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Recognition and Predictability of Climate Variability within South-Central Florida

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Abstract

The increasing ability to understand and forecast regional climate anomalies is a valuable asset for water management authorities. To truly benefit from this increased understanding, it is necessary to have a global perspective of the ocean and atmospheric systems that may affect a given region. The statistical ties of Florida's winter climate to the El Nino-Southern Oscillation (ENSO) process have already been well documented. The purpose of this presentation is to report on additional factors, including solar activity and the strength of Atlantic Ocean Thermohaline current that appear to significantly contribute to seasonal to decadal climate variability in south central Florida. These various global factors are integrated and down scaled with the aid of artificial neural networks. While most previous studies have emphasized the statistical connection between Florida's climate and ENSO during the winter and spring months, this effort emphasizes the climate variability that occurs during the months of May through October.

Introduction

Lake Okeechobee, located in south central Florida, provides a valuable indicator of climate variability that has occurred within this region during the 20th century. This lake has a surface area that covers nearly 730 square miles (1891 km^2) and a tributary basin with a surface area that is more than 5 times larger. Even small anomalies in net rainfall (rainfall minus evapotranspiration) depths over this extensive region can be greatly amplified in the Lake hydrologic records. By analyzing the long term variability in these records, distinct climate shifts in Florida climate regimes become apparent. Although the effects of the El Nino-Southern Oscillation phenomena during Florida's dry season months (November through April) have gained much of the media's attention during recent years, climate shifts during Florida's wet season (May through October) have been just as significant. The purposes of this paper are to:

- 1. identify long term climate variability within central and southern Florida with global and solar phenomena, and
- 2. illustrate one application of artificial neural networks as one methodology for down scaling the effects of these larger scale phenomena for regional hydrologic prediction.

Solar Activity

In spite of increasing statistical evidence of a relationship between variations in solar activity and the earth's climate fluctuations (Labitzke and van Loon 1989, 1992, 1993), no completely acceptable theory has been introduced which explains how the small changes in the ultra-violet energy flux across the outer bounds of the earth's atmosphere due to sunspot cycles can be translated into climatic fluctuations. Willet (1987) has elaborated that solar eruptive activity such as solar flare activity may cause disturbances of the geomagnetic field and the temperature and wind fields of the upper atmosphere. This strong spot heating of the atmosphere was suggested as a mechanism which could disrupt the zonal weather circulations and allow solar activity to contribute significantly to climate fluctuations without appreciable changes in energy flux. The aa index of geomagnetic activity was taken by Willet to be the best indicator of solar eruptive phenomena. This index also follows an approximate 11- year cycle of activity, but generally lags the sunspot cycle and contains many more perturbations. With the recent advent of high altitude space observatories and highly sophisticated measuring devices, the importance of phenomena such as coronal mass ejections, coronal streamers, solar flares and cosmic rays on space weather and the terrestrial environment are now just beginning to be understood. Besides emitting a continuous stream of plasma called the solar wind, the sun periodically releases billions of tons of matter in what are called coronal mass ejections at speeds as high as 2000 km per second. These explosions of material from the Sun's upper atmosphere have been hard to detect and monitor prior to the high altitude solar observatories due to their white light energy frequency being dimmed by the sun's brightness and the diffusive properties of the earth's atmosphere. Their consequences to terrestrial systems when emitted in the direction of earth are only now being recognized. Tinsley and Deen (1991), Tinsley and Heelis (1993) and Tinsley et al. (1994), documented a number of correlations between solar wind and cosmic ray variations and changes in various atmospheric parameters, such as Atlantic storm tracks, surface temperatures, and area integrated storm intensity. Svensmark and Friis-Christensen (1997) found that the short term changes (days to weeks) in the cosmic ray intensity affects the global cloud cover and therefore may influence weather predictability.

In a more conventional approach to understanding the solar climate connection, Haigh (1996) successfully simulated observed shifts of the subtropical westerly jets and changes in the tropical Hadley circulation that appear to fluctuate with the 11 year solar cycle. Photo-chemical reactions in the stratosphere are included in the model that enhance the effects of the variations of the solar irradiance energy. Even a small shift in the strength and positioning of these global scale climate systems would have significant effects on Florida's climate. Reid and Gage (1988), Reid (1989) , and White, and D.L. Cayan (1996) reported on the similarities between secular variations of solar activity and that of the global sea surface temperature.

In summary, solar activity affects the earth and it's atmosphere in many ways over different time scales. These may be broken down into the following categories: 1. Short duration sporadic events, 2. The 11 - and 22 - year sunspot cycle, 3. Longer secular solar cycles.

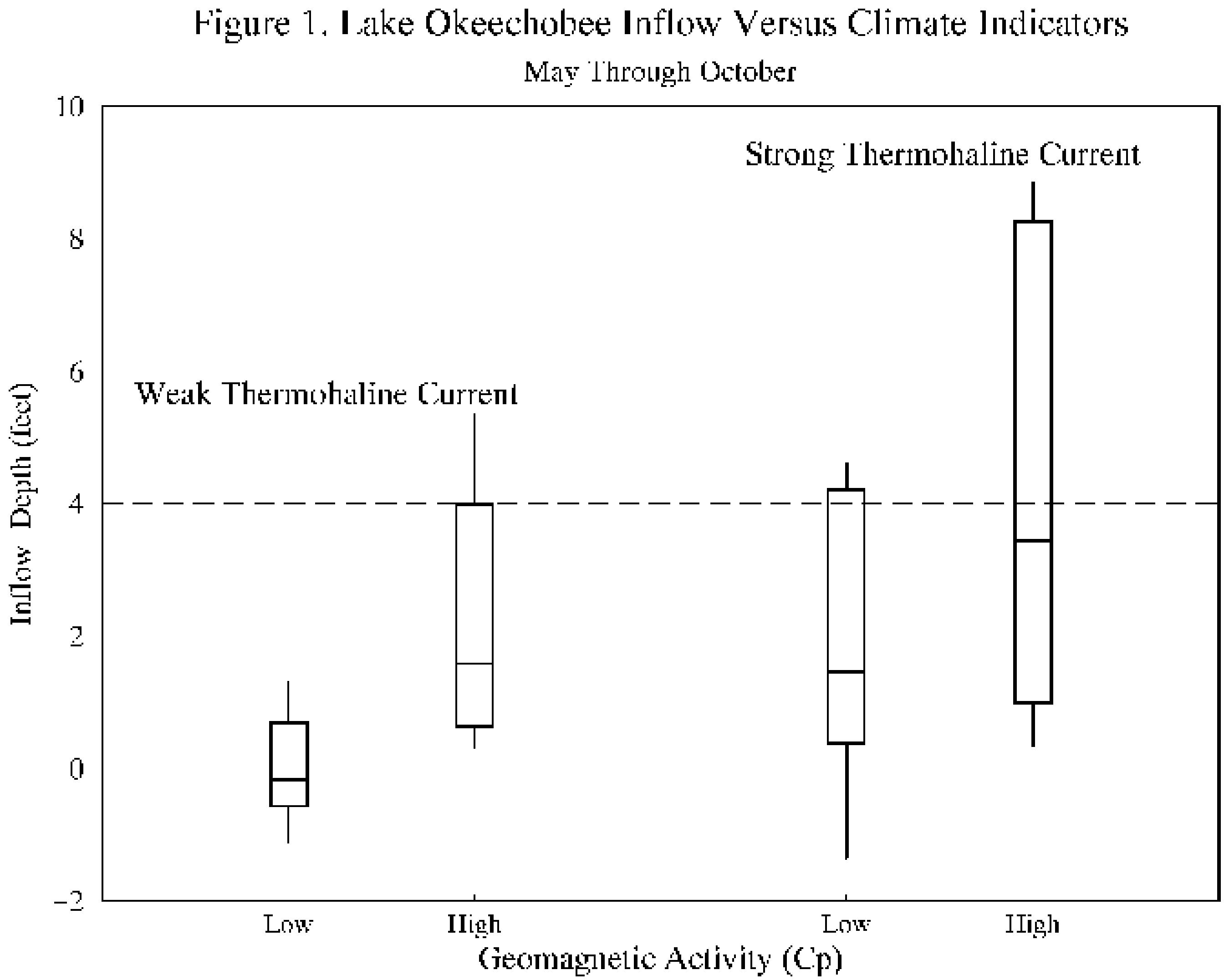
Atlantic Ocean Thermohaline Current (AOTC)

Gray et al (1997) recognized the importance of multi-decadal shifts of the AOTC on tropical activity. The strong phase is normally associated with an increased number of more intense tropical activity within the Atlantic Basin. When the North Atlantic Ocean is experiencing warmer anomalies and the South Atlantic Ocean cooler anomalies the AOTC is described as being in a stronger state. When the anomalies reverse themselves, the current is described as being in a weaker state. Sea surface temperature and salinity levels suggests that the

AOTC was in a strong state for several decades prior to 1970, a weak state from 1970 through 1993 and only in recent years has returned to a strong state. Gray et al's 1997 report gives a detailed synopsis of the AOTC and the effect this variation had on the climate regime of the Atlantic Ocean basin.

Lake Inflows Versus Climate Indices

The wet season (May through October) inflows to Lake Okeechobee versus the geomagnetic index and the AOTC are evaluated for the period from 1930 through 1996. The data is first separated into categories of weak and strong AOTC. Each of these categories are then further categorized into terciles of low, medium and high geomagnetic activity (average Cp value for the nine months preceding the wet season). Quartiles of lake inflows for the lowest and highest terciles of geomagnetic activity are illustrated in Figure 1. The various combinations of high or low geomagnetic activity are paired to either a strong or weak thermohaline current as depicted. Inflows are reported in terms of equivalent depth by dividing the Lake inflow by the its surface area. Figure 1 illustrates a marked shift towards below normal inflow for the combination of low geomagnetic activity and the weak state of the thermohaline current. Likewise, above normal inflows appear to be associated with high geomagnetic activity and the strong state of the thermohaline current.



A similar analysis was completed for Lake inflows
(wet season only) versus the Nino 3 index with no such visible shifting in Lake inflows for
warm events versus cold events. However, the importance of the El Nino Southern-Oscillation
phenomena on Atlantic Basin tropical activity has already been documented, so that it has been to decided to retain as an input in this analysis (Gray, 1984).

Application Of Artificial Neural Networks (ANNs)

ANNs is a computational method inspired by studies of the brain and nervous system of living
organisms. Appealing aspects of ANNs are their applicability to complex non-linear problem
sets, their adaptiveness to adjust to new information and their ability to make predictions from inputs in which the relationships between the predictors and the predicted are not

completely understood. Among the variety of neural network paradigms, back propagation is the most commonly used and has been successfully applied to a broad range of areas such as speech recognition, autonomous vehicle control, pattern recognition and image classification. This is the methodology selected for making the inflow forecast. Zhang and Trimble (1996) first reported on the application of ANNs for predicting Lake Okeechobee inflows from global and solar indices. This effort has continued to be reviewed and refined since the original documentation. The most significant adaptation to the original methodology, which included the sunspot number and the Southern Oscillation Index, was the inclusion of the strength of the AOTC as a predictor of Lake Okeechobee inflow. In addition, a logarithmic transformation of Lake Okeechobee inflow was made to reduce the skewness of the data set.

Figure 2 illustrates the results for the predicted versus actual inflows for the wet season. The r2 was ~.6 for both the training (1932-1988) and testing period (1989-1996). A more in depth review of this methodology appears in the Proceedings of the Second International Workshop on Applications of Artificial Intelligence in Solar-Terrestrial Physics (Trimble, Neidrauer and Santee, 1997).

Figure 2. Lake Okeechobee Six Month Inflow Depths

May Through October