Combining remote-sensing instruments at work during the COPS Campaign in order to provide vertical profiles of temperature, humidity and wind

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ABSTRACT

In the prospect of a possible discontinuance of the Nancy meteorological synoptic station, due to human costs and technological evolution, a survey, conducted by forecasters has stressed the need to maintain high-resolution measurements of temperature, humidity and wind in the region, at least up to 4 km height.

Consequently, a locally-managed project at the Strasbourg regional centre of Météo-France has been launched in order to study the capabilities offered by a combination of ground-based remote-sensing instruments as an alternative to radio soundings. To this purpose, the COPS Campaign was considered a good opportunity due to the large network of such instruments implemented on five super sites in the nearby region of Alsace and Black Forest during summer 2007.

This study was made on the available data using UHF profilers, sodars, lidars, radiometers and GPS. Various techniques of observation were evaluated with radiosoundings as reference, first on individual instruments, and then on particular combinations based on their complementary effectiveness.

A first evaluation study [1], made in the first half of 2008, demonstrated the effectiveness of wind profile observations using a combination of UHF profiler and sodar, but it could not give a definite answer concerning humidity and temperature retrieval on a continuous basis. It has now been completed with a validation of radiometric data at three sites, which have shown good prospects for temperature measurements, with still open questions concerning accurate humidity profiles.

This paper will present up-to-date results and methodology used to exploit the combination of remote-sensing instruments for operational purposes.

1. THE INSTRUMENTAL NETWORK

The COPS (Convective and Orographically-induced Precipitation Study) is an international field campaign including 11 universities, 3 research centres, and 2 meteorological services intended to identify the physical and chemical processes responsible for the deficiencies in quantity precipitation forecast over low-mountain regions with the goal to improve their model representation [2]. For the field experiment, a region in south western Germany/eastern France (Fig. 1) has been selected, where, on the one hand, severe thunderstorm activity is frequent in summer with significant amounts of precipitation and risk of flash flood events. On the other hand, the skill of numerical weather forecasts in this region is particularly low.

To this purpose, 5 instrumented supersites, called respectively V, R, H, M and S, have been implemented during the 2007 summer experiment:

The instruments used for this study are listed below:

•V supersite (July 2007):
- –UHF radar (CNRM)
- –Sodar (CNRM)
- –Raman lidar (IGN-SA
- –Radio soundings)

•R supersite
- –UHF radar (Manchester university)
- –Radiometer (Salford university)
- –Radio soundings•

R, H and M supersites (for Radiometer evaluation)
- –3 Radiometers (Salford University, AMF)
- –Radio soundings

All sites
- GPS receiver network

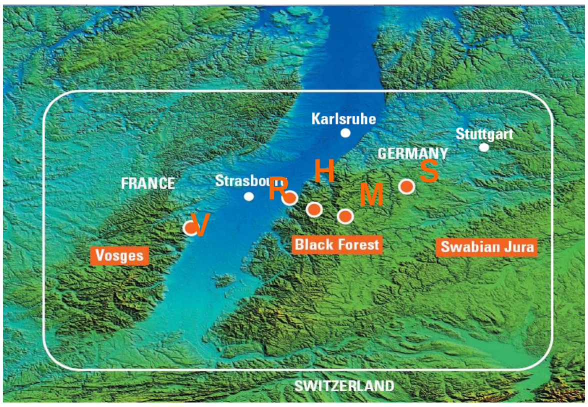

Figure 1. *The 5-site instrumental network operating during COPS*

In the next chapters, validation of wind, humidity, and temperature will be examined from the results obtained with those various remote-sensing systems, either individually, or by combining several of these instruments. In all the following cases, the local radio soundings have been used as reference.

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2. WIND

2.1 UHF radar

UHF radar are already known to give accurate information on wind force and direction. This have been confirmed with the UHF radars operating on V and R supersites (Fig. 2). However, quite often, the measurement is disturbed in the first hundred meters, due to ground echoes.

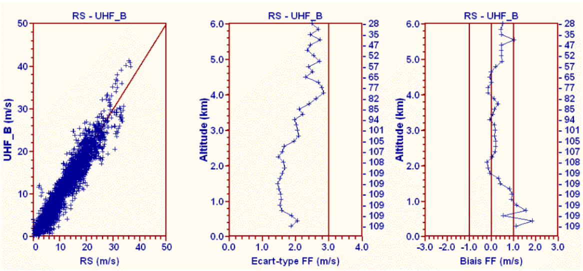

Figure 2. *Statistical comparison of the horizontal wind data obtained from the UHF wind profiler (UHF) versus those measured by radio sonde (RS). Left: Scatterplot of wind values (x-axis RS measurements, y-axis UHF), Middle: Standard deviation with height, and Right: Bias with height. The numbers at the right of middle and right figures represent the number of cases taken for the statistics at each range.*

At these lower levels, a sodar could be used to complete the data and to provide more accurate measurements.

2.2 Sodar

For the V site, comparisons of UHF and sodar during the same periods often show a good agreement in common altitudes, but at certain times very large discrepancies have occurred, indicating that care should be taken when trying to combine the data of each of these instruments.

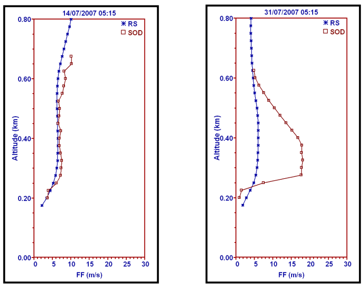

Figure 3. *Some examples of comparison of wind speed between radio sounding (RS) and sodar (SOD)*

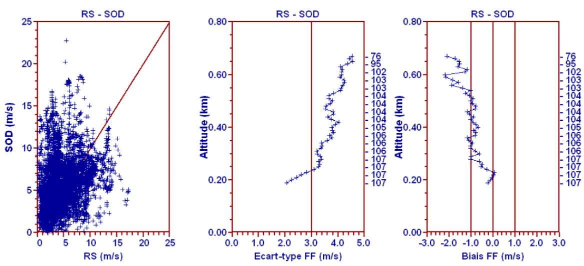

Figure 4. *As in Fig. 2, but using sodar wind data versus those measured by RS*

As shown on Fig. 3, non negligible standard deviation and bias have been observed above 300 m, which shows some limitations as this stage for an automated operational use of the combination with the UHF radar.

However, it is considered that the sodar, already being a manufactured instrument, is potentially able to provide accurate data in the first km height in all meteorological conditions.

3. HUMIDITY

3.1 Lidar

Lidar data of V site were compared to radio soundings over the month of July.

Accuracy of lidar data is good in the first 1000 meters, but quickly worsens above this height (Fig. 5).

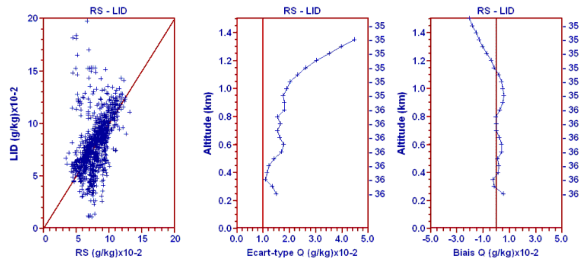

Figure 5. *As in Fig. 1, but using lidar humidity data versus those measured by RS*

However, sensibility to rain and day light conditions may strongly limit its operational use. As indicated in Fig. 6, the data availability may not suffice to insure systematic operational measurement.

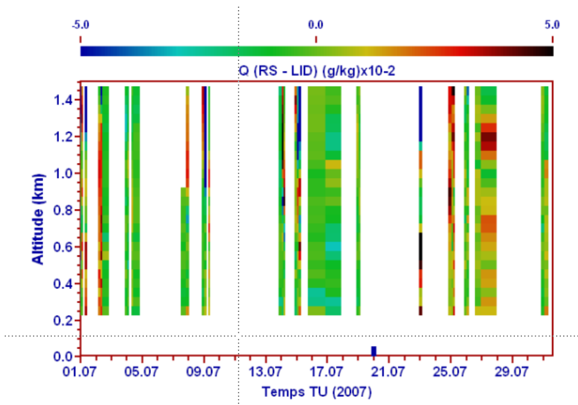

Figure 6. *Time evolution of lidar humidity profiles during July 2007.*

Here, availability of data is about 30%, which shows that lidar measurements can be very helpful when available, but need to be completed by other systems for insuring a sufficient time coverage.

3.2 Radiometer

At the time of this study, the humidity profiles provided during COPS by the radiometer were not yet available. In order to complete these important data, we show here (Fig. 7) the results obtained during a previous experiment in Payerne, Switzerland in 2003-2004 [3].

The standard deviation remained close to 20% in relative humidity on the whole range extending up to 10 km height.

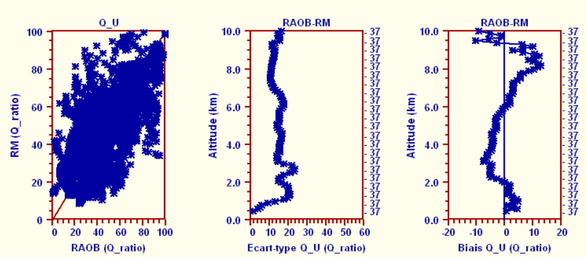

Figure 7. *As in Fig. 2, but using sodar wind data versus those measured by RS*

Recently, still more improvement has been obtained with the radiometric technology [4], which shows that radiometer is a promising tool for the future automated ground-based remote-sensing systems.

3.3 UHF radar with radiometer

Wind profilers have already been used to determine humidity profile measurements, provided the temperature profile and at least one humidity reference point are known [3][5][8]. The technique has been applied to the UHF radar operating at V and R sites after extracting lower level data such as the signal-to-noise ratio, noise and signal width.

The reference data used for this study include temperature profile and total humidity. In the first step, they were extracted from the RS measurements (Fig. 8). Then gradually, other remote-sensing instruments were called for, such as radiometer for the temperature profile (Fig. 9), and GPS for the integrated water vapour (IWV) (Fig. 10).

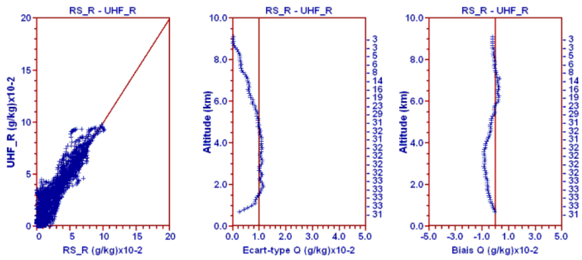

Figure 8. *As in Fig. 2, using humidity data derived from UHF wind profiler versus those measured by RS. Here Temperature profile and total humidity are extracted from RS.*

When using only RS reference data, the standard deviation does not exceeds about 1 g/kg, and the bias is quite small.

Not surprisingly, the quality of the retrieved profiles worsens each time we introduce new measurement errors in the method. First by using the temperature profile from the radiometer (Fig. 9), the standard deviation may reach 2 g/kg between 2 and 5 km height.

When IWV from GPS is added (Fig. 10), a stronger bias is observed due to the extra humidity measured by the GPS station between the ground and the first range gate of the UHF radar.

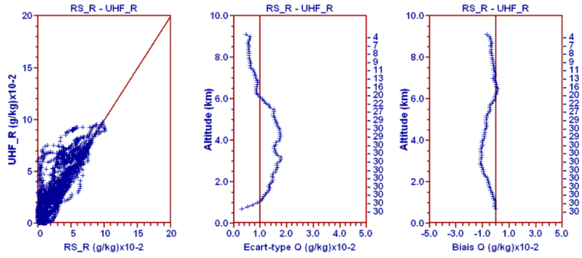

Figure 9. *As in Fig. 4, with temperature profile extracted from radiometer measurements, and total humidity extracted from RS.*

In this case, a correction factor could be used to estimate the relative part of humidity included in this lower level, as has been already successfully implemented on the MU radar in Japan [8].

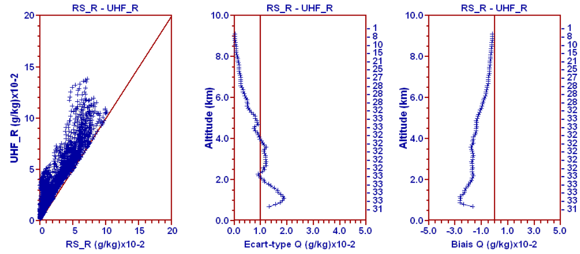

Figure 10. *As in Fig. 4, with temperature profile extracted from radiometer measurements, and total humidity extracted from GPS station located at the ground level.*

The humidity provided by the radiometer could give more informations about the performances of this technique as has been tested on the Swiss UHF radar in Payerne [3]. However, as already mentioned, accurate data were not yet available.

4. TEMPERATURE

4.1 Radiometer

Post-treated radiometer temperature profiles of R, H, M supersites were compared to radio soundings

The statistics show a quite good agreement for T profile (Fig. 11). Direct comparisons of single profiles with radio soundings confirm considerable smoothing of vertical variation by radiometer. Consequently, , this result has to be confirmed in temperature inversion situation.

A similar behaviour was found for the three studied radiometers.

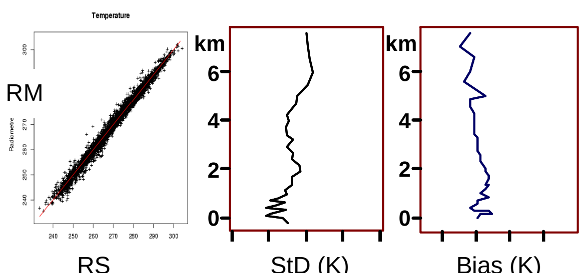

Figure 11. *As in Fig. 2, using temperature data derived from radiometer UHF wind profiler versus RS.*

4.2 Other techniques

There are several other ways for measuring temperature profiles with remote-sensing instruments, which have not been used during COPS.

One of the most encouraging is the Radio Acoustic Sounding System (RASS), which provides, when combined with UHF or VHF radars, highly accurate virtual profiles in the radar range [9], with less than 1K standard deviation.

Their main practical limitation is the noise pollution, which may restrict application near inhabited areas.

5. CONCLUSION

The COPS Campaign was a good opportunity to test the capabilities of various ground-based remote-sensing instruments to provide on an operational basis the basic meteorological parameters, such as wind, temperature, and humidity in the first km height.

If no "ready-to-use" system can be proposed at this stage, conformably to the conclusions of the COST 720 Action Final Report, good prospects still exist depending on the parameter under study.

- For wind profiles, a combination of UHF profiler and sodar represents a promising tool for measurements in the first km height practically down to the ground. If needed, the VHF profiler could complete the profile in the higher troposphere and lower stratosphere.

- For humidity measurements, mixed results have been registered: Good validations were obtained with lidar in the first km height, but data are not always available and need to be completed with other instruments.

In the absence of radiometric measurements, humidity retrieval techniques using UHF radar have given encouraging results, but their quality depends on other instruments, as they need the temperature profile, data given for example by the radiometer, and a humidity reference such as the IWV provided by the GPS. In this last case IWV data should be corrected by the estimated value inside the UHF radar range.

- For temperature, quite good accuracy has been obtained with radiometric measurements. However, in case of sharp inversion in the lower level, the smoothing effect of the instrument may locally hinder the quality of the measurements.

To this time, none of the studied combinations has given a definite answer in terms of accurate temperature and humidity profiles, but the last improvements made on several instruments, such as the radiometer, let the door open for significant progress in this area.

With the completion of the data base, more results are expected to evaluate the practical capabilities of integrated ground-based remote-sensing instruments.

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