Observations of the Cold Air Outflow from a Basin Cold Pool through a Low Pass

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1. Introduction

A major meteorological field experiment was conducted in the 500-m diameter Grünloch (also known as the Gstettneralm) limestone sinkhole in the Eastern Alps near Lunz, Lower Austria, from October 2001 to early June 2002 to observe the strong nighttime temperature inversions that form there and have been reported by earlier investigators (Schmidt, 1930; Sauberer and Dirmhirn, 1954, 1956). As part of this experiment, instruments were deployed to observe the nighttime outflow of cold air that builds up overnight in this sinkhole through a low pass called the Lechner Saddle. Two other contributions in this volume by Whiteman et al. (2003) and Eisenbach et al. (2003) discuss the inversion breakup and the structure of the cold-air pools in this sinkhole.

2. Topography and Instrumentation

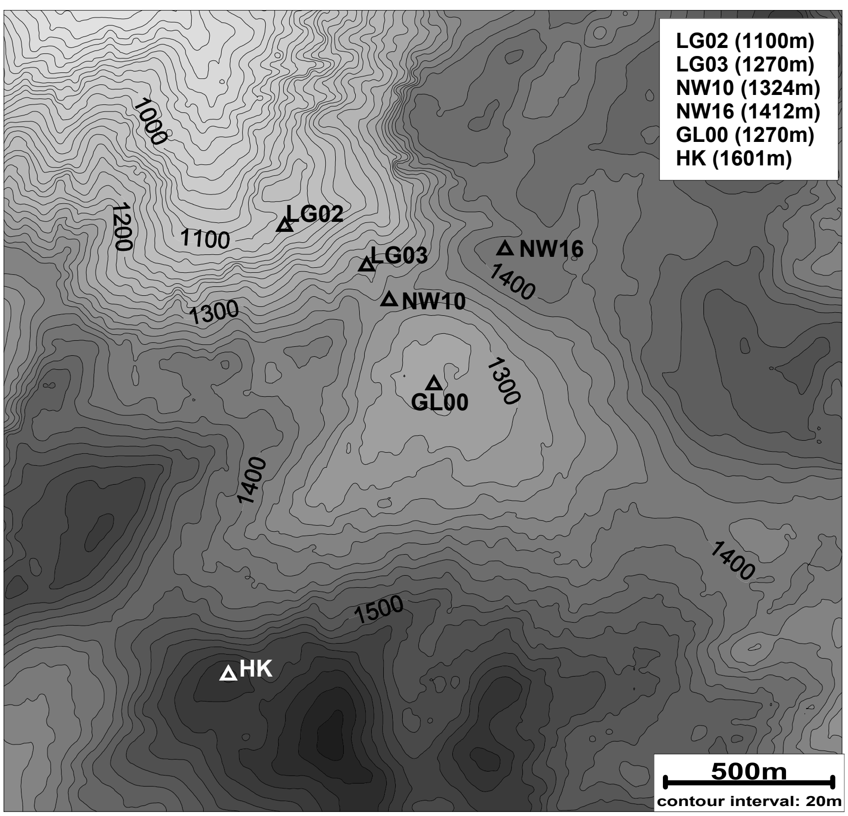

Figure 1: Topographic map of the Grünloch sinkhole indicating the measurement sites and their elevations.

The topography of the Grünloch region and the sites of meteorological instrumentation are shown in Figure 1. The Grünloch is situated on the wooded Dürrenstein plateau, 5 km south of Lunz, Lower Austria. To the northwest the steep, rugged Lechnergraben Valley leads down to the main Ybbs valley. The Lechner Saddle (NW10), the lowest pass, is located on the northwest side of the Grünloch at an elevation 54 m above the 1270 m MSL basin floor. The drainage area of the Grünloch is about 2.1 km^2 and the highest mountain tops are 380 m above the basin floor. Because of the low minimum temperatures in the sinkhole, a vegetation inversion is present in the Grünloch, with no trees growing at the lowest altitudes. Wind data were collected from weather stations located on the basin floor (GL00), on the Lechner Saddle (NW10), and on the summit of the Kleiner Hühnerkogel (HK). Fifty-eight temperature data loggers were placed on three lines that ascended the basin sidewalls, in some nearby smaller sinkholes, and in other locations including LG02, LG03, NW10 and NW16. During a special observing period in early June a series of tethered balloon soundings was made from the basin center (GL00); solar and terrestrial radiation measurements were also made there.

3. Observations and Results

Potential temperature inversions of more than 25 K over a 80 to 120-m depth form in this sinkhole during clear calm nights as outgoing longwave radiation produces a layer of cold, dense air above the sidewalls that drains downward into the basin (see Fig. 2). The basin volume below the Lechner Saddle fills with cold air very soon after sunset and continues to cool throughout the night. Once this confined cold-air pool is in place, the air flowing down from the sidewalls is too warm to enter the pool and simply flows over the top of the cold air pool and exits in a steady 30-m-deep flow through the Lechner Saddle. This flow can be seen very clearly in tethersonde soundings over the basin center (Fig.4). Soundings there show completely calm winds in the high static-stability cold pool below the Lechner Saddle's altitude. Above this level, however, the stagnant air is surmounted by a less stable layer in which winds blow toward the northwest through the Lechner Saddle. On the Lechner Saddle, a weather station recorded winds with an anemometer at a height of 2.5 m above

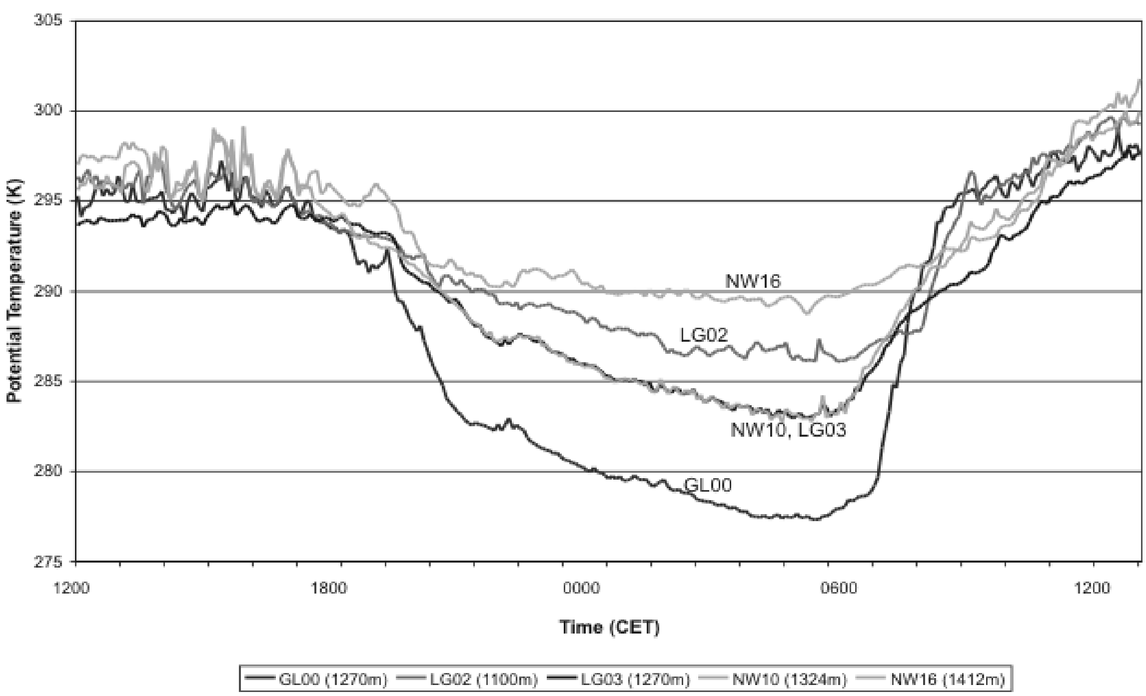

Figure 2: Potential temperature time series from 2-3 June 2002. Site locations are shown in Fig. 1. At LG02 the influence of the basin air can still be seen even though there has already been some mixing with warmer ambient air. NW16 is above the sinkhole inversion.

ground (Fig.3). Winds on the saddle go through a short (1-2 hour) “acceleration period” from calm in the early evening to a constant 0.8-1.2 m/s speed that is maintained through the rest of the night. The wind direction becomes steady out of the southeast, indicating a flow out of the basin through the saddle. This scenario occurs on clear undisturbed nights, varying only slightly through the course of the year. Similar features have also been observed in Japan by Yoshino (1984) who reported a weak inversion layer containing down-slope winds on the top of a stronger stability cold-air pool.

Two temperature loggers were operated in the Lechnergraben, a deep gorge or channel below the saddle. Data from these loggers (Fig. 2) indicate that the cold air that flows across the saddle continues down the channel as a katabatic flow, mixing somewhat with the warmer ambient air as it falls. The flow descends the channel into the upper Ybbs Valley, whose floor is 700 m below the Lechner Saddle. Temperatures at the two sites are marginally warmer than the cold air flowing over the saddle because of adiabatic warming and mixing with the ambient air during the descent. The known saddle geometry and the mean flow through the saddle will allow us to estimate the nighttime volume flux.

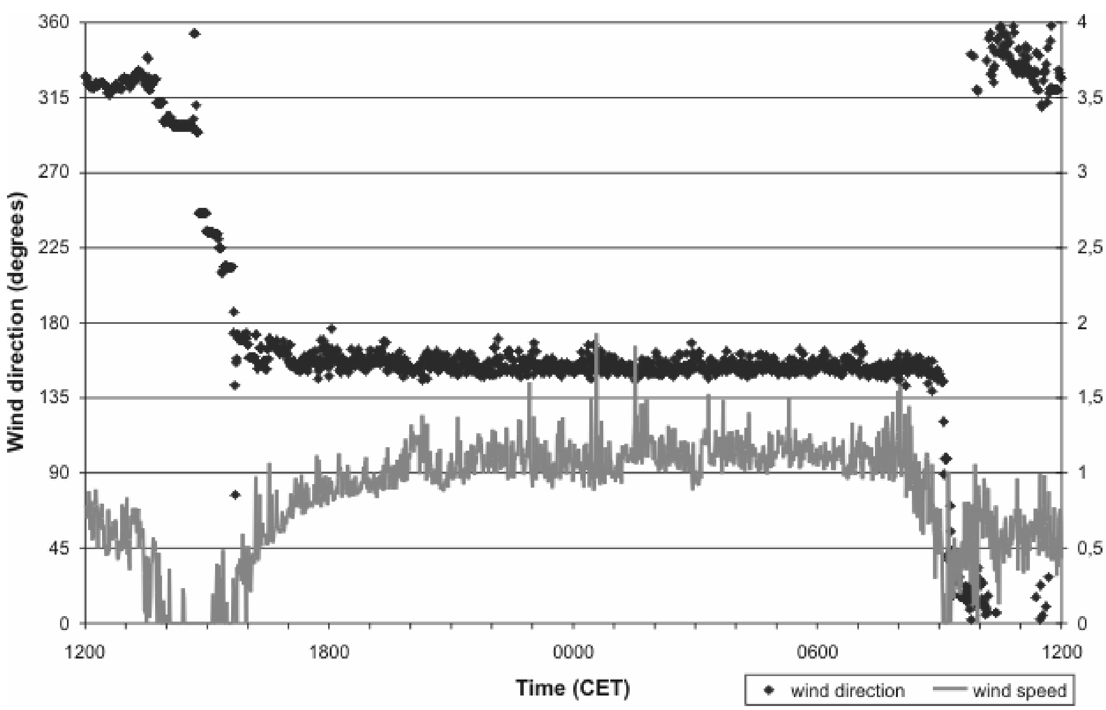

Figure 3: Wind speed (grey line) and wind direction (black symbols) at the Lechner Saddle (Fig. 1, NW10) from 1200 CET 18 October 2001 to 1200 CET 19 October 2001. The steady flow from SSE starts before astronomical sunset (1704 CET) and continues until two hours after astronomical sunrise (0628 CET).

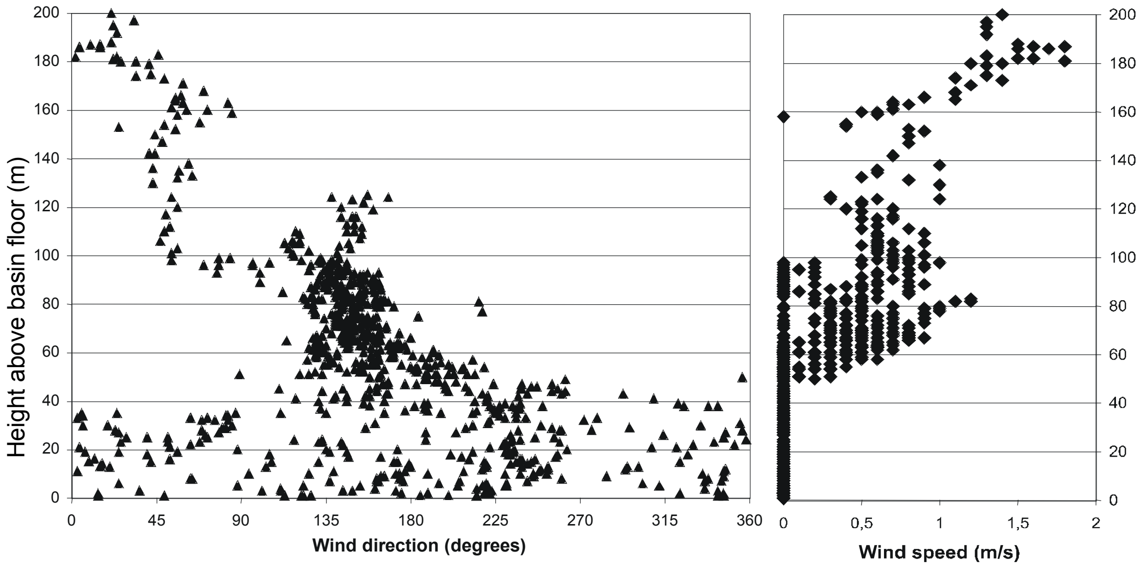

Figure 4: Wind direction and wind speed from tethersonde measurements, as combined from several soundings made between 0200 and 0500 CET on 3 June 2002.

ACKNOWLEDGMENTS

We thank the participants of the field program for assistance in operating the equipment and thank Mr. P. Kupelwieser for providing access to the Grünloch. Two of the authors (BP and SE) thank the University of Vienna, the state of Lower Austria, and the U.S. Department of Energy's (DOE) Pacific Northwest National Laboratory (PNNL) for fellowships served at PNNL in 2002 and 2003. PNNL is operated for the DOE by Battelle Memorial Institute. BP, SE and CDW wish to acknowledge partial research support from the DOE under the auspices of the Atmospheric Sciences Program of the Office of Biological and Environmental Research.

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