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Vertical Motion and Growth of Precipitation Measured by Dual Phased Array Weather Radar Every 30 Seconds

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1. INTRODUCTION

The first X-band phased array weather radar (PAWR) developed in Japan was installed at Osaka University, Suita in May 2012. The one of aims of the PAWR is to observe and predict rapidly-developing localized heavy rainfall. The PAWR is one-dimensional phased-array radar system with an electronic scan in an elevation direction and a mechanical rotation in an azimuth direction. To reduce 3D measurement time, we use fan-beam transmitting and Digital Beam Forming (DBF) receiving using 128 antenna elements. Although it is possible to select several observation sequences, we usually operate a dense 3D observation with about 100 elevation angles from 0 to 90 degree in 30 seconds. The 100 m range resolution data covers over the observation area of 60 km radius (Yoshikawa et al. 2013, Ushio et al. 2015, Ruiz et al. 2015).

The second and third PAWRs were

subsequently installed at NICT advanced ICT Research Institute, Kobe, and NICT Okinawa electromagnetic technology center, Onna in March 2014, respectively. In the common observation area between Suita PAWR and Kobe PAWR, we can get dual-Doppler measurement in a 3D space every 30 seconds. In this study, the vertical motion and growth of a precipitation core in a cumulonimbus cloud are investigated using both 3D radar echo images every 30 seconds and 3D wind vectors derived from dual-Doppler analysis.

2. DATA

The observed 3D data are translated into a Cartesian grid, which size is 125 x 125 x 125 m or 250 x 250 x 250 m, using Cressman scheme. Although we want to use smaller grid data to investigate fine structure of precipitation, we cannot get enough special resolution in far ranges.

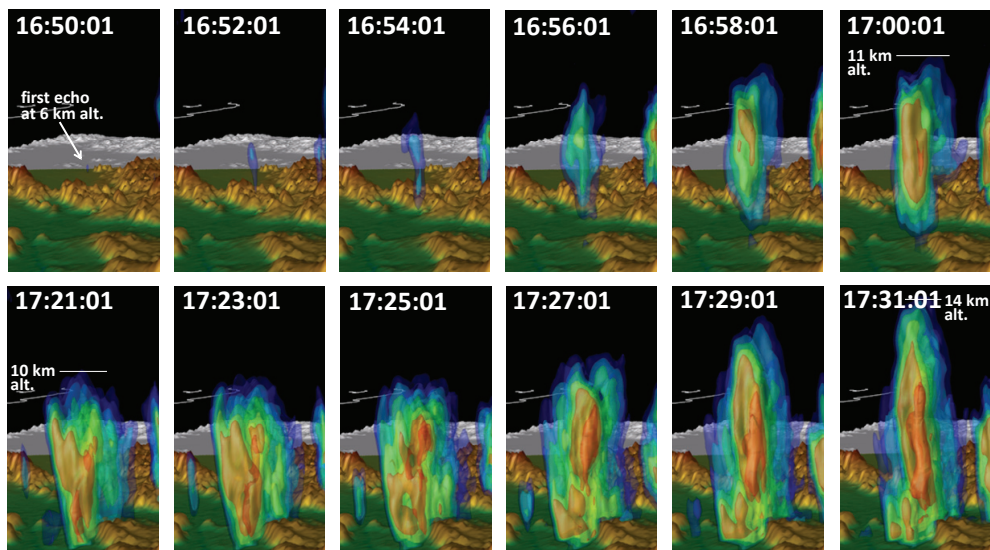


Fig.1. Precipitation growth from a first echo in an isolated cumulonimbus observed in 07 August 2015.

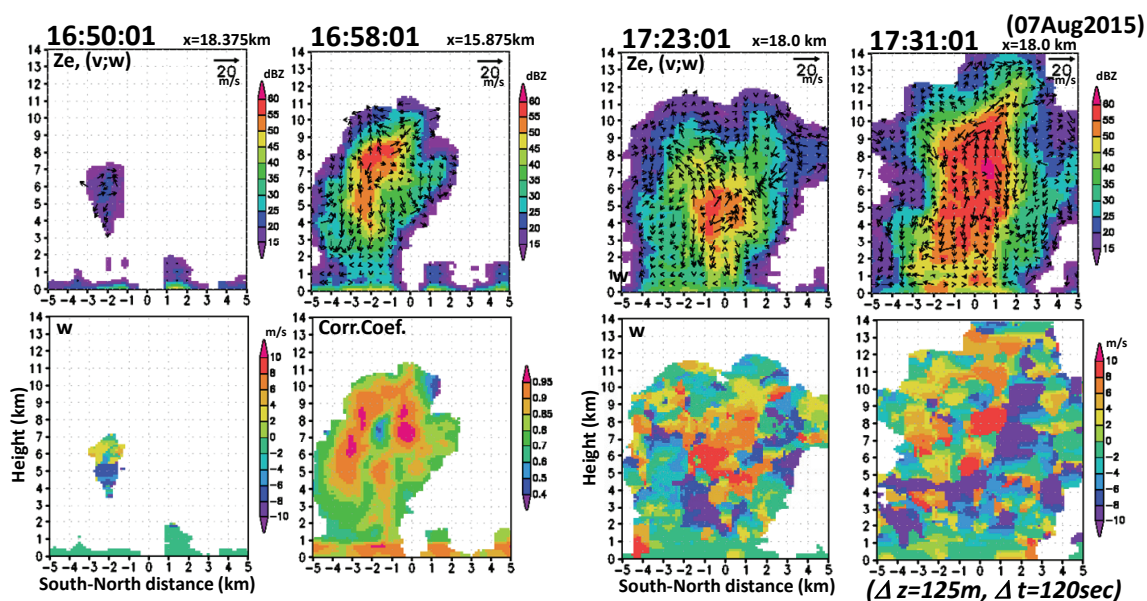


Fig.2. Vertical cross sections of reflectivity and the 3D motion vectors calculated by 3D-TREC (upper panels). The distribution of vertical component of the motion vectors in the same slices (lower panels except second). The distribution of correlation coefficient of 3D-TREC (second lower panel).

3. THREE-DIMENSIONAL TRACKING RADAR ECHOES BY CORRELATION

Figure 1 shows the 3D visualization of radar reflectivity observed in 07 August 2015 every 2 minutes even though the original data were recorded every 30 seconds. We found that a first echo appears at the height of 6 km, and it develops and spreads vertically in a narrow isolated cumulonimbus cloud. The echo reaches to the top of the height of 11 km in 10 minutes after the appearance (17:00JST). After the developed echo was decaying (17:21JST), some small convections appear in the echo top region. And one of the convections develops rapidly at 17:29JST. To evaluate the motion of the precipitation core quantitatively, we apply a 3D-TREC (Tracking Radar Echoes by Correlation) algorithm, which is modified from the original proposed by Rinehart and Garvey, 1978. Although COTREC (Continuity TREC) by Li et al.1995 is popular for now-casting, we have not used it because the continuity equation is not satisfied in the 3D motion vectors of precipitation. Table 1 shows the relationship between the resolution of the motion vector and grid size. Since we want to have the resolution of the motion vector is about 1 m/s, the grid size of 125 m and 120 sec time-difference data are used in

grid size	30sec	60sec	120sec (2 min)	240sec (4 min)
62.5 m	2.1 m/s	1.05 m/s	0.52 m/s	0.26 m/s
125 m	4.2 m/s	2.1 m/s	1.05 m/s	0.52 m/s
250 m	8.3 m/s	4.2 m/s	2.1 m/s	1.05 m/s

Table.1. Resolution of the motion vector derived from 3D-TREC with a relationship between grid size and time difference.

this study. Although the original every 30 seconds data cannot provide enough precision of the motion vector, it should be useful for speed-up calculation of 3D-TREC. Figure 2 shows the results of 3D-TREC. At the first echo stage (16:50), the upward motion vectors appear in the upper half, while on the other hand the downward motion appear in the lower half. The tendency is the same in the following developing stage, although the distribution of the vertical motion vector gets more complicated. The distribution of the correlation coefficient (16:58) shows that the low correlation in the center of the strong echo. The reason may be influenced from the precipitation growth.

4. DUAL-DOPPLER ANALYSIS

Figure 3 shows the dual-Doppler analysis area, which is a common observation area between Kobe and Suita PAWRs. The analyzed organized precipitation system observed on 11



Fig.3. Observation range of Kobe and Suita PAWRs and dual-Doppler observation area. The colored area over the Osaka-bay shows convective echo measured by dual PAWRs.

September 2014, which size is about 40 x 20 km, is shown in the same figure. Figure 4 shows the 3D wind vectors in both horizontal sections (CAPPI at the height of 4 km) and vertical sections from the dual-Doppler analysis every 30 seconds. In the vertical sections we find general convective circulation with in/out flows. We can get observed 3D wind vectors very high time-resolution (30 seconds) for the first time. However, the distribution of the wind vectors on both horizontal and vertical slices is almost nothing on changing within a short period of 30 seconds. The feature of wind vectors of convective circulation indicates that the

kinematic structure is maintained for at least several minutes.

5. DISCUSSION

Figure 5 shows the comparison between wind vectors from dual-Doppler analysis and motion vectors from 3D-TREC algorithm in the same vertical slices. Although the horizontal vectors look similar to one another, the vertical vectors are very different from each other. In the dual-Doppler analysis, the vertical wind vectors are calculated from horizontal wind divergence using a continuity equation. Consequently, the vertical winds are entirely independent from the vertical motion derived from 3D-TREC algorithm. The vertical motion of a precipitation core is a result from both vertical winds (up/down-draft) and terminal falling velocity of precipitation particles. At the same time, the precipitation core is growing in the convection.

In principle, Doppler velocity reflects the motion of precipitation particles. Because the particles are swept by wind, the particle horizontal motion indicates the horizontal wind velocity. However, looking as if the precipitation is an aggregate system like a cloud, the measured Doppler velocity represents in- and

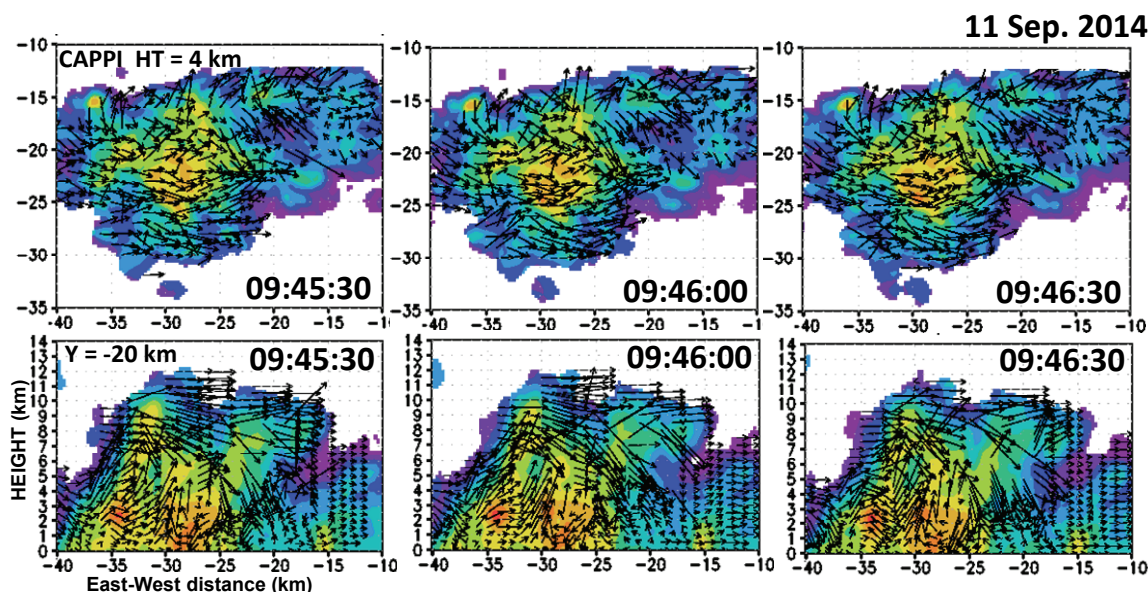


Fig.4. Dual-Doppler analysis every 30 seconds. Horizontal sections of reflectivity and wind vectors (u and v) in the height of 4 km (upper panels), Vertical sections of reflectivity and wind vectors (u and w) at Y= -20 km (lower panels) calculated by dual-Doppler analysis on 11 September 2014.

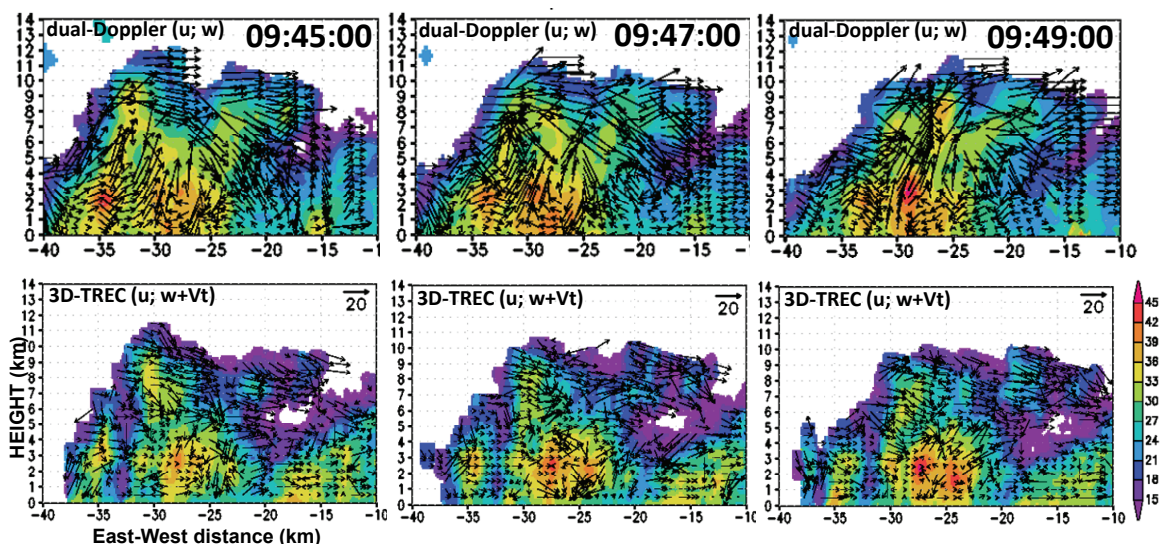


Fig.5. Comparison between wind vectors from dual-Doppler analysis (upper panels) and motion vectors from 3D-TREC algorithm (lower panels) in the same vertical slices every 2 minutes.

out-flow from the system and convergence and divergence. Although the explanation of the vertical motion and growth is complicated, the every 30 seconds 3D measurement has an advantage in investigating the precipitation development.

6. SUMMARY

The phased array weather radar (PAWR) measures precipitation development from the first echo appearance with high spatial-temporal resolution (100 m, 100 EL angles, 30 seconds). The 3D-TREC algorithm reveals the vertical motion and growth of precipitation. Every 30 seconds data will be useful to speed-up calculation of 3D-TREC. The dual-Doppler analysis shows that wind vectors in the convective circulation every 30 seconds. The distribution of the wind vectors are maintained for at least several minutes. Precipitation is basically growing in the updraft region, although the vertical motion calculated by 3D-TREC is different from the dual-Doppler vertical wind.

Acknowledgments

The PAWR data are archived in the NICT Science Cloud and made available to public through <http://pawr.nict.go.jp/>. This study was supported by CREST, JST.

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