Comments from Public Consultation on ECV Requirements 13/01 – 13/03 2020 for:

# Glaciers

## ECV Product: Glacier Ice Thickness

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| --- | --- | --- | --- | --- | --- |
| **Name** | Glacier Ice Thickness | | | | |
| **Definition** | Global dataset of glacier ice thickness | | | | |
| **Unit** | m | | | | |
| **Note** | Glacier ice thickness is measured in-situ by the radio-echo sounding (Plewes and Hubbard, 2001). | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Derivation and References and Standards** |
| **Horizontal Resolution** |  |  | G |  |  |
| B |  |  |
| T |  |  |
| **Vertical Resolution** | m | The vertical resolution highly dependent on the frequency of GPR. | G | ~1 | Vertical resolution for 20 MHz GPR |
| B |  |  |
| T | ~5 | Vertical resolution for 200 MHz GPR |
| **Temporal Resolution** |  |  | G |  |  |
| B | 5 years | Length of time period between two surveys usually used in glaciology. |
| T | Decadal | The frequency “decadal” refers to the lowest requirement on the length of the time period needed between two surveys to avoid missing geometry change information. |
| **Timeliness** |  | In view of the low need for temporal sampling, the timeliness is not so important. | G |  |  |
| B |  |  |
| T |  |  |
| **Required Measurement Uncertainty** | m | Uncertainty at point location. | G |  |  |
| B |  |  |
| T | ~5 | Uncertainties even only consider at specific point can be influenced by various factors. As evaluated from an example study, uncertainty at point location is around 5 m. (Lapazaran et al., 2016) |
| **Stability** |  | Glacier ice thickness surveyed independently. No cumulative effect of the measurement system should be considered. | G |  |  |
| B |  |  |
| T |  |  |
| **Standards and References** |           Plewes, L. A. and B. Hubbard ( 2001). "A review of the use of radio-echo-echo sounding in glaciology." Progress in Physical Geography 25(2): 203-236.            Lapazaran, J. J., J. Otero, A. MartÍN-EspaÑOl and F. J. Navarro (2016). "On the errors involved in ice-thickness estimates I: ground-penetrating radar measurement errors." Journal of Glaciology 62(236): 1008-1020. | | | | |
| **Adaptation and Extremes** | | | | | |
|  | Relevant? (Yes/No) | Sugg. Req. sufficient? (Yes/No) | Explanation | | |
| **Adaptation[2]** | Yes | Yes | Ice thickness of glaciers is the important data to evaluate water storage in glaciers. | | |
| **Extremes[3]** | No |  |  | | |

[1]Goal (G); Breakthrough (B)(not mandatory, more as one possible); Threshold (T), for definitions see [Guidelines](http://tiny.cc/ecv-review)

[2] Is the ECV Product directly relevant to support Climate Adaptation?

[3] Can the ECV Product be used to monitor climate extremes or aspects of extremes?

### Comment 1

|  |  |
| --- | --- |
| Author: Matthias Huss | Email: matthias.huss@unifr.ch |
| Temporal resolution: There is no need to repeat ice thickness measurements at regular intervals (here 5 years are stated). Changes in ice volume are monitored through digital elevation models (=> remote sensing) that cover the entire glacier. Ice thickness measurements point observations that are unsuitable to detect a change in overall volume. If ice thickness (and concurrent surface elevation) has once been measured, the total volume can be inferred by adding ice volume change derived from remote sensing. Thus, I suggest to make no statements in the field "temporal resolution"  Besides the measurement of ice thickness using GPR, also other approaches might be mentioned, e.g. boreholes, gravimetry, seismics etc. | |

## ECV Product: Glacier Mass Change

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| --- | --- | --- | --- | --- | --- |
| **Name** | Glacier Mass Change | | | | |
| **Definition** | Global dataset of glacier (surface) mass changes from glaciological method | | | | |
| **Unit** | kg per m2 | | | | |
| **Note** | Glacier mass change is measured in-situ by the glaciological method (Cogley et al. 2011, Zemp et al. 2013). | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Derivation and References and Standards** |
| **Horizontal Resolution** |  |  | G |  |  |
| B |  |  |
| T |  |  |
| **Vertical Resolution** | m w.e. m-2 |  | G |  |  |
| B | 0.01 | The vertical resolution “0.01 m or 10 kg per m2” refers to the precision of ablation stake and snow pit readings at point locations |
| T | 0.05 | Lowest requirement in glaciology |
| **Temporal Resolution** |  |  | G | monthly | Monthly observations in melting season to depict melting processes. |
| B | seasonal | The frequency “seasonal to annual” refers to the measurement campaigns which ideally are carried out at the time of maximum accumulation (in spring) and of maximum ablation (at the end of hydrological year). |
| T | annual | The frequency “seasonal to annual” refers to the measurement campaigns which ideally are carried out at the time of maximum accumulation (in spring) and of maximum ablation (at the end of hydrological year). |
| **Timeliness** | days |  | G |  |  |
| B |  |  |
| T | 365 | Ideally, glaciological measurement become available after completion of the annual field campaigns. The WGMS grants a one-year retention period to allow investigators time to properly analyze, document, and publish their data before submitting the data. |
| **Required Measurement Uncertainty** | m w.e. m-2a-1 | Glacier‐wide (random) uncertainty estimate including uncertainties from point measurements, snow, firn and ice density conversions, and extrapolation to glacier-wide results. | G |  |  |
| B | 0.2 | The required measurement uncertainty “200 kg m-2 a- 1” (= 0.2 m w.e. m-2 a-1) refers to the glacier-wide annual balance which is interpolated from the point measurements. The target value was selected based on a review of long‐term mass balance measurement series (Zemp et al. 2013). |
| T | 0.5 | Lowest requirement in glaciology. |
| **Stability** | kg per m2 | Glacier-wide bias in mass change measurements over a decade. | G |  |  |
| B |  |  |
| T | 2 | The stability can be assessed by validation and – if necessary – calibration of a glaciological times series with decadal results from the geodetic method (cf. Zemp et al. 2013). As a rule of thumb, stability is recommended to be better than 300 kg m-2 a-1 (cf. Zemp et al. 2013). |
| **Standards and References** |           Zemp, M., Thibert, E., Huss, M., Stumm, D., Rolstad Denby, C., Nuth, C., Nussbaumer, S.U., Moholdt, G., Mercer, A., Mayer, C., Joerg, P.C., Jansson, P., Hynek, B., Fischer, A., Escher-Vetter, H., Elvehøy, H., and Andreassen, L.M. (2013): Reanalysing glacier mass balance measurement series. The Cryosphere, 7, 1227-1245, doi:10.5194/tc-7-1227-2013.            Zemp, M., Frey, H., Gärtner-Roer, I., Nussbaumer, S. U., Hoelzle, M., Paul, F., … Vincent, C. (2015). Historically unprecedented global glacier decline in the early 21st century. Journal of Glaciology, 61(228), 745–762. <http://doi.org/10.3189/2015JoG15J017> | | | | |
| **Adaptation and Extremes** | | | | | |
|  | Relevant? (Yes/No) | Sugg. Req. sufficient? (Yes/No) | Explanation | | |
| **Adaptation[2]** | Yes | Yes | Mass change of glaciers is a proxy to evaluate runoff, contribution to SLR and how long glaciers can sustain in future. | | |
| **Extremes[3]** | Yes | Yes | Intensive melting (high mass lost) is the main factor to extreme events like glacial flood, glacier surge and glacial lake outburst. | | |

[1]Goal (G); Breakthrough (B)(not mandatory, more as one possible); Threshold (T), for definitions see [Guidelines](http://tiny.cc/ecv-review)

[2] Is the ECV Product directly relevant to support Climate Adaptation?

### Comment 1

|  |  |
| --- | --- |
| Author: Matthias Huss | Email:matthias.huss@unifr.ch |
| Please check the units given in the "units" column:  m w.e. m-2 is not correct. It should either be kg m-2 (SI units and thus preferred), or m w.e. (also m w.e. yr-1 is used) | |

### Comment 2

|  |  |
| --- | --- |
| Author: MRI Scnatweb | Email: mountainresearchinitiative@gmail.com |
| For mountain glaciers, glacier mass change is important for processes such as glacier retreat and run off. Resolution of <500m needed  Not enough in-situ measurements available.  Based on discussions and preliminary outcomes of the GEO GNOME workshop for identifying ECVs to monitor and understand mountain climate change. More information on the workshop here: LINK. | |

### Comment 3

|  |  |
| --- | --- |
| Author: Fierz Charles | Email: fierz@slf.ch |
| If it is a change, then the unit should carry the notion of time (see uncertainty).  Why should the uncertainty of the measurand itself enter into the vertical resolution? There is a link, yes, but look at the unit: m w.e. m-2 = 10+3 kg m-4 | |

## ECV Product: Glacier Elevation Change

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | Glacier Elevation Change | | | | |
| **Definition** | Global dataset of glacier elevation changes from geodetic methods. | | | | |
| **Unit** | m/year | | | | |
| **Note** | Glacier elevation change is measured in-situ and remotely sensed using the geodetic method (Cogley et al. 2011, Zemp et al. 2013). | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Derivation and References and Standards** |
| **Horizontal Resolution** | m |  | G | 1 | The fine resolution (1-5 m) data be used to extract mass change and dynamic characteristics in area with abnormal topography (quite steep slope, ice fall, calving snout…). |
| B | 25 | A stable size of raster for measuring volume change (Joerg and Zemp, 2014). |
| T | 90 | Resolution of SRTM, which most widely used as reference to extract elevation change. |
| **Vertical Resolution** | m |  | G | 0.01 | Annual mass change of glaciers be evaluated with data with vertical resolution < 0.01 m (e.g. Xu et al., 2019). |
| B | 2 | Roughly corresponding to the resolution to evaluated the annual mean mass change if elevation change observed decadal. |
| T | 5 | The targets for vertical resolutions refer to requirements for differences of digital elevation models (dDEM) in mountainous terrain (e.g. Joerg and Zemp, 2014). |
| **Temporal Resolution** |  |  | G | Yearly | To evaluate annual mass change and detect the signal of potential abnormal events (e.g. surge). |
| B |  |  |
| T | Decadal | The frequency “decadal” refers to the length of the time period needed between two geodetic surveys in order to safely apply a density conversion from volume to mass change (cf. Huss 2013, Zemp et al. 2013). |
| **Timeliness** |  | In view of the low need for temporal sampling, the timeliness is not so important. | G |  |  |
| B |  |  |
| T |  |  |
| **Required Measurement Uncertainty** | m | Glacier‐wide (random) uncertainty estimate based on a quality assessment of the digital elevation model differencing product over stable terrain. | G |  |  |
| B | 2 | The required measurement uncertainty refers to the glacier-wide uncertainty estimate based on a quality assessment of the dDEM product over stable terrain. The value of “2m per decade” (= 0.2 m m-2 a-1) is set in relation to the corresponding uncertainty requirement of the glaciological method. |
| T |  |  |
| **Stability** | m | Glacier-wide bias in elevation change measurements over a decade. | G |  |  |
| B | 2 | The stability of “2 m/decade” refers to a bias in the glacier‐wide change of 0.2m m-2 a-1, which is about one third to half of the average annual ice loss rate over the 20th century (Zemp et al. 2015) and is good enough for validation of glaciological series (Zemp et al. 2013). |
| T |  |  |
| **Standards and References** |           Huss, M. (2013). Density assumptions for converting geodetic glacier volume change to mass change. The Cryosphere, 7(3), 877–887. <http://doi.org/10.5194/tc-7-877-2013>            Joerg, P. C., & Zemp, M. (2014). Evaluating Volumetric Glacier Change Methods Using Airborne Laser Scanning Data. Geografiska Annaler: Series A, Physical Geography, 96(2), n/a-n/a. <http://doi.org/10.1111/geoa.12036>            Zemp, M., Thibert, E., Huss, M., Stumm, D., Rolstad Denby, C., Nuth, C., Nussbaumer, S.U., Moholdt, G., Mercer, A., Mayer, C., Joerg, P.C., Jansson, P., Hynek, B., Fischer, A., Escher-Vetter, H., Elvehøy, H., and Andreassen, L.M. (2013): Reanalysing glacier mass balance measurement series. The Cryosphere, 7, 1227-1245, doi:10.5194/tc-7-1227-2013.            Zemp, M., Frey, H., Gärtner-Roer, I., Nussbaumer, S. U., Hoelzle, M., Paul, F., … Vincent, C. (2015). Historically unprecedented global glacier decline in the early 21st century. Journal of Glaciology, 61(228), 745–762. <http://doi.org/10.3189/2015JoG15J017>            Xu, C., Li, Z., Li, H., Wang, F., & Zhou, P. (2018). Long-range terrestrial laser scanning measurements of summer and annual mass balances for Urumqi Glacier No. 1, eastern Tien Shan, China. The Cryosphere Discussions, 1-28. doi: 10.5194/tc-2018-128. | | | | |
| **Adaptation and Extremes** | | | | | |
|  | Relevant? (Yes/No) | Sugg. Req. sufficient? (Yes/No) | Explanation | | |
| **Adaptation[2]** | Yes | Yes | In most parts of the World, glacier elevation change is used to evaluate mass change and contribution to runoff and SLR. | | |
| **Extremes[3]** | Yes | No | The sudden change in glacier elevation is a signal for glacier surge. The temporal resolution for observations we have now is too low to capture the signals. | | |

[1]Goal (G); Breakthrough (B)(not mandatory, more as one possible); Threshold (T), for definitions see [Guidelines](http://tiny.cc/ecv-review)

[2] Is the ECV Product directly relevant to support Climate Adaptation?

[3] Can the ECV Product be used to monitor climate extremes or aspects of extremes?

### Comment 1

|  |  |
| --- | --- |
| Author: Matthias Huss | Email: matthias.huss@unifr.ch |
| Timeliness might still be relevant: In the case of fresh snow, poor contrast often does not allow photogrammetrical evaluation of the images. Furthermore, acquisitions should be made towards the ice of the ablation season.  Please correct a small error in a unit (for uncertainty): 0.2 m m-2 a-1 => 0.2 m a-1  In general it might be worthwhile to better describe the methods used:  - Photogrammetry (e.g. ASTER)  - Laser Altimetry (e.g. ICESat)  - Radar (e.g. SRTM)  - etc.  and mention the drawbacks of the individual approaches (e.g. contrast for photogrammetry, spatial coverage for laser altimetry, radar penetration for radar, etc) | |

### Comment 2

|  |  |
| --- | --- |
| Author: MRI Scnatweb | Email: mountainresearchinitiative@gmail.com |
| For mountain glaciers, glacier elevation change is important for processes such as glacier retreat and run off. Resolution of <500m needed  Not enough in-situ measurements available.  Based on discussions and preliminary outcomes of the GEO GNOME workshop for identifying ECVs to monitor and understand mountain climate change. More information on the workshop here: LINK. | |

## ECV Product: Glacier Area

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | Glacier Area | | | | |
| **Definition** | Worldwide inventory of map-projected area covered by glaciers. | | | | |
| **Unit** | Km2 | | | | |
| **Note** | Glacier area is the map-projected size of a glacier in km2. The product comes as worldwide inventory of glaciers outlines with various related attribute fields (e.g. area, elevation range, glacier characteristics). Typically, a minimum size of 0.01 or 0.02 km2is applied, as a glacier must flow by definition and ice patches smaller than this are likely stagnant. | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Derivation and References and Standards** |
| **Horizontal Resolution** | m |  | G | 1 | Spatial resolutions better than 15 m (e.g. the 10 m from Sentinel 2) are preferable as typical characteristics of glacier flow (e.g. crevasses) only become visible at this resolution (Paul et al. 2016). |
| B | 20 | The horizontal resolution of 15‐30 m refers to typically used satellite sensors (Landsat and ASTER) to map glaciers. |
| T | 100 | At coarser resolution the quality of the derived outlines rapidly degrades. |
| **Vertical Resolution** | m | Glacier area is a horizontal 2D product. Vertical resolution is not necessary defined usually. | G |  |  |
| B |  |  |
| T | 100 | The vertical resolution is referring to the glacier area distribution with elevations (i.e. hypsometry), usually given per 50 or 100 m elevation bins. |
| **Temporal Resolution** | years |  | G | 1 | The temporal sampling “Annual” means that each year the availability of satellite (or aerial) images should be checked to not miss the year with the best snow conditions (i.e. snow is only found on glaciers and not hiding their perimeter). |
| B | 10 | Decadal data used to evaluate glacier change in regional scale. |
| T | 50 | The longest time period with glacier inventories covered. |
| **Timeliness** | years |  | G |  |  |
| B |  |  |
| T | 10 | For multi-temporal inventories at decadal resolution, the timeliness of the product availability is not so important. |
| **Required Measurement Uncertainty** |  | Random error of glacier outlines produced in dependency of remote sensing imagery used, with respect to the total glacier area | G | 1% | Glacier outlines mapped with high resolution (1 m) remote sensing images (take glacier area in average as 1 km2) |
| B | 5% | Glacier outlines mapped with medium resolution (15-30 m) remote sensing images (take glacier area in average as 1 km2) |
| T | 20% | Glacier outlines mapped with low resolution (100 m) remote sensing images (take glacier area in average as 1 km2) |
| **Stability** |  | Glacier area at different times extracted independently. No cumulative effect of the measurement system should be considered. | G |  |  |
| B |  |  |
| T |  |  |
| **Standards and References** |           Paul, F., N. Barrand, E. Berthier, T. Bolch, K. Casey, H. Frey, S.P. Joshi, V. Konovalov, R. Le Bris, N. Mölg, G. Nosenko, C. Nuth, A. Pope, A. Racoviteanu, P. Rastner, B. Raup, K. Scharrer, S. Steffen and S. Winsvold (2013): On the accuracy of glacier outlines derived from remote sensing data. Annals of Glaciology, 54 (63), 171-182            Paul, F., S.H. Winsvold, A. Kääb, T. Nagler and G. Schwaizer (2016): Glacier Remote Sensing Using Sentinel-2. Part II: Mapping Glacier Extents and Surface Facies, and Comparison to Landsat 8. Remote Sensing, 8(7), 575; doi:10.3390/rs8070575.            Zemp, M., Frey, H., Gärtner-Roer, I., Nussbaumer, S. U., Hoelzle, M., Paul, F., … Vincent, C. (2015). Historically unprecedented global glacier decline in the early 21st century. Journal of Glaciology, 61(228), 745–762. <http://doi.org/10.3189/2015JoG15J017> | | | | |
| **Adaptation and Extremes** | | | | | |
|  | Relevant? (Yes/No) | Sugg. Req. sufficient? (Yes/No) | Explanation | | |
| **Adaptation[2]** | Yes | Yes | Glacier area is a proxy to evaluate solid water resource storage in a region and roughly exhow much runoff can be released in melting season. | | |
| **Extremes[3]** | Yes | Yes | Regions with large glaciers or large number of glaciers tend to be in the risk of glacier disaster (runoff flood, surge, and glacier lake outburst). | | |

[1]Goal (G); Breakthrough (B)(not mandatory, more as one possible); Threshold (T), for definitions see [Guidelines](http://tiny.cc/ecv-review)

[2] Is the ECV Product directly relevant to support Climate Adaptation?

[3] Can the ECV Product be used to monitor climate extremes or aspects of extremes?

### Comment 1

|  |  |
| --- | --- |
| Author: Matthias Huss | Email: matthias.huss@unifr.ch |
| Remark on "Extremes": I would not say that regions with large or many glaciers are more prone to disasters. Other factors are much more important (slope, stability, etc). However, an inventory allows assessing these factors. Also an inventory is absolutely necessary for all modelling studies (individual glacier or regional/global scale) | |

### Comment 2

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| --- | --- |
| Author: Philipp Rastner | Email: pippo.rast@gmail.com |
| **Definition:**  Glaciers distribution data from the Randolph Glacier Inventory for year 2000  Why not use the title from the Climate Data Store in Copernicus?  **Note:**  Glacier area is the map-projected size of a glacier in km2. The product comes as worldwide inventory of glaciers outlines with various related attribute fields (e.g. area, elevation range, glacier characteristics). Typically, a minimum size of 0.01 or 0.02 km2 is applied, as a glacier must flow by definition and ice patches smaller than this are likely stagnant.  Maybe like this:  The worldwide glacier inventory consists of a) glacier polygons in vector shape file format and b) their related topographical parameters appended in the attribute table (e.g. area, elevation range, glacier characteristics). The glacier area is the map-projected size of a glacier in km2 to a defined time stamp (based on the acquisition of the satellite image/map). The minimum size threshold is 0.01 or 0.02 km2 to avoid that small ice patches are considered as glaciers.  **Horizontal resolution:**  1 Spatial resolutions better than 15 m (e.g. the 10 m from Sentinel 2) are preferable as typical characteristics of glacier flow (e.g. crevasses) only become visible at this resolution (Paul et al. 2016).  Maybe:  Spatial resolutions better than 15 m (e.g. the 10 m from Sentinel 2) are preferable if the related satellite imagery is available and cloud and snow conditions allow.  **Vertical resolution:**  Glacier area is a horizontal 2D product. Vertical resolution is not necessary defined usually.  Maybe:  Glacier area is a horizontal 2D product (Surface - single level).  100: The vertical resolution is referring to the glacier area distribution with elevations (i.e. hypsometry), usually given per 50 or 100 m elevation bins.  This is in my opinion wrong in this context. I would suggest to remove it. Leave the field empty.  **Temporal resolution:**  1: The temporal sampling “Annual” means that each year the availability of satellite (or aerial) images should be checked to not miss the year with the best snow conditions (i.e. snow is only found on glaciers and not hiding their perimeter).  Maybe:  In case of a new inventory for a certain region and time stamp, the satellite scene with the least snow conditions should be used. This requires considering satellite scenes in the years before and after (i.e. snow cover should not hide the glacier perimeter)  10: "AT" regional scale  50: is this of relevance?  **Timeliness:**  G: Time stamp given by the acquisition of the satellite image  B: ?  10: The timeliness is always important. One has however to say that, when working with historical data, it is often not available.  **Required Measurement Uncertainty**  Random error of glacier outlines produced in dependency of remote sensing imagery used, with respect to the total glacier area  Maybe  Random error of glacier outlines produced in dependency of a) remote sensing imagery used and b) occurrence of debris cover.  1%: i don't understand that: (take glacier area in average as 1 km2) maybe remove it. same below.  5%: Somehow i miss the problem with the debris in here. Is this not of relevance?  20%  **Stability:**  I agree to the system of stability if a fixed threshold is used with the same type of satellite imagery. I miss however the issue of the manual correction of debris cover on glacier and the issue of the interpreter. The last two points are highly variable trough time and decrease the stability of the product drastically.  **References:**  Maybe add:  Error sources and guidelines for quality assessment of glacier area, elevation change, and velocity products derived from satellite data in the Glaciers\_cci project  Paul et al. 2017.  Thank you,  P. Rastner  University of Zurich | |

### Comment 3

|  |  |
| --- | --- |
| Author: ECMWF | Email: ecresgcosreqs@gmail.com |
| For use in modelling for reanalysis applications a global annual coverage at 1km (or better) with the glacier cover fraction per unit area is recommended as product. Reanalysis are currently in the 10-100 km range of resolution, however they tend to have subgrid heterogeneity treatment in the surface energy balance and a fractional coverage enable to uptake the information more promptly (starting from ASTER Landsat Sentinel-2 data record directly is too computationally demanding for global modelling applications). | |