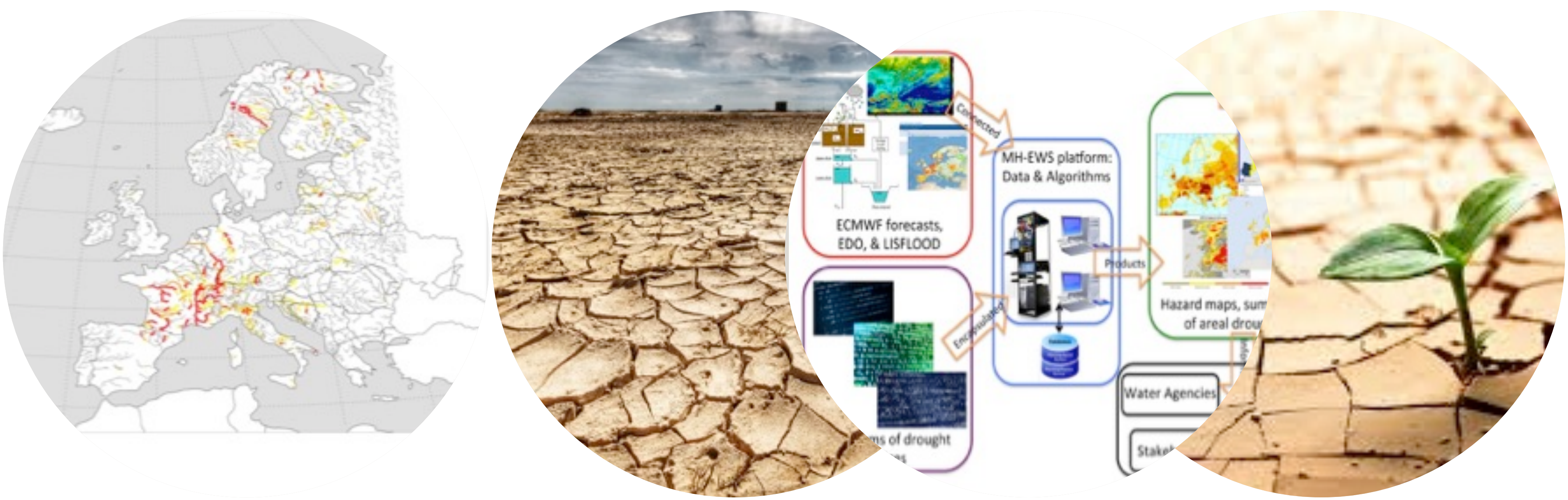
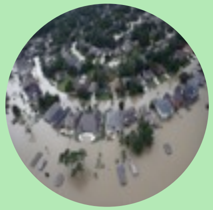
Skill of hydrological drought forecasts outperforms meteorological ones

Samuel J. Sutanto & Henny A. J. Van Lanen
Hydrology and Quantitative Water Management Group
Wageningen University and Research, the Netherlands



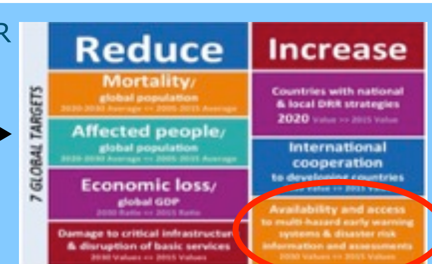
Background

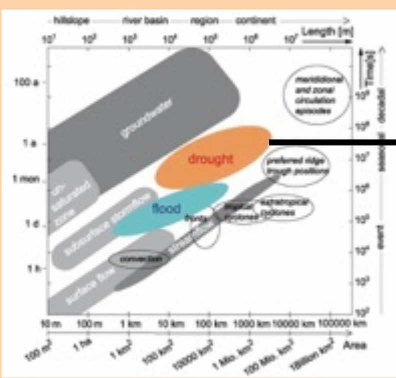
 ≈  ≈ 

DROUGHT IMPACTS
Comparable damages and losses to other weather-related disasters

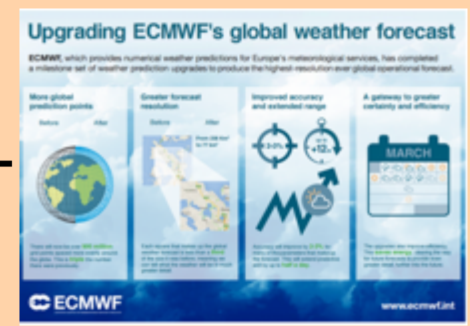
DEWS is required to reduce the drought impacts

One of Sendai's DRR global targets





Unlike EWS for short time-scale hazards (e.g., flood, flash flood), DEWS should be able to produce warning signal from sub-season up to seasons.



Improvement of **SEASONAL** weather forecasting system

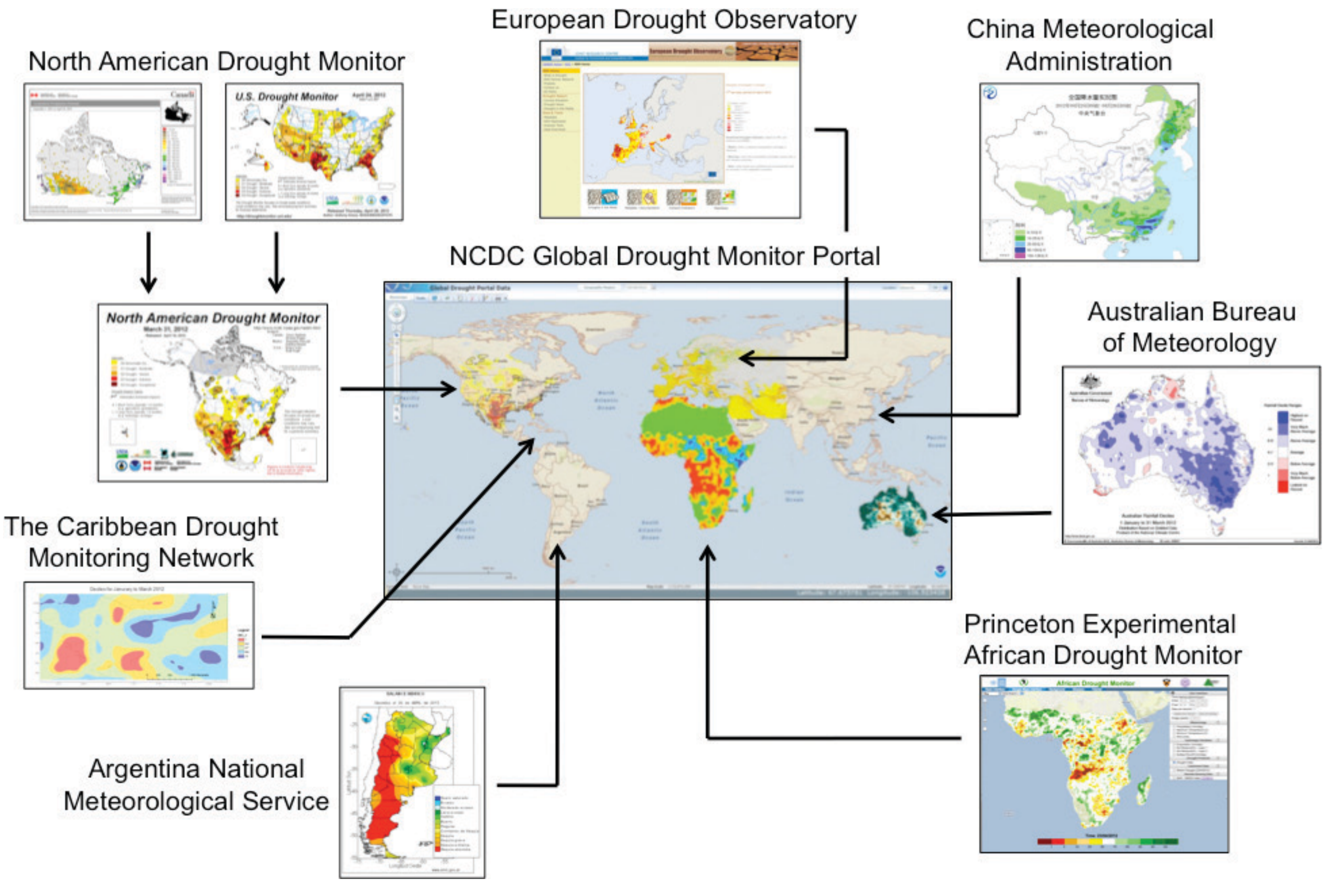
WAGENINGEN UNIVERSITY
WAGENINGEN UR

Sources: Poljansek et al., 2017, Stahl and Hisdal, 2004, & ECMWF

ANYWHERE

Background

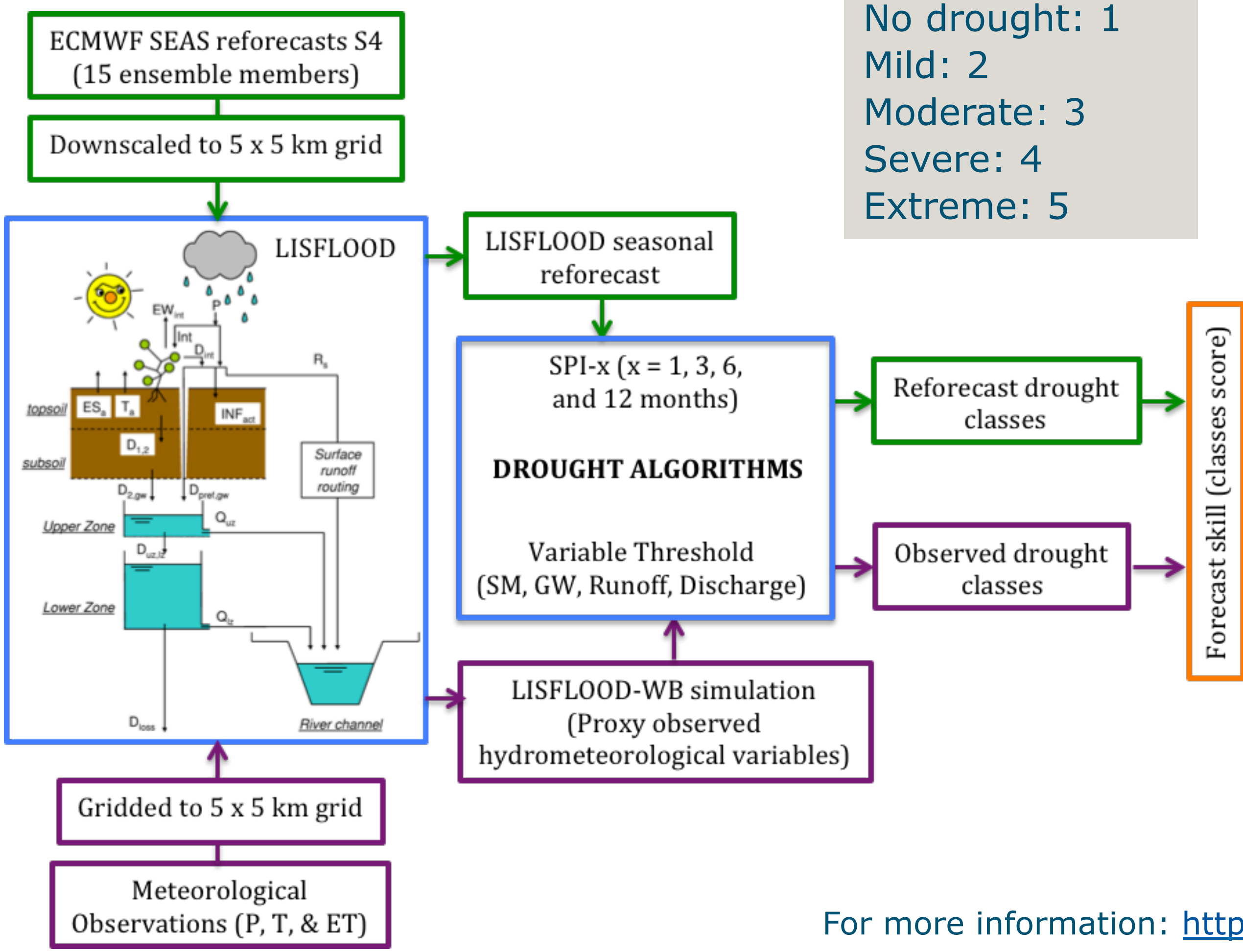
World drought monitoring and EWS



- Most do not produce seasonal DEWS.
- Based on meteorological drought forecasts (SPI-x).
- Hydrological drought forecasts (soil moisture anomaly & streamflow).
- Skill is encouraging for first 3 months dependent on region, season, & variables.

Source: Pozzi et al. (2013)

Data and method



EU drought 2003
No drought: 1
Mild: 2
Moderate: 3
Severe: 4
Extreme: 5

DEWS in ANYWHERE:

- Using SPI-x, SPEI-x, SRI-x, and SGI-1.
- Using variable threshold method on runoff, discharge, groundwater, & soil moisture.
- Providing the drought characteristics (duration, deficit volume, onset, & termination).
- Providing resolution 5 x 5 km (pan-EU maps).
- Providing areal drought indices.

For more information: http://anywhere-h2020.eu/catalogue/

WAGENINGEN UNIVERSITY WAGENINGEN UR

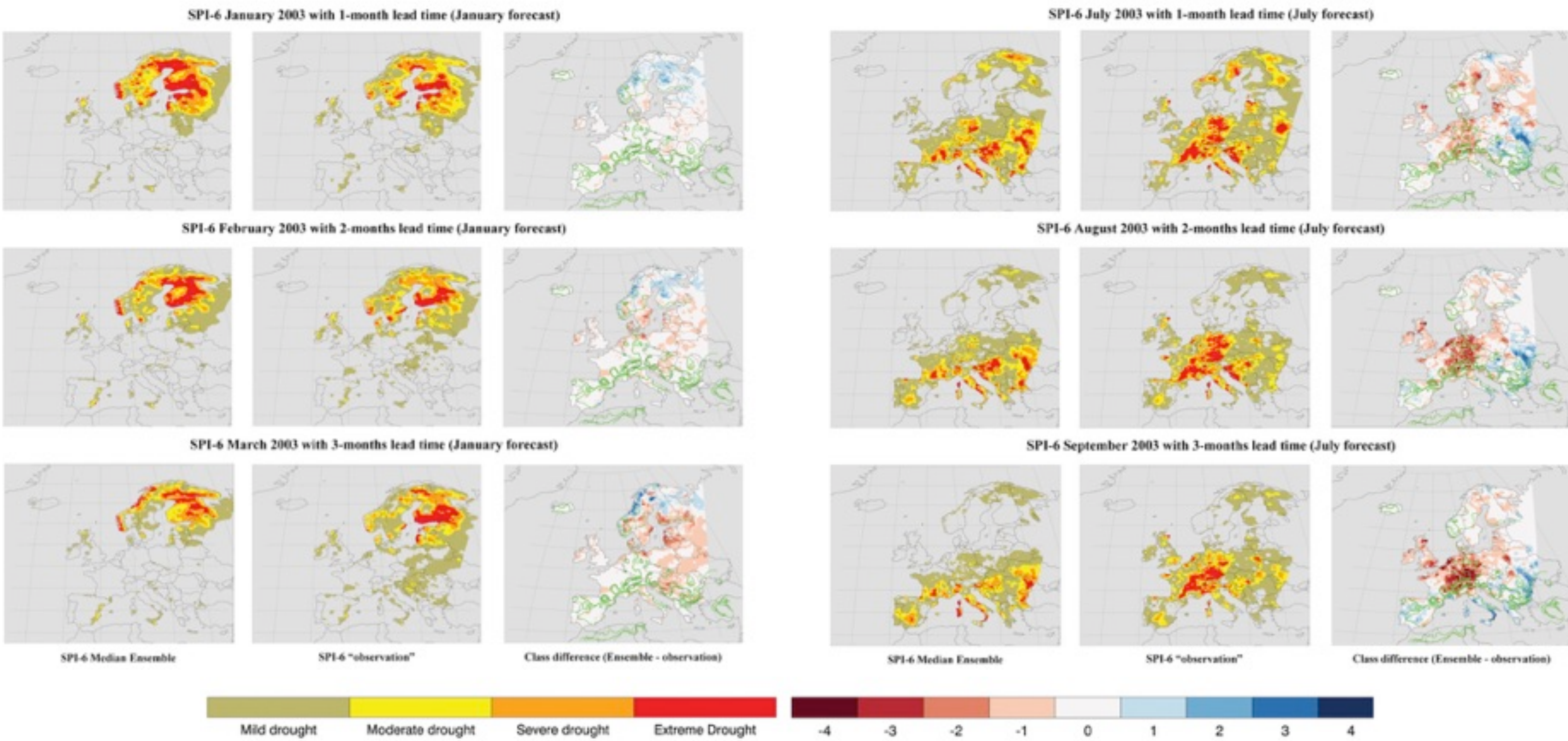
ANYWHERE

Meteorological drought forecasting skill

Forecasted SPI-6 done on January 2003 for median of ensembles, observed, and drought class difference with lead time of 3 months (winter, left), and done on July 2003 (summer, right)

Winter

Summer



Meteorological drought forecasting skill

Comparison of the drought classes derived from the median ensemble forecasts and observed for the pan-EU drought 2003. Skills for SPI-x (% of cells that agree/disagree).

Green colors indicate high forecasting skill, yellow colors indicate medium forecasting skill, & red colors indicate low forecasting skill

- = forecast<observed
+ = forecast>observed

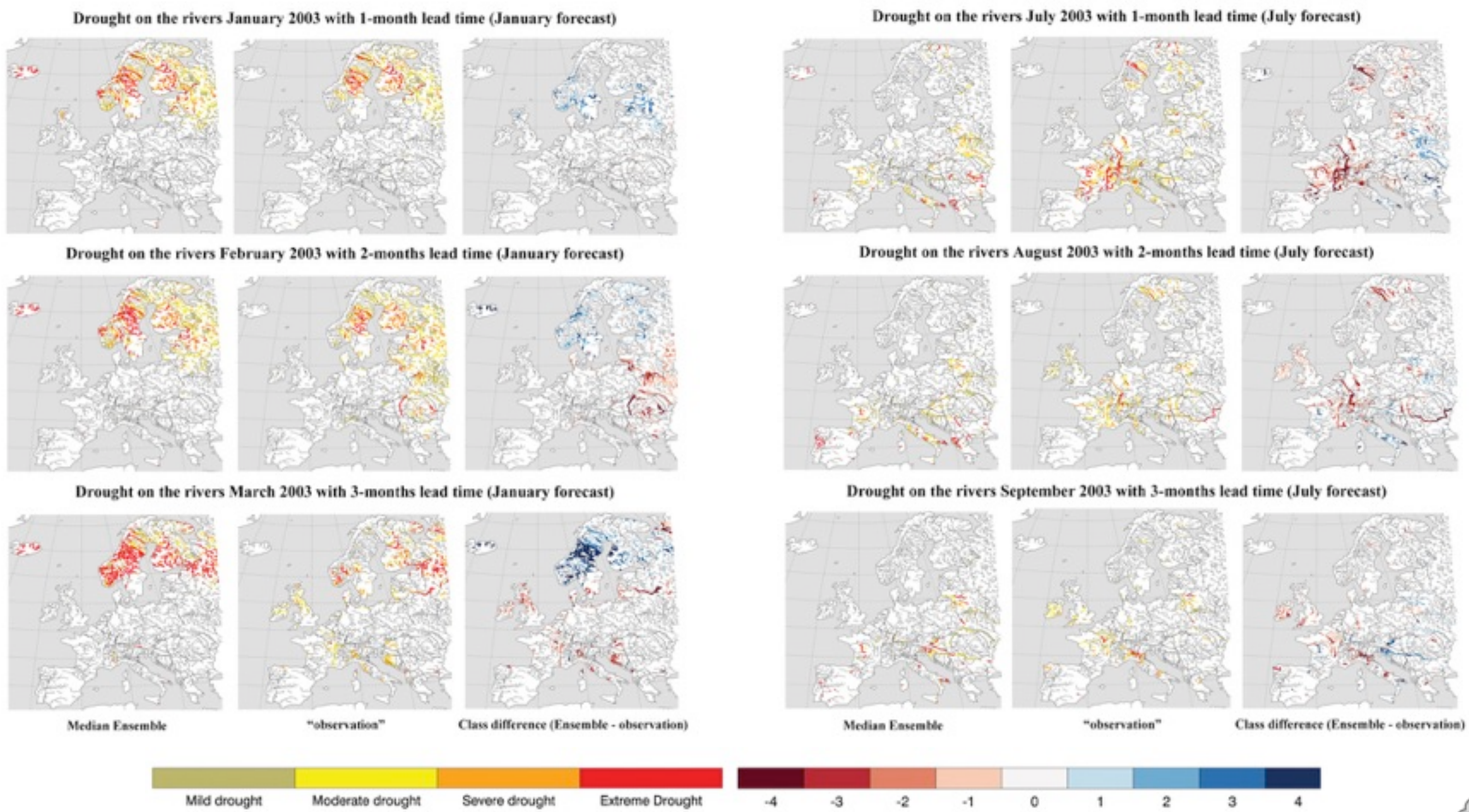
The skill becomes higher with increase of SPI accumulation period (increase of antecedent memory).

Season	Class difference	The percentage of areas affected by drought for different SPI indices, lead times, and seasons																			
		SPI-1 with lead times of					SPI-3 with lead times of					SPI-6 with lead times of					SPI-12 with lead times of				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Winter (DJF)	none	47.6	36.7	34.9	46.6	44.1	67.8	44.9	33.4	38.7	40.8	80.4	69.4	54.7	52.2	42.4	85.8	76.1	68.3	67.7	63.3
	+1	18.7	8.5	11.8	6.1	6.0	10.4	14.8	14.8	8.0	3.8	8.6	9.5	11.1	6.4	7.0	6.3	8.3	7.4	5.0	4.8
	+2	1.3	0.2	0.1	0.0	0.1	1.5	1.8	0.8	0.2	0.1	0.5	1.2	0.8	0.4	0.5	0.1	0.6	0.6	0.5	0.4
	+3	0.3	0.0	0.0	0.0	0.0	0.3	0.3	0.2	0.1	0.0	0.0	0.1	0.3	0.1	0.1	0.0	0.0	0.1	0.1	0.1
	+4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	-1	19.1	30.5	35.1	35.8	28.2	15.7	26.5	27.7	30.2	37.6	10.1	18.1	24.0	26.0	34.0	7.8	14.4	21.1	23.7	26.7
	-2	5.8	11.0	10.0	7.3	11.1	3.9	8.2	13.3	12.1	10.2	0.3	1.6	6.8	10.3	10.1	0.0	0.5	2.3	2.9	4.2
	-3	4.3	7.0	4.3	3.1	6.8	0.4	3.0	7.2	7.8	5.2	0.0	0.1	2.1	4.0	4.2	0.0	0.0	0.0	0.1	0.4
	-4	2.9	6.0	3.6	1.0	3.7	0.0	0.5	2.5	3.0	2.3	0.0	0.0	0.1	0.6	1.5	0.0	0.0	0.0	0.0	0.0
Spring (MAM)	none	42.8	43.2	42.3	44.6	42.2	50.9	36.7	38.9	40.1	42.3	71.4	52.2	43.0	39.2	39.7	85.3	73.4	65.0	59.2	54.9
	+1	7.6	5.0	10.7	11.0	17.1	7.9	6.7	4.7	6.9	10.9	5.9	6.1	6.9	6.5	5.7	3.7	4.3	5.3	5.9	6.5
	+2	0.4	0.1	0.4	0.8	1.2	0.8	0.3	0.3	0.8	2.3	0.4	0.5	0.4	0.5	0.6	0.0	0.3	0.3	0.4	1.5
	+3	0.1	0.0	0.0	0.2	0.2	0.2	0.1	0.1	0.1	0.5	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0
	+4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
	-1	31.4	33.5	29.5	27.8	26.5	31.1	32.7	35.4	32.7	28.4	20.7	30.0	32.5	33.0	32.9	10.9	21.0	25.6	28.5	31.4
	-2	9.3	10.2	9.3	8.7	7.1	7.8	14.4	11.5	10.8	8.7	1.4	9.3	11.4	12.3	11.0	0.0	0.9	3.5	5.3	5.7
	-3	5.0	5.3	5.1	4.3	4.1	1.3	7.3	6.4	6.1	4.7	0.0	1.6	4.7	6.4	6.4	0.0	0.0	0.2	0.6	1.0
	-4	3.4	2.6	2.7	2.5	1.6	0.1	1.9	2.5	2.4	2.1	0.0	0.1	0.9	1.8	3.3	0.0	0.0	0.0	0.0	0.0
Summer (JJA)	none	40.8	42.7	46.7	44.5	40.8	57.1	49.1	45.2	43.4	43.3	61.7	54.9	51.9	46.0	46.5	75.2	68.3	62.2	56.7	50.5
	+1	13.6	14.4	21.6	17.6	29.7	11.4	12.9	16.0	20.1	25.2	10.5	11.5	15.0	17.4	19.6	8.6	8.4	13.4	14.9	18.8
	+2	1.1	1.2	1.2	0.9	1.7	1.6	2.3	2.9	3.6	3.8	1.1	1.8	2.9	3.9	3.6	0.7	0.5	0.8	2.2	3.2
	+3	0.2	0.2	0.2	0.1	0.3	0.2	0.4	0.6	0.8	1.8	0.2	0.3	1.0	1.5	1.8	0.0	0.0	0.0	0.2	0.3
	+4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.0	0.0	0.4	0.3	0.7	0.0	0.0	0.0	0.0	0.1
	-1	29.5	28.1	18.9	27.0	21.8	24.3	24.6	22.4	22.5	19.8	23.2	23.4	20.4	22.0	18.8	14.6	20.0	20.9	21.5	20.4
	-2	8.5	7.1	6.2	6.5	4.3	4.3	7.0	7.0	5.4	3.3	2.9	6.3	5.6	5.9	5.7	0.8	2.4	2.4	3.8	5.0
	-3	4.2	4.0	3.7	2.4	1.2	1.0	3.1	4.0	2.6	1.4	0.3	1.7	2.4	2.5	2.6	0.0	0.3	0.3	0.7	1.6
	-4	1.9	2.0	1.5	0.8	0.1	0.1	0.6	1.7	1.5	0.8	0.0	0.1	0.2	0.5	0.7	0.0	0.0	0.0	0.0	0.1
Autumn (SON)	none	51.1	47.6	47.3	53.0	55.6	69.2	60.4	51.0	55.0	58.8	73.4	66.0	64.0	63.0	63.6	81.2	72.7	68.2	65.1	64.4
	+1	16.8	19.3	20.4	20.0	15.7	13.3	17.0	21.6	22.9	21.1	12.4	14.9	15.3	18.0	18.2	8.4	11.3	13.8	15.5	15.1
	+2	1.1	0.4	0.6	0.4	0.7	1.2	1.3	1.9	1.3	0.9	0.8	1.5	1.6	1.3	1.1	0.1	0.6	1.1	1.3	1.3
	+3	0.1	0.1	0.1	0.1	0.0	0.1	0.2	0.5	0.4	0.2	0.1	0.3	0.3	0.3	0.4	0.0	0.0	0.1	0.1	0.3
	+4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	-1	22.2	26.7	26.4	21.4	21.8	14.8	18.2	22.3	19.1	18.2	12.9	14.4	15.6	15.1	15.4	10.1	14.1	14.4	15.6	16.5
	-2	6.4	4.5	4.3	4.0	4.7	1.1	2.1	2.0	1.0	0.6	0.5	2.5	2.5	1.8	1.0	0.1	1.1	2.1	2.1	2.0
	-3	1.9	1.1	0.8	0.7	0.9	0.1	0.7	0.4	0.1	0.1	0.0	0.3	0.6	0.4	0.2	0.0	0.0	0.2	0.2	0.3
	-4	0.3	0.3	0.1	0.4	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Hydrological drought forecasting skill

Forecasted drought on discharge done on January 2003 for median of ensembles, observed, and drought class difference with lead time of 3 months (winter, left), and on July 2003 (summer, right)



ANYWHERE

Hydrological drought forecasting skill

Comparison of the drought classes derived from the median ensemble forecasts and observed for pan-EU drought 2003. Skills (% of cells that agree/disagree).

Green colors indicate high forecasting skill, yellow colors indicate medium forecasting skill, & red colors indicate low forecasting skill

- = forecast<observed
+ = forecast>observed

The long-term memory variables (e.g., SM & GW) have higher skill than short-term memory variables (e.g., RO & Di)

Season	Class difference	The percentage of areas affected by drought for different lead times, and classes																			
		SM with lead times of					GW with lead times of					Runoff with lead times of					Discharge with lead times of				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Winter (DJF)																					
	none	94.9	87.1	79	79.7	82.9	90.4	85.8	78.5	79.6	84.1	94.3	90	85.6	88.2	90.5	91	83.8	78.7	82.5	85.7
	+1	3.23	6.77	9.27	6.43	2.17	5.37	5.9	9.77	8	3.03	3.97	6.4	7.53	4.1	1.37	3.27	5.53	4.47	2.83	0.73
	+2	0.17	0.47	0.83	0.5	0.13	0.03	0.07	0.23	0.37	0.33	0.07	0.17	0.3	0.2	0.1	1.17	1.93	1.9	1.47	0.5
	+3	0.03	0.1	0.13	0.07	0	0	0	0.03	0.1	0.03	0.03	0.07	0.1	0.07	0	0.73	0.97	1.37	0.97	0.3
	+4	0	0	0	0	0	0	0	0	0.03	0	0	0	0.07	0.03	0	0.97	2.53	6.53	3.87	1.23
	-1	1.67	5.47	10.6	13.1	14.5	4.13	8.2	11.5	11.9	12.4	1.73	3.47	6.5	7.5	8.03	1.57	3	3	2.67	2.97
	-2	0	0.03	0.1	0.2	0.23	0	0	0	0	0	0	0	0.03	0.1	0.07	0.6	1.17	1.87	2.1	2.7
	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0.57	1.33	2.03	3.03
	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.23	0.4	0.83	1.53	2.63
Spring (MAM)																					
	none	84.2	74.3	73.5	71.4	72	82.6	77.7	82.3	80.9	78.6	89	85.3	87.5	87.7	89	81.3	77.6	79.7	78.4	80.6
	+1	6.33	5.97	3.5	2.53	3.57	7.83	5.7	1.77	2.2	5.1	6.5	4.03	1.57	1.53	2.1	4.17	1.73	0.9	1.1	1.67
	+2	0.1	0.3	0.03	0	0.03	0.1	0.3	0.2	0.03	0	0.07	0.13	0.07	0	0	2.17	1.17	0.57	0.2	0.43
	+3	0	0.03	0	0	0	0	0.07	0.07	0	0	0	0.03	0.03	0	0	1.4	0.93	0.27	0.2	0.2
	+4	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0	3.87	4.43	1	0.27	0.3
	-1	9.27	19	22.5	25.2	22.9	9.37	16.3	15.6	16.8	16.2	4.37	10.1	10.3	9.83	7.77	3.33	3.77	4.8	5.87	6.3
	-2	0.1	0.33	0.47	0.77	1.37	0	0	0	0	0	0	0.07	0.1	0.07	0.03	1.7	3.5	4.13	4.8	4.23
	-3	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	1.17	3.57	4.4	4.67	3.47
	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.87	3.2	4.23	4.13	2.37
Summer (JJA)																					
	none	81.6	72.6	73.9	76.4	77.8	85.9	79.5	76.6	76.6	76.8	92.4	90.5	90.8	91.3	90.2	79.6	79.4	83.5	87.1	88.3
	+1	4.73	6.03	7.13	8.93	10.6	4.67	6.03	9.5	10.1	12.2	2.73	3.27	3.8	3.83	5.3	2.63	2.73	3.03	2.63	2.7
	+2	0	0	0.13	0.33	0.63	0	0	0	0	0.03	0	0	0	0.03	0.1	1.4	1.23	1.43	1.33	1.2
	+3	0	0	0	0.03	0.13	0	0	0	0	0	0	0	0	0	0.03	0.83	0.63	0.57	0.5	0.6
	+4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	0.7	0.7	0.83	1.57
	-1	13.5	20.3	17.1	12.7	9.77	9.37	14.3	13.9	13.2	11	4.6	5.77	5.13	4.93	4.67	6.9	6.47	4.8	3.53	2.37
	-2	0.13	0.93	1.53	1.43	0.97	0	0	0	0	0	0.03	0.03	0.03	0.07	0.07	3.57	3.7	2.67	2.07	1.53
	-3	0	0	0.1	0.07	0.07	0	0	0	0	0	0	0	0	0	0	2.33	2.93	2.07	1.33	1.13
	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.63	2.1	1.1	0.53	0.57
Autumn (SON)																					
	none	89.8	85.3	85.3	86.6	87.1	87.4	84.7	85.7	87.4	86.6	95.1	93.5	92.5	92.1	90.8	89.7	91	90.6	90.4	87.7
	+1	6.23	8.2	7.43	6.83	7.03	7.13	7.67	7.53	7.7	9.43	2.3	2.9	4.07	4.7	5.63	2.63	1.73	2.43	2.77	4.37
	+2	0.2	0.5	0.57	0.6	0.63	0	0	0	0	0.07	0	0	0.1	0.13	0.17	1.13	0.7	0.87	0.83	1.33
	+3	0	0.1	0.2	0.23	0.27	0	0	0	0	0	0	0	0	0	0.03	0.47	0.43	0.33	0.43	0.63
	+4	0	0	0	0.07	0.07	0	0	0	0	0	0	0	0	0	0	0.73	0.73	0.77	1	2
	-1	3.7	5.53	6.27	5.53	5.87	5.37	7.6	6.63	4.93	3.9	2.63	3.83	3.67	3.37	2.73	3.3	2.23	2.33	2.73	2.53
	-2	0.07	0.23	0.17	0.1	0.03	0	0	0	0	0	0	0.03	0	0	0	1.13	1.57	1.23	0.8	0.67
	-3	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0.57	1.03	0.87	0.53	0.27
	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.27	0.53	0.57	0.47	0.37

Concluding remarks

- Hydrological drought forecasts have **higher skill** than meteorological forecasts (shown by more green colors).
- The low predicting skill in hydrological drought in spring may relate to the timing of snow melting associated with poor skill in temperature prediction, simplification snow module, & coarse elevation data used by LISFLOOD.
- Both drought forecasts underestimate the drought class up to max 2 classes lower than observed.
- Clearly, the skill of meteorological drought forecasts improves with the increase of antecedent memory (aggregation levels, e.g. SPI-12).
- The hydrological variables with longer memory (e.g., soil moisture & groundwater) have higher skill than short-term memory variables (e.g., runoff & discharge).

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Thank You for Your Attention

facebook.com/wageningenuniversity
twitter.com/uniwageningen
youtube.com/wageningenuniversity
Pinterest.com/wageningenuni

WAGENINGEN UNIVERSITY
WAGENINGEN UR