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Wavelet Application for Cloud Initial Stage Development Based on Boundary Layer Radar and Himawari-8

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1. Introduction

For Hydrometeorological disaster prevention, especially related with the localized torrential rainfall known as Guerilla Heavy Rainfall, it is necessary to analyze the early structure (initial stage development) of a cumulonimbus cloud before it is generated into raindrop [1]. One of major force that could trigger the initial stage of cumulonimbus cloud is updraft. This study is intended to analyze the updraft-downdraft coherent structure that located above the boundary layer height correlated with the cloud albedo existence.

Wavelet method are the main method that is used in this study which have two application. First is to define the coherent structure of the updraft-downdraft from the vertical velocity data of BLR. Second, wavelet is applied as a correlation method between the coherent structure with the cloud albedo from Himawari-8 data.

2. Data and Methodology

Continuous Wavelet Transform (CWT) is used to identified the coherent structure based on the vertical velocity data from Boundary Layer Radar (BLR) located in Kobe urban area, Japan. BLR have been applied with both Range Imaging (RIM) and Adaptive Clutter Suppression (ACS) technique to improve height resolution and quality of the observation data. Paul mother wavelet are applied in CWT with scale and time step resolution are 28 scale and 2.5 minutes respectively. In order to determine the boundary layer height, every peak of certain period of BLR echo power are then calculate using median [2].

Second application is to find the correlation between the coherent structure in each level of height with the existence of the cloud albedo. Himawari-8 with 0.64 μm spectrum (band 03) are used as an indicator of cloud albedo above the BLR location. This is because this wavelength gave a large reflectance and small absorption value for clouds object compared to land [3].

Wavelet Transform Coherency (WTC) method is used in order to analyze the connection between two process (in this term is the coherent structure and cloud albedo) based on the time intervals and frequency occurrence [4]. The target scale in this study is microscale-localized phenomena with time scale limited from 5 am until 4 pm JST in summer season due to solar activity for generating convection. Two case study in 13 August 2018 and 17 August 2019 are presented in this paper. The dataset is also have been separated from large heavy precipitation phenomena such as Typhoon.

3. Result and Discussion

First application of the wavelet method is the detection of the coherent structure from BLR vertical velocity data in every 100 meters of level, start from 300 meter until 3400 meters of height. The coherent structure identification then compared with the boundary layer height to observe the maximum coherent structure elevation.

Figure 1 is the example of case study in August 13, 2018. Fig 1a is the BLR vertical velocity with updraft downdraft activity represented by the positive and negative value. Fig 1b is the example of vertical velocity value in single elevation (i.e 1 km) with a moving average filter. Meanwhile Fig 1c is the CWT power spectrum based on Fig 1b. The CWT power spectrum can distinguish the updraft-downdraft coherent structure (marked by black solid line), the duration and time when it starts.

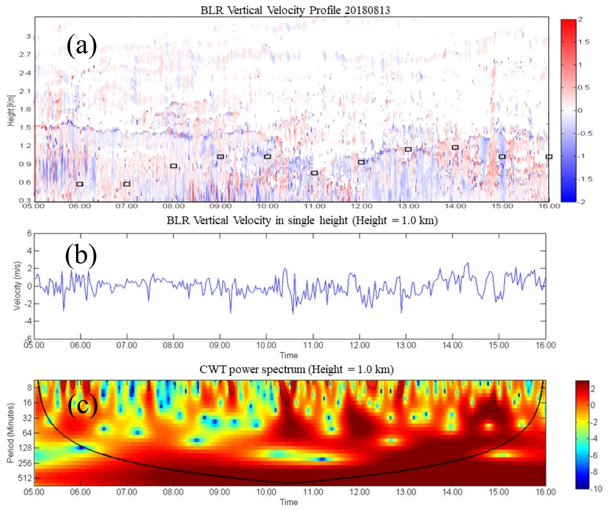
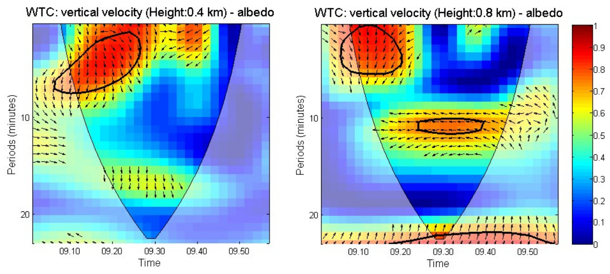


Figure 1. Case study 13 August 2018, (a). Vertical velocity profile with boundary layer height estimation (square box), (b). Vertical velocity in 1.0 km height, (c). WCT power spectrum.

Based on the coherent structure identification from CWT result and the boundary layer height, the author then classified the vertical velocity and cloud albedo data with certain period. For case study August 13, 2018 the period is 6-7 am, 9-10 am, 11am-12 pm. Meanwhile from case study August 17, 2019 the period is 8-9 am, 9-10 am, 11am-12 pm, 13-14 pm.

The classified dataset of vertical velocity and cloud albedo then applied using WTC. Colored data represent the correlation level (high = 1, low = 0). Black line area represented the 95% of confidence level. Arrow represent the phase correlation with four classification based on the arrow direction, Right arrow (in phase), left arrow (anti phase),Down arrow (vertical velocity leading cloud albedo by 90^0 or 2.5 minutes), Up arrow (cloud albedo leading vertical velocity by 90^0 or 2.5 minutes). Figure 2 is the example of the WTC result in the period of 9 am until 10 am.



(a) (b)

Figure 2. WTC result, (a) 20180813 for 0.4 km height, (b) 20190817 for 0.8 km height.

4. Conclusion

From two case study showed that coherent structure is not generating new convective cloud, but intensify the cloud structure (based on the increasing cloud albedo) that passing by. High correlation exists in certain height of coherent structure and cloud albedo. High correlation in the lower level of height with down arrow of phase coherency showed that updraft – downdraft coherent structure exists before the initial stage of cloud generation. Further analysis is needed to find out if the updraft-downdraft coherent structure that exist close to or penetrate the boundary layer height has potential for detection the cloud stage.

References

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