# *Impact of Climate Change on Water Resources of a Semi-arid Basin- Jordan*

**Prof. Fayez Abdulla**
**Civil Engineering Department**
**Jordan University of Science & Technology**

**Presented at the**

**Water in an Arid Land, the Engineered Water Cycle in Jordan**

**Queen Rania Al-Abdullah Center for Environmental Science & Technology**

**Aug, 29, 2012**

# Climate Change Impacts

Changes in GHGs are projected to lead to regional and global changes:

- Temperature and precipitation
- Soil moisture
- Increase in sea level,
- Increase in the incidence of extreme high temperature events, floods and droughts.

## Water Resources Systems & Climate Change

- Water resources systems are designed and operated to cope with the expected natural variability of climate such as floods and drought.

- These systems may not be adequate to handle significant long-term climate changes.

- Therefore, the possible future global warming, with climate drying or wetting, raises concern about impacts on water resources.

## Water Resources Systems & Climate Change

- **Variability of climate parameters, such as precipitation and temperature, is amplified by hydrological processes.**

## Water Resources Systems & Climate Change

- **Traditionally, water resources systems are designed on the assumption that the statistical characteristics of the prevailing climatic and hydrometeorological processes never change (stationary).**

- **It is absolutely necessary that future projects be designed and all projects be operated taking into account the fact that climate is non-stationary**

# Regional Impacts of Climate Change

*(arid and semi-arid region of the Middle-East)*

- **Desertification**

- A decrease in soil moisture throughout the region may lead to increased areas of desertification
- Little change is expected in vegetation in arid (or desert) region

- The impact may be considerable in the semiarid lands of the region

# Regional Impacts of Climate Change

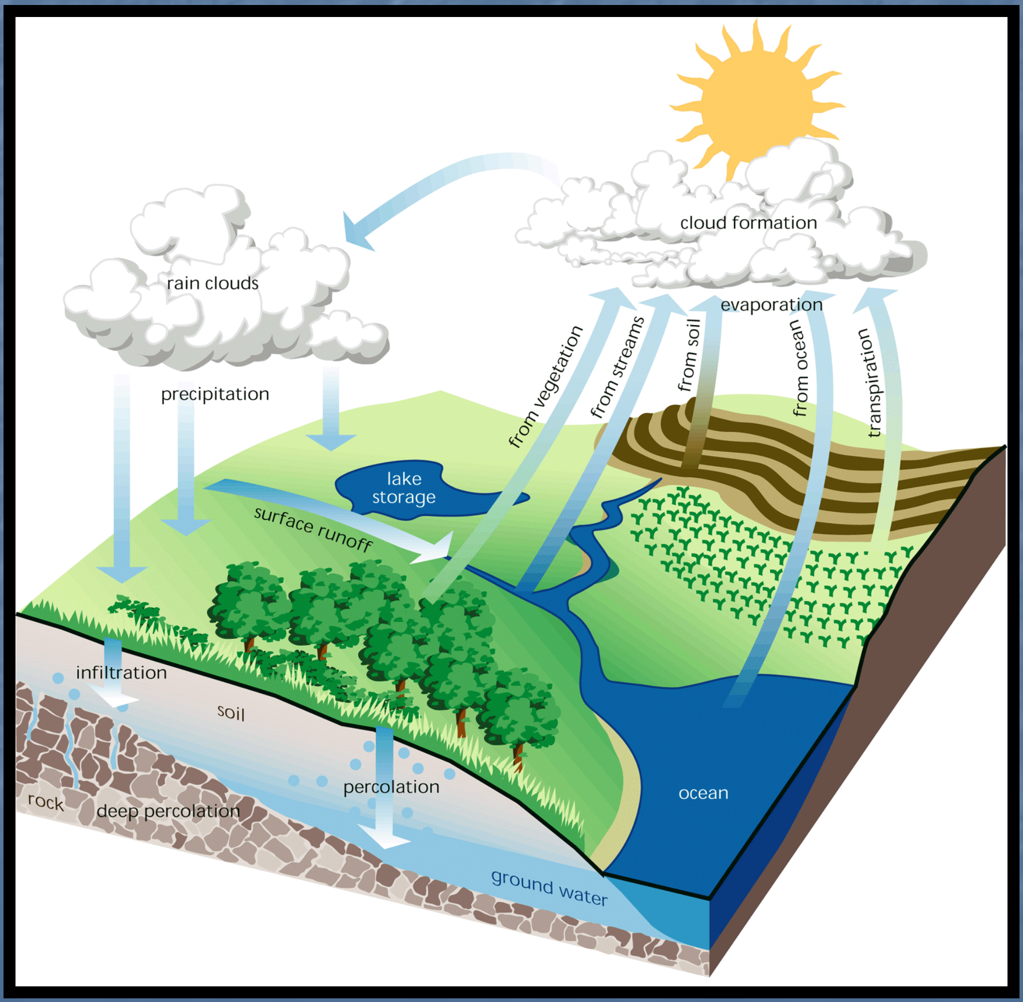
*(arid and semi-arid region of the Middle-East)*

## Hydrology

- Water shortage is already a problem in many countries of the arid region and it will be increased with climate change.

-Arid region could experience large decrease in runoff of up to 40% in some basins

# Objectives

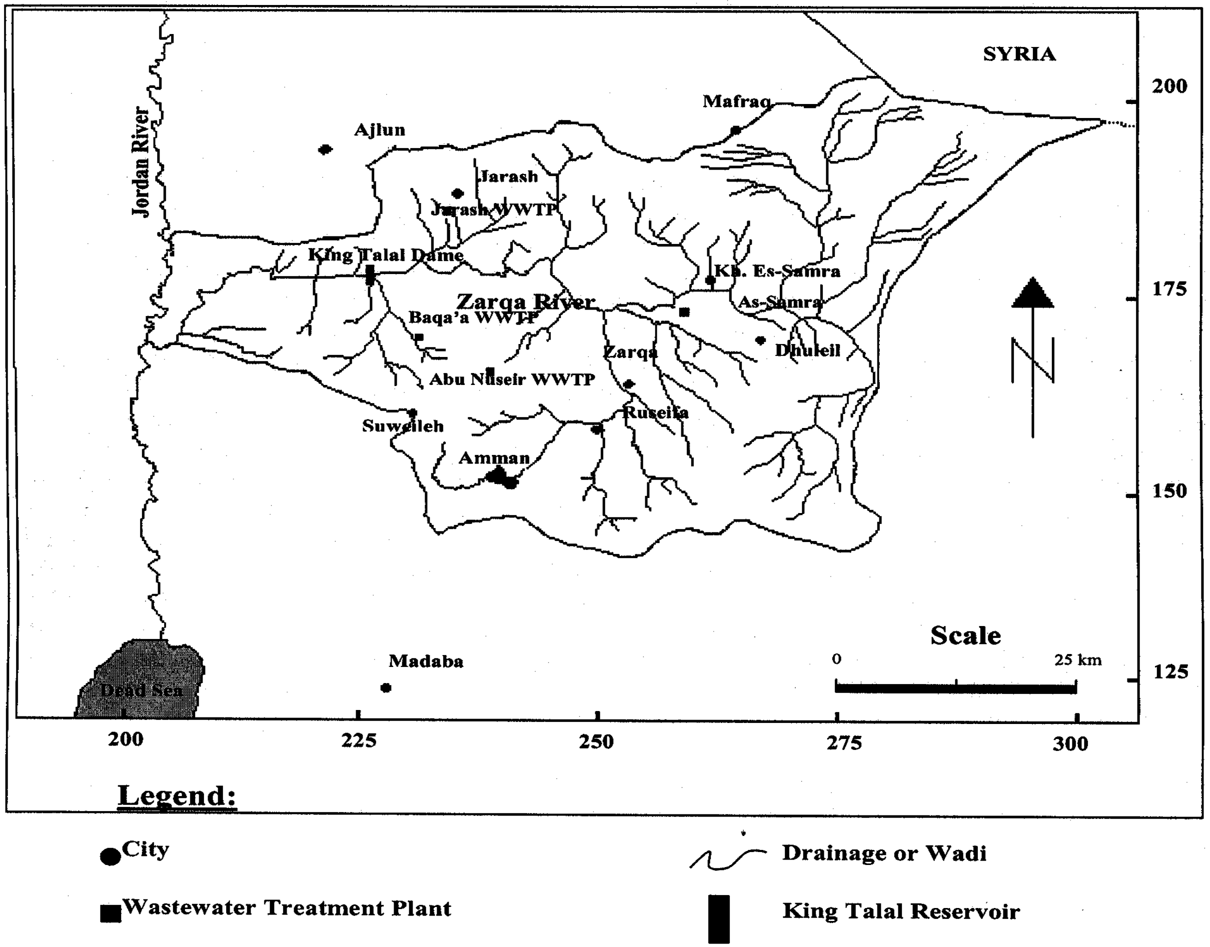



- Develop Climate Change Scenarios for Jordan
- **investigate the impact of climate change on monthly runoff of Zarqa River Basin under alternative climate change scenarios**

# Methodology

- Data collection
- Data preparation
- Climate change Scenarios
- Rainfall-Runoff Modeling (Calibration and Validation)
- Climate change impact

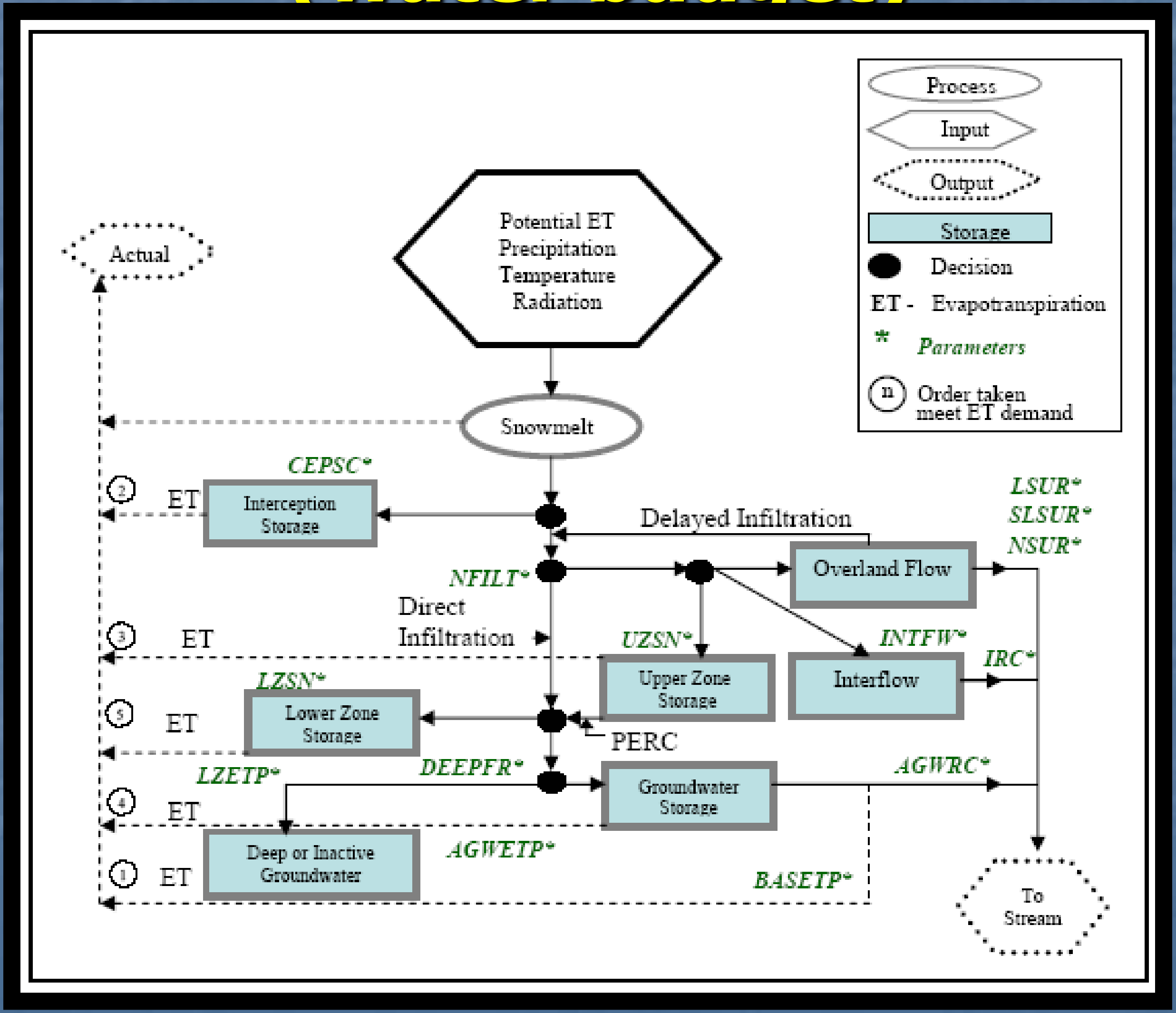
# STUDY AREA


SYRIA
Jordan River
Mafraq
Ajlun
Jarash
Jarash WWTP
King Talal Dame
Kh. Es-Samra
As-Samra
Zarqa River
Baqa'a WWTP
Zarqa
Dhuleil
Abu Nuseir WWTP
Ruseifa
Suweileh
Amman
Madaba
Dead Sea
Scale
0
25 km
200
175
150
125
200
225
250
275
300
Legend:
City
Wastewater Treatment Plant
Drainage or Wadi
King Talal Reservoir

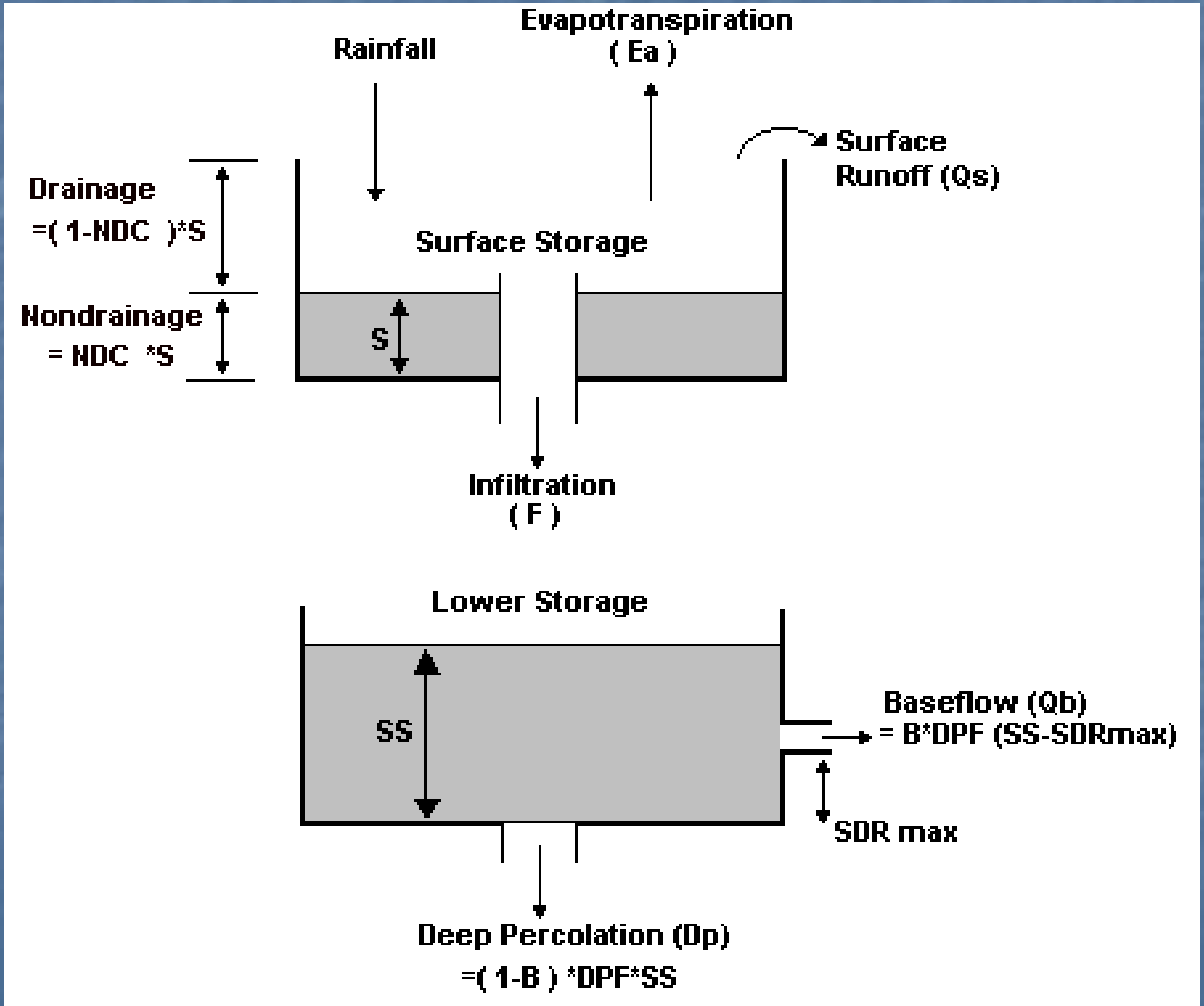
# STUDY AREA

- Zarqa River Basin is a major surface water system and was selected to reflect actual changes to the existing water resources of Jordan
- Drainage Area 3300 Sq. Km
- Elevation -350 to 1100 m a.ms.l.
- Mean Annual Rainfall 400 mm (W) and 150 mm (E)
- KTD is the largest Dam with Capacity of 86MCM

# Standard watershed modeling in HSPF (water budget)

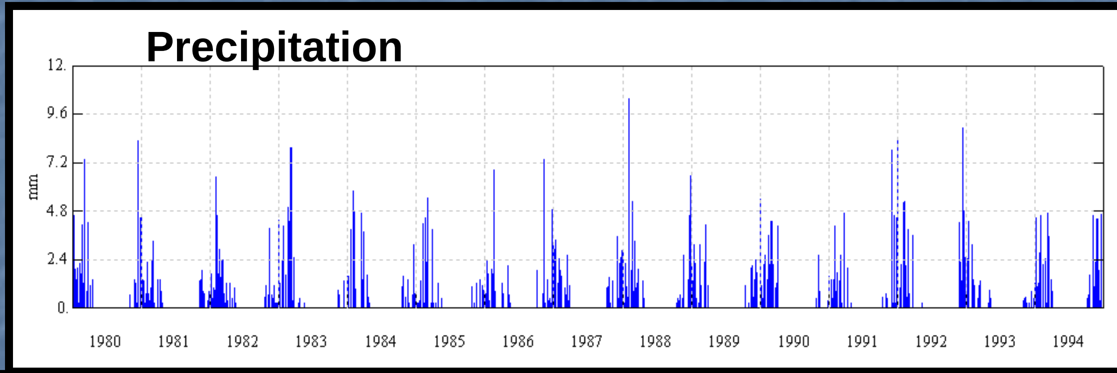


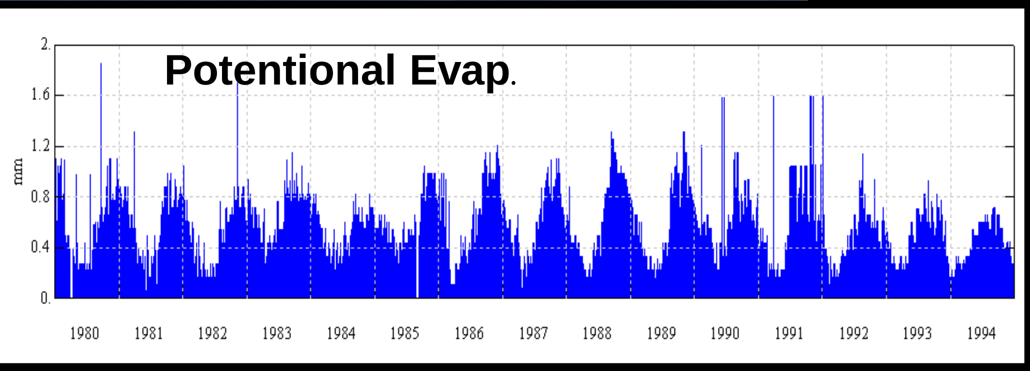
# SFB MODEL

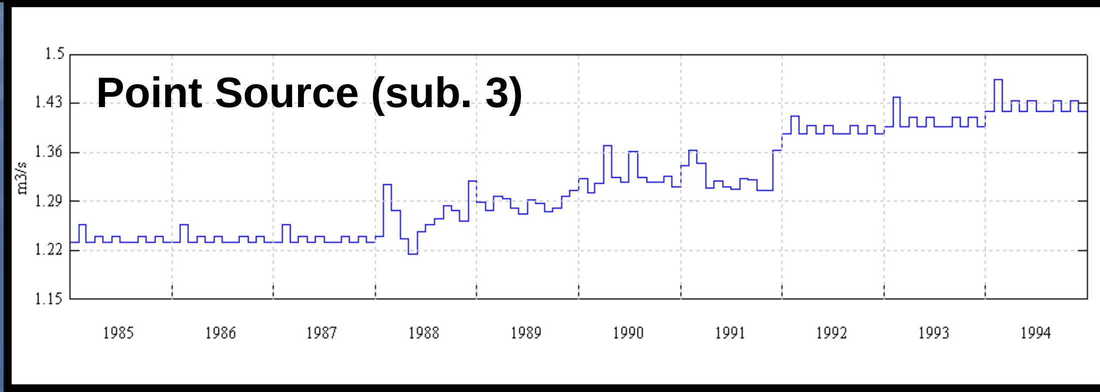


Evapotranspiration
( Ea )
Rainfall
Surface
Runoff (Qs)
Drainage
=( 1-NDC )*S
Surface Storage
Nondrainage
= NDC *S
S
Infiltration
( F )
Lower Storage
SS
Baseflow (Qb)
= B*DPF (SS-SDRmax)
SDR max
Deep Percolation (Dp)
=( 1-B ) *DPF*SS

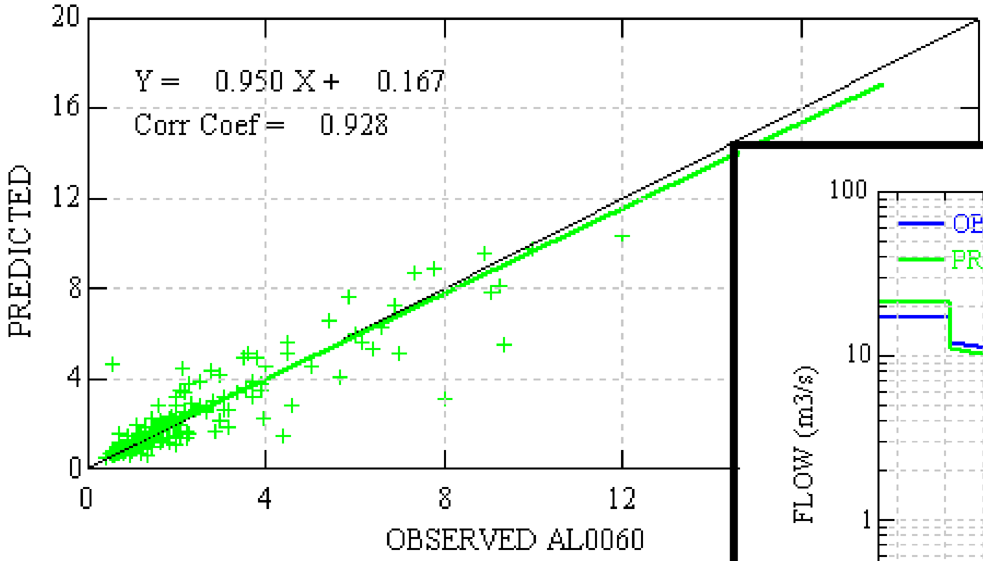
# Rainfall, Evaporation & Point source data

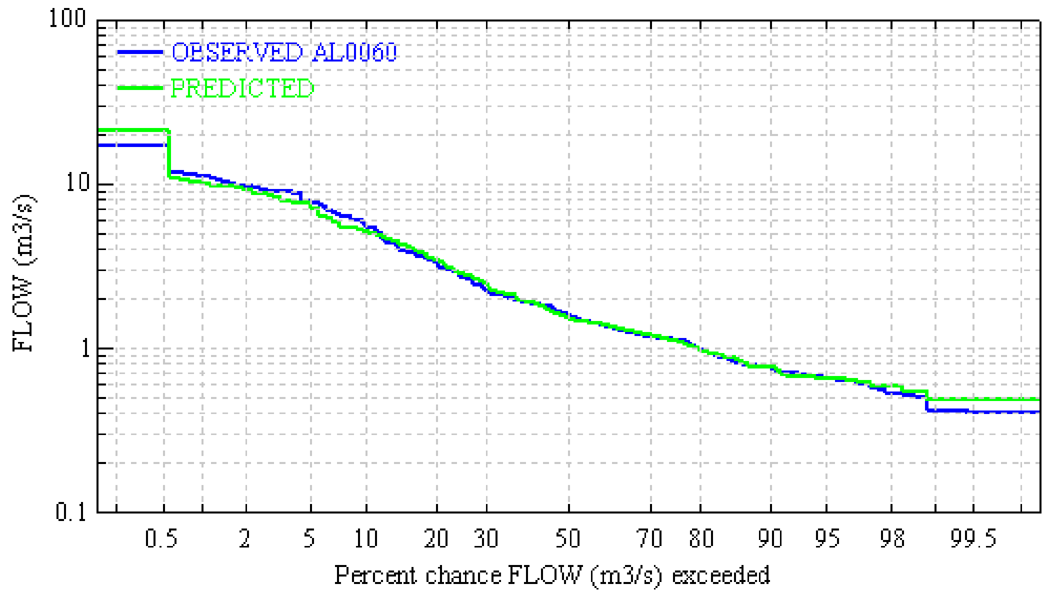


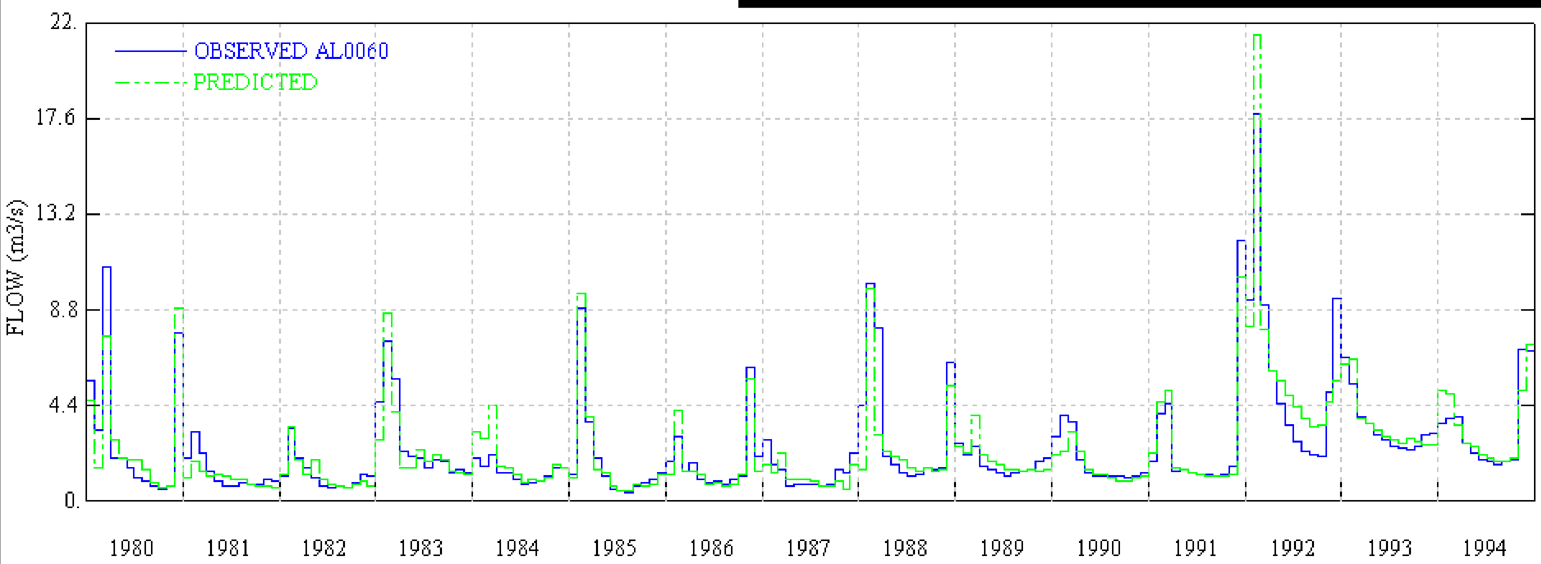



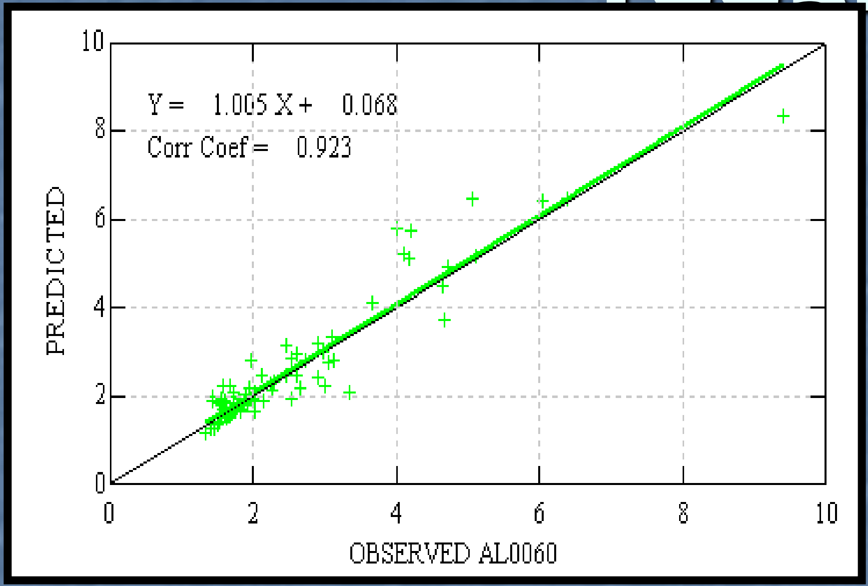
# Monthly mean flow



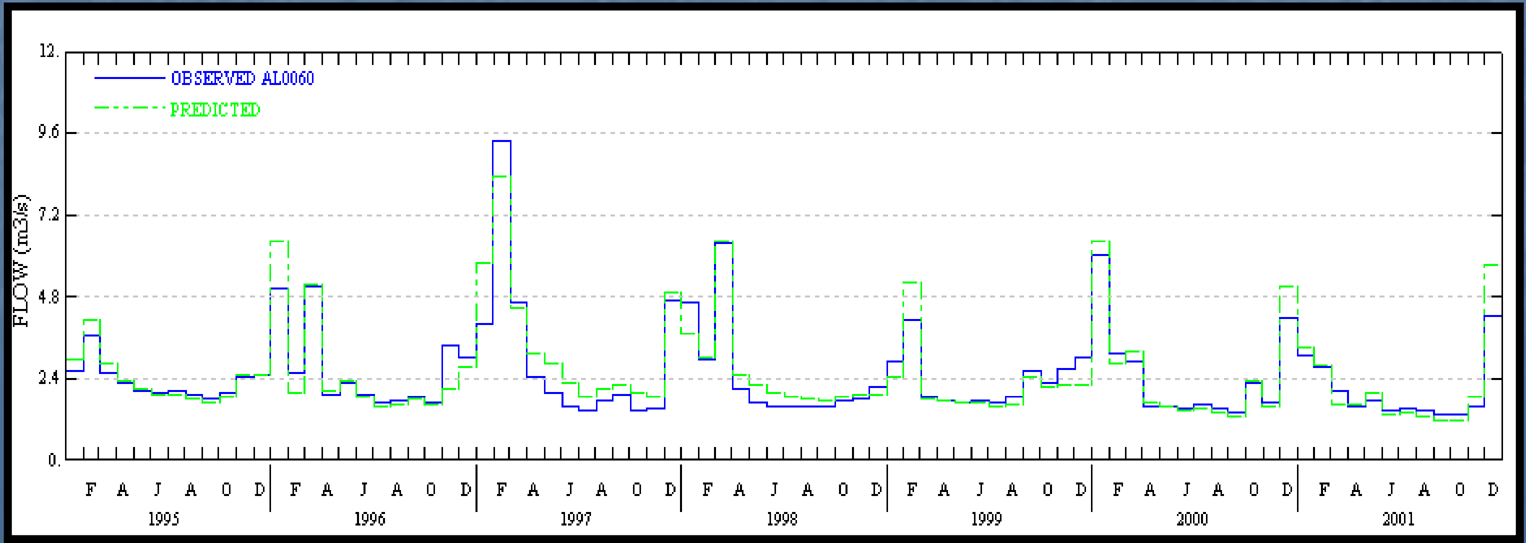



# Validation process (HSPF) 1995-2001




**Monthly mean flow**



# Climate Change SCENARIOS

- **BASELINE CLIMATE SCENARIOS**
- **GCM CLIMATE CHANGE SCENARIOS**
- **INCREMENTAL CLIMATE CHANGE SCENARIOS**

# BASELINE CLIMATE SCENARIOS

**Thirty-eight years (1964-2002) of historical climate and hydrological data were used to develop the baseline scenarios**

- ***Daily temperature***
- ***Daily precipitation***
- ***Daily streamflow***
- ***Daily potential evaporation***

# CLIMATE CHANGE SCENARIOS

***GCMs Climate Change Scenarios***

***Review has been made for the existing GCMs***

***Two GCMs are used Hadley and MPI Models***

- ***Resolution in grid size (2.5 x 3.75 deg lat. xlong.)***
- ***Recently have been used in number of climate change studies***
- ***The outputs of Hadley and MPI models have been retrieved and extracted from IPCC Data Distribution Center (DDC) for climate change studies***

# CLIMATE CHANGE SCENARIOS

***GCMs Climate Change Scenarios***

***Outputs include monthly temperature and precipitation***

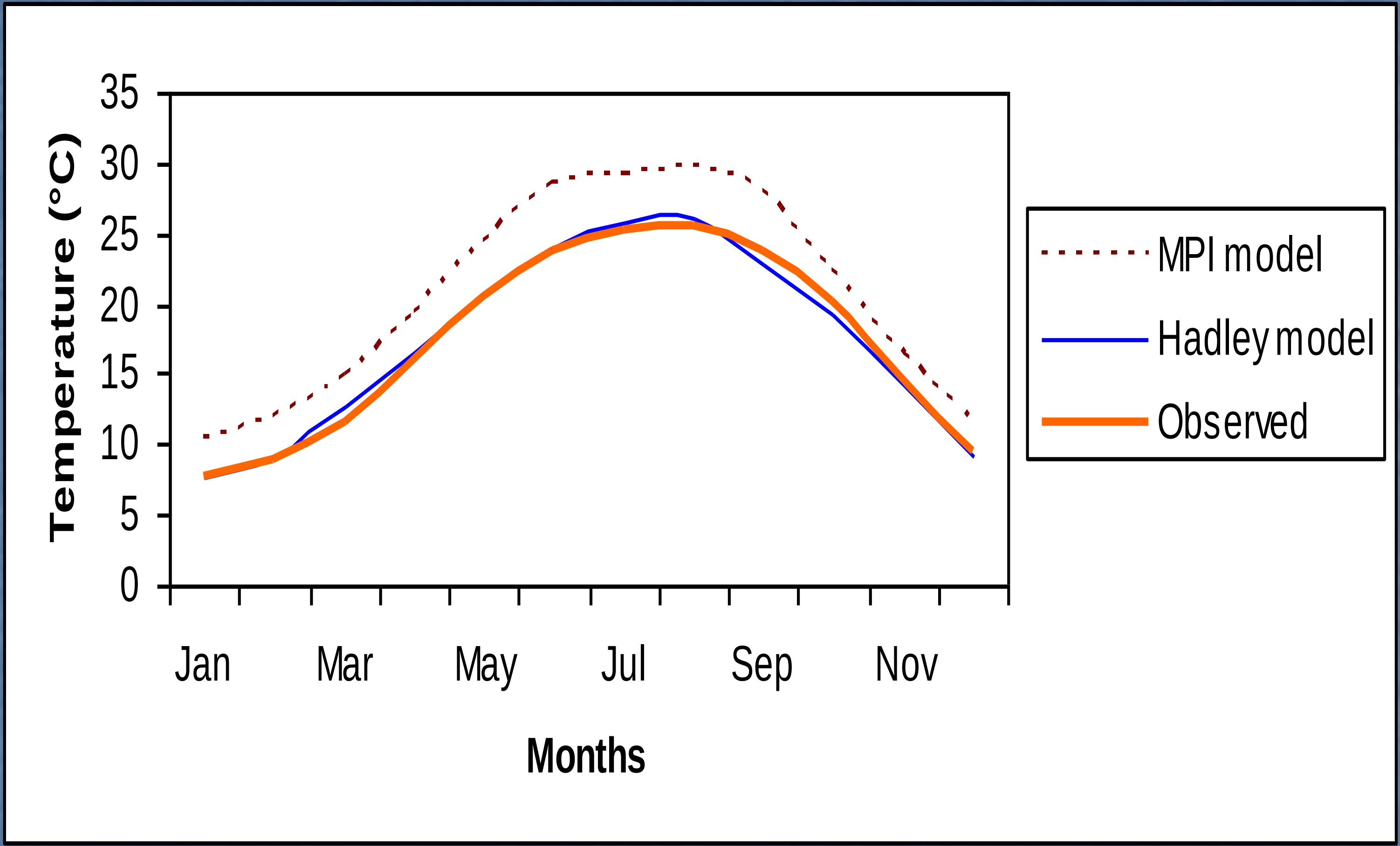
***1xCO2 (Current Run)***

***2xCO2 (Transient Run or Climate Change Run)***

***Re-grid this global data to the area of interest at coarse resolution in our case the Jordan at 1 degree resolution***

***Need latitude and longitude and Elevations for the new points***

# GCM SELECTION




**Comparison of baseline 1960-2000 average mean monthly temperature and 1× CO2 GCM scenarios for Zarqa River Basin**

# Statistical adjustment for difference between $2xCO_2$ and current ($1xCO_2$) as estimated Hadley and MPI models for Zarqa River basin.

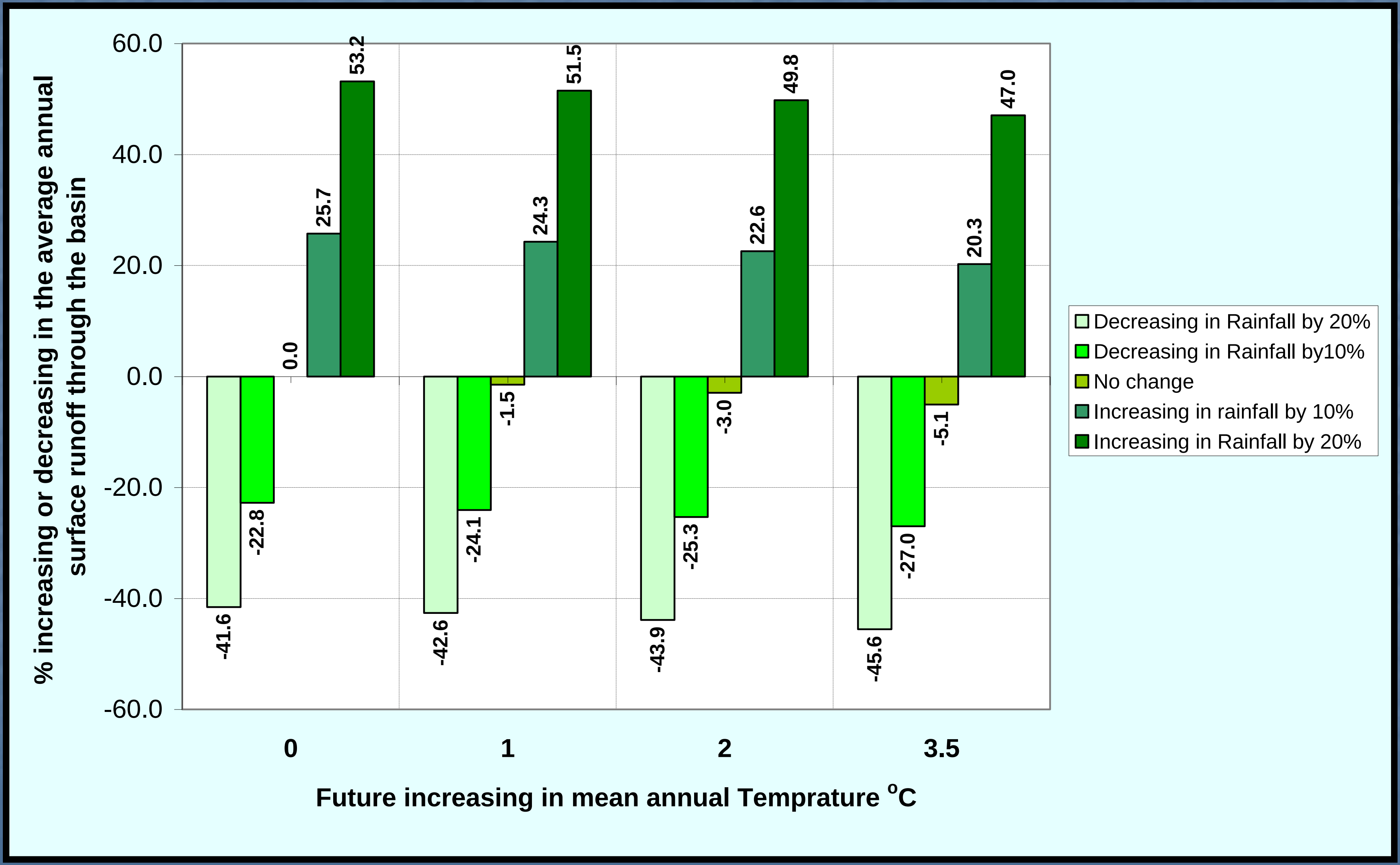
| Month | Hadley Model | | MPI Model | |
|---|---|---|---|---|
| | Temperature Difference | Precipitation Ratio | Temperature Difference | Precipitation Ratio |
| January | 1.43 | 0.73 | 1.04 | 1.07 |
| February | 0.98 | 0.84 | 0.49 | 0.64 |
| March | 1.29 | 1.05 | 0.37 | 1.28 |
| April | 0.71 | 1.28 | 1.17 | 0.91 |
| May | 0.31 | 1.5 | 1.37 | 1.77 |
| June | 0.95 | --- | 2.29 | --- |
| July | 0.31 | --- | 2.26 | --- |
| August | 0.5 | --- | 2.74 | --- |
| September | 0.8 | --- | 2.51 | --- |
| October | 1.11 | 0.87 | 2.91 | 1.37 |
| November | 0.52 | 0.79 | 1.94 | 0.88 |
| December | 1.16 | 0.7 | 1.21 | 0.83 |
| Average | 0.85 | | 1.63 | |

# Incremental Climate Change Scenarios

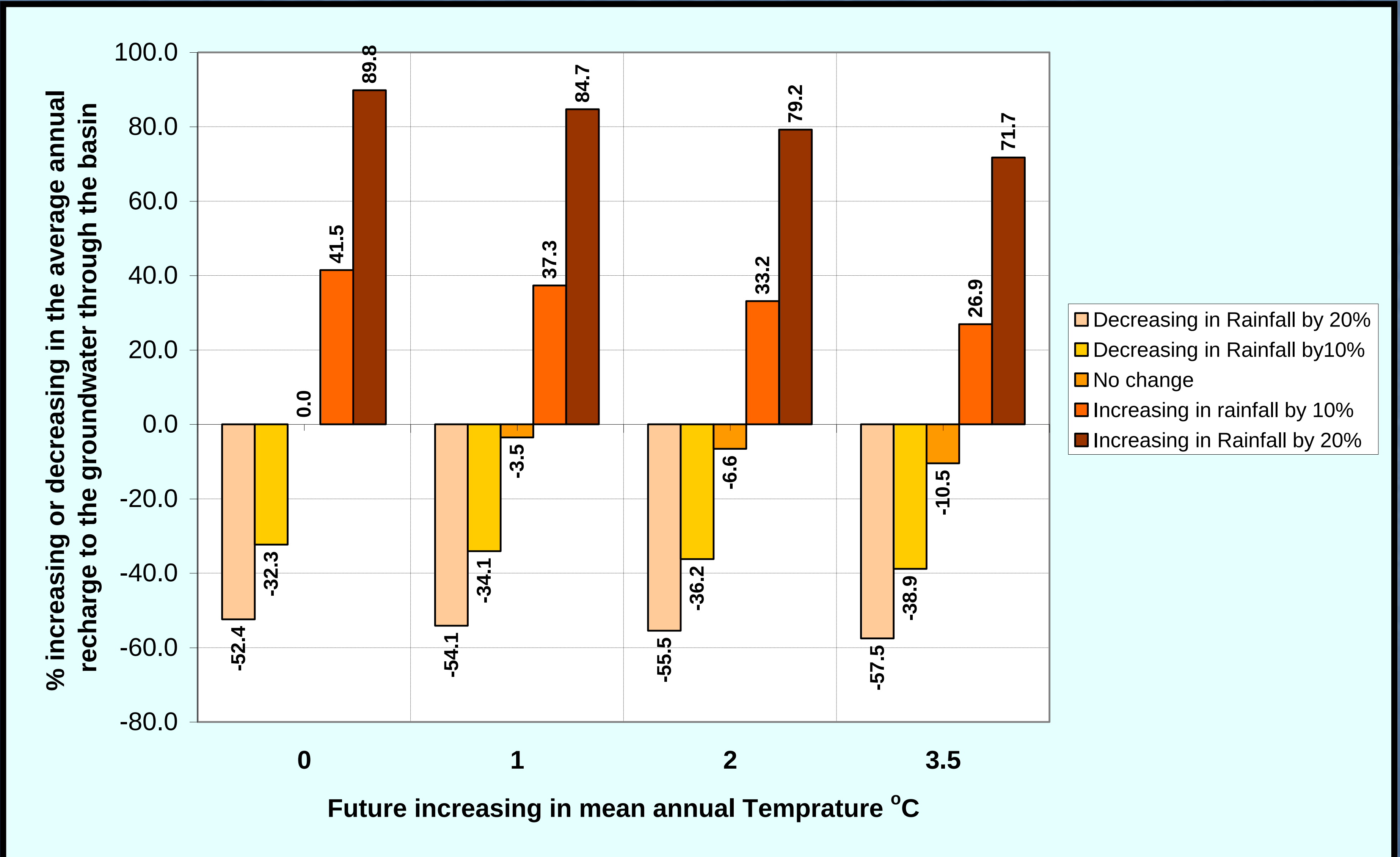
- it is anticipated to further increase by 1–3.5 ºC over the next 100 years.
- This will lead to change precipitation by ±20%

| | | Rainfall Scenarios | | | | |
|---|---|---|---|---|---|---|
| | | -20% | -10% | 0 | 10% | 20% |
| Temp. Scenarios | +0 ºC | ■ | ■ | | ■ | ■ |
| | +1 ºC | ■ | ■ | ■ | ■ | ■ |
| | +2 ºC | ■ | ■ | ■ | ■ | ■ |
| | +3.5 ºC | ■ | ■ | ■ | ■ | ■ |

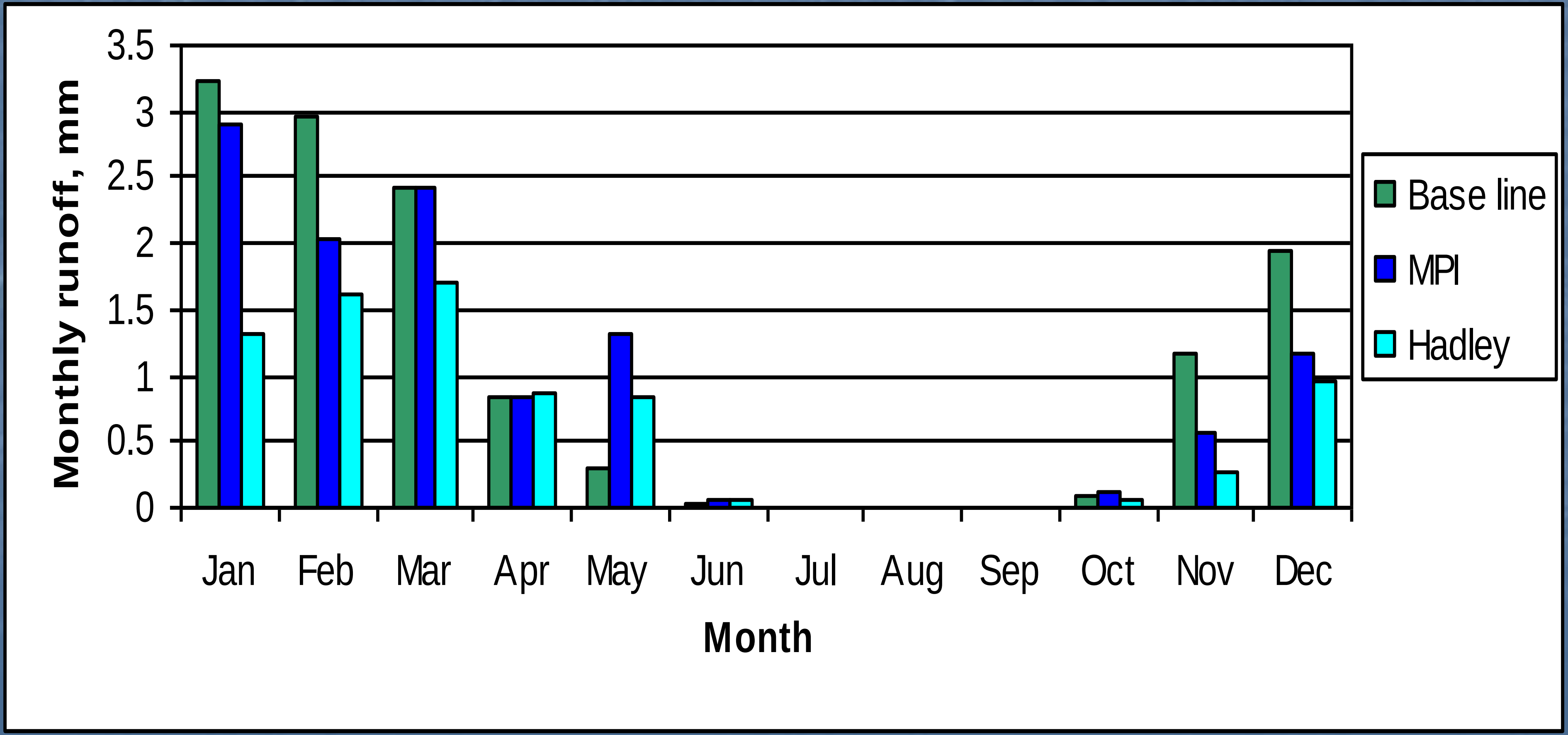
# Climate Scenario Effect on Surface runoff (HSPF)



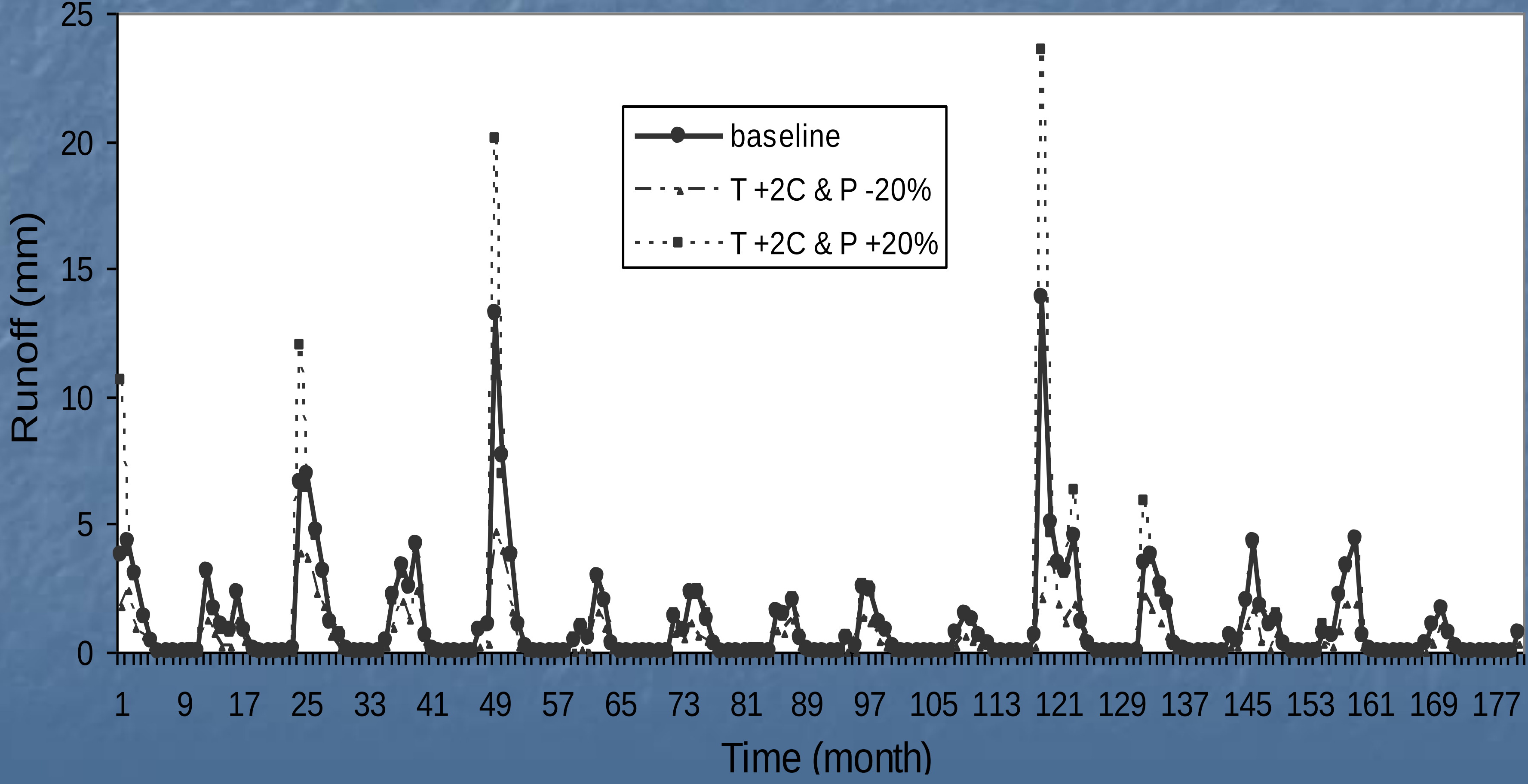
# Climate Scenario Effect on Discharge to GW (HSPF)



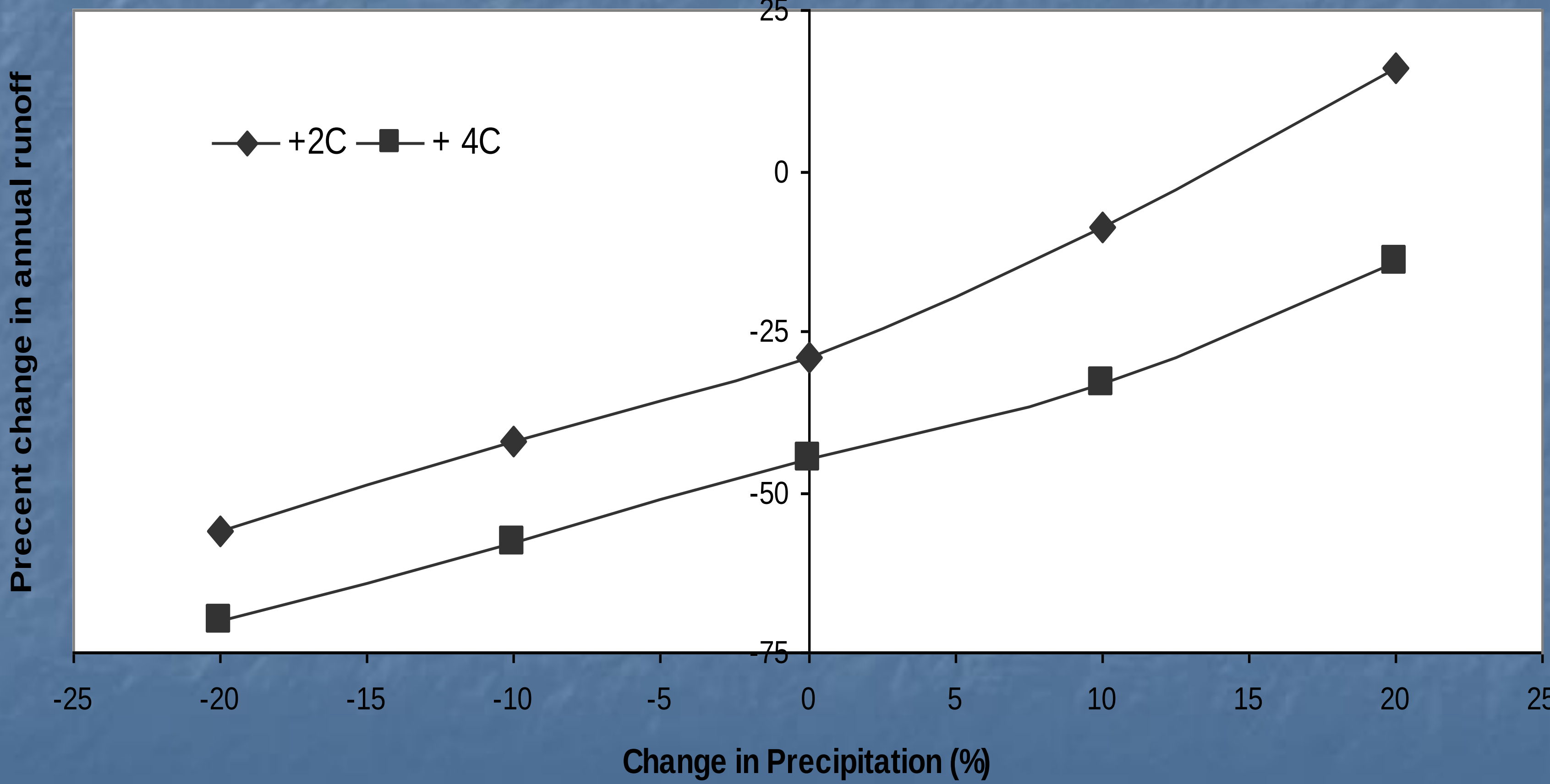
# Changes in Monthly Runoff of Zarqa River Basin Under Different GCMs Scenarios



# Changes in Monthly Runoff of Zarqa River Basin Under Different Incremental Scenarios



# Mean Annual Runoff Changes Under Different Incremental Climate Change Scenarios



# CLIMATE CHANGE SCENARIOS RESLUTS FOR JORDAN

*Hadley model is well representative for the Zarqa River basin in terms of temperature simulation*

*Hadley and MPI simulations were not close to the observed data for all sites. Unfortunately, most of the GCMs highly overestimate precipitation during winter.*

*MPI model suggests that by 2040 the mean temperature is expected to increase by 1.7 in Jordan.*

*Hadley model suggests that the mean temperature are expected to increase by 0.89 C.*

*In the middle of the current century  the mean annual temperature tends to increase by 2.5 C and 1.7 C using both MPI and Hadley model .*

*By the year 2100 the mean monthly temperature increase according to Hadley model tends to increase by 4 C.*

# CLIMATE CHANGE SCENARIOS RESLUTS

*Precipitation in Jordan tends to decrease in the period from November to February and tends to increase in March to May*

*For example, the MPI model suggests that precipitation will be decreased by 4% to 22% at the study area. However, the Hadley model suggests that in this period precipitation tends to decrease by 17% at Amman station.*

# CLIMATE CHANGE ASSESSMENT

## Results of Runoff Vulnerability

- ***The runoff decreases as temperature increases.***

- ***The timing of the peak flow is not changed but the magnitude of these peaks are reduced.***

- ***The effect of adding or subtracting 10 percent of precipitation alone to the observed record was as expected. Greater precipitation translated into higher runoff volume during winter. The opposite phenomena occurred when precipitation amounts were reduced by 10 percent.***

# CLIMATE CHANGE ASSESSMENT

## Results of Runoff Vulnerability

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- ***The effect of adding or subtracting 10 percent of precipitation alone to the observed record was as expected. Greater precipitation translated into higher runoff volume during winter. The opposite phenomena occurred when precipitation amounts were reduced by 10 percent.***
- ***The largest change in annual runoff occurred when combining a +4C with a -20% change in precipitation***

# CONCLUSIONS

- ***Both sets of climate change scenarios resulted in decreases in monthly runoff. Also, the timing of the peak flow is not changed but the magnitudes of these peaks are reduced. Differences in hydrological results among all climate cases are due to wide range of changes in climate variables.***

- ***The GCM scenarios for 2x CO2 obtained from the Hadley and the MPI models resulted in similar possible future river flows. Both models showed that the increase in temperature would reduce the monthly runoff for the rainy season except for April (no change) and May (increase). The overall trend indicated that mean annual runoff will be reduced by approximately 12% (in case of Hadley Model) and 40% (in case of IMP model).***

# CONCLUSIONS (cont)

- *The largest change in annual runoff (reduced by 70% of the current level) occurred when combining a +4C with a –20% change in precipitation. These results are similar to those reported by other researchers in the Middle East.*

- *For the incremental scenarios with temperature change from +2C to +4C and precipitation reduced by 10%, the annual runoff will be deceased from about 40 to 60%.*

- *With decreasing precipitation the effect could be critical, particularly during long and extreme droughts. However, for incremental scenarios with temperature changes from +2C to +4C, and precipitation increased by 10%, the annual runoff shows a decrease from 10 to 30%.*

- *The annul runoff in the Zarqa River basin will increase to approximately 20% under the incremental scenario in which the temperature +2oC and precipitation increased by 20%.*

# CLIMATE CHANGE ASSESSMENT

## Results of Runoff Vulnerability

- ***The runoff decreases as temperature increases.***
- ***The timing of the peak flow is not changed but the magnitude of these peaks are reduced.***
- ***The effect of adding or subtracting 10 percent of precipitation alone to the observed record was as expected. Greater precipitation translated into higher runoff volume during winter. The opposite phenomena occurred when precipitation amounts were reduced by 10 percent.***

# CONCLUSIONS

- Runoffs and groundwater recharge would decrease significantly if the climate warming is accompanied with 10% to 20% drop in rainfall. Up in this range the impact of a rainfall drop dwarfs that of temperature increase.

# Thank You