

Radar profiles of rain rate, reflectivity and fall speed of precipitation particles

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1. Introduction

The MRR2 is a low cost 24 GHz FM-CW-Doppler radar rain profiler, *Klugmann et al., 1995, Löffler-Mang et al., 1999*. It measures the fall velocities of the precipitation particles and deduces the rain rate from their fall velocity spectra. From these measurements rain rates, liquid water contents and drop size spectra can be derived. One apparent problem then is that during parts of the year in temperate climates and in the free atmosphere the precipitation appears in the solid phase (ice crystals, snow flakes, graupel or hail). Other difficulties are the attenuation in precipitation, which is large in this frequency band, and the vertical velocity of the ambient air, which affects the fall speed of the drops. The MRR2 also measures the intensity of the return signal.

For radar analysis and forecasting of precipitation the vertical reflectivity profile of the lower atmosphere (which generally the ordinary weather radar beam is above due to the topography and the curvature of the earth) is very important, see for instance *Löffler-Mang et al., 1999*, and the MRR2 produces just such profiles.

The usefulness of this type of instruments is also exploited in other applications. It is a precipitation sensor candidate for present weather sensors. It is used as a precipitation indicator by customers as different as the Häkkinen Formula 1 Racing Team and the Onsala Space Observatory, *Gradinarsky et al., 1999*.

2. The radar signature of the Bright Band

According to our experience the Bright Band, BB, is a common feature in temperate climates when the 0° C isotherm is above the ground. Since the BB and the vertical reflectivity profile have a large impact upon the radar mapping and forecasting of precipitation we will discuss its radar signature. Traditionally, the BB is depicted in vertical reflectivity profiles as a pronounced maximum or 'nose', and so it appears also on the MRR2, Fig. 1. However, it is more evident on the MRR2 rain rate profile, where it also occurs somewhat higher.

Fig. 2 shows fall velocity spectra above, in and below a BB. Above the BB the dominant peak is at about 2 m/s, the fall speed of the ice crystals/snow flakes. Their spectra are fairly narrow, as also other researchers have found, see for instance *Gossard et al., 1990*, and *Duvernoy et al., 1996*. In this region there is also a broad maximum, centered at about 6 m/s. Such a bimodal spectrum appears often, though not always, above the BB. Descending through the BB the ice crystal peak is displaced toward higher velocities and together with the 6 m/s peak forms a broad spectrum. Below the BB there is a fairly broad raindrop spectrum with the peak at about 7 m/s.

3. The vertical velocity of the ambient air

Since the vertical movement of the air affects the fall velocities of the rain drops, the rain rate retrieval, based on fall velocities in quiet air, becomes erroneous. The vertical wind error is probably the most serious limitation of this

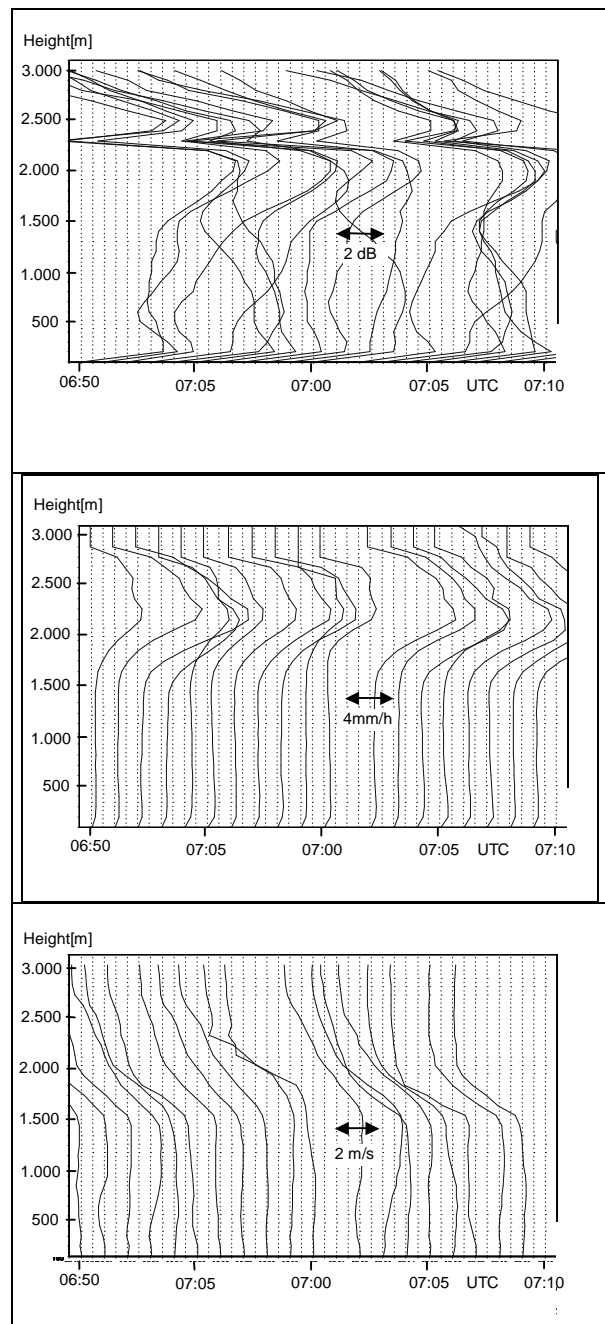


Figure 1. Vertical time cross sections of reflectivity (uppermost Fig.), rain rate (middle Fig.) and fall speed of the precipitation particles (lowest Fig.). The Figures show how the BB appears in these 3 parameters. In the reflectivity image there is an artefact at 2300 m height. A later software has reduced/eliminated this artefact. Christiansö, 7 Nov. 1999, 06:50-07:10 UTC.

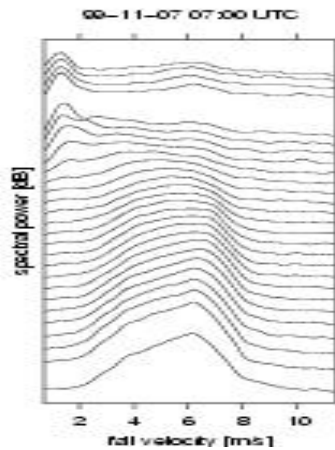


Figure 2. Radar reflectivity spectra for Christiansö, 7 Nov. 1999, 07:00 UTC. The spectra are stacked in range, that is height, above the radar antenna. Vertical scale is the reflectivity factor in dB. The range spacing is 100 m. The BB occupies mainly the interval 1800-2200 m. Three range gates, 2400-2600 m, are omitted due to an artefact at these levels, which appears in Fig. 1.

technique. So far correction schemes as suggested for example by (Probert-Jones et al. 1962, Hauser et al. 1984, Klaasen 1988) have not been applied, because their efficiency is difficult to assess in our application. For small deviations from zero ($|w| < 0.5$ m/s) the retrieval error is about $\frac{\Delta R}{R}(w) \approx \alpha\% / (m/s)$ (Richter, 1993). The error is not linear with respect to the vertical wind, with the consequences of some mean bias also for $w = 0$. While these are extreme events, we estimate that the w -induced standard deviation is less than 20% in stratiform rain, which can be inferred from comparison of rainrates, derived from radar reflectivity and from Doppler spectra, see Fig. 3

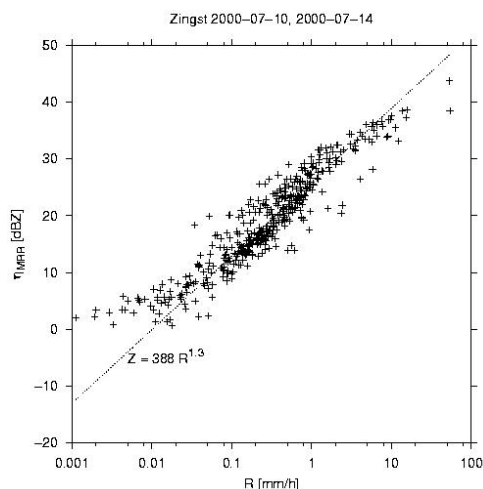


Figure 3. Rain rates computed with the ordinary Z-R relation versus the method used by the MRR2.

4. An attenuation experiment

Since the attenuation of rain is severe in this frequency band and since the available literature data is fairly old, a special experiment was performed to get empirical attenuation data. Two MRR2 were mounted horizontally, one on the roof of the building of the Umweltbundesamt in Zingst (10 m above

the ground) and one on the roof of the Meteorological Institute in Hamburg (60 m above the ground). Assuming that the longterm precipitation rate is constant over the measuring range (about 1 km) and applying the geometrical range correction, the scattering cross section should be constant with range, if there was no rain attenuation. Longterm measurements showed an attenuation that was appreciably, a factor of about 10, larger than the attenuation given in the literature, Fig. 4.

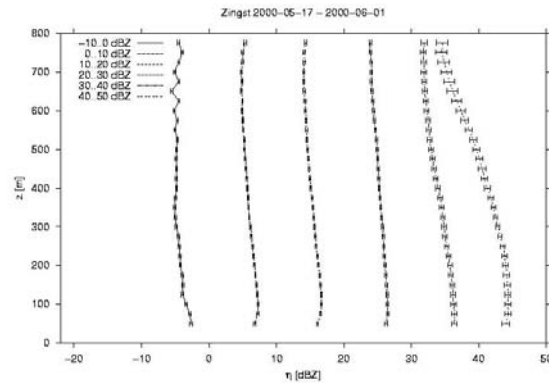


Figure 4. Reflectivity against range from a horizontally mounted MRR2 antenna.

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