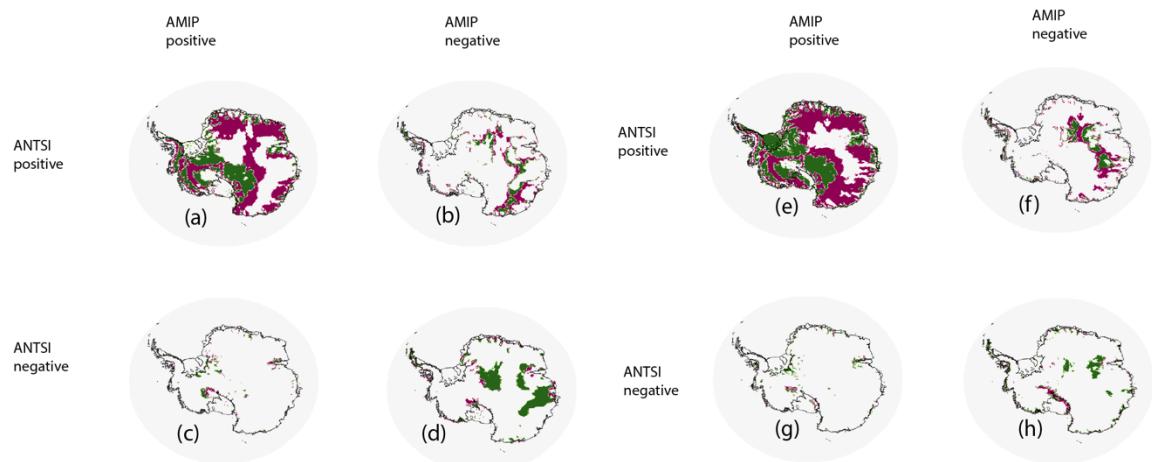


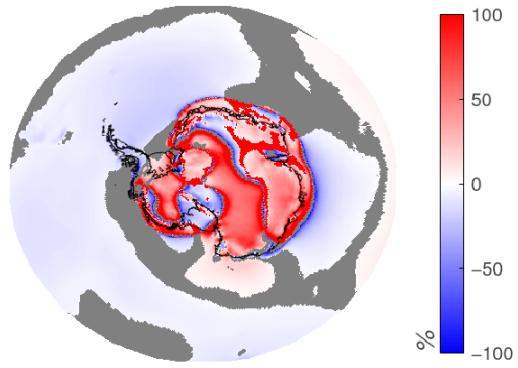
## Supplementary:



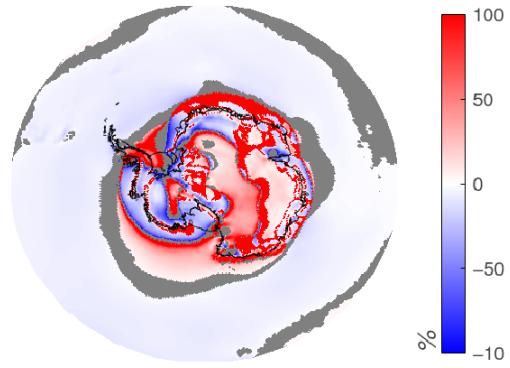
Supplemental Figure 1: Regions of increased/decreased bias as compared to outside sources. Green indicates where SMB bias is reduced in ANTSI (vs AMIP), purple indicates where SMB bias increased in ANTSI (vs AMIP). With the reconstruction (a)(b)(c)(d), with RACMO2.3 (e)(f)(g)(h)

	Full		Grounded Ice Sheet		Ice Shelves	
	AMIP	ANTSI	AMIP	ANTSI	AMIP	ANTSI
E. Ant	40.20 (±5.69)	99.43 (±30.42)	10.58 (±1.76)	34.00 (±10.71)	29.63 (± 4.01)	59.43 (±20.00)
W.Ant	67.50 (±6.58)	80.41 (±12.43)	16.58 (±2.27)  -0.09 GT/yr <sup>2</sup>	20.67 (±4.09)	50.92 (±4.47)	59.74 (±8.78)
AP	55.71 (±4.56)	53.20 (±9.69)	18.13 (±1.58)	19.83 (±3.09)	37.58 (±3.10)	33.36 (±6.69)  0.26 GT/yr <sup>2</sup>
Total	163.42 (±11.23)	227.04 (±49.66)	45.29 (±3.74)	74.51 (±13.67)	118.13 (±7.70)	152.53 (±27.39)

Supplemental Table 1: Surface melt values (in mmwe) for each region, model source as listed. Interannual trends shown in red using the Mann-Kendall test where p values are < 0.05.

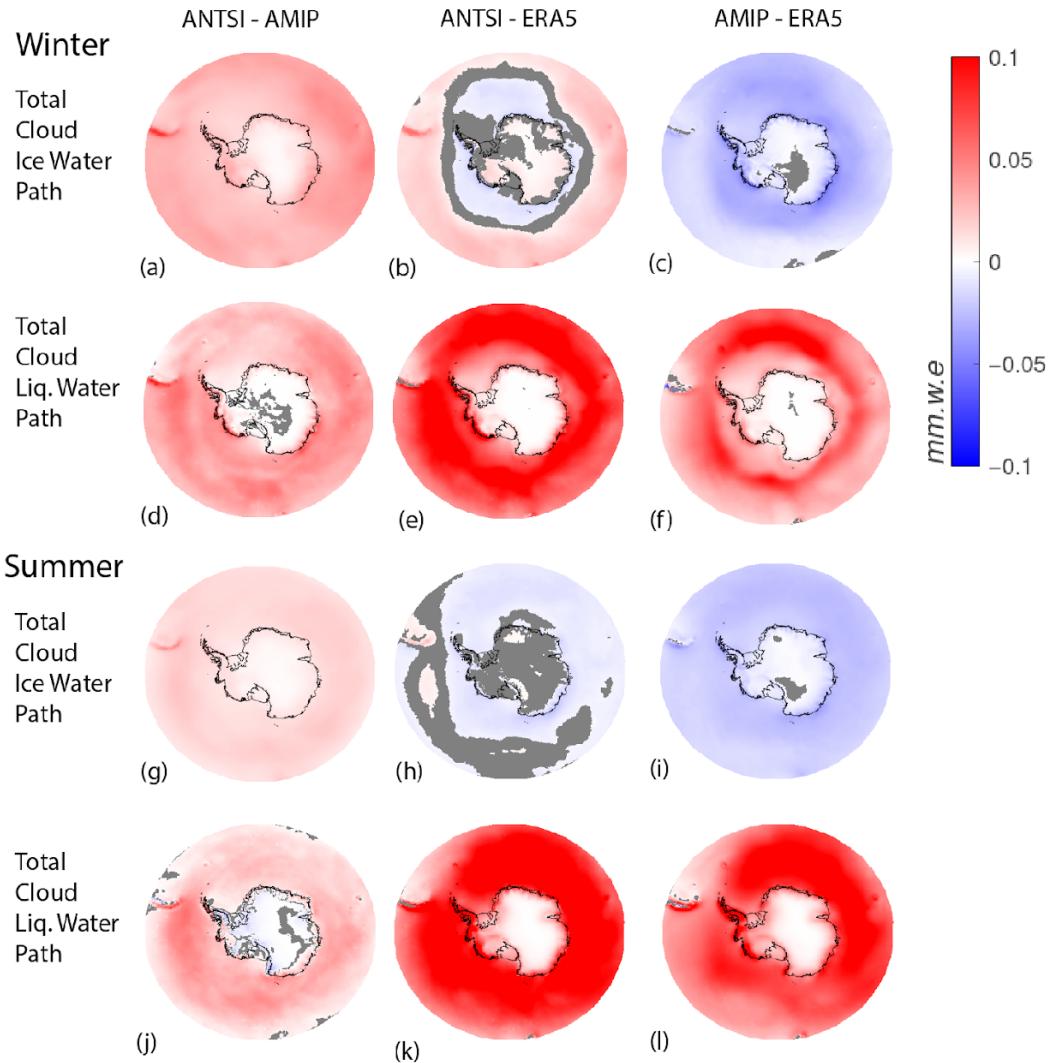


(a) Winter integrated zonal vapor transport (ANTSI - AMIP)



(b) Summer integrated zonal vapor transport (ANTSI - AMIP)

Supplemental Figure 2: Relative difference (ANTSI-AMIP) for Integrated vapor transport in the zonal direction for (a) winter (b) summer



Supplemental Figure 3: Mean total cloud water path in Winter(JJA) and Summer(DJF) for ANTSI – AMIP (left column), ANTSI-ERA5 (middle column), AMIP-ERA5 (right column). Winter Total Cloud Ice Water Path (a) (b) (c). Winter Total Cloud Liq. Water Path (d) (e) (f). Summer Total Cloud Ice Water Path (g) (h) (i). Summer Total Cloud Liq. Water Path (j) (k) (l).

Reference	Ocean		Ice Sheet	
	Bias +	Bias -	Bias +	Bias -
<b>Winter</b>				
<b>ERA5</b>	$0.45 \pm 0.74$	$-1.12 \pm 1.11$	$1.76 \pm 1.26$	$-1.61 \pm 1.19$
<b>AMIP</b>	$0.45 \pm 0.56$	$-0.31 \pm 0.38$	$2.62 \pm 1.27$	$-1.07 \pm 0.81$
<b>Summer</b>				
<b>ERA5</b>	$0.49 \pm 0.76$	$-0.61 \pm 0.80$	$1.59 \pm 1.13$	$-0.68 \pm 0.66$
<b>AMIP</b>	$0.29 \pm 0.41$	$-0.17 \pm 0.27$	$1.11 \pm 0.68$	$-0.64 \pm 0.80$

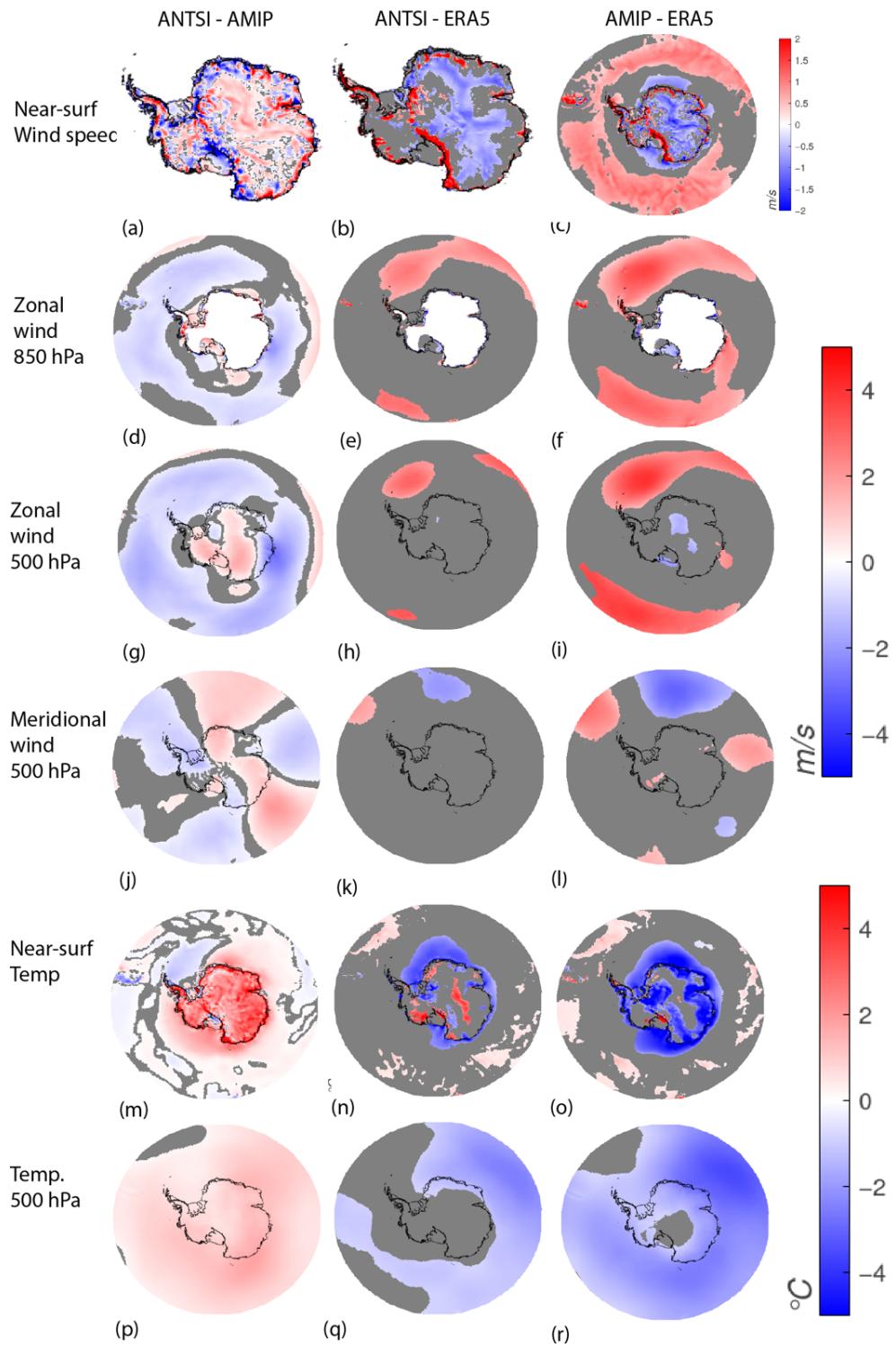
Supplemental Table 2: Mean and standard deviation of near surface temperature biases (ANTS1 - reference dataset) compared to ERA5 and AMIP. Values are separated by season (Winter is JJA, Summer is DJF), by bias direction (positive or negative) and by values over the ocean (below - 55°latitude) vs over the ice sheet.

Reference	Ocean		Ice Sheet	
	Bias +	Bias -	Bias +	Bias -
<b>Winter</b>				
<b>ERA5</b>	$0.77 \pm 0.58$	$-1.09 \pm 0.47$	$0.13 \pm 0.10$	$-0.57 \pm 0.37$
<b>AMIP</b>	$0.74 \pm 0.41$	$-0.19 \pm 0.16$	$0.98 \pm 0.31$	no cases
<b>Summer</b>				
<b>ERA5</b>	$0.37 \pm 0.26$	$-0.84 \pm 0.49$	$0.19 \pm 0.14$	$-0.30 \pm 0.25$
<b>AMIP</b>	$0.59 \pm 0.29$	$-0.13 \pm 0.09$	$0.96 \pm 0.14$	no cases

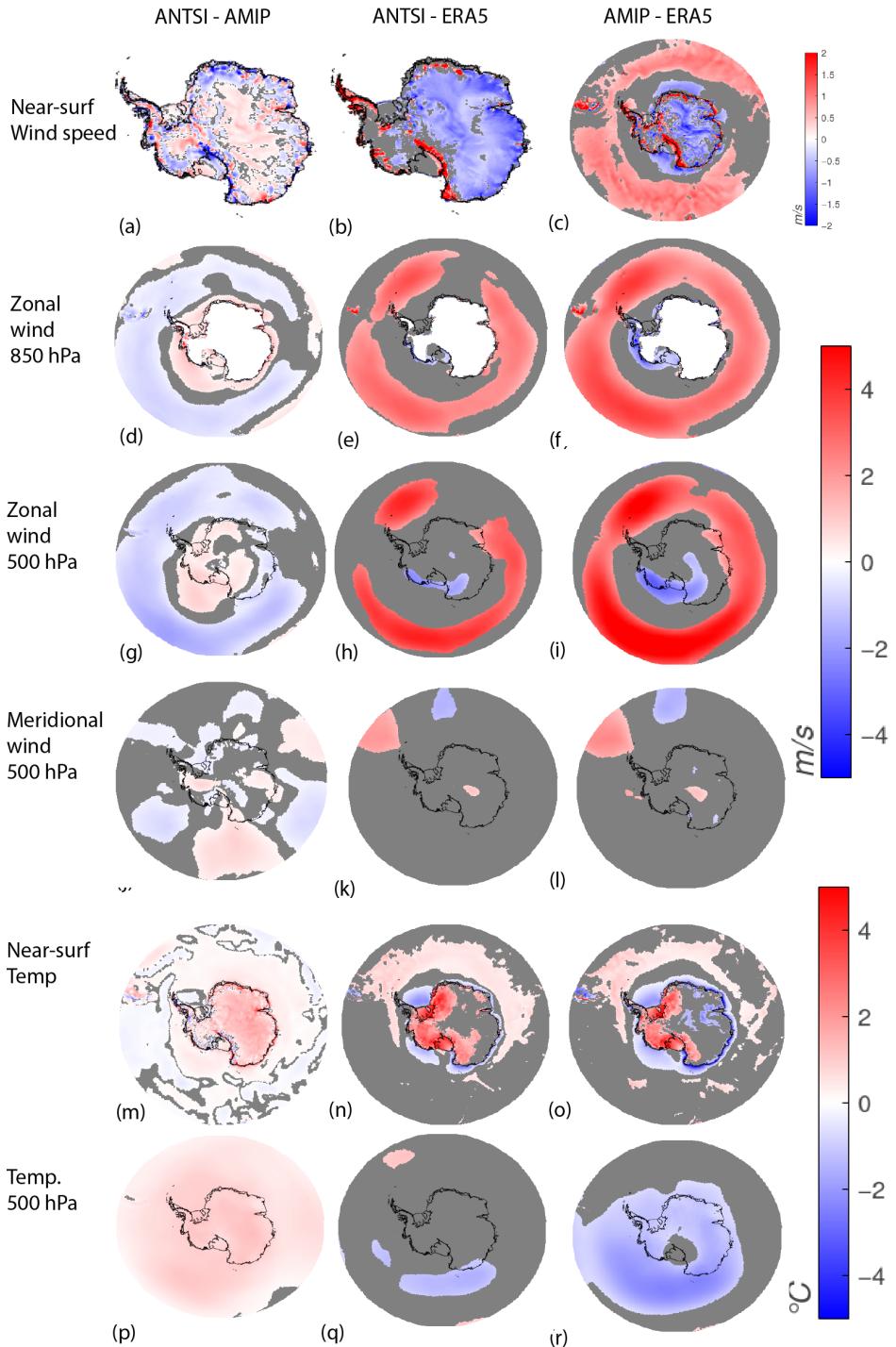
Supplemental Table 3: 500 hPa temperature biases (ANTS1 - reference dataset) in °C, compared to ERA5 and AMIP. Values are separated by season (Winter is JJA, Summer is DJF), by bias direction (positive or negative) and by values over the ocean (below -55°latitude) vs over the ice sheet.

	Ocean		Ice Sheet	
Bias sign	+	-	+	-
<b>Winter</b>				
<b>ERA5</b>	$0.72 \pm 0.53$	$-0.81 \pm 0.90$	$1.00 \pm 1.13$	$-0.52 \pm 0.30$
<b>AMIP</b>	$0.32 \pm 0.28$	$-0.66 \pm 0.72$	$0.53 \pm 0.55$	$-0.74 \pm 0.77$
<b>Summer</b>				
<b>ERA5</b>	$0.87 \pm 0.58$	$-0.87 \pm 0.87$	$0.88 \pm 0.81$	$-0.63 \pm 0.32$
<b>AMIP</b>	$0.34 \pm 0.31$	$-0.69 \pm 0.74$	$0.28 \pm 0.28$	$-0.42 \pm 0.44$

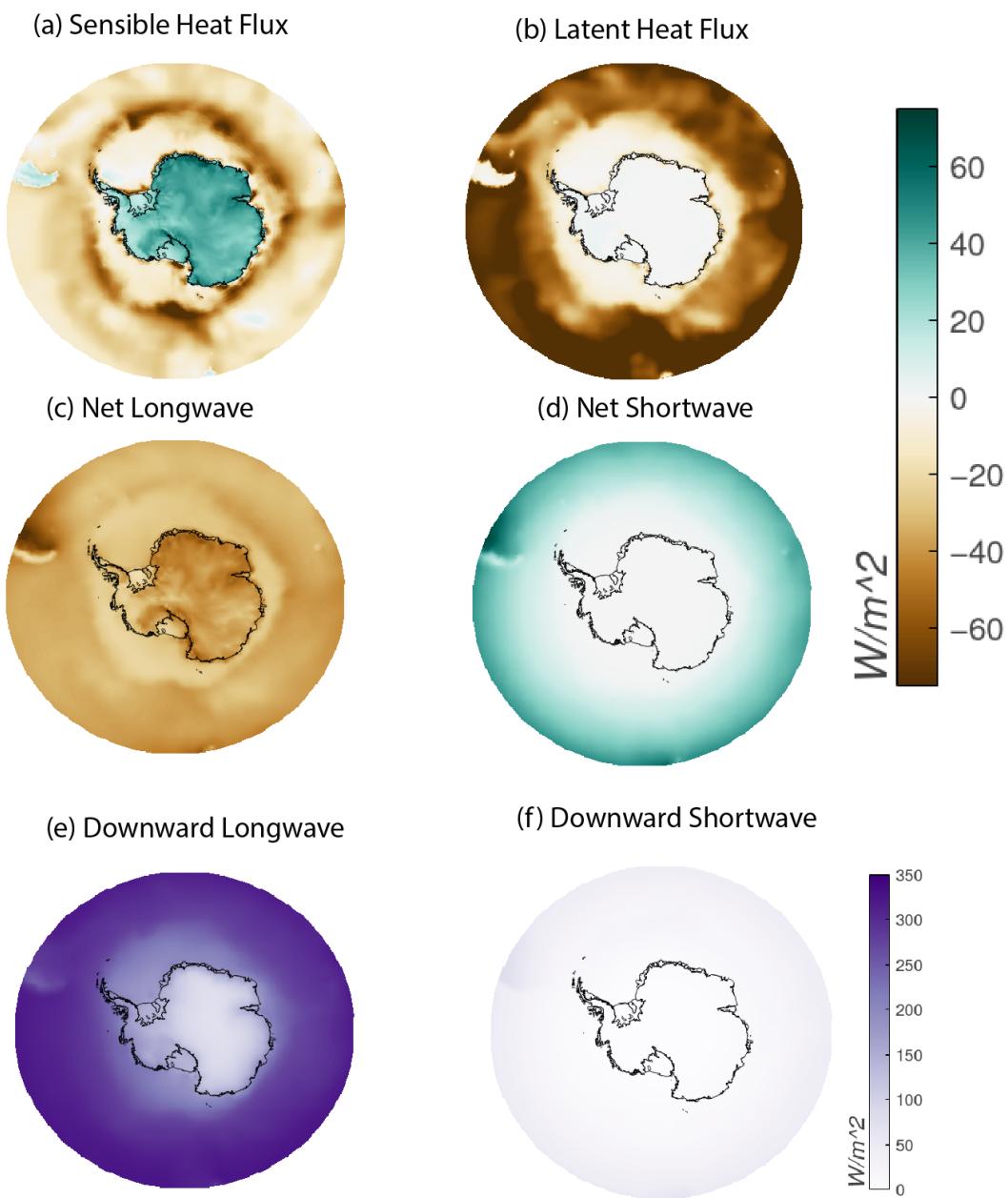
Supplemental Table 4: 10m windspeed biases (ANTS1 - reference dataset) in m/s, compared to ERA5 and AMIP. Values are separated by season (Winter is JJA, Summer is DJF), by bias direction (positive or negative) and by values over the ocean (below  $-55^{\circ}$ latitude) vs over the ice sheet.



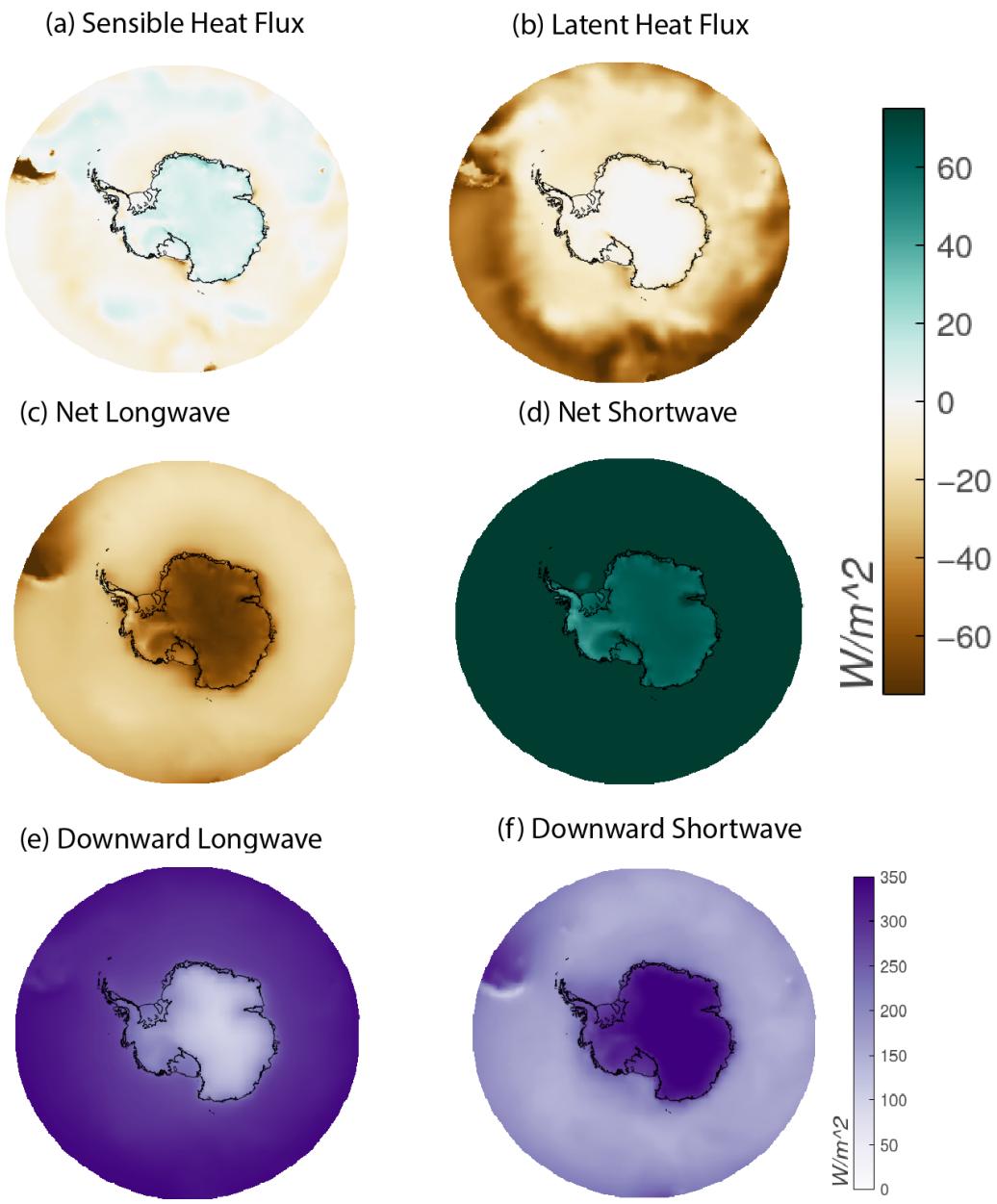
Supplemental Figure 4: Mean Winter (JJA), 1979-2014 , main climate variables for ANTSI – AMIP (left column), ANTSI-ERA5 (middle column), AMIP-ERA5 (right column). For Near Surface Wind Speed (a)(b)(c), Zonal wind at 850 hPa (d)(e)(f), Zonal wind at 500 hPa.,Meridional wind (southward) at 500 hPa (j)(k)(l). Near-surface-temperature (m)(n)(o). Temperature at 500 hPa (p)(q)(r)



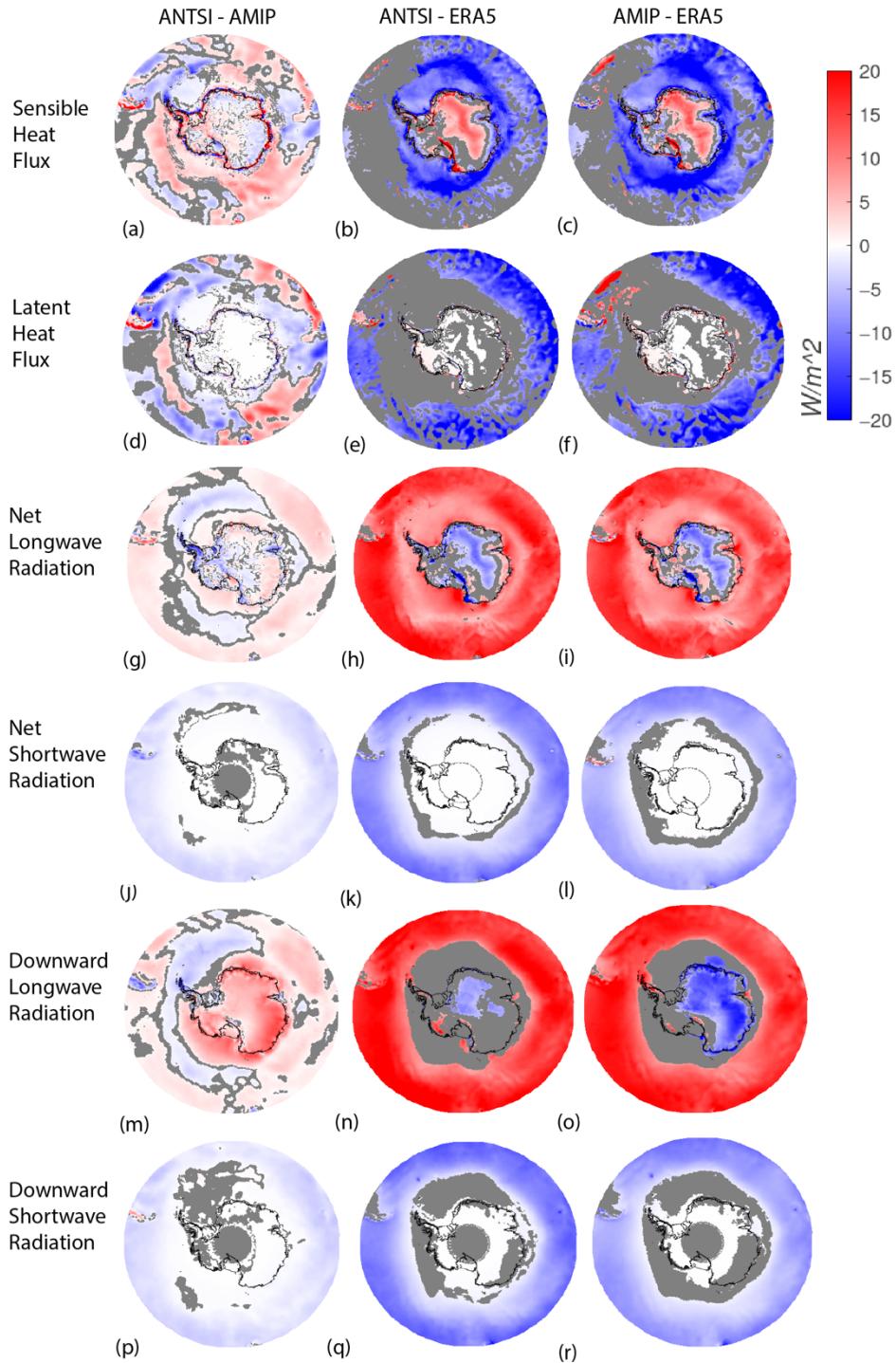
Supplemental Figure 5: Mean Summer (DJF), 1979-2014 , main climate variables for ANTSI – AMIP (left column), ANTSI-ERA5 (middle column), AMIP-ERA5 (right column). For Near Surface Wind Speed (a)(b)(c), Zonal wind at 850 hPa (d)(e)(f), Zonal wind at 500 hPa., Meridional wind (southward) at 500 hPa (j)(k)(l). Near-surface-temperature (m)(n)(o). Temperature at 500 hPa (p)(q)(r)



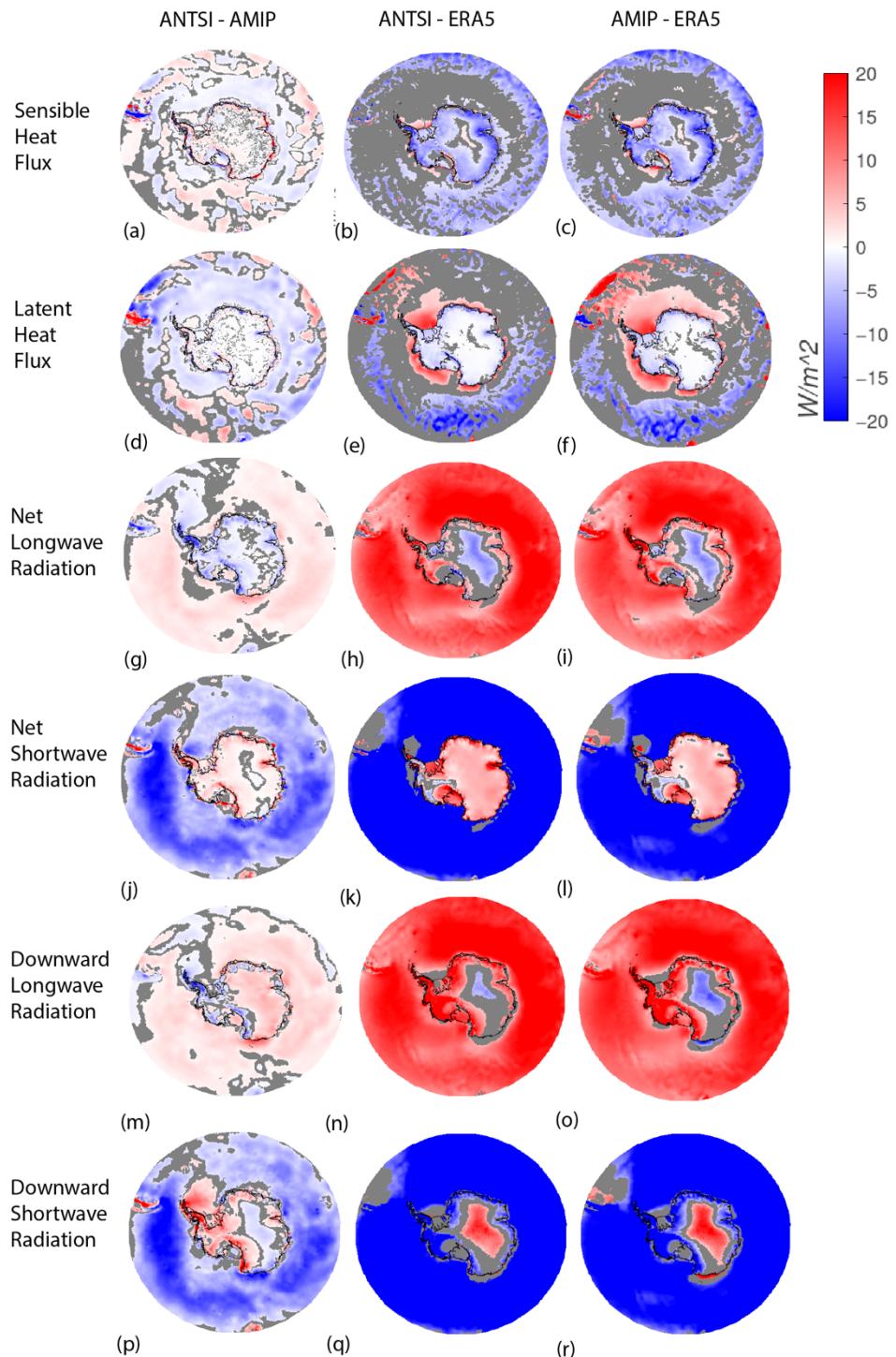
Supplemental Figure 6: Mean radiation balance for Winter (JJA) from ANTSI, 1979-2014. All values directed at the surface. For (a) Sensible Heat Flux (b) Latent Heat Flux (c) Net Longwave Radiation (d) Net Shortwave Radiation (e) Downward Longwave Radiation (f) Downward Shortwave Radiation



Supplemental Figure 7: Mean radiation balance for Summer (DJF) from ANTSI, 1979-2014. All values directed at the surface. For (a) Sensible Heat Flux (b) Latent Heat Flux (c) Net Longwave Radiation (d) Net Shortwave Radiation (e) Downward Longwave Radiation (f) Downward Shortwave Radiation



Supplemental Figure 8: Winter (JJA) radiation balance comparisons, for ANTSI-AMIP (left column), ANTSI – ERA5 (middle column), AMIP-ERA5 (right column). For sensible heat flux (a)(b)(c), latent heat flux (d)(e)(f), net longwave radiation (g)(h)(i), net shortwave radiation (j)(k)(l), downward longwave radiation (m)(n)(o), downward shortwave radiation (p)(q)(r)



Supplemental Figure 9: Summer (DJF) radiation balance comparisons, for ANTSI-AMIP (left column), ANTSI – ERA5 (middle column), AMIP-ERA5 (right column). For sensible heat flux (a)(b)(c), latent heat flux (d)(e)(f), net longwave radiation (g)(h)(i), net shortwave radiation (j)(k)(l), downward longwave radiation (m)(n)(o), downward shortwave radiation (p)(q)(r)