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Calibration and use of integrated hydrological models in a large groundwater basin in Northern Italy

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We present and discuss the main steps of the implementation and use of the ground water flow model of a large alluvial aquifer system underlying a densely settled and heavily irrigated territory, with a special focus on the estimation of the distributed recharge and on the calibration of the model. The 2500 km^2 grounwater basin lies in the Padana plain (Northern Italy), one of the most developed industrial and agricultural areas of Europe, and is bordered by the rivers Adda, Oglio and Po. The model implementation was urged by the water management and administration authorities in the area, which in the last years have been under increasing pressure for the release of pumping consents, especially from the irrigation sector. Indeed, the limitation to water withdrawal from rivers to ensure the minimum instream flow, along with a sequence of very dry years, pushed the farmers to seek new sources of irrigation water. On the other side the water authorities are trying to drive a process of transformation of the irrigation systems, towards an increase of their water use efficiency. The same authorities, however, are aware that this process must be carefully controlled in order to protect a number of groundwater dependent ecosystems, that are largely dependent on the distributed recharge due to irrigation. Therefore, the main practical goals of the model is to provide a tool for the assessment of both the sustainability of increased groundwater withdrawals and the effects of changes of the irrigation systems characteristics.
Distributed recharge, mainly due to rainfall and irrigation, has been often treated in a simplified way in many applications of groundwater models, in spite of the fact that the unsaturated zone scientific community has achieved significant progresses in the modelling of soil-water-atmosphere interactions. Indeed, especially when irrigation systems are densely spread over a large area but poorly efficient, the distributed recharge term may represent the driving input in dynamics of the interactions between the phreatic aquifer and surface water bodies. The appropriate estimation of the distributed recharge is therefore an essential step for the implementation of a groundwater flow model, playing a significant role in one of the most delicate phases, the model calibration phase. Indeed, the calibration of a regional scale groundwater model still remains a difficult and challenging task and the examples of successfully calibrated models are quite limited.
In the Adda-Oglio basin a distributed model is applied to estimate the aquifer recharge. The model combines a module for the simulation of all the components of the irrigation systems and a module for the continuous simulation of the soil water balance in the root zone. The distributed aquifer recharge is one of the main inputs of the finite difference ground water flow model, which takes into account the heterogeneity of the transmissivity field, the drainage from sources at the footwall of the alluvial terraces and from flowing wells, the water exchanges between the aquifer and the Serio river crossing the northern part of the study area, the abstraction from shallow and deep water wells. The Comparison Model Method (CMM) is used for solving the inverse problem and computing an equivalent transmissivity set that is physically consistent at the scale of the direct model. The calibrated model is used to define criteria of sustainability of groundwater withdrawals - which are now being adopted by one of the main water licensing authorities - and to simulate the effects of different measures to increase irrigation water use efficiency - which are currently under analysis by the irrigation management agencies.