DETECTION OF RAPIDLY DEVELOPING CUMULUS AREAS FROM MTSAT-1R SHORT-TIME-INTERVAL IMAGES

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I. INTRODUCTION

MSC/JMA has started Rapid Scan (RS) observation which covers the limited near-Japan area and has 5-minute interval, using MTSAT-1R since June 2011. We are now developing nowcasting product 'Rapidly Developing Cumulus Areas' (RDCA) mainly for aviation users to detect severe weather expected to be evolved into thunderstorms. RDCA is produced from RS images.

In this presentation, we summarize RDCA algorithm, describe several examples of thunderstorms and RDCA products, and analyze their characteristics.

II. RDCA BASIC ALGORITHM

For detection of developing trend, we use parameters listed in TABLE I, using visible and infrared bands. We referred to the EUMETSAT's Convective Initiation product, and a part of interest fields is adopted for RDCA.

First, clear regions which have high 10.8μm brightness temperature (TB) are excluded. Thin cirrus regions which have high difference between 10.8μm and 12μm TB are also excluded. Second, candidate areas which have potential to develop are extracted, using visible reflectance and difference between 6.8μm and 10.8μm TB. After these proceedings, we detect signals of development. When vertically developing cumulus exists, roughness appears in cloud optical depth and cloud top temperature. To detect this characteristic, difference between maximum (or minimum) and average of visible reflectance and 10.8μm TB in target area, standard deviations of them are used. Time-trend parameters calculated from successive two RS images are used to detect a rapid development. For consideration of cumulus movement in 5 minutes, motion cancellation process which is based on retrieval of Atmospheric Motion Vectors using RS images is applied (Shimoji 2010). Slope index based on the relation between cloud effective radius retrieved by 3.8μm and temperature (10.8μm) at the top of cloud is also used to estimate a rapid development (Rosenfeld and Lensky, 1998). It is expected to become larger if strong upwelling flow exists in cumulus (Okabe et al., 2011).

We consider 9 conditions using these parameters in RDCA current version. Thresholds are determined for each parameter by comparison to thunderstrokes observed by

Test#	Parameters
1	Visible reflectance
2	Difference of visible reflectance between maximum and mean
3	Standard deviation of visible reflectance
4	Difference of 10.8μm TB minimun and mean
5	Standard deviation of 10.8μm TB
6	Difference of 10.8μm and 12.0μm TB
7	Difference of 6.8μm and 10.8μm TB
8	Slope index
9	Time trend of visible reflectance maximum
10	Time trend of visible reflectance mean
11	Time trend of 10.8μm TB minimum
12	Time trend of 10.8μm TB mean
13	Pinpoint falldown of 10.8μm TB

TABLE I. Parameters used in RDCA algorithm

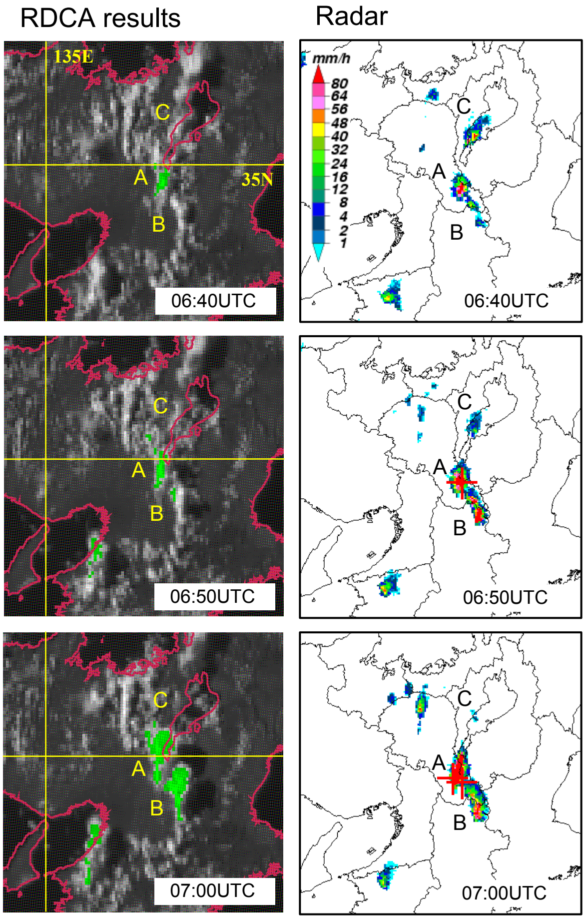

FIG. I Example of RDCA images and radar (11 July 2011). Areas detected by RDCA are marked green on visible image. Red crosses on radar charts mean thunderstrokes.

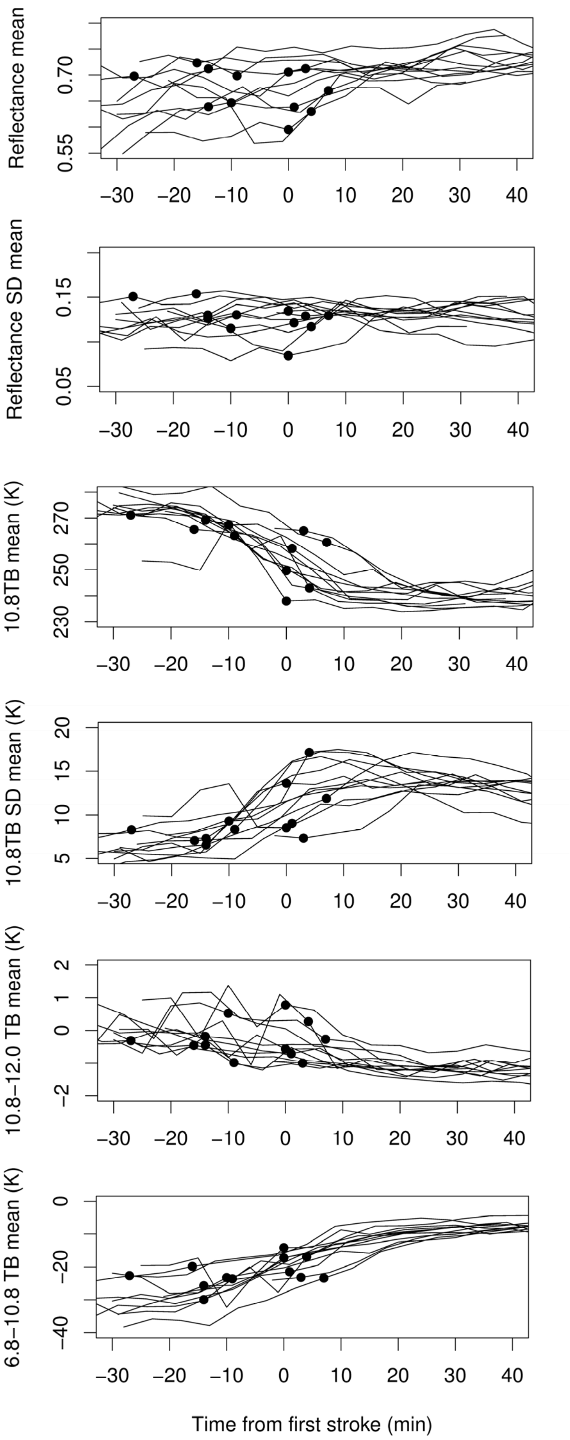

FIG. II Time sequence of some parameters for isolated developing cumulus (12 samples of 9 to 12 July 2011). Filled circles mean the first detected time by RDCA for each sample.

ground detection system. Here, 'thunderstroke' (or 'stroke') means only cloud to ground lightning. Areas which satisfied more than 7 conditions are detected as rapidly developing areas in RDCA current version.

III. RDCA RESULTS

FIG. I shows a RDCA detection of developing cumulus with thunderstrokes which occurred in the middle of Japan on 11 July 2011, green on RDCA results shows detected areas. Corresponding rain radar charts are also shown in FIG.I. In this example, cell 'A' and 'B' developed in short time. 'A' was detected by RDCA about 10 minutes before first stroke occurred. 'B' was detected almost at the same time intense echo appeared in radar. RDCA didn't detect cell 'C' that was already in decay stage.

FIG. II shows the time sequence of some parameters based on 12 samples of 9 to 12 July 2011 which had a lot of isolated cumuli or cumulonimbi with thunderstorms occurred around Japan. All samples used here were in land. The origin of abscissa means the time of first stroke of each sample occurred. Time sequence of 10.8μm TB has clear trend, 10.8μm TB started decreasing and standard deviation of TB started increasing about 10 minutes before first stroke. There was a slight peak on 10.8μm TB standard deviation after first stroke. In difference of infrared bands, 10.8μm minus 12μm TB decreased and 6.8μm minus 10.8μm TB increased before and after first stroke. When first stroke occurred, mean 10.8μm TB of most samples were 250K to 260K, and 6.8μm minus 10.8μm TB was approximately -20K. There are some differences in characteristics of each parameter including visible band, and they depend on the stages of cumulus lifecycle. We should investigate more samples in detail.

Scores of RDCA current version are calculated from data of 9 to 12 July 2011. In four days total, Probability of Detection (POD) was 0.54, Threat Score (TS) was 0.16, and False Alarm Rate (FAR) was 0.81. One of the reason FAR was large is due to our validation in which only cloud to ground lightning was used.

IV. DISCCUSSION

We could not have a plenty of time before first stroke occurred. Shown in FIG. II, averaged 10.8μm TB was lower than 270K when developeing trend was detected by RDCA, avearged leadtime was less than 10 minutes. Therefore, improvement of detection for high temperature cloud (lower cumulus) is most important for early detection.

Fig. III shows an example of sensitivity check of parameter compared to thunderstrokes, only for high 10.8μm TB region (273.15K to 288.15K) and non-time-trend parameters (Parameter-1 to 7 listed in TABLE I). In calculation of probabilities, we treated samples which captured strokes within 60 minutes from initial as 'hit'.

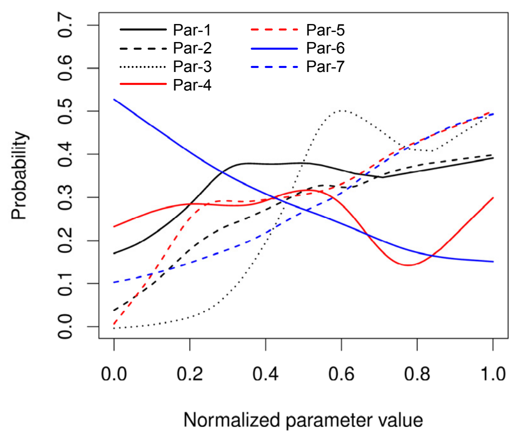

FIG. III A relation between parameter values and probabilities of thnderstroke using data of 11 July 2011 (03:00UTC to 07:55UTC).

Abscissa values are normalized by maximum and minimum of each parameter. In this example, probability of thunderstroke varied with changes of parameter value. This characteristic suggest parameters used in RDCA are effective for early detection of developing lower cumulus expected to be evolved into thunderstorms if we improve methodology to treat these parameters.

V. CONCLUSION AND FUTURE PLAN

We could detect many developing cumuli which rose under instable environment mainly occurred in summer afternoon. Some parameters used in RDCA had interesting characteristics for developing or mature stages of cumulus, as described in FIG. II and FIG. III. We should investigate characteristics of them in several cases which depend on areas, time, and pressure patterns, based on both empirical and theoretical methods.

The number of satisfied condition is used for final detection in RDCA current version, as described in chapter II. However, we will be able to estimate probability of rapidly development if the characteristics of parameters are adequately used. Update of methodology of treating parameters is considered as a key to improve the accuracy of early detection.

VI. REFERENCES

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