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# A multi-method recharge estimation tool applied to four contrasted karstic systems (France): a simple and robust approach

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Managing groundwater from a quantitative standpoint should be based on a precise estimation of the available resource. For karstic aquifers, the resource estimation can represent a huge challenge due to the limited knowledge in terms of geometry and structure. One way to provide water managers with operational information for such aquifers is to estimate the **aquifer recharge**.

To obtain both a realistic estimation of groundwater recharge and a confidence interval at the hydrogeological basin scale, the greatest possible number of methods should be used and their results compared.

## ESPERE, a multi-method MS-Excel application for estimating aquifer recharge

ESPERE – a French acronym for *Estimation of effective rainfall and groundwater recharge* - applies different commonly-used recharge estimation methods in an MS-Excel spreadsheet + VBA application, in which the user enters time series and parameter data for the aquifer being studied. It allows quantifying recharge for a daily to annual time step and visualizing related uncertainties (including comparison with modeling results). ESPERE is a freely-available tool (Lanini et al, *submitted to Groundwater*)

ESPERE is a french acronym for *Estimation de la Pluie Efficace et de la REcharge selon différentes méthodes*

### Multi-Method Effective Rainfall and Groundwater Recharge Estimation

#### Guidelines

- 1) If needed, click on "data cleaning" to remove old data and parameters from all Spreadsheets. Enter new time series data on the "Data" sheet.
- 2) Select the methods you want to apply, and fill in the parameter table below.
- 3) Select "Hydrological year" if you want the annual results to be displayed from September 1 to August 31 (instead of January 1 to December 31).
- 4) RUN the simulation.
- 5) At the end of calculation, you can save the simulation in a new Excel file by clicking on SAVE.

Property	Unit	Value	Information
Groundwater recharge area surface	km <sup>2</sup>	177	Used to convert effective rainfall into infiltrated water volume (water budget and Turc methods), as well as baseflow into recharge (filter methods)
Runoff/infiltration partition coefficient		0.34	Used to convert effective rainfall into recharge (water budget and Turc methods). 0 if Recharge = Effective rainfall, 1 if there is only runoff (no recharge).
Soil storage capacity	mm	48	Needed for the water budget methods (Thornthwaite and Dingman).
Latitude	°	43.7	Needed only for the Dingman - Hamon water budget method
Specific Yield (Sy)		0.0037	Needed only for the Water Table Fluctuation method
Hydrogeological catchment surface	km <sup>2</sup>	64.2	Used to convert groundwater recharge into infiltrated water volume for the WTF method

Specific Parameters	
Crop coefficient	
Accounting for crop type and development stage in evapotranspiration estimation (water budget methods)	<a href="#">Click here to enable this option and to define parameters</a>
Flowrate filters	
BFimax	1
k (recession constant, ranging between 0 and 1)	0.6

Indicative values (from Eckardt, 2005): BFimax=1: spring flows; BFimax=0.8: perennial streams with porous aquifers; BFimax=0.5: ephemeral streams with porous aquifers; BFimax=0.25: perennial streams with hard rock aquifers

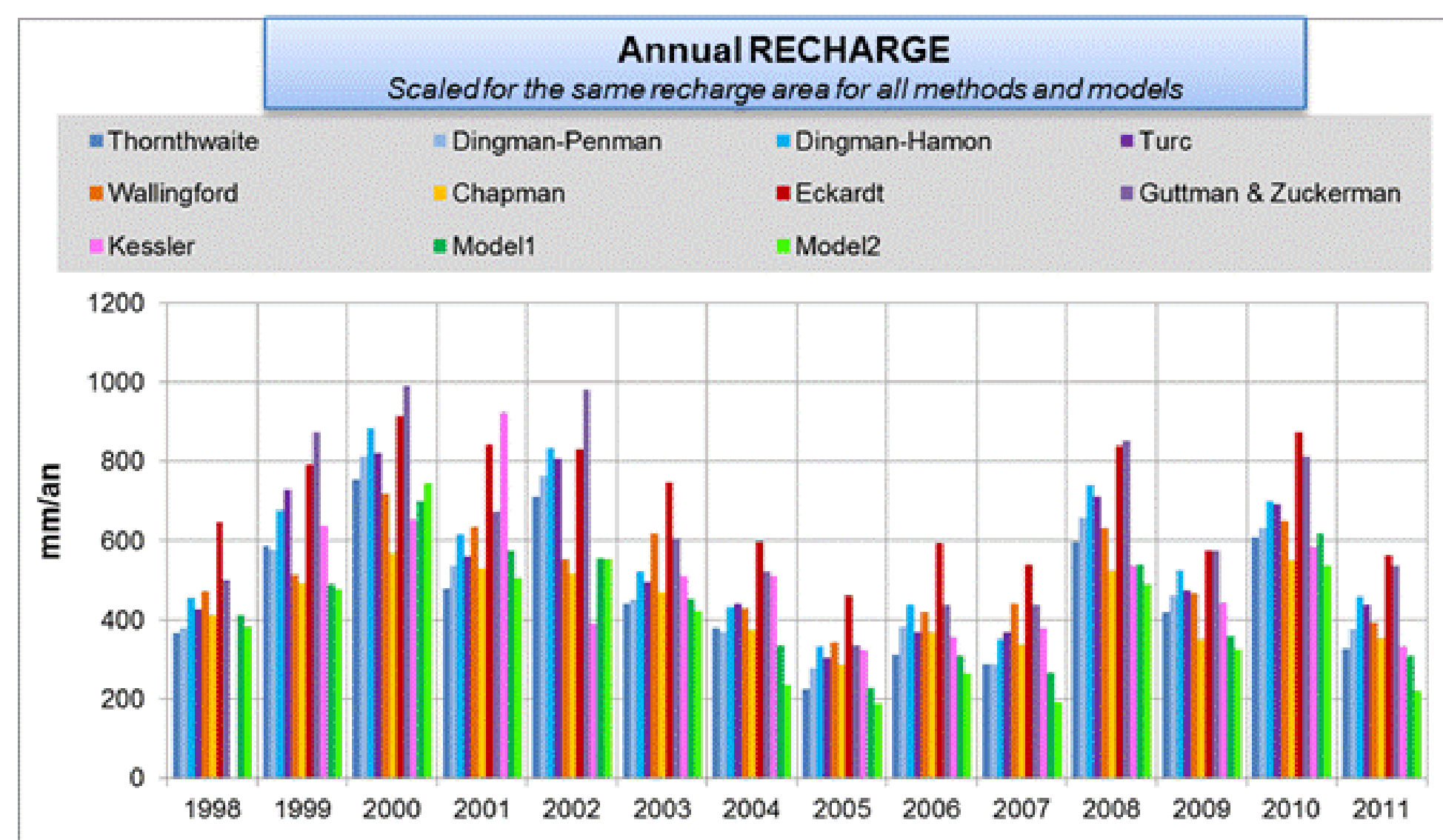
Data cleaning

Hydrological year

METHODS	
<b>Effective rainfall estimation</b>	
<input type="checkbox"/>	Turc
<input checked="" type="checkbox"/>	Thornthwaite
<input checked="" type="checkbox"/>	Dingman - Penman
<input checked="" type="checkbox"/>	Dingman - Hamon
<b>Groundwater Recharge estimation</b>	
<input checked="" type="checkbox"/>	Empirical relationship (Guttman & Zuckerman)
<input checked="" type="checkbox"/>	Kessler
<input checked="" type="checkbox"/>	Water Table
<input checked="" type="checkbox"/>	Filters and BFI

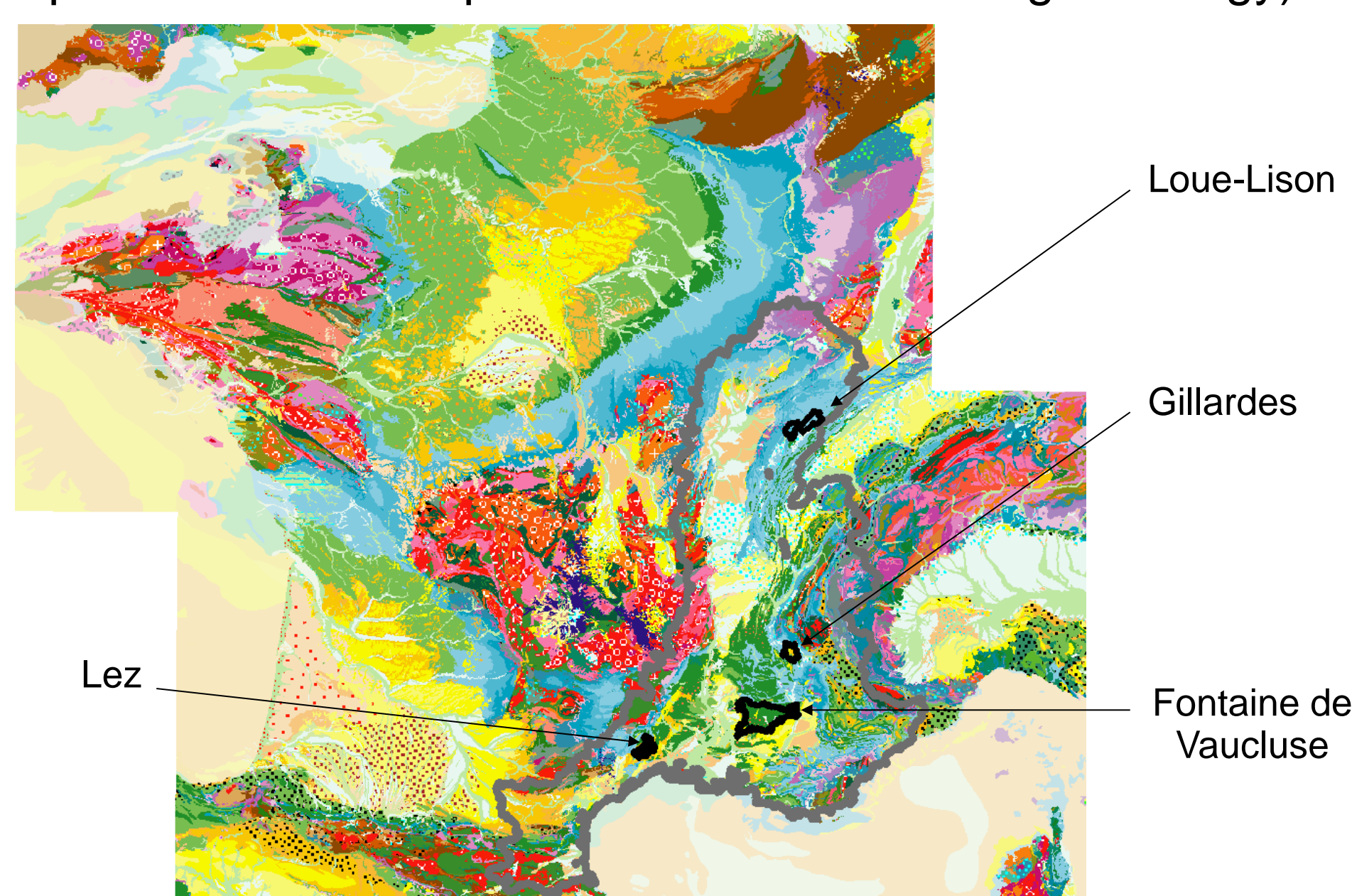
The procedures included in ESPERE allows either calculating recharge directly or deriving it from effective rainfall using a runoff/infiltration partition coefficient.

The current version of ESPERE includes four categories of methods - empirical, water budget, water-table fluctuation, and discharge filtering methods - and operate for a daily to yearly time step.



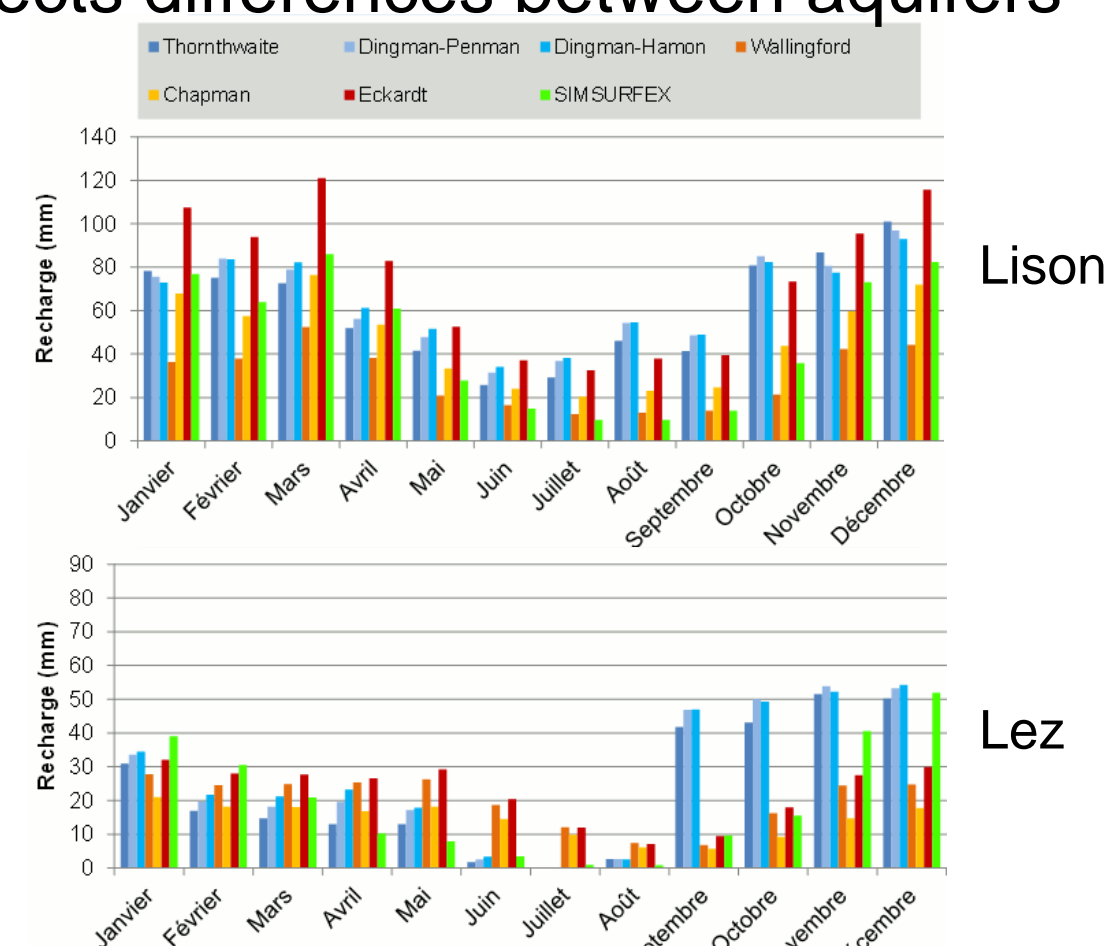
## 4 contrasted karst systems

The Loue-Lison, Gillardes, Fontaine de Vaucluse and Lez springs drain amongst the most important karst aquifers of France. Submitted to contrasted climate conditions and pumping strategies (Loue, Lison, Gillardes and Fontaine de Vaucluse nearly not exploited and Lez exploited with active recharge strategy).



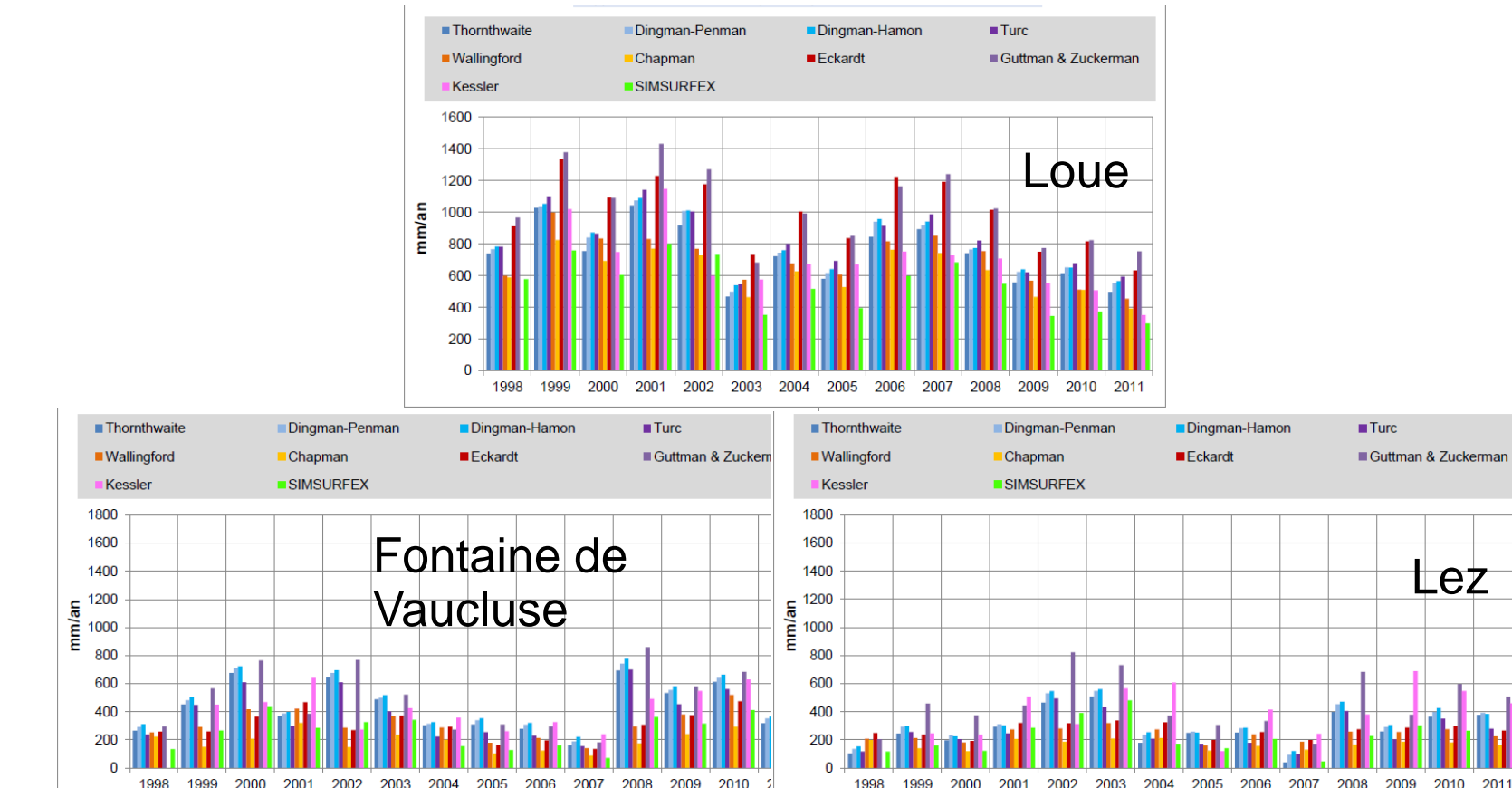
## Understanding aquifer dynamics

Comparing monthly recharge estimations using multiple methods provide information on seasonal snowmelt and aquifer storage effects differences between aquifers



Recharge estimated using Thornth. water balance (effective rainfall infiltrated using Surfex (Masson et al., 2013) runoff/infiltration ratio) is higher/lower than that calculated considering snowmelt (Ding.-Pen.) in winter/spring or autumn. Differences between climate-based and discharge or groundwater level - based estimated monthly recharge inform on the autumn storage capacity of the karst system

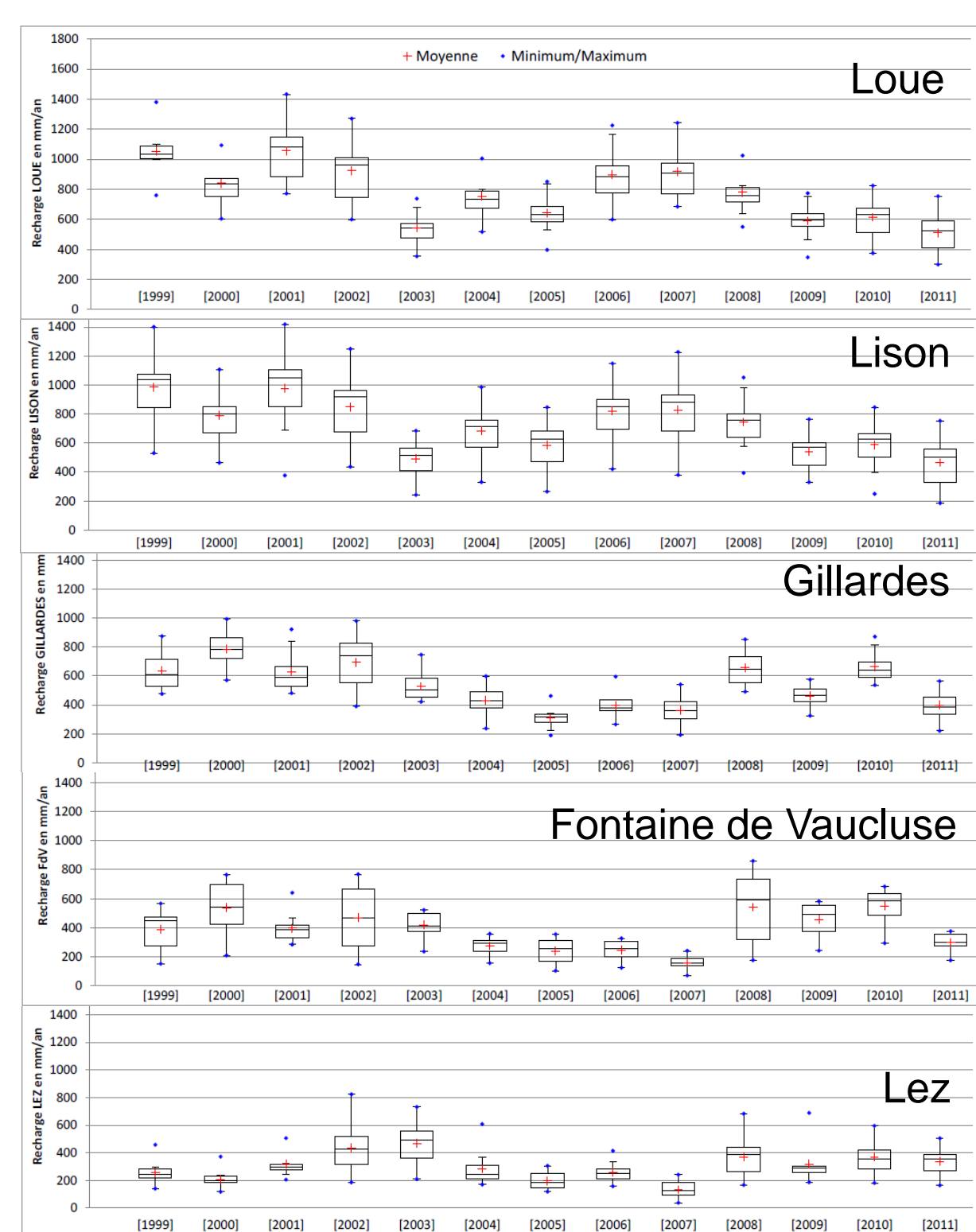
Comparing annual recharge estimations illustrates the climate context influence and allows quantifying interannual variability



Annual recharge	Loue	Lison	Gillardes	Fontaine de Vaucluse	Lez
Mean (mm)	778	718	534	383	304
Stand. Dev. (mm)	161	197	113	121	111
SD/Mean (%)	21	27	21	32	36

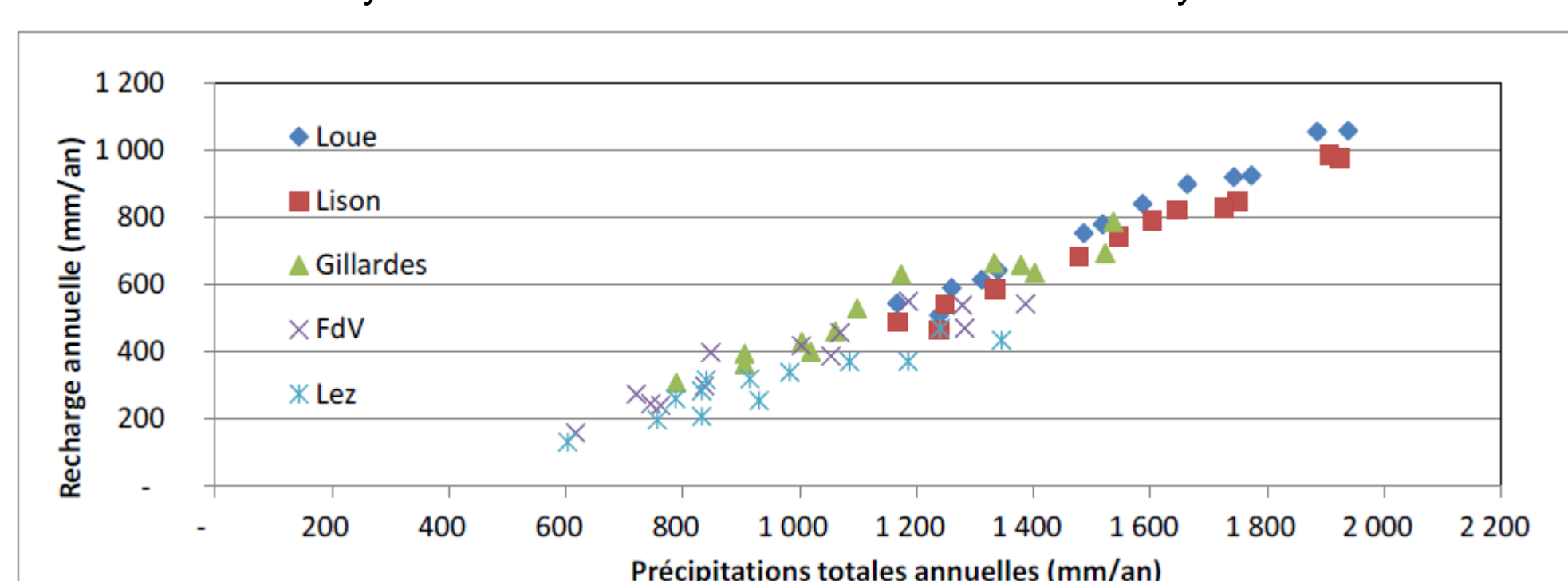
Recharge in the northern systems is higher, dispersion around the mean recharge value is higher for southern systems

## Assessing uncertainty



Annual dispersion of results and year-to-year differences varies from northern to southern systems (example: 1999-2000, 2003-2004 or 2007-2008).

A linear relation between annual recharge and precipitation can be observed and allows identifying the amount of precipitation needed to start recharge of a given karst system (from 200-250 mm for southern systems to more than 400 mm for northern systems)



Resulting mean annual actual evapotranspiration (ETR = precipitation - effective precipitation) is compared to those computed using Surfex (Masson et al., 2013) and those compiled by Zhang et al., (2001), over more than 250 river basins over the world, considering a lower (pasture) and a higher (forest) value for the soil water content. This illustrates the extremely low ETR that is observed over karst systems, corresponding to higher recharge rates compared to other common types of aquifers.

