Applying Convolutional Neural Networks for Detection of Overshooting Cloud Tops with Himawari-8 Satellite Data

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Introduction

An overshooting cloud top (OT) refers to a cloud shaped like a dome shooting out of the top of a cumulonimbus (AMS).

OTs occur when a rising air parcel in a deep convective cloud penetrates through the equilibrium level due to the rising parcel’s momentum from strong buoyant updrafts within a thunderstorm.

Rather than identifying individual pixels, we try to find OTs through
- the contextual information of pixels (i.e. dome-like shape) with rough-textured surfaces and lower temperatures compared to the surrounding clouds.
- based on the ability of Convolutional Neural Networks (CNN) to extract spatial characteristics.

1. Data used in this study
   - Reflectance images from Himawari-8 0.64μm (channel 3) visible data (500 m spatial res.)
   - Brightness temperatures (TB) from Himawari-8 11.2μm (channel 14) infrared data (2 km)

2. Goal
   - to investigate the application of CNN for the detection and monitoring of OTs using Himawari-8 geostationary satellite data over the Southeast Asia and Southwest Pacific regions.

3. Target: Binary OT detection ("OT occurrence" vs. "no OT occurrence") on a patch basis

Procedure of the CNN-based OT detection

1. Example of chopping images
   - Class 1 (OT) or 0 (non-OT) is labeled for each patch.
   - Overlapping vertically and horizontally from the center of an OT reference
   - Goal: pumping samples for OT class

2. Schematic overview of the CNN model in this study

3. Post-process 1: Clear sky filtering
   - Pixels (< Min + λσ) in Patch
   - Pixels with TBs that were lower than the sum of the minimum value (min) of TBs in bundled patches times the scaling factor (λ) (i.e., pixels < min + λσ) were found.

4. Post-process 2: Local OT region detection
   - Both detection rates and false alarms were not made biased by solar zenith angles.

Results and Discussion

1. The capability of the CNN model at different solar zenith angles for validation data
   - Both detection rates and false alarms were made biased by solar zenith angles.

2. Validation of OTs detected by the CNN model
   - Comparison with random forest results [Kim et al., 2017]

3. Comparisons of model performances for different OT detection techniques

4. Detection of time series OTs
   - In the mesoscale convective complexes, many OTs occur and disappear within two hours.
   - There are some sudden false alarms, showing spatially disordered detection over time.

Why we need the information of OTs?
- can be used for various research on hail estimation and monitoring of severe convective storms
- related with local and global climate systems owing to lower stratospheric water vapor by OTs