Joint High Resolution Climate-Hydrology Simulations for the Middle East and the Upper River Jordan Catchment

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Motivation

- water availability per capita in the Middle East one of the lowest worldwide (150 m^3/a)
- distribution of resource freshwater has high conflict potential
- future availability may be further restricted by population pressure and climate change
- hydrological focus: Upper Jordan catchment

$\Rightarrow$ provides 1/3rd of drinking water resources in Israel

Regional Climate Change Middle East and Upper Jordan River

Scientific Challenge

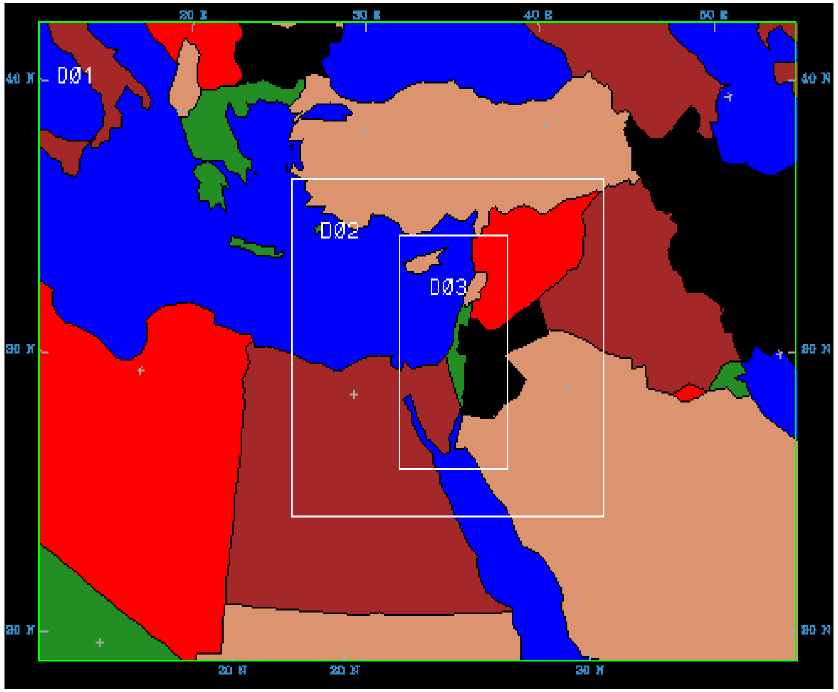
1) Changes in the regional climate can differ significantly from the overall trend of global climate change

2) Region has sharp climatic gradients: subhumid mediterranean ↔ arid climate

3) Resolution of global climate models are too coarse for hydrological impact studies
   ⇒ Higher resolution information required that account for regional and local geographic features (particularly orography, land use and water bodies)

Approach:
Dynamic downscaling of global climate scenarios

The Mesoscale Meteorological Model MM5

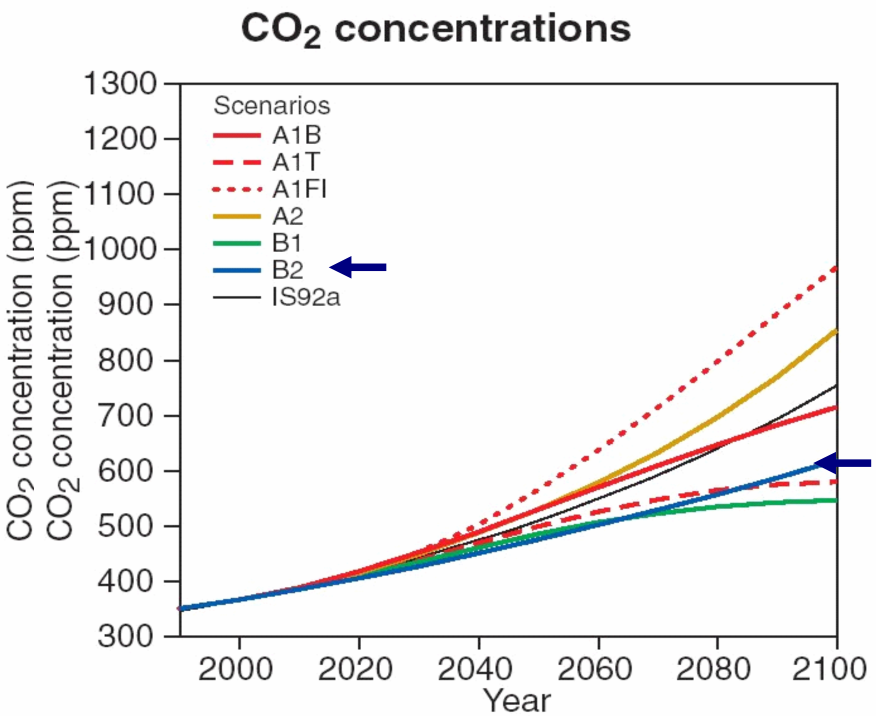


- Dynamic Downscaling of ECHAM4 with MM5
- 3 nests: 54x54 km^2, 18x18 km^2, 6x6 km^2
- 26 Vertical Layers, Model Top: 100 mbar
- Coupled OSU-Land-Surface Model
- Time slices: 1961-1990 & 2070-2099

Global Scenarios

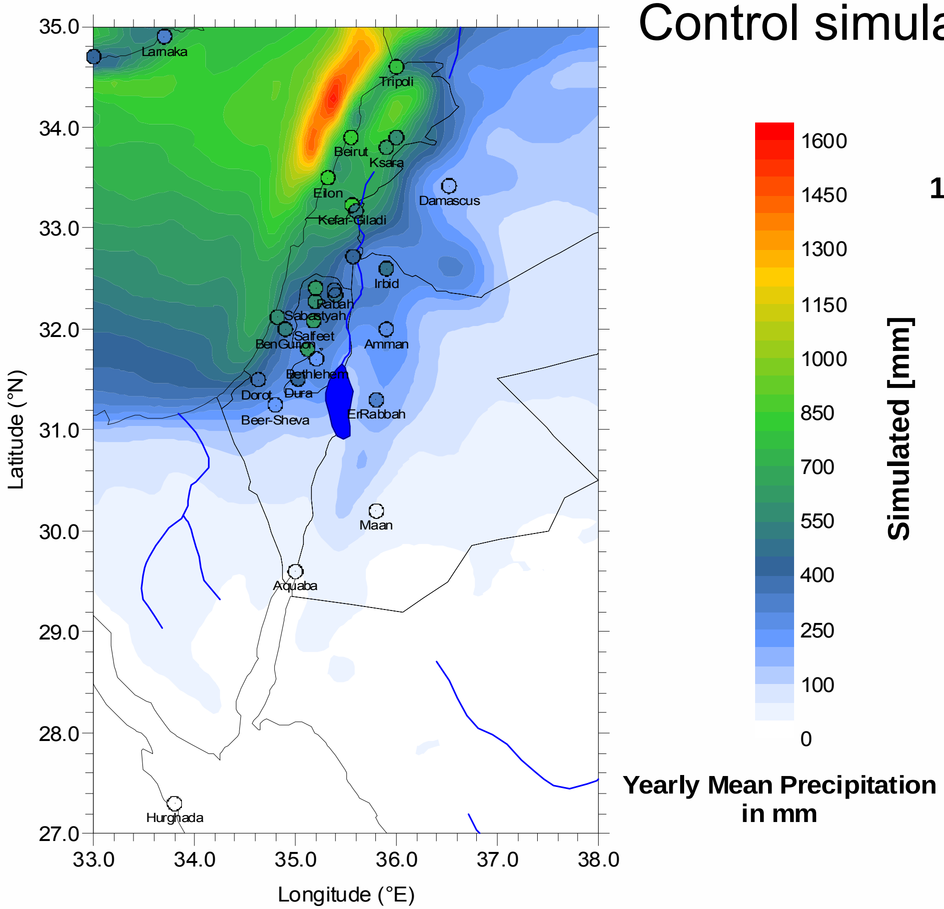
- **This study: scenario B2**
  (*"local solutions"*)
- Increase of CO_2: 30%

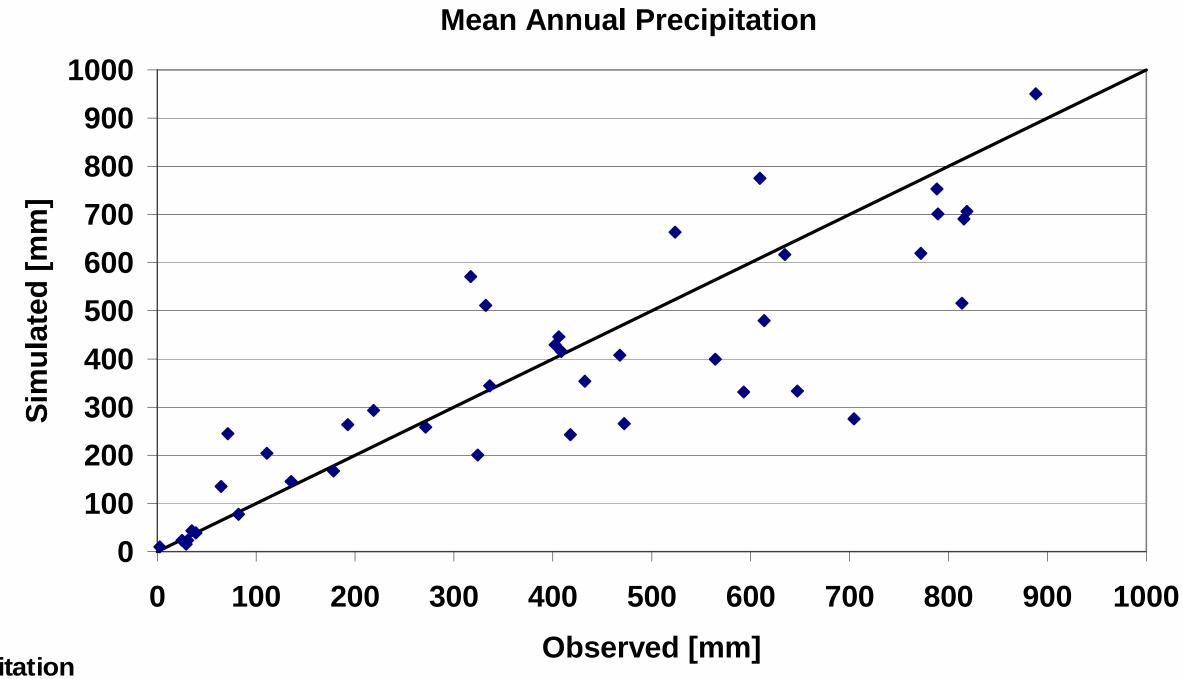
  1990: 350 ppm
  2070: 500 ppm
- Focus on time slices
  1961-1990 & 2070-2099



Performance of regional climate simulations for hydrological impact analysis

Control simulations (present day climate)

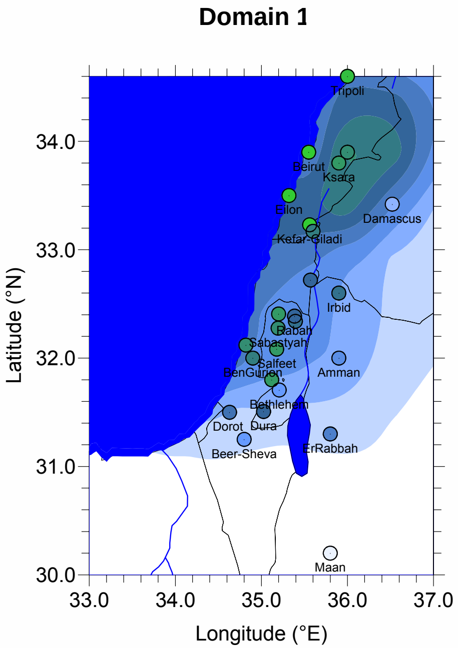


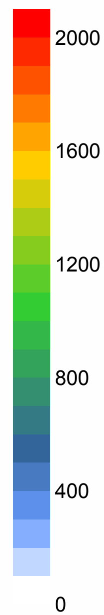


Simulated annual mean precipitation (ECHAM4 + MM5, Δx=18 km, 1961-1990)
vs. observed long term annual mean (for selected stations 1961-1990)

High resolution Control Run

Intermediate results of 6 km runs: mean 1961-1975





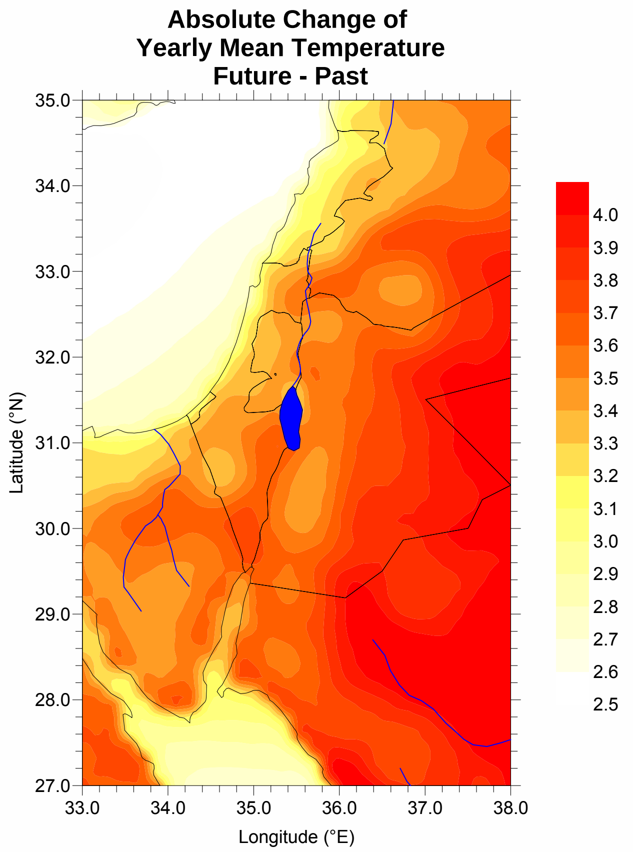
Yearly Mean Precipitation 1961-1975

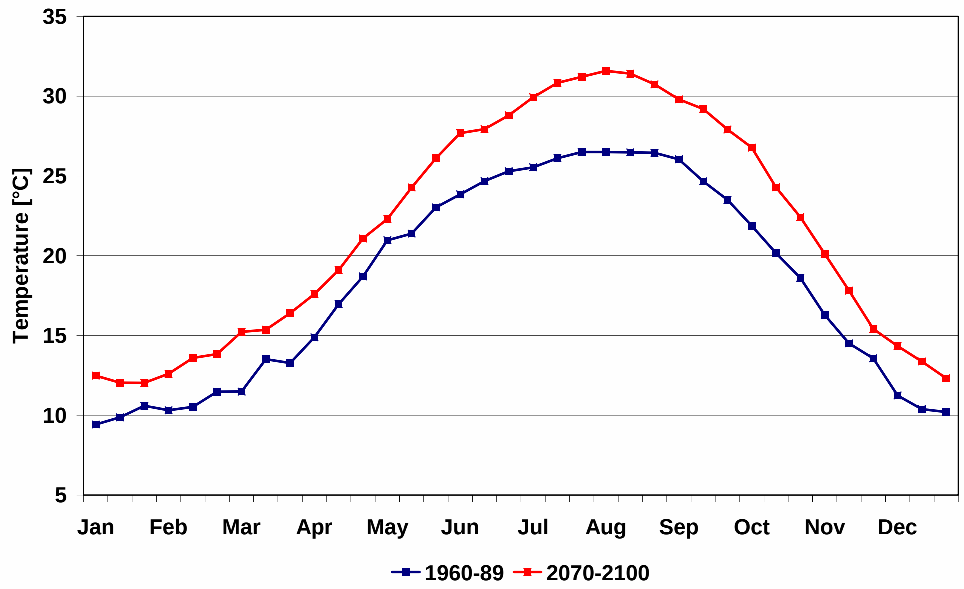
54km 18 km 6 km

… more detailed spatial information: land-sea & orography dependent features

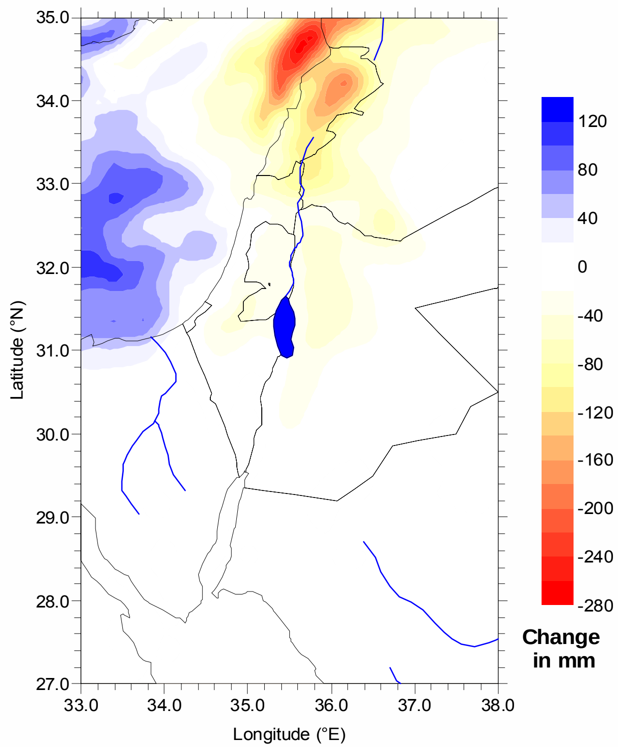
Regional Climate Change Middle East and Upper Jordan River

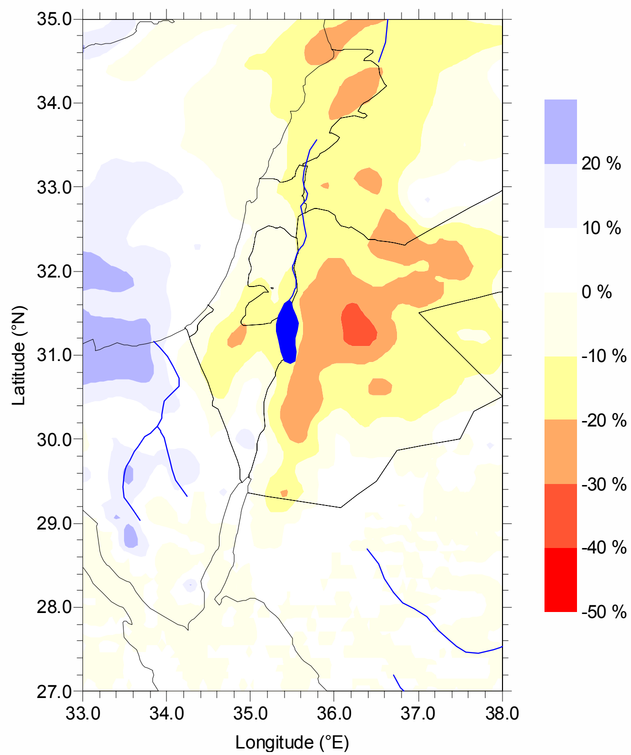
What are the expected changes in temperature?





What are the expected changes in precipitation?

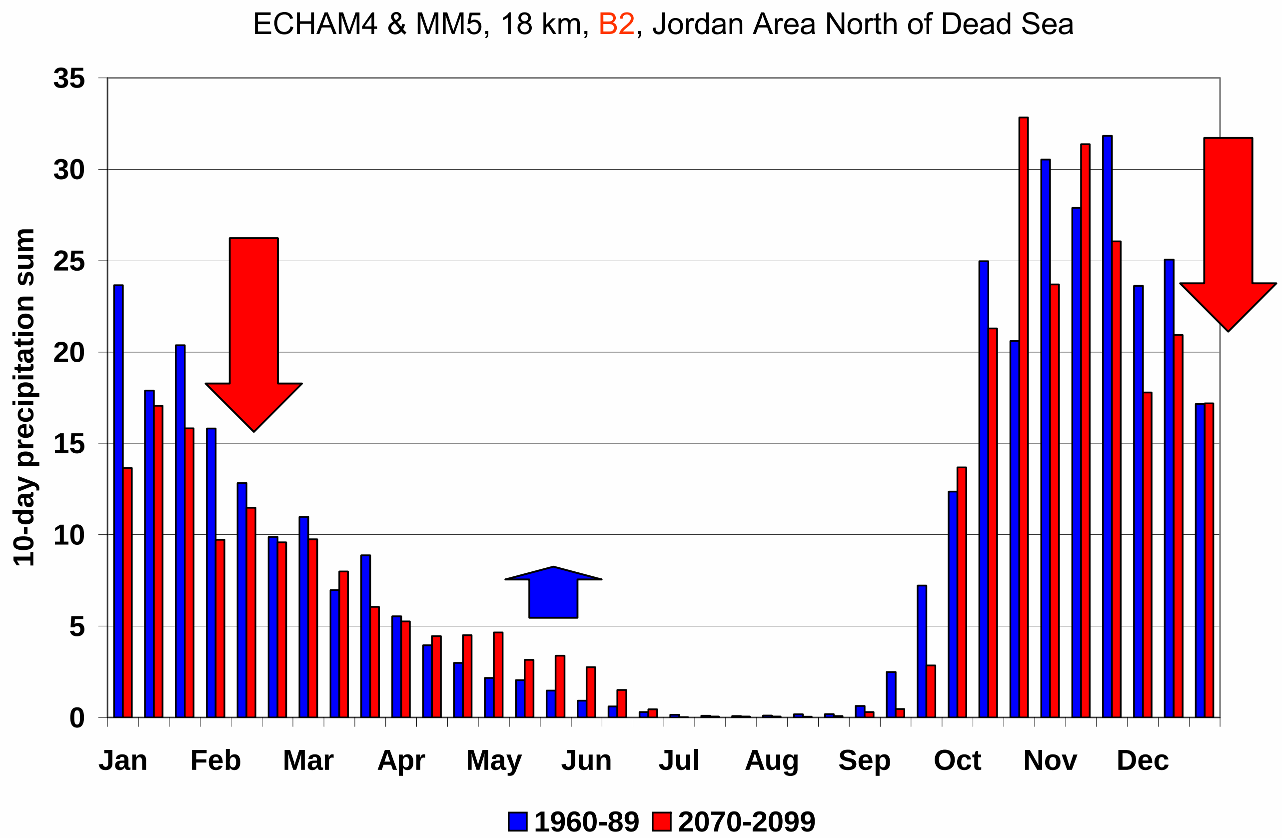




ECHAM4 & MM5, 18 km, B2, 2070-2099 vs 1961-1990

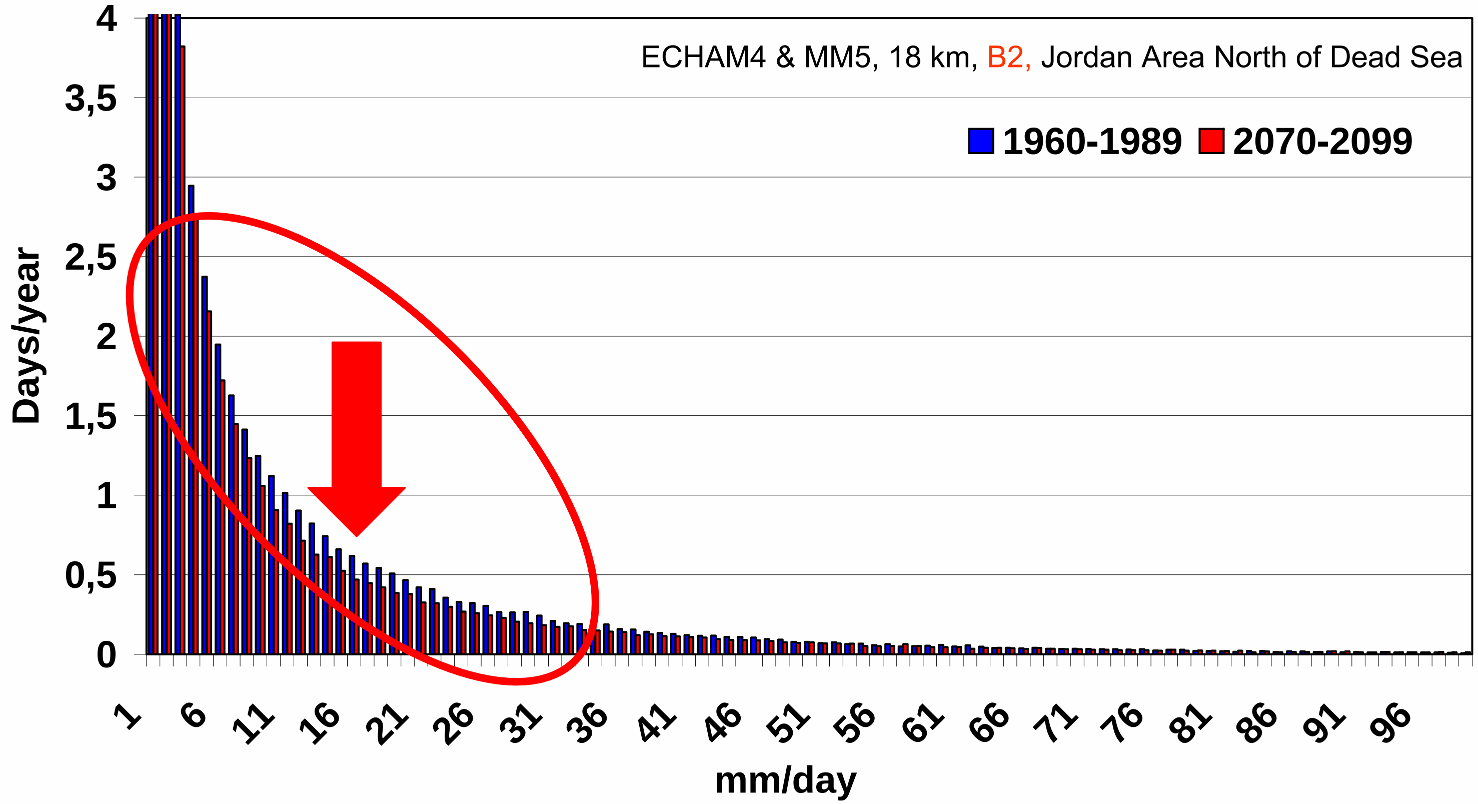
Regional Climate Change Middle East and Upper Jordan River

How does the temporal distribution of precipitation change?



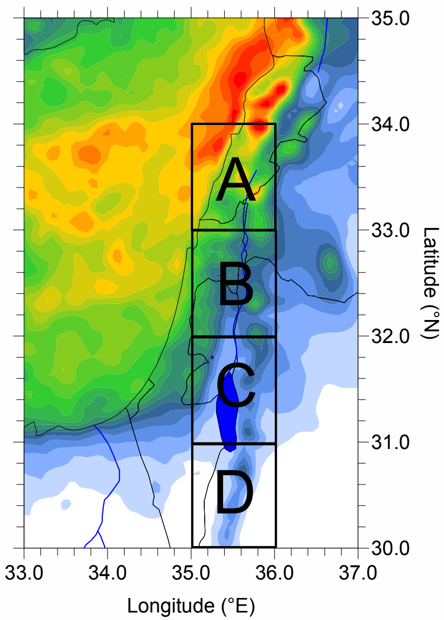
Strongly decreased winter, slightly increased absolute late spring precipitation

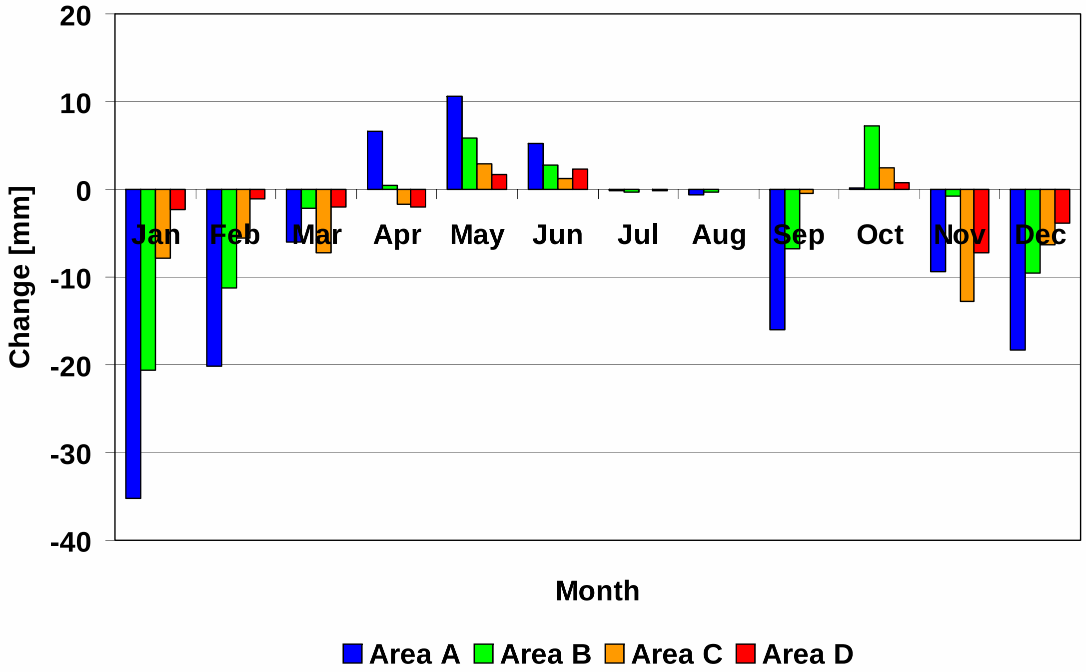
How do precipitation intensities change?



Tendency towards decrease of precipitation intensity

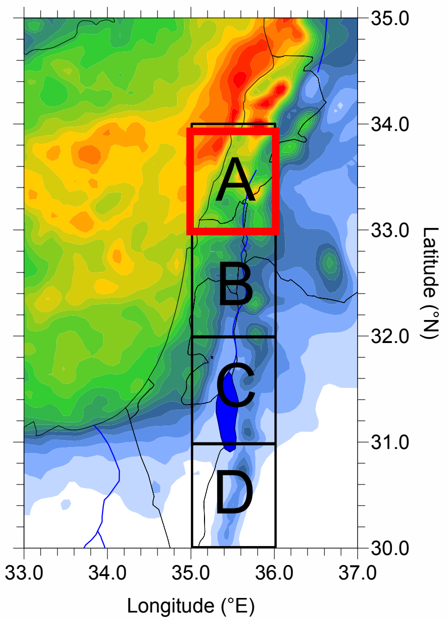
How does seasonal precipitation change depend on the region?

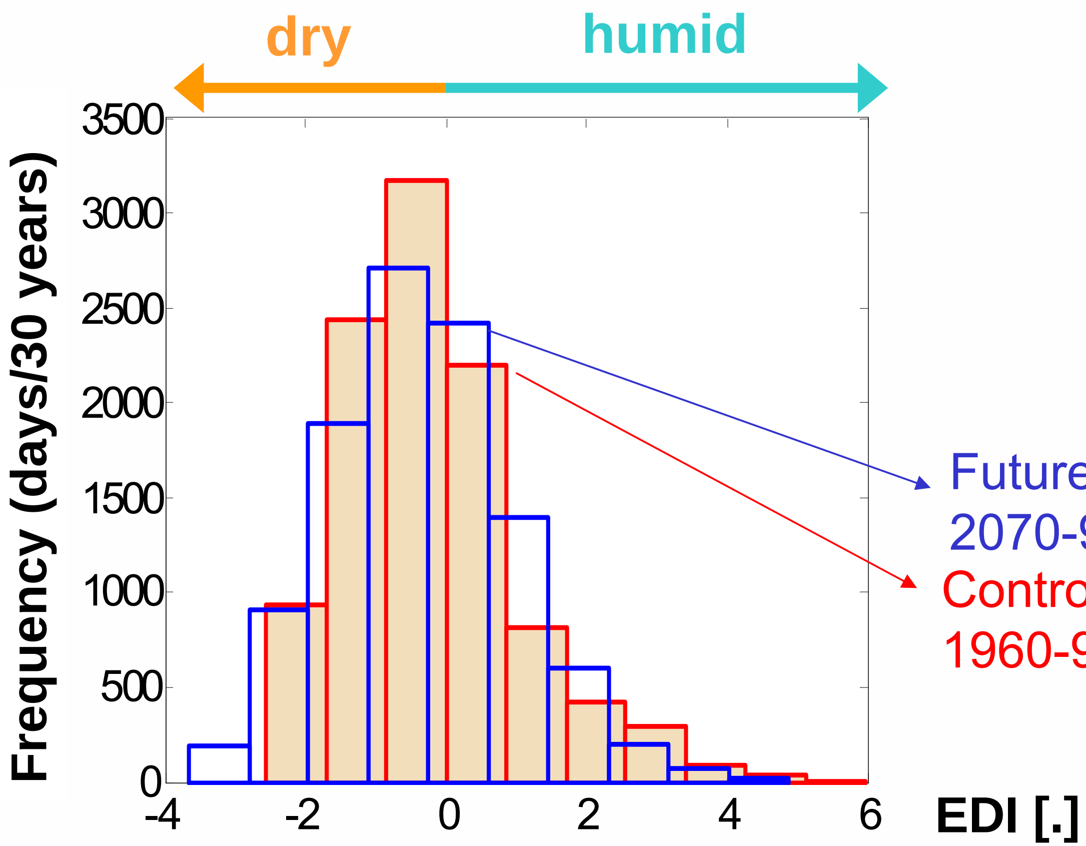




For all subregions: Decreased winter, increased spring precipitation

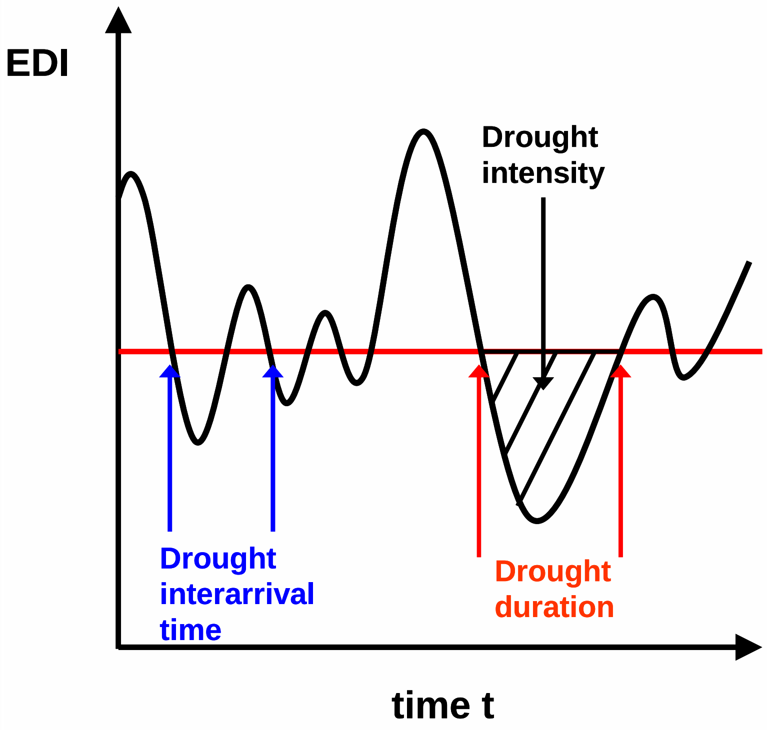
Are drought risks changing? Analysis of effective drought index EDI

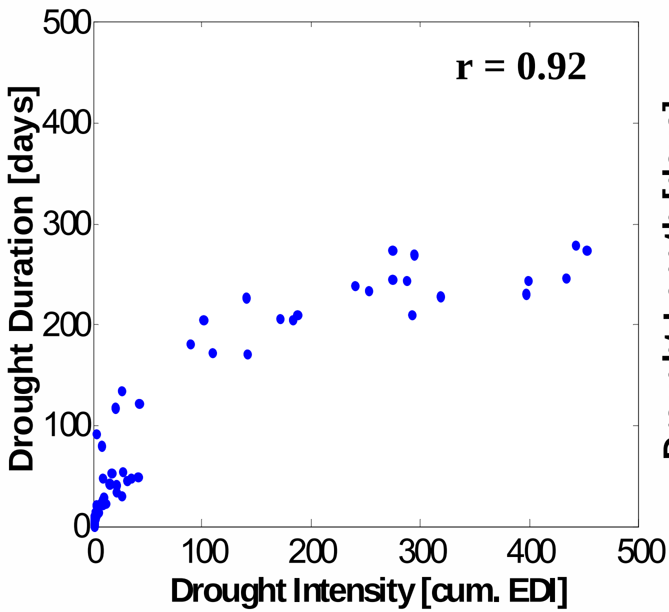


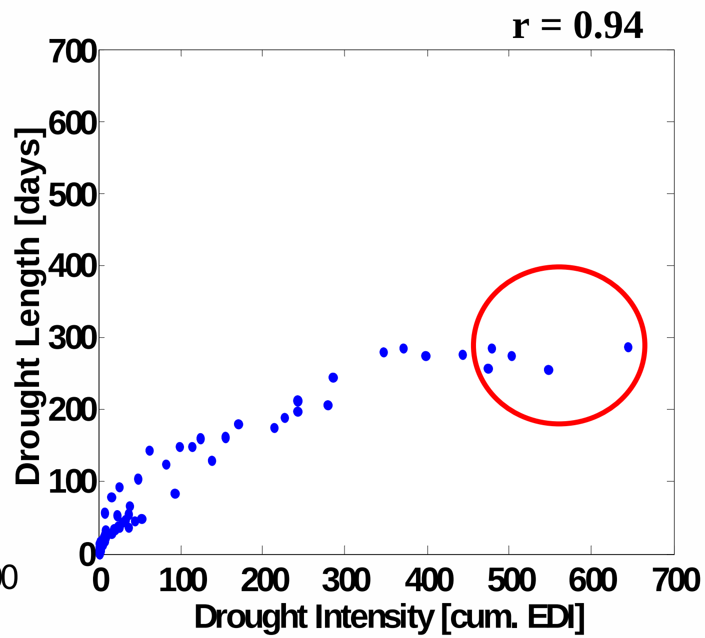


Subregion A: shift towards drier conditions & increased drought risks

Are drought risks changing? Analysis of effective drought index EDI







Subregion A: Increasing drought intensities, but "unchanging" drought durations

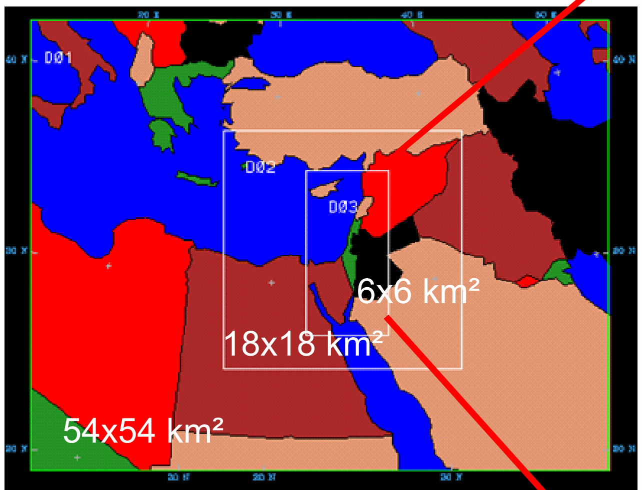
How does the expected atmospheric change

translate into change of terrestrial hydrology

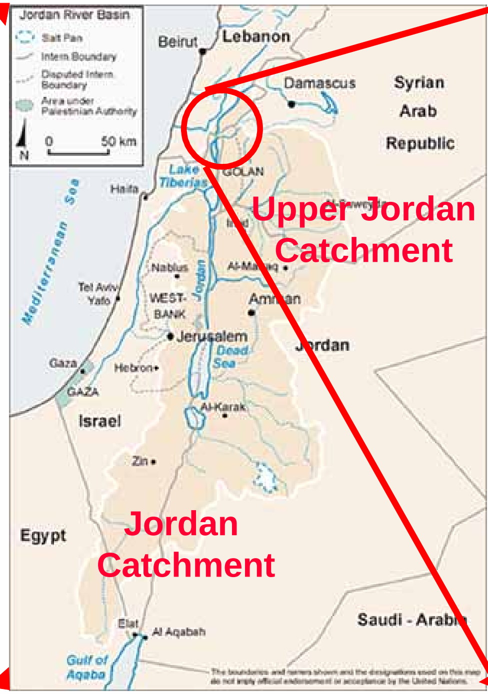
of Upper Jordan Catchment?

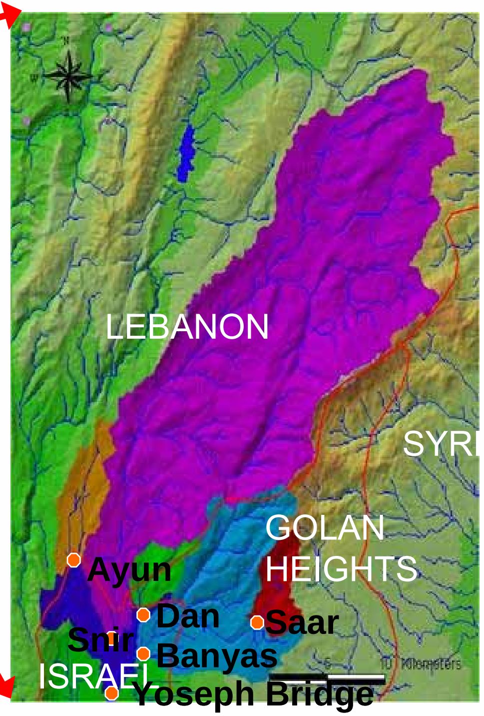
Example of joint climate-hydrology simulation for hydrological impact analysis

Eastern Mediterranean/Near East (**EM/NE**) & Upper Jordan River Catchment



MM5





WaSiM

High resolution dynamical downscaling of global climate scenarios

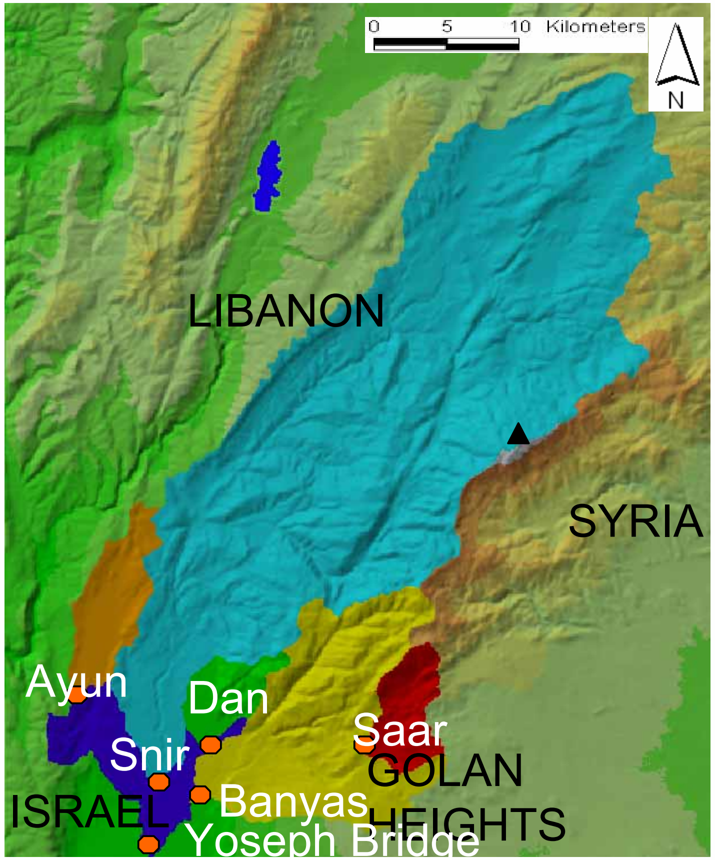
Distributed hydrological modeling of surface and subsurface water balance in 90 m resolution

Hydrological Model WaSiM-ETH

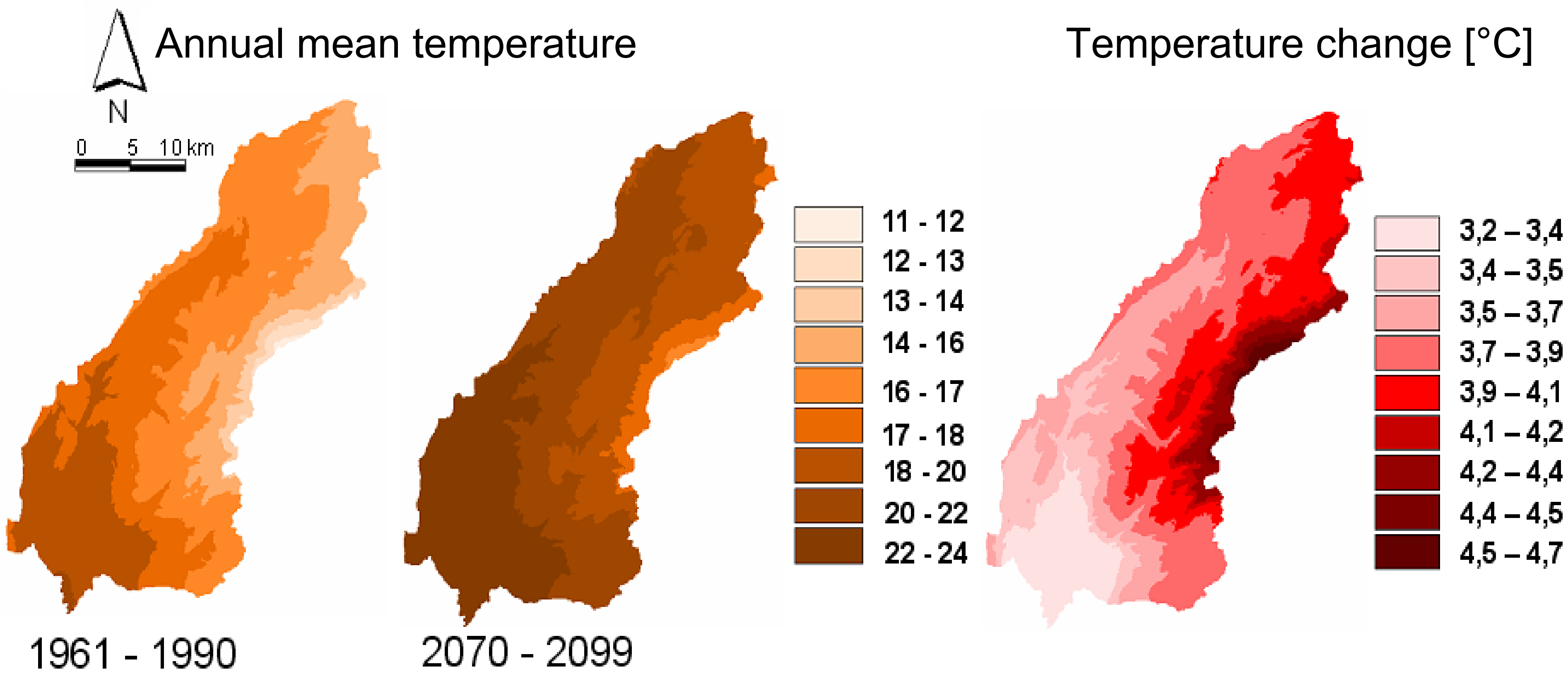
Physically based algorithms
for vertical water fluxes & groundwater:
- Evapotranspiration: soil and vegetation specific (Monteith)
- Flow through unsaturated zone (Richards)
- Suction head & hydraulic conductivity (van Genuchten)
- 2-dim groundwater model dynamically
  coupled to unsaturated zone

Conceptual approaches for lateral runoff aggregation
- Traveltime approach folded with linear storage
- Discharge routing: cinematic wave

Setup Upper Jordan River catchment
- spatial resolution: 90x90 m², temporal resolution: daily
- subdivision into 6 sub-catchments

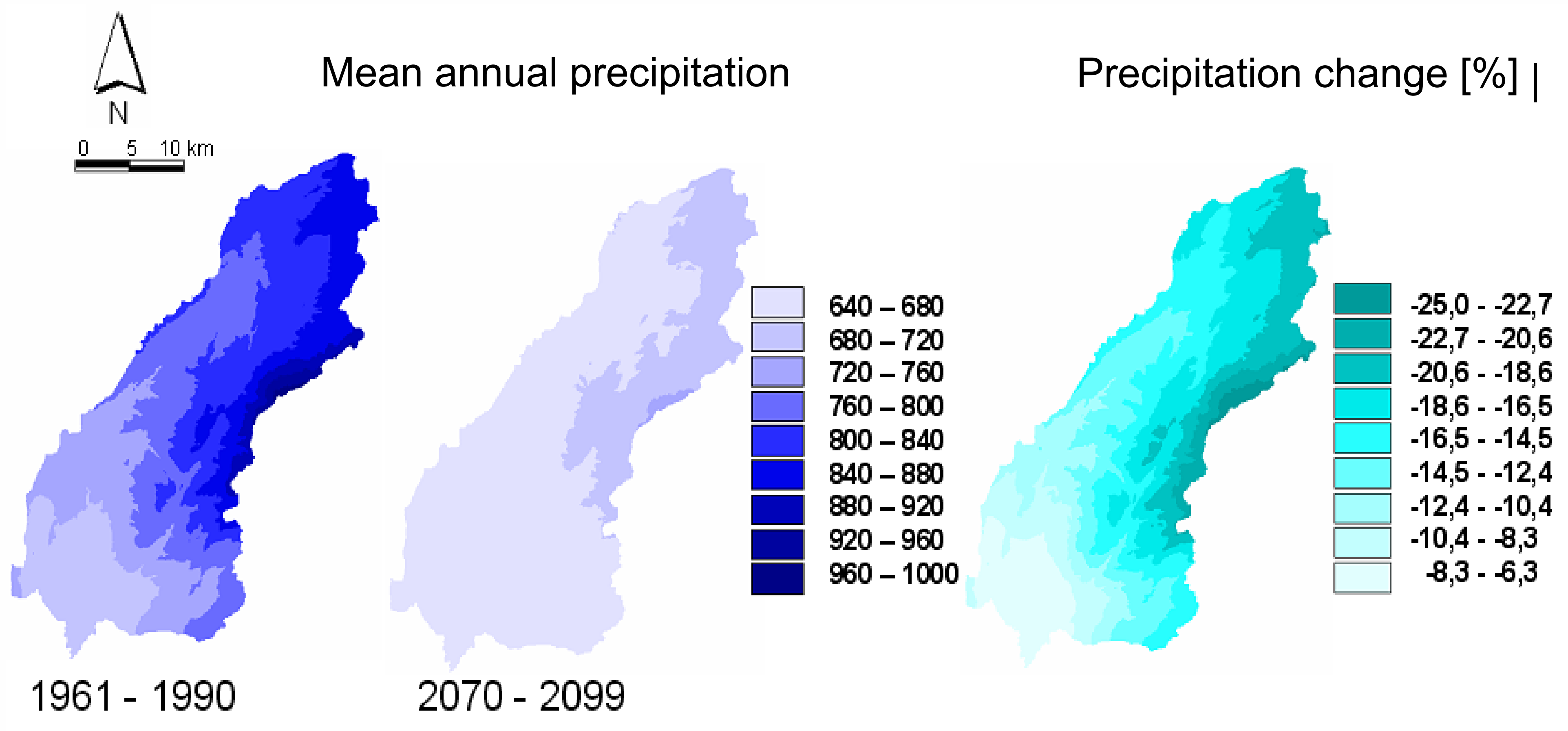


Joint climate-hydrology simulation for hydrological impact analysis



Upper Jordan River catchment

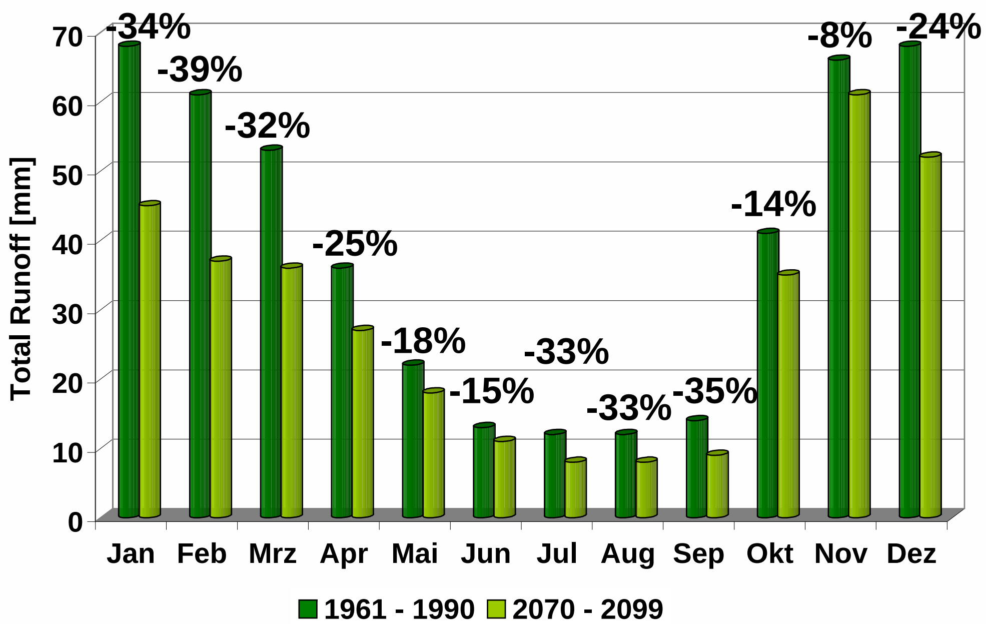
Joint climate-hydrology simulation for hydrological impact analysis



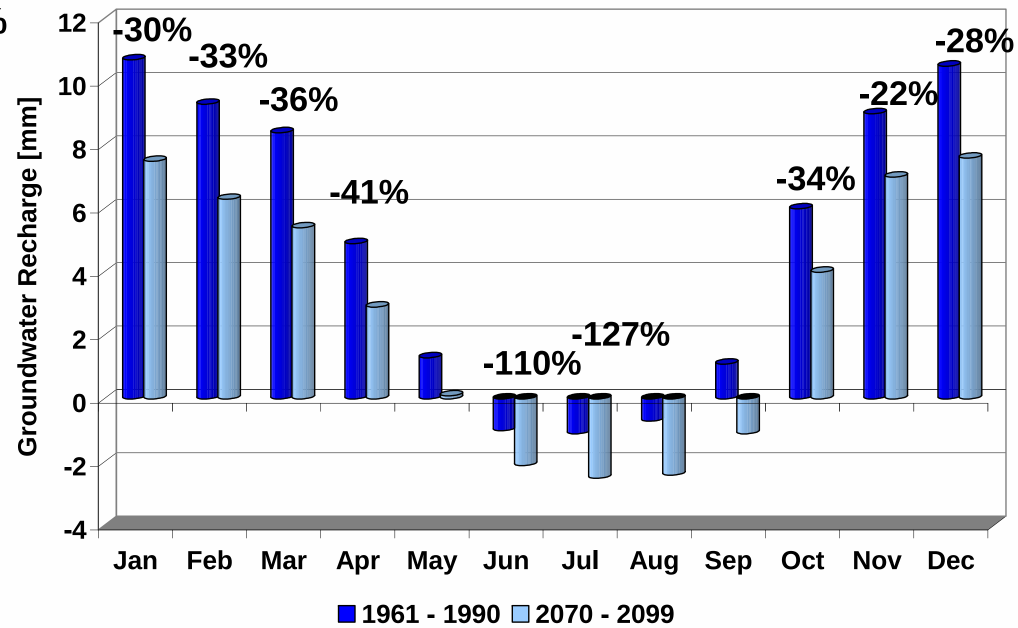
Upper Jordan River catchment

Joint climate-hydrology simulation for hydrological impact analysis

Runoff



Groundwater Recharge



Upper Jordan River catchment

Summary & Conclusions

Climate change Jordan River area north of Dead Sea (2070-99 vs. 1961-90):

- Temperature increase of annual mean up to 3.5°C
- Summer temperatures up to 5°C

- Decreasing winter (35%), slightly increasing spring precipitation
- Decrease of precipitation intensities
  ⇒ impact on conditions for reservoir filling?
- Increased drought intensities

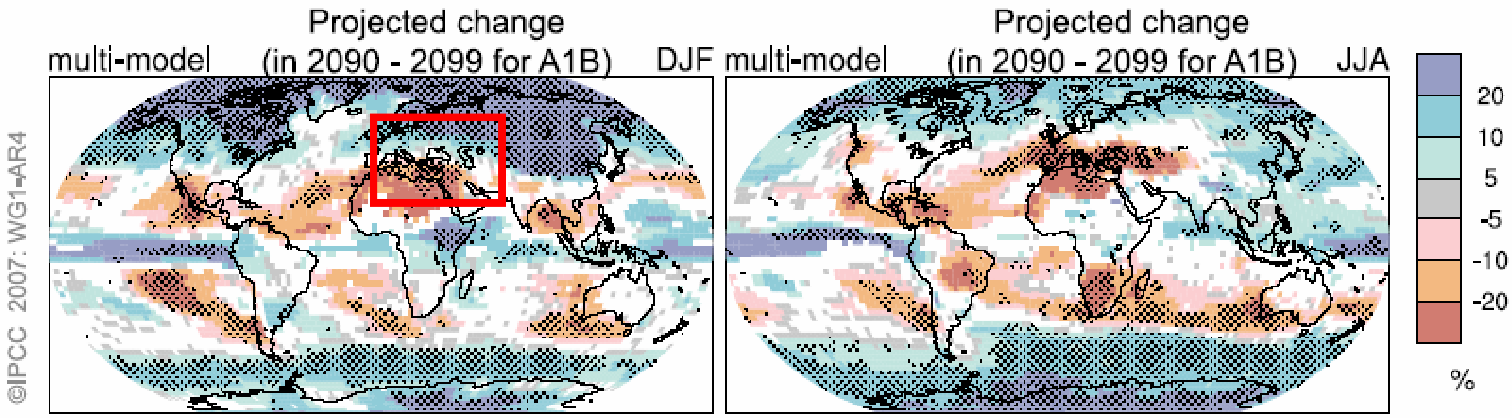
Upper Jordan River

- In spite increased spring precipitation, decreased spring runoff recharge
- Significant reduction of snow

⇒ Significantly reduced water availability & increased drought risks!

Thank you for your attention

Scientific Challenge



IPCC 4AR, 2007

Eastern Mediterranean/Near East:
is in between increasing and decreasing dominant large scale patterns of DJFprecipitation change

Regional Climate Scenarios

Population Growth Economic Development
Technological Progress

⇓

Emission Scenarios
Greenhouse Gas Concentrations

⇓

Global Climate Models

⇓

Global Climate Scenarios

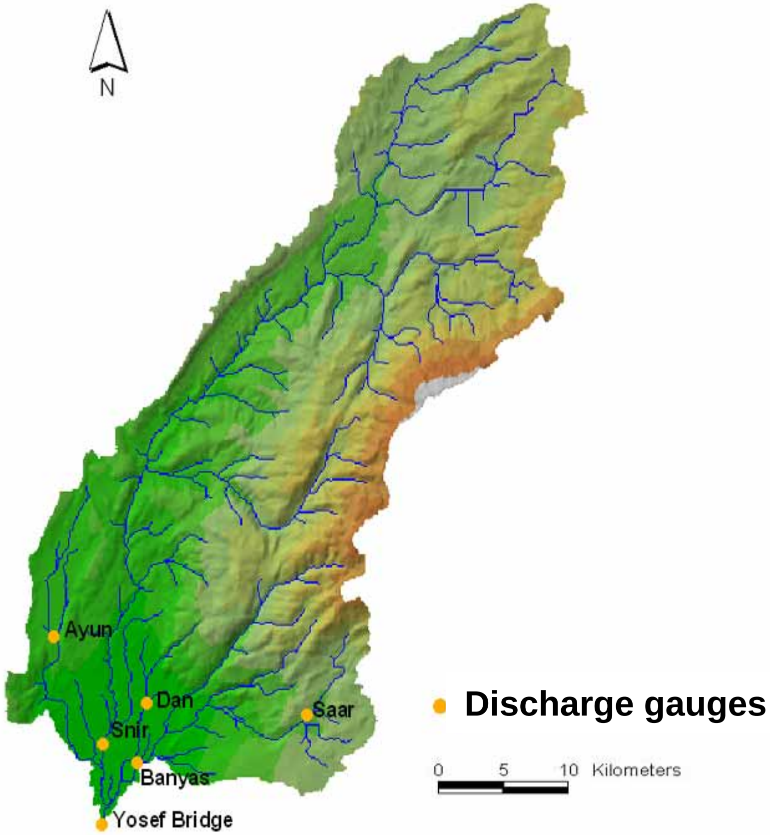
⇓

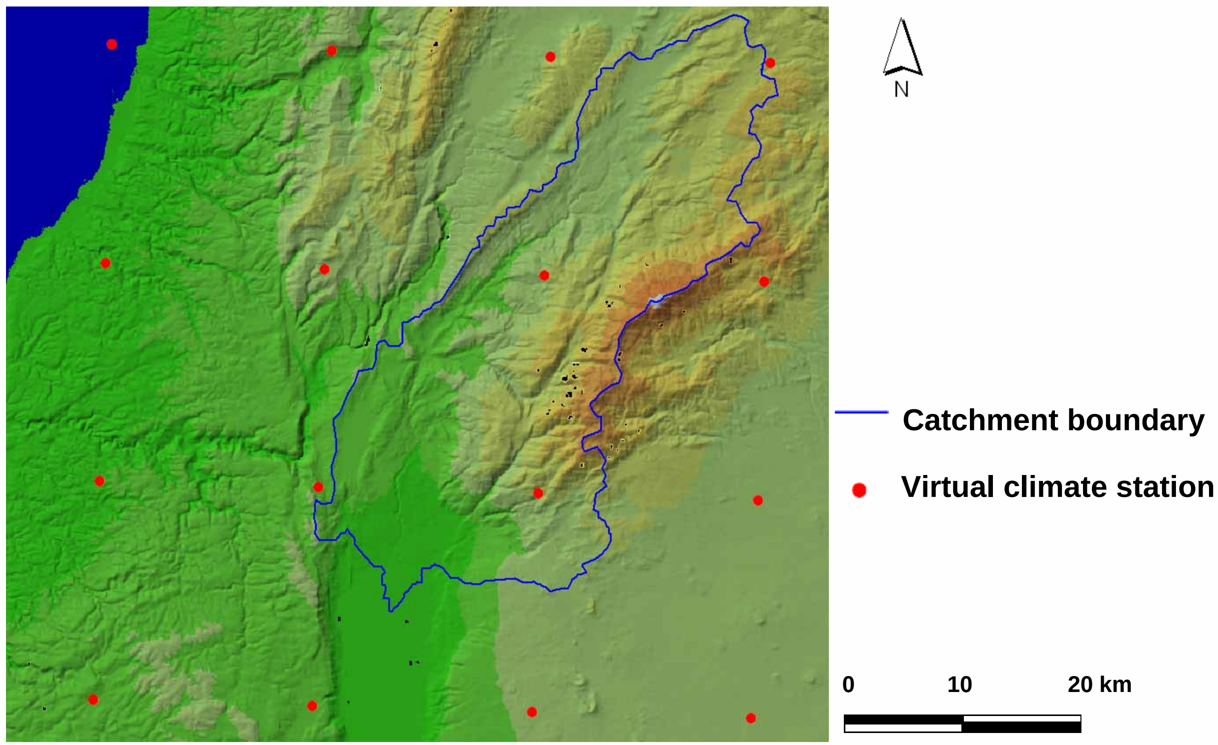
Downscaling Methods

⇓

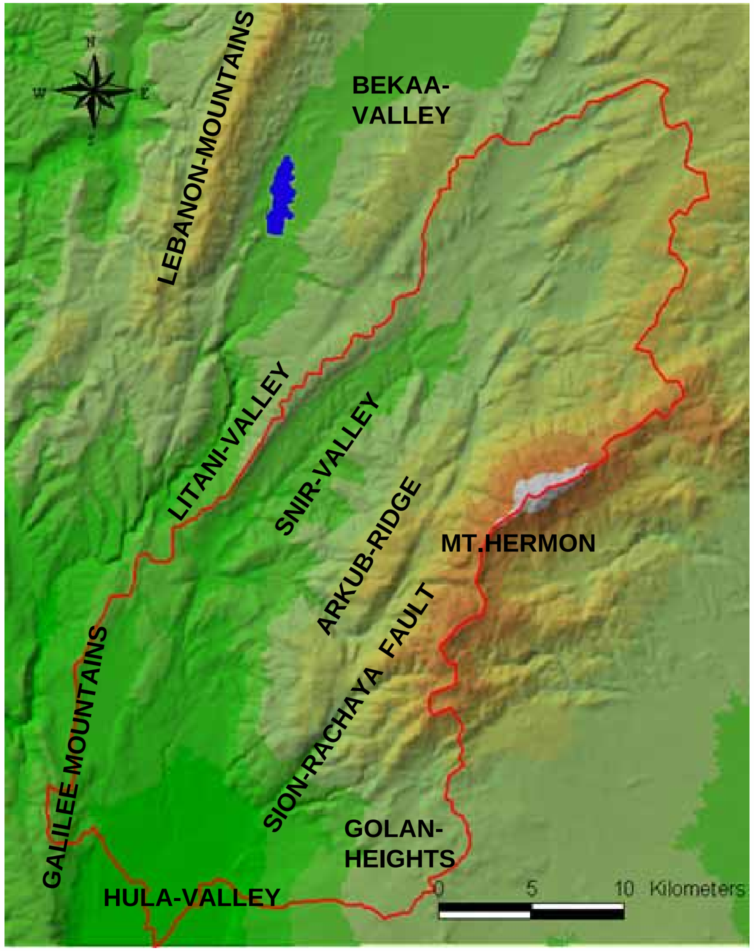
Regional Climate Scenarios

Joint climate-hydrology simulation for hydrological impact analysis





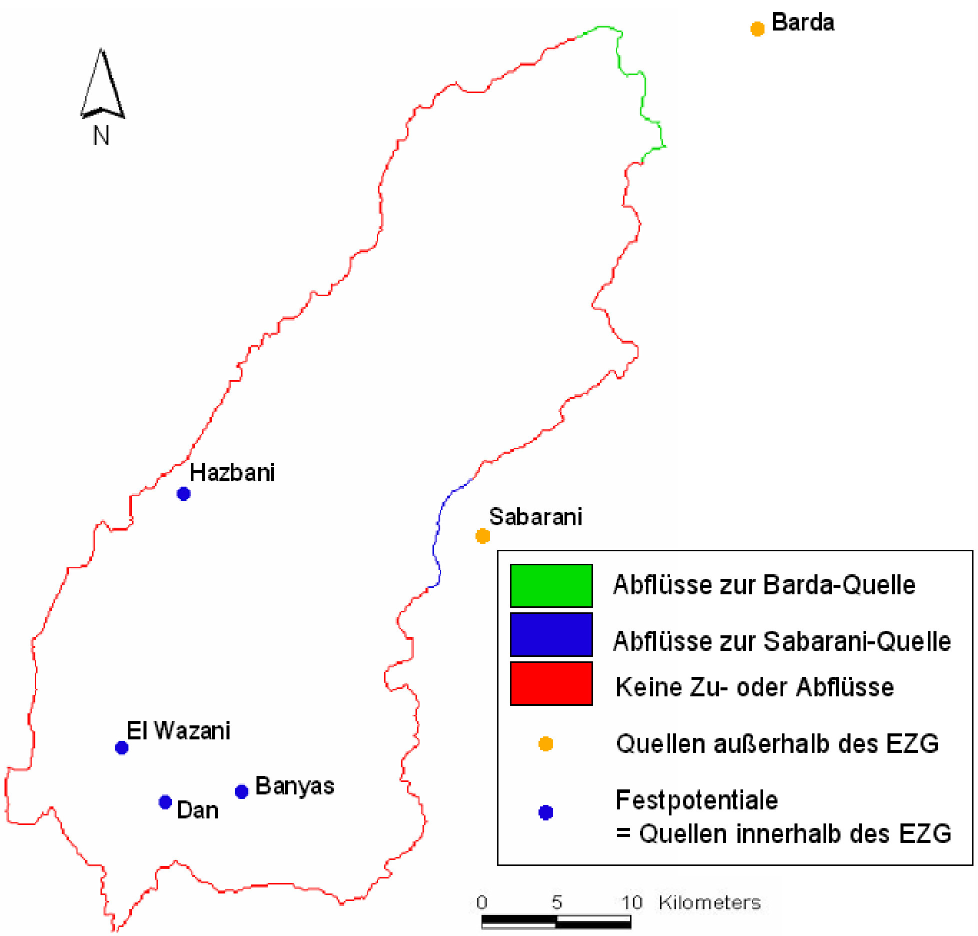
The Upper Jordan Catchment



- **Area:** 855 km²
  - Max. height: 2814 m.a.s.l. (Mount Hermon)
  - Min. height: 80 m.a.s.l. (Hula-Valley)
- **Complex hydrogeology** & groundwater/surface water interactions
- **Precipitation:**
  - 750 mm/a: in the valleys
  - 1200-1500 mm/a: top of Mt. Hermon
- **Cross-bordering:** Lebanon, Syria, Israel, Golan Heights
- Restricted and **limited data availability**
- **6 Gauges:** Ayun, Snir, Banyas, Dan, Saar, Yoseph Bridge

Boundary Conditions for Groundwater Model

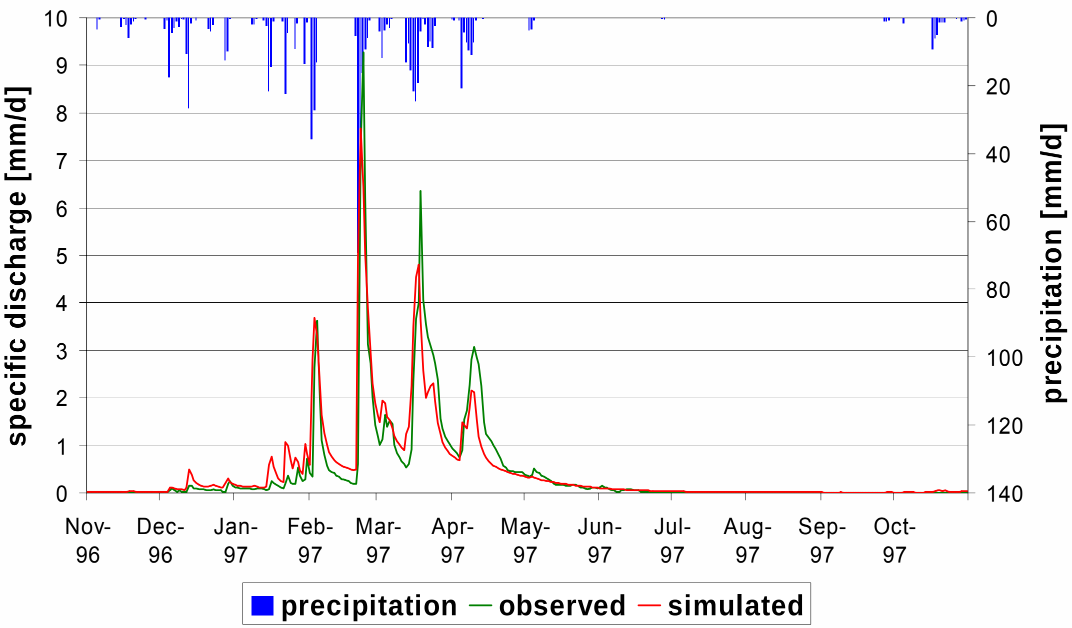
Maximum depth of unsaturated zone assumed:
= 100 m



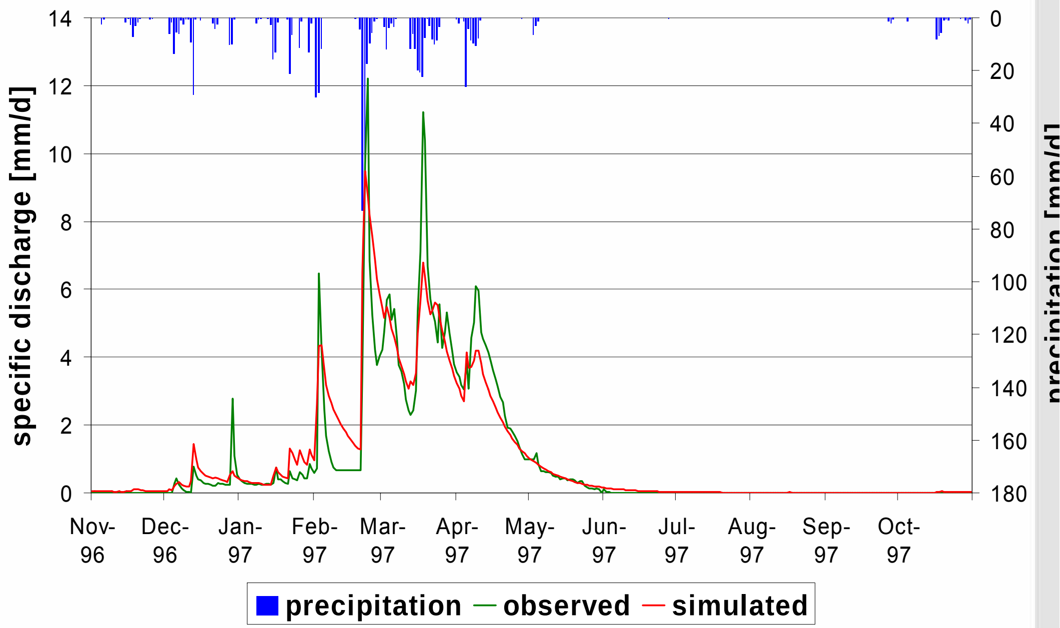
Regional Climate Change Middle East and Upper Jordan River

Hydrological Simulations

Episode	Gauge	Banyas	Saar	Snir	Ayun	Yoseph Bridge
Validation (1998)	**NSE-lin**	0.8525	0.4066	0.3839	0.5527	0.7402
	NSE-log	0.7894	0.2997	0.6128	0.4098	0.5502
Calibration (1997)	**NSE-lin**	0.7187	0.5938	0.782	0.7311	0.8408
	NSE-log	0.4602	0.5377	0.69	0.3726	0.6472

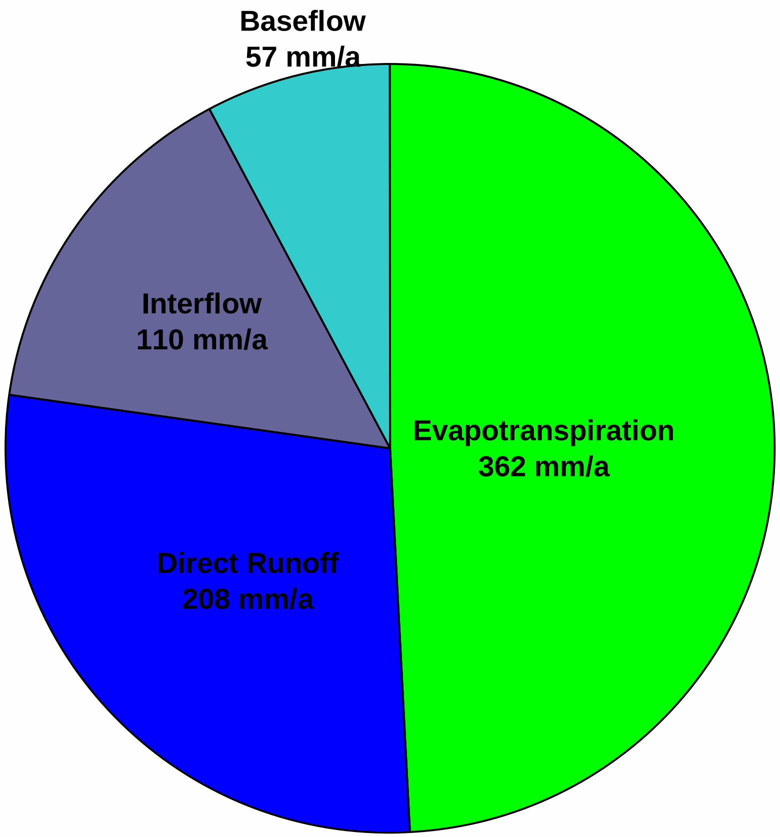


Gauge Ayun

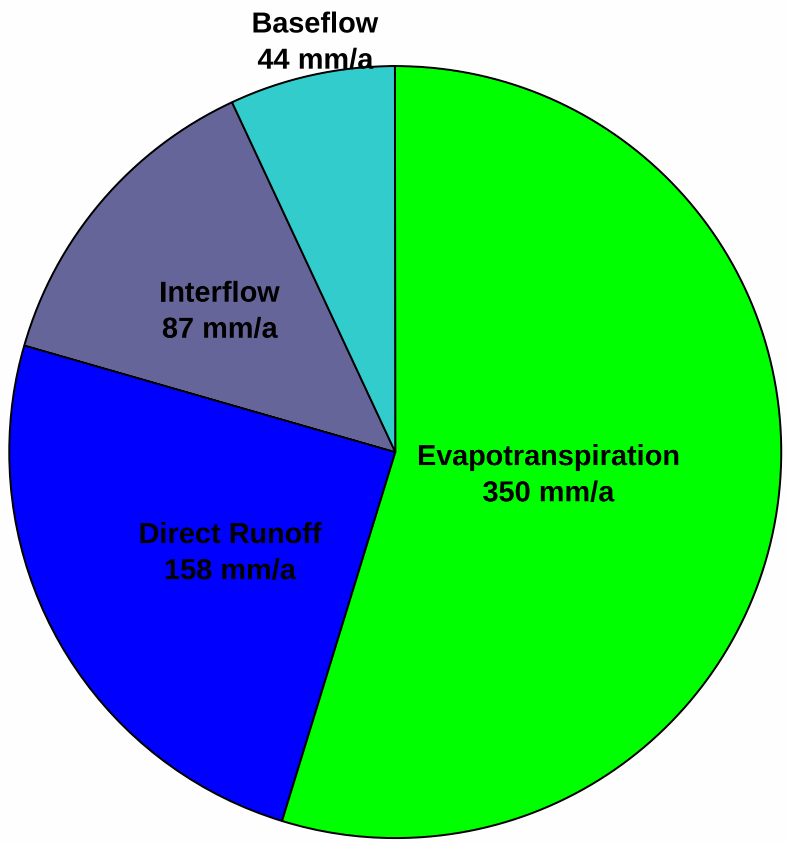


Gauge Saar

Joint climate-hydrology simulation for hydrological impact analysis



1961-90



2070-99

Q_{tot}+ET:	737mm	$\Rightarrow$	639 mm (-13%)
Q_{tot}:	375 mm	$\Rightarrow$	289 mm (-23%)