Studying the Spatial Variations of Stable Isotopes (^{18}O and ^{2}H) in Precipitation and Groundwater Resources in Zagros Region

Mojtaba Heydarizad

Abstract**—**Zagros mountain range is a very important precipitation zone in Iran as it receives high average annual precipitation compared to other parts of this country. Although this region is important precipitation zone in semi-arid an arid country like Iran, accurate method to study water resources in this region has not been applied yet. In this study, stable isotope $\delta^{18}O$ content of precipitation and groundwater resources showed spatial variations across Zagros region as southern parts of Zagros region showed more enriched isotope values compared to the northern parts. This is normal as southern Zagros region is much drier with higher air temperature and evaporation compared to northern parts. In addition, the spatial variations of stable isotope $\delta^{18}O$ in precipitation in Zagros region have been simulated by the models which consider the altitude and latitude variations as input to simulate $\delta^{18}O$ in precipitation.

Keywords**—**Groundwater, precipitation, simulation, stable isotopes, Zagros region.

I. Introduction

IRAN is located in very tectonic active region in Alpine-Himalayian orogenic belt which extends from the Atlantic Ocean in the west to western Pacific in the east. This orogenic belt has been considered as the remains of great ancient Thetys existed between two Paleo mega continents "Eurasian and Gondwana" during Paleozoic-Mezosoic eras. Iran has consisted of several geological-structural units which have relatively unique records of magmatic activities, metamorphism, stratigraphy, orogenic events, and tectonics. Iran has been divided to several structural-sedimentary basins including Zagros, Alborz, Kopeh Dagh and Central Iran. Zagros region can be classified to three zones thrust Zagros, Folded Zagros and simple folded Zagros.

Zagros region extends from the southern Province of Hormozgan or even Persian Gulf basin to northwestern Iraq territories with the elevation from 2000 m to more than 4000 m in the mountainous peak. This mountain range has a total length of 1600 km (990 mi). The highest point in Zagros mountain range is Dena mountain with the elevation of 4409 m. Zagros region has several characteristic including the lack of magmatism and metamorphism after Triassic age, and existence of large anticline with small syncline among them which is due to the active pressure from Arabian plate. Sedimentation without considerable hiatus from Triassic to Miocene ages is almost seen in every parts of Zagros region in Iran and also Iraq. According to structural classification, Zagros can be classified to Folded Zagros and Khuzestan Plate. Zagros region is generally consisting of limestone, marl, shale, sandstone, conglomerate and evaporates with no or rare magmatic or metamorphiqc outcrop.

Zagros Mountain contains various climatic zones. In the southern part of Zagros mountain range, dry and hot climate dominates, while in the northern part of this mountain range cold and humid climate dominates. Zagros mountain range also influences climate and precipitation distribution across Iran. Studying the precipitation variations in Zagros mountain range is very complicated compare to other mountains regions in Iran due to the existence of different valleys and ridges with different orientations [1].

Stable isotopes (^{18}O and ^{2}H) technique as precious method in water resources studies has been applied in many studies in the world, but stable isotope method is not common in Iran due to the lack of stable isotope analysis equipment in Iran. Several parameters such as moisture origin, amount effect, latitude effect, altitude effect and temperature effect have been considered as an important factor influence the stable isotopes ^{18}O and ^{2}H content of precipitation. The latitude and altitude variations are important parameters in mountainous area like Zagros mountain range. The role of latitude and altitude variations have been done in many investigations including [2]-[7]. In this study, the spatial variations of stable isotopes in precipitation and groundwater resources in Zagros region have been studied. In addition, the variation of stable isotopes in Zagros region precipitation has also been modelized.

II. Materials and Methods

The Zagros region in Iran has been shown in Fig. 1. The stable isotope (^{18}O and ^{2}H) data in precipitation and groundwater resources have been gathered from the PhD and MSc dissertation thesis and also scientific reports to develop stable isotope distribution maps in this region. Samples were analyzed for stable isotopes compositions (^{18}O and ^{2}H) using Delta plus XP isotope ratio mass spectrometer (IRMS) and Los Gatos Research (LGR) OA-ICOS. The stable isotopes (^{18}O and ^{2}H) were expressed relative to Vienna Standard Mean Ocean Water (VSMOW) and are given as parts per thousand (per mil, ‰) with analytical standard uncertainties of ± 0.1 ‰ and ±1‰ for both $\delta^{18}O$ and $\delta^{2}H$, respectively. To simulate the $\delta^{18}O$ & $\delta^{2}H$ isotope spatial variations in Zagros region, geographical parameters including Latitude, and Altitude were considered.

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III. Results and Discussion

A. Studying Iso-Distribution Map of $\delta^{18}O$, δ^2H and d Excess in Precipitation and Groundwater Resources in Zagros Region

In Zagros region in Iran, the variation in stable isotope of precipitation and groundwater (Fig. 2) distribution corresponds well except for anomalies spot between groundwater and precipitation observed in some parts. This may be due to recharge of groundwater by depleted high elevation precipitation instead of local precipitation. In most of the stations, groundwater samples depicted small depletion compare to precipitation. The D excess demonstrates more complicated patterns as two obvious anomalies have been observed in groundwater and precipitation data. In the eastern and northern part of Zagros region, D excess demonstrated more depleted values compared to precipitation followed by depleted $\delta^{18}O$ and δ^2H values and demonstrated groundwater recharge by high elevation precipitation. In contrast, in central part of Zagros region, more enriched value of D excess is followed by more depleted $\delta^{18}O$ and δ^2H due to groundwater recharge by high elevation precipitation which is generated from cold region. However, local precipitation influenced by secondary evaporation depicted depleted D excess. Secondary evaporation observed in local precipitation in this region was also in close agreement with hot and semi-dry climate dominated in this part of Iran.

Fig. 1 Location of the study region (Zagros) in Iran

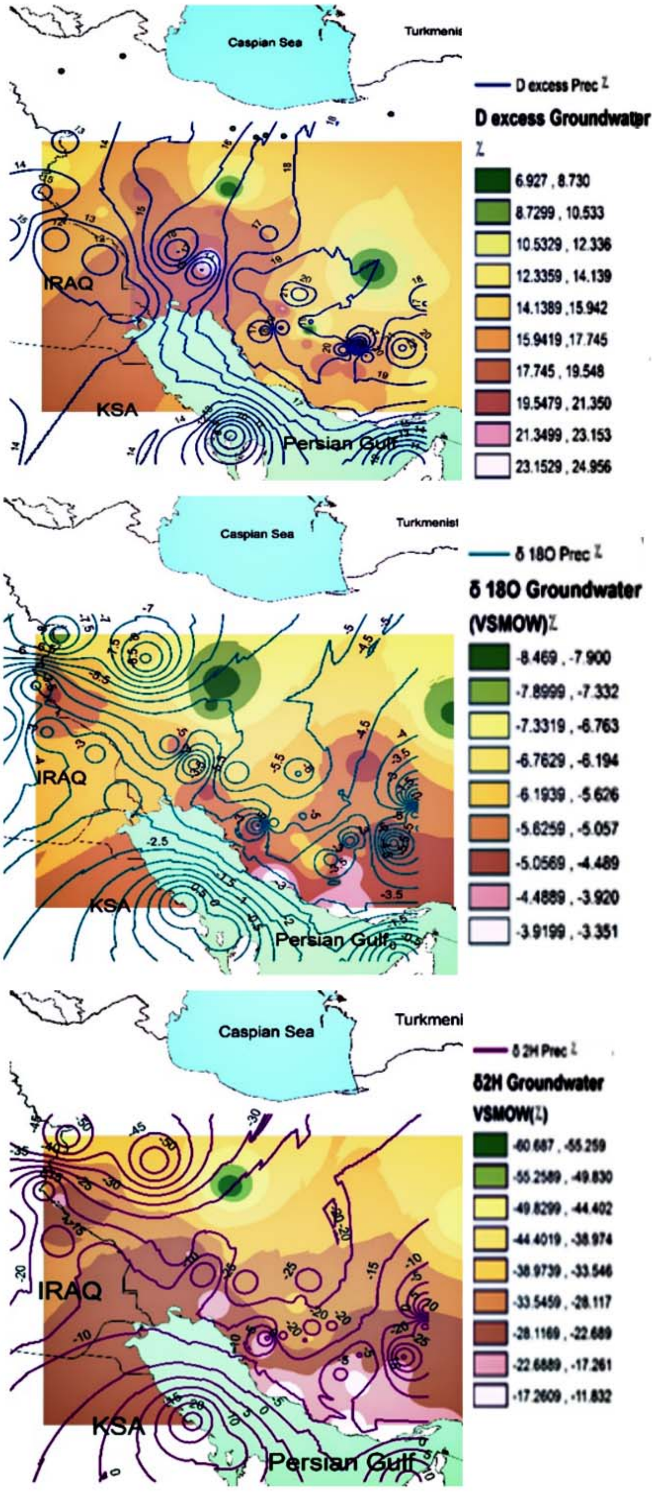

Fig. 2 Distribution of $\delta^{18}O$, $\delta^{2}H$ and d excess in groundwater samples across Zagros region and mean $\delta^{18}O$, $\delta^{2}H$ and d excess precipitation contour map

B. Average $\delta^{18}O$ Isotope Content Dependence to Latitude in Precipitation

Determination latitude and altitude variation effect on $\delta^{18}O$ fluctuation in precipitation have been studied firstly by [5], [8] have been studied, the $\delta^{18}O$ isotope correlation relative to latitude in USA and Greece precipitation. In all these studies, they have modelized the effect of latitude and altitude through two step regression technique. In the first step, they used stations at <200 m elevation to evaluate latitudinal variation while, the effect of topography has been minimized. Mean annual $\delta^{18}O$ in precipitation have been modelized using Sinusoid curve fitting method and second-order polynomial best describes the correlation between $\delta^{18}O$ (dependent variable) and latitude (independent variables) in global scale. In our study, as no stations with <200-meter elevation exist in North Iran, studying latitude effect on $\delta^{18}O$ can only be done for Zagros region (1).

$$\delta^{18}O_{PPT}=-0.0776[Lat]^2+3.9293[Lat]-49.241 \quad r^2=87.14 \quad (1)$$

To study simulation effect of altitude and latitude for stations over 200-meter elevation, firstly $\delta^{18}O$ value is calculated for all the stations using (1), deviations are observed between the measured $\delta^{18}O$ and the calculated $\delta^{18}O$ in stations with > 200-meter elevation, and deviation increment occurs by station elevation increment. The effect of altitude is considered as the least squares' regression between station altitude and residuals (the difference observed between measured $\delta^{18}O$ and calculated values (2)) [8].

$$RES_{PPT}=-0.0017\ Alt \quad r^2=0.433 \quad (2)$$

To study the simultaneous effect of latitude and altitude on the isotopic composition of precipitation in >200-meter elevation stations in Zagros region, both equations (1) and (2) are added, resulting in a first order estimation of $\delta^{18}O$ in >200-meter elevation stations (3) [8].

$$\delta^{18}O_{PPT}=-0.0776[Lat]^2+3.9293[Lat]-0.0017[Alt]-49.241 \quad (3)$$

The distribution map of $\delta^{18}O$ in precipitation, the simulated $\delta^{18}O$ and the measured $\delta^{18}O$ in the studied station and residual map of precipitation in Zagros region are shown in Fig. 3.

Differences are observed between the measured and simulated values by model ranges from -3.82 to 7.68 ‰. In southern part of Zagros region in the vicinity of the Persian Gulf, the model estimated more enriched value compared to measured ones. However, in northern part of Zagros region, the simulated values are much more depleted compared to the measured values, which demonstrate the dominant influences of other parameters that have not been considered in simulation such as storm track trajectory, relative humidity, continental and amount effects which reduce the depletion gradient from southern to northern part of Zagros region.

IV. Conclusion

Zagros region is very important for Iran as this region receives much larger amount of precipitation compared to other parts of Iran. Application of accurate stable isotope method in both groundwater and precipitation in this region showed that both precipitation and groundwater resources showed more enriched isotope values in southern Zagros compared to northern part. Some anomaly zones were observed between groundwater resources and precipitation in south parts of Zagros due to local parameters which should be studied in more details. In addition, the simulation of δ^{18}O in precipitation in Zagros region considers the altitude and latitude to simulate δ^{18}O in precipitation. Finally, the variation of δ^{18}O in precipitation and simulated values has been compared, and the zones of anomalies have been determined.

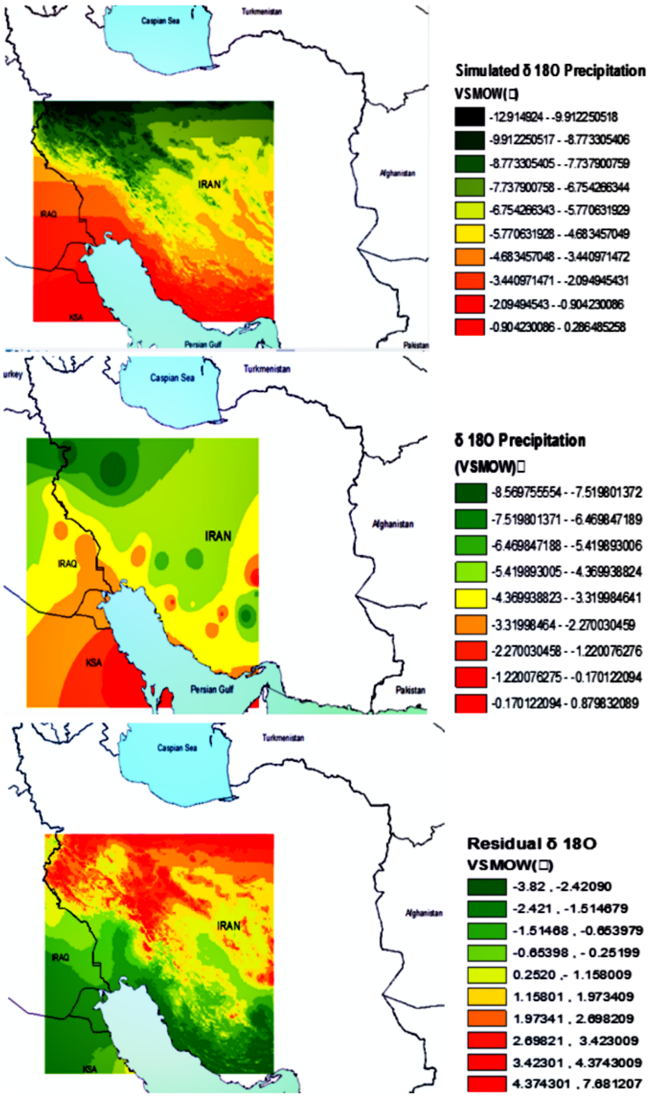

Fig. 3 Simulated δ^{18}O in precipitation based on developed equation, measured $\delta\ ^{18}$O in studied station, residual map of (measured-simulated) δ^{18}O in precipitation events in Zagros region

ACKNOWLEDGMENT

The author appreciates the staff of Ferdowsi University of Mashhad (FUM) and Shiraz university who helped us do this research. Special thanks to Mr. Syamak Mahmoudi Sivand for providing needed data for this research.

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