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Hydrology and Earth System Sciences Discussions

Interactive comment on "Impact of climate change on groundwater point discharge: backflooding of karstic springs (Loiret, France)" *by* E. Joigneaux et al.

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The authors want to acknowledge the Anonymous Referee for his relevant comments and agree with most of his observation. As said by the Referee, our article is perhaps too short and must be more detailed. Please find below our responses to the different comments.

Section 2 : the presentation of the study area is not clear and fig. 1 and the description at the bottom of p.2238 should be improved

Some information about hydrology of the Val d'Orléans has been added to the text:

Tracer studies (both artificial and natural) have shown that the Loire river waters infiltrating the aquifer mainly at Jargeau arrive within a few days (3 to 4 days for the nearest ones) at many temporary springs (Fig. 1) (Albéric and Lepiller, 1998; Lepiller, 2006). Most of them are found along the Loiret river, which starts at the Bouillon Spring. Its mean flow is nearly 1m3/s and principally depends on the Loire river flow. However, under specific hydrological and meteorological condition, the first and major springs of the Loiret river, the Bouillon and Abîme springs, can become sinks. It happens when the Loire is at a low level and there has been heavy local precipitation in the Dhuy watershed (216 km^2), this river being an affluent of the Loiret river (confluence 1 km downstream of the Bouillon Spring). Surface waters of the Dhuy river backflow along the Loiret river and disappears into the Abîme and Bouillon resurgences which become sinkholes (Albéric, 2004).

Section 3.1: It should be made clearer that the direct observation of backflooding are only available for 4 years, and that in order to have a longer period for the climate change impact study, past events are estimated using a hydrological model, that needs as input precipitations and observed Dhuy riverflows.

These details have been added on the beginning of the section 3.1: Backflooding events were observed and studied from 1997 to 2001 principally; the observation is still active today but since 2002 only a small number of events have been seen. So the period 1997-2001 can be called the backflooding reference period. However, this time period is too short to study efficiently the impact of climate change on the study area. Knowing if backflooding events have already happened in the past is essential to determine if this phenomenon is recent or not. The data necessary for reconstructing past backflooding events and studying the precipitation trend in the Val d'Orléans are the daily river flows of the Loire at Orléans and of the Dhuy, which are available in the Hydro database. The hydrological model is just used to fill the gaps in the Dhuy river flow data, not to reconstitute past backflooding events.

Sections 4.1: This section is not clear. Fig 3 can hardly be read, due to tiny legends.

It would be better to present Fig 3 before Fig2, since the eq1 is derived according to the observations used in Fig 3, whereas Fig 2 presents a longer time period. The observed backflooding event should be presented with a different symbol than estimated backflooding events in fig 2.

The legend of Fig. 3 has been modified (see below in the fig.1) in order to have a better understanding. However, Fig. 3 can't be presented before Fig.2 because the equation 1 comes from the limit between the absorbing or emissive functioning of the Bouillon Spring, presented in Fig. 2. The time period of Fig. 3 (January 1997 to December 2001) is just a little more longer than in Fig. 2 (June 1997 to December 2001).

Sections 4.2 and 4.3: These sections present the results of the hydrological model. It would be interesting to have an idea of the sensitivity of the model errors on the number of backflooding events estimated on the period 1966-2009. How the numbers of events vary according to other different but plausible parameter sets?

The Gardenia model is used to complete the Dhuy flow time series from 1971 to 1974 and to 1977 to 1978. This model simulates the water cycle using a system with several consecutive reservoirs. In this study three reservoirs are simulated: a superficial reservoir which corresponds to the first centimeters of soil, an intermediate reservoir representing the unsatured zone, recharged by surpluses occurring above the capacity of the superficial reservoir, and a ground reservoir recharged by the intermediate one, and drained by percolation or slow runoff outside. The two hydrological parameters which control these reservoirs are RUMAX and RUIPER: RUMAX represents the water retention capacity of the superficial reservoir, and RUIPER the water level in the intermediate reservoir when percolation and fast runoff are in equilibrium. Several simulations were tested with different values of RUMAX and RUIPER. When RUMAX or RUIPER are too high (more than 300mm for RUMAX and 25mm for RUIPER), the high Dhuy river flows are too much underestimated and backflooding events are less frequent. When these two parameters are too low (less than 100mm for RUMAX and 10mm for RUIPER), the high Dhuy river flow are too much overestimated, and there is

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too much backflooding events calculated. Consequently, the best values kept for this study were 205mm for RUMAX and 15mm for RUIPER.

Section 4.4: Here, there is a need to give more details on the assumption: why do you use a 3-day running average? Why not using 1-day or 7-day? How were assigned the coefficients associated to the weather type? How such assumptions affect the results?

The average river flow corresponding to each WT is the weighted moving average of the flows over the three days following the appearance of the WT; i.e. the appearance of a WT on day ‘d’ will influence the flow of the Dhuy for the next three days. Indeed, it has been observed that heavy precipitation on the study area can affect the Dhuy river flow during a maximum of three days after the storm. The assigned percentages are 0.6 for d+1, 0.3 for d+2 and 0.1 for d+3 but variations of less or more 0.1 in these coefficients do not change radically the results. Moreover, the weighted moving average of flow is just used to classify the weather types and is not used in specific calculation.

Section 4.4: Moreover, more details should be given to describe the impact of the weather types on the area under study. I suggest providing at least a table that will give for each weather type the average precipitation rate over the basin under study and over the upstream Loire basin, or other more significant information.

The impact of each WT can be also given by the variability of precipitation compared to the mean seasonal precipitation (See below fig.2 = table 1). Some WT can be named “wet” WT if they cause more precipitation than the seasonal mean, and “dry” WT if they cause less precipitation. However, it is not possible to know precisely their impact on the precipitation in the Loire basin: the same WT can trigger different precipitation rate along the Loire river.

Section 4.4: One key issue here is why did the analysis of the weather types was not used to characterize the Loire riverflow? The WTs analysis should provide enough information since a precise estimate of the Loire riverflow is not needed, and that only the low flow period of the Loire River needs to be estimated. It seems that by studying the Dhuy River, only half of the work was done. The extension of the proposed method on the Loire river, by providing a characterisation of the Loire behaviour would complete the work. The authors should at least explain why such work was not done: is the WTs analysis fails to give insight on the Loire behaviour? Does it represent too much work?

Linking daily weather types with Dhuy river flows is easy because the Dhuy is a local river in a small catchment (216km^2) and reacts instantaneously to the precipitation (between one day and maximum three days according to the precipitation rate). For the Loire river, the scale is not the same. The Loire riverflow is very difficult to link to weather type occurrences because of its basin dimensions: the river will take several days or weeks to integrate the impact of each weather type. It is the accumulation of several weather types which will contribute to the river flow. However, we know that there's a lack of work in the article if we don't study the Loire behaviour. So now we're trying to link monthly occurrences of weather types with the monthly Loire river flow with the method of principal components analysis. The first results of this work show that only a few weather types have a real obvious impact on the Loire river flow. In the revised manuscript we'll be able to show how these weather types occurrences vary in the future according to the five models used.

Section 4.5: Interesting results, but it is disapointing not to reach a conclusion because of the lack of analysis of the Loire riverflow.

As said above, the Loire river behaviour can be linked to a few weather types but at the monthly scale only. The analysis of these weather types occurrences in the future will allow us to reach a more specific conclusion.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 2235, 2011.

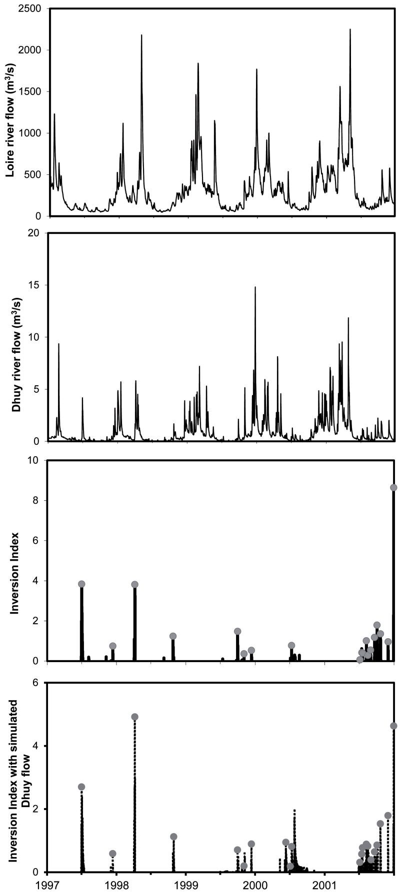

Fig. 1. Fig. 3. Observed backflooding events and calculated backflow indices for 1997 to 2001.

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"Dry" WTs	Variability of precipitation	"Wet" WTs	Variability of precipitation	Other WTs	Variability of precipitation
DJF0	-62%	DJF2	39%	DJF8	8%
DJF1	-89%	DJF3	177%	DJF5	9%
DJF4	-32%	DJF6	104%	JJA2	8%
DJF7	-54%	MAM1	55%	JJA4	1%
MAM0	-60%	MAM3	41%	JJA6	8%
MAM2	-11%	MAM5	32%	SON0	-5%
MAM4	-91%	MAM6	100%		
MAM7	-17%	MAM8	120%		
MAM9	-54%	JJA5	189%		
JJA0	-40%	JJA7	183%		
JJA1	-80%	JJA8	190%		
JJA3	-66%	SON1	41%		
JJA9	-63%	SON3	144%		
SON2	-45%	SON4	65%		
SON6	-50%	SON5	22%		
SON7	-85%	SON8	154%		

Fig. 2. Table 1. Variability of precipitation on the Val d'Orléans for each weather type.