USING AVHRR DATA FOR DETECTION OF EL NINO/LA NINA IMPACTS ON LAND ECOSYSTEMS

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ABSTRACT

El Nino/La Nina consequences for land ecosystem were examined using the new AVHRR-based three-channel vegetation index (VT), widely used for monitoring drought. A typical pattern of vegetation conditions was identified around the world during the recent events. Features and trends of the 1997/98 El Nino including its intensity, extent, and impact on vegetation are also discussed.

INTRODUCTION

The Advanced Very High Resolution Radiometer (AVHRR) carried by the National Oceanic and Atmospheric Administration’s polar-orbiting satellites has the capability of identifying vegetation condition, including stress. A new numerical index has been developed using three AVHRR channels (Kogan, 1990, 1997). This index was instrumental in early drought detection, monitoring, and analysis of impact on agriculture around the world (Unganai and Kogan 1998; Kogan 1995, 1997; Hayes and Decker 1996; Liu and Kogan 1996). This index was applied to identify world areas where vegetation responds strongly to El Nino/ La Nina events.

DATA AND ALGORITHM

Radiances measured by the AVHRR sensor on board NOAA-9, 11, and 14 polar-orbiting spacecrafts were extracted from the NOAA/NESDIS Global Vegetation Index (GVI) data set (Kidwell 1997) from April 1985 through November 1997. They include weekly composite reflectance in the visible (Ch1) and near infrared (Ch2), and emission in the thermal (Ch4) bands for each 0.15° grid box of the world. The Ch1 and Ch2 values were calibrated and the Normalized Difference Vegetation Index (NDVI) was calculated (Kidwell 1997). The Ch4 radiance was converted to brightness temperature (BT) using a look-up table, and corrected for non-linear behavior of the sensor.

The three-channel algorithm includes procedures for complete removal of high frequency noise from
yearly NDVI and BT time series, identification of vegetation seasonal cycle, and detection of low frequency fluctuations associated with weather-induced changes in vegetation condition (Kogan, 1995, 1997). The new Vegetation and Temperature index (VT) scales vegetation condition from extreme stress (zero) to favorable (100).

EL NINO/LA NINA AND IMPLICATIONS

El Nino is one part of a multi-year cycle of the coupled ocean-atmosphere interaction in the tropical Pacific, called El Nino/Southern Oscillation-ENSO (WMO 1995). A typical characteristic of this cycle is the emergence of a huge mass of warm water in the central and eastern tropical Pacific. At the end of this cycle, warm water is substituted with a pool of water with below normal sea surface temperature (SST), manifesting the appearance of the cold phase, called La Nina.

Normally, surface water is warmed by the sun and pushed by the equatorial trade winds to the western Pacific, while cool water wells up from deep reaching eastern part near South America cost. During El Nino, the equatorial trade winds get reduced causing warm water to slide eastward. Warmer ocean affects atmospheric circulation, disturbing normal pattern of air pressure, tropical rainfall, and winds, which ultimately interact with and affect mid-latitude jet streams leading to changes weather around the globe (Ropelewski and Halpert 1989, NOAA 1997). Excessive rains in one part of tropical Pacific and extra-tropical areas and droughts in other parts are major events occurring during El Nino and La Nina years.

LINKS BETWEEN ENSO AND VT

It was noticed before that there is relationship between SST and precipitation anomalies in some parts of the world (McBride and Nicholson 1983, Ropelewski and Halpert 1989). These results were supported by correlation analysis of NDVI and SST anomalies for Africa, Australia and South America (Myneni et al 1996). However, it is known that El Nino/La Nina events affect other areas of the globe (NOAA 1997). Besides, it was shown recently, that NDVI alone does not adequately represent vegetation condition (Kogan 1997). Therefore, we investigated geographic extent of El Nino/La Nina implication for land ecosystems using both NDVI/BT-based VT.

First, average patterns of vegetation condition during the two El Ninos (1986/87 and 1991/92) were compared with the two La Nina (1988/89 and 1995/96) years. Both areas show a very coherent difference in the pattern of conditions. There are two patterns, in the early stage, the differences in conditions between El Nino/La Nina years are minimal and random. Later, conditions are very different. This period of the large difference is January-June in Southern Africa and August-February in Argentina. The pattern of vegetation condition is opposite for these locations: in Southern Africa, conditions deteriorate in El Nino and improve in La Nina years, while in Argentina, they are opposite. Further, we correlated SST monthly anomaly collected from Reynolds and Smith (1994) for the NINO 3.4 region (5°S to 5°N and 120°W to 170°W) with VT index aggregated from weekly to monthly values for each pixel of the world. The results are shown in Figure 2 (correlation coefficient
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Fig. 1. Average vegetation condition during El Nino (1987-88 and 1991-92) and La Nina (1988-89 and 1995-96); left - South Africa (24-25°S, 25-26°E) right - Argentina (35-36°S, 64-62°W).

is greater than 0.35 or less than -0.35). It is important to emphasize that all 13 years were included in the correlation analysis. During these years only four ENSO events were observed. Therefore, correlation coefficients are not large. However, global coverage permitted us to select areas most sensitive to SST change. Two types of correlation are identified: negative when El Ninos are accompanied by drought which cause severe vegetation stress, and positive in the areas with favorable conditions during El Ninos and stressful during La Nina years. Most of the areas have negative correlation.

Figure 2. Areas with elevated correlation between ENSO anomaly and VT index; inside each area absolute value of correlation coefficient changes from 0.35 to 0.55.

Scattered plot of ENSO versus VT for two areas (US/Mexico and Southeast Asia area) with opposite type of teleconnection is shown in Figure 3. During El Ninos, Southeast Asia experiences deficit of rainfall resulted in drought and severe vegetation stress, while in La Nina years, vegetation conditions in the region are favorable. The same type of relationship is observed in norther and eastern Brazil and Southern Africa. Opposite to that situation southern US and adjacent regions of Mexico experience droughts during La Nina years. Other areas such as Argentina, eastcentral China and central India also show sensitivity to El Nina/La Nina events.

Figure 3. Correlation between VT index and Nino 3.4 SST anomaly (*100) in US/Mexico region (left) and Southeast Asia (right).
VEGETATION CONDITIONS DURING THE 1997/98 EL NINO

In the first 9 months of the 1997/98 El Nino development, the most noticeable impacts have been in the Tropics and subtropics. The eastern Pacific received above normal rainfall, while in many areas of the western tropical Pacific it was far below normal. Severe dryness affected large land masses in Indonesia, eastern Australia, New Guinea, and northern South America, causing uncontrollable wildfires (NOAA 1997).

In the region of the strongest El Nino impact, VT estimates indicated severe vegetation stress in Southeast Asia. Unfavorable conditions were also recorded in central India and eastern Brazil. In southern Africa, vegetation conditions until the late 1997 were mostly fair and did not differ much from the two-year average of the recent El Nino years. Meanwhile, as the 1997/98 growing season progressed, vegetation condition in southern Africa did not deteriorate as it occurred during the 1986/87 and 1991/92 El Ninos. In early April 1998, El Nino impact was observed only in some areas. Between 12°S and 34°S, vegetation was stressed on only 18 percent of the area in 1998 compared to 85 percent during 1986/87 and 1991/92 El Nino years.

REFERENCES