NEAR REAL-TIME DEFORESTATION MONITORING
IN TROPICAL ECOSYSTEMS USING SATELLITE IMAGE TIME SERIES

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1. INTRODUCTION

Monitoring forest disturbances is critical for addressing its impact on carbon storage and fluxes, biodiversity, and other socio-ecological processes [1, 2]. Satellite remote sensing enables cost-effective and accurate monitoring at frequent time steps over large areas. Several methods are available to detect disturbances within satellite image time series [3, 4]. However, methods to detect changes within newly acquired satellite images are lacking. There is a critical need for methods that enable rapid and automated analysis of satellite image time series to detect forest disturbances in near-real time, especially in regions of less developed countries (e.g. Asia, Africa) [2].

Here, we test and optimise an approach to monitor and detect tropical deforestation in near-real time by comparing it with a seasonal-trend model fitted onto the historical time series. The method detects disturbances in near-real time by comparing newly acquired satellite data with a modelled stable period based on historic satellite time series data. The method allows the differentiation between normal and abnormal change in near-real time and is based on the Break For Additive Seasonal Trend (BFAST) concept [5, 6, 7]. Testing is done by analysis of 16-day MODIS satellite image time series (MOD13Q1) for areas in the Brazilian Amazon region for which optimised deforestation systems (e.g. PRODES-DETER, IMAZON) are available.

Preliminary results illustrate that abrupt changes at the end of time series are successfully detected while being robust for high noise levels due to intense cloud cover. Cloud masking remains important as the clouds can be detected as an abnormal change. The method is publicly available within as the \textit{bfastmonitor} function within the BFAST package for R (http://bfast.r-forge.r-project.org/). The proposed method is an automatic and robust change detection approach that can be applied on different types of data (e.g. Landsat data and future sensors like the Sentinel constellation that provide higher spatial resolution at regular time steps) since it is fast and does not require time series gap filling. The method can be integrated within current operational early warning systems and has the potential to detect a wide variety of disturbances (e.g. deforestation, flood damage, etc.).

2. MATERIAL AND METHODS

2.1. Near real-time deforestation monitoring

When investigating disturbances using satellite data, many approaches [5, 8] focus on the question if and where disturbances occur in the season and trend component of a given observed time series $t = 1, \ldots, n$. Here, we want to investigate a different question: \textit{Do new observations $t = n, n+1, \ldots$ still conform with the expected behaviour of the historical sample $t = 1, \ldots, n$}?

Thus, we want to detect disturbances at the end of a time series by comparison with representative, i.e. stable, historical observations [7].
Here, this approach is tested for the detection of deforestation events in tropical forests able within newly acquired satellite images by automatically identifying a stable history period within already available satellite image time series to model normal expected behaviour against which abnormal events (e.g. deforestation) can be detected [7].

2.2. MODIS satellite images and deforestation data

We selected the 16-day MODIS NDVI composites with a 250m spatial resolution (MOD13Q1 collection 5). The MOD13Q1 16-day composites were generated using a constrained view angle maximum NDVI value compositing technique [9]. The MOD13Q1 images were acquired from 24 February 2000 until the end of 2011 the northern part of the Mato Grosso, Brazil (tiles h12v10 and h12v09). The detected deforestation events using the bfastmonitor approach are compared with deforestation data from existing operational deforestation monitoring systems i.e. PRODES (Amazon Deforestation Monitoring Project) monthly deforestation maps produced by the Brazilian National Institute for Space Research (INPE) [10].

3. PRELIMINARY RESULTS AND FURTHER WORK

Fig. 1 illustrates a NDVI time series that contains a significant disturbance that due to its magnitude is very likely to be caused by deforestation. The information on the magnitude of detected significant breaks that is retrieved by the algorithm is then used to produce a MODIS based map of the magnitude of the detected significant disturbances as an indication of potential deforestation events (Fig. 2). Two areas with large negative magnitudes ($|\Delta NDVI| > 0.4$) of the significant change flagged in the monitoring period (mid 2010 until end of 2010) are shown in Fig. 2. Both correspond to areas that were also classified by PRODES as deforested area for that year. Further work includes efforts to improve outliers removal (cloud effects) and calibration/validation with available monthly PRODES deforestation maps in 2010 and 2011.

![Fig. 1. MODIS 16-day NDVI time series analysed by the bfastmonitor approach for a forested area in Mato Grosso, Brazil. Deforestation is detected at the end of 2010 (vertical red dashed line). The bfastmonitor approach automatically identifies a stable history period (green dots) which is used to model the normal, representative data variation (blue line) to differentiate normal from abnormal events within a time series.](image-url)
Fig. 2. MODIS based map illustrating the magnitudes of the detected significant disturbances potentially related to deforestation occurring in the study area. Two areas with large negative magnitudes ($|\Delta NDVI| > 0.4$) of the significant change flagged in the monitoring period (mid 2010 until end of 2010) are shown. Both correspond to areas that were also classified by PRODES as deforested area for that year. Significant disturbance with a high magnitude as such potentially indicates deforestation occurring in near real-time.

4. REFERENCES


[8] Michael A. White, Kirsten M. de Beurs, Kamel Didan, David W. Inouye, Andrew D. Richardson, Olaf P. Jensen, John O’Keefe, Gong Zhang, Ramakrishna R. Nemani, Willem J. D. van Leeuwen, Jesslyn F. Brown, Allard de Wit, Michael
