IMPACT OF CLIMATE CHANGE OVER THE ARABIAN PENINSULA

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Motivation:

- In arid and semi-arid regions of the world the demand for fresh water resources is increasing due to:
  - increasing populations, and
  - scarcity of fresh water supplies.
- These areas are the most affected by climate change.
- Among others, climate change could affect precipitation patterns and magnitudes.

Objectives:

Provide remote sensing-based solutions for hydrologic issues in the Arabian Peninsula.

- Change in patterns and magnitudes of precipitation (climate change-related?)
- Partitioning of precipitation over Red Sea Hills watersheds.

Data & Objectives :

PHASE I:

Identify the spatial and temporal climate change-related variations in precipitation over the AP.

PHASE II:

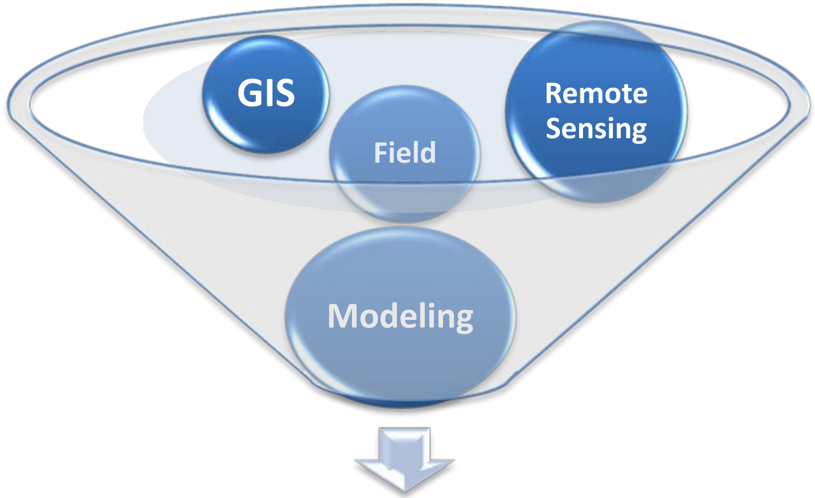
Quantify the partitioning of precipitation into recharge, runoff, and initial losses.

Phase I	Phase II
Rain Gauges	Rain Gauges
	Temperature
	Wind Speed
	Relative Humidity
	Stream Flow

FIELD DATA

REMOTE SENSING DATA

Methods & Objectives :



Integrated Approach

PHASE I:

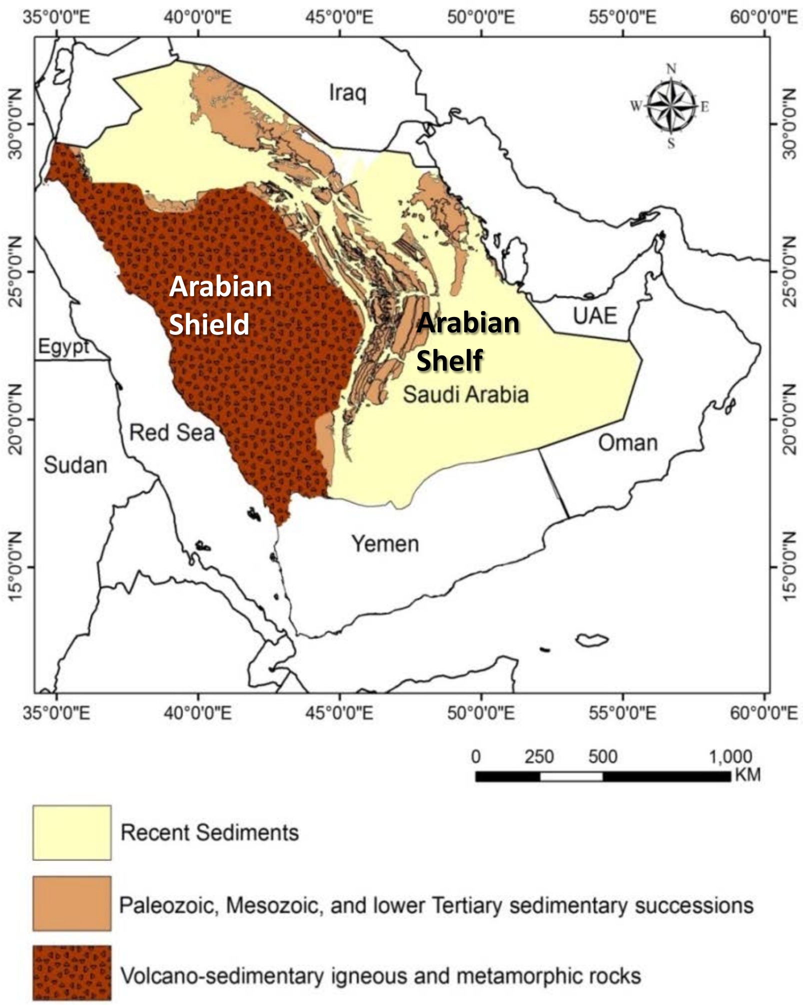
Identify the spatial and temporal climate change-related variations in precipitation over the AP.

PHASE II:

Quantify the partitioning of precipitation into recharge, runoff, and initial losses.

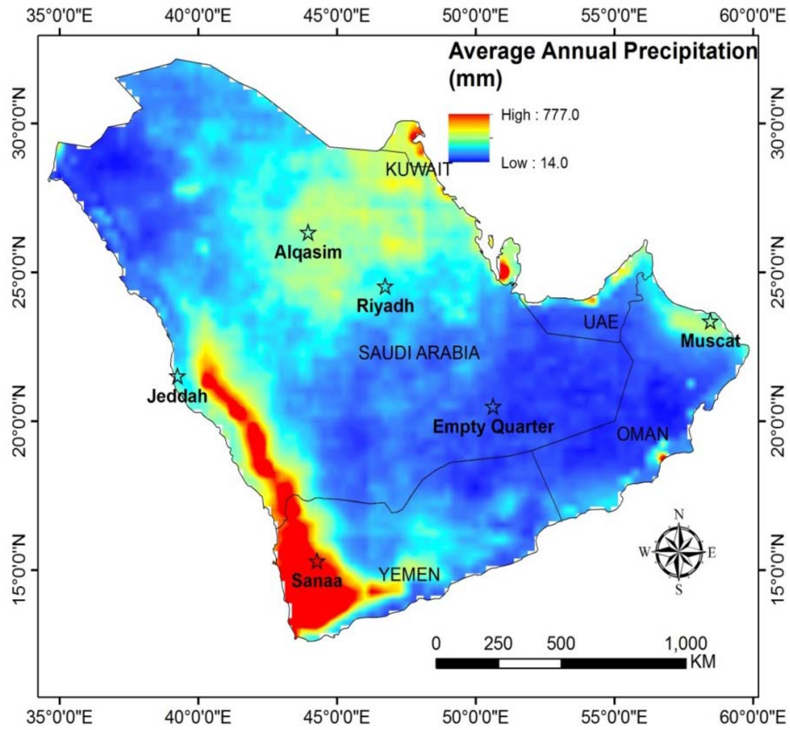
Arabian Peninsula: Geology

- The AP is divided into two major regions—the Arabian Shield and the Arabian Shelf.
- The Arabian Shield, a complex of **igneous and metamorphic rocks of Precambrian age**, occupies the western third of the AP.
- The Arabian Shelf is composed of **Paleozoic, Mesozoic, and lower Tertiary strata** exposed in central Arabia, and crops out along a curved belt bordering the Shield.



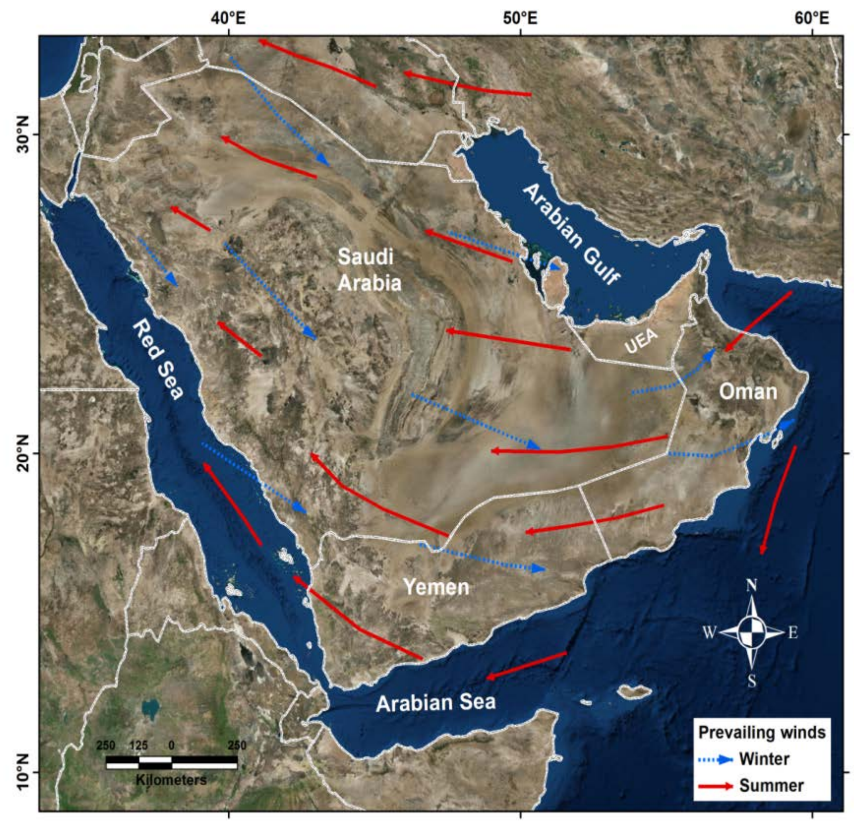
Arabian Peninsula: Climate (1)

- Temperatures in AP are high in summer and in some places can reach more than 50°C (122°F).
- The annual rainfall averages in the AP from less than 50 mm to 250 mm but could reach up to 750 mm in the southwest corner of the AP.



Arabian Peninsula: Climate (2)

- Precipitation in the AP is controlled by two main wind regimes.
  - **Monsoon** winds in the summer season (April to September).
  - **Westerly** winds in the winter season (October to March).



PHASE I:

Identify the spatial and temporal climate change-related variations in precipitation over the AP.

PHASE II:

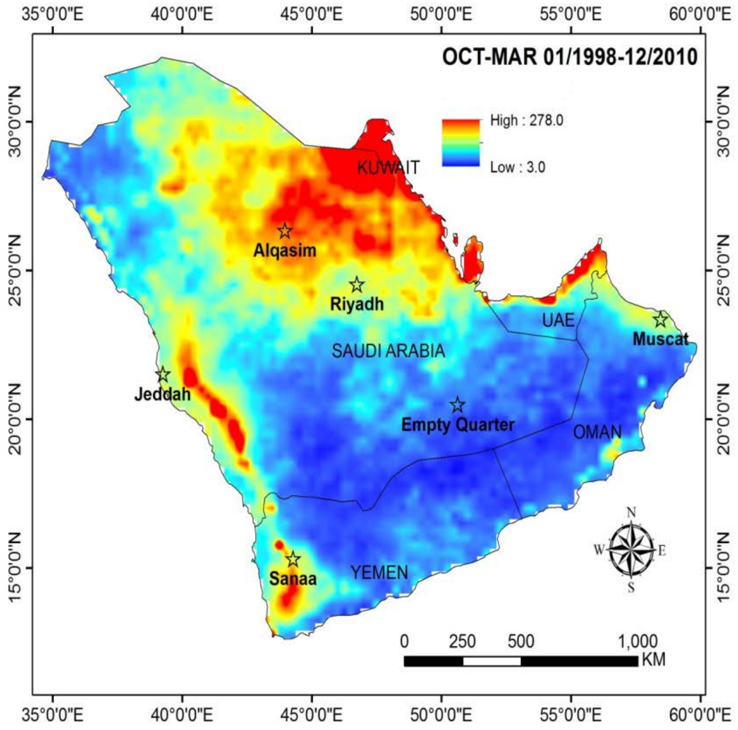
Quantify the partitioning of precipitation into recharge, runoff, and initial losses.

Phase I:

- **Goal**:
  - Identify the spatial and temporal climate change-related variations in precipitation over the AP.
- **Data**:
  - Climate Prediction Centers (CPC) Merged Analysis of Precipitation (CMAP).
  - provides global coverage 2.5° × 2.5° monthly precipitation datasets based on gauge data and satellite-derived 1979 to 2011.
- **Methods**:
  - Trends in rainfall over two seasons through two different periods.

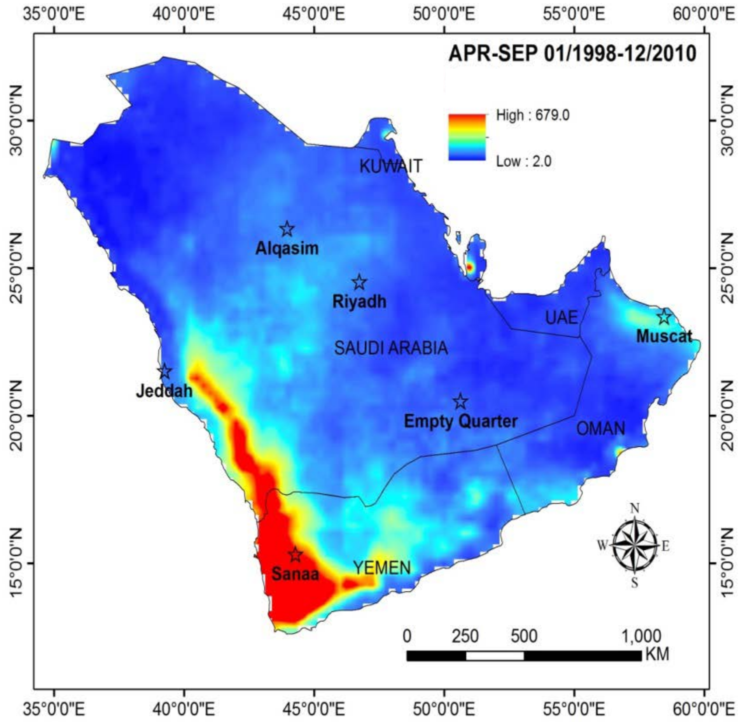
Precipitation Patterns: Two Seasons

Winter



Average annual precipitation during the winter (October – March) season.

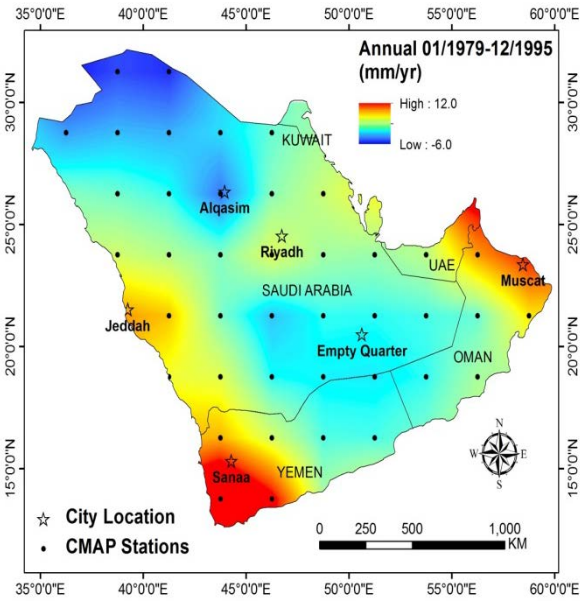
Summer



Average annual precipitation during the summer (April – September) season

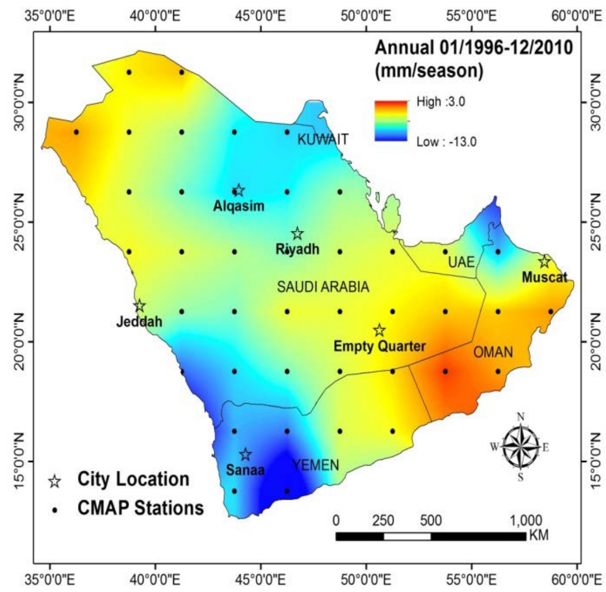
Precipitation Patterns: Two Periods

1979-1995



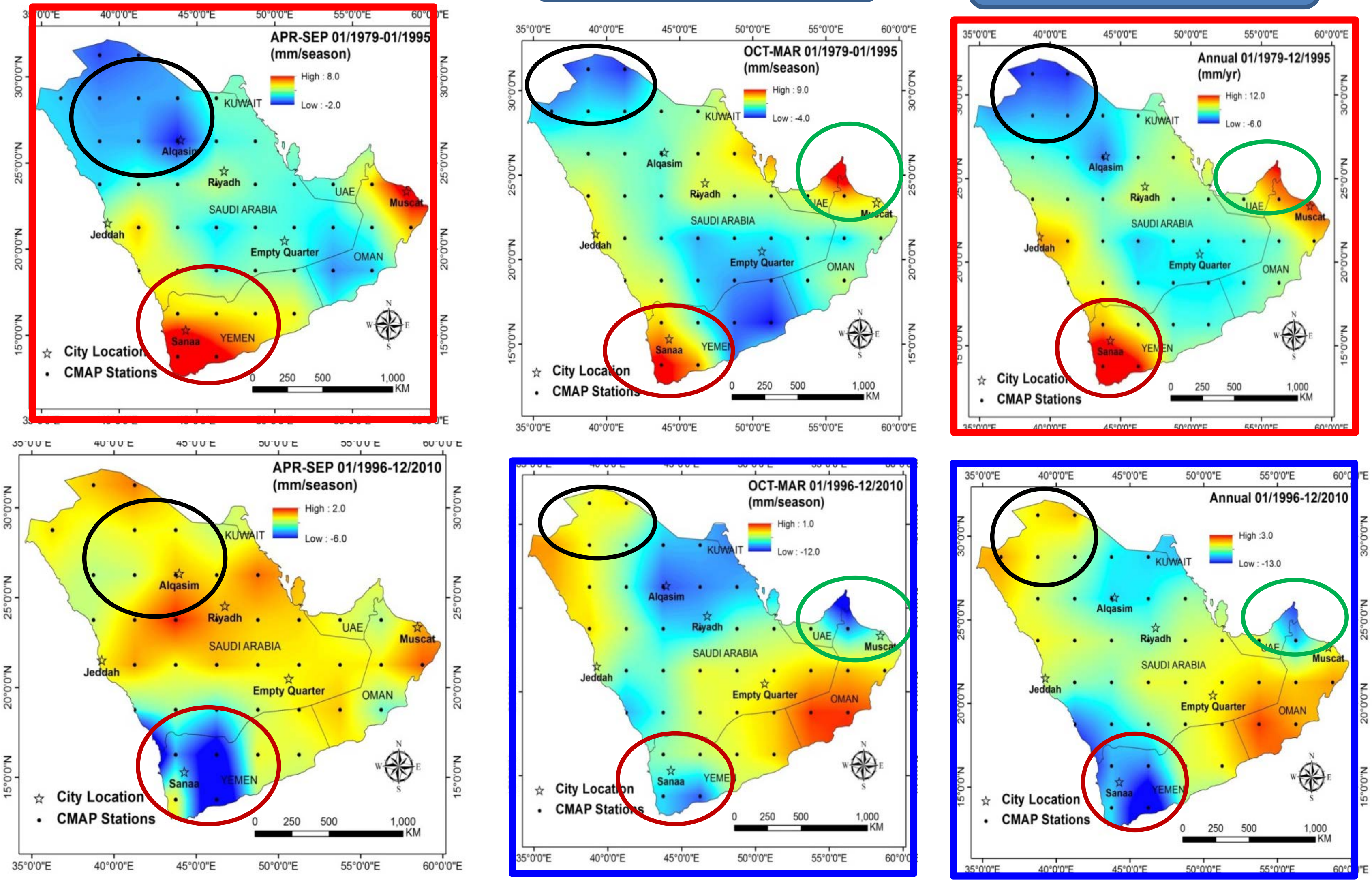
Trend (mm/yr) generated from CMAP-derived annual rainfall data that span the period from January 1979 through December 1995.

1996-2010



Trend (mm/yr) generated from CMAP-derived annual rainfall data that span the period from January 1996 through December 2010.

	Summer	Winter	Yearly
1979 - 1995			
1996 - 2010			



Trends in Rainfall

Phase I: Conclusions

- Global warming and/or multiyear variability related to ocean teleconnections can influence sea and land surface temperatures, which in turn affect precipitation rates and patterns.

- Monsoonal wind regimes-resulted precipitation patterns dominate the period from 1979-1995 and make up the bulk of the precipitation over the AP.

- Westerly wind regimes-resulted precipitation patterns dominate the period from 1996-2010 and make up the bulk of the precipitation over the AP.

PHASE I:

Identify the spatial and temporal climate change-related variations in precipitation over the AP.

PHASE II:

Quantify the partitioning of precipitation into recharge, runoff, and initial losses.

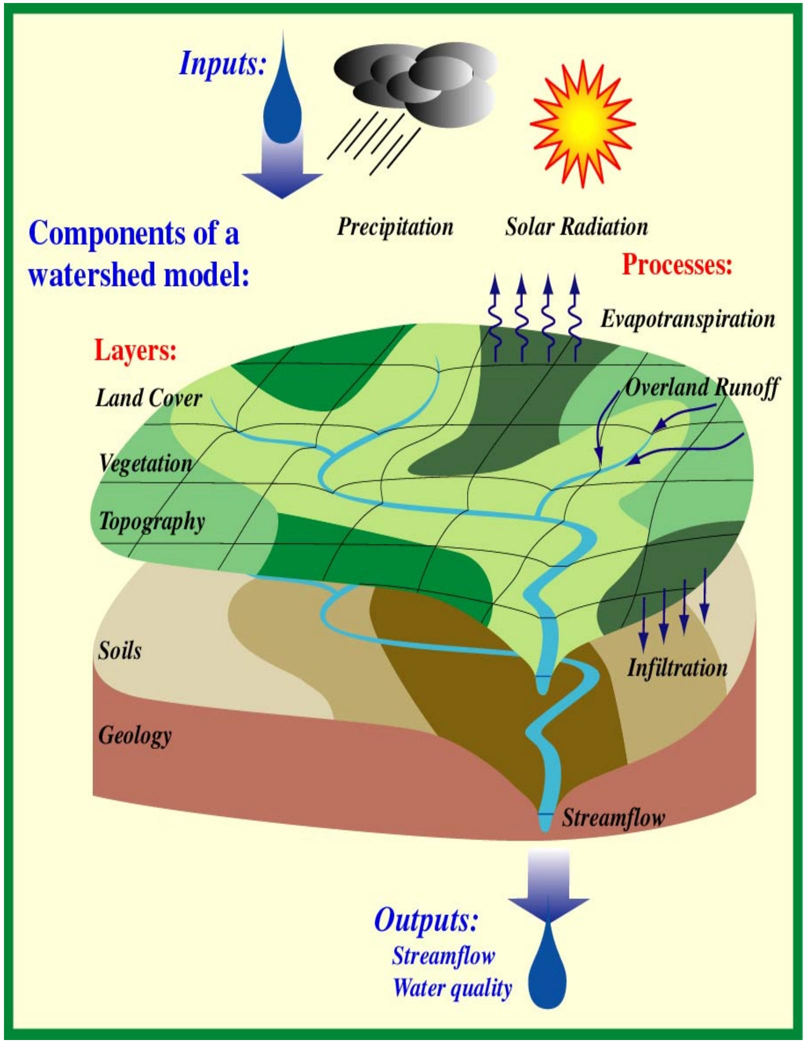
Phase II:

- **Goal**:
  - Quantify the partitioning of precipitation into recharge, runoff, and initial losses.
- **Methods**:
  - Soil and Water Assessment Tool (SWAT).
    - Continuous model.
    - Public domain and GIS friendly.
    - Open source code developed and supported by USDA.
    - Computes several hydrologic variables.

SWAT

Inputs:

- Precipitation
- Topography
- Geology/Soil
- Landuse
- Meteorological datasets (solar radiation, air temperature, relative humidity, and wind speed)
- Other Parameters

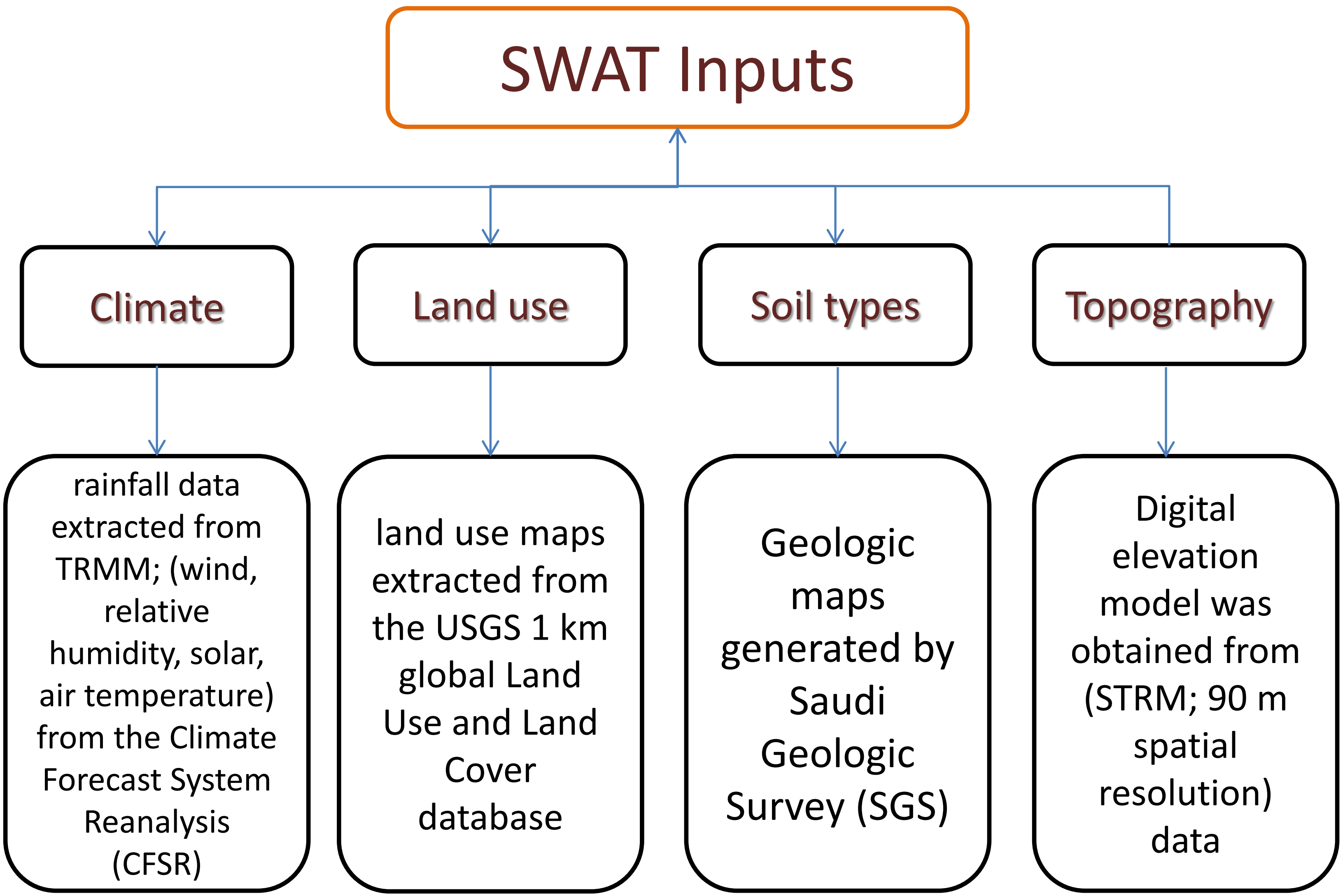


Source: SWAT documentation

Outputs:

- Recharge
- Evapotranspiration
- Evaporation
- Infiltration
- Overland flow
- Runoff

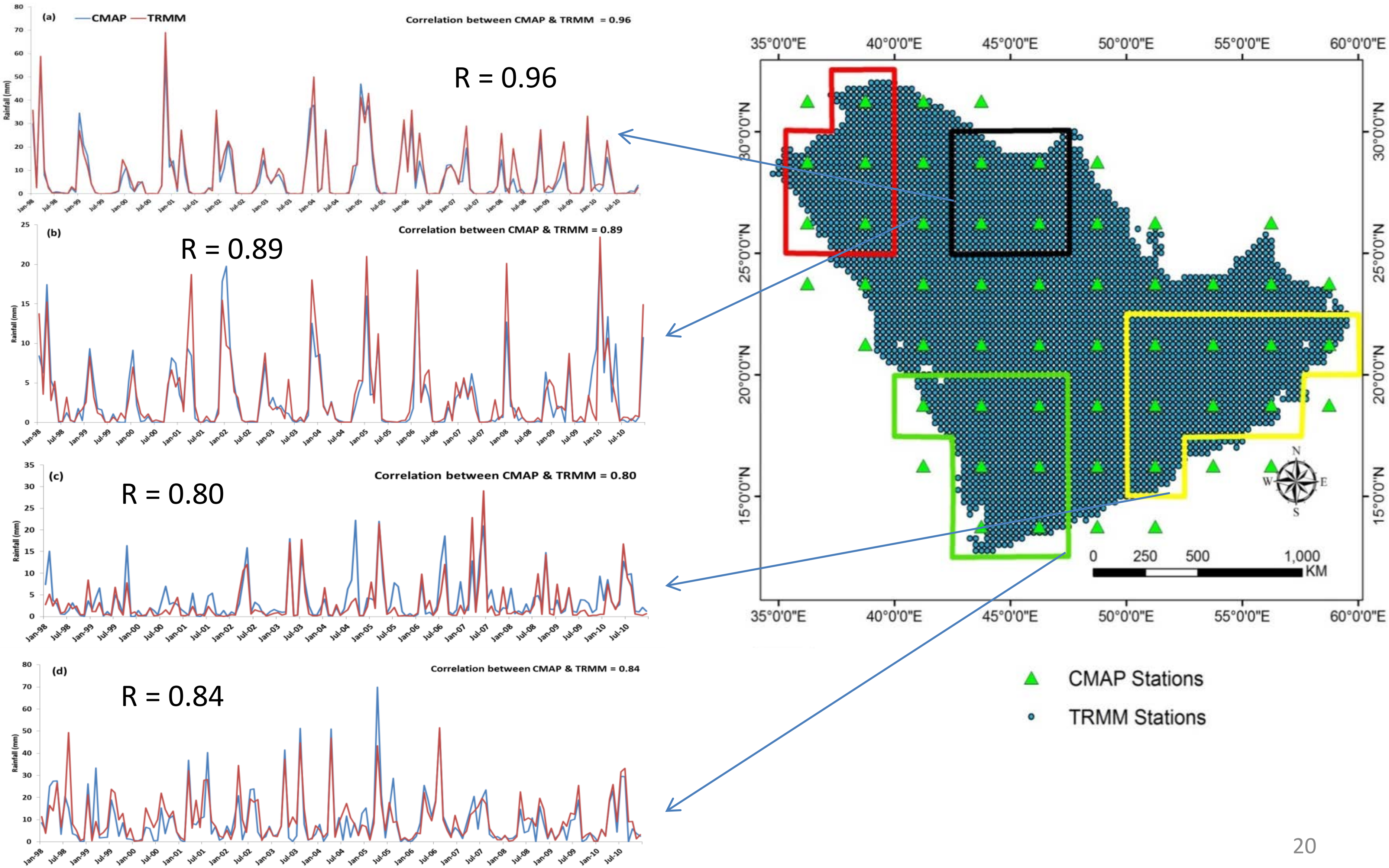
SWAT Inputs:


SWAT Inputs
Climate
Land use
Soil types
Topography
rainfall data extracted from TRMM; (wind, relative humidity, solar, air temperature) from the Climate Forecast System Reanalysis (CFSR)
land use maps extracted from the USGS 1 km global Land Use and Land Cover database
Geologic maps generated by Saudi Geologic Survey (SGS)
Digital elevation model was obtained from (STRM; 90 m spatial resolution) data

SWAT Rainfall Inputs:

- CMAP data:
  - Temporal Resolution: Monthly
  - Spatial Resolution: 2.5° × 2.5°
  - Temporal coverage: 1979-2011
- TRMM data:
  - Temporal Resolution: 3 hr
  - Spatial Resolution: 0.25° × 0.25°
  - Temporal coverage: 1998-Present

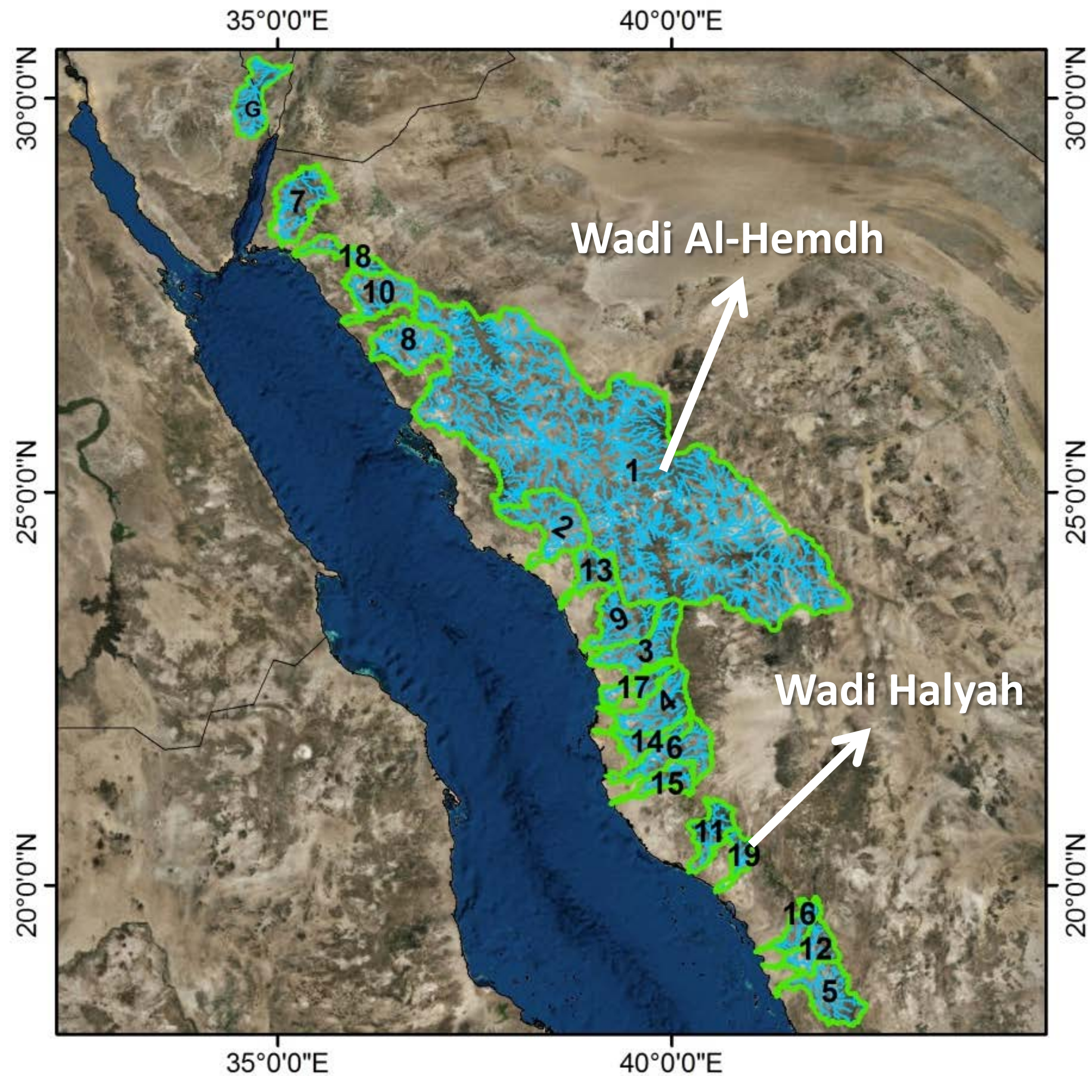
CMAP/TRMM comparison:



SWAT Watersheds:

107769 Km^2 (Wadi Al-Hemdh)

1825 Km^2 (Wadi Halyah)



1. Wadi Al-Hemdh
2. Wadi Yanbu An-Nakhl
3. Wadi Rabigh
4. Wadi Khulays
5. Wadi Haly
6. Wadi Fatimah
7. Wadi Ifal
8. Wadi Thalbah
9. Wadi Masturah
10. Wadi Damah
11. Wadi Al-Lith
12. Wadi Yabah
13. Wadi Al-Safra
14. Wadi As Sughu
15. Wadi Numan
16. Wadi Qanunah
17. Wadi Qidayd
18. Wadi Shiqri
19. Wadi Halyah

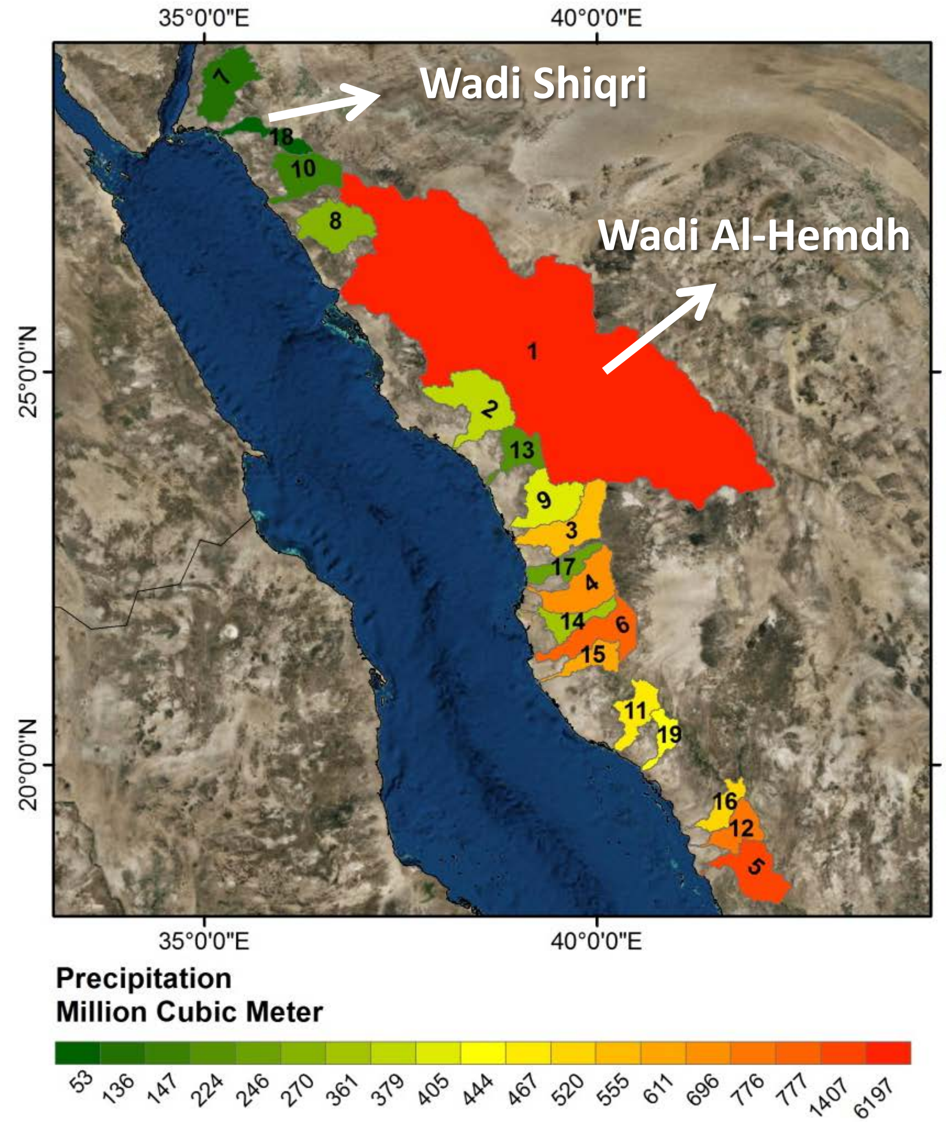
G. Wadi Girafi

SWAT Results (1):

1998-2010

$6197 \times 10^6\ m^3$ (Wadi Al-Hemdh)

$53 \times 10^6\ m^3$ (Wadi Shiqri)



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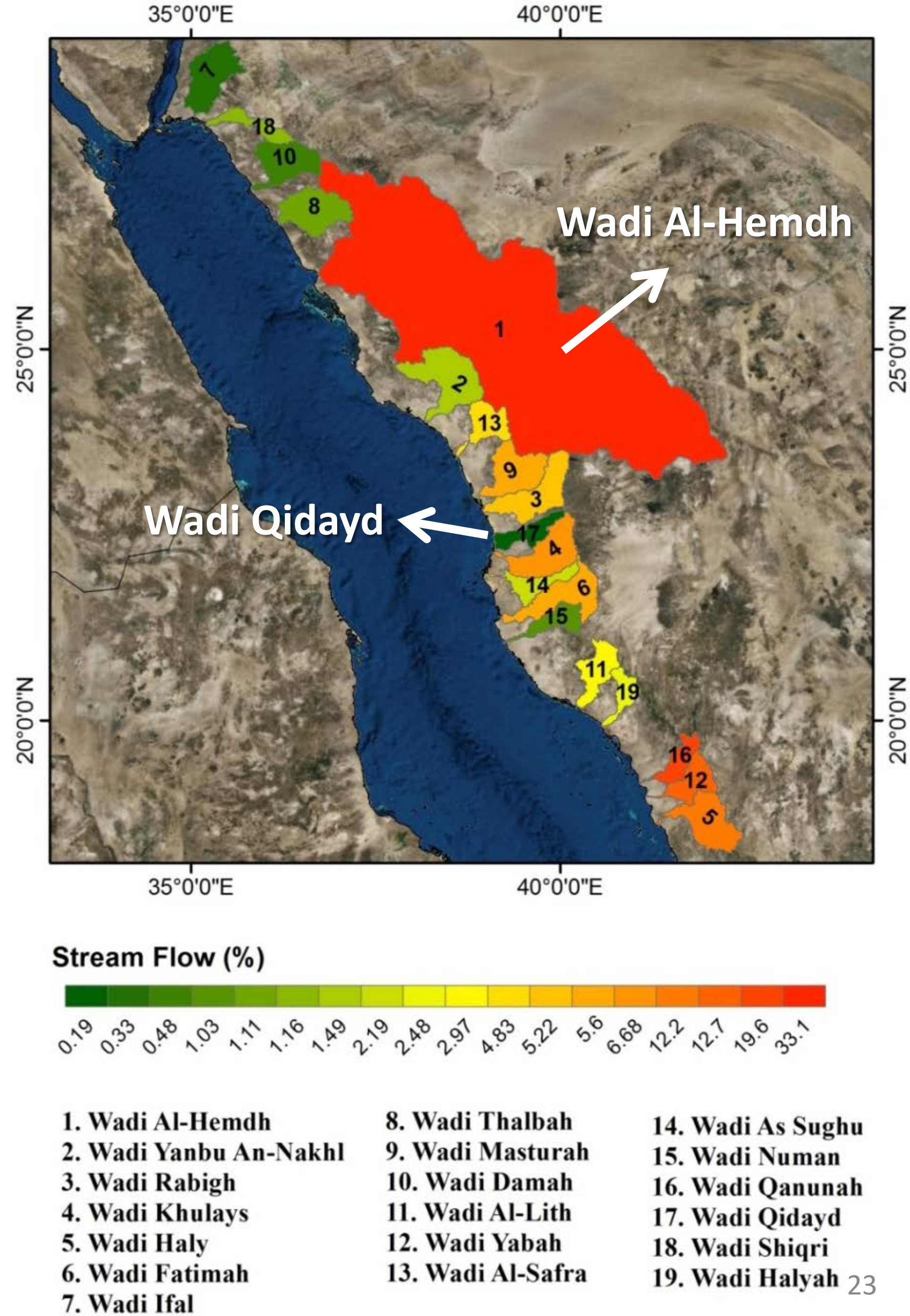
SWAT Results (2):

1998-2010

33% of rainfall (Wadi Al-Hemdh)

<1% of the rainfall (Wadi Qidayd)

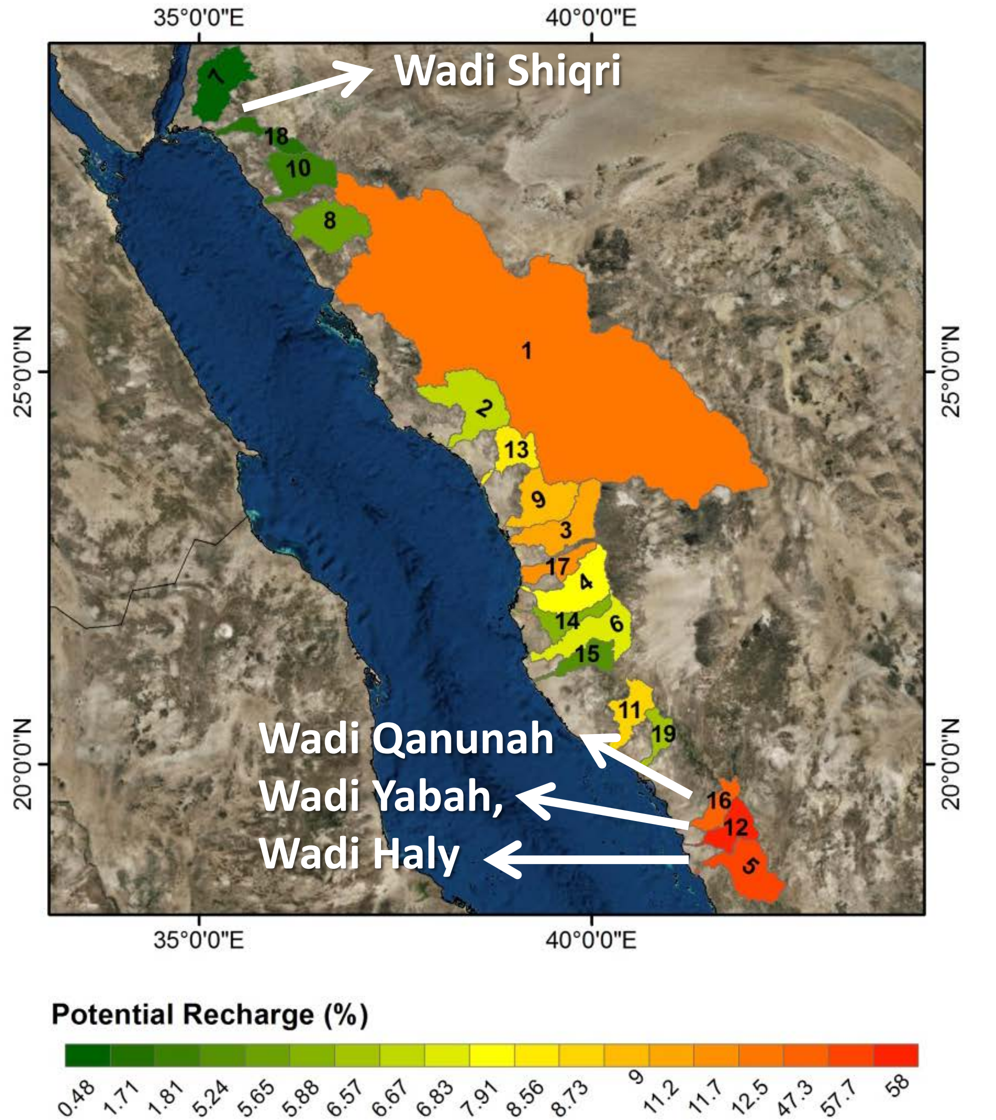


SWAT Results (3):

1998-2010

40% of rainfall (Wadis Haly, Yabah, and Qanunah)

<1% of the rainfall (Wadi Shiqri)



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Phase II: Conclusions

- CMAP data is highly correlated with TRMM data,
- Increasing the proportion of areas occupied by basement and/or increasing precipitation amounts increases the proportion of stream flow,
- The larger the amount of precipitation and the runoff, the greater the amount of transmission losses and potential recharge.

Thank You