The Glaciers of HARMONIE

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Abstract
HARMONIE is a convection permitting non-hydrostatic model that includes the multi-purpose SURFEX surface model. It is developed for high resolution (1-3 km) weather forecasting and used for a number of different regions in Europe and the Mediterranean. The version HCLIM is being developed for regional climate model. Here we run it for Greenland. By improving the characterisation of glacier surfaces within SURFEX we show that weather forecast errors over both the Greenland ice sheet and smaller glaciers can be significantly reduced. The improvements also facilitate increasingly accurate ice melt and runoff computations, which are important both for ice surface mass balance estimations and for commercial applications such as hydropower forecasting. These improvements will also benefit the operational HARMONIE domains that cover the Svalbard archipelago, the Alps and the Scandinavian mountain glaciers. Future uses of HCLIM for these regions, where accurately characterising glacial terrain will be crucial for climate and glaciological applications, are also expected to benefit from this improvement.

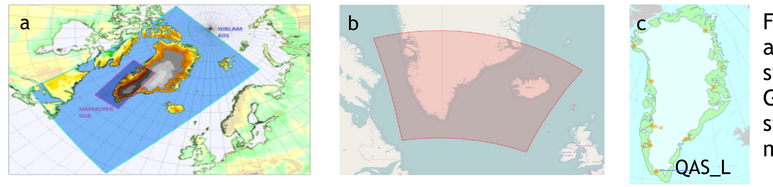


Figure 1c PROMICE automatic weather stations around Greenland, QAS_L station is used for model testing.

Figure 1 HARMONIE domains for Greenland and Iceland, a) is GLB domain for Greenland (also used in development here) b) IGA domain over which model updates will be applied when complete

HARMONIE Set-Up

HARMONIE has many different possibilities in set-up and can be run with different physical, dynamical and surface schemes. Here we use the DMI GLB operational NWP set-up

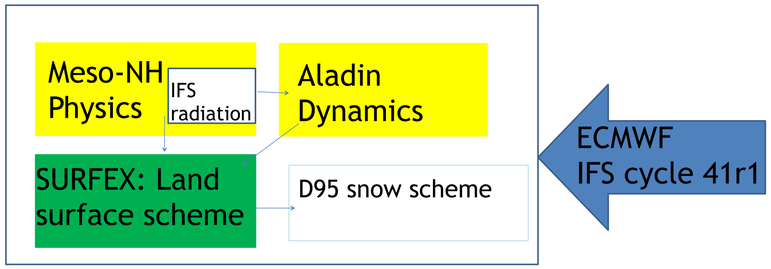


Figure 2. Operational HARMONIE set-up

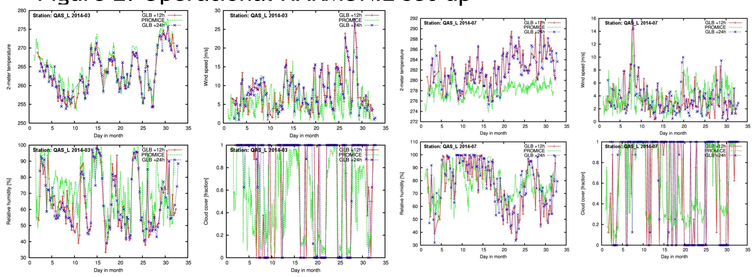


Figure 3. Operational (GLB) HARMONIE represents weather over ice sheet well as shown here clockwise from top left 2m temperature, wind speed, cloud cover (note observations are uncertain below 0.2) and relative humidity when compared with QAS_L data, left March, right July 2014

When snow melts away from the glacier surface and bare ice is exposed, modelling results deteriorate, suggesting an inadequate surface parameterisation.

We modified HARMONIE to simulate melting over ice by fixing the radiative surface temperature.
Modified HARMONIE simulates the melt out of surface snow reasonably well but there is a cold bias in the skin temperature

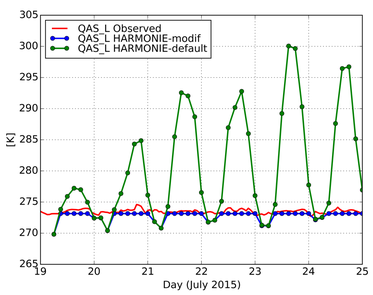


Figure 4 compares skin temperature at QAS_L with default and modifed HARMONIE

Model Evaluation: Snow cover and albedo

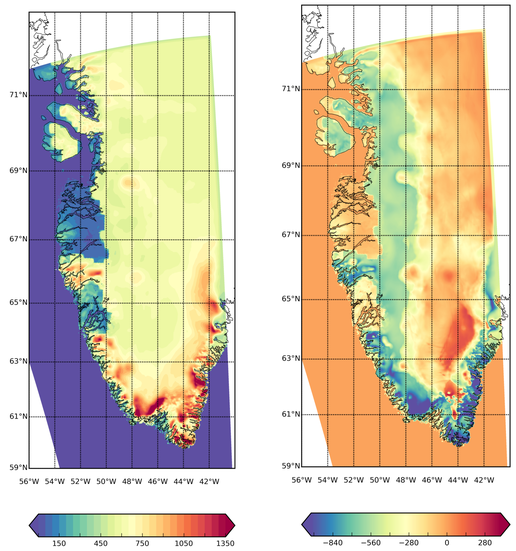


Figure 5. Change in surface snow cover in Snow Water Equivalent (kg m^{-2}) from (left) 1st April to (right) 31st August 2015.

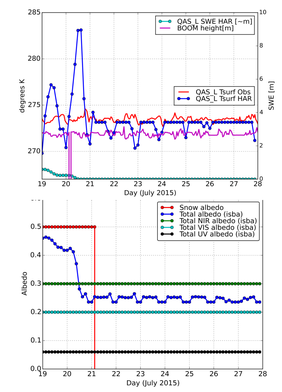


Figure 6. a)Comparison of observed and modelled skin temperature compared with measured snow height at QAS_L b) the decline of the albedo in different bands over same period

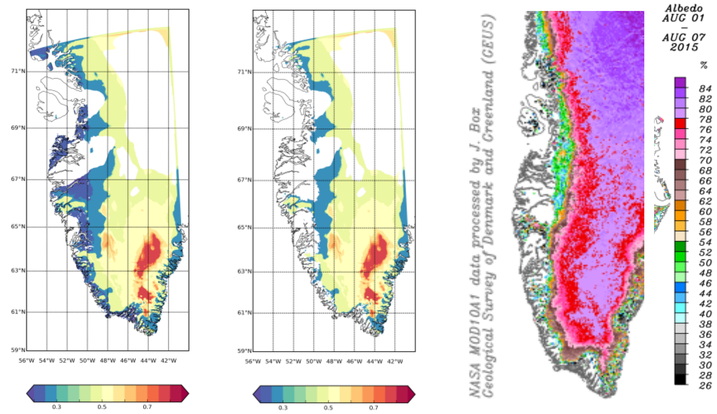
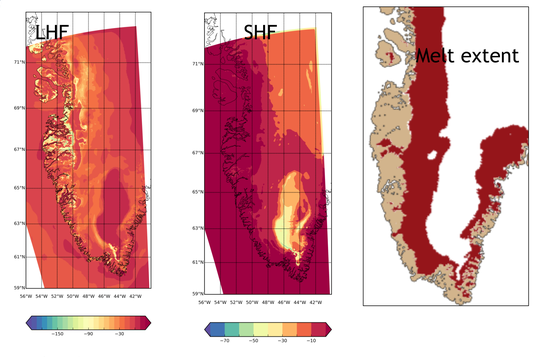


Figure 7. a) Total albedo with cloud cover masked out for one day in July, b) over glaciers c) MODIS (MOD10A) average over 1 week. HARMONIE total albedo is too low over bare ice

Non-radiative fluxes

7th July 2015



27th July 2015

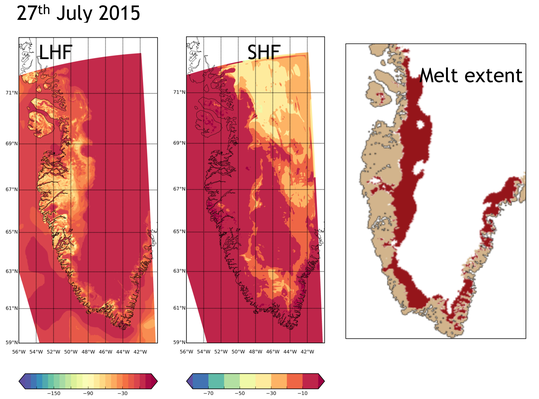


Figure 8 Latent (LHF) and Sensible (SHF) heat fluxes for two days in July 2015, the 7th was a high melt event, the 27th was a relatively low melt day Compare with Greenland melt extent courtesy of Peter Langen, DMI calculated from the HIRLAM-newsnow model available on polarportal.dk

The latent heat flux is much higher than the sensible heat flux on both days (note different colour scale) and the pattern correlates well with melt extent from HIRLAM. Fausto et al. have recently questioned model simulations of the different types of heat fluxes during extreme melt events. Further work on this is surely needed. Both HCLIM and HARMONIE will be useful tools for this.

Future Work

This preliminary work is encouraging, we expect to have a working glacier scheme before the end of 2016, still missing:

- Surface albedo of bare ice
- Surface Mass Balance computation
- Retention and Refreezing in the snowpack, CROCUS in SURFEX is one solution
- Turbulent flux parameterisations over ice and snow