Full report of the 4th OGGM workshop

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Session Introduction / State-of-art:

- Fabien Maussion - What is OGGM ?

OGGM is a community asking for scientific questions: OGGM e.V. ! https://oggm.org/oggmev/ - Develop an open-source model adaptable at global scales - OGGM is a modeling framework, modular - Federation of "users" and "developers" … - 220 000 glaciers in the world - Robust model: numerical robustness, results not totally depending on boundary conditions - Glacier centric approach: each glacier is modeled independently -> it does not mean that any glacier of the 200k glaciers will be modeled "accurately" - Tools existing: RGI, GIS, Flowlines, Catchments, Automated data processing (climate, WGMS, thickness) … - Start from prepro workflow can be used to used the data and tools to have the data for your glacier - Mass-balance model from Marzeion et al., 2012, basic temperature index model - Showing the cross-validation results of mass balance (data from WGMS) - Much better, use geodetic data for mass balance calibration - Different glacier evolution models - Ice thickness models - Big issue: which set of parameters we want to apply globally ? - Continuous test integration - Sure that the model results change over time - OGGM contribution -> modular ? -> get other people in our train to use the framework of OGGM BUT keep their mass balance / ice dynamic tools -> letting the people doing their work in their own repository and acknowledge & cite the right paper - Modularity is achieved by persistent on disk - Limited tasks & quite easy to jump into the model - We can't solve it all - Individual modules should be kept separated and maintained by their developer - Codebase history -> things are changing - Lot of challenges: new users, being transparent, mor physics into the model, what we can do and not do, feedbacks from the users/developers …

- Fabien Gillet-Chaulet - Synergy with Elmer/Ice ?

A finite element, open-source, multi-physics software - Elmer/Ice refers to the solvers to solve glaciological problems - Since 2003 with 116 papers - Large community of users around the world - Not designed to be an ice flow model - most applications are related to ice-sheets but several time on mountain glaciers -> full mechanical equations (full-stokes, SIA, SSA) - Lot of different modules/capabilities for different applications - Applications for thermal regime, cavity collapse, theoretical experiments, glacier evolution for one glacier (mass balance depending only on the altitude) - Relatively easy to do simulation for one glacier - J. Furst -> thickness reconstruction in Svalbard with mass conservation - Elmer/Ice really focused on ice dynamics, mostly useful for process-based studies, fast glacier (high order equations -> steep, sliding, calving ...) - Lot of data to calibrate or constrain - Time to understand the model, to use it … - Focusing on individual

glaciers - Computational time can be a constrain. What about finite differences ? - In one week, you can learn to run the model examples and your glacier ! - Paraview software - **Coupled the feedbacks between the glacier geometry and surface mass balance - Use the surface mass balance over the glaciers to the finite elements of elmer/ice - Without surface velocity, uncertainty increases** - Everything is in the configuration file - Around 10 people contributing to the code of Elmer/Ice - Collection of software, less integrated than OGGM - Regional scale of glacier with and without data, focus on thickness inversion - Glaciers with surface velocities of course ! (100 - 10000 glaciers).

Session the Future of OGGM:

- Ben Marzeion - Bremen projects

Glacier evolution on postcards and pencils - Marco Möller postdoc in Bremen better understanding between ice sheet and ocean, and peripheral glaciers, substantial part form glaciers - What is peripheral glaciers -> connectivity 2 in RGI is ice sheet, 0 and 1 is glacier - Double counting is still an issue - Similarity with GRACE - Funding projects: PhD ArcticTrain look at couple effect from glacier into ocean and how the transport of heat between the two entities - Bea's PhD replacement: freshwater availability on the large scale, detection and attribution - Julia's new position: attribution to specific emission pathway, different impacts at what time the emission happened ; time series of the response of emission from company - H2020 project: Eu call for cryosphere and sea-level, projections ; invited to the second stage of the proposal ; Matthias Huss, Frank Paul & Ben Marzeion -> calibration / validation using geodetic mass balance (Huss), snapshot of RGI (Paul) and debris-covered glaciers (Marzeion) + glacierMIP second generation ; Computer cluster in Bremen -> next year having tutorial on the new cluster (Timo).

- Fabien Maussion - OGGM in the cloud

Implementing the same method as an other method (interpolation of glacier without data, science reproducibility), how to do ? Sharing their code ? Code available on request … lot of difficulties ! - Reproducible on science -> new parameterization in a model -> writing a paper and open license code - Use the same data, same model, results can become very different -> probleme of the library due to the chaotic problem ! -> Steady state very sensitive to the boundary conditions -> Sharing the environment as the code/data - Difficulty to install OGGM for all students -> use cloud-based solution (computer pre-prepared) with internet connection - Big data to be solve with the cloud - Open source, open science: Jupyter, github, open journals, open repositories, open licences, … how we value the output in science ? - Preparing data, code … not only paper - Difficulties from agencies and employers - Reproducible science -> Binder, google colab, code ocean … -> publish a computer environment (capsules, docker) - Making money and company/university/institution to pay for this service - Of course. there is open source solution for containers ! - OGGM available in the cloud: available and nice for users on super computer with JupyterHub -> provide only notebooks ; cloud is service on your browser not on your computer locally ; container: capsules that provide all needed to run OGGM ; Jupyter Hub to provide capsules to all users with google clusters - Control of who is doing runs on the cluster - Environment and scripts are kept !!! - **WE ONLY USE OGGM ON THE CLOUDS FOR USERS AND SHARING DATA** - Read only the pre-processing states.

- Zora Schirmesiter- OGGM educational

Status of the educational platform about glaciers - 3 students - 1669 very important for Innsbruck University - Educational materials about glaciers, diverse audience, open source, cloud based - Web applications, interactive notebooks (glacier experiments), graphics … - Scientific communication - Graphics used by presenters - Interactive notebooks on Binder and play around with the parameters - Still lot of code in the notebooks.

Session Glacier in the Past:

- Julia Eis - Initialisation of glacier in 1850

Summary of TC paper -> application only in synthetic experiments ; solutions are often non unique -> determination of a set of possible glacier candidates - Why no application to the real world ? Round table about different topics.

- Madlene Pfeiffer - Sensitivity of high Alpine geosystems to climate change since 1850

Multidisciplinary project - Reconstruction of climate and glacier evolution on a centennial time scale - explaining the reaction of alpine geosystems to past and present climate change - Significant change since Little Ice Age - Temperature in the Alps increase more than twice the global average - Differences in time evolution (3 time slices) since 1850 - Human visual evidence of dramatic glacier retreat - **Should we write a manual for researchers/public to take glacier pictures in the field to do photogrammetry ? -** 1. Is it possible to identify significant changes of single processes in alpine geosystems related to climate change? - 2. How do system components, their properties and processes interact, and do such interactions enhance or attenuate the impact of climate change? - 3. How do changes of single components or through interactions propagate through the system? - Objective 1: Ensemble of temporally and spatially highly resolved data sets of the atmosphere over the Alps during the last 150 years - Objective 2: Produce reconstructions of mass balance, runoff, volume, area, ice flow, and geometry of all the glaciers in the focus regions from 1850 to present - Objective 3: Quantify to which degree the uncertainty of glacier reconstruction can be reduced by using dynamically downscaled forcing fields - Interactions between the different components of the Alpine system like retreat of glaciers ?

- David Parkes - model length changes 850 - present.

Bulk view on OGGM performance at 1000 year timescales and across RGI regions. New RGI-Leclerq links (some questionable) - still quite a few glaciers for each region - simulation results for normalized lengths averaged per RGI regions. Experiments with constant temp / precip.

- Matthias Dusch - modeling glacier reconstruction

Glacier in the Holocene - Smaller 10 000 - 5 000 bp ; Alpine glacier maxima in the last millennium ; Modeling glacier length changes in the Alps based on tree-ring based temperature reconstructions for the last 2500 years - **Big question: How to select random climate ? Which period do we use ? Do we select all the years of the period by removing the one selected or do we pick up always one sample over all possibilities ? The response is probably climate dependent** - Focus on the recent better know period and how to calibrate the model - tree-ring reconstruction -> only summer temperature - Not good reconstruction -> changing glen A, bed shape, ice thickness inversion, mass balance, precipitation factor … - Spin-up until the length matches the observation - Errors from the observations have to be taken into account - **Initialisation with length could have different volume** ! -> response time of glaciers different because the mass repartition (and thus the dynamic) could be different with the same length - Precipitation gradient effect important but do not resolve all differences - **Formulation of Marzeion's mass balance model is so robust globally !** - Mer de glace glacier is driven by precipitation in 1880 - 1900 period. Baseline climate in OGGM = CRU dataset -> **using ERA5 as baseline and ERA20C for long time mu star calibration** - What is important is the mass of precipitation more than the variability - Doing the mu star calibration with different RGI outlines / DEM elevation models.

Session Glacier Surface Mass Balance:

- Anouk Vlug - Natural climate variability influence

Canadian Arctic glaciers - **Difference between ensemble mean and individual members** - This effect is stronger for smaller glaciers - Due to the threshold for temperature -> climate variability - Difference between ensemble mean results and ensemble mean forcing - Big influence on glacier volume from temperature anomalies & temporal window size (sensitivity experiments) - CRU july temperature variability is lower than CESM temperature variability - Scaled anomalies & mean from ensemble mean forcing for 1960 - 1991 -> better results ! - **RACMO SMB and CESM OGGM SMN agree each other during the last 50 years** - We are as good as RACMO ! - What is the forcing for RACMO ?

- Anton Butenko - shortwave radiation parameterization in OGGM surface mass balance

OGGM surface mass balance - Data from CRU and WGMS to calibrate mu star - Difference between observed and modeled SMB - Enhanced temperature index model including shortwave radiation from Cazzorzi and Dalla Fontana - Problem by doing it globally - Including also shading - Including also albedo - Do we want a better RMSE or a better SMB profile - **Do we want more parameters ? it could be but we want global parameter** - Putting the parametrizations in the model as a choice - We need more measurements and if we need to redo all the cross-validation of the model !

- Jordi Bolibar - Glacier surface mass balance using deep learning

SMB modeling in a nutshell - Deep Artificial Neural Network -> nonlinear statistical model ; depth allow capturing more complex patterns in data -> glacier wide mass balance ; Amazing among of data in the French Alps - **Doing new calibration of mu star with new DEM/RGI** - Which are the meteorological and topographical explain the glacier-wide SMB in a certain region -> function with predictors for SMB - Glacier SMB strongly correlated in space ; Climate creates internal variability -> spatiotemporal cross-validation (leave one-glacier-out and leave one-year-out) - Deep learning have better results than linear approach in space - 28% of non linear behaviour - Same thing in time-> 35% of non linear behaviour - bias is reduced in time but less in average - Deep learning SMB models can be powerful in glaciology with the right physical assumptions - Used to extend time series within a region - Can we use ALPGM to estimate glacier ice thickness - **Temperature-index model is not linear** - Integrating deep learning into OGGM.

Session Glacier Ice Thickness:

- Fabien Maussion - Global ice thickness inversion

Next paper about factors of uncertainty in global ice thickness inversion - Fixed the global parameters for the ice thickness inversion -> glen A and sliding ; If we use default parameters, overestimation of ice thickness compared to GlaThiDa ; Which topography we would like to use for the future ? - Sensitivity analyses and fixed these 2 parameters - Having option starting for this pre-processing steps and this DEM and this baseline climate - The results are that A could be 1.2 and 2.5 - We have thicker glaciers at global scale.

- Fabien Maussion - COMBINE model

Retrieving bed topography from surface information is an inverse problem ; s = M(b) -> b =M-1 (s) ; Non-linear diffusion model -> not possible to find the backward model (Julia's talk 2018) ; Run forward model on "realistic" topography for 2200 years, case Borden ; Ice cap is flat -> how much information gives us about the thickness - Definition of a cost function to minimize -> minimize the distance between the forward model and the observed surface -> unstable formula -> using a regularization terms - Penalization strong gradient in the bed and ice out the outlines - Not possible to explore the total field of possibilities (following the gradient and find the local minimum) -

Gradient is extremely nonlinear - For each time step of forward OGGM modeling, pytorch is storing the machine learning (adjoint of the model) - Until convergence is reach - For each simulation (200-250 iteration steps) 2000 years simulation ; For ice caps, there is not enough information (too flat) to retrieve ice thickness - Problem in regularization - Problem about the presence of ice caps with simple 2D SMB model (because of exposition …) -> inverse an caps - Use a mask to allow accumulation just where there is accumulation - **Distributed is not the final simulation** - If we want to do distributed model, we need probably more complex model of SMB.

- Beatriz Recinos - Calving in Greenland

Marine-terminating glaciers in OGGM - Improve calving in Alaska and Greenland - Calving in Greenland from peripheral glaciers 35 km3 yr -1 -> most of the time, calving is much larger than precipitation, therefore, is necessary to constrain the temperature sensitivity to avoid negative values. When we clip or constraint mu_star to be zero, we are assuming that MT-glaciers in Greenland do not experience melting (that is not true for most glaciers in Greenland) - But some glaciers in the north might not experiment melting - We want to find glaciers that are always below zero and take them out from the k sensitivity experiment, in order to find a k value, that result in a linear relationship between the Frontal ablation and the k value (Method I for calibrating k). Use RACMO data to estimate mu_star and compare with values from OGGM (Method II for calibrating k). Use velocity data to constrain k values that can match resultant surface velocities (still needs more thought, Method III) .

- Marco's part: First time there is calving flux estimate for Greenland peripheral glaciers from OGGM cross-section and remote sensing surface velocity -

How do we deal with advance and retreat of the glaciers dynamically ; Same what happen if Marine-terminating glaciers because land-terminating glaciers ?

- Jenna Sutherland: control of proglacial lakes on outlet glaciers during the Last Glacial Maximum in New Zealand

Using the LGM outlines instead of the RGI outline -> problem of not using bed information.

Session Diversity of OGGM:

- Fabien Maussion (Moritz) - implementing alternative evolution models in OGGM

Put VAS in OGGM base code (from Marzeion et al., 2012) - Using pre-processing steps in OGGM - Comparable to use VAS and dynamical part of OGGM model - Maybe we might adjust the parameters - Demonstration of modularity -> HUSS, VAS and OGGM models - 1D-squeeze huss model - Use VAS to find a solution in the past.

- Samia Melki - rock glaciers

First year of PhD - Modeling rock glaciers - Mixture of ice and rocks in permafrost conditions, mode slowly - Described over the last century - Ice fraction in rock glaciers around 40 and 70% - 1300 km2 of rock glaciers against 250 km2 for white glaciers - Mean annual velocity 10 cm/year to 2 m/year - Changing in the surface velocity of rock glaciers due to climatic conditions, highest speed year in 2015 -> acceleration of Laurichard glacier in the last decade - Maybe destabilization of rock glaciers in the Alps -> observation in situ (GPS, orthoimagery …) of velocity and direction - Marcer et al., 2018 -> map of destabilization - more destabilization are found close the Italy border - Lot of hazard for rock glaciers -> modeling the rock glacier rheology - Heterogeneous material - glacier behavior not well known - different sensitivity parameters - **Problem of DEM resolution** - Changing in resistivity into the glacier - **Sliding & slope most important ? No deformation ???** - Laurichard: around 1.5 meter per year in the central part - No mass balance - Surface temperature measurements have annual cycle -> correlation between air temperature and surface temperature - Accumulation term is not snow accumulation but rock fallen from the mountains and frozen water

-> constant mass accumulation ; Ablation with melting ice - **Accumulation at the bottom for ever ?** - Glen A is a factor of temperature and rock/ice concentration - **Definition of Glen ?** - Heat conduction as the governing process to seasonal to multi-annual variations in rock glacier velocity - **Local process community and global evolution community links !** - Influence of boundary effects - **2005 Arenson law in OGGM ?** - Velocity is not dependent of the z axis (SIA) .

- Nicolas Champollion - projections of global glacier change during the 21st century

global settings:
oggm settings: default pcpsf, itmix glenA, no Antarctica, Greenland yes
global results: similar behaviour like Bens model and Hock et al 2019, a bit more melt (greenland)
europe: 80-90 glacier mass loss
new zealand: no plateau where mass loss stabilizes
next steps: calibrate initial ice thickness, calving of tidewater glaciers, ice sheet peripheral glaciers (at least greenland)
take home: globally glaciers will melt until 2040-50 for all scenarios. after 2050: rcp2.6 deceleration and rcp8.5 acceleration
uncertainties: initial total ice mass, differences between GCM simulations, GCM temp and prcp variability
surface ablation governs global glacier evolution, ice dynamic accelerates the melt.

Session Open Discussion:

- Data limitation

For much choices about data for users - More useful to have the choice - Important to deal with uncertainties - For example, date of RGI outlines and DEM topography - Storing in the cluster or clouds, all the difference combinations of initial dataset - **Everybody is welcome to help doing the pre-preprocessing steps and programming** - Doing the documentation how to have your own data ? Bea ;-) -> writing an example - Knowing how many glaciers are not working for all the different preprocessing steps - If you want one glacier, you have to download small regions (1000) but there is glacier examples - Data limitations, we are not able to solve but we should do communication - Changing the name from Leclercq / RGI links - Communication about data limitation in both directions: to the data providers and that the model can not solve all your problems -> **OGGM place to list the issues in FAQ and Troubleshooting in the OGGM documentation (and maybe a link to a blog post), for programming in GitHub** ! - **I you find errors from you, share it with others**.

- Uncertainties / Maintenance

Lot of methods to deal with uncertainties - For the model itself - **Time to solve the issues -> we need an engineer !** - Important to interact on the problems / issues - You received an e-mail differently if you are pinned or not (to your gmail address or to general oggm address).

- Communication

If you find an error or something, do it ! More tutorials on Binder other than on the OGGM documentation web page ; Tutorials are uploaded through github OGGM-edu repository ; **Creating a documentation / road map / design document about uncertainties in github** -> David :-) ; OGGM blog, OGGM mailing list (users, announce), OGGM github, OGGM documentation ; OGGM slack, OGGM hackmd, OGGM open discourse ... More contribution about OGGM documentation from everybody as every year ! - OGGM e.V. non profit organisation - Member of google for Nonprofits - OGGM social media (twitter, …) - We are TechSup member - **How to encourage people to bringing things up ?**

Session Beginner Tutorials:

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Session Experienced Users:

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Open remark:

- ➔ For next year workshop, should we have less presentations but more general and build from few participants (for example, one per session about the thematic of the session) and have a 30 minute presentation followed by 1 hour discussion.
- ➔ Link to an OGGM survey: https://docs.google.com/forms/d/e/1FAIpQLSddsblxzr0VVFEMwKTuX7rbQE-4MFLhA7RPK9DhRj2IGEUaOw/viewform?usp=pp_url

Pictures: