ACCURACY OF ANNUAL AND MONTHLY LUMPED WATER BALANCE MODELS FOR THE ASSESSMENT OF RIVER DISCHARGE IN THE MEDITERRANEAN AND BLACK SEAS DRAINAGE BASINS

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Abstract
Accuracy of 16 annual and monthly water balance models (WBM) for modelling annual river discharge were assessed on an extended discharge series data set for Mediterranean and Black Sea rivers. Results indicate a better accuracy of some monthly models to reproduce inter-annual mean, variability and trends. Using gauged discharge filled with monthly WBM and extrapolating to the whole drainage basins, freshwater discharge to the Mediterranean Sea (excluding the Nile) significantly decreased in 1960-2009 (-22%, p<0.05), while decrease was not significant for the Black Sea.

Keywords: North-Western Mediterranean, Hydrology, Black Sea, South-Eastern Mediterranean, River input.

Materials and Methods: A previous data set of discharge series [1] in Mediterranean and Black Sea rivers was extended through data mining from national and international water agencies. This new data set includes 467 monthly or annual series within the 1960-2009 period for downstream stations and sub-catchments greater than 1000 km². If possible, gaps in time series were completed using linear regression with neighboring stations (r² > 0.80). The corresponding rainfall and potential evapotranspiration time series were extracted from the CRU TS 3.10 climatologies. For water discharge modeling, we tested the accuracy of 16 monthly and annual WBM: 3 free-parameter annual WBM, 6 one-parameter annual WBM and 8 monthly multiparameters WBM. Parameters were calibrated by maximizing an objective function (Favg), which is the average of Nash-Sutcliffe model efficiency coefficient (NS), the NS of logarithmically transformed flow, the Pearson correlation coefficient and the bias score. The magnitude of discharge trends was estimated using the slope of the Kendall-Theil robust line. We used the Kolmogorov-Smirnov test (KS) to compare the equality of observed and modeled trend distributions. The Pearson correlation coefficient and the mean absolute error were used to test the similarity of trend patterns. For extrapolation of the water budgets to the entire Mediterranean Sea drainage basin, we combined observed and modeled discharge values in order to fill the data gaps in the observed time series. We extrapolated to the whole drainage basins using ratio between discharge modeled with free-parameter annual WBM and in and outside gauged catchments.

Results: For the Mediterranean Sea drainage basin, the mean coverage of the whole basin by gauged catchments is only about 20% (excluding the Nile). Taking account spatial variation in precipitation depth, this coverage increases to 36% for total precipitation. Using the 3 free-parameter annual WBM, gauged discharge account for about 50% of the total freshwater discharge. For the Black Sea, the mean coverage by gauged catchments is better and reaches 73% of the whole drainage area. 77% of total rainfall and 85% of the total freshwater discharge. Model calibration of WBM for discharge series >10 years allow to increase the spatial coverage with 26% for the Mediterranean Sea and 81% for the Black Sea. This coverage represents 43% of precipitation and about 55% of freshwater discharge for the Mediterranean Sea and, respectively, 84% and 91% for the Black Sea. WBM performances are highly dependent on the model type. The lowest Favg scores are observed for the three free-parameter WBM, with only 1 to 7% of the discharge series having Favg > 0.60. For one-parameter WBM, these percentages increase to 13-20%. The WBM performing best are multi-parameters monthly models. Here, Favg > 0.6 could be reached for 51 to 54% of the discharge series with the models GR2M [2], ABCD [3] and ZH3 [4]. Using observed discharge series filled with these three monthly WBMs and extrapolating discharge to the whole Mediterranean (excluding the Nile) and Black Sea basins, we computed an interannual mean of freshwater discharge of 365-367 km³ yr⁻¹ and 351-355 km³ yr⁻¹ for the 1960-2009 period. Correlations between observed and modeled absolute trends are significant (p < 0.05) for all WBM. Best Pearson correlation coefficient reaches 0.75 for two monthly WBM: ZH3 and GR2M. Lowest mean absolute error was about 1.4 mm yr⁻¹ for 3 monthly WBM: GR2M, ZH3 and ABCD. The hypothesis of the KS test for similar distributions was rejected for all WBM. All WBM slightly overestimate the occurrence of weak negative trends (74-87%) for modeled discharge and 60% for observed discharge) but underestimate occurrence of strongest negative trends. Looking the cumulative trends at downstream gauging stations, observed and modeled value for the Mediterranean Sea are very close with respectively -38 km³ and -34 to -36 km³ for GR2M, ABCD and ZH3. For the Black Sea, the cumulative trends is < -1 km³ for observed discharge but between -34 and -36 km³ for this three models. This difference is mostly explained by the difference between observed and modeled trend for the Danou. Using gauged discharge filled with monthly WBM and extrapolated to whole drainage basin, a 22-23% decrease in river discharge was calculated for the Mediterranean drainage basin (p<0.05, excluding the Nile) while no significant trend was detected for the Black Sea drainage basin.

References

Fig. 1. Modeled annual river water discharge from 1960 to 2009 for 26% and 81% of the whole Mediterranean (MED) and Black Sea (BLK) drainage basins. AN: Annual water balance, MO: Monthly water balance. The last number specifies the count of calibrated parameters.