Modelling the surface hydrology of George VI Ice Shelf, Antarctica

Surface Melt in Antarctica

In 2002 the Larsen B Ice Shelf on Antarctica spectacularly collapsed. 3250 km^2 of ice, twice the surface area of Greater London, was lost. Before the collapse, lakes of melt water up to 4 km in length were observed on the ice shelf and are thought to have played a role in its disintegration. Recent observations suggest that some of Antarctica's ice shelves have developed surface hydrology networks but the role they play in ice shelf stability is not yet fully understood (Bell et al., 2018).

Modelling surface melt is key to understanding how and why it is currently occurring, and also how this might evolve and affect ice shelf stability in the future. Here we investigate another Peninsula ice shelf, the George VI Ice Shelf, which experiences significant surface melting and pond formation.

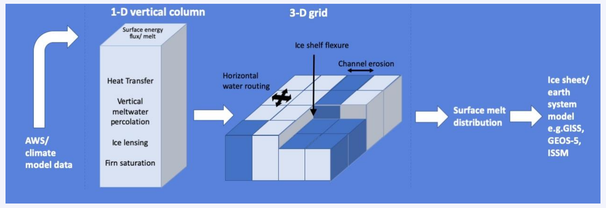
MONARCHS- MOdel of aNtARctic iCe shelf surface Hydrology and Stability

MONARCHS is designed to take the 1-D vertical column ice shelf surface lake model of Buzzard et al. (2018) and create a 3-D grid of multiple columns. This allows us to calculate the surface energy balance, heat transfer, density changes and vertical percolation of each ice column, whilst also allowing lateral water transport between columns both at the surface and the subsurface. This enables us to account for the following processes:

- Ice lens formation
- Lake formation and freeze-up
- Topography evolution over multiple melt seasons

In addition, work is ongoing to incorporate the following processes into the model:

- River formation
- Ice erosion by water flow
- Ice shelf flexure due to water loading

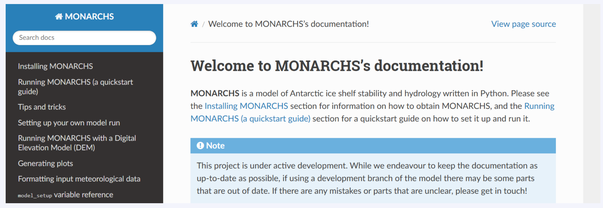


1 MONARCHS model structure overview

Model Availability

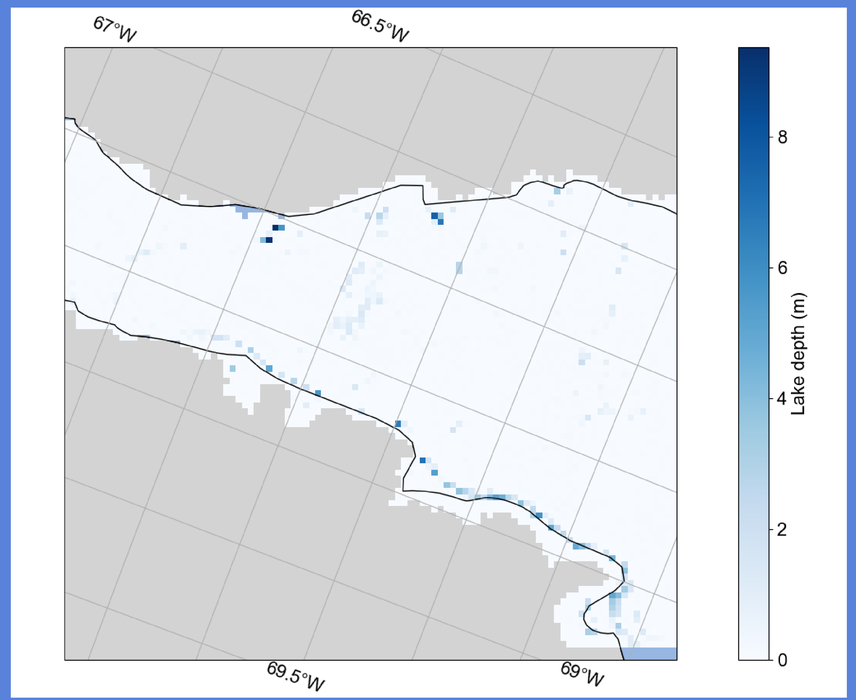
The code for MONARCHS will shortly be made publicly available. Through Docker a version of MONARCHS suitable to run in parallel on HPC will be shared, and the Python code will also be accessible through GitHub. Full documentation is available at https://monarchs-ice.github.io/

We intend for MONARCHS to be a community model and are happy to assist with its use, take on feedback for future use (see questions bottom right) or enable you to develop your own version of the model. If you'd like to use the model before publication please reach out and we'd be happy to assist you.



2 MONARCHS online documentation

Visit the MONARCHS website here



3 Lake depths found from the MONARCHS simulation of George VI Ice Shelf on 20th December 2017.

Sammie Buzzard[1], Alex Robel[2], Jon Elsey[3]

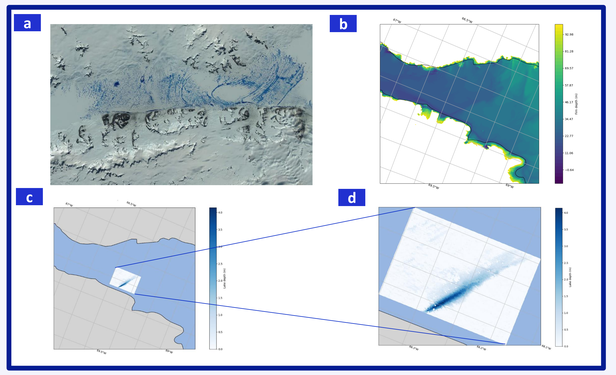
1. Centre for Polar Observation and Modelling, Department of Geography and Environmental Sciences, Northumbria University
2. Ice and Climate Group, School of Earth and Atmospheric Sciences, Georgia Tech
3. Centre for Environmental Modelling and Computation, University of Leeds

MONARCHS case study- George VI Ice Shelf

George VI Ice Shelf experiences significant surface lake coverage during Austral summer (Fig 4a). To simulate this, MONARCHS was run from 1st Jan 2010 for 10 years. The model run has a 20 cm vertical resolution, 1 km horizontal resolution and timesteps of 1 hour (vertical processes) and 24 hours (lateral water movement). The REMA DEM was used to initialise firn depths and ERA-5 reanalysis data was used as forcing for the surface energy balance and precipitation components.

The output of this is shown in Fig 3 where we can see lakes forming over 2.84% of the ice shelf surface. Extensive firn densification and ice lens formation also occurs.

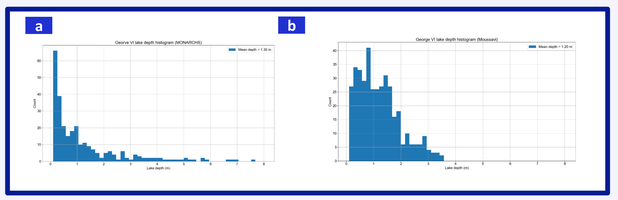
The resolution at which MONARCHS is run is flexible depending on the research question. In Figure 4(c-d) we show example output of smaller subset of the original domain run at a higher horizontal resolution of 200 m.



4 **A MONARCHS case study of the George VI ice shelf: (a) Sentinal-2 (ESA-Copernicus) imagery showing significant surface melt coverage of George VI during an extreme melt event in January 2020, (b) REMA DEM depths used to initialise the model, (c) the location of the smaller subset model run, (d) model output lake depths from the smaller subset.**

Validation

We compared MONARCHS with the Moussavi et al. (2020) Antarctic lake depth dataset for 20th December 2017 (Fig 5). MONARCHS performed well in terms of lake coverage, with Moussavi et al. finding 3.90% lake coverage compared with MONARCH's 2.84%. While the locations of lake occurrence were similar in the model and the observational data, MONARCHS did produce some smaller deeper lakes in areas where Mousaavi et al. found larger areas of shallower lake coverage. While lake location is heavily influenced by topographical lows in the DEM used to initialise the model, we are also currently investigating the influence of lateral flow speed on lake depth as this has been noted as a large uncertainty in firn hydrology modelling (The Firn Symposium Team, 2024).



5 **Histograms of the lake depths found for the case study area on George VI during Dec 2017 for (a) MONARCHS and (b) Moussavi et al. (2020).**

- **What would you like to see incorporated into MONARCHS?**
- **What data do you have we could use to calibrate or validate MONARCHS?**

References:

Buzzard S., D. Feltham, D. Flocco. A mathematical model of melt lake development on an ice shelf, *Journal of Advances in Modeling Earth Systems, 2018.*

Buzzard S., D. Feltham, D. Flocco. Modelling the fate of surface melt on the Larsen C Ice Shelf, *The Cryosphere, 2018.*

Bell, R.E., Banwell, A.F., Trusel, L.T., Kingslake, J. (2018). Antarctica surface hydrology and impacts on ice-sheet mass balance. Nature Climate Change, **8**, 1044–1052

Moussavi, M., Abdalati, W., Halberstadt, A., Pope, A., & Trusel, L. (2020) "Supraglacial Lakes in Antarctica" U.S. Antarctic Program (USAP) Data Center. doi: https://doi.org/10.15784/601401

Firn on ice sheets, The Firn Symposium Team, (2024), In: Nature Reviews Earth & Environment