



# Application of statistical techniques to study stable isotopes ( $^{18}\text{O}$ and $^2\text{H}$ ) characteristics of precipitation in Iran (Southwest Asia)

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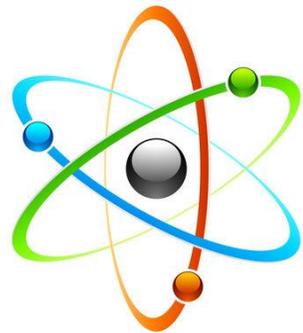
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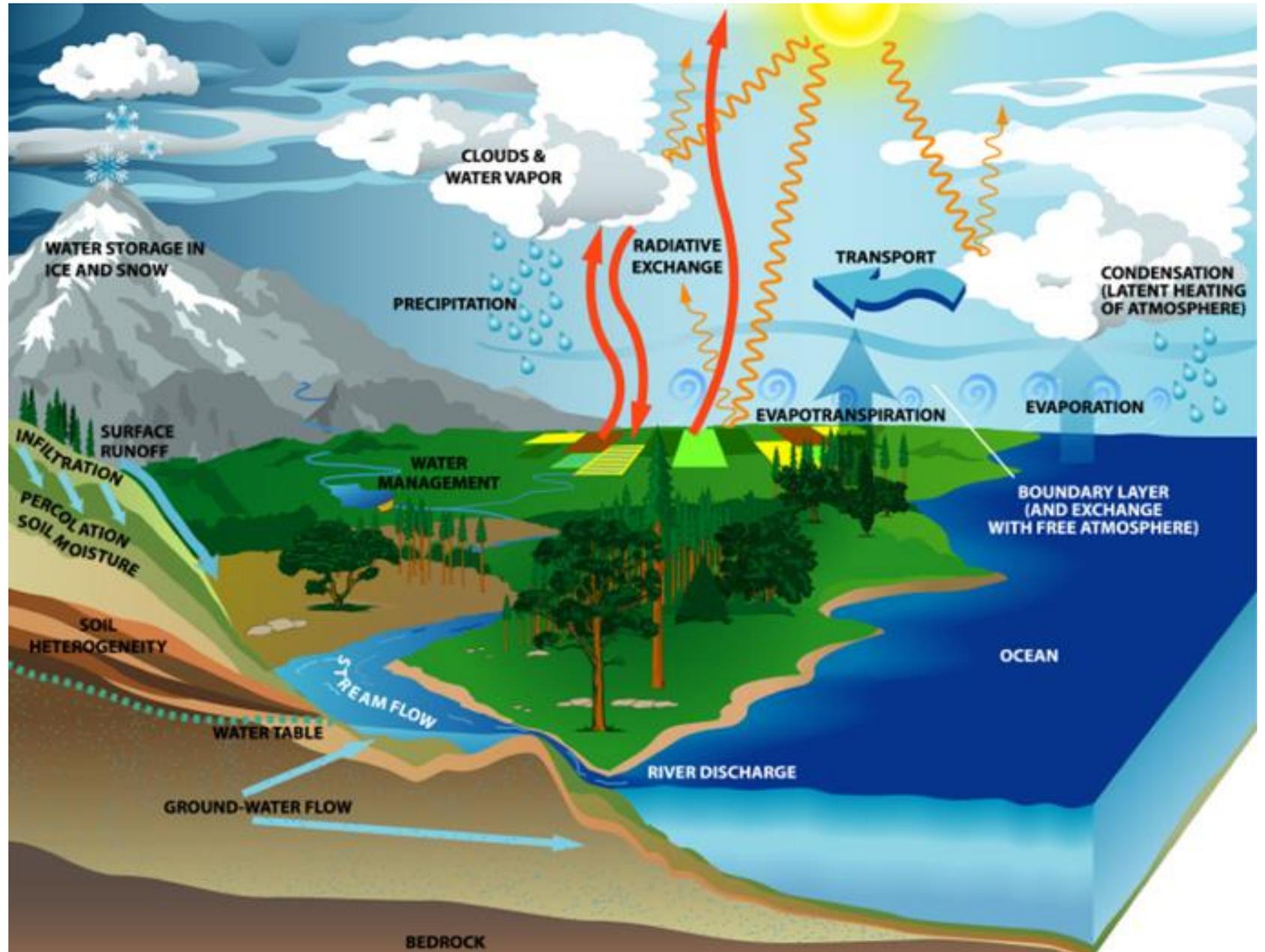
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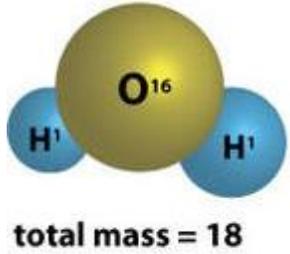
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# The water cycle

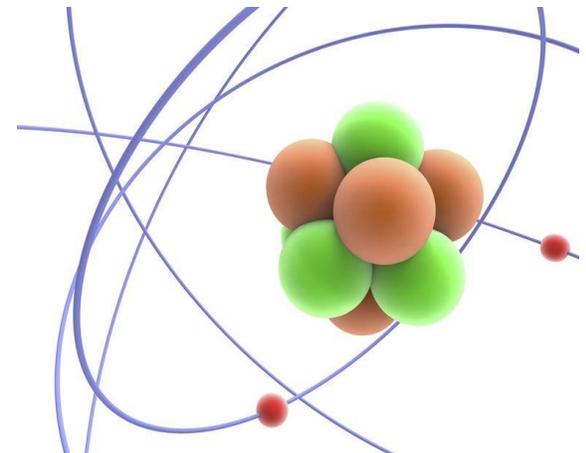
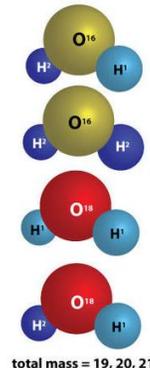
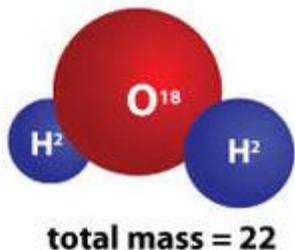


# Oxygen and Hydrogen isotopes in water

## Tracing the hydrological cycle



- Stable isotopes technique presents crucial information regarding the climate condition of the moisture origin as well as climate condition in precipitation sampling sites.
- There are so many studies regarding the application of stable isotopes in precipitation in Iran. Most of these studies are local small scale investigations, while some of them are large scale studies that cover all of Iran.
- The aim this research is to perform a comprehensive study on stable isotopes characteristics of precipitation in Iran using statistical techniques.



# Who used stable isotopes technique in water resources for the first time?

Harmon Craig (March 15, 1926 – March 14, 2003)



The screenshot shows the Science journal website interface. At the top, there is a navigation bar with the AAAS logo, a 'Become a Member' link, and a search bar. Below this is a dark header with the 'Science' logo and dropdown menus for 'Contents', 'News', 'Careers', and 'Journals'. The main content area features the article title 'Isotopic Variations in Meteoric Waters' by Harmon Craig, published in Science on May 26, 1961. It includes social media share icons (Facebook, Twitter, LinkedIn, Email) and a 'Log in to view PDF' button. On the right side, there is a 'Science' journal cover thumbnail and a list of 'ARTICLE TOOLS' such as 'Email', 'Request Permissions', 'Citation tools', 'Print', 'Alerts', and 'Share'. At the bottom right, there is a 'MY SAVED FOLDERS' section with a 'Save to my folders' option.

# Stable isotopes studies in precipitation across Iran



Source: <https://www.ilkehaber.com/haber/iranda-kuraklik-nedeniye-barajlarda-kriz-alarmi-49332.htm>

# Drought in Iran



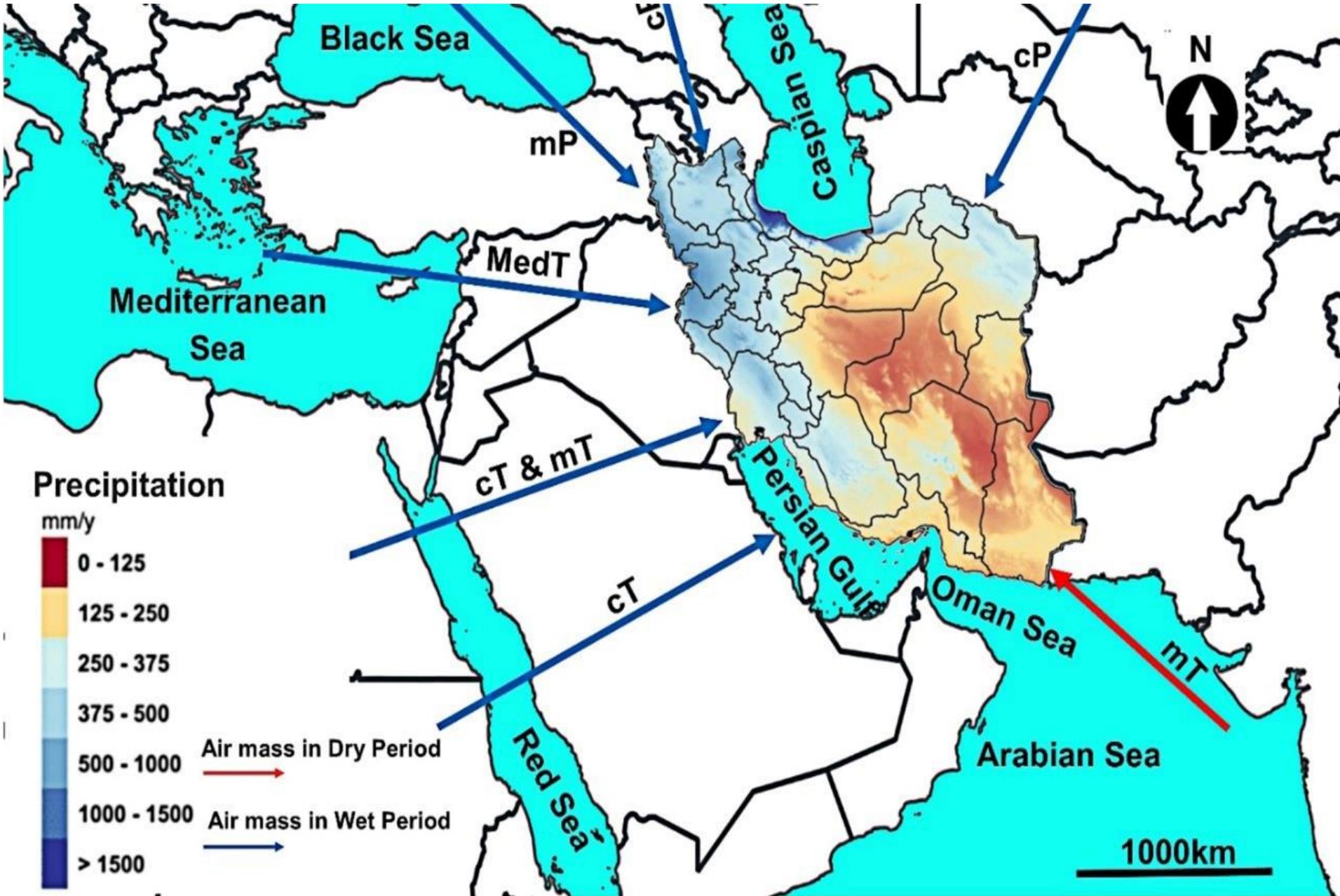
After: Global framework for climate services, WMO 2021  
Source: <https://gfcs.wmo.int/DESIR>



After: <http://www.payvand.com/news/12/oct/1094.html>

Iran  
Climatology

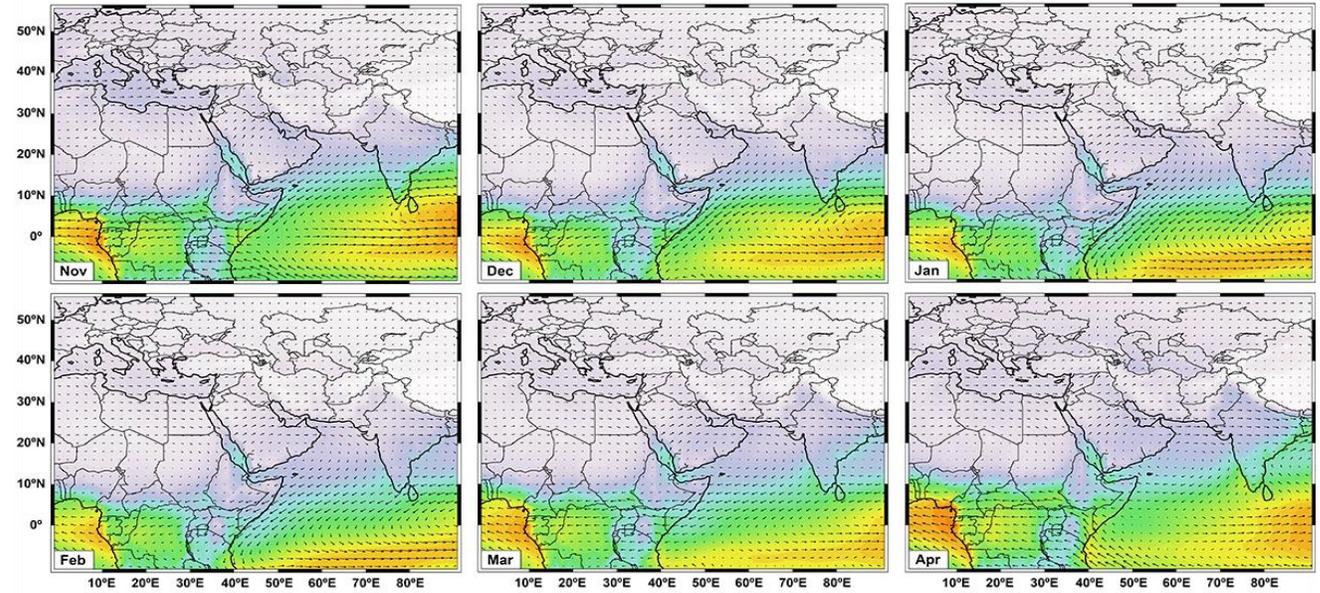
The precipitation amount variations as well as the main air masses influence Iran



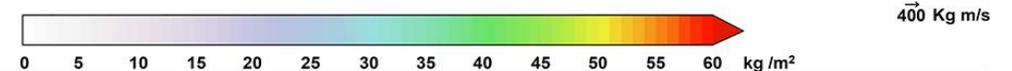
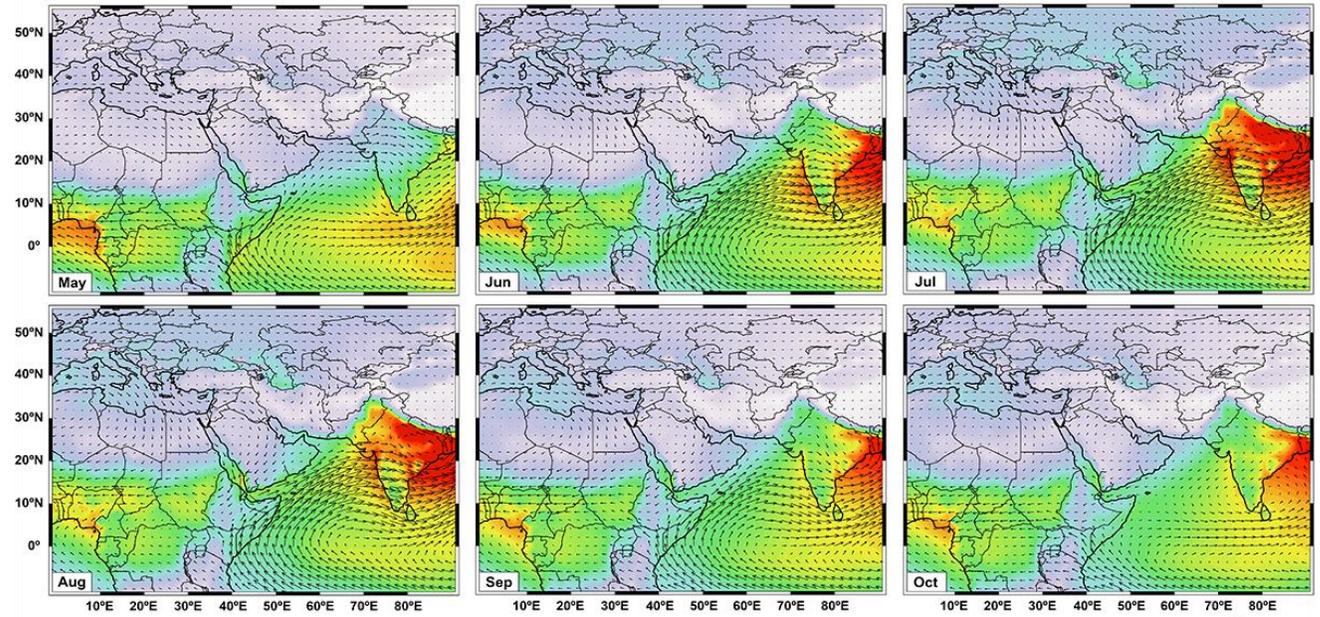
The vertically integrated moisture flux (VIMF) (arrows) and the total column water vapour (shaded).

Data from the ERA Interim Reanalysis with a resolution of  $1^\circ \times 1^\circ$  for the period 1981-2015 (data obtained from ERA-Interim (Dee et al. 2011)).

Wet and cold period (November - April)



Dry and hot period (May - October)



## Stable isotopes studies in Iran

In this study, stable isotopes ( $^{18}\text{O}$  and  $^2\text{H}$ ) and d-excess have been studied in 34 stations across Iran. Stable isotopes data have been presented in delta notation ( $\delta$ ), which is the relative deviation of the sample from the standard (Vienna Standard Mean Ocean Water (VSMOW)) by Eq. 1:

$$\delta^{18\text{O}}_{\text{sample}} = \left( \frac{\left(\frac{^{18}\text{O}}{^{16}\text{O}}\right)_{\text{sample}}}{\left(\frac{^{18}\text{O}}{^{16}\text{O}}\right)_{\text{reference}}} - 1 \right) * 1000\% \quad \text{VSMOW} \quad (1)$$

The analytical standard uncertainties for precipitation samples were  $\pm 0.1\%$  and  $\pm 1\%$  for  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$ , respectively. Stable isotopes data have been gathered from PhD and MSc thesis as well as scientific papers.

**Stable isotopes studies in Iran**

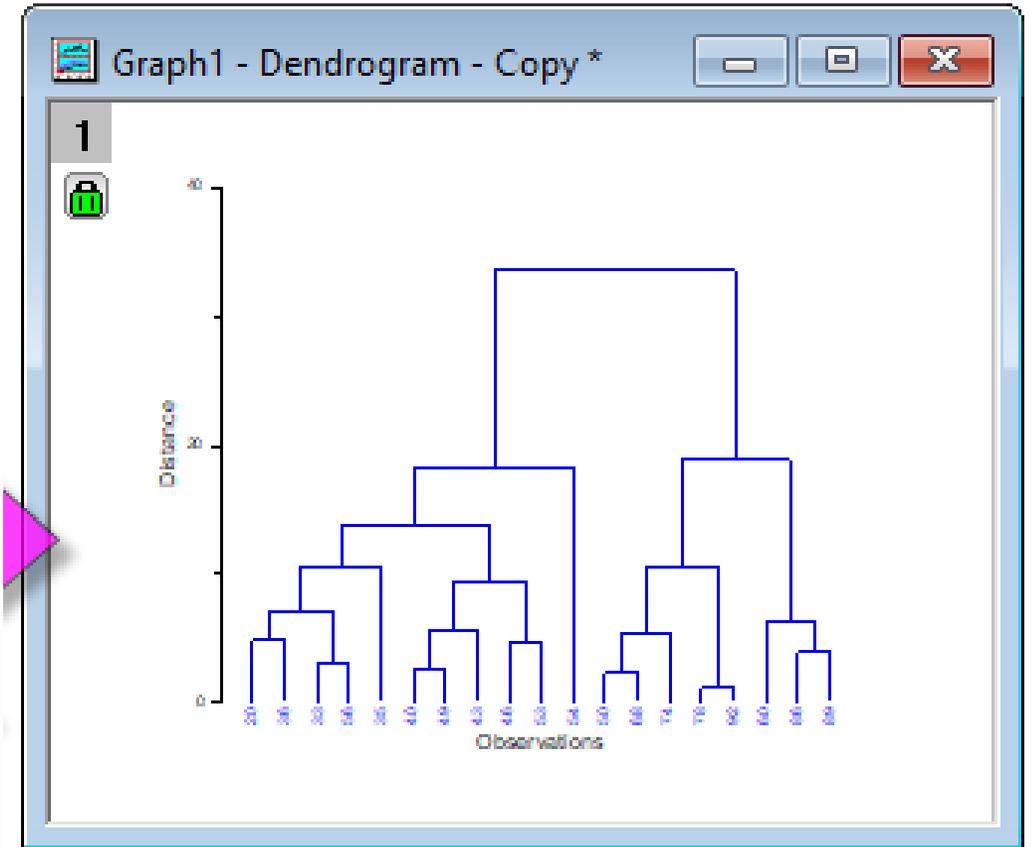
The studied precipitation sampling stations across Iran.

Row	Station	N	E	Row	Station	N	E
1	Abadeh	52.7	31.2	26	Shirinbahar	49.5	31.5
2	Abolabas	49.5	31.3	27	Sirjan	55.7	29.4
3	Alvand	45.6	34.5	28	Marvdasht	52.8	29.8
4	Ardekan	52.0	30.3	29	Tehran	51.4	35.7
5	Arsanjan	53.0	29.9	30	Tehran-Airport	51.4	35.6
6	Bajgah	52.6	29.7	31	Zarghan	52.4	29.5
7	Darab	54.5	28.7	32	Zarivar	46.2	35.5
8	Dasht Arjan	52.0	29.6	33	Birjand	59.2	32.9
9	Damavand	52.1	35.7	34	Dorfak-Gilan	49.6	37.2
10	Estahban	54.0	29.1				
11	Fasa	53.4	28.5				
12	Gorgan	54.5	36.8				
13	Hamadan	48.5	34.8				
14	Hashtgerd	50.6	35.9				
15	Isfahan	51.6	32.0				
16	Jahrom	53.6	28.5				
17	Kazeroon	51.6	29.6				
18	Khersan	50.8	31.5				
19	Mashhad	59.6	36.3				
20	Paveh	46.4	35.0				
21	Rafsanjan	56.0	30.4				
22	Sabalan	48.0	38.4				
23	Sarcheshmeh	55.7	29.4				
24	Shahrood	55.0	36.4				
25	Shiraz	52.5	29.6				

Stable isotopes studies in Iran

- Cluster Analysis (CA) has been used to classify studied stations based on their stable isotopes characteristics.

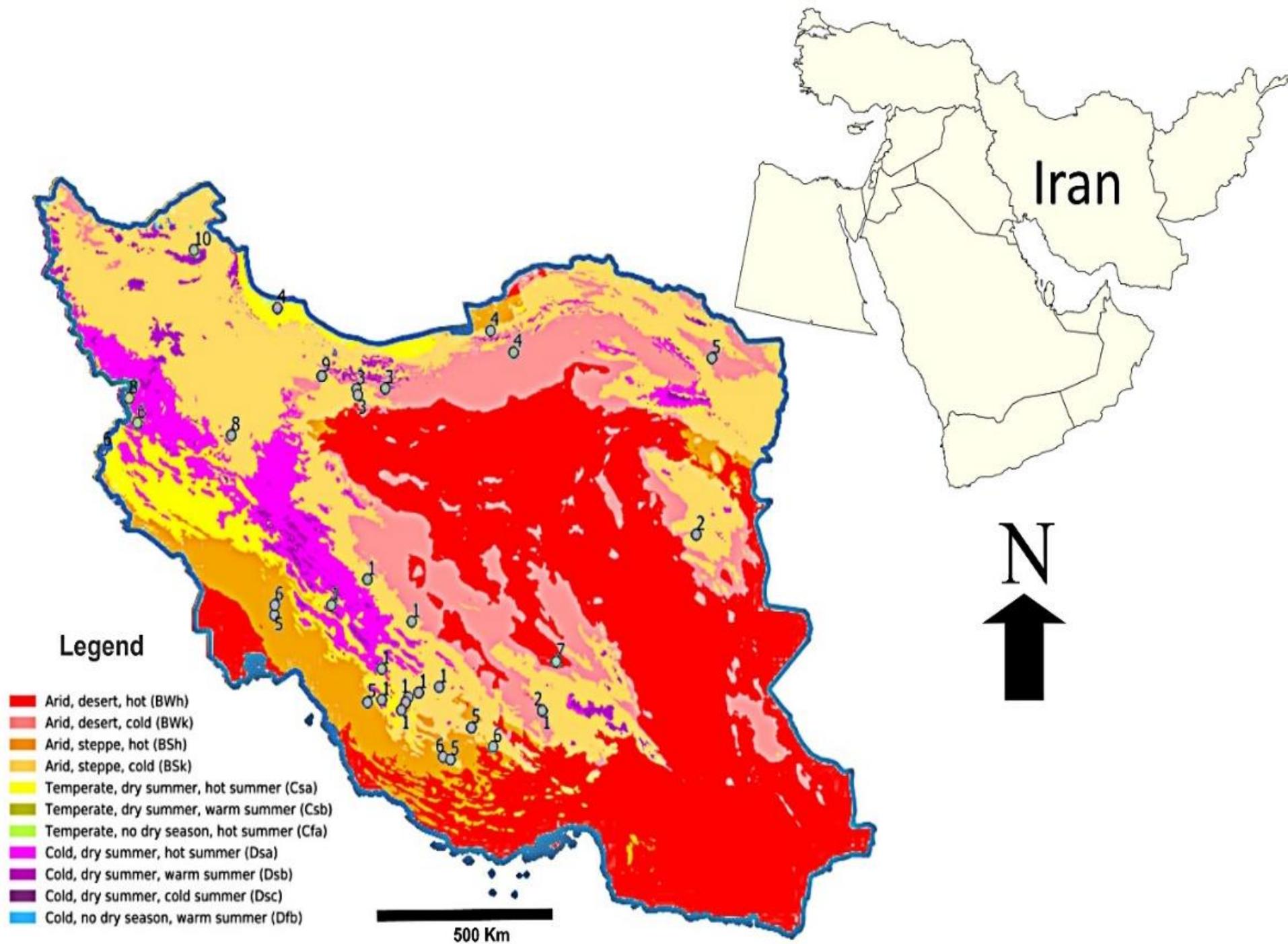
## Cluster Analysis



- Studied stations have been classified to 10 clusters based on CA analysis.

Stable isotopes studies in Iran

The spatial distribution of the studied stations based on their clusters across Iran plotted on the Koppen climatic zones.





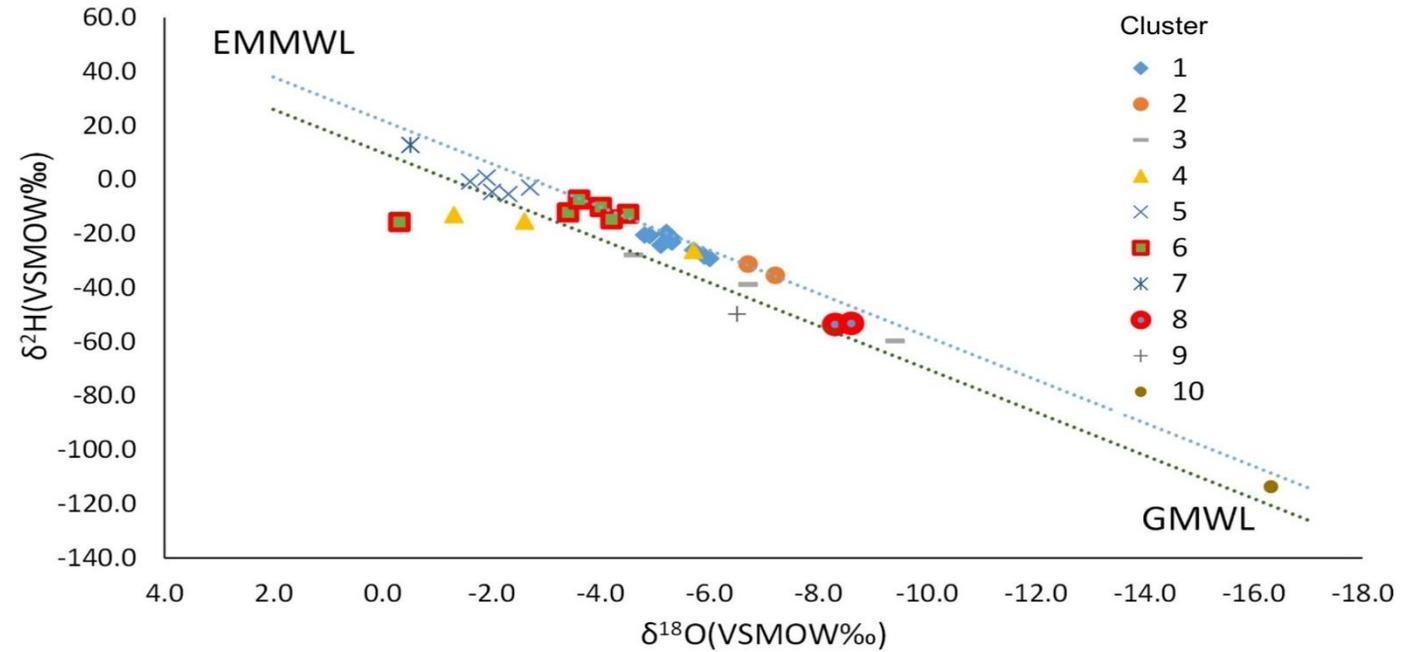
# Results

The average stable isotopes signatures in the studied stations based on their clusters across Iran.

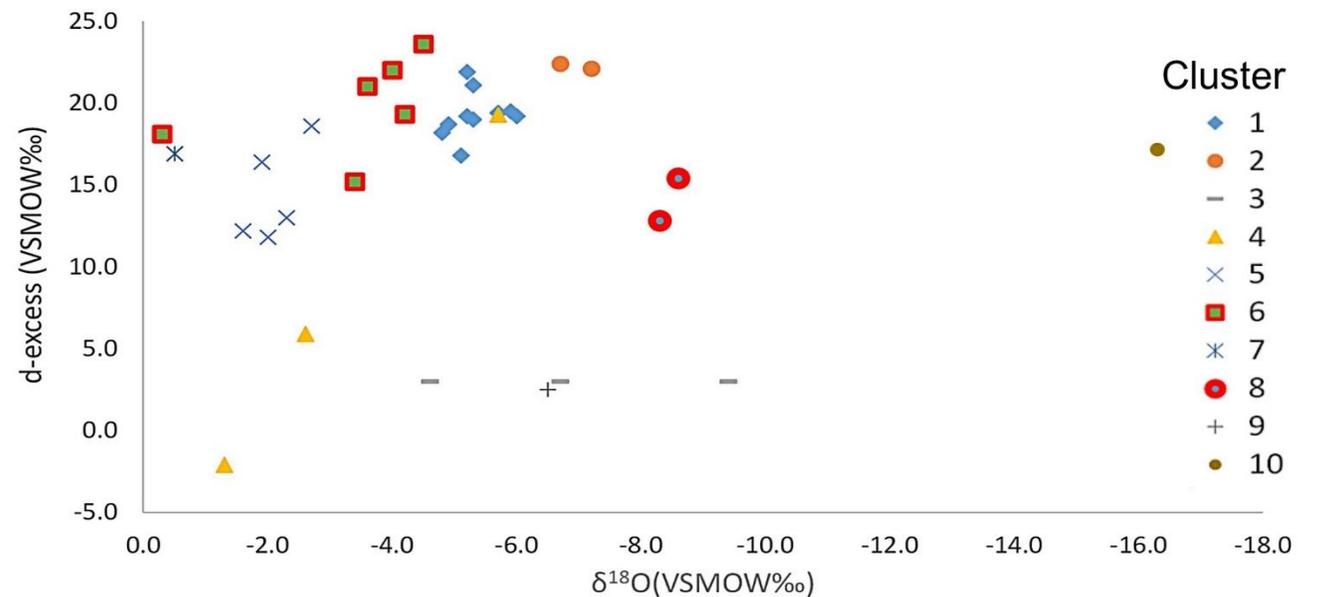
Cluster	Climate Zone	Ave. $\delta^{18}\text{O}$	Ave. $\delta^2\text{H}$	Ave. D-excess	Station
		( $\text{‰VSMOW}$ )			
1	BSk	-5.34	-23.51	19.30	Abadeh, Ardekan, Arsanjan, Bajgah, Dahte-Arjan, Isfahan, Khersan, Zarghan, Takht Jamshid, Sarcheshmeh
2	BSk and BWk	-6.95	-33.30	22.75	Sirjan and Birjand
3	BSk and BWk	-6.90	-42.03	13.40	Damavand, Tehran, Tehran airport
4	Cfa, BWk, and BSk	-3.20	-18.07	7.70	Gorgan, Shahroud, Rasht
5	BSh	-2.10	-5.30	14.40	Abolabas, Jahrom, Mashhad, Kazeroun, Estahban
6	BSh, DSa	-3.35	-12.12	19.87	Alvand, Darab, Shirin bahar, Fasa, Paveh, Shiraz
7	BWh	-0.50	12.90	16.90	Rafsanjan
8	DSa, BSk	-8.45	-53.40	14.10	Zarivar and Hamadan
9	BSk	-6.50	-49.70	2.50	Hashtgerd
10	Dfb	-16.30	-113.6	17.10	Sabalan

# Results

Plotting the stable isotopes signatures in the studied stations across Iran on GMWL and EMMWL.



Plotting d-excess vs  $\delta^{18}\text{O}$  values in the studied stations across Iran.





## Conclusions

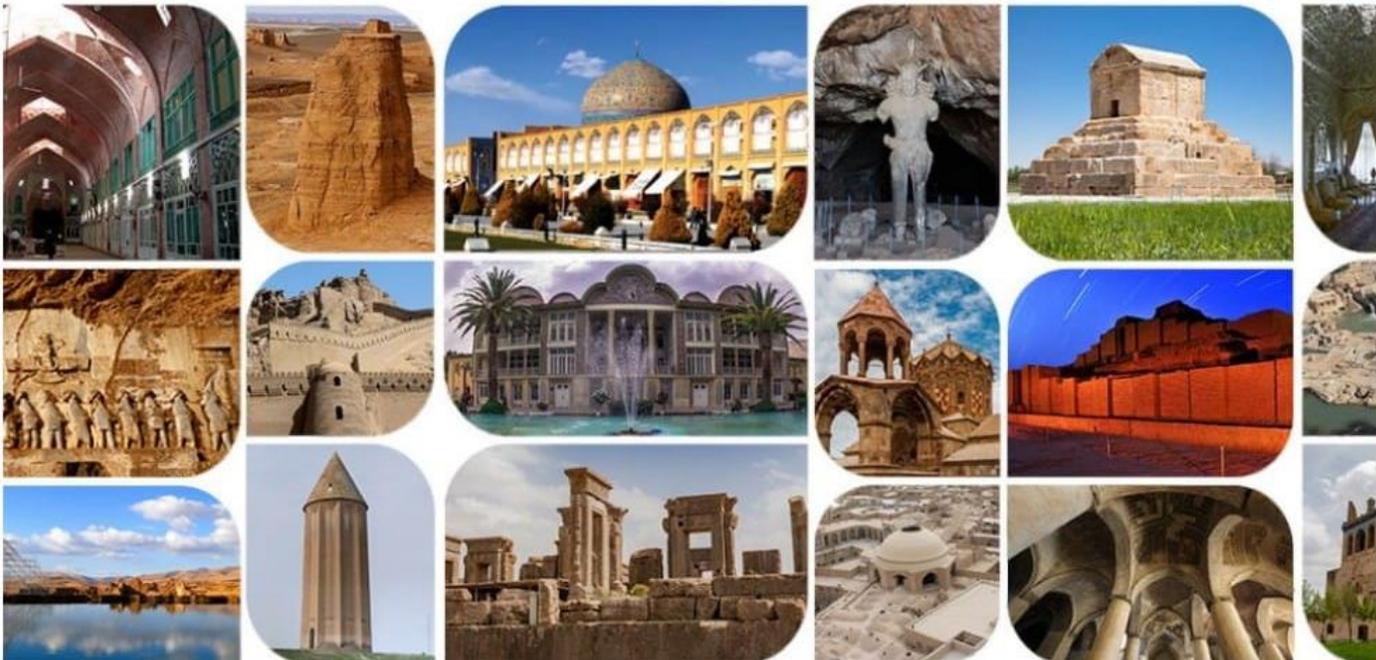
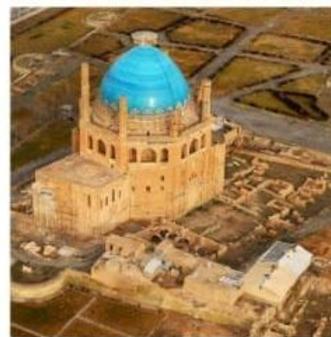
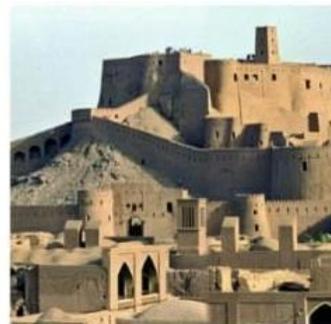
- The studied stations have been classified to 10 clusters by Cluster analysis (CA), according to stable isotopes characteristics of precipitation. Stations locate in each cluster show some differences in  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  values and d-excess.
- This study shows that stable isotopes signatures in precipitation across Iran is significantly under the influence of the climatic conditions of the sampling stations as well as precipitation moisture source regions.
- The spatial variations of stable isotopes signatures in precipitation have been linked to climatic zones where the studied stations are located.



## Suggestion

- The method used in this study can also be applied in other part of the world to classify the precipitation sampling stations based on their stable isotopes characteristics.

*The precipitation has been a crucial component of the climate on the cultural heritage evolution of Iran*



*Thank you for your time*