

Supplement of **Amundsen Sea Embayment accumulation variability measured with GNSS-IR**

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1 Introduction

Here we provide additional information on comparisons between accumulation from reanalysis products at the sites of the GNSS receivers, composite anomalies, the significance testing for composite anomalies, and the Rossby wave calculations.

2 Comparison between reanalysis and GNSS-IR

- 5 Using the nearest grid cell of different reanalysis products (MERRA-2 and ERA-5) and high-resolution climate simulations (RACMO-2), we compare simulated accumulation rates with measured accumulation rates (Gelaro et al., 2017; Hersbach et al., 2020; van Wessem et al., 2018).

3 ERA5 composite analysis

3.1 Anomalies

- 10 Anomalies were calculated by subtracting the historical seasonal means for the observational period (2009–2022) from the respective environmental variable for each individual JJA and DJF snowfall event (including the days building up to the event).

3.2 Significance testing

- 15 A difference of means test was used to determine the significance of extreme snow accumulation at the GNSS sites associated with and without blocking present and tested at the 95% level. Special care must be taken in the interpretation of multiple statistical hypothesis tests (i.e. when each of many tests corresponds to a different location; Wilks, 2016). A Student's t-test was used to determine regions where geopotential height, temperature, and Integrated Vapor Transport anomalies are significantly different from zero at the 95% level.

Table S1. Comparison of MERRA-2, RACMO2, and ERA5 reanalysis products and GNSS-IR derived accumulation histograms of event frequencies for (A) LTHW, (B) UTHW, and (C) KHLR GNSS sites (reanalysis product histogram – GNSS-derived accumulation histogram). Accumulation measured with GNSS-IR plotted against accumulation determined from reanalysis products for (A) LTHW, (B) UTHW, and (C) KHLR GNSS sites. [Reflector height time series observation summary](#)

site name (GNSS-IR or surface core)	start date	end date	days where accumulation could be extracted or averaged
Kohler (KHLR)	2010-01-24	2019-09-04	2231
Lower Thwaites (LTHW)	2009-12-12	2021-03-08	2941
Upper Thwaites (UTHW)	2009-01-01	2021-03-23	3282
PIGD (Johnson et al., 2018)	2016-01-31	2016-12-19	324
PIG4 (Johnson et al., 2018)	2016-01-30	2016-12-21	327
PIG3 (Johnson et al., 2018)	2016-01-30	2016-12-24	330
PIG2 (Johnson et al., 2018)	2016-01-29	2016-12-26	333
PIG1 (Johnson et al., 2018)	2016-01-28	2016-12-28	336
D115 (Johnson et al., 2018)	2016-01-29	2016-12-20	327
Cavity Camp ADG (MacLennan et al., 2022)	2020-01-29	2020-02-17	19
Channel Camp ADG (MacLennan et al., 2022)	2020-01-29	2020-02-17	19

- Austral summer sea surface temperature anomalies. Days for each panel indicate the shifted index for composite average prior to (or on) the day of extreme precipitation observed at the GNSS-IR stations located on Thwaites Glacier, which are plotted as orange and blue stars.
- Austral summer geopotential height anomalies at the 500 hPa pressure level. Days for each panel indicate the shifted index for composite average prior to (or on) the day of extreme precipitation observed at the GNSS-IR stations located on Thwaites Glacier, which are plotted as orange and blue stars.
- Austral winter Outgoing longwave radiation (OLR) anomalies. Days for each panel indicate the shifted index for composite average prior to (or on) the day of extreme precipitation observed at the GNSS-IR stations located on Thwaites Glacier, which are plotted as orange and blue stars.
- Same as fig. S4 but with austral summer OLR anomalies.
- Austral winter Rossby wave source anomalies calculated from 200 hPa winds. Days for each panel indicate the shifted index for composite average prior to (or on) the day of extreme precipitation observed at the GNSS-IR stations located on Thwaites Glacier, which are plotted as orange and blue stars.
- Same as fig. S6 but with austral summer Rossby wave anomalies.

Table S2. Parameters used in Metropolis-Hastings algorithm that define the inverse methods.

Parameter.(unit if applicable)	Description	label and value if fixed
mast height.(m)	The height of the antenna mast in meters.	6.125
Initial viscosity.(Pa · s)	The viscosity of the snow relates stress due to overburden pressure and near-surface densification between the surface and the base of the anchor.	$\eta = 7.77e^{12}$
Initial density.(kg/m ³)	Surface snow density	$\rho_{snow} = 300$
gravitational constant.(m/s ²)	gravitational acceleration	$g = 9.8$
objective functional	metric used to select the best-fit solution.	ϕ
modeled reflector height.(m)	modeled reflector height at time $t = k$	R_{out_k}
observed reflector height.(m)	observed reflector height at time $t = k$	R_{obs_k}
model step for accumulation.(m)	standard deviation of Gaussian distribution used to select potential accumulation at each step	$\sigma = 0.01$
model step for snow density.(kg/m ³)	standard deviation of Gaussian distribution used to select potential snow density	$\sigma = 3$
model step for viscosity.(Pa · s)	standard deviation of Gaussian distribution used to select potential snow viscosity	$\sigma = 1e10$
Regularization parameter	Parameter that controls the false positive acceptance rate of model parameters (See Equation 6)	$B = 1e5$

Table S3. [Reflector height time series observation summary](#)

	MERRA-2	RACMO-2	ERA-5
Kohler (KHLR)	0.305	0.301	0.325
Lower Thwaites (LTHW)	0.211	0.156	0.140
Upper Thwaites (UTHW)	0.203	0.216	0.219
MERRA-2	1.0	0.807	0.764
RACMO-2	0.807	1.0	0.690
ERA-5	0.764	0.690	1.0

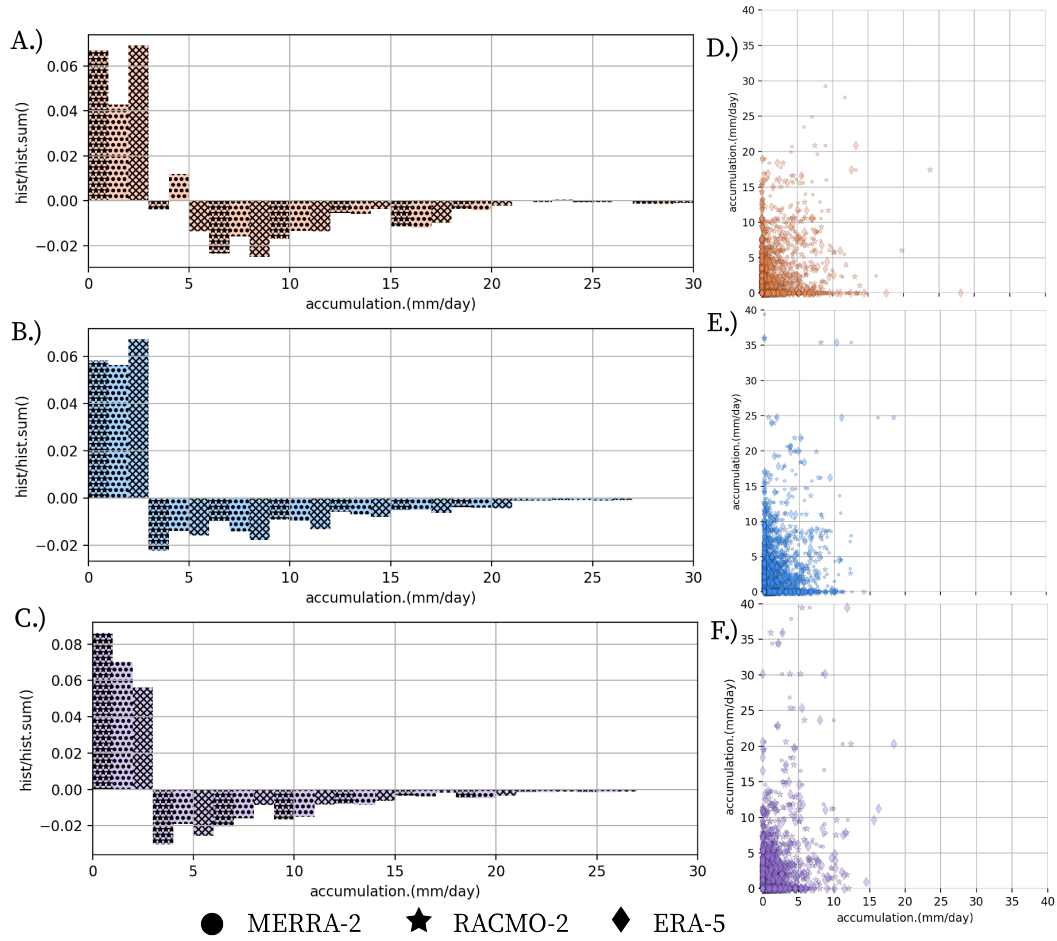


Figure S1. Comparison of MERRA-2 (circles), RACMO-2 (stars), and ERA5 (diamonds) reanalysis products and GNSS-IR derived accumulation histograms of event frequencies for (A) LTHW, (B) UTHW, and (C) KHLR GNSS sites. Histogram difference of reanalysis accumulation and observed accumulation shown in (A-C) are referenced to the reanalysis product (reanalysis product histogram - GNSS-derived accumulation histogram). Accumulation measured with GNSS-IR plotted against accumulation determined from reanalysis products are also shown for (D) LTHW, (E) UTHW, and (F) KHLR GNSS sites.

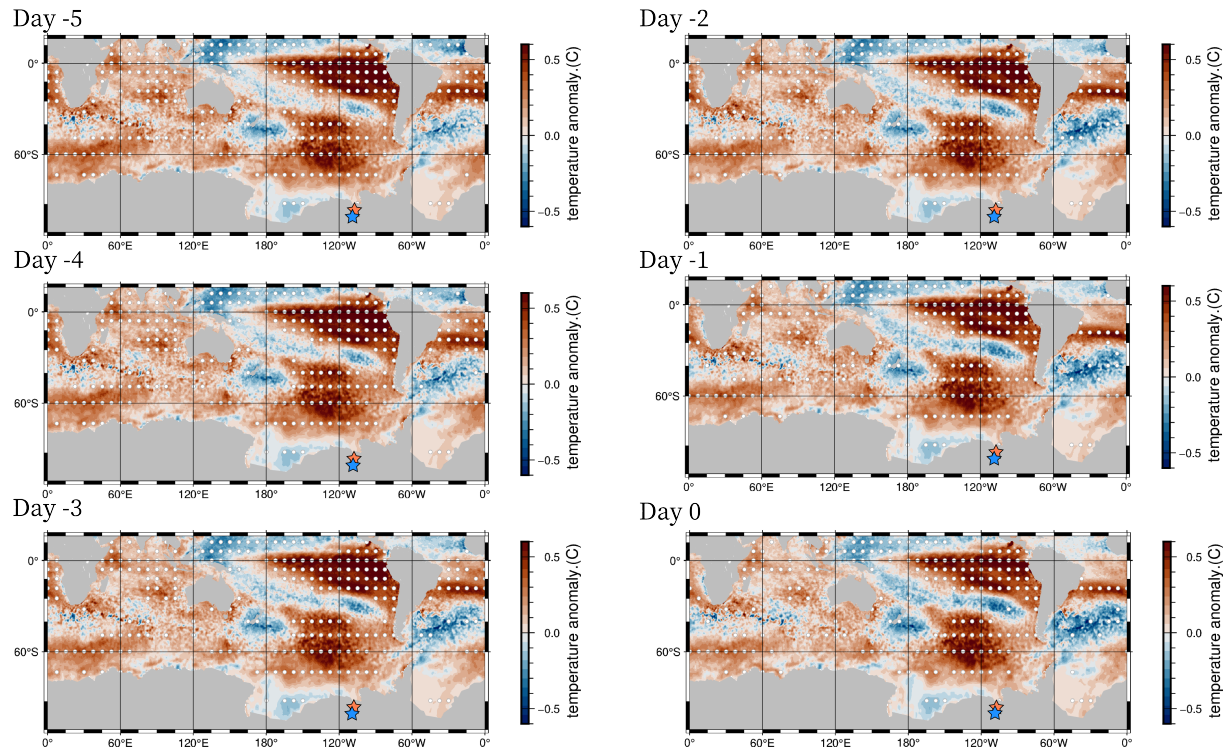


Figure S2. Austral summer sea surface temperature anomalies. Days for each panel indicate the shifted index for composite average prior to (or on) the day of extreme precipitation observed at the GNSS-IR stations located on Thwaites Glacier, which are plotted as orange and blue stars.

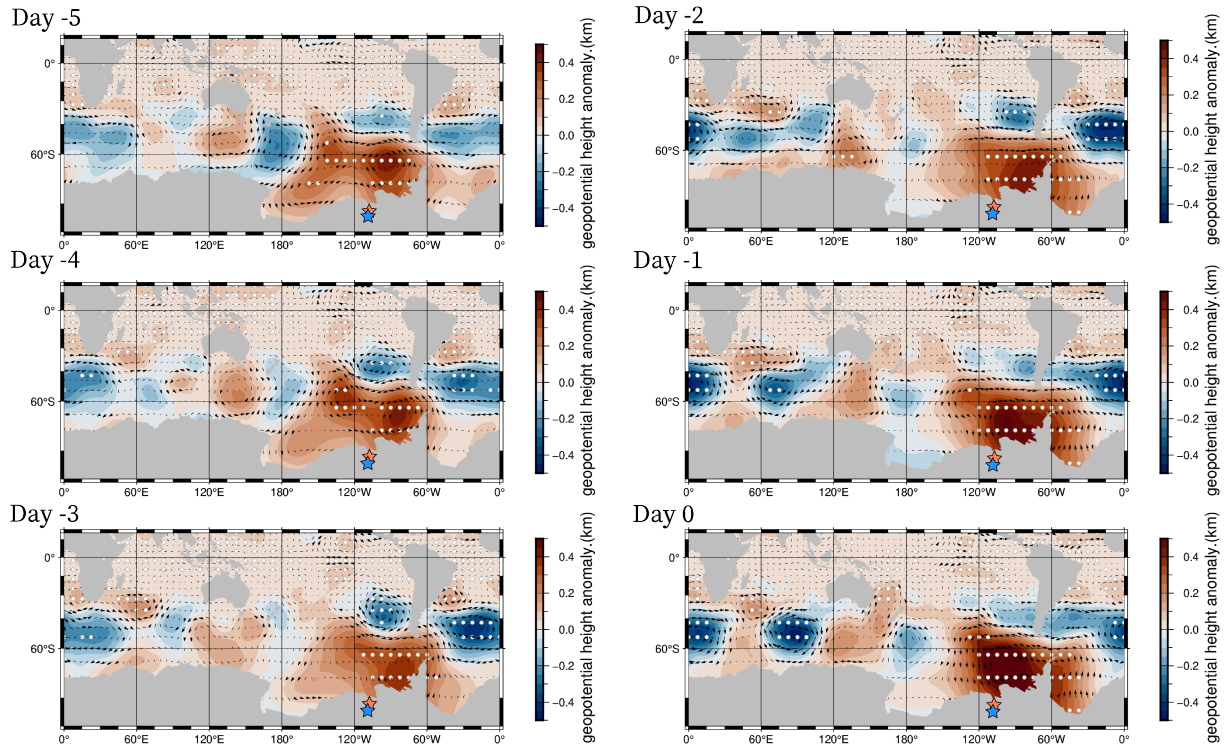


Figure S3. Austral summer geopotential height anomalies at the 500 hPa pressure level. Days for each panel indicate the shifted index for composite average prior to (or on) the day of extreme precipitation observed at the GNSS-IR stations located on Thwaites Glacier, which are plotted as orange and blue stars.

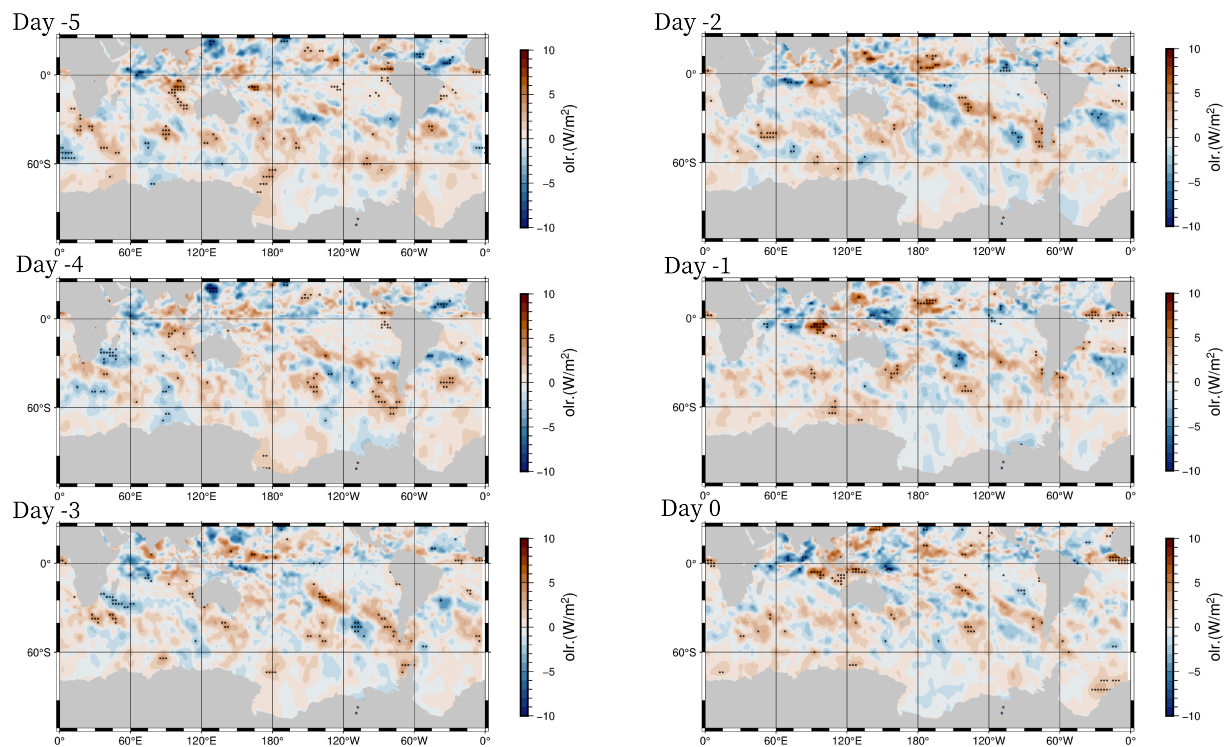


Figure S4. Austral winter Outgoing longwave radiation (OLR) anomalies. Days for each panel indicate the shifted index for composite average prior to (or on) the day of extreme precipitation observed at the GNSS-IR stations located on Thwaites Glacier, which are plotted as orange and blue stars.

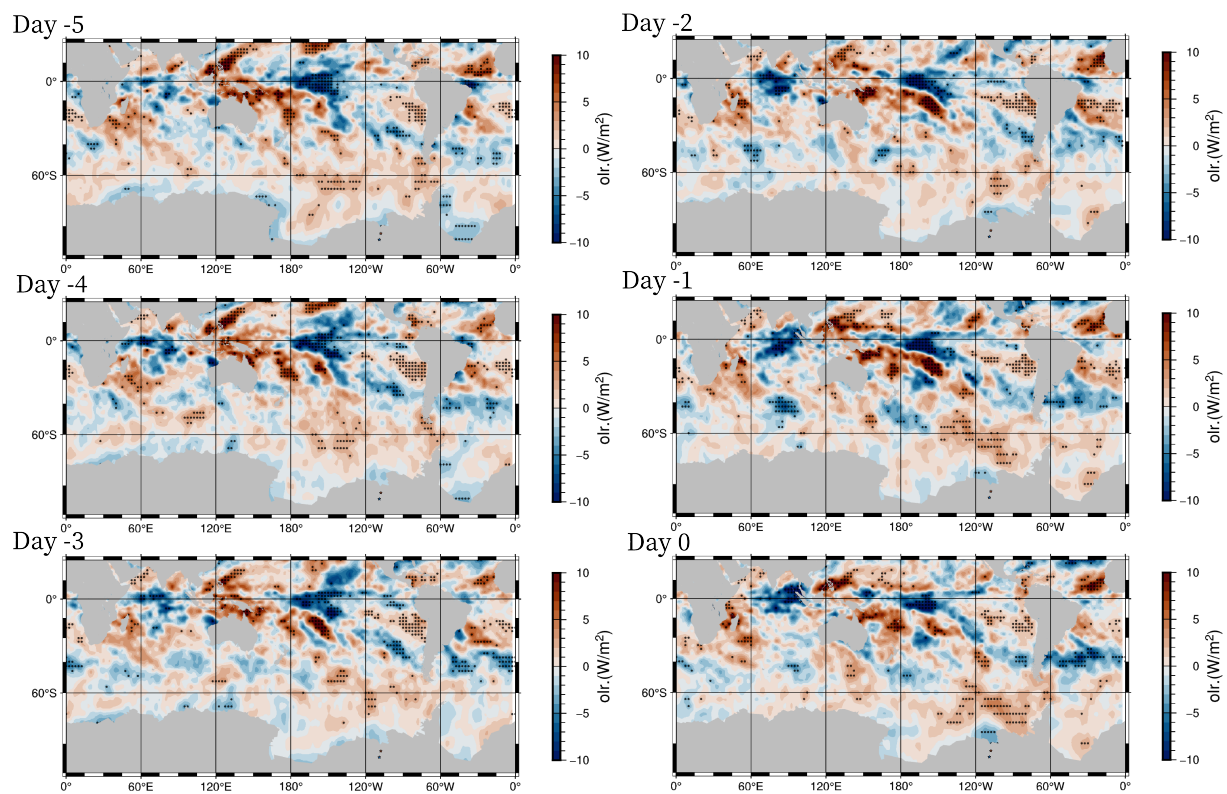


Figure S5. Same as fig. S4 but with austral summer OLR anomalies.

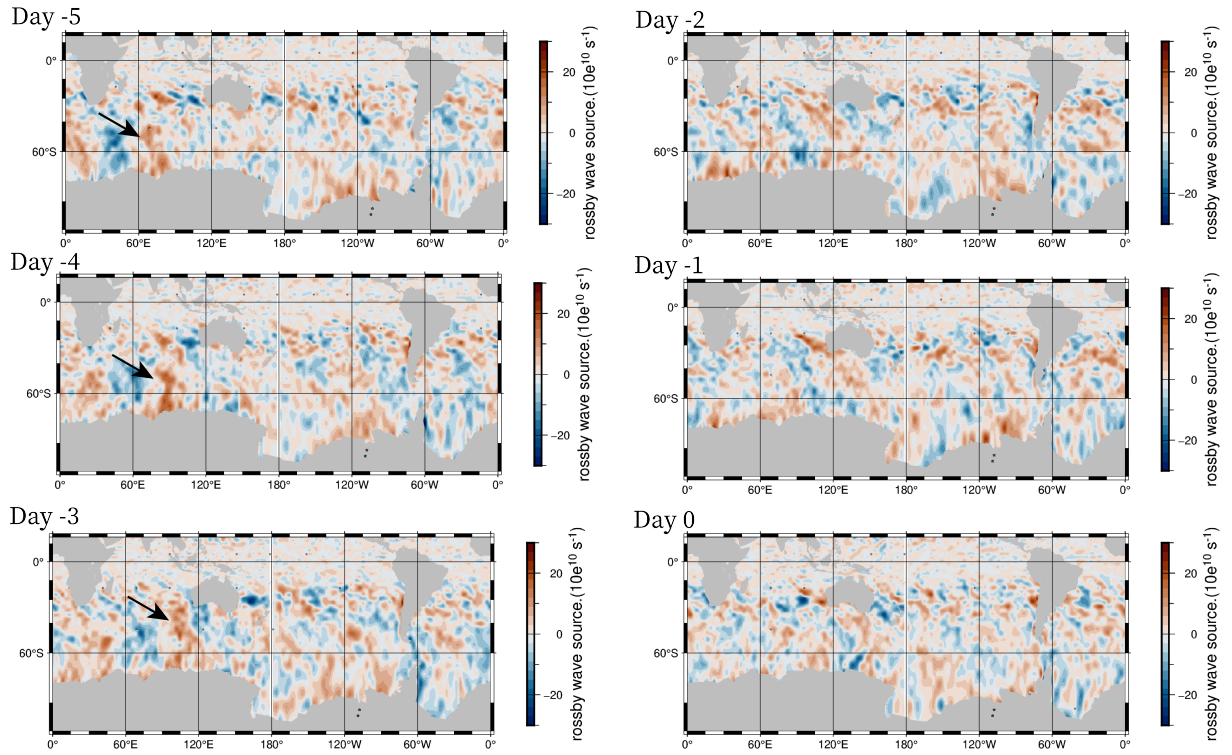


Figure S6. Austral winter Rossby wave source anomalies calculated from 200 hPa winds. Days for each panel indicate the shifted index for composite average prior to (or on) the day of extreme precipitation observed at the GNSS-IR stations located on Thwaites Glacier, which are plotted as orange and blue stars.

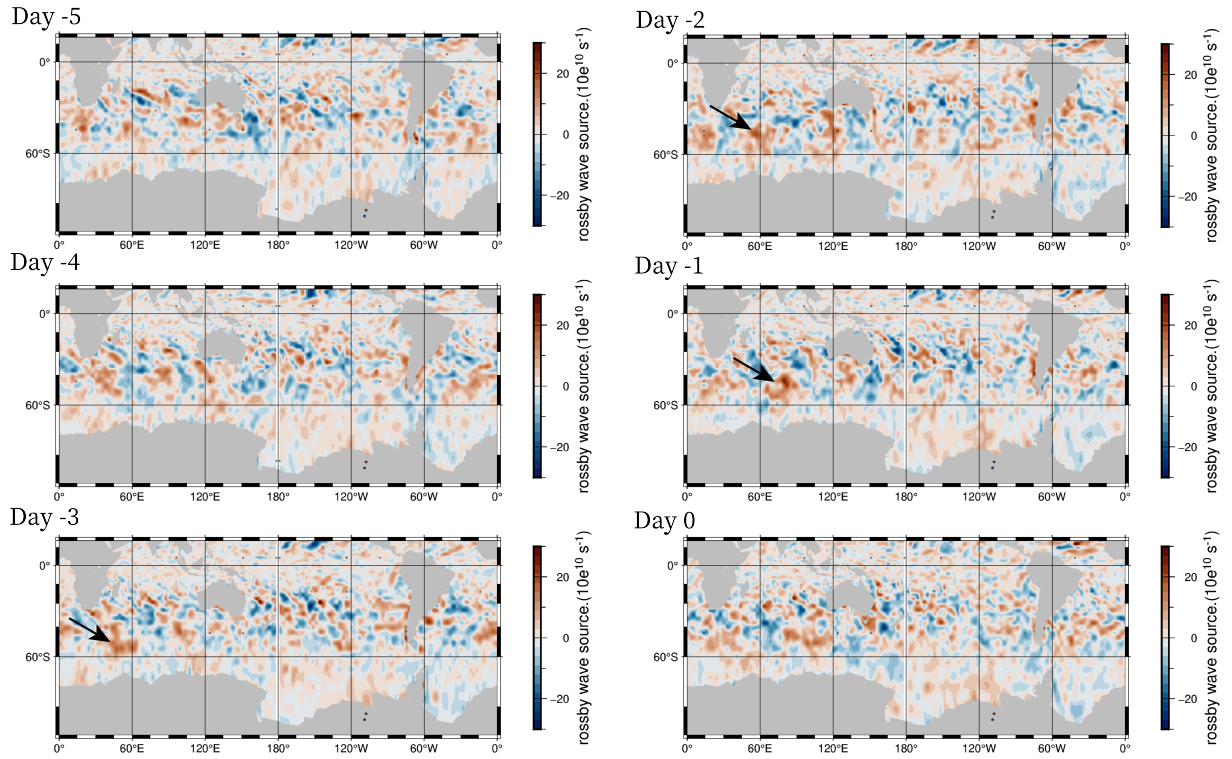


Figure S7. [Same as fig. S6 but with austral summer Rossby wave anomalies.](#)

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