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Drought Duration Curves:
A method to quantify and explain differences in droughts

HYDROLOGY

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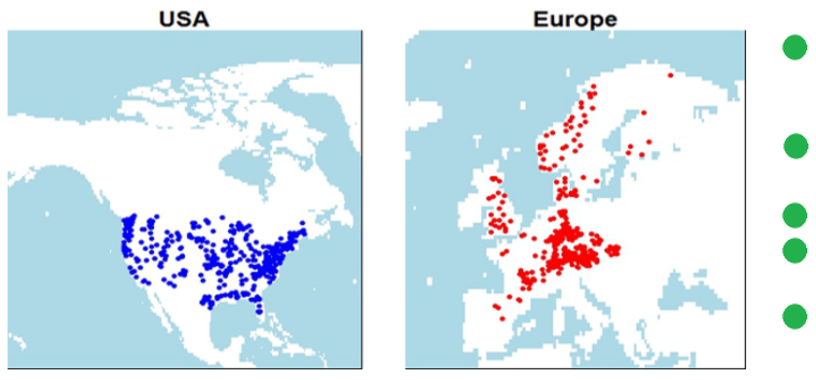
USA versus Europe

Introduction and Objectives

Climate zones or basin characteristics are often used to cluster and analyze drought characteristics.

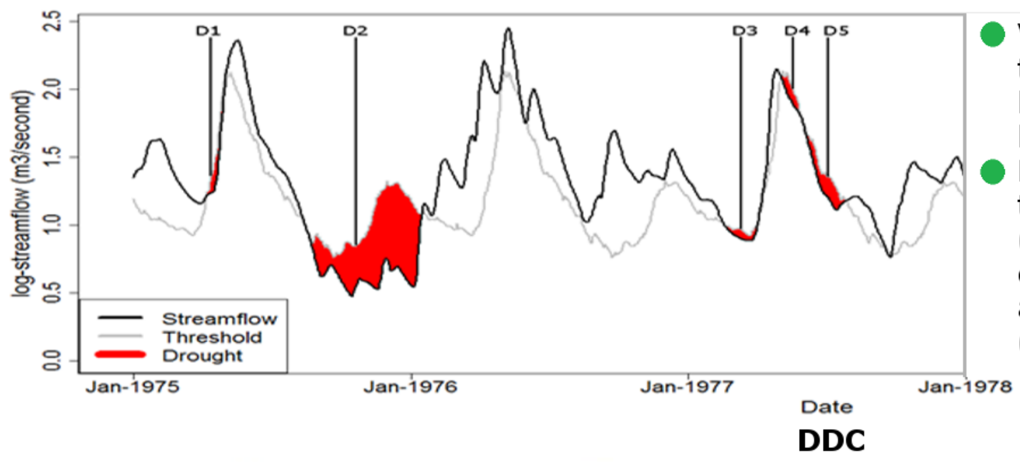
- How representative are these groups regarding drought durations?
- What factors influence drought duration in the USA and Europe?
- How uniform are these factors for these two areas?
- Who has to deal with the longest droughts: **USA** or **Europe**?

Data and selection criteria

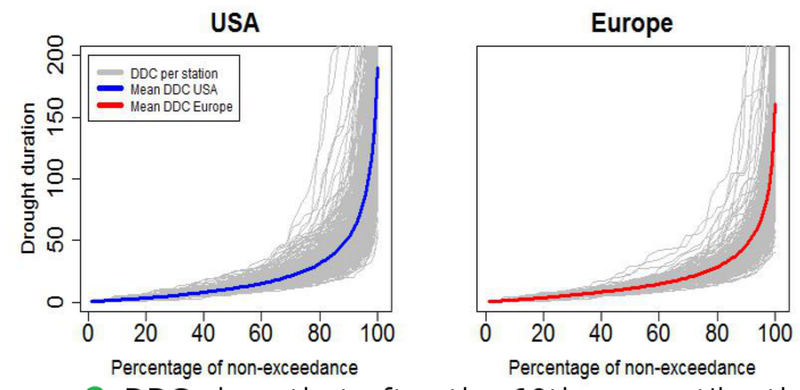


- Near natural streamflow data from: Hydro-Climatic Data Network dataset (**HCDN-2009**) and European Water Archive (**EWA**)
- Continuous and daily data availability between **1970-2010** and **1965-2005**
- Daily 20-percentile flow is never zero
- Precipitation and temperature from **PRISM** (800m resolution, via USGS) and **E-OBS** (0.25° resolution).
- Köppen-Geiger climates and aridity index are derived from these data

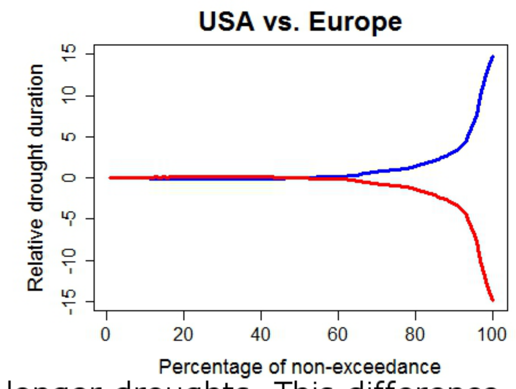
Drought duration identification



- Variable threshold level method with a threshold level of 20 percent and backwards smoothing of the hydrograph by 10 days
- Per station, drought durations are transformed to Drought Duration Curves (DDC) which are based on the principle of flow duration curves, only now with ascending sorting of drought durations (D1<D3<D4<D5<D2 for this example)



Subtract mean DDC Europe/ USA from mean total DDC



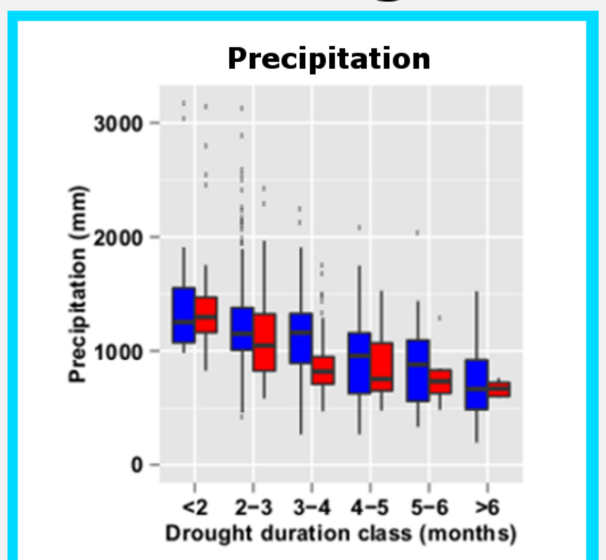
- DDC show that after the 60th percentile, the USA experiences longer droughts. This difference increases to about 30 days towards the highest percentiles of the DDC.

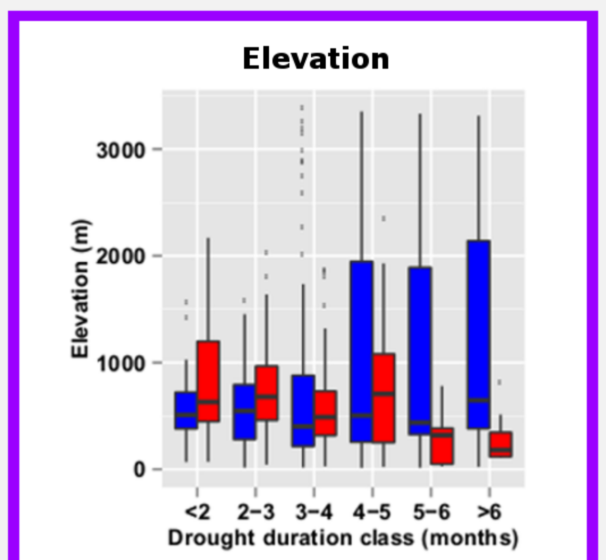
Testing influential factors

2 approaches

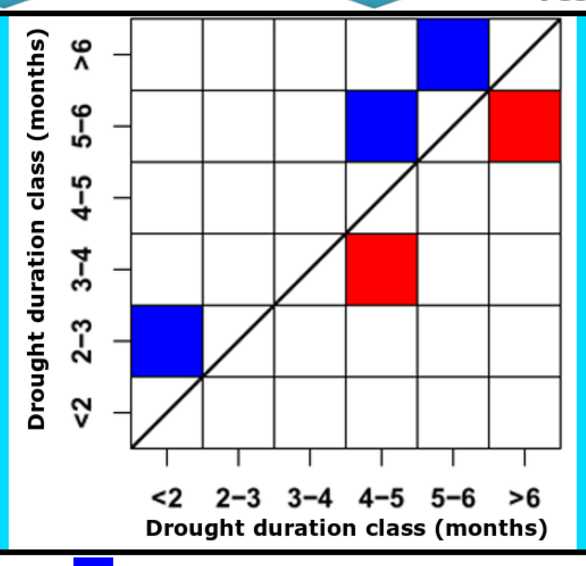
Testing similarity	Grouping procedure	Factors	Approach 1		Approach 2	Factors	Grouping procedure	Testing similarity
Apply the KS-test on factors between all combinations of DDC classes	Group factors based on mean drought duration between the 95th-100th percentile (monthly interval)	Precipitation Elevation	Based on single factors	**DDC**	Based on climate classification factors	Köppen-Geiger De Martonne Aridity index	Group DDC based on predefined factor classes	Apply the KS-test on DDC (per percentile, between 80th-100th percentile) between all combinations of factor classes

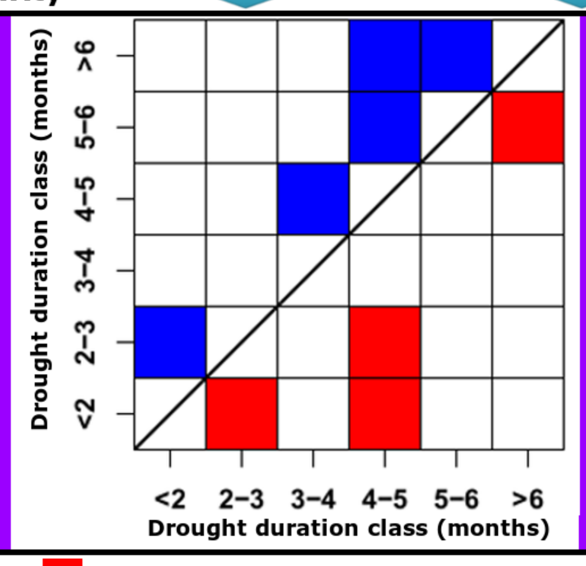
Approach 1: Single factors





Testing similarity

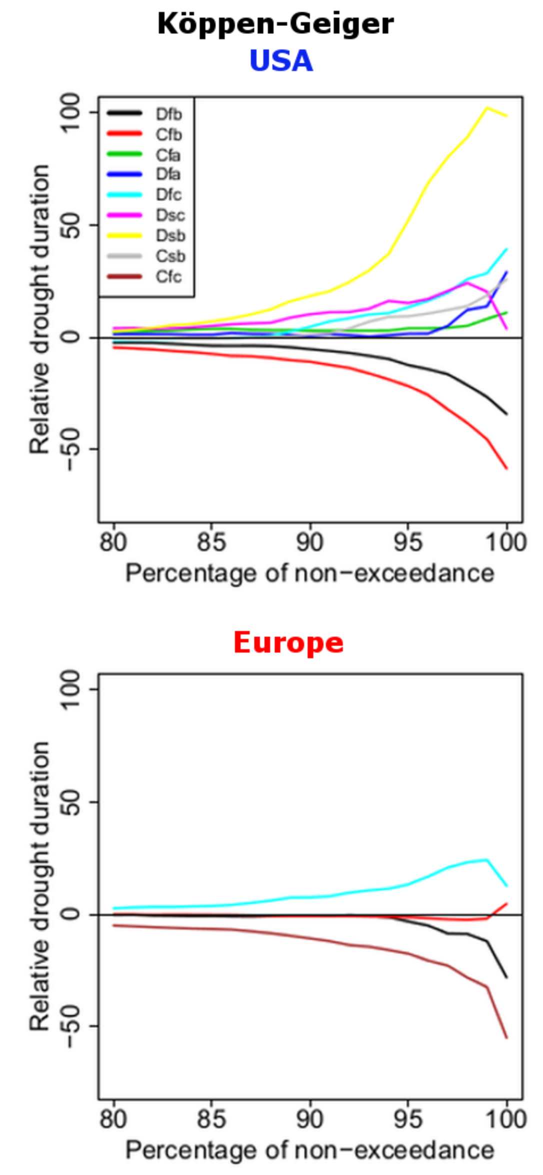


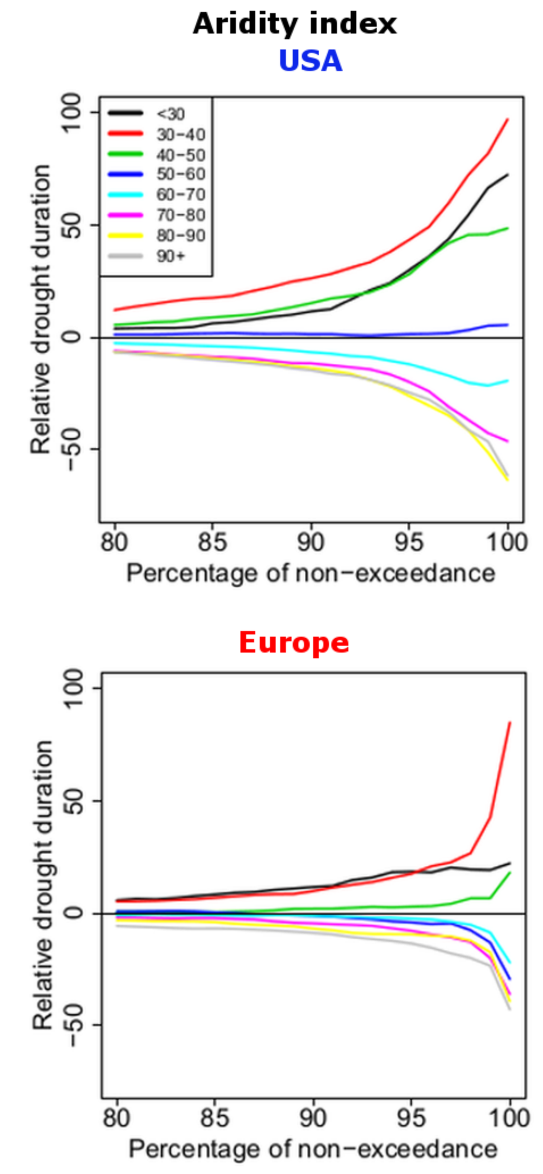


Similarity between classes USA — Similarity between classes Europe

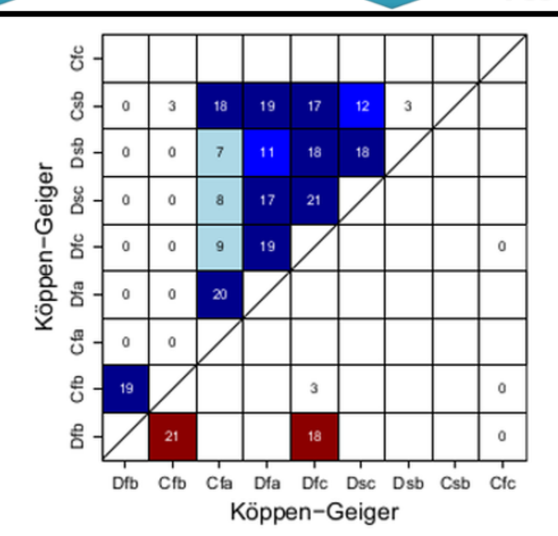
- **Precipitation** decreases with increasing DDC classes. The differences are mostly significant, except for similarities between some of the neighboring classes, indicating a strong influence of this factor.
- **Elevation** shows a different pattern for the different areas. Where longer drought duration classes are located at higher elevations in the USA, it is the other way around for Europe. Longer drought duration classes have similar elevations and these elevations are significantly different from the other drought duration classes.

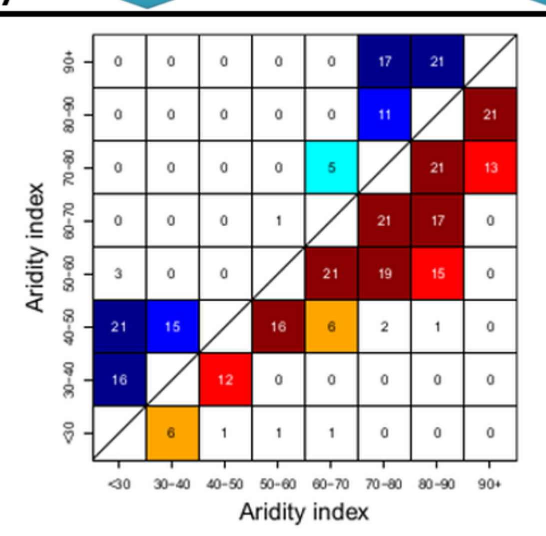
Approach 2: Climate classification factors





Testing similarity





Number of percentiles with significantly similar drought durations

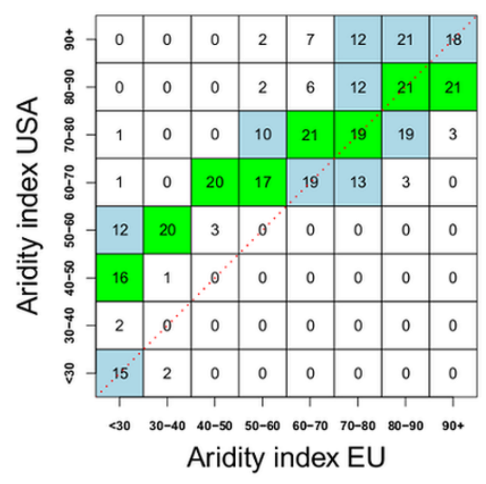
USA		Europe	
<5	No similarity	<5	No similarity
5+	Little similarity	5+	Little similarity
10+	Intermediate similarity	10+	Intermediate similarity
15+	High similarity	15+	High similarity

- **Köppen-Geiger** climates in the USA show an ordering of DDC, where non-seasonal warm summer climates have the shortest droughts, followed by non-seasonal hot summer climates and by the longest droughts for the seasonal and cold summer climates. However, these differences are often not significant, only between the non-seasonal warm summer climates and the rest. For Europe, only the Cfc climate shows significantly shorter droughts.
- **The aridity index** shows a clear ordering of DDC from the most arid to the least arid groups. These differences are mostly significant, except some similarities between neighboring classes.

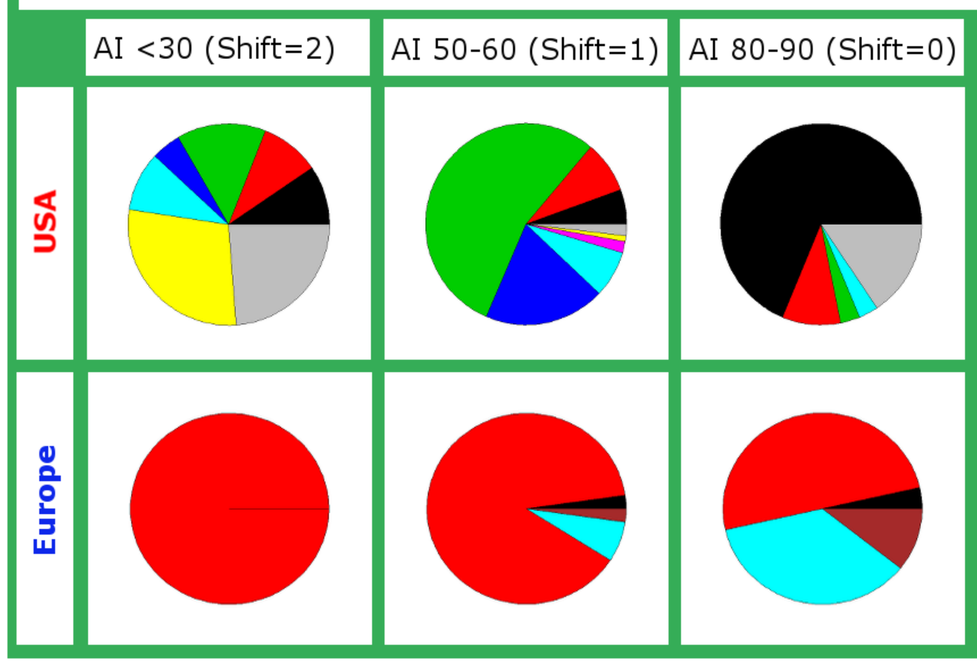
Similarity between areas? Aridity index USA vs. Europe

Max similarity

Similarity >10



- DDC of aridity index (AI) classes of Europe are compared with DDC of AI classes of the USA.
- Low AI classes of Europe (<30-50) are most similar to higher AI classes of the USA (shift by 2). USA: Mostly seasonal climates. Europe: Non-seasonal warm summer climates.
- Intermediate AI classes of Europe (50-70) show most similarity with classes that have a little higher AI in the USA (shift by 1). USA: Mostly hot summer climates. Europe: Again non-seasonal warm summer climates.
- Highest AI classes: A 1 to 1 relation is observed. Both areas mainly consist of non-seasonal warm summer climates in these classes.



Not seasonal	
Cfb, Dfb	Warm summer
Cfa, Dfa	Hot summer
Cfc, Dfc	Cool summer
Seasonal	
Csb, Dsb	Warm summer
Dsc	Cool summer

Conclusions

- The USA have longer droughts and different factors influence (the difference in) drought duration.
- Absolute precipitation has a similar and significant influence on DDC for both areas.
- DDC grouped by Köppen-Geiger climate classification show the influence of seasonality and hot/cold summer climates on DDC. However, differences are mostly not significant.
- The aridity index is a good proxy for drought durations on both continents. However, they are not directly comparable between the two areas.

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Acknowledgements:
Streamflow USA: Lins, Harry F. "USGS Hydro-Climatic Data Network 2009 (HCDN–2009).
Streamlow Europe: Stahl, K., Hisdal, H., Hannaford, J., Tallaksen, L. M., van Lanen, H. A. J., Sauquet, E., Demuth, S., Fendekova, M., and Jódar, J.: Streamflow trends in Europe: evidence from a dataset of near-natural catchments, Hydrol. Earth Syst. Sci., 14, 2367-2382, doi:10.5194/hess-14-2367-2010, 2010.
Precipitation and temperature USA: PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu
Precipitation and temperature Europe: E-OBS dataset from the EU-FP6 project ENSEMBLES (http://ensembles-eu.metoffice.com) and the ECA&D project (http://www.ecad.eu)" "Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones and M. New. 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201"

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