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Hydrology and Earth System Sciences Discussions

Interactive comment on "HYDROGEIOS: A semi-distributed GIS-based hydrological model fordisturbed river basins" *by* A. Efstratiadis et al.

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1. General response to referee comments

The authors appreciate the three reviewers for their positive comments, regarding our holistic approach on modelling complex hydrosystems. According to their suggestions, we proceeded to a minor revision of the paper, as explained below.

2. Reply to comments of referee 1 (A. Koussis)

a) We share your reservation regarding the term "disturbed", introduced to describe water resource systems that are significantly affected by human interventions. On the other hand, we should cautiously use the alternative idiom "modified" (which has been prevalent due to the WFD), since this mainly refers to water bodies than basins.

Nonetheless, given that the model emphasises on the quantification of discharge along river networks, we agree to make the change, which also led to altering the title of the paper.

b) The main concept of the groundwater modelling component was the use of a limited number of cells, to describe the flow problem through a parsimonious parameterisation. This is implemented via an Integrated Finite Difference approach, synoptically depicted by Rozos and Koutsoyiannis (2005), which ensures significant flexibility in the representation of the aquifer. The flow model, as described by eq. 4, is indeed non-linear, but is linearised if assuming approximately constant cross section areas Aij between adjacent cells during each computational time step, which the model allows to be arbitrarily small (this point is clarified in the revised document).

c) We agree on the similarities with Mazi et al. (2004), also dealing with hybrid calibration strategies. In the revised document, we have cited this reference.

d) Apparently, the simulated hydrographs of springs are smoother that the observed ones, due to the parsimonious modelling approach, based on Darcian equations describing water interchanges between groundwater tanks, in addition to the rough discretisation of the groundwater flow field. This is more evident for the Melas and Polygyra hydrographs (Figs. 12 and 13), the variability of which is rather small if compared to the observed one. In the revised version, section 5.4, we added some comments about the relatively poor (although better than previous attempts) representation of this highly complex system, with many uncertainties. The lack of extended spatial information, regarding both surface and groundwater resources, does not allow a more detailed schematisation and parameterisation, which would probably (but not definitely) improve the performance of the aforementioned spring hydrographs.

e) We agree with the comment regarding the use of term "flood"; hence, in the revised document, we substituted it by the phrase "high flow".

f) We are grateful for the detailed editorial corrections on the manuscript, which we followed in the revised document.

3. Reply to comments of referee 2 (P. Krause)

a) We have clarified in the revised manuscript that we used an ArcGIS platform to manipulate spatial data and generate the various geographical layers, in the form of unions and intersections; this, however, is not restricting.

b) Given that the model conceptualisation is not based on pure physics, and taking into account the coarse spatial representation of hydrological mechanisms, we believe that it is impossible to use a priori defined "effective" values for soil parameters, as the capacity of moisture tanks. However, since the parameterisation retains some physical sense (by assigning parameters on HRUs rather than on sub-basins), we can bring in catchment attribute (distributed) data within optimisation, by appropriately restricting the boundaries of the search space. Additionally, within our hybrid calibration strategy, we checked the values obtained after the optimisation and rejected solutions that appeared to be far from physically reasonable values of the corresponding parameters. This stands as a key point of our approach, also helping to deal with the equifinality problem. To clarify it, we have added a discussion in section 5.3.

c) In order to keep a parsimonious parameterisation, we restricted the number of HRUs by combining only two soil properties, permeability and terrain slope. Moreover, the incorporation of land use information was redundant, since the latter is almost overlapping with slope. Indeed, mountainous areas of high slope are covered by forests, whereas plain areas, characterised by small slopes, are dominated by crops and generally low vegetation. However, land use was necessary for calculating the potential evapotranspiration at a sub-basin scale, which is input to the model. We have inserted this discussion in the revised document, section 5.2.

d) Regarding the technical corrections, we made the necessary modifications to the text.

4. Reply to comments of referee 3

a) The parameterisation is in accordance with the aim of the study, which focuses on the representation of surface and groundwater runoff as well as the water management regime across the river basin. To realistically describe even the most dominant processes, especially in a hydrosystem of significant heterogeneities and uncertainties, it is unavoidable to use many parameters. On the other hand, to identify and explain them it is necessary to introduce as many criteria as implied by the rule of thumb that a single response should be represented through no more than 5-6 free parameters (see discussion in section 2). Thus, we achieved to enhance the information embedded within calibration, by establishing, in addition to the typical statistical metrics to fit the model on the observed hydrographs, some empirical criteria to control the (unmeasured) groundwater responses. From this point of view, the model is not over-parameterised, since the number of parameters (˜100) is "compatible" to the number of fitting criteria (˜40).

b) The single-optimisation approach, based on the use of a weighted objective function, aimed to provide a best-compromise parameter set, which was necessary for the water management study. However, the hybrid calibration strategy, allowed studying quite well the interactions between the various criteria and also handling with equifinality (see also reply to referee 2). We agree that a pure multiobjective calibration approach, aiming at a simultaneous generation of Pareto optimal parameter sets, should ensure a deeper insight to the problem. In fact, we recently made a series of multiobjective analyses, helping to trap a slightly better solution. We hope to publish the results of our research in a forthcoming paper.

c) Regarding the comment about the spatio-temporal variability of rainfall in the studied river basin, the referee is referenced to earlier studies of our team. Mamassis and Koutsoyiannis (1996) studied the influence of atmospheric circulation (weather type) on characteristics of rainfall events (duration, total depth) in a large area on mainland Greece and found that introducing "weather type" information does explain significant

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portion of the variance of the above characteristics. This holds for point rainfall while for the spatial extent of rainfall fields weather type was a significant factor. The study was extended to flood events (Mamassis, Koutsoyiannis and Nalbantis, 1994) and again no significant portion of the variance of the discharge volume was explained by weather type. In HYDROGEIOS the spatial extent of a hydrological response unit (a few km2 to some tens of km2) is rather small and the influence of weather type is expected to be insignificant. Of course, spatial variation of rainfall within the whole watershed is explicitly taken into account in the model which is a semi-distributed one. Regarding runoff, the above-mentioned results led us to ignore weather type classification for monthly runoff also since aggregation into monthly values tends to eliminate any influence of weather type (already small) due to mixing of different weather types within a month. The referee is right to mention runoff regime which in our study area is governed both by strong rainfall events, with limited spatial extension, and by long lasting advective rainfall sequences, covering large areas. We believe that the methodology of HYDROGEIOS can easily handle cases with runoff regimes that are different from that of our case study. Finally, we would like to stress the fact that the choice of monthly time step in simulations was dictated by operational needs.

References

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Mamassis, N., and D. Koutsoyiannis, Influence of atmospheric circulation types in space-time distribution of intense rainfall, Journal of Geophysical Research-Atmospheres, 101(D21), 26267-26276, 1996

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