

***Interactive comment on* “Conditional simulation of surface rainfall fields using modified phase annealing” by Jieru Yan et al.**

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Received and published: 29 January 2020

ISSUE: Lack of practical guidelines (1) The authors answer the 5 questions raised by the reviewer in order to make this work more 'user-friendly'.

Q.1: How is the covariance of the 'starter' inferred from observations?

This question has been answered in the previous reply. We repeat here. The covariance of the starter is obtained using the radar quantile map (continuous quantiles from 0.000 to 0.999). The radar quantile map is transformed into a standard normal field, i.e. the reference field Z^* , using the inverse of the standard normal distribution function (Eq.4), and the covariance is computed therefrom. The acquisition of the covariance has nothing to do with the distribution function of surface rainfall nor rain-gauge data.

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Q.2: Which gauge density is required to ensure good results?

It is hard to give a precise answer to this question. Yet we would love to share some of our experience. Good results of this methodology are not only built on the gauge density, but equally important is the distribution of the rain-gauges in the domain of interest. The data configuration used in this work is not ideal for this methodology (see Figure 3, the left panel), as the distribution of the rain-gauges is not uniform and relatively centered in the middle, especially in the east-west direction and we lack rain-gauges in the four corners. Therefore we have to select events whose storm center is relatively centered according to the spatial distribution provided by radar. And the main purpose of the selection is to ensure the sampled quantiles (by the rain-gauges) are more or less uniformly distributed in $[0,1]$. As for the gauge density, the author cannot give a specific number. In this work, the 12 stations are at a distance of approximately 4 km between each other, which is relatively dense. Normally, with a denser network of rain-gauge (of good quality), good performance is more guaranteed.

Q.3: What is the maximum extent of the domain of interest that can be considered?

If one only uses the original radar quantile map, namely, without displacing the entire grid and without integrating the uncertainty of the radar-indicated rainfall pattern, there is no limit on the extent of the domain. One only needs to ensure the distribution of rain-gauges in the domain of interest. Yet it is recommended the measurement height of weather radar is as close to the ground surface as possible, such that it is more likely that the radar-indicated rainfall pattern aloft is close to what's happening on the ground. Thus, if one could make a choice (e.g. locations where the measurement ranges of two or three radars intercepts), choose the one with the smallest measurement height.

If one uses the methodology described in Section 3 to integrate the uncertainty of the radar-indicated rainfall pattern, there should be a limit on the maximum extent of the domain. Because it is considered that the entire field moves with a single vector under the assumption that the relevant wind field is uniform. If the extent of the domain is

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too large, the feasibility of the proposed methodology is suspicious. The extent of the domain in this work is (39km X 39km), the selection of this extent is limited by the gauge data availability. With this spatial extent, quite often we could find dozens of displacement vectors that bring up the concordance of radar and gauge data. It is hard to provide a specific number of the maximum extent, yet it is the authors' feeling, if the gauge-data accessibility is not the limiting factor, one could enlarge the extent to 50 km or more, provided that the probability matrix obtained according to the procedure described in Section 3 has some pattern (not a random field).

Q.4: Why selecting a final resolution of 500 m in space and 30 min in time? In particular, why not adopt the temporal resolution of the radar (5 min)? I suppose that a bit of temporal aggregation is required to smooth out some of the mismatches between radar and rain gauge observations, but in this case why 30 min?

The reviewer is correct that the 5 min resolution (time resolution of radar) is not used partly due to the concern of the mismatch of the measurement time between radar and rain-gauge data, which could be smoothed out by temporal aggregation. Yet equally important is the quality of the rain-gauge data (see the answer to Q.5, the second paragraph). Then why 30 min? In fact, 30 min is only the choice of the authors, one could choose 15 min, etc. It is worth mentioning that the estimates of spatial rainfall have great potential to be used as the data source for the early detection of flooding. For this specific purpose, the hydrological response time of the target area is of interest. For highly urbanized areas, the response time could be 15 min or less, yet for rural areas, the response time could be 30 min or longer. For our case, the 15 min and 30 min events are most noteworthy. The authors just select a 30-min event as an illustrative example.

As for the choice of the spatial resolution, 500 m, it is largely due to the resolution of the raw radar data (C-band) in polar coordinates: azimuthal resolution 1 degree (x360) and gate length 1 km (x128). The spatial resolution of the raw radar data decreases as the distance from the radar/center increases. As the domain is located in the lower-middle

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range (around 45 km from the center v.s. 128 km of the radar measurement range), we think 500 m is proper to capture the spatial information provided by radar. Besides, 500 m is a very commonly-seen spatial resolution for many utilities in the field of urban hydrology.

Q.5: What are the requirements in terms of rain gauge and radar data quality?

The goal of raw radar data processing, under the context of this manuscript, is to maintain the accuracy of radar-indicated spatial ranks. Radar data after subject to normal quality control process and without the contamination from the bright band effect could be used. In this work, the raw radar data are only subject to the two processes: clutter removal and attenuation correction. Besides, there is no requirement for the accuracy of the Z-R relation, one could choose an arbitrary Z-R relation at hand to perform the conversion. In our case, we used the one ($Z=256 \cdot R^{1.42}$) adopted by the German Weather Service. One could also use the radar data without applying the Z-R conversion, namely in dBZ.

The requirement on the quality of rain-gauge data is relatively high, as we assume that the rain-gauge data represent the ground truth. As has already mentioned in the previous reply, we repeat here: rain gauges might be poor in capturing the instantaneous rain intensity, but the measurement error diminishes rapidly as the integration time increases (Fabry, 2015). Thus the method is not recommended to be used to estimate spatial rain-intensity fields. Spatial rainfall of the accumulation time, say 15 min, 30 min, or longer is the target of the proposed methodology.

ISSUE: Lack of practical guidelines (2) As for the suggestion by the reviewer that "more examples should be shown ...", the author has a different opinion. The purpose of showing the example is to demonstrate the capability of the methodology. One example is already enough and more examples would be a little bit repetitive. With all the practice guidelines specified above (the authors thank the reviewer for raising the issue "lack of practical guidelines"), the authors hope it is enough

to convince the potential users.

The author has noticed that provided DOI in 'Data availability' is erroneous. Please try the following URL. This does not include the source codes to perform the proposed methodology. We will consider providing the codes later.

URL = "https://figshare.com/articles/Input_data_for_conditional_simulation_of_surface_rainfall_field_30_min_accumulated
doi = "10.6084/m9.figshare.11515395.v1"

ISSUE: Minor comments The authors agree with most of the suggestions by the reviewer except for the following 2 points, where the authors would love to present some slightly different views.

(1) The reviewer is right that the proposed methodology is flexible that any global statistic could be used instead of the directional asymmetry and one could even combine several statistics in the objective function. Yet if one combines several components, the relationship of different components is noteworthy: if the components assist each other, it might turn out that the addition of different components takes limited effect; if the components do not interfere with each other (or the mutual influence is minor), which from the author's view is the ideal case, then everything is OK (the effect, as well as the convergence time); yet the worst case, if the components prevent each other, then there might be a problem in the convergence.

The combination of different components in the object function falls in the first case, yet the author insists on retaining this part. First, the reviewer is correct that using the pattern-only objective function is already good enough to produce nice results, and the effect of adding the component directional asymmetry does not deserve the extra computational costs (although we did not point it out explicit in the manuscript, as the author hopes the readers make their own judgments). However, the author thinks that scientific papers do not have to show success and perfection all the time, some slight failure provides a very good opportunity to learn lessons from. Besides, by adding the component asymmetry, the capability of the proposed methodology in

fulfilling statistics of higher order is demonstrated and it does help in decreasing the estimation uncertainty, though to a minor extent, see the comparison of the two panels in Figure 10.

(2) Concerning the issue: the local impact of rain-gauges The standard deviations (stdev) of realizations co-located with rain-gauges are zeros, which shows the fulfillment of the local constraints (point equality constraints). Rain-gauge observations play the role of "local" constraints, and the effect of conditioning to rain-gauges should be local. Thus, it is expected that the stdev increases when moving away from the rain-gauges. However, the authors think that the increase of the stdev is within the acceptable range. For the worst case, see Figure 5 (right), the maximum stdev is 1.6 mm. By integrating the uncertainty of the radar-indicated rainfall pattern, the stdev is reduced to 0.6 mm (also the maximum of the entire field), see Figure 5. For an event with a peak value of more than 10 mm, this is acceptable.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2020-4>, 2020.

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