

Potential of Pan-European Seasonal Hydrometeorological Drought Forecasts Obtained from a Multihazard Early Warning System

Samuel J. Sutanto, Henny A. J. Van Lanen, Fredrik Wetterhall, and Xavier Llor

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Corresponding author: S. J. Sutanto, samuel.sutanto@wur.nl

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In the supplementary material, we provide a detailed analysis of the drought class score of seasonal ensemble hydrological drought forecasts, as part of the validation. We have presented the median (Fig. ES1) and 25th percentile (Fig. ES2) of 15 ensemble members. The analysis was carried out for the pan-European 2003 drought by comparing the drought class difference derived from seasonal reforecasts of the runoff and the proxy observed runoff. Forecast scores, that is. percent of cells that agree (none; no class difference) and disagree (−4 to +4 class differences), are provided for the standardized runoff index (SRI) with accumulation periods of 1, 3, 6, and 12 months for the four seasons as the starting forecast months, with different lead times (1–5 months). Light green color indicates high forecasting skill, light brown color indicates medium forecasting skill, light red color indicates low forecasting skill, and white color indicates 0% of area (see appendix B for the explanation of the color coding).

A screen shoot of the Multi Hazard-Early Warning System (MH-EWS) platform showing drought in precipitation-evaporation forecasted in May 2019 is shown in Fig. ES3. Figure ES3 also shows the hazards that are forecasted by the MH-EWS, such as flood, fires, storm surge, heatwaves, drought, and many more.

Season	Class difference	SRI-1 with lead times of (month)					SRI-3 with lead times of (month)					SRI-6 with lead times of (month)					SRI-12 with lead times of (month)				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Winter (DJF)	none	72.3	57.1	44.5	40.9	43.6	86.9	70.9	49.8	41.4	41.7	91.2	82.2	68.8	58.1	51.5	94.2	86.9	77.5	69.4	63.9
	+1	11.1	13.4	15.7	13.6	8.7	6.7	12.1	15.9	14.2	9.6	5.0	9.4	12.0	11.7	9.7	2.9	6.9	10.7	10.3	8.0
	+2	12.0	20.5	24.4	30.8	36.1	5.2	11.6	20.5	27.6	34.4	3.3	6.5	12.1	19.9	28.1	2.8	5.6	10.1	17.2	23.1
	+3	2.1	2.7	4.1	3.6	1.5	0.7	2.6	4.6	3.6	1.8	0.3	1.2	3.7	3.3	1.5	0.0	0.4	1.3	1.3	1.0
	+4	1.7	3.7	5.9	7.0	8.0	0.3	1.0	4.0	7.6	8.4	0.1	0.2	1.1	4.4	6.8	0.0	0.1	0.3	1.5	3.4
	-1	0.4	1.1	2.4	1.5	0.6	0.1	0.8	2.3	1.7	0.6	0.0	0.3	1.8	1.3	0.7	0.0	0.0	0.2	0.3	0.3
	-2	0.2	0.6	1.6	2.1	2.0	0.0	0.2	1.0	2.4	2.6	0.0	0.0	0.1	0.7	1.4	0.0	0.0	0.0	0.1	0.2
	-3	0.1	0.4	1.0	0.6	0.2	0.0	0.1	1.0	0.8	0.4	0.0	0.0	0.3	0.4	0.3	0.0	0.0	0.0	0.0	0.0
-4	0.1	0.1	0.4	0.6	0.4	0.0	0.1	0.2	0.4	0.7	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
Spring (MAM)	none	58.2	46.1	48.3	51.1	55.0	74.7	57.0	50.8	44.8	45.7	82.6	71.1	63.5	55.6	49.0	89.7	81.3	74.9	69.6	67.1
	+1	14.5	9.9	9.4	10.3	13.7	11.3	10.1	8.4	8.4	9.8	8.6	8.4	6.6	6.5	7.1	6.6	7.9	5.7	5.2	5.4
	+2	18.7	29.3	30.8	28.4	23.3	9.2	23.7	30.9	34.0	32.2	5.0	14.7	24.8	30.1	32.7	3.2	9.7	17.9	21.9	22.2
	+3	3.4	3.0	1.0	0.6	0.6	2.7	3.0	1.2	0.6	0.7	2.5	2.9	1.1	0.7	0.7	0.4	0.8	0.5	0.5	0.9
	+4	2.2	6.9	7.7	6.9	4.9	0.4	3.3	6.6	8.8	8.4	0.1	0.7	3.1	6.1	8.0	0.0	0.1	0.9	2.5	3.8
	-1	2.0	2.2	0.3	0.1	0.1	1.3	2.0	0.5	0.1	0.1	1.0	1.8	0.4	0.1	0.1	0.0	0.1	0.1	0.1	0.1
	-2	0.4	1.9	1.9	1.7	1.4	0.1	0.6	1.7	2.9	2.7	0.0	0.0	0.3	0.9	2.2	0.0	0.0	0.0	0.1	0.3
	-3	0.6	0.9	0.2	0.0	0.0	0.3	0.9	0.3	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
-4	0.1	0.3	0.4	0.3	0.3	0.1	0.0	0.3	0.6	0.7	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	
Summer (JJA)	none	69.5	62.4	56.2	51.0	47.4	85.5	71.7	57.4	50.3	45.1	89.9	80.6	70.2	59.9	51.5	92.5	86.7	80.1	73.9	67.8
	+1	10.1	12.4	21.8	25.8	28.6	5.6	9.6	17.1	22.8	28.7	3.8	6.3	12.4	18.3	23.5	3.5	5.6	9.4	13.0	16.1
	+2	17.0	19.2	15.9	16.5	15.1	8.1	15.0	18.2	17.6	15.6	5.9	11.7	14.1	15.9	16.1	3.8	7.3	9.0	10.2	11.7
	+3	1.0	0.9	1.9	2.8	4.7	0.4	0.7	1.6	2.6	4.1	0.2	0.3	1.0	2.1	3.2	0.1	0.1	0.9	1.5	2.4
	+4	2.0	3.8	3.4	3.5	3.2	0.3	2.2	4.0	4.4	3.7	0.1	0.9	1.7	2.7	3.6	0.0	0.3	0.6	1.2	1.5
	-1	0.1	0.1	0.2	0.4	0.8	0.0	0.1	0.2	0.4	0.8	0.0	0.0	0.1	0.3	0.7	0.0	0.0	0.0	0.1	0.2
	-2	0.3	0.9	1.0	0.9	0.9	0.0	0.4	1.1	1.4	1.4	0.0	0.1	0.3	0.5	1.0	0.0	0.0	0.0	0.1	0.3
	-3	0.1	0.1	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
-4	0.0	0.1	0.1	0.2	0.2	0.0	0.0	0.1	0.3	0.4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
Autumn (SON)	none	67.8	56.1	54.9	56.8	54.8	81.6	67.8	56.7	52.3	51.9	86.9	75.1	68.0	63.6	59.0	92.8	85.7	78.9	72.9	67.8
	+1	16.3	23.3	22.7	21.3	20.1	10.2	17.4	22.5	25.5	24.9	8.1	14.3	18.0	20.2	22.6	4.5	9.1	12.9	16.4	18.9
	+2	12.9	15.2	15.4	15.2	17.2	7.0	11.5	15.0	15.7	15.9	4.4	8.3	9.9	11.3	13.0	2.7	4.8	6.6	8.0	9.7
	+3	1.1	2.0	2.7	2.3	3.0	0.6	1.3	2.6	3.0	3.7	0.3	1.2	2.0	2.4	3.0	0.0	0.3	1.0	1.7	2.2
	+4	1.4	2.4	2.1	1.9	1.9	0.5	1.6	2.0	1.6	1.2	0.2	0.8	1.3	1.2	1.1	0.0	0.1	0.4	0.7	0.8
	-1	0.2	0.3	0.8	0.7	0.9	0.1	0.3	0.7	1.0	1.1	0.0	0.2	0.5	0.7	0.8	0.0	0.0	0.1	0.3	0.4
	-2	0.2	0.5	0.5	0.4	0.3	0.1	0.3	0.5	0.3	0.1	0.0	0.1	0.3	0.3	0.2	0.0	0.0	0.0	0.1	0.1
	-3	0.1	0.1	0.2	0.2	0.3	0.0	0.0	0.2	0.3	0.4	0.0	0.0	0.1	0.2	0.3	0.0	0.0	0.0	0.0	0.0
-4	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Fig. ES1. SRI drought forecasting scores for the pan-European 2003 drought: difference (percentage of area in Europe) between the drought classes derived from the median of 15 ensemble forecasts and the observed. SRI is presented for different accumulation periods covering 1, 3, 6, and 12 months.

Season	Class difference	SRI-1 with lead times of (month)					SRI-3 with lead times of (month)					SRI-6 with lead times of (month)					SRI-12 with lead times of (month)				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Winter (DJF)	none	71.5	55.6	40.8	39.1	44.8	86.7	68.9	45.5	35.6	39.1	90.8	80.4	66.6	55.1	49.6	94.3	86.1	76.2	68.0	65.5
	+1	15.5	21.8	23.9	19.8	20.9	8.9	17.0	21.2	20.0	19.3	6.8	13.5	17.4	17.2	17.6	4.3	10.5	15.5	16.3	14.0
	+2	6.6	11.1	16.6	20.9	22.8	2.5	6.6	15.1	22.3	26.1	1.6	3.2	7.6	15.3	22.5	1.3	2.7	5.7	11.5	16.4
	+3	4.1	6.1	7.0	6.6	3.4	1.4	4.6	8.0	6.9	4.2	0.6	2.2	4.7	5.3	3.6	0.0	0.7	2.2	2.9	2.1
	+4	0.8	1.5	4.0	5.0	4.9	0.2	0.4	2.6	5.7	6.2	0.1	0.1	0.3	2.3	4.0	0.0	0.0	0.1	0.5	1.2
	-1	1.2	2.4	4.1	4.8	1.7	0.3	1.6	4.4	5.0	1.9	0.1	0.5	2.8	3.4	1.5	0.0	0.0	0.3	0.7	0.6
	-2	0.1	0.2	1.1	1.5	1.3	0.0	0.1	0.6	1.5	1.9	0.0	0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.0
	-3	0.3	1.0	2.3	2.6	1.0	0.0	0.3	2.0	2.6	1.1	0.0	0.0	0.5	1.0	0.7	0.0	0.0	0.0	0.1	0.1
-4	0.0	0.0	0.2	0.3	0.3	0.0	0.1	0.1	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Spring (MAM)	none	56.5	46.5	50.3	53.6	56.1	73.4	56.7	52.8	49.2	50.3	81.4	70.7	67.2	61.1	53.2	88.5	80.9	78.9	74.3	71.3
	+1	20.6	18.9	18.3	18.7	21.8	15.3	17.3	16.8	15.7	16.8	11.4	13.7	12.5	11.9	14.4	9.3	12.1	9.9	9.5	9.8
	+2	10.6	18.6	20.0	17.2	12.4	4.4	15.2	20.5	23.7	20.9	2.3	8.0	15.0	20.7	23.5	1.4	4.9	9.4	13.7	14.7
	+3	6.1	5.1	3.6	4.0	4.9	3.8	4.8	3.4	3.3	4.0	2.9	3.8	2.6	2.7	2.7	0.8	1.7	1.2	1.5	2.3
	+4	0.9	4.0	4.6	4.2	2.8	0.2	1.5	4.0	5.7	5.4	0.0	0.2	1.2	2.7	4.7	0.0	0.0	0.2	0.7	1.4
	-1	3.4	3.7	1.3	0.6	0.6	2.1	3.2	1.5	0.7	0.9	1.8	3.0	1.0	0.5	0.5	0.1	0.3	0.3	0.2	0.3
	-2	0.1	0.9	1.0	0.9	0.6	0.0	0.1	0.8	1.7	1.7	0.0	0.0	0.0	0.2	0.8	0.0	0.0	0.0	0.0	0.1
	-3	1.7	2.6	0.6	0.1	0.1	0.7	1.8	0.8	0.3	0.2	0.1	0.7	0.6	0.2	0.2	0.0	0.0	0.0	0.0	0.1
-4	0.0	0.1	0.2	0.1	0.1	0.1	0.0	0.1	0.3	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
Summer (JJA)	none	69.4	61.7	53.5	45.2	38.9	86.3	71.9	54.9	46.7	37.5	90.8	82.2	70.2	57.0	45.5	92.7	86.7	79.0	71.7	64.0
	+1	16.1	20.9	27.6	32.2	33.8	8.7	15.8	23.8	28.6	33.5	6.3	10.6	18.0	25.1	30.4	5.5	9.4	14.0	17.9	22.4
	+2	8.4	10.4	8.1	6.8	6.9	3.8	8.6	10.8	9.3	7.8	2.5	6.0	7.8	9.2	9.1	1.5	3.3	4.5	5.4	6.1
	+3	4.1	4.0	7.6	11.3	14.5	1.0	2.1	6.3	9.5	13.6	0.3	0.8	2.6	5.8	9.6	0.3	0.6	2.1	4.0	5.7
	+4	0.8	1.9	1.9	1.7	1.4	0.1	0.9	2.2	2.5	2.2	0.0	0.3	0.7	1.3	2.0	0.0	0.1	0.2	0.5	0.8
	-1	0.9	0.6	1.2	2.8	4.3	0.1	0.4	1.1	2.1	3.9	0.0	0.1	0.4	1.2	2.2	0.0	0.0	0.2	0.4	0.9
	-2	0.1	0.3	0.4	0.4	0.3	0.0	0.1	0.5	0.8	0.7	0.0	0.0	0.1	0.2	0.5	0.0	0.0	0.0	0.0	0.1
	-3	0.2	0.1	0.2	0.6	0.8	0.0	0.1	0.2	0.4	0.8	0.0	0.0	0.1	0.3	0.6	0.0	0.0	0.0	0.0	0.1
-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Autumn (SON)	none	62.5	44.9	46.4	47.8	45.0	79.1	61.3	46.6	39.7	41.9	84.9	69.9	59.7	53.8	47.9	91.9	82.4	73.3	65.3	59.1
	+1	26.2	36.8	32.1	32.8	31.9	16.2	28.2	34.4	37.9	35.1	12.5	23.1	27.8	31.0	34.0	7.0	15.3	21.1	25.6	29.1
	+2	5.6	4.9	5.6	5.4	6.7	2.6	4.4	5.6	5.7	5.4	1.6	2.8	3.7	4.2	5.1	0.9	1.4	2.2	2.8	3.4
	+3	4.1	9.3	10.0	8.5	9.5	1.6	4.6	8.7	10.6	11.1	0.8	3.3	6.0	7.4	8.8	0.1	0.8	2.8	4.9	6.2
	+4	0.5	0.8	0.9	0.7	0.6	0.1	0.5	0.8	0.6	0.3	0.1	0.2	0.5	0.5	0.4	0.0	0.0	0.1	0.2	0.2
	-1	0.8	2.6	3.4	2.6	3.2	0.3	1.1	3.1	3.7	4.0	0.1	0.7	1.9	2.4	2.9	0.0	0.1	0.5	1.1	1.7
	-2	0.1	0.2	0.1	0.1	0.1	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	-3	0.2	0.5	1.1	0.8	1.4	0.0	0.2	0.8	1.4	1.5	0.0	0.1	0.3	0.6	0.8	0.0	0.0	0.0	0.1	0.2
-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Fig. ES2. SRI drought forecasting scores for the pan-European 2003 drought: difference (percentage of area in Europe) between the drought classes derived from the 25th percentile of 15 ensemble forecasts and the observed. SRI is presented for different accumulation periods covering 1, 3, 6, and 12 months.

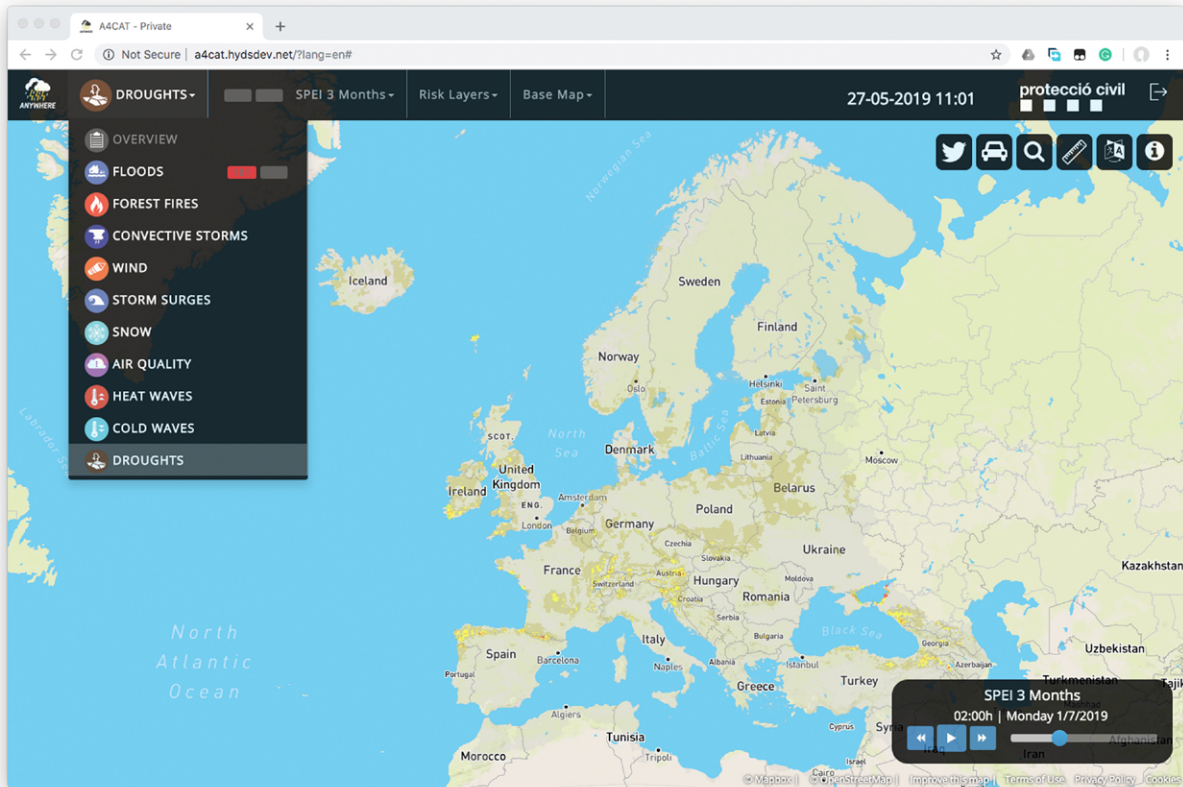


Fig. ES3. The standardized precipitation evaporation index (SPEI) for July 2019 forecasted in May 2019 (i.e., a 3-month lead time) for the pan-European region, as shown by the MH-EWS platform. The pull-down menu in the upper left shows the hazards that are forecasted by the MH-EWS, such as flood, fires, storm surge, heatwaves, and drought.