Correlating Satellite Cloud Cover with Sky Cameras

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Abstract

The role of clouds is manifold in understanding the various events in the atmosphere, and also in studying the radiative balance of the earth. The conventional manner of such cloud analysis is performed mainly via satellite images. The Moderate Resolution Imaging Spectroradiometers (MODIS) installed on National Aeronautics and Space Administration (NASA) Earth Observing Systems (EOS) Terra and Aqua satellites is an excellent source of such important and long-term record of climate data. Amongst other useful products, one of the important contributions from MODIS images is cloud mask that indicates the presence of cloud over a particular area. However, its use is limited because it can provide a top-view of cloud formation, effectively neglecting the low-lying clouds. It also has low temporal and spatial resolutions, as its satellites passes over Singapore only twice a day. Therefore, images captured using ground-based sky cameras are now slowly gaining popularity amongst the remote sensing analysts.

In this paper, we study the relation between the cloud mask obtained from MODIS images, with the coverage obtained from ground-based sky cameras. This will help us to better understand cloud formation in the atmosphere – both from satellite images and ground-based observations.

We designed and deployed our custom-built sky cameras at the rooftop of our university building (1.3483° N, 103.6831° E). These ground-based sky camera captures the sky scene at an interval of 2 minutes. These sky cameras capture images in the visible-light spectrum, and have a higher temporal and spatial resolutions, as compared to the conventional satellite images. We use the ratio of red and blue color channels to detect clouds in the captured sky/cloud image [1]. This captured sky/cloud images assist us in computing the cloud coverage, which is defined as the ratio of the sky scene covered by clouds.

The cloud mask values are obtained from the MODIS products. The cloud mask values calculated from MODIS products have spatial resolution of 1 km$^2$ (1 pixel) and is available twice a day (4 UTC and 7 UTC). In this experiment, we process cloud mask values for 3 km by 3 km area (9 pixels) with the location of sky camera as the center. The value of cloud mask can take any values 0, 64, 128 or 192; 0 indicates 100 % cloudy condition and 192 indicates the cloud free condition. For this paper, we take the average cloud coverage over the 9 pixel area and normalize it to the range of 0 and 100, such that the 0 represent no cloud and 100 represent full cloud conditions.

In our experiments $^1$, we consider all the MODIS data in the year 2015. We process cloud mask values for 3 km $\times$ 3 km area (9 pixels) with the sky camera as the center location. We compute the average of the entire 9 pixel block (excluding invalid data points). We also compute the cloud coverage of the nearest sky camera image, captured by our sky camera. Figure 1 shows the statistical analysis of the average cloud mask value with respect to the cloud coverage from images. We bin the average cloud mask values into 4 distinct bins, as the actual cloud mask has 4 distinct levels. We observe the general trend between cloud mask and cloud coverage – the cloud coverage increases with an increase in the cloud mask values. However, there is a higher variation in cloud coverage for higher cloud mask values. This is because of the possible area mismatch between MODIS and ground-based sky cameras.

In the extended paper, we will provide further visual comparative results between satellite- and ground-based images. This analysis between satellite- and ground-based observations will provide the remote sensing analysts further insights into cloud formation, and understanding the role of clouds in the radiative balance of the earth.

REFERENCES


$^1$The source codes of these experiments will be made available online in the final version.