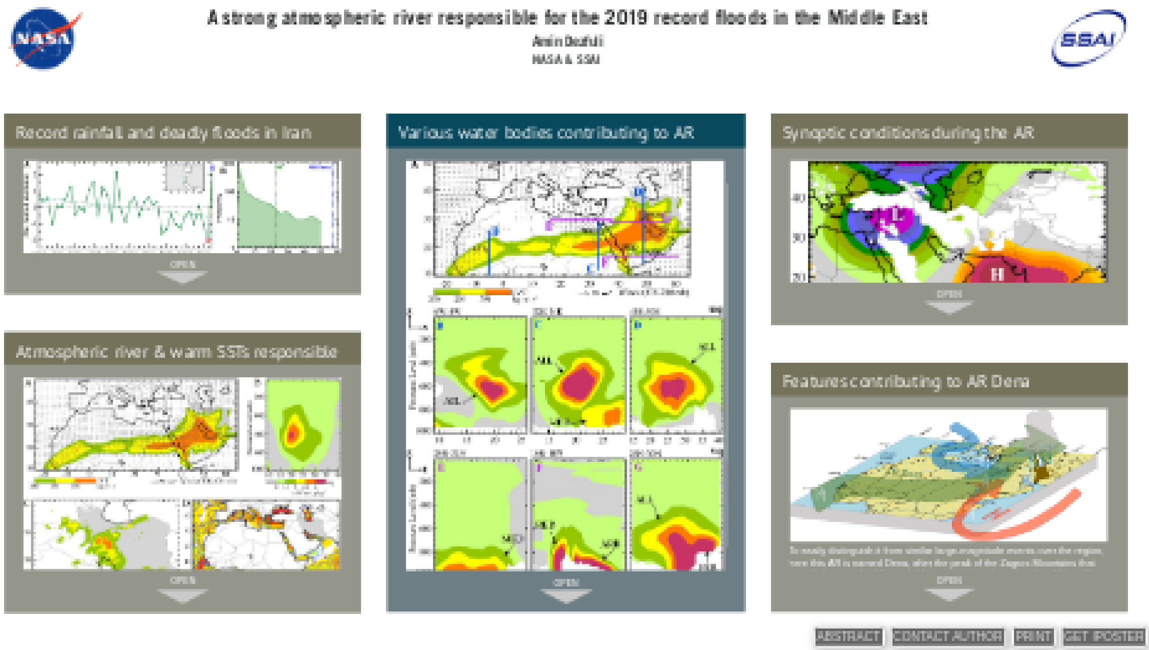
A strong atmospheric river responsible for the 2019 record floods in the Middle East



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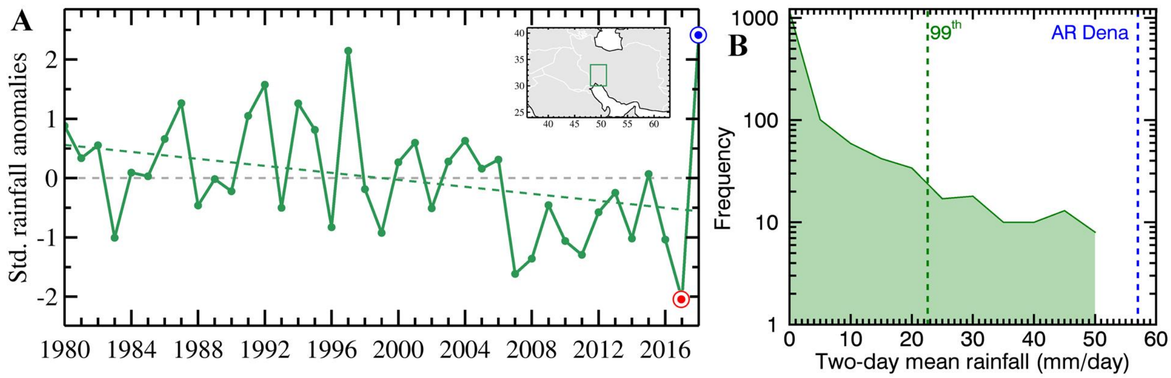
PRESENTED AT:

AGU FALL MEETING

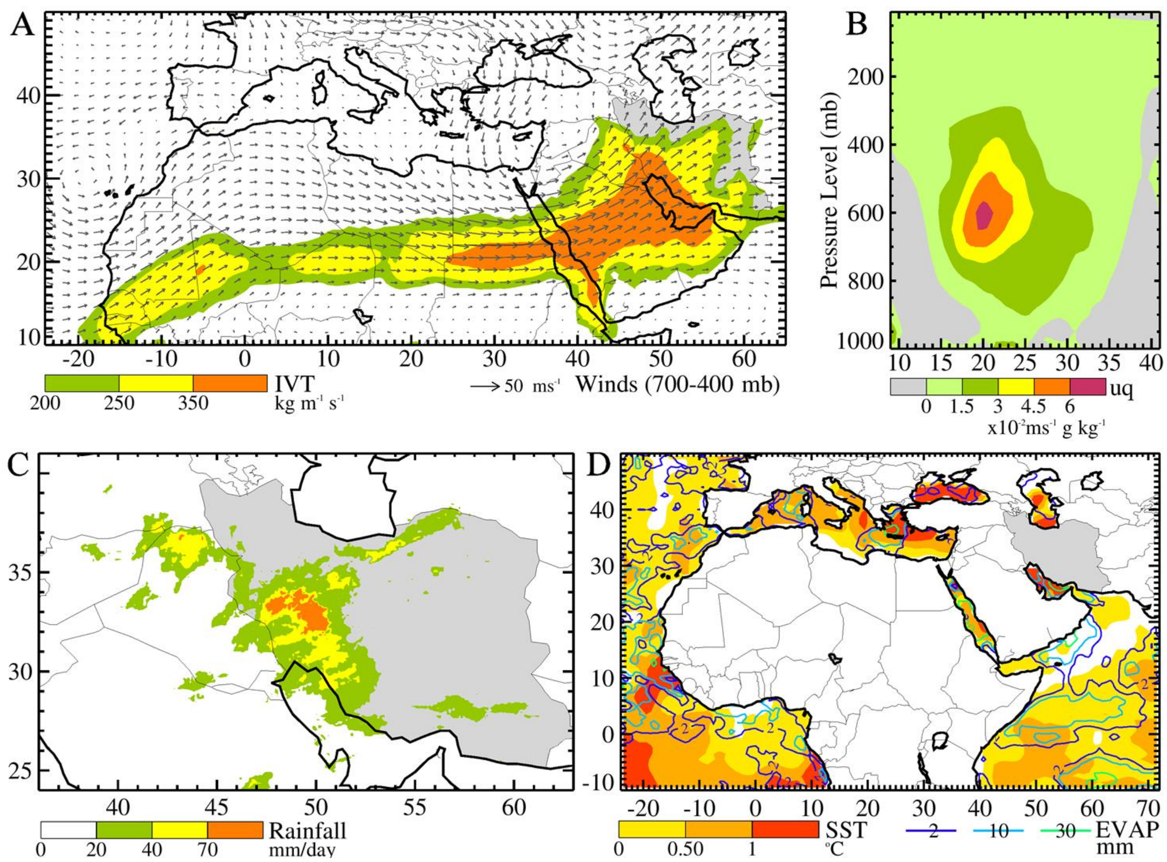
Online Everywhere | 1–17 December 2020

RECORD RAINFALL AND DEADLY FLOODS IN IRAN



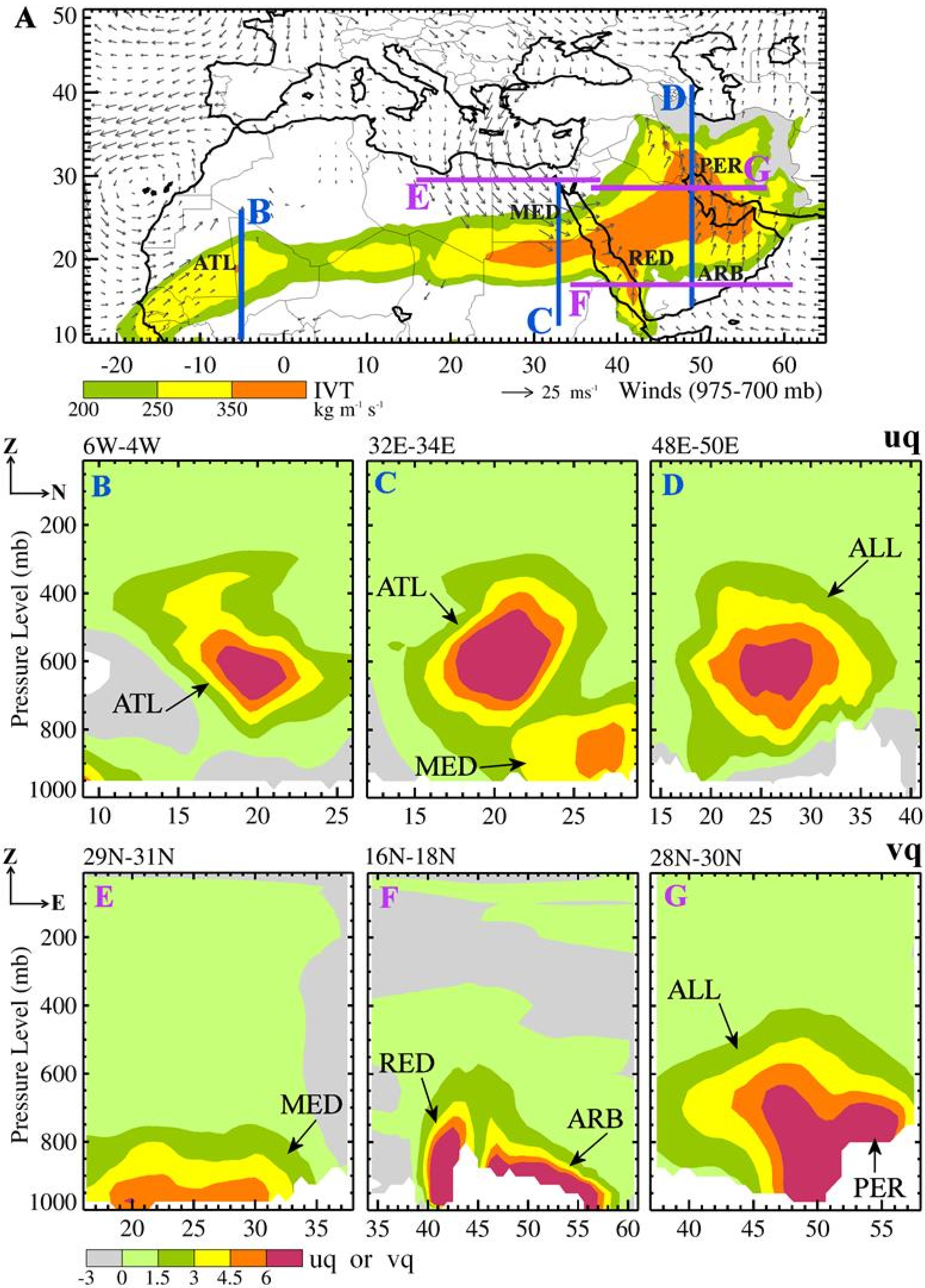
- Record rainfall in late March 2019 led to unprecedented flooding across several Middle Eastern countries and caused enormous damages and casualties, particularly in Iran. The intense rains have made the 2018/19 rainy season (October–March) the wettest in the past four decades, a sharp contrast with the prior year, which was the driest over the same period. Thus, this event is an example of rapid dry-to-wet transitions and intensification of extremes, potentially resulting from climate change.
- The precipitation in March 2019 contributed significantly to the total seasonal rainfall. The 2-day mean rainfall from IMERG "late run" was 57 mm/day for 24–25 March. This exceeds the historical maximum of ~50 mm/day. Some areas received ~400 mm rainfall during this AR.

ATMOSPHERIC RIVER & WARM SSTS RESPONSIBLE



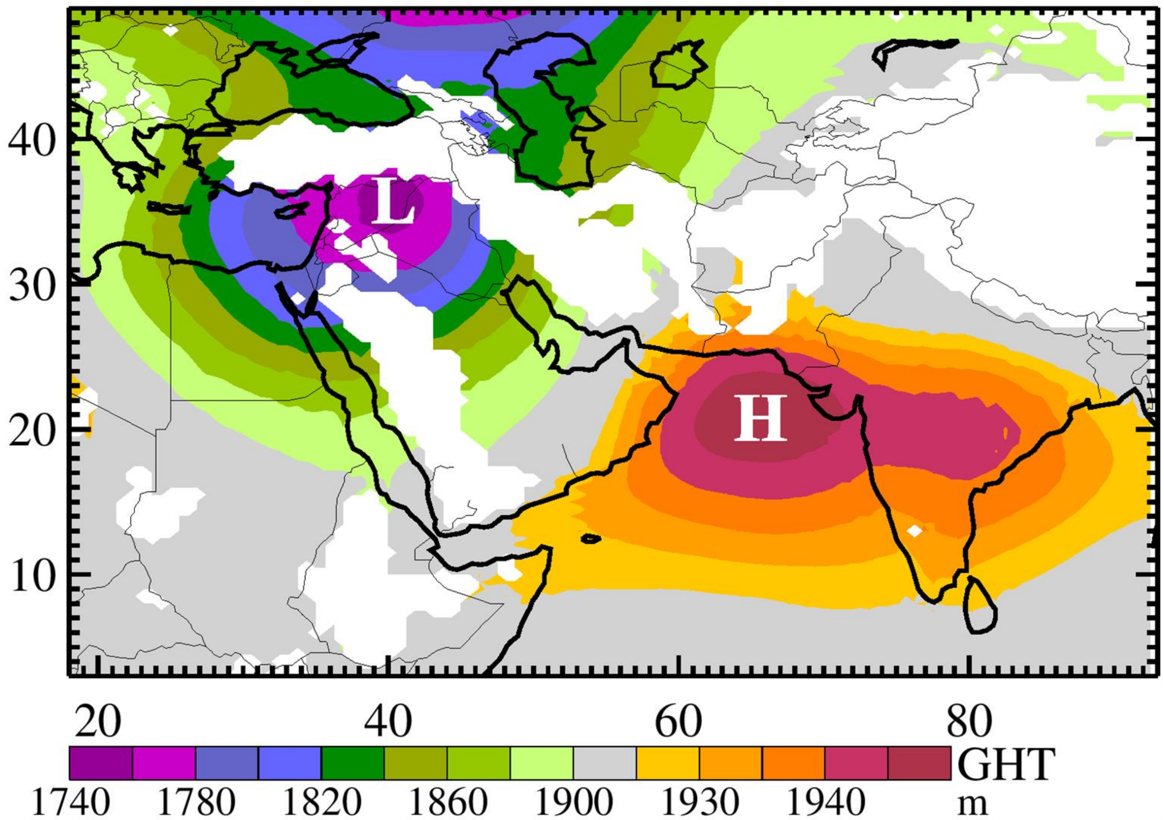
- Using vertically integrated water vapor transport (IVT) and winds at 700-400 hPa layer from MERRA-2 Reanalysis data during 24-25 March 2019, we were able to deterct an atmospheric river taht was responsible for the floods. The AR originated in the North Atlantic Ocean and propagated nearly 9,000 km across North Africa and the Middle East before its final landfall over the Zagros Mountains, where the maximum rainfall occurred.
- The warm SST and higher than normal evaporation over all surrounding seas facilitated the moisture supply to the AR.

VARIOUS WATER BODIES CONTRIBUTING TO AR



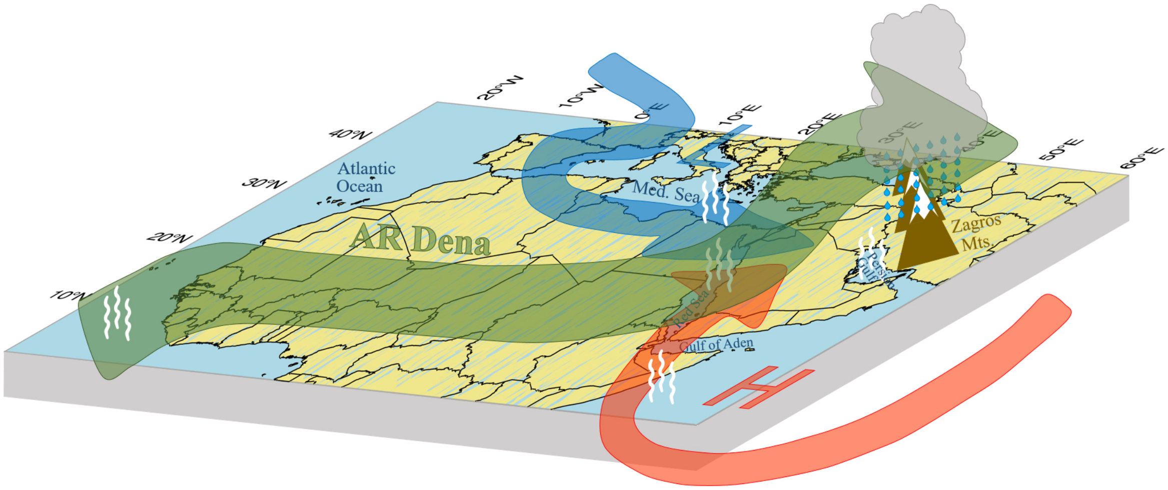
Various water bodies contributing to the AR, such as the Atlantic Ocean (ATL), Mediterranean Sea (MED), Red Sea (RED), Arabian Sea (ARB), Persian Gulf (PER), and all the basins (ALL). (a) IVT pattern and winds at the 975-700 hPa layer. (b)–(d) Vertical cross section of zonal moisture transport (uq), across the latitudes shown with blue lines in (a). (e)–(g) Vertical cross section of meridional moisture transport (vq), across the longitudes shown with purple lines in (a). Unit of moisture transport is 10^{-2} m s^{-1} g kg^{-1}.

SYNOPTIC CONDITIONS DURING THE AR



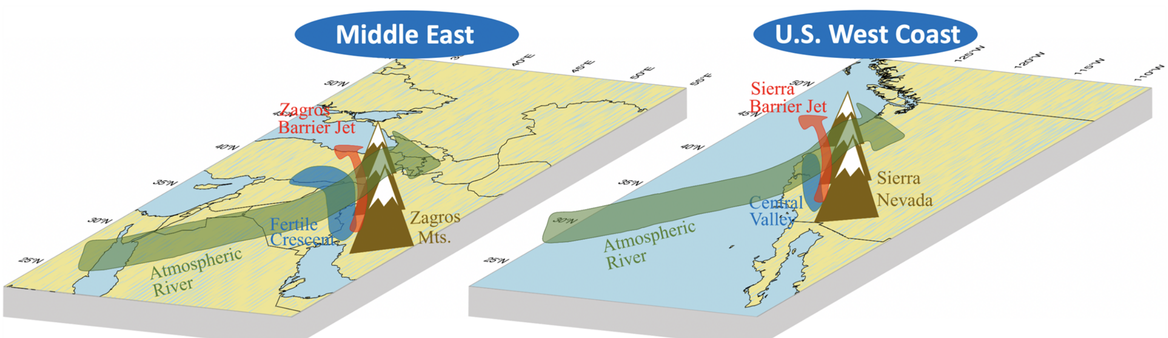
- Configuration of low and high pressure systems facilitated moisture transport from regional water basins.
- This AR can be characterized in the context of tropical-extratropical interactions as it owes its existence to the combined effects of a subtropical jet and a mid-latitude system.

FEATURES CONTRIBUTING TO AR DENA



To easily distinguish it from similar large-magnitude events over the region, here this AR is named Dena, after the peak of the Zagros Mountains that provided orographic lift needed for precipitation formation. In addition, Dena is a female Persian name.

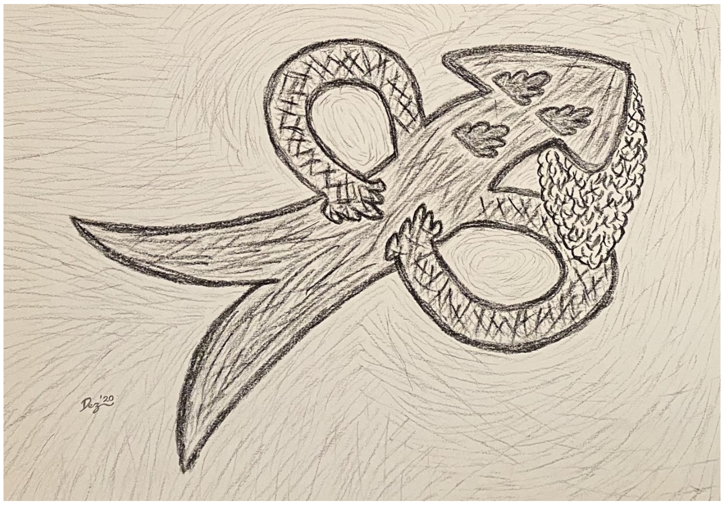
Extent of the AR (green arrow), low pressure (blue arrow) and high pressure (red arrow) areas associated with a midlatitude weather system, evaporation over seas and oceans (wavy white lines), and other geographical features that contribute to formation of the AR and precipitation are shown.



There are several geographical similarities between the Middle East and U.S. West Coas:

- Southeast-northwest oriented mountains (Zagros vs. Sierra Nevada)
- Fertile plain adjacent to Mts. (Fertile Crescent vs. Central Valley)
- Latitudinal extension
- AR-Mts. interactions precipitation formation
- Low-level jets (Zagros Barrier Jet vs. Sierra Barrie Jet

And, their main difference is distance from the ocean.



"Miss Dena, the Atmospheric River": This is my amateur artistic interpretation of the schematic above with legs for subtropical and midlatitude jets, clouds for eyes and mouth and precipitation as hair, and the low and high paired as two arms. More of my meteorological art has appeared in:

Dezfuli, A., 2020. Climate-inspired drawing: How I enjoy amateur art. Bulletin of the American Meteorological Society, 101, 759-760.

The results of this study has been published in the following article:

Dezfuli, A., 2020. Rare atmospheric river caused record floods across the Middle East. Bulletin of the American Meteorological Society, 101(4), pp.E394-E400.

ABSTRACT

Atmospheric rivers (ARs) cause some of the weather-related disasters around the world. While many studies have shown the contribution of ARs to precipitation in the coastal regions such as western Europe and the U.S. West Coast, little is known about their mechanisms and impacts on flooding in the Middle East. This study shows that an AR was responsible for the record floods during March 2019 across the Middle East. Iran in particular was hit hardest with the floods that left a death toll of at least 76 and an early estimate of $2.5 billion (U.S. dollars) damage to its infrastructures.

The heavy precipitation produced by this AR made the 2018/19 rainy season the wettest in the past four decades. By contrast, the prior year (2017/18) was the driest over the same period. This is a compelling example of rapid dry-to-wet transitions that may enhance the chance of landslides and impose challenges to water resources management.

The AR originated in the Atlantic Ocean and propagated across North Africa and the Arabian Peninsula before its final landfall over the Zagros Mountains. On its nearly 9000 km journey, the AR received additional moisture from the Mediterranean, Red, and Arabian Seas, and the Persian Gulf. Moisture transport by this AR during 24-25 March 2019 is estimated at more than 150 times the aggregated discharge of the four major rivers in the region, that is, the Tigris, Euphrates, Karun, and Karkheh. Anomalously warm sea surface temperatures in all surrounding basins and coincidence of a midlatitude system and a subtropical jet provided the necessary ingredients for formation of this strong AR.

This work underlines the fact that the impacts of rain-producing ARs are not limited to the coastal regions. Such ARs can travel very long distances away from the oceans and affect remote arid and semi-arid regions like the Middle East. This study examined an individual AR, though one associated with record floods. However, it attempts to draw attention to the need for more AR-related research over the Middle East.