DEVELOPMENT OF THE BROADBAND RADAR NETWORK WITH HIGH RESOLUTION

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Abstract

A small-baseline weather radar network consisting of the Ku-band broadband radars (BBR) for meteorological application has been developed. The BBR is a remarkably high-resolution close-range Doppler radar designed for detecting and analyzing rapidly evolving weather phenomena such as severe thunderstorms, tornadoes, and downbursts, which often cause damage to our lives seriously. A radar network with several BBRs (the BBR network) observes multi-directionally and simultaneously these severe phenomena with high resolution in space and time, and with high accuracy. In this presentation, the concept of the project and the initial observation results of the BBR network are presented.

Introduction

Lightning producing thunderstorm is one of the most damaging meteorological phenomena to our lives and understanding thunderstorm both from electrical and dynamical aspects is one of the

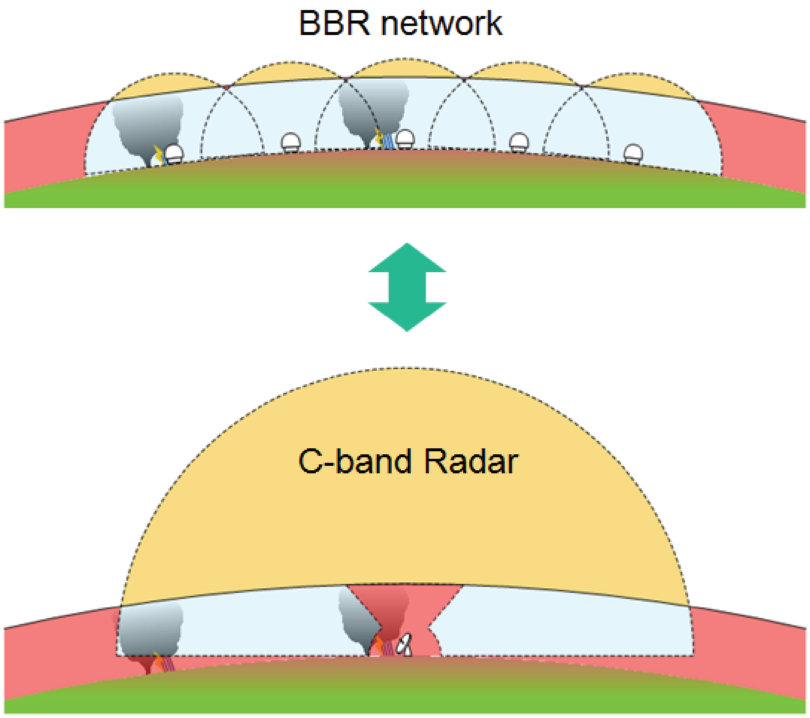

Fig. 1. The basic principle of BBR network

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major scientific goals in meteorology and atmospheric electricity. With the use of C-band or S-band radar system with large antenna, dynamical structure of thunderstorm can be obtained remotely over a wide range. Despite of the tremendous capability of such a wide range big radar system, it still perform poorly to explicitly observe and analyze the rapidly and locally evolving severe thunderstorm producing tornado, microburst and so on, because the radar beam overshoots at far range due to the earth's curvature and the antenna beam also broadens with increasing distance from the radar. In order to overcome these problems, a Broad Band Radar (BBR) Project was firstly granted by the Ministry of Internal Affairs and Telecommunication, Japan to develop a fast scanning and short range radar network with high spatial resolution for observing rapidly evolving thunderstorms.

A small-baseline weather radar network is a novel strategy to detect rapidly growing weather phenomena such as severe thunderstorms, tornadoes, and downbursts. A weather radar network consisting of Ku-band broad-band radars (BBR), which we have been proposing and developing, can provide good coverage in terms of accuracy and resolution to a large area through a network of radars as illustrated in Fig. 1. Each radar node can observe precipitation profiles from 50 m to 15 km with the high range resolution of several meters in 55 seconds per volume of scan, which finely resolves tornadoes, downbursts, and so on. Low-power transmission and low-cost design are suitable for a radar of precipitation radar network system. In this paper, the first radar of the BBR network with volume-scanning capability is presented. The descriptions of the new BBR about the basic concept, configuration, and signal-processing procedure are presented. After the volume-scanning (spiral) observation results of a thunderstorm are shown as initial observation results to present the availability of the high-resolution observation for precipitation by the BBR, a result on the network observation is described to demonstrate operations of the BBR network through the analysis of a precipitation system that moved through the test bed area last year.

The Ku-band BBR Network

The BBR transmits and receives wide-band (80 MHz (max)) signals at Ku-band (a center frequency of 15.75 GHz) to use pulse compression, which gives us high resolution and signal-to-noise ratio (SNR) for distributed scatterers (e.g., precip-itation particles). High SNR achieved by pulse compression reduces to integrate coherent or incoherent pulses, and allows us to scan over the whole sky (a volume scan with 30 elevations) within a short time of 1 minute roughly. A use of a bistatic antenna system to reduce a direct coupling level (-70 dB) and not to turn a receiver off during its transmission enables the BBR to observe from a very close range of 50 m. In order to compensate strong precipitation attenuation at Ku-band, the BBR is designed as a close-range radar to a maximum range of 15 km for precipitation with a reflectivity factor above 20 dBZ with a low transmission power of 10 W. These basic concepts miniaturized the BBR to be installed easily. The photograph of the BBR is shown in Figures 2. More details of the BBR have been presented in Yoshikawa et al. [2010]. These capabilities of the BBR are appropriate to observe small-scale phenomena particularly enough.

Two BBRs have already been deployed in Osaka, Japan. One is installed on the top of a building in Toyonaka campus, Osaka University, Osaka, Japan (This radar is called "Toyonaka radar", hereafter). Another one is installed on a building in Osaka works of Sumitomo Electric Industries, Ltd., Osaka, Japan (This is called "SEI radar", hereafter). The baseline interval of these radars is about 14.32 km, and the area covered by both BBRs is about 294.18 km^2 in a surface of the ground, which is calculated in a maximum range of the BBR of 15 km. When observing up to 20 km with a modified observation mode (instead of the maximum range, sensitivity gets worse.), the overlapped area increases to 696.32 km^2. Now the SEI radar has many obstacles closely around, and the view of the SEI radar is limited as shown in the initial observation results. Therefore, in the near future, the SEI radar will be moved to a site having less obstacles. In addition, one more BBR will be deployed in Nagisa sewage plant. We consider the three BBR network, which will cover north Osaka area as Figure 3, is a test bed of the BBR network for both the evaluation and operation.

An Early Data Case

The initial observation results of reflectivity factor in an altitude of 1000 m in any one minute during five minute observation (from 13:54 to 13:59 on Sep. 14, 2010) are shown in Figure 4. The Toyonaka radar (Panels (a-1) through (a-5)) could not detect some north-east directions due to a closely equipped lightning rod. Since the SEI radar (Panels (b-1) through (b-5)) was interfered by many obstacles around, the received data indicated that the inputs of the ADC are saturated in most directions for south and two directions in north-east. Additionally, the SEI radar received more coupling noises also due to the obstacles. Precipitation attenuation was not corrected since it is considered that the affection is small in this case. In spite of these blockage, the two BBRs detected the same pattern of precipitation in the overlapped area with the high resolution, and the data integration of the BBR network provided impressive results. Panels (c-1) through (c-5) show the integrated reflectivity Ze_{INT} of both radars plotted on every 20 m planar grid in the overlapped area. In these panels, the precipitation patterns (especially, the pattern of zonal ranges around 5 km and meridional ranges from -10 to -2 km) were realistically clarified. The blind area of the SEI radar by the saturation (a zonal range of 9 km and a meridional range of -6 km, roughly) were retrieved by the Toyonaka radar (due to the data rejection processing). Noisy areas of the SEI radar were also restored by the Toyonaka radar with high SNR. Thus, in the BBR network, one BBR supports in an area not observed well by another BBR. Furthermore, the data integration is easily and accurately performed in the BBR network since the observation delay between the BBRs are within 1 min. For example, in the case of 4 min delay, we must integrate Panels (a-1) and (b-5) in which their shapes, positions, and magnitudes of precipitation do not clearly agree. When they are merged without any assumption and with a simple method, the shapes are stretched wider and heavy-rain cells are blinded. Therefore, the BBR network provides high-quality images by complimenting each other BBR, and these initial results suggest the availabilities to detect and analyze small-scale phenomena.

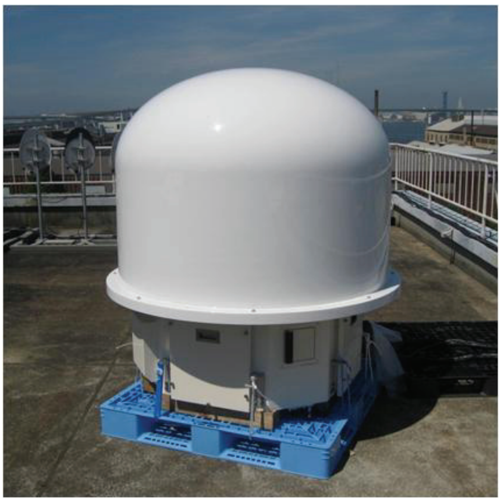

Fig. 2 Photograph of the BBR

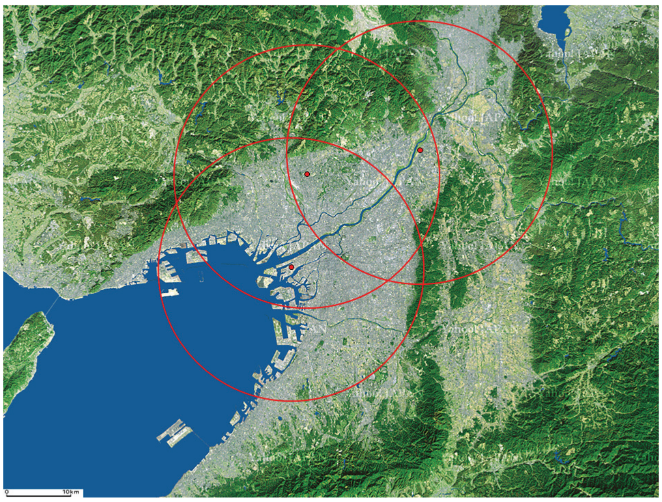

Fig. 3 Deployment of the BBR network

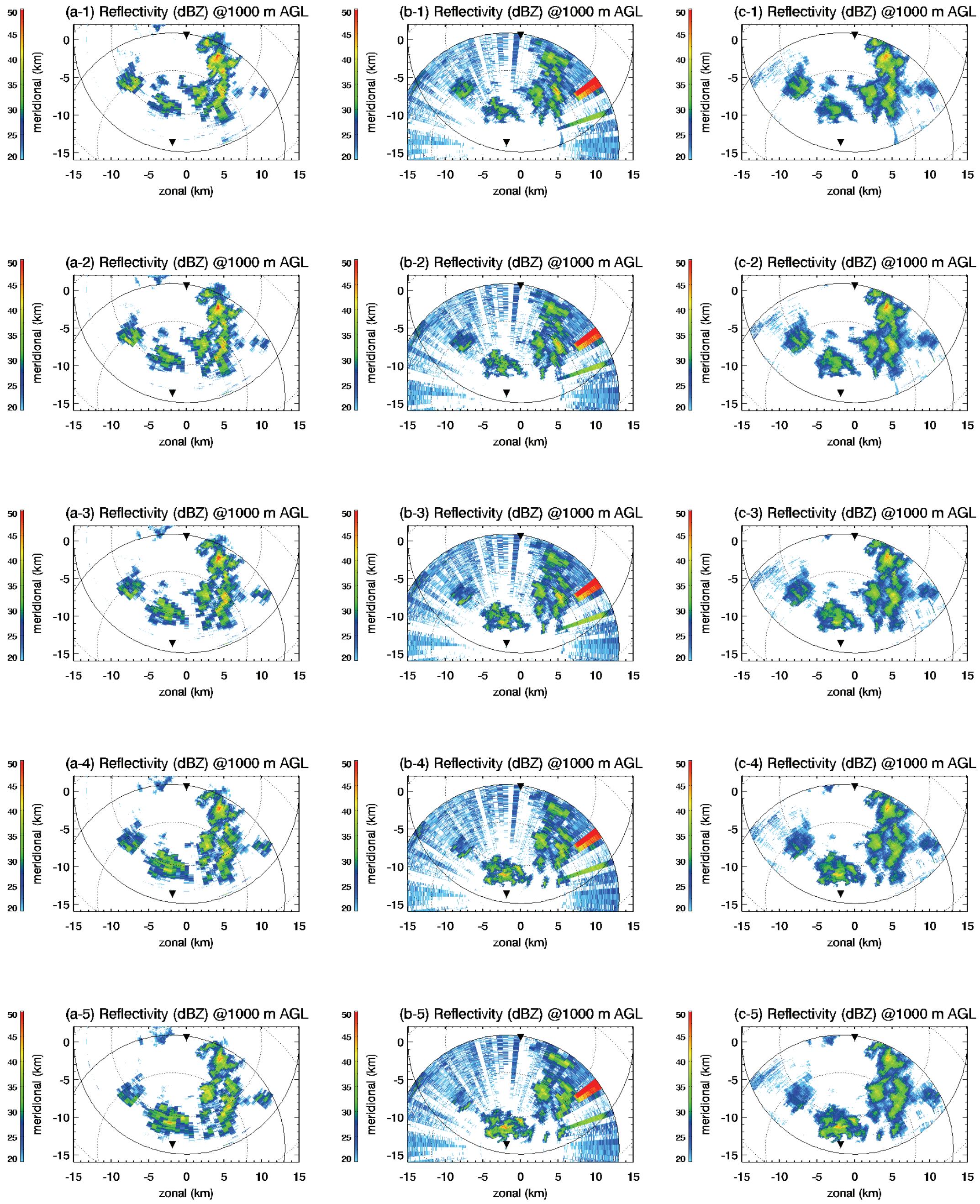

Fig. 4 Examples of the five minutes observation by the BBR network

References

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