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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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

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

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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, 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)

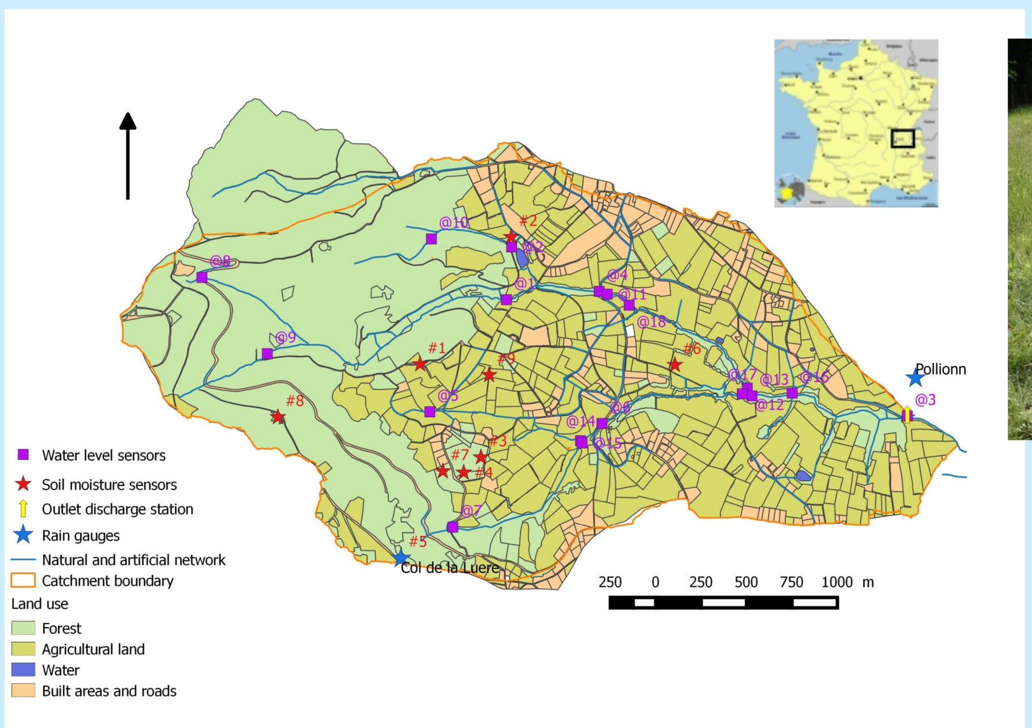

Figure 1: Location and land use of the study catchment. Location of the various sensors

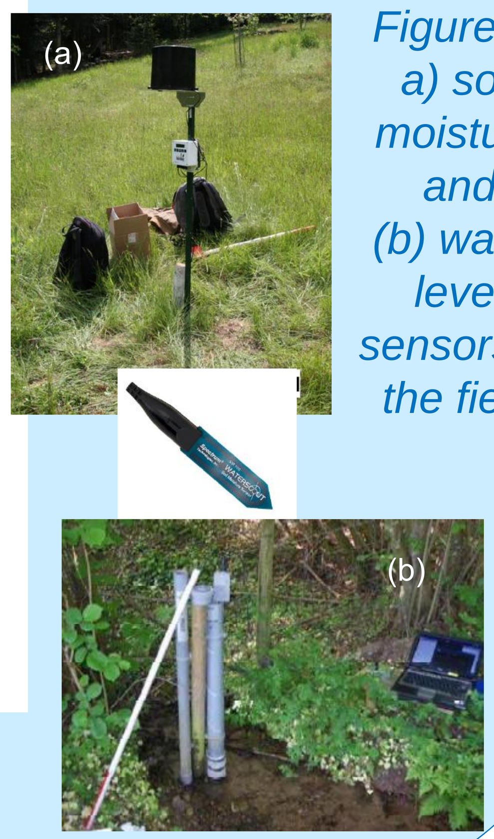

Figure 2: a) soil moisture and (b) water level sensors in the field

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

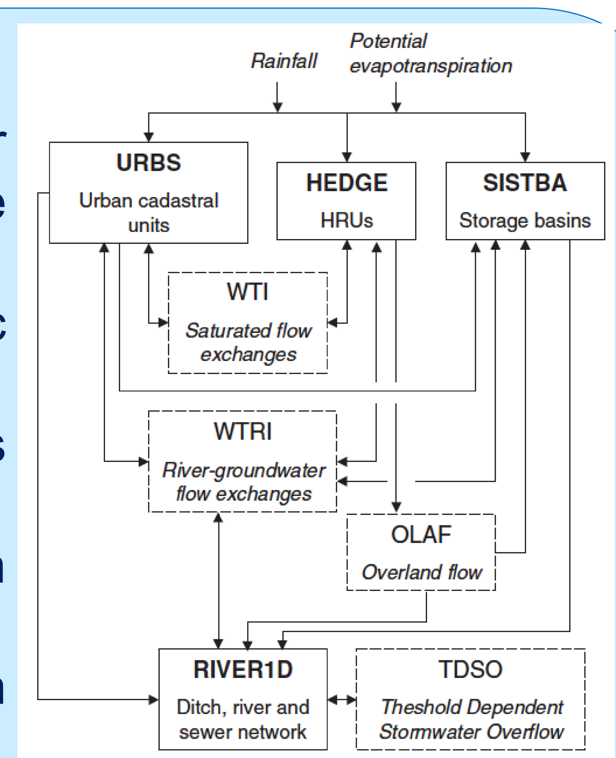

Figure 3: PUMMA model and coupling between process modules (from Jankowfsky et al., 2014)

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

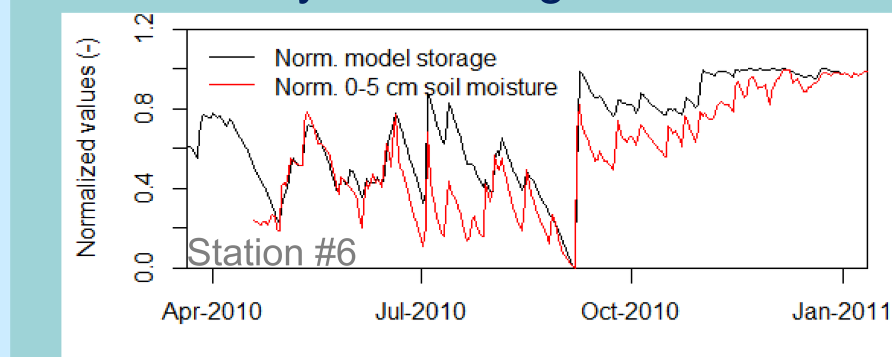

Figure 4 : Normalized observed surface soil moisture and simulated soil water storage

Stream intermittency

Model underestimation of no flow and continuous flow periods

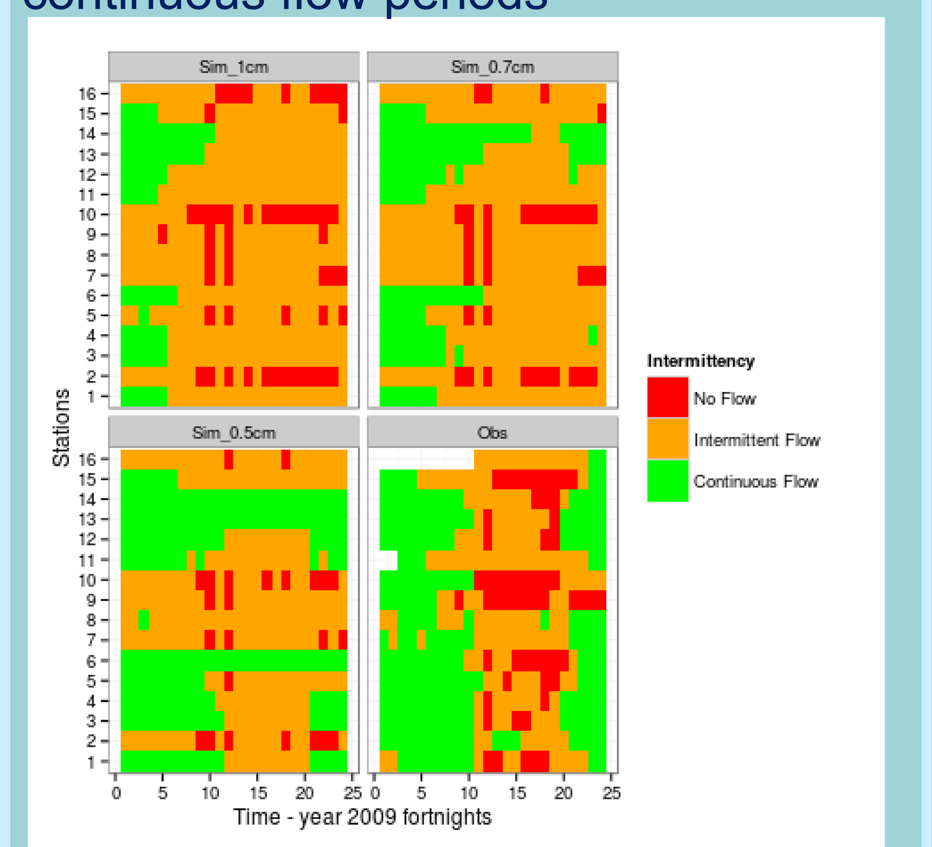

Figure 5: Comparison of Simulated (Top and Bottom Left) and Observed (Bottom Right) stream intermittency patterns for year 2009 divided into 24 fortnight periods for water level sensors @1 to @16.

Reaction/response times

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

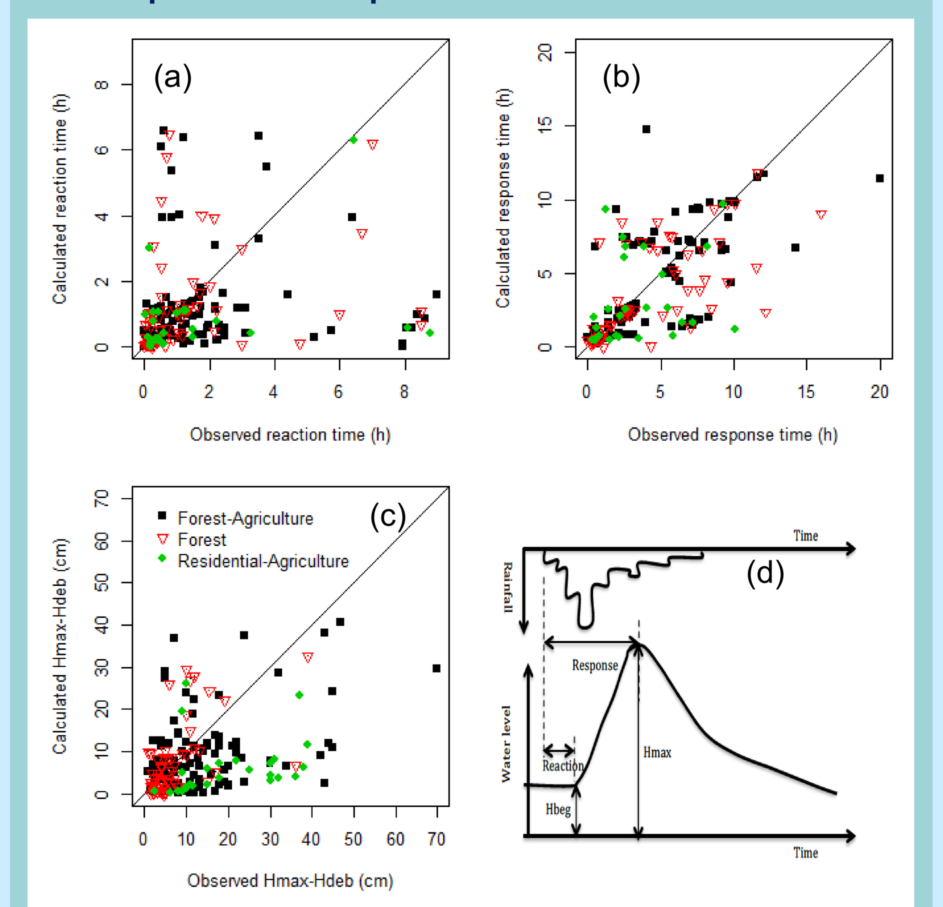

Figure 6: Observed and simulated reaction (a) and response (b) times (see definition in (d)) and response amplitude H_{max}-H_{beg} (c). Points colored by land use. (d) Scheme for the extraction of reaction and response times, and the response amplitude

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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