**Figure S1.** Ocean mooring temperature observations from the Palmer LTER grid location 300.100 for years 2007, 2008, and 2011. Mooring deployments were nominally one year long. Missing data in January occurrent when there was a gap between annual mooring retrieval and deployment. Temperature sensor details are provided in Table S1, and interpolation methods used between sensors are detailed in the text.

**Figure S2**. Observed Palmer LTER temperature and salinity data from CTD cast and mooring observations, and the empirical temperature-salinity relationship used in Equation 1.

**Figure S3**. Temperature and salinity profiles acquired by the Palmer LTER during austral summer in the vicinity of the ocean mooring, compared to KEI model results. Shown are profiles bracketing each simulation period for each simulation (see Section 2.6 for descriptions of simulations FREE, IC, TC, and ITC) starting in 2007 (row a), 2008 (row b) and 2011 (row c). Temperature and salinity profiles on the left were used to initialize each simulation, and temperature and salinity profiles on right show the comparison between observations and simulations on the next observation date, after approximately 1 year of simulation time.

**Figure S4a.** The 2007-08 monthly mean wind vectors (grey arrows) for the WAP region (from ERA5), overlaid on sea-ice concentration (blue gradient) (from GSFC Bootstrap sea ice concentration). Colored lines in the sea ice represent fronts of constant sea ice concentration: green = 75% mean location for month/year in question; dashed green= 75% mean location for the 1979-2012; red = 15% mean location for month/year in question; dashed red = 15% mean location for 1979-2012. The red ‘M’ marks the location of the Palmer LTER 300.100 mooring.

**Figure S4b.** As Figure S4a but for 2008-09.

**Figure S4c.** As for Figure S4a but for 2011-12.

**Figure S5a.** Daily mean heat fluxes and heat content for 2007-08 simulations. Vertical black dashed lines enclose the satellite-observed sea-ice period. (a) Fractional sea ice concentration. (b) Atmospheric heat flux to the ocean planetary boundary layer (PBL), positive downward. (c) Ocean heat flux from the PBL to sea ice (positive upwards). (d) Ocean heat content (J above seawater freezing temperature) of the top 60 m of the ocean. (e) Ocean heat flux across the permanent pycnocline to the PBL (positive upwards). The range limits on the y-axis were optimized (saturated) to show greater detail during the ice-covered period. (f) The planetary boundary layer turbulent mixing depth as calculated by the KPP mixing scheme.

**Figure S5b.** As for Figure S5a but for 2008-09.

**Figure S5c.** As for Figure S5a but for 2011-12.

**Figure S6.** Depth-time difference between simulated ocean temperature (IC) and assimilated ocean temperature (ITC) for (a) 2007, (b) 2008, and (c) 2011. Vertical dotted lines represent satellite observed ice-on and ice-off dates.

**Table S1.** Mooring Sensor details from the 300.100 mooring location (66.50 ºS, 69.87 ºW) during modeled years (2007, 2008, 2011). Moorings were deployed in January or February and sampled for approximately one year (~350 days) before retrieval. Sensor types as follows: T = temperature, P = pressure, S = conductivity/salinity, CT = current and temperature. Sensor models as follows: 39T/TP = Seabird Electronics 39 temperature recorder, 37 = Seabird Electronics 37 temperature conductivity recorder, AEM = Alec Infinity EM Current/Temperature Meter. All sensors were factory-calibrated at manufacturers’ recommended intervals before deployment.

Seabird Temperature sensor details:

* Initial Accuracy = 0.002 ºC
* Typical Stability = 0.0002 ºC/month
* Resolution = 0.0001 ºC

Seabird Conductivity sensor details:

* Initial Accuracy = 0.0003 S/m
* Typical Stability = 0.0003 (S/m)/month
* Resolution = 0.00001 S/m

Infinity EM Temperature sensor details:

* Accuracy = 0.02 ºC
* Resolution = 0.001 ºC

2007

|  |  |  |  |
| --- | --- | --- | --- |
| Type | Nominal pressure (dBar) | Model | Sampling rate (min) |
| TP | 38.2 | 39TP | 10 |
| T | 48.6 | 39T | 10 |
| T | 59.1 | 39T | 10 |
| TP | 69.5 | 39TP | 10 |
| T | 79.4 | 39T | 10 |
| TP | 91.0 | 39TP | 10 |
| T | 116.9 | 39T | 10 |
| TP | 153.1 | 39TP | 10 |
| T | 204.6 | 39T | 10 |
| TPS | 279.5 | 37 | 10 |
| T | 433.6 | 39T | 10 |

2008

|  |  |  |  |
| --- | --- | --- | --- |
| Type | Nominal pressure (dBar) | Model | Sampling rate (min) |
| TP | 34.0 | 39TP | 10 |
| T | 44.0 | 39T | 10 |
| T | 53.9 | 39T | 10 |
| TP | 63.9 | 39TP | 10 |
| T | 76.3 | 39T | 10 |
| TP | 90.6 | 39TP | 10 |
| T | 116.3 | 39T | 10 |
| TP | 152.2 | 39TP | 10 |
| T | 203.4 | 39T | 10 |
| TPS | 277.6 | 37 | 10 |
| T | 430.7 | 39T | 10 |

2011

|  |  |  |  |
| --- | --- | --- | --- |
| Type | Nominal pressure (dBar) | Model | Sampling rate (min) |
| TP | 29.7 | 39TP | 15 |
| TP | 35.0 | 39TP | 15 |
| T | 40.2 | 39T | 15 |
| T | 44.2 | 39T | 15 |
| T | 49.3 | 39T | 15 |
| T | 61.6 | 39T | 15 |
| TP | 75.9 | 39TP | 15 |
| CT | 90.9 | AEM | 30 |
| T | 107.9 | 39T | 15 |
| TP | 122.0 | 39TP | 15 |
| T | 137.6 | 39T | 15 |
| TP | 157.6 | 39TP | 15 |
| CT | 193.3 | AEM | 30 |
| TP | 234.0 | 39TP | 15 |
| TP | 279.5 | 39TP | 15 |
| TP | 367.0 | 39TP | 15 |
| TP | 423.4 | 39TP | 15 |