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Discussions

Interactive comment on “A coupled atmospheric-hydrologic modeling system with variable grid sizes for rainfall-runoff simulation in semi-humid and semi-arid watersheds: How does the coupling scale affects the results?” *by* Jiyang Tian et al.

Jiyang Tian et al.

hettyliu@126.com

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Main comments: Point 1: More information of the Hebei model and the calibration of its parameters should be given. What is the advantage of using the Hebei model in the study area? What are the parameters calibrated in section 3.2 and how are they calibrated? Why choosing the 7 floods in Fuping and 6 floods in Zijingguan to calibrate the model? What are the values of the calibrated parameters finally used in the

coupled system? Reply: Thanks for the reviewer’s suggestion. The Hebei rainfall-runoff model is specially developed to describe the runoff generation mechanisms in the semi-humid and semi-dry area of Northern China, which has been successfully applied in Hebei Province for rainfall-runoff modeling and real-time flood forecasting. Due to the perennial water shortage and groundwater overexploitation, both storage-excess and infiltration-excess is found with great seepage along the river channel during the storm season. The obvious advantage of the Hebei model is the consideration of both storage-excess and infiltration-excess mechanisms for rainfall-runoff generation. It is a well-known conceptual model in China, as popular as the Xin’anjinag model. The model is easily used, and can widely be applied to other semi-humid and semi-arid watersheds with complicated (both storage-excess and infiltration-excess) mechanisms for rainfall-runoff generation. The description for the storage-excess part in the Hebei model is the same as the Xin’anjiang model. On the other hand, to reflect the heterogeneity of the infiltration capacity across the catchment, a distribution curve is adopted and expressed as Eqn. (2). The Horton infiltration model is also applied to obtain the infiltration volume for the river channel seepage. When the calculation interval is one hour, the infiltration volume can be calculated by the Eqn. (16). In order to clarify this issue, the following sentences are added in Line 22-28, Page 6: “Due to the perennial water shortage and groundwater overexploitation, both storage-excess and infiltration-excess is found in the study area with great seepage along the river channel during the storm season. The obvious advantage of the Hebei model is the consideration of both storage-excess and infiltration-excess mechanisms for rainfall-runoff generation. The model is easily applied and can be used in other semi-humid and semi-arid watersheds. In the Hebei model, the description for the storage-excess part is the same as that in the Xin’anjiang model. On the other hand, the infiltration capacity across the watershed is described by a distribution curve described below, and the Horton model is applied to calculate the seepage along the river channel during the river routing.” A new table below (Table 6) is added to show the calibrated parameter values on Page 6. The ranges of the parameter values are determined based on the application experiences of the Hebei model, which has been used in Northern China for more than two decades. The SCE-UA (Shuffle Complex Evolution) method is used to calibrate the parameters of the Hebei model (Duan et al., 1994). Actually, we have very limited choices when selecting the calibration data. Considering the semi-humid and semi-dry conditions of the study area, the soil is relatively dry before the storm season, and there is not many storm events leading to significant peak discharges. In this case, 7 storm events in Fuping and 6 storm events in Zijingguan are chosen to calibrate the model. Detailed information (i.e., the cumulative rainfall amounts and the peak discharges) of the events are summarized in the table below. Considering there are already many table in the manuscript, this table is not shown. When calibrating the model, the calibration events are bounded together to calculate one NSE value as the objective function. In order to guarantee reasonable values for the initial model conditions, the 24-h storm event is not independently used, but with a continuous antecedent period of data with the length of 15-days before the start of the event. In this sense, the events used for calibrating the model is some kind of "continuous" time series data. The following sentences are added in Line 29, Page 10 and Line 1-7, Page 11 to supplement more details about the model calibration and validation: "The SCE-UA (Shuffle Complex Evolution) method (Duan et al., 1994) is used to calibrate the parameters and the calibrated values are shown in Table 6. Due to the limited observational data, 7 storm events in Fuping and 6 storm events in Zijingguan are selected and used to calibrate the Hebei model, and another 2 from each sub-watersheds are used for model validation. In order to guarantee reasonable values for the initial model conditions, the storm events are not independently used, but with an antecedent period of data with the length of 15-days before the start of the event. The validation results show an average NSE value of up to 0.686, indicating the calibrated models are reliable for further applications. It should be noted that the four storm events in Section 2.2 are different from those used for calibration and validation."

Reference: Duan, Q., Sorooshian, S., Gupta, V. K. Optimal use of the SCE-UA global optimization method for calibrating watershed models, J. Hydrol., 158(3-4), 265-284,

doi: 10.1016/0022-1694(94)90057-4, 1994.

Point 2: I think the gridded Hebei model is a semi-distributed model. The main goal of establishing the gridded Hebei model is to match the rainfall simulation from the NWP system. Hence, the Hebei model does not consider the spatial variability of the underlying condition of the watersheds. If so, I do not quite understand why the soil storage capacity and the infiltration capacity is discretized across the grid cells? Reply: Thanks for the referee's question. As the referee mentioned, the gridded Hebei model is a semi-distributed model and does not consider the spatial variability of the underlying condition of the watersheds. According to Eq. (4)-(6), the soil storage capacity and the infiltration capacity significantly affects and determines the runoff generation. In the lumped Hebei model, the two crucial elements are described by two distribution curves across the watershed (as shown by Fig. 7). When the gridded Hebei model is built, the soil storage capacity and the infiltration capacity needs to be determined in each grid cell. That is why the two elements are discretized in each of the grid cells. Based on the theory of the TOPMODEL, it can be assumed that areas with similar topographic indices have the same hydrological response. Experimentations carried out in the study area showed that the soil storage capacity and the infiltration capacity of different grid cells can be obtained and dispersed using the topographic indices as Eqn. (17) and (18).

Point 3: The errors of the coupled system generally come from two parts: the NWP system and the hydrologic model. Since the WRF model is used (the rainfall error of which is normally quite considerable), I believe the accuracy of the simulated rainfall is the main factor affecting the performance of the coupled system (although there might also be uncertainties from the hydrologic model). Could the authors specify the rainfall errors from each storm events and quantity how much the system errors come from the rainfall simulations? A further question is, how to improve the simulated rainfall from the NWP system in order to improve the performance of the coupled system. For example, some grid-based observations, such as QPEs from the weather radar might be helpful. Reply: Thanks for the reviewer's suggestion. In the manuscript, Table 7 shows the simulation results of the coupled atmospheric-hydrologic systems based on WRF simulated rainfall for the four storm events, whereas Table 10 shows the simulation results of the coupled systems based on the corrected gridded rainfall for the four storm events. The differences of evaluation statistics between Table 7 and Table 10 reflects the system errors from the WRF rainfall simulations, which can be easily obtained by the subtraction of the corresponding values in Table 7 and 10. There are two main methods using the weather radar observations to improve the rainfall simulations, which are radar QPE or QPF and radar data assimilation for the NWP model. The following paragraph is added in Line 25-32, Page 13 and Line 1-4, Page 14, and a new table (Table 11) is further added. "Comparing the results from Table 7 and Table 10, the system errors from the rainfall simulations (as shown in Table 11) can be easily obtained by the subtraction of the corresponding values in Table 7 and Table 10. For event 1, the average |Rl|-|Rl-corrected|, |Rf|-|Rf-corrected| and NSE-corrected-NSE of the three different grid sizes caused by the rainfall simulations is 7.26%, 7.00% and 0.1469. In the same way, the average |Rl|-|Rl-corrected|, |Rf|-|Rf-corrected| and NSE-corrected-NSE of the three grid sizes is 7.47%, 6.34% and 0.1116 for event 2. A notable case is event 3. |Rl|-|Rl-corrected| of event 3 with the grid size 3×3 km (7.96%) is the highest among the three grid sizes, and the highest |Rf|-|Rf-corrected| (3.56%) comes from the grid size 9×9 km. Due to the errors of the rainfall simulations, all the NSEs decline more than 0.5 for the three grid sizes. For event 4, the average |Rl|-|Rl-corrected|, |Rf|-|Rf-corrected| and NSE-corrected-NSE of the three grid sizes caused by the rainfall simulations is 7.32%, 6.58% and 0.0991. It can easily be found that the magnitudes of most errors in Table 11 are higher than those of Table 10, which indicates that the accuracy of the simulated rainfall is the main factor affecting the performance of the coupled system. In order to improve the rainfall simulation in small and medium scale catchments, radar data with high spatiotemporal resolution should be a good choice, such as radar QPE or QPF and radar data assimilation for the NWP model (Xiao and Sun, 2007; Harader et al., 2012)."

References: Xiao, Q., Sun, J. Multiple-Radar Data Assimilation and Short-Range Quantitative Precipitation Forecasting of a Squall Line Observed during IHOP_2002, Mon. Weather Rev., 135(10), 3381-3404. doi: 10.1175/MWR3471.1, 2007. Harader, E., Borrell-Estupina, V., Ricci, S., et al. Correcting the radar rainfall forcing of a hydrological model with data assimilation: application to flood forecasting in the Lez catchment in Southern France, Hydrol. Earth Syst. Sci., 16, 4247–4264, doi: 10.5194/hess-16-4247-2012, 2012.

Point 4: I agree that Cv is used to describe the evenness of rainfall for both spatial and temporal distributions. However, a critical value of 0.40 for evenness in space and 1.00 for evenness in time, is hard to follow. Explain how the threshold is obtained. You can say event 1 has relatively even distributed rainfall according to Cv rather than using the value of 0.4 as a threshold. Reply: Thanks for the reviewer's suggestion. The spatial and temporal Cv values of the historical storm events from 1985 to 2018 in the study area are calculated to analyse the characteristics of the rainfall evenness. In reality, in comparison to the southern part of China, it is difficult to find absolute even rainfall events in Northern China in either spatial or temporal dimensions. In this study, a threshold of 5% is used to separate even and uneven storms. Thus, the storm events with a spatial Cv < 0.4 or with a temporal Cv < 1.0 can both account for 5% of the total storm events from 1985 to 2018. It should be mentioned that values of 0.4 and 1.0 are calculated by statistical analyses of the historical storm events, thus may not be transferable to other areas with different meteorological conditions. In the revised manuscript, the related descriptions for these two thresholds are removed. Instead, the spatial and temporal evenness of rainfall distribution is ranked among different storm events. The following sentences can be found in Line 22-24 Page 4: "The smaller is the value of Cv, the more even is the rainfall distribution in space or time. According to Table 3, the ranking of the distribution evenness of rainfall in space is event 2 > event 1 > event 4 > event 3 and that in time is event 1 > event 2 > event 4 > event 3."

Point 5: It is concluded from the study that for storm events with uneven rainfall distributions, a finer coupling scale can lead to a better performance of the coupled system, however, the coupling scale shows less impact on the system for events with uneven distributions. To my opinion, these conclusions are highly dependent on the case studies. Considering the study only focusing on two semi-humid and semi-dry watersheds with limited storm events involved, it is better to point out that the results are some kind of site-specific. More case studies are needed before more general conclusions can be achieved. Reply: We are grateful for the reviewer's kindly remind. The following sentences are added in Line 21-23 Page 13: "Considering the study only focusing on two semi-humid and semi-dry watersheds with limited storm events involved, the results in this study should be verified by more case studies before more general conclusions can be achieved."

Spelling and grammar mistakes should be checked carefully throughout the manuscript: Page 2, line 5 and line 9: "atmosphere-hydrologic" should be "atmospheric-hydrologic" Page 5, line 11: "Based on the historical storm events in the study area, and using 5% as a cutoff" should be "Based on the historical storm events in the study area by using 5% as a cutoff" Page 10, line 21: "Grid center coordinates. . .for driving the hydrologic model" should be "The coordinates of the grid cell centers. . .to drive the hydrologic model" Page 11, line 22: ". . .three grid sizes led to different simulation results for different rainfall events" should be ". . .different rainfall events have different simulation results with the three grid sizes". Page 12, line 4: "Considering the spatial distribution characteristics of the rainfall. . ." should be "Considering the characteristics of the spatial rainfall distributions. . ." Page 12, line 29: ". . .the WRF model had the ability to reflect the spatial distribution of the rainfall" should be ". . .the WRF model was able to capture the spatial patterns of the simulated rainfall. . ." Page 13, line 4 ". . .similar simulation results with three different grid sizes. . ." should be ". . .similar simulation results of the three different grid sizes. . ." Reply: All the spelling and grammar mistakes are revised accordingly. The whole manuscript is checked through carefully with other typos corrected.

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The storm events used to calibrate the model

Date	Sub-watershed	24-h rainfall accumulations (mm)	Peak discharges (m^3/s)
02/07/1997	Zijingguan	51.31	163
05/07/1998	Zijingguan	68.37	129
29/06/2006	Zijingguan	48.55	100
03/07/2007	Zijingguan	36.96	25
01/09/2012	Zijingguan	38.58	20
11/08/2013	Zijingguan	40.74	33
06/07/2000	Fuping	60.86	330
24/07/2001	Fuping	56.03	105
13/08/2004	Fuping	32.85	102
14/08/2006	Fuping	24.64	41
30/08/2010	Fuping	20.43	33
29/06/2012	Fuping	25.42	48
29/06/2013	Fuping	19.68	38

Fig. 1.

Table 6 Calibrated parameters in the Hebei model

Parameters	Units	Suggested values	Descriptions	parameter values for Fuping	parameter values for Zijingguan
u	none	0-0.1	Decreasing speed of the infiltration rate with the increase of the soil moisture	0.02	0.02
f_c	mm/h	1-2	stable infiltration rate	1.5	1.5
n	none	0.3-0.8	exponent of the distribution curve for the infiltration capacity	0.53	0.50
b	none	0.3-0.5	exponent of the distribution curve for the moisture storage capacity	0.49	0.50
WMM	mm	80-300	maximal moisture storage capacity of a certain grid cell	240	238
f_m	mm/h	20-200	maximum infiltration capacity of a certain grid cell	120	120
A	$(m^3/s)^{-\omega} s$	0-1	confluence parameter	0.85	0.85

Fig. 2.

Table 11. The system errors from the rainfall simulations for four storm events.

Storm event	Grid size	$\lvert R_l \rvert - \lvert R_{l\text{-corrected}} \rvert$ (%)	$\lvert R_f \rvert - \lvert R_{f\text{-corrected}} \rvert$ (%)	$NSE_{\text{-corrected}}-NSE$
	1×1 km	9.39	7.06	0.0831
Event 1	3×3 km	7.02	7.84	0.2790
	9×9 km	5.36	6.11	0.0785
	1×1 km	6.57	5.77	0.0964
Event 2	3×3 km	5.96	6.40	0.0884
	9×9 km	9.89	6.86	0.1499
	1×1 km	2.28	1.08	0.5357
Event 3	3×3 km	7.96	2.07	0.5659
	9×9 km	1.19	3.56	0.5738
	1×1 km	5.62	5.89	0.0301
Event 4	3×3 km	7.13	6.88	0.0660
	9×9 km	9.20	6.96	0.2011

Fig. 3.