Model simulations of inversion buildup and cold-air outflow in a small Alpine sinkhole

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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 simulation

- CM1 *(Bryan and Fritsch 2002, MWR, 130, 2917–2928)*
- Stretched grid: $\Delta x = \Delta y$ =30–150 m, Δz =10–400 m
- The simulation is initialized with a quiescent and dry atmosphere.
- 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).

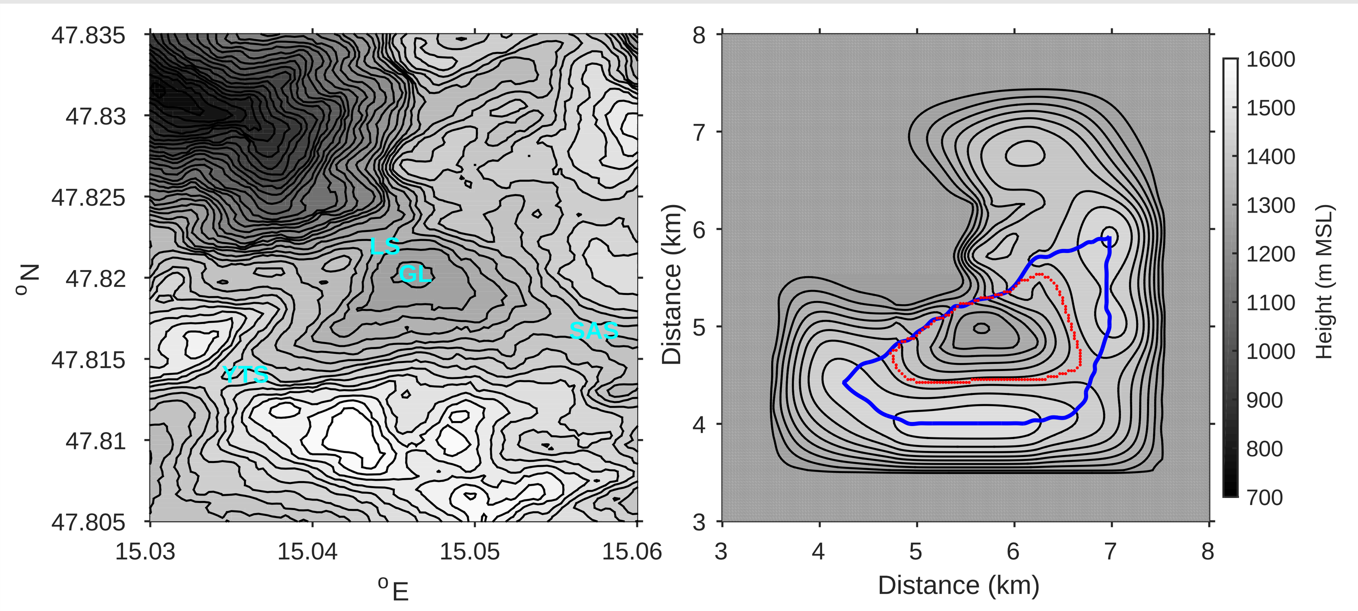

Fig. 1: Gruenloch topography (left) and idealized model topography (right). GL—Grünloch, LS—Lechner Saddle, SAS—Seekopfalm Saddle, YTS—Ybbstaler Saddle. The blue and red lines indicate the locations of the vertical and horizontal cross sections in Figs. 4 and 6, respectively.

Temperature inversion buildup

- Comparison of the model simulation with tethered-balloon measurements from 20 October 2008:

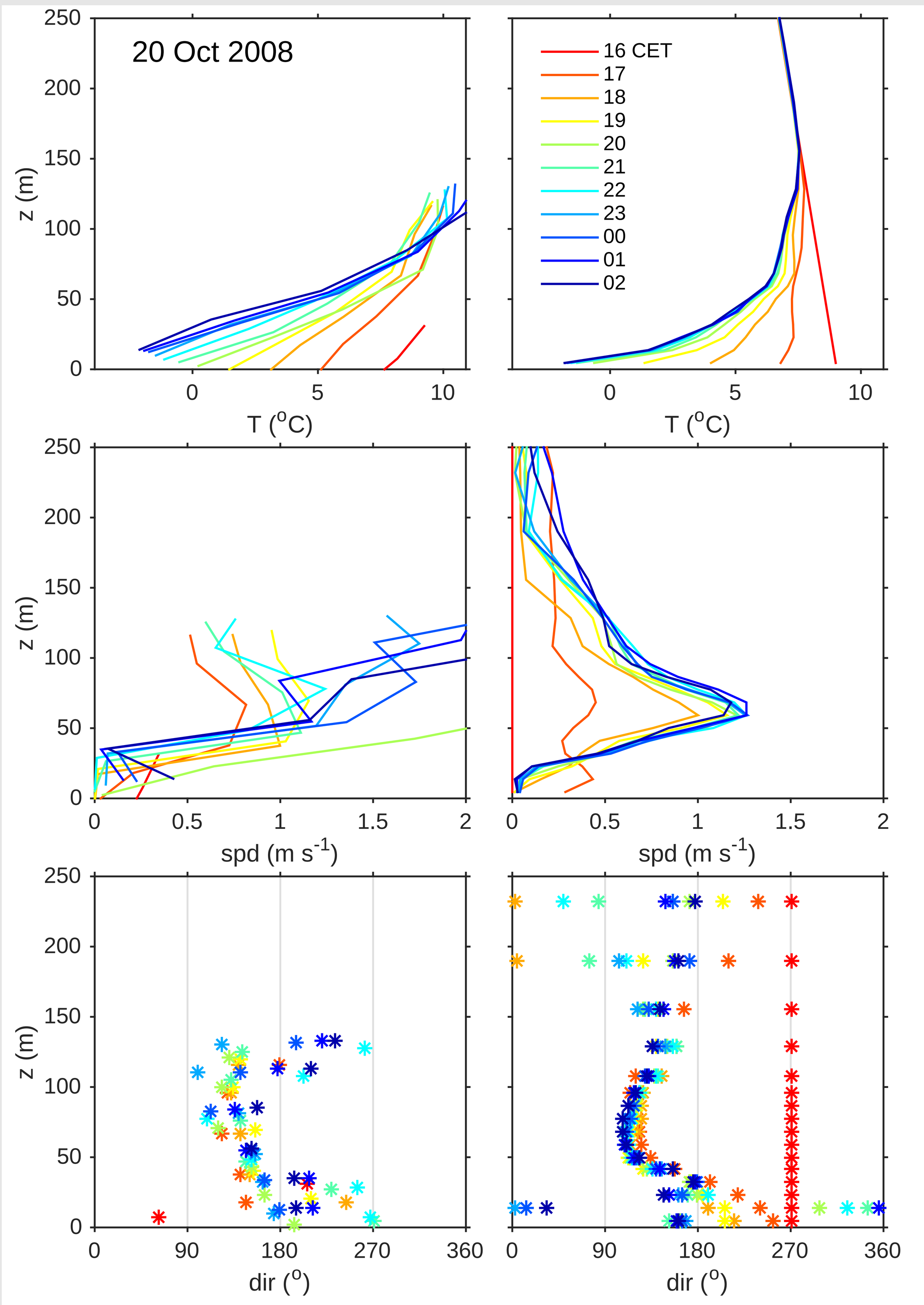

Fig. 2: Vertical profiles of temperature, wind speed, and wind direction in the Grünloch from tethersonde observations (left) and the model simulation (right).

- An approximately 150-m deep inversion forms, with the highest stability within the lowest 50–100 m.
- The strong cooling after sunset is followed by small temperature changes later during the night.

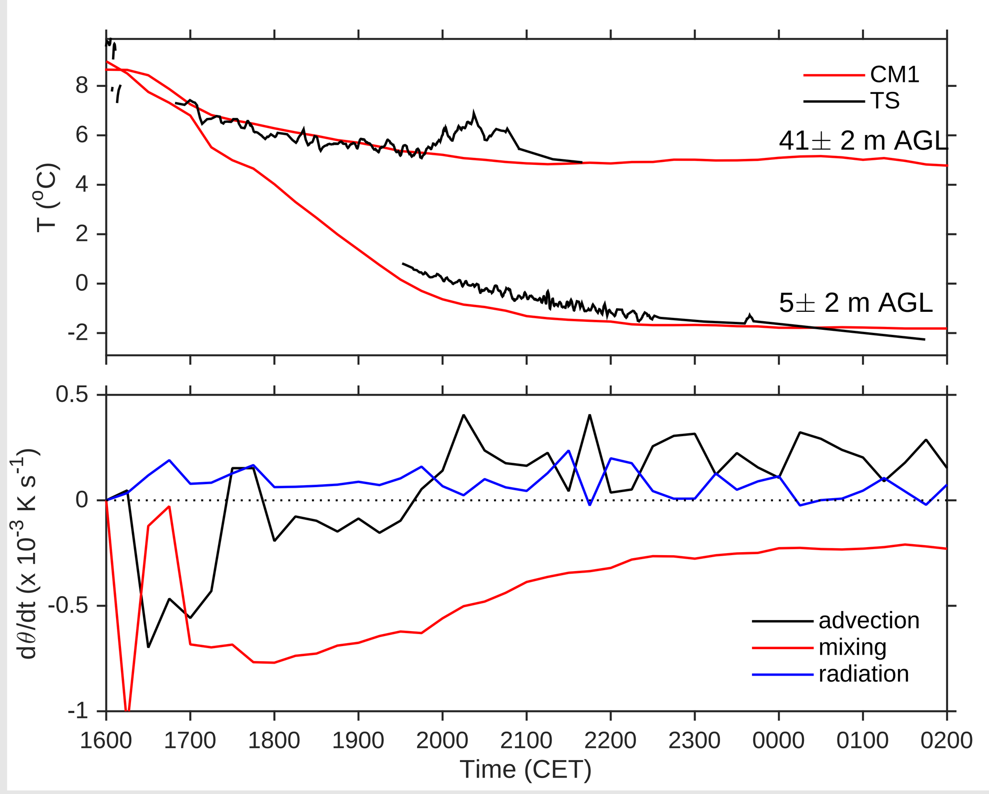

Fig. 3: Time series of simulated and observed temperatures at 5 and 41 m AGL (top) and potential temperature tendency terms at 5 m AGL (bottom).

- A jet-like wind profile forms, with maximum wind speeds near the top of the layer with highest stability and near the height of the Lechner Saddle.
- The wind turns from southerly to southeasterly at the height of the jet maximum, that is, towards the direction of the Lechner Saddle.

Cold-air outflow

- Air flows out of the basin through the Lechner Saddle, mostly below the height of the Seekopfalm Saddle.
- Above the height of the Seekopfalm Saddle, the flow is mostly directed into the basin along the surrounding topography.

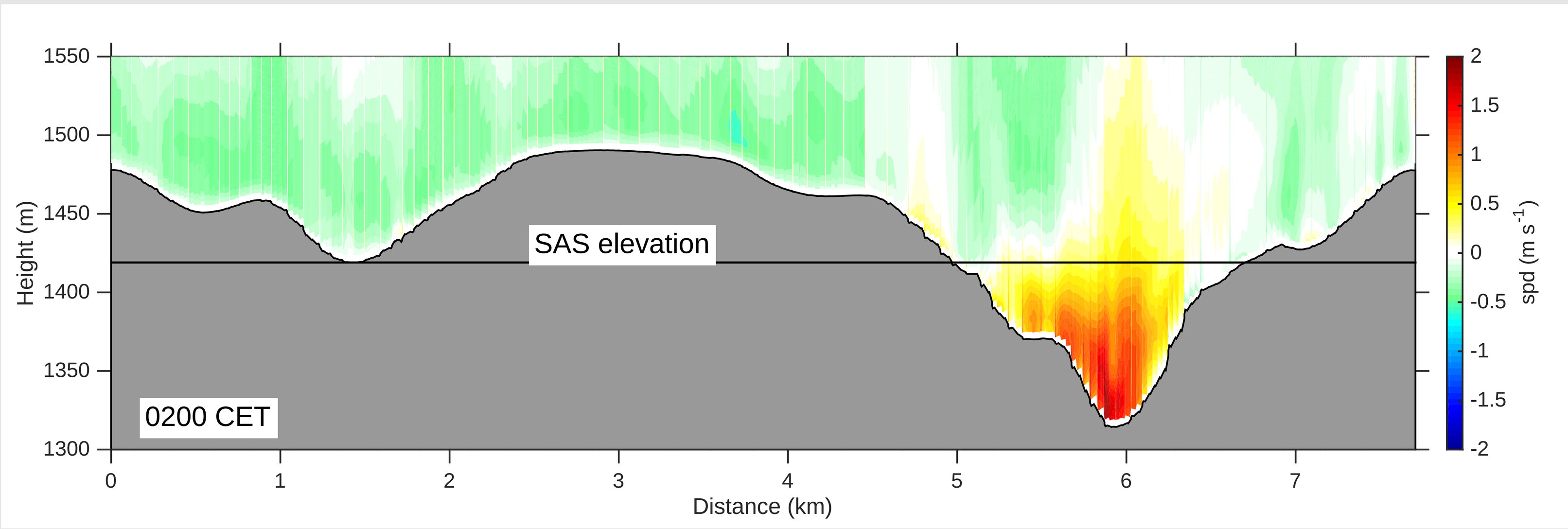

Fig. 4: Wind speed perpendicular to the surrounding topography. The cross section is along the blue line in Fig 1.

- The katabatic flow along the east sidewall separates from the surface near the top of the layer with highest stability.
- A jet-like wind structure over the basin connects the katabatic flow on the east sidewall and the outflow through the Lechner Saddle.

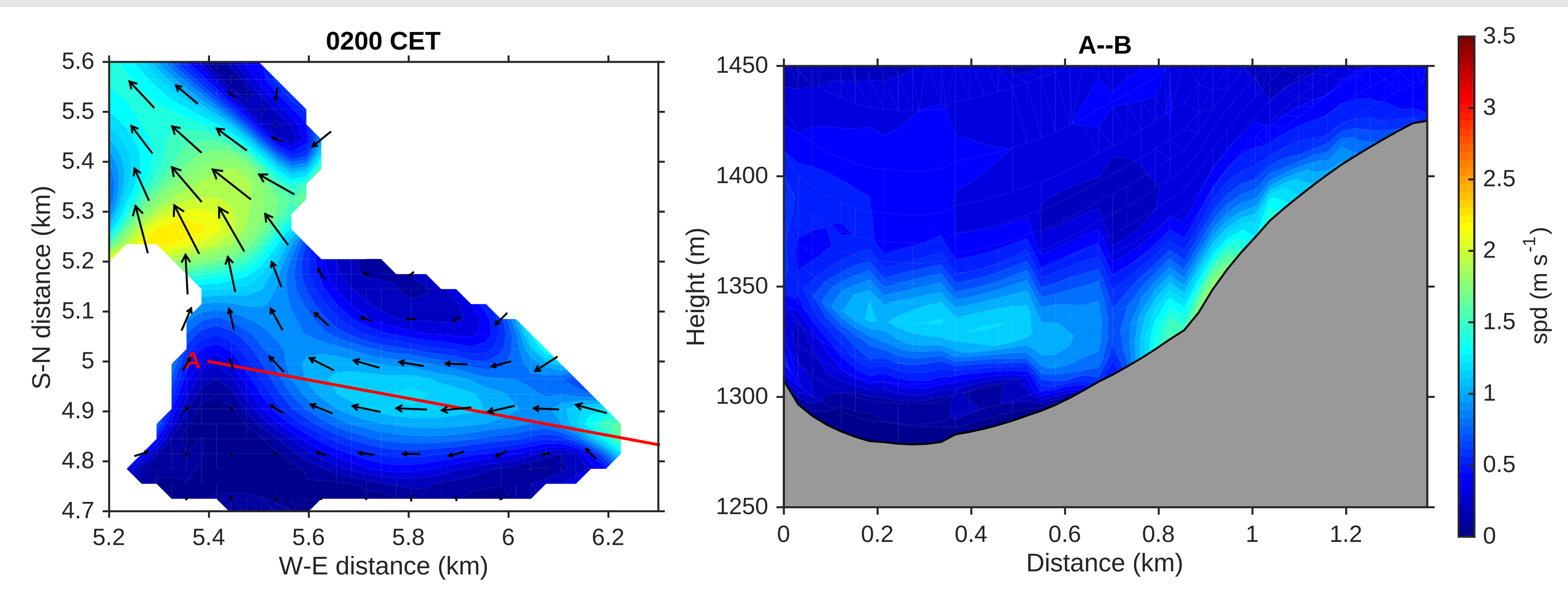

Fig. 5: Horizontal cross section of wind speed and wind arrows approximately 10 m above the height of the Lechner Saddle (left) and vertical cross section of wind speed along the red line (right).

Mass budget

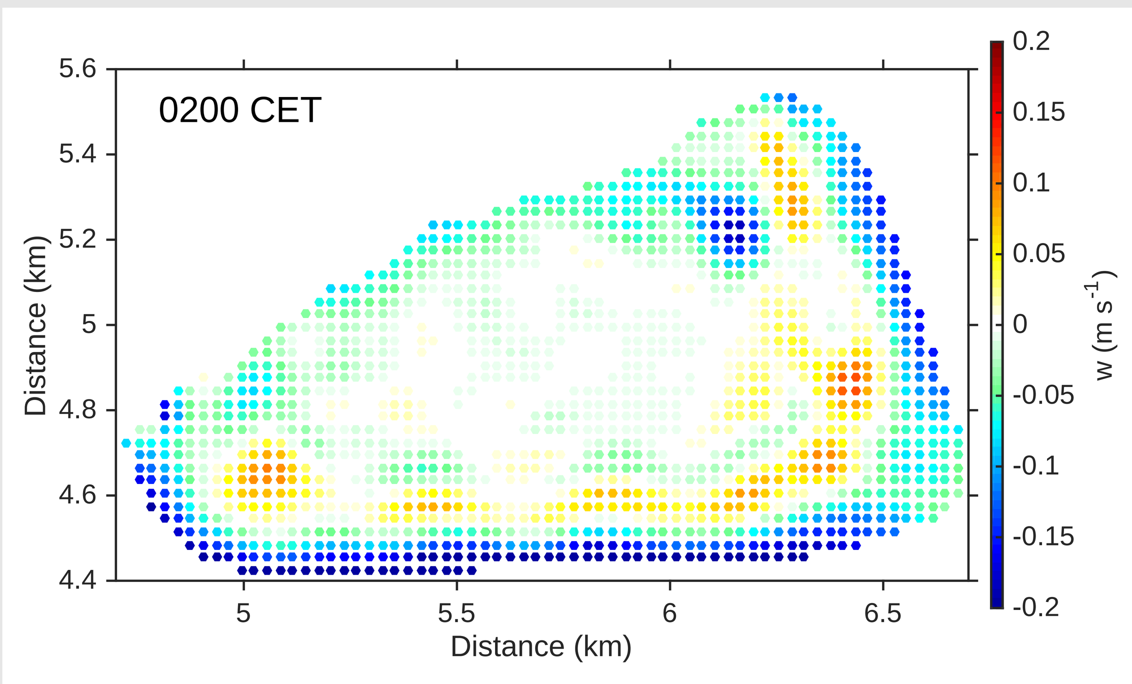

Fig. 6: Vertical velocity at the height of the Seekopfalm Saddle within the area indicated by the red line in Fig. 1.

- Katabatic flows along the sidewalls result in sinking motions.
- Upward motions occur in the layer adjacent to the katabatic-flow layer.
- Vertical velocities over the interior of the basin are weak.

- Comparison of the outflow through the Lechner Saddle with the inflow through katabatic flows along the sidewalls:

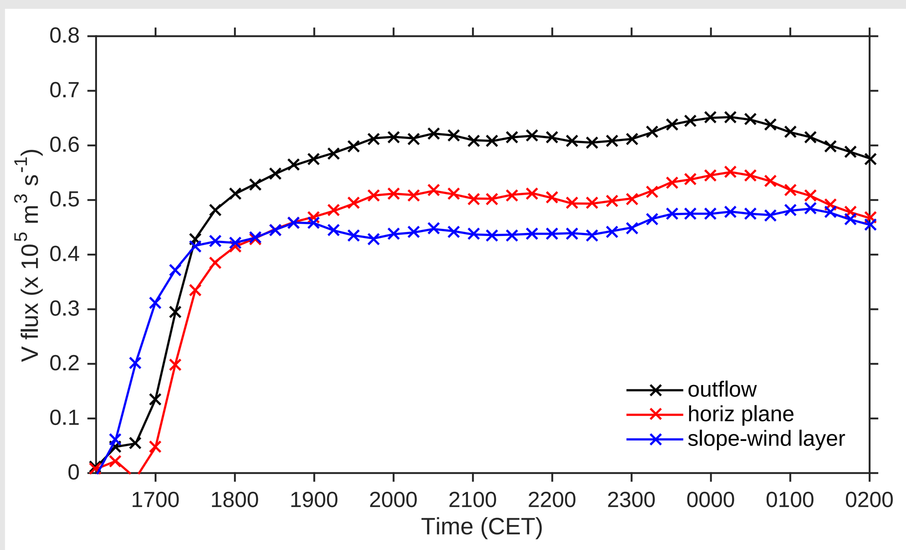

Fig. 7: Time series of volume flux through the Lechner Saddle below the height of the Seekopfalm Saddle, through a horizontal plane at the height of the Seekopfalm Saddle, and the vertical flux in the slope-wind layer at the height of the Seekopfalm Saddle.

- The upward motions adjacent to the slope-wind layer are mostly balanced by the weak downward motions over the basin interior.

Tendency terms

- Pressure-gradient driven cold-air outflow:

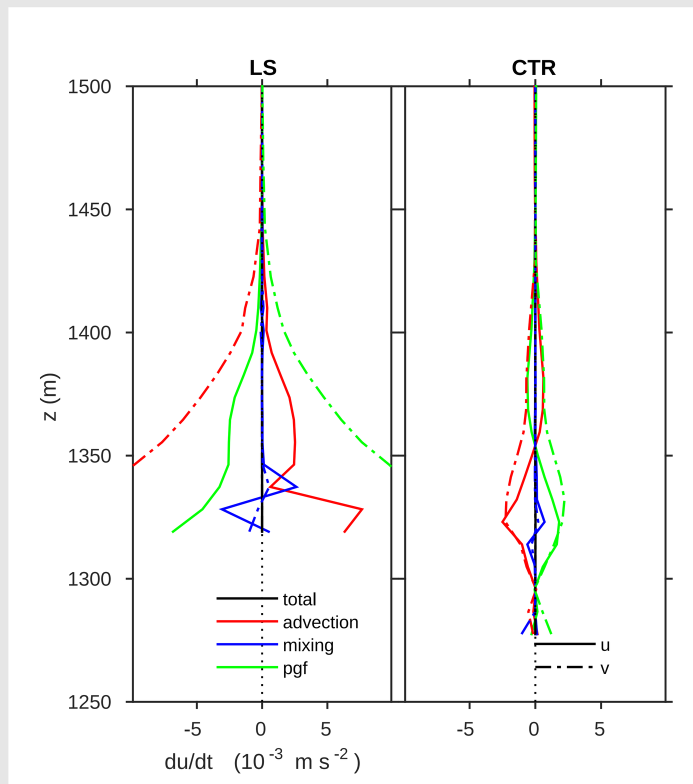

Fig. 8: Time-averaged vertical profiles of *u* and *v* tendency terms at the Lechner Saddle (LS) and the center of the Grünloch (CTR) between 2200 and 0400 CET.

Suggested reading

Steinacker, R., and Co-authors, 2007: A sinkhole field experiment in the eastern Alps. Bull. Amer. Meteor. Soc., 88, 701-716.

Pospichal, B., S. Eisenbach, C. D. Whiteman, R. Steinacker, and M. Dorninger, 2003: Observations of the Cold Air Outflow from a Basin Cold Pool through a Low Pass. Extended Abstracts, ICAM 2003, 153-156.

Acknowledgements

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