SIMILARITIES IN LONG-TERM PERIODICITIES OF TEMPERATURE AND MONSOON RAINFALL ACROSS INDIA

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ABSTRACT

Monsoon rainfall across India is known to have long-term periodic variations, but no significant trend. Temperature, on the other hand, is generally believed to be increasing due to the well-known phenomenon of global warming. Here we show that both temperature and rainfall have exhibited similar long-term periodicities across India for over a century. Despite significant geographical separation and climatic differences between the desert of western Rajasthan and the wet foothills of the eastern Himalayas for instance, regions across the vast country show strikingly similar variations in annual monsoon rainfall and mean temperature with periods as long as 60 years. This suggests a possible common underlying periodic phenomenon, turning us to examine the influence of Jupiter and Saturn. We show that a nonlinear regression function on a time series of the combined ephemerides of Jupiter and Saturn with both temperature and rainfall produced R^2 values of up to 0.78. Could the influence of Jupiter and Saturn account for more than half of long-term periodicity in India's weather phenomenon? At the least, this deserves a more detailed investigation.

1 INTRODUCTION

The monsoon is the lifeline of the Indian economy and its people. Agriculture is largely dependent on well distributed and adequate monsoon rains. India gets most of its annual rainfall through the Southwest monsoon making it pivotal for the millions of farmers dependent on rainfall as the only source of water for their crops. Since 2012, the Indian Meteorological Department (IMD) has been issuing operational forecasts for the monsoons through a dynamical global Climate Forecasting System (CFS) model developed by the National Centers for Environmental Prediction (NCEP), USA. However, these forecasts are not perfect. Longer the period of forecast, the more uncertainty there is. Hence, India requires accurate long-range forecasts for different regions of the country which may necessitate moving towards a wider range of analytical methods of forecasting.

In this paper, we explore the long-term periodicity in monsoon rainfall as well as temperature over the subcontinent in an attempt to help improve the quality of long-term weather forecasts. Periodicity in monsoon rainfall over India has long been studied by various researchers and even finds mention in ancient Indian texts. In this work, we show that similar periodicity is exhibited by temperature as well. Although India is a country with diverse geographical features, both temperature and rainfall show similar periodic variations for periods as long as 60 years. We further explore a celestial origin, the influence of Jupiter and Saturn, for this phenomenon. Here, we do not develop a climatic model that incorporates this periodicity, but rather show the existence of this periodicity through data analysis and time series methods in the hope that periodicity can be one of the factors that may be taken into account during the issuance of future monsoon forecasts. For instance, perhaps its more likely, by accounting for periodicity, that the monsoon rains during a certain year would be forecasted to be above normal because 60 years ago a similar pattern was observed.

2 PREVIOUS WORK

Earth has long been a witness to many climatic cycles such as the 90,000-year Ice Age cycle. Evidence for such cycles also exists in ancient, sacred Indian texts in Sanskrit which depict the existence of cycles in rainfall and present astronomical explanations for them. In Iyengar (2009), cycles in rainfall of periods 3, 5, 7, 18 and 60 years are noted. Iyengar explains the 60-year cycle as the product of the five-year Vedic cycle, called Yuga, and the twelve-year sidereal cycle of Jupiter.

Recently, efforts have been made to estimate and discover cycles in Indian rainfall and ascertain a possible cause for this periodicity. Agnihotri et al. (2002) suggests that the 60-year cycle in Indian monsoon appears to be of solar origin and supports previous research on the solar control on Indian monsoon on a multi-decadal timescale. Notable among other works that study rainfall across India are Azad et al. (2010) and Jagannathan & Parthasarathy (1973) which examine the presence of trends and oscillations in the average annual rainfall using data from different regions across India and a power spectral analysis.

Unlike Iyengar (2009), Agnihotri et al. (2002), Azad et al. (2010) and Jagannathan & Parthasarathy (1973), that show periodicities in rainfall, sometimes with explanations of their cause, our paper identifies periodicities in both temperature and rainfall and also explores their astronomical origin in terms of the influence of Jupiter and Saturn. Scafetta (2010) states that Jupiter and Saturn are the reason for observing the 20-year and 60-year cycles in several global temperature records. We validate this in the context of Indian climate by constructing a non-linear regression model to explain the influence of Jupiter and Saturn on weather in India by observing R^2 values. Thus, the approach taken in this work is a purely data-driven, analytical one. We note that the model is only used to fit the data and explain its goodness of fit, and not used for any prediction. The correlation indicated by the R^2 values may indeed be the result of a causation as stated in Scafetta (2010).

3 LONG-TERM PERIODICITY OF RAINFALL AND TEMPERATURE

To estimate the long-term periodicities of temperature and rainfall, we made use of temperature and rainfall data obtained from the IITM, Pune (`http://www.tropmet.res.in/DataArchival-51-Page`) Mooley (2016), Rupa Kumar (2012), which was originally sourced from the IMD. The data period for rainfall is 1871 to 2014 and that for temperature is 1901 to 2007. We now describe the data sets.

The temperature data is arranged region-wise, with a header record for each region followed by 107 data records (1901 to 2007) each containing the monthly average maximum and minimum temperatures, for each of the months from January to December. India has been delineated into seven homogeneous regions based on climatic and geographical characteristics, namely Western Himalaya (WH), Northwest (NW), North Central (NC), Northeast (NE), West Coast (WC), East Coast (EC) and Interior Peninsula (IP) having a total network of 121 measuring stations. This data is obtained from the raw data of the stations converted to a monthly anomaly time series and interpolated onto a 0.5°x 0.5°grid. The rainfall data is arranged subdivision-wise with a header record for each subdivision followed by 144 data records (1871 to 2014), each record containing data for one year's twelve-monthly total rainfall values. The monthly rainfall for each of the 30 meteorological subdivisions is obtained as a weighted rainfall series with the weights as the district area for each rain gauge station in that region.

An analysis of the long-term periodicities in temperature and rainfall phenomena using these data sets was carried out using the Lomb-Scargle periodogram Lomb (1976), Scargle (1982), VanderPlas (2018), a well-known tool for the detection and characterization of periodicity in both uneven-sampled and even-sampled time-series data. It was observed that temperature and rainfall had remarkably similar periodicities, although homogeneous regions of India have vastly different climates and absolute values of temperature and rainfall.

4 RESULTS AND DISCUSSION

The similarity in periodicities between rainfall and temperature is evident from Table 1. Since there exist many more rainfall subdivisions than temperature homogeneous regions, we mapped one or more rainfall subdivisions to a single temperature homogeneous region. Sample periodograms for the IPIND and SIKNT regions are shown in Fig. 1. It may be noted here that the mapping of the rainfall and temperature regions is approximate, the best we could do given available data, and yet, the similarities are significant.

The striking similarity in the long-term periodicities between temperature and rainfall led us to explore the possibility of a common cause that is influencing both temperature and rainfall periodicities. Agnihotri et al. (2002), Iyengar (2009), and Jagannathan & Parthasarathy (1973) mention sunspot activity and the combined orbits of Jupiter and Saturn as plausible factors affecting weather phenomenon on Earth. Since sun-spot activity has primarily an eleven-year cycle and most prominent periodicities in the temperature and rainfall periodograms range beyond that to about sixty years, we decided to explore the influence of Jupiter and Saturn as a tenable common determinant going by the analysis presented by Scafetta (2010).

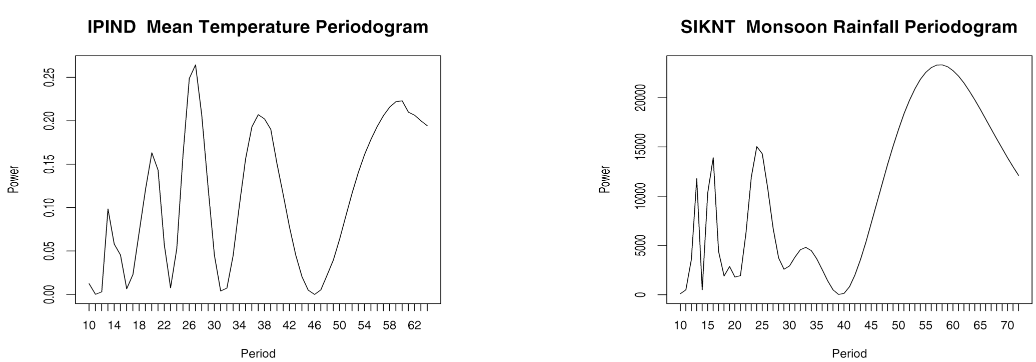
Using ephemeris data (sourced from `https://www.astro.com/swisseph/swepha_e.htm`) from 1901 to 2007, we attempted to build an analytical, non-linear regression model between angles of Jupiter and Saturn for both temperature and rainfall. To decompose trends and cycles in a time series, we regress on linear and sinusoidal functions of the time series *t* and length of cycle *d*. Since we wanted to explore the influence of Jupiter and Saturn, the coefficients were made to adhere to Newton's Universal Law of Gravitation with the influence being directly proportional to the mass and inversely proportional to the square of the distance.

$$x(t) = \beta_0 t + \beta_1 \cos(\frac{2\pi(t-1)}{d}) + \beta_2 \sin(\frac{2\pi(t-1)}{d}), \quad \beta = \frac{(angle)(relative\ mass\ of\ the\ planet\ to\ Earth)}{(relative\ distance\ of\ planet\ to\ Earth)^2}$$

This model was examined for the goodness of fit using the squared correlation coefficient R^2 values. The highest R^2 value of 0.78 was obtained for both the WCIND (West Coast) temperature homogeneous region and COAPR (Coastal Andhra Pradesh) rainfall subdivision. Most R^2 values are in the range of 0.4 - 0.6 which is a significantly high correlation in this area of climatic modeling. This correlation may indeed be the result of causal dependencies as stated in Scafetta (2010).

Table 1: Lomb-Scargle temperature and rainfall periodogram peaks

Region	**Prominent Periodicities**
IPIND Interior Peninsular India - Temperature	14, 20, 27, 37, 59
SIKNT South Interior Karnataka - Rainfall	12, 16, 24, 34, 58
NEIND North East India - Temperature	11, 21, 27, 38, 61
ASMEG Assam and Meghalaya - Rainfall	11, 14, 18, 24, 36, 55
NWIND North-West India - Temperature	10, 12, 17, 26, 36, 56
WRJST Western Rajasthan - Rainfall	13, 17, 22, 34, 56
ECIND - East Coast India - Temperature	12, 20, 27, 37, 60
ORISS - Orissa Rainfall	12, 15, 24, 34, 54
WCIND - West Coast India - Temperature	13, 21, 27, 37, 57
KERLA - Kerala - Rainfall	12, 18, 28, 44
NCIND - North Central India - Temperature	11, 13, 20, 27, 38, 56
EMPRA - Eastern Madhya Pradesh - Rainfall	11, 17, 23, 32, 60



(a) IPIND Region Mean Temperature

(b) SIKNT Region Monsoon Rainfall

Figure 1: Lomb-Scargle Periodograms

5 Conclusion and Future Work

Long-term periodic variations in temperature and rainfall are evident through a visual inspection of the Lomb-Scargle periodograms. In order to find an astronomical origin for this similarity in periodicities of both temperature and rainfall, we considered the influence of Jupiter and Saturn. Our non-linear regression model produced R^2 values of up to 0.78 indicating that up to seventy-eight percent of the long-term periodic variations in temperature and rainfall phenomenon in India could be potentially explained from the combined effects of Jupiter and Saturn. Perhaps, global warming is just a smaller part of a longer periodic cycle of the Earth. At the least, we believe the influence of Jupiter and Saturn on weather in India cannot be disregarded and deserves a more careful study. With the monsoon having the capacity to sway the Indian economy and directly affect the lives of its farmers and all other citizens to a great extent, better forecasts can go a long way in ensuring higher agricultural productivity, food security, more efficient power management as well as mitigation of weather-related natural disasters.

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