Update of precipitation and temperature data for GRADE Rhine

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De Bilt, 2011 | Report

Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

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Version 4

Date 2 November 2011
Status Final

Colofon

Title	Update of precipitation and temperature data for GRADE Rhine
Project	Neerslaggenerator voor GRADE 2011/2012, Work done under contract "Zaaknummer 31007187.0005" to the Ministry of Infrastructure and the Environment, Rijkswaterstaat Centre for Water Management, Lelystad, The Netherlands

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Present situation

In the simulations with the Rainfall generator for the Rhine basin (Wójcik et al., 2000; Beersma et al., 2001, Beersma, 2002), the resampling procedure is 'driven' by the precipitation and temperature data of 34 stations (4 in Switzerland, 25 in Germany, 4 in France and 1 in Luxembourg). For hydrological simulations in GRADE the generated time series for these 34 stations are converted to precipitation and temperature series for 134 HBV sub-basins. This conversion makes use of the fact that each day in the generated series for the 34 stations corresponds with a historical date. Long simulations for the 134 HBV sub-basins are then simply obtained by replacing the generated station data for each day by the sub-basin precipitation and temperature for the corresponding historical date. This type of simulation is referred to as passive simulation. Passive refers to the fact that the 134 sub-basins are not directly represented in the feature vector of the resampling algorithm and therefore do not directly or actively 'drive' the simulation. This distinction between active simulation of the station data and passive simulation of the sub-basin data has a historical background. At the start of the development of the Rainfall generator for the Rhine basin no sub-basin data were available at all, only station data.

Both the daily precipitation and temperature for the 34 meteorological stations and the 134 HBV sub-basins have been made available for the period 1961-1995. The sub-basin data became later known as the CHR-OBS data. Short descriptions of these data can be found in Eberle et al. (2005), de Wit and Buishand (2007) and Görgen et al. (2010). Recently an overestimation of mean annual precipitation in seven HBV sub-basins in the French part of the southern Upper Rhine was found (Görgen et al., 2010). This overestimation was attributed to the limited number of rainfall stations in this area used for the compilation of the CHR-OBS data. For three sub-basins mean annual precipitation turned out to be 20%-30% higher than the mean annual precipitation from the HYRAS dataset (see below). The overestimation of the mean precipitation had a significant effect on the modeled flows at the gauging station Maxau on the Upper Rhine.

The need for an update

The time has come that time series ending in 1995 are no longer believed to be representative of the present-day climate. The limited length of the historical time series used for resampling is an important source of uncertainty of the GRADE instrument. For the Meuse basin, this uncertainty was quantified by resampling from 33-year sub-series of the historical 1930-1998 data (Leander and Buishand, 2008; Kramer and Schroevers, 2008). A similar study has been planned for the Rhine basin. For this study, it would be desirable to have historical precipitation and temperature data over a period of about 60 years. Though GRADE has been developed to simulate long flow sequences at the gauging station Lobith in the Netherlands, it is important for the trustworthy of the instrument that it works also satisfactorily in upstream parts of the river Rhine. With the present CHR-OBS data this may be difficult to achieve for the Maxau gauging station.

Replacing the CHR-OBS data

A new gridded daily data set HYRAS for the Rhine basin (and a few other river basins) has recently been prepared by the German Weather Service (DWD) under contract of the German Federal Institute of Hydrology (BfG). The HYRAS grid has a spatial resolution of 5 km × 5 km. All available station data has been used for gridding. The gridded precipitation and temperature data in HYRAS cover the period 1950-2006. A regular update is not foreseen yet. Further, the distribution of the HYRAS data is limited for use in the KLIWAS project for which it was created and for other climate-change projects that are performed in cooperation with BfG or DWD. Since modifications are foreseen in the near future, the use of the present HYRAS dataset is discouraged, in particular the temperature fields (E-mail Enno Nilson (BfG) to Hendrik Buiteveld (WD), dated 10 December 2010). For the daily precipitation fields a new version (indicated as version 2.0) will be released in the autumn of 2011, provided that the validation yields a positive result and that there are no objections from the national weather services that made station data available for HYRAS (E-mail Enno Nilson (BfG) to Rita Lammersen (WD) et al., dated 10 May 2011). The use of these data in GRADE, requires that BfG becomes an associated partner of GRADE (E-mail: Silke Rademacher (BfG) to Hendrik Buiteveld (WD), dated 11 May 2011).

An alternative to the HYRAS data is the CHR-Interim dataset prepared by BfG. Daily precipitation and temperature in this dataset are averaged over the same sub-basins as in CHR-OBS. The data for the seven French sub-basins of the southern Upper Rhine have been replaced using provisional HYRAS data. The CHR-interim dataset also covers the period 1950-2006. The dataset should be considered as an interim product, it will be outdated when the HYRAS data are fully validated.

The CHR08 precipitation dataset (Photiadou et al., 2011) partly replaces and extends the CHR-OBS daily precipitation. For the Alpine part of the Rhine basin, an extended version of the Alpine dataset (Frei and Schär, 1998) was used for the period 1970-2000. It turned out that this leads to more accurate discharges for the Swiss part of the Rhine basin than the use of CHR-OBS. In particular, the simulated maximum discharge (typically during spring) appeared to be much lower than that obtained with the CHR-OBS precipitation. This seems somewhat at variance with the results for Basel in the RheinBlick2050 project for Basel (Görgen et al., 2010). For the French part of the Rhine basin both CHR-OBS and CHR08 are based on a gridded dataset from the University of Trier. Precipitation might therefore also be overestimated in parts of the French Upper Rhine basin in CHR08. The extension to 2008 is based on the precipitation data used for operational flow forecasting: hourly precipitation from automatic weather stations in Germany (46 stations) and precipitation data from synoptic weather stations (about 200 stations in 2000 and a sudden increase to about 650 stations in early 2006). See Weerts et al. (2008) for a description of these data. The data are not corrected for systematic differences between the measurements of the daily rain gauge network. The use of different data sources over time may introduce inhomogeneities, in particular for the Swiss part of the basin. The impact of these inhomogeneities on extreme river flows at Lobith may be small, because these are mainly due to large-scale multi-day rainfall events downstream of Switzerland.

Station data that drive the precipitation and temperature simulations

The precipitation and temperature data of the 34 stations were obtained from the CHR data base. An extension for the period after 1995 and backward in time to 1950 may be problematic if it turns out that some stations were not operational during part of the 1950-1960 period or were closed after 1995. Further, part of these data are not freely available. It is, however, not foreseen that the budget and time needed to acquire these data will be a big obstacle.

In contrast to the driving rainfall series for the rainfall generator for the Meuse basin, the homogeneity of the historical 34 precipitation series in the Rhine basin have not been tested for homogeneity. The need for it could be questioned. Because of the larger number of rainfall stations, the effect of an inhomogeneity in a single precipitation series is relatively small.

An important question is whether one should continue to resample from the 34 station series first. Direct resampling from the sub-basin average data is simpler and should actually be followed if these sub-basin averages were regularly updated. The differences between passive and active simulation of the sub-basin averages are small for the distribution of the 10-day winter extremes, standard deviations and autocorrelations (Beersma, 2011).

The E-OBS data could be an alternative for driving the precipitation and temperature simulations. This is a European gridded daily observational dataset covering the period from 1950 to the present. These data are available on a regular 0.25 degrees latitude and 0.50 degrees longitude grid ($\approx$ 25 km $\times$ 25 km), a rotated polar grid with a 0.22 degrees resolution and two coarser grids. A full description of this dataset can be found in Haylock et al. (2008). The number of stations used for gridding varies strongly over Europe. In the most recent update (E-OBS version 5.0, September 2011) about 1000 precipitation and temperature stations in Germany were added. The station density is, however, low in the Swiss and French parts of the Rhine basin. The E-OBS data should therefore not be used as input for the hydrological simulations. An advantage of the E-OBS dataset is that is regularly updated. The use of the E-OBS data to drive the precipitation and temperature simulations implies that a second nearest neighbour search has to be done to resample the average precipitation and temperature for the 134 HBV sub-basins. This approach has successfully been applied for the Meuse basin (Leander and Buishand, 2004, Leander et al., 2005; Buishand and Leander, 2011).

Updates needed for a unified rainfall generator for the Rhine and Meuse basins

For some studies in the Netherlands it is necessary to examine the simultaneous occurrence of extreme flows of the rivers Rhine and Meuse. For the development of a unified rainfall generator for the two river basins, it would be convenient that the historical data used for resampling cover the same period. The Meuse basin has been divided into 15 HBV sub-basins. The daily average precipitation for these sub-basins cover the period 1961-2007 (Buishand and Leander, 2011). For the Belgian part of the basin, the area-average precipitation amounts were derived from the daily values for 31 sub-basins that were routinely calculated by the Royal Meteorological Institute of Belgium. Since these data were also obtained for the

period 1951-1960 by KNMI, an extension back to 1951 is possible for the Belgian part of the Meuse basin. It should be noted that the HYRAS version 2.0 daily precipitation fields will also cover most of the Meuse basin (E-mail Enno Nilson (BfG) to Rita Lammersen (WD) et al., dated 10 May 2011). This should be verified before new data requests are made. A request for additional precipitation data from Météo France for the period 1951-1960 to make such an extension for the French part of the Meuse basin might be considered. Daily temperature data from 11 stations have been interpolated to the 15 HBV sub-basins of the river Meuse for the period 1967-2008 (Buishand and Leander, 2011). For 5 of these stations temperature is also available for the period 1951-1966; for Belgium there are six additional stations with daily maximum and minimum temperatures from 1954 to 1998. Since the extension of the historical precipitation and temperature series with data for the period 1998-2008 (Buishand and Leander, 2011) was a tedious exercise, the feasibility to use the E-OBS data for future updates should be explored.

Conclusions and recommendations

Three different datasets have been created recently that cover a longer period than the CHR-OBS data. The two German datasets HYRAS and CHR-Interim refer to the period 1950-2006 but are not freely available. The condition that BfG becomes an associated partner of GRADE for the use of the HYRAS data has been fulfilled. A regular update of the HYRAS data is not ensured. CHR-Interim is a temporary product that will not be updated. The CHR08 dataset does not cover the period 1950-1960 and does not contain temperature. The hydrological simulations in Photiadou et al. (2011) use daily temperatures from the E-OBS dataset. Inhomogeneities may be introduced through the use of different data sources over time. Quantitative comparisons between the HYRAS and CHR08 databases have not been made. Especially for the simulation of extreme flows in the upper part of the Rhine basin the choice of the dataset can be important.

The new version 2.0 of HYRAS will be the most extensive homogeneous daily precipitation data set for the Rhine basin in the near future. The use of this dataset in GRADE for the coming years is highly recommended. Daily temperature fields from HYRAS will not be available before 2012. Therefore, the use of daily temperature from the E-OBS data in GRADE should be studied.

The present precipitation and temperature simulations for the Rhine basin are driven by the daily precipitation and temperature data from 34 stations. This dataset has not been regularly updated. It is therefore useful to explore whether the resampling process can be driven by the E-OBS data.

For a unified rainfall generator for the Rhine and Meuse basins, it is desirable to have a common data base of daily precipitation and temperature from 1951. This requires additional daily precipitation data for the French part of the Meuse basin for the period 1951-1960. Part of these data may be borrowed from the HYRAS dataset. The use of daily temperature from the E-OBS data should also be studied for the Meuse basin.

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