

# What caused the record floods of March 2019 across the Middle East?

Amin Dezfuli



Dezfuli (2019): Rare atmospheric river caused record floods across the Middle East.  
*Bull. Amer. Meteor. Soc.*

# Scale of the floods and consequences

- Unprecedented floods across the Middle East; Iran hit hardest.
- Affected 26 out of 31 provinces in Iran.
- Early estimates: \$2.5 billion worth of damage to infrastructures, homes, agriculture, ...

*(Reuters, 2019)*



*(Photo courtesy of Internet Archive)*



# Scale of the floods and consequences

- Damaged one-third of the country's roads.
- Destroyed 700 bridges.
- Death toll of at least 76.
- Forced mass emergency evacuations.

*(Reuters, 2019)*



*(Photo courtesy of Internet Archive)*

# Scale of the floods and consequences

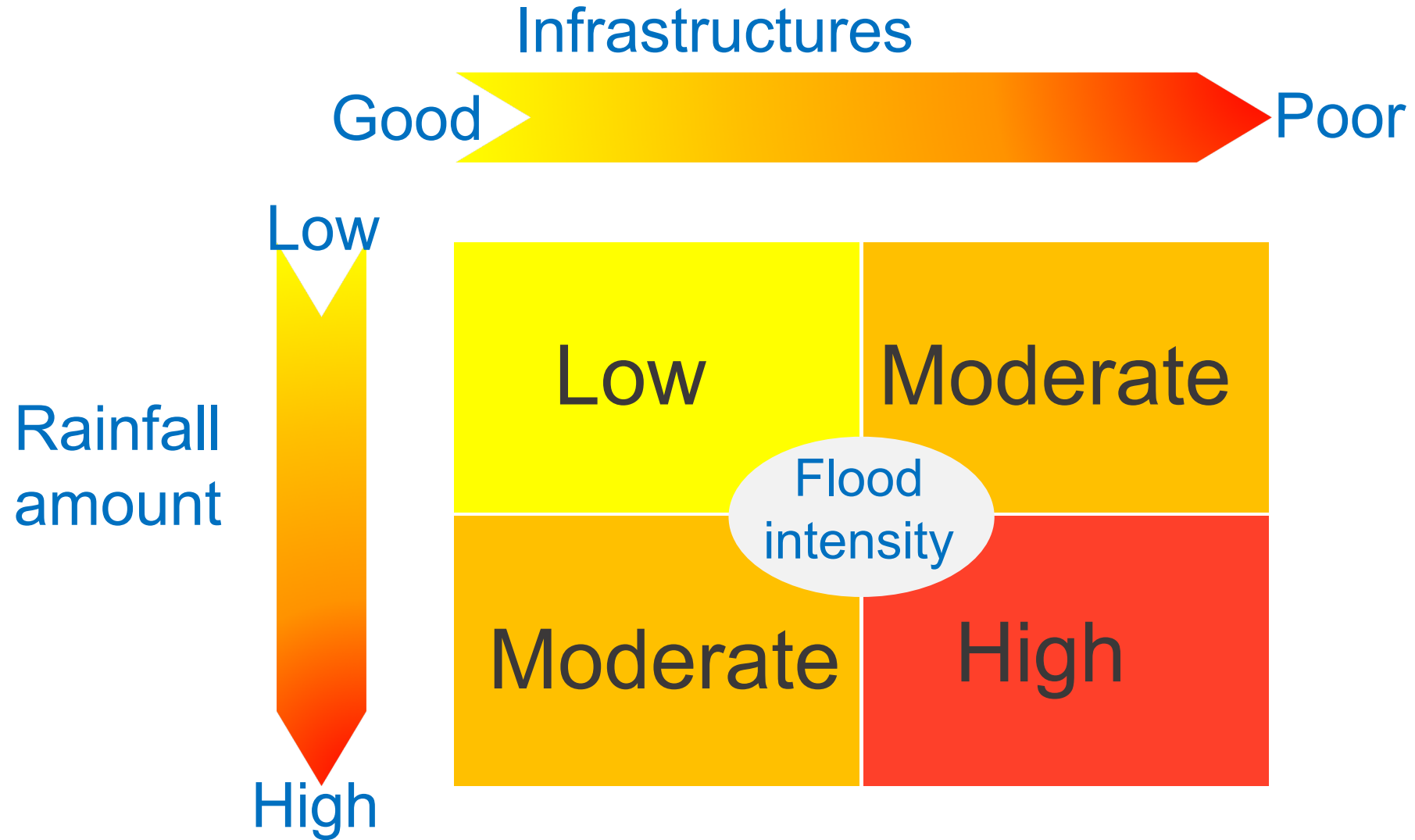
- Chance of flooding remained high several weeks after the event since major dams were brought to their maximum level and could not hold more water influx resulting from the snow melting in spring.
- People are still wrestling with the aftermath of the crisis!



*(Photo courtesy of Internet Archive)*



# What causes an extreme flood?



# Weather phenomena act at different scales

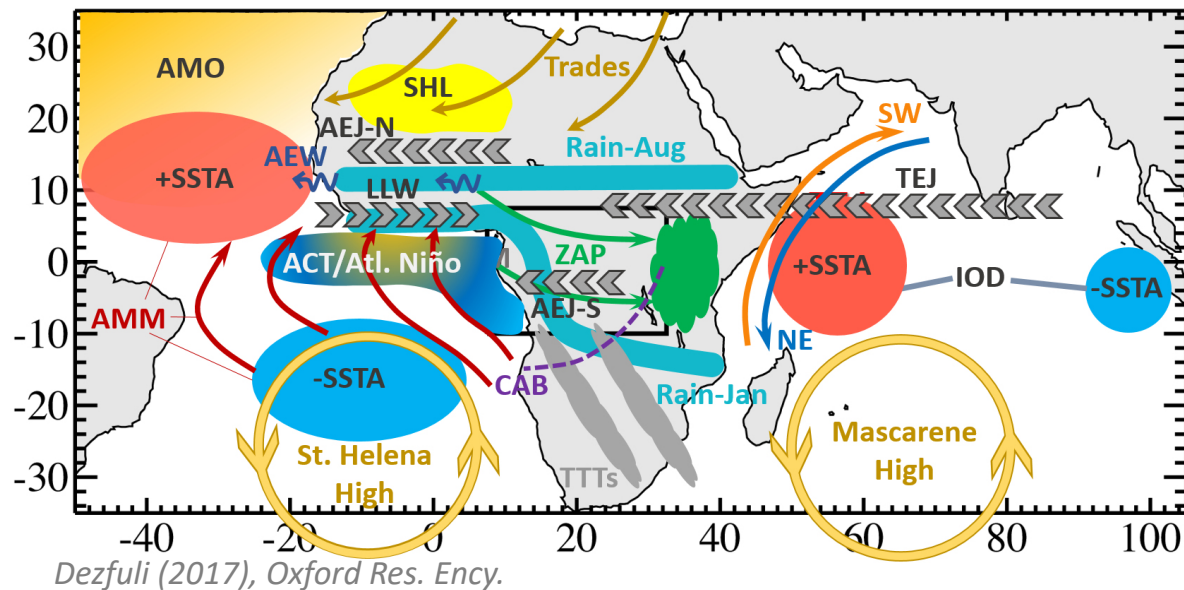
Each weather event is a result of aggregated interactions between several features.

**Large-scale** El Nino, NAO, PDO, QBO, MJO, IOD, PDO, ...

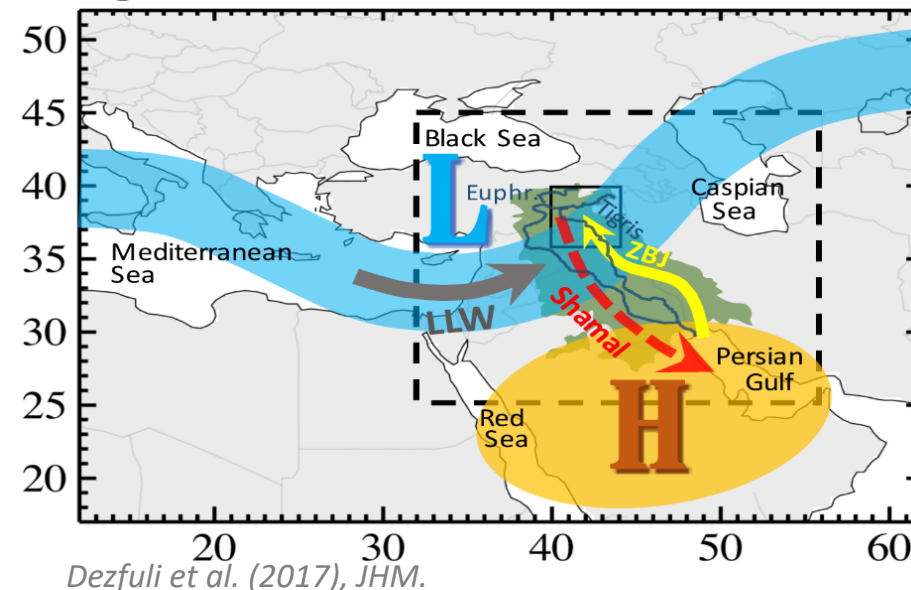
**Regional** Monsoons, mountains, lakes, low-level jets, ...

**Local** Land cover, land-sea contrast, moisture recycling, ...

Local and remote drivers of rainfall in Africa

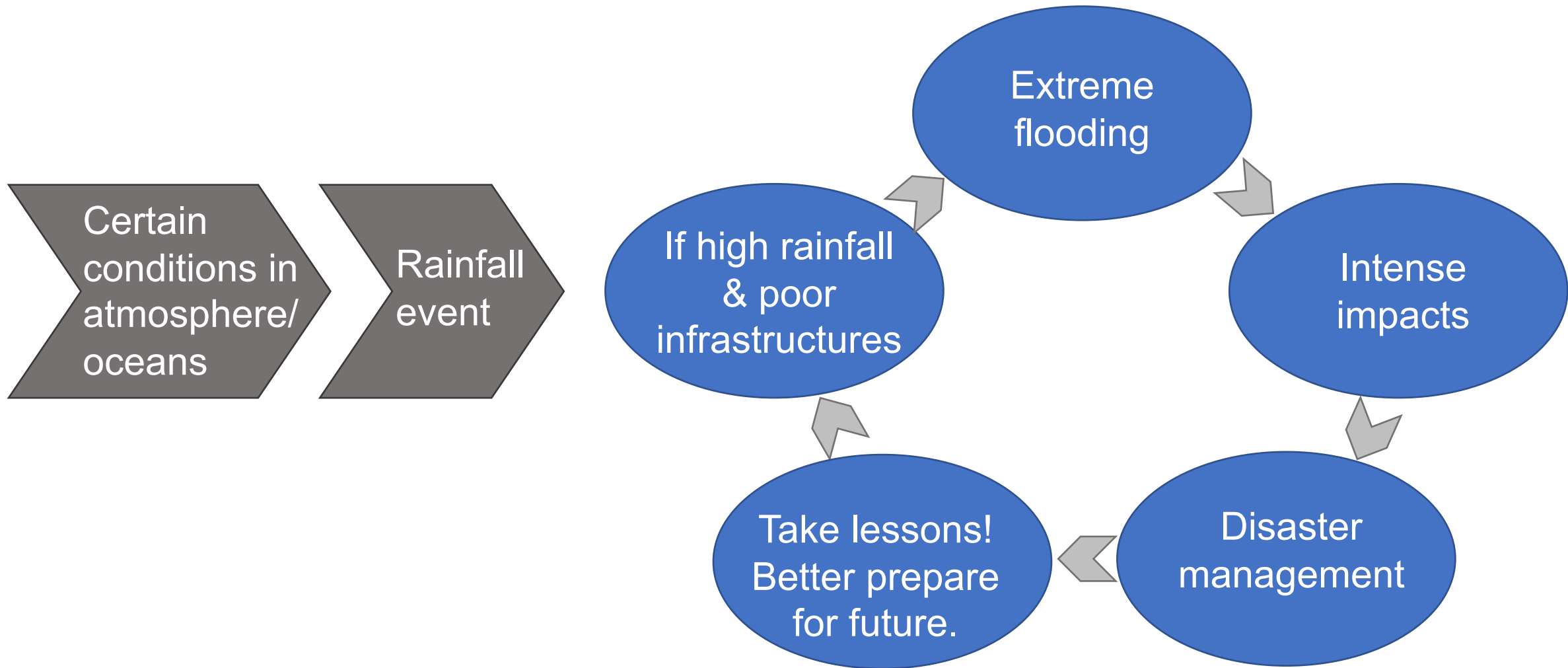


Regional drivers of rainfall in Middle-East





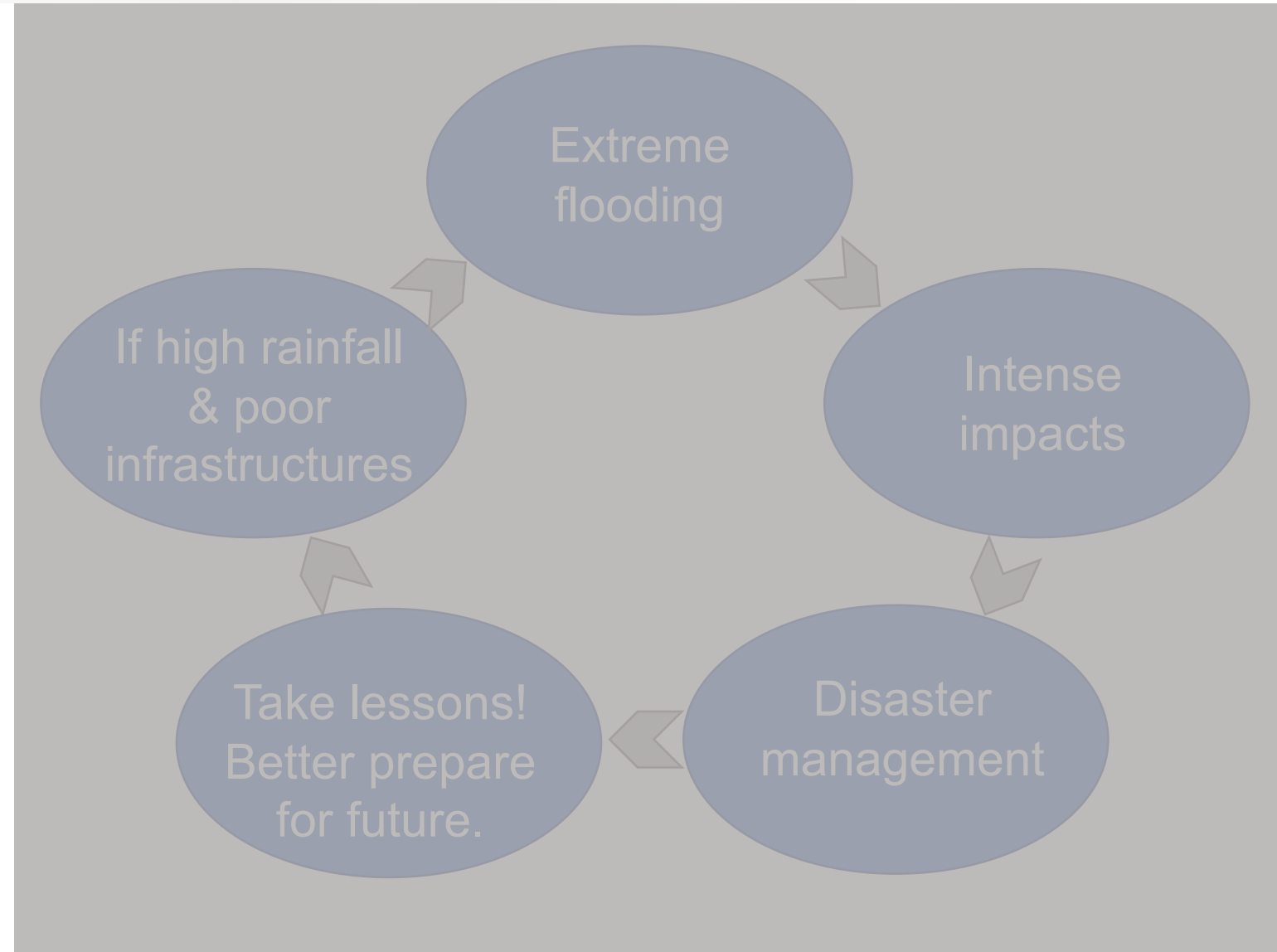
# Rainfall-flood-impacts-management loop



# Rainfall-flood-impacts-management loop

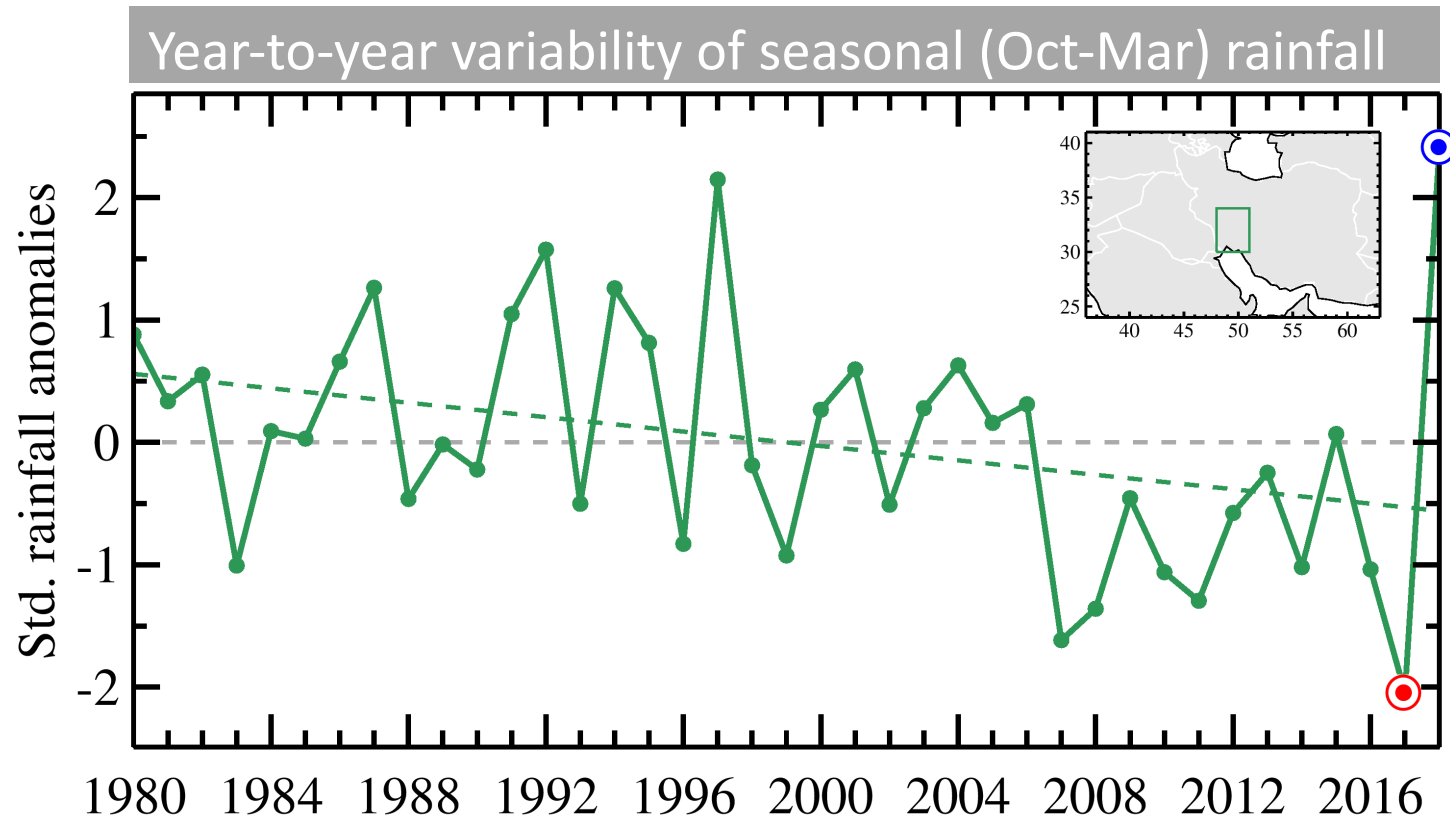


- Improve predictions
- Understand climate change impacts

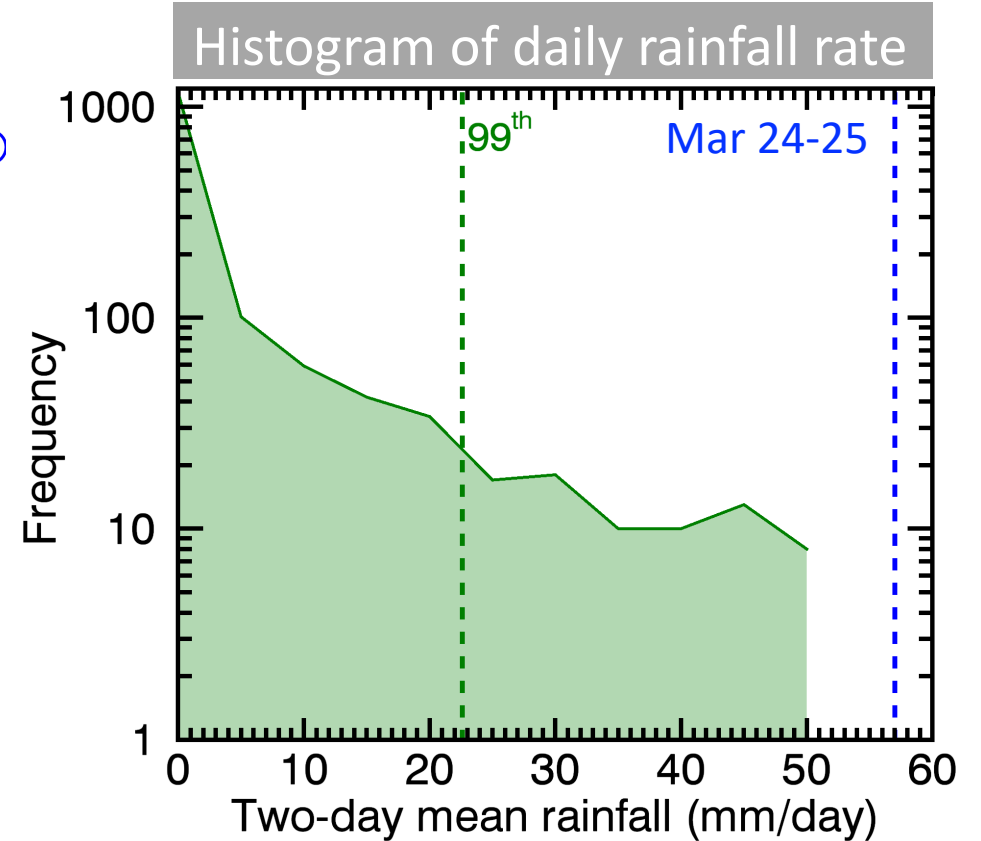




# Comparing rainfall conditions in 2019 with the past



- 2017-18 to 2018-19: the most rapid dry-to-wet transition
- Increased chance of landslides



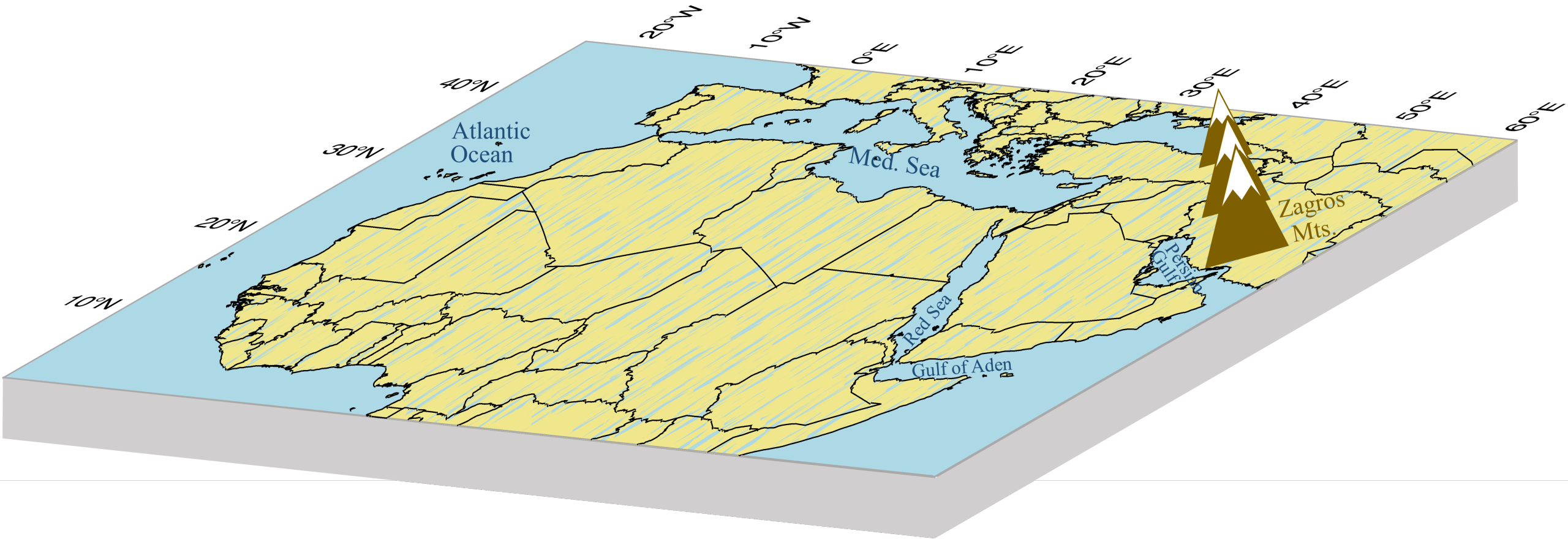
- March 24-25, 2019: the record two-day rainfall event



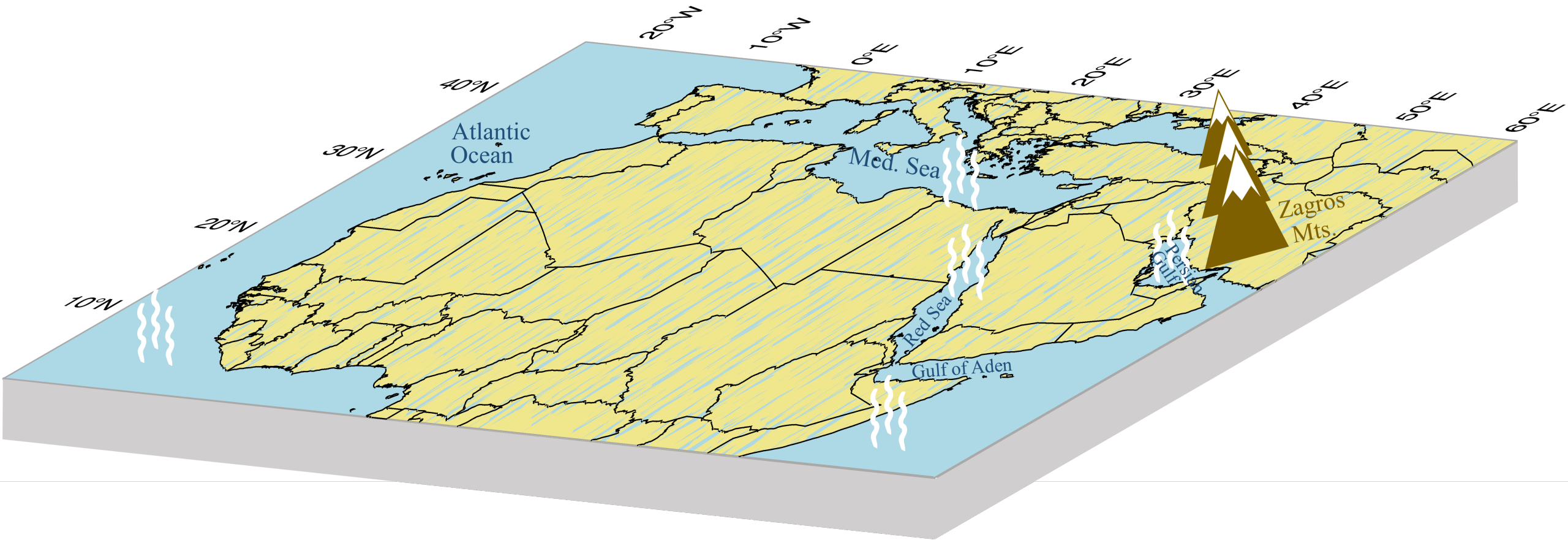
# Story of record rainfall during 24-25 March, 2019



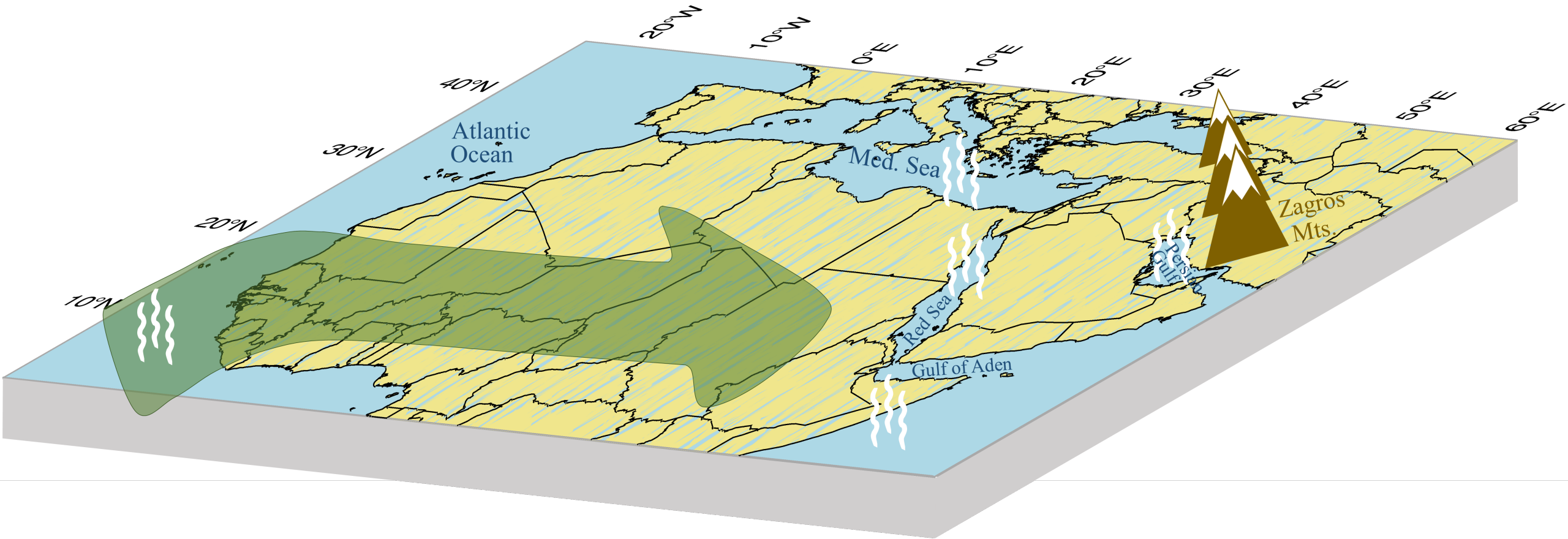
# Geographical features affecting climate of Iran



# All waters warmer than normal in March 2019 → more evaporation



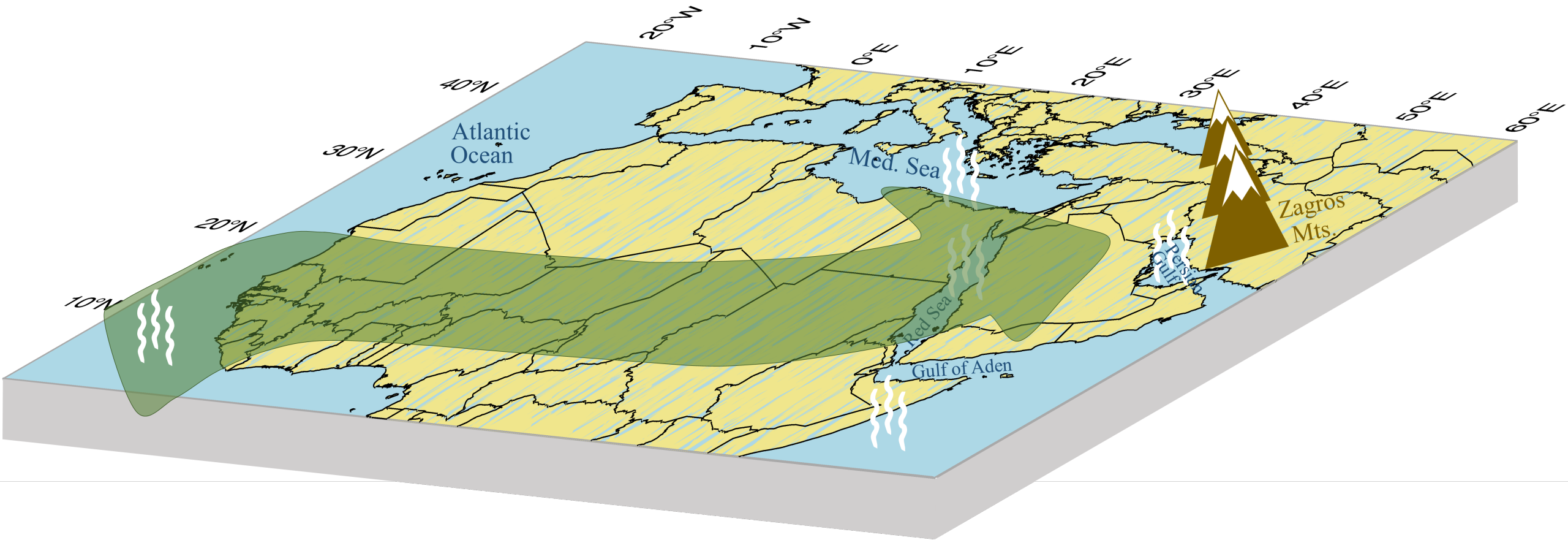
# Subtropical jet: moisture transport from Atlantic



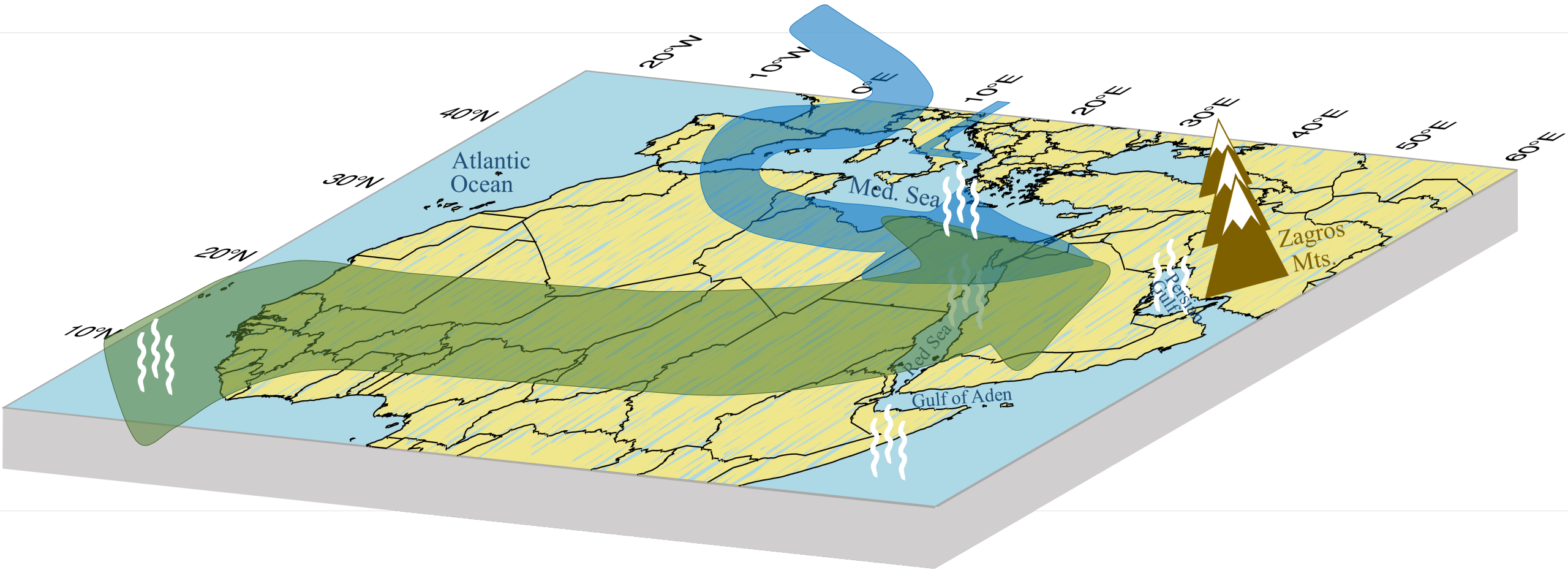


# An Atmospheric River (AR) forms

AR: long, narrow, and transient corridor of strong horizontal water vapor transport from tropical or extratropical moisture sources.

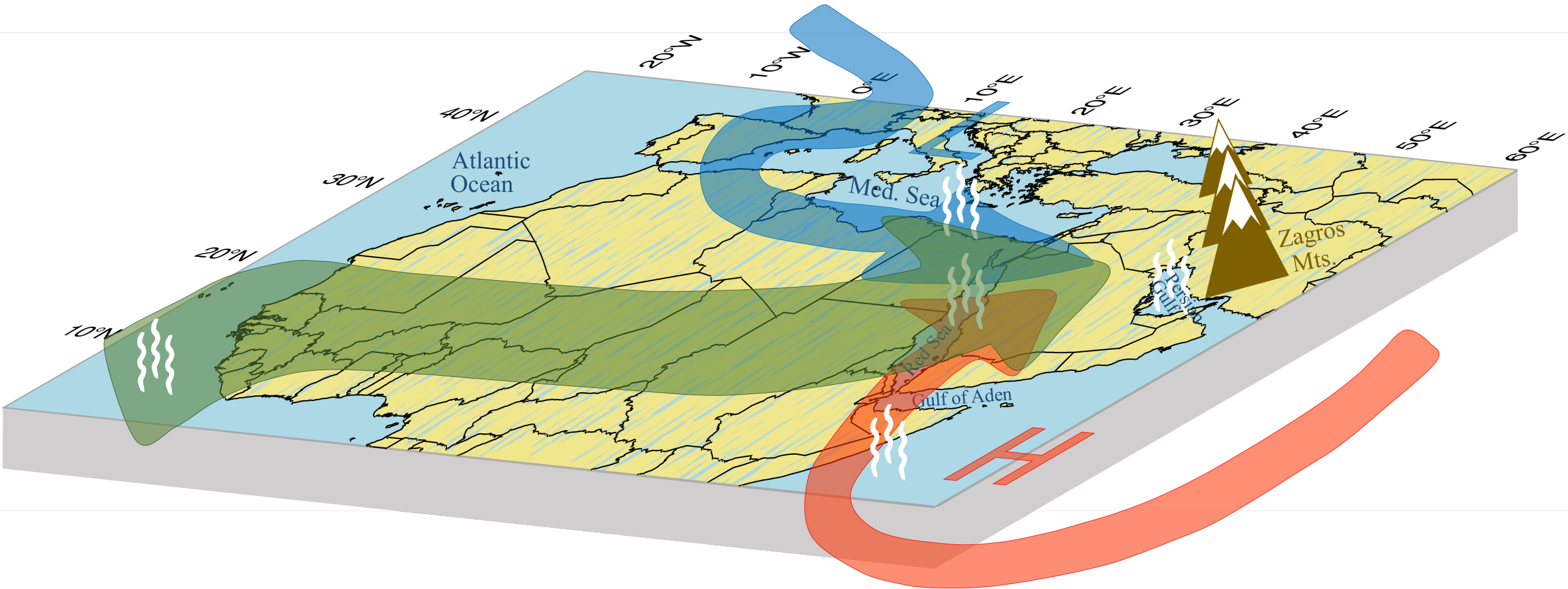


# Low-pressure system: additional moisture from Mediterranean

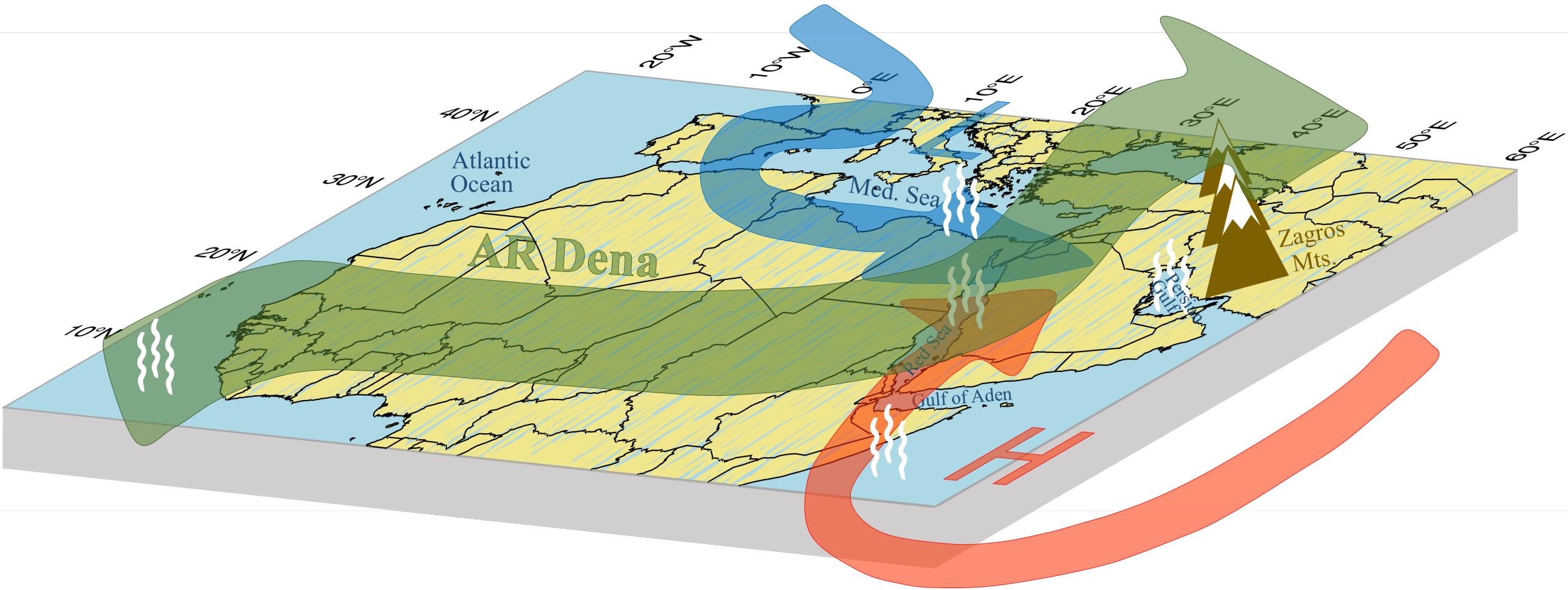




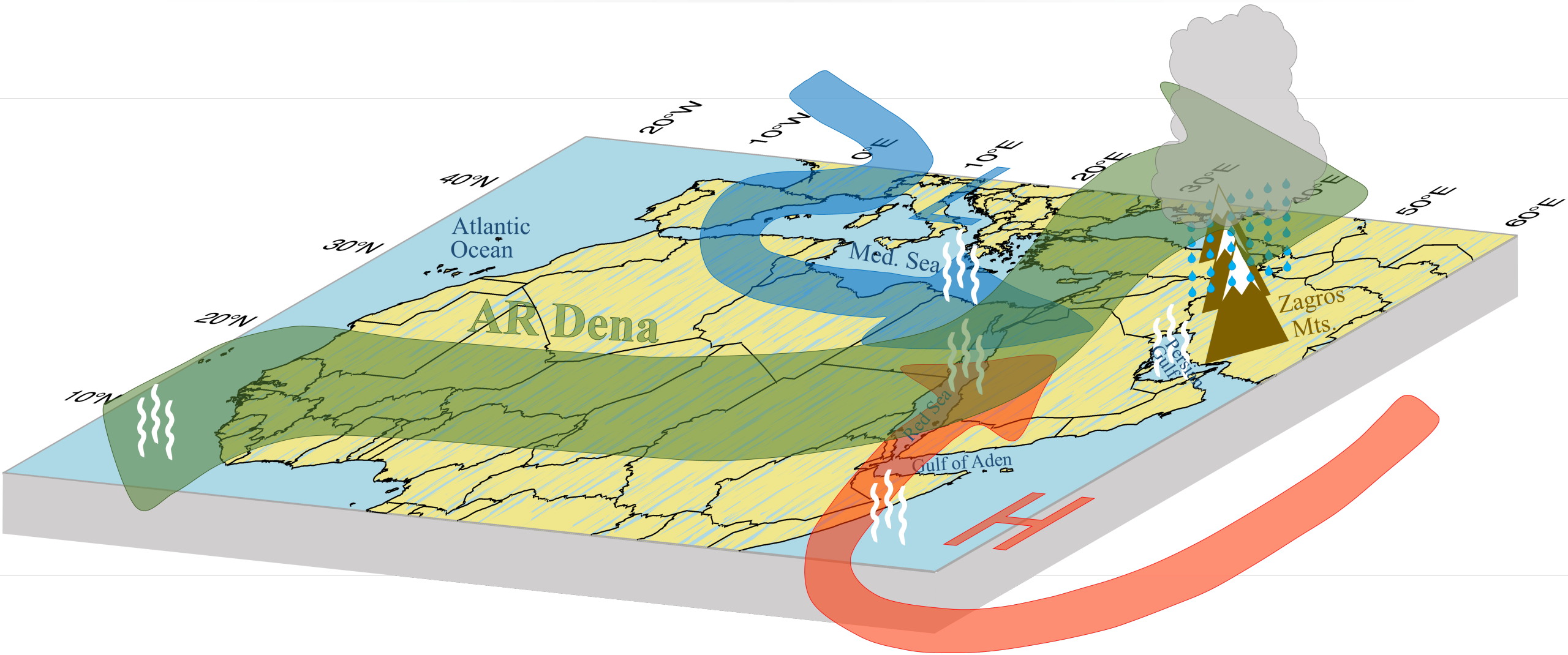
# High-pressure system: more moisture from Red Sea, etc.



# AR propagates further, hits Zagros, and rises

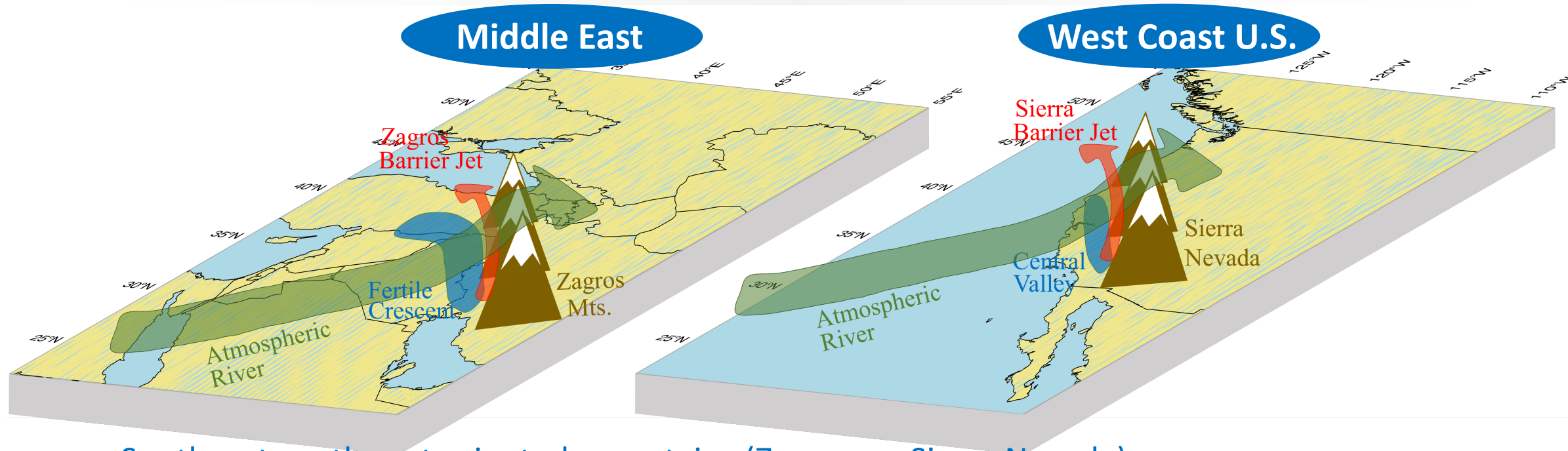


# Moist air cools, and heavy rainfall forms



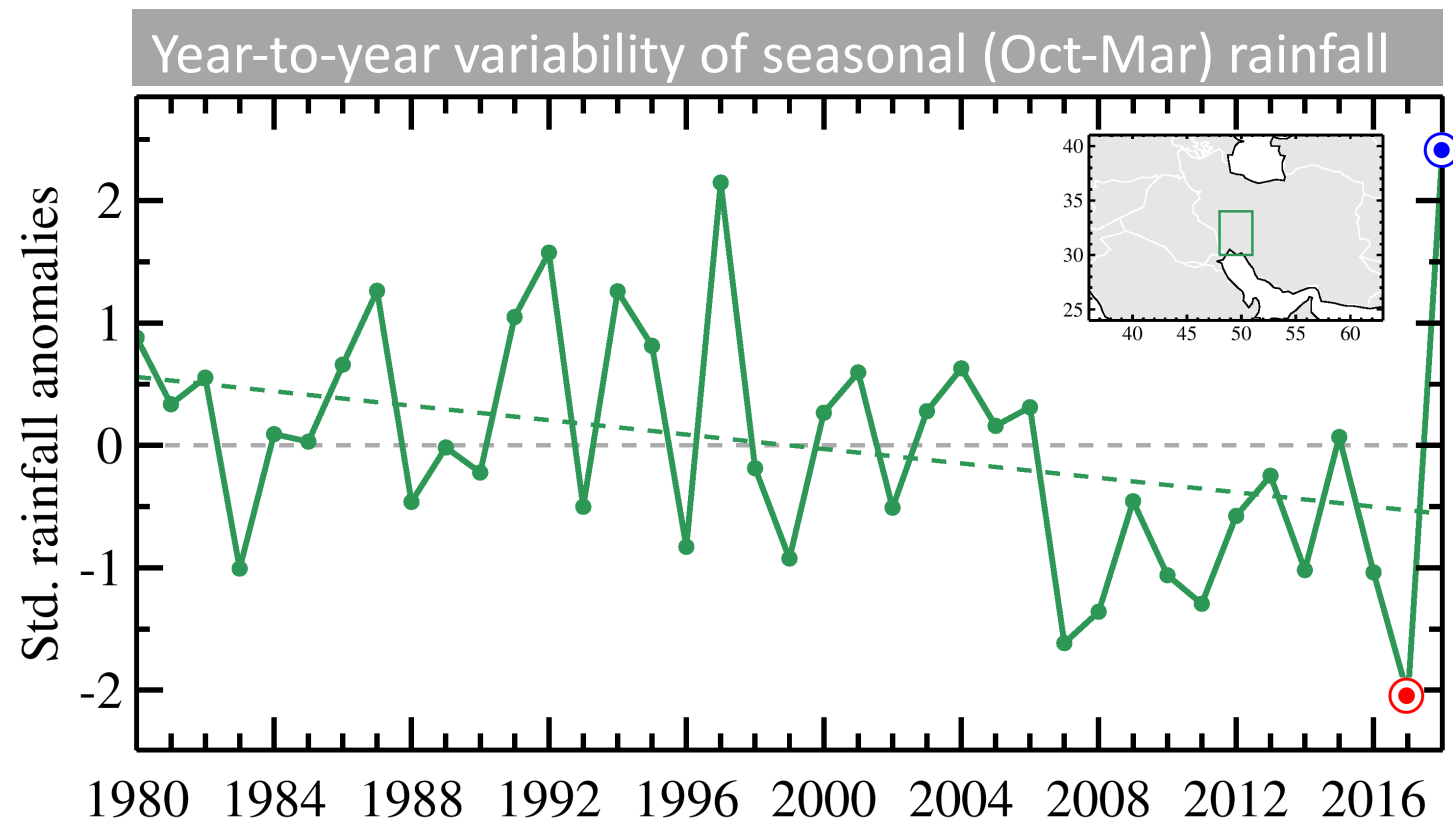


# Geographical similarities between Middle East & West Coast U.S.

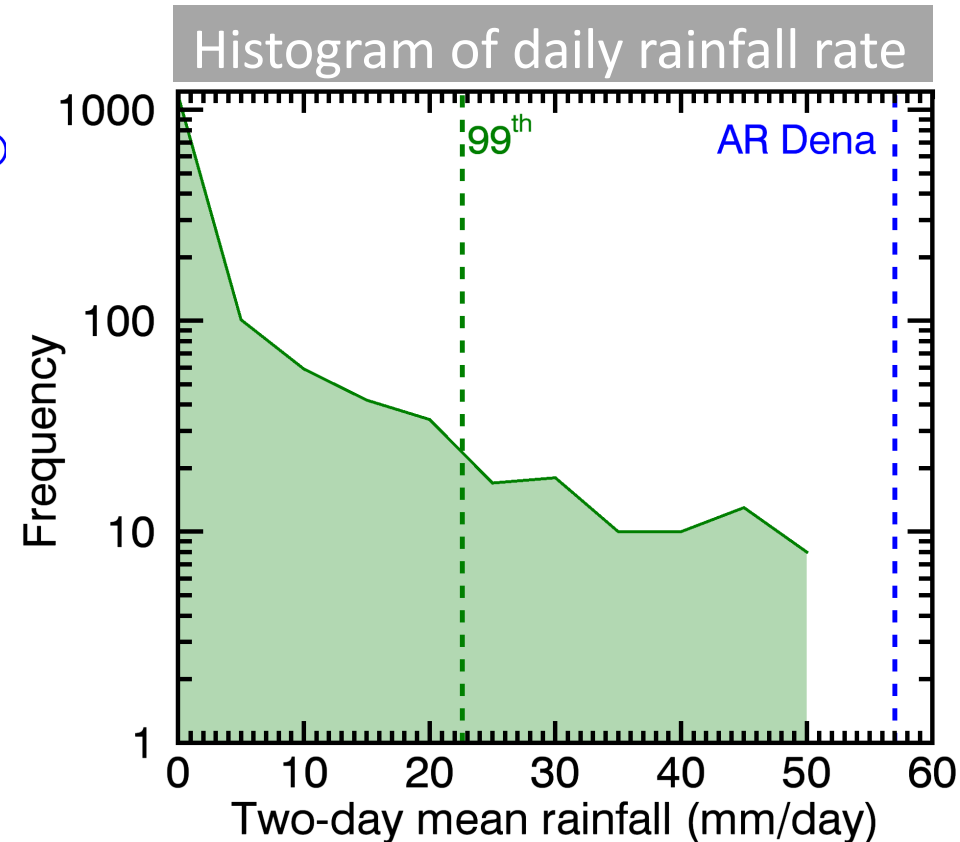


- Southeast-northwest oriented mountains (Zagros vs. Sierra Nevada)
- Fertile plain adjacent to Mts. (Fertile Crescent vs. Central Valley)
- Latitudinal extension
- AR-Mts. interactions precipitation formation
- Low-level jets (Zagros Barrier Jet vs. Sierra Barrie Jet)
- Main difference: distance to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

# Comparing rainfall conditions in 2019 with the past



- 2017-18 to 2018-19: the most rapid dry-to-wet transition
- Increased chance of landslides

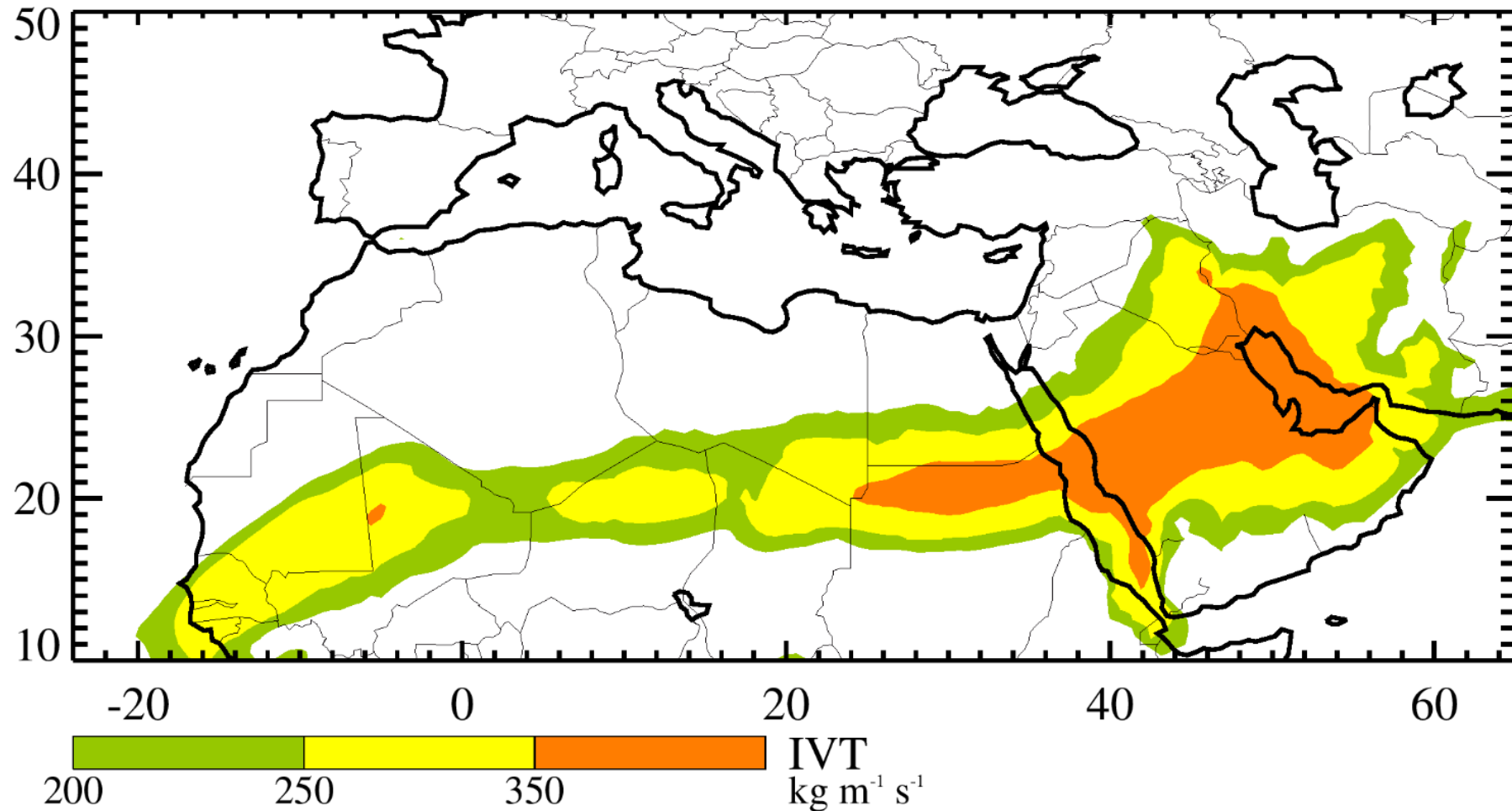


- March 24-25, 2019: the record two-day rainfall event



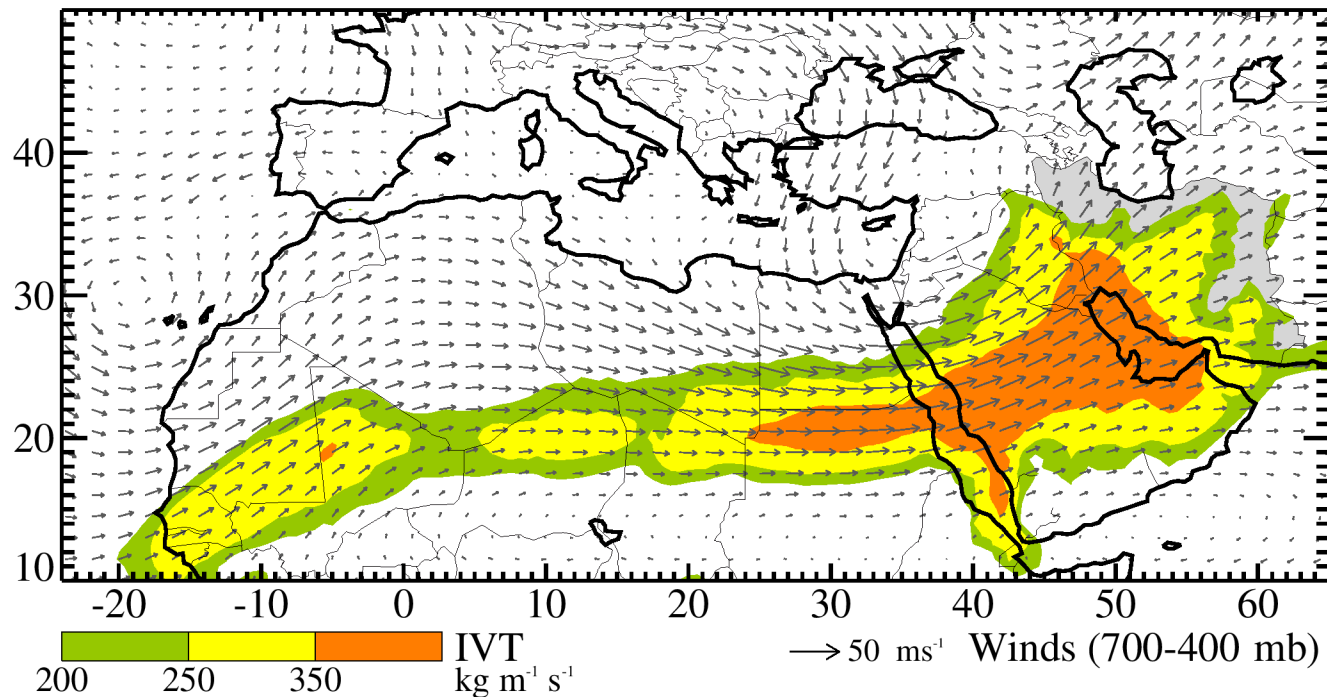
## Identify AR Dena

Using NASA's MERRA2 data average over 24-25 March:  
Integrated water vapor transport (IVT)  $> 200 \text{ kg m}^{-1} \text{ s}^{-1}$

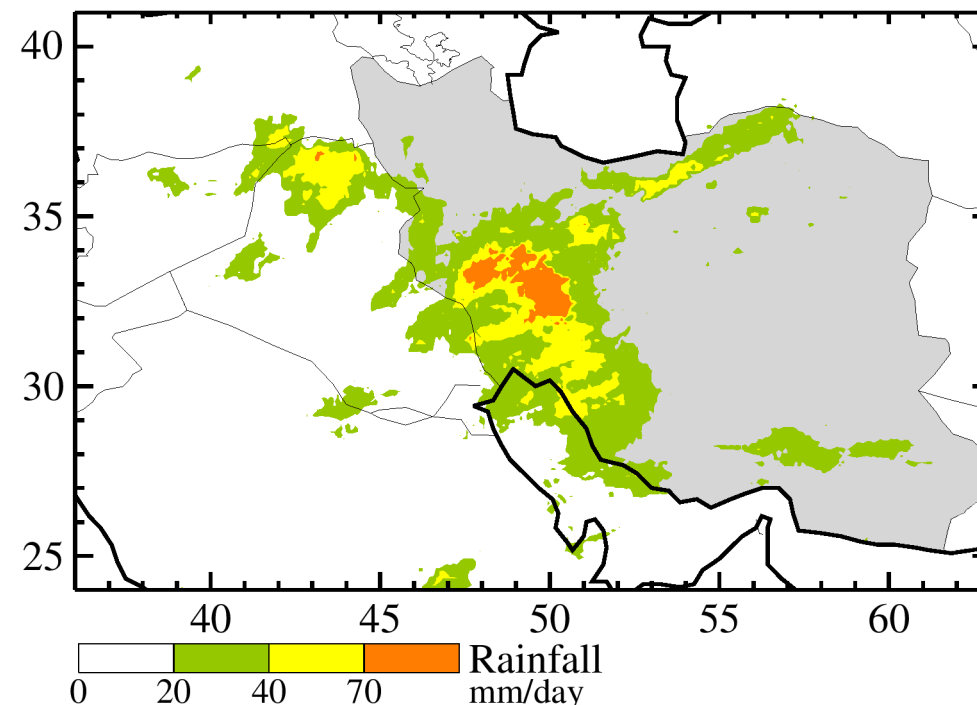


# AR Dena, horizontal winds and rainfall patterns during March 24-25

Total moisture flux (IVT) and winds ( $\sim 3000$ - $5500$  m)



IMERG satellite rainfall

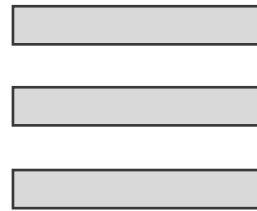


- Subtropical jet and cut-off low are apparent.

- Rainfall maximum over Zagros Mts.

## How much water?

Water  
transport by  
**AR Dena**



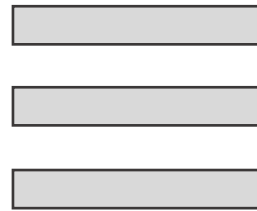
?

X

Combined flow of  
**Tigris** +  
**Euphrates** +  
**Karun** +  
**Karkheh**

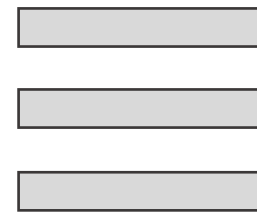
## How much water?

Water  
transport by  
**AR Dena**



150 X

Combined flow of  
**Tigris** +  
**Euphrates** +  
**Karun** +  
**Karkheh**



6 Billion

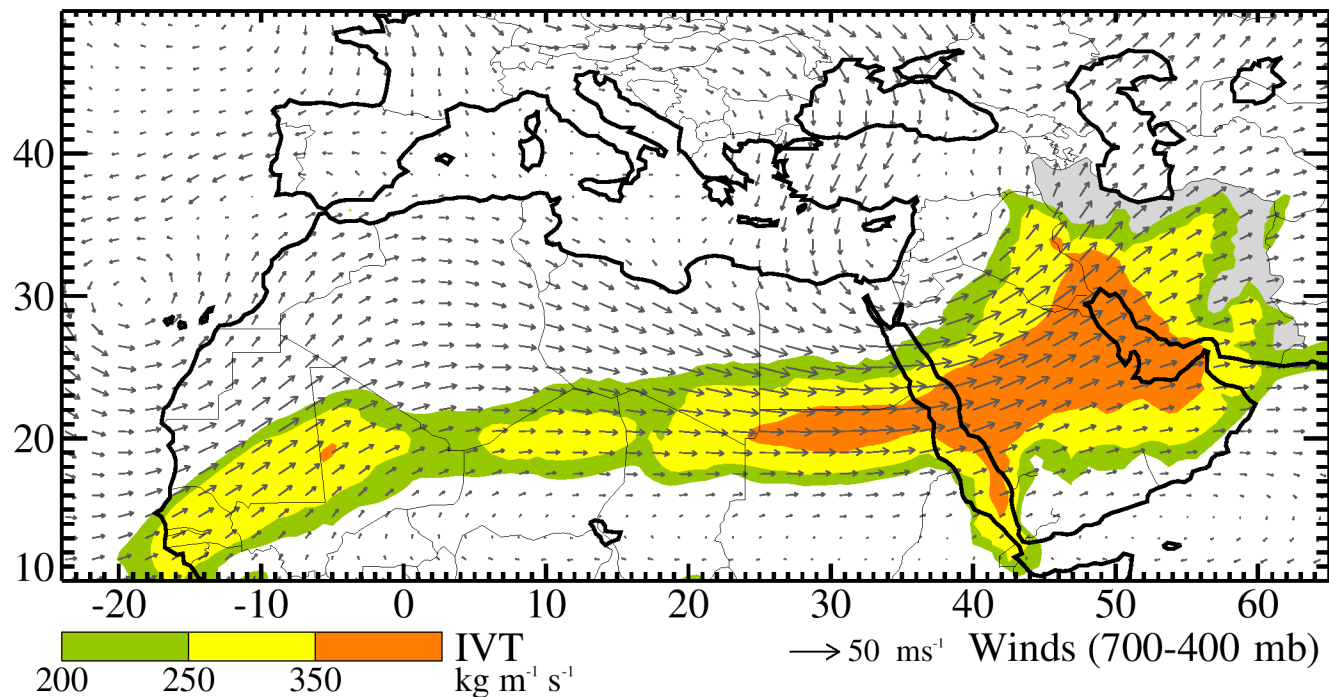
(in two days)





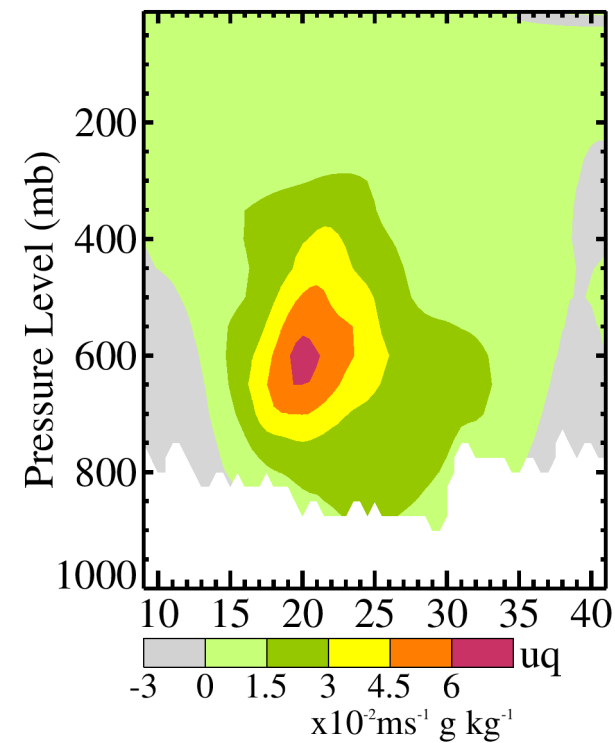
# Horizontal and vertical structure of the AR

Total moisture flux (IVT) and winds ( $\sim 3000$ - $5500$  m)



- Subtropical jet and cut-off low are apparent.

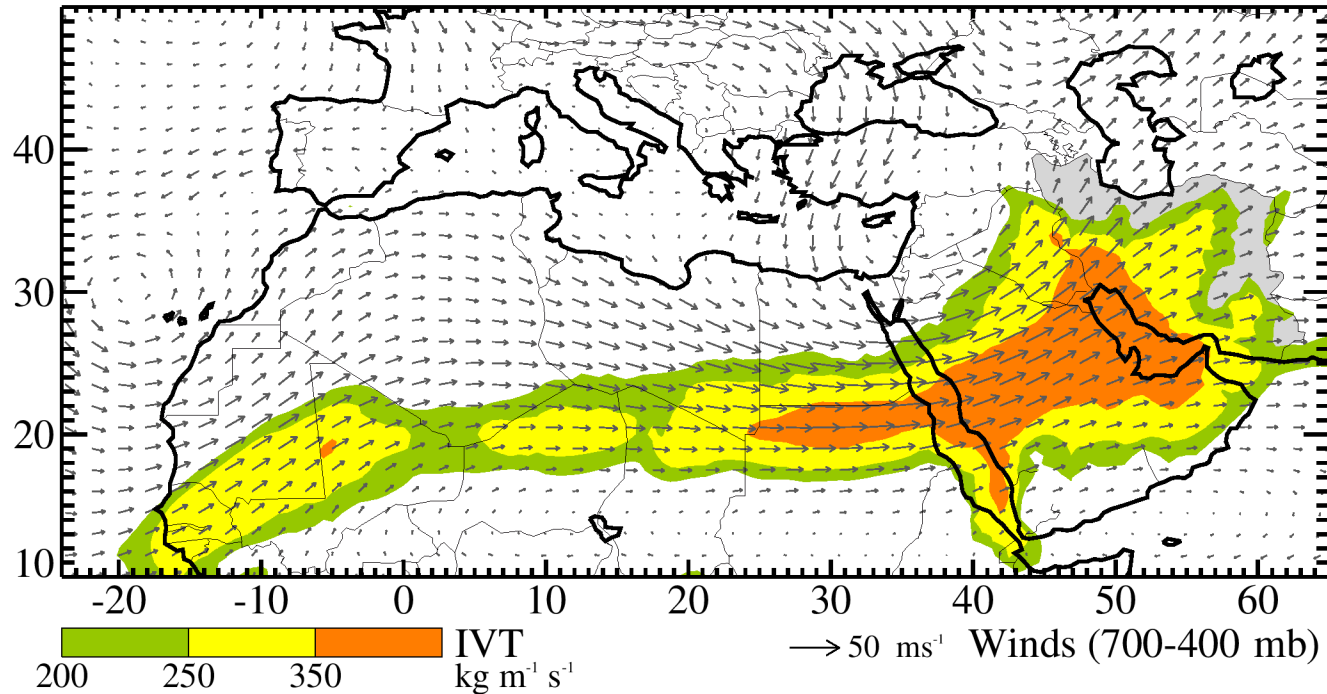
Vertical cross-section of moisture flux



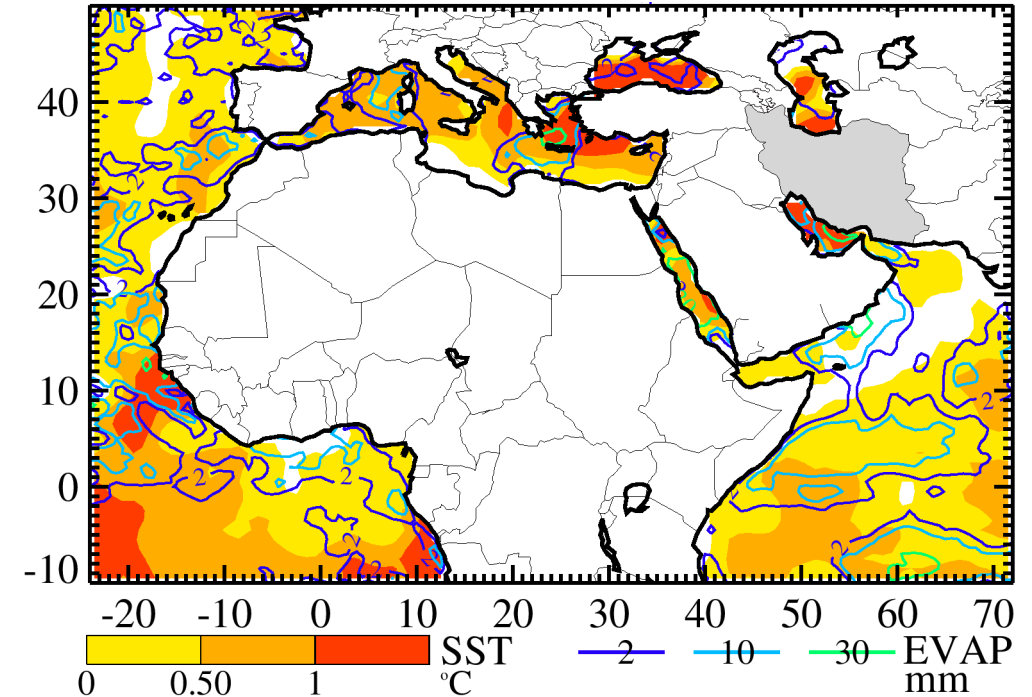
- AR core at  $\sim 3000$ - $5500$  m layer

# AR Dena, SST and evaporation patterns

Total moisture flux (IVT) and winds ( $\sim 3000$ - $5500$  m)



SST & evaporation anomaly, Mar 2019



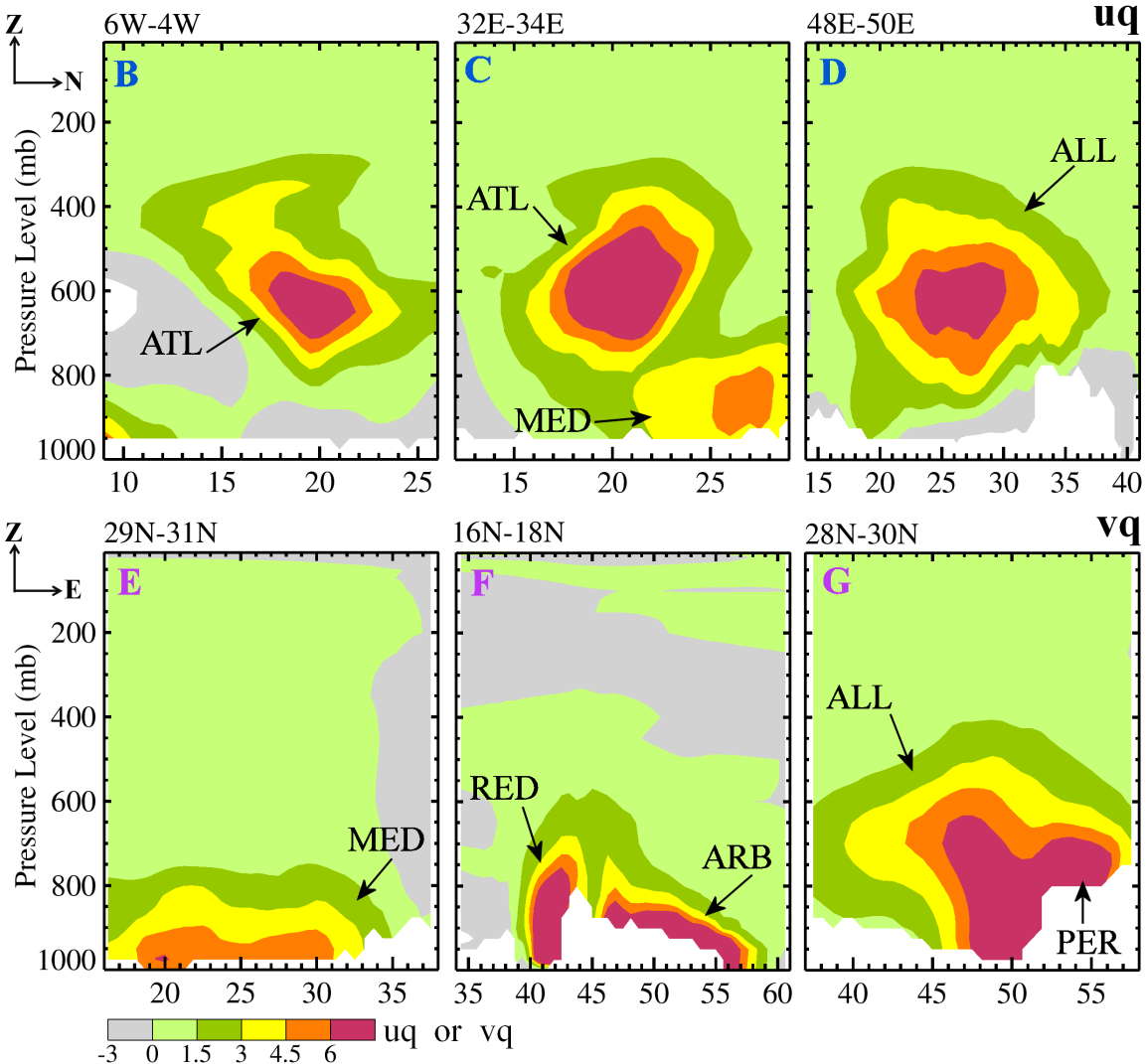
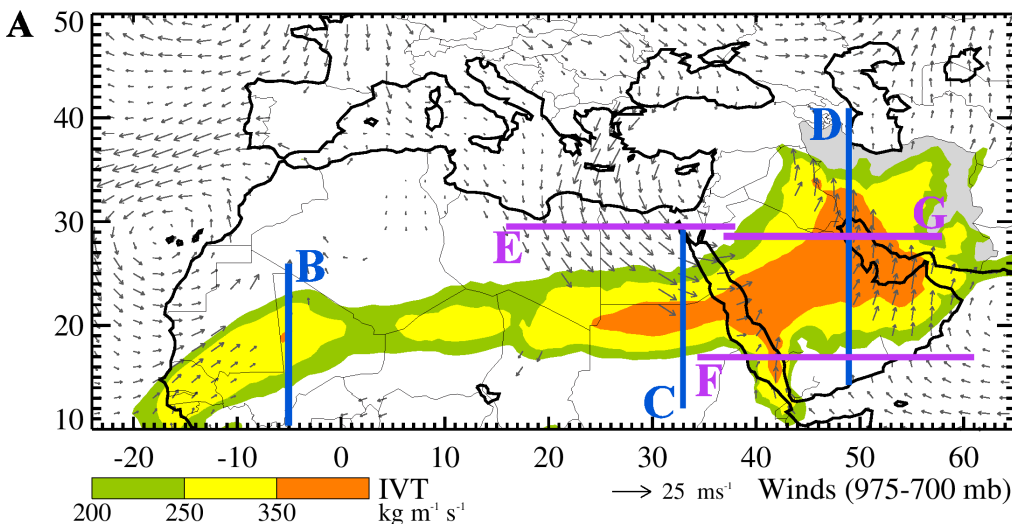
- Subtropical jet and cut-off low are apparent.

- All water basins warmer than normal with more evaporation

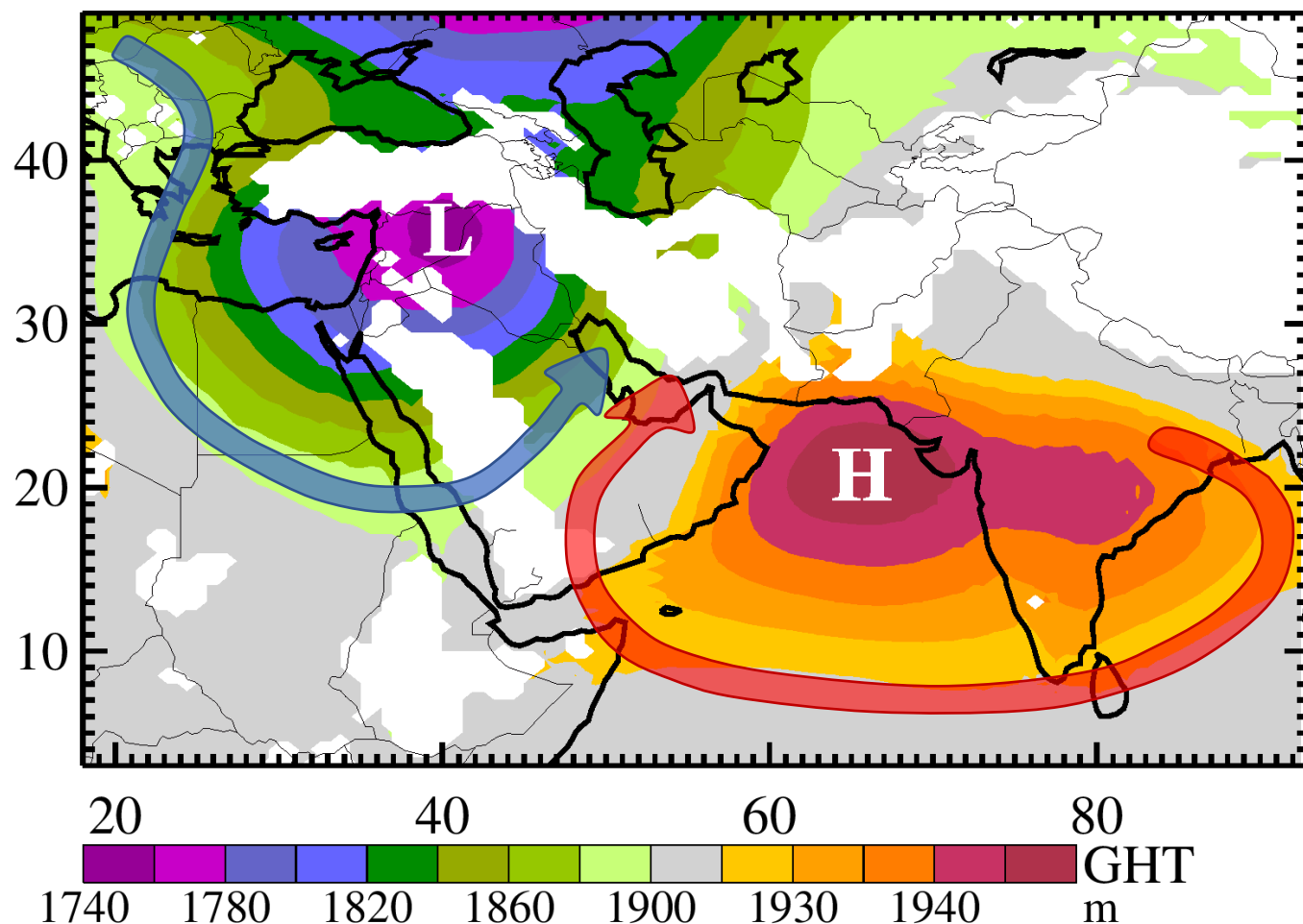


# Moisture contribution of various water basins to AR Dena

Vertical cross-section of moisture transport



## Geopotential heights (GHT) in the lower troposphere (925-700 mb)

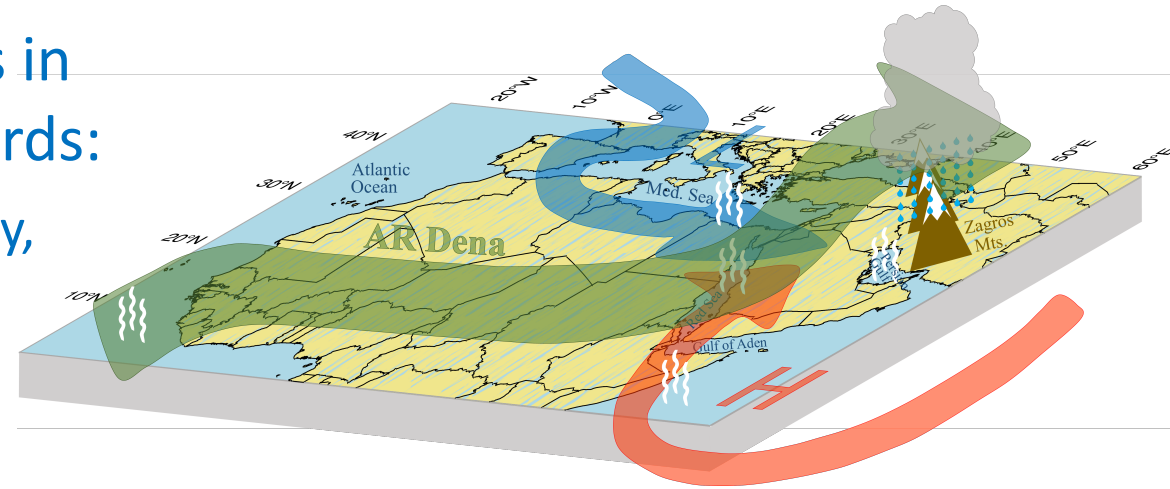


- Configuration of low and high pressure systems facilitated moisture transport from regional water basins.



## Future work

- Perform a comprehensive analysis of all ARs in the region, using the 40-year MERRA-2 records:
  - Better understand statistics of the ARs (frequency, inter-annual variability, trends, etc)
  - Processes responsible for formation of the ARs
- Skills of subseasonal-to-seasonal (S2S) predictions of frequency of extreme events
- Perform hybrid dynamical-statistical approach using machine learning techniques
- Hydrology modeling and impact analysis
- Future projection of the ARs in the region



Dezfuli (2019): Rare atmospheric river caused record floods across the Middle East. *Bull. Amer. Meteor. Soc.*