

HBV MODELLING IN SEVERAL EUROPEAN COUNTRIES

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ABSTRACT

In order to investigate the performance of the HBV model under different hydrological and climate conditions the model was applied to 12 catchments in different countries throughout Europe. The catchments are situated from the Spanish Guadiamar River in the south to the Norwegian Mosselva River in the north, and from the Lithuanian Susve River in the east to the Irish Lough Derg/Lough Ree in the west. The study cover a wide range of the different hydrometeorological conditions existing in Europe; catchment sizes ranging from 500-14 000 km², relief (internal altitude difference) from 0-1800 m. and annual average precipitation between 500-1000 mm. Land use varies between 3-80% coverage of forest, 16-80% arable land and 0-8% lakes. The results show that the HBV model delivers good predictions for water flow in the countries of northern and middle Europe while the most southern countries, such as Greece, show less good correspondence with observations. These catchments have a quick rainfall-runoff response due to steep topography and absence of lakes, which made it difficult to capture the recessions after peak flows. Blind-tests (i.e. with hidden observation data) was performed in some catchments to evaluate the HBV capability for predictions in ungauged basins.

INTRODUCTION

The HBV model was developed at SMHI during the early 1970's. In different model versions HBV has been applied in more than 40 countries all over the world. It has been applied to countries with such different climatic conditions as for example Sweden, Zimbabwe, India and Colombia. The model has been applied for scales ranging from lysimeter plots (Lindström and Rodhe, 1992) to the entire Baltic Sea drainage basin (Bergström and Carlson, 1994; Graham, 1999). The model is used for flood forecasting in the Nordic countries, and many other purposes, such as spillway design floods simulation (Bergström et al., 1992), water resources evaluation (for example Jutman, 1992, Brandt et al., 1994), nutrient load estimates (Arheimer, 1998).

The HBV model is a component in the EuroHARP project (www.euroharp.org) of the 5th EU framework programme (EVK1-CT-2001-00096). One goal in

EuroHARP is to investigate model performance under different environmental conditions, and to document model applicability and performance. This presentation focuses on the results of HBV modelling in 12 European catchments, most of which are part of the EuroHARP project. The catchments are situated from Spain to Norway, and from Ireland to Lithuania (Fig. 1). Moreover, model suitability for predictions in ungauged basins were investigated for two catchments, where the model performance was evaluated for applications without calibration (i.e. blind tests).

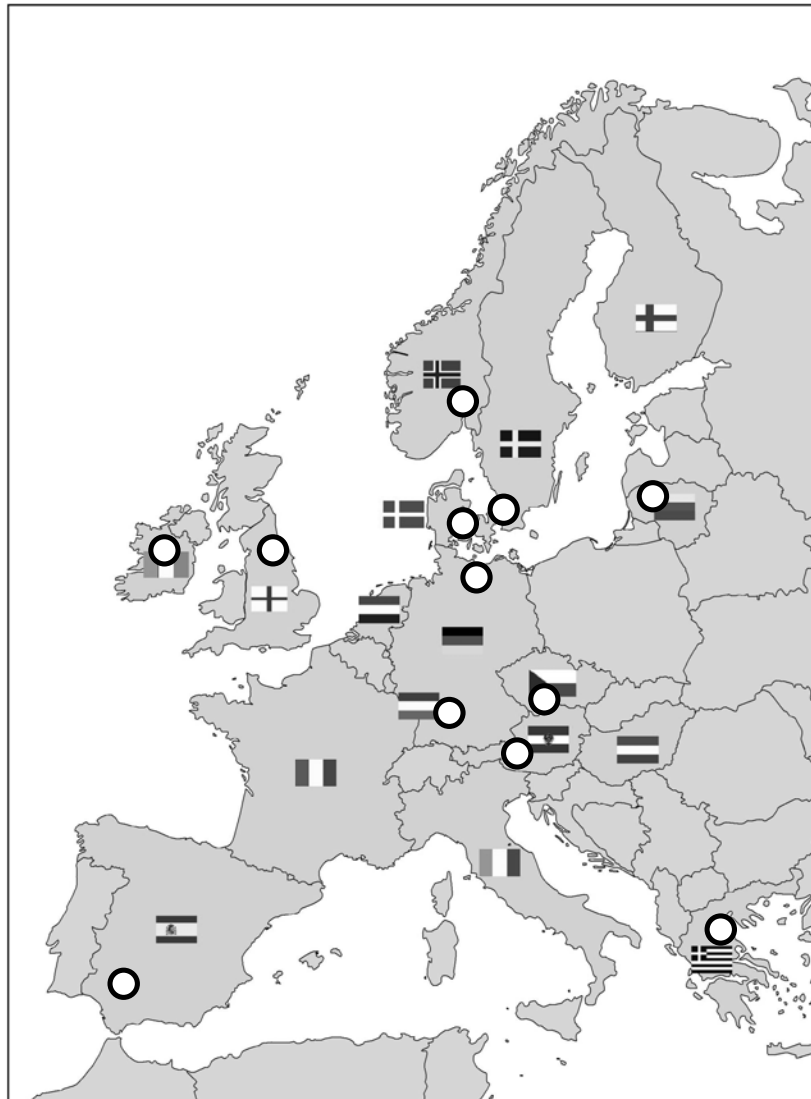


Figure 1. Locations of the 12 catchments modelled (dots) and notation of all the countries involved in the EuroHARP project (flags).

METHODS AND MATERIAL

The HBV model (Bergström, 1976; Lindström et al., 1997) is a rainfall-runoff model, which includes conceptual numerical descriptions of hydrological processes at the catchment scale. The general water balance can be described as:

$$P - E - Q = \frac{d}{dt} [SP + SM + UZ + LZ + lakes]$$

where:

P = precipitation

E = evapotranspiration

Q = runoff

SP = snow pack

SM = soil moisture

UZ = upper groundwater zone

LZ = lower groundwater zone

lakes = lake volume

HBV can be used as a semi-distributed model by dividing the catchment into subbasins. Each subbasin is then divided into zones according to altitude, and the elevation zones are further divided into different vegetation zones (e.g. lakes, forested and non-forested areas). The model is normally run on daily values of rainfall and air temperature, and daily or monthly estimates of potential evaporation. The model consists of subroutines for meteorological interpolation, snow accumulation and melt, evapotranspiration estimation, a soil moisture accounting procedure, routines for runoff generation and finally, a simple routing procedure between subbasins and in lakes (Lindström et al., 1997). Several parameters are normally tuned to fit the model output with observed values (i.e. calibration). An automatic calibration routine has been developed and is today an essential component in the practical work (Lindström, 1997). Model performance is evaluated by using the explained variance by Nash and Sutcliffe (1970) and the relative volume error.

The EuroHARP database (www.euroharp.org) was used for model set-up in each catchment, except for the German catchments where model input data was available from Fogelberg (2003). For some catchments the database was extended with synoptic meteorological data from ECOMET to receive complete precipitation time-series. The EuroHARP catchments cover a wide range of the different hydrometeorological conditions existing in Europe; catchment sizes ranging from 500-14 000 km², relief (internal altitude difference) from 0-1800 m. and annual average precipitation between 500-1000 mm. Land use varies between 3-80% coverage of forest, 16-80% arable land and 0-8% lakes (Table 1).

Table 1. Characteristics of catchments studied in Europe.

Country	Catchment size (km ²)	Land use (%)		Relief (m)	Average runoff (l/s/km ²)	Average Precip. (mm)	Average Temp. (°C)
		Forest	Lakes				
Denmark	486	3	4	12-112	9.5	896	9
Sweden	1942	45	3	0-200	12.9	700	7
Norway	690	80	7	25-275	14.4	810	6
Greece	2797	36	0	50-1900	13.9	993	14
England	3315	4	1	5-680	16.5	900	10
Check republic	1189	28	2	318-765	5.5	669	8
Austria	2574	59	~0	393-1820	12	905	11
Spain	807	18	~0	4-500	8.7	555	17
Germany, Neckar	13957	37	~0	150-1250	11.8	820	9
Germany, Warnow	3066	22	4	10-150	4.2	530	9
Lithuania	1165	29	0.5	30-130	5.3	589	7
Ireland	10600	3	8	0-150	18	960	10

RESULTS AND DISCUSSION

Model performance and applicability

For most catchments the HBV model gave reasonable accuracy compared to observed time-series, with R^2 above 0.7 and an relative volume error less than 5% (Table 2). However, a few catchments were more poorly modelled. The model did not capture the flow dynamics in the most southern catchments of Greece and Spain, which resulted in low R^2 values (0.5 and 0.59, respectively). These catchments have a quick rainfall-runoff response due to absence of lakes, steep topography or sparse vegetation cover, which made it difficult to capture the recessions after peak flows. The precipitation pattern may also be more intense and local, and probably not fully included in the meteorological observations of rainfall data for the whole catchment.

For the German river Warnow it was also difficult to find representative precipitation data and the present modelling was based on a 1°grid, which resulted in that the whole catchment was part of one single grid. The uncertainty in model result is probably caused by poor meteorological data also in this case. For the Lithuanian catchment, on the other hand, the low accuracy with observations is related to limited information of observed water flow; only monthly measurements were available. This means that daily model results are

compared to the more smooth dynamics of monthly values, and it is possibly that the model capture the dynamics more correctly than what may be described by monthly observations. It should also be noted that for Lithuania the overall volume error is very low (0.002).

Table 2. Results from HBV modelling of water flow in 12 European catchments.

Country	Modelled period	R ²	Rel. volume error
Denmark	1990-2000	0.82	0.03
Sweden	1985-1999	0.84	0.01
Norway	1990-2000	0.82	0.0001
Greece*	1984-1992	0.51	-0.09
	1993-1996	0.50	-0.08
England	1990-2000	0.84	0.01
Check republic	1993-2000	0.73	0.02
Austria	1993-1996	0.73	-0.0003
Spain	1996-1999	0.59	0.15
Germany, River Neckar	1993-1997	0.88	-0.05
Germany, River Warnow	1988-1999	0.64	-0.01
Lithuania*	1989-2000	0.66	-0.002
Ireland	1992-1995	0.84	0.03

* Two time-periods were modelled for Greece due to sudden lap in observed time-series.

* Only monthly observations of river discharge available for the Lithuanian catchment.

Predictions in ungauged basins

In the Blind test procedure when observed river discharge data was hidden for the modeller, parameter values were based on model experience under Swedish conditions. Both for Norway and England, these model parameters, which were chosen from HBV modelling in central Sweden (i.e. Svealand), seem representative enough for a reasonable prediction in ungauged basins (Fig. 2). Although, a rating curve for lakes was necessary in Norway and the volume error was somewhat high (0.15) for the English catchment (Table 3).

After calibration the model was more in correspondence with observed time-series, with R² above 0.8 and a volume error of 0.03. This new parameter setting was then evaluated for an independent validation period (without further calibration), which actually resulted in better model accuracy than during the calibration period; the explained variance (R²) increased and the volume error decreased for both catchments (Table 3).

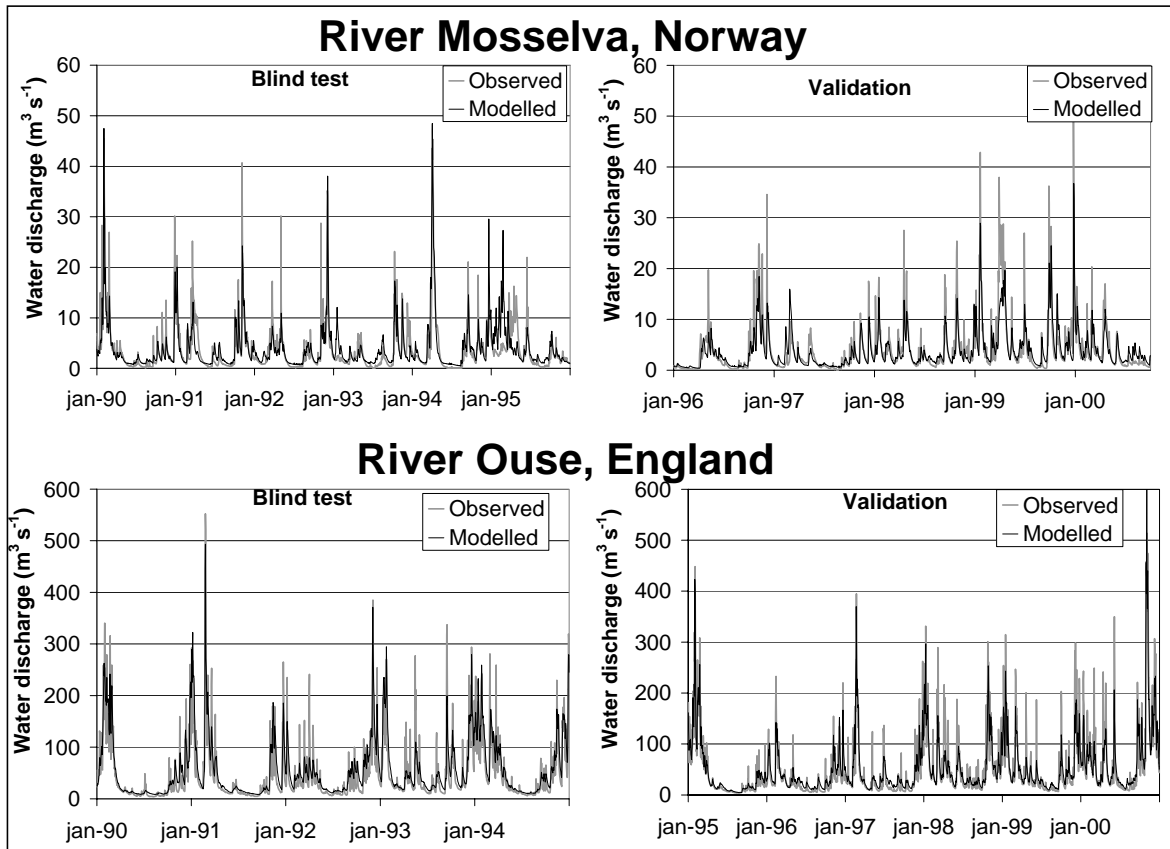


Figure 2. HBV simulation of river discharge for the uncalibrated blind test (left), and during the independent validation period (right) in Norway and England, respectively.

Table 3. Statistics of HBV performance in the blind test without calibration, after calibration and during the independent validation period.

Country	Modell status	Modelled period	R ²	Rel. volume error
Norway	Uncalibrated	1990-1995	0.33	-0.04
	Uncalibrated, but with general lake-rating curve	1990-1995	0.74	-0.03
	Calibrated	1990-1995	0.81	0.01
	Independent validation	1995-2000	0.82	-0.004
England	Uncalibrated	1990-1995	0.79	0.15
	Calibrated	1990-1995	0.83	0.03
	Independent validation	1995-2000	0.85	0.005

CONCLUSIONS

- The HBV model seems to be a useful tool for modelling river discharge in the entire Europe. However, for trustworthy results it is necessary with precipitation data of good quality and relevant spatial resolution.
- Model performance is of good accuracy in northern and middle Europe, while it is more difficult to capture the peakiness of the flow in the most southern countries.
- The HBV model can be used for predictions in ungauged basins (at least in Northern Europe) using a general parameter setting based on experiences from other regions, if the meteorological data available is of good quality.

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