Thermal Wind Circulations in a Small Alpine Sinkhole

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AMS 17th Conference on Mountain Meteorology

June 2016

Burlington, VT

46

INTRODUCTION

Grünloch basin

- Limestone sinkhole in the eastern Alps of Austria
- Diameter: ≈1 km, depth: ≈100–200 m
- Three major saddles intersect the surrounding ridgeline (Fig. 1): Lechner Saddle (≈55 m above the basin floor), Seekopfalm Saddle (≈130 m), and Ybbstaler Saddle (≈180 m).

Model simulations

- CM1 *(Bryan and Fritsch 2002, MWR, 130, 2917–2928)*
- Stretched grid: $\Delta x = \Delta y$ =30–150 m, Δz =10–400 m
- The simulations are initialized with a quiescent atmosphere and temperature and humidity profiles from nearby Vienna radiosoundings.
- The model topography is a simplified and smoothed representation of the Grünloch topography (Fig. 1): Lechner Saddle (≈50 m above the basin floor) and Seekopfalm Saddle (≈150 m).

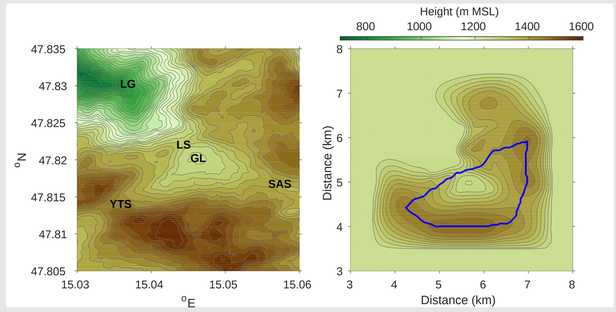

Fig. 1: Gruenloch topography (left) and idealized model topography (right). GL—Grünloch, LS—Lechner Saddle, SAS—Seekopfalm Saddle, YTS—Ybbstaler Saddle. The blue line indicates the location of the vertical cross section in Fig. 5.

NIGHTTIME SIMULATION

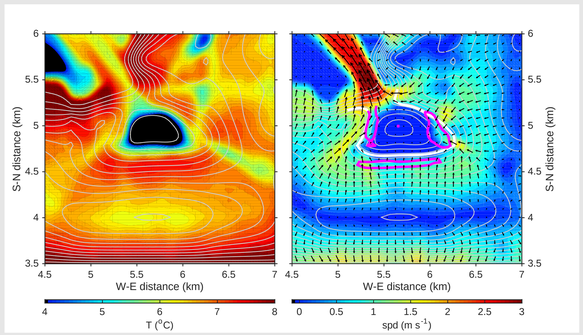

Fig. 2: Near-surface wind and temperature fields at 0400 CET. The bold white line shows the topography contour line at 1332 m MSL, which corresponds to the average top of the near-surface inversion layer. The magenta contour lines show the time-averaged areas of neutral buoyancy along the slope.

- Near-steady solution reached during the first half of the night.
- An approximately 70–80-m deep inversion layer forms above the basin floor.
- Weak downslope flows (1–1.5 m s^{-1}) form along the sidewall.

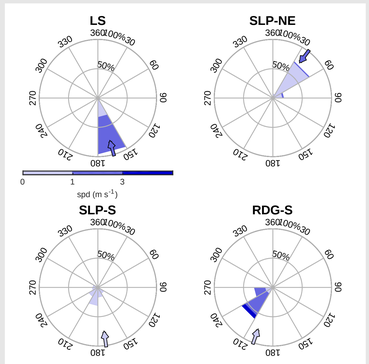

Fig. 3: Observed wind distributions between 2200 CET 20 Oct and 0400 CET 21 Oct at the Lechner Saddle (LS), on the northeast slope (SLP-NE), on the south slope (SLP-S), and on the south ridge (RDG-S). The colored arrows show averaged model wind direction and speed at nearby grid points (2200–0400 CET).

- Downslope winds do not have sufficient negative buoyancy to penetrate the basin-floor inversion but separate from the slopes near the top of the most stable layer.
- Increased downslope winds occur downstream of gaps in the surrounding topography to the east and southwest.
- A steady south-southeasterly outflow occurs through the Lechner Saddle.
- Qualitatively good agreement exists between near-surface observations and simulation.

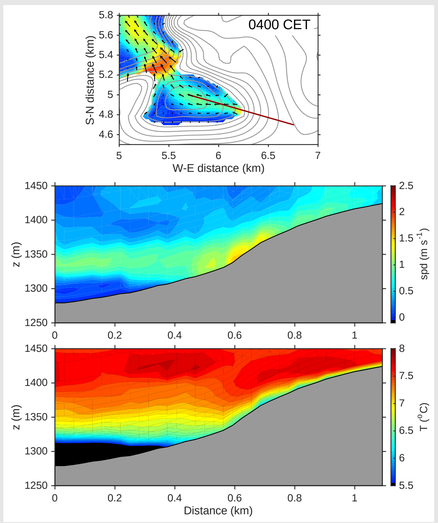

Fig. 4: Wind speed and horizontal wind arrows at 1330 m MSL, i.e., approximately 15 m above the elevation of the Lechner Saddle (top). Vertical cross sections of wind speed (middle) and temperature (bottom) along the transect indicated by the red line in the top panel.

- The katabatic winds that separate from the slope near the top of the inversion layer flow across the the basin towards the Lechner Saddle, where the air drains down the adjacent Lechner Gorge.
- The jet-like flow across the basin remains relatively narrow both vertically and horizontally.
- The outflow through the Lechner Saddle is mostly confined to heights below the elevation of the Seekopfalm Saddle, the second-lowest gap in the surrounding topography.

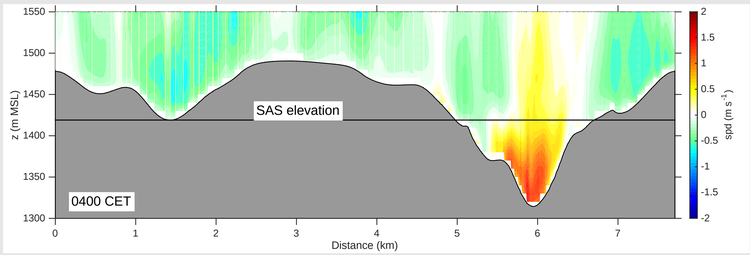

Fig. 5: Wind speed perpendicular to the surrounding topography. The cross section is along the blue line in Fig 1.

MORNING SIMULATIONS

- Simulations are run with different amounts of snow cover, approximating the effect of snow covering the grass at low elevations and trees extending above the snow at high elevations.

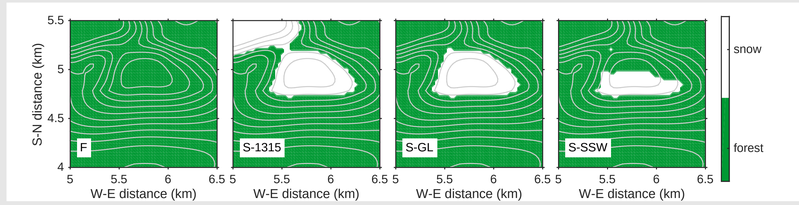

Fig. 6: Vegetation cover for simulations with forest cover (F), with snow below 1315 m MSL (S-1315), with snow below 1315 m MSL within the Grünloch (S-GL), and with snow below 1315 m MSL only on the south sidewall within the Grünloch (S-SSW).

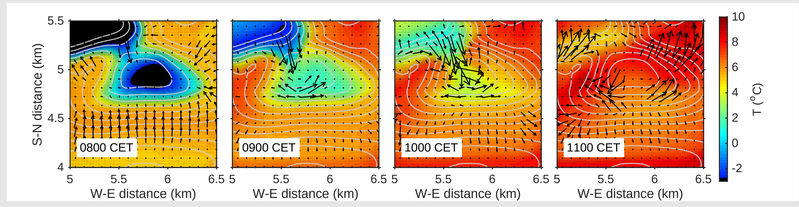

Fig. 7: Near-surface temperature and wind fields at different times for simulation F (forest cover).

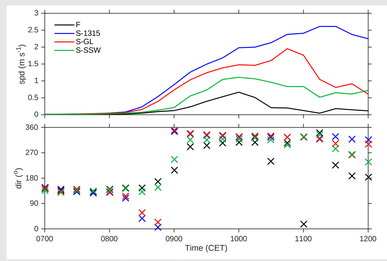

Fig. 8: Time series of near-surface wind speed and wind direction averaged over several basin-floor grid points

- An inflow develops through the Lechner Saddle into the Grünloch, which warms faster than the adjacent Lechner Saddle.
- A weak easterly cross-basin flow towards the more strongly irradiated east-facing sidewall develops over the basin floor.
- The cross-basin flow is replaced by northerly winds as the inflow through the Lechner Saddle pushes farther towards the basin center and continues up the south and east sidewalls.

- The strength of the inflow through the Lechner Saddle increases strongly with the presence of a snow cover in the basin.
- The stronger inflow leads to an earlier destruction of the easterly cross-basin flow over the basin floor.

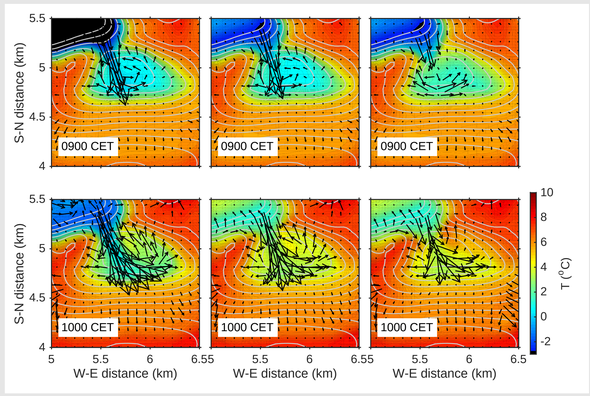

Fig. 9: Near-surface temperature and wind fields at 0900 and 1000 CET for simulations S-1315 (left), S-GL (middle), and S-SSW (right).

Acknowledgments

This research was supported by the National Science Foundation through grant AGS-1361863.