Supplementary Material I

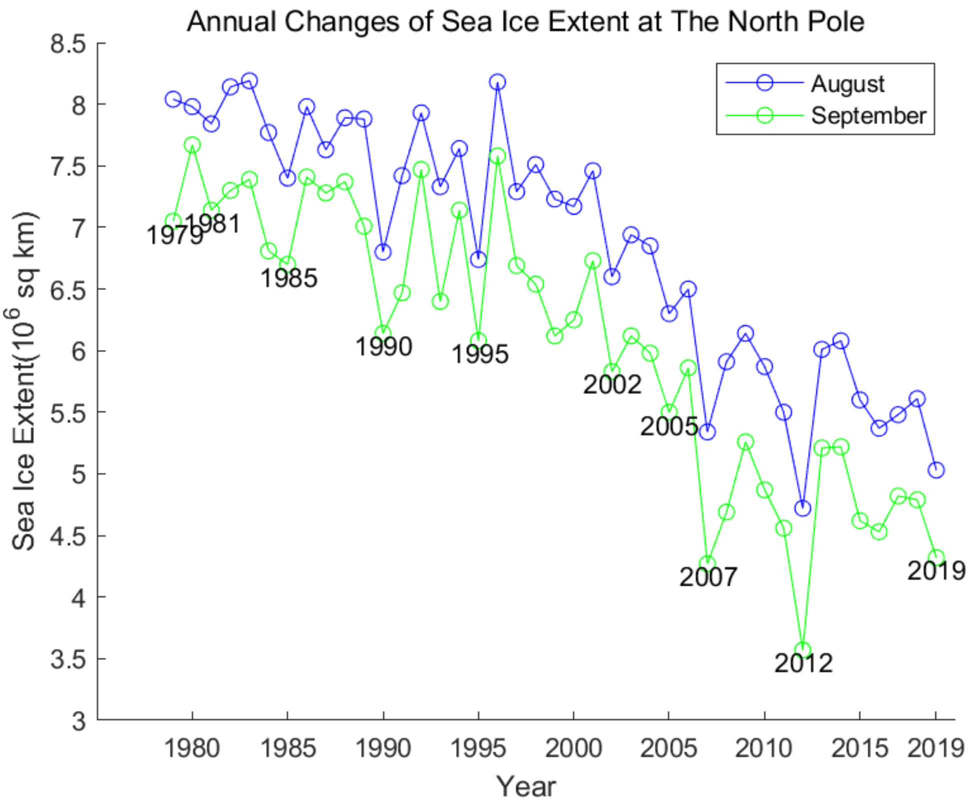

Figure S1 Annual changes of sea ice extent in the Arctic on August and September.

Supplementary Material II

Table S1. The longitude, latitude, and sampling start time of the 58 stations.

Station	Longitude	Latitude	Date and time	Station	Longitude	Latitude	Date and time
BL01	171.87E	54.58N	24/08 06:33:22	**BS04**	170.13W	64.33N	29/08 08:20:48
BL02	172.77E	55.27N	24/08 13:02:20	**BS05**	169.41W	64.33N	29/08 10:11:39
BL03	174.57E	56.57N	24/08 23:36:43	**BS06**	168.71W	64.33N	29/08 12:05:17
BL04	175.60E	57.39N	25/08 07:27:26	**BS07**	168.11W	64.33N	29/08 14:01:38
BL05	177.41E	58.30N	25/08 18:03:27	**BS08**	167.45W	64.37N	29/08 15:14:42
BL06	178.41E	58.72N	27/08 00:06:14	**BT12**	167.12W	74.32N	03/09 05:54:45
BL07	179.51W	60.04N	27/08 13:46:35	**BT13**	167.82W	74.75N	01/09 08:00:24
BL08	179.00W	60.40N	27/08 17:28:25	**BT14**	167.85W	75.03N	01/09 11:17:22
BL09	178.21W	60.80N	27/08 21:38:45	**BT15**	167.82W	75.33N	01/09 14:36:37
BL10	177.23W	61.29N	28/08 02:32:42	**BT16**	167.80W	75.64N	01/09 18:11:55
BL11	176.17W	61.93N	28/08 07:25:10	**BT25**	167.81W	74.74N	02/09 20:59:52
BL12	175.01W	62.59N	28/08 12:18:21	**BT26**	171.21W	74.60N	01/09 04:20:21
BL13	173.43W	63.29N	28/08 18:19:56	**BT27**	169.32W	74.35N	03/09 09:42:37
BL14	172.40W	63.77N	28/08 22:08:49	**M11**	166.44W	74.80N	02/09 18:08:27
BR00	174.09W	56.95N	08/09 15:52:39	**M12**	172.00W	75.21N	02/09 14:48:17
BR01	173.69W	57.41N	08/09 11:26:24	**M13**	172.01W	75.61N	02/09 10:55:12
BR02	173.22W	57.90N	08/09 07:31:37	**M14**	172.00W	76.03N	02/09 02:53:16
BR03	172.73W	58.40N	08/09 04:22:07	**M15**	171.96W	75.82N	01/09 22:43:37
BR04	172.25W	58.91N	08/09 00:26:27	**R01**	169.87W	66.21N	30/08 02:09:33
BR05	171.30W	59.90N	07/09 17:25:13	**R02**	168.75W	66.89N	30/08 05:40:07
BR06	170.35W	60.91N	07/09 11:09:28	**R03**	168.75W	67.50N	30/08 09:16:57
BR07	169.67W	61.65N	07/09 06:18:06	**R04**	168.75W	68.19N	30/08 13:09:21
BR08	168.89W	62.40N	07/09 01:13:13	**R05**	168.76W	68.81N	30/08 17:17:20
BR09	168.42W	62.91N	06/09 21:16:20	**R06**	168.75W	69.53N	30/08 21:11:26
BR10	167.93W	63.40N	06/09 18:11:50	**R07**	168.75W	70.33N	31/08 02:08:10
BR11	167.47W	63.90N	06/09 14:01:53	**R08**	168.75W	71.17N	31/08 07:18:38
BS01	171.39W	64.32N	29/08 02:52:43	**R09**	168.75W	71.99N	31/08 11:56:35
BS02	170.82W	64.33N	29/08 04:42:27	**R10**	168.74W	72.90N	31/08 16:38:02
BS03	170.12W	64.33N	29/08 06:31:27	**R11**	168.74W	74.15N	31/08 23:57:32

Supplementary Material III

Table S2. Equipment for temperature and salinity measurement.

Instrument	**Model**	**Sampling frequency**	**Conductivity resolution**	**Temperature resolution (°C)**	**Pressure resolution (db)**
Lowered CTD	SBE 911 Plus	24	0.00004	0.0002	0.001
Underway multi-element system	SeaBird FerryBox	1	0.005	0.0001	--

Supplementary Material IV

Table S3. ADCP Model

Instrument	**Model**	**Bin size**	**Sampling depth**	**No. Bins**	**Pings/Ens**	**Time/Ping(s)**
Lowered ADCP	Teledyne RDI WHSentinel 300kHz	2~8m	110m	14~50	1	1
Underway ADCP1	Teledyne RDI WHMariner 300kHz	4m	110m	50	1	0.5
Underway ADCP2	Teledyne RDI OS 38kHz	24m	960m	40	1	3

Supplementary Material V

The evaluation of the CCMP wind

The wind observed by the shipboard automatic meteorological station (AWS) was used to evaluate the Version 2 Cross-Calibrated Multi-Platform (CCMP) Wind Vector Analysis Product (Wentz et al., 2015) over the period from Aug. 24 to Sep. 6. The wind speed bias, wind speed root-mean-square error (RMSE hereafter), and wind direction RMSE of the CCMP wind product were 1.29 m, 2.37 m, and 27.46°, respectively. The correlation coefficients of the zonal (meridional) wind between the CCMP wind and the wind measured by the ship were 0.92 (0.91). The mean difference in the zonal (meridional) wind between the CCMP wind and the wind measured by the ship was 0.51 m/s (0.29m/s). This meant that the CCMP wind product behaved well in the target region.

Supplementary Material VI

According to the temperature, salinity, and density profiles, they were identified into three classes: type A profiles within the mixed layer were almost completely homogenous and showed no gradient or fluctuation; type B profiles showed obvious fluctuation, as shown in the red box in (d), (e), and (f) of; type C profiles showed both obvious gradient (black line in (g), (h), and (i) of **Figure S2**) and fluctuations within the mixed layer. BR01, BR00, and BL08 show the profiles of the temperature, salinity, and density of types A, B, and C, respectively (**Figure S2**). Due to the existence of fluctuations (in the red box in (d), (e), and (f) of **Figure S2**) in the temperature, salinity, and density profiles, suitable criteria were required to obtain the MLD. A group of criteria was evaluated in Section 3.1.2. These criteria were adopted from previous studies, including the optimal definition that employs a density-based criterion having a fixed temperature difference of $\Delta T = 0.8°C$ and variable salinity from Kara et al. (2000) and 0.03 kg/m^3 from de Boyer Montégut et al. (2004).

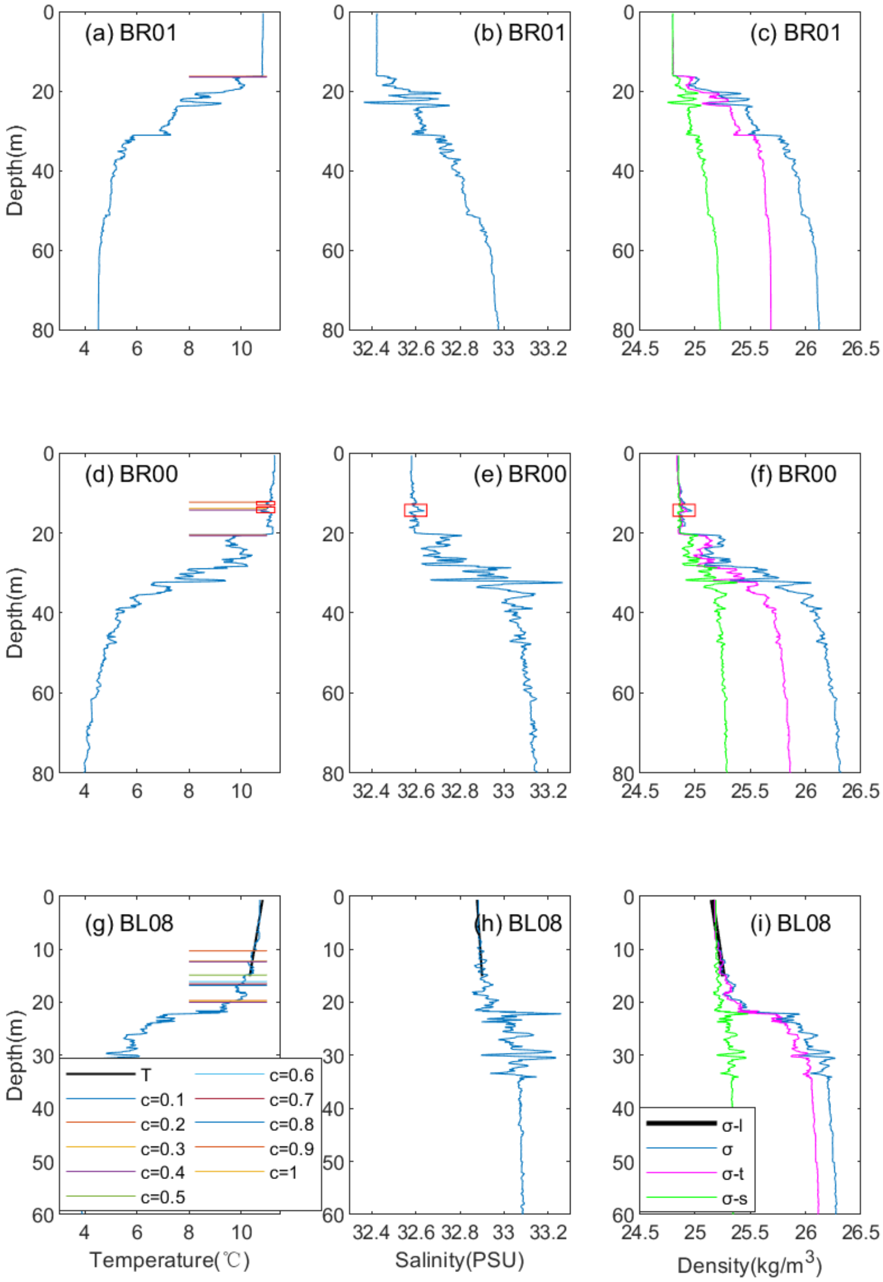

Figure S2. Three types of temperature, salinity, and density profiles. (a), (b), and (c) Type A temperature, salinity, and density profiles, respectively, which had almost the same MLDt using different criteria. (d), (e), and (f) Type B temperature, salinity, and density profiles, respectively. The MLDt calculated from this temperature profile using different temperature criteria was distributed around the local extremum. The local extremum in the red boxes might lead to a smaller MLDt than the real MLDt. (g), (h), and (i) Type C temperature, salinity, and density profile, respectively. The MLDt calculated from the type C temperature profile using different temperature criteria had more differences, and the distributions were more dispersed. Horizontal lines in different colours show different MLDt responding to a group of temperature criteria in (a), (d), and (g). The variable c in the legend represents the temperature criteria, which ranged from 0.1 to $1°C$. The black solid lines in (g), (h), and (i) show the linear regression of the temperature, salinity, and density profiles within the mixed layer. The magenta (green) solid line in (i) shows the density profile calculated from the depth-related temperature (salinity) and the fixed salinity (temperature) at a depth of 5 m.

As **Figure S2** and **Figure S3** showed, the type A stations had almost the same MLD using different criteria; the MLD calculated from type B stations using different temperature criteria were distributed around the local extremum; the MLD calculated from type C stations using different temperature criteria had more difference, and the distributions were more dispersed.

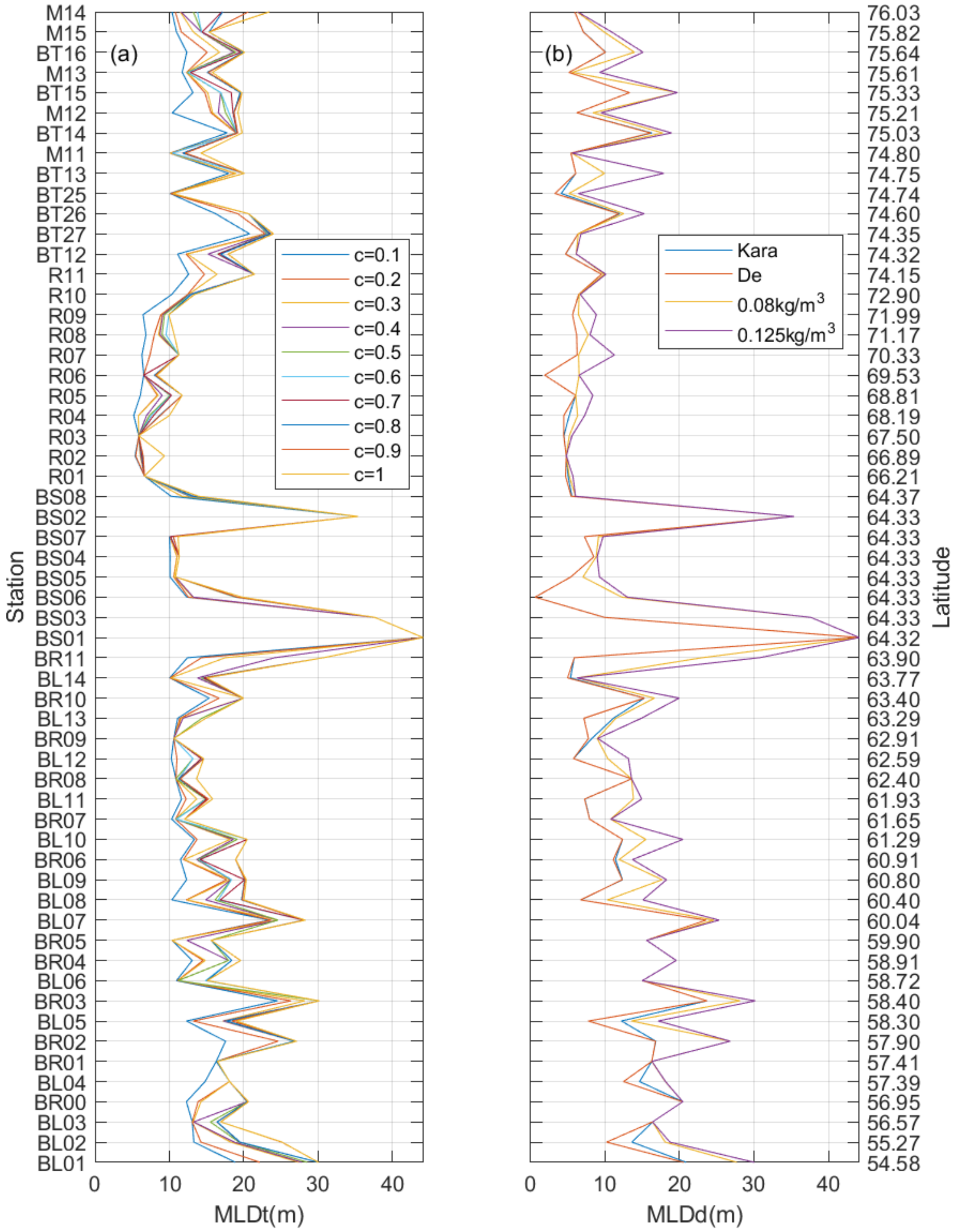

Figure S3. (a) The MLDt corresponding to a group of temperature criteria. The variable c in the legend represents the temperature criteria, which ranged from 0.1 to 1 $^{\circ}C$. (b) The MLDd corresponding to the criteria from Kara et al. (2000), 0.03 kg/m^3 from de Boyer Montégut et al. (2004), 0.08 kg/m^3, and $\Delta\sigma$=0.125kg/m^3.

“Kara”, “De”, “$0.08\mathrm{k}g/m^3$”, and “$0.125\mathrm{k}g/m^3$” refer to the criteria from Kara et al. (2000), de Boyer Montégut et al. (2004), $\Delta\sigma$=$0.08\mathrm{k}g/m^3$, and $\Delta\sigma$=$0.125\mathrm{k}g/m^3$, respectively. Both the left and right panels were in ascending order of latitude.

Supplementary Material VII

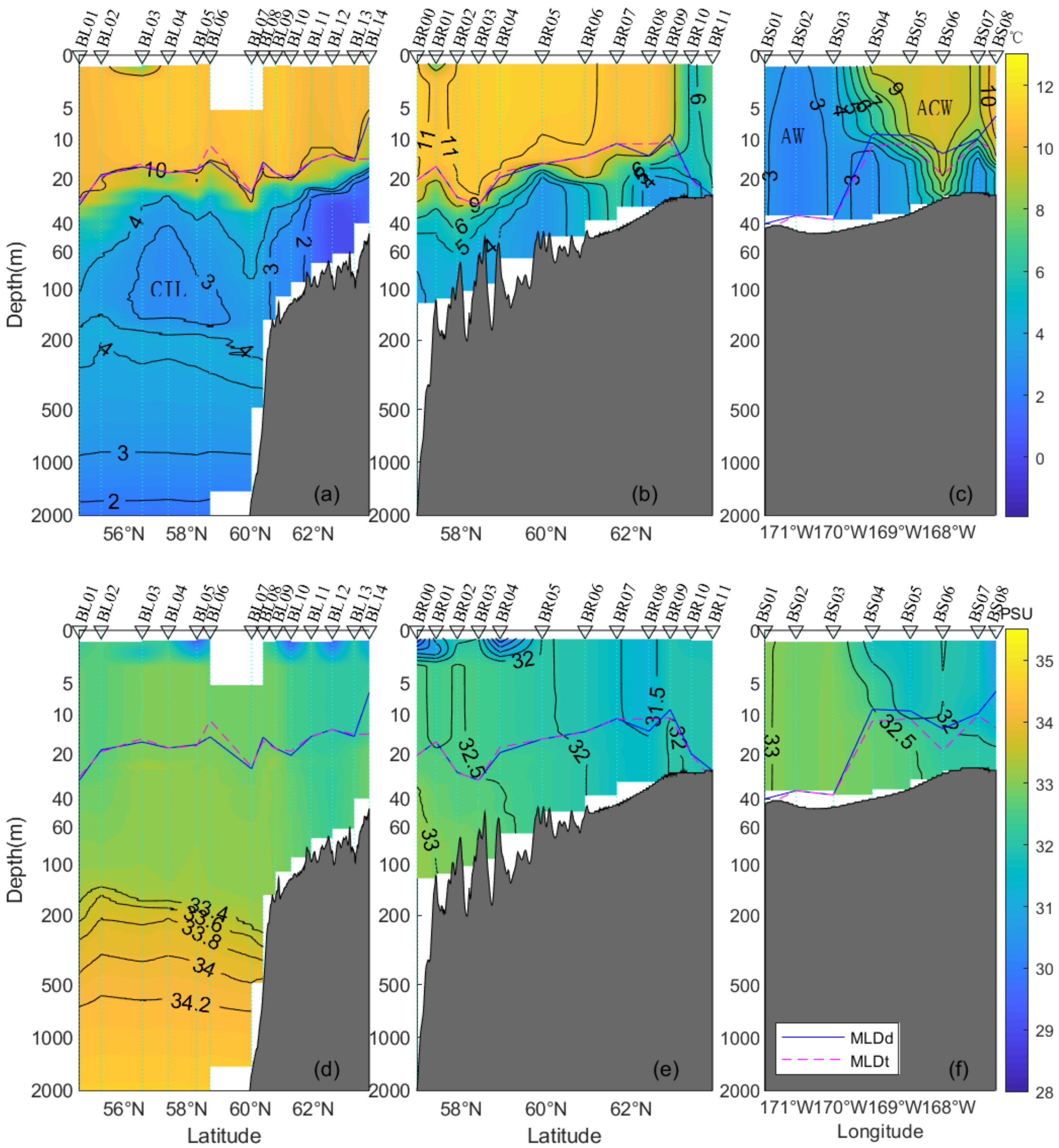

Figure S4. The upper panels: the temperature profiles. The lower panels: the salinity profiles. The left (a, d), middle (b, e), and right (c, f) columns: sections of BL, BR, and BS, respectively. The blue solid line represented the MLDd. The magenta dashed line represented the MLDt.

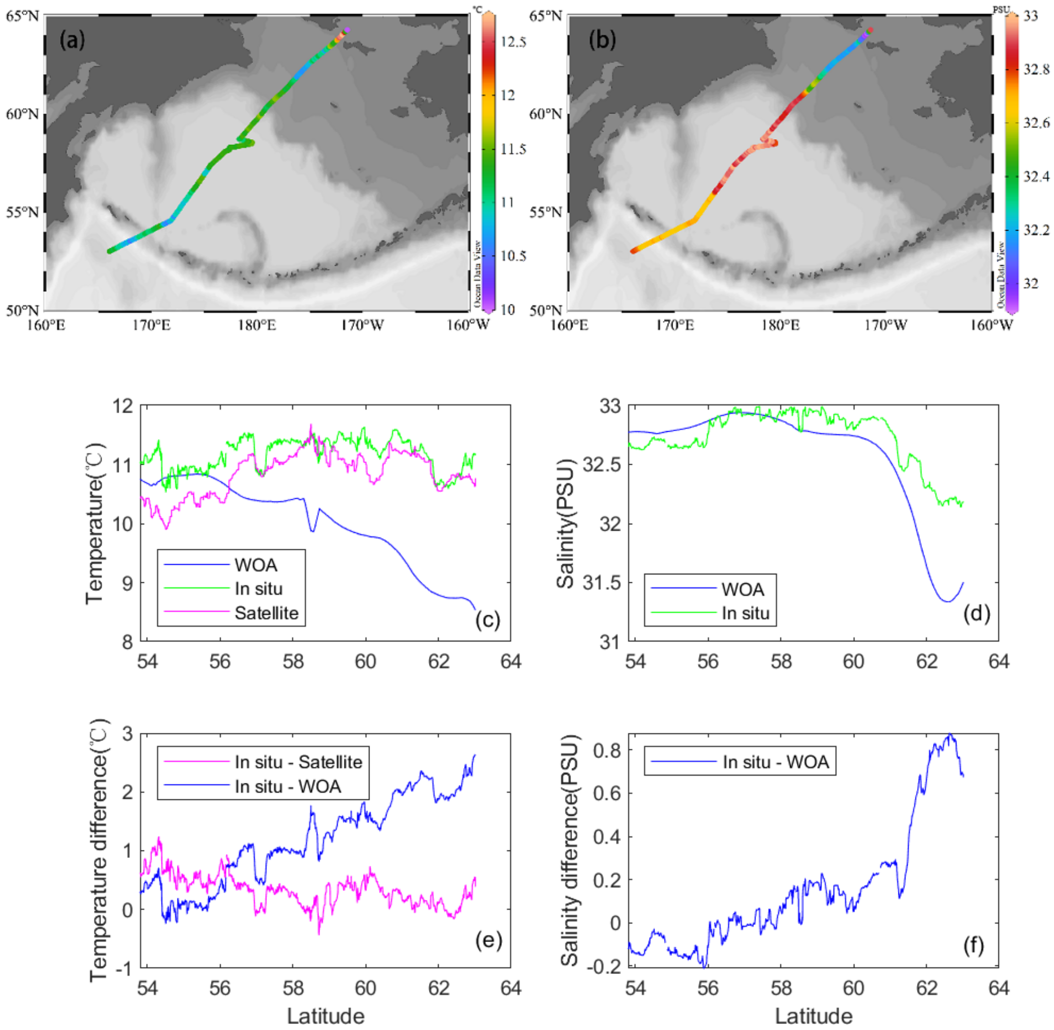

Figure S5. (a) Sea surface temperature from the in situ observations during the expedition in the Bering Sea. (b) Sea surface salinity from the in situ observations during the expedition. (c) Comparison of the sea surface temperature from the WOA (average of August and September), in situ observations, and satellites. (d) Comparison of the sea surface salinity from the WOA and in situ observations. (e) The difference in the sea surface temperature between the in situ observations and the WOA, satellite. (f) The difference in the sea surface salinity between the in situ observations and the WOA.

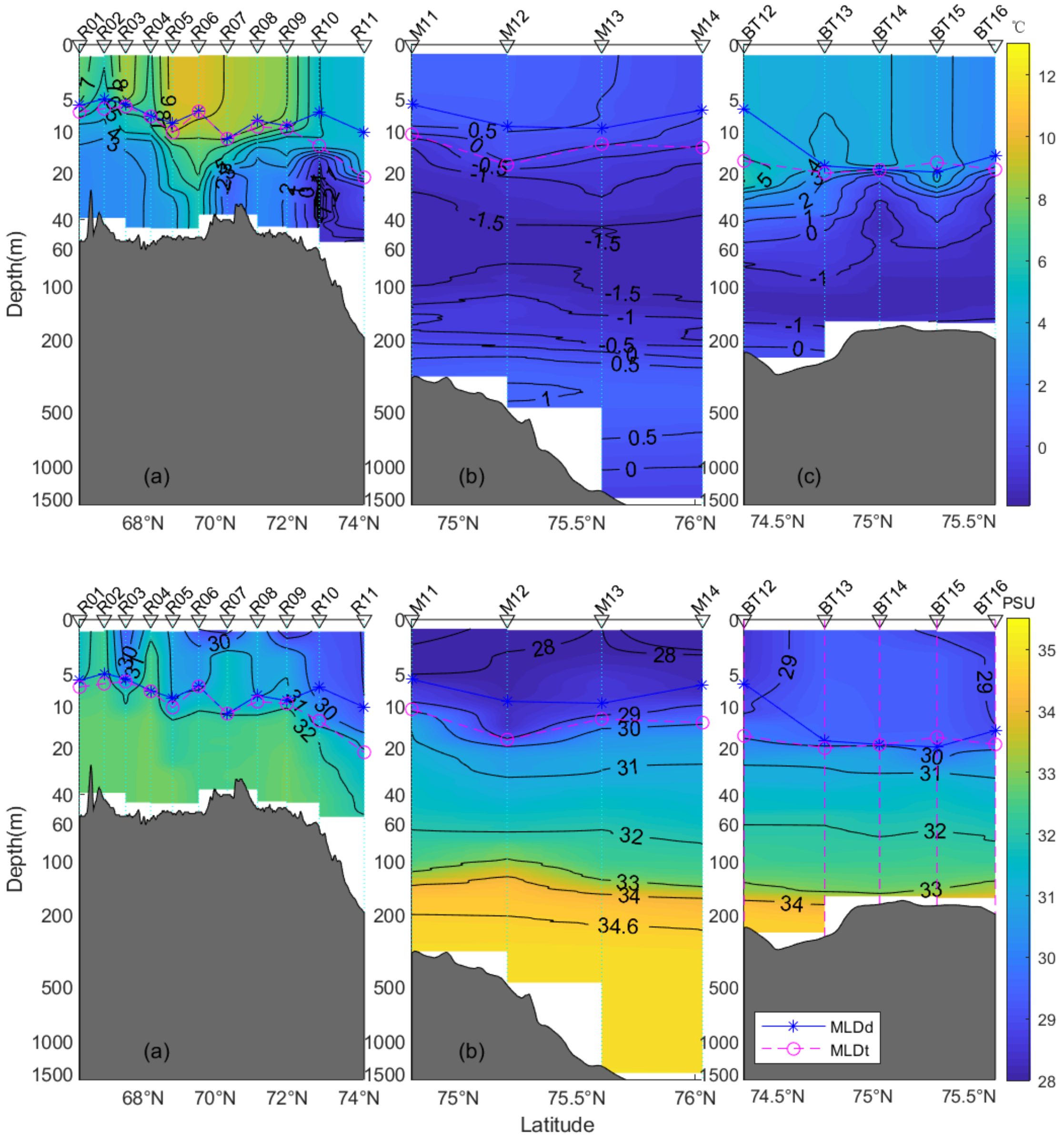

Figure S6. The upper panel represents the MLD from temperature and density. The lower panel represents the difference between MLDd and MLDt. The left (a, d), middle (b, e), and right (c, f) columns represent Section R, M, and BT respectively. The magenta dashed lines represent the MLD calculated from the temperature, and the blue solid lines represent the MLD calculated from the density. The magenta bar indicates that the MLDt was larger than the MLDd, and the blue bar indicates that the MLDd was larger than the MLDt. Notice that the Y-axis was reversed.

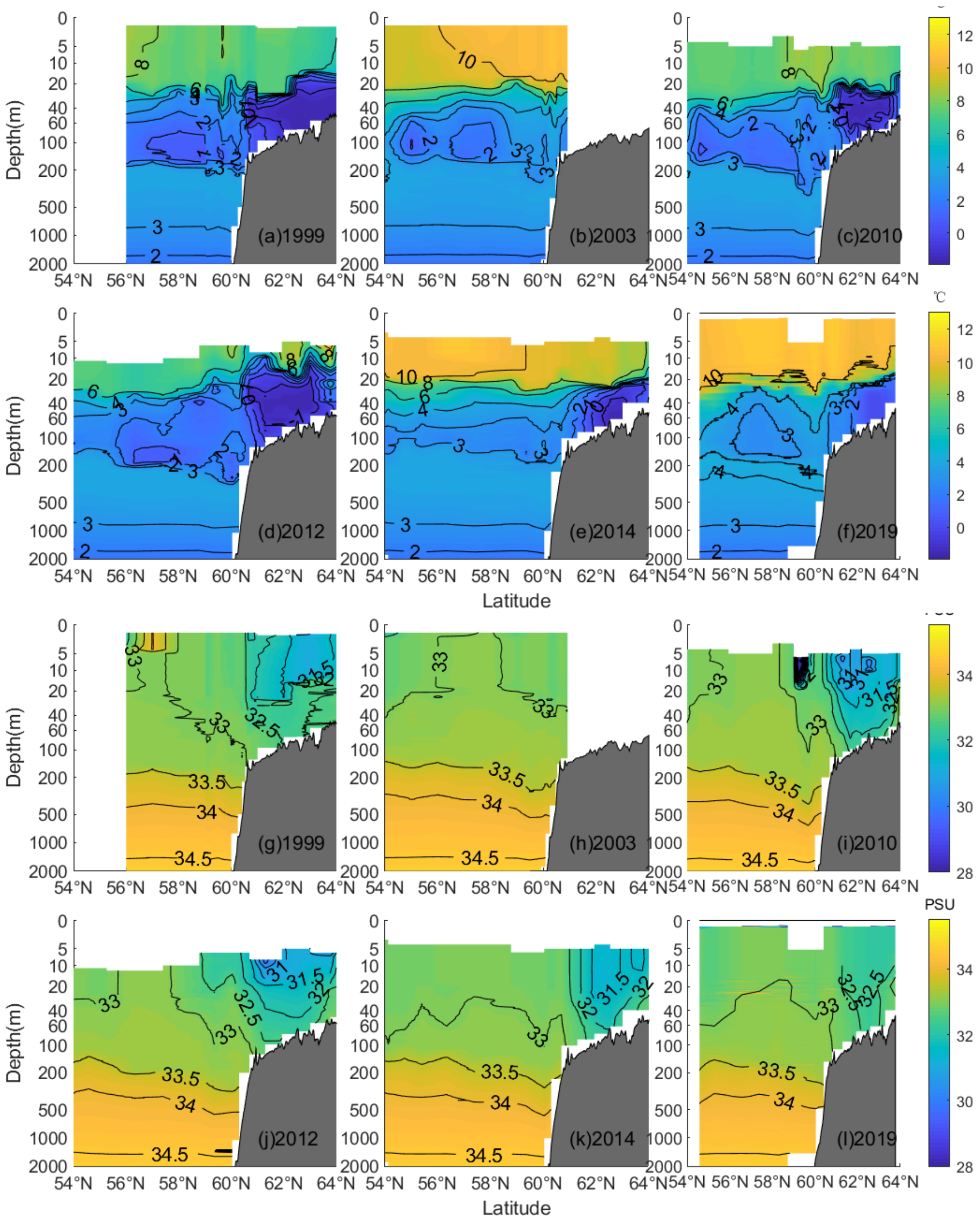

Figure S7. Temperature ((a)~(f)) and salinity ((g)~(l)) profiles along the BL section in the Bering Sea from the Chinese National Arctic Research Expeditions. These expeditions were all carried out in summer.

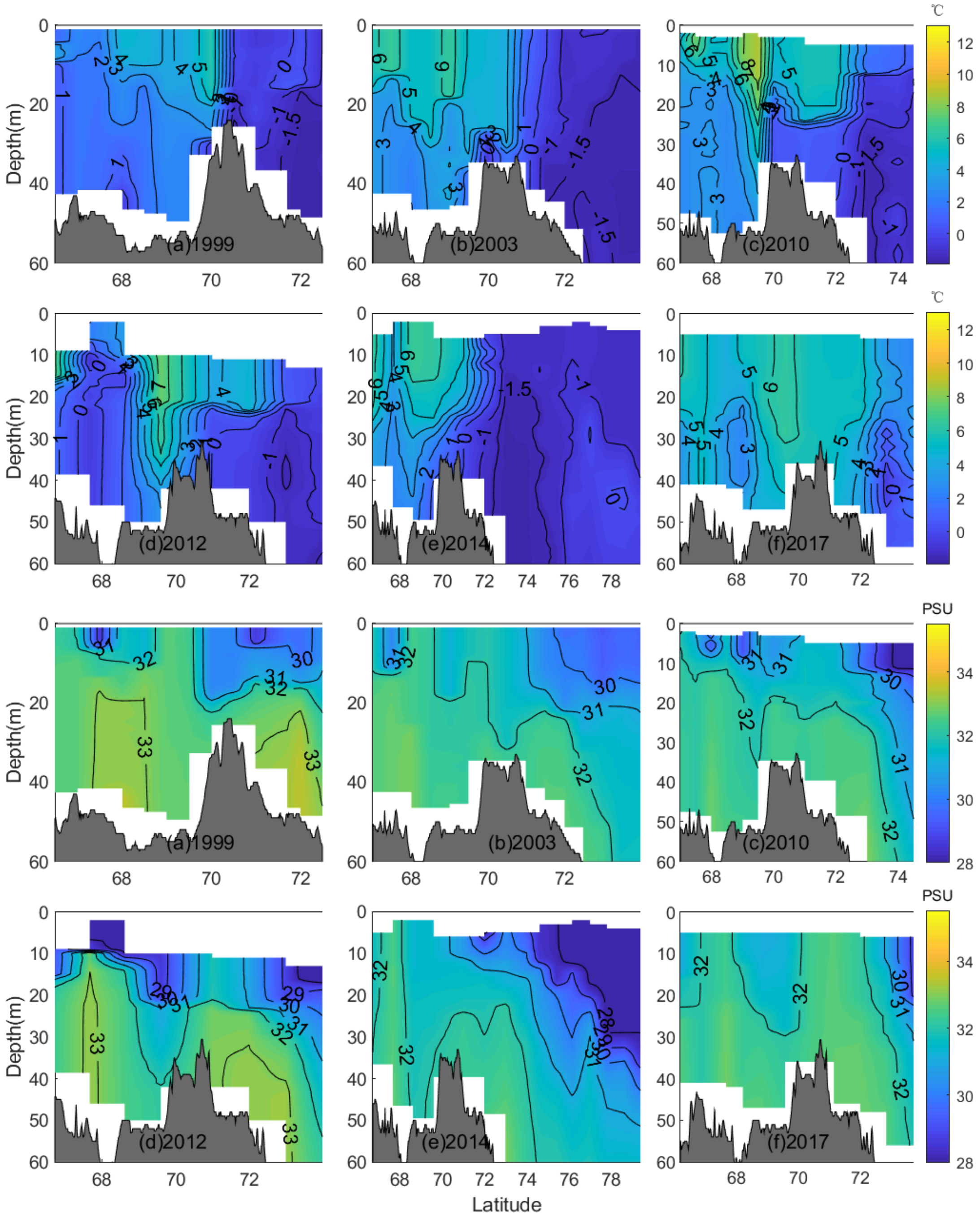

Figure S8. Temperature ((a)~(f)) and salinity ((g)~(l)) profiles along Section R in the Chukchi Sea from the Chinese National Arctic Research Expeditions. These expeditions were all carried out in summer.

Supplementary Material VIII

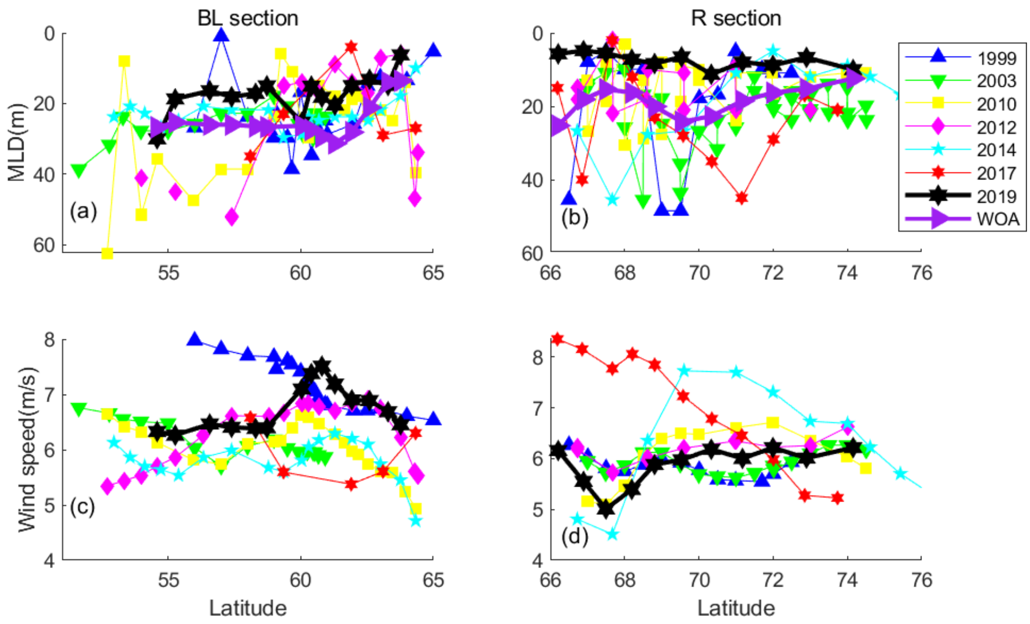

Figure S9. (a) The mixed layer depth along BL Section. (b) The mixed layer depth along R section. (c) The wind speed along BL section. (d) The wind speed along R section.