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Recognition of Effective Climate Variables on Dez Dam Inflow

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Abstract

Applying climatological Ocean-Atmospheric data with available meteorological and hydrological data lead to increasing accuracy and lag time of river inflow prediction which has high economic benefits. To forecast Dez river streamflow, recognition of local and long range variables has been performed in this study, considering the importance of south-west region of Iran in providing water for agriculture and hydroelectric power and also the lack of appropriate meteorological data in this region (specially snow data). Appropriate variables for predicting Dez river streamflow at the beginning of April and also with 3 and 6 month lags has been studied by correlation analysis of Dez Dam inflow in dry season (April to August) with various seasonal climate variables from the prior winter (JFM), fall (OND) and summer (JAS) in this way. Beside rainfall and hydrometric data, ordinary climate Indices such as SOI, PDO and NAO and also sea surface temperature of adjacent waterbodies and 500 mb Geopotential high have been used. Results showed high correlation between Dez river Inflow with ENSO indices and sea surface temperature, specially in the Mediterranean Sea.

Introduction

Identifying appropriate climatic variables to predict Inflow of Dez dam in the south west of Iran has been studied in this article. Incompleteness or the lack of weather and snow data (especially in the mountainous regions), have increased the importance of identifying the long range and local climate indices such as sea surface temperature.
South west of Iran with regard to the watery rivers which emanate from western hillside of Zagros heights, is a strategic region because of hydroelectric power production, agricultural and drinking water supplement and also inter-basin transferring of water. Dez River watershed (31° ~ 34 °N and 48° ~ 50 °E), located in south west of Iran, in western hillside of Middle Zagros heights and is considered part of the Persian Gulf basin in Iran's hydrological divisions. Winter precipitation dominates this watershed with 44 percent of total annual rainfall and fall and spring precipitation ratio is 29 and 24 percent respectively.
Dez river is the second watery (biggest) river in Iran. Considering the production about 520 megawatts hydroelectric power in the year and also irrigation of 125 thousand hectares of downstream agricultural lands and supplement of drinking water in major cities and also inter-basin water transferring, prediction of volume of Inflow to dam specially in dry seasons is important with regard to economic and social benefits and can be effective in planning, decision-making and management. Then, this article discusses the appropriate variables recognition to predict April to August Inflow to this dam (about 56 percent of total annual inflow).

Background

Synoptic circumstances and the general atmosphere circulation beside local and geographical conditions are the major factors in climate variation of a region. Then variation of ocean-atmospheric variables such as pressure and temperature of ocean surface, air pressure in different levels of atmosphere and temperature or wind factors provide useful information for researchers to predict climate condition in different regions.
In recent decades rainfall prediction based on long-range phenomena (such as NAO, ENSO and PDO) and also the local effective in rainfall indices (such as SST, SLP and other atmospheric variables) has been usual in various parts of the world. The possibility of relationship determination between the streamflow and simultaneously (or with delay) climate indices, amused many of the researchers attention. Soukup et al. (2009) increased the accuracy of North Platte River streamflow prediction by using sea surface temperature in Pacific and Atlantic Ocean and 500 mb Geopotential high beside utilization of ENSO, PDO and MJO.
Various studies have been done about climate phenomena effect on Middle East meteorological and hydrometric variables. For example Cullen et al. (2002) indicates dependence of temperature, rainfall and streamflow variations in Middle East on North Atlantic Oscillation phenomena.
Various studies has been done In Iran about the effect of common climate Indices on different regions climate. Probing the relation between regional ocean-atmospheric variables and meteorological and hydrometric variables is common in western Zagros; among these studies we can mention the study of effect of Persian Gulf SST on south and southwest of Iran [Nazemossadat, 1998] and rainfall prediction and drought and wetness forecasting in this region by using local ocean-atmospheric variables such as pressure and temperature of adjusted seas surface.[Karamouz et al. 2008]

Data

Meteorological and hydrological data have been used in the study for a 30 - year period from 1978 until 2007, including the Dez dam inflow streamflow volume in TeleZang Station, seasonal rainfall in 8 rain station (Figure1), prevalent climate index seasonal average values, seasonal surface temperature of watershed adjusted seas and 500 mb geopotential. Hydrometric and rainfall data have been obtained from Khuzestan Water & Power Authority, climate Indices have been emerged from Climate Diagnostic Center (http://www.cdc.noaa.gov) and surface temperature, SST and 500 mb Geopotential high obtained from NCEP/NCAR reanalysis project data by spatial resolution of 2 °×2° (longitude ×latitude).(http://www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl).

Approach

The purpose of this research is the recognition of suitable climate variables for using in models to predict the April to August Dez dam inflow in the beginning of April and also with 3 and 6 month lags. Therefore, the relationship between Dez dam inflow in April to August and seasonal values of meteorological and climatic variables prior to beginning of April, January to March (JFM), October to December (OND) and July to September (JAS) have been studied by correlation analysis and variables with correlation coefficient significant at the 95% confidence level or higher have been found. 95% confidence level is r = +/- 0.36 as for time series length, 30 years.

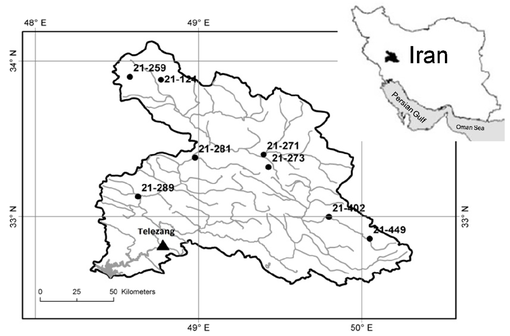

Figure 1- Location of Dez Dam watershed in Iran and location of Dez Dam, Telezang hydrometric station and considered rain stations in Dez Dam Reservoir watershed

Data Diagnostic

- Streamflow
The characteristics of the annual streamflow volume (in million-cubic meters) and monthly streamflow distribution in Telezang station have been plotted in Figure2. As it is shown, the AMJJA includes 56 percent of annual streamflow.

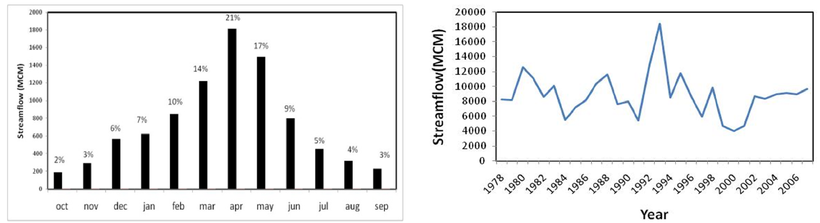

Figure 2-Characteristics of streamflow in Dez Dam, TeleZang Station: (a) Annual streamflow (b) Monthly streamflow distribution

- Hydroclimatic Indices

Table 1 shows the correlation coefficient between AMJJA streamflow volume and 16 seasonal teleconnection indices that have been widely studied and used in the hydroclimatic literature. SOI, MEI, BEST, ONI, Nino1+2, Nino3, Nino4 and Nino3.4 are ENSO indices that different atmospheric and ocean variables have been used in their calculations (NAO and PDO are North Atlantic and Pacific Decadal Oscillations Indices respectively). TNA, TSA and AMO represent SST anomalies in Atlantic Ocean in different zones. NOI is an index of climate variability based on the difference in SLP anomalies at the North Pacific High and near Darwin Australia. WHWP represents monthly anomaly of the ocean surface area warmer than 28.5°C in the Atlantic and eastern North Pacific. Loading pattern of AO (AAO) is defined as the first leading mode from the EOF analysis of monthly mean height anomalies at 1000-hPa (NH) or 700-hPa (SH).

- Precipitation

Eight rainfall stations with 30 years monthly data in Dez dam watershed have been used to analyze the rainfall. In table 2, specifications of the 8 rain stations considered in this study and also the correlation coefficients between the amount of rain in these stations in the JFM and OND and the streamflow volume of the AMJJA has been determined (the amount of rainfall in JAS is about zero and not considered).

- Local SST and Z_{500}

When examining the impacts of oceanic–atmospheric climate variability, a significant influence on that variability comes from various dynamics at different pressure levels in the atmosphere. In order to reference the height of the various pressure regimes, the term "Geopotential height" is used. In essence, geopotential height is the height to the pressure zone of interest, as measured above the mean sea surface elevation.
One of the most effective factors in rainfall process is the sea surface temperature. In fact, it can be said that climate variables changes often are affiliated to the sea surface temperature changes and this factor played a major role in controlling climate processes like evaporation, atmosphere pressure and temperature changes. With regard to the geography of Iran and the role of the Zagros heights in the east of the study region in the distribution of rainfall, it can be said that rainfall in the Dez watershed involves low level rainfall system affected by the water temperature of Red Sea and the Persian Gulf (Sudanese systems) and also upper level rainfall systems under the influence of the water temperature in the Black Sea, Mediterranean and North Atlantic (Mediterranean systems). Figure 3 shows the correlation between the streamflow volume and Sea Surface temperature anomalies in these waterbodies in winter (AMJ).

Table 1 - List of potential Climate Indices used in this study and correlation coefficient between seasonal value of these signals with April to August streamflow volume in Dez river (bolded values are significant in 95 percent of confidence)

		Correlation Coefficient with AMJJA Streamflow		
Abbreviation	Full Name	AMJ	OND	JFM
PDO	Pacific Decadal Oscillation	***0.38***	***0.46***	***0.27***
SOI	Southern Oscillation Index	-0.30	***-0.56***	***-0.50***
NAO	North Atlantic Oscillation	0.18	-0.08	0.07
AMO	Atlantic multidecadal Oscillation	-0.26	-0.23	-0.05
AO	Arctic Oscillation	0.09	0.09	0.16
MEI	Multivariate ENSO Index	***0.40***	***0.50***	***0.54***
TNA	Tropical Northern Atlantic Index	-0.15	-0.05	0.17
TSA	Tropical Southern Atlantic Index	***-0.41***	-0.33	-0.23
WHWP	Western Hemisphere warm pool	-0.06	0.05	0.27
ONI	Oceanic Nino Index	***0.43***	***0.47***	***0.51***
NOI	Northern Oscillation Index	***-0.33***	***-0.48***	***-0.41***
BEST	Bivariate ENSO Timeseries	***0.37***	***0.51***	***0.52***
NINO1+2	Extreme Eastern Tropical Pacific SST *(0-10S, 90W-80W)	0.21	***0.36***	***0.37***
NINO3	Eastern Tropical Pacific SST (5N-5S,150W-90W)	***0.37***	***0.43***	***0.47***
NINO3.4	East Central Tropical Pacific SST* (5N-5S)(170-120W)	***0.42***	***0.45***	***0.51***
NINO4	Central Tropical Pacific SST *(5N-5S) (160E-150W)	***0.41***	***0.43***	***0.50***

Table 2- List of Rain Stations used in this study and correlation coefficient between seasonal rainfall April to August streamflow in Dez river

Station no.	Station	Latitude (°N)	Longitude (°E)	Elevation (m)	Correlation Coefficient (with AMJJA streamflow)	
					OND	JFM
21-124	Brojerd	33.88	48.77	1520	-0.05	***0.37***
21-259	Vanaaei	33.9	48.58	2000	0.03	0.34
21-271	Cham Zaman	33.4	49.4	1830	-0.02	0.31
21-273	Kamandan	33.32	49.43	1930	0.05	0.18
21-281	Cham Chit	33.38	48.98	1290	-0.04	***0.46***
21-289	Keshvar	33.13	48.63	770	0.15	***0.63***
21-402	Zard Ghahreh	49.8	33	2000	0.32	***0.37***
21-449	Charkhofalak Sibak	50.05	32.86	2490	0.23	0.13

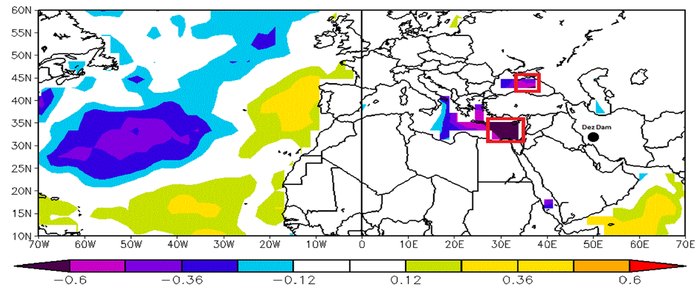

Figure 3- Correlation maps between JFM sea surface temperature and AMJJA streamflow

Conclusion

The main goal of this study was recognition of ocean-atmospheric variables beside the available hydroclimatic information for the prediction of dry season streamflow volume in Dez dam at the beginning of April and in 3 and 6 months lag. Basin hydroclimatic information such as streamflow and precipitation was used in traditional predictions and one point which are not always up to date and in some basins not available or appropriate in terms of quality.
Atmospheric circulation variables such as in the NCEP/NCAR reanalysis project are updated monthly and have global coverage. In addition, a longer lead time should be expected of inflow forecasts using these variables because local climate variability is the result of preexisting atmospheric circulation conditions.
In Dez watershed winter rainfall includes half of the annual rainfall and snow characteristics have important role in the accuracy of models prediction. Deficiency of available snowpack information causes applying available and considerable ocean-atmospheric variables in this study. Correlation analysis demonstrates that the prior annual and seasonal streamflow have no significant correlation with AMJJA streamflow volume but winter rainfall in some stations has. It was found that ENSO indices have significant relationship with streamflow and also PDO index in fall (OND) is an effective variable in dry period streamflow prediction in Dez watershed, but NAO index has no significant correlation with Dez dam streamflow volume.
The correlation coefficient between April to August streamflow volume and 500 mb geopotential height increase to r = -0.6 in some regions and this variable is a good candidate to predict the streamflow volume. SST anomalies in adjacent seas to the watershed have inverse correlation with AMJJA streamflow volume and correlation coefficient in the Black and Mediterranean Sea is higher specially in the east part of Mediterranean sea equal to r = -0.74 on JFM season (zero month lag). Also with a 6 month lag, the North Atlantic western shores show significant correlation coefficient. (r = -0.64)

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