Use of distributed water level and soil moisture data in the evaluation of the PUMMA periurban distributed hydrological model: application to the Mercier catchment, France

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HS2.1.3
Spatial patterns evaluation and process-physics understanding in distributed hydrologic modeling
Poster A.55

Use of distributed water level and soil moisture data in the evaluation of the PUMMA hydrological model Application to the Mercier catchment 6.6 km^2,France

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1. CONTEXT AND OBJECTIVES

Context:

- Use of distributed hydrological models in a hypothesis testing framework (Clark et al., 2011)
- Evaluation of models using distributed data

Objectives:

- Assessment of the value of distributed networks of surface soil moisture and water level sensors to identify problems with models parameters and representations
- Application to the PUMMA (Peri-Urban Model for landscape Management, Jankowfsky et al., 2014) distributed model in the Mercier catchment (6.6 km^2, France)

2. STUDY AREA AND DATA

Study catchment:

- Mercier catchment, south-east France, close to Lyon city
- Gneiss geology and soils with a low retention capacity.
- Three dominant land uses used as a basis for the PUMMA model mesh

Available data (Fig. 1)

- Two rain gauges with a variable time step
- Discharge at the outlet with a variable time step
- Network of water level in streams (18 locations), 2 to 5 min time step, 2007-2010, (Sarrazin, 2012)
- Surface soil moisture network (7 locations), 2 min time step, 2010-2011 (Dehotin et al., 2015)

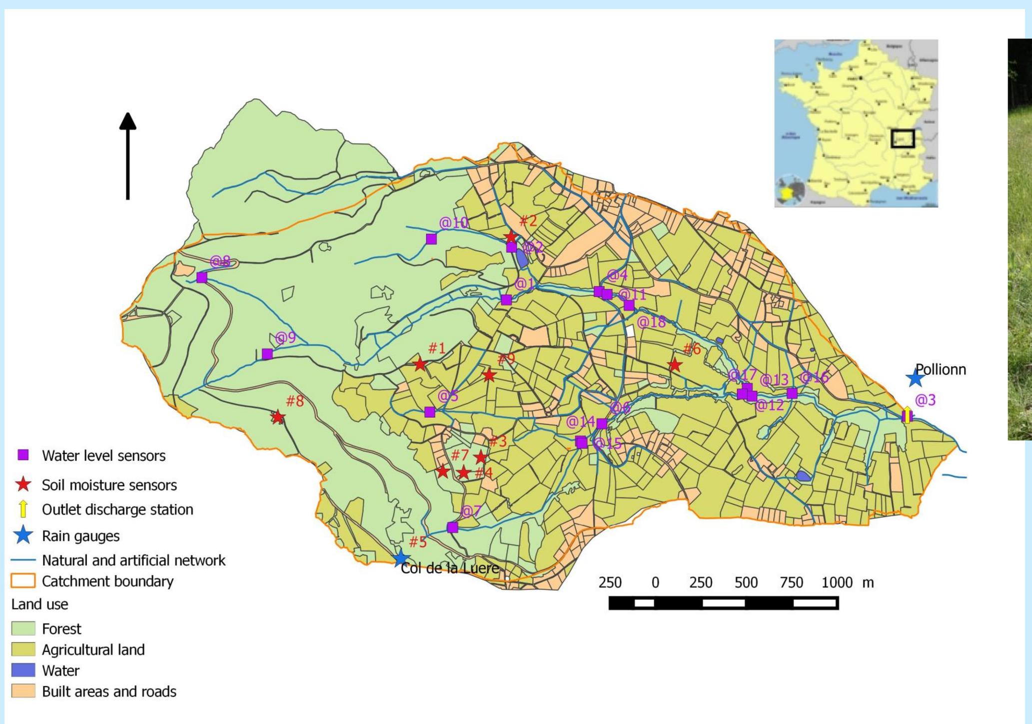

Figure 1: Location and land use of the study catchment. Location of the various sensors

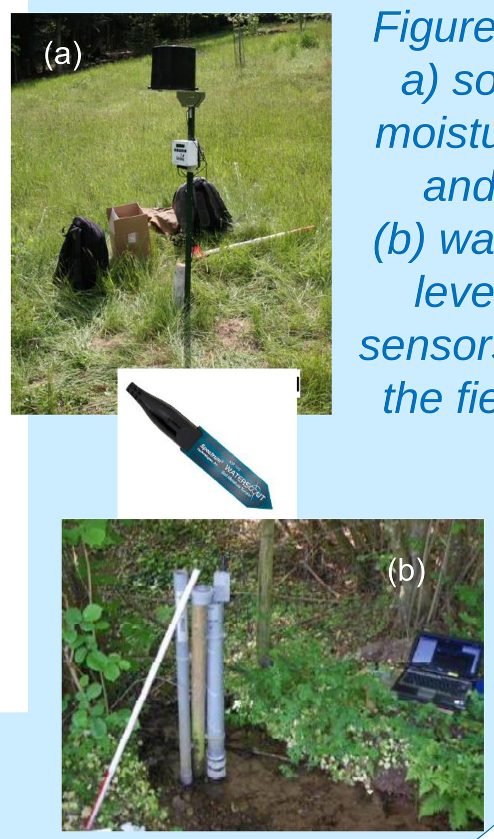

Figure 2: a) soil moisture and (b) water level sensors in the field

3. THE PUMMA MODEL

- Model mesh made of irregular polygons corresponding to land-use patterns
- Modular structure with specific modules according to land-use
- Main hydrological processes accounted for:
  - ➢ Evapotranspiration and infiltration in soil
  - ➢ Saturation excess surface runoff on forest/agriculture surfaces
  - ➢ Subsurface flow
  - ➢ Flow routing in the natural and artificial hydrographic network

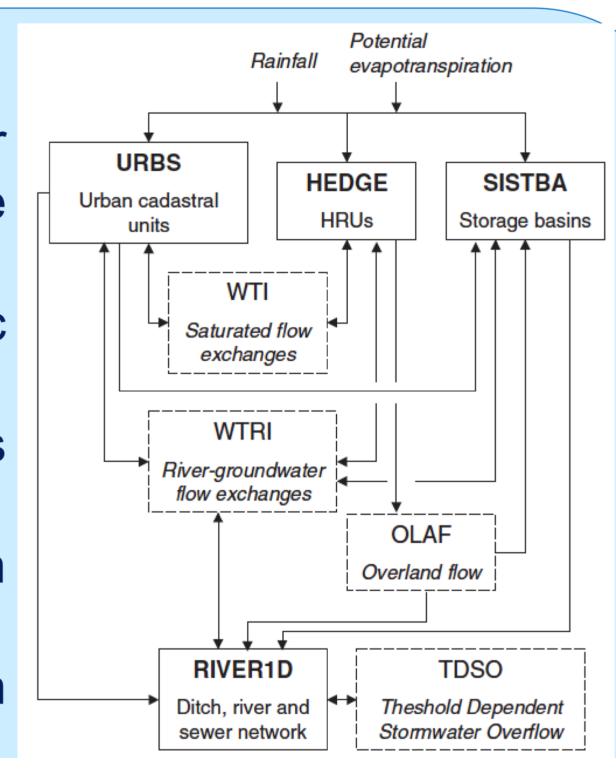

Figure 3: PUMMA model and coupling between process modules (from Jankowfsky et al., 2014)

4. MODEL SET UP AND EVALUATION

Model set up:

- Simulation with a variable time step for rainfall and hourly ET0 over the 2007-2010 period using 2006 as warm-up period
- Parameters specification from observations and Jankowsky et al. (2014) previous study on a neighboring catchment
- No calibration to relate mismatch between observation and model to model parameters and process representations

Stepwise evaluation methodology:

- Simple consistency checks (water balance and flow components)
- **Comparison (NSE, bias) between observed/simulated discharge at the annual and event time scales**
- **Analysis of soil water storage dynamics** using a normalized moisture index

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

- **Simulation of stream intermittency**: 1cm water level threshold on observations to define the flow/no flow patterns by fortnight, test of 0.5, 0.7, 1 cm threshold for modelled values
- **Simulation of response and reaction times**
- Reproduction of observed controls on hydrological response (antecedent moisture, rainfall volume/intensity)

5. RESULTS

Evaluation on discharge

Annual:

- Low Nash on Q, better on $\sqrt{Q}$
- Low bias
- Variable performance from one year to the other. Better results in wet conditions

Hourly	2007-2008	2008 (wet)	2009 (dry)
NSE_Q	0.01	0.41	-0.33
NSE_√Q	0.27	0.39	0.45
PBIAS (%)	-8	9.3	1.3

Events:

- Good dynamics
- Volume overestimation
- Better results in wet conditions

6min time step	All events (20)	Wet (12)	Dry (8)
NSE_Q	-3.5	-2.4	-6.5
R^2	0.6	0.7	0.4
PBIAS (%)	62.7	46.7	86.9
Peak flow lag (h)	-0.4	-0.4	-0.4
Peak flow error(-)	1.4	0.9	6.9

Soil water storage dynamics

- Correlation normalized observed surface soil moisture / normalized simulated soil water storage: R^2 =0.42 [0.04,0.79] and $\tau_{Kendall}$ = 048 [0.01, .71] (average of 7 stations)
- Ability of the model to capture the autumn dry/wet change in soil moisture

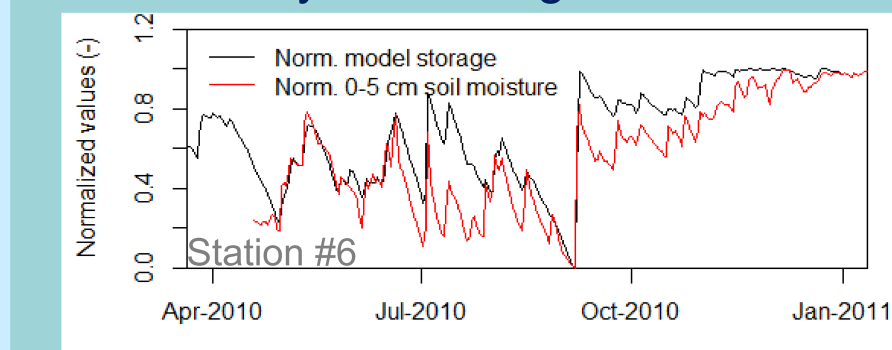

Figure 4 : Normalized observed surface soil moisture and simulated soil water storage

Stream intermittency

Model underestimation of no flow and continuous flow periods

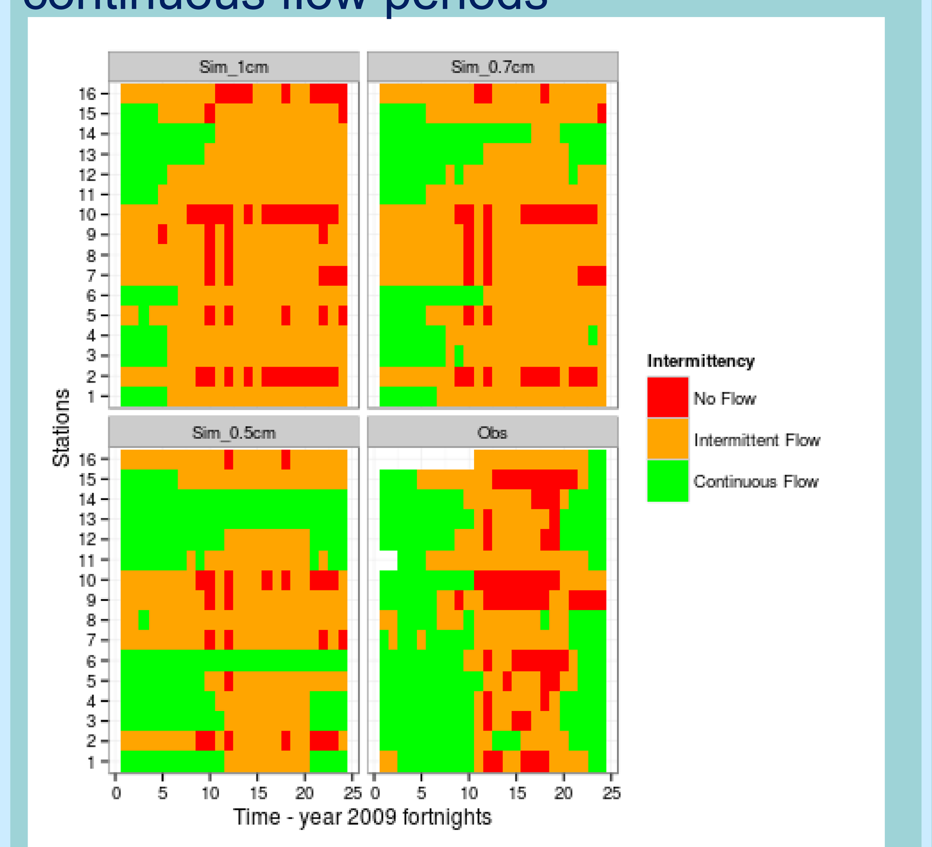

Figure 5: Comparison of Simulated (Top and Bottom Left) and Observed (Bottom Right) stream intermittency patterns for year 2009 divided into 24 fortnight periods for water level sensors @1 to @16.

Reaction/response times

Model underestimation of response/reaction times, overestimation of response amplitude

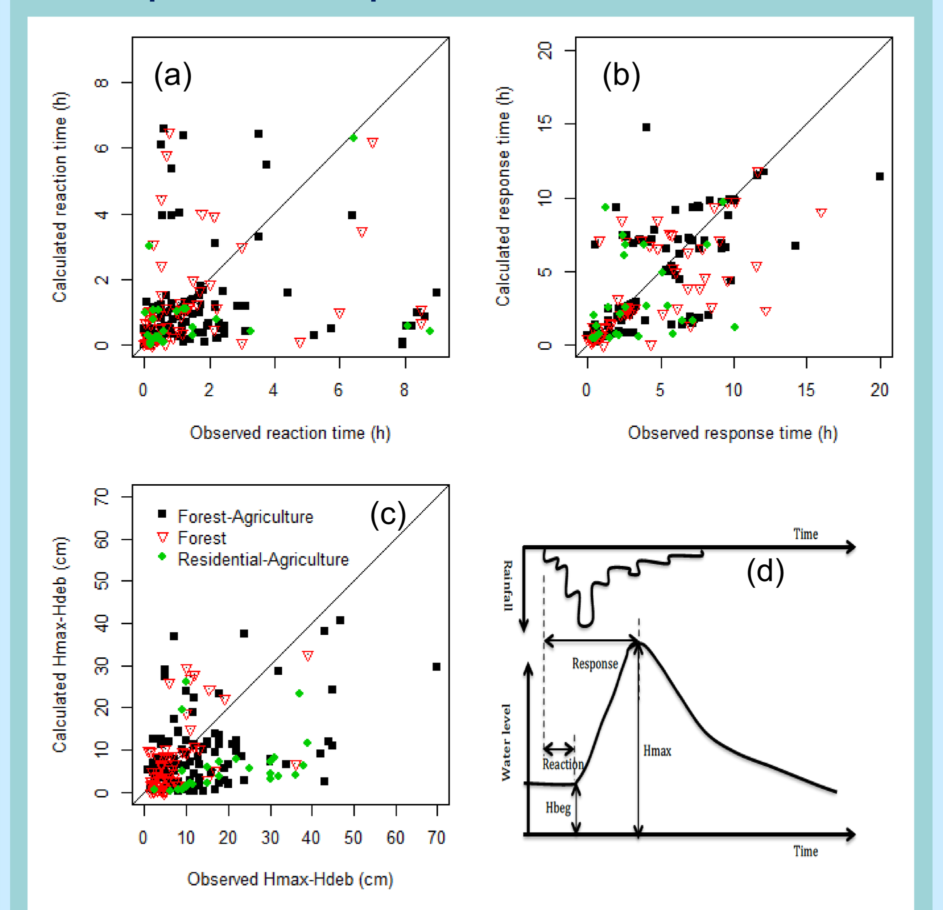

Figure 6: Observed and simulated reaction (a) and response (b) times (see definition in (d)) and response amplitude H_{max}-H_{beg} (c). Points colored by land use.
(d) Scheme for the extraction of reaction and response times, and the response amplitude

6. CONCLUSIONS

- Surface soil moisture and distributed water level data useful to provide a diagnostic on the model dynamics, but not on runoff quantity
- Quantitative information on catchment soil water storage (Vannier et al., 2014) and distributed discharge would be required to improve model parameters
- Main component to improve: soil water storage and topology

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