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Hydrology and Earth System Sciences Discussions

Interactive comment on "An integrated model for the assessment of global water resources – Part 1: Input meteorological forcing and natural hydrological cycle modules" *by* N. Hanasaki et al.

N. Hanasaki et al.

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Dear Reviewer,

Thank you for your comments. All of your three comments pointed out fundamental issues of global hydrological model. Here are our replies.

—

This paper is very interesting and ambitious as well. I am debating with myself: should I give it an easy pass since the authors have put so much efforts or I need act as checker before it is truly ready for prime time. Listed below my three concerns:

1) There is one problem with the paper in that most of the information on the six modules (and repeated in this article) can be found in many previous publications and studies. What is new/innovation about this two-part paper? Is because it put the six modules together? What is your theoretic basis and assumption to justify we can totally assess/model global water resources by integrating the six modules? Why these modules, why six?

First, our two papers are new because they showed the results of global water resources assessment taking into account the seasonality of water resources and water use (Part 2; Section 5). To achieve this goal, we needed to estimate both the availability of water resources and water demand at less than annual interval. We developed a model specially designed for this challenging problem. Indeed, Alcamo et al. (2007) reported a global water resources assessment using the 90 percentile streamflow, and a few global models (e.g. WaterGAP2 of Alcamo et al., 2003) integrated natural and anthropogenic sub-models. Our two papers discuss how our model and assessment are different from those of earlier studies, and in which part ours are better than them (Part 1, Section 1 and Part 2, Section 5).

Second, we do not insist that our model enables us to totally assess or model global water resources. We point out that the most of earlier global water resources assessments were annual basis. We highlight the importance of sub-annual perspective, and propose a practical method to achieve it (Part 1, Section 1)

Third, the reasons why we need six modules are described across Part 1 and Part 2. We can summarize them as follows. First, to estimate renewable water resources, the land surface hydrology module and the river routing module are indispensable. Estimating agricultural water demand is particularly important in global water resources assessments because 85 percent of consumptive water is used for agriculture (Shiklomanov, 2000), with considerable seasonality because the water is needed only during cropping periods (Part 2, Section 2.1). The crop growth module plays a quite important role in our model. Reservoirs buffer the seasonal variation of streamflow and fill the gap between the timing of streamflow and water demand. Therefore, reservoir operation is an important player in our sub-annual basis assessment (Part 2, Section 2.2). There is no doubt about the need for the anthropogenic withdrawal module. One of the most basic dynamics in water resources problems is that the withdrawal in the upper stream limits that in the lower stream (Part2, Section 2.4). The environmental flow requirement is a quite new topic in global hydrology. However, we can't withdraw water from channel until it completely run out (Part 2, Section 2.3). We understand that there are many other important issues to consider, but we started from these six modules that we judged most essential for our goal.

This logic may be less clear unless you read through Part 1 and Part 2. If necessary, we will add this discussion to the introduction of Part 1.

Your introduction part: "we tried to avoid model calibration involving the fit of simulated results to available observation records. It is well established that hydrological models do not reproduce observed hydrographs very well without model calibration (or model parameter tuning). However, in global-scale hydrological modeling, model calibration is a difficult issue. There are a few reasons for this. First, it is virtually impossible to calibrate the model worldwide because of the limited availability of observations, especially in developing countries. Second, both models and input meteorological forcing and validation data contain considerable uncertainty (Oki et al., 1999), and it is not always easy to attribute errors in simulations to improper settings of model parameters. Moreover, we intended to apply the model to future projection under climate change. Thus, the transparency and physical validity of the model are quite important because the simulated results are highly model dependent. Therefore, we extensively exam-

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ined the simulated results of the model using model inherent parameters; even this sometimes produces large errors"

2) I agree that it is almost impossible to calibrate the global scale hydrologic model worldwide, the exact reason you gave up calibration. Since each module accounts certain degree of error/uncertainty, how the error/uncertainty will propagate through the integrated system from data end to prediction end while you manage to keep the mass and energy balance budget closed? Any reliable strategy suggested here?

> Propagation of error occurs in any model which has more than one process. Let's take a distributed hydrological model as an example. An error/uncertainty in the evaporation process influences the soil water process, and it propagates to runoff and other processes. The influence of error remains afterward by erroneous state variables such as soil moisture, and propagates to downstream by the routing process.
>
> The authors believe that the only practical and reliable strategy is to examine and validate each process. In our two papers, we extensively validate our modules, and discuss potential countermeasures we need to take in near future.
>
> In any case, it should be avoided that a part or the whole system falls into an unrecoverable condition as a result of amplification of an error. Our model was designed with especial care for this point. For example, the reservoir operation module is designed when storage of a reservoir is significantly decreased, the release is reduced to recover storage. In this way, the module avoids the condition of continuous spill over or run out. (Part 2, Appendix B)

3) We might have certain degree of confidence/control of natural aspect of the system (such as routing, meteorological input data, and crop growth etc.), but it is extremely

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difficult or even infeasible at this stage to model/ figure out the anthropogenic activities (e.g. water withdrawal module) at the daily time scale, the elemental temporal resolution of this system. Recall that you even gave up calibrating the hydrological model, how can someone parameterize/calibrate the anthropogenic activities. Convince me if I am way too conservative.

> Basically, human acts rationally. We do not expect that our model can reproduce the individual activity or judgment of reservoir operators or farmers in the real world. However, reservoir operators seldom release water in floods and farmers seldom sow in periods unsuitable for cropping. Even a simplistic model that assumed rational act of humans, we have shown that the historical reservoir operations (Hanasaki et al., 2006) or basic crop calendar (Part2, Section 4.1) can be fairly reproduced.
>
> Again, we do not insist that we completed a perfect global water resources model. We discussed the performance and uncertainty of the anthropogenic modules in detail that you concerned (Part 2 Section 4). Some reviewers even said that we discussed too much. We admit that our current model contains considerable uncertainties; however, we showed the outputs of our model meets criteria of application to our goal, a global water resources assessment taking into account subannual variability.

My recommendation, therefore, is that HESSD should not accept this heavy-duty and well written paper at present form because there are many known unknown. This is not an indication that the manuscript is not interesting to audiences. I am almost sure that what you are trying to do is extremely important. In short, in my opinion this integrated system is not ready for prime time given its present contents. I am looking forward to seeing an improved version.

> The role of scientists is not to show the complete and perfect under-

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standing, but to show the best knowledge for the present. If our research is "interesting to audiences" and "extremely important", then the methodology and results should be published. It will stimulate the discussion in the community, and contribute to the better understanding.

At the initial stage, the Global Climate Models (GCMs) contained considerable uncertainties. Improvements were accumulated in the past few decades, and now GCMs largely influence international policy makers. If there were no publication of GCMs until they become perfect, important scientific activities such as IPCC were not realized. Your comment discourages the advance in hydrological modeling linking natural and anthropogenic systems, which is an important field in hydrology. If your comment is adopted, we wonder almost any paper on modeling can't be accepted in HESSD or HESS.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 4, 3535, 2007.