Verification by Full Volume Scan Radar Observation of Vertical Rainfall Profile Estimated by an Orographic Rainfall Model Based on the Seeder-Feeder Mechanism

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1. Introduction

Orographic effects such as the seeder-feeder mechanism can be responsible for enhancing localized heavy rainfalls in mountainous regions, thus leading to flash floods and sediment disasters. If those effects are not considered, the precipitation forecast in mountainous regions on the meso-β scale may be limited to until one or two hours ahead.

Therefore, to improve the accuracy of short-term rainfall prediction in mountainous regions, Nakakita et al. [1, 2] proposed a methodology that combines a physically-based model based on the seeder-feeder mechanism to assess the orographic rainfall effect, with application to radar image extrapolation techniques using a translation model. In this study, with the data observed by a C-band radar operating in full volume scan mode, we propose a methodology to utilize the radar Plan Position Indicator (PPI) and investigated the accuracy of the calculated orographically enhanced rain fields with the Constant Altitude Plan Position Indicator (CAPPI) radar's data.

2. Calculation Method of Orographic Rainfall

In this study, we utilize a physically-based method based on the seeder-feeder mechanism proposed by Tatehira [3] for calculating orographic and non-orographic rain fields from observed radar rainfall measurement. The orographic effect is quantified by calculating the flux of cloud water content in a rising air parcel along with the wind, and the radar observed rainfall at the lowest PPI angle (R_{radar}) is interpreted as the summation of orographic rainfall (R_O) and non-orographic rainfall (R_n).

Figure 1 shows the calculation procedure for separating orographic and non-orographic rainfall based on the seeder-feeder mechanism. First, the cloud water content (L) is calculated from atmospheric variables for a total of seven vertical layers. Then, the radar observed rainfall is separated into two parts (R_O and R_n) by simultaneously solving the equations shown in Figure 1. Consequently, to calculate the rainfall in layers above the radar beam height, it is assumed that the previously calculated non-orographic rainfall can be expressed as the sum of the orographic rainfall and non-orographic rainfall of this current upper layer. In this way, each layer's orographic rainfall above the radar beam height can be calculated successively from the previously calculated layer. Meanwhile, to calculate the rainfall in layers below the radar beam height, it is assumed that the observed rainfall corresponds to the non-orographic rainfall for the layer below. Therefore, the orographic rainfall can also be calculated successively until the surface level.

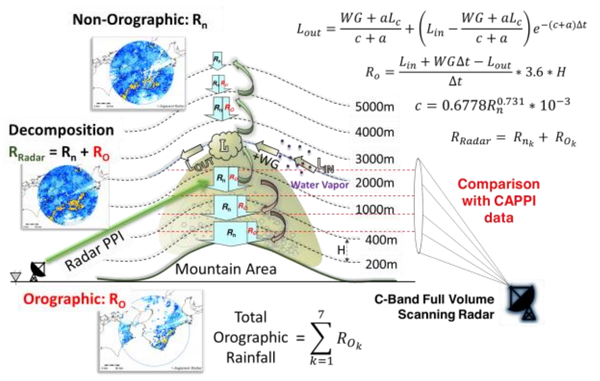

Figure 1. Schematics of the procedure for calculating orographic and non-orographic rainfall.

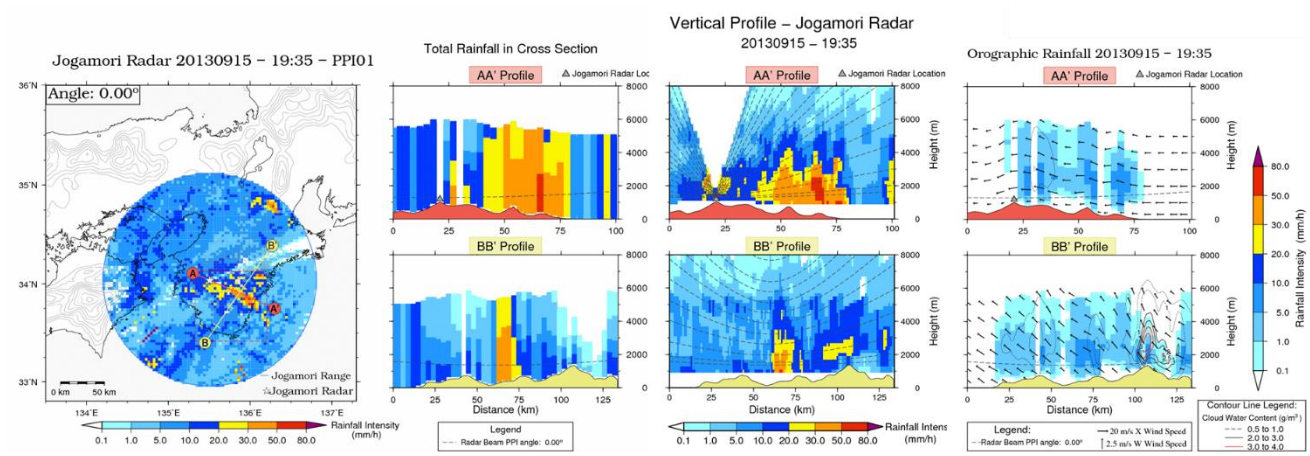

Figure 2. Two-dimensional observed rainfall intensity distribution and respective vertical rainfall profile

3. Results and Discussion

Figure 2 shows the radar rainfall intensity, both the calculated and observed vertical rainfall profile and the calculated orographic rainfall for the Typhoon 1318 at 19:35 JST. It is possible to verify that the calculated and observed vertical rainfall structure is in agreement, significantly below the 3000m height. However, there is a lack of agreement between the observed and calculated rainfall intensity for the most upper layers because the current methodology assumes that all the precipitation particles are in the liquid form of raindrops. Besides, the utilization of the actual radar beam height for estimating the vertical rainfall profile provides the opportunity to calculate the increment of orographically generated rainfall intensity below the radar beam height until the surface (Figure 3). This increment was estimated to be up to 20 mm/h, with a total accumulation for a 12h period of approximately 120mm in the Kii peninsula.

4. Conclusion

The physically-based method based on the seeder-feeder mechanism could adequately represent the orographic enhancement for the analyzed typhoon events. Besides, considering the radar beam height, it was possible to estimate rainfall increment on the surface level due to the orographic effect below the radar beam height. This could useful information for preventing and mitigating disasters driven by orographically enhanced heavy rainfalls where the lowest radar beam height cannot observe high rainfall intensity near the ground, such as the Typhoon 1919 in the Kanto region. For future work, we plan to investigate the utilization of different PPI elevation angles for the separation process and verify possible discrepancies between the estimated vertical profile. We also plan to utilization of ice-phase particles in the computation process to further improve the vertical rainfall profile calculation.

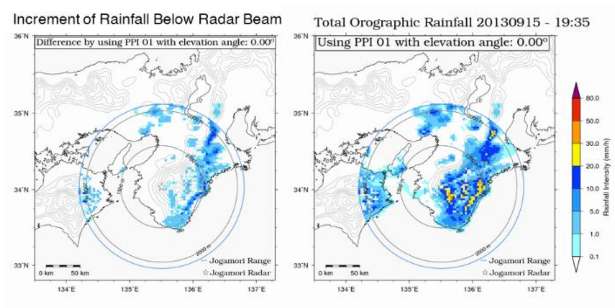

Figure. 3. Increment of rainfall intensity below radar beam and the total orographic rainfall intensity.

References

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3. Tatehira R., 1976. Orographic rainfall computation including cloud-precipitation interaction, Tenki v.23, pp.95-100.