J2000-Rhône: a distributed hydrological model including water-use modelling to assess sustainability of the water resource

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1. CONTEXT AND OBJECTIVES

Context:

Mediterranean and Alpine catchments are hot spots of climate, land use and practices changes, raising questions about the future of water resources in these catchments. To anticipate such changes and compare different adaptation solutions, process-based distributed models can provide useful results for stakeholders, provided the models are able to handle water uses impact and management.

Objectives:

- Develop a distributed hydrological model over the whole Rhône catchment
- Include a representation of the prevailing water uses : dam influence / irrigation / drinking water
- Use this tool for prospective studies as to the future of the water resource

2. THE RHONE CATCHMENT

Study catchment (Fig. 1)

- A 95 000 km^2 watershed
- A large diversity in topography (from 0 to 4807 m), climates (Alpine, Oceanic, Mediterranean)
- A large anthropogenic impact on water resources through a large diversity of water uses: dams and derivations, irrigation, drinking water (around 13 M inhabitants)

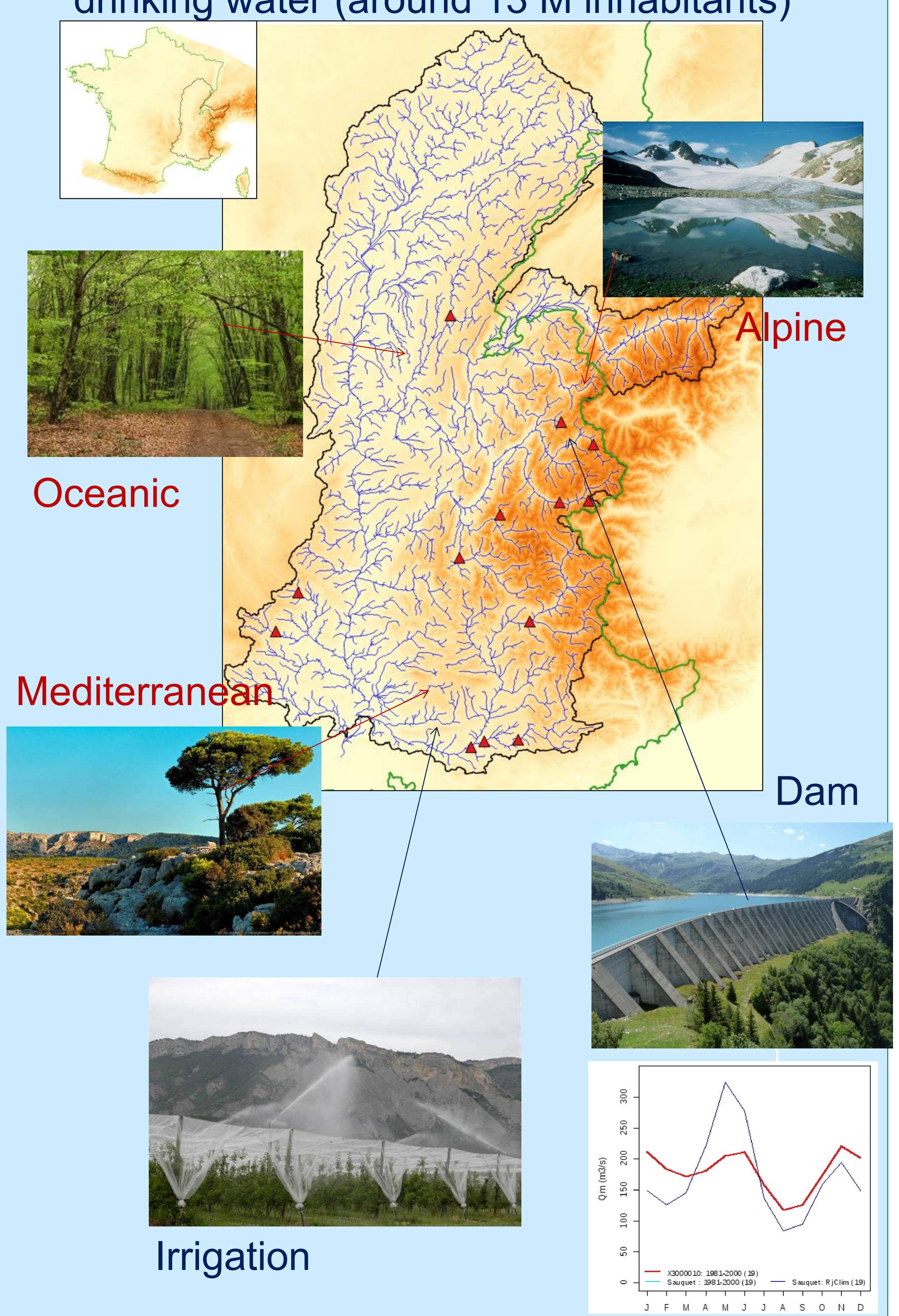

Figure 1: Location and topography of the Rhône catchment. Red triangles are the main dams. Photos illustrate the various landscapes and water uses (irrigation, dams). The bottom graph shows the impact of a dam on the interannual monthly water cycle

3. J2000-RHONE: MODEL DESCRIPTION AND SET UP

J2000-Rhône principles

- A fully distributed process-based hydrological model, based on the Hydrological Response Unit (HRU) concept (modeling units considered homogeneous in terms of topography, geology, land use and soil properties) (Fig. 2)
- Modular open-source codes modules developed in the JAMS modeling platform
- Natural hydrology: adaptation of the J2000 model (Krause et al., 2006) to the French context (Fig.3)
- Building of new modules for dams and derivations (Fig. 5), irrigation (Fig. 6) and drinking water (econometric model)

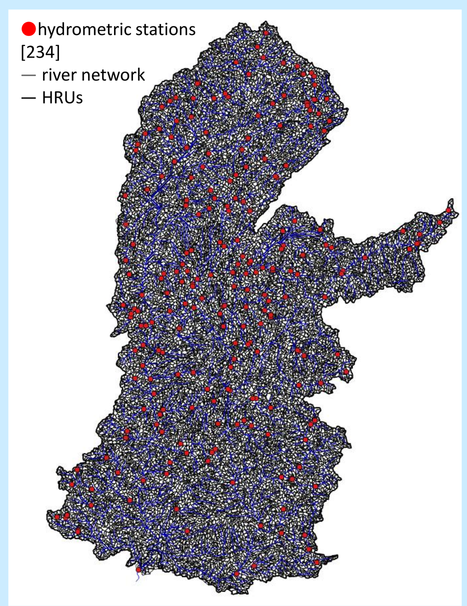

Figure 2: HRUs of the Rhône catchment and discharge gauging stations used for the evaluation

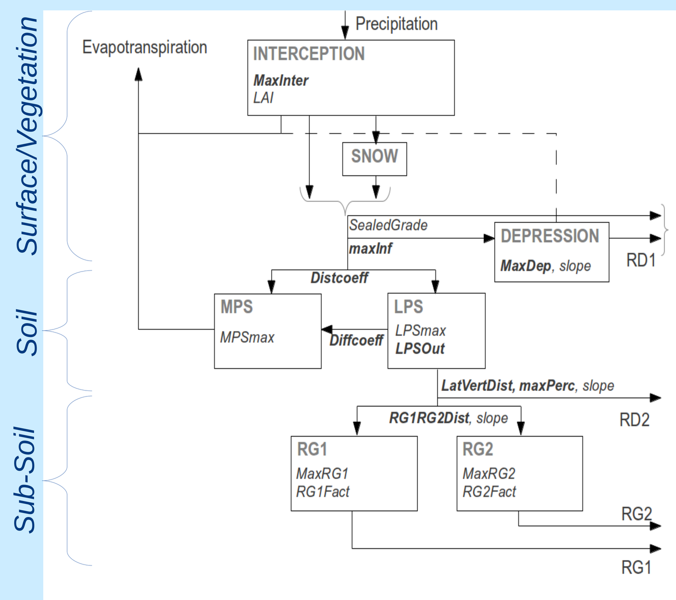

Figure 3: Processes modelled at the HRU scale. Routing of the three runoff components is performed from HRU to HRU until reaching the river where a kinematic wave approximation is used

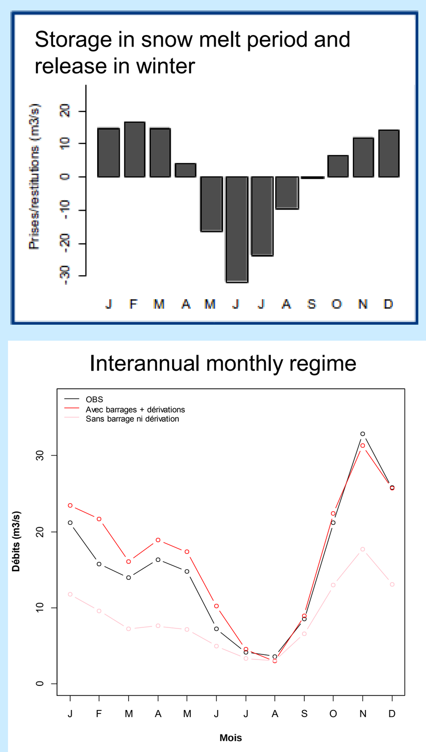

Figure 5: Dam and derivation module. (a) An interannual objective function is estimated from data and applied daily to the model. (b) Illustration for the Loire-Ardèche derivation

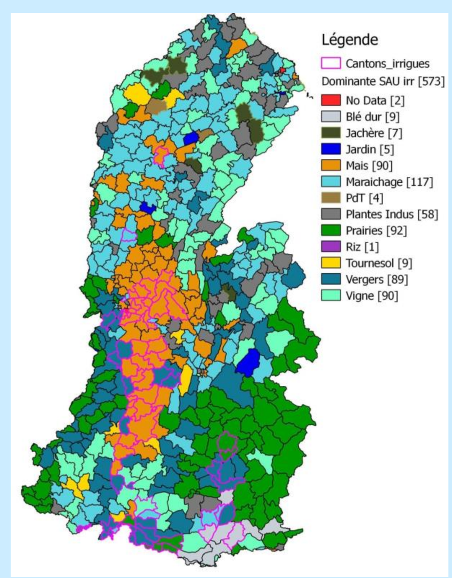

Figure 6: Main irrigated crop at the "canton" scale randomly distributed on the HRUs. Irrigation (aspersion, drip, gravitational) is computed as the difference between water demand and available water with two parameters: objective % soil filling and network efficiency. Water is taken in the closest river reach

Input data

- Input rainfall and reference ET0 computed from SAFRAN climate data base (Vidal et al., 2010) + crop coefficient for the main land uses
- ASTER 30 m DTM aggregated to 200 m
- Corine Land Cover 2006
- Pedology: Soil European Data base 1/1000000
- Geology at 1/250000 (BRGM)
- Location and volume of the main dams
- RGA 2010 data base for information on irrigated surfaces and crops + association of an irrigation type to each crop

Model set up and evaluation

- Model run at the daily time step for 1985-2012
- Parameter assigned according to available knowledge and literature
- No calibration, but an iterative improvement of the model to keep a physical meaning to parameters

5. MODEL RESULTS AND PROSPECTIVE SCENARII

Model evaluation in natural conditions

- The iterative strategy of model improvement leads to improved performance (Fig. 7)
- Distinction between plain and mountain
- Adjustment of soil water storage capacity, impervious fraction

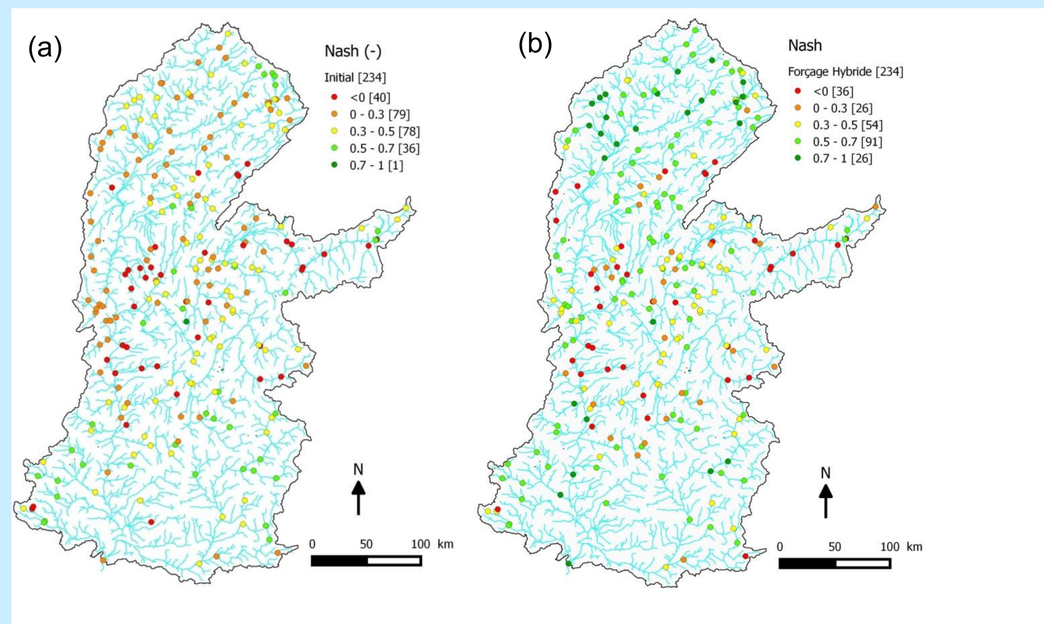

Figure 7: Nash criteria (a) before and (b) after model improvement. The number of stations with Nash >0.5 increases from 16% to 50%

Pressure on resources due to drinking water (Fig. 8)

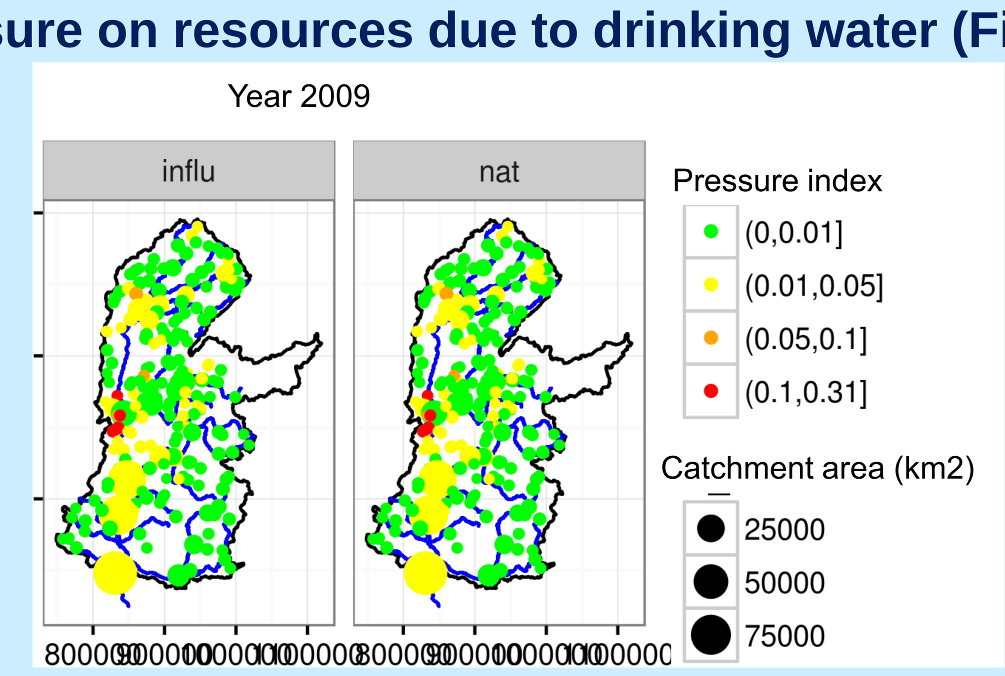

Figure 8: Computed drinking water pressure index (demand/resource) for year 2009 for natural (left) and influenced hydrology (right)

Climate and irrigation change scenario (Fig. 9)

- One climate change scenario (one GCM only)
- Change irrigation practices (from aspersion to drip)
- Compute a Water Stress Index (WSI=demand/resource)

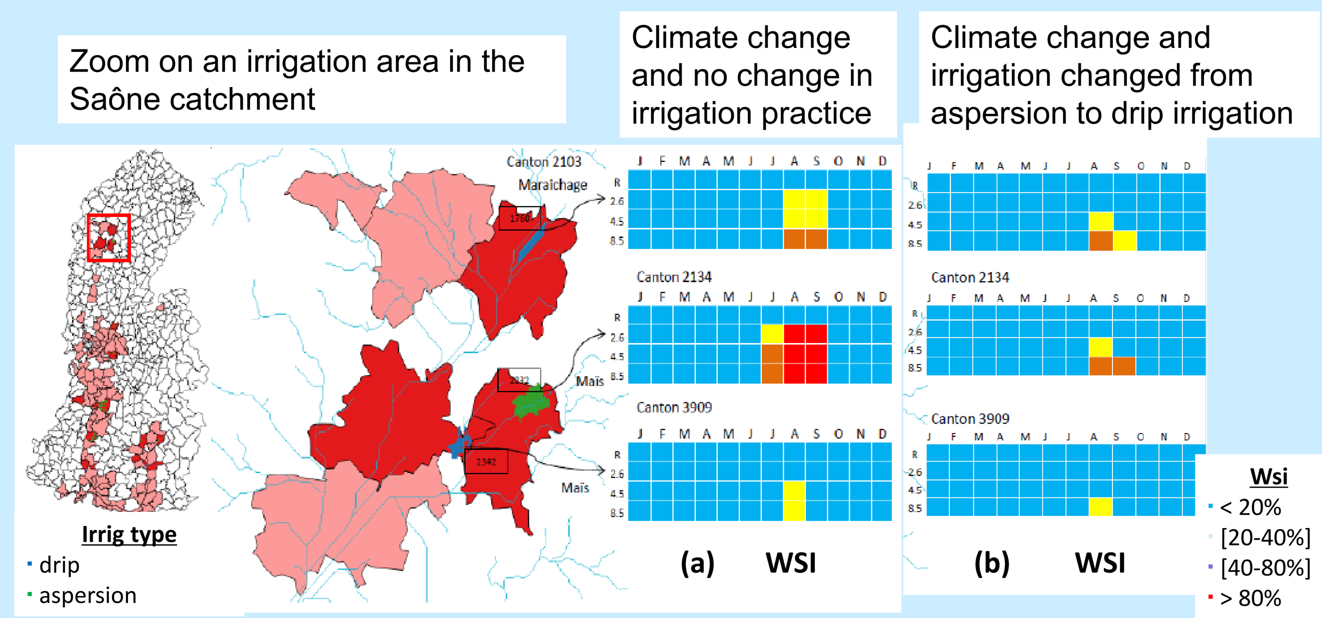

Figure 9: Interannual monthly WSI computed for three typical "cantons" with (a) climate change only (from top to bottom: ref, RPC 2.6, 4.5, 8.5) and (b) with climate change and change of irrigation from aspersion to drip irrigation

6. CONCLUSIONS AND PERSPECTIVES

Main achievements

- A model set up at the scale of the whole Rhône catchment, and including the main water uses
- Feasibility for use in climate and practices changes sensitivity analyses demonstrated

Directions for improvements

- Formalization of the iterative model improvement based on hydrological signatures (on-going PhD)
- Get data at the right scale to better specified water withdrawals points
- Coupling with agent-based model for irrigation decision

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