

Supplementary Info

Sect S1 - Datasets used in comparison plots

Climate Model Comparison

We use outputs from three regional climate models for comparison purposes with the SMB BHM posterior, RACMO2.3p2 (~5.5 km and ~27 km resolution) (Melchior Van Wessem et al., 2018; van Wessem et al., 2016) and MARv3.6.4 (35 km resolution) (Agosta et al., 2019). As the observations used in the BHM represent deviations in ice sheet height or mass from a balance state, we calculate annual anomalies at the ice sheet basin and sector scale with reference to a 1979-2002 baseline mean for each model. For comparison of elevation changes between the RACMO ~5.5km model and the BHM output, the modelled SMB mass change was converted to elevation change using the surface density field of the model output.

Ice Discharge Comparison

For comparison of ice discharge estimates from the mass budget approach with the ice dynamics posterior in our study, we use the latest 40-year time series of annual Antarctic ice discharge (Rignot et al., 2019 - Supplementary Dataset 1). To enable comparison with the anomaly discharges presented in our study we calculate the ice discharge anomalies for 2003 – 2017 period w.r.t the mean annual discharge over the 1979 – 2002 period. The 1σ uncertainties on the discharge are given as the standard deviation of the reference ice discharge as calculated from the reference velocity map used in the study.

Ice Sheet Mass Balance Exercise (IMBIE) Comparison

IMBIE annual mass trends (Shepherd et al., 2018) for the Antarctic Peninsula are determined through calculation of the difference in cumulative mass at the calendar year end (Jan 1st) with that of the previous year. The cumulative time series can be found in the supplementary material of (Shepherd et al., 2018).

Text S2 – West Palmer Land Δ velocity methodology

In order to estimate changes in ice sheet velocity for the West Palmer Land region (basin Hp-I) over the 2003-2019 period of this study, we utilise annual observations of ice sheet velocity from the MEaSURES program (Mouginot et al., 2017a, 2017b). The dataset consists of annual ice sheet velocity mosaics, with each year consisting of data between July 1st of one year to June 30th the following year. The data is posted at 1 km spatial resolution (EPSG:3031). The observations are derived primarily from speckle tracking of Synthetic Aperture Radar (SAR) image acquisitions, with the inclusion of Landsat-8 optical image tracking after 2013.

Spatial coverage over the Hp-I basin is somewhat limited prior to 2013, due to SAR scene availability and the ability to coherently track speckle patterns in regions where there are large variations in snowfall accumulation (e.g. Western side of the Antarctic Peninsula). Therefore, to maximise spatial coverage, we merge the annual velocity products by taking the mean x and y velocity components for acquisitions over two time periods, 2005-2011 and 2011-2017. The subsequent velocity magnitudes from these two time periods are then differenced (Fig S1b) in order to estimate changes in ice surface velocity between the two epochs.

Table S2 – Comparison Studies Used in Antarctic Peninsula Mass Balance Comparison

Study	Observation Approach	Drainage Basin	Time period	Mass Trend \pm 1σ Gt yr⁻¹
McMillan <i>et al</i> (2014)	Altimetry/SEC	Zwally <i>et al</i> (2012)	2010 – 2013	-23 \pm 18
Rignot <i>et al</i> (2019)	IOM	Rignot <i>et al</i> (2013)	1999 - 2009	-29.1 \pm 3
Rignot <i>et al</i> (2019)	IOM	Rignot <i>et al</i> (2013)	2009 - 2019	-45.1 \pm 3
Rignot <i>et al</i> (2008)	IOM	Rignot <i>et al</i> (2013)	2006 - 2007	-60 \pm 46
Zwally <i>et al</i> (2015)	Altimetry/SEC	Zwally <i>et al</i> (2012)	2003- 2008	-29 \pm 2
Luthcke <i>et al</i> (2013)	Gravimetry	Luthcke <i>et al</i> (2013)	2003 - 2010	-37.7 \pm 14
Schröder <i>et al</i> (2018)	Altimetry/SEC	Rignot <i>et al</i> (2013)	1992 - 2010	2.8 \pm 12.3
Schröder <i>et al</i> (2018)	Altimetry/SEC	Rignot <i>et al</i> (2013)	2010 - 2017	-4.5 \pm 8.7
Velicogna <i>et al</i> (2014)	Gravimetry	Velicogna <i>et al</i> (2014)	2003 - 2013	-31 \pm 4
Smith <i>et al</i> (2020)	Altimetry/SEC	Zwally <i>et al</i> (2012)	2003 - 2019	-39 \pm 5
Martin-Espanol <i>et al</i> (2016)	Combination	Sasgen <i>et al</i> (2013)	2003 - 2006	8.3 \pm 7.7
Martin-Espanol <i>et al</i> (2016)	Combination	Sasgen <i>et al</i> (2013)	2007 - 2009	-30.7 \pm 6.8
Martin-Espanol <i>et al</i> (2016)	Combination	Sasgen <i>et al</i> (2013)	2010 – 2013	-62.2 \pm 7.4
Martin-Espanol <i>et al</i> (2016)	Combination	Sasgen <i>et al</i> (2013)	2003 - 2013	-28 \pm 7.2
Shepherd <i>et al</i> (2018)	Altimetry/SEC	Rignot <i>et al</i> (2013)	2003 - 2010	-10 \pm 9
Shepherd <i>et al</i> (2018)	Gravimetry	Rignot <i>et al</i> (2013)	2003 -2010	-23 \pm 5
Shepherd <i>et al</i> (2018)	IOM	Rignot <i>et al</i> (2013)	2003 - 2010	-51 \pm 24

Table S3 – Comparison Studies Used in West Palmer Land (IMBIE Basin Hp-I)

Study	Observation Approach	Drainage Basin	Time Period	Mass Trend \pm 1σ Gt yr⁻¹
Wouters <i>et al</i> 2015	Gravimetry	Zwally <i>et al</i> (2012)	2003 -2005	3 \pm 20
Wouters <i>et al</i> 2015	Gravimetry	Zwally <i>et al</i> (2012)	2007 - 2009	-11 \pm 13
Wouters <i>et al</i> 2015	Gravimetry	Zwally <i>et al</i> (2012)	2003 - 2009	-5 \pm 7
Wouters <i>et al</i> 2015	Gravimetry	Zwally <i>et al</i> (2012)	2010 - 2014	-34 \pm 12
Wouters <i>et al</i> 2015	Altimetry/SEC	Zwally <i>et al</i> (2012)	2003 - 2005	12 \pm 18
Wouters <i>et al</i> 2015	Altimetry/SEC	Zwally <i>et al</i> (2012)	2007 - 2009	-6 \pm 13
Wouters <i>et al</i> 2015	Altimetry/SEC	Zwally <i>et al</i> (2012)	2003 - 2009	2 \pm 19
Wouters <i>et al</i> 2015	Altimetry/SEC	Zwally <i>et al</i> (2012)	2010 - 2014	-35 \pm 7
Sasgen <i>et al</i> 2019	Combination	Sasgen <i>et al</i> (2013)	2011 - 2017	-1.3 \pm 24
Sasgen <i>et al</i> 2019	Altimetry/SEC	Sasgen <i>et al</i> (2013)	2011 - 2017	10.5 \pm 3.2
Sasgen <i>et al</i> 2019	Gravimetry	Sasgen <i>et al</i> (2013)	2011 - 2017	-1.2 \pm 2.9
Sasgen <i>et al</i> 2019	Gravimetry	Sasgen <i>et al</i> (2013)	2011 - 2017	-4 \pm 0
Sasgen <i>et al</i> 2019	Gravimetry	Sasgen <i>et al</i> (2013)	2011 - 2016	-13.6 \pm 0
Smith <i>et al</i> 2020	Altimetry/SEC	Zwally <i>et al</i> (2012)	2003 - 2019	-14 \pm 3
Mcmillan <i>et al</i> 2014	Altimetry/SEC	Zwally <i>et al</i> (2012)	2010 - 2013	-11 \pm 11

Figure S1 – 2010 Posterior Standard Deviation Uncertainties

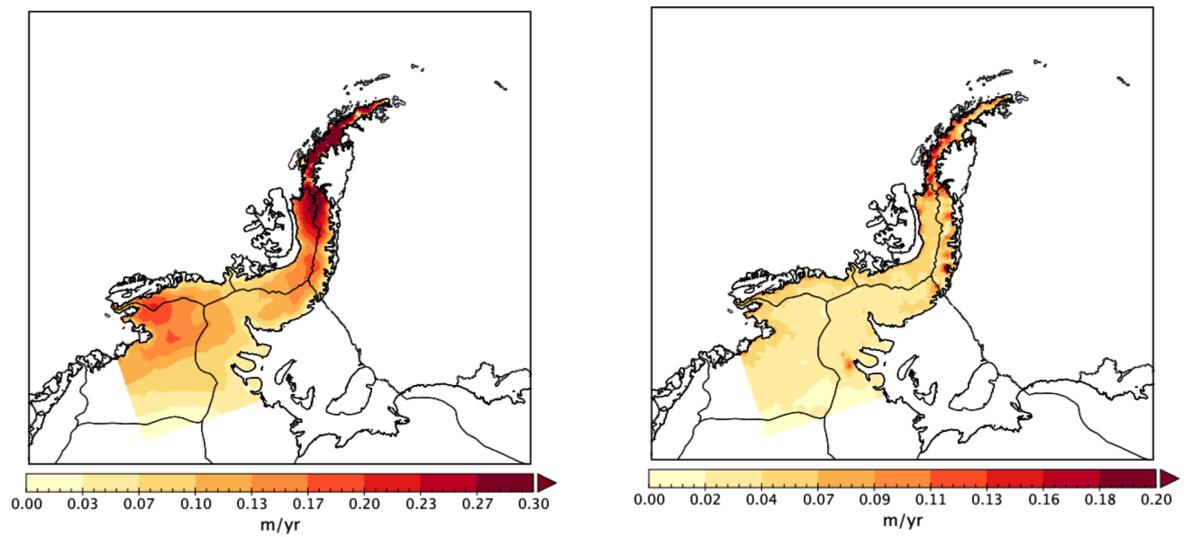


Figure S1 - **Left**) Posterior standard deviation of the SMB spatial field for the year 2010. **Right**) Posterior Standard deviation of the ice dynamics process posterior for the year 2010. Basin outlines (Rignot et al., 2011, 2013), grounding line and ice shelf outlines are shown in black (Depoorter et al., 2013).

Figure S2 – Ice Shelf Basal Melting and grounded ice velocity differences for the George VI ice shelf

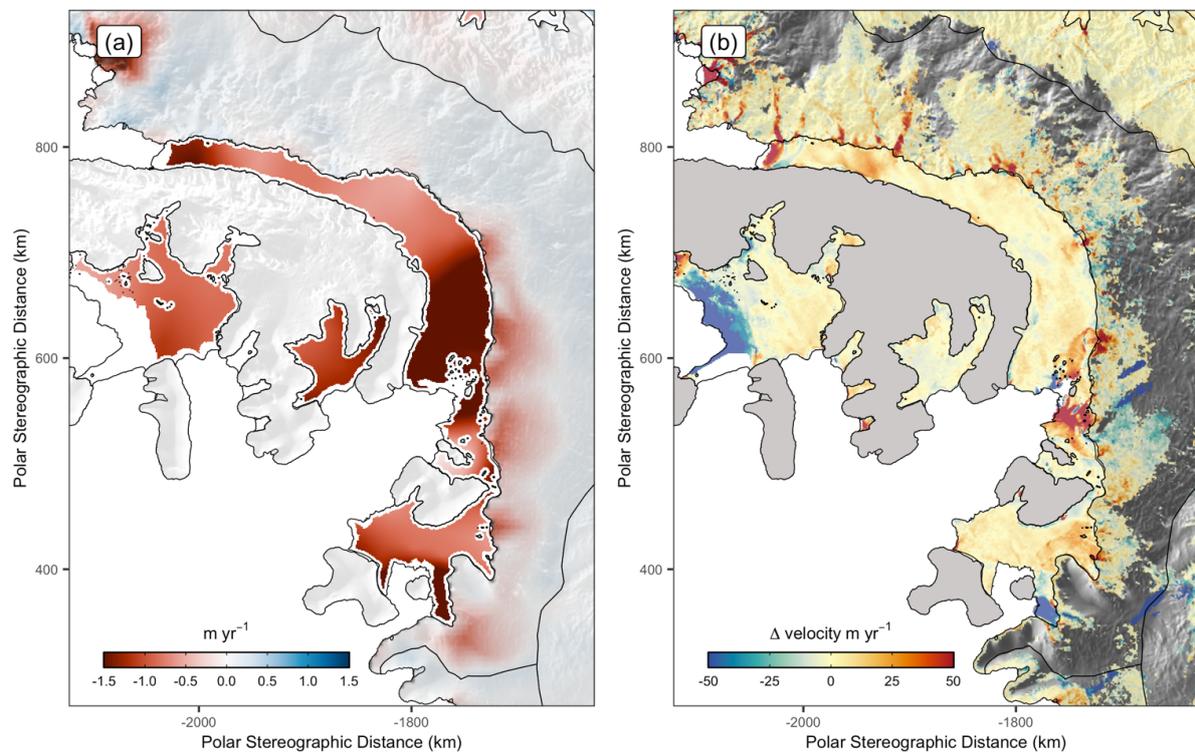


Figure S2 – a) Grounded ice sheet elevation trends due to ice dynamics over West Palmer Land (see Fig. 1 for location) for the year 2016 from the BHM solution plotted with the trend in net ice shelf mass balance for the period 1994–2016 derived from satellite altimetry (Adusumilli et al., 2018). **b)** Difference in velocity magnitude between the merged 2005 – 2011 and 2011–2017 merged velocity product (See text S2 for methodology). All data overlay over the REMA DEM hill shade (Howat et al., 2019)

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