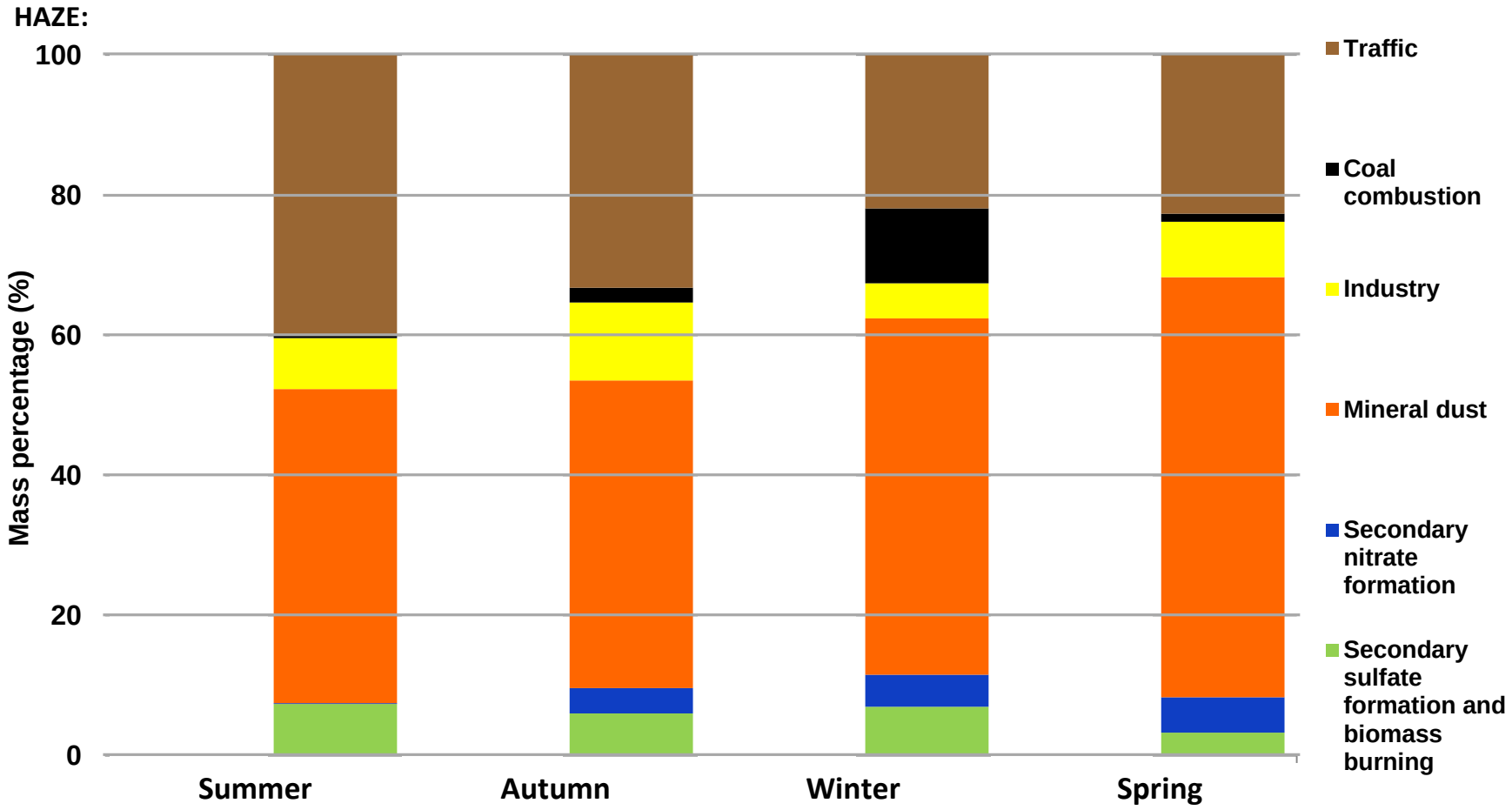
Sample B

PM mass

ICP-MS *(Inductively Coupled Plasma Mass Spectrometry),*
PEDXRF *(Polarized Energy Dispersive X-ray Fluorescence)*

Source Apportionment: Results

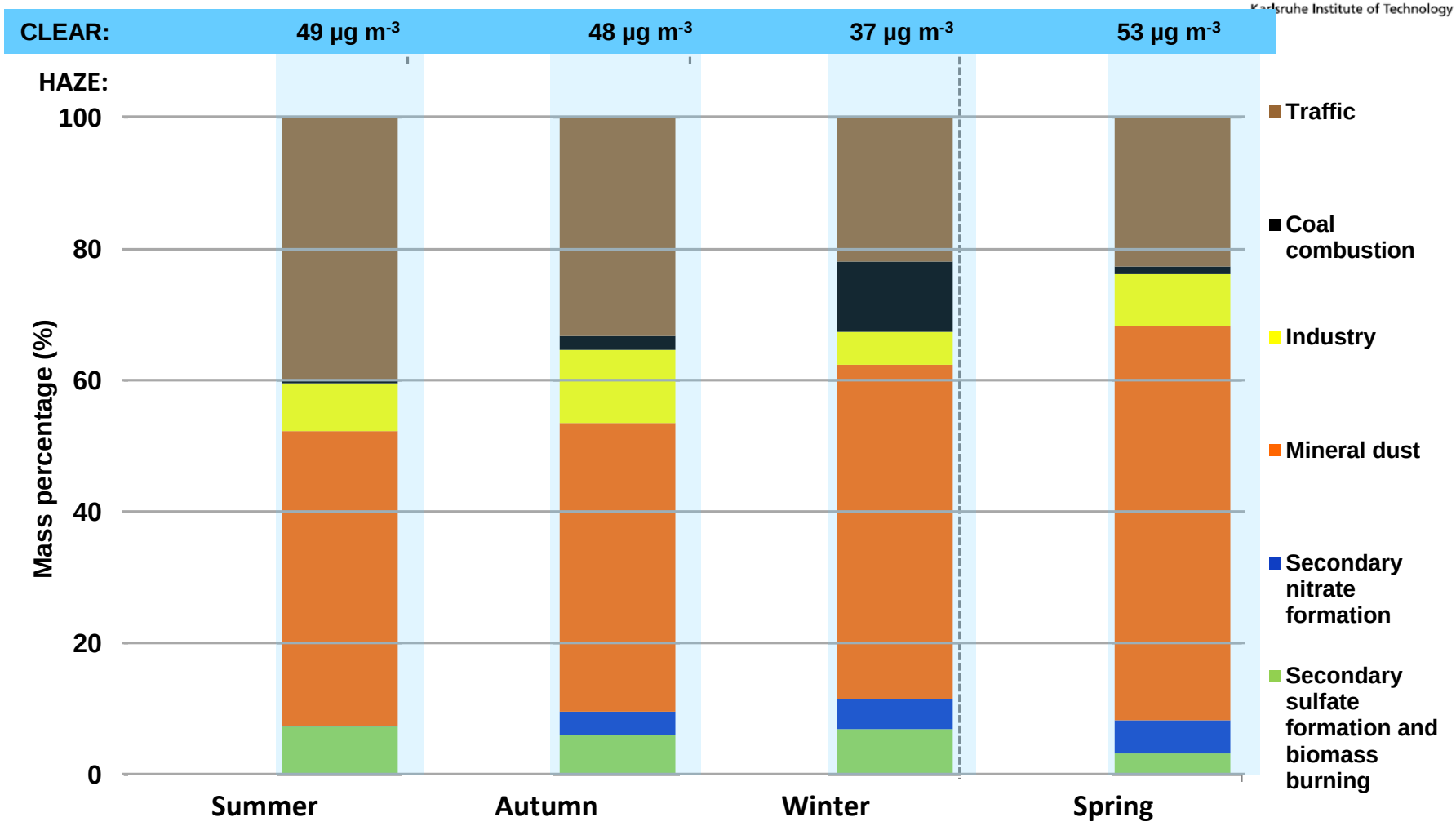
CLEAR:	49 µg m^{-3}	48 µg m^{-3}	37 µg m^{-3}	53 µg m^{-3}



PhD Thesis Rongrong Shen 2015:
Annual variation of chemical composition and source apportionment of particulate matter in Beijing

Source apportionment analysis

Source Apportionment: Results



PhD Thesis Rongrong Shen 2015:
Annual variation of chemical composition and source apportionment of particulate matter in Beijing

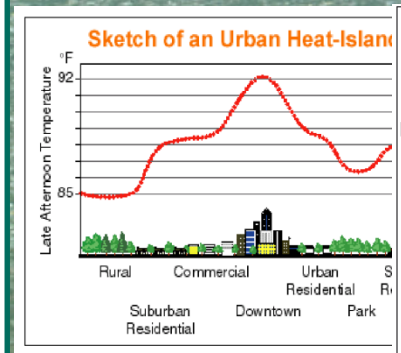
Source apportionment analysis

Source Apportionment: Results

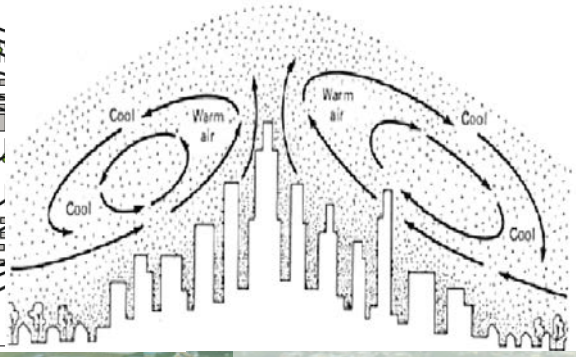
- **Mineral dust** → inner Asia loess and desert areas in combination with the steep topography have significant impact on local air quality (→ Beijing)
- **Mineral dust reduction** → planting of specific grasslands; recultivation of steppes and coal degradation regions
- **Haze** → fine and anthropogenic particles and stagnant weather conditions
- **Haze** → different seasons - different sources – different source regions
- **Haze reduction** → NO_3^-, SO_4^{2-}, and NH_4^+ in the regional scale
- **Haze reduction** → higher standard of cleaning equipment's; road cleaning standards; emissions from construction dust

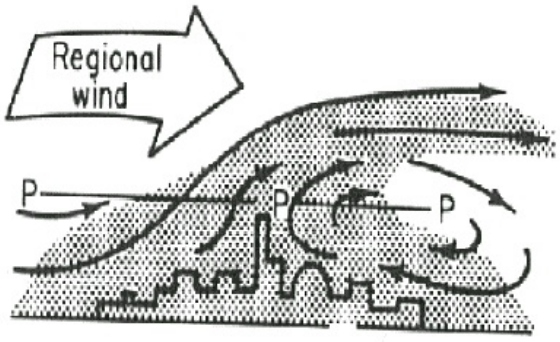
Urban Heat Island (UHI): Phenomena

- "Urban Heat Island" (UHI) refers to the tendency for a city or town (urbanized areas) to remain **warmer than its surroundings**.
- The **annual mean temperature** of a large city may be **1°–2°C warmer** than the surrounding areas, and on individual calm, clear **nights** may be up to **12°C warmer (→ Heat Island Intensity)**.
- **Closed isotherms** indicating an area of the surface **(→ island)** that is relatively warm; most commonly associated areas of human disturbance such as towns and cities (urbanized areas).
- The warmth extends vertically to form an **urban heat dome** in near calm, and an **urban heat plume** in more windy conditions.



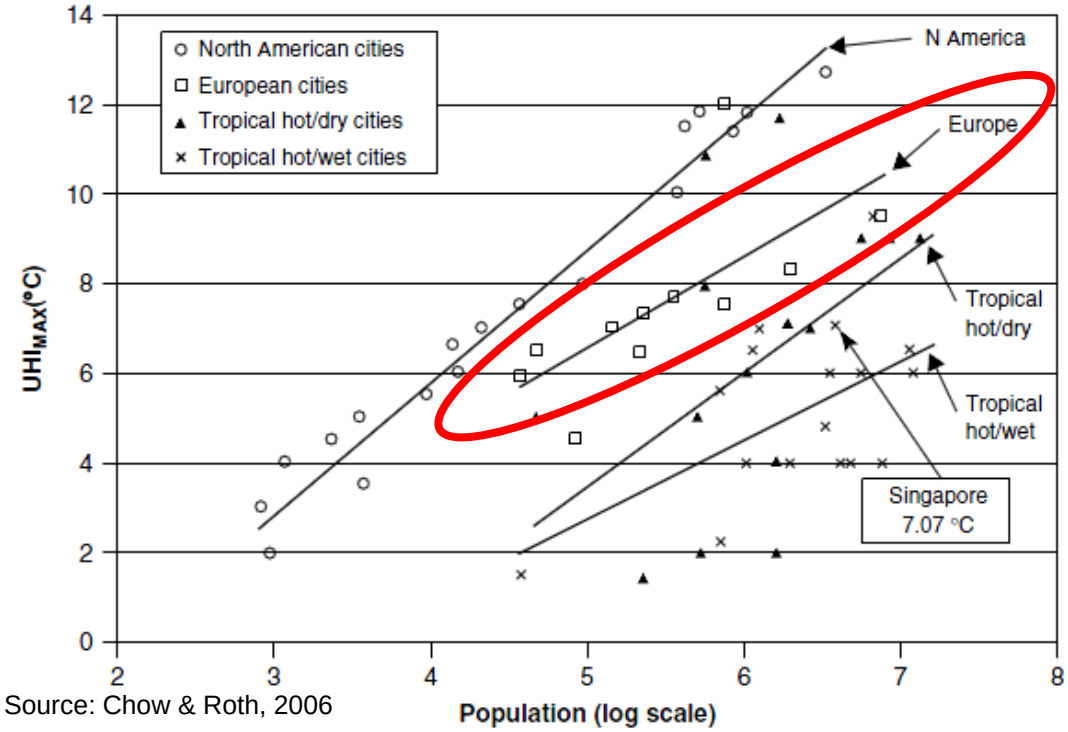
Source: Lawrence Berkeley National Lab.



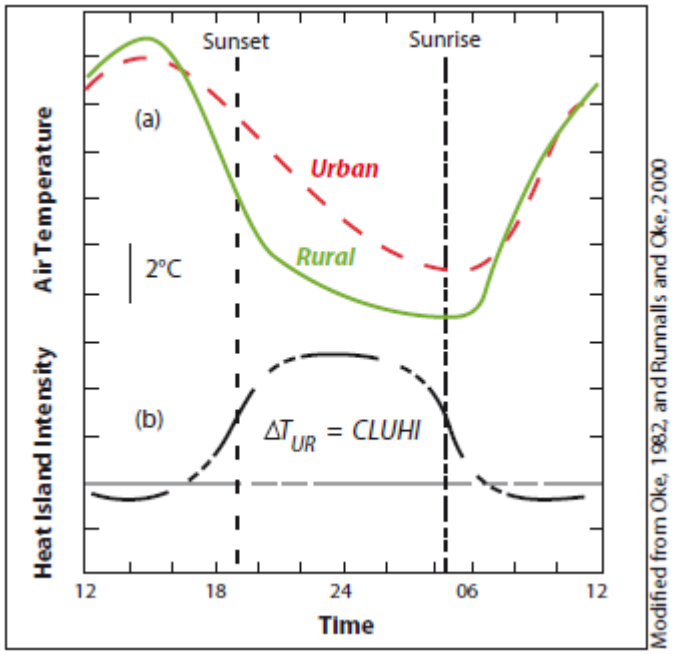


Source: NASA Global Hydrology and Climate Center

UHI: Intensity and Magnitude



Source: Chow & Roth, 2006



Source: EPA, 2009

UHI: Mitigation Measures …

- **Increasing albedo**
  reflectivity of surfaces / buildings, …
- **Increasing vegetation cover**
  green roofs, parks, avenue trees, …
- **Decreasing runoff**
  open water spaces, ponds, control of impervious surface areas, …
- **Decreasing anthropogenic heating**
  air conditioning, industrial facilities, …..
- **Increasing structural and natural shading**
  ancient city structures

Foto: Mstyslav Chernov, Quelle: http://upload.wikimedia.org/wikipedia/commons/c/c1/Oia_%28panoramic_cityscape%29._Santorini_island_%28Thira%29%2C_Greece.jpg

UHI: … and its Benefits

- **on meteorology**

  reduction of temperature, wind effects, …

- **on emissions**

  reduction of emissions, aerosols, contribution to green house emissions, …

- **on air quality**

  reactions, photochemistry, regional influence, effective air pollution control strategy

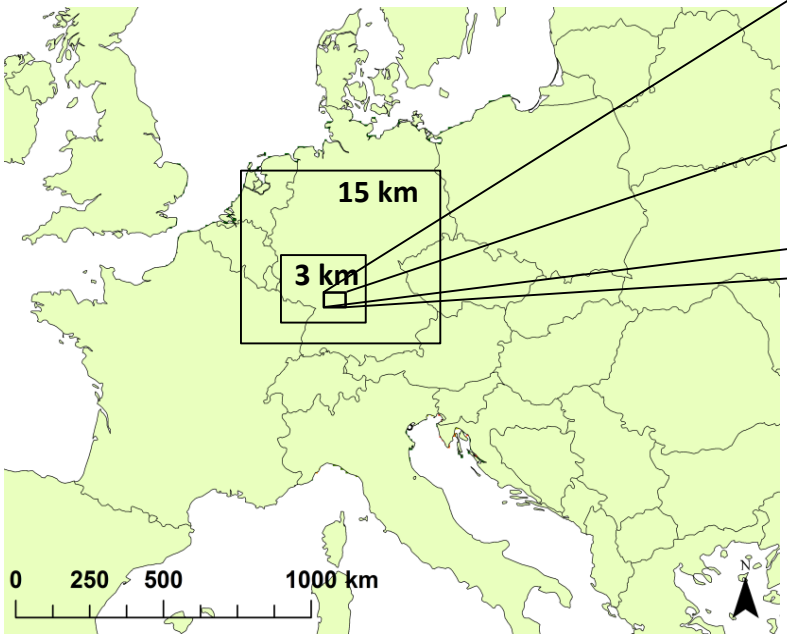
- **on human health**

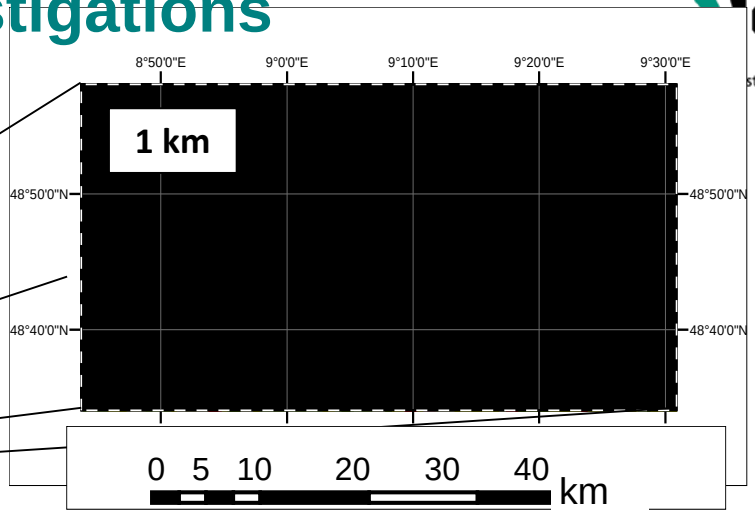
  mortality, morbidity, heat stress, comfort,….

- **on economy**

  health care system, energy consumption (e.g. 100 $ per air conditioned house), ….

UHI: (WRF) Modelling Investigations





‚Corine' Land Use

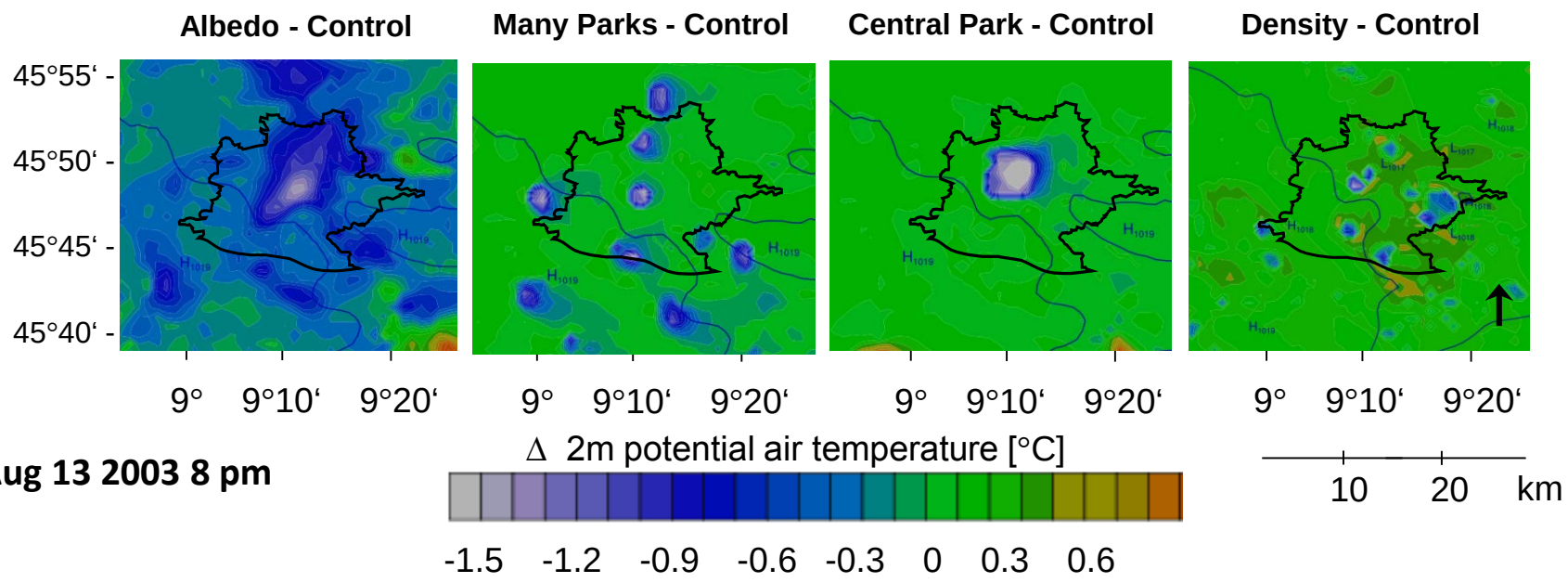
- Dryland Cropland and Pasture
- Irrigated Cropland and Pasture
- Mixed Cropland
- Grassland
- Deciduous Broadleaf Forrest
- Evergreen Needleleaf Forrest
- Mixed Forrest
- Water
- Herbaceous Wetland
- Wooded Wetland
- Sparsely Vegetated, Barrer
- Low Intensity Residential
- High Intensity Residential
- Industrial/ Commercial

„Urban"

- Initial- und dynamical boundary conditions: ***ERA-Interim 0.5°*** Reanalysis
- Land surface processes: ***NOAH LSM***
- Parametrization of sub-grid scale processes: ***BEP Urban Canopy Model***
- Modelling time frame**: Aug 8 – Aug 18 2003**

PhD Thesis Joachim Fallmann, 2014:
Numerical simulations to assess the effect of urban heat island mitigation strategies on regional air quality.

UHI: Simulated Mitigation Strategies



Aug 13 2003 8 pm

PhD Thesis Joachim Fallmann, 2014:
Numerical simulations to assess the effect of urban heat island mitigation strategies on regional air quality

Impact of mitigation strategies on heat island intensity

Scenario	Control	Albedo	Many Parks	Big Park	Density
T mean urban [°C]	33.1	31.5	32.5	32.3	32.4
T max [°C]	34.3	31.9	33.5	33.3	33
UHI; delta Θ	**2.52**	**0.84**	**1.47**	**1.19**	**1.32**

UHI: Any other Implications?

Stuttgart / Germany „fair weather situation in summer“

Cold Air

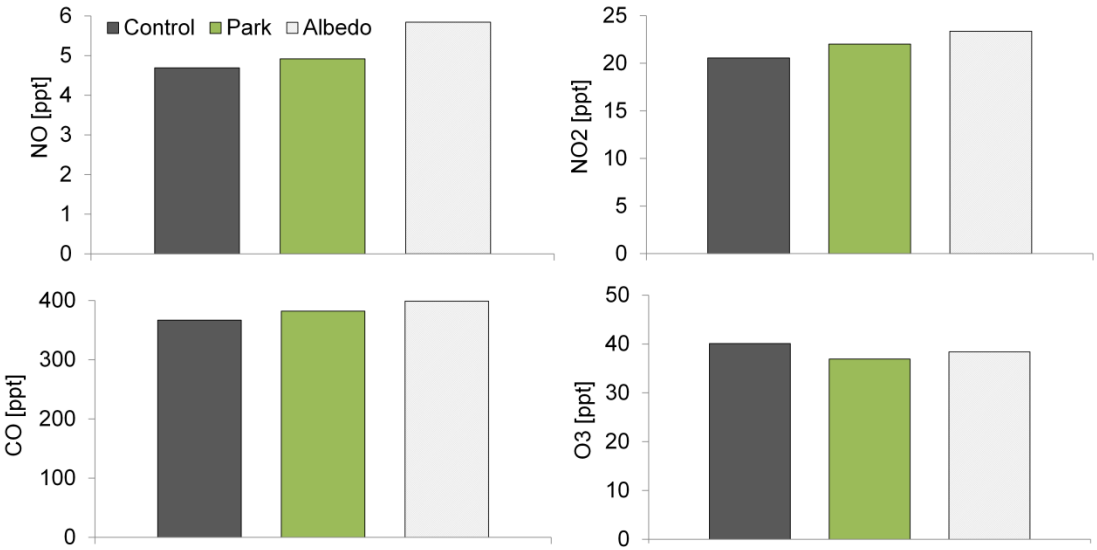
Inversion Layer

www.stadtklima-stuttgart.de

UHI: Impact on Air Quality

Karlsruhe Institute of Technology

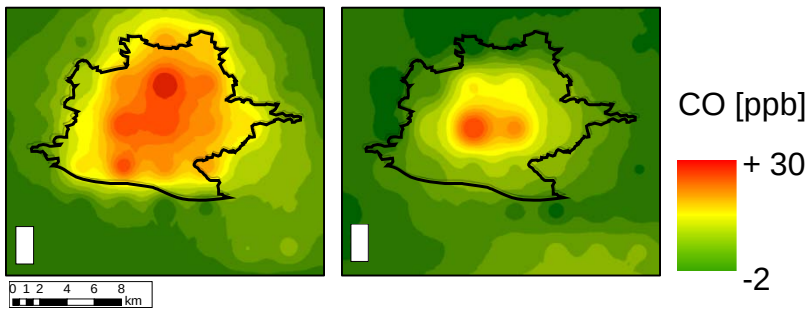
Control
Park
Albedo



Mean concentration for modelling period

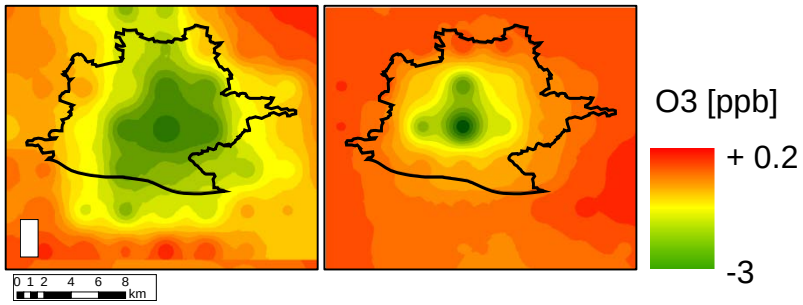
Primary pollutants (e.g. CO)

‚Albedo' ‚Park'

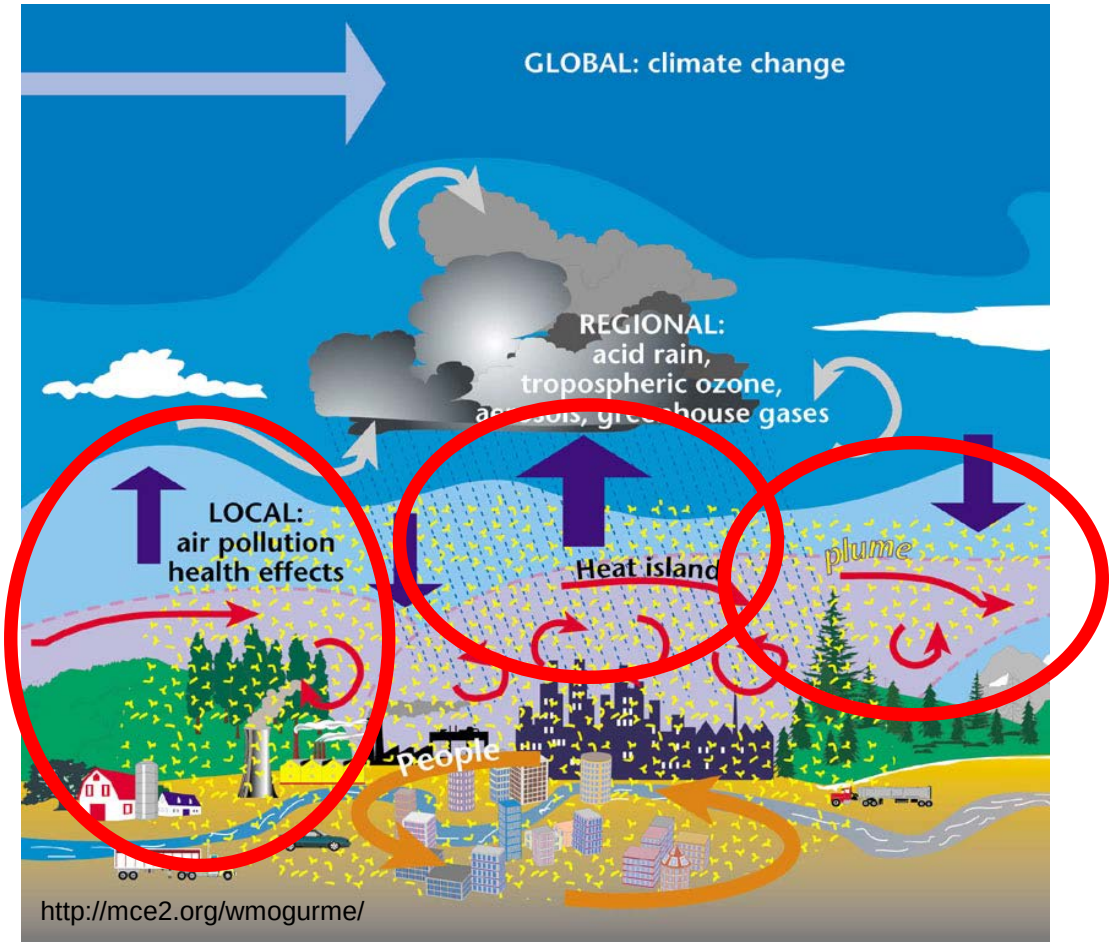


Secondary pollutants (e.g. ozone)

‚Albedo' ‚Park'



Urban-Rural Interactions
Cities as Reaction Vessels



Driving Forces

- Anthropogenic / biogenic / geogenic emissions
- Land use change
- Radiation & heat budget
- Climate Change

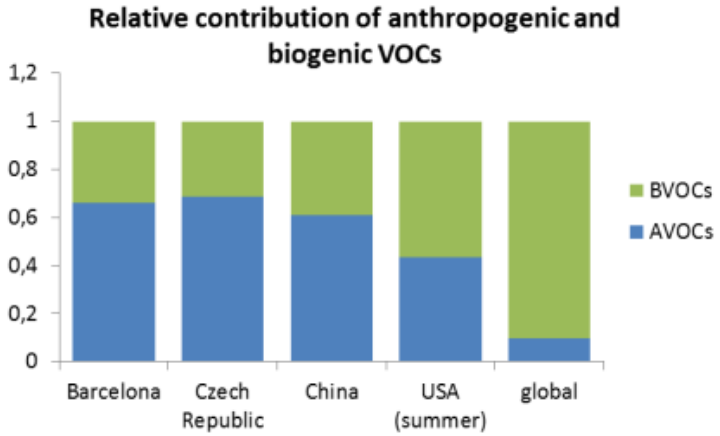
Resulting Impacts

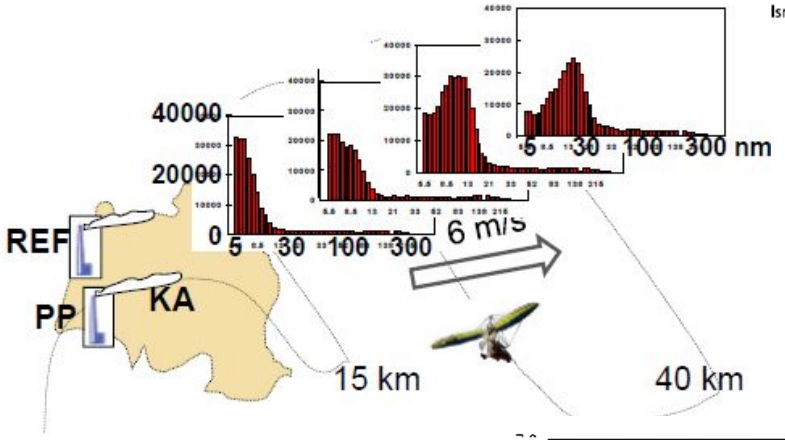
- Heat Island Effects
- Composition & dispersion of pollutants
- Adverse health effects

Challenges

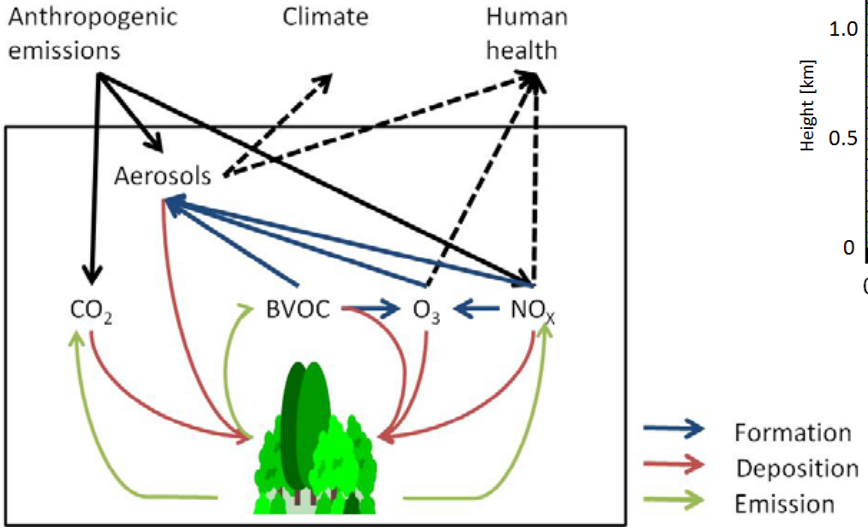
Isruhe Institute of Technology

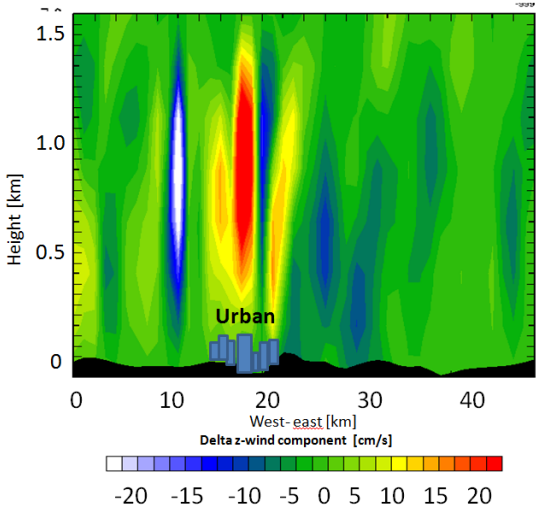
Aerosol Chemistry & Physics





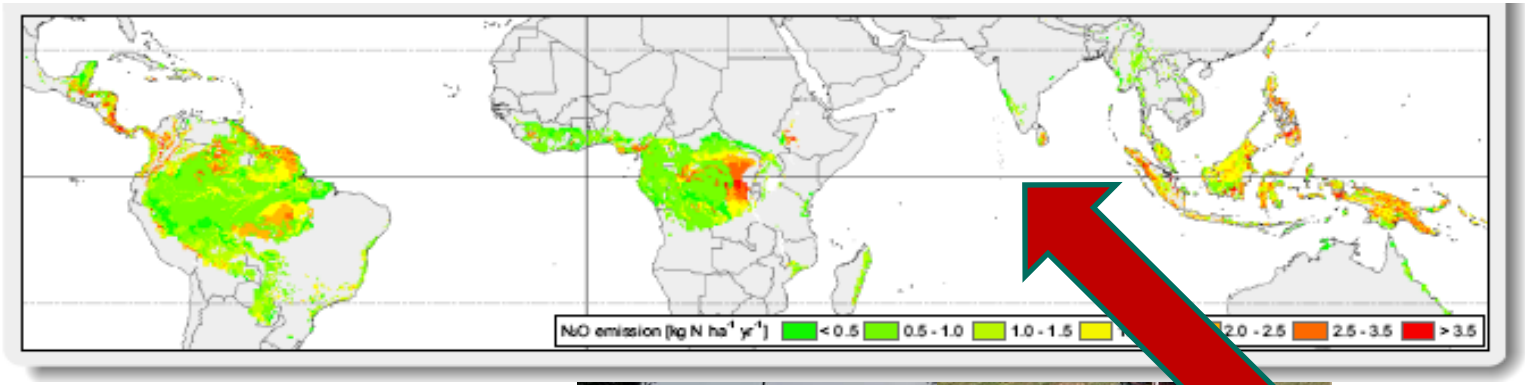
Impact of anthropogenic - biogenic emissions on urban climate – health – air quality

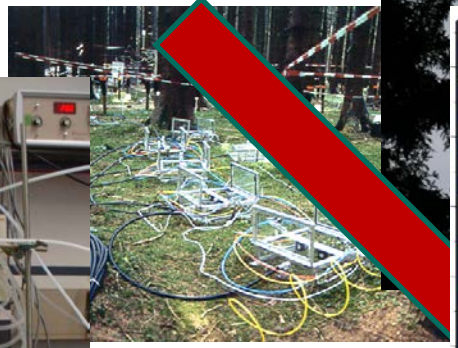


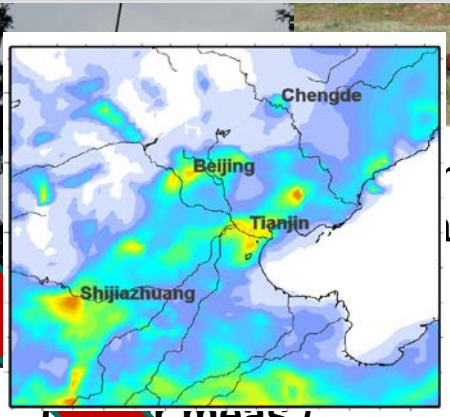


Mitigation & Adaptation strategies

Outlook: Overcoming the Scales





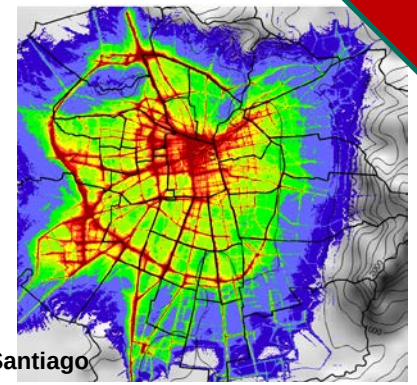


global scale
mote sensing)

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.)

Outlook: What are the next steps?

Karlsruhe Institute of Technology

Urban research at national and international level

BMBF Research Program 'Urban Climate under C

- Module A: Development of a comprehensi model
- Module B: Evaluation of the urban cli
- Module C: Review of practicabilit urban climate models in respect to a urban developmen limate

Helmholtz-Urban-Researc

- Overall urban res ich incl. engineering, natural-, health- and social sciences but a and urban planning components. Thematic priorities. Long term (10-3 ional pioneering role. KIT as coordinator and PI.

EU-HOR

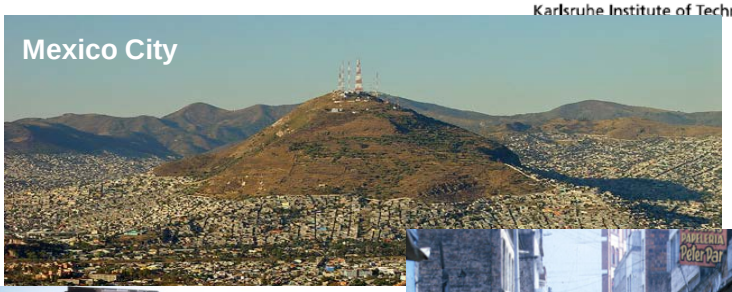
- r quality and reducing the carbon footprint of European cities (proposals under review)

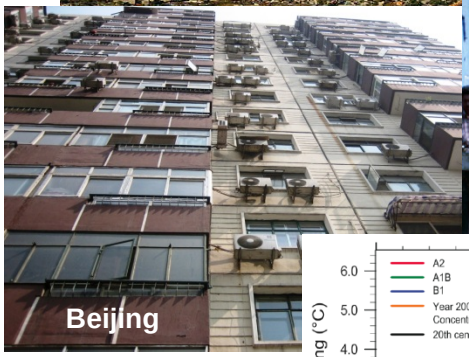
Federal Ministry of Education and Research (BMBF) has announced 2015: Future City

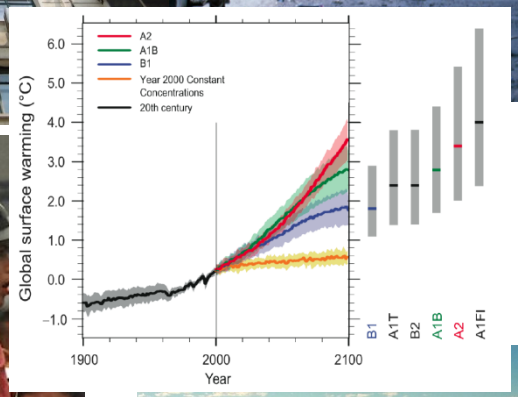
Integrated Approach

- Land use change
- Energy
- Mobility
- Social science
- Climate change

- **Air quality & well being**
- **Health impact**
- **Economical benefit**





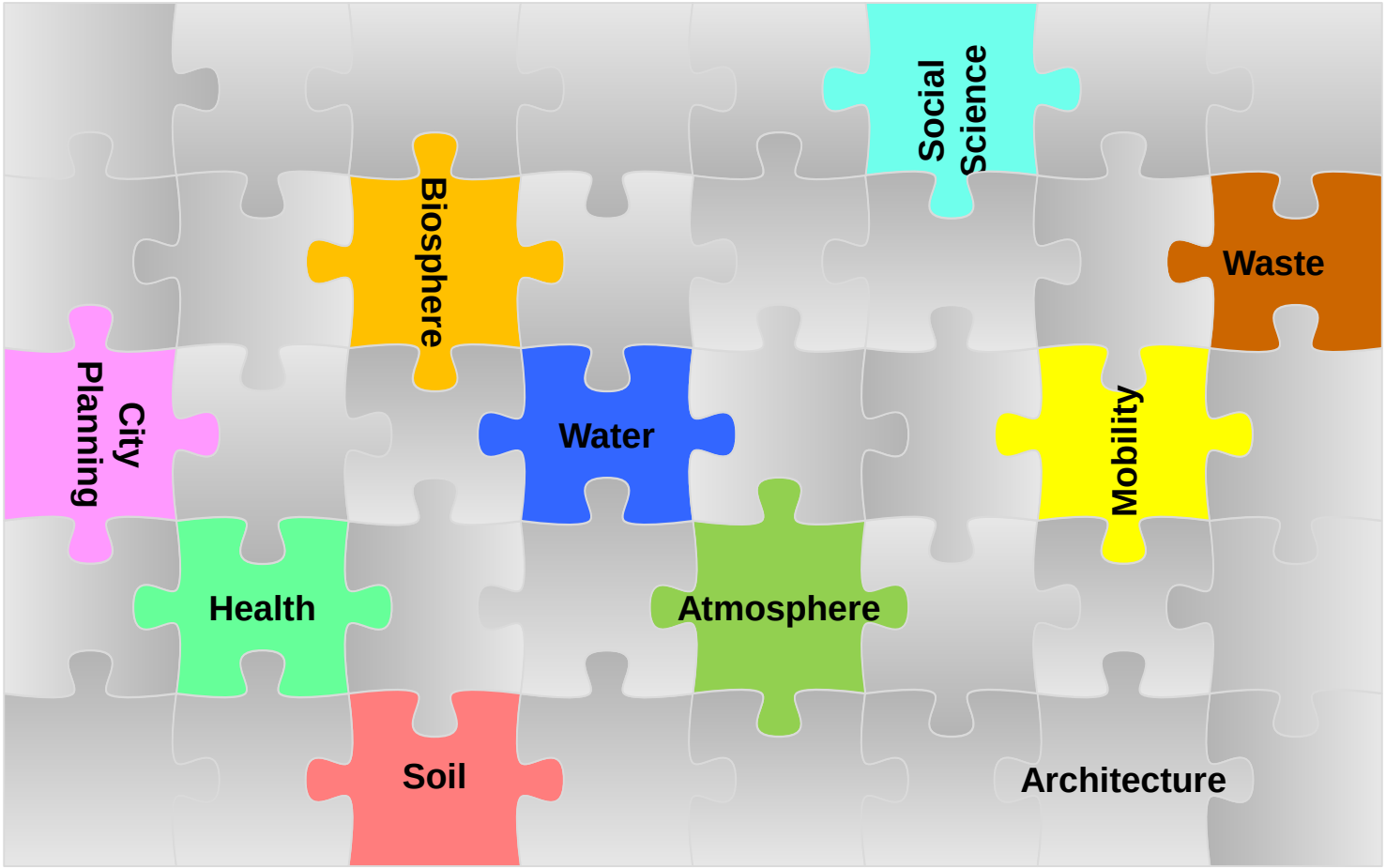


Conclusions

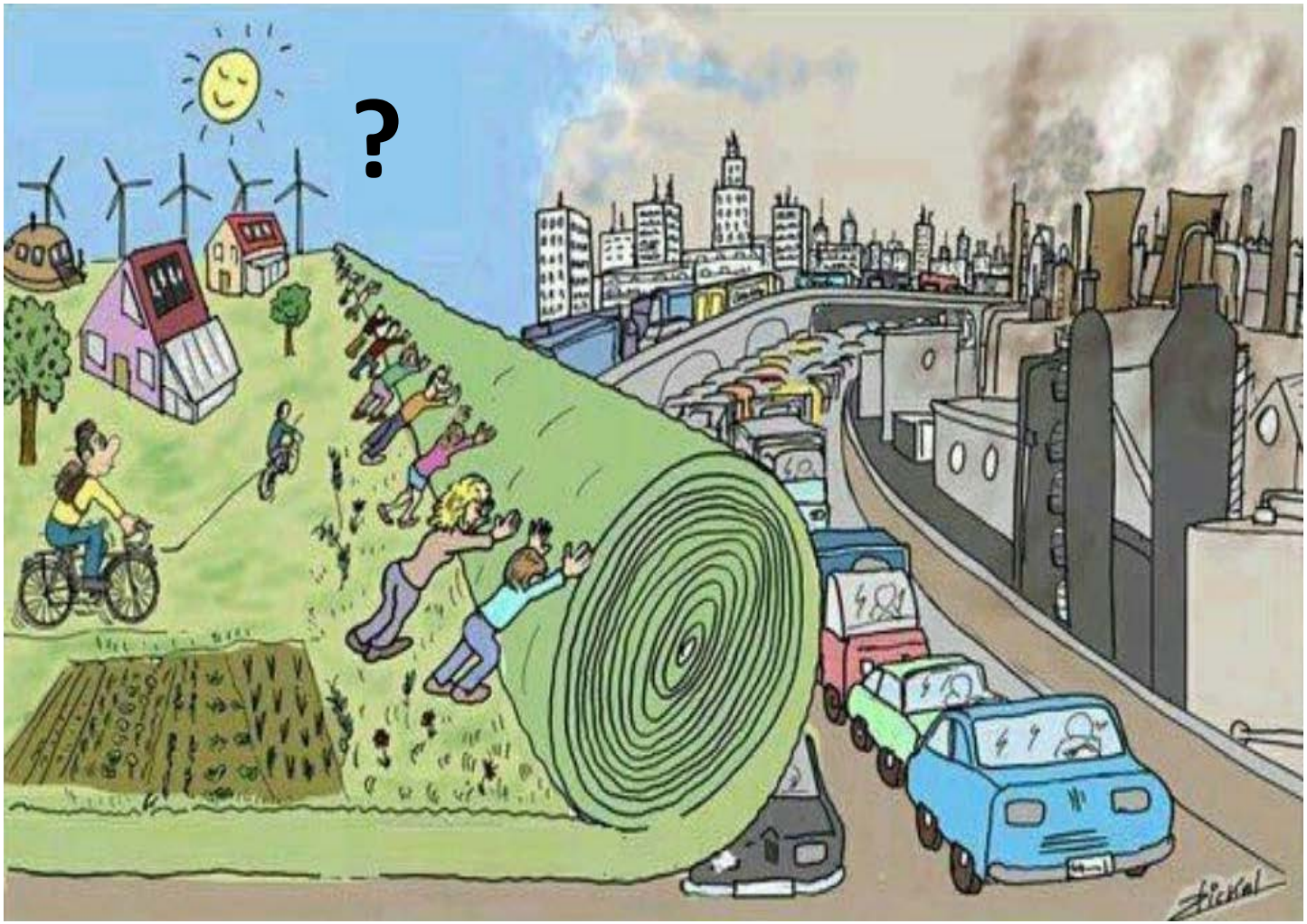
- Successful sustainable development of cities needs linked knowledge of different disciplines
- Scenario development (mitigation & adaptation) needs multidisciplinary views and approaches
- Traffic modeling & traffic emission modeling and its impact on air quality and health can demonstrate such linkages
- Complex processes can only be described and assessed by multi-scale modeling
- High quality standards are needed not only for the urban level but also for the regional surrounding of cities

„It is now understood that the battle against climate change will likely be won - or lost - in cities……targeted research at the city level is needed to enable policy makers to understand the magnitude of the impacts …… (World Bank 2008)

A little bit less complex



… or can we do it more easier ?




Muchas gracias por su atención
and best regards from Germany