Distance Metric-based Forest Cover Change Detection using MODIS Time Series

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1. Abstract

With growing archive of global observations from NASA's MODIS instruments, high temporal frequency data provides new opportunities for identification and characterization of land cover change processes at regional to global scales. We present a simple yet effective distance metric-based change detection method for identifying changed pixels at annual time steps using 500 m MODIS NBAR time series data. The approach we developed uses distance metrics to measure similarity of a pixel's annual time series to other same-class pixels, as well as similarity between annual time series from two different years. We evaluate our approach using two case studies over 2003-2010.

2. Distance Metrics

Within-year Distance:

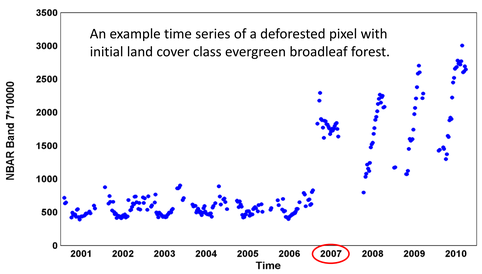
$$D^2_{yr} = (X_{i,yr} - \overline{X}_{r,b,c})' \Sigma^{-1}_{r,b,c} (X_{i,yr} - \overline{X}_{r,b,c})$$

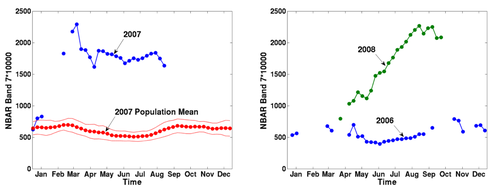
Between-year Distance:

$$D^2_{yr-1,yr+1} = (X_{i,yr-1} - X_{i,yr+1})' (X_{i,yr-1} - X_{i,yr+1})$$

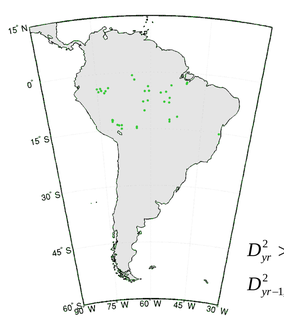
$X_{i,yr}, X_{i,yr-1}, X_{i,yr+1}$: *s* by 1 annual time series of feature (spectral bands, indices) for pixel *i* of land cover class *c*.

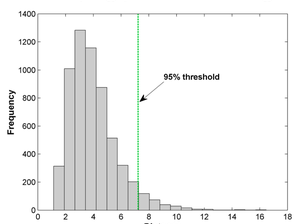
$\overline{X}_{r,b,c}, \Sigma^{-1}_{r,b,c}$: Mean and covariance matrix of class *c* population, defined as class *c* training data in Olson biogeographic realm *r* and biome *b*.





The class population is from the land cover training site database used to produce the MODIS land cover product (MCD12Q1), for each IGBP class divided by Olson biogeographic realms and biomes. The distribution of within- and between-year distances for the population is used to derive thresholds for identifying potential change.



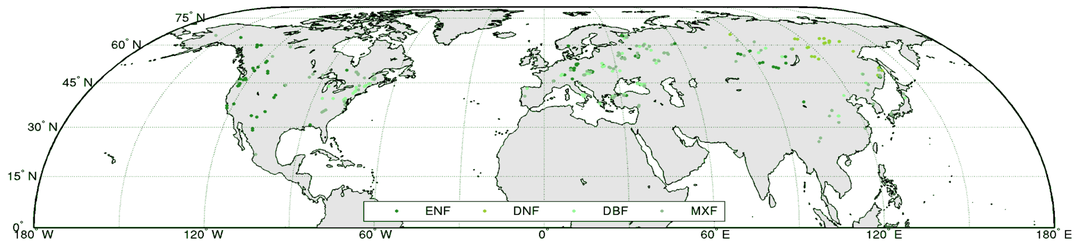


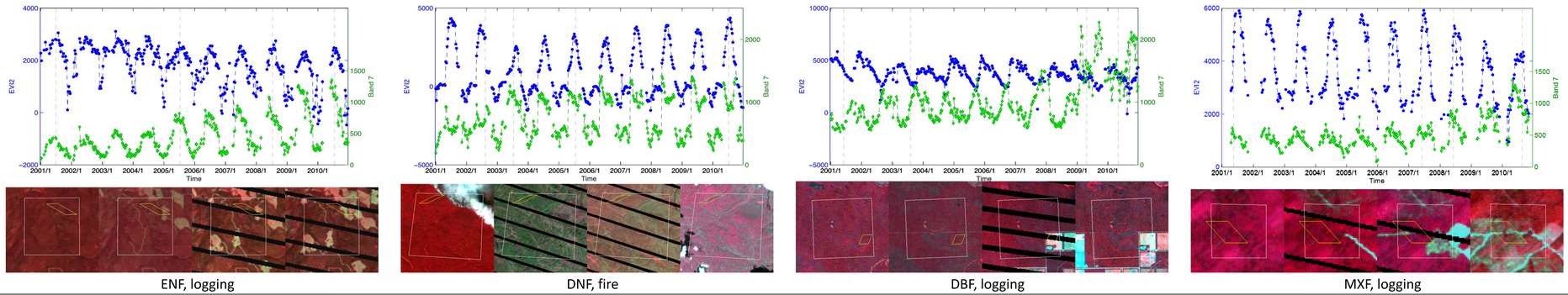
$$D^2_{yr} > T_{within-year}$$
$$D^2_{yr-1,yr+1} > T_{between-year} \Rightarrow potential\ change\ in\ yr$$

Class population for EBF in South America in biome 'Tropical and Subtropical Moist Broadleaf Forests'

3. Temperate and Boreal Forests

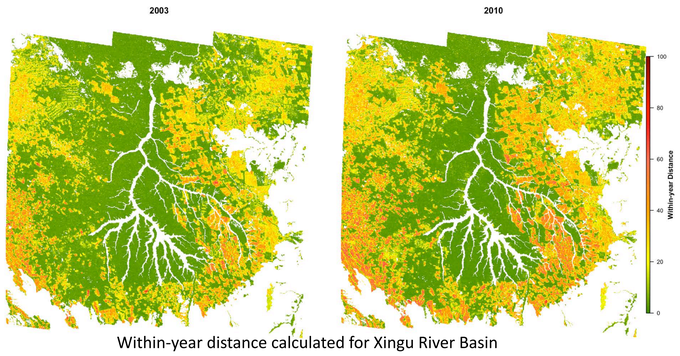
We selected 269 Temperate and Boreal forest training sites (~3600 500 m MODIS pixels) in North America and Euroasia including Evergreen Needleleaf Forest, Deciduous Needleleaf Forest, Deciduous Broadleaf Forest, and Mixed Forest classes. We used gap-filled and smoothed two-band EVI and band 7 NBAR time series data. Visual examination confirmed disturbed pixels in all classes included in our analysis, affected by logging and fire. The majority of change pixels are from Temperate coniferous forests.



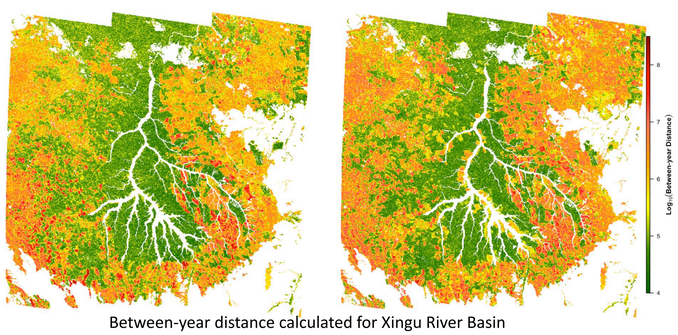


ENF, logging | DNF, fire | DBF, logging | MXF, logging

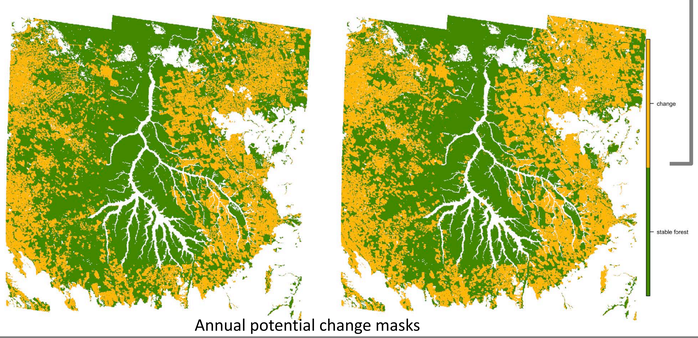
4. Tropical Forests: Xingu River Basin



Within-year distance calculated for Xingu River Basin

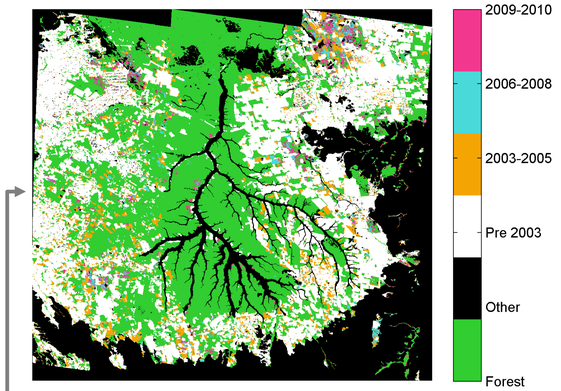


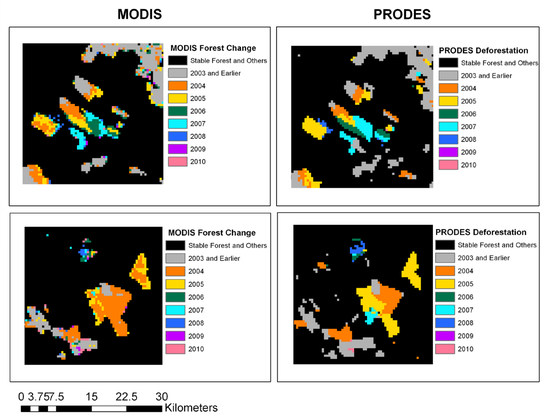
Between-year distance calculated for Xingu River Basin

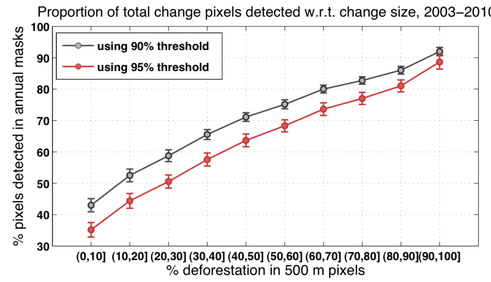


Annual potential change masks

We also applied our method in the Xingu River Basin, Mato Grosso, Brazil (~260000 km^2). The PRODES dataset produced by Brazil's National Institute for Space Research (INPE) is used to generate forest mask and reference data for evaluation of the change detection results. We pre-processed MODIS NBAR band 7 time series to include only dry season (May-September) for distance calculation.







	Spatial agreement				Temporal agreement	
	>0%*		>20%		>0%	>20%
	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy
95% threshold	82.29%	72.32%	90.33%	63.27%	77.56%	78.97%
90% threshold	86.84%	66.67%	93.54%	57.23%	78.33%	79.11%

*PRODES change year = the year deforestation > 0%

5. Summary

- A distance-based change detection method evaluated with 500m MODIS NBAR time series data. Case studies show that this approach is able to detect forest clear cut as well as fire disturbance.
- More evaluation of application for large areas in various forest ecosystems is needed. Further work includes tracking the processes of disturbance and recovery, exploring the characterization of change intensity, and generalization beyond forest cover change.

6. References

- Lambin, E., and A. Strahler (1994), Change-vector analysis in multitemporal space: A tool to detect and categorize land-cover change processes using high temporal-resolution satellite data, Remote Sens Environ, 48 (2), 231-244.
- Johnson, R., and E. Kasischke (1998), Change vector analysis: a technique for the multispectral monitoring of land cover and condition, Int J Remote Sens, 19 (3), 411-426.
- PRODES Digital, http://www.dpi.inpe.br/prodesdigital/