D202

Analysis of Kinematics and Dynamics Mechanisms during Cell Merging in Multicell Thunderstorms using X-band Polarimetric Radar Observations

〇Fauziana AHMAD, Kosei YAMAGUCHI, Eiichi NAKAKITA

1. Introduction

The majority of thunderstorm vorticity research is based on observations of quasi-stationary convection, supercells, and tornadoes in mid-latitude regions. This study investigated the approaches that might be used to quantify the typical trends of vorticity throughout the cell merging process, which is relevant for cloud mechanism studies. Cell merging analysis can be used to detect potential opportunities for increased precipitation during cloud seeding and to accurately quantify the severity of multicell thunderstorms [1].

A vertical vorticity threshold of $>0.03\mathrm{s}^{-1}$ was constructed and a vorticity pair was found in the baby rain cells using pseudo-vorticity analysis to find baby rain cells in Guerilla heavy rainfall episodes [2]. A signature pattern of cell merging between new cells and multicell was observed, revealing an increase in the strength of new cells' core vorticity following the merger. The influence of kinematic mechanisms such as updraft and divergence resulted in the persistence of core vorticity intensity in the multicell [3].

Thus, vorticity is a significant feature in investigating cloud dynamics and may be used to investigate multicell growth. As a result, the goals of this study are to investigate the kinematics and dynamics mechanisms that occur during cell merging between new cells and multicell that are associated to vorticity intensification.

2. Data and Methodology

The multicell storms was observed in the Kinki region, Japan for nearly 2-hours observation. The radiosonde data from Shionomisaki station showed that the weak vertical shear occurred during the event that appropriated for the multicell formation and not affected by Baiu front or tropical cyclone. The X-band dual polarization radar namely Tanokuchi and Katsuragi stations were deployed in the Dual-Doppler analysis provides radar reflectivity (Z_h) and three-dimensional winds with the spatial resolution 1 km x 1 km x 0.25 km.

$$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} \qquad (1)$$

The equation (1) is used for the extraction of vorticity distribution that were interpolated into a Cartesian coordinate system Constant Altitude Plan Position indicator (CAPPI). In the development of vertical vorticity within an updraft, the local change of vertical vorticity could be expressed as shown in equation (2)

$$\frac{d\zeta}{dt} = \xi\frac{\partial w}{\partial x} + \eta\frac{\partial w}{\partial y} + \zeta\frac{\partial w}{\partial z} \quad (2)$$

where (ξ, η, ζ) is the three-dimensional relative vorticity vector, and we have neglected the Coriolis force and baroclinic generation of vertical vorticity, which did not contribute to $d\zeta/dt$ in a major way [4]. The first and second terms of the right-hand side of equation (2) is referred as tilting of horizontal vorticity meanwhile the third term is indicated the stretching of the vortex tube which used in the dynamics analysis.

$$\text{Divergence} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \qquad (3)$$

The convergence is also the vital component that influenced the increment of core vorticity with the stretched vortex tube as referred to in equation (3).

3. Results and Discussion

The study showed seven new cells were generated in the range of 20 km from the core of the storm, which was defined in the alphabetical order of A, B, C, and etc. In the analysis, all the new cells merged with the storm except cell C, which was partially merged with the multicell. New cell B, which developed close to the storm, showed the highest intensity of core vorticity at the early stage of multicell formation. Therefore, the kinematic mechanisms such as updraft and convergence were investigated with the additional influence of the dynamics mechanisms that might affect the intensity of core vorticity.

The vertical cross-section throughout new cells C, B and existing cell A in Figure 1 showed the updraft still remained in cell B, which was associated with the developing stage. Meanwhile, the downdraft in cells C and A exhibited the dissipating stage. The updraft and convergence were well-correlated with the vertical vorticity, where the stretching of the vortex tube occurred significantly at the boundary of cell B. Therefore, we could find that the updraft, convergence, and stretching are the factors that enhance the intensity of core vorticity. Meanwhile, tilting showed less effect on the intensity. The quantitative analysis throughout the entire storm, as shown in Figure 2, presented the similarity effects on the increment of core vorticity intensity.

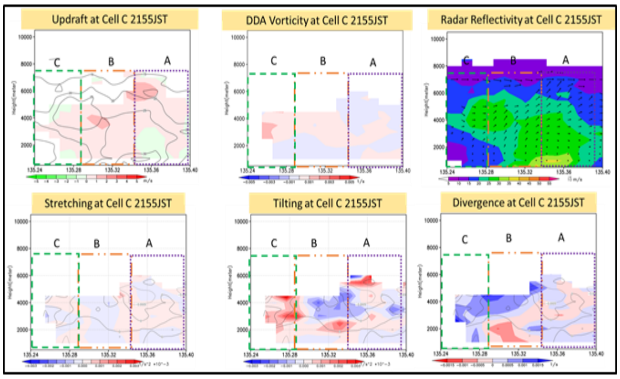

Figure 1. Vertical cross section for the analyses of the updraft, vorticity, and radar reflectivity (top) during the merging of cell C with multicell B and stretching, tilting, and divergence analysis (bottom).

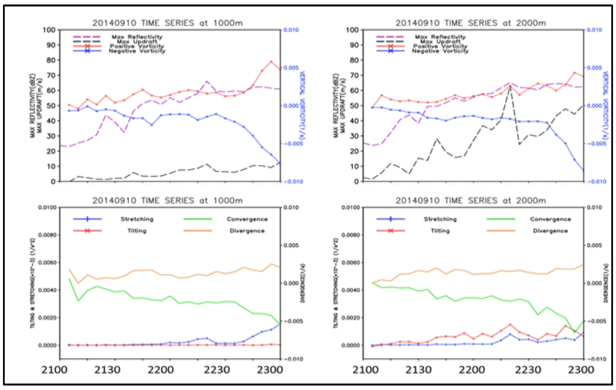

Figure 2. Core vorticity, maximum reflectivity, dynamics (stretching and tilting) and kinematics mechanism (convergence, updraft) during the entire storm at 1 and 2 km.

4. Conclusion

From this study, the three-dimensional wind fields derived from Dual-Doppler analysis are examined to investigate the dynamics and kinematics mechanisms in the merging of new cells to multicell formation related to the vertical vortex tube analysis. The core vorticity intensity mainly increased due to the existence of stretching and convergence at the lower level, and updraft and downdraft that frequently appeared on the preferred flank with condition of weak shear keeps the gust front near the storm updraft.

5. References

[1] Stalker, J. R., and Knupp, K. R., 2003: Cell Merger Potential in Multicell Thunderstorms of Weakly Sheared Environments: Cell Separation Distance versus Planetary Boundary Layer Depth. Mon. Wea. Rev., 131(8), pp. 1678-1695.

[2] Nakakita, E., et al., (2017). Early Identification of Baby-Rain-Cell Aloft in a Severe Storm and Risk Projection for Urban Flash Flood. Advances in Meteorology (Article ID 5962356).

[3] F.Ahmad. et al., (2021). Analysis of Cell Merging from New Cells to Multicell Formation with Dual Doppler and Vorticity Analysis, DPRI Annuals, No.64 B, 2021, pp. 208-216.

[4] Markowski, P. and Richardson Y., 2010: Mesoscale Meteorology in Midlatitudes, John Wiley & Sons, Ltd., ISBN: 978-0-470-74213-6.