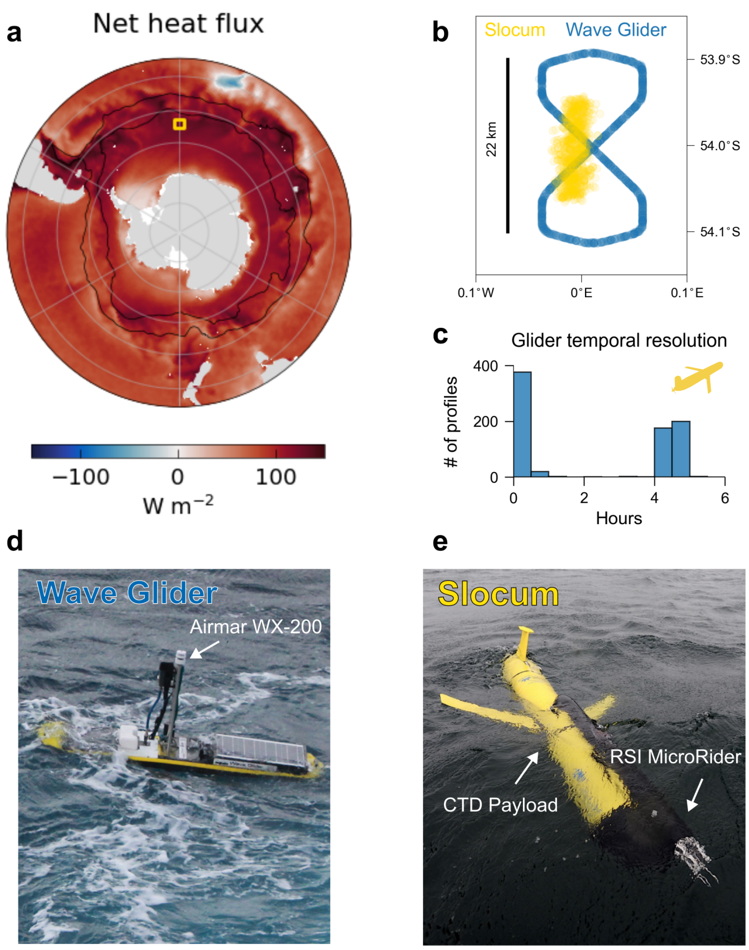
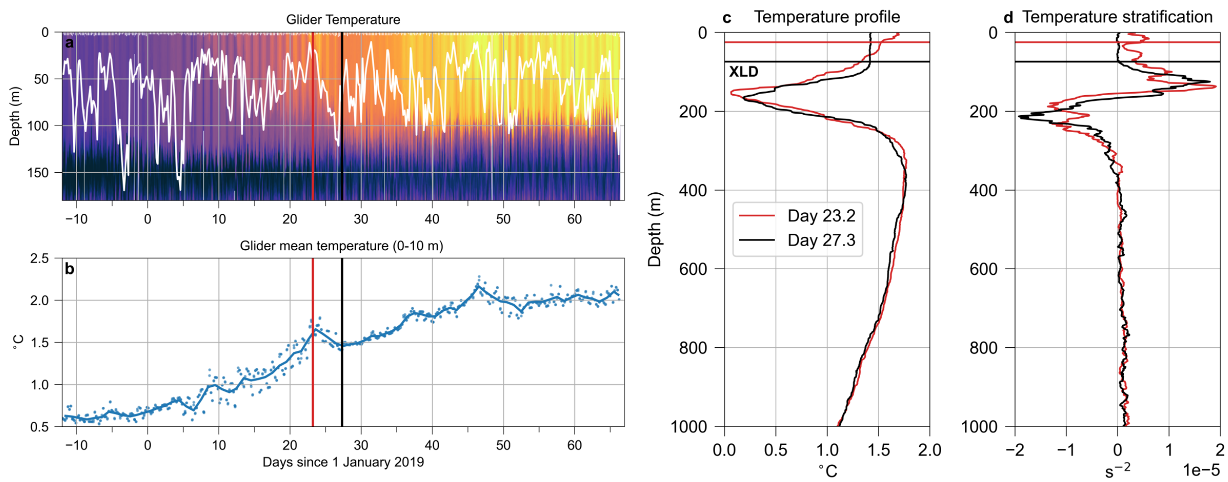
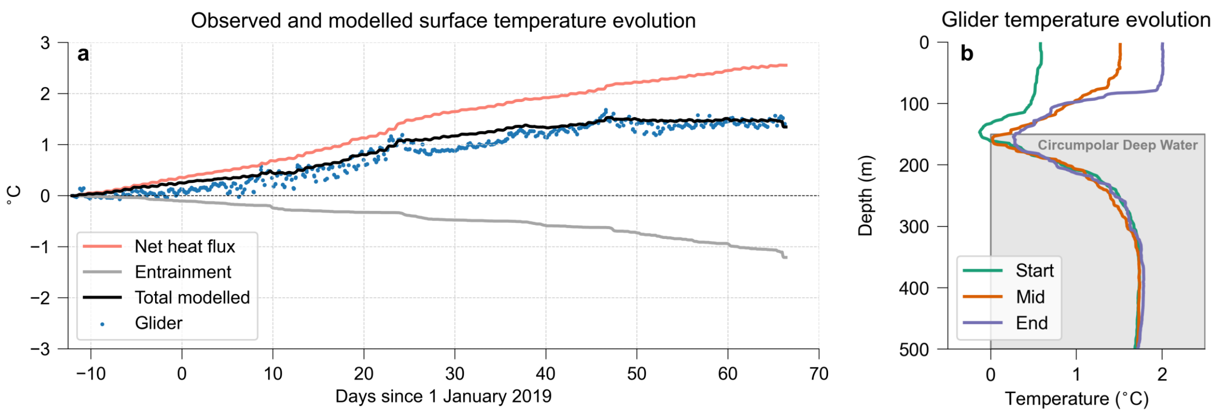
Supplementary Information for ”Storms regulate Southern Ocean summer warming” by du Plessis and co-authors.



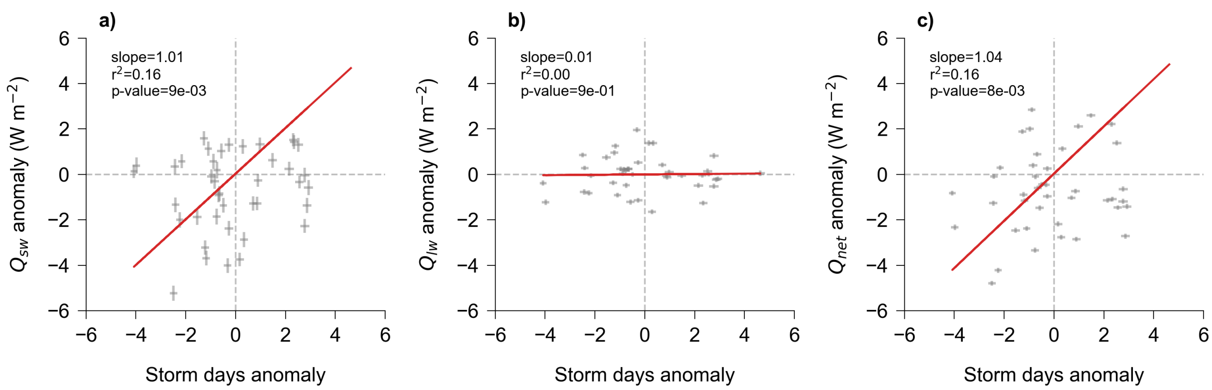
Extended Data Figure 1. SOSCEx-STORM field campaign and robotic platforms. (a) ERA5 reanalysis net air-sea heat flux averaged over the field campaign. Field campaign location is depicted as the yellow box. (b) Tracks of the Slocum profiling glider (yellow) and surface Wave Glider (blue). (c) Temporal resolution of the time between Slocum glider sea surface temperature observations. (d) Liquid Robotics Wave Glider and (e) Webb Teledyne Slocum glider. Photos courtesy of Sarah Nicholson.



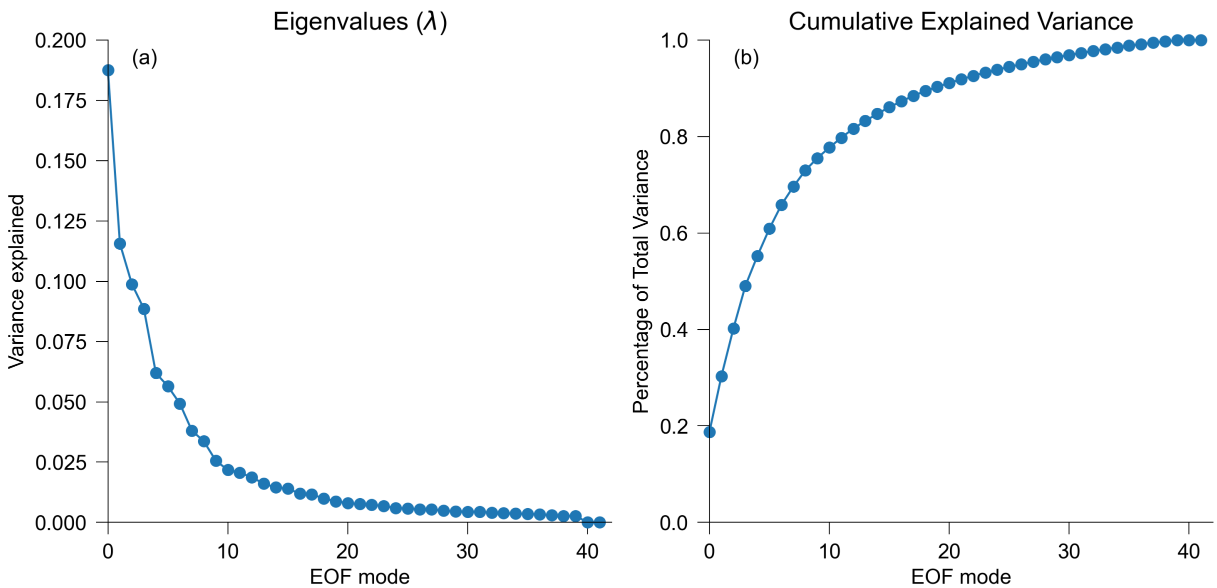
Extended Data Figure 2. Storm-driven entrainment event. (a) Section plot of the Slocum glider temperature indicating the mixing layer depth (XLD) as the white line. The red and black lines represent the time stamp of two profiles compared in (c) and (d). (b) Time series of the sea surface temperature from the Slocum glider observations (line represents the daily mean). Red and black lines are the same as in (a). (c) Temperature, and (d) temperature stratification profiles for the upper ocean before (red, day 23.2) and after (black, day 27.3) the storm encountered on 24 January 2019. The respective horizontal lines depict the depth of the XLD for each given profile.



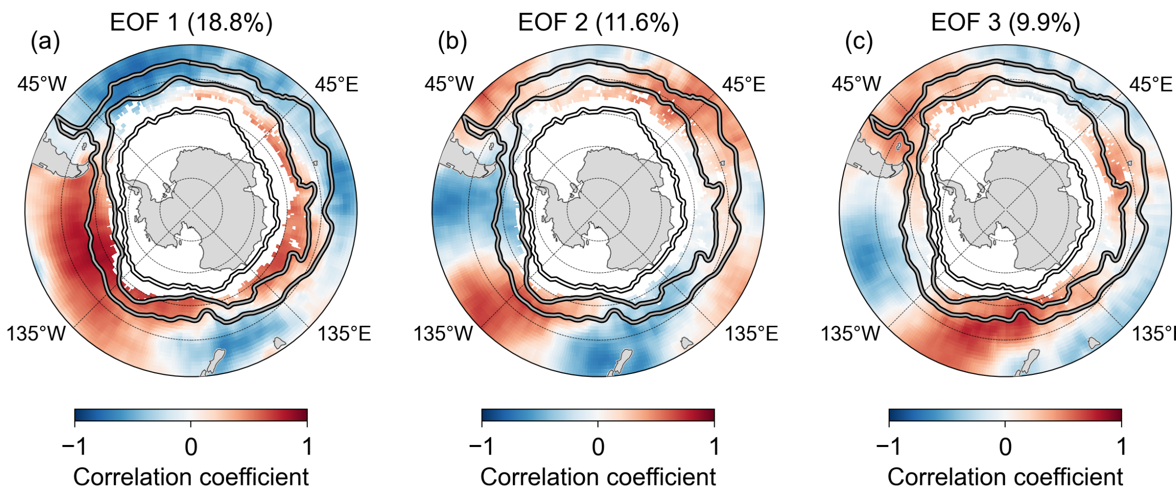
Extended Data Figure 3. Mixed layer temperature budget explains summer warming. (a) Slocum glider sea surface temperature (blue dots) compared against the sea surface temperature estimated from the mixed layer budget (see Methods) using only the air-sea heat flux (pink line) and entrainment (gray line) terms. The net modelled temperature (the sum of the air-sea flux and entrainment temperature) shown in the black line. (b) Seasonal evolution of the upper ocean (top 500 m) temperature from the glider. The three profiles represent the beginning (green line), middle (orange line), and end (purple line).



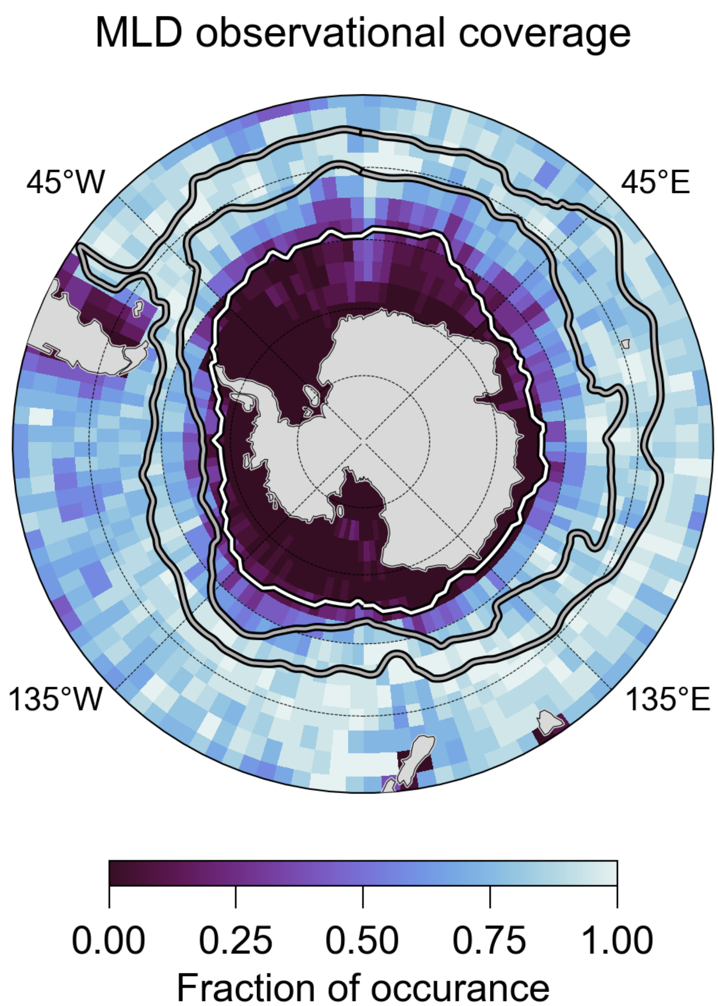
Extended Data Figure 4. Interannual changes in air-sea heat flux and number of storm days. (a-c) Scatter plots showing the relationship between the summer Southern Ocean ice-free mean shortwave (a), longwave (b), and net (c) heat flux anomaly from ERA5 reanalysis and the total number of storm days for the respective year.



Extended Data Figure 5. Empirical Orthogonal Function eigenvalues. (a) Eigenvalues (λ) for the EOF (Empirical Orthogonal Function) analysis quantifying the amount of variance in the SST_{max} that is explained by each EOF. λ represents the portion of the total variance captured by the EOF. The larger the eigenvalue, the more variance that EOF explains. The eigenvalues are sorted in descending order, so the first EOF (associated with the largest eigenvalue) explains the most variance, the second EOF explains the next most, and so on. (b) The cumulative sum of the eigenvalues in (a).



Extended Data Figure 6. Empirical Orthogonal Function of the seasonal maxima in sea surface temperature. First three EOFs (a-c) of the detrended and standardized SST_{max} (see Methods). Percentages indicate the amount of the variance explained by each EOF. Color indicates the correlation coefficient between the EOF and the detrended SST_{max}. Gray lines show the location of the Polar Front (south) and Subantarctic Front (north). White line shows the location of the climatological December sea ice edge.



Extended Data Figure 7. Southern Ocean data coverage of mixed layer depth observations. Map of fractional occurrence of summer (DJF) mixed layer depth measurements for the time period between 2004 and 2022 using profiles from the EN4 dataset.