A revised evaluation of Antarctic subglacial conditions and the contribution of basal melt to present day sea-level rise

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I. Introduction and method

- Antarctic subglacial conditions can be elucidated through several techniques. However, since direct measurements are only limited to a few deep drillings to the bed, a substantial amount of ice sheet and thermodynamical modeling is always involved. This can be done based either on a fully coupled thermomechanical ice sheet model, or on a thermodynamical model coupled with present-day ice sheet geometry and environmental conditions.
- Based on the method of Pattyn (2010), we present an update of the basal temperate conditions using new data of bedrock elevation, ice thickness (Le Brocq et al. 2010), observed surface velocities obtained from interferometric analysis (Rignot et al. 2011) and a new subglacial lakes inventory (Wright et al., under review).
- This revised calculation of the englacial temperature field allows us to improve our knowledge of basal melting and its contribution to present-day sea-level rise.

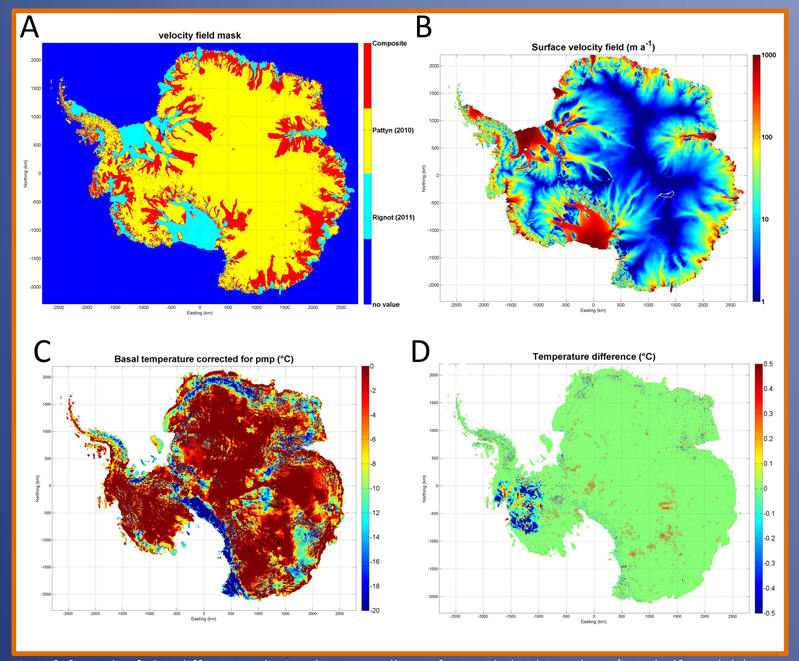

Fig 1 [A] Mask of the different velocity data. In yellow: from a hybrid ice sheet/ice shelf model (Pattyn 2010), in light blue: obtained from interferometric analysis (Rignot et al. 2011), in red obtained by mixing these two data. [B] Antarctic ice velocity field derived from Rignot et al. (2011) and Pattyn (2010) truncated at 1000 m a^{-1}. The white line indicates the subglacial Lake Vostok. [C] Mean basal temperature corrected for pressure melting (°C). [D] Basal temperature difference between this study and Pattyn (2010) (°C) truncated at -0.5 and 0.5. Subglacial lakes used to constrain GHF are shown in red circles.

- ✓ Calculation of a new surface velocity field (Fig. 1A-B) and incorporation of new data sets.
- ✓ Incorporation of subglacial lake distribution to correct geothermal heat flux (GHF) distribution
- ✓ Calculation of temperature *T* and basal melt, calibration of model (velocity *v*, temperature, …)
- ✓ $$\frac{\partial T}{\partial t} = \nabla\left(\frac{k}{\rho c}\nabla T\right) - v\cdot\nabla T - \frac{2}{\rho c}\varepsilon\sigma$$
- ✓ Analysis of 18 experiments (6 sets of corrected GHF x 3 sets of lake influence areas)
- ✓ New estimates are compared with the initial basal temperature calculation and melt rate (Pattyn, 2010)

II. Basal temperature

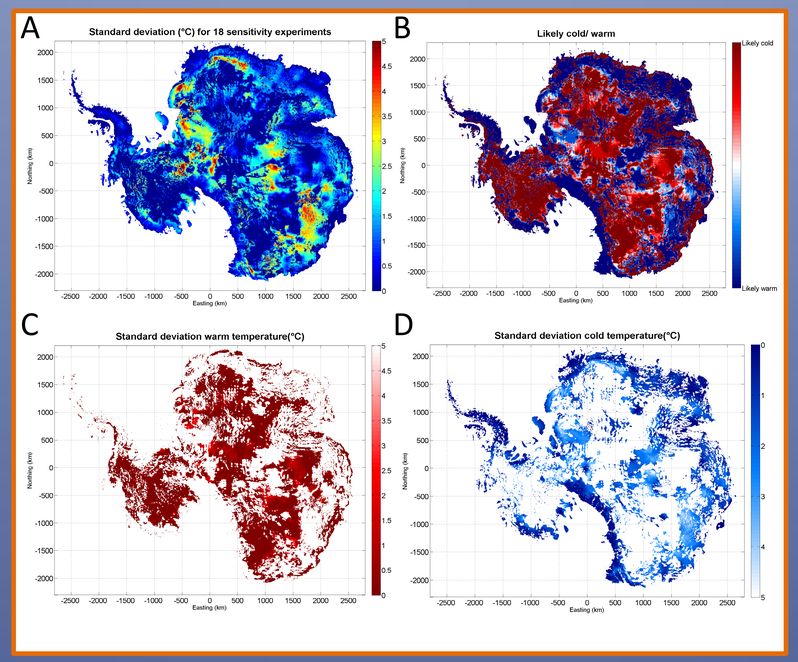

Fig 2. [A] Standard deviation (°C) for the 18 sensitivity experiments. [B] Likelihood of cold and warm bed (scale from 0: cold-based in all experiments; to 18: warm in all experiments). [C] Standard deviation (°C) for the 18 sensitivity experiments and where the likelihood of T is warm. [D] Standard deviation (°C) for the 18 sensitivity experiments and where the likelihood T is cold.

- More than 50 % of the grounded part of the Antarctic ice sheet is at pressure melting point (Fig. 2).
- The differences of temperature between this study and the result of Pattyn (2010) are minor (Fig. 1D).
- The incorporation of subglacial lakes allows to refine GHF estimates and to map small-scale variability in basal temperature conditions.

References

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3. Rignot, E., Mouginot, J., Scheuchl, B., 2011. Ice Flow of the Antarctic Ice Sheet, Science 333, 1427-1429.
4. Wright, A., Siegert, M., The Identification and Physiographical Setting of Antarctic Subglacial Lakes: An Update Based on Recent Discoveries (under review).
5. Tulaczyk, S., Hossainzadeh, S., 2011. Antarctica's Deep Frozen "Lakes", Science 331, 1524-1525.
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III. Basal melt rate

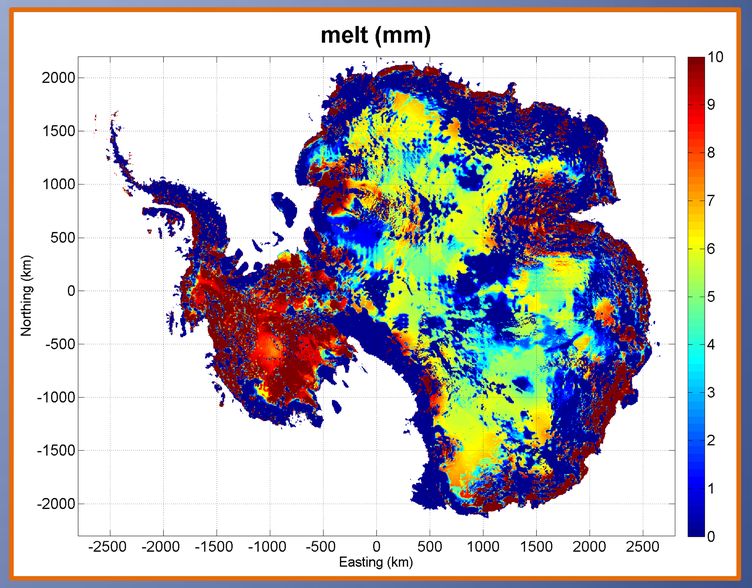

Fig 3. Mean basal melting rate truncated at 10 mm $year^{-1}$

- Highest basal melt rate occurs in WAIS (Fig. 3.).
- The mean basal melt rate is about 65 Gt $year^{-1}$ (Tab. 1).
- New data from AGAP (Antarctica's Gamburtsev Province) and BEDMAP2 programs should improve the basal conditions.

	150	250	350
FM	72.2	74.4	77.5
SR	57.3	61.5	66.4
FM+SR	65.4	68.6	72.0
P	54.2	58.2	62.7
P+SR	55.8	59.8	64.5
FM+P+SR	61.4	64.7	68.4
Mean	61.1	64.5	68.6

Table 1. Total basal melt rate (Gt $year^{-1}$) underneath the grounded ice sheet for the 18 experiments (sets of geothermal heat flux (left) and sets of lake influence areas (top, in km)).

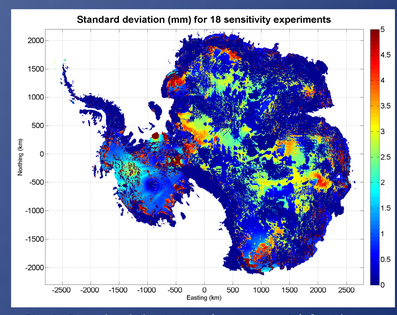

Fig 4. Standard deviation (mm year-1) for the 18 sensitivity experiments.

IV. Take home message

- **Ice thickness and velocities influence most the basal temperature.**
- **Antarctic ice sheet is generally warm-based: 55% of bed at pmp.**
- **New datasets have improved ensemble calculations of Pattyn (2010).**
- **Basal melt rates of 65 Gt $year^{-1}$; 3% of surface mass balance.**