Currents and water mass structure and in and near the Gulf of Anadyr

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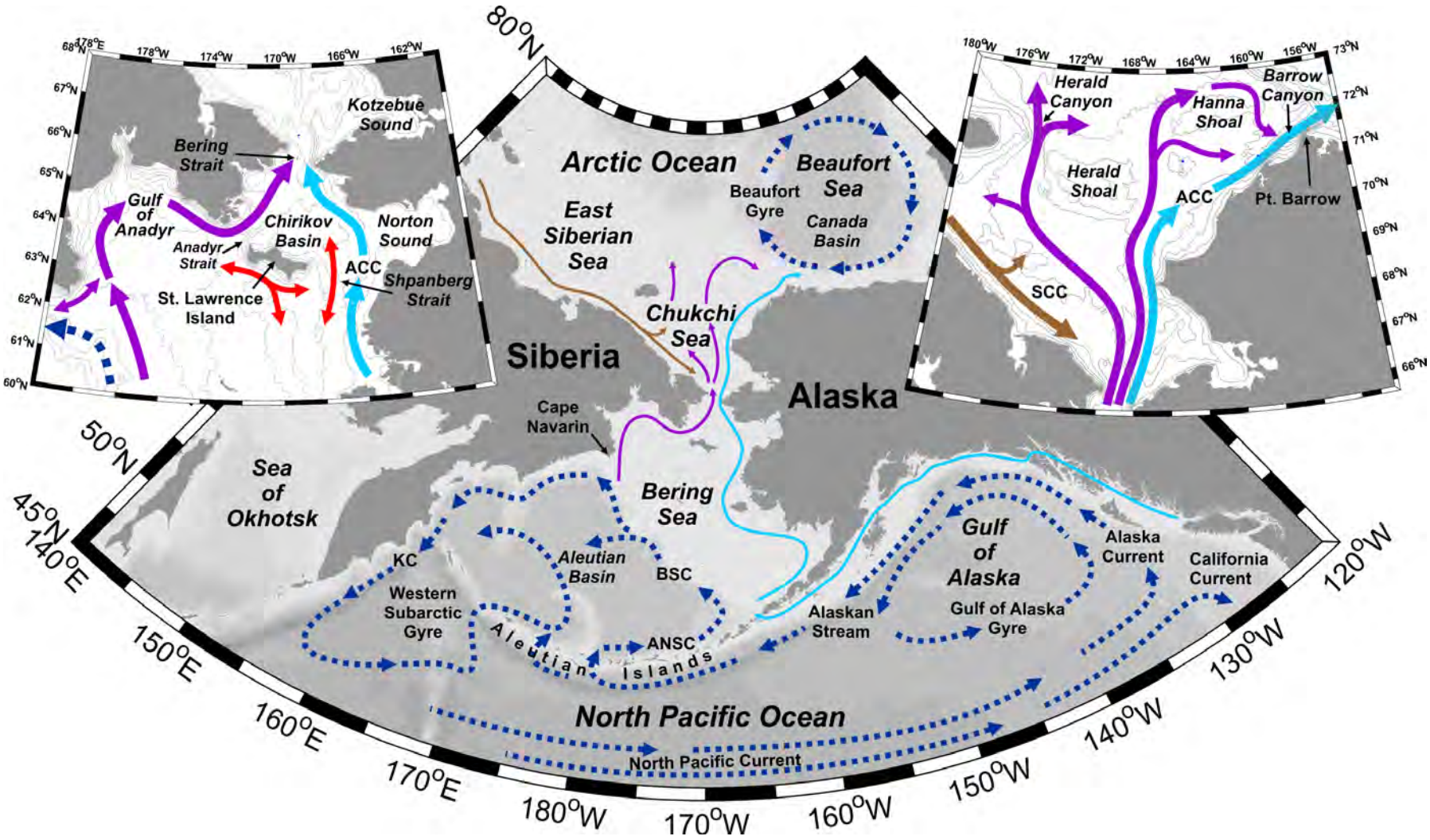
PICES 25th Anniversary
N. Bering Sea Workshop
San Diego, CA
3 Nov. 2016

Guiding Questions

- What are the primary flow pathways in the Northern Bering Sea?
- How important are baroclinic currents in the Gulf of Anadyr?
- Where/when does water mass modification occur?
- How do recent years compare to past decades?

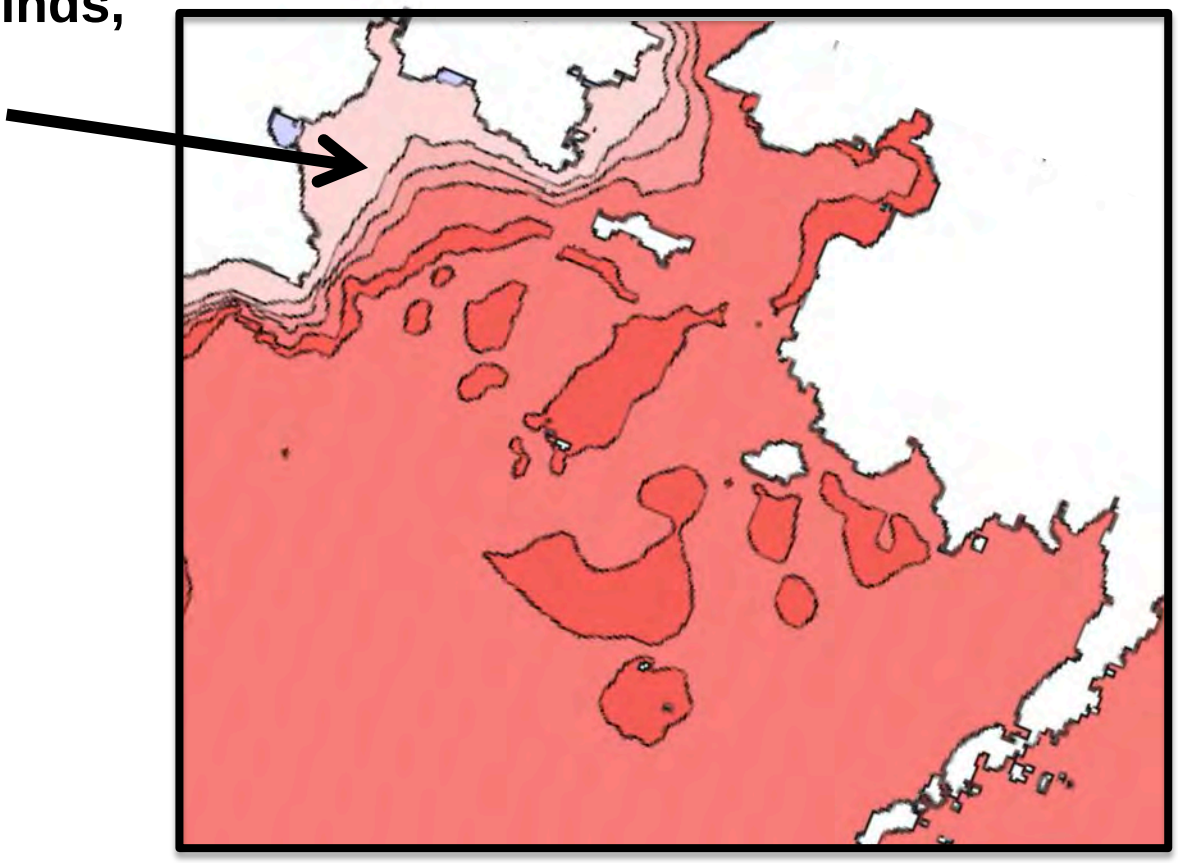
Overview

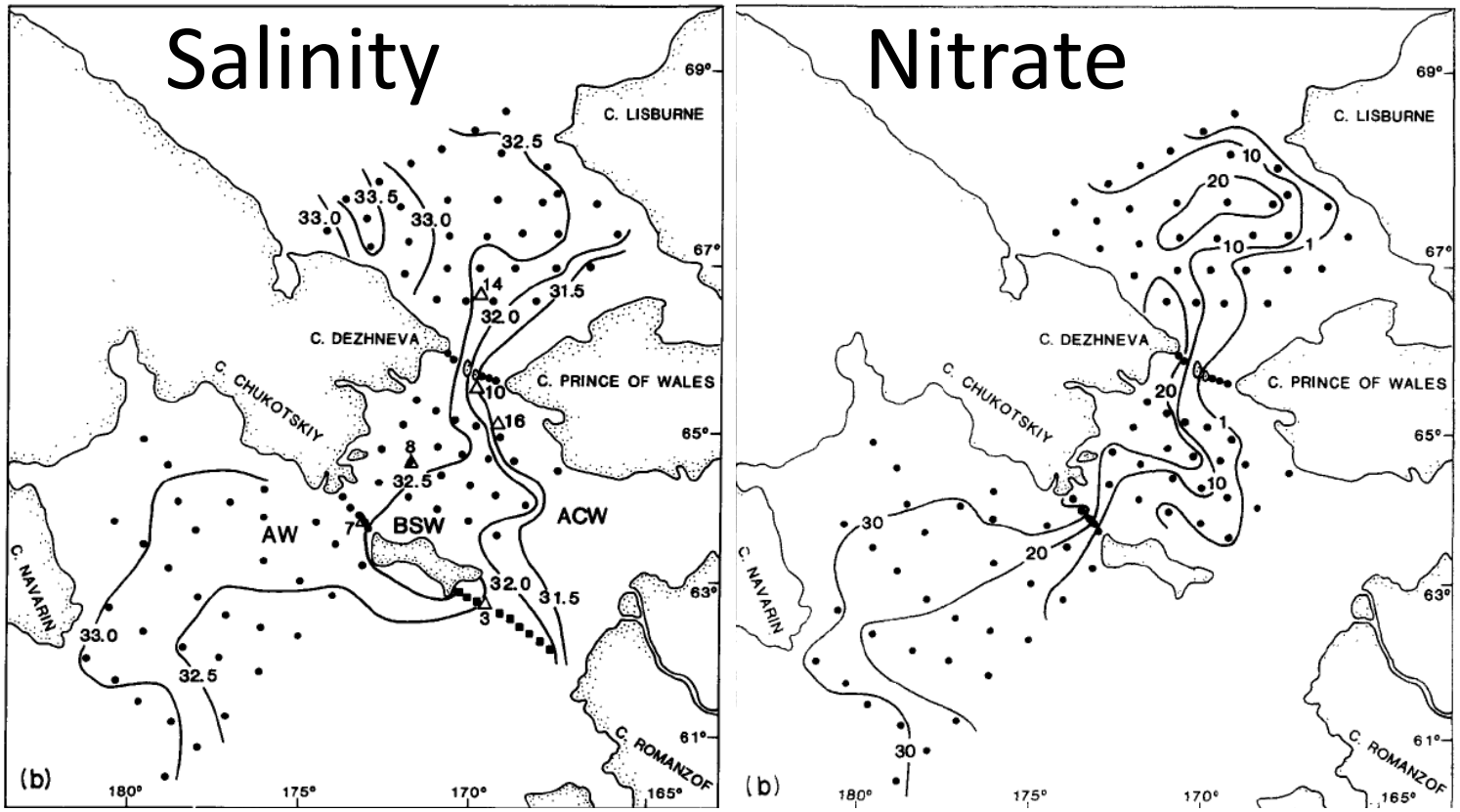
- Regional circulation
- Northern Bering Sea CTD data
  - 2000-2012
- Late Summer Water Masses
  - defining, structure, messages
  - advection & mixing
  - new insights?
- Heat wave of 2014-2016


Kotzebue Sound
Bering Strait
Gulf of Anadyr
Anadyr Strait
Chirikov Basin
Norton Sound
ACC
Shpanberg Strait
St. Lawrence Island
Arctic Ocean
Beaufort Sea
Beaufort Gyre
Canada Basin
East Siberian Sea
Chukchi Sea
Siberia
Alaska
Cape Navarin
Herald Canyon
Hanna Shoal
Barrow Canyon
Herald Shoal
ACC
Pt. Barrow
SCC
Sea of Okhotsk
Bering Sea
KC
Aleutian Basin
BSC
Western Subarctic Gyre
Aleutian Islands
ANSC
Alaskan Stream
Gulf of Alaska
Gulf of Alaska Gyre
Alaska Current
California Current
North Pacific Ocean
North Pacific Current
80°N
50°N
45°N
140°E
150°E
160°E
170°E
180°W
170°W
160°W
150°W
140°W
130°W
120°W

Mean flow pathway (modeled)

In the absence of winds, flow streamlines compress into the Gulf of Anadyr

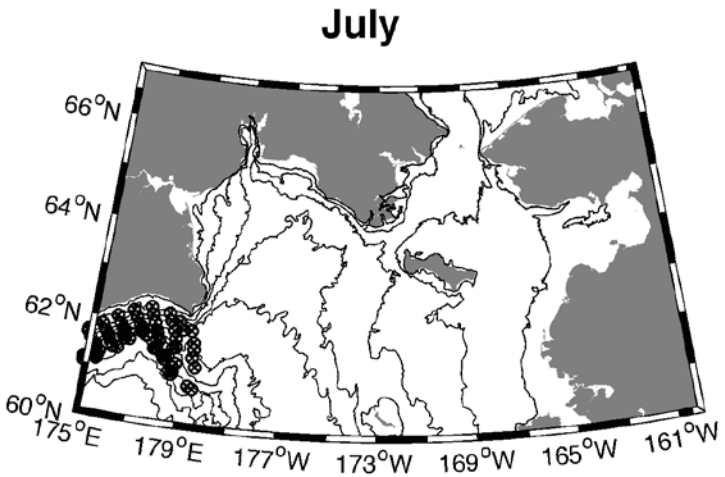


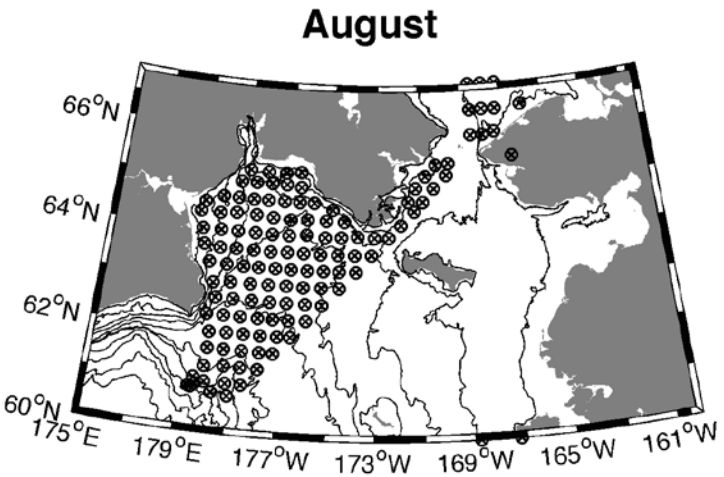


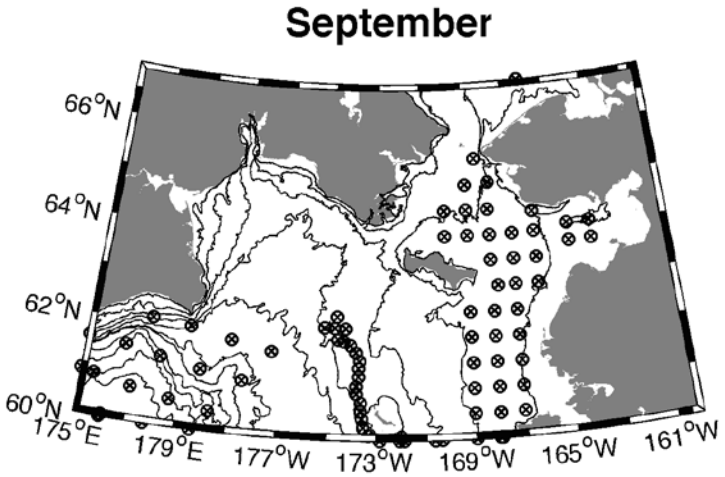
1988 August Near-Bottom S & NO_3

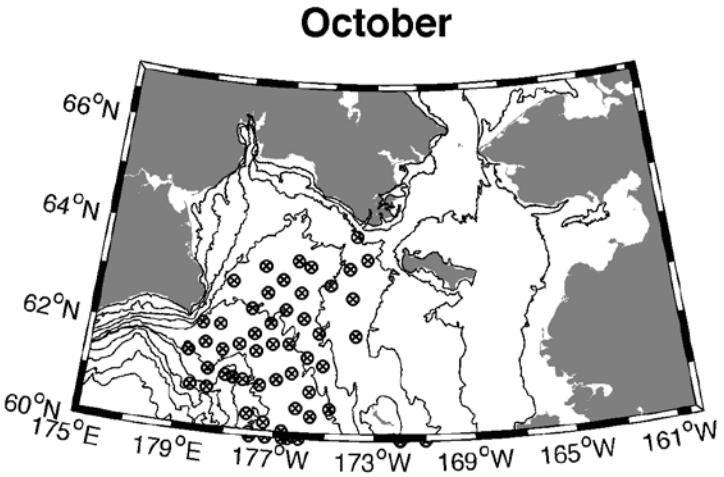
[Walsh et al., 1989]

2012 CTD Station Distribution

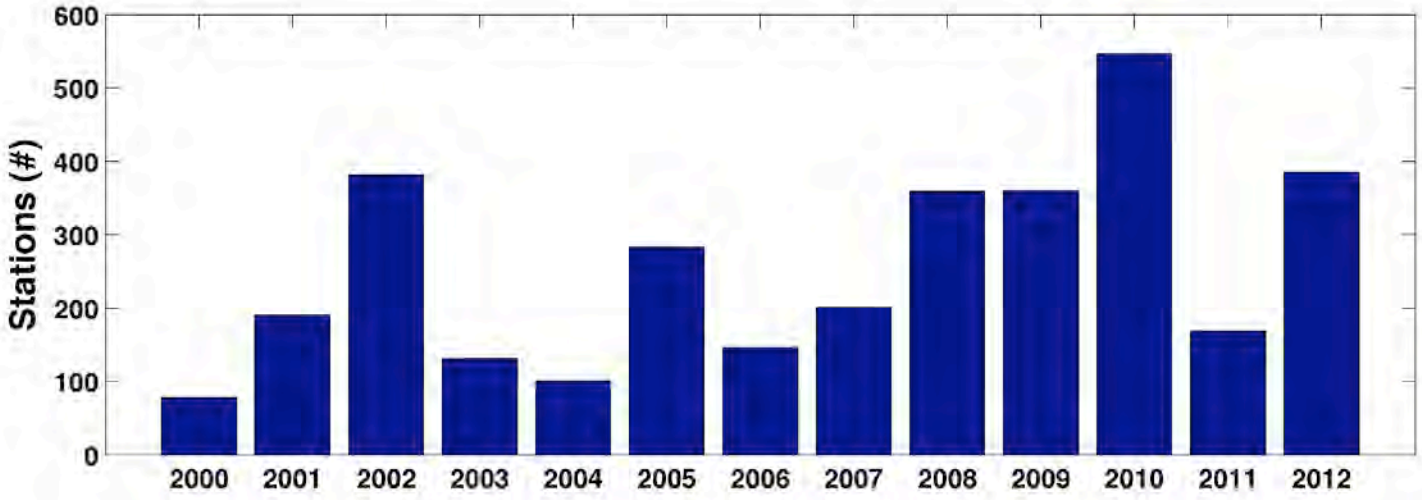








CTD Temporal Distribution



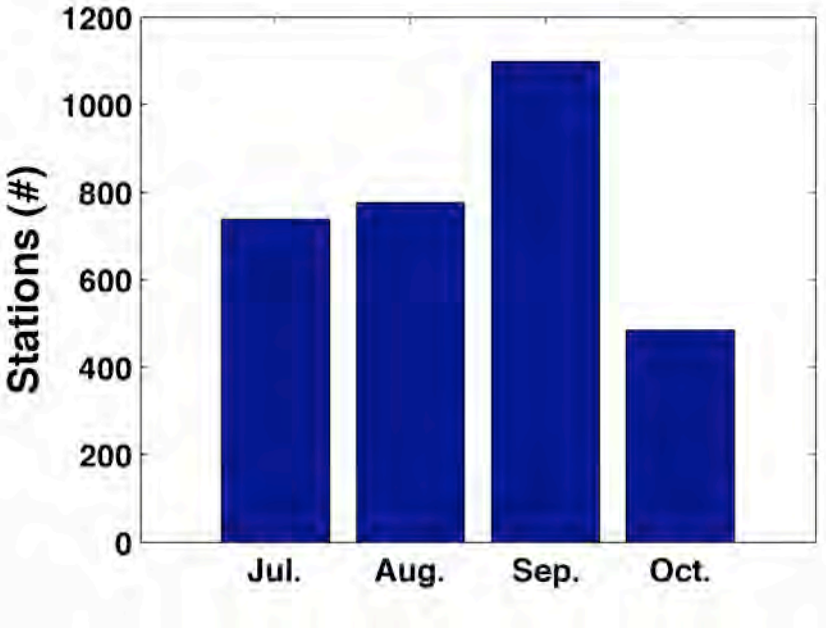
CTD data from:

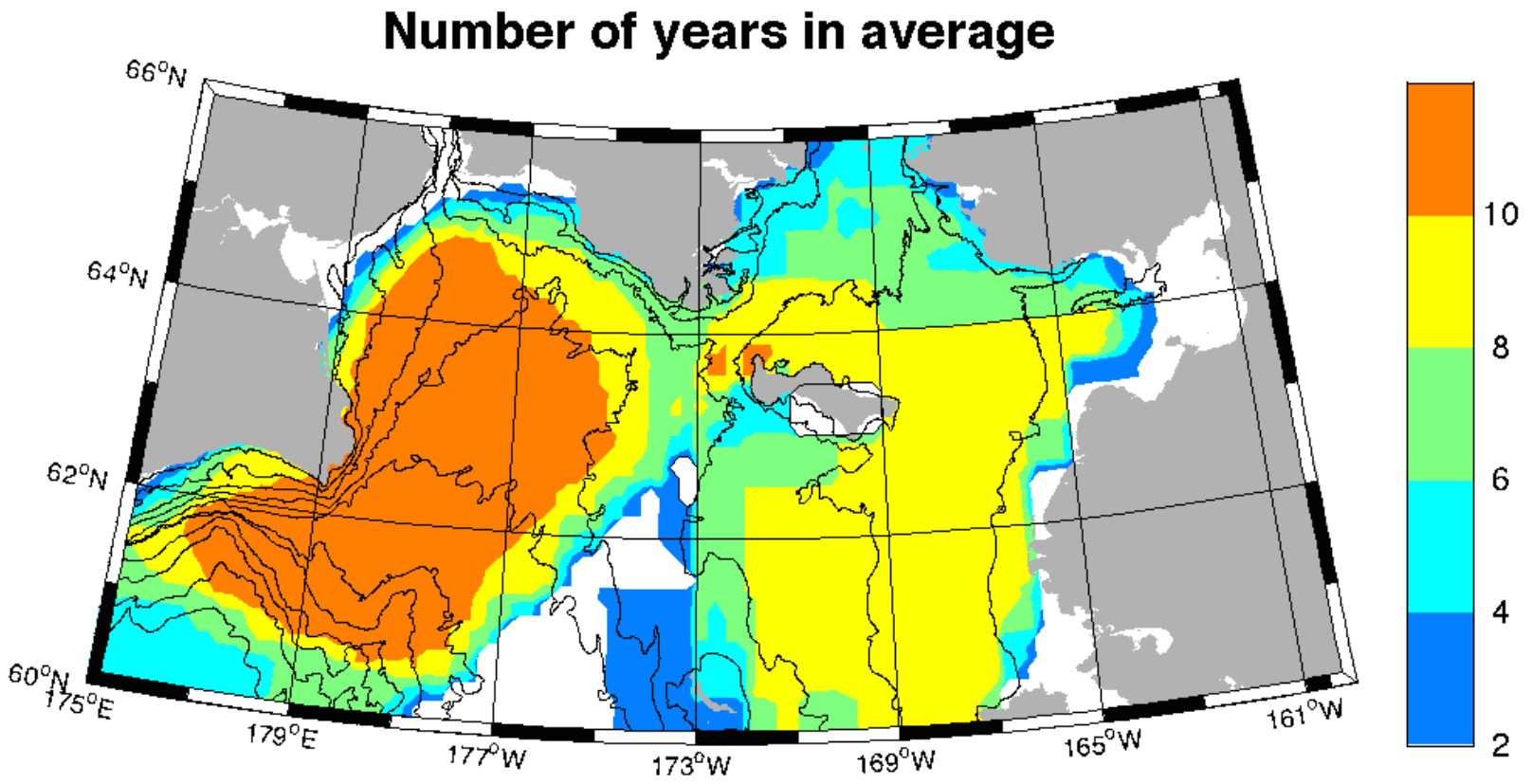
TINRO

BASIS

BEST/BSIERP

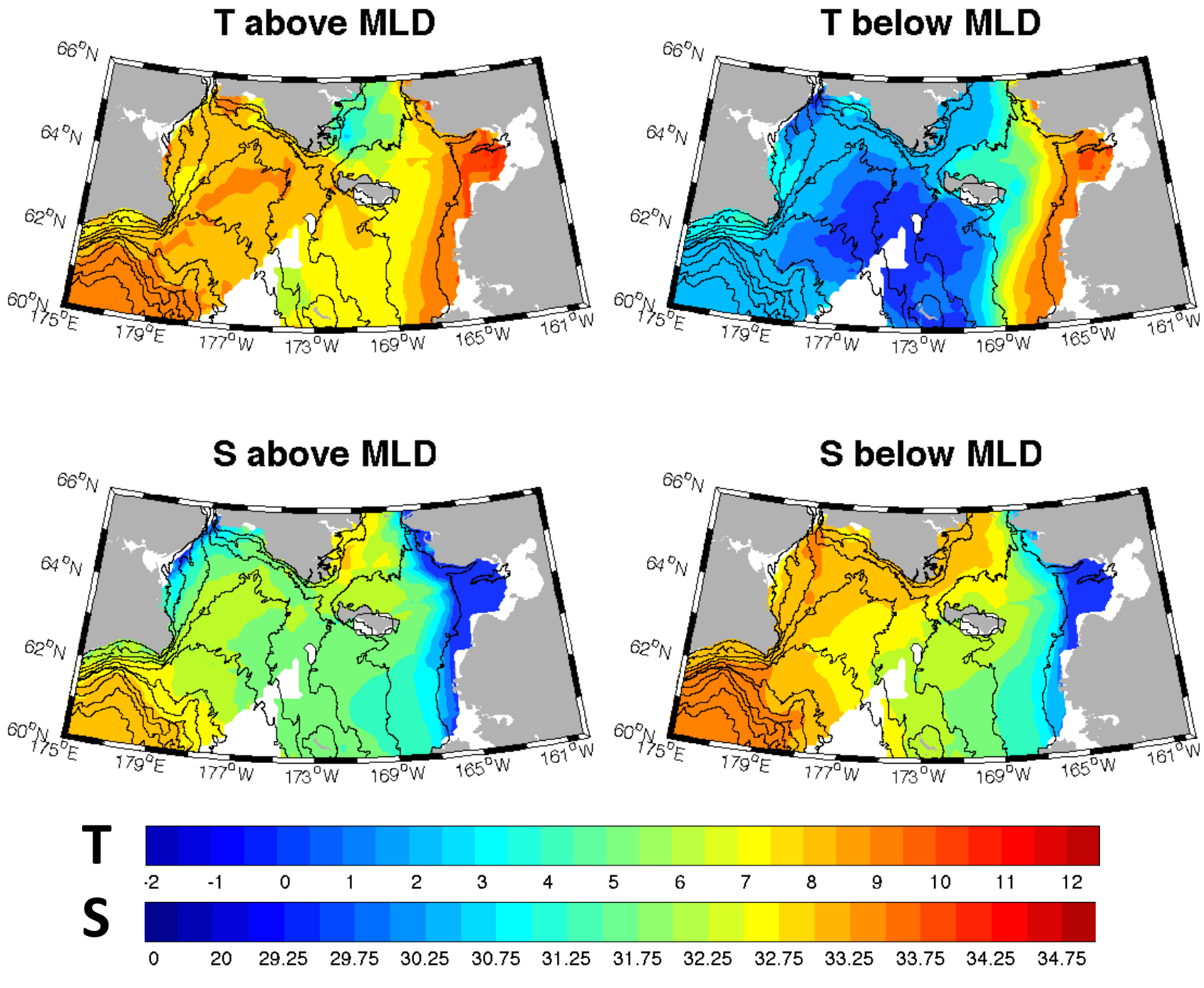
ArcticEIS



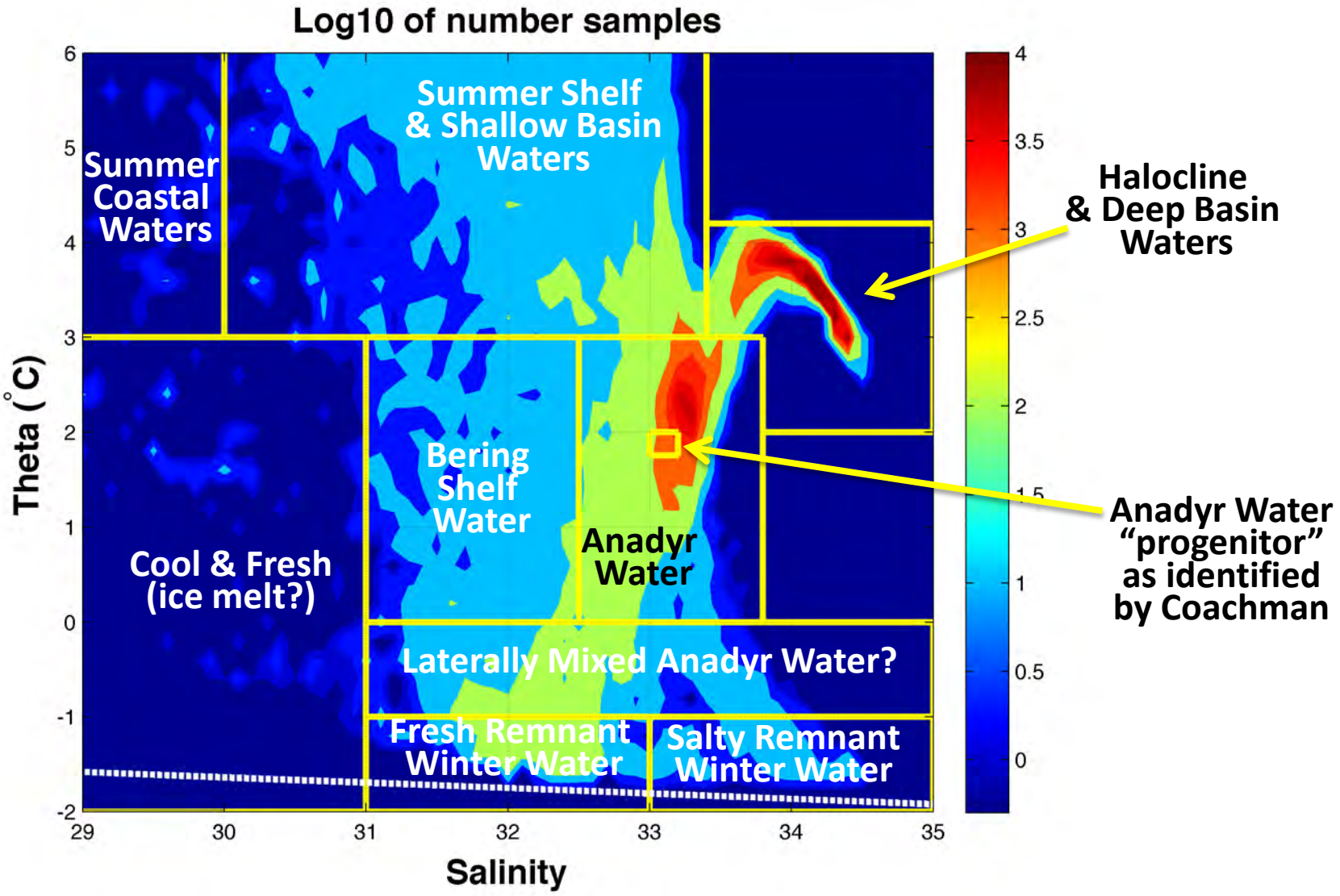


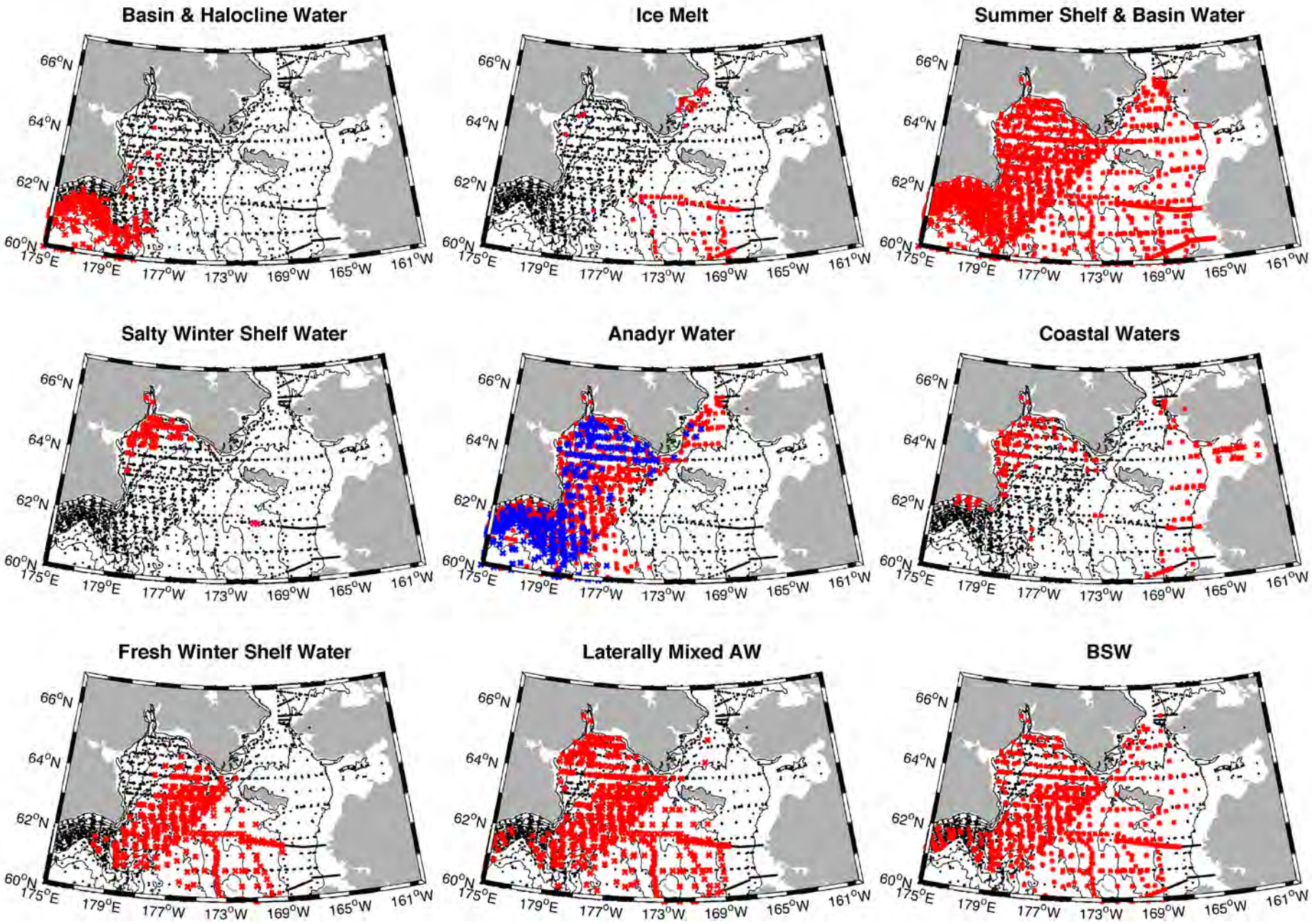
Data gridded into
0.1° Latitude x 0.2° Longitude bins

2000-2012
August/September
CTD data

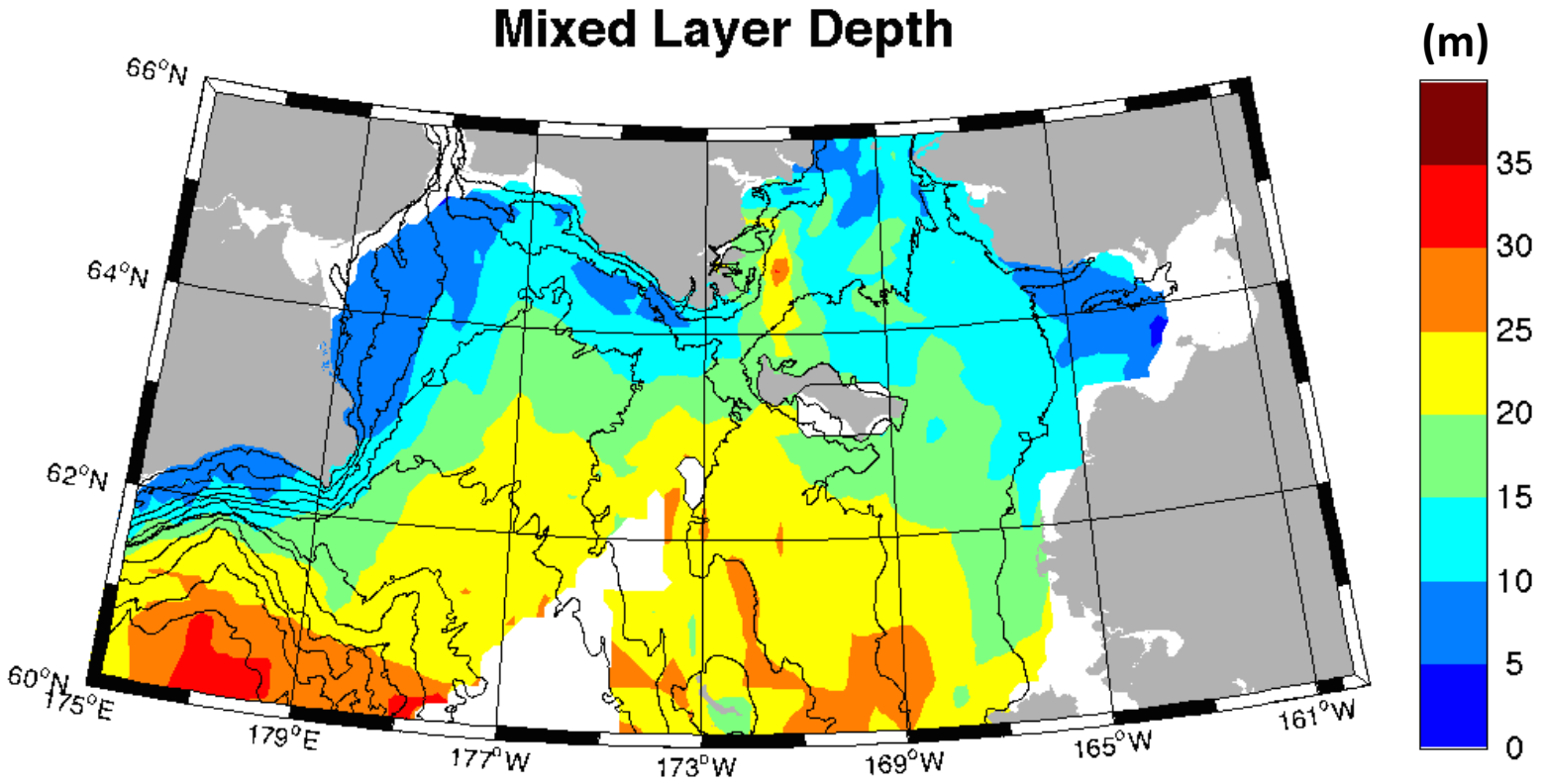

T above MLD
T below MLD
S above MLD
S below MLD
66°N
64°N
62°N
60°N
175°E
179°E
177°W
173°W
169°W
165°W
161°W
T
-2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12
S
0 20 29.25 29.75 30.25 30.75 31.25 31.75 32.25 32.75 33.25 33.75 34.25 34.75

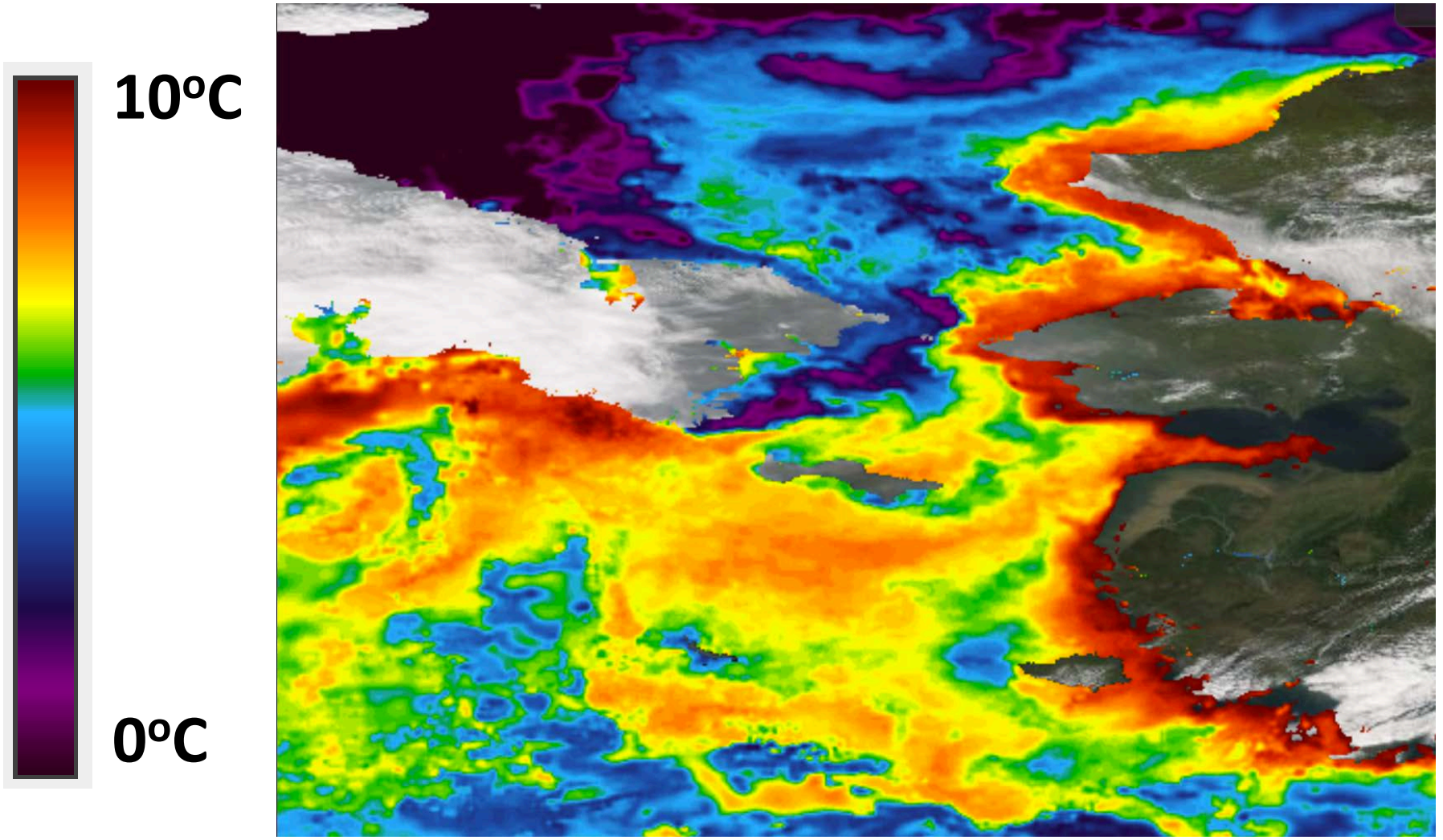
Late summer water masses: as many as 11 distinct components




Basin & Halocline Water
Ice Melt
Summer Shelf & Basin Water
Salty Winter Shelf Water
Anadyr Water
Coastal Waters
Fresh Winter Shelf Water
Laterally Mixed AW
BSW
66°N
64°N
62°N
60°N
175°E
179°E
177°W
173°W
169°W
165°W
161°W

August-September MLD



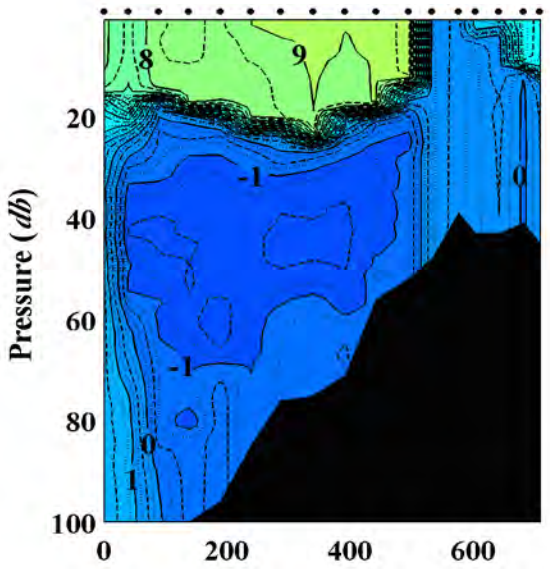


Cold plume in Anadyr Strait a well-known recurrent feature.

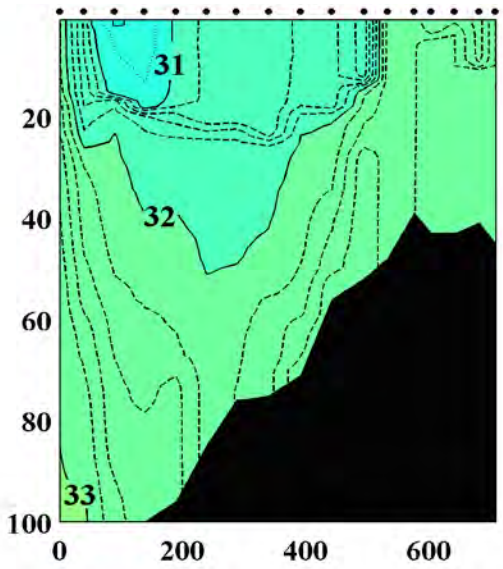
SST: 8 August 2012 [NASA Worldview]

Gulf of Anadyr SW-NE Cross-section

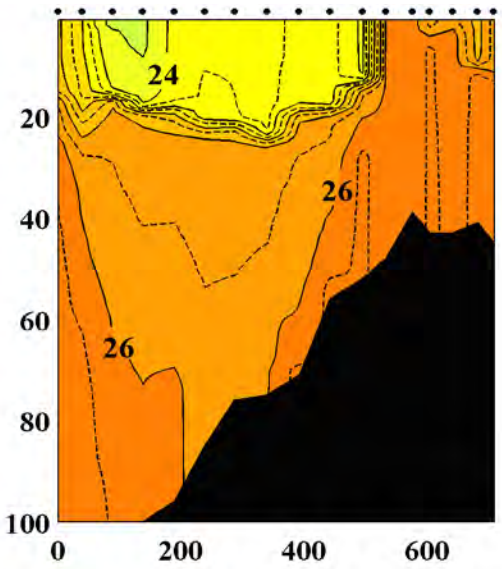
Temperature



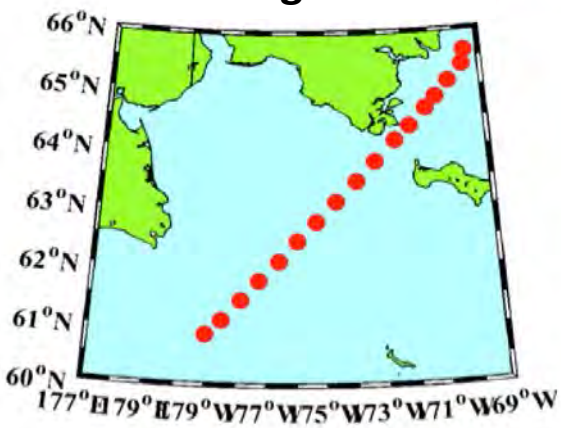
Salinity



Density (kg m^{-3}-1000)



3-16 August 2012

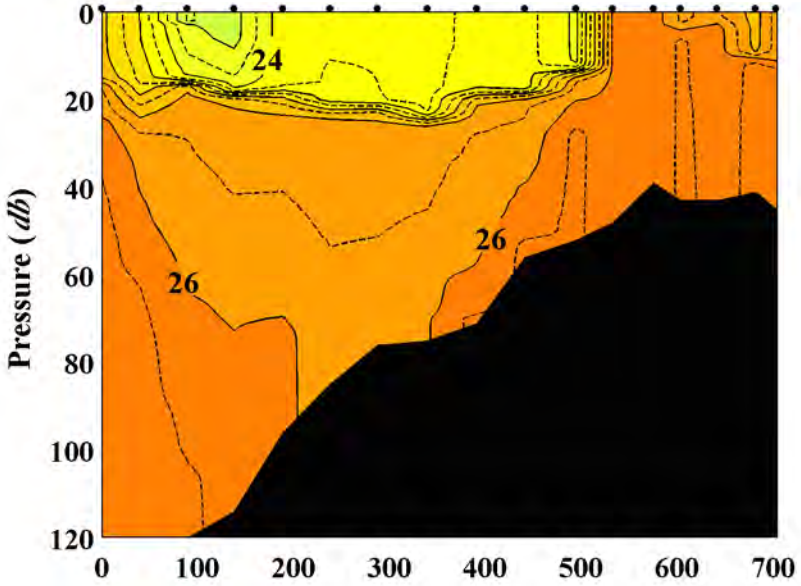


Notes:

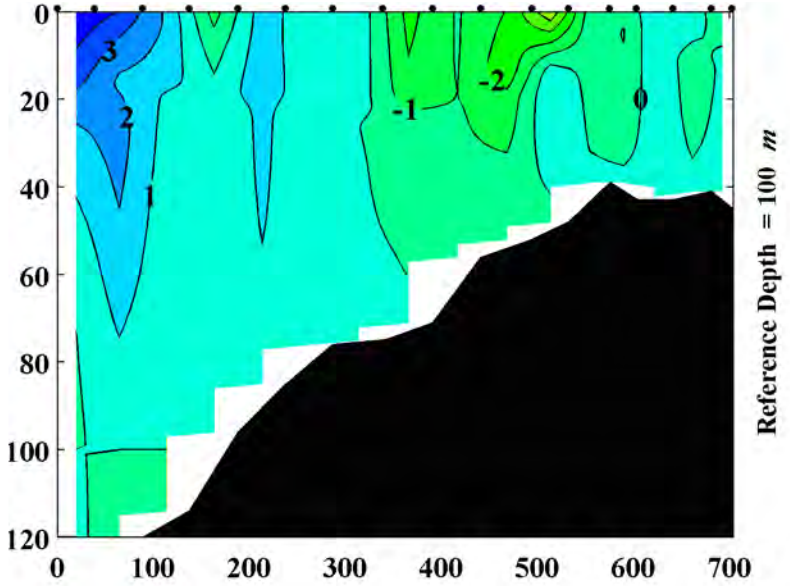
- Stratification up to Anadyr Strait, then mixed
- Fresh jet near slope
- Near-bottom thermal inversion

Gulf of Anadyr SW-NE Cross-section

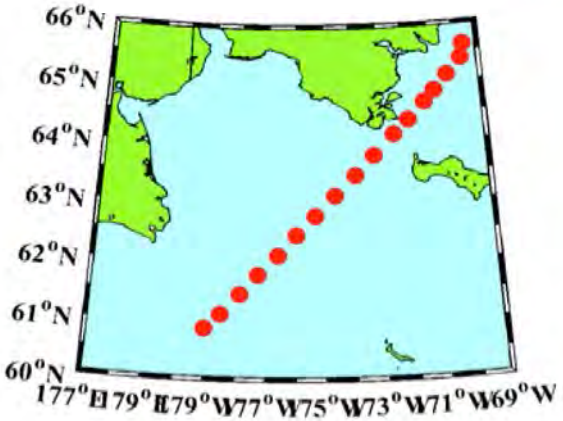
Density (kg m^{-3}-1000)



Geostrophic Velocity (cm/s)



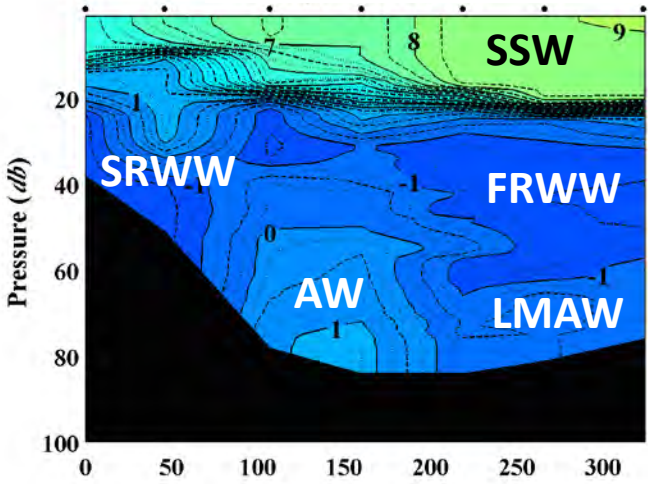
3-16 August 2012



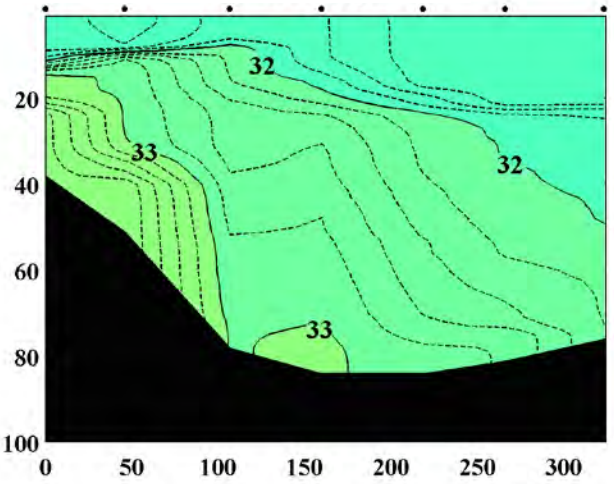
Animation

Gulf of Anadyr NW-SE Cross-section

Temperature



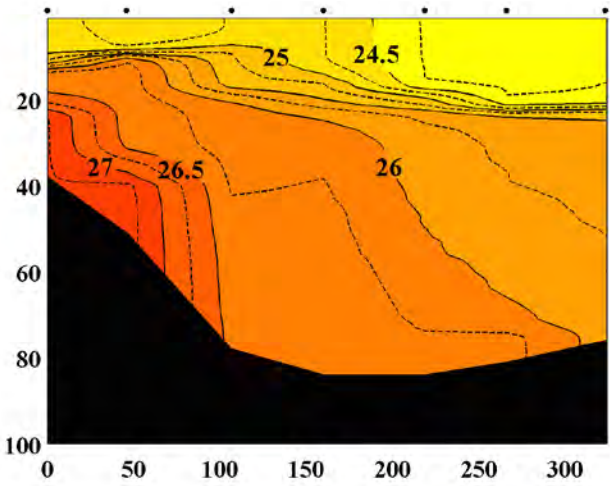
Salinity

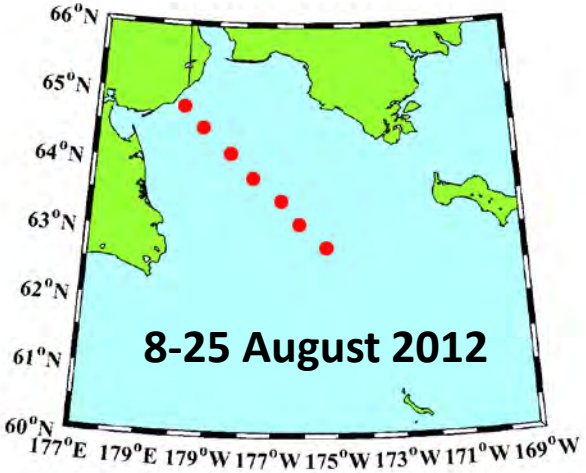


We find

Anadyr Water
Summer Shelf Water
Salty Remnant WW
Fresh Remnant WW
Laterally Mixed AW

Density (kg m^{-3}-1000)

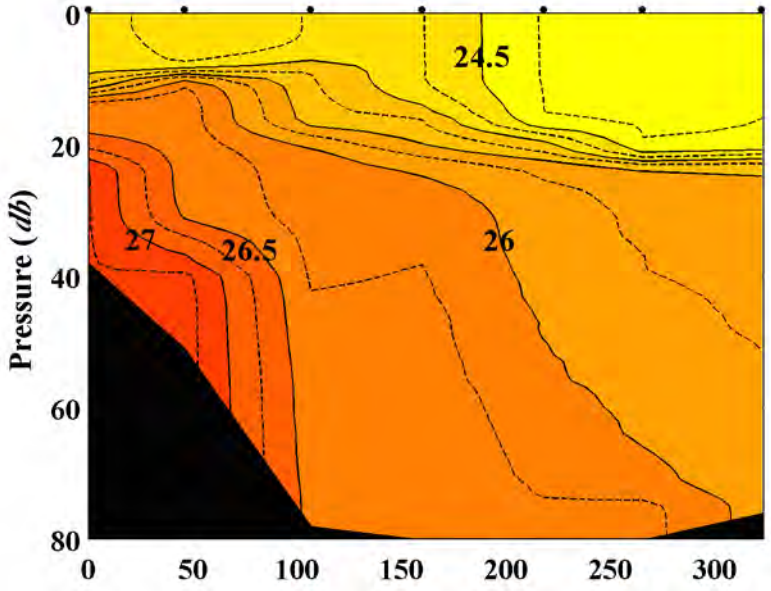




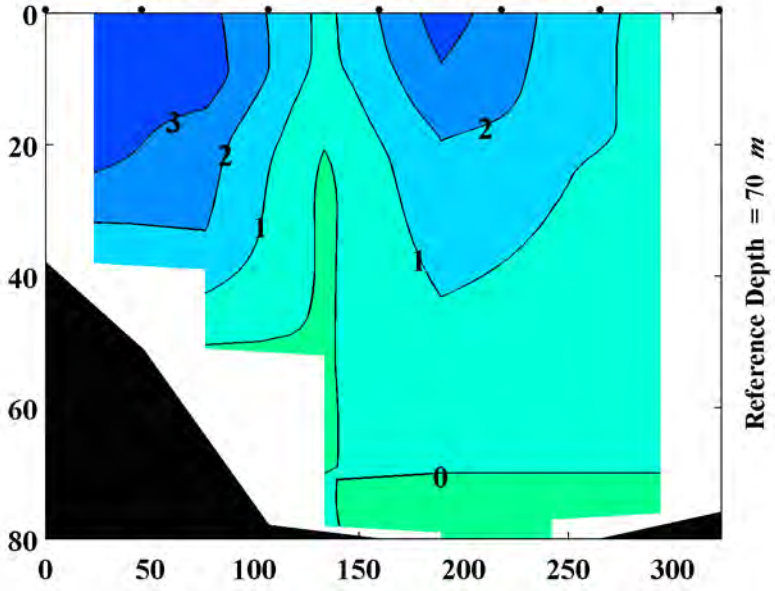
Two baroclinic Jets:

Two pathways toward Anadyr Strait

Density (kg m^{-3}-1000)

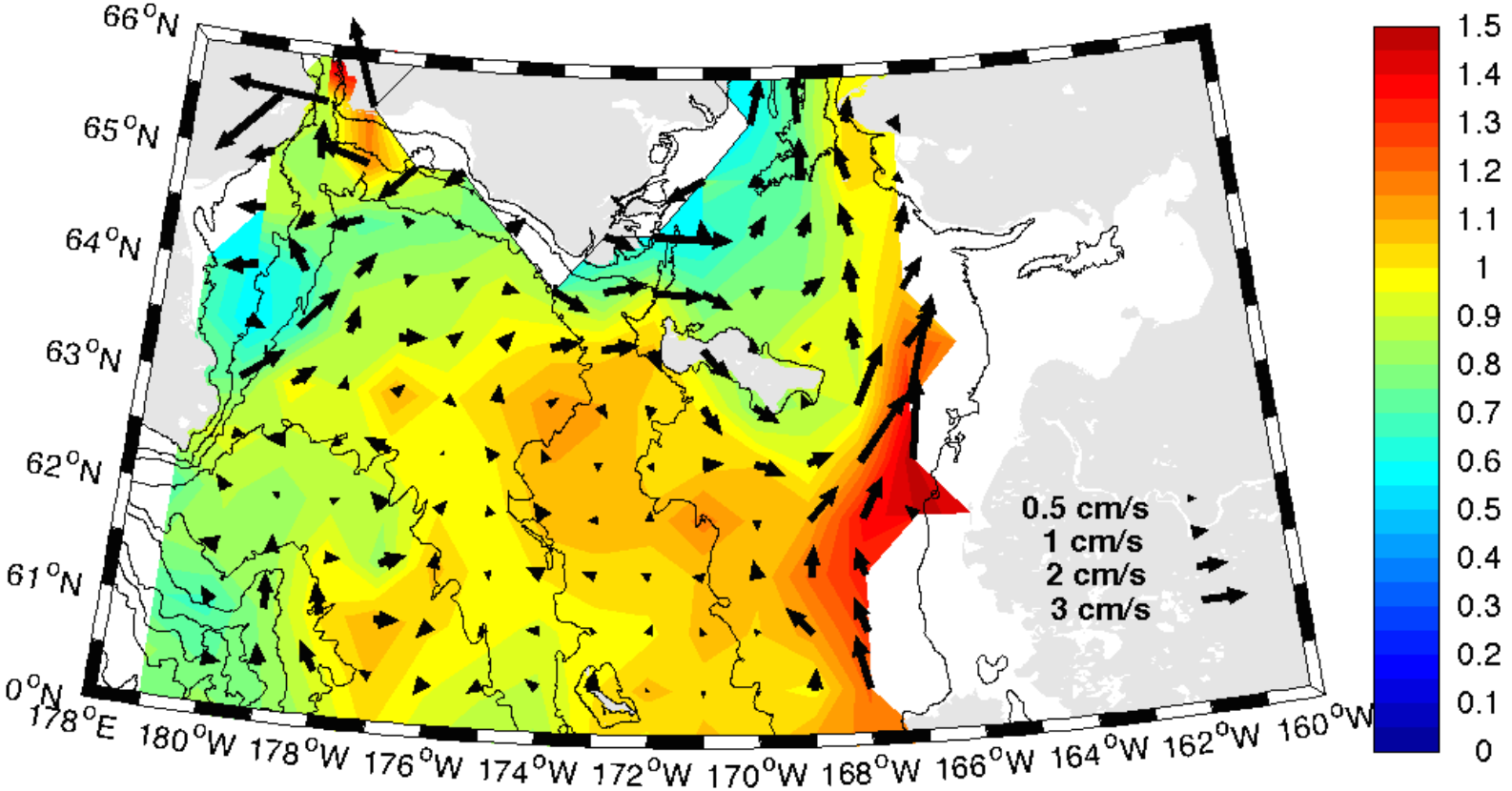


Geostrophic Velocity (cm/s)



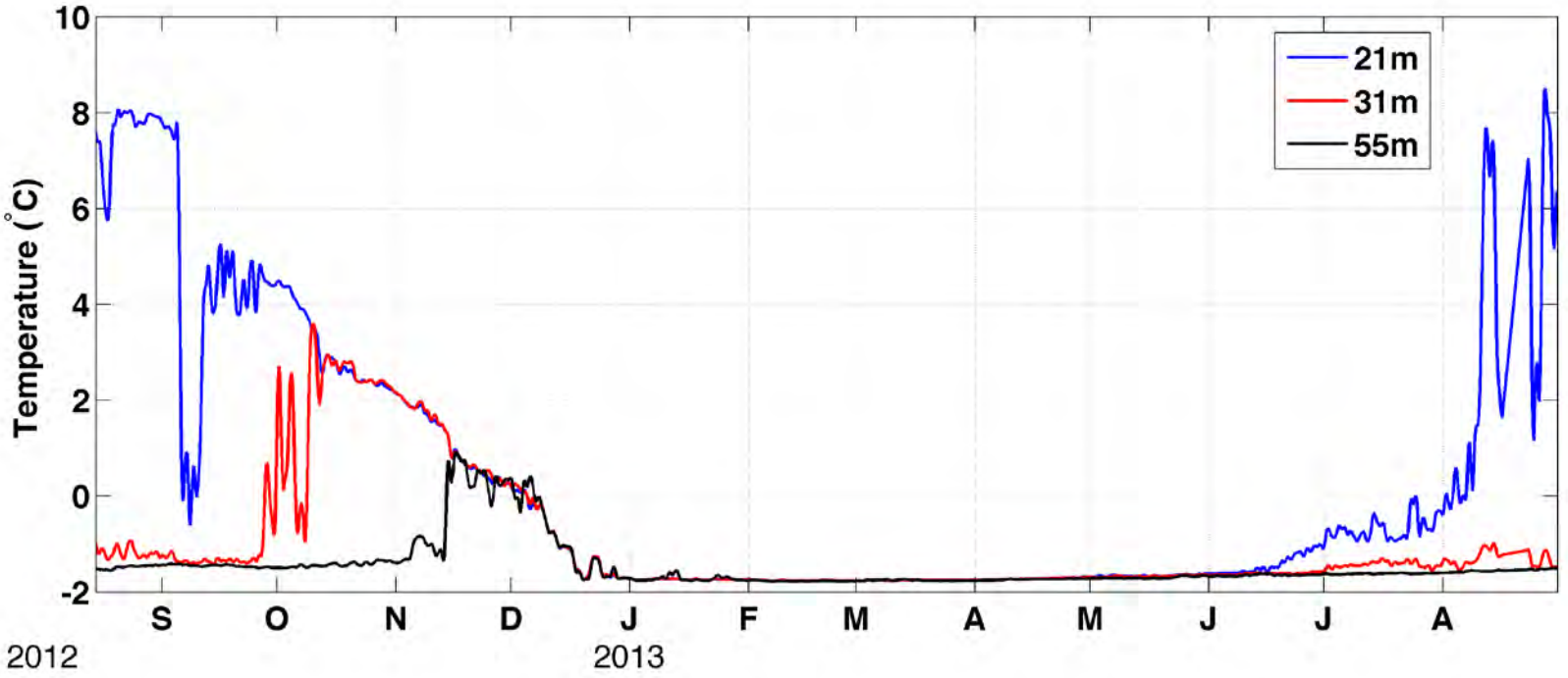
Approx. location of Mooring M8

2000-2012 Mean
0-30 db Geopotential Height Anomaly



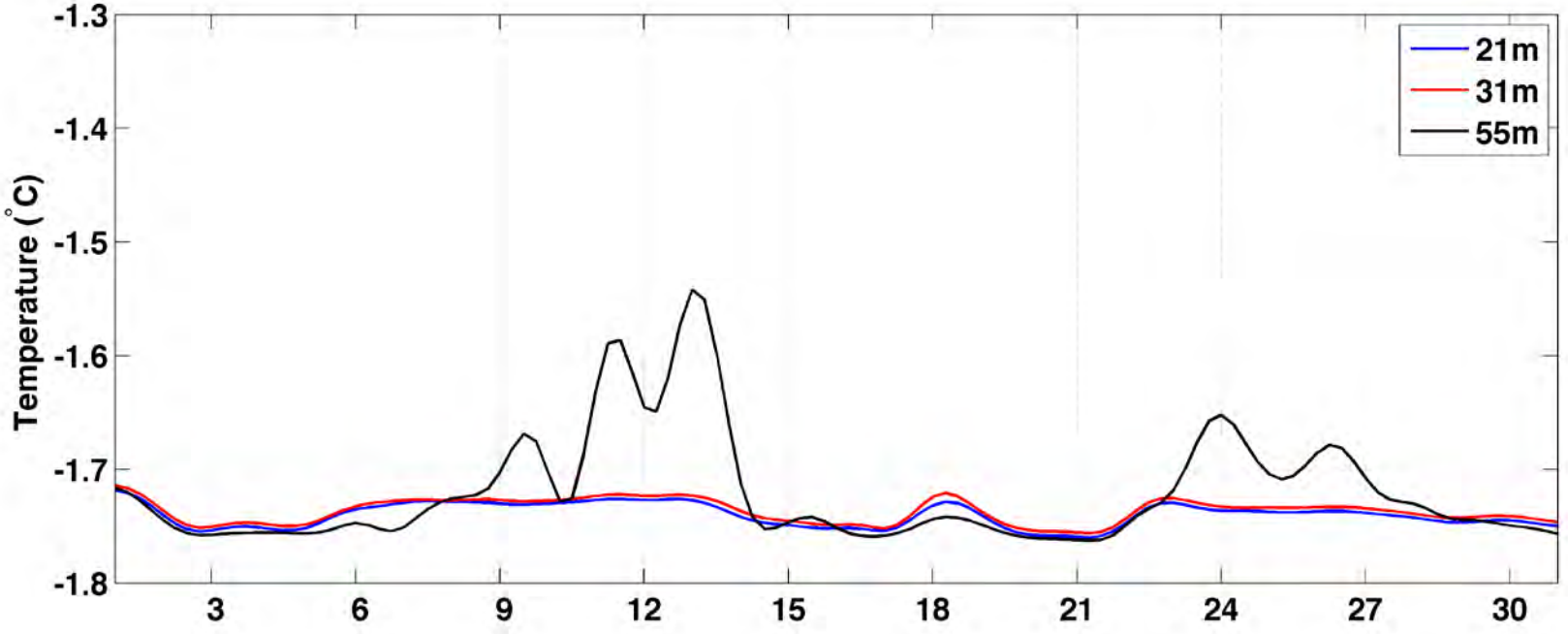
*** Baroclinic transport does not appear to account for more than ~0.1 Sv of the total Anadyr/Bering Strait throughflow**

Mooring M8 Temperature



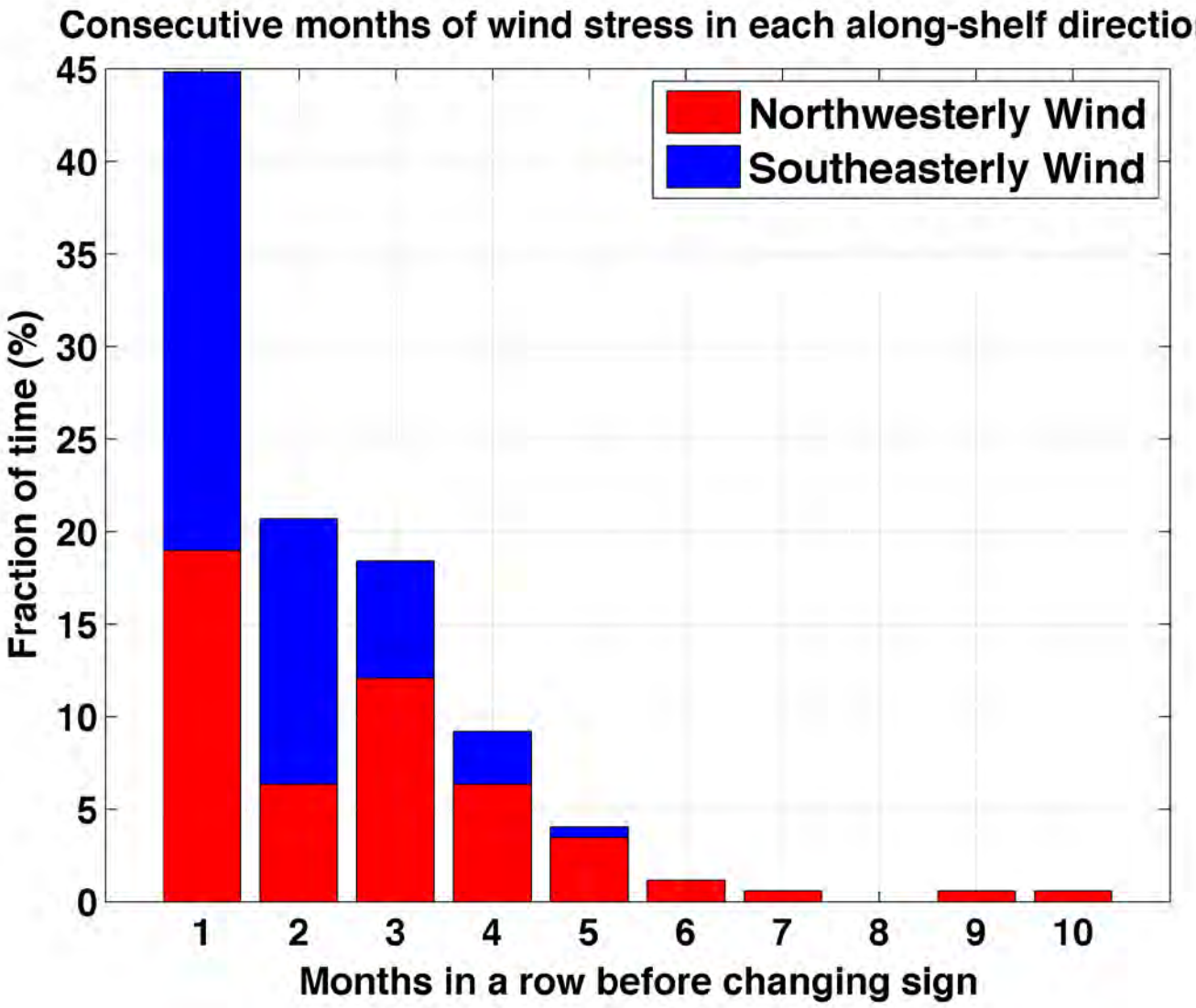
August 2012 - August 2013

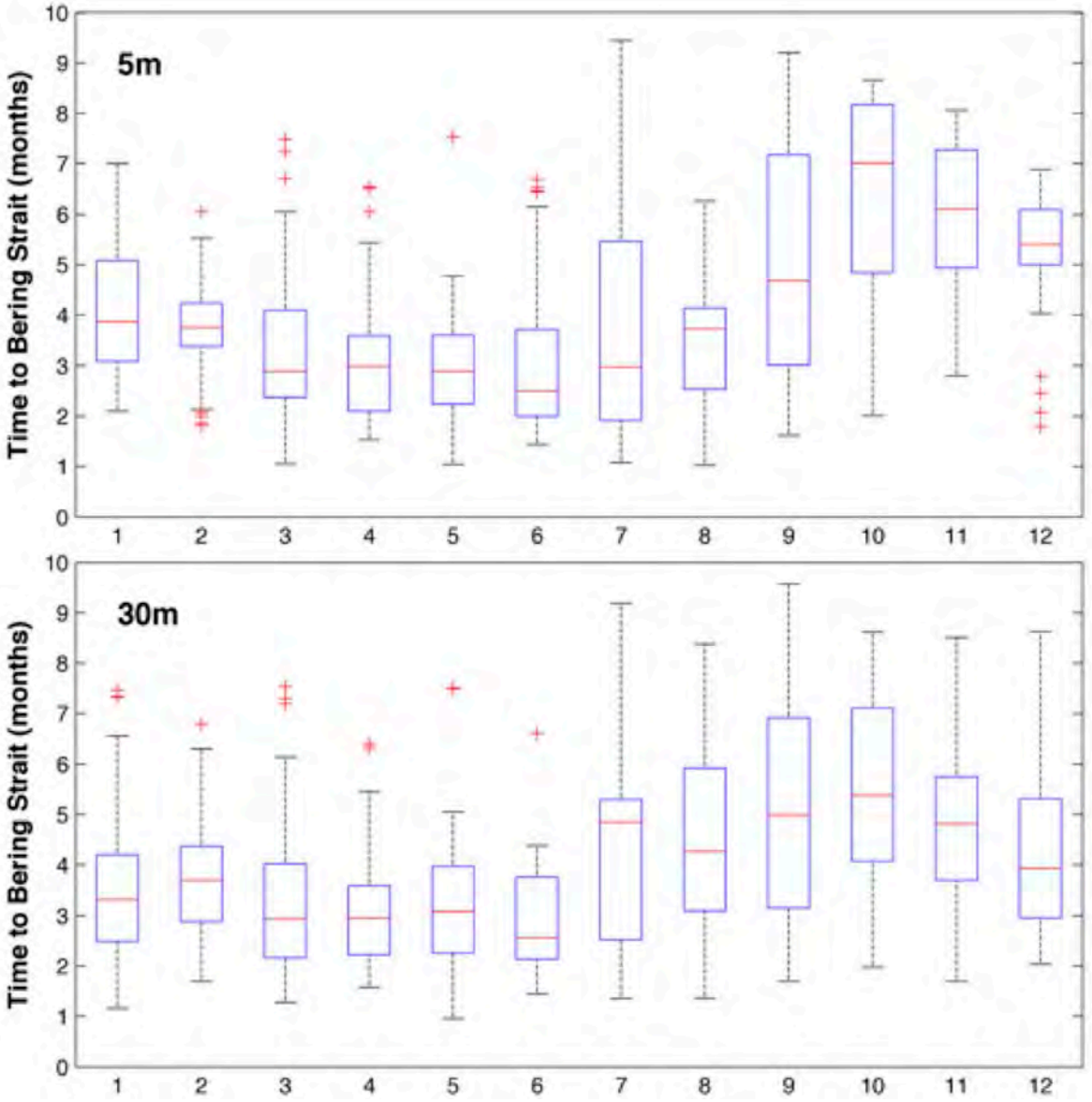
Mooring M8 Temperature



January 2013

Example of heat advected along the seafloor in winter. Event of 9-14 January was associated with a strong (presumably wind-driven) eastward flow.

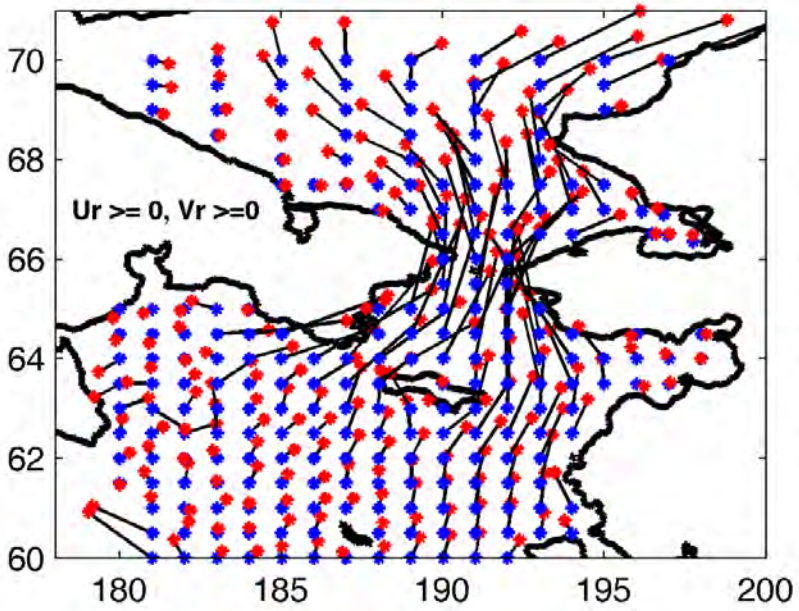

Consecutive months of wind stress in each along-shelf direction
Northwesterly Wind
Southeasterly Wind
Fraction of time (%)
0
5
10
15
20
25
30
35
40
45
1
2
3
4
5
6
7
8
9
10
Months in a row before changing sign



Influence of Depth & Season

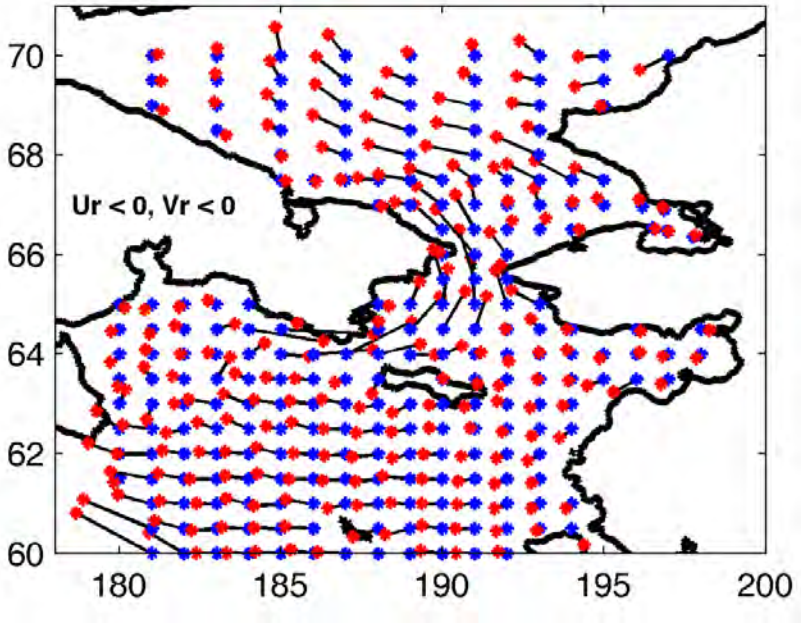
on amount of time for modeled floats to move from SW Gulf of Anadyr (near Cape Navarin) to Bering Strait

Southerly Winds



Winter (Oct-Apr)
10-day mean modeled near-surface float trajectories based on wind direction

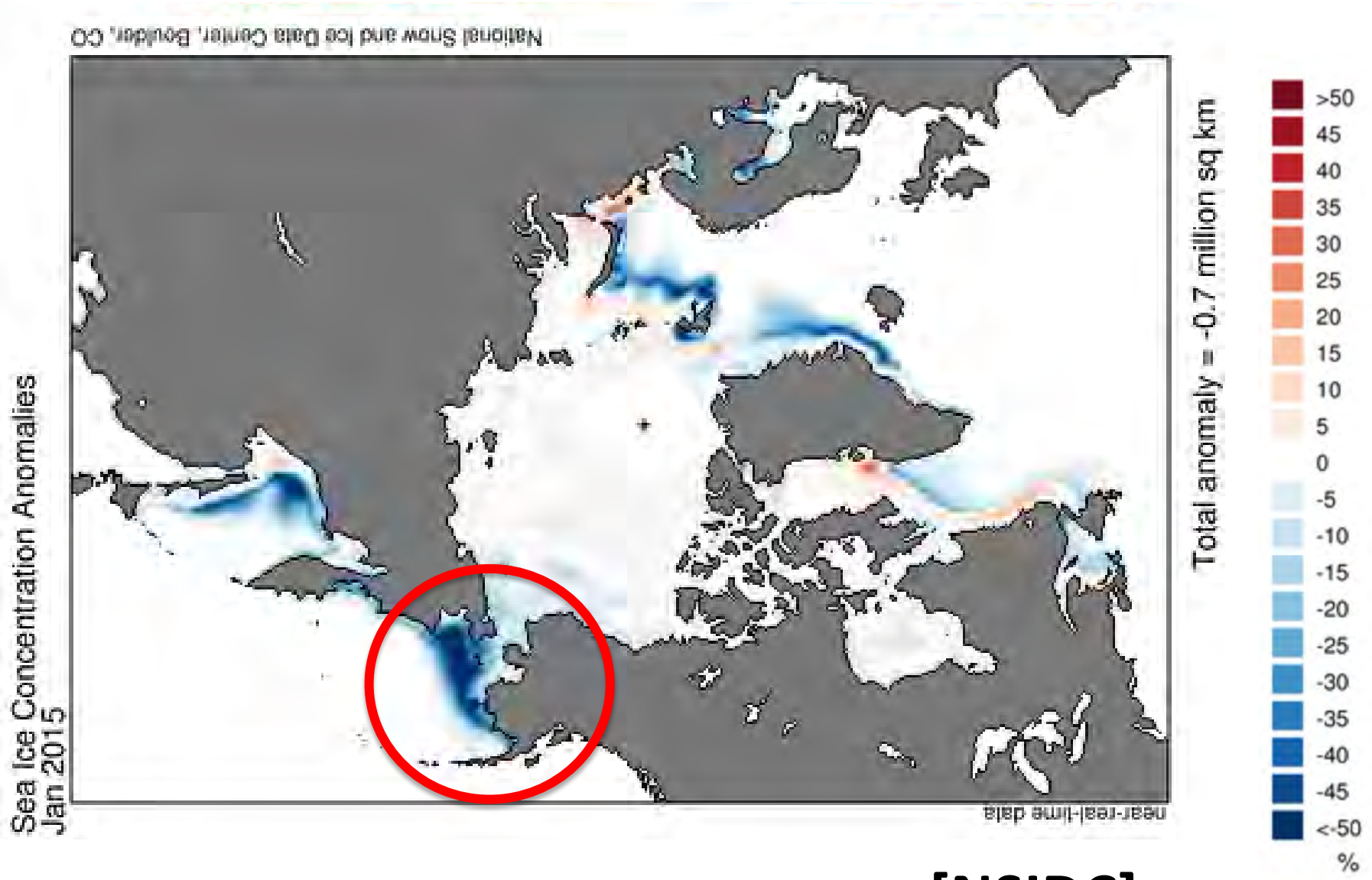
Northerly Winds



Floats begin at blue dots and travel to red dots. Red dots show the mean position of many repeated float deployments.

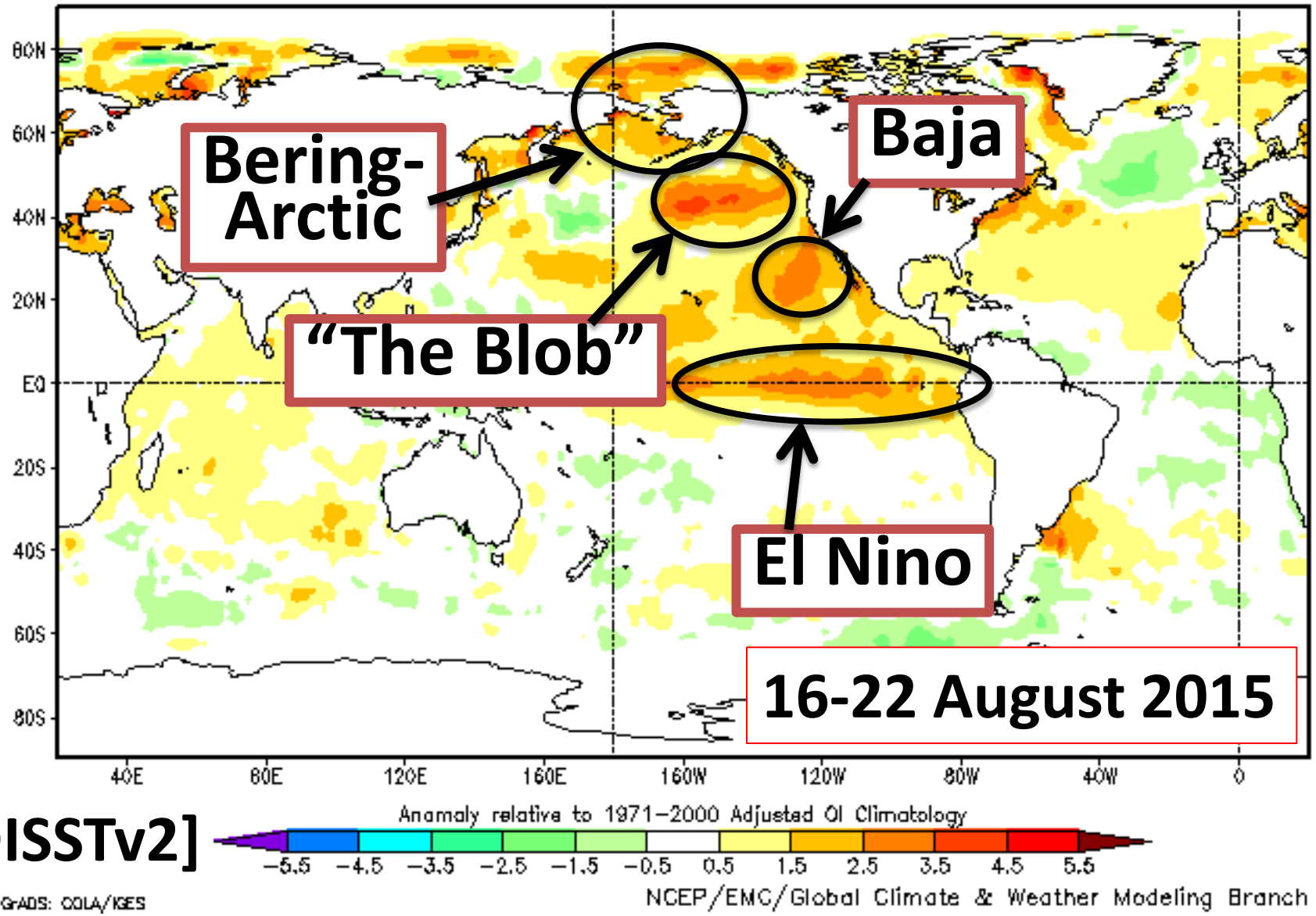
How do recent years compare to prior decades?

January 2015 Sea Ice Anomaly



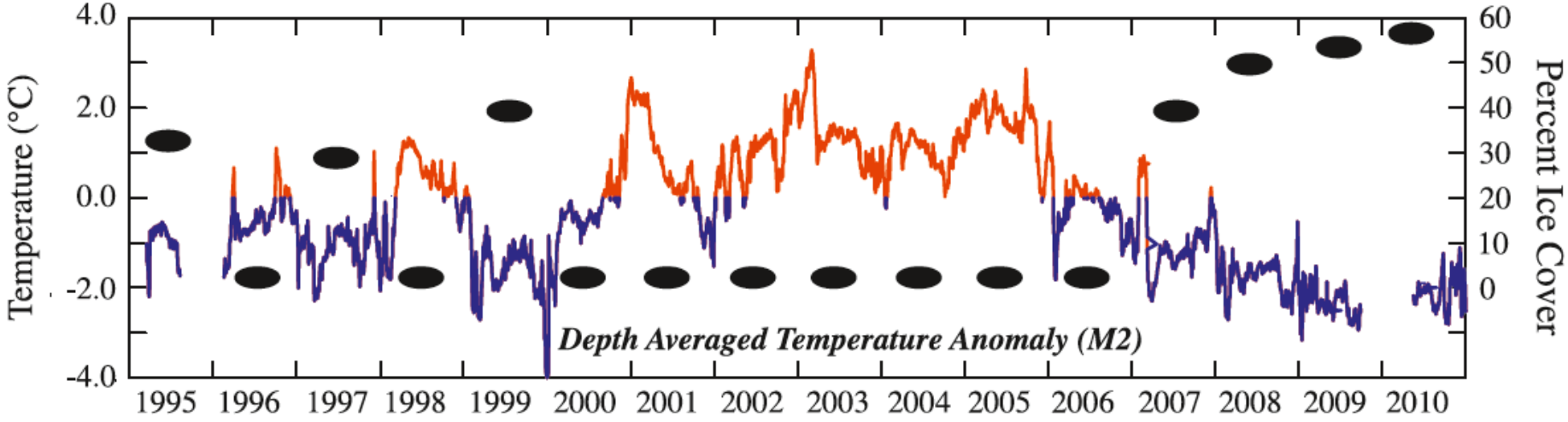
[NSIDC]

2015: Four centers of N. Pacific surface heat anomalies



[OISSTv2]

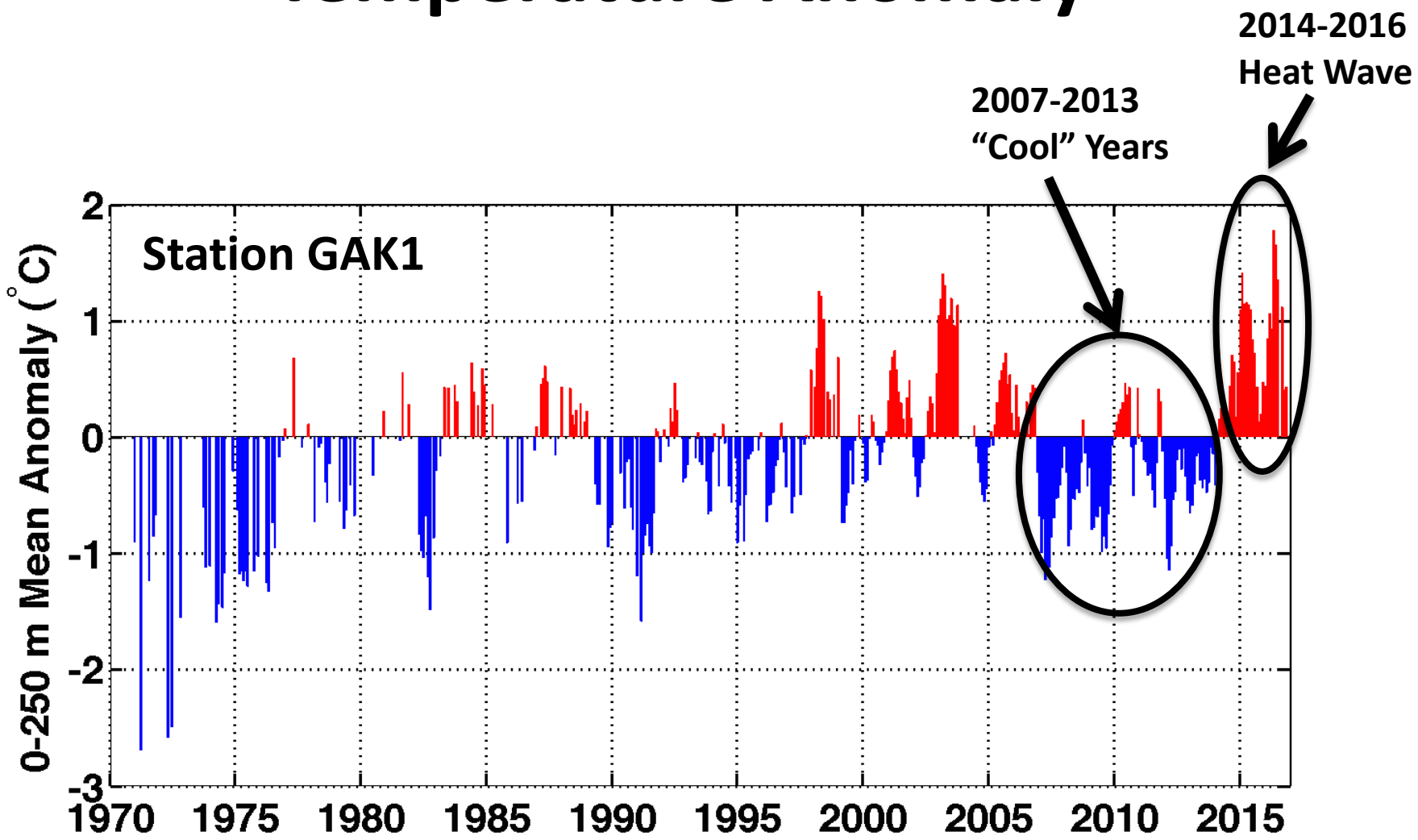
SE Being Sea: Mooring M2 Temperature Anomalies



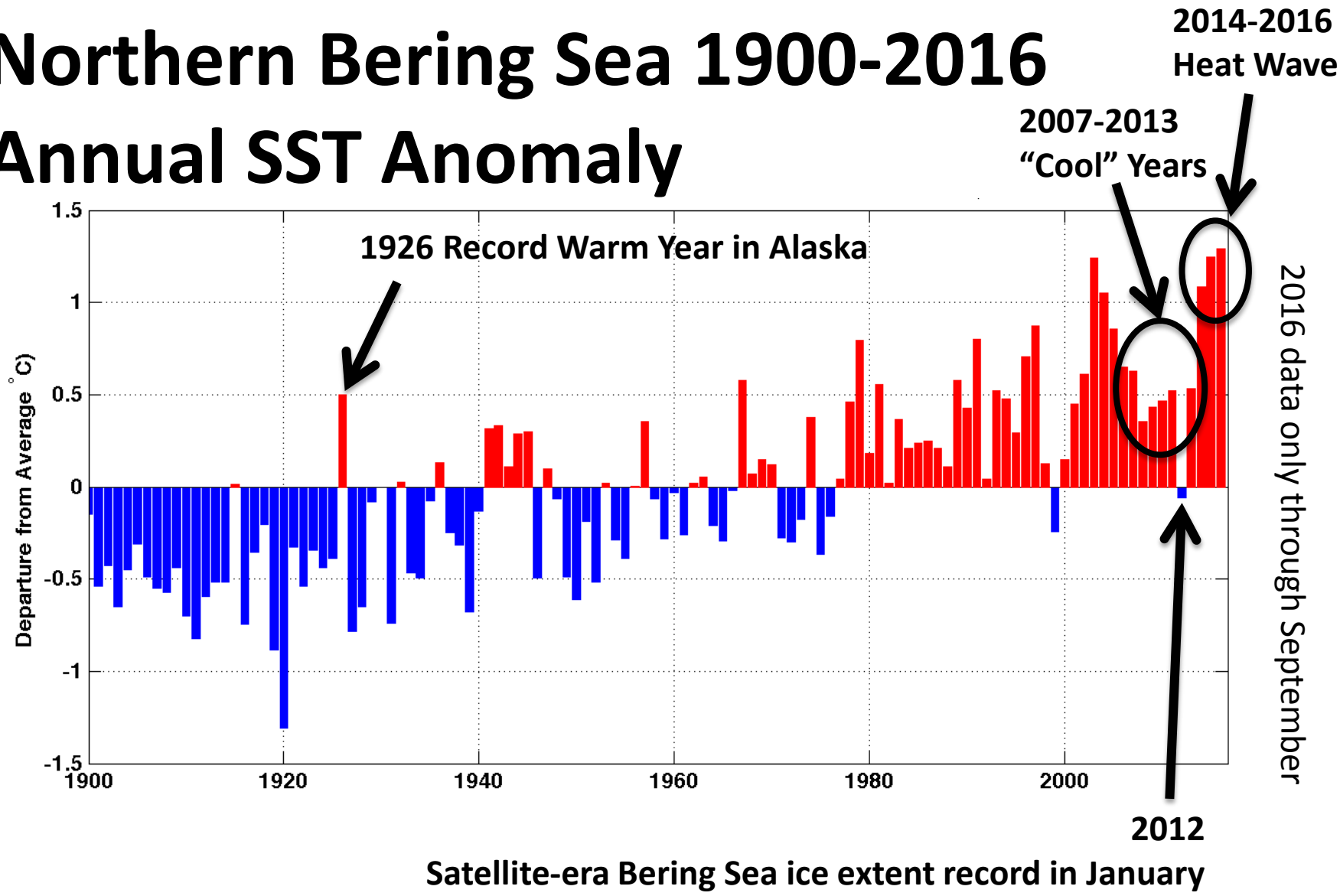
[Stabeno et al., 2012]

M2 record of warm/cool intervals
is coherent with other N. Pacific time series….

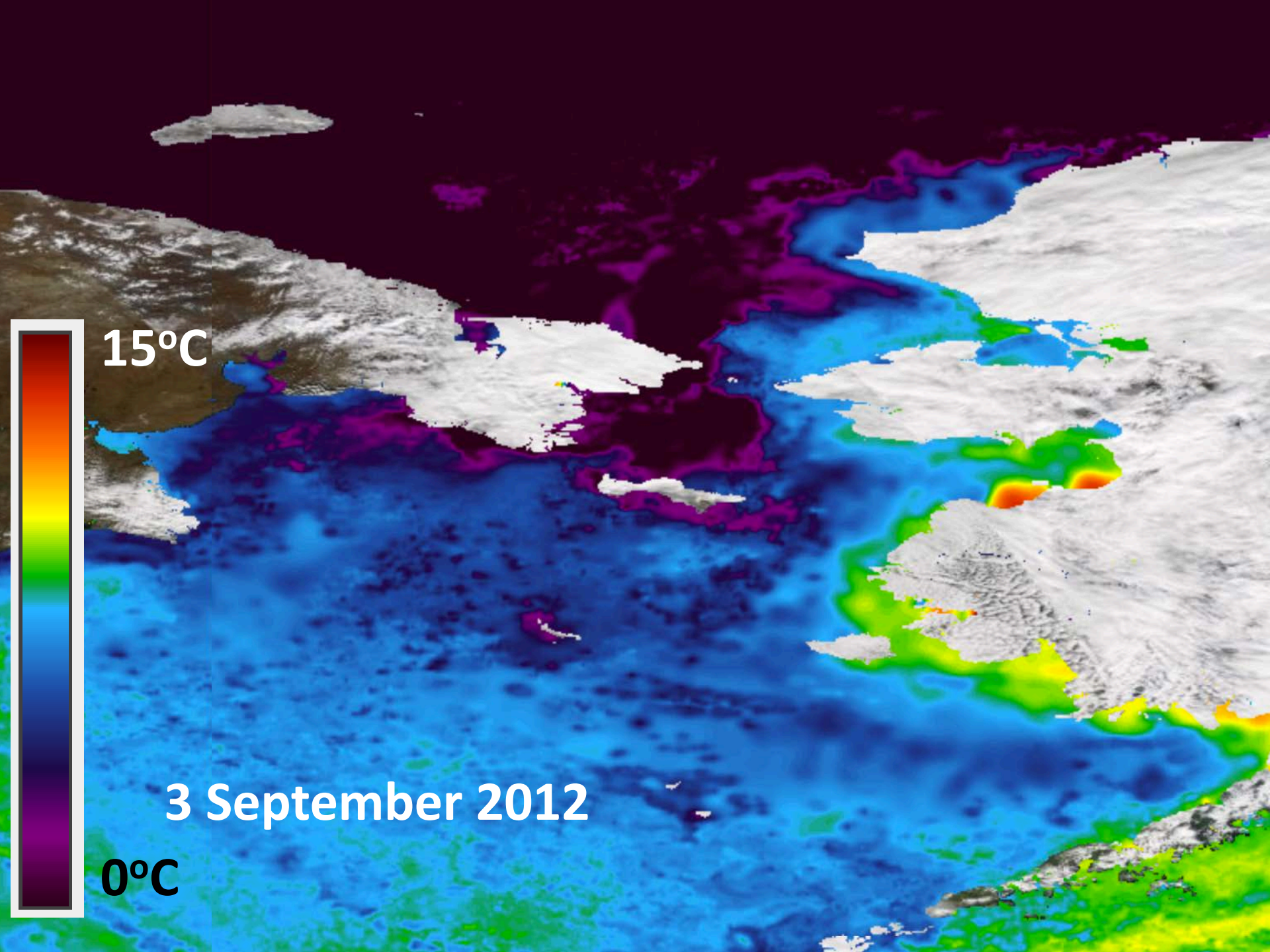
Coastal Gulf of Alaska Temperature Anomaly

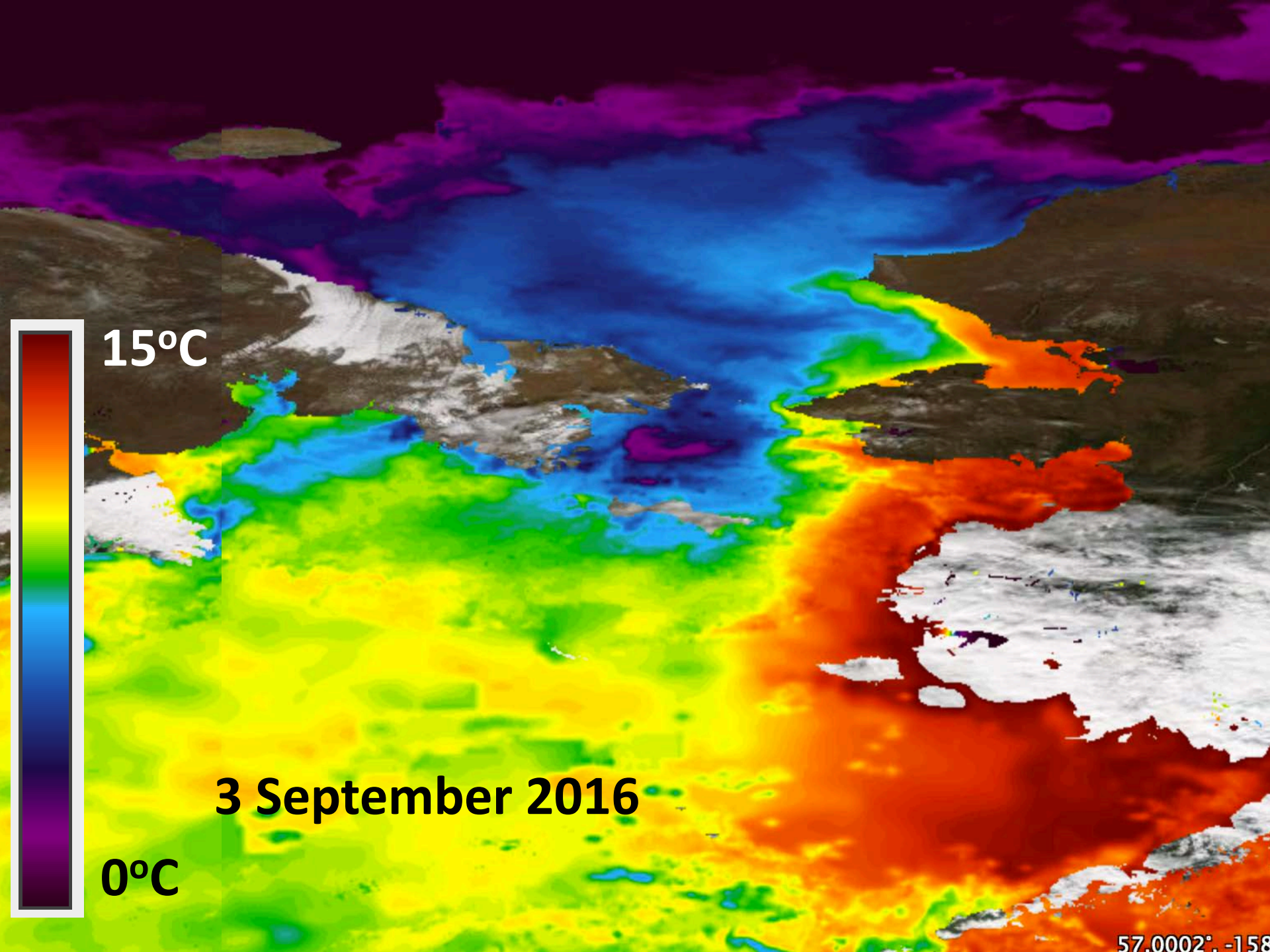


Northern Bering Sea 1900-2016 Annual SST Anomaly

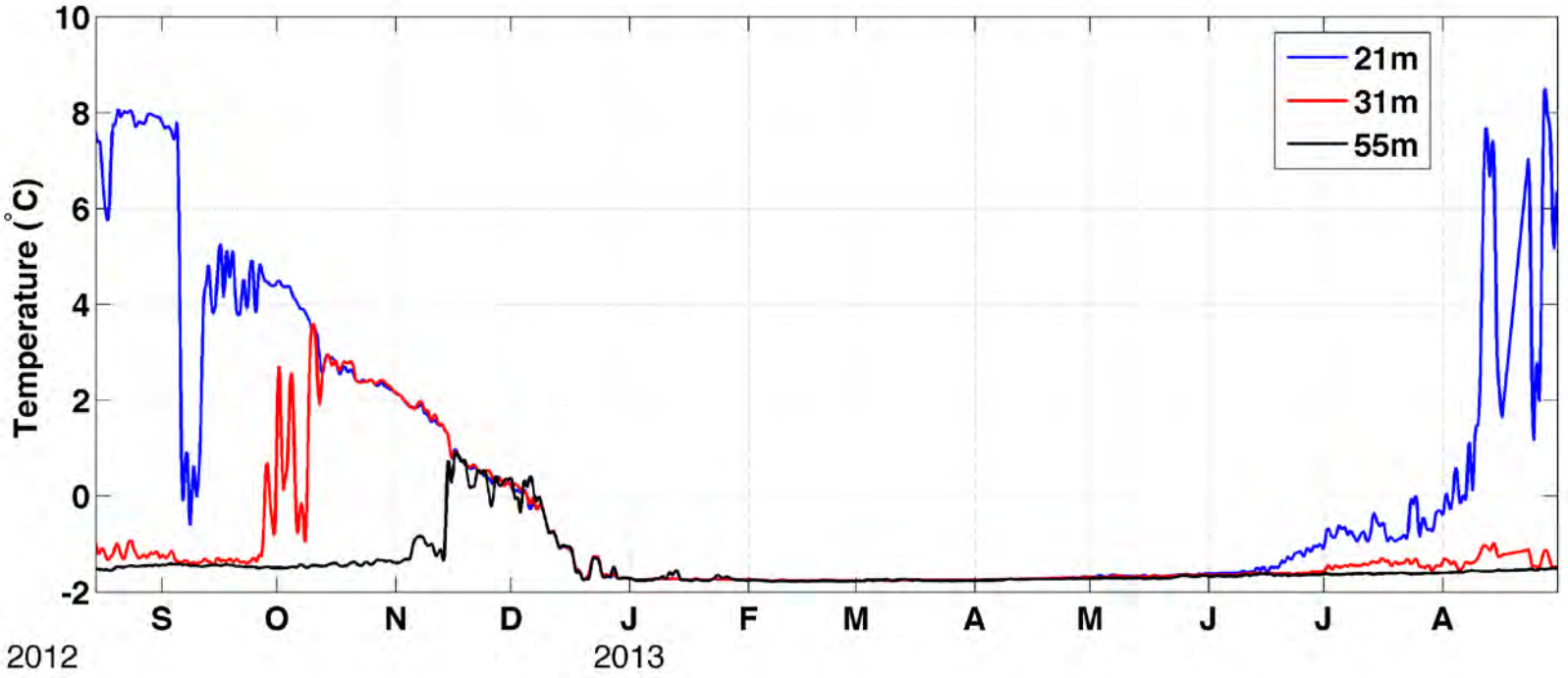


[ERSST.v3b over 60-66N, 175E to 160W]


15°C
0°C
3 September 2012

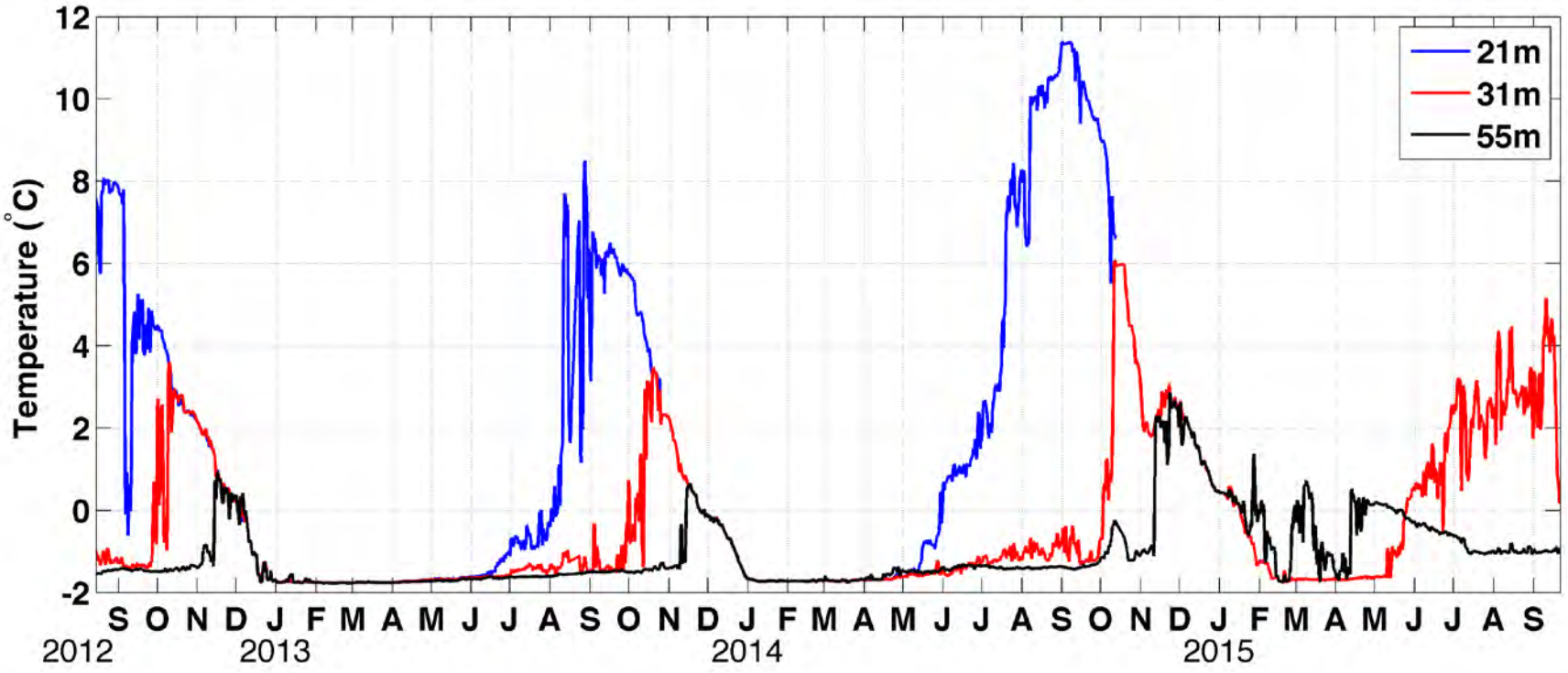

15°C
0°C
3 September 2016
57.0002°, -158

Mooring M8 Temperature



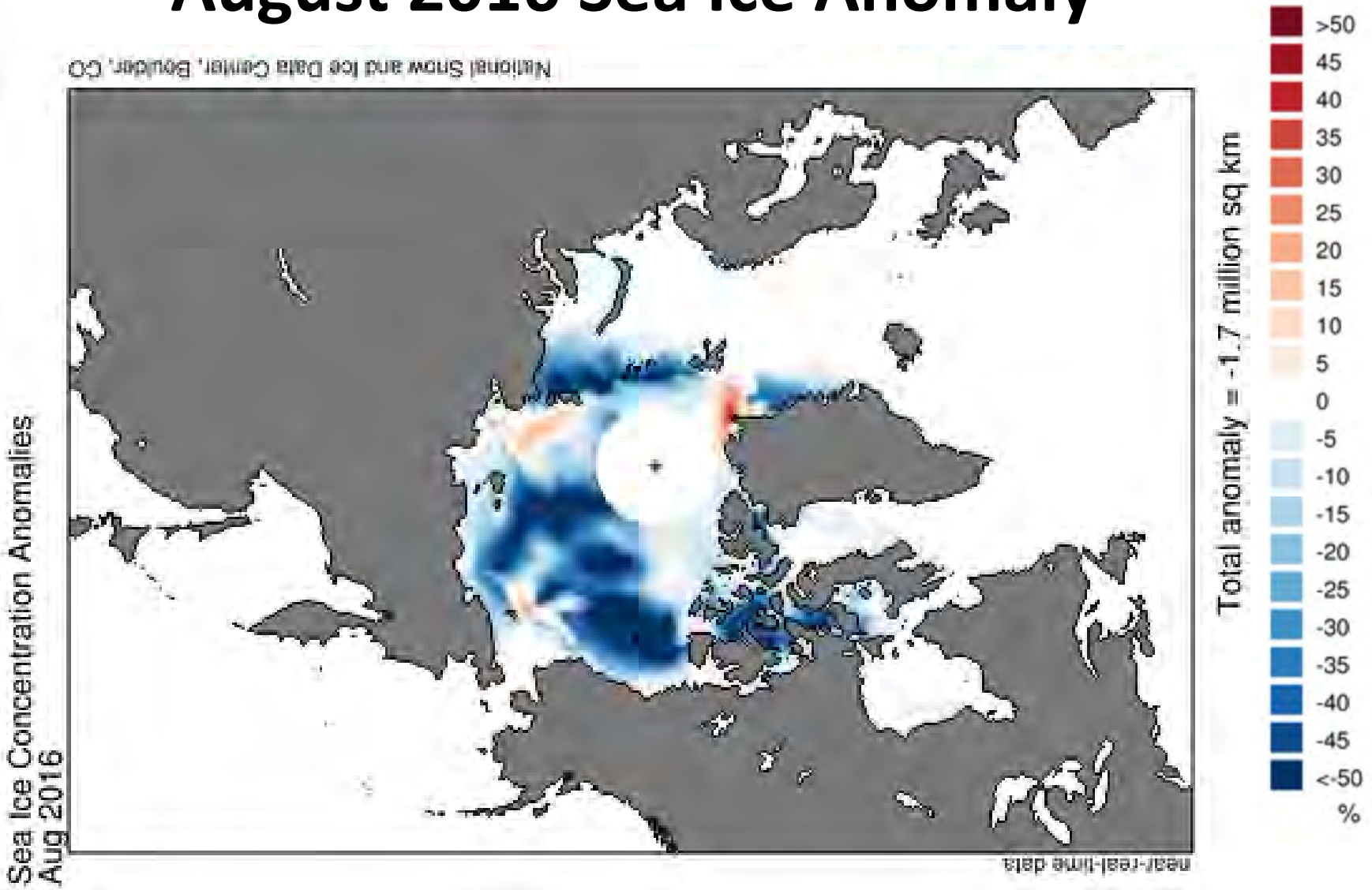
August 2012 - August 2013

Mooring M8 Temperature



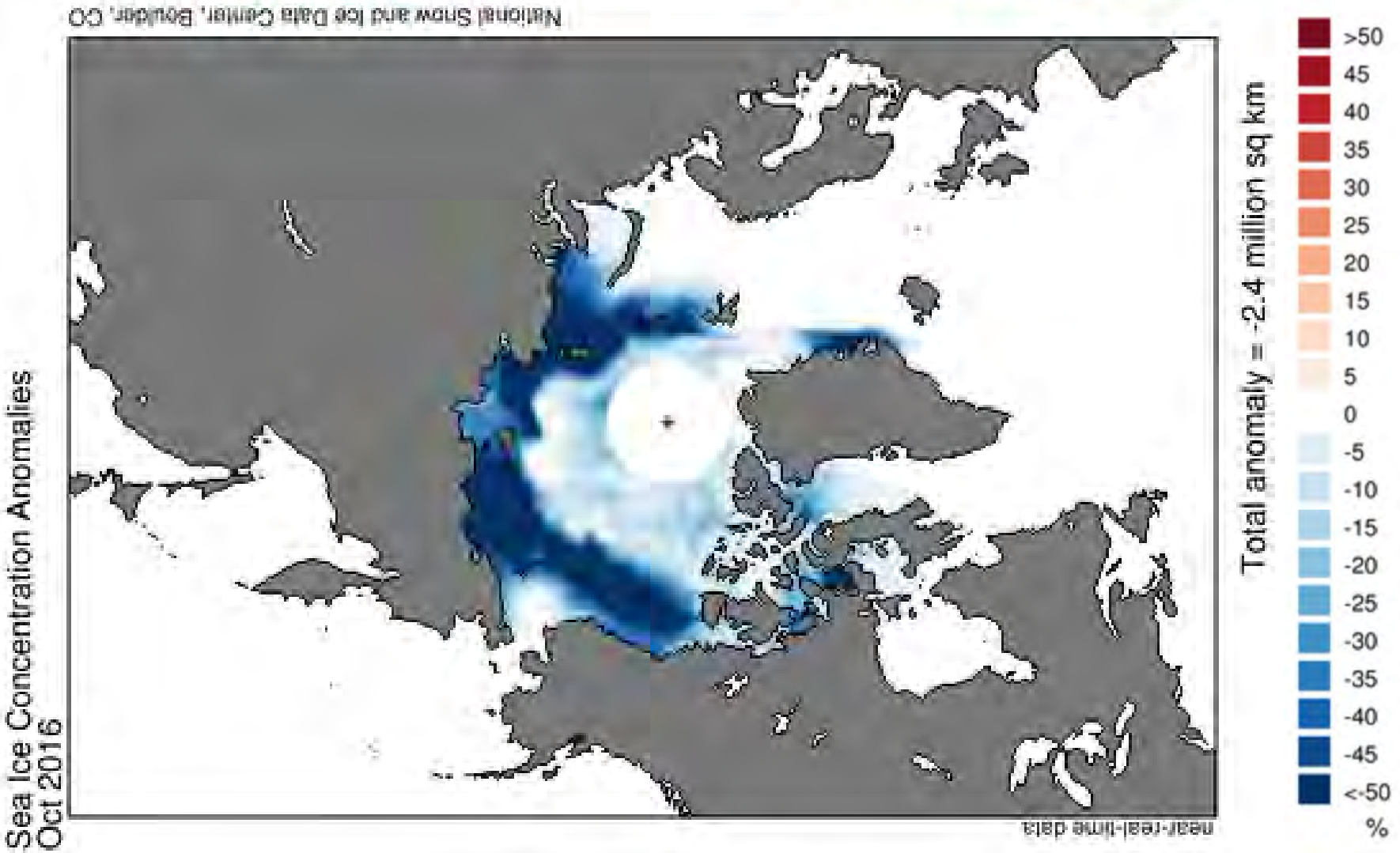
Note lack of freezing temperatures near the seafloor in 2015

August 2016 Sea Ice Anomaly



[NSIDC]

October 2016 Sea Ice Anomaly



[NSIDC]

Recap

- Excellent CTD coverage across the entire Northern Bering Sea in first decade-plus of 2000 millenium. Great value in combined Russian-US datasets.
- Mean thermohaline fields reflect the important regional drivers: Pacific-Arctic pressure head, Anadyr Current, River Discharges, Winter Freezing
- Individual cross-sections provide insight to the roles of advection and mixing
- Recent thermal conditions appear to be outside the envelope of nearly the entire last century.