Use of rapid scan data for retrieving properties of growing convective storms

Atsushi Hamada and Yukari N. Takayabu
Atmosphere and Ocean Research Institute, the University of Tokyo, Japan

Introduction

Images from geostationary satellites in the visible, infrared, and water vapor channel have extensively been used to identify cloud types and cloud-top properties (e.g., Rossow & Shiffer 1991), to observe evolution of cloud system (e.g., Rickenbach et al. 2008), and to derive wind fields by tracking clouds and/or water vapor (e.g., Velden et al. 1997). Currently the image intervals of 15-30 minutes for full disk become the standard. However, even shorter intervals are needed to properly capture the early development of deep convective clouds, since the transition from shallow to deep convection can take place within minutes. Deep convection plays an important role in nowcasting of severe events and related flash floods. The convection initiation (CI; e.g., Weckwerth & Parsons 2006) should hence be predicted in numerical weather prediction models. However, forecasting CI still remains a significant challenge mainly due to the lack of observational data to assess the weather conditions yielding CI.

The advent of the Japanese Multifunctional Transport Satellite (MTSAT) made it possible to take far eastern regional images at the interval of 5 minutes with spatial resolutions of ~1 and ~4 km in visible and infrared channel, respectively. These images are suitable for monitoring and identifying the initiation of deep convection.

In this study, we aimed to describe the common characteristics of initial development of convective storms, such as cloud-top evolution, updraft strength, and precipitation intensity, by using the rapid-scan imagery. Preliminary results from a case study during the campaign which conducted in the summers of 2010 and 2011 are reported here.

Data

MTSAT-1R rapid scan
- Channels: 1 in the visible (VIS) / 4 in the infrared (IR) (10.8, 12, 6.8, 3.8 um)
- Observation region: 110E—150E, 20N—50N
- Observation period: August—September 2010, June—September 2011
- Horizontal resolution: 1km (VIS) / 4km (IR) at nadir
- Temporal resolution: 5min (only daytime)

AMeDAS (Automated Meteorological Data Acquisition System) raingauge
- Temporal resolution: 10min

Analysis procedure

1. Subjectively select typical cases clearly showing initial development of convective clouds
2. Set a rectangle frame encompassing the event with ~1deg width in longitude/latitude
3. For each frame, compute following values:
   - TBmin := minimum value of 10.8-um brightness temperature (TB) [K]
   - d(TBmin)/dt := time derivative of TBmin [K/5min]
   - Area := the number of pixels with a given values of TB [pixels]
     (e.g., Area210 = number of pixels with TB < 210 K in the frame)
   - d(ln(Area))/dt := time derivative of normalized area [1/5min]

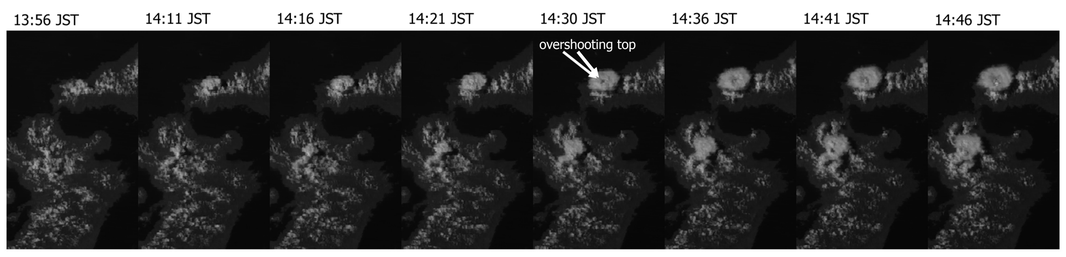
+ d(TBmin)/dt is a proxy of vertical flow strength:
  $w = dz/dt = dT/dt \cdot (dT/dz)^{-1} \sim dTb/dt \cdot (dT/dz)^{-1}$ for thick clouds
+ d(ln(Area))/dt is a proxy of horizontal divergence:
  $dA/dt = hdiv(A\mathbf{u}) \Rightarrow A^{-1} \cdot dA/dt \sim hdiv(\mathbf{u})$

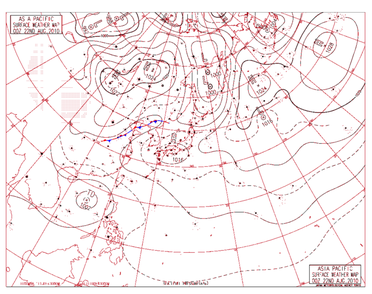
Case study

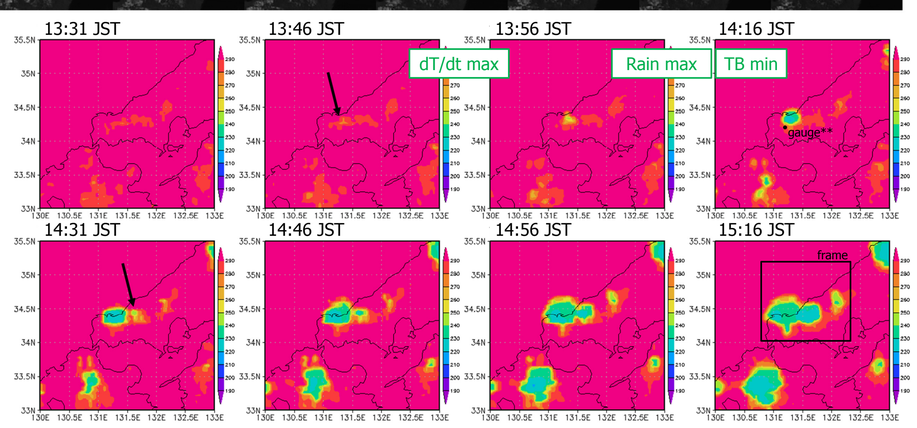
We selected two cases of isolated convective events in relatively calm weather condition.

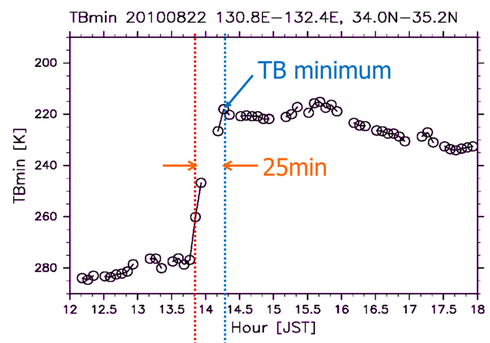
Case 1: 2010/08/22

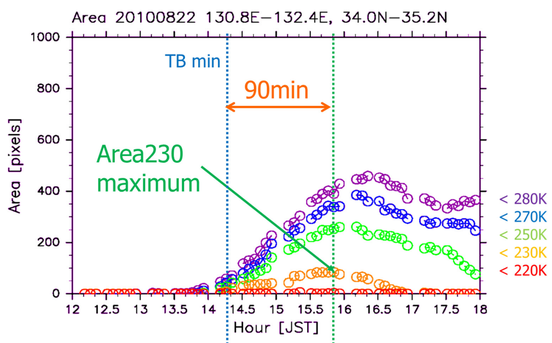
Right: VIS images (every 5 min)
Lower right: IR TB images (every 15 min)
Bottom: Weather map (09JST)

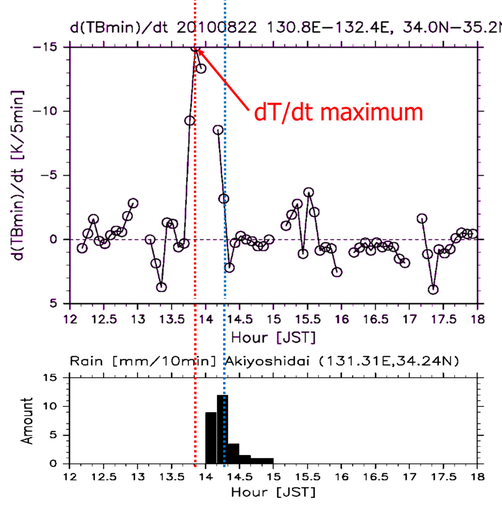


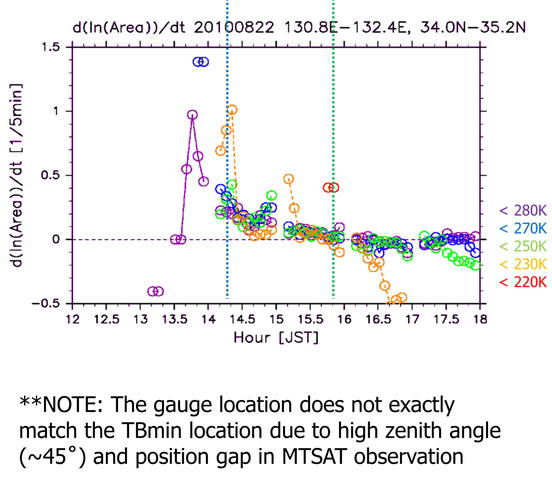












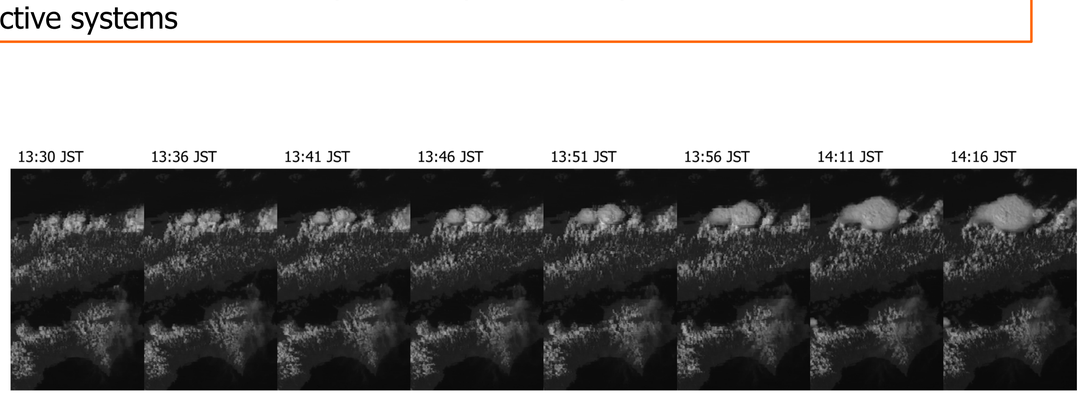
+ Rapid scan images with 5-min interval well capture the evolution of convective clouds, from the initiation of convection to the decay of overshooting tops
+ Initiation of deep convection — 10-15min → Updraft maximum
  — 25-30min → Highest cloud top — ~90min → Largest extension of thick anvils
+ Highest rain rate seems to be observed at almost same time as the maximum updraft

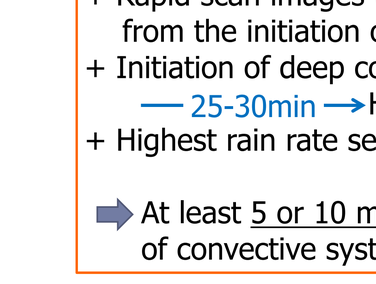
➡ At least 5 or 10 min interval is required to quantitatively describe the initial evolution of convective systems

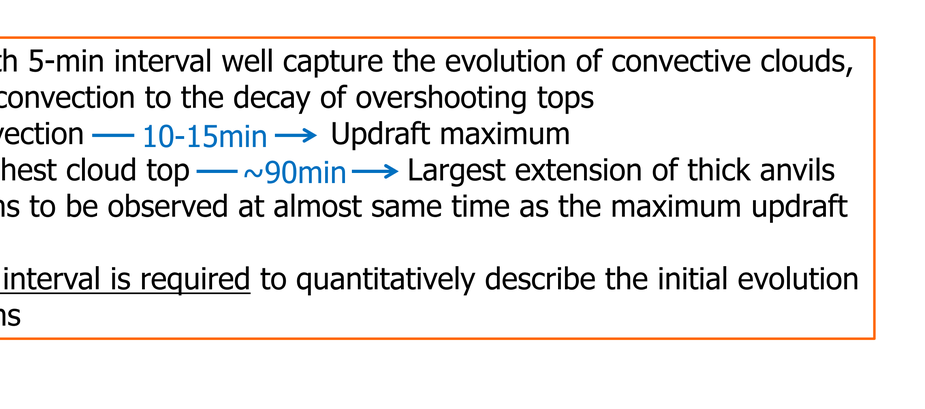
**NOTE: The gauge location does not exactly match the TBmin location due to high zenith angle (~45°) and position gap in MTSAT observation

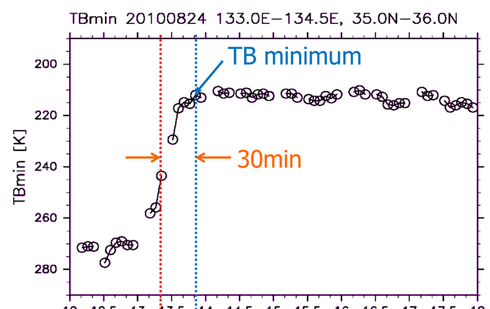
Case 2: 2010/08/24

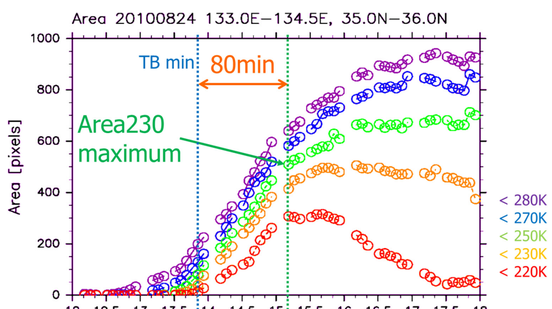
Right: VIS images (every 5 min)
Lower right: IR TB images (every 15 min)
Bottom: Weather map (09JST)











Summary

- Rapid scan observation with 5-min interval well captures the initial evolution of convective system
- Maximum updraft is observed ~10-15 minutes after the initiation of convection, and highest cloud top is observed 25-30 minutes after that. Highest rain rate seems to be observed at almost the same time as the maximum updraft
- To properly describe the growing stage of rain system, the interval of less than 10-min is desirable

Acknowledgment

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