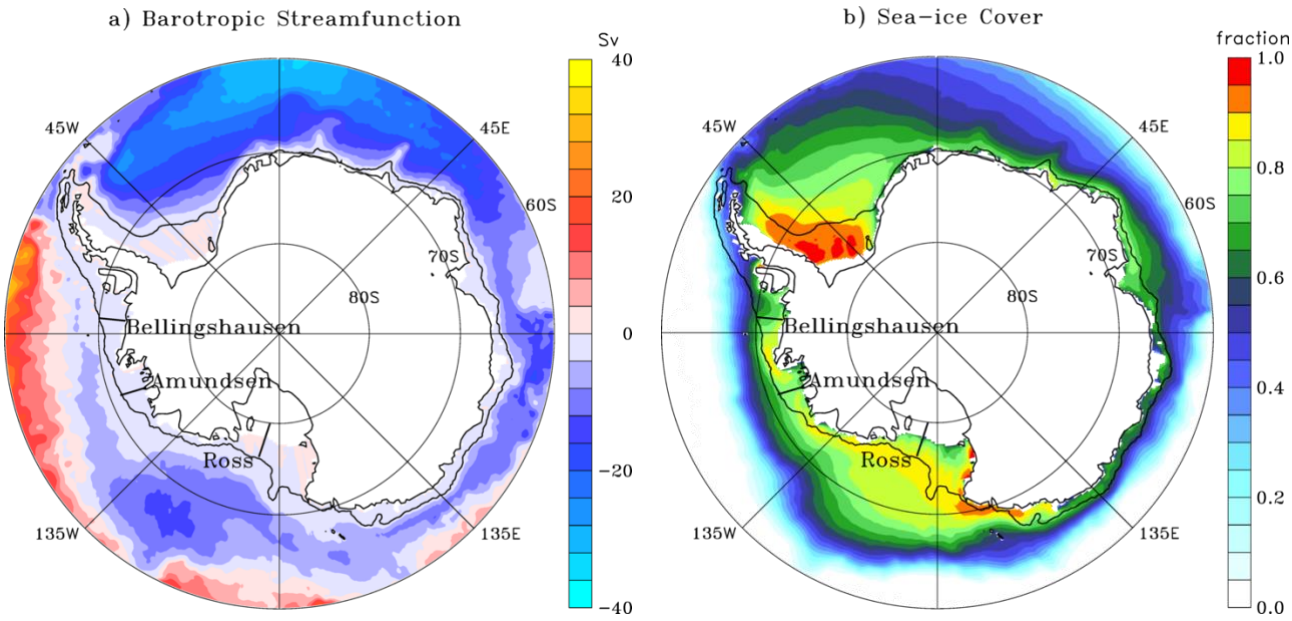
Table 1. Overview of lagged regression and correlation computations.

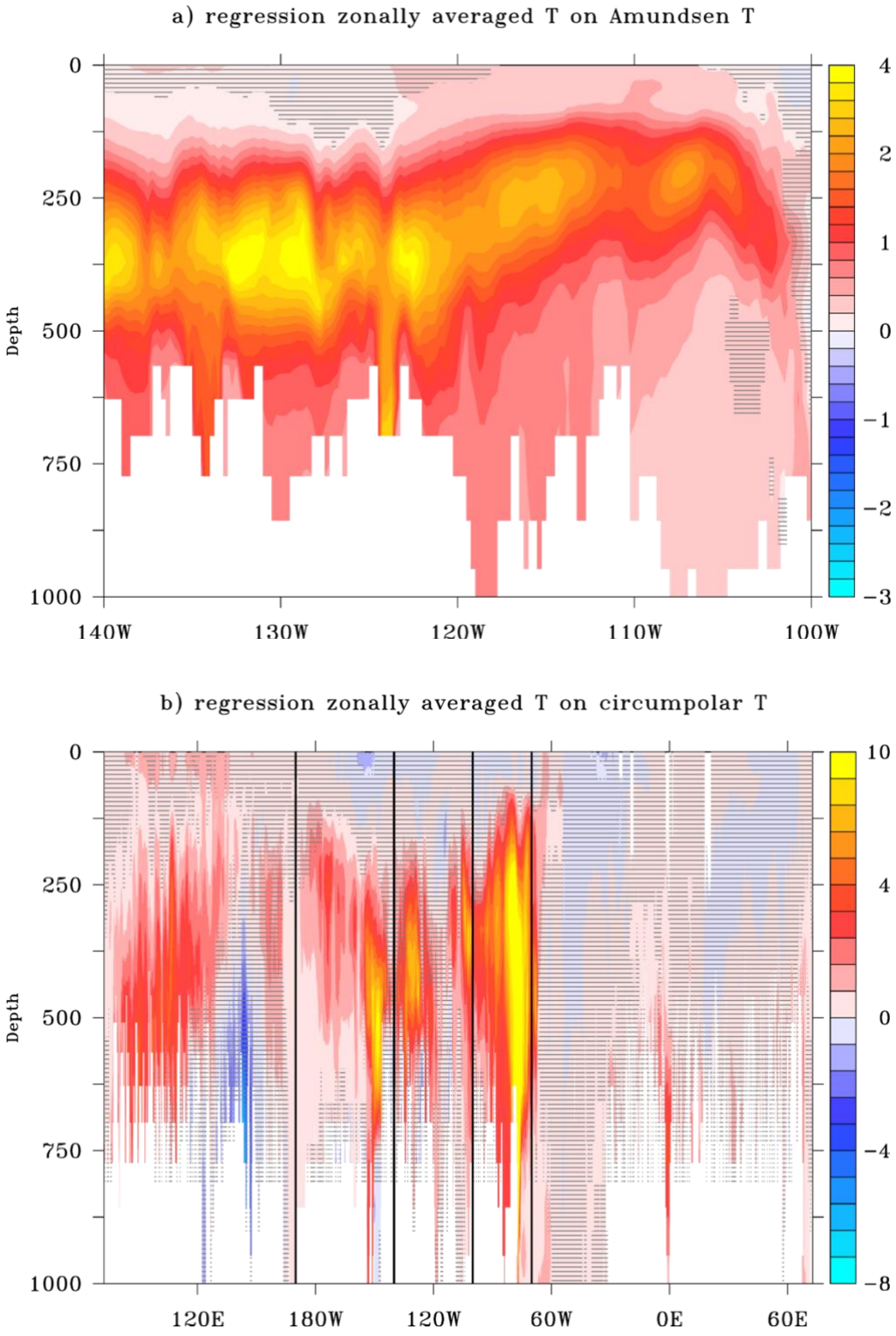
p	q	Figure
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{k}(T.dxdydz)/Vol_{ACS}$	6a and 6c
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{k}(S.dxdydz)/Vol_{ACS}$	6b and 6d
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{k}(T.dxdydz)/Vol_{200-400}$	9a, 9e and 9f
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{k}(T.dxdydz)/Vol_{600-800}$	9b
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{k}(T.dxdydz)/Vol_{400-600}$	9c and 9d
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{j,k}(T.dxdydz)/Vol_{Shelf200-400}$	10a
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{j,k}(T.dxdydz)/Vol_{Slope200-400}$	10b
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{j,k}(T.dxdydz)/Vol_{Shelf600-800}$	10c
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{j,k}(T.dxdydz)/Vol_{Slope600-800}$	10d
$\sum_{i,j,k}(T.dxdydz)/Vol_{ASlope200-400}$	$\sum_{j,k}(T.dxdydz)/Vol_{Shelf200-400}$	11a
$\sum_{i,j,k}(T.dxdydz)/Vol_{BSlope200-400}$	$\sum_{j,k}(T.dxdydz)/Vol_{Shelf200-400}$	11b
$\sum_{i,j,k}(T.dxdydz)/Vol_{Slope200-400}$	$\sum_{j,k}(T.dxdydz)/Vol_{Shelf200-400}$	11c
$\sum_{i,j,k}(T.dxdydz)/Vol_{AShelf}$	$\sum_{j}(T.dxdydz)/Vol_{AShelf}$	S2a
$\sum_{i,j,k}(T.dxdydz)/Vol_{ACS}$	$\sum_{j}(T.dxdydz)/Vol_{ACS}$	S2b
$\sum_{i,j,k}(\frac{dT}{dt}.dxdydz)/Vol_{AShelf}$	τ_x	S3c
$\sum_{i,j,k}(\frac{dT}{dt}.dxdydz)/Vol_{BShelf}$	τ_x	S3d
$\sum_{i,j,k}(\frac{dT}{dt}.dxdydz)/Vol_{AShelf}$	$\sum_{k}(V.dz)_{Amundsen200-400}/200$	S3e
$\sum_{i,j,k}(\frac{dT}{dt}.dxdydz)/Vol_{AShelf}$	$\sum_{k}(V.dz)_{Amundsen400-600}/200$	S3f

In this Table *T* denotes temperature, *S* salinity, *v* meridional velocity, *V* the absolute velocity, τ_x zonal windstress, SLP sea-level pressure, and *Vol* is volume (dxdydz). The subscripts *ACS* indicates full-depth averages for the whole Antarctic Continental Shelf, *Aslope* and *Ashelf* are zonally averaged between 140°W and 100°W, (Amundsen Sea), and *Bshelf* between 100°W and 70°W (Bellingshausen Sea).



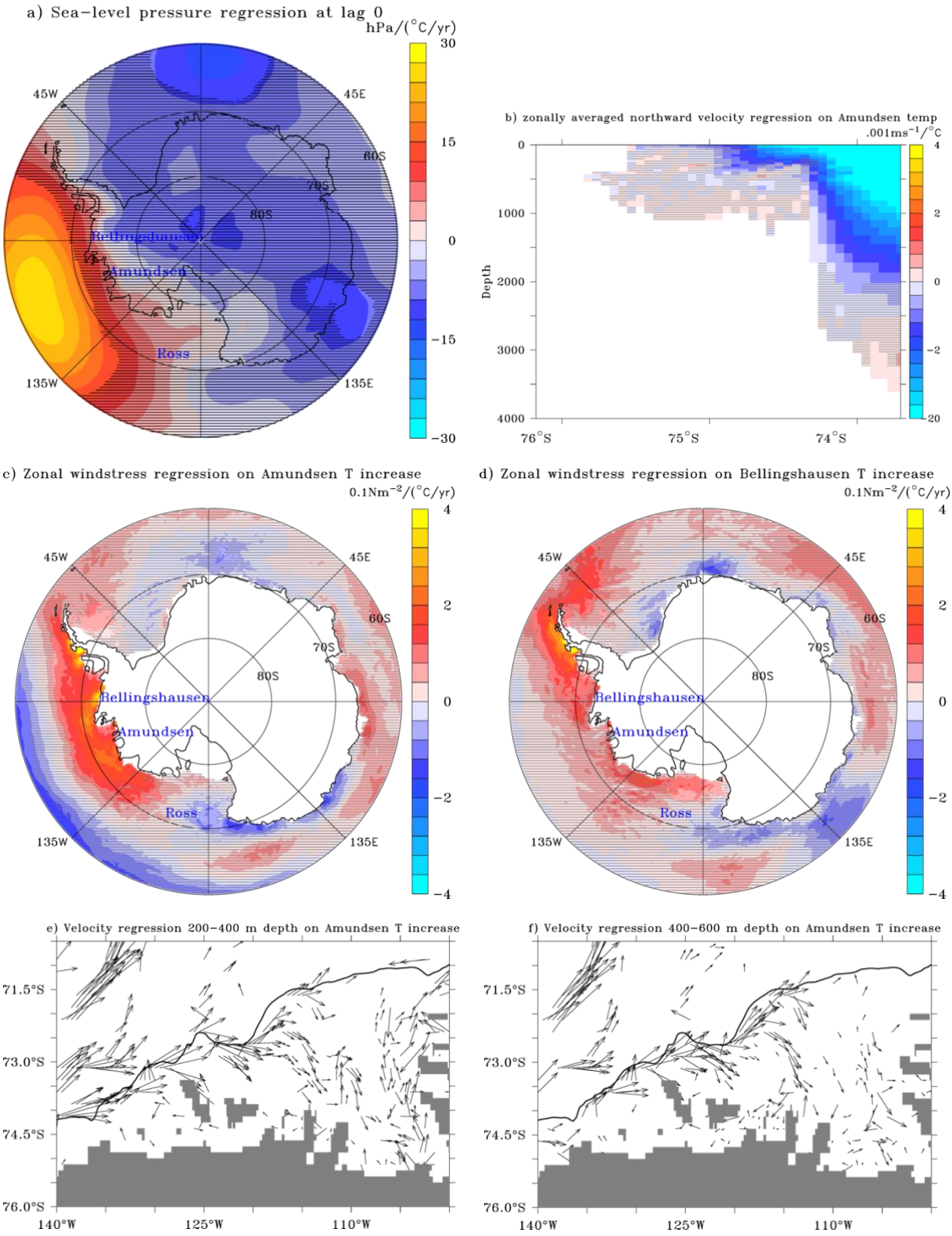
Supplementary Figure 1. a) Annual mean barotropic streamfunction and b) sea-ice cover averaged over the period 1982-2017.

To elucidate why the Amundsen sector is a hotspot for upwelling of deep CDW anomalies, we calculate the regression of sea-level pressure (SLP) and westerly wind stress onto the warming rate (dT/dt) in the Amundsen sector of the Antarctic shelf. Coinciding with the peak in warming rate, the SLP anomaly is positive, weakening and shifting negative SLP westward (Supplementary Fig. 2a). Subsequently, a westerly wind stress anomaly occurs over the shelf and slope (Supplementary Fig. 2c), facilitating CDW upwelling. Concurrently, flow onto the shelf along deep troughs increases (Supplementary Fig. 2e,f). In particular, the eastward/southward undercurrent (Walker et al., 2013) in the central Amundsen shelf is enhanced when the warming rate in the Amundsen sector peaks. The westward-flowing Antarctic Slope Current then weakens, providing more time for anomalies on the slope to upwell onto the shelf. Also, during peak warming, the zonally averaged meridional flow has become increasingly southward on and above the slope, flooding the Amundsen sector of the shelf (Supplementary Fig. 2b). Unlike the horizontal circulation, the zonally averaged overturning circulation correlates less well with warming rate than with temperature itself in the Amundsen sector. We infer that the zonally averaged overturning is not only a driver of, but also a response to, warming in the Amundsen sector of the shelf. Note that the SLP and wind stress signals associated with peak warming in the Bellingshausen sector are markedly different from the signals during peak warming in the Amundsen sector (Supplementary Fig. 2d). The eastward wind stress to the north of the Ross, Amundsen and Bellingshausen sectors is now enhanced everywhere to the south of 40°S, and peaks over the Bellingshausen Sea.



Supplementary Figure 2. Regression of meridionally averaged temperature on the shelf at lag 0 on a) averaged temperature in the Amundsen sector of the shelf, b) averaged temperature over the whole Antarctic shelf (units °C °C^{-1}). Non-significant values according to a two-sided Student's T-test are overlaid by grey horizontal lines. Black vertical lines indicate the boundaries of the Ross, Amundsen, and Bellingshausen sectors.

Supplementary Fig. 2 shows the vertical and longitudinal pattern of meridionally averaged temperature anomaly when a) the three-dimensional average of the temperature in the whole Amundsen sector of the shelf peaks, and b) the three-dimensional average of the temperature in whole Antarctic shelf peaks, which occurs ~ 9 years later. These figures support analyses of the propagation of temperature anomalies in three layers: 200-400m, 400-600m, and 600-800m.



Supplementary Figure 3. a) Regression of sea-level pressure on temperature increase averaged over the Amundsen sector of the shelf at lag 0 (units in hPa / (°C / year)). b) Zonally averaged northward velocity in the Amundsen sector regressed on horizontally and vertically averaged temperature in the Amundsen sector (units 10^{-3} m s^{-1} / °C). c,d) Regression of zonal wind-stress on temperature increase at lag 0 c) averaged over the Amundsen sector of the shelf d) regressed on temperature increase over the Bellingshausen sector of the shelf (units 0.1 Nm^{-2} / (°C / year)). Non-significant values according to a two-sided Student's T-test are overlaid by grey horizontal lines. e,f) Regression of the velocity on temperature increase in the Amundsen sector of the shelf at lag 0, e) averaged over 200–200m depth, f) averaged over 400–600m depth (units ms^{-1} / (°C / year)). Only significant regression values are plotted. Continental shelf boundary in (e), (f) are indicated by a black line, land is indicated in solid grey.