Response to Referee #2

We appreciate the time and effort of the reviewer and thank the reviewer for the constructive comments. We addressed all the comments, and will include corresponding changes in the revised manuscript.

In the following text, we use blue font for the reviewer comments, black font for our replies, and italics for the revisions in the manuscript.

Comments

[C2-1]

The paper presents improvements on the parametrization of the MOSART surface water model. State of art methods are used to update river model and inundation parametrization. The model is evaluated in the Amazon basin and several simulations were performed to evaluate the role of the DEM, river geometry parameters, and backwater effects. The subject addressed by the paper is important. With new data available for regional/global hydrologic simulations, there are several new efforts to improve hydrological models. And the documentation of new improvements/updates of models, as the MOSART, fits the goal of GMD journal. Also, the study of impact of model errors and different parametrizations are important guide future model developments. The paper is generally clear. However, it seems that most of the conclusions from paper analyses were already provided by the past modelling studies in the Amazon (e.g. Paiva et al., 2013, Getirana et al. 2012, Yamazaki et al., 2011, Beighley et al., 2009; Baugh et al., 2013). For example, the past studies already pointed for the importance backwater effects and flooding, performed sensitivity studies on the role of river geometry errors and DEM errors on amazon simulations. So I guess that it would be better to present the paper as a documentation of the improvements of a specific model (MOSART) to move toward state of art methods. And to clarify that the analyses could reproduce similar conclusions from the past studies. So, as the documentation of model parametrizations fits the GMD journal scope, I think that the paper could be published. But it needs to be reviewed clarify the actual contributions, by addressing the comments above and below.

Reply: We thank the reviewer for the positive evaluation and suggestions. We will clarify the contribution mainly as the incorporation of an inundation scheme into the MOSART model. The related revisions will be added in several sections: Abstract, Introduction, Methods and data, Sensitivity study, and Conclusion and discussion.

Our initial manuscript was not clear in the comparisons with previous studies. Following the suggestions of the reviewers, we will also add more discussions on comparisons between our study and former studies. While previous studies provided the foundation for the approach we adopted in our study and some of our results agree with those of former studies, our study has also provided some new points in terms of methodologies, model results and analyses. These are elaborated below.

1. Methods

1.1 DEM correction

We explicitly considered the spatial variation of the vegetation-caused biases in the DEM data, which alleviated biases for hydrological modeling in the entire Amazon Basin. The DEM correction was based on the spatially varied vegetation-height map and land cover dataset.

In most previous studies of hydrological modeling for the entire Amazon Basin, the DEM was lowered by a uniform height for vegetated area (Coe et al., 2008; Paiva et al., 2013a). Although spatial variation of vegetation-caused biases in DEM was also considered in previous hydrodynamic modeling studies, it was performed only in a comparatively small area of the central Amazon region (Baugh et al., 2013; Wilson et al., 2007). We generalized the approach by using land cover data and vegetation height data that have global coverage so the method can be used in the entire Amazon Basin and other regions.

1.2 Refining channel geometry

We refined the basin-wide empirical formulae for channel cross-sectional dimensions in various subregions to improve the representation of spatial variation in channel geometry (Table 1). In many former studies, the basin-wide formulae were used (Beighley et al., 2009; Coe et al., 2008; Getirana et al., 2012; Yamazaki et al., 2011).

Paiva et al. (2013a) accounted for spatial variation of channel geometry formulae and used various coefficients in their formulae for six zones of the Amazon Basin (Table 1 of Paiva et al. 2013a). But they did not compare the results of diverse subregion formulae with those of the basin-wide formulae.

2. Sensitivity study

The sensitivity analyses of former studies primarily examined the impacts of various factors (e.g., the inundation scheme, channel geometry, Manning coefficients or backwater effects) on the total flooded area of the central Amazon region (Figs. 9 and 13 of Yamazaki et al. 2011) or the entire Amazon Basin (Fig. 10 of Paiva et al. 2013a), and streamflow and river stages of a few mainstem gauges (Figs. 13, 5a and 5b of Yamazaki et al. 2011; Fig. 10 of Paiva et al. 2013a).

Paiva et al. (2013a) examined the impacts of perturbing precipitation, elevation profiles or maximum soil water storage on modeled surface hydrology (Figs. 10 and 11 of Paiva et al. 2013a). Complementary to their study, we examined the impacts of five other factors (i.e., including the inundation scheme, correcting DEM, refining channel geometry, adjusting Manning coefficients, and considering backwater effects) on modeled surface hydrology at various locations spread over the Amazon Basin, including inundation of 10 subregions (Fig. 11), streamflow and river stages of more than 10 gauges (at both the mainstem and tributaries) (Figs. 8 and 9), the water-surface profile along the mainstem (Fig. 10).

Our sensitivity study yielded several new points as follows.

2.1 Impacts of including the inundation scheme

This point was not explicitly discussed in the initial manuscript. Following the suggestions of both reviewers, in the revision this point was investigated and discussed.

Our investigation related to river stages was different from the former study. To our knowledge, only Yamazaki et al. (2011) explicitly examined the impacts of the inundation scheme on water depths at the gauge station (Fig. 5b of Yamazaki et al. 2011) and water depths along the mainstem (Fig. 7 of Yamazaki et al. 2011). They conducted three simulations: the diffusion wave simulation with the inundation scheme (FLD+Diff), the kinematic wave simulation with the inundation scheme (FLD+Kine), and the kinematic wave simulation without the inundation scheme (NoFLD). Therefore, while examining the impacts of the inundation scheme on water depths (or river stages), they used the kinematic wave river routing method, but we used the diffusion wave river routing method, which was more advanced (e.g., could represent the backwater effects) (Figs. 9 and 10).

2.2 Impacts of correcting DEM

The vegetation-caused biases in DEM were alleviated with various approaches in a few previous studies in the partial or entire Amazon Basin (Baugh et al., 2013; Coe et al., 2008; Getirana et al., 2012; Paiva et al., 2011, 2013a; Wilson et al., 2007; Yamazaki et al., 2011). To our knowledge, most of these studies did not examine and explicitly report the impacts of DEM correction on the modeled results. Only Baugh et al. (2013) showed the impacts of DEM correction on floodplain water levels and inundation in a comparatively small area in the central Amazon region (Figs. 2 and 5 of Baugh et al. 2013).

Our study examined and explicitly reported the impacts of alleviating vegetation-caused biases in DEM on modeled surface hydrology in the hydrological modeling for the entire Amazon Basin (Figs. 8, 9, 10 and 11). These impacts were not explicitly reported in the past.

2.3 Impacts of refining channel geometry

While examining the impacts of adjusting channel geometry on modeled surface hydrology, we used a method different from those of previous studies, where the channel widths or depths of all the channels were perturbed by a uniform percentage (or a uniform amount) (Fig. 13 of Yamazaki et al. 2011; Fig. 10 of Paiva et al. 2013a).

We refined the basin-wide formulae of channel geometry for various subregions. The channel-geometry changes were caused by the process of refining channel cross-sections and those change ratios were different for various subregions (Table 1). We compared the results of diverse subregion formulae with those of basin-wide formulae to reveal the impacts of adjusting channel geometry on modeled surface hydrology (Figs. 8, 9, 10 and 11). Our method had more physical mechanism than the former method of perturbing channel geometry uniformly in the entire basin.

2.4 Impacts of considering backwater effects

Our model results showed the impacts of backwater effects on flood extent and river stages were more prominent than those of the previous study. To our knowledge, only Yamazaki et al. (2011) explicitly reported the impacts of backwater effects on flood extent (Fig. 9 in Yamazaki et al. 2011) and river stages (Figs. 5b and 7a in Yamazaki et al. 2011). In our study, the impacts of backwater effects on flood extent (Fig. 11) and river stages (Figs. 9 and 10) were more prominent than those of Yamazaki et al. (2011). These differences may be due to the discrepancies in channel geometry or floodplain topography between the two studies.

Our model results showed that backwater effects could advance the flood peak in the Madeira subregion (Fig. 8c). To our knowledge, this phenomenon has not been discussed in the previous modeling studies in the Amazon Basin.

In summary, while our modeling approach and improvements do not differ conceptually from those already explored in previous studies, we attempted to generalize various methods for application over the entire Amazon Basin, which is important as MOSART is used in global Earth System Models. We also provided more comprehensive evaluation of our simulations and analysis of sensitivity of the simulations to various factors, which yielded some findings that have not been discussed in former studies.

[C2-2]

Introduction: I feel that the main goal of this paper should be to document improvements on the MOSART model. So it is important to provide more details in the intro section.

Reply: We agree with the reviewer’s assessment. We will revise the Introduction to more explicitly state our objective for implementing and documenting an inundation parameterization in the MOSART model for global application.

[C2-3]

Page 2. Line 25. Which of these challenges were addressed by this paper in a novel way that was not done by the past efforts?

Reply: In the initial manuscript, the comparisons between our study and previous studies were not clear. As discussed in the reply to the first comment [C2-1], on one hand, our study was based on the important foundation of previous studies; on the other hand, our work also yielded some new points in terms of methodologies, model results and sensitivity analyses.

[C2-4]

Page 3. Line 9. Vegetation errors from SRTM DEM were removed globally by F.E. O'Loughlin et al. 2016 RSE. Please review and discuss it in the paper.

Reply: We thank the reviewer for directing us to this study related to our work. O'Loughlin et al. (2016) used both vegetation height data and vegetation density data to estimate vegetation-caused biases embedded in the SRTM DEM data, and for the first time created the 'Bare-Earth' global high resolution DEM from the SRTM data. They also compared their methods with the static correction method used by Baugh et al. (2013). Their study will be discussed in the revised manuscript.

[C2-5]

Page 3. Line 22. See also analyses from Paiva et al., 2013 WRR.

Reply: Paiva et al. (2013a, WRR) analyzed the sensitivities of streamflow, water depths and flooded area to the channel width and depth. The citation of this reference will be supplemented.

[C2-6]

Objectives. What is the new proposed contribution? If the contributions are limited to updating MOSART model with state of art methods, then I think that you should specify it in the objectives and introduce MOSART in the intro section.

Reply: As discussed in our replies to the first and second comments ([C2-1] and [C2-2]), we will make our objectives more clear in the Introduction section. As a reply to a similar comment from the first reviewer, we will add a new section to compare the simulations with and without the inundation parameterization to document its impacts on the overall performance of MOSART. Figures 8, 9, and 10 will be updated to include results for the simulation without inundation for comparison with various simulations that include the inundation parameterizations. The three figures are also attached in the Appendix at the end of this Response.

[C2-7]

2.1. How the model defines what is main river network and tributary subnetwork?

Reply: In the MOSART model, each computation unit (subbasin or grid cell) has a major channel (or main channel) and a tributary subnetwork which includes tributaries within the computation unit. Please see the following figure from Li et al. (2013).

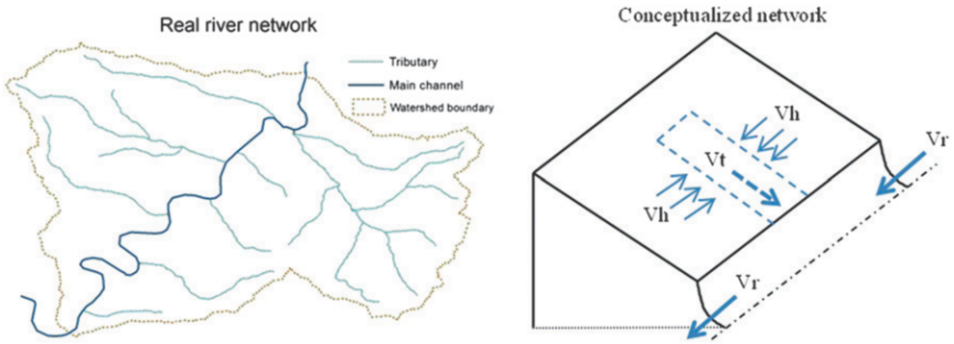

FIG. 1. Conceptualization of river network in MOSART. The runoff generated first enters the tributaries (surface runoff via hillslope routing and subsurface runoff without hillslope routing); it is then routed through the tributaries (here conceptualized as a single equivalent channel, as shown by the light blue dashed lines) and is finally discharged into the main channel. The value V_h is the overland flow during hillslope routing, V_t is the channel velocity within the tributaries, and V_r is the channel velocity within the main channel.

The main channels of all the computation units constitute the main-channel network of the entire basin.

The following text will be added in the first paragraph of Section 2.1 :

"*In this model, each computation unit (subbasin or grid cell) has a major channel (or main channel) and a tributary subnetwork which includes tributaries within the computation unit.*"

[C2-8]

Eq.1. It seems g can be removed from equation.

Reply: "*g*" will be deleted from this equation.

[C2-9]

Continuity equation is not shown. Please show it.

Reply: The continuity equation will be added.

[C2-10]

How these equations (kinematic and diffusive) are solved? Please provide details on the numerical methods. finite difference, finite volumes, implicit, explicit? Criteria for time step, spatial discretization? What is done to avoid mass errors.

Reply: The explicit finite difference method is used to solve the equations. The computation units can be grid cells or subbasins. The Courant condition is used for choosing the time step. In this Amazon application, the time step is one minute when the diffusion wave method is used. The cumulative mass error is less than 0.5 percent in these multi-year simulations.

The following text will be added at the end of Section 2.1:

"*In this model, the equations are solved with the explicit finite difference method. Either square grid cells or irregular subbasins can be used as computation units. The time-step size is selected to satisfy the Courant condition to ensure stable computation.*"

[C2-11]

2.2. It is not clear how you compute river bed elevation? Is it simply the lowest DEM pixel of the catchment? How the model accounts for the fact that SRTM DEM does not see the river bed? And the fact that the river profile is not flat?

Reply: In Fig. 1b, the elevation profile and the fraction of channel area (A_c) can determine the elevation of the channel bank top (E_t). The channel bed elevation (E_b) is: $E_b = E_t - d$, where d is the channel depth and is estimated in Section 2.5. The channel bed could be lower than the lowest DEM pixel of the catchment because the DEM does not see the channel bed.

In the elevation profile of Fig. 1b, the longitudinal profile of the channel bed is deemed to be flat, which is different from the actual condition in the real world. This assumption may bring about some error when estimating the flooded area.

Fig. 1b will be updated in the manuscript: (1) In the amended elevation profile, the channel bed elevation was lowered; (2) The bank top elevation (E_t) and the channel bed elevation (E_b) were indicated. Please find the revised Fig. 1 in the Appendix of this response.

The following text will be added in the second paragraph of Section 2.2:

"*The channel bed elevation equals the difference of the bank top elevation and the channel depth which is estimated in Sect. 2.5. The channel bed could be lower than the lowest DEM pixel of the computation unit because the DEM do not reflect the channel bed elevation.*"

[C2-12]

2.3. How the basins are defined? What is the input data? Hydrosheds? Please make it clear.

Reply: Yes, the subbasins were extracted from the HydroSHEDS DEM. The following text will be revised and moved from Section 2.4 to Section 2.3.

"*The 3-second resolution HydroSHEDS DEM data developed by United States Geological Survey (USGS) (http://hydrosheds.cr.usgs.gov/) was used in this study. The hydrologically conditioned HydroSHEDS DEM was used to generate the digital river network and subbasins.*"

[C2-13]

Pag. 6 Line 30. What is the criteria to define river length? How time step is defined? How these choices affect model errors (model numerical stability, mass errors, numerical dispersion, …) ? Please clarify and discuss it.

Reply: We used comparatively coarse subbasins (the average area is 1091.7 km^2) due to computational costs. Each subbasin has a main channel. The main channel length varies with the subbasin size.

The time step was determined based on the Courant condition and some test simulations. The time step of one minute was used so that the simulations were stable. The cumulative mass error for the entire Amazon Basin was less than 0.5 percent in the simulations.

The following text will be added in the first paragraph of Section 2.3 :

"*Comparatively coarse subbasins were adopted due to the consideration of computational costs. … … To ensure stable computation, the time-step size was determined based on the Courant condition and some experimental simulations. The time step of one minute was used for all the simulations.*"

[C2-14]

2.4. Vegetation Errors. Was the corrected DEM validated ? Please justify and compare these methods to the global SRTM DEM product free of veg errors recently developed by F.E. O'Loughlin et al. 2016 RSE.

Reply: Our method was based on that of Baugh et al. (2013). Moreover, we also used a high resolution (3 arc-second) land cover dataset when estimating the vegetation-caused biases in the SRTM DEM data.

O'Loughlin et al. (2016) used both vegetation height data and vegetation density data to estimate vegetation-caused biases in the SRTM DEM data. They also compared their methods to that of Baugh et al. (2013), which was named the static correction method. They stated that the static correction method was effective, but moderately worse than their methods. Their study will be discussed in the revised manuscript.

[C2-15]

2.6. Line 16. What literature was used to define Manning at 0.03 and 0.05? I feel that the parametrization of Manning needs more justification (past studies or calibration). How these choices will impact model results?

Reply: Previous studies were cited to justify our choice of the Manning coefficients. The sensitivity study part (Section 4.3) discusses the effects of the Manning coefficients on model results. Refining the Manning coefficients could improve streamflow hydrographs. The increase of the Manning coefficient could affect flood extent, streamflow and river stages in local, upstream or downstream subbasins.

The text will be revised as follows:

"*Following Getirana et al. (2012),* $n_{\max}$ *and* $n_{\min}$ *were set as 0.05 and 0.03, respectively. In addition, a few other studies of the Amazon Basin adopted a similar range of values between 0.03 and 0.05 for the Amazon Basin (e.g., Beighley et al., 2009; Paiva et al., 2013a; Yamazaki et al., 2011).*"

[C2-16]

2.7. Line 6. Why average manning of 0.03 ? You should use the average Manning from the reference simulation or use other approach to isolate the effect of variable vs constant manning.

Reply: We conducted a new simulation using the Manning coefficient of 0.04 (the average of 0.03 and 0.05) for all the channels (abbreviated as ‘n004’). We compared the Nash–Sutcliffe efficiency coefficients (NSEs) of streamflow between the simulation ‘n004’ and the control simulation (which used varied Manning coefficients) (revised Table 4). The control simulation performed better than the simulation ‘n004’ at a majority of the 13 stream gauges.

Section 2.7 and Table 2 will be revised to add the description of the simulation ‘n004’.

[C2-17]

2.7. What is optimal combination? Was any calibration performed?

Reply: The original manuscript was not clear. It meant that in the control simulation, the preferred methodologies were used at each aspect. We did not try to calibrate parameters to improve the modeled results.

The text will be expanded to be more specific as follows:

“*In the control simulation (abbreviated as “CTL”), the preferred methodologies for five aspects were used: (1) the inundation scheme was turned on; (2) vegetation-caused biases in the DEM data were alleviated; (3) the basin-wide channel geometry formulae were refined for different subregions; (4) the Manning roughness coefficient varied with the channel size; (5) the diffusion wave method was used to represent river flow in channels. The results of the control simulation were used in the model evaluation (Sect. 3).*”

[C2-18]

3.1. How the model performance compare to past modelling studies in the Amazon? Please discuss it in the manuscript.

Reply: The modeled streamflow results were compared with a few previous studies. The following text will be added to the second paragraph of Section 3.1:

“*In general, the simulated streamflow results are comparable to those of a few previous studies (e.g., Getirana et al., 2012; Yamazaki et al., 2011) and slightly worse than those of Paiva et al. (2013a).*”

[C2-19]

3.2. Equation 7. Do you use this equation to estimate a parameter for simulation? If yes, this explanation should appear o section 2. Why this approach were selected? How it compares to previous studies? How this choice impact model results? See Paiva et al., 2013 for an analyses of impact of bed elevation errors on simulations.

Reply: The relative riverbed elevations from this equation can be deemed as parameters for channel routing computation. Actually, riverbed slopes (S_0 in Equation (2)) are directly used in the channel routing computation in this study. This approach is the same as those of previous studies (Beighley et al., 2009; Getirana et al., 2012; Paiva et al., 2011, 2013a; Yamazaki et al., 2011).

The Equation (7) and the related descriptions will be moved to the methodology part (Section 2.5).

In this study, the method for estimating the riverbed slope may be different from those of previous studies. The riverbed slopes of this study were directly derived from the DEM. Some previous studies first alleviated errors caused by water depths or vegetation heights, then used the corrected DEM to derive riverbed slopes (e.g., Paiva et al., 2011). So the method of our study has less physical mechanism and may have more uncertainties than those of some previous studies.

Paiva et al. (2013a) studied the sensitivities of streamflow, water depths and flooded area to riverbed elevations. In scenario simulations, riverbed elevations were perturbed by 3m, 1m, -1m, or -3m. In our understanding, the riverbed elevations of the entire basin were raised or lowered by a uniform value in any single simulation. So this treatment did not affect the riverbed slopes used in channel routing computation. Actually this treatment reduced or increased the channel depths, which decreased or enlarged the channel conveyance capacities. In our study, the impacts of channel cross-sectional geometry on surface hydrology were studied in a different way (Section 2.5 and 4.3).

[C2-20]

3.2. How model performance for river elevation compares to previous modelling studies in the amazon? Please discuss it in the manuscript.

Reply: The simulated river-stage results were compared to some previous studies. The following text will be added to the third paragraph of Section 3.2:

“ *Overall, in terms of the timing and magnitude of fluctuations, the modeled river stages of this study are comparable with some previous investigations* (Coe et al., 2008; Getirana et al., 2012; Paiva et al., 2013a). ”

[C2-21]

3.3. How model performance for flood extent compares to previous modelling studies in the amazon? Please discuss it in the manuscript.

Reply: The modeled inundation results were compared to a few previous studies. The following text will be added at the end of Section 3.3:

“ *The flood extent results were compared with those of a few previous studies which also used the GIEMS data* (Getirana et al., 2012; Paiva et al., 2013a; Yamazaki et al., 2011). *As mentioned above, the GIEMS data had non-negligible uncertainties. So the comparison to this data should not be deemed as a criterion for judging different modeling studies. The spatial inundation patterns of this study were slightly better than those of Getirana et al. (2012), and comparable to those of Yamazaki et al. (2011) and Paiva et al. (2013a). In terms of monthly total flooded areas, this study, Getirana et al. (2012) and Paiva et al. (2013a) were comparable at the whole-basin scale; this study and Getirana et al. (2012) were closer to the GIEMS data than Paiva et al. (2013a) at the subregion scale.* ”

[C2-22]

4.1. How these analyses compare to previous analyses of impact of DEM and floodplains on Amazon simulations from previous modelling studies?

Reply: The vegetation-caused biases in DEM were alleviated with various approaches in a few previous studies. To our understanding, most of those studies did not explicitly report the effects of the DEM correction on the modeled results except Baugh et al. (2013). The following text will be added to Section 4.2 Correction of DEM (previous Section 4.1):

“*The vegetation-caused biases in DEM data were alleviated with various approaches in a few previous studies of modeling the surface water dynamics in the Amazon Basin* (Baugh et al., 2013; Coe et al., 2008; Getirana et al., 2012; Paiva et al., 2011, 2013a; Wilson et al., 2007; Yamazaki et al., 2011). *Most of these studies did not examine and explicitly report the effects of the DEM correction on the modeled results. Baugh et al. (2013) demonstrated that alleviating vegetation-caused biases in DEM could improve the modeled water levels and inundation over floodplains adjacent to a 280-km reach of the central Amazon.*”

The impacts of using the inundation scheme on modeled surface hydrology were examined and reported in a few studies: (1) Yamazaki et al. (2011) showed the effects on streamflow, water depths, and flow velocities at the Obidos gauge; and the effects on the mainstem water-surface profile; (2) Getirana et al.

(2012) demonstrated the effects on streamflow of a few mainstem gauges; (3) Paiva et al. (2013a) reported the effects on streamflow at the Obidos and Manacapuru gauges.

In the revised manuscript, we will add a new subsection (Section 4.1 Inundation representation) to report the impacts of using the inundation scheme on modeled surface water dynamics including: (1) Streamflow at 13 mainstem and tributary gauges; (2) River stages at the 13 gauges; (3) the mainstem water-surface profile.

[C2-23]

4.2. It is not change in channel storage capacity that changes simulation. It is changes in channel conductance capacity.

Reply: "*channel storage capacity*" will be revised to be "*channel conveyance capacity*" throughout the manuscript.

[C2-24]

4.2. How these analyses compare to previous analyses of channel geometry from previous modelling studies?

Reply: Some previous studies (e.g., Paiva et al., 2013a; Yamazaki et al., 2011) also investigated the sensitivities of modeled surface hydrology to channel geometry. They pointed out the importance of channel geometry that motivated similar analysis in our study. At the same time, the methods and results of our study had some new points: (1) channel-geometry changes were caused by the process of refining channel cross-sections and those changes were spatially varied (Table 1); (2) we examined the effects of channel-geometry changes on modeled surface hydrology at spatially distributed locations (i.e., different subregions, tributary and mainstem gauges, and the mainstem); (3) some of our result-analyzing approaches were different from those of former studies.

The following text will be added to the end of "Section 4.3 Adjustment of channel geometry" (previous Section 4.2):

" *The sensitivities of modeled surface hydrology to channel geometry were also investigated by some former studies (e.g., Paiva et al., 2013a; Yamazaki et al., 2011). Yamazaki et al. (2011) perturbed the channel width or depth by a uniform percentage for all the channels and examined the effects of these channel-geometry changes on streamflow of the Obidos gauge and the flooded area over the central Amazon region. Paiva et al. (2013a) perturbed the channel width by a uniform percentage or perturbed the channel-bottom level by a uniform height, which was equivalent to perturbing the channel depth by a* *uniform value, and investigated the effects of these channel-geometry changes on streamflow of the Obidos gauge, channel water depths of the Manacapuru gauge, and the total flooded area of the entire Amazon Basin. These two studies showed the sensitivities of modeled surface hydrology to channel geometry, and the interactions between streamflow, water depths and inundation. These previous studies pointed out the importance of channel geometry and provided motivation for similar analysis. In this study, channel-geometry changes were caused by the process of refining channel cross-sections and those changes were spatially varied (Table 1). We examined the effects of channel-geometry changes on inundation of 10 subregions, streamflow of 13 gauges, river stages near 11 gauges, as well as the mainstem water-surface profile. In addition, the effects of channel-geometry changes on modeled surface water dynamics were analyzed with approaches of which some were different from those of the former studies. "*

[C2-25]

4.3. I'm not sure if this analysis is conclusive. It is not possible to be sure that the differences in results are related to variable Manning or if it is because a specific value of 0.03 was chosen. This value may be different from the average value of the control simulation. I suggest the computation of the average Manning from control simulation and using this value for the new simulation.

Reply: We conducted a new simulation "n004" which used a constant Manning roughness coefficient of 0.04 (i.e., the average of 0.03 and 0.05) for all the channels. We compared the streamflow Nash–Sutcliffe efficiency coefficients (NSEs) of three simulations (CTL, n004 and n003). The beginning part of "Section 4.4 Varying the Manning coefficients" (previous Section 4.3) will be revised as follows:

" *The streamflow Nash–Sutcliffe efficiency coefficients (NSEs) of the simulation "CTL" were compared with those of the simulations "n003" and "n004" (Table 4). The NSEs of the simulation "CTL" are higher than those of the simulation "n004" at 10 of the 13 gauges (except Fazenda vista alegre, Itapeua and Manacapuru), and higher than those of the simulation "n003" at 12 of the 13 gauges (except Obidos). These results suggest that the spatially varied Manning coefficients are more appropriate than the uniform Manning coefficient of 0.03 or 0.04 for the simulations of this study.*

The spatially varied Manning coefficients range from 0.03 to 0.05 and are equal to or larger than the Manning coefficient of 0.03. The results of the simulation "CTL" are compared to those of the simulation "n003" to reveal the effects of Manning coefficient increases on modeled surface water dynamics. "

[C2-26]

4.3. How these analyses compare to previous analyses of Manning role from previous modelling studies?

Reply: A few former studies (e.g., Paiva et al., 2013a; Yamazaki et al., 2011) also investigated the sensitivities of simulated surface hydrology to the Manning roughness coefficient. They revealed the importance of the Manning coefficient and motivated similar analysis in our study. At the same time, the approaches and analyses of this study had some new points: (1) the Manning coefficient increase depended on the channel depth; (2) we examined the effects of Manning coefficient changes on modeled surface hydrology at spatially diverse locations (i.e., different subregions, tributary and mainstem gauges, and the mainstem).

The following text will be added to the end of "Section 4.4 Varying the Manning coefficients" (previous Section 4.3):

" *A few previous studies for the Amazon Basin (e.g., Paiva et al., 2013a; Yamazaki et al., 2011) conducted numerical experiments to reveal the sensitivities of modeled surface hydrology to the Manning coefficient. Yamazaki et al. (2011) perturbed the Manning coefficient by a uniform percentage for all the channels and examined the effects of the Manning coefficient change on streamflow of the Obidos gauge and the flooded area over the central Amazon region. Using a similar approach, Paiva et al. (2013a) investigated the effects of the Manning coefficient change on streamflow of the Obidos gauge, channel water depths of the Manacapuru gauge, and the total flooded area of the entire Amazon Basin. These studies revealed that increasing the Manning coefficient could raise the river stage, enlarge the flooded area, and reduce and delay the flood peak. In this study, instead of being perturbed uniformly, the Manning coefficient varied with the channel depth. We examined the effects of Manning coefficient changes on flood extent of 10 subregions, streamflow of 13 gauges, river stages near 11 gauges, and the mainstem water-surface profile.* "

[C2-27]

Figure 10. This figure is confusing. It's hard to understand the break in the profile. Please review it.

Reply: Figure 10 has been replotted to avoid the break and to use the same y-axis for the entire river length. This figure will be updated in the revised manuscript. Please find the revised Fig. 10 in the Appendix of this response.

[C2-28]

4.4. Line 20. See also analyses on the importance of backwater effects for amazon simulations from Paiva et al., 2013 WRR and Paiva et al., 2013 Hyd.Process. Please compare and discuss in the manuscript.

Reply: Paiva et al. (2013b, HP) demonstrated the important impacts of backwater effects on streamflow of the mainstem and tributaries, and discussed the important role of backwater effects in the inundation dynamics and river stages of the Amazon Basin. Paiva et al. (2013a, WRR) showed the important impacts of backwater effects on streamflow of two mainstem gauges.

We examined the impacts of backwater effects on flood extent in 10 subregions, streamflow of 13 gauges, river stages near 11 gauges, and the mainstem water-surface profile.

The following text will be added or revised:

"*Paiva et al. (2013b) used the dynamic wave method to represent river flow in the Solimoes River basin, which is the western upstream portion of the Amazon Basin. They discussed the important role of backwater effects in the inundation dynamics of the Amazon. In this study, we examined the impacts of backwater effects on flood extent in the 10 subregions constituting the Amazon Basin (Fig. 11), and demonstrated the spatial pattern of flood extent changes caused by backwater effects (Figs. 12j and 12k).*"

"*These backwater effects on hydrographs agree with the results of Paiva et al. (2013)*" will be replaced with "*These results agree with Paiva et al. (2013a, 2013b), which demonstrate the important role of the backwater effects on streamflow of the mainstem and tributaries of the Amazon Basin.*"

"*In addition, to our knowledge, this phenomenon of backwater effects on the streamflow timing has not been discussed in the previous modeling studies in the Amazon Basin.*"

"*The result of this study also agrees with Paiva et al. (2013b) which discussed the backwater effects on river stages in the Solimoes River basin.*"

[C2-29]

Conclusions. Line 20. Review Yamazaki et al., 2013. WRR for discussion in Catchment vs grid based simulations.

Reply: Yamazaki et al. (2013, WRR) used a special computation unit, which had characteristics of both catchment unit and grid unit. Using their computation unit could preserve the river flow pathway better than using the grid unit. Their computation units were more even than catchment units in terms of area. Their method will be discussed in the revised manuscript.

[C2-30]

Conclusions: I’m not sure if there are new conclusions /findings that were not addressed by the past modelling studies in the Amazon (e.g. Paiva et al., 2013, Getirana et al. 2012, Yamazaki et al., 2011, Beighley et al., 2009; Baugh et al., 2013). The past studies already pointed for the importance backwater effects and flooding, performed Sensitivity studies on the role of river geometry errors and DEM errors on amazon simulations. It is important to recognize that the analyses from this paper only reproduced similar conclusions from the past studies. And also clarify that the new contribution from this paper is mostly on updating/improving the parametrization of an specific model, i.e. MOSART model by including improvements tested or suggested by the previous studies.

Reply: We thank the reviewer for the constructive suggestions.

In the initial manuscript, the comparisons between our work and previous studies were not clear. The manuscript will be improved at this aspect. As discussed in our reply to the first comment [C2-1], on one hand, our work was based on the important foundation of previous studies; at the same time, our investigation also had a few new points in terms of methodologies, simulation results and sensitivity analyses.

Following the suggestion of both reviewers, the contribution of incorporating the inundation scheme into the MOSART model will be described more clearly than before in the revised manuscript.

References:

Baugh, C. A., Bates, P. D., Schumann, G. and Trigg, M. A.: SRTM vegetation removal and hydrodynamic modeling accuracy, Water Resour. Res., 49(9), 5276–5289, doi:10.1002/wrcr.20412, 2013.

Beighley, R. E., Eggert, K. G., Dunne, T., He, Y., Gummadi, V. and Verdin, K. L.: Simulating hydrologic and hydraulic processes throughout the Amazon River Basin, Hydrol. Process., 23(8), 1221–1235, doi:10.1002/hyp.7252, 2009.

Coe, M. T., Costa, M. H., Botta, A. and Birkett, C.: Long-term simulations of discharge and floods in the Amazon Basin, J. Geophys. Res. Atmospheres, 107(D20), LBA 11-1, doi:10.1029/2001JD000740, 2002.

Coe, M. T., Costa, M. H. and Howard, E. A.: Simulating the surface waters of the Amazon River basin: impacts of new river geomorphic and flow parameterizations, Hydrol. Process., 22(14), 2542–2553, doi:10.1002/hyp.6850, 2008.

Getirana, A. C. V., Boone, A., Yamazaki, D., Decharme, B., Papa, F. and Mognard, N.: The Hydrological Modeling and Analysis Platform (HyMAP): Evaluation in the Amazon Basin, J. Hydrometeorol., 13(6), 1641–1665, doi:10.1175/JHM-D-12-021.1, 2012.

Junk, W. J., Piedade, M. T. F., Wittmann, F., Schöngart, J. and Parolin, P., Eds.: Amazonian Floodplain Forests, Springer Netherlands, Dordrecht. [online] Available from: http://link.springer.com/10.1007/978-90-481-8725-6 (Accessed 25 March 2016), 2011.

Li, H., Wigmosta, M. S., Wu, H., Huang, M., Ke, Y., Coleman, A. M. and Leung, L. R.: A Physically Based Runoff Routing Model for Land Surface and Earth System Models, J. Hydrometeorol., 14(3), 808–828, doi:10.1175/JHM-D-12-015.1, 2013.

O'Loughlin, F. E., Paiva, R. C. D., Durand, M., Alsdorf, D. E. and Bates, P. D.: A multi-sensor approach towards a global vegetation corrected SRTM DEM product, Remote Sens. Environ., 182, 49–59, doi:10.1016/j.rse.2016.04.018, 2016.

Paiva, R. C. D., Collischonn, W. and Tucci, C. E. M.: Large scale hydrologic and hydrodynamic modeling using limited data and a GIS based approach, J. Hydrol., 406(3–4), 170–181, doi:10.1016/j.jhydrol.2011.06.007, 2011.

Paiva, R. C. D., Buarque, D. C., Collischonn, W., Bonnet, M.-P., Frappart, F., Calmant, S. and Bulhões Mendes, C. A.: Large-scale hydrologic and hydrodynamic modeling of the Amazon River basin, Water Resour. Res., 49(3), 1226–1243, doi:10.1002/wrcr.20067, 2013a.

Paiva, R. C. D., Collischonn, W. and Buarque, D. C.: Validation of a full hydrodynamic model for large-scale hydrologic modelling in the Amazon, Hydrol. Process., 27(3), 333–346, doi:10.1002/hyp.8425, 2013b.

Wilson, M., Bates, P., Alsdorf, D., Forsberg, B., Horritt, M., Melack, J., Frappart, F. and Famiglietti, J.: Modeling large-scale inundation of Amazonian seasonally flooded wetlands, Geophys. Res. Lett., 34(15), L15404, doi:10.1029/2007GL030156, 2007.

Yamazaki, D., Kanae, S., Kim, H. and Oki, T.: A physically based description of floodplain inundation dynamics in a global river routing model, Water Resour. Res., 47(4), W04501, doi:10.1029/2010WR009726, 2011.

Appendix

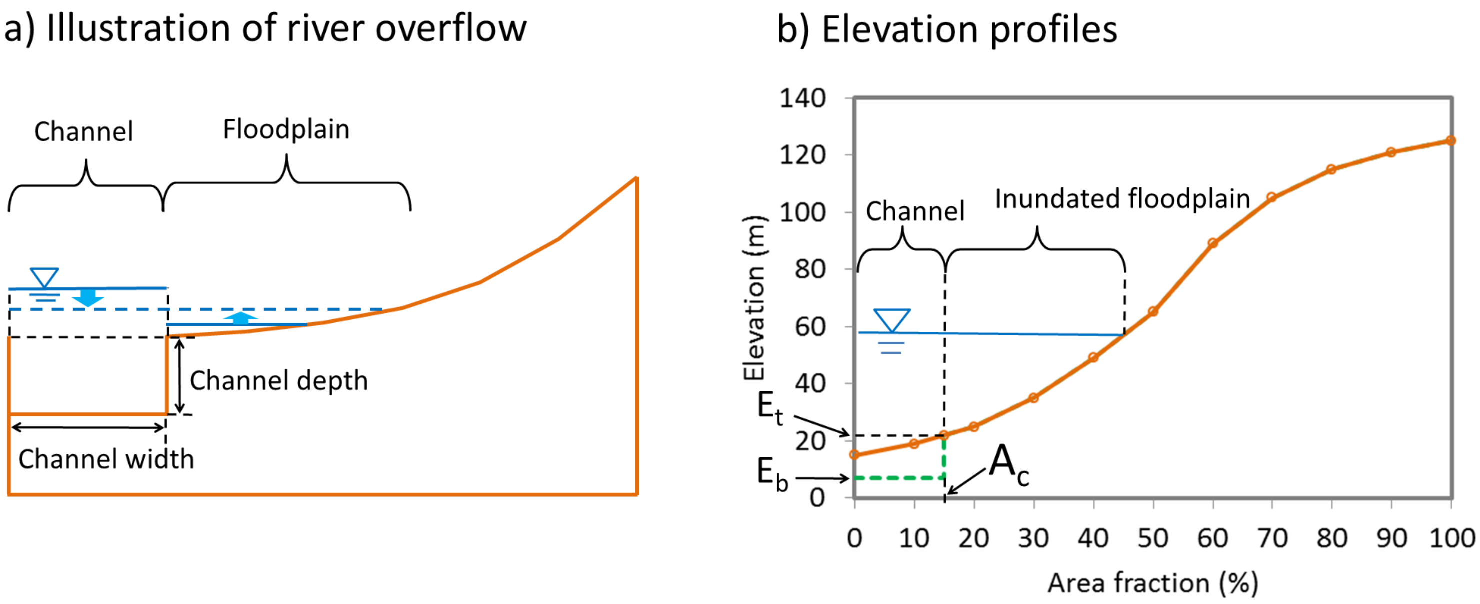

Figure 1. Illustrations of the macro-scale inundation scheme: (a) Illustration of river overflow; (b) Elevation profiles of a computation unit (e.g., a grid cell or subbasin). The brown solid line is the original elevation profile. The green dash line is the amended elevation profile (its non-channel part overlaps with the original elevation profile). A_c is the fraction of the channel area in the computation unit; E_t is the bank top elevation; and E_b is the channel bed elevation.

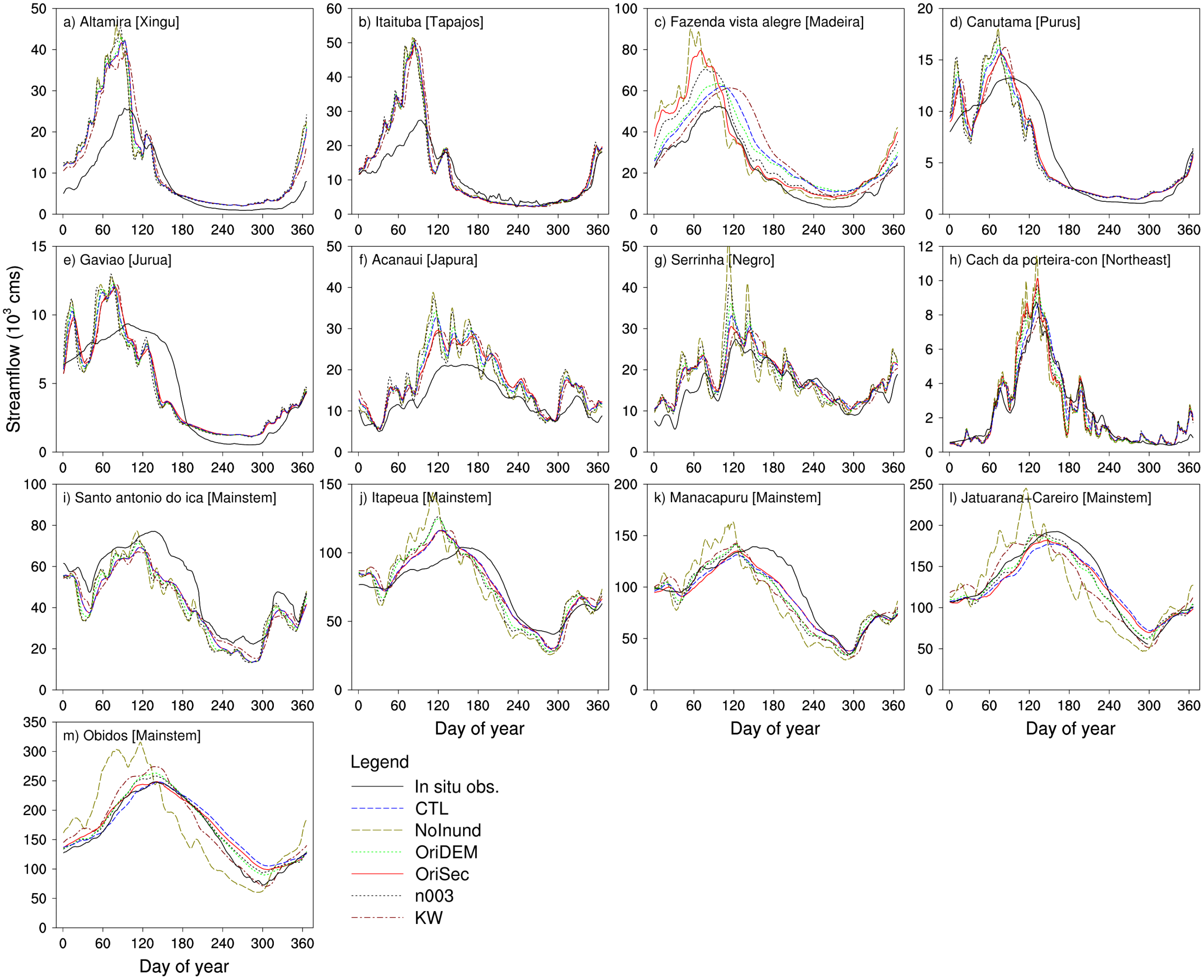

Figure 2. Observed and modeled daily streamflow of year 2005 at 13 stream gauges. Setup of the six simulations is described in Table 2: CTL – Control simulation; NoInund – Without inundation scheme; OriDEM – Using the original DEM (with vegetation-caused biases); OriSec – Using basin-wide channel geometry formulae; n003 – Using a uniform Manning roughness coefficient (i.e., 0.03) for all the channels; KW – Using kinematic wave method to represent river flow.

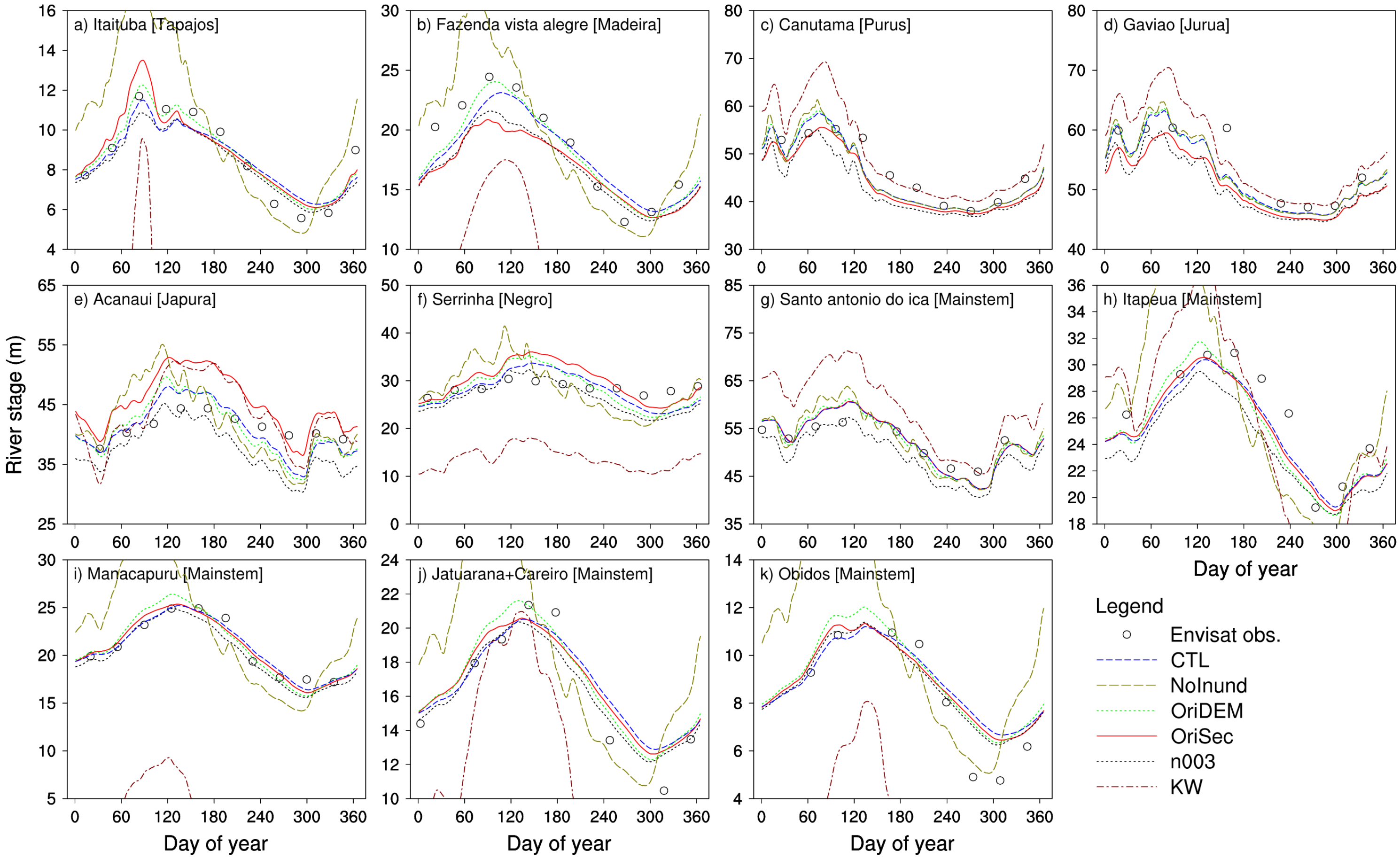

Figure 3. **Observed and modeled river stages at the daily scale in year 2005 for the subbasins containing or close to 11 of the 13 stream gauges. Setup of the six simulations is described in Table 2: CTL – Control simulation; NoInund – Without inundation scheme; OriDEM – Using the original DEM (with vegetation-caused biases); OriSec – Using basin-wide channel geometry formulae; n003 – Using a uniform Manning roughness coefficient (i.e., 0.03) for all the channels; KW – Using kinematic wave method to represent river flow.**

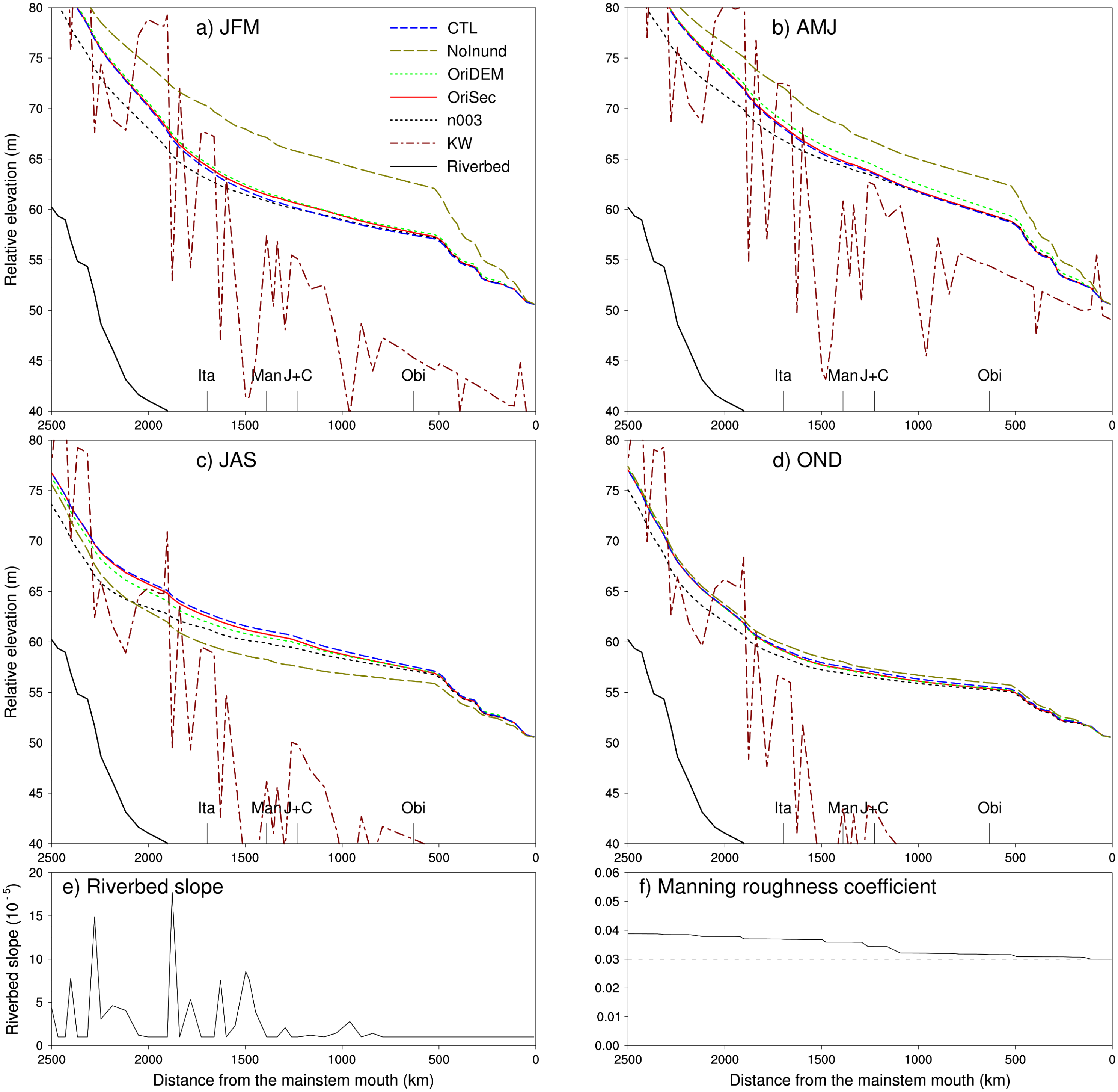

Figure 4. Modeled average river surface profiles along the mainstem in the four seasons of year 2005: (a) JFM (January, February and March; the period of rising flood); (b) AMJ (April, May and June; the period of high water); (c) JAS (July, August and September; the period of falling flood); and (d) OND (October, November and December; the period of low water). Results of six simulations are shown. The four stream-gauge locations are labeled on the x-axis: Ita – Itapeua; Man – Manacapuru; J+C – Jatuarana+Careiro; Obi – Obidos. Riverbed slopes (e) and Manning roughness coefficients (f) along the mainstem are also shown. In the panel (f), the solid curve shows spatially varied Manning coefficients used in five simulations; the dotted line shows the uniform Manning coefficient of 0.03 used in the simulation "n003".