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Einflüsse von meteorologischen Parametern, Emissionsreduktionsmaßnahmen und Klimawandel auf die Luftqualität in Städten – einige internationale Beispiele

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- The KIT
- Strategic topics
- Problems
- Process studies
- Future work

KIT Portfolio

260 km

KIT - Centres

- Energy
- Climate and Environment
- Nano and Micro Scale Science
- Astroparticle Physics

KIT Center Climate and Environment

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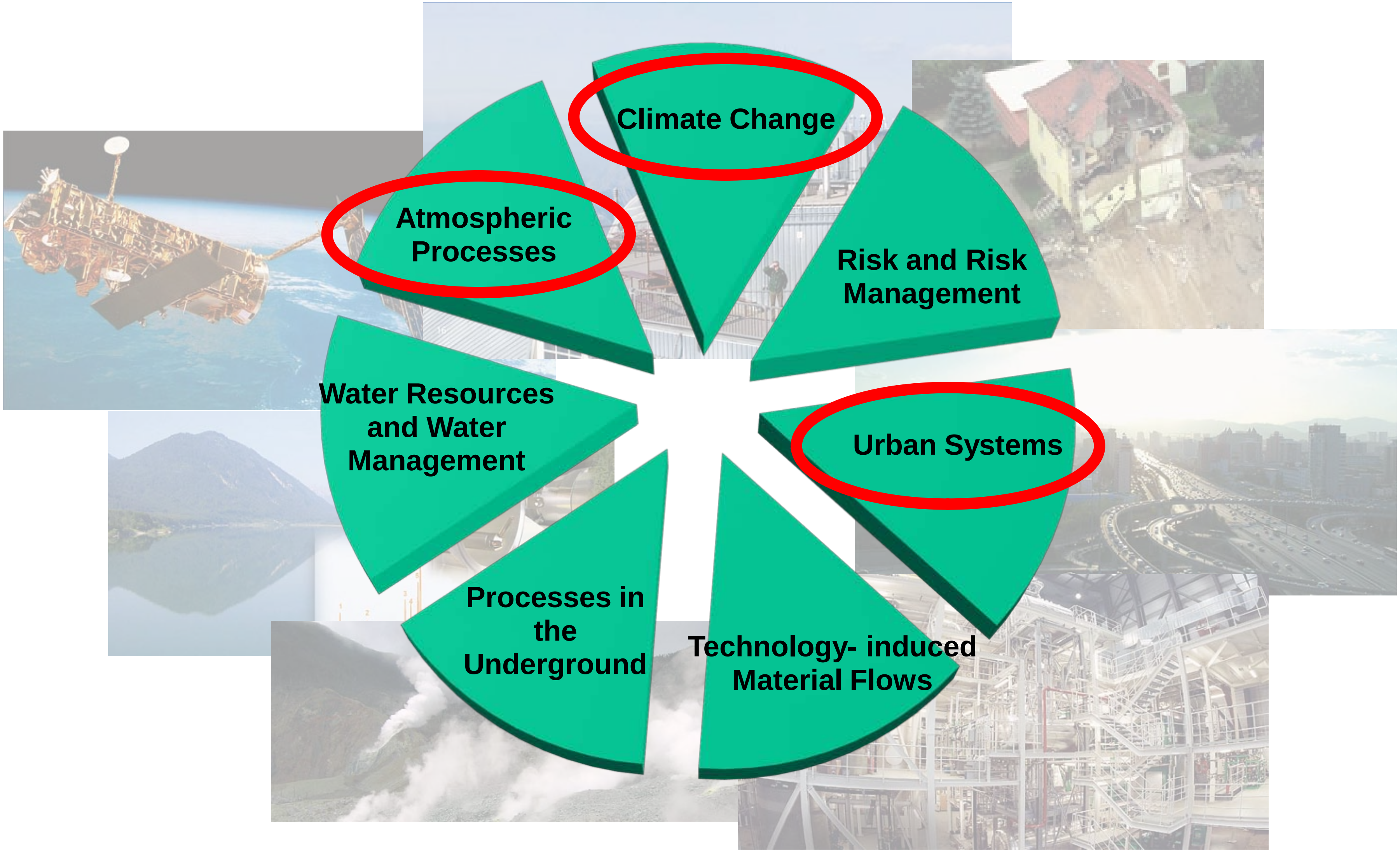
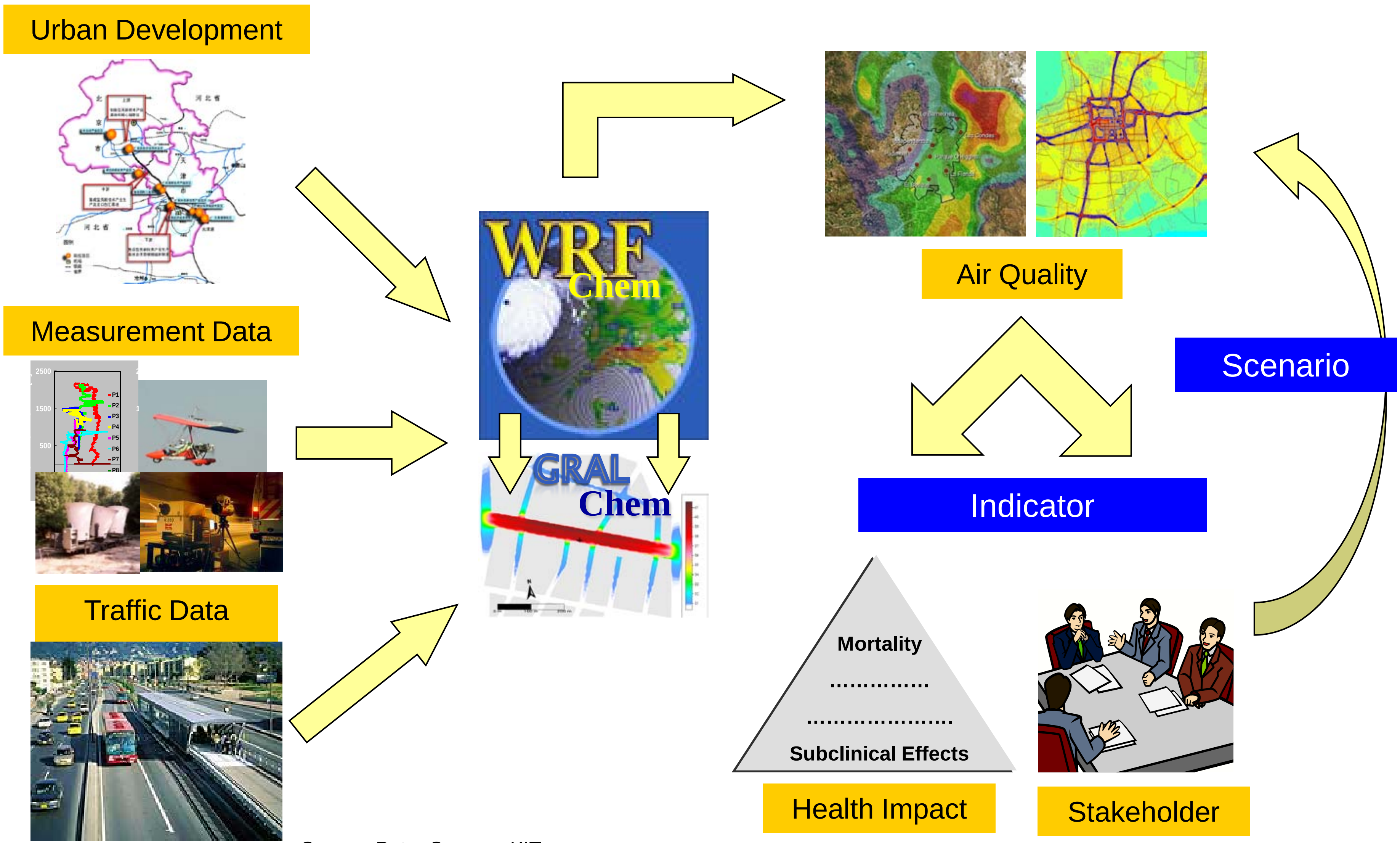


Integrated Approach



Source: Peter Suppan, KIT

Relevant strategic topics
of the working group
"Regional coupling of ecosystem - atmosphere coupling"

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- Knowledge about the interaction of coupled ecosystem – atmosphere processes within a changing climate
- Aerosol research (fine / ultra-fine particles) – loads / composition / formation / sources
- Coupling between urban air quality and regional climate change
- Process studies of air pollution relevant for health protection and legislation (NO_2, PM_{10}, $PM_{2.5}$)

Problems

Climate protection or improvement of air quality / health protection? Or both?

Decisions for emission reduction measures

- Gasoline or Diesel motor: PM, NO_2, NH_3 emissions
- Aircraft: VOC, CO, NO_x emissions and contrails
- Odour and noise emissions or GHG emissions

Problems

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- Changing NO_2/NO_x ratios in ambient air
- Threshold exceedances - sustainable reduction of NO_2, PM_{10}
- Load, character and source apportionment of ultrafine particles in the urban background
- Air pollutants and health impact
  - Which pollutants are relevant?
  - Which concentrations/exposures influence health impacts?

Process studies

Emission source strengths

Scientific questions

Emission source strengths from hard to measure and inhomogeneous sources

- Important input data for emission inventories
- Continuous measurements to determine temporal variations
- High effort of in situ measurement techniques
- Influences on measured emission data by sampling techniques

Tasks

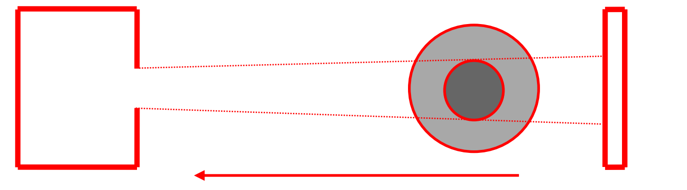
Development of non-intrusive measurement methods

- Determination of gas concentrations by spectrometric measurements: CO, CH_4, CO_2, N_2O, NO, NO_2, NH_3, SO_2, HCl, HNO_3, Ozone, BTX, HCHO

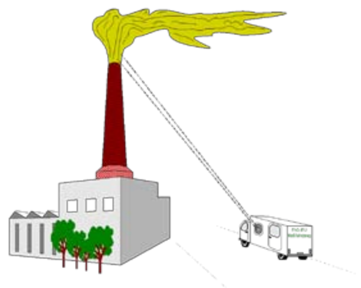
- Application in measurement vans

Tasks

Passive spectrometry: hot gases



- Smoke stack and flare effluents
- Aircraft engine emissions
- Emission indices by using CO_2 emission index



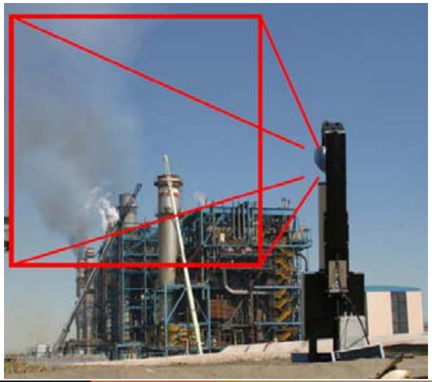
Results

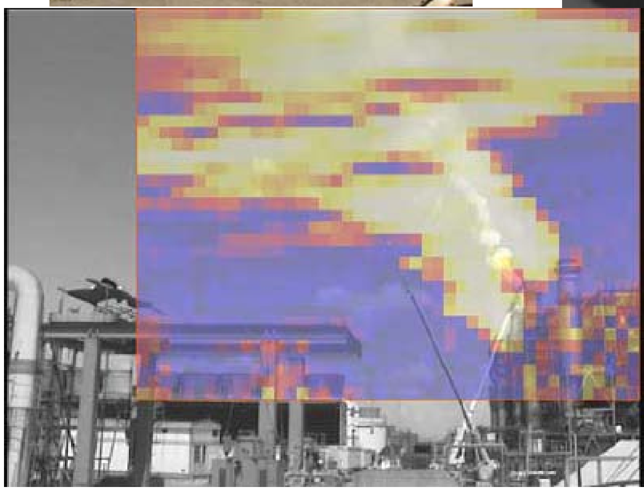
- Determination of unknown compounds (N_2O), concentrations
- APUs are a serious emission source at airports

Haus, R., Schäfer, K., Bautzer, W., Heland, J. Mosebach, H., Bittner, H., Eisenmann, T.: Mobile FTIS-Monitoring of Air Pollution. Applied Optics 33, 24, 5682-5689 (1994).
Haus, R., Wilkinson, R., Heland, J., Schäfer, K.: Remote Sensing of Gas Emissions on Natural Gas Flares. Pure and Applied Optics 7, 4, 853-862(1998).

Schäfer, K., Heland, J., Lister, D.H., Wilson, C.W., Howes, R.J. , Falk, R.S., Lindermeir, E., Birk, M., Wagner, G., Haschberger, P., Bernard, M., Legras, O., Wiesen, P., Kurtenbach, R., Brockmann, K.J., Kriesche, V., Hilton, M., Bishop, G., Clarke, R., Workman, J., Caola, M., Geatches, R., Burrows, R., Black, J.D., Hervé, P., Vally, J.: Non-intrusive optical measurements of aircraft engine exhaust emissions and comparison with standard intrusive techniques, Applied Optics 39, 3 (2000).

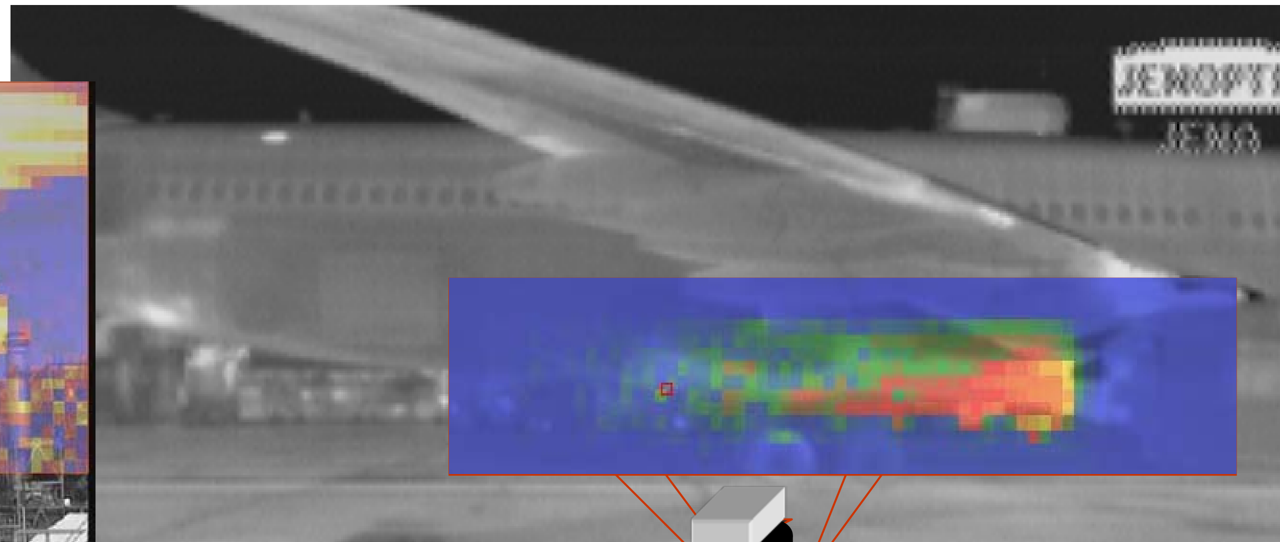
Imaging FTIR with scanning mirror

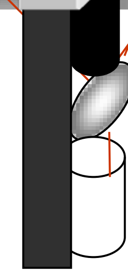


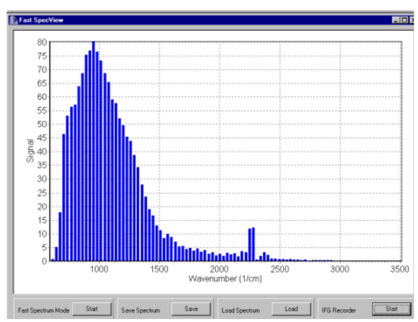


Aircraft exhaust plume:

approximated length 11 m, diameter 2.4 m



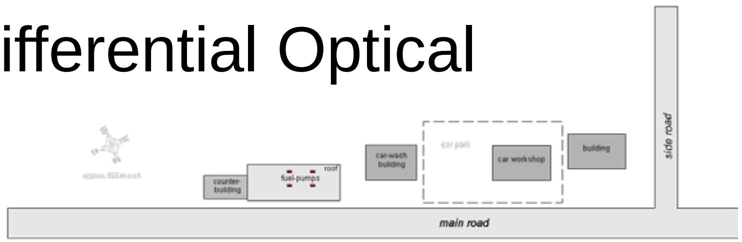




Tasks

Active spectrometry (Infrared radiation source / lamp)

- Open-path FTIR spectrometry and Differential Optical Absorption Spectroscopy



- Absorption paths of 50 up to 500 m

- Path-integrated concentration through plume

Results

- Control of vapour recovery systems at gasoline stations
- Ventilation of tank ships forbidden

Friedrich, R., Wickert, B., Emeis, S., Engewald, W., Hassel, D., Hoffmann, H., Michael, H., Schäfer, K., Sedlmaier, A., Schmitz, T., Stockhause, M., Weber, F.-J.: Development of Emission Models and Improvement of Emission Data for Germany. Journal of Atmospheric Chemistry 42, 179-206 (2002).

Schäfer, K., Jahn, C., Sturm, P., Lechner, B., Bacher, M.: Aircraft emission measurements by remote sensing methodologies at airports. Atmospheric Environment 37, 37, 5261-5271 (2003).

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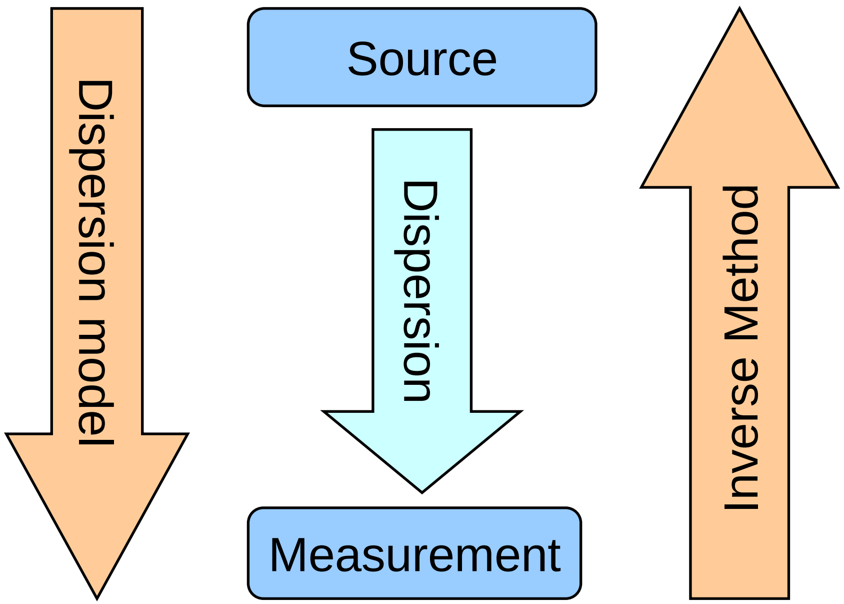
Task

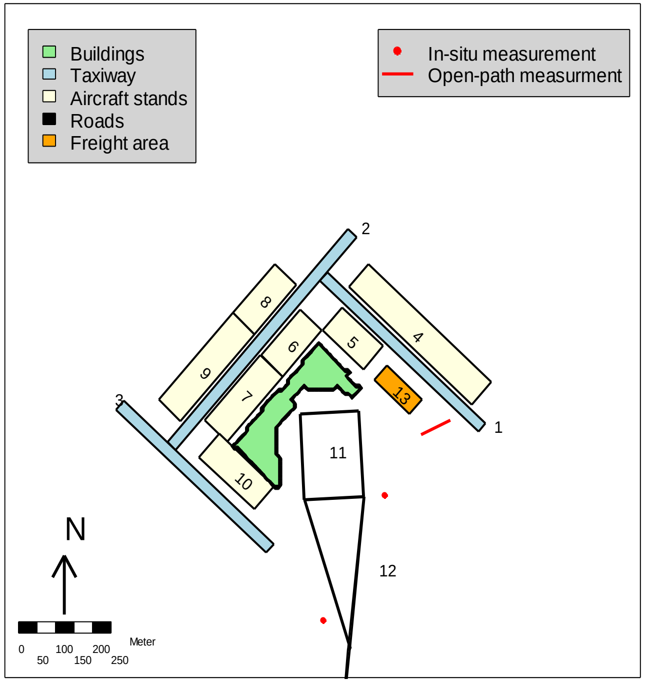
Emission source strengths by inverse dispersion modelling

Result

Single source strengths of inhomogeneous sources



Schäfer, K., Steinecke, I., Emeis, S., Stockhause, M., Sussmann, R., Trickl, T., Reitebuch, O., Hoechstetter, K., Sedlmaier, A., Depta, G., Gronauer, A., Seedorf, J., Hartung, J.: Inverse Modelling on the Basis of Remote Sensing to Determine Emission Rates. Meteorologische Zeitschrift, Neue Folge 7, 7-10 (1998).



Schürmann, G., Schäfer, K., Jahn, C., Hoffmann, H., Bauerfeind, M., Fleuti, E., Rappenglück, B.: The impact of NO_x, CO and VOC emissions on the air quality of the airport Zurich. Atmospheric Environment 41, 103-118 (2007).

Process studies

Description of air quality in street canyons

Tasks

Instruments for the application of the European Guideline

96/62/EU: creation of 12-months air pollutant maps

- Validation of a meso-/micro-scale model system with a spatial resolution of 200 m^2 (14 m x 14 m)
- Data from measurements in a street canyon and in 1 km x 1 km surrounding (Göttinger Straße, Hannover)

Result

Data bank ValiData established

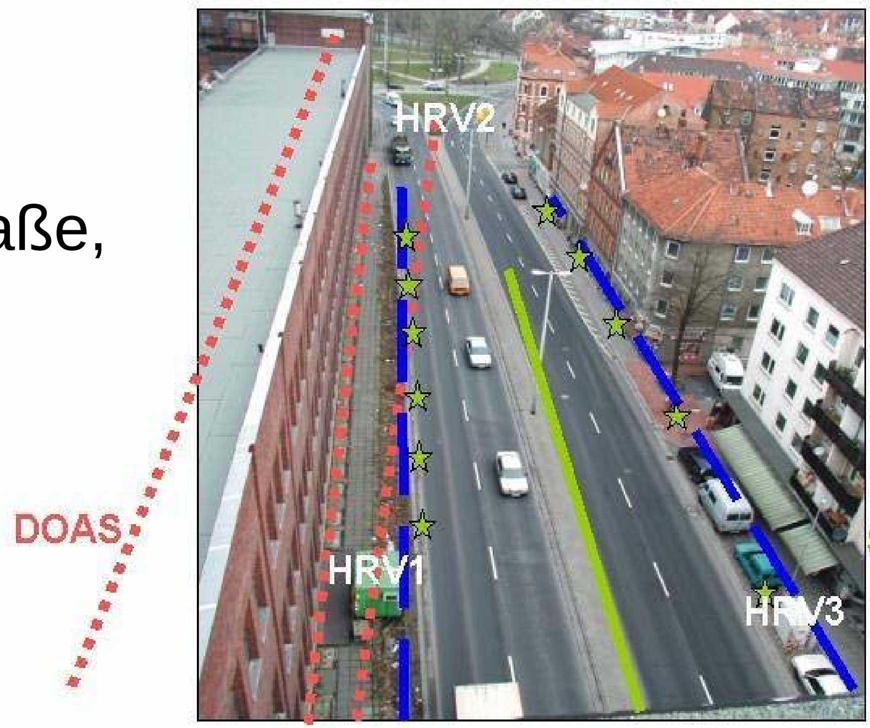
Task

Study of vortex circulation within street canyon

Result

Determination of the horizontal concentration distribution by long-term open-path CO and SF_6 measurements

street canyon
Göttinger Straße,
Hannover



SF_6 line source and sampling sites (stars)

FTIR

Schäfer, K., Emeis, S., Hoffmann, H., Jahn, C., Müller, W., Heits, B., Haase, D., Drunkenmölle, W.-D., Bächlin, W., Schlünzen, H., Leitl, B., Pascheke, F., Schatzmann, M.: Field measurements within a quarter of a city including a street canyon to produce a validation data set. International Journal of Environment and Pollution, 25, 1/2/3/4, 201-216 (2005).

Process studies

Influences upon air pollution

Scientific questions

- Which regional meteorological situations (transport and exchange conditions),
- which chemical processes (e.g. secondary aerosol formation),
- which emission processes

cause high air pollutant exposures?

In particular:

- Local wind systems and secondary circulation systems
- Mixing layer height: spatial variation of air pollutants, long-term study
- Urban area – surroundings interactions

Schäfer, K., Emeis, S., Hoffmann, H., Jahn, C.: Influence of mixing layer height upon air pollution in urban and sub-urban area. Meteorol. Z. 15, 647-658 (2006).

Alföldy, B., Osán, J., Tóth, Z., Török, S., Harbusch, A., Jahn, C., Emeis, S., Schäfer, K.: Aerosol optical depth, aerosol composition and air pollution during summer and winter conditions in Budapest. Science of the Total Environment 383, 1-3, 141-163 (2007).

Augsburg

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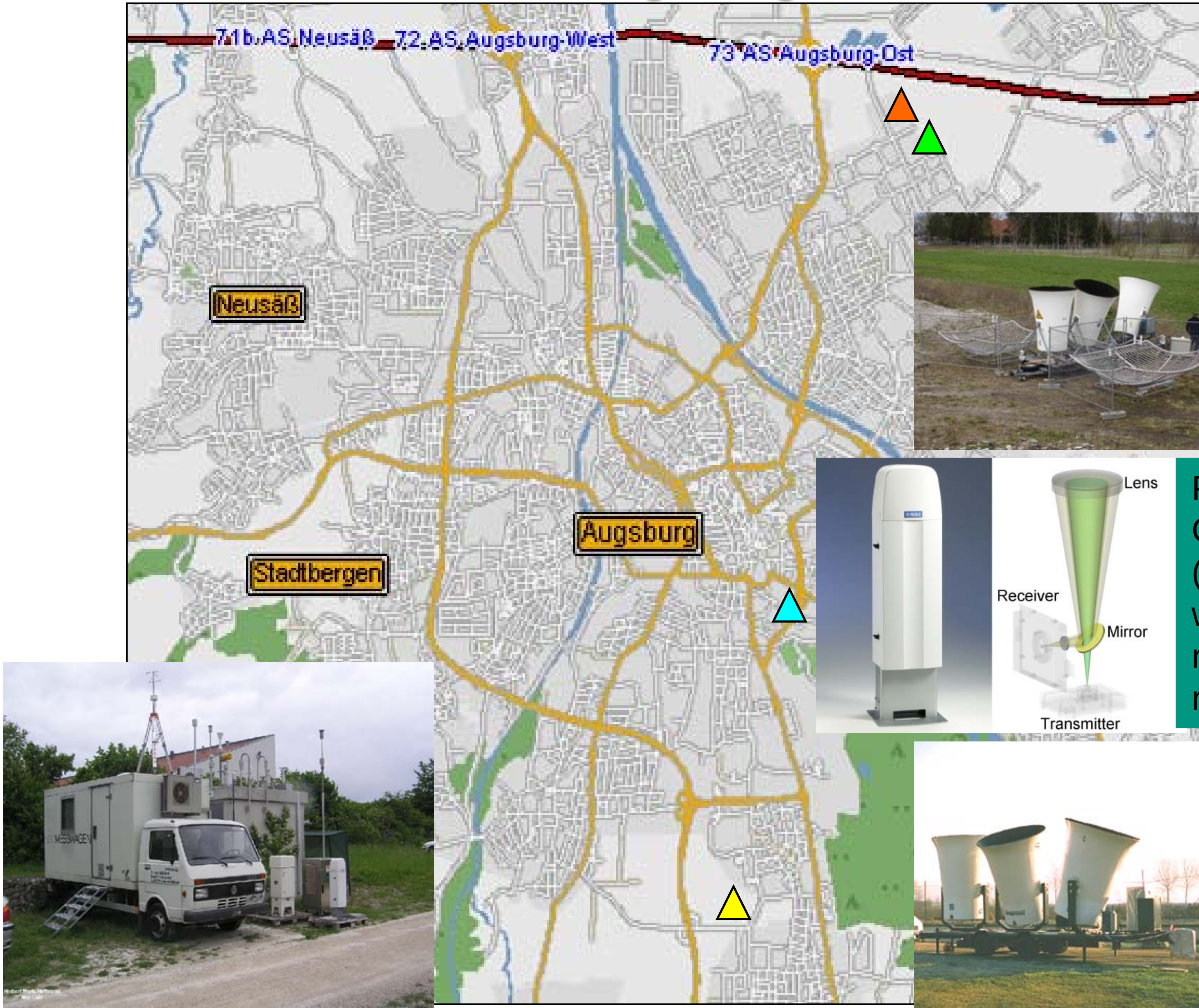


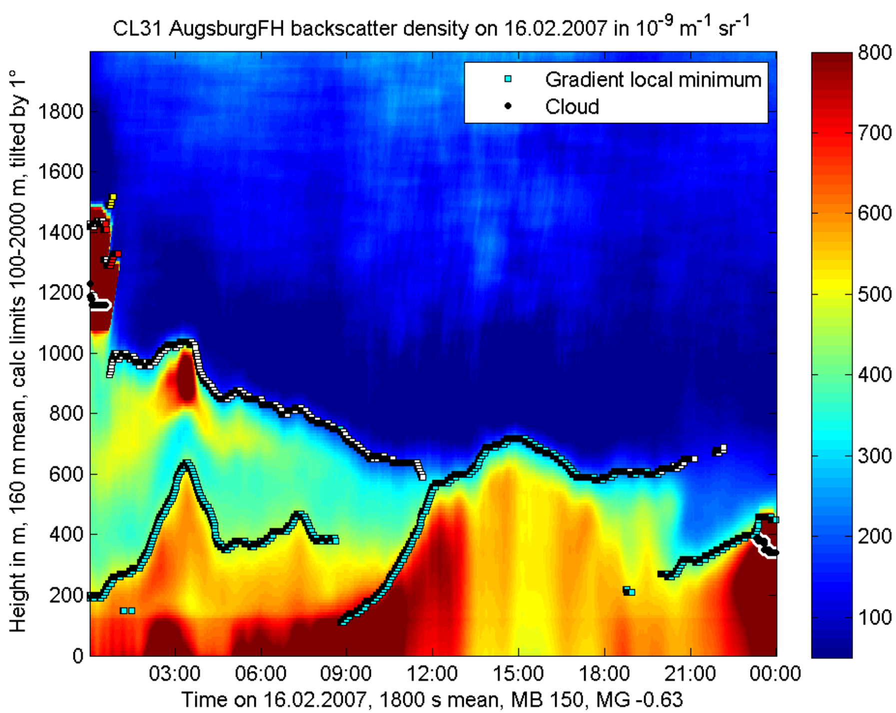
Wind, turbulence, temperature profiles
SODAR-RASS (METEK)
acoustic frequ.: 1500 – 2200 Hz
radio fr.: 474 MHz

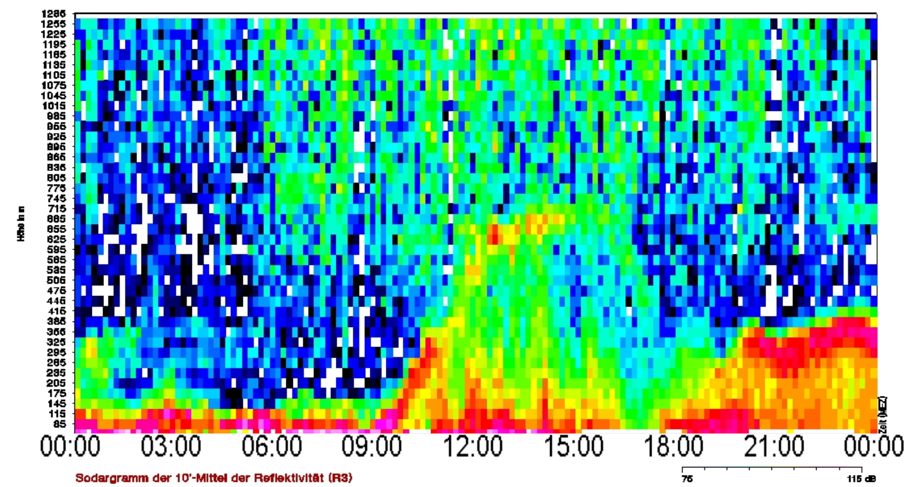
Particle backscatter Ceilometer (Vaisala CL31)
wave length: 910 nm
range: 4000 m
resolution: 5 m

Wind, turbulence profiles
Large SODAR (METEK DSDR3x7)
frequency: 1500 Hz

Ceilometer and SODAR measurements

backscatter intensities





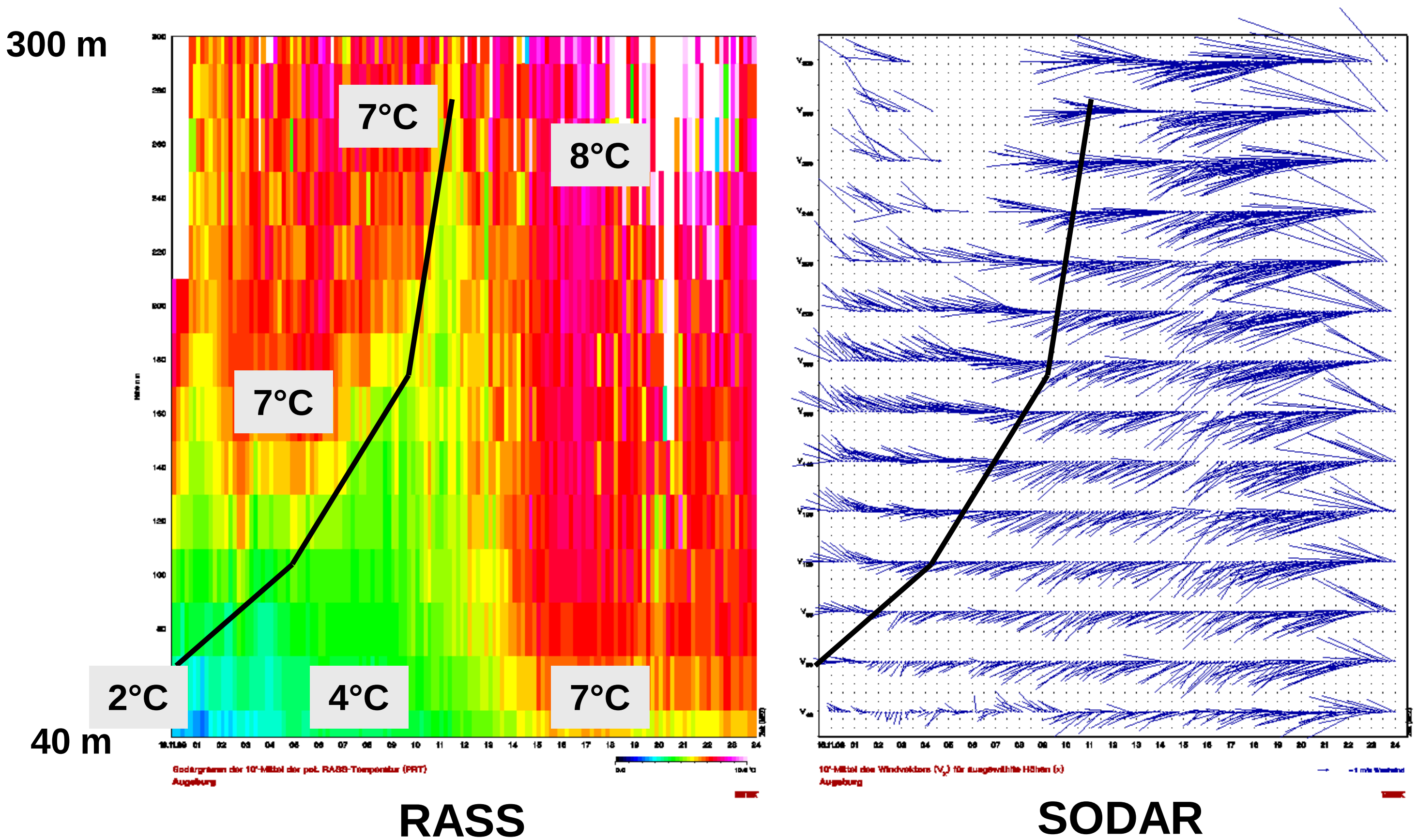
Source: Stefan Emeis, KIT

Wiegner, M., Emeis, S., Freudenthaler, V., Heese, B., Junkermann, W., Münkel, C., Schäfer, K., Seefeldner, M., Vogt, S.: Mixing Layer Height over Munich, Germany: Variability and comparisons of different methodologies. Journal of Geophysical Research - Atmospheres, 111, D13201 (2006).

Schäfer, K., Vergeiner, J. Emeis, S., Wittig, J., Hoffmann, M., Obleitner, F., Suppan, P.: Atmospheric influences and local variability of air pollution close to a motorway in an Alpine valley during winter. Meteorologische Zeitschrift, 17, 3, 297-309 (2008).

RASS and SODAR measurements

potential temperature and profiles of horizontal wind
(also available: vertical wind, turbulence parameters)



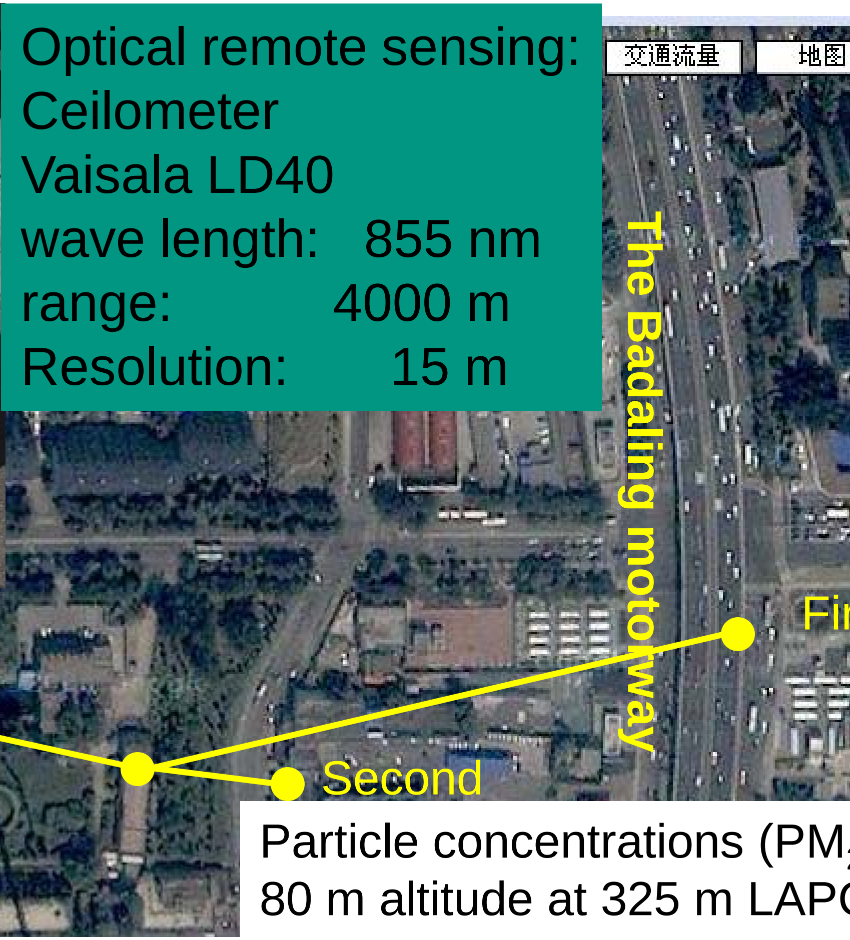
Source: Stefan Emeis, KIT

Emeis, S., Münkel, C., Vogt, S., Müller, W., Schäfer, K.: Determination of mixing-layer height. Atmospheric Environment 38, 2, 273-286 (2004).

Beijing

Measurement sites: LAPC tower, ceilometer, DOAS

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



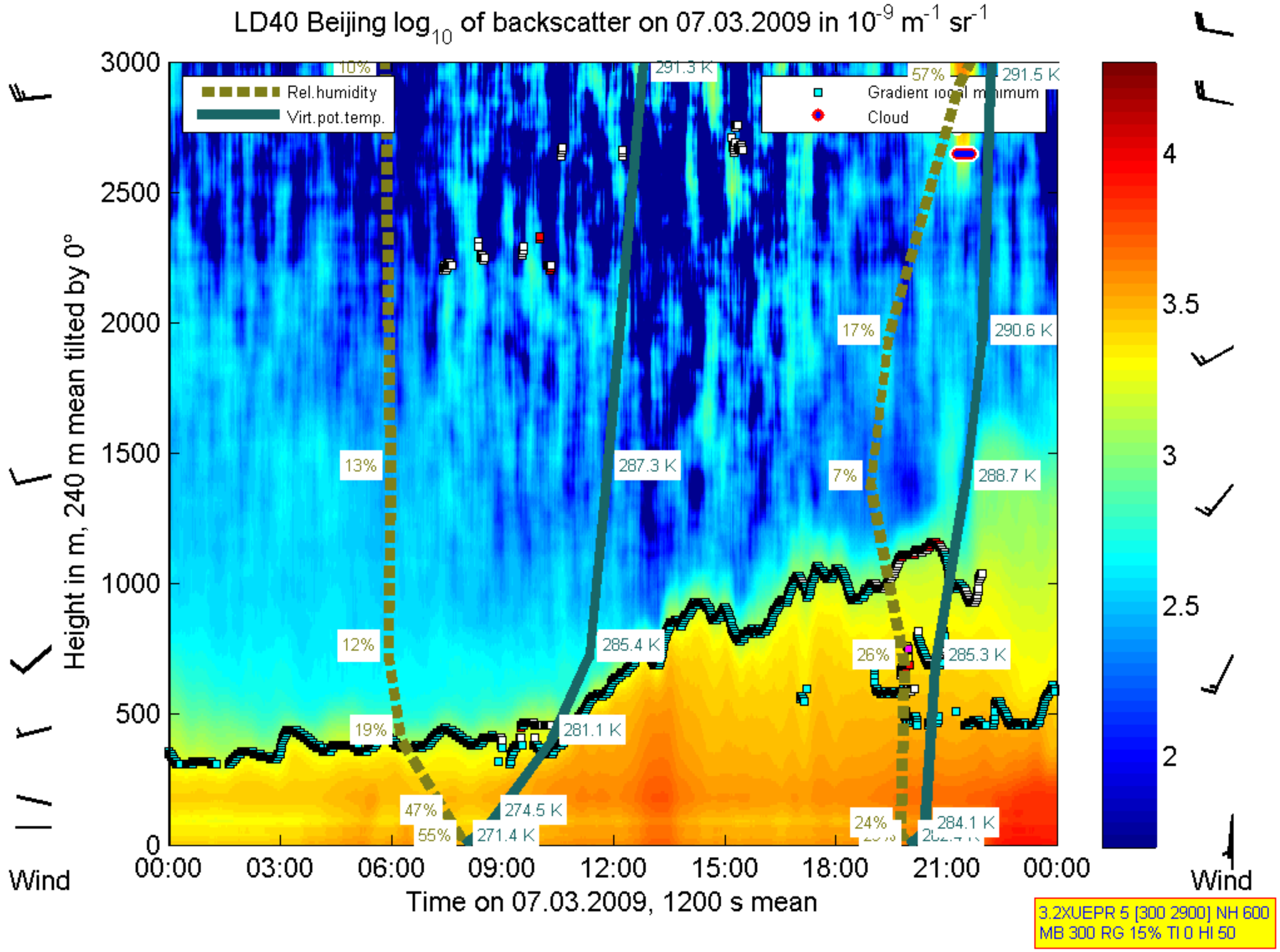
Particle concentrations ($PM_{2.5}$) on 8 m and 80 m altitude at 325 m LAPC tower

Münkel, C., “Mixing height determination with lidar ceilometers results from Helsinki Testbed,” Meteorol. Z. 16, 451-459 (2007)

Emeis, S., Schäfer, K., Münkel, C.: Observation of the structure of the urban boundary layer with different ceilometers and validation by RASS data. Meteorol. Z. 18, 149-154 (2009).

Evaluations in Beijing

Higher particulate loads during winds from South-West



Results

Wind influences upon air pollution

- Under strong background flows:
  reduced concentrations for all pollutants without distinct maxima and minima of diurnal cycle

- Under the development of local flows:
  high concentrations of air pollutants

- Influences of wind speed upon CO, NO, NO_2 and PM_{10}
  concentrations in the order of 20 %

Tasks

Determination of mixing layer height (MLH)

- Limits the vertical distribution of emitted air pollutants with consequences for dilution and transport
- Essential for the determination of speed and range of vertical dispersion
- Influenced by future climate change and thus important for the quality of living in large cities

Dandou, A., Tombrou, M., Schäfer, K., Emeis, S., Protonotariou, A.P., Bossioli, E., Soulakellis, N. Suppan, P.: A comparison between modelled and measured mixing layer height over Munich. Boundary-Layer Meteorology 131, 425–440 (2009).

Results: Influence of MLH upon air pollution in urban and sub-urban area

Hannover, Munich, Augsburg, Budapest, Beijing, Zurich Airport, Mexico City International Airport, Athens International Airport, Paris CDG

- Correlation with MLH smallest inside street canyons
- Correlation with MLH larger in winter than in summer
- Influences of MLH upon CO, NO, NO_2 and PM_{10} concentrations in the order of 20 %, up to 50 %

➔ therefore better MLH determination necessary

➔ deployment of ceilometers for continuous operation

Results

Influence of MLH upon air pollution

- Significant influence upon Cu and Zn mass concentrations (not for Al, K and Ca) of observed $PM_{2.5}$ samples

- Influence upon ultra-fine particle concentrations

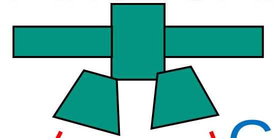
  - maximum for 0.1 – 0.5 µm with R^2 ~ 0.36 in winter

  - 50 – 100 nm with R^2 ~ 0.19 in summer

Process studies

Results for spatial distribution of PM

Task: Input for the ICAROS platform



Satellite images (Landsat)

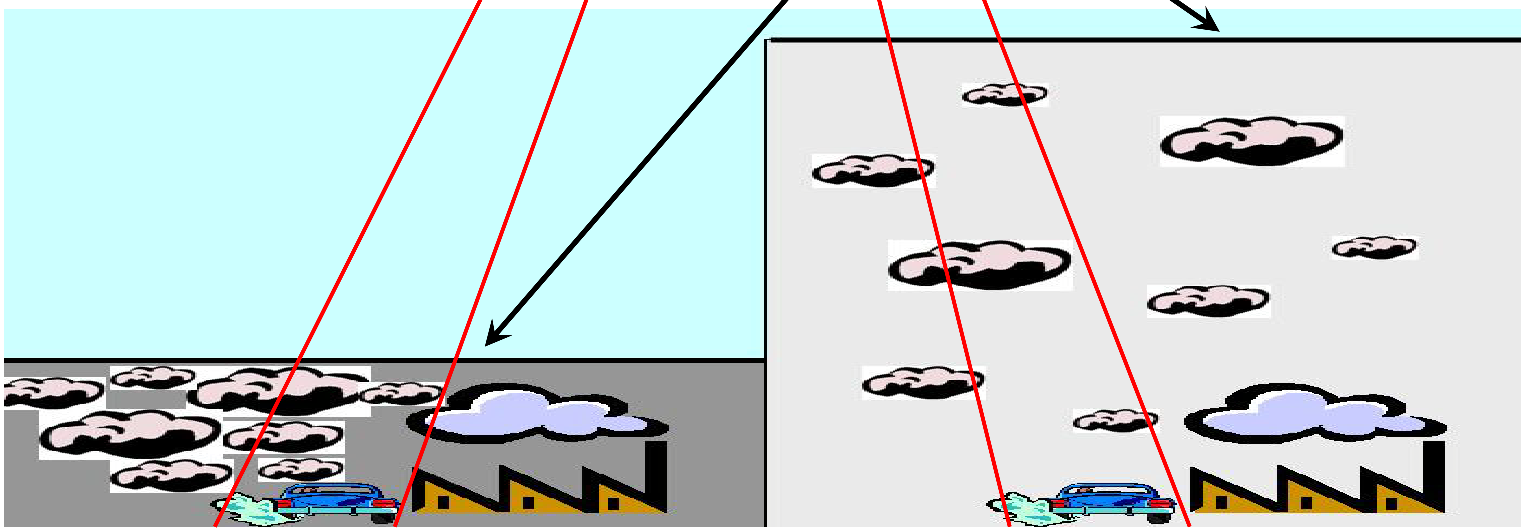
100 km x 100 km, 30 m x 30 m

520 nm: PM size 0.2 - 1.0 µm

- reference - clear atmosphere
- polluted situation

Ground-based measurements

- Aerosol mass extinction efficiency β_{ext} = a PM
- MLH - SODAR, RASS, ceilometer



Soulakellis, N.A., Sifakis, N.I., Tombrou, M., Sarigiannis, D., Schäfer, K.: Estimation and mapping of aerosol optical thickness over the city of Brescia – Italy using diachronic and multiangle SPOT 1, SPOT 2 and SPOT 4 imagery. Geocarto International, 19, 4, 57-66 (2004).

Schäfer, K., Harbusch, A., Emeis, S., Koepke, P., Wiegner, M.: Correlation of aerosol mass near the ground with aerosol optical depth during two seasons in Munich. Atmospheric Environment, 42, 18, 4036-4046 (2008).

Results: PM_{10} concentrations on 20 April 2007

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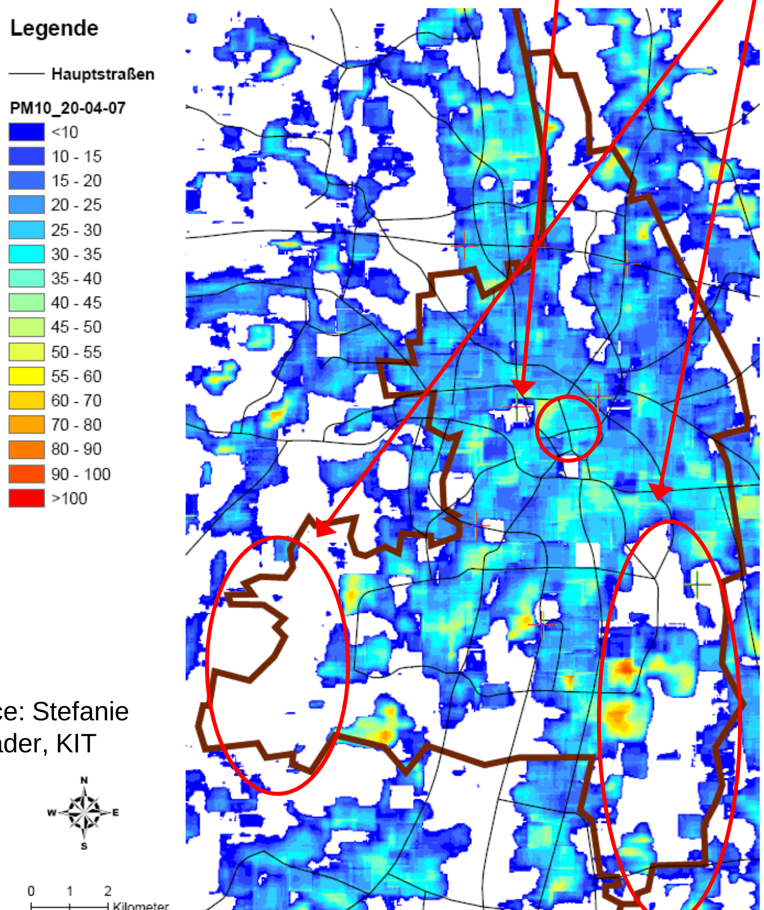
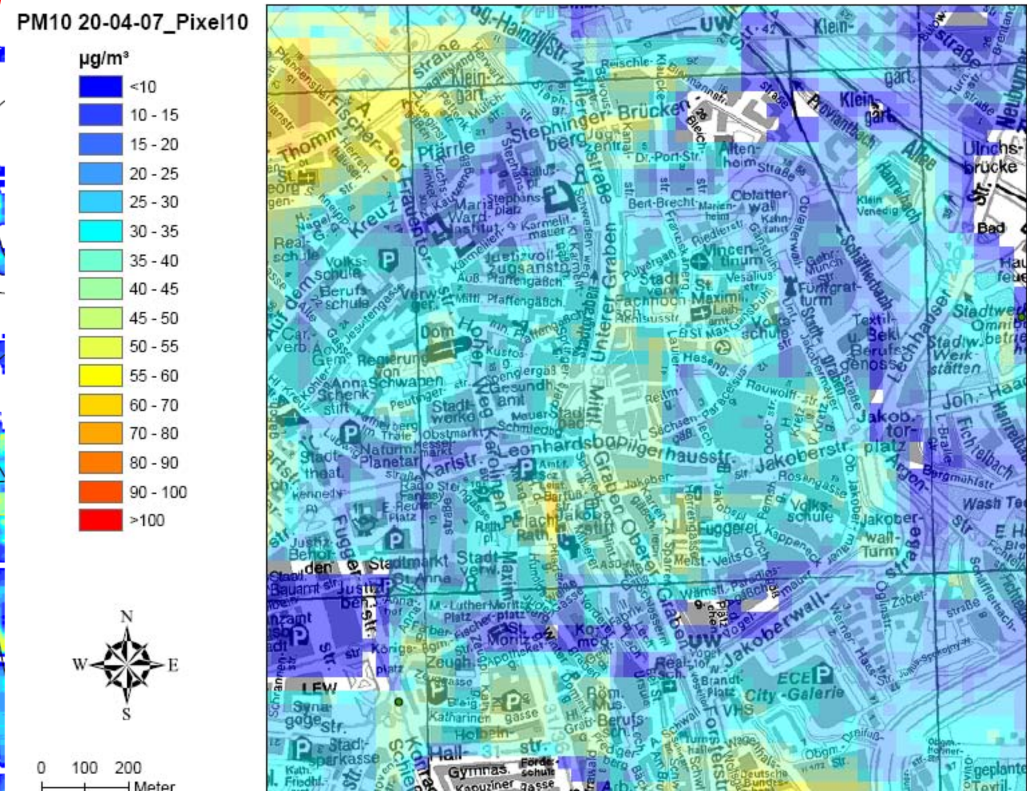
Differences in built-up areas, bright roofs
Agricultural / forest areas

Inner city: Karlstr., Unterer Graben, Oberer Graben



Source: Stefanie Schrader, KIT



Comparison with measured values by monitoring network: 55 – 65 µg m^{-3}, R^2=0.8

Future work
and perspectives

Emission source strengths

Further development of non-intrusive methods to determine emission source strengths

- Inverse dispersion modelling (aerosols)
- Continuous determination of mixing layer heights - application of mass balance method
- Open-path flux gradient method

Air quality in Augsburg

Coupling of experimental and modelling process studies

- Analyses of model results
- Improvement of parameterization schemes of modelling:
  MLH, secondary aerosol formation with HMGU, University of Augsburg, University of Rostock, IMGG of KIT, UBA, DWD
- Improvements of air quality by emission reduction measures with environmental zones in cities

Air quality in Beijing

- Source apportionment for PM (PhD Rong-rong Shen)
  - $PM_{2.5}$ filter sampling with 2 High-volume samplers from June 2010 on with CUMTB, CAS, CUGB, CRAES
  - PM composition from filter samples (April – August 2009, June 2010 – June 2011) in cooperation with IMG, IGG, HMGU and University of Rostock

- Application of satellite-based remote sensing data systems and coupling with numerical modelling (PhD Stefanie Schrader)
  - Master Thesis work at University of Thessaloniki together with Dimosthenis Sarigiannis and Nicolas Moussiopoulos

Acknowledgement

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