Modis Maximum NDVI, Minimum Blue, and Average Cloud-free Monthly Composites of Southeast Asia

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Abstract- Using MODIS data and several different compositing algorithms utilizing the average cloud free days in a compositing period, maximum ndvi, or dual maximum NDVI/minimum blue, multi resolution composites (250m, 500m, 1km) have been produced for Southeast Asia, with spectral bands ranging from the visible to short-wave infrared with a single band in the thermal (for land and sea surface temperature). A total of nine composites have been produced for the months of May and August in 2003, including blue, green, red, NIR, three in the SWIR, and several to specifically monitor vegetation health.
Keywords: Compositing, Modis, Vegetation, Southeast Asia

1. INTRODUCTION

Cloud-free composite images are an effective method for establishing a regional view of Southeast Asia. In addition, they provide a baseline for regional environmental studies of vegetation health, land and sea surface temperature, and other environmental parameters. Thus, it was deemed of the utmost importance to create an effective method of compositing, selecting pixels that most represent the radiation being reflected or emitted from the earth's surface, in the face of the persistent haze and cloudiness prevalent in tropical Southeast Asia.

The NASA MODIS team has developed a compositing methodology incorporating the use of combined Bi-directional Reflectance Function (BRDF), constrained-view maximum NDVI value compositing (CV-MVC), and maximum NDVI value compositing (MVC), depending upon how many cloud free days are available [4,5,7]. BRDF and CV-MVC require a greater number of cloud-free days in a given period to function effectively. It is then not surprising that these two methods work well in the relatively cloud-free arid to temperate zones, but not over tropical rainforest areas with persistent cloud cover [7]. This paper presents monthly composites based on alternative compositing techniques to that of NASA's, or variations on the MVC approach, that may be more suited to the tropics.

2. MATERIALS AND METHODS

1) Compositing area

The full extent of the composite coverage encompasses a vast area within the reach of the ground station at the Centre for Remote Imaging, Sensing and Processing (CRISP), from latitude 30°N to 25°S, and longitude 70°E to 140°E: nearly all of Southeast Asia, and a sizeable portion of south Asia. As this study focuses on Southeast Asia, the compositing region has been reduced to the area shown in Figure 2.

2) Satellite data and preparatory processing

The composites have been created using Terra MODIS direct broadcast data received and processed in CRISP. CRISP has successfully integrated the NASA surface reflectance code (PGE11) into the MODIS processing system. Several of the composites created for temporal analysis of vegetation have been created using CRISP's in-house Rayleigh correction program. The compositing process utilizes the IMAPP cloud-mask algorithm, produced by the University of Wisconsin MODIS group, to differentiate between cloud-affected and cloud free pixels.

3) Compositing Methodologies

There are three different surface reflectance compositing techniques utilized in this study. The first method uses an average cloud-free and maximum NDVI algorithm. If the pixel is deemed cloud-free its surface reflectance value is averaged with the other cloud-free pixels in that pass. If a pixel for a given period only has "uncertain" pixels, which may have sub-pixel clouds, then the maximum NDVI pixel is taken. The next compositing method uses a dual maximum ndvi/ minimum blue algorithm (MNMB), aiming to be simple and effective at selecting against cloud or haze affected pixels, as wavelengths in the blue region of the spectrum are sensitive to cloud and haze. The third and final compositing method is the one to which the previous two will be compared, the traditional MVC algorithm. The composites are created on a monthly basis, just enough to create a nearly cloud-free scene on all but the most cloudy areas.

3. RESULTS

1) Regional Cloudiness and Haze

Clouds pose a significant obstacle to compositing in Southeast Asia. To analyse the cloudiness that accompanied each composite creation, a running total of the number of cloud-free days for a given pixel was recorded. (Figure 1)

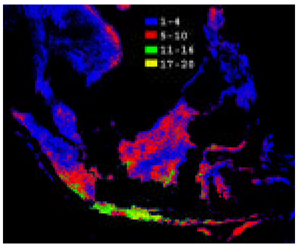

Figure 1: the number of cloud-free passes for the July-August composite.

The total number of daytime Terra passes for the compositing period between 11 July 2003 and 11 August 2003 was fifty-two passes. The percentage of cloud-free passes to total passes for any pixel in a given composite never went above 50%. This is not surprising as sizeable areas of Southeast Asia are reported to have permanent cloud-cover. Achard estimates that 20% of Sumatra and Peninsular Malaysia, and 9% of Borneo are permanent cloud-cover areas [1].

Regional haze, from forest fires to other types of aerosol pollution, is a considerable obstacle in the production of composites in Southeast Asia, and one of the reasons why the average cloud-free composite method gave a poor result. The image in Figure 2 shows cloud and haze contamination in south Sumatra, Java, and South and Central Kalimantan. The cloud contamination is due to the IMAPP cloud mask's inability to perfectly filter out cloud-affected pixels, which was also found to be the case in NASA's cloud mask algorithm, PGE04, in a study conducted at CRISP (John Low, unpublished).

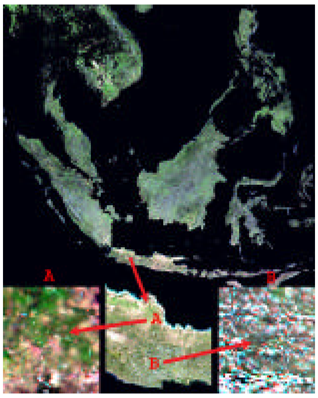

Figure 2: July Average Cloud-free Composite: The above image reveals the geographical extent for this study. The three image tiles display two geographically distinct regions in Java. A nearly cloud-free image of a lowland area outside Jakarta (A), and a), and a mountainous and cloud contaminated region to the south (B).

2) Composite Products

True Colour and False Colour SWIR composites have been produced for the time period from 11 July 2003, to 11 August 2003 with the three aforementioned compositing techniques. A detailed discussion of the composite products follows in section 4.

3) Vegetation Index Composites

For the July/August composites, the maximum and average NDVI images were created and compared, using simple differencing: the average NDVI image minus the maximum (Figure 3). Most notable is the striking contrast between the Northern and Southern portions of the difference image. The maximum NDVI deviated from the average in the South, but not in the North. An explanation for this is closely tied to the weather patterns present in the region at the time of compositing.

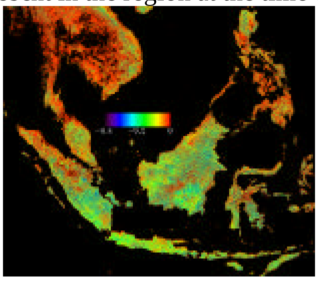

Figure 3: a difference image between two NDVI composites, both from the period July 11-August 11 2003, by the average cloud-free and MVC compositing methods. Average NDVI minus

During this period, the North is experiencing monsoon, evidenced by the rain-swollen Tonle Sap Lake in Cambodia, while the Southern portion of the image, including Kalimantan, South Sumatra and Java, is experiencing drier weather. Thus, within this period, we would expect the North to be cloudy (Figure 1), the vegetation health better, and the NDVI to be higher. Both the aforementioned would tend to bring the average NDVI closer to the maximum in the North. The opposite case exists in the South: fewer clouds and the start of the dry season means more cloud-free days and the gradual drying out of vegetation. This would lead to a marked decrease in NDVI over the compositing period, which may result in a reduced average NDVI in spite of a high maximum NDVI figure.

4. DISCUSSION AND CONCLUSIONS

1) Compositing Algorithms

The different compositing techniques presented in this paper and the initial results provide clues to creating an effective composite in the cloud-affected region of Southeast Asia.

The averaging methodology was used to account for variation within the compositing period, due to the extended length of each compositing period necessary for this region. Over relatively cloud-free areas, specifically parts of Java, the algorithm functioned effectively. However, in areas with more clouds, the limits of the cloud mask became apparent, with misclassified cloudy pixels being averaged, resulting in a mixed cloud/non-cloud composite pixel (Figure 2). The IMAPP cloud mask also misidentified bare and/or burned peat land in Sumatra (Riau) and bare land in other parts of the region as cloudy or uncertain cloudy. This posed a serious problem for compositing in areas where land conversion into these classes is happening rapidly [6]. With the present state of both the IMAPP and NASA cloud mask algorithms, more research must be done before averaging of the cloud-free days becomes an option for compositing, as the MVC method is currently superior.

The MNMB algorithm shows promise. The results contained pixels which from a visual analysis were clear in areas that were previously haze- and cloud-affected in the average cloud-free composite image. This was clearly evident in South-western Kalimantan, a region of plantation and forest burning during this period (Figure

4). The Maximum NDVI/ Minimum Blue method has one striking drawback: the problem of cloud shadow contamination. The MVC method naturally selects against cloud-shadow pixels.

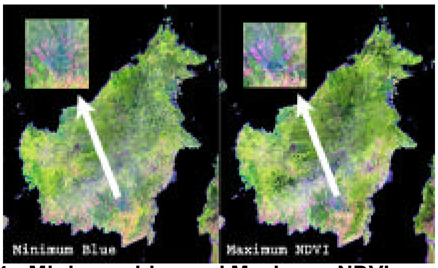

Figure 4: Minimum blue and Maximum NDVI composites, with an illustration of particulary hazy area.

To take an initial step at solving this problem with MNMB, maximum NDVI was used for pixel selection for NDVI values below .70, while minimum blue selection was used for those values above, for more than 60% of the image pixels. Thresholding was a simple, but not perfect, solution to the problem and certainly demands further study to allow for a compositing algorithm which uses solely minimum blue. Cloud shadow identification is present in the IMAPP and NASA cloud-mask algorithms and is presently being integrated into the compositing code.

2) Regional and Seasonal Vegetation Change

With the NDVI and NDWI composites created for the May/ June and July/ August month-long compositing periods, simple difference maps have been created, revealing seasonal and regional changes in vegetation health and water content. (Figure 5)

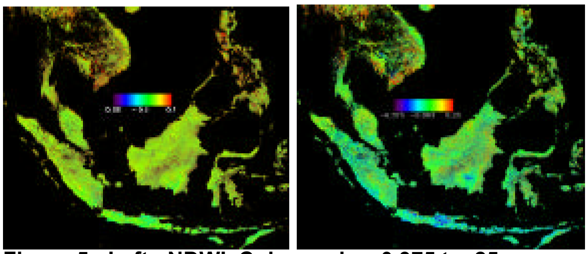

Figure 5: Left: NDWI. Color scale: -0.375 to .25
Right: NDVI. Color scale: -0.26 to 0.10

With the onset of the inter-monsoon period from May to August, the vegetation becomes dryer and would be expected to show a decrease in both NDVI and NDWI, especially in Kalimantan, Sumatra, and Java. This can be seen in Figure 6, where on a regional scale the NDVI has dropped by .05, and more precipitously in Java, which commonly has NDVI values dropping .2 units from May to August. The change isn't nearly as strong as one increases in latitude. In the North, NDVI values in many cases increased, with a regional average of approximately .1 units, while the NDWI stayed constant. Of interesting note in Java are the different seasonal vegetation regimes between high and low elevation. High on the volcanoes, NDWI and NDVI showed little change from May to August. In direct contrast to this were the surrounding lowlands, which decreased noticeably in both NDWI and NDVI. This is not surprising, as the highlands would certainly get a more constant supply of water from orographic uplift of air masses, and the resulting rain.

There were some anomalies in Sumatra, Kalimantan, and Java. One example is near the city of Jakarta, where there is a marked increase in both NDVI and NDWI that cannot be explained by seasonal change. Such anomalies may be caused by human's intervention in the natural system, *e.g.* irrigated agriculture; regardless of the cause, it certainly merits a more in depth analysis.

Alternate compositing methods to the commonly used MVC exist, and show promise, as indicated by this study. This area of research merits further exploration due to the necessity for and applicability of accurate composites for regional visualization and environmental monitoring in Southeast Asia.

REFERENCES

[1] Achard, F. and C. Estreguil, 1995. Forest Classification of Southeast Asia Using NOAA AVHRR Data, *Remote Sensing of the Environment*, 54: 198-208.

[2] Holben, B.N., 1986. Characteristics of maximum-value composite images from temporal AVHRR data, *International Journal of Remote Sensing*, 7: 1417-1434.

[3] Huete, A. R. and H.Q. Liu, 1997. A Comparison of Vegetation Indices over a Global Set of TM Images for EOS-MODIS, *Remote Sensing of the Environment*, 59: 440-451.

[4] Huete, A. R., C. Justice, and W. Leeuwen, 1997. MODIS Vegetation Index (MOD 13), *MODIS Algorithm Theoretical Basis Document, Version 3*.

[5] Leeuwen, W., A. Huete, and T. Laing, 1999. MODIS Vegetation Index Compositing Approach: a prototype with AVHRR data, *Remote Sensing of the Environment*, 69: 264-280.

[6] Miettinen, J. and S. C. Liew, 2003. Connection between fire and land cover change in Riau Province, Sumatra from 1998 to 2002, *Geoscience and Remote Sensing Symposium IGARSS '03.* Proceedings.

[7] Miura, T., K. Didan, A. Huete, and E. Rodriguez, 2001. A performance evaluation of the MODIS vegetation index compositing algorithm, *Geoscience and Remote Sensing Symposium, IGARSS '01*, 4: 1812-1814.