

# Summer water masses and fish communities in the north-western Bering and western Chukchi Seas in 2003-2010

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# **Introduction**

- The northern Bering and southern Chukchi Seas region may be considered as the 'bridge' between the Pacific and Arctic Oceans. In summer, warm currents exist there which bring relatively warm Pacific waters into Arctic Ocean
- This process is also responsible for the nutrients and organisms transport, including fish
- During the past 15 years, substantial climate change occurred in the region
- In the first decade of the 21<sup>st</sup> century, TINRO-Center conducted 4 field campaigns aimed at multidisciplinary physical-biological research of the north-western Bering and south-western Chukchi Seas (2003, 2007, 2008, and 2010)
- The main objective of these field works were evaluation of the modern state of the ecosystem, as it expected to change under changing climate

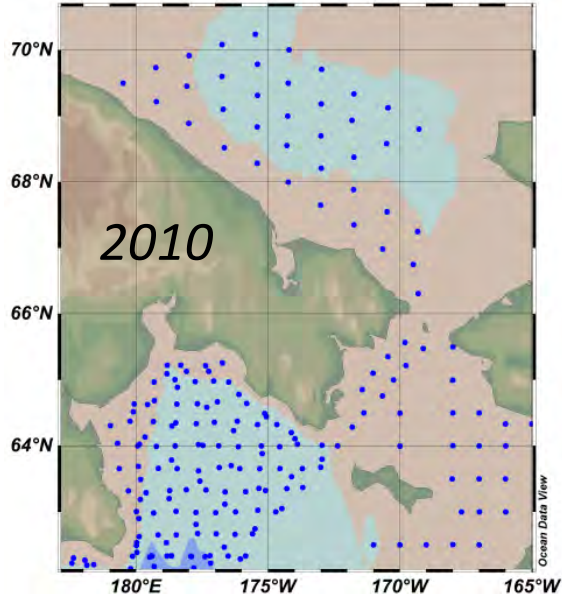
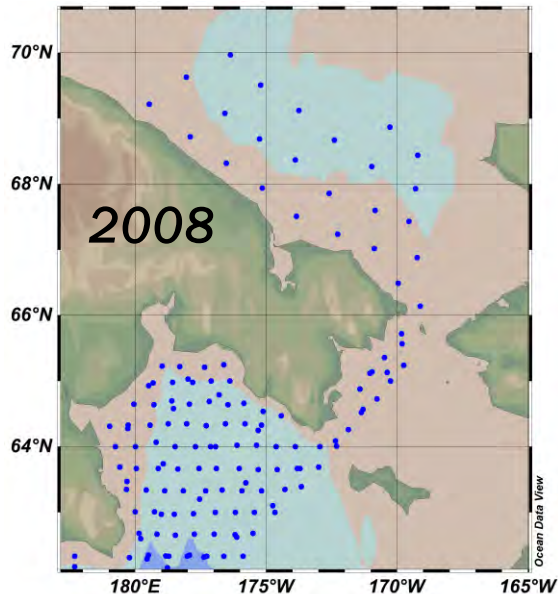
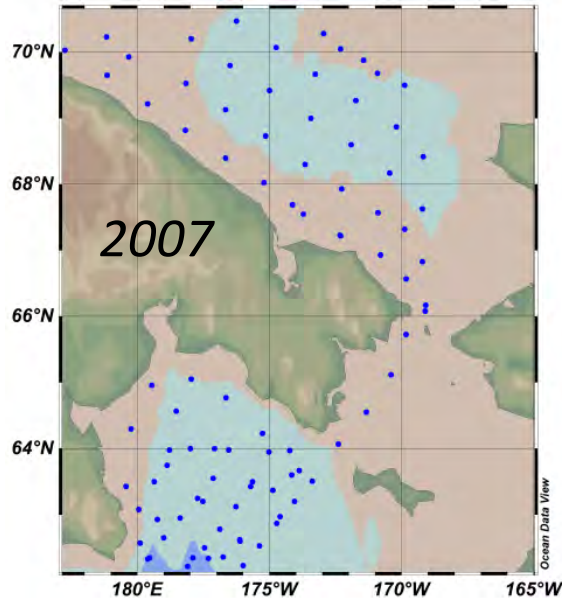
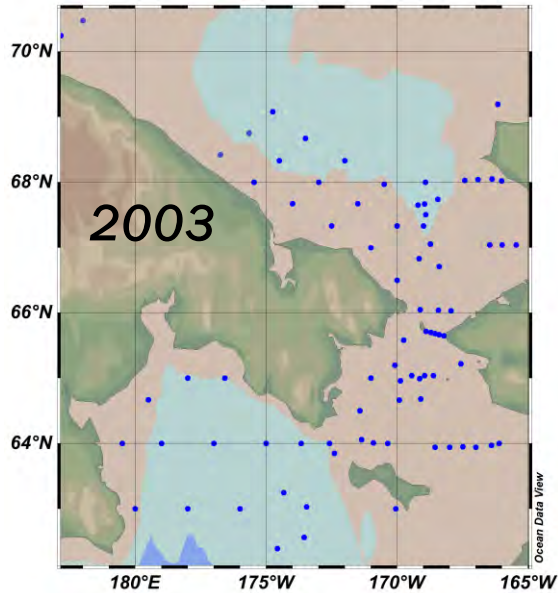
# **Introduction**

Objective – to evaluate the influence of water masses on commercial fish distribution in the north-western Bering – southwestern Chukchi Seas in 2003, 2007, 2008, and 2010

The study focuses on:

- Identification of water masses of the northern Bering – southern Chukchi Seas based on data of TINRO-Center (Russia) and NODC (USA)
- comparison of years in regard to the water mass distribution
- evaluation of role of the Navarin (Anadyr) current in Pacific water transport into the Arctic
- investigation of multiannual variability of temperature field in the Gulf of Anadyr and identification of types of years (warm, normal, cold) relative to the mean climatic state of 1990-2015
- analysis of association of fish species to the water masses in 2003, 2007, 2008, and 2010

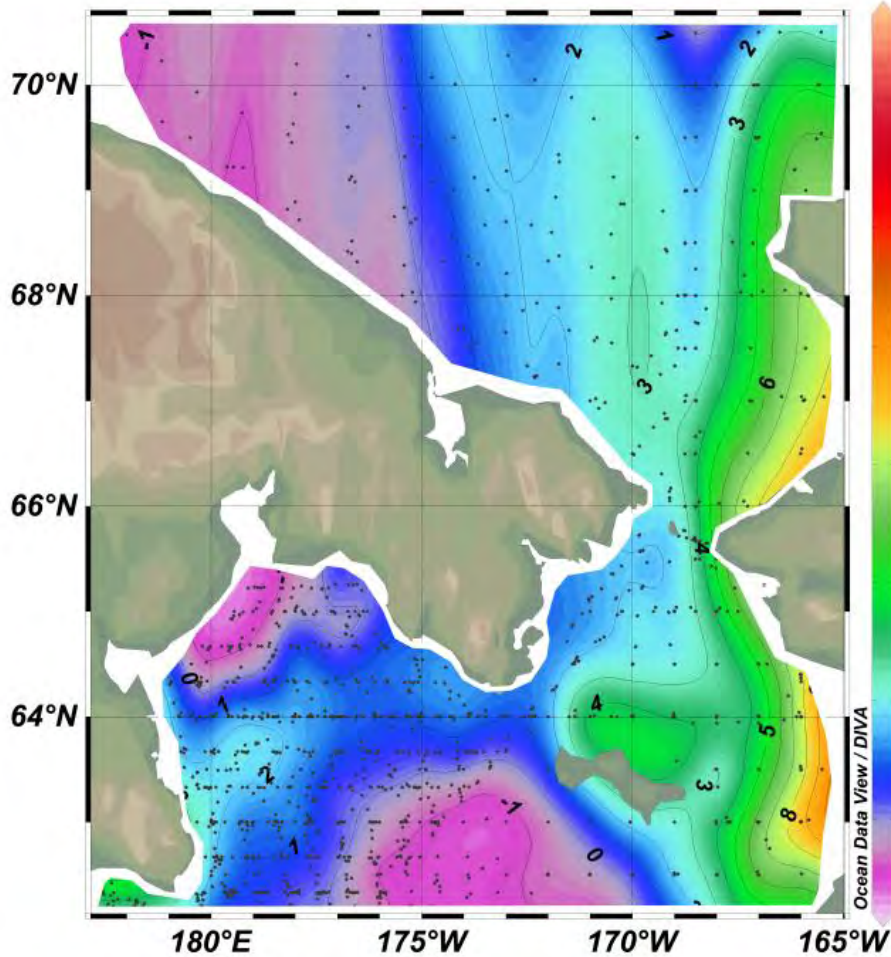
# Data



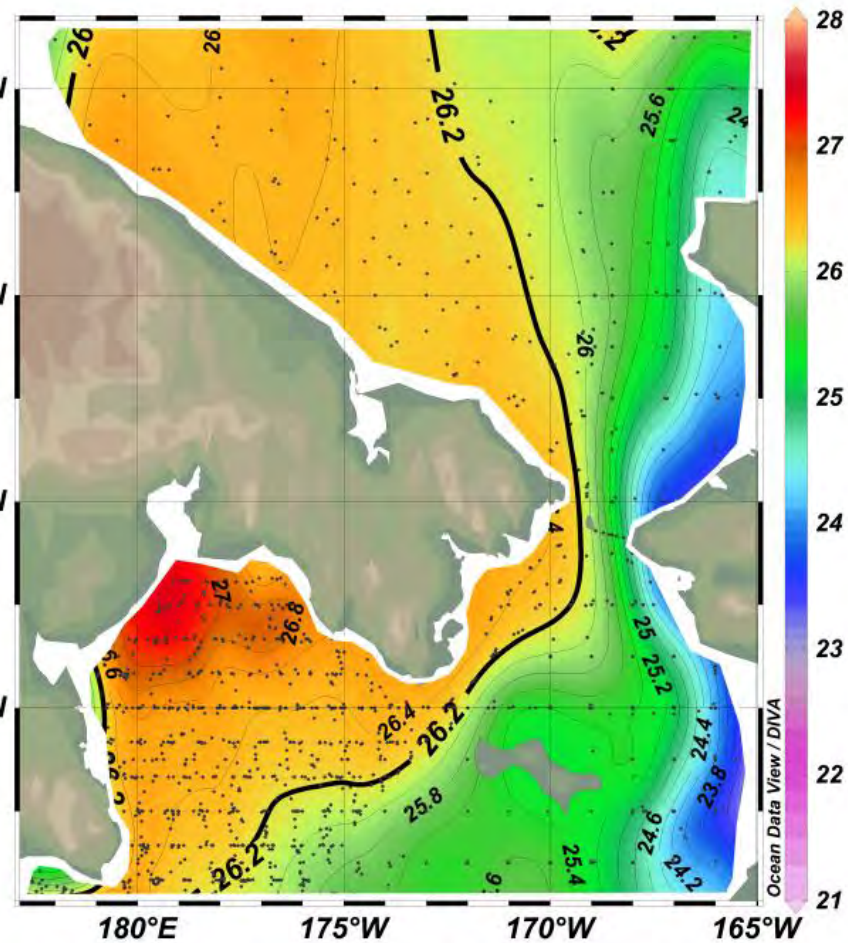
- CTD data from both TINRO-Center (Russia) and WOD NODC (USA)
- During the TINRO-Center cruises, CTD stations are made in prior to the trawling
- In the Bering Sea, pelagic trawling was performed in all years, and bottom trawling in 2008 and 2010
- In the Chukchi Sea, pelagic trawling has been done in 2003, 2007, and 2008, and the bottom trawling in 2010
- Trawl mouth was 30 m high during pelagic, and 3-4 m high during bottom trawling



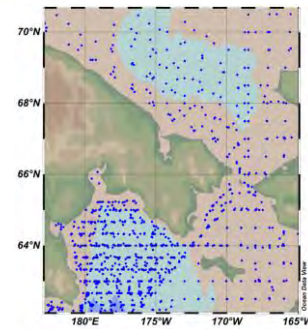
# Data: combination of 2000-2015



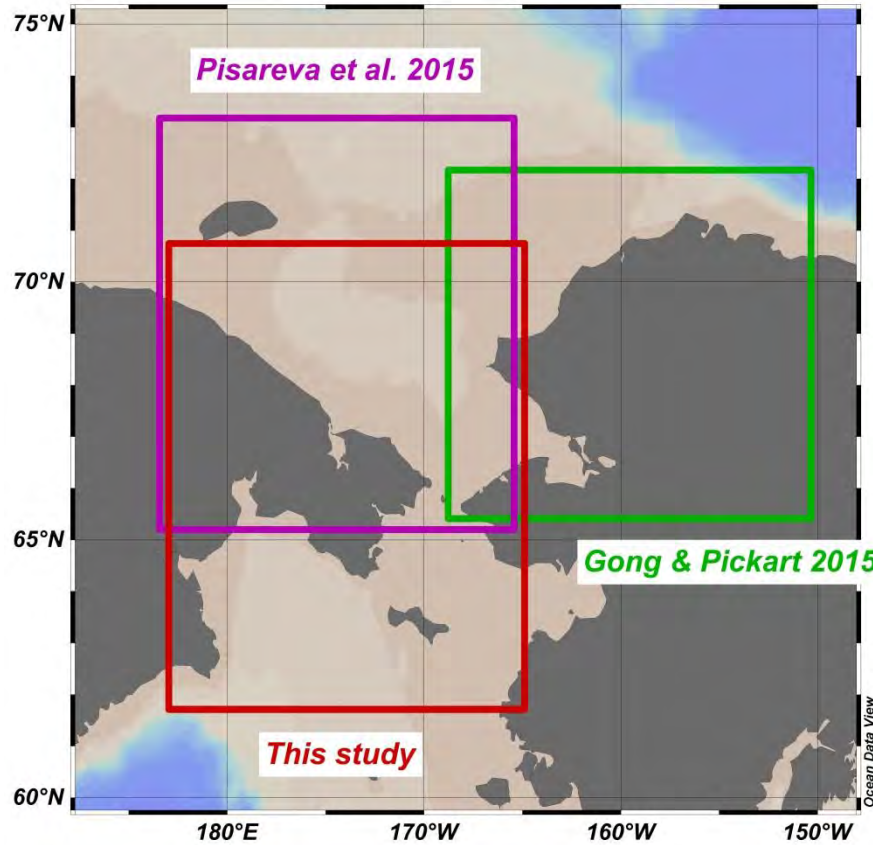
T °C, bottom layer



$\sigma$ , bottom layer



# Methods: classification of water masses



*Bering* Summer W  
 Newly ventilated Pacific winter W  
 Remnant Pacific winter W  
 Atlantic W  
 Alaska Coastal W  
 Melt W  
 + Siberian Coastal W  
 (Pisareva et al. 2015)

'Anadyr W'  
 ( $T > 1$ ,  $S > 33$ )  
 'Bering Shelf W'  
 ( $0.5 < T < 2.0$ ,  $32.5 < S < 32.8$ )  
 'Alaska Coastal W'  
 ( $S < 32$ )

(Coachman et al. 1975)

Chukchi Summer W  
 Winter W  
 Remnant winter W  
 Atlantic W  
 Alaska Coastal W

(Brugler et al. 2014)

Chukchi Summer W  
 Newly ventilated Pacific winter W  
 Remnant Pacific winter W  
 Atlantic W  
 Alaska Coastal W  
 + Melt W – early and late

(Gong & Pickart 2015)



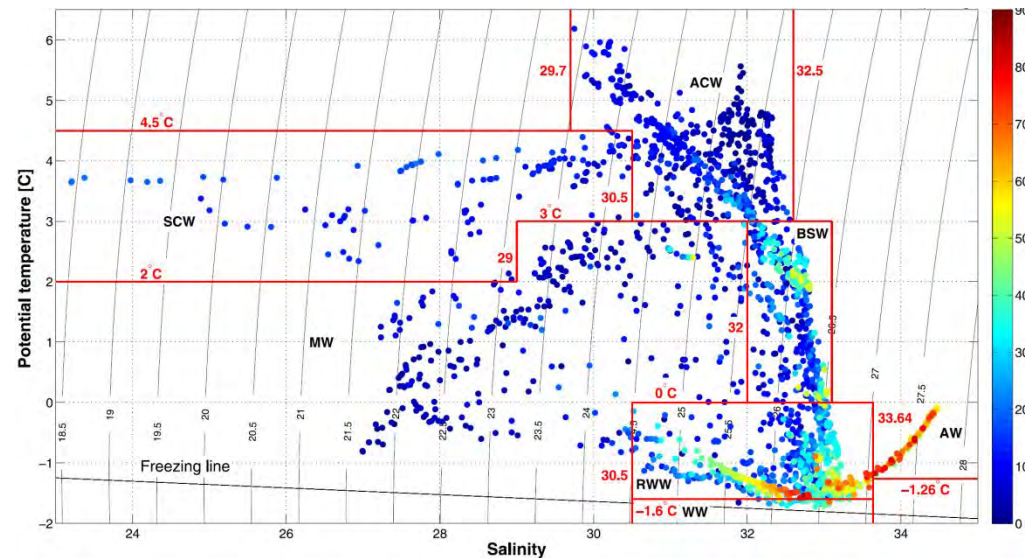
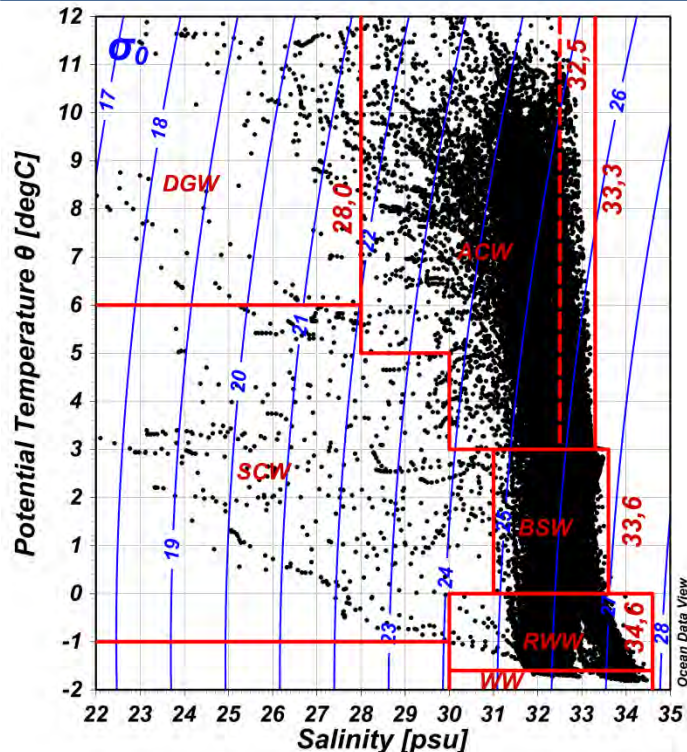


# Methods: classification of water masses

Bering Summer W  
 Newly ventilated Pacific winter W  
 Remnant Pacific winter W  
~~Atlantic W~~  
 Alaska Coastal W + *Anadyr Coastal W*  
~~Melt W~~  
 Siberian Coastal W (includes Melt W)  
 + *Gulfs W*

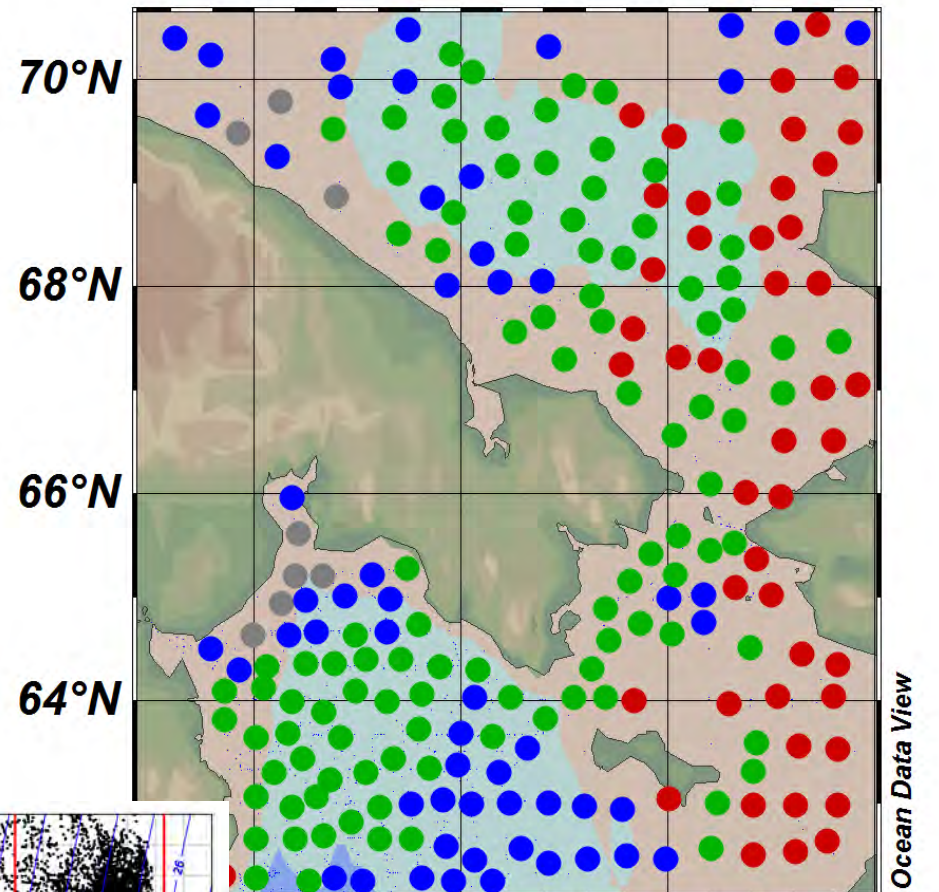
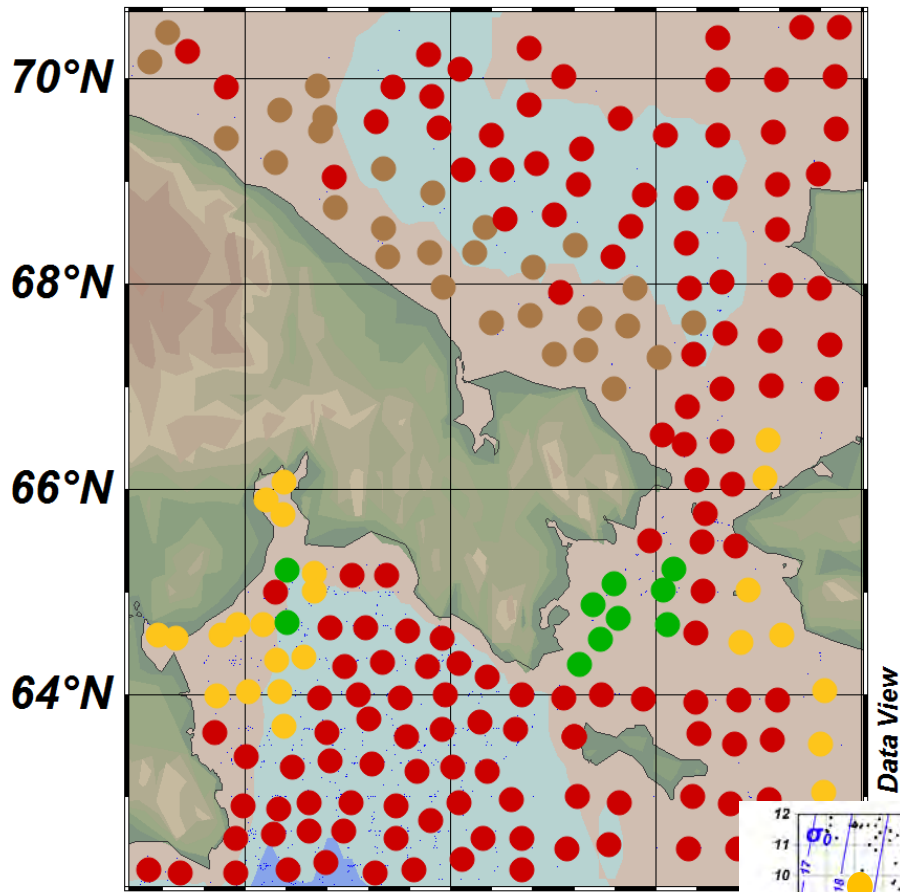
*Bering* Summer W  
 Newly ventilated Pacific winter W  
 Remnant Pacific winter W  
 Atlantic W  
 Alaska Coastal W  
 Melt W  
 + Siberian Coastal W

(Pisareva et al. 2015)

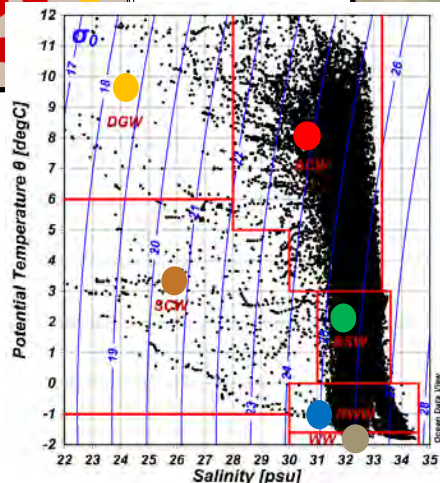


Water masses in July-September 2000-2015.

# Data: combination of 2000-2015



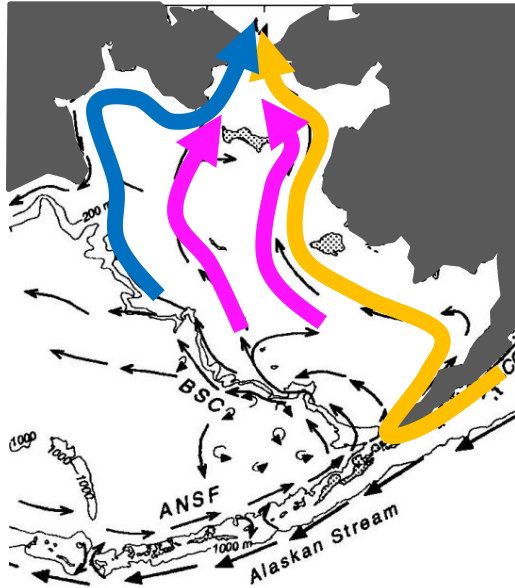
- ACW – Alaska (+Anadyr) coastal W
- SCW – Siberian coastal water
- DGW – Diluted gulfs water
- BSW – Bering Summer water



- ACW – Alaska coastal water
- BSW – Bering Summer water
- RWW - Remnant Pacific WW
- WW - Newly vent. Pacific WW



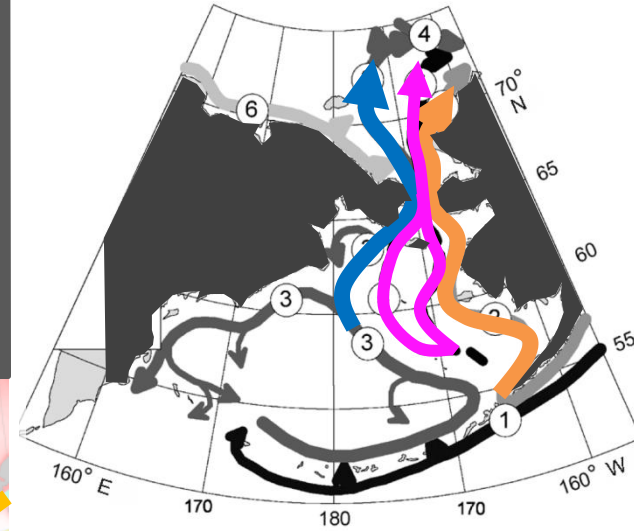
# Schemes of currents



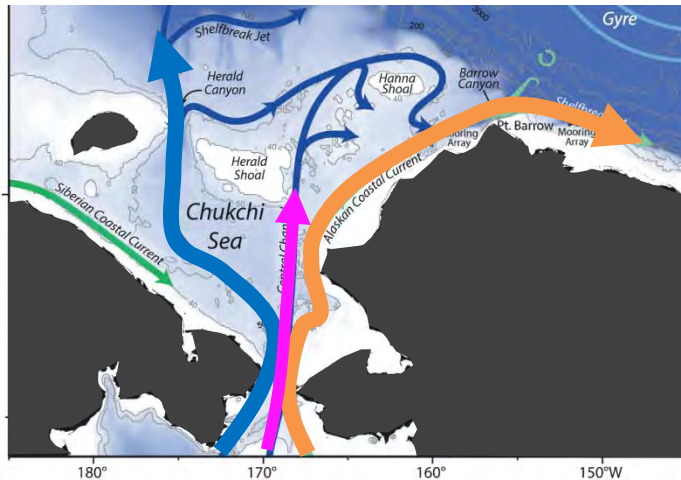
(Woodgate et al. 2015  
after Stabeno et al. 1999)



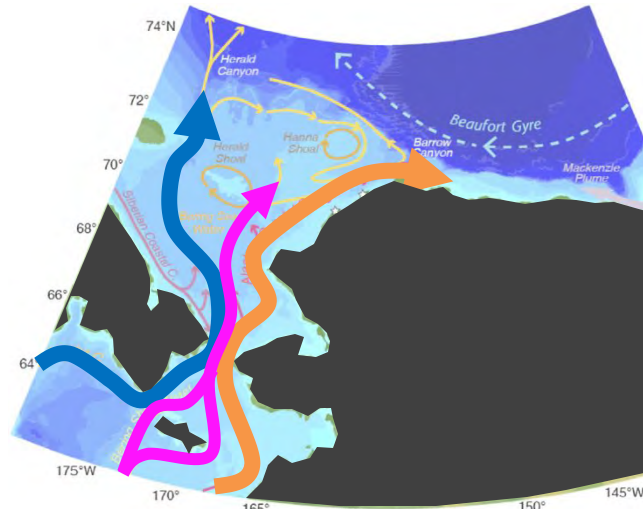
(Danielson et al. 2011)



(Mastrykov 2012)



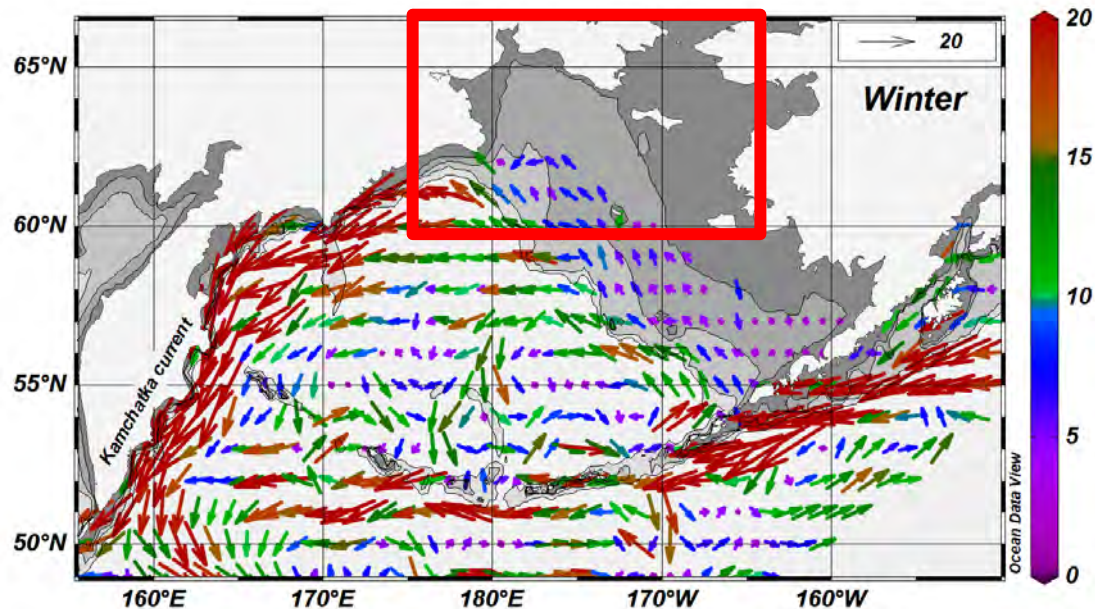
(Brugler et al. 2014)



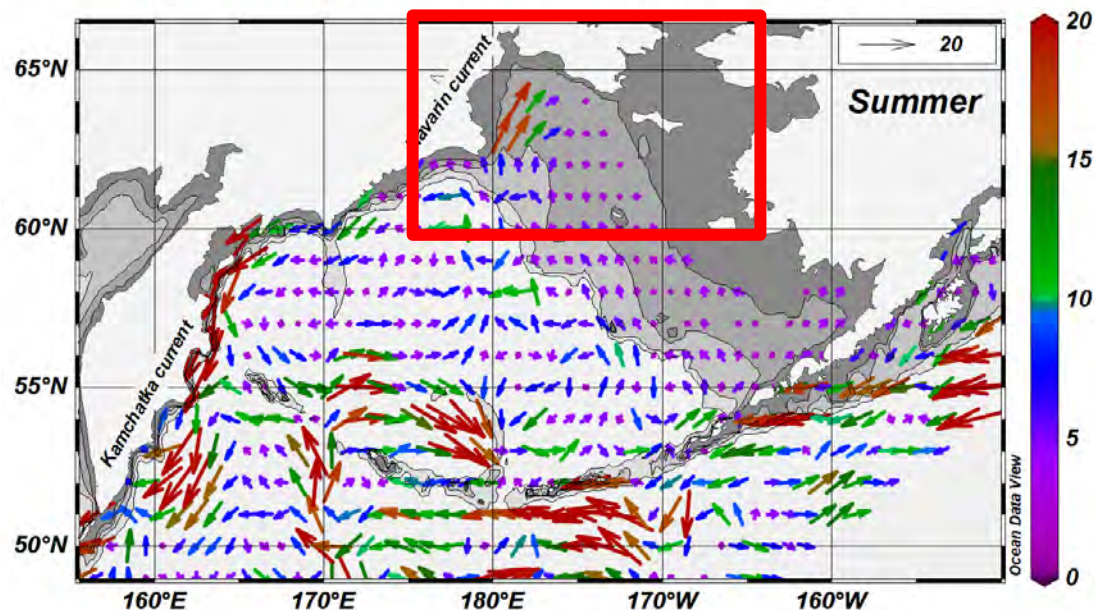
(Wood et al. 2015)

- Navarin (Anadyr) W.
- Alaskan Coastal W.
- Bering Shelf W.

# Currents from holey-sock drifters at 40 m

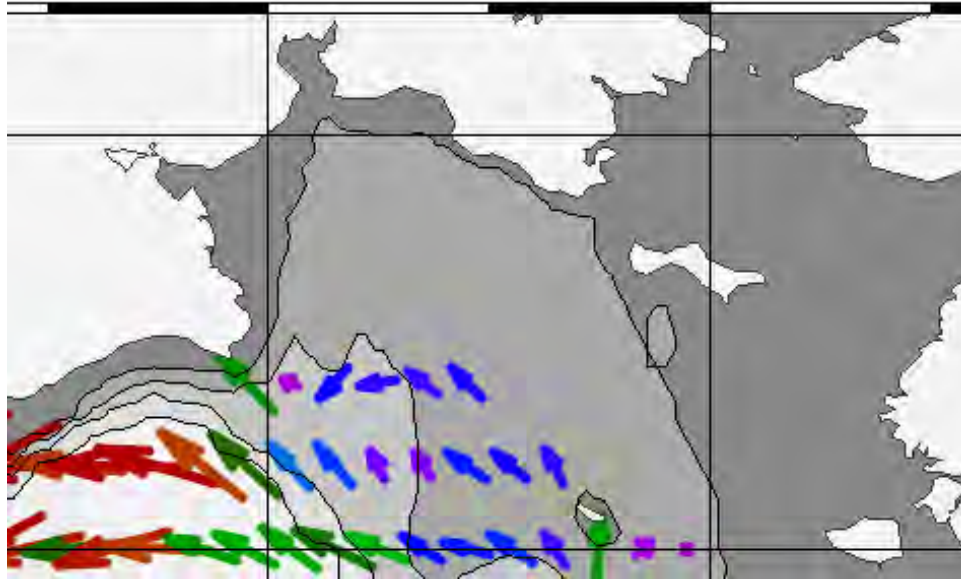


Winter:  
No Navarin  
Current

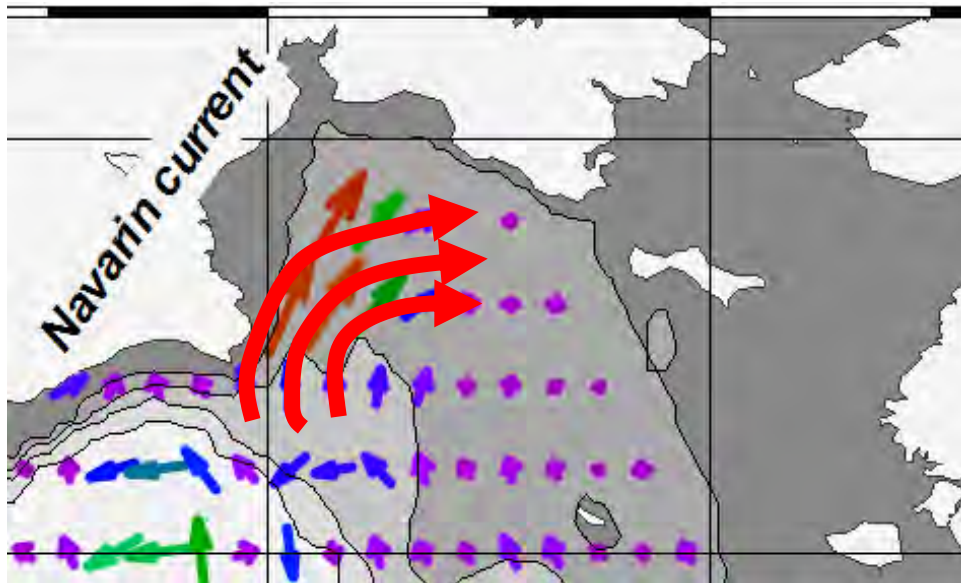


Summer:  
Navarin C. is  
evident in  
multiyear  
record

# Currents from holey-sock drifters at 40 m



Winter:  
No Navarin  
Current



Summer:  
Navarin C. is  
evident in  
multy-year  
record

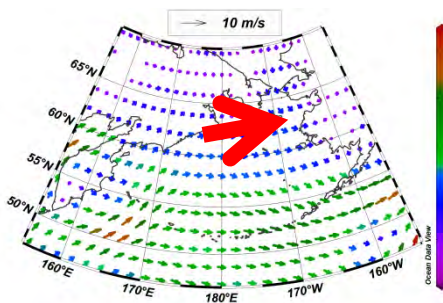
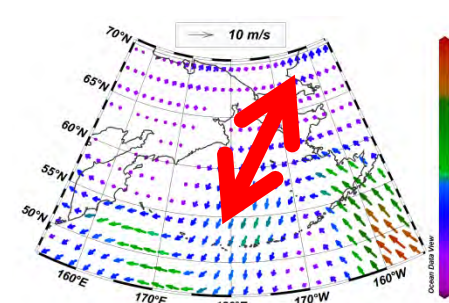
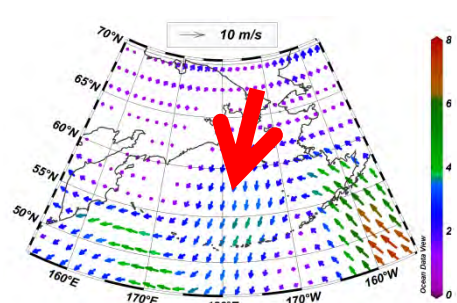
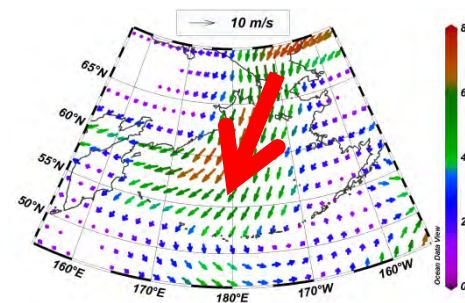


# Navarin (Anadyr) current evolution in spring

## Case of May-Jun 208: sea ice field evolution



## Case of May-Jun 2008: wind direction



1-10 May 2008

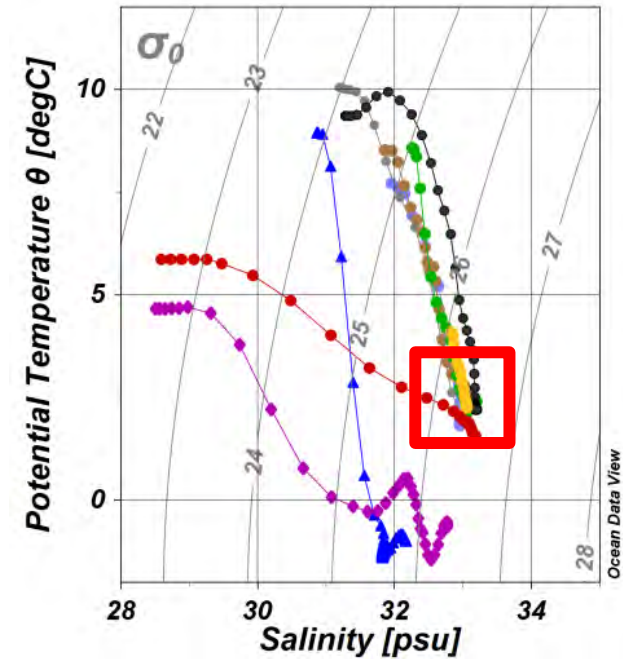
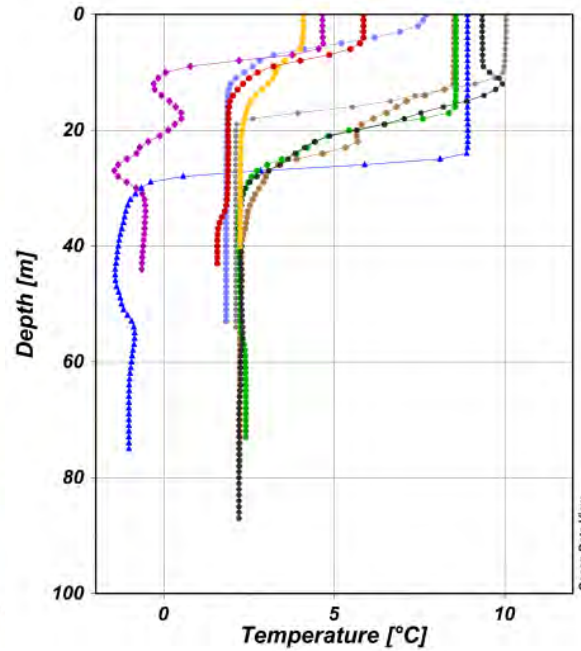
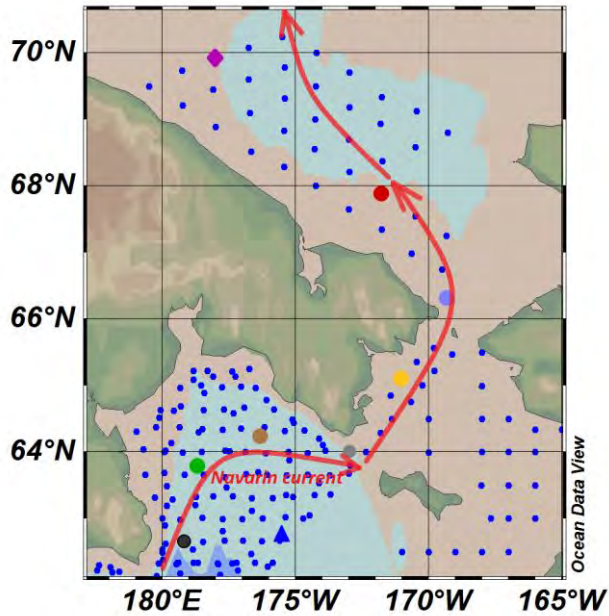
11-20 May 2008

21-31 May 2008

1-10 Jun 2008

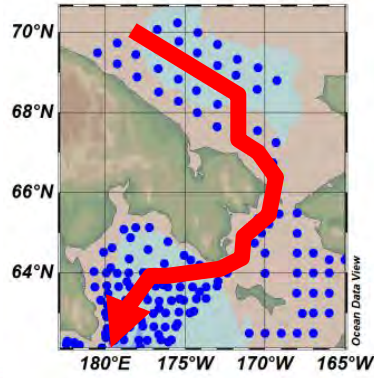
# Navarin (Anadyr) current T,S-structure

August-September 2010

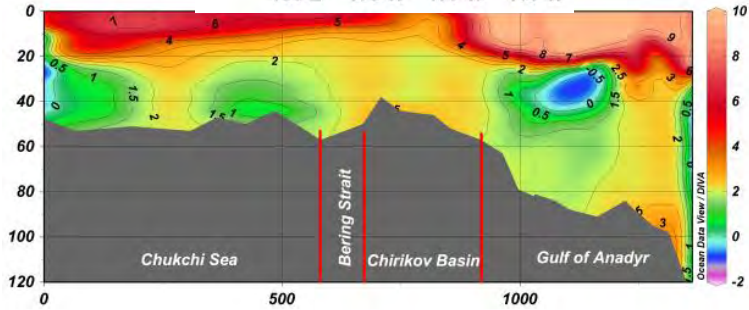
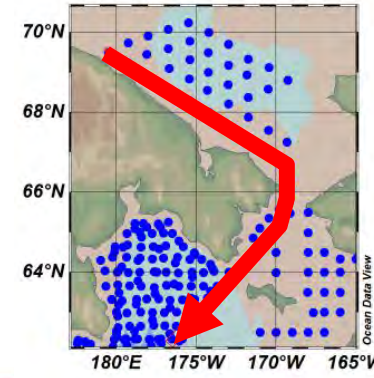




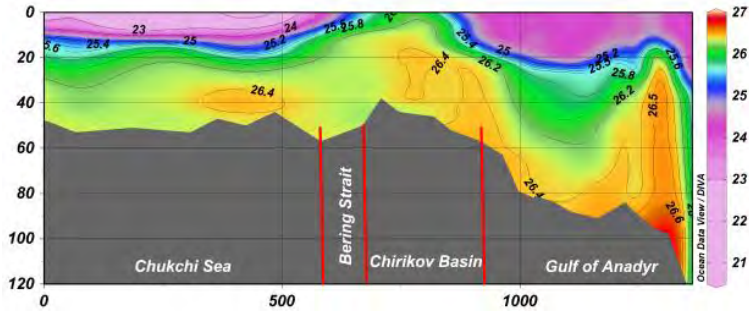
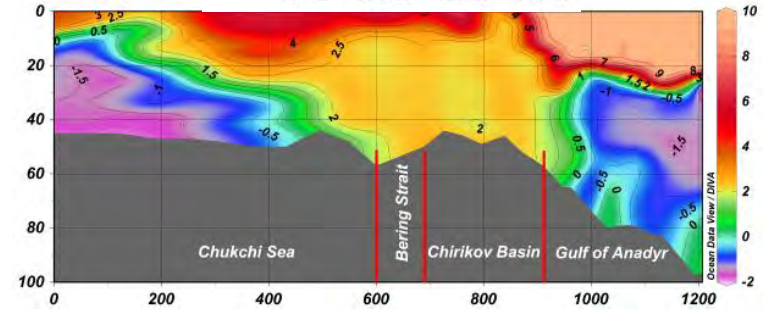
# Navarin (Anadyr) current T,S-structure



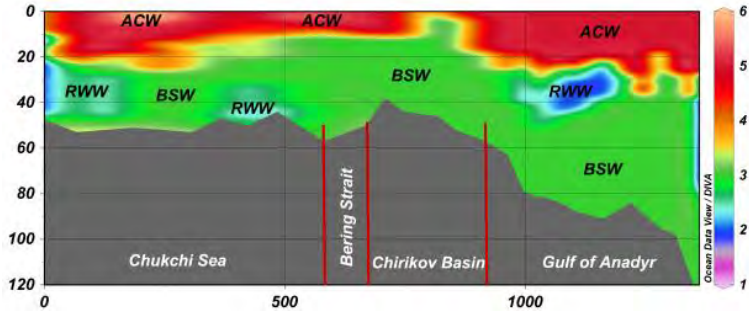
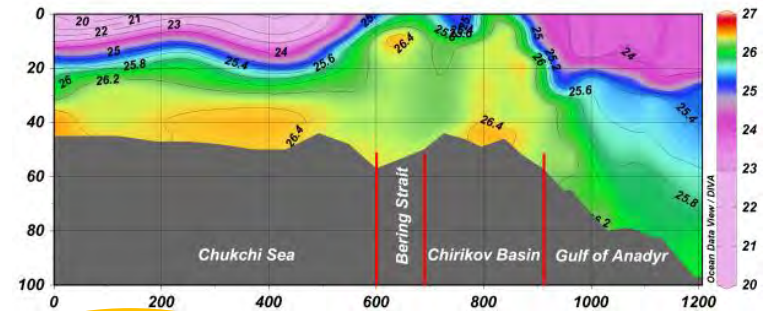
Summer 2010



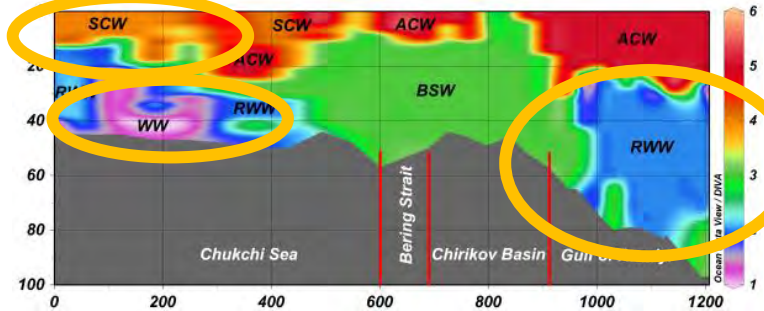
T



$\sigma$



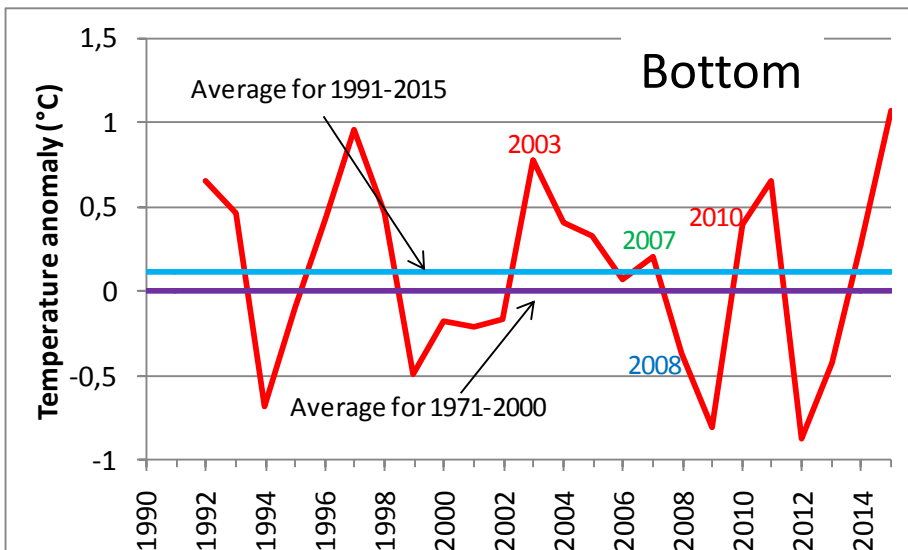
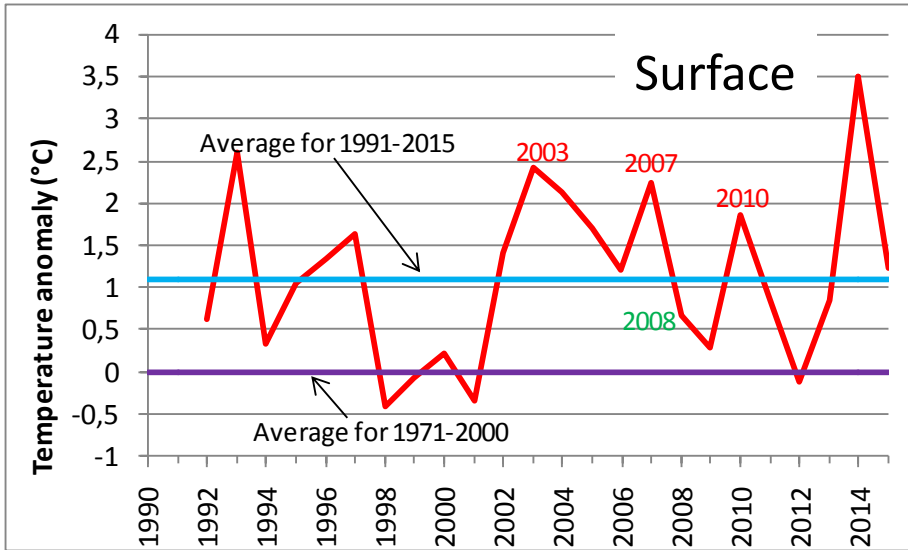
WM





# Warm/cold years relative to 1991-2015

## Gulf of Anadyr



# ***Warm/cold years relative to 1991-2015***

## **Gulf of Anadyr**

Year	Surface	Bottom
2003	Warm	Warm
2007	Warm	Normal
2008	Normal	Cold
2010	Warm	Warm

## **Chukchi Sea**

Year	Surface	Bottom
2003	Cold	Warm
2007	Warm	Warm
2008	Normal	Normal
	(Luchin, Panteleev 2014)	
2010	Normal	Normal

# *Warm/cold years relative to 1991-2015*

## Gulf of Anadyr

Year	Surface	Bottom
2003	Warm	Warm
2007	Warm	Normal
2008	Normal	Cold
2010	Warm	Warm

## Chukchi Sea

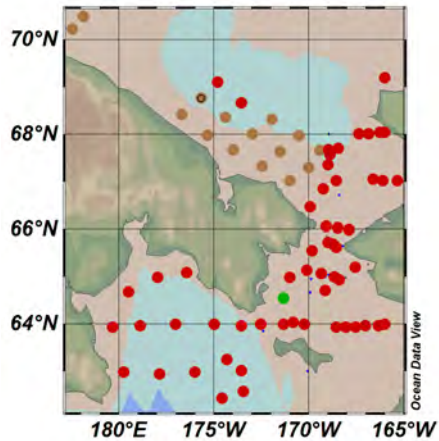
Year	Surface	Bottom
2003	Cold	Warm
2007	Warm	Warm
2008	Normal	Normal
2010	Normal	Normal

(Luchin, Panteleev 2014)

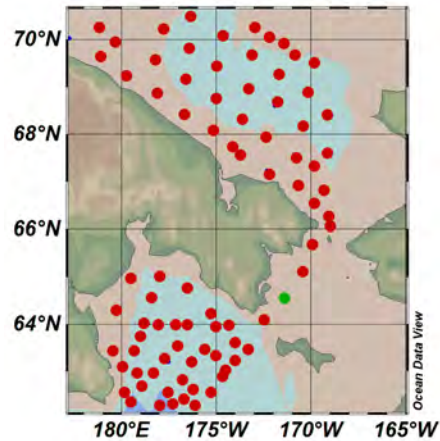


# Water masses at 5 m

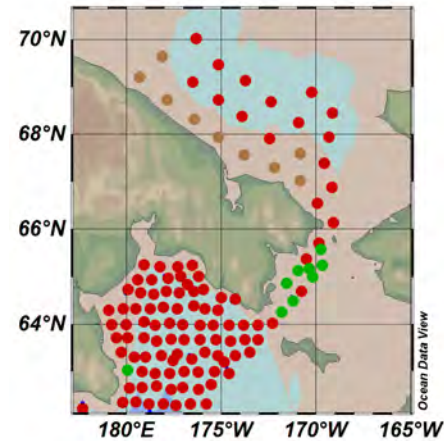
2003



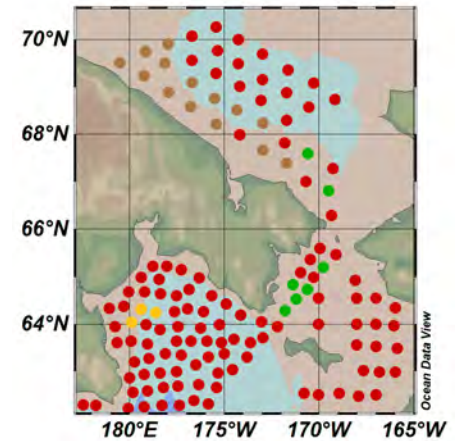
2007



2008



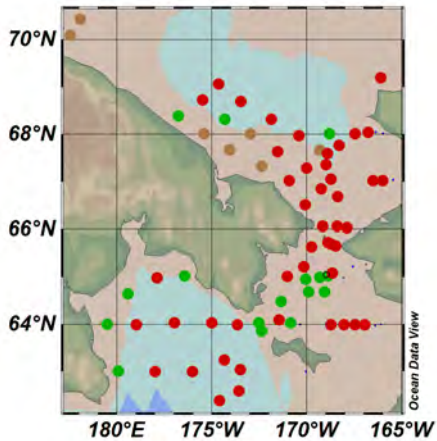
2010



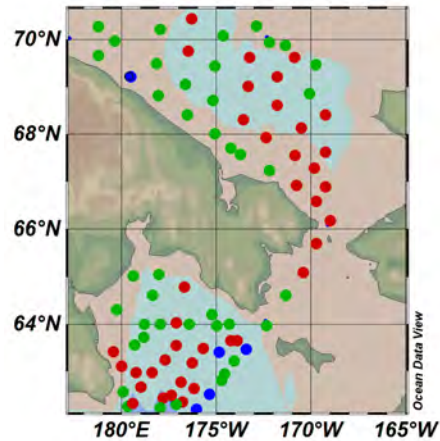
- Alaska (Anadyr) coastal water (**ACW**)
- Siberian coastal water (**SCW**)
- Bering Summer water (**BSW**)
- Diluted gulf water (**DGW**)

# Water masses at 20 m

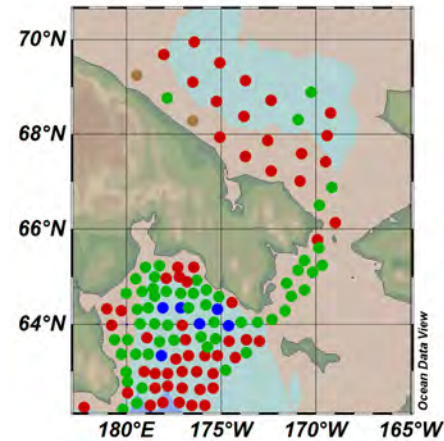
2003



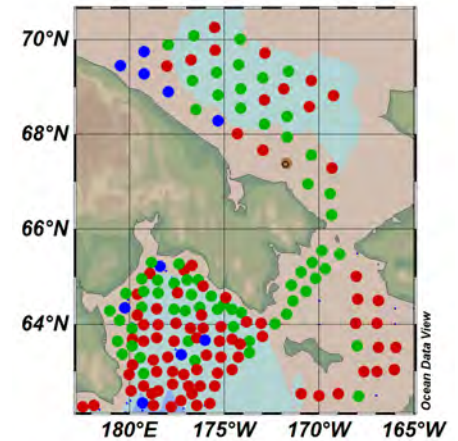
2007



2008

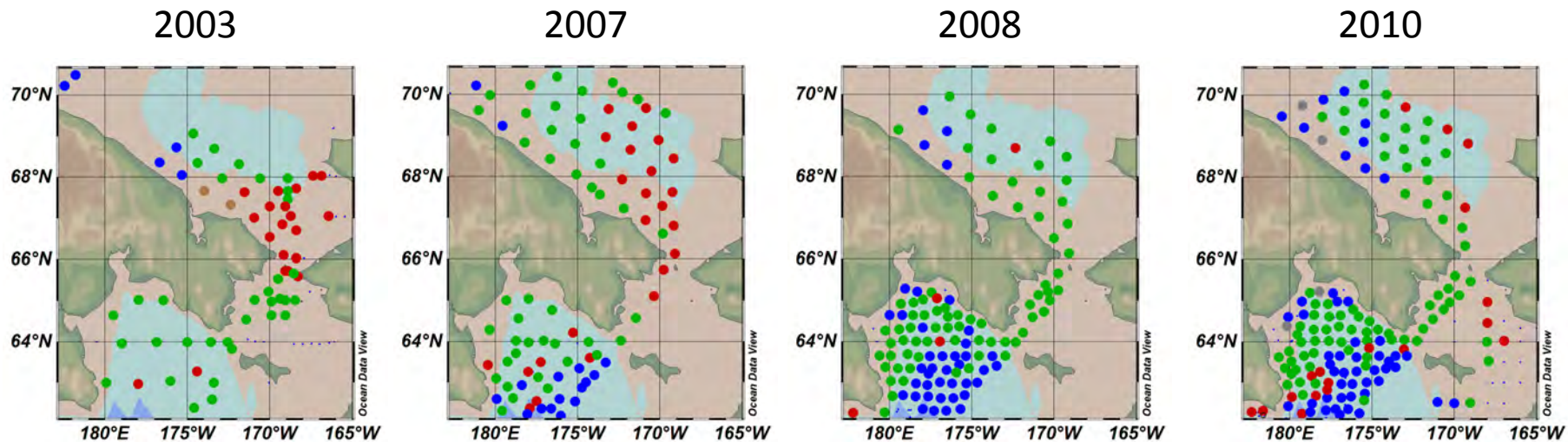


2010



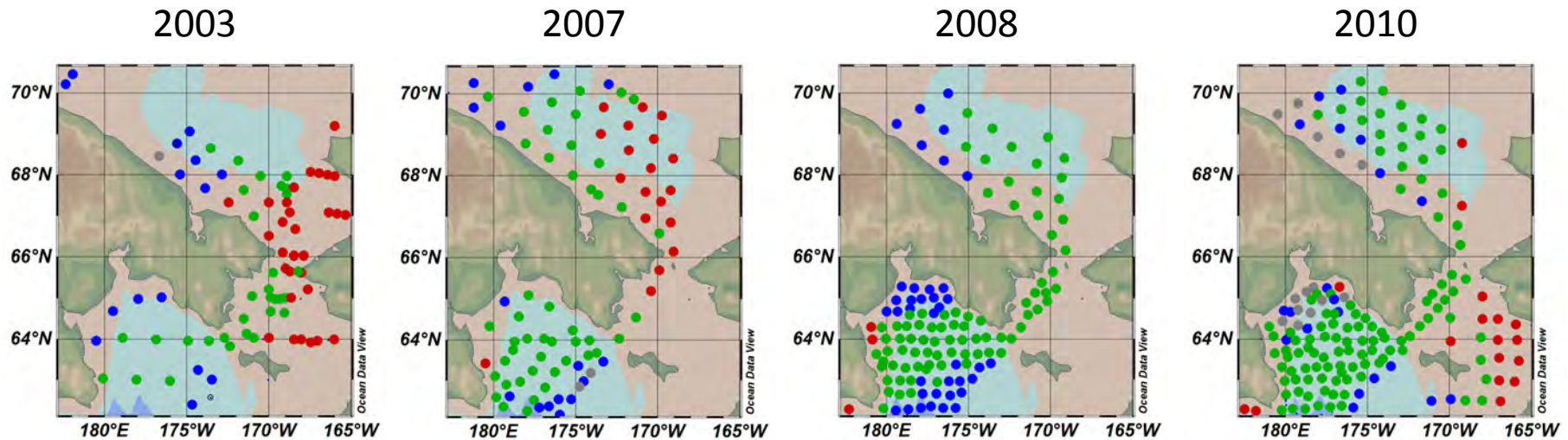
- Alaska (Anadyr) coastal water (**ACW**)
- Siberian coastal water (**SCW**)
- Bering Summer water (**BSW**)
- Remnant Pacific winter water (**RWW**)

# Water masses at 30 m



- Alaska (Anadyr) coastal water (**ACW**)
- Siberian coastal water (**SCW**)
- Bering Summer water (**BSW**)
- Remnant Pacific winter water (**RWW**)
- Newly ventilated Pacific winter water (**WW**)

# Water masses near bottom

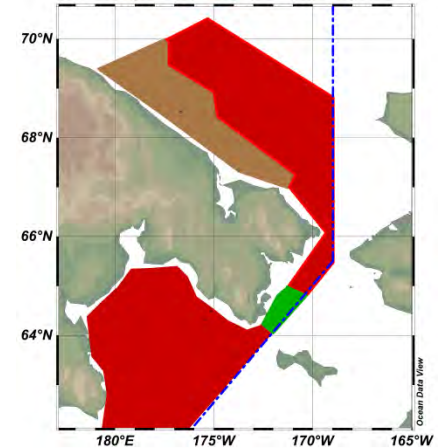
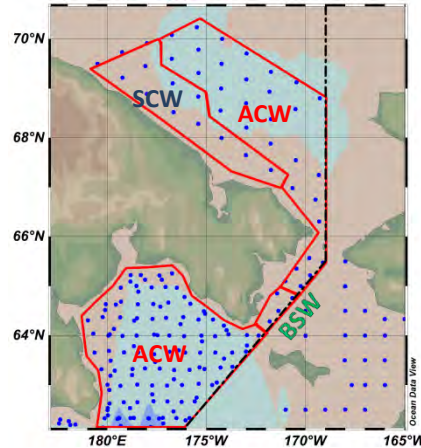
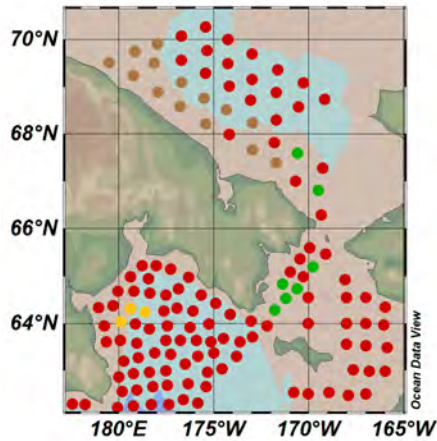


- Alaska (Anadyr) coastal water (**ACW**)
- Bering Summer water (**BSW**)
- Remnant Pacific winter water (**RWW**)
- Newly ventilated Pacific winter water (**WW**)



# Distribution of dominant water masses

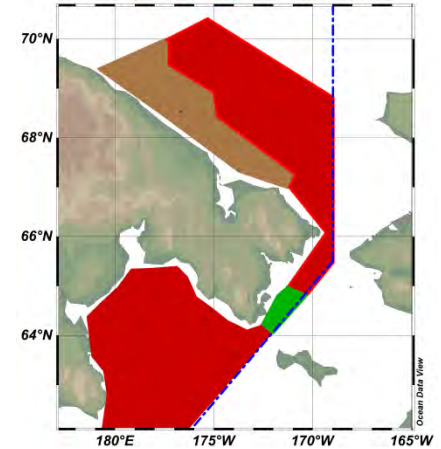
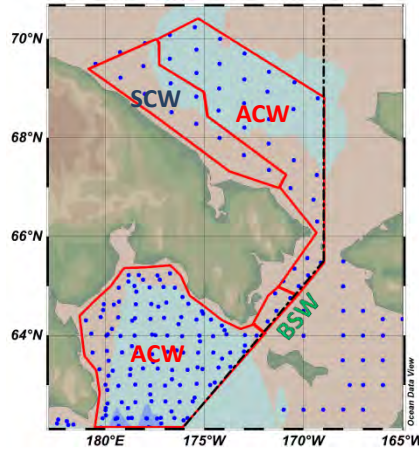
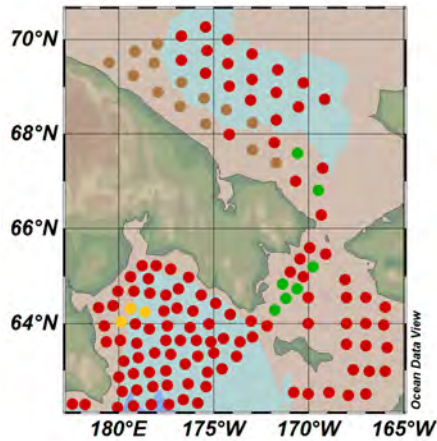
## Example from Summer 2010



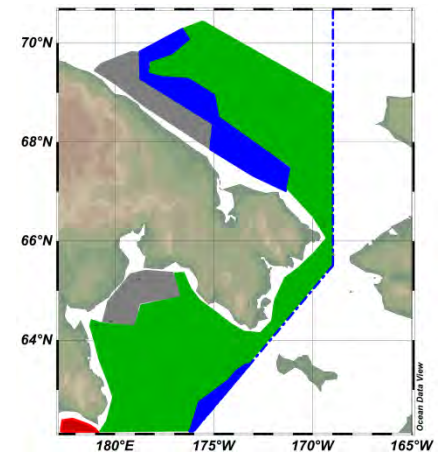
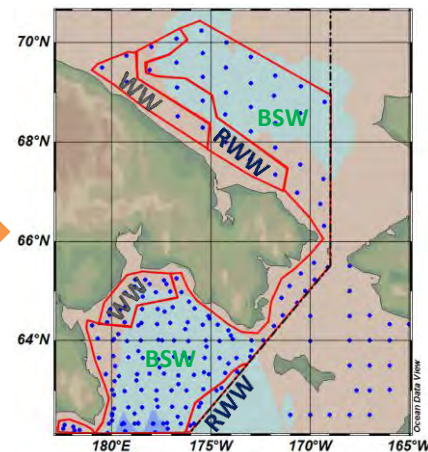
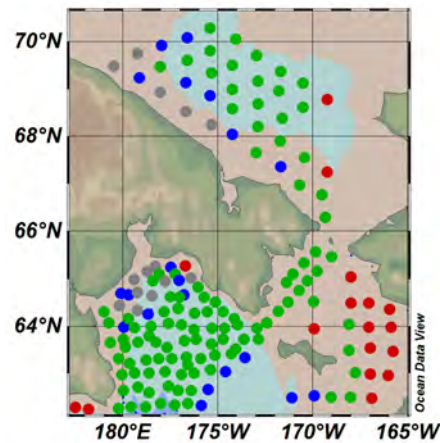
5 m

# Distribution of dominant water masses

## Example from Summer 2010

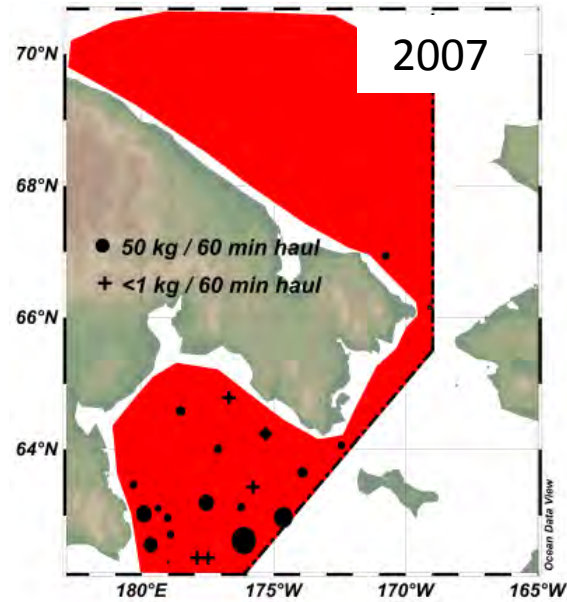
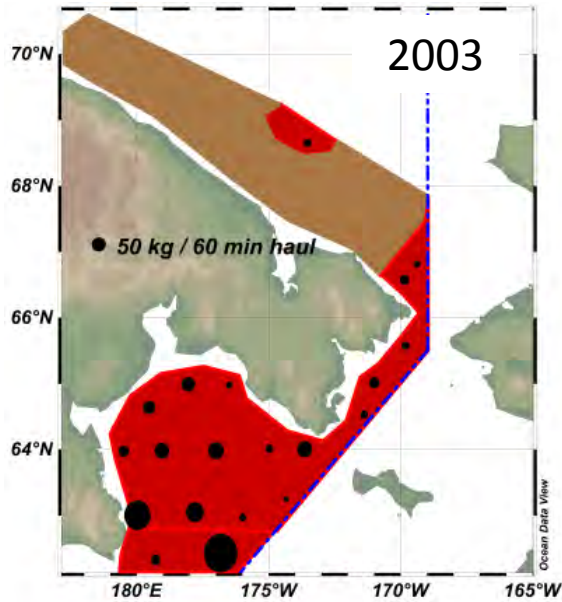


5 m

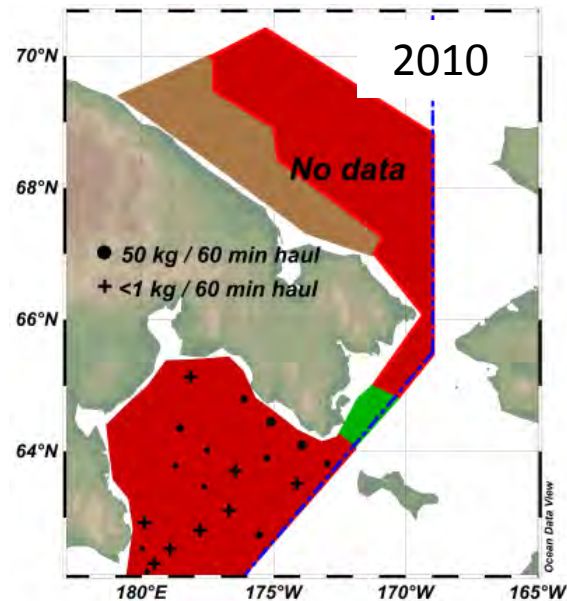
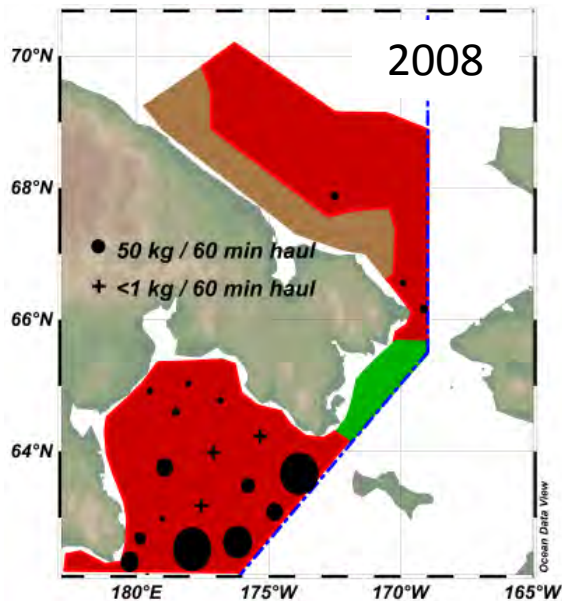


bottom

# Distribution of fish species: Chum salmon



WM @ 5m



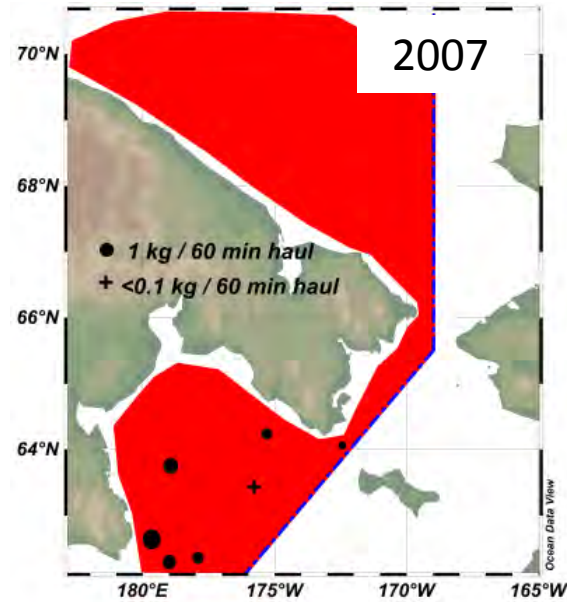
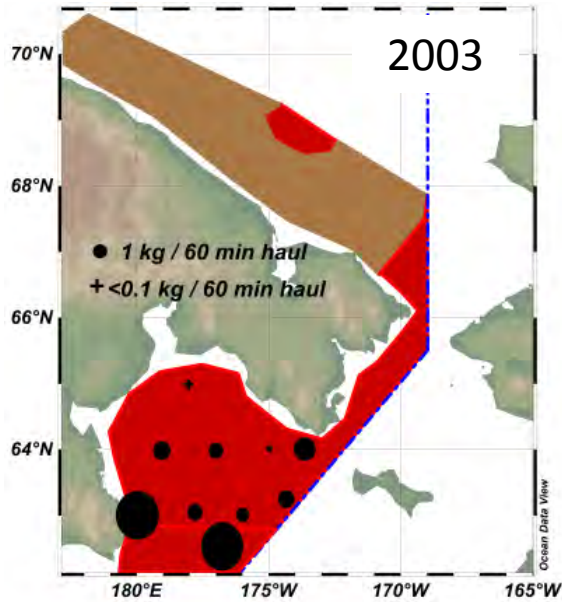
- Chum salmon was caught only in the ACW
- Chum salmon avoided BSW in the Chirikov Basin in 2008 and 2010
- In the Chukchi Sea, only several individuals were caught in 2003, 2007, and 2008

in Chukchi Sea

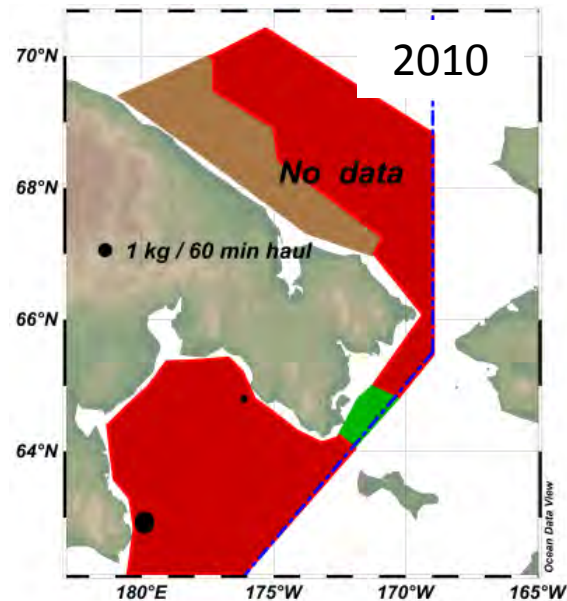
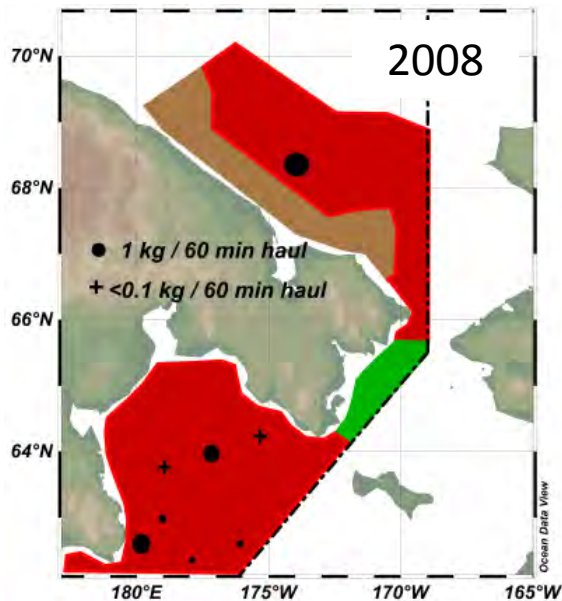
Year	N	L, cm
2003	7	70-77
2007	4	62-72
2008	5	66-82



# Distribution of fish species: Sockeye salmon



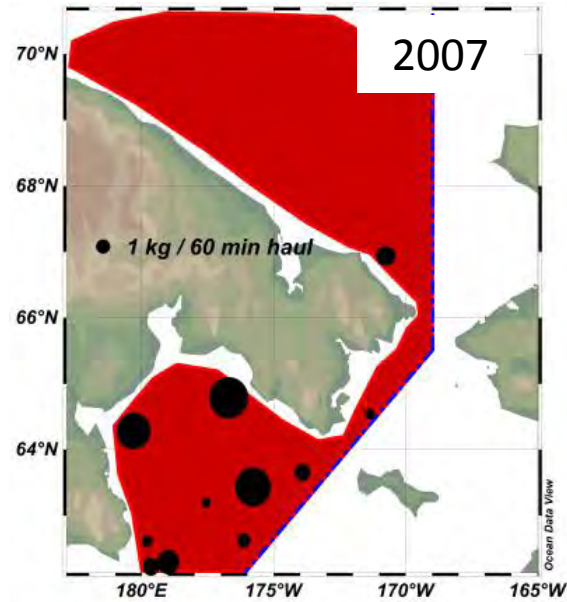
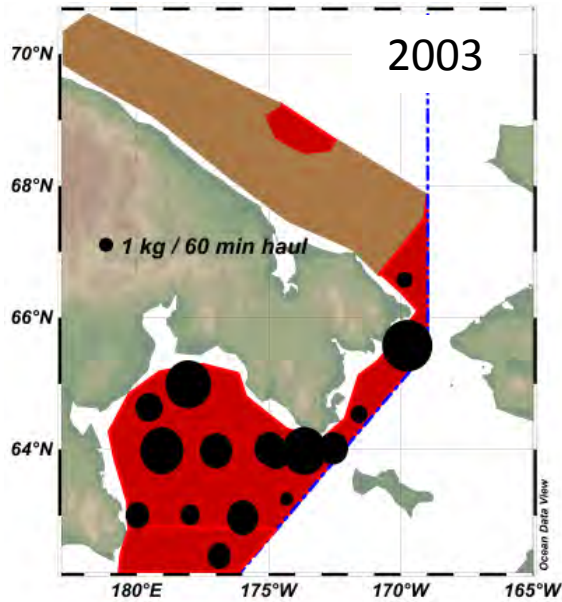
WM @ 5m



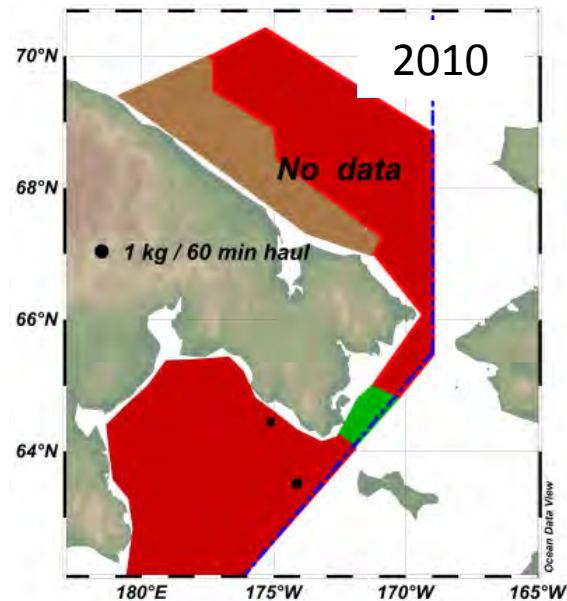
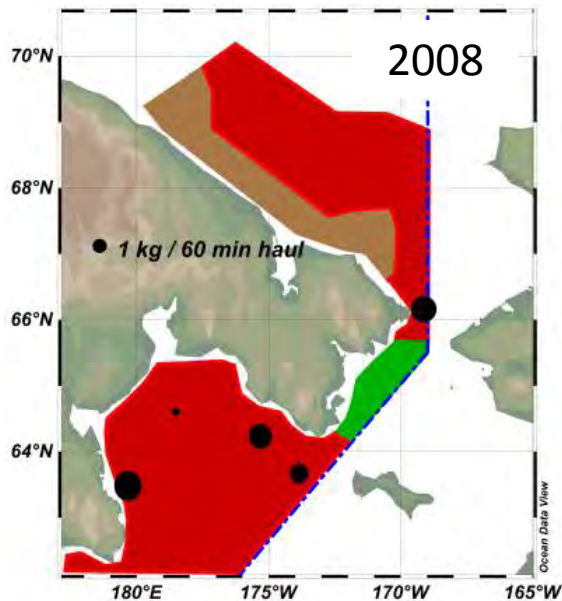
- Sockeye salmon was caught only in the ACW
- In the Chukchi Sea, only one individual was caught in 2008

in Chukchi Sea		
Year	N	L, cm
2003	0	
2007	0	
2008	1	64

# Distribution of fish species: Chinook salmon



WM @ 5m



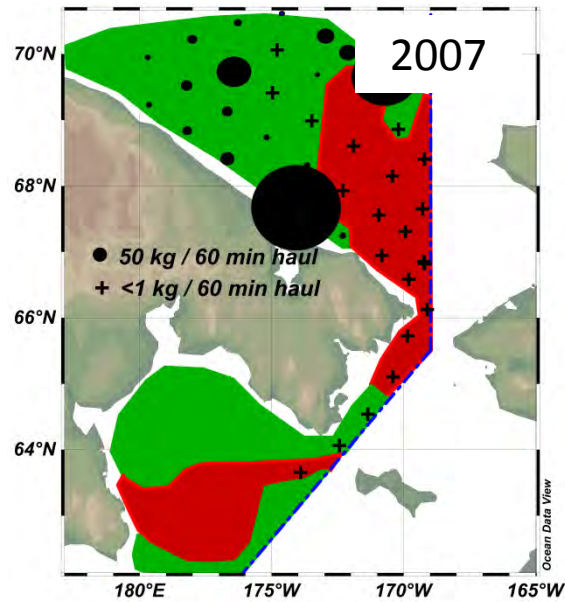
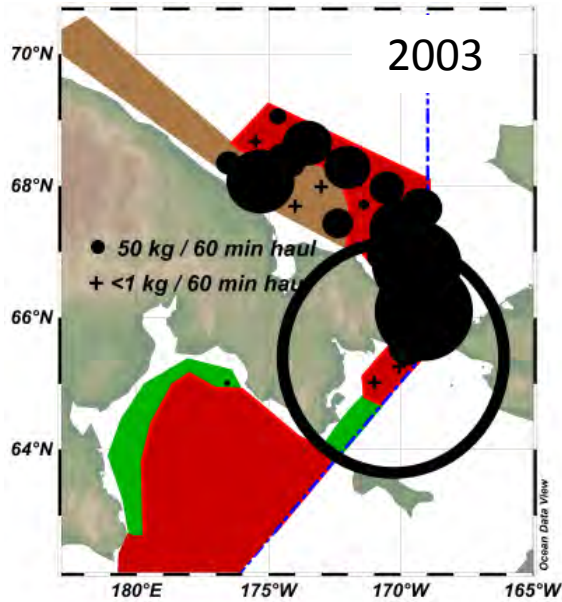
- Chinook salmon was caught only in the ACW
- Chinook salmon avoided BSW in the Chirikov Basin in 2008 and 2010
- In the Chukchi Sea, only one impuberal individual was caught in 2003, 2007, and 2008, perhaps, representing local population

in Chukchi Sea

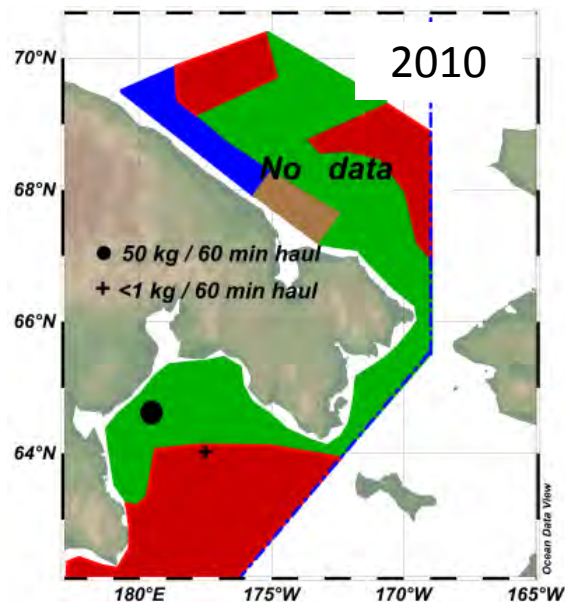
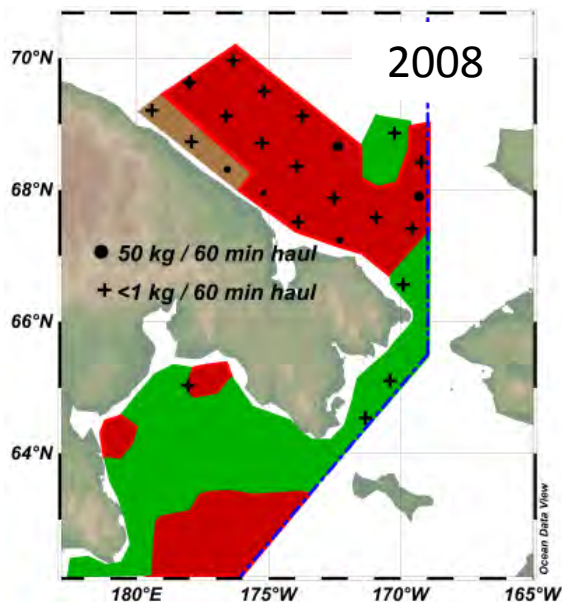
Year	N	L, cm
2003	1	45,3
2007	1	57,5
2008	1	69,5



# Distribution of fish species: Polar Cod



WM @ 20m

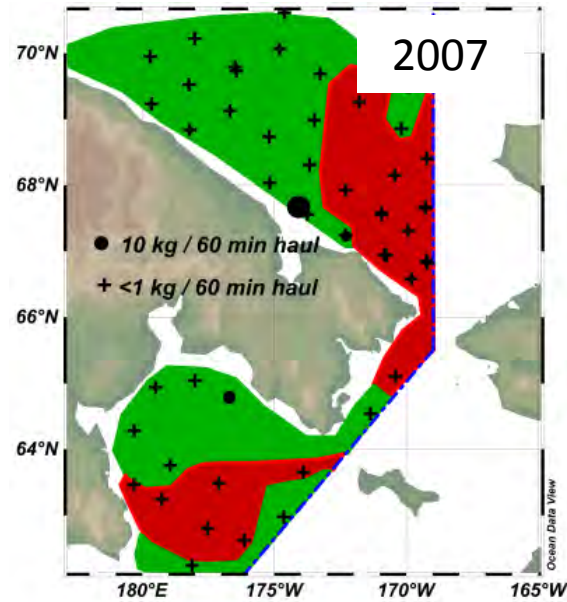
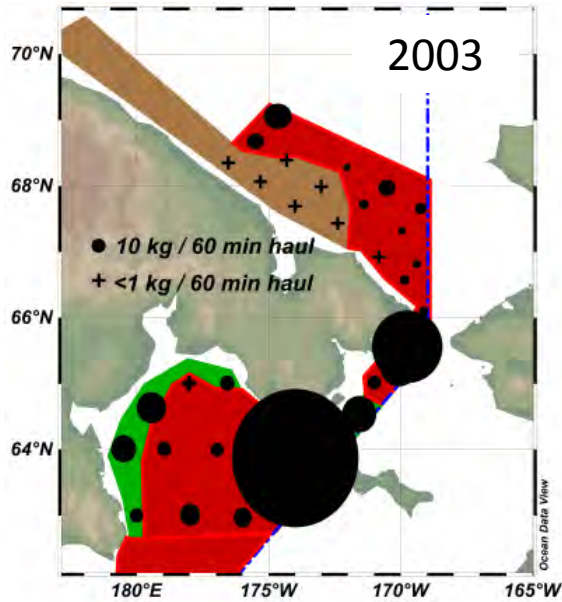


- Substantial variability of Polar Cod abundance
- During 'normal' years (2003, 2008), Polar Cod was present mostly in ACW
- During 'warm' 2007, it moved north-west and was present mostly in the BSW

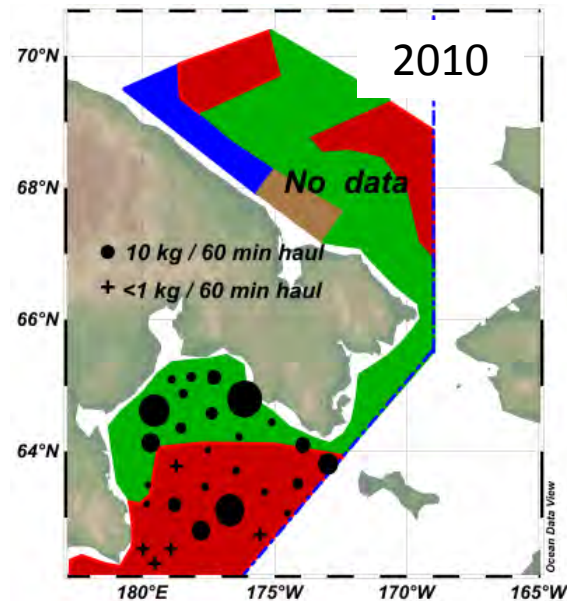
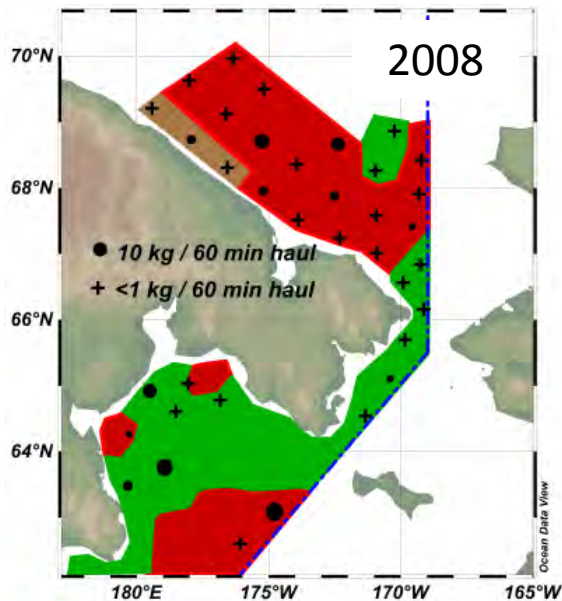
Year	10 <sup>3</sup> t	Abundance, t/km <sup>2</sup>
2003	674	14,4
2007	119	0,8
2008	12,6	0,1



# Distribution of fish species: *Capelin*



WM @ 20m

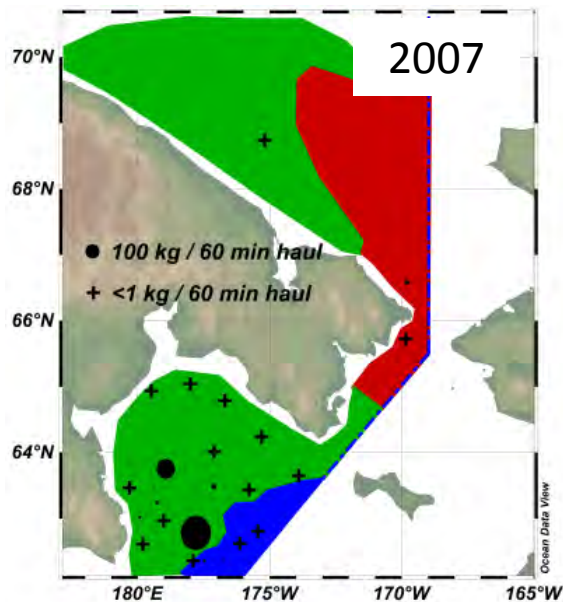
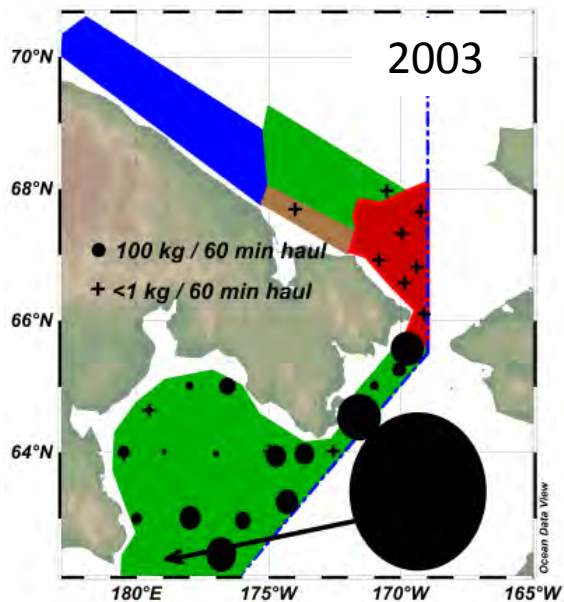


- No apparent preference to WM
- In the Gulf of Anadyr, Capelin was most abundant when bottom temperature was relatively warm – in 2003 and 2010
- In the Chukchi Sea, Capelin was most abundant during years of 'average' bottom temperature (2003, 2008)

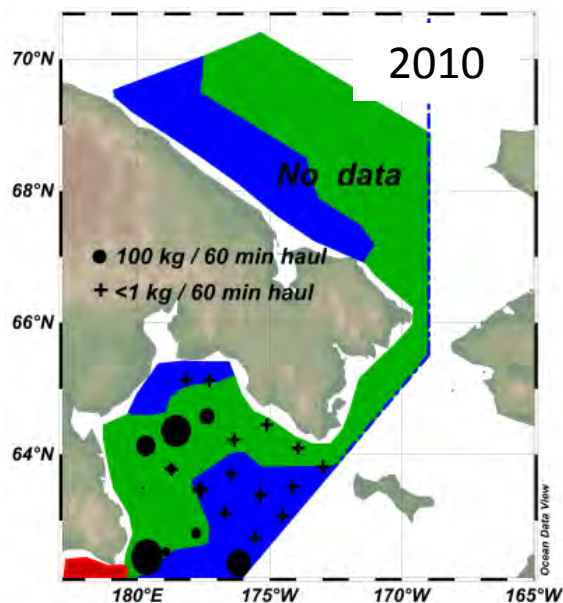
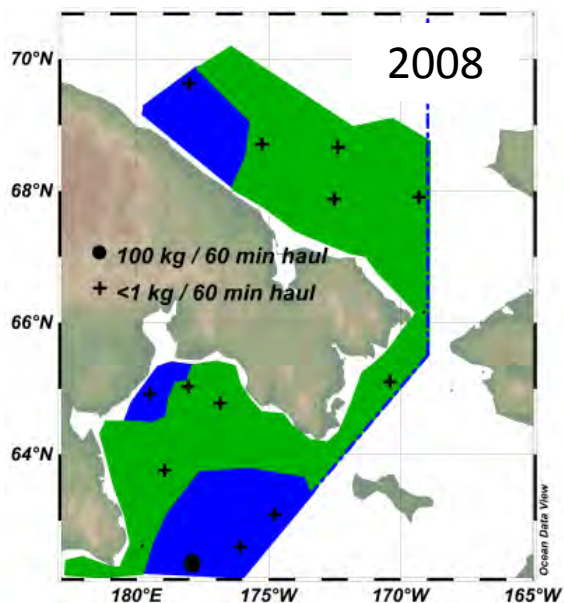
in Chukchi Sea

Year	10 <sup>3</sup> t	Abundance, t/km <sup>2</sup>
2003	5,9	0,1
2007	0,6	0,004
2008	4,0	0,4

# Distribution of fish species: *Walleye Pollock*



WM @ 30m

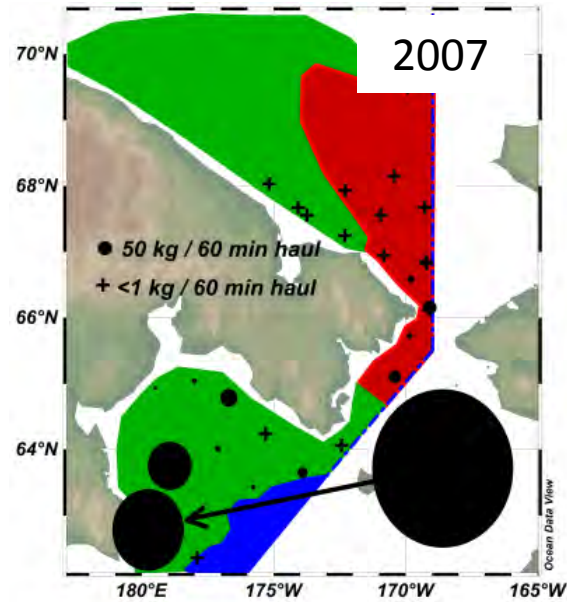
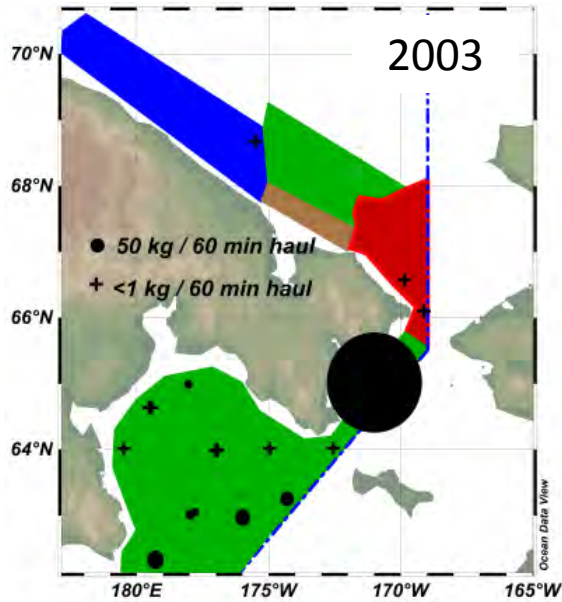


- Denser aggregation in the BSW than in the RWW
- Walleye Pollock juveniles were sparse yet present in the Chukchi Sea during all surveys
- During years of large abundance, as 2003, more Walleye Pollock goes to the Chukchi Sea

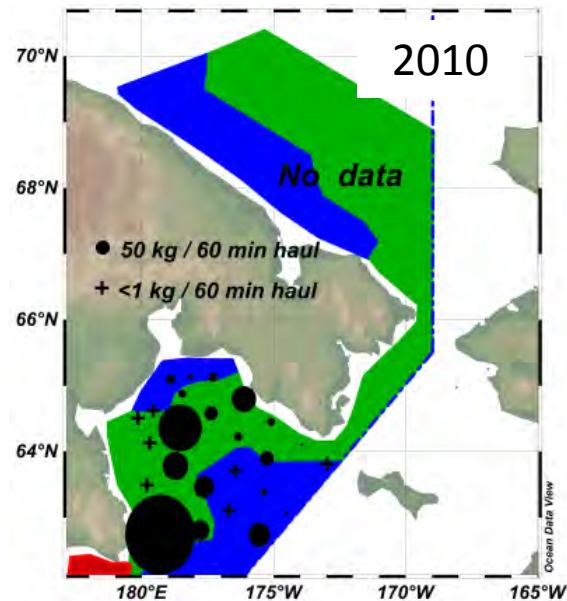
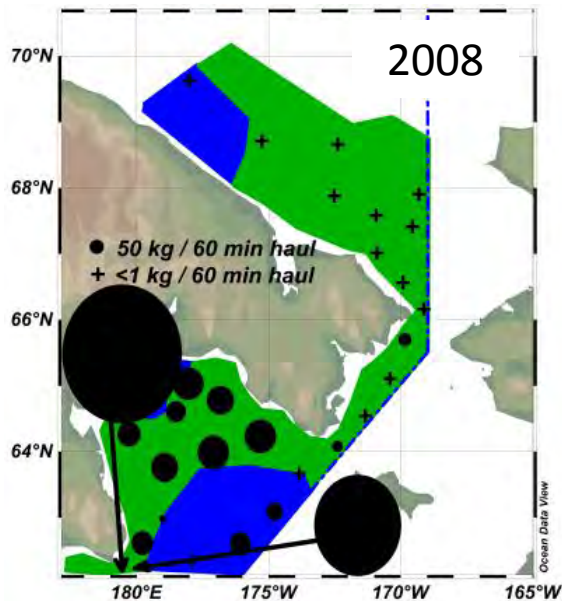
Year	10 <sup>3</sup> t	Abundance, t/km <sup>2</sup>
2003	150	0,0032
2007	40	0,0004
2008	70	0,0007



# Distribution of fish species: Herring



WM @ 30m

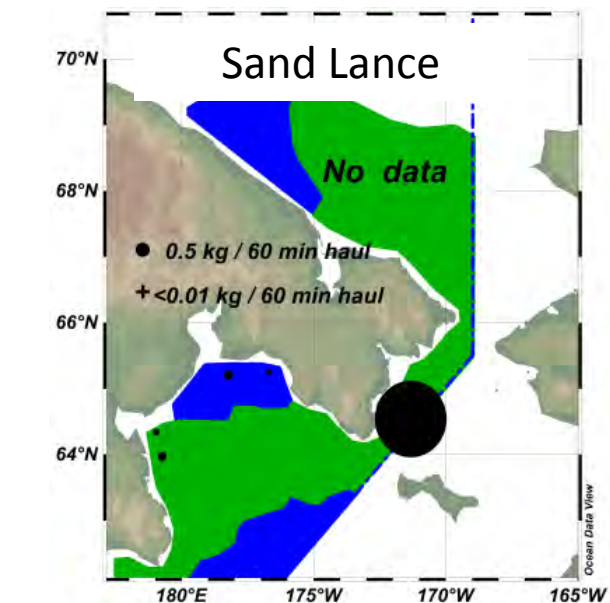
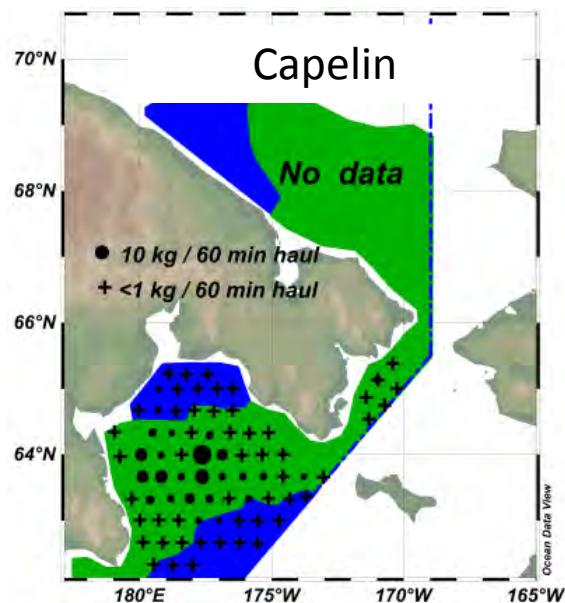
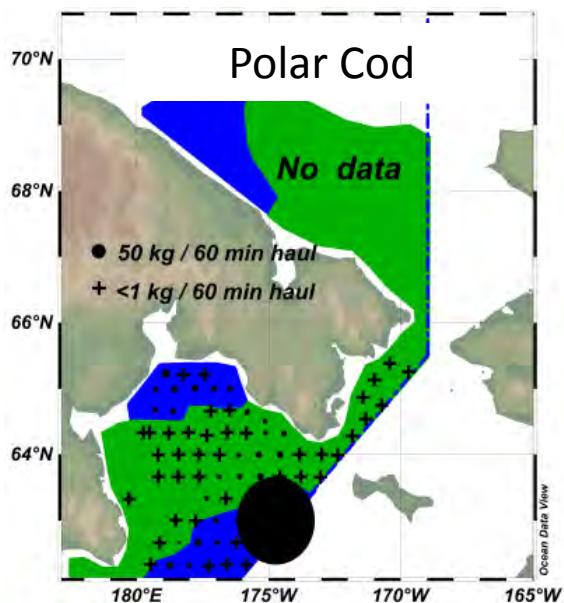
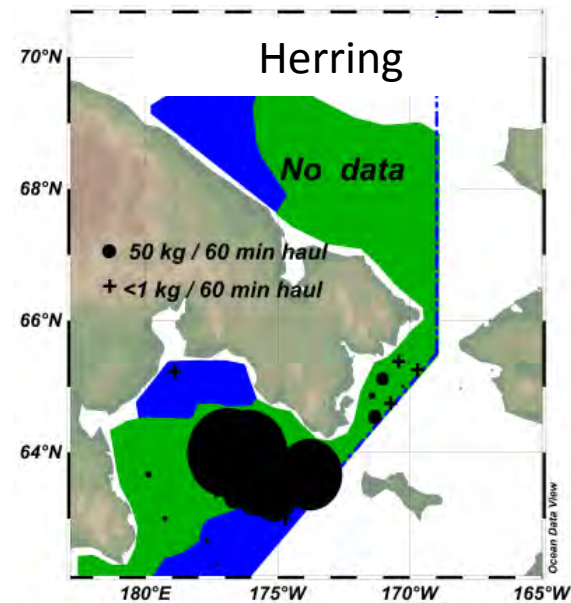
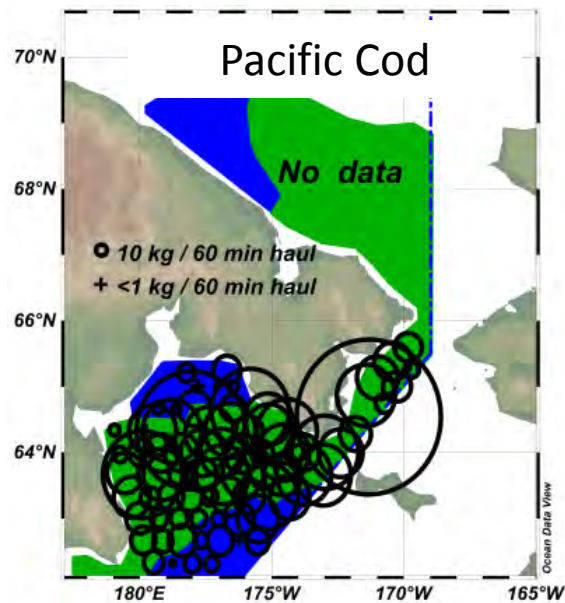
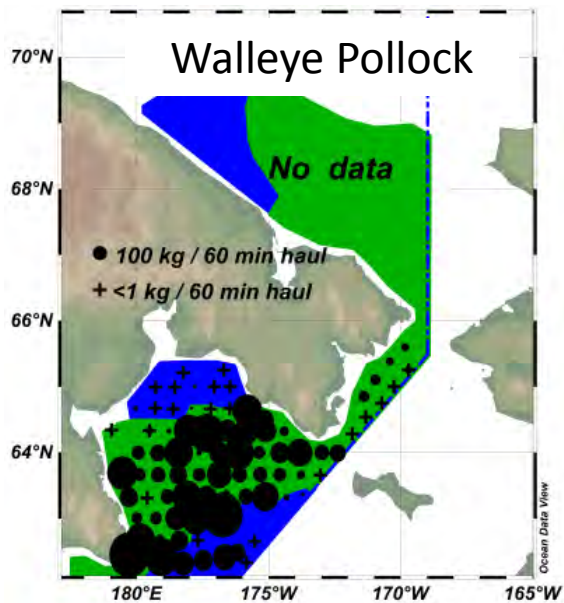


- Denser aggregation in the BSW than in the RWW
- There are two Herring groups: local group in the Chukchi Sea and another local group of the East Bering Sea (Glebov, pers. comm., 2016)

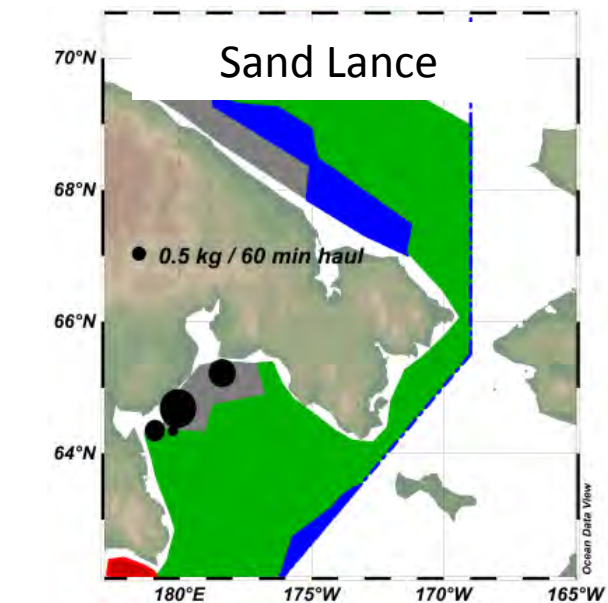
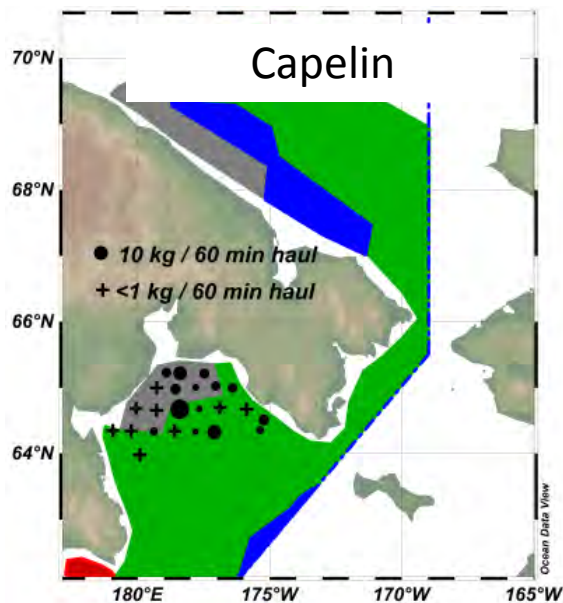
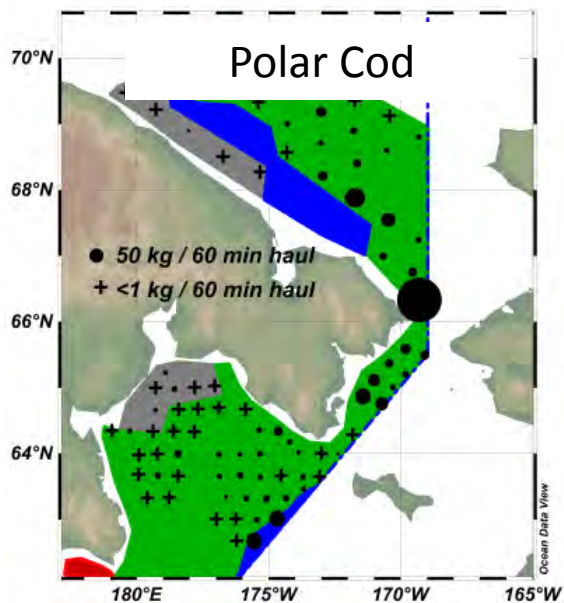
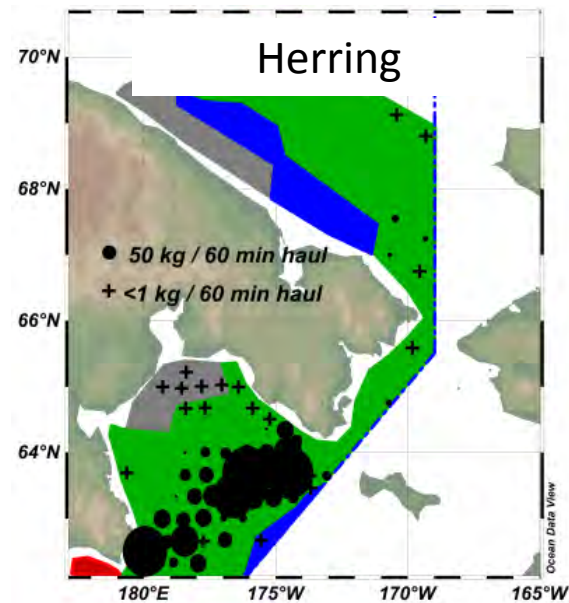
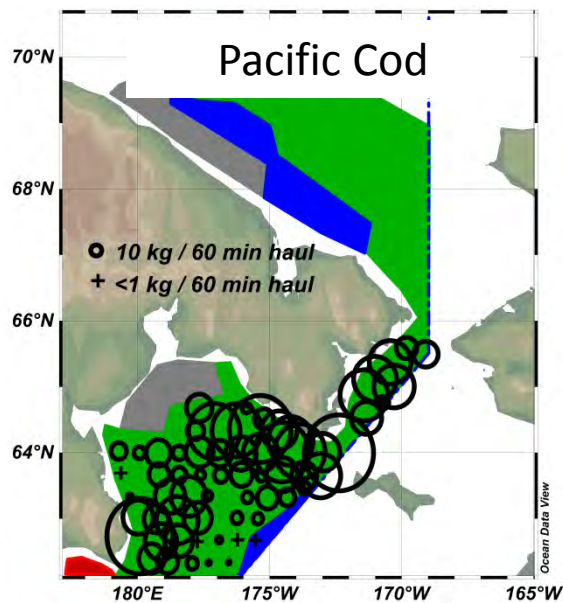
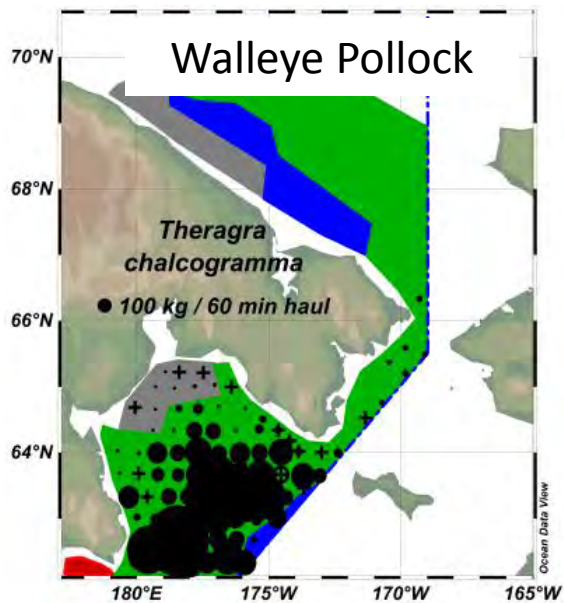
Year	10 <sup>3</sup> t	Abundance, t/km <sup>2</sup>
2003	20	0,0004
2007	210	0,0014
2008	50	0,0005



# Bottom trawling in 2008



# Bottom trawling in 2010



# **Conclusion**

- Six WM were classified in the study area: Anadyr+Alaska Coastal W (ACW), Diluted Gulf W, Siberian Coastal W, Bering Summer W (BSW), Remnant Pacific Winter W, Newly Ventilated Winter W
- Navarin (Anadyr) current is the main pathway for transportation of relatively warm and salty BSW into the Arctic. It forms in spring due to changes in wind direction
- Main aggregations of Pacific Salmons, Walleye Pollock, Pacific Cod, and Herring in the Gulf of Anadyr occurred in the ACW.
- In the Chukchi Sea, only several mature individuals of chum, sockeye, and chinook were caught. They also were distributed mainly within ACW
- During cold and normal years, Polar Cod feed near the Bering Strait within ACW. During warm years, it moves north-westward into area of BSW