Hydrometeorological extremes in a changing climate

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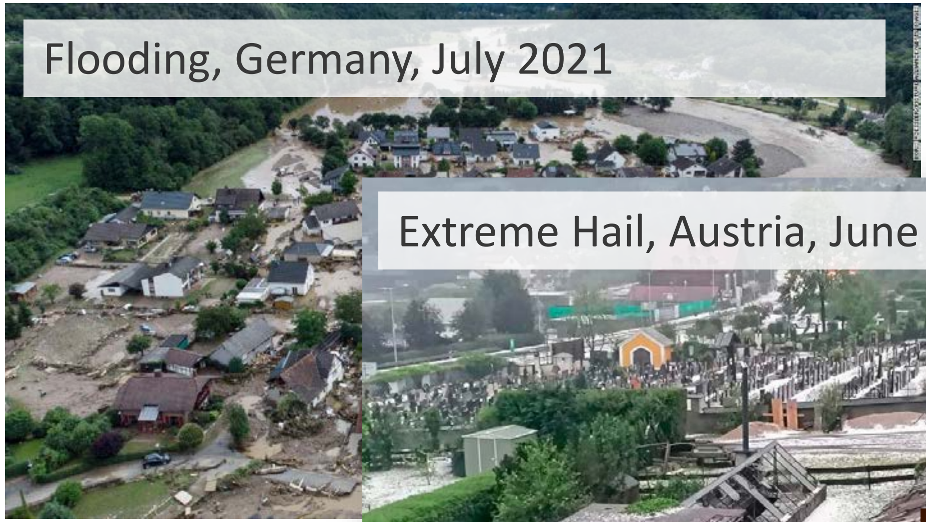
A summer of disasters…


Flooding, Germany, July 2021


Extreme Hail, Austria, June 2021


Wildfires, Greece, July 2021


Tornado: Czech Republic, June 2021

uwz.at

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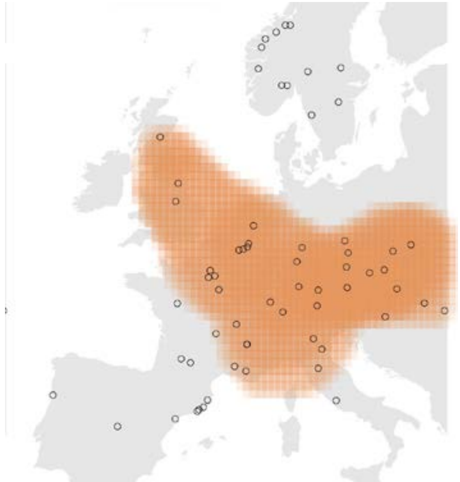
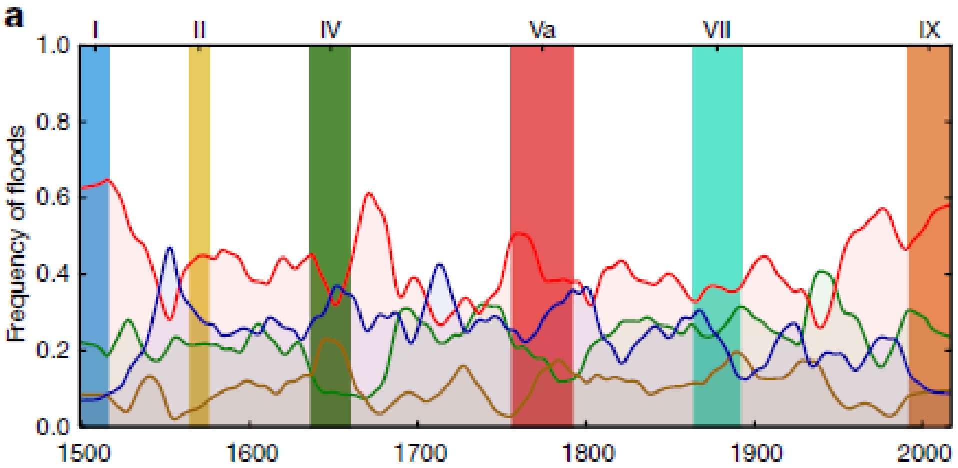
What is the role of climate change on extreme events like floods and droughts?

Floods

ASI/Land Tirol/BH Landeck

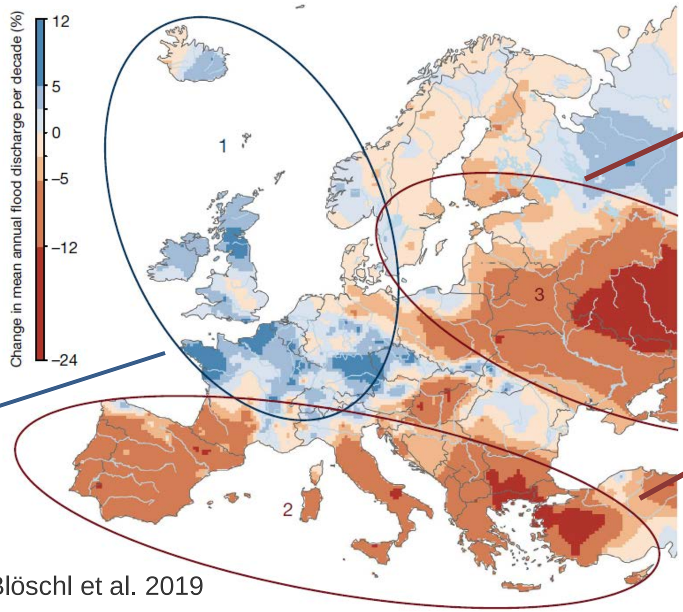
Floods in the past





Blöschl et al. 2020

Northwestern Europe: increasing rainfall and soil moisture



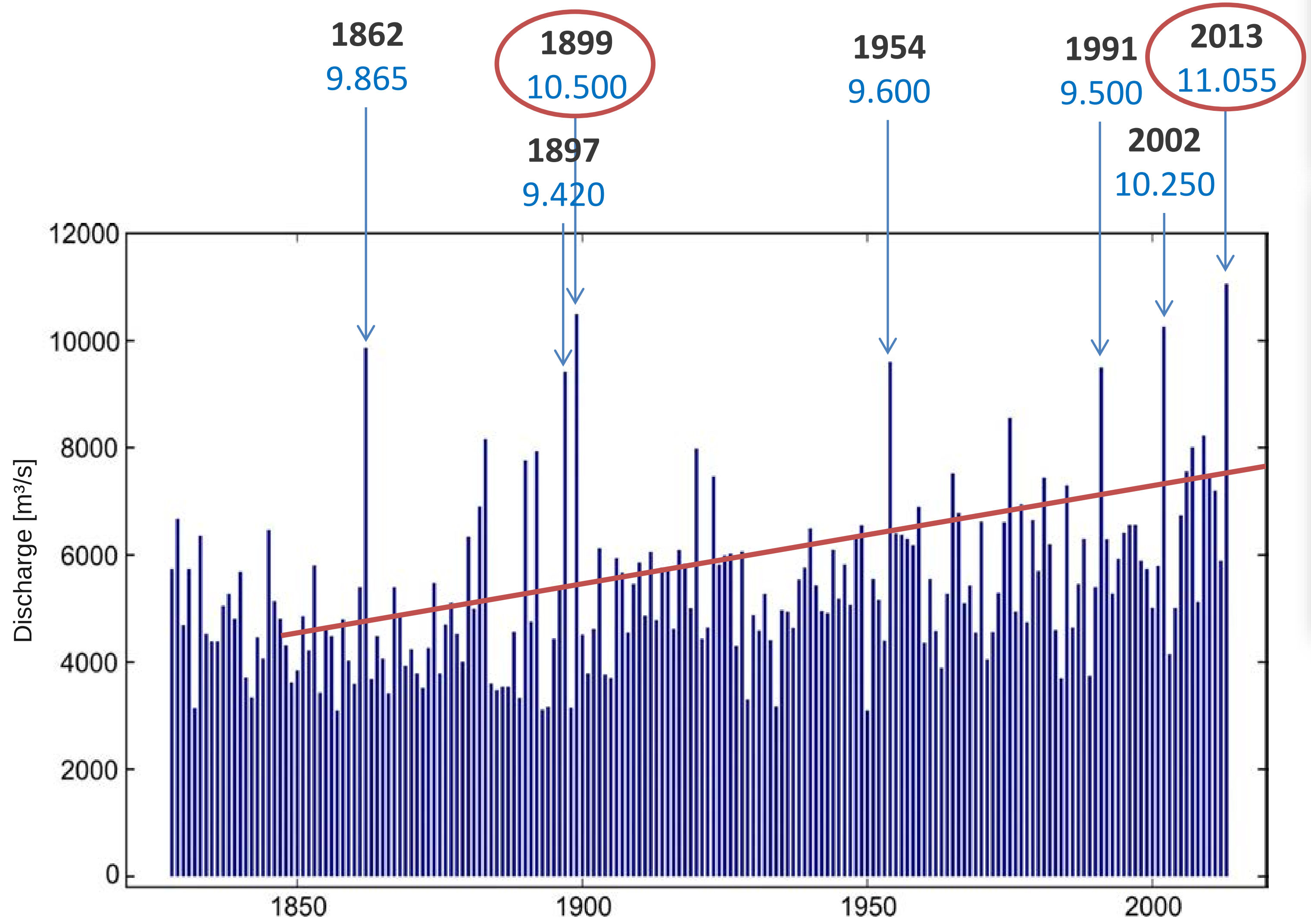
Eastern Europe: decreasing and earlier snowmelt

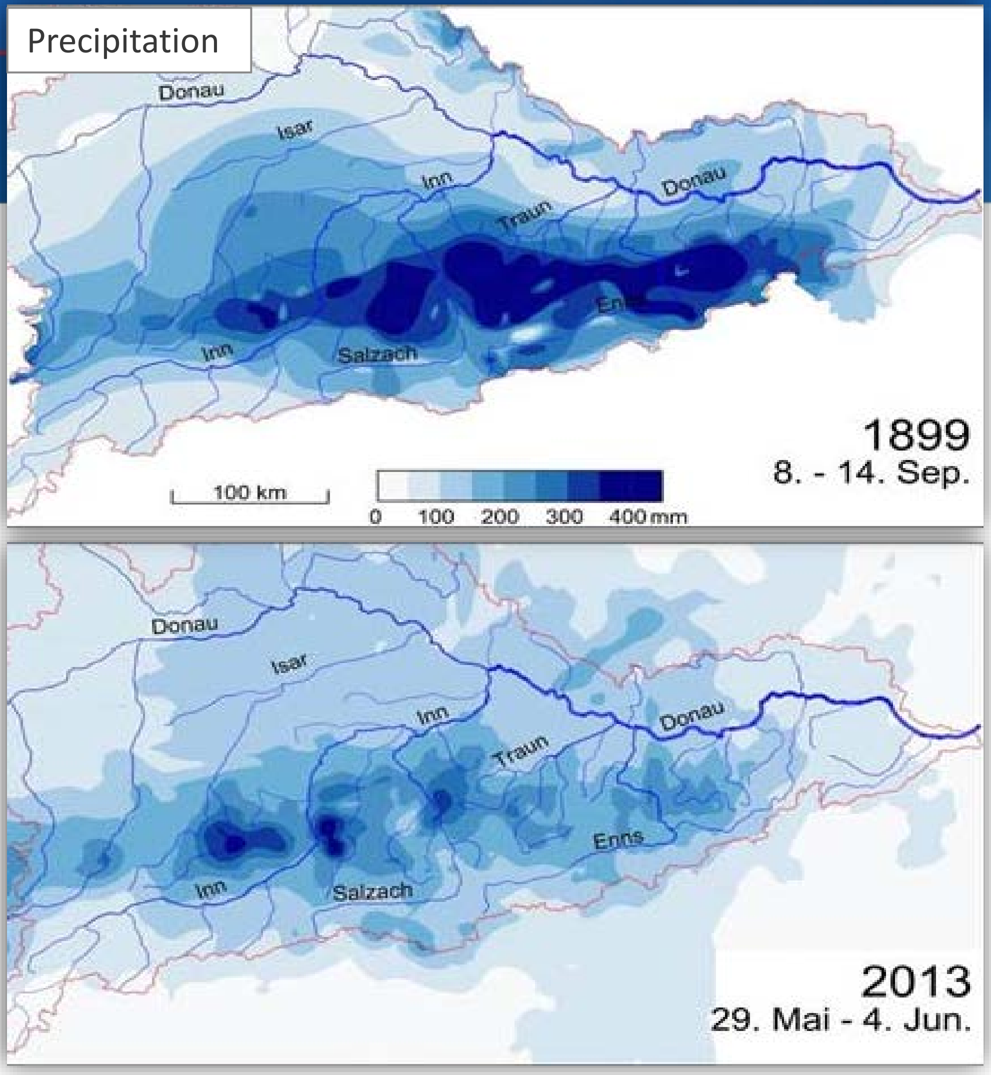
Southern Europe: decreasing rainfall and increasing evaporation

Blöschl et al. 2019

Recent floods in context of the past

Long term annual flood peak discharges on the Danube (Vienna)

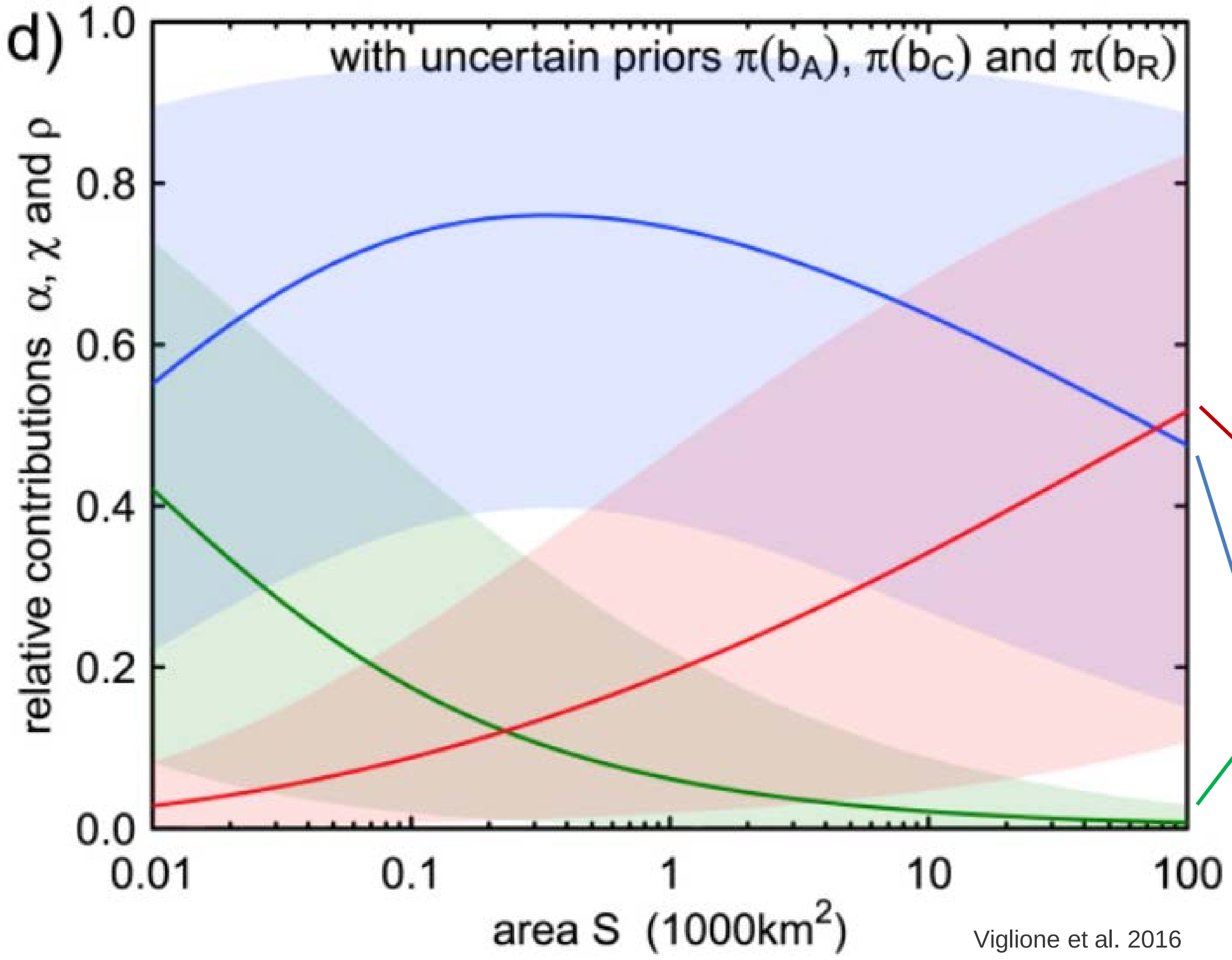




Year	Flood volume [10^9 m^3]	Retention volume [10^9 m^3]
1899	6,6	2
2013	6,1	< 0,5

Fingerprinting of flood trends – contribution of the atmosphere

- Investigation on flood trends in Central Europe contributors to the trend



Viglione et al. 2016

Atmospheric controls act mainly on small to medium sized catchments considering flood changes
→ Precipitation intensity and convection increasingly important

River (loss of retention volume, levee construction etc.)

Catchment (land use change, soil compaction, urbanization etc.)

Atmosphere (increasing precipitation intensity, role of convection etc.)

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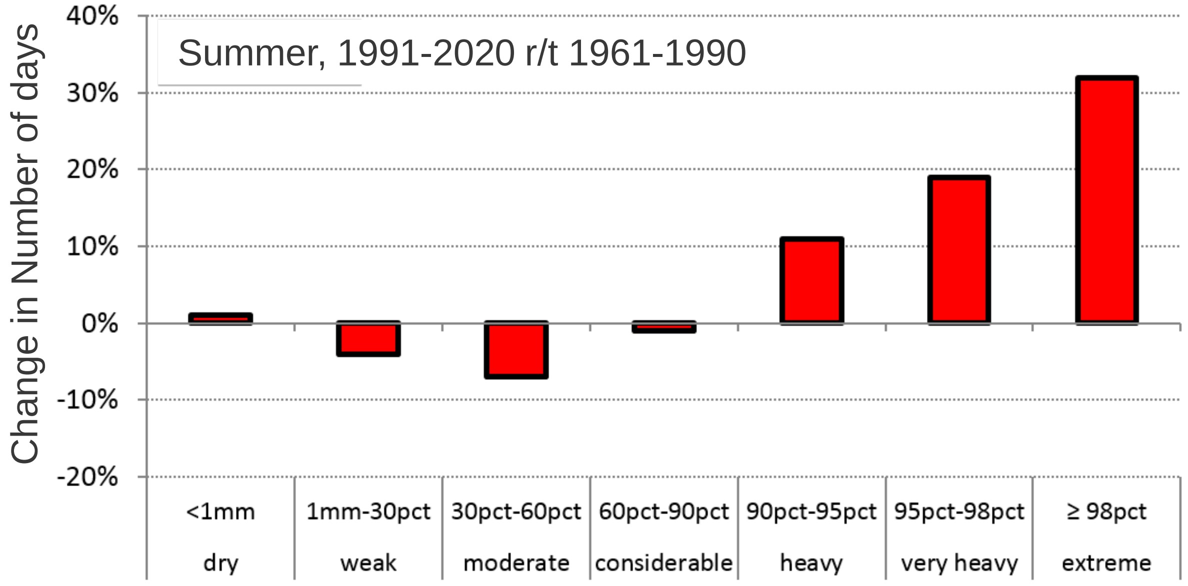
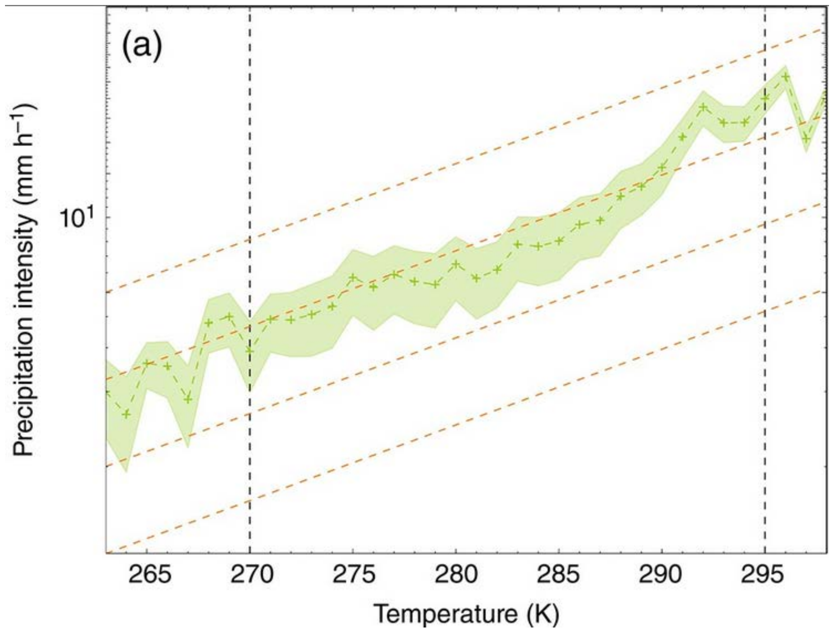
Changes in precipitation intensity on daily and hourly time scales

- Changes in days with distinct intensity classes – an example for Austria





Substatial increase of days with heavy to extreme daily precipitation sums

Hourly precipitation intensity nearly linearly scales with temperature changes following the Clausius-Clapeyron relation

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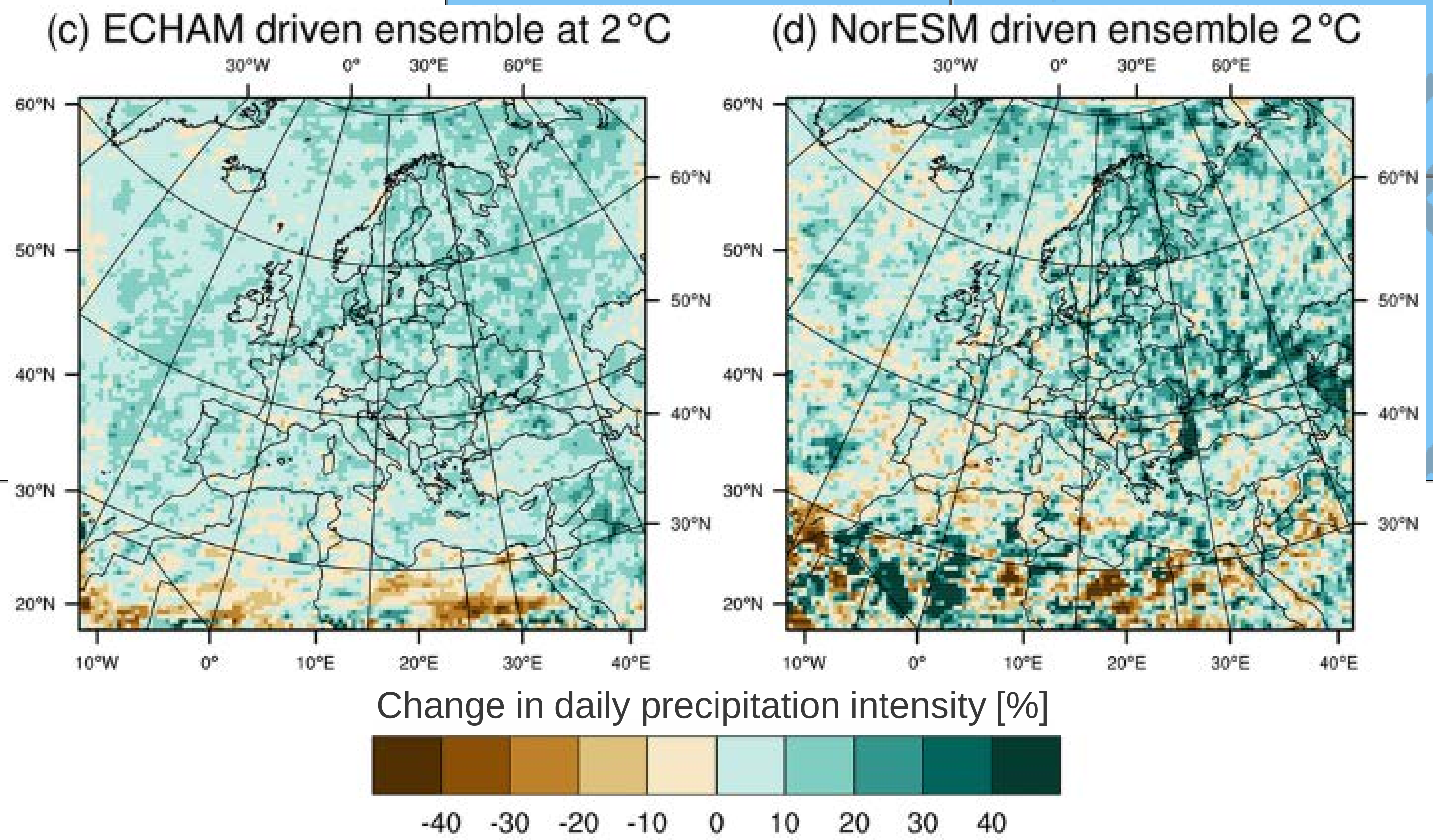
Future outlook

Region	Observed trends	Detection and attribution; event attribution	Projections 1.5 °C	Projections 2 °C
All Europe	Significant intensification of heavy precipitation (Sun et al., 2020)	Robust evidence of a human contribution to the observed intensification of heavy precipitation (Paik et al., 2020)	CMIP6 models project an increase in the intensity and frequency of heavy precipitation (Li et al., 2020a). Median increase of more than 0% in the 50-year Rx1day and Rx5day events compared to the 1°C warming level (Li et al., 2020a)	CMIP6 models project a robust increase in the intensity and frequency of heavy precipitation (Li et al., 2020a). Median increase of more than 2% in the 50-year Rx1day and Rx5day events compared to the 1°C warming level (Li et al., 2020a)
			Intensification of heavy precipitation: *High confidence* (compared with the recent past (1995-2014)) *Likely* (compared with pre-industrial)	Intensification of heavy precipitation: *Likely* (compared with the recent past (1995-2014)) *Very likely* (compared with pre-industrial)



Droughts

Droughts in the past

A messy problem…

Article | Published: 15 March 2021

Recent European drought extremes beyond Common Era background variability

Ulf Büntgen, Otmar Urban, Paul J. Krusic, Michal Rybníček, Tomáš Kolář, Tomáš Kyncl, Alexander Ač, Eva Koňasová, Josef Čáslavský, Jan Esper, Sebastian Wagner, Matthias Saurer, Willy Tegel, Petr Dobrovolný, Paolo Cherubini, Frederick Reinig & Miroslav Trnka

Nature Geoscience **14**, 190–196(2021) | Cite this article

Abstract

Europe's recent summer droughts have had devastating ecological and economic consequences, but the severity and cause of these extremes remain unclear. Here we present 27,080 annually resolved and absolutely dated measurements of tree-ring stable carbon and oxygen ($\delta^{13}C$ and $\delta^{18}O$) isotopes from 21 living and 126 relict oaks (*Quercus* spp.) used to reconstruct central European summer hydroclimate from 75 BCE to 2018 CE. We find that the combined inverse $\delta^{13}C$ and $\delta^{18}O$ values correlate with the June–August Palmer Drought Severity Index from 1901–2018 at 0.73 ($P < 0.001$). Pluvials around 200, 720 and 1100 CE, and droughts around 40, 590, 950 and 1510 CE and in the twenty-first century, are superimposed on a multi-millennial drying trend. Our reconstruction demonstrates that the sequence of recent European summer droughts since 2015 CE is unprecedented in the past 2,110 years. This hydroclimatic anomaly is probably caused by anthropogenic warming and associated changes in the position of the summer jet stream.

Article | Open Access | Published: 19 March 2021

Past megadroughts in central Europe were longer, more severe and less warm than modern droughts

M. Ionita, M. Dima, V. Nagavciuc, P. Scholz & G. Lohmann

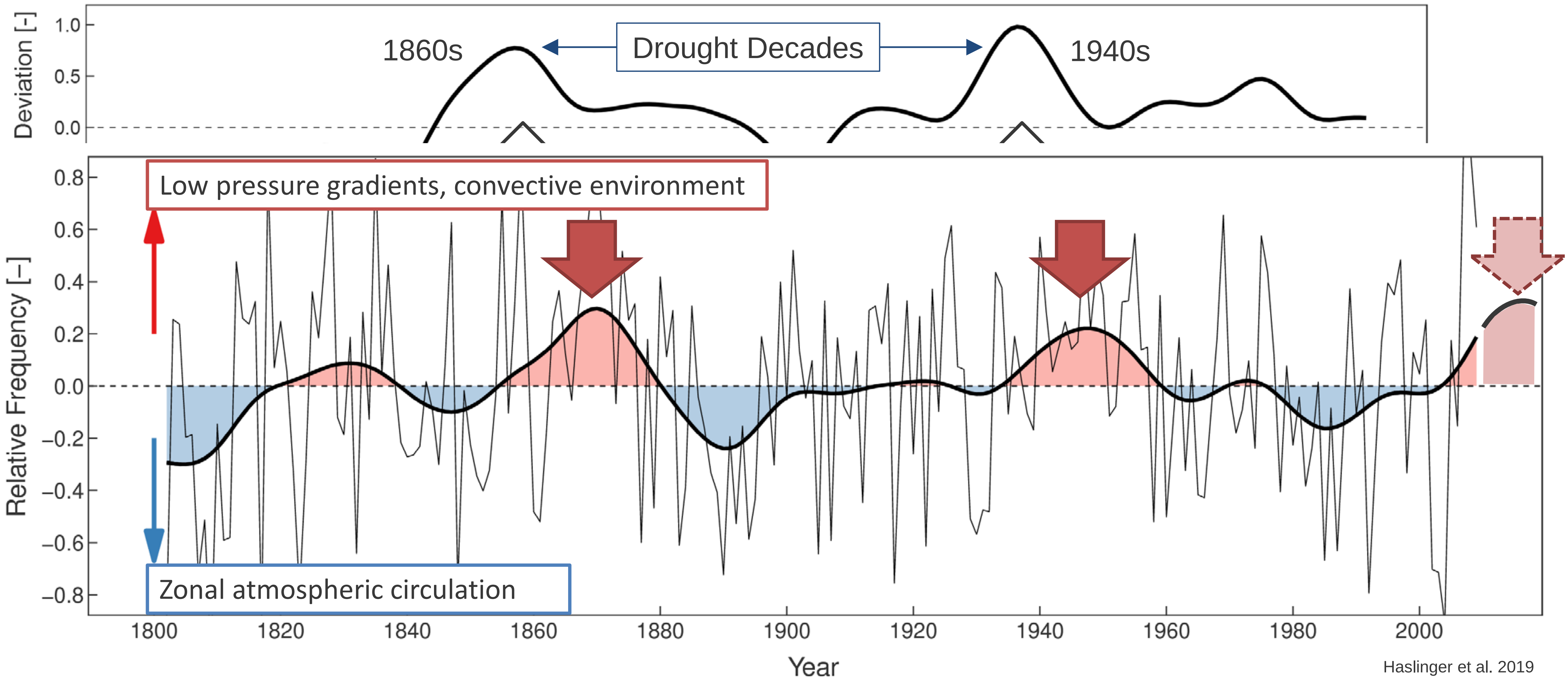
Communications Earth & Environment **2**, Article number: 61 (2021) | Cite this article

Abstract

Megadroughts are notable manifestations of the American Southwest, but not so much of the European climate. By using long-term hydrological and meteorological observations, as well as paleoclimate reconstructions, here we show that central Europe has experienced much longer and severe droughts during the Spörer Minimum (~AD 1400–1480) and Dalton Minimum (~AD 1770–1840), than the ones observed during the 21st century. These two megadroughts appear to be linked with a cold state of the North Atlantic Ocean and enhanced winter atmospheric blocking activity over the British Isles and western part of Europe, concurrent with reduced solar forcing and explosive volcanism. Moreover, we show that the recent drought events (e.g., 2003, 2015, and 2018), are within the range of natural variability and they are not unprecedented over the last millennium.

Droughts in the past, an example for the Alpine region

b) Average of drought features (Intensity, Duration, Frequency)

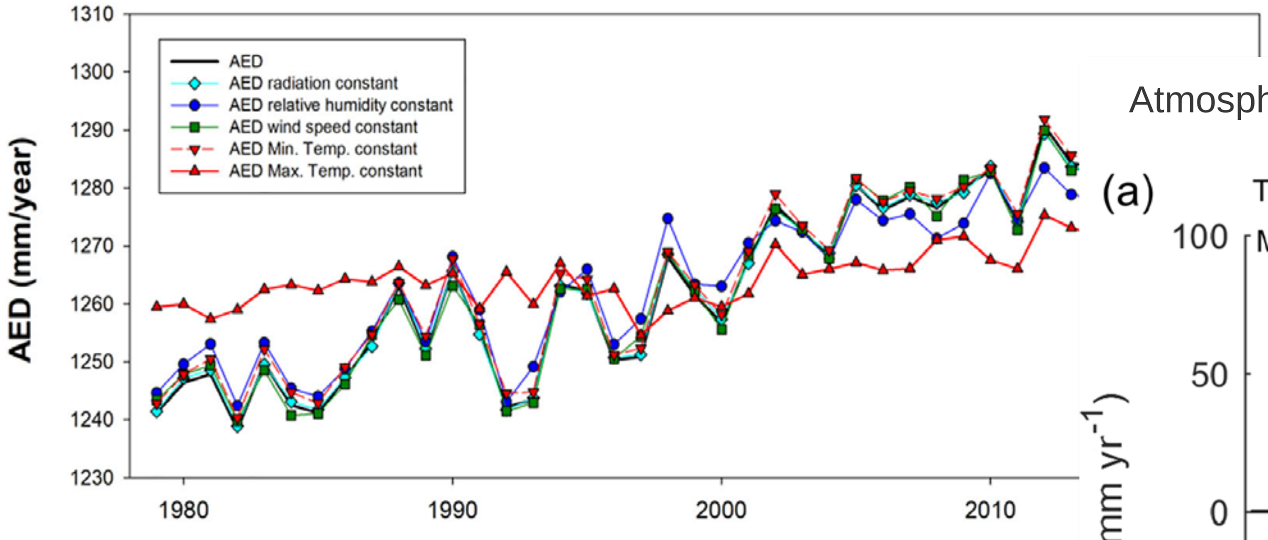


Haslinger et al. 2019

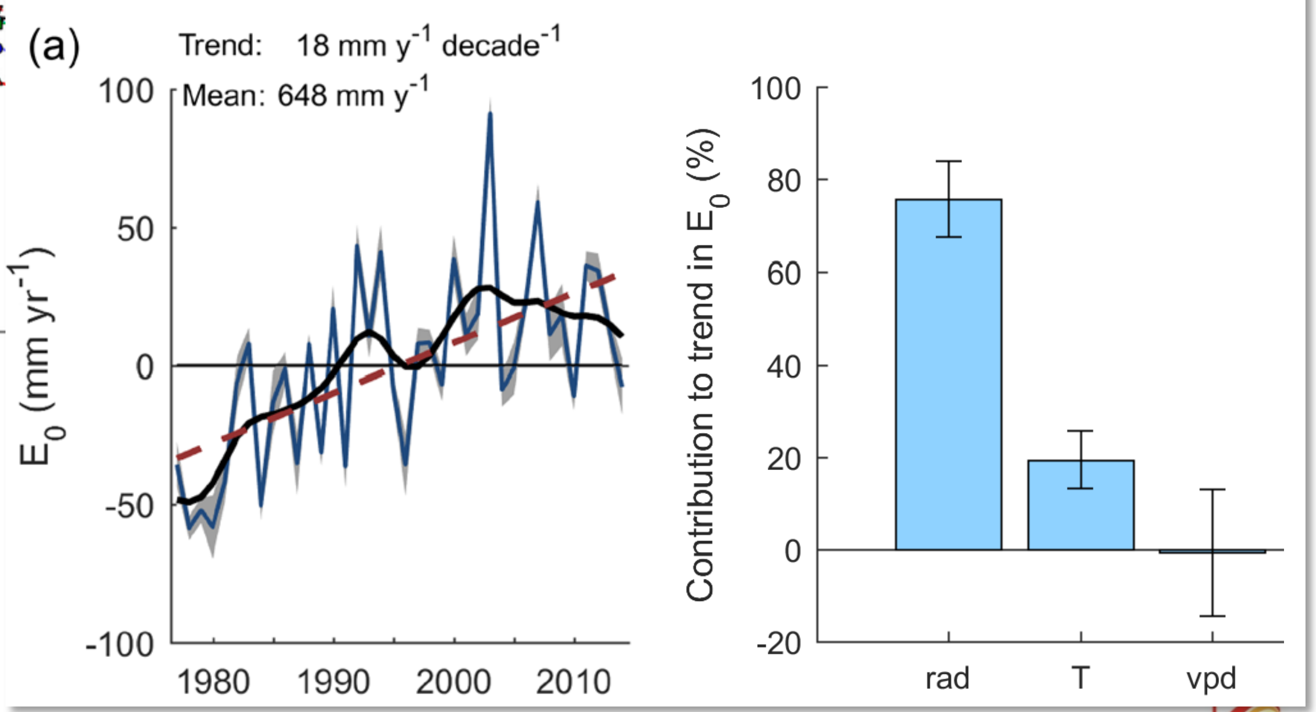
Droughts in the past

Changes in atmospheric evaporative demand

Global trend in atmospheric evaporative demand



Atmospheric evaporative demand in Austria and drivers of change



Global and regional increase in atmospheric evaporative demand

Drivers in Central Europe:

1) Increase in surface radiation
2) Increase in temperature

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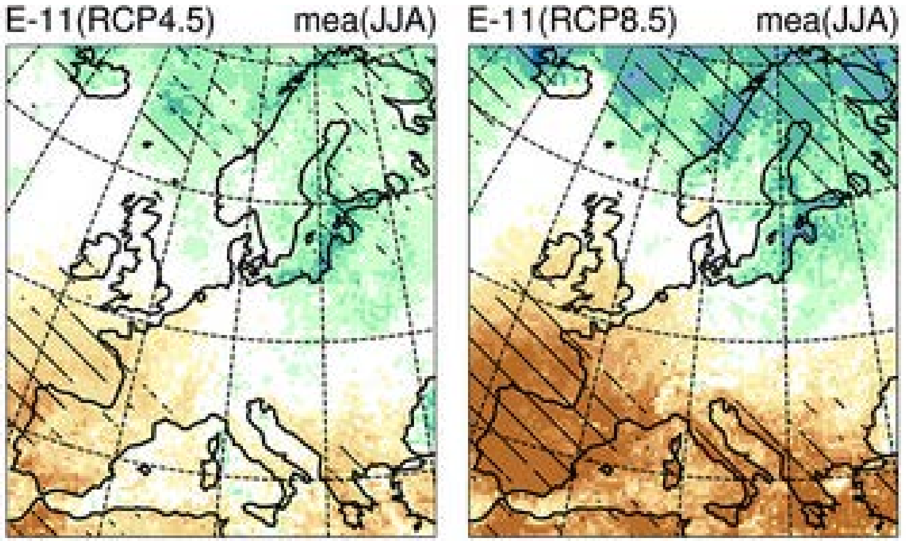
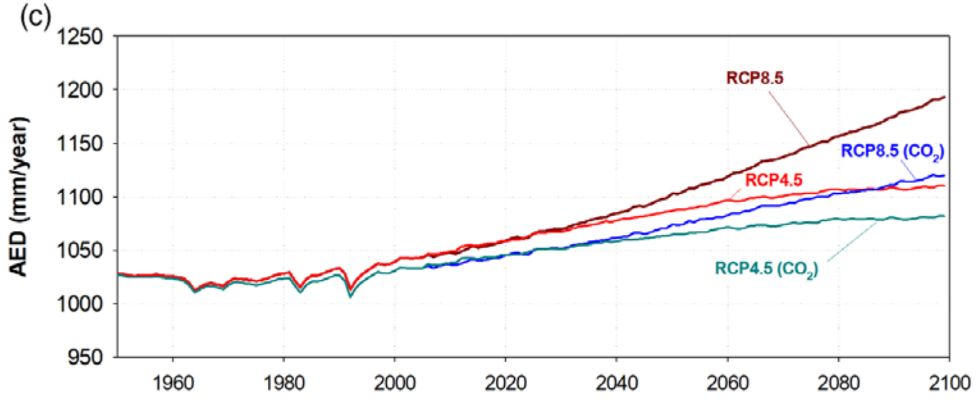
Future outlook until the end of the 21st century

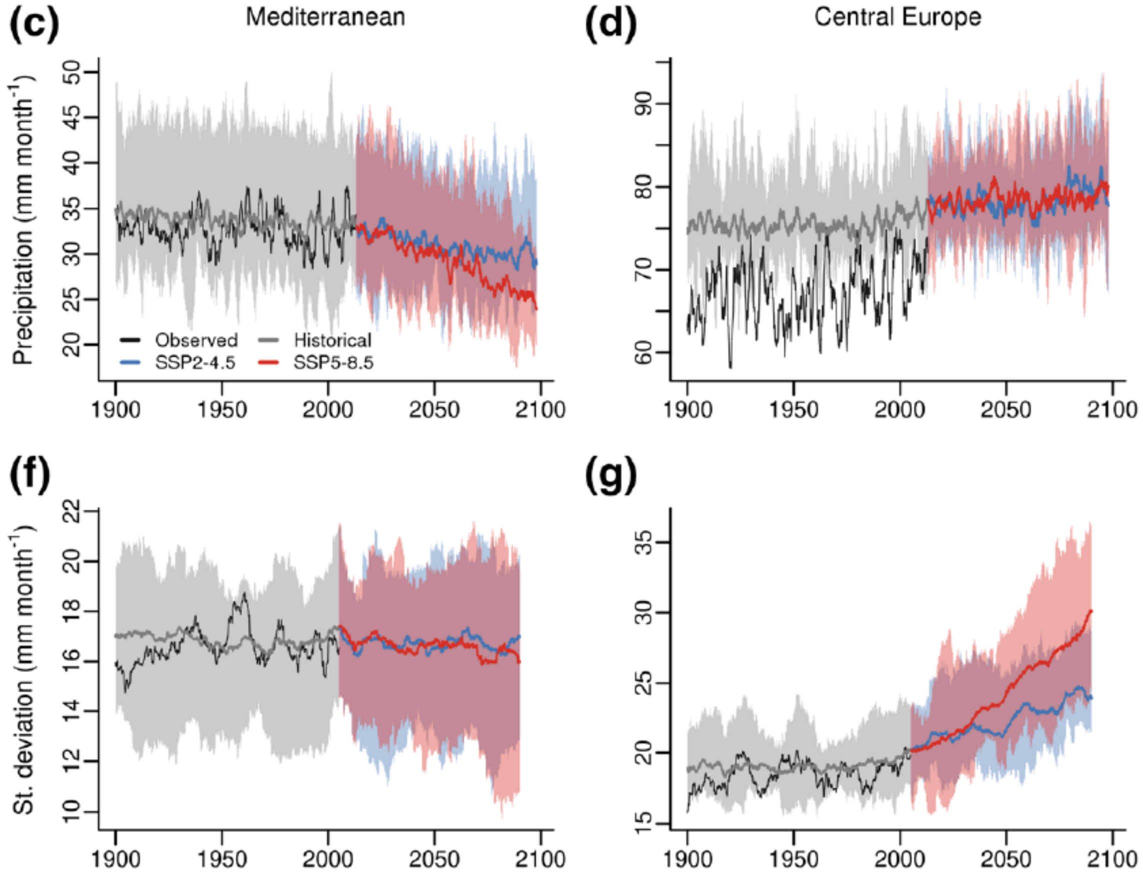
Changes in mean summer precipitation



Changes in global atmospheric evaporative demand



Changes in mean precipitation and interannual variability



Future outlook

Region and drought types		Observed trends	Detection and attribution; event attribution	Projections	
				+1.5 °C	+2 °C
	HYDR	*Low confidence*: **Weak or insignificant** trends (Stahl et al., 2010; Bard et al., 2015; Caillouet et al., 2017; Moravec et al., 2019; Vicente-Serrano et al., 2019;	*Low confidence:* **Limited evidence** because of **lack of studies.**	*Low confidence*: **No or weak changes**; CORDEX simulations: no change in most of domain, slight wetting over the Alps (Forzieri et al., 2014; Touma et al., 2015; Marx et al.,	*Medium confidence*: **Increase** in drying, mostly in western part of domain: summer season surface runoff compared to pre-industrial (Cook et al., 2020); annual discharge in substantial part of domain (Schewe et al.,
	HYDR	*Low confidence*: No **enough data and limited studies** (Gudmundsson et al., 2021)	*Low confidence*: **Limited evidence** because of **lack of studies**	*Low confidence:* **Limited evidence. One study shows lack of signal** (Touma et al., 2015)	*Low confidence*: **Inconsistent** changes. Some studies with increases in drought/decrease in runoff: (Forzieri et al., 2014) [11 RCMs forced with CMIP5 models and the LISFLOOD model] : Decrease in the 20 yr return level minimum flow and deficit volumes; (Cook et al., 2020): decrease in summer surface runoff in CMIP6 models. Some studies with no change in HYDR drought or runoff: (Touma et al., 2015; Roudier et al., 2016) [11 RCMs]: No substantial changes in the severity of the low flows; (Schewe et al., 2014): No substantial changes in the annual runoff.

Take home messages

Floods:

- Temporal clustering of floods on a long term perspective in Europe (flood rich vs. flood poor periods)
- Multiple drivers for large scale floods, climate vs. catchment vs. river characteristics
- Climate change is altering precipitation regimes → increase in short term intensity on hourly and daily time scales → increasing risk of small scale flooding with climate change

Droughts

- Temporal clustering of droughts on a long term perspective in Central Europe (drought decades)
- Little changes in precipitation amount, increase in atmospheric evaporative demand
- Future drought risk is driven by increasing interannual variability and atmospheric evaporative demand

In general:

Internal climate variability substantially shifts probabilities for hydrometeorological extremes, internal climate variability is underestimated in state-of-the arte climate models (O'Reilly et al. 2021, Nature)

Thank you for your kind attention

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