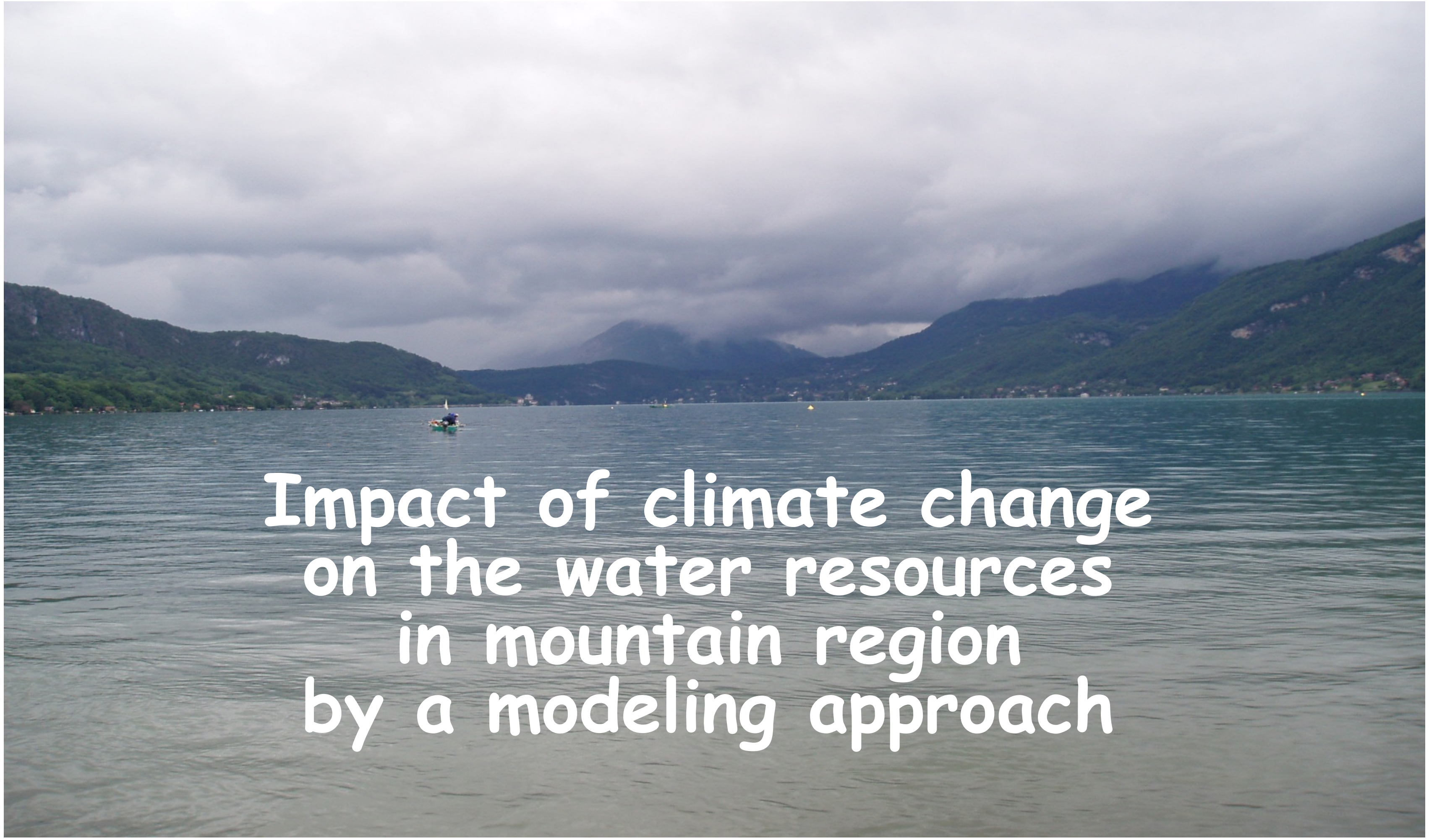
4ième semaine de l'Eau, Beyrouth , 20-23 février 2013



Impact of climate change on the water resources in mountain region by a modeling approach

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ARTELIA Eau & Environnement - France

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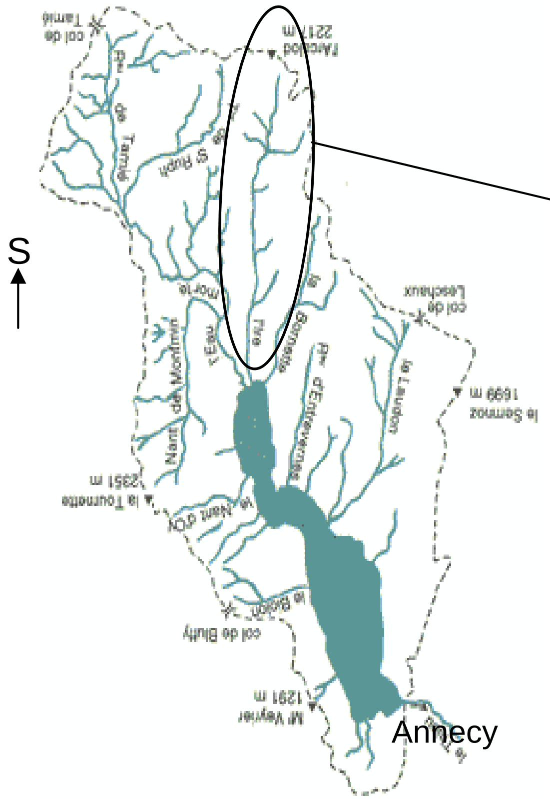
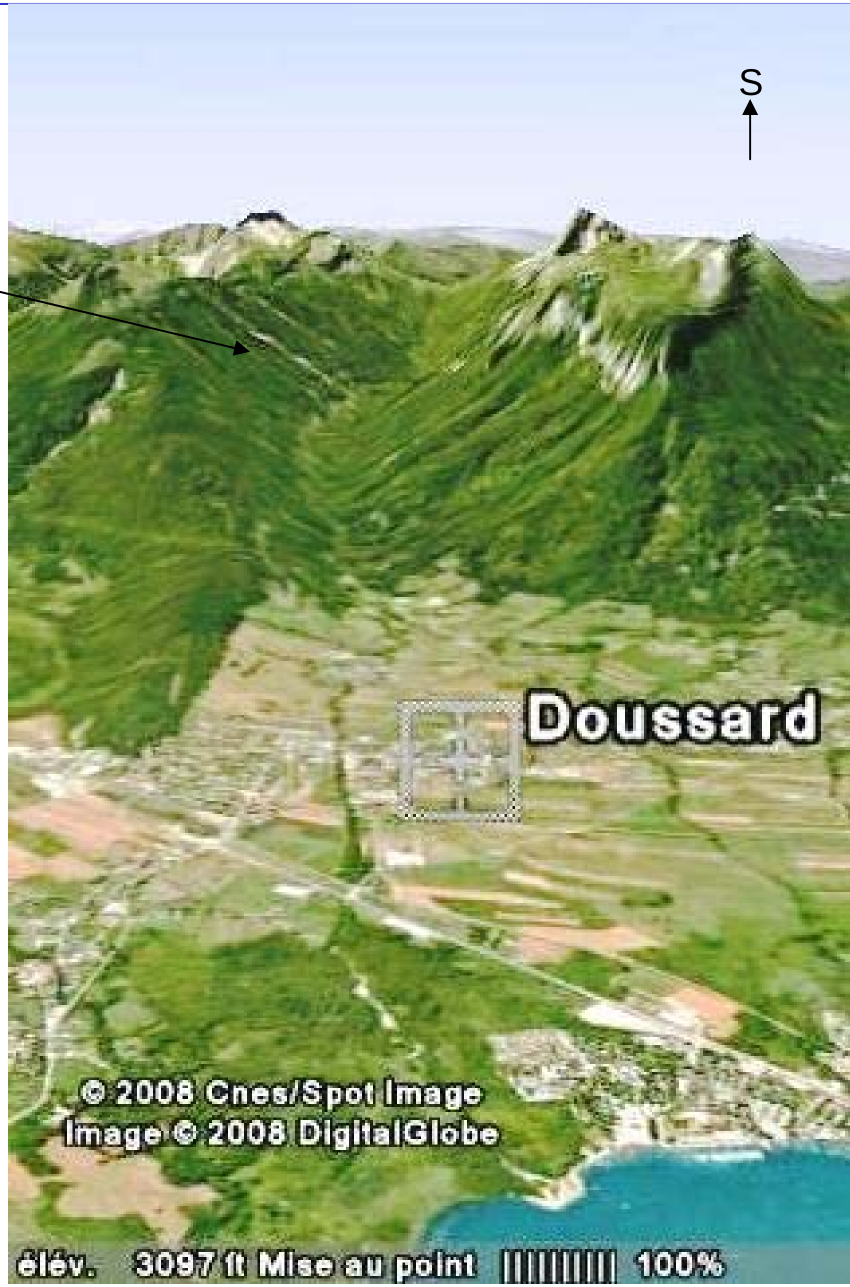
Outline

- Presentation of the catchment area and the modelling tool.
- Construction of the Ire area model
- Consequences of the climate variations on the water resources.

Impact of climate change on water resources by modeling approach





Surface : 23 km²

Length : 12.5 km

Altitude: 450 à 1600 m

Slope: ~ 9%

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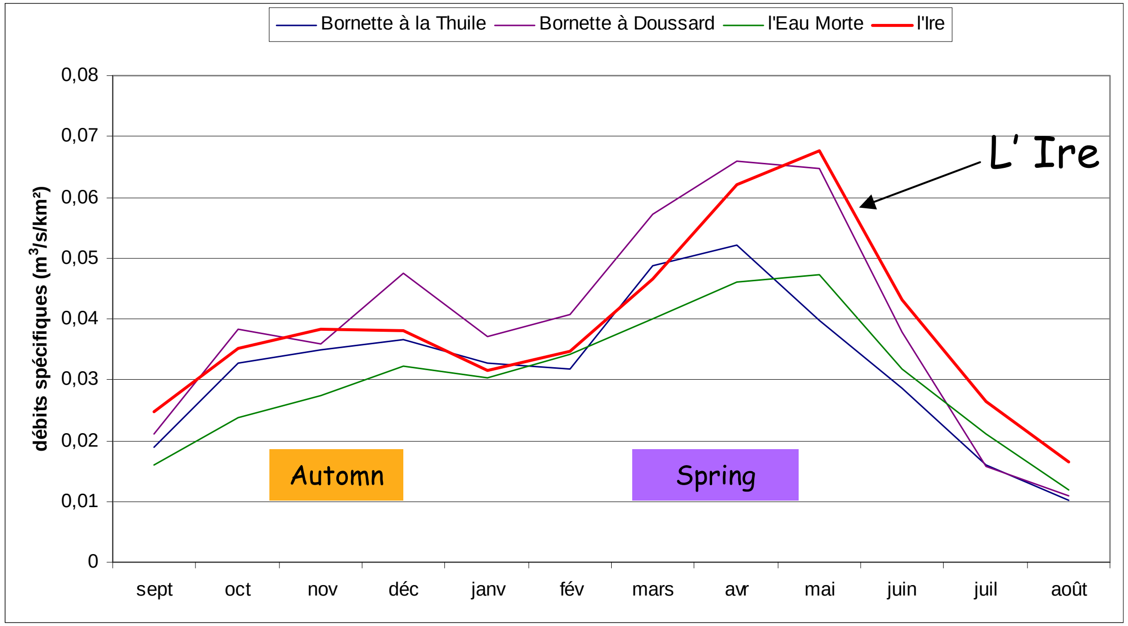
Impact of climate change on water resources by modeling approach

Mountain climate

- Average rain falls Annecy: 1 200 mm/year
- Nival-rain scheme



Objective : hydrologic modelling of the Ire catchment area

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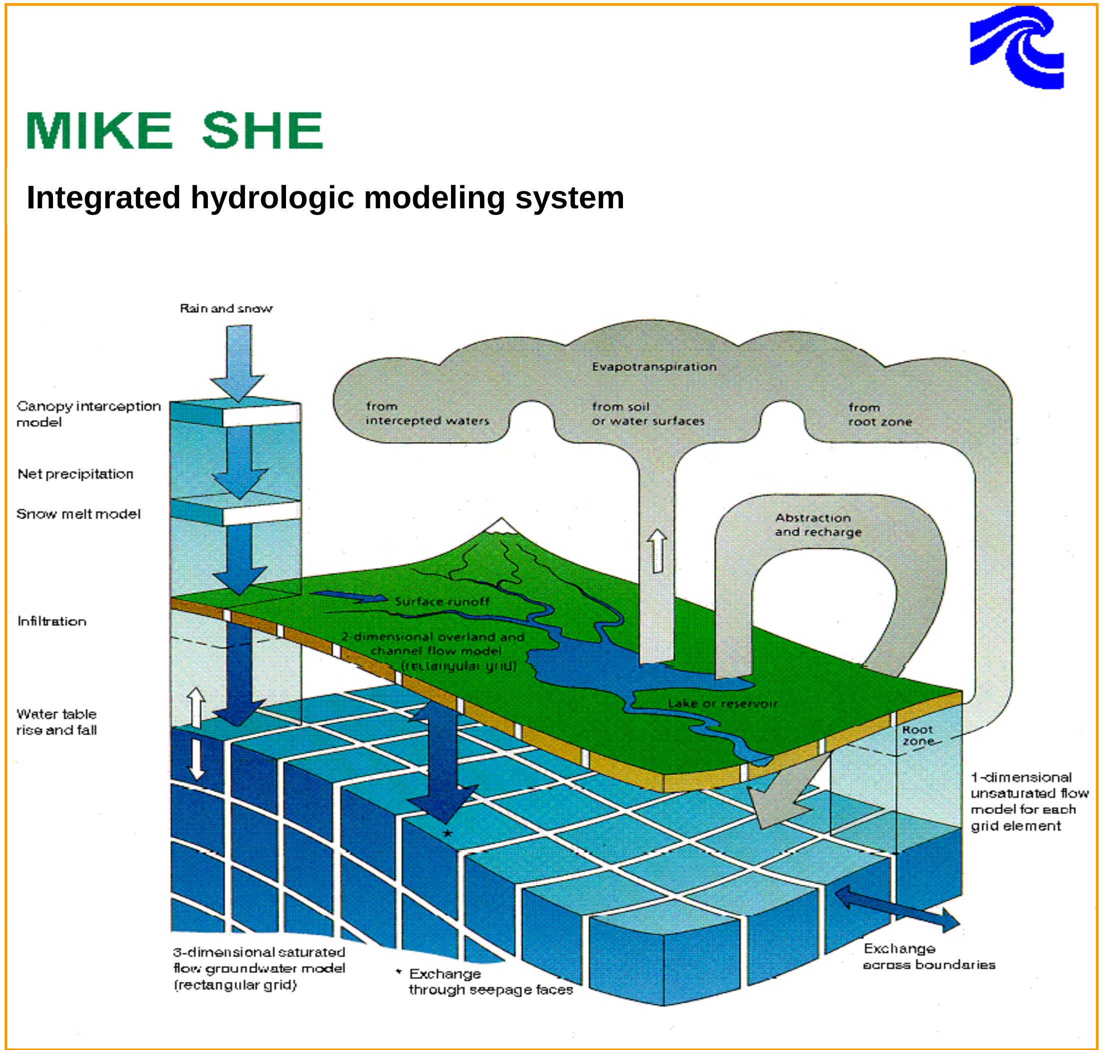
Modelling tool : MIKE SHE software



<u>Input data :</u>

- Rainfalls
- Temperatures
- Evapotranspiration

<u>Analyzed output data</u> :

- River discharge at the outlet

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Construction of the Ire-area model

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Input data

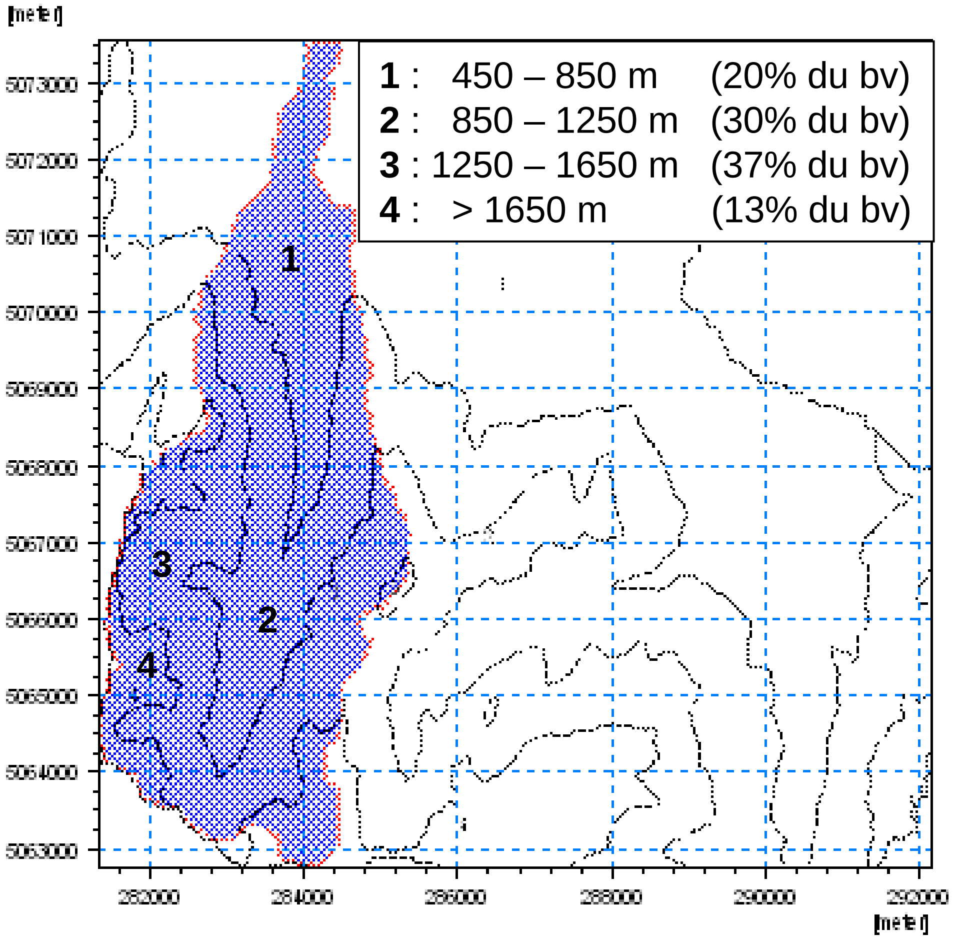
Modifications of temperatures and waterfalls

- Zone 1 : T – 1°C ; P +20%
- Zone 2 : T – 3,4°C ; P +40%
- Zone 3 : T – 5,8°C ; P +60%
- Zone 4 : T – 6,8°C ; P +80%

Evapotranspiration:

Calculated from the temperature based on the Oudin formula.

Areas versus altitude



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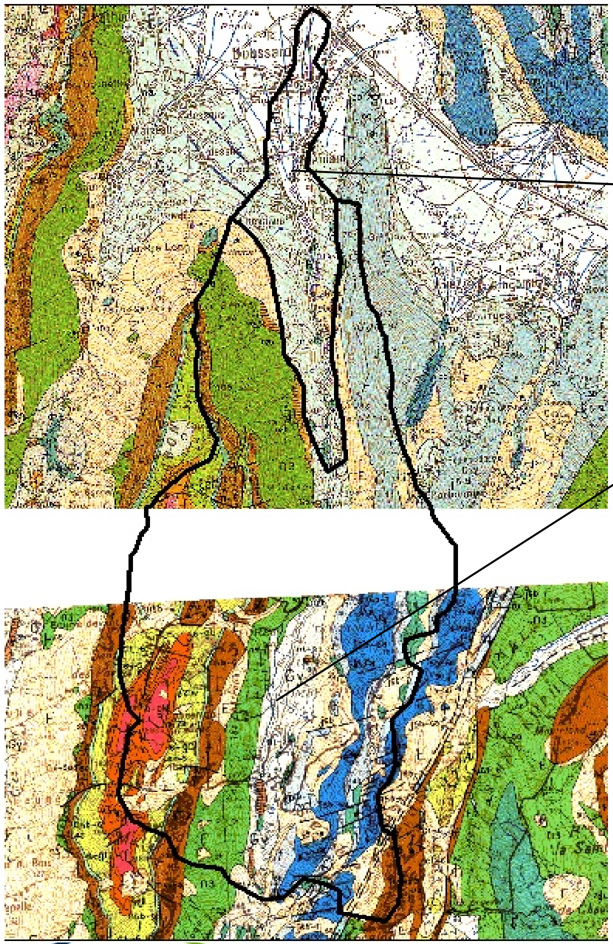
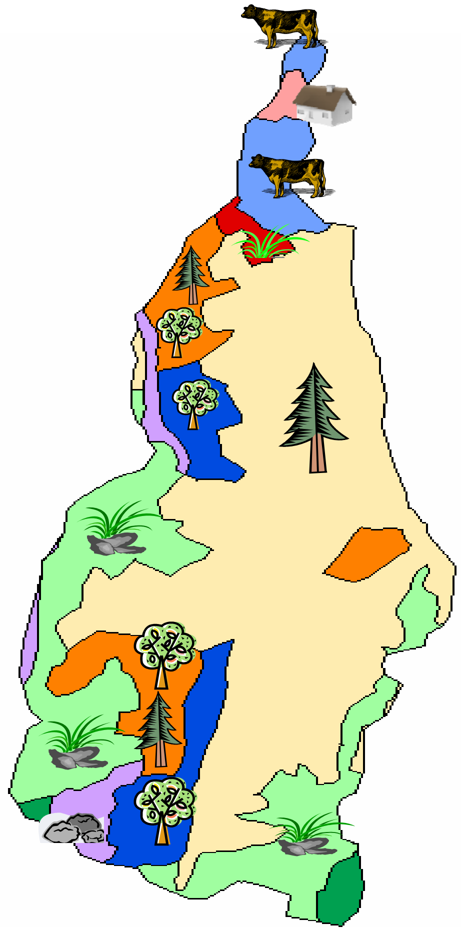
Impact of climate change on water resources by modeling approach

Saturated and unsaturated areas



- Downstream zone :
  - Thick & stratified floor
  - Permeable underground.
- Upstream zone :
  - Thin & homogenous floor.
  - Low permeable underground.

(Corine Land Cover)



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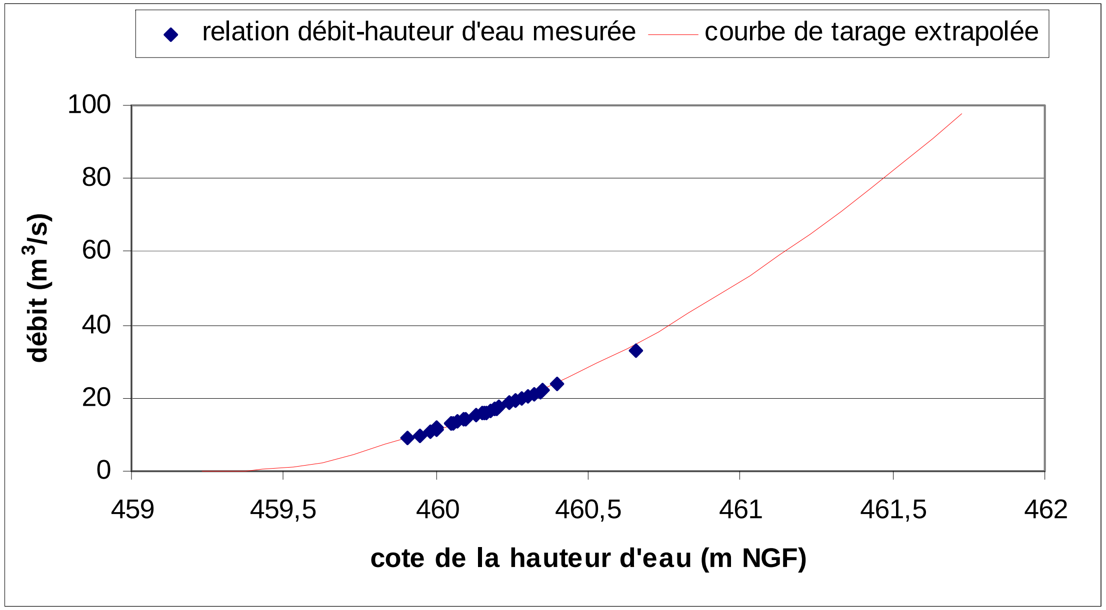
Conditions related to limits and time steps

- No outflow at upstream limits
- Water table at 459 m from the upstream limits
- Water level condition at the outlet.



- Daily time steps

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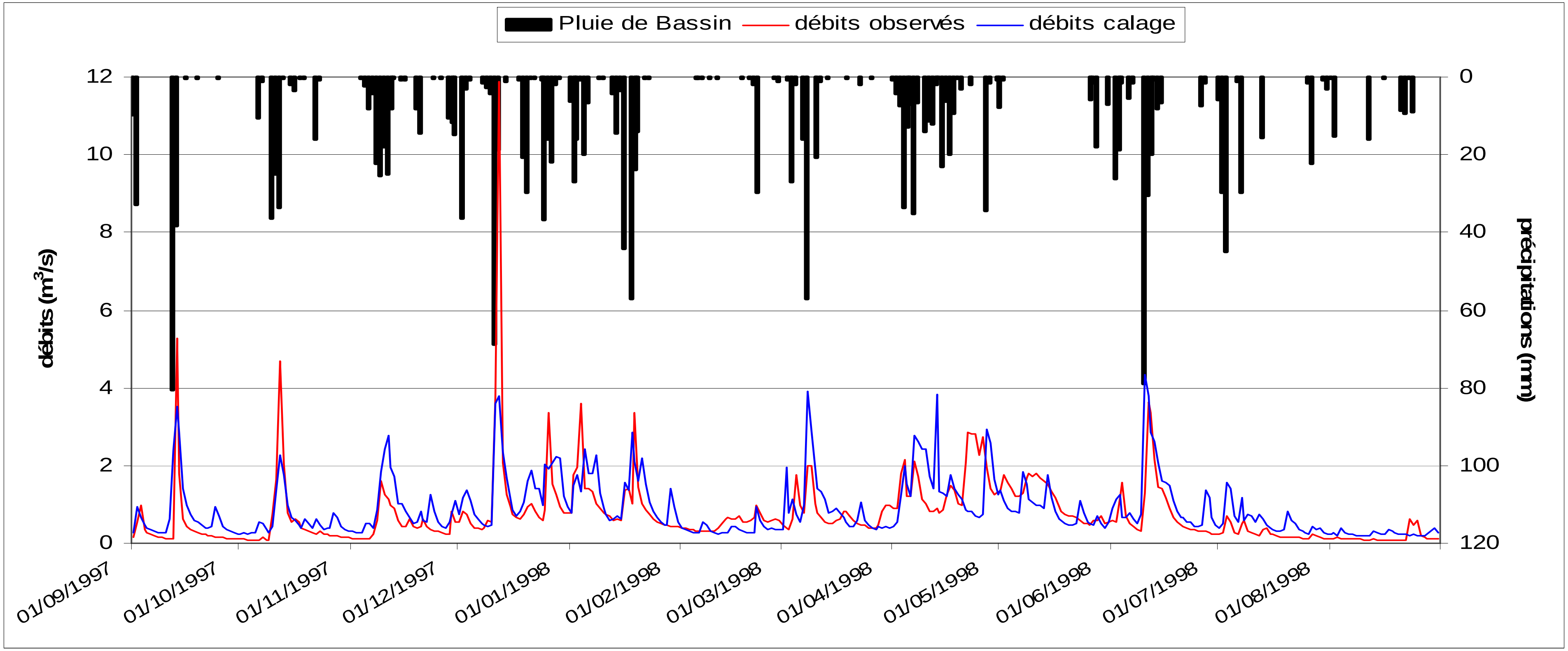
Calibration-validation process

Initialisation of the model during the 1996-1997 period
Calibration based on the observed data during the 1997-1998 period

Objective of the calibration :
To better reproduce the river discharge at the outlet

Impact of climate change on water resources by modeling approach

Results of the calibration : V= 118%; Nash= 44%



Simultaneous peaks.

Underestimated automn and winter peaks

Excessive low-water levels (summer & automn)

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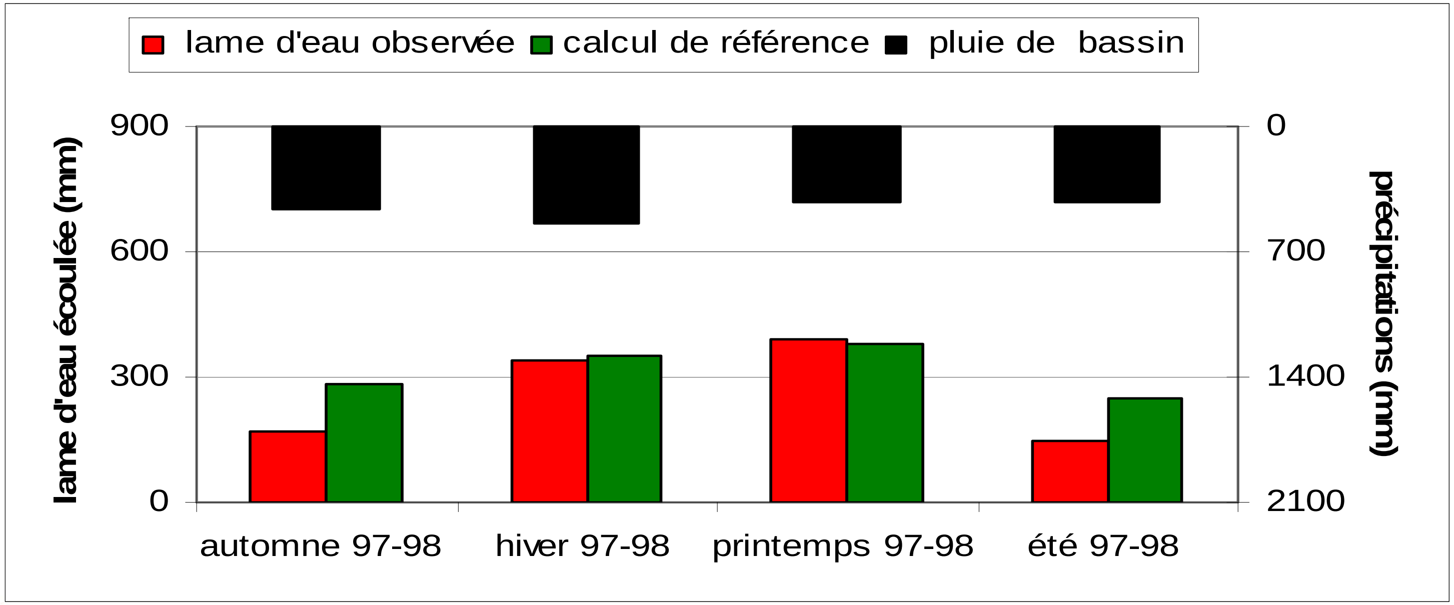
- Validation for the 1993-1998 period

	1993-94	1994-95	1995-96	1996-97	1997-98	total
V	93%	105%	110%	132%	123%	**110%**
Nash	41%	40%	44%	19%	37%	**41%**

- Reference calculation for a comparison with predictive calculations



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The model is regarded as being representative of the hydrological cycle of the Ire area in order to study the seasonal volume variations

The model may be applied as a forecast tool in order to run climate changes scenarios

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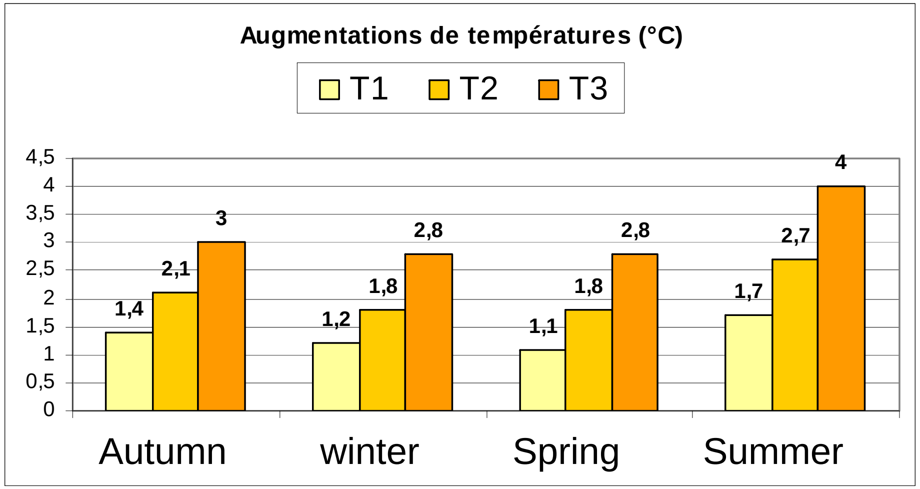
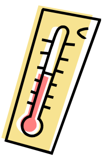
Climate Change scenarios

In the Alpine Climate

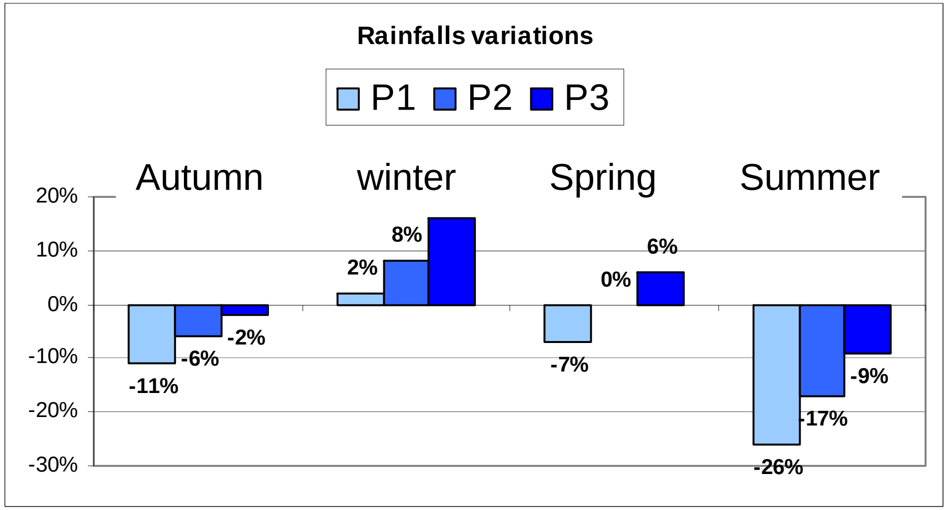
2050 Alps Northern side scenarios Temperatures & Rainfalls variations (Switz weatherforecast, 2005)

3 scenarios of temperatures changes





3 scenarios of rainfalls changes



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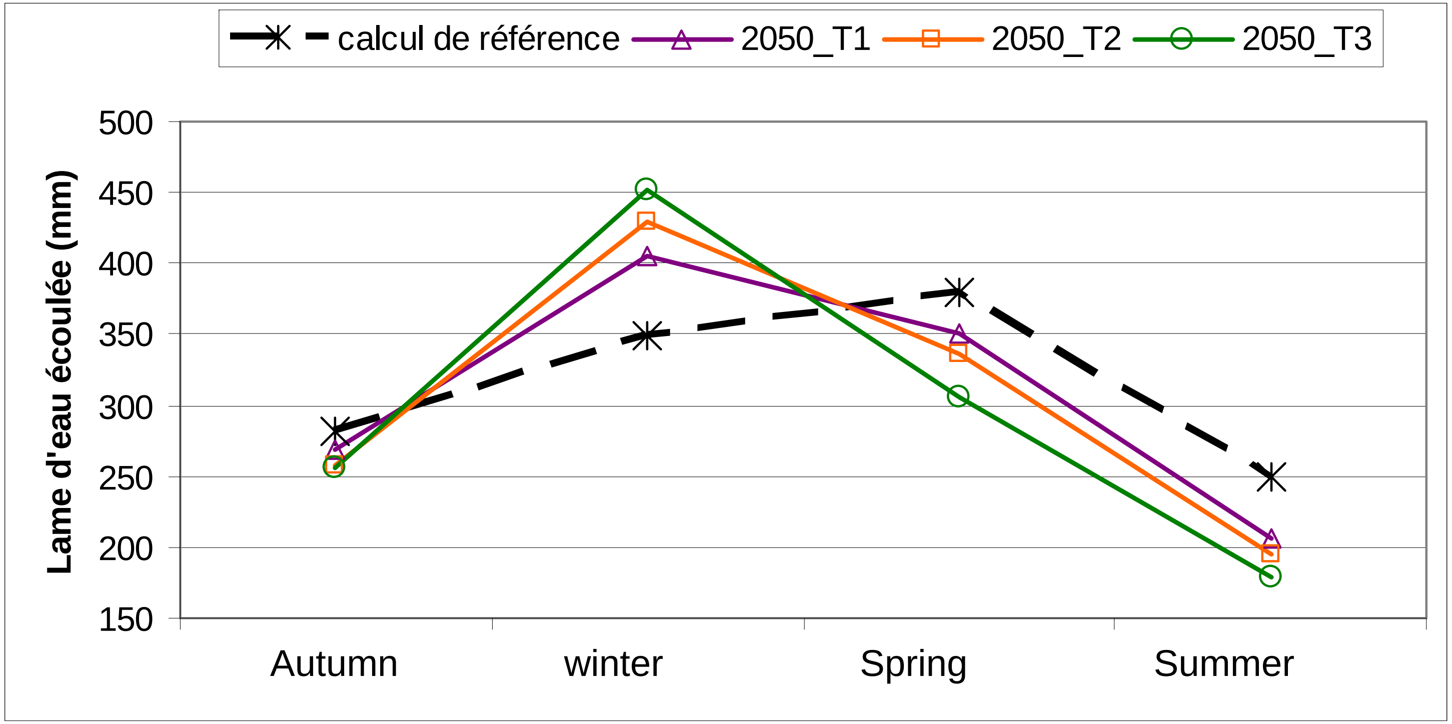
2050 scenarios with temperature variations

Consequences of the ↗ in temperatures on seasonal river discharges

Comparison between reference calculations and 2050 scenarios



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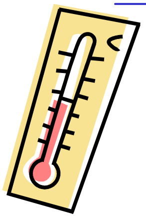
Impact of climate change on water resources by modeling approach

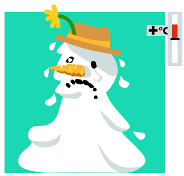


River discharge ratios : Q2050 / Qréf

	autumn	winter	spring	summer
2050_T1	- 5%	+ 16%	- 8%	- 17%
2050_T2	- 8%	+ 23%	- 11%	- 22%
2050_T3	- 9%	+ 29%	- 20%	- 28%

Volume increase in **winter** :

- Rise up of snow-rain limit in altitude.
  - More precipitations as rainfalls
  - Less precipitations stored as snow
- Snow melting in early season



Volume decrease during other seasons

⇘ Of input through melting & ⇗ evapotranspiration

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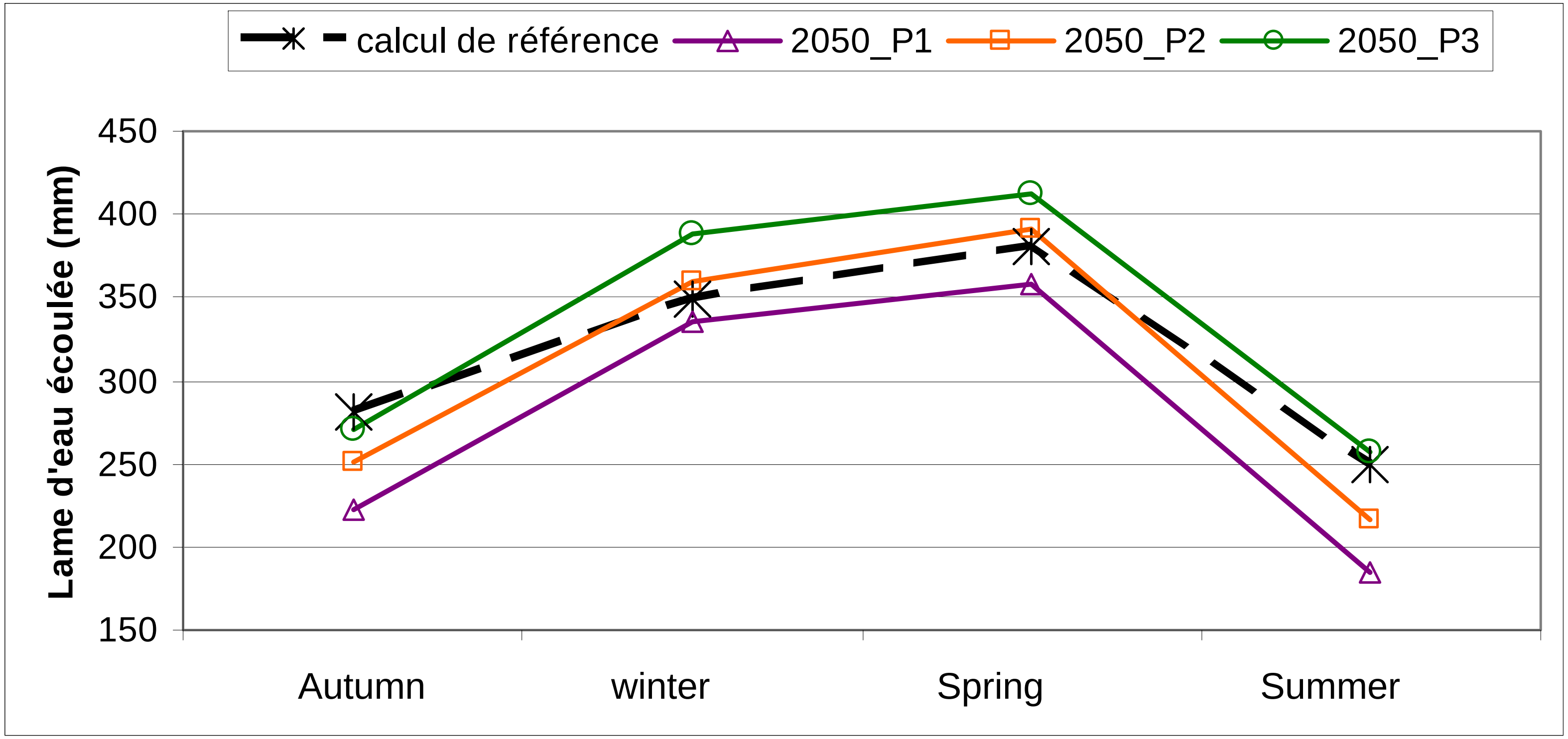
2050 scenarios with RAINFALLS variations

Comparison between reference calculation & 2050 scenarios



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2050 scenarios with RAINFALLS variations

	autumne	winter	spring	summer
Rainfalls variations P1	**-11%**	**+2%**	**-7%**	**-26%**
Impact on discharge: Q2050_P1 / Qréf	**-21%**	**-4%**	**-6%**	**-26%**

Rainfalls are less important during spring, summer & autumn period

↳ run off volume ↘

↳ the ground dries up

In winter rainfalls ↗, dry ground absorbs water

↳ volumes decrease

2050 scenarios with temperatures & rainfalls variations

	autumn	winter	spring	summer	yearly
	T +2,4°C / P -6%	T +1,8°C / P +8%	T +1,8°C / P 0%	T +2,7°C / P -17%	
Q2050/Qref	- 16%	+ 25 %	- 11 %	- 37%	- 7 %

- In winter: ↗ P = ↗ V
  ↗ T = ↗ V (- snow & + melting)
  ⚠ ↳ Flood risks during winter in 2050

- In summer & in autumn:
  ↘ P = ↘ V
  ↗ T = ↘ V (↘ input from snow melting & ↗ loss from evapotranspiration)
  ⚠ ↳ Severe drought risks in 2050

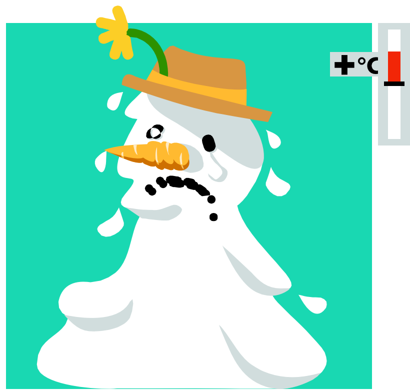
- Decrease in annual input

Conclusions

The model allows to quantify the **impact of climate changes scenarios** on the Lac d'Annecy and its whole catchment area

↳ **Integrated River basin management Plan** for local end-users and stakeholders in the framework of both the local/national water policy development and the WFD requirements.

Thank you for your attention!



For more questions

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$$V = \frac{\sum_{i=1}^{n} Q_{cal,i}}{\sum_{i=1}^{n} Q_{obs,i}} \times 100$$

$$Nash = 100 \times \left(1 - \frac{\sum_{i=1}^{n} \left(\sqrt{Q_{obs,i}} - \sqrt{Q_{cal,i}}\right)^2}{\sum_{i=1}^{n} \left(\sqrt{Q_{obs,i}} - \overline{\sqrt{Q_{obs}}}\right)^2} \right)$$

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Evapotranspiration:

Calculée à partir de la température
Formule de Oudin

$$ETP = \frac{\text{Re}}{\lambda\,\rho} \times \frac{Ta + 5}{100} \quad si \quad Ta > -5°C$$

$$ETP = 0 \quad si \quad Ta \leq -5°C$$

Re : rayonnement extraterrestre ($MJ/m^2/j$)
λ : flux de chaleur latente (MJ/kg) (constant)
ρ : masse volumique de l'eau (kg/L)
Ta : température de l'air (°C)

Paramètres Calés

	Secteur amont	Secteur aval
Zone Saturée	Conductivités hydrauliques horizontale et verticale $Kh=10^{-6}$ $Kv=10^{-7}$ m/s	Conductivités hydrauliques horizontale et verticale $Kh=10^{-4}$ $Kv=10^{-5}$ m/s
	Porosité efficace = 0.005	Porosité efficace = 0.4
	Coefficient d'emmagasinement = 0.01	Coefficient d'emmagasinement = 0.2
	Coefficient de porosité = 0.2	Coefficient de porosité = 0.2
zone Non saturée	0.5 m Sable fin (Ks = $5x10^{-6}$ m/s) 21.5 m Calcaire (Ks = 10^{-7} m/s)	0.5 m Sable fin (Ks = $5x10^{-6}$ m/s) 3 m Sable & Argile (Ks = $2x10^{-8}$ m/s) 18.5 m Calcaire (Ks = 10^{-7} m/s)
Ruissellement	Nombre de Manning = 3	
	Stockage temporaire = 3 mm	
Précipitation	Température de fonte = -1 ° C	
	Facteur degré-jour = 1 mm/j/° C	

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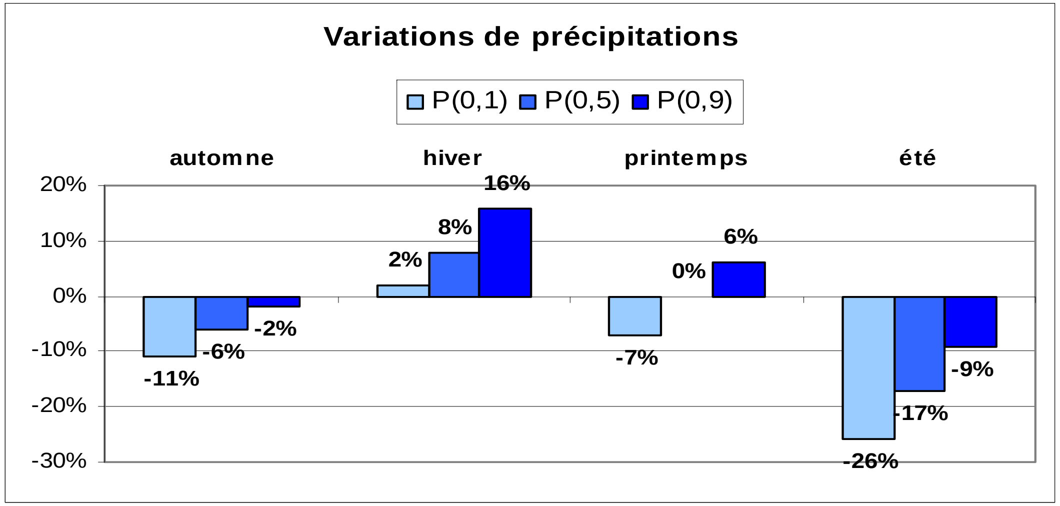
Rainfalls variations affect directly outflows : P↗ = V ↗ et P↘ = V ↘

Sometimes a time gap because of ground drying up * or saturation♦

	automne	hiver	printemps	été
2050_P1	- 21%	- 4% *	- 6%	- 26%
2050_P2	- 10%	+ 3%	+ 3%	- 13%
2050_P3	- 4%	+ 11%	+ 9%	+ 3% ♦



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Scenarii 2050 avec variations de températures et de précipitations

	automne	**hiver**	**printemps**	**été**	**annuel**
2050_T1_P1	- 25 %	+ 14 %	- 12 %	- 41 %	**- 13 %**
2050_T1_P2	- 17 %	+ 18 %	-5 %	- 32%	**- 6 %**
2050_T1_P3	- 10 %	+ 33%	+ 0,3 %	- 20 %	**+ 3 %**
2050_T2_P1	- 27 %	+ 16 %	- 16 %	- 43 %	**- 15 %**
2050_T2_P2	- 16%	+ 25 %	- 11 %	- 37%	**- 7 %**
2050_T2_P3	- 9 %	+ 38%	- 4 %	- 30 %	**+ 1 %**
2050_T3_P1	**- 30 %**	+ 24%	**- 27%**	**- 47 %**	**- 17 %**
2050_T3_P2	- 24 %	**+ 35 %**	- 21 %	- 44%	**- 11%**
2050_T3_P3	- 14 %	**+ 46 %**	- 12 %	- 31%	**- 0,2 %**