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Unveiling the Significance of Paleoclimatic Studies in Advancing Future Climate Prediction: a case study of southeastern Iran

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Unveiling the Significance of Paleoclimatic Studies in Advancing Future Climate Prediction: A Case Study of Southeastern Iran

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Unveiling the Significance of Paleoclimatic Studies in Advancing Future Climate Prediction: A Case Study of Southeastern Iran

Author: Alireza Vaezi

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Extended Abstract

Introduction

Earth's climate has varied due to natural causes such as the change in solar insolation, orbital motion, orogeny, and ocean circulation pattern in the past (Bytnerowicz et al., 2007; Nakicenovic et al., 2000). However, since the industrial revolution began during the 18th-century, a sharp increase in greenhouse gas emissions (i.e., carbon dioxide, methane, nitrous oxide, and ozone) have resulted in global warming and a drastic change in existing climatic conditions (Le Treut et al., 2010; IPCC 2019;). In particular, human activities associated with the burning of fossil fuels have increased carbon dioxide levels in the atmosphere from 280 ppm in 1750 to more than 400 ppm in recent years (IPCC 2019, 2021). Since the 1970s, globally averaged surface temperature data have shown a linear warming trend of ca. 0.9 °C (Millar et al., 2017). Unlike temperature, which has increased globally, precipitation records indicate a variable response both in frequency and intensity (Archer & Rahmstorf, 2011; Konapala et al., 2020). Hence, there is an ongoing debate about how global warming will affect future precipitation because it has important implications for agriculture practices and food supply (Donat et al., 2016).

The lives of more than two billion people in South and West Asia depend on the summer monsoon precipitation on both short and long timescales (Clift & Plumb, 2008; Cullen et al., 2000). Therefore, understanding how the monsoons will change in the face of the anticipated increase in greenhouse gas emissions and rising global warming is a fundamental challenge. Also, the General Circulation Models (GCMs) face difficulty in simulating the regional distribution of monsoon (Turner & Annamalai, 2012) due to a multitude of physical processes and interactions that influence precipitation (Sperber et al., 2013). To reduce the uncertainty in climate models associated with monsoons and their intensity, we must understand the processes driving monsoons, seasonality, and fluctuations (Turner & Annamalai, 2012; Wang et al., 2017; Zhisheng et al., 2015).

It is suggested that the increase in greenhouse gas concentrations will intensify monsoons mainly due to an increased land-sea difference in temperature and a northward shift of the Inter-Tropical Convergence Zone (ITCZ) (Cao & Zhao, 2020; Li & Ting, 2017; Sachs et al., 2009). One such region of the world is southeastern Iran, which lies on the extreme northern border of the monsoonal domain that may be significantly affected by changes in the monsoon pattern and intensity. Southeastern Iran, straddled between the Indian Ocean Summer Monsoon (IOSM) precipitation zone and the Mid-Latitude Westerlies (MLW) precipitation zone, makes it highly sensitive to changes in climatic conditions (Hamzeh et al., 2016; Rashki et al., 2021; Vaezi et al., 2019). Furthermore, paleoclimate records indicate that intensity and variation of IOSM and MLW have changed significantly since the late Pleistocene affecting the regional hydrological conditions (Vaezi et al., 2019; Clift & Plumb, 2008; Stevens et al., 2001). Therefore, establishing a better understanding of atmospheric circulation patterns and precipitation in the distant past could help in improving our assessment of future climate change scenarios and variations in regional precipitation patterns (Mehterian et al., 2017).

GCMs have been widely used to study atmospheric patterns and eventual effects on the global and regional scales. However, output data from GCMs are typically coarse to estimate the hydrological response to climate change on a regional scale. Thus, there is a need to downscale the data from a coarse resolution in GCMs to a 'local' sub-grid-scale, weather station scale (Busuioc, 2008; Wilby et al., 2002), which can be achieved either by statistical or dynamical methods. Amongst the statistical downscaling methods, the Long Ashton Research Station Weather Generator (LARS-WG) has been extensively applied and tested in different climatic regions (Luo & Yu, 2012; Qian et al., 2004; Semenov et al., 2002, 2013; Semenov & Barrow, 1997; Street et al., 2009). The simulations in these studies highlight the capability and accuracy of the model in simulating climate change and projections for the future.

We try to reconstruct linkages between paleoenvironmental conditions and variability in IOSM and MLW outputs that contributed to various environmental changes in the interiors of West Asia since the Last Glacial Maximum (LGM). Our approach in constructing a multi-proxy climate record in the Jazmurian playa is to use grain-size analyses, elemental and mineralogical composition, magnetic susceptibility, stable oxygen and carbon isotope composition, and chemical biomarker distribution.

In the present study, as a comprehensive climate-driven investigation of the arid Iranian plateau, we will develop a general understanding of the qualitative and quantitative impact of changes in precipitation and temperature pattern and their impacts. In this context, daily precipitation and daily maximum (T_{max}) and daily minimum (T_{min}) temperatures in the Jazmurian playa in southeastern Iran will evaluated for the distant future scenario extending from 2061-2080 using statistically downscaled outputs from the 5 GCMs with the LARS-WG model under RCPs 4.5 and 8.5. The predicted results of future hydrological changes based on different global warming scenarios will used to evaluate the performance of the models. To verify if these changes may have also occurred in the past when no direct measurements of precipitation or temperature are available, we will refer to the results of paleoclimate studies. This study will reconstruct the linkages between paleoenvironmental conditions and variability in IOSM and MLW outputs that contributed to various environmental changes in the interiors of West Asia since the late Pleistocene. We will compare the variations in future atmospheric circulation and related changes in precipitation to the past cold and warm periods. The predicted simulations and paleoclimate events superimpose a complex mosaic, which can gauge our response and adaptation to climate change scenarios.

Geographical setting

The Jazmurian playa (*Hamun e Jazmurian*, in Persian) is an elongated tectonic depression surrounded by high mountains in southeastern Iran (Figure 1. A and 1B). The center of the Jazmurian basin sporadically fills with water forming a seasonal freshwater lake, which remains dry most of the year. The playa is located at an altitude of about 350 m above mean sea level and receives water from the Halil River in west and the Bampur River in east. The Halil River flows 390 km through fertile agricultural lands before emptying into the Jazmurian playa and provides ca. 75% of the annual freshwater input into the playa (Frs, 1975). The common rock types in the catchment consist of Quaternary deposits (sandstone, conglomerate, marl, gypsum, and gravel) deposited on the river terraces and fans (GSI, 2001). Further north, the landscape consists of volcanic rocks (breccia and basalts) along with sedimentary rocks (e.g., sandstone and limestone).

Climate on the Iranian Plateau in southwest Asia is largely governed by complex interactions between the southwest Indian Ocean Summer Monsoon (IOSM), the Mid-Latitude Westerlies (MLW), and the northeast Siberian Anticyclone (Hamzeh et al., 2016; Sharifi et al., 2015). The intensity and variation of these atmospheric circulation patterns have changed dramatically since the late Pleistocene resulting in significant variability in climate and hydrological conditions in the region (Clift & Plumb, 2008; Stevens et al., 2001). For example, the middle to late Holocene southward shifting of the Intertropical Convergence Zone (ITCZ), and the associated changes on the IOSM, were the major climatic events that influenced the regional landscape (Sharifi et al., 2015; Fleitmann et al., 2007; Staubwasser and Weiss, 2006). Modifications in regional orography, changes in the dynamics of lake/fluvial systems, and interference from the subtropical high, have all exerted strong impacts in shaping the bio-climatic zones on the Iranian plateau (Bayat et al., 2017; Djamali et al., 2010; Kehl, 2009).

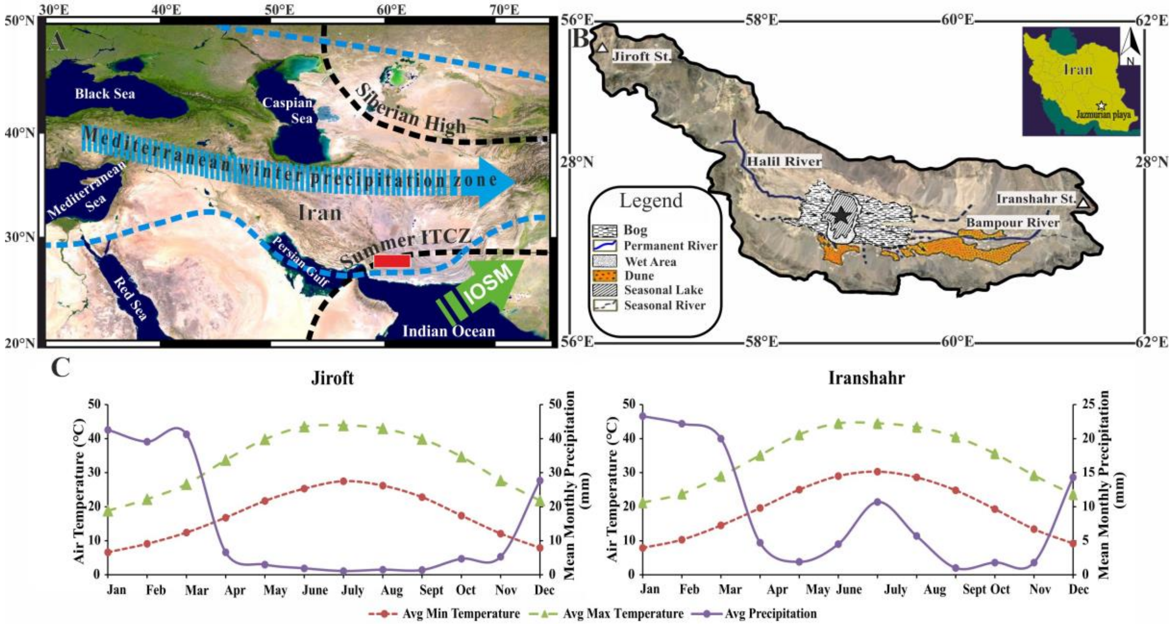

Figure 1: Major climate systems over West Asia (Sharifi et al., 2015; A. Vaezi et al., 2019) and location of the Jazmurian coring site (marked as a star).

The Jazmurian playa is situated in a unique climatological setting, centered between the IOSM precipitation zone of south Asia and the Mediterranean winter precipitation zone. The Jazmurian playa is also situated at the northern margin of the Inter-Tropical Convergence Zone (ITCZ). Regional paleoclimatic conditions here are strongly linked with the position of the ITCZ and its migration over geological time. The local climate is hot and arid during summer with relatively mild winters. The mean annual temperature is around 26 °C with mean maximum and minimum temperatures at 44 °C (June and July) and 7 °C (January), respectively (Fig. 1C). Evaporation rate is ca. 2500 mm per year (Rashki et al., 2017) - considerably higher than total precipitation in the region. Annual rainfall in the western part of Jazmurian basin, at the Jiroft weather station (170 km west of the coring site), is about 176 mm which then decreases to 112 mm to the east at the Iranshahr weather station (150 km east of the coring site; data from Iran Meteorological Organization, 1985-2010; www.irimo.ir). Based on a 25-year average monthly precipitation record at two weather stations, the highest precipitation occurs from January to

March, with the dry season between April and November (Fig. 1C). The eastern part of the basin also receives some precipitation from monsoons during July. Since the playa is at an elevation 250 m lower than the two weather stations, it is reasonable to expect slightly lower annual precipitation and higher temperatures at the coring site (Fig. 1B).

Purpose and aims

In this study on future and paleoclimate changes in an arid region of southeastern Iran situated on the north most border of IOSM, we presented

1) Future simulated precipitation and temperature shifts based on different scenarios in GCMs

2) Trace real paleoclimatic changes that happened in the Jazmurian playa since the late Pleistocene.

2) The paleoenvironmental records are used to examine the relationship between predicted changes in precipitation (variability in IOSM and MLW output) based on different scenarios.

By now, the research team has presented four papers:

- **Vaezi, A.,** Routh, J., Rana, A., Nasseri, M. (2023). Linking Future Hydroclimatological Changes with Past Climatic Conditions in Southeastern Iran: Insights from Models and Observations. doi:10.21203/rs.3.rs-1031226/v1

- Sharifi-Yazdi, M., Tavakoli, V., Salehi-Noparvar, S., **Vaezi, A.,** Naderi Beni, A., Nazemi, M., … Routh, J. (2022). Influence of the Late Quaternary climate on sedimentology of the Jazmurian Playa, SE Iran. Journal of Paleolimnology. doi:10.1007/s10933-022-00239-8

- Zandifar, S., Tavakoli, V., **Vaezi, A.,** Naeimi, M., Naderi Beni, A., Sharifi-Yazdi, M., & Routh, J. (2022). Influence of transport mechanism on playa sequences, late Pleistocene-Holocene period in Jazmurian Playa, southeast Iran. Arabian Journal of Geosciences, 15(7). doi:10.1007/s12517-022-09918-2

- **Vaezi, A.,** Ghazban, F., Tavakoli, V., Routh, J., Beni, A.N., Bianchi, T., Curtis, C., Kylin, H. (2019). A late Pleistocene-Holocene multi-proxy record of climate variability in the Jazmurian playa, southeastern Iran. Palaeogeography, Palaeoclimatology, Palaeoecology, 514, 754-767.

Linking future hydroclimatological changes with past climatic conditions in southeastern Iran: Insights from models and observations

Alireza Vaezi, Joyanto Routh, Arun Rana, Mohsen Nasseri

Abstract

We compare the predicted results of future hydrological changes based on a thirty-year (1989-2019) weather dataset with paleoclimatic changes inferred based on established proxies from the Jazmurian playa in southeastern Iran. Parallels between expected changes in the future were compared to past climatic conditions to trace the impact this region has undergone in the distant past. The study area is affected by the Indian Ocean Summer Monsoon (IOSM) and the Mid-Latitude Westerlies (MLW). The maximum and minimum temperatures and precipitation were predicted for the future (2061- 2080) by statistical downscaling outputs of 5 GCM models (EC-EARTH, GFDL-CM3, HadGEM2-ES, MIROC5, MPI-ESM-MR) under RCP 4.5 and RCP 8.5. The results show that the 20-years average of the mean temperatures ((Tmax + Tmin)/2) will increase in the range of 3.2 to 4.6 °C under RCP 8.5 compared to the base period. The trends suggest that the region will experience drier conditions than the baseline period in the future under both scenarios. In addition, the GCM predicts a considerable decline in MLW precipitation and little change in future IOSM precipitation under both scenarios compared to the baseline. The decrease in MLW precipitation is consistent with other GCM predictions and real paleoclimatic changes that happened during past warm/wet periods in the region. However, considering the close relationship between the increase in the Earth's radiation budget and enhanced IOSM precipitation in southeast Iran since the late Pleistocene, we postulate that more intensive IOSM activity can be expected in the future.

Keywords: Climate change, temperature, precipitation, paleoclimate, Jazmurian playa.

Influence of the Late Quaternary climate on sedimentology of the Jazmurian Playa, SE Iran

Masoud Sharifi-Yazdi, Vahid Tavakoli, Sara Salehi-Noparvar, Alireza Vaezi, Abdolmajid Naderi Beni, Maziyar Nazemi, Srimanti Duttagupta, Joyanto Routh

Abstract

The Jazmurian Playa in southeast Iran is a sediment archive that has preserved climate and environmental changes since the late Pleistocene. The late Pleistocene was dominated by sub-arid to arid climate interspersed with short-time warm and humid conditions that impacted the vegetation cover and landscape. This study used sedimentological variations in a sediment core, supported by geochemical and mineralogical characteristics, to reconstruct climate change impacts and water-level fluctuations in the playa. These changes were inferred using grain-size data, magnetic susceptibility, total organic matter content, carbonate content, elemental concentrations, and mineralogical composition in the ^{14}C-dated sediment core. Based on the inferred water level fluctuations in the playa, the core was divided into two major units. Unit 2 belonged to the late Pleistocene, characterized by a cold and dry climate. In contrast, Unit 1 was deposited during the Holocene, a time marked by prevailing warm and humid conditions, with short periods

of intense dust storms. Since the late Holocene, the IOSM (Indian Ocean Summer Monsoon) has played a dominant role in regional climate. Water-level fluctuations related to humidity significantly influenced the sedimentological variables, including grain-size distribution, sorting, skewness, and roundness. During cold and arid conditions, the water level was low, and coarse sediments were deposited in the playa, with low organic matter content, low concentrations of Cu, Mn, P, and V, and evaporite minerals. In contrast, high organic matter content, presence of illite, and high concentrations of Cu, Mn, P, and V and low values of ICV (Index of Compositional Variability) imply a warm and humid climate during the Holocene. The paleoclimate reconstruction in the playa provides evidence about ongoing changes that are closely related to the paleohydrological conditions in this region.

Keywords: Climate change, Playa, Elemental analyses, Water level, Magnetic susceptibility, Total organic matter

Influence of transport mechanism on playa sequences, late Pleistocene-Holocene period in Jazmurian Playa, southeast Iran

Samira Zandifar, Vahid Tavakoli, Alireza Vaezi, Maryam Naeimi, Abdolmajid Naderi Beni, Masoud Sharifi-Yazdi, Joyanto Routh

Abstract

Inland basins such as lakes and playas are promising sedimentological archives for recording paleoenvironmental conditions. In this study, a 5-m long sediment core from Jazmurian Playa in southeast Iran was investigated to understand the transport mechanism and palaeohydrological conditions in this region from the late Pleistocene to Holocene. Grain size analysis, total organic materials, calcimetry, elemental analysis, ^{14}C-age dating and scanning electron microscopy were used for this purpose. The core was divided into 8 zones (Jaz-A to H) based on macroscopic, sedimentological and geochemical characteristics. Si and Al represented as fine-grained particles were considered as allochthonous inputs into the playa. Comparing carbonate content and size analysis of the grains, it was demonstrated that carbonate particles are terrigenous and have been transported to the basin. Total organic materials of the samples were used to infer the transporting and environmental energies as well as oxidation state of the depositional setting. The presence of Ti and Zr indicated dry conditions, whereas Rb indicated wet conditions. The alternation of wet and dry conditions in the region was evident from the different forms of sediment transport mechanisms and deposition. Windy, arid and calm conditions were dominant from the base of the core to the 11.45 ky BP. This condition was inferred based on the low Rb and high Ti and Zr, grain surface characteristics (based on scanning electron microscopy imaging), and presence of evaporative minerals. The climate was relatively wet ca. 11.45 to 10.6 ky BP which was deduced from high Ca, Si and total organic materials. From 10.6 to 3.5 ky BP, a transition zone from wet to dry climate was dominant in the basin. The sediments in the playa were transported mainly by the wind under dry conditions at the topmost interval of the studied core.

Keywords: Jazmurian Playa, palaeohydrological conditions, Holocene, climate, Iran

A Late Pleistocene-Holocene multi-proxy record of climate variability in the Jazmurian playa, southeastern Iran

Alireza Vaezi, Fereydoun Ghazban, Vahid Tavakoli, Joyanto Routh, Abdolmajid Naderi Beni, Thomas S. Bianchi, Jason H. Curtis, Henrik Kylin

Abstract

We present a multi-proxy record from a 5-m long sediment core from the Jazmurian playa in southeastern Iran to provide insights into globally-recognized major climatic events since the Last Glacial Maximum (LGM). In particular, we examined how variability in the Indian Ocean Summer Monsoon (IOSM) and Mid-Latitude Westerlies (MLW) contribute to distinct environmental changes in this arid to hyper-arid region in the interior of West Asia. While interior West Asia showed cold windy conditions during the LGM and post-LGM, southeast Iran experienced quiescent conditions similar to south Asia. The presence of fine-grained sediments, low magnetic susceptibility, and a decrease in aeolian inputs from ca. 21 to 14 cal kyr BP, suggests that effects of both wind and precipitation were minimal during these quiescent conditions. Increased fluvial inputs, coupled with a low abundance of evaporite minerals in Jazmurian sediments, indicated a greater influence of the IOSM between 14 and 13.2 cal kyr BP. In contrast, the Jazmurian playa was dry and dusty between 13.2 and 11.4 cal kyr BP, as reflected by an increase in aeolian sands, and the presence of evaporite minerals. This was followed by a period of strong IOSM activity during the early Holocene, coinciding with higher fluvial input ca. 11.4 cal kyr BP. The early Holocene in southeast Iran was wetter than other analogs in south Asia because of inputs from both IOSM and MWL. Several intense dry periods with sharp increases in aeolian inputs occurred after the early Holocene, due to the southward migration of the Intertropical Convergence Zone. Precipitation sources changed from a monsoon-dominated regime to one influenced mainly by the MLW during the late-Holocene. These results show that palaeoenvironmental changes in the Jazmurian playa, located at the border of IOSM and MLW zones, were primarily governed by global and regional paleoclimatic changes.

Keywords: Paleoenvironment, Monsoon, Westerlies, Sediments, Chemical proxies, Aeolian.

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