Prototype of LSA SAF Burnt Area Product

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INTRODUCTION

Accurate information about location and extent of burnt area is required and of particular interest for the scientific communities dealing with meteorological and climate models in what concerns reliable estimations of biomass burned. In addition, the apparent global increase in the incidence, extent, and severity of uncontrolled burning have led to calls for international environmental policies concerning fire.

Because of the very broad spatial extent and the limited accessibility of some of the largest areas affected by fire, the instruments on-board satellites are the only available operational systems capable to collect cost-effective Fire Burnt Area (FBA) data at spatial and temporal resolutions appropriate to most modeling applications.

Fire-related processes have long been identified as applications with great potential to be derived from SEVIRI/Meteosat and AVHRR/Metop. In this particular the LSA SAF Team has developed two products, the Fire Detection and Monitoring (FD&M) and the Fire Radiative Power (FRP) products that take advantage of high temporal resolution of SEVIRI/Meteosat to detect and monitor active fires over Africa and Europe. In turn, the AVHRR sensor on-board Metop has been shown to have capability to discriminate burnt areas on a near global basis.

Methods to discriminate FBA over large regions may be grouped into two categories, active fires detection and post-fire burn detection. The aim of the present work is to develop a method that synergistically combines the hotspot approach, using information from the currently operational FRP product and post-fire detection based on NDVI differencing strategies.

DATA AND METHODS

Radiometric data consist of top of the atmosphere (TOA) values of Red and NIR reflectance, as acquired by the MODIS instrument on-board TERRA and AQUA satellites. Data were extracted from the Aqua MODIS Level 1B 1 km V5 product and correspond to channels 1 (Red, 0.620-0.670 µm) and 2 (NIR, 0.841-0.876 µm), covering the period of May-June 2014. Data were screened for missing/inconsistent values and then re-projected onto the study area, a regular 0.01°× 0.01°lat-lon grid, defined between the latitude circles of 24 and 27°S and the meridians of 27 and 30°E. Located in the southern bottom of the African continent (Fig. 1), the study area is a region of about 300×300 km with vast areas of pasture and agricultural fields and patches of forest and shrub.

Figure 1 - Geographical location of the study area

Post-fire analysis is here performed through multi-temporal image compositing of the normalized difference vegetation index (NDVI). Compositing is an operational means of mitigating the gap of information about the land surface due to the presence of cloudy pixels; it also contributes to reduce the daily reflectance variability and residual atmospheric effects. NDVI provides a measure of vegetation greenness and photo-synthetic activity and has been widely used for burnt area detection. When green vegetation is burned, NDVI decreases owing to a rise in red reflectance and decrease in NIR reflectance.

Daily images of NDVI were composited over 1-month periods (May and July) using the minimum albedo criterion. Minimum albedo NDVI composites ($NDVI_{min}$) have been shown to more effectively retain the burn signal in environments where the spectral response to burning is short-lived. The chosen span of one month represents a compromise between the need to retain the burned signal and the requirement of having a reasonable number of pixels to generate a meaningful $NDVI_{min}$ field (Fig. 2, top left panel). In order to identify pixels where there is a strong decrease in NDVI, a map of differences ($NDVI_{diff}$) was computed (Fig. 2, top right panel) by subtracting values of $NDVI_{min}$ of May from those of June. Monthly maximum composites of NDVI ($NDVI_{max}$) were also generated (Fig. 2, bottom left panel) in order to identify regions of high values of $NDVI_{max}$ that are not likely to burn.

Identification of pixels of burned areas is performed in two stages. In the 1st stage, the analysis is restricted to pixels belonging to 3x3 pixel buffer zones centered in pixels where active fires (from the FRP product) were identified during the compositing period. Pixels in the 3x3 buffer zone are then classified as burned ones (Fig. 2, bottom right panel) when there is a strong evidence of a decrease in NDVI, namely when:

1. The value of $NDVI_{min}$ is lower than 0.1;
2. The value of $NDVI_{diff}$ is lower than 0;
3. The value of $NDVI_{max}$ is lower than 0.3;
4. The date of occurrence of $NDVI_{min}$ follows the date of occurrence of the hotspot.

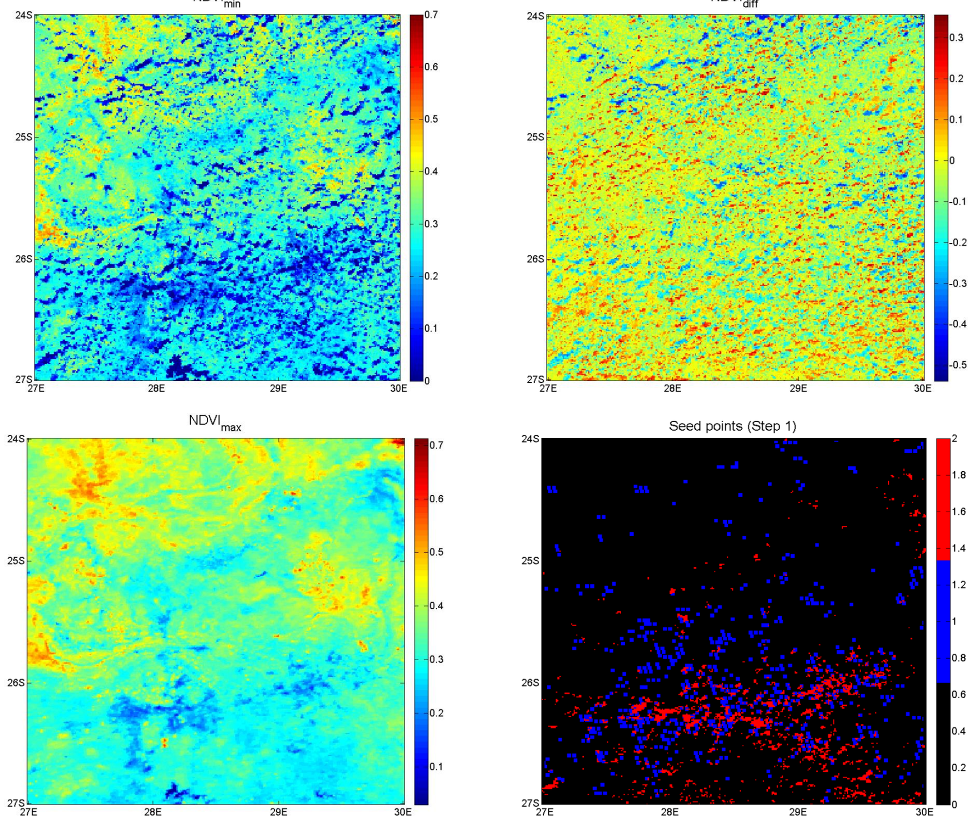
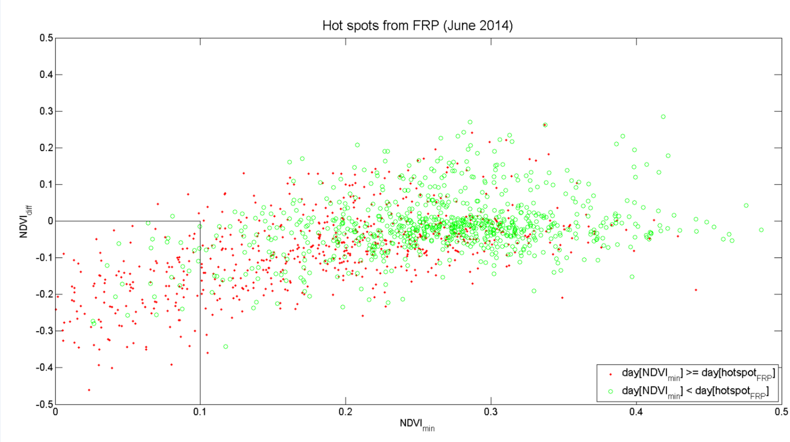


Figure 2 - Maps over the study area of $NDVI_{min}$, $NDVI_{diff}$, $NDVI_{max}$ and initial seed points (red dots indicate pixels near hotspots that were considered as first seeds, whereas the blue ones correspond to those that were not retained as seed points).

Reasons behind the choice of the four above criteria may be clarified by plotting, for each hotspot detected, the associated values of $NDVI_{min}$ against those of $NDVI_{diff}$ and then discriminating according to dates of occurrence of hotspots compared to those of $NDVI_{min}$ (Fig. 3). A large fraction of hotspots occurring after the date of $NDVI_{min}$ are associated to quite large values of $NDVI_{min}$ (larger than 0.30) and/or to positive values of $NDVI_{diff}$. On the other hand, a very large fraction of hotspots (169 out of 194) with $NDVI_{min}$>0.1 and $NDVI_{diff}$<0 has a date of occurrence preceding the date of occurrence of $NDVI_{min}$.

Figure 3 - $NDVI_{min}$ vs. $NDVI_{diff}$ for hotspots detected during June 2014. Red dots (green dots) identify pixels where the date of occurrence of the hotspot precedes (follows) the date of occurrence of $NDVI_{min}$. The black vertical and horizontal lines indicate the used thresholds for $NDVI_{min}$ and $NDVI_{diff}$.



The 2nd stage aims at identifying pixels that although presenting less intense signals in either $NDVI_{min}$ or $NDVI_{diff}$ are likely to be burned because of their vicinity to pixels already classified as burned. The weaker radiometric signal may be due to partial burning or to low fire severity. The procedure consists in the following steps:

1. Let all pixels classified as burnt pixels in the stage I be considered as seed points;
2. For each seed point, let a grid of 5x5 pixels be defined centered at the considered seed point; let $E[NDVI_{min}]$ and $\delta[NDVI_{min}]$ be the mean and the mean absolute deviation of seed points within the grid. Let $NDVI^{*}_{min}$ be the value of $NDVI_{min}$ for a pixel inside the grid that is not a seed point; this pixel is then classified as a burned area pixel and considered as a new seed point if the two following conditions are fulfilled:
   - 2.1 $NDVI^{*}_{diff} < -0.1$;
   - 2.2 $NDVI^{*}_{min} \leq E[NDVI_{min}] + \delta[NDVI_{min}]$.
3. Step 2 is recursively performed until no new seed points are generated.
4. The burnt area is obtained by summing up all identified burned area pixels

RESULTS AND FUTURE WORK

The proposed algorithm was applied to the monthly composites of May and June 2014, leading to the identification of 2188 burnt area pixels (Fig. 4, left panel). A visual comparison against a true color background in high resolution (1 m) suggests that burned areas tend to follow the patterns of the landscape and, after zooming (Fig.4, right panel), there is evidence that the patches of burnt pixels are confined by geographical barriers. Dates of occurrence of the burnt pixels were then assigned based on respective dates of $NDVI_{min}$ (Fig. 5). Results reveal a temporal homogeneity over the different patches, feature that reinforces the plausibility of obtained results.

The following issues are currently or will be investigated in the near future:

1. Application of the algorithm to whole year and to Brazil and Mediterranean Europe.
2. Refinement of date assignment of burnt areas by analysis of time series of daily values of NDVI
3. Application of the algorithm to areas outside the MSG disk (e.g. Australia) using other sources for hotspot information.
4. Replacing MODIS data by Metop.
5. Incorporation of land cover / land use data and of a cloud mask, and refinement of thresholds.
6. Validation against burnt scars from higher resolution instruments over pre-selected regions and temporal windows.

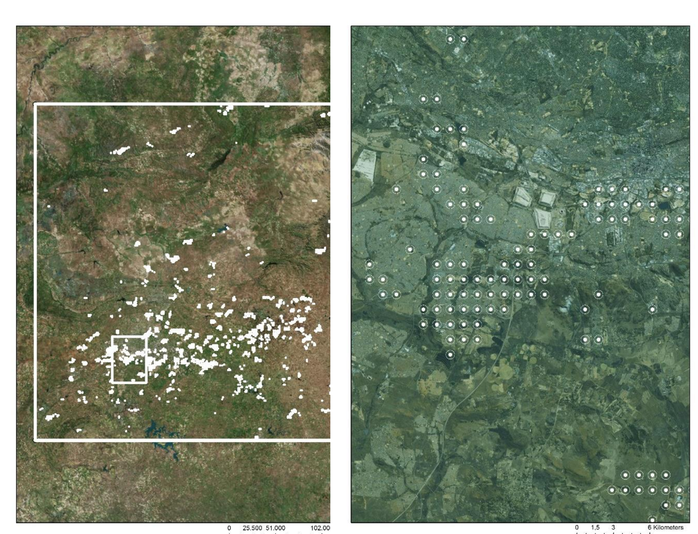


Figure 4 - Map of identified burnt pixels (white dots) viewed over a 1m resolution visible image. The large white rectangle (left panel) delimits the study area and the small white rectangle in the inside identifies an area that was zoomed (right panel))

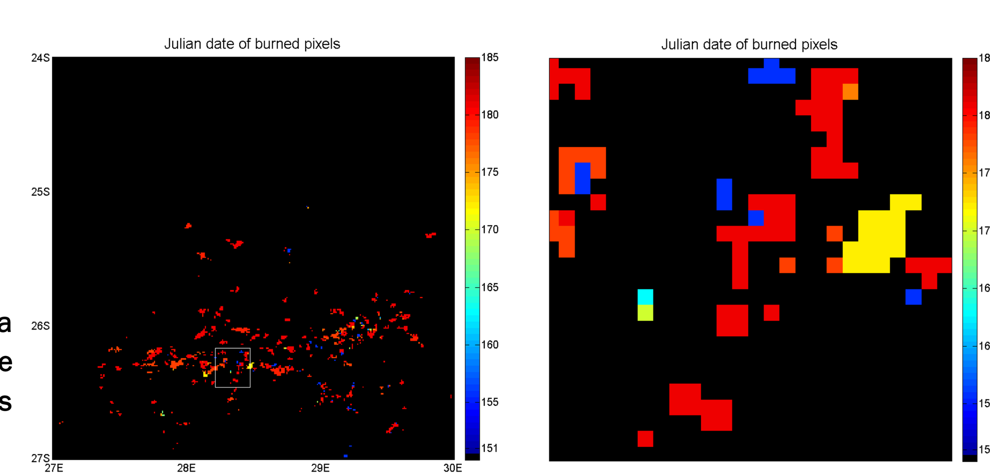


Figure 5 - Dates (in Julian days) assigned to burnt area pixels over the study area (left panel); the small white square inside the study area identifies an area that was zoomed (right panel).

Acknowledgements: This study was performed within the framework of the LSA SAF project, co-funded by EUMETSAT.

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