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RESEARCH ARTICLE

A MODEL INVESTIGATION OF AZORES IMPACTS OVER FRANCE.

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Abstract

The influence of North Atlantic Oscillation (NAO) variability over climate of France is investigated by several authors. In this paper, the centers of action approach are applied to study spring precipitation (March to May) variability over France, taking into account variations in the components of NAO; (i) the Azores High (AH) and (ii) the Icelandic Low (IL) pressure systems. Our results show that the north-south shifts of the Azores High has significant impact on interannual variations of spring precipitation over France, there being more precipitation when the Azores High shifts southward versus when it is northward. The present study showing that when AH. This article demonstrates that when the AH system moves towards south there is relevant moisture and hot air ascends from the Atlantic Ocean and enter into France. We construct a regression equation for spring rainfall over France in which the AH latitude and Arctic Oscillation are independent variables and it explains 23 percent of the variance of precipitation during 1981-2016.

Introduction:-

In the European region, human activities have been markedly influenced due to variability in precipitation. Recently, regional economies of several parts of Europe have been severely damaged due to such climate anomalies in different parts of Europe e.g. (Christensen and Christensen, 2003; Schär et al., 2004; Marsh and Hannaford, 2007; Lenderink et al., 2009). Europe has come up with these outcomes in 2002 and 2005 when this continent was hit with heavy rainfall and disastrous floods (Seneviratne et al, 2006). On the other hand, nearly all of the western central Europe faced lack of rainfall along with high temperatures in July to early August of 2003 that results in catastrophic forest fires in southern France, Spain, and Portugal. Thus both inadequate and excessive rainfall resulted in strikingly loss and damage to the regional economies. (Igor I. Zveryaev, 2004). For the most part, the majority of the study conducted for implications of NAO has been for the winter months, as the winter season offers a dynamically active seasonal window where perturbations extend to the largest amplitude. NAO is a dipolar (North-South oriented) pattern measured at sea-level pressure. The northern pole of NAO is located over Iceland, whereas, the approximate location of the southern pole lies over the Azores. The dipolar pattern of NAO gives a contrasting meridional pressure for the North Atlantic region. The positive phase of NAO (NAO+) reflects terrains of below-

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average heights and pressure at high latitudes of North Atlantic and above-normal heights and pressure of Central North Atlantic. The negative NAO phase (NAO-) represents the anomalous opposite values as compared to those of positive NAO. The two NAO phases are attributed to basin-wide changes in intensity and location of Jet stream and storm tracks of North Atlantic.

Maximum moisture takes a northward shift during the positive phase of NAO, which results in intense westerly flow and warm maritime air across continental Europe. This lowers the polar outbreak over the continent while bringing in a warmer climate to central and southern parts of the continent with a cooler climate over the NW Atlantic area (Rogers & Van Loon 1979). One of the best and proven techniques to study and monitor the time-constrained temporal variability of NAO is the use of Indices, which can be created by taking into account the differential pressure between dipole stations (North-South). Recently, different indices have been used by researchers; varying by the difference in station and time and averaged yearly intervals. Several studies have taken into account the relation between the European climate and large scale pressure fields (NAO). There are pronounced implications of varying atmospheric circulation over the Atlantic over the precipitation patterns of the continent (Hurrell 1995). These implications are also profound in our study area France, with several previous studies establishing a positive relationship between Spring (March-May) precipitation and NAO in the France. The high impacts of NAO over the European climate makes it an impulsion to quantify the seasonal and inter-annual NAO predictability. Previous studies have focused the Lagged North Atlantic Sea Surface Temperatures (SST) to simulate and predict inter-annual precipitation rates. Provided that the SST can be efficiently used to predict NAO, there's a greater chance to estimate precipitation well in advance, which can prove to be a significant contribution of hydrological planning and management.

This study is focused to estimate the effects of Sea level pressure variations on Spring precipitation over France using climate indices. In France, spatially sound trends in rainfall have been observed in 20th century. (Moisselin et al. 2002). Therefore, the existing climatic records of France are required to be enhanced, such as precipitation and circulation patterns. The first objective of this work is to explore that up to what extent the atmospheric circulation relates with the seasonal variability in precipitation of France. In this paper, we present the analysis of appropriate correlations between the two above stated parameters and rainfall of France from 1981 to 2016 and to narrate the comprehensive behavior of precipitation patterns in France.

Data and Method:-

Seasonal averages are enumerated through Monthly averaged data. The precipitation data is acquired from Centre for Environmental studies and their latitude/longitude resolution is 0.25 x 0.25 (http://data.ceda.ac.uk/badc/cru/data/cru_cy/cru_cy_4.01/data/pre/). Similarly we obtained the climate indices including SOI, TNA and AO from climate prediction center (Website: www.ncdc.noaa.gov). We have also used the NAO index which is defined by Hurell and available at Climate Prediction Centre (CPC), National Centre of Environmental Prediction (NCEP), USA. The monthly indices of the centres of action updated to 2017 are listed at the website: https://you.stonybrook.edu/coaindices/. The study undertakes the creation of a Spring climatological map of France using rainfall data. Correlation between spring precipitation NAO, COA and several other indices including SOI, TNA, AO. Since the calculation of partial correlation coefficients means checking on the influence of one variable while keeping all other variables constant, thereby, the partial correlation of rainfall data was calculated in the second step by keeping constant parameters which characterized significant results for previous correlation and keeping independent the precipitation data for France. This helps in simulating a strong impact on precipitation patterns. In last round we construct multiple regression model qualitative assessment of rainfall fluctuations in different epochs.

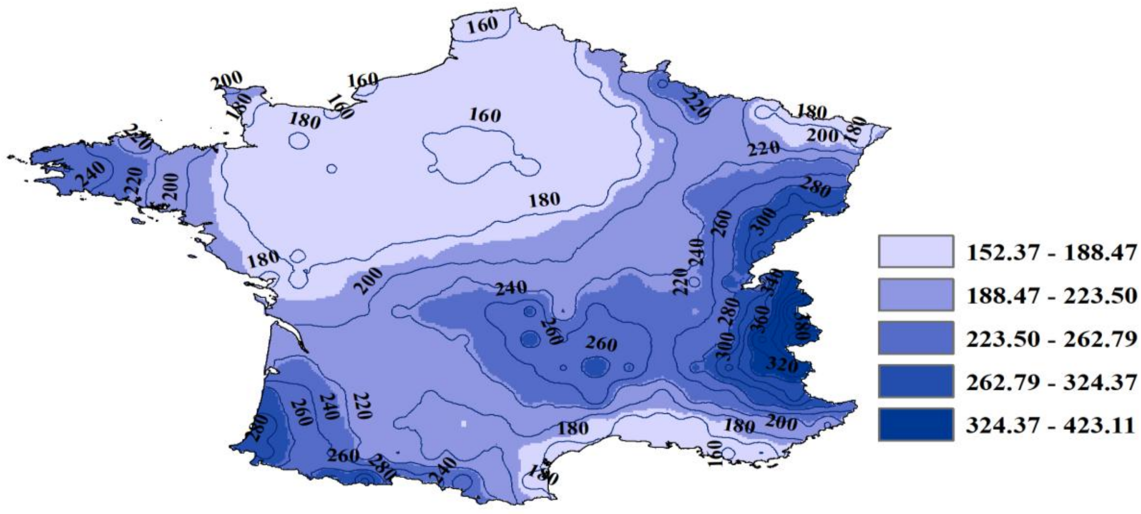

Figure 1:-MAM Rain Climatology from 1981 to 2016

Results and Discussion:-

The spring rainfall patterns over France for March to May are displayed in Figure 1. The spatial rainfall distribution is shown for the period of 1981 to 2016. The eastern side of France experiences the most rainfall, with values ranging over 280 mm per annum. The central north region experiences the weakest gradient of rainfall, lower than almost all of the rainfall profile of France.

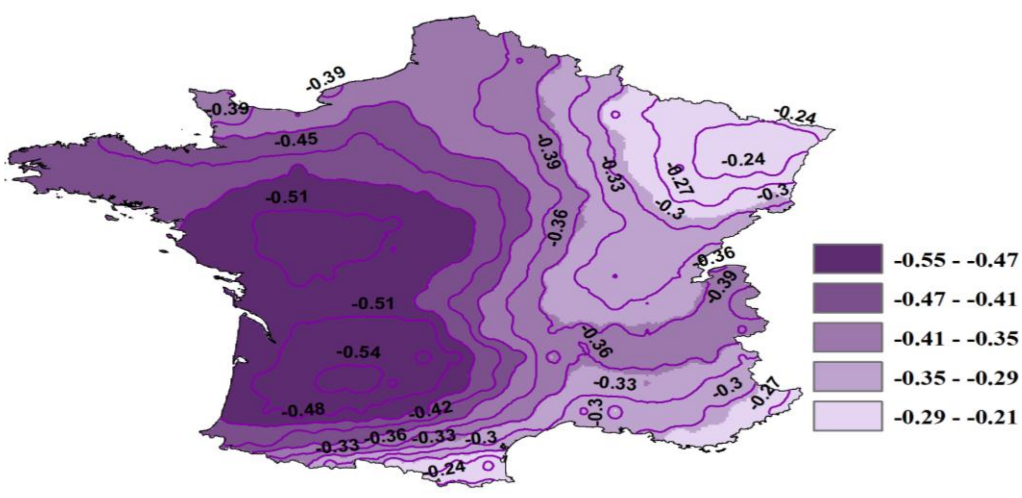

Figure 2:-Correlation map of MAM Rain with AZHLT from 1981 to 2016

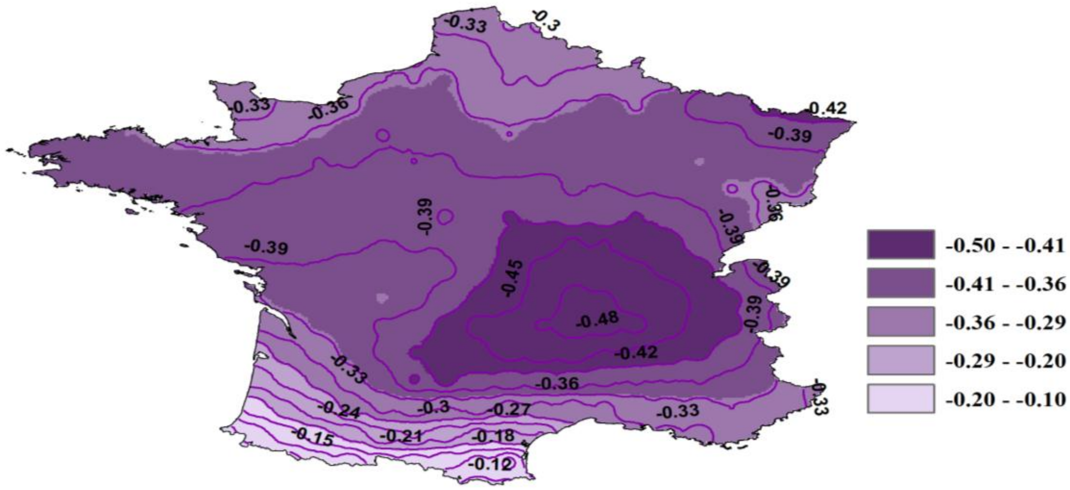

Figure 3:-Correlation map of MAM Rain with AO from 1981 to 2016

The individual effect of both AZHLT and AO is estimated by using correlation maps. We computed the correlation pattern of AZHLT and AO for spring precipitation at individual grid points. The spatial correlation values indicate the influence of AZHLT and AO in Figure 2 and 3.

Predictors	Correlation	Detrended Correlation
TIME	-0.15	-0.00
AZHLN	**-0.29**	**-0.31**
AZHLT	**-0.49**	**-0.51**
AZHPS	-0.13	-0.14
ILLLN	0.23	0.22
ILLLT	**-0.38**	**-0.36**
ILLPS	0.15	0.15
AO	**-0.45**	**-0.44**
NAO	**-0.30**	**-0.32**
SOI	0.08	0.11

Correlation significant, at 0.05 level of significance, are in bold.

Table 1:-Highlights the correlation of important parameters of the study. Here Detrended correlation is performed to remove interannual variations

Predictors	Partial Correlation Coefficients
Rain and AZHLN	-0.08
Rain and AZHLT	**-0.37**
Rain and ILLLT	0.10
Rain and AO	**-0.32**
Rain and NAO	0.10

Values significant at 0.05 level of significance are in bold

Table 2:-The partial correlations are shown. The correlation of each pair is calculated by controlling the effect of all the other variables

The correlation between France spring rainfall and important predictors of its variability are shown in Table 2. Here AZHLN, AZHLT, ILLLT, AO and NAO show modest correlation with spring rainfall during 1981 to 2016. The table also provides the detrended correlation values of these variables so as to cancel the effect of interannual variation in the parameter values. The statistical analysis of the individual role of important predictors is further established by checking which index reflects the direct contribution to the regional temperature variability. By performing partial correlation, we isolate the effect of mutual correlations between AO, NAO, AZH and IL indices by taking correlations between France spring precipitations and them, keeping all the other indices fixed. The results are shown in Table 2, and indicate that the primary influence on interannual variations of France spring rainfall is AZHLT and AO.

The combined effect of AZHLT and AO is estimated by constructing a multiple regression model between them and the rainfall. The regression equation is

$$\text{MAM RAIN} = 635.74 - 12.68*\text{AZHLT} - 18.84*\text{AO}$$

where the coefficient of determination is 29.88%. The combined effect of both AZHLT and AO shows a very small covariance, as shown by the Variance Inflation Factors (VIFs), which are mainly used as an evidence of lack of collinearity among explanatory variables. The VIFs are estimated as 1.4 for both AZHLT and AO (acceptable range is less than or equal to 10). The residual plot, along with the actual and predicted rainfall is plotted in Figures 4 and 5 respectively. The residual plot shows a clear scatter of residuals with no particular trend present. In Figure 5, the predicted MAM rainfall of France is plotted over actual values against time. Both of these plots show modest agreement, with more deviations at the extremes.

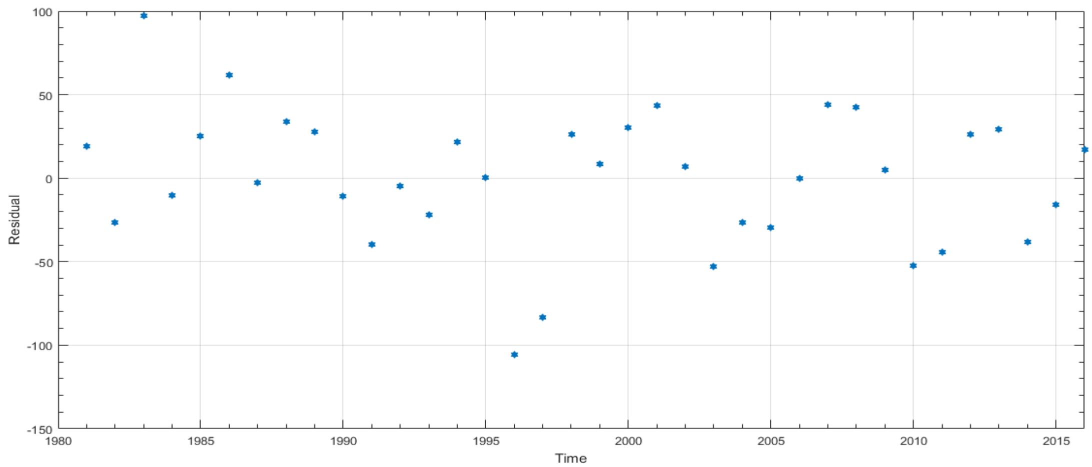

Figure 4:-Residual plot of the regression model using AZHLT and AO as explanatory variables

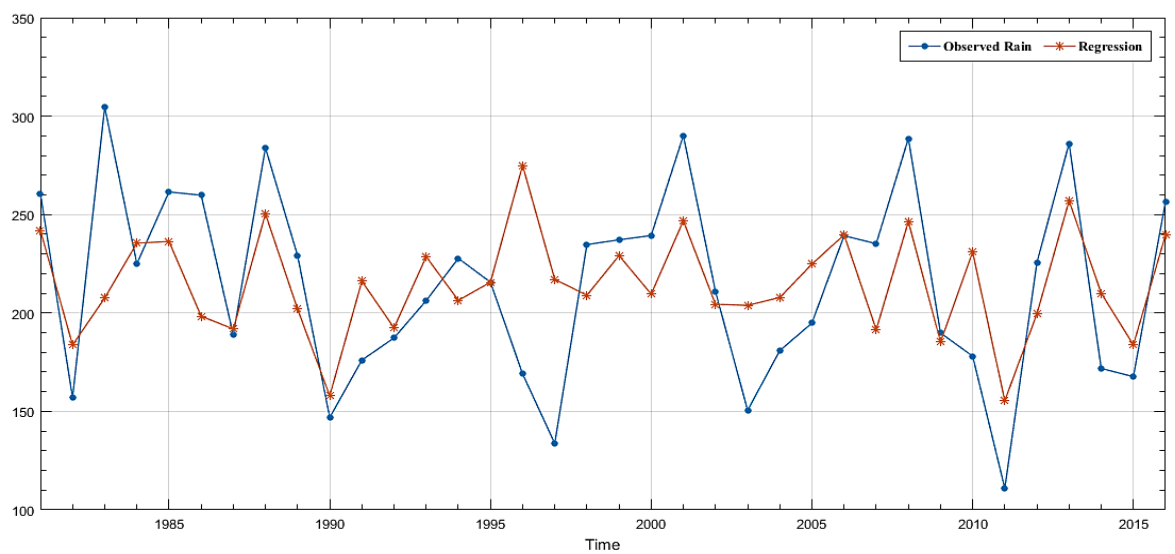

Figure 5:-Time series comparison between observed spring (MAM) precipitation over France and the regression model

Conclusion:-

The issue of best paradigm to represent atmospheric variability in the north Atlantic region remains equivocal for NAO and AO. It is evident that there's a strong correlation between NAO and climatic variables in France. Its influence is at peak in northern and southern parts of the country with a weaker correlation in central region. The paper established the impacts of inter-annual zonal migration of NAO from the Azores high and Icelandic lows on Spring precipitation in France. On the other hand, the statistical correlation is significant between COA indices, AO and Spring rainfall in France. In this paper the four aforementioned criteria by Wallace would favor the AO as the better paradigm, which is also reflected by higher correlation values, in contrast to NAO, as shown in Table 1 and 2. Provided that the NAO is predicted in advance, it would allow an early rainfall prediction for Spring months in France, which can be significant for monitoring, planning, and management of hydrological and agricultural activities in the country. The effect of COA indices is apparent, as shown in Table 1 and 2 and the regression equation. By considering the fluctuations in the position of the Azores High, this paper has shown that the primary influence on the seasonal variations of winter precipitation over France is the zonal migration of the Azores high and AO.

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