Jamaica's Mid Summer Dry Spell

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Abstract:

The Caribbean Sea region experiences a bimodal precipitation pattern with peaks in the late spring and early summer separated by a local minimum during the mid summer. This decrease of mid summer precipitation is collectively known as the mid summer dry spell (MSD). The MSD has both a consistent seasonal cycle as well as a variable inter-annual cycle. This inter-annual variability determines the magnitude of the MSD, or precipitation difference between the bimodal peaks, as well as the timing and duration of overall mid summer precipitation minimum.

Fluctuations in the semiannual North Atlantic Subtropical High (NASH) appear to be the leading factor of mid summer precipitation in Jamaica. These fluctuations are captured within a Modified Bermuda High Index that act as an early spring precursor to mid summer precipitation rates. The seasonal cycle is also characterized by increased vertical wind shear within the region during the MSD period that acts to inhibit convection.

The inter-annual cycle is characterized by variations in overall NASH strength and extension, which leads to variations in vertical wind shear and vertical distributions of temperature and moisture in the mid-troposheric level. Vegetation responds to both the seasonal and interannual cycles and can be detected through NDVI strength classifying vegetation stress levels.

Introduction

The Intra-Americas Sea (IAS), comprised of the areas contained within the Caribbean Sea and the Gulf of Mexico, exhibits a bimodal precipitation pattern with peaks occurring during the late spring and late summer (Fig.1). The relative minima between the bimodal peaks is commonly referred to as the period of "mid summer drought" (Magana 1999). However, this minima is technically not a true drought as precipitation exits during this period, but at a measurable decrease compared to the rainy season average between late spring and late summer months. Because of this misnomer, there has been an effort to rename the mid summer period as the *mid summer break* (Giannini 2000), *mid summer minimum* (Gamble et al 2007), or *mid summer dry spell* to more accurately describe the hydrologic phenomena. Local vernacular within Central America uses the terms canicula and veranillo to describe the mid summer precipitation depression.

Throughout this research, I selected the term mid summer dry spell as it most accurately describes the true mid summer precipitation pattern as well as maintaining the original abbreviation MSD (Mid Summer Drought) that is common in much of the research literature. For the continuation of this paper, the relative summer time precipitation minima within the IAS rainy season will be referred to as the mid summer dry spell with the common abbreviation of MSD.

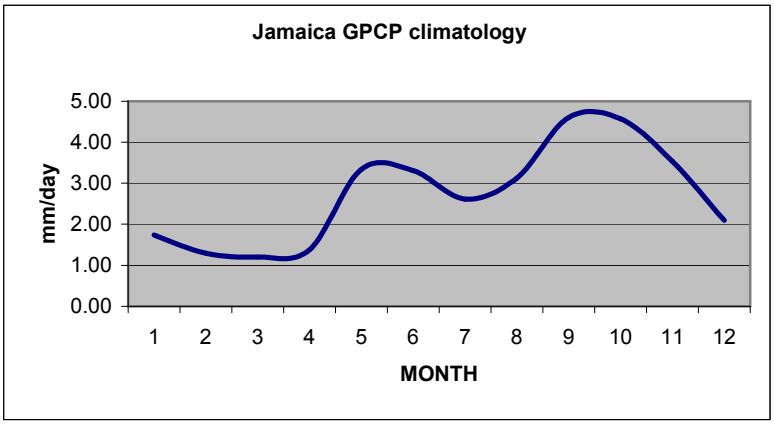

Fig.1 Annual precipitation climatology from the GPCP 2.5 degree gridbox containing St. Elizabeth, Jamaica. The MSD period is seen as the depression between the bimodal peaks.

The MSD varies both spatially and temporally throughout the IAS with the leading mode of precipitation occurring earlier in the spring in the eastern IAS and later in the spring towards the western portions of the IAS. Also, the magnitude of the MSD, or the average difference between the bimodal peaks and the minima, is greater towards the western IAS compared to the magnitude of the eastern IAS (Fig.2). In addition to the seasonal variation mentioned above, the MSD also has significant inter-annual variation

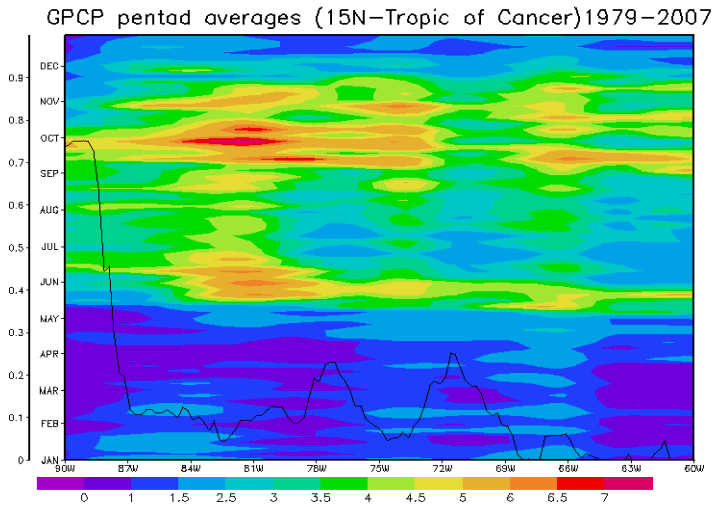

Figure 2. Spatial and temporal variability are captured illustrating an earlier onset towards the east with a stronger MSD signal toawards the west. This figure contains the region from 15N – 23.5N.

with the magnitude and duration of rainfall minima. Some years the MSD can resemble the average precipitation of the bimodal peaks, while during other years the MSD can be significantly less than the surrounding rainy peaks.

The motivation leading to this research attempts to fill in a much needed forecasting void to alert farmers whose crops are affected by the MSD variability. This mid summer precipitation variability represents major challenges for farmers who are dependent upon rainy season moisture, May to September, with a variable dry spell (July-August) during this critical productive period. To assist with this goal, I include qualitative information from collaboration between geographers at the University of the West Indies at Mona who have provided information collected from over four hundred climate / agriculture directed interviews from Jamaican farmers (Fig.3). With their assistance a bridge between the farming perceptions and climate diagnostics will improve the efforts in delivering a long-term agricultural climate outlook that is sensitive to farmer's needs in terms of MSD inter-annual variability. For this specific case, I examine the region of the St. Elizabeth parish in the southwest corner of Jamaica, which is known to be the "bread-basket" of the country.

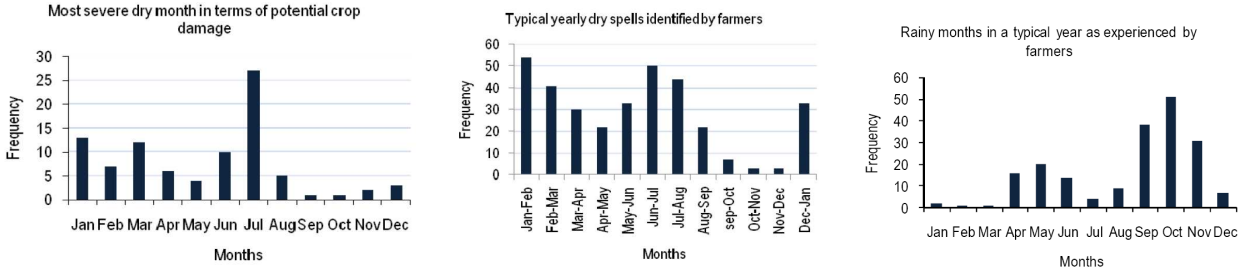

Figure 3. Jamaican farmers perceive the July MSD period to be especially critical in terms of potential crop damage. Courtesy Donovan Campbell at The University of the West Indies at Mona.

Data

Precipitation data is derived from the Global Precipitation Climatology Project version 2 (GPCP) that provides a global coverage of precipitation rates (millimeters per

day) at a 2.5-degree spatial resolution. Included with this product are monthly and pentad temporal resolutions that were used to illustrate the seasonal cycle. Atmospheric variables were captured from the NCAR/NCEP global Reanalysis Data Set (Kalney et al 1996) at the monthly scale at a global 2.5-degree spatial resolution. Vegetation response was collected via the Aqua-MODIS NDVI product at a 250m spatial resolution with a 16 day average granual composite. The NDVI data used is from the earliest available record from 2001 and includes all images through 2007. Fractional land percent cover at a 2.5 degree resolution to describe possible diurnal effects was retrieved from the NASA Goddard Space Flight Center Laboratory for Atmospheres. Other explored data leading to future work include the 1 by 1.25 degree TOMS aerosol index as well as the NOAA North Atlantic Oscillation index from 1948 to present.

Seasonal Cycle

The general MSD seasonal cycle is a result of both atmospheric and oceanic variables that act together to suppress overall convection, which leads to a decrease in precipitation. The primary driver of the seasonal cycle is the strengthening of the semiannual North Atlantic Subtropical High (NASH) into the summer months. The transition from spring to summer results in a stronger NASH with a southwest extension towards the Caribbean Sea. The maximum strengthening and extension of the NASH coincides with the timing of the MSD onset within the central Caribbean Sea. As the strengthening occurs, a maximum meridional surface pressure gradient develops between 35N,40W and 20N,40W which in turn forces a strong easterly zonal flow from the Atlantic into the Caribbean basin. This enhanced zonal flow reinforces the existing trade-winds and coincides with the mature phase of the near surface 925hPa semiannual Caribbean Low Level Jet (CLLJ). The CLLJ then acts to reduce local sea surface temperatures off of the northern coast of South America due to upwelling and increased evaporation. Together, the cool surface waters and the CLLJ transport relatively cool and dry air into the Jamaican region, which acts to limit convection (Fig.4).

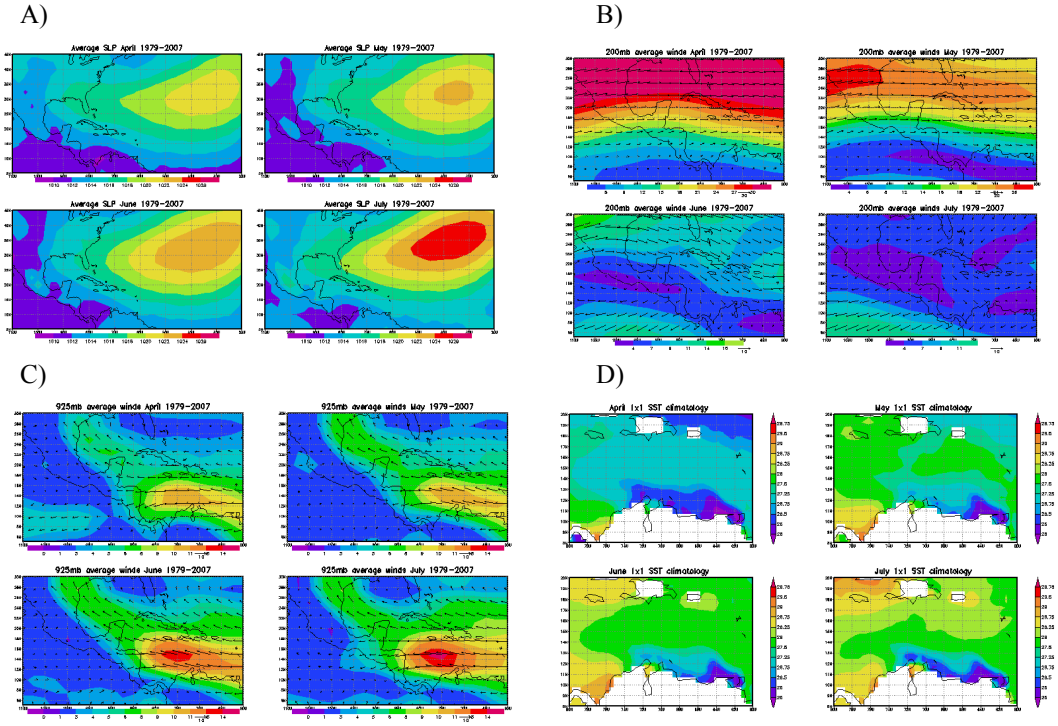

Figure 4. Seasonal cycles of A) NASH, B) 200hPa upper air flow, C) near surface 925hPa CLLJ, and D) local SST cooling along northern South America.

In addition, the wind shear throughout the region increases as the mild upper level 200hPa westerly winds over the IAS decrease while the lower level (CLLJ, tradewinds) easterly winds increase dramatically. Overall, this change in vertical wind structure acts to inhibit convection through an increased shear environment.

Remote dipole sea surface temperature features also act to maintain the seasonal cycle by supporting large-scale circulation. Overall cooling of the sea surface temperatures in the Nino3 region (5S-5N, 150W-90W) into the summer coincides with overall warming of the Tropical North Atlantic (TNA) (5N-25N, 56W-16W) sea surface temperatures at the same time. Changes to the warm TNA affect the amount of available moisture entering the region.

A consistent feature throughout the IAS region into the summer is a cooling and drying of the mid-tropospheric level (600hPa) that reaches a maximum extent during the MSD period (Fig.5). The origin of this cool and dry layer is suspected to be from the extension of the NASH into the region that advects cooler air from a cooler sea surface temperature region easterward of the IAS warm pool with the drying associated with the subsidence of the NASH. It is also worthwhile to note that during the MSD period of the rainy season in the IAS the surface pressures increase. The surface pressures have an absolute maximum during the dry winter season, but exhibit a relative maxima that coincides with the MSD period.

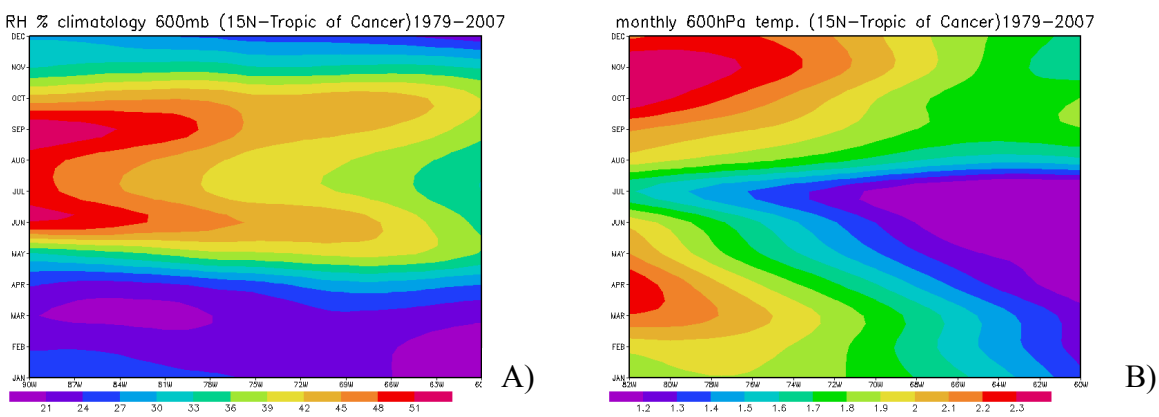

Figure 5. A) Relative Humidity at the 600hPa level showing a decrease into the MSD period. B) Temperature at the 600 hPa level illustrating a cool advection into the region during the MSD period.

<u>Inter-annual cycle</u>

While the MSD is an annual climatological feature, it does express year to year variation in terms of total precipitation and duration of relative dryness. Some years the rain rate during the MSD varies little with the bimodal peaks, while during other years the reduced precipitation associated with the MSD varies greatly. In addition to the total MSD precipitation variability, there is also variability in the timing and duration of the MSD onset.

One method to capture a sense of this variability is to understand the variability associated with the primary driver of the MSD: the NASH. To accomplish this a

Modified Bermuda High Index (MBHI) was created to describe the maximum spatial gradient of the NASH, which is a leading component to the magnitude of the CLLJ. The original Bermuda High Index was created to describe the seasonal variability in surface pressure from the NASH to New Orleans, LA. However, since this index does not necessarily reflect the drivers of the MSD a *modified* Bermuda High Index was generated along the lines introduced by Gamble to capture the climate variability within the Caribbean. The MBHI is calculated by subtracting the sea level pressure at 20N,40W from the general NASH center at 35N,40W using the NCAR NCEP Reanalysis Data (Fig.6). The calculations range from January 1, 1979 to December 31,2007 to match the same period of GPCP derived precipitation. The monthly MBHI was then correlated to GPCP July precipitation with the strongest correlation between July rainfall and the MBHI occurring in March with a correlation coefficient of –0.64. This translates into an inverse relationship between the NASH induced strengthening of the CLLJ with July precipitation in Jamaica.

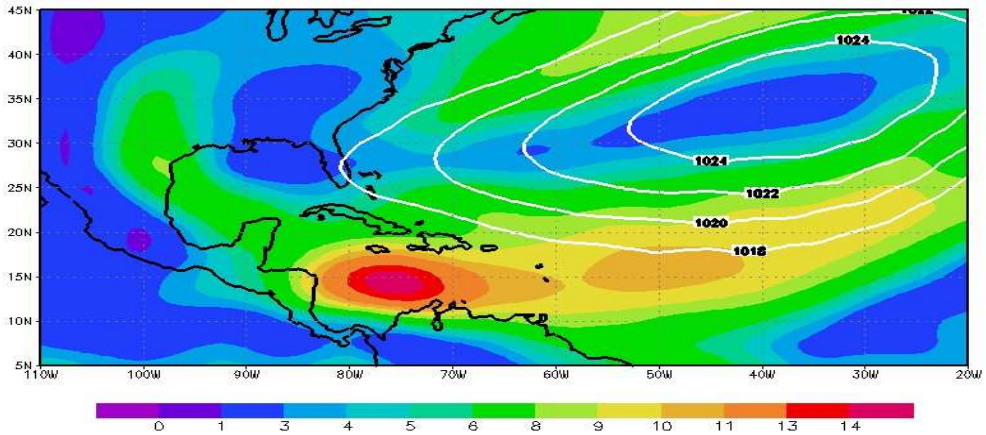

Figure 6. The Modified Bermuda High Index (MBHI) capturing the strongest meridional SLP gradient that translates to changes within the CLLJ. The NASH is superimposed upon shaded CLLJ magnitude values during July. Both contours and shaded regions represent 1979-2007 climatology.

In addition to the local climate forcing of MSD precipitation, ENSO was also examined to determine the role of a possible global teleconnection. El Nino years were found to coincide with a stronger MSD magnitude when compared to both La Nina years and ENSO neutral years of the ENSO year 0 (Fig.7). This MSD enhancement during ENSO year 0 is coincident with an increased shear environment resulting from an increased upper level westerly flow with an increased near surface CLLJ easterly flow. The increased CLLJ during El Nino years is evident by comparing the sea surface temperature anomalies along the northern coast of South America. El Nino years exhibit a negative sea surface temperature anomaly in this region that is directly related to the strengthened CLLJ during El Nino years.

A multi-year composite of dry and wet MSD years was created in attempt to understand the general circulation that determines the characteristics of weak or strong MSD years. Due to the variability of MSD onset, a simplified multi-year composite was created to describe July precipitation only (the average MSD peak season along with the

greatest farming respondents of summertime dryness). Comparisons were made between the top five driest Julys and the top five wettest Julys within the 1979-2007 GPCP record. Vertical temperature and moisture profiles from these composites show that stronger MSD summers are characterized by cooler and drier mid-troposheric levels. While the origin of this cool and dry air would need to be quantified through a three dimensional backtracking model, I can hypothesize that the NASH contributes to this environment through advection from cooler sea surface temperature regions along with an overall reduction in convection.

While little attention was dedicated to other remote forcings, it is worth noting that the Jamaican region reaches an atmospheric aerosol maximum during the MSD period. It is hypothesized that this aerosol transport originates from the Sahara and can relay negative precipitation feedbacks through radiative forcings. The North Atlantic Oscillation (NAO) also exhibited a strong negative correlation between early spring NAO phase with July rainfall in Jamaica (r = -0.61). The positive phase is associated with a strong southerly NASH resulting in stronger MBHI gradients working to suppress MSD precipitation. Much attention will be dedicated with these and other remote forcings of the MSD including the possible effect of the Madden Julian Oscillation (MJO) upon Jamaican MSD rainfall.

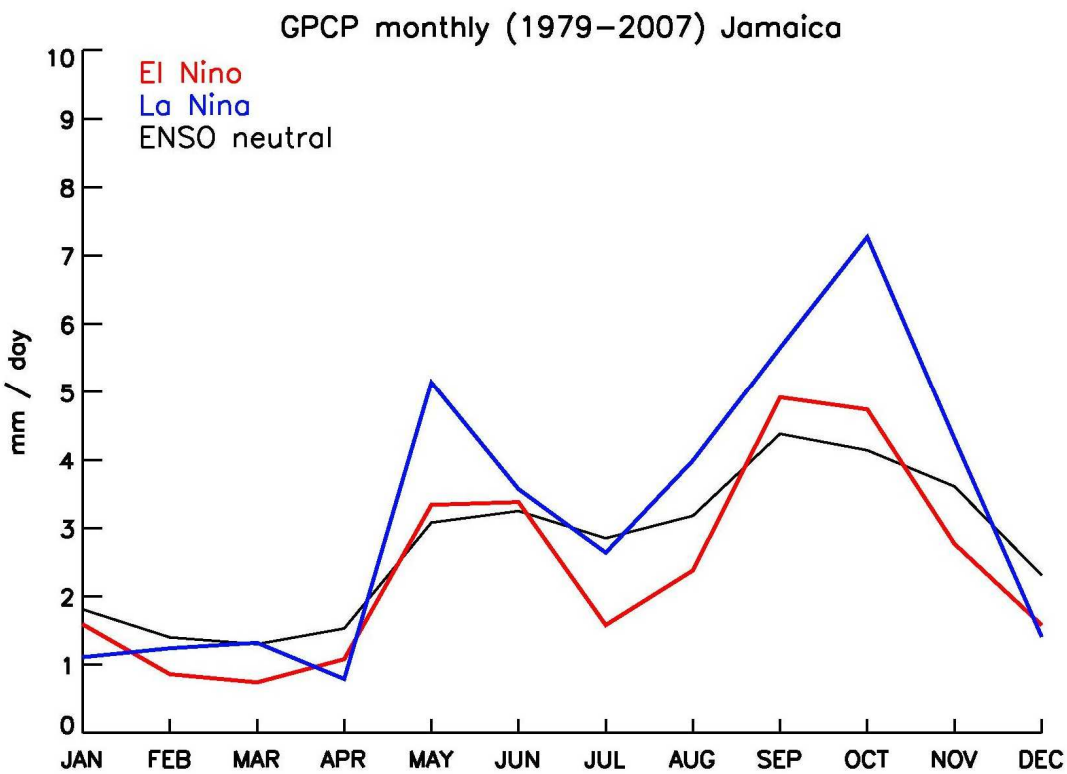

Figure 7. Jamaican GPCP precipitation for El Nino, La Nina, and ENSO neutral years for ENSO year 0.

Vegetation

A Normalized Difference Vegetation Index (NDVI) was derived from Terra MODIS to determine the impact that the summertime climate has on Jamaican

vegetation. As expected, vegetation changes were detected during the summer months that respond to the bimodal cycle, but at a normal lagged response. Likewise, years with a greater MSD magnitude correspond to years with greater NDVI summer variation. In all years, a mid summer reduction in NDVI is sensed with an accompanying increase into the late summer as the late rain season begins (Fig.8).

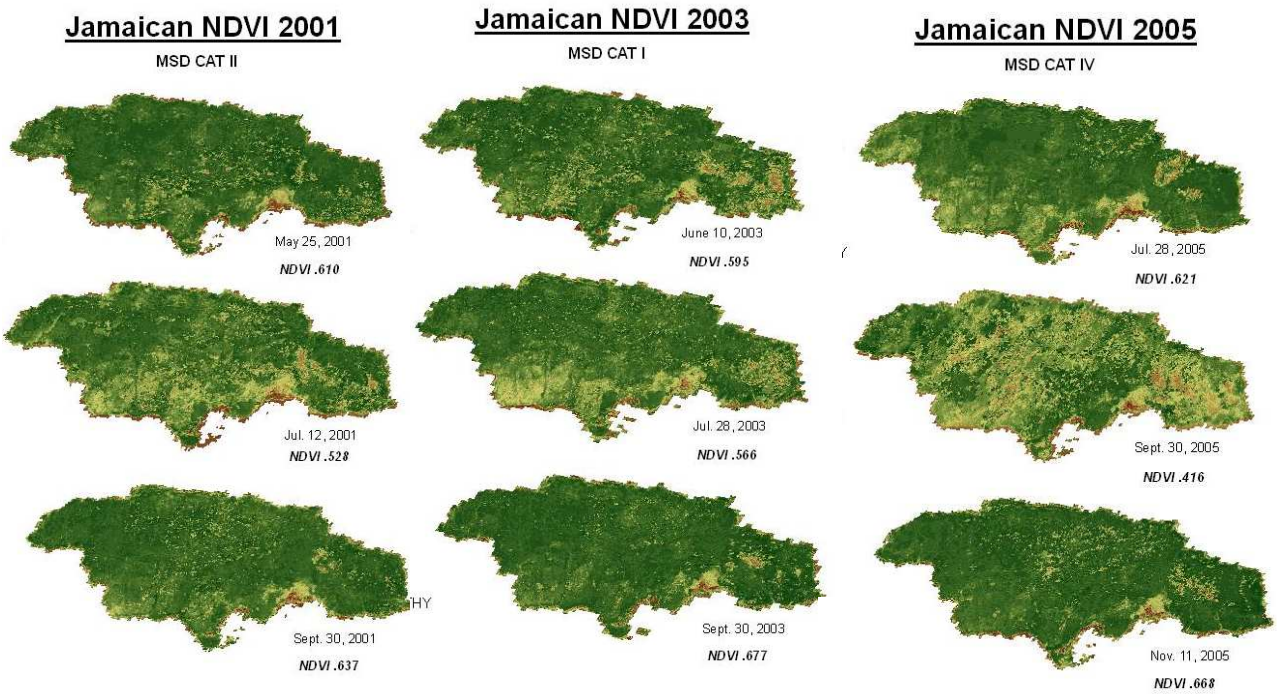

Figure 8. Jamaican NDVI response during the May – Sept. rainy season. Note the lagged NDVI response to the MSD period along with the recovery after late season rains.

This approach is simply an estimate to detect ground level variability as vegetation responds to many factors outside of precipitation alone. Future work will involve isolating the St. Elizabeth parish from Jamaica to calculate more specific NDVI descriptive statistics that relate to the central agricultural region of the country. In addition, primary productivity can also be derived from Terra MODIS to assess vegetation response as well.

Final Remarks

The MSD is an annual occurring climatic event that poses significant insecurities to the success of Jamaican farming. An improved sense of the causes of MSD variability is vital in preparing farmers for their crop planning cycles. Farming securities are becoming increasingly important in Jamaica as the labor force is experiencing a transition from traditional agricultural practices to a more tourism serviced based economy. An MSD advanced warning system will create an improved sense of economic security that can maintain an active agricultural economic sector rather than shifting it to a more temporary tourism based economy. As recent history has proven, global terrorism and rising oil costs can have disastrous consequences on tourism and the economies that depend on it. With the rise of global food insecurity and the cost and demand of fresh

water the need for accurate rainy season forecasts is paramount for present day economies that depend on local agricultural productions.

Acknowledgements:

I am extremely grateful for motivation and support given to me by Dr. Scott Curtis, my advisor at East Carolina University, along with Dr. Rosana Nieto-Ferreria, my thesis committee member, who are both former NASA Goddard Space Flight Center employees. In addition, I would like to thank Dr. Guojun Gu for his assistance as my mentor during the GSSP program along with valuable support from Dr. George Huffman during the summer. A sincere gratitude exists for all of those within building 33 who graciously took the time and effort to help me along the way with my project. Finally, Valerie Casasanto and Val Buxton were both instrumental in providing the foundations for an extremely rewarding and valuable experience.

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