Glacier Monitoring Using GEDI Data in Google Earth Engine: Outlier Removal and Accuracy Assessment

Sapienza Università di Roma

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Abstract

Climate change has notably altered the elevation of mountain glaciers, particularly in alpine regions. Alpine glaciers play a pivotal role not only as indicators of climate change but also as crucial elements for human and wildlife well-being, regulating freshwater supply and providing vital habitats in Europe.

Consequently, continuous monitoring of these glaciers offers valuable insights into their changing structure and surface dynamics [1]. While Unmanned Aerial Vehicles (UAV) offer the most precise method for tracking glacier surface changes, their practicality is often hindered by cost limitations and challenging in-situ measurements in extreme weather or remote areas. Therefore, remote sensing and satellite altimetry emerge as a feasible alternative in such scenarios. Numerous LiDAR and RADAR altimetry sensors, such as Jason-2 and 3, CryoSat, and ICESat-1 and 2, have been employed.

However, the Global Ecosystem Dynamics Investigation (GEDI), a reliable source of altimetry data, has been overlooked due to its restricted latitude range of 51.6 and -51.6 [2]. GEDI has proven its efficacy in measuring forest and canopy top height, monitoring lakes and water resources and generating Digital Surface Models (DSM). Google Earth Engine (GEE), a cloud-based platform renowned for its ability to integrate diverse datasets and potent analytical tools, has recently incorporated GEDI into its extensive repository [3].

In this poster we see the assessment of GEDI data over glacial environment by comparing the GEDI epochs with the most contemporary (as much as possible) DSM.

Study Area and Data

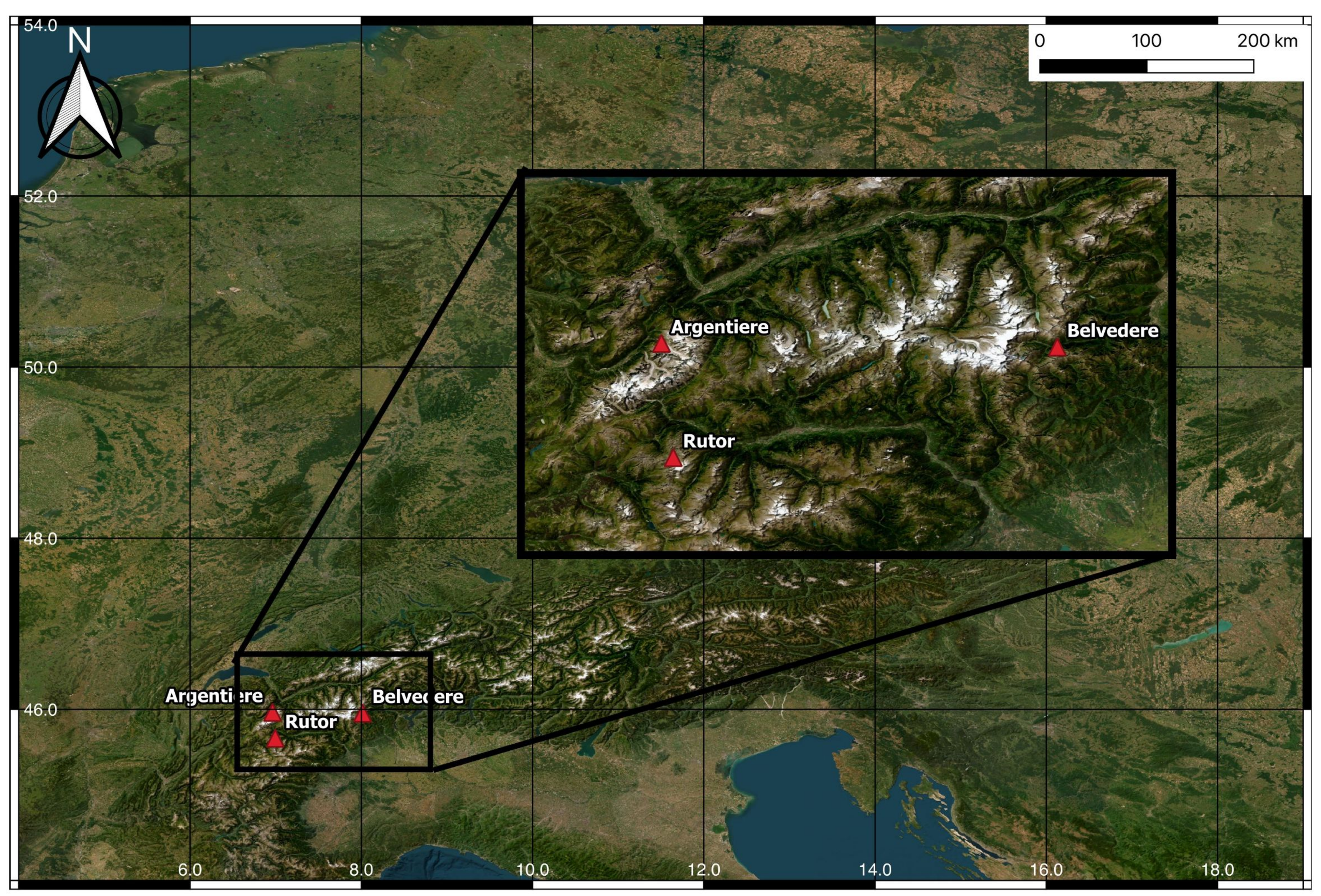

Figure 1. Location of the three investigated glaciers within the Alps

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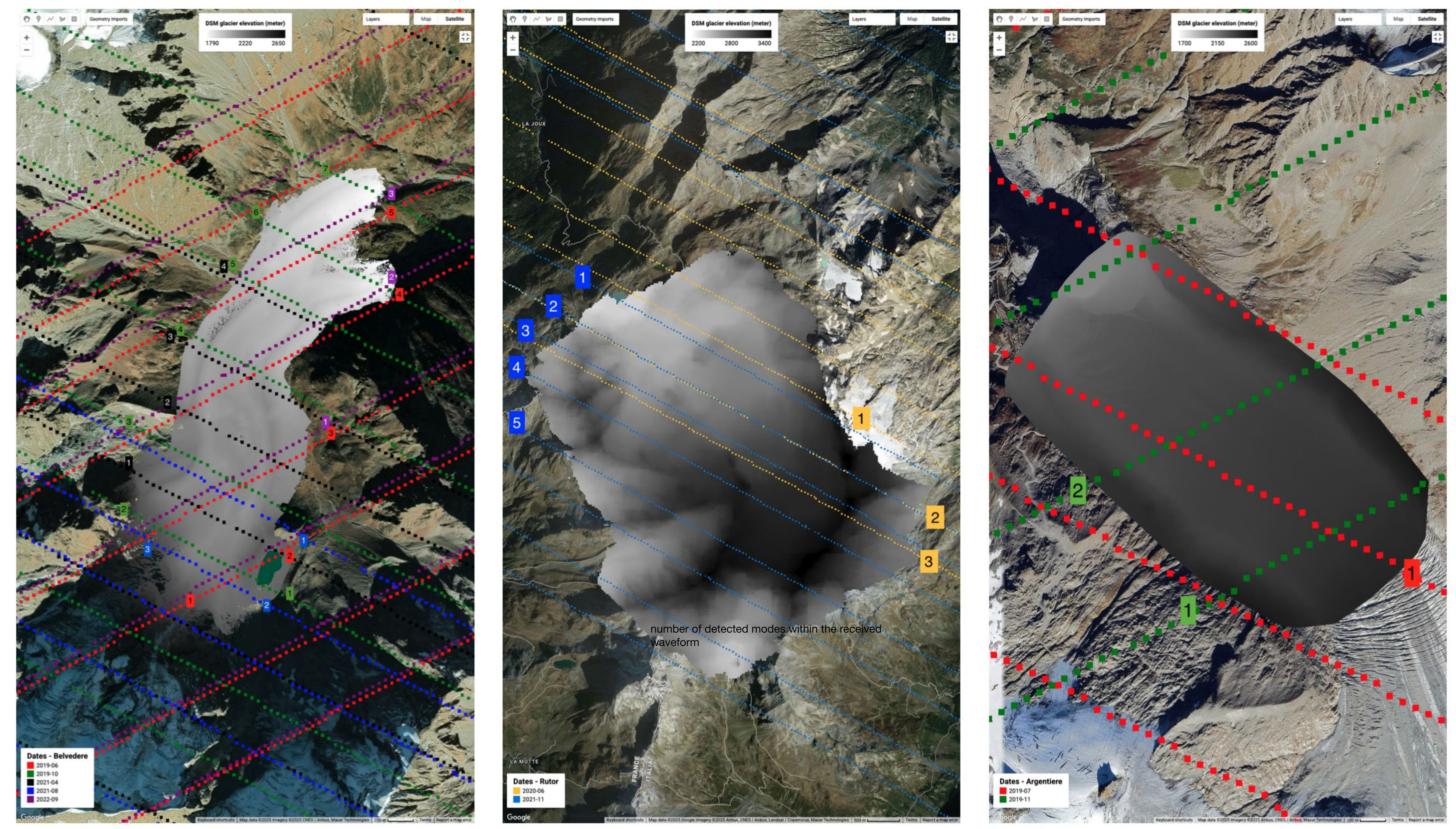
Glacier	Date	GSD (m)	Platform and method	Coverage (km^2)	Vertical datum	Horizontal reference
Belvedere	2019-07-29 to 08-02	0.06	UAV photogrammetric point cloud [9, 23, 24, 25]	≈1.8	RDN2008	UTM zone 32N
Belvedere	2021-07-28 to 29	0.04	UAV photogrammetric point cloud [9, 23, 24, 25]	≈1.8	RDN2008	UTM zone 32N
Belvedere	2022-07-25 to 27	0.027	UAV photogrammetric point cloud [9, 23, 24, 25]	≈1.8	RDN2008	UTM zone 32N
Rutor	2020-09	0.5	Aerial photogrammetry DSM [6, 7]	≈8.3	RDN2008	UTM zone 32N
Rutor	2021-09	0.5	Aerial photogrammetry DSM [6, 7]	≈8.3	RDN2008	UTM zone 32N
Argentière	2019-09-13	1	UAV photogrammetric DSM [26, 41]	≈2.55	WGS84 eliposid	UTM zone 32N

Table 1. Acquisition date, Ground Sampling Distance (GSD), area, and datum information of the used glacier DSMs as reference



(a) Belvedere glacier (DSM 2022) **(b)** Rutor glacier (DSM 2020) **(c)** Argentière glacier (DSM 2019)

Figure 2. GEDI tracks over different glaciers on available dates. The highlighted numbers show the number of the profile segments in the profiles (available in supplementary materials). The GEDI tracks that are not considered in numbering are removed entirely or partially after the outlier removal procedure or were not part of the glacier and belonged to the surrounding area.

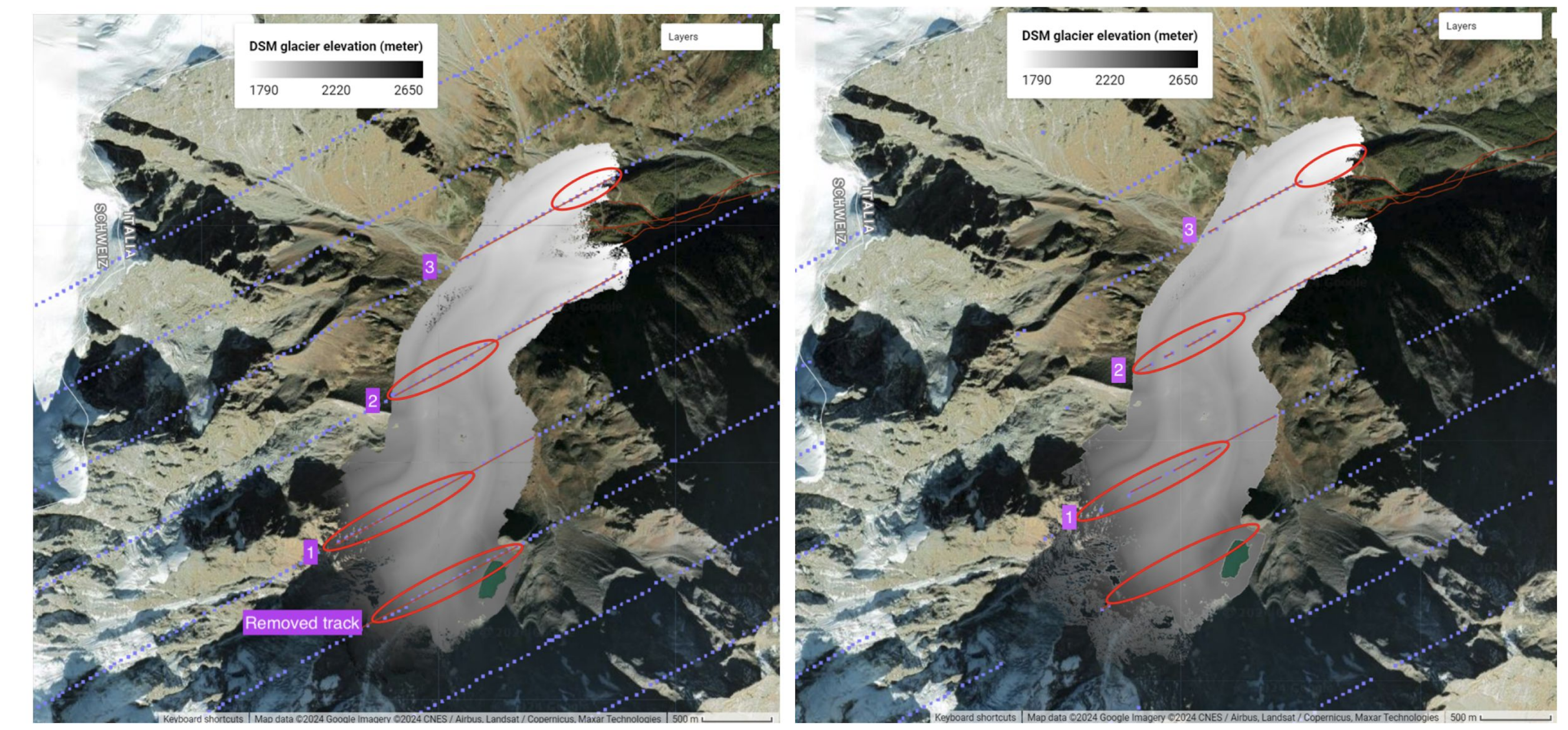
Methods

- Number of detected modes within the received waveform: all footprints with a number of detected modes higher than zero as inliers.
- Surface flag: indicates whether the elevation measurement of the considered footprint is within 300 meters of either the TanDEM-X elevation at the GEDI footprint location

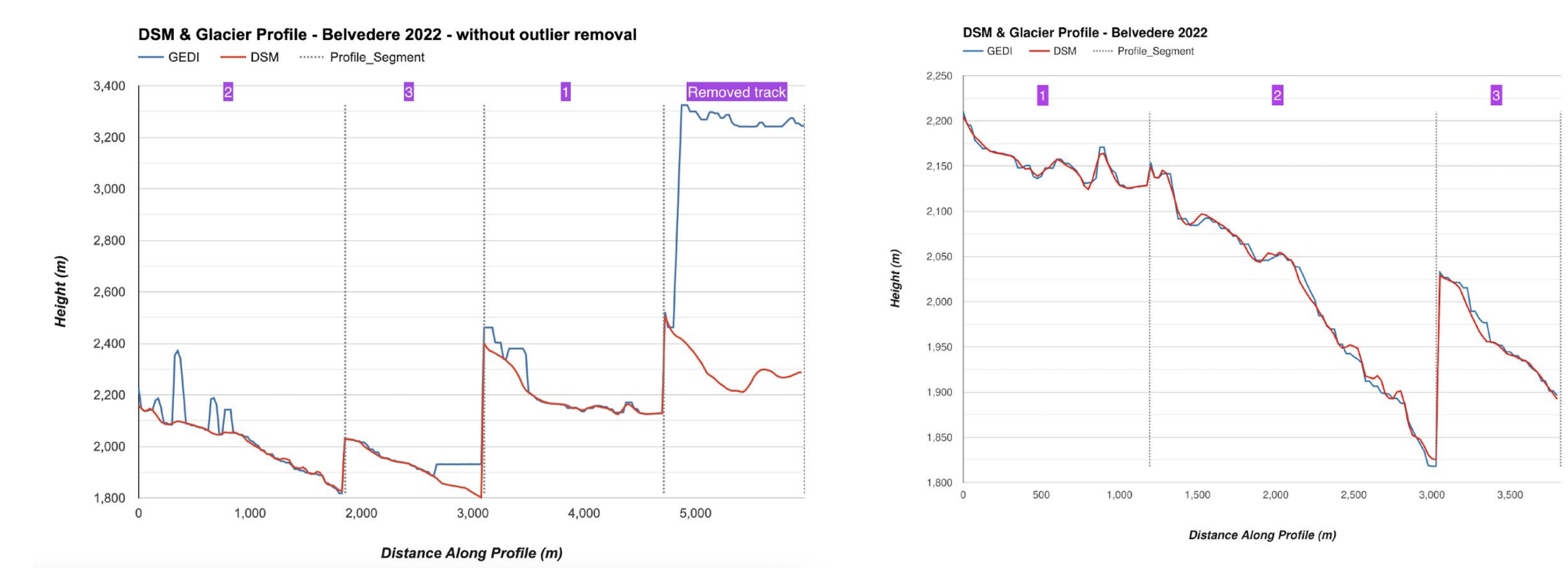
Results

Glacier -	GEDI date yyyy-mm-dd	Reference survey date yyyy-mm-dd	Mean (m)	Median (m)	Maximum (m)	Minimum (m)	SD (m)	NMAD (m)	RMSE (m)	MAE (m)	c -	R^2 -	ρ -
Belvedere	2019-06-27	2019-07-29 – 08-02	0.54	1.13	11.72	-13.98	5.38	3.94	5.54	4.18	60	0.9980	0.9990
Belvedere	2019-10-17	2019-07-29 – 08-02	-3.93	-2.32	8.12	-27.84	6.46	4.59	7.62	5.21	82	0.9969	0.9990
Belvedere	2021-04-12	2021-07-28 – 29	-0.10	1.11	14.87	-14.86	6.01	5.89	6.01	4.79	53	0.9926	0.9964
Belvedere	2021-08-13	2021-07-28 – 29	-0.27	-0.49	11.10	-8.52	5.11	4.03	4.55	3.46	22	0.9864	0.9935
Belvedere	2022-09-08	2022-07-25 – 27	-0.48	-0.34	11.54	-14.70	4.53	2.80	4.44	3.15	66	0.9988	0.9994
Rutor	2020-06-09	2020-09	2.33	3.60	12.04	-10.12	5.23	4.30	5.54	4.69	63	0.9988	0.9996
Rutor	2021-11-05	2021-09	-0.28	-0.05	12.13	-12.26	2.76	1.33	2.70	1.67	86	0.9997	0.9999
Argentière	2019-07-01	2019-09-13	4.87	4.82	8.89	-1.06	2.35	2.31	5.37	4.97	26	0.9879	0.9988
Argentière	2019-11-19	2019-09-13	-0.35	-0.66	2.73	-2.85	1.45	1.30	1.47	4.97	19	0.9879	0.9988
Average	–	–	0.26	0.76	10.35	-11.80	4.36	3.39	4.80	4.12	53	0.9941	0.9982

Table 2. Statistics of difference between GEDI and the reference DSM for each glacier (mean, median, maximum, minimum, standard deviation (SD), normalized median absolute deviation (NMAD), root mean square error (RMSE), and mean absolute error (MAE)) along with the number of the footprints (c) after applying the outlier removal procedure

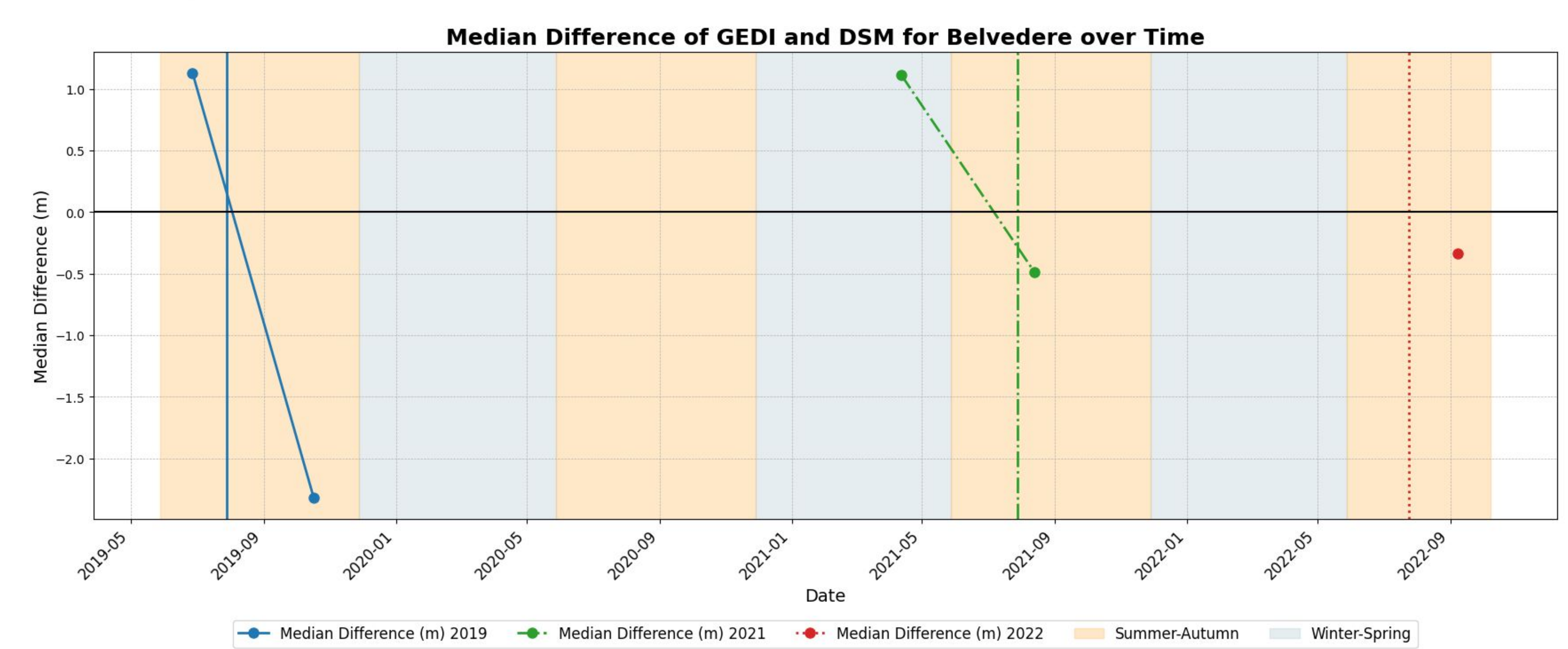


(a) Footprints before outlier removal **(b)** Footprints after the outlier removal



(c) Before the outlier removal **(d)** After the outlier removal

Figure 3. The effectiveness of outlier removal procedure – Belvedere Glacier.



References

[1] Belloni, V., et al. (2023). High-resolution high-accuracy orthophoto map and digital surface model of Forni Glacier tongue (Central Italian Alps) from UAV photogrammetry. Journal of Maps, 19(1), 2217508

[2] Hamoudzadeh, A., et al.: Gedi Data Within Google Earth Engine: Potentials And Analysis For Inland Surface Water Monitoring, EGU General Assembly 2023, Vienna, Austria, EGU23-15083

[3] Hamoudzadeh, A., et al. (2023). GEDI data within Google Earth Engine: preliminary analysis of a resource for inland surface water monitoring. In The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.