Challenges of AVHRR Vegetation Data for Real Time Applications

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Abstract

Remote sensing data has long been used to monitor global ecosystems for floods and droughts and AVHRR data, as one of the first product, has many users interested in receiving the data within hours of acquisition. With the introduction of a new series of sensors in 2000 (the AVHRR/3 series), the quality of the NDVI datasets available for real time environmental monitoring has declined. This paper provides evidence of problems of cloud contamination, calibration and noise in the real time data which are not present in the historical AVHRR NDVIg dataset. These differences introduce significant uncertainty in the use of the real time data, degrading their utility for detecting climate variations in near real time.

Keywords: AVHRR, NDVI, decision support, drought, real time data

Introduction

Remote sensing data used to monitor global ecosystems for floods and droughts have increased in importance in recent years. Increasing population density, industrialization and vulnerability to climate extremes has motivated the development of web-based geospatial decision support tools. These tools need accurate, reliable, synoptic information on environmental extremes which is often derived from remote sensing data. This paper focuses on the weaknesses, strengths and opportunities posed by vegetation datasets developed for real time anomaly identification (Brown et al. 2006; van Leeuwen et al. 2006).

Vegetation data records have typically also been used for a variety of monitoring tasks in Africa, including drought and flood monitoring in the context of famine early warning (Brown et al. 2007). Termed 'near real time datasets', the earth observation datasets are produced hours after data acquisition and are processed into image products and posted on the web for viewing by analysts from a variety of disciplines (Brown 2008; van Leeuwen et al. 2006). This paper evaluates two real time vegetation datasets derived from NOAA AVHRR data and compares them to the long term data record GIMMS AVHRR NDVIg dataset from the same period. For comparison, real time data from SPOT Vegetation will also be examined, although the products from this sensor are only available several days after acquision.

Remote sensing data is used to measure environmental processes span scales from short term local to long term global processes. Using earth observations from existing satellite resources (e.g. AVHRR, MODIS, and SPOT Vegetation) and extensive field studies, scientists have developed indicators of vegetation activity, disturbance and fire activity (Brown et al. 2006; Buermann et al. 2003; Hicke et al. 2003). These data are also used in computer models to evaluate ecosystem productivity and carbon fluxes over the past two decades and into the future (Neigh et al. 2007; Slayback et al. 2003). Data from remote sensing is particularly useful in Africa, where other sources of data are less robust (Fensholt et al. 2006). Figure 1 shows the anomaly data from March, 2008 from the AVHRR sensor.

Like long term data records, these real time datasets must be self-consistent, calibrated and issues related to the remote sensing system need to be addressed. Just like all vegetation data products, most serious problems afflicting these datasets are clouds, which render any observation useless by obstructing the target, and to a lesser degree, effects of the bidirectional reflectance distribution function or BRDF (Brown et al. 2006). This paper examines the success of these real time data products to balance the need for rapid delivery with processing that removes the effects of clouds and BRDF and other artifacts in the data.

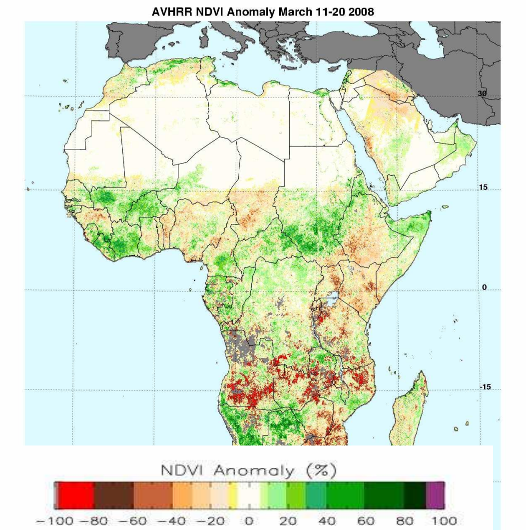

Figure 1. AVHRR percent anomaly March 11-20, 2008

Data and Methods

Data used in this study include the AVHRR NDVIg product (G), the real-time G product (RG), the NOAA-17 real time product (N17), and the S10 SPOT Vegetation data (SP) reprojected and regridded to match the Albers 8km resolution of the GIMMS data. The following section describes the datasets and then the methods will be described.

Data products

The GIMMS NDVIg Historical dataset is a 15 day, maximum value AVHRR normalized difference vegetation data composites (Holben 1986) from the NASA Global Inventory Monitoring and Modeling Systems (GIMMS) group at the Laboratory for Terrestrial Physics (Tucker et al. 2005) from July 1981 to December 2006. The GIMMS operational dataset incorporates data from sensors aboard NOAA-7 through 14 with the data from the AVHRR on NOAA-16 and 17 using SPOT data as a bridge for a by-pixel inter-calibration. After calibration, the AVHRR NDVI data dynamic range was adjusted to values of –0.05 to 0.95 to match more closely that of the SPOT- and MODIS-based NDVI. In addition, the NDVIg data has had an algorithm applied that replaces pixels with missing data, data obscured by clouds and data with depressed values due to significant sub-pixel cloud contamination with interpolated data.

The AVHRR real time datasets include the RG and the N17 datasets. The RG real time NDVI product uses the same code as was used to produce the NDVIg, but with a calibration computed once every six months. The RG product has had the inter-calibration of the datasets applied and the adjusted dynamic range of the NDVIg dataset, but has not had the interpolation routine removing clouds. Cloud detection is a T5 temperature threshold technique, using 285 Kelvin for Africa.

The N17 data is a NOAA-17-only dataset processed using the imbedded information present in NOAA-17 level 1b AVHRR data. This release uses three methods to detect daytime clouds over land, including a T5 temperature threshold of 285 degrees Kelvin over Africa, the cloud, snow and cloud shadow method (Saunders and Kriebel 1988) as implemented in the SPOT Vegetation dataset and the NOAA CIMSS Level-1b (v4) CLAVR-x method (Heidinger et al. 2006). The navigation has been improved by correcting the registration offset between ascending/descending nodes and GAC Earth location interpolation.

The SPOT Vegetation data used in this study are VGT-S10 (ten day synthesis) products. The ‘S10-composited’ data (spectral band data, data quality and NDVI) covering the period May-1998 to June-2004 were acquired for analysis. Post-processing includes reprojection from the native global Mercator to a continental Albers projection, regridding to 8km resolution, regional sub-setting, cloud screening, and land masking (Brown et al. 2006). The SPOT data was processed in collaboration between the USDA's Foreign Agricultural Service (FAS) Production and Crop Assessments Division (PECAD) and NASA/GSFC's GIMMS group.

Methods

To compare the information from multiple datasets, we examined both time series extracted from the data and data from the entire continent of Africa from September 2002 to December 2007. Table 1 lists the locations where time series data were extracted and examined. We subtracted time series from each other to determine the differences between the information in the real time datasets and the NDVIg datasets, and we compared the ability of these real time datasets from AVHRR to identify periods of flood and drought to that of the SPOT data. We used also the mean, standard deviation and variance of the continental data as a measure of its stability.

City	Country	Region	Latitude	Longitude
Bonkoukou	Niger	West	14.04	3.22
Louga	Senegal	West	15.63	-16.17
Kano	Nigeria	West	11.89	8.53
Mongo	Chad	West	12.12	18.64
Malakal	Sudan	East	9.53	31.65
Goba	Ethiopia	East	4.74	39.30
Baydhabo	Somalia	East	3.12	43.64
Dodoma	Tanzania	South	-6.09	35.71
Mbandaka	DRC	Central	0.05	18.26
Messina	South Africa	South	-22.25	30.09
Dutlwe	Botswana	South	-23.98	23.90
Tsumeb	Namibia	South	-19.25	17.71

Table 1. Locations where time series were extracted in Africa

Results

Figure 2 shows the difference between the GIMMS NDVIg and the two AVHRR real time products, the N17 and the RG, period by period. Several issues of the real time datasets can be noted from the figure: systematic cloud contamination, calibration issues across sensors and noise. The difference between the real time and historical NDVIg dataset in some regions varies seasonally due to cloud contamination which affects the real time data more than the post-processed, corrected NDVIg data. Large differences in calibration can also be seen which change through time, with significant shifts in 2004 due to the change from NOAA-16 to

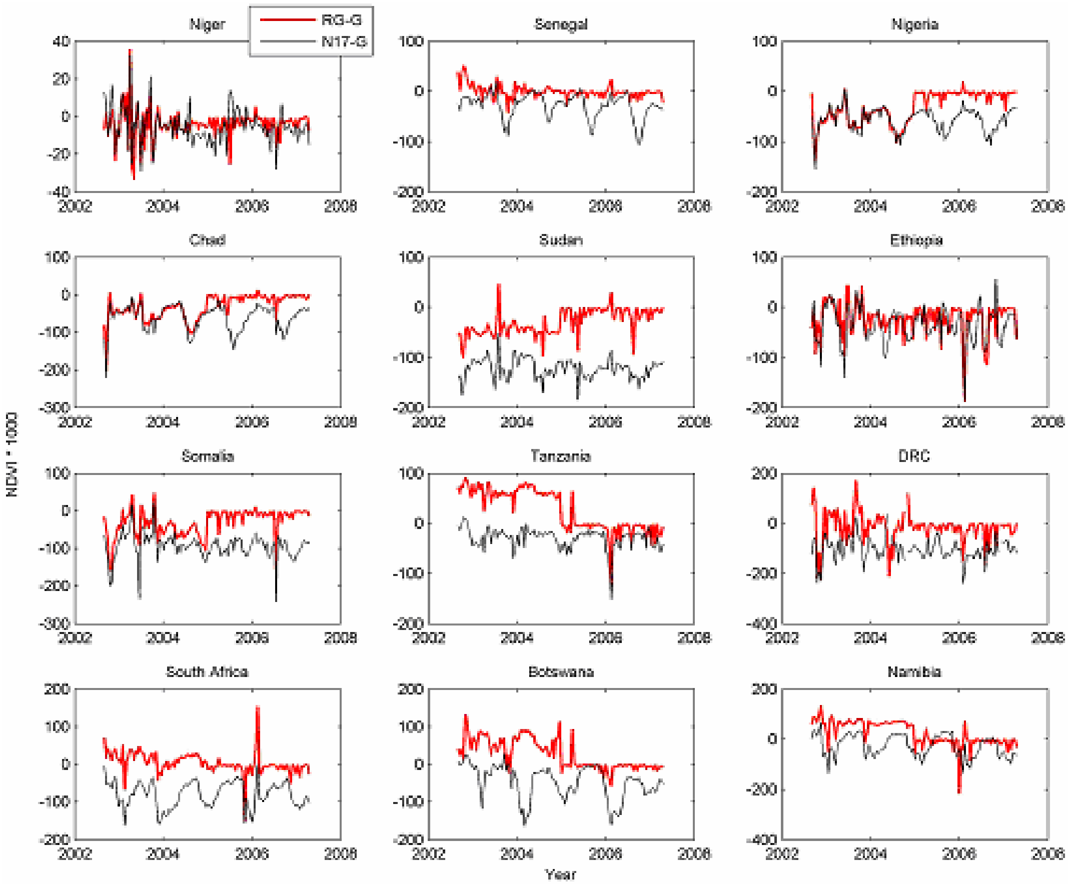

Figure 2. Time series of AVHRR real time datasets subtracted from the AVHRR GIMMS NDVIg dataset.

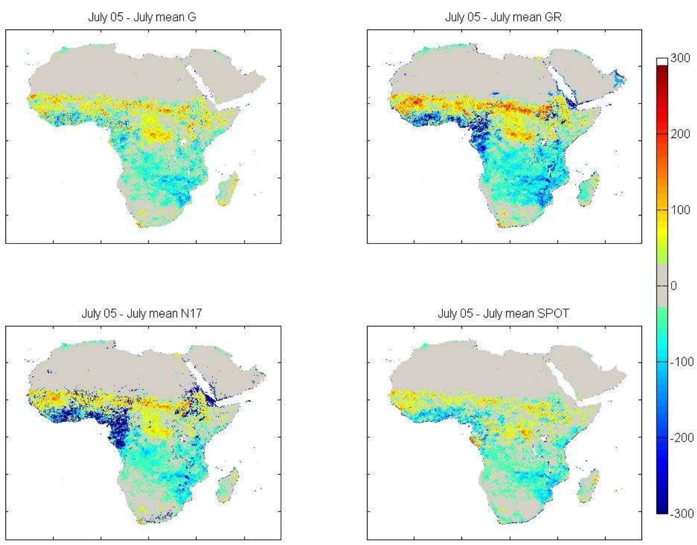

Figure 3. July 2005 anomaly from mean data from 2002-2007, showing difference between products for the same period.

NOAA-17 data in the RG product. The N17 product only uses data from NOAA-17. The RG product also has significantly more high frequency noise than the N17 product.

Figure 3 shows the varying continental-scale anomalies resulting in the different processing schemes of the real time datasets, even for the same period. Although the overall pattern of the anomaly is similar, with the exception of the cloud-induced negative anomaly focused on the Guinea coast which varies in size depending on the product, the size of the anomaly varies by product. The anomalies are nearly twice in the GR product than the G anomaly and the SPOT anomaly. The N17 anomaly is slightly larger than the G anomaly, but still significantly cloud contaminated.

Discussion

AVHRR's wide spectral bands cause the data to be quite sensitive to water vapor in the atmosphere. Increases in water vapor results in lower NDVI signal, which can be interpreted as an actual change if no correction is applied (Pinheiro et al. 2004). The maximum value composite lessens these artifacts (Brown et al. 2006), but issues obviously still remain. This study shows that when comparing cloud-corrected NDVIg data to real-time data without significant post-processing cloud removal causes significant false negative anomalies. These false negative anomalies cause difficulty for operational data users seeking to use AVHRR data to monitor widespread changes in food availability or pasture for animals. As the historical NDVIg data has improved in stability, completeness, and utility for scientific trend analysis, it has become much more difficult to match in real time processing as the techniques used to correct the data do not do well at the ends of time series (such as decomposition techniques).

Efforts by the GIMMS group to produce a new real time data product, such as the N17 product, have resulted in a much better calibrated product, but one with significant differences from the historical dataset in cloud detection. Although the N17 product detects more clouds and flags them than the historical data, the result is a significant decline in the amount of data available for trend detection. The quality of the product then suffers, as much of the area of interest is obscured behind cloud masks as Figure 3 shows.

The SPOT Vegetation data product is far superior to either of the AVHRR data products due to a much higher data density due to its 1km resolution and to its superior cloud detection. SPOT data has had significant problems with calibration, however, which have reduced the mean productivity in Africa making for anomaly products that are higher than they should be.

Conclusions

Perceptions of declining quality of real-time AVHRR data since the introduction of the AVHRR/3 sensor are demonstrated by this analysis. The GIMMS group had to greatly increase the level of complexity of the calibration, navigation and cloud removal techniques in order to incorporate data from both the AVHRR/2 NOAA-7 through 14 with the AVHRR/3 series of NOAA-16 and 17. This complexity has severely impacted the ability to implement a reasonable process on data that must be delivered within hours of acquisition.

Despite over two and a half decades of research and analysis and a high degree of similarity between the AVHRR/3 sensors, calibration and cloud detection issues in real time data still remain. These are land-cover dependent, with some regions showing much better similarity between the real time and historical NDVIg dataset than others. As we move into the VIIRS era where AVHRR data will not be available, we can anticipate serious problems bringing multiple datasets together when their design is completely different. Thus this research shows that investment in research on AVHRR data integration with MODIS and VIIRS datasets is essential, as well as the continuation of the AVHRR sensor to ensure data continuity if the research does not come to fruition.

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