DEVELOPMENT OF MODIS DAILY DYNAMIC CLOUD-FREE COMPOSITE ALGORITHM FOR DETECTING SHORT-TERM CHANGES

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ABSTRACT: To obtain cloud-free image from high temporal resolution satellite imagery such as MODIS and AVHRR, static composite method has been frequently used. The static composite algorithm uses non-overlapping composite period (8-day, 16-day, or a month). Although static composite algorithms (maximum NDVI, minblue, minVZA, etc.) are simple and easy to apply, these algorithms are not suitable for the observing near-real time phenomena. In this study, we suggest the MODIS daily dynamic cloud-free (MDDC) composite algorithm that uses today's image and past daily images. New daily dynamic composite algorithm uses the cut and patch method of cloud-masked daily MODIS data using MOD35 product. Because this MDDC composite algorithm generates the daily cloud-free MODIS image of the most current information, it can be used to monitor short-term changes, such as forest fire scar or heavy snow. The MDDC composite algorithm detects burned area and heavy snow area which can't detect using the static composite algorithm. The MDDC composite algorithm also provides the date on which short-time changes occurred.

1. INTRODUCTION

High temporal resolution satellite images detect short-term changes that occur in one week (Gao et al., 2006). However the cloud covered area obscures the observations and is serious problem in usage of AVHRR or MODIS data at regional, continental and global levels (Cihlar et al., 2004). For solving this cloud problem and providing clear-sky image, the static cloud-free composite algorithm of 8, 16 day or month period has been developed. Image composition is the selecting the pixels with the highest quality from multiple scenes within a predefined time interval and merging them into a composite image (Fontana et al., 2009). Cloud-free composited temporal products are used for monitoring or forecasting vegetation, land surface phenology, burned land area, land cover mapping and land cover change (Chuvieco et al., 2008). Although the static cloud-free composited NDVI product such as AVHRR, MODIS, and SPOT MVC product are often used in time-series analysis, these products still include a lot of such noise (Chen et al., 2004). Additionally, the low temporal resolution of static composition algorithm as 8, 16-day, month period inhibits to detect short-term changes (< 1week) in ecosystem monitoring, in particular for the transition periods of green-up and senescence (Ahl et al., 2006). Therefore, a new composite algorithm is necessary for providing the most recent information. The purpose of the study is to develop a new composite algorithm of MODIS data, which provides the most up to date information. The MODIS daily dynamic cloud-free (MDDC) composite monitors short-term changes such as forest fires and heavy snow.

2. METHODS

2.1 Dataset used

This study used 250m and 500m MODIS radiance dataset (MOD02QKM, MOD02HKM) for fusion and composition. MODIS geolocation dataset (MOD03) was used for re-projecting MOD02 dataset. As cloud and shadow mask data, we used MODIS cloud mask product (MOD35). For testing and validating of the MDDC composite algorithm, three MODIS dataset acquired during rainy, non-rainy and dry season were retrieved. During rainy season, MODIS data showed the heavy cloud containments comparing with non-rainy season. The effectiveness of MDDC composite algorithm was validated with the May 2010 and April 2011 MODIS dataset, appropriately detecting short-term changes such as forest fires and heavy snow.

2.2 MDDC composite method

The static composite algorithm produced one cloud-free image by compositing daily MODIS data during the static period (8-, 10-, 16- days, and a month). The proposed MDDC composite algorithm used multi-temporal MODIS data sets during the dynamic period, and produced daily cloud-free composite images. The optimal period of compositing was conducted by the cloud containments and multi-temporal MODIS data sets acquired at previous days were used for dynamic daily compositing.

Figure 1 showed the detail procedure of MDDC composite algorithm. To improve MODIS spatial resolution, the 500 m MOD02HKM product and the 250 m MOD02QKM product were fused using local mean and variance matching (LMVM) fusion method. The LMVM filter was applied to normalize the high resolution and low resolution image using the local mean and variance value of the two target images (Karathanassi *et al*., 2007). Daily 250 m fused MODIS radiance images were used in MDDC composite procedure.

MDDC composite algorithm used the cut and patch method on the cloud area of each daily MODIS image. The accuracy of cloud and shadow detection effected at the quality of dynamic composited image. In this study, we used MOD35 1km cloud and shadow mask generated using thermal and visible bands. This MOD35 cloud mask algorithm used many threshold tests for different cloud types over ocean, vegetated and desert surfaces (Ackerman et al., 2006). Because MOD35 algorithm was hard to detect thin clouds on the cloud boundary, clouds were still shown on the cloud edge in the MODIS image masked. For more accurate masking of cloud and shadow, we applied the 250m buffering at MOD35 cloud and shadow mask. The daily MOD02 dataset masked using cloud and shadow mask were used for dynamic cloud-free compositions.

The cut area of MOD02 data on reference day T was patched by using other MOD02 dataset acquired at T-1, T-2 day, and so forth. The number of images used for the composition was determined by the amount of cloud cover of less than 5%. The number of images (days) was defined as the dynamic period. The static composite algorithm produced one cloud-free image by compositing daily MODIS data obtained during the static period (8-,10-,16- days, and a month). The proposed daily dynamic composite algorithm used multi-temporal MODIS data during the dynamic period and produces daily cloud-free composite images.

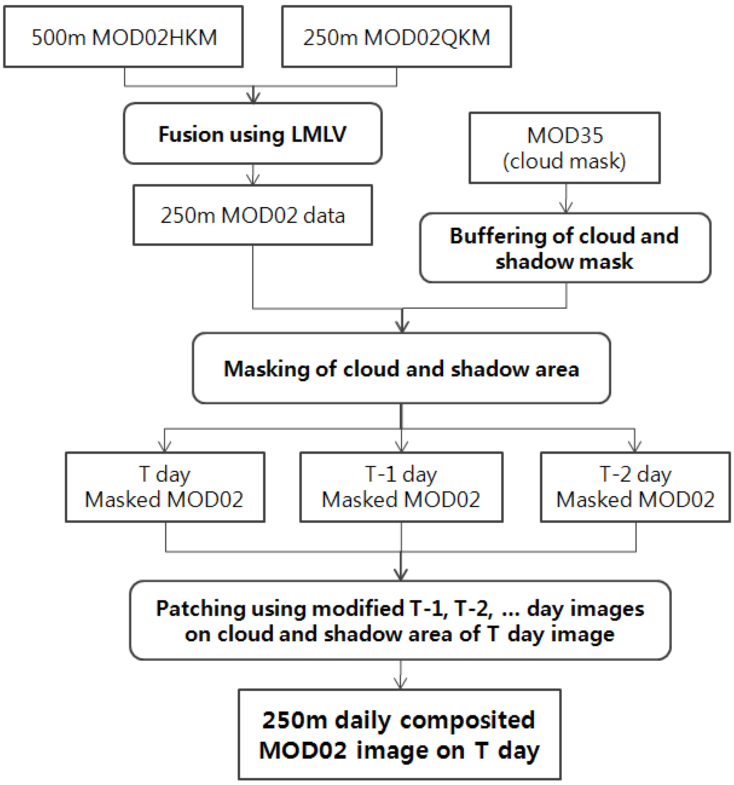

Figure 1. Total flow-chart of MDDC composite algorithm

2.3 Validation of MDDC composite algorithm

In order to validate the proposed MDDC composite algorithms, two short-term change events were detected using statistic and MDC composite algorithm. For a forest fire that occurred on May 7, 2010, the size of burned area was about 86 ha. For a reference dataset, we used the fire and burned area information provided by the National Forest Fire Information System (http://sanfire.forest.go.kr). To detect the forest fire scars, it was used the normalized burned ratio (NBR) showing the spectral difference of forest and burned area as formula 1(Loboda et al., 2007). The change of NBR value of composite images before and after forest fire was generated and analyzed.

$$NBR = \frac{\rho_{NIR(band2)} - \rho_{SWIR(band7)}}{\rho_{NIR(band2)} + \rho_{SWIR(band7)}} \quad (1)$$

As additional short-term change, the area of high snowfall was detected using two composite algorithms. Land cover change by the heavy snow disappeared even during two or three day by snow thawing. There was high snowfall over 10cm throughout the central part of South Korea on March 24, 2011.

3. RESULTS

3.1 Effectiveness of MDDC composite algorithm in dry season

Figure 2 showed two cloud-free composite images using the MDDC and static composite algorithms. If the MODIS image showed a small amount of clouds, a cloud-free image under 10% cloud coverage can be generated using only two or three daily MODIS images in MDDC composite algorithm (Figure 2(a)). MDDC algorithm provided date information of the MODIS images used in generating daily cloud-free composite images, as shown in Figure 2(b). Date information at each pixel of composite image helped to accurately detect short-term changes. The 8-day composite image was generated by applying the minblue algorithm at eight MODIS images during October 1~ 8.

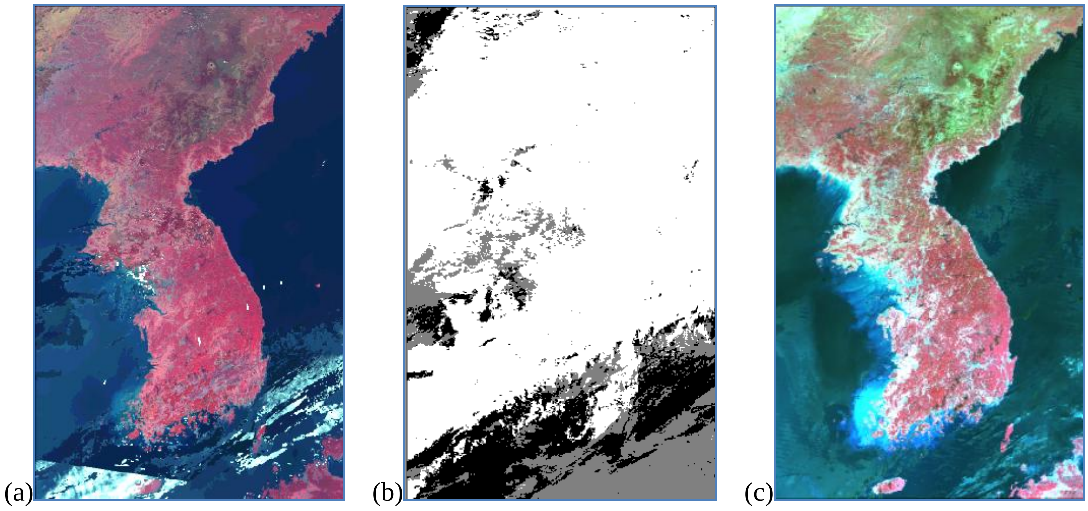

Figure 2. (a) MDDC composite image using three MODIS daily images of October 5, 4, and 3, (b) date information of MODIS daily images used in MDDC composite (white: October 5, gray: October 4, black: October 3), (c) 8-day composite image using ten images during October 1 ~ 8 day.

During October in 2009, MDDC composite images were generated using two to six daily images. The cloud-free composite mage of October 11 was generated using only two daily MODIS images. The MDDC composite algorithm more effectively showed current information in contrast to the static composition algorithm during the non-rainy season. In rainy season of July, 2009, two dynamic and static composited MODIS images were not free of clouds. The cloud-free MODIS image can be generated using many daily MODIS images over 30 days.

3.2 Detection of short-term changes

In order to detect a burned area, daily 250m cloud-free composite images were generated, and 8-day 500m composite images during May 2010 were also generated. Figure 3(a) shows a 250m fused MDDC composite image, this image was sharper than the 500m 8-day composited image (Figure 3(b)). The LMVM fusion method provided the best fusion results for the spatial resolution and spectral fidelity. Figure 3(a) is the MDDC composite image of May 9 generated by using three images (May 9, 8, and 7). Because the forest fire occurred on May 7, a forest scar can be detected in the cloud-free composite image of May 9. In contrast the 8-day composite image of May 1 to 8 did not show the burned area (Figure 3(b)). Figure 3(c) shows NBR temporal pattern acquired from MDDC and 8-day composite data on burned area. After the forest occurred on 7 May, 2010, the NBR value decreased greatly. However, the burned area was detected much later on May 16 in 8-day composite data. As shown in Figure 3, the dynamic composite algorithm provided short-time change information efficiently. The date from the dynamic composite product also accurately detected the dates on which short-term changes occurred.

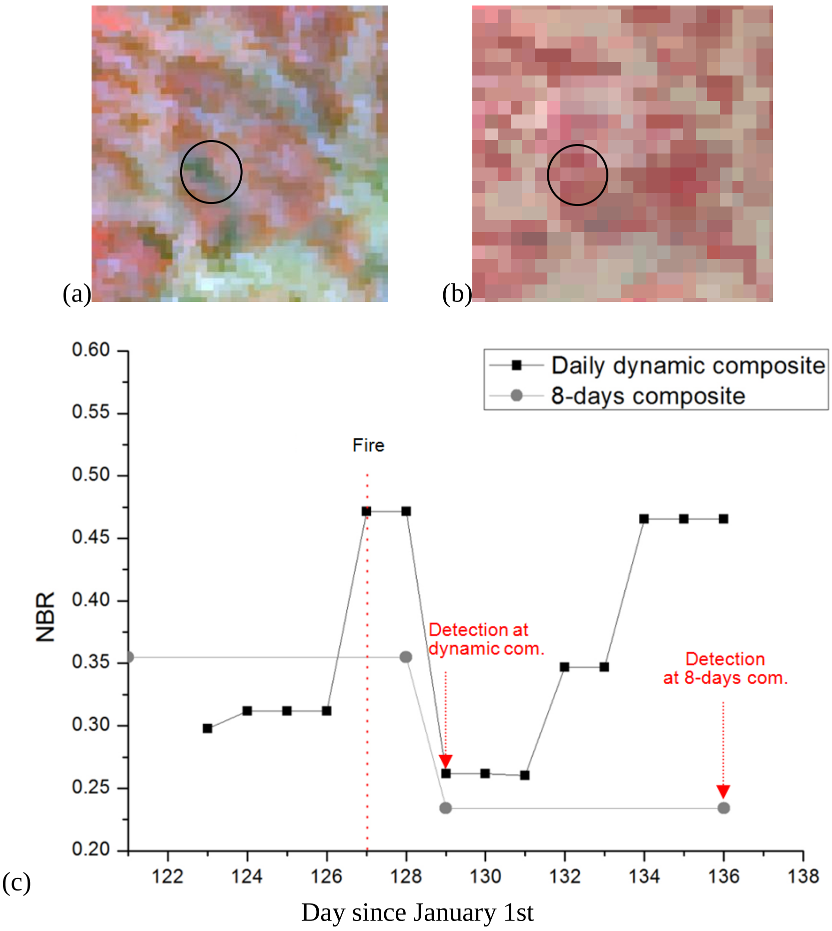

Figure 3. NIR-red-green color images of MDDC composite image of May 9(a), 8-day composite images during May 1~8(b), black circle - burned area, and NBR temporal pattern of MDDC and 8-day composite dataset at burned area(c)

MDDC and 8-day composite images are compared on the area of large snowfall (Figure 4). In MDDC composite image of March 25, 2011 generated using three images during March 23, 24, 25, the distribution and area of large snowfall were well monitored. However, two 8-day composite images of March 22 to 29 and March 30 to April 6 did not show the snow. These results are caused by two reasons that the static composite algorithm selected no-snow pixels showing a lower radiance in blue band and snow was thawing during three days. MDDC composite algorithm is very useful in monitoring the short-term change as snowfall.

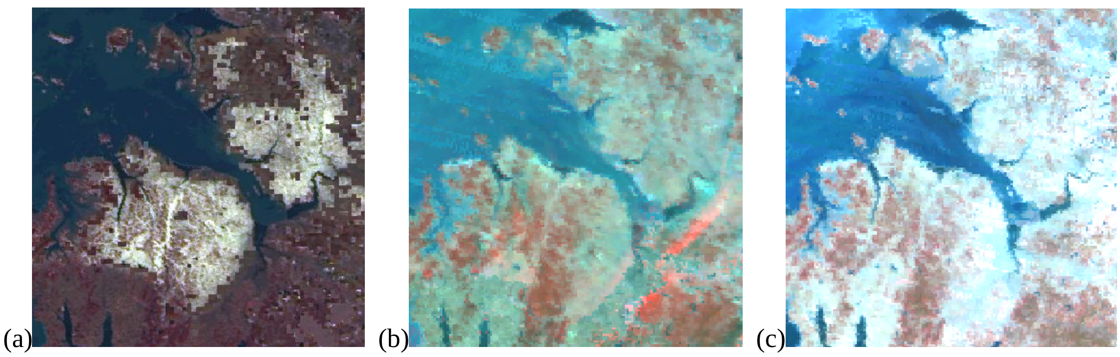

Figure 4. NIR-red-green color images of MDDC composite image of March 25(a), 8-day composite images during March 22~29(b), and March 30 ~ April 6(c).

4. CONCLUSIONS

The MDDC composite algorithm offered the daily 250m fused cloud-free MODIS image. The 250m MODIS dataset may improve various MODIS land products as burned area detection or classification. In dry season, MDDC composite image was generated using two to six daily images. The MDDC composition algorithm more effectively showed current information in contrast to the static composition algorithm. The MDDC composite algorithm detected short-term changes and improved the detection rate of the burned and snow areas. The MDDC composite algorithm also provided the date of daily MODIS images used in compositing each pixel. This additional information accurately detected the date on which short-time changes occurred. However, MDDC composite algorithm was not effective in rainy season because of heavy cloud coverage. In order to be effective, the daily dynamic composite method must be applied to the MODIS data that was acquired during the non-rainy season or a specific period (ex. dry season) in which many short-term changes occurred rather than being applied over one year.

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