Seasonal heat transfer in the bottom sediment-sea water column of Amurskii Bay

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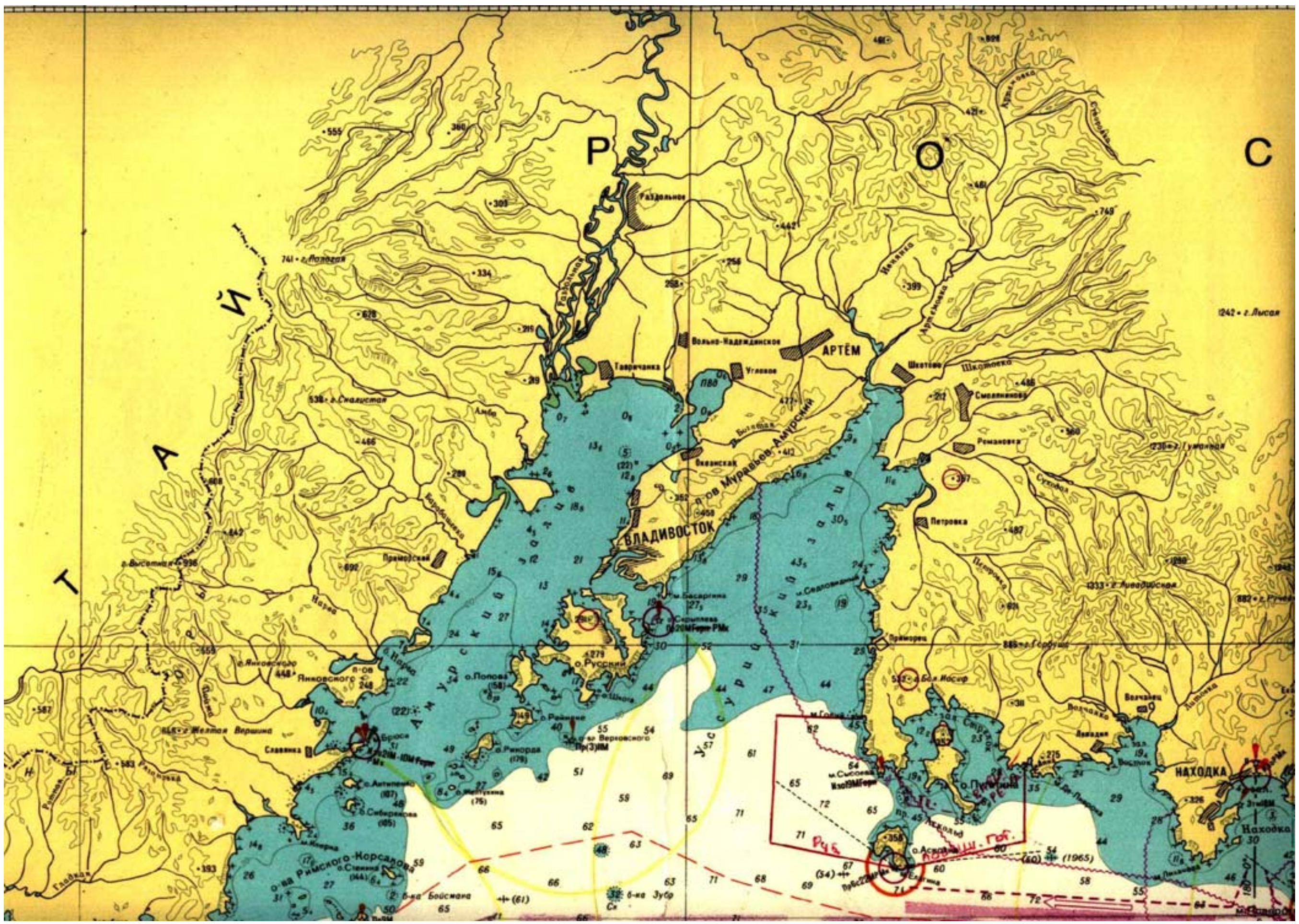
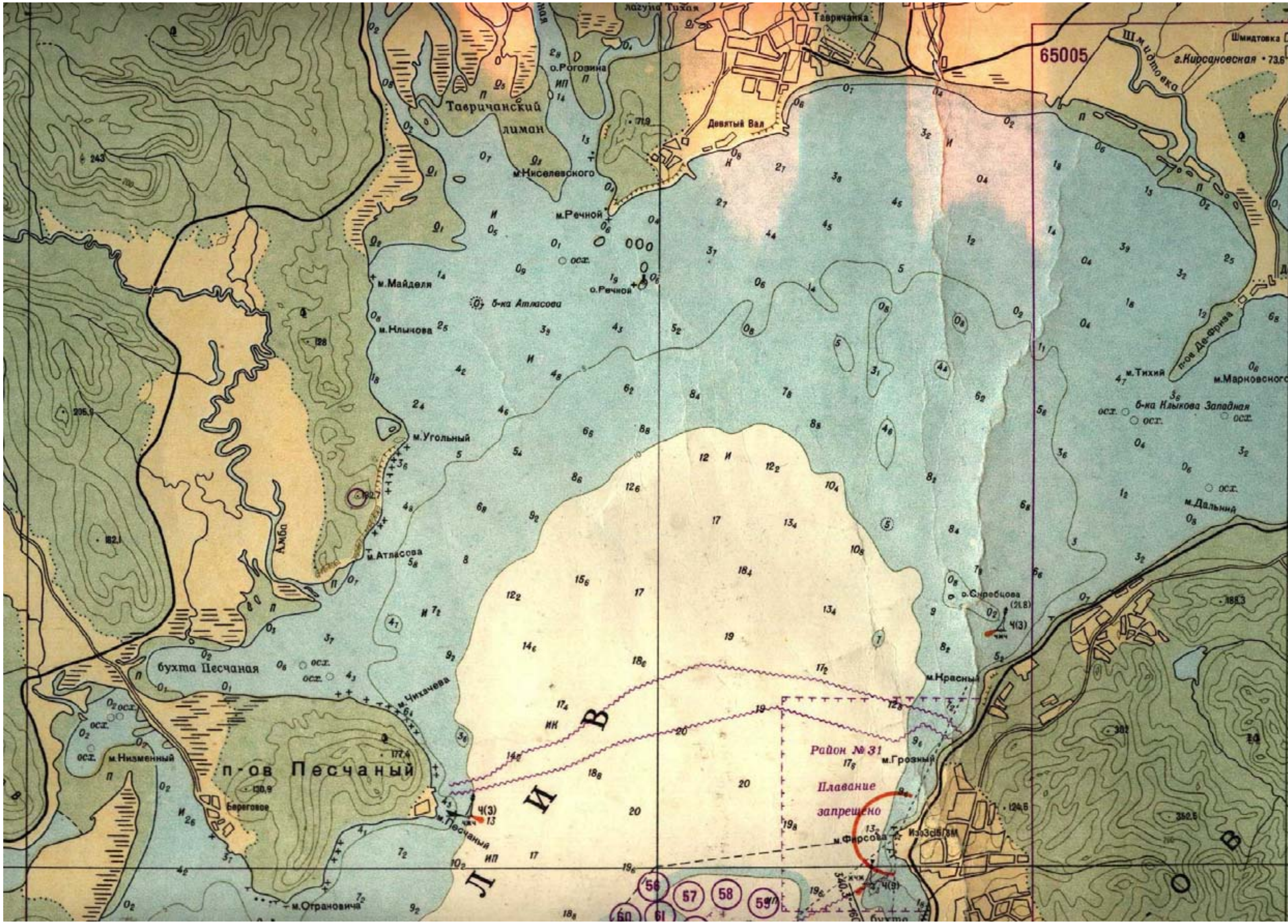


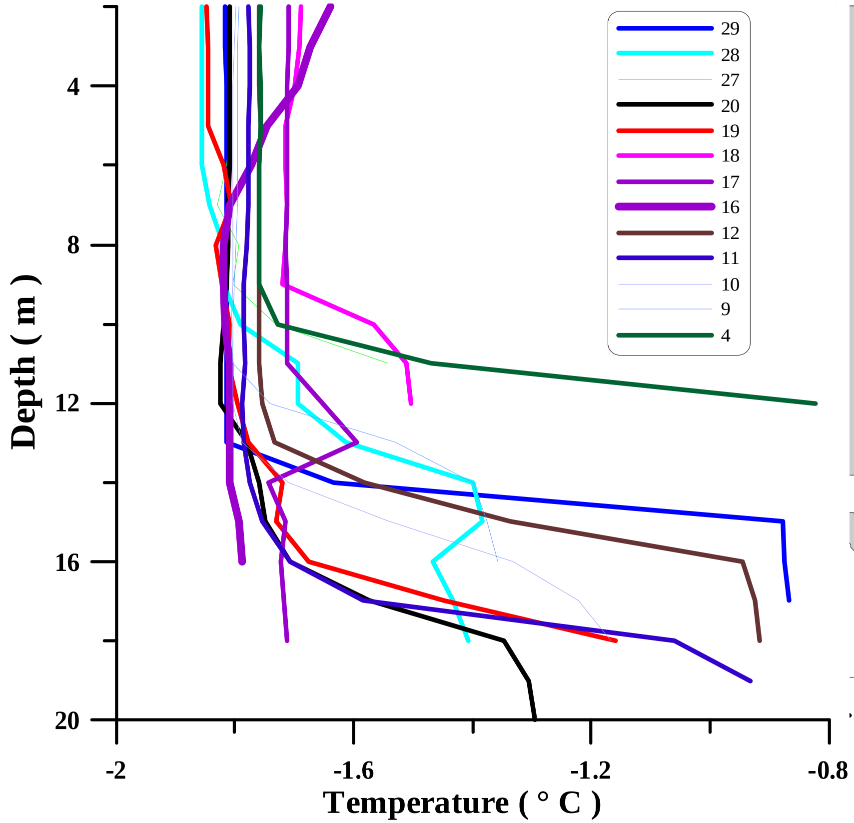
Water temperature, conductivity, salinity profiles from the surface to the bottom (with resolution 4Hz) were measured by SBE 19 at 35 stations in Feb. –Mar. 2005, 2006

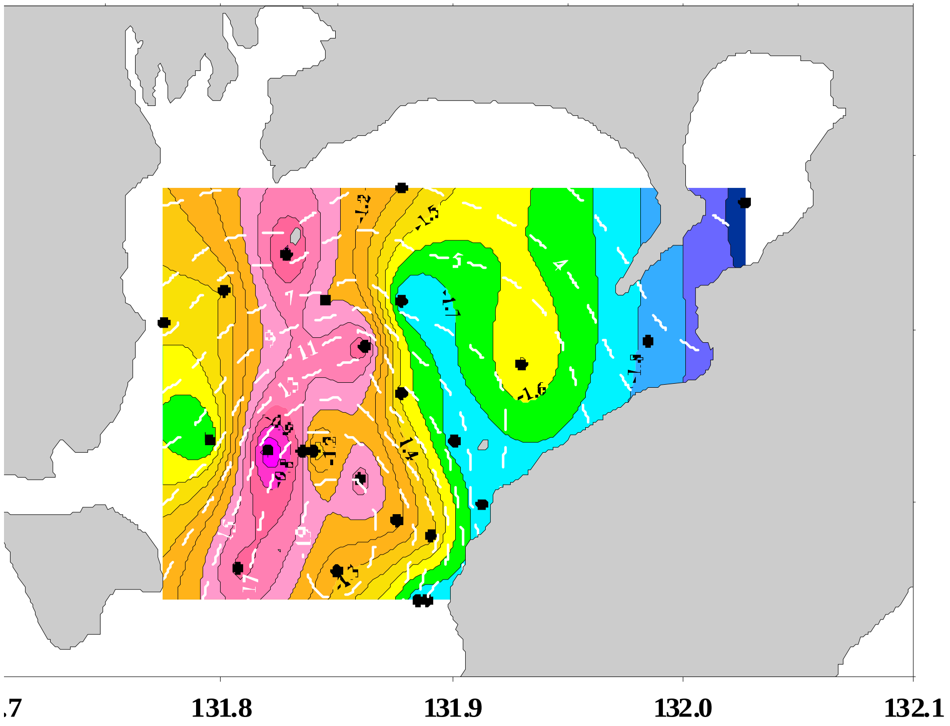
Amurskii Bay shallows with depth 2-19 m, where the most of the Cold Brian Water is forming due to brain rejection during ice formation



Motivation

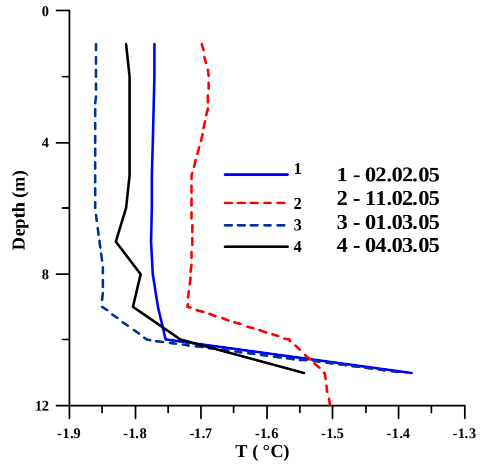
Water temperature (°C) vertical profiles show increased temperature of the brine water in thin near bottom layer (thickness is about 1-2 m)

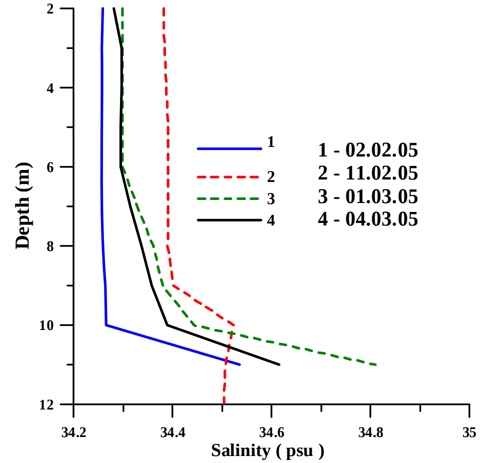




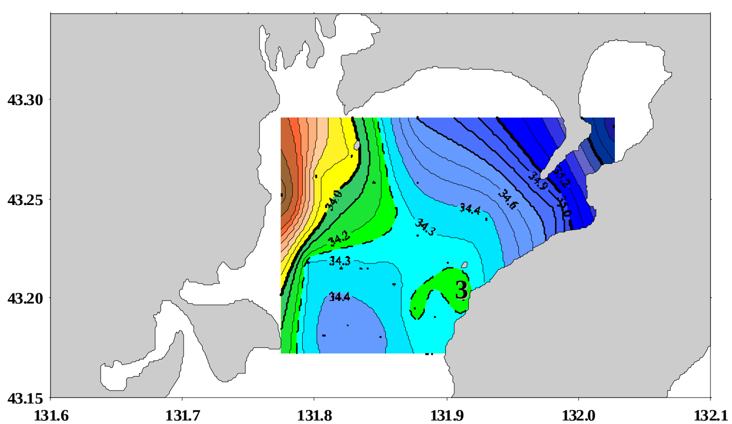
Ponomarev, Lobanov et al., 2005

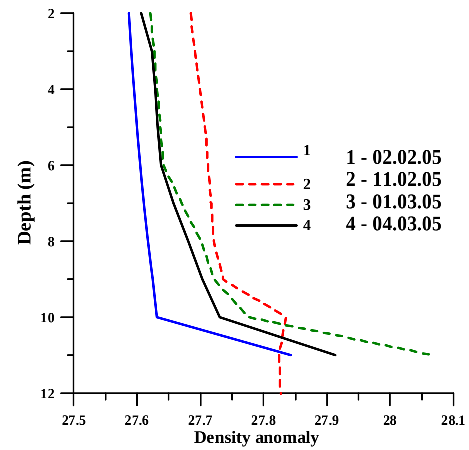
Temperature (T), salinity (S), and density vertical profiles at the station 3/ 3a in relatively low salinity eastern bay area impacted by city run off in 2 Feb. (curv 1), 11 Feb. (curv 2), 1 Mar. (curv 3), and 4 Mar. (curv 4)





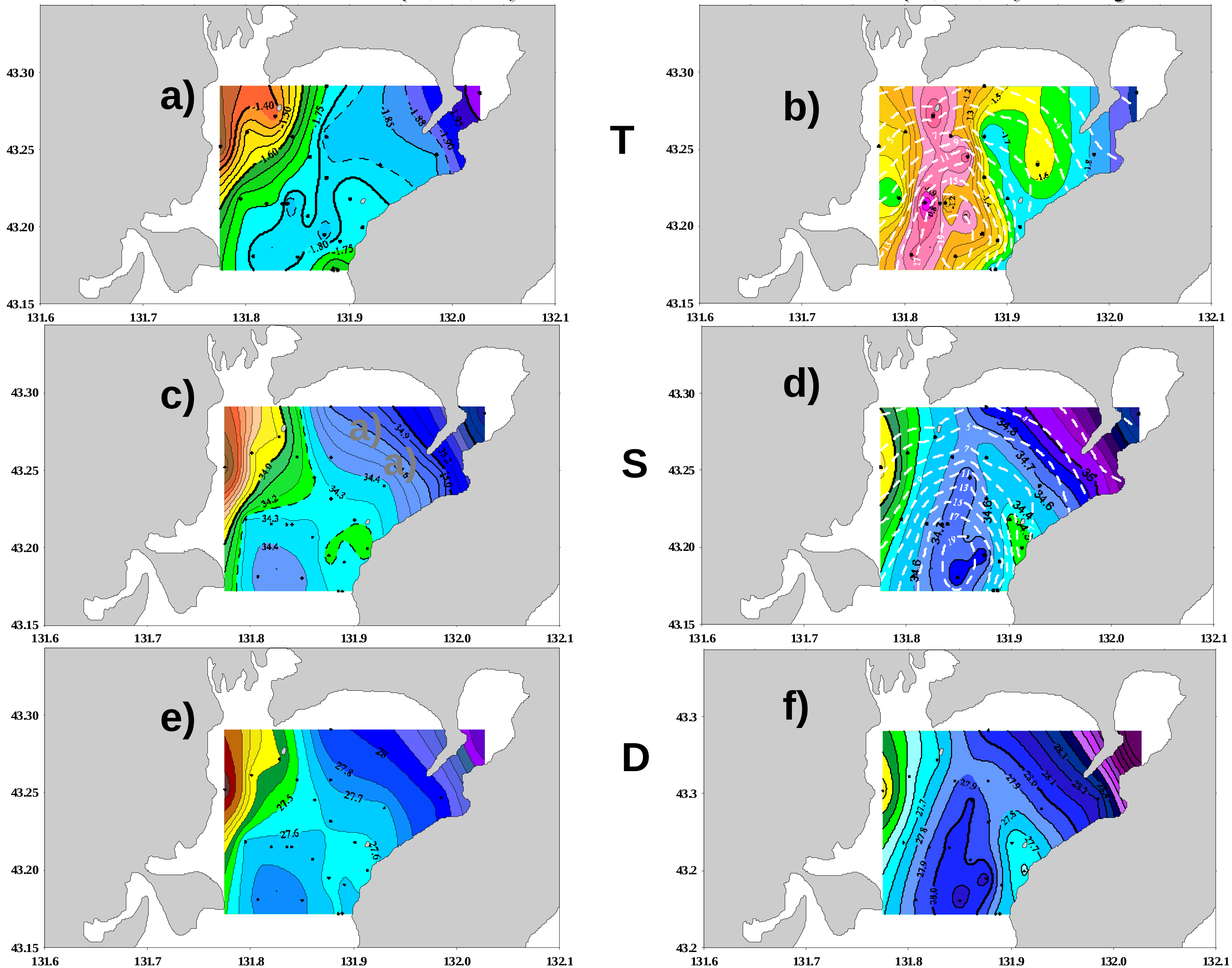
Salinity at 2m depth





Ponomarev, Lobanov et al., 2005

Temperature (a, b), Salinity (c, d), and Density (e, f) in the surface (a, c, e) and bottom (b, d, f) layers



Possible causes of the CBW temperature rise in the near-bottom layer of shallows in February

It might be due to influence of several factors related to :

- **the upward heat flux in winter at the top of sediment which accumulated heat in relatively thick layer during summer season (amplitude of the water temperature annual cycle is about 24 °C);**

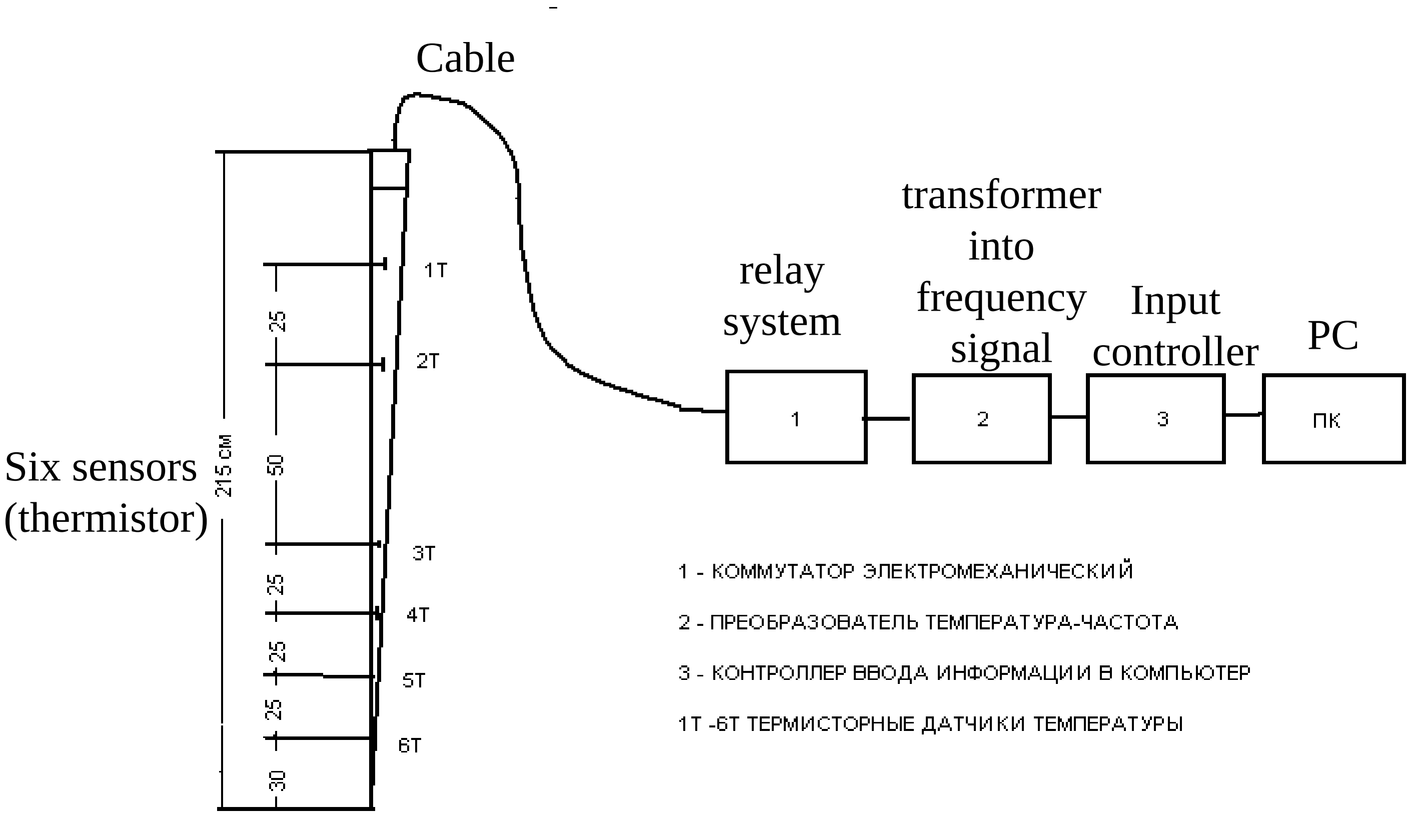
- **the organic matter oxidation through the bacteria at the top of sediment in the Amurskii Bay shallows;**

source of the organic matter in fall are Razdolnaya River and dead alewife fish killed near the fresh water front by the needle-like ice rapid formation in the beginning of the cold season.

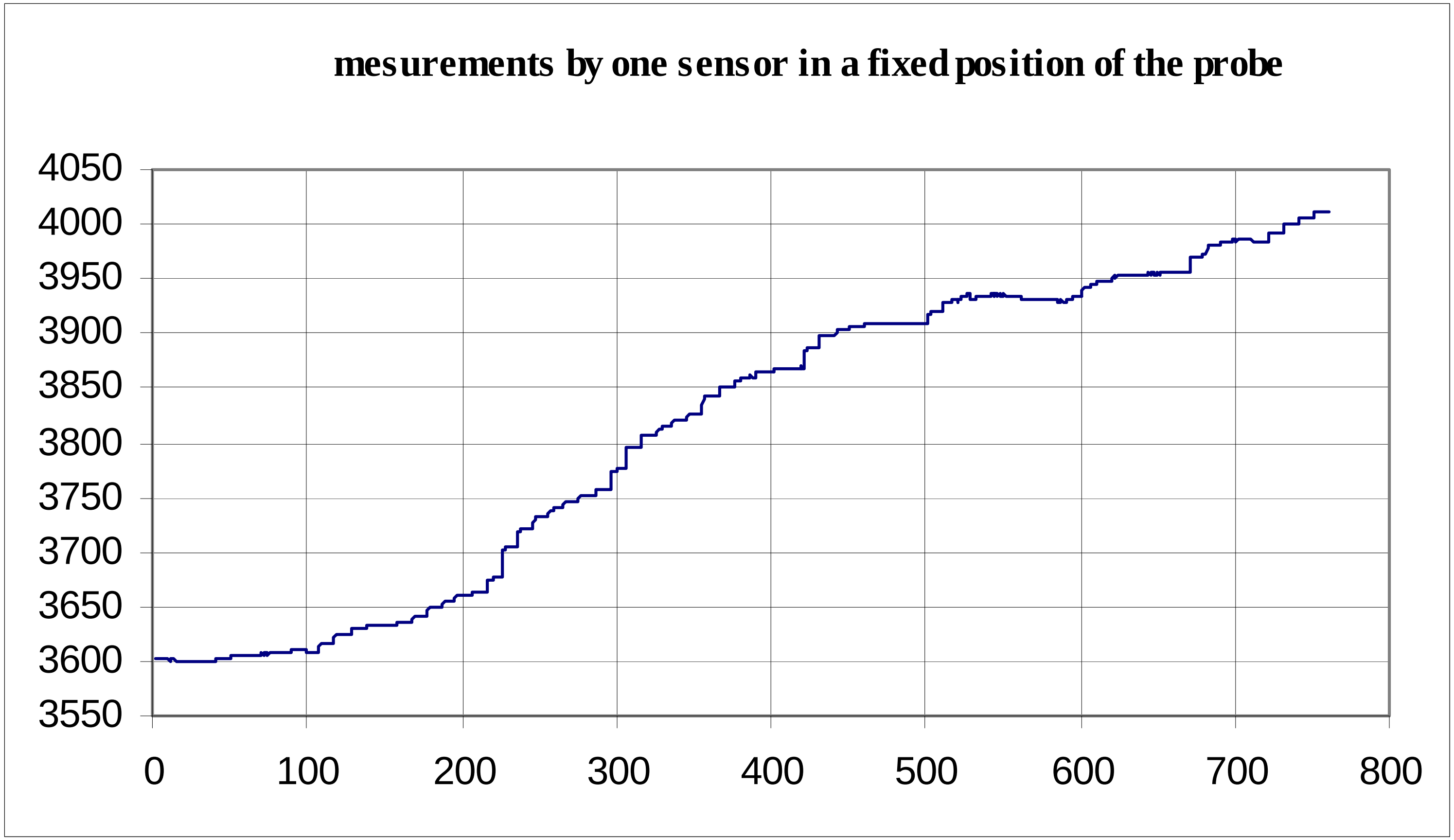
Main goals are to :

- measure temperature profiles in sediments in winter, spring, and fall;
- estimate thermal diffusivity coefficient averaged in the top layer of sediments using simple numerical model of heat conductivity;
- estimate heat flux at the top of sediment from the observation data and simple model

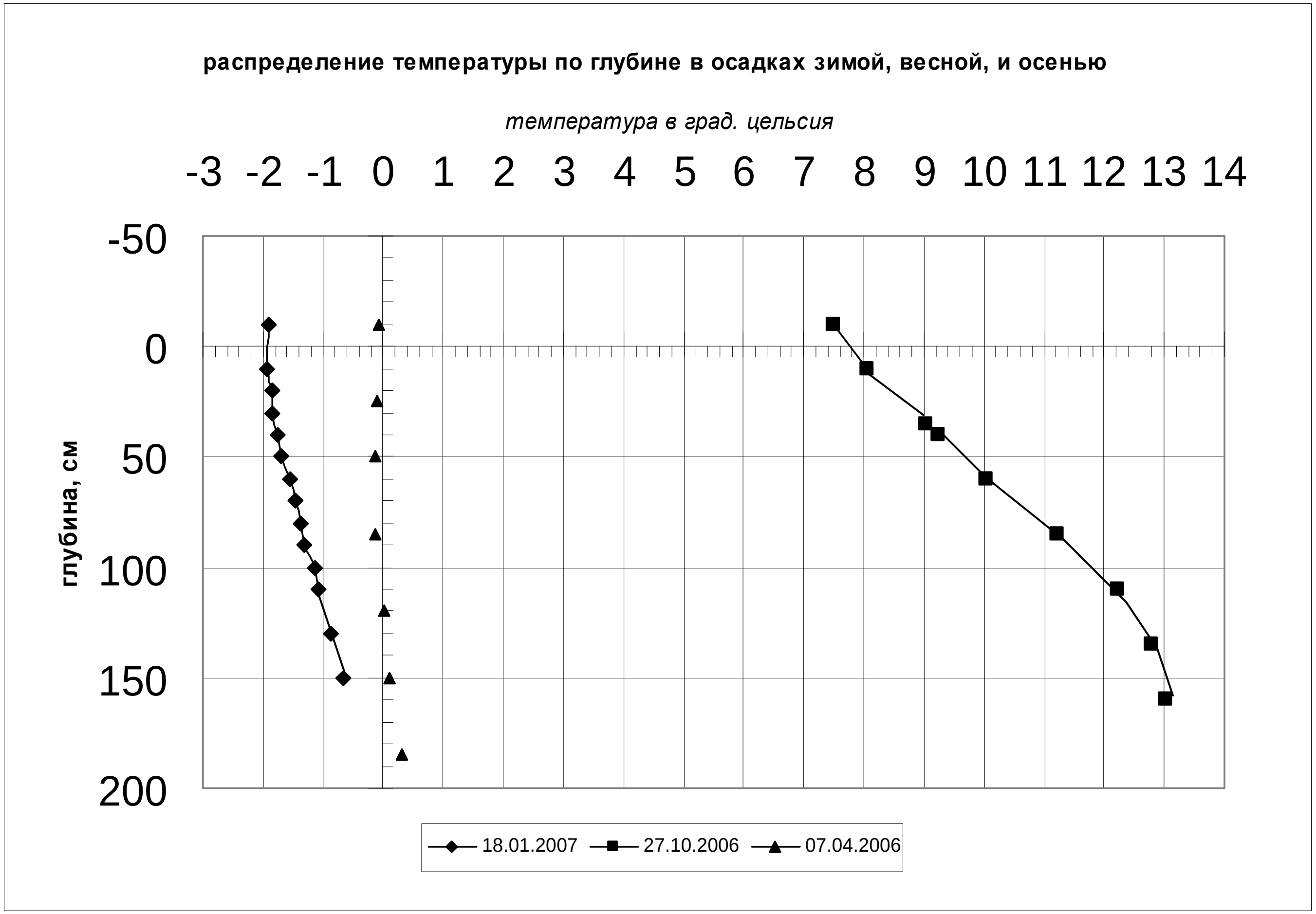
Scheme of simple temperature profiler for upper 2 m sediment layer in sea shallows constructed by Boris Burov in POI



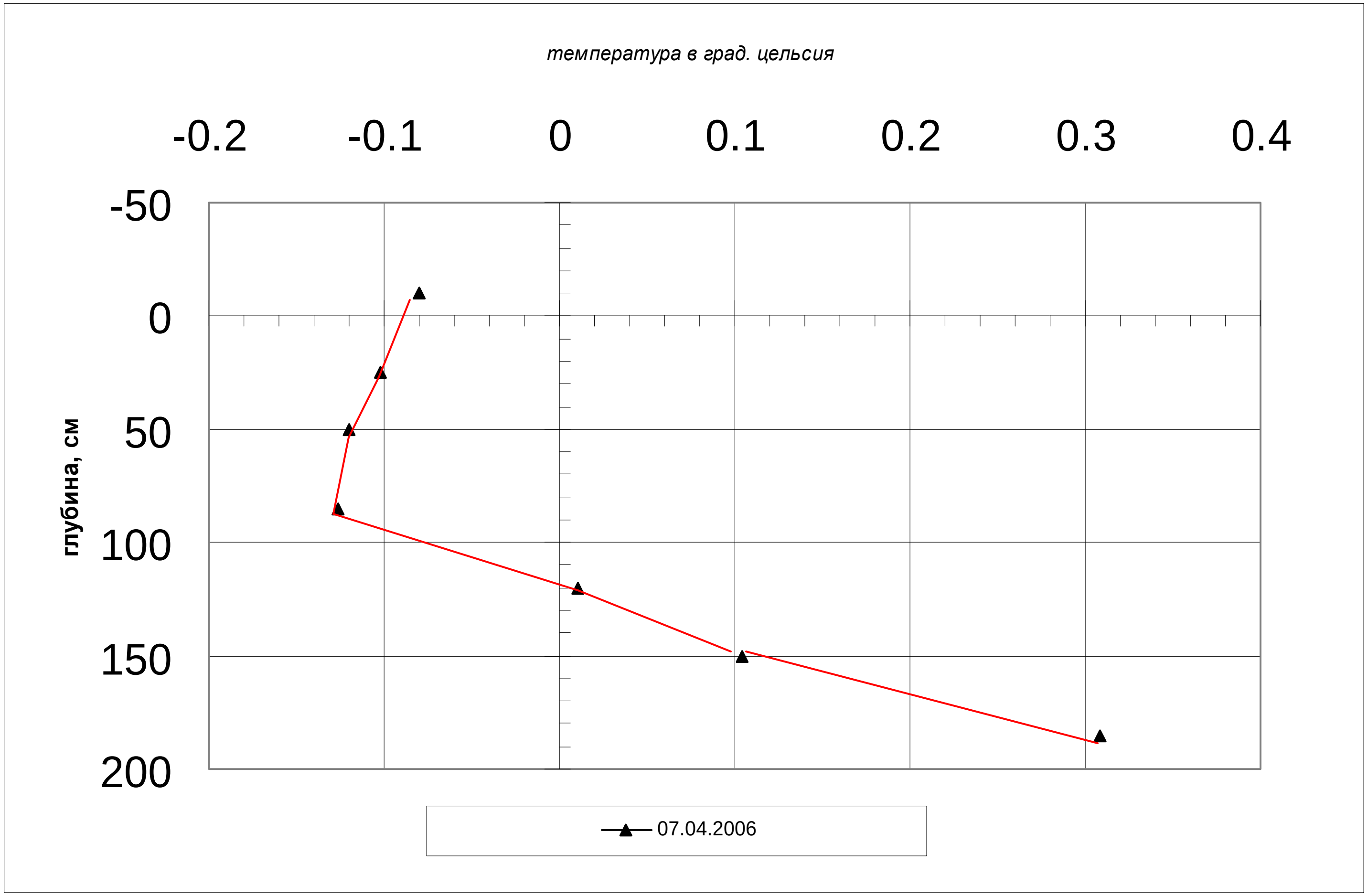
Composite signal in frequency from one sensor (thermistor) related to temperature profile.
Signal becomes steady state in each fixed position of the profiler be in about 5 minutes
We measure temperature by 6 sensors in sediment 2 m layer during 1-1.5 hour.



Temperature profile in sediments in 18 January, 7 April, and 27 October



Temperature profile in the upper layer of sediments (layer thickness is about 2m) in 7 April 2006 with local minimum at 90 cm depth



Heat transfer model to simulate annual cycle of the temperature profiles

Thermal diffusivity equation for temperature T(z,t) :
$$\frac{\partial T(z,t)}{\partial t} = a^2 \frac{\partial^2 T(z,t)}{\partial z^2}$$

where a^2 (t) is a thermal diffusivity coefficient (m^2/day) averaged in the sediment column.

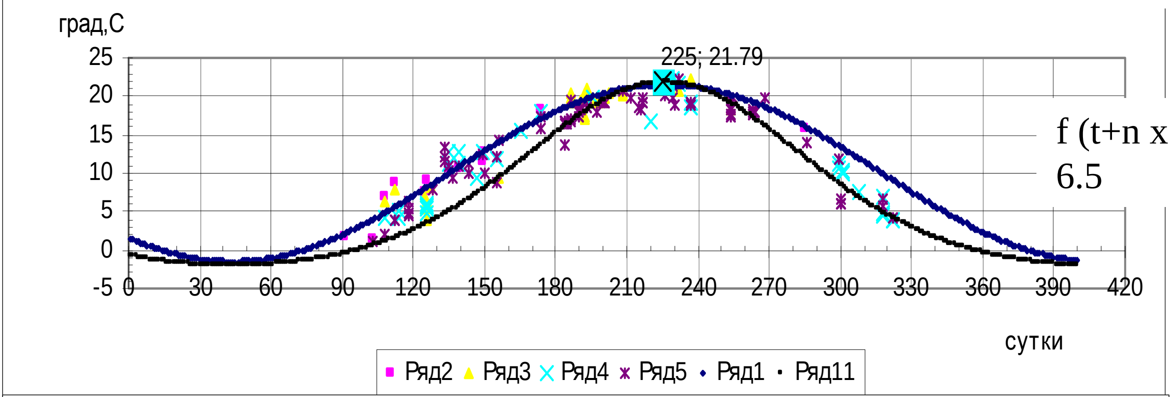
Boundary condition for T(0,t) at the top of sediment (z=0): $T(0,t) = f(t + n \times 365,\ h)$
which is empirical function found from the observational records in the Amur Bay
Boundary condition for at depth z = 20m in sediments: $T(20,t) = 7\ C^{\circ}$

The thermal diffusivity coefficient a^2 in situ is unknown. Nevertheless, a thermal conductivity coefficient Q is measured at POI laboratory in different layers of the sediment column from our station in the Amur Bay by Svininnikov (Burov, Lazaryuk, Ponomarev, Svininnikov, 2007).
It is found at the laboratory that **q** = **0.92 W/(m °C)** is **q** averaged in sediment column layer **0.1–1.2m**.

Correspondent a^2 = 0.053m^2/day estimated by a^2 = q / (Density * Cp)
Cp = 8.4 * 10^2 J/ (kg °C) Density = 1800 kg/m^2
a^2 was fixed during first step of the model integration in time during 8-10 years.
After that we compare annual cycle of the simulated T(z) with our observed T(z) in 18 January, 7 April, and 27 October a^2 solution by inspection

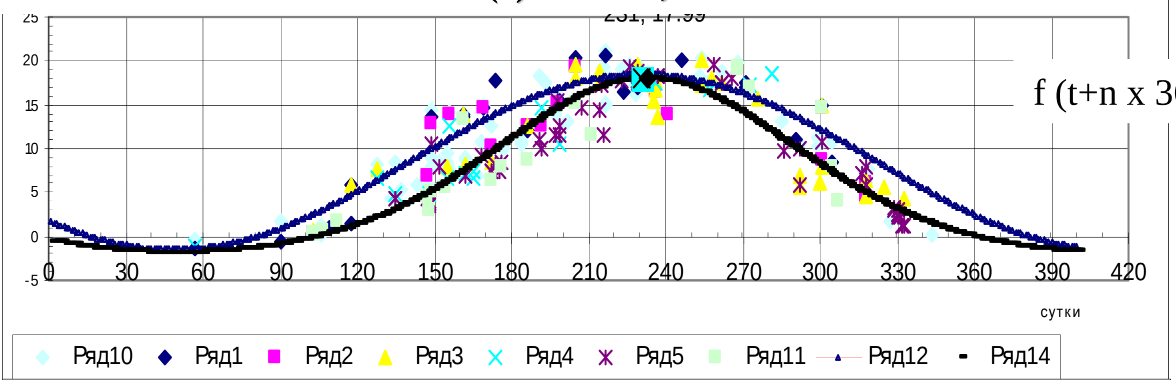
Approximation of observed near-bottom water temperature seasonal cycle in the Amurskii Bay shallows with different depth and Boundary condition in the Heat Transfer Model

(a) 5 m



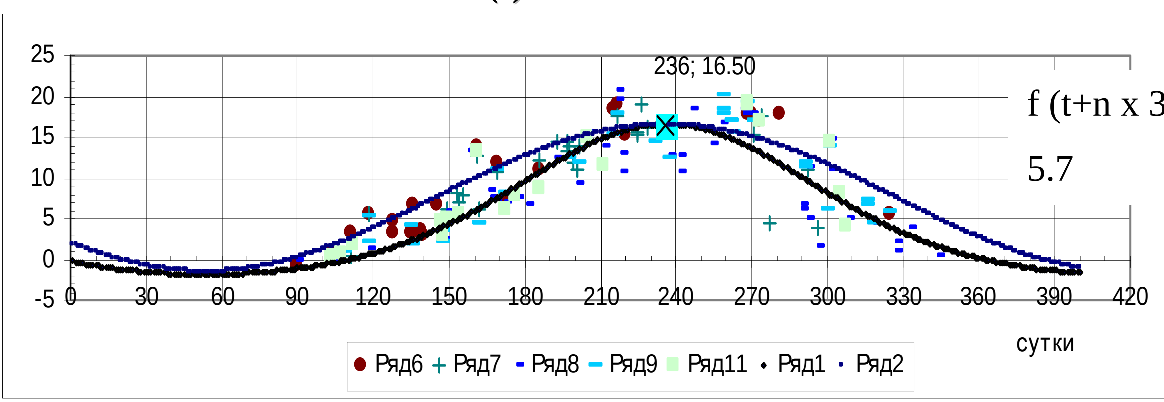
f (t+n x 365,h=5) =11.2 • 2.4 **sin((t-134)•6.28/365) – 6.5

(b) 10 - 15 m;



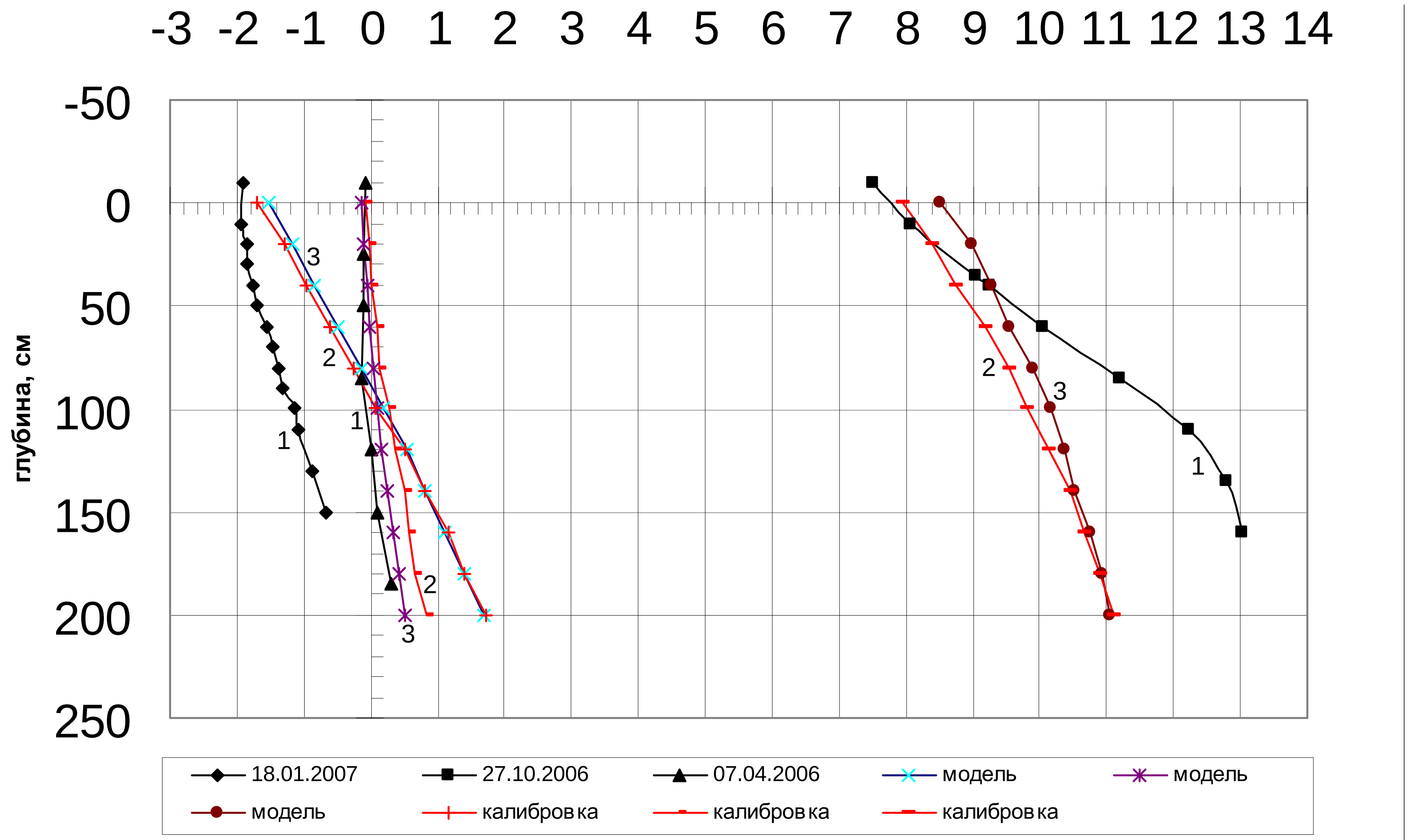
f (t+n x 365,h=15) = 10 • 2.4 **sin((t-140)•6.28/365) - 6

(c) 15 – 20 m

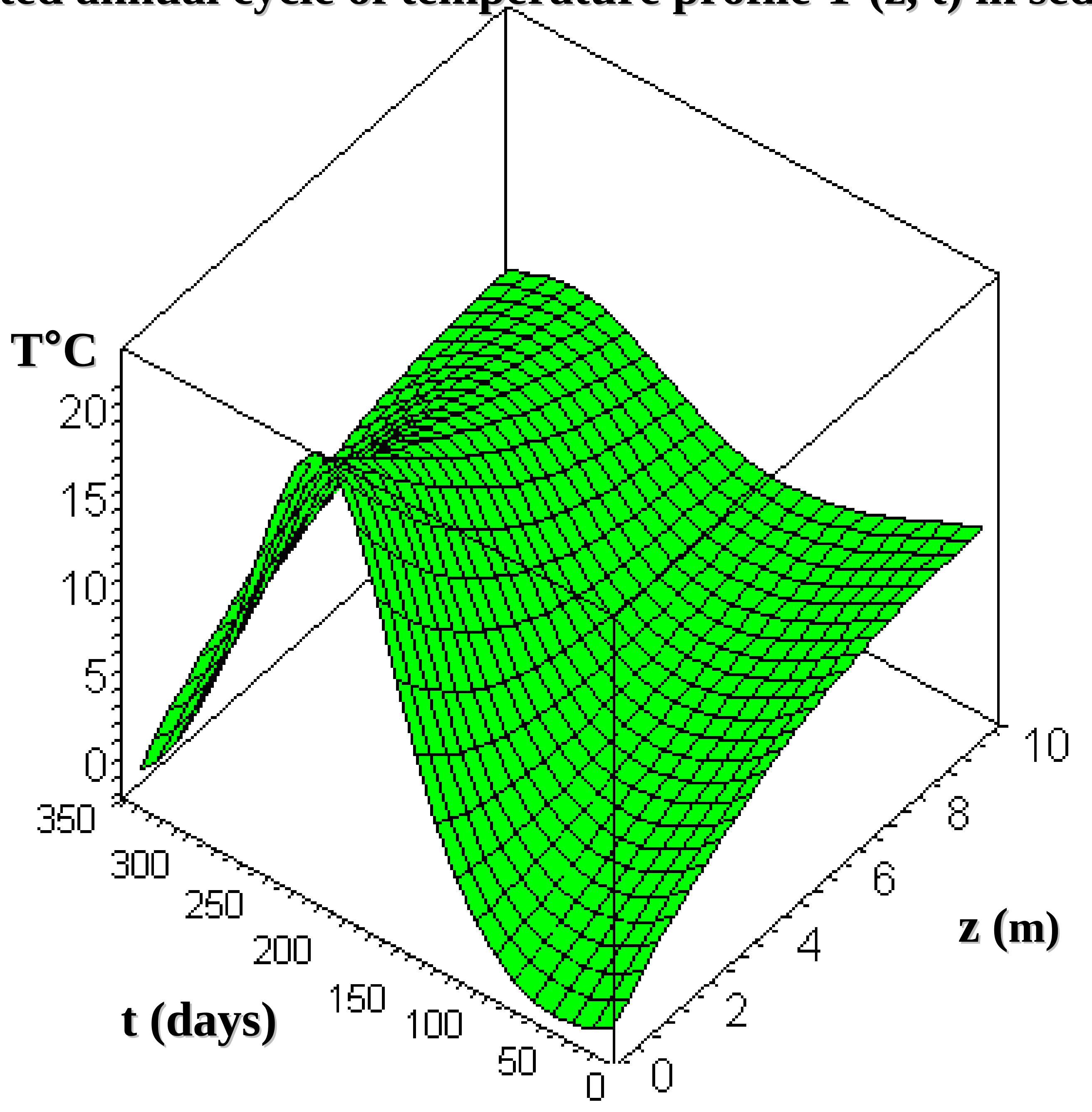


f (t+n x 365,h=20) = 9.3 • 2.4 **sin((t-145)•6.28/365) – 5.7

Measured (1) and simulated (3) temperature profiles in sediments (layer thickness is about 2m) in 18 January, 7 April 2006, and 27 October



Simulated annual cycle of temperature profile T (z, t) in sediments



Conclusion

- According to direct measurements of temperature profiles in the sea water and upper 2 m layer of sediments the heat flux at the top of sediments in the in the Amurskii Bay during winter is inversed in comparison with summer.

- The simulation of the heat transfer in sediments shows coefficient of thermal diffusivity **q** in the upper layer of the bottom sediments during winter (January-March) is in 5-6 times higher than that in October.

- Heat flux from the sediment to sea water estimated by P = **q** ($\Delta T/\Delta h$), at the top of sediments is about

3 W/m^2 in October and

4-5 **W/m^2 in January** estimated from where coefficient of thermal diffusivity **q = 0.92 W/m·°C** in October, while **q = 4.6 – 5.5 W/m·°C** in January.

It is in 10 times higher then geothermal flux in the Japan Sea.

Thus the heat transfer in the upper layer of sediments predetermined by different physical processes in winter and warm period of a year.

In winter the vertical temperature gradient substantially decreases but the heat transfer can intensify by the micro-convection in the sediments pore space.

Summary

- The heat accumulation in sediments of the subarctic narrow bays during warm season can play important role in biological activity at the top of sediments and near-bottom layer of the bay.

Thank you for attention