TRENDS IN DROUGHT ACROSS EUROPE AND THEIR LINKS TO ATMOSPHERIC CIRCULATION

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ABSTRACT

We study trends in drought across the central latitude strip of Europe (defined as the region 47.5–52.5 °N and 2.5–27.5 °E) during 1980–2019 and their links to atmospheric circulation. Drought characteristics are based on difference between potential evapotranspiration and precipitation in E–OBS data, and atmospheric circulation is characterized in terms of circulation types classified using daily sea level pressure patterns from the NCEP/NCAR reanalysis. Circulation types supporting drought in vegetation season (April–September) are identified, and we analyse changes in their occurrence since 1980, seasonal changes, and the connection with drought trends in individual European regions (from Western to Eastern Europe). The results show that the drought trends in the central latitude strip of Europe in the warm-half year were associated with changes in atmospheric circulation since the 1980s, with largest increases in the frequency of dry circulation types occurring in the regions and months affected by pronounced drying.

DROUGHT & ATMOSPHERIC CIRCULATION TYPES

DROUGHT TENDENCY:

$$(PET - P) > 0$$

Oudin formula: $PET = \frac{0.408\, R_e (TG+5)}{100}, if\ TG + 5 > 0$

$PET = 0\ otherwise$

ATMOSPHERIC CIRCULATION

- anticyclonic, cyclonic, and directional circulation types (CTs)
- based on Jenkinson & Collison (1977) indices (strength, direction and vorticity)

DRY CTs

- positive mean PET-P differences for AMJJAS season (April-September)

= all anticyclonic CTs and some directional CTs different for every region

Table 1: Mean frequencies and PET-P values for individual CTs and regions over 1980–2019. The values refer to the whole vegetation season (April-September). Brown (cyan) shading highlights dry (wet) tendency of a given CT; no shading in the frequency column stands for CTs not included in dry or wet as their mean PET-P value is in the interval (-0.5, 0.5) mm/d.

AMJJAS

	E5		E10		E15		E20		E25	
	freq. [%]	PET-P [mm/d]	freq. [%]	PET-P [mm/d]	freq. [%]	PET-P [mm/d]	freq. [%]	PET-P [mm/d]	freq. [%]	PET-P [mm/d]
A	10.4%	2.6	11.7%	2.5	12.2%	2.5	12.0%	2.5	10.0%	2.5
AN	5.4%	2.2	5.1%	1.5	4.6%	1.8	5.1%	1.9	4.9%	2.0
ANE	4.7%	2.5	4.6%	2.1	4.4%	1.9	4.1%	2.1	3.9%	2.1
AE	3.1%	2.7	3.4%	2.5	3.1%	2.4	2.9%	2.3	3.0%	2.2
ASE	1.7%	3.0	1.9%	2.8	2.3%	2.7	2.5%	2.6	2.7%	2.4
AS	2.0%	2.4	1.9%	2.5	1.9%	2.6	2.9%	2.4	3.1%	2.7
ASW	4.0%	1.6	3.8%	1.7	4.2%	2.1	4.1%	1.7	3.7%	2.3
AW	6.8%	1.4	7.0%	1.0	6.5%	1.4	5.6%	1.7	4.5%	1.9
ANW	6.0%	1.9	6.1%	1.5	6.6%	1.6	6.2%	1.8	5.9%	1.7
C	3.0%	-2.3	3.6%	-2.8	4.0%	-3.3	3.1%	-3.0	3.5%	-3.0
CN	1.4%	-3.0	1.7%	-5.5	1.5%	-3.4	1.9%	-3.5	2.3%	-3.3
CNE	1.5%	-1.3	1.6%	-2.9	1.6%	-2.9	1.4%	-3.1	2.1%	-2.7
CE	1.4%	0.3	1.8%	-0.0	2.1%	-1.4	1.6%	-0.8	2.1%	-2.1
CSE	1.6%	0.4	2.1%	1.0	2.2%	0.2	2.0%	-0.8	1.6%	-0.5
CS	1.6%	-1.6	1.6%	-0.6	2.1%	0.1	2.2%	-0.4	1.8%	-0.6
CSW	2.2%	-2.5	2.1%	-2.2	2.0%	-1.1	1.6%	-0.9	1.5%	-0.4
CW	1.6%	-2.8	2.3%	-2.5	1.7%	-1.5	1.4%	-1.2	1.2%	-1.6
CNW	1.3%	-3.6	1.6%	-3.3	1.2%	-2.1	1.3%	-1.7	1.9%	-2.5
N	4.8%	-0.0	4.1%	-1.0	4.4%	-0.6	5.9%	-0.6	6.6%	-0.4
NE	4.5%	1.6	3.7%	0.4	4.9%	-0.1	4.7%	0.1	5.4%	0.2
E	4.3%	2.4	4.0%	1.9	3.8%	1.1	3.4%	0.8	3.8%	0.9
SE	2.8%	2.4	3.2%	2.6	3.3%	2.1	3.9%	1.5	3.8%	1.6
S	3.6%	0.9	3.1%	1.6	3.6%	1.9	5.4%	1.6	5.2%	1.7
SW	7.1%	-1.3	5.8%	-0.5	4.9%	-0.1	5.2%	0.5	4.1%	1.1
W	7.5%	-1.2	6.9%	-1.3	6.2%	-0.6	4.3%	-0.0	4.6%	0.2
NW	5.5%	-0.6	5.3%	-1.2	4.7%	-0.1	5.2%	0.3	6.8%	0.0

STUDY AREA & INPUT DATA

STUDY AREA

- focus on central latitude strip of Europe
- 5x5° long-lat grid boxes
- centres at [5°E, 50°N], [10°E, 50°N], [15°E, 50°N], [20°E, 50°N] and [25°E, 50°N]

INPUT DATA

- NCEP/NCAR reanalysis (sea level pressure)
- E–OBS data (temperature, precipitation)
- 1980–2019 period

VEGETATION SEASON

- April–September (AMJJAS)
- divided into two parts: early vegetation season (April–June, AMJ) and late vegetation season (July–September, JAS)

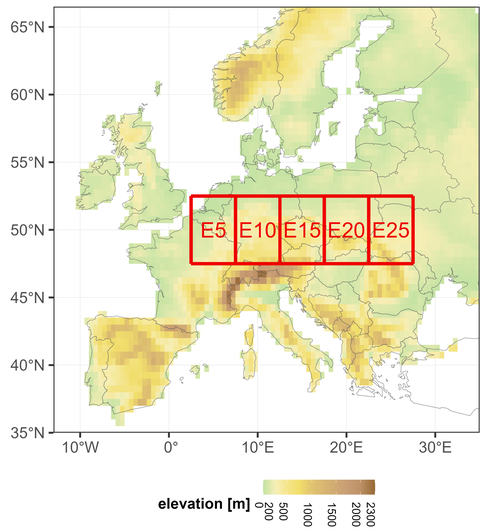

Figure 1: Study regions.

RESULTS

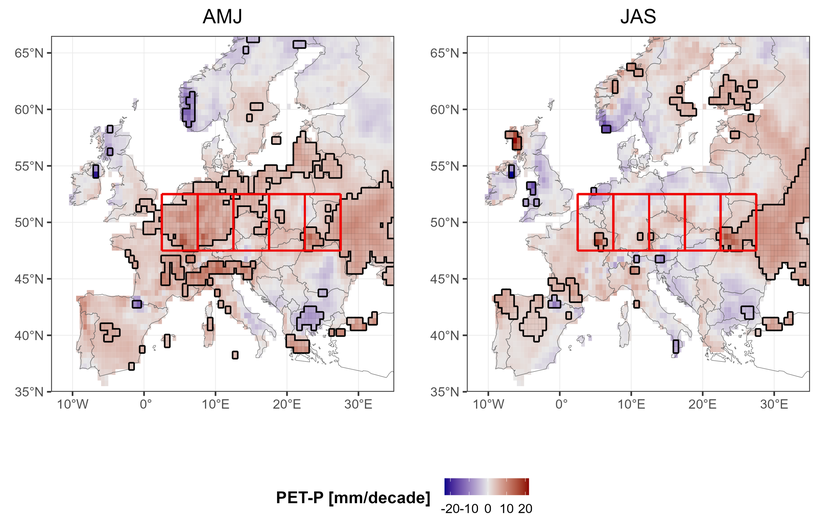

Figure 2: Trends in the PET-P linear regression model for the two seasons (AMJ and JAS) over 1980–2019. The black outline shows areas where the trends are significant at p=0.05.

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Table 2: Linear trends of frequencies of dry CTs with their p-values for the AMJ (left) and JAS (right) seasons over 1980–2019. For the definition of dry CTs see Table 1. The green shading shows regions where the p-values are significant at p=0.05.

dry CTs

	trend AMJ [%/decade]	p-value AMJ [-]	trend JAS [%/decade]	p-value JAS [-]
E5	1.58	0.167	-1.43	0.213
E10	2.78	0.003	-0.34	0.750
E15	2.79	0.008	0.67	0.536
E20	2.60	0.011	1.07	0.357
E25	1.63	0.094	2.28	0.043

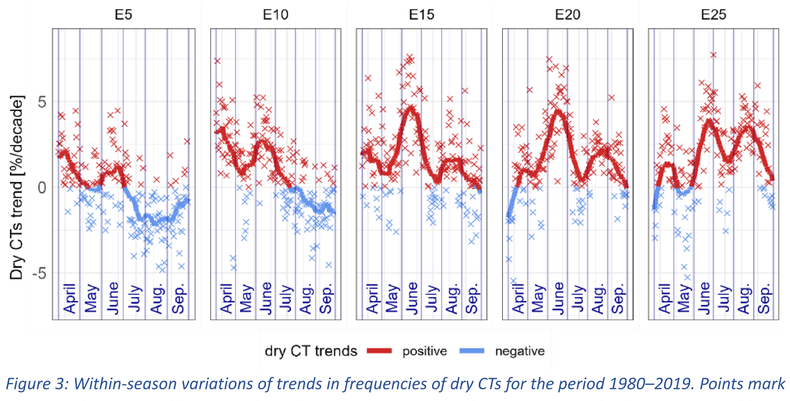

Figure 3: Within-season variations of trends in frequencies of dry CTs for the period 1980–2019. Points mark trends estimated for 31-day moving windows centred on a given day, and solid lines show the 31-day moving averages of the trends. For the definition of dry CTs see Table 1.

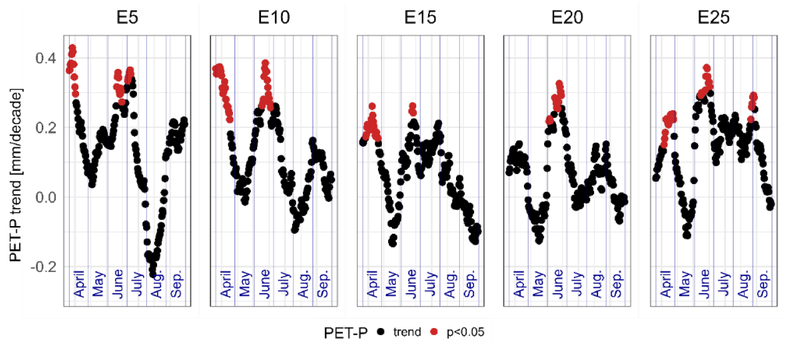

Figure 4: Trends of PET-P in 31-day moving windows from April to September for the period 1980–2019. Red points mark trends significant at p=0.05.

SUMMARY

- in AMJ drought develops mainly in Western and Central Europe; in JAS drying trends are located in Eastern Europe
- the dry types include all anticyclonic types in all regions, and northeast to south (southwest in Eastern Europe) directional types
- conduciveness of directional circulation types to drought depends on region (more than that of anticyclonic types)
- drying trends are found in the AMJ season in Western and Central Europe, in the JAS season only in Eastern Europe
- significant drought development and increasing trend of dry circulation types are similarly found in April and June, and in the eastern area also in August
- the drought trends in the central latitude strip of Europe in the warm-half year were associated with changes in atmospheric circulation since the 1980s