Reply to Nicholas Jarvis

We would like to thank Nicholas Jarvis for his truly relevant comments on the manuscript and we are glad that he finds that this work may show an interest for the hydrological community of subsurface drainage. We agree with most of the comments and we propose an answer for each specific comment and a suggestion for correction accordingly hereafter.

Comment:

1. Line 177: The origin and meaning of this equation is unclear and should be explained. Perhaps a figure could help? Where does the number 0.4 come from? In principle, this looks like another parameter to me, even if you assumed it here to be a constant.

- Reply: the reviewer is right, this point remained unclear in the text. The idea is to consider the volume of the storage from 0 to the S_{inter} parameter as an approximate concept of the water holding capacity. As so, the available water capacity that could be easily used by crops is a part "a" of this volume. We agree with the reviewer, a might be considered as a fifth parameter to be calibrated. However, to keep SIDRA-RU as parsimonious as possible, a is set at a fix value. Indeed, Tournebize et al. (2015) showed that a might be included from 60% to 70% of the water holding capacity on French drained plots. Thus, we choose to fix this proportion at 60% and so to fix the S_{RFU} level at 40% of S_{inter}. We propose the following correction at the line 176 of the original version of the manuscript after "Two parameters control the RU module.":

"Two parameters control the RU module. On the one hand, the S_{inter}(mm) parameter is an intermediate threshold of the soil reservoir defining the water quantity needed to generate flow in the reservoir before saturation of the storage (see Eq. (2)):

$$S_{RFU} = a * S_{inter} \quad (2)$$

The factor a is set to 0.4 due to the water capacity that could be easily usable by the crops (RFU for "Réserve Facilement Utilisable" in French) representing approximately 60% of S_{inter} (approximate concept of the water holding capacity) on French drained soils (Tournebize et al., 2015)."

Comment:

2. Line 186: in principle, α is also a parameter that apparently has been previously calibrated against experimental data and is now set as a constant. However, in principle, it should depend on soil hydraulic properties and is therefore not a constant for different soil types. It's not a very important point, but the author's claim that there are only 4 parameters to calibrate in this model is in my opinion a little dubious. As far as I can see, it should be six.

- Reply: the reviewer is right, α might also require a calibration. However, a sensitivity analysis from an article currently being published (Henine et al., In publication) showed that α is not sensitive to the KGE' criterion used in the study. Consequently, to limit uncertainties relative to the calibration process for a non-sensitive parameter, α is set to $1/3$ due to previous experimental tests.

Comment:

3. Line 202: You should also mention another important assumption here. You also assume that recharge to groundwater is negligible i.e. that all excess water is routed to the drainage system. This seems to be a reasonable assumption for your study sites, because the water balances are simulated quite well, but it will definitely not always be the case. For example, wide-spaced drainage systems are often installed in fields with slowly permeable subsoils (e.g. in soils with morainic parent material). Annual recharge to groundwater is definitely not a negligible term of the water balance in such cases. It should be discussed here whether your model could be adapted to account for this kind of hydrogeological situation (and if so, how).

- Reply: The referee is right, recharge to groundwater is neglected in this study. We will mention this assumption in the revised version of the manuscript. French drained plots suffering from permanent infiltration issues represent less than 10% of the total drained areas (Lesaffre, 1987) and since 2009 the French law prohibits the use of drainage systems on such soils. Furthermore, most of French drained soils belongs to the hydromorphic soils category showing temporary waterlogging issues due to a perched water table (Lagacherie and Favrot, 1987). In this context, neglecting recharge to groundwater seems to be quite reasonable. However, SIDRA-RU may be used without this assumption, integrating the depth infiltration to the Hooghoudt's equation according to the principle of equivalent depth (Bouarfa and Zimmer, 1998).
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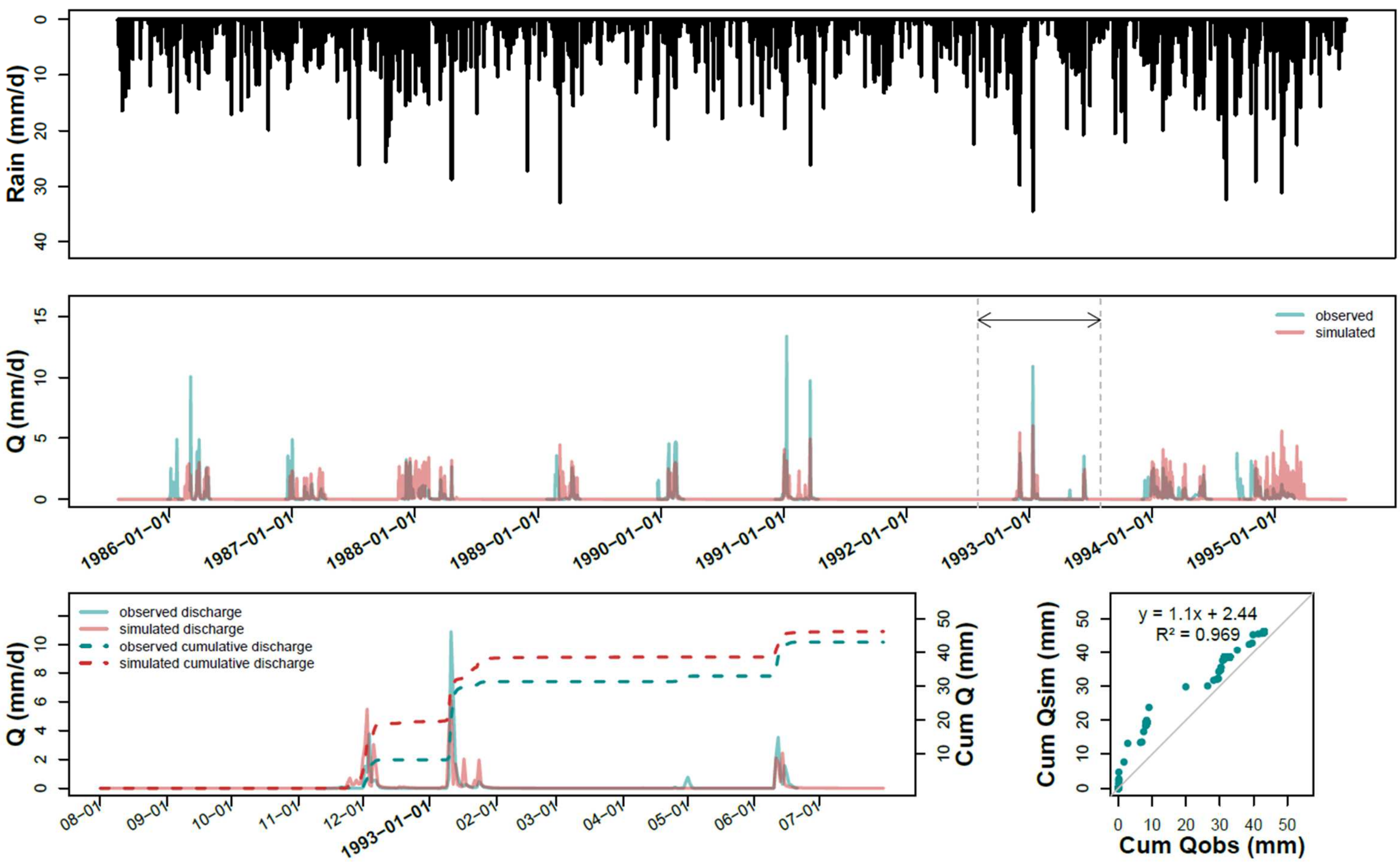
Comments:

4. Lines 301-303: It would help readers to better understand the model limitations for clay soils if the authors also showed some plots of the results for the Courcival site at this point.

- Reply: the reviewer is right, presenting the case of Courcival, among the clayey soils, would obviously be interesting to show the reader a situation in which SIDRA-RU is not good, introducing a new figure. We propose the following correction after the line 314 in the Results part:

"Unlike at *La Jaillière*, SIDRA-RU at *Courcival* (see Fig. 5), plot lying on a swelling clayey soil, shows larger discrepancies between observed and simulated discharges on the plots. The red and blue curves do not coincide on a significant part of the chronicles. From 1985 to 1995, simulated discharges often start later than the observed ones with delays approximately ranging from 2 weeks to 2 months. The start of the drainage season is defined here when significant discharges appear. The plots on the cumulative drained discharge on 1992-93 show that the annual drained water balance diverges by +3 mm from simulations but the linear regression shows a slope equal to 1.1, which is quite high and shows that the cumulative discharges are not well simulated. These results are consistent with the fact that SIDRA-RU at *Courcival* shows an unsatisfactory KGE' value."



”

We also propose to reword the paragraph from line 498 to line 507:

“On non-deformable clayey soils such as *Saint Laurent*, SIDRA-RU shows relevant performances. However, at *Courcival*, plot lying on a deformable swelling clayey soil, SIDRA-RU performances are significantly weaker. In this respect, the latter is not an exception in the drainage model community. Indeed, the literature identifies clayey soils as a recurring problem for drainage modeling (Robinson et al., 1987; Snow et al., 2007), especially in mole drainage, as currently practiced on heavy clayey soils and swelling clays (Jarvis and Leeds-Harrison, 1987; Tuohy et al., 2016). This finding is mainly due to a difference in hydraulic characteristics between silty soils, on which the model design is primarily based, and heavy or swelling clayey soils. The latter are characterized by natural pedological deformations, like soil surface fracturing, that lead to preferential flow zones before saturation (Beven and Germann, 1982; Jarvis and Leeds-Harrison, 1987). The horizontal soil profile is no longer homogeneous, which contradicts one of the main hypotheses of SIDRA. Moreover, agricultural practices like plowing exacerbate this phenomenon and therefore affect soil porosity. One way to improve results at *Courcival* is to artificially locate pipe at 30 cm depth instead of 90 cm as it is.”

<u>Comment:</u>

5. Lines 310-311: do you mean that the model gets the timing of the start of drainage in clay soils wrong by a whole month? Please clarify. It would help to show this in a figure (see point 4).

- Reply: Indeed, the start of the drainage season, i.e. the date when the first significant discharges are observed, on clayey soils often appears with one-month delay in simulation compared to observed data. Without being systematic, this is mainly specific to this soil texture, the delay is weaker on silty soils and silty-clayey soils. As you propose, the latter figure may also be used to illustrate that half of the studied period is concerned by this delay. We propose to include this explanation to the correction proposed for the comment 4. We propose to add the following correction at the line 508 after the above-mentioned paragraph proposed as correction:

"Furthermore, the issues observed on clayey soils are specifically significant on the start of the drainage season. At *Saint Laurent*, delays occur more frequently than on silty soil and the more the plot is defined by heavy or swelling clayey soil, the larger the delay. At *Courcival*, these delays are around one month."

<u>Comment:</u>

6. Lines 331-332 and 579-581: it will not be possible to accurately model pesticide or nitrate leaching based on the RU hydrological model, because the unsaturated zone is modelled as a single box. Leaching of nutrients and contaminants in soil cannot be accurately modelled using such a lumped hydrological model for the unsaturated zone. Physics-based modelling approaches are necessary. This should be acknowledged in some suitable way.

- Reply: the authors do not completely agree with this comment. The referee is right, it is often necessary to use more physically based approaches than the RU module to represent the unsaturated zone to accurately model pesticide and nitrate leaching. However, using pedotransfer functions from conceptual approaches is also possible (Jury and Roth, 1992), and already used on drained soils (Magesan et al., 1994). Combined with SIDRA-RU and within this framework, the PESTDRAIN module already exists for the pesticide leaching (Branger et al., 2009) and the SIDRA-N module is currently developed to simulate nitrate leaching in the team to which the main author of the present study belongs. Both of modules include several compartments (one fast and one slow pathways) with few parameters and show interesting performances.

<u>Comment:</u>

7. Lines 498-500: Yes, most hydrological models work less well on clay soils and SIDRA-RU does not seem to be an exception. But it should be acknowledged that there are exceptions. For example, MACRO was originally designed to simulate flow processes in structured soils and it has been shown to work very well in heavy clays (Köhne et al., 2009). There are three main reasons for this. It accounts for non-equilibrium water flow in soil macropores as well as vertical heterogeneity in their hydraulic properties, while the drainage module also assumes horizontal saturated flow (Dupuit-Forcheimer assumptions) to a seepage surface above the drain (exactly as figure 11 shows).

- Reply: The referee is right and we propose the following correction to complete the discussion dealing with performances of subsurface drainage models on clayey soils, after the line 507:

“Some models show their efficiency to simulate drainage discharge on such soils, as the MACRO model (Köhne et al., 2009), originally designed to simulate flow processes in structured soils like heavy clayey soils (see Fig. 12). However, these models are based on a more physically oriented approach than SIDRA-RU. Building on this type of concept would probably improve the latter simulating drainage discharges on clayey soils but would call into question its generalist nature.”

Technical corrections:

The referee identified various technical corrections listed line by line that will be carried out as requested.

Dealing with the KGE’ criterion, we cannot link the zero value to any particular interpretation unlike the NSE criterion (see Knoben et al. (2019): “there is no specific meaning attached to KGE’=0”). However, if we consider the mean flow benchmark as reference (corresponding to NSE = 0), the model must show a KGE’ value above -0.41 to prove a better simulation than the mean flow (Knoben et al., 2019). We propose to include the following sentence into the text after the line 242 after “KGE' values range from $-\infty$ to 1”:

“The model performance is better as KGE' increases towards 1. If the reader intends to use the mean flow benchmark as reference (corresponding to NSE = 0) to assess KGE’, the target value is KGE' = -0.41 (Knoben et al., 2019).”

Regarding the English language issues, the article has already been corrected by a native speaker, as mentioned on the certificate attached to this document. However, the article will be reviewed a second time before the final submission to carry out the language issues highlighted by the referee.

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Robert Sachs
Translator / Copy-editor

March 3, 2021

To whom it may concern,

This certificate is intended to inform you that I, Robert Sachs, a professional French-English translator, proofreader and copy-editor with over 20 years experience working in close collaboration with the French research community, have reviewed and modified this article ("Robustness of a parsimonious subsurface drainage model at the French national scale"), on behalf of its lead author Alexis Jeantet. My assigned role was to correct the spelling / grammar / syntax of the manuscript in addition to improving its readability. I was naturally not involved in any of the strategic decisions regarding the article's outline, contents or dissemination of results. The scope of my function was primarily at the word / sentence level, in ensuring a quality of expression that would not detract from the authors' emphasis.

Furthermore, it is the role of the copy-editor to tighten the language, clean up syntax and avoid overt grammatical mistakes, in rendering a copy as cogent and efficient as possible for the reader, but not to realign sentences in a manner that would potentially subvert the authors' intended communication.

I remain at your entire disposal for any subsequent exchange you feel could be fruitful in the given context:
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Many thanks for your attention and consideration.

Best regards,

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