When Darkness Comes

High-resolution numerical studies on the effect of turbulence on the structure of nocturnal radiation fogs

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In Short

- The parallelized large-eddy simulation model PALM
- High-resolution large-eddy simulation of nocturnal radiation fog
- First time simulate radiation fog with a Lagrangian cloud model
- 10,000 processor cores or more required

***Figure 1:** The PALM logo.*

Fog as a meteorological phenomenon can have a strong impact on the economy but also on personal safety by reducing the visibility in the atmospheric boundary layer [2]. Total economic losses associated with fog on aviation, marine and land transportation are comparable to those of winter storms [3]. Despite the fact that there is abundant literature on fog research, our knowledge about the physical processes that lead to fog formation and its microstructure remains partial. This is due to the fact that many complex processes like radiative cooling of the underlying surface, turbulent mixing and the microphysics of fog interact non-linearly with each other. Often, so-called Kelvin-Helmholtz instabilities develop at the fog top, leading to enhanced vertical mixing of the fog. Moreover, surface heterogeneity regarding vegetation and soil characteristics can further complicate the predictability of fog and induce local circulations that play an important role for the patchiness often observed in fog layers. As a direct consequence, the fog forecasting capability of today's numerical weather prediction models is still poor.

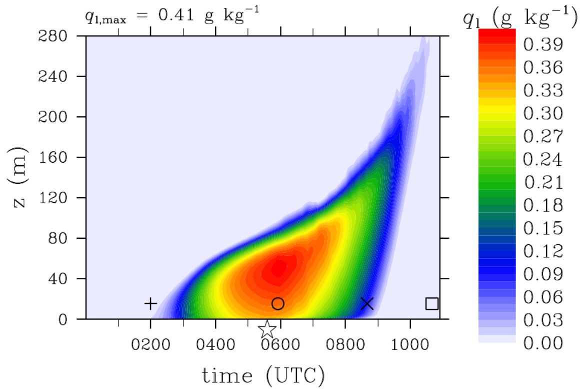

***Figure 2:** Height-time cross section of the horizontally-averaged liquid water content specific humidity q_l. Time marks related to the fog life cycle, formation, maximum liquid water content within the cloud, lifting, and dissipation, are marked by plus signs, circles, crosses, and squares, respectively. Additionally, the time of sunrise is marked by a star symbol. The model domain was approx. 1 km $\times$ 1 km $\times$ 0.5 km ($x \times y \times z$) with a grid spacing of 1 m.*

In this project, high-resolution large-eddy simulation (LES) is used to investigate the effect of turbulence on nocturnal radiation fogs. Fig. 2 shows the temporal development of radiation fog. The results of previous simulations of this project are in good agreement with observational data from the super-sites at Cabauw (The Netherlands)[4] . For the realization and execution of the project, the LES model PALM is used, which has been developed at the Institute of Meteorology and Climatology at Leibniz Universität Hannover. The model code is based on Fortran 95, with some 2003 extensions. Parallelization is achieved using MPI. The model is designed to run on massively parallel computer architectures and has shown excellent performance and scalability on up to 20,000 processor cores and more. A detailed description of the model in its current version 4.0 can be found in [1]. In this project, PALM (see also Fig. 1 is and will be used at very high resolution $\leq$ 1 m with both an Eulerian bulk cloud physics scheme and an embedded Lagrangian cloud model (LCM) that allows for explicitly resolving aerosols and fog droplets.

This innovative approach allows studying fog droplet-turbulence interactions for the first time with an coupled LES-LCM. This will allow new insights in the field of fog microphysics e.g. the development of the 3D cloud droplet size distribution (DSD) in a fog layer or a detailed representation of the activation and growth process of fog droplets.

The aim of this study is to achieve a comprehensive view on the key parameters that determine the life cycle of radiation fog as well as its three-dimensional macro- and microstructure. Moreover, the effect of a nocturnal fog layer on the morning transition and the daytime boundary layer will be studied. The effect of surface heterogeneity on nocturnal radiation fog will be investigated by means of LES with prescribed idealized regular and observed irregular surface heterogeneities.

WWW

https://palm.muk.uni-hannover.de

More Information

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[2] T. Bergot, *Quart. J. R. Met. Soc.* **139**, 1099-1112 (2013). doi:10.1002/qj.2051

[3] I. Gultepe, G. Pearson, and Coauthors, *Bull. Amer. Meteorol. Soc.* **90**, 341-359 (2009). doi:10.1175/2008BAMS2354.1

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Project Partners

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