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Cloud Cover Correction of Detected Hotspots Over Indonesia

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The presence of fires may be detected by space-based remote sensing. Fire detection algorithms allow fire “hotspots” to be mapped, providing information on fire extent, fire frequency and seasonal patterns of fire occurrence. However, fire can only be detected if the land is clearly visible from space.. Cloud covering the land may obscure the satellite view and therefore the presence of fire cannot be observed. This phenomena will reduce the number of fire pixels detected by satellites from space. As a consequence, the number of fires or hotspots observed may be lower than the actual number of fires. We present a method to extrapolate the number of observed hotspots in Indonesia based on observations of cloud cover.

Keywords: Indofire, cloud cover, hotspot, extrapolation.

1. INTRODUCTION

Fire Watch Indonesia (FWI), otherwise known as the IndoFire system [1], was developed to fulfill the Indonesian Government’s need for a fire monitoring system as a base system for forest fire control and forest management. This fire monitoring system is used by the three agencies authorized for fire monitoring in Indonesia: the Forestry Ministry, the Ministry of Environment, and LAPAN (National Institute of Aeronautics and Space) [1, 2]. The IndoFire system was developed in 2007 as a collaborative project between the Indonesian Government and the Australian Government, through AusAID and the Western Australian government department, Landgate [1]. The IndoFire system allows detection and mapping of fire hotpots (FHS) over Indonesia.

One of the factors affecting detection of fires using a remote sensing system is cloud cover[3, 4]. Indonesia, as an archipelago country located in the tropics with a humid climate, is characterized by frequent cloud cover. Some of the agricultural practices involve extensive use of fire. These practices, coupled with naturally occurring fires, contribute to variable fire regimes[5]. The high incidence of cloud cover tends to constrain the ability of fire monitoring from space using satellite data.

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It is possible to quantify the amount of cloud cover, and from this estimate the impact of cloud on the number of detected fires. Seielstad [6] determined that on average, 53% of fires in Alaska were not detected remotely by fire detection algorithms due to interference by clouds. Flannigan and Haar [7] found similar results, reporting that 59% of fires in central Alberta were undetected by fire detection algorithms due to cloud cover.

This paper presents a study of the relationship between temporal patterns of fire activity and cloud coverage in Indonesia. This paper also presents an approach to estimating a corrected fire hotspot number based on using remotely sensed cloud cover proportions.

2. METHODS

The simple approach adopted to adjust the FHS number was to determine the cloud cover proportion over land then use this to extrapolate to a cloud free FHS value.

Since cloud coverage obstructs the detection of FHS by satellite, the true number of fires within the area is greater than the number of FHS detected by satellite alone. The true number of fires can be approximated by using an extrapolation technique. The approach adopted here is to estimate the number of FHS for the whole Indonesian area that is free from cloud.

The FHS number was determined from fire pixels

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which were detected by the Indofire algorithm using MODIS data over Indonesia. The fire pixels detected by the Indofire system were accessed from the website http://IndoFire.landgate.wa.gov.au/IndoFire.asp. The steps of working proccesses are given in the list below.

1. Retrieving data of detected FHS from Indofire for a decade
2. Extracting the data and counting the yearly number of FHS for the decade
3. Retrieving cloud cover data over Indonesia for a considered decade
4. Plotting averaged yearly cloud cover and its standard deviation as an error bar
5. Overlay yearly detected FHS number and the affiliated cloud cover
6. Estimate the real number of FHS by extrapolating the detected FHS based on cloud cover fraction

The existing cloud that obscures the satellite sensor observing fire can be retrieved from the Giovani's website that is http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=MODIS_MONTHLY_L3. Fractions of cloud coverages are provided on a monthly basis worldwide. The cloud coverage data for the region of interest that is Indonesia can be retrieved by constraining the search area within a specified latitude and longitude border for certain range of time. The use of latitude and longitude values which borders Indonesian areas are Latitude 6N to 11S and Longitude 95E to 141E. The Giovanni website then displays the result of the cloud coverage request and returns data which are downloadable. For instance, by inputting the latitude-longitude border of Indonesia, we can get the cloud cover data over Indonesia in the intended range of time.

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3. EXPERIMENTAL RESULT

Figure 1 shows the annual cloud fraction, which is derived from the average of monthly cloud fraction data for every year, over Indonesia for the period 2001 to 2010, obtained from Giovanni GES DISC. The figure shows the high fraction of cloud coverage over Indonesia; it ranges from 70% to 90%. The high coverage of cloud potentially obscures fire observation from space using satellite remote sensing. Active fires which possibly occur in the area covered by cloud, might not be detected by a remote sensing satellite because the thermal radiance emitted from fires cannot pass through the existing cloud.

Error bars in the figure represent the standard deviation of monthly data every year for the region selected. For example, the average cloud cover for 2001 over Indonesia based on monthly data was 82.8% with standard deviation 10.3%. This means that in 2001 the cloud coverage over Indonesia was 82.8% ± 10.3%, or in the range of 72.5% up to 93.1%. A similar calculation is applied to all cloud-affected data in Figure 1 for the decade 2001-2010. This calculation gives the average cloud coverage over Indonesia for the decade 2001-2010 as 80.4% ± 9.0%. This means that on average the whole Indonesian areas were covered by cloud 80.4% of the time for the decade 2001-2010. The fraction of cloud coverage was up and down every year along the decade. But the trend of data increased for the whole year in the decade. It was reported that Indonesia dealt with a lot of flooding in this decade[8]. The flooding in 2002 as reported occurred in Java but flooding and heavy rain happened in 2010 for Indonesia. The rain was mainly associated with the existing cloud. The big and high fraction of cloud indicates the big rain will fall. In this matter we can say that the trend of rainfall is closely related to the trend of cloud cover. Therefore, the trend of cloud cover in Indonesia increased gradually in the decade of 2001-2010.

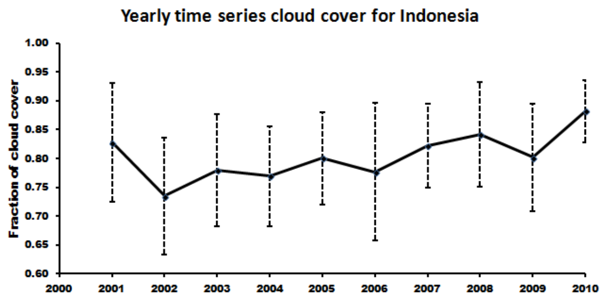

Figure 1. Yearly time series cloud cover for Indonesia (Latitude 6N to 11S and Longitude 95E to 141E) for the decade 2001-2010. Data are derived from the average monthly cloud cover data every year from Giovanni GES DISC (Goddard Earth Science Data and Information Services Center). Error bars represent the standard deviations of cloud cover for the region selected.

The true number of FHS represented by the extrapolated number of FHS is calculated by referring the number of detected FHS by Indofire and the value of cloud cover in the corresponding area. For example, there were 12,615 FHS detected by the IndoFire system during 2001 over the Indonesian area (see , with 83% cloud coverage. This means that (100-83)% = 17% of the Indonesian area that is free from clouds has 12,615 FHS. We therefore expect that in a 100% clear area we will detect 12615/0.17=73,414 FHS. This calculation method is applied to extrapolate the actual number of yearly fires detected by Indofire based on the cloud coverage statistics as shown in Figure 1. The result of the yearly extrapolated FHS data in the decade 2001-2010 is shown in Figure 2.

The pattern of FHS occurrence in Figure 2 shows that the average number of FHS detected using IndoFire data is only 19.6% of the average number of actual fires based on the yearly extrapolation number of FHS over the decade 2001-2010. This result is a realistic value because the average of cloud cover in Indonesia, based on Figure 1, for the decade 2001-2010 is about 80.4%.

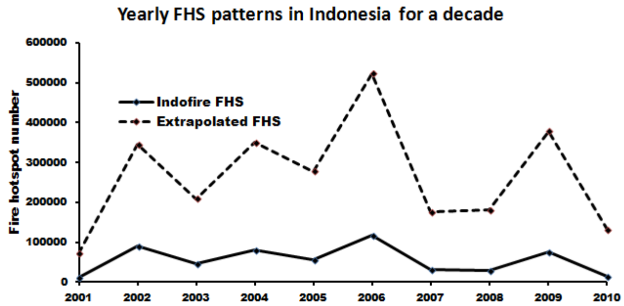

Figure 2. The time series of yearly IndoFire FHS and extrapolated number of actual fires over Indonesia for the decade 2001-2010.

The actual number of fires (referred to here as extrapolated FHS data shown by dash dot) potentially provides a more realistic overview of the year-to-year variability in fire occurrence; however, it is important to note that there is potential error to get different results of occurring fire activity due to differences in the cyclic nature of variability in cloud cover. Presenting the number of occurring fire only from the detected fire by satellite leads to an information's error due to high fraction of cloud cover. Although the trend of detected FHS (drawn by bold line) is similar to the trend of the real number of occurring fire (dot line), the information of the corrected cloud cover of detected FHS by satellite is important.

Extrapolating the number of occurring FHS based on cloud cover of a small range of time will better describe actual fire activity, because an estimation of the number of FHS is made in almost real conditions of cloud coverage. For example, extrapolating the number of FHS based on yearly cloud coverage patterns will implicitly estimate the fire activity in dry season (which normally has low cloud coverage) based on wet season cloud coverage. The yearly cloud coverage data is an average of cloud cover in a year, and the greatest contribution of cloud cover comes from the wet season. In contrast the average number of FHS in a year is mostly derived from fire in the dry season. It is possible to generate a false estimation of the number of FHS; however, predicting the number of FHS based on monthly cloud patterns will minimize the false estimation of fire activity in the dry season using cloud coverage of the wet season. Therefore, monthly data of cloud coverage more accurately describe the pattern of cloud cover related to the existing seasons in Indonesia (dry and wet seasons).

Averaging the fraction of cloud cover over the year gives the assumption that the cloud fraction is the same for month by month. In fact, Indonesia is covered by higher cloud in wet season compared to dry season. On this basis we average the monthly extrapolated FHS number to describe the yearly number of the occurring fire.

4. CONCLUSIONS

Cloud cover existence obscures fire monitoring because it blocks the viewing of land surfaces from space. The increasing cloud coverage leads to the decreasing possibility of observing clear land where fires may occur. Based on the Giovanni-GES DISC cloud fraction data, Indonesia had high cloud coverage in between 70% and 90% over a decade (2001-2010). This leads to the reduction of the number of FHS detected using the IndoFire system by 80.4% from the number of extrapolated FHS estimated as fire. With reference to the investigated data, Indonesia was on average covered by cloud in about 80.4%. From those cloud coverage values, we can say that the visible clear land in Indonesia was 19.6% in average. Based on this research we suggest that the fraction of cloud cover needs to be considered in reporting the number of occurring FHS in Indonesia Without considering cloud fraction, a potential error is expected to occur up to 80% in the report of FHS number occurring in Indonesia. With respect to the pattern of yearly FHS number provided in the Indofire system, it is, therefore, better to leave the information in the yearly FHS approximation number, instead of stated average number in a decade.

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