Supplementary Materials to

How do extreme ENSO events affect Antarctic surface mass balance?

The Cryosphere

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Introduction

This supporting information provides supplementary figures, tables and text to the main manuscript of *How do extreme ENSO events affect Antarctic surface mass balance?*

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Section 1.1: Classifying Central Pacific and Eastern Pacific El Niño indices

Text S1.

Central Pacific (CP) El Niño events and Eastern Pacific (EP) El Niño events are classified in the same way as Macha et al. (2024) according to the Ren and Jin (2011) N_{CP} and N_{EP} indices respectively:

$$N_{EP} = N_3 - \propto N_4 \quad \text{(S1)}$$

$$N_{CP} = N_4 - \propto N_3 \quad \text{(S2)}$$

Where:

$$\propto = \begin{cases} \frac{2}{5} N_3 N_4 > 0, \\ 0, otherwise \end{cases}$$

Here, N_3 is the Niño-3 index, which is the SST anomaly averaged over the regions 5ºN--5ºS and 150º-90ºW, and N_4 is the Niño-4 index, which is the SST anomaly averaged over the regions 5ºN--5ºS and 160ºE--150ºW (Ren and Jin, 2011). Niño-3 and Niño-4 indices are sourced from NOAA (Rayner et al. 2003), based on the HadISST dataset. We use 3-month seasonal averages from 1979--2018 CP and EP El Niño indices (Equations 1; 2).

Section 2.1: Calculating Outliers

Text S2.

We identify outliers in each regional cumulative SON SMB anomaly dataset using Equations S1-S3 (Mudelsee, 2010) for Figure 5.

$$IQR = Q3 - Q1 \quad \text{(S3)}$$

$$Upper\ Outlier\ Bound = Q3 + 1.5\ IQR \quad \text{(S4)}$$

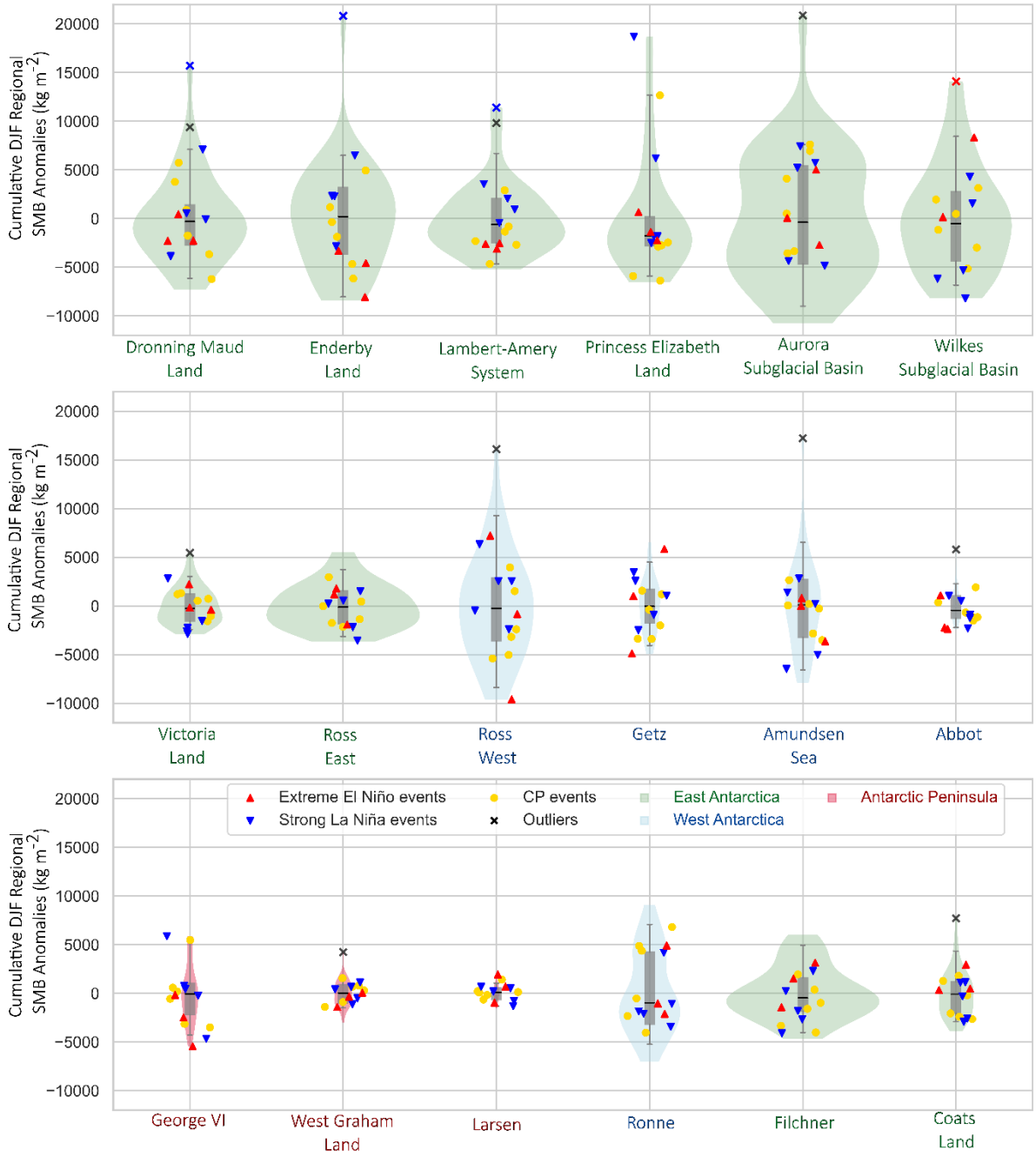
$$Lower\ Outlier\ Bound = Q1 - 1.5\ IQR \quad \text{(S5)}$$

where:

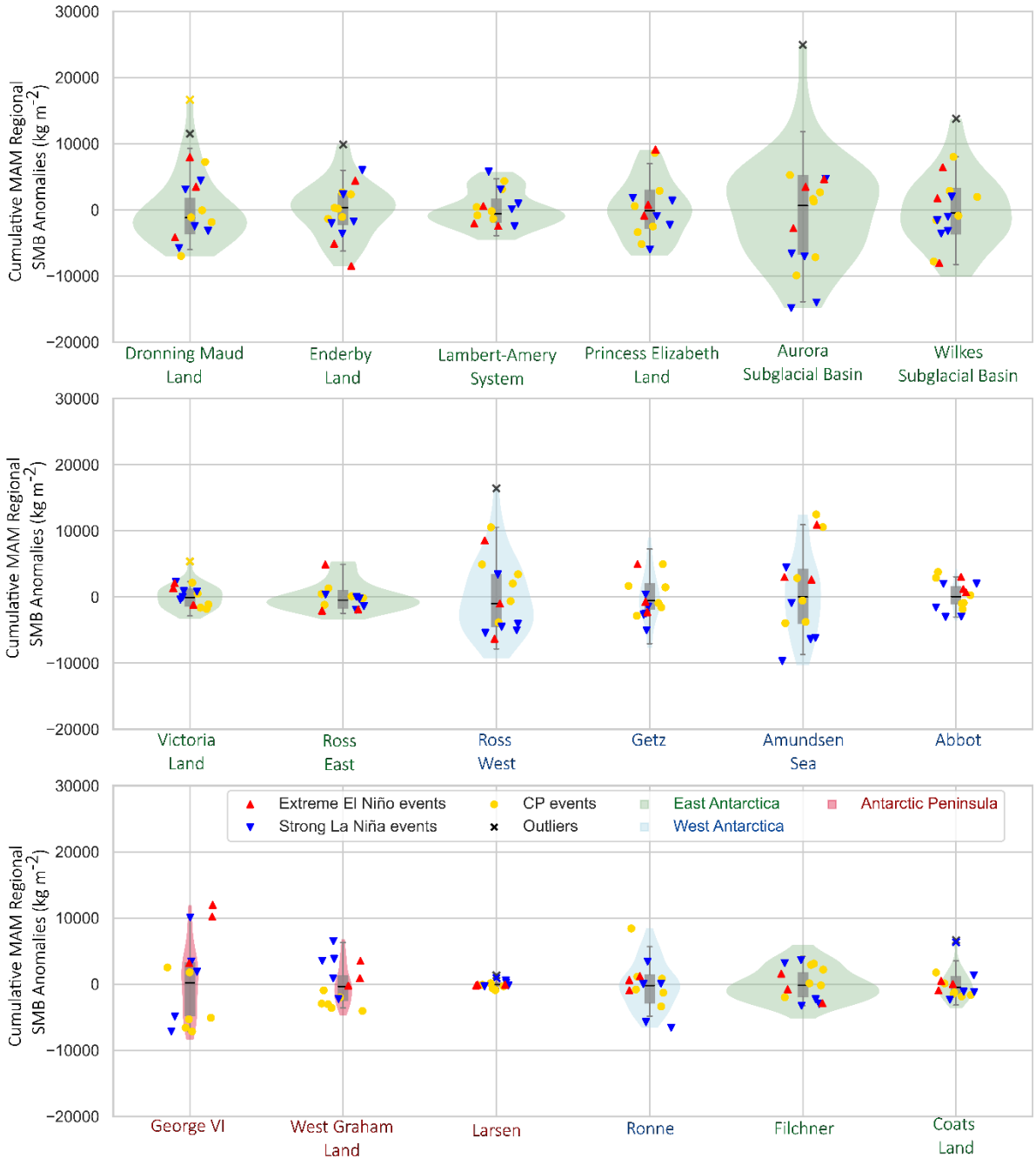
$Q1 = lower\ quartile\ (25th\ percentile)$

$Q3 = upper\ quartile\ (75th\ percentile)$

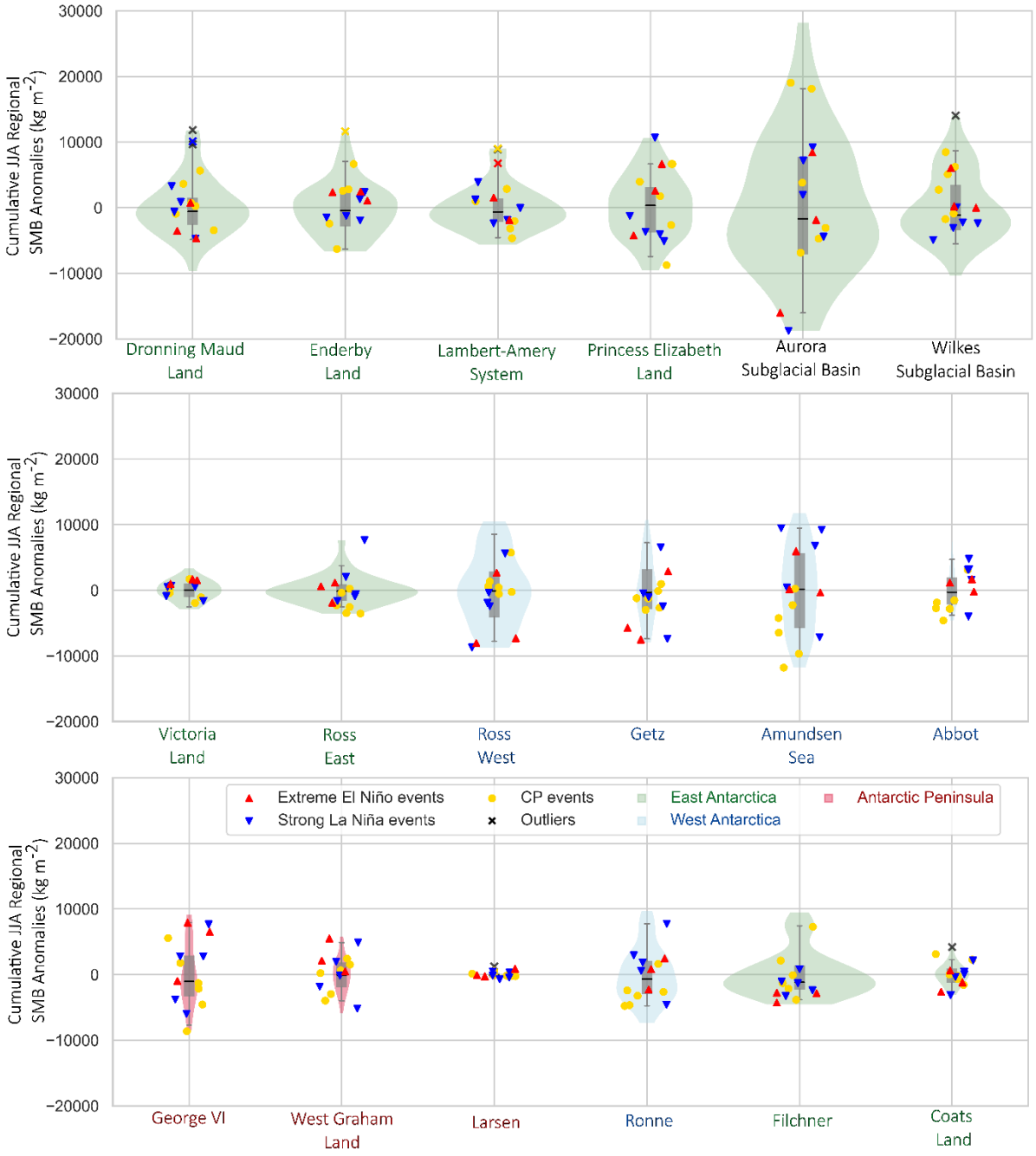
Section 3.1: Violin plots of SMB



Supplementary Figure S1. Relationship between extreme ENSO events and regional Antarctic surface mass balance anomalies during DJF. Density curves of regional cumulative DJF SMB anomalies for each Antarctic Ice Sheet regional catchment (a-j), scaled by the regional catchment size. Box plots show the interquartile range (IQR), with medians (black line) and whiskers (5th and 95th percentiles). East Antarctic (light green), West Antarctic (light blue) and Antarctic Peninsula (pink) catchments, outliers (crosses; see supplement), extreme El Niño events (red), strong La Niña events (blue) and Central Pacific El Niño events (yellow) are highlighted.



Supplementary Figure S2. Relationship between extreme ENSO events and regional Antarctic surface mass balance anomalies during MAM. Density curves of regional cumulative MAM SMB anomalies for each Antarctic Ice Sheet regional catchment (a-j), scaled by the regional catchment size. Box plots show the interquartile range (IQR), with medians (black line) and whiskers (5th and 95th percentiles). East Antarctic (light green), West Antarctic (light blue) and Antarctic Peninsula (pink) catchments, outliers (crosses; see supplement), extreme El Niño events (red), strong La Niña events (blue) and Central Pacific El Niño events (yellow) are highlighted.



88

89 **Supplementary Figure S3. Relationship between extreme ENSO events and regional**
90 **Antarctic surface mass balance anomalies during JJA**. Density curves of regional
91 cumulative JJA SMB anomalies for each Antarctic Ice Sheet regional catchment (a-j), scaled
92 by the regional catchment size. Box plots show the interquartile range (IQR), with medians
93 (black line) and whiskers (5th and 95th percentiles). East Antarctic (light green), West
94 Antarctic (light blue) and Antarctic Peninsula (pink) catchments, outliers (crosses; see
95 supplement), extreme El Niño events (red), strong La Niña events (blue) and Central Pacific
96 El Niño events (yellow) are highlighted.

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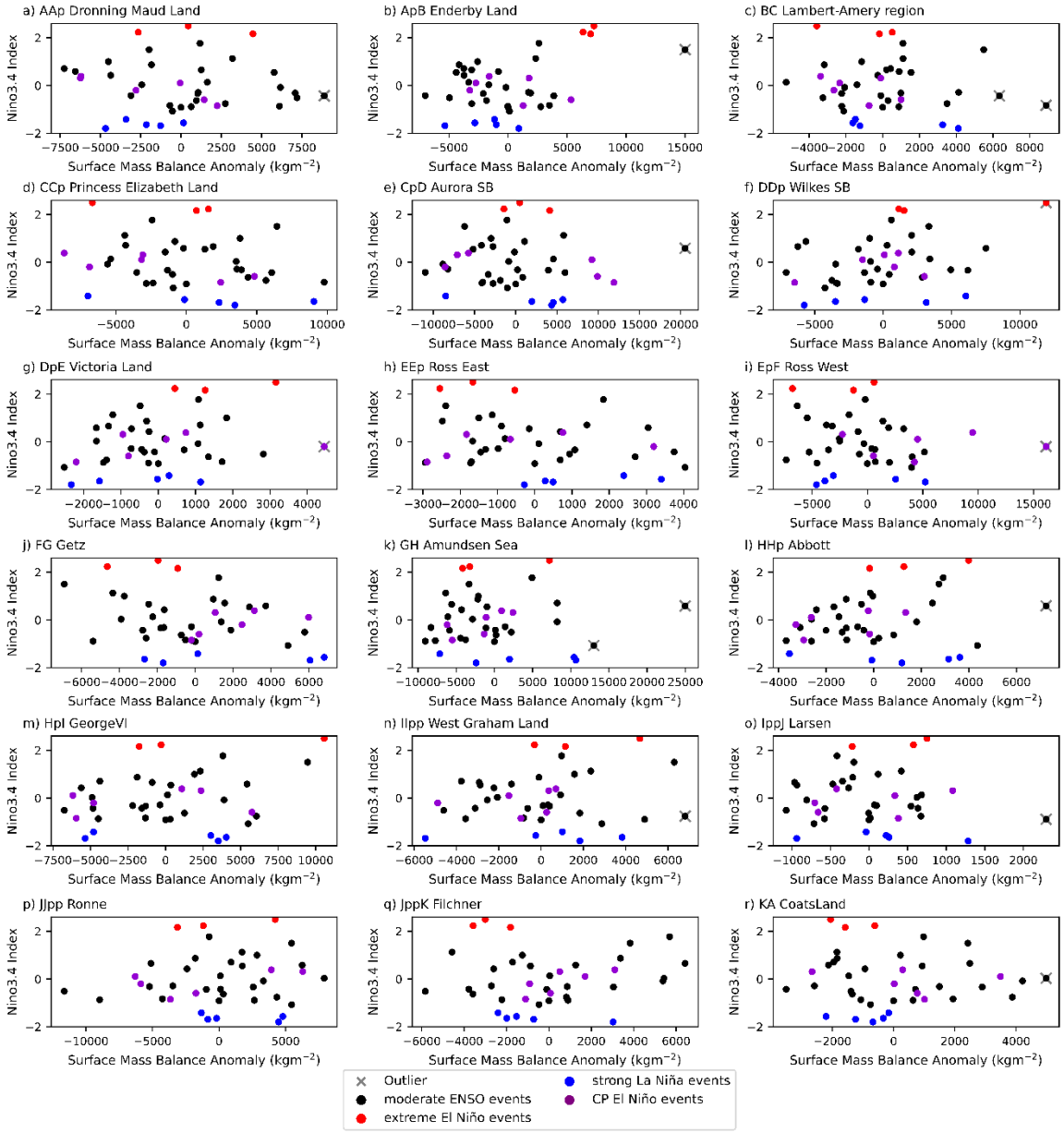
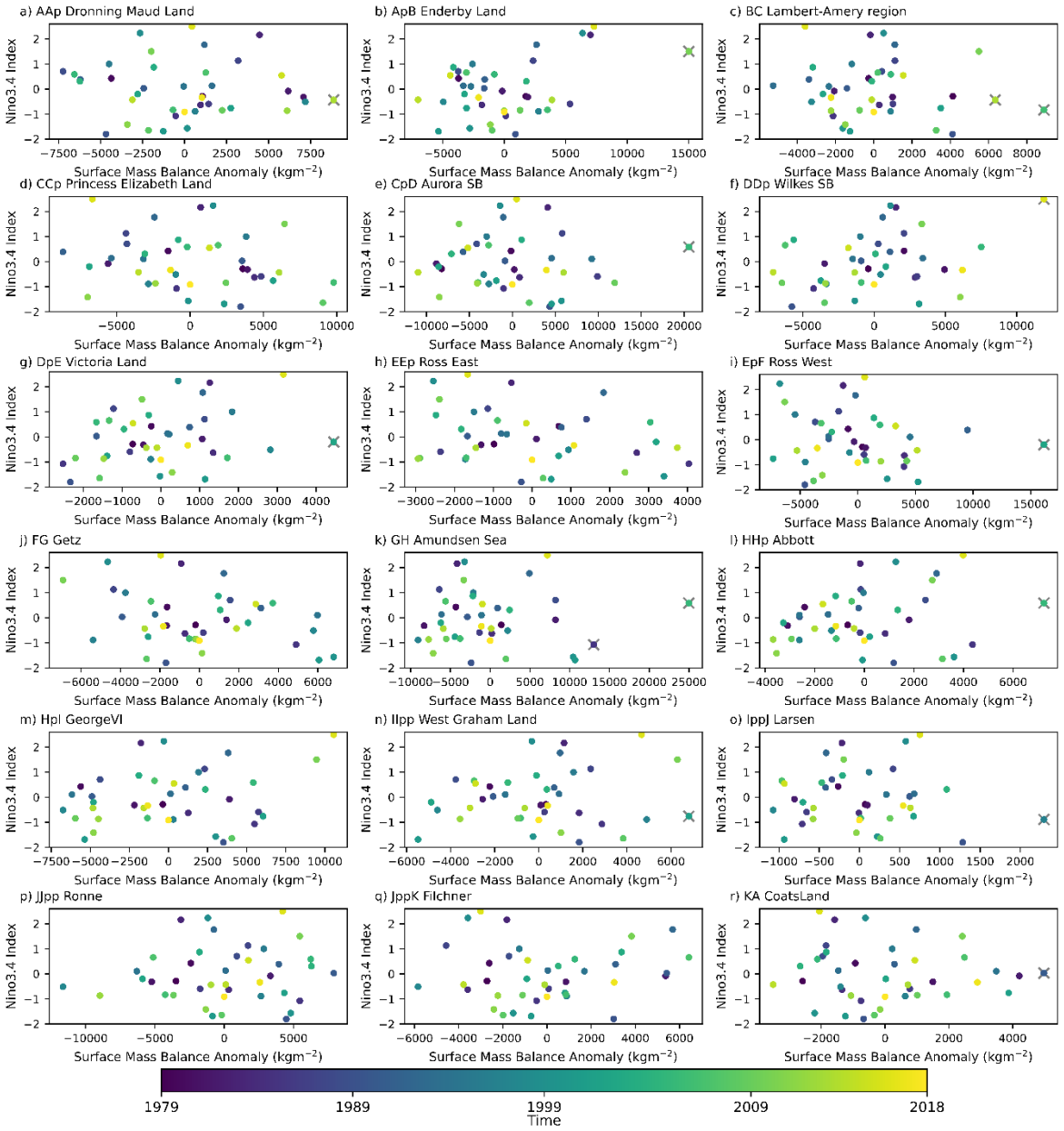
Section 3.2: Scatter plots of SMB



Supplementary Figure S4. Scatter plots of regional cumulative SON surface mass balance anomaly from 1979-2018 against the Niño3.4 Index across all Antarctic Ice Sheet regional basins (a-r). No trendlines are included as no trendline is statistically significant at the 5% confidence level using a two-tailed Students' *t* test. Outliers (grey cross), moderate ENSO events (black), extreme El Niño events (red), strong La Niña events (blue) and Central Pacific El Niño events (purple).



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107 **Supplementary Figure S5.** Scatter plots of regional cumulative SON surface mass balance
108 anomaly from 1979-2018 against the Niño3.4 Index across Antarctic Ice Sheet regional
109 basins (a-r), coloured according to year (colour bar).

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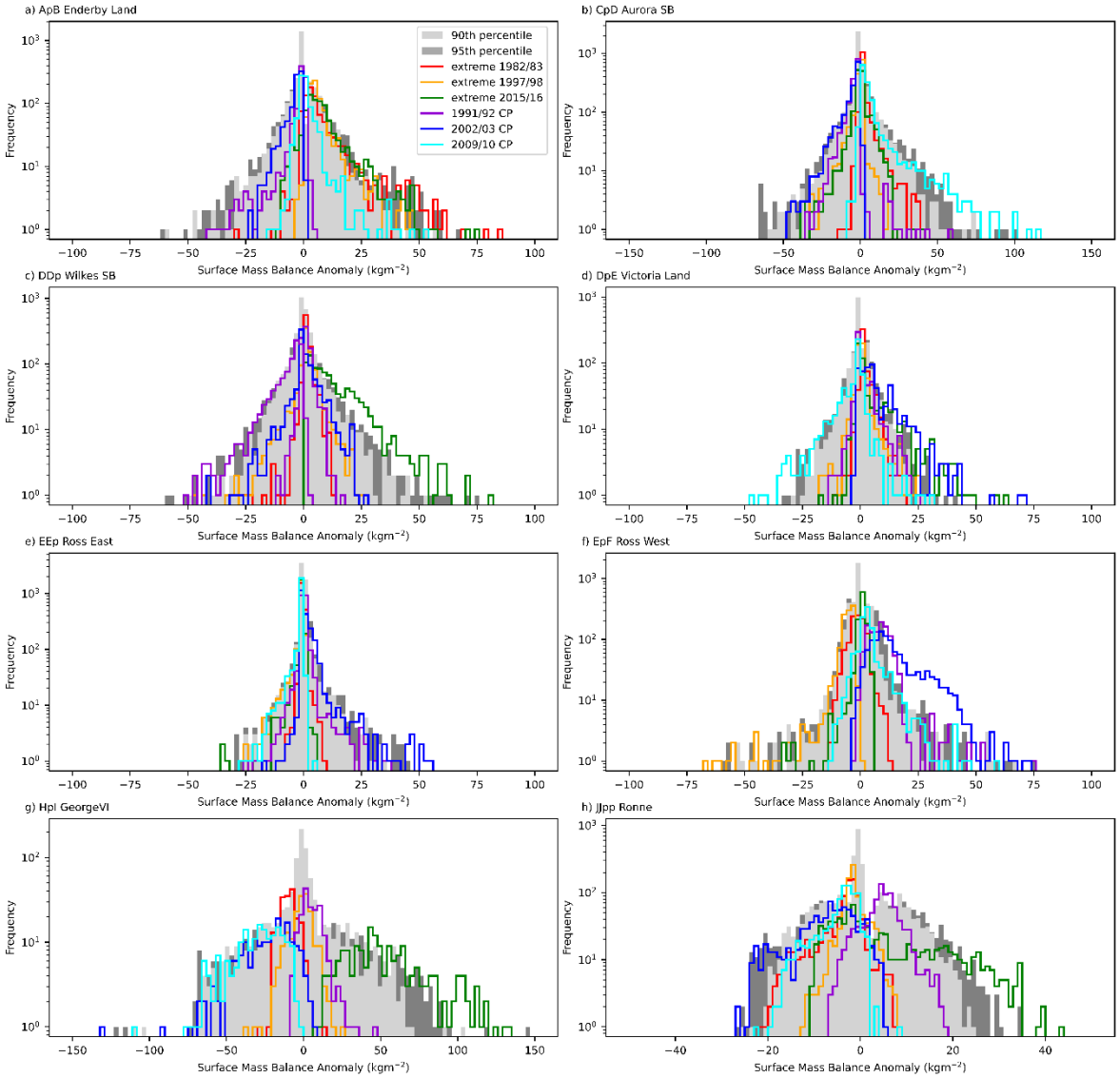
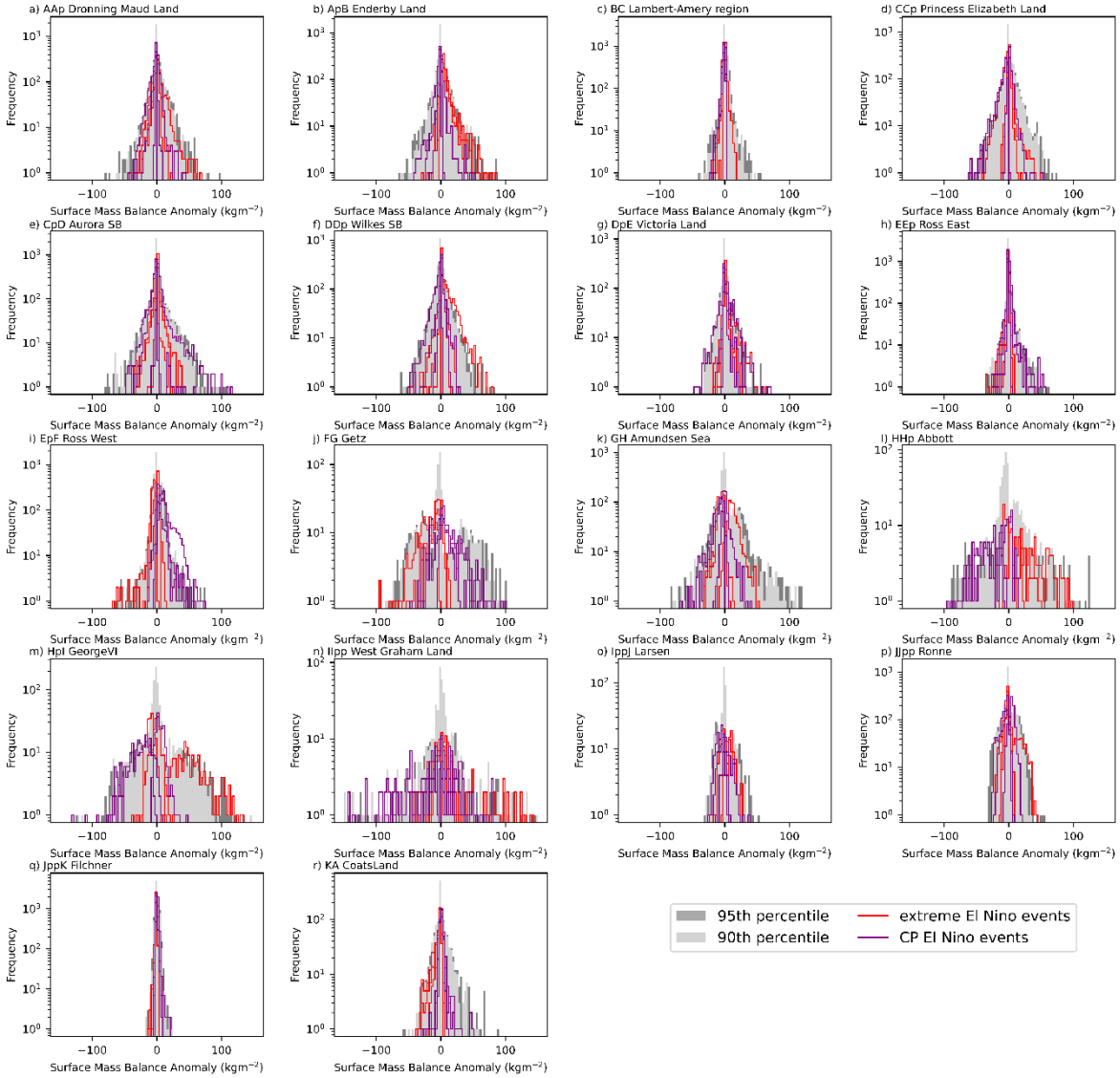
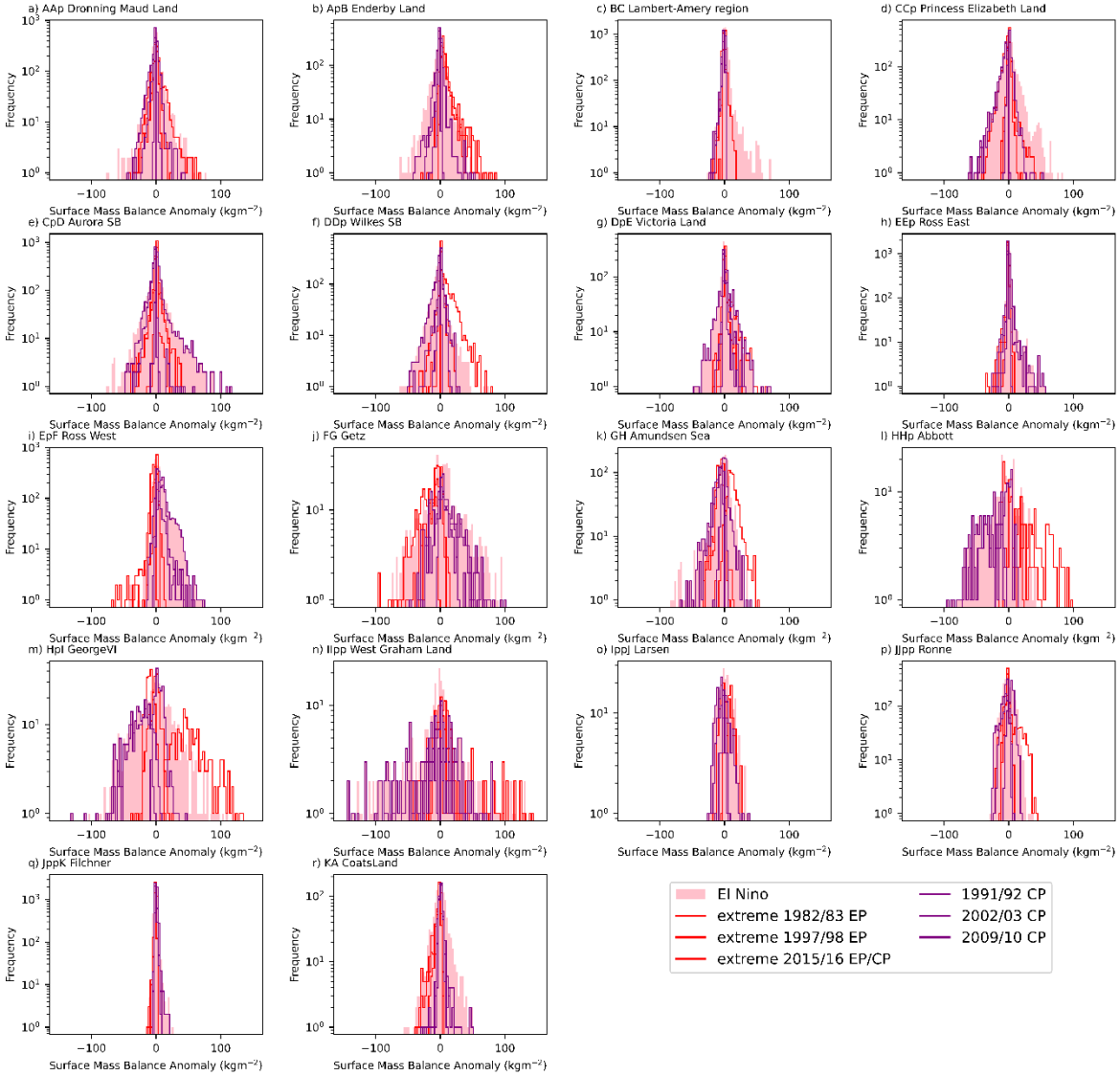
Section 4.1: Regional SMB histograms during extreme El Niño events



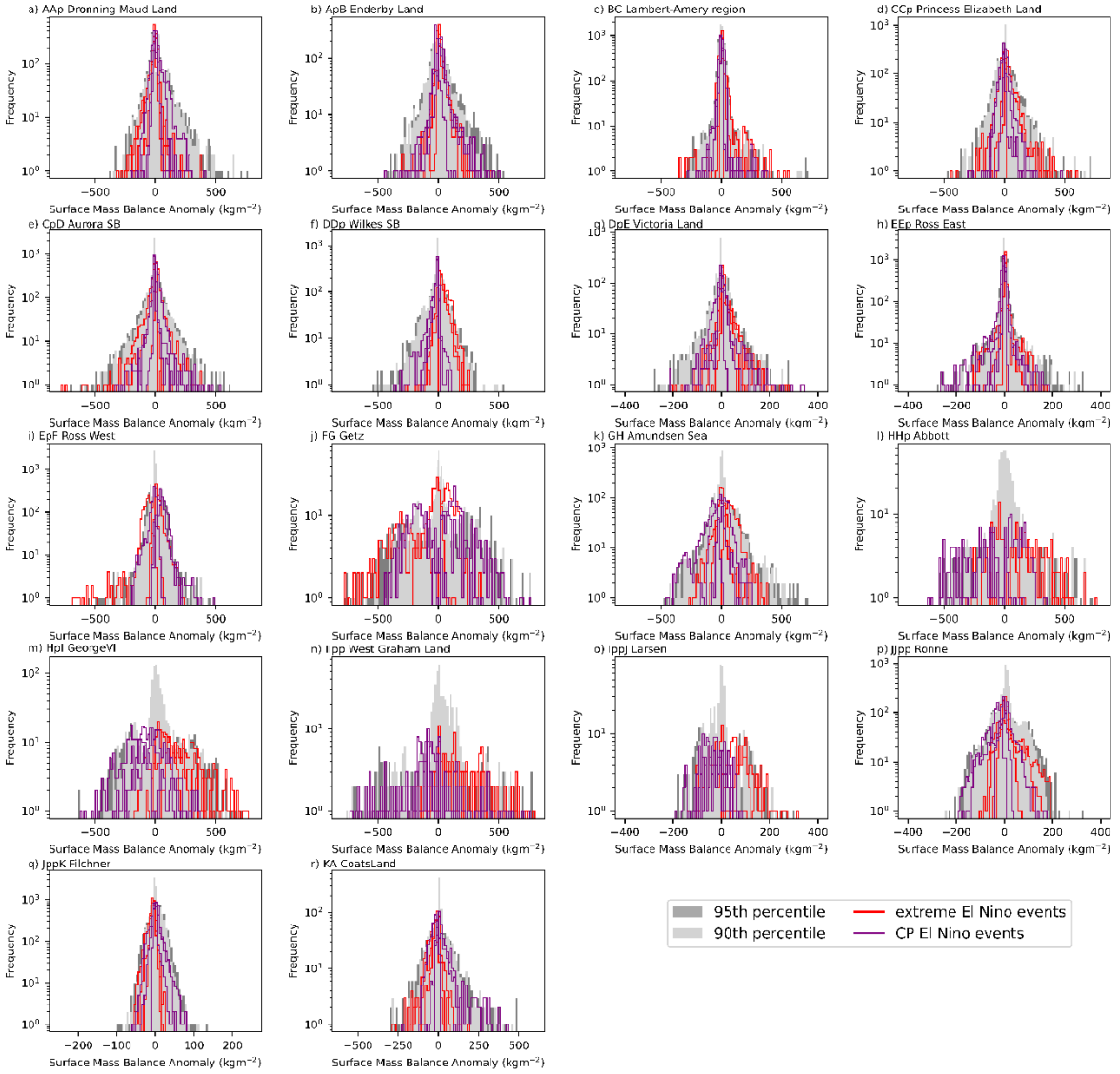
Supplementary Figure S6. Probability distributions of regional Antarctic surface mass balance anomalies during extreme El Niño events and CP El Niño events. Regional SMB probability distributions of SMB anomalies in SON for extreme El Niño events: 1982/83 (red), 1997/98 (orange) and 2015/16 (green); and CP El Niño events: 1991/92 (purple), 2002/03 (blue) and 2009/10 (cyan). Regional 90th (light grey shading) and 95th percentile (dark grey shading) SMB anomalies for SON for 1979-2018 period.



Supplementary Figure S7. Probability distributions of regional Antarctic surface mass balance anomalies during extreme El Niño events and CP El Niño events in SON. Regional SMB probability distributions of SMB changes in SON for extreme El Niño events (red lines) and CP events (purple lines), and regional 90th (light grey shading) and 95th percentile (dark grey shading) SMB anomalies for SON for 1979-2018 period.



Supplementary Figure S8. Regional SMB probability distributions of SMB changes in SON for El Niño events excluding extreme events (pink shading), during extreme El Niño events (red lines) and CP events (purple lines)



Supplementary Figure S9. Regional SMB probability distributions of cumulative annual SMB anomalies (relative to 1979-2018 average) for extreme El Niño events (red lines) and CP events (purple lines), and regional 90th (light grey shading) and 95th percentile (dark grey shading) SMB anomalies for 1979-2018 period.

Section 4.2: Statistical significance testing of regional SMB anomalies distributions during extreme El Niño events.

	Kolmogorov-Smirnov (K-S) test											
	1982/83		1997/98		2015/16		1991/92		2002/03		2009/10	
	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*
AAp	**0.330**	**<0.001**	**0.187**	**<0.001**	**0.152**	**<0.001**	**0.546**	**<0.001**	**0.467**	**<0.001**	**0.308**	**<0.001**
ApB	**0.539**	**<0.001**	**0.680**	**<0.001**	**0.562**	**<0.001**	**0.250**	**<0.001**	**0.511**	**<0.001**	**0.261**	**<0.001**
BC	**0.263**	**<0.001**	**0.110**	**<0.001**	**0.396**	**<0.001**	**0.370**	**<0.001**	**0.330**	**<0.001**	**0.175**	**<0.001**
CCp	**0.331**	**<0.001**	**0.354**	**<0.001**	**0.579**	**<0.001**	**0.615**	**<0.001**	**0.534**	**<0.001**	**0.422**	**<0.001**
CpD	**0.481**	**<0.001**	**0.162**	**<0.001**	**0.087**	**<0.001**	**0.569**	**<0.001**	**0.574**	**<0.001**	**0.521**	**<0.001**
DDp	**0.452**	**<0.001**	**0.281**	**<0.001**	**0.628**	**<0.001**	**0.336**	**<0.001**	**0.186**	**<0.001**	**0.540**	**<0.001**
DpE	**0.492**	**<0.001**	**0.184**	**<0.001**	**0.258**	**<0.001**	**0.141**	**<0.001**	**0.531**	**<0.001**	**0.251**	**<0.001**
EEp	**0.201**	**<0.001**	**0.465**	**<0.001**	**0.371**	**<0.001**	**0.155**	**<0.001**	**0.201**	**<0.001**	**0.488**	**<0.001**
EpF	**0.104**	**<0.001**	**0.651**	**<0.001**	**0.367**	**<0.001**	**0.680**	**<0.001**	**0.744**	**<0.001**	**0.447**	**<0.001**
FG	**0.266**	**<0.001**	**0.563**	**<0.001**	**0.326**	**<0.001**	**0.468**	**<0.001**	**0.326**	**<0.001**	0.085	0.144
GH	**0.393**	**<0.001**	**0.347**	**<0.001**	**0.638**	**<0.001**	**0.326**	**<0.001**	**0.509**	**<0.001**	**0.376**	**<0.001**
HHp	**0.303**	**<0.001**	**0.490**	**<0.001**	0.753	0.241	**0.264**	**<0.001**	**0.609**	**<0.001**	**0.543**	**<0.001**
Hpl	**0.422**	**<0.001**	**0.231**	**<0.001**	**0.751**	**<0.001**	**0.390**	**<0.001**	**0.485**	**<0.001**	**0.611**	**<0.001**
IIpp	**0.221**	**0.002**	**0.172**	**0.005**	**0.356**	**<0.001**	**0.164**	**0.014**	**0.402**	**<0.001**	**0.184**	**0.002**
IppJ	**0.239**	**<0.001**	**0.408**	**<0.001**	**0.512**	**<0.001**	**0.342**	**<0.001**	**0.408**	**<0.001**	**0.316**	**<0.001**
JJpp	**0.361**	**<0.001**	**0.259**	**<0.001**	**0.220**	**<0.001**	**0.450**	**<0.001**	**0.403**	**<0.001**	**0.402**	**<0.001**
JppK	**0.209**	**<0.001**	**0.469**	**<0.001**	**0.450**	**<0.001**	**0.395**	**<0.001**	**0.203**	**<0.001**	**0.329**	**<0.001**
K	**0.369**	**<0.001**	**0.312**	**<0.001**	**0.288**	**<0.001**	**0.292**	**<0.001**	0.163	0.208	**0.378**	**<0.001**

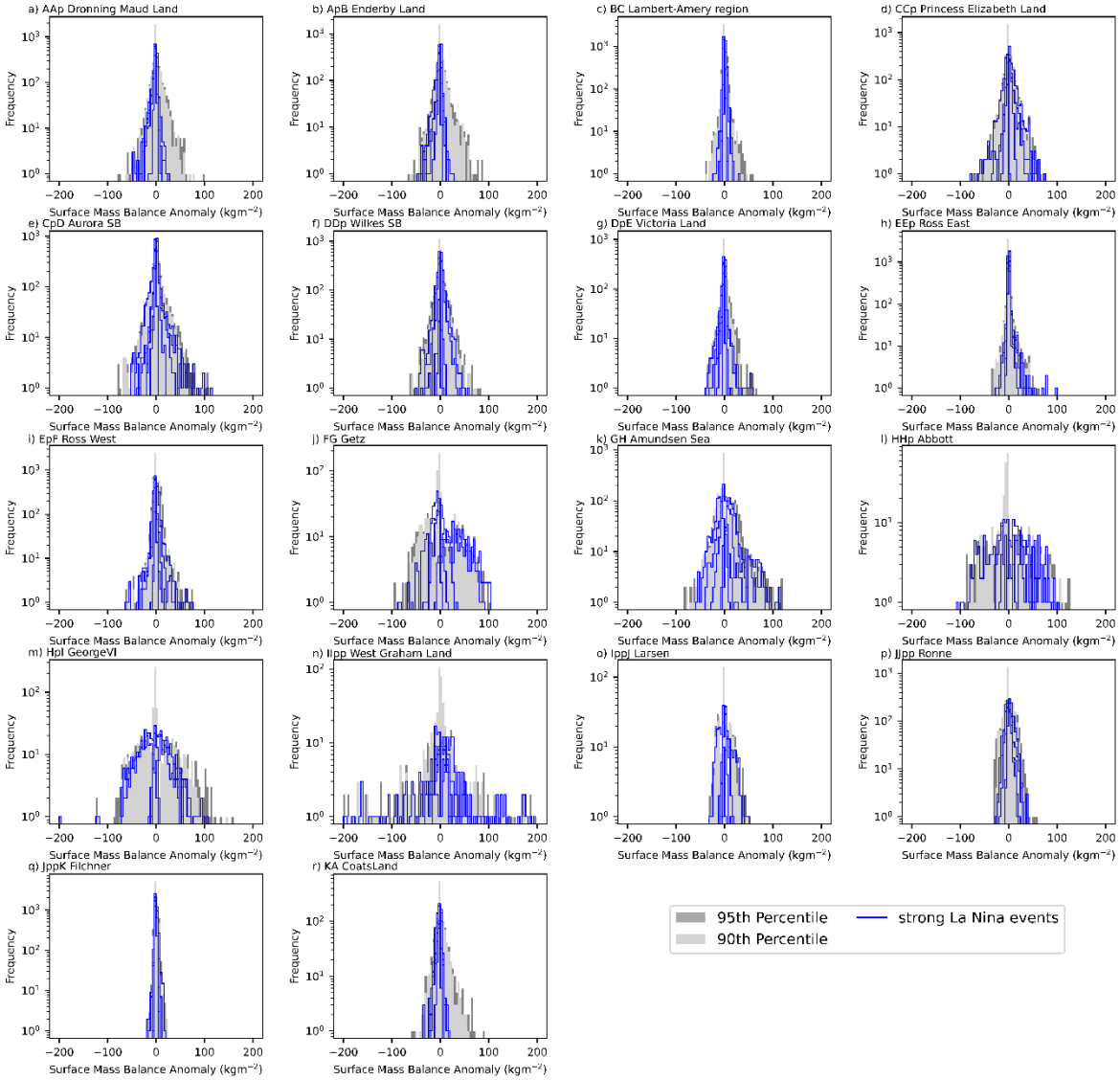
Supplementary Table S1. Kolmogorov-Smirnov test statistics and *p-value* results showing statistically significant difference in SMB SON distributions for extreme El Niño events (1982/83, 1997/98, 2015/16) and CP El Niño events (1991/92, 2002/03, 2009/10) for each Antarctic region compared to the SMB SON distribution for the region for the full 1979-2018 time period with Monte-Carlo Sampling and 1000 simulations. Results in **bold** are statistically significant at the 5% significance level.

		Kolmogorov-Smirnov (K-S) test									
		1997/98		2015/16		1991/92		2002/03		2009/10	
		statistic	*p-value*	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*
AAp	1982/83	**0.4212**	**<0.001**	**0.25597**	**<0.001**	**0.75072**	**<0.001**	**0.68577**	**<0.001**	**0.20248**	**<0.001**
	1997/98	0.000	1.000	**0.33047**	**<0.001**	**0.38109**	**<0.001**	**0.3171**	**<0.001**	**0.47851**	**<0.001**
	2015/16			0.000	1.000	**0.69628**	**<0.001**	**0.61032**	**<0.001**	**0.16523**	**<0.001**
	1991/92					0.000	1.000	**0.30946**	**<0.001**	**0.85005**	**<0.001**
	2002/03							0.000	1.000	**0.76504**	**<0.001**
ApB	1982/83	**0.20629**	**<0.001**	**0.14219**	**<0.001**	**0.75758**	**<0.001**	**0.89977**	**<0.001**	**0.50583**	**<0.001**
	1997/98	0.000	1.000	**0.12238**	**<0.001**	**0.92424**	**<0.001**	**0.98718**	**<0.001**	**0.669**	**<0.001**
	2015/16			0.000	1.000	**0.80769**	**<0.001**	**0.89277**	**<0.001**	**0.55245**	**<0.001**
	1991/92					0.000	1.000	**0.59557**	**<0.001**	**0.26923**	**<0.001**
	2002/03							0.000	1.000	**0.77156**	**<0.001**
BC	1982/83	**0.33525**	**<0.001**	**0.60046**	**<0.001**	**0.6194**	**<0.001**	**0.58611**	**<0.001**	**0.17394**	**<0.001**
	1997/98	0.000	1.000	**0.45867**	**<0.001**	**0.38576**	**<0.001**	**0.2744**	**<0.001**	**0.26693**	**<0.001**
	2015/16			0.000	1.000	**0.09357**	**<0.001**	**0.27669**	**<0.001**	**0.54363**	**<0.001**
	1991/92					0.000	1.000	**0.19805**	**<0.001**	**0.52928**	**<0.001**
	2002/03							0.000	1.000	**0.50459**	**<0.001**
CCp	1982/83	**0.16945**	**<0.001**	**0.89075**	**<0.001**	**0.90301**	**<0.001**	**0.85842**	**<0.001**	**0.23523**	**<0.001**
	1997/98	0.000	1.000	**0.9175**	**0.016**	**0.92642**	**<0.001**	0.88852	0.106	**0.3311**	**<0.001**
	2015/16			0.000	1.000	**0.10814**	**<0.001**	**0.05128**	**<0.001**	**0.92419**	**<0.001**
	1991/92					0.000	1.000	**0.12152**	**<0.001**	**0.93088**	**<0.001**
	2002/03							0.000	1.000	**0.90635**	**<0.001**
CpD	1982/83	**0.43324**	**<0.001**	**0.46996**	**<0.001**	**0.94726**	**<0.001**	**0.92857**	**<0.001**	**0.31976**	**<0.001**
	1997/98	0.000	1.000	**0.18158**	**<0.001**	**0.68892**	**<0.001**	**0.68892**	**<0.001**	**0.5988**	**<0.001**
	2015/16			0.000	1.000	**0.64486**	**<0.001**	**0.65421**	**<0.001**	**0.50868**	**<0.001**
	1991/92					0.000	1.000	**0.11081**	**<0.001**	**0.97597**	**<0.001**
	2002/03							0.000	1.000	**0.96061**	**<0.001**
DDp	1982/83	**0.20348**	**<0.001**	**0.64635**	**<0.001**	**0.31665**	**<0.001**	**0.44831**	**<0.001**	**0.90098**	**<0.001**
	1997/98	0.000	1.000	**0.54516**	**<0.001**	**0.16104**	**<0.001**	**0.28509**	**<0.001**	**0.76061**	**<0.001**
	2015/16			0.000	1.000	**0.66268**	**<0.001**	**0.57345**	**<0.001**	**0.98803**	**<0.001**
	1991/92					0.000	1.000	**0.24157**	**0.023**	**0.86289**	**<0.001**
	2002/03							0.000	1.000	**0.72035**	**<0.001**
DpE	1982/83	**0.37961**	**<0.001**	**0.32337**	**<0.001**	**0.52197**	**<0.001**	**0.4007**	**<0.001**	**0.72408**	**<0.001**
	1997/98	0.000	1.000	**0.2478**	**<0.001**	**0.2355**	**<0.001**	**0.52373**	**<0.001**	**0.41476**	**<0.001**
	2015/16			0.000	1.000	**0.27768**	**<0.001**	**0.32865**	**<0.001**	**0.46924**	**<0.001**
	1991/92					0.000	1.000	**0.48155**	**<0.001**	**0.33743**	**<0.001**
	2002/03							0.000	1.000	**0.69596**	**0.047**
EEp	1982/83	**0.34936**	**<0.001**	**0.22254**	**<0.001**	**0.28571**	**<0.001**	**0.27676**	**<0.001**	**0.4743**	**<0.001**
	1997/98	0.000	1.000	**0.25365**	**<0.001**	**0.48986**	**<0.001**	**0.43517**	**<0.001**	**0.21641**	**<0.001**
	2015/16			0.000	1.000	**0.43517**	**<0.001**	**0.36822**	**<0.001**	**0.34559**	**<0.001**
	1991/92					0.000	1.000	**0.17067**	**<0.001**	**0.54125**	**<0.001**
	2002/03							0.000	1.000	**0.46157**	**<0.001**
EpF	1982/83	**0.62098**	**<0.001**	**0.44986**	**<0.001**	**0.77921**	**<0.001**	**0.84085**	**<0.001**	**0.53818**	**<0.001**
	1997/98	0.000	1.000	**0.93008**	**<0.001**	**0.99264**	**<0.001**	**0.98896**	**<0.001**	**0.89052**	**<0.001**
	2015/16			0.000	1.000	0.77921	0.107	**0.86569**	**<0.001**	**0.45538**	**<0.001**
	1991/92					0.000	1.000	**0.29255**	**<0.001**	**0.49402**	**<0.001**
	2002/03							0.000	1.000	**0.62466**	**<0.001**

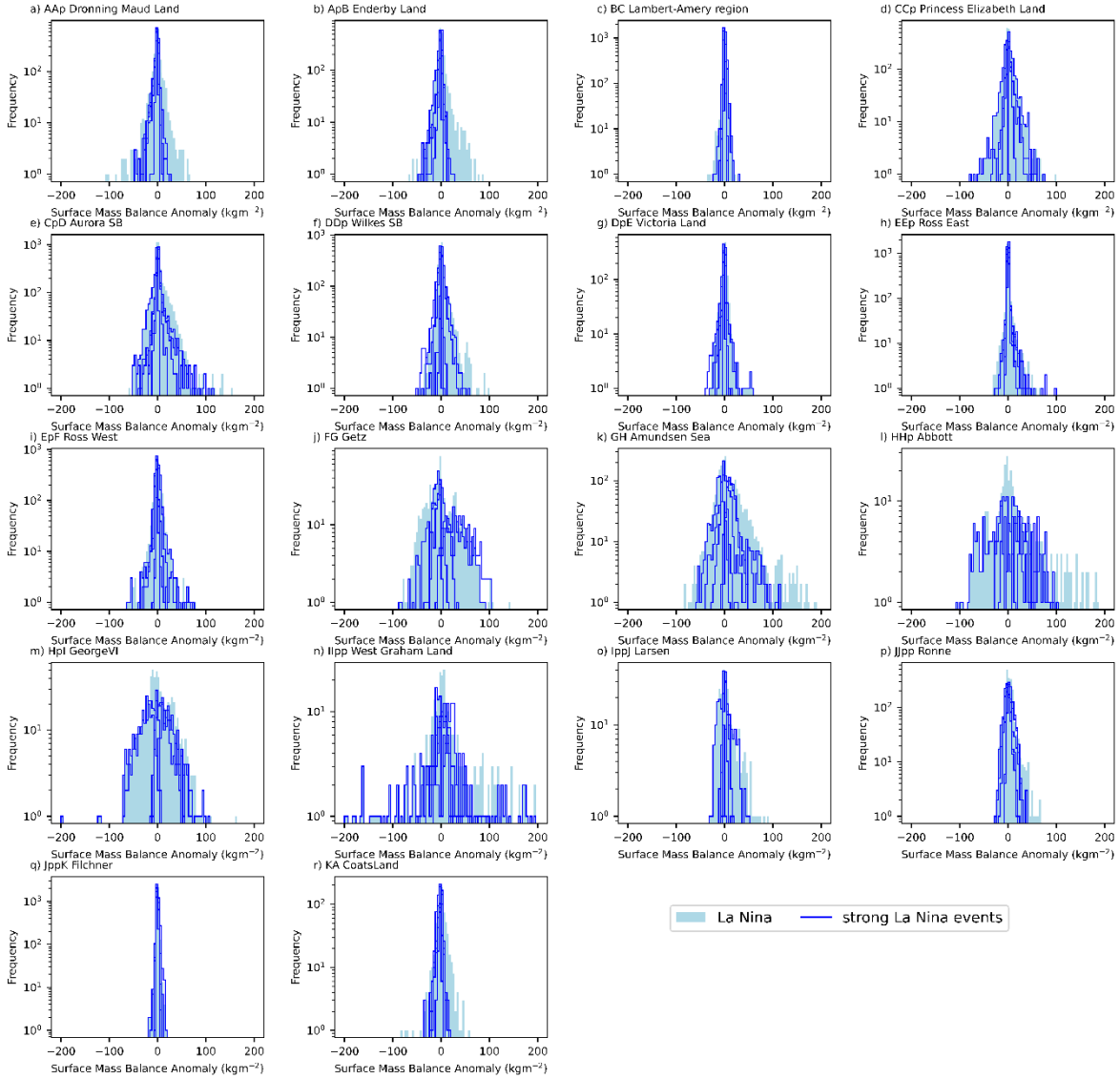
Supplementary Table S2. *(continued on next page)* Kolmogorov-Smirnov test statistics and *p-value* results showing statistically significant difference between SMB SON distributions between each extreme El Niño event (1982/83, 1997/98, 2015/16) and each CP El Niño event (1991/92, 2002/03, 2009/10) for each Antarctic region, with Monte-Carlo Sampling and 1000 simulations. Results in **bold** are statistically significant at the 5% significance level.

		Kolmogorov-Smirnov (K-S) test									
		1997/98		2015/16		1991/92		2002/03		2009/10	
		statistic	*p-value*	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*
FG	1982/83	**0.625**	**<0.001**	**0.21591**	**<0.001**	0.65909	**<0.001**	**0.54545**	**<0.001**	**0.26136**	**<0.001**
	1997/98	0.000	1.000	**0.44318**	**<0.001**	0.98864	**<0.001**	**0.8125**	**<0.001**	**0.56818**	**<0.001**
	2015/16			0.000	1.000	0.73864	**<0.001**	**0.61932**	**<0.001**	**0.35227**	**<0.001**
	1991/92					0.000	1.000	**0.1875**	**<0.001**	**0.4375**	**<0.001**
	2002/03							0.000	1.000	**0.30114**	**<0.001**
GH	1982/83	**0.22442**	**<0.001**	**0.90305**	**<0.001**	**0.68402**	**<0.001**	**0.2316**	**<0.001**	**0.1526**	**<0.001**
	1997/98	0.000	1.000	**0.92819**	**<0.001**	**0.59246**	**<0.001**	**0.37702**	**<0.001**	**0.19569**	**<0.001**
	2015/16			0.000	1.000	**0.7289**	**<0.001**	**0.96409**	**<0.001**	**0.92998**	**<0.001**
	1991/92					0.000	1.000	**0.81329**	**<0.001**	**0.63375**	**<0.001**
	2002/03							0.000	1.000	**0.21903**	**<0.001**
HHp	1982/83	**0.59524**	**<0.001**	0.95238	0.064	**0.14286**	**<0.001**	0.89286	**<0.001**	**0.79762**	**<0.001**
	1997/98	0.000	1.000	**0.63095**	**<0.001**	**0.52381**	**<0.001**	0.9881	**<0.001**	**0.97619**	**<0.001**
	2015/16			0.000	1.000	**0.878**	0.281	0.810	**<0.001**	0.91526	0.084
	1991/92					0.000	1.000	0.83333	0.362	**0.71429**	**<0.001**
	2002/03							0.000	1.000	0.15476	0.072
HpI	1982/83	**0.52941**	**<0.001**	**0.9893**	**<0.001**	**0.78075**	**<0.001**	**0.51872**	**<0.001**	**0.68984**	**<0.001**
	1997/98	0.000	1.000	**0.96257**	**<0.001**	**0.37968**	**<0.001**	**0.65241**	**<0.001**	**0.80214**	**<0.001**
	2015/16			0.000	1.000	**0.89305**	**<0.001**	0.784	0.069	0.617	0.181
	1991/92					0.000	1.000	**0.86096**	**<0.001**	**0.97326**	**<0.001**
	2002/03							0.000	1.000	**0.20321**	**<0.001**
IIpp	1982/83	**0.21875**	**<0.001**	**0.34375**	**<0.001**	**0.16667**	**<0.001**	**0.59375**	**<0.001**	**0.38542**	**<0.001**
	1997/98	0.000	1.000	**0.48958**	**<0.001**	**0.21875**	**<0.001**	**0.45833**	**<0.001**	**0.26042**	**<0.001**
	2015/16			0.000	1.000	**0.38542**	**<0.001**	**0.64583**	**<0.001**	**0.41667**	**<0.001**
	1991/92					0.000	1.000	**0.55208**	**<0.001**	**0.33333**	**<0.001**
	2002/03							0.000	1.000	**0.35417**	**<0.001**
IppJ	1982/83	**0.5679**	**<0.001**	0.71605	0.011	**0.22222**	**<0.001**	**0.48148**	**<0.001**	**0.4321**	**<0.001**
	1997/98	0.000	1.000	**0.22222**	**<0.001**	0.7037	0.252	**0.80247**	**<0.001**	**0.20988**	**<0.001**
	2015/16			0.000	1.000	**0.83951**	**<0.001**	**0.83951**	**<0.001**	**0.39506**	**<0.001**
	1991/92					0.000	1.000	**0.34568**	**<0.001**	**0.60494**	**<0.001**
	2002/03							0.000	1.000	**0.7037**	**<0.001**
JJpp	1982/83	0.2503	**<0.001**	**0.44164**	**<0.001**	**0.77617**	**<0.001**	**0.35981**	**<0.001**	**0.14801**	**<0.001**
	1997/98	0.000	1.000	**0.38628**	**<0.001**	**0.68592**	**<0.001**	**0.55836**	**<0.001**	**0.38267**	**<0.001**
	2015/16			0.000	1.000	**0.35018**	**<0.001**	**0.44525**	**<0.001**	**0.47774**	**<0.001**
	1991/92					0.000	1.000	**0.75572**	**<0.001**	**0.80987**	**<0.001**
	2002/03							0.000	1.000	**0.29723**	**<0.001**
JppK	1982/83	**0.47135**	**<0.001**	**0.4627**	**<0.001**	**0.41477**	**<0.001**	**0.2**	**<0.001**	**0.32937**	**<0.001**
	1997/98	0.000	1.000	**0.1236**	**<0.001**	**0.84108**	**<0.001**	**0.36685**	**<0.001**	**0.52865**	**<0.001**
	2015/16			0.000	1.000	**0.83748**	**<0.001**	**0.29441**	**<0.001**	**0.47568**	**<0.001**
	1991/92					0.000	1.000	**0.58919**	**<0.001**	**0.72288**	**<0.001**
	2002/03							0.000	1.000	**0.18883**	**<0.001**
K	1982/83	**0.35613**	**<0.001**	**0.1396**	**<0.001**	**0.65527**	**<0.001**	**0.50427**	**<0.001**	**0.70085**	**<0.001**
	1997/98	0.000	1.000	**0.32479**	**<0.001**	0.34473	0.106	**0.39886**	**<0.001**	**0.48718**	**<0.001**
	2015/16			0.000	1.000	**0.54416**	**<0.001**	**0.4188**	**<0.001**	**0.63533**	**<0.001**
	1991/92					0.000	1.000	**0.1567**	**<0.001**	**0.19658**	**<0.001**
	2002/03							0.000	1.000	**0.22792**	**<0.001**

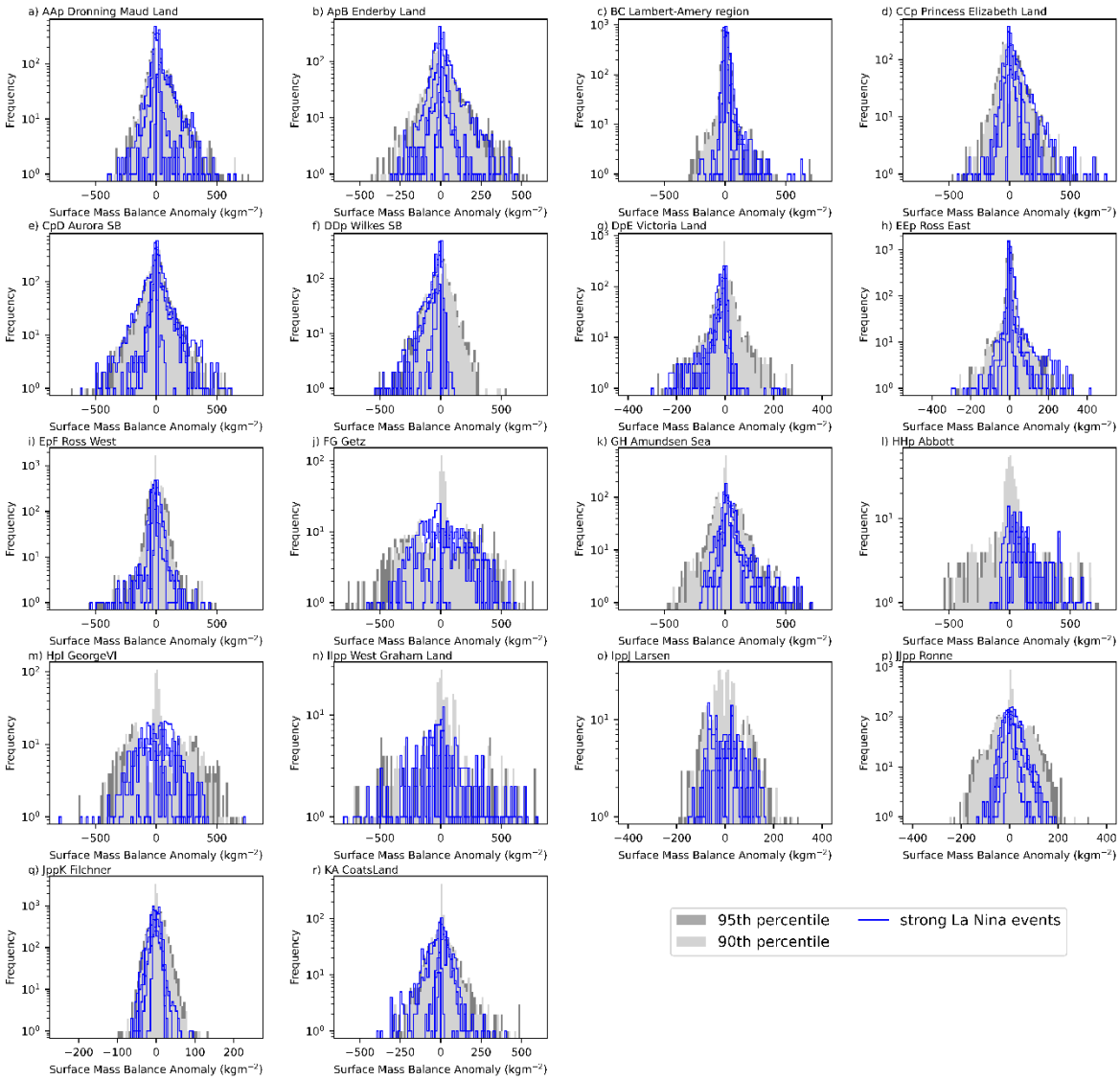
Section 5.1: Regional SMB histograms during strong La Niña events



Supplementary Figure S10. Regional SMB probability distributions of SMB changes in SON for strong La Niña events (blue lines), and regional 90th (light grey shading) and 95th percentile (dark grey shading) SMB anomalies for SON for 1979-2018 period.



Supplementary Figure S11. Regional SMB probability distributions of SMB changes in SON for La Niña events excluding strong events (light blue shading), during strong La Niña events (blue lines).



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166 **Supplementary Figure S12.** Regional SMB probability distributions of cumulative annual
167 SMB anomalies (relative to 1979-2018 average) for strong La Niña events (blue lines) and
168 regional 90th (light grey shading) and 95th percentile (dark grey shading) SMB anomalies for
169 1979-2018 period.

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Section 5.2: Statistical significance testing of regional SMB anomalies distributions during strong La Niña events.

	Kolmogorov-Smirnov (K-S) test									
	1988/89		1998/99		1999/00		2007/08		2010/11	
	statistic	p-value	statistic	p-value	statistic	p-value	statistic	p-value	statistic	p-value
AAp	**0.266**	**<0.001**	**0.231**	**<0.001**	**0.181**	**<0.001**	**0.227**	**<0.001**	**0.257**	**<0.001**
ApB	**0.413**	**<0.001**	**0.233**	**<0.001**	**0.629**	**<0.001**	**0.495**	**<0.001**	**0.531**	**<0.001**
BC	**0.218**	**<0.001**	**0.320**	**<0.001**	**0.390**	**<0.001**	**0.226**	**<0.001**	**0.598**	**<0.001**
CCp	**0.527**	**<0.001**	**0.208**	**<0.001**	**0.544**	**<0.001**	**0.300**	**<0.001**	**0.346**	**<0.001**
CpD	**0.236**	**<0.001**	**0.290**	**<0.001**	**0.563**	**<0.001**	**0.292**	**<0.001**	**0.208**	**<0.001**
DDp	**0.409**	**<0.001**	**0.485**	**<0.001**	**0.352**	**<0.001**	**0.538**	**<0.001**	**0.176**	**<0.001**
DpE	**0.566**	**<0.001**	**0.511**	**<0.001**	**0.388**	**<0.001**	**0.172**	**<0.001**	**0.498**	**<0.001**
EEp	**0.434**	**<0.001**	**0.505**	**<0.001**	**0.454**	**<0.001**	**0.276**	**<0.001**	**0.171**	**<0.001**
EpF	**0.364**	**<0.001**	**0.346**	**<0.001**	**0.221**	**<0.001**	**0.399**	**<0.001**	**0.203**	**<0.001**
FG	**0.342**	**<0.001**	**0.625**	**<0.001**	**0.234**	**<0.001**	**0.601**	**<0.001**	**0.510**	**<0.001**
GH	**0.368**	**<0.001**	**0.767**	**<0.001**	0.056	0.085	**0.580**	**<0.001**	**0.101**	**<0.001**
HHp	**0.508**	**<0.001**	**0.714**	**<0.001**	**0.212**	**<0.001**	**0.552**	**<0.001**	**0.281**	**<0.001**
HpI	**0.404**	**<0.001**	**0.595**	**<0.001**	**0.624**	**<0.001**	**0.224**	**<0.001**	**0.482**	**<0.001**
IIpp	**0.478**	**<0.001**	**0.272**	**<0.001**	**0.192**	**<0.001**	**0.484**	**<0.001**	**0.411**	**<0.001**
IppJ	**0.341**	**<0.001**	**0.478**	**<0.001**	**0.449**	**<0.001**	**0.749**	**<0.001**	**0.651**	**<0.001**
JJpp	**0.200**	**<0.001**	**0.535**	**<0.001**	**0.314**	**<0.001**	**0.191**	**<0.001**	**0.643**	**<0.001**
JppK	**0.423**	**<0.001**	**0.042**	**<0.001**	**0.174**	**<0.001**	**0.280**	**<0.001**	**0.454**	**<0.001**
K	**0.176**	**<0.001**	**0.209**	**<0.001**	**0.360**	**<0.001**	**0.197**	**<0.001**	**0.313**	**<0.001**

Supplementary Table S3. Kolmogorov-Smirnov test statistics and *p-value* results showing statistically significant difference in SMB SON distributions for strong La Niña events (1988/89, 1998/99, 1999/00, 2007/08, 2010/11) for each Antarctic region compared to the SMB SON distribution for the region for the full 1979-2018 time period with Monte Carlo Sampling and 1000 simulations. Results in **bold** are statistically significant at the 5% significance level.

		Kolmogorov-Smirnov (K-S) test							
		1998/99		1999/00		2007/08		2010/11	
		statistic	*p-value*	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*
AAp	1988/89	**0.191**	**<0.001**	**0.233**	**<0.001**	**0.238**	**<0.001**	**0.320**	**<0.001**
	1998/99	0.000	1.000	**0.388**	**<0.001**	**0.245**	**<0.001**	**0.452**	**<0.001**
	1999/00			0.000	1.000	**0.195**	**<0.001**	**0.166**	**<0.001**
	2007/08					0.000	1.000	**0.288**	**<0.001**
ApB	1988/89	**0.645**	**<0.001**	**0.900**	**<0.001**	**0.893**	**<0.001**	**0.473**	**<0.001**
	1998/99	0.000	1.000	0.593	<0.001	**0.347**	**<0.001**	**0.728**	**<0.001**
	1999/00			0.000	1.000	**0.477**	**<0.001**	**0.928**	**<0.001**
	2007/08					0.000	1.000	**0.960**	**<0.001**
BC	1988/89	**0.528**	**<0.001**	**0.334**	**<0.001**	**0.108**	**<0.001**	**0.797**	**<0.001**
	1998/99	0.000	1.000	0.661	0.103	**0.525**	**<0.001**	**0.389**	**<0.001**
	1999/00			0.000	1.000	**0.286**	**<0.001**	**0.883**	**<0.001**
	2007/08					0.000	1.000	**0.823**	**<0.001**
CCp	1988/89	**0.727**	**<0.001**	**0.182**	**<0.001**	**0.713**	**<0.001**	**0.870**	**<0.001**
	1998/99	0.000	1.000	**0.749**	**<0.001**	**0.236**	**<0.001**	**0.202**	**<0.001**
	1999/00			0.000	1.000	**0.829**	**<0.001**	**0.880**	**<0.001**
	2007/08					0.000	1.000	**0.219**	**<0.001**
CpD	1988/89	**0.404**	**<0.001**	**0.633**	**<0.001**	**0.328**	**<0.001**	**0.361**	**<0.001**
	1998/99	0.000	1.000	**0.812**	**<0.001**	**0.132**	**<0.001**	**0.175**	**<0.001**
	1999/00			0.000	1.000	**0.853**	**<0.001**	**0.700**	**<0.001**
	2007/08					0.000	1.000	**0.163**	**<0.001**
DDp	1988/89	**0.868**	**<0.001**	**0.178**	**<0.001**	**0.923**	**<0.001**	**0.277**	**<0.001**
	1998/99	0.000	1.000	**0.834**	**<0.001**	**0.138**	**<0.001**	**0.603**	**<0.001**
	1999/00			0.000	1.000	**0.873**	**<0.001**	**0.245**	**<0.001**
	2007/08					0.000	1.000	**0.664**	**<0.001**
DpE	1988/89	**0.953**	**<0.001**	**0.821**	**<0.001**	**0.703**	**<0.001**	**0.445**	**<0.001**
	1998/99	0.000	1.000	**0.399**	**<0.001**	**0.678**	**<0.001**	**0.794**	**<0.001**
	1999/00			0.000	1.000	**0.548**	**<0.001**	**0.659**	**<0.001**
	2007/08					0.000	1.000	**0.617**	**<0.001**
EEp	1988/89	**0.289**	**<0.001**	**0.842**	**<0.001**	**0.700**	**<0.001**	**0.488**	**<0.001**
	1998/99	0.000	1.000	**0.854**	**<0.001**	**0.728**	**<0.001**	**0.488**	**<0.001**
	1999/00			0.000	1.000	**0.423**	**<0.001**	**0.388**	**<0.001**
	2007/08					0.000	1.000	**0.290**	**<0.001**
EpF	1988/89	**0.176**	**<0.001**	**0.329**	**<0.001**	**0.759**	**<0.001**	**0.555**	**<0.001**
	1998/99	0.000	1.000	**0.330**	**<0.001**	**0.696**	**<0.001**	**0.454**	**<0.001**
	1999/00			0.000	1.000	**0.568**	**<0.001**	**0.298**	**<0.001**
	2007/08					0.000	1.000	**0.419**	**<0.001**

Supplementary Table S4. *(continued on next page).* Kolmogorov-Smirnov test statistics and *p-value* results showing statistically significant difference between SMB SON distributions between each strong La Niña events (1988/89, 1998/99, 1999/00, 2007/08, 2010/11) for each Antarctic region, with Monte Carlo Sampling and 1000 simulations. Results in **bold** are statistically significant at the 5% significance level.

		Kolmogorov-Smirnov (K-S) test							
		1998/99		1999/00		2007/08		2010/11	
		statistic	*p-value*	statistic	*p-value*	statistic	*p-value*	statistic	*p-value*
FG	1988/89	**0.943**	**<0.001**	**0.494**	**<0.001**	**0.813**	**<0.001**	**0.841**	**<0.001**
	1998/99	0.000	1.000	**0.761**	**<0.001**	**0.972**	**<0.001**	**0.159**	**<0.001**
	1999/00			0.000	1.000	**0.778**	**<0.001**	**0.665**	**<0.001**
	2007/08					0.000	1.000	**0.949**	**<0.001**
GH	1988/89	**0.937**	**<0.001**	**0.339**	**<0.001**	**0.930**	**<0.001**	**0.355**	**<0.001**
	1998/99	0.000	1.000	**0.792**	**<0.001**	**0.820**	**<0.001**	**0.741**	**<0.001**
	1999/00			0.000	1.000	**0.594**	**<0.001**	**0.115**	**<0.001**
	2007/08					0.000	1.000	**0.600**	**<0.001**
HHp	1988/89	**0.798**	**<0.001**	**0.488**	**<0.001**	**0.964**	**<0.001**	**0.774**	**<0.001**
	1998/99	0.000	1.000	**0.917**	**<0.001**	**0.832**	**<0.001**	**0.940**	**<0.001**
	1999/00			0.000	1.000	**0.726**	**<0.001**	**0.369**	**<0.001**
	2007/08					0.000	1.000	**0.417**	**<0.001**
Hpl	1988/89	**0.556**	**<0.001**	**0.631**	**<0.001**	**0.299**	**<0.001**	**0.856**	**<0.001**
	1998/99	0.000	1.000	**0.096**	**<0.001**	**0.679**	**<0.001**	**0.963**	**<0.001**
	1999/00			0.000	1.000	**0.733**	**<0.001**	**0.947**	**<0.001**
	2007/08					0.000	1.000	**0.695**	**<0.001**
Ilpp	1988/89	**0.323**	**<0.001**	**0.583**	**<0.001**	**0.271**	**<0.001**	**0.792**	**<0.001**
	1998/99	0.000	1.000	0.333	0.061	0.323	0.052	0.594	0.084
	1999/00			0.000	1.000	**0.583**	**<0.001**	**0.344**	**<0.001**
	2007/08					0.000	1.000	**0.781**	**<0.001**
IppJ	1988/89	**0.778**	**<0.001**	0.741	0.709	**0.988**	**<0.001**	**0.951**	**<0.001**
	1998/99	0.000	1.000	**0.074**	**<0.001**	0.975	0.744	**0.296**	**<0.001**
	1999/00			0.000	1.000	**0.951**	**<0.001**	**0.346**	**<0.001**
	2007/08					0.000	1.000	**0.988**	**<0.001**
JJpp	1988/89	**0.685**	**<0.001**	**0.502**	**<0.001**	**0.153**	**<0.001**	**0.838**	**<0.001**
	1998/99	0.000	1.000	**0.750**	**<0.001**	**0.579**	**<0.001**	**0.929**	**<0.001**
	1999/00			0.000	1.000	**0.454**	**<0.001**	**0.721**	**<0.001**
	2007/08					0.000	1.000	**0.833**	**<0.001**
JppK	1988/89	**0.397**	**<0.001**	**0.591**	**<0.001**	**0.685**	**<0.001**	**0.178**	**<0.001**
	1998/99	0.000	1.000	**0.199**	**<0.001**	**0.304**	**<0.001**	**0.434**	**<0.001**
	1999/00			0.000	1.000	**0.140**	**<0.001**	**0.595**	**<0.001**
	2007/08					0.000	1.000	**0.721**	**<0.001**
K	1988/89	**0.228**	**<0.001**	**0.513**	**<0.001**	**0.356**	**<0.001**	**0.185**	**<0.001**
	1998/99	0.000	1.000	**0.379**	**<0.001**	0.236	0.106	**0.379**	**<0.001**
	1999/00			0.000	1.000	**0.202**	**<0.001**	**0.598**	**<0.001**
	2007/08					0.000	1.000	**0.459**	**<0.001**