Large-scale simulation of karst processes - parameter estimation

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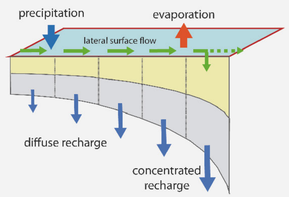
MOTIVATION

Karst develops through the dissolution of carbonate rock. Karst groundwater in Europe is a major source of fresh water contributing up to half of the total drinking water supply in some countries. Climate model projections suggest that in the next 100 years, karst regions will experience a strong increase in temperature and a serious decrease of precipitation - especially in the Mediterranean region. Previous work showed that the karstic preferential recharge processes result in enhanced recharge rates. But as there is fast water flow form the surface to the aquifer, there is also an enhanced risk of groundwater contamination.

THE MODEL



We simulate groundwater recharge with a new type of semi-distributed model that considers the spatial heterogeneity of the karst system by distribution functions.

DATA

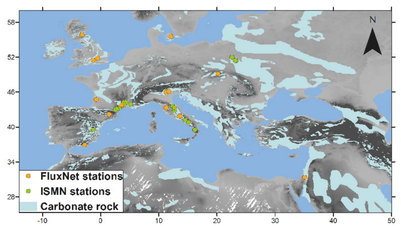
Variable	Spatial resolution	Time period	Frequency	Source
Precipitation	0.25°	2002–2012	daily	GLDAS-2
Temperature	0.25°	2002–2012	daily	GLDAS-2
Net radiation	0.25°	2002–2012	daily	GLDAS-2
Snow water equivalent	0.25°	2002–2012	daily	NOAHv3.3/GLDAS-2
Carbonate rock areas	vector data	–	–	
Elevation	3″	–	–	SRMT V2.1
Rock permeability	vector data	–	–	
Actual evaporation	individual locations	individual periods	daily	FLUXNET
Soil moisture	Individual locations	individual periods	daily	ISMN

PARAMETER ESTIMATION SCHEME

1. Initial model parameter ranges

A newly developed parameter estimation scheme is applied to derive parameter sets and remaining parameter uncertainty for four karst landscapes using AET (Fluxnet) and soil moisture (ISMN) observations for 2002-2012.

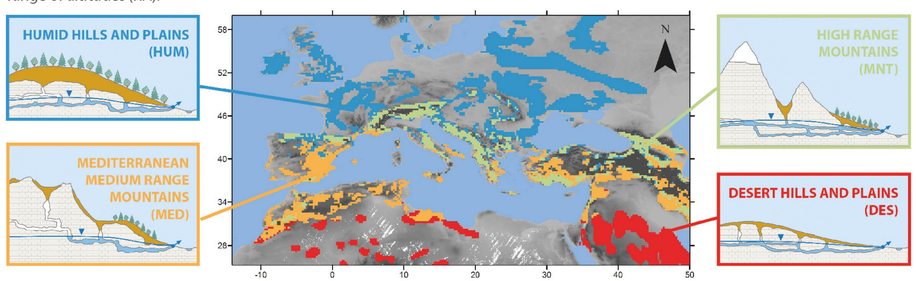
Initial parameter ranges are the same for all karst landscapes. They are assessed by prior experience with the model at the catchment scale.



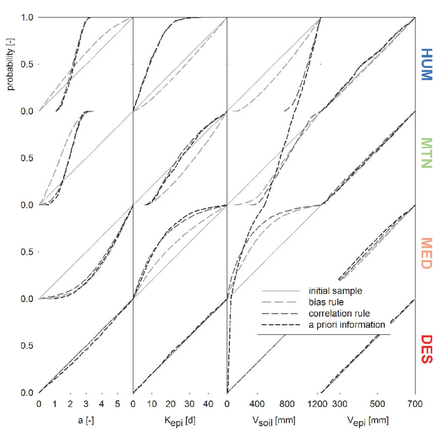
Four typical karst landscapes are defined using cluster analysis (k-means method) and 3 climatic and topographic descriptors: aridity index (AI), average days per year with snow cover (DS) and the range of altitudes (RA).

Descriptor	Unit	Number of cluster/karst landscape			
		1. HUM	2. MTN	3. MED	4. DES
AI	[–]	0.80	0.98	3.18	20.00
DS	[a^{-1}]	85	76	16	1
RA	[m]	228	1785	691	232

2. Definition of karst landscapes



3. Confinement of parameter ranges

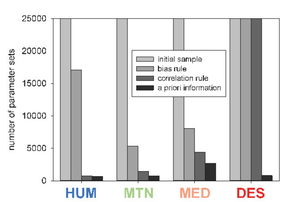


We sample 25,000 parameter sets within the initial parameter ranges and apply them to the model to obtain 25,000 simulated time series for each of our observation sites. For each of the four karst landscapes we apply three „soft rules" to confine the initial parameter set:

1. **Bias rule:** retain only the parameter sets that produce a bias between observed and simulated actual evaporation lower than 75%.

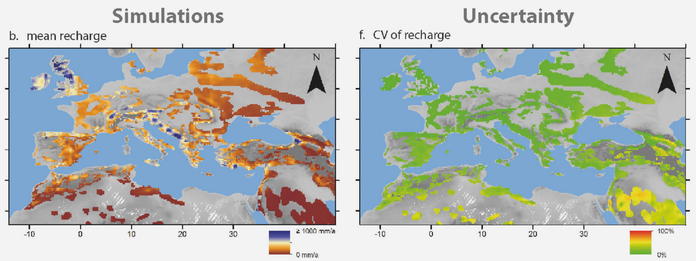
2. **Correlation rule:** retain only the parameter sets that produce a positive coefficient of correlation between observations and simulations of both actual evaporation and soil moisture.

3. **A priori information:** retain only parameter sets, in which the soil parameter Vsoil falls within the feasible ranges for the chosen karst landscape.



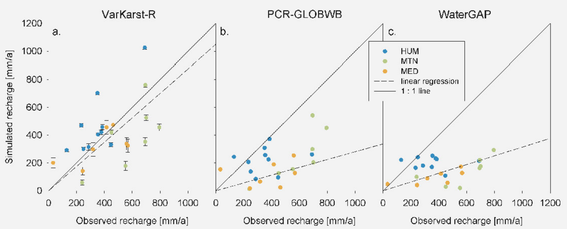
RESULTS

The simulations show high annual recharge rates in Northern Europe and in the high mountain areas, very low values occur for Southern Europe and Northern Africa. The parameter uncertainty due to the limited data availability remains low in most of the study domain.



EVALUATION

Comparison with recharge volumes assessed from the literature shows that although there is a considerable spread across the simulations, their bulk plots well around the 1 : 1 line.



Another comparison with simulated recharge volumes of 2 other large-scale models we find a strong tendency of under-estimation, in particular at the MTN and HUM regions.

SYNTHESIS

Our novel parameter estimation scheme allowed to set up a large-scale karst recharge model over all karst regions in Europe, Northern Africa and the Middle East. The simulated pattern of recharge rates and comparison to independent observations indicate an overall realism of the model. Consequently, the model can be used to derive relevant measures of the climate sensitivity of recharge to support present and future water management.

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References
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