COST 733 mid-term Conference, 22-24 October 2008, Krakow, Poland

Hydrological applications in COST 733

Christel Prudhomme[1], Anne K. Fleig[2], Reinhard Schiemann[3], Christoph Frei[3], Lena M. Tallaksen[2] & Hege Hisdal[2]

[1] Centre for Ecology and Hydrology, Wallingford, OX108BB, UK, chrp@ceh.ac.uk; [2] Department of Geosciences, UiO, P.O.Box 1047, Blindern, 0316 Oslo, Norway, a.k.fleig@geo.uio.no
[3] Federal Office of Meteorology and Climatology MeteoSwiss, Krähbühlstrasse 58, 8044 Zurich, Switzerland, reinhard.schiemann@meteoswiss.ch

Flood flow occurrence (CEH)

Aims and Objectives

Flood occurrence has been linked to weather types of the Grosswetterlagen classification (manual classification) in Germany [1]. 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, using the objective classifications developed within COST733. 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 flood probability at a future multi-decadal time horizon.

Data and methods

Daily flow series from over 400 catchments where obtained from the EWA, BRDC, NRFA & HYDRO archives. Flood events were identified following the Peak-over-Threshold method [2] (average of 3 peaks per year). Two 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?

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

PI2 is compared with the binomial probability of at least *k* days out of *N** of *WTi* using historical frequencies of occurrence. Here *N** = 10 days . 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

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.

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

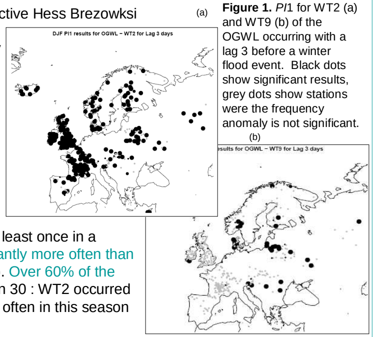


Figure 1. *PI*1 for WT2 (a) and WT9 (b) of the OGWL occurring with a lag 3 before a winter flood event. Black dots show significant results, grey dots show stations were the frequency anomaly is not significant.

Figure 2 shows that all over Europe (a) WT2 occurred at least once in a window of 7 days before a winter flood event and significantly more often than would be expected by chance (*PI*2 *with* N* = 7 days, k=1). Over 60% of the tested sites have a conditional probability *PI*2 greater than 30 : WT2 occurred more than 30% of the time before a flood event (b), more often in this season than would be expected by chance.

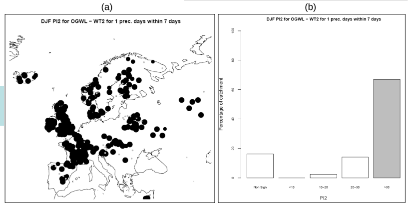


Figure 2. Map of *PI*2 assessing the occurrence of WT2 (OGWL) at least once during the 7 days before a winter flood event (a), and percentage of catchments with *PI*2 greater than 30 (b). Same key as Figure 1.

Conclusion

The results presented were obtained with OGWL and investigated possible association of some Weather Types with the occurrence of large floods in Europe. Evidence was found that, in winter, WT2 occurs more often before a flood than the rest of the time and when a flood occurred, more than 30% of the time WT2 occurred at least once in the 7 days preceding the flood, more often than expected from chance alone. The increase of WT2 occurrence in the future might thus be associated with higher flood risk in Europe. Further research is needed to test other classifications, and to evaluate if at the opposite, some WT never precede a flood (e.g. WT9), which could suggest lower flooding risk if their occurrence increases.

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] Bayliss AC, Jones RC (1993) Peaks-over-threshold flood database: summary statistics and seasonality, Vol 121. Institute of Hydrology, Wallingford
[3] 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/servlet/is/Entry.987.Display/)
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/).

Hydrological drought (UiO)

Aims and Objective

In addition to flood, drought is the other hydrological extreme that can cause severe problems. Droughts are slowly developing and severity increases with increasing duration and extend. By identifying weather types (WT) which contribute to the development of droughts, hydroclimatological processes leading to severe hydrological droughts can be studied. The objective of this study is to compare objective weather type classifications (WTCs), with respect to analyzing links between weather types and hydrological drought in north-western Europe. The inter-comparison considers (1) classification algorithm, (2) input variables and (3) number of defined WTs.

Data

Regional hydrological drought: Daily Regional Drought Area Index series (RDAI; 1964–2001) for four regions in Great Britain and two in Denmark [1].

RDAI:
- based on at-site drought series derived from streamflow records [2];
- represents the proportion of the total drought-affected catchment area within a region.

Drought: - defined as RDAI > 0.7.

Regional hydrological drought characteristics: vary between the regions, e.g.
- short but frequent droughts (Scotland, GB1),
- few but long droughts (southern and central England, GB4; Figure 1).

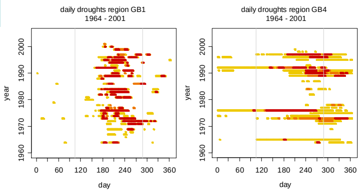


Figure 1 Regional drought development in regions GB1 and GB4; Red: $0.7<RDAI\leq1$; Orange: $0.5<RDAI\leq0.7$; Yellow: $0<RDAI\leq0.5$.

Weather Type Classifications: Daily catalogues of the 71 automatic WTCs from COST733 [3] and the subjective Hess-Brezowsky Grosswetterlagen (HBGWL [4]) are used:
- 24 different classification algorithms;
- one or two sets of input variables (SLP as common one);
- different numbers of WTs (approx. 9, 18 and 27).

Method

Identification of WTs, which may be associated with the development of hydrological drought (for each region):

I: Frequencies of WTs prior to and during the five most severe droughts events ($F_{e,WT}$) are compared to the normal frequencies of the weather type during the same period of the year for 1961–2001 (F_{WT}),

- WTs with $\mu FA_{WT} = \frac{1}{5}\sum_{e=1}^{5}\frac{F_{e,WT} - \mu F_{e,WT}}{\sigma F_{e,WT}} > 0$ are selected as group WT_{pos}.
- Duration of the considered period depends on the regional drought characteristics, (d_{region} = 30 to 180 days).

II: Correlation analyses for the summer period only (16 April – 15 October) between WT_{pos}-frequencies (total of all WTs in WT_{pos}) and drought to compare WTCs:
- daily: moving d_{region}–day sums of WT_{pos}-frequencies; and daily RDAI;
- seasonal: total summer WT_{pos}-frequencies; and the number of drought days during the summer (for GB4 WT_{pos}-frequencies during the summer + the previous winter are used).

Results

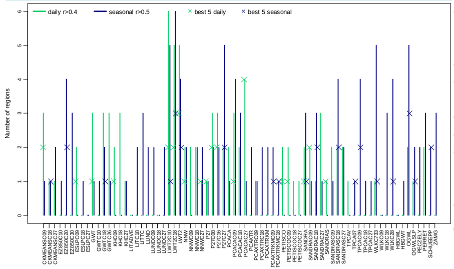


Figure 2 Number of regions for which a WTC **(1)** obtained a correlation coefficient *r* > 0.4 and 0.5 for the daily (green bars) and seasonal (blue bars) analysis, respectively, **(2)** is among the five WTCs with highest *r*-values (crosses).

Conclusions

- → Not all WTCs are suitable to identify WTs associated with regional hydrological drought;
- → depends on classification algorithm;
- → influences of input variables and number of WTs vary between algorithms.
- → Best results with LWT [5];
- → above average results with OGWL [6];
- → both are objective WTCs based on subjective WTCs (Lamb Weather Types [4] and HBGWL);
- → HBGWL results are much below average.

- ➔ **Objective WTCs considering the expert knowledge of a subjective WTC may be preferable over both purely mathematically defined WTCs and subjective WTC catalogues.**

References and Acknowledgements

[1] Fleig AK, Tallaksen L M, Hisdal H, Hannah DM & Stahl K: Regional hydrological droughts and objective Grosswetterlagen in north-western Europe (in prep.).
[2] Fleig AK, Tallaksen LM, Hisdal H. & Demuth, S. (2006) A global evaluation of discharge drought characteristics. *Hydrol. Earth Syst. Sci.* **10**, 535–552.
[3] COST733-Harmonisation and Applications of Weather Type Classifications of European Regions. http://cost733.org/.
[4] Gerstengarbe FW, Werner PC & Rüge U (1999) Katalog der Großwetterlagen Europas nach Paul Hess und Helmuth Brezowsky 1881-1992. 5th ed. http://www.pik-potsdam.de/~uwerner/gwl/
[5] James PM (2007) An objective classification method for Hess and Brezowsky Grosswetterlagen over Europe. *Theor. Appl. Climatol.* **88**, 17–42
[6] James PM: Second-Generation Lamb Weather Types - A new generic classification method with evenly-tempered type frequencies. *6th Annual Meeting of the EMS / 6th ECAC, 4-8 September 2006.*

The authors greatly acknowledge:
- Cedric Laize and the UK National River Flow Archive, CEH (http://www.ceh.ac.uk/data/nrfa/index.html, for the British discharge data;
- the National Environmental

Precipitation mapping (MeteoSwiss)

Motivation

Gridded precipitation climatologies based on high-density station networks and spanning several decades are available in the Alpine region (e.g., Figure 1, [1]).

- However, there is a time delay (typically days-weeks) until observations from all stations are digitised and much less data are available for quasi real-time precipitation gridding.
- How to approach this problem?

Can weather-type information help in near-real time gridding of daily precipitation?

Here,

- We test a reduced-space optimal interpolation (RSOI) method for the construction of daily precipitatio from a sparse gauge network.
- Stratify the method according to a weather types classification [2,3] and compare with results from th unstratified interpolation.

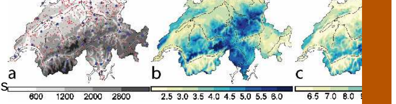


Figure 1. Overview of the study area. **(a)** Gauges of the sparse ne stations; blue circles), the dense network (549 stations; red dots) a topography (in m; shading). **(b,c)** Long-term mean and standard d daily precipitation (mm per day).

Reduced-space optimal interpolation

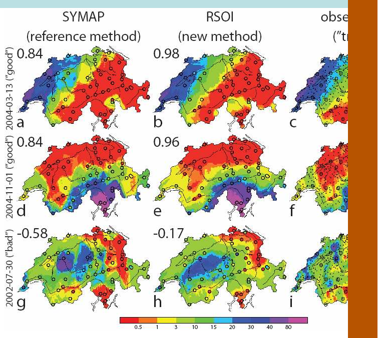
- is an interpolation method normally applied in climate reconstruction. Here, it is tested for near real-t gridding of dailly precipitation.
- RSOI combines information from

(i) high-quality precipitation grids based on the dense network (for calibration, not available in real-tim
(ii) sparse gauge data available in quasi real-time

- RSOI is based on principal component analysis of the calibration data, truncation of the data space, estimation of principal component scores from the sparse gauge data. See [4] for details.

Examples

Figure 2. Examples of gridded daily precipitation (mm/d). **(left)** Gridding from the sparse network in terms of a reference method[1], **(centre)** RSOI from the sparse network, **(right)** precipitation grid based on the dense network. The top two rows show cases with good interpolation results, the bottom row shows a case where gridding from the sparse network is very difficult. Numbers show the value of a mean-squared-error skill score used to evaluate the interpolations.



Weather types

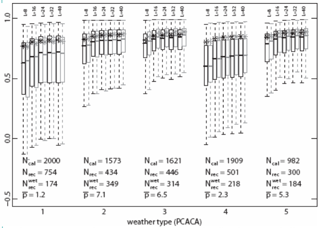


Figure 3. Boxplot statistics for the distributions of daily mean-squared-error skill scores for unstratified RSOI (black) and RSOI stratified with respect to the five PCACA[2,3] weather types (grey). For each weather type, the annotations are (i) the number of days in the calibration period, (ii) the number of days in the reconstruction period, (iii) the number of wet days (with domain-mean precip > 1 mm/d) considered in the evaluation, and (iv) the domain-mean precipitation for the weather type considered. Results are shown for different values of the reduced-space dimension *L* (a parameter of RSOI).

Conclusion

- Reduced-space optimal interpolation is suita gridding daily precipitation data.
- For the setup tested here, RSOI clearly outp reference method (based on climatological ca the SYMAP algorithm, [1]).
- Stratification with respect to weather types c improve the interpolations for some weather t

References

[1] Frei, C. and C. Schär, 1998: A precipitation climatology of the Alps from hig rain-gauge observations. *Int. J. Climatol.*, **18**, 873-900.
[2] PCACA weather types classification developed by Domingo Rasilla,Univers Cantabria, Departamento de Geografía, Spain.
[3] COST Action 733: Harmonisation and Applications of Weather Type Classi European Regions, www.cost733.org.
[4] Kaplan, A., Y. Kushnir, M.A. Cane, and M.B. Blumenthal, 1997: Reduced sp analysis for historical datasets: 136 of Atlantic sea surface temperatures. *J. Ge* **102**, 27835-27860.