GLOWA

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Institute for Meteorology and Climate Research
Atmospheric Environmental Research (IMK-IFU)

Combined high resolution climate – hydrology simulations in the Eastern Mediterranean and the Upper Jordan catchment

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Introduction:

Sufficient freshwater availability is a central prerequisite for peaceful agricultural and industrial development in the water scare environment of the Eastern Mediterranean and Near East. In spite of its small size the Upper Jordan Catchment (UJC) is of great importance for the region as it provides the majority of the whole Jordan's discharge and 1/3rd of the freshwater resources of Israel. Hydrological modeling is required to understand terrestrial water balance and to provide scientifically sound estimates on water availability. With the hydrological model WaSiM it is the first time that a physically based model is set up for this region that accounts both for the entire terrestrial water balance and in particular for the groundwater – surface water interaction. To investigate future water availability under conditions of climate change regional climate simulations has been performed with the regional climate model MM5 for different scenarios and coupled in a one way manner to WaSiM.

Climate modeling:

Method:

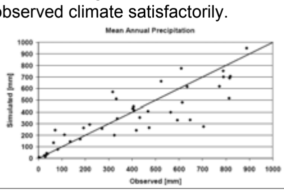
Dynamical downscaling of global meteorological fields with **MM5**
Input: GCM ECHAM4
Scenarios: A2 + B2 (see CO2-concentrations of IPCC-scenarios on fig.)
Three nesting steps (grid size of 54, 18, 6km, see figure right))
26 vertical levels
Time slice experiments (Control run 1961-1990) and Future (2070-99)
Transient runs 1961-2050

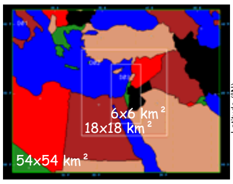
Current status:

- Control run and scenario B2 (2070-2099) finished for domain 2
- Control run finished for domain 3 (1961-1975), scenario B2 in progress
- transient runs with scenarios A2 + B2 finished for domain 1 (1961-2050), domain 2 untill 2045

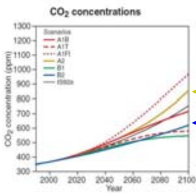
Validation:

The Control run has been validated by comparing modeled and long term observed (1961-1990) mean annual precipitation for 41 meteorological stations in domain 2. The Figure below indicates that the simulations reproduce the observed climate satisfactorily.



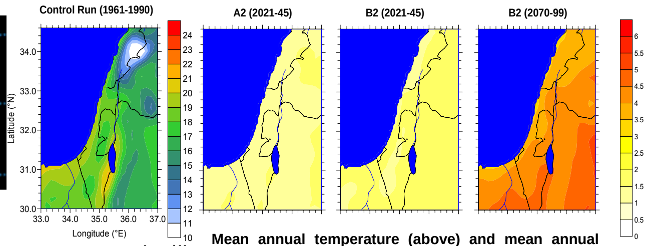


Domain Setup of MM5

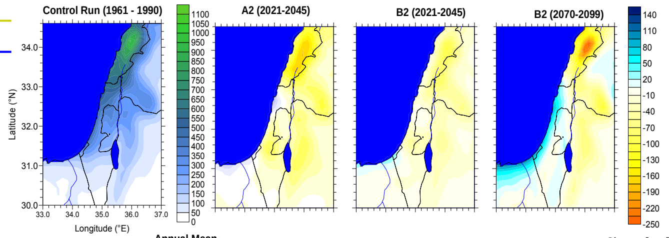


CO-concentrations of IPCC-scenarios

Results:

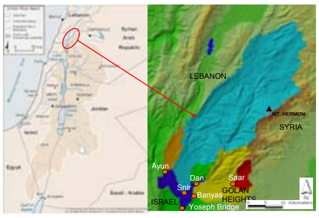


Mean annual temperature (above) and mean annual precipitation (below) for the control run and changes in the future for the scenarios A2 and B2 in different time slices (results of domain2)



Hydrological Modeling:

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 (karst) & groundwater/surface water interactions
Precipitation:
750 mm/a: in the valleys
1200-1500 mm/a: top of Mt. Hermon with snow cover in the winter
Cross-bordering: Lebanon, Syria, Israel, Golan Heights

The hydrological model WaSiM:

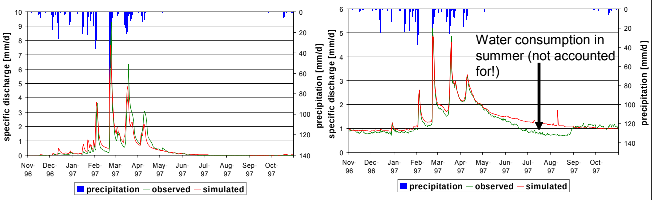
- Physically based algorithms for most process descriptions
- Spatial model resolution for UJC: Δx²=450x450 m²
- Temporal model resolution for UJC: 24h
- Flow through unsaturated zone after Richards Δz=0.5m, 200 layers (!)
- Evapotranspiration: soil and vegetation specific after Penman-Monteith
- Snow accumulation & -melt
- Discharge routing: cinematic wave
- 2-dim groundwater model dynamically coupled to unsaturated zone

Calibration & Validation results:

The hydrological model was calibrated for the hydrological year 1997 and validated for 1998. The model performance was detected by comparing the simulated with the measured discharge of the subcatchments using the Nash-Sutcliffe Efficiency (NSE). The table shows the results of the calibration and the validation for each subcatchment. The both exemplary graphs show that the model is able to describe the observed river discharges satisfactorily.

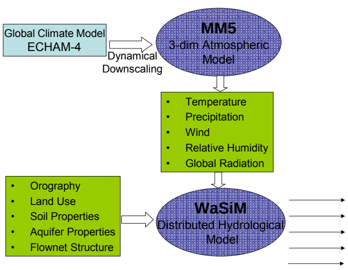
$$NSE = 1 - \frac{\sum_i \varepsilon_i^2}{\sum_i (x_i - \bar{x})^2} = 1 - \frac{\sum_i (y_i - x_i)^2}{\sum_i x_i^2 - \frac{1}{n}\left(\sum_i x_i\right)^2}$$

Time	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

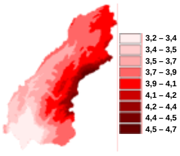


Simulated and observed discharge at the gauges Saar (left) and Yoseph Bridge (right)

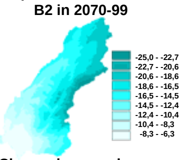
Coupled climate-hydrology modelling:



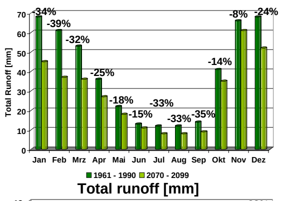
Coupling scheme



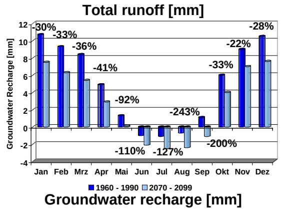
Change in annual mean temperature for scenario B2 in 2070-99



Change in annual mean rainfall for scenario B2 in 2070-99



Total runoff [mm]



Groundwater recharge [mm]

The Figure on the left side shows the coupling scheme used for the combined climate-hydrology simulations. This combined simulations have up to now only been performed for the control run and the time slice 2070-99 of the scenario B2 based on the MM5 simulations with a resolution of 18km (domain2). Results show a increase of annual mean temperature of up to 4.5K and a decrease of winter precipitation up to 30%. So total runoff and groundwater recharge decrease significantly (see graphs left).

Outlook:

After all climate simulations (transient + time slices) have been finished, the other combined climate-hydrology simulations will be conducted.
To improve the validation of WaSiM environmental tracer data (^{18}O) will be used beside observed runoff.
To detect uncertainties in climate modeling a additional GCM (HadCM3) will be used for dynamical downscaling.

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