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Element of a pluri-disciplinary project on karstic reservoir characterization : groundwater modelling of the Dévoluy Massif, France.

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Objectives : the aim of this study is to understand the behavior of a mountainous karstic reservoir. Exploration of hydrodynamic and meteorological data coupled to simulation on KarstMod platform with a snow routine module helps to decipher if discharge variations at the springs are related wether to recharge processes or properties of storage and flow in the reservoir.

How the snow routine works in KarstMod

Snow routine parameters in KarstMod

T_s	0.0	to	0.0	°C
MF	5.0	to	6.0	mm/°C
CFR	0.3	to	0.8	
CWH	0.05	to	0.25	

Subcatchments parametrisation

N°	Proportion	Temperature shift (°C)
1	0.35	1.92
2	0.33	-1.05
3	0.32	-4.65

Model

$Q_s = Q_{hyES} + Q_{ES} + Q_{LS} + Q_{MS} + Q_{CS}$

Temperature and precipitation

temperature: T_s

precipitation: snowfall, rainfall

solid component ↔ snowmelt ↔ liquid component

refreezing ↔ snow

Modified from Pianosi and Wagener (2016)

Degree day factor :
 $M = MF \times TDD$

M (mm/d) : water from melted snow per day
MF = DDF : melting factor or degree-day factor (mm / °C . Day)
TDD = Active melting temperature (°C)
TDD = Air Temp. - T_s
(T_s = threshold temperature, default = 0°C)

CFR (refreezing factor)
CWH (water holding capacity)

Case study : the Dévoluy karstic reservoir

Geological map showing Tertiary, Senonian, Lower Cretaceous and upper Jurassic, and Jurassic black shales. Also shows Dogger and upper Liás, Carbonated Liás, and Trias.

Reservoir Cover

Basement

400 m

Discharge :
- Max. 29m³/s
- Min. 200l/s
- Mean 5m³/s

Data :
- EDF gauge station : Q, T°C, P
- Météo France SAFRAN models : P, T°C, PET

Workflow : modelling a snow-influenced karstic aquifer

Field observations and data visualisation

Model 1 :
Classical configuration with two reservoir and no snow routine

Model 2 :
Adding snow routine

Model 3 :
Adding subcatchments

Model 4 :
Refining model with third reservoir

Comparison between discharge at Gillardes spring and upstream location

key elements

Step 1 : identifying the role of snow in the recharge

During spring and summer, discharge increases at the Gillardes spring while there is no significant Q rise in la Souloise river.

Modelling without snowroutine shows that part of the discharge is lost during spring and summer.

Step 2 : Implementing snow routine in the model

Snow routine helps to better match observed discharge during spring and summer.

Subcatchments in snow routine enhance the recharge simulation (rainfall, snow and snowmelt) over the catchment area.

Adding third reservoir allows to better reproduce fast variations in discharge.

Discussion

How to use the model once it is well calibrated ?

1/ Highlights the variations in flow rate in relation with the conditions of reservoir recharge. Possible causes of variation in recharge in Dévoluy: artificial snow at the ski resort, P and/or T°C variations due to climate change.

2/ Provides a better understanding of the hydrodynamic of the system in relation with groundwater management : Architecture of the system, contribution of each reservoir to the discharge at spring, water resources.

Conclusion and way-forward

Importance of recharge mechanisms : work is needed on recharge modeling to improve rainfall-discharge modeling with conceptual models («reservoir or compartments models» like KarstMod). Good model structure is not enough.

Snow routine module is efficient : the degree-day method used by KarstMod is effective when applied to a karstic spring.

Way-forward : threshold temperature or temperature shift in the subcatchments could be used to simulate futur climate change with KarstMod.

References and acknowledgments :

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KarstMod is free to use and can be downloaded via : www.sokarst.org