Recharge scenarios to identify controls of catchments' sensitivity to drought

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HYPER Droughts

Drought controls

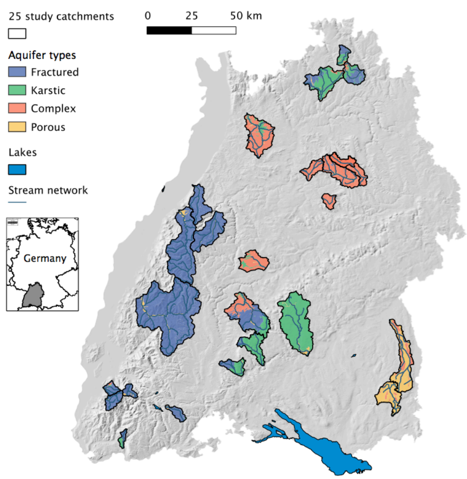
What are controls of drought propagation?	Water input	Water availability
Control in catchment hydrology	Climate, e.g. recharge variability	Storage, e.g. represented by geology
Occurence due to....	Rainfall deficit or snowfall, extrem ET	Small or empty storages
Drought characteristics	Frequency Duration	Deficit Persistence
	Climate control +	*Catchment control*
	Short- and long-term sensitvity to drought	

Catchments' sensitivity to drought

Research question
How rapid and intense do catchments react to modified recharge patterns and on what time scales do they recover from different drought events?

Hypothesis
The timescale on which recharge (deficit) propagates through groundwater into streamflow (drought) is determined by geology (catchment storage).

Setup, study catchments and data



Geology

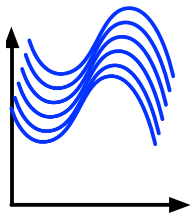
karstic aquifer type

fractured aquifer type

complex aquifer type

porous aquifer type

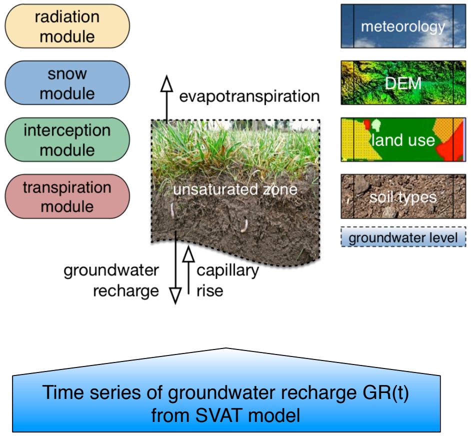
Climate



e.g. similar precipitation regimes

Recharge from SVAT model

HYDROLOGY



Model features

1. Soil water balance model to simulate vertical water fluxes of the soil-vegetation-atmosphere continuum (SVAT)
2. Model incorporates all relevant near-subsurface processes
3. Geology is the remaining dominant control of recharge propagation into baseflow

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Baseflow from groundwater models

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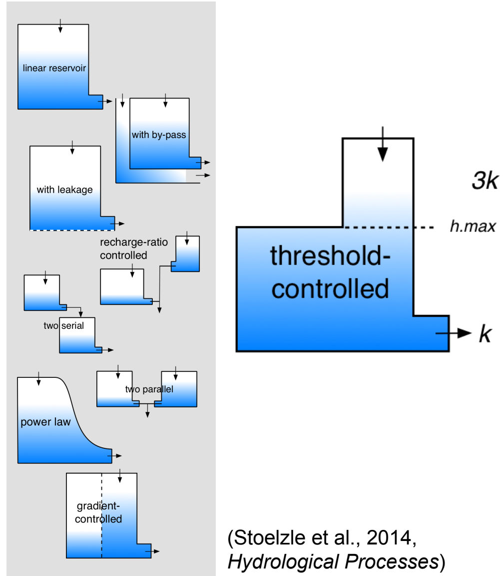

(Stoelzle et al., 2014, *Hydrological Processes*)

Model features

1. Properties of different geology are best represented by different groundwater model structures
2. The overall best model structure is the FLEX model
3. Storage depletion is 3x-increased above threshold h.max (allowing for short- and long-term recession behavior)

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Scenarios I: Historical recharge

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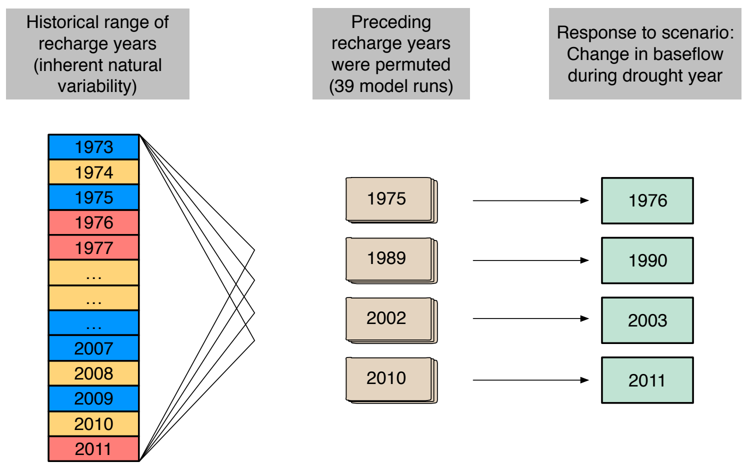

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Scenarios I: Results

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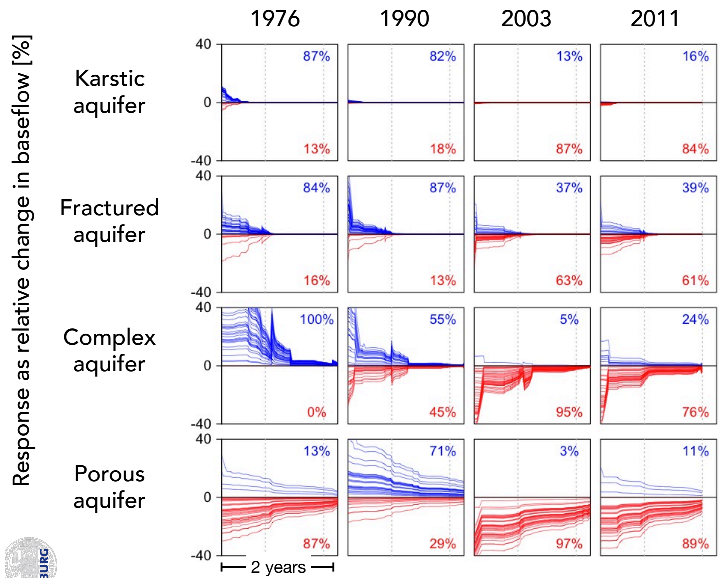

39 response hydrographs:
blue=wetter
red=drier

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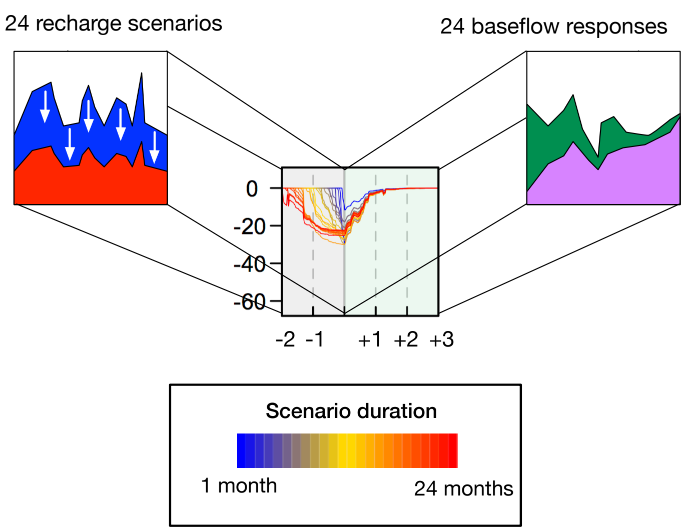
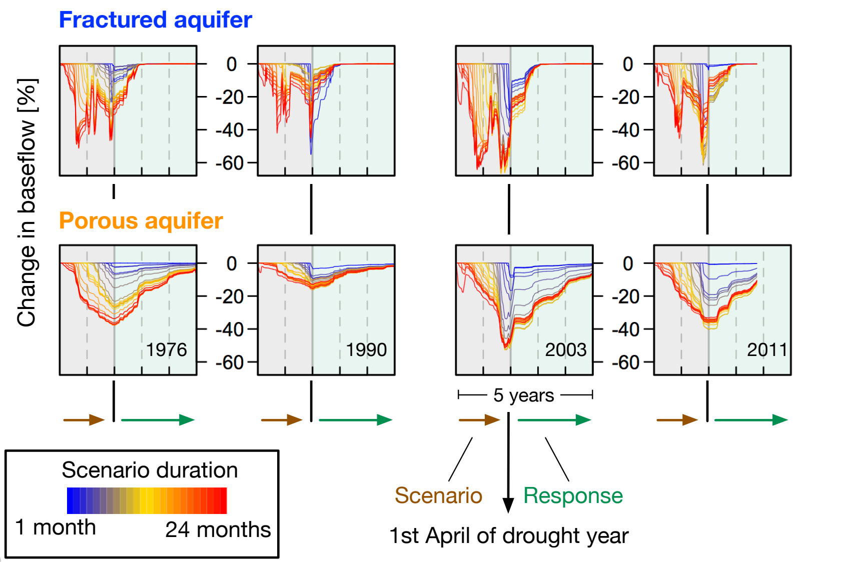
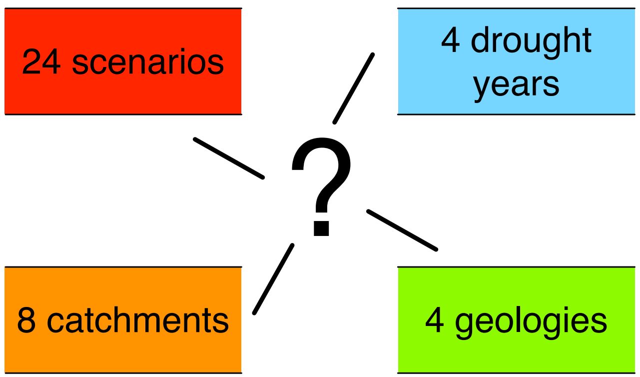
Scenarios II: Return period 50 years



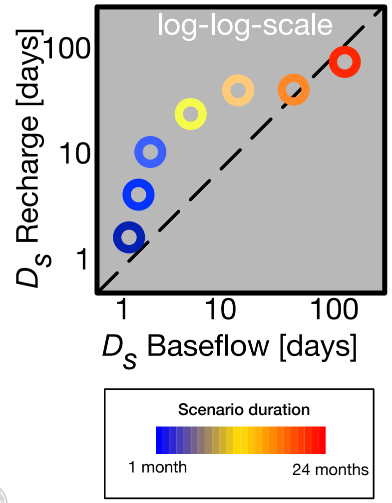
Response (in baseflow hydrograph)



Assessment of sensitivity to drought?



Standardized deficits D_s



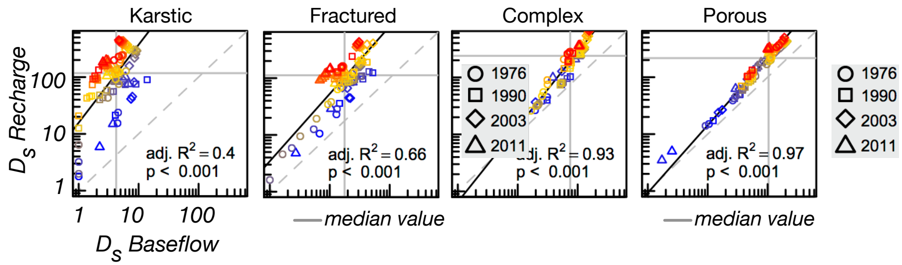
„How many days with mean flow are required to reduce deficit(s) to zero?"

$$D_s = \frac{Deficit\ d_i}{Flow\ \bar{q}} \left[\frac{mm}{mm/d}\right]$$

Sceanarios with different durations

see also: Van Loon et al., 2014, J. Geophys. Res. Atmos.

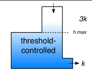
Short- and long-term sensitivity



Karstic/Fractured aquifers	Complex/Porous aquifers
Scenario deficit is larger than response deficit	Scenario deficit is equal to response deficit
Event-specific sensitivity (e.g. 1976 ≠ 2003)	Linear relationship between scenarios and response (same duration)
Short-term drought sensitivity	Long-term drought sensitivity → drought persistence

Synthesis: Controls under same climate

Aquifer type	Relationship: scenario duration & response duration	Sensitvity to short-term recharge deficit	Post-drought recovery from long-term recharge deficits	Standarized Deficits Recharge/ Baseflow [days]	Water age during drought [days]	Specific drought controls
Karstic	Event-specific	very high	short	100/5	< 50	
Fractured	Event-specific + antecedent winter	high	moderate	100/20	> 150	
Complex	mostly linear	small	long	110/70	> 300	
Porous	mostly linear	small	long	110/100	> 200	



Take home messages

1. Short- and long-term sensitivity to drought can be explained by geology
2. A linear relationship between scenarios and response indicated more catchment-controlled drought propagation
3. Climate and catchments controls (together with water age) are valuable precursors for drought early warning systems

Thank you for your attention!