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MedWater

Sustainable management of politically and economically relevant water resources in hydraulically, climatically and ecologically highly dynamic carbonate aquifers of the Mediterranean region

(Duration: 1.7.2017 – 30.6.2020)

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MedWater — GRoW GLOBALE RESSOURCE WASSER

Das Projekt wird vom Bundesministerium für Bildung und Forschung (BMBF) im Rahmen der Fördermaßnahme „Globale Ressource Wasser (GRoW)“ gefördert.

MedWater – German Partners

Koordination:

- TU Berlin, Chair for Hydrogeology - *Prof. Dr. Irina Engelhardt*

German Partners:

- University of Göttingen, Chair of Applied Geology - *Prof. Dr. Martin Sauter*
- University of Bayreuth, Chair for Ecology and the Environmental Sciences - *Prof. Dr. Thomas Koellner*
- University of Würzburg, Department of Remote Sensing - *Prof. Dr. Christopher Conrad, Dr. Sarah Schönbrodt-Stitt*
- VisDat GmbH - *Dr. Micha Gebel*
- BAH Berlin (Office for Applied Hydrogeology) - *Dr. Ruben Müller*

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- Università degli Studi di Napoli Federico II, Italy - *Prof. Dr. Pantaleone De Vita*
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- MEKOROT Israel National Water Co Ltd., Israel - *Dr. Yossi Guttman*
- Hydrological Service Israel (HSI) – *Dr. Yakov Livshitz*
- Ben-Gurion University of the Negev, Israel - *Dr. Meidad Kissinger*
- Hebrew University of Jerusalem, Israel - *Prof. Efrat Morin*
- Ariel University, Israel – *Dr. Yaakov Anker*
- Palestinian Water Authority, Palestine - *Dr. Subhi Saham and Dr. Hazem Kitana*

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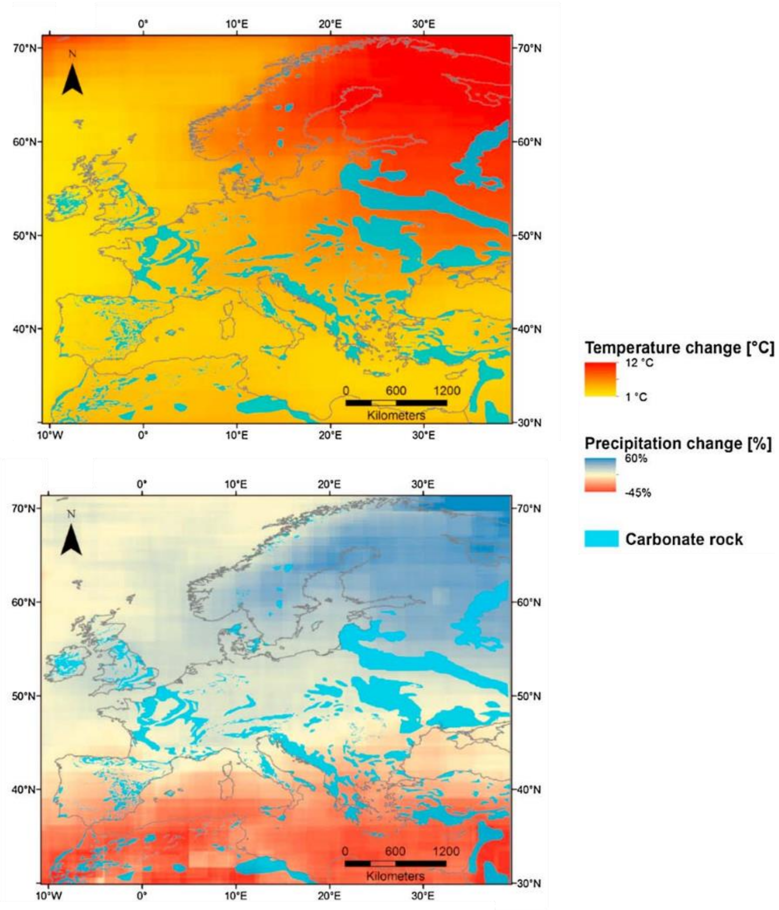
Motivation

- The Mediterranean region is already affected by **water scarcity** in many areas
- It is expected to be a "hotspot" for **climate change**
- **Carbonate aquifers** are characterized by a **high hydraulic diffusivity** (T/S) which implies a **low storage capacity**.

→ Carbonate aquifers **require dedicated water management concepts**

→ A **fully integrated approach** is needed taking into account groundwater resources, recharge, and the ecosystem.



Predicted mean change in temperature and precipitation until 2090 (Hartmann et al., 2014)

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What are the Effects of Climate Change?

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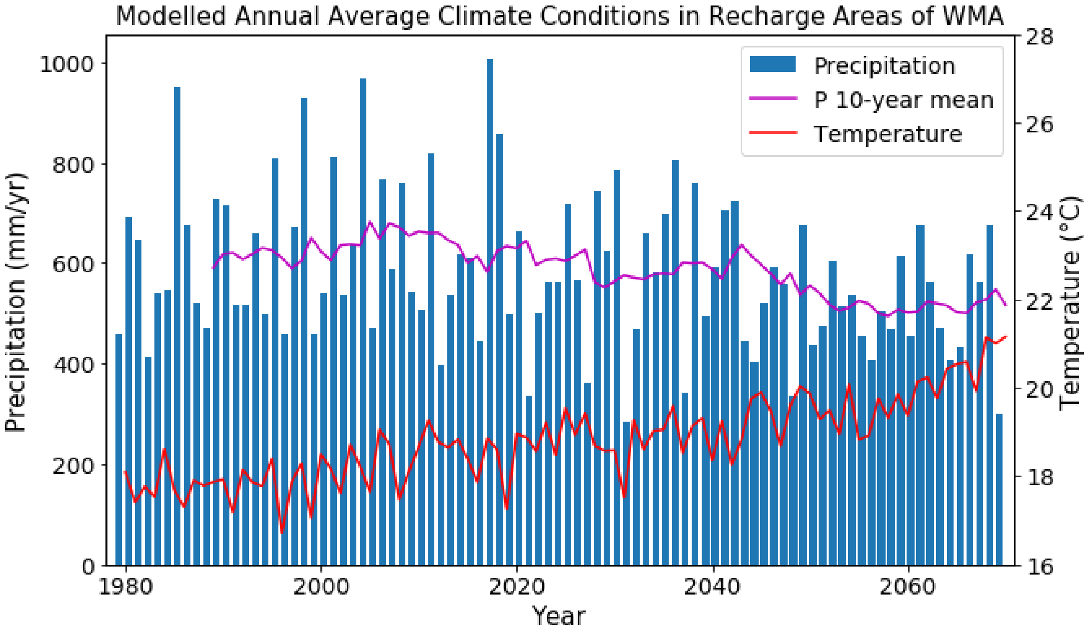
Simulation results (scenario RCP 4.5) for precipitation and temperature between 2010 and 2070 in the recharge area of the Western Mountain Aquifer, Israel, show:

- Increase in mean winter temperature > 2°C
- 20% reduction in 10-year mean precipitation
- Clear trend of a reduction of very wet years



Visualisation Climate Prediction - CIRA

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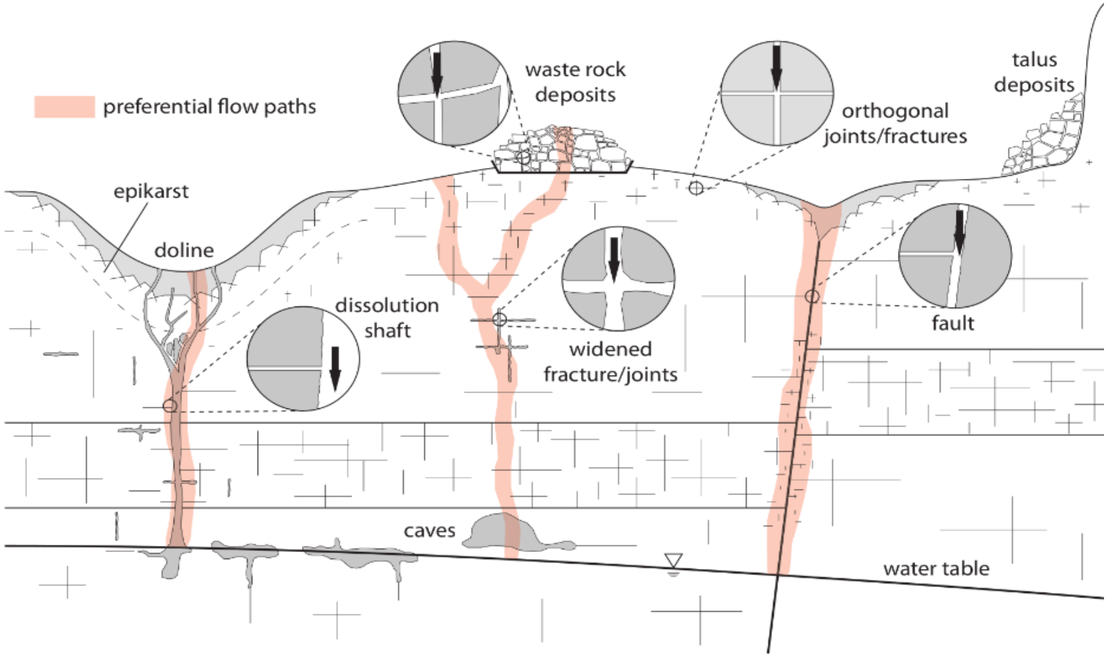
What are the Specifics of Karst Systems?

- ~10% of the Earth's continental area are carbonate rocks
- Karst aquifers supply ~25% of the world population with drinking water (Ford & Williams, 2007)
- Carbonate systems show a highly variable hydraulic response to hydrological events



Conceptual model of infiltration within karst (Kordilla et al., 2018)

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What are the Specifics of the Mediterranean Region?

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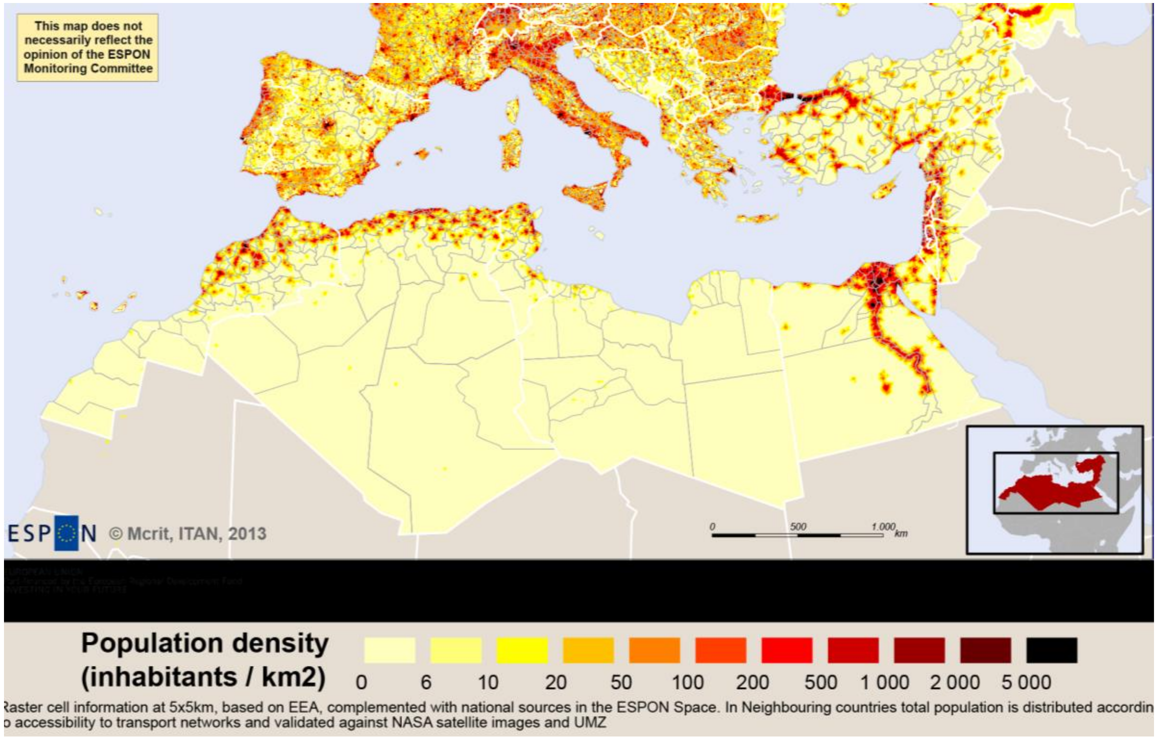
- Precipitation occurs as episodic and erratic events
- Recharge and discharge are often based on small numbers and highly variable
- High urbanization trend and population growth



Density of population in 2010 (CIST)

What does the Integrated Approach of MedWater consist of?

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Integrated approach accounts for:

- **Interaction** of climate change, ecology, surface water and groundwater
- **High variability** of the hydrological system and its event-based pattern
- Complex **recharge mechanisms**

Expected results comprise:

- **Global transfer** of the obtained results
- Optimized **water management strategies**
- **Decision Support System (DSS)**

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What is the basis for process and data based Water Management Tools?

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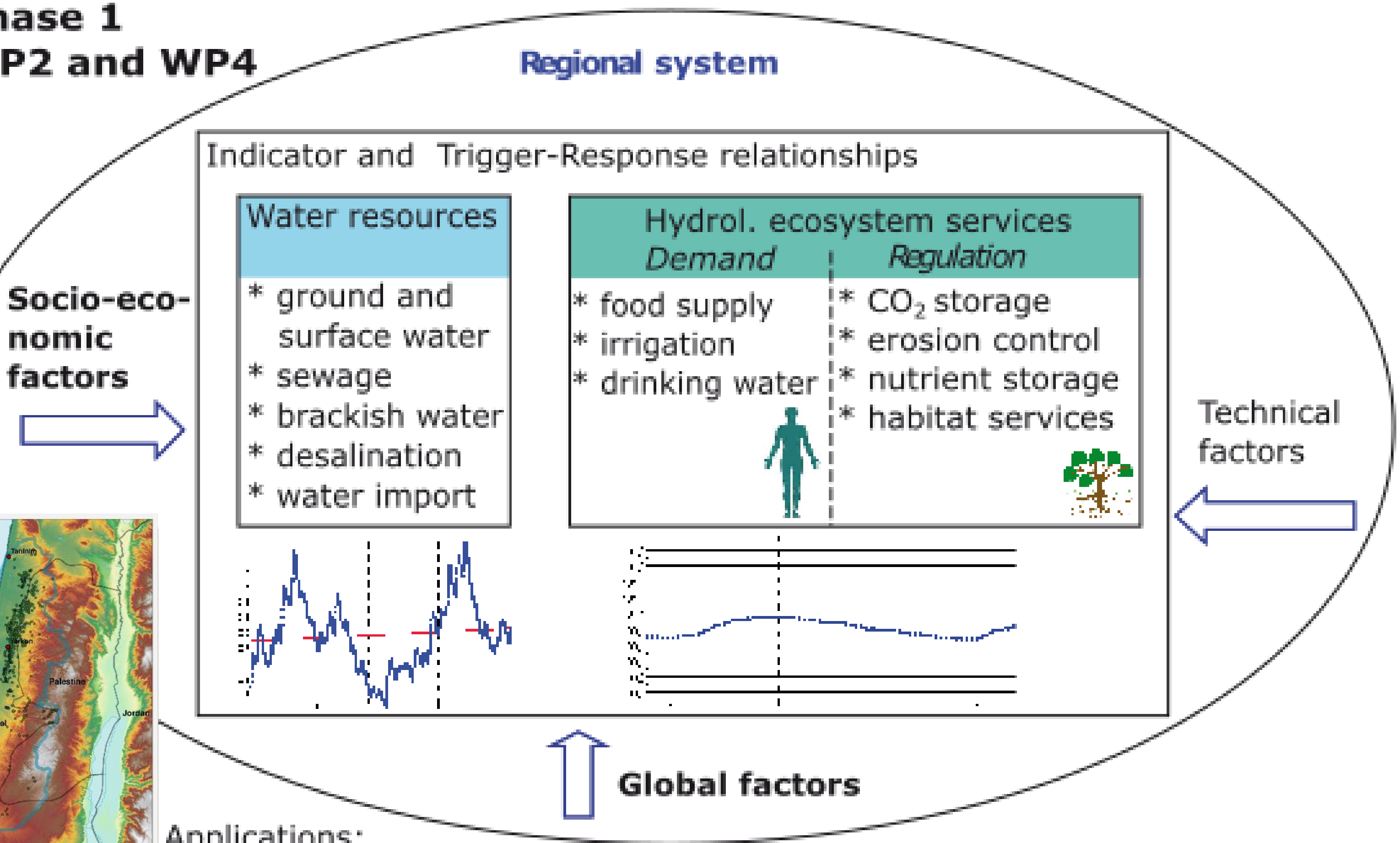
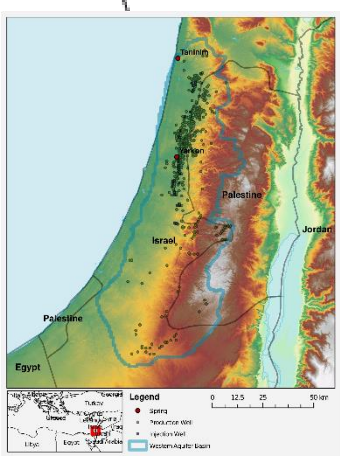
Phase 1
WP2 and WP4





Applications:
Regional system
Mountain-Aquifer, Israel / West Bank

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What is the basis for process and data based Water Management Tools?

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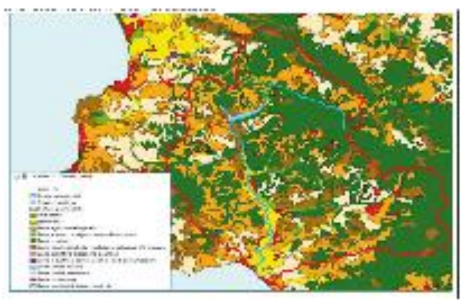
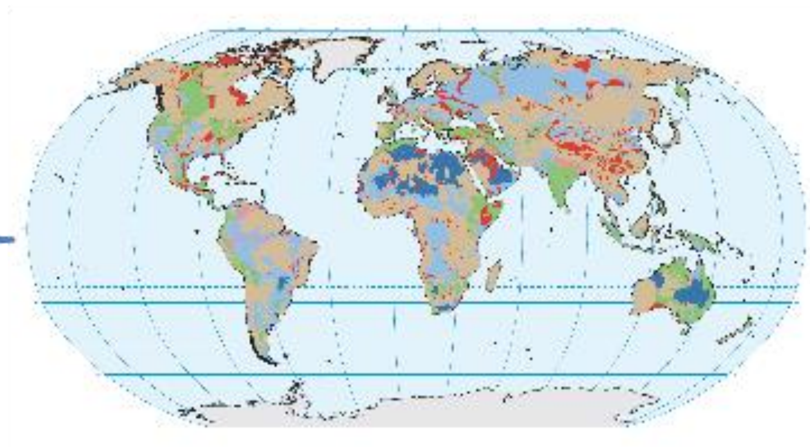
Phase 3
WP6 and WP7

Transfer into global assessment matrix

Verification
at transfer locations
Alento catchment, Italy
Lez catchment, France





Real-Time DSS for optimal management of vulnerable carbonate aquifers

CGMW (2010), Williams & Fong (2010) ; red = carbonate aquifers

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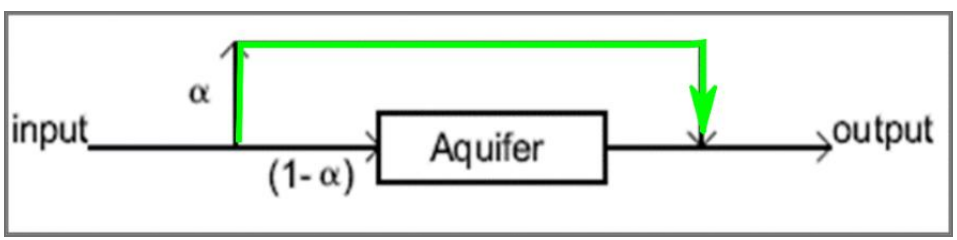
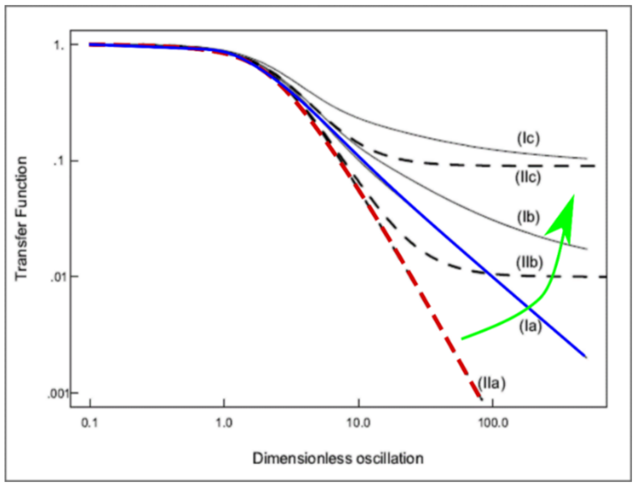
Statistical Model for System Characterization

Simplest, lumped parameter model, just based on precipitation and spring discharge time series which predicts the system behavior only in the observed domain.

- **Transfer Function (TF**) derived in the frequency domain **to convert input signal to output signal** (e.g. Dupuit, Linear Reservoir)
- The **α coefficient** represents the fraction of the **rapid bypass component** (Moléant, 1999)





TF for idealized models in frequency domain and influence of rapid flow component α, varied between 0 and 0.3 (Moléant, 1999)

Combined Model

$$|H(\omega)|^2_{comb} = \left|\left(H_{aquif}(\omega)(1-\alpha)+\alpha\right)\right|^2$$

Single Continuum Model considering the Karst Development

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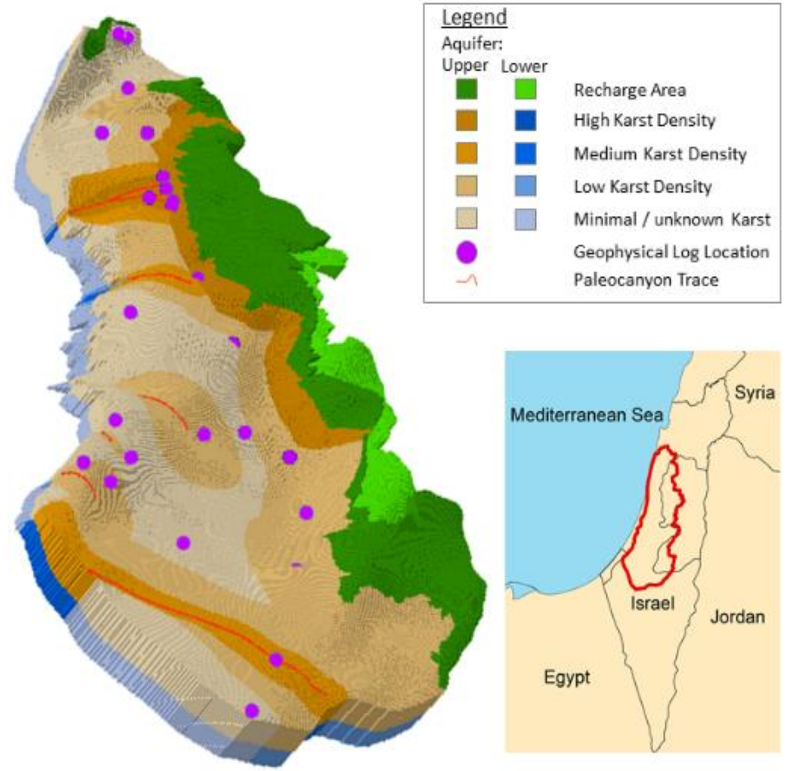
Numerical model with reasonable data demand and less predictive power:

- Reduced number of parameter due to **data scarcity** and parameter **uncertainty**
- Increased density of conduits close to **paleo-canyons**
- Distribution of karstified areas that display the **genesis of the karst system** during the geological history

➡ Pseudo-genetic **Stochastic Karst Simulator SKS** (Borghi, 2012) to generate the conduit network



Modflow model that accounts for zones of karst density (Laskow et al., 2011)

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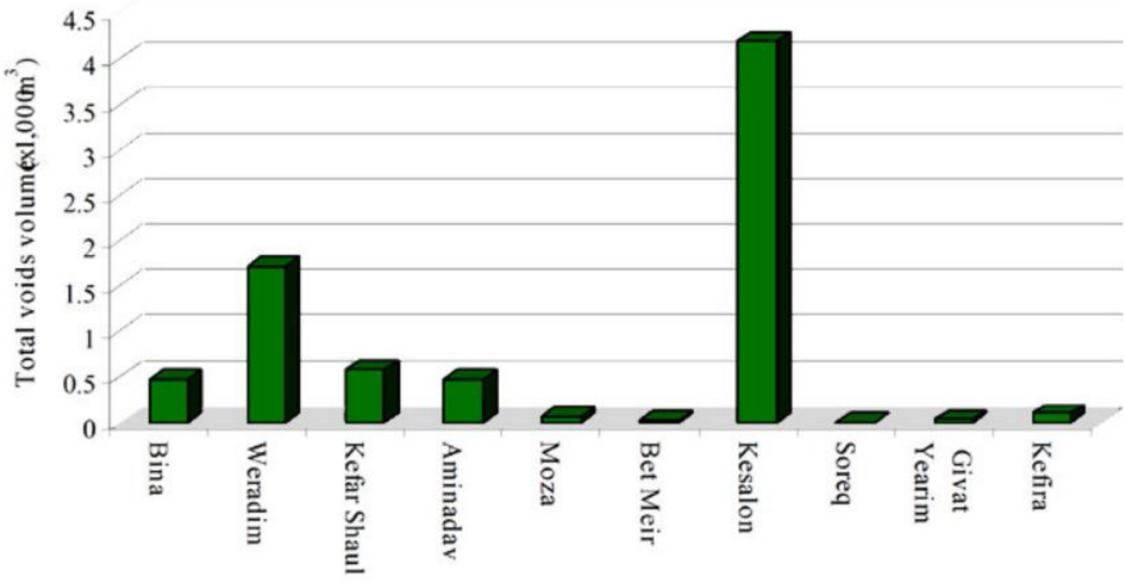
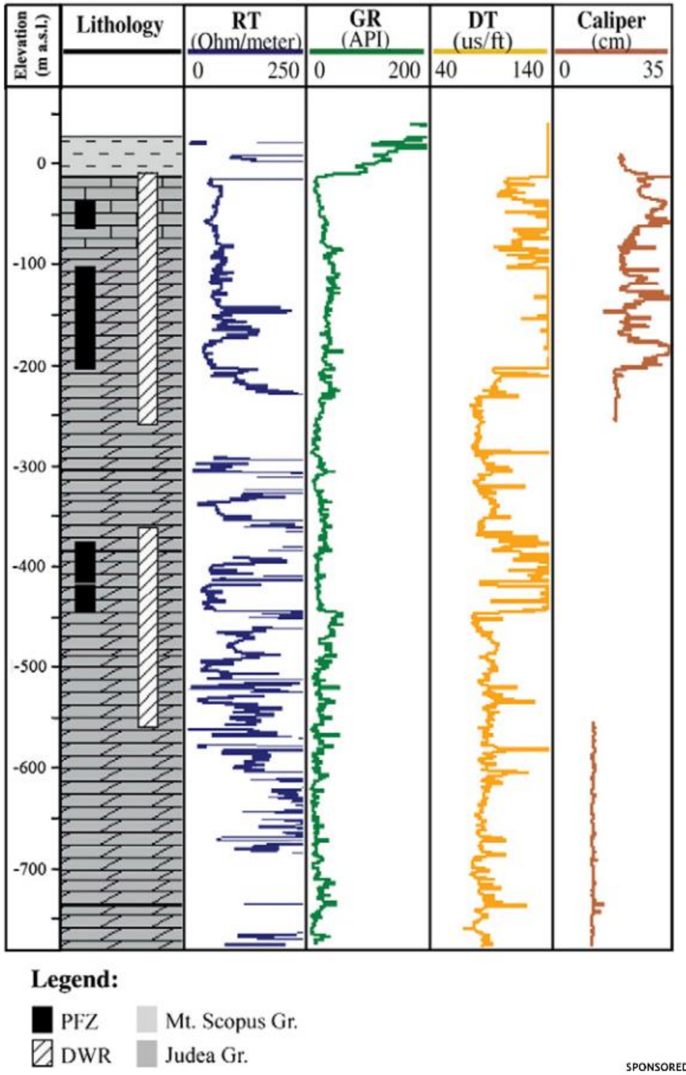
Soft Data Employed for Model Calibration

Karstified zones and karst heterogeneity from lithological data and geophysical borehole logs

High vertical heterogeneity of the WAB displayed by total void volumes (Frumkin, 2006)





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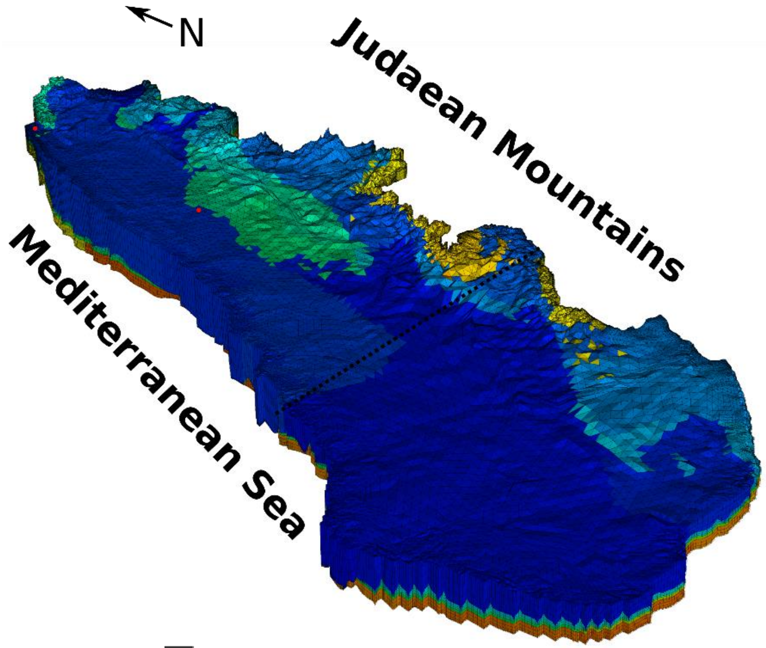
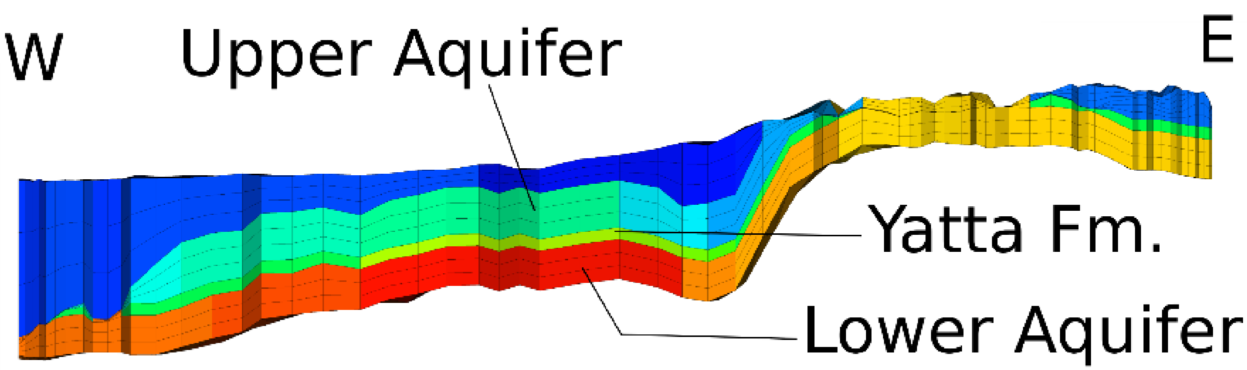
Double Continuum Model with a Deterministic approach

Numerical model with high data demand and high predictive power:

- Coupled model of **surface and subsurface** flow
- **Exchange between the two domains** (matrix and conduit) is enabled using a Darcy-type head controlled exchange term





Discretization of the WMA model using HydroGeoSphere (HGS)

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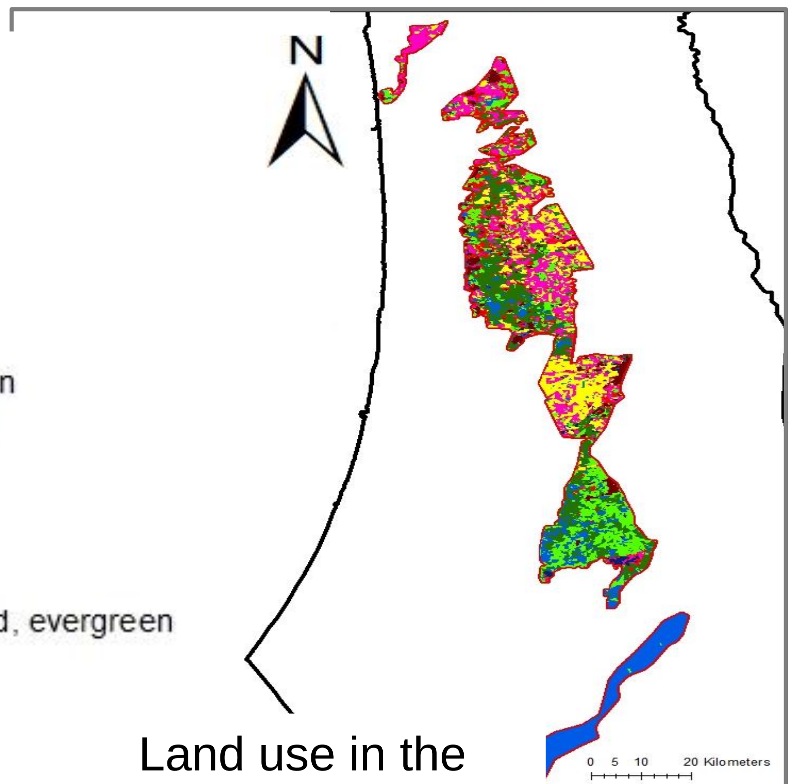
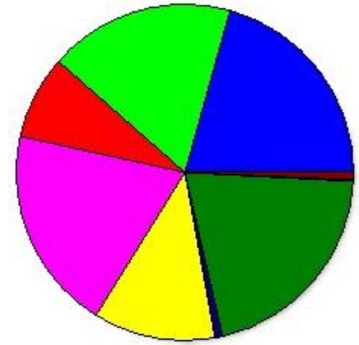
Factors beyond Hydrology that affect Recharge and the Water Resources

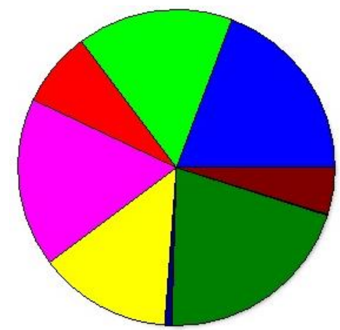
The distribution of land use within the recharge area of the WAB changed with respect to urbanization.



Land use in the recharge area 2015



Land use distribution in 1992



Land use distribution in 2015

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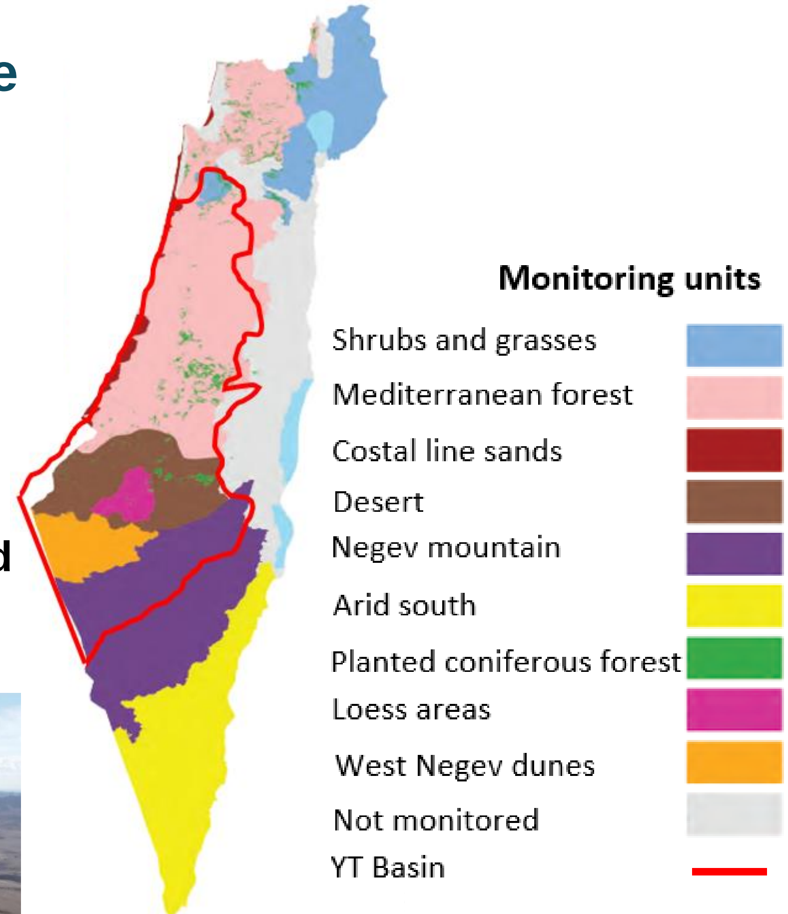
Factors beyond Hydrology that affect Recharge and the Water Resources

MedWater also accounts for the impact of different vegetation types on recharge

Mediterranean forest
Rainfall: 500-750 mm

Shrubs and Grassland
Rainfall: 500-600 mm

Negev Desert and Dunes
Rainfall: <350 mm



Monitoring Units (State of Nature Report, 2016)

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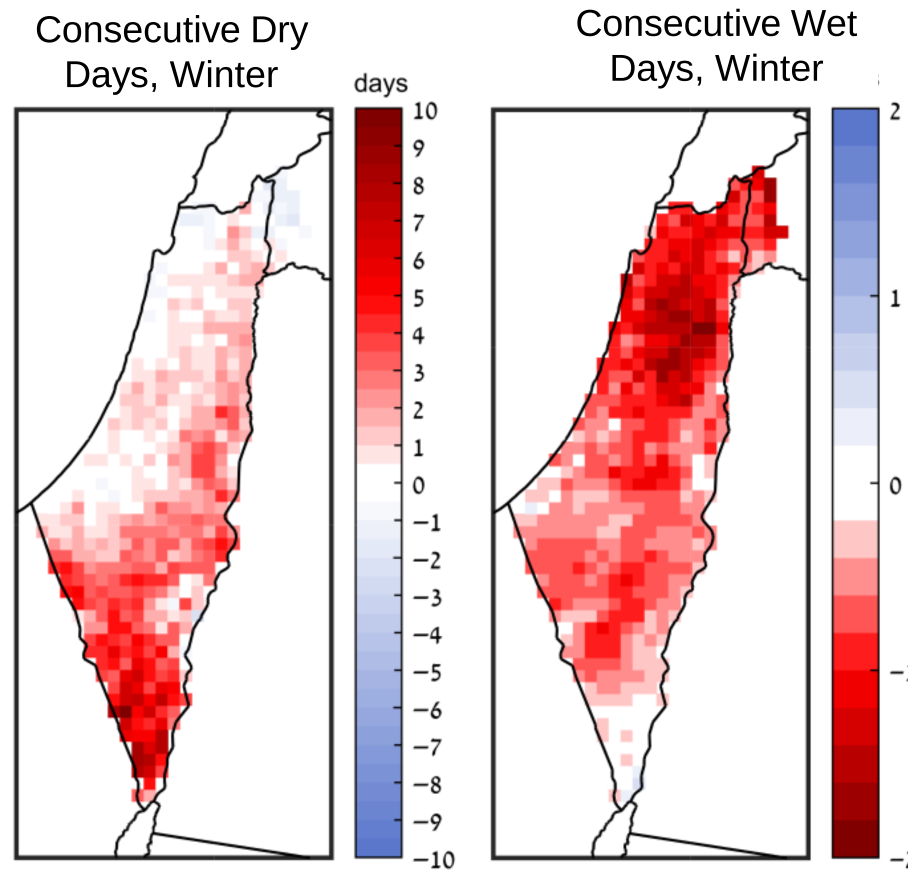
Scenario Analysis – Water Supply

The numerical models allow for the implementation of climate prediction calculated for Israel (MedCORDEX, Italian Aerospace Research Centre)

- **RCP4.5** climate scenario
- **8 km grid**, focussed on Israel
- **Daily time-step** from 1980 to 2071

Predictions:

- **less rainfall**, but **more extreme events**
- In winter **longer dry periods** (up to 8 d) and **shorter wet periods** (up to 2 d)



Difference between ref. period (1981-2010) and projection period (2041-2070)

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Definition of Socio-Economic Scenarios:

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Three Scenarios from variation of
Six Management Factors:

F1. Irrigation efficiency

F2. % water supply from desalination

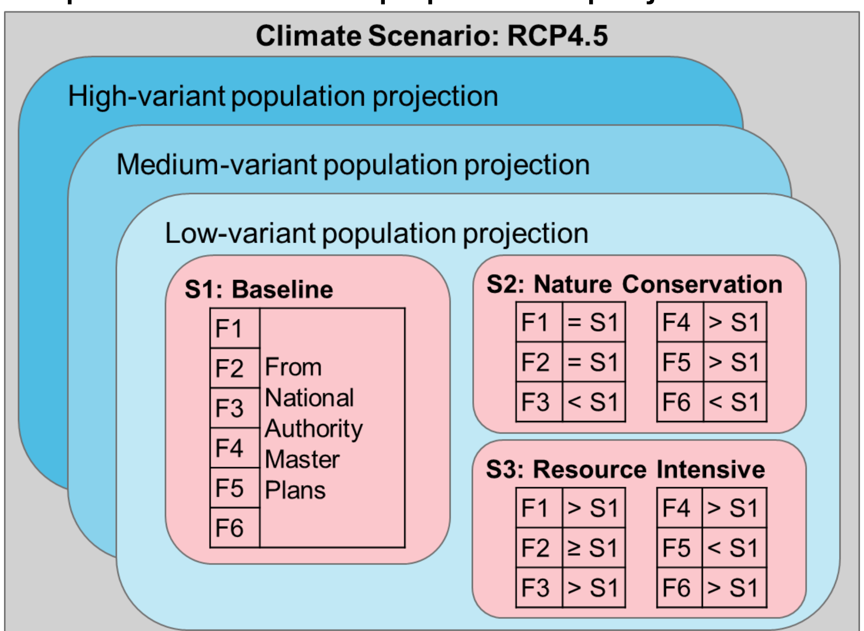
F3. % land area for agriculture / urban

F4. % waste water treated

F5. % land area for nature

F6. Per-capita water consumption

Repeated for three population projections:



S1: <u>“Baseline”:</u>

- All factors from national authority Master Plans

S2: <u>“Nature Conservation”:</u>

- < urban / agricultural land
- > wastewater treatment rates
- > land for nature conservation
- < per-capita consumption

S3: <u>“Resource Intensive”:</u>

- > irrigation efficiency
- > reliance on desalination
- > urban / agricultural land
- > wastewater treatment rates
- < land for nature conservation
- > per-capita consumption

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Definition of Socio-Economic Scenarios:

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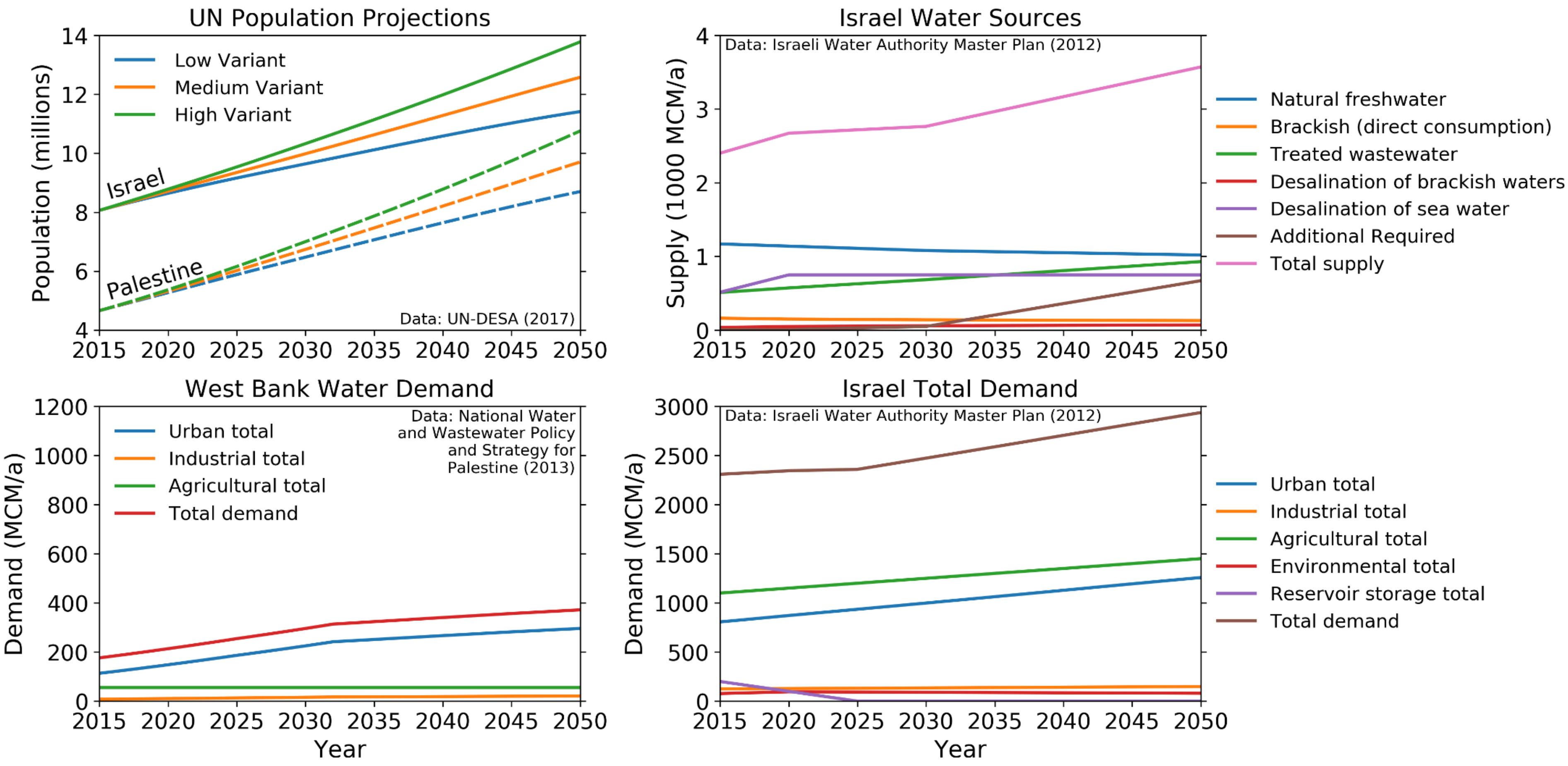
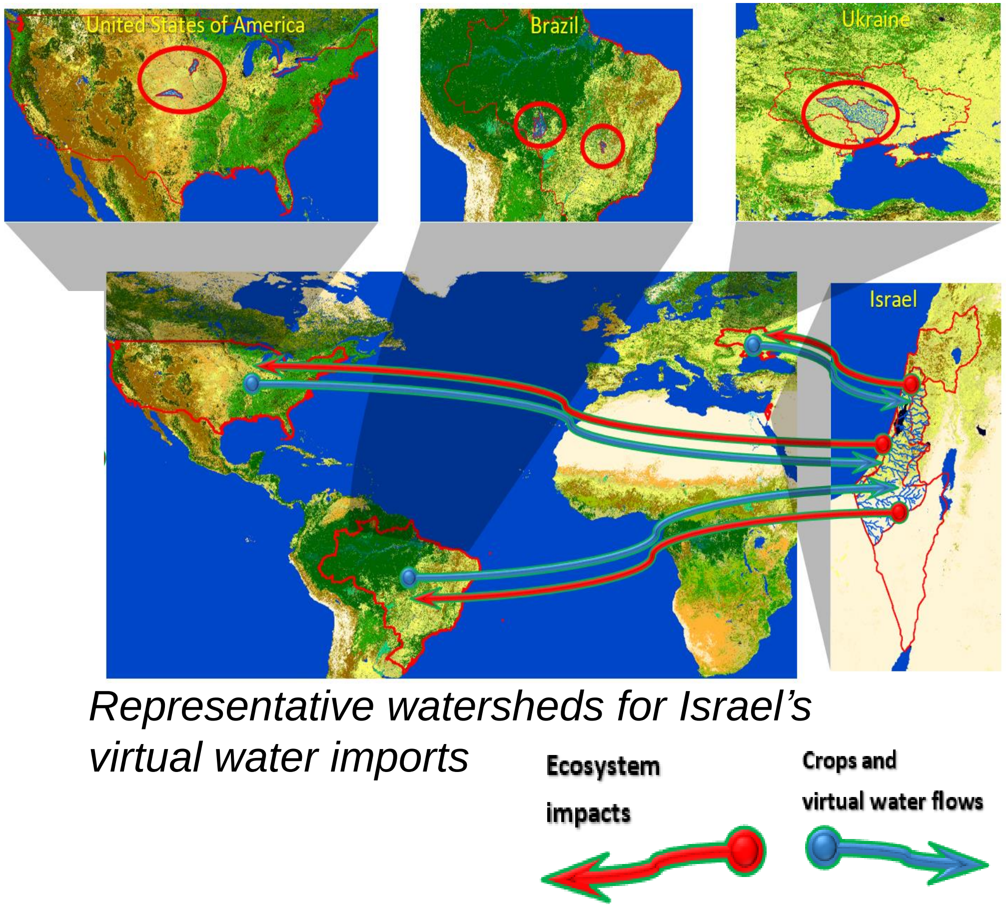
“Baseline” scenario based on national authority Master Plans:



Import and Export of Virtual Water

Development of interregional SWAT models to examine virtual water fluxes and its impacts on ecosystem services and wetland biodiversity

- **import** of virtual water via **wheat**, **maize,** and **soybean** (60% of all crop imports) mainly from USA, Ukraine and Brazil
- **export** of virtual water via **potatoes** (28% of crop exports), **vegetable** (18%), **fruits** (13%), **juices** (10%) and **cotton** (2%)



Representative watersheds for Israel's virtual water imports

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Multi-Objective Optimization (MOO)

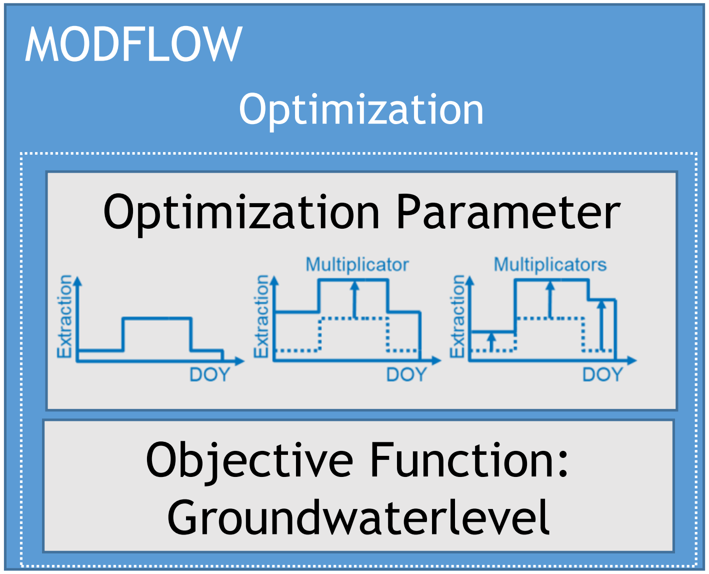
- Development of an external MOO-Algorithm for **simulation-based optimization**
- Definition of contrary **fitness criteria** (e.g. salt water intrusion due to overpumping, reaching the "green or red line", minimize energy consumption, etc.)

Input:

- Groundwater level from the calibrated groundwater model
- Information about well location, extraction rates, ecology, alternative water resources

Output:

- Optimized well positions
- Optimized extraction pattern for well groups



Transfer from Regional to Global Scale

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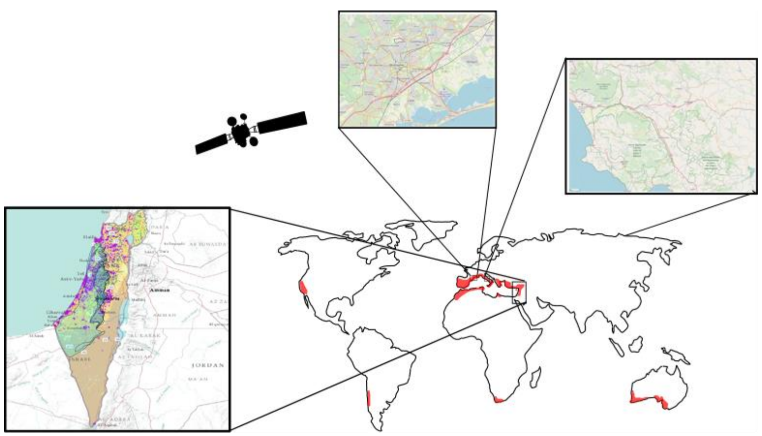
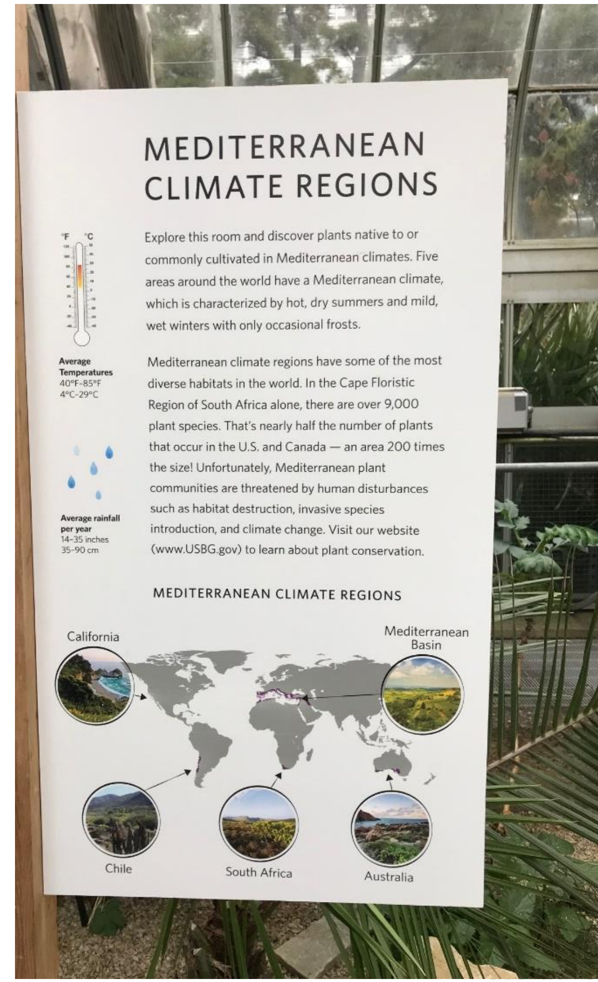
One of the key goals of MedWater is to develop an upscaling method to generalize the results:

1. Step: Upscaling of **plot-scale processes** to regional scale
2. Step: Regional models of Israel are **transferred and verified at further study areas** in Italy and France
3. Step: Development of **transfer functions** allow to transfer results from regional to the global scale (Mediterranean climate regions)





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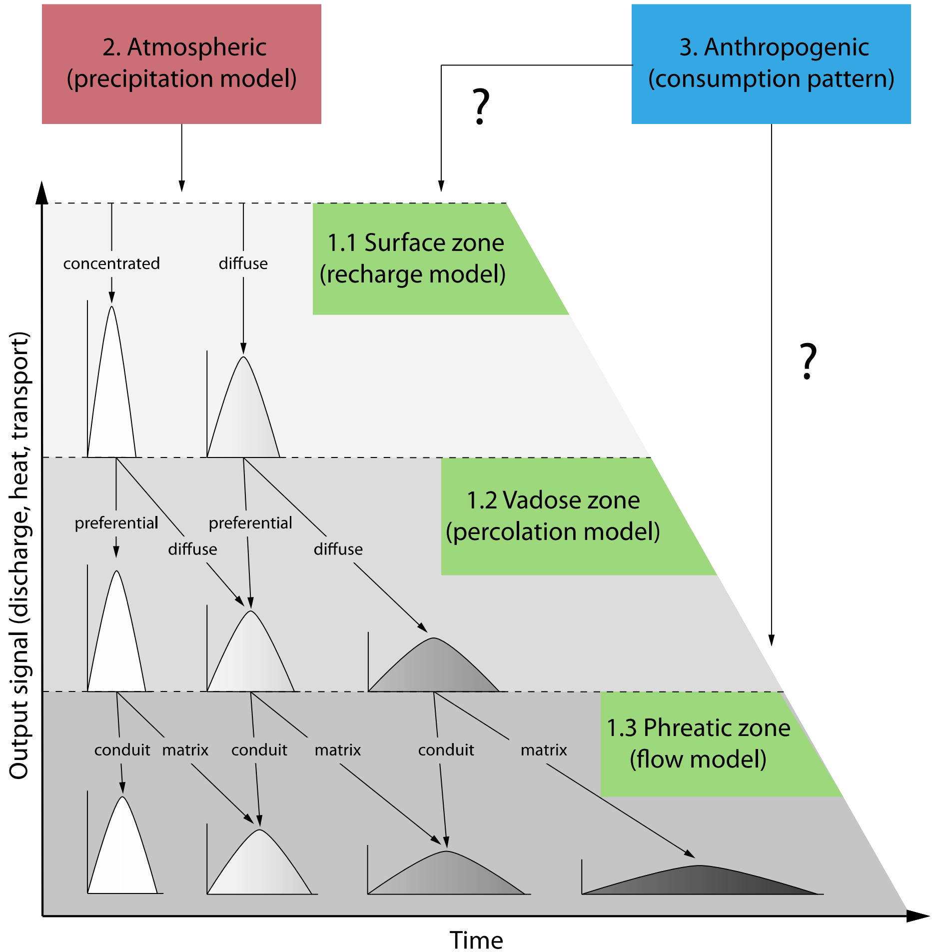
Discharge Response of Karst Aquifers

Step 1: The development of transfer function requires understanding of the interaction of individual compartments in a karst system



The final signal is composed of effects and characteristics of:

1. Atmospheric input
2. Anthropogenic input
3. Aquifer
   - Surface zone (1.1)
   - Vadose zone (1.2)
   - Phreatic zone (1.3)

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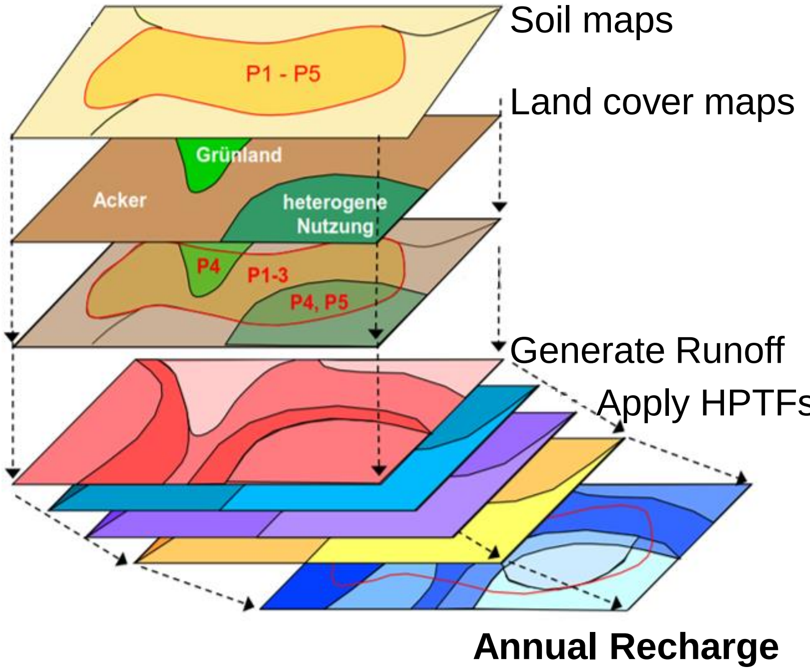
Hydro-Pedotransfer Functions for Surface Zone Processes within Karst Aquifers

Step 2: Hydro-Pedotransfer functions (HPTFs) enable calculation of daily recharge at regional scale

- Derived by calculating water fluxes in the unsaturated zone for **synthetic scenarios**
- Results are analysed using **non-linear multiple regression analysis**
- **Data from remote sensing** are employed to apply HPTFs to further karst aquifers in the Mediterranean region.



Application of the TUB-BGR Method (HPTFs) for annual percolation rates in Germany

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Test Site in Italy for Transfer Methodology

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New installations in the **Capudifume Catchment**:

- **Precipitation:** Rain Gauges
- **Meteorological data:** Weather Station
- **Spring Discharge:** CTD Divers and Multiparameter Sensor
- **Soil moisture** sensors

Recharge zone Capodifume Catchment

Soil moisture sensors (measuring depth: 10 cm)

Rain gauge on top of Monte Chianiello

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Global Transfer

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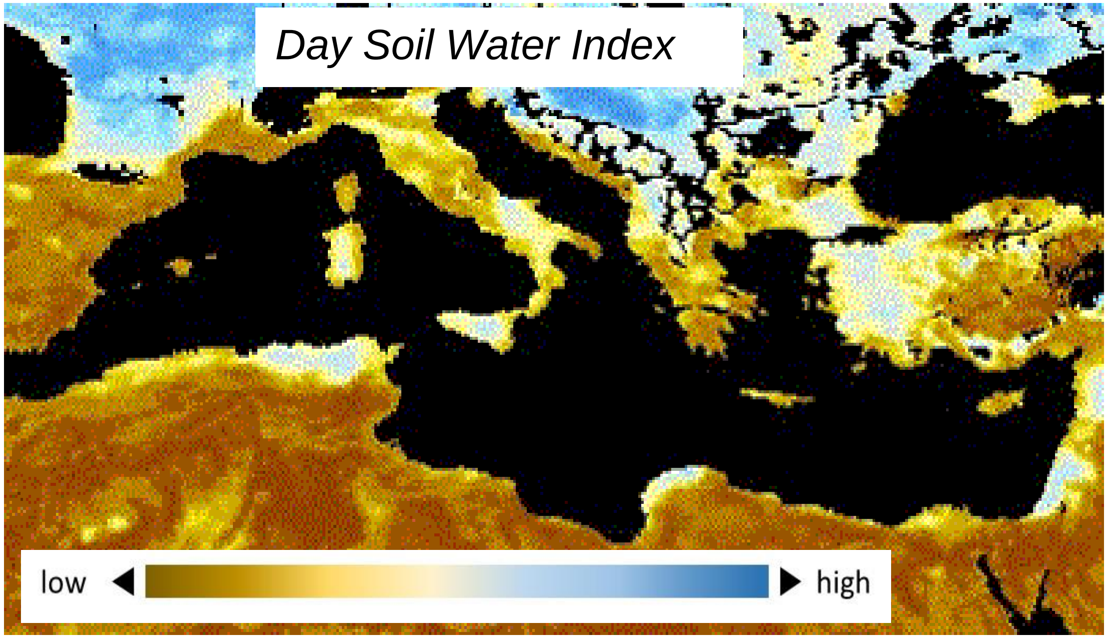
Step 3: Remote sensing data are used for global transfer and provide valuable information such as:

- **Global data** such as land use, soil, climate, and topography of global carbonate aquifers
- **Local-specific data** such as land cover and soil moisture information for identified carbonate aquifers



Soil Water Index

- Globally available with a 12.5 km grid
- 1 m depth
- Since 2007 – ongoing
- Time step: daily, averaged for 10 days

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Results –
Calibration of the Double Continuum Model

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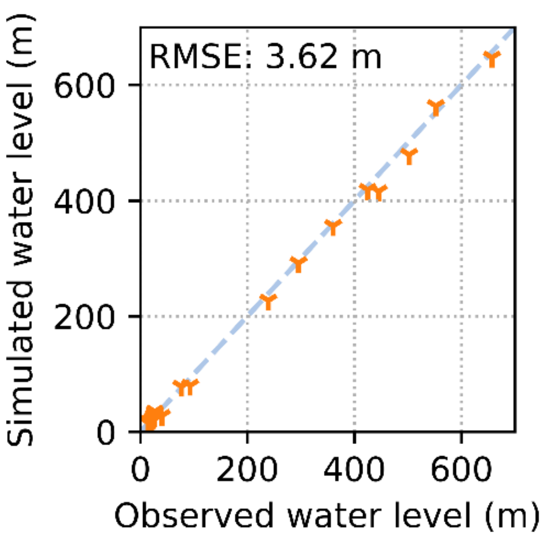
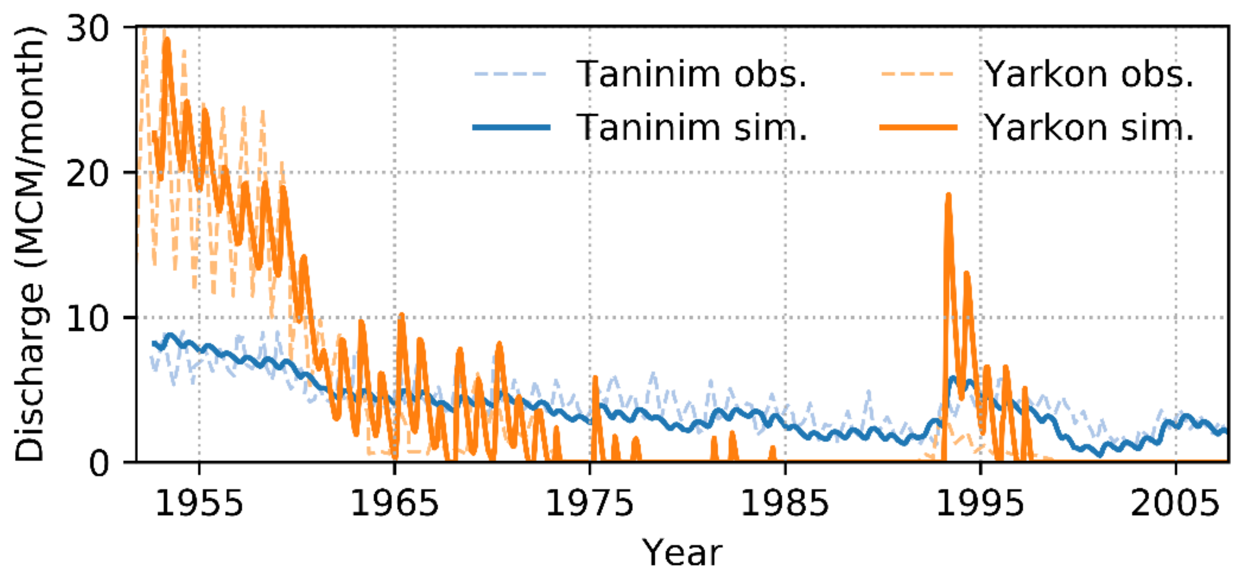
- Initial single-continuum model to pinpoint boundary conditions
- Calibrated to the GWL under undisturbed conditions (prior to 1950s)
- Drying up of the Yarkon as a calibration target





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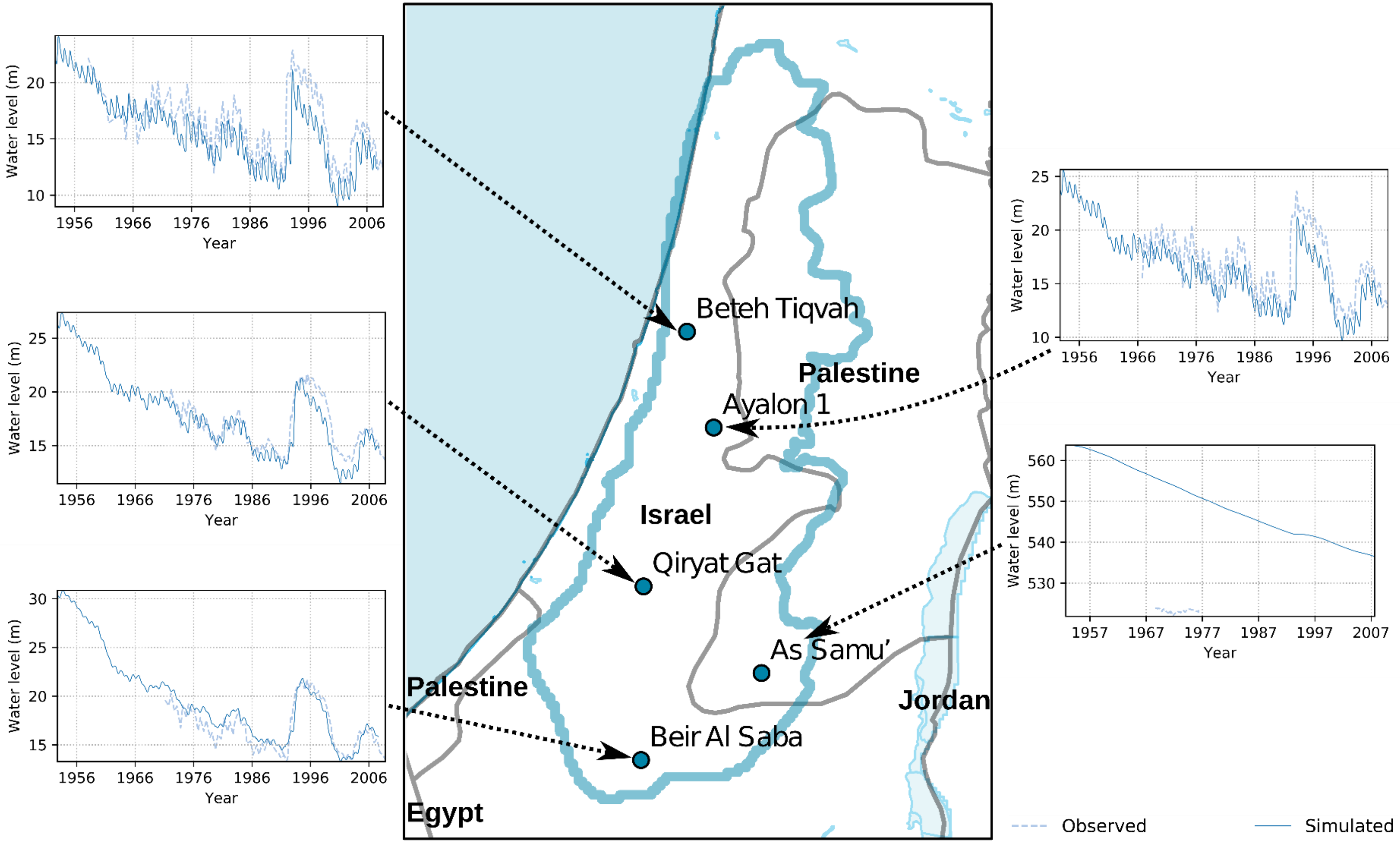
Results –
Calibration of the Double Continuum Model



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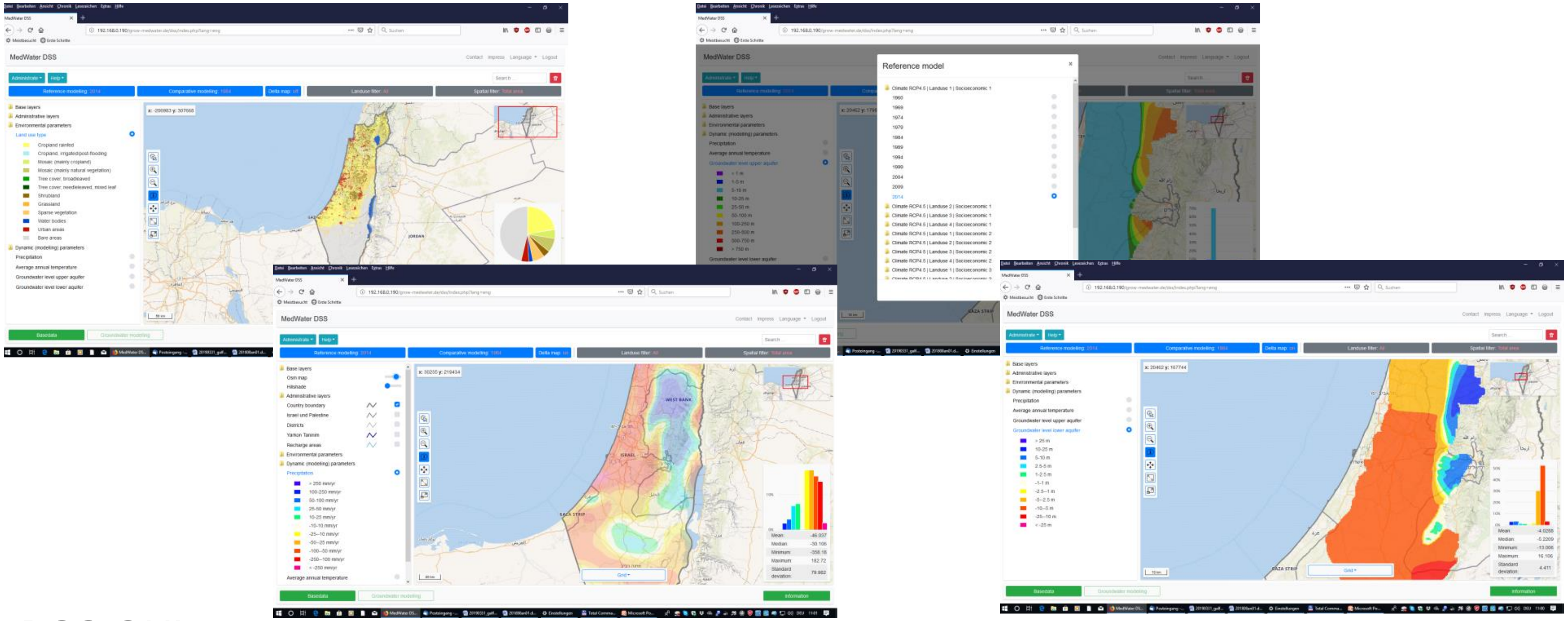
Products – Decision Support System (DSS)

The DSS consist of three interlinked components:

1. **Import routine** converts numerical model results and configuration files into the DSS data environment
2. **Control environment** to select "passive" scenarios (basedata) and configure "active" scenarios (e.g. add wells, change pumping rate, live processing)
3. **Graphical user interface** (**GUI**) to visualize the modelling results



DSS GUI

DSS Workflow and Data Storage

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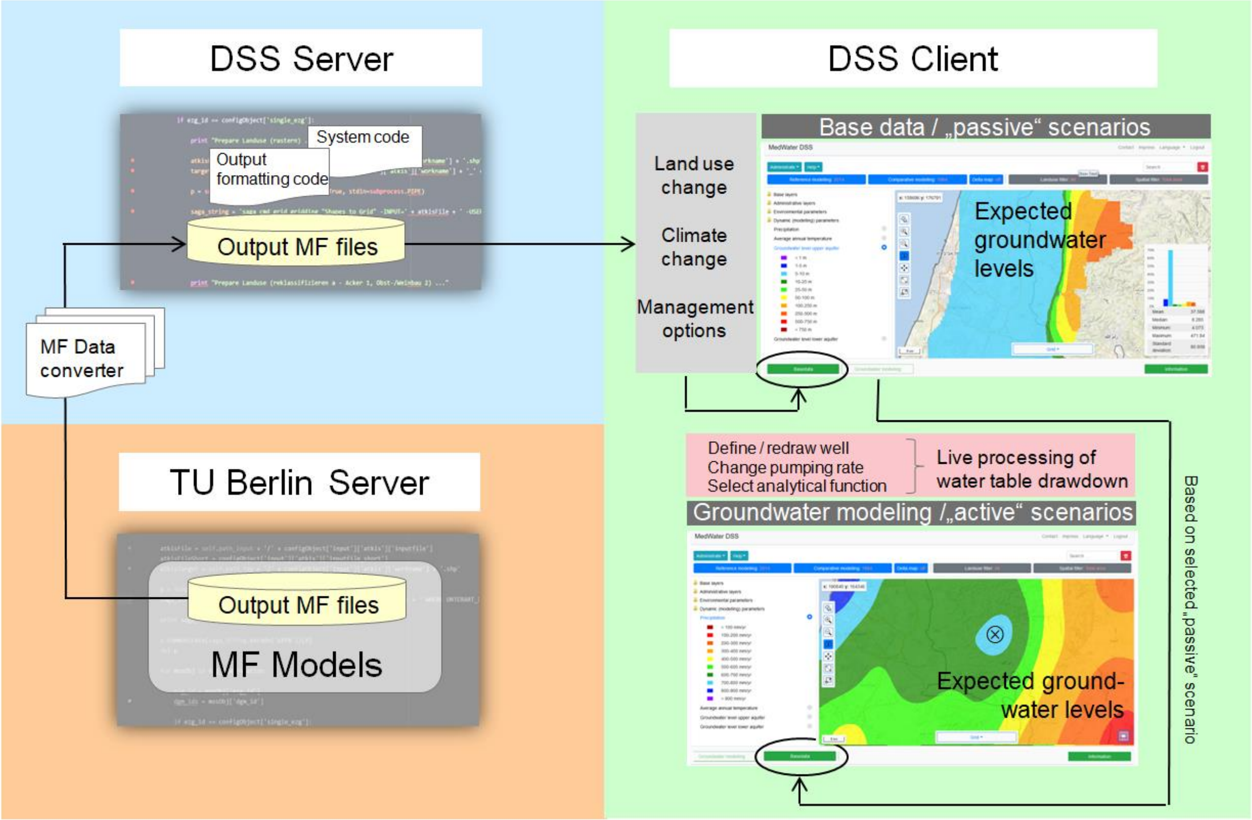
Based on close cooperation and interaction with our stakeholder in Israel a concept of the Web-based DSS was developed and continuously adjusted:



The DSS **simplifies** the modeling process for the end-user.

It focusses on the **impact of water extraction and shifts in climate** on the available water resources.

GUI shows **key results as diagrams and gives recommendations.**

Dissemination & Knowledge Transfer

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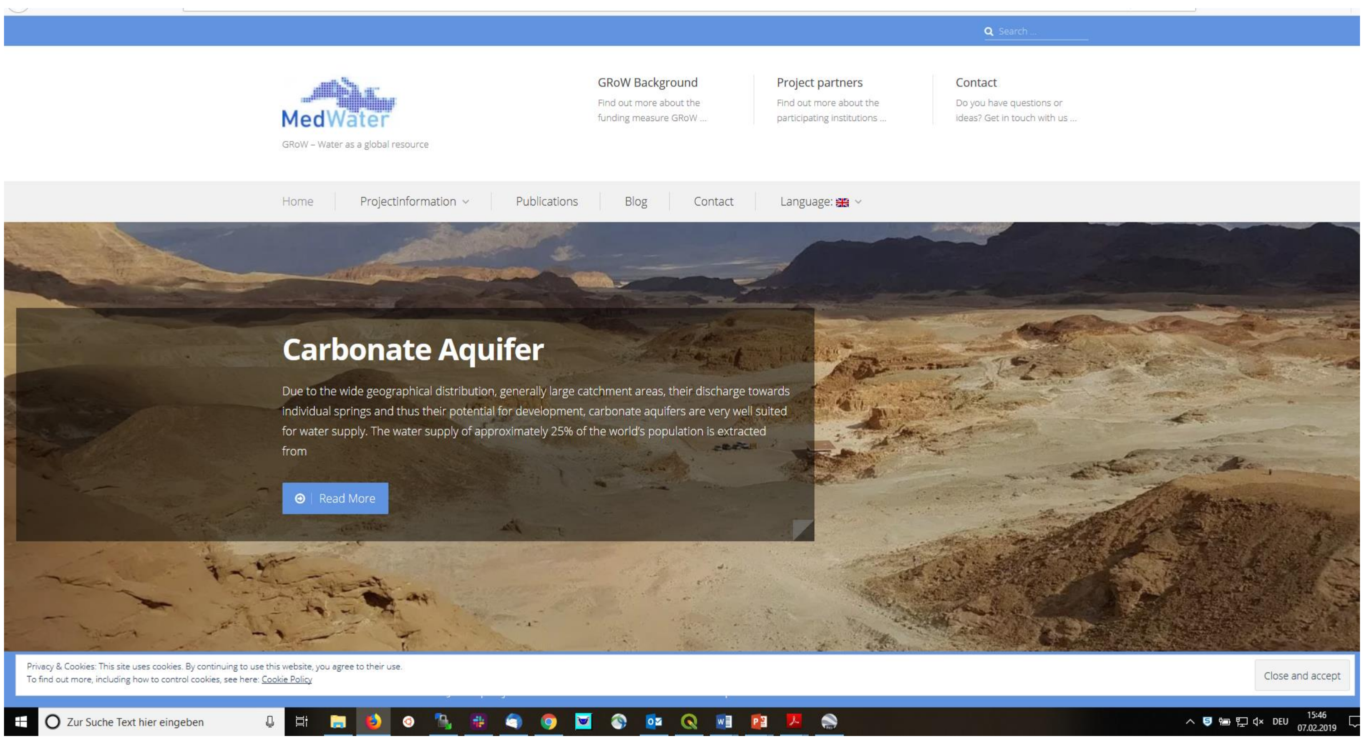
- Design of **data platform** to ensure data handling under high security issues
- **Workshop for scenario catalogue** – needs and concerns of stakeholders
- **Homepage** to inform about the project progress and new activities
- **Training and workshops** of local users for application of the DSS



MedWater Homepage

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Intermediated Project Summary

- ✓ **Modeling tools identified and new methods tested**
- ✓ **Data collected and suitability checked**
- ✓ **New field site identified and instrumented (Italy)**
- ✓ **Alternative hydraulic characterization techniques employed (aquifer genesis model, geophysical borehole data)**
- ✓ **Integration of stakeholder demand into modelling and DSS concept**

Thank you for your attention