Importance of the spatial heterogeneity in the non-linear response of a small Mediterranean catchment

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INTRODUCTION

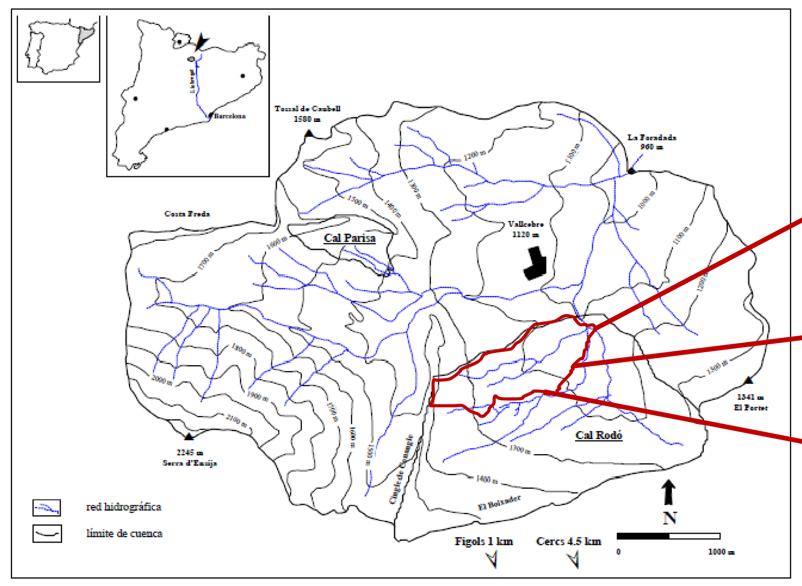
Mediterranean catchments are characterized by strong non-linearities in their hydrological behavior. The main aim of this work is analyzing how the non-linear hydrological behavior of a small Mediterranean catchment can be reproduced by means of mathematical modelling.

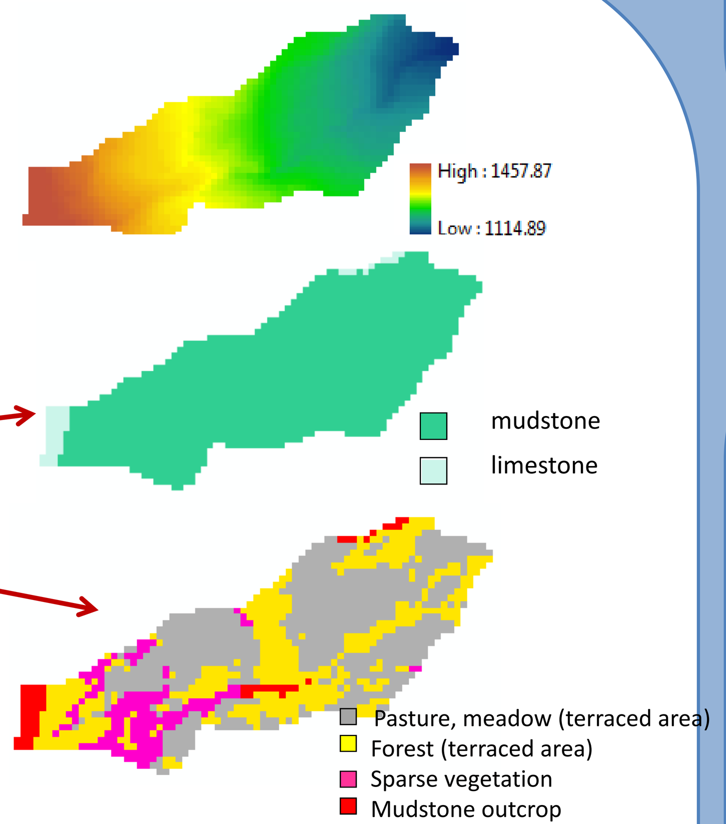
To address these issues the hydrological modeling of the Can Vila catchment (northeast of Barcelona, Spain) was carried out. Three hydrological models were considered: two lumped models called LU3 and LU4 and a distributed model called TETIS. Furthermore, a multi-criteria analysis was employed to determine which model was more suitable to represent the observed behavior of this small catchment.

RESEARCH QUESTION

The question is: are observed non-linearities due to spatial heterogeneity or to non-linear mechanisms that should be taken into account into our models conceptual schemes?

STUDY AREA: CAN VILA





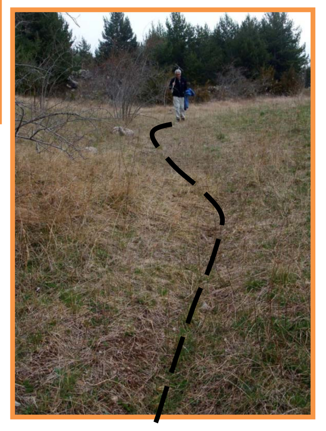
SMALL TERRACE

BIG TERRACE

High step between terrace

Small step between terrace

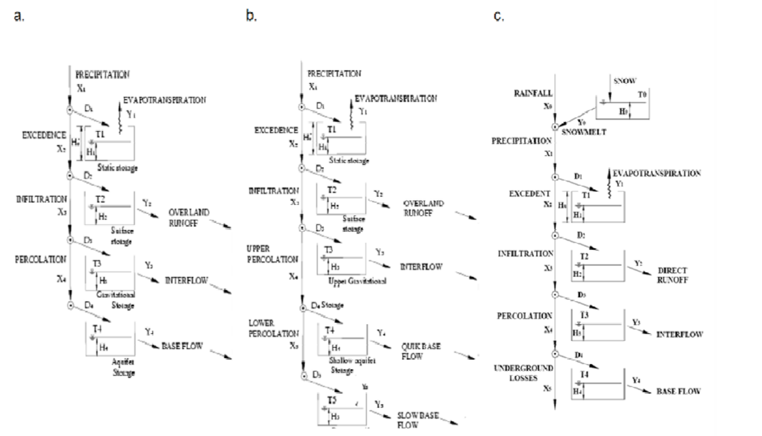
Pool formation



Formation of its own drainage network

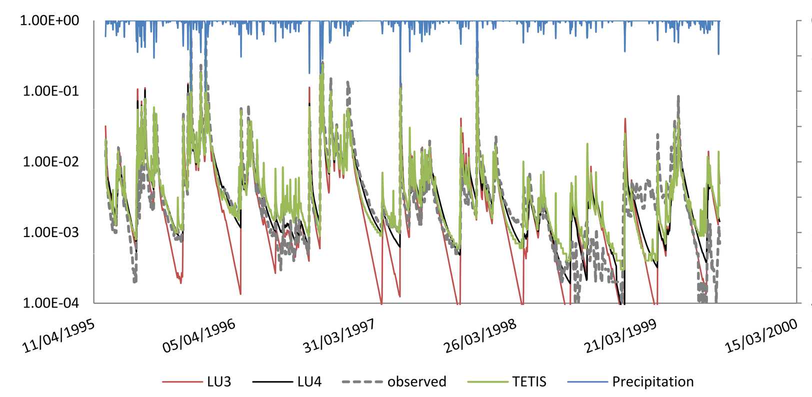
STRONG HETEROGENEITY

HYDROLOGICAL MODELS



Schematic representation of a) the LU3 model structure (catchment-scale); b) the LU4 model structure (catchment-scale); c) the TETIS model structure (cell-scale).

CALIBRATION



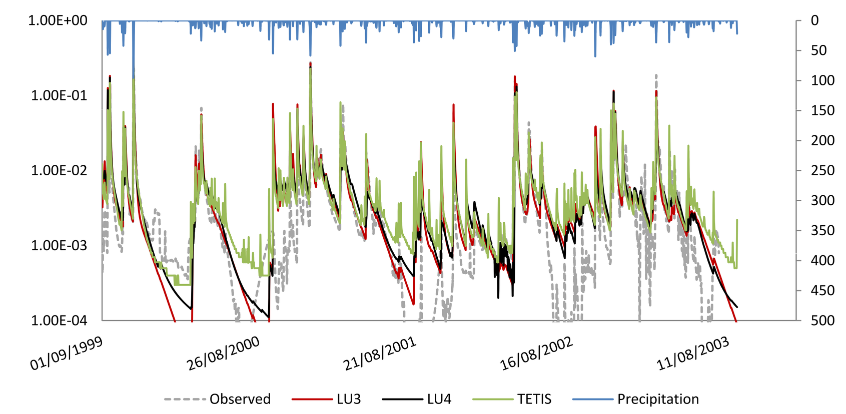
WET PERIOD: 11/05/1995 - 31/08/1999

Model	Nash	Volume Error
LU3	0.810	14.33%
LU4	0.871	8.98%
TETIS	0.822	10.11%

DRY PERIOD: 01/09/2003 - 31/08/2008

Model	Nash	Volume Error
LU3	0.501	2.39%
LU4	0.601	-11.33%
TETIS	0.670	-16.72%

VALIDATION



PERIOD 1: 01/09/1999 – 31/08/2003

Model	Nash	Volume Error
LU3	0.782	27.40%
LU4	0.826	21.70%
TETIS	0.812	21.55%

PERIOD 2: 01/09/2008 – 31/12/2009

Model	Nash	Volume Error	
LU3	0.335	54.78%	**rejected**
LU4	0.537	35.32%	
TETIS	0.623	32.40%	

MULTI-OBJECTIVE ANALYSIS (I)

MODELS:

The multi-objective analysis was carried out for the best models: LU4 and TETIS.

OBJECTIVES OF THE ANALYSIS:

- Verify if the result of the automatic calibration was included into the Pareto frontier.
- Compare two selected models capability to reproduce equally well the wet and the dry period simultaneously.

OBJECTIVE FUNCTIONS:

Nash and Sutcliffe efficiency index

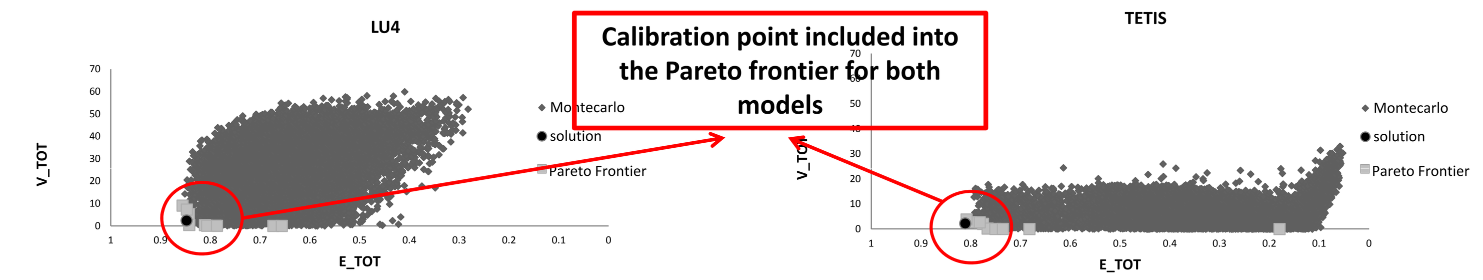
$$E = 1 - \frac{\sum_1^n (X_{sim} - X_{obs})^2}{\sum_1^n (X_{obs} - \overline{X_{obs}})^2}$$

Volume Error

$$V(\%) = \frac{\sum_1^n (X_{sim} - X_{obs})}{\sum_1^n X_{obs}} * 100$$

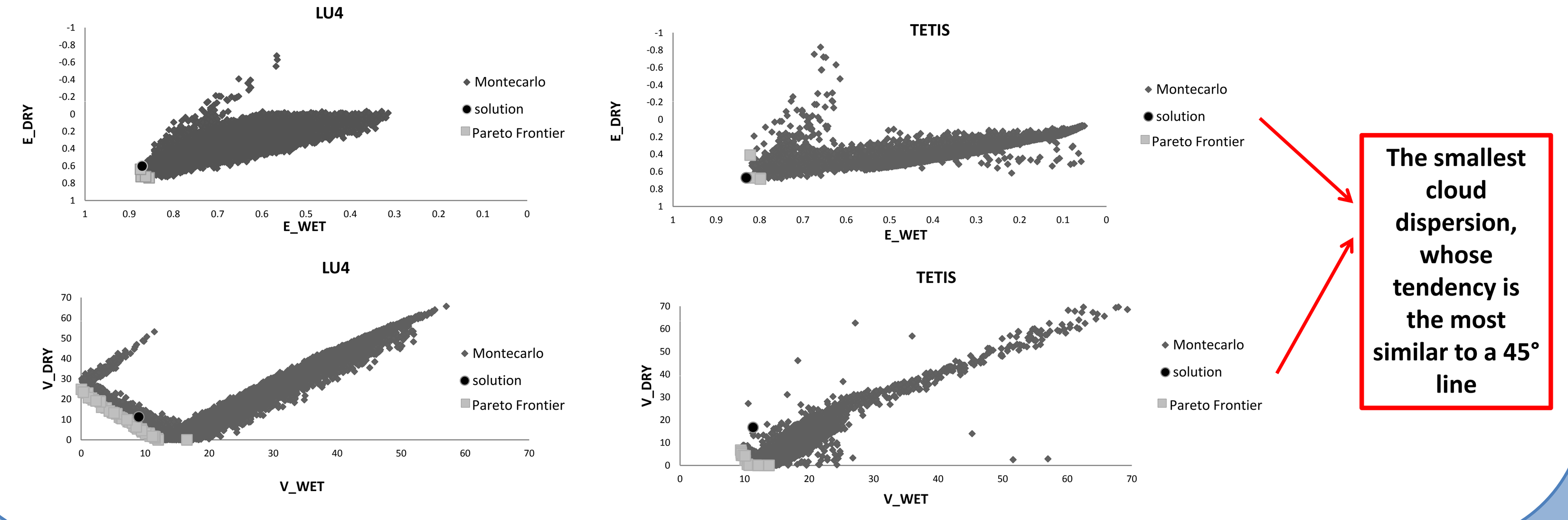
MULTI-OBJECTIVE ANALYSIS (II)

E_{TOTAL} : E index computed for the whole calibration period
V_{TOTAL} : V error computed for the whole calibration period



MULTI-OBJECTIVE ANALYSIS (III)

$E_{DRY/WET}$: E index computed for the dry/wet calibration period
$V_{DRY/WET}$: V error computed for the dry/wet calibration period



CONCLUSIONS

The non-linear catchment dynamic could be explained considering a threshold-mechanism for the saturated zone recharge, leading to a switching behavior of the deep aquifer (LU4), or including the basin spatial heterogeneity through the application of a linear distributed model, TETIS. These two approaches provided very similar results in terms of goodness of fit indexes. However, further test (models temporal validation) and analysis based on 10.000 MC simulations suggested the distributed TETIS model as a more robust model due to its capacity to behave consistently during the wet and the dry periods. For this reason, the TETIS model represented the most reasonable choice for the Can Vila catchment, where the spatial heterogeneity (in particular the small terraces) seems to govern the catchment hydrological responses. This also led to the conclusion that the LU4 model was likely to give good results for the wrong reason.

ACKNOWLEDGEMENTS

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