Quantification of large-scale and long-term groundwater resources in karst aquifers under Mediterranean climate: deterministic versus stochastic approaches

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Motivation

Water scarcity in many regions of the world will be exacerbated by **climate change**. **Carbonate aquifers** provide valuable water resource in the Mediterranean region, but are v**ulnerable** to over-exploitation due to their low storage capacity.

Sustainable management of Mediterranean karst aquifers is a key issue at local & regional scale. However, the response of carbonate aquifers to **high-intensity precipitation events** & **droughts** is controlled by the distribution and type of karst features and the karst system.

Key Objective:

To **identify optimal modelling concepts** for highly dynamic & complex carbonate systems to improve management concepts for local water user management.

Study Area: Western Mountain Aquifer (WMA)

Located in Israel & Palestinian Territories (Figure 1).

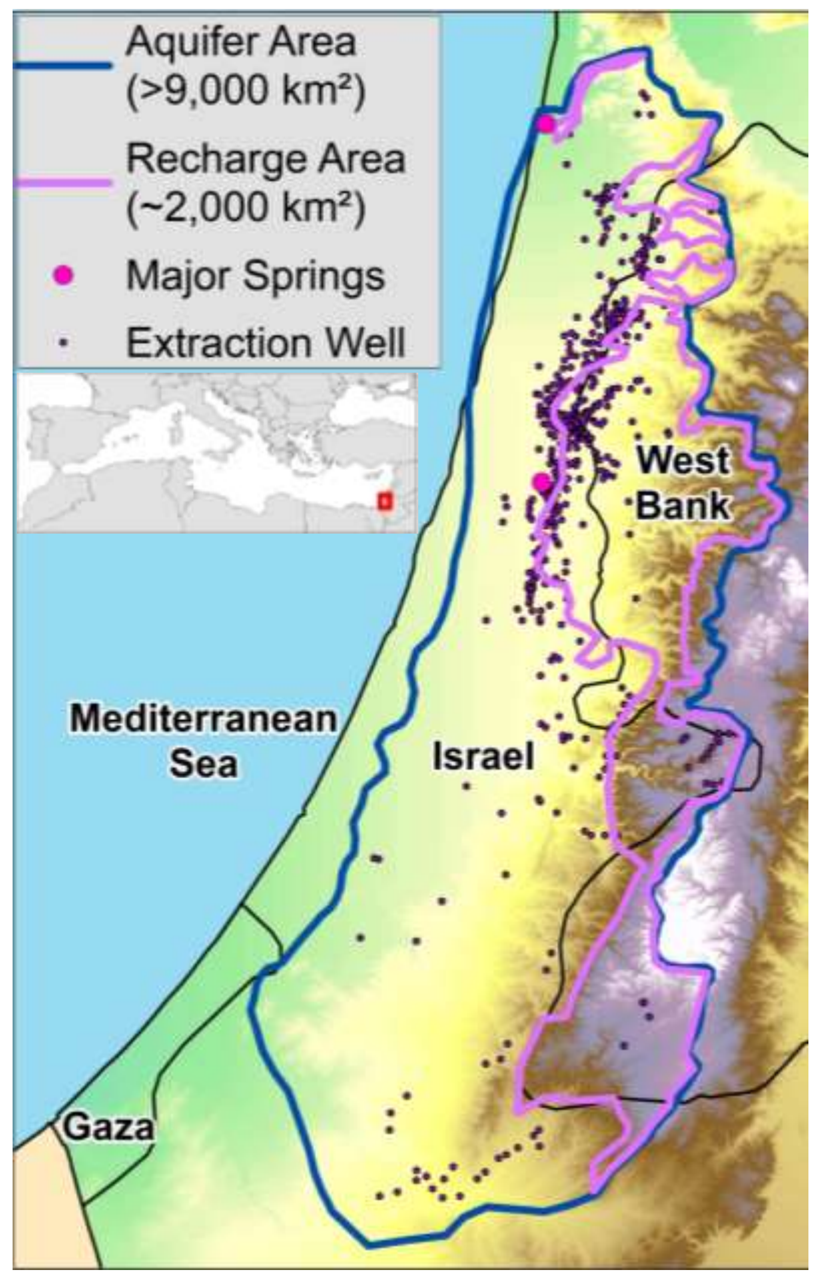


Figure 1: WMA location (data from Abusaada & Sauter, 2012)

Cretaceous carbonate aquifer with developed karst system.

Two limestone and dolomite sub-aquifers (both ~350 m thick) separated by argillaceous aquitard (~100 m thick).

Predicted Climate Change in the Recharge Area of the WMA (CIRA) (Figure 2).

- >2° increase in temperature.
- 20% reduction in precipitation.
- Reduction in frequency of very wet years.

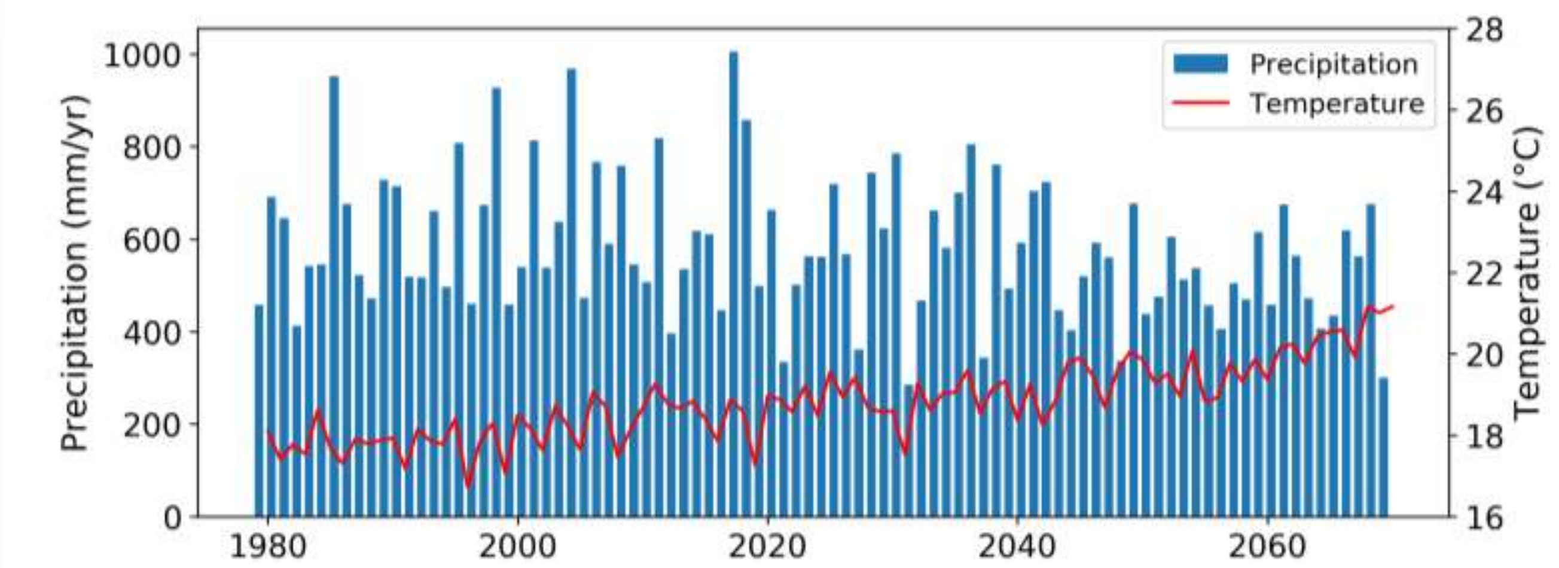


Figure 2: Simulated Precipitation and Temperature in Recharge Areas of the WMA

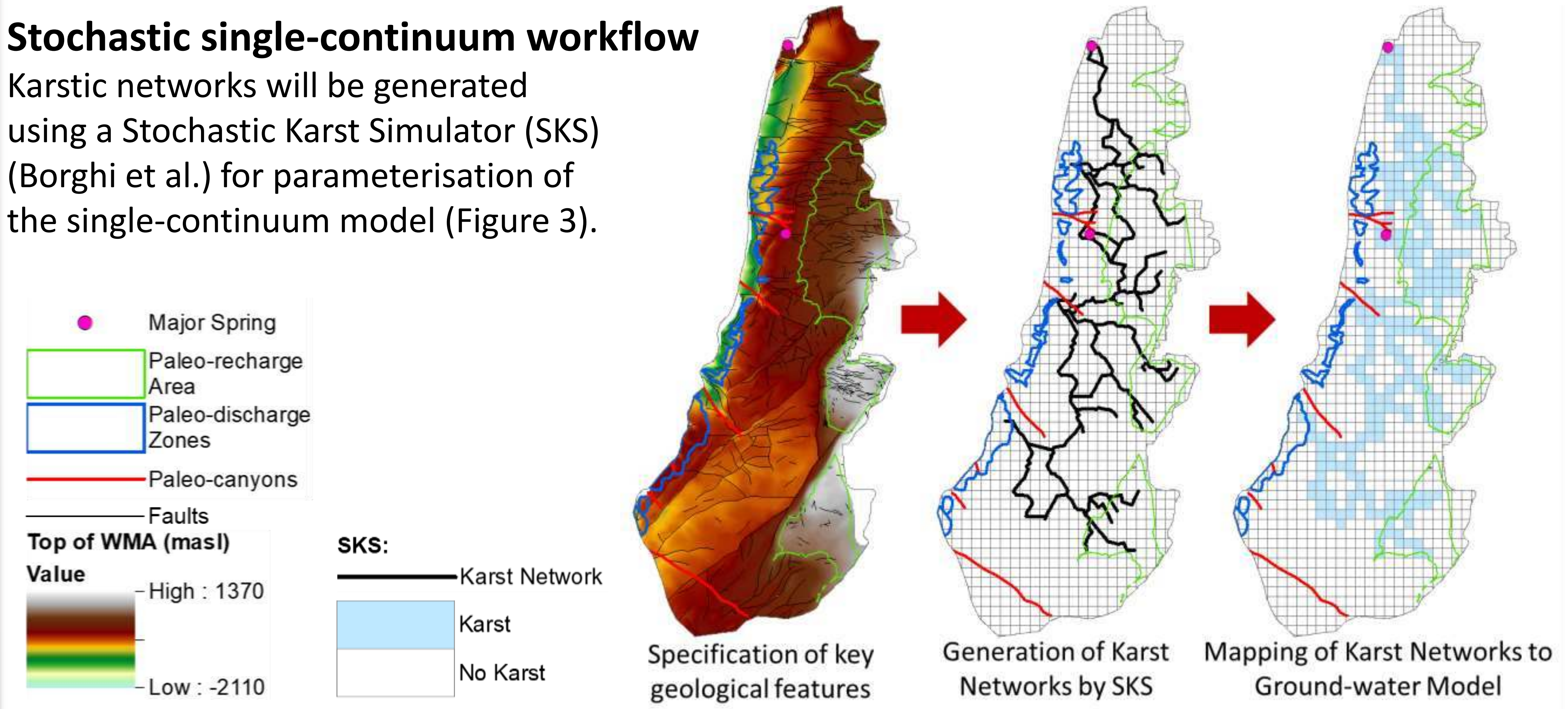
Selection of a Suitable Numerical Modelling Approach

Two modelling approaches are used for comparison:

Deterministic multi-continuum approach	Stochastic single-continuum approach
Model code: **HydroGeoSphere**.	Model code: **MODFLOW & SKS.**
1. Considers surface routing, **unsaturated & saturated flow**.	1. Considers **saturated flow only**.
2. **Recharge is simulated directly.**	2. Recharge from external calculation
3. Parameterised with literature values	3. Parameterised with karstic networks from pseudo-genetic Stochastic Karst Simulator (SKS)
4. Calibrated with piezometric pressure head & discharge time series.	4. **Less reliant** on high-quality observation time-series.
5. Enhanced simulation of response to extreme rainfall events.	5. Stochastic parameterisation allows **estimation of uncertainty.**
6. Subject to considerable **parameter uncertainty**.	6. Fewer parameters, accounting for **data scarcity.**

Stochastic single-continuum workflow

Karstic networks will be generated using a Stochastic Karst Simulator (SKS) (Borghi et al.) for parameterisation of the single-continuum model (Figure 3).



Specification of key geological features

Generation of Karst Networks by SKS

Mapping of Karst Networks to Ground-water Model

Figure 3: Schematic flow diagram for stochastic single-continuum modelling approach

Deterministic multi-continuum model

Geological layers adapted from Abusaada & Sauter (2012) (Figures 4 and 5).

High- & low hydraulic conductivity domains used to represent conduits & fissured matrix, respectively.

First-order exchange between surface and sub-surface domains allows simulation of rapid and diffuse recharge.

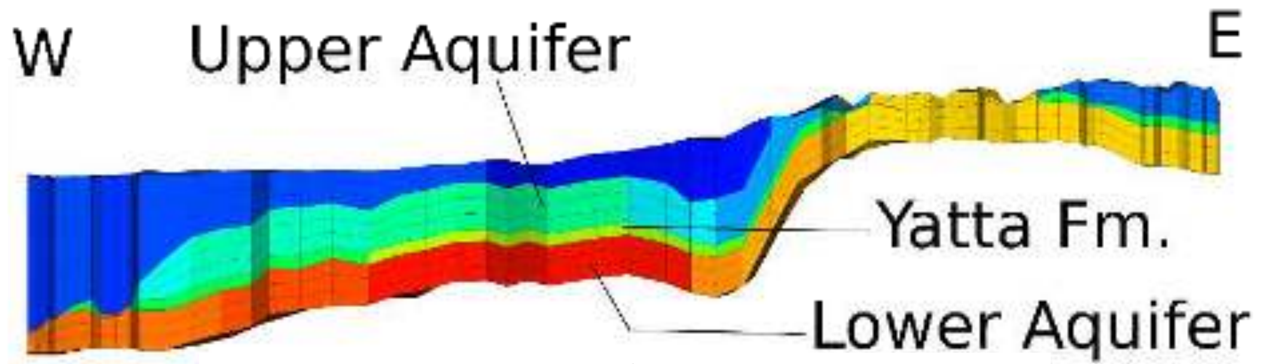


Figure 4: E-W transect of multi-continuum model

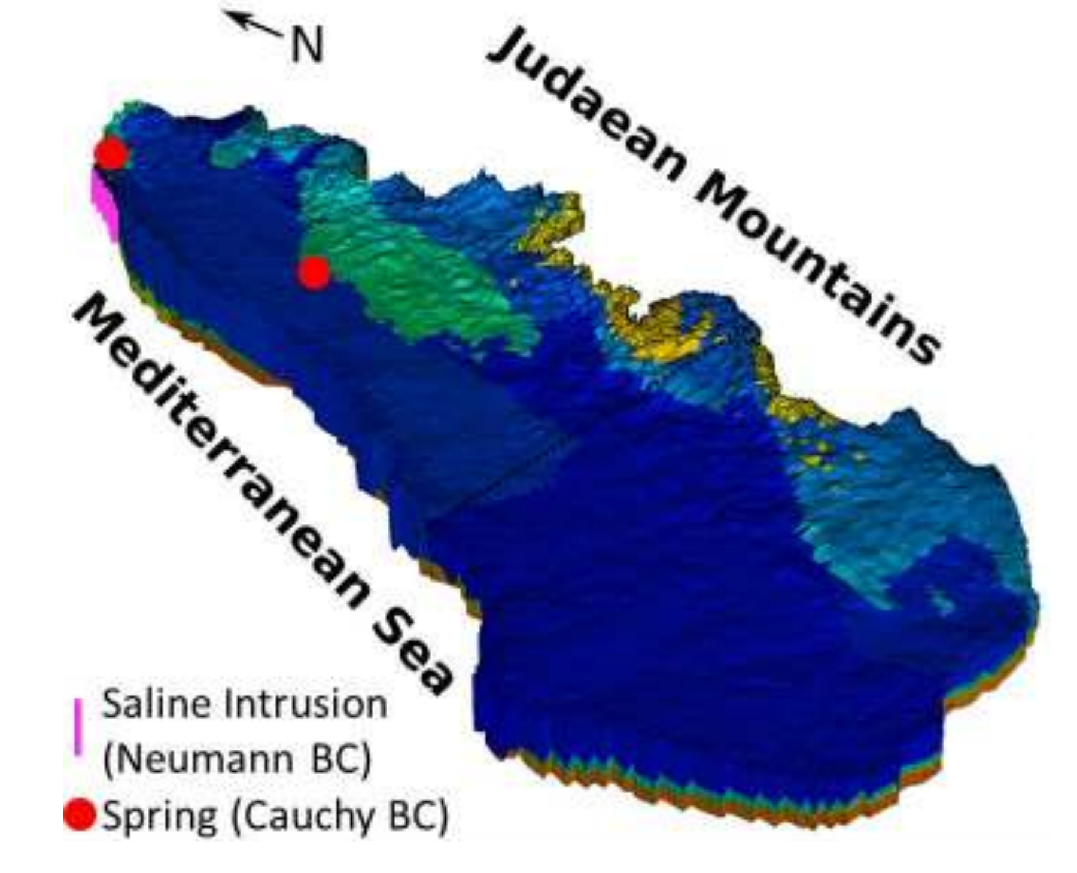


Figure 5: Multi-continuum model discretisation and boundary conditions

First Results

Derived geological and climatic development (Figure 6)

Messinian Salinity Crisis (5.96 – 5.33 Ma) key period for karstification due to major sea-level decline & development of canyons at coast, allowing for development of karst to substantial depth.

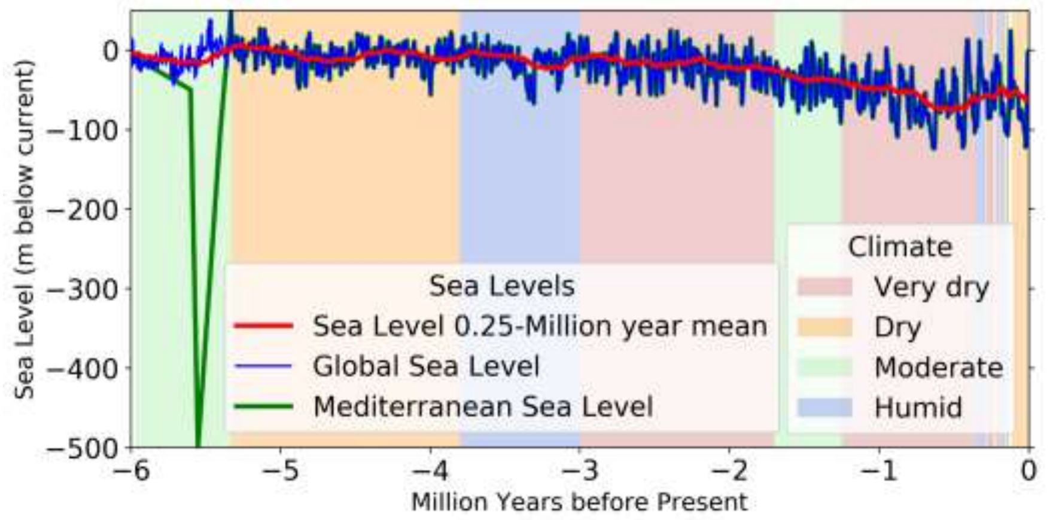


Figure 6: Global and Mediterranean sea levels and climate conditions for Israel region. Data compiled from Miller et al. (2005), Vaks et al., (2013) and Frumkin et al. (2000).

Calibration Results for Multi-continuum Model

Calibrated to piezometric pressure head and discharge observations from Abusaada & Sauter (2012) (Figure 7).

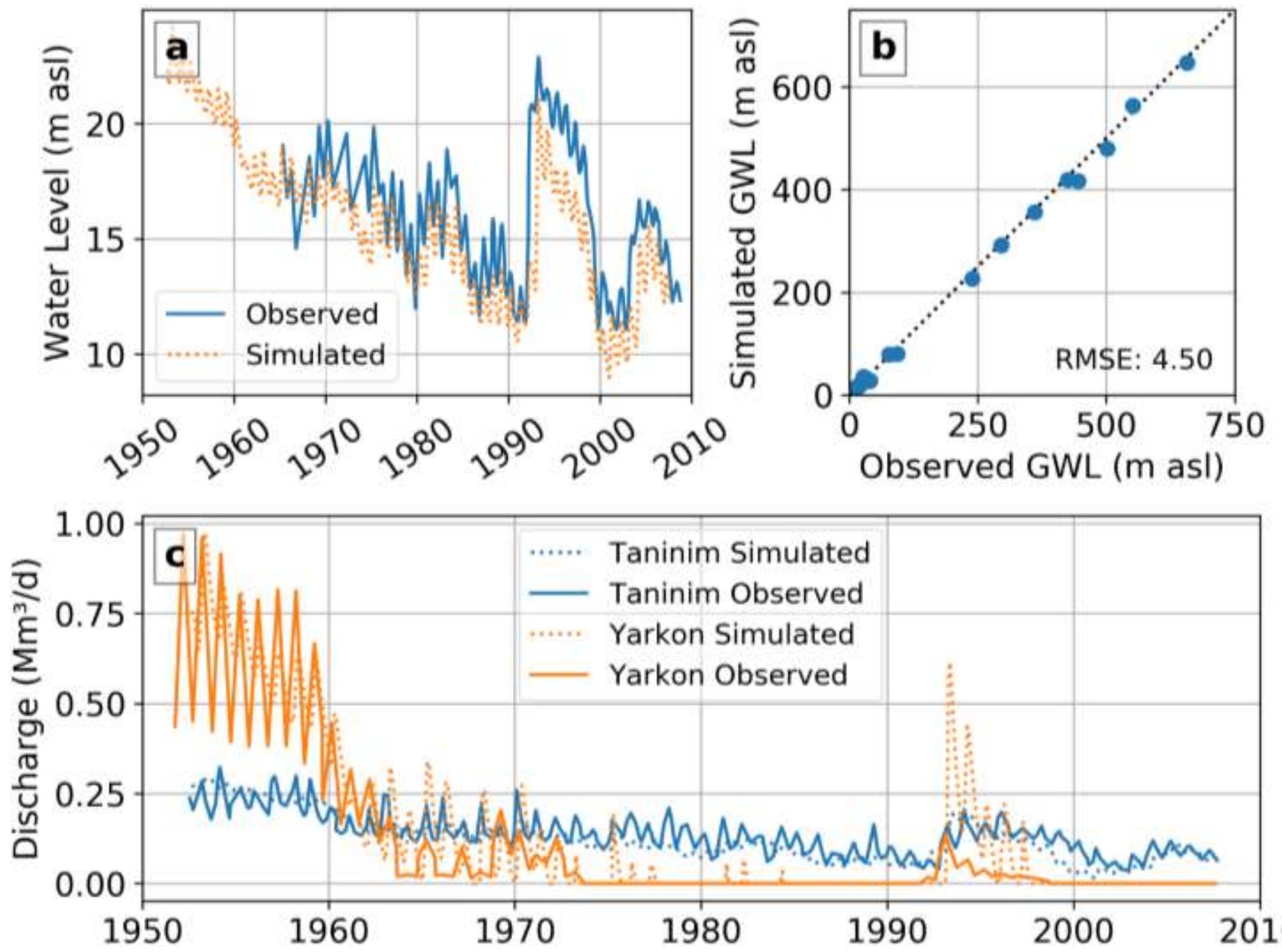


Figure 7: a) Transient peizometric head at well Beteh Tiqva (coastal region); b) Simulated Vs observed heads for initial steady state run; c) Transient spring discharge at two spring locations

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