## 7 Bathymetric and Hydrologic Studies on the NE Sakhalin Shelf

The Oceanology department of POI undertook an independent analysis of the data acquired during the 2004 expedition on the NE Sakhalin shelf using their own methods and algorithms. The oceanologists also developed a hydrological model of the area. This section describes how the bathymetric and hydrologic data acquired on the NE Sakhalin shelf was processed to create a bathymetric map and enable research on the temporal-spatial variations of hydrology in the study area. This data will be used to build acoustic models which will be used to model the acoustic fields generated by known sources and analyze the impact of bathymetry and hydrology on the propagation of these fields. The data will also be used to investigate the impact of temperature and salinity variations on benthos development.

### 7.1 Bathymetry map

Figure 7.1 shows the profiles along which the bathymetric data was acquired using the sonar on the *Academik Oparin*, 252000 depth measurements were taken in 2004 and were used to build the map. The data were interpolated into an even grid using a Kriging algorithm[37] [Allen, 1973]. Figure 7.2 shows a bathymetric map with contours and Figure 7.3 is a 3D profile of the same data. A notable feature of the bathymetry in the area is the NE orientation of the bathymetric channels in the area. This bathymetric terrain could be the result of geologic processes, or, because the area has a sandy bottom and current transport of the sediment is common, the consequence of shelf currents.

### 7.2 Impact of wind and tides on the thermohaline structure in August and September

A subset of the hydrology study area was selected for further analysis. The following co-ordinates bounded this area: 52.4° to 53.3° N, 143.1° to 143.7° E (Figure 7.4). The characteristics of the study area were defined by its small size and location. At a climatic spatial-temporal scale the area is located on the SW edge of the cyclonic circulation of the Sea of Okhotsk, one of the major components of which is the Eastern Sakhalin current. This current is created by the discharge of water from the Amur River into Sakhalin Bay and bordering Amur firth. A characteristic of this water mass is its low salinity of 26-30 psu (Practical Salinity Units). Farther south the water is more saline (Figure 7.5).

[37] This Kriging algorithm was part of the Surfer mapping package developed by Golden Software.

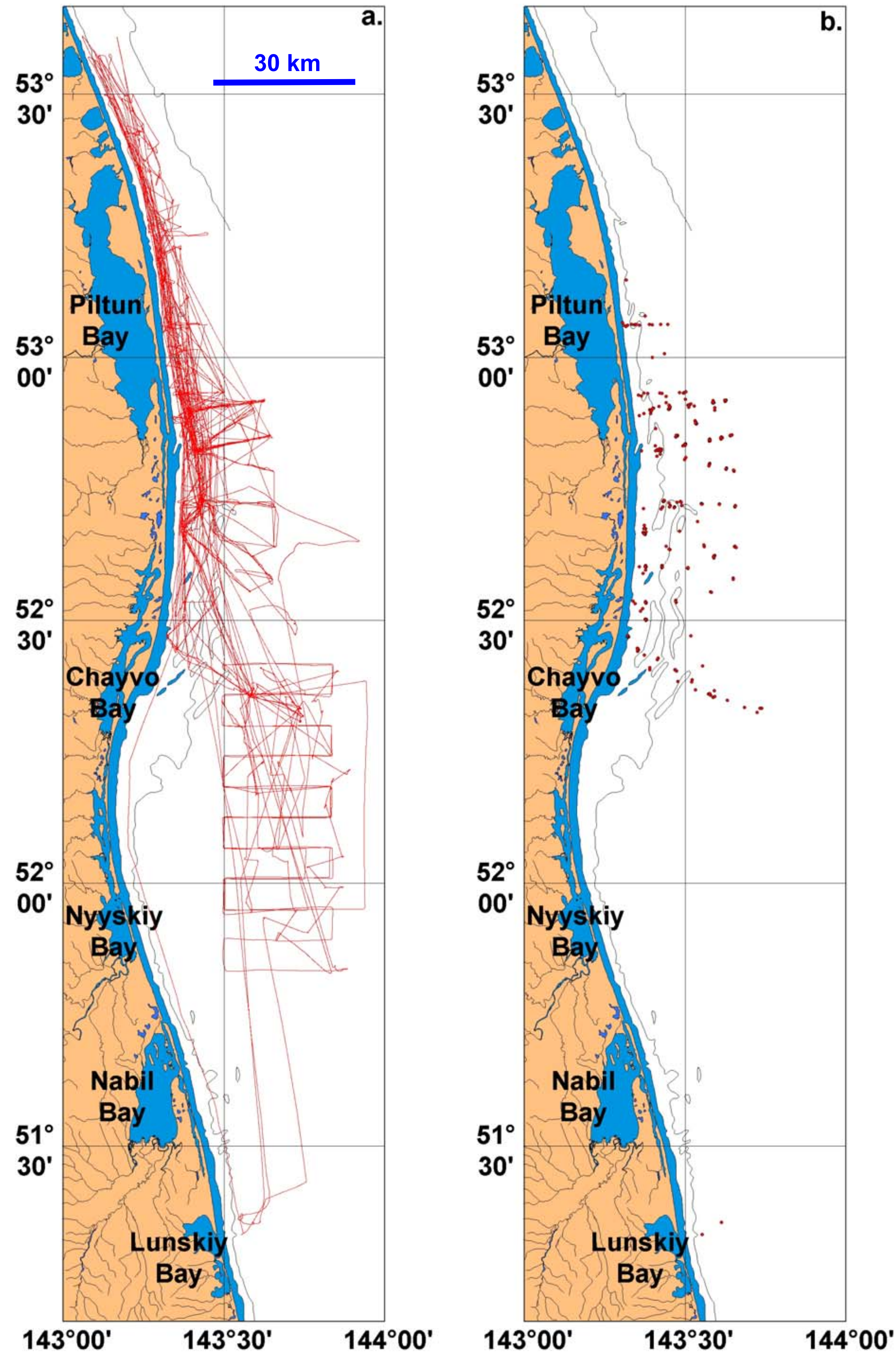
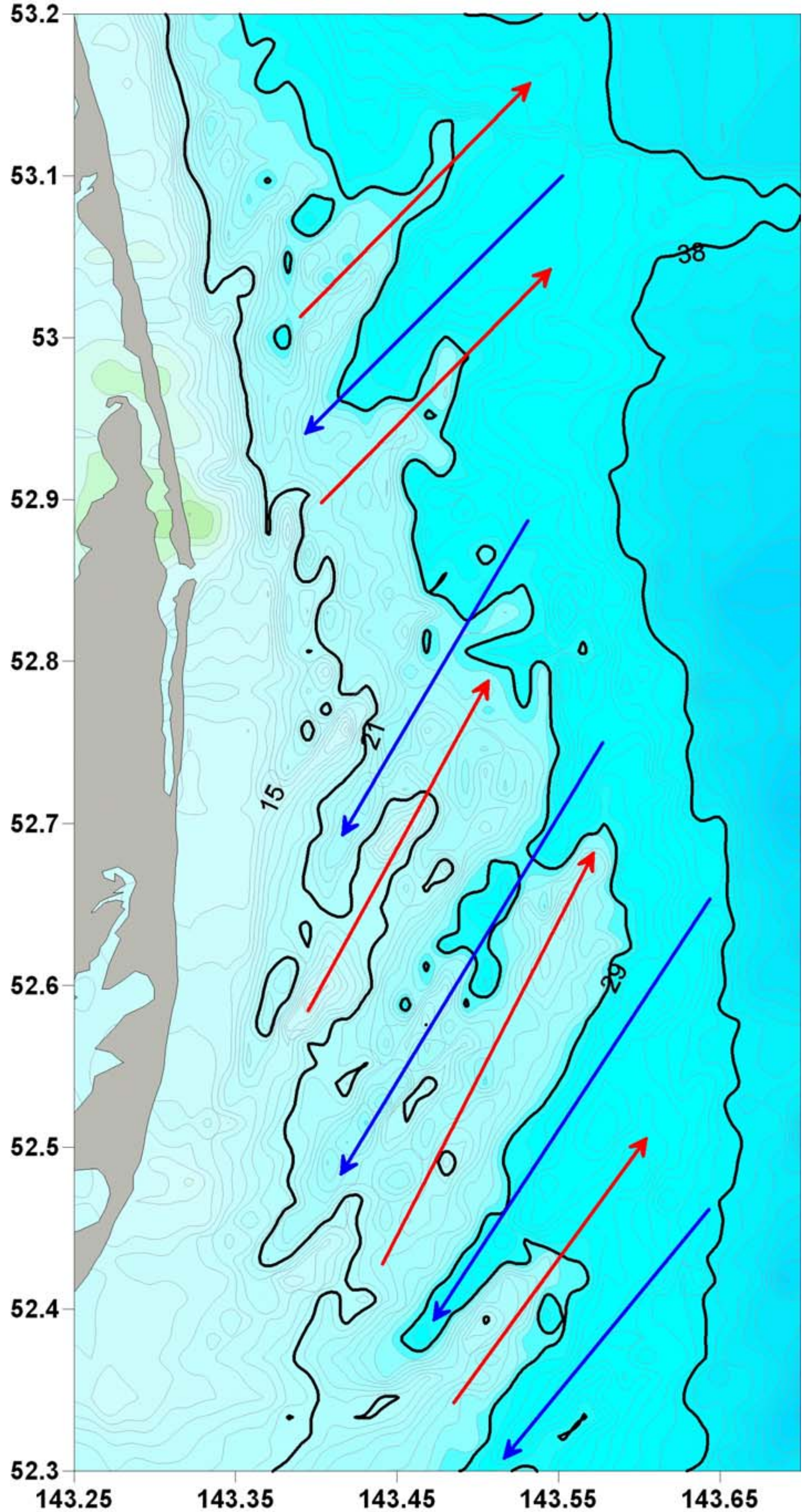



**Figure 7.1 - Map of the NE Sakhalin Shelf showing the bathymetric grid (a) and locations where vertical hydrologic profiles were acquired.**




**Figures 7.2 - Bathymetric map of the study area with contours. Note the dominant NE-SW orientation of the bathymetric structures.**

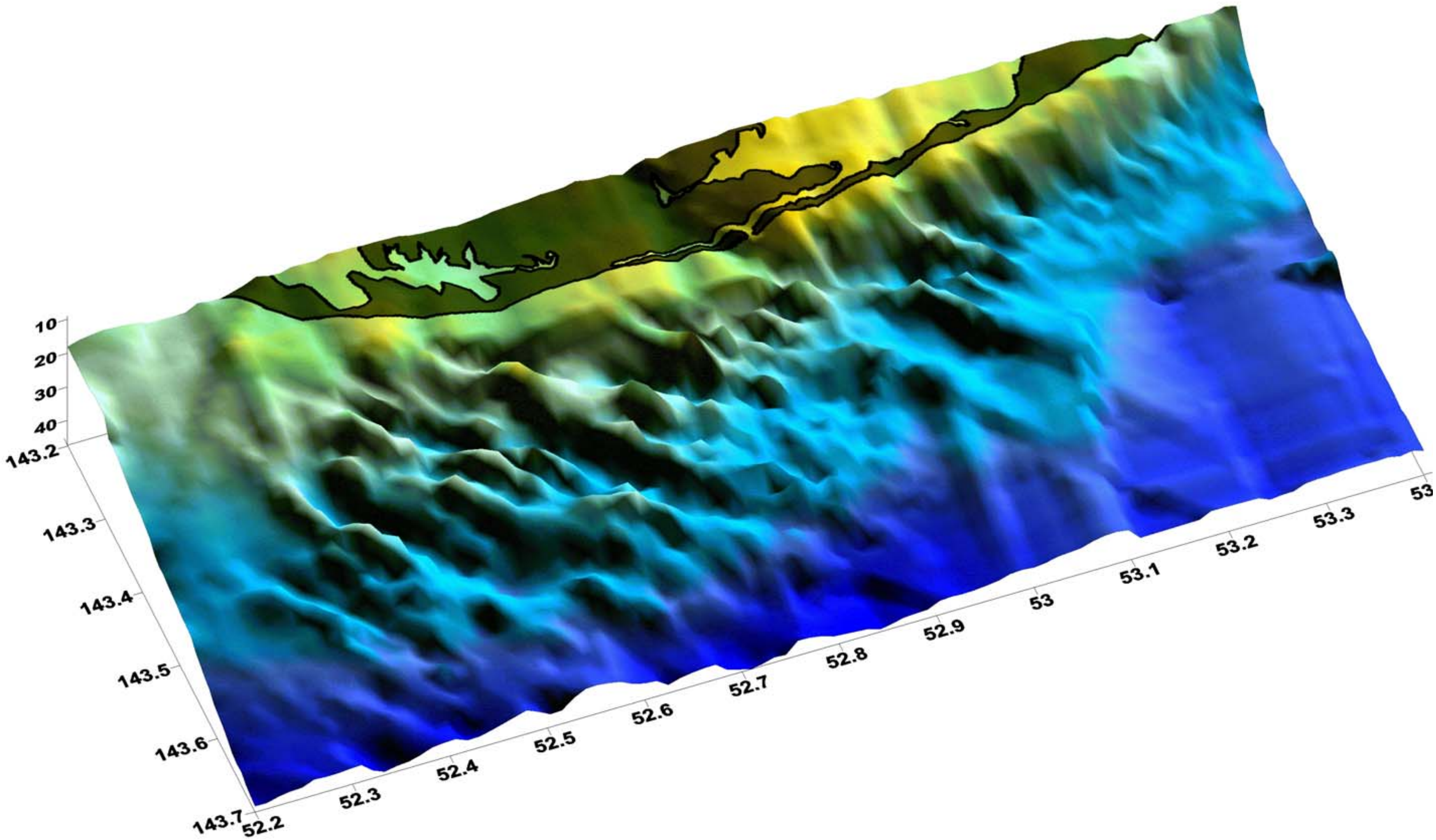



**Figure 7.3 - 3D bathymetric map of the study area.**

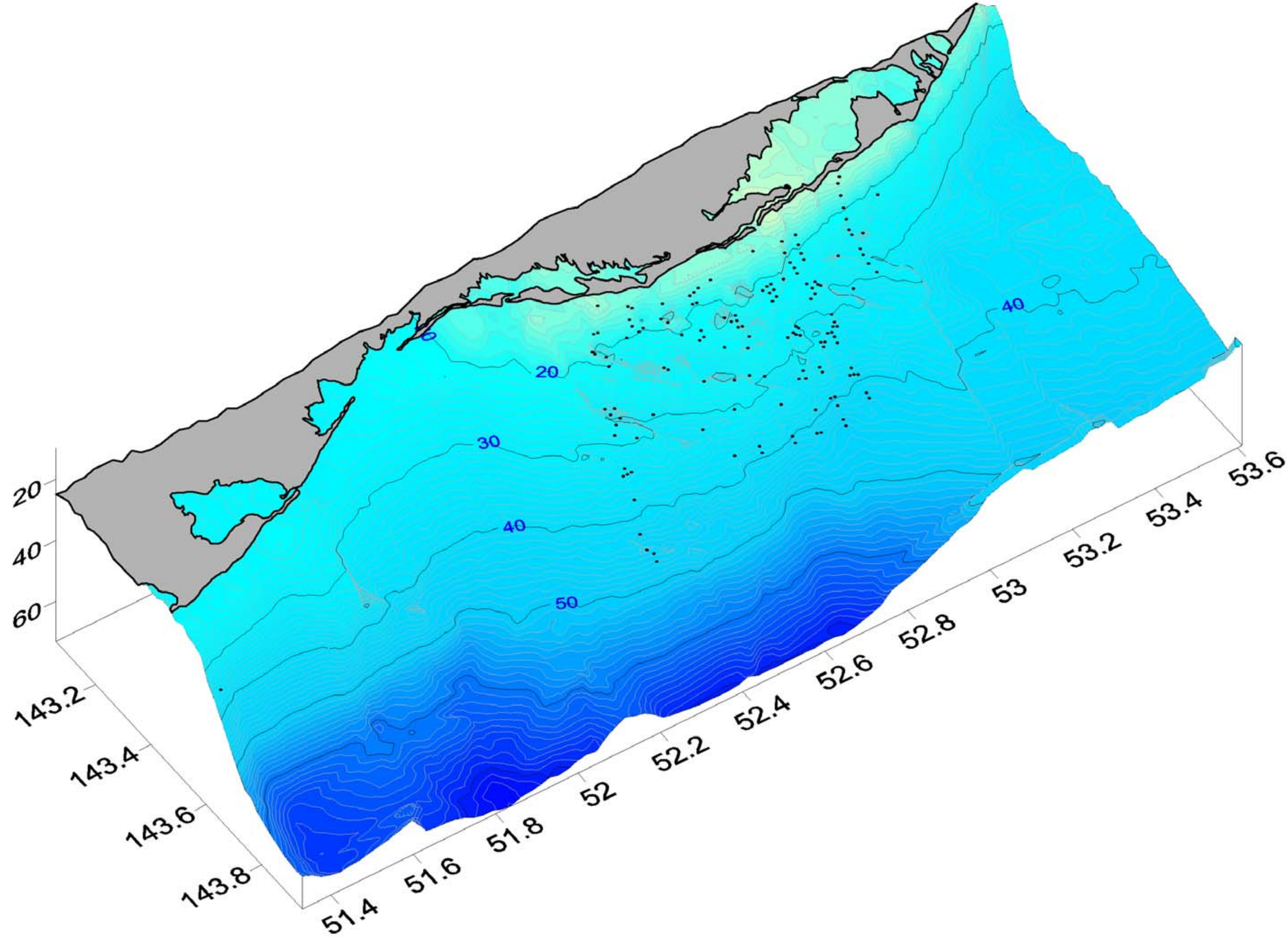



**Figure 7.4 - Map of the study area showing the locations where vertical hydrologic profiles were acquired.**

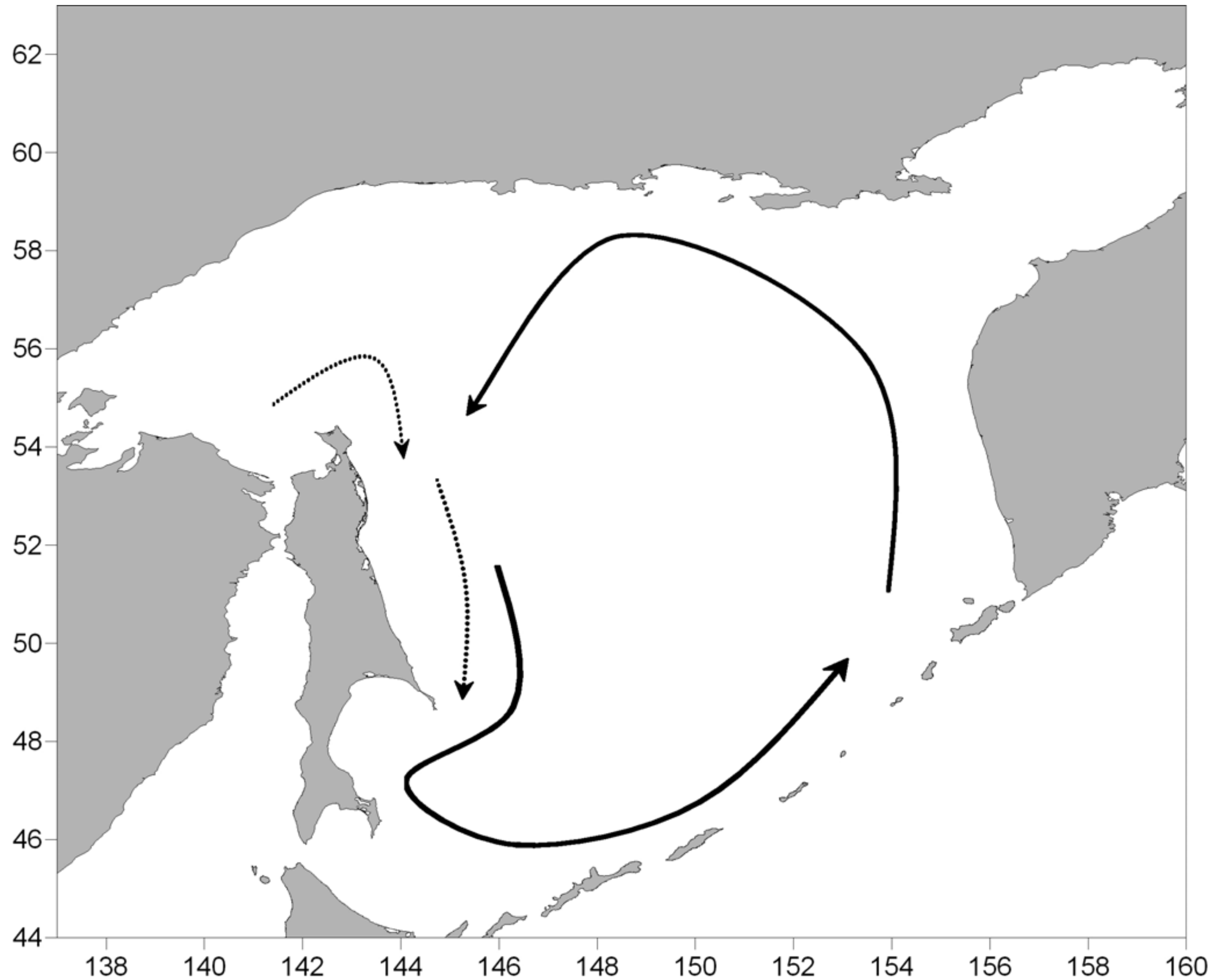



**Figure 7.5 - Simplified scheme of water circulation in the Sea of Okhotsk, the dotted line is the Eastern Sakhalin current. Based on current maps by Shrenk L.I. (1874), Leonov A.K. (1960) and Moroshkin K.V. [Гидрометеорология и гидрохимия морей, 1998].**

The effect of the current on the surface temperature field is not so clear since the temperature diffusion coefficient is an order of magnitude lower than the salinity diffusion coefficient. A fundamental condition of the thermohaline water structure on the shelf is the presence of a front separating the well-mixed homogeneous water of the shelf and the more stratified deeper water (Figure 7.6). The structure of this thermohaline front is complicated by the inflow of less saline water either from the near-shore area or carried by the Eastern Sakhalin current. At the surface, the salinity front is usually farther from the shore than the temperature front.

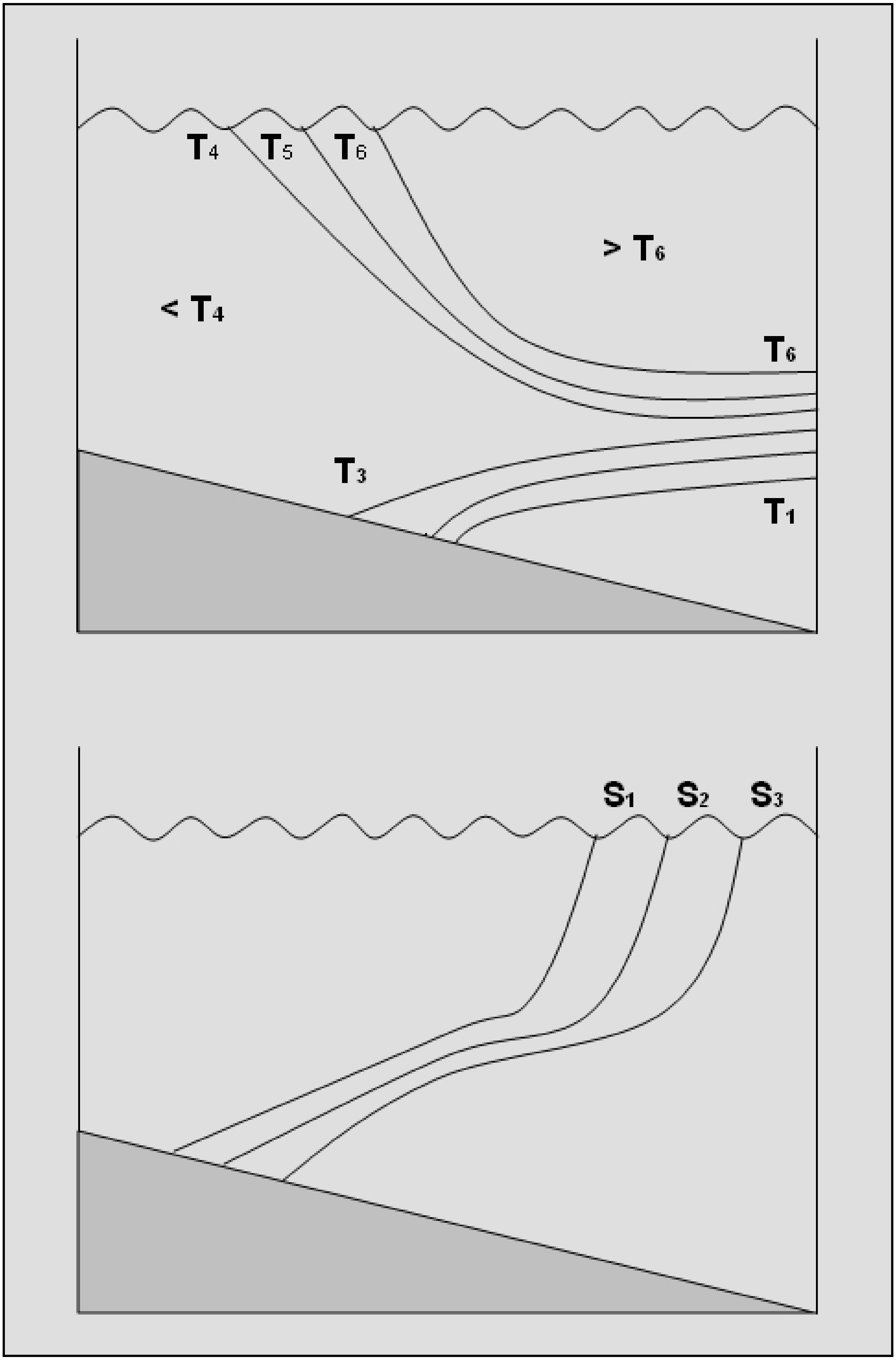



**Figure 7.6 - Schematic showing the structure of the thermohaline front on the NE Sakhalin shelf. Top: temperature; Bottom: Salinity.**

These factors control the gross thermohaline water structure in the study area. Smaller scale spatial and temporal variations are mainly regulated by the following factors:

- The location of the Eastern Sakhalin current and the shelf front related to it is impacted greatly by wind. With a prevailing southerly wind, the center of the current moves farther from the shore and upwelling increases. This results in the movement of salt water from the shelf slope towards the bottom [Bowden, 1983].
- The impact of tide driven waves entering the Sea of Okhotsk through the Kuril straits can cause some temporal variations in the thermohaline structure [Атлас океанов, 1974].[38]
- The sea floor bathymetry significantly impacts near shore and shelf water circulation. Figure 7.7 shows a schematic of the possible near shore water circulation as proposed by Leont'ev I.O. [Леонтьев, 2001].

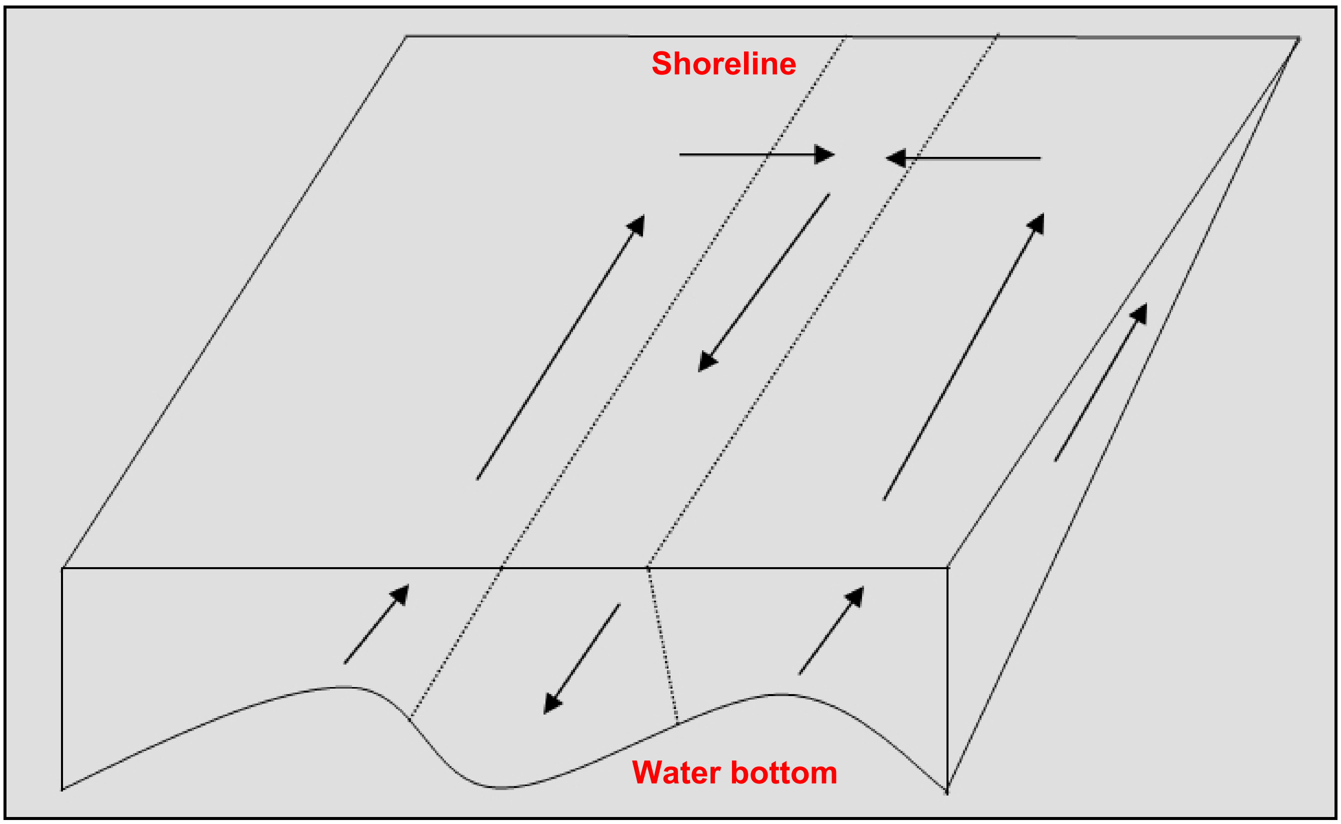



**Figure 7.7 - Schematic showing the proposed near shore water circulation in an area with an irregular bottom (after Leont'ev).**

[38] Temporal and spatial effects are inseparably linked and it is incorrect to assume that wind causes spatial variations and tides temporal variations. However, the duration of this study was less then 2 days and the wind was almost stationary. The dynamics of the hydrology were therefore controlled by the tides.

Considering the range of factors impacting the thermohaline structure in the study area analysis of the temperature and salinity stratification should commence with averaged values. Figure 7.8 displays averaged vertical profiles of temperature and salinity for two months (August and September), and three depth regimes. The variation in wind action during the analysis period was used to select the time limits[39].

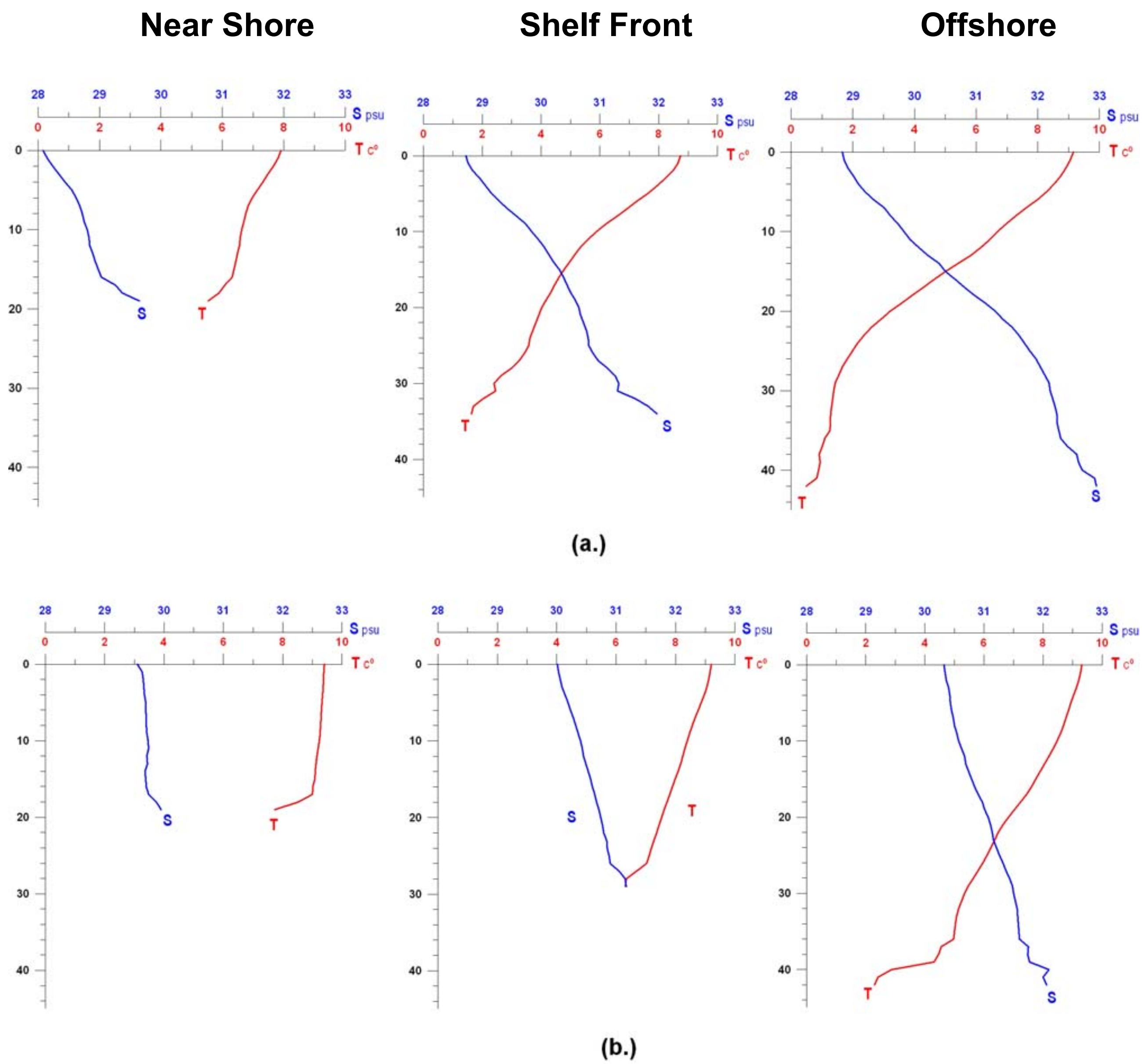



**Figure 7.8 - Vertical profiles of temperature (T) and salinity (S) averaged for (a) August and (b) September for three different locations with depths up to (left) 20 m; (middle) 30 m; and (right) 40 m.**

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[39] Storms occurred on the 10th and 25th August and the 1st, 9th and 17th September. The strongest wind recorded for the period was during a powerful typhoon on 1 and 2 September. September was the month with the most cyclonic activity.

### *7.2.1 Average values for August*

- The near shore shelf (within 20 m contour) is a relatively mixed zone. The temperature is 5.5-8°C, and salinity 28-30 psu.
- The shelf front occupies water depths from 20-30 m. The temperature gradient is 1-8.4°C and the salinity gradient 28-31.5 psu.
- Further offshore is the water mass of the Sea of Okhotsk. The temperature is 0.5-8.6°C and the salinity 28.7-32.6 psu.

### *7.2.2 Average values for September*

- The temperature of the shelf water is 7.7-9.4°C and the salinity 29.55-29.95 psu within the 20 m bathymetric contour. The temperature and salinity are 6.3-9.2°C and 30-31.2 psu respectively within the 30 m contour. Thus the region occupied by shelf water expanded in September. The main reason for this expansion was increased wind action leading to greater mixing and the formation of a surface quasi-homogeneous layer (SQHL). Additionally, since the transfer of SQHL water offshore increased, upwelling also increased, and this resulted in the intrusion of water from the Sea of Okhotsk into the shelf zone.
- The boundary of the shelf front moved to the 40 m bathymetric contour and region occupied by sea water contracted. The temperature was 3-9.2°C, and the salinity 30.2-32.2 psu.

Although wind had the greatest influence on the hydrodynamic structure of the area, tides also had an impact. Figures 7.9(a), (b), and(c) illustrate the link between tides and the variation in thermohaline structure. The two-layer current structure can be clearly seen here. The surface flow is towards the shore; this is corroborated by the transfer of warmer and less saline water to the near shore area. The area of warm, less saline water near the 25 m bathymetric contour could be an indication of Eastern Sakhalin current meandering towards the shore. At water depths less than 20 m, the current flows towards the sea as evidenced by lowered salinity and increased temperature.

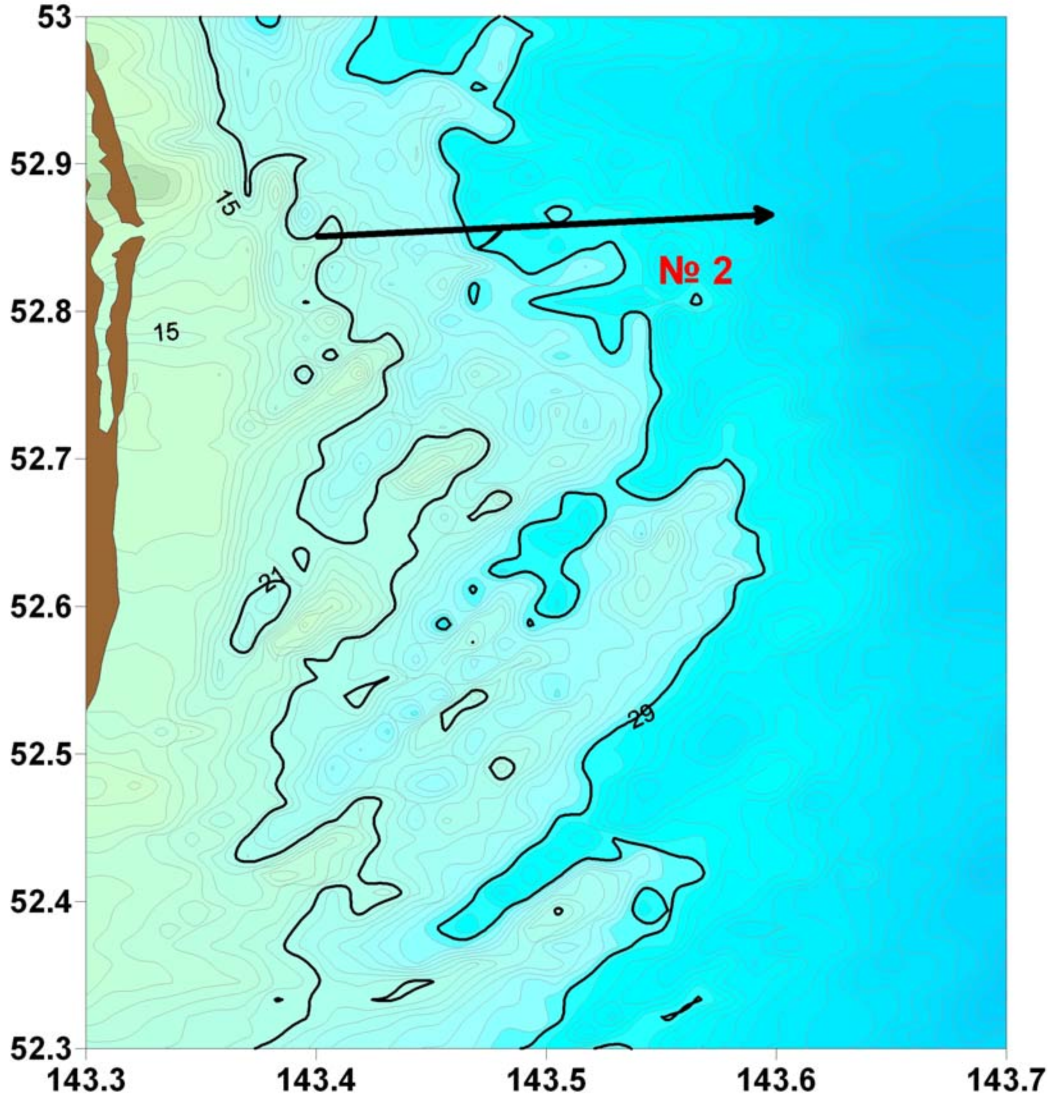


**Figure 7.9(a) - Map showing the location of profile #2.**

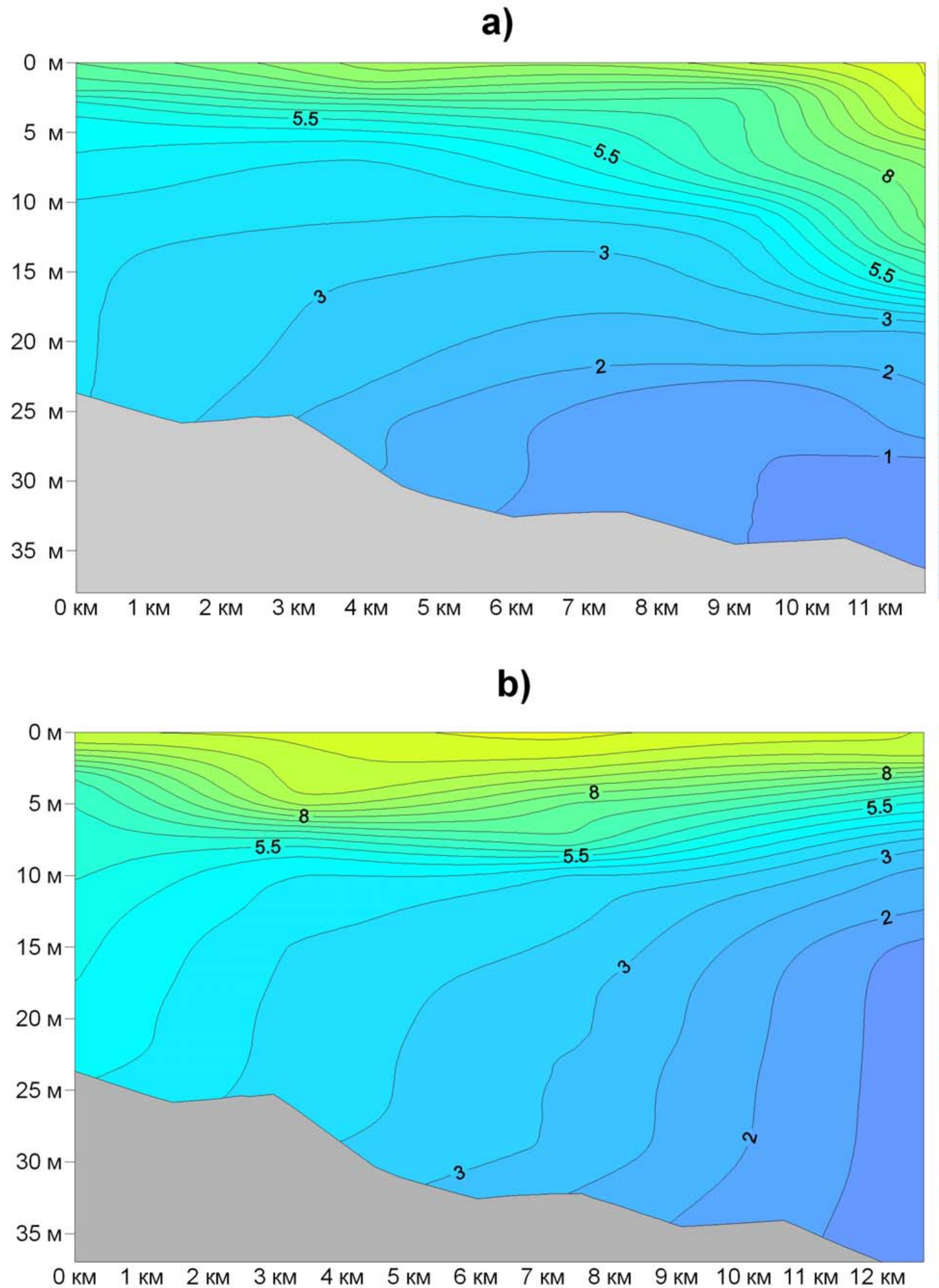


**Figure 7.9(b) - Temperature field T(z,r) for profile #2. (a) Low tide; (b) High tide.**

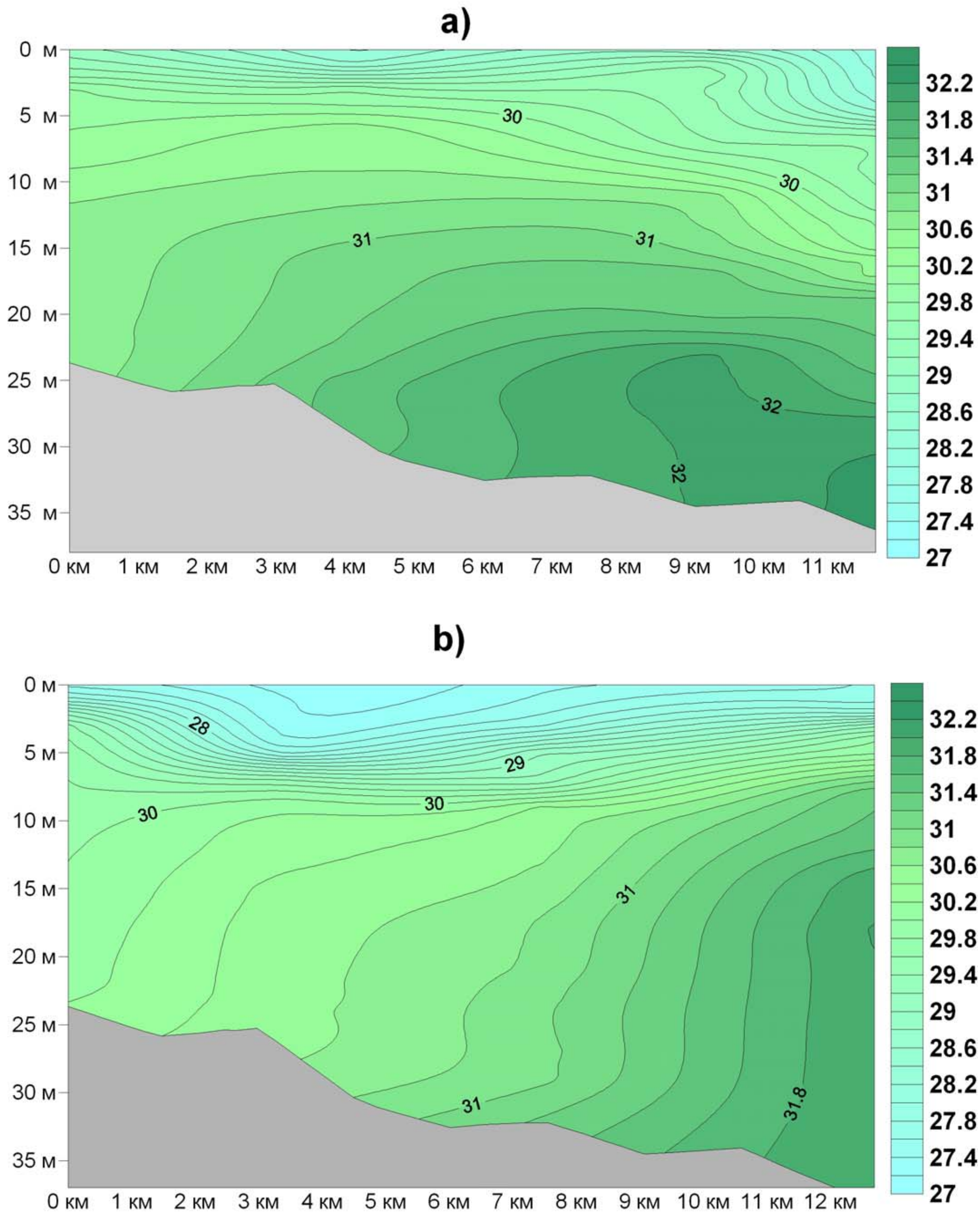


**Figure 7.9(c) - Salinity field S(z,r) for profile #2. (a) Low tide; (b) High tide.**

## 8 Results and Conclusions

1. The upgraded Autonomous Underwater Acoustic Recorders (AUARs) designed and developed at POI recorded 6735 hours (almost 281 days) of acoustic data. The AUARs recorded high fidelity data for frequencies from 1-10,000 Hz and periodically from 1-15,000 Hz.
2. Eight new AUARs were built by POI in 2004, bringing the total to 13 (one AUAR was lost in 2003). In 2004 a new HF broadband piezo-ceramic transducer was manufactured to supplement the old LF and HF transducers.
3. These AUARs and transducers were used to record ambient and anthropogenic acoustic levels on the NE Sakhalin shelf. They were also used to make synchronous measurements of broadband signals both at a source location along proposed pipeline routes and receiver locations at the edge of the Piltun gray whale feeding area. These measurements allow an accurate estimation of the TL between the proposed pipeline routes and the Piltun feeding area.
4. The bathymetric and hydrologic parameters of the area were studied in detail using the sonar of the *Academik Oparin* and a hydrologic sonde.
5. Spectral analysis of the acoustic energy generated by wind and surface waves again showed a good correlation between noise and sea state proposed by Knudsen and data from the NE Sakhalin shelf. Spectral analysis of acoustic data from Acoustic station A5 (depth ~20 m) and the Arkutun-Dagi monitor station (44 m) showed that during a storm the broadband (100 Hz to 15 kHz) ambient noise level increased by more than 20 dB relative to good weather conditions. During a storm the ambient noise level in the Offshore feeding area reached 80 dB re 1 μPa/Hz in the frequency band from 50-800 Hz and 55 dB re 1 μPa/Hz at 15 kHz.
6. The analysis again shows that at shallow (10 m) water depths the noise produced by wind and surface waves is much lower than at deeper (20 m) water depths. During a typhoon the difference in ambient noise level decreases.
7. Data was recorded for 23 days at the PA-B-10 monitor station and for 21 days at the Odoptu-S-10 monitor station. These stations were at the 10 m bathymetric contour directly offshore from the South and 2nd (respectively) land-based behavioral monitoring stations. These stations were synchronously occupied for three days during the 2004

field season (South behavioral and PA-B-10 monitor station - 16 August, 2nd behavioral and Odoptu-S-10 monitor station - 11 and 19 September).

8. Analysis of the variation of TL with frequency and range TL(*f,r*) has shown that for relatively long (8-20 km) shallow (20-30 m) profiles the TL is affected much more by the influence of the bottom and surface than by the spatial distribution of sound velocity C(*z,r*). The impact of sea-surface waves is greatest for acoustic energy at frequencies above 2 kHz and is proportional to frequency and profile length. For example, for 3 kHz acoustic energy propagating from PTL-11-A to the Piltun-S monitor station (5) (Figure 3.2), the proportional increase in TL with frequency has a coefficient of ~-19 dB/kHz due to dissipation by rough stormy waves.
9. A comprehensive frequency dependent transmission loss (TL(*f*)) study was undertaken on 11 acoustic profiles connecting points on the proposed pipeline routes with points at the 20 m contour bounding the southern and eastern edges of the Piltun feeding area. TL measurements were conducted for frequencies from 24 Hz to 15 kHz and included the profile bathymetry as well as hydrologic measurements at the transmission point, the receiving point and several points along the profile. Hydrologic measurements were taken twice at each transmission point, at the beginning and at the end of transmission, to measure any change in hydrology with time. These frequency dependent transmission loss and associated bathymetry and hydrology measurements are used to build theoretical models to estimate the propagation from each pipeline route during construction. The TL measurements show that the TL is high at low (<50 Hz) frequencies, generally reaches a minimum somewhere between 100 Hz and 1 kHz and increases at high frequencies. The exact value of TL is dependent on the bathymetry and hydrology along the profile.
10. Experimental and theoretical studies of frequency dependent transmission loss TL(*f*) were conducted on three profiles in the Orlan/Chayvo area. These profiles started at the proposed Orlan platform, and at two points (PTL12-A, PTL13-A) located on the proposed Orlan-Chayvo pipeline route, and ended at the Piltun-S monitor station (5), located on the southern border of the Piltun feeding area.

    The measured transmission losses were:

    - For the profile from the Orlan platform the TL was ~75 dB in the frequency range from 800-3000 Hz, increasing at frequencies above 3 kHz.

- For profiles PTL-12 and PTL-13 the TL was ~70 dB for frequencies from 700 to 1500 Hz, and ~75 dB for frequencies from 1.5-3 kHz.
- For all three profiles oriented parallel to the coast the signal to noise in the frequency range from 24-32 Hz was too low for TL measurements to be obtained. Estimates from theoretical models were therefore used; these TL estimates of >115 dB agree with experimental data gathered on a profile from the Orlan platform to the Orlan monitor station.

11. Experimental studies of frequency dependent transmission loss TL(*f*) were also conducted on three profiles starting at the same locations (the proposed Orlan platform, PTL12-A, and PTL13-A) and ending at the Orlan monitor station (3), located on the Western border of the Offshore feeding area. A further TL profile starting at the Orlan platform location and passing through the Orlan monitor station to the Arkutun-Dagi monitor station (TLP-2) was also analyzed.

    The measured transmission losses were:

    - For the profile from the Orlan platform the Orlan monitor station the TL was ~95 dB in the frequency range from 24-32 Hz, and ~60 dB at frequencies from 1-3 kHz.
    - For profiles PTL-12 and PTL-13 the TL was ~65 dB for frequencies from 700 to 1500 Hz, and ~70 dB for frequencies from 1.5-3 kHz.
    - For profile PTL-13 the TL was ~95 dB for frequencies from 24-32 Hz. For profile PTL-12 the signal to noise in the frequency range from 24-32 Hz was too low for TL measurements to be obtained.

12. Measurements of the source signature of the research vessel *Academik Oparin* were taken for a variety of operating conditions. These showed that:

    A. When the *Academik Oparin* was sailing at a speed of 12 knots:

    - Most of the acoustic energy generated by the *Academik Oparin* is concentrated in the frequency band from 15-3300 Hz.
    - The power spectral density level of low frequency (30-120 Hz) narrowband energy reached 130 dB re 1 $\mu Pa^2/Hz$ at distance 50-100 m.
    - There is a power spectral density peak at 500-600 Hz, with levels reaching 112 dB re 1 $\mu Pa^2/Hz$ (at 100 m). The reduction in the broadband power spectral density level within the frequency range from 100 Hz to 10 kHz was inversely proportional to frequency.
    - At a distance of 5 km from the Arkutun-Dagi monitor station (44 m depth) tonal

components at frequencies of approximately 540, 790 and 900 Hz reached 100, 85 and 79 dB re 1 $\mu Pa^2/Hz$ respectively. Narrowband spectral components at frequencies of approximately 33, 50 and 70 Hz were 85, 95 and 94 dB re 1 $\mu Pa^2/Hz$ respectively.

- The broadband acoustic energy level (at 5 km) decreased from 84 to 50 dB re 1 $\mu Pa^2/Hz$ between 600 Hz and 3500 Hz.
- The spectral density level 100 m ahead of the vessel was ~10 dB lower than 100 m astern.
- When sailing at 5 km from the Arkutun-Dagi monitor station the *Academik Oparin* generated tonal and narrowband components between 50 Hz and 600 Hz that are 10-15 dB higher than the ambient noise levels measured during a storm (83-65 dB re 1 $\mu Pa^2/Hz$ between 300-3000 Hz).

B. When the *Academik Oparin* was maneuvering at low speed at the 20 m contour:

- Spectral analysis of acoustic energy generated by the *Academik Oparin* 1.6 km from the Odoptu-S-10 monitor station (10 m depth) revealed that the narrowband acoustic level within the 35-700 Hz frequency band was 20 dB higher (~100 dB re 1 $\mu Pa^2/Hz$) than the ambient noise levels measured during a storm.
- At 1.6 km the spectral density levels of tonal components at 50, 100 and 600 Hz reached 105 dB re 1 $\mu Pa^2/Hz$.

C. When the *Academik Oparin* was drifting with engine stopped:

- Five tonal components at frequencies below 150 Hz with spectral levels of 68, 73, 71 and 74 dB re 1 $\mu Pa^2/Hz$ were seen in the spectrum of the *Academik Oparin* when 1.3 km from the Piltun-S monitor station.
- The maximum spectral level of acoustic energy is between 200 Hz and 600 Hz and is ~76 dB re 1 $\mu Pa^2/Hz$ 1.3 km from the Piltun-S monitor station.
- In the frequency band from 700 Hz and 15 kHz the reduction in broadband power spectral density was inversely proportional to frequency.

13. Measurements of the acoustic output of the Photo-ID zodiacs when equipped with 40 hp 4-stroke and 2-stroke outboard motors showed that at a distance of ~100 m:

- The average acoustic energy generated by the 40 hp 4-stroke outboard motor at 25 km/hr is lower than at 7 km/hr. At 25 km/hr the zodiac's outboard motor produced narrow band acoustic energy whose level reached 105 dB re 1 $\mu Pa^2/Hz$

at 170 Hz. At 7 km/hr the outboard motor produced narrow band acoustic energy that reached 109 dB re 1 $\mu Pa^2/Hz$ in the frequency range from 40-115 Hz and a 104 dB re 1 $\mu Pa^2/Hz$ tonal component at ~980 Hz.

- Broadband and narrowband acoustic levels generated by the 2-stroke outboard motor are more than 15 dB higher than those generated by the 4-stroke outboard motor.

14. Temporal analysis of acoustic signals recorded at a variety of locations on the NE Sakhalin shelf showed that:
    - At night, impulses, probably generated by marine animals, were observed at all the monitored locations. These acoustic impulses had a duration of between 2 and 100 ms and amplitudes of more than 2 Pa (126 dB re 1 $\mu$Pa/Hz).
    - Impulses generated by seismic or engineering surveys were periodically observed. These impulses had a cycle time of approximately 10 seconds, a duration of ~3.5 s and amplitude that could exceed 2 Pa (126 dB re 1 $\mu$Pa/Hz).
15. A bathymetric map of the area was generated from the 8400 km of bathymetric profiling conducted by the *Academik Oparin.*
16. Three hundred and twenty-three vertical hydrologic profiles were acquired in the study area. This data was used to analyze the spatial and temporal characteristics of the hydrology including the impact of tides and cyclones and led to the following observations:
    - Wind is a major factor defining the structure and variation of the hydro-physical fields on the NE Sakhalin shelf.
    - Southerly winds dominate during the summer season; this semi-stationary wind field is disturbed by tropical cyclones, which also excite water mixing and upwelling.
17. The average spatial distribution of temperature and salinity was:

    A. August:
    - The near shore shelf zone ($\leq$20 m) is relatively mixed with temperatures between 5.5 - 8$^\circ$C, and salinity 28-30 psu.
    - The shelf front occupied water depths from 20-30 m. The temperature (1-8.4$^\circ$C) and salinity (28-31.5 psu) gradients are sharper.
    - Further offshore (>30 m) is the water mass of the Sea of Okhotsk. The temperature is 0.5 - 8.6$^\circ$C, and the salinity 28.7-32.6 psu.

B. September:

- The near shore shelf zone - temperature 7.7-9.4°C and salinity 29.55-29.95 psu.
- Within the 30 m contour - temperature 6.3-9.2°C and salinity 30-31.2 psu.

## 9 Future plans

In 2003 and 2004 POI developed and manufactured 13 digital AUARs for acoustic studies on the NE Sakhalin shelf conducted as part of the gray whale research program. These self-contained recorders have significantly greater dynamic range (96 dB) and bandwidth (1 to 15,000 Hz) over sonobuoys allowing accurate, synchronous acoustic measurements to be made across the NE Sakhalin shelf. A large quantity of data is expected from the 2005 field expedition. POI is investigating methods to archive this large volume of field data.

Some refinements will be made on the 13 AUARs fabricated in 2003 and 2004, building on the experience gained from the 2004 field expedition to improve the handling and operating time for the recorders. These include:

- The operating system for the AUAR will be changed from DOS to QNX. This operating system will improve the real-time fault recovery capabilities of the AUAR.
- A two channel (20 kHz and 30 kHz sample rate) system was used to maximize the dynamic range of the AUAR. Experience from the 2004 expedition has indicated that 96 dB of dynamic range was sufficient for the range of amplitudes encountered. One channel (30 kHz sample rate) will be used in 2005, improving both the bandwidth of the signals recorded and the operating time of the AUAR.
- The gain will be changed to minimize the instrument noise at low input amplitudes.
- The flash memory capacity will be increased to 1 GB to reduce the dead time.
- The hard-drive capacity will be increased to 80 GB to increase the recording time.
- Testing indicates that the AUAR will be able to operate continuously for ~18 days.

These changes in conjunction with those made in 2004 (container shape, hydrophone and program modes) will significantly improve the operational performance of the AUARs. POI will continue to investigate methods to reduce the effect of flow noise on acoustic and TL measurements.

One new AUAR will be constructed in 2005, bringing the total number of AUARs available to the program to 14. Two AUARs will also be fabricated with lower sensitivity. These will be much smaller having an operational time of three to four days. They are designed for ease of deployment during TL experiments, and will be capable of recording transducer signals at short ranges.

One of the goals of the 2005 acoustic program is to monitor in real time the sound level at the 20 m bathymetric contour bounding the southeastern and southern sections of the Piltun feeding area.  Four AUARs will be equipped with a surface radio transmitter in addition to their standard recording capabilities.  These surface units will transmit acoustic data over the frequency band from 20-5000 Hz using an analog radio channel.  This data will be received and recorded in real time at Piltun lighthouse.

A new low-frequency transducer will be constructed in 2005.  This transducer, in conjunction with the mid-frequency transducer developed in 2004 and a complex broadband signal generator will allow improved TL estimation at frequencies from 15-15000 Hz.

The comprehensive TL studies initiated in 2002 and 2003 and extended in 2004 will be further augmented in 2005 with the main objective being the calibration of acoustic models along key profiles over the NE Sakhalin shelf.  These TL and model studies will investigate sound propagation from the planned construction/development areas to the Piltun and Offshore gray whale feeding areas.

As in 2004 detailed hydrologic profiling using the sonde and vessel sonar will be conducted in the study area.  The bathymetric and hydrologic data will be used in the construction of theoretical acoustical and hydrodynamic models and numerical experiments.  This data will allow the impact of variations in the hydrologic field on sound propagation to be investigated and will improve the accuracy of numerical modeling.  The bathymetric and hydrologic studies will be designed to investigate the impact of meteorological parameters such as phase of the tide or changes in wind parameters to estimate their impact.

The integration between the acoustic and hydrologic research and other components of the western gray whale research program initiated in 2004 will be expanded in 2005.  Two integrated programs will be conducted in 2005, these are:

- Recording of ambient and anthropogenic acoustic levels at the 10 m bathymetric contour offshore from the behavioral monitoring stations.  Computation of the energy level in 10-minute windows over the monitoring period[40].

[40] This is an extension of the work initiated during the 2004 acoustic expedition.

- Investigation of the correlation between the spatial distribution of benthos and variations in bathymetry and hydrology in the study area (Figure 9.1). A special hydrologic study will investigate the NE trending bottom topography to determine if the benthos concentrations are related to the hydrodynamics of the area.

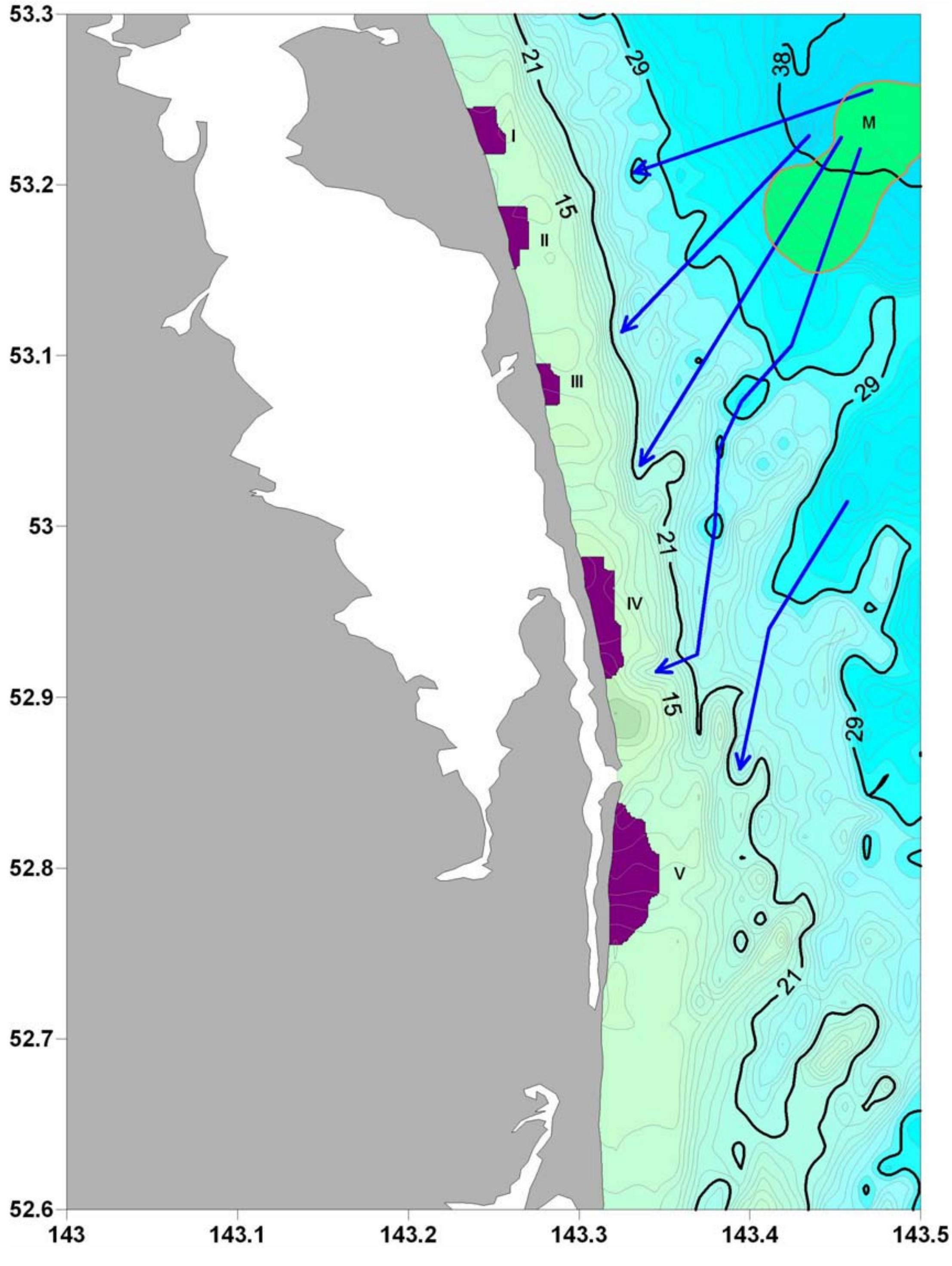


**Figure 9.1 - The variation in amphipod density (purple) and bivalve biomass (M) overlain on the bathymetry of the study area.**

## 10 Acknowledgements

The authors would like to thank the V.I. Il`icev Pacific Oceanological Institute, FEB Academy of Sciences of Russia (POI), (Тихоокеанский океанологический институт им. В.И. Ильичева ДВО РАН), for assistance in performing this work.

The authors would also like to acknowledge the following personnel from POI, who while they did not contribute to the report, contributed significantly to the success of the program in the field. Scientists Sc. S.V. Borisov (Борисов С.В.), A.V. Gritsenko (Гриценко А.В.) and Dr. A.A. Solov'ev (Соловьев А.А.).

The authors wish to thank the crew of the *Academik Oparin* for their hospitality and assistance while conducting acoustic measurements on the NE Sakhalin shelf. They would also like to thank the leader of the expedition Yuri Yakovlev (IBM) for his support, attitude and the management of the safety program for the 2004 field season as well as all the scientists participating in the expedition.

Finally the authors would like to express their gratitude to Dr. Sc. G.I. Dolgih (Долгих Г. И.)(POI), Dr. Sc. V.G. Petnikov (Петников В.Г.)(Institute of general physics, Moscow), Drs. R.T. Houck, H.R. Melton, and M. Santala (ExxonMobil Upstream Research Co.), as well as Dr. L Aerts (SEIC) and Dr. C.I. Malme (LGL) for reviewing this report.

Our special thanks go to the investment companies, their employees and consultants, without whom the present work could not have been conducted. These include:

LGL Ltd. - S.R. Johnson, S. Meier, and S.B. Yazvenko.

Exxon Neftegas Ltd. - M.R. Jenkerson, and H.R. Melton.

Sakhalin Energy Investment Company Ltd. - L. Aerts, T. Konovalova.

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## Appendix A - Description of data used for the TL studies

**Table A1 - Operational times, parameters and locations of AUARs at monitor stations 3 to 8.**

| Station | | Date | | Time | | Time | AUAR | Location | | Z | Gain | | Sens. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | # | Start | End | Start | End | | # | Latitude | Longitude | (m) | LF | HF | (mV/Pa) |
| Orlan | 3 | 3-Aug | 18-Aug | 22:00 | 23:50 | 362.0 | № 6 | 52°21.217 | 143°35.325 | 32 | 16 | 100 | 50.8 |
| Orlan | 3 | 7-Sep | 20-Sep | 10:00 | 6:30 | 308.5 | № 10 | 52°21.803 | 143°35.201 | 32 | 40 | 200 | 51.5 |
| Orlan | 3 | 21-Sep | 24-Sep | 21:00 | 2:10 | 53.2 | № 9 | 52°21.752 | 143°35.246 | 34.5 | 40 | 200 | 54.4 |
| Orlan | 3 | 27-Sep | 30-Sep | 17:00 | 9:10 | 64.2 | № 3 | 52°21.576 | 143°34.681 | 32 | 40 | 200 | 50.1 |
| Arkutun-Dagi | 4 | 3-Aug | 18-Aug | 22:00 | 17:30 | 338.0 | № 1 | 52°19.857 | 143°43.942 | 42 | 16 | 100 | 50.1 |
| Arkutun-Dagi | 4 | 19-Aug | 1-Sep | 6:38 | 2:00 | 283.4 | № 10 | 52°20.088 | 143°44.086 | 43 | 40 | 200 | 51.5 |
| Arkutun-Dagi | 4 | 7-Sep | 19-Sep | 11:30 | 14:30 | 276.5 | № 4 | 52°19.156 | 143°44.072 | 43.5 | 40 | 200 | 51.46 |
| Piltun-S | 5 | 28-Aug | 1-Sep | 17:00 | 09:20 | 81.3 | № 2 | 52°40.180 | 143°22.078 | 17.5 | 40 | 200 | 51.6 |
| Piltun-S | 5 | 24-Sep | 28-Sep | 17:30 | 15:30 | 94.0 | № 4 | 52°40.242 | 143°22.375 | 18 | 40 | 200 | 52.1 |
| Piltun-S | 5.1 | 4-Sep | 7-Sep | 17:00 | 11:04 | 66.1 | № 13 | 52°40.760 | 143°22.588 | 18 | 40 | 200 | 51.1 |
| Piltun-S | 5.2 | 24-Sep | 25-Sep | 17:30 | 00:00 | 24.0 | № 8 | 52°40.657 | 143°22.354 | 17 | 40 | 200 | 52.3 |
| Piltun | 6 | 6-Aug | 19-Aug | 13:00 | 07:40 | 299.0 | № 7 | 52°49.180 | 143°25.570 | 20.7 | 16 | 100 | 52.4 |
| Piltun | 6 | 27-Aug | 8-Sep | 20:00 | 11:30 | 255.5 | № 1 | 52°49.421 | 143°24.450 | 20 | 40 | 200 | 50.8 |
| Piltun | 6 | 18-Sep | 20-Sep | 16:39 | 06:08 | 37.5 | № 9 | 52°49.517 | 143°24.420 | 19.5 | 40 | 200 | 54.4 |
| Piltun | 6.1 | 27-Aug | 31-Aug | 21:00 | 07:30 | 75.0 | № 7 | 52°49.142 | 143°24.827 | 22 | 40 | 200 | 52.4 |
| PA-B-10 | 7 | 6-Aug | 21-Aug | 22:20 | 12:00 | 337.7 | № 3 | 52°52.982 | 143°20.576 | 11.5 | 16 | 100 | 50.8 |
| PA-B-10 | 7 | 22-Sep | 1-Oct | 9:15 | 9:00 | 215.8 | № 10 | 52°53.018 | 143°20.270 | 9 | 40 | 200 | 51.5 |
| PA-B-20 | 8 | 4-Sep | 16-Sep | 15:00 | 16:30 | 289.5 | № 5 | 52°53.955 | 143°23.270 | 19.5 | 40 | 200 | 50.31 |
| PA-B-20 | 8 | 18-Sep | 19-Sep | 17:50 | 23:24 | 29.6 | № 1 | 52°53.921 | 143°23.282 | 20 | 40 | 200 | 50.8 |

**Table A2 - Operational times, parameters and locations of AUARs at monitor stations 8, 10, and 11 as well as acoustic stations A4 to A8.**

| Station | | Date | | Time | | Time | AUAR | Location | | Z | Gain | | Sens. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | # | Start | End | Start | End | | # | Latitude | Longitude | (m) | LF | HF | (mV/Pa) |
| PA-B-20 | 8.1 | 18-Sep | 19-Sep | 17:37 | 02:38 | 9.0 | № 11 | 52°53.986 | 143°23.481 | 21 | 40 | 200 | 50.8 |
| Odoptu-S-10 | 10 | 10-Sep | 25-Sep | 21:17 | 5:48 | 344.5 | № 2 | 53°03.685 | 143°18.281 | 11 | 40 | 200 | 51.6 |
| Odoptu-S-10 | 10 | 24-Sep | 1-Oct | 14:00 | 11:00 | 165.0 | № 6 | 53°03.630 | 143°19.000 | 14.3 | 40 | 200 | 52.3 |
| Odoptu-S-20 | 11 | 9-Aug | 21-Aug | 14:00 | 19:40 | 274.0 | № 8 | 53°03.763 | 143°20.097 | 20.9 | 16 | 100 | 52.1 |
| Odoptu-S-20 | 11 | 10-Sep | 12-Sep | 21:05 | 00:52 | 27.8 | № 12 | 53°03.521 | 143°19.725 | 20 | 40 | 200 | 52.8 |
| Odoptu-S-20 | 11 | 23-Sep | 1-Oct | 17:00 | 11:30 | 186.5 | № 11 | 53°03.660 | 143°19.858 | 20.5 | 40 | 200 | 52.4 |
| Piltun-1 | A.4 | 6-Aug | 14-Aug | 22:20 | 01:00 | 169.7 | № 12 | 52°43.100 | 143°22.466 | 15.5 | 16 | 100 | 52.8 |
| Piltun-1 | A.4 | 28-Aug | 1-Sep | 17:00 | 23:30 | 78.5 | № 8 | 52°42.781 | 143°22.027 | 17 | 40 | 200 | 51.72 |
| Piltun-1 | A.4 | 24-Sep | 28-Sep | 16:00 | 16:20 | 96.3 | № 7 | 52°42.913 | 143°22.353 | 15 | 40 | 200 | 52.4 |
| Piltun-2 | A.5 | 6-Aug | 18-Aug | 08:00 | 05:16 | 288.0 | № 5 | 52°43.409 | 143°25.635 | 23.5 | 16 | 100 | 50.31 |
| Piltun-2 | A.5 | 28-Aug | 8-Sep | 15:00 | 10:00 | 235.0 | № 12 | 52°42.900 | 143°25.600 | 21 | 40 | 200 | 52.8 |
| Piltun-2 | A.5 | 4-Sep | 11-Sep | 16:38 | 18:26 | 169.8 | № 9 | 52°43.785 | 143°25.815 | 22 | 40 | 200 | 52.3 |
| Piltun-2 | A.5.1 | 28-Aug | 31-Aug | 17:00 | 24:00 | 55.0 | № 5 | 52°42.864 | 143°25.762 | 21.5 | 40 | 200 | 50.31 |
| Piltun-2 | A.5.1 | 22-Sep | 23-Sep | 13:00 | 18:40 | 29.7 | № 4 | 52°43.344 | 143°26.016 | 22 | 40 | 200 | 52.1 |
| Piltun-3 | A.6 | 6-Aug | 17-Aug | 13:00 | 08:00 | 251.0 | № 10 | 52°49.286 | 143°25.040 | 20.7 | 16 | 100 | 51.5 |
| Piltun-3 | A.6 | 14-Sep | 16-Sep | 21:00 | 16:15 | 43.3 | № 1 | 52°49.493 | 143°24.436 | 20 | 40 | 200 | 50.8 |
| Piltun-3 | A.6.1 | 14-Sep | 16-Sep | 21:00 | 10:10 | 37.2 | № 11 | 52°49.232 | 143°24.950 | 21 | 40 | 200 | 50.8 |
| PA-B-1 | A.7 | 6-Aug | 21-Aug | 15:00 | 10:30 | 345.0 | № 2 | 52°55.810 | 143°20.470 | 13.7 | 16 | 100 | 51.6 |
| PA-B-2 | A.8 | 6-Aug | 21-Aug | 14:00 | 08:30 | 346.0 | № 4 | 52°55.897 | 143°21.711 | 22.2 | 16 | 100 | 52.1 |