

# Scaling methods of leakage correction in GRACE mass change estimates revisited for the complex hydro-climatic setting of the Indus basin

V. Tripathi, A. Groh, M. Horwath, R. Ramsankaran

## Responses to reviewer 1

please see as well Decading Karakoram Anomaly

**Reply:** We thank the reviewer for providing us an opportunity to highlight this interesting phenomenon. The ‘Karakoram Anomaly’ is termed as the stability or anomalous growth of glaciers in the central Karakoram, in contrast to the retreat of glaciers in other nearby mountainous ranges of Himalayas and other mountainous ranges of the world (Dimri, 2021). Various mass balances over this region have shown to be balanced or slightly positive (Farinotti et. al., 2020). There is, however, significant uncertainty over the reasons for this anomaly which seems to be caused by absence of reliable in-situ observations in this region.

However, GRACE observations of such small (nearly stable) trends will be contaminated with the nearby large negative trends due to leakage. This can be seen in figure 1, where the red bounding box demarcates the extent of Karakoram (Dimri, 2021). The scaled trends for these pixels lying within Indus basin (rightmost subfigure) are extremely small but negative (ranging from -0.01 to -0.1 Gt/y). The uncertainty associated with these values is however, nearly double. The two major limitations for the uncertainty of these values come from the inability of GRACE to resolve this extremely small signal from this phenomenon and the inability of underlying model to simulate this anomalous behavior at the current  $1^0$  resolution, seen by large negative trends in the corresponding pixels (leftmost subfigure).

However, scaling does seem to make a distinction between pixels of Karakoram with less negative trends and the adjacent pixels of Ladakh region with more negative trends, which cannot be seen in unscaled GRACE fields (middle subfigure). We feel this to be a hopeful result indicating the presence of anomalous behavior in Karakoram, but further analysis of this phenomenon will be out of scope of this study.

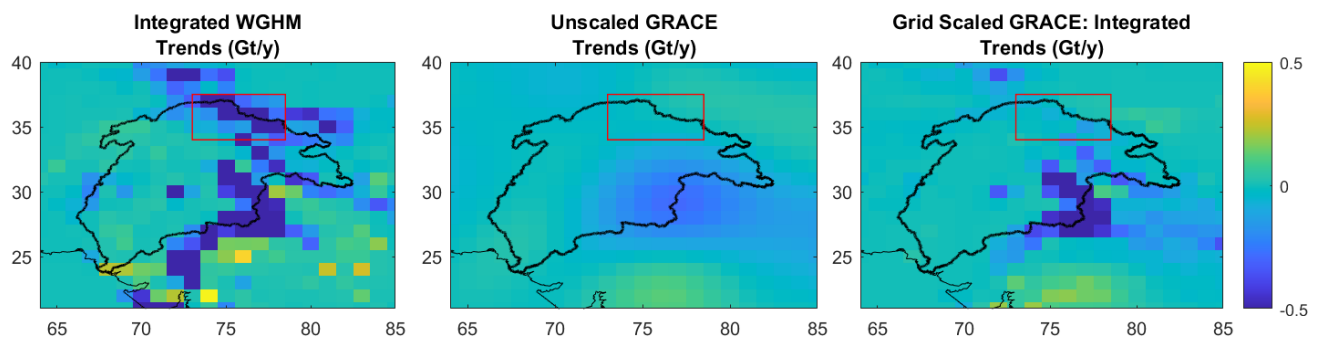


Figure 1 Integrated WGHM, Unscaled GRACE and Scaled GRACE trend map in Gt/y at  $1^0$  resolution. The red box indicates the extent of Karakoram where the anomaly is to be identified.

We will include this discussion in the revised version of the manuscript.

## References

Dimri, A. P.: Decoding the Karakoram Anomaly, *Science of The Total Environment*, 788, 147864, <https://doi.org/10.1016/j.scitotenv.2021.147864>, 2021.

Farinotti, D., Immerzeel, W. W., de Kok, R. J., Quincey, D. J., and Dehecq, A.: Manifestations and mechanisms of the Karakoram glacier Anomaly, *Nat. Geosci.*, 13, 8–16, <https://doi.org/10.1038/s41561-019-0513-5>, 2020.