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THRESHOLD-VARIATION ANALYSIS OF MOD14 ALGORITHM MODEL USING MODIS DATASETS OVER TROPICAL AREA IN INDONESIA

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ABSTRACT: The Moderate Resolution Imaging Spectroradiometer (MODIS) which is equipped with thermal bands for measuring the temperature of the earth's surface has been widely utilized in fire detection activities. Of the fire detection algorithms developed for MODIS the most commonly applied algorithm principle is the contextual algorithm. Such global algorithms for fire detection can be customized for local or regional areas to improve the accuracy of fire detection. For this reason there has been substantial research performed to apply and assess how accurate the global algorithm results are in certain local or regional areas. In principle, fire pixels detection is base on dichotomizing assessed imagery pixels values using certain threshold value. Determining the best threshold value leads to optimal detection results and minimum errors. This paper analyses the impact of variation of T_4 and ΔT threshold values on outputs from the MOD14 algorithm using MODIS data within different seasons in Indonesia. Analysis is conducted by analysis of the sensitivity of detected Fire Hotspots (FHS) to changes of T_4 and ΔT and also through statistical calculations. The results show that the sensitivity of the MODIS FHS algorithm is different between dry and wet seasons which indicates the need for different threshold values to be applied to optimise fire detection using MODIS within dry and wet seasons.

KEY WORDS: MODIS, contextual-algorithm, threshold, seasons, tropical-area.

1. INTRODUCTION

1.1. Background

Fire plays a significant role within most terrestrial vegetation alteration and land cover change. During biomass burning gases and particulate matter are released into the atmosphere and contribute to atmospheric chemical reactions and physical processes. Biomass burning with the release of gases and aerosols potentially makes a significant contribution to climate change. Also, the change in the balance of an ecosystem due to the impact of burning biomes can affect the resilience of the ecosystem to adapt to climate change. Hence monitoring fire occurrence is significant in managing the impact of climate change. Scientists and policy decision makers in many countries are directing resources to the study of the effect of forest burning on the environment.

Indonesia government agencies which monitor fire using different satellite-based fire detection algorithms include the ASEAN Specialised Meteorological Centre (ASMC) in Forestry Ministry and Indofire in National Institute of Aeronautics and Space (LAPAN). Because agencies apply different methods in different locations and times based on their governmental roles, they often report different results in a number of detected Fire Hotspots (FHS). Validation activities are therefore important to estimate the correct number of FHS.

Fire detection activities are performed not only in Indonesia but also in many areas of the world. NASA's science teams extensive research on fire detection issues has led to the development of an algorithm called 'MOD14 algorithm' which is applied globally but gives differing results on a regional basis. Researchers around the world continue to assess the accuracy of MOD14-based FHS detection method in their own areas to evaluate errors of omission and commission.

The most reliable data to validate results of recognised FHS from satellites is ground truth data. The Forestry Ministry as the authorised Indonesian government agency has this task. It collects fire data from local forestry agency (BKSDA) and also performs its own field validation. Ground data collection requires considerable effort in terms of funding, facilities, manpower, and time. Hence ground data are limited and in order to have confidence in FHS detection results other validation methods are required. As an example, LAPAN validates FHS detection using a combination of ground data and high resolution satellite imagery such as Système Pour l'Observation de la Terre (SPOT) imagery for which they run their own satellite receiver in Pare-Pare Sulawesi.

The LAPAN approach did not provide a definite estimate of FHS detection accuracy reportedly due to some environmental factors. Here, haze and cloud were reported as a key factor influencing the accuracy of fire detection (Vetrita, Haryani, and Komaruddin, 2012).

Additionally, another environmental factor such as precipitation was reported as one other factor which obscured fire occurrence detection in the Brazilian Amazon region (Schroeder, Csiszar, and Morisette, 2008). Precipitation in Indonesia varies considerably between dry season and wet season. A high level of precipitation is commonly encountered in the wet season and there is typically little rain in dry season.

To account for environmental influences the statistical analysis of suitable temperature threshold values within the fire detection algorithm is another approach which has been used to investigate the accuracy of FHS detection. Liew et.al. (2006) proposed method to retrieve the optimal thresholds for fire detection from a statistical point of view. This paper studies the impacts of applying various thresholds in the MOD14 algorithm using MODIS datasets over Indonesia by considering the sensitivity of FHS detection in the dry and wet seasons.

1.2. Fire detection principle

Most satellite-based or airborne remote sensing instruments are designed to measure a combination of surface and atmospheric signals in the visible and near infra red spectrum. To gain better result in fire and burned scars monitoring from a fire detection perspective, the MODIS instrument aboard the Terra and Aqua satellites were designed to have improved satellite-based FHS detection capabilities by the addition of more channels in the thermal band compared its predecessor instruments, NOAA-AVHRR (National Oceanic and Atmospheric Administration - Advanced Very High Resolution Radiometer).

In satellite remote sensing especially for passive remote sensing sensors, fire existence can be detected by thermal infra red sensors because most of the fires emit radiation in this range (3 – 12 μm) so satellite-base sensors for fire detection purposes are focus on this wavelength range.

Each channel of the satellite-based sensor has different sensitivity to land surface thermal properties. The radiated energy of fires can be derived from a combination of several channels. Kaufman, Kleidman, and King (1998) found in their simulation that the best channel to derive fire radiated energy is the 3,9 μm channel because the relationship of the fire radiated energy and the apparent temperature is least sensitive to the mixture of temperature in the fires. They prove that the greatest contrast images between the fire pixel and the surrounding pixels is shown from the 3,9 μm channel.

Accordingly, the most commonly used wavelength bands for fire detection are 4 μm and 11 μm. The 4 μm channel is highly sensitive to the radiated energy emitted from fire, so it has a key role in remote sensing of fire. Brightness temperature calculated from this channel is notated as T_4. Additionally the 11 μm channel on is not as sensitive as the 4 μm channel but it is less influenced by surface reflection. Thus fire detection algorithms consider differences in sensed radiation from both channels.

1.3. Contextual Algorithm

Giglio, et.al (2003) performed fire detection using a contextual algorithm that exploits the strong emission of mid-infrared radiation from fires. The algorithm examines each pixel of the MODIS swath, and ultimately assigns to each one of the following classes: missing data, cloud, water, non-fire, fire, or unknown. The algorithm uses brightness temperatures derived from the MODIS 4 μm and 11 μm channels, denoted by T_4 and T_{11}, respectively.

2. RESEARCH METHODS

The first step in contextual algorithm is a screening test. All examined pixels which cannot pass this test have no chance to go into next steps and they are automatically classified as non fire pixels. The focusing of this research is on the screening step due to its very significant role in the fire detection algorithm. All pixels are examined where their value sit above the determined threshold value of T_4 and $\Delta T = T_4 - T_{11}$.

This paper analyses FHS detection in respect to the variation of the T_4 and ΔT threshold values in the MOD14 algorithm using MODIS datasets over Indonesia. Curves of detected FHS numbers are constructed as the various values of T_4 and ΔT. Threshold values are changed in order to investigate the sensitivity of MODIS FHS detection in the dry and wet seasons over Indonesia.

This investigation has been conducted by partitioning MODIS data into two groups. The first group is MODIS data acquired within the dry season (Aug – Sep 2009) and the second group is datasets from the wet season (Feb 2010). The performance of the MOD14 FHS algorithm is evaluated for each group using graphs of FHS sensitivity and a T-test statistical analysis.

3. RESULTS AND DISCUSSIONS

This paper is concerned only with T_4 and ΔT parameters as they are used on both day and night time MODIS datasets. Iterating the various values of T_4 and ΔT threshold produce the graphs shown in Figure 1 and Figure 2.

Considering the shape of the curves in both figures it is clear that FHS detection is more sensitive to the change in T_4 threshold values rather than ΔT changes. This is used as a basis for further analysis into whether there is significant seasonal influence on the sensitivity of the fire detection algorithm over Indonesia.

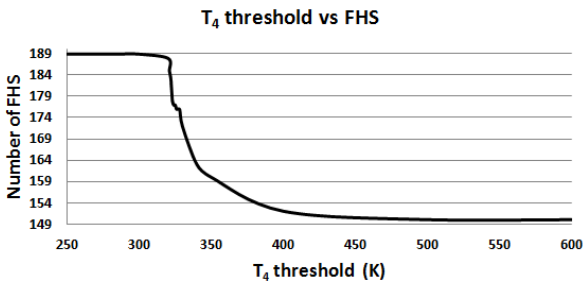

Figure 1. Plot of T_4 threshold values (K) and detected FHS number

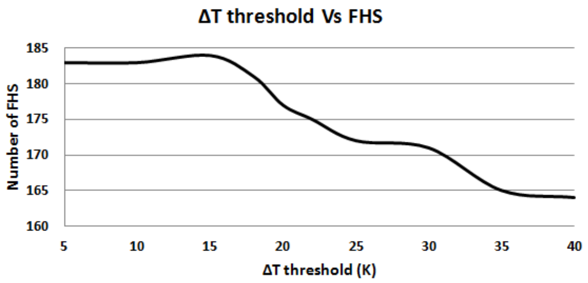

Figure 2. Plot of ΔT threshold values (K) and detected FHS number

Indonesia has only two seasons - the. dry season and the wet season. In the dry season precipitation is very low and most vegetation suffers from drought and is prone to be burning. Naturally, the dry season has a higher average temperature than the wet season.

Investigation of seasonal impacts to fire detection has been conducted by changing threshold values then recompiling the MOD14 algorithm. By normalising the detected number of FHS in dry and wet season separately as percentages, a variation of the T_4 threshold values results in different sensitivity curves as shown in Figure 3 and Figure 4.

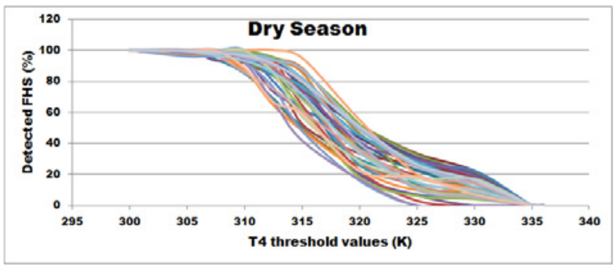

Figure 3. Dry season plot of T_4 threshold values (K) and relative detected FHS (%)

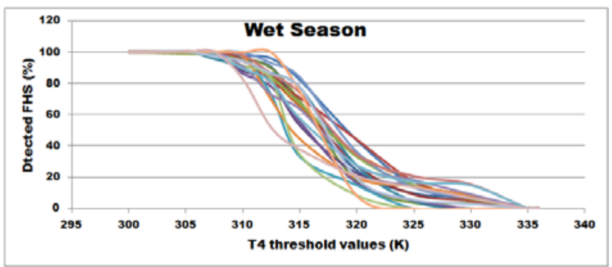

Figure 4. Wet season plot of T_4 threshold values (K) and relative detected FHS (%)

The difference in the curves between the dry season and wet season data is clearly seen by calculating average number of fires detected in each season. The average values from the curves in Figure 3 and Figure 4 is shown in Figure 5.

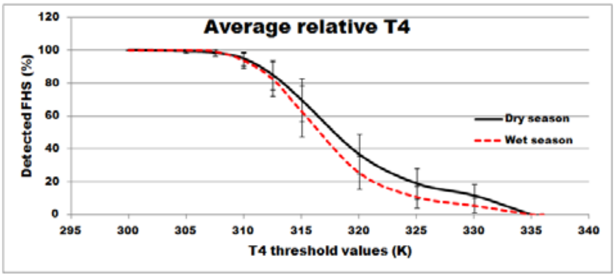

Figure 5. Plot of T4 threshold values (K) and average of relative detected FHS (%)

Figure 5 shows that the MOD14 algorithm displays different sensitivity when it is applied to dry season data compare to wet season data. It indicates that to obtain a certain level of FHS detection sensitivity a higher T_4 threshold value is required in the dry season compare to the wet season.

To confirm the claim above, a statistical analysis was performed to the dry and wet season data groups. The analysis of T-test is mostly used to assess the means differences between two groups (Moore and McCabe, 2003). The T-test is applied to the FHS data from Figure 5 and the results are shown in Table 1.

Table 1. Results of T-test analysis

	Mean	Std. Deviation	Significance (2-tailed)
Dry season	55.8391	42.57335	.001
Wet season	52.7209	44.27578	.003

The results of the T-test analysis show that the dry season data has a statistically significant higher mean value than the wet season data. It indicates that for a given threshold of T_4, the MOD14 algorithm possesses higher sensitivity for dry season datasets compared to the other season. The 2-tailed significance values from the T-test analysis from both seasons sit under 0.05 (Table 1) which confirms that both datasets display significantly different means of the population (Pallant, 2011). We can interpret this as meaning that there is a change in the sensitivity of the MOD14 algorithm to choice of T_4 threshold between the dry and wet seasons and that the accuracy of FHS detection is also significantly different between dry and wet season as a result. Accordingly we find that in the wet season a lower T_4 threshold value is required to gain the same accuracy in FHS detection as dry season. This is a logical finding because increased rain in the wet season leads to decreasing environmental temperature and the temperature of fires are also lower as a result.

4. CONCLUSSIONS

The screening test is the first step of the contextual fire detection algorithm for MODIS and has two significant parameters namely T_4 and ΔT, of which T_4 affects the accuracy of FHS detection significantly more than ΔT. The MOD14 algorithm shows different sensitivity to the choice of T_4 threshold between dry and wet season in Indonesia based on the characteristics of the curves of detected FHS. Statistical analysis indicates that the dry season fire detection algorithm requires a higher T_4 threshold value compared to the wet season in order to provide results at the same level of accuracy. We believe this to be due to the lower environmental temperature characteristic of the wet season which exhibits significantly higher rainfall.

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