Response to the comments of the reviewers

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Dear Reviewer 3,

we are very grateful to the reviewer for the helpful comments and suggestions. In the following we address individually the comments to the manuscript 'URANOS v1.0 - the Ultra Rapid Adaptable Neutron-Only Simulation for Environmental Research' submitted to GMD. Reviewer's comments on the manuscript are bold, our answers italic and the latexdiff of the submitted paper indented in quotation.

Reviewer 3

The publication shows a profound knowledge of the authors about the existing programs and the underlying physics and IT concepts. There are, however, some points that would improve the document:

For people from other fields of research it is partly difficult to read, because the methods are not always described, e.g. half a sentence on how CRNS works would be helpful.

We added to the introduction the following part:

> The graphical user interface offers features specifically tailored to the needs of the field of Cosmic-Ray Neutron Sensing. The novel method retrieves subsurface soil moisture by measuring flux of cosmic-ray induced neutrons that scatter at the soil interface. With typical footprint ranges of hundreds of meters for stationary and beyond one kilometer for mobile sensors, it specifically addresses research questions in complex environments.

Similarly, there are terms used that are not common to all fields. They should either be explained or alias names added, especially
- Is „evaporation" of neutrons the same as „spallation"of neutrons?
- Is „ray-casting" the same as „ray-tracing"?

The term spallation does not appear in the manuscript as currently it is not implemented due to its lack of relevance for environmental applications. We have clarified the term evaporation at its first occurrence:

> such as evaporation, the delayed emission of MeV neutrons from excited nuclei

We have added an explanation for ray casting:

> Ray casting follows tracks from the source to the point of detection, contrary to ray tracing, which follows tracks backwards from the point of detection, but requires mostly deterministic interactions.

Equation (1) to (4) are only consistent, if (3) and (4) calculate $p(x)\mathbf{d}p$, not $p(x)\mathbf{d}x$.

This statement is not clear to the authors. There might be a confusion here. $p(x)dx$ is dp, integrating pdp would simply yield $[1/2\, p^2]$.

In Eq.(5), the second ξ should be replaced by anything else, e.g. ξ'. As it is written now, the equation is not correct.

Yes, we changed the equation to an equivalent symbol.

Surprisingly, it sounds like the authors have doubts about the Monte Carlo method.

The authors might not have doubts about the method itself but about whether or not its application is justified. The Monte Carlo method is especially suitable for neutron calculations, but for other particle species like photons with a much higher flux it is probably not.

Some suggestion for text improvement:
- 47 - 49: can be omitted, as the programs are described in the following paragraphs?

We have removed the sentences.

- Chapter 1.2: it could be added that the programs dedicated to neutron instrumentation and virtual neutron experiments (McStas, VITESS, RESTRAX, ...) also allowed fast simulations by restricting its use to neutrons and ignoring nuclear reactions

We have added this proposition:

> Restricting the calculation to neutrons and ignoring other nuclear reactions has been proven useful to increase computational speed in programs dedicated to neutron instrumentation and their representation in virtual experiments, like McStas (Lefmann and Nielsen, 1999), VITESS (Wechsler et al., 2000) and RESTRAX (Šaroun, J. and Kulda, J., 1997).

- 106 - 112:: I cannot see the problem of the multigroup method

The multigroup method is motivated by the idea to describe the ensemble correctly, not individual neutrons. For example for providing criticality calculations. They are not only sensible to the thermal budget of the entity but also involve that the neutron flux changes the state of objects within the simulation time. As provided in the text, if neutrons undergo just one or two collisions it lacks the randomness, especially associated with outliers within the calculation.

- 119: performance of GEANT4: what is missing, speed or accuracy or ...?

We have added that information:

> the computational speed of GEANT4 in typical scenarios is significantly lower than those of other codes.

- 156 - 15: I don't understand that.

For thermal neutron energies, the Doppler broadening due to the relative velocity of neutron and its target influences the cross section as well. Not taking this into account leads to an incorrect scattering probability. We have added:

> i.e. taking into account the Doppler effect.

- 214f: Why? What is done instead?

Using ensemble statistics means to treat neutrons by analytical expressions like Fermi-age equations. Besides that in this highly complex task of CR neutrons the author does not even know whether such expressions can be derived out without mainly relying on perturbative calculations, ensemble statistics is useful for describing large numbers of particles. In case of typical neutron simulations this might not be the case. It also becomes complicated if certain effects are mainly due to kinematic outliers.

- 226: „Whereas"-> „While"

We have changed that.

Style: often there are too few commas in too long sentences.

We identified a number of long sentences and reduced their length.

Figure 1:
I wonder if neutrons are generated in the source or the soil layer.
An explanation of the particle symbols and a vertical scale would be good.

Both, their generation mostly takes place in the source layer, however, as indicated by the 'dot' at the evaporation label, neutrons can also be generated by other processes.
We have added the description of the particle symbols to the figure.
For the sake of the illustration the vertical scale has been compressed for the atmosphere and stretched for the ground. With both having a density difference of a factor of 1000, it is hard to provide an informative but still realistically scaled graph. We have added an annotation to the caption.

Figure 2:
- I think the „Layer stack" is still a „Neutron stack".
- Is there no flight direction stored?

The layer stack is the geometrical representation of the simulation domain, through which a neutron has to propagate. the neutron stack comprises neutrons with their initial (randomly generated) properties or neutrons which were generated by other processes during the simulation.
There is in fact a specific variable which only stores the flight direction (forward/backward) in order to facilitate some calculations. The figure does not explicitly mention the direction, however, it is included in the neutron vector.

Thank you very much for the review of our manuscript.