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Variability of seasonal floods in the Upper Danube River basin

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Abstract: The objective of this study is to analyse the spatial variability of seasonal flood occurrences in the Upper Danube region for the period 1961-2010. The analysis focuses on the understanding of the factors that control the spatial variability of winter and summer floods in 88 basins with different physiographic conditions. The evaluation is based on circular statistics, which compare the changes in the mean date and in the seasonal flood concentration index within a year or predefined season.

The results indicate that summer half-year and winter half-year floods are dominant in the Alps and northern Danube tributaries, respectively. A comparison of the relative magnitude of flood events indicates that summer half-year floods are on average more than 50% larger than floods in winter. The evaluation of flood occurrence showed that the values of seasonal flood concentration index (median 0.75) in comparison to the annual floods (median 0.58) shows higher temporal concentration of floods. The flood seasonality of winter events is dominant in the Alps; however, along the northern fringe (i.e. the Isar, Iller and Inn River) the timing of winter half-year floods is diverse. The seasonal concentration of summer floods tends to increase with increasing mean elevation of the basins. The occurrence of the three largest summer floods is more stable, i.e. they tend to occur around the same time for the majority of analysed basins. The results show that fixing the summer and winter seasons to specific months does not always allow a clear distinction of the main flood generation processes. Therefore, criteria to define flood typologies that are more robust are needed for regions such as the Upper Danube, with large climate and topographical variability between the lowland and high elevations, particularly for the assessment of the effect of increasing air temperature on snowmelt runoff and associated floods.

Keywords: Seasonality; Summer and winter floods; Upper Danube River basin; Comparative hydrology.

INTRODUCTION

The growth of population and assets in flood prone areas has increased the impacts of floods, therefore flood management through mitigation, protection and damage control is becoming increasingly important (e.g. Di Baldassarre et al., 2014; Zeleňáková et al., 2011). One of the prerequisite of effective flood management is a sound understanding of the underlying flood processes in the region of interest. Recent severe floods worldwide have sparked a renewed interest in the analysis of long hydrological data to investigate the main drivers and patterns of flood regimes and their changes.

The Upper Danube region has been affected several times by extreme floods, most of which occurred in the summer season of the year. For example, major floods occurred in August 1897, September 1899, July 1954, August 2002, with the latest flood in late May and early June 2013 (e.g. Blöschl et al., 2013; Mitková et al., 2005; Pekárová et al., 2008, 2014).

As floods are generally not limited to a specific season, seasonality analysis can provide insight and explanations on regimes and drivers of the extreme events. This has been shown in various studies over both small and large river basins (e.g. Black and Werritty, 1997; Collins et al., 2014; Hlavčová et al., 2015; Koutroulis et al., 2010; Szolgayová et al., 2014) as well as over diverse geographical regions (e.g. Glaser et al., 2010; Parajka et al., 2009, 2010; Petersen et al., 2012). A summary of flood regimes and associated changes in Europe can be bound in Hall et al. (2014).

The seasonality of annual flood and precipitation maxima in the Alpine – Carpathian region has been analysed in several studies. For example, Merz et al. (1999) and Merz and Blöschl (2003) used flood seasonality as an indicator to describe different flood types based on the timing of floods. Beurton and Thieken (2009) analysed monthly frequencies of annual floods in Germany and divided the country into three regions based on the identified flood regime. Parajka et al. (2009 and 2010) applied a seasonality index to identify the main climatic and physiographic drivers behind the floods generating processes. Parajka et al. (2009) evaluated the differences in precipitation, long-term hydrological regime and annual floods along a transect from Austria to Slovakia. Parajka et al. (2010) then extended the analysis to the Alpine Carpathian range. The evaluation of annual flood seasonality in both studies demonstrated an important role of soil moisture, evaporation and snow processes on flood generation, but none of these studies analysed the summer and winter flood separately.

The aim of this study is to extend the analyses of previous studies and to explore the seasonal floods in the Upper Danube River basin. The main motivation is to evaluate and compare the seasonal flood concentration for winter (December–May) and summer (June–November) half-year. The analysis focuses on the understanding of the factors that control the spatial changes of winter half and summer half-year flood occurrences in 88 basins with different physiographic conditions.

The paper is organised as follows. First, we describe the methods applied for flood seasonality assessment. Next, we introduce the study region and the data used in the analysis. The results section compares floods in the summer and winter half-year and evaluates the temporal concentration seasonal floods. Finally, we discuss the factors that control the spatial patterns of the observed variability of seasonal floods in the Upper Danube basin.

METHODS AND DATA

Flood seasonality assessment

The analysis of flood seasonality is based on circular statistics (e.g. Bayliss and Jones, 1993; Burn, 1997; Magilligan and Graber, 1996). The date of each flood event is plotted on a unit circle, where the position of the event Θ_i is defined as:

$$\Theta_i = D\, 2\pi / Y, \tag{1}$$

where $D = 1$ is chosen for 1 January and $D = 365$ for 31 December (366 for leap years), Y is number of days in the year. The concentration of the date of occurrence around the mean date is represented by the length of vector r, which is defined as (Bayliss and Jones, 1993):

$$r = \sqrt{\bar{x}^2 + \bar{y}^2} \tag{2}$$

where the position of $\bar{x}$ and $\bar{y}$ coordinates represents the mean date obtained from the sample of n extreme events by following relationships:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n}\cos(\Theta_i) \tag{3}$$

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n}\sin(\Theta_i) \tag{4}$$

The length of vector r represents the concentration of the flood occurrences (referred to as ‘concentration index’ thereafter) and ranges from zero (high variability of the date of occurrence, low seasonality) to $r = 1$ (all flood events occur on the same day, low variability of the date of occurrence, high seasonality).

In order to investigate the influence of the magnitude of extreme events on the temporal flood concentration, the r index is estimated separately for all (r_{all}) values and for the three largest (r_3) seasonal maxima values. It is expected that higher value of r is obtained for r_3 in comparison with r_{all}, as less data is used and therefore the temporal concentration of floods can be expected to be higher.

To allow for the comparison of the magnitude of summer and winter flood discharges, the relative average discharge difference, Δ Q, is calculated:

$$\Delta Q = \frac{\Sigma Q_s^i - \Sigma Q_w^i}{\Sigma Q_w^i} \cdot 100\,, \tag{5}$$

where Q_s^i and Q_w^i are the summer and winter flood discharge maxima in year i, respectively.

Study area and data

The flood seasonality is evaluated for the Upper Danube River basin, which includes the region of the South Germany, the East part of Switzerland, Austria and Slovakia. The study area is characterised by large climate and topographical variability between the lowland areas of the Pannonia Plain and the highest elevations in the Alps and Western Carpathian Mountains. The Upper Danube basin is situated in a temperate climate zone at the border of the Atlantic and the Continental part of Europe. The mean annual temperature varies from about 10°C in the lowlands to less than –8°C in the Alps and –3°C in the Tatra Mountains. The mean annual precipitation also exhibits strong spatial variability. A general decrease of precipitation along the West to East gradient is imposed by an increase caused by orographic enhancement. The lowest precipitation occurs in the lowlands (less than 400 mm/year), while the largest precipitation totals occur on the highest windward slopes of the Alps (more than 3000 mm/year) and the Carpathian Mountains (more than 1,500 mm/year).

The flood seasonality is derived from daily runoff data provided by the Global Runoff Data Centre (GRDC, 2014). The dataset includes 88 stations (Figure 1), with less than 10% of missing data over the period 1961–2010. Part of the GRDC dataset for Slovakia was complemented with data from the Slovak Hydrometeorological Institute. The size of the river basins studied is up to 130,000 km^2, with 60 basins being smaller than 1,000 km^2. The mean basin elevation ranges between 217 to 1,598 m a.s.l. (Table 1). A table of all stations and with their basin characteristics (i.e. area, elevation, and location) is provided in Appendix 1 as Table A1.

The annual flood series at each station represent the largest flood events (in terms of peak discharge). For the seasonal analysis, the annual flood data at each station is split into half-years based on the expected timing of the flood generation processes in the analysed region. The seasonal flood maxima are derived in two steps. First, the date and half-year of annual maximum of daily runoff is determined for each year and station. In the second step, the runoff maximum in the other half-year is computed. In order to assure temporal independence between the summer half-year and winter half-year peaks, the individual peaks identified for each season had to be at least 30 days apart. This step is of particular importance for basins with an area larger than 1000 km^2, where summer-year and winter half-year flood events tend to occur in narrow time intervals. The seasonal flood series therefore represent the largest flood events (in terms of peak discharge) in the winter half-year (December–May) or the summer half-year (June–November) periods, respectively.

RESULTS

The fraction of winter and summer floods of the full annual maxima series (without splitting the data into winter and summer half-years) of each station is presented in Figure 1. There is a distinct difference between the ratio of seasonal annual floods in the upper part of Danube River together with its northern tributaries and the southern tributaries originating in the Alps. Winter floods are dominating at the tributaries of the Danube River from Germany and Western Carpathians, whereas annual summer floods are prevalent in the highest parts of the Upper Danube basin. Overall, annual summer floods account for the highest numbers of flood occurrences with 56% of all annual maximum floods in the entire study area occurring in the summer, and in the Alps, the annual summer floods account to 75%.

The map of the relative average discharge differences between summer and winter flood discharge maxima (calculated after equation 5) is shown in Figure 2. Discharge differences larger than 50% are found at 54 out of the 88 stations analysed.

At these stations, summer half-year floods tend to be noticeably larger than winter half-year floods. On the other hand, winter half-year floods are more than 20% larger than summer half-year floods for seven stations. At four stations (Kysucké Nové Mesto, Liptovský Mikuláš – Western

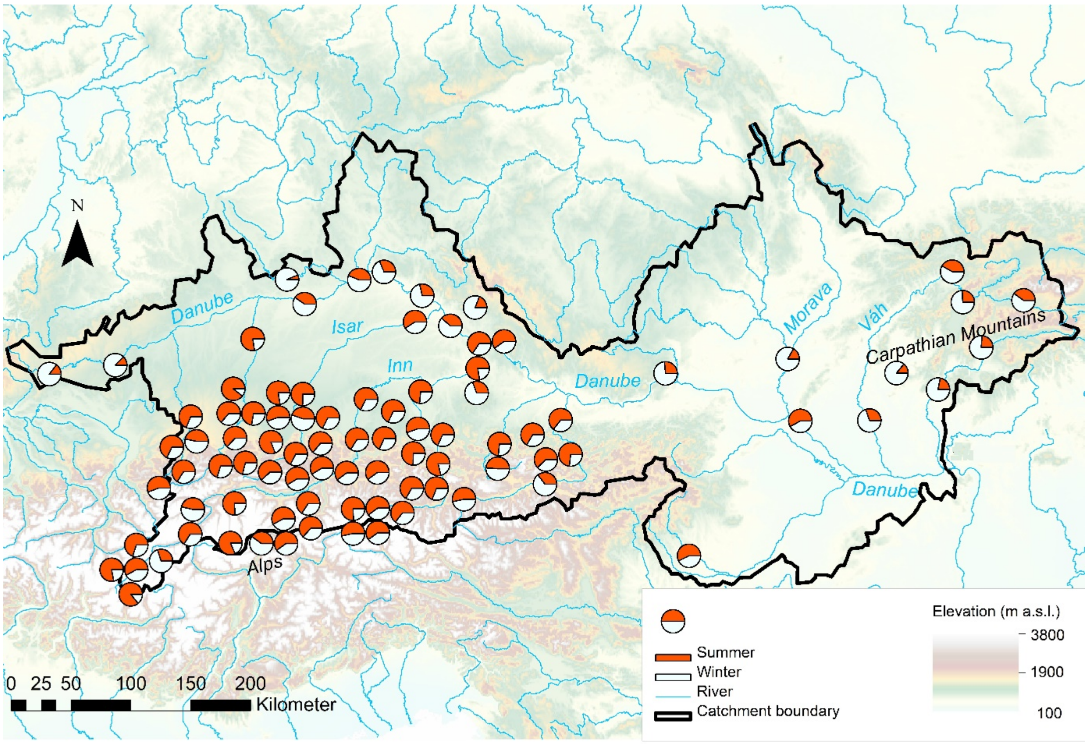

Fig. 1. Topography (m a.s.l.) and river network of the Upper Danube. Colours of the symbols indicate the ratio of summer (June–November) and winter (December–May) flood events in the annual maxima series. Symbol locations are spatially adjusted to their original location to avoid overlap.

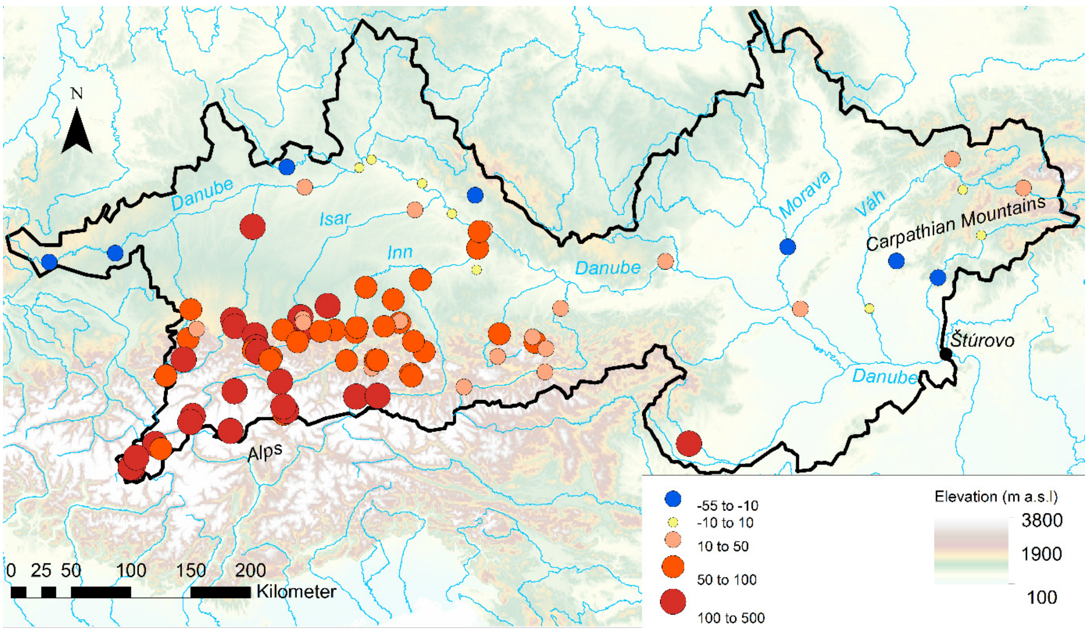

Fig. 2. Relative average discharge difference, Δ Q, between summer half (June–November) and winter half (December–May) flood peaks (%), (Eq. 1). Higher summer half-year flood events are plotted in red, higher winter half-year flood events in blue. Size of symbols indicates the absolute magnitude of the discharge differences.

Table 1. Characteristics of gauged basins based on sub-basins. 1. Danube to Inn (tributaries: Iller, Lech, Altmuhl, Isar), 2. Inn (tributaries: Salzach), 3. Danube to Štúrovo station (tributaries: Traun, Enns, Morava, Vah, Hron).

Sub-basin	Number of stations	Range of mean basin elevation (m a.s.l.)	Range in basin size (km^2)
Danube to Inn	29	480–1,700	8–76,653
Inn	40	389–2,912	6–47,496
Danube to Štúrovo	19	389–1,485	55–131,331

Carpathian Mountains, Imbach – Pannonian Plain and Wertach – Alps) the number of winter half-year floods is larger, but the flood discharges in summer are, on average more than 20% larger than those in the winter half-year are.

In Figure 3 the cumulative distribution functions (cdfs) of the flood concentration index for seasonal and annual floods is shown. The comparison of *rall* indicates that winter and summer floods have a similar temporal concentration for 70% of the stations. The seasonal concentration index of annual floods is generally lower than that of the seasonal flood series, as for the calculation of the concentration of the seasonal events the date of the occurrence is restricted to only half a year, resulting in a lower temporal variability of the date. The median of concentration index for winter and summer half-year (*rall)* is 0.74 and 0.75, respective-ly, compared to 0.58 for the annual flood series. There are 16 stations with winter *rall* larger than 0.90, whereas only two stations in the summer half-year obtain such high temporal The concentration. flood concentration for all floods (*rall*) is generally smaller compared to the three largest floods (*r3*). The median of r_3 for the summer half, winter half, and annual floods is 0.92, 0.90, and 0.82 respectively. These high values indicate that the largest events tend to occur in the same time of the year, while smaller events can occur throughout the winter half or summer half-year. The comparison of the cumulative distribution functions indicates that, in contrast to the r_{all} distributions, 20% of the stations have concentration of winter floods significantly lower than summer floods (i.e. r3 of lower 20% quantile for winter and summer floods equals 0.51 and 0.83, respectively).

Figure 4 shows the heterogeneous spatial patterns of r_{all} (top panels) and r_3 (bottom panels) values in the summer (left panels) and winter (right panels). The seasonal concentration index of all winter flood events (r_{all}) is the highest in the Alps. Along the northern fringe of the Alps at the Isar, Iller and Inn the timing of winter half-year floods is less concentrated. In contrast, the lowest r_{all} summer values are observed along the Bavarian Danube and left Danube tributaries including stations in the Morava, Váh and Hron River basins (spatial locations of the rivers see Figure 6). The seasonal concentration index of the three largest summer floods is higher, i.e. they occur within the same time of the year. For example, the three largest floods at Landau (r_3 = 0.84) occur only in June and August. The stations with lower values for winter r_3 partly coincide with stations that have also low r_{all} values; however, there are some stations in the Inn and Salzach basins, which have a low seasonal concentration index for the three largest floods. In the Western Carpathians the three largest floods are mostly dominating in the winter season, this is likely caused by a combination of snowmelt and rainfall. On the other hand, at some stations, the seasonal flood concentration index of the three largest winter floods is lower than that of all events.

It can be seen in Figure 4 that there is a considerable variability of flood occurrences not only in time but also in how this temporal variability manifests itself in space. To understand better the factors influencing the temporal spread of the flood events, the relationship of the flood concentration index and basin characteristics such as basin area and mean elevation is presented in Figure 5. The upper left panel indicates that the timing of winter and summer half-year maximum floods becomes more concentrated (larger values of *r*) with increasing elevation of the basins. Generally, basins with mean elevation above 1200 m a.s.l. have summer r_{all} larger than 0.7. The summer floods in low elevated basins have very low seasonal concentration index with r < 0.6, regardless of basin size. For all winter events (upper right panel), a well-defined seasonality is observed in basins with mean elevation above 1500 m a.s.l. This also applies to some larger basins (basin size > 1000 km^2) situated at mean elevations between 400 m and 800 m a.s.l. Overall, the seasonal flood concentration index for all flood events (r_{all}) seems to be stronger influenced by mean basin elevation and basin area compared to the r_3. The three largest events for summer and winter generally show a higher index but do not seem to be stratified by basin characteristics. The three largest events in winter (bottom right) tend to exhibit a lower flood concentration index than in summer for some specific stations, but for station in higher elevation the r_3 is higher or at least equal to summer. A distinct region can be identified in Figure 5 where the seasonality of the three largest winter floods are more spread in time than in other basins. The basins in this region are typically situated at elevations from 1000 to 1500 m a.s.l. and range from 20 to 1000 km^2 in size and are located in the Alps (at the border of Tirol and Salzburg in Austria, see Figure 4).

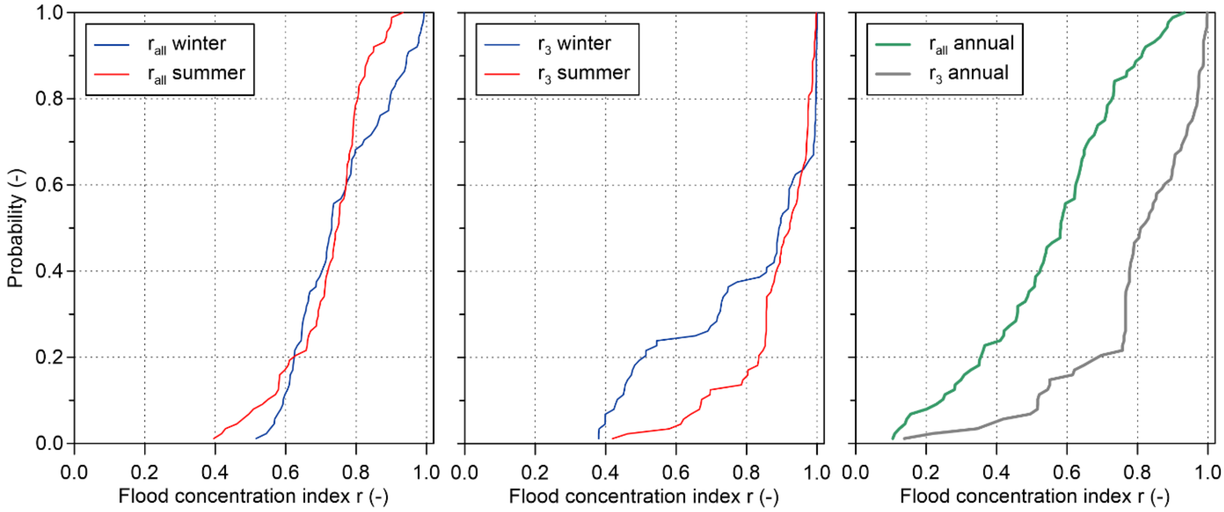

Fig. 3. Cumulative distribution functions of the flood concentration index *r* for winter (December–May), summer (June–November) half-year and annual flood events in the period 1961–2010. The flood concentration index is estimated for all (r_{all}) and the three largest floods (r_3).

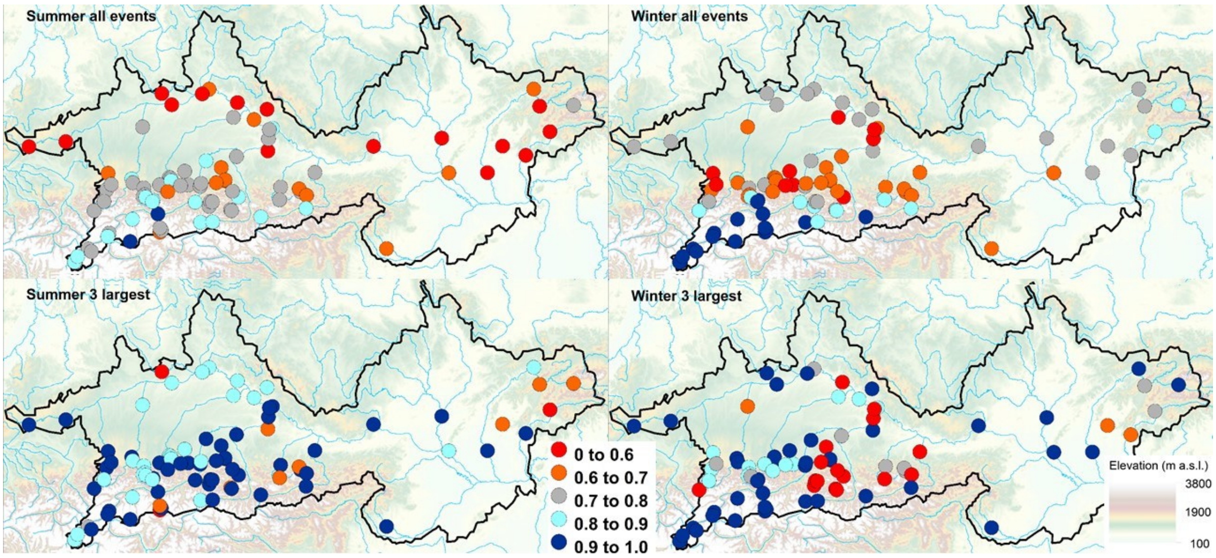

Fig. 4. Seasonal flood concentration index r, for all (r_{all}) (upper panels) and three largest flood events (r_3) (lower panels) in summer half-year (June–November) (left) and winter half-year (December–May) (right).

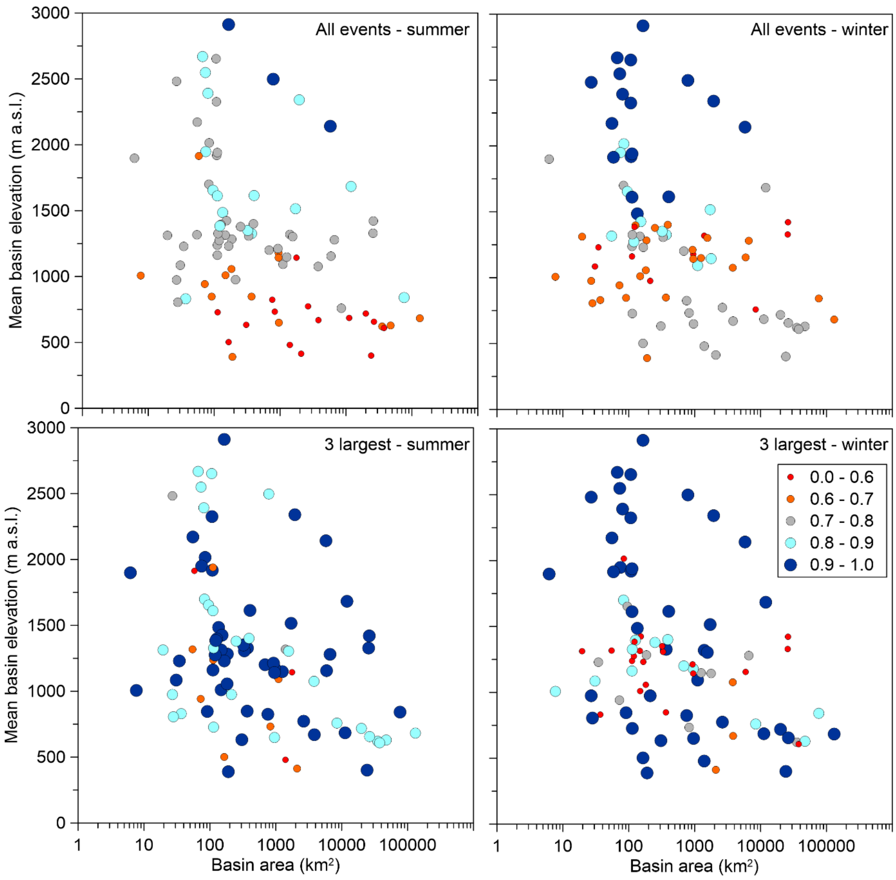

Fig. 5. Seasonal flood concentration index r, (values see legend) as a function of basin area and mean basin elevation for all events (r_{all}) (upper panels) and the three largest events (r_3) (lower panels) in summer half-year (June–November) (left) and winter half-year (December–May) (right).

The spatial patterns of the seasonal flood concentration index do not only depend on basin size and mean elevation (as shown in Figure 5), but also on river network topology and its spatial location and the choice of the months that constitute the winter and summer seasons. This can be seen in Figure 6, which shows the change in the seasonal flood concentration index along the Inn River and its tributaries. The top panel shows the location of the selected 14 stations along the river reach, the bottom panels show the dates of summer (left) and winter (right) half-year floods. Each line represents the date of occurrence of one seasonal flood in the period 1961–2010. The results indicate that, if one splits the year into December–May (winter) and June-November (summer) half-years, the winter floods in the upper part of the Inn (i.e. Inn above Innsbruck No. 6 in Fig. 6) have high seasonal flood concentration index and typically occur only in May. This can be explained based on the

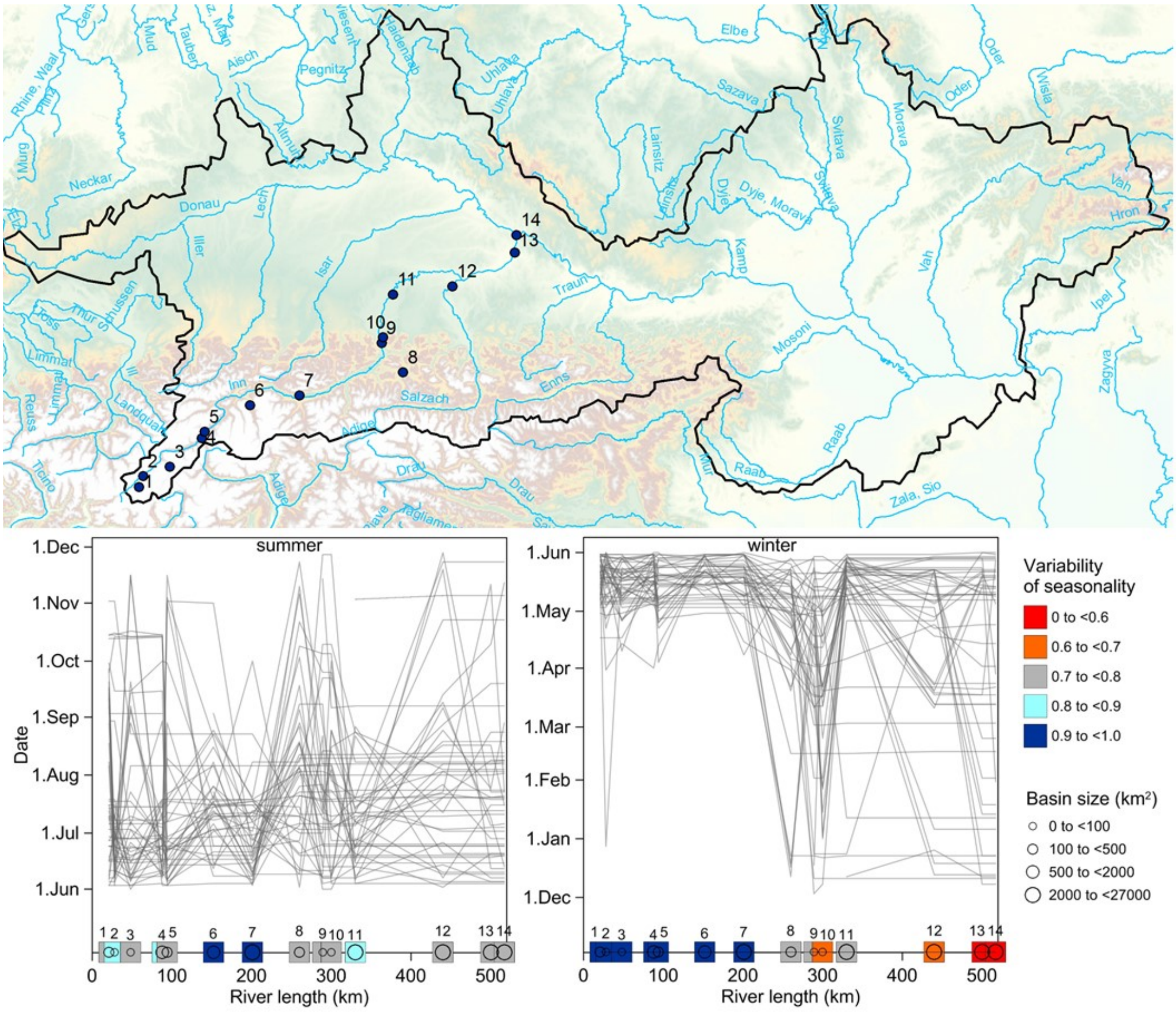

Fig. 6. Variability of flood seasonality expressed by seasonal concentration index along the Inn River, including tributaries, for summer half-year (June–November) (left) and winter half-year (December–May) (right). Each line represents one year from the period 1961–2010. The basins are listed in Table 2. The colour of the rectangles indicates the variability of seasonality, the size of the circles the basin size.

Table 2. Selected stations in the Inn River basin.

No.	GRDC ID	River name	Station name	Area (km^2)	Mean basin elevation (m a.s.l.)
1	6943150	Berninabach	Pontresina	107	2652
2	6943170	Chamuerabach	La Punt - Chamues	73.3	2549
3	6943115	Ova dal Fuorn	Zernez	55.3	2171
4	6943100	Inn	Martinsbruck	1945	2341
5	6243450	Schalklbach	Schalklhof	107.8	2325
6	6243400	Oetztaler Ache	Tumpen	785.5	2498
7	6243030	Inn	Innsbruck	5792	2142
8	6243201	Kitzbuehler Ache	St. Johann in Tirol	332.4	1307
9	6343510	Euzenauer Bach	Muehlhausen	6.2	1899
10	6343520	Steinbach	Nussdorf	28	806
11	6343100	Inn	Wasserburg	11983	1684
12	6343500	Salzach	Burghausen	6649	1280
13	6243850	Inn	Schaerding	25663.8	1329
14	6343900	Inn	Passau-Ingling	26084	1421

knowledge that due to the high elevation precipitation usually accumulates as snow between December and March/April, resulting in rare floods, whereas snowmelt and rain-on-snow processes can cause frequent flooding in May and subsequent months. The upper Inn also shows a well-defined flood seasonality in the summer half of the year. Summer half-year floods tend to be significantly larger (see Fig. 2) than winter floods and are caused mainly by synoptic precipitation, sometimes combined with the occurrence of high soil moisture due to late snowmelt. As elevations decrease downstream along the Inn, the flood generation processes become more variable. The Kitzbühler Ache, a tributary to the Inn (No. 8 in Fig. 6), shows a lower temporal flood concentration index for both, summer and winter half-year floods. The lower values for the flood concentration index continue in the lower lying areas until the Inn reaches the confluence with the Danube. The low seasonal concentration index is particularly evident for the winter half-year, where the timing of the snowmelt is predominately controlled by the elevation of the contributing basin, but is also visible in the summer half-year, where several flood-generating processes are mixed.

DISCUSSION AND CONCLUSIONS

This study analyses the variability of floods in the Upper Danube basin for the winter and summer half-year. In addition to previous studies on the flood seasonality of that region, the emphasis is placed on whether the variability of flood seasonality of winter and summer floods is different from that of annual floods, and on which factors can control the spatial pattern detected.

When comparing the results with the assessment of annual floods in Parajka et al. (2009, 2010), it becomes clear that extending the dataset spatially by including a recent decade of flood observations does not change the overall spatial patterns of annual flood seasonality. Summer half-year floods (June–November) tend to dominate in the Alps, while winter half-year floods (December–May) are more frequent in the pre-alpine, low-elevation areas of Southern Germany and Slovakia.

The general pattern of increasing seasonal flood concentration index with increasing mean basin elevation (Figure 5) is consistent with results in Parajka et al. (2009), and stronger summer flood seasonality in basins with mean elevations above 1200 m a.s.l. is also found. These stations belong mainly to Eastern Switzerland, Northern lower Alpine region in Austria, South-Eastern part of Austria, which coincides with Group 1 of the flood regime cluster defined by Parajka et al. (2010) and Flood Regime Cluster C determined by Beurton and Thieken (2009). In Group 1, the main flood generation processes are characterized by extreme rainfall and floods in summer. On the other hand, a high flood concentration index in winter is observed in basins with mean elevation below 1500 m a.s.l., in the pre-alpine region of Southern Germany and in basins in the central Carpathians. These regions (Group 2, 4 and 8 based on the classification of Parajka et al. (2010)) are characterized by a mix of different weather patterns and are typically located in hilly regions, at lower elevations than Group 1. Wet soils in winter are typically responsible for so called ‘Christmas floods’ in the pre-alpine region of Southern Germany (Sui and Koehler, 2001) mainly due to low evaporation, snow cover and frequent rain-on snow events.

The evaluation of the flood seasonality along the Inn River shows that decreasing basin elevation coincides with a decrease of the seasonal flood concentration index throughout the year. This decrease propagates to lower elevations and further downstream. The analysis along the Inn River also indicates that splitting the year into fixed summer and winter periods (here June-November and December-May respectively) does not always allow a clear distinction of the main flood generation processes, which would be important for identifying snowmelt. Therefore, criteria to define flood typologies that are more robust are needed. This is of particular importance for regions that require the assessment of the effects of increasing air temperatures on snowmelt runoff and floods, as the timing of snowmelt is strongly dependent on the basin elevation, which makes it difficult to discern a fixed summer, and winter period that could satisfy the requirements of all stations.

Additionally, in order to follow the lines of reproducibility and repeatability of experiments advocated by Ceola et al. (2015), our analysis is based on the publicly available open runoff dataset (see Table A1) maintained by the Global Runoff Data Centre in Koblenz. Our results and tools used in the seasonality assessment will be published in the Virtual Water-Science Laboratory, established in the context of the EU funded research project “Sharing Water-related Information to Tackle Changes in the Hydrosphere – for Operational Needs (SWITCH-ON)”, (http://www.water-switch-on.eu/). Virtual laboratories are fundamental prerequisites that allow researchers to validate results and share hydrological knowledge, experience and expertise in the light of global water management problems Ceola et al. (2015). In the future, we plan to analyse the change of seasonality and flood magnitude across different transect in Europe. The assessment of frequency and seasonality of flood peaks that exceed a threshold (not just annual flood peak maximum) will allow more robust interpretation of flood regime and its change in Europe.

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APENDIX

Table A1. List of GRDC stations used in analysis. Time series extended by using Slovak Hydrometeorological Institute data are marked by * next to the station name.

GRDC ID	River name	Station name	Area (km^2)	Station elevation (m a.s.l.)	Mean basin elevation (m a.s.l.)	LAT	LON
6142150	Morava	Moravsky Jan	24129	146	400.681	48.6027	16.9386
6142200	Danube	Bratislava*	131331	128	682.499	48.1402	17.1096
6142520	Nitra	Nitrianska Streda*	2094	158	413.335	48.5244	18.1741
6142551	Kysuca	Kysucke Nove Mesto*	955	346	649.728	49.2978	18.786
6142620	Vah	Sala*	11218	109	685.725	48.1617	17.8834
6142640	Turiec	Martin*	827	390	733.071	49.0694	18.9125
6142650	Hron	Banska Bystrica*	1766	334	1143.49	48.73	19.13
6142660	Hron	Brehy*	3821	195	669.532	48.4072	18.6478
6142680	Vah	Liptovsky Mikulas*	1107	568	1092.626	49.0873	19.606
6242020	Lech	Lech (Tannbergbruecke)	84.3	1437.48	2015.461	47.21	10.14
6242200	Ilzbach	Neudorf bei Ilz	190.1	277.85	389.076	47.0828	15.9436
6242250	Enns	Steyr	5915.4	283.97	1154.973	48.0394	14.4267
6242251	Enns	Altenmarkt im Pongau	134.5	838.96	1485.326	47.3828	13.4258
6242260	Steyr	Kniewas	184.9	468.61	1283.204	47.7653	14.1706
6242270	Steyrling	Steyrling	72.4	497.67	941.52	47.8031	14.1386
6242281	Teichlbach	Teichlbruecke	148.6	571.19	1010.712	47.7236	14.2964
6242290	Paltenbach	Selzthal	368.7	632.93	1326.636	47.5483	14.3061
6242420	Krems	Imbach	305.9	230.4	633.32	48.4458	15.5681
6242600	Traun (trib. Danube)	Ebensee	1257.6	422.98	1148.502	47.8061	13.7675
6242610	Altausseer Traun	Altaussee (Traun)	54.5	709.47	1317.387	47.635	13.7681
6243030	Inn	Innsbruck	5792	565.95	2142.115	47.2761	11.3969
6243110	Venter Ache	Vent	164.7	1877.08	2912.293	46.8628	10.9186
6243200	Kitzbuehler Ache	Kitzbuehel (Bahnhofsbruecke)	153	736.29	1424.357	47.4553	12.39
6243201	Kitzbuehler Ache	St. Johann in Tirol	332.4	649.88	1306.977	47.52	12.4192
6243210	Aschauer Ache	Sperten	147.4	668.97	1314.729	47.52	12.4031
6243220	Fieberbrunner Ache	Almdorf	165.3	660	1230.554	47.5197	12.4425
6243230	Leoganger Ache	Uttenhofen	112.3	719.2	1237.647	47.4414	12.8197
6243235	Urslaubach	Saalfelden	119.5	730.2	1274.607	47.4281	12.8389
6243260	Obersulzbach	Sulzau	80.7	882.2	2391.134	47.23	12.25
6243270	Felber ache	Haidbach	74.5	888	1948.421	47.2531	12.4864
6243300	Brixentaler Ache	Bruckhausl	322.3	590	1351.081	47.4911	12.1044
6243350	ObernbergerSeebach	Gries am Brenner	58.3	1177.65	1913.823	47.0369	11.4794
6243355	Schmirnbach	St. Jodok am Brenner	108.8	1099.23	1919.395	47.0631	11.5003
6243360	Gschnitzbach	Steinach am Brenner	111.4	1041.84	1940.225	47.0933	11.4658
6243400	Oetztaler Ache	Tumpen	785.5	923.95	2498.263	47.1633	10.9108
6243450	Schalklbach	Schalklhof	107.8	983.19	2325.504	46.9381	10.49
6243800	Antiesen	Haging	164.9	378.67	502.341	48.2736	13.4511
6243850	Inn	Schaerding	25663.8	299.8	1328.968	48.4361	13.4417
6342200	Iller	Kempten	954.6	656	1177.97	47.732	10.317
6342210	Osterach	Reckenberg	126	768	1395.742	47.51	10.33
6342220	Traufbach	Spielmannsau	82.8	1000	1699.8	47.35	10.31
6342500	Danube	Ingolstadt	20001	360	718.591	48.754	11.422
6342510	Lech	Augsburg Wertach	3800	456.78	1075.742	48.4105	10.8896

GRDC ID	River name	Station name	Area (km^2)	Station elevation (m a.s.l.)	Mean basin elevation (m a.s.l.)	LAT	LON
6342512	Lech	Lechbrueck	1713.9	721	1515.68	47.6975	10.8006
6342520	Altmuehl	Eichstaett	1400	84	479.596	48.887	11.1946
6342530	Wertach	Wertach	34.5	909	1229.229	47.59	10.41
6342540	Trauchgauer Ache	Trauchgau	26.9	786	974.457	47.65	10.83
6342570	Ammer	Oberammergau	113.6	830	1326.328	47.6	11.06
6342600	Danube	Regensburg/Schwabelweis	35399	324.49	620.714	49.018	12.144
6342800	Danube	Hofkirchen	47496	299.6	629.31	48.676	13.116
6342900	Danube	Achleiten	76653	287.7	840.652	48.582	13.504
6342910	Danube	Oberndorf	26448	331.15	655.775	48.947	12.015
6342920	Danube	Pfelling	37687	308.16	608.161	48.88	12.747
6342925	Isar	Landau	8467	333.65	759.131	48.6774	12.6945
6342926	Isar	Lenggries	1402.73	670	1318.577	47.6849	11.5732
6342927	Isar	Bad Toelz	1558.8	631	1302.682	47.7801	11.5418
6342928	Isar	Mittenwald-Karwendelsteg	404	904	1614.281	47.45	11.27
6342930	Loisach	Kochel	684.9	596	1200.523	47.6667	11.3645
6342931	Loisach	Garmisch UDP	393.5	686	1401.032	47.51	11.09
6342932	Loisach	Garmisch ODP	250.2	711	1378.952	47.4843	11.0649
6342935	Partnach	Partenkirchen	95.4	730	1654.708	47.48	11.12
6342940	Ellbach	Bad Toelz	19.5	678	1312.831	47.77	11.57
6342945	Gaissach	Gaissach	36.8	660	830.595	47.74	11.58
6342947	Schronbach	Sylvenstein	7.7	787	1006.222	47.59	11.54
6342950	Leutascher Ache	Mittenwald	111.6	936.7	1612.744	47.43	11.26
6342960	Mitternacher	Eberhardsreuth	113	434	727.224	48.83	13.36
6342970	Danube	Hundersingen	2647.01	542.53	773.158	48.0725	9.3963
6342980	Danube	Kirchen-Hausen	759.88	657.34	825.203	47.93	8.68
6343100	Inn	Wasserburg	11983	430	1684.261	48.059	12.233
6343110	Leitzach	Erb	211.6	540	975.081	47.8881	11.831
6343111	Leitzach	Stauden	111.7	748	1161.991	47.71	11.9354
6343120	Rottach	Rottach	30.7	727	1086.135	47.69	11.78
6343500	Salzach	Burghausen	6649	352	1280.166	48.159	12.834
6343510	Euzenauer Bach	Muehlhausen	6.2	473	1898.669	47.71	12.17
6343520	Steinbach	Nussdorf	28	535	805.694	47.75	12.18
6343530	Traun (trib. Inn)	Stein	367.4	493	848.698	47.99	12.55
6343535	Weisse Traun	Siegsdorf	182	598	1056.95	47.82	12.65
6343537	Rote Traun	Wernleiten	91.2	598	846.844	47.83	12.65
6343555	Ramsauer Ache	Ilsank	122.5	576	1384.664	47.62	12.95
6343560	Saalach	Unterjettenberg	927.3	494	1212.687	47.69	12.82
6343570	Tiroler Achengrossache	Staudach	951.9	532	1142.793	47.78	12.48
6343900	Inn	Passau-Ingling	26084	289	1421.271	48.562	13.443
6943100	Inn	Martinsbruck	1945	1035	2341.024	46.89	10.47
6943110	Ova da Cluozza	Zernez	26.9	1509	2482.222	46.69	10.12
6943115	Ova dal Fuorn	Zernez	55.3	1707	2171.362	46.66	10.19
6943150	Berninabach	Pontresina	107	1804	2651.969	46.49	9.91
6943160	Roseggbach	Pontresina	66.5	1766	2669.574	46.49	9.89
6943170	Chamuerabach	La Punt - Chamues	73.3	1767.98	2548.92	46.5693	9.936