An evaluation tool for detecting potential sites of million year-old ice in Antarctica

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The challenge

•Finding continuous and undisturbed 1.5 million year-old ice is a keystone to understand the quaternary climate and the mid-Pleistocene transition (MPT) enigma.[2,3]

•Obtaining suitable potential sites of million year-old ice in Antarctica requires:

- **Thick ice** to resolve the signal at sufficient high resolution Sufficiently **high accumulation** to resolve lower layers;
- **Slow-moving ice** to prevent distortions due to ice flow;
- **Cold basal environment**, since old layers may not have melted away, which is in conflict with the good insulation of the ice induced by the thickness, increasing the likelihood of temperate bed conditions;
- The consideration of the uncertainty on the **geothermal heat flux** (GHF);

The simple model

BASIS: calculation of the minimum GHF needed to reach the pressure-melting point at the bottom.

METHODOLOGY analytical model, valid in the absence of horizontal ice advection.[5]

- Accumulation rate, thickness and surface temperature from the same data sets as the ensemble model;
- Correction of the areas where subglacial lakes were detected; [7]

•EXPERIMENTAL FRAMEWORK:

- Combination of the 3 GHF data sets (G_{mean})
- Calculation of uncertainties (σ_G)

•RESULTS:

- Maximum GHF (mWm^{-2}) needed to keep the bed below the pressure-melting point (G_{min}).

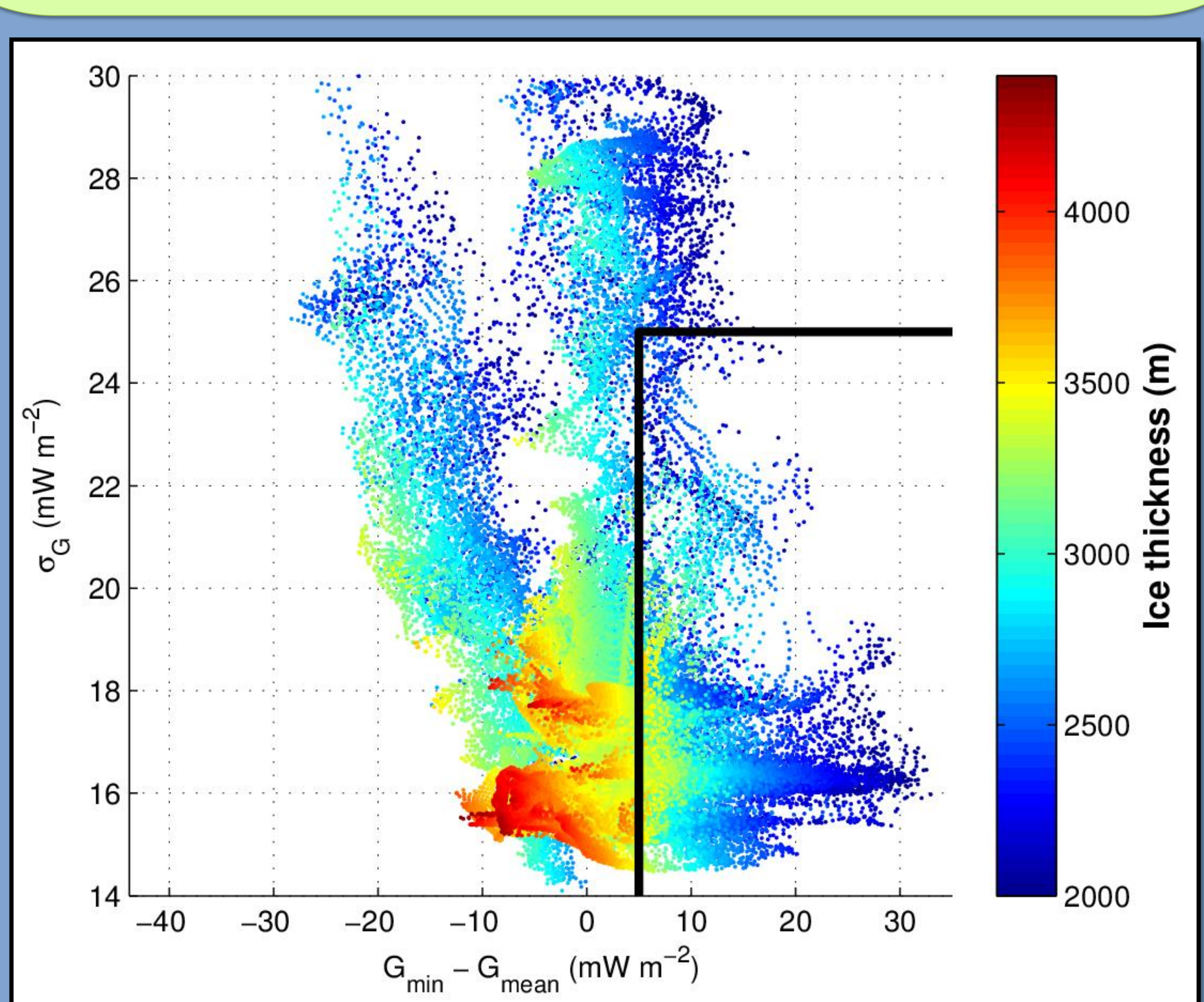

Fig 1. Scatter plot of $\Delta G = G_{min} - G_{mean}$ versus σ_G for all points with ice thickness H > 2000m and horizontal flow speed $<2myr^{-1}$. The color scale depicts ice thickness for each of the grid points. Negative values of ΔG show where the pressure-melting point is reached, hence basal melt occurs. Positive values mean that the minimum required heat flow to reach the pressure-melting point is higher than the mean of the three GHF data sets. Points lying within the rectangle are likely to be cold-based, taking into account the variability of GHF.

The matlab tool

- Allows:

-choice of parameters on: the velocity field, the ice thickness, the basal temperature.

-results depicted for the simple model, the ensemble model and both models.

- Creates:

-a txt file with the planimetric and geographic coordinates, ice thickness, basal temperature and velocity field.

-a ".bin" and a ".hdr" file to use in gis.

- Available on:

http://homepages.ulb.ac.be/~bvlieffe/old-ice.html

Potential drilling sites

•Unfortunately, the Antarctic ice sheet is generally warm-based, especially in the interior where ice is thick, so the best places to drill are most likely the warmest.

However:

a) Subglacial mountain areas (Gamburtsev Subglacial mountains) are potentially of interest, but high local variability (not resolved by model) may lead to large variations (deeply incised valleys may be prone to temperate basal conditions).

•B) In the vicinity of known drilling sites (Dome C, Dome F, Dome A), conditions may be favourable.

•Your turn to discover potential sites using the matlab tool.

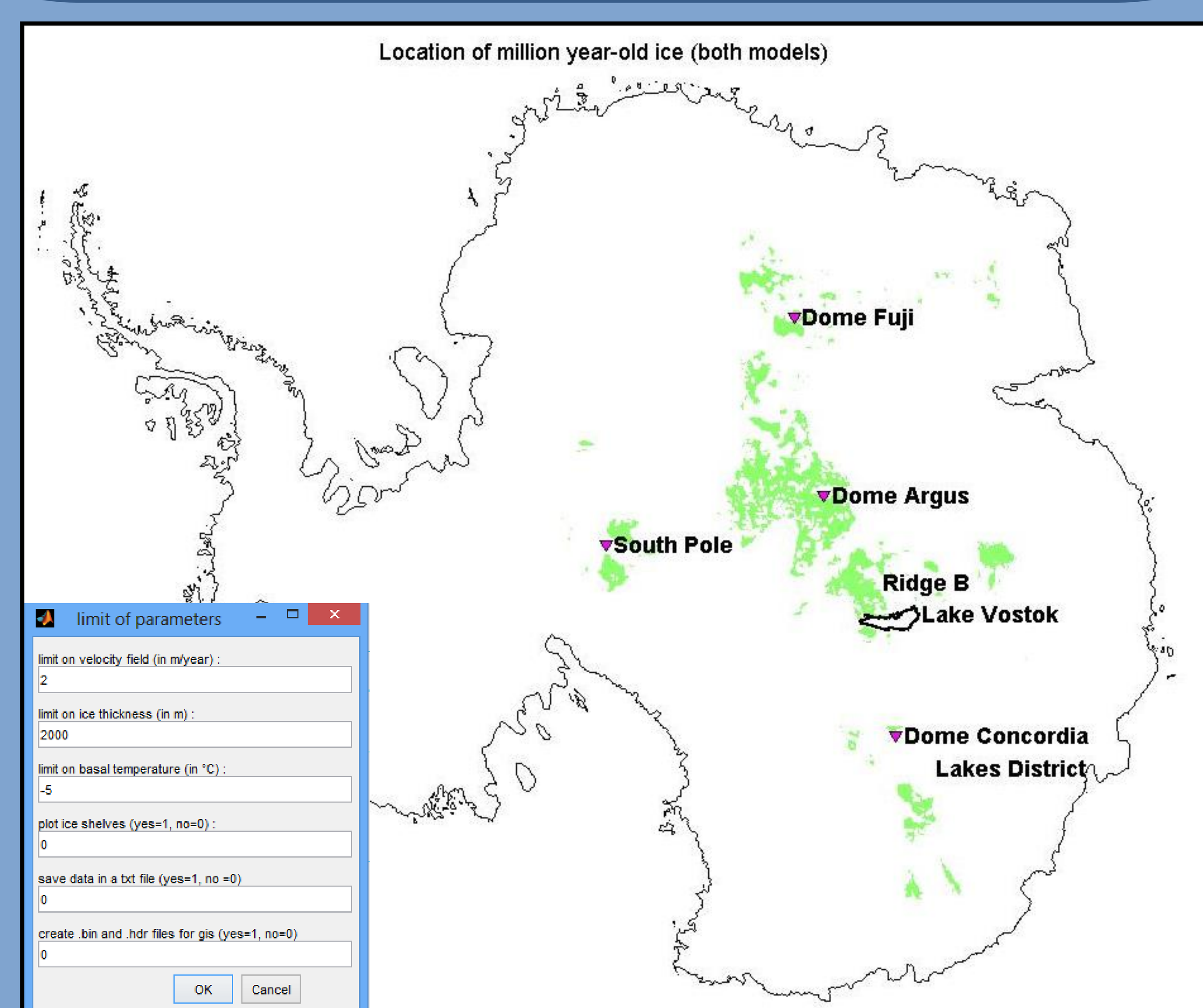

Fig 2. Potential locations of cold basal conditions in areas with ice thickness H > 2000 m, and horizontal flow speeds $<2myr^{-1}$ according to both models. Inset = the matlab prompt box for the choice of parameters.

The ensemble model

•BASIS: thermodynamical model coupled with present-day ice sheet geometry and environmental conditions. [4]

•METHODOLOGY similar to Pattyn (2010) [4], updated and adapted to specifically delineating potential drilling areas

- Surface topography and ice thickness updated from Bedmap2 on 5 km resolution;
- Horizontal flow field obtained from heuristic rule combining interferometric velocities with modelled estimates;
- 3 different sets of GHF: Fox Maule, Shapiro & Ritzwoller, Puruker[8];
- Correction of GHF via measured temperature profiles & subglacial lake inventory[7];
- Correction of surface velocities across large subglacial lakes with ice stream model.

•EXPERIMENTAL FRAMEWORK:

- 15 experiments (3 GHF datasets combined with different types of corrections on GHF using subglacial lake proxies, i.e. influence zones).

•RESULTS:

- Likelihood of cold basal temperatures as a function of environmental and geometrical parameters.

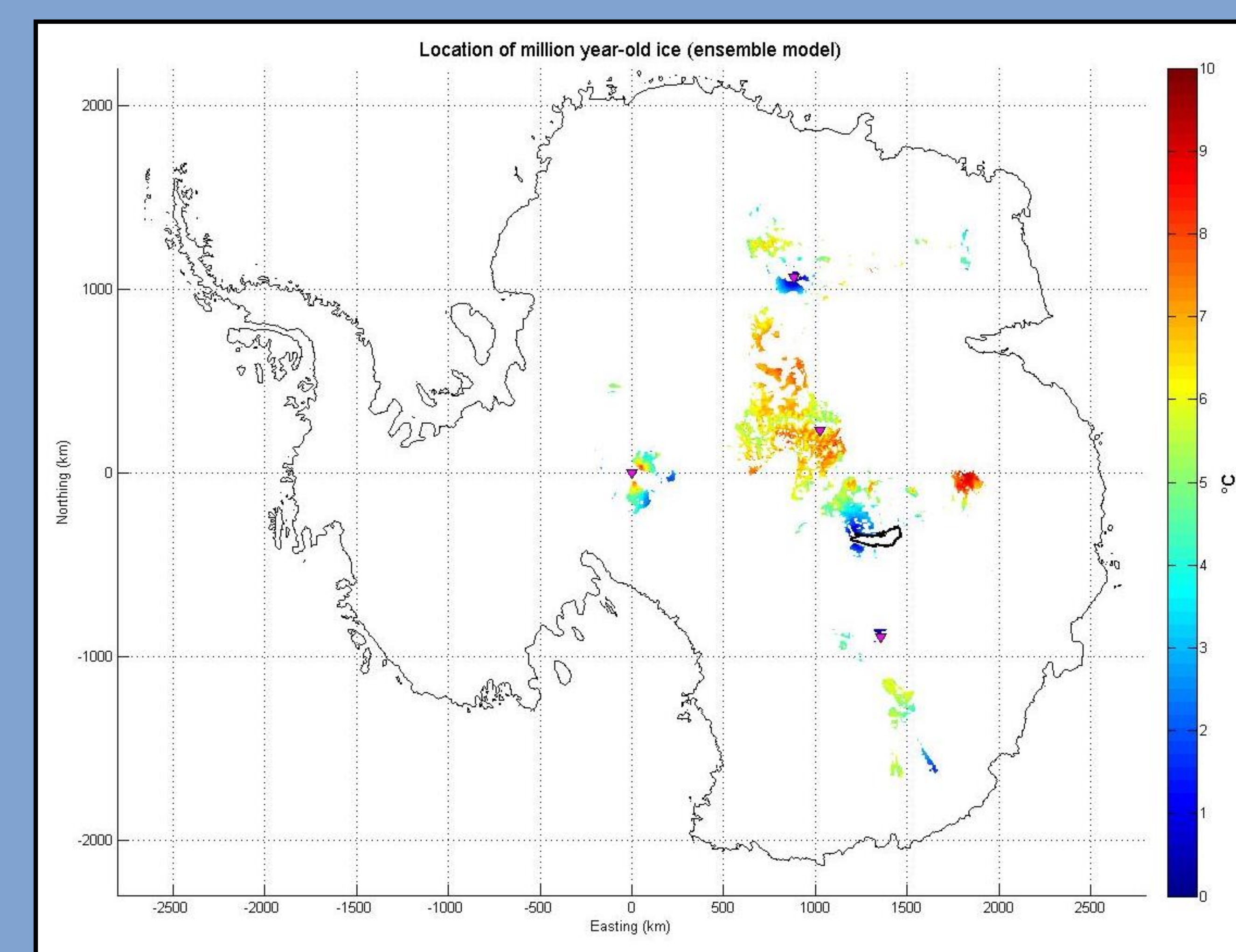

Fig 3. Potential locations of cold basal conditions in areas with ice thickness H > 2000 m, and horizontal flow speeds $<2myr^{-1}$ and basal temperatures as calculated with the full model <−5 C. The colorbar denotes the RMSE (°C) based on the ensemble calculations.

References

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