EGU General Assembly 2009
Vienna, Austria, 19 – 24 April 2009

LES modeling of surface-induced free convection in a complex valley driven by turbulent flux measurements

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Overview

During the COPS[1] (Convective and Orographically-induced Precipitation Study) field campaign in 2007 observations have been made that indicate a significant influence of valley wind systems in low mountain regions on the initiation of free convection. Current Numerical Weather Prediction (NWP) models do not resolve or parameterize such small scale orographically induced wind systems nor their further effects on the atmosphere.
This presentation shows the first steps of a study that systematically investigates the effects of small-scale valley wind systems by both, analysing multiple observations and Large-Eddy Simulations (LES) of the atmospheric boundary layer based on these observations.
The main data set we will use here was recorded by an eddy-covariance (EC) measuring station. This station was placed in the Kinzig valley (Black Forest, south-western Germany).

Generation of Near-ground Free Convection

Free convection events (FCEs) occur in the atmospheric surface layer if buoyant forces dominate over shear forces within turbulence production and can be detected with the help of the stability parameter ζ (ratio of the measurement height to the Obukhov length) for values of ζ below -1 (Fig. 1a). In the Kinzig valley[2], FCEs are suspected to be triggered by a change of the local circulation system in the morning hours (Fig. 1c) when a wind speed collapse is obvious in the Sodar measurements (Fig. 1f).

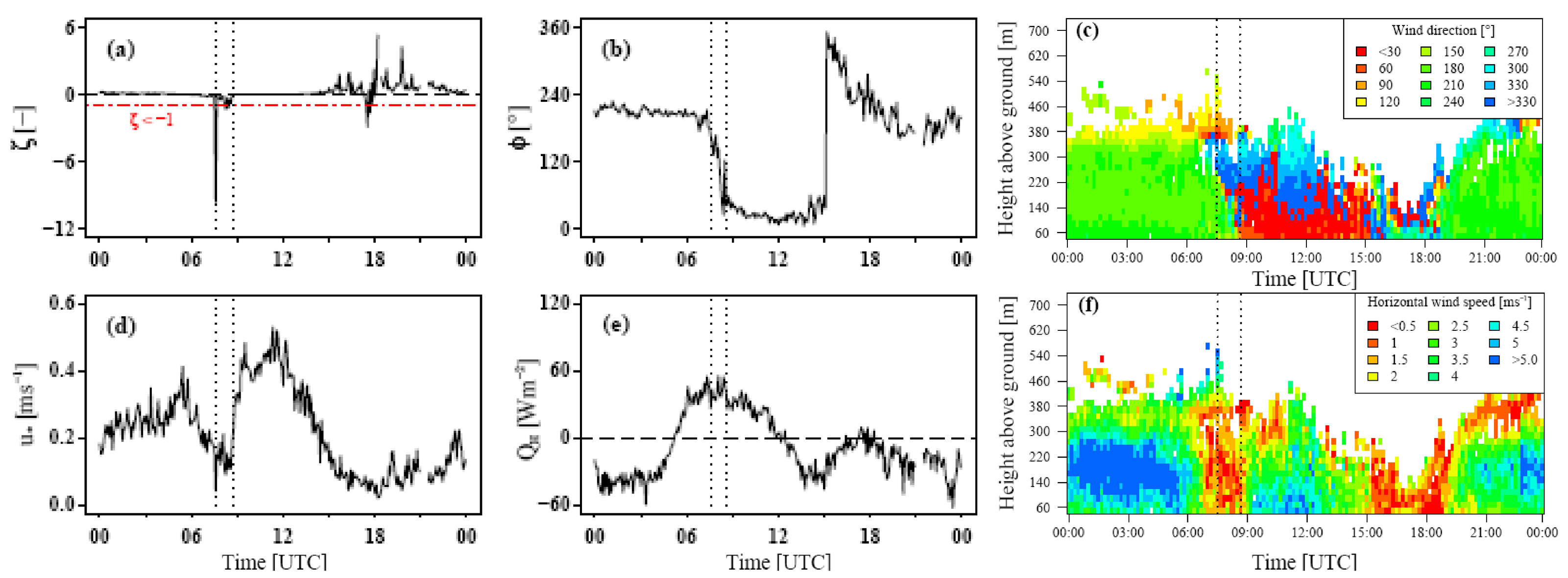

Figure 1: Stability parameter ζ (a), wind direction (b), friction velocity (d) and sensible heat flux (e) measured with the eddy-covariance (EC) system and Sodargramms of the wind direction (c) and the horizontal wind speed (f) for COPS IOP8b (15 July 2007) at Fußbach. The black dotted lines in each graph indicate the period of destabilisation of near-ground air masses in the morning hours (7:35 UTC to 8:40 UTC) due to low values of ζ.

Aims of the Simulations

1. Reproduction of the observed free convection events
2. Examining whether the suspected mechanism was responsible for the observed free convection
3. Quantification of the involved processes
4. Additional information from the modeled 3D-fields shall be used for further interpretation of the measurements

Computational Model

The Model used in this study is EULAG[3] (Eulerian/semi-Lagrangian model for fluids). An LES version of this Multi-scale Model is used with following main characteristics:

- ✓ Subgrid-scale Model: standard TKE closure
- ✓ Microphysics: bulk microphysics for warm clouds (water vapor, liquid cloud water and rain water)
- ✓ Grid: terrain following sigma coordinate system/ optional immersed boundary with Cartesian grid
- ✓ Grid spacing: about 10-30m in all directions

First Model Runs

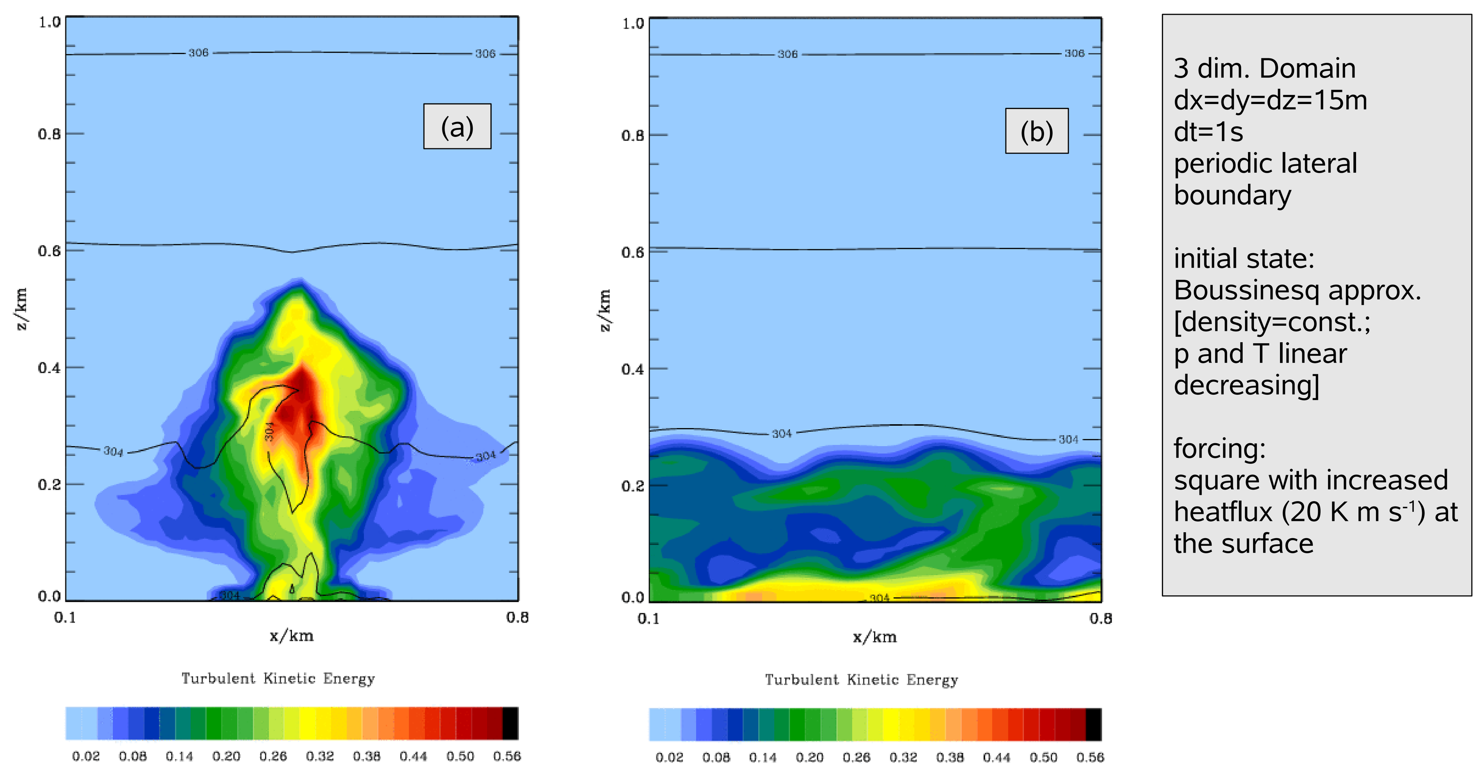

Figure 2: Simulations of a rising plume of hot dry air without wind (a) and with superimposed wind of u=5 m·s^{-1} (b). The normed Turbulent Kinetic Energy [m^2·s^{-2}] is color coded. Isolines of the Potential Temperature in black.

Set-up Plan

At first, idealized simulations are made with artificial initial and boundary conditions (BC) and an idealized topography (Fig. 3a). The lateral BC are set to be periodic. This basic setup is currently serving as an environment to develop analysis tools for later use.
Starting from this base a set of successively more complex configurations is prepared which will lead to the problem of non-periodic lateral BC and heterogeneous surface properties at the lower boundary (Fig. 3b and Fig. 4).

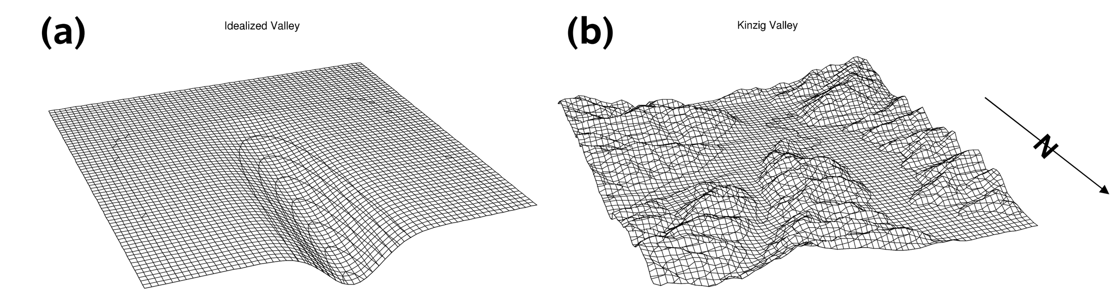

Figure 3: Idealized topography (a) and real topography of the Kinzig valley at 180m resolution (b).

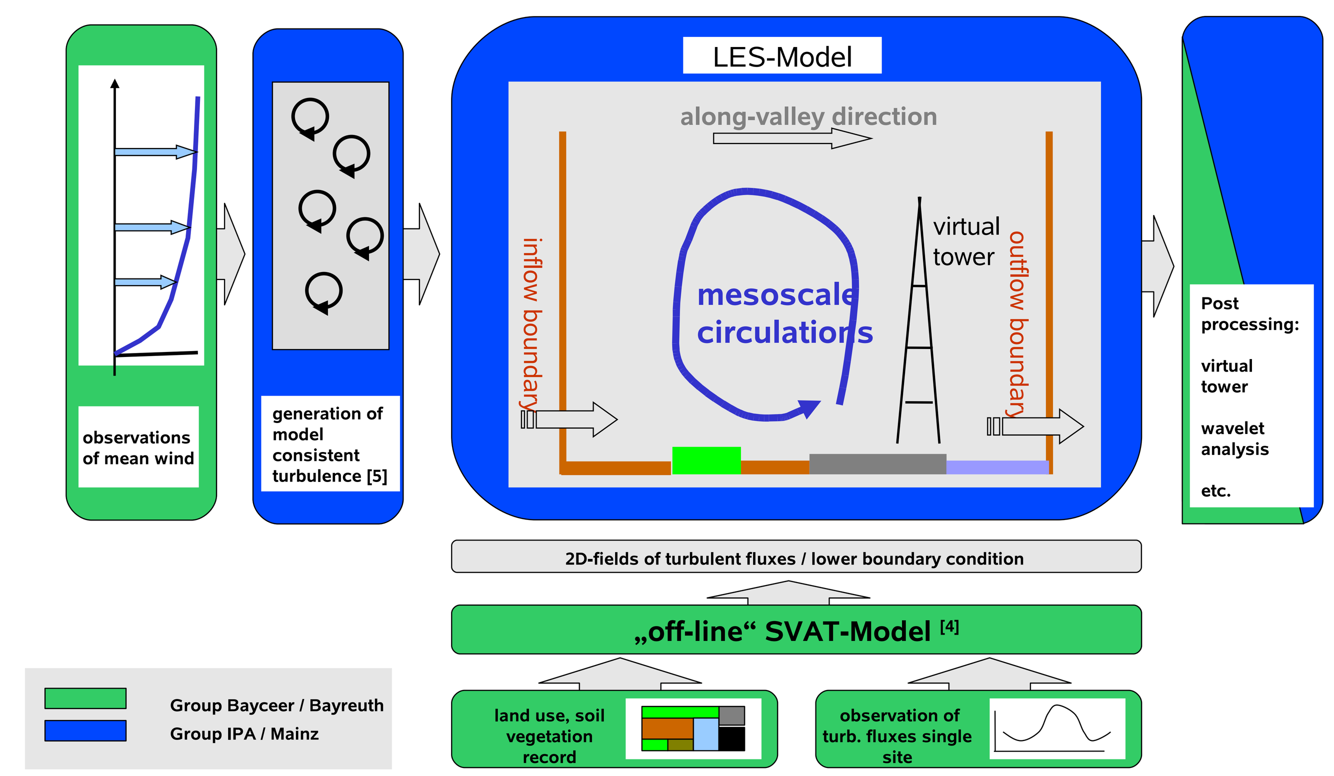

Figure 4: Schematic illustration of the model setup.

Conclusions

Our study may contribute to a more detailed understanding of the processes that are involved in the initiation of convection and therefore may help to improve the quality of NWP.

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