

Reply to “Comment on essd-2022-448” by Kwang-Il Kim (Referee)

Referee comment on "Global physics-based database of injection-induced seismicity" by Kivi et al., Earth Syst. Sci. Data, 2023

### **General comments:**

This paper presents comprehensive physics-based database of injection-induced seismicity with descriptions related to its physical and statistical implications for understanding and forecasting of induced seismicity. I think the database adequately covers the vast range of physical parameters from worldwide injection-related geo-energy applications. The manuscript is well written and structured. I see the paper as a useful contribute to ESSD, if the below minor comments are handled appropriately.

*Authors' response: We thank the reviewer for his careful consideration and positive assessment of the paper.*

### **Specific comments:**

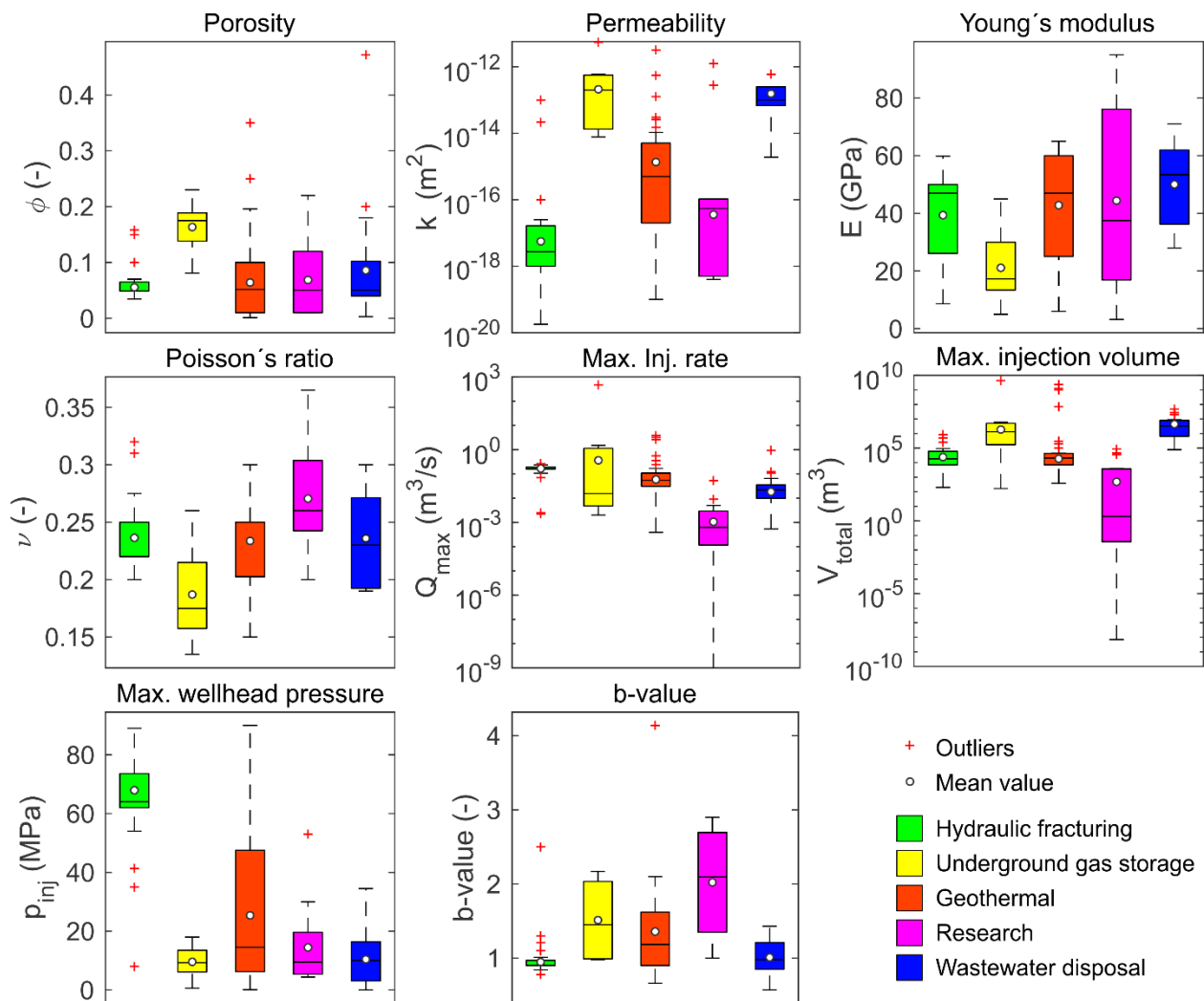
1. This study seems not to discriminate the term “induced” and “triggered”, although both terms indicate different nucleation mechanism in some studies (Dahm et al., 2015; McGarr et al., 2002, Ellsworth et al. 2019). Particularly, Ellsworth et al. (2019) classified the mainshock of the Mw 5.5 Pohang earthquake as triggered seismicity, which was initiated by anthropogenic forcing and propagated beyond the bounds of the stimulated region. Other seismic events that occurred during hydraulic stimulations were termed as induced seismicity, of which magnitudes are limited to within the spatial dimension of the stimulated volume (Kim et al., 2022). As mentioned in the manuscript, Mw 5.5 Pohang earthquake is regarded as a representative counter-example of magnitude scaling relations driven by McGarr (2014), but McGarr and Majer (2023) argue that the relationship is intended for earthquakes induced, not triggered. Thus, some descriptions regarding the term “induced” and “triggered” might be needed in the manuscript for the further understanding of the physical mechanism of seismicity.

*Authors' response: We generally agree that defining the terms “induced” and “triggered” can be of help in some studies to highlight particular features of earthquakes, e.g., their origin or causing mechanisms. Yet, the decision on whether an earthquake has been triggered or induced is usually debatable and a consensus is not always reached. Indeed, there is no quantitative threshold to discriminate between the two types of seismicities. For this reason, we have preferred not to attempt to distinguish in our database between induced and triggered seismicity. In the manuscript, we tend to consistently use the term induced for all earthquakes of anthropogenic origin. Yet, for the case of Pohang earthquake, we already mentioned its triggered origin: “...the 2017  $M_{max}$  5.5 Pohang earthquake in Korea, triggered by stimulation of an EGS, ... ” (page 4, lines 89-90). In the revised version of the manuscript, we will add a statement to emphasize that we do not distinguish between induced and triggered earthquakes and consistently use the term induced for all earthquakes of anthropogenic origin, with the exception of Pohang, which has been studied in detail and a committee of experts agreed on its triggered origin.*

*Regarding the existing magnitude scaling relations, we already mentioned their limitations. We will emphasize that the seismic forecasting capability of these models is limited. We believe that the compiled database will help testing the applicability of these models and develop alternatives that better include the underlying physics.*

2. In Figure 5, parameters with the logarithmic scale of y-axis such as permeability, maximum injection rate, maximum injection volume show that the mean value is plotted outside of the boxplot probably due to extremely large or small value of outliers. Particularly, the permeability for “research” is generally one or two order lower than the permeability for “geothermal”, but mean values of both types indicate contrasting result. Mean values calculated by excluding the outliers can better represent the characteristics of the given parameters.

*Authors’ response:* We thank the reviewer for this comment. The average values have been calculated after excluding outliers and will be used in the revised manuscript. The new plot is shown below.



**Figure 5.** Boxplot for a number of database parameters. From bottom to top, the box indicates the first quartile, median and third quartile of the data. Whiskers represent the minimum and maximum values, excluding outliers. The mean values are also calculated after excluding outliers. Outliers reside outside the range defined by 1.5 times the interquartile range added to the third quartile and subtracted from the first quartile

## Technical corrections

1. L172. The project number is missing in first column of the given excel file.
2. Host rock properties in Figure 2. There is a typo in the unit of thermal expansion coefficient. ( $1/^{\circ}\text{K} \rightarrow 1/\text{K}$ )
3. L193: “hydrogeological” properties needs to be changed to “thermal and hydrogeological” properties, as thermal conductivity and thermal expansion coefficient are included in the reservoir rock properties.

*Authors' response: Corrections have been made in the revised manuscript.*