Reply for the comment on egusphere-2024-198 (Referee #1)

Title: Geomorphic indices for unveiling fault segmentation and tectono-geomorphic evolution with insights into the impact of inherited topography, Ulsan Fault Zone, Korea

Major comments	
Comment	**Reply**
For geomorphic modelling of cases B1 and B2, the uplift rates of eastern end were set 18 mm/kyr and 42 mm/kyr, respectively. The uplift rate of 18 mm/kyr for the northern part of the block was calculated based on a relationship between the incision rate and the distance. The authors should give more explanation for its validity, because such an uplift rate is smaller than the CADR value. Similarly, the uplift rate of 42 mm/kyr was obtained based on a relationship between the average CADR and the distance in the southern part.	For both cases B1 and B2, the uplift rates of the eastern end during the second stage are zero (Fig. 4). In Case B1, the uplift rate 2.5 km east of MDD is 18 mm kyr^{-1} with a gradient towards the east of -22.27 mm kyr^{-1} km^{-1}, based on the relationship between the incision rate and the distance. We then extrapolated the uplift rate towards the east using this gradient until the uplift rate reaches zero. In Case B2, the uplift rate at the fault location (western flank) is set to 42 mm kyr^{-1}, based on the ratio of CADRs in the northern and southern parts. We set the uplift rate to decrease to zero at the 2 km east of MDD because most knickpoints on the eastern-flank channels in the southern part are located within this distance. On the western flank, the modelled uplift rates (118 mm kyr^{-1} in the northern part and 42 mm kyr^{-1} in the southern part) are comparable to the CADRs. However, on the eastern flank, the modelled uplift rates are significantly lower than the CADRs. There are several possible reasons for this discrepancy: (1) The uplift rate gradient could be overestimated. (2) The CADRs reflects not only the faulting along the UFZ but also the other kinds of tectonic movement. Both of those reasons are plausible, but we could not quantify the extent to which the uplift rate gradient is overestimated or the degree to which other types of tectonic movement contribute to the uplift rates in the study area. Consequently, we assumed a linear decrease in uplift rate from the fault location and calculated the uplift rates as

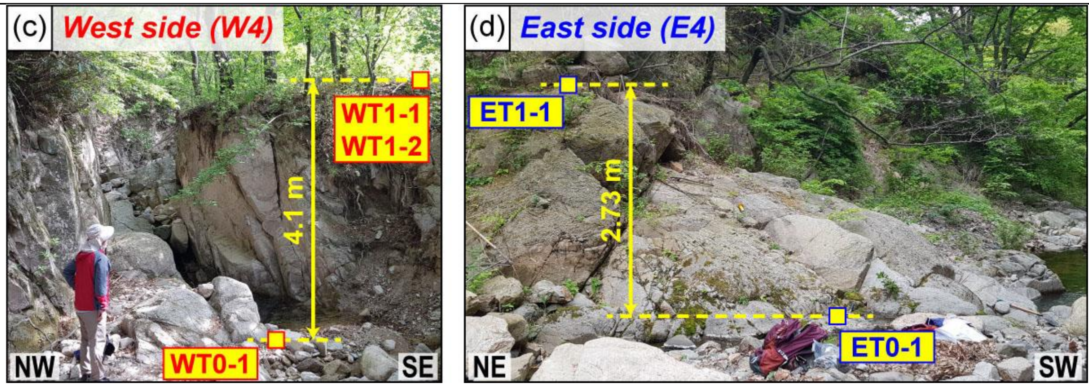
	described above .
The UFZ has been divided into five segments based on geomorphology analyses alone. I understand how difficult it will be to obtain some data in an urbanized area. However, it will be more convincing if the authors can provide some other data, for example, the GPS slipping rates, stress accumulation, InSAR deformations.	Thank you for your valuable suggestion regarding the integration of additional data types such as GPS velocity fields and InSAR measurements to delineate fault segments. Indeed, these geodetic methods are critical for identifying 'rupture segments' that delineate the historical rupture limits for seismic events and are particularly useful in tectonically active regions. However, our study area in the southeastern part of Korea is characterized by its tectonic quiescence, being situated within an intraplate region. This low level of tectonic activity is a primary reason why neither this study nor other recent research in the area (e.g., Cheon et al., 2023) have employed these geodetic data for segment division. In this context, our segmentation of the Ulsan Fault Zone (UFZ) was aimed at identifying 'geological segments' based on geomorphic evidence, which is more feasible and justifiable given the regional tectonic setting. We believe that this approach remains valid and appropriate for the geological characteristics and data availability pertaining to the UFZ.
Base on the modelling, results, segment 1 was considered to migrate westward, while segments 2–5 has migrated eastward. However, such a discrepancy was not explained in detail.	Thank you for your comment. We address the exceptional westward migration of MDD within segment 1 in the section ‘5.2.1 Northern part of the UFZ: segments 1 and 2.’ The first paragraph of this section explains that both segments 1 and 2, which they have been in topographic and geometric disequilibrium, and the MDD in segment 1 is migrating westwards, approaching equilibrium in section 5.3. In the second paragraph, we explain that the distinct patterns of geomorphic indices are attributed to <u>(1) the channel length between the fault and the channel head and (2) difference in tectonic activity</u>. We intended that these consequently influence the direction of MDD migration. You can find this: **[Lines 718–726]** “The differences between the two segments can be attributed to two possible factors: (1) the channel length between the fault and the channel head and (2) tectonic activity.

	Channel lengths between the fault and the channel heads are longer in segment 1 than in segment 2. In segment 1, buried faults are developed in the incised valley, far to the west from the mountain front (Cheon et al., 2023). The response time of a channel to tectonic events increases with increasing channel length between the fault and channel head. Therefore, in segment 1, it is plausible that the most recent tectonic signal from Quaternary fault slip has not yet been transferred to the channel head. Secondly, the inferred tectonic activity, based on topographic metrics and the CADR (Figs. 7 and 8), is higher in segment 2 than in segment 1. Topographic metrics might be expected to have responded less sensitively to uplift in segment 1 because of its lower tectonic activity than that of segment 2.”

Minor comments

Comment	**Reply**
The geomorphic indices should be italic.	We will change them to italics throughout the manuscript
For Figures 1a and 1b, I suggest to add the movement properties of the major faults (strike, normal, or thrust) if possible. Can the active faults and ancient faults be marked by different colors (Red and Black) in Figure 1b? I suggest to add the names beside the major fault, e.g., Ulsan Fault. I also have a question. There are three moderate earthquakes shown in the Figure 1a, but why most of them do not occur along the major fault belts?	The major faults in the Figure 1a were developed during the Mesozoic. However, there is not enough evidence supporting that most of them, except for the Yangsan and Ulsan Fault Zone, have been reactivated under the present stress regime. That is why we did not mark the movement properties of those fault zones. In the same context, identifying active and ancient faults within the Ulsan Fault Zone also remains controversial based on the research cases until now. We may be able to add the movement property of the Yangsan Fault Zone in Figure 1a and the name of major fault in Figure 1b. The M_W 5.5 earthquake (12 Sep. 2016) occurred near the Yangsan Fault zone, which is one of the biggest fault zones in Korea. The focal mechanism of this earthquake is also consistent with the main slip component (right-lateral strike slip) of this fault zone. The M_W 5.4 earthquake (15 Nov. 2017) is known as an ‘(anthropogenically) induced earthquake’, which is caused by the fluid injection for the geothermal resource development (Grigoli et al., 2018; Kim et al., 2018). This may be the reason why this event did not occur along the major fault zones. The M_L 4.0 earthquake (30 Nov. 2023)

	is considered to have occurred due to the reactivation of ENE–WSW-striking strike-slip fault, which is related to the formation of a Tertiary basin in the southeastern Korea.  **Focal mechanisms of three earthquakes around the study area (Korea Meteorological Administration, 2017; Kim et al., 2018; Korea Meteorological Administration, 2018, 2023).**
I suggest to add the methodology description of the students t-test.	We think that it is not appropriate to make a separate section in the 'Methods' part solely for Student's t-test as it is a widely applied statistical method. However, we admit the explanation for Student's t-test is quite simple in the manuscript. We will add several sentences about Student's t-test at the end of sections 3.1.3. *** [Lines 227–228]** "*We then used Student's t-test which is a statistical method to determine whether two groups are statistically significantly different from each other. We applied this Student's t-test (two-tailed, $p < 0.05$) to statistically compare the values of the topographic metrics between the western and eastern flanks of the TMR*".
The channel incision rate was calculated based on cosmogenic nuclide. Thus, I suggest to add the outcropping and sampling description. What is the kind of the rock? What is the thickness of the sample?	The fluvial terraces where we collected samples are strath terrace (bedrock terrace). , We already included the pictures of those terraces in the Figures 3c and 3d and marked the sample locations on them.



Figures 3c and 3d

The thickness of the sample is already listed in the Table 3.

Sample name	Latitude (° N, dd)	Longitude (° E, dd)	Elevation (m)	Thickness (cm)
WT0-1	35.6985	129.3514	232	5.0
WT1-1	35.6985	129.3514	236	3.5
WT1-2	35.6985	129.3514	236	2.5
ET0-1	35.7069	129.3921	207	4.0
ET1-1	35.7069	129.3922	209	5.0

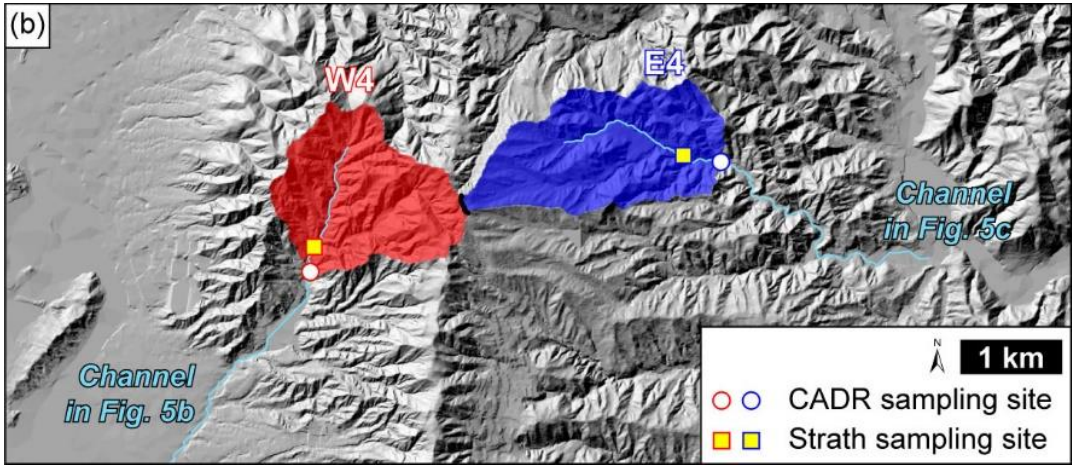
A part of Table 3 (the right side of this table is cut because of a lack of space).

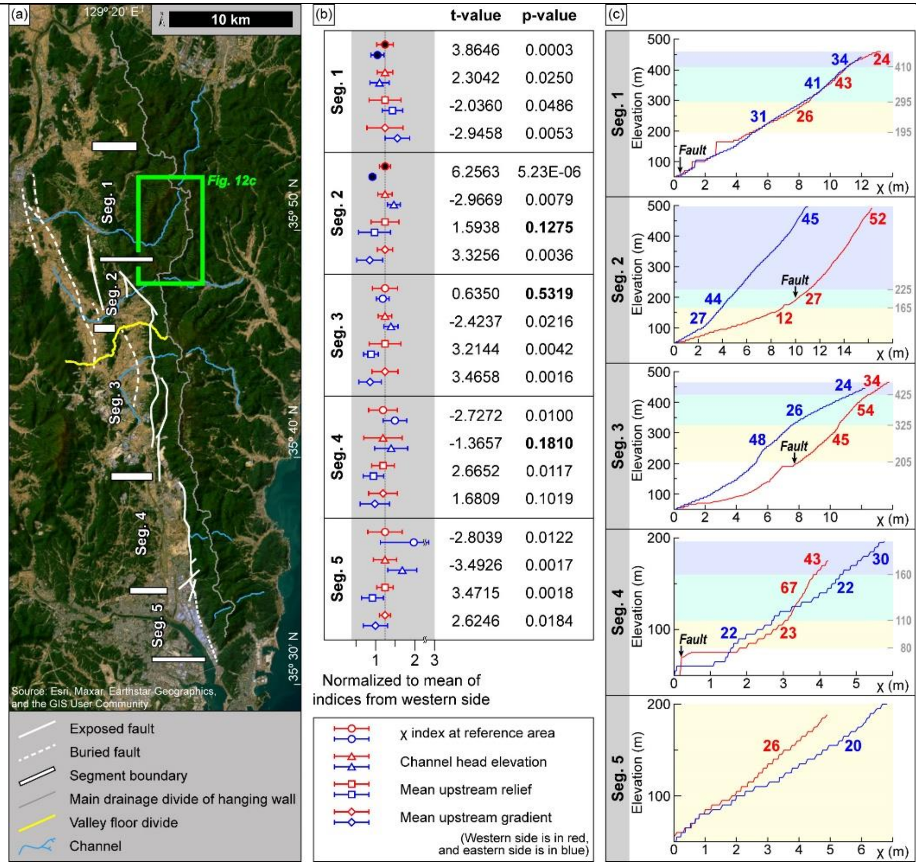
Both strath terraces consist of granite, and we will add this in the section 3.2.2.

*** [Line 306]** *The sampled strath terraces are located in the drainage basin from which the W4 and E4 CADR samples were taken.* *<u>All terraces consist of granite bedrock.</u>*

I suggest to add the Ulsan Fault in Figure 3a.

Thank you for your suggestion. Figure 3a is designed to illustrate the locations of the catchments where we collected the samples and to present the CADR results. We considered marking the UFZ on the map, but the boxes displaying the CADR results obscure the fault lines, which led us to omit them. We will revisit the layout to see if

	the fault lines can be included without cluttering the visual presentation of the data.
Channels 5b and 5c should be clearly shown on 5a.	We agree with your observation regarding the difficulty in discerning the channels in Figures 5b and 5c. However, Figure 5a does not sufficiently clarify this detail. We will mark the channels in Figure 3b. We have also added a sentence to the caption of Fig. 3 to address this change.  **Figure 3b** *** [Line 436]** *The locations of these channels are marked in Fig. 3b.*
Figure 9 was started to cite in chapter Discussions, behind the Figure 10.	We will adjust the placement and sequence of Figure 9 (between Figure 11 and Figure 12) in the revised manuscript. Consequently, the current Figure 10 will be renumbered as Figure 9, and the current Figure 9 will become Figure 10.
Figure 12c should be clearly shown on Figure 2a.	We have already marked the location and area of Figure 12c in Figure 9a, but we acknowledge that it is not clearly visible. We will change it to a bright colour to enhance visibility.

	 **Figure 9**
The chapter Conclusions is too much lengthy. In fact, some of the content are not the conclusions.	We agree that the 'Conclusion' section is overly lengthy and contains content that is not directly related to the conclusions. We will streamline this section by removing the fourth paragraph and reducing the detail in the second and third paragraphs, eliminating a total of 363 words. * **[Lines 794–826]** *The Ulsan Fault Zone (UFZ) has been one of the most active fault zones*

	on the Korean Peninsula since its reactivation ~ 5 Ma. Our study area, the eastern, mountainous, hanging wall block of the UFZ, has undergone regional uplift under an ENE–WSW-oriented neotectonic maximum horizontal stress after 5 Ma. This study aimed to evaluate the relative tectonic activity along the UFZ, characterise the past and present geomorphic processes operating along the UFZ, and infer landscape evolution patterns in response to tectonic perturbation involving reactivation of the UFZ. *We evaluated the relative tectonic activity along the fault zone using topographic metrics, and catchment-averaged denudation rates (CADRs) and bedrock incision rate derived using in situ cosmogenic ^{10}Be. We divided the eastern UFZ block into five geological segments based on the relative tectonic activity we assessed. This study represents the first segmentation based on the relative tectonic activity of the UFZ inferred from topographic metrics.* *We also interpreted the tectono-geomorphic evolution of the study area by modelling landscape evolution and comparing the values and patterns of topographic metrics of the modelled topography with those observed in the study area. We interpret that the northern UFZ (segments 1 and 2) underwent regional asymmetric uplift (westward tilting) prior to Quaternary reverse faulting since ~ 2 Ma. The southern UFZ (segments 3–5) was negligibly affected by asymmetric uplift before Quaternary reverse faulting, as channel lengths (distance between the Ulsan Fault and the channel head) were sufficiently short to adjust quickly to the uplift. Our analysis and interpretation of the tectono-geomorphic evolution of the UFZ show that inherited topography can influence the subsequent geomorphic processes and topographic response to neotectonic reverse fault slip. The topographic metrics we utilized can therefore be regarded as characterizing not only the present topography, but also as holding information resulting from the accumulation of a history of tectonic and erosion.* *Our study clearly demonstrates that topographic metrics can be used to infer differential tectonic activity (i.e., variable fault slip and surface uplift) and that modelling can be used to infer possible influences of inherited topography in intraplate regions with extremely low strain rates and fault slip rates, and extremely high erosion rates.*

References

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