Geophysical Research Abstracts
Vol. 15, EGU2013-3128, 2013
EGU General Assembly 2013


# The origin of high and low flows in the river Rhine: particle tracing and water quality calculations in a distributed hydrological model

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The ability to quickly link a complete water quality model to any distributed hydrological model can be of great value. It provides the hydrological modeller with more information on the performance of the model by being able to add particle tracing and independent mass balance calculations to an existing distributed hydrological model. It also allows for full catchment water quality calculations forced by emissions to different hydrological compartments, taking into account the relevant processes in the different compartments of the hydrological model.

A combined distributed hydrological model and hydrochemical model (Delwaq) have been combined within the modeling framework OpenStreams to model large scale hydrological processes in the Rhine basin upstream of the Dutch border at Lobith. Several models have been setup to evaluate (1) the origin of high and low flows in the Rhine basin based on subcatchment contribution and (2) the contribution of different land covers to the total flow with special reference to urban land cover. In addition (3) the relative share of fast and slow runoff components in the total river discharge has been quantified, as well as the age of these two fractions, both as a function of time. Finally (4) the transmission of a pollutant released in infiltrating water and undergoing sorption has been simulated, as a first test for implementing full water quality modelling.

The results of a thirty-five year run using daily time steps for 1975 to 2010 were analysed for monthly average contribution to the total flow of each subcatchment and the different land cover types both for average flow conditions and for the top ten and bottom ten flow percentiles. Furthermore, a number of high and low flow events have been analysed in detail. They reveal the large contribution of the basin area upstream of Basel to the dry season flow, especially during the driest summers. Flood conditions in the basin have a more varied origin with the Moselle being the main contributor. The amount of urban land cover (6.7%) generated a fairly large amount of (quick) runoff. In times up to 21 % of the flow at Lobith is generated in urban areas. The location of urban areas (in general close to the river) in combination with the associated impermeable surfaces most probably cause the relatively large contribution of urban areas. The fast runoff fraction at Lobith has an average age between 5 and 25 days, depending on the hydrology within the year, while the slow runoff fraction shows an average age between 300 and 600 days, again depending on the hydrology within the year. The time needed to flush out 90% of the total volume of water from the basin is about 20 years.