

Comparison of measured and forecasted water-vapor profiles during COPS 2007

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ABSTRACT

Measurements with the multiwavelength Raman polarization lidar BERTHA (Backscatter Extinction lidar Ratio Temperature Humidity profiling Apparatus) have been performed during COPS (Convective Orographically induced Precipitation Study) in the Black Forest, Germany, from June to August 2007.

Profiles of the water-vapor mixing ratio from BERTHA are compared with data from radiosonde and an airborne DIAL (Differential Absorption Lidar) LEANDRE2 onboard the French Safire Falcon). The data of the two lidar systems are in better agreement (average difference of -0.03 g kg^{-1}) than the comparisons of BERTHA and the radiosonde data (average difference smaller than 0.5 g kg^{-1}). The discrepancy between lidar and radiosonde data is attributed to the drift of the radiosonde during its ascent.

Raman lidar data are compared with short-range outputs of the COSMO-DE model (Consortium for small-scale modeling; www.cosmo-model.org) of the German Weather Service. It is shown that the short-range forecast of water-vapor mixing ratio within the residual layer yields values that are on average 7.9% smaller than the measurement. In the free troposphere predicted values are 9.7% smaller than the measurement.

1. INTRODUCTION

COPS is an international field measurement campaign in the frame of the German Research Society priority program Quantitative Precipitation Forecast, that took place in southwestern Germany and eastern France in the summer of 2007 June-August. The aim of this field measurement campaign was to investigate and improve the quantitative precipitation forecast over complex terrain with four-dimensional observation of the atmosphere [1].

The Institute for Tropospheric Research participated in this experiment with a wind lidar and the lidar BERTHA at the COPS-supersite M in the Murg-Valley.

The aerosol lidar Bertha emits 6 laser pulses, simultaneously, and measures the elastically and inelastically backscattered light for determination of aerosol optical parameters, water vapor, and temperature profiles. The lidar BERTHA is described in [2] and [3] in more detail.

Based on [4], this contribution shows the comparison of the water-vapor profiles of BERTHA with forecasted profiles of the model COSMO-DE.

2. SYSTEM INTERCOMPARISONS

First, water-vapor mixing-ratio profiles were compared that were measured with lidar and radiosondes on 14 July 2007 and 01 August 2007. The difference between the values of the lidar and the radiosonde measurements is $0.53 \pm 0.59 \text{ g kg}^{-1}$ on 14 July 2007 and $0.27 \pm 0.53 \text{ g kg}^{-1}$ on 01 August 2007. The differences between the radiosonde measurements and the lidar measurements may arise because of radiosonde drift into drier air layers.

Second, the BERTHA data were compared with DIAL LEANDRE2 data on board SAFIRE-Falcon measured at 1937 and 2018 UTC 31 July 2007. While the Raman lidar directly measures the water-vapor mixing ratio, the DIAL method determines the absolute humidity. Only with a temperature profile (radiosonde) the mixing ratio can be determined. The comparison at 1937 UTC 31 July 2007 took place at twilight conditions which prohibited intercomparisons above the altitude of 3.5 km. The difference of the lidar profiles is much lower in contrast to the comparisons with radiosonde data. The deviations are less than 1 g kg^{-1} in all heights. At 1937 UTC the mean difference was -0.03 g kg^{-1} and the standard deviation was 0.36 g kg^{-1} and at 2018 UTC the mean difference was 0.01 g kg^{-1} and the standard deviation was 0.32 g kg^{-1} .

The exceptional agreement of both lidar data which were obtained in the same atmospheric volume shows, that the water-vapor profiles measured by BERTHA can be used for further studies.

3. MODEL COSMO-DE

COSMO is an operational local model of the German Weather Service [5]. The model delivers a 21-hour forecast in steps of 1 hour. The model runs 8 times a day. It covers an area of $1300 \times 1200 \text{ km}^2$. The grid points are equidistant with $0.025^\circ \approx 2.8 \text{ km}$. By this relatively high resolution of model COSMO-DE it is possible to cover also small scale phenomena as convection or local influences due to topography. The model comprises 50 layers and is operated with 25-s time steps.

4. COMPARISON OF MEASURED WITH FORECASTED WATER-VAPOR DATA

For comparison with the lidar measurements, the nearest grid point at geographical coordinates 48.5618°N , 8.40618°E , and an altitude of 670.0 m is used. This grid point was 700 meters away from the lidar measurement site and the humidity values of the

four surrounding grid points next to this grid point differed at most 0.1 g kg^{-1} . Because of this, the lateral model error of the water-vapor values was small compared to measurement error.

The model predictions of the COSMO-DE have been compared with 15 evening lidar measurements of the water-vapor mixing ratio. As the convection processes in the mixing layer are of crucial importance, the comparison was performed separately regarding the residual layer and the free troposphere. The results are summarized in Table 1. For the residual layer has to be noted that the COSMO-DE predicted values of water-vapor mixing ratio are on average 7.9% lower than the measured values. Only the measurement on 15 July 2007 showed a higher predicted value. To check whether the predicted values were significantly smaller than the measured, a t-test was performed and showed with $t(0.99,14) = 2.624 < 5.17$ that the predicted values from the model were significantly smaller than the values measured by lidar, i.e., that during the investigated time period COSMO-DE underestimated the humidity in the residual layer.

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Date	Top of Residual Layer (km)	Residual Layer		Free Troposphere	
		Difference (%)	Standard Deviation (%)	Difference (%)	Standard Deviation (%)
30 June 2007	1.90	-3.1	19.8	-12.4	26.7
13 July 2007	1.45	-3.7	15.0	6.8	23.4
14 July 2007	2.10	-8.0	14.5	-6.3	31.2
15 July 2007	3.75	3.1	26.8	7.9	57.2
18 July 2007	4.00	-7.3	14.5	-9.3	24.0
25 July 2007	2.00	-13.5	17.4	1.2	73.4
26 July 2007	2.00	-6.6	16.5	-15.5	47.1
31 July 2007	2.05	-7.5	13.3	-6.3	20.4
01 August 2007	1.10	-9.2	12.5	-11.5	31.0
05 August 2007	1.50	-2.1	7.5	-84.2	101.7
12 August 2007	3.20	-5.9	12.2	6.5	26.4
15 August 2007	2.90	-22.2	23.4	-	-
23 August 2007	2.20	-13.9	15.3	0.6	20.4
24 August 2007	2.80	-7.0	9.8	-7.6	17.7
25 August 2007	2.80	-11.1	14.4	-6.5	52.9
Mean		-7.9	15.5	-9.7	39.5

Table 1: Mean Difference of COSMO-DE predicted water vapor mixing ratio to the measured values and corresponding standard deviation. Values are shown for the residual layer (with measured top of residual layer) and free troposphere up to 8 km height [4].