Mesoscale and submesoscale dynamic structures off the Russian coast in the northwestern Japan/East Sea and their impact on chlorophyll-a concentration: satellite imagery and moored profiler measurements

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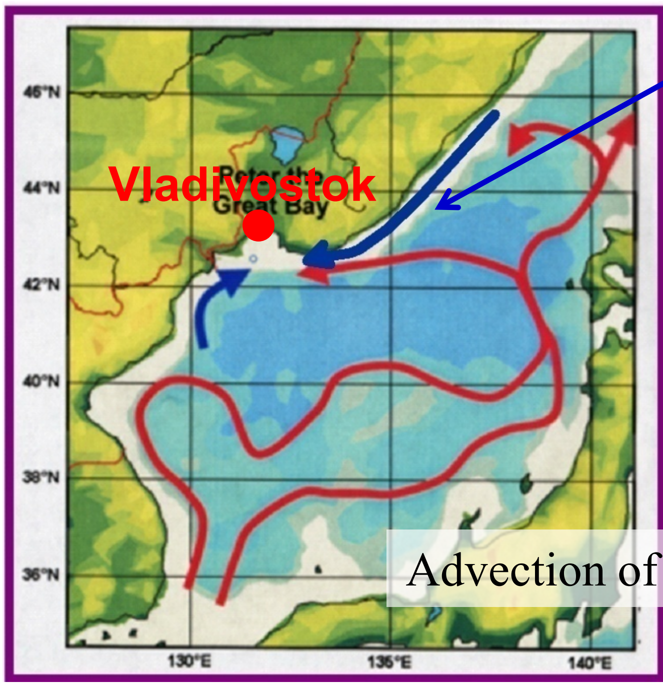
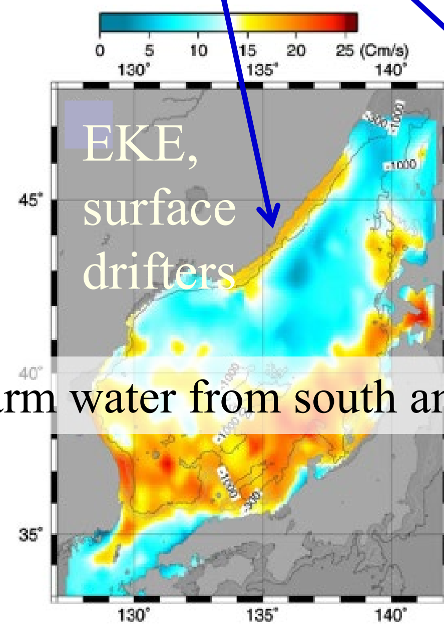
Background: the dynamically active zone in the Primorye (Liman) Current area (the northwestern Japan Sea)

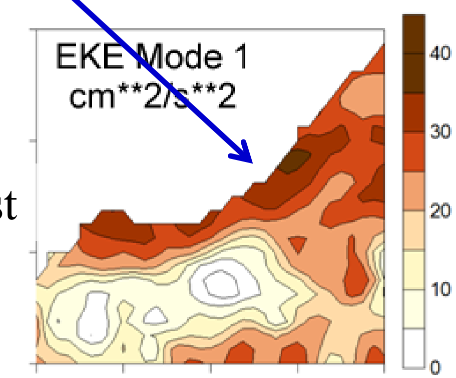
Slope eddies

Primorye Current area





Satellite IR imagery (Ginzburg et al., 1998)



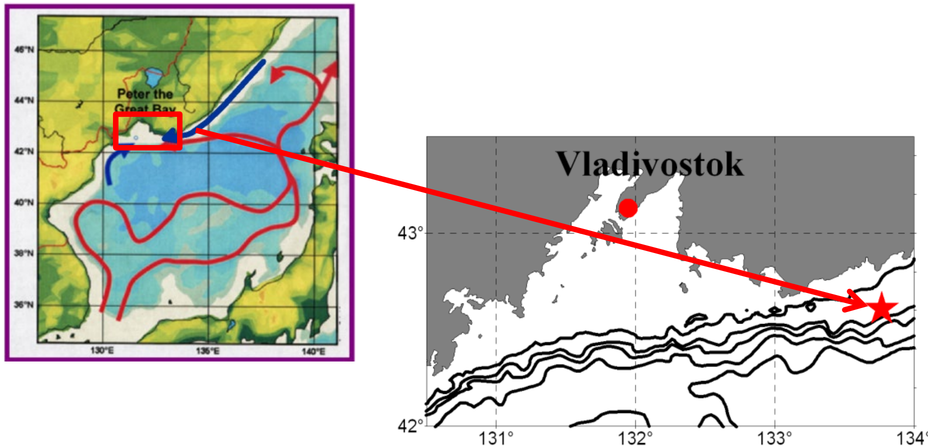
Advection of warm water from south and east

Slope eddies, shelf waves, alien water intrusions with eddies, streamers, and filaments.

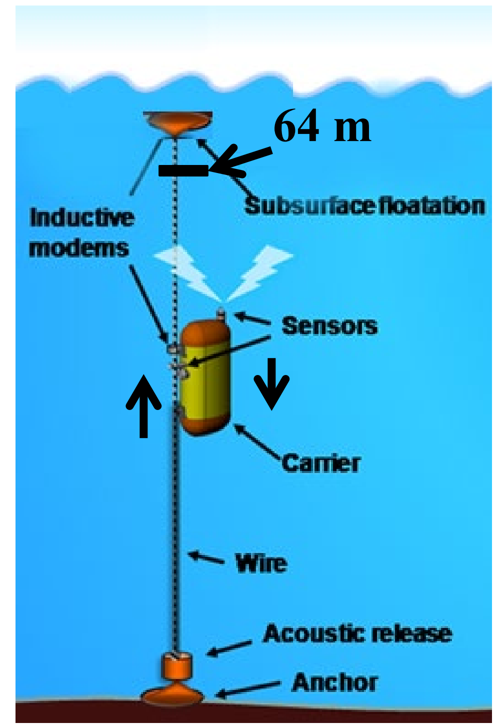
(Lee, Niiler, 2005)

Satellite altimetry, AVISO, 1993-2015 (Trusenkova, 2014)

To study the dynamically active zone within the Primorye Current



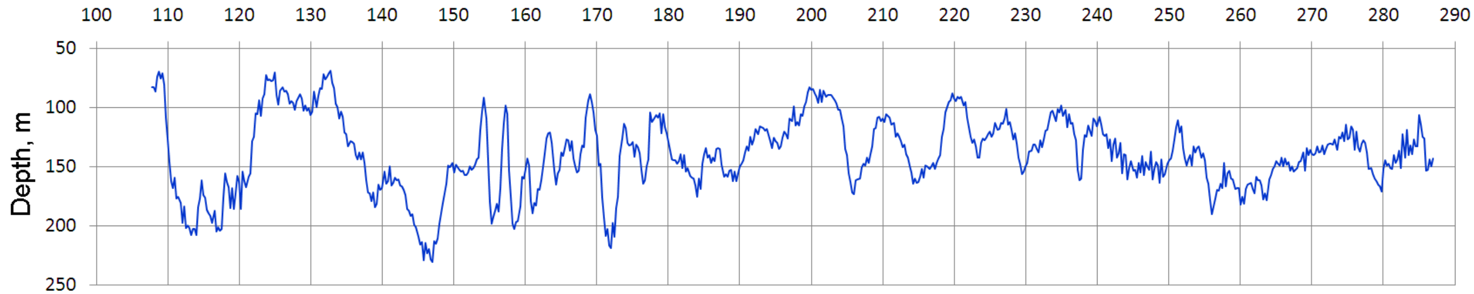
Aqualog moored profiler
installed at the continental slope
(42.5°N, 133.8°E),
depth of 440 m. April 18 through
October 15, 2015.
Unique data for half a year with high
resolution in depth and time.



(Ostrovskii et al., 2013)

Vertical fluctuations in the pycnocline

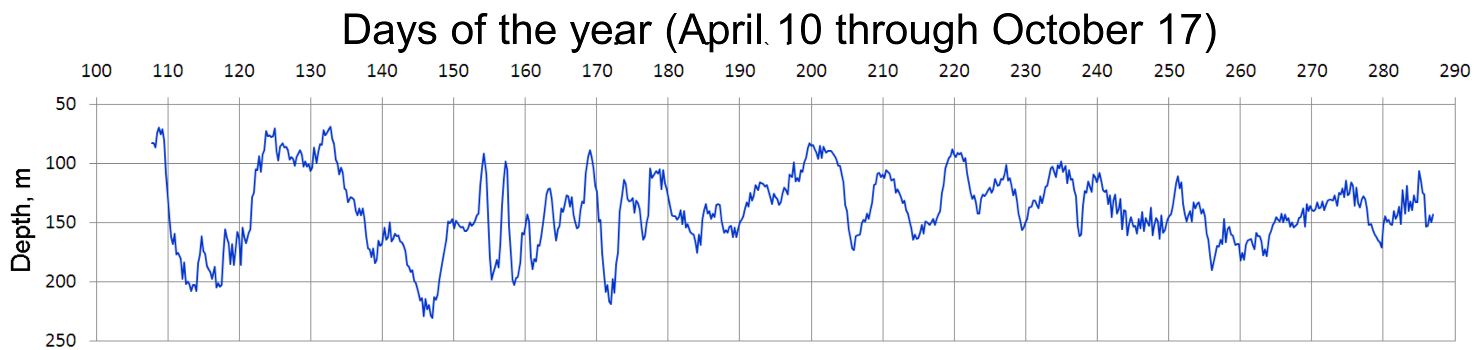
Days of the year (April 10 through October 17)



27.15σ_t isopycnal depth (140±31 m) – a good indicator of pycnocline fluctuations ~ dynamic height (R > 0.9) (Trusenkova et al., 2018)

Periods: 2 – 6 days (in June), 8–12 & 20–30 days (before mid August), 110 – 130 days (the whole observation time).

Vertical fluctuations in the pycnocline



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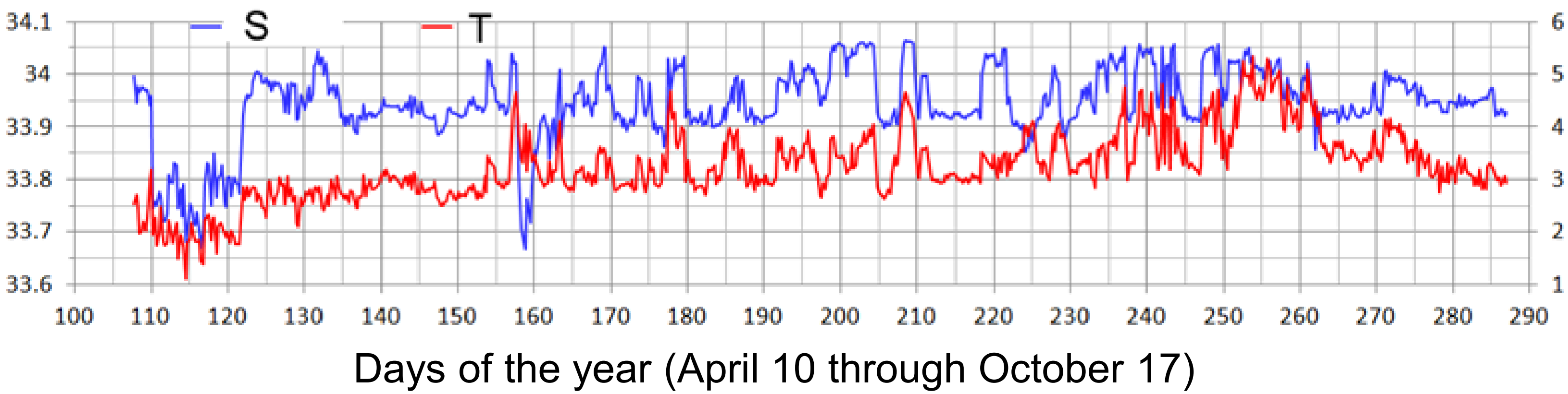
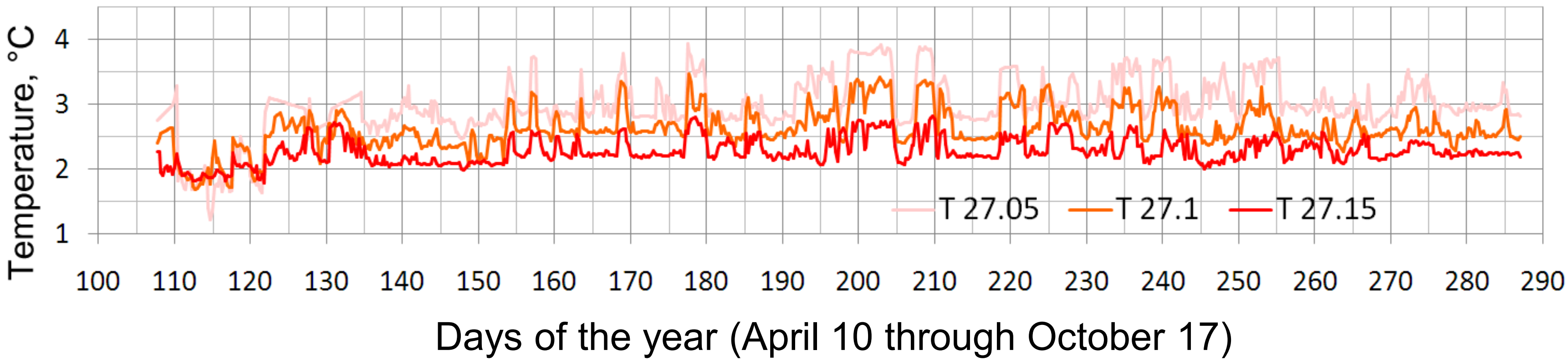
T & S in the upper profiled layer (64–70 m)



Another kind of variability

T at the upper isopycnals (sigma = 27.05 – D27.15 kg/m^3)



Short-lived thermohaline anomalies at the upper isopycnals (64–150 m)
as indicators of alien water intrusions

What is the source of this variability?

Is it possible to identify dynamic structures?

Satellite information?

Purpose of the study

To link thermohaline anomalies from the *Aqualog* data
to dynamic patterns observed from satellite imagery,
to check the vertical extent of surface mesoscale and submesoscale
features and to relate them to surface Chl-a from satellite data

Satellite data

Infrared imagery: AVHRR/NOAA (1 km); VIIRS/Suomi-NPP (375 m).

Visible imagery: Chl-a, GOCI/COMS, 500 m

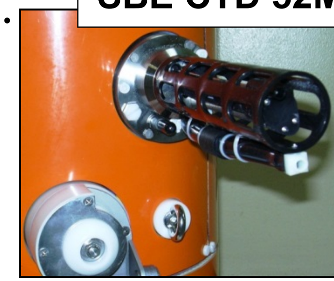
April – October 2015: frequent clouds;
however, set of good images found to discuss cases of alien water intrusions.

Aqualog data

Period: April 18 through October 14, 2015.
Upward/downward casts 4 times a day, sampling every 0.2–1 m, from **64 m** through 300 m.

Below the seasonal pycnocline of the subarctic water structure.

SBE CTD 52MP



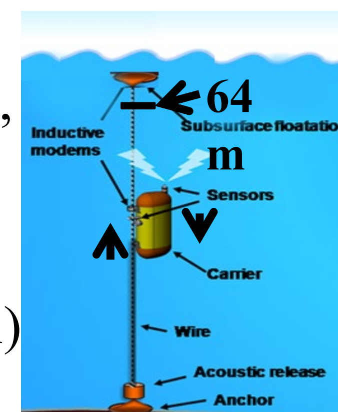
CTD measurements by SBE CTD 52-MP.

T, S, and sigma interpolated to 1 m depth and 6 hour intervals.

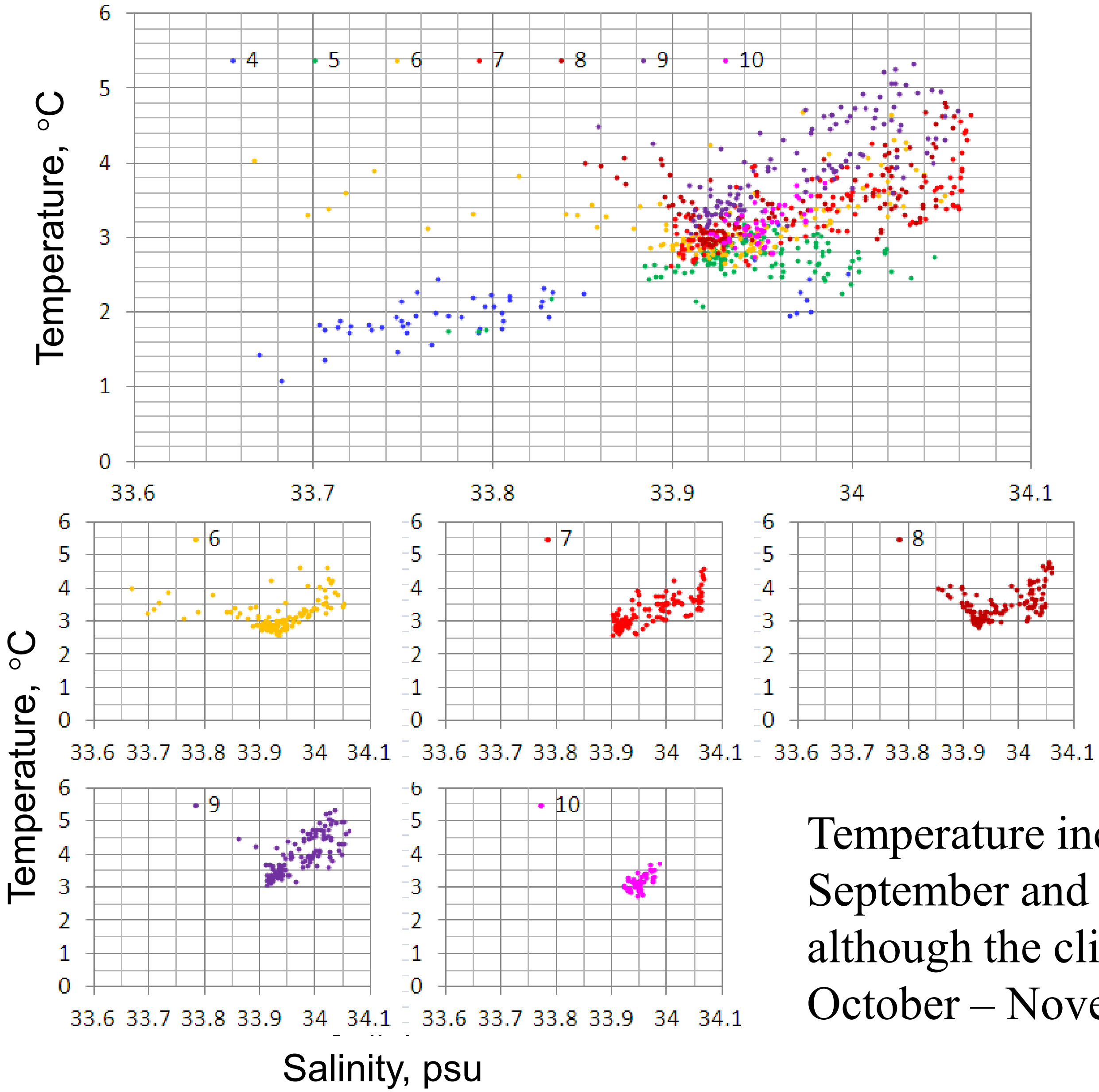
Mooring site, instruments, primary data processing and data corrections are discussed by Lazaryuk et al. (2017).

Using specially developed techniques of dynamic errors correction, T errors were decreased to **0.002 °C** and S errors to **0.003** psu (WOCE standard).

Thermohaline anomalies considered (**above 0.1 °C and 0.005 psu**) exceed errors.



T,S scatter diagrams (mean in the upper profiled layer; 64–70 m)

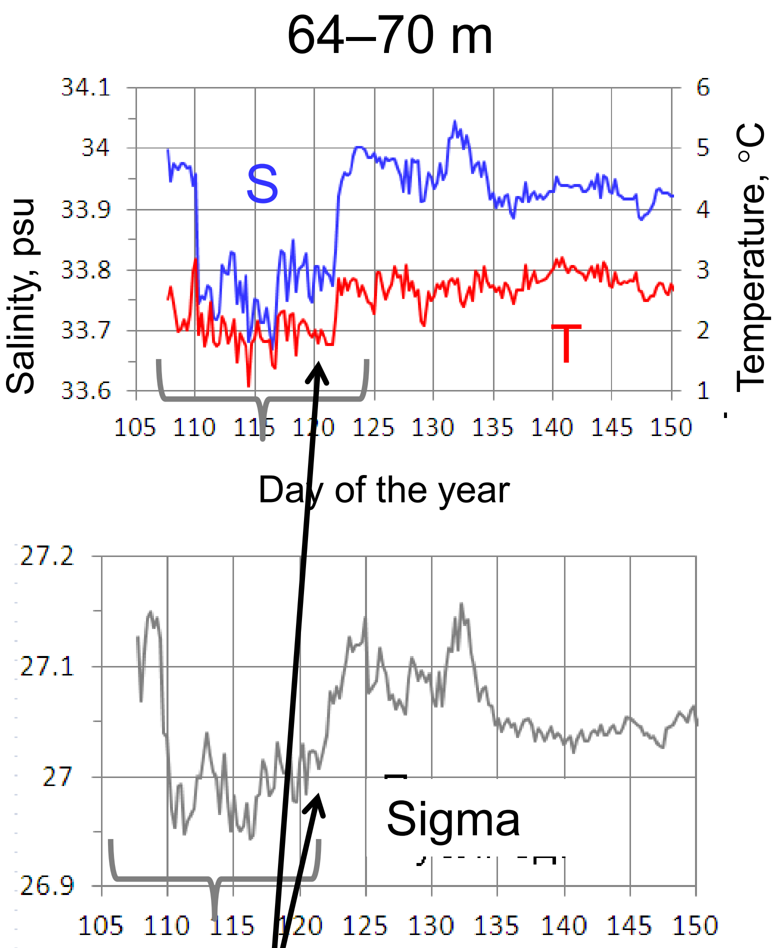


Months:

4 for April,
5 for May,
6 for June,
7 for July,
8 for August,
9 for September,
10 for October.

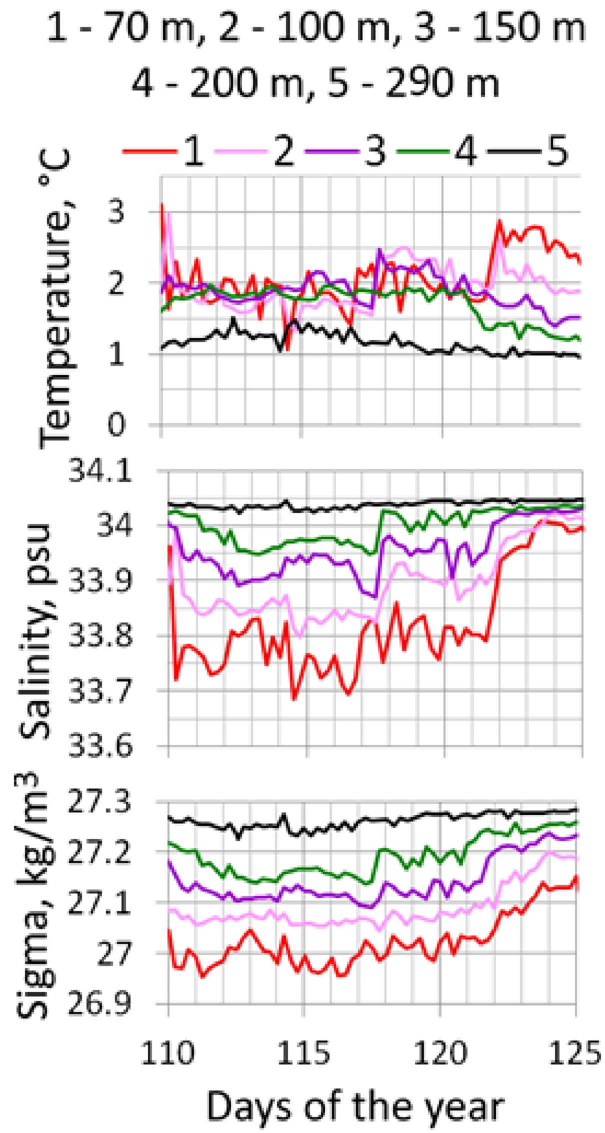
Temperature increase from April to September and decrease to October, although the climatic max at 70 m is in October – November (Luchin et al., 2003).

Thermohaline anomalies from April 21 through May 1 (111 – 121 days of the year)

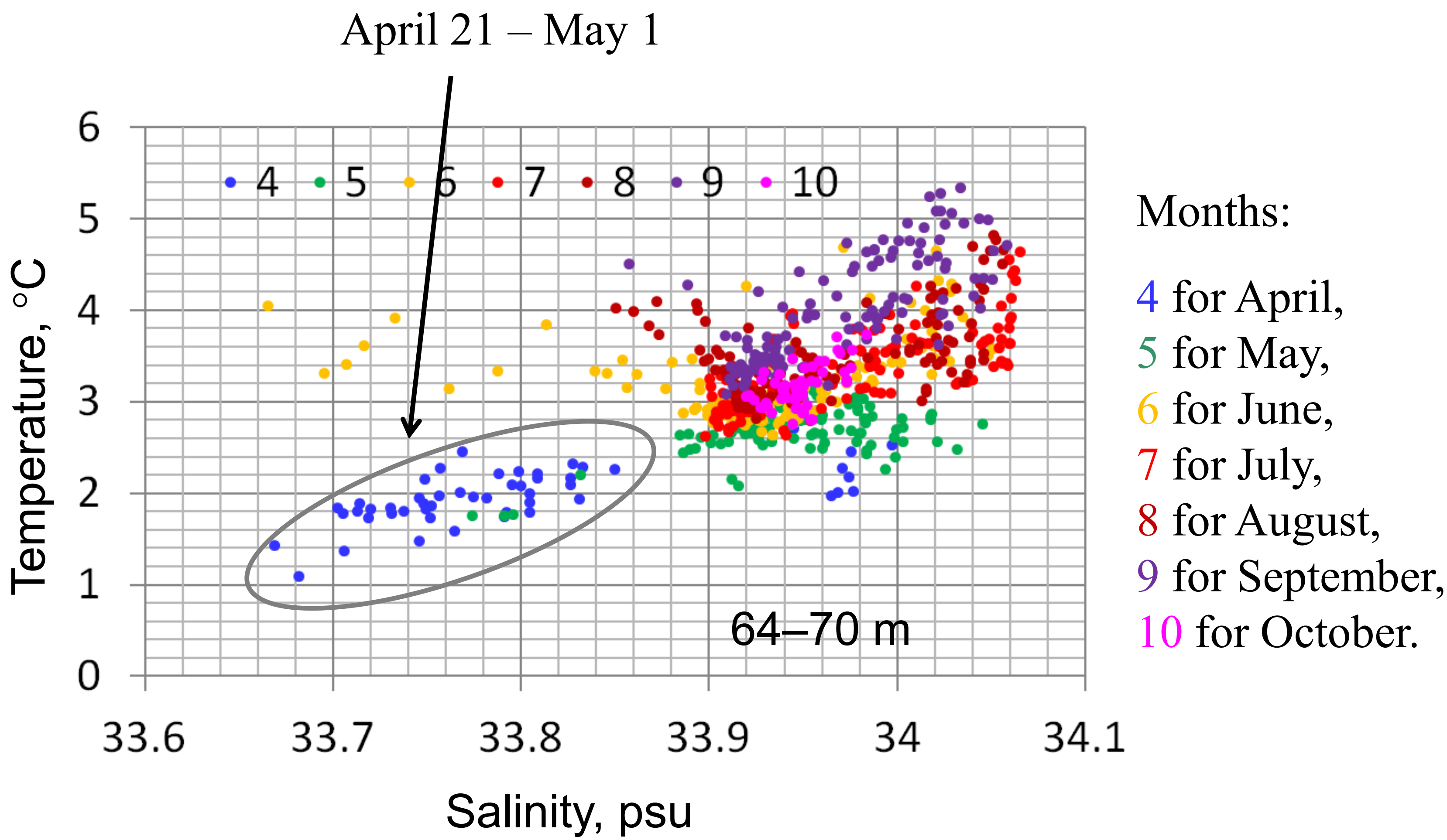


Mean for 111–121 days:
$T_{64–70}$: 1.92 °C,
$S_{64–70}$: 33.768 psu,
sigma: 26.99 kg/m^3.

T, S, sigma jump on May 2

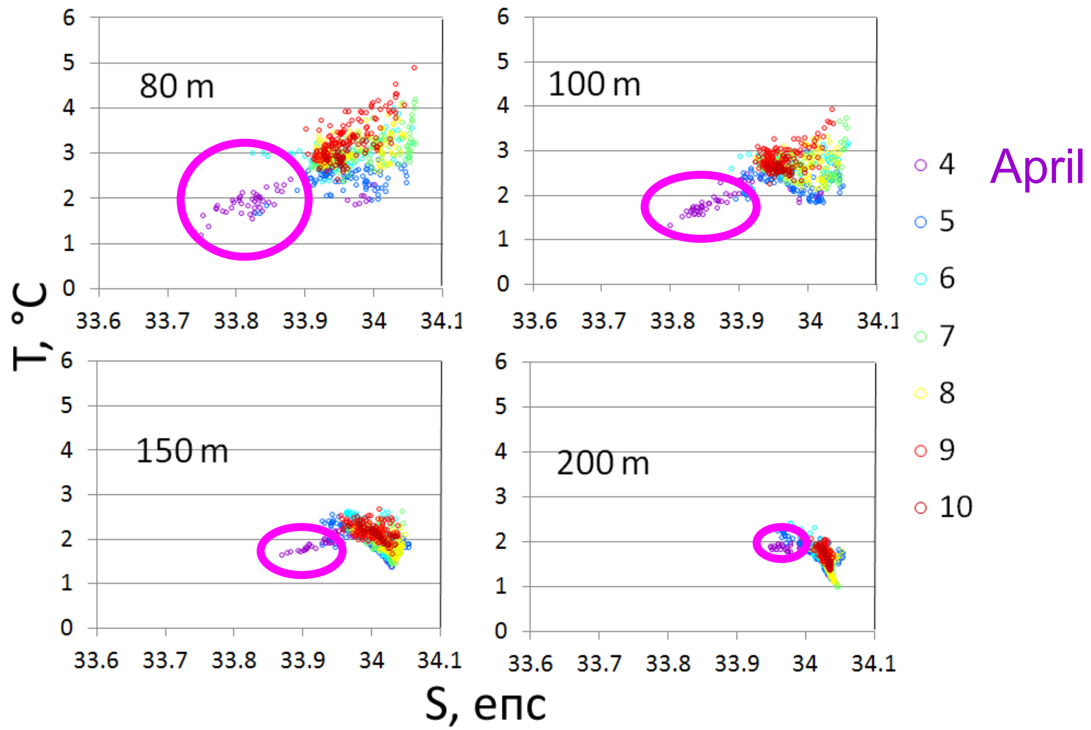


Anomalies down to 150 m



No such anomalies in other months.

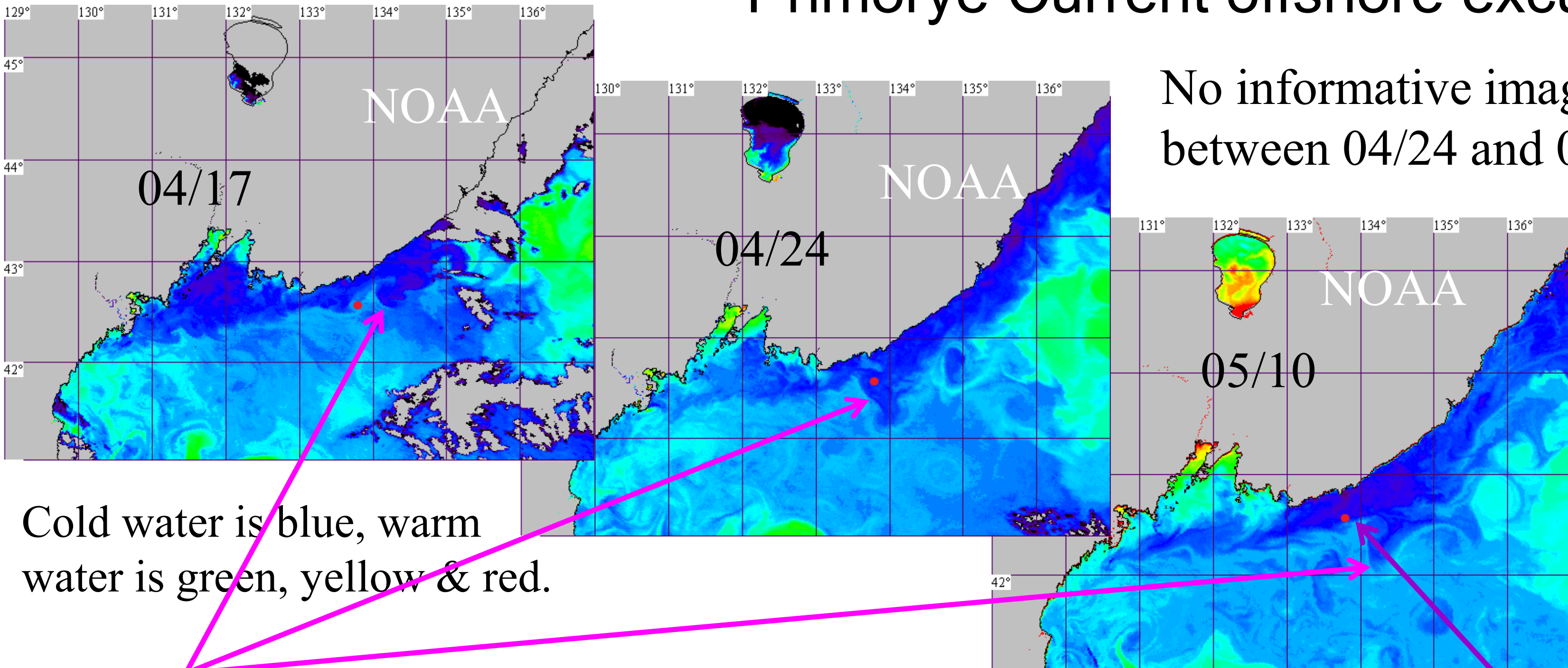
T,S scatter diagrams



Cold fresh water intrusion (down to 150 m)

Primorye Current offshore excursion

No informative images between 04/24 and 05/10.



Cold water is blue, warm water is green, yellow & red.

The front shifts first to the west, then to the east.

Aqualog location

Primorye Current offshore excursion

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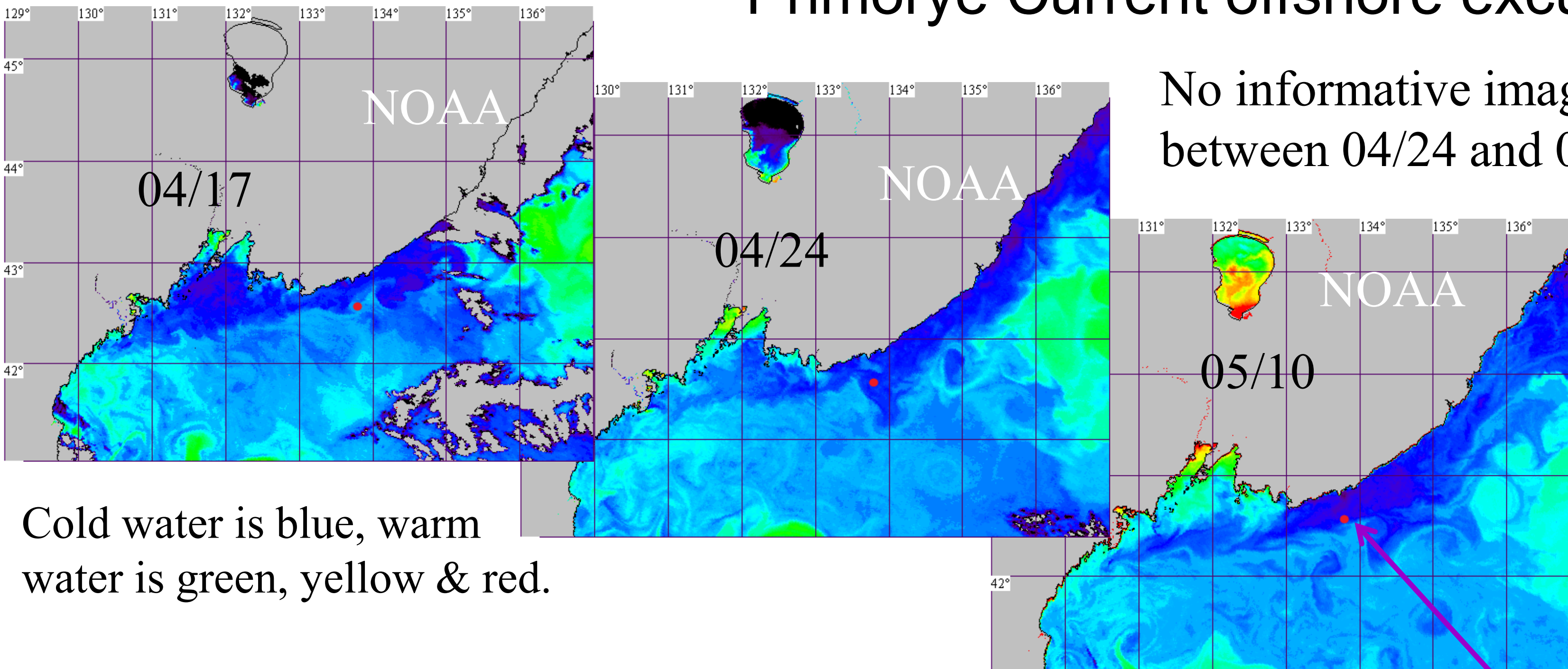

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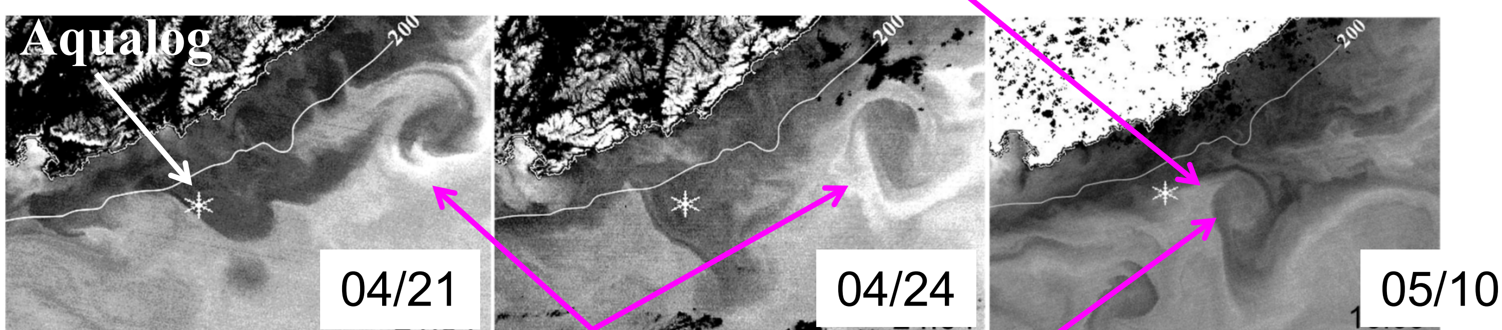
Aqualog location

High-resolusion from Suomi/NPP

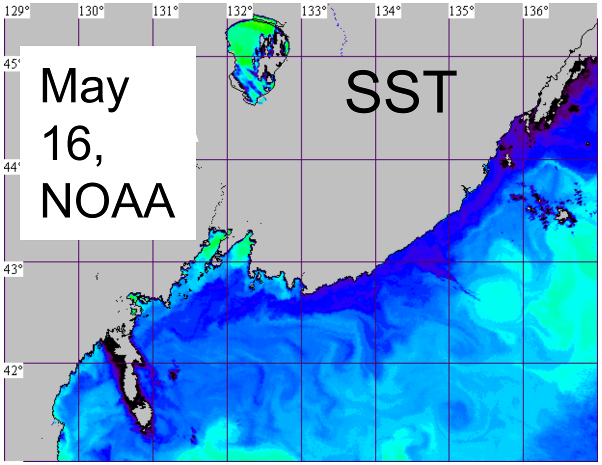
Wedge of warm water

Cold water is dark, warm water is light.

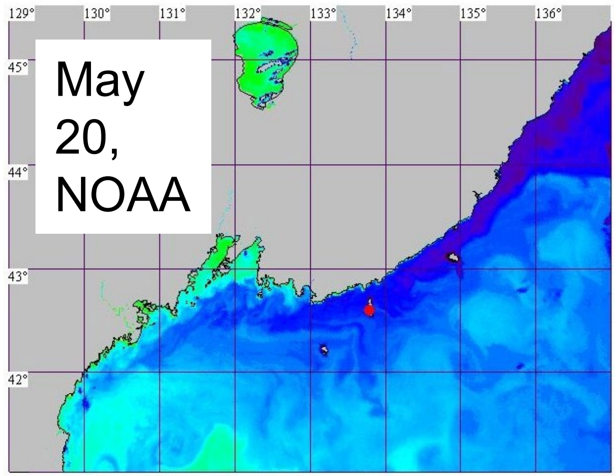


Eddy moving southwestward and merging with the front.

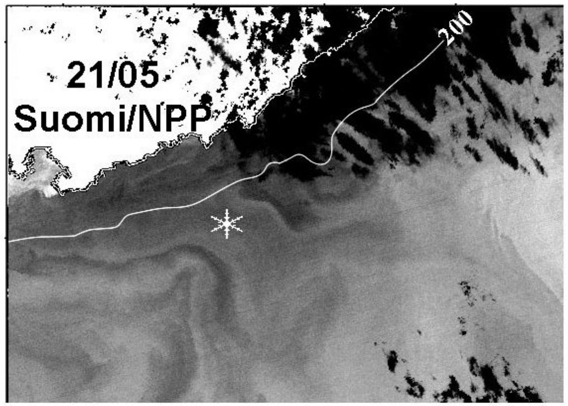
Wedge-like structure due to instability



SST



SST



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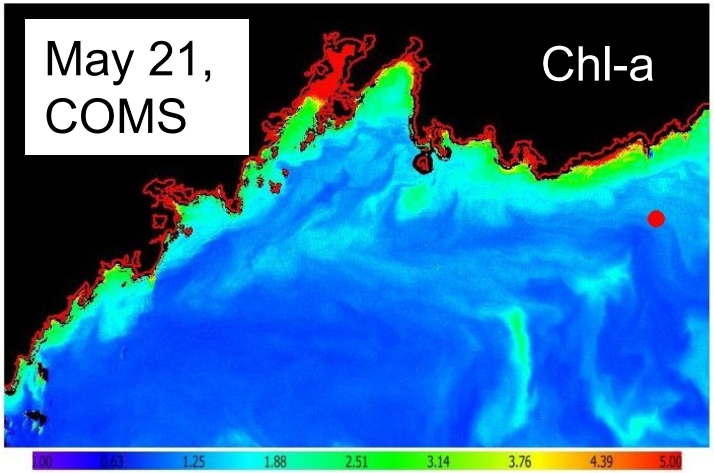
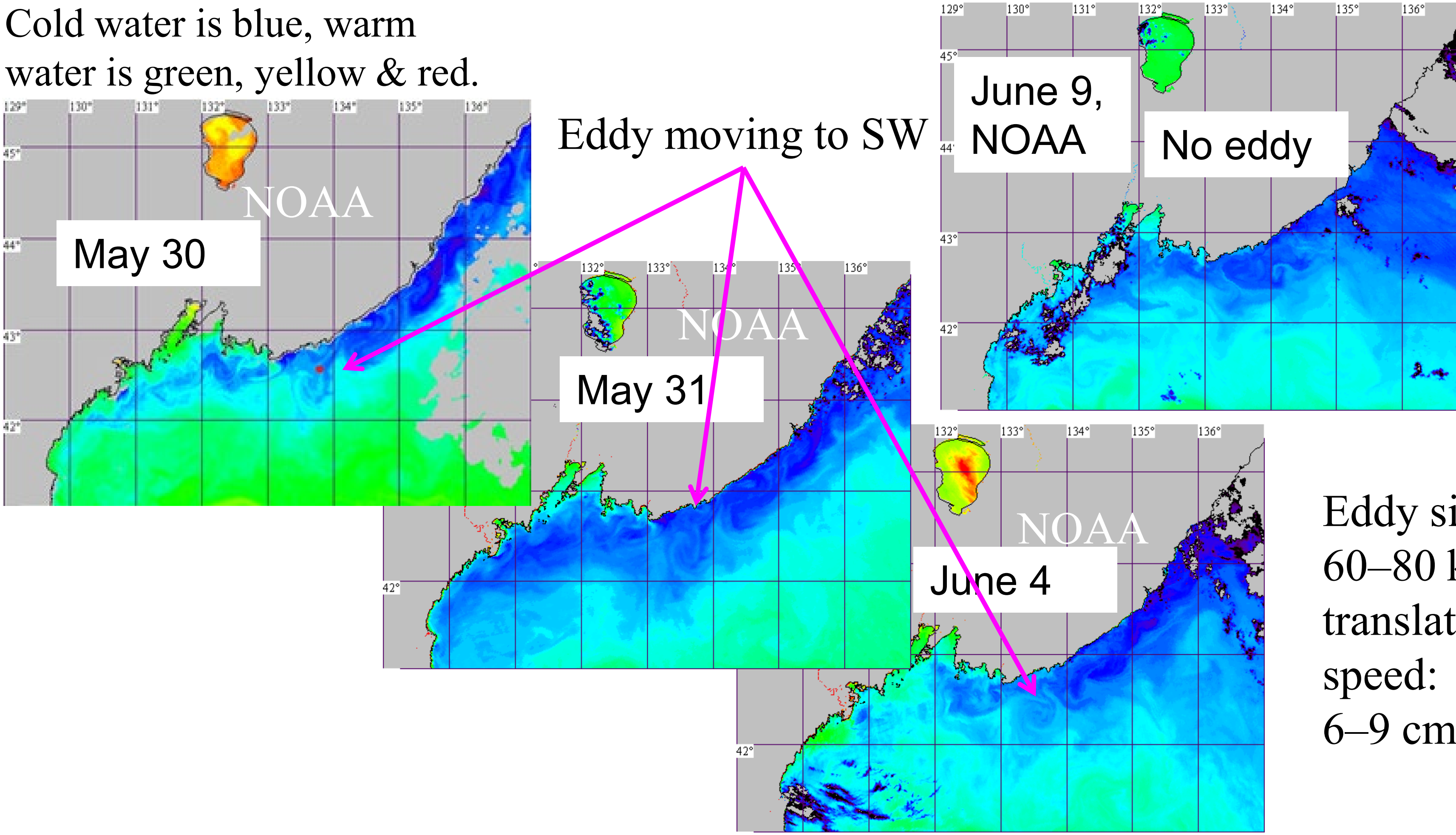


Cold water of the Primorye Current, rich in Chl-a.

Alternating cold and warm water in SST & rich and poor in Chl-a

Large anticyclonic eddy in late May – early June

Cold water is blue, warm water is green, yellow & red.



Eddy size: 60–80 km, translation speed: 6–9 cm/s.

Large anticyclonic eddy in late May – early June

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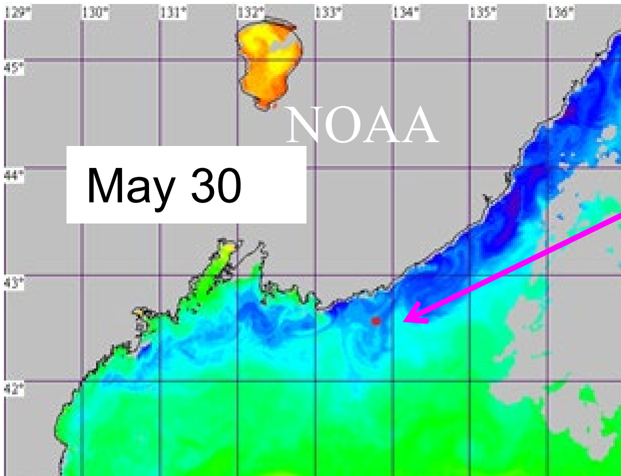
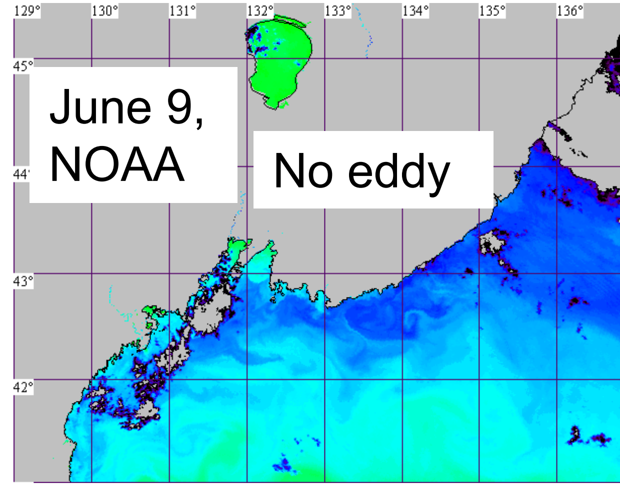
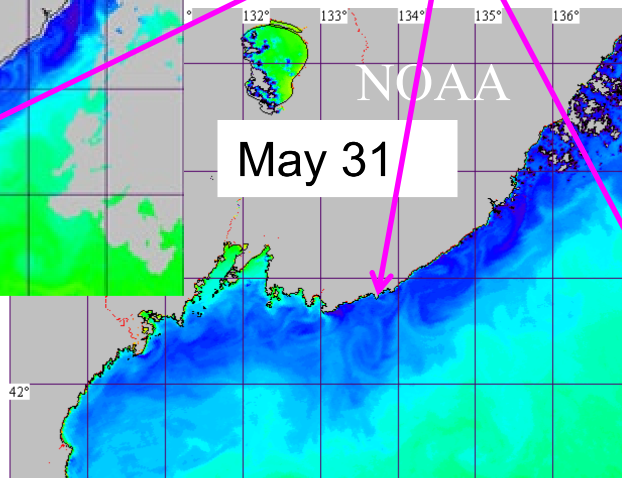
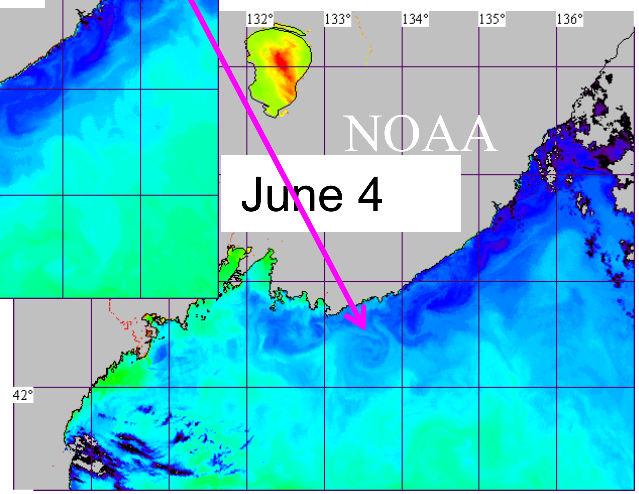


Eddy moving to SW







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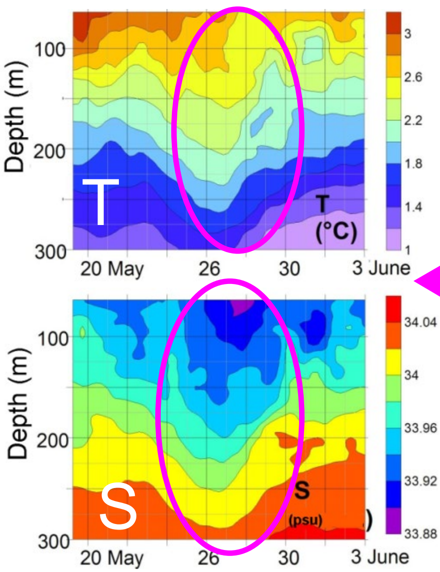

Eddy signature in Aqualog data:

cool & fresh water at 60 – 100 m,
warm & fresh water at 150–300 m

Large anticyclonic eddy in late May – early June

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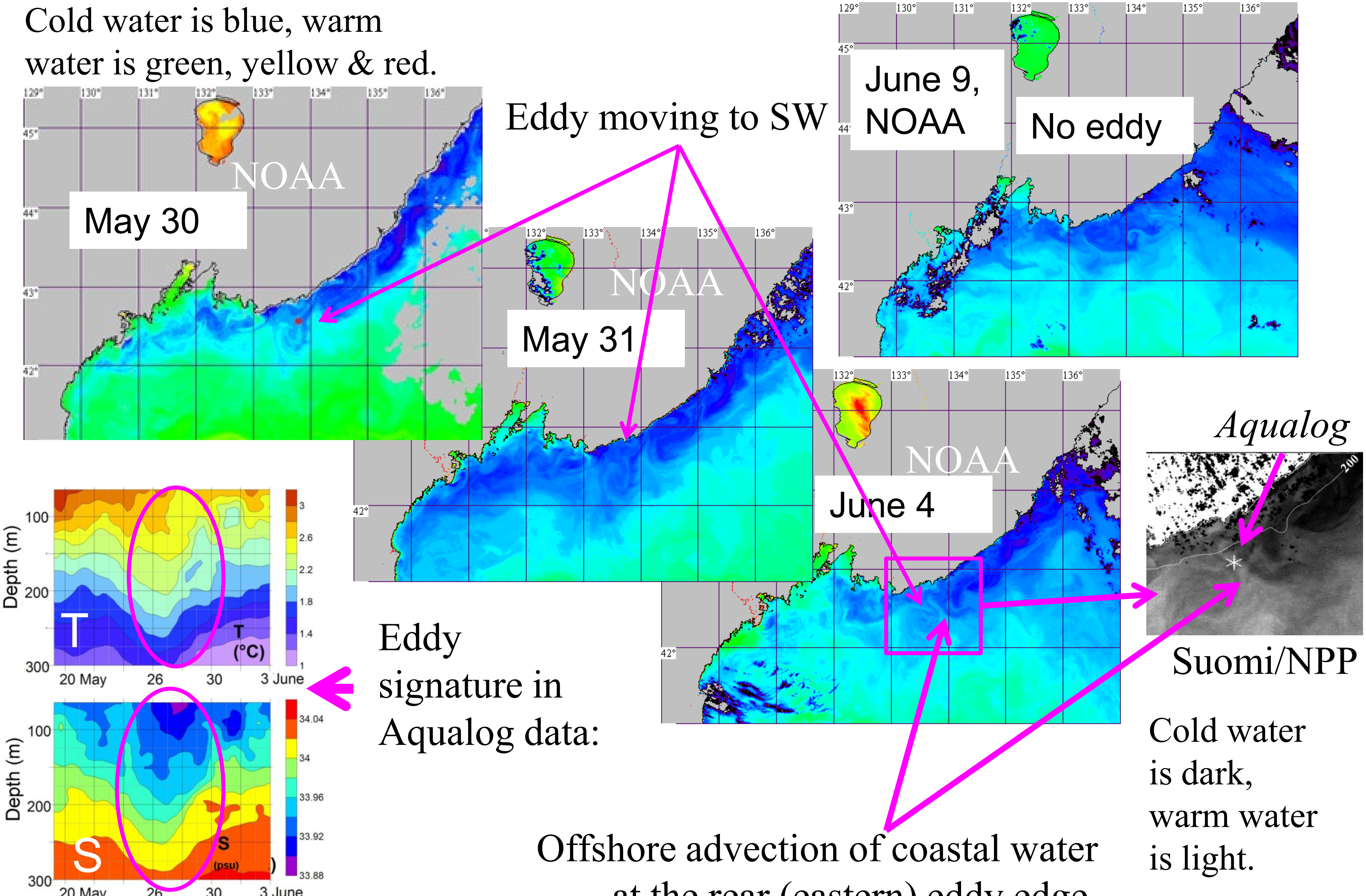
Eddy moving to SW



Aqualog

Suomi/NPP

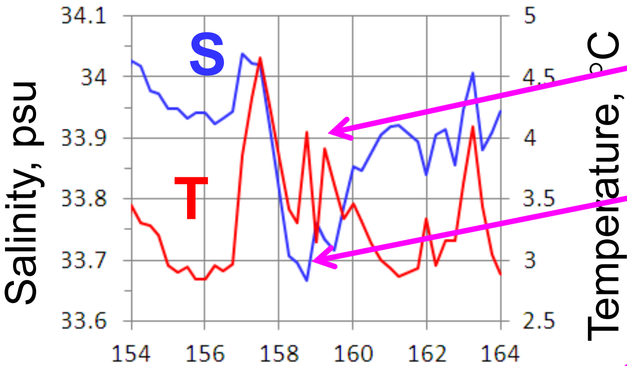
Cold water is dark, warm water is light.

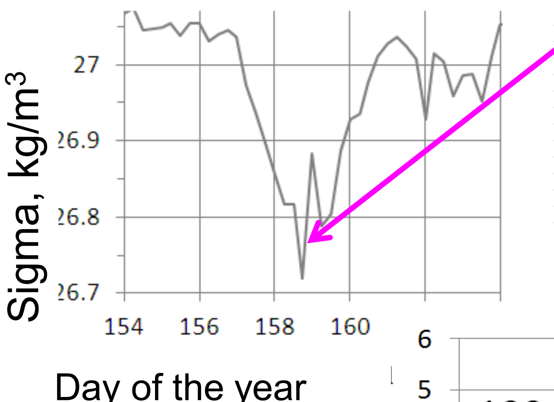
Eddy signature in Aqualog data:

Offshore advection of coastal water at the rear (eastern) eddy edge.

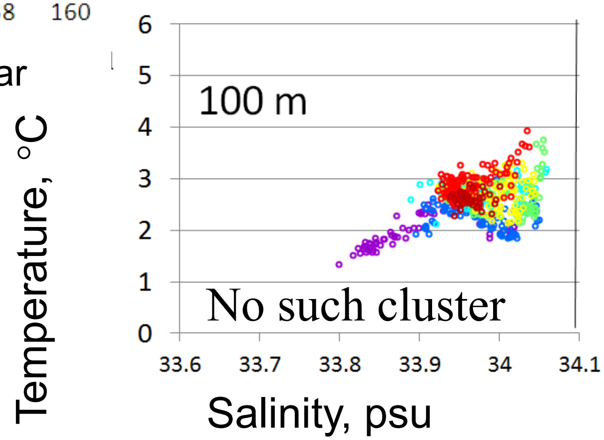
Warm and fresh coastal water
June 7–8 (158–159 days of the year)

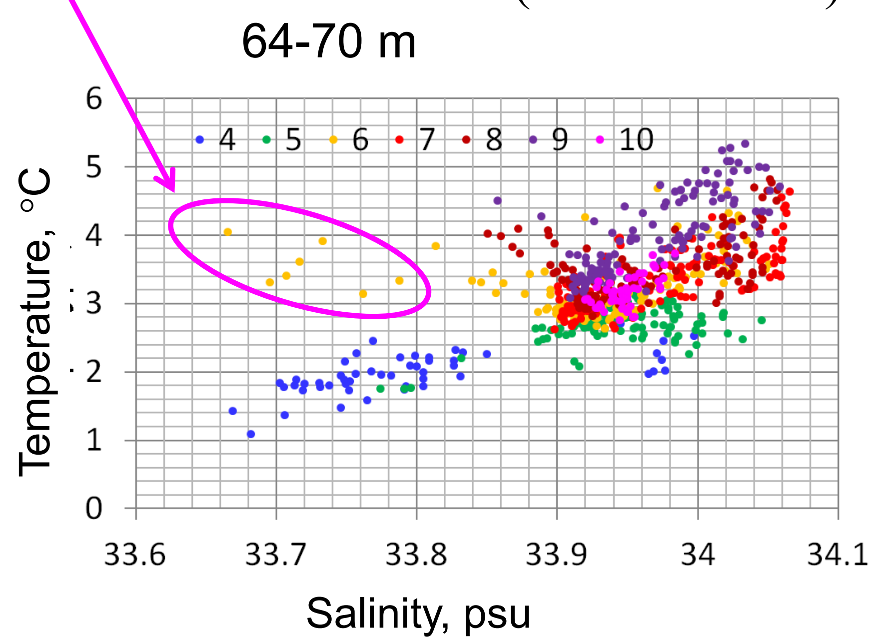
Increased T (3.5–4.0 °C),
very low S (33.713 psu;),
sigma (26.87 kg/m^3; абс. min for the whole time).



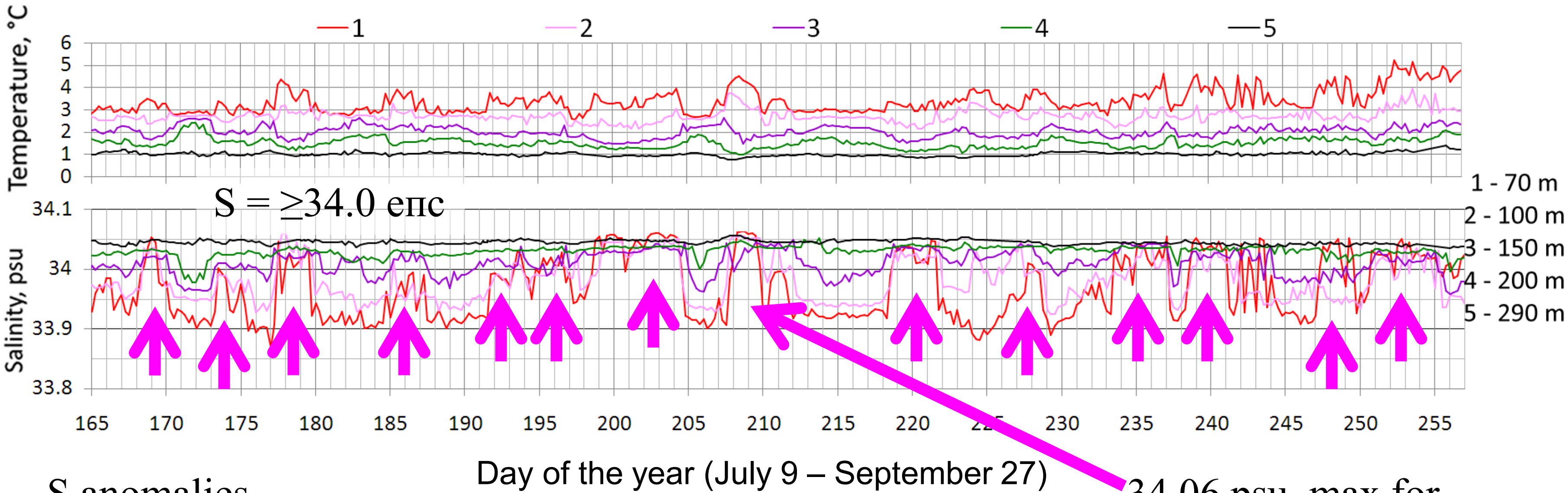


June: cluster of warm low salinity water (down to 80 m)



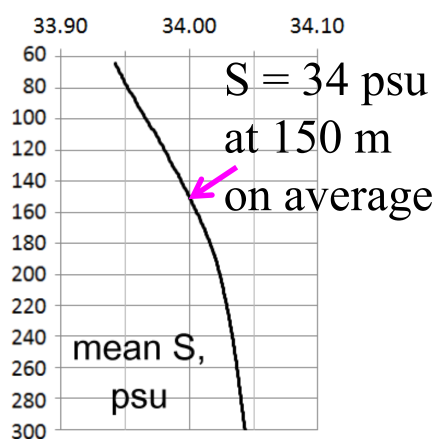


Intrusions of warm and salty water
(from mid June through mid September)



S anomalies down to 150 m

34.06 psu, max for the whole time



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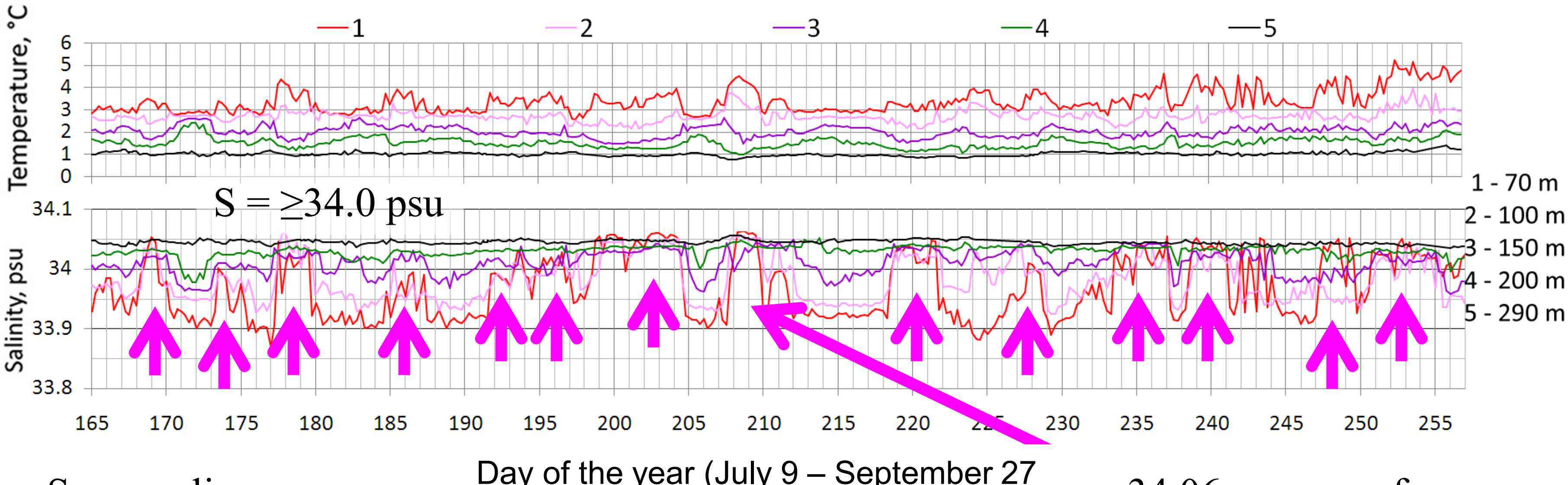

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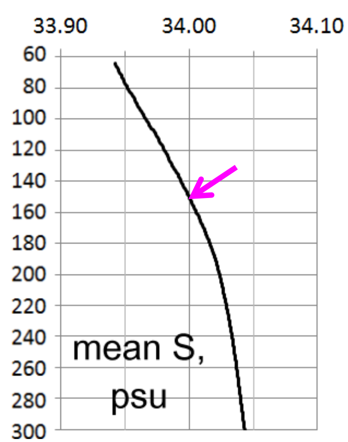
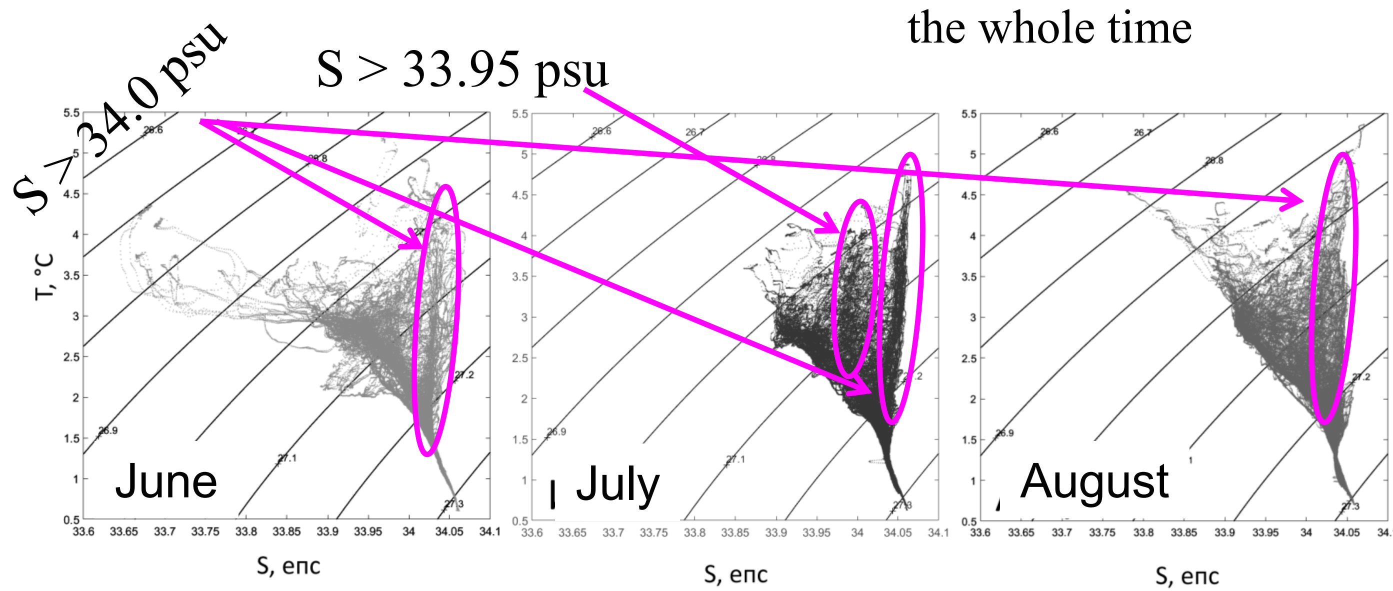
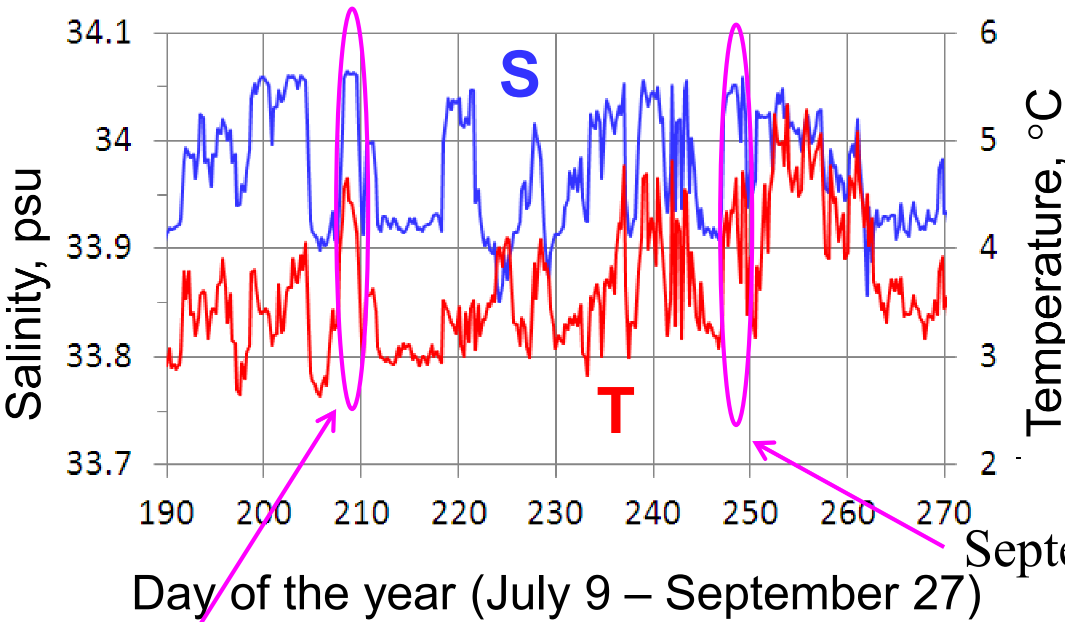




Positive T & S anomalies
(from mid June through mid September)

64-70 m

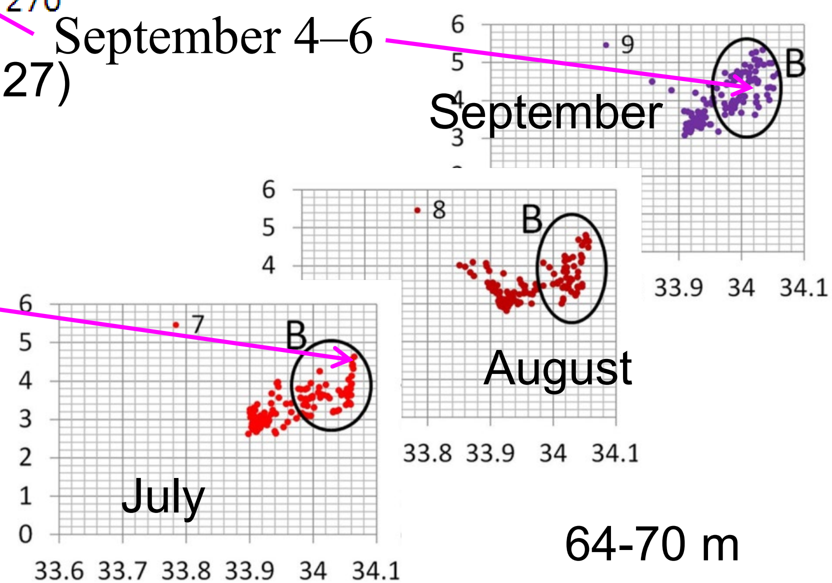


July - August:
T = 3.5–4.0 °C,
S > 34 psu.

September:
T = 3.5–5.5 °C,
S > 34 psu.

September 4–6

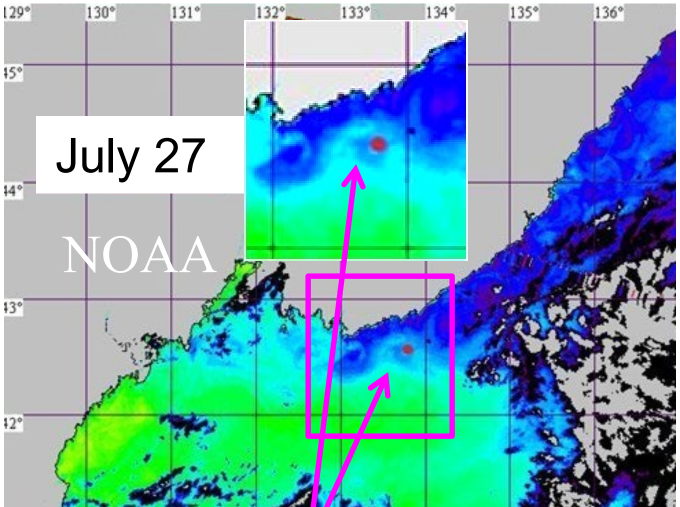
July 27–28



Increased T and S (> 34 епс) → originate from the southern Sea, transformed subtropical water

64-70 m

Satellite images: warm water advection towards the Russian coast (July 27 and September 4)



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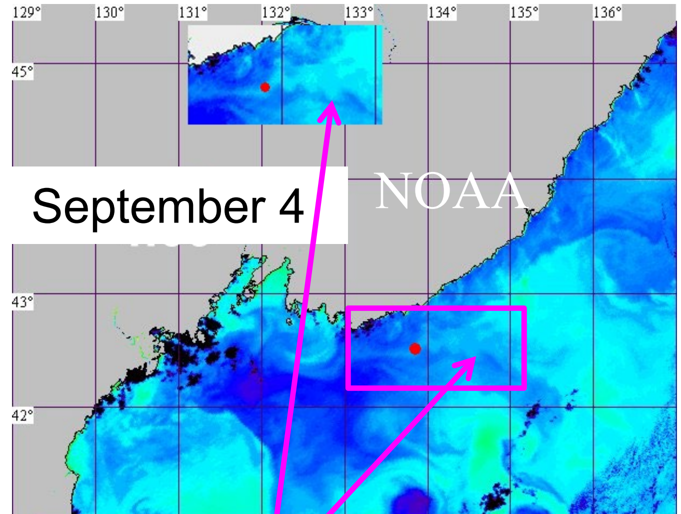
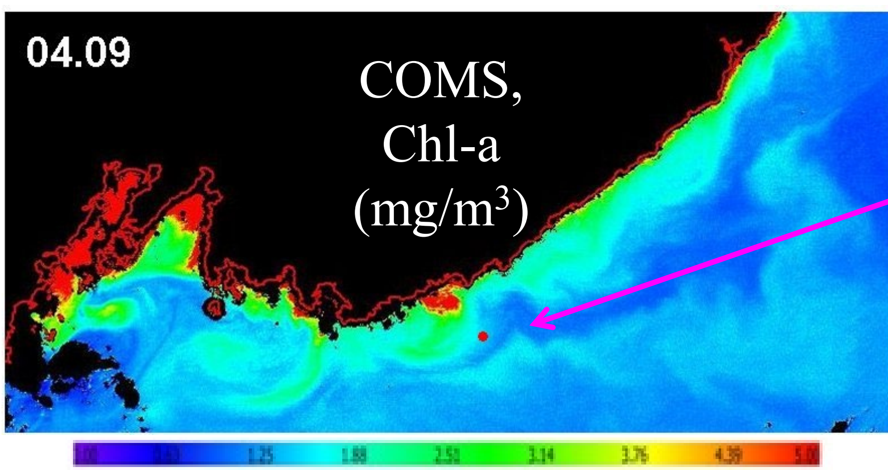


From the south

From the east



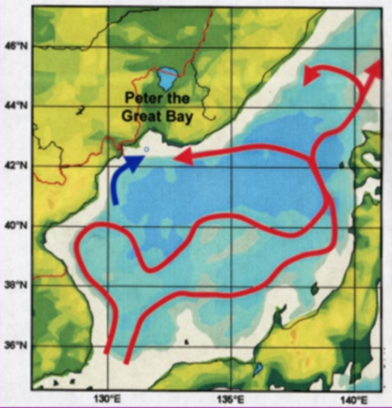
Decreased Chl-a from the east.

Warm water advection towards the Russian coast

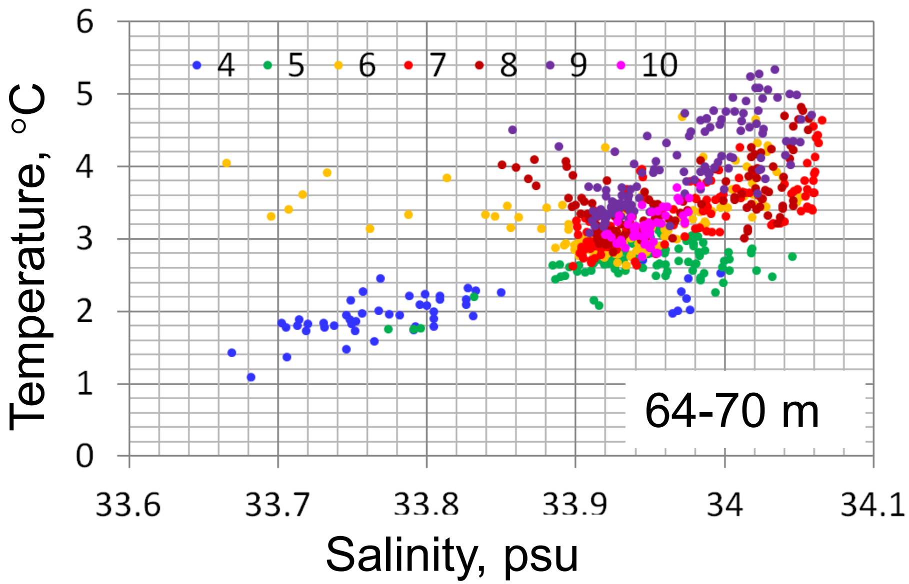
Frequent cloudy conditions in summer 2015:
no informative NOAA IR images on June 16 – July 7,
July 8 – July 26, July 28 – September 3, September 8 – October 2;
no informative Suomi/NPP IR images
on June 16 – September 3, September 8 – October;
no informative COMS visible images on June 11 – September 4.

However, an increased S (> 34.0 psu) → transformed subtropical water.

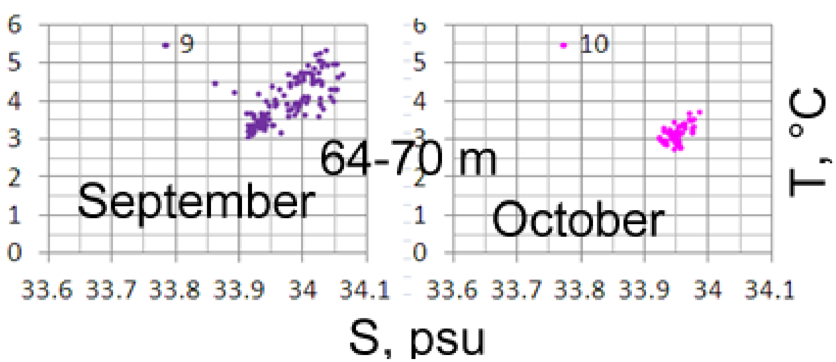
On northward advection of warm water:
Danchenkov et al., 2002; Lobanov et al., 2007;
Nikitin, Yurason, 2008.

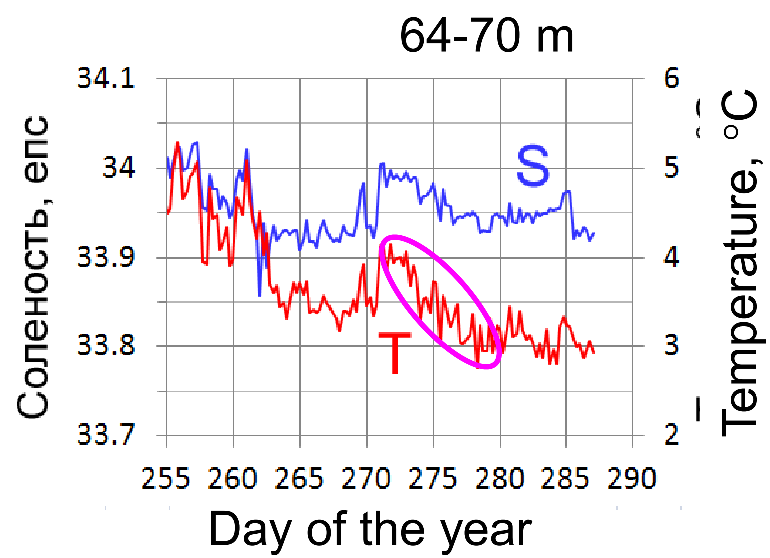


Temperature decrease in October



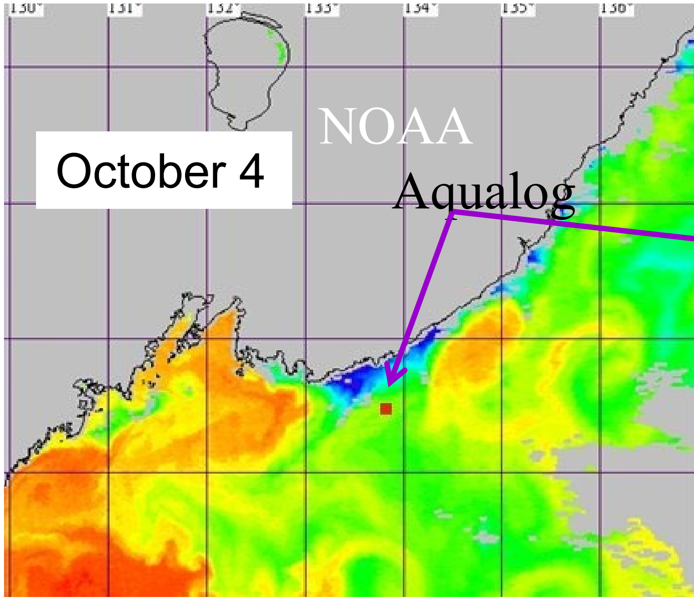
September 30 – October 3
(273 – 276 days of the year):
$T_{64–70}$ decreased from 4.1 to 3.1 °C);
S almost not changing.





Seasonal T max: October – November
(Luchin et al., 2003).

Upwelling in October



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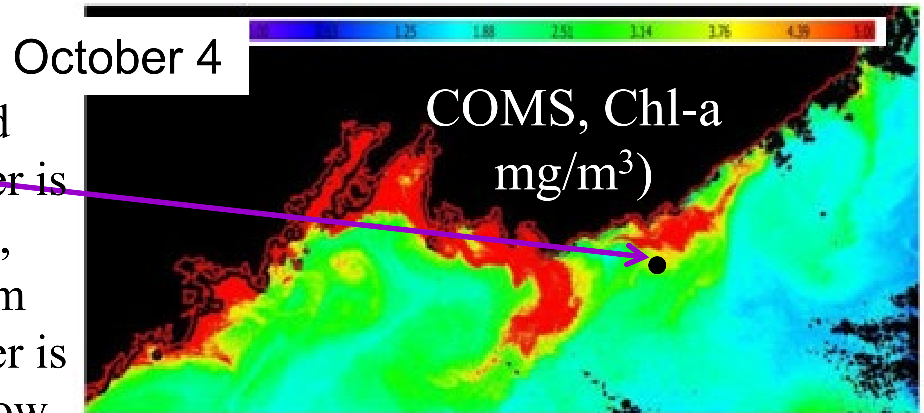
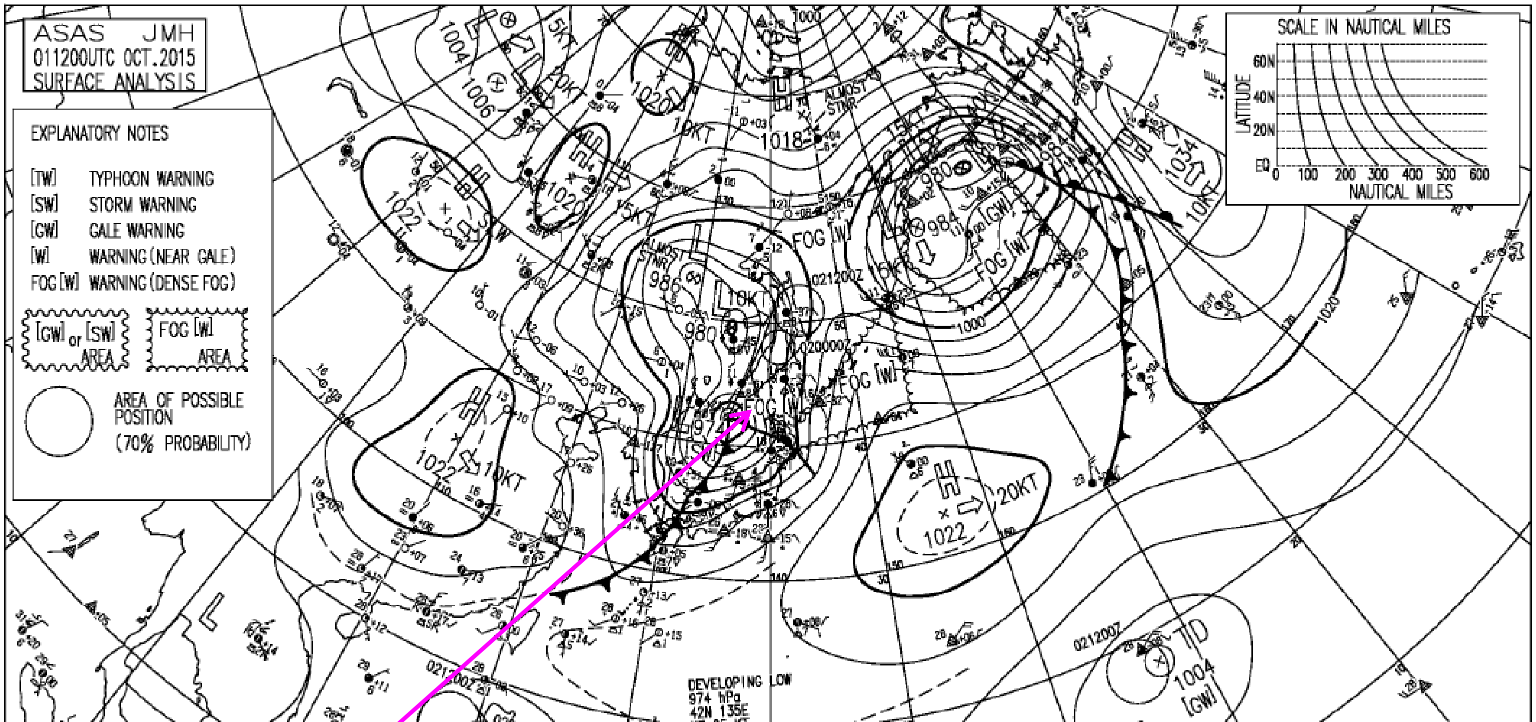


Surface manifestation closer to the coast

Wind upwelling?

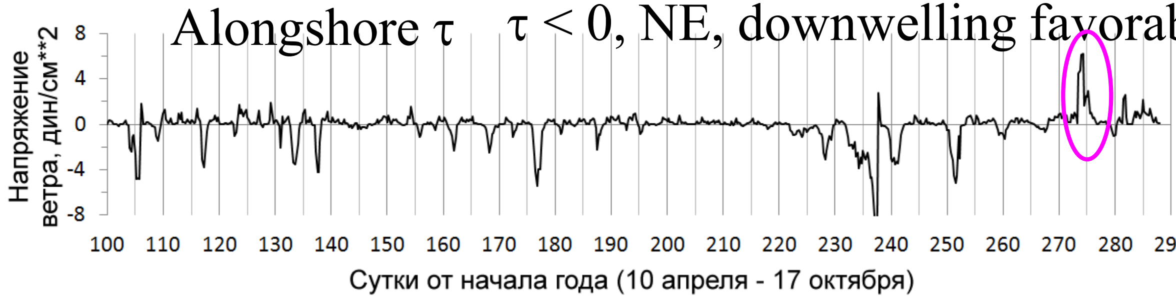
SLP, JMA, October 1, 12 UTC



τ > 0,SW, upwelling favorable,

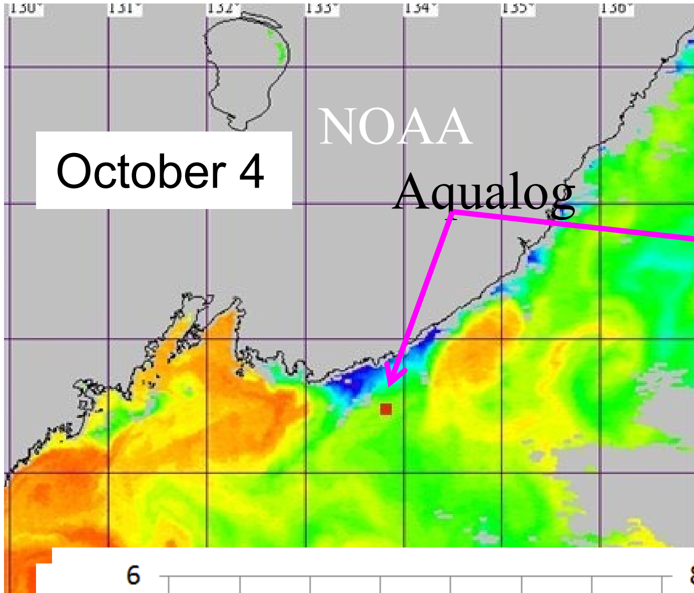
τ < 0, NE, downwelling favorable

Alongshore τ



September 30 – October 2: cyclone passage, strong wind

Upwelling in October



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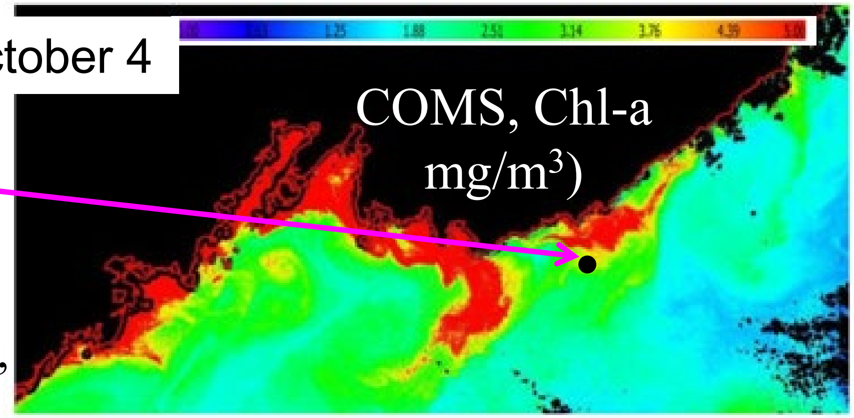

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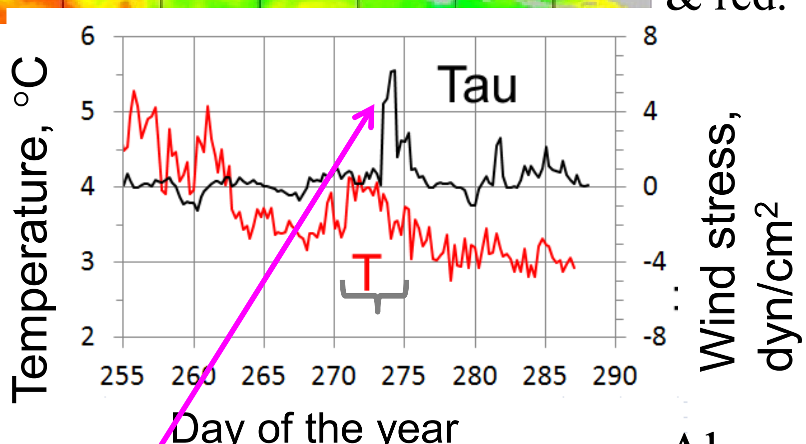
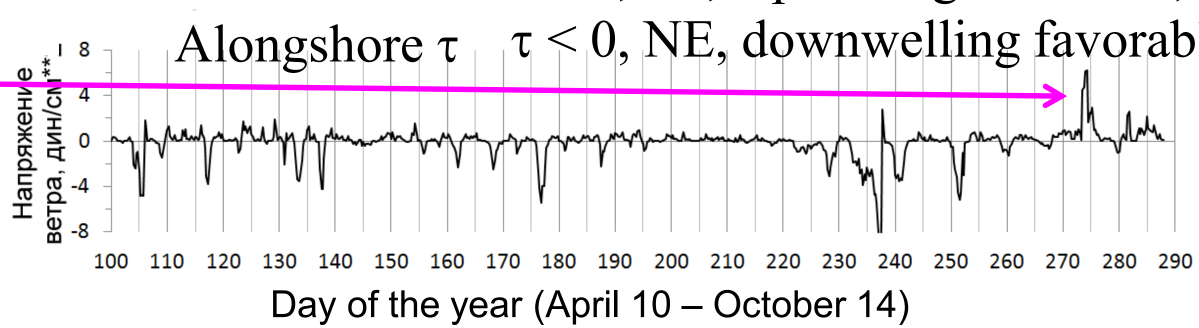


April – September: strong wind was mostly donwwelling favorable (easterlies).

$\tau > 0$,SW, upwelling favorable,

$\tau < 0$, NE, downwelling favorable



September 30 – October 2: cyclone passage, strong wind

Conclusion

T,S-indices, 64 – 70 m

Water mass	*T (° C)*	*S (psu)*
Primorye Current, April	1 – 2.5	33.67 – 33.85
Coastal water, June	3.0 – 4.0	33.67 – 33.82
Subtropical water, July - August	3.5 – 4.8	34.00 – 34.06
Subtropical water, September	3.5 – 5.5	34.00 – 34.06
Upwelling, late September – early October	2.9 – 3.3	33.93 – 33.95

Linked to dynamic structures using satellite imagery

Thank you for your attention!