Proposal for IACS Working Group on Debris-Covered Glaciers

Working group co-chairs: Lindsey Nicholson, Francesca Pellicciotti, David Rounce

Background:

Many global mountain ranges currently support abundant debris-covered glaciers, glaciers mantled for part of their tongues on a layer of rock debris. The proportion of the glacierized surface that is debris covered is expected to increase under continuing negative glacier mass balance due to ongoing climate change. Knowledge of how debris-covered glaciers will respond to climate change will therefore have important implications for planning of hydrological resource and future global sea-level change. There has been growing interest in research on debris-covered glaciers over the last decade and thus it is timely to create a working group to draw these activities together to optimize the scientific impact of ongoing research activities. The overarching aim of the debris-covered glaciers working group is to advance our understanding of how debris impacts glacier response to climate at the local, regional, and global scale. This is a necessary precursor to accurately represent debris-covered glaciers in models of regional runoff and sea-level change projections.

Objectives:

Leveraging the expertise of the debris-covered glaciers community, the objectives of the working group are to:

1. *coordinate knowledge excha*nge
    a. promote participation at annual working group meetings
    b. expand visibility of debris-covered glaciers though international conference sessions
    c. produce a special journal issue on debris-covered glaciers
    d. facilitate sharing of previously unpublished datasets, model code and model results on open data sharing platforms
    e. create and maintain a working group webpage for duration of the project detailing progress
    f. Identify future research priorities and future goals to be included in a second phase of working group activities
2. *perform a comparison of debris thickness estimation methods at various scales*
3. *perform a debris-covered glacier ablation model comparison at various levels of complexity and scales*

Description of objectives and deliverables:

Objective 1: Knowledge exchange

Co-leads: Lindsey Nicholson and David Rounce

Motivation: At present there is limited exchange between research groups, no standardized protocols of best practice in handling debris-covered glaciers in terms of field data collection or model treatment exist, and data related to debris-covered glaciers remains sparse and are generally not openly available, all of which hampers efficient progress in research. This objective will draw the research community together and foster efficient collaborations, in order to maximize the scientific gain from the available data and research activities.

Firstly, through this working group we will create a collaborative community to share research ideas at annual gatherings for the duration of the working group, the aim of which is to steer the next steps in debris-covered glaciers research and establish research partnerships. In addition to discussing and advancing the deliverables of this working group, these working group meetings offer a fertile ground for openly discussing and developing strategies to solve scientific challenges of including debris-covered glaciers in Earth system models that are beyond the scope of this working group. The meeting organizer will reach out to contributing experts to discuss solutions to problems such as how to quantify and include debris supply rates within global glacier models and how to account for time-evolving debris cover extent and thickness with the aim of identifying scientific challenges for future research and goals for a second phase of the working group. Secondly, activities of the debris-covered glaciers research community will be promoted via a series of curated international conference sessions in Europe and North America. This builds on the success of the EGU debris-covered glaciers session in past years but aims to be less Euro-centric, and arrange these meetings in different seasons of the year in order to attract as wide participation as possible. By doing so we intend to attract further, and in particular, interdisciplinary contributions to the advancement of our scientific understanding of debris-covered glaciers. Thirdly, the working group team will lead the preparation of a journal special issue on debris-covered glaciers. Finally, we will create and maintain an IACS working group webpage. This will consist of a static working group webpage, ideally hosted by IACS, coupled to secondary webpages hosted on a shared github account that can be accessed by multiple working group members and linked to the IACS frontpage. The github webpage tools are designed for collaborative work, and employ markdown language that requires no previous website coding experience, further facilitating inclusion of many participants with different technical backgrounds. These pages will serve two purposes: (i) tracking progress towards the working group objectives; (ii) creating a centralized hub of links to available datasets, model code and output hosted independently via established data repositories. To facilitate open sharing of previously unpublished datasets and model code to a centralized repository (e.g. Zenodo.org), we will prepare data upload guidelines that include recommended inclusion of valuable metadata such as details of sensors, settings and data processing used, as well as any advice on how to replicate or improve the dataset. Working group members will be called upon to lead the way in this initiative and we will further encourage the wider network to follow suit via an initial email call to cryolist and subsequent calls at working group meetings and debris covered glacier conference sessions. We do not envisage a legacy plan for this website, but, as provision of datasets and codes associated with the publication is likely to become mandatory in coming years, the focus is to gather and collate available data and lessons learned, up to 2021, to provide a platform for community data sharing, and to promote the habit of publicly sharing resources within the community.

Objective 1: Deliverables and dates

1a. Organize and chair annual working group meetings at international conferences with debris-covered glaciers sessions (see deliverable 1b)

1b. Organize international conference sessions on DCGs

- AGU Rounce 12/2018
- IUGG Pellicciotti 07/2019
- EGU Nicholson 04/2020

1c. Organize and edit special issue associated with IUGG session on debris-covered glaciers

- Identify working group members for editing duties Month 1
- Propose special issue of Frontiers on debris-covered glaciers Month 2
- Call for papers 02/2019
- Reviewing of manuscripts 08/2019
- Editorial decisions Dependent on Journal
- Publication of Special Issue Dependent on Journal

1d. Data sharing initiative

- Consultation with IACS regarding website hosting options Month 1
- Preparation of IACS working group data hub website Month 2
- Brief text of research into debris-covered glaciers for website Month 2
- Guidelines for sharing data via Zenodo Month 3
- Share available data via Zenodo and IACS website hub Month 4 - end
- Open call for contributions to data repository via Cryolist Month 5 - end

Objective 2: Debris thickness mapping comparison project

Co-leads: Francesca Pellicciotti and David Rounce

Motivation: The thickness of debris is known to greatly alter a glacier's mass change, yet estimating the debris thickness remains a challenge. The debris thickness mapping comparison project seeks to advance our understanding of how well debris thickness can be estimated and how debris thickness varies on the glacier, regional, and global scale.

The debris thickness mapping comparison project will have two major components: (i) collect all available measurements of debris thickness from glaciers across the globe and (ii) compare how the various methods that have been used to estimate the thickness of debris-covered glaciers perform with the aim of advancing our understanding of how debris thickness could be mapped at the regional or global scale. The various methods that will be considered are integrating surface temperature from satellite imagery with energy balance models, defining empirical relationships between surface temperature and debris thickness, and inverting the Østrem curve using an energy balance model and surface lowering estimates. These approaches vary greatly in terms of their complexity, computational expense, and data requirements, which will impact their ability to be applied on a regional or global scale. One of the major limiting factors for understanding how the debris thickness varies is a lack of in-situ measurements. These measurements have been collected via manual excavation, ground penetrating radar, or surveying above exposed ice cliffs, but since these methods are both labor and time-consuming, they typically have only been measured over localized areas of a couple glaciers. In line with Objective 1d, one of the goals of the debris thickness mapping comparison project will be to consolidate all of the previous debris thickness measurements into a central repository in order to enable a proper assessment of how various methods for mapping debris thickness perform. In addition to the debris thickness measurements, we will also encourage the sharing of other important datasets (e.g., meteorological data and debris properties), which are typically required by the methods used to map the debris thickness. Based on data availability, the working group will identify and select our benchmark glaciers for the debris thickness comparison. The goal of this comparison is to identify how well the various methods perform compared to one another and assess the accuracy of these debris thickness estimates over glaciers where data is available, which will ultimately provide guidance for how debris thickness can be mapped at regional or global scales.

Objective 2: Deliverables and dates

2a. Open call for participants — Month 2 – 3

- A participant is defined as any individual that provides a dataset used in the comparison or a method for estimating the debris thickness of at least one of the working group's benchmark glaciers (see 2b).

2b. 1st debris thickness comparison project meeting at AGU 2018 — 12/2018

- Identify and select benchmark glaciers that will be used for comparison
- Set the standardized input (meteorological data, debris properties, DEMs, thermal imagery, glacier outlines, etc.) and output (resolution of debris thickness maps [pixels, bins, etc.] and other parameters [e.g., debris volume]) that will be used to for the debris thickness comparison
- Set realistic time frame for when the debris thickness estimates need to be submitted (likely May 2019 to provide time to consolidate results prior to IUGG 2019)
- Participants unable to attend in person will be able to join via video

2c. 2nd debris thickness comparison project meeting at IUGG 2019 — 07/2019

- Report initial results of the debris thickness comparison to the working group
- Discuss timeline to synthesize model results into a publication for the special issue (see Objectives 1c and 2d)

- Identify potential challenges for mapping debris thickness on the regional/global scale (e.g., spatial and temporal resolution of meteorological data, mixed-pixel effect, etc.) and discuss potential for second comparison project with the aim of expanding the results of the 1st publication to a regional/global scale

2d. Synthesize the results into a paper 08/2019

- Assess the performance of different models at a single spatial scale
- How does model performance vary with scaling?
- What are the constraints are imposed by input data quality?
- Recommendations for application of these methods

<u>Objective 3: Melt model comparison project</u>

Co-leads: Lindsey Nicholson and Francesca Pellicciotti

Motivation: The impact that debris thickness has on the surface mass balance is well known: A thin layer of <few centimeters enhances ablation compared to that of clean ice through increased absorption of solar radiation and efficient energy transfer to the ice beneath; however as the debris thickness increases, melt rate decreases, because an increasing portion of energy absorbed at the debris surface is re-emitted to the atmosphere over the diurnal cycle rather than being available for melting the underlying ice. Thus debris cover more than a few centimeters thick reduces the ablation rate compared to clean ice. This first effect is generally not well-represented in existing models, but a variety of debris-covered ice melt models are able to reproduce the second effect, especially when provided with well-quantified inputs. Models span from simple degree-day models with empirical factors adjusted to account for the average effect of debris to energy-balance models with varying degree of complexity. Their validation is difficult, especially beyond the point scale, and their transferability is still little understood, also because of scarcity of data. The melt model comparison project therefore seeks to compare the performance of these various debris-covered melt models to determine what level of complexity is required to accurately estimate the melt of debris-covered glaciers with the ultimate goal of providing guidance as to how debris-covered glacier melt can be incorporated into large-scale, long-term modeling efforts.

The melt model comparison project will have three major components: (i) collect all available measurements of surface melt, debris temperature, and debris properties from glaciers across the globe, (ii) compare the performance of various melt models using standardized inputs and quantify how the inclusion of more complex processes impact melt rates, and (iii) synthesize the model comparison results to provide guidance for incorporating debris-covered glacier melt into large-scale modeling efforts. One of the major limiting factors for understanding how well debris-covered glacier melt models perform on a larger-scale is that most debris-covered melt models are developed using well-quantified inputs for glaciers in a specific region. Less computationally expensive temperature index models typically rely on site-specific measurements of surface melt, but it is unclear how these degree-day factors transfer to other regions. Conversely, computationally more expensive energy balance models often have to make assumptions regarding the debris properties, turbulent heat fluxes, moisture in the debris, etc., which often involve the use of site-specific data.

This melt model comparison project seeks to assess the performance of these various models through the use of standardized input from debris-covered glaciers across the globe. For this objective to be successful, the melt model comparison project first aims to collect available measurements that may be used as input data (meteorological data, debris properties, etc.) or used to assess model performance (surface melt data, debris temperature measurements, etc.). Based on the available data, the melt model comparison will be conducted in a first step at a point scale for various benchmark glaciers across the globe. The results from the comparison will then be synthesized to identify key processes that influence melt and aim to provide guidance for large-scale modeling efforts. If doable in terms of data and resources, comparison will be made also at the distributed, glacier-wide scale. For this, meteorological variables and surface properties need to be extrapolated in space, thus providing information about the model performance when included in large-scale modelling efforts.

Objective 3: Deliverables and dates

3a. Open call for participants — Month 6-9

- A participant is defined as any individual that provides a dataset used in the comparison or a debris-covered glacier melt model (see 3b).
- Review and publish datasets annually on Zenodo open data portal (with DOI)

3b. 1st melt model comparison project meeting at IUGG 2019 — 07/2019

- Development of framework that will be used for comparison
  - Point scale modeling
  - Identify and select benchmarks glaciers and datasets to evaluate model performance
    - Meteorological data, debris properties, temporal spacing, etc.
    - Surface melt measurements, debris temperature measurements, etc.
    - All datasets must be stored in open repositories
  - Output specifications, which will vary based on model complexity
    - All models: surface melt
    - Energy balance models: debris temperature, energy balance fluxes
- Set realistic time frame for when the melt model results need to be submitted
  - Dec 2019 to provide time to consolidate results prior to EGU 2020
- Participants unable to attend in person will be able to join via video

3c. 2nd melt model comparison project meeting at EGU 2020 — 04/2020

- Report initial results of melt model comparison and share results at conference
- Discuss timeline to synthesize model results into a publication for the special issue (see Objective 1c)

3d. Synthesize the results into a paper — Year 2-3

- Assess performance of various models
  - Do any models consistently over- or underestimate melt?

    - How robust are temperature index models compared to enhanced temperature index and energy balance models?
    - How transferable are melt factors derived from specific regions?
- Identify how various amounts of model complexity affect melt and other processes
- Provide guidance for incorporating debris-covered glacier melt into large-scale models

Working group members:

The working group will leverage the expertise of the debris-covered glaciers community, which will comprise various research groups throughout the globe. A list of confirmed members is shown below. Additionally, each objective will begin with an open call for participants using email lists like the cryolist in addition to advertising this working group at conferences and meetings.

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