Air motion from potential temperature analysis on a meso-β-scale over complex terrain during POLLUMET 1990 and 1991

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Summary. Aspects of the local wind system in a mountain valley were investigated for fine weather situations. In addition to customary wind observations and analyses, the quasi-conservative nature of potential temperature was exploited. It provides an indication of the transport of air masses, and its analysis supplies information on the local wind in the mountainous terrain. Changes of air masses due to mountain and valley winds can be identified in the time series of potential temperature.

Criteria were developed for the determination of the onset of the mountain and valley winds based upon the time series of potential temperature. In this context, the potential temperature serves as an objective indicator of the air mass change independent of wind data and the associated uncertainties. The interpretation of the "front-lines" of the air masses yields insight to the dynamics of the valley wind, and the interaction of transport and pollution processes.

Lokalwinde aus einer Analyse der potentiellen Temperatur auf einer meso-β-Scale über komplexem Terrain während POLLUMET 1990 und 1991


Die Interpretation der "Frontlinien" der neuen Luftmassen erlaubt Einsicht in die Dynamik des lokalen Windsystems und in die Wechselwirkungen zwischen Transportvorgängen und Schadstoffkonzentrationen.

1. Introduction

The planetary boundary layer (PBL) is the living space of people and of nearly all land animals and land plants. Human activities have induced numerous changes in the chemical composition of especially this layer of air. For a better understanding of the chemical processes, the investigation of the transport mechanism is of great importance. In addition, it should be recalled that atmospheric dynamics, in particular turbulence, determines to a great extent also the reaction kinetics of relevant chemical transformations (this is commonly referred to as diffusion controlled kinetics). In this paper, a technique is outlined that provides information of air motion relevant for transport in complex terrain.

Under so-called weak exchange conditions, i.e., with flat large-scale pressure distribution, the wind field in complex terrain is driven entirely by mesoscale pressure gradients linked directly to local thermal processes. This means that differently inclined and differently exposed surfaces absorb varying amounts of radiation energy which subsequently results in surface heating. This in turn warms the lowest air layers, initiating a circulation in which the warmer, less dense air masses rise while the cooler ones sink. During the night, a reverse process takes place driven by the cooling of the surfaces due to infrared radiation.

These processes have been investigated in great detail (for an overview see OKE 1987; for a detailed treatment, WHITEMAN 1990), and are commonly referred to as slope wind systems and valley mountain wind systems. Fig. 1 shows the air motion in an idealized valley for different times of the day. In practice, the flow pattern is much more complex due to the complicated topography.

In complex terrain it is extremely difficult to site wind sensors, anemometers and wind vanes, in such a way that their data are representative for a sufficiently large area. Even small topographic features have a significant influence on the local wind field. Alternate methods less prone to such local disturbances are tethered balloons, Lagrangian tracers (smoke, chaff, balloons etc.), or remote sensing (acoustic sounders, doppler lidars etc.). However, these again suffer from inadequate spatial and/or temporal resolution, moreover, all these methods are rather expensive and require considerable maintenance in operational use.

In the framework of POLLUMET, a national, interdisciplinary research project investigating air pollution and meteorology, an examination was undertaken of the transport and transformation of chemical constituents as they move from the highly polluted Swiss Plateau to Alpine regions. Wind fields were monitored on three different scales namely synoptic, mesoscale, and local, and several local observing systems were set up. However, the analysis described here deals only with the one in the topographically complex area in the Alpine foothills comprising parts of the Lake of Lucerne (mainly Urnersee) in central Switzerland.