International Journal of Thin Films Science and Technology

http://dx.doi.org/10.18576/ijtfst/130210

Extreme Rainfall over Iraq for some Cases and its Association with Atmospheric Rivers (ARs)

Ahmed Z. AL-Khawaja[1], Asraa k. Abdul kareem[2,], and Dheyaa A. Bilal[3]*

[1] Department of Regional Meteorological training center, Iraqi Meteorological Organization and Seismology, Iraq
[2] Department of Atmospheric Science, College of Science, Mustansiriyah University, Baghdad, Iraq
[3] Department of Physics, Collage of Education for Pure Science, Thi Qar University, Iraq

Received: 22 Feb. 2024, Revised: 23 Apr. 2024, Accepted: 27 Apr. 2024
Published online: 1 May 2024

Abstract: Heavy rainfall is closely associated with atmospheric rivers (Ars), which are long, narrow bands and ephemeral corridors with significant water vapor flux. Globally, atmospheric rivers (ARs) are the cause of a number of hydroclimatic extremes. Their mechanisms and roles in the Middle East's flooding are not well known. This paper uses a vertically integrated moisture flux transit (IVT) based model to evaluate the relationships between Ars and intense rainfall. We consider two scenarios of heavy precipitation over Iraq in 2023 and 2012. The findings indicate that Ars is responsible for all of Iraq's extreme rainfall occurrences, which occur throughout the rainy season. consequences of the primary sources of ARs in Iraq. Red Sea, north Africa, and Gulf of Aden. For those intense (Ars) traveling through the area, the red sea is an essential supply of moisture.

Keywords: Atmospheric Rivers (ARs), extreme rainfall, IVT, Iraq.

1 Introduction

Heavy precipitation often occurs in small areas and resulting from extensive systems that draw moisture from distant regions particularly in regions that are semi-arid or arid, Severe rainfall cannot be caused by localized water vapor, Consequently, moisture moves into these areas (Haydarizad et al., 2018; Barati and Heydari, 2003; MOHAMMADI and MASOUDIAN, 2010). Extreme cases of rainfall were a significant natural disaster that devastated the Middle East's agriculture, economy, human lives, and transportation (Bozkurt et al., 2021; Dezfuli, 2020; Sadeghi et al., 2021) According to Ralph et al. (2018), atmospheric rivers are strong horizontal water vapor transport corridors that are long, narrow, and transitory that originate from tropical or extratropical moisture sources. These corridors contribute to a portion of the hydroclimatic extremes that occur globally. Research has demonstrated how ARs affect weather-related natural disasters across different regions, although little is known about their mechanisms and contribution to flooding in the Middle East (Krichak et al. 2012; de Vries et al. 2013; Tubi et al. 2017; de Vries et al. 2018; Akbary et al. 2019). similar to the western U.S. (Ralph et al. 2006; Guan et al. 2013; Lavers and Villarini 2015). As climatic extremes like droughts and floods have become more frequent and intense in recent decades, human populations and natural ecosystems in the Middle East have faced severe consequences (Hötzl 2008; Masih et al. 2011; Gleick 2014). The term "ARs" is used in recent studies to describe moisture transport. Atmospheric rivers carry 90% of the water vapor that is moved across the midlatitudes and toward the poles (Dettinger et al., 2018; Zhu and Newell, 1998). ARs are frequently linked to heavy precipitation events in subtropical regions.

Events of intense rainfall are frequently linked to ARs in subtropical regions. areas of intensive water vapor transport that are usually connected to a low-level jet stream in front of an extratropical cyclone's cold front (Loudyi and Kantoush, 2020). This moist corridor stretches over two thousand kilometers in length and less than a thousand kilometers in width (Dettinger, 2011; Neiman et al., 2008; Ralph et al., 2004). (ARs) not only result in significant rainfall over land, but also in heavy rainfall in the ocean. (ARs) have been the subject of much research in the past ten years. Around the world, including in the western United States, researchers looked into the relationship between heavy precipitation and ARs (Barth et al., 2017; Neiman et al., 2008; Ralph et al., 2018; Ralph et al., 2006). The Korean Peninsula (Moon et al., 2019), Japan (Hirota et al., 2016), Northern India (Laskhmi et al., 2018), China (Chen et al., 2020), and other parts of Asia (ARs) have been observed to experience heavy summer rainfall. ARs are associated with extreme winter rainfall in the Middle East and North Africa (Akbary et al., 2019; Dezfuli, 2020; Massoud et al., 2020), North-eastern Arizona (Payne and Magnusdottir, 2014), and South Africa (Ramos et al., 2017). According to Lavers and Villarini (2013) and Warner et al. (2015), winter (AR) events are linked to the majority of extreme precipitation events that happen along the west coast of North America and Western Europe. In order to strengthen ARs, elevations are crucial. Water vapor transport (IVT) and rainfall magnitude over the central

*Corresponding author E-mail: dr.asraa.atmsc@uomustansiriyah.cedu.iq

United States and Europe are strongly correlated, as demonstrated by studies conducted by Guan et al. (2018) and Nayak et al. (2016). Areas classified as (ARs) normally have an IVT of more than 250 kg m-1 s-1 (Ralph et al. 2018). While there have been many studies on atmospheric rivers worldwide, the majority have only been carried out in the US and Europe.

Numerous research works have examined the impact of atmospheric rivers on the Middle East's heavy precipitation. References: Dezfuli, 2020; Salimi and Saligheh, 2016. demonstrates how major floods are being caused by ARs along Iran. Shademani (2015) studied the effects of ARs on two episodes of intense rainfall that resulted in flooding in Iran's west and south.

According to Salimi and Saligheh (2016), Iran forms roughly 12 atmospheric rivers each year. Aqeel Ghazi (2021) describes the physical and synoptic characteristics of torrential rains over Iraq and neighboring regions. study by Hayat Mahdi Aliakbar (2021) Investigate how severe rains affect the estimation of probable maximum precipitation for selected areas of Iran. In this paper, two cases in two chosen months will have their IVT thresholds set. Its objective is to use vertically integrated water vapor transport (IVT) to examine the relationship between heavy precipitation and atmospheric radiation (AR) during the rainy season over Iraq in two scenarios (December 2012, 2012, and April 2023) and to analyze the entry routes and origin locations of AR based on a specific IVT threshold.

2 data and methods:

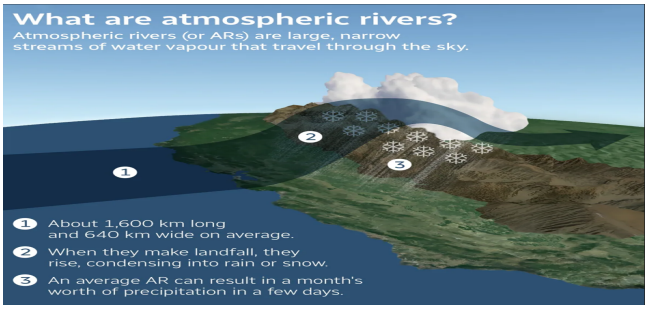


Fig. 1: Explain the mechanism of ARs.

Iraq is located in Asia and is one of the countries that occupy the region's northeast. To the north, Iraq borders Turkey, eastern Iran, Syria, and Jordan. To the south, Iraq is bordered by the Arabian Gulf, Kuwait, and Saudi Arabia.

The analysis of the intense rainfall linked to ARs is the purpose of this paper, daily precipitation data was used from the GPM global precipitation measurement for December 2012 and April 2023. To determine the maximum amount of rainfall over Iraq for the cases of 25–27 December and 11–13 April and determination days with extreme rainfall from the Iraqi meteorological organization and seismology After separating extreme rainfall events, the first thing we do is identify ARs during these events. One useful method for researching the variations in moisture in different parts of the world is to use the IVT. The IVT is now widely used in research to detect ARs. We use integrated moisture flux transport (IVT) to identify ARs because of their high correlation with extreme rainfall during ARs events. ARs are based on IVT, which is measured using meridional winds, zonal humidity, and specific humidity as inputs. We take the integration from 1000 hpa to 300 hpa with a 100 hpa interval for 8 levels (1000, 900, 800, 700, 600, 500, 400, 300) of data for (q,u,v) obtained from ECMWF (ERA5) with spatial resolution 0.25 x 0.25 and temporal resolution Hourly for gridded data, we use pressure levels from 1000 to 300 hpa because most of the water vapor transportation occurs in the low level of the troposphere.

Equation of IVT:

$$\sqrt{(\frac{1}{g}\int_{1000}^{300} \boldsymbol{qu}.\boldsymbol{dp})^2 + (\frac{1}{g}\int_{1000}^{300} \boldsymbol{qv}.\boldsymbol{dp})^2}$$

Where u is zonal wind and meridional wind in units (m/s), q is specific humidity (kg/kg^{-1}), g is the gravitational acceleration (9.8 m/s^{-2}) and dp is the pressure differential between two successive levels. The IVT units are Kg m^{-1}s^{-1} We use the IVT threshold for each month in the two cases to identify the ARs by extracting the maximum value of IVT over Iraq, the threshold over the region of study, and the date we used for the time daily reanalysis date (00, 06, 12, 18).

3 Results and Discussion:

Results show that after extracting the IVT threshold, which is 250 kg m^{-1}s^{-1} over Iraq and surrounding regions and taking the maximum value of IVT over Iraq for December and April and taking maximum IVT during ARs events, the examination for events shows that conditions of atmospheric rivers were present in two cases, as illustrated in tables (1) and (2).

Table 1: Two cases of extreme rainfall events related to atmospheric river events in Iraq

Events	Maximum Rainfall Over selected areas of Iraq Baghdad, Karbal, Basra mm/day	Maximum IVT monthly mean over Iraq	Maximum IVT during ARS events over Iraq	Length KM	resource
December 2012/12/25	Baghdad=67.5 Karbala=42.5 Basra=35	100 Kg m^{-1}s^{-1}	450 Kg m^{-1}s-1	1600	Gulf of Aden and Red Sea
April 2023/4/12	Badra=50.9 Karbala=55 Hella=65 Dohuk=59.5 Sulaymaniyah=90.3 Tuz=100.6	120 Kg m^{-1}s^{-1}	800 Kg m^{-1}s^{-1}	1800	North Africa and Red Sea

Table 2: Atmospheric rivers categories

Category	Strength	Impact	Max IVT
1	Weak	Primarily beneficial	**250-500**
2	Moderate	Mostly beneficial also hazardous	**500-750**
3	Strong	Balance of beneficial and hazardous	**750-1000**
4	Extreme	Mostly hazardous	**1000-1250**
5	Exceptional	Primarily hazardous	**1250**

Case of December 25–26, 2012:

In December 2012, an extreme case of rainfall over some parts of Iraq, including the south and south central of Iraq, led to extreme rainfall, which led to some financial losses and damage to humans. Some stations in Iraq received over 67 mm of rainfall during this event.

This study shows that atmospheric rivers cause this event. This AR originates over the Gulf of Aden and enters Iraq from the south by crossing the Red Sea. In this event, the IVT values ranged from 350 to 500 in the south and south central of Iraq, as shown in Fig. 2. The moisture transformation over Iraq passes over the Red Sea, and it has been shown that the Red Sea has played a role in intensifying the moisture and feeding it up It's important to describe how extreme IVT and extreme rainfall interact. This work shows a strong correlation between extreme IVT and rainfall. When IVT reaches its peak over Iraq (450 kg $m^{-1}s^{-1}$) at 25th December at (12:00and 18:00 local time, rainfall is increasing, and threshold for IVT its important for tracking the IVT result which shows in this case the Gulf of Aden and the Red Sea as its main sources of heavy rainfall in the south and south central of Iraq. And we track ARs for three days, from 25 to 27. At last, the ARs begin to decay until they vanish.

Case of April 11-12-13, 2023:

In the second case of extreme rainfall that happened in 12th April 12, 2023, some places suffered financial damage, like Najaf and Tuz, and some benefited from it, like the north of Iraq (Sulaymaniyah and Erbil). This event had an effect on most of Iraq, and the maximum IVT in this case over Iraq during this event was 800 kg $m^{-1}s^{-1}$), at(6:00and 18:00 local time).as in fig(3) 12 April and rainfall recording in Iraq from the Iraqi meteorological organization and seismology over some places reach above (100 mm). This ARs begins in Africa and continues to be oriented from Red Sea and reach Iraq, crossing 4142km in his path. This explains how the ARS comes from a far distance over the arid and sim arid regions. It's obvious that ARs will decay on day three; in some cases, they will last for four days, but in many cases, they will decay and vanish within three days. All ARs will cross large distances before they vanish.

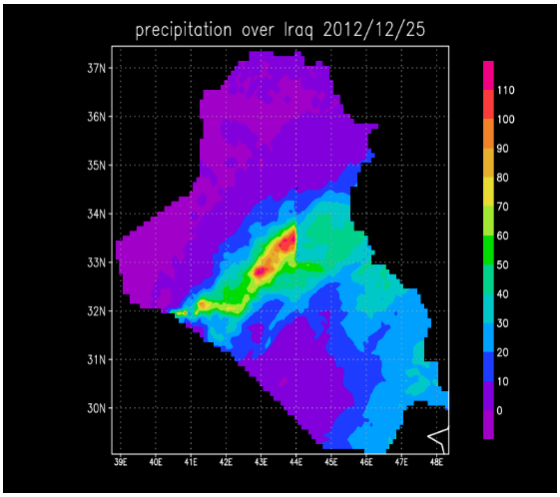
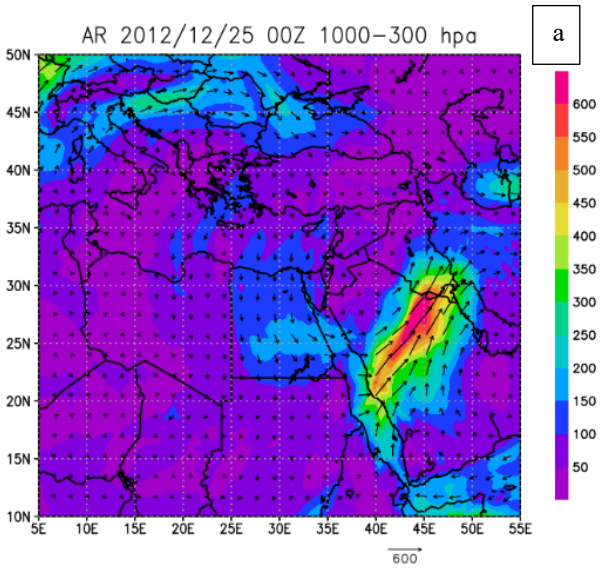
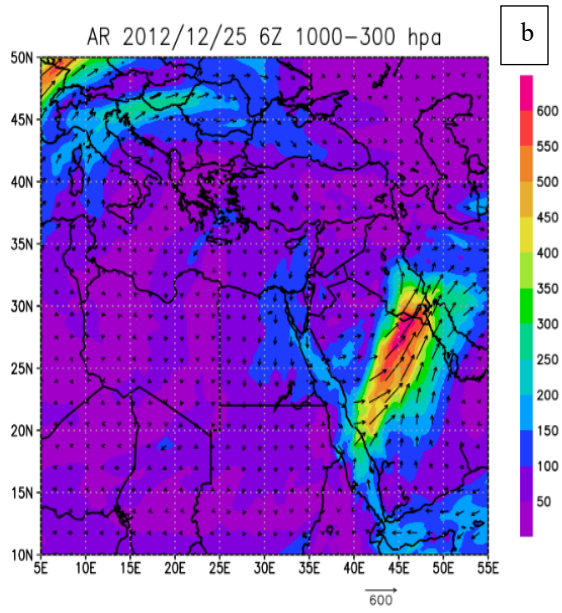
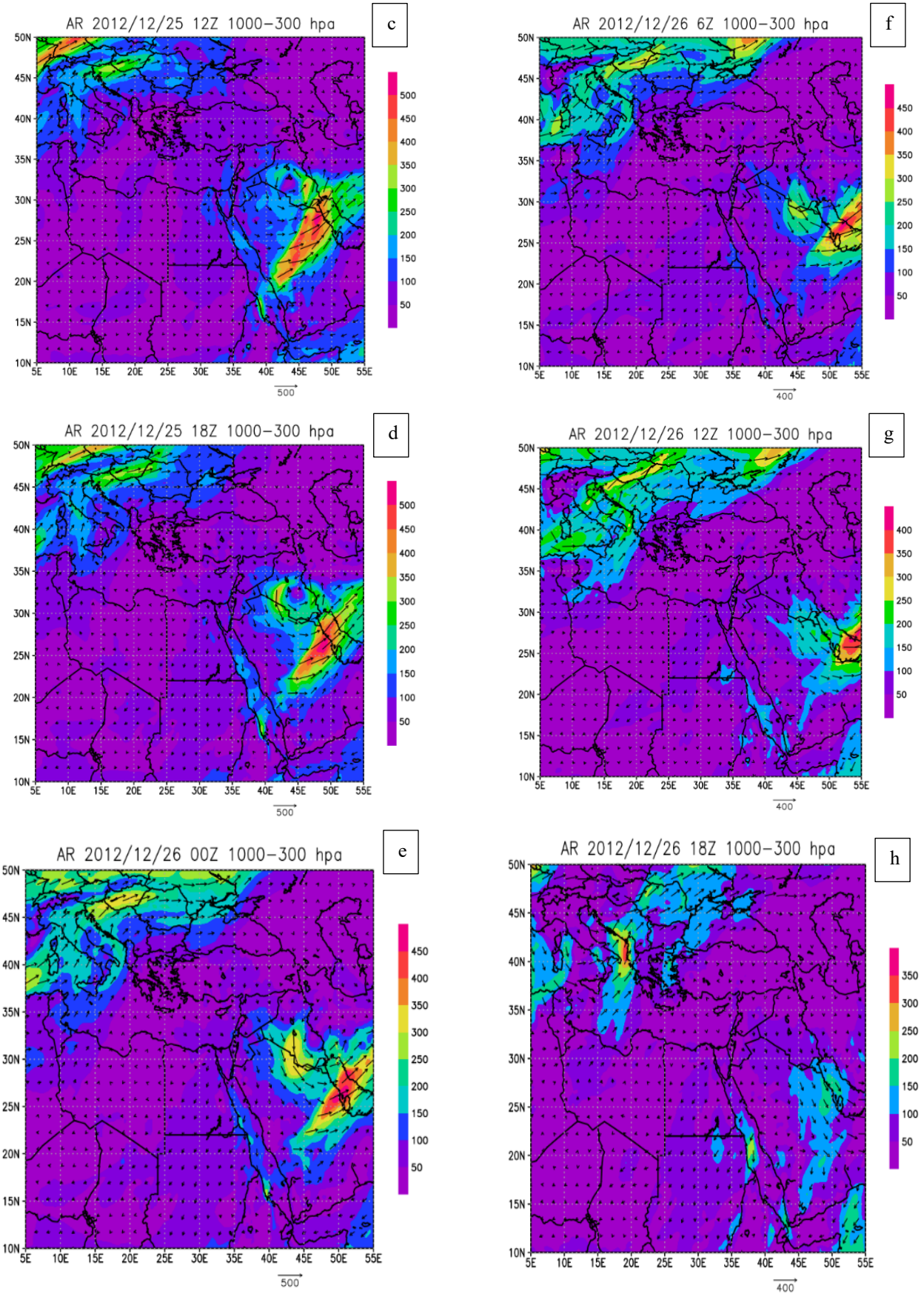


Fig. 2: precipitation over Iraq for 25 of December during ARs events







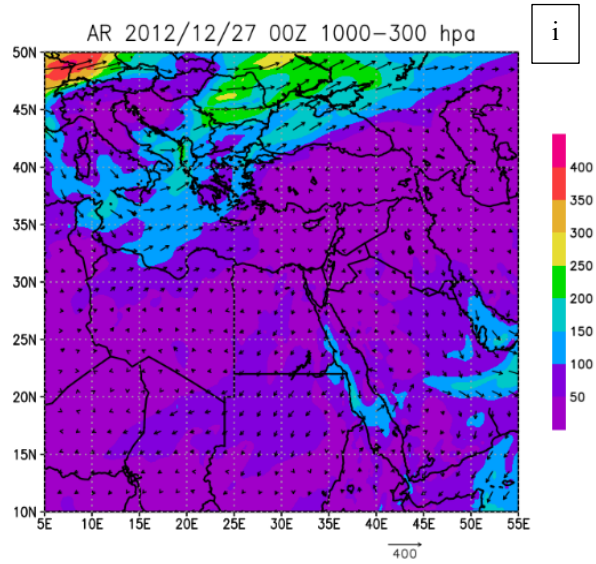


Fig. 3: show the cases of ARs during three days for (00,06.12.18) in local time for Iraq for December 25-26-27.

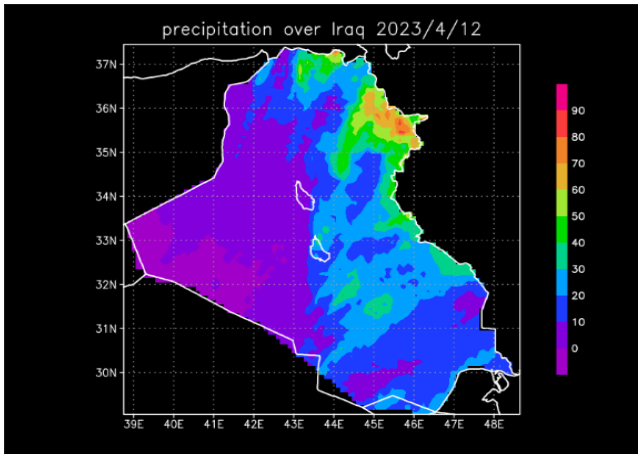
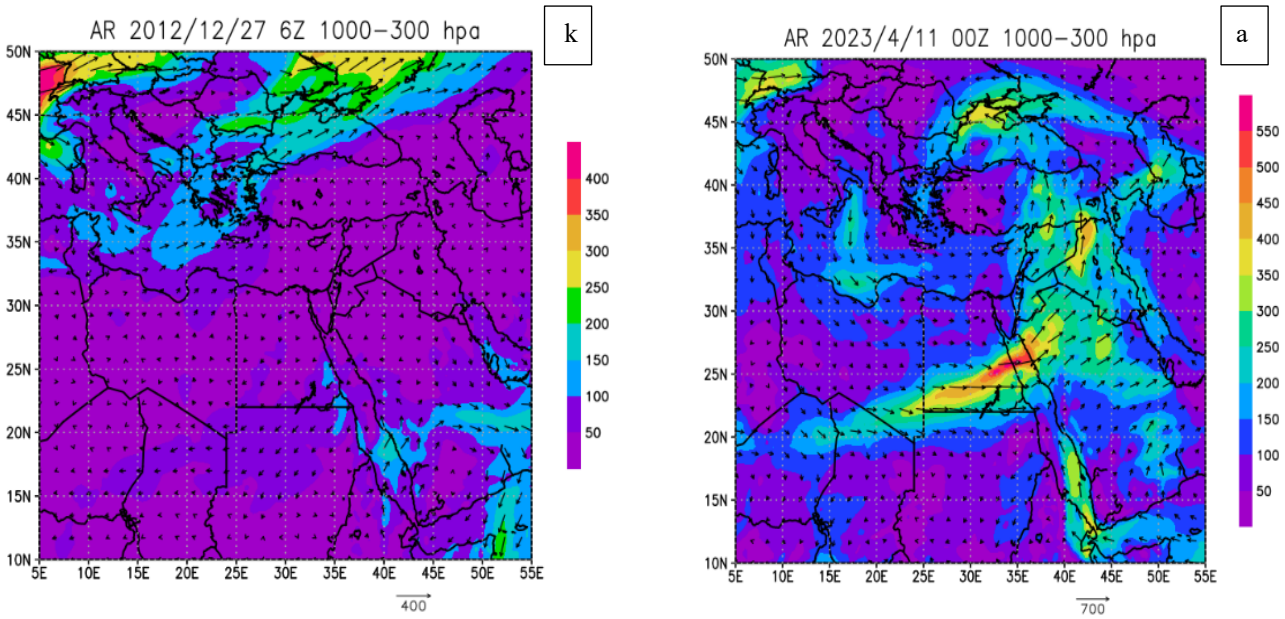
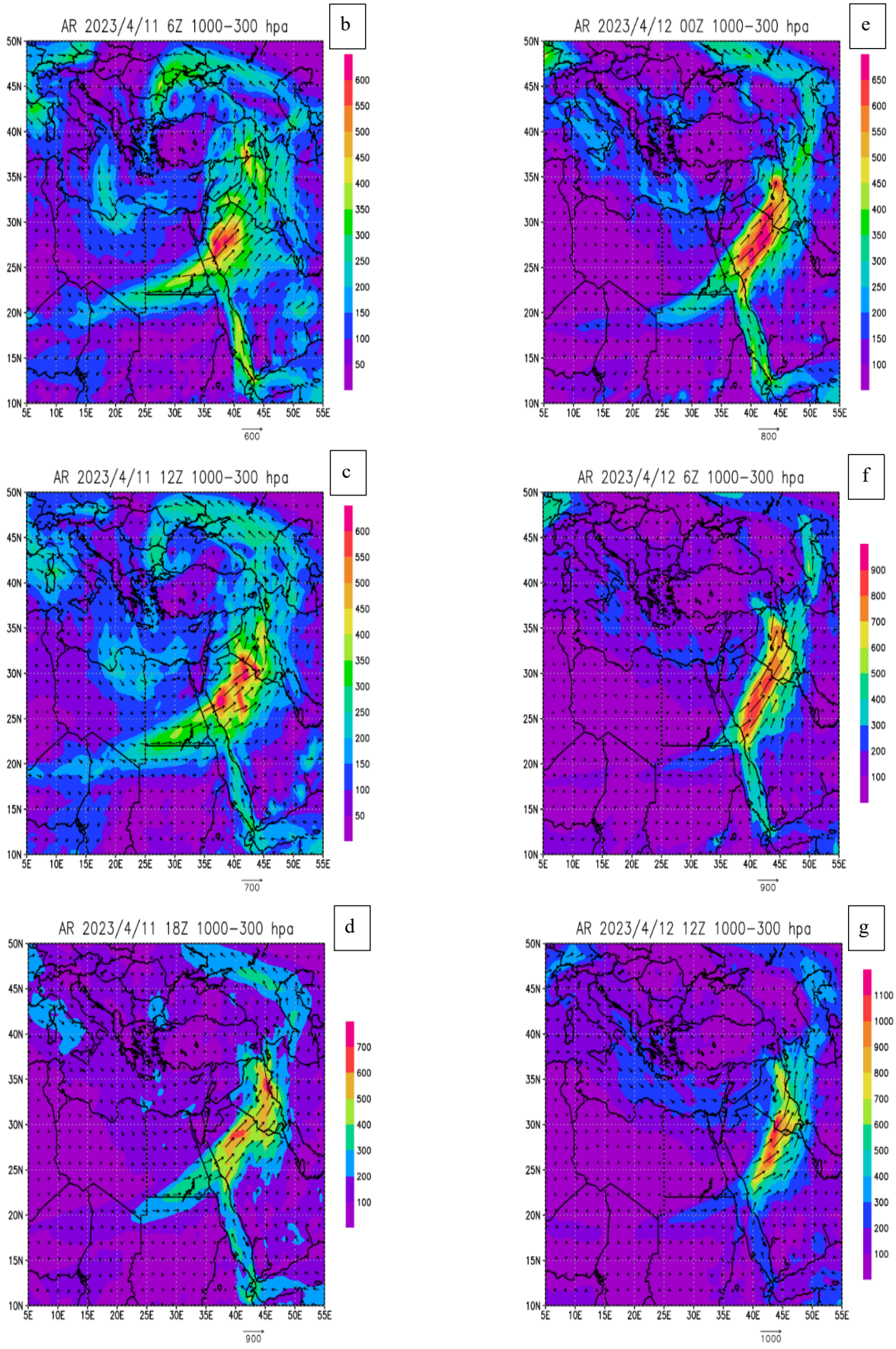


Fig. 4: precipitation over Iraq for 12 April





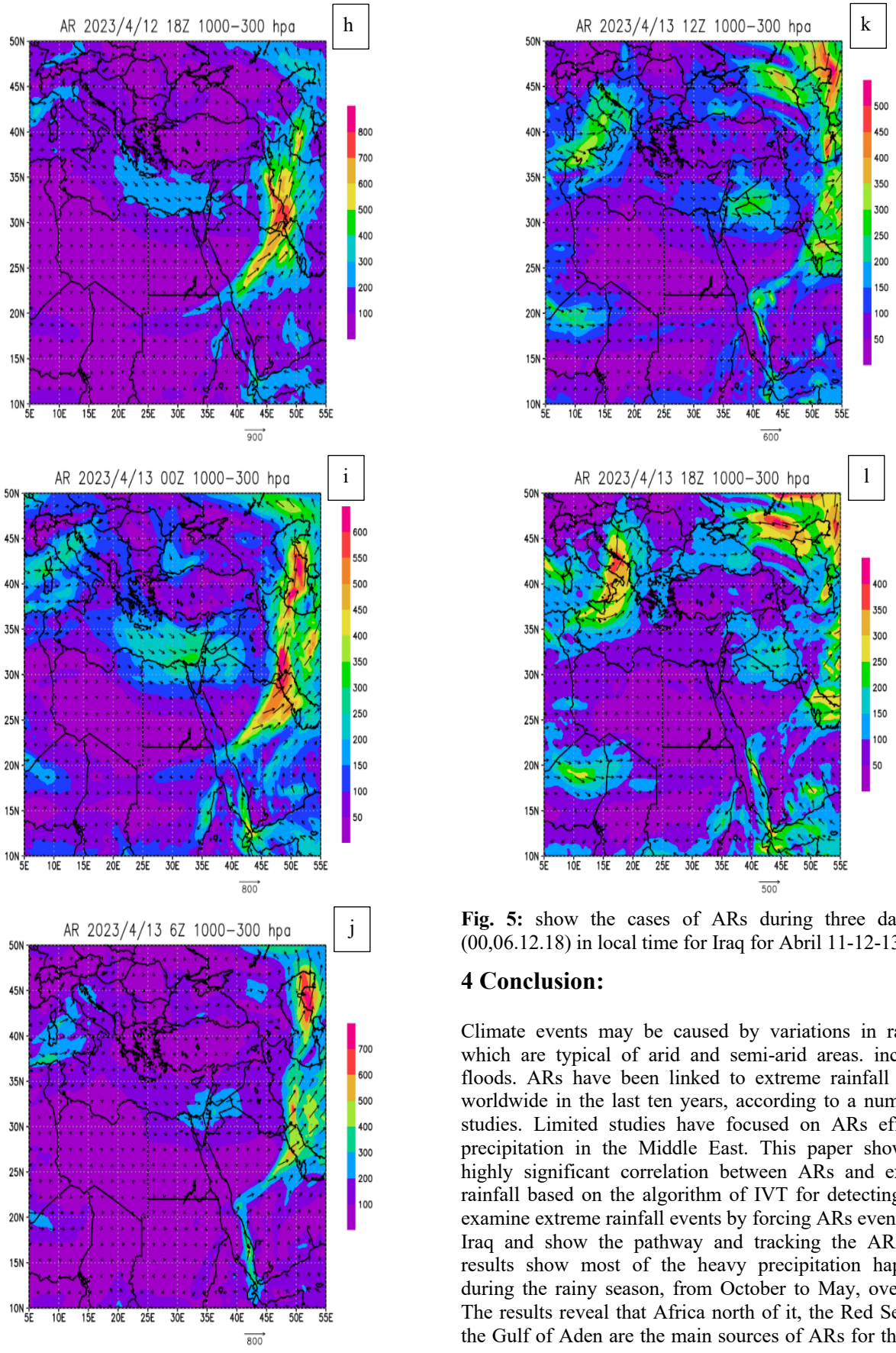


Fig. 5: show the cases of ARs during three days for (00,06.12.18) in local time for Iraq for Abril 11-12-13.

4 Conclusion:

Climate events may be caused by variations in rainfall, which are typical of arid and semi-arid areas. including floods. ARs have been linked to extreme rainfall events worldwide in the last ten years, according to a number of studies. Limited studies have focused on ARs effecting precipitation in the Middle East. This paper shows the highly significant correlation between ARs and extreme rainfall based on the algorithm of IVT for detecting ARs. examine extreme rainfall events by forcing ARs events over Iraq and show the pathway and tracking the ARs. The results show most of the heavy precipitation happened during the rainy season, from October to May, over Iraq. The results reveal that Africa north of it, the Red Sea, and the Gulf of Aden are the main sources of ARs for the area,

but the most effective and most frequent ARs entering the region during the rainy season are the most likely to work as the potential source for feeding up moisture during AR events. The direction and magnitude of IVT play a crucial role in AR detection. The region's water resources can be impacted by ARs by causing precipitation, according to analysis of the extreme event cases. By studying the moisture source and their pathway for heavy rainfall events and examining their correlation with ARs, the number of various damages caused by floods can be reduced, and we can use these extreme cases in growing crops and save this rainfall in dams. This work will improve our understanding of the importance of Ars for the rainfall patterns in Iraq.

References:

[1] N. A. Barth, G. Villarini, M. A. Nayak, and K. White, "Mixed populations and annual flood frequency estimates in the western United States: The role of atmospheric rivers," Water Resources Research, vol. 53, pp. 257-269, 2017.

[2] J. M. Cordeira, F. M. Ralph, and B. J. Moore, "The development and evolution of two atmospheric rivers in proximity to western North Pacific tropical cyclones in October 2010," Monthly Weather Review, vol. 141, pp. 4234-4255, 2013.

[3] D. A. Lavers and G. Villarini, "The contribution of atmospheric rivers to precipitation in Europe and the United States," Journal of Hydrology, vol. 522, pp. 382-390, 2015.

[4] F. M. Ralph, M. D. Dettinger, M. M. Cairns, T. J. Galarneau, and J. Eylander, "Defining “atmospheric river”: How the Glossary of Meteorology helped resolve a debate," Bulletin of the American Meteorological Society, vol. 99, pp. 837-839, 2018.

[5] A. De Vries, H. Ouwersloot, S. B. Feldstein, M. Riemer, A. El Kenawy, M. McCabe, et al., "Identification of Tropical–Extratropical Interactions and Extreme Precipitation Events in the Middle East Based on Stratospheric Potential Vorticity Intrusions and Poleward Moisture Transport," in 98th American Meteorological Society Annual Meeting, 2018.

[6] D. L. Douluri, "Heavy Precipitation and Flooding Associated with Atmospheric Rivers over the Indian Region," IIT Kharagpur, 2020.

[7] M. Akbary, S. Salimi, S. A. Hosseini, and M. Hosseini, "Spatio-temporal changes of atmospheric rivers in the Middle East and North Africa region," International Journal of Climatology, vol. 39, pp. 3976-3986, 2019.

[8] N. Esfandiari and H. Lashkari, "The effect of atmospheric rivers on cold-season heavy precipitation events in Iran," Journal of Water and Climate Change, vol. 12, pp. 596-611, 2021.

[9] D. Loudyi and S. A. Kantoush, "Flood risk management in the Middle East and North Africa (MENA) region," vol. 17, pp.379-380, 2020.

[10] P. H. Gleick, "Water, drought, climate change, and conflict in Syria," Weather, climate, and society, vol. 6, pp. 331-340, 2014.

[11] B. Guan and D. E. Waliser, "Detection of atmospheric rivers: Evaluation and application of an algorithm for global studies," Journal of Geophysical Research: Atmospheres, vol. 120, pp. 12514-12535, 2015.

[12] F. Zereini and H. Hötzl, Climatic changes and water resources in the Middle East and North Africa: Springer, 2008.

[13] A. M. Abdul-Jabbar and A. K. Abdulkareem, "Predicted the Cumulative Annual Rainfall in Iraq using SDSM Modal," Al-Mustansiriyah Journal of Science, vol. 32, 2021.

[14] A. G. Mutar, A. Khtan, and L. E. George, "Synoptic Characteristics of Torrential Rains in Southwest and Southeast Iraq: A Case Study," Al-Mustansiriyah Journal of Science, vol. 32, pp. 1-7, 2021.

[15] A. G. Mutar, A. Khtan, and L. E. George, "Effect of Sea Salt AOT on Precipitation Processes Associated with Red Sea Moisture Flux on Iraq, a Case Study," Al-Mustansiriyah Journal of Science, vol. 33, pp. 1-7, 2022.