Water properties, heat and volume fluxes of Pacific water in Barrow Canyon during summer 2010: results from the DBO-5 repeat transect

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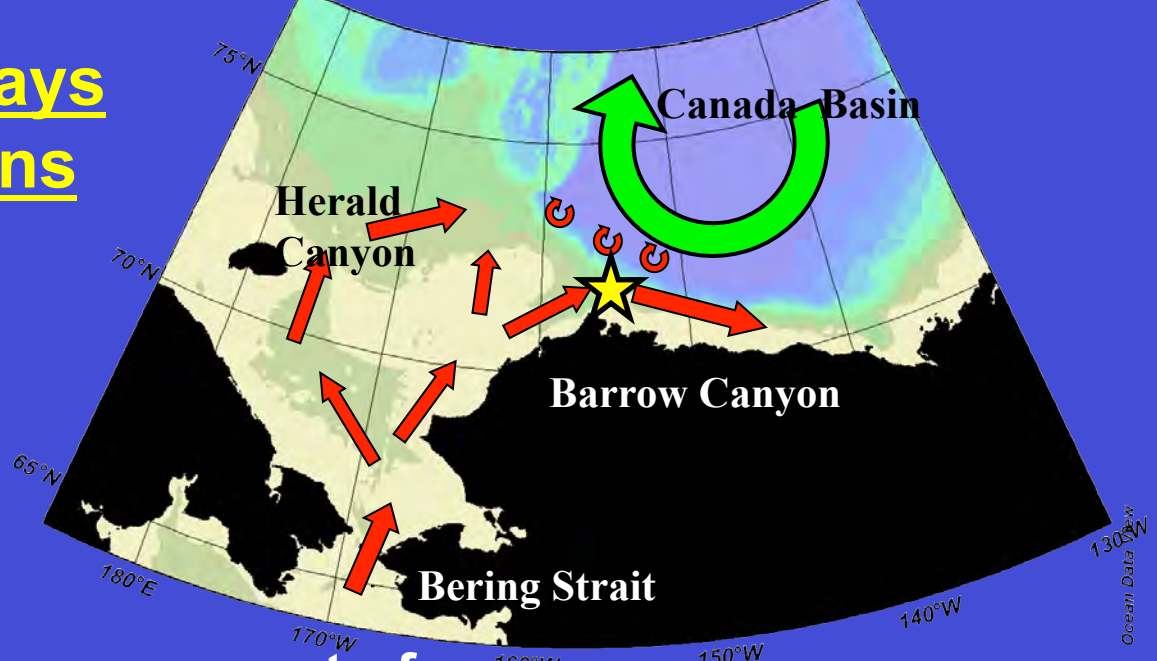
Pacific Water pathways into the Arctic Basins



- ✓ Pacific Water supply large amount of heat, freshwater (Woodgate et al., 2012) and nutrient (Walsh et al., 1989) into the Canada Basin.
- ✓ During summer, it mainlys mainly on the eastern path along the Alaskan coast to Barrow Canyon. In summertime, 70% of Pacific Water exits the Chukchi Sea through Barrow Canyon (Itoh et al., 2013).

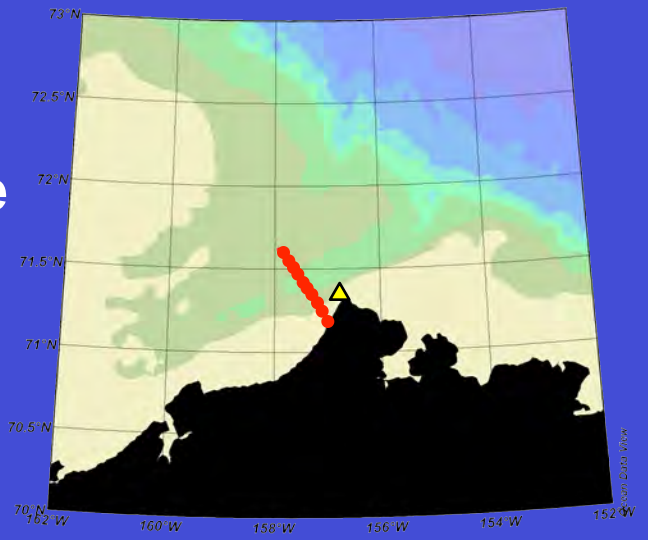
Purpose of this study

To examine water property and evaluate volume, heat and freshwater fluxes in Barrow Canyon during summer 2010.

DBO-5 Barrow Canyon repeat hydrography

Six repeat CTD and ADCP transects from mid-July to late-September in summer 2010.

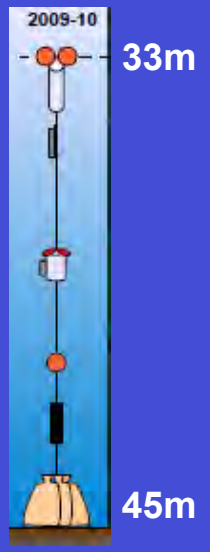
merit: capturing detail structures of Barrow Canyon through flow and water properties. Especially, temperature of upper 20-30m is critical for heat flux estimation.



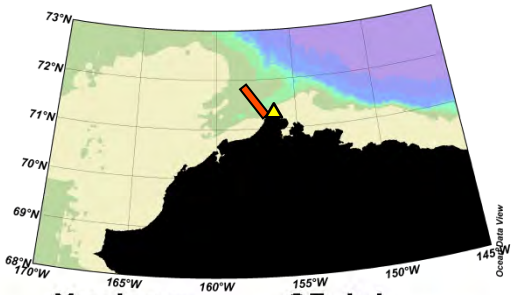
Mooring nearby DBO-5 line

Temperature, salinity and velocity time series from 2009 to 2011, which is operated by Hokkaido Univ., Japan and UAF, USA.

merit: measuring time series and filling the gap between the six surveys.

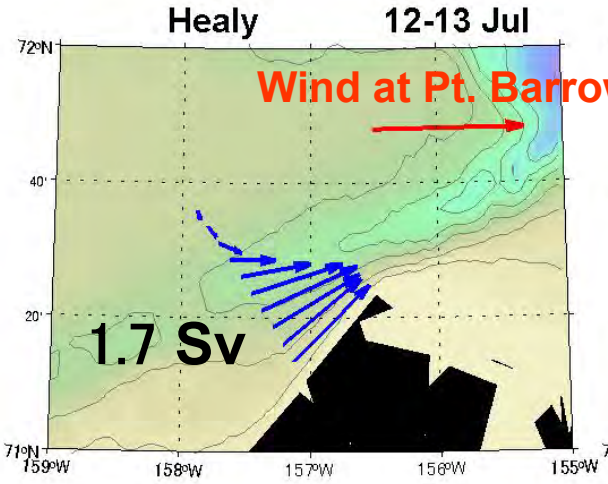


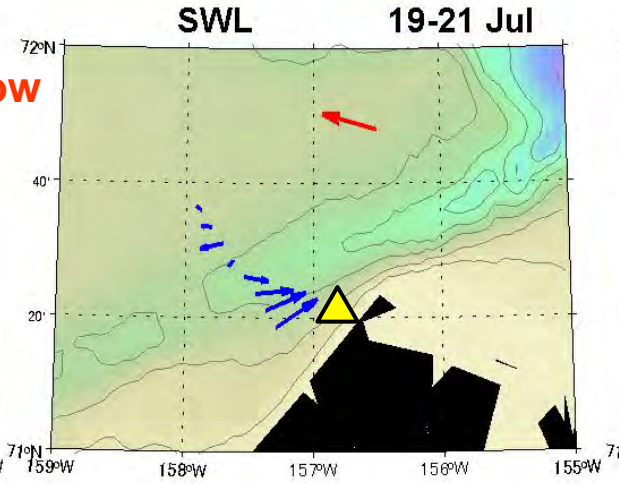
Barrow Canyon through flow

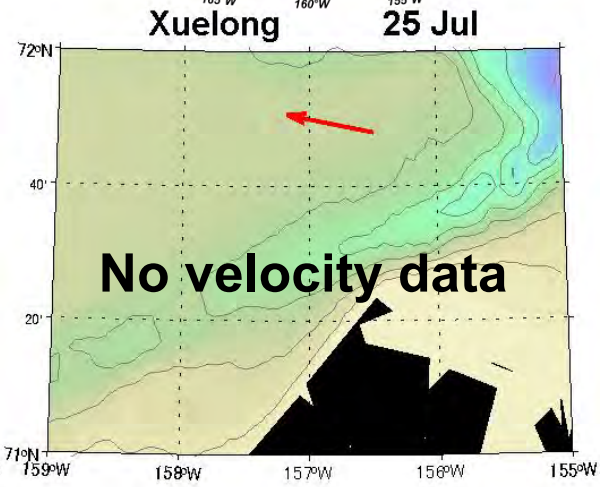


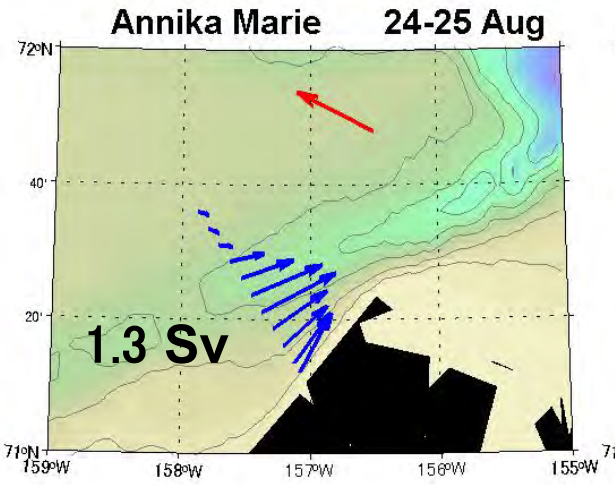
Depth averaged velocity

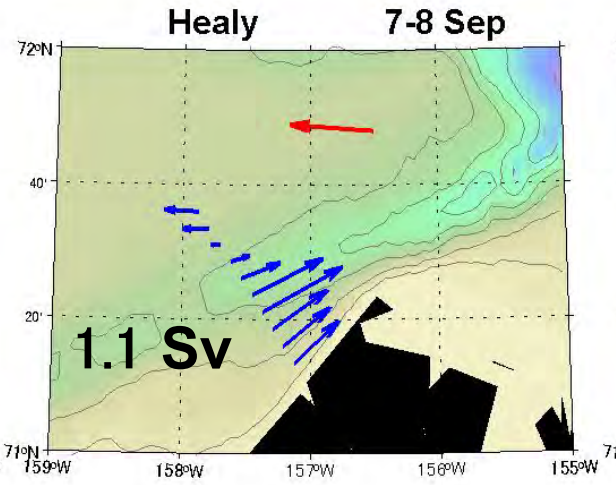
Mooring Station

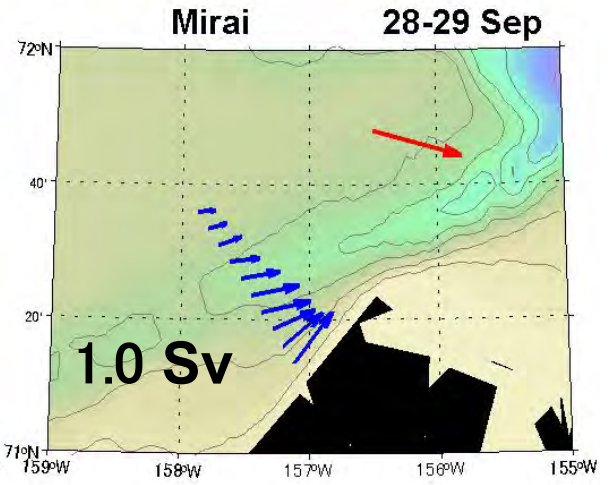




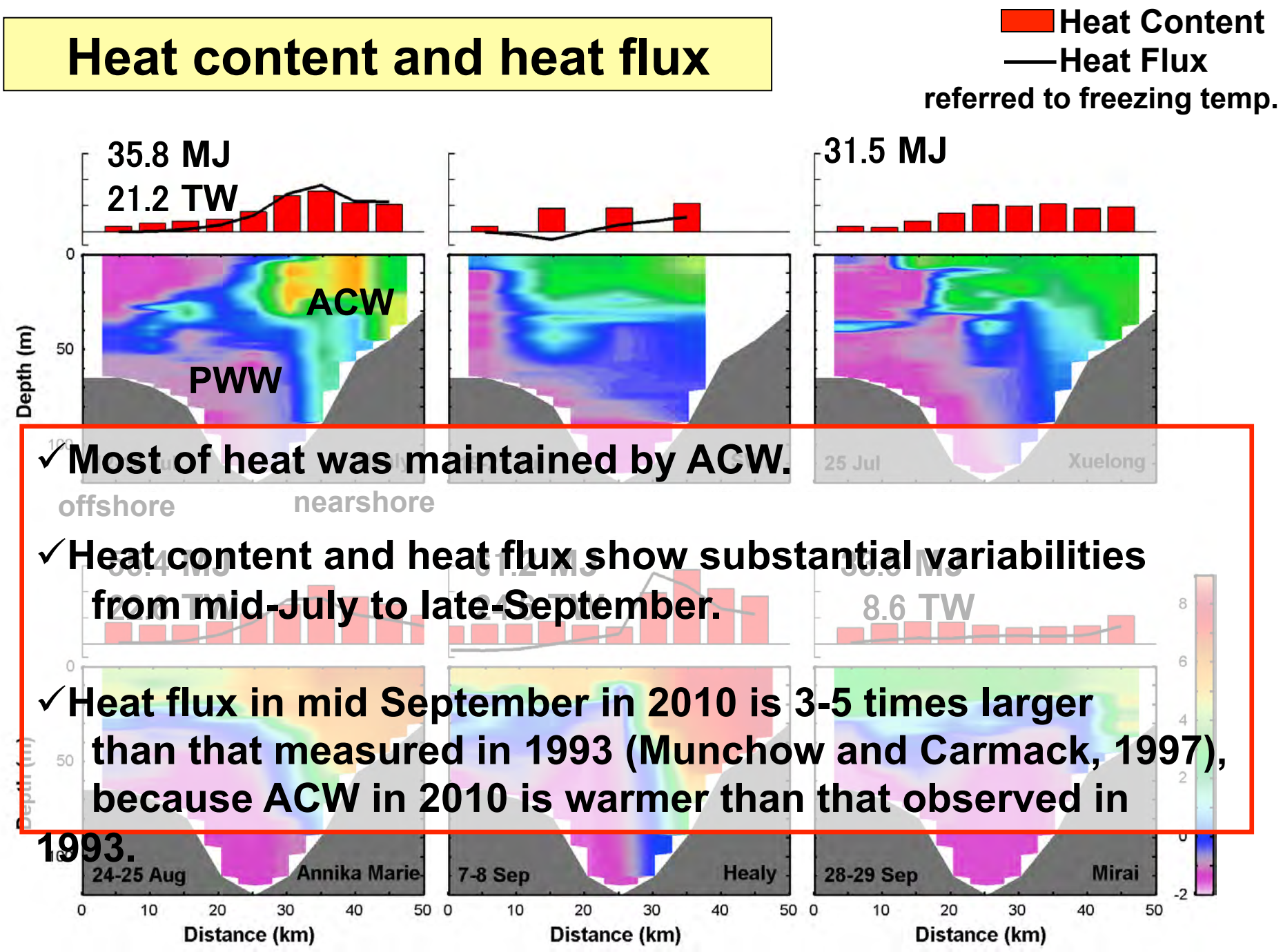






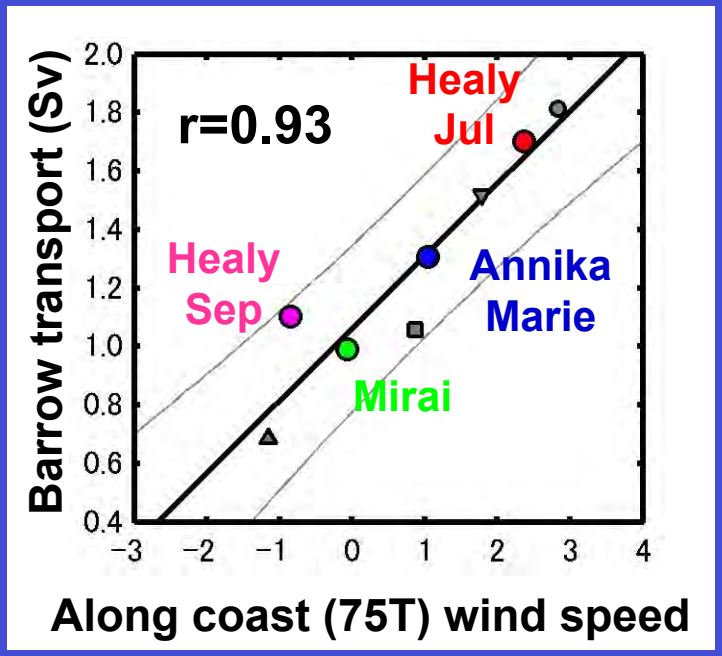


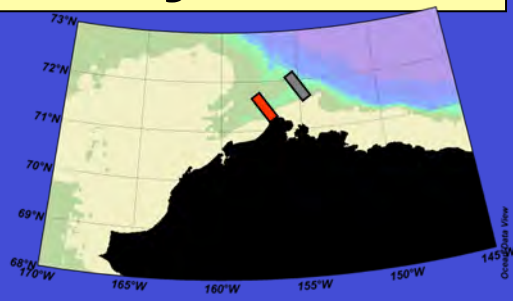
Heat content and heat flux



- ✓Most of heat was maintained by ACW.
- ✓Heat content and heat flux show substantial variabilities from mid-July to late-September.
- ✓Heat flux in mid September in 2010 is 3-5 times larger than that measured in 1993 (Munchow and Carmack, 1997), because ACW in 2010 is warmer than that observed in 1993.

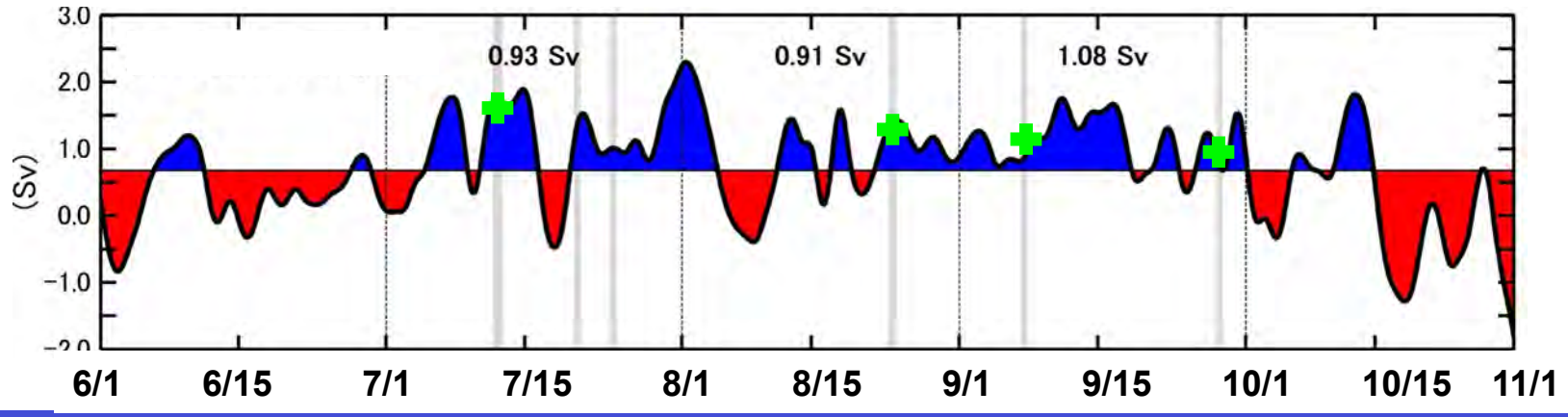
Relation between transport and along-canyon wind





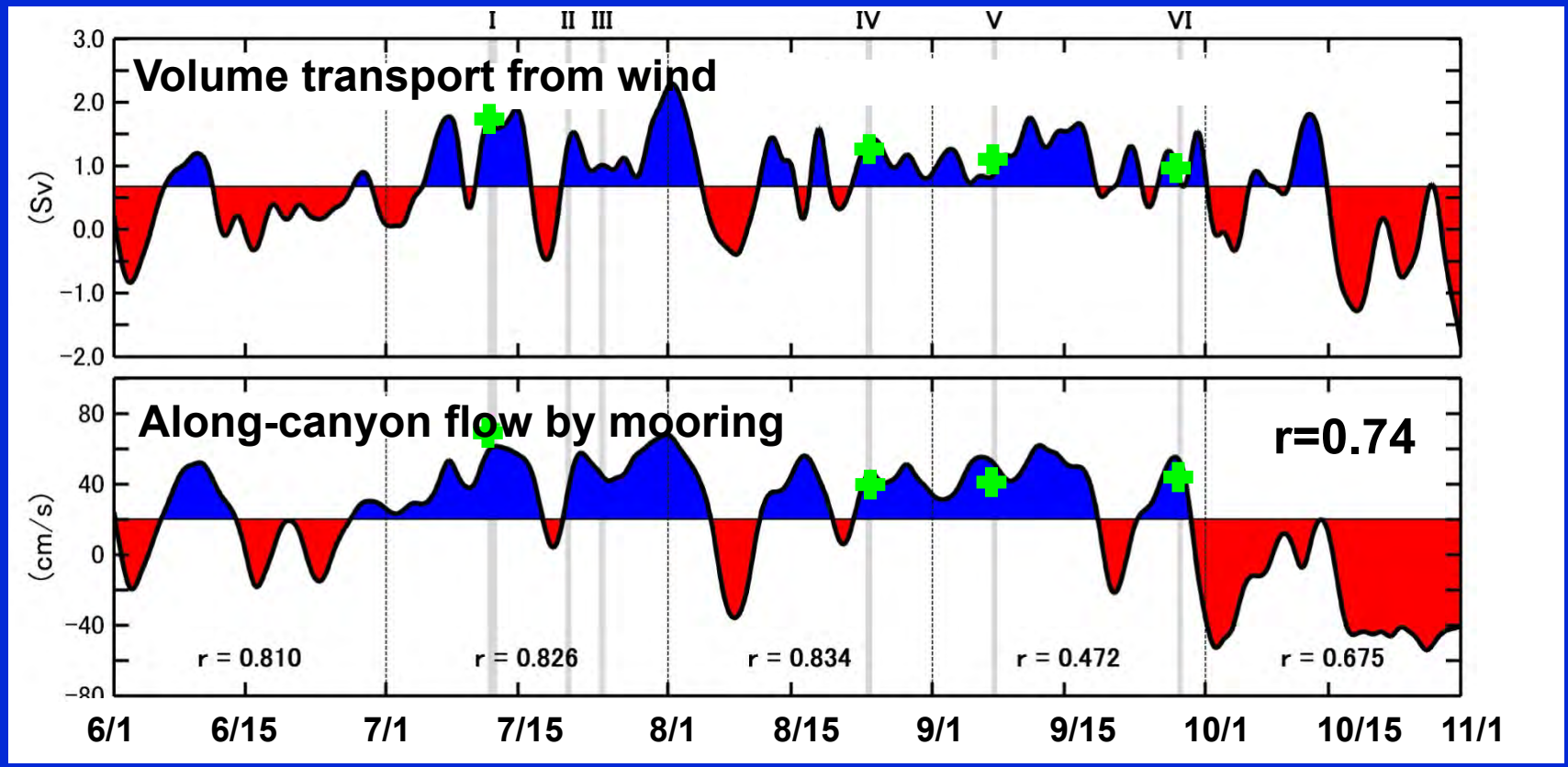
- along-canyon transport and along-coast wind highly correlated.
- Zero wind transport is 1.1 Sv.
- Averaged transport for July to September in 2010 is 0.98 Sv.

Volume transport through correlation of wind and transport



✚ Data from DBO-5 transect.

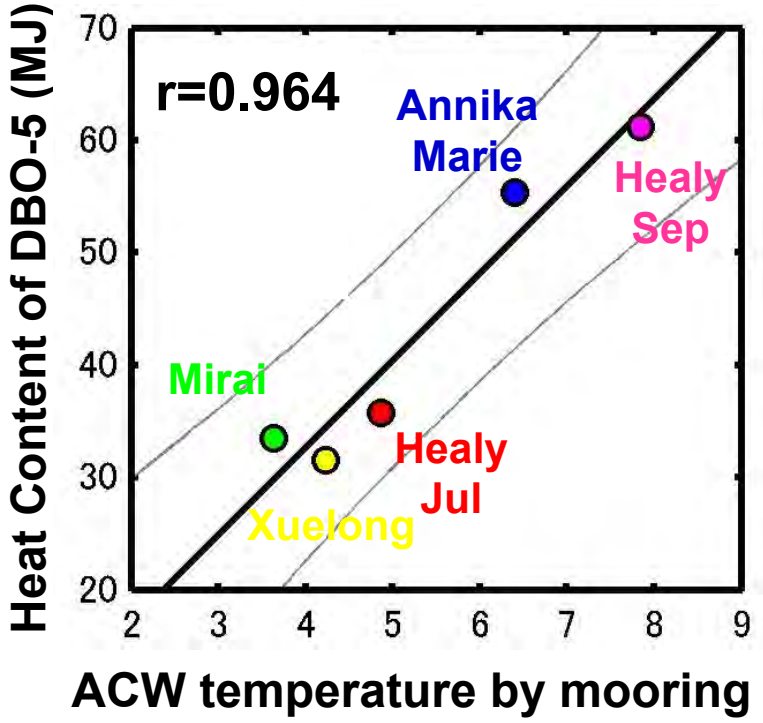
Transport and along-canyon flow

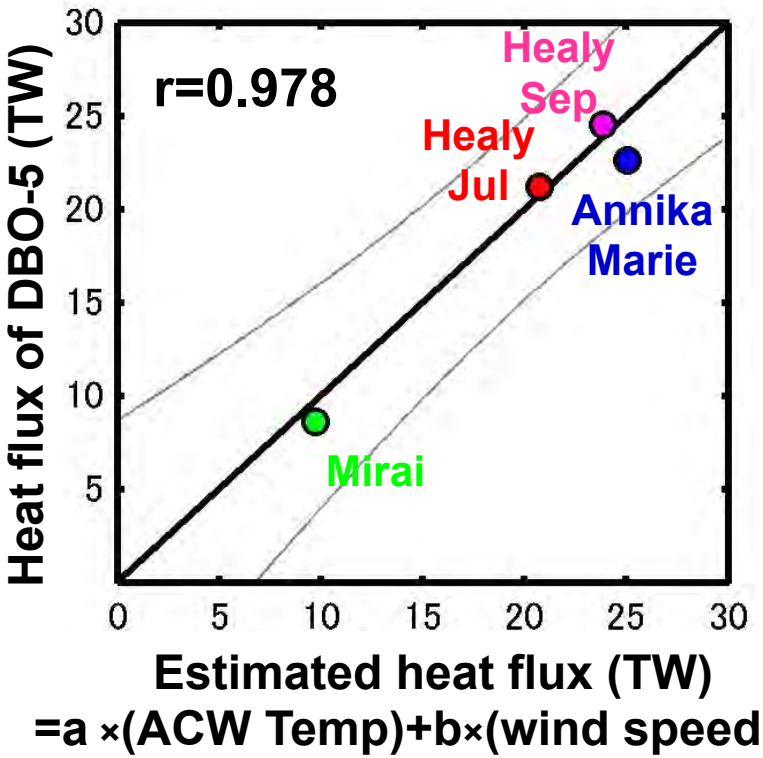


✚ Data from DBO-5 transect.

✓They are significantly correlated (>98%). It supports our estimation of volume transport from the wind.

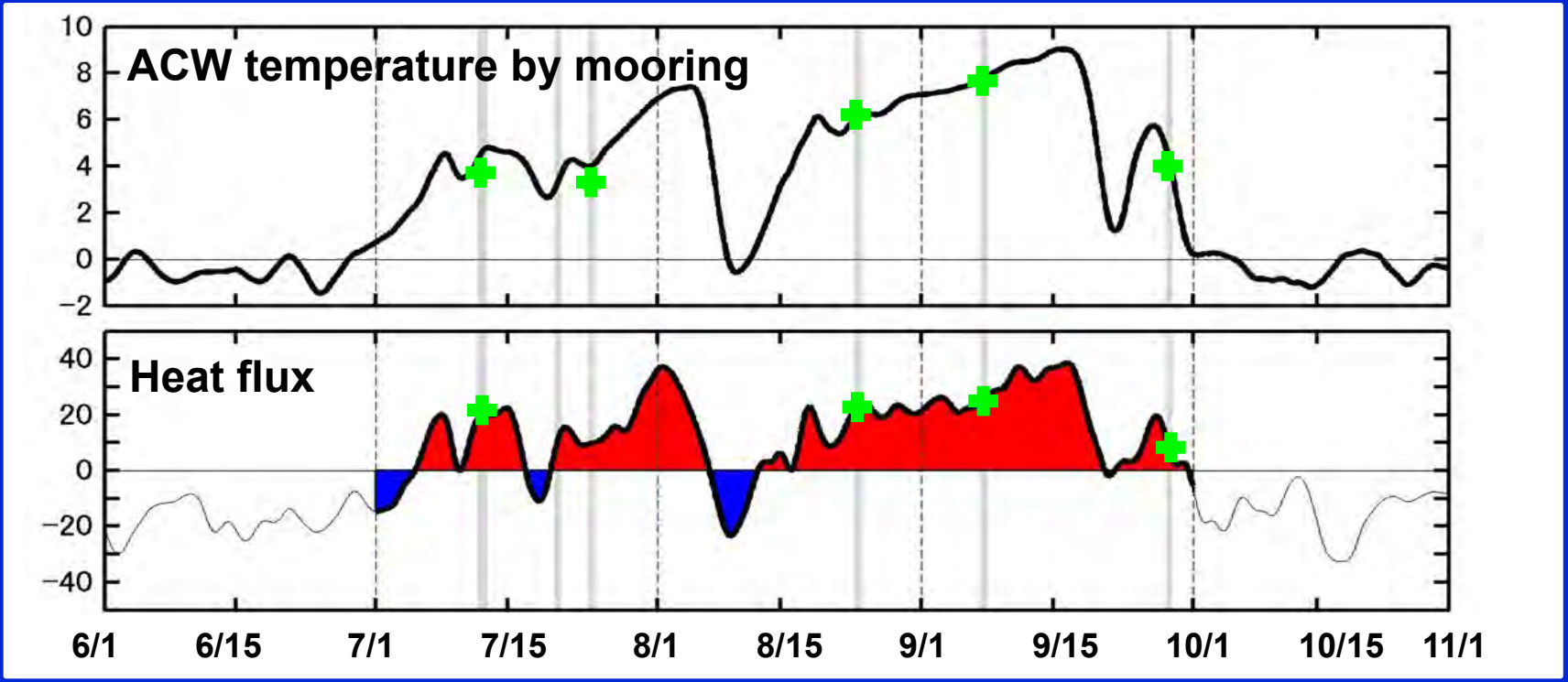
Heat flux estimation





✓Time series of heat flux during summer can be estimated by those of temperature of ACW core by mooring and along-coast wind

Heat flux estimation



Data from DBO-5 transect.

✓Averaged heat flux for July to September in 2010 is 15 TW, corresponding to heat for melting 360,000 km^2 area of 1m ice.

✓Annual averaged heat flux in 2010 is 3.34TW. It is 1.7 times larger than averaged values for 2001-2007 and as much as record maximum in 2007.

Summary

- ✓ Based on the repeat section of DBO-5 in summer 2010, Pole ward volume transport varies between 1.0 to 1.7 Sv. Heat flux varies widely, ranging 8.6 – 24.6 TW.
- ✓ The barrow canyon transport linked to the local along-coast winds such that, under westerly winds the volume flux increased.
- ✓ The averaged transport estimated from the wind data for July-September was 0.98 Sv.
- ✓ The annual averaged heat flux in 2010 was estimated to be 3.34 TW, which is as large as the record maximum for 2001-2007 observed previously in 2007.

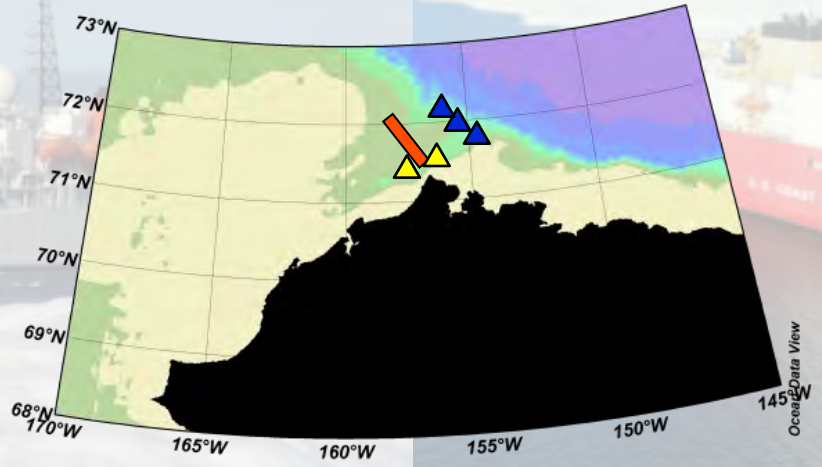
Future

- ✓ Further examination with increasing data number and period will help to realize more accurate estimation of fluxes through DBO-5, especially for heat content and heat flux.

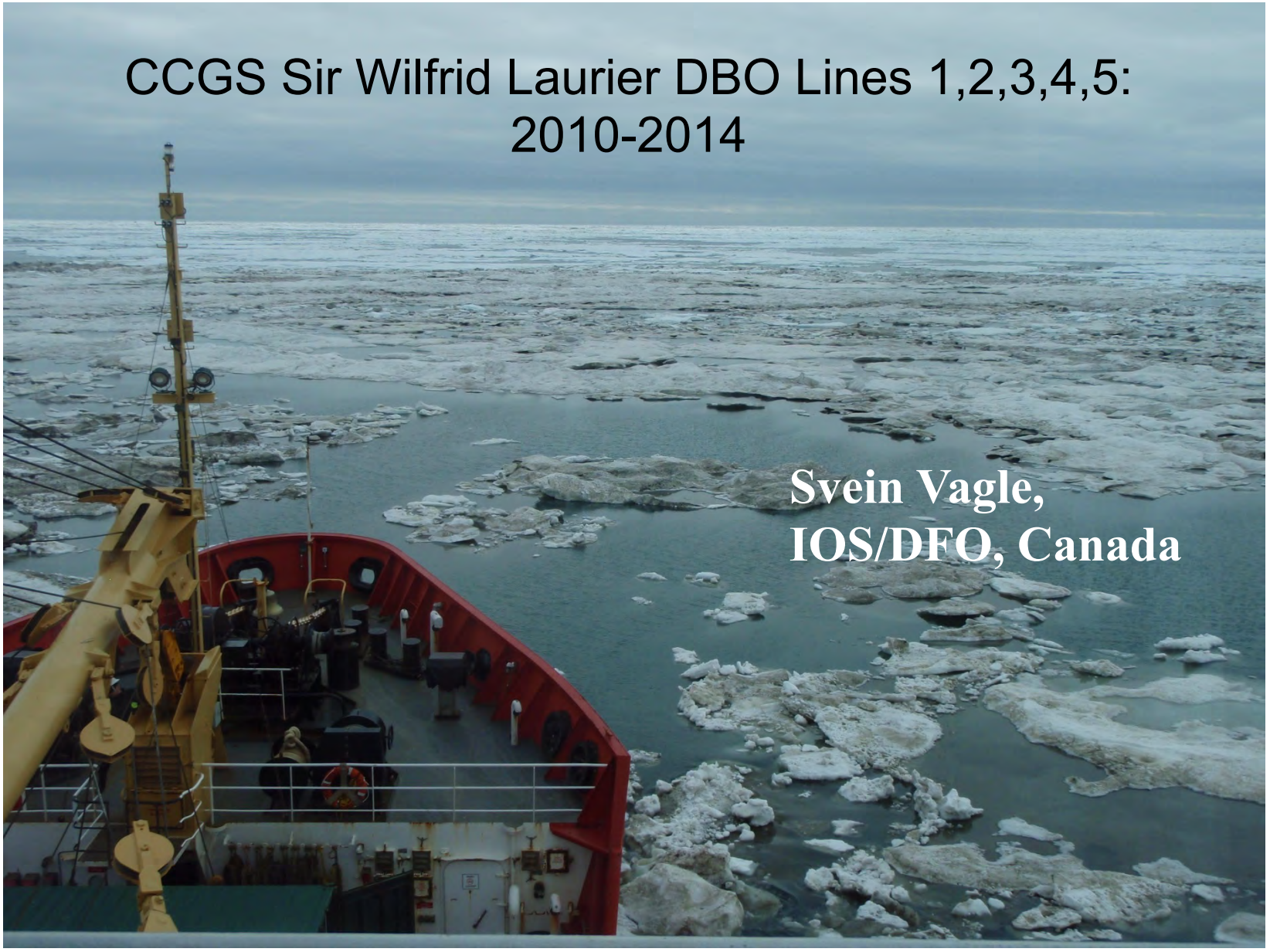
  Moorings at the core of ACW nearby DBO-5 by Hokkai Univ and UAF were continued since 2009 until now.

- ✓ Comparing to results from moorings at the mouth of Barrow Canyon by JAMSTEC will also help to evaluate this estimation.

  Three moorings were continued since 2001, although 2008-2010 and 2013-2014 was missing.



CCGS Sir Wilfrid Laurier DBO Lines 1,2,3,4,5: 2010-2014



Svein Vagle,
IOS/DFO, Canada

SWL Science:

Victoria to Barrow
July 4 to July 23, 2014 (Same time every year)

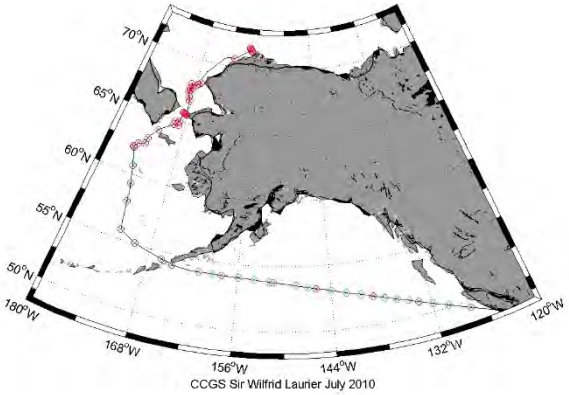
Science activities:

- Continuous sea surface water monitoring (T,S,F,O2,weather)
- 20 UCTD profiles across NE Pacific (see next slide)
- Bird and mammal observations (More intense in DBO area)
- Water collected for Fukoshima isotope analysis

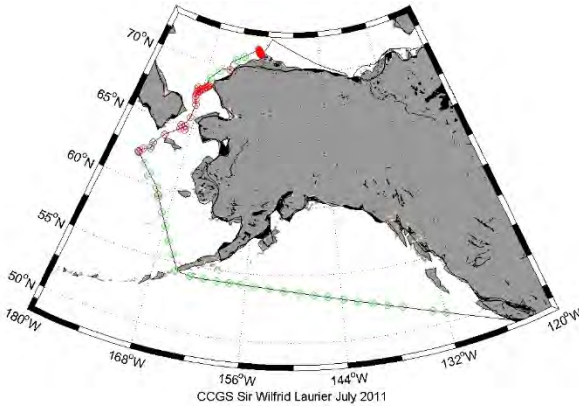
DBO specific:

- 47 science stations (should have been 54, but had to skip 7 Barrow Canyon stations due to ice)
- 47 CTD/Rosette casts (Nutrients, Ba, O18, DIC/Alk, Chlorophyll at 33 stations)
- 30, 150 kHz ADCP over the side deployments (Backscatter and currents)
- 33 Bongo plankton net hauls
- 32 Benthic sampling stations
- 2 SVP drifters deployed
- 1 Optix package deployment (Clark University)
- Phytoplankton incubation experiments (UVIC)

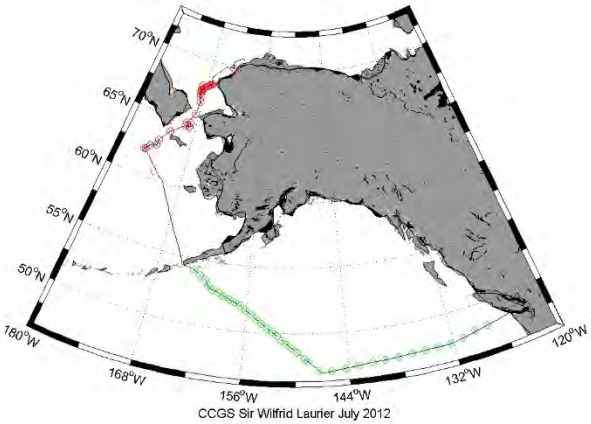
Ship tracks and sampling stations, Sir Wilfrid Laurier, July 4-24.



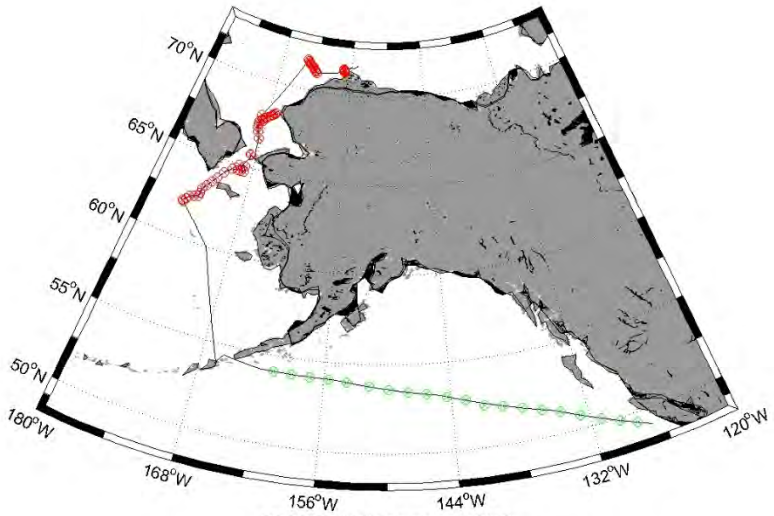
CCGS Sir Wilfrid Laurier July 2010



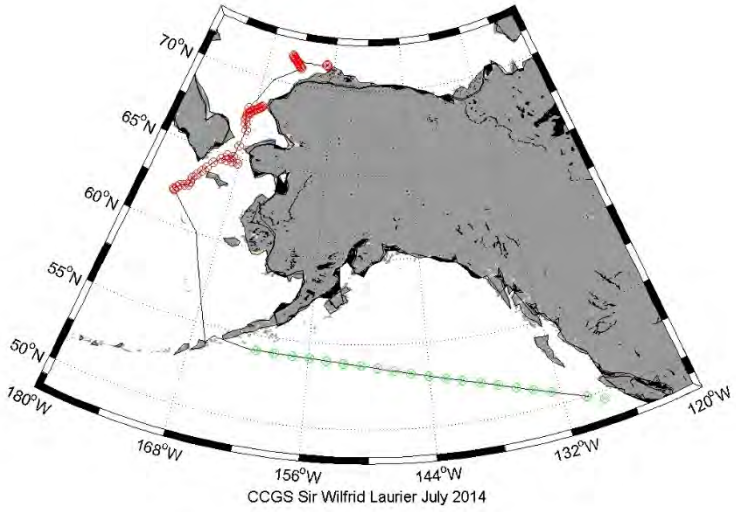
CCGS Sir Wilfrid Laurier July 2011



CCGS Sir Wilfrid Laurier July 2012

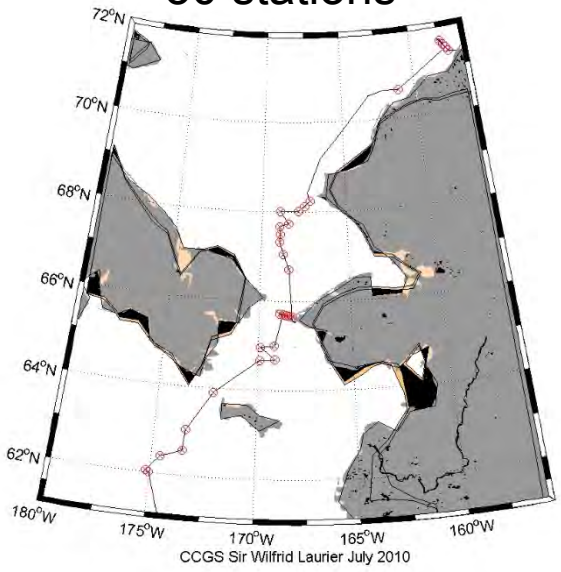


CCGS Sir Wilfrid Laurier July 2013

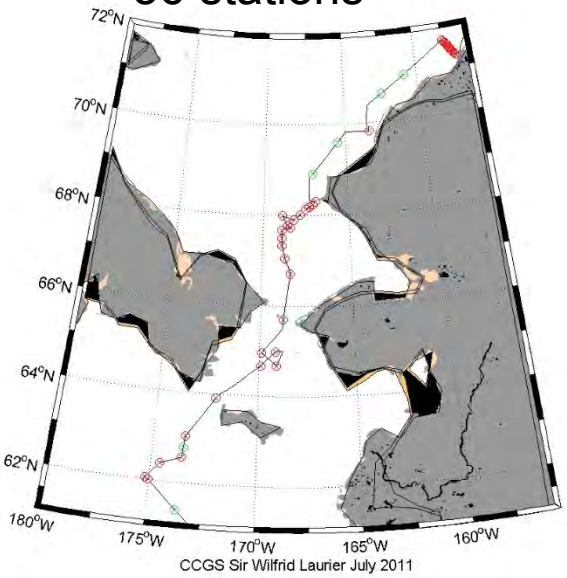


CCGS Sir Wilfrid Laurier July 2014

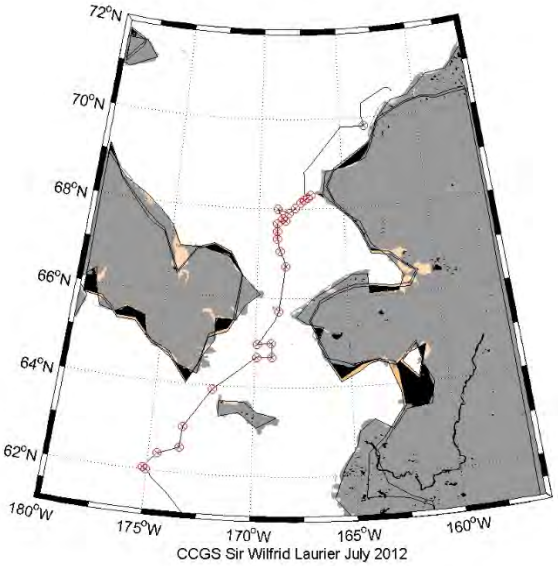
30 stations



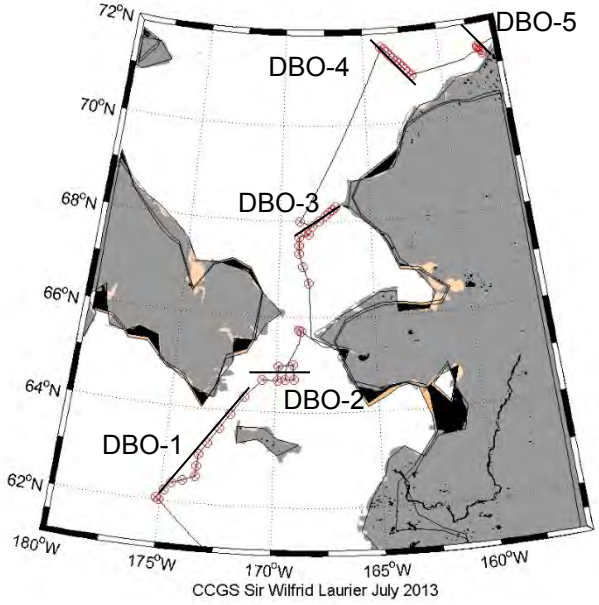
36 stations



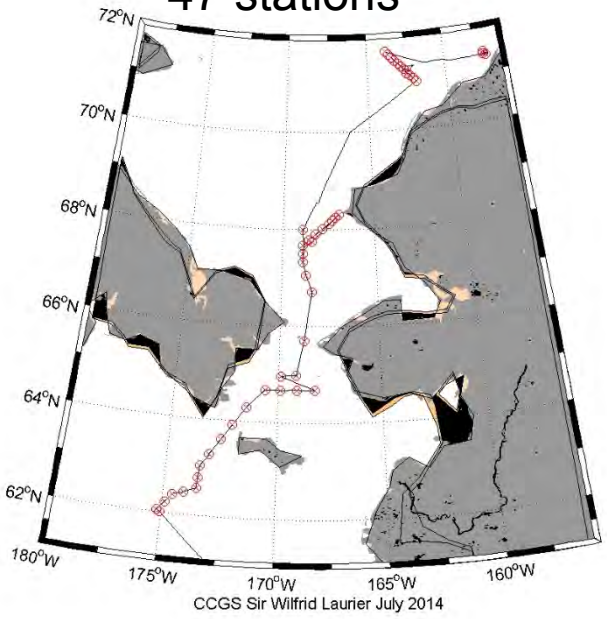
26 stations (ice)



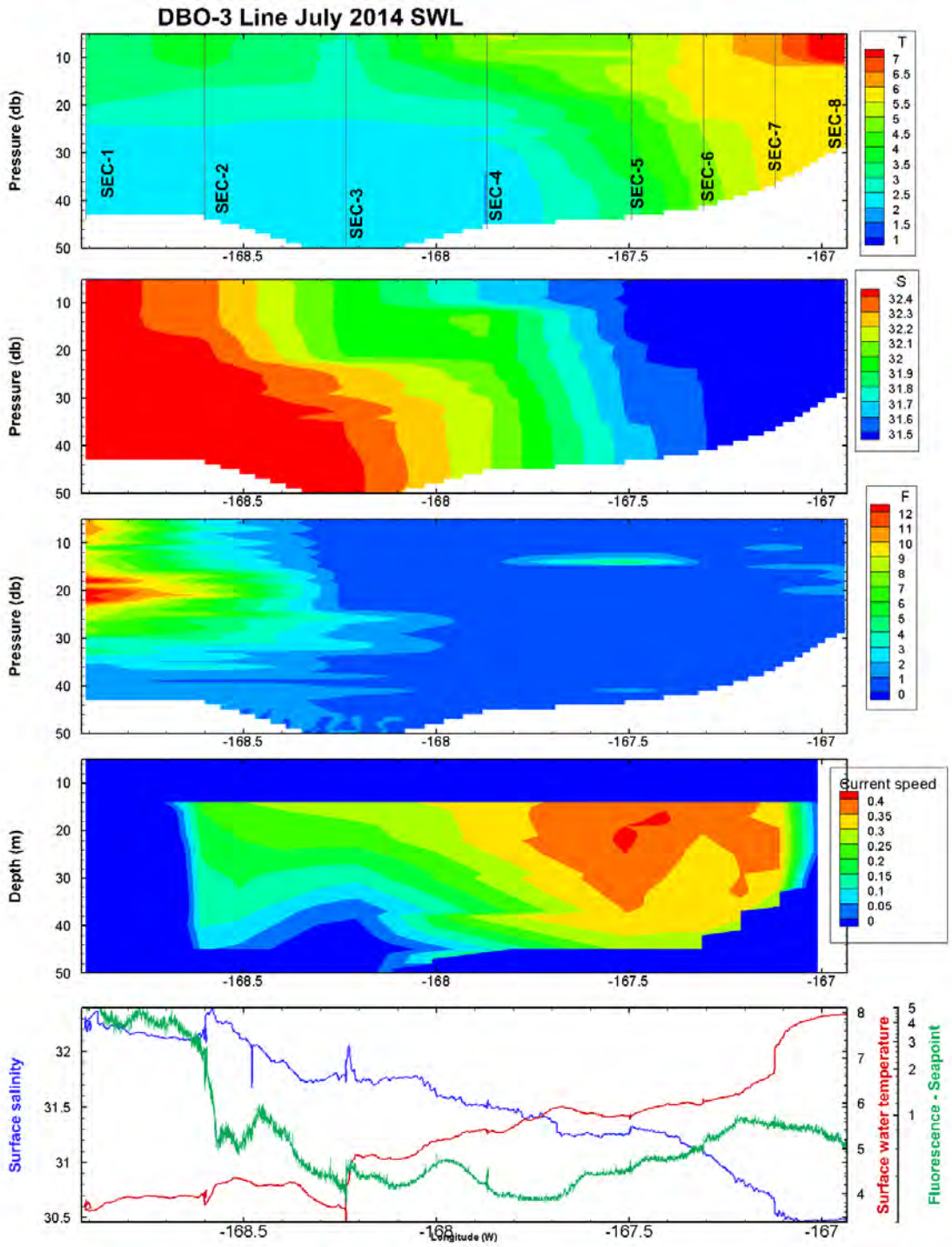
50 stations

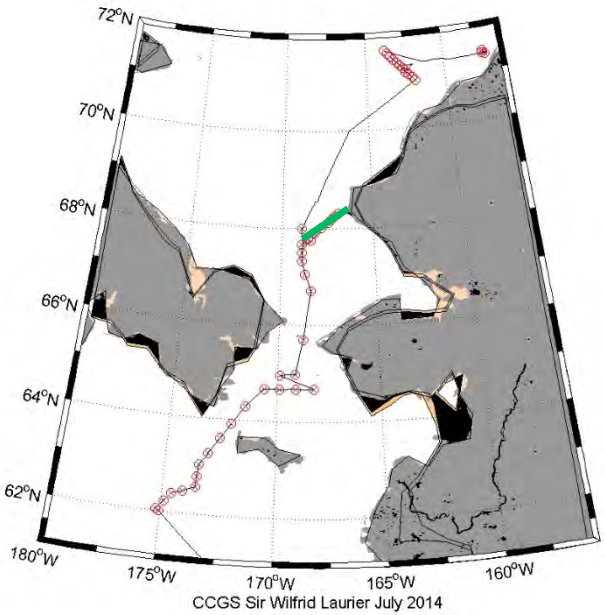


47 stations



DBO specific stations.





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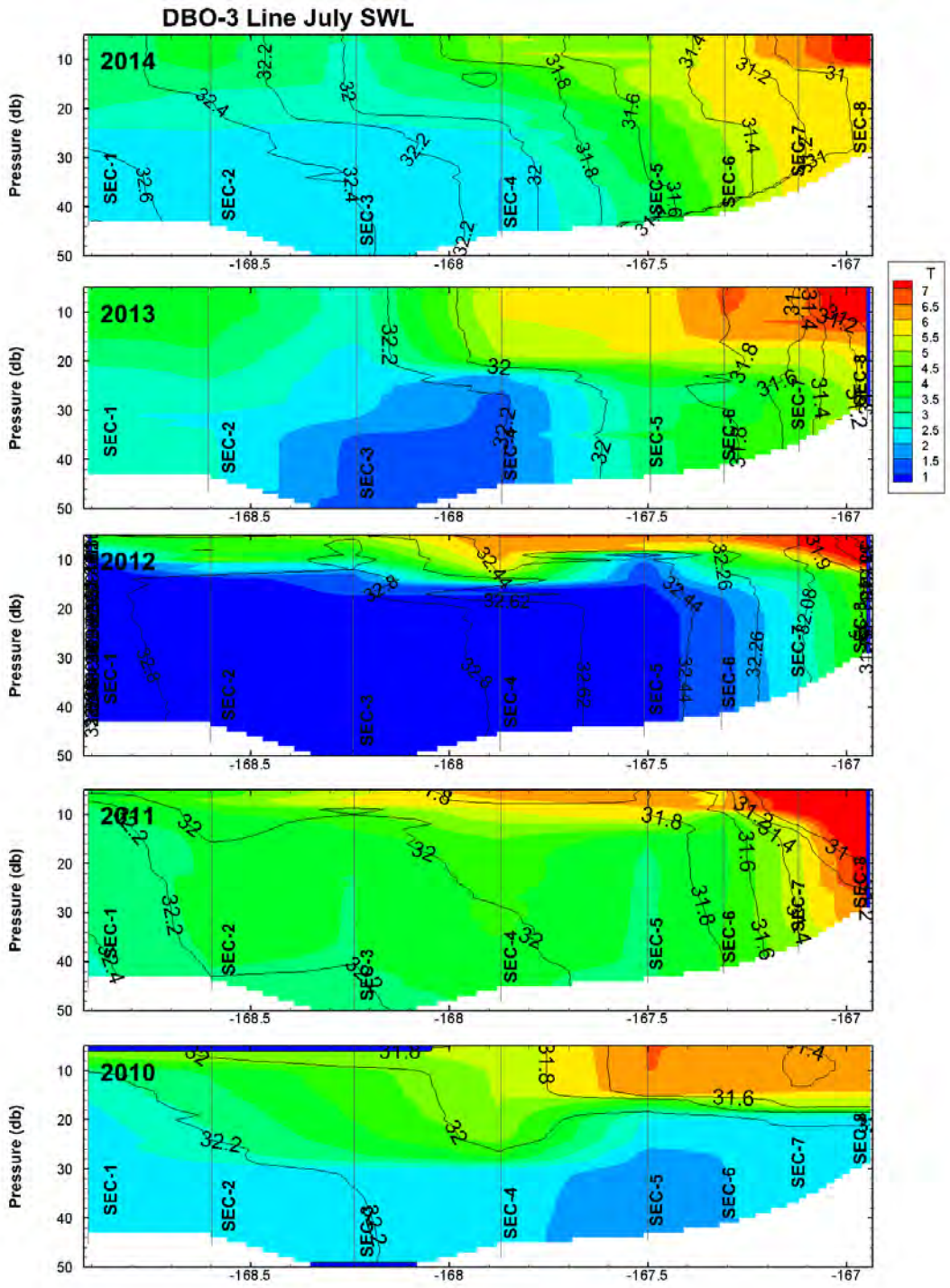
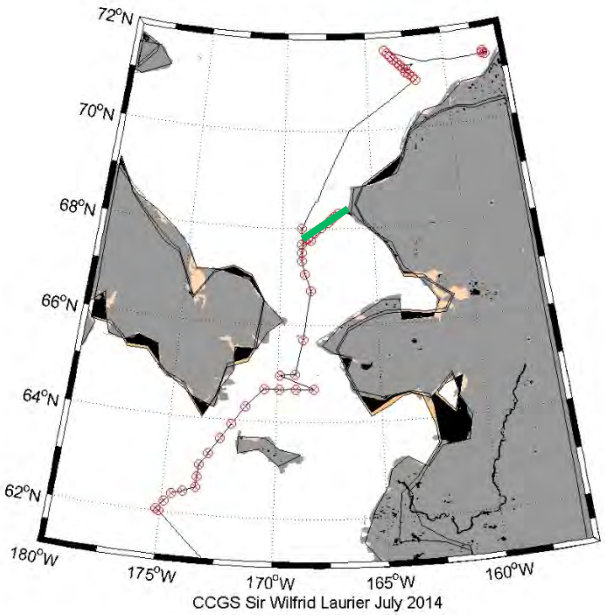
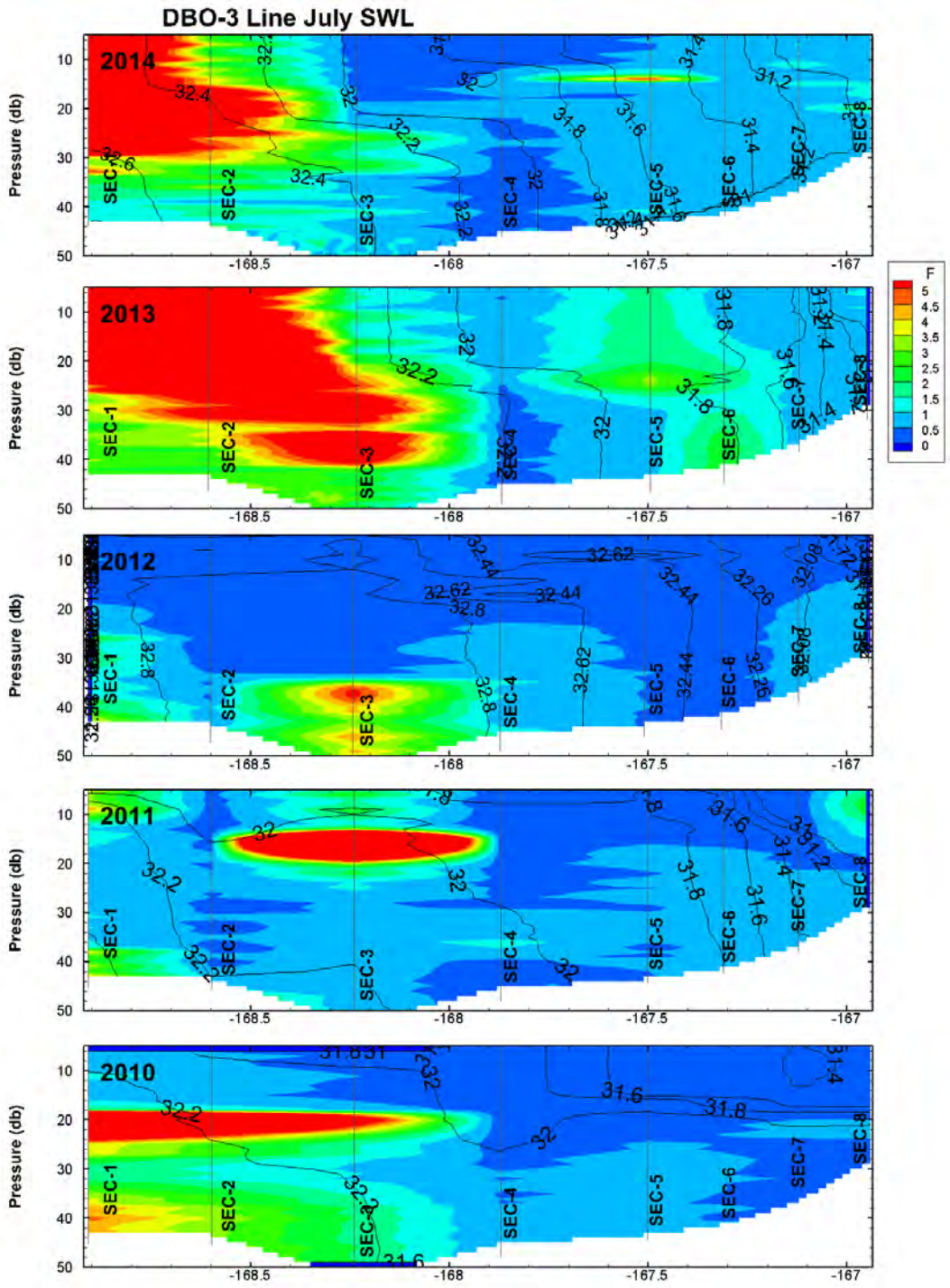
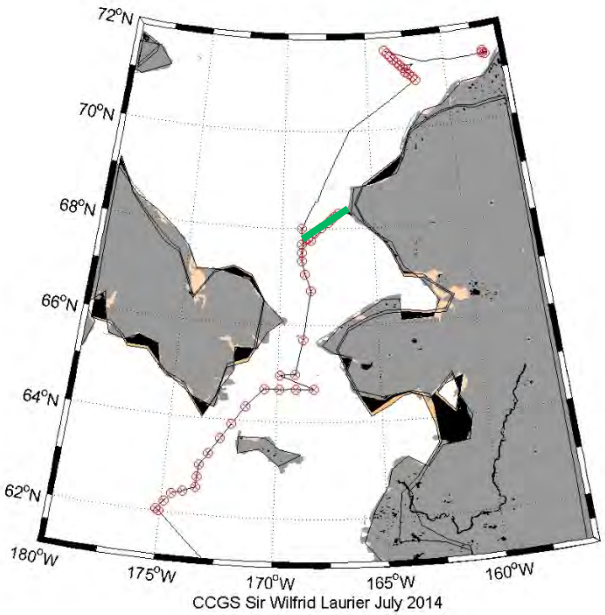

DBO-3 Line July SWL
2014
2013
2012
2011
2010
Pressure (db)
SEC-1
SEC-2
SEC-3
SEC-4
SEC-5
SEC-6
SEC-7
SEC-8
-168.5
-168
-167.5
-167
T

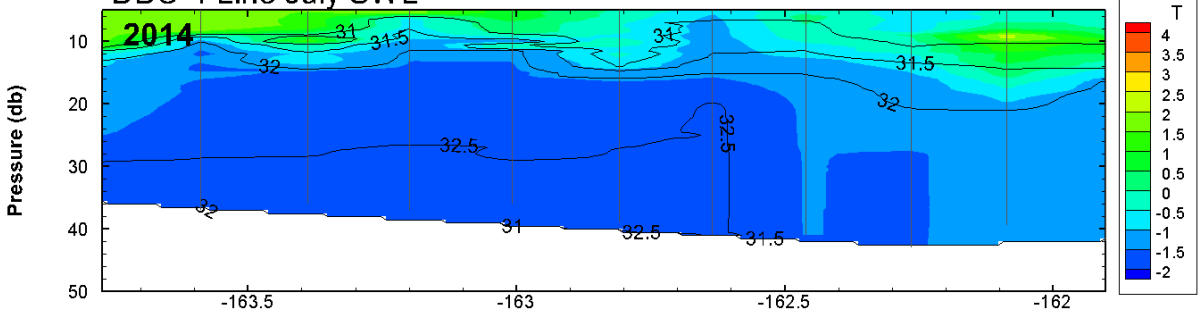

72°N
70°N
68°N
66°N
64°N
62°N
180°W
175°W
170°W
165°W
160°W
CCGS Sir Wilfrid Laurier July 2014

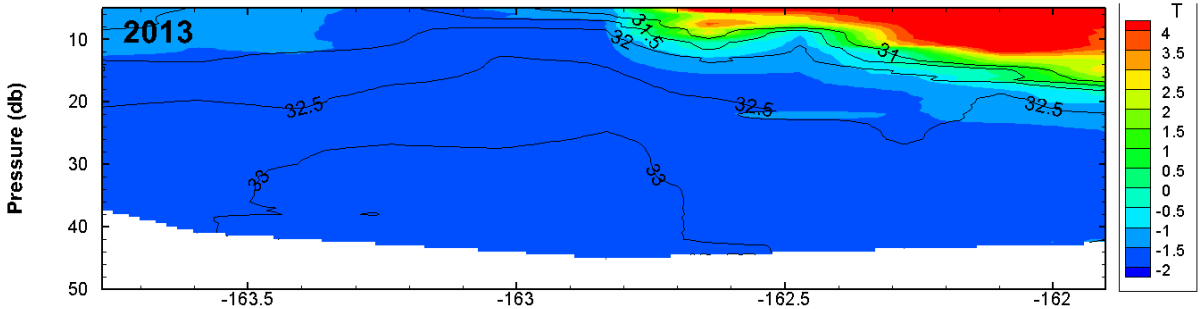


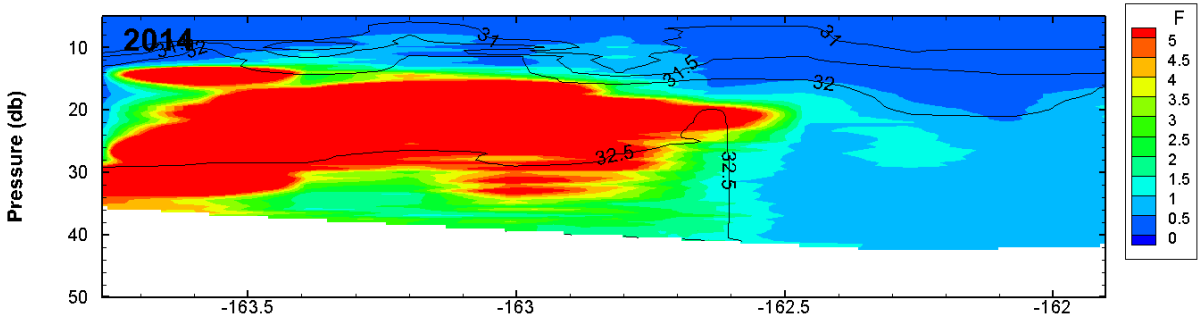


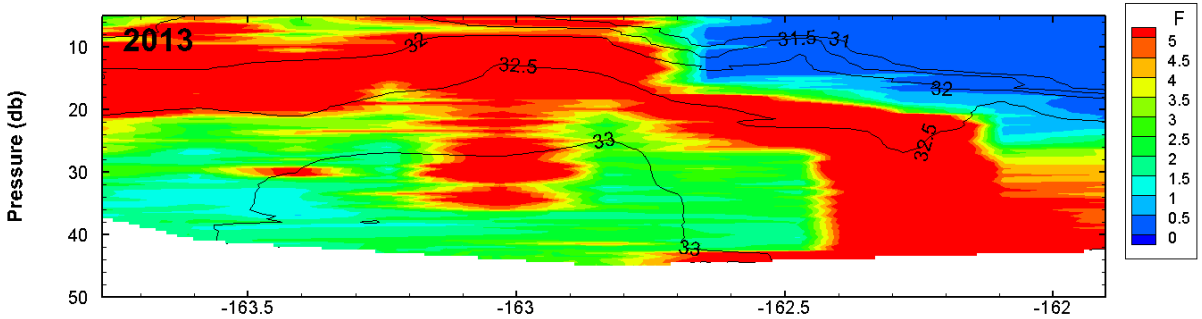
CCGS Sir Wilfrid Laurier July 2014

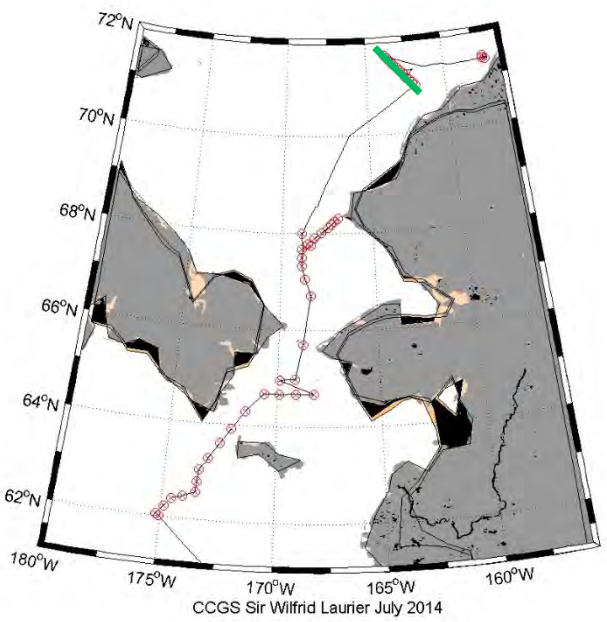
DBO-4 Line July SWL

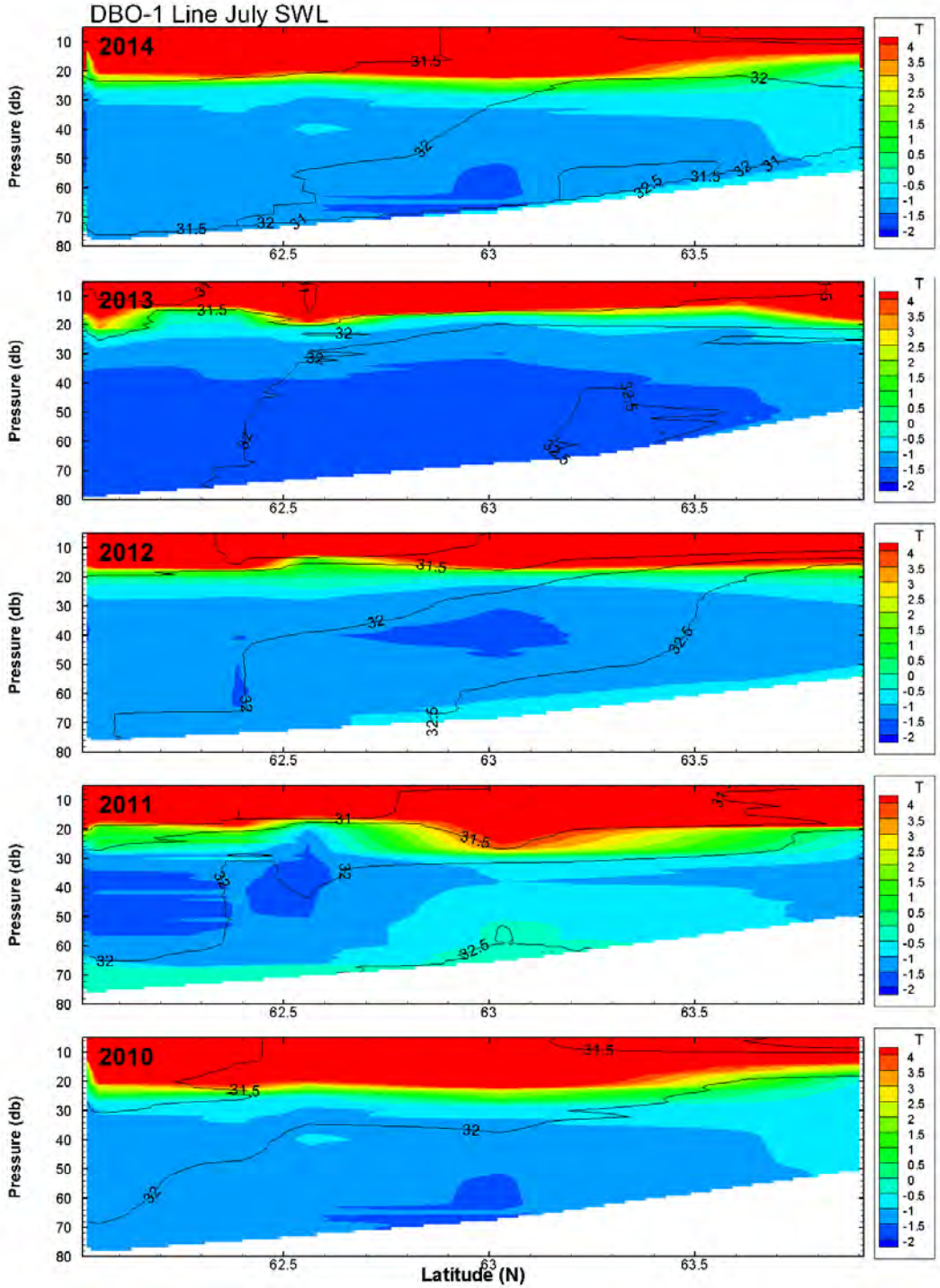


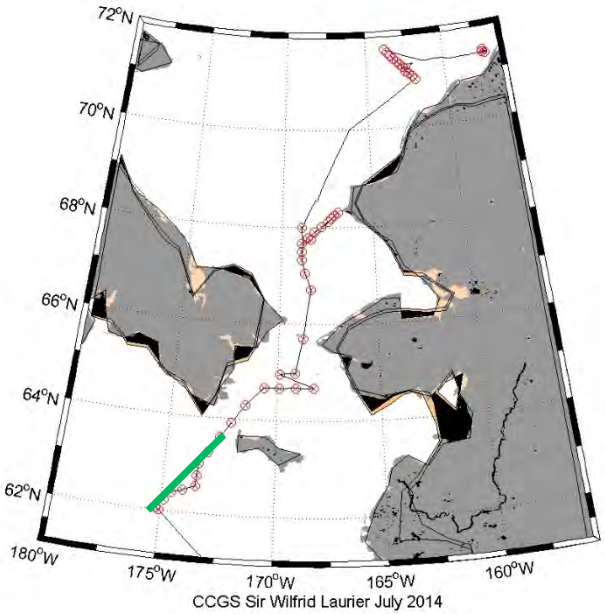




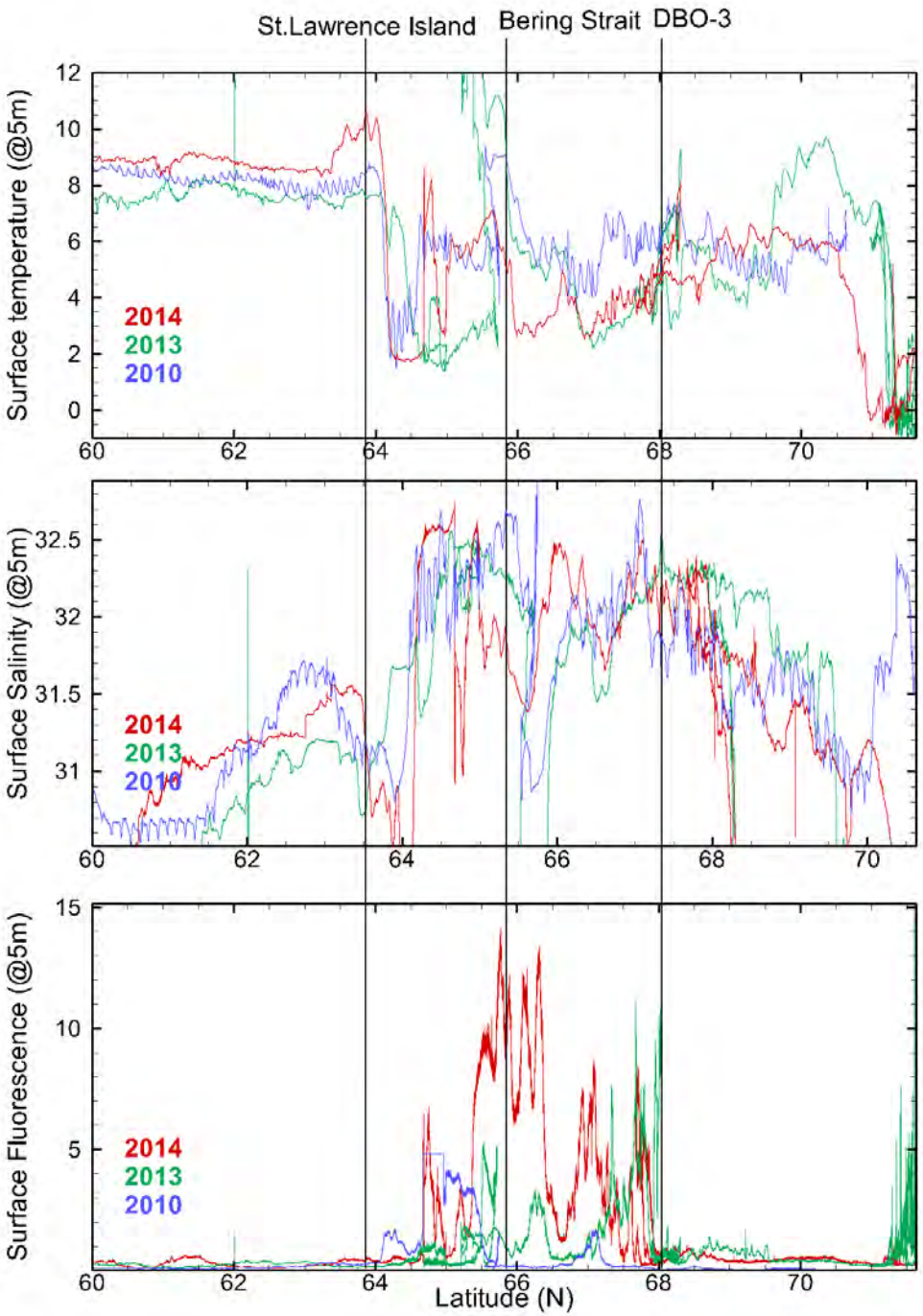


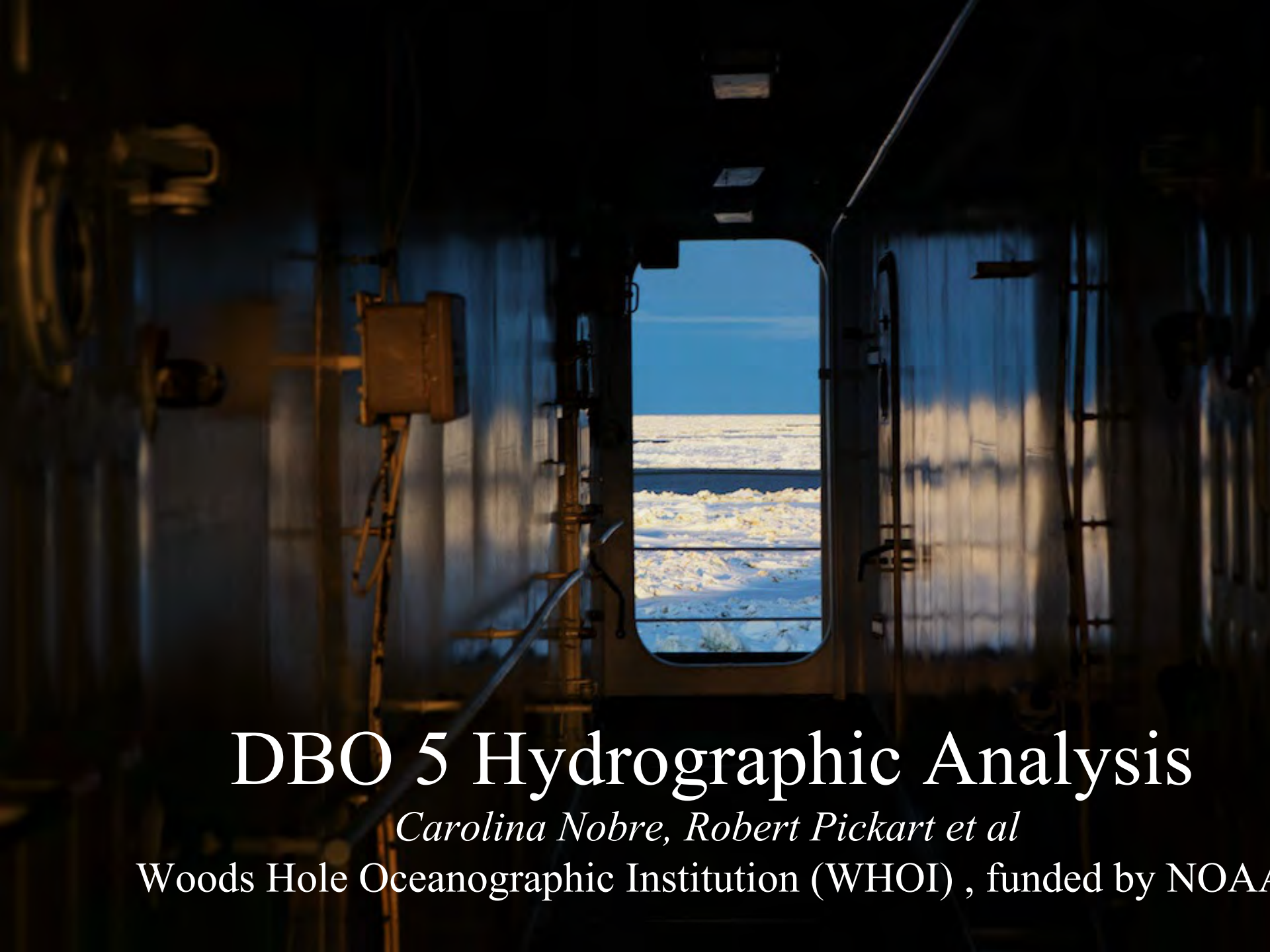



DBO-1 Line July SWL
2014
2013
2012
2011
2010
Pressure (db)
Latitude (N)
T


72°N
70°N
68°N
66°N
64°N
62°N
180°W
175°W
170°W
165°W
160°W
CCGS Sir Wilfrid Laurier July 2014

Underway, TSG



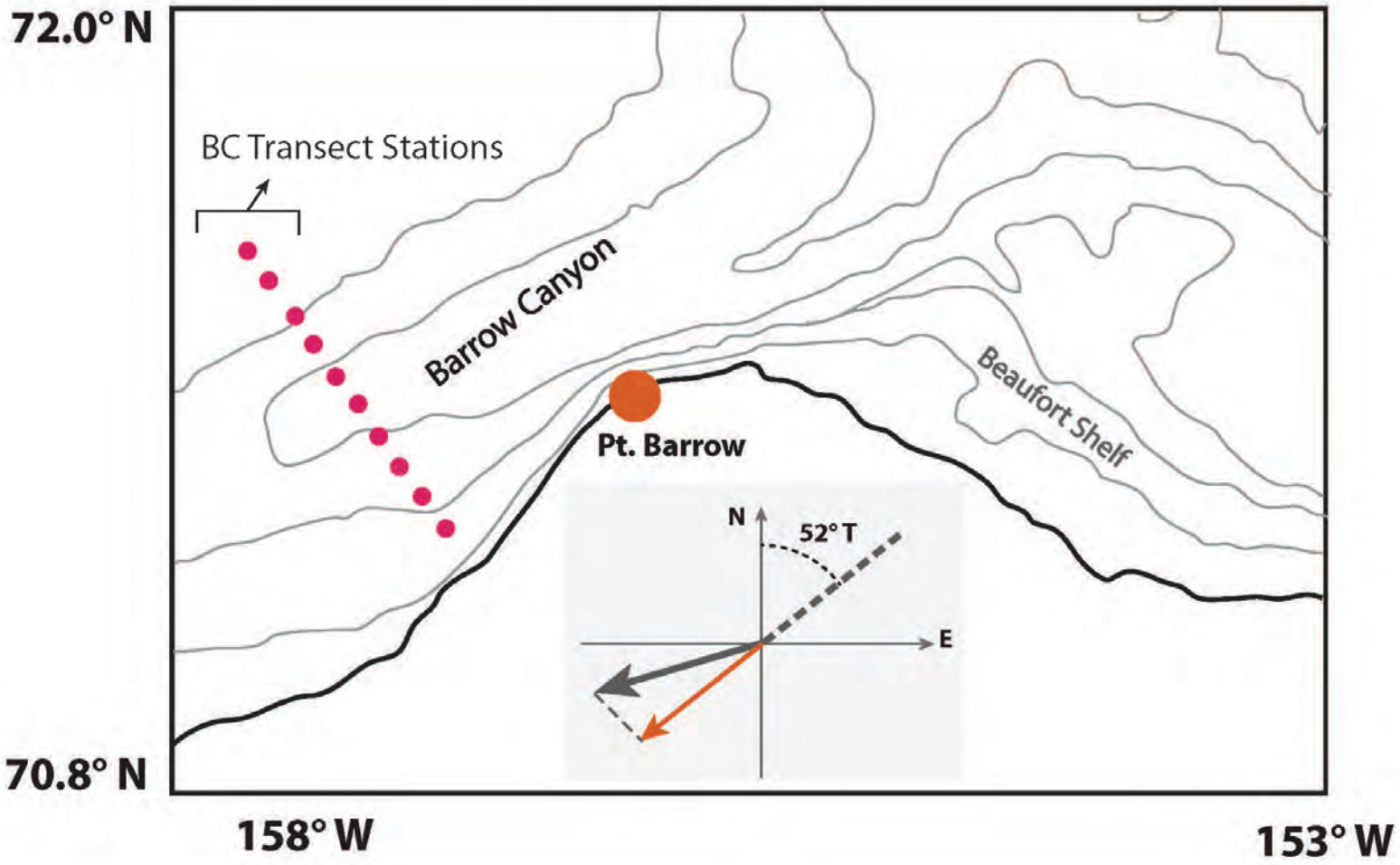


DBO 5 Hydrographic Analysis

Carolina Nobre, Robert Pickart et al

Woods Hole Oceanographic Institution (WHOI) , funded by NOAA

Barrow Canyon Station Positions and Wind Data



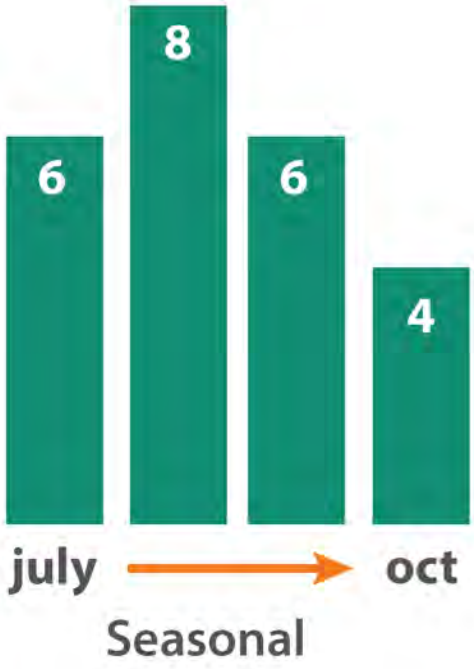
From 2010 – 2013 there were:

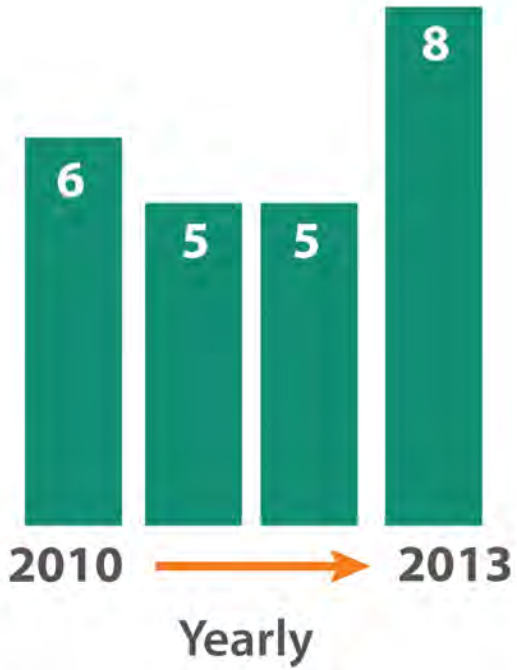
24 occupations of the Barrow Canyon transect

11 contributing Chief Scientists

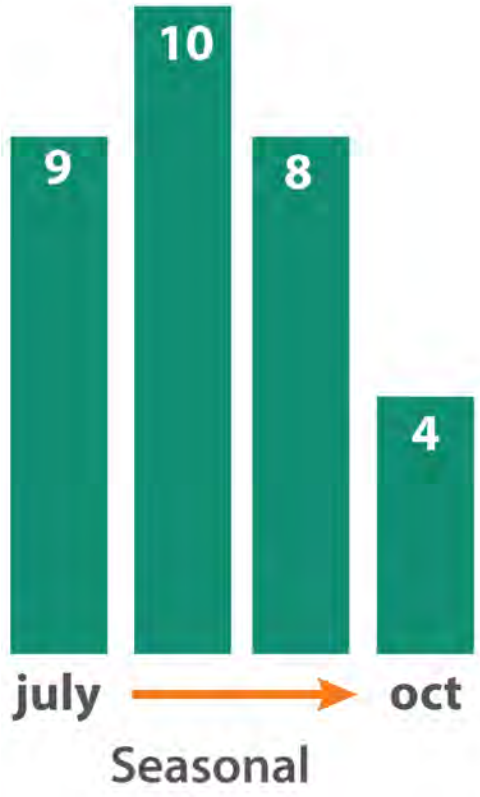
202 total CTD casts

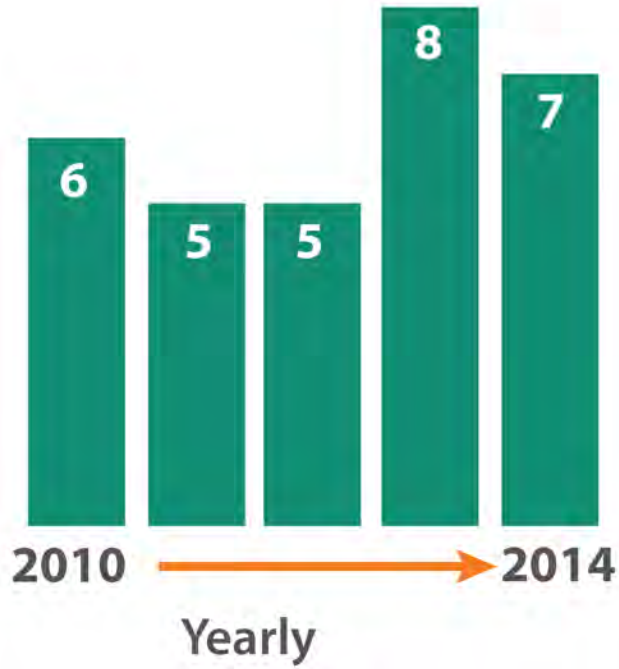
24 Occupations of Barrow Canyon Section from 2010- 2013





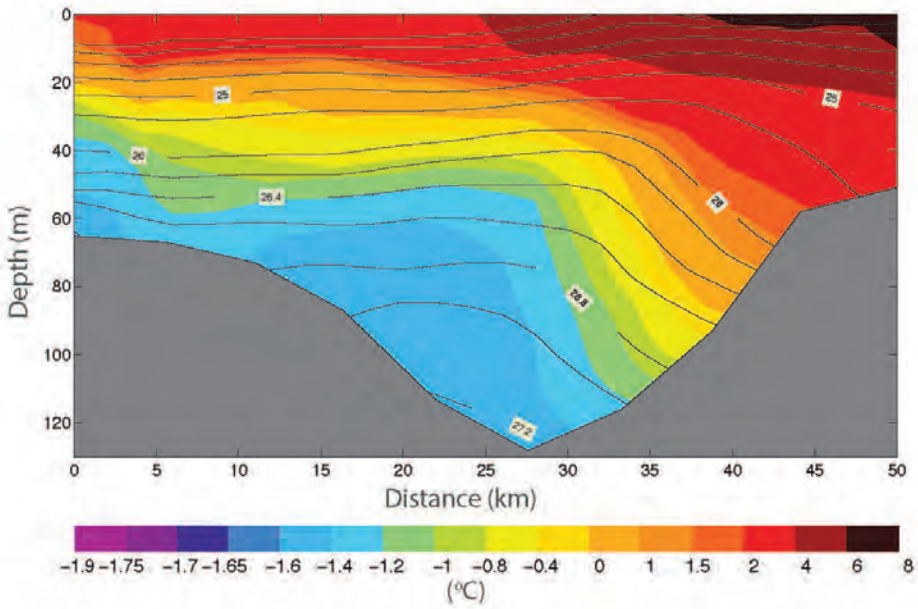
31 Occupations of Barrow Canyon Section from 2010- 2014



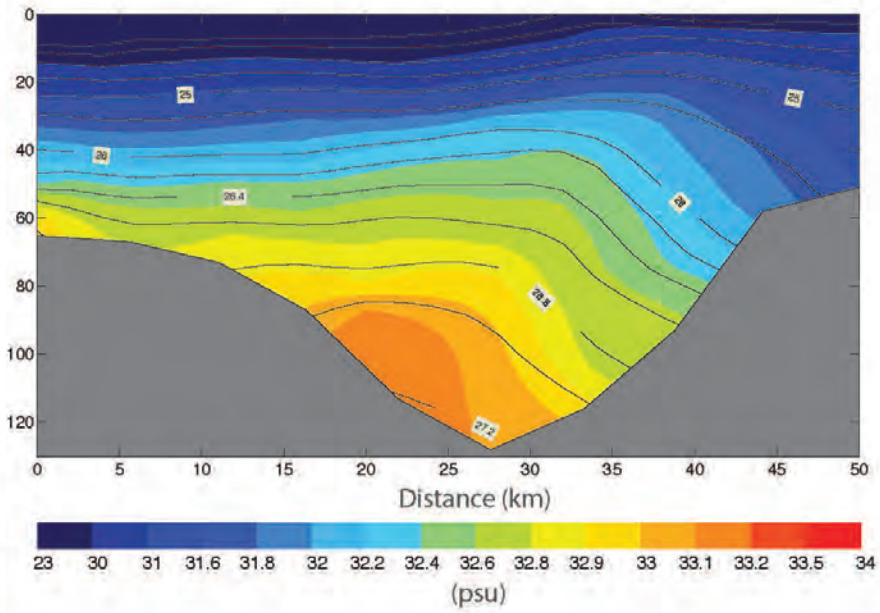


Mean Temperature and Salinity Fields for Barrow Canyon

Potential temperature (color) overlain by potential density (contours)

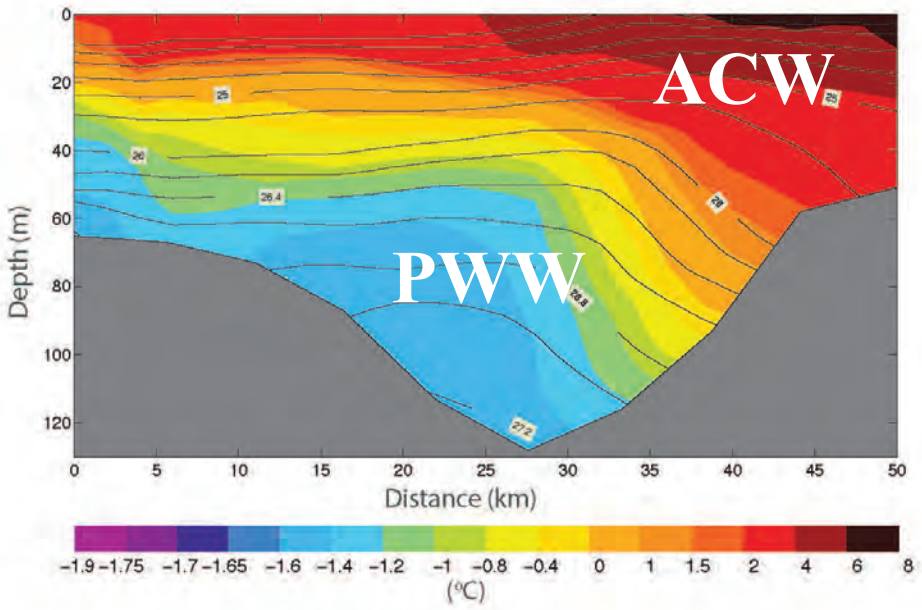


Salinity (color) overlain by potential density (contours)

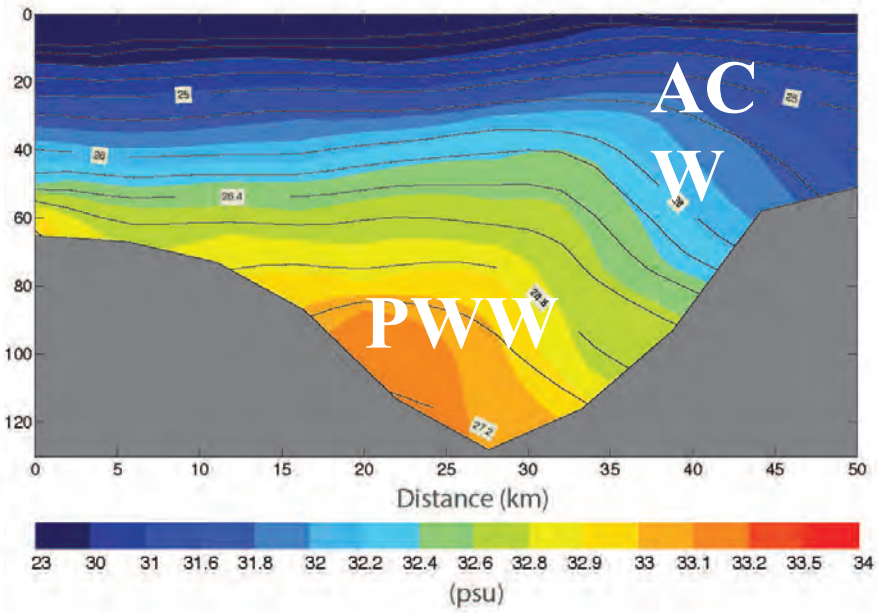


Mean Temperature and Salinity Fields for Barrow Canyon

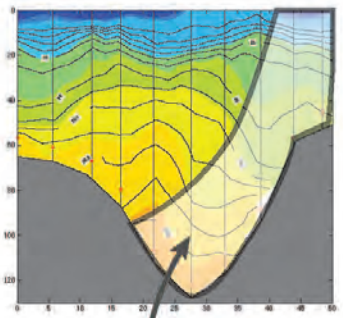
Potential temperature (color) overlain by potential density (contours)



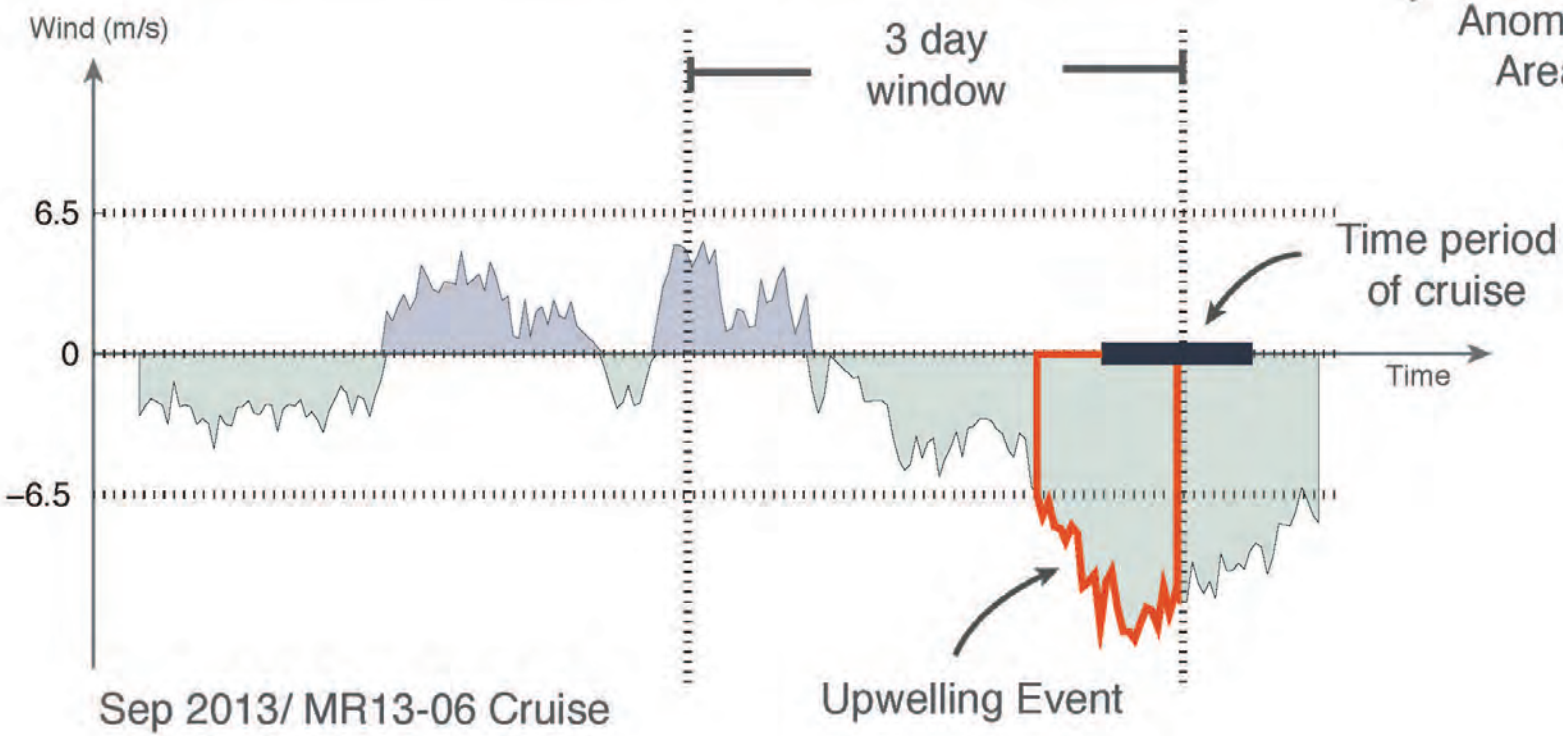
Salinity (color) overlain by potential density (contours)

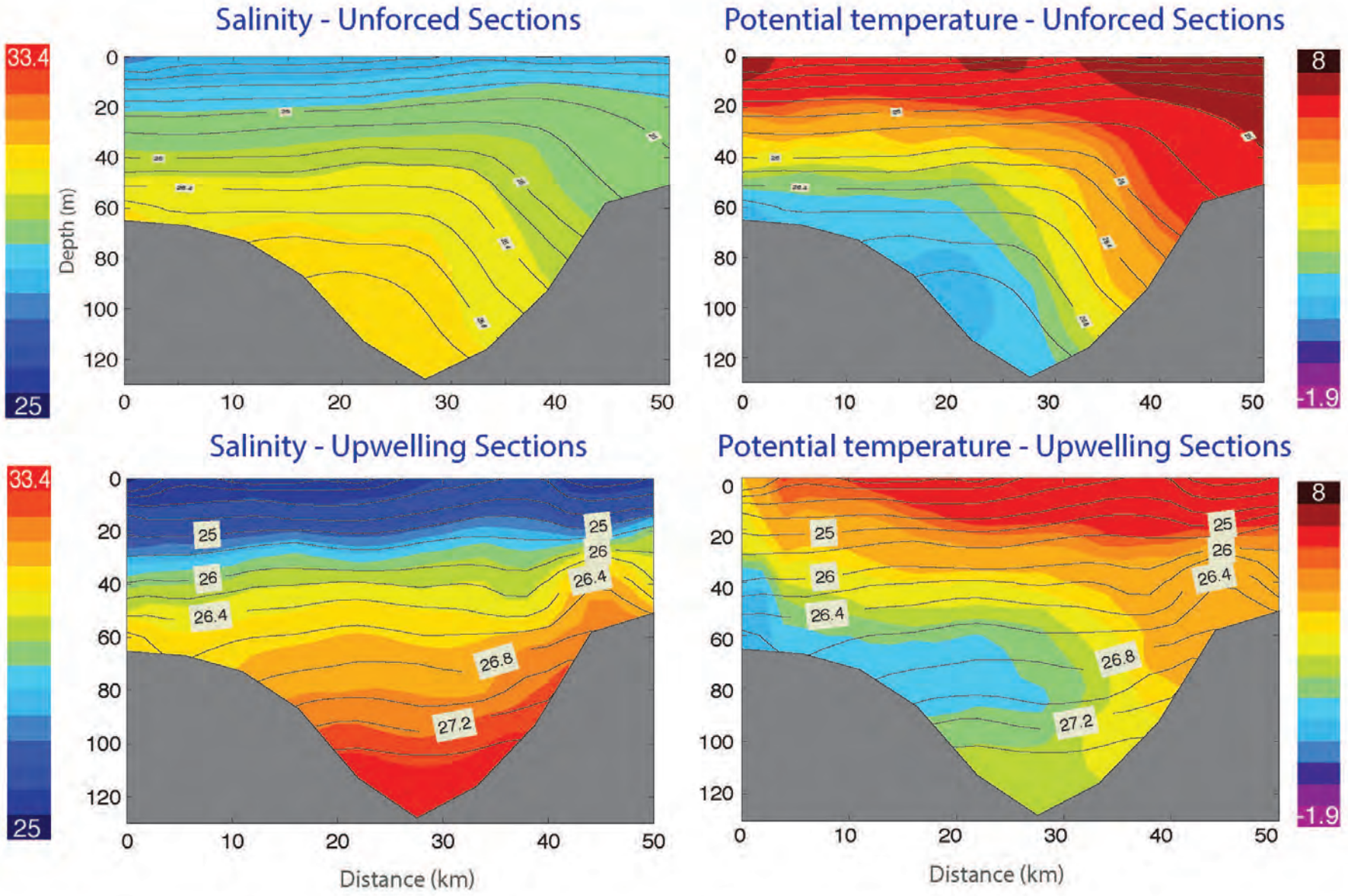


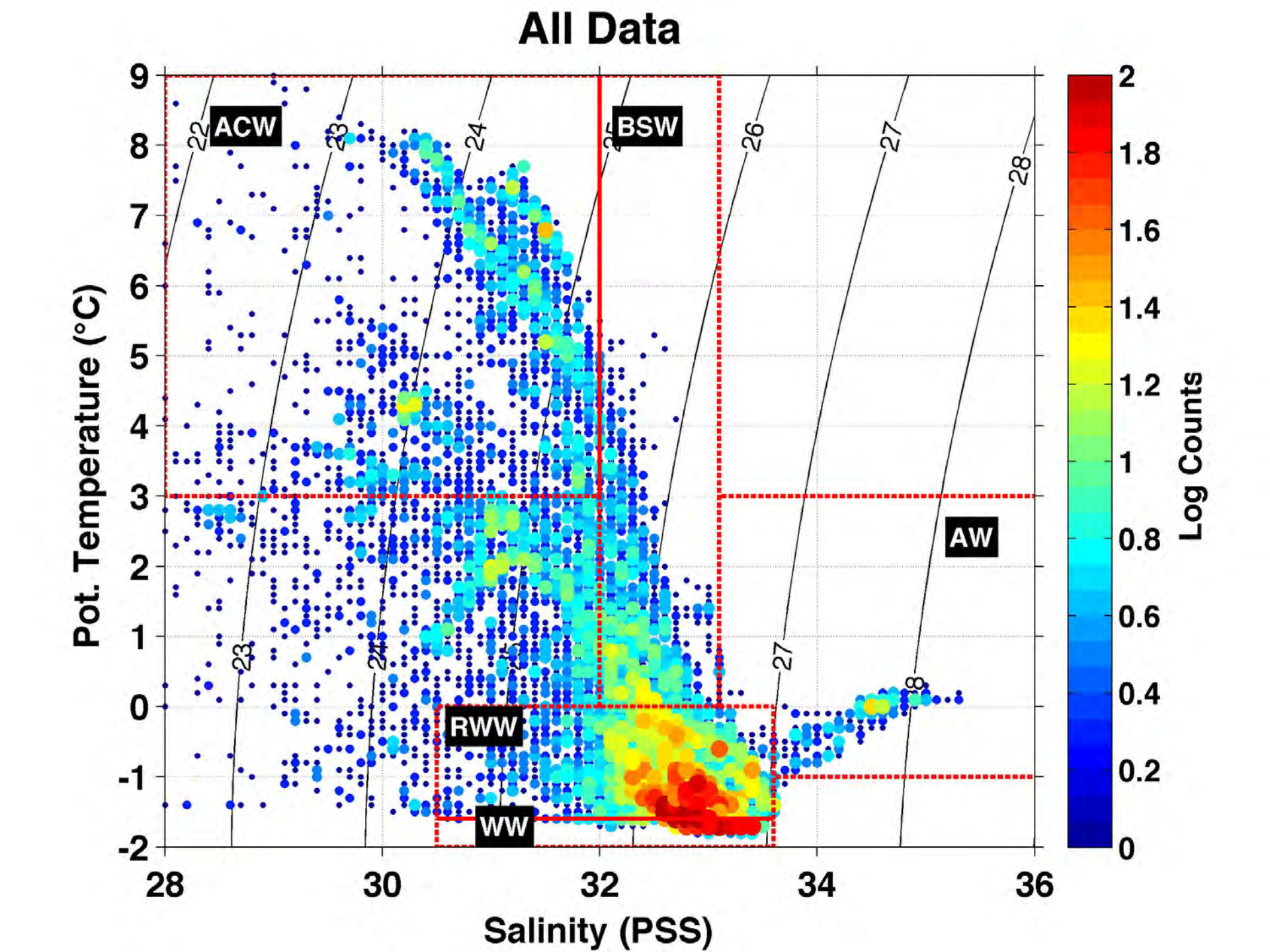
The highest correlation between the along canyon component of the wind and the density anomaly was for **a wind speed exceeding 6.5m/s**, within a **window of 3 days**

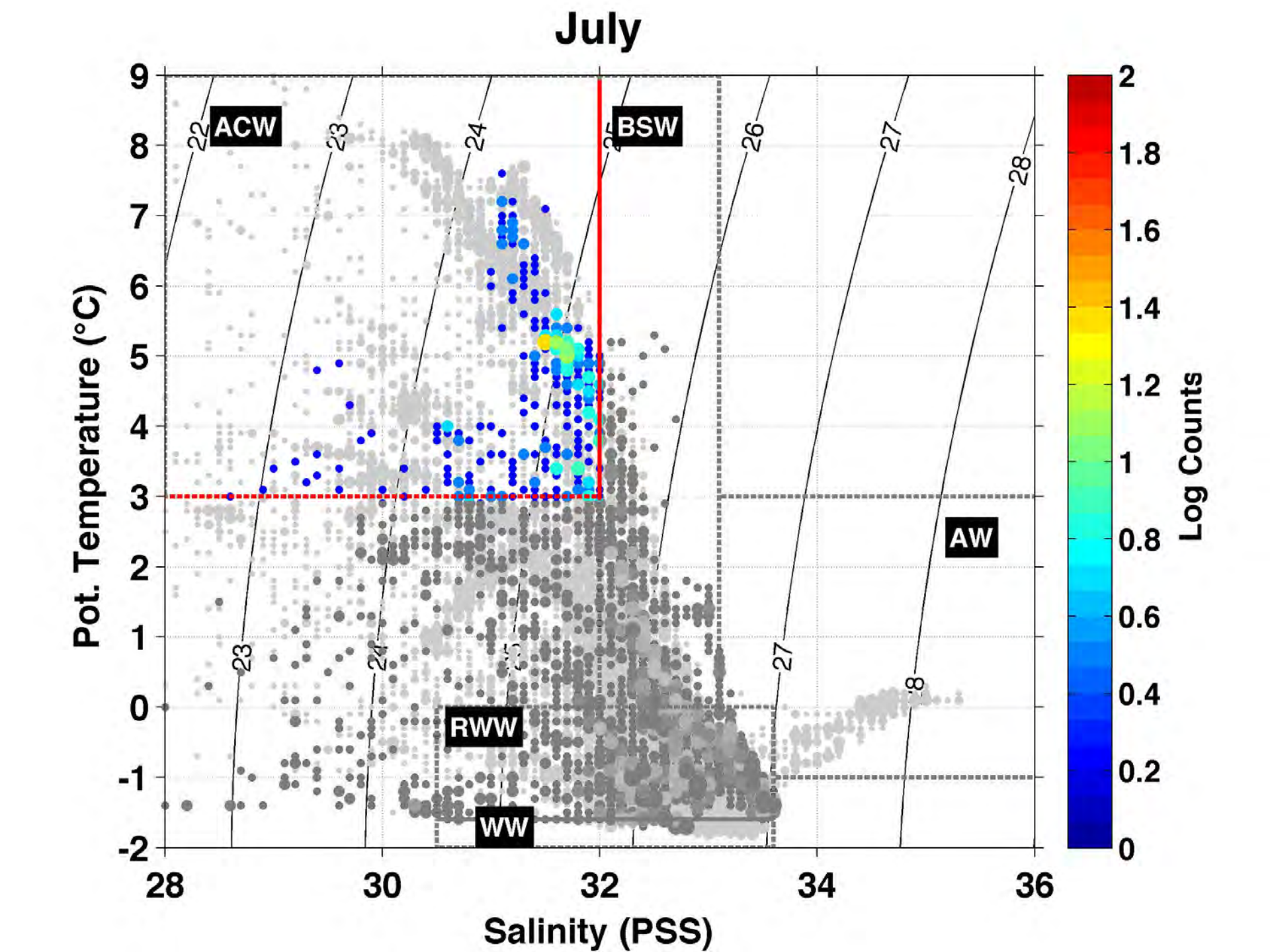


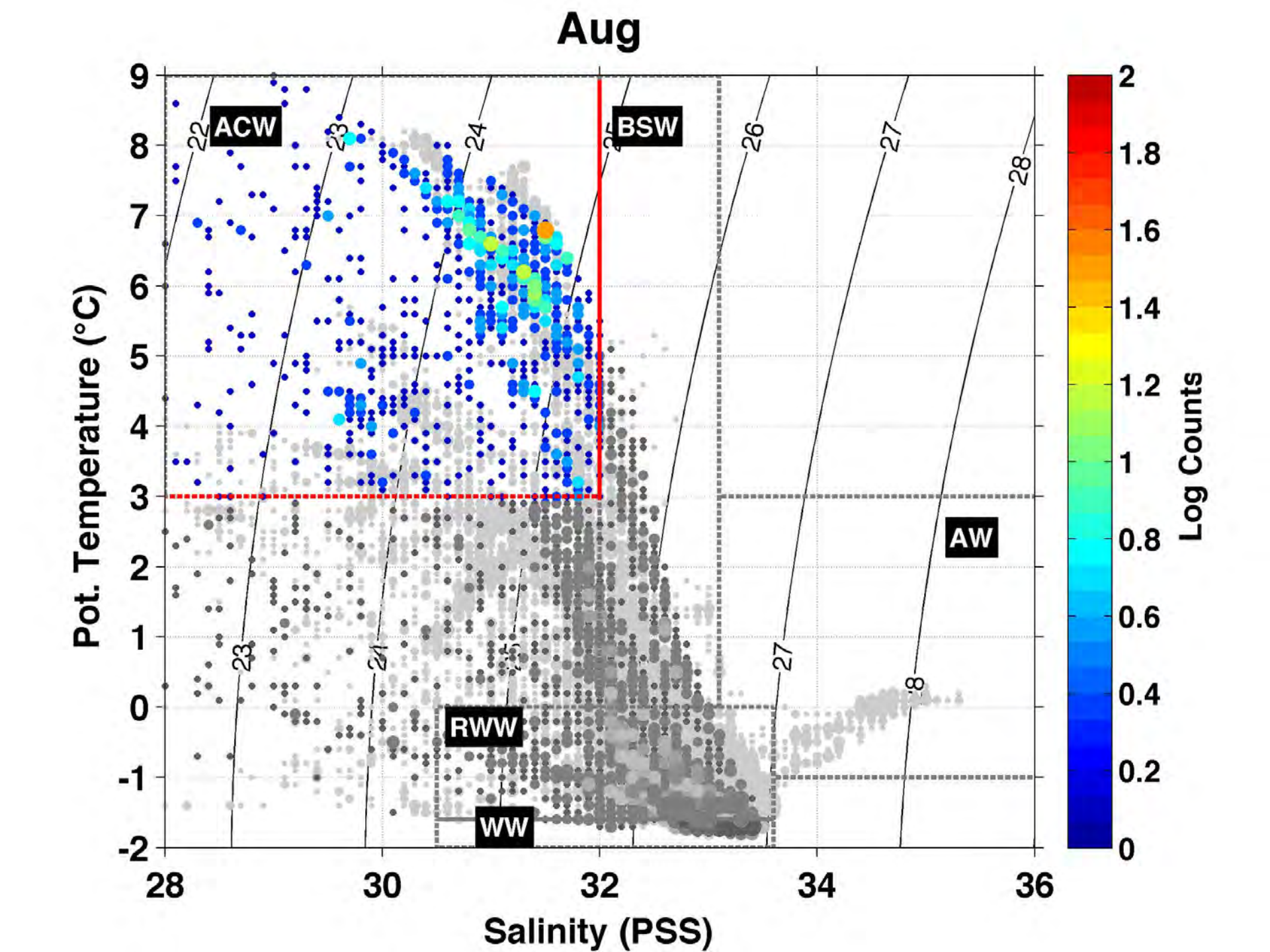
Density Anomaly Area

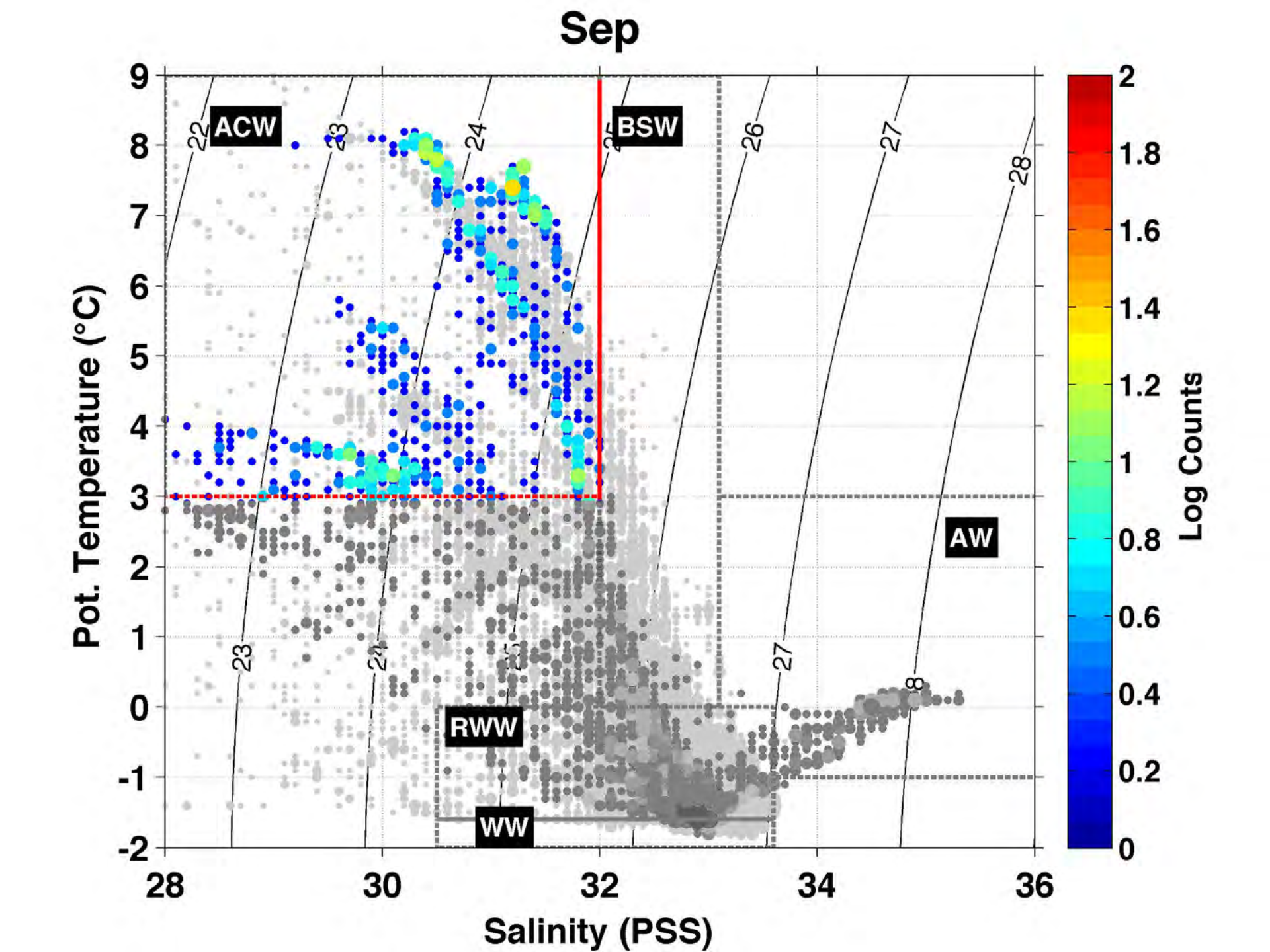



Salinity - Unforced Sections
Potential temperature - Unforced Sections
Salinity - Upwelling Sections
Potential temperature - Upwelling Sections
33.4
25
8
-1.9
Depth (m)
Distance (km)
0
20
40
60
80
100
120
0
10
20
30
40
50
25
26
26.4
26.8
27.2


All Data
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
22
23
24
25
26
27
28
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


July
ACW
BSW
AW
RWW
WW
22
23
24
25
26
27
28
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


Aug
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
22
23
24
25
26
27
28
21
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


Sep
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
22
23
24
25
26
27
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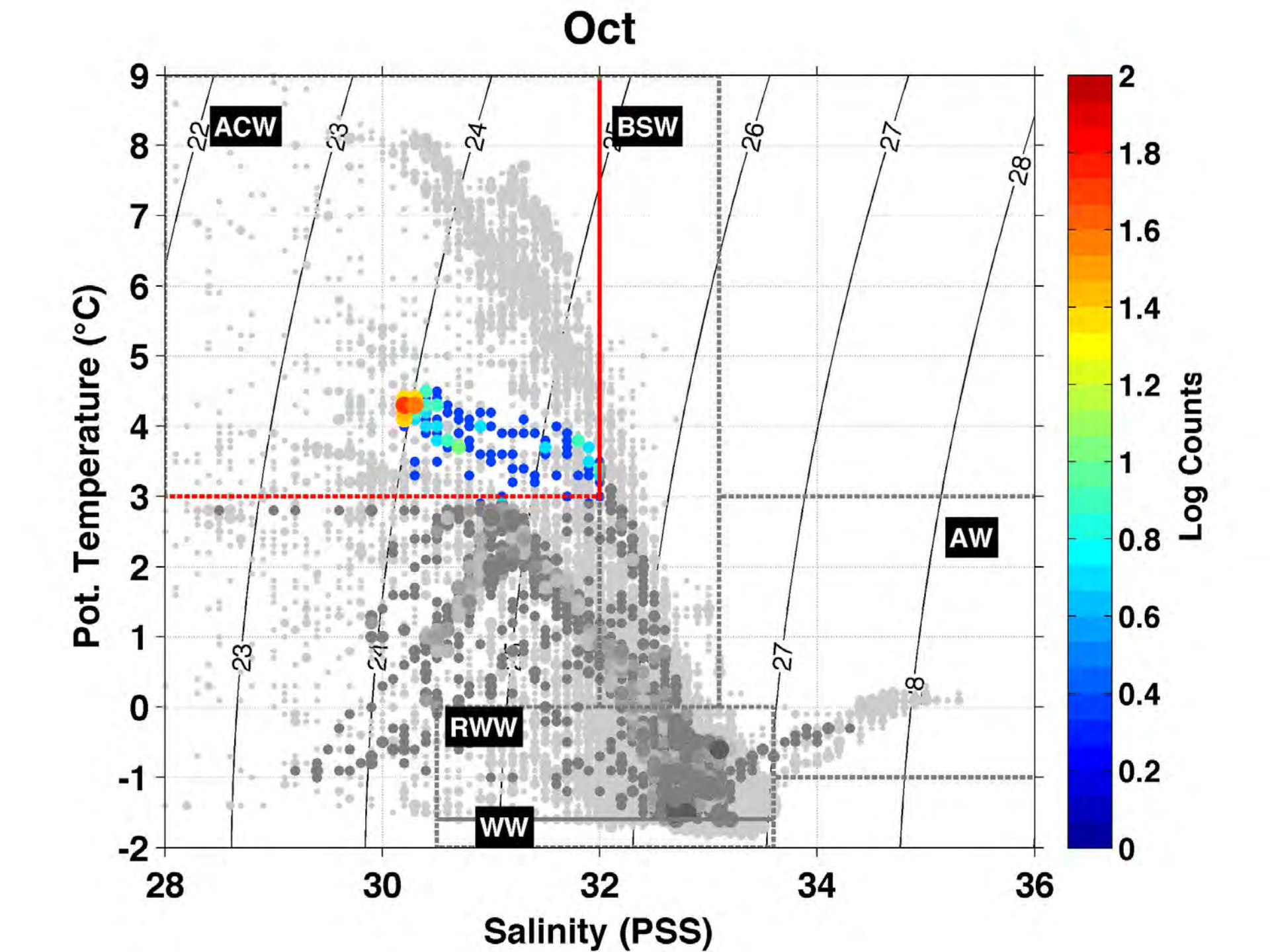
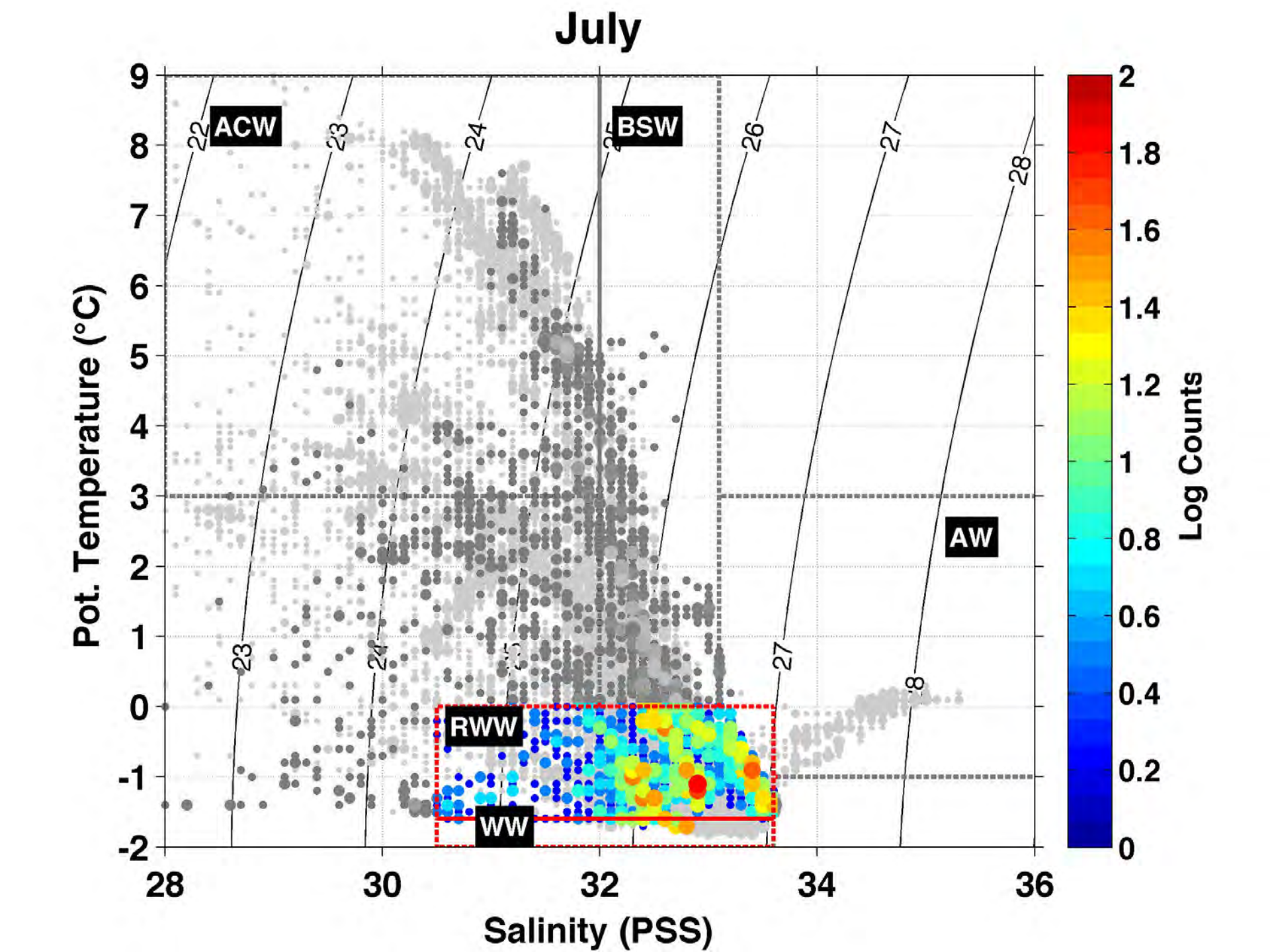
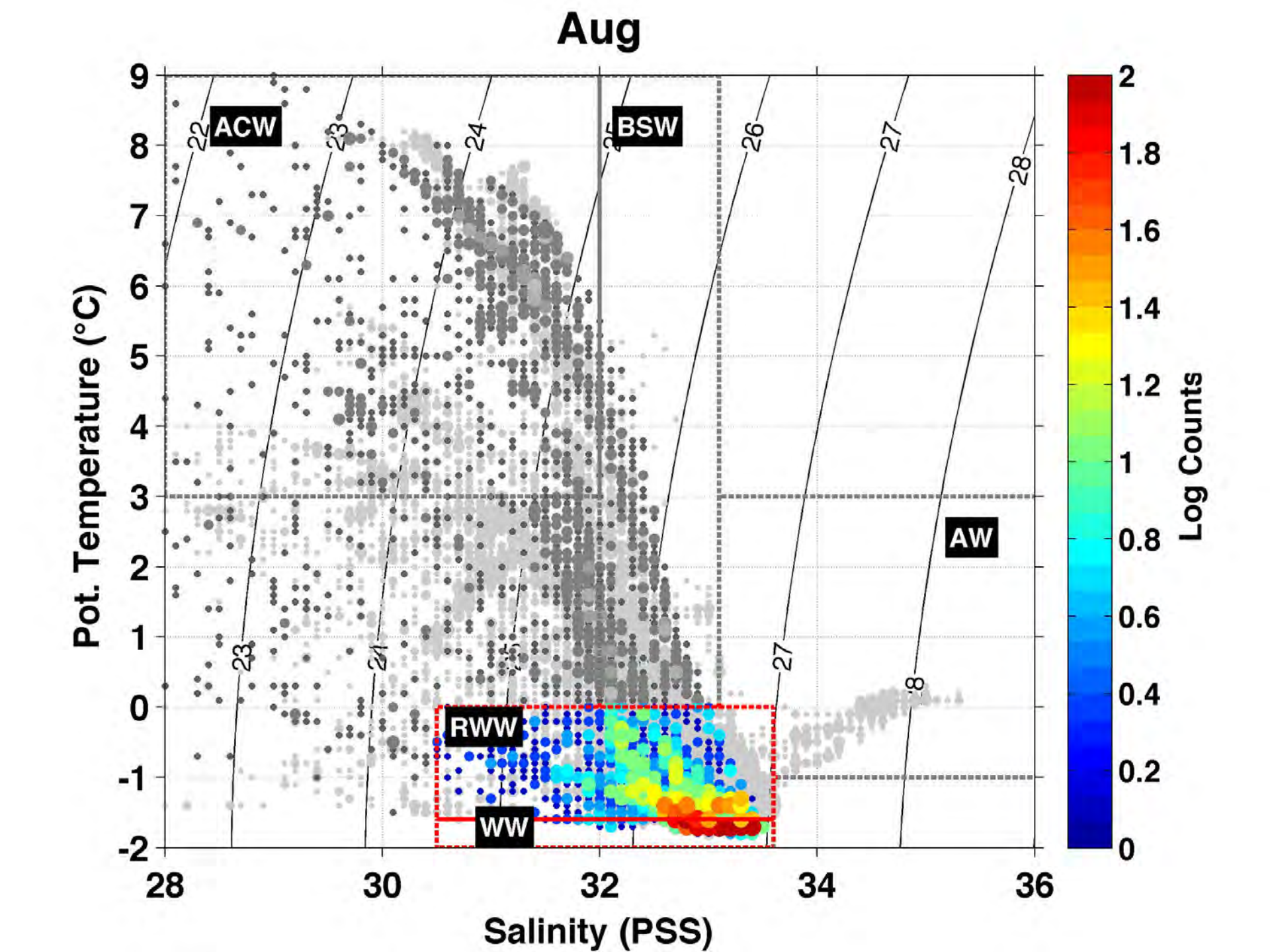
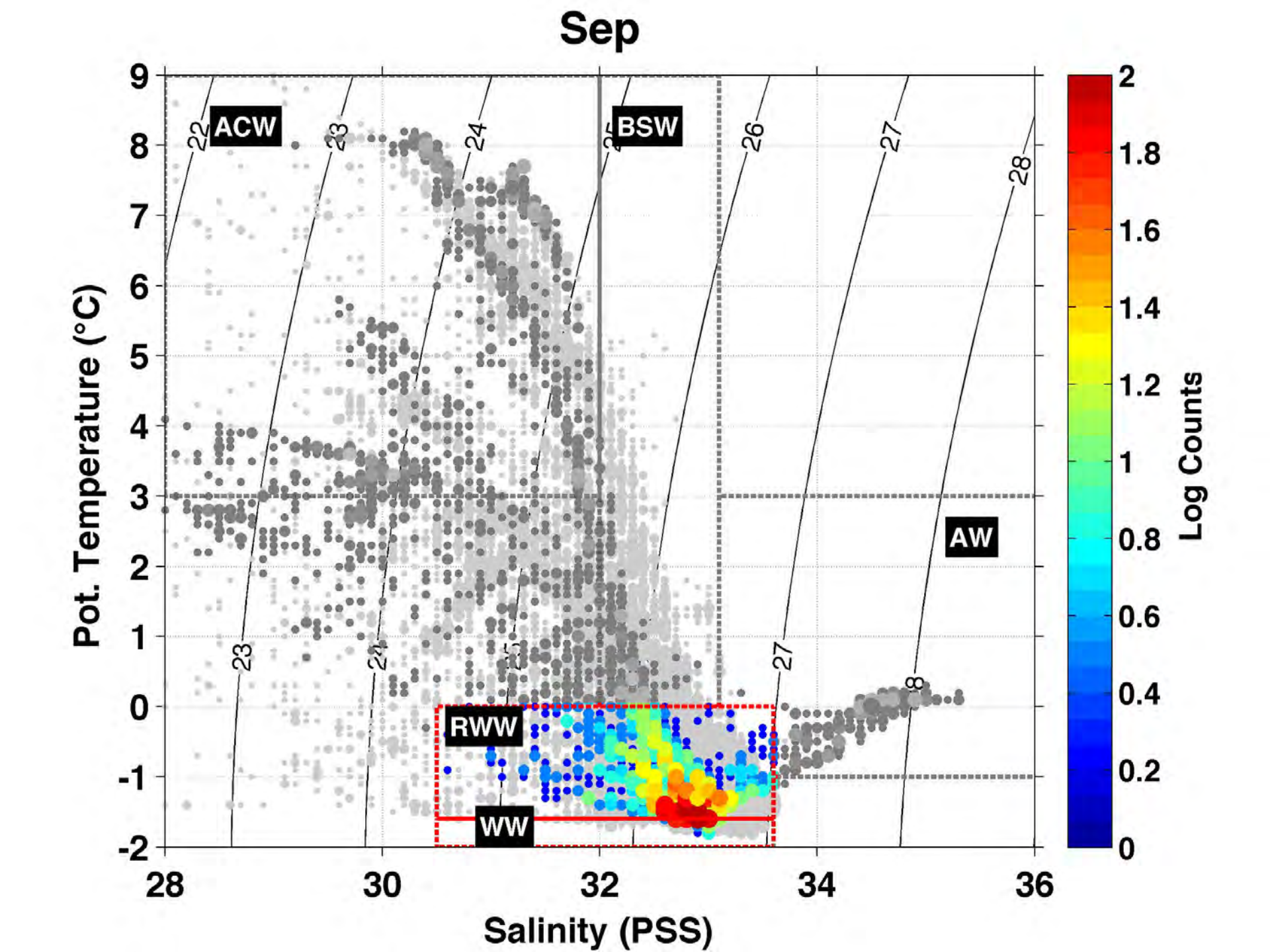
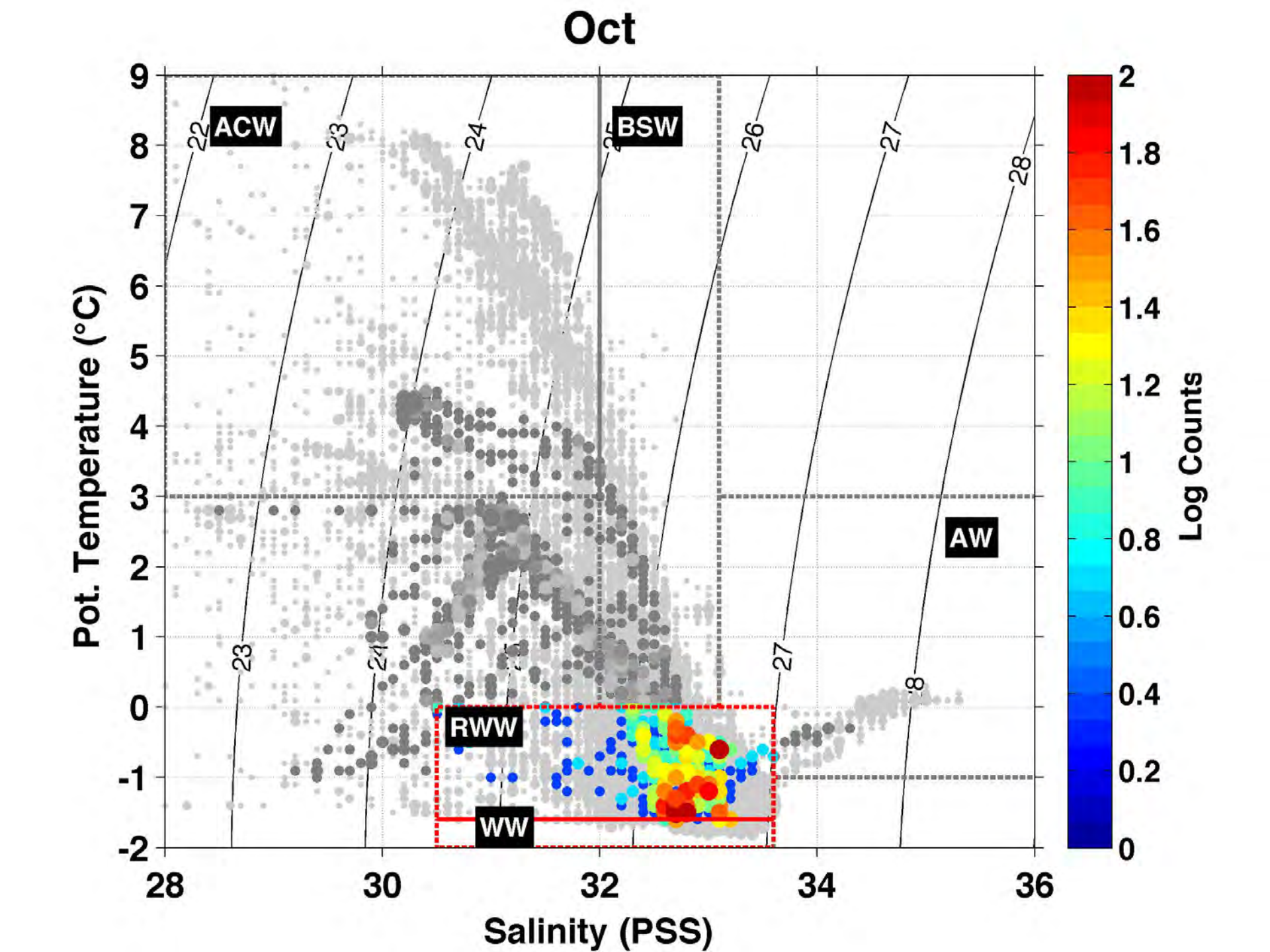
21
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


Oct
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
22
23
24
25
26
27
28
21
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


July
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
22
23
24
25
26
27
28
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


Aug
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
22
23
24
25
26
27
28
21
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


Sep
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
22
23
24
25
26
27
28
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0


Oct
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
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24
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1.4
1.2
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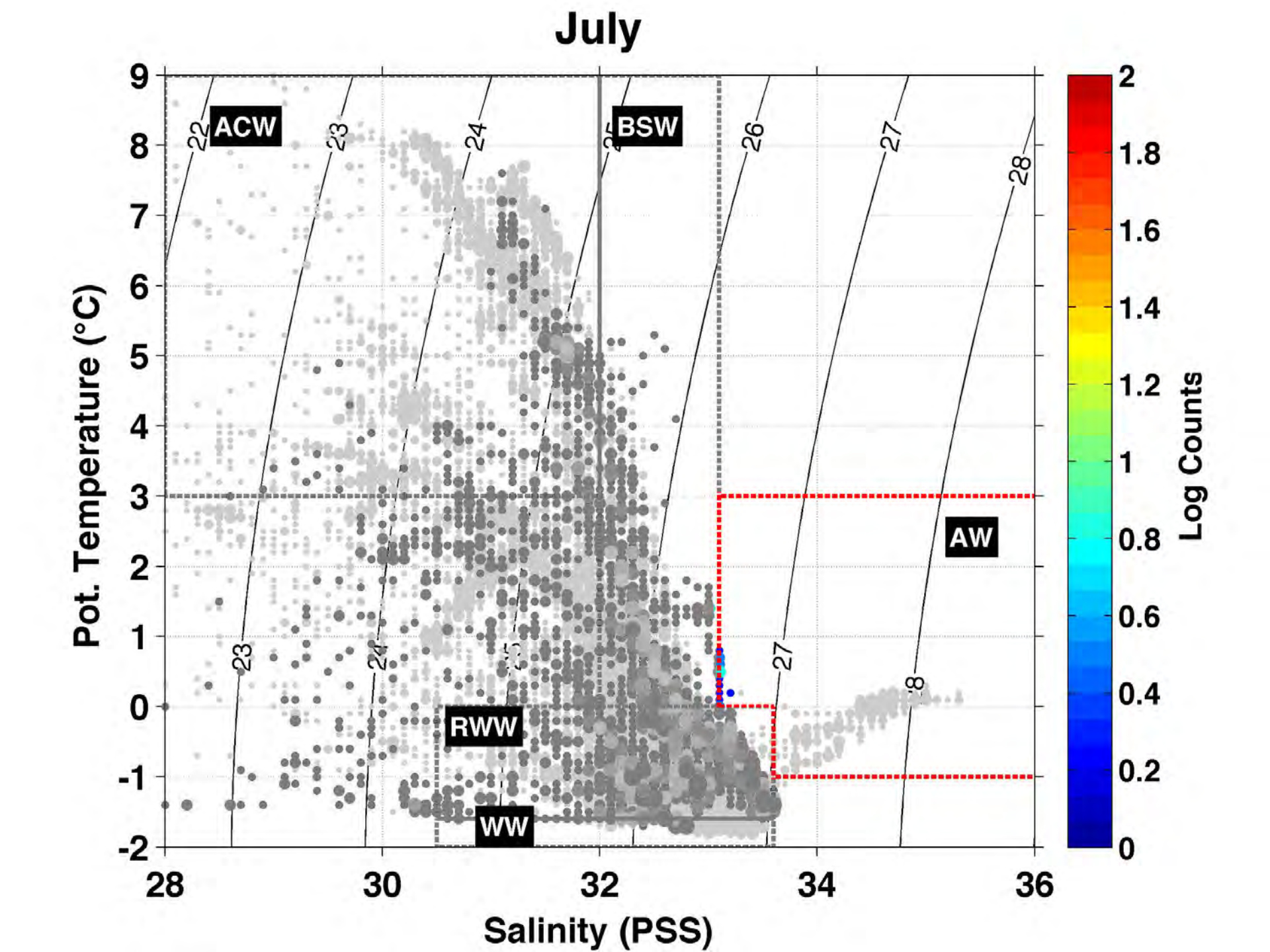
0.8
0.6
0.4
0.2
0


July
ACW
BSW
AW
RWW
WW
22
23
24
25
26
27
28
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
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34
36
2
1.8
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1.4
1.2
1
0.8
0.6
0.4
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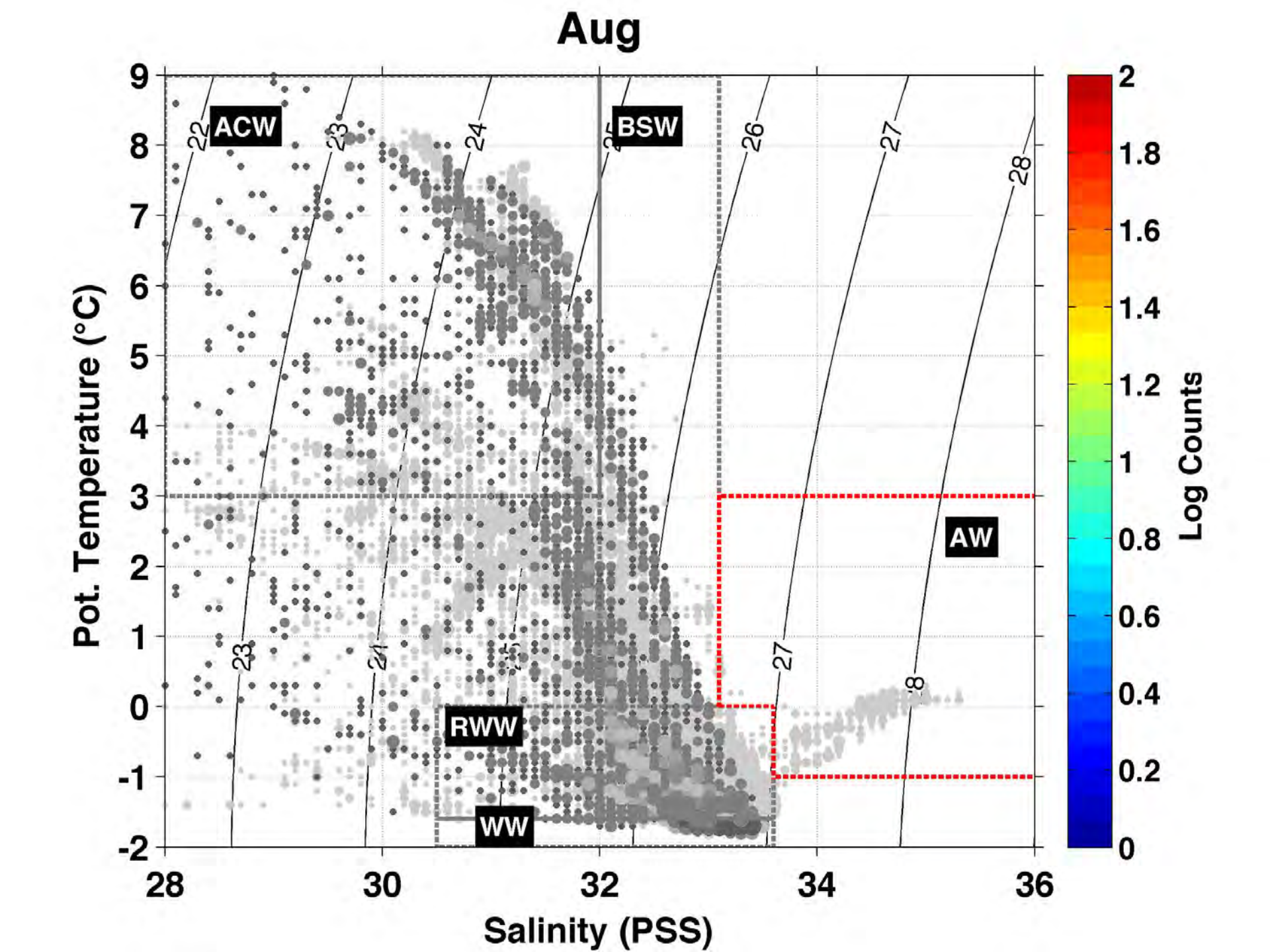
Aug
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
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5
4
3
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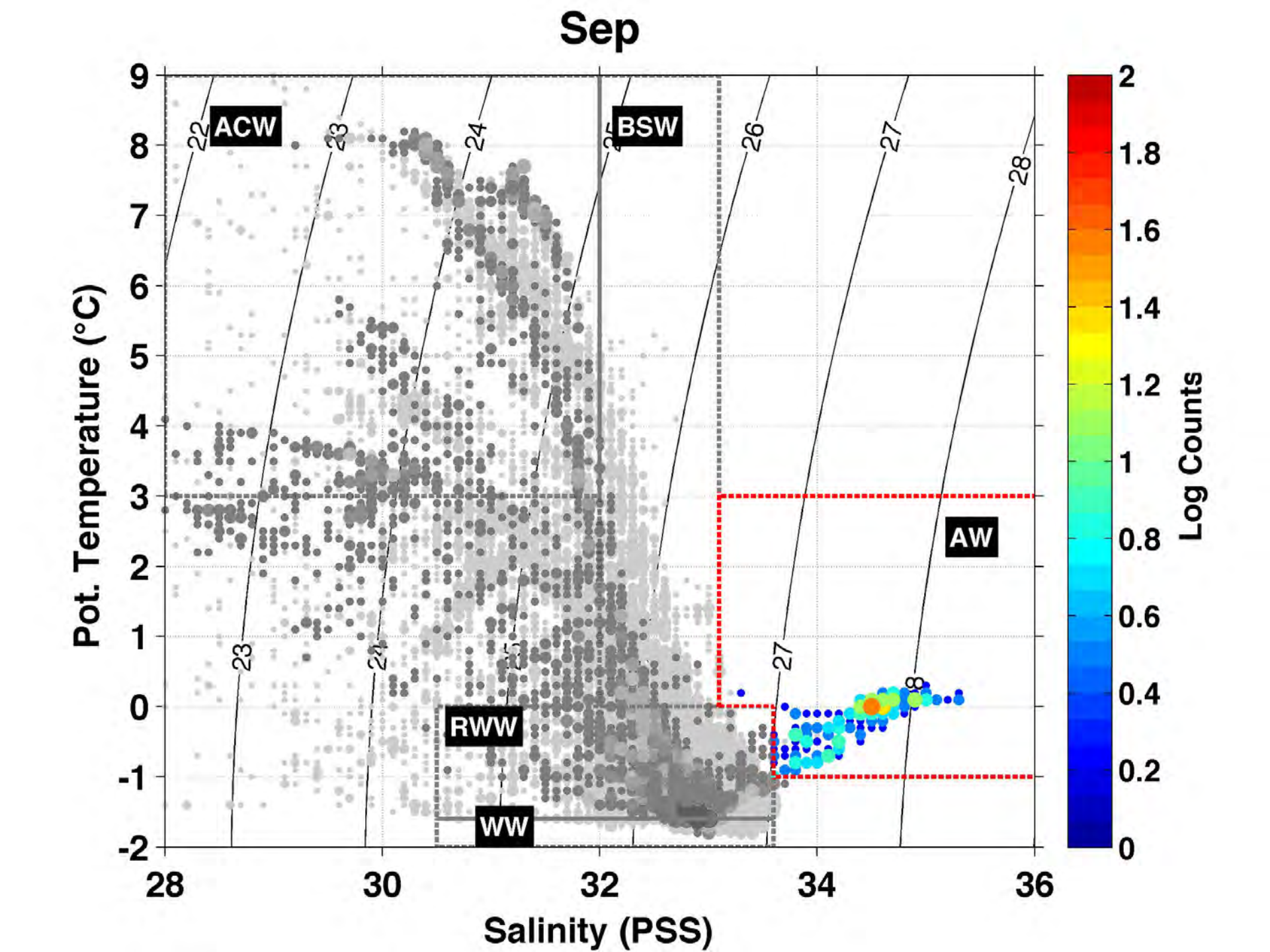
Sep
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
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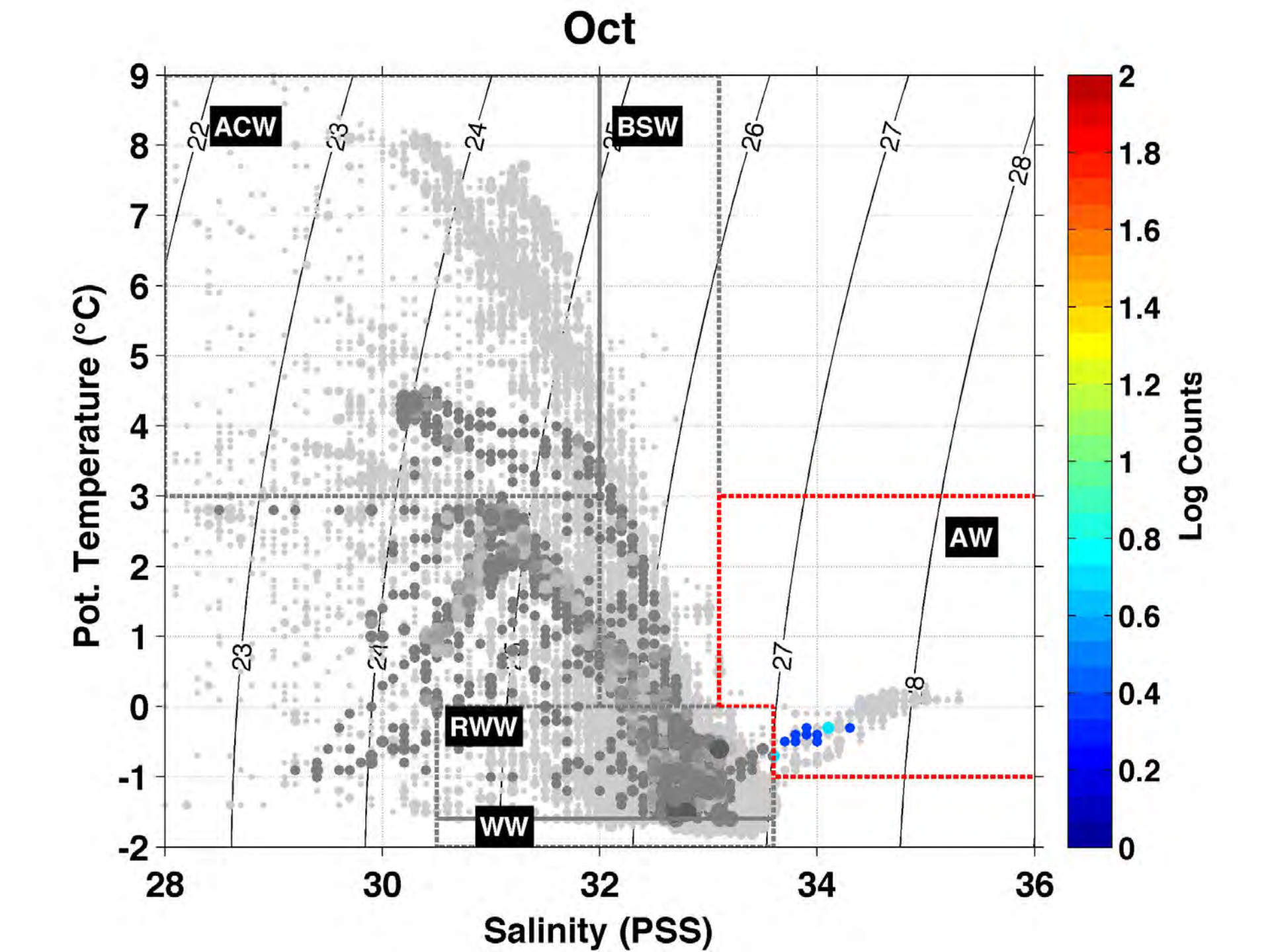
Oct
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
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-1
-2
28
30
32
34
36
22
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1.4
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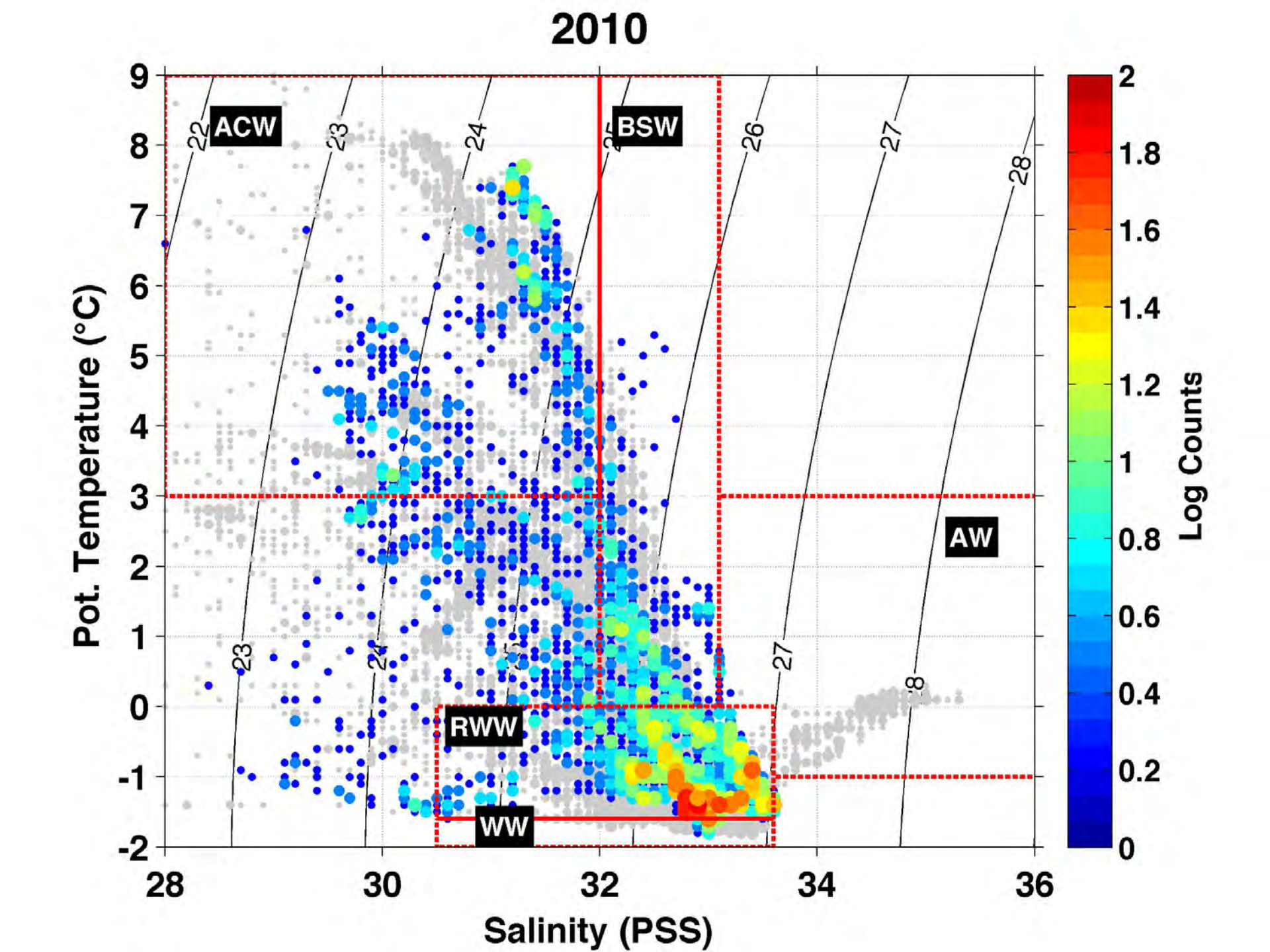
2010
ACW
BSW
AW
RWW
WW
22
23
24
25
26
27
28
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
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36
2
1.8
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1.4
1.2
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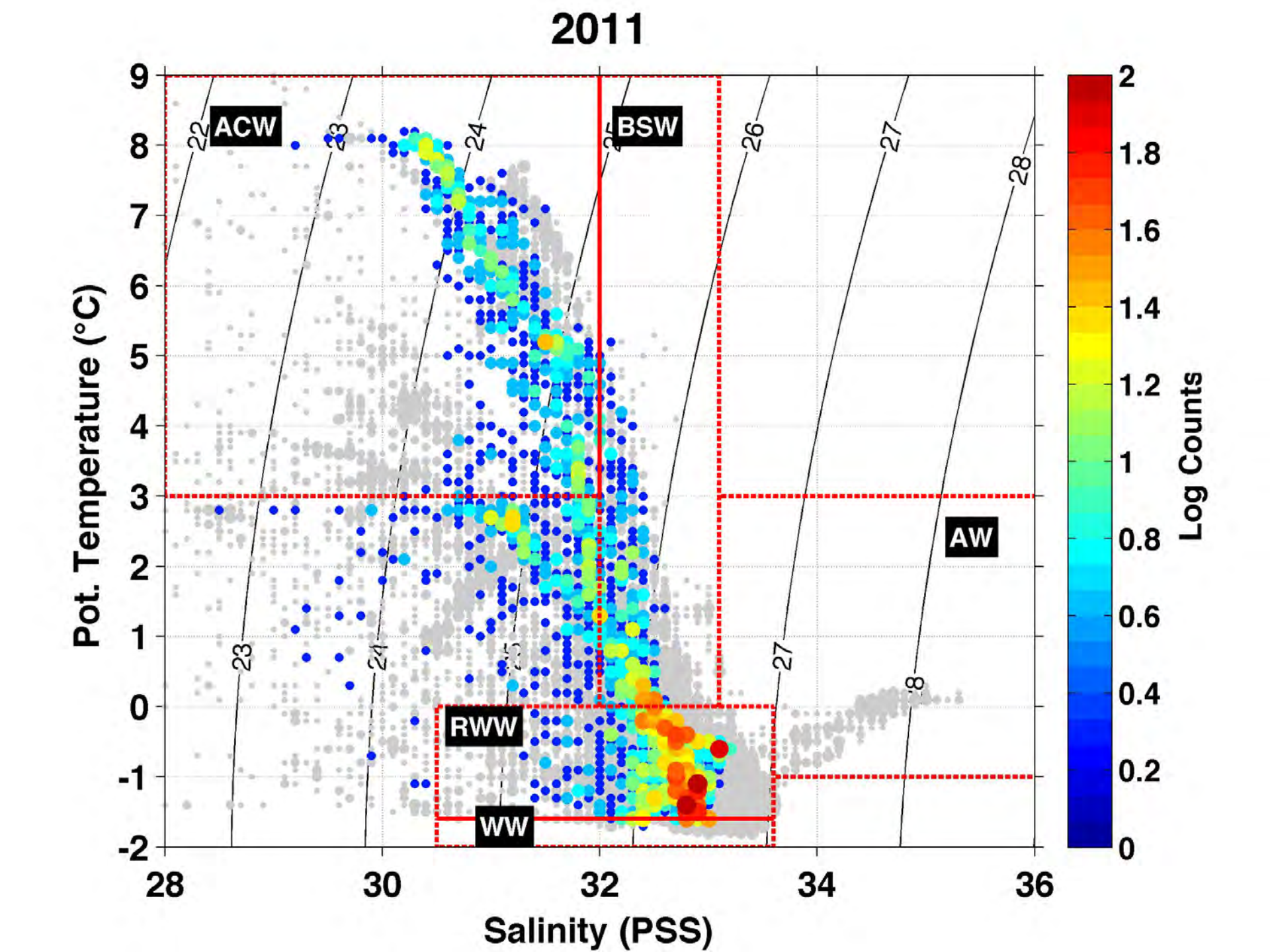
2011
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
22
23
24
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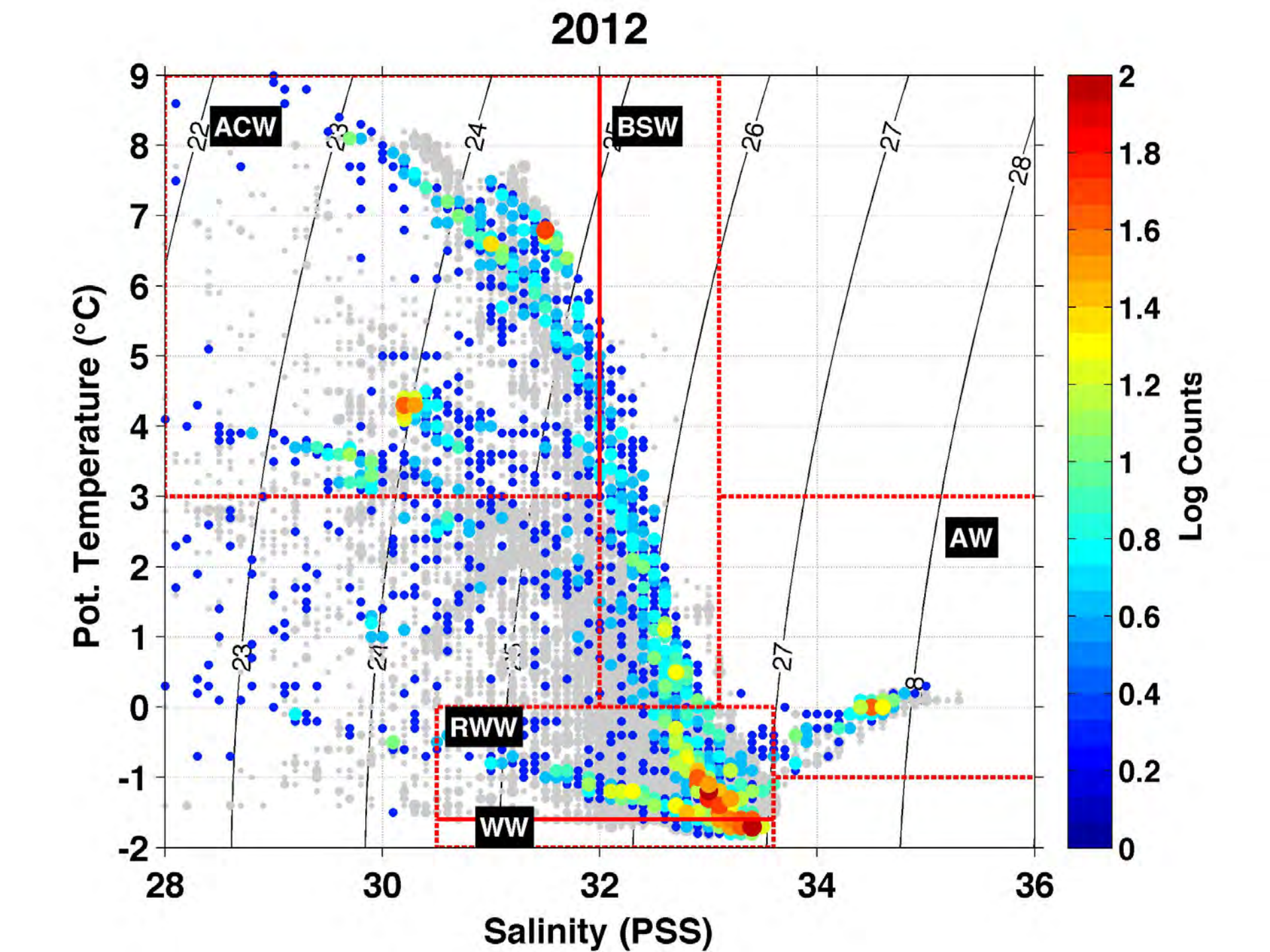
26
27
28


2012
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
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22
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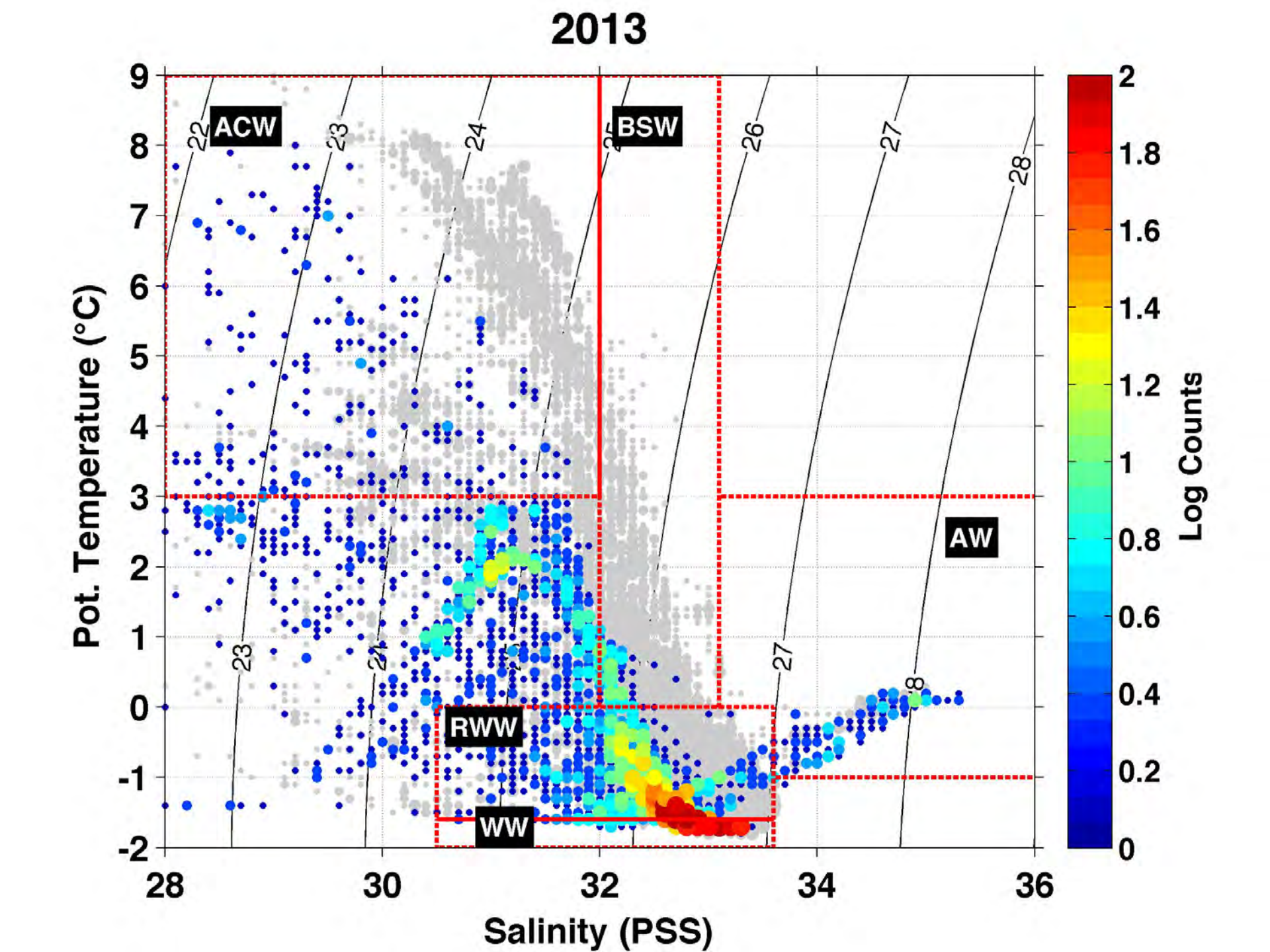
28


2013
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts
9
8
7
6
5
4
3
2
1
0
-1
-2
28
30
32
34
36
22
23
24
25
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1.4
1.2
1
0.8
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0.4
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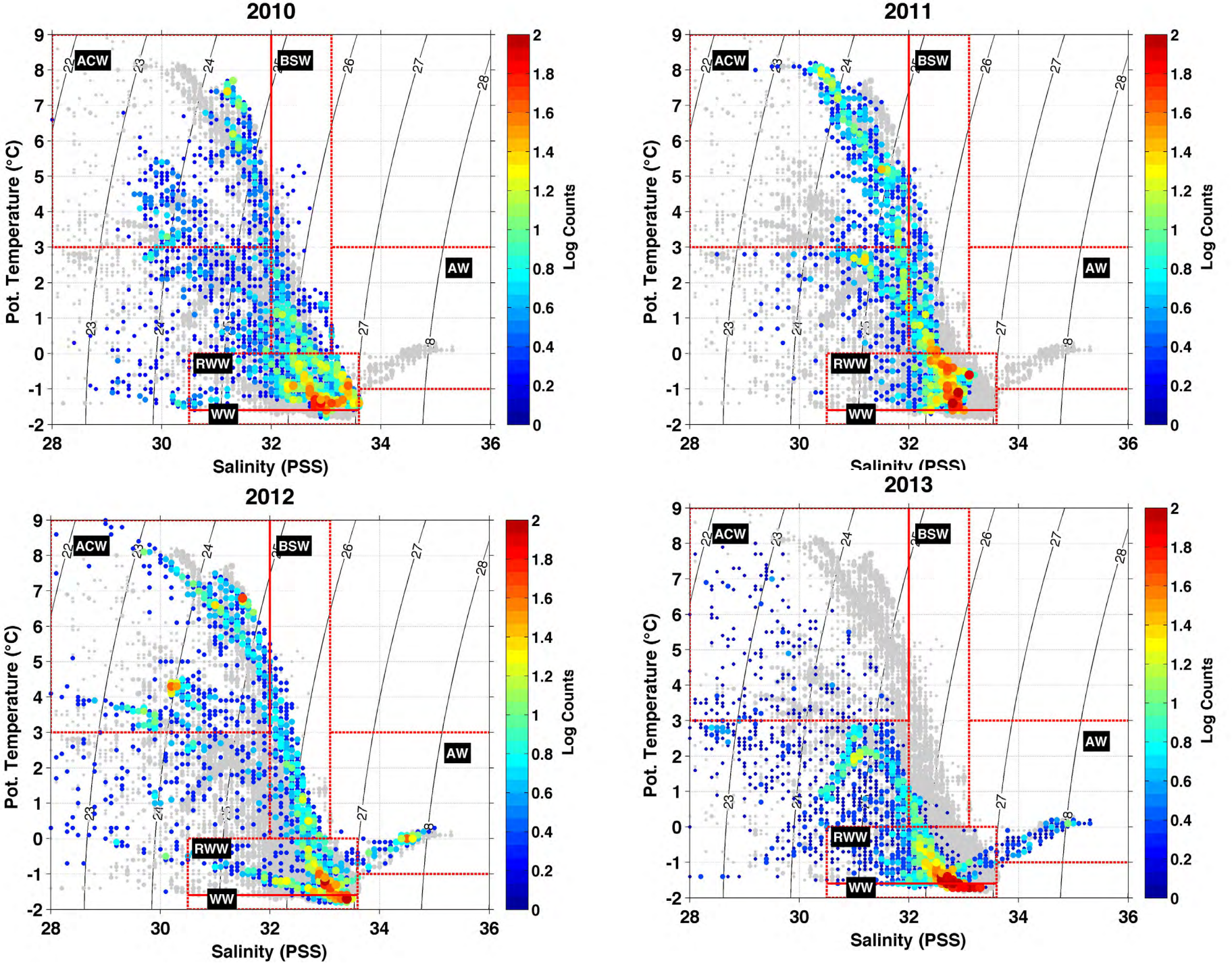
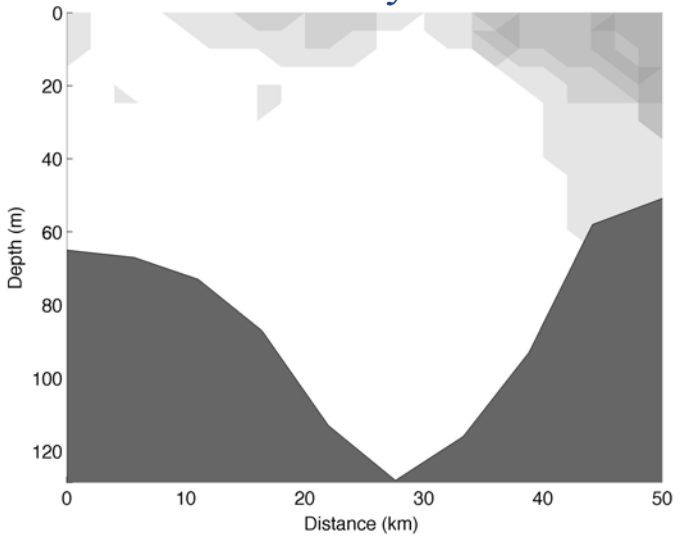
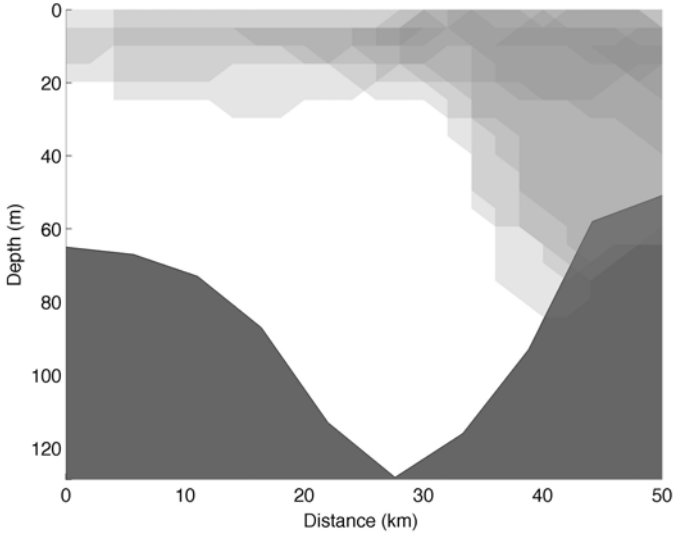

2010
2011
2012
2013
ACW
BSW
AW
RWW
WW
Pot. Temperature (°C)
Salinity (PSS)
Log Counts

Alaskan Coastal Water (ACW)

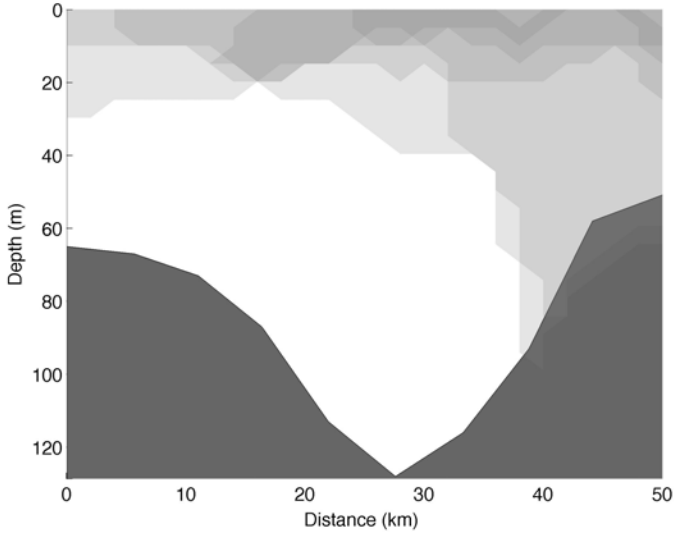
July



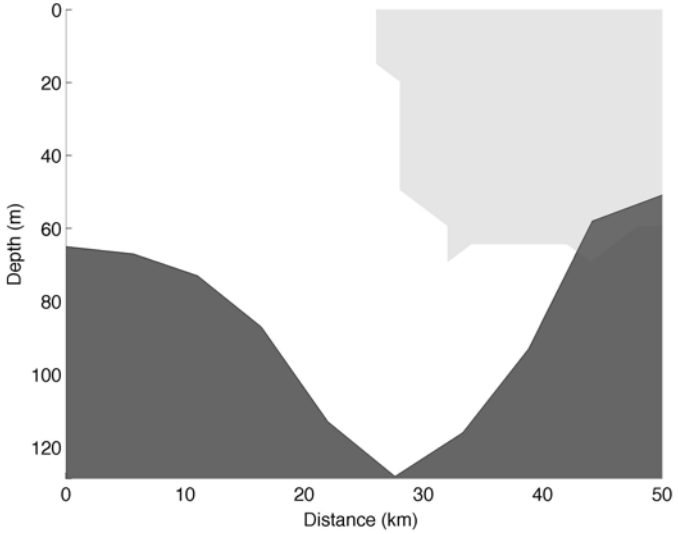
August



September

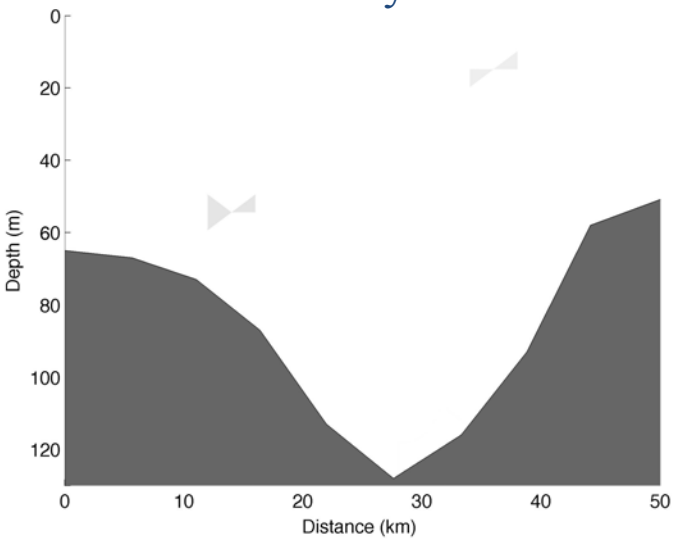


October

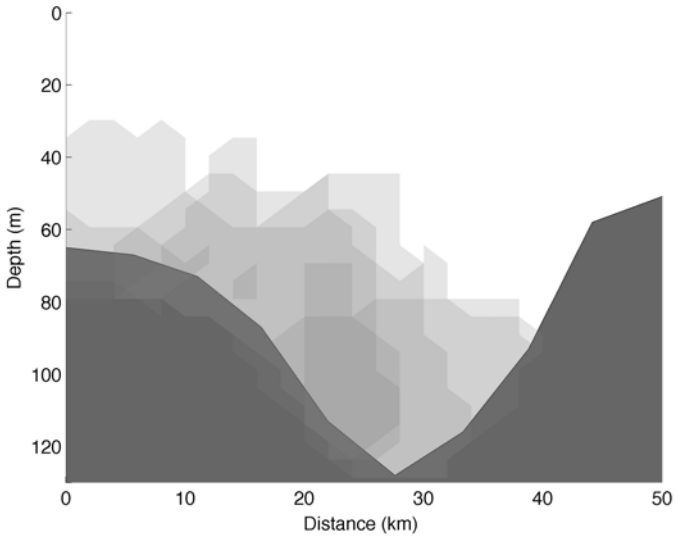


Winter Water (WW)

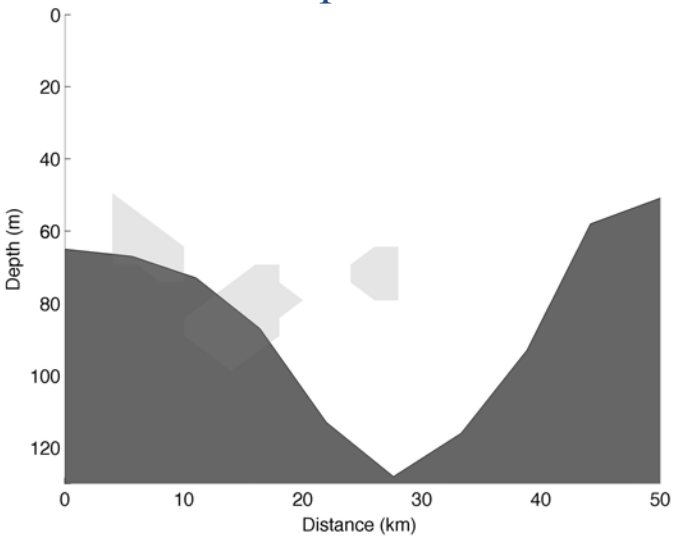
July



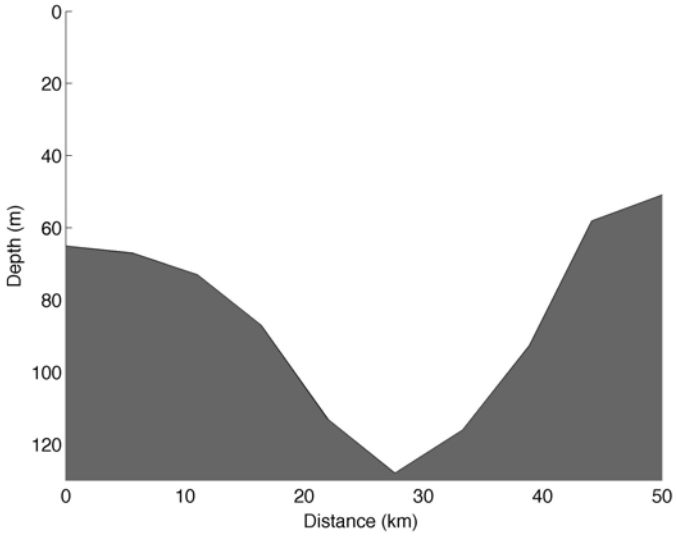
August



September

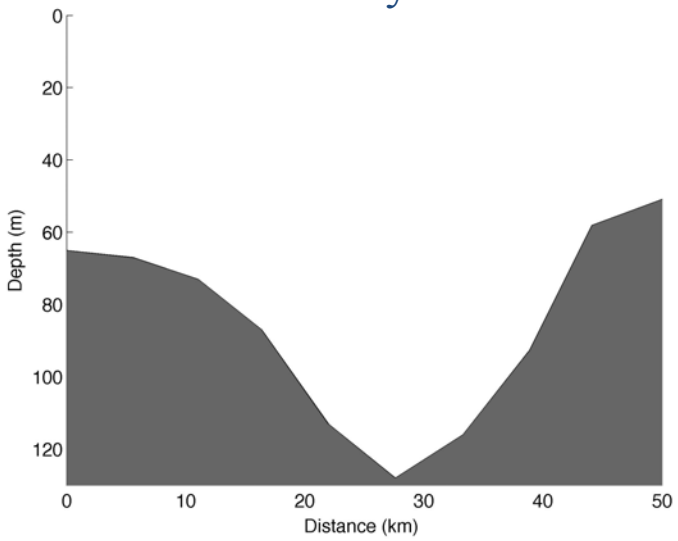


October

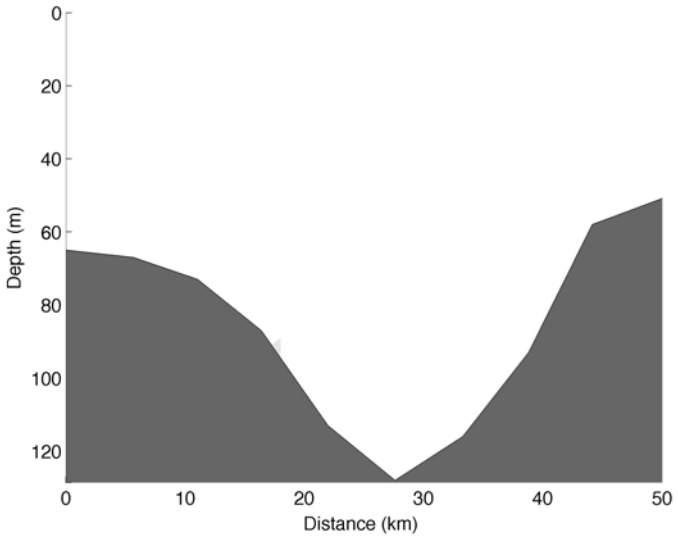


Atlantic Water (AW)

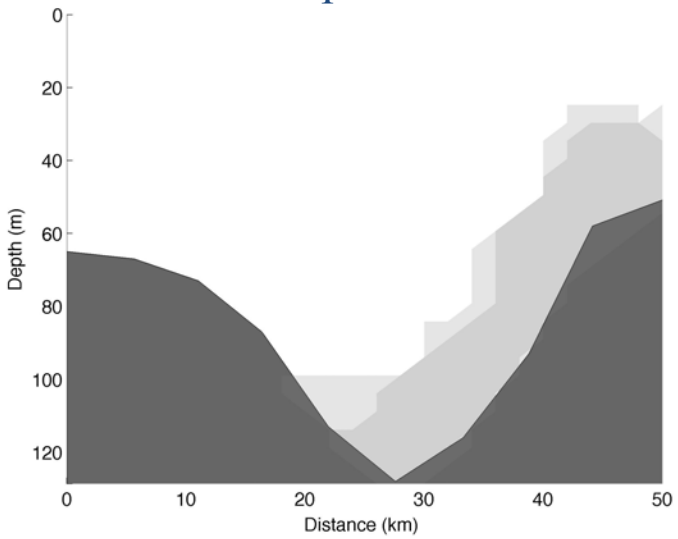
July



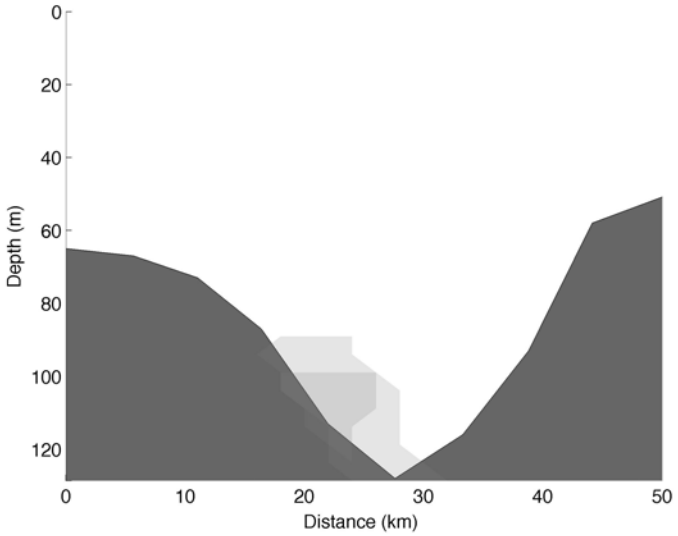
August



September



October



Going Forward

- Continued water mass analysis
- Investigate ventilation in the interior basin
- Further quantify upwelling events
- Explore nature of the interannual variability