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Predicting future compound and cascading drought and heatwave in Europe including their impacts

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Background & objective

- Increase of drought and heatwave events + compound & cascading (CnC) events + impacts due to CC in Europe.
- Challenge: many studies analyzed future drought & heatwaves as singly, no prediction future hazard impacts.
- Objective: to predicts the characteristics of CnC drought & heatwaves and their impacts using **an ML model** under different SSPs (SSP1-2.6 and SSP5-8.5).

Data & method

- 5 GCMs & CWatM HM from ISIMIP.
- Tmax, Tmin, & SM data (10 km).
- His: 1953-2014, Fut: 2039-2100 (62 yr).
- Drought: the SMI.
- Heatwaves: VTM (90th) & 9 days CMW*.
- Characteristics: duration, number of events, & frequency
- Updated impact database (EDII & Heatwaves)**

Characteristics of CnC events

- Increase of compound drought and heatwaves (CDH) by 30 events > reference under SSP5-8.5 (Fig. 1a).
- Highest change for CDH duration in the west, south, and east Europe (Fig. 1b,c).
- Frequency of CDH will increase around 0.4 event per year with maximum frequency of 0.76 (Fig. 1d)

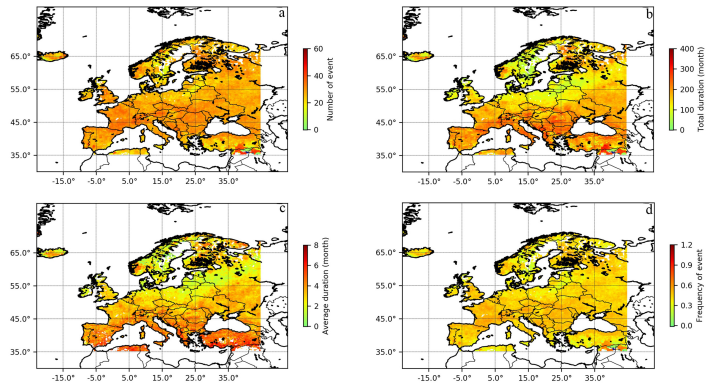

Figure 1. Changes in compound event characteristics across Europe under SSP5-8.5 (median): a) number of compound, b) total duration (month), c) average duration (month) and d) frequency.

Summary of single & CnC events

- Table 1 summarizes the characteristics of single & CnC events in Europe under different scenarios.
- CnC:

	NE	WE	EE	SE
N of events	↓	↑		
Duration	↓			↑
Frequency	↓	↑	↑	↓

↑ High ↓ Low

- Remark: high CnC events in WE, high CnC duration in SE, & low increase of characteristics in NE.

Table 1. A summary of singe and CnC hazard characteristics in each European region. Units: D=month, H=day, CnC=month.

	Number of events			Total duration			Average duration			Frequency of events		
	Historical	SSP1-2.6	SSP5-8.5	Historical	SSP1-2.6	SSP5-8.5	Historical	SSP1-2.6	SSP5-8.5	Historical	SSP1-2.6	SSP5-8.5
Drought												
NE	83.9	106.3	123.7	118.8	157.6	204.3	1.4	1.5	1.7	1.4	1.7	1.9
WE	88.9	116.9	130.7	118.8	172.0	223.7	1.3	1.5	1.8	1.4	1.9	2.1
EE	77.7	103.1	123.9	120.3	161.6	221.7	1.6	1.6	1.8	1.3	1.7	1.9
SE	84.2	111.9	129.3	115.7	169.3	231.8	1.4	1.5	1.8	1.4	1.8	2.1
Heatwave												
NE	51.9	114.8	248.5	227.6	639.3	1639.5	4.3	4.5	5.6	2.2	2.7	3.0
WE	54.4	221.5	392.8	233.2	1269.6	2985.9	4.3	5.3	7.2	2.2	2.9	3.7
EE	65.9	207.1	385.8	299.4	1141.5	3066.8	4.5	5.4	7.9	2.2	2.9	3.6
SE	65.4	231.4	416.8	303.5	1493.8	4102.5	4.6	5.4	9.0	1.9	2.6	3.5
Compound												
NE	4.9	15.2	30.0	10.4	44.1	128.7	2.1	2.8	4.5	0.1	0.2	0.5
WE	5.0	24.6	35.5	9.9	88.2	190.4	2.0	3.4	5.5	0.1	0.4	0.6
EE	6.6	21.4	34.9	15.0	72.5	188.6	2.3	3.4	5.5	0.1	0.3	0.6
SE	5.1	20.7	33.9	11.3	81.3	215.1	2.2	3.7	6.4	0.1	0.3	0.5
Cascading												
NE	10.5	25.9	38.3	26.3	78.7	164.7	2.5	2.9	4.3	0.2	0.4	0.6
WE	10.7	35.4	40.3	25.5	123.9	212.4	2.4	3.5	5.4	0.2	0.6	0.7
EE	13.2	33.5	40.1	34.3	114.8	218.4	2.6	3.4	5.4	0.2	0.5	0.6
SE	10.7	31.1	38.6	26.9	119.9	242.2	2.5	3.7	6.3	0.2	0.5	0.6

Predicting hazard impacts in Germany

- Fig. 2 shows the projections of drought and heatwave impacts in Germany under SSP1-2.6 & SSP5-8.5.
- Economic: increases from 3 to 5 months (median).
- Non-economic: increases 1 month longer for each SSP.
- Ecosystem: increases twice, from 2 to 4 months.
- Humans: increase double and quadruple.

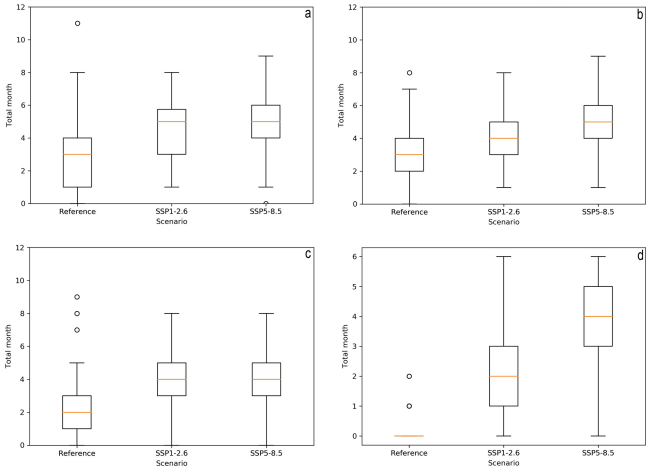

Figure 2. Change in the total month of future impacts: a) for economic sector, b) for non-economic sector, c) for ecosystem sector, and d) for heatwave impact on human.

Conclusion and outlook

- Heatwaves ↑↑↑ Drought ↑↑ CnC events ↑↑↑↑

South Europe:
- Longest duration

West Europe:
- Highest number of events

Impacts:
- Drought: in average 2 months longer
- Heatwaves: 2 and 4 months longer

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Reference:
* Sutanto et al. (2019). Exploring compound and cascading dry hazards, https://doi.org/10.1016/j.envint.2019.105276.
** Stahl et al. (2016). impacts of European drought events, https://doi.org/10.5194/nhess-16-801-2016.

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