Water Vapour Intercomparison Effort in the Frame of the Convective and Orographically-Induced Precipitation Study

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ABSTRACT

An intensive water vapour intercomparison effort, involving airborne and ground-based water vapour lidar systems, radiosondes with different humidity sensors, GPS and microwave radiometers (MWR), was performed in the frame of *COPS* (01 June - 31 August 2007). The main objective of this work is to provide accurate error estimates for the different water vapour profiling sensors. Simultaneous and co-located data from different sensors are used to compute relative bias and root-mean square (rms) deviations as a function of altitude.

Comparisons between airborne *CNRS DIAL* and ground-based Raman lidar *BASIL* (25 in total) indicate a mean relative bias between the two sensors of 2.1 % (0.12 g/kg) in the altitude region 0–3.5 km a.g.l. Based on the 3 comparisons between *BASIL* vs airborne *DLR DIAL*, the mean relative bias is -3.5 % (-0.24g/Kg) in the altitude region 0–3 Km. On the present statistics of comparisons between *BASIL* vs both airborne *DIALs* and *GPS* and putting equal weight on the data reliability of each instrument, it results in the bias values of: *BASIL* Raman Lidar 0.3 %, *DLR DIAL* -3.2 %, *CNRS DIAL* 2.4 % and GPS 2.0 %.

An inter-comparison between radiosondes indicates that RS80-A and RS80-H are affected by several systematic sources of errors. After correction for these error sources, mean bias between RS80 (A&H) and RS92 is found to be reduced to -4.5 %. Comparisons (5 in total) between the two airborne *DIAL's* (*CNRS DIAL* and *DLR DIAL*) over the COPS region result in mean relative bias of 6.0 % (0.53 g/Kg) in the altitude 0-3 Km. The ongoing comparisons between *BASIL* vs *GPS, MWR* and radiosondes and between the water vapor lidars located at different sites especially benefiting from the extraordinary performances of the ground-based *UHOH DIAL system*, will be discussed at the conference.

1. INTRODUCTION

High-quality water vapour observations are necessary to improve our understanding of the earth's climate system, as well as to improve weather forecasts. Lidar systems based on the application of the *DIAL* and Raman techniques have the potential to fill the observational gaps of conventional profiling systems. Lidar measurements of atmospheric humidity are characterized by high resolution and accuracy, as well as by the capability to cover a substantial portion of the troposphere. The present work aims at providing error estimates for the water vapour profiles measured by different water vapour profiling sensors based on an intensive inter-comparison effort. Comparisons between airborne DIAL and ground-based Raman have been reported in literature [1, 2, 3] extending up to 4 km. However, the number of inter-comparisons so far is rather low, hardly permitting general statements about respective instrument performance. We propose to extend the inter-comparison to a larger measurement sample and number of instruments, to higher levels, and to a larger variety of weather conditions. We also wish to estimate the impact on the reduction of the overall measurement error in water vapour profiling based on the synergetic use of information coming from different sensors.

2. RESULTS

The measurements illustrated in this paper were performed in the framework of *COPS–Convective and Orographically-induced Precipitation Study* - held in the period 01 June - 31 August 2007. The main goal of *COPS* was the characterization of precipitation processes based on the synergy of a new generation of research remote sensing systems operated on ground, aircrafts, and satellites. *COPS* data represent a unique dataset for assimilation and validation of mesoscale models and will lead to an improved in-depth process understanding. The whole life cycle of convective precipitation from the initiation of convection, to the formation and development of clouds, to the formation and development and decay of precipitation was observed in detail, based on the consideration of 34 intensive observation periods (IOPs).

Previous studies [5] revealed that comparison of airborne and ground-based lidars are possible if distance between the aircraft footprint and the ground-based system is not exceeding 10 km, as the sampled air masses may vary over larger distances.

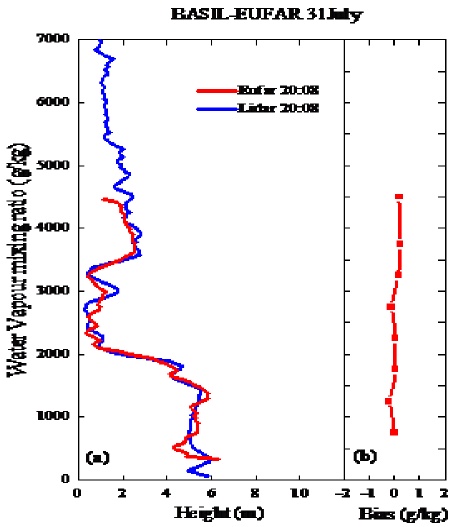

FIGURE 1. *Comparison between BASIL and CNRS DIAL at 20:08 UTC on 31 July 07 (panel a), and deviation between the two sensors (panel b).*

2.1 BASIL vs AIRBORNE DIAL'S

The Univ. of BASILicata Raman lidar system (*BASIL)* was deployed throughout the duration of *COPS* in Supersite R (Achern, Rhine Valley, Lat: 48.64 ° N, Long: 8.06 E, Elev.: 140 m). Raman lidar measurements were run between 25 May and 30 August 2007 and more than 500 hours of measurements were collected, distributed over 58 measurement days.

A total of 25 comparisons were found between *BASIL* vs *CNRS DIAL*, including the three dedicated flights performed during *COPS* in the frame of the *EUFAR* Project H2OLidar (16 July, 25 July and 31 July). In order to reduce statistical fluctuations, we considered for the *CNRS DIAL* an integration time of 80 sec, corresponding to a horizontal integration length of 12-15 km. The integration time for *BASIL* was taken to be 1 min. The vertical step of the measurements is 25 m for the *CNRS DIAL*, while it is 30 m for *BASIL*. Vertical resolution is 250 m and 150 m, respectively. In our analysis we considered only *DIAL* profiles within 10 km from *BASIL*.

Figure 1 illustrates an example of comparison between *BASIL* and *CNRS DIAL* at 20:08 on 31 July 07. The right portion of fig. 1 shows the deviations between the two sensors. The two profiles show a very good agreement, with deviations not exceeding 0.5 g/kg. Larger deviations between the two instruments are occasionally found at different times at the top of the boundary layer, where the effect of in-homogeneities may be larger.

Thus based on all the 25 inter-comparisons between BASIL and CNRS DIAL the relative bias is found to increase with altitude, with a mean value of 2.1 % (0.12 g/kg) in the altitude region 0–3.5 km above ground level (a.g.l). Similarly, between BASIL and DLR DIAL total 3 inter-comparisons are possible. The mean relative bias between these two profiling sensors is -3.5 % i.e. fraction of g/kg in the altitude region 0–3 km a.g.l. RMS has a limited variability with altitude, with a mean value of 13 % (0.45 g/kg) in the same altitude region.

2.2 BASIL vs IWV SENSORS

Also inter-comparison between *BASIL* and the Integrated Water Vapour (IWV) sensors is ongoing. Data from *GPS*, Microwave Radiometer (MWR) and Radiosondes (integrated to 10 Km) are used for this purpose. All these sensors are in good agreement with *BASIL* over long time periods from morning to evening. Based on the available data-sets for *BASIL*, *GPS* and the two airborne DIAL's, and putting equal weight on the data reliability of each instrument, results in bias values for *BASIL* of 0.3 %, for *DLR DIAL* of -3.2 %, for *CNRS DIAL* of 2.4 % and for *GPS* of 2.0 %, as sketched in Figure 2.

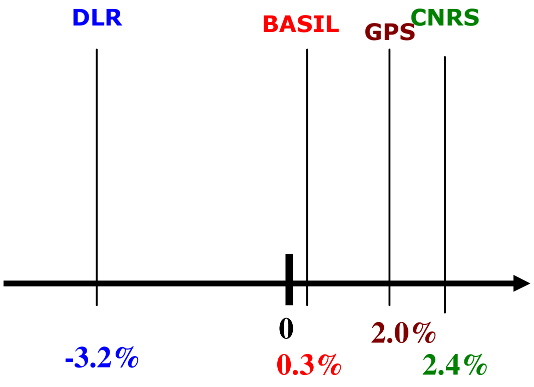

FIGURE 2. *Resulting bias values after putting equal weight on all water vapour sensors.*

2.3 IGN Raman lidar vs CNRS DIAL

IGN Raman lidar, used for tropospheric water vapor profiling, was located in the supersite V (lat:48.44^{0} N, long: 7.55 ^{0} E, Elev: 154 m) of the Vosges mountain. Based on the available dataset 6 comparisons were possible between IGN Raman Lidar and CNRS DIAL, with 3 during day time and 3 during night. The night time comparisons were good as compared to the day time comparisons. The mean relative bias for all the 6 intercomparison is 8.17 % (0.16 g/kg) in the altitude range from 0 - 4.5 km.

2.4 BERTHA vs CNRS DIAL

BERTHA Raman lidar was located in the supersite M (lat: 48.55 ^{0} N, long: 8.41 ^{0} E, Elev: 500 m) in the Murg valley. Besides other atmospheric quantities BERTHA Raman lidar provides water vapor measurements during night time. A total of 6 night time intercomparisons between BERTHA and CNRS DIAL were available. Mean relative bias is -5.6 % (-0.124 g/kg) in the altitude 1 – 4.5 km a.g.l.

2.5 CNRS DIAL vs DLR DIAL

Five intercomparisons were possible over the COPS region between the two airborne DIALs: the CNRS DIAL and the DLR DIAL. The water vapor profiles were considered when the DIALs were within the distance of 10km. Figure 3 shows an example of the intercomparison between these DIALs on 30 July 2007 at 11:53 UTC. The left panel shows the profiles from the two DIALs while the right panel shows the bias. Mean relative bias is -10 % (- 0.17 g/kg) in the altitude region 0.5 – 4 km a.g.l.

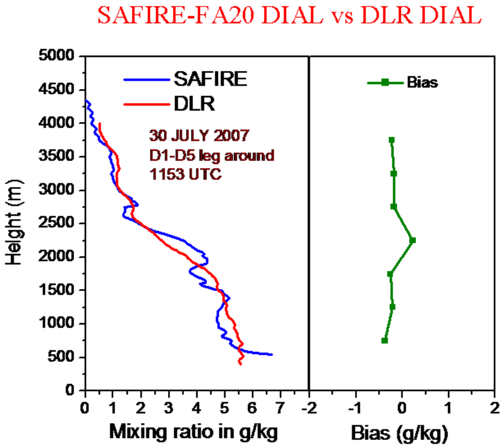

FIGURE 3. *Comparison between CNRS DIAL and DLR DIAL at 11:53 UTC on 30 July 07 (left panel), and deviation between the two sensors (right panel).*

Considering all the five intercomparisons, mean relative bias between CNRS DIAL and DLR DIAL is 3.73 % (0.168 g/kg) in the altitude region 0.5 – 4 km a.g.l.

2.6 Radiosonde intercomparison on July 13th

A total of 226 radiosondes were launched in Supersite R during COPS. Radiosondes with different humidity sensors, namely Vaisala RS92, RS80-A and RS80-H were considered. RS92s were considered from July 13th to August 2nd and from August 21st to August 30th (for a total of 95 sondes), while RS 80s were launched in all other periods (88 RS80-A and 43 RS80-H). Vaisala RS80-A and RS80-H radiosondes are known to have accuracy limitations that result from several identified sources of systematic error [4, 5].

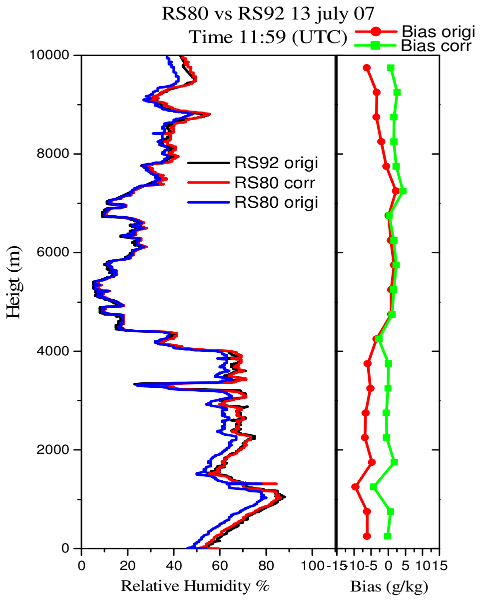

FIGURE 4. *Comparison between RS80-A and RS92 at 11:59 UTC on 13 July 07 (panel a); the figure also shows the bias between the two sensor types (panel b).*

Specific algorithms have been developed to correct for these errors [4, 5, 6]. Based on the comparison of RS92 sondes with GPS and Microwave Radiometer solar radiation-induced dry bias of RS92 sondes was found to be marginal. Figure 4 (left portion) shows the comparison between RS80-A and RS92 at 11:59 UTC on 13 July, showing RS80-A profile both before and after the application of the correction algorithms. The right portion of figure 4 shows the deviations between the two sensor types, before and after the application of the correction algorithms. For this specific case study, mean bias of RS80-A vs. RS92 in the altitude region 0–4.75 km a.g.l. is -8.51 % and -0.45 %, respectively before and after the application of correction algorithms. Mean bias between RS80 (A&H) and RS92 for the five inter-comparison launches on 13 July 07 is found to be approx. -4.5 % from a value of -12 %.

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