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Temporal Analysis And Long Term Prediction Of Point Precipitation.

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Abstract: Precipitation analysis is embedded in a range of important hydrological studies for hydraulic works construction and maintenance. To help in understanding precipitation variability requires generating synthetic models that could predict precipitation. This work proposed a model of the form $Y \equiv 11.29382855 + -2.61335717 \sin\frac{2\pi}{365}t + 0.568607773 \cos\frac{2\pi}{365}t$ for estimating daily precipitation for Kumasi. The model showed deviations from trend in extreme weather conditions. The model also shows years of lower than average rainfall. The approach used legacy data from 1963 to 2003 to obtain model parameters and recommended future improvement in the model through detrended methods.

Keywords: Precipitation, Rainfall, Kumasi, Julian calculator

1. Introduction

Precipitation or rainfall is a hydrological phenomenon that varies in magnitude in space as well as in time. Rainfall information is an important input in the hydrological modeling, prediction extreme precipitation events such as draught and flood, estimating quantity and quality of water and ground water. The ability to predict the onset and duration of the dominant rainfall season in a region is important for agricultural and natural resources management.

It is also of scientific interest in understanding factors that influence the regional hydrologic cycle especially in regions with rain-fed agriculture where the timing of the onset and end of the rainy season becomes even more important than the rainfall distribution or amount [1], [2].

The basic understanding of the spatial and temporal variability of hydrological parameters has an important role for the human life, as water is one of the most vital resources for agriculture and other uses. In this respect, the qualification of rainfall as one of the most essential components of the hydrologic cycle is important.

Understanding the amount of precipitation and its distribution across the landscape is critical to making decision in farming. Gridhar and Viswanadh,[3] mentioned that rainfall is one of the critical factors when planning agriculture programs such as crops and water management, erosion control, and flood control. In Order to plan efficient programs, it is necessary to understand rainfall patterns and the spatial distribution of rainfall across the landscape [4]. The accurate estimation of precipitation is required to assess water resources; because it is not only used for water supply, but also has a vital role in preserving environmental conditions.

Agriculture is primarily and heavily dependent on climate and for that matter the climatic factors- rainfall, sunshine hours, temperature, relative humidity and length of the drought period result in cycle-to-cycle variability of crops production. The little understood and uncontrollable natures of climate factors affect agricultural, economic, social and environmental sustainability of a

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country.

Different trends show an increase in average temperature and more volatile rainfall patterns [5]. Among all climatic variables, rainfall is one of the most important because of its two sided effects as a deficient resource, such as droughts and as a catastrophic agent, such as floods.

Traditionally rainfall is measured using rain to annual and in different areas. It has also been found that, precipitation varies among eco regions. There have been previous attempts at classifying the country into such have been suggested for modeling precipitation. As pointed out however by [6], in contrast to the modeling of temperature, modeling precipitation presents several challenges. First there is the challenge of the accurate measurement of precipitation as most techniques involve physically collecting raindrops from which we measure the precipitation amount. The results are thus affected by factors such as local wind. Secondly, spatial correlation is an elusive measure as unlike temperature that is highly correlated across nearby regions, rainfall can be much localized. But the major third challenge is in selecting a proper distribution to describe the precipitation data.

Some authors have attempted to model precipitation statistically. For instance, [7] proposed a model for tropical rainfall at a single location for a fixed period the amount of rainfall is modeled as a transformed normal variable with dynamic parameters, while the event of rain or dry is modeled by truncating the same normal variable. Wilks, [8] on the other hand, proposed a multi-site model tor precipitation using a combination of two-state Markov process for the rainfall occurrence and a mixed exponential distribution for the precipitation amount. Richardson and Wright [9], proposed the use of a Gamma function.

Hydrological models and also Geostatistical tools embedded in GIS also implements some of models for area rainfall.

Geostatistics might be viewed as simply a methodology for interpolating data on an irregular pattern. Geostatistics is concerned with spatial data sand as such each data value is associated with a location in space.

There is a wide choice of interpolation techniques for rainfall mapping that range from simple approaches, such as Thiessen

gauges, but the information then becomes only available after it has rained and is therefore unavailable for planning. However, since large amounts of such data have been collected over the years, they may be investigated for rainfall trends and variability to better inform agricultural decision-makers.

Several studies have been carried out on rainfall at different temporal scales from daily

eco regions based using cluster analysis.

Several mathematical and statistical models

polygons, the inverse distance and polynomial fitting to more complex approaches such as kriging ([10]; [11]). The kriging method is based on the theory of regionalized variables (ReV) and, consequently, it has become an essential element in the area of geostatistic. Dealing with rainfall as a spontaneous quantity the best method to use could have been the geostatistic method but handling data in the daily manner without position and taking the study area as point makes it a little unadvisable to use geostatistic but rather other statistical methods that could provide reliable trends for the data.

Rainfall/precipitation modeling in the past years has been tackled with different kind of models such as the stochastic and logistic. But most of these have been done based on yearly and monthly basis and for more than one station and in that case position inclusive. This research seeks to find a logistic kind of model for daily rainfall of a point (Kumasi) and position exclusive from the mode of modeling

2. Method And Materials

2.1 Study Area

Kumasi, which is the capital of Ashanti region is located in the transitional forest zone and is about 270km north of the national capital, Accra (Figure 2.1). It is between latitude 6.35°–6.40° and longitude 1.30° – 1.35°, an elevation that ranges between 250 – 300 meters above sea level with an area of about 254 square kilometers. The unique centrality of the city as a traversing point from all parts of the country makes it a special place for many to migrate to. The Metropolis falls within the wet sub-equatorial type. The average minimum temperature is about 21.5°c and a maximum average temperature of 30.7°c. The average

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humidity is about 84.16 per cent. The climatic conditions in Kumasi are known not to be .

The city falls within the moist semi-deciduous South-East Ecological Zone. Predominant species of trees found are Ceiba, Triplochlon, and Celtis with Exotic Species. The Kumasi Metropolis lies within the plateau of the South–West physical region which ranges from 250-300 metres above sea level. The topography is undulating. The city is traversed by major rivers and streams, which include the Subin, Wiwi, Sisai, Owabi, Aboabo, and Nsuben among others.

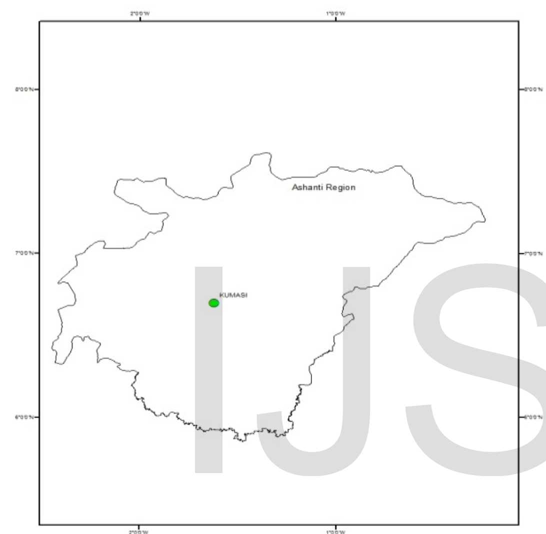

Figure 1 Ashanti Region showing Kumasi as a Point

2.2 MATERIALS

2.3 DATA PREPARATION

harsh as compared to the north

Rainfall data values were arranged in daily basis. The data covered only one station, which is Kumasi, (Table1.0). The data is from 1960 to 2003.

STATIONS	EASTINGS(TM)	NORTHINGS(TM)
Kumasi	674551.625	736625.503

Table 1 Showing rainfall station

2.4 SOFTWARE

i. Microsoft Office (Excel) 2010 version and (XLSTATS)
ii. Julian-Gregorian-Dee Date Calculator 6.9t

2.5 METHOD

Rainfall dates (years, months and days) were converted into Julian days by the help of a Julian calculator fig. 2.2. This enabled the days to be ordered consecutively instead of monthly and yearly division in the precipitation data (Table 2). Usually in the tropical regions, rainfall belt is known to be between April to September so it was therefore decided to this investigation to the rainy months of April to September by cutting out all months that do not fall within the rainfall belt (that is January to march were cut out and maintaining April to September known to be the rainfall season range). We propose a single-site model in a spirit similar to Wilks (1998) that the mean conditional daily precipitation can be modeled as $Y \equiv d_0 + d_1 \sin\frac{2\pi}{365}t + d_2 \cos\frac{2\pi}{365}t$ where Y is the precipitation and t is the time in Julian days and d_0, d_1, and d_2 are constants to be determined.

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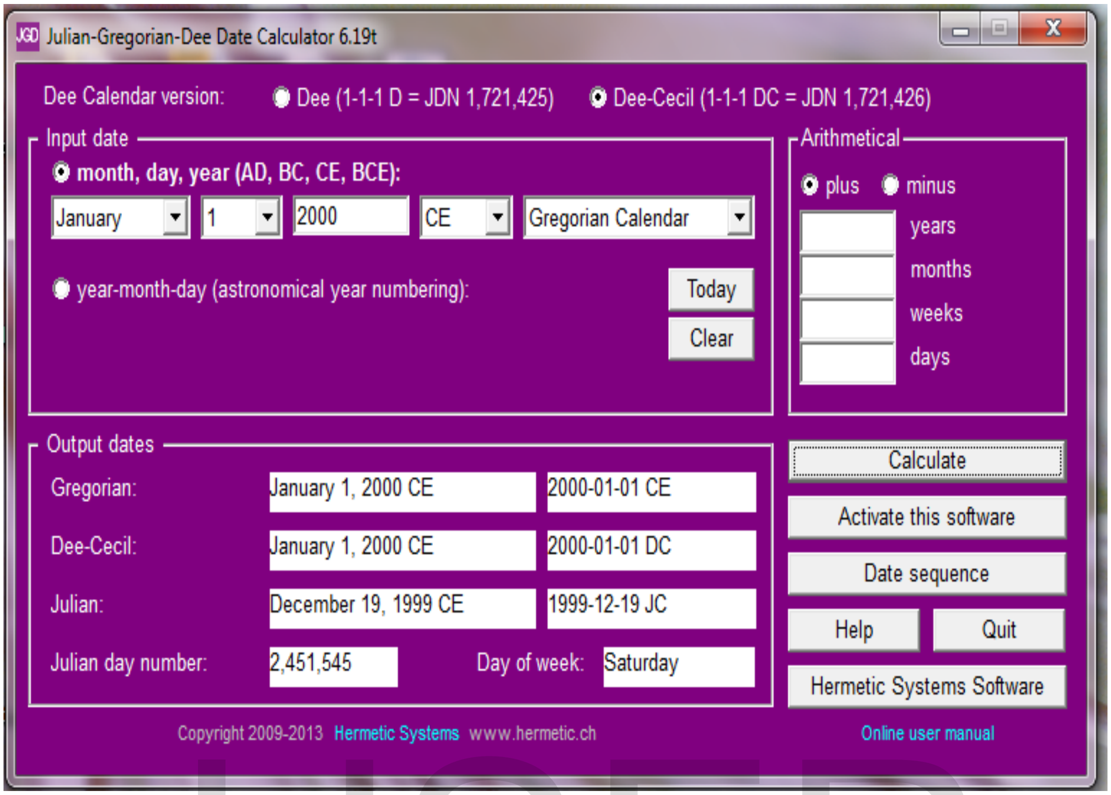

Figure 2 Julian day calculator used to convert dates to Julian day number.

Source: [12]

Table 2 Sample Julian Day and Precipitation Data

JULIAN DAY NUMBER	Precipitation	⟦2π/365⟧ t	sin	cos	Coef d_0
2437027.00	24.90	41951.49	-0.9741	0.226116	1
2437028.00	24.90	41951.5	-0.97006	0.24285	1
2437030.00	19.60	41951.54	-0.96113	0.276097	1
2437033.00	14.70	41951.59	-0.9456	0.325342	1
2437035.00	1.00	41951.62	-0.93384	0.357698	1
2437040.00	6.60	41951.71	-0.89963	0.436651	1
2437044.00	43.70	41951.78	-0.86746	0.497513	1
2437045.00	0.50	41951.8	-0.85876	0.512371	1
2437046.00	5.30	41951.81	-0.84982	0.527078	1
2437048.00	8.40	41951.85	-0.83117	0.556017	1
2437050.00	13.50	41951.88	-0.81154	0.584298	1
2437053.00	3.00	41951.93	-0.7803	0.625411	1
2437054.00	44.70	41951.95	-0.76941	0.638749	1
2437055.00	3.00	41951.97	-0.75831	0.651899	1
2437056.00	5.30	41951.98	-0.74697	0.664855	1
2437059.00	0.50	41952.04	-0.71166	0.702527	1
2437060.00	3.00	41952.05	-0.69946	0.714673	1

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2437061.00	13.20	41952.07	-0.68705	0.726608	1
2437062.00	7.60	41952.09	-0.67444	0.738326	1
2437064.00	0.30	41952.12	-0.64863	0.761104	1
2437068.00	1.30	41952.19	-0.59473	0.803928	1
2437071.00	5.30	41952.24	-0.55244	0.833556	1
2437072.00	6.40	41952.26	-0.53801	0.842942	1
2437073.00	0.80	41952.28	-0.52342	0.852078	1
2437075.00	0.50	41952.31	-0.49378	0.869589	1
2437079.00	1.50	41952.38	-0.43278	0.901502	1
2437080.00	8.40	41952.4	-0.41719	0.908818	1
2437081.00	0.30	41952.42	-0.40149	0.915864	1
2437085.00	48.50	41952.48	-0.33752	0.941317	1
2437087.00	2.80	41952.52	-0.30492	0.952378	1
2437089.00	11.20	41952.55	-0.27196	0.962309	1
2437091.00	1.30	41952.59	-0.23867	0.9711	1
2437092.00	2.50	41952.6	-0.22192	0.975065	1
2437093.00	6.40	41952.62	-0.2051	0.97874	1
2437094.00	86.10	41952.64	-0.18823	0.982126	1
2437095.00	0.30	41952.66	-0.17129	0.98522	1
2437096.00	5.10	41952.67	-0.15431	0.988023	1
2437099.00	1.30	41952.73	-0.1031	0.994671	1
2437100.00	6.90	41952.74	-0.08596	0.996298	1
2437101.00	0.50	41952.76	-0.0688	0.99763	1
2437103.00	5.80	41952.79	-0.03442	0.999407	1
2437104.00	0.50	41952.81	-0.01721	0.999852	1
2437105.00	1.80	41952.83	-2.3E-12	1	1
2437106.00	32.00	41952.85	0.017213	0.999852	1
2437107.00	49.30	41952.86	0.034422	0.999407	1
2437108.00	14.00	41952.88	0.05162	0.998667	1
2437109.00	2.00	41952.9	0.068802	0.99763	1
2437110.00	59.40	41952.91	0.085965	0.996298	1
2437111.00	5.80	41952.93	0.103102	0.994671	1
2437113.00	22.90	41952.97	0.137279	0.990532	1
2437114.00	10.40	41952.98	0.154309	0.988023	1
2437120.00	2.00	41953.09	0.255353	0.966848	1
2437137.00	0.30	41953.38	0.523416	0.852078	1
2437140.00	2.30	41953.43	0.566702	0.823923	1
2437143.00	2.80	41953.48	0.608477	0.793572	1
2437144.00	9.40	41953.5	0.622047	0.78298	1
2437146.00	6.40	41953.53	0.64863	0.761104	1
2437147.00	0.30	41953.55	0.661635	0.749826	1
2437150.00	12.40	41953.6	0.699458	0.714673	1
2437151.00	37.80	41953.62	0.711657	0.702527	1

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2437152.00	0.80	41953.64	0.723644	0.690173	1
2437153.00	0.30	41953.65	0.735417	0.677615	1
2437156.00	2.30	41953.71	0.769415	0.638749	1
2437157.00	7.40	41953.72	0.780296	0.625411	1
2437158.00	1.30	41953.74	0.790946	0.611886	1
2437160.00	4.30	41953.78	0.811539	0.584298	1
2437161.00	10.20	41953.79	0.821477	0.570242	1
2437163.00	0.80	41953.83	0.840618	0.541628	1

The method of least squares was used to solve for d_0 , d_1, and d_2. The results of the least squared solution gave the following results:

d_0 = 11.29382855

d_1 = -2.61335717

d_2 = 0.568607773

2.6 **Model validation**

The results were used in the derived model equation to obtain expected trend values. These trend values show a kind of averaging values and hence there were large deviations especially in cases of extreme abnormal precipitation values. Testing for trend in a data set is useful for determining which data points are representative of the condition of interest. Trends in a data set may also result from climatic shifts or anthropogenic influences. It was assumed that the effect of trend would allow the data to be de-trended so resulting chaos in the data may also be modeled separately to improve on the model. This is recommended for future works.

3.0 RESULTS AND ANALYSIS

The results from the model of daily point precipitation for Kumasi gave $Y \equiv 11.29382855 + -2.61335717\, sin\frac{2\pi}{365}t + 0.568607773\, cos\frac{2\pi}{365}t$ where Y is the precipitation and t is the time in Julian days. This model is derived using the raining season months of April to September using legacy data from 1963 to 2003. The results show some agreement fairly but a marked departure in situations of extreme recorded precipitation.

From the rainfall data, JUNE appears to record more rainfall in Kumasi within the rainfall belt season than any other month. Based on the scatter graph produced for June within the range of twenty years, the result yielded an R^2 = 0.0139 value. This is not entirely unexpected as it shows that there is an average rainfall over the years instead of an increasing or a decreasing trend. The absence of trend hence is indicative of average rainfall pattern instead of an increasing or decreasing pattern.

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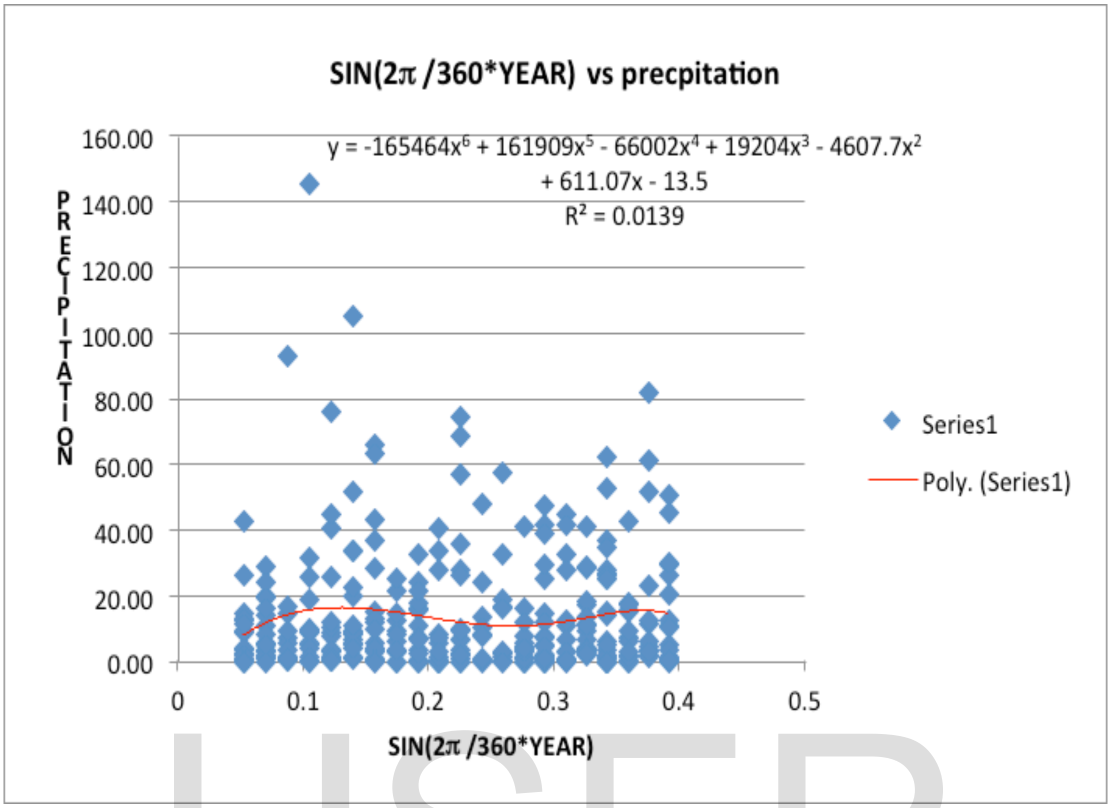

Figure 3 SCATTER DIAGRAM OF PRECIPITATION AGAINST TRANSFORMED YEARS.

Another scenario was also used where the years were plotted against average of the precipitation of JUNE in the various years. The results show the same kind of averaging with little increasing trend.

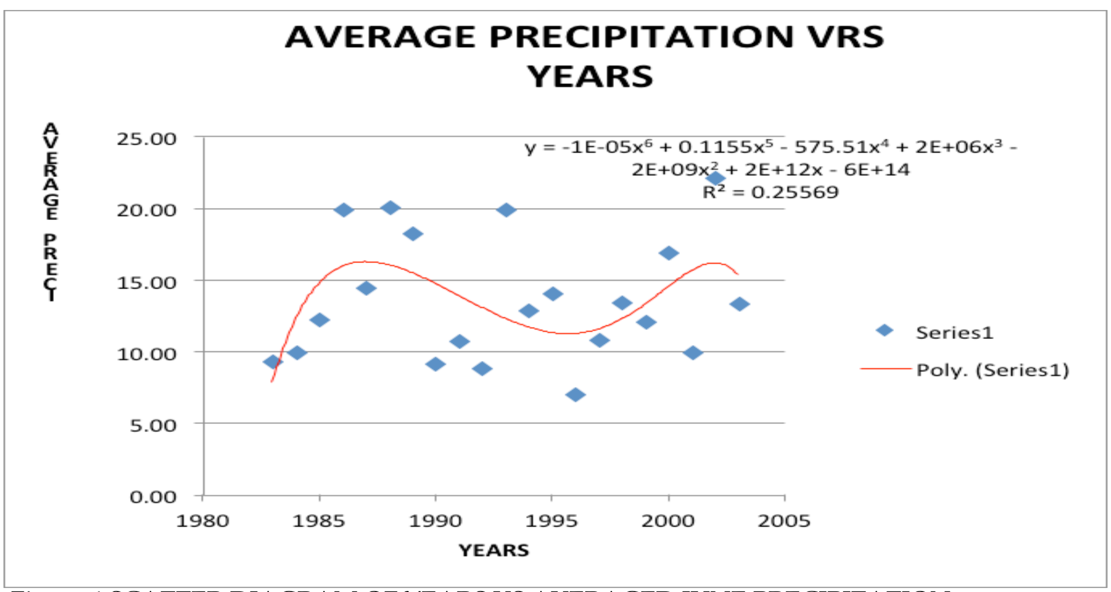

Figure 4 SCATTER DIAGRAM OF YEARS VS AVERAGED JUNE PRECIPITATION

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Conclusion

Accurate measurement of precipitation is important not only to weather forecasters and climate scientists, but also to wide range of decision makers including hydrologists, agriculturalists, emergency managers, industrialists and other applications. The description of the rainfall variability in time is among the fundamental requirements for a wide variety of human activities as well as water resources project design, management and operation.

This study has proposed a model for estimating daily precipitation values. We propose to further calibrate, and compare the performance of this model. Our analyses show that there may be other effects, which were not accounted for in this model. We therefore propose a detrended improvement for future works. The observation in this project support the notion that there is cyclical trend when considering daily rainfall data of just a point weather station, but averaging the daily rainfall in a month could provide a slight stronger trend for the point.

Recommendations

Undoubtedly, many issues are still pending and further research is required. For instance, spatial correlation may be very important even for point precipitation modeling. The rainfall trend is also tempered with based on some topographical factors such as elevation,latitude and longitude. Precipitation is known to increase with elevation depending on the size and orientation.The nature of how close or far, of a place is to the sea can bring about high rainfall. Temperature was also not considered in our formulation. We propose that future development to precipitation simulation models will attempt downscaling techniques that could improve algorithms to more faithfully represent the stochastic and physical dynamics of precipitation, and inclusion of low- frequency oscillations and spatial distribution of parameters in daily precipitation models.

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