Toward the Combination of Active and Passive Remote Sensors for Temperature and Humidty Profiling

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ABSTRACT

Collocated radiometer, wind profiler and ceilometer data have been compared with hourly radiosondes. The radiometer measurements show the general evolution of the atmosphere but cannot detect detailed structures of the temperature and humidity profile. In contrast, the signal to noise ratio of the wind profiler reveals lots of structure linked to change in the refractive index. In addition to cloud base information, ceilometer data can in certain situation locate temperature inversions. The location of such discontinuities could be used in the radiometer retrieval to improve the vertical resolution of the retrieved profile.

Keywords: Microwave radiometer, wind profiler, ceilometer, profiling temperature, water vapour, radiosonde.

1. INTRODUCTION

Future UK operations require several sites using ground based remote sensing techniques to provide an upper air network with better spatial and temporal resolution than currently exists. There is currently a network of 5 wind profilers that covers the UK and winds are operationally assimilated in our global and mesoscale model. Our goal is to get a continuous monitoring of the first 3 km of the troposphere to improve the humidity field and the boundary layer description for numerical weather prediction (NWP). A part of our work is to investigate how a synergy between different ground based remote sensing instruments, like wind profiler, radiometer cloud radar and lidar ceilometer could meet our user needs. A 12-channel microwave radiometer is being trialed and a low cost cloud radar is under development.

A wind profiler and a ceilometer are operationally operated at Camborne in the southwest of England. At present only the wind and the cloud base information obtained from these instruments are used operationally. As it will be illustrated in this paper more information about the vertical structure of temperature and humidity is available in the return signal of the wind profiler and of the ceilometer. The main cause of wind profiler radar returns is due to a Bragg scattering on turbulent inhomogeneities in the refractive index. Therefore there is a close link between the return signal and the gradient in the temperature and the humidity profile. Some studies [1], [2] have shown that from a wind profiler associated with other instruments as RASS, radiometer, GPS, humidity profiles could be retreived at the vertical resolution of the radar.

Three intensive observation periods have been conducted, when radiosondes were launched hourly. These cover three different situations: development of the convective boundary layer, cloud evolution and clear air situation.

2. DEVELOPMENT OF THE CONVECTIVE BOUNDARY LAYER CASE STUDY

Figure 1 shows the time-height evolution of the wind profiler signal to noise ratio (SNR). Superimposed in white circles are the cloud bases detected by the ceilometer,which show a lot of broken cloud. The cloud base is in the middle of a wide layer of high wind profiler signal to noise ratio, except for a couple of clouds which are just at the edge of the wind profiler signal. For these clouds, the cloud base appears to be more steady. The altitude range covered by the wind profiler with a high SNR increase from 1000 m at 08:00 to its maximum (2150 m) at around 11:30. The increase in the spread of the strong wind profiler SNR which also coincide with the spread of the cloud base is likely to be due to the

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development of convection in air which is nearly saturated. When looking at the radiosonde measurement there is indeed a very humid layer.

Above what appears to be the signature of the convective boundary layer, another zone of enhanced signal is highlighted in white. This line nearly coincides with a strong discontinuity in the refractive index (transition between a humid layer to a dry one associated with a temperature inversion). The time height evolution of the square of the gradient of the refractive index ($(dn/dz)^2$) in Figure 2 shows this discontinuity clearly. $(dn/dz)^2$ can't reproduce the signature of the convective boundary layer because mixing is not taken into account. The mixing is accessible through the width of the Doppler spectra, but more signal processing has to be done to make this information accurate [3].

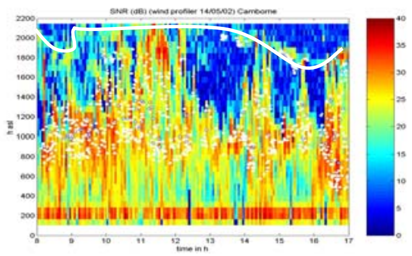

Figure 1 - Time height series of signal to noise ratio of wind profiler (dB scale) on 14/5/02 at Camborne. White and blue circle show cloud base reported by ceilometer.

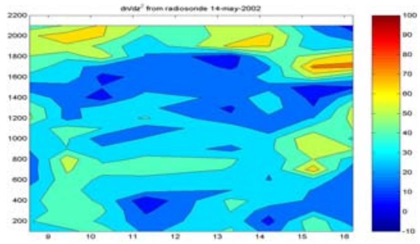

Figure 2 - Time-height series of square gradient of the refractive index (dB scale) computed from hourly radiosonde on 14/5/02.

With a very coarse vertical resolution the radiometer (Figure 3) indicates a humid layer with clouds which correspond to the radiosonde measurement. The general evolution of the temperature is also reproduced (Figure 4). A couple of non-realistic measurements exist between 10:30 and 12:30. These are likely to be the result of cloud contamination. As shown by the ceilometer, the cloud cover is very variable and it is possible that within one minute (which is the radiometer acquisition time) clouds appear and disappear into the field of view of the radiometer.

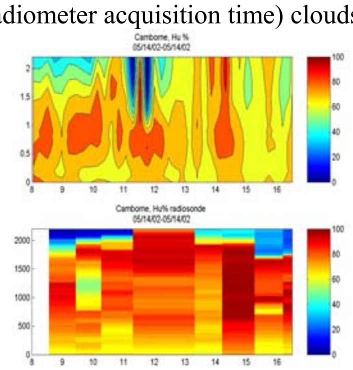

Figure 3 - Time-height series of humidity profile from radiometer (upper panel) and radiosonde (lower panel), Camborne 14/5/02.

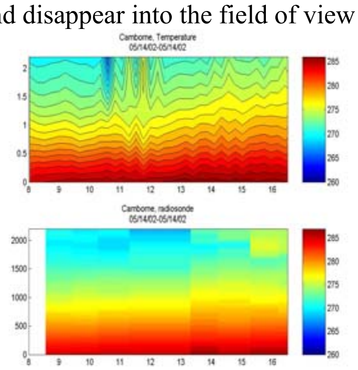

Figure 4 - Time-height series of temperature profile from radiometer (upper panel) and radiosonde (lower panel) , Camborne 14/5/02.

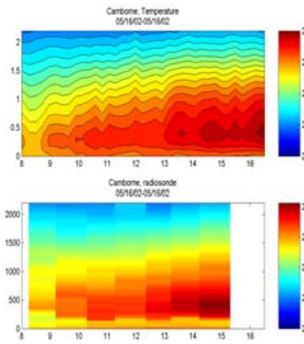

Figure 5 - Same as figure 4 but for 16/05/02.

3. CLOUD EVOLUTION CASE STUDY

On the 2nd example of wind profiler data (Figure 6), there is a layer of strong signal between 200 m and 600 m. Above this layer, there are a couple of structures.There are two types of cloud base: from 08:00 to 11:00 the cloud base is very variable and coincides with strong signal, and from 12:30 to 15:00 the cloud base is more stable and is located below the enhanced wind profiler signal. During the morning low stratus break up into convective cumulus of moderate extent. By the afternoon, an extensive sheet of less convective stratoculmulus appears at 1000 m.

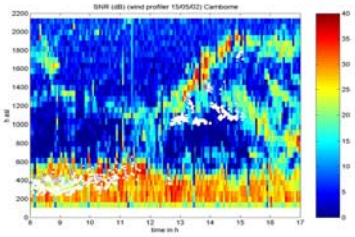

Figure 6 - Same as figure 1 but for 15/5/02

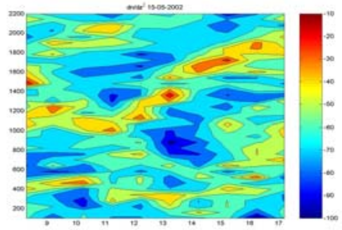

Figure 7- Same as figure 2 but for 15/5/02

The evolution of $(dn/dz)^2$ shown in Figure 7 is in good agreement the signal to noise ratio evolution above the first layer of strong signal. This seems to indicate that the structures seen by the wind profiler above 600 m are not dominated by convection. As in the previous example, the radiometer reproduces the general tendency for the temperature and the humidity but didn't catch any temperature inversion.

4. CLEAR AIR SITUATION

For the third case (Figure 8), there is no low-level cloud. Nevertheless the ceilometer indicates a layer (Figure 9). This layer just fits underneath the local maximum of the wind profiler and corresponds to a temperature inversion. It also reproduces some of the oscillations seen in the wind profiler signal. Aerosol or haze, trapped underneath the temperature inversion backscatter the ceilometer signal. The evolution of $(dn/dz)^2$ shown of Figure10, reproduces the signal to noise ratio. In this case the radiometer was able to reproduce the temperature inversion, as shown in Figure 5.

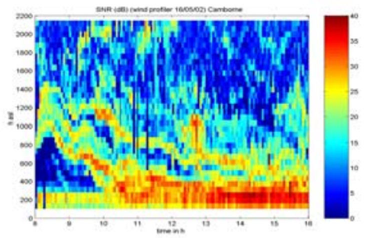

Figure 8 - Same as figure 1 but for 16/5/02

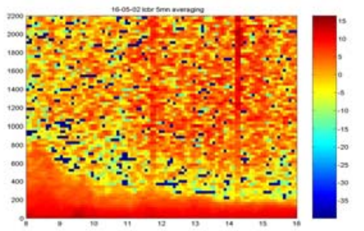

Figure 9 - Ceilometer data averaged over 5 mn for 16/5/02.

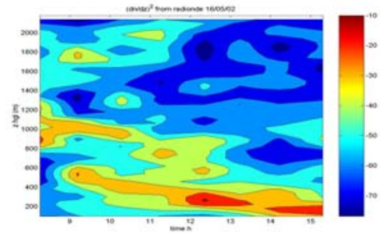

Figure 10 - Same as figure 2 but for 16/5/02.

5. SUMMARY OF CASE STUDIES

These three examples show a lot of information in the wind profiler SNR. Information from the Doppler width about the mixing should improve the interpretation of the signal. The collocation with the ceilometer has allowed us to identify two strengths of convection and confirmed the presence of temperature inversion. A collocated cloud radar would allow complete discrimination between clear air echo and cloud echo.

In the future, we hope to enhance the vertical resolution of the retrievals from ground-based microwave radiometers with co-located active instruments, such as wind profilers by using an estimation of the gradient of the refractive index with the radiometer assimilation.

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