UrbENO - an urban observatory in the context of larger holistic research strategies

Stefan Emeis
IMK-IFU, Karlsruhe Institute of Technology, Garmisch-Partenkirchen
stefan.emeis@kit.edu
Some urban facts

- Since **2007** more than **50 %** of the world’s population live in urban agglomerations; it is estimated that **70 %** do so by **2050**
- Until 2030 there will be **59 cities** with more than 5,000,000 inhabitants and **23 megacities** with more than 10,000,000 people. (Brennan-Galvin 2000)
- Urban agglomerations in China increased from **20 %** to **41 %** (between 1980-2005)
- Europe has an **urbanization rate of 72 %**
- **1.2 %** of the land surface is considered to be urban
Interaction of urban agglomerations with Global Change

cities ➔ trace gas emission ➔ changed radiative properties of the air ➔ contribution to global warming

➔ aerosol production ➔ changed clouds and precipitation patterns ➔ regional dimming

➔ heat ➔ changed regional circulations

➔ growing urban population ➔ more emissions ➔ more heat ➔ more fresh water demand

Global Change ➔ warmer and partly dryer climate ➔ even warmer cities ➔ less fresh water availability

➔ more people ➔ larger cities ➔ larger climate impacts ➔ problems in food and water supply

Colour code: radiation; air dynamics; air quality/chemistry; water cycle
A city and its regional interrelations due to climate change, anthropogenic emissions and energy production

Climate
- Enhanced long-distance transport (Cubin 2004)
- Enhanced cold rain (Cubin 2004)

Air chemistry
- More storms/lightnings (Cubin 2004)
- Less warm rain, greenhouse gases, ozone precursors, more/other aerosols, higher MLH (Cubin 2004)

Increased risks

Heating stabilization
- Reduced insolation
- Heating stabilization

Reduced insulation
- More ozone
- Enhanced washout (Cubin 2004)

Cooling in the surroundings
- Changed deposition

Mountains, sensible regions
- Biosphere
- Aquifers
- Biomass, food, water

City
- Urban heat island
- Urban emissions
- Advection of salt particles (Cubin 2004)

Land
- Enhanced warm rain (Cubin 2004)
- Enhanced washout (Cubin 2004)

Sea
- Cooling, reduced evaporation

Advection of biogenic emissions

Energy production
- Many small particles, pollutants, heat
- Convection (heat island), turbulence (roughness)

Urban planning (adaptation, mitigation)
Peculiarities of the climate in **urban agglomerations**

- buildings ➔ flow obstacles ➔ reduced mean wind speed
  ➔ increased turbulence
  ➔ flow convergence at upwind edge ➔ mean upward motion ➔ more clouds, precipitation

- trapped short wave radiation (multiple scattering in street canyons, etc.)

- retained long wave radiation (reduced sky view)

- storage of heat

- impervious surfaces ➔ stronger run off during precipitation events

- less humidity available for evaporation

- less vegetation ➔ less humidity available for evaporation

- human beings ➔ anthropogenic heat production

- trace gas emissions ➔ changed chemical properties of the air

- reduced air quality ➔ health risks

- aerosol production ➔ changed clouds, precipitation

- reduced air quality ➔ health risks

- reduced visibility

---

**excess heat** (UHI) ➔ upward motion over cities ➔ compensating inflow from rural areas

- enhanced chemical reactions ➔ photo-oxidants ➔ health risks

- health risks (missing cooling at night)

---

**Colour code:** radiation; air dynamics; air quality/chemistry; water cycle
The urban ecosystem – a reaction chamber with global impact

Internal processes and exchange with surrounding compartments of the Earth system

- urban heat island
- secondary circulation
- natural emissions (inside and outside of the cities)
- anthropogenic emissions
- air chemistry, aerosol formation
- impact on local and regional air quality
- impact on regional and global climate
Interaction of urban agglomerations with air quality

cities ➔ trace gas emission ➔ changed atmospheric composition
  ➔ changed atmospheric cleansing potential
  ➔ reduced air quality
  ➔ production of secondary trace gases (e.g., ozone)

greater aerosol production ➔ reduced air quality
  ➔ reduced photolysis
  ➔ increased deposition

greater less winds ➔ reduced air quality

greater more heat ➔ faster chemical reactions (e.g., more ozone)
  ➔ shifted chemical equilibria
  ➔ secondary circulations bring rural biogenic and urban anthropogenic emissions together
  ➔ enhanced import of fresh air

Correlation between measured ozone and temperature at an urban centre

Colour code: radiation; air dynamics; air quality/chemistry; water cycle
Warmer cities influence local and regional climate
(Clouds over Manhattan on May 28, 2011)
UrbENO - an urban observatory
UrbENO

Why UrbENO

- understand how a complex system is working
- understand the possible impacts of global/climate change on cities
- being able to manipulate such a complex system towards sustainability
Example of manipulating a complex system

UHI mitigation (WRF simulation with UCM)

impact on air quality

done by Joachim Fallmann, KIT

primarily emitted pollutants (CO, Nox)

secondarily formed pollutant (ozone)
Basic questions

- what data is needed for future urban research, planning, development and policies?
- how can this data be provided?
- how can future monitoring strategies look like which capture complex temporal and spatial dynamics?
- which challenges emerge from the enormous amount of data?
- how can this data (and subsequent research results) be stored and made available to researchers and stakeholders?
- how to include citizens (their needs and abilities, social networks)?
- do unknown data sources exist which have not been accounted for so far?
involving citizens / recently unknown data sources

Cell phone fine dust sensors

Clean air alongside busy roads?
The smartphone fine dust sensor is intended to measure concentration in real time.
(Photo: Patrick Langer, KIT)

Institute of Telematics
Chair for Pervasive Computing Systems / TECO

Project: FeinPhone

START/END
• 03/2015 – 06/2016

PARTNERS
• Siemens AG

RESEARCH TOPICS
• Environmental Sensing
• Mobile Computing
• Participatory Sensing
Cell phone signal attenuation
by atmospheric humidity and precipitation

10 GHz – 40 GHz
Cellular Radio Links (~75 %)

Fiber optics (~25 %)

involving citizens /
recently unknown data sources
Involving citizens / recently unknown data sources

Precipitation maps from microwave attenuation

UrbENO

Challenges

related to the urban system

- high dynamics and complexity of urban development (partly unplanned)
- complex large-scale spatial and socio-economic dimensions and connections
- small-scale multitude of different compartments (representativeness?)
- highly varying entities of spatial and socio-economic relations
- high density and partly overlapping of different land use
Challenges related to the monitoring systems

- integration of a large multitude of data capture and monitoring systems
- necessity of defining and shaping reference systems
- large amounts of highly heterogeneous data (e.g., different time base)
- short update cycles due to dynamic developments
- provisions for multi-scale assessments, up- and downscaling options
UrbENO

Challenges

related to data storage and dissemination

- integration of a large multitude of heterogeneous data
- harmonisation of heterogeneous data
- data quality assessment and control (QA/QC)
- provision of meta data
- storage media
- extraction software for various users
Existing/earlier projects

Germany:

HGF: TERENO, Risk Habitat Megacities
DFG: Megacities – Megachallenge
BMBF: Future Megacities

Europe:

IUME (EEA, Towards an Integrated Urban Monitoring in Europe)
ClearfLo (Clean Air for London)
Lyon (existing urban data base)
Santander (existing urban data base)

USA:

NEON (National Ecological Observation Network), LTER (Long-term Ecological Research Network)

Intern’l:

AURIN (Australia Urban Research Infrastructure Network)
“aims to determine the long-term ecological and climatic impact of global change at regional level”

- the effects of Global Change on terrestrial systems are regionally differentiated → requires a network approach
- … with complex feedbacks between compartments (soil, water, bio-, atmosphere) → requires a platform approach
- long-term observation
  - as non-manipulative field experiment
  - detection of trends
  - validation of terrestrial environmental models

UrbENO will be in some analogy to TERENO and complements it.
UrbENO

**embedded into larger programs / initiatives**

- KIT urban research (survey of existing competence)
- Helmholtz Association (HGF) urban research initiative
- Germany: national platform “City of the Future” (NPZ, Nationale Plattform Zukunftstadt)
- Europe: Horizon2020: “smart cities”

**all these programs / initiatives are heading for a more holistic approach, not just ecosystem exchange fluxes**
UrbENO

coordinated within the Helmholtz Association (HGF)
open to other groups

tentative schedule

2016-2017   conceptual work
2018-2019   first observational sites
2020-20…. operational phase
Vielen Dank für Ihre Aufmerksamkeit
Die TERENO-Observatorien

$\Sigma = 15\text{Mio }\text{€ über die letzten 3 Jahre}$
TERENO: Ziele & Fragen

Ziel

Eine interdisziplinäre und langfristige Beobachtungsplattform schaffen (in enger Zusammenarbeit mit Helmholtz-Gemeinschaft & Universitäten)

Forschungsfragen

• Konsequenzen der beobachteten und erwarteten Klimaänderung auf Grundwasser, Böden, Vegetation, Fließgewässer)

• Rückkopplungen zwischen Landoberfläche & Atmosphäre (Wasser, Stoffe, Energie)

• Einflüsse von Böden und Landnutzungsänderungen auf Wasserhaushalt, Bodenfruchtbarkeit, Biodiversität und regionales Klima

• Konsequenzen anthropogener Eingriffe auf terrestrische Systeme
Anthroposphere comprises cities and agricultural areas.

Urbanisation has been the most drastic change in land use and land surface properties ever.

Stefan Norra therefore suggested the term astysphere.

The astysphere surrounds the globe like a spider net. The knots are the cities, and the silks represent the connecting transport network (Norra 2009).