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The identifiability analysis for setting up measuring campaigns in integrated water quality modelling

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ABSTRACT

Identifiability analysis enables the quantification of the number of model parameters that can be assessed by calibration with respect to a data set. Such a methodology is based on the appraisal of sensitivity coefficients of the model parameters by means of Monte Carlo runs. By employing the Fisher Information Matrix, the methodology enables one to gain insights with respect to the number of model parameters that can be reliably assessed. The paper presents a study where identifiability analysis is used as a tool for setting up measuring campaigns for integrated water quality modelling. Particularly, by means of the identifiability analysis, the information about the location and the number of the monitoring stations in the integrated system required for assessing a specific group of model parameters were gained. The analysis has been applied to a real, partially urbanised, catchment containing two sewer systems, two wastewater treatment plants and a river. Several scenarios of measuring campaigns have been considered; each scenario was characterised by different monitoring station locations for the gathering of quantity and quality data. The results enabled us to assess the maximum number of model parameters quantifiable for each scenario i.e. for each data set. The methodology resulted to be a powerful tool for designing measuring campaign for integrated water quality modelling. Indeed, the crucial cross sections throughout the integrated wastewater system were detected optimizing both human and economic efforts in the gathering of field data. Further, a connection between the data set and the number of model parameters effectively assessable has been established leading to much more reliable model results.

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1. Introduction

In urban drainage water quality evaluations, data availability issues are generally quite common both in research and practical applications (Vanrolleghem et al., 1999; Freni et al., 2009a; Mannina and Viviani, 2010). Such problems are basically due to the fact that the data gathering campaigns can be technically complex and economically demanding.

Integrated urban drainage modelling is generally defined as modelling of the interaction between two or more physical systems, i.e. sewer system (SS), wastewater treatment plant (WWTP) and receiving water body (RWB) (Rauch et al., 2002). An integrated urban drainage model is therefore made up of sub-models representing any combination of the above-mentioned three elements. Therefore integrated urban drainage models can be considered complex model characterised by several model parameters, model variables and data demanding for calibration/validation.

When dealing with complex modelling approaches, such as integrated urban drainage ones, in a context with insufficient field data, classical calibration approaches may lead to several equally consistent parameter sets and it is difficult to have sufficient confidence about the obtained results (Kuczera and Parent, 1998). The concept of existence as well as uniqueness of a parameter set that guarantee the best fit between measured and simulated data, can be thus replaced by the equifinality concept (Beven and Binley, 1992) accepting the fact that more parameter sets may exist able to provide a good fit between simulated and measured data.

These considerations take the primary consequence that, for a given model structure and a given experimental layout, some modelling parameters cannot be reliably calibrated because the available information is not sufficient to identify their specific effect on modelling output. An obvious solution is model reduction by restricting the model description to what is observed by the data (Jakeman and Hornberger, 1993). Another possible option consists of the extension of available database by increasing the number of measurement stations, the number of monitored variables or the period/frequency of the monitored period. The extension and the improvement of monitoring campaign can be economically demanding and a method for "a priori" evaluation of its impact on modelling output can be relevant for estimating the trade-off between monitoring economic demand and the increased model

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response reliability. Such a method can address the design of the monitoring campaign by defining the most effective variables and locations to be monitored in the analysed system. Identifiability analysis can constitute an optimal solution for addressing the aforementioned issue. Indeed, identifiability analysis enables one to assess the number of model parameters with respect to the data set available (Brun et al., 2002).

Bearing in mind such considerations, the paper presents a methodology based on identifiability analysis for setting up measuring campaigns in integrated water quality modelling. In particular, the methodology was applied to a real case study characterised by a semi-urbanised catchment represented by two sewer systems, two wastewater treatment plants and a river. Several scenarios of measuring campaigns have been considered each constituted of different monitoring stations for the data gathering. The methodology resulted to be a powerful tool for designing measuring campaign for integrated water quality modelling.

2. Materials and methods

2.1. The case study

The analysis was based on a complex integrated system: the Nocella catchment (Fig. 1). Such a case study is a partially urbanised catchment located nearby Palermo in the North-Western part of Sicily (Italy). The entire natural basin has a surface of 99.7 km^2, and has two main branches that flow primarily East to West.

The two main river branches join together at 3 km upstream from the estuary. The southern branch is characterised by a smaller elongated basin, and receives water from a large urban area (Partinico) and a smaller one (Borgetto). Both urban areas are characterised by relevant industrial activities partially connected to a WWTP, and partially directly connected to the RWB. The northern branch was monitored during previous studies (Freni et al., 2010) and, to this purpose, the catchment end was equipped with a hydro-meteorological station (Nocella a Zucco) able to measure rainfall depth, river depth and velocity (Fig. 1). The monitored river reach receives wastewater and stormwater from two urban areas (Montelepre and Giardinello, with a catchment surface equal to 70 and 45 ha, respectively) drained by combined sewers (both on the right side of the main river reach – see Fig. 1). The sewer system serves 7000 and 2000 inhabitants, for Montelepre and Giardinello, respectively. Each sewer system is connected to a WWTP equipped with a combined sewer overflow (CSO) device (schematization of the system is presented in Fig. 2). The WWTPs are characterised by simplified activated sludge processes with preliminary mechanical treatment units, an activated sludge tank, and a final circular settler. Rainfall was monitored by four rain gauges distributed over the basin. Both ultrasonic external probes and automatic 24-bottle water quality samplers were located throughout different cross section of the integrated system in order to collect both quantity and quality data. Seven events have been measured for both quantity and quality aspects in the different cross sections of the integrated catchment. Table 1 presents the main characteristics of the monitored rainfall events and the consistence of water quantity and quality database. Further details concerning the case study and monitoring campaign can be found in Freni et al. (2010) and Candela et al. (2009).

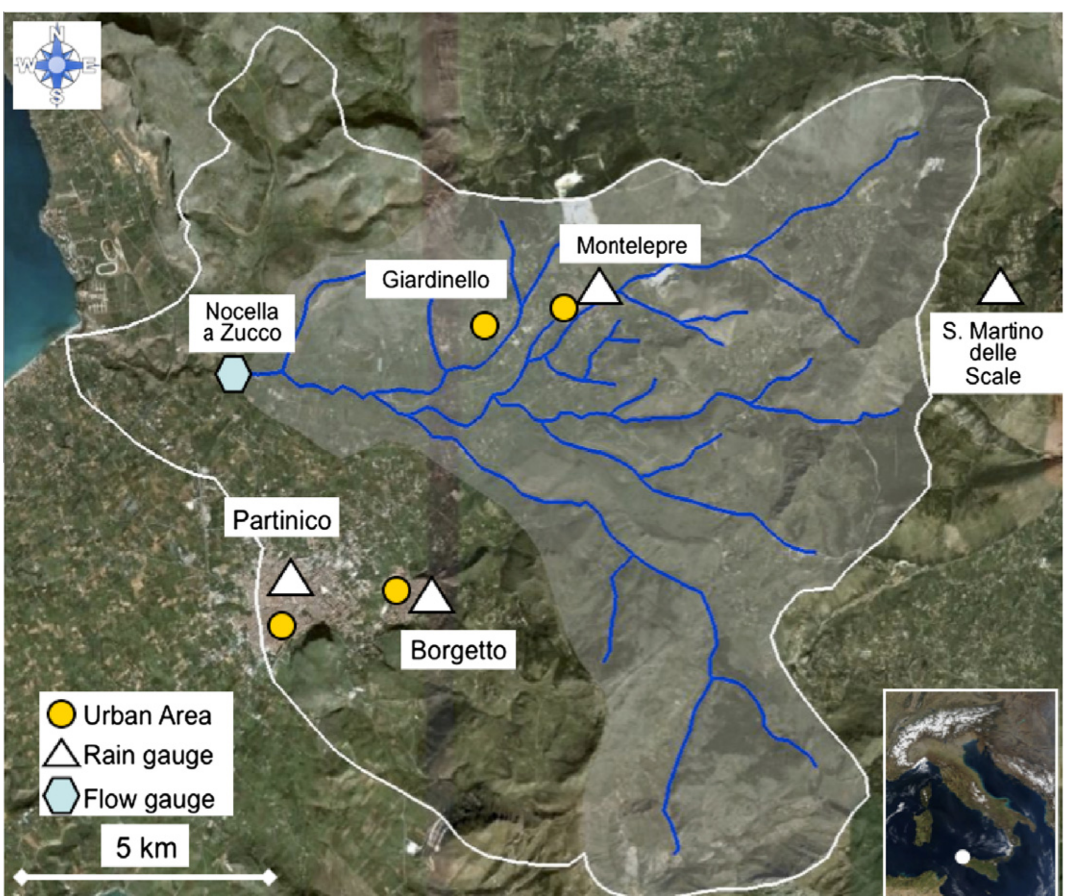

Fig. 1. Overview of the Nocella basin (basin boundaries are in white) with indication of the four included urban areas: the monitored sub-catchment is shaded, rain gauges are indicated by triangles, and the flow gauge station is indicated by an hexagon, urban areas are indicated by circles.

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