P4.5 3-D WIND MEASUREMENTS WITH THE S-BAND ATMOSPHERIC PROFILER TARA

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1. INTRODUCTION

To measure the three-dimensional wind field with radar, one has to observe a volume from three independent directions. This is best done using three systems at sufficiently large separation. However, if one assumes long correlation lengths for the wind fields, 3-D fields can be measured from one position by measuring in three slightly different directions. This is done with wind profilers that usually operate at low frequencies. In this paper first results of wind measurements using an S-band atmospheric research radar, TARA, are shown. Results are compared to measurements from an UHF wind profiler and from radiosondes.

2. SYSTEM DESCRIPTION

The Transportable Atmospheric Radar TARA, is an S-band transportable profiler; Heijnen (1999). Being based on the FM-CW principle, it makes use of two antennas, one for transmitting and one for receiving, see Figure 1. Each antenna uses three feed clusters to generate time-multiplexed beams in three directions; Moumen (2001). One of the beams is directed along the symmetry axis of the antenna while the two other beams are directed under a 15º angle in two orthogonal planes. The central beam is dual polarized. As both antennae are controlled independently, this makes it possible to measure a full polarimetric scattering matrix. Because TARA is a fully coherent, it is capable of doing Doppler measurements. This in combination with the polarization capabilities makes it possible to measure the full polarization scattering matrix within a Doppler resolution cell. Combining the Doppler capability with the three beams will allow for the measurement of a 3-D wind profile.

TARA is designed to be a research instrument. Therefore, it is flexible in its system settings like resolution and sensitivity. The range resolution can be changed from 3 till 75 *m*. The minimum sweep is 1 *ms*. All antenna parameters can be changed on a sweep-to-sweep base (equivalent to a pulse-to-pulse base for a pulsed radar). However, due to processing limitations it is currently done on a Doppler spectrum base. Doppler processing includes the calculation of the first three moments of a Doppler spectrum of 512 cells. In range 512 resolution cells are calculated. All system parameters are computer controlled; Heijnen (2000). The FM-CW principle allows for a fully solid state radar. The minimum detectible reflectivity factor that can be measured at 5 *km* distance with a sweep time of 10 *ms* and a range resolution of 30 *m* is -21 *dBZ*. This can be measured using the maximum transmit power of 100 *W* with a receiver noise figure of 1 dB. For Bragg scattering, the minimum detectable signal corresponds to a structure constant C_n^2 of $4 \cdot 10^{-16} m^{-2/3}$. These numbers are without Doppler processing which can lead to an extra 10 *dB* in sensitivity.

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Figure 1: The TARA system. Clearly visible are the multiple feed systems to generate off-axis beams.

3. ACCURACY

The radar hardware will set a limit to the resolution in the velocity measurement. With 512 Doppler resolution cells, the minimum velocity that can be measured with a sweep time of 1 *ms* and a frequency of 3.3 *GHz* equals 8.8 *cm/s*. Because of the small scan-angles, this will result in an accuracy of 0.6 *m/s* in the horizontal velocity and is calculated by quadratic addition of the contributions of each beam. These values will go down linearly with increasing sweep times. Although system settings will have a limiting effect on the accuracy, a full analysis of the errors will have to include the signal-to-noise ratio, SNR, in the measurements too. In all the measurements that are shown, the SNR for the TARA system was clipped at 10 *dB*, making sure that low SNR will not affect the accuracy in the measurements.

4. MEASUREMENTS

As a first example, a measurement of a cloud is shown in Figure 2. The top figure shows the reflectivity as measured with the central beam, while the bottom figure shows the horizontal wind velocity as calculated from three beams. The cloud is clearly visible at an altitude between five and seven kilometers. The wind velocity in the cloud has a laminar structure showing that the horizontal correlation length is sufficiently long. Under the cloud, a turbulent layer with an altitude up to 2 *km* can be seen. In this layer the assumption on the correlation length becomes questionable as can be deduced from the rapid variations in the wind speed. System artifacts show up as horizontal lines.

The measurement was done with a sweep time of 1 *ms* and a transmit power of 100 *W*. The frequency bandwidth was 7.5 *MHz* leading to a spatial resolution of 20 *m*. As the measurement sequence to measure the wind speed contained four individual profiles, the time resolution for the presented profiles is 2 *s* (512 sweeps are used for one Doppler spectrum).

A comparison of the horizontal wind speed is made with measurements from a radiosonde launched in De Bilt, 30 *km* away from TARA, and with a 1290 *MHz* wind profiler co-located to TARA; Klein Baltink (1998), see Figure 3. The radiosonde was launched at 13.30 *h* local time; half an hour after the TARA measurement was started. The profiler has a time resolution of 1 *h* and spatial resolutions of 100 *m* and of 400 *m*. To reduce the scatter in the TARA data in the turbulent layer, the TARA data was averaged over 12 *min* and the wind velocity was calculated from the averaged data. Although significant differences occur between the observations of the different systems, the trends are the same. Most of the differences can be explained from the measurement set-up. It must also be mentioned here that the wind profiler data can be processed with a time resolution of 15 *min*.

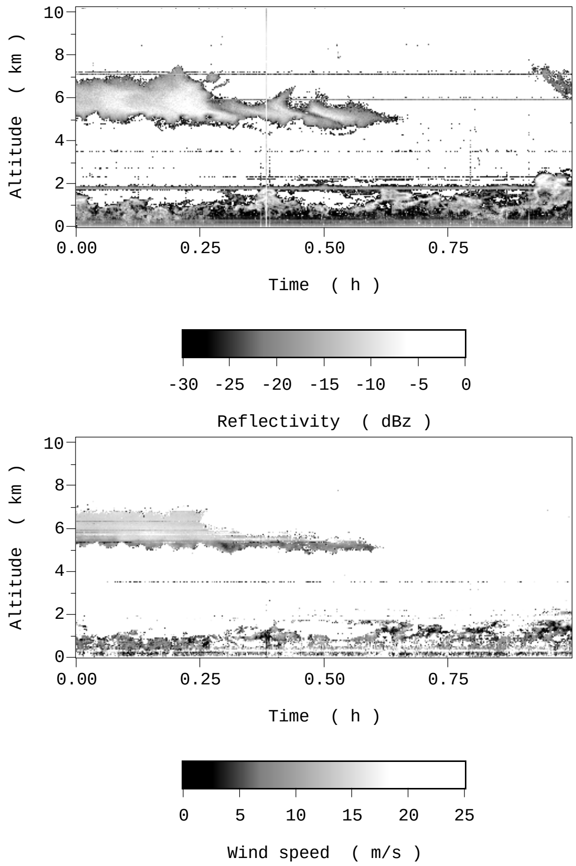

Figure 2: Measurements of a cloud. Top the reflectivity and bottom the horizontal wind speed.

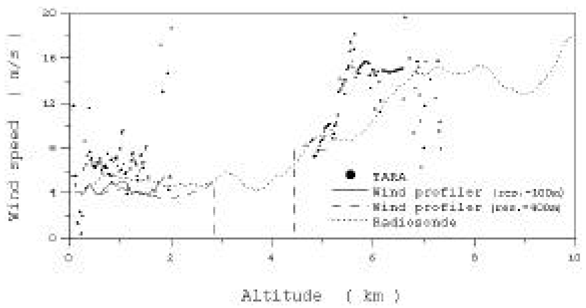

Figure 3: Comparison of measurements from TARA, (0 - 12 *min* averaged), with measurements from a wind profiler and from a radiosonde.

This has no big influence on the profile from the wind profiler.

As a second example, a measurement during snowfall is taken. In this measurement the TARA system had a sweep time of 2 *ms* and a transmit power of 1 *W*. In Figure 4 the wind speed and direction are shown as measured with TARA and as measured with the wind profiler. The measurement covers a period of four hours. The wind profiler data was processed

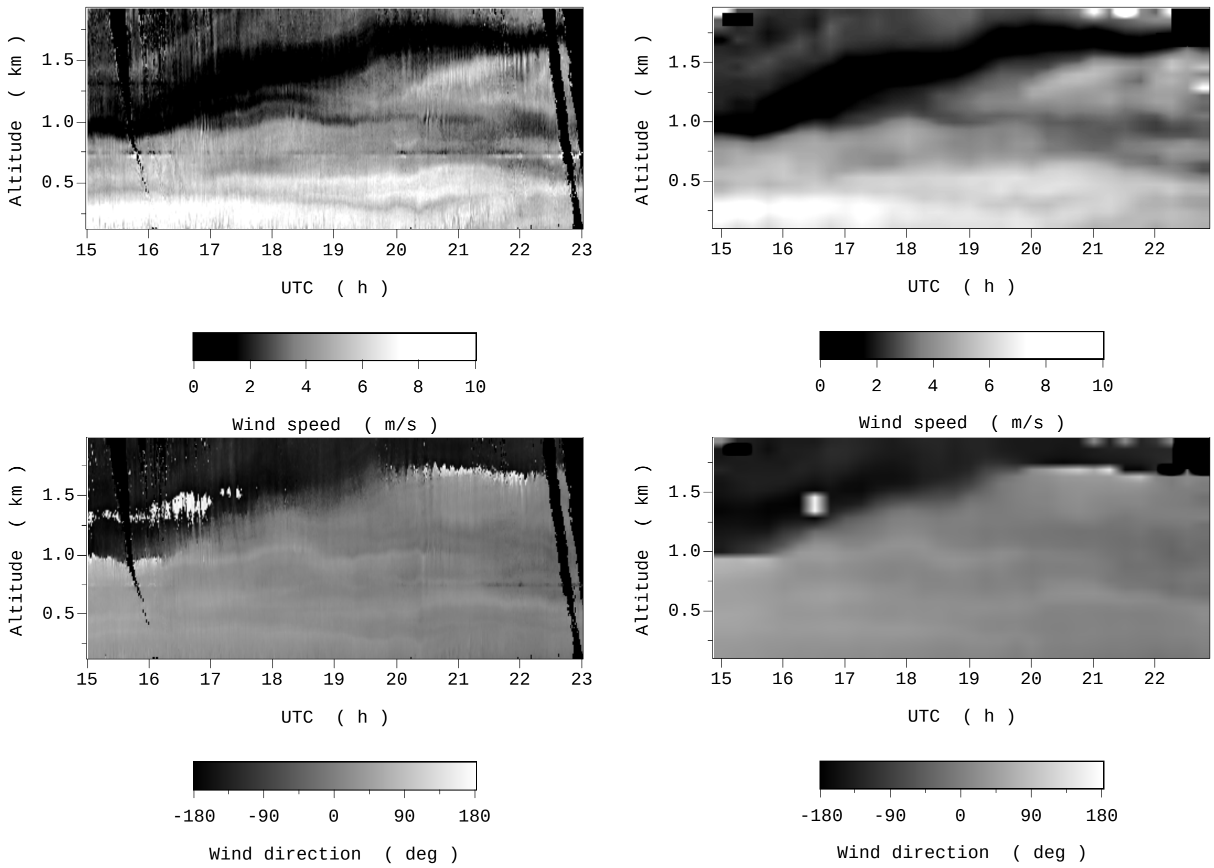

Figure 4: Wind speed measured during snowfall on the 27th of December 2000. Top panels wind speed; bottom panels wind direction, left panels TARA; right panels wind profiler.

with a 15 *min* time resolution and a 100 *m* spatial resolution. TARA was processed with an 8 *s* time resolution and a 15 *m* spatial resolution. The measurement clearly shows the similarity of the two systems. It also shows that in this for TARA favorable situation, the high time and spatial resolution will allow for process studies of the wind velocity. It should be remembered, however, that at an altitude of 1 *km* the separations between the scattering volumes for the three beams is already 500 *m*. At a velocity of 3 *m/s* it takes 166 *s* to travel this distance. So variations on timescales shorter than two minutes should be treated carefully.

5. CONCLUSIONS

First results of high temporal resolution wind measurements with the S-band profiler TARA are presented. Compared to wind profiler data generally good agreement was found. In case of turbulence scattering, differences are found but the trend in the vertical profile is the same. In case of particle scattering, the similarity between the two systems is not limited to trends alone but also to numerical values.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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