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# Abrupt, gradual and phenological change analysis using satellite image time series

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Trend and seasonal change significantly affects exchanges of carbon, water and energy between the Earth's land surface and the atmosphere. Although land surface change can be assessed using satellite imagery, the ability to account for a mixture of change types such as abrupt disturbances (e.g. fires, insect attacks), seasonal changes (e.g. climate induced phenological change) and gradual trends (e.g. land degradation) within time series is lacking.

We examine land surface change by separating out abrupt, seasonal, and gradual changes in time series of satellite image data. We describe how to detect and characterize change in time series with a method for detecting Breaks For Additive Seasonal and Trend (BFAST) in time series [2]. BFAST integrates the decomposition of time series into trend, seasonal, and noise components with methods for detecting significant changes (i.e. break points). Time and number of change is iteratively estimated by fitting piecewise linear models, which can then be used to characterize the different change types by their magnitude and direction of change. The aim of this study is to highlight the capacity of BFAST to detect and characterize trend and seasonal change at a continental scale using satellite image time series of Australia. The specific objectives are: (1) study changes in seasonal and trend components of Normalized Difference Vegetation Index (NDVI) time series between 2000–2009 for Australia; (2) validate detected trend and seasonal change using field and climate data; (3) characterize phenological change by extracting phenological metrics (i.e. timing of the start of the season (SOS)).

We selected the 16-day MODIS NDVI composites with a 5.6 km spatial resolution (MOD13C1 collection 5), since this product provides frequent temporal information ideal for continental to global scale spatio-temporal studies. We applied the approach on 16-day NDVI image time series for Australia between 2000 and 2009. This study showed that BFAST is able to detect and characterize spatial and temporal changes at a continental scale. Results also illustrate that BFAST is able to accurately detect phenological breaks in time series and provide information about the type of phenological change (e.g. change in SOS) while dealing with abrupt and gradual changes in time series. The methodology presented has several advantages. First, the method is globally applicable since it analyzes each pixel individually without the setting of thresholds. Second, it identifies phenological change independent of the type of change while exploiting the full temporal details of the seasonal growth cycle. Finally, BFAST is not specific to a particular data type and can be applied to time series without the need to normalize for land cover types, select a reference period, or change trajectory. The method can be applied to other disciplines dealing with seasonal or non-seasonal time series, such as biology, hydrology, and climatology.

The methods described in this study are available in the BFAST package for R [1] from CRAN (http://cran.r-project.org/package=bfast). The method can be integrated within monitoring frameworks and used as an alarm system to flag when and where changes occur. By having better tools to identify, monitor abrupt, gradual, and phenological changes, one will be better able to assess land surface responses to forcing from environmental and climate factors.

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**References**

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