Short-term variability of the thermohaline stratification under the seasonal pycnocline in the Primorye Current zone in the Japan/East Sea

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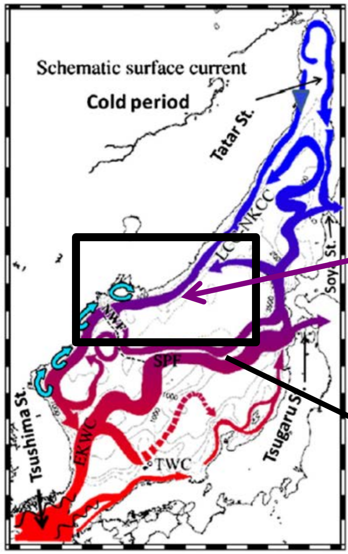
PICES-2017 Annual Meeting
S9: Meso-/submeso-scale processes and their role in marine ecosystems

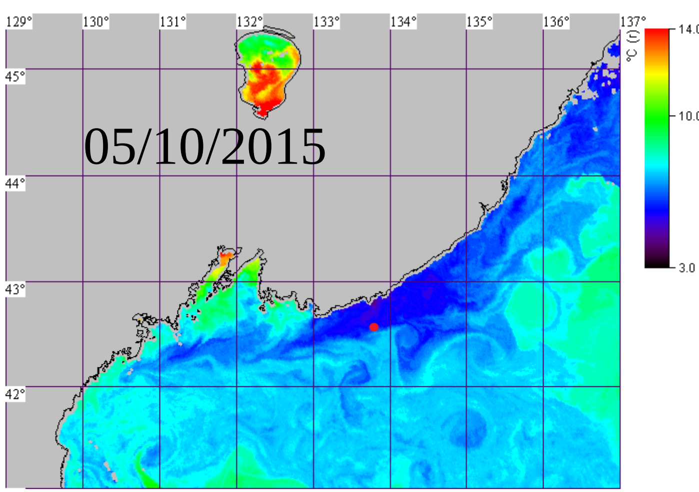
Background: The northern Japan/East Sea

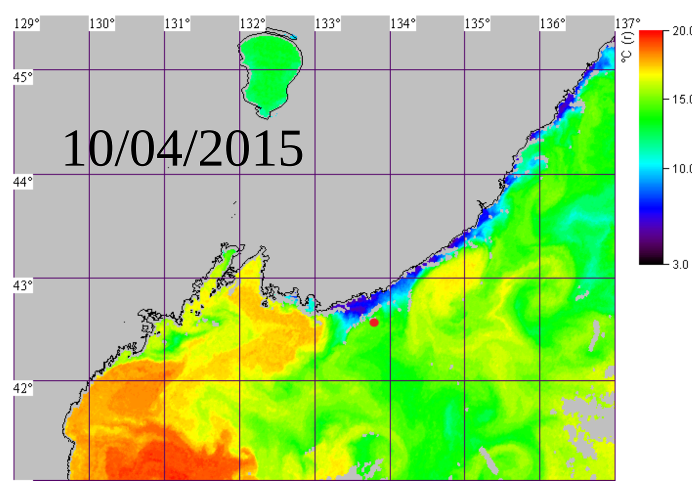


(Yoon, Kim, 2009)

- narrow sea shelf;
- steep bottom slopes (large depth gradients);
- Primorye (Liman) Current;
- hydrodynamic instabilities;
- mesoscale and submesoscale eddies;
- shelf waves;
- warm water advection from the east.

NOAA SST

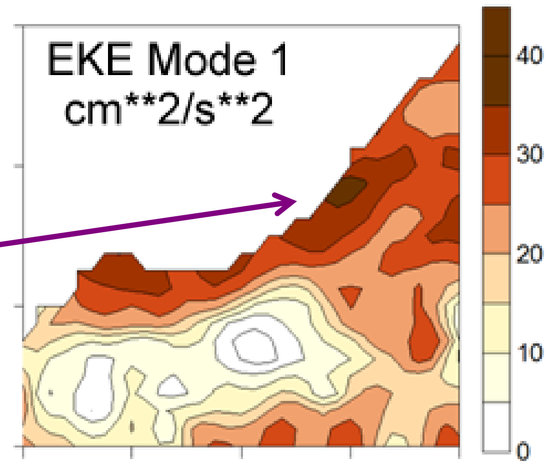




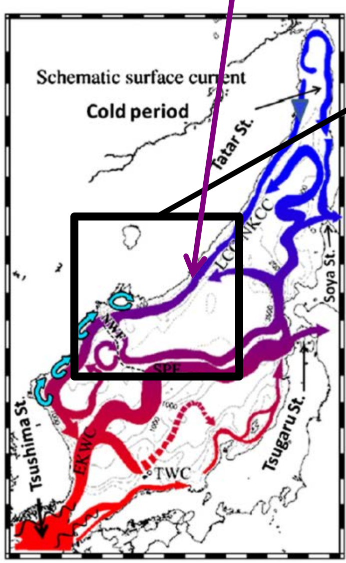
(Ladychenko and Lobanov, 2015)

Background: EKE in the northern Japan/East Sea
(satellite altimetry, AVISO sea level anomalies, 1993-2015)

EKE local maximum within the Primorye (Liman) Current area



(Trusenkova, 2011-2016).

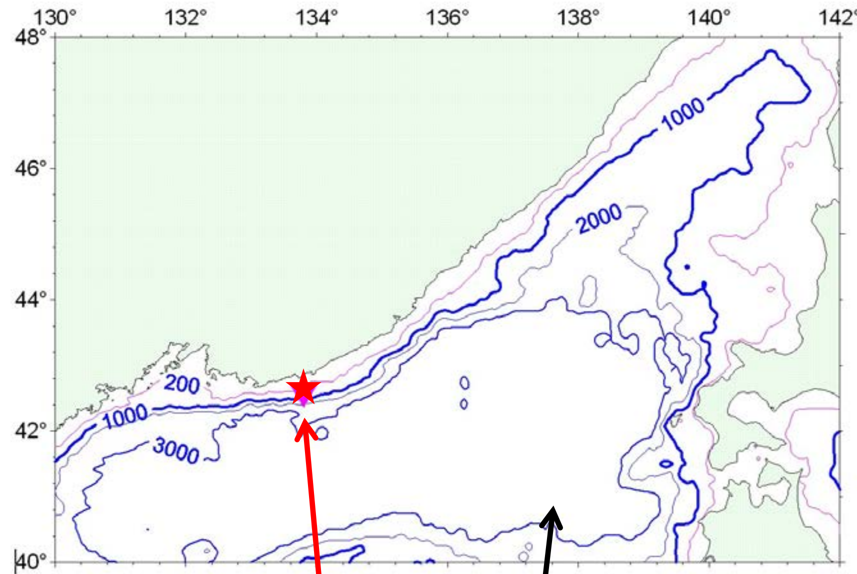


Maximum in October – November, minimum in March – April.

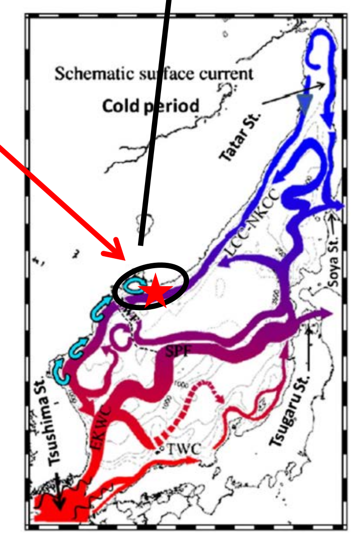
Instabilities moving with the Primorye Current can be both eddies and waves.

The intense vertical motions associated with long waves and mesoscale and submesoscale eddies result in strong vertical displacements of isopycnals at time scales from few days to a month and more.

To observe these variations in more detail we deployed moored profiler Aqualog at the upper portion of the continental slope off the Primorye (Russia) coast from **April 18 through October 15, 2015**.



Aqualog profiler location (42.5°N, 133.8°E), depth of 440 m



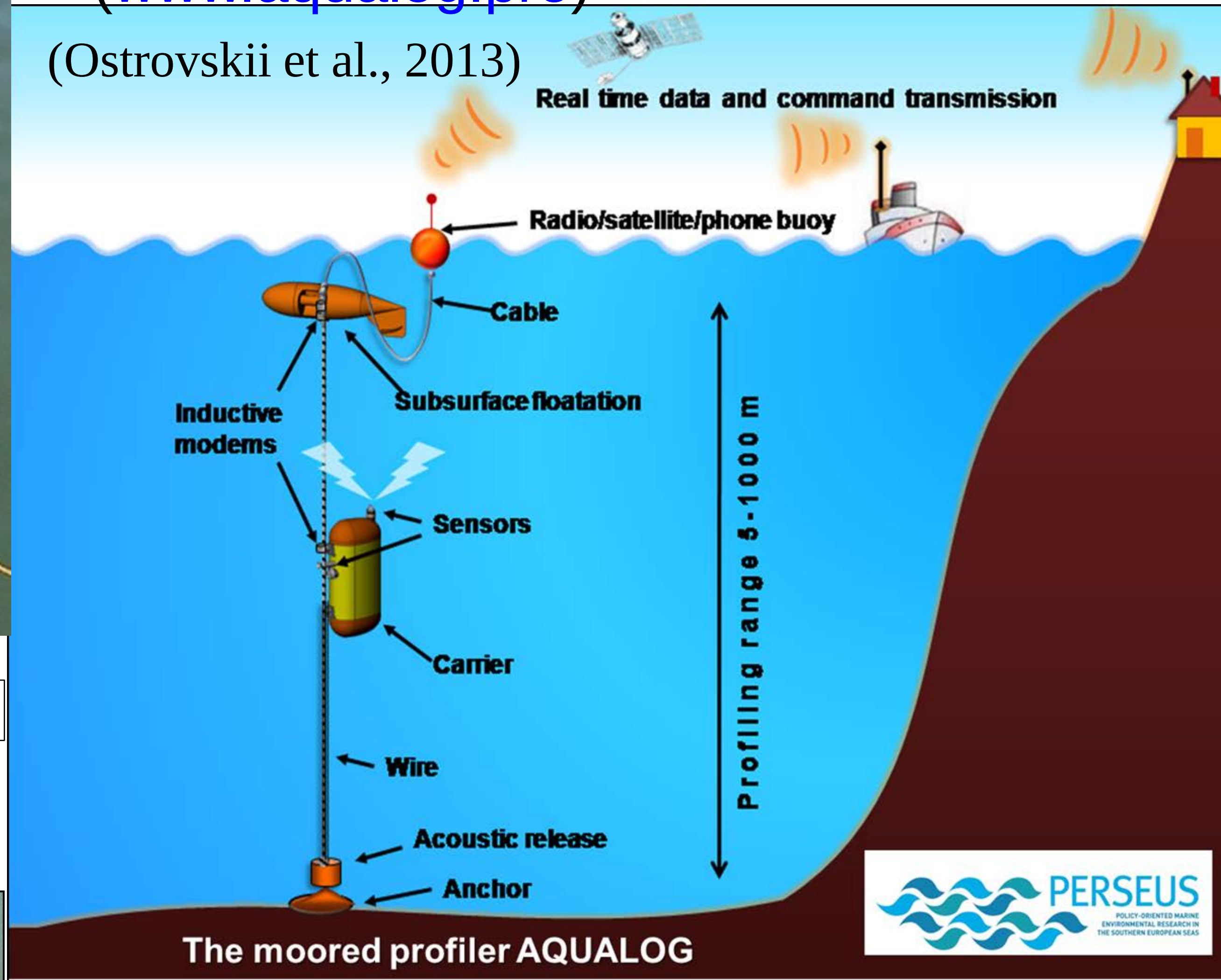
Purpose of the study

To determine time scales and magnitudes
of fluctuations of thermohaline stratification
in the Primorye (Liman) Current area
by using data of the moored Aqualog profiler
and check wind forcing by using CFSR/NCEP Reanalysis data

The Moored Profiler Aqualog

(www.aqualog.pro)

(Ostrovskii et al., 2013)



Multisensor platform for autonomous vertical profiling in the ocean (P.P. Shirshov Institute of Oceanology, RAS).

Data

Temperature, conductivity and pressure measurements by the SBE 52-MP Moored Profiler CTD.

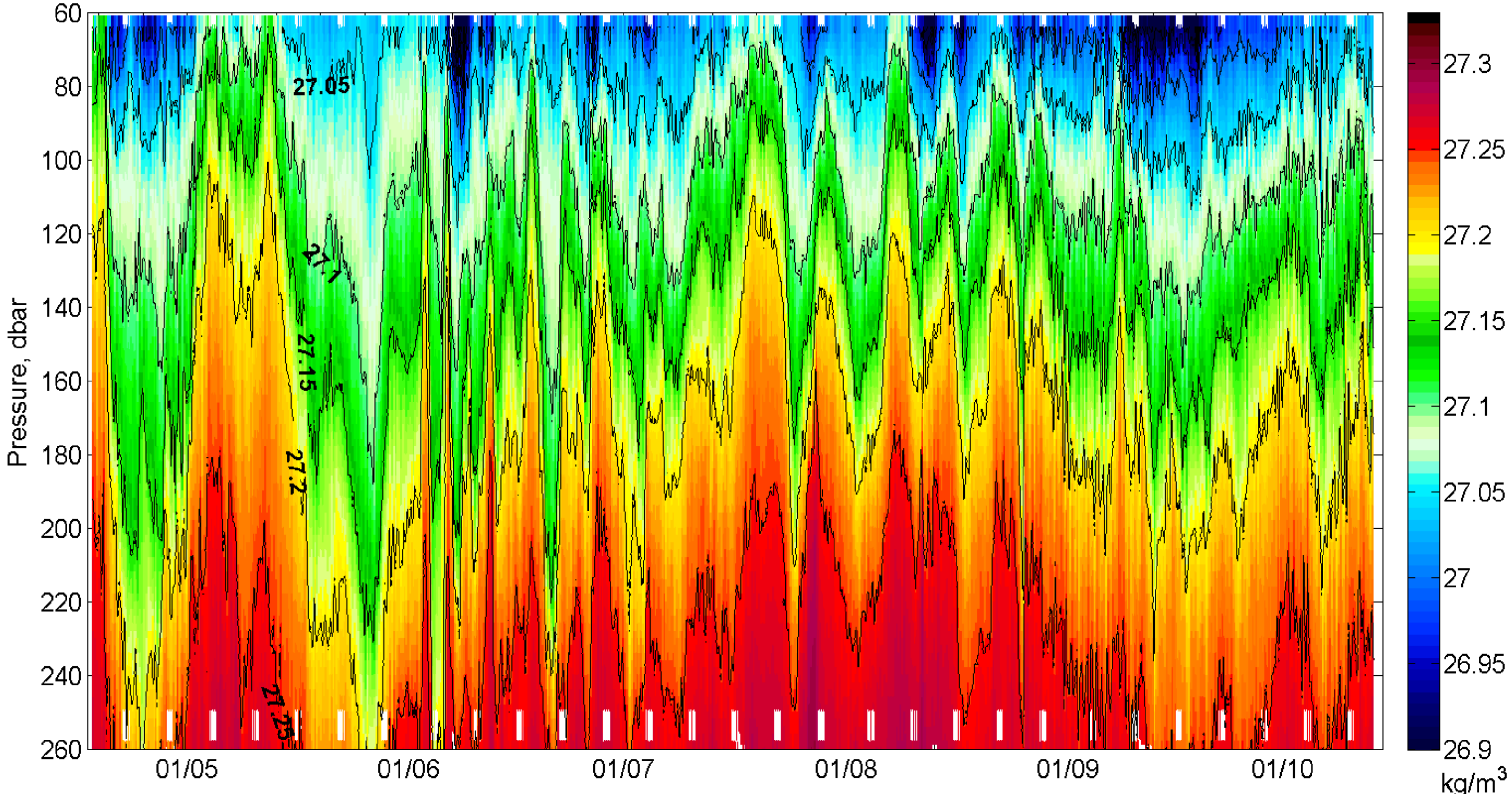
Period of measurements: from 18 April through 15 October, 2015.

Density computed from temperature and salinity measured in the upward casts in the depth range of 64 - 260 m 4 times per day.

The 64-260 m layer lies below the seasonal pycnocline of the subarctic water structure.

CFSR/NCEP Reanalysis, 0.2°, 1 hr, ~7 km away from the Aqualog location.

Time – depth diagram of density variation

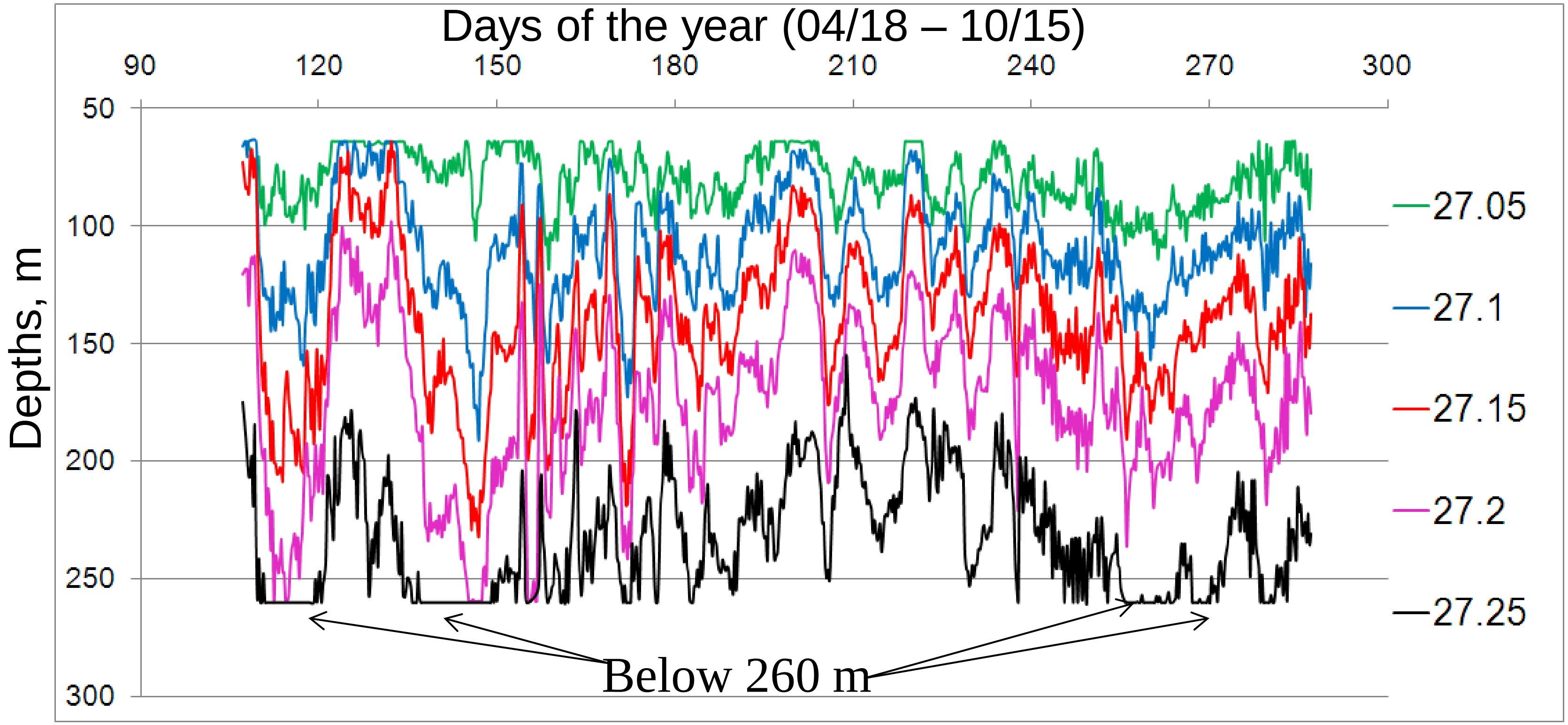


April 18 - October 15, 2015.
Depth range 64–260 m (below seasonal pycnocline).

Density was found to vary **between 26.9 kg/m^3 and 27.3 kg/m^3**.

Notice strong intraseasonal variability.

Time-depth diagrams of isopycnal depths



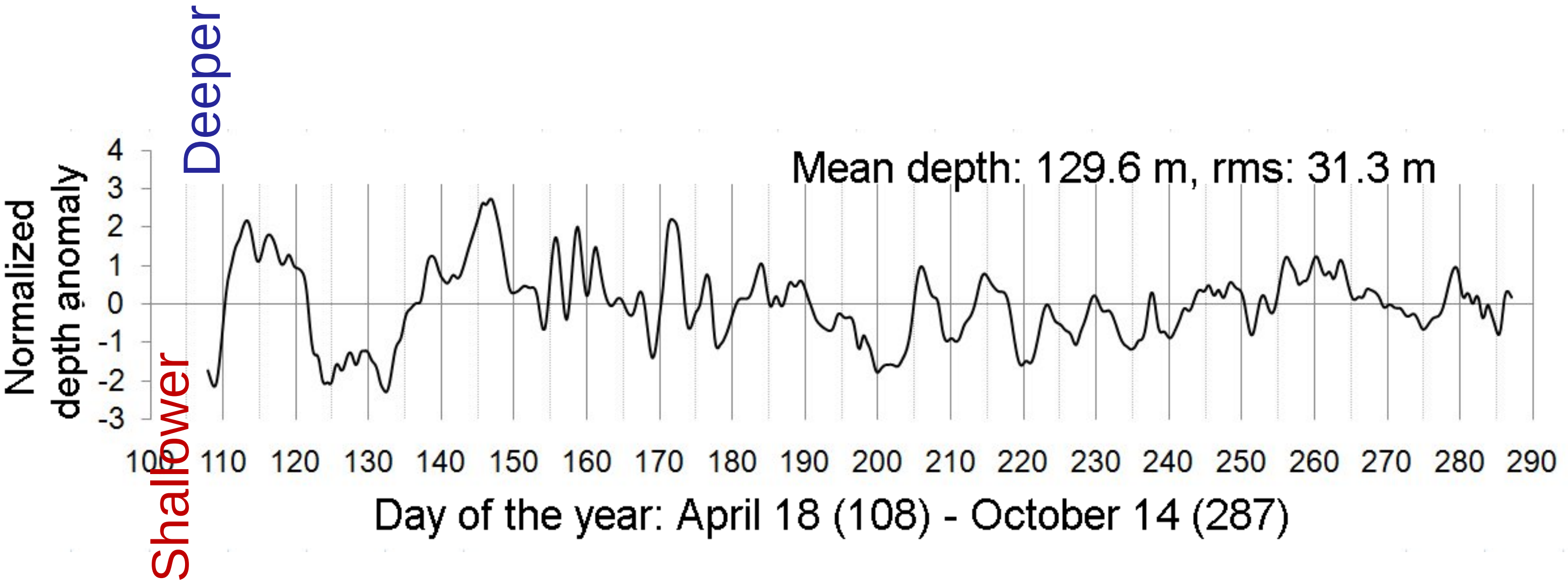
The depths of the **27.0–27.25** kg/m^3 isopycnals were computed.

Variation of the 27.0–27.25 kg/m^3 isopycnals were coherent (R ~ 0.7-0.9).

The **27.15 kg/m^3** isopycnal is chosen for the analysis, as it was always within the 64–260 m layer during the observation period.

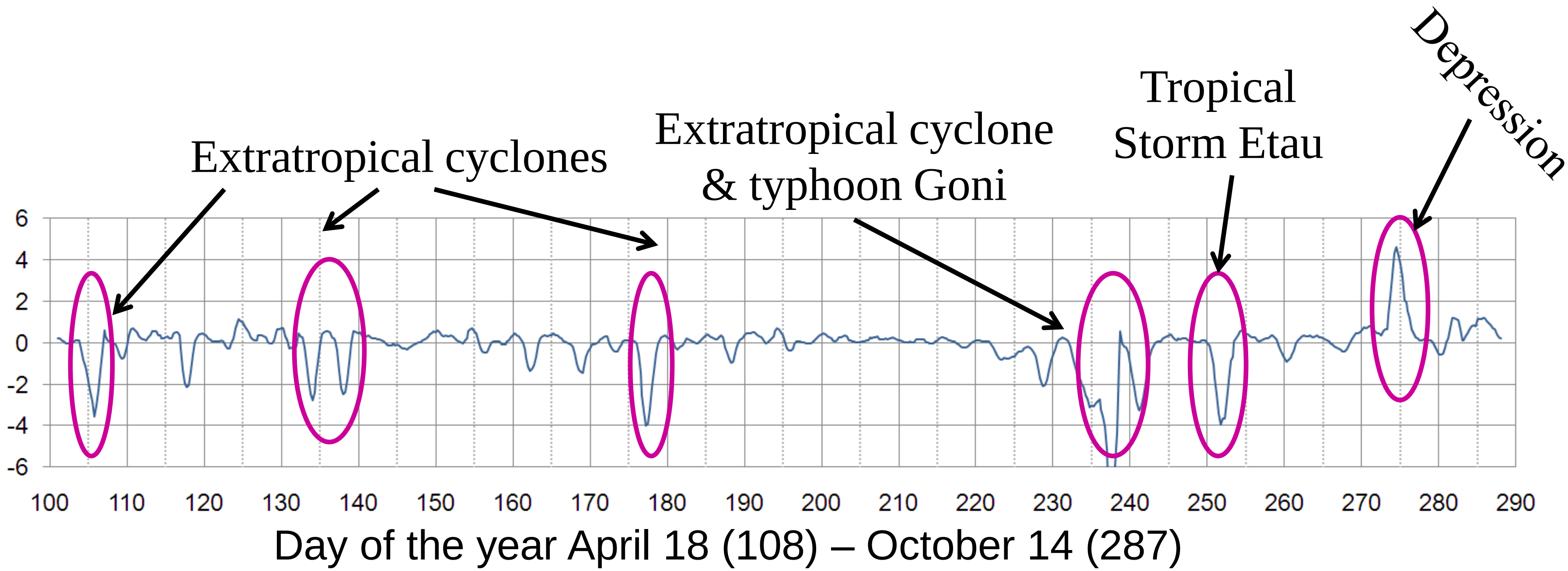
The **27.25 kg/m^3** isopycnal was below 260 m in some periods.

Normalized anomaly of the 27.15 kg/m^3 isopycnal depth



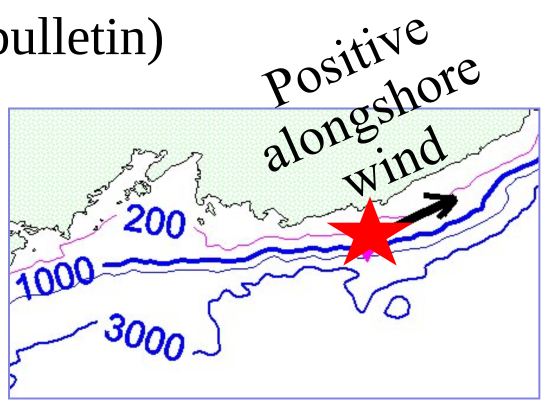
Multi-scale variability.

Alongshore wind stress
(CFSR/NCEP Reanalysis)

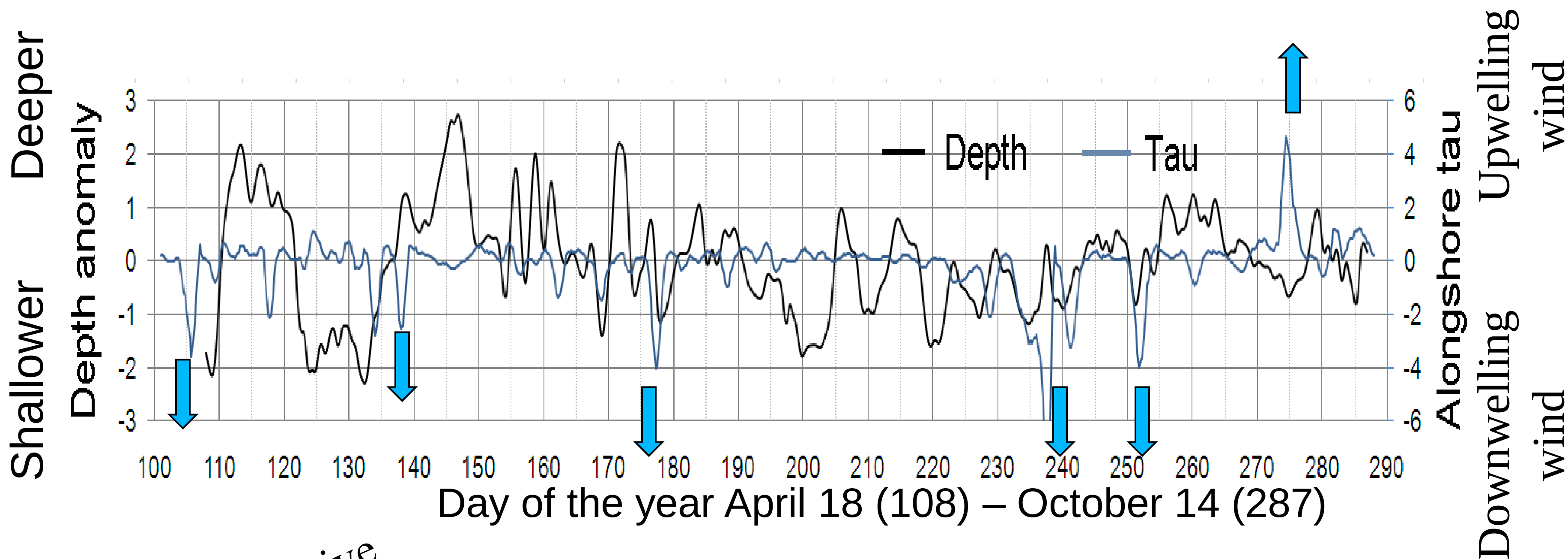


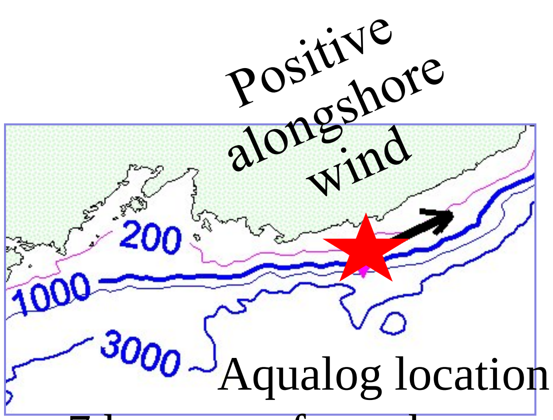
(Info on cyclones from FERHRI monthly bulletin)

On average: $\tau < 0.5$ dyn/cm^2;
$|\tau| \sim 2 – 6$ dyn/cm^2 during the passages of cyclones / typhoon / tropical storm



Alongshore wind stress
(CFSR/NCEP Reanalysis, 0.2°, 1 hr)





~7 km away from the Aqualog location

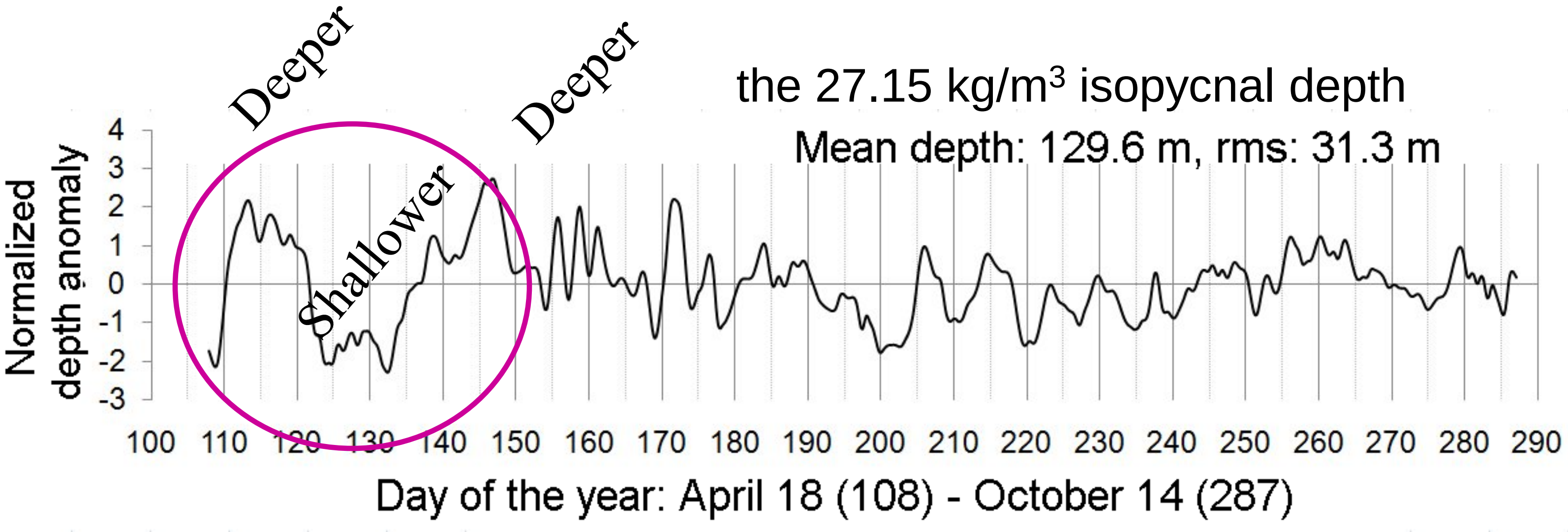
Westerlies, positive alongshore component: upwelling expected;

Easterlies, negative alongshore component: downwelling expected.

No downwelling, neither upwelling detected.

Short duration of the strong wind events?
Above 64 m? Reanalysis wind is not good enough?

Intense vertical density fluctuations
(04/18 – 05/31, 2015)



04/18 – 05/31: intense fluctuations, with RMS of 46.9 m, amplitude > 80 m.

Deep phase: 04/18 – 05/01.

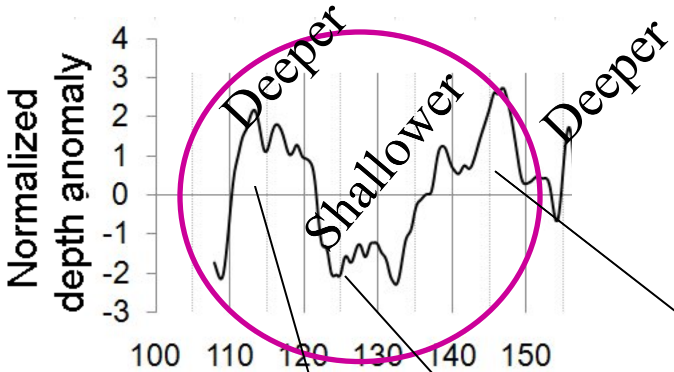
Shallow phase: 05/02 – 05/15.

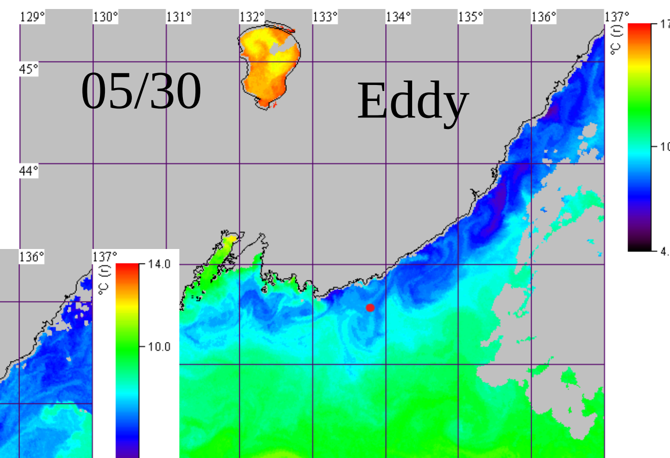
Deep phase: 05/16 – 05/31.

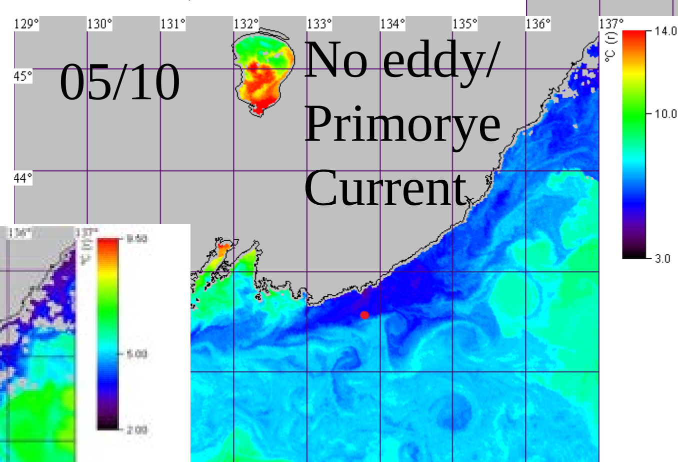
No such fluctuations afterwards

Can this be related to large mesoscale structures?

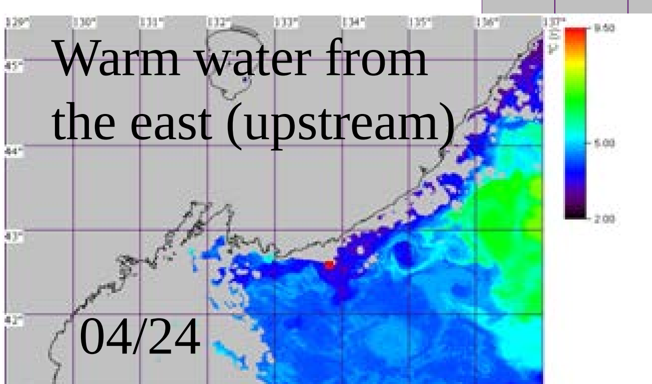
Deeper: 04/18 – 05/01
Shallower: 05/02 – 05/15
Deeper: 05/16 – 05/29







Not enough images due to cloudy conditions



Aqulog location shown by the red dot

(NOAA SST; Ladychenko, Lobanov, 2015)

Time-frequency domain analysis

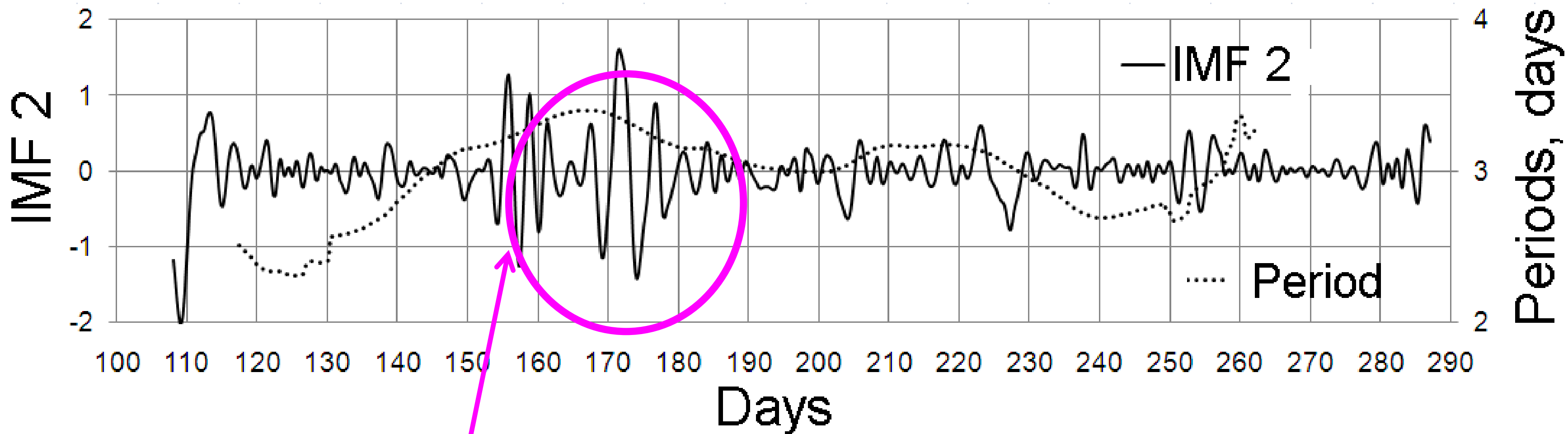
To elucidate higher-frequency variability Hilbert-Huang transform is applied.

Five Intrinsic Mode Functions (IMF 1 – 5) and the residual term are derived using Huang transform.

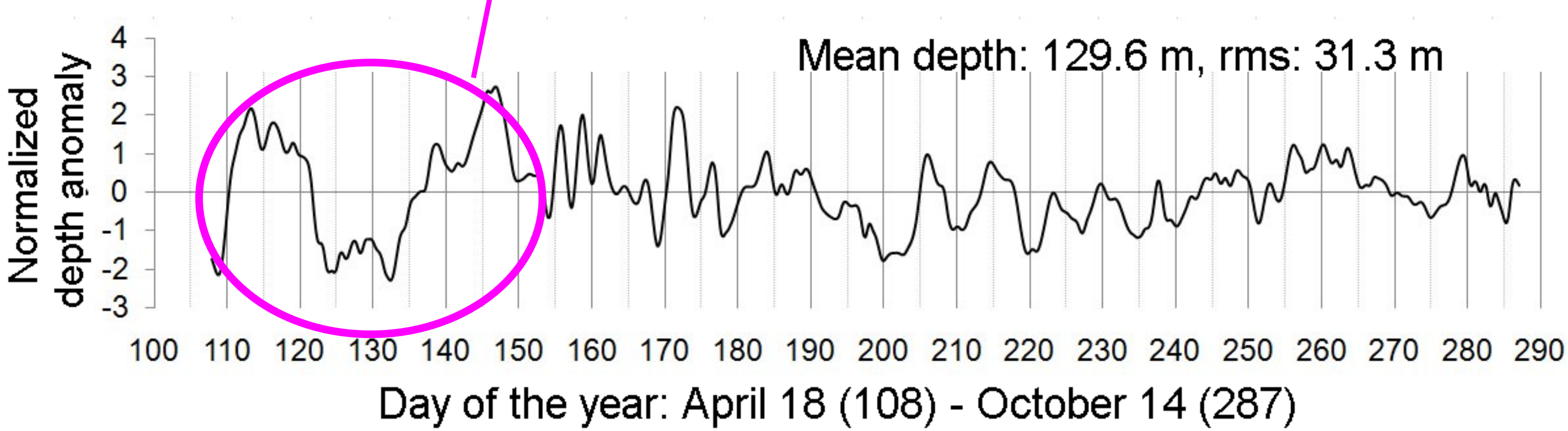
Hilbert instantaneous frequencies (periods) are computed and smoothed with running windows.

IMF 1 represents high-frequency noise, probably due to data errors.

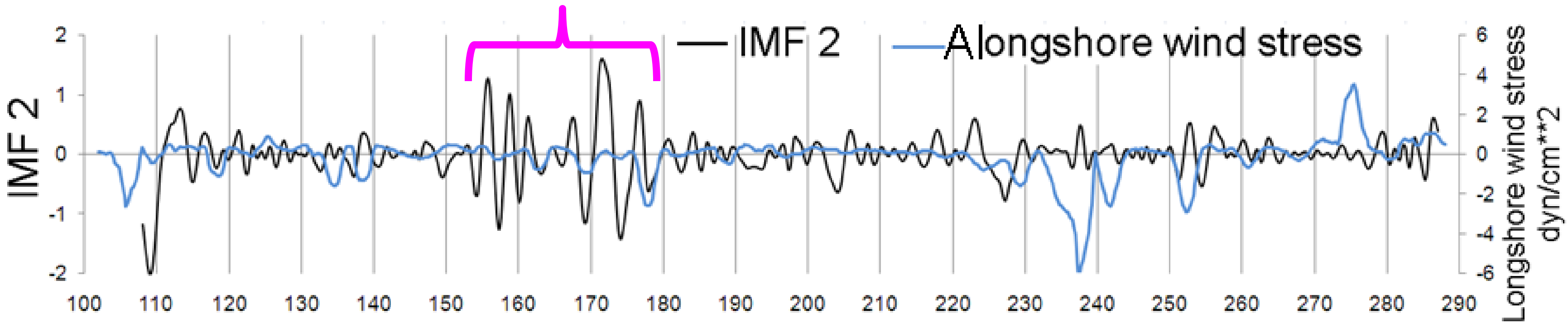
IMF 2: submesoscale with periods of 2–3.5 days
(passage of disturbances through the Aqualog location)



Strong in June after the decay of the strong fluctuations in April – May, amplitude > 20 m



Possible local wind forcing
(periods within atmospheric synoptic scale)

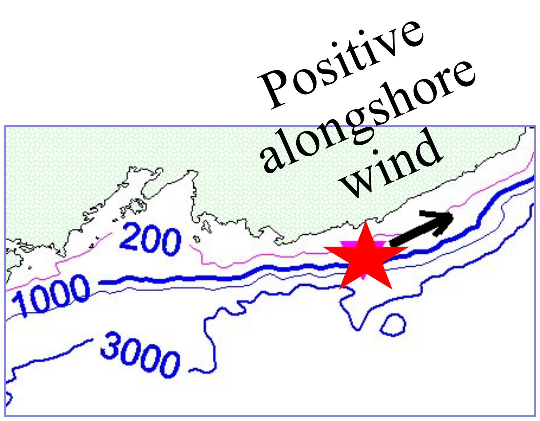


Day of the year April 18 (108) – October 14 (287)

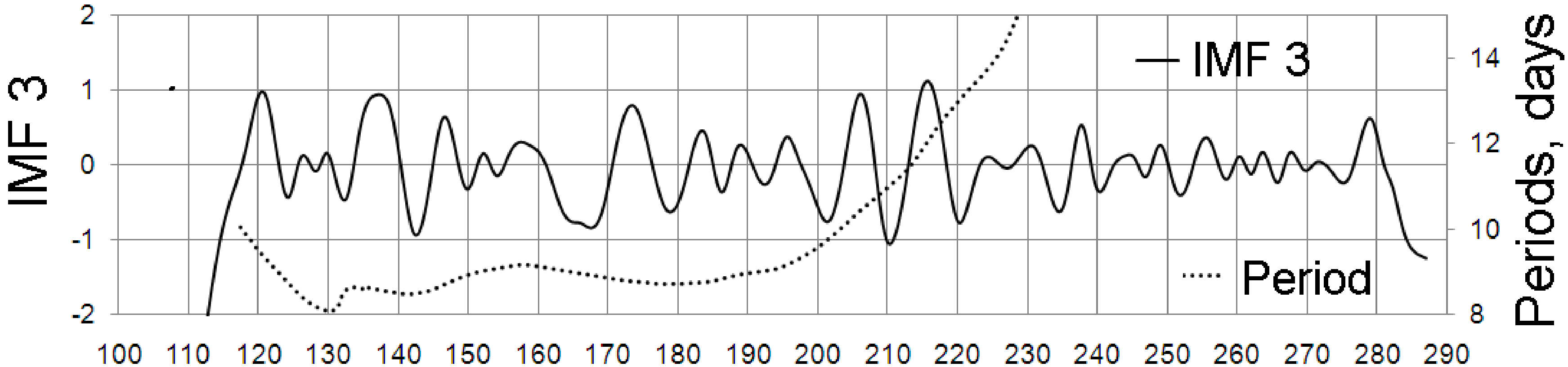
No direct relationship with the local wind speed

(from the nearest grid location of NCEP – CSFR) →

non-local forcing



IMF 3: mesoscale with periods of 8 – 13 days
(passage of disturbances through the Aqualog location)

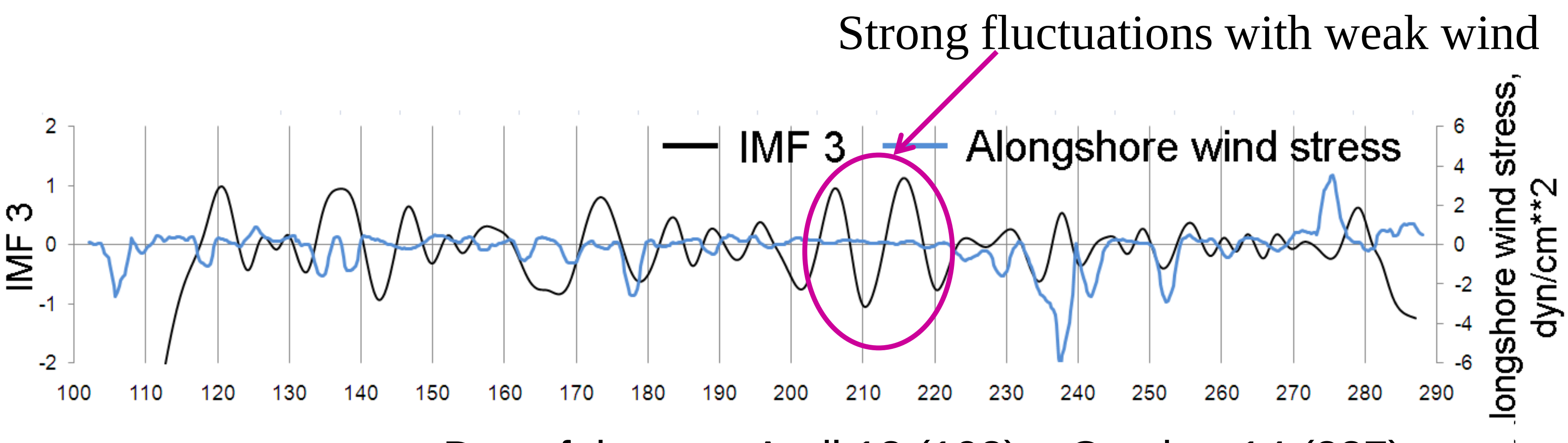


Day of the year April 18 (108) – October 14 (287)

The intense fluctuations from late April through mid August, amplitude > 20 m.

Periods of 8 – 13 days (from late April through mid August): within life times of mesoscale eddies which are short-lived in this subarctic area (Ladychenko, Lobanov, 2013).

No linkages with local wind



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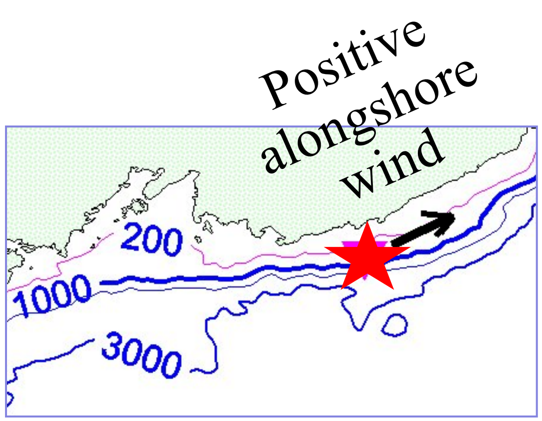
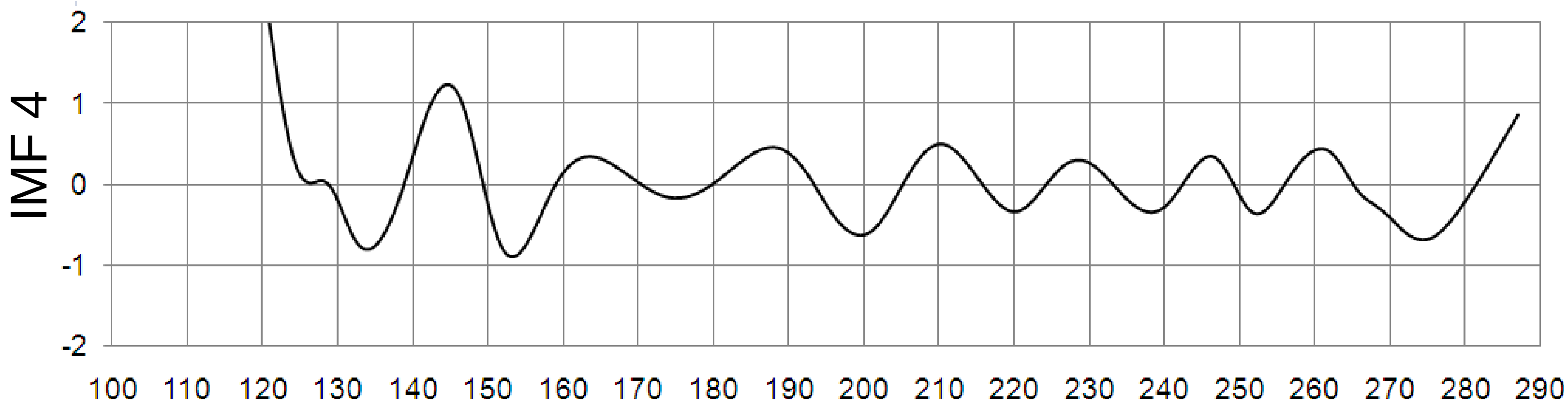


IMF 4: passage of wave-like disturbances with periods of 18-22 days

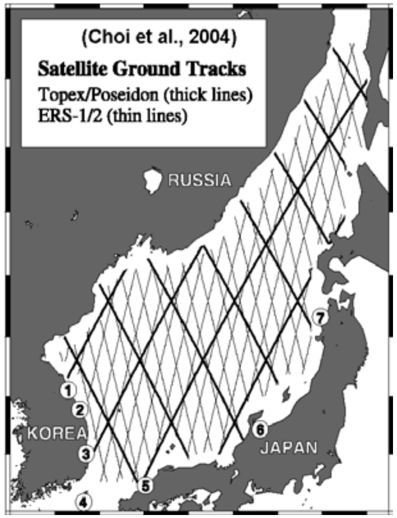


Day of the year April 18 (108) – October 14 (287)

Regular oscillations,
period ~ 18–22 days, amplitude ~ 20 m.

Shelf waves (topographic Rossby waves)?

What does EKE represent in the Primorye Current area ?



T/P, Jason:
every ~10 days.
ERS/Envisat/Saral:
every 35 days.

Time scales from Aqualog:

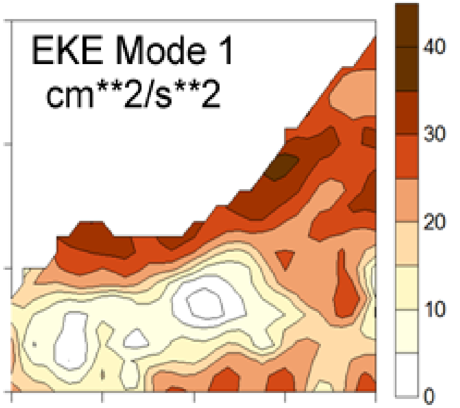
2–3.5 days (not seen in satellite data);

8–13 days (partially seen in satellite data);

18–22 days (wave-like; seen in satellite data);

1 month (unclear nature; seen in satellite data).

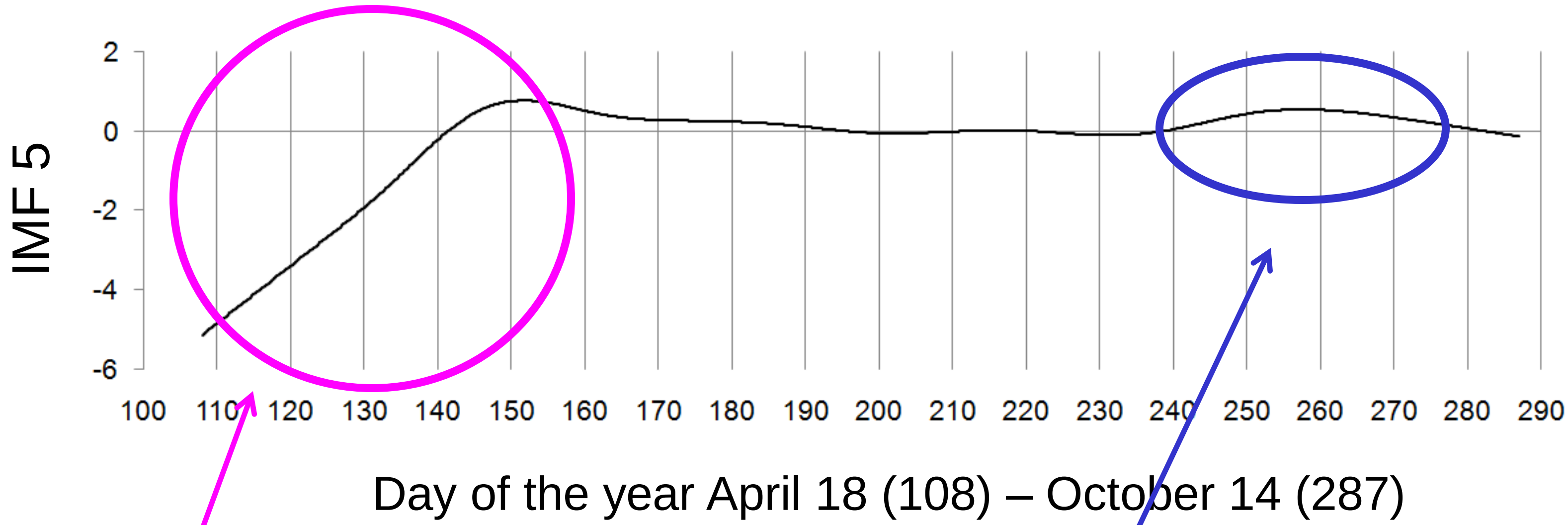
Eddy kinetic energy is not energy of eddies!



(Trusenkova, 2011-2016).

Instabilities moving within the Primorye Current can be both eddies and waves, with EKE representing waves and large eddies.

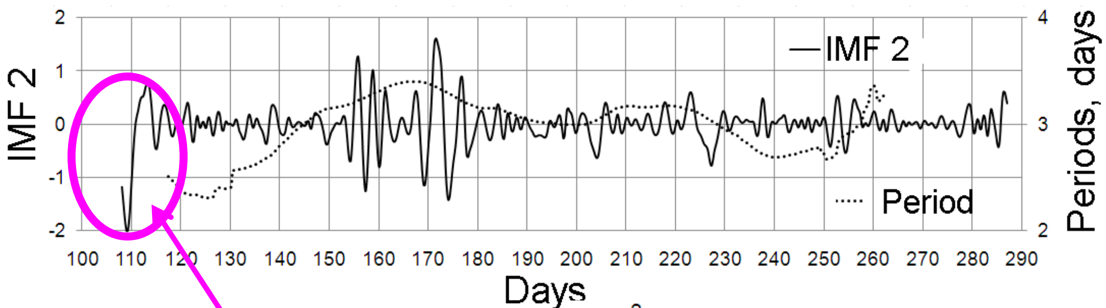
IMF 5 : strong edge effects, weak anomaly



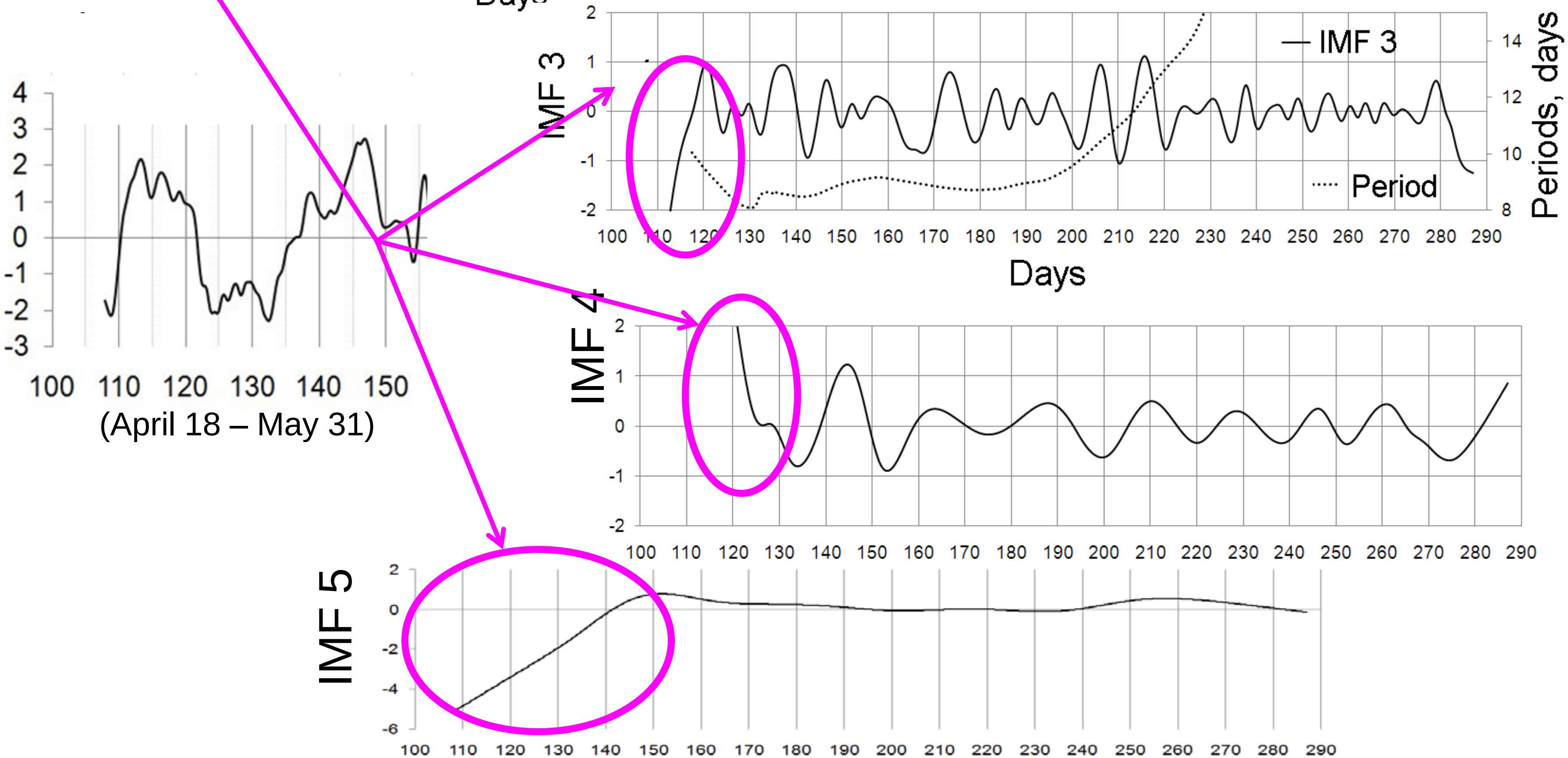
Edge effect

Weak anomaly (deepening by 15 m) on August 28 – September 27

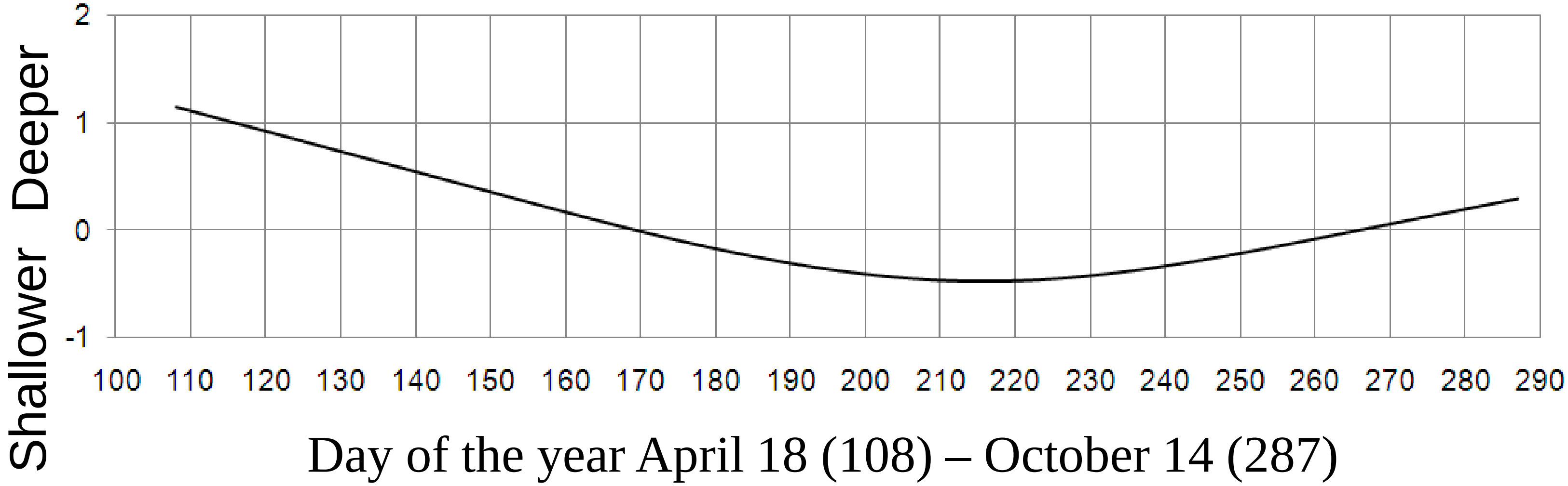
Edge effects in IMF 2 – 5:
representation of variability in April 18 through May 31



Strong oscillations ons April 18 – May 31 are not captured in any other way!



Residual term: secular trend



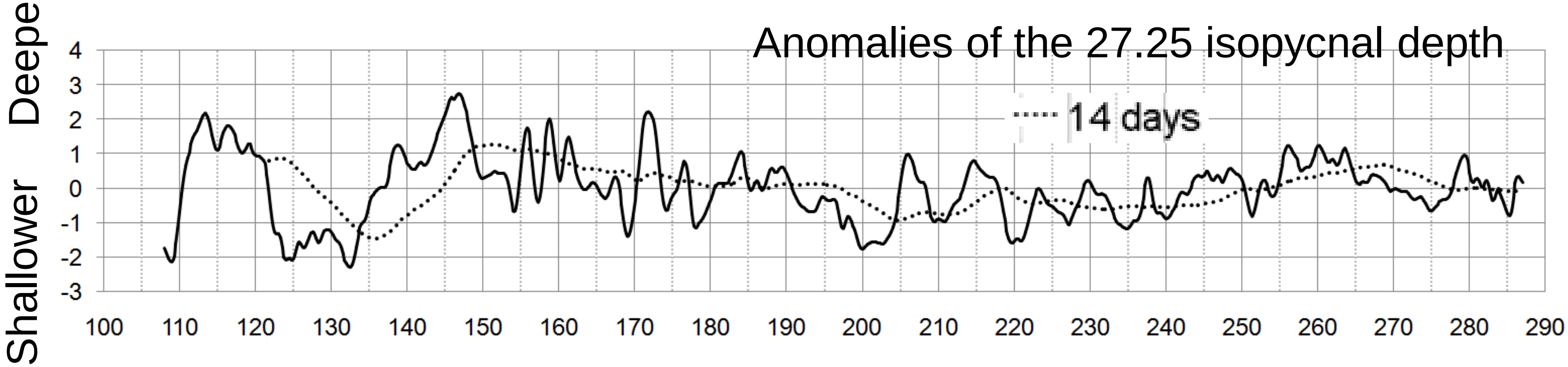
Day of the year April 18 (108) – October 14 (287)

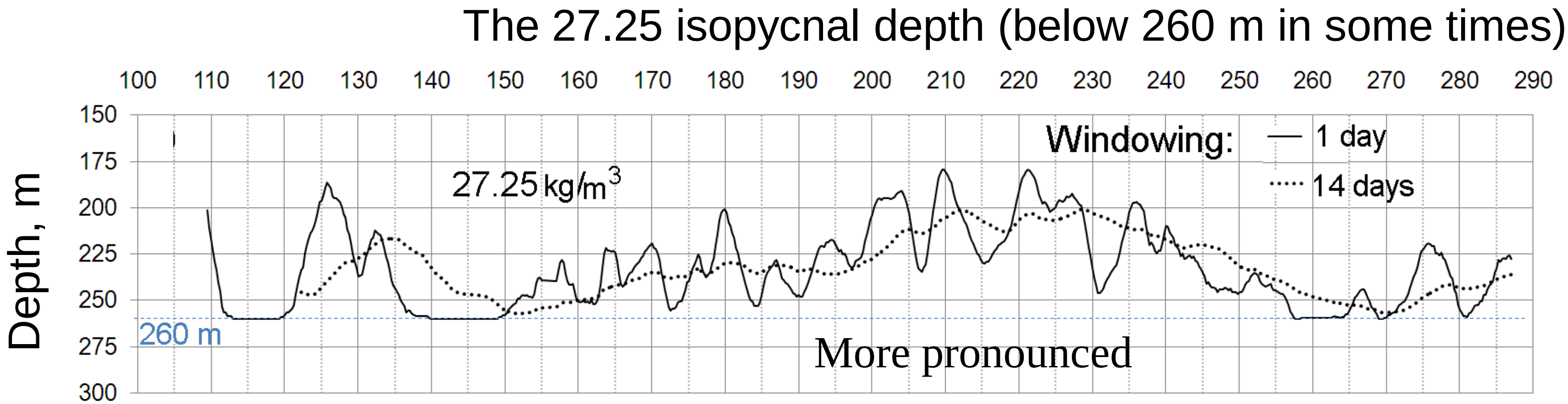
Shallowing from mid April through mid August and deepening afterwards.

Deepening since mid August due to downward heat flux from the surface;
causes of shallowing before are unclear.

How about edge effects?

Low-frequency oscillation

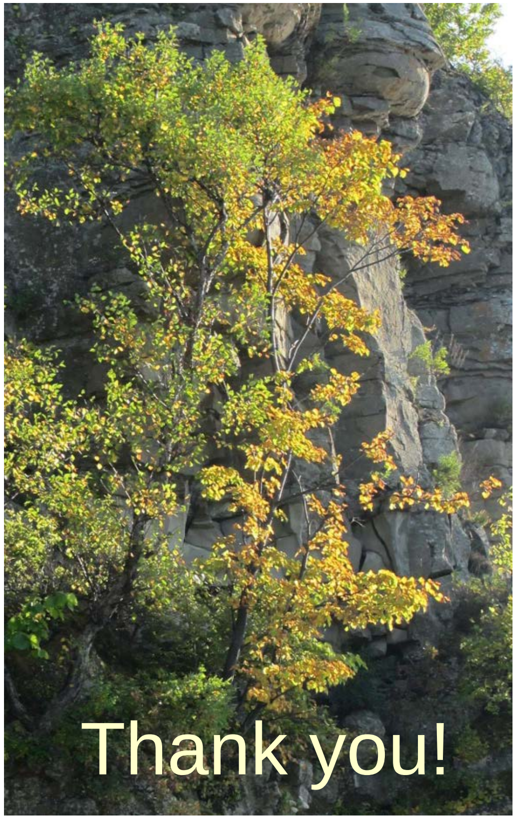




Day of the year April 18 (108) – October 14 (287)

Shallowing from June through mid August and deepening afterwards with amplitude of ~60 m.

Conclusion



Fluctuations at several time scales were found:

- 2–3.5 days (submesoscale);
- 8–13 days (mesoscale);
-18–22 days (wave-like);
- 1 month (from 04/18 through 05/31 – unclear nature);
- low-frequency: shallowing from June through mid August and deepening afterwards (possibly seasonal).

No linkages with local alongshore wind stress → non-local forcings, disturbances propagating from the upstream of the Primorye Current.

Future work:

Analysis of kinetic energy using Aqualog measurements of current velocity