EGU 2009 HS-5.15 'Large-scale hydrology: understanding and predicting hydrological variations' 20-24 April 2009, Vienna, France

WATCH Water and Global Change · cost · CEH Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL

Is flood occurrence in Europe linked to specific atmospheric circulation types?

Christel Prudhomme & Marie Genevier - Centre for Ecology and Hydrology, Wallingford, OX108BB, UK, chrp@ceh.ac.uk

Aims and Objectives

Flood occurrence has been linked to some large-scale circulation classification in Arizona [1] but previous work has largely focused on small regions and analysed such links at the catchment level. This pan-European study evaluates

(1) if such links exist anywhere in Western Europe,
(2) if some weather types are associated to large-scale floods and
(3) if results depend on the classification algorithm.

The work was undertaken under the EU-funded project WATCH '*Water and Global Change*' (http://www.eu-watch.org) and forms part of the activities of the EU COST-733 action '*Harmonisation and applications of weather type Classifications for European Regions*' (http://www.cost733.org/).

The existence of significant relationships would show the hydrological relevance of the corresponding classification. This could be exploited by using the same algorithms to derive Weather Types (WT) from GCM outputs and anticipate large-scale floods as a seasonal time frame or evaluate changes in flood risk at a future multi-decadal time horizon.

Data

Daily flow series from over 400 catchments were considered (**Figure 1**). Data was obtained from the FRIEND European Water Archive, the Global Runoff Data Centre, the UK National River Flow Archive and the French Banque HYDRO archives. They are all gratefully acknowledged.

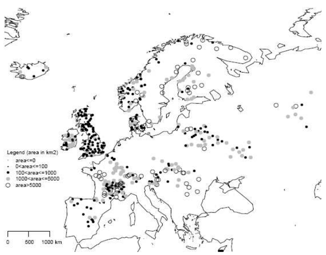
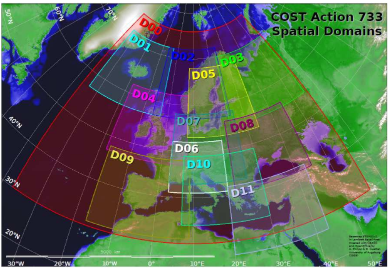


Figure 1. Location of gauging stations of catchments analysed in this study. The size and type of symbols show the catchment areas.

Figure 2. Spatial domains of the weather types and circulation classifications developed within the COST action 733



The weather types and circulation catalogues developed within COST733 were used. They are defined following 27 different weather type classification methods [2], applied in various setups. 21 of the methods used are derived automatically, the remaining 6 classifications are subjective originally developed for specific regions, but included for reference. The dataset used in this study consists of 64 daily catalogues, all estimated using data from ERA-40 over the entire European domain (Domain 0, 30N-76N and 37W-56E, **Figure 2**) and includes and objective version of the Grosswetterlagen by Hess and Brezowsky classification, separately analysed here.

Methods

For each catchment, flood events were identified following the Peak-over-Threshold method [3], where all the largest independent mean daily flows recorded above a fixed threshold are sampled. This threshold is defined for each catchment so that an average of 3 peaks per year is selected for each flood series.

Three hypothesis were tested and their significance level evaluated:

• *PI*1: Is a weather type occurring more frequently during a flood event than usual?

$$PI1_{WT_i,season} = 100 * \left(\frac{n\ day_{season}\ Flood\ with\ WT_i\ /\ n\ day_{season}\ Flood}{n\ day_{season}\ with\ WT_i\ /\ n\ day_{season}} - 1\right)$$

• *PI*2: Is the persistence of a weather type followed by a flood event?

$$PI2(i) = pr(WT = i \ \ for \geq k\ days, 0 \leq k \leq N^*)$$

*PI*2 is compared to the binomial probability of at least *k* days in *N** of *WTi* from historical occurrence frequencies.

• *PI*3: Is the same weather type showing the strongest association with flood occurrence across the whole domain?

For each classification, *WTi* are ranked according to their *PI1* or *PI2* values and the average of the highest rank of all catchments calculated. *PI3* measures how consistent is the flood discrimination power of the classification.

$$PI3_{PI1,season} = \frac{\overline{Max(Rank_{PI1,WTi,season})}}{NbClasses}$$

For each station, a catalogue of flood event was constructed, the weather type associated with each event and up to *N** preceding days identified and *PI*1 and *PI*2 calculated.

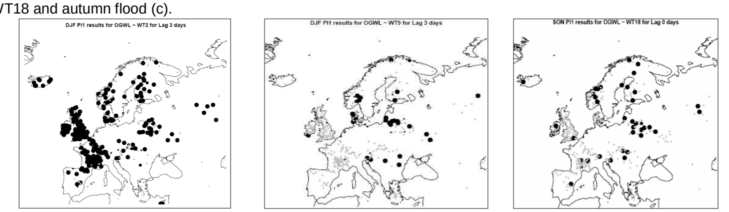
Results – Objective Grosswetterlagen

Each indicator was calculated for the day of the flood and for up to 10 days before the flood. Evaluation of the indicators was done for the whole flood series, as well as for separate seasons.

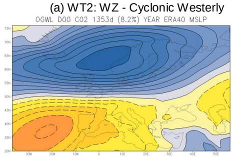
For each indicator and time lag considered, results are displayed on maps showing, for a given *WT*, the associated indicator value (size of dots) and level of significance (colour). The Pan-European relevance of a weather type is assessed by histograms of the percentage of stations falling into a certain bracket value.

• *PI*1: Is a weather type occurring more frequently during a flood event than usual?

Figure 3 illustrates *PI*1 for winter for three WTs of the objective Hess-Brezowksy classification (OGWL) derived from ERA-40 re-analyses developed within the COST733 [4]. For the great majority of stations analysed, WT2 occurs in winter more often during 3 consecutive days before a flood event than on any other period (a). At the opposite, there is no significant association between WT9 and winter flood occurrence (b) or WT18 and autumn flood (c).



(a) WT2: WZ - Cyclonic Westerly (b) WT9: HM - High over Central Europe (c) WT18: NEA - Anticyclonic North-Easterly



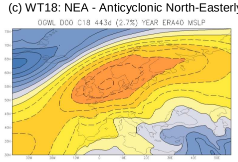
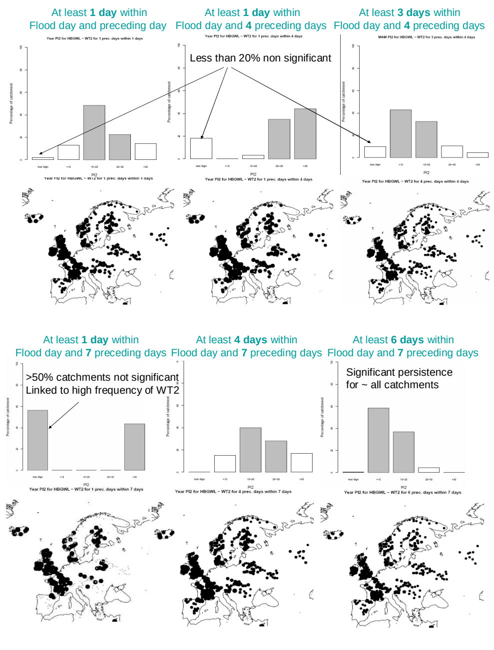


Figure 3. *PI*1 for WT2 (a), WT9 (b) & WT18 (c) of the OGWL occurring in the 3 days (a and b) before a winter flood event or the day of an autumn flood. Black dots show significant results, grey dots show stations where the frequency anomaly is not significant. The composite maps of the sea level pressure anomalies show that low pressure systems centred over northern Europe are generally associated with WT2 (WZ cyclonic westerly of H-B, generally associated with winter flooding NW Europe and in the Alps). In contrast, anticyclonic conditions prevail for WT18, which corresponds to the Anticyclonic North-Easterly type of HB, generally described as with no associated flooding.

• *PI*2: Is the persistence of a weather type followed by a flood event?



PI2 is a measure of the probability of occurrence of a given weather type, conditional to the occurrence of a flood, and its significance is compared to the binomial probability of this weather type. **Figure 4** shows how important the persistence of WT2 is to flood occurrence. For a window of 4 days preceding a flood event, the conditional probability *PI2* (*PI2 with* N* = 4 days) is significantly larger than would be expected by chance for over 80% of the catchments. When the explored window increases, the conditional probability associated with flood events first reduces as WT2 is a relatively common type not always occurring during flood, but when this weather type persists (at least 4 or 6 days in a 7-days window before a flood), the conditional probability to be associated with flood is significant for virtually all catchments: WT2 occurred at least 4 or 6 times in a period of 7 days before a winter flood event, and more often in this season than would be expected by chance alone.

Figure 4. Maps of *PI2* assessing the occurrence of WT2 (OGWL) for several persistence, and histograms of *PI2* over the domain for the same persistence. Same key as **Figure 3**.

Comparison of classification methods

A summary measure was calculated to compare the strength of links between weather-type and flood occurrence for different catalogues. *PI3* was calculated for the 64 catalogues for up to 10 days before the flood using *PI1*. *PI3* is equal to 1 when the same weather type is associated with the highest *PI1* for all the considered catchments, and its value increases when the largest *PI1* is associated with different *WTi* across Europe. A low *PI3* indicates the existence of the same weather type associated with flood occurrence at a pan-european level.

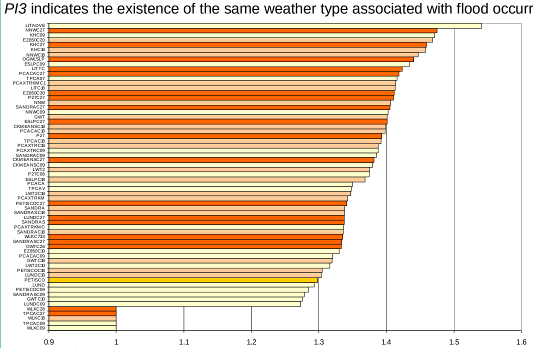
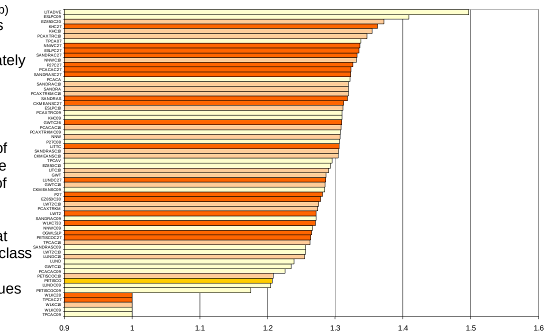


Figure 5. *PI3* derived from *PI1* over the whole year for a 1-day (a) and 10-day (b) window (x-axis). The colour of bars indicates the number of classes of the classification, the darker the colour the higher the number of classes. The abbreviated name of the catalogue is given in the y-axis



Amongst the considered catalogues, some algorithms were used to produce classification with approximately 9, 18 and 27 classes to investigate the effect of class number on the discriminatory power of a classification. The number of classes of the catalogues are represented by the colours of the bars of **Figure 5**.

Preliminary analysis on *PI3* derived from *PI1* showed that no strong impact due to the class number was discernable. However, the lowest *PI3* values tend to correspond to classifications with 9 to 18 classes, regardless of the persistence duration considered. Interestingly, the OGWL does not appear to provide the most spatially consistent results.

Conclusion

The study investigated whether links between specific weather types and flood events could be identified, and if the same weather type was associated with flooding at the pan-european level.

Using the Objective version of the well-known Hess-Brezowsky Grosswetterlagen classification, evidence was found that some weather types are consistently associated with the occurrence of flood (WT2, corresponding to the Clyconic Westerly type of H-B) and some others virtually never occur during flood events (e.g. WT18, or Anticyclonic North-Easterly). From those results, there is evidence that the increase of OGWL-WT2 occurrence in the future might be associated with higher flood risk in Europe.

The discriminatory power of different classification algorithms at the pan-european level was compared using a summary index calculating if a single weather type has the best flood association throughout Europe. Preliminary results indicate that the effect of the class number is small, but best results are obtained for catalogues with small number of classes. No classification technique (e.g. k-means, hierarchical clustering, PCA, threshold-based, neural-network) was found to consistently outperform others.

The results obtained are promising, but further research is needed in particular to test seasonality and persistence of weather types. Indices such as the brier-score might also be considered.

References

[1] Duckstein L, Bardossy A, Bogardi I (1993) Linkage between the occurrence of daily atmospheric circulation patterns and floods: an Arizona case study. Journal of Hydrology 143:413-428
[2] Philipp A., J. Bartholy, C. Beck, M. Erpicum, P. Esteban, X. Fettweis, R. Huth, P. James, S. Jourdain, F. Kreienkamp, T. Krennert, S. Lykoudis, S. Michalides, K. Pianko, P. Post, D. Rassilla Álvarez, R. Schiemann, A. Spekat, F. S. Tymvios (2009): COST733CAT - a database of weather and circulation type classifications. Physics and chemistry of the Earth (submitted)
[3] Bayliss AC, Jones RC (1993) Peaks-over-threshold flood database: summary statistics and seasonality, Vol 121. Institute of Hydrology, Wallingford
[5] James PM (2007) An objective classification method for Hess and Brezowsky Grosswetterlagen over Europe. Theoretical and Applied Climatology 88:17-42

Global Runoff Data Centre (http://grdc.bafg.de/)
European Water Archive (http://ewa.bafg.de/)
UK National River Flow Archive (http://www.ceh.ac.uk/data/nrfa/index.html)
Banque Hydro, France (http://www.hydro.eaufrance.fr/).