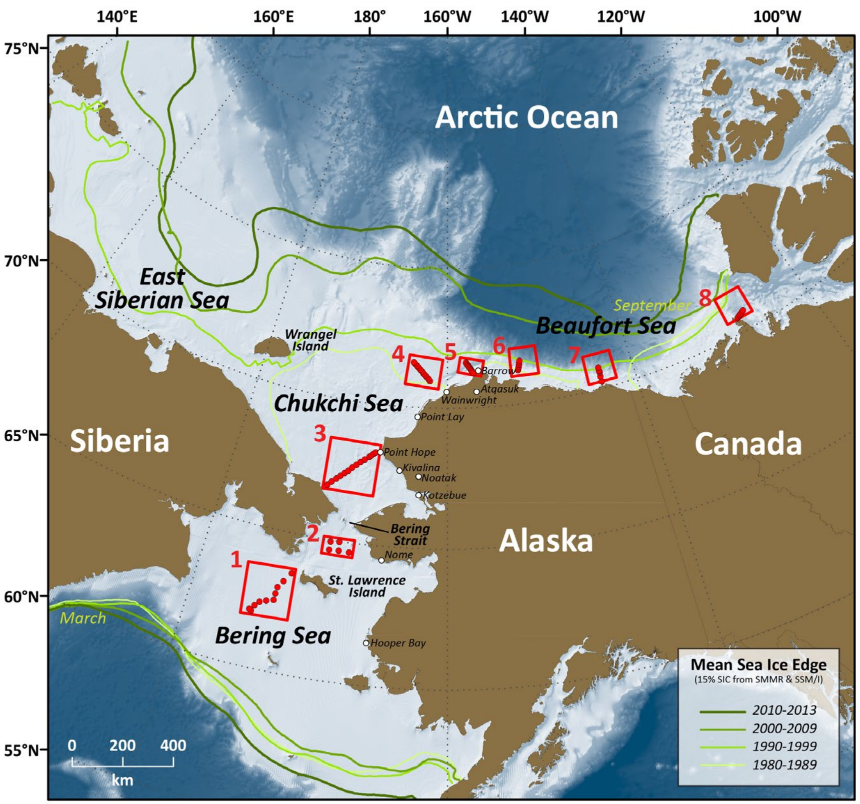
Linking Physics to Biology: the Distributed Biological Observatory (DBO)



[modified by Karen Frey from Grebmeier et al. 2010, EOS 91]

➢ **Lee Cooper Sampling and Analytical Tasks on Sir Wilfrid Laurier**

- Sediment and Water Column Chlorophyll,
- Nutrients, DOC (with Karen Frey)
- Seafloor video*
- Sediment Grain Size, TOC, C/N ratios and δ^{13}C and δ^{15}N of organic fractions
- Stable isotopes of oxygen

*Short edited segments from each DBO station are available on youtube.com. Search term "distributed biological observatory"

Full digital files for each DBO station are accessible for 2016-2019 on a Google drive, Freshwater flow through Bering Strait ~2300 km^3 (2001) to ~3500 km^3 (2014) (Based upon deep Atlantic salinity of 34.8)

) 124–154

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Increases in the Pacific inflow to the Arctic from 1990 to 2015, and insights into seasonal trends and driving mechanisms from year-round Bering Strait mooring data

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ABSTRACT

Year-round *in situ* Bering Strait mooring data (1990–2015) document a long-term increase (~0.01 Sv/yr) in the annual mean transport of Pacific waters into the Arctic. Between 2002 and 2015, all annual mean transports (except 2005 and 2012) are greater than the previously accepted climatology (~0.8 Sv). The record-length maximum (2014: 1.2 ± 0.1 Sv) is 70% higher than the record-length minimum (2001: 0.7 ± 0.1 Sv), corresponding to a reduction in the flushing time of the Chukchi Sea (to ~4.5 months from ~7.5 months). The transport increase results from stronger northward flows (not fewer southward flow events), yielding a 150% increase in kinetic energy, presumably with impacts on bottom suspension, mixing, and erosion. Curiously, we find no significant trends in annual mean flow in the Alaskan Coastal Current (ACC), although note that these data are only available 2002–2015.

Record-length trends in annually integrated heat and freshwater fluxes (primarily driven by volume flux trends) are large (0.06 ± 0.05 × 10^{20} J/yr; 30 ± 20 km^3/yr; relative to −1.9 °C and 34.8 psu), with heat flux lows in 2001 and 2012 (~3 × 10^{20} J) and highs in 2007 and 2015 (~5.5 × 10^{20} J), and a freshwater range of ~2300 km^3 (2001) to ~3500 km^3 (2014). High-flow year 2015 (volume transport ~1.1 Sv) has the highest annual mean temperature recorded, ~0.7 °C, astoundingly warmer than the record-length mean of 0.0 ± 0.2 °C, while low-flow year 2012 (~0.8 Sv) is also remarkably cold (~ −0.6 °C), likely due to anomalously weak northward flow in January–March, partly driven by anomalously strong southward winds in March.

A seasonal decomposition of properties of the main flow shows significant freshening in winter (~0.03 psu/yr, January–March) likely due to sea-ice changes, but no trend (or perhaps salinization) in the rest of the year. A seasonal warming trend in the strait proper in May and June (~0.04 °C/yr) is reflected in a trend to earlier arrival (0.9 ± 0.8 days/yr) of waters warmer than 0 °C. Contrastingly, no significant trend is found in the time of cooling of the strait. The strait's seasonal increasing transport trends (~0.02 Sv/yr) are largest from May–November, likely due to the large wind-driven variability masking the signal in other months.

We show that Ekman set-up of waters along the coast in the strait can explain the strong correlation of the water velocity with along-strait winds (as opposed to across-strait winds). We highlight the strong seasonality of this relationship (r ~ 0.8 in winter, but only ~0.4 in summer), which reflects the weak influence of the (seasonally weak) winds in summer. By separating the flow into portions driven by (a) the local wind and (b) a far-field (Pacific-Arctic "pressure-head") forcing, we find the increase in the Bering Strait throughflow is primarily due to a strong increase in the far-field forcing, not changes in the wind. We propose a higher annual mean transport for the strait for the 2000s, (1.0 ± 0.05 Sv) based on recent flow increases, and present estimated seasonal climatologies for properties and fluxes for the strait and for the ACC. Heat and freshwater seasonalities are strongly influenced by the ACC and stratification.

Finally we conclude that year-round *in situ* mooring are still the only currently viable way of obtaining accurate quantifications of the properties of the Pacific input to the Arctic.

1. Introduction to the Bering Strait throughflow

The flow through the Bering Strait is the only oceanic input from the Pacific to the Arctic Ocean. In addition to driving most of the oceanic properties in the Chukchi Sea (Woodgate et al., 2005a), the Bering Strait throughflow, although comparatively small in volume (~0.8 Sv,

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Woodgate (2018) Progress in Oceanography 160: 124–154

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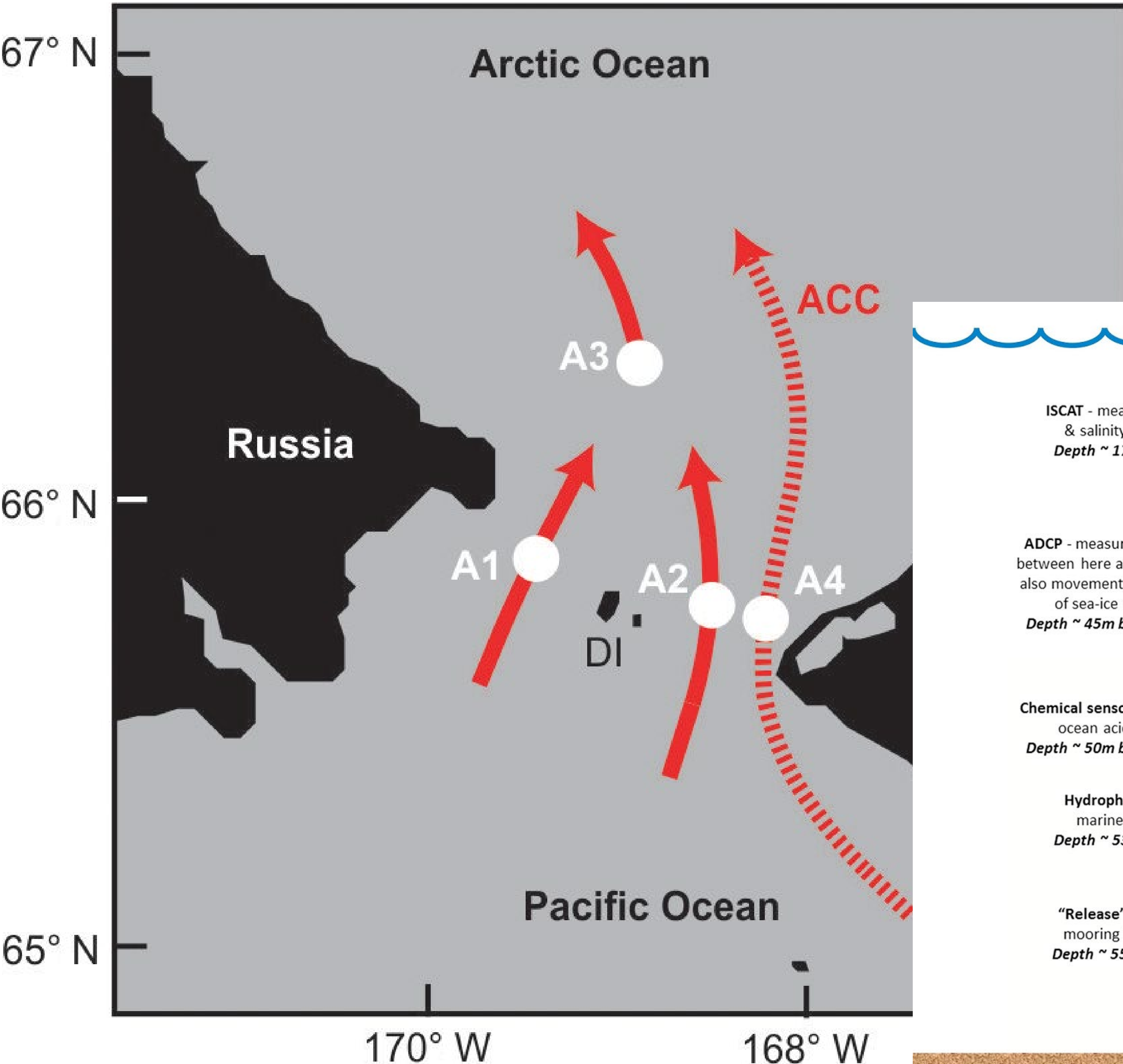
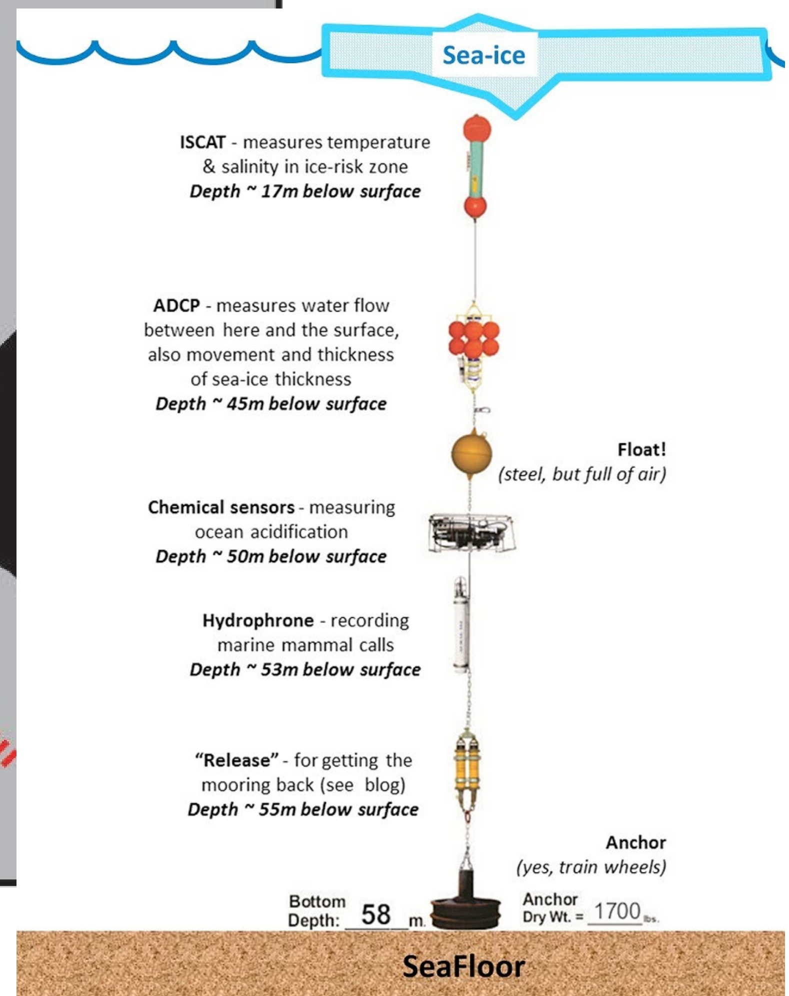
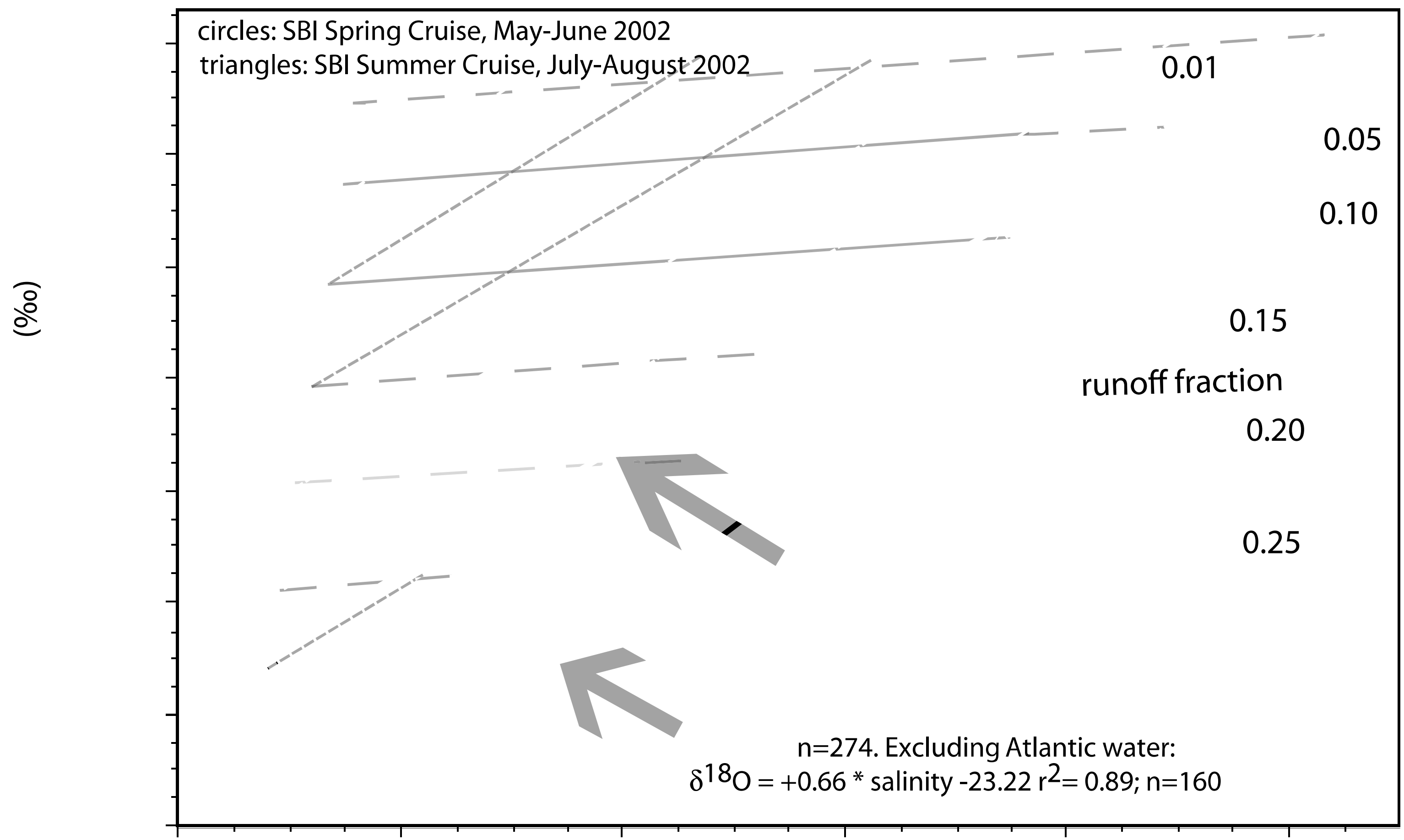
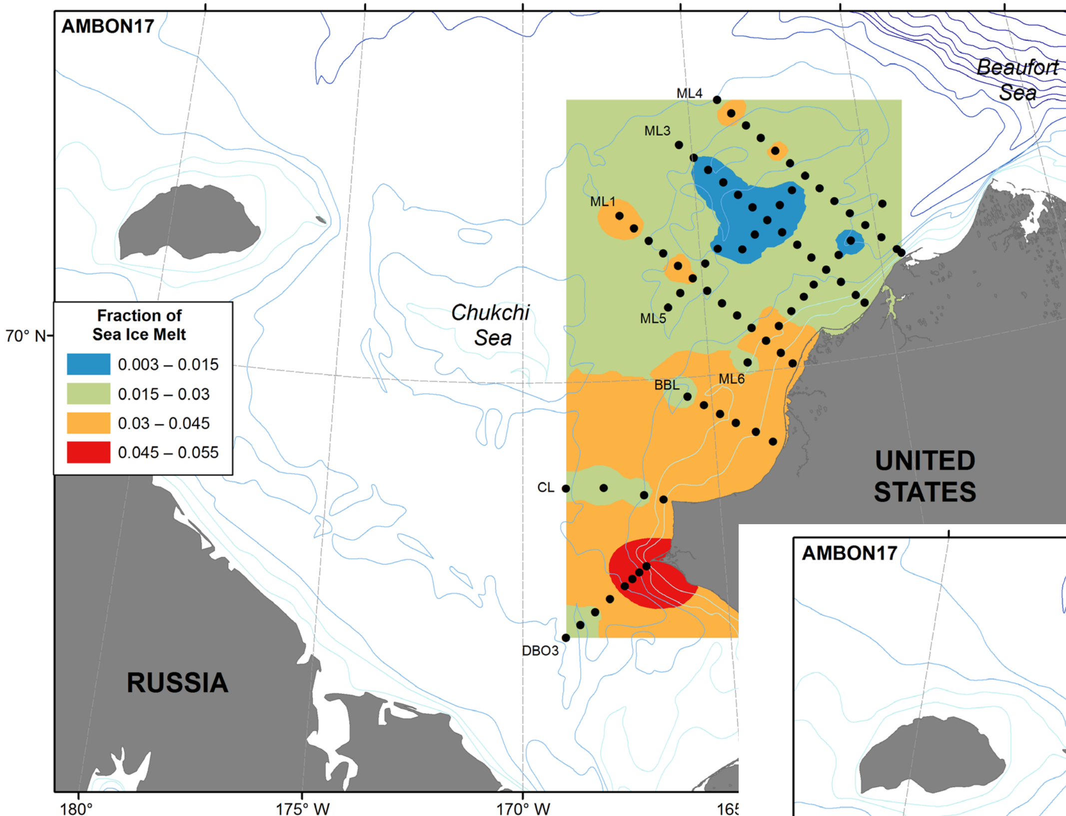




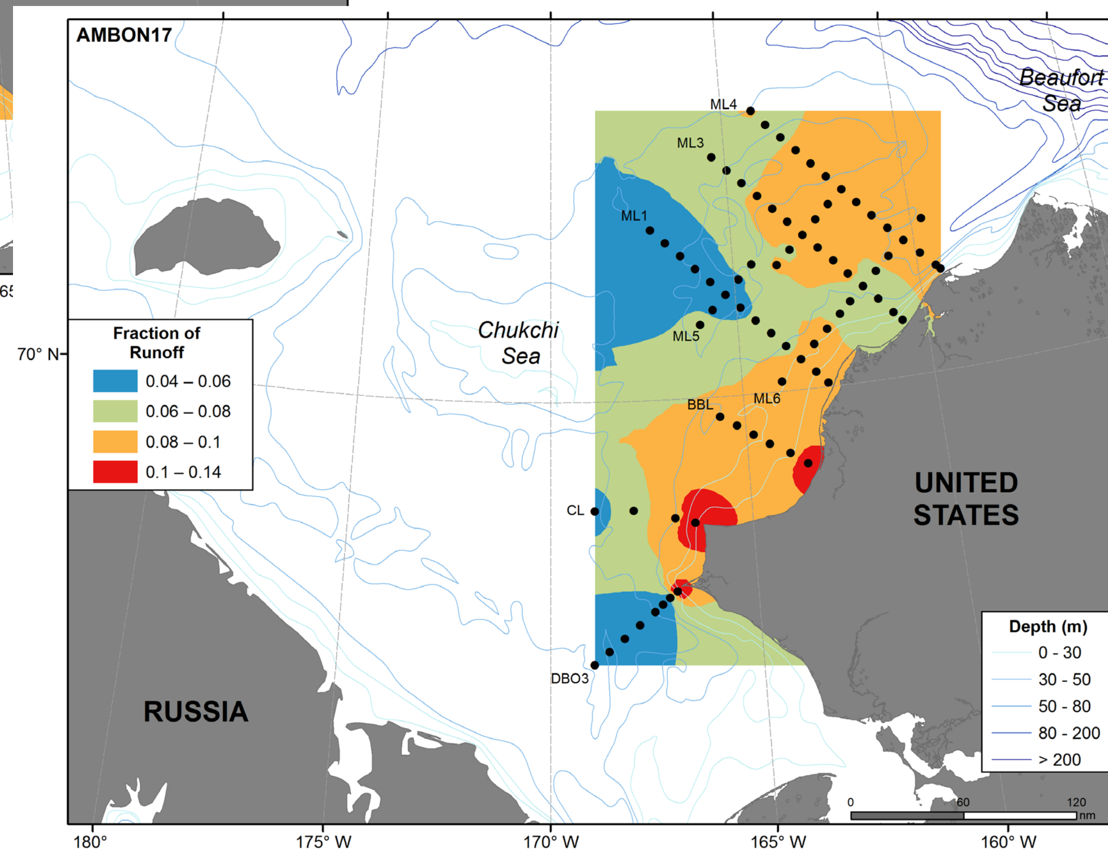
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 110, G02013, doi:10.1029/2005JG000031, 2005





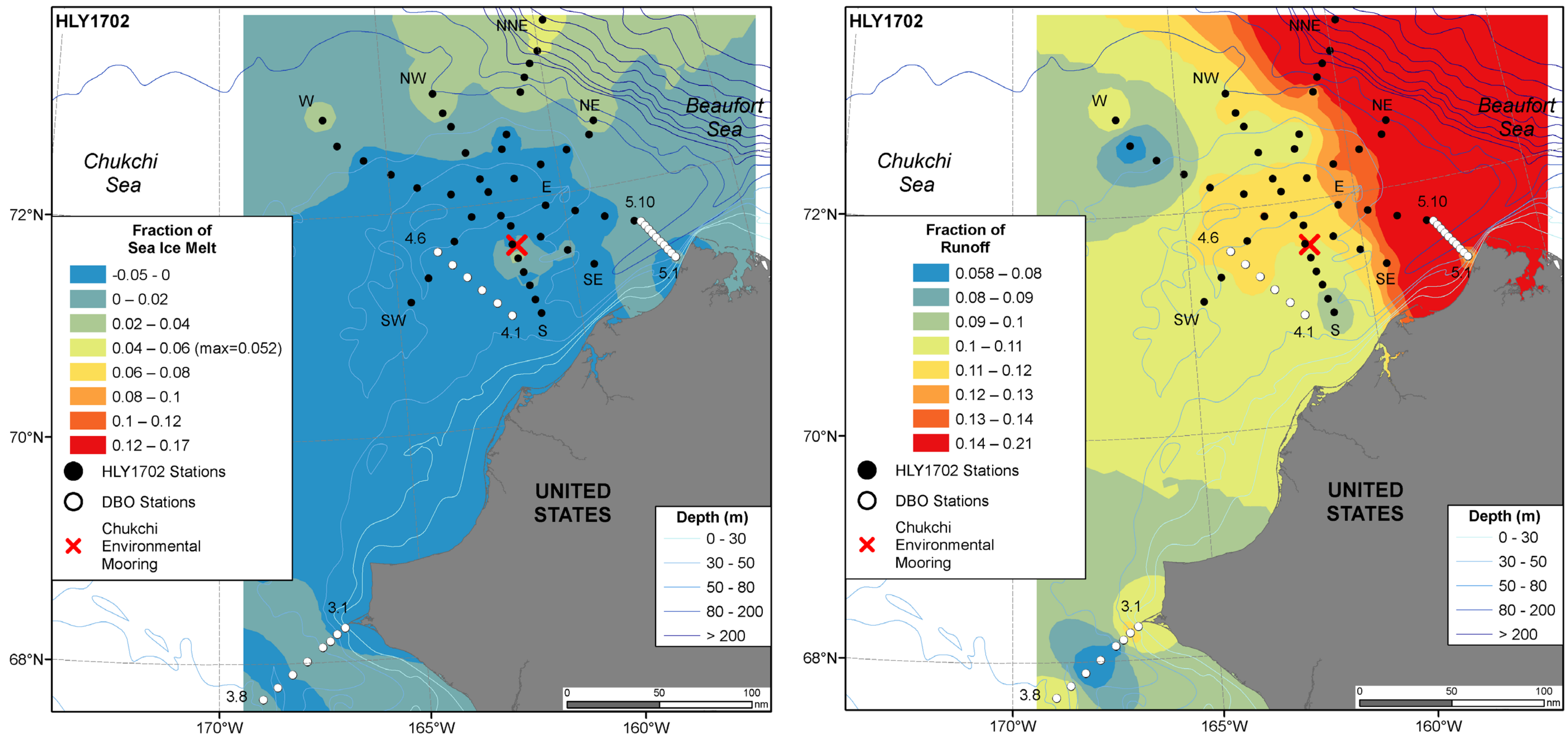
Melted sea ice <1% to 5.5% of surface water

Runoff (up to 14% of surface water)



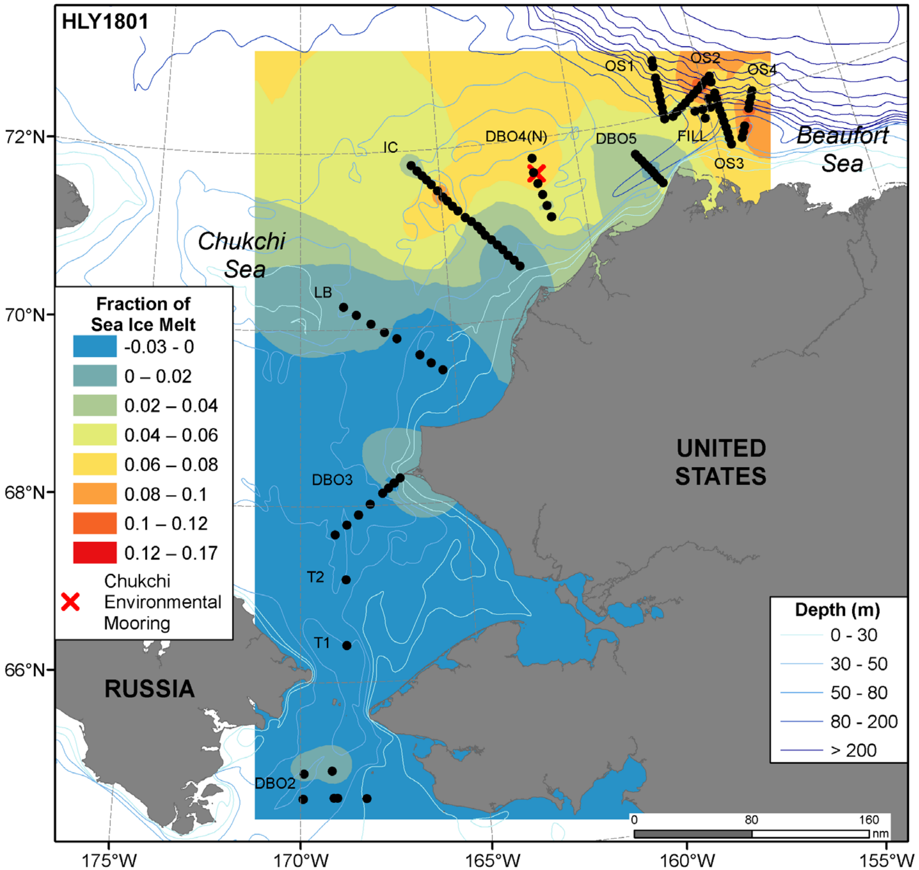
Cooper, unpublished

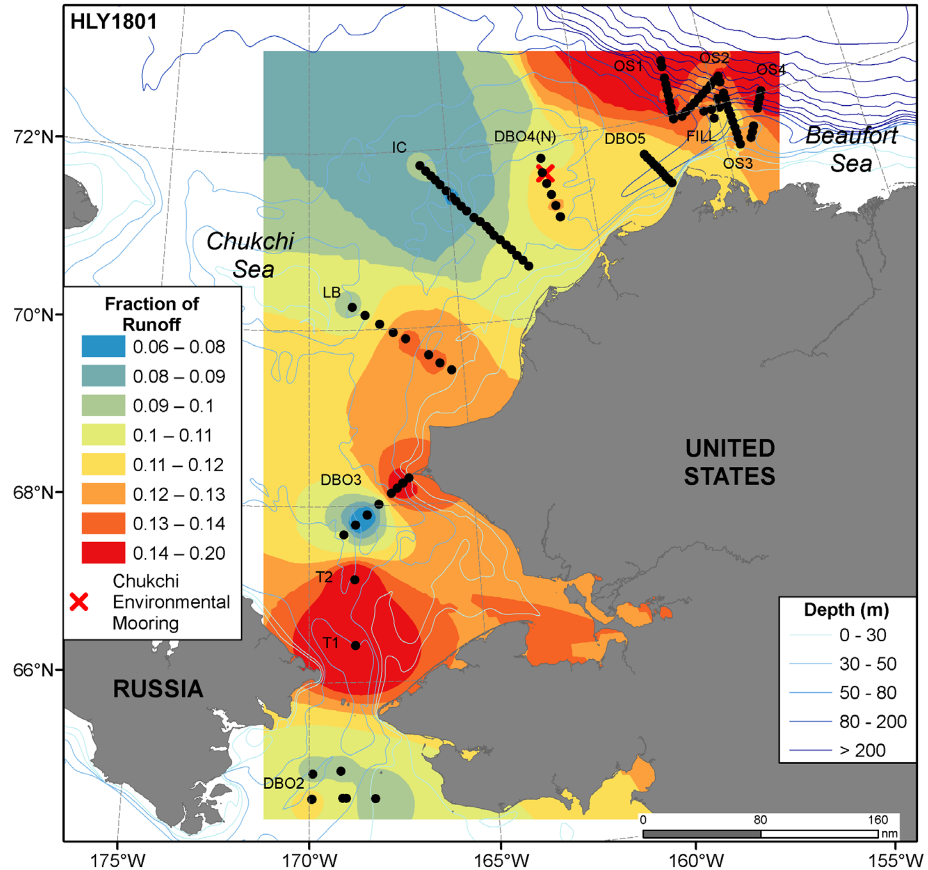
Fractions of melted sea ice and runoff in surface waters (Low ice year – 2017)



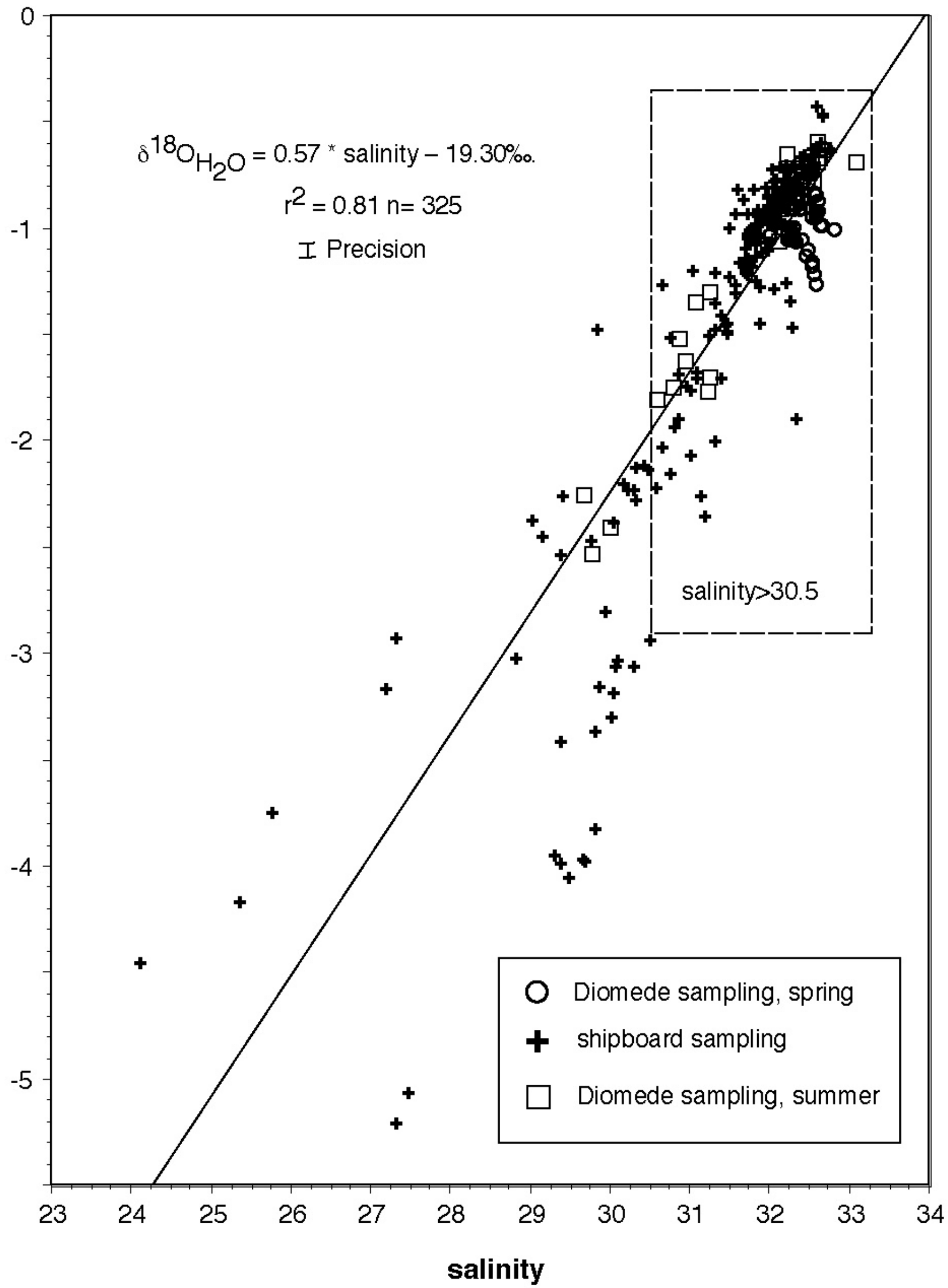
Cooper, unpublished

Fractions of melted sea ice and runoff in surface waters (2018)





Cooper, unpublished



Freshwater end-member in Bering Strait $\delta^{18}O$ = ~-19‰ (similar to Mackenzie River) Cooper et al. 1997 estimated -21.1‰ for Bering Continental Shelf Bottom water

🡐 Melted sea ice

🡒 Brine injection

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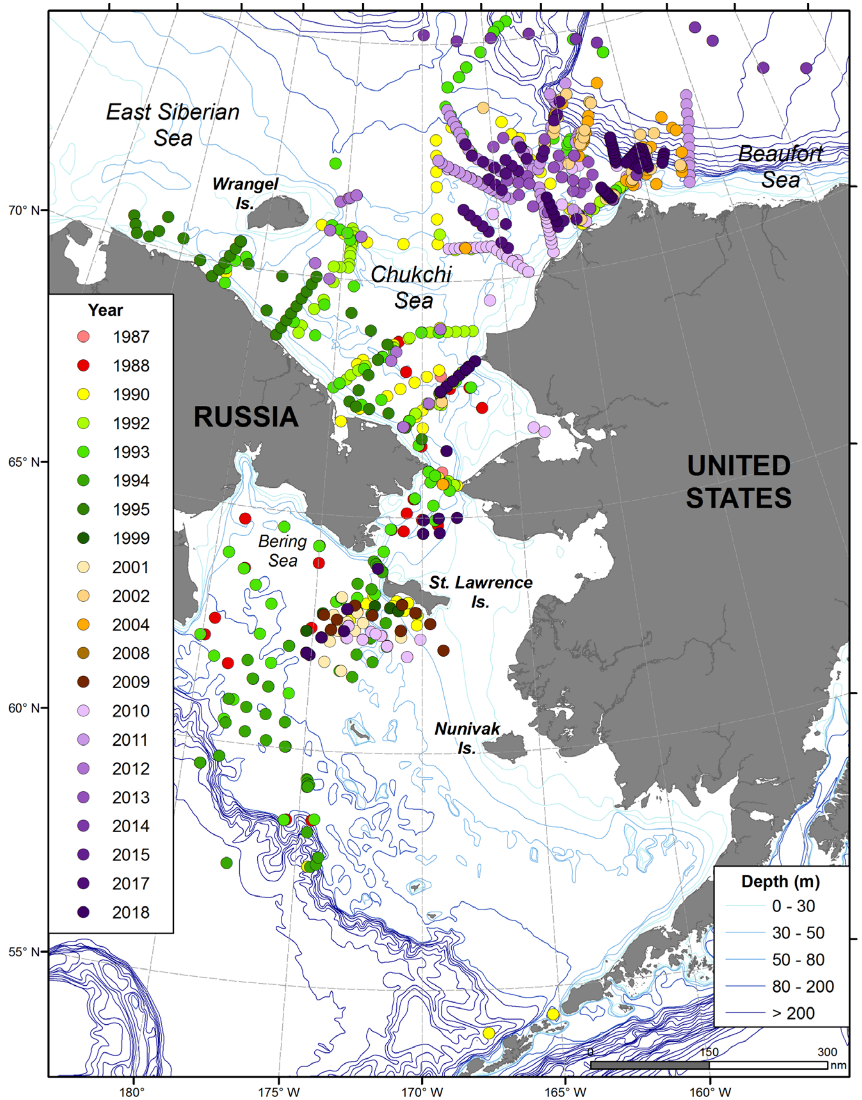
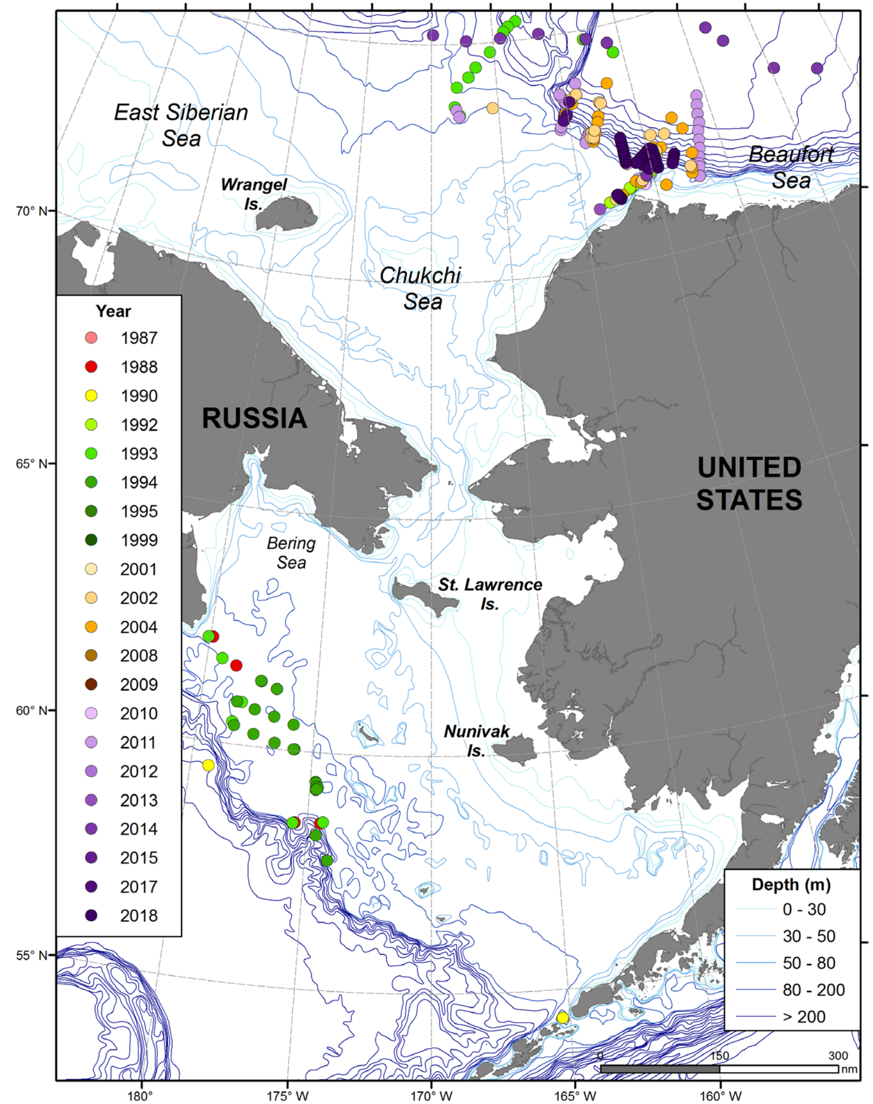
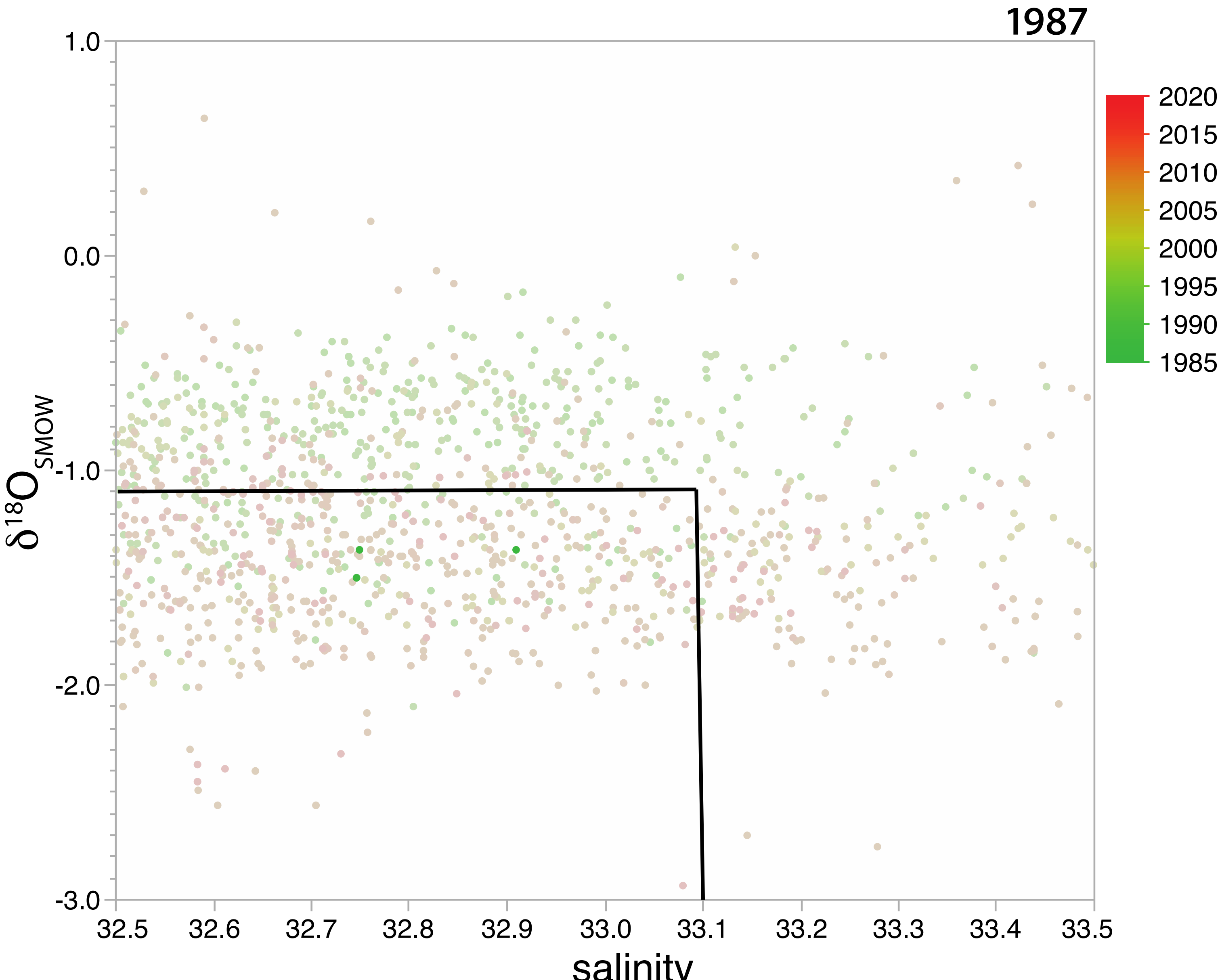
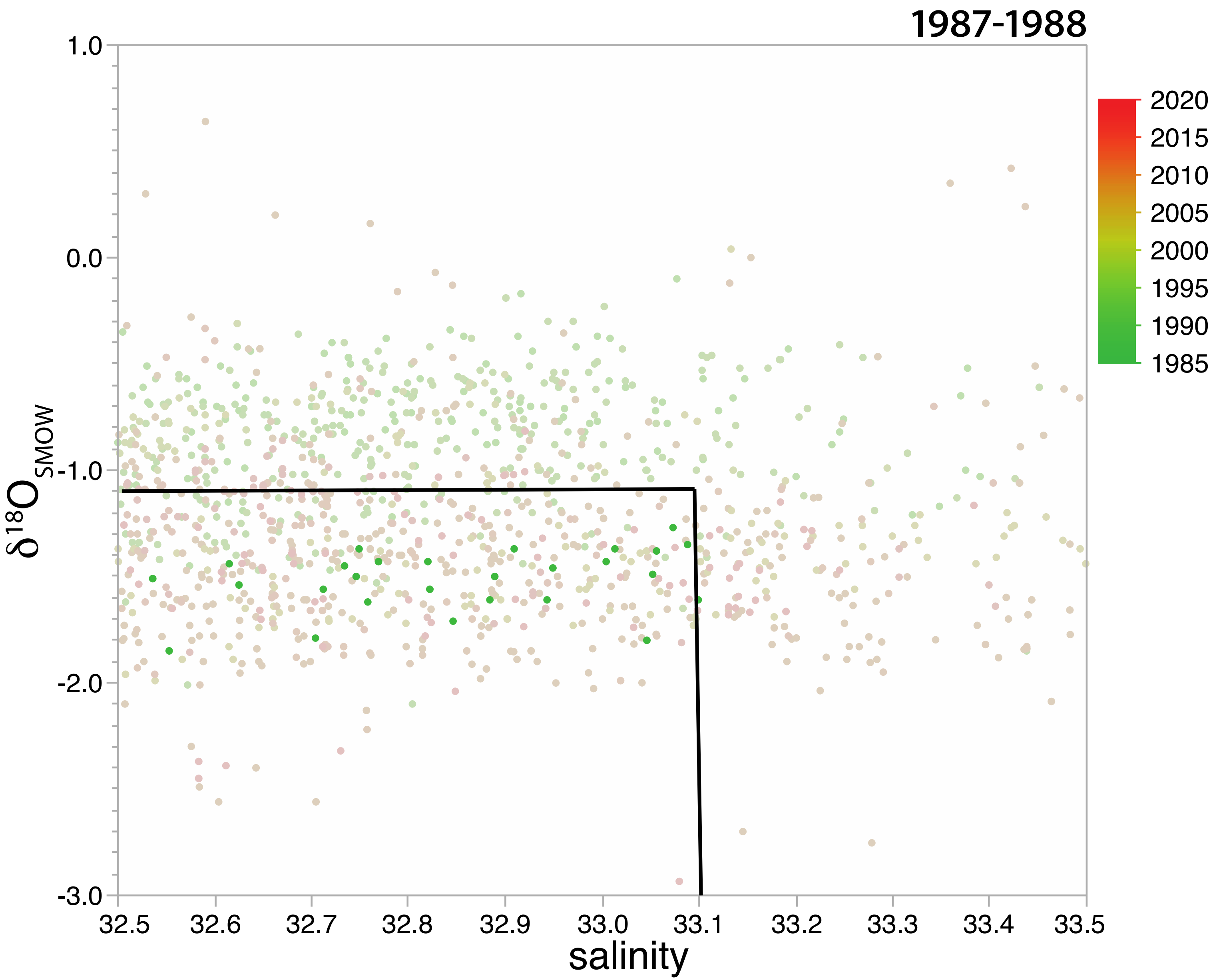
Salinity between 32.5 and 33.5



Depth >100 m

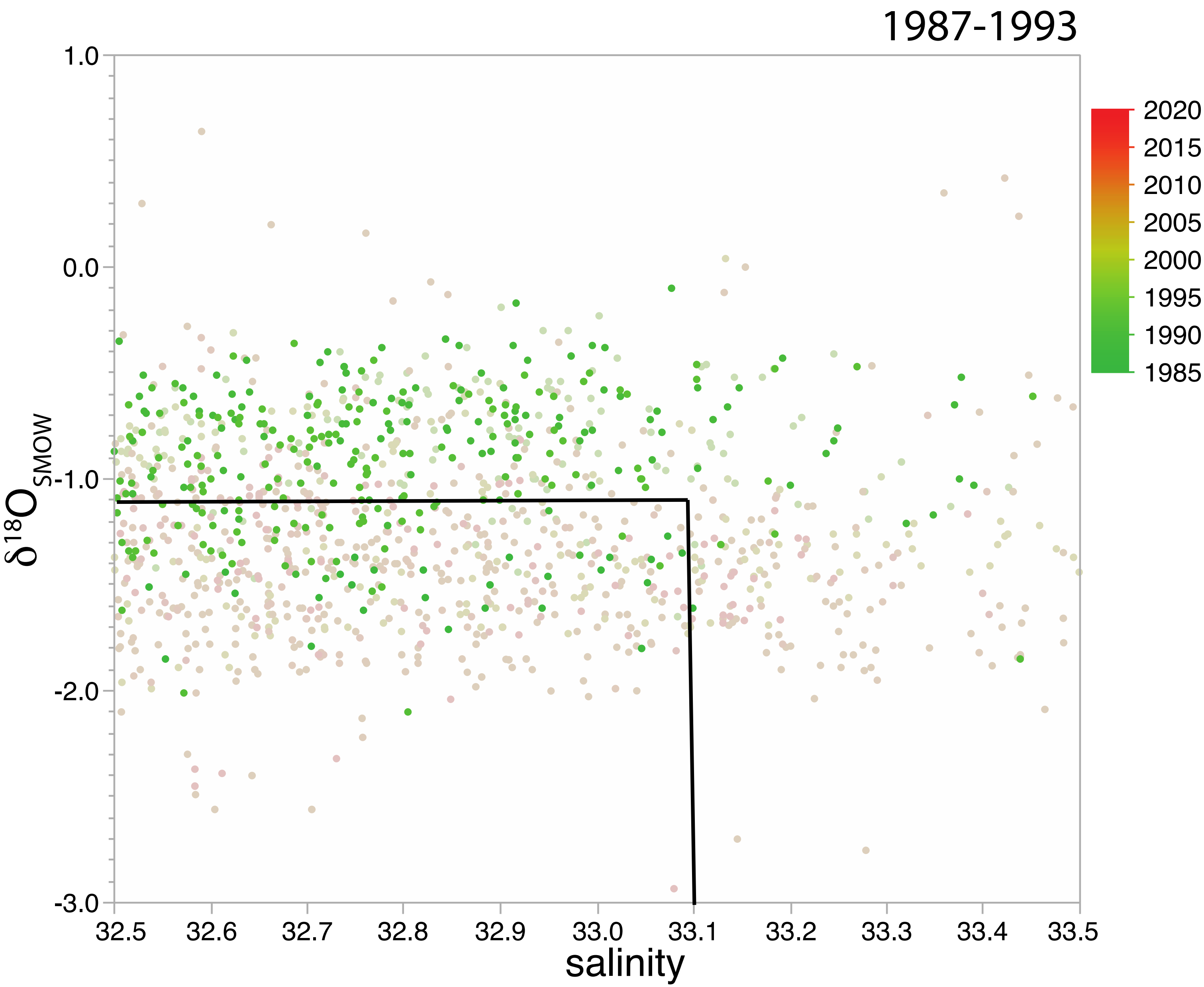



1987
1.0
0.0
-1.0
-2.0
-3.0
δ18O SMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985

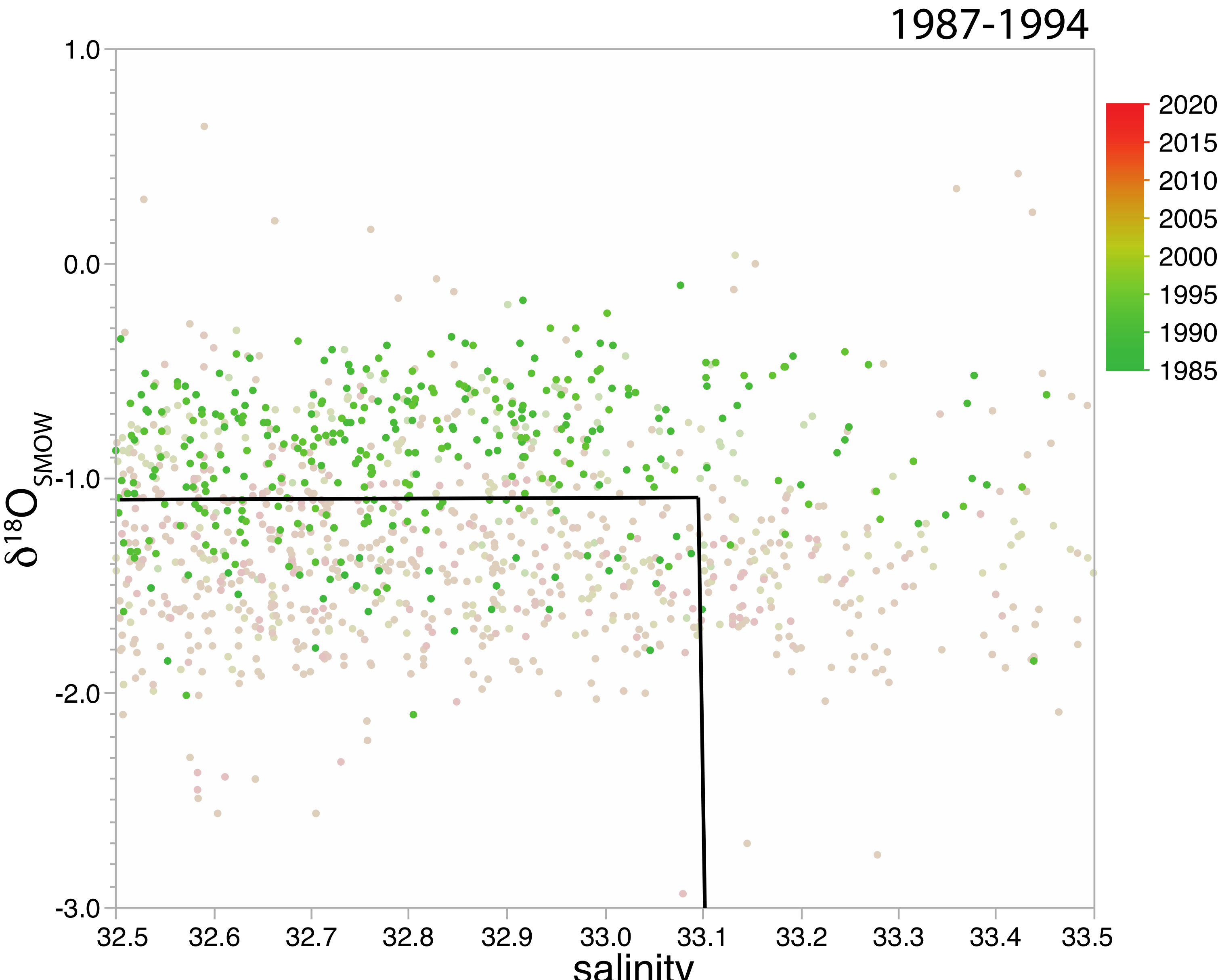

1987-1988
1.0
0.0
-1.0
-2.0
-3.0
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
δ18OSMOW
2020
2015
2010
2005
2000
1995
1990
1985

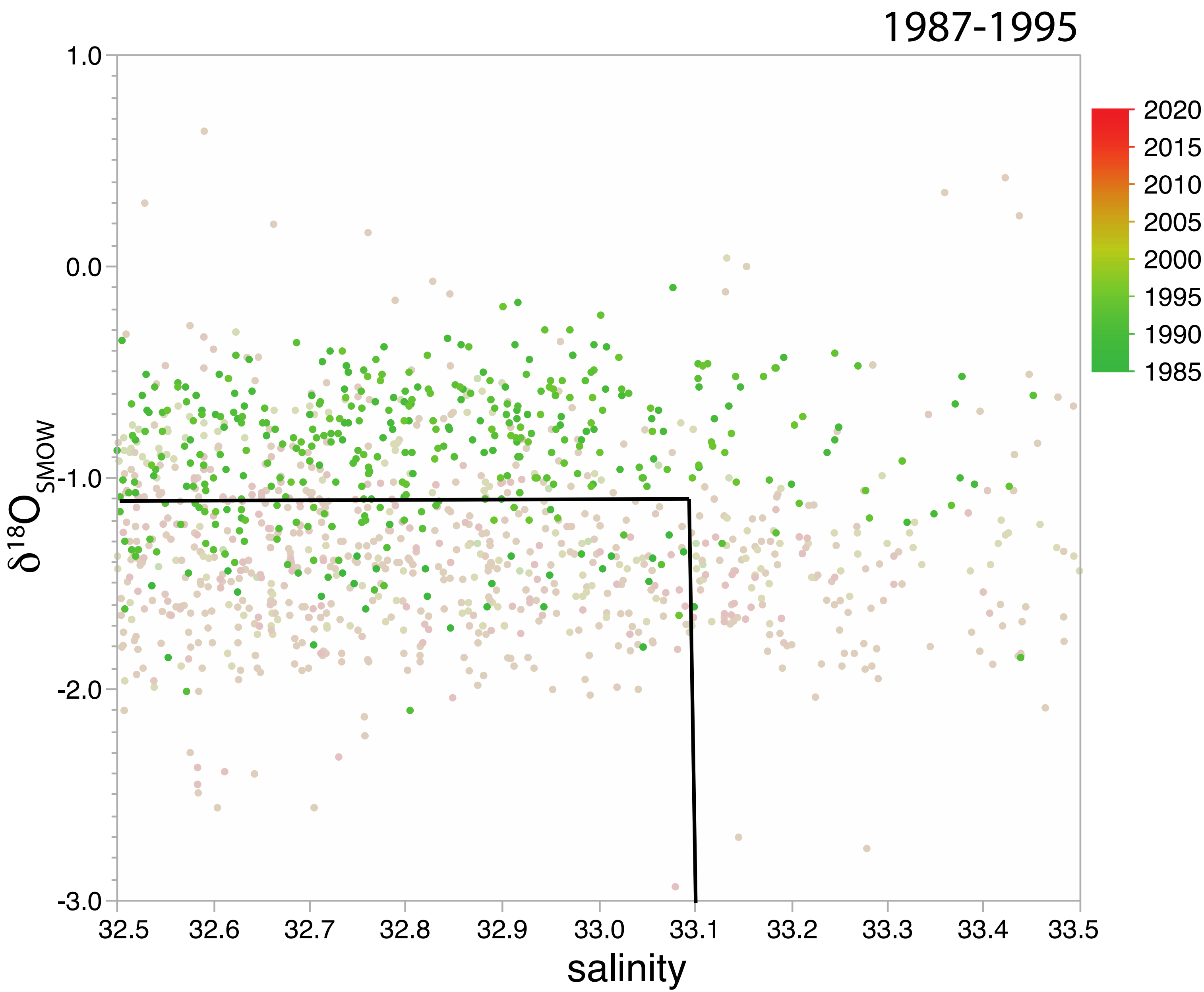
1987-1990
1.0
0.0
-1.0
-2.0
-3.0
δ18OSMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985


1987-1992
1.0
0.0
-1.0
-2.0
-3.0
δ18O SMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985

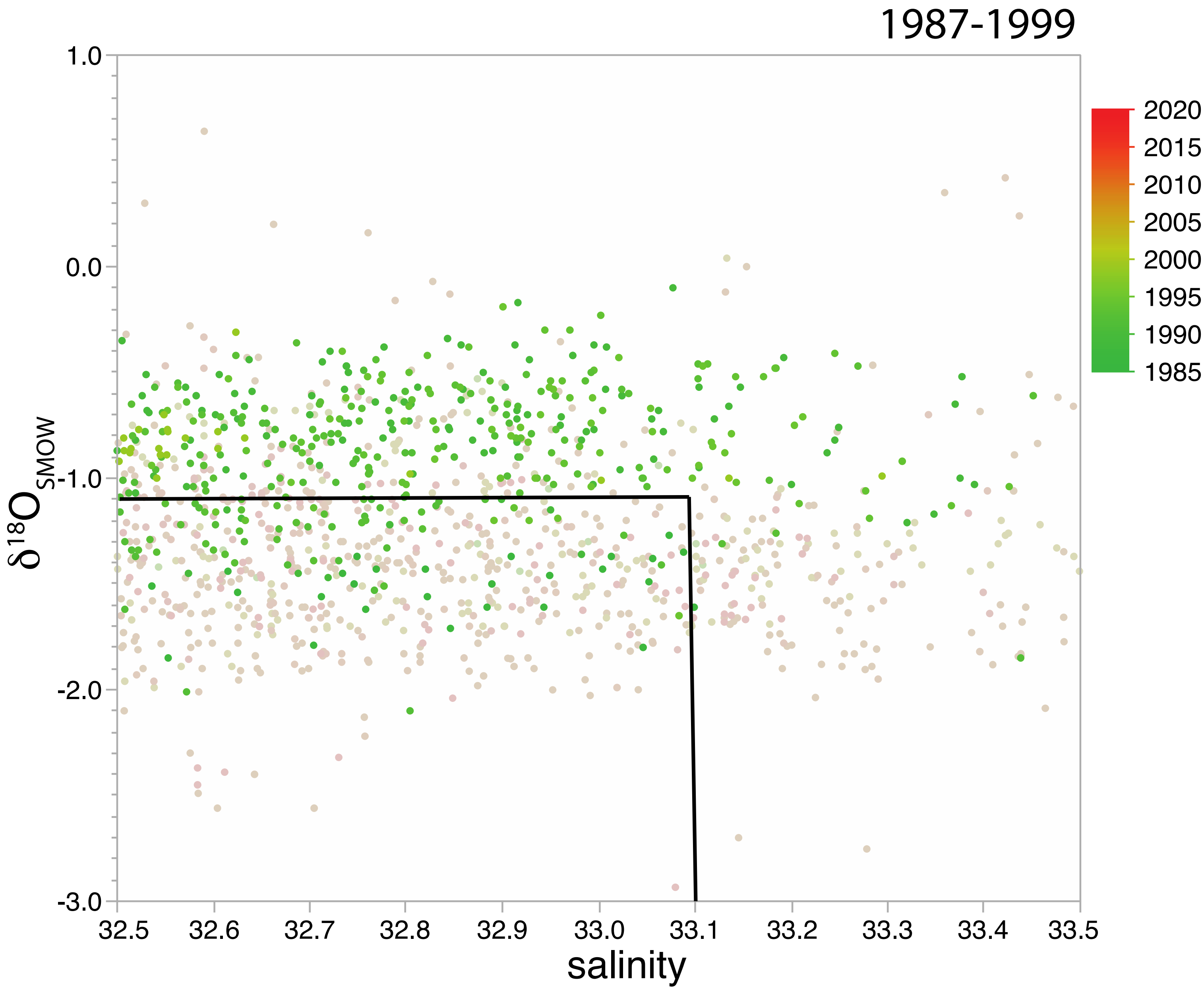


1987-1993
1.0
0.0
-1.0
-2.0
-3.0
$\delta^{18}O_{SMOW}$
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985


1987-1994
1.0
0.0
-1.0
-2.0
-3.0
δ18OSMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985



1987-1995
1.0
0.0
-1.0
-2.0
-3.0
δ18OSMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985



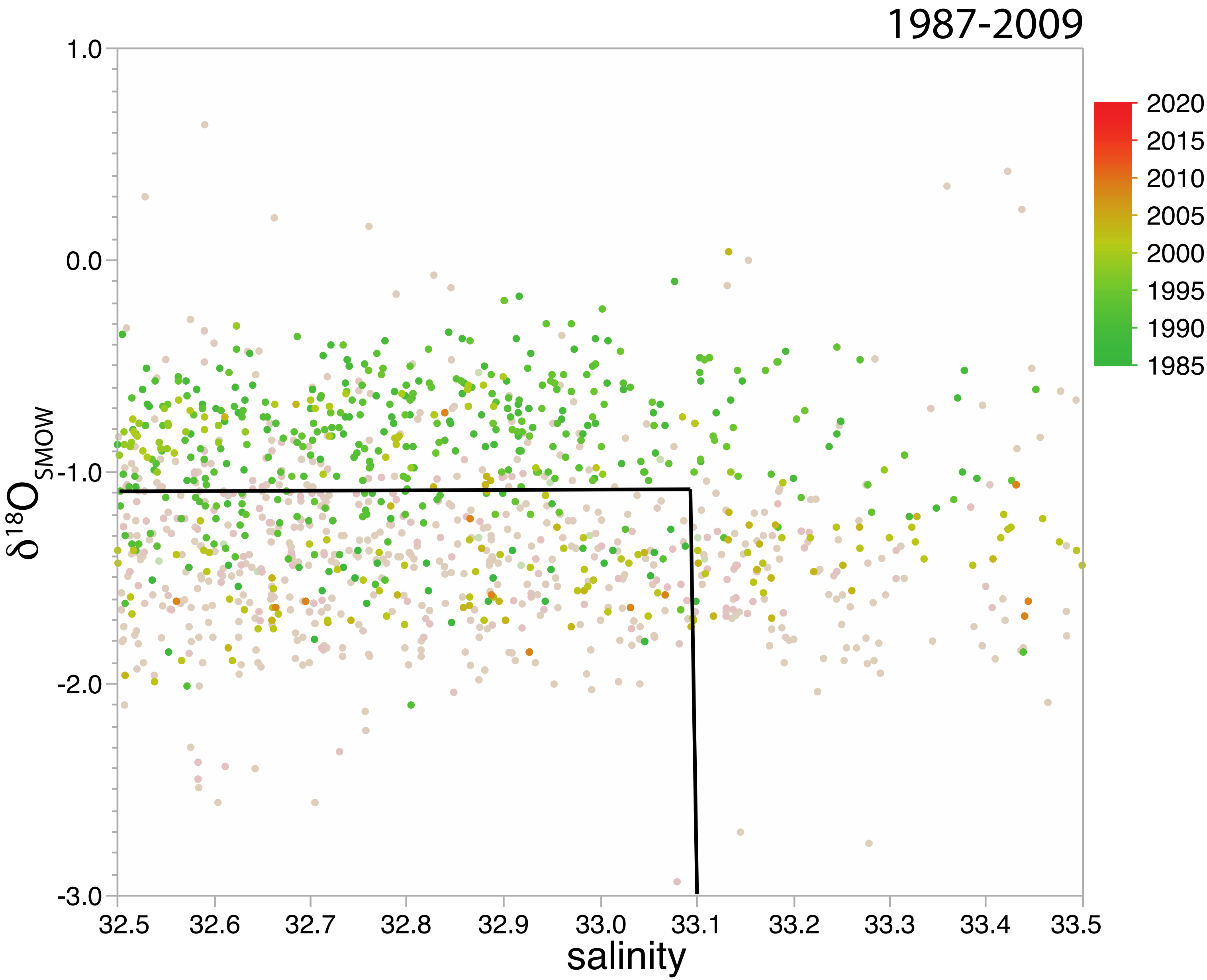
1987-1999
1.0
0.0
-1.0
-2.0
-3.0
δ18OSMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985


1987-2001
δ18OSMOW
salinity
1.0
0.0
-1.0
-2.0
-3.0
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
2020
2015
2010
2005
2000
1995
1990
1985

1987-2002
1.0
0.0
-1.0
-2.0
-3.0
$\delta^{18}O_{SMOW}$
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985

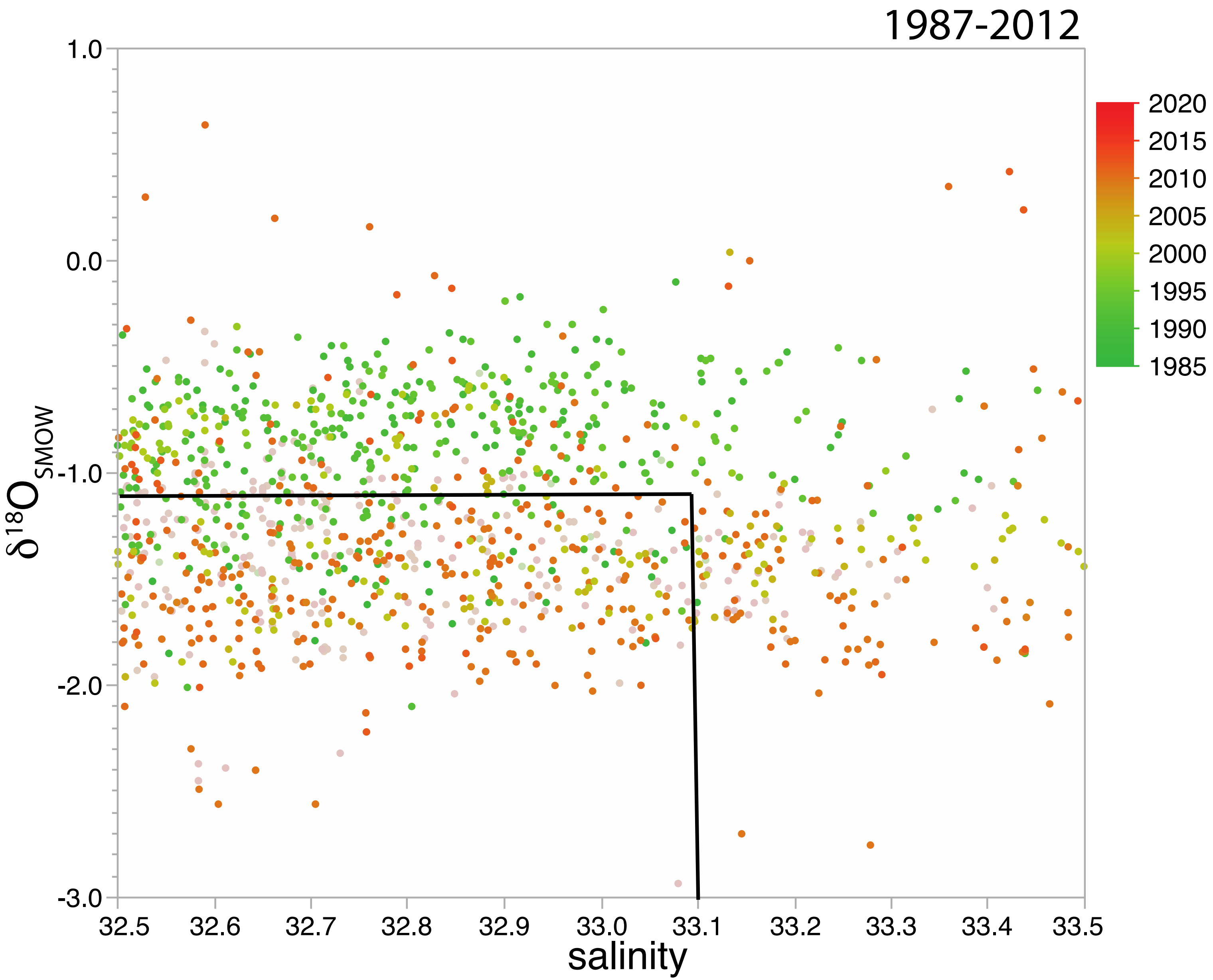

1987-2004
1.0
0.0
-1.0
-2.0
-3.0
δ18O SMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985

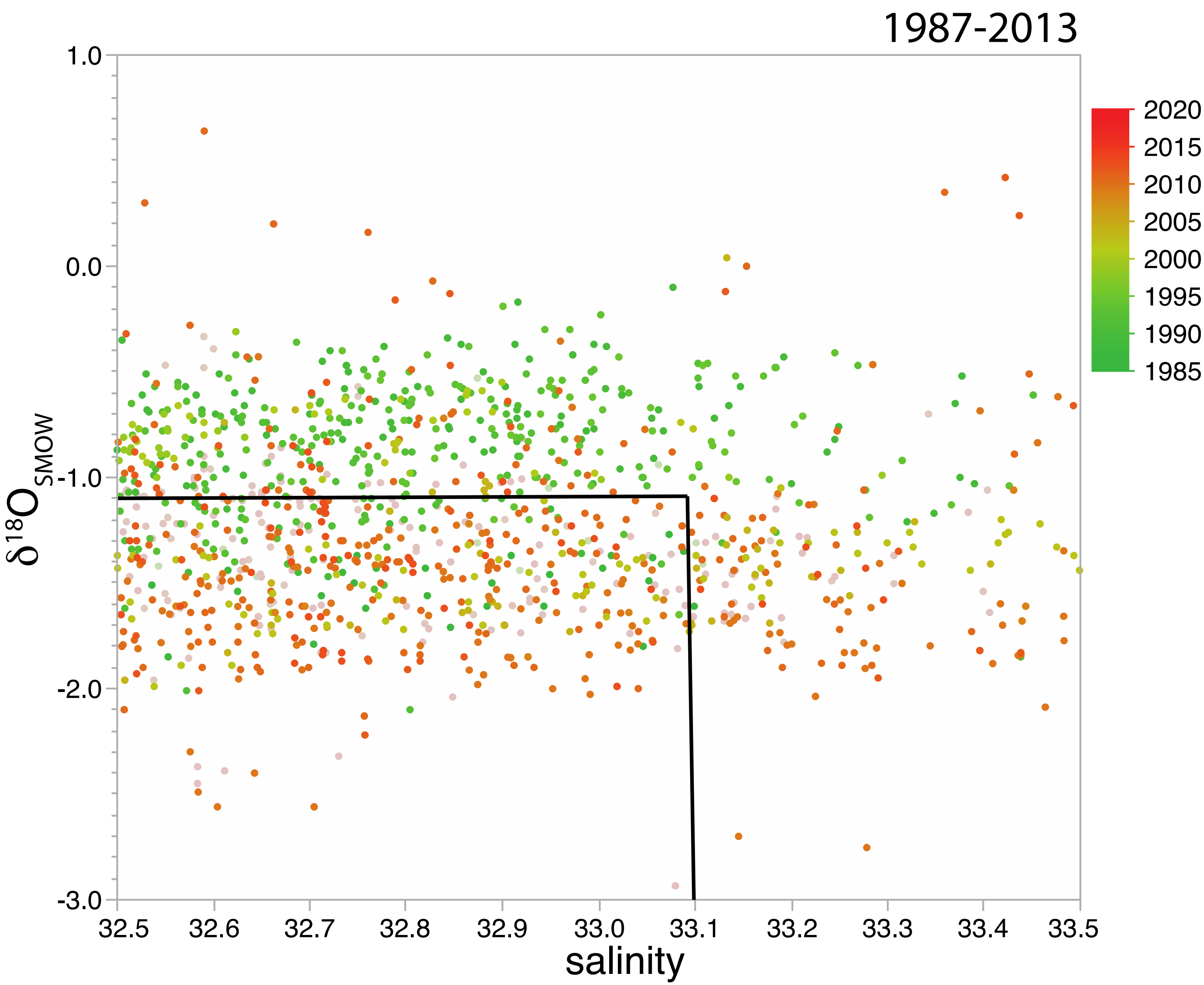
1987-2008
1.0
0.0
-1.0
-2.0
-3.0
δ18O SMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985


1987-2009
1.0
0.0
-1.0
-2.0
-3.0
$\delta^{18}O_{SMOW}$
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985


1987-2010
δ18O SMOW
salinity
1.0
0.0
-1.0
-2.0
-3.0
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
2020
2015
2010
2005
2000
1995
1990
1985

1987-2011
1.0
0.0
-1.0
-2.0
-3.0
δ¹⁸O SMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985


1987-2012
δ18O SMOW
salinity
1.0
0.0
-1.0
-2.0
-3.0
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
2020
2015
2010
2005
2000
1995
1990
1985


1987-2013
1.0
0.0
-1.0
-2.0
-3.0
$\delta^{18}O_{SMOW}$
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
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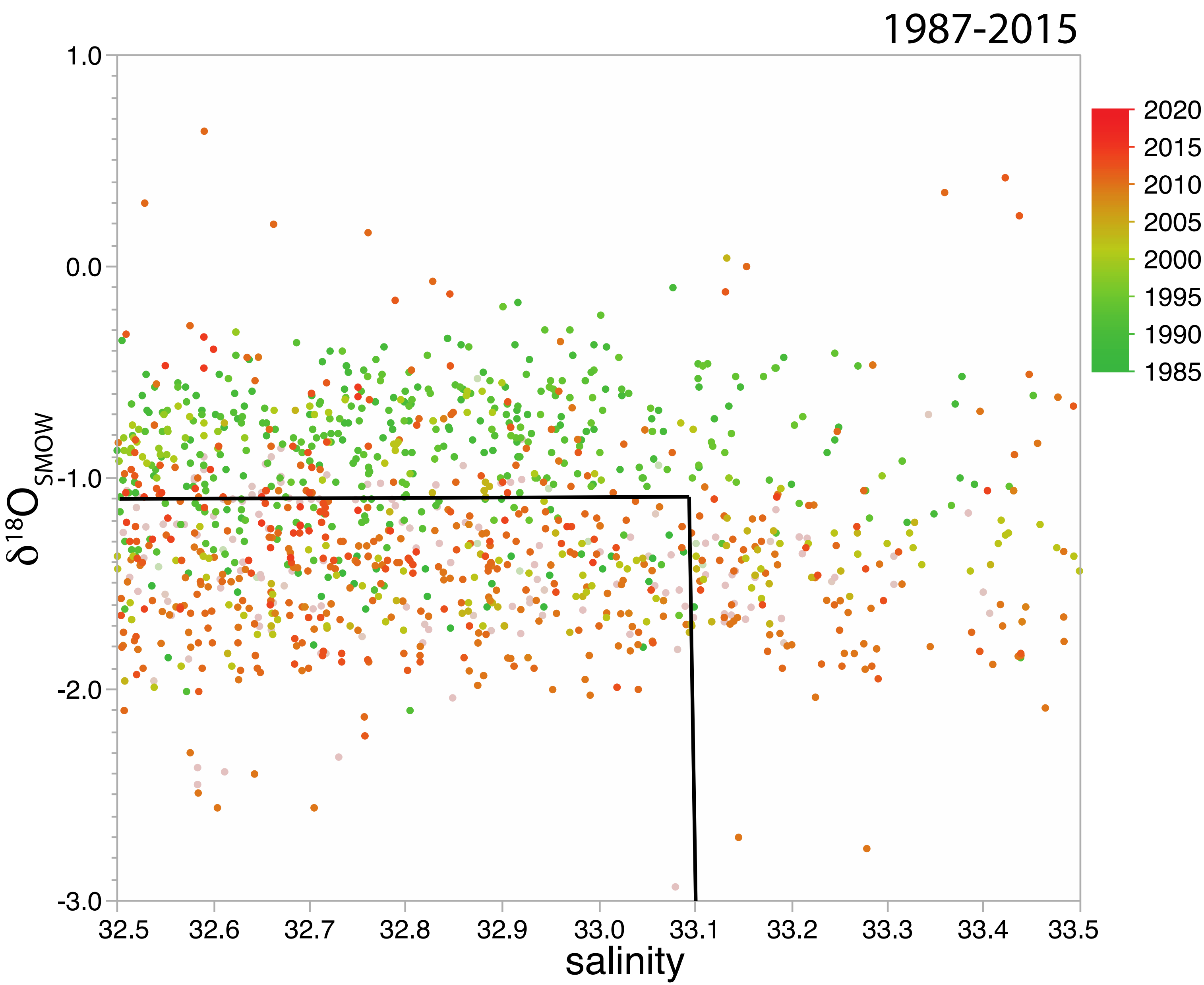
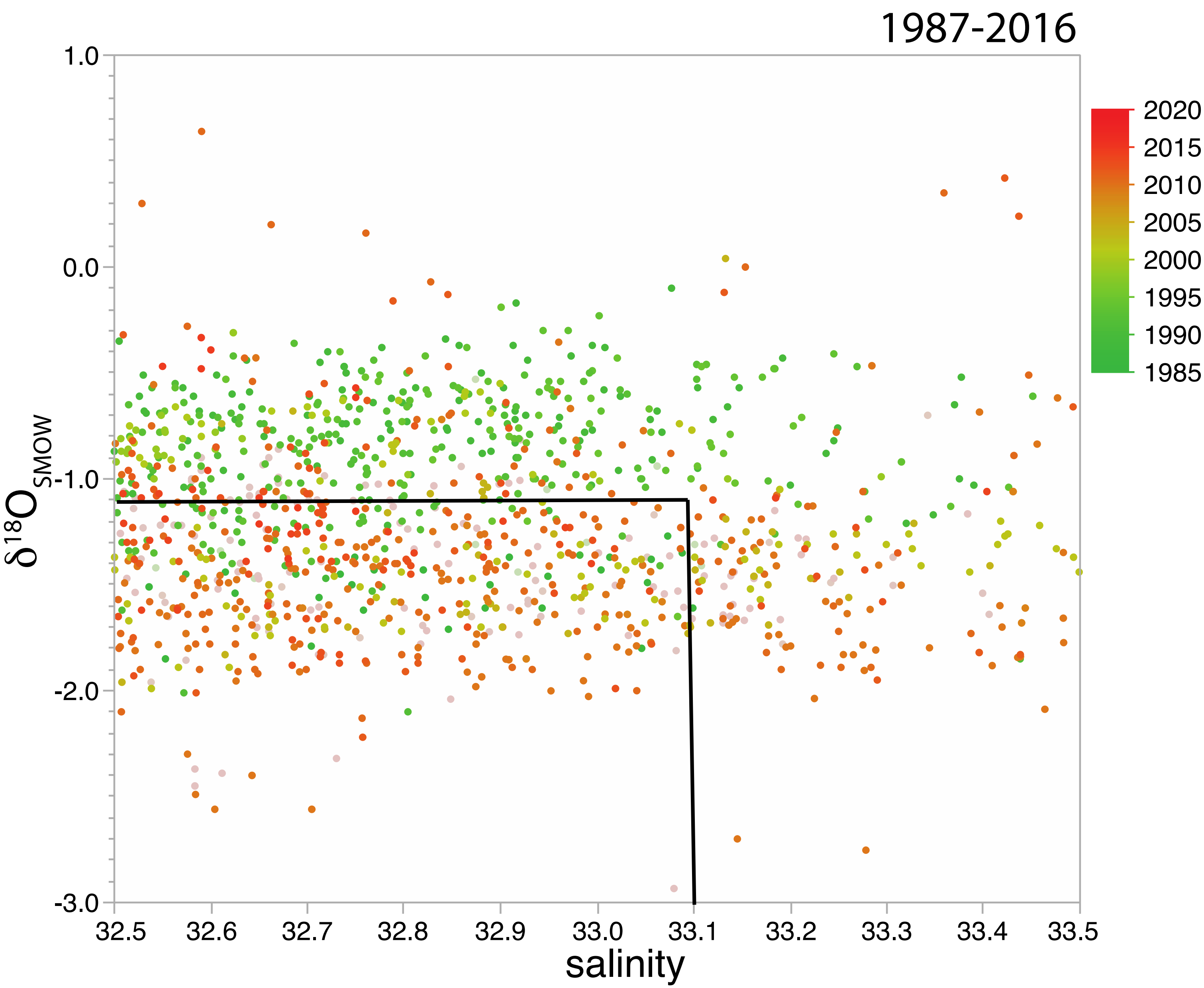
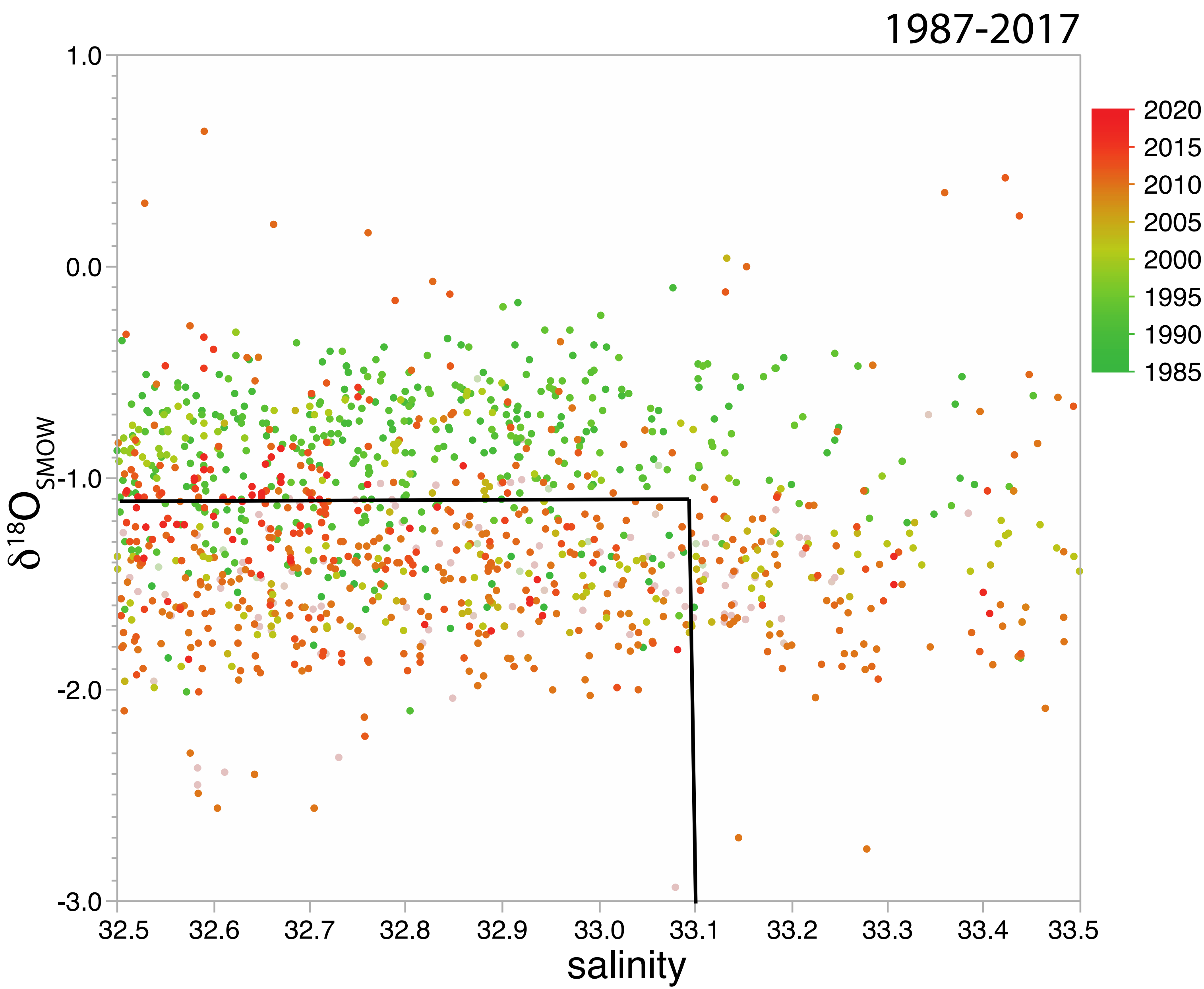
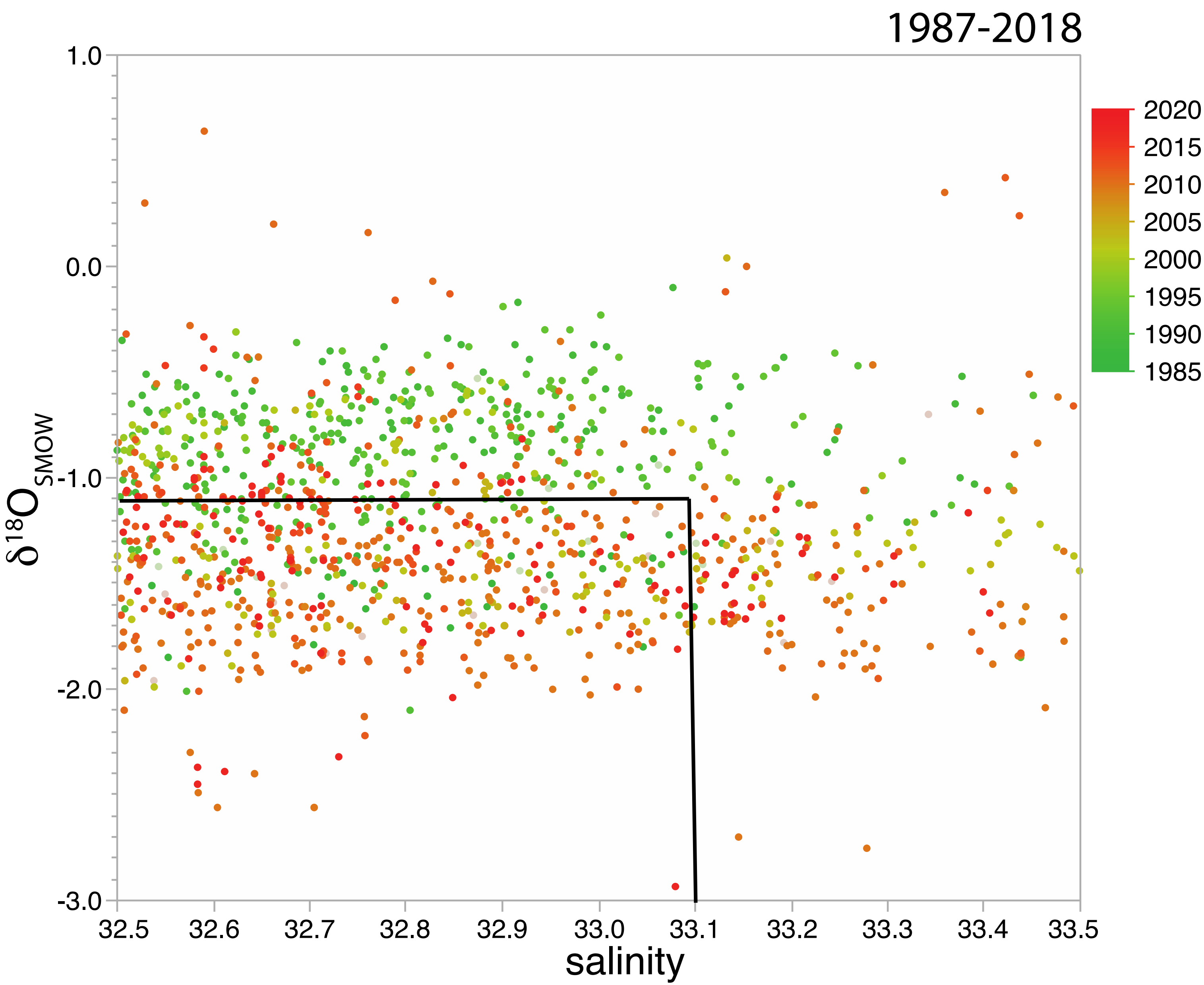


1987-2015
1.0
0.0
-1.0
-2.0
-3.0
δ18OSMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985

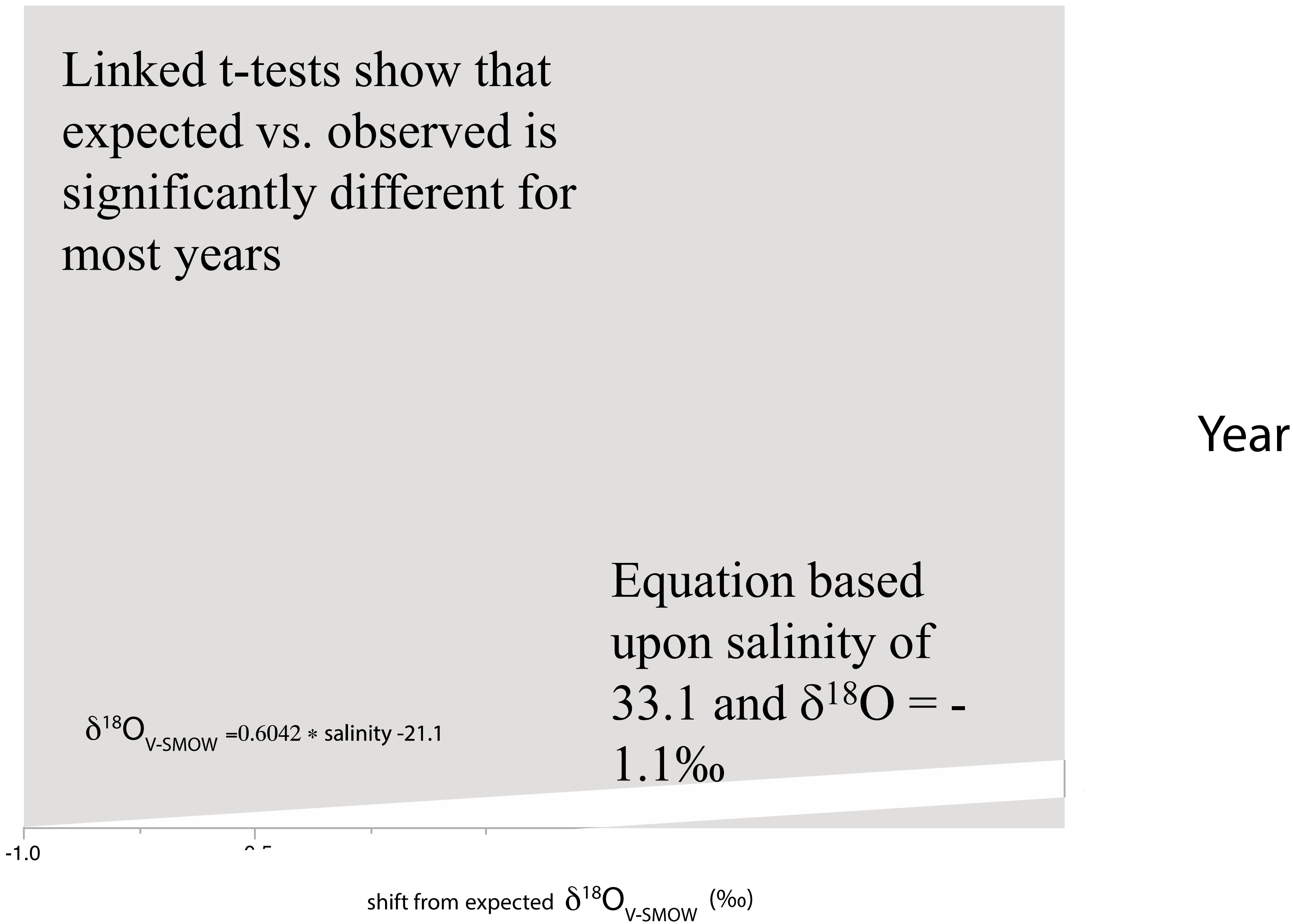


1987-2016
δ18O SMOW
salinity
1.0
0.0
-1.0
-2.0
-3.0
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
2020
2015
2010
2005
2000
1995
1990
1985


1987-2017
1.0
0.0
-1.0
-2.0
-3.0
δ18OSMOW
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985



1987-2018
1.0
0.0
-1.0
-2.0
-3.0
$\delta^{18}O_{SMOW}$
32.5
32.6
32.7
32.8
32.9
33.0
33.1
33.2
33.3
33.4
33.5
salinity
2020
2015
2010
2005
2000
1995
1990
1985


Linked t-tests show that expected vs. observed is significantly different for most years
Equation based upon salinity of 33.1 and $\delta^{18}O$ = -1.1‰
$\delta^{18}O_{V\text{-}SMOW} = 0.6042 * \text{salinity} - 21.1$
Year
-1.0
shift from expected $\delta^{18}O_{V\text{-}SMOW}$ (‰)

Assumptions

$\delta^{18}O_{end\text{-}member}$ of freshwater in Bering Strait inflow remains ~-19.3‰

Salinity of upper halocline remains 33.1

change in freshwater volume is proportional to

$(\delta^{18}O_{end\text{-}member})(x)$ = [(33.1) * original $\delta^{18}O$ value of upper halocline)] relative to:

$(\delta^{18}O_{end\text{-}member})(x)$ = [(33.1) * new $\delta^{18}O$ value of Upper halocline)]

Change from -1.1 to -1.6‰ corresponds to 45% increase in freshwater flow

Acknowledgements

Many for help in collecting shipboard samples on many US, Canadian, and Russian Flagged Vessels

Cédric Magen and Dana Biasatti for mass spectrometric analysis; Alynne Bayard for GIS and video editing; Jackie Grebmeier for 30+ years of collaboration in the bering Strait region

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