Automated Tracking of Shallow Maritime Clouds on Geostationary Imagery to Extract Lifecycle Characteristics

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Introduction: Why track shallow cumulus?

Shallow cumulus clouds are prominent features of the maritime tropics that process and exchange air between the boundary layer and free troposphere. Modern geostationary satellites have advanced greatly to capture shallow cumulus at resolutions (e.g., 0.5-km spatial and 2.5-min temporal) comparable to the fluctuations seen in cumulus evolution. Such capabilities make it possible to detect and track the lifetimes of shallow maritime cumulus. By measuring cloud lifetimes, one can investigate how environmental conditions are influencing such measurements over the domain of interest. Coupling the satellite data with ground-based sources, such as from field campaigns, can verify what internal cloud processes may be occurring that leads to the observed cloud behavior.

In this study, we implement a focused approach to cloud tracking that probes specific environments from the NASA Cloud, Aerosol, and Monsoon Processes Philippines Experiment (CAMP[2]EX) field campaign. 19 research flights were conducted to assess the impact of aerosol on cloud properties and the ensuing precipitation. After extensive development and testing of our tracking tool, 4 flights are analyzed here for changes in cloud longevity, initiation characteristics, and development behaviors. Cloud ensembles are selected in specific areas with actual field sampling to distinguish potential environmental factors and make comparisons between datasets. The ensembles are finally examined for any unique properties emanating from the cumulus growth, maturity, and dissipation stages.

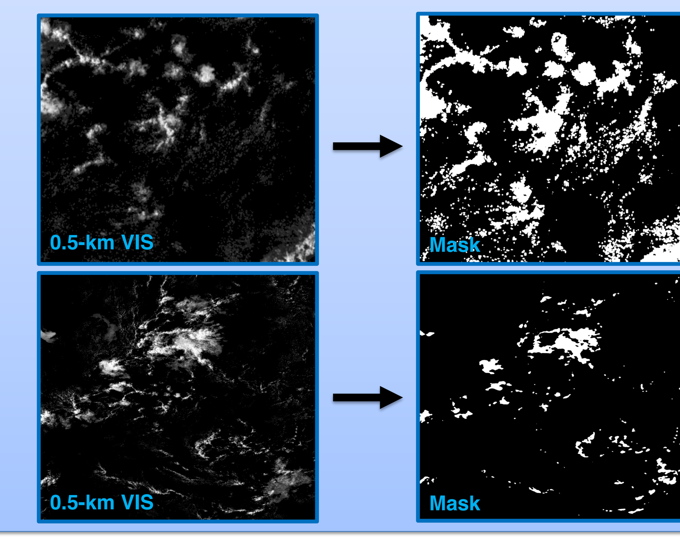
Data and Observation Period

- Japan Meteorological Agency's (JMA) Himawari-8 satellite acquired Rapid Scan (2.5-min) imagery during the period of CAMP[2]EX (late Aug-early Oct 2019) and over the flight sampling areas.
- 16 spectral channels are available on the satellite's primary sensor, the Advanced Himawari Imager (AHI), with VIS at 0.5-km resolution and IR at 2-km resolution.
- Only the red channel (Band 3) is applied in cloud segmentation here to obtain the best resolution possible for probing cumulus lifecycle, thus limiting our analyses to daytime hours.
- Collocated longwave IR (Band 13) brightness temperature (BT) is applied to evaluate changes in cloud-top height and infer cloud development.

Method and Workflow

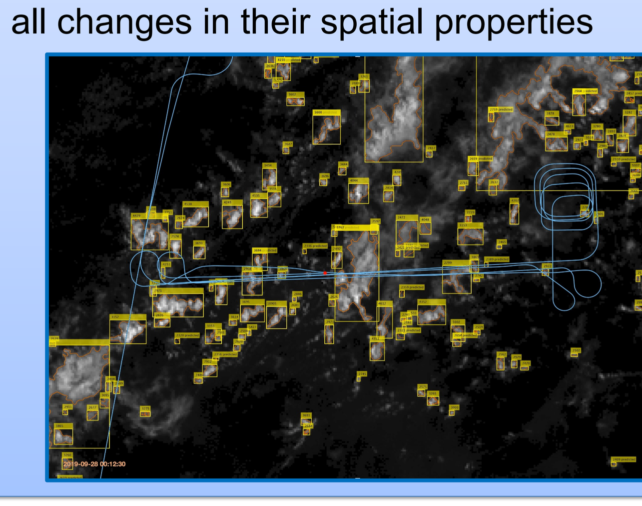
Segmentation

- Define tracking domain with minimal cirrus
- Choose visible reflectance threshold for an initial cloud mask
- Blur mask to reduce noise effects
- Optimize parameters to increase tracking stability and refine desired cloud structures



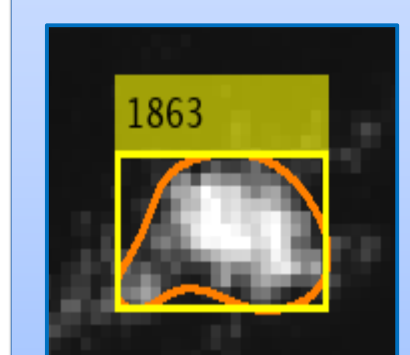
Tracking

- Specify parameters to initialize tolerances in object detection and motion
- On each frame, calculate object centroids and assign IDs for new objects
- Predict motion of "active" objects with their defined Kalman filters
- Terminate objects that have dissipated and log all changes in their spatial properties

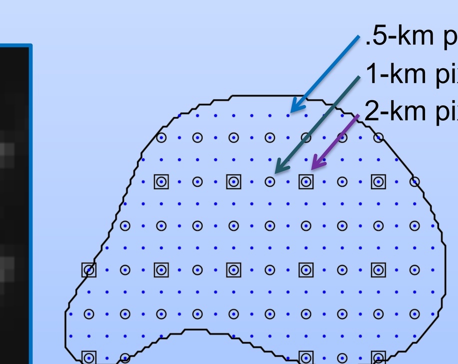


Cataloging

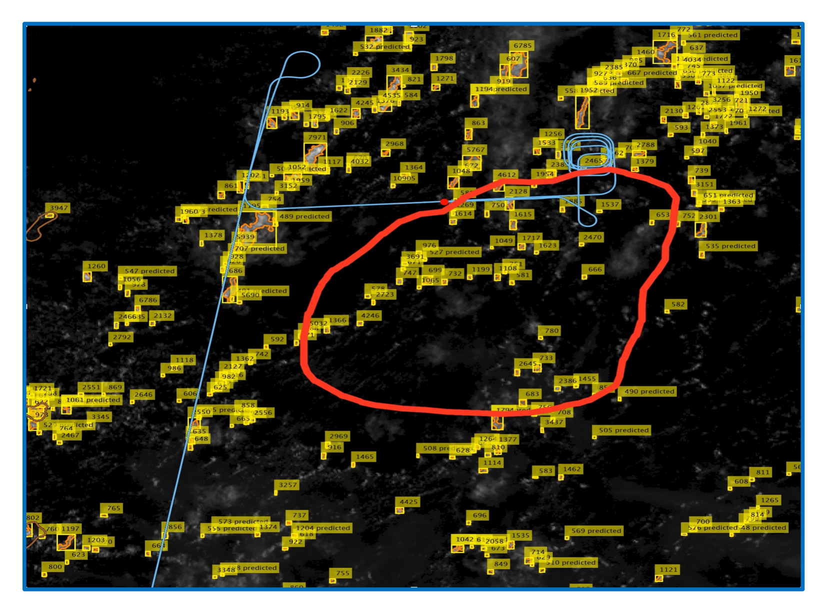
- Retrieve native AHI dataset containing full spectra for frames used in tracking
- Distribute timesteps from all cloud tracks across parallel processors
- Use cloud boundaries logged in tracks to find enclosed AHI pixels and extract radiances
- If necessary, average 0.5-km or 1-km band data to compare with 2-km IR bands



Tracked cloud snapshot

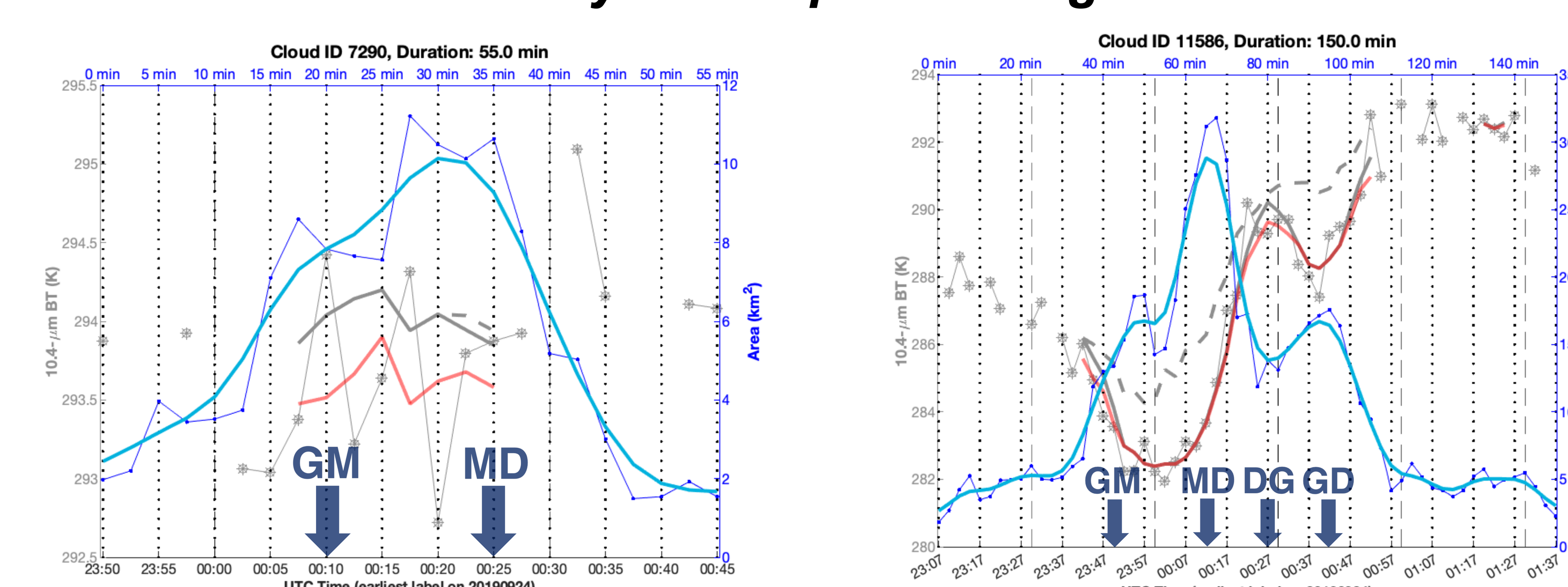


Cloud Ensembles



Complex cloud formations (e.g., broken lines) complicate results on the full tracking domain. Picking an ensemble, as above in the red region, focuses the analysis on more isolated cloud tracks occurring near the field sampling (blue track).

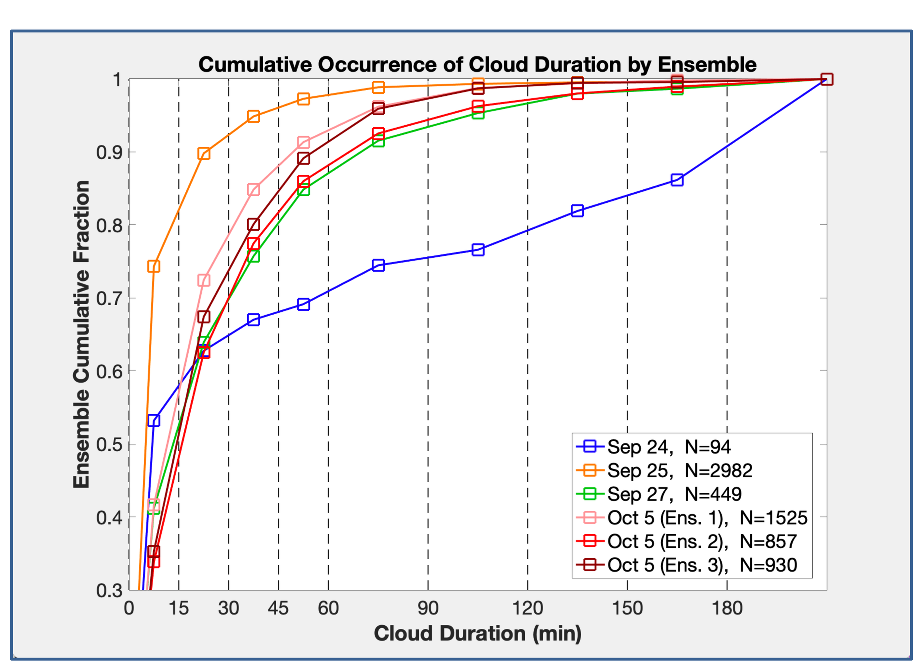
Identify Development Stages

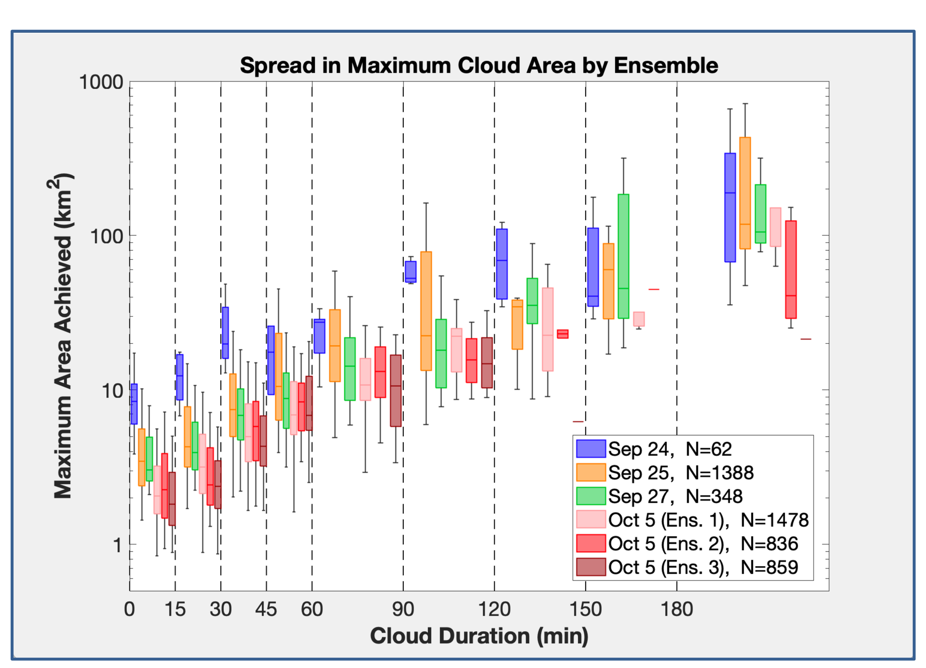


Above are two example cloud tracks taken from an ensemble on 2019 Sep 25. Development stages are identified by visual inspection of the area (blue) and brightness temperature (gray or red) curves. Times are tabulated as stage transitions denoted by 2-letter codes: GM=Growth-Maturity, MD=Maturity-Decay, GD=Growth-Decay, DG=Decay-Growth, etc.

Results

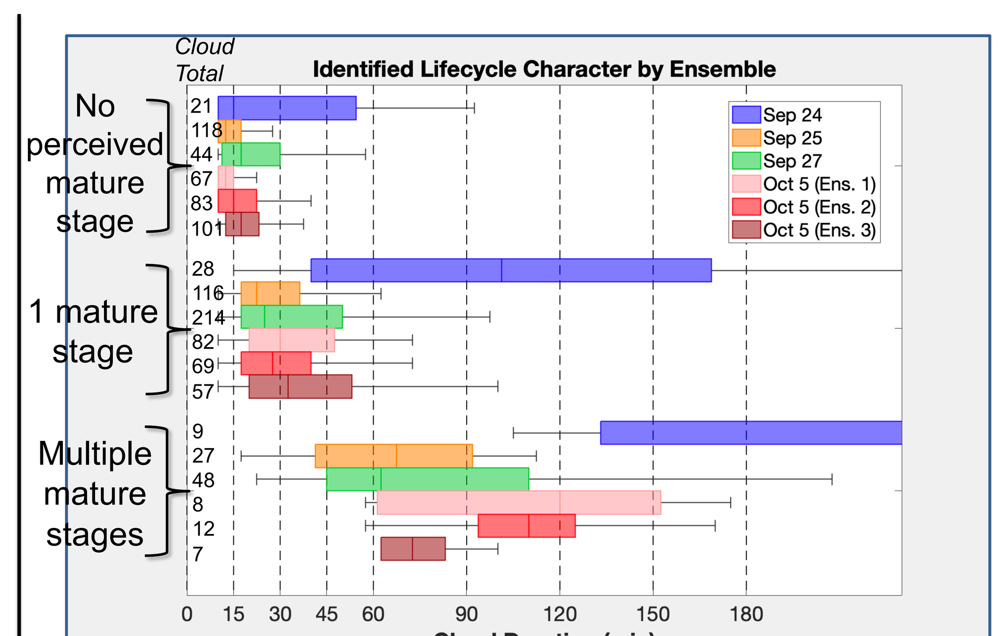
Lifetimes and Achieved Area

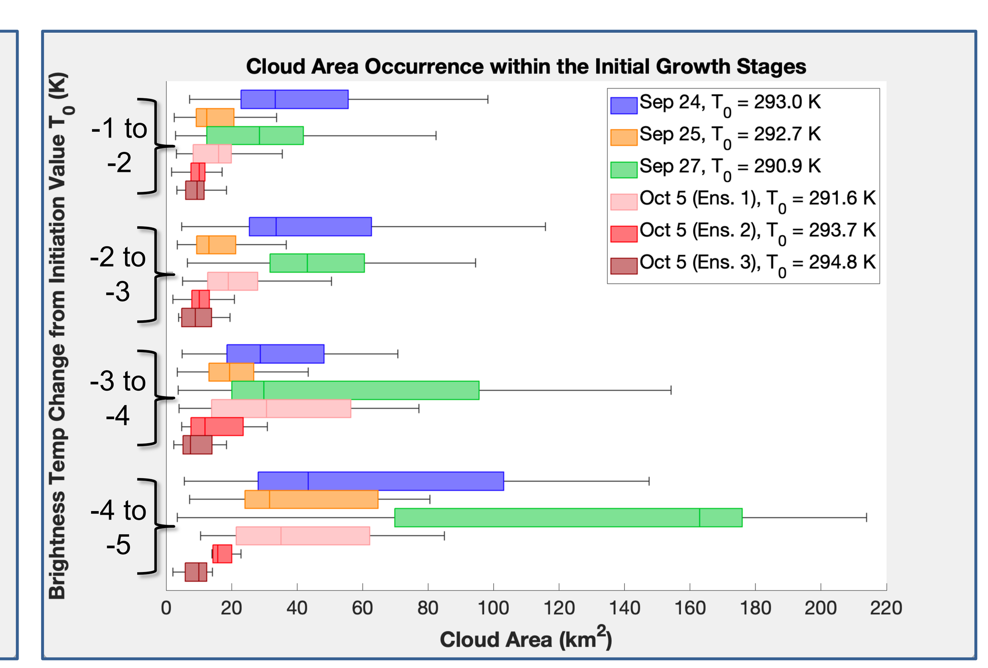




- Ensembles after 9/24 are mostly short-lived (< 30 min) cumulus, exponentially decreasing in frequency at greater lifetimes.
- Ensembles with more complex lifecycles weigh toward higher lifetimes (see 9/24).
- Increasing lifetime yields a larger max area, but with trend lines shifted slightly by ensemble.
- A higher masking threshold reduces sample size, which applied to 9/24 given organized convective cells.

Cloud Growth Identification and Behavior





- A mature stage is likely discernable once clouds reach > 15-min lifetime.
- Multiple mature stages seem to appear after at least 45-60 min duration.

- Initiation BT (T_0), as determined from small clouds (~2-4 km^2) in ensemble, is assumed a baseline for measuring initial cloud growths.
- Despite significant overlap in area ranges, a minor increase during growth is evident from 9/25, 9/27, and Oct 5 (#1).

Conclusions

- Cloud tracking with geostationary imagery provides measurements of cloud lifetime that vary with environmental influences.
- Selecting ensembles for analysis appears beneficial for narrowing the number of possible influences spanning the tracking domain.
- In general, longer lifetimes suggest increased cloud area and complex lifecycles with multiple mature stages.
- Noisy variations in BT are common when identifying stages, a likely cause for the difficulty in relating BT drops to initial growths in area.
- Still need to relate environment variables (e.g., shear or instability) quantitatively to the apparent lifecycles found within ensembles.

Acknowledgement

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