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wgms World Glacier Monitoring Service

ISC (WDS)
IUGG (IACS)
UNEP
UNESCO
WMO

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WGMS Report 2021 & Program 2022

1. Introduction

Internationally coordinated glacier observation was initiated in 1894 with the foundation of the *Commission Internationale des Glaciers* at the 6th *International Geological Congress* in Zurich, Switzerland. Since 1986, the *World Glacier Monitoring Service* (WGMS) has maintained and continued the collection of standardized information about distribution and ongoing changes of glaciers. Today, the WGMS is a service of the *International Association of Cryospheric Sciences* (IACS) within the *International Union of Geodesy and Geophysics* (IUGG) as well as a member of the *World Data System* (WDS) of the *International Science Council* (ISC), and works under the auspices of the *United Nations Environment Programme* (UNEP), the *United Nations Educational, Scientific and Cultural Organization* (UNESCO), and the *World Meteorological Organization* (WMO). The WGMS maintains a scientific collaboration network of *Principal Investigators* and *National Correspondents* in all the countries involved in glacier monitoring.

Based on a decision in 2009 relating to the participation of Switzerland in the *United Nations Framework Convention on Climate Change* and the *Global Climate Observing System* (GCOS), the *Swiss Federal Council* decided to provide long-term funding through GCOS Switzerland to the *Department of Geography* of the *University of Zurich* (UZH) for the operational lead and coordination of the WGMS. In 2021, the original contract between the UZH and MeteoSwiss was replaced by a long-term framework agreement and a four-year finance agreement (2021−24), to be extended after successful evaluation.

Beside this, WGMS products and projects have recently been supported by national and international organizations such as the *Cryospheric Commission* of the *Swiss Academy of Sciences*, *Swiss Agency for Development and Cooperation* (SDC) and *University of Fribourg*, IACS, and UNESCO. As in the past years, the WGMS has strengthened its remote sensing capacities within ESA's *Climate Change Initiative* (CCI) and in the *Copernicus Climate Change Service* (C3S).

Detailed information about the WGMS, its partner organizations, monitoring strategy, and data products are available on the WGMS website: https://wgms.ch.

In addition, the GTN-G website gives an overview on the overarching structure of international glacier monitoring as well as on the available global datasets: https://gtn-g.org.

2. Annual Report for 2021

2.1 Status report

In 2021, the WGMS successfully accomplished all its operational tasks, in spite of the ongoing pandemic. In addition, the WGMS published a new version of the *Fluctuations of Glaciers* (FoG, WGMS, 2021a) database, the fourth *Global Glacier Change Bulletin* (WGMS, 2021b; https://wgms.ch/ggcb), as well as several scientific publications and media reports. At the beginning of the year, the service pushed the negotiations of the UZH and MeteoSwiss to finalize the long-term framework agreement and the four-year finance agreement for the period 2021−24. Based on this, the WGMS database infrastructure project successfully started in the second quarter of 2021. Moreover, WGMS staff members have been active on numerous international boards, including the GCOS *Steering Committee*, the WDS *Scientific Committee*, and several IACS working groups.

2.2 Activities

Core business and special tasks

The operational tasks of the WGMS include the management of its databases and website, the response to data and information requests, and the periodic contact with its scientific collaboration network of *National Correspondents, Principal Investigators*, and partner institutions. In addition, the WGMS was present at various national and international conferences, meetings and workshops and was actively involved in selected education and public outreach activities.

In 2021, the core team responded to more than 30 data requests and about 100 information requests received by email. Due to the facilitated online access to glacier data, the number of data requests sent by email to the WGMS is decreasing. Nevertheless, these remaining requests often require more effort because of special demands. The WGMS website registered about 14-20,000 visits per month on average and the GTN-G website about 2-4,000 visits per month. Thus, the use of both websites has increased significantly. Besides the home page (https://wgms.ch), the pages on recent mass balance data (https://wgms.ch/latest-glacier-mass-balance-data), on the WGMS reference glaciers (https://wgms.ch/products_ref_glaciers), and the FoG browser (https://wgms.ch/fogbrowser) were the most visited.

For the *wgms Glacier App*, no more user statistics are available for 2021 due to the decommission of *Google Analytics* for mobile apps and due to the lack of support for a new version. We decided to keep the app running as long as there are no major issues with new operating systems. We are currently looking into the option for a spin-off project with an external partner such as a museum.

Beside these operational tasks, the main efforts in 2021 were the production, publication, and shipment of the fourth *Global Glacier Change Bulletin* (WGMS, 2021b; https://wgms.ch/ggcb), the update of the online products, the finalization of the new agreements between UZH and MeteoSwiss on the long-term support of the WGMS, the successful application of the WGMS as an official UZH technology platform, and the writing of proposals for the next phase of the C3S and for a Glacier Mass Balance Intercomparison Experiment (GlaMBIE) as part of ESA's Polar Science Cluster. We experienced increasing challenges related to the shipment of hardcopies of the bulletin due to the pandemic and changing custom and other postal regulations.

In addition, the WGMS completed the following tasks in 2021:

- Control and quality check of data from the *Call-for-Data* 2018/19 (including *Near-time reporting* for 2019/20) and online publication of the latest database version with the respective *Digital Object Identifier*,
- Organization of glacier monitoring sessions at EGU and AGU conferences,
- Update and minor revision of the WGMS and GTN-G websites,
- Update of the WGMS cooperation and address database (from SMD4GC project),
- Appointment of a new *National Correspondent* for India,
- Glacier safety training in the Susten region,
- *Call-for-Data* for the observation period 2019/20 and *Near-time reporting* for 2020/21,
- Integration of geodetic volume change estimates with global coverage from Hugonnet et al. (2021, Nature),
- Lecture series on *Glacier Mass Balance Measurements & Analysis* (GEO851),
- Online publication of mass-balance values for 2019/20 and preliminary values for 2020/21,
- Videoconference with WGMS *National Correspondents* and *Principal Investigators*,
- Reporting for 2021 and planning for 2022.

In 2021, several letters of support related to national and international glacier monitoring were provided on request to institutions in Canada, Georgia, Greenland, India, Kazakhstan, and Switzerland.

Due to the delay in the finalization of the new WGMS agreements, the search for a WGMS database manager was conducted in early 2021; Ethan Welty started his position in June 2021. A concept for the revision of the

WGMS database infrastructure was developed and discussed in a first workshop with the department IT in December 2021. A new data submission form – checking data against the meta-data scheme of the FoG database – was developed and tested in the call-for-data. An additional workshop with national and international partners will be organized in early 2022. Based on the outcome of this workshop, we will finalize the concept and set the agenda for the implementation of the related components (i.e., database migration, data submission wizard, tools for data quality control, user interfaces, and application programming interface).

International collaborations

In close collaboration with the *US National Snow and Ice Data Center* (NSIDC) in Boulder and the *Global Land Ice Measurements from Space* (GLIMS) initiative, the WGMS has been in charge of the *Global Terrestrial Network for Glaciers* (GTN-G) since its creation in 1998. In 2008, the three bodies proposed a generic structure and terms of reference for a GTN-G *Steering Committee* (including an *Executive Board* and an *Advisory Board*) to the IACS Bureau. This proposal was approved in 2009 and at the beginning of 2011, the *Advisory Board* (under the lead of IACS) was finally filled with representatives from data user and producer communities, as well as from international organizations (see https://gtn-g.ch/contact). Over the past years, periodical meetings of officers from NSIDC, GLIMS, and the WGMS were held to discuss and coordinate key tasks. In 2021, joint (virtual) conference sessions were set up at EGU in Vienna, Austria, and at AGU in San Francisco, United States, dedicated to the monitoring of glaciers from in-situ and remotely sensed observations. In addition, the different bodies are currently working on a joint publication with the title *Democratizing glacier data – maturity of worldwide data sets and future ambitions*. This publication will build the basis for the GTN-G self-evaluation in 2022.

In Kyrgyzstan, Tajikistan, Uzbekistan and Kazakhstan, local researchers performed the measurements on their respective glaciers in a major part by themselves, in spite of the pandemics and because of the ending of the project *Cryospheric Climate Services for improved Adaptation* (CICADA) in 2020. The capacity-building activities in Central Asia will be continued in new projects by the University of Fribourg and other partners: the project *'Cryospheric Observation and Modelling for improved Adaptation in Central Asia' (CROMO-ADAPT)* funded by SDC, the University of Fribourg and WSL will start in January 2022 to 2025 with a possible continuation of another four years to get full sustainability for cryospheric in situ measurements on permafrost, snow and glaciers for most of the Central Asian countries. In January 2022, the project PAMIR was funded by the Swiss Polar Institute led by University of Fribourg and WSL, generating strong support for fieldwork and installation of modern technology in the mountain range of the Pamir covering several parts of interdisciplinary research for high mountain areas, where glacier research covers the largest part of research topics. A third project, which will probably start in March 2022 funded by GEF/UNESCO with the title '*Strengthening the resilience of Central Asian countries by enabling regional cooperation to assess cryospheric systems to develop integrated methods for sustainable development and adaptation to climate change'*. This project will also be used to increase new and modern technology for in situ observations on long-term monitored glaciers in Central Asia. All three projects in Central Asia will use large parts of their projects to increase capacity building and enhance gender balance. In the Andes and in the Himalayas, capacity-building and twinning activities related to glacier monitoring are carried out by partner institutions in Grenoble, France.

Relations with the international umbrella organizations were maintained, for example with the participation of the WGMS in the GCOS *Steering Committee* (M. Zemp) and the WDS *Scientific Committee* (I. Gärtner-Roer). In addition, the WGMS was actively involved in IACS working groups (*Randolph Glacier Inventory, Regional Assessment of Glacier Mass Change;* https://cryosphericsciences.org/activities/working-groups), in the writing team of the upcoming GCOS *Status Report*, and as reviewers of IPCC SROCC and AR6.

2.3 Outreach

The WGMS staff was active at several national and international meetings, mainly by virtual attendance:

22.2.2021: GTNs and TOPC (virtual),
25./26.3.2021: Alpine Glaciology meeting (virtual),
19.-30.4.2021: European Geosciences Union (virtual),
18.-20.5.2021: Copernicus C3S General Assembly (virtual),
20.5.2021: GCOS-WGMS Annual meeting (virtual),
15./16.6.2021: 10. GTN-H Panel, 20 year anniversary (virtual),
29.6.2021: RAGMAC mini conference (virtual),
24.-25.8.2021: High Summit COP26 in Minoprio, IT,
25.8.2021: UZH Core & Staff Day, Zurich, CH,
13./14.9.2021: Swiss National GAW/GCOS Symposium (virtual),
15.-17.9.2021: ESA Polar Science Cluster Collocation Meeting (virtual),
8.-11.11.2021: Russian conference on "Dynamics and interaction of the Earth's geospheres" (virtual),
17.11.2021: IACS Open Plenary Meeting (virtual),
19./20.11.2021: Swiss Geoscience meeting (virtual).

In addition, the WGMS team was actively involved in a large number of educational and public outreach events. Among other things, it contributed to the *European State of the Climate* report, to an elaborate documentary on *ARTE*, as well as to a widely distributed article in the *Guardian*. An overview is given on the WGMS webpage showing a selection of articles, videos, and audio files from newspapers and other media with reference to the WGMS: https://wgms.ch/media.

2.4 Publication of data and results

In 2021, the WGMS staff was involved in the following selected publications related to glacier monitoring:

Aggarwal, A., Frey, H., McDowell, G., Drenkhan, F., Nüsser, M., Racoviteanu, A. and M. Hoelzle (2021): **Adaptation to climate change induced water stress in major glacierized mountain regions.** Climate and Development: 1-13.

Barandun, M., Pohl, E., Naegeli, K., McNabb, R., Huss, M., Berthier, E., Saks, T. and M. Hoelzle (2021): **Hot spots of glacier mass balance variability in Central Asia.** Geophysical Research Letters, 48: e2020GL092084.

Denzinger, F., Machguth, H., Barandun, M., Berthier, E., Girod, L., Kronenberg, M., Usubaliev, R. and M. Hoelzle (2021): **Geodetic mass balance of Abramov Glacier from 1975 to 2015.** Journal of Glaciology, 67(262): 331-342.

Dorigo, W., Dietrich, S., Aires, F., Brocca, L., Carter, S., Cretaux, J.F., Dunkerley, D., Enomoto, H., Forsberg, R., Güntner, A., Hegglin, M., Hollmann, R., Hurst, D.F., Johannessen, J.A., Kummerow, C., Lee, T., Luojus, K., Looser, U., Miralles, D.G., Pellet, V., Recknagel, T., Ruz Vargas, C., Schneider, U., Schoeneich, P., Schröder, M., Tapper, N., Vuglinsky, V., Wagner, W., Yu, L., Zappa, L., Zemp, M. and V. Aich (2021): **Closing the water cycle from observations across scales: Where do we stand?** Bulletin of the American Meteorological Society. https://doi.org/10.1175/BAMS-D-19-0316.1

GCOS (2021). **The Status of the Global Climate Observing System 2021: The GCOS Status Report.** (GCOS-240), WMO, Geneva, Switzerland, 381 pp. https://gcos.wmo.int/en/gcos-status-report-2021

Kääb, A., Jacquemart, M., Gilbert, A., Leinss, S., Girod, L., Huggel, C., Falaschi, D., Ugalde, F., Petrakov, D., Chernomorets, S., Dokukin, M., Paul, F., Gascoin, S., Berthier, E. and J. Kargel (2021): **Sudden large-volume detachments of low-angle mountain glaciers - more frequent than thought.** The Cryosphere, 15, 1751-1785; https://doi.org/10.5194/tc-15-1751-2021.

Kronenberg, M., Machguth, H., Eichler, A., Schwikowski, M. and Hoelzle, M., (2021): **Comparison of historical and recent accumulation rates on Abramov Glacier, Pamir Alay**. Journal of Glaciology, 67(262): 253-268.

Mattea, E., Machguth, H., Kronenberg, M., Van Pelt, W.J.J., Bassi, M. and M. Hoelzle (2021): **Firn changes at Colle Gnifetti revealed with a high-resolution process-based physical model approach.** The Cryosphere, 15: 3181–3205.

Saks, T., Pohl, E., Machguth, H., Dehecq, A., Barandun, M., Kenzhebaev, R., Kalashnikova, O. and M. Hoelzle (2021): **Glacier runoff variation since 1981 in the upper Naryn river catchments, Central Tien Shan.** Frontiers in Environmental Science.

Tielidze, L. G., Nosenko, G. A., Khromova, T. E., and F. Paul (2021, in review): **Strong acceleration of glacier area loss in the Greater Caucasus over the past two decades.** The Cryosphere Discuss.; https://doi.org/10.5194/tc-2021-312

Thomson, L., Brun, F., Braun, M. and M. Zemp (2021): **Editorial: Observational assessments of glacier mass changes at regional and global level.** Front. Earth Sci., 8:641710. doi: https://doi.org/10.3389/feart.2020.641710.

WGMS (2021a): **Fluctuations of Glaciers Database.** World Glacier Monitoring Service, Zurich, Switzerland. https://doi:10.5904/wgms-fog-2021-05.

WGMS (2021b): **Global Glacier Change Bulletin No. 4 (2018–2019).** Zemp, M., Nussbaumer, S.U., Gärtner-Roer, I., Bannwart, J., Paul, F., and Hoelzle, M. (eds.), ISC(WDS)/IUGG(IACS)/UNEP/UNESCO/WMO, World Glacier Monitoring Service, Zurich, Switzerland, 278 pp. Publication based on database version: https://doi.org/10.5904/wgms-fog-2021-05.

Zemp, M. and B. Marzeion (2021): **Dwindling relevance of large volcanic eruptions for global glacier changes in the Anthropocene.** Geophysical Research Letters, 48 (12), e2021GL092964. https://doi.org/10.1029/2021GL092964.

2.5 Conclusions

Glacier monitoring has been internationally coordinated by the World Glacier Monitoring Service (WGMS) and its predecessor organizations for more than 125 years. Thanks to long-term core funding from GCOS Switzerland (since 2010) and support from the University of Zurich, the WGMS successfully transformed from an ad-hoc effort to a professional data service firmly rooted in the international glacier monitoring and research communities. Within the new framework for the budget period (2021−24), we are ready to further consolidate glacier monitoring within the WGMS network for in-situ observations and to tackle both the new opportunities and challenges of geodetic glacier-change assessments from spaceborne sensors.

3. Annual work plan for 2022

3.1 Activities

As in previous years, WGMS operations consists of annual core business, aligned with the hydrological year, and special tasks.

The special tasks for 2022 are to (i) revise the FoG database schema, migrate the database to a server-based solution, and develop an internal user interface, (ii) develop improved data quality assurance and quality control tools, (iii) prepare reports on the maturity of GTN-G data products and on the progress of the national implementations of the international monitoring strategy, (iv) prepare GTN-G self-evaluation reports for IACS and WDS, and (v) contribute to publications related to the IACS working groups RAGMAC and RGI/GLIMS. In addition, the WGMS team supervises BSc, MSc and PhD theses, employs interns, and hosts visiting scientists working in the field of glacier monitoring and research.

The following schedule lists the main activities for 2022.

1. Quarter (Jan-Mar)

- Annual report and account balance for 2021, program and budget for 2022,
- Check and upload of data for 2019/20 and *near-time reporting* for 2020/21,
- Ad hoc estimates of global glacier mass-changes in 2020/21,
- Workshop on new WGMS database concept,
- Revision of the FoG database schema,
- Report on the maturity of GTN-G data products,
- Retreat on the future of the *Global Glacier Change Bulletin* and on the GTN-G evaluation.

2. Quarter (Apr-Jun)

- FoG data quality assurance and quality control,
- Database release (FoG-2022-0X),
- Migration of FoG database to a server-based solution,
- Report on the progress of national implementations of the international monitoring strategy,
- Publication related to IACS working group RAGMAC.

3. Quarter (Jun-Sep)

- Actualisation of digital online products (FoG-2022-0X),
- Development of an internal user interface,
- Safety training/crevasse rescue training,
- Contribution to IACS *Working Groups* RGI & RAGMAC (e.g., workshop, publication),
- GTN-G self-evaluation report.

4. Quarter (Oct-Dec)

- *Call-for-Data* for observation period 2020/21& *near-time reporting* for 2021/22,
- Publication related to IACS WG RGI/GLIMS,
- Annual telecons with WGMS NCs and PIs,
- Lecture series on *Glacier Mass Balance Measurements & Analysis* (GEO851),
- Prepare reporting 2022 and program 2023.

3.2 Outreach

In 2022, several glacier monitoring activities of WGMS, NSIDC, GLIMS, and different IACS working groups are planned. Conference sessions on glacier monitoring are set up for the EGU General Assembly and planned for the AGU Fall Meeting (USA), ideally including splinter meetings of the GTN-G *Executive Board* and of the IACS WGs. Additional meetings, e.g., Alpine Glaciology Meeting in Munich (DE), ESA Living Planet Symposium in Bonn (DE), IGS Meeting in Reykjavik (IS), Koni Steffen Symposium Davos (CH), GCOS Climate Conference in Darmstadt (DE), will be attended by the WGMS staff physically or virtually, depending on the COVID situation.