Full report of the 4th OGGM workshop

17 – 21 June 2019, Grenoble, France

Participants: Ben Marzeion, Fabien Maussion, Nicolas Champollion, Anton Butenko, Julia Eis, Madlene Pfeiffer, Beatriz Recinos, Anouk Vlug, Run Zhang, Patrick Schmitt, Zora Schirmeister, Matthias Dusch, Jenna Sutherland, Samia Melki, Antoine Rabatel, Jordi Bolibar, Fabien Gillet-Chaulet and David Parkes.

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:

....

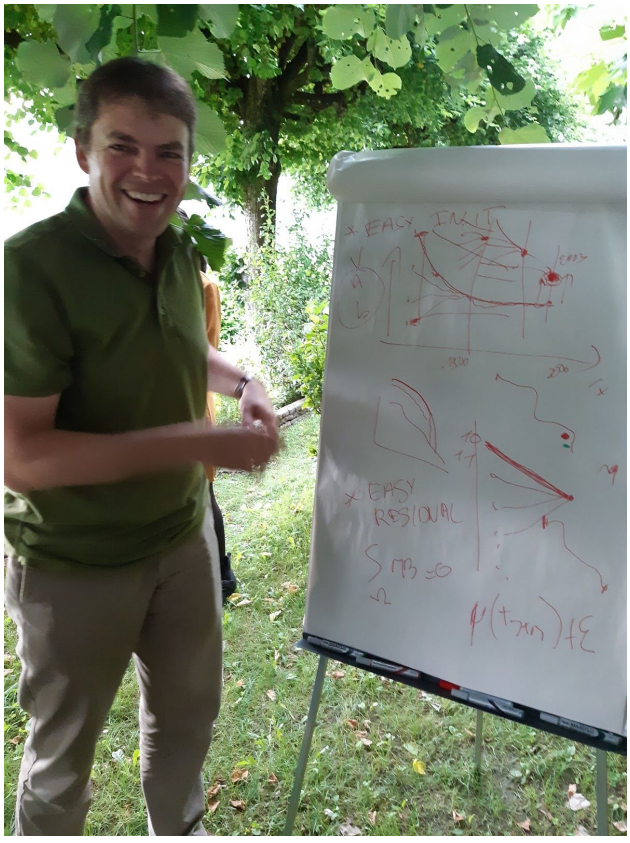
Session Experienced Users:

...

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:


EASY
EASY
RESIDUAL