Basal temperature calculations of the Greenland ice sheet

B. Van Liefferinge[1] and F. Pattyn[1]

[1]Laboratoire de Glaciologie (DSTE), Université Libre de Bruxelles, Belgium (bvlieffe@ulb.ac.be)

I. Abstract and Motivation

• Greenland subglacial conditions can be elucidated through several techniques. However, since direct measurements are only limited to a few deep drillings to the bed, there is always a substantial amount of ice sheet and thermodynamical modeling involved. This can either be done based on a fully coupled thermomechanical ice sheet model, or a thermodynamical model coupled with present-day ice sheet geometry and environmental conditions.

• Based on the method of Pattyn (2010) and Van Liefferinge and Pattyn (2013) we propose the basal temperate conditions using new data of bedrock elevation, ice thickness (Bamber et al. 2013), observed surface velocities obtained from interferometric analysis (Rignot et al. 2012) and geothermal heat flux (GHF) (Puruker, 2013).

•We discuss glacial-interglacial paleo-reconstruction and compare the results with the thawed conditions of the bed.

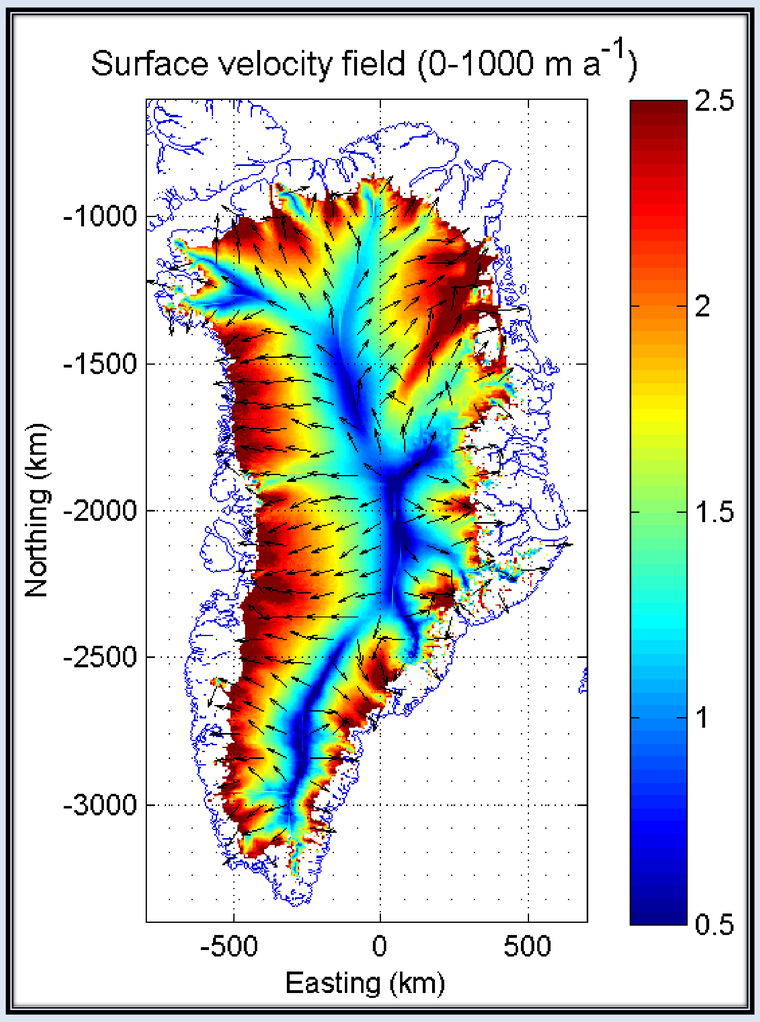

Fig 1. Greenland ice velocity field derived from Rignot and Mouginot. (2012) and from balance fluxes method (Lebrocq 2006), truncated at 1000 m a^{-1}. Values < 20m a^{-1} are based on balance velocities.

II. Methods

- ✓ Calculation of a new surface velocity field (Fig. 1) and incorporation of new data sets (bed topography, ice thickness, …).
- ✓ Correction of GHF using basal temperature gradients from deep borehole drillings (Fig. 2).
- ✓ Modification of accumulation rates: higher accumulation leading to higher vertical advection (instead of a paleo-reconstruction).
- ✓ Calculation of temperature *T* and calibration of model (velocity *v*, temperature, …) (Fig. 4).
- ✓ $$\frac{\partial T}{\partial t} = \nabla\left(\frac{k}{\rho c}\nabla T\right) - v\cdot\nabla T - \frac{2}{\rho c}\varepsilon\sigma$$

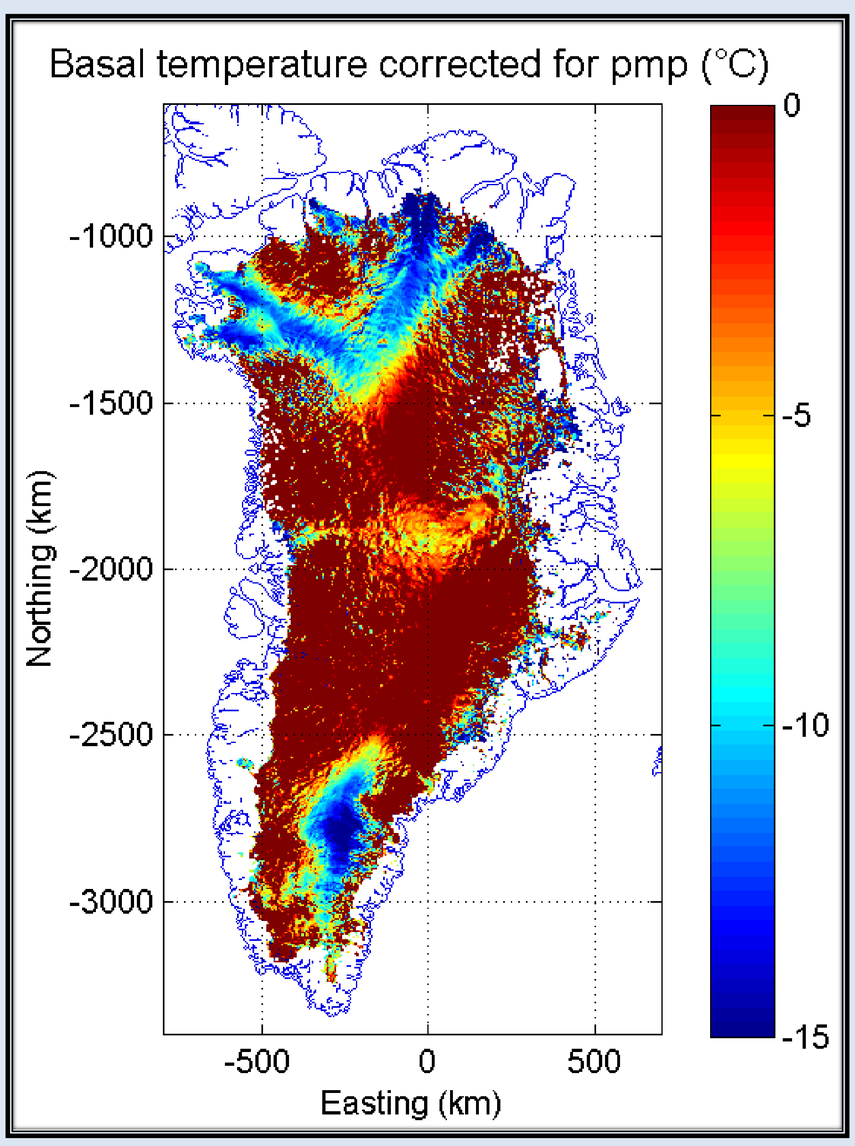

Fig 4. Basal temperature corrected for pressure melting (°C) truncated at -15 °C

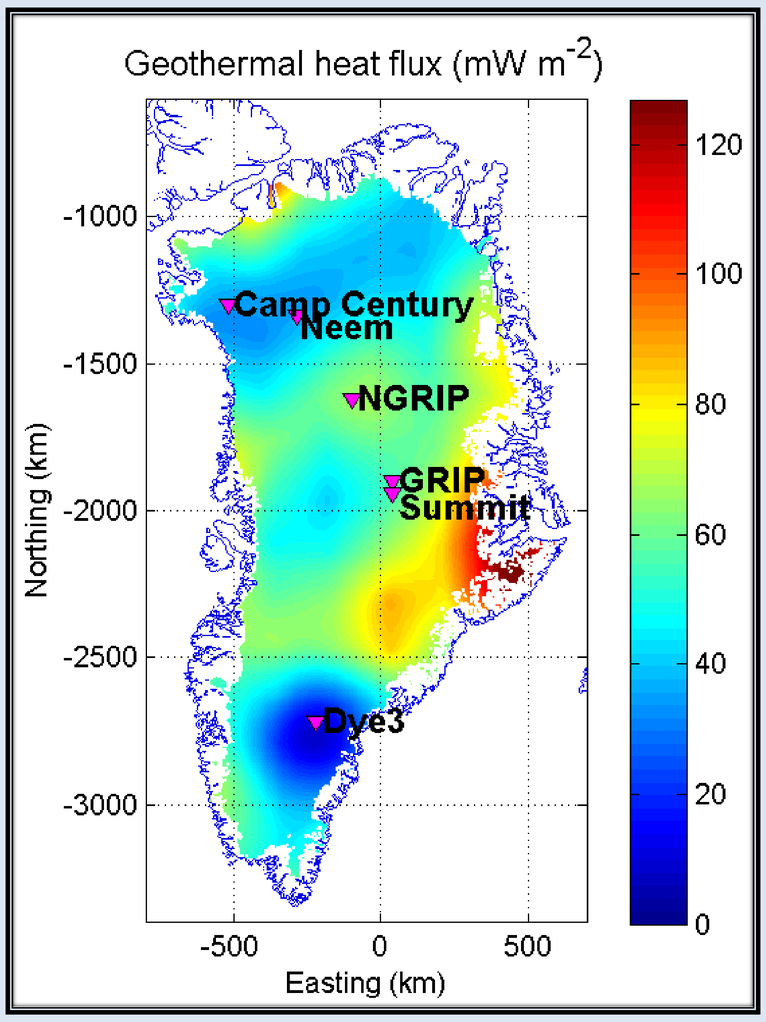

Fig 2. GHF database (mW m^{-2}) Purucker (2013) and gaussian correction. Magenta triangles denote the major drilling sites.

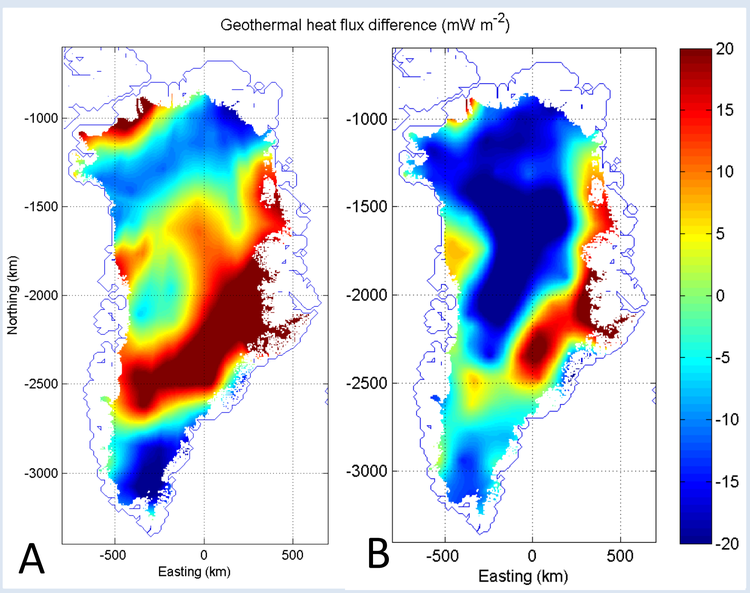

Fig 3. A: Geothermal heat flux difference between Shapiro/Ritzwoller and Purucker data sets truncated at -20 and 20 mW m^{-2}. Positive values denote higher GHF in the Purucker data set. B: Geothermal heat flux difference between Fox-Maule et al. and Purucker data sets truncated at -20 and 20 mW m^{-2}. Positive values denote higher GHF in the Purucker data set.

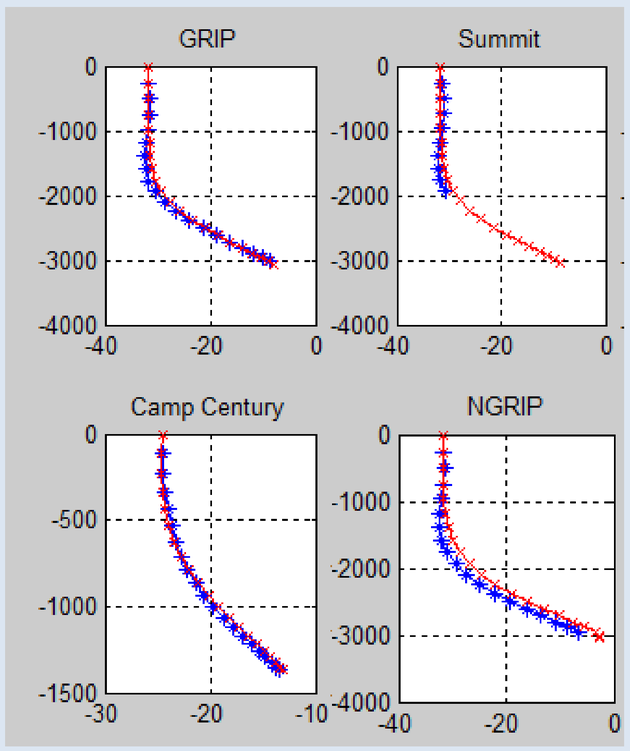

Fig 5. Observed (blue) and modelled (red) temperature profiles (◦C).

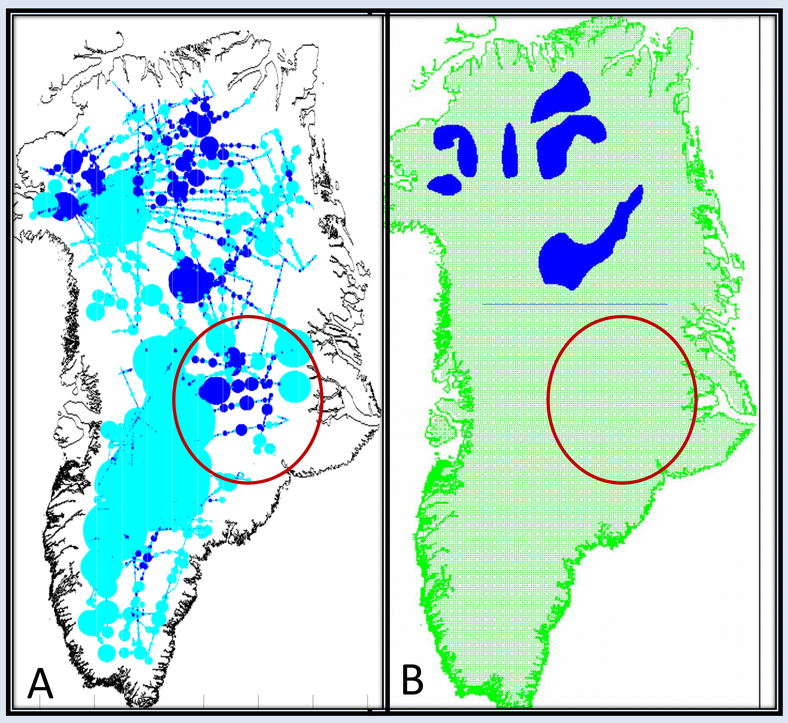

Fig 6. A: Areas of thawed (dark blue) and freezed (light blue) bed, proposed by Oswald at Castine workshop (May 2011) B: Oswald and Gogineni: mapping basal melt under the northern greenland ice sheet, (blue) Areas in which a large proportion of the bed is thawed and extensive effective continuity is found. The outlines are drawn manually to provide an overview.

III. Results and outlook

- Accumulation rate (responsible for vertical advection), velocity field and geothermal heat flux are the major parameters controlling the basal temperature.
- A large part of the Greenland ice sheet is at the pressure melting point. At some places in contradiction with the Oswald's thawed map (Fig. 6).

In the future :

- ✓ Make a glacial-interglacial paleo-reconstruction: variation of precipitations is high during this transition (time dependency).
- ✓ Use the thawed condition map to constrain the model (as with the subglacial lakes in Antarctica) and RES data.
- ✓ Produce a ensemble model using different GHF data sets (Fig. 3A, 3B)

References

1. Van Liefferinge, B. and Pattyn, F., 2013, Using ice-flow models to evaluate potential sites of million year-old ice in Antarctica, Clim.Past, 9, 2335-2345.
2. Pattyn, F., 2010. Antarctic subglacial conditions inferred from a hybrid ice sheet/ice stream model, Earth Planet. Sci. Lett. 295, 451-461.
3. Bamber,J., et al., 2013, A new bed elevation dataset for Greenland, the cryosphere, 7, 499–510
4. Oswald, G., and Gogineni, S., 2012, mapping basal melt under the northern greenland ice sheet, IEEE transactions on geoscience and remote sensing, vol. 50, no. 2
5. Purucker, M., 2013, Geothermal heat flux data set based on low resolution observations collected by the CHAMP satellite between 2000 and 2010, and produced from the MF-6 model following the technique described in Fox Maule et al. (2005), http://websrv.cs.umt.edu/isis/index.php/Greenland_Basal_Heat_Flux
6. Rignot, E., Mouginot, J., 2012, ice flow in greenland for the international polar year 2008–2009, geophysical research letters, vol. 39, l11501