Response to RC-2 review of the manuscript:

“Characterizing groundwater heat-transport in a complex lowland aquifer using paleo-temperature reconstruction, satellite data, temperature-depth profiles, and numerical models”
Manuscript ID: hess-2021-586.

General comments:

The paper by Casillas-Trasvina et al. aims to simulate the heat transport in the Neogene aquifer. Although this manuscript collects a lot of data, which can be useful for other works, it is difficult to read and the presentation should be more concise and to the point. I have the following main comments:

1. It is not clear why the model needs paleo-temperature to work. Also, I really doubt that simulating 10519 years yields meaningful results, given that the flow model is stationary.

Response: To increase the accuracy of the simulated temperature and hence a good simulated vs observed temperature performance, the simulated temperature has to be able to stabilize (or reach a steady-state) and for this we require to estimate initial conditions (initial temperature values for each stress period).

To show the importance of performing the paleo-temperature simulations to provide initial conditions for further stress periods, a test was performed. (Disturbed) simulations increasing 1 degree at the initial top boundary condition at various time steps (years before present i.e. 10000yr, 9000yr, 8000yr, 7000yr, 6000yr, 5000yr, 4000yr, 3000yr, 2000yr, 1000yr, 900yr, 800yr, 700yr, 600yr, 500yr, 400yr, 300yr, 200yr, 100yr) and for the remaining of the simulation period were performed. The simulated temperature-depth (TD) profile from all these models was obtained for the same location (on well R-54f). The results of this test are shown in Figure 1. On Figure 1a, it is shown the simulated TD profile at the last time step (present time) from a normal (undisturbed) forward model run. On Figure 1b, the figure shows the differences between the disturbed and normal (undisturbed) simulated TD profiles, pointing out to the time required for the model to reach a steady-state given a change of 1 degree in the top boundary temperature condition. This supports the use of a relatively long time series which it is actually a process that is not computationally intensive. The model in total has 337 stress periods and runs in around 40 minutes For the 9 time steps in the stress period between 10000yr and 2000yr before present (in steps of 1000 years) it requires around a minute (approximately 64 seconds) to compute offering a temperature stabilization of up to 30% per temperature degree of change in the temperature top boundary condition.

Similarly as done in previous works in the area (Casillas-Trasvina et al., 2021; Gedeon, 2008; Rogiers et al., 2015), and as indicated in the body if the manuscript (section 3.2.1 Conceptual model, line 215), the aquifer is assumed to be in dynamic equilibrium, with no long-term trends in groundwater fluxes, which allows us to simulate the groundwater flow in steady-state. For the purposes of our research we find this assumption acceptable.

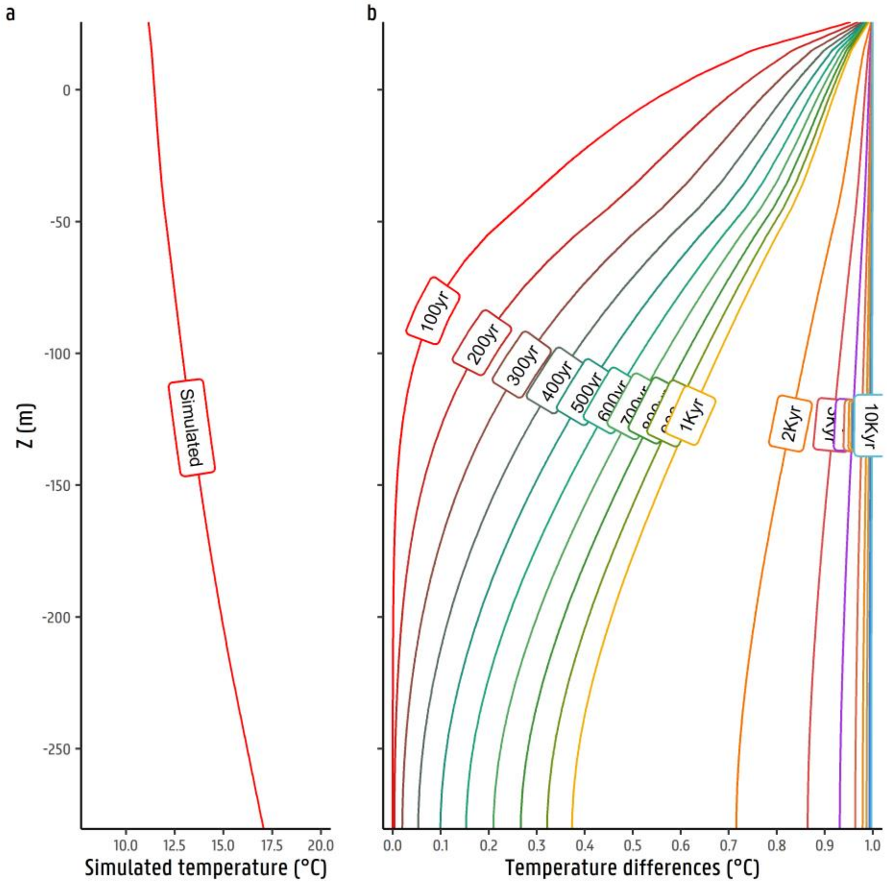

Figure 1 a) Temperature depth (TD) profile simulated at observation well (i.e. R-54f) at the end of the coupled groundwater flow and heat transport undisturbed simulation (present time). b) Temperature difference at the same observation well between the TD profile at the end of each disturbed simulation (present time) minus the undisturbed simulation.

Casillas-Trasvina, A. C., Rogiers, B., Beerten, K., Wouters, L. and Walraevens, K.: Exploring the hydrological effects of normal faults at the boundary of the Roer Valley Graben in Belgium using a catchment-scale groundwater flow model, Hydrogeol. J., (0123456789), doi:10.1007/s10040-021-02423-y, 2021.

Gedeon, M.: Neogene Aquifer Model., SCK-CEN external report ER-48, 100 pages. Report prepared by SCK•CEN in the framework of ONDRAF/NIRAS programme on geological disposal, under contract CCHO- 2004-2470/00/00, DS 251-A51.2008.

Rogiers, B., Labat, S. and Gedeon, M.: An assessment of dilution tests and ambient temperature logging for quantifying groundwater flow in the Neogene aquifer., SCK-CEN Extern. Rep., 2015.

2. Peclet number: I have not understood why the Pe number is smaller than 1 in some parts of the aquifer. I really doubt that transport can be diffusive in aquifers.

Response: Peclet numbers in the large majority of the aquifer are well above a value of 1 (Pe >> 1). However, in the Berchem & Voort Formation, Peclet numbers are above and around 1 in the majority of the formation and increasing up to around 10 towards the Diest Formation, right above it. The values of Pe ≤ 1 are very few, mostly near to 1, and found near the bottom of the aquifer where groundwater flow velocities are at the lowest as in these areas the fluxes occur near the bottom no-flow boundary of the model. Research has been previously performed as summarized by Vandersteen et al. (2014), pointing out the low hydraulic conductivity values for the Berchem & Voort Formation (as low as 0.02 m/d), and thus not particularly acting as a barrier/clay, but with modest advective/diffusive behavior.

Vandersteen, K., Gedeon, M. and Beerten, K.: A synthesis of hydraulic conductivity measurements of the subsurface in Northeastern Belgium, Geol. Belgica, 17(3–4), 196–210, 2014.

Minor comments:

1. Ln. 85: a full stop is missing before This work.

Response: Included a full stop "." after "techniques" in "…techniques. This work…"

2. Figure 2: Please write also in the caption the source of the map

Response: Reference to the map is included in the caption, reading as follows:

> '*Figure 2. Plan view of the study area as discretized in the second layer of the numerical model. It indicates faults (emphasis on the highlighted Rauw Fault), cross section, temperature-depth profile locations, and modelled formations derived from the hydrogeological 3D model from Deckers et al., (2019).* '

Deckers, J., De Koninck, R., Bos, S., Broothaers, M., Dirix, K., Hambsch, L., Lagrou, D., Lanckacker, T., Matthijs, J., Rombaut, B., Van Baelen, K. and Van Haren, T.: Geologisch (G3Dv3) en hydrogeologisch (H3D) 3D-lagenmodel van Vlaanderen. Studie uitgevoerd in opdracht van: Vlaams Planbureau voor Omgeving (Departement Omgeving) en Vlaamse Milieumaatschappij.,., 2019.

3. Ln. 137: avoid abbreviation. Use was not instead of was't.

Response: "Wasn't" changed to "was not".

4. Figure 3: the figure is not clear. It should be somehow indicated that b) is the inset in a). Also the curves are not clear and the data from Eindhowen look completely missing.

Response: Agree. Indication ‘b’ in the red square of figure a is included. In the caption, it is indicated that figure b is an inset of figure a. Additionally, the curves are replotted to be more clearly shown (thicker lines) and showing the data from the station Eindhoven.

5. Ln. 162: what is i.a. ?

Response: i.a. (inter alia) is Latin for "among other things”.

6. Ln. 185: there is a parenthesis that is not open before.

Response: Removed parenthesis “)”.

7. Ln. 229: full stop missing after the parenthesis.

Response: Included full stop “.” after “(2019)” in “…is based on Deckers et al. (2019). The…”.

8. Eq. (1) and (2) vectors should be distinguished from scalar by using bold characters.

Response: The vectors included in Equations 1 and 2 were formatted as bold characters.

9. Ln. 336: which are cases 2 and 3?

Response: The modelling cases 2 and 3 are indicated right after the paragraph; line 341 “Model 2: Thermal conduction”, and line 348 “Model 3: Heat-transport without faults”. In line 335, “modelling cases” is changed to “model 2 and model 3 (see below)” for clarification.