3D Wind Field Estimation with Higher Spatial Resolution Using Multi Compact X-Band Weather Radars

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1.Introduction

Wind shear in a localized region usually causes serious damage on transport systems. Real-time observation of wind field with dual polarimetric Doppler weather radars gives us the most effective solution for preventing the damage caused by wind. Fig 1 shows weather map of Japan on April 4, 2016. Cold front came from west and severe weather hit Osaka-Bay area. Around the Osaka-Bay area, three Doppler radars have been deployed and observed rain distribution at ※6:00 a.m. is shown in Fig 2. Three radars are installed at KOBE (Kobe University), KIU (Kobe International University), and INT (FURUNO INT center). A case study for estimation of 3D wind field using the triple-Doppler analysis is presented here.

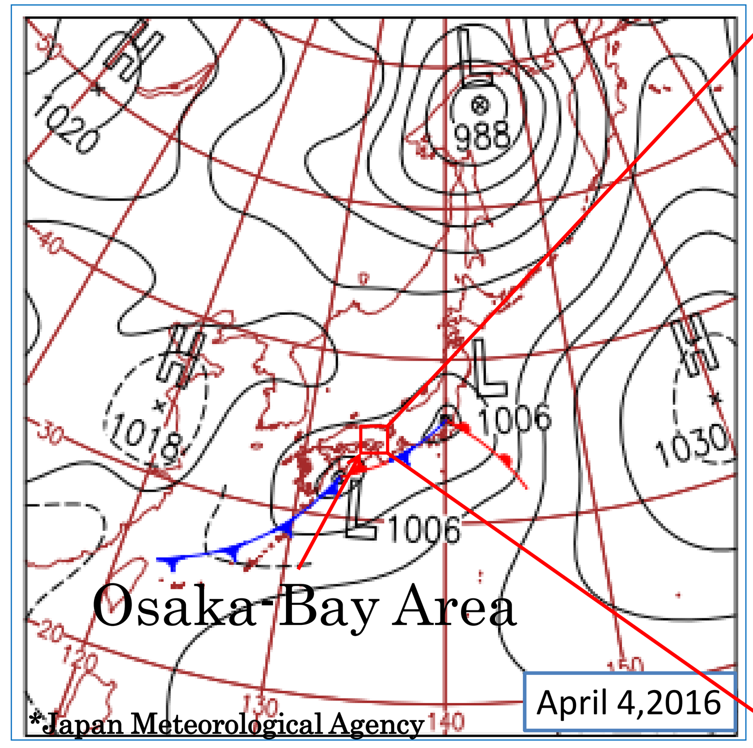

Fig 1 : Weather Map

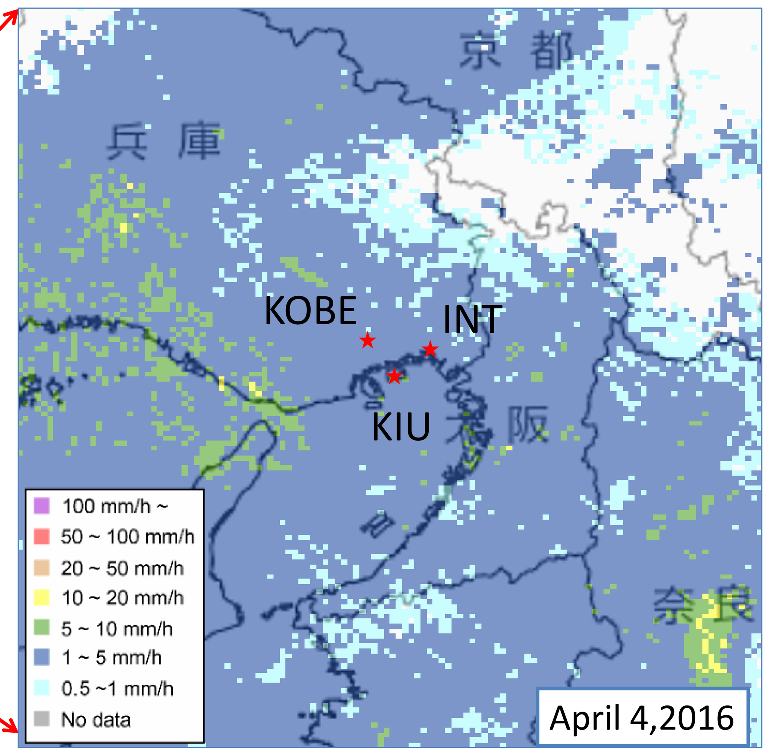

Fig 2 : Rain Distribution

*Used the map of The Geospatial Information Authority of Japan Digital Japan Portal Web Site.

※Local time

2.Triple-Doppler Analysis

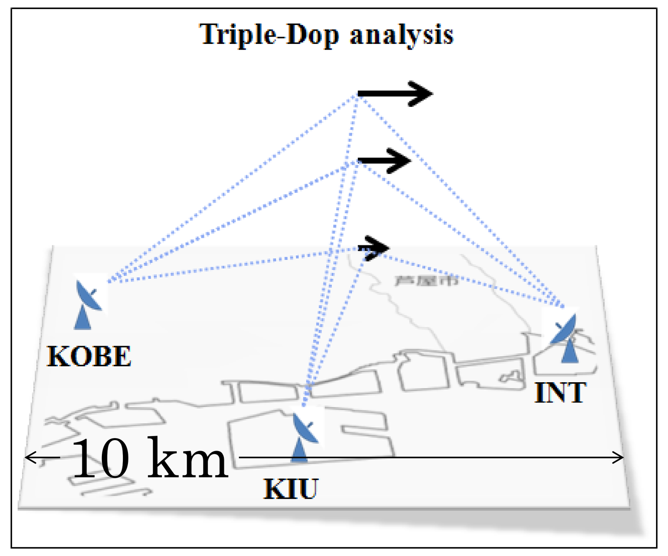

Fig 3: Triple-Doppler analysis

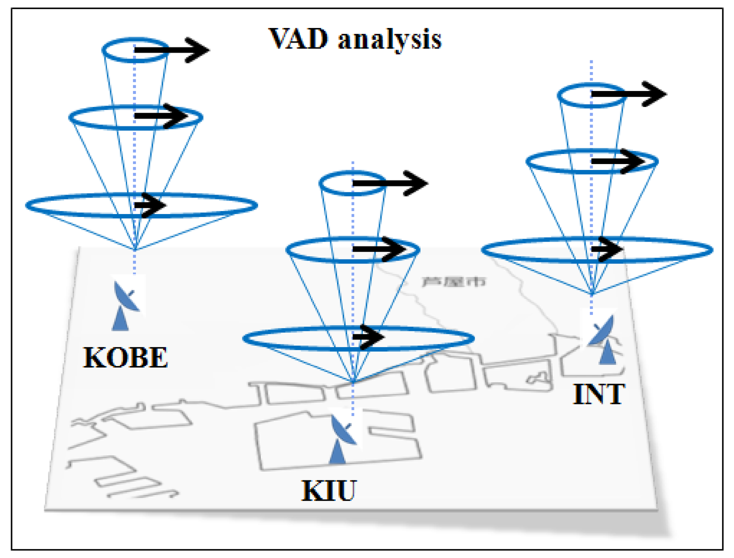

Fig 4: VAD analysis

Observation Time
April 4, 2016 6:00-7:00 every 2 min
Data Grid Size
100 m
Scanning elevation
7,14,22,29,37,44 51,58,64,69,75,90 deg
Antenna rotation
7 rpm
Pulse
Short pulse 1μsec Long pulse 50μsec

Table 1: Radar strategy

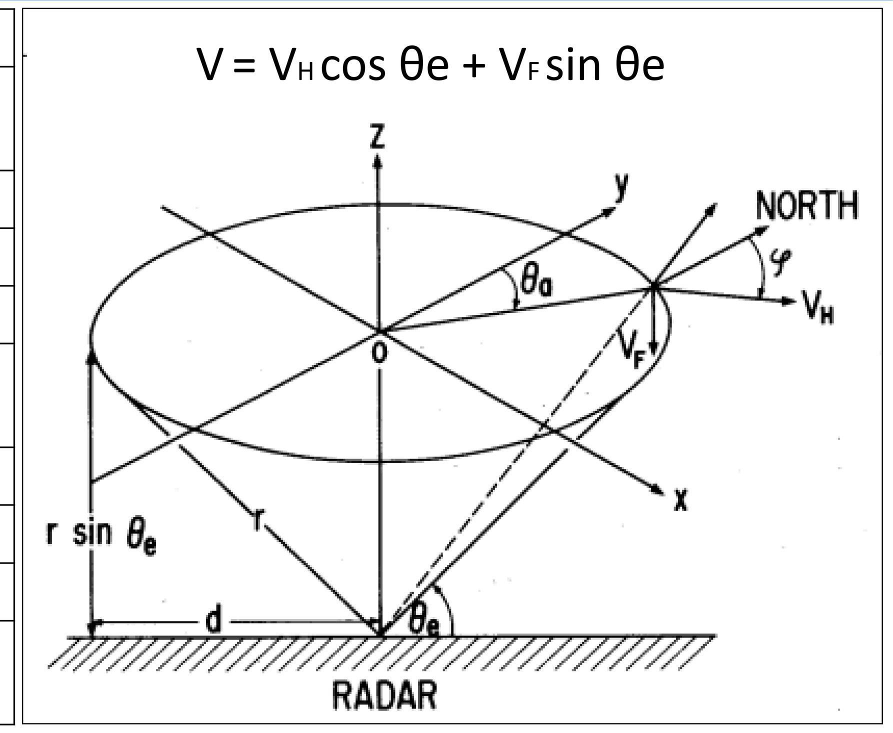

Fig 5: Estimation with VAD

By deploying the three radars within 10 km range, 3D wind field is directly estimated by the triple-Doppler analysis as shown in Fig 3. And Fig 4 shows the VAD analysis using each radar. VAD analysis is useful to get reference wind field to compare with triple-Doppler analysis. Fig 5 shows estimation of horizontal wind field. The wind field around the Osaka-Bay is observed in real time using the Multi-Radar System. Radar strategy is presented in Table 1.

3.Comparison of wind speed

Fig 6 shows a comparison of wind speed between triple-Doppler analysis and VAD analysis. X-axis indicates horizontal wind speed and y-axis indicates altitude. Black line shows MSM (Meso-Scale Model) data released from the Meteorological Agency. This result shows that VAD analysis and triple-Doppler analysis are precise and reliable among three radars. In addition there is not so much difference from MSM. RMSE is 0.9 m/s and correlation coefficient is 0.95. Although VAD method can only analyze average wind field with liner approximation, triple-Doppler method can directly analyze 3D distribution of wind field.

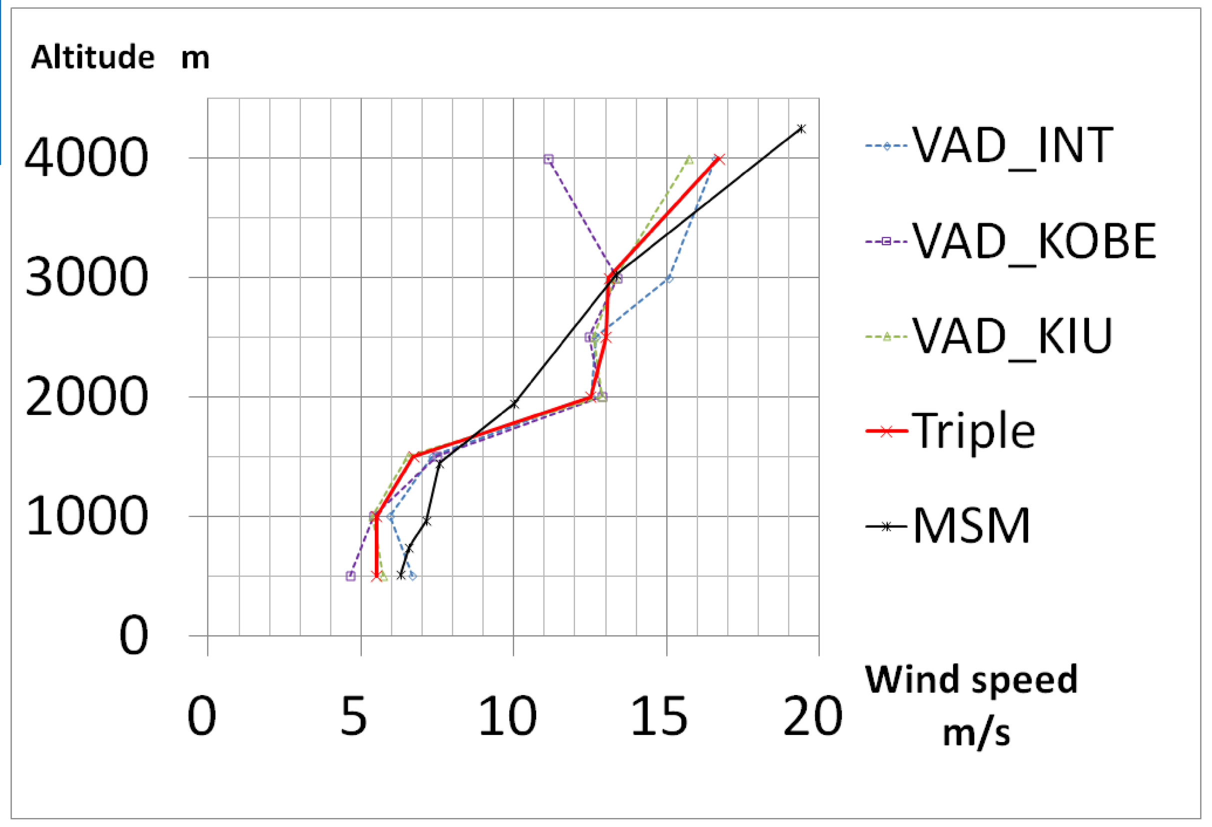

Fig 6: Comparison of Wind speed between triple and VAD

RMSE: 0.9 m/s Triple vs. VAD in 60 min average
Correlation coefficient: $R^2 = 0.95$

4.Comparison of wind direction

Fig 7 shows a comparison of horizontal wind direction between triple-Doppler analysis and VAD analysis. A typical wind shear is observed in the altitude between 1500 m and 2000 m. In this case, most wind direction is about 250 deg and there is not so much difference at each altitude because rain type is stratiform. The same trend can be seen in MSM. The result shows good correlation. RMSE is 7.2 deg and correlation coefficient is 0.70. The value of correlation coefficient is low because the change in the wind direction is small. But there is practically no problem.

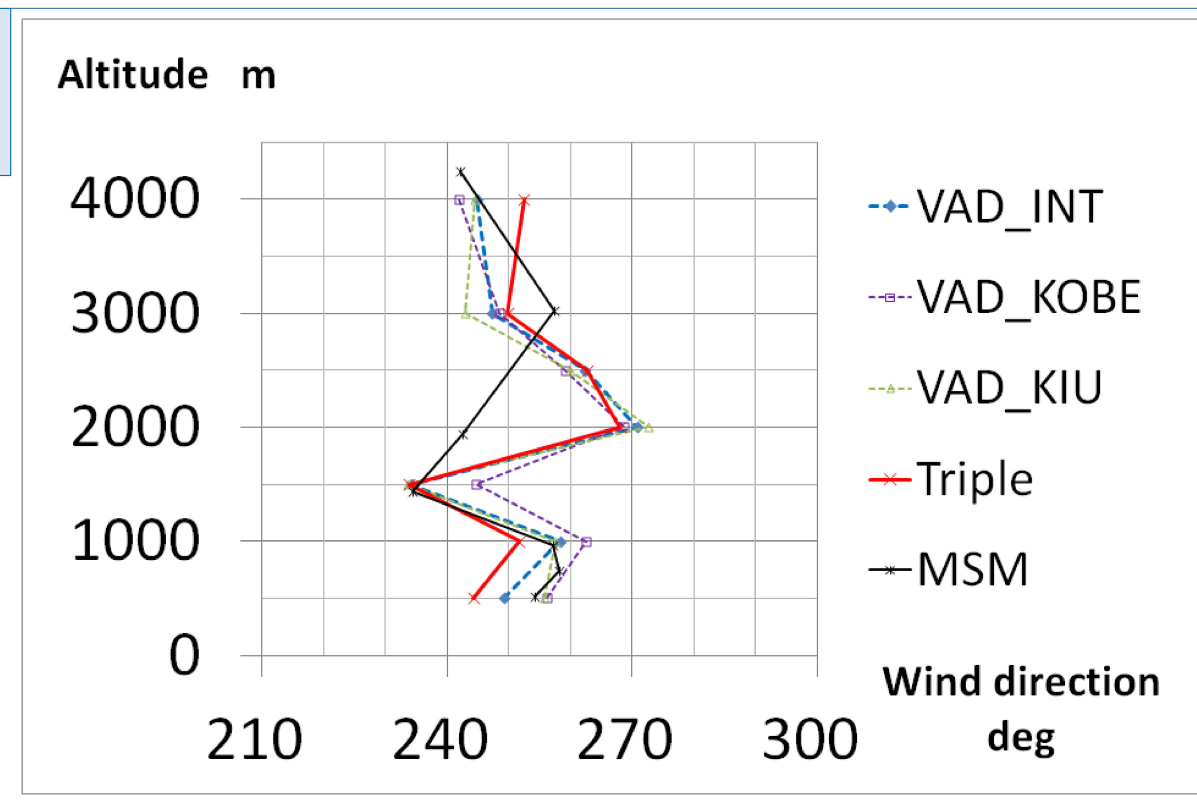

Fig 7: Comparison of wind direction between triple and VAD

RMSE: 7.2 deg Triple vs. VAD in 60 min average
Correlation coefficient: $R^2 = 0.70$

5.Comparison of vertical raindrop speed

Fig 8 shows a comparison of vertical raindrop speed between triple-Doppler analysis and VAD analysis. As in Fig 6 and Fig 7, the result shows good agreement in horizontal wind field. In the altitude lower than 2500 m the vertical speed is fast due to liquid particle. On the other hand, in the altitude higher than 3000 m the vertical speed is slow due to ice particle. The altitude between 2500m and 3000m is the melting layer and the speed is changing drastically. This result shows that it is possible to observe 3D wind field by triple-Doppler method. Moreover melting layer is observed with high resolution, and helps improve the accuracy of hydrometeor classification (Fig 9).

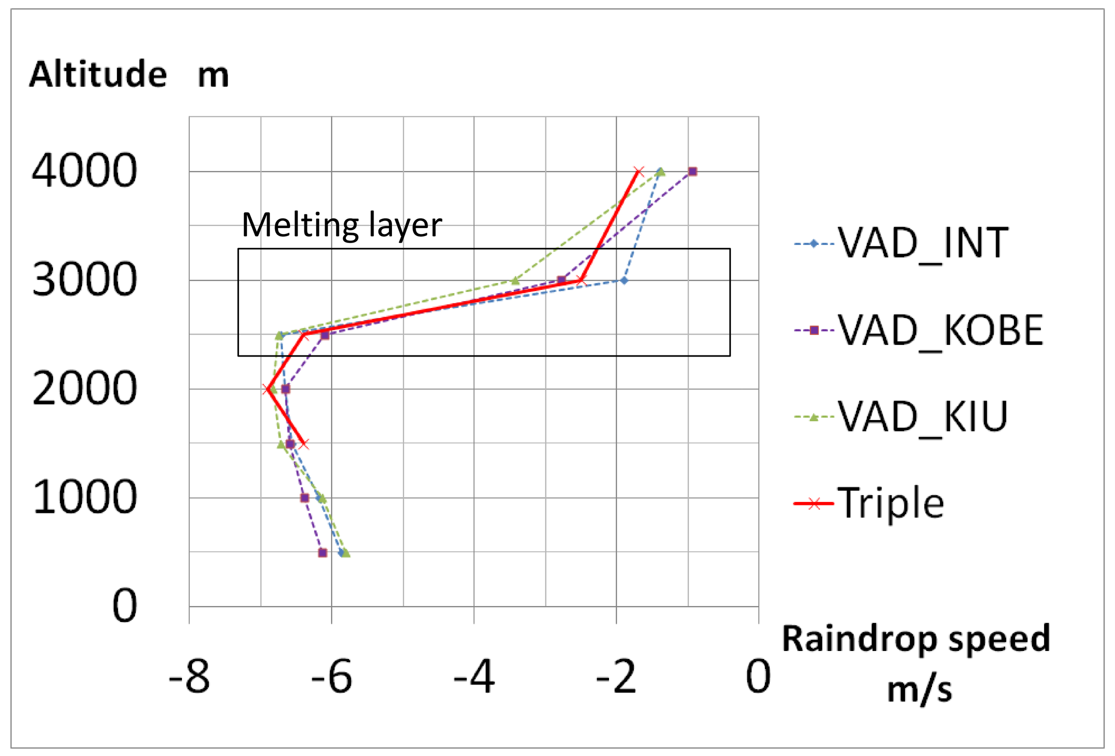

Fig 8: Comparison of vertical raindrop speed between triple and VAD

RMSE: 0.5 m/s Triple vs. VAD in 60 min average
Correlation coefficient: $R^2 = 0.98$

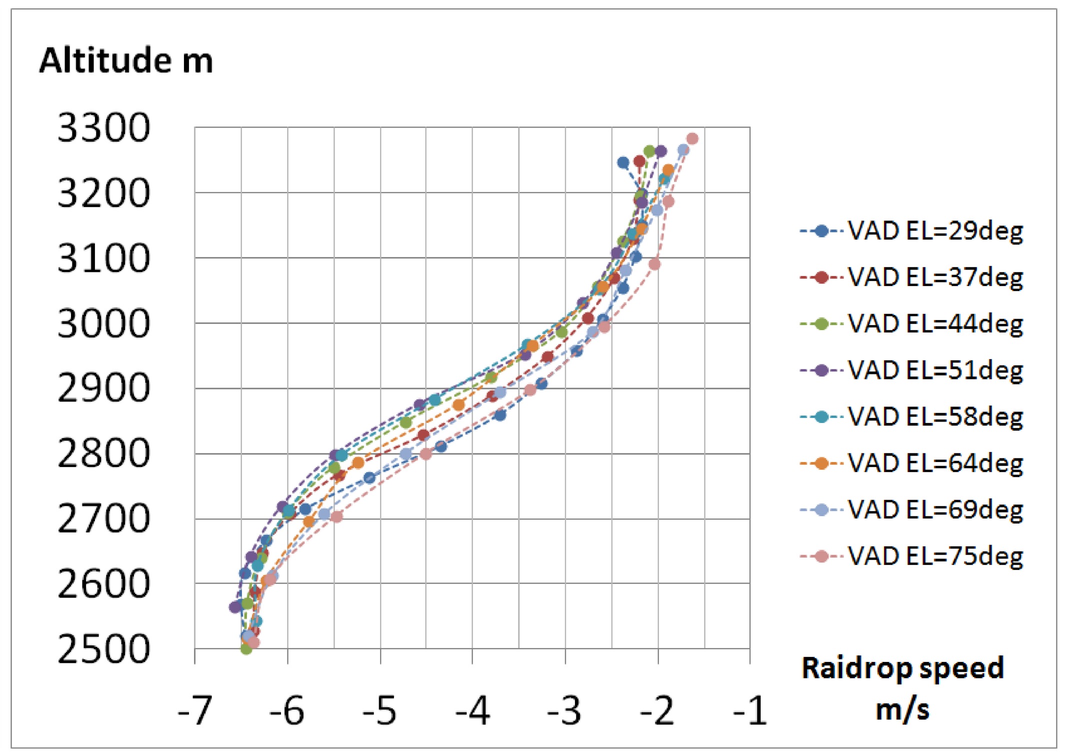

Fig 9: Detail of melting layer in Fig8

Analyzed by VAD method in 29-75deg at 6:00

6.Conclusions

The Multi-Radar System has been developed and deployed around the Osaka-Bay area. By deploying the three radars within 10 km range, 3D wind field is directly estimated by the triple-Doppler analysis.

The interesting case study on April 4, 2016 is presented. The estimated 3D wind field is good correlation between triple-Doppler analysis and VAD analysis. This result is reliable because there is not so much difference from the MSM model. Triple-Doppler analysis has a great advantage to observe 3D wind field accurately.

Especially melting layer is observed by VAD method with high resolution, and it helps improve the accuracy of hydrometeor classification.