Investigation of meteorological influences upon particle compositions on the basis of measurements in urban systems

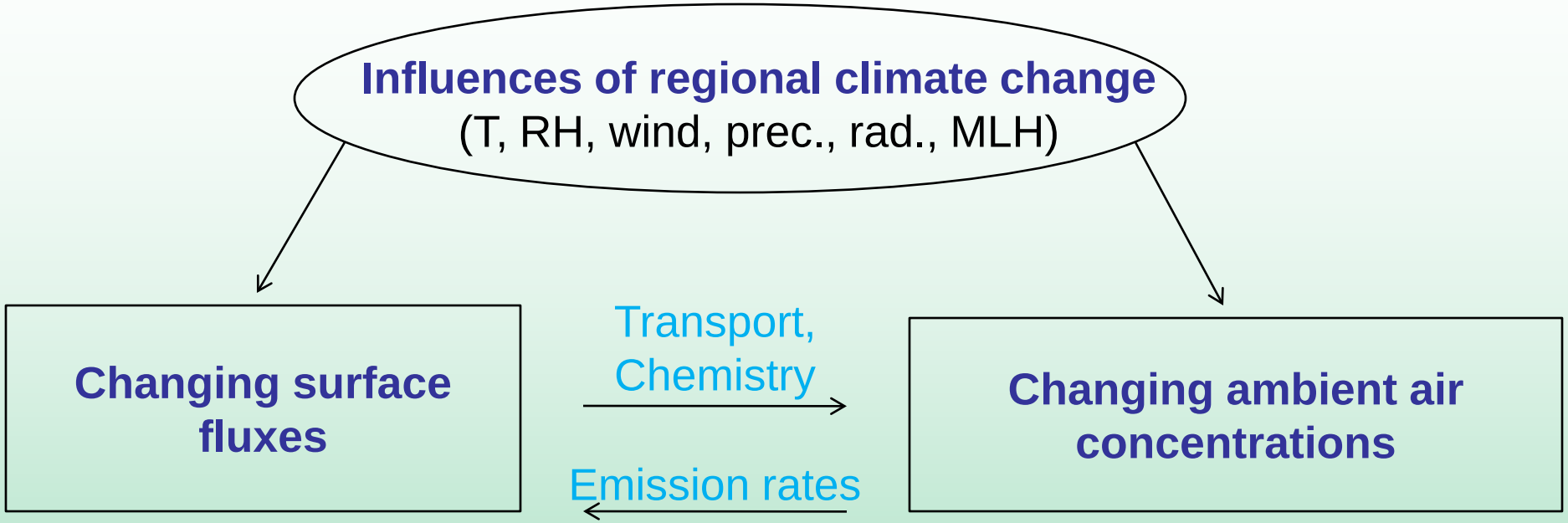
Klaus Schäfer, Stefan Emeis, Carsten Jahn, Maria Hoffmann, Renate Forkel, Rong-rong Shen, Stefanie Schrader, Peter Suppan

- Strategic background
- Process studies
  - Methodology
  - Influences upon air pollution
- Future work and perspectives

Strategic background

Strategic topics

- Knowledge about the interaction of climate, biosphere, ecosystems and human activities
- Aerosol research (fine / ultra-fine particles) – loads / composition / formation / sources
- Process studies of air pollution relevant for health protection and legislation (NO_2, PM_{10}, $PM_{2.5}$)



Differences of scales in space and time

Process studies

Methodology

Scientific questions

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

cause high PM exposures?

In particular:

- Local wind systems and secondary circulation systems
- MLH: 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 (2006), 647-658.

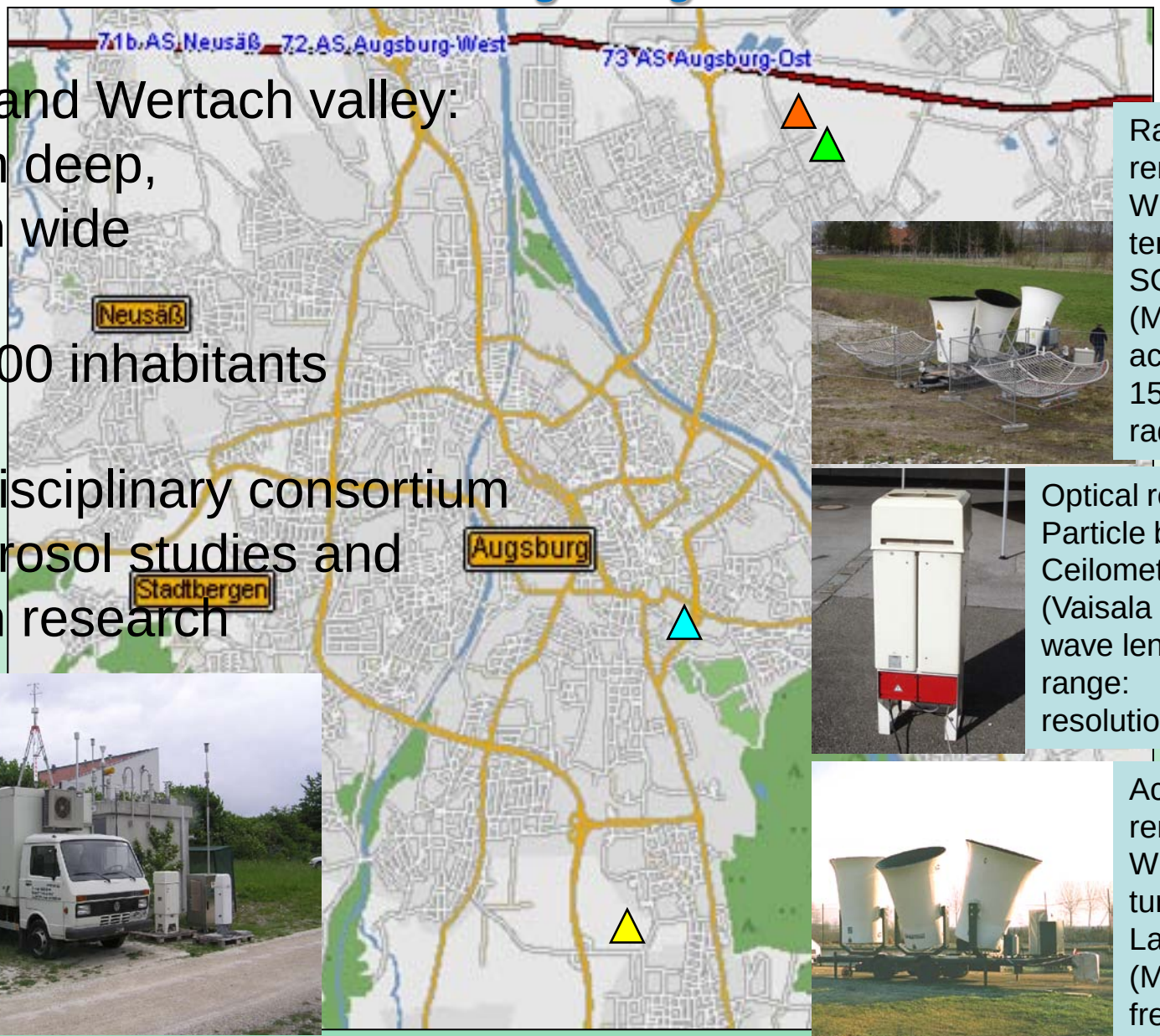
Wiegner, M., Emeis, S., Freudenthaler, V., Heese, B., Junkermann, W., Münkel, C., Schäfer, K., Seefeldner, M., Vogt, S.: Mixing Layer Height over Munich, Germany: Variability and comparisons of different methodologies. Journal of Geophysical Research - Atmospheres, 111 (2006), D13201.

Augsburg

Lech and Wertach valley:
100 m deep,
10 km wide

275 000 inhabitants

Interdisciplinary consortium for aerosol studies and health research



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

Optical remote sensing:
Particle backscattering Ceilometer
(Vaisala LD40/CL31)
wave length: 855/910 nm
range: 4000 m
resolution: 15/5 m

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

Beijing

Measurement sites: LAPC tower, ceilometer, DOAS

Optical remote sensing:
Ceilometer
Vaisala LD40 or CL31
wave length: 855 or 910 nm
range: 4000 m
Resolution: 15 or 5 m

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, 2, 149-154 (2009)

Process studies

Influences upon air pollution

Two evaluations in Augsburg

- Correlation between air pollutant concentrations and wind speed

  Prevailing wind directions: West-South-West (220 - 280°) with maximum wind speeds, secondary North-East (60-90°)

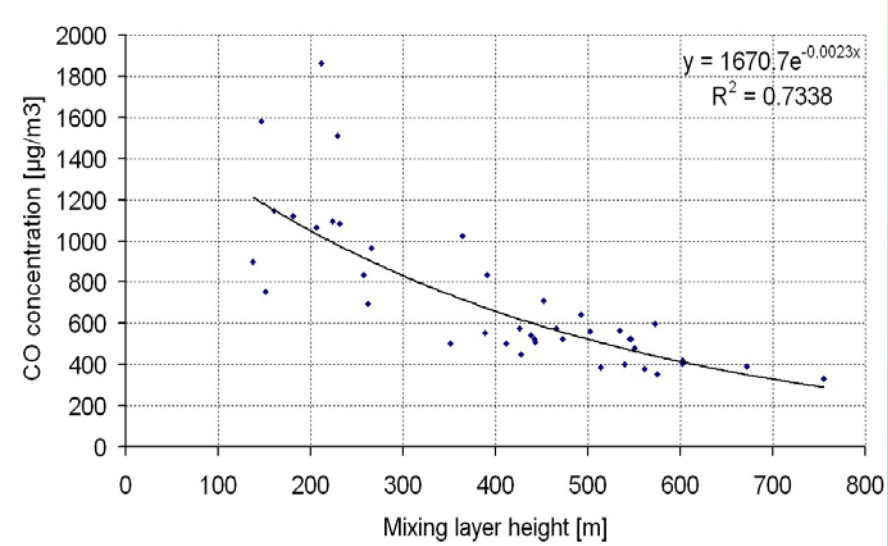
  Correlation coefficients R^2 for NO: 0.20, NO_x: 0.25, CO: 0.15, PM_{10}: 0.25

- Correlation between UFP (ultra-fine particles) concentrations and MLH

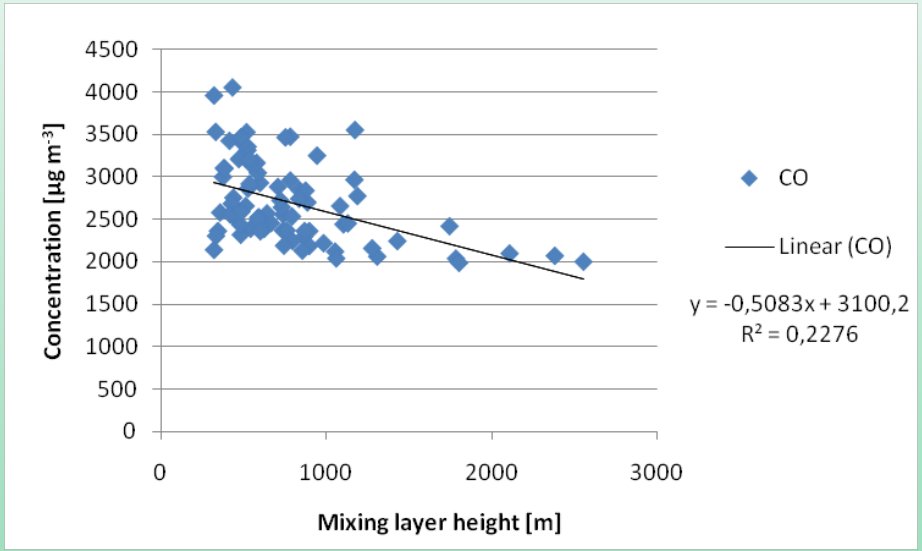
  Correlations maximum for 0.1 – 0.5 µm with R^2 0.36 in winter and 50 – 100 nm with R^2 0.19 in summer

Correlation air pollutant CO - MLH

Urban stations Munich
10 – 29 May 2003 and
27 Nov. – 19 Dec. 2003



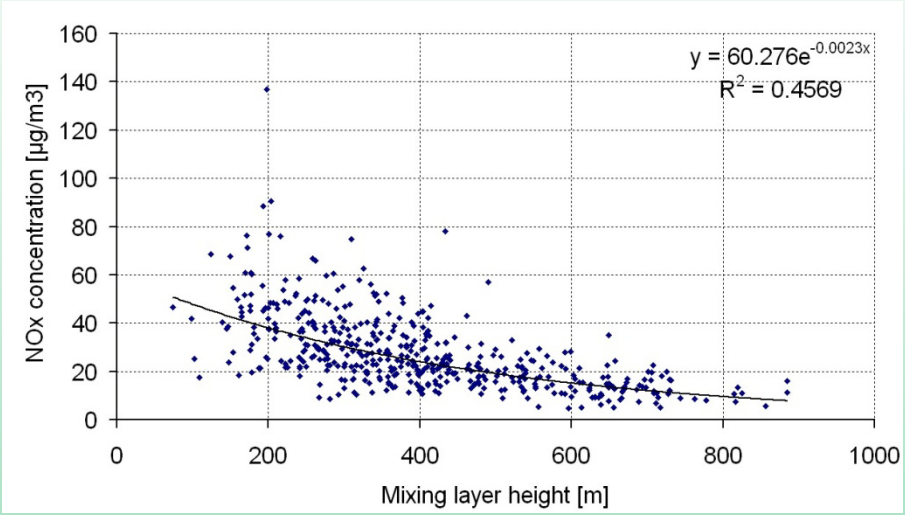
Mexico City International Airport
12 – 16 April 2006



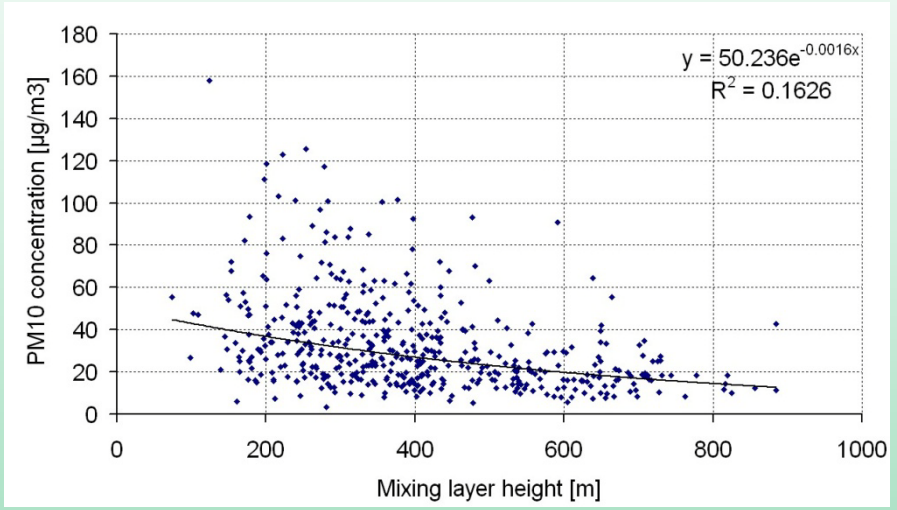
Schäfer, K., S. Emeis, H. Hoffmann, C. Jahn: Influence of mixing layer height upon air pollution in urban and sub-urban areas. Meteorol. Z., 15, 647-658 (2006).

Correlation air pollutants (roof station Hannover) - MLH

October 2001 - April 2003



NO_x

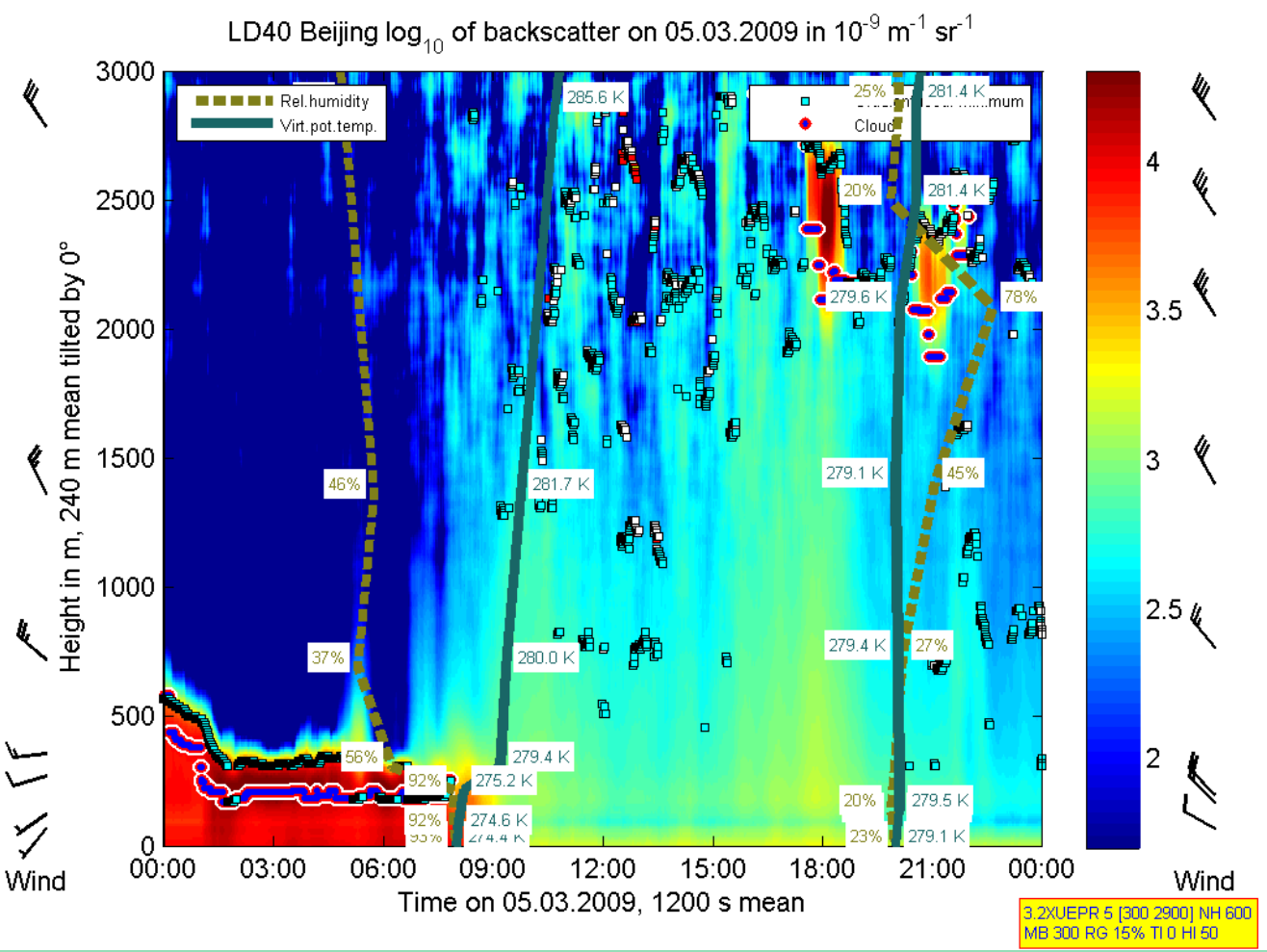


PM_{10}

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).

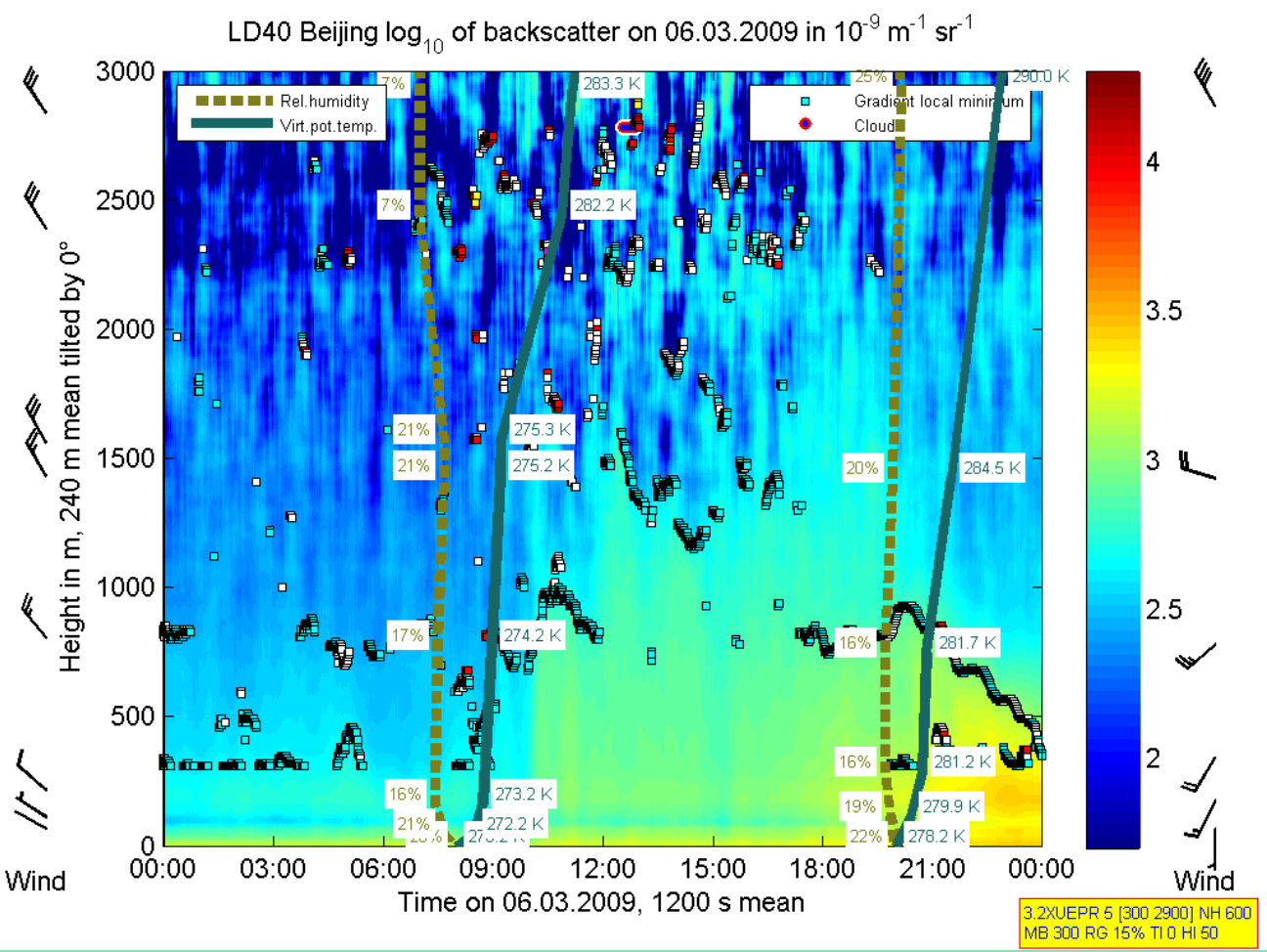
Evaluations in Beijing

Low particulate load and winds from West / North-West



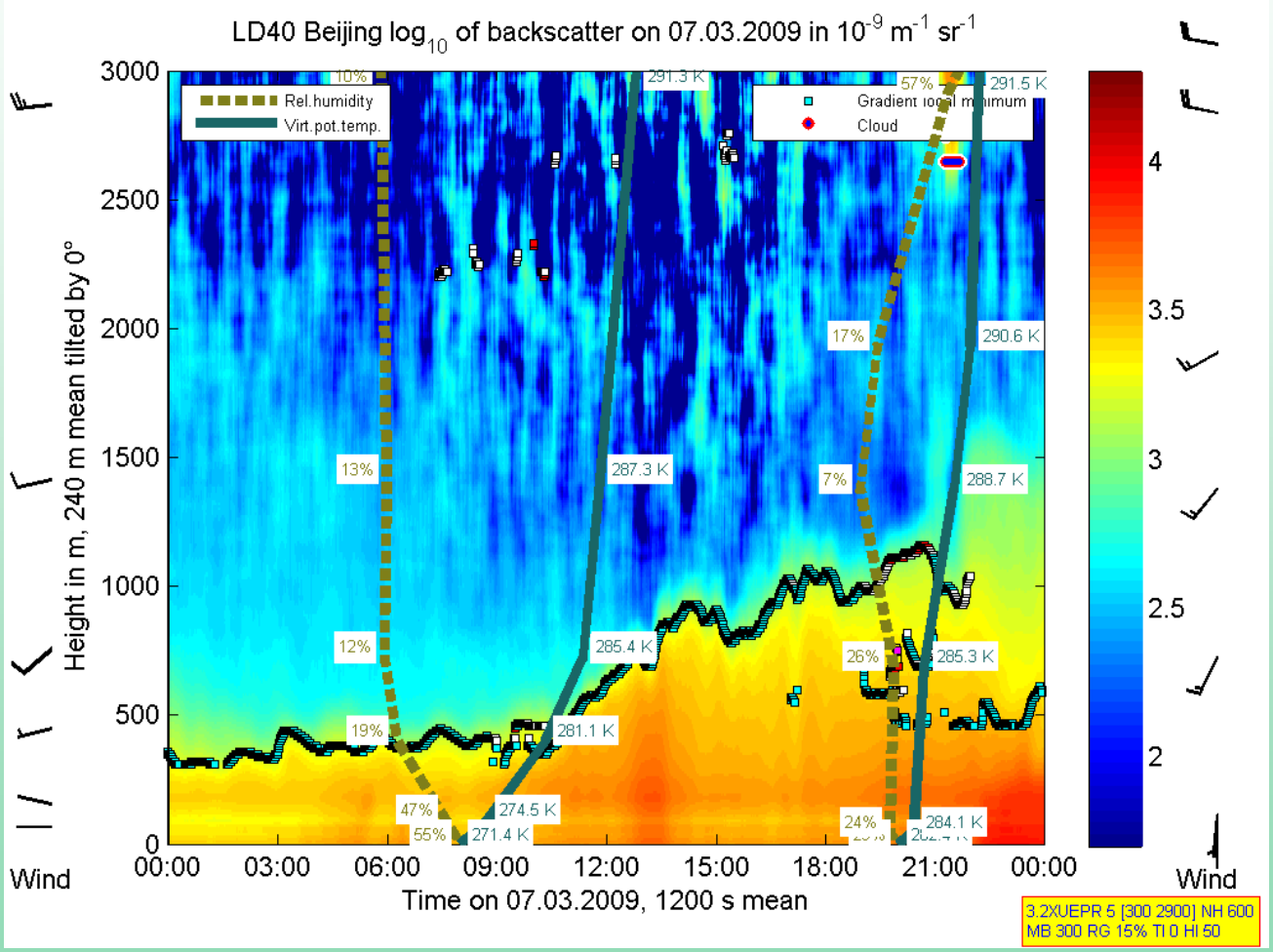
Evaluations in Beijing

Higher particulate loads during winds from South-West



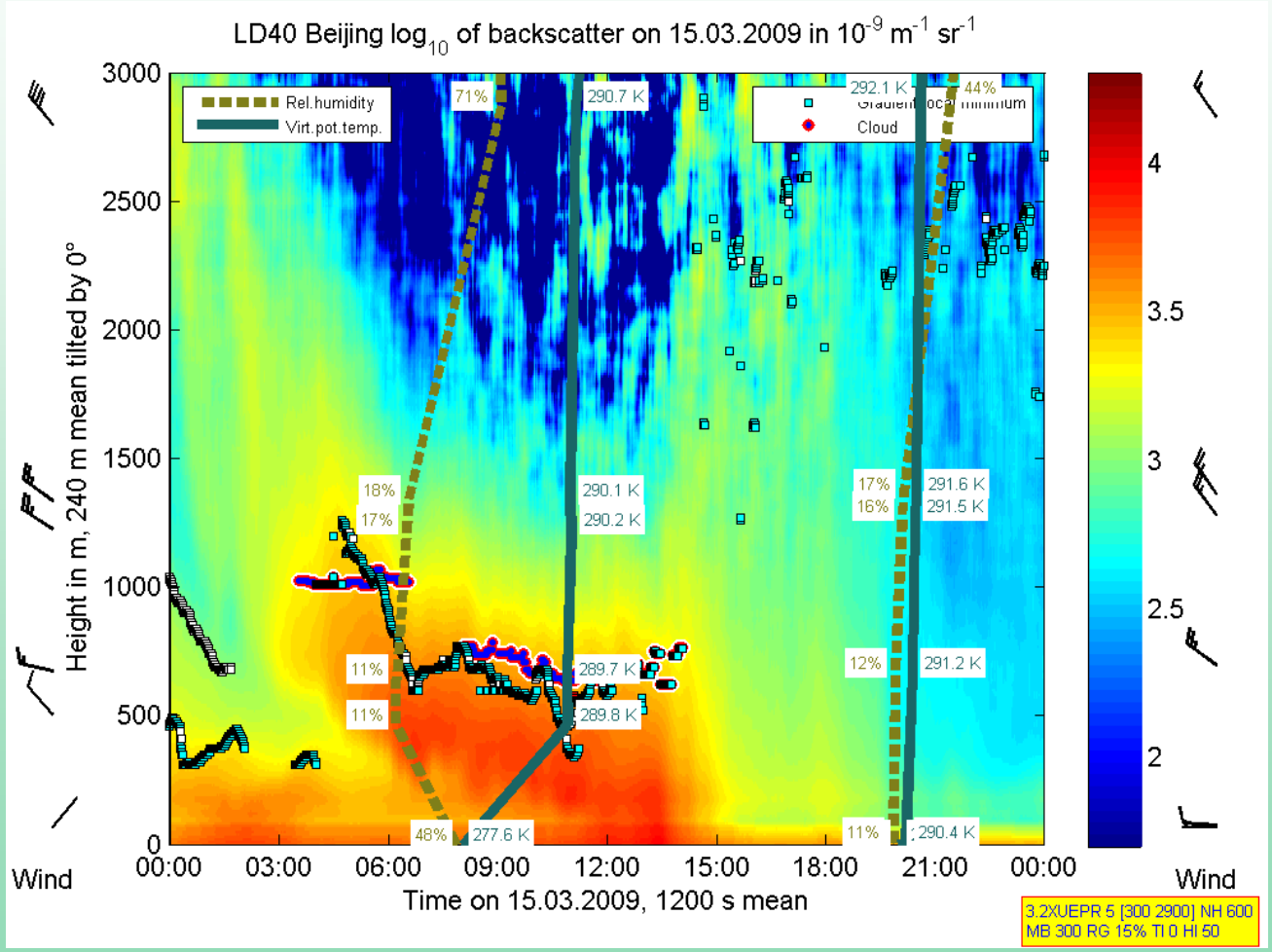
Evaluations in Beijing

Higher particulate loads during winds from South-West



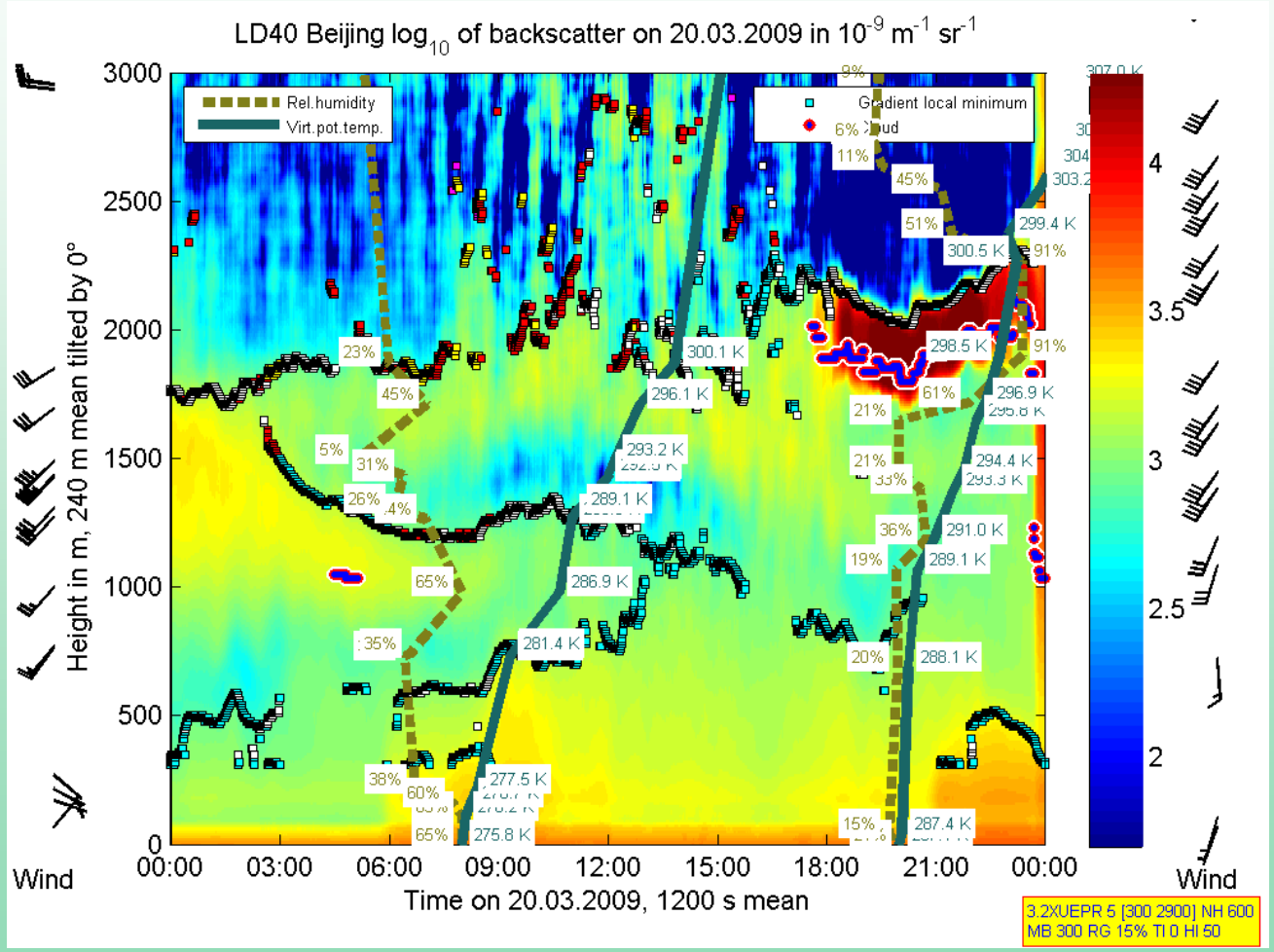
Evaluations in Beijing

Dust clouds



Evaluations in Beijing

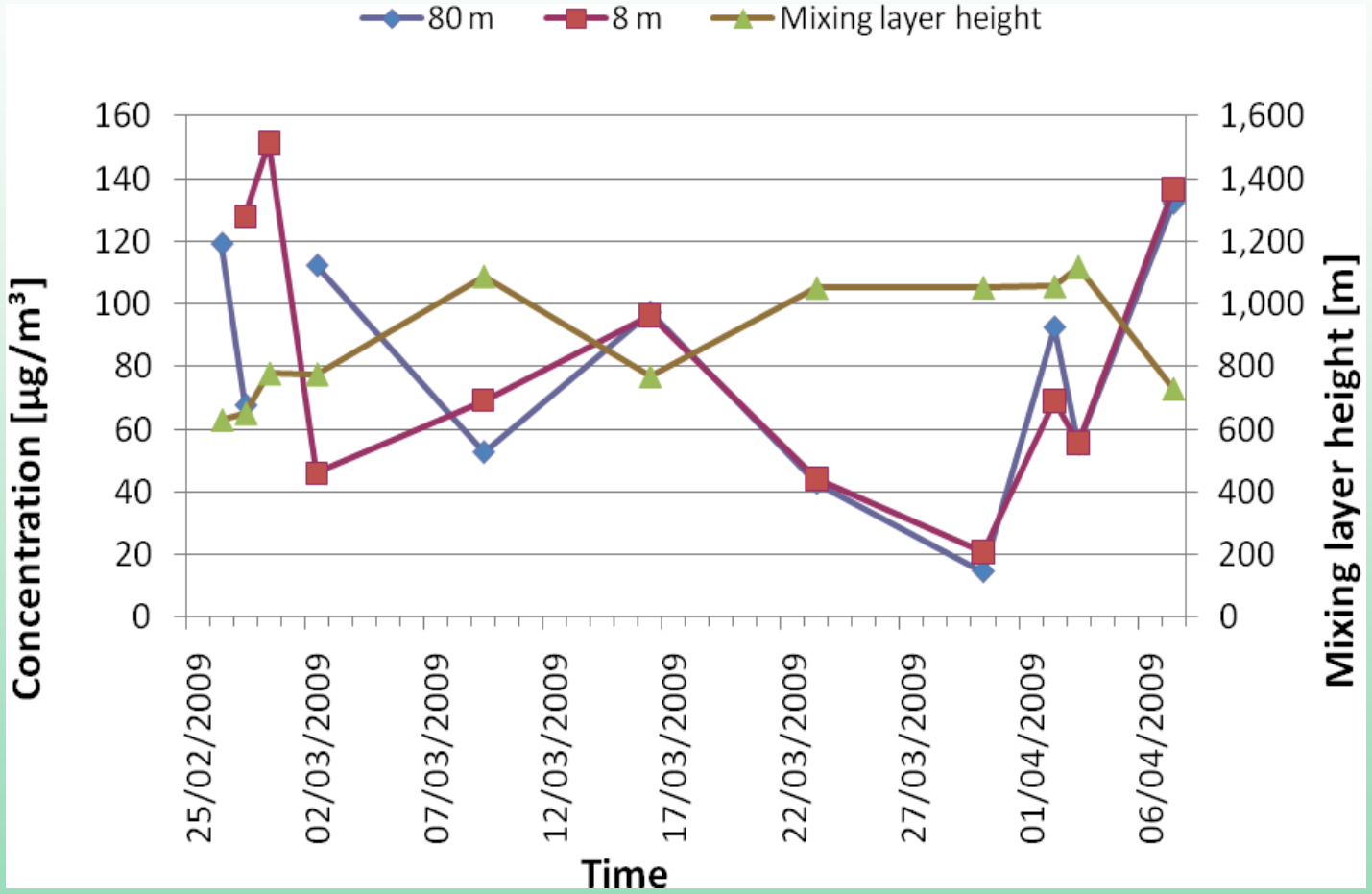
Multiple layering of the lower atmosphere



Evaluations in Beijing

Concentrations of $PM_{2.5}$ in 8 m and 80 m height as well as MLH

- Quartz fibre filters (25 mm or 50 mm in diameter, Whatman)
- Mini Volume Sampler (Leckel GmbH, Berlin)
- Pump rate 200 l/h
- Weighting procedures at the IMG



Norra, S., Hundt, B., Stüben, D., Cen, K., Liu, C., Dietze, V., Schultz, E., „Size, morphological and chemical characterization of aerosols polluting the Beijing atmosphere in January/February 2005." In: Morrison, G.M.; Rauch, S. (Eds.): Highway and Urban Environment, Springer, Berlin (2007)

Evaluations in Beijing

High $PM_{2.5}$ load near the surface is coupled with MLH much lower than 1000 m

If planetary boundary layer higher than 1000 m often a multiple layering of the boundary layer is observed

Influence of MLH upon the variance of the observed $PM_{2.5}$ concentrations is significant, also from daily-mean TEOM data in both heights (R^2 ~ 0.4) and for the ^{65}Cu and ^{66}Zn mass concentrations (not for ^{27}Al, ^{39}K and ^{42}Ca)

Future work and perspectives

Augsburg

Urban area – surroundings interactions: linkage to Höglwald site

- Installation of SODAR, ceilometer LD40, NO_x (NH_3 DOAS)
- Determination of exchanges between Augsburg and Höglwald

Coupling of experimental and modelling process studies

- Analyses of model results and source apportionment: gases, PM concentrations, size distribution, composition, $\delta^{13}C$
- Improvement of parameterization schemes of modelling: MLH, secondary aerosol formation

Co-operations

Project group „Aerosols, health and climate change“

- SFH – GAP – Graswang – DWD Hohenpeißenberg – Höglwald – Augsburg – DWD Oberschleißheim, satellites
- Process studies (weather situations / circulation systems / primary compounds and chemical transformations - secondary aerosol formation)
- Information about background and spatial variations of air pollution (e.g. roughness influence upon MLH)

Contributions to networks such as TERENO (and possibly ICOS)

- Urban area – surroundings exchanges
- MLH determination

Beijing

Source apportionment for PM (PhD student Rong-rong Shen)

- PM_{10} filter samples from January 2008 – August 2009: CUMTB
- $PM_{2.5}$ filter sampling with 2 High-volume samplers from June 2010 on: CUMTB, LAPC
- 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 student Stefanie Schrader)

Co-operations

Stefan Norra, Nina Schleicher *Institute of Geography and Geoecology (IGG), Institute of Mineralogy and Geochemistry (IMG), Karlsruhe Institute of Technology, Karlsruhe, Germany*

Joachim Vogt *Institute of Regional Science (IRS), Karlsruhe Institute of Technology, Karlsruhe, Germany*

Jürgen Schnelle-Kreis, Mike Pitz*, Annette Peters, Josef Cyrys* *Helmholtz Zentrum München, German Research Center for Environmental Health, Neuherberg*
**University of Augsburg, Environment Science Center, Augsburg, Germany*

Yuesi Wang, Jin-yuan Xin, Gui-qian Tang, Hong Ling *State Key Laboratory of Atmospheric Boundary-Layer Physics and Atmospheric Chemistry (LAPC), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, P. R. China*

Christoph Münkel *Vaisala GmbH, Hamburg, Germany*

Longyi Shao *Department of Resources and Earth Science, China University of Mining and Technology (CUMTB). Beijing, P. R. China*

Fahe Chai, Yizhen Chen *Laboratory for Urban and Regional Atmospheric Environmental Research, Chinese Research Academy of Environmental Sciences (CRAES), Beijing, P. R. China*

Volker Dietze, Uwe Kaminski *Competence Center Biometeorology, Air Pollution Department, German Weather Service (DWD), Freiburg, Germany*

Nicolas Brüggemann, Wolfgang Junkermann *Institute for Meteorology and Climate Research, Atmospheric Environmental Research Branch, Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany*

Acknowledgement

We like to thank for financial support within the frame of a start-up project for the formation of the Karlsruhe Institute for Technology (KIT) as well as the KIT centre Climate and Environment

Thank you very much for your attention