Drought severity characterization based on hydro meteorological indices

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Photography encouraged

Context

The Meuse River catchment: vulnerable to drought hazard

- Water managers are concerned about drought hazard on the French Meuse River catchment (Fig. 1).
- Hydrologists of DREAL Grand-Est need new statistical tools to better anticipate drought warning levels.
- These needs are particularly exacerbated in a climate change context.

A need to use simple hydro-meteorological indices

- Météo-France provides at a 10-day time step maps of SSWI (Standardised Soil Wetness Index) at an 8km spatial resolution to Water Agencies (Fig. 2).

Aim of this work

- To develop a simple prediction model that can be transposed to ungauged stations to assess the probability of reaching different drought warning levels based on available spatial hydro-meteorological indices.

The French Meuse River catchment

- Catchment area:10,120 km^2
- Main river: 500 km long
- Altitude: 100-570 m a.s.l.

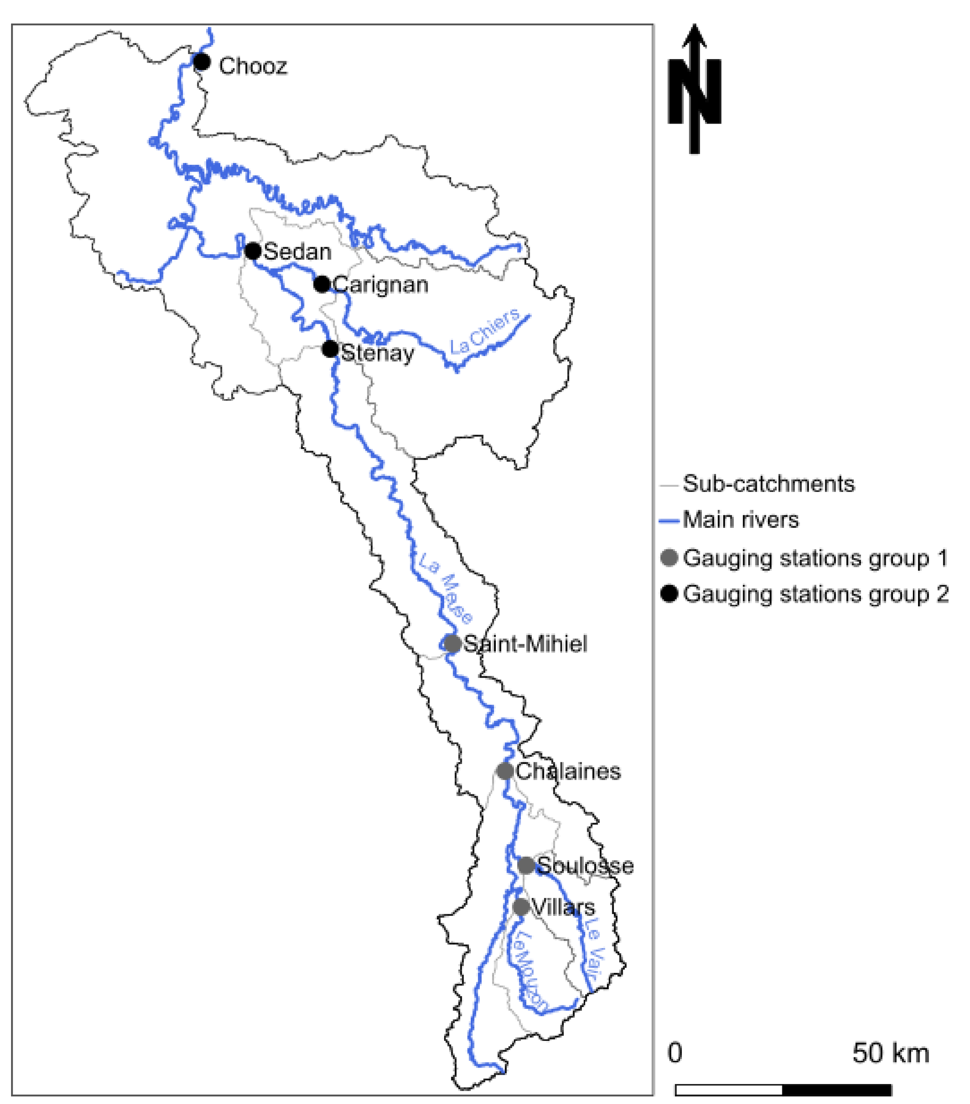

Figure 1: The Meuse River catchment in France, with the main gauging stations used in this study divided into two groups (split sample test approach)

Data

Hydrological data:

- Observed VCN3 (minimum streamflow over a 3-day rolling mean) at a weekly time step
- Drought warning levels (yellow, orange and red) for 8 gauging stations (DREAL Grand Est, Table 1)

Meteorological data:

- SSWI maps at a 10-day time step (Météo-France, Fig. 2)

Table 1: Drought warning levels on the French Meuse catchment
Source: DREAL Grand-Est

Station Code	Station Name	Basin area (km^2)	Yellow warning level (m^3/s)	Orange warning level (m^3/s)	Red warning level (m^3/s)
B1092010	Le Mouzon à Circourt-sur-Mouzon [Villars]	405	0.15	0.09	0.02
B1282010	Le Vair à Soulosse-sous-Saint-Élophe	443	0.5	0.36	0.21
B1340010	La Meuse à Vaucouleurs [Chalaines]	869	1.95	1.38	0.8
B2220010	La Meuse à Saint-Mihiel	823	3.2	2.2	1.2
B3150020	La Meuse à Stenay	1364	8.66	6.4	4.13
B4001010	La Chiers à Longlaville	151	0.54	0.41	0.27
B4631010	La Chiers à Carignan	1816	8.6	7.1	5.6
B5020010	La Meuse à Sedan	622	22.6	18.25	13.9
B6111010	La Semoy à Haulmé	1336	3.78	2.65	1.51
B7200000	La Meuse à Chooz	2291	30.5	22.25	14

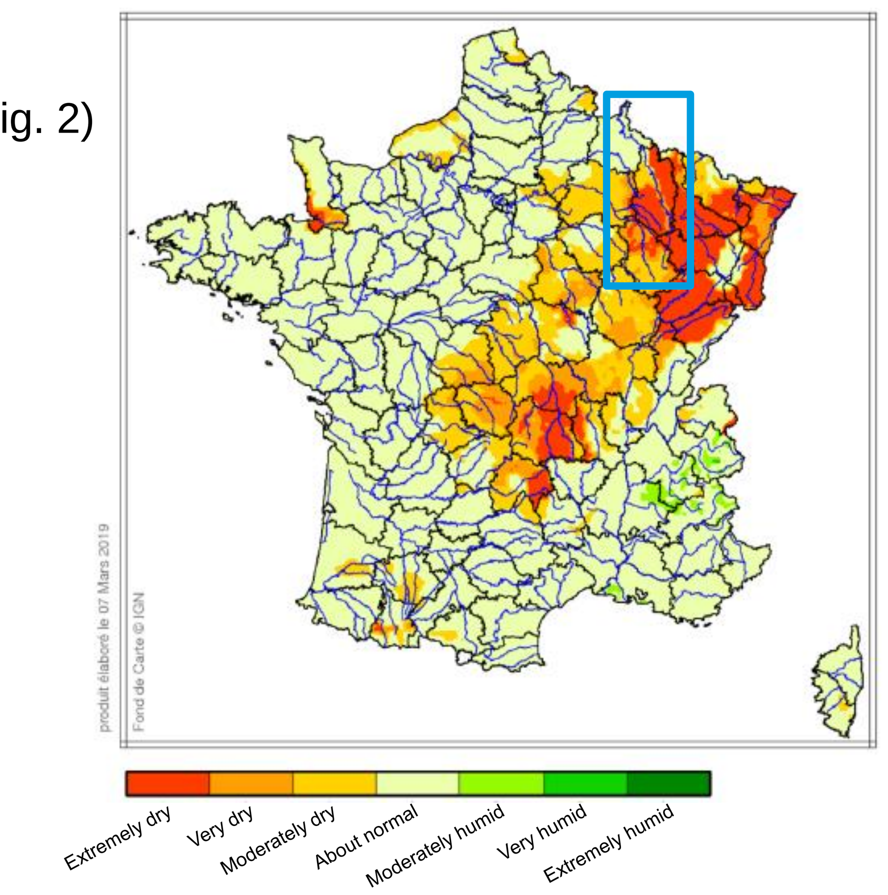

Figure 2: SSWI3 map for the December 2018 – February 2019 period.
Source: Météo-France

Method

- Compute the proportion of catchment area (Fig. 3):
  - Moderately Dry: SSWI between -0.84 and -1.28 (quantiles 0.2 and 0.1),
  - Very Dry: SSWI between -1.28 and -1.75 (quantile 0.04),
  - Extremely Dry: SSWI below -1.75.
- Apply a logistic regression model (Eq. 1) between weekly VCN3 below each drought warning levels (= 0 or 1) and the proportion of catchment that is Moderately, Very, and Extremely Dry:
  - Split Sample Test approach:
    - For the total number of stations
    - With 2 samples of 4 stations
  - Sensitivity of number of time steps before the drought warning level prediction:
    - Including one time step before the VCN3 value
    - Including three time steps before the VCN3 value

Eq.1: logistic regression model

$$p(1|x) = \frac{e^{b0+b1.x1+\cdots+bn.xn}}{1+e^{b0+b1.x1+\cdots+bn.xn}}$$

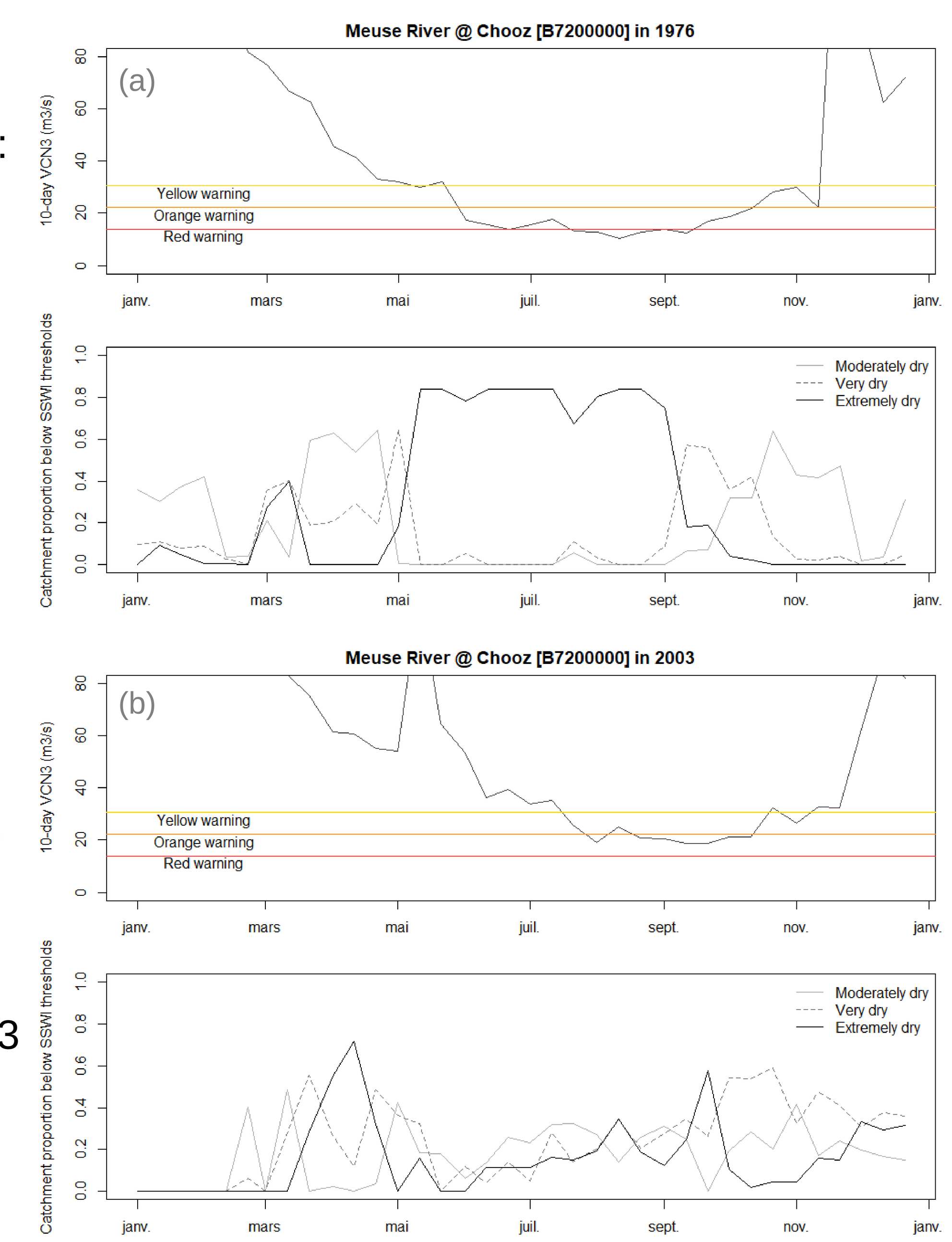

Figure 3: Series of VCN3 (top rows) and catchment proportion below SSWI levels (bottom rows) for the Meuse River in Chooz in (a) 1976 and (b) 2003

Results

Table 2: Logistic regression coefficients for each drought warning level for the 8 catchments together

	Yellow warning	Orange warning	Red warning
Intercept (b0)	-2.49 ***	-3.87 ***	-8.03 ***
Proportion of Moderately Dry (b1)	1.59 ***	1.68 ***	2.87 ***
Proportion of Very Dry (b2)	0.94 ***	1.20 ***	2.63 **
Proportion of Extremely Dry (b3)	2.33 ***	3.03 ***	5.91 ***

Table 3: Logistic regression coefficients for each drought warning level for SST group 1

	Yellow warning	Orange warning	Red warning
Intercept (b0)	-2.39 ***	-3.67 ***	-8.68 ***
Proportion of Moderately Dry (b1)	1.27 ***	1.37 ***	3.54 **
Proportion of Very Dry (b2)	0.66 ***	0.92 ***	2.57 ·
Proportion of Extremely Dry (b3)	2.19 ***	2.91 ***	6.41 ***

Table 4: Logistic regression coefficients for each drought warning level for SST group 2

	Yellow warning	Orange warning	Red warning
Intercept (b0)	-2.64 ***	-4.13 ***	-7.77 ***
Proportion of Moderately Dry (b1)	2.25 ***	2.25 ***	2.51 ·
Proportion of Very Dry (b2)	1.17 ***	1.59 ***	2.89 *
Proportion of Extremely Dry (b3)	2.53 ***	3.11 ***	6.00 ***

Significance of parameter values with 2 tailed p-value test: Pr(>|z|): 0 ******* 0.001 ****** 0.01 ***** 0.05 · 0.1 1

Table 5: Validation of the logistic regression models in the split sample test approach: success rate of good prevision

Calibration sample	Yellow warning	Orange warning	Red warning
Group 1	0.89 (204 events)	0.97 (75 events)	0.99 (5 events)
Group 2	0.88 (197 events)	0.96 (55 events)	0.99 (7 events)

- The logistic regression parameters seem stable between both catchment groups and validation shows high performance (Split Sample Test).
- For Red warning prediction, SSWI indicators of « Very Dry » catchment proportion does not add information to predict red drought warning, while « Moderately Dry » and « Extremely Dry » indicators are more relevant: collinearity of parameters.
- Using SSWI indicators 1 time-step ahead is enough for drought warning prediction; using earlier time-steps does not increase the prediction performances.

Perspectives

- Monthly SPI (Standardized Precipitation Index) and SSWI are available and provided by Météo-France and could be jointly used to develop a new monthly model for drought warning prediction.
- These prediction models can be used to predict drought warning levels in ungauged catchments.
- Hydrological modelling will be used to analyse future changes in catchment proportion reaching the warning thresholds in a climate change context in a probabilistic framework.

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