Manuscript: hessd-10-6897-2013: Inverse streamflow routing

Major remarks

The authors present an interesting approach to estimate runoff at the grid scale from streamflow measurements at river gauges. This approach may help to improve the data availability for specific catchments. Unfortunately the paper is currently written in a way that the reader might think that the authors find the golden solution for all problems related to the availability of gridded runoff and gaps in streamflow time series. Thereby, the authors largely neglect the limitations of their method and associate characteristics with their method that the method cannot hold. Here, the reader might think that the their estimated runoff data are almost as good as observations, which would be misleading for future studies that might compare simulated runoff data to runoff yielded by the inverse streamflow routing. Consequently a large part of the conclusions section has to be rewritten, as there are a lot of statements that are not justified. These comprise, e.g., page 6915, lines 21, 25++, page 6916, lines 10.

The test catchment used for the application of the new method contains a large number (75) of stream gauges. Thus, it is not completely surprising that the inverse method yields some reasonable runoff distribution. But it is likely that this large number of gauges is necessary to yield those results. As such a dense gauge network is not present for many rivers of the globe; this certainly will limit the applicability of the method. Consequently this should be tested, which can be easily done by reducing the numbers of gauges used for the inverse routing. Here, gauges should be randomly selected except for the station at the outlet of the catchment that may always be part of the subsamples of gauges. For lower number of stations, certainly the complexity of the topography might play an important role.

Given the large number of stations within the catchment, it is necessary to evaluate the added value of the inverse routing technique in comparison to the more simple approach of distributing every measured streamflow over the associated sub-catchment (For example, if a sub-catchment has one inflow Q1 and an outflow Q2, then the discharge Q2 is equally distributed over the area A2 solely belonging to the gauge station 2, while Q1 is distributed equally to the catchment area A1 of station 1. Note that the full catchment area of station 2 is A1+A2.). Will similar pattern arise as for the inverse routing method? If yes, then the inverse routing is likely not adding much value to the distribution and its quality just originates from the large number of stations. (Note that a hint on this is given on page 6911, where it is written that '*the shape of patches follows the boundaries of sub-basins that drain to the input gauge locations*.') If a more reasonable pattern is estimated, then this would show an added value of the method.

In summary, I suggest that the authors should focus on what their method can do, and clearly point out what it cannot. Then, the paper may be accepted for publication after major revisions have been made.

Minor Comments

In the following suggestions for editorial corrections are marked in *Italic*.

<u>p. 6898 – line 17</u>

It is written: “Now inverse routing bridges the gap and provides a best, if not only, mean to estimate runoff field at any spatial or temporal scales from observations.”

This a good example for the major problem of the paper addressed above. First, for long-term annual averages, observed streamflow measurements are sufficient to bridge the gap. Second, for specific catchment with a high number of stations (or simple topography), the method may bridge the gap on finer temporal scales, but this will likely not be the case for catchments with only a few gauges and/or a complex topography.

p. 6901 – line 17
Eq. 1 is not the St. Venant equation. It is a diffusive wave equation!

p. 6902 – line 4
… prescribed and *are* independent …

p. 6904 – Sect. 2.2
If you only account for travel times, then retention characteristics within the catchment are neglected. This is part of the simplifications of your method (which is ok.), and should be stated.

p. 6908 – line 24
If D is set to 0 all over the basin, then no diffusion takes place, Then Eq. (1) becomes a simple advection equation. If this is part of the method, this is ok. But then I don’t understand all the effort you make by using Eq. (1) in sect. 2.2 and all their related derivatives. It seems that you initially pretend to use a sophisticated advection-diffusion approach, which later on turns out not to be the case.

p. 6910 – line 8
… usefulness *of* inverse …

p. 6911 – line 15
Here follows another example for statements that suggest more than the method can probably do, as ‘*the very strong capability*’ of the method is very likely caused by the high number of gauges (see major remarks above).

p. 6912 – line 2
… case *in* Fig. 4 …

p. 6912 – line 21-27
Why innovation is defined as the difference between the synthetic truth (thick green line) and initial guess (blue line) of streamflow?
I would expect that innovation, which is caused by the inverted method, is somehow related to the streamflow constructed from the inverted method. Please clarify.

p. 6913 – line 9-11
It is written:
‘*As the inverted runoff fields can perfectly reconstruct the streamflow time series at 10 input gauge stations in Fig. 8, they can also reconstruct the streamflow at any point on the river network*’.

Actually I strongly doubt this. The perfect match is just by definition of the method. At least you may show this by reducing the number of gauges, and then by simulating streamflow at gauges that were not used for the inverse routing. To show real positive characteristics of your method, you have to significantly reduce the number of stations (see also major remarks above).

p. 6913 – line 15-17
Again I doubt the generality of this statement. It will work in catchments with good river gauge density. But it will likely fail in large catchments with a low number of stations.

p. 6913 – line 25
It is written: …not the same well as…
Grammar seems wrong – please correct!

p. 6914 – line 1
… consistently *lower* basin …

p. 6914 – line 6.
… but *is* often …

p. 6914 – line 8-11
It is written:
'*This suggests it is more difficult to make significant improvement to the initial guess using real gauge measurements, especially when the initial guess is already very reasonable. Large biases can be easily corrected but small spatial details are much more difficult to recover*.'

This is directly related to the effect that runoff is estimated by the method, not reconstructed, and that the station density plays a role. More spatial details could obviously only be recovered if the station density would be higher! (see also major remarks)

p. 6914 – line 18
… streamflow *is* not the natural …

Figs. 3, 7, 8, 10
Axis descriptions, legends and panel titles are too small. Please increase their size.