Change detection from satellite data time series using pixel value distributions

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Abstract

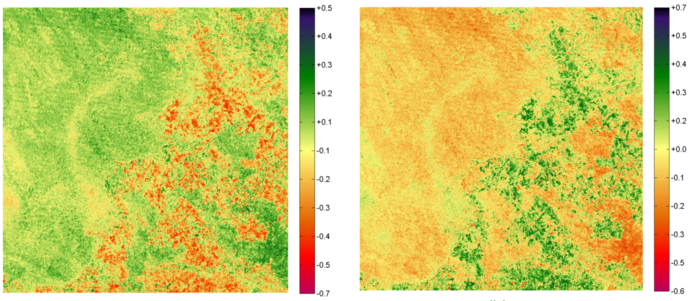
In this paper, we explore new methods to perform change detection and trend analysis in times series of optical satellite images. The methods rely on the comparison of cumulative distribution functions of pairs of images. This study is part of the ReCover project (EU-FP7), coordinated by VTT.

Data, study site and pre-processing

The study area was located in the eastern part of the Chiapas state in Mexico. The dataset includes images acquired during the dry season (January through March) between 1986 and 2003 by Landsat 4, 5, and 7 (SLC on) at Path 20 / Row 49. An area of 2000 x 2000 pixels was extracted from each image, covering a national park (west) and unprotected forest areas (east) - **Fig. 1**. For all images, geometric and radiometric corrections were performed using in-house software, and clouds were masked out. The best cloud-free image in the series (**Fig. 1 (b)**) was used as a reference for radiometric calibration of the other 21 images.

Mann-Kendall trend test on the whole image time series

The Mann-Kendall test [1] [2] has been successfully applied to the analysis of environmental data [3]. **Fig. 2** shows the monotonic trends in the image time series for RED band and NDVI, highlighting areas with a decreasing trend (in red) and an increasing trend (in green/blue). Other vegetation indices (e.g. VI, EVI, SAVI and Woodiness index) were tested with similar results. The highest decreasing trend in NDVI shows on the east part of the image where clear-cuts occurred regularly. Increasing trends in NDVI occur also on the same area, corresponding to agricultural fields or forest regrowth after clear-cuts.



(a) RED band (b) NDVI

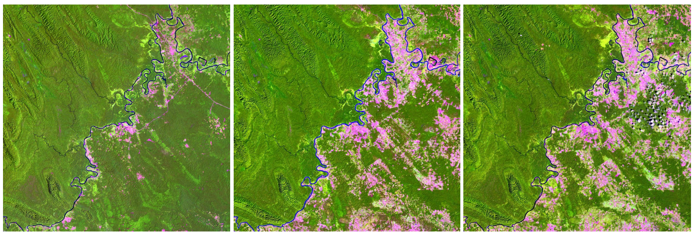
Figure 2. Mann-Kendall monotonic trends (τ) in Chiapas image time series

Pair-wise cumulative distribution functions

We consider now a pair of images instead of the whole image time series. In this case we chose the images in **Fig. 1 (b)** and **Fig. 1 (c).** Cumulative distribution functions (CDF) were extracted pixel by pixel for an image band or a feature (e.g. a vegetation index), in a window of typically 11 x 11 pixels. **Fig. 3** shows the CDF from the RED band of the earlier (blue curve) and later image (red curve) at 9 visually selected sample points exhibiting either change, no change or false alarms, e.g. changes corresponding to seasonal variation or wrong calibration rather than a real change in land cover. We can use distances between CDFs to quantify changes.

Kolmogorov-Smirnov distance

The Kolmogorov-Smirnov (K-S) is a non-parametric statistical test for one-dimensional CDFs that can be used to compare two samples. The K-S distance between empirical CDFs is defined as the maximum distance between the CDFs along the probability axis. This distance does not make any assumption about the shape of the distributions. On **Fig. 3** the K-S distance represents the highest vertical distance between the red and blue curves.



(a) TM5 – 1986-03-13 (b) TM7 – 2000-01-23 (c) TM7 – 2003-02-16

Figure 1. Sample Landsat images (5-4-3 as RGB) from time series in Chiapas

Other distances based on CDFs

From the observation of pair-wise CDFs (**Fig. 3**), we propose two other measures for change detection :

- Maximum shift between CDFs ("horizontal distance" HD) : this is the same principle as the K-S distance, but along the axis of histogram bins.
- Area between curves (ABC) : absolute normalized area of the region between the two curves. This is seen as an improvement over the Maximum shift of even the K-S distance in the sense that the ABC measure utilises all points of the CDFs rather than just a maximum.

Based on the 9 samples on **Fig. 3**, these two distance measures should be small on no-change cases and higher in case of changes. Interestingly, the two distance measures are higher in case of real changes than in case of false alarms on undesired changes. ABC had high returns on no-change areas over dark forest. HD has much less of those, but missed some real changes. Thresholded ABC image looked like a fair change map.

Conclusions and future work

The algorithms are computationally intensive and require optimisations to be applied on larger datasets. An extension of this work will be to consider several features, and use K-S distance and other CDF-derived distances in dimension 2 or higher. Another improvement will be to automatically optimise the thresholds to produce change maps based on the K-S test confidence interval.

References

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[3] Helsel, D.R. and R. M. Hirsch, 2002. *Statistical Methods in Water Resources Techniques of Water Resources Investigations*, Book 4, chapter A3. U.S. Geological Survey, 522 pages.

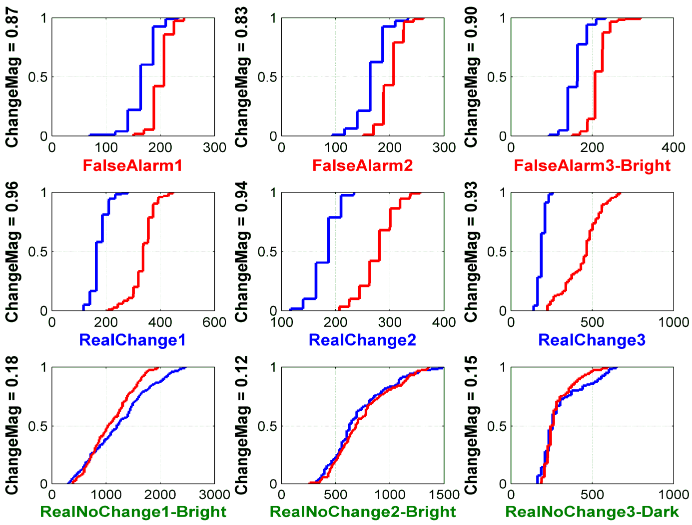

Figure 3. CDF of RED band from earlier (blue curve, TM7 – 2000-01-23) and later (red curve, TM7 – 2003-02-16) images, extracted on 11x11 pixels around 9 representative samples with real changes, no change and false alarms

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