Valley-wind characteristics in the Alpine Rhine Valley: Measurements with a wind-temperature-profiler and numerical simulations

S. Vogt[1]; R. Werner[2] ; G. Zaengl[3]

[1]Forschungszentrum Karlsruhe, Institut für Meteorologie und Klimaforschung, Karlsruhe
[2]Umweltinstitut des Landes Vorarlberg, Bregenz
[3]Meteorologisches Institut der Universitaet, München
Siegfried.vogt@imk.fzk.de

Abstract: At the beginning of the MAP intensive measurements phase (Sept.1999), a late summer high-pressure weather system prevailed for nearly three weeks over the Alps. As a result a pronounced valley wind system developed. By means of a wind–temperature-profiler (WTR), the wind and temperature characteristics were measured continuously in the middle of the Alpine Rhine valley near Rankweil. Numerical simulations have been performed with the MM5 model for one selected day (24h cycle of valley wind system). Model calculation and WTR measurements of wind and temperature are in good agreement.

Keywords - *MAP, Wind-Temperatur-Radar, Valley-Wind, MM5 numerical simulation*

1. INTRODUCTION

One of the scientific objectives addressed the four-dimensional variability of the Foehn flow in the Rhine valley (see Bougeault, 2001). To investigate Foehn phenomena a very dense observing network was installed during the MAP special observing period in the Rhine valley target area. Our Wind-Temperature-Radar (WTR) was continuously operating in the middle of the Rhine valley south of Lake Constance for nearly 3.5 months. At the beginning of the MAP intensive measurements phase (Sept.1999), a late summer high-pressure weather system prevailed for nearly three weeks over the Alps. As a result a pronounced valley wind system developed. We will present valley wind characteristics as a function of day and night time as seen by the WTR. Additionally, numerical simulations have been performed with the MM5 model for one selected day (24h cycle of valley wind system).

2. WIND-TEMPERATURE-RADAR

The Wind-Temperature-Radar (WTR) is a mobile system, especially designed for probing the lower atmosphere, i.e. the planetary boundary layer. More details will be found in Bauer-Pfundstein (1999). All measurements are based on the backscattering of electro-magnetic waves in the atmosphere. Waves are scattered either on microturbulent fluctuations of the atmospheric refraction index which is associated with fluctuations of the temperature and humidity, or on artificial fluctuations of the refraction index, which are generated by the transmission of an appropriate sound source.

Table 1. Technical data of the wind profiler-RASS (left column: electro-magnetic waves, right column: acoustic waves).

Frequency	1290 MHz	2700 – 3000 Hz
Power	6400 W	320 W
Antenna aperture	3.2m x 3.2m	1.6m x 1.6m
Antenna gain	33.5 dB	33.5 dB
Beam direction	± 8.5° off zenith in N-S-W-E	±8.5° off zenith in N-S-W-E
Antenna type	8 x 8 pyramidal horns	8 x 8 exponential horns
Number of range gates	78	24
Width of range gate	60 m (variable)	60 m (variable)
Averaging time per beam	10 sec (variable)	10 sec (variable)
Averaging time wind and temperature	30 min (variable)	30 min (variable)

The WTR is operating in two modes: the RASS-mode and the clear-air-mode. In the RASS-mode the WTR records the air temperature by detecting the propagation of sound pulses with a RADAR. In the clear-air-mode the WTR observes the electro-magnetic structure parameter of the refractive index C_n^2, which in contrast to its acoustic counterpart is mainly dominated by moisture fluctuations but much less by temperature fluctuations.. The radiofrequency is centered at 1.29Ghz, corresponding to a wavelength of 23cm.
The sound source is not only used to measure the vertical sound velocity and hence the temperature, but also to estimate the wind components in the so-called RASS-mode. The combination of the RASS-mode and the clear-air-mode allows estimating two independent and redundant wind profiles.

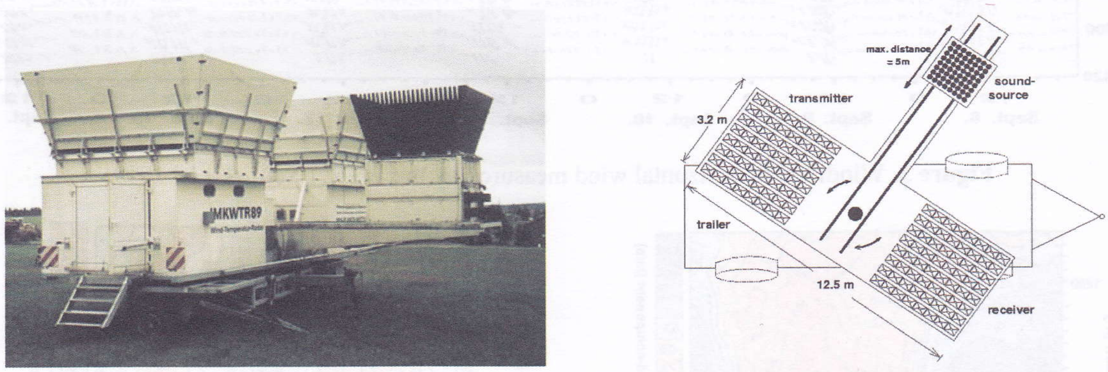

Figure 1. WTR in operation, right hand side: bird's eye view of the WTR.

3. SYNOPTIC SITUATION

Beginning with the second week of September 1999 high pressure was extending from Spain to Russia. During the next days- up to Sept. 12 - the core of the high get stronger and the high pressure system was moving NE into northern Russia. From September 12 till 14 a strong ridge over the Central part of Europe was still there.

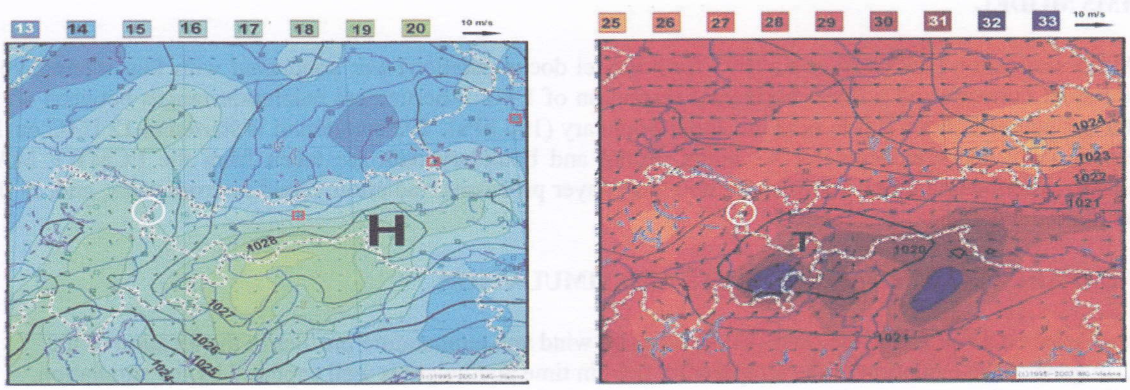

Figure 2. Wind, potential Temperature and Pressure fields of Sept. 10.1999 (VERA Analysis)
left side: night time 3UTC right side: day time 15 UTC.

4. MEASUREMENTS

The daily variation of wind speed and direction can be seen best by a time versus height plot of the horizontal wind vector, see Fig.3. The exchange between up valley wind and down valley wind is effective up to a height of nearly 2000m asl, i. e. throughout the whole valley cross section. The time scale of switching from up valley to down valley wind has no big variation from day to day. Transition from down valley to up valley wind is around 10UTC, whereas the up valley wind came to an end at 19UTC at ground level. The up valley wind is still present one or two hours longer in the upper heights (Fig. 4).
Vertical winds are also changing periodically, (Fig. 5) indicating a cross valley wind system; down winds in the middle of the Rhine valley during strong solar insolation and up winds after sunset and in the early morning hours. This wind circulation system is probably forced by the mountain slope wind system.

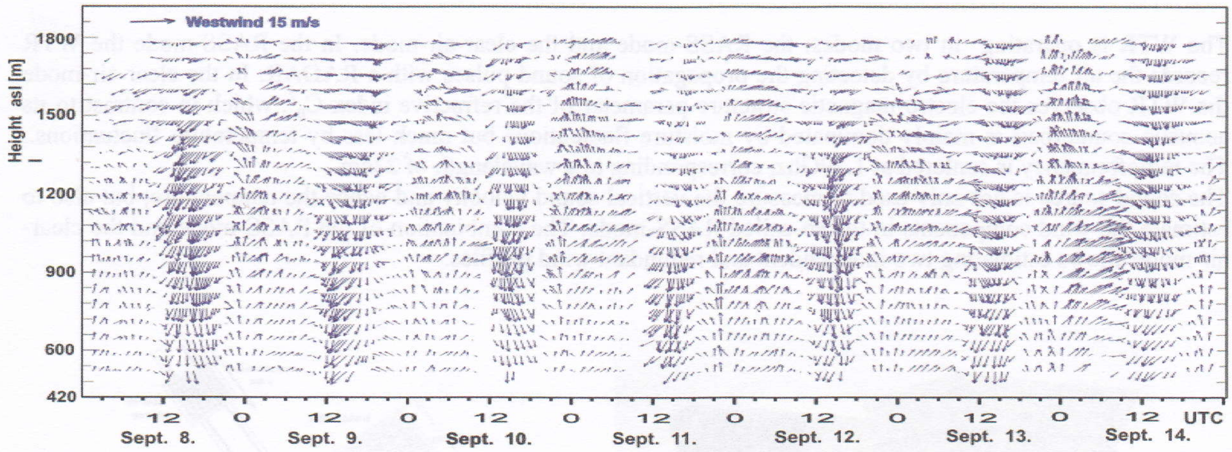

Figure 3. Windfield of horizontal wind measured by the WTR. (Sept. 8 – 14 1999)

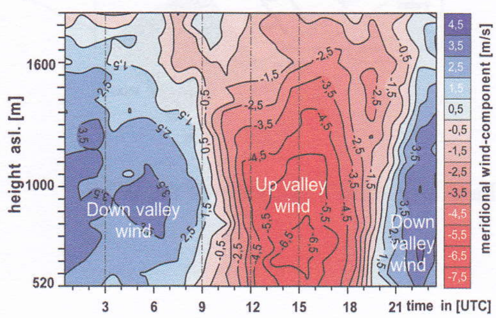

Figure 4. Mean meridional wind component (Sept. 8 – 14 1999)

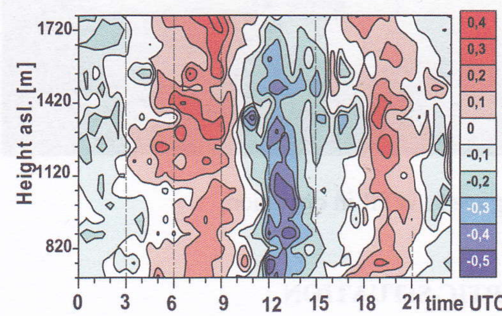

Figure 5 Mean vertical wind component (Sept. 8 – 14 1999)

5. MM5 MODEL

The MM5 simulation (see Grell et al. 1995 for a model documentation) was conducted with four interactively nested model domains and a finest horizontal resolution of 1 km. The vertical resolution ranges between 40 m near the ground and about 700 m near the upper boundary (100 hPa). The simulation is started at 12 UTC on 11 September 1999 and conducted for 42 hours. Initial and boundary data are taken from the ECMWF MAP reanalyses. Parameterizations are used for boundary-layer processes, radiation, cloud microphysics, and, in the two outer model domains, convection.

6. COMPARISON OF MEASUREMENTS AND SIMULATION

We have selected a full 24h cycle (Sep. 12) to compare wind and temperature profiles at the location of the WTR. In general the evolution of the temperature field in time and height is well captured by the simulation. (Fig. 6).One should notice that the lowest altitude for the WTR measurements is 520m asl, whereas the simulation starts at 440m asl.

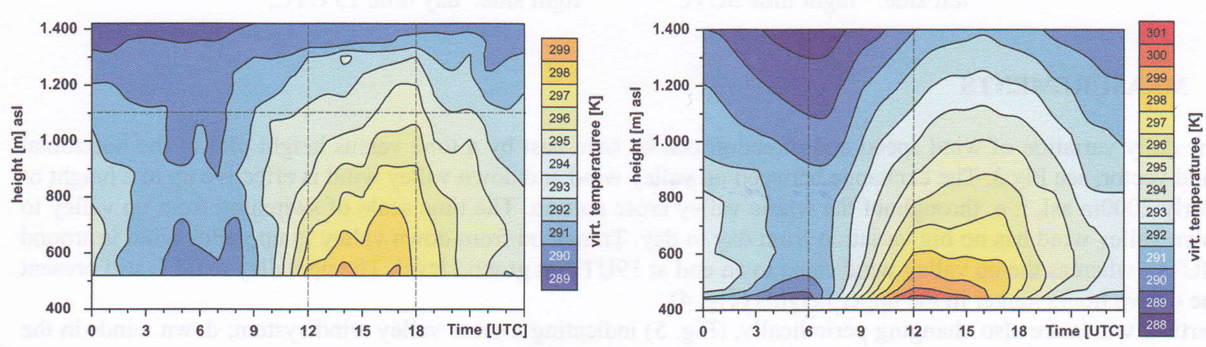

Figure 6 Virtual temperature as a function of height and time.
Left hand side: WTR measurements, right hand side MM5 simulation.

The simulated late night time temperatures are 1 to 2 K lower. The maximum of the simulated temperature is already reached during noon below 600m.
Vertical profiles of virtual temperature for selected time intervals are shown in Fig.7. Bigger differences between measurements and simulation are obvious during down valley conditions; simulation is colder.

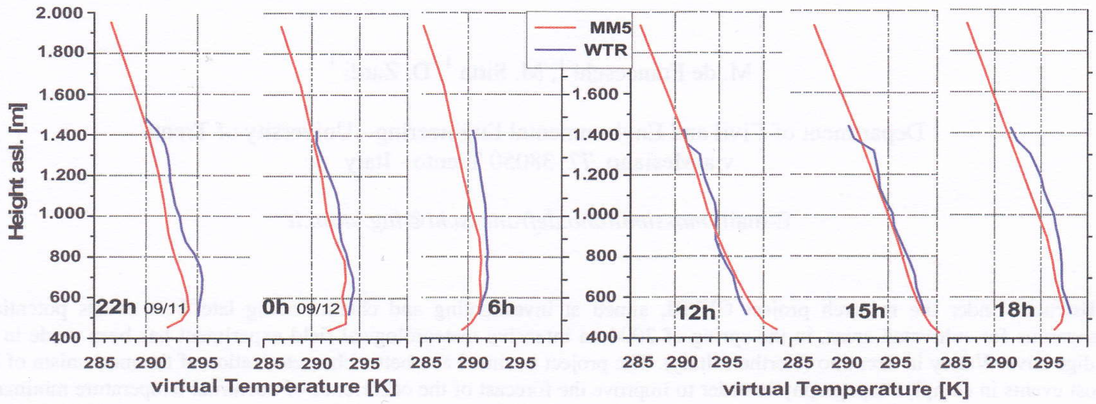

Figure 7 Vertical profiles of the virtual temperature. In blue color are the WTR measurements, in red color are the MM5 simulations. Selected down valley conditions are in the left hand side, right hand side shows up valley conditions.

More differences are evident in the wind field calculations, see Fig 8. The speed of up valley winds around 1000m asl is underestimated in the simulation. During down valley condition no distinct wind speed maximum near ground level can be seen by the WTR.

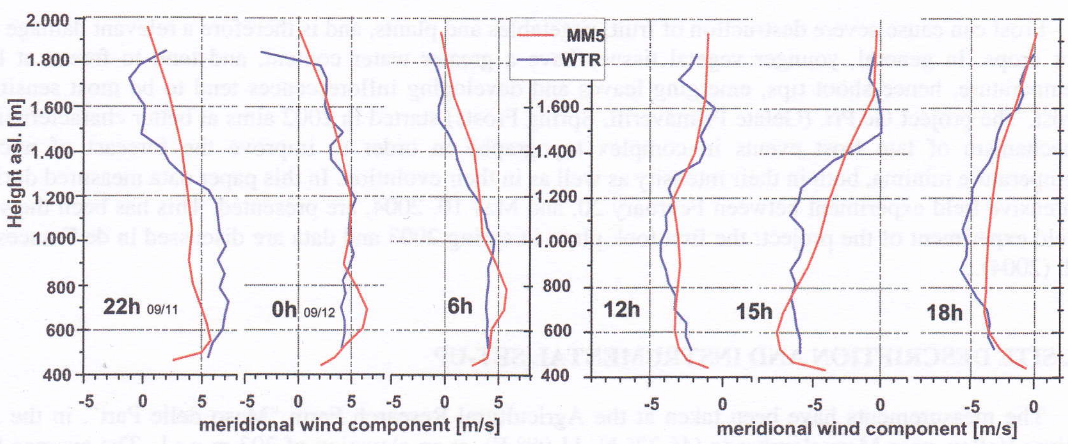

Figure 8 Vertical profiles of the meridional wind component. In blue color are the WTR measurements, in red color are the MM5 simulations. Selected down valley conditions are in the left hand side, right hand side shows up valley conditions.

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