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Geoscientific Model Development Discussions

GMDD

Interactive comment

Interactive comment on "GSFLOW-GRASS v1.0.0: GIS-enabled hydrologic modeling of coupled groundwater–surface-water systems" *by* G.-H. Crystal Ng et al.

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RESPONSE TO REVIEWER 1

Boldface: Reviewer 1's original comments and additional clarifications (latter added to the corresponding original comment)

Italics: Our response

We thank the referee for their time in reviewing our manuscript and providing feedback.

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Discussion paper

<u>General comments:</u> The manuscript presents the development of a suite of tools for preparing the input, submitting the simulation runs, and visualizing the output of the groundwater–surface-water coupled GSFLOW model. The proposed suite of tools is developed exploiting the functionalities of the open-source GIS software GRASS and ad-hoc Python scripting. Authors tested the developed toolkit presenting test cases based on three catchments having different physiographic features. The manuscript is generally well written and with a logical and easy-to-follow structure. While I concur with the authors on the potential of such kind of efforts to encourage the use of complex surface-subsurface coupled hydrological models, I question the actual novelty and technical advancements presented in their work. Besides a suite of GIS extensions and scripts, the manuscript does not propose new technical solutions for the problem at-hand. For this reason, and for those elaborated below, I consider this contribution not suitable for GMD standard.

(Additional clarification:) I evaluated the paper not suitable for GMD for the lack of novelty and technical advancements. I did not question the utility itself of the proposed toolkit and I did not express any issue concerning the fit of the subject addressed in this work with the scope of the journal.

We are glad the reviewer found that our manuscript was generally well-written and fits within the GMD scope, but we are obviously very disappointed that the referee did not consider it to be suitable for GMD standard. Our work does offer new technical solutions for making integrated hydrologic modeling more accessible; this review brought to our attention that the first manuscript version indeed failed to explain these novel aspects and technical contributions and instead focused too much on simply documenting the contents of the toolbox. We appreciate that the reviewer raised this issue, and we have substantially revised the manuscript to address this serious shortcoming in the original presentation.

In particular, we first clarified that while some of the individual scripting components within the toolbox may appear straightforward, our work's innovation is the entire bundled package. Our substantially edited Introduction now emphasizes that existing software for integrated hydrologic models fail to provide freely accessible toolkits that fully cover pre- to post-processing steps (p. 2 Lines 22-30), and that GSFLOW-GRASS addresses that critical gap stymieing the use of integrated hydrologic models (p.2 Line 31- p. 3 Line 6).

We then explained that the major technical advancement of our work was to create a new set of GRASS-GIS tools that can robustly and automatically generate surface and subsurface model domains suitable for hydrological modeling – these are critical for GSFLOW-GRASS to be widely applicable to a diverse range of hydro(geo)logical settings. We now realize that the original manuscript version documented these new GRASS GIS extensions but provided almost no background on the challenges of creating robust and automated tools, which have led to a general unavailability of such solutions predating our toolbox. A new paragraph has been added to the Introduction to present the technical advancements with these GRASS GIS extensions (p. 3 Lines 7-21). Further, we have entirely re-written Section 3.2 on the GRASS GIS domain builder (p. 10-12), so that it now explicitly describes what was implemented to solve specific known problems with stream network delineation. Finally, we also made major changes to Section 4 on the Examples, in order to explain how each example demonstrates a different strength and capability of the domain builder (specifically, p. 21 Lines 3-10 for Shullcas, p. 21 Line 32- p. 22 Line 4 for Santa Rosa, and p. 23 Line 10- p. 24 Line 4 for Cannon River). These examples demonstrate how GSFLOW-GRASS handles known challenges with various degrees of drainage integration, landscape relief, and grid resolution, as well as the presence of irregular coastal boundaries.

The technical advancements of our GRASS GIS tools were recently highlighted as a new release feature on the GRASS GIS website: https://trac.osgeo.org/grass/wiki/Grass7/NewFeatures74 (including a figure with our Cannon River watershed example)

– see the screenshot in Figure 1.

In addition to major revisions to the Introduction, GRASS GIS Domain Builder section, and Examples section, we essentially re-wrote the Abstract and Conclusion to highlight these new and technical contributions.

Specific comments:

1. In presenting/justifying their work, I think authors overlooked a bit too much the key technical issues preventing the widespread use of complex, physically based surface-subsurface coupled hydrological models in a decision-making framework. Here, I would argue that preparing the input is certainly a necessary and important step in the modeling exercise but not the most challenging one. In fact, if we agree that computationally efficient and numerically stable codes are needed to "promote science-driven decision making" then ad-hoc tools allowing a dynamic (e.g. in-situ visualization) inspection of such physical and numerical model response are probably much more needed, especially when we approach big-data problems. Saying that, I do not see the positioning of the effort presented in this manuscript with respect to these grand challenging tasks.

(Additional clarification:) I highlighted some of the grand challenges (e.g., big-data problems) that, in my opinion, modelers are facing when performing large-scale high-resolution surface-subsurface coupled simulations. In this context, in-situ visualization (i.e., the use of libraries to dynamically connect running simulations and graphical outputs) is of particular interest in the geoscience community. My concern was that the paper did not even mention/discuss how the methodology they are proposing reconcile with such grand challenge.

We believe that the need to create long model input files does in fact present a critical challenge for many potential users who may lack the necessary software skills or who might wish to carry out initial model tests before committing time to its use. In support *of the value of our toolbox, we would like to share that over just April 9 to 22 (the maximum length of time tracked by GitHub), our GSFLOW-GRASS repository received 173 views and 22 unique visitors, and one user from a major research university sent us an email that opened with "Thank you so much for sharing the GSFLOW-GRASS toolkit. This toolkit really relieves my struggle of preparing inputs." - and all of this is with absolutely no effort to advertise our toolkit.*

However, we do acknowledge that there are other grand challenges to integrated hydrologic modeling, and we appreciate the reviewer's suggestion about in-situ visualization. In response, we have expanded our toolbox to include an additional tool "plotGSFLOWTimeSeries_Runtime.py", which is now incorporated into our Run script to generate runtime time series plots of simulated discharge and precipitation. This new capability is described in the revised manuscript on p. 17 Lines 12-13 and p. 18 Lines 10-13.

2. The outcome of the presented developments is clearly reflected in the results section. Here, authors describe three test cases illustrating the physical settings of each study area and discussing the potential outcome of a surface-subsurface coupled modeling approach. However, these results appear the repetition of the same exercise without much insight on the novelty of the proposed approach. For instance one could argue that such kind of plots can be simply obtained with some visualization scripts developed from scratch.

(Additional clarification:) I questioned the insights gained from the three test cases. Authors reply that each of them demonstrates particular technical challenges solved by the proposed toolkit where 'other' approaches would fail. If this is the case, you need to provide evidence, from a simple visual inspection of Figure 5-6-7 I do not see it.

A user can indeed develop from scratch similar visualization scripts, but we believe that *the need to do so presents a major impediment to many potential users who may lack the programming knowledge or may not be able or wish to invest the time for it. Our toolbox includes pre- and post-processing capabilities that make the GSFLOW model widely accessible.*

We do acknowledge, however, that the original manuscript version presented the 3 examples in a way that did not describe how each one presents a particular challenge that the new GRASS GIS extensions address. As mentioned earlier in this response, we addded paragraphs to each example to do so, specifically: p. 21 Lines 3-10 for Shullcas, p. 21 Line 32- p. 22 Line 4 for Santa Rosa, and p. 23 Line 10- p. 24 Line 4 for Cannon River. These aspects are also summarized in the Conclusions: "The results show that the new and automated GRASS GIS extensions can automatically and consistently build topologically complete linked surface and subsurface flow domains in settings that are typically challenging for standard GIS tools, including steep topographies, irregular coastal boundaries, and low-relief terrains that lack integrated drainage." (p. 24 Lines 31-33).

We further realized that we should have more clearly highlighted the types of hydrologic / hydrogeologic processes of management concern that can be evaluated with aid of GSFLOW-GRASS through each example; we have edited the last paragraph of each example to better express these types of processes and how they are depicted with the GSFLOW-GRASS visualization tools. These processes are also summarized in the edited Conclusion: "these examples further demonstrate that GSFLOW-GRASS is a flexible tool for investigating the role of groundwater-surface water interactions in modulating dry-season discharge, controlling runoff in erosion-prone landscapes, and imposing possible water-quality threats in agricultural and recreational watersheds." (p. 25 Lines 1-3).

3. In a similar vein to the previous point, at the end of the introduction authors argue that the developments of such automated toolkit will enable rigorous test-

ing. Absolutely true but a concrete path forward and tangible results are not presented in this context. Wouldn't it be an interesting way to demonstrate the utility of such kind of tools?

As we discussed in our response to the previous comment 2., we realize that our original manuscript version failed to adequately explain how the 3 examples demonstrated the utility of GSFLOW-GRASS. We have substantially edited our manuscript to now explain how each of these examples showcase a particular capability of the domain builder as well as a different scientific and/or resource management concern affected by groundwater-surface interactions that can be probed with the aid of GSFLOW-GRASS (see manuscript lines referenced above). As a concrete path forward, we also suggest future tests of the performance of ungridded surface domains with GSFLOW-GRASS (p. 9 Lines 6-7), and we list potential future extensions of GSFLOW-GRASS in the Conclusion (p. 25 Lines 9-17).

4. In several parts of the manuscript, authors refer to a similar work, i.e., Gardner et al., which is currently under review for another journal. As the content of the cited work cannot be evaluated, these statements are unverifiable by the reader/reviewer, which is obviously not acceptable. Moreover, considering the potential overlap between the two contributions, as also acknowledged by the authors, it is not possible to weight the actual contribution of this work. For instance, one may ask if moving from ArcGis to GRASS or using ungridded versus gridded data would be enough to motivate an additional publication.

(Additional clarification:) I raised the issue of a cited publication, which is currently under review for another journal. Authors' argumentation is that the work received positive comments and it will be likely out very soon. At this time it is not. Therefore, it is not possible for any reviewer or person eager to comment on the manuscript to have an idea on the content of the cited work. In other words, being aware of these positive comments on the contribution, you should have

included in the discussion later in the review process.

We now recognize that it is unreasonable to expect a reader to follow detailed comparisons with an unpublished and unavailable manuscript. One of our co-authors, Rich Niswonger, is also a co-author of the Gardner et al. submitted manuscript (as well as one of the GSFLOW developers at USGS). He reports that the manuscript is still in re-review at this time. Because the Gardner et al. work is not actually central to GSFLOW-GRASS, we minimized our discussion of that work – mostly in the Introduction and the “User-specified settings and model inputs" section. We now only mention it as one of the other software options to facilitate integrated hydrologic model implementation that do not offer a complete pre- to post-processing set of tools. We view it as a real benefit for the community to have these two new packages with different features (differences in discretization, handling of input data, availability of post-processing tools, and software platforms), so that users can choose the one most suitable for their application. Rich Niswonger’s role as co-author has not been to develop the GSFLOW-GRASS software, but it has been to ensure that GSFLOW-GRASS is not overly duplicative of the package by Gardner et al. (of which he is a developer), and that GSFLOW-GRASS is constructed in a way that the USGS considers will be effective for increasing the accessibility of GSFLOW. The multiple softwares (free and proprietary) available for implementing MODFLOW serve as an example that having more than one software package for a model can be valuable for supporting an extensive user-base.

5. It appears that for some of the most critical parameters (e.g., Manning’s parameter) authors present their approach referring to homogeneous values. In so doing, they advocate that field data on channel geometries come in a variety of forms difficult to accommodate in a generalized approach. Wouldn’t it be the motivating reason for such geoscientific developments as the one presented here? Data fusion tools are in my opinion the key for facilitating the coherent ingestion

of large source of information into a distributed model input data structure. An example along this line is represented by the work of Leonard and Duffy, 2013.

References: Lorne Leonard, Christopher J. Duffy, Essential Terrestrial Variable data workflows for distributed water resources modeling, Environmental Modelling & Software, 50, 85-96, 10.1016 /j.envsoft.2013.09.003, 2013.

Our original GSFLOW-GRASS version did include an option for spatially heterogeneous hydraulic conductivity inputs, which was implemented in the Santa Rosa Island example. However, we agree with the reviewer that a heterogeneous channel width and Manning's n parameter would also be important to include, and in response, we modified the toolbox to accommodate this through the Settings file (as described on p. 9 Line 29 and on p. 17 Line 5).

We acknowledge the value of linking integrated modeling with existing databases for model inputs, but we consider this beyond the scope of our current work, which aims to provide a generalized solution for implementing GSFLOW-GRASS. We reference software tools that do fuse data products with hydrologic models, including Leonard and Duffy (2013) as suggested by the reviewer (p. 10 Lines 3-5); we then point out that these databases are generally only available in observation-rich places and thus we do not include any in the first GSFLOW-GRASS version, which serves as a general basis for further development (p. 10 Lines 7-8). Our revised conclusion discusses future extensions of GSFLOW-GRASS to include links to spatial databases to generate model inputs (p. 25 Lines 12-13).

Although GSFLOW-GRASS currently does not offer spatially heterogeneous solutions for inputs beyond hydraulic conductivity and Manning's n, we created a new GRASS GIS tool, v.gsflow.mapdata, in response to the reviewer's valid concern about it. This tool can take any spatially variable data in a raster or vector GIS format and map it to one of the GSFLOW discretization structures: sub-basin HRUs for PRMS surface-water processes, regular grid cells for MODFLOW groundwater processes, *gravity reservoirs that link the HRUs and MODFLOW grid cells, or stream segments or reaches for MODFLOW streamflow processes. This helps users add data from any source to the GSFLOW-GRASS data structures for input into the model. The new v.gsflow.mapdata tool is presented on p. 9 Line 30- p. 10 Line 8. Throughout the rest of the revised manuscript, we also mention how this tool can be implemented to create specific spatially distributed inputs, including the climate inputs and soil / land-cover parameters (p. 12 Line 26, p. 14 Lines 19 and 29, p. 15 Lines 16 and 29, and p. 17 Line 1).*

<u>**Technical corrections:**</u>

1. Authors argue that models using triangulated irregular networks show better water balance performance over steep catchments. This is a quite interesting statement but ad-hoc citation is needed to substantiate this.

We realize that we left out some details and should have specified that TINs show better water balance performance IF they are implemented with the finite volume method (because the finite volume method is mass-conserving), and that TINs cover complex surface domain more efficiently (fewer units) than grid cells. We edited the text to say all of this on p. 4 Line 15-16.

2. According to the author's opinion, PRMS does not implement Richards equation but instead applies an 'efficient' calculation to determine input and output for HRU. What's the meaning of 'efficient' here?

By "efficient," we mean computationally fast. We clarified this on p. 6 Lines 5-6.

3. I do not see the precipitation lines in Figure 5-6-7.

As we mentioned in our preliminary response to the reviewer: we see the blue pre-

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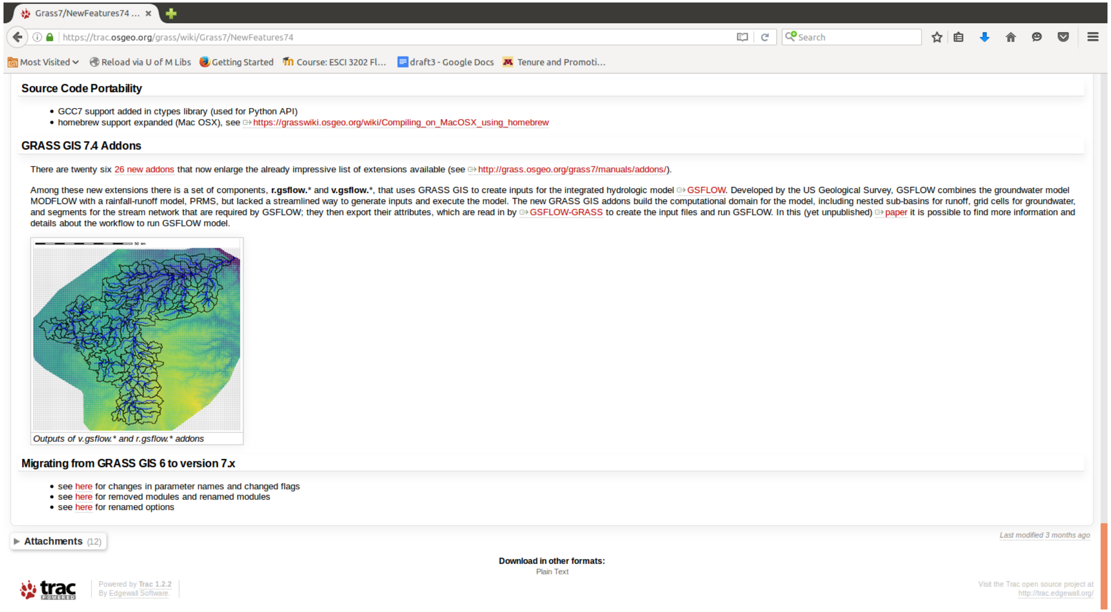
cipitation lines clearly in these figures. We are unsure why they do not appear for the reviewer and wonder if there is an issue with the file conversion. If more information could be provided (e.g., do the blue lines fail to appear at all, or do they appear but just not clearly?), we can address it.

Interactive comment on Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2017-321, 2018.



Grass7/NewFeatures74 ...

https://trac.osgeo.org/grass/wiki/Grass7/NewFeatures74

Most Visited Reload via U of M Libs Getting Started Course: ESCI 3202 Fl... draft3 - Google Docs Tenure and Promoti...

Source Code Portability

- GCC7 support added in ctypes library (used for Python API)
- homebrew support expanded (Mac OSX), see https://grasswiki.osgeo.org/wiki/Compiling_on_MacOSX_using_homebrew

GRASS GIS 7.4 Addons

There are twenty six 26 new addons that now enlarge the already impressive list of extensions available (see http://grass.osgeo.org/grass7/manuals/addons/).

Among these new extensions there is a set of components, **r.gsflow.*** and **v.gsflow.***, that uses GRASS GIS to create inputs for the integrated hydrologic model GSFLOW. Developed by the US Geological Survey, GSFLOW combines the groundwater model MODFLOW with a rainfall-runoff model, PRMS, but lacked a streamlined way to generate inputs and execute the model. The new GRASS GIS addons build the computational domain for the model, including nested sub-basins for runoff, grid cells for groundwater, and segments for the stream network that are required by GSFLOW; they then export their attributes, which are read in by GSFLOW-GRASS to create the input files and run GSFLOW. In this (yet unpublished) paper it is possible to find more information and details about the workflow to run GSFLOW model.

Outputs of v.gsflow. and r.gsflow.* addons*

Migrating from GRASS GIS 6 to version 7.x

- see here for changes in parameter names and changed flags
- see here for removed modules and renamed modules
- see here for renamed options

Attachments (12)

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Fig. 1. Screenshot of GRASS GIS' new features - includes GSFLOW-GRASS add-ons

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