Authors response-point by point

Answers to the comments of NHESS-2018-357-SC1-supplement

We thank to reviewer of SC1-supplement for his/her thoughtful comments and clear suggestions. He/she not only indicated the crucial points in our research but also suggested the way how to improve them. Thanks to the comments, the manuscript has been revised as follows.

- L15, page 3. How did you convert and smooth data by the time dimension? Is it the average of four 2 km pixels and 30 min?

“Rephrased”

P 4 line 7-20

To perform this study, we created virtual data whose resolution was similar to those of MTSAT 1R/2 (Table 2). Specifically, four pixels of 2 km were converted into one pixel of 4 km, and the time interval was increased from 10 minutes to 30 minutes. In other words, it was calculated as the average of four 2-km pixels in the process of observing clouds every 30 minutes. The number of detected cloudy pixels by resolution is illustrated in Figure 2. A tropical thunderstorm was found to be located in the area of 12 km. The dark grey pixels indicate the ones detected, whereas clouds and the light grey pixels indicate clear-sky pixels. Using the 4-km resolution imagery only 2 cloudy pixels were detected in the middle area with the 4- km resolution imagery; in contrast, 18 cloudy pixels can be detected with the 2-km resolution imagery. It is noteworthy that the high-resolution imagery was able to detect cloudy pixels located at a curved boundary. However, the low-resolution imagery tended to simplify the change rate of minimum BT11, and the detection of cloudy pixels at a curved boundary was somewhat hard (Walker et al., 2012). Hereafter, the virtual MTSAT is called the low-resolution (4 km and 30 minutes) imagery and the Himawari-8 is called the high-resolution (2 km and 10 minutes) imagery so as to facilitate the intuitive understanding of the spatiotemporal resolution difference. Our final study aim was to quantitatively establish the high-resolution imagery low-resolution imagery and compare their effectiveness in the advanced predictability of tropical thunderstorms.

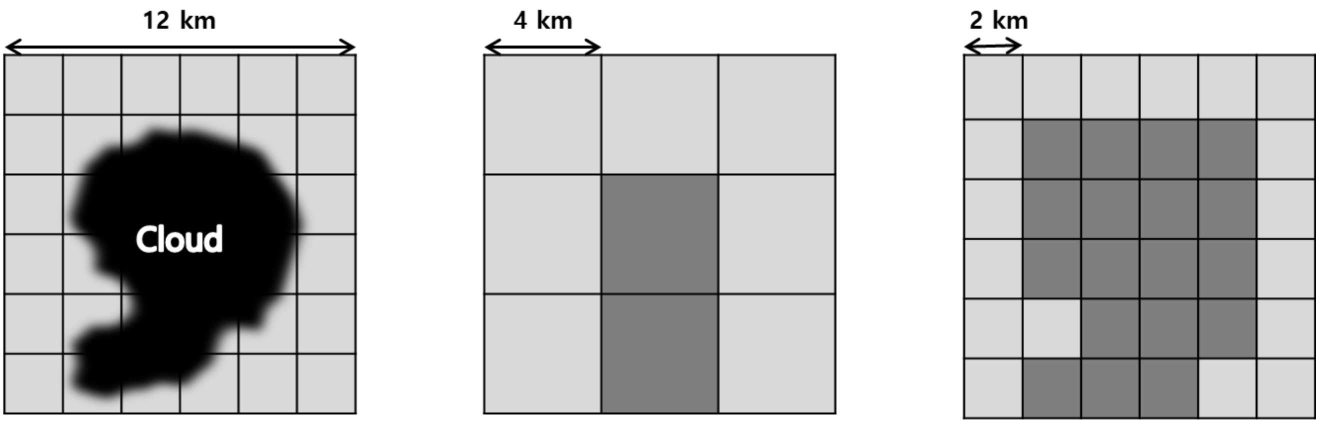


Figure 2. Illustrations of 12 × 12-km pixels with different resolutions. The dark grey indicates the cloudy pixel, and the light grey indicates the clear-sky pixel. Only 2 cloudy pixels can be detected with the 4-km resolution imagery; in contrast, 18 cloudy pixels can be detected with the 2-km resolution imagery. The number of pixels at the cloud boundary varies depending on the resolution (Walker et al., 2012).

- L26, page 3. Why did you convert brightness temperature to integer?

"We simply call the brightness temperature at 10.45 into BT11 for readability." Among the 16 existing bands, the brightness temperature at 10.45 μm (BT11) was used for monitoring the vertical growth of clouds.

Answers to the comments of NHESS-2018-357-RC1-supplement

We thank to the reviewer of RC1-supplement for his/her productive comments and thoughtful guide. He/she not only indicated the crucial points in our research but also suggested the way how to improve them. Thanks to the comments, the manuscript has been revised as follows.

Major overarching issues:

- The number of events (clouds) considered in this manuscript should be increased. To validate the efficacy of this approach, images from other months and from both day and night should be considered. The authors' comment about considering daytime only because "the floating population is most active during the daytime" is misinformed. During darkness, many people will be asleep and the lack of direct sunlight may impair the ability of the population to respond to the given hazard effectively. An improvement of lead time during darkness would be a significant contribution to the body of research. As such, it is recommended that both day and night are considered in this analysis.

"This is a very helpful comment. Only eight clouds are a small number to show enough conclusions. We selected clouds that occurred during the day and night in July and August 2017. We added a total of 60 cloud cases, 30 per month. Specifically, Table 1 shows information about cloud data. It's a good idea to add 2018 data. However, we didn't have enough time to get the 2018 data. Instead, we used data for two months in 2017 which are July and August, when tropical clouds were frequently observed each year."

P 10

Table 1. The number of selected convective clouds during observation time.

Month	Observation time	Sample number
July 2017	03:00-06:50 UTC (daytime) 21:00-24:50 UTC (nighttime)	20 10
August 2017	03:00-06:50 UTC (daytime) 21:00-24:50 UTC (nighttime)	20 10

Specific comments:

- P1 L10: suggest using the term ‘significant damage’ instead of ‘heavy damage’.

“Tropical thunderstorms cause significant damage to property and lives, and a strong research interest exists in and efforts have been focused on the advance and improvement of the thunderstorm predictability by s atellite observations.”

- P1 L27: change ‘lost’ to ‘loss’.

“These severe events cause extensive economic losses, environmental degradation, and subsequent damage to human life.”

- P2 L3: what about storm surge and coastal inundation?

“Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal the significant vulnerability and exposure of some ecosystems and many human systems to the current climate variability (Pachauri and Meyer, 2014).”

- P2 L11: what do you mean by “grounded”? Do you mean ground-truthed?

“Removed”

- P3 L5: suggest changing “growing” to “developing”.

“Changed”

- P3 L6: why is only August considered? This needs to be clarified. The review recommends considering other months in this analysis.

- P6 L2: This study is validated using a small number of clouds, over a small range, during daylight hours. This needs to be clarified in this sentence.

“We added a total of 60 cloud cases. Table 3 includes the result of updated analysis”

P 10

Table 3. The lead time according to imagery for cloud No. 1-20 occurred in the daytime of July 2017, No. 21-30 in the nighttime of July 2017, No. 31-50 in the daytime of August 2017, and No. 51-60 in the nighttime of August 2017.

No.	Cloud-scale (km)	Lead time (minutes)		Lead time difference (minutes) (A minus B)
		2 km and 10 min imagery (A)	4 km and 30 min imagery (B)	
1	120	180	60	120
2	104	160	30	130
3	120	140	30	110
4	120	180	30	150
5	120	180	60	120
6	40	130	30	100
7	40	140	0	140
8	44	120	0	120
9	64	120	30	90

10	40	180	60	120
11	40	130	0	130
12	48	90	0	90
13	96	180	60	120
14	104	120	0	120
15	120	140	30	110
16	80	180	60	120
17	56	100	0	100
18	80	180	30	150
19	96	180	0	180
20	56	100	0	100
21	40	160	0	160
22	72	150	30	120
23	120	140	30	110
24	96	120	30	90
25	84	130	0	130
26	100	180	60	120
27	60	100	0	100
28	100	130	0	130
29	104	120	0	120
30	96	180	60	120
31	100	120	30	90
32	32	100	0	100
33	48	120	30	90
34	100	180	30	150
35	112	180	60	120
36	64	120	30	90
37	100	180	60	120
38	96	140	0	140
39	68	120	0	120
40	80	130	30	100
41	44	90	0	90
42	60	100	0	100
43	100	120	0	120
44	96	120	30	90
45	68	100	0	100
46	88	140	30	110
47	108	180	30	150
48	124	180	60	120
49	104	140	0	140
50	100	120	0	120
51	120	130	30	100
52	66	110	0	110
53	80	130	0	130
54	120	180	60	120
55	120	100	0	100
56	40	180	30	150
57	56	180	0	180
58	56	100	0	100
59	88	160	0	160
60	92	180	30	150

- P3 L22: check the date for Schmit et al., reference.

“Correted” (Schmit et al., 2005).

- P3 L29: change “statuses” to “status”

“Changed”

- P4 L15: check the date for Housze reference.

“Correted” (Houze Jr, 2004)

- P4 L18-L19: check grammar.

“grammar check is completed”

- P5 L5: Is “100 min” a typo? Do you mean 10 min?

“10 minutes”

- Fig 2a: Including coordinates and a continent basemap would be useful.

“Figure 1 indicated the region of interest in this study including coordinates”

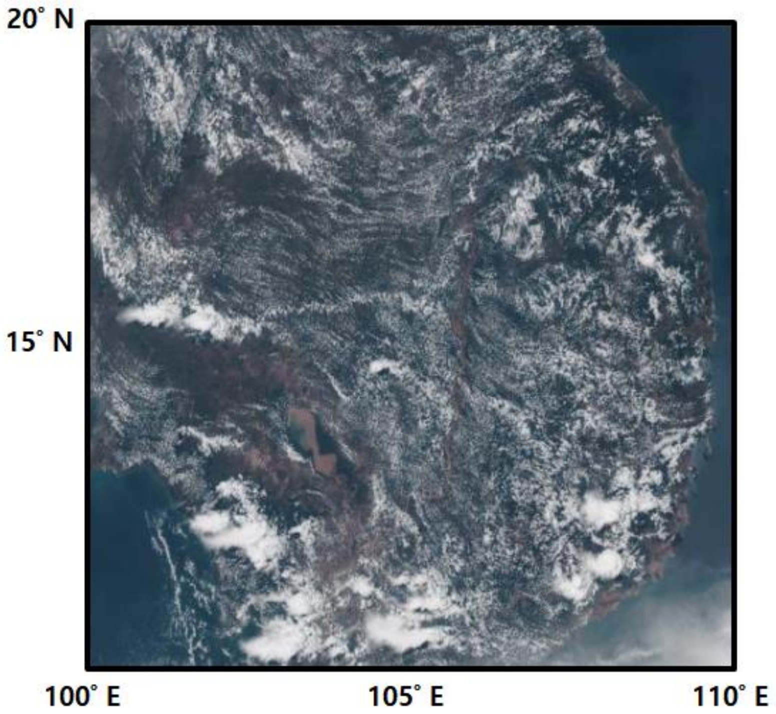


Figure 1. Himawari-8 AHI RGB image taken for this study area on 19 August 2015, 05:50 UTC. Several convective clouds (white color) are visible in the southern part of the area.

Answers to the comments of NHESS-2018-357-RC2-supplement

We thank to reviewer of RC2-supplement for his/her productive comments and keen insight. He/she not only indicated the crucial points in our research but also suggested the way how to improve them. Thanks to the comments, the manuscript has been revised as follows.

General comments:

• The goal of this study is very clear. However, I believe that using solely 8 clouds to draw conclusions on the difference in lead time between the old and new observational satellite data is too little. The authors need to include much more data, i.e., increase the amount of observed clouds, simply by extending the amount of observation days (now only 10 & 11 Aug 2017). Why not using for instance all the thunderclouds observed in August 2017 & 2018?

"Only eight clouds are a small number to show enough conclusions. We selected clouds that occurred during the day and night in July and August 2017. We added a total of 60 cloud cases, 30 per month. Specifically, Table 1 shows information about cloud data. It's a good idea to add 2018 data. However, we didn't have enough time to get the 2018 data. Instead, we used data for two months in 2017 which are July and August, when tropical clouds were frequently observed each year. "

P 10

Table 1. The number of selected convective clouds during observation time.

Month	Observation time	Sample number
July 2017	03:00-06:50 UTC (daytime) 21:00-24:50 UTC (nighttime)	20 10
August 2017	03:00-06:50 UTC (daytime) 21:00-24:50 UTC (nighttime)	20 10

• Fig 1 & 2 only include the data based on the new satellite observations. I believe its worthwhile to include in the figures as well the behavior of the virtual (lower resolution) data. In this way it is easy for the reader to see the difference between the two.

"We totally agree with this comment. Figures have revised for the reader to compare high-resolution and low-resolution data. Figure 3 and 4 include high- and low-resolution data."

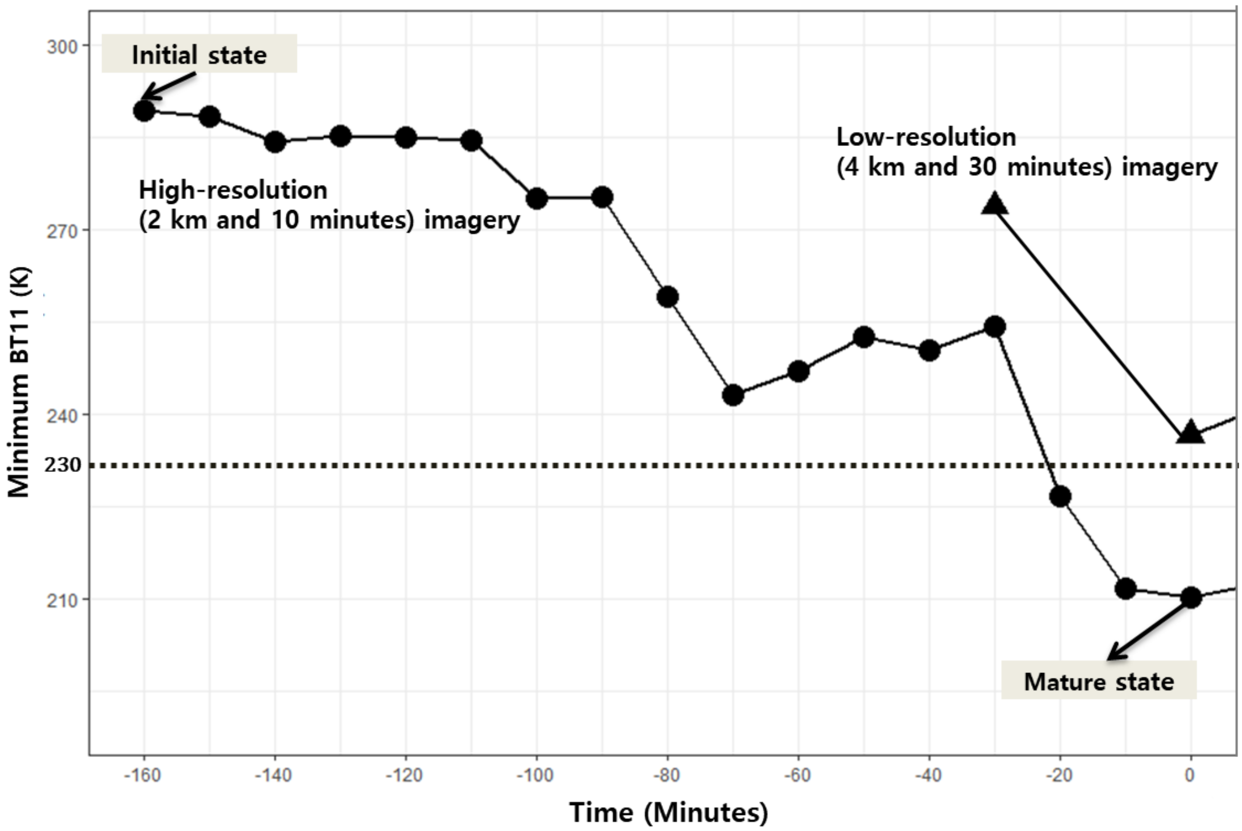


Figure 3. An example of temporal changes in minimum BT11 among thunderstorm pixels (10 August 2017, 03:10–05:50 UTC) for the high-resolution (2 km and 10 minutes) imagery (circle) and the low-resolution (4 km and 30 minutes) imagery (triangle). In this study, the lead time was defined as the time between the initial state and the mature state (time 0). The negative sign of time indicates the time ahead of the mature state of a tropical thunderstorm.

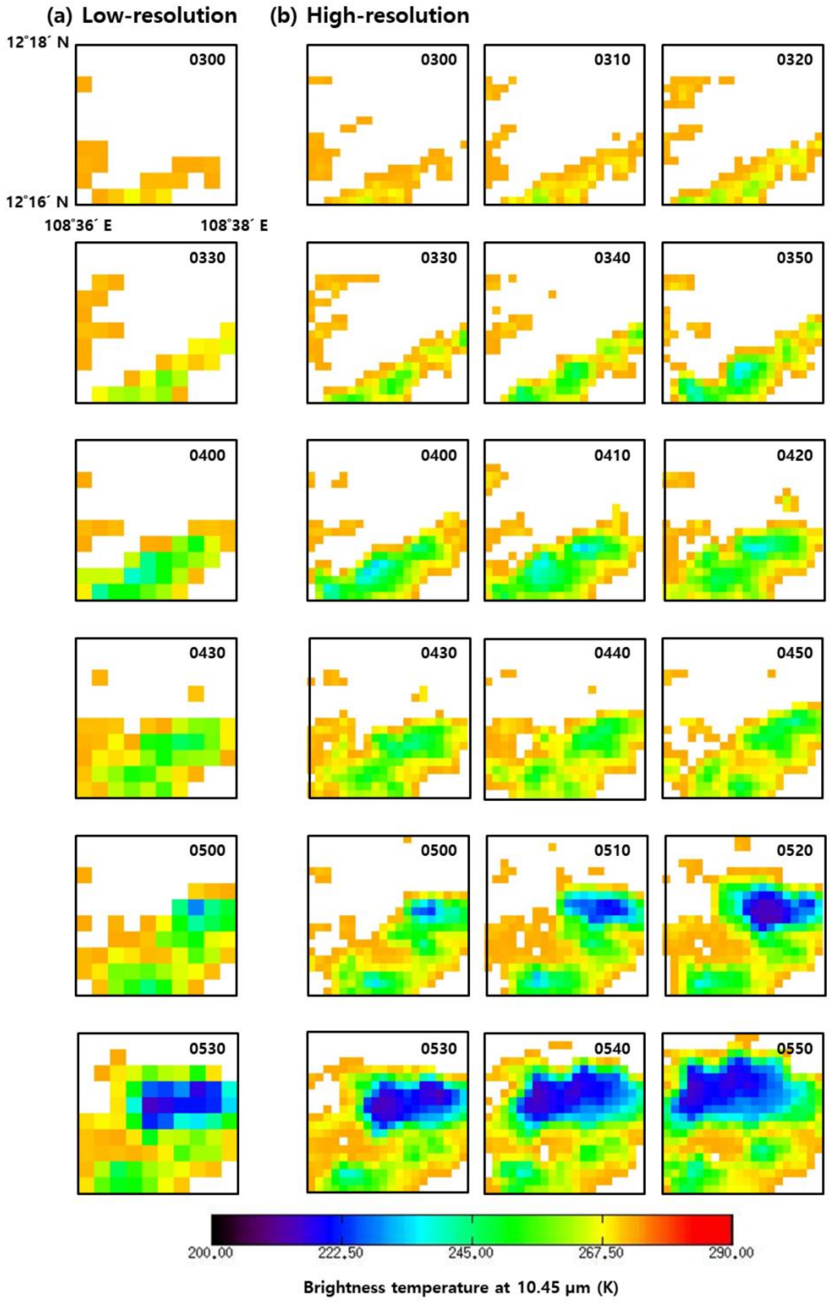


Figure 4. An example of the thunderstorm development process through BT11 images (10 August 2017, 03:00–05:50 UTC); (a) the low-resolution (4 km and 30 minutes) imagery and (b) the high-resolution (2 km and 10 minutes) imagery.

Specific comments (chronological in appearance):

1. Introduction:

• p1, L27, typo: "… lead to extensive economic losses"

"These severe events lead to extensive economic losses, environmental degradation, and subsequently, damage to human life."

• p2, L10/11: please rephrase "should be grounded" in this sentence. It is not clear what you mean.

"Removed"

• p2, L16: "(briefly, min)": what do you mean?

"Removed"

• p2, L20/21: "Moreover, … measurements": there are of course advantages using satellite in stead of ground-based observations, but also disadvantages. A network of radars, such as NEXRAD in the US or OPERA in Europe do provide high-resolution precipitation observations over a large area continuously with a higher spatial resolution compared to satellite observations.

"This is very helpful comment. We added to the manuscript that some countries are using high-resolution radar system as well as satellites as follows."

P2 line 12-15

Aimed at disaster risk reduction, the European Operational Program for Exchange of Weather Radar Information (OPERA) continuously provides precipitation data of higher spatial resolution over a large area (Huuskonen et al., 2014). The Next Generation Weather Radar (NEXRAD) system (Klazura and Imy, 1993) has been employed for this purpose in the United States.

2. Data and Method

• p2, L30-p3,L2: so is this the only reason why the authors chose this particular region to investigate?

"The region examined in this study is from 10℃N to 20℃N and from 100℃E to 120℃E and is closely monitored by the Mekong River Commission. The Mekong River Commission is the only inter-governmental organization interacting directly with the governments of Cambodia, Lao PDR, Thailand, and Viet Nam to jointly manage the shared water resources and the sustainable development of the Mekong River (Jacobs, 2002). Unfortunately, this area is known as a vulnerable-disaster region because of its high risk of extreme weather. The global impacts of climate change have contributed to changes in the weather patterns that are felt across the Mekong River Commission region. The warmer atmosphere has the potential to contain more moisture, which increases the possibilities for thunderstorms invigoration under equal other conditions. The temperature increase associated with global climate change was generally assumed will to lead to increased thunderstorm intensity and associated heavy precipitation events (Schefczyk et al., 2015)."

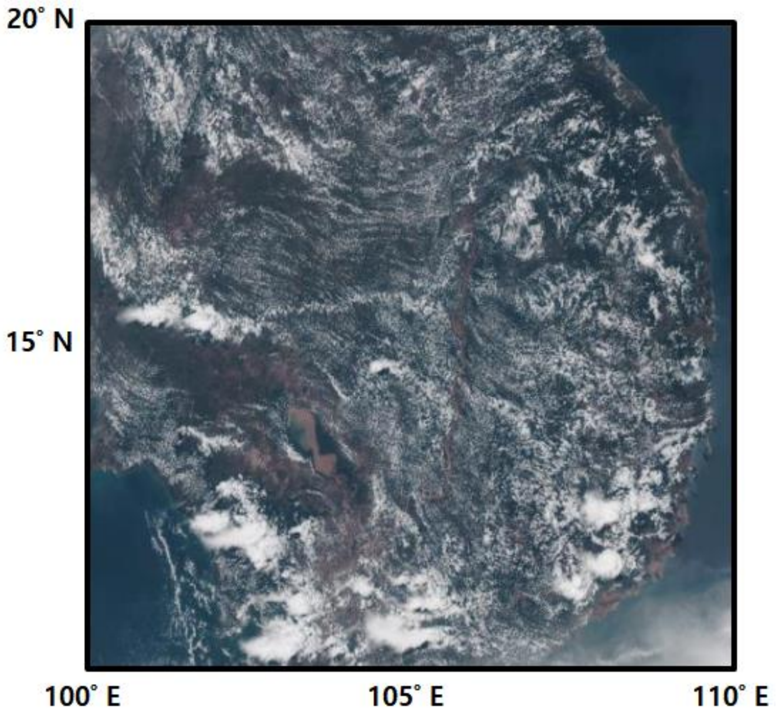


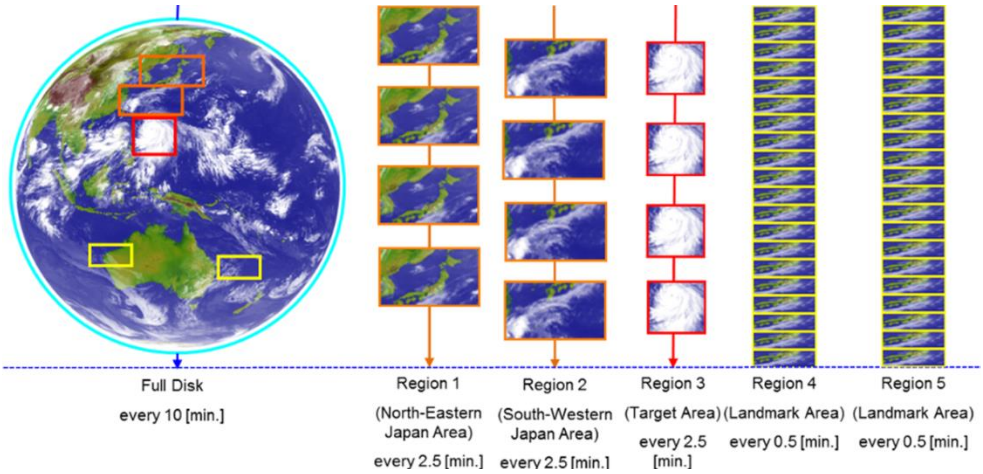
Figure 1. Himawari-8 AHI RGB image taken for this study area on 19 August 2015, 05:50 UTC. Several convective clouds (white color) are visible in the southern part of the area.

• p3, L6: please rephrase " ...dramatically uprising in the clean sky"

"clouds which are developing within 2 hours in the clear sky"

• p3, L11,12: Regions 1, 2 and 3 are mentioned in the text but its not totally clear where those are located. A new figure indicating the three regions would clarify this.

“The observation range and time interval vary for each area in Himawari-8 AHI observation. In Southeast Asia, it does not belong to specific targeted regions which are from Region 1 and Region 5 like below.



Subfigure 1. Observation time interval by targeted areas of Himawari-8 AHI.

Thus, this study only observed Southeast Asia, high-resolution data provided per 10-minutes were used. Different time cycles of observation for each region are not covered in detail.”

• p3, L14: Reference to JMA/MSC is now “2017”, however, in the reference list it is “2018”

“Corrected” (JMA/MSC: Himawari-8/9 Imager (AHI), 2018)

• p3, L29: “… whose resolution is similar to the MTSAT ...”

“Corrected”

3. Determining thunderstorm pixels and defining the lead time

• p3, L31: please add a reference(s) for " … BT11 of clouds, which insofar, has been shown to be highly associated with the predictability of thunderstorms [references]"

"References are written and rearrange the paragraph"

P4 line 23-28

Sixty thunderstorms were subjectively selected based on the RGB images over Southeast Asia. The size of the selected thunderstorms was determined to be less than 120 km because such convective scales typically accompany precipitation (Houze Jr, 2004). We set the rectangular target boundaries depending on the thunderstorm size. In the target boundary, the BT11 values were monitored to determine the thunderstorm pixels and phases (initial/mature states) for the whole life cycle of thunderstorms. Since temporal changes in BT11 inform vertical drift velocity, the current status of clouds can be a key diagnose the probability of imminent heavy rains/lightning soon (Vila et al., 2008).

• p4, L8: please rephrase "… time passed from when the ..." into " time in between the cloud … and ..."

"Rephrased" The lead time was defined as the time between the initial state and the mature state.

• p4, L15: reference (Houze, 204) → 2004

"Correted" (Houze Jr, 2004)

4. Improved predictability by comparing lead time differences

• p4, L25: please rephrase: "the sooner early clouds"

"Removed"

• p4, L26 add references: "Some previous studies have shown … [references]"

"Removed"

• p4, L29: 8 clouds are not a lot to build your conclusions upon

"We added a total of 60 cloud cases."

P 10

Table 3. The lead time according to imagery for cloud No. 1-20 occurred in the daytime of July 2017, No. 21-30 in the nighttime of July 2017, No. 31-50 in the daytime of August 2017, and No. 51-60 in the nighttime of August 2017.

No.	Cloud-scale (km)	Lead time (minutes)		Lead time difference (minutes) (A minus B)
		2 km and 10 min imagery (A)	4 km and 30 min imagery (B)	
1	120	180	60	120
2	104	160	30	130
3	120	140	30	110
4	120	180	30	150
5	120	180	60	120
6	40	130	30	100
7	40	140	0	140
8	44	120	0	120
9	64	120	30	90
10	40	180	60	120
11	40	130	0	130
12	48	90	0	90
13	96	180	60	120
14	104	120	0	120
15	120	140	30	110
16	80	180	60	120
17	56	100	0	100
18	80	180	30	150
19	96	180	0	180
20	56	100	0	100
21	40	160	0	160
22	72	150	30	120
23	120	140	30	110
24	96	120	30	90
25	84	130	0	130
26	100	180	60	120
27	60	100	0	100
28	100	130	0	130
29	104	120	0	120
30	96	180	60	120
31	100	120	30	90
32	32	100	0	100
33	48	120	30	90
34	100	180	30	150

35	112	180	60	120
36	64	120	30	90
37	100	180	60	120
38	96	140	0	140
39	68	120	0	120
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43	100	120	0	120
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46	88	140	30	110
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48	124	180	60	120
49	104	140	0	140
50	100	120	0	120
51	120	130	30	100
52	66	110	0	110
53	80	130	0	130
54	120	180	60	120
55	120	100	0	100
56	40	180	30	150
57	56	180	0	180
58	56	100	0	100
59	88	160	0	160
60	92	180	30	150

• p5, L2: what is meant with "the floating population"?

"Removed"

• P5, L7/8: remove the brackets "(...)"

"Removed"

• p5, L19: What is meant with "it is difficult to reflect the whole cloud"

"Changed"

P5 line 22- P6 line 2

Figure 4 depicts the spatial distribution of BT11 used to determine the cause of the difference in the lead time between the different resolutions. Figure 4a and 4b are the result of the low-resolution imagery and that of the high-resolution imagery (10 August 2017, 03:00–05:50 UTC). The amount of change of BT11 within the observation time interval is closely related to determining the initial state. In Figure 4a, pixels with a variation of 15 K or more are recognized as thunderstorm every 30 minutes. In contrast, in Figure 4b, pixels with a variation of 5 K or more are recognized as thunderstorm every 10 minutes. This can cause difficulty to detect the initial state using low-resolution imagery because of the BT11 variation which is proportional to the observation time interval. Also, Figure 4a shows that the boundaries of clouds are not clear from 03:00 to 04:00 UTC and there seems to be a limitation to track continuously developing storms from 04:00 to 05:00 UTC because the low-resolution imagery could not detect cloudy pixels whose scale was between 2 km and 4 km. Figure 4b shows the BT11 at the boundary, was nearly 270 K (orange), and the area of the cloudy pixels, which was nearly 250 K (green Interestingly, in Figure 4b, it can be seen that small clouds were formed from 04:00 to 04:50 UTC, but one dominant cloud which was below 230 K (blue) dramatically increased its size from 04:50 to 05:50 UTC. This phenomenon indicates that the properties of a rapidly developing thunderstorm can be captured by the high-resolution imagery. Therefore the high-resolution imagery accurately can monitor the change of BT11 and be advantages in the detection of early clouds.

• p5, L18-L31: it would be worthwhile to include in Figure 2 the behaviour of the "virtual" lower resolution MTSAT data. In that way, the reader can check visually directly the difference for this particular case.

"That's a good point."

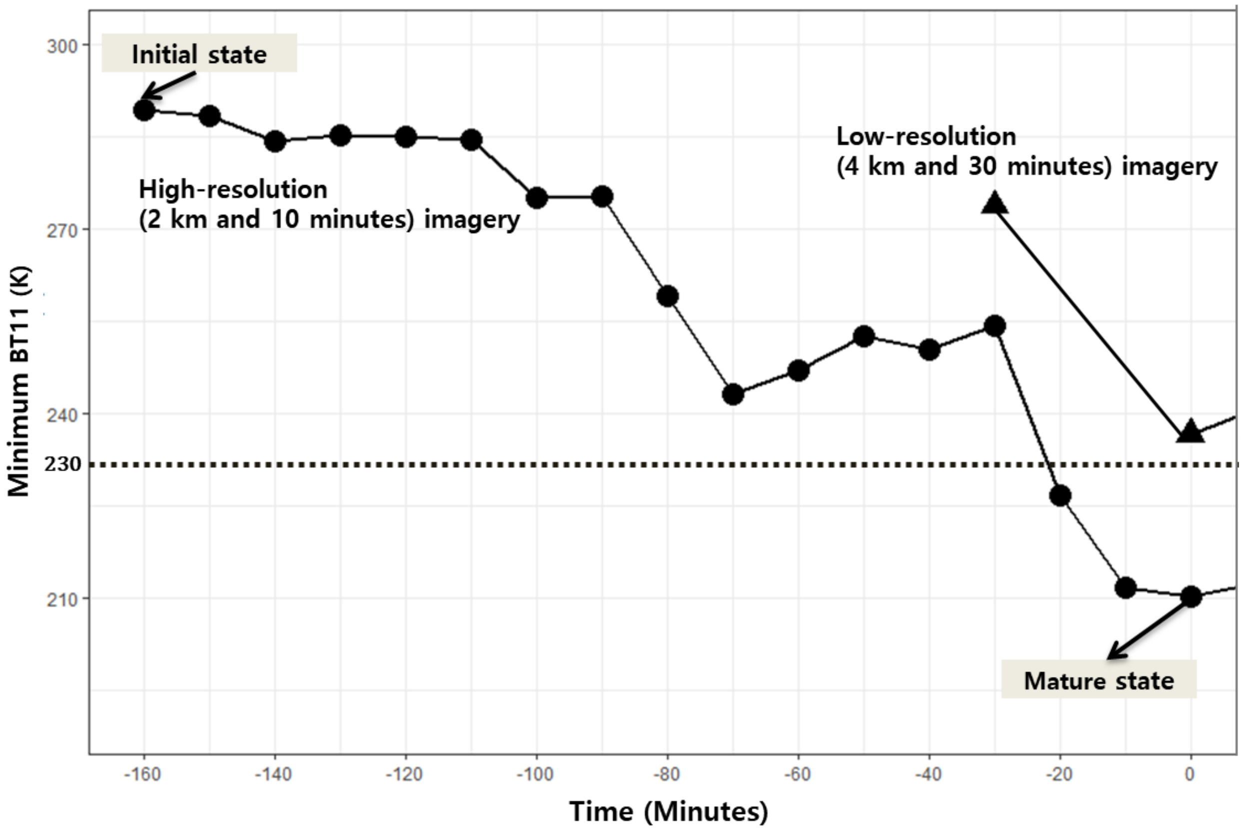


Figure 3. An example of temporal changes in minimum BT11 among thunderstorm pixels (10 August 2017, 03:10–05:50 UTC) for the high-resolution (2 km and 10 minutes) imagery (circle) and the low-resolution (4 km and 30 minutes) imagery (triangle). In this study, the lead time was defined as the time between the initial state and the mature state (time 0). The negative sign of time indicates the time ahead of the mature state of a tropical thunderstorm.

5. Conclusions and limitation

• p6, 1 sentence: this is expected. Even without this study one expects that newer instruments provide higher quality data, which in turn have a positive effect for any meteorological purpose. Exactly what you wrote on p6, L13-15.

"Changed"

P6 line5-11

In this paper, we compared an infrared channel at 10.45 μm of the high-resolution imagery and the low-resolution imagery. It was difficult to track the rapid BT11 changes in the clouds during the process of their development. The lead time of 60 cloud samples determined by the low-resolution imagery was not sufficiently accurately measured to monitor the whole development process of tropical thunderstorms. In contrast, the lead time of the high-resolution imagery was from 90 minutes and to 180 minutes before the cloud reached its mature state. Therefore, the higher spatial and temporal resolution of satellite observations can be valuable as it would alarm for tropical thunderstorms over Southeast Asia approximately two hours earlier than the low-resolution one based on the validation using 60 thunderstorms events.

• p6, L9-10: please rephrase " … and the mature deep convective with heavy rain"

"Corrected"

P6 line14-19

Second, future studies are needed to determine whether thunderstorms are rainy after the lead time. To more accurately examine the lead time, validation with surface precipitation data based on ground observation is further required. Also, the near-real radar data can be useful to validate the precipitation if the surface precipitation data have not been well managed. Finally, the lead time can differ depending on the region, since the lead time can be affected by various environmental factors such as wind direction and speed, atmospheric profiles, and the characteristics of the geolocation.

• p6, L23: "if applied to real technology". Do you mean " if implemented operationally?"

"Changed" Implemented operationally under real-life conditions, the high-resolution (2 km and 10 minutes) imager is of great significance to the provision of practical assistance to effective disaster management.

• p6, L26-27: " For example, Cambodia … satellite data are 4 km.": I am wondering if this is really the best place/appropriate (in a scientific article) referring to a specific country. I believe it is better to write in general terms that there are countries in southeast Asia who receive 4km data. For example, last line of the summary is written in more general words, which is in my opinion better.

"Absolutely, you are right. Thanks for your sincere comment!"

P6 line29-32

Although many developing countries in Southeast Asia use Himawari-8 satellite data, few countries carefully consider the importance of satellite resolution. A longer lead time is beneficial to the reduction of the risk of natural disasters caused by thunderstorms and the timely evacuation in such adverse events. Moreover, the low-resolution imagery is more effective in data storage than the low-resolution imagery.

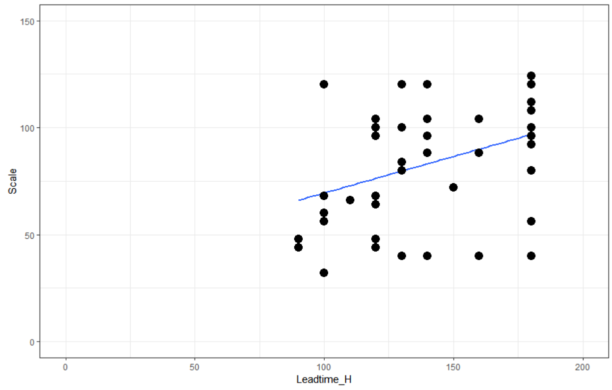
Tables:

I think Table 1 & 3 could be transformed into 1 single table. The observation times in Table 1 can be put into Table 3. However, since more data will be included in the paper, the authors should think about how to restructure those tables. I can imagine that when you have not 8, but for example 80 observed clouds it would be better not to use a table but to make a figure of the distribution of the lead times & cloud scales … Is there maybe a relation between the cloud scale and the lead time? More things can be done when including more data!

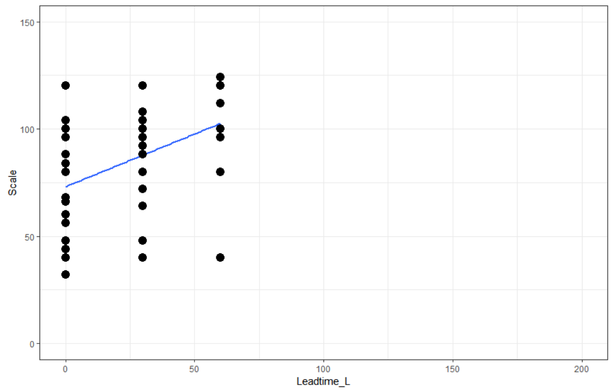
"60 cloud examples are difficult to represent in a single table. The results are divided into Tables 1 and 3."

At the same time, thank you for suggesting new ideas related to this study. To analyze the correlation between cloud size and lead time, a preliminary test was conducted with 60 cloud samples. As a result, it was difficult to see a notable correlation between cloud scale and lead time. We consider that the number of samples will be increased to identify the relationship between cloud size and lead time. But, your idea is worth studying in the future. More detailed assumptions and definition of cloud-scale will be needed to precede the research.

(a) Correlation : 0.3755376



(b) Correlation : 0.3755376



Subfigure 2. The correlation between the lead time and cloud scale; (a) the high-resolution (2 km and 10 minutes) imagery and (b) the low-resolution (4 km and 30 minutes) imagery.

Figures:

• Figure 1: Please rephrase last sentence in the caption of this figure. At the moment, it is not clear. + Include the low-resolution data in this figure as well for direct comparison.

• Figure 2: I would like to see for Fig. 2 a & b that the authors include the virtual (lower resolution) data in order for the reader to see directly the difference between the new and old observational data.

"All figures are updated for better understanding"

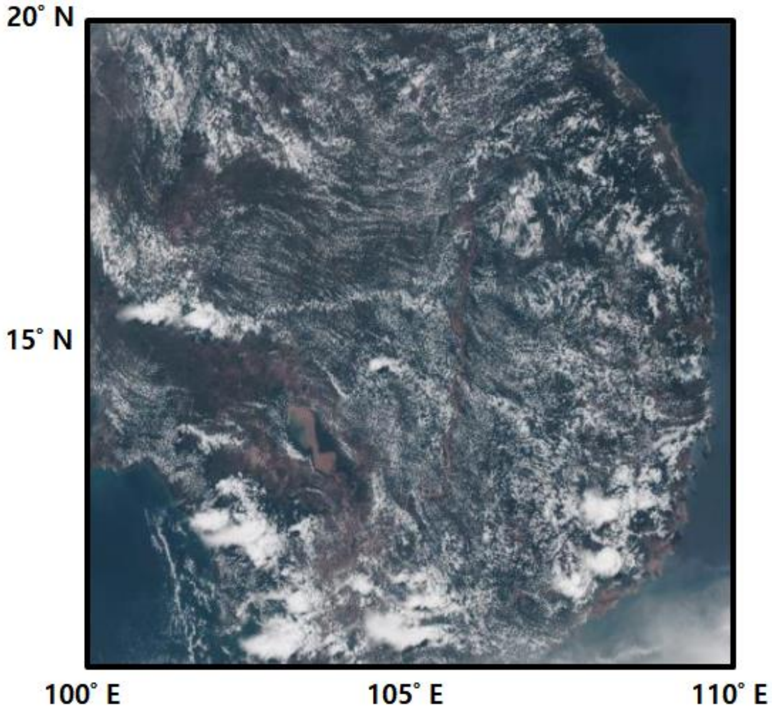


Figure 1. Himawari-8 AHI RGB image taken for this study area on 19 August 2015, 05:50 UTC. Several convective clouds (white color) are visible in the southern part of the area.

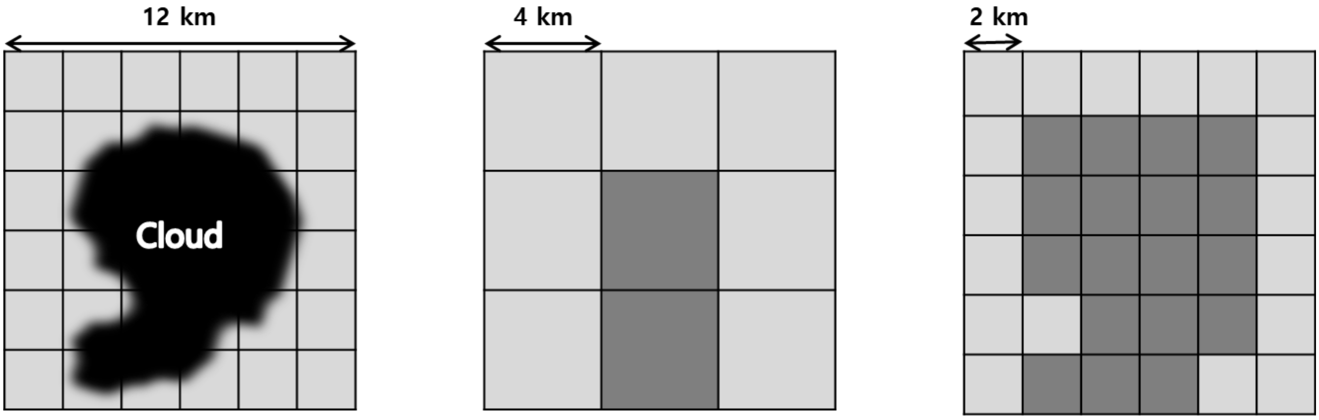


Figure 2. Illustrations of 12 × 12-km pixels with different resolutions. The dark grey indicates the cloudy pixel, and the light grey indicates the clear-sky pixel. Only 2 cloudy pixels can be detected with the 4-km resolution imagery; in contrast, 18 cloudy pixels can be detected with the 2-km resolution imagery. The number of pixels at the cloud boundary varies depending on the resolution (Walker et al., 2012).

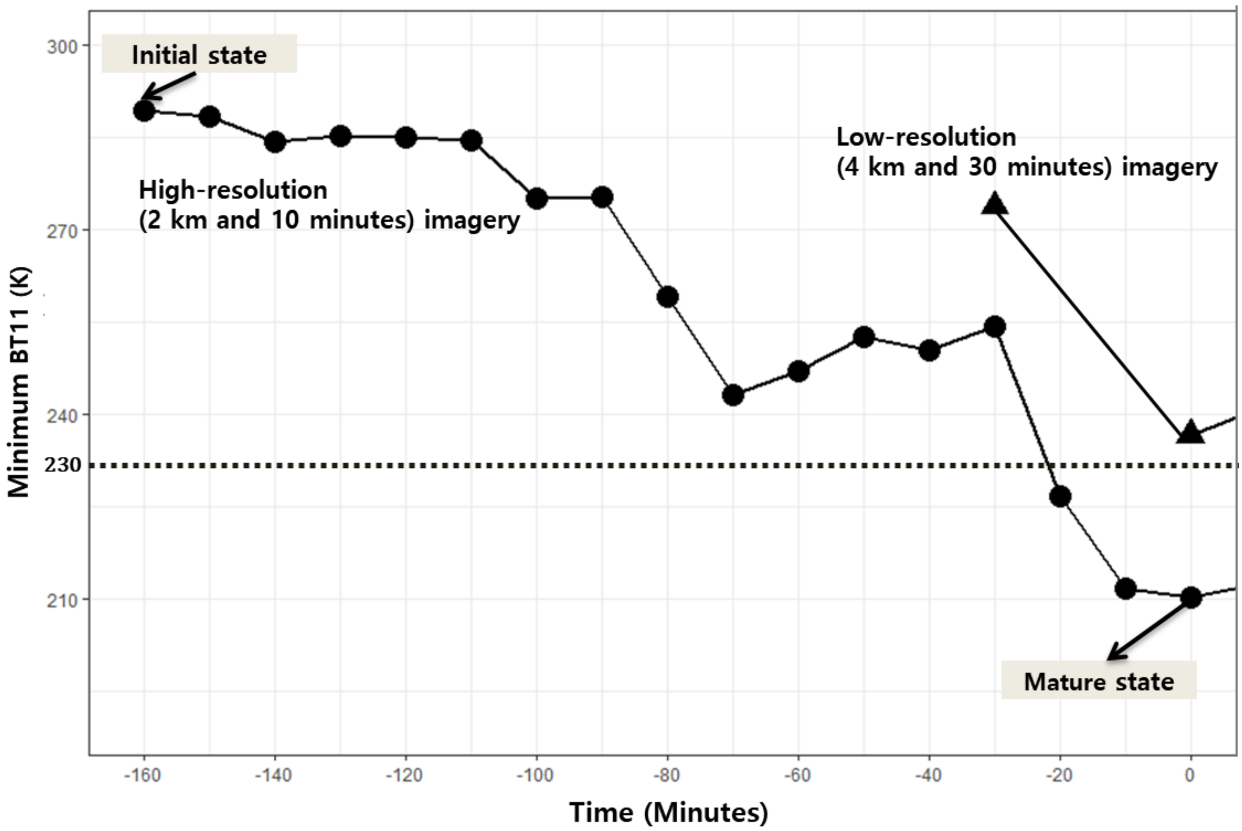


Figure 3. An example of temporal changes in minimum BT11 among thunderstorm pixels (10 August 2017, 03:10–05:50 UTC) for the high-resolution (2 km and 10 minutes) imagery (circle) and the low-resolution (4 km and 30 minutes) imagery (triangle). In this study, the lead time was defined as the time between the initial state and the mature state (time 0). The negative sign of time indicates the time ahead of the mature state of a tropical thunderstorm.

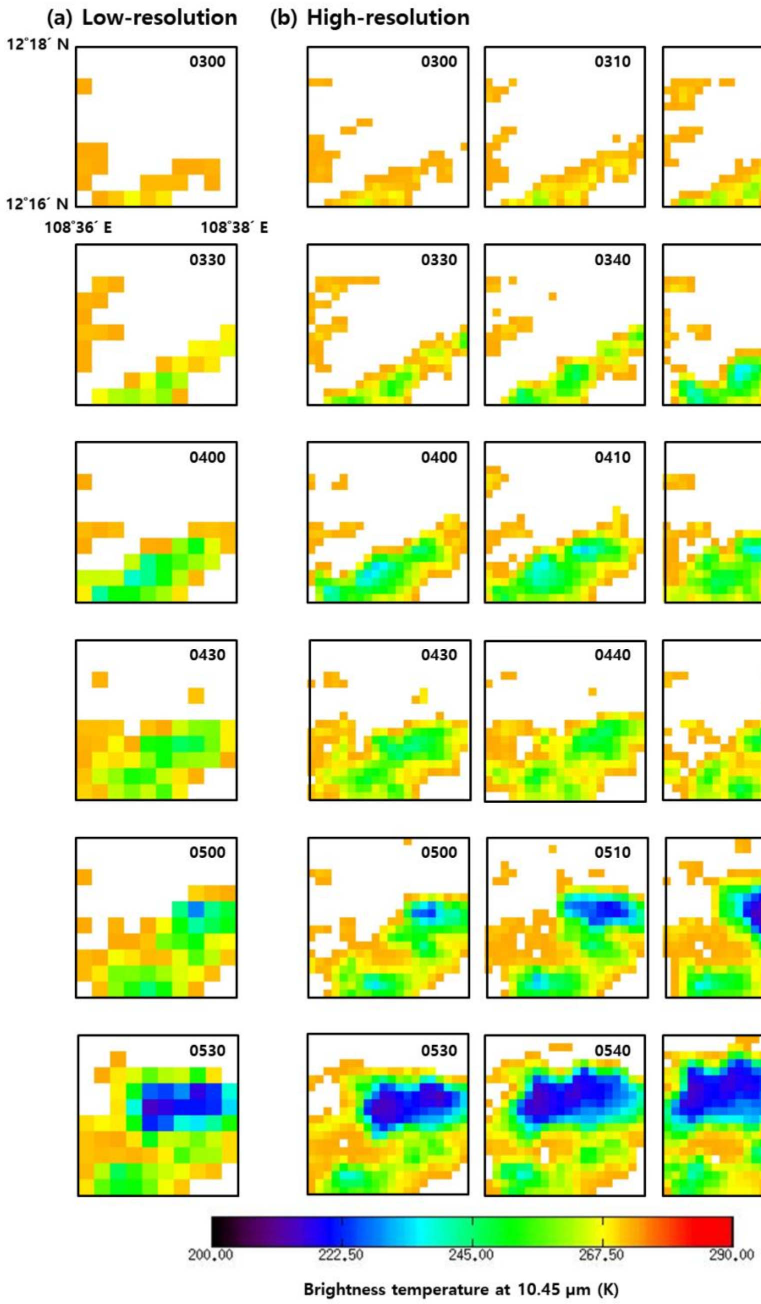


Figure 4. An example of the thunderstorm development process through BT11 images (10 August 2017, 03:00–05:50 UTC); (a) the low-resolution (4 km and 30 minutes) imagery and (b) the high-resolution (2 km and 10 minutes) imagery.