CONDITIONAL PROBABILITIES OF TRANSITIONS FROM ARID TO HUMID ENVIRONMENT AND VICE VERSA IN EUROPE DURING 1766-2015

Zuzana Bešťáková[1,2], Petr Máca[1], Jan Kyselý [1,2], Ujjwal Singh[1], Yannis Markonis[1], Martin Hanel[1]
[1]**Czech University of Life Sciences**, Faculty of Environmental Sciences, Prague, Czech Republic
[2]**Institute of Atmospheric Physics**, Czech Academy of Sciences, Prague, Czech Republic

ABSTRACT

Currently, there are changes in the hydroclimatic system, with most of Europe affected by droughts. Recent reconstructions on historical precipitation and temperature fields can be used for determination of impacts of meteorological, hydrological and agricultural droughts. Those reconstructions are available for European continent in gridded form (Casty et al.,2007). Aridity index, defined as a fraction of potential evapotranspiration and precipitation, can be used for characterization of humid – wet -- and arid – dry -- regions. It represents the ratio between energy availability and water availability. This study deals with conditional probabilities of transitions from arid to humid environment and vice versa. The aridity index was used to determine the transitions on annual basis for the European continent for 1766-2015. The probabilities were calculated for each year, and for 10-year, 20-year and 30-year periods. It is shown that the recent droughts followed the drying of substantial part of Europe starting in 2014 (Hanel et al., 2018). The changes are most pronounced in Northern and Central Europe.

ARIDITY INDEX AND ITS TRANSITION PROBABILITIES

The Aridity index (AI) represents the relative water and energy availability in the hydrological system of a catchment. The climate is assessed according to AI. AI is defined as potential evapotranspiration (PET) standardized by precipipitation (P):

$$\mathrm{AI} = \frac{\mathrm{PET}}{\mathrm{P}},$$

where PET and P are in units mm/year. PET is the maximum amount of water that can be taken away from the system by unlimited amount of water. If evapotranspiration is limited by energy availability, then AI <1 corresponding to a humid catchment (w). If evapotranspiration is limited by water availability, then it is an arid catchment(d), value AI>1.

We study transitions between individual periods (1-year, 10-year, 20-year, 30-year):

$$\mathrm{AI}_{\mathrm{PREV}} < 1 \;\&\; \mathrm{AI} < 1 \rightarrow \mathrm{ww}$$

$$\mathrm{AI}_{\mathrm{PREV}} > 1 \;\&\; \mathrm{AI} > 1 \rightarrow \mathrm{dd}$$

$$\mathrm{AI}_{\mathrm{PREV}} < 1 \;\&\; \mathrm{AI} > 1 \rightarrow \mathrm{wd}$$

$$\mathrm{AI}_{\mathrm{PREV}} > 1 \;\&\; \mathrm{AI} < 1 \rightarrow \mathrm{dw},$$

where $\mathrm{AI}_{\mathrm{PREV}}$ represents AI in previous period.

STUDY AREA AND INPUT DATA

The used data describe the whole Europe. For the period 1950-2015 three data sets are compared:

A. CRU data (Q_{CRU}, P_{CRU}, PET_{CRU}) (Hanel et al., 2018)
B. GRUN data (Q_{GRUN}, P_{CRU}, PET_{CRU}) (Ghiggi et al., 2019)
C. E-OBS data (Q_{GRUN}, $P_{E\text{-}OBS}$, PET_{CRU}) (ECAD, 2020)
D. MEAN of data layers (GRUN + E-OBS)

where Q is runoff. The subscripts (CRU, GRUN, E-OBS) indicate the origin of the data (P, Q, PET) from the input data files CRU (Casty et al., 2007), GRUN (Ghiggi et al., 2019), E-OBS (ECAD, 2020).

RESULTS

Histograms of 10-year IA values for all data sets

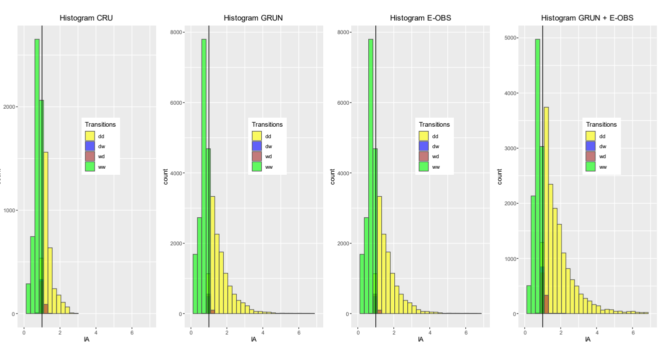

Fig 1: Histograms of 10-year IA values for all data sets (CRU, GRUN, E-OBS, mean of GRUN + E-OBS) for the period 1950-2015.

- most values occur around the value one
- most values are on the line between wet and dry catchment

Plotted 10-year periods for mean of data layers GRUN and E-OBS

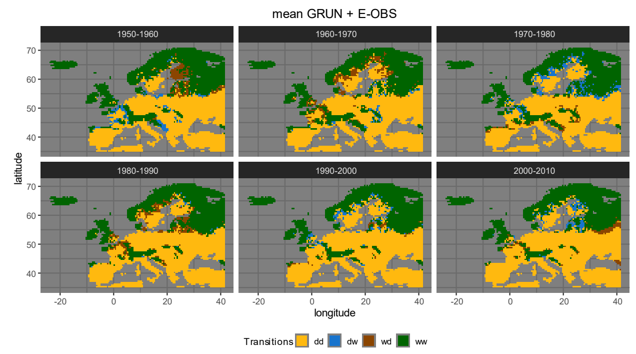

Fig 2: Plotted transitions of 10-year periods from mean of data layers GRUN and E-OBS. All maps are drawn for the period 1950-2015 (excluding the last five years).

Plotted 10-year periods for three sets of data

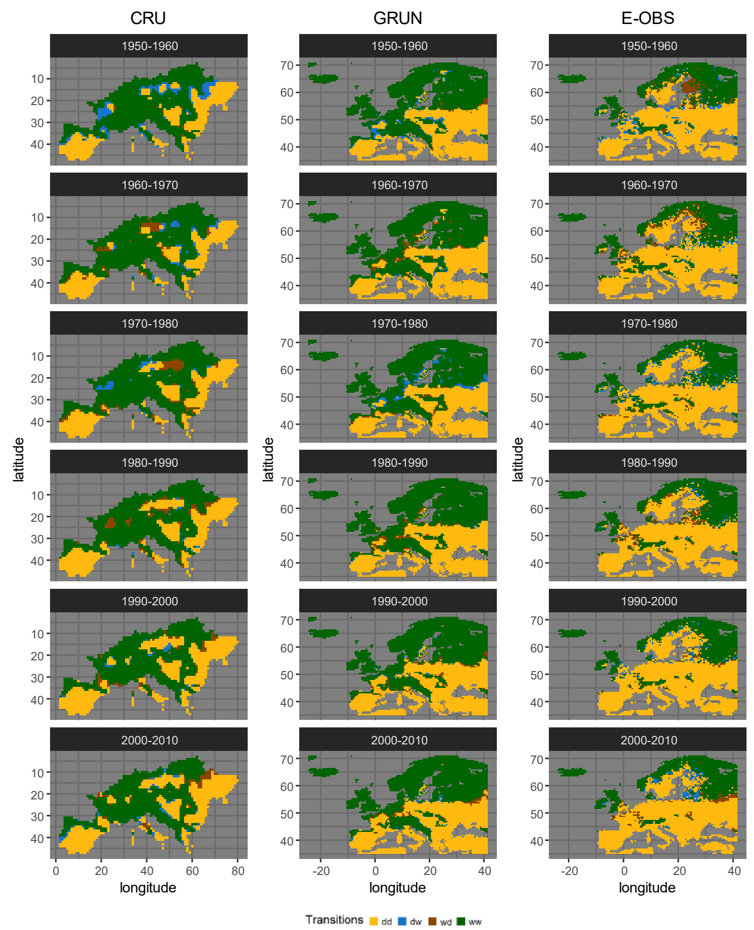

Fig 3: Left column: plotted transitions of 10-year periods of CRU data. Middle column: plotted transitions of 10-year periods of GRUN data. Right column: plotted transitions of 10-year periods of E-OBS data. All maps are drawn for the period 1950-2015 (excluding the last five years).

- transition to arid catchment, especially in recent decades
- the biggest changes in Central Europe

Plotted probabilities of 1-year MEAN data set transitions

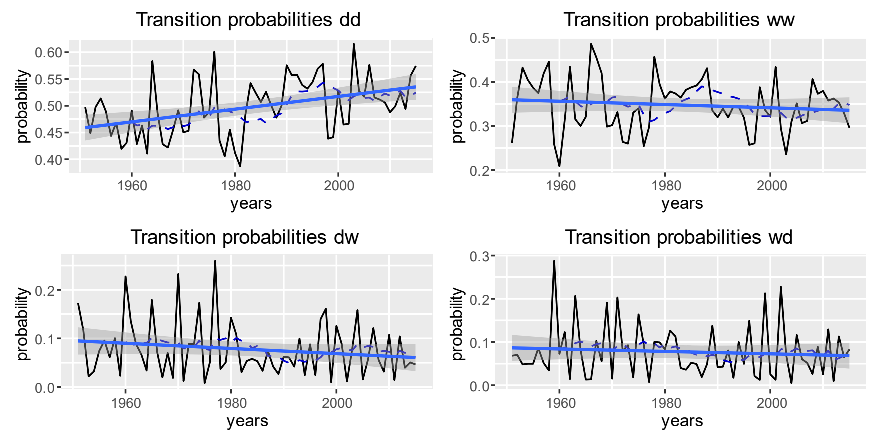

Fig 4: Plotted probabilities of one-year MEAN data set transitions, for the period 1950-2015

- "dd" increases, "ww" slightly decreases, "dw" and "wd" slightly decrease
- the decrease of "dw" and "wd" is caused by the transfer of gridpoints to the dry state, in which they already remain

Table of probabilities of MEAN transitions of the data set for individual 10-year periods

obd_10	dd_prob	dw_prob	wd_prob	ww_prob
1950-1960	0.5188	0.0370	0.0450	0.3992
1960-1970	0.5484	0.0154	0.0586	0.3776
1970-1980	0.5440	0.0630	0.0216	0.3715
1980-1990	0.5607	0.0049	0.0611	0.3734
1990-2000	0.5903	0.0315	0.0154	0.3628
2000-2010	0.5761	0.0296	0.0285	0.3658

Tab 1: Table of probabilities of MEAN transitions of the data set for individual 10-year periods for period 1950-2015 (excluding the last five years). The columns "dd_prob", "dw_prob", "wd_prob" and "ww_prob" show the probabilities of occurence of individual transitions for individual decade periods.

SUMMARY

- three data sets compared (Fig 3)
- large spatial uncertainty (Fig 3)
- the biggest changes are taking place in Central Europe (Fig 3)
- the probability of transition "dd" increases, "ww" slightly decreases (Fig 4, Tab 1)
- the probabilities of the "dw" and "wd" transitions slightly decrease (Fig. 4), which can be explained by the transition to a dry state, in which the gridbody already remains (Tab 1)
- most values of AI are located closely around identity (Fig 1)

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