# Finding the Line Between Clouds and Clear Sky

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## Motivation

Clouds have a direct impact on the amount of short-wave and long-wave radiation that reaches the surface of the Earth by reflecting, scattering, absorbing, and reemitting the incoming and outgoing radiation. Clouds affect aviation operations and surface air temperatures day and night. Solar power generation is directly related to incoming shortwave energy during the day. Traditional methods to measure how much cloud is present often use visible light all-sky cameras, but these do not work at night. Our thermal IR all-sky camera observes the temperatures of cloud bases consistently day and night every 30 sec.

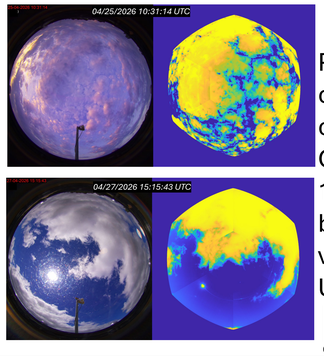

*(left) Visible all-sky camera uses a fish-eye lens. (right) Thermal IR camera mechanically scans and combines 7 separate images.*

## Data and Methods

We use data from NCSU's Eastern Carolina Atmospheric Observing Site (ECOAS) in Plymouth, NC to analyze cloud characteristics. An Infrared Thermal All-Sky Camera measures cloud base and clear sky temperatures. Lower cloud bases have warmer temperatures than higher cloud bases. Once clouds are distinguished from clear sky, we can calculate cloud fraction. Cloud fraction describes what proportion of the sky is covered with clouds and varies from 0 for clear skies to 1 for overcast. Sequences of the cloud fraction describe cloudiness transitions.

## Summary of Findings

While it is easy for the human eye to distinguish clouds from clear sky portions of cloud images, it is difficult to fully automate since clear sky temperatures vary with atmospheric conditions and time of day and overcast periods have no clear sky to contrast against. To develop an empirical relation that distinguishes cloud from background sky, we identified clear sky areas in Thermal IR images by hand for different atmospheric temperature profiles. Cloud fraction changes as clouds move across the sky and evolve at the same time. Initial work indicates that cloud fraction can vary from nearly clear to overcast on time scales of minutes to hours.

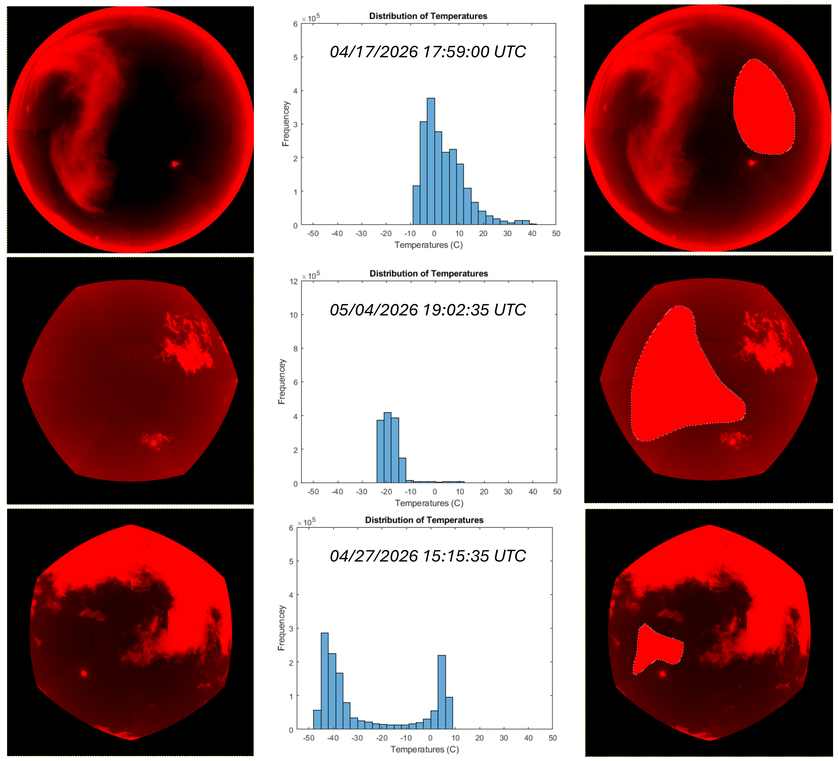



## Visible vs Infrared

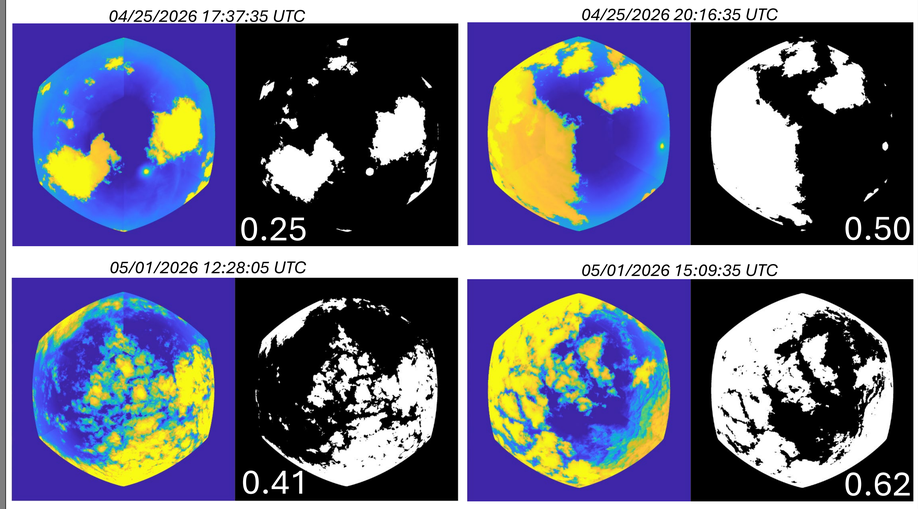
Pairs of Visible (left) and Thermal IR (right) All-sky camera images for two different times. The quality of information on clouds from a Visible All-Sky Camera varies with sun angle. At a low sun angle at 10:31 UTC (5:31 am local time) (top row), cloud boundaries are harder to discern in the visible light view as compared to later in the morning at 15:15 UTC (10:15 am local time) (bottom row).

## Identifying Background Sky

We found that clear sky IR temperatures vary considerably with surface temperature and the temperature profile so a single threshold to distinguish cloud from clear sky was not workable. To create an adaptive threshold method to reliably identify cloud from background sky we looked at dozens of examples across several months of data. Photo editing software (GNU Image Manipulation Program, GIMP) lets us view, enhance, and edit the image. We identified a clear sky portion in each example image by hand. Data from within the clear sky mask for different surface temperatures is input to an empirical relation that adapts to surface temperature conditions.

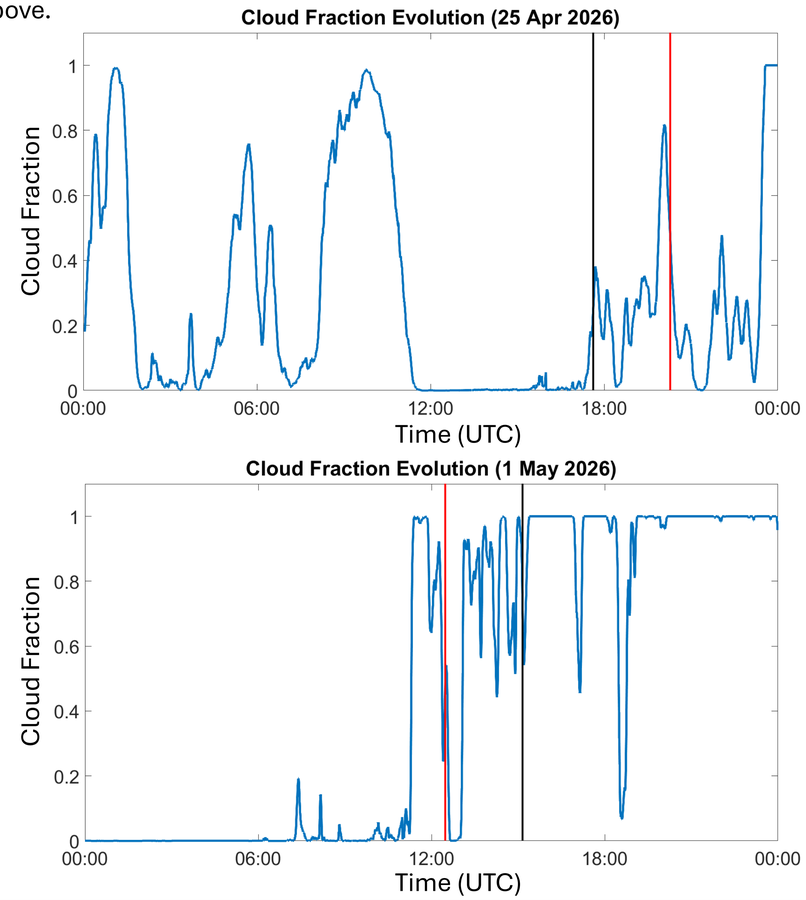



## Examples of Cloud Fraction Identification




Pairs of images showing relative Thermal IR temperatures (blue-yellow) and identified cloud fraction (white and black). Numbers are cloud fraction values.

Cloud fraction time series for two example days show both more gradual and more rapid changes. Vertical lines correspond to times of images in panel above.

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