Breakpoint analysis with the BFAST algorithm applied to global vegetation index

Laura Holtzman¹, Kirsten M. de Beurs¹
¹Geography and Environmental Sustainability, College of Atmospheric & Geographic Sciences, University of Oklahoma
laholtzman@ou.edu, kdebeurs@ou.edu

Overview

Detecting abrupt changes in time series of remotely sensed data is an important approach to monitoring land use and land cover change. Time series change detection can be used to analyze series types of data including temperature, carbon emissions and NDVI.

NDVI is Normalized Difference Vegetation Index, derived from Near infrared and red bands of satellite data and measures health of vegetation. NDVI ranges from -1 to 1, where values closer to 1 indicates healthier and denser vegetation.

Objective

In this study, we will use BFAST on the global GIMMS3g NDVI product to test the sensitivity of the BFAST algorithm in determining break changes.

What is BFAST?

• Breaks For Additive Seasonal Trend is an additive decomposition linear model that decomposes time series accordingly: \( Y_t = T_t + S_t + e_t \).  
  • \( Y_t \) is observed data at time \( t \), \( T_t \) is the trend component, \( S_t \) is the seasonal component, \( e_t \) is the remainder component or residual component (output is shown on Fig. 7, 11, and 15).
  • Determines magnitude and date of significant breakpoints in time series
  • Ordinary least squares residuals-based moving sum test is applied to the trend and seasonal component to see if breakpoints occur.
  • The BFAST algorithm allows the user to set a minimal time between breakpoints and number of breaks to identify.
  • Analyses were carried out using R statistical software: http://bfast.r-forge.r-project.org/ (Verbesselt et al. 2010)

Case Studies

Case 1: Western Oklahoma and North Texas
34°59'59.94"N, 99°59'59.94"W

Case 2: Yellowstone National Park, Wyoming
44°59'59.94"N, 110°59'59.94"W

Case 3: Southern Australia
30°00'06"S, 141°00'06"E

Study Regions

<table>
<thead>
<tr>
<th>Study Regions</th>
<th>Data</th>
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<tbody>
<tr>
<td>GIMMS3G</td>
<td>This project used global NDVI values from the Global Inventory Modeling and Mapping Studies (GIMMS).</td>
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<tr>
<td>GIMMS scaled values are:</td>
<td>- NDVI = 0.0 – 1000</td>
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<td></td>
<td>- Water = –1000</td>
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<td></td>
<td>- Null = 5000</td>
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<tr>
<td></td>
<td>- Temporal Resolution = 15 day composites (2 observations a month).</td>
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<td></td>
<td>- Spatial Resolution = Resampled to a 1 degree lat/lon resolution.</td>
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Conclusions

BFAST is able to detect abrupt changes in locations where events that affect NDVI occur. Issues that arise with using BFAST:  
• breakpoints exist that cannot be explained  
• magnitude results are difficult to interpret  
• amount of breaks inputted can not be individually adjusted for trend and seasonal component.

Case Study 1: A breakpoint that occurs in 2007 (Fig. 8) indicating an abrupt decrease in NDVI is not apparent in the drought monitor graph (Fig. 6).

Case Study 2: The greatest magnitude change occurred in 2010, which has greater decrease in NDVI values than the Yellowstone National Park Wildfire in 1988.

Case Study 3: A break in seasonality occurs, however there is no option to adjust the number of breaks in the seasonal component separate from the trend.

It is possible that there was a different driver affecting NDVI values for the issues above.

Data Use

To recover NDVI values ranging -1 to 1 use NDVI = float(raw/10000)

Future Work

• Apply BFAST to entire global time series and compare breakpoints using other change detection methods.
• Derive an algorithm that analyzes breakpoints that are not driven by seasonality.

References:

Figure 1 (below): Land cover images of the contiguous United States and Australia. Images courtesy of the National Land Cover Dataset and Australian Government.

Figure 2 (below): land cover of Case Study 2. Yellow box highlights pixel location.

Figure 3 (below): land cover of Case Study 3. Yellow box highlights pixel location.

Figure 4 (below): land cover of Case Study 3. Yellow box highlights pixel location.

Figure 5: Median NDVI values for the adjusted GIMMS3g data from January 1982 to December 2011.

Figure 6 (above): US Drought Monitor Statistics Graph for Beckham County, OK from January 2000 to December 2011. Courtesy of the National Drought Mitigation Center.

Figure 7 (above): BFAST output. The minimum time between breakpoints inputted is one year and the number of breaks inputted is three.

Figure 8 (above): Negative step change at each breakpoint.

Figure 9 and 10 (above): Palmer Drought Severity Index for 1988 and Statistics Graph for Park County, WY from January 2000 to December 2011. Both courtesy of the National Drought Mitigation Center.

Figure 11 (above): BFAST output. The minimum time between breakpoints inputted is one year and the number of breaks inputted is four.

Below: Deseasonalized time series (black line) with trends (green line) and breakpoints (dashed green line) where a purple line signifies the slope of values during the breakpoint and a red line indicates the breakpoint with greatest magnitude of change.

Figure 12 (above): Negative step change at each breakpoint.

Figure 13 and 14 (above): Rainfall percentage for Australia in January 2010 and February 2010. Both courtesy of the Bureau of Meteorology for the Australian government.

Figure 15 (above): BFAST output. The minimum time between breakpoints inputted is one year and the number of breaks inputted is one.

Figure 16 (above): Positive step change at the breakpoint.

Figure 17 (above): Negative step change at each breakpoint.

Figure 18 (above): Positive step change at each breakpoint.