# Current mooring observations in the area of the South Kuril Islands

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## Abstract

Our knowledge of dynamic processes in the area adjacent to the South Kuril Islands is very limited because of a lack of current mooring observations. The information related to currents in this region was obtained from satellite-tracked drifters (Rabinovich and Thomson, 2001; Ohshima *et al.*, 2005). To investigate currents in this region, the Sakhalin Research Institute of Fisheries and Oceanography installed two moorings in the shelf waters of Urup and Kunashir islands in 2003. Experimental studies of dynamic processes were conducted from 2004–2005 in the areas adjacent to Kunashir Island. Diurnal tidal currents strongly dominate on the northern shelf of Urup Island, especially the east-directed component. Tidal currents are almost rectilinear and very steady. Stable east-directed residual currents with an average velocity of 10–12 cm/s were found from April until September which means that there was an outflow of Okhotsk Sea water to the Pacific Ocean through Urup Strait during this period. We found significant amplification of the current in October and November, with the current direction becoming northeast. Autumn typically is a time of atmospheric fields changing to the so-called winter monsoon, with its strong northwesterly winds; however, we did not find this changing in the fall of 2003, from reanalysis data. Another cause of current amplification probably followed, besides the baroclinic effect. However, the noted phenomena are still unclear because there were no salinity sensors at the moorings. A temperature maximum (8–9°C) was found in the second half of October (about two times greater than in August). A similar current amplification was observed near Ekaterina Strait in September–October. We also found tides weakening at this time.

## Introduction

Our knowledge of dynamic processes in the area adjacent to the South Kuril Islands is very limited because of the scarcity of current mooring observations. Direct current measurements have been carried out in Ekaterina and Freez straits (Luchin, 1996; Fux, 1997) but they were relatively short period observations (two or three weeks) which were focused on the study of tidal currents. Very strong tidal currents which cause mixing of the Ohkotsk Sea and Pacific Ocean waters were found in the straits. The same information related to currents in this region was also obtained from satellite-tracked drifters (Thomson *et al.*, 1997; Rabinovich, Thomson, 2001; Ohshima *et al.*, 2005). Strong diurnal tidal motions were found on the shelf waters of Urup and Iturup islands. Low-frequency eddy-induced drifter oscillations were observed in the area of the Kuril Trench.

To investigate currents in this region, the Sakhalin Research Institute of Fisheries and Oceanography installed two moorings on the Okhotsk Sea shelf of Urup and Kunashir islands in 2003. Experimental studies of dynamic processes were conducted from 2004–2005 in the areas adjacent to Kunashir Island. Mooring current measurements were mainly directed to the study of seasonal changes in circulation.

## Observations

The first mooring “Leya-1” was installed on the shelf of Urup Island on February 28, 2003, at coordinates 46°28′ N and 150°09′ E (Table 1, Fig.1). Total depth in this spot equaled 110 m and a current meter, SonTek Argonaut MD, was fastened at a depth of 30 m. The current meter included a water temperature sensor. The mooring was lifted on board the R/V *Dmitry Peskov* on November 19, 2003. The period of observations amounted to 265 days.

The second mooring "Leya-2" was installed on the shelf of Kunashir Island on June 10, 2003, at coordinates 44º39′ N 146º26′ E, close to Ekaterina Strait. Total depth in this spot equaled 126 m and an acoustic Doppler current profiler, SonTek ADP, was placed on the sea bottom housed in a special stainless frame. The ADP measured currents in 15 layers with each layer 8 m thick. The mooring was lifted onto the R/V *Dmitry Peskov* on October 16, 2003. The period of observations amounted to 127 days.

The experimental study of currents was continued on August 2, 2004. The mooring "Leya-3", with the same equipment used for Leya 2, was installed a small distance east of Leya-2 (Table 1). The depth was 130 m, and the ADP measured current velocities in 15 layers of thickness 8 m each. Unfortunately, one block of ADP memory was damaged which resulted in significant data gaps from August 2 to December 10. Because of the gaps, we did not use these data for analysis. The mooring was lifted onto the R/V *Dmitry Peskov* on June 30, 2005.

Almost simultaneous to the deployment of Leya 2, current mooring measurements were carried out on the Pacific side of Ekaterina Strait (Fig.1, Table 1). The mooring "Olga" was installed on August 3, 2004 (current measurements started at 0:00 Sakhalin summer time, August 4). A three-dimensional acoustic current meter, SonTek Argonaut, was used. Total depth was 210 m, and the depth of the current meter was about 45 m. The mooring was fixed by a 200-kg ballast, and an acoustic breaker, Edge Tech, was fastened 3 m above it. The length of the halyard was 160 m, and the vertical tension of the halyard was provided by several silumin buoys which were fastened above the current meter. The number of buoys was insufficient to hold the current meter in place, so the depth of the current meter was changed under the influence of the currents (mainly tidal currents). This effect was noted from the hydrostatic pressure data (Argonaut was fitted with water temperature and pressure sensors). The mooring was lifted onto the R/V *Dmitry Peskov* on July 3, 2005.

**Table 1** Information about SakhNIRO moorings in the area of South Kuril Islands.

| Mooring | Current meter | Latitude (N) | Longitude (E) | Total depth (m) | Current meter depth (m) |
|---|---|---|---|---|---|
| Leya-1 | Argonaut MD | 46°28′ | 150°09′ | 110 | 30 |
| Leya-2 | ADP | 44º39′ | 146º26′ | 126 | 15 layers |
| Leya-3 | ADP | 44º41′ | 146º42′ | 130 | 15 layers |
| Olga | Argonaut MD | 44º11′ | 146º51′ | 210 | 45 |
| Shalila | Argonaut MD | 43º30′ | 145º51′ | 27 | 25 |

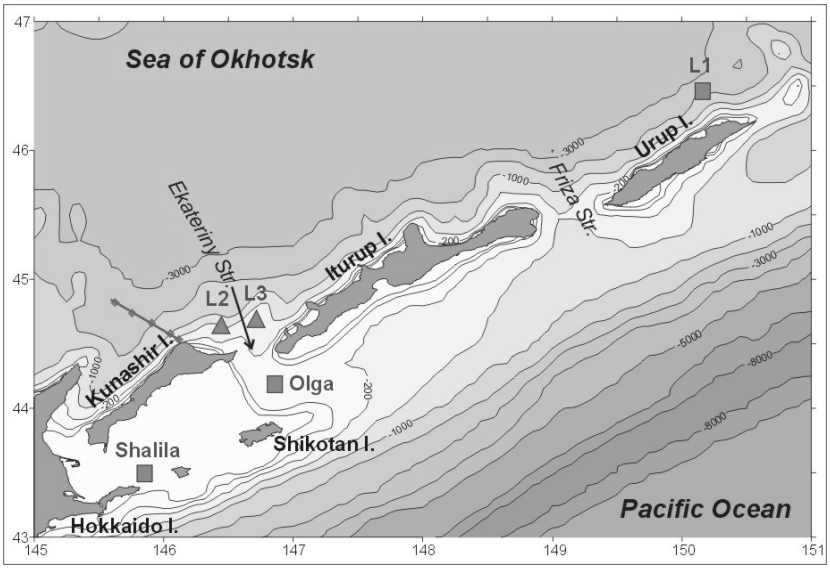


**Fig. 1** Mooring locations in the areas adjacent to the South Kuril Islands. Moorings Leya-1, -2, and -3 are marked by L1, L2, and L3, respectively.

About one and half months earlier, on May 14, 2005, the mooring "Shalila" was installed near Tanfilieva Island (Fig. 1, Table 1). A three-dimensional acoustic current meter, SonTek Argonaut, was placed in a crab trap which was set on the sea bottom. Total depth was about 27 m, and currents were measured at 25 m depth. The Argonaut was also fitted with water temperature and pressure sensors. The mooring was lifted onto the R/V *Dmitry Peskov* on October 29, 2005.

## Results and Discussion

East- and north-directed current components, which were measured on the shelf waters of Urup Island, are shown in Figure 2. Diurnal tidal currents strongly dominate, especially the east-directed component. Tidal currents are almost rectilinear and very steady. A well-expressed fortnightly modulation of tides was found, which is typical for areas with predominantly diurnal waves. The amplitude of the main diurnal constituent $K_1$ measured 17 cm/s, and the main semidiurnal $M_2$ constituent measured 10 cm/s.

Ten-day mean vectors of residual currents (tides were predicted and subtracted) on the shelf of Urup Island and wind vectors (reanalysis data) are shown in Figure 3. We found a stable east-directed residual current with an average velocity of 10–12 cm/s from April until September which means that there was an outflow of Okhotsk Sea water to the Pacific Ocean through Urup Strait during this period. We found significant amplification of the current in October and November, with the current direction becoming northeast.

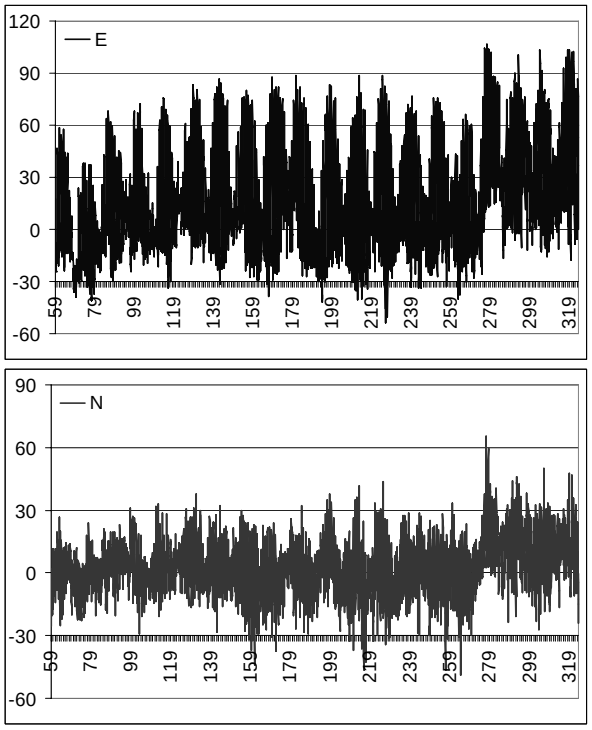


**Fig. 2** East-directed and north-directed current components (cm/s), Leya-1 mooring. Bottom axis is time (2003, Julian days).

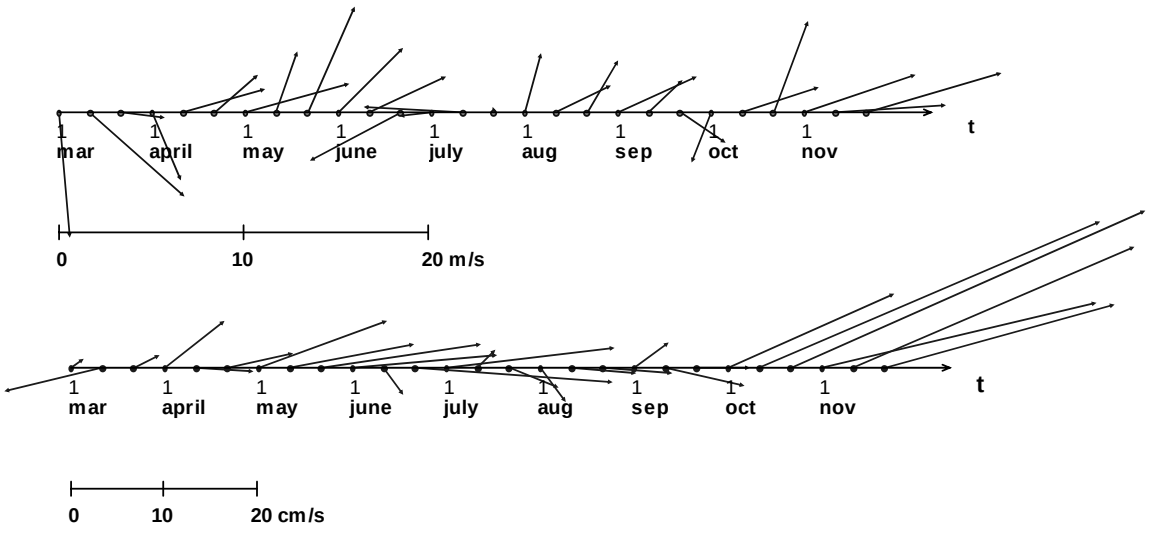


**Fig. 3** Ten-day mean vectors of residual currents (Leya-1 mooring, bottom) and wind (reanalysis, top) from March 1 to November 19, 2003.

Autumn typically is a time of atmospheric fields changing to the so-called winter monsoon, with its strong northwesterly winds; however, we did not find this changing in the fall of 2003. Another cause of current amplification may have been due to changes in water temperature and salinity. The current meter had a temperature sensor but no salinity sensor, so we could not study salinity changes. It is very interesting that a temperature maximum (8–9°C) was found in the second half of October, which was about two times greater than in August (Fig. 4). This late temperature increase is probably connected with current amplification.

East and north-directed current components on the shelf of Kunashir Island (Leya-2 mooring) are shown in Figure 5. Diurnal tidal currents strongly dominate, especially in the north-directed component. Tidal currents are almost rectilinear and steady until September. A well-expressed fortnightly modulation of tides was found from June to August. The amplitude of the main diurnal constituent $K_1$ measured 25 cm/s, and that of the main semidiurnal constituent $M_2$ was 12 cm/s.

Five-day mean current vectors in the middle and near-bottom layers in the area adjacent to Ekaterina Strait (Leya-2) are shown in Figure 6. Southeasterly currents (which correspond to the outflow to the Pacific Ocean), with an average velocity of 10–15 cm/s were from June until mid-September. Significant current amplification and counter-clockwise vector turning were observed in the fall season. A northeasterly current was found in the middle layer and a northerly current in the near-bottom layer. The amplification was similar to that on the Urup shelf.

A strong northeasterly current was observed from January to mid-February 2005 (Leya-3 mooring, see Fig. 7). From the middle of February, an outflow to the Pacific Ocean was observed, especially in the middle layer.

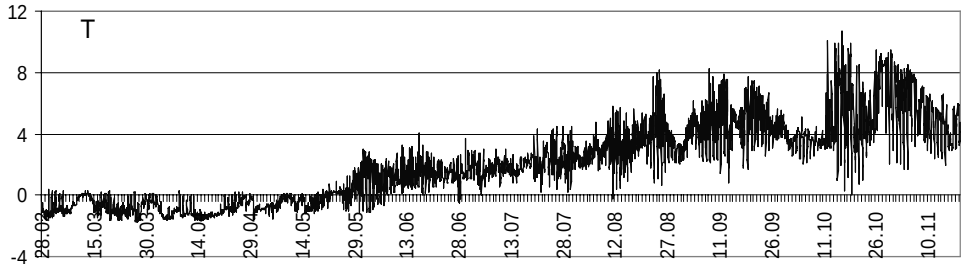


**Fig. 4** Water temperature changes (°C) on the shelf of Urup Island at 30 m depth.

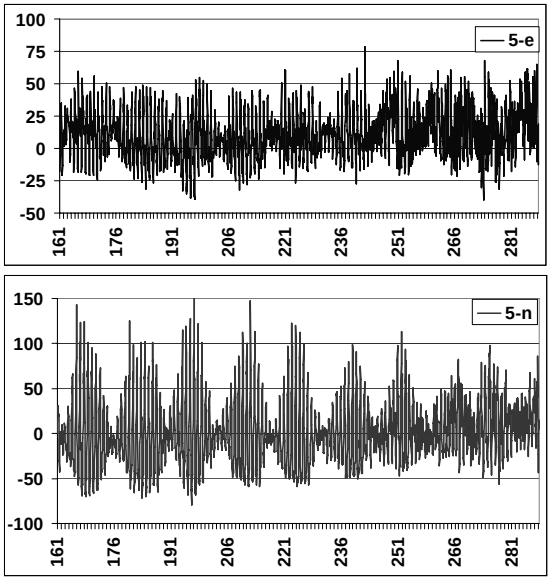


**Fig. 5** East-directed and north-directed current components (cm/s), Leya-2 mooring, fifth layer (about 80 m depth). Bottom axis is time (2003, Julian days).

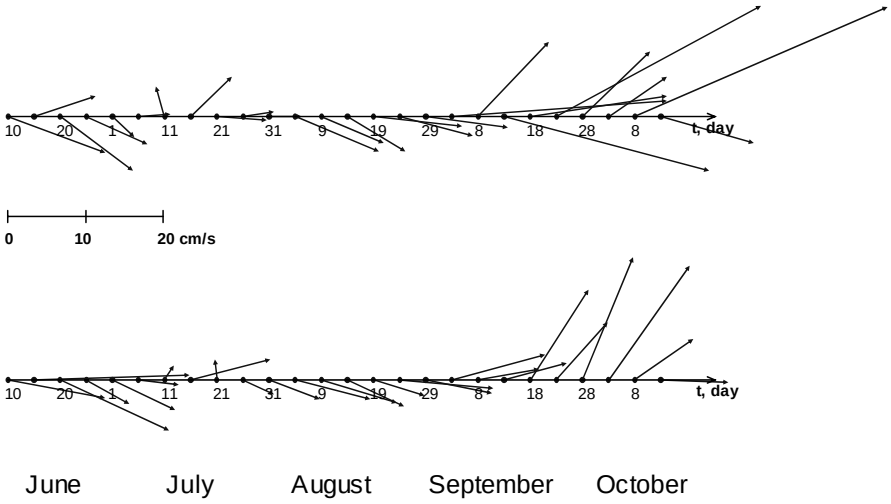


**Fig. 6** Five-day mean vectors of residual currents at a depth of 48 m (middle layer) and 120 m (near-bottom layer) on the Kunashir shelf (Leya-2 mooring) from June 10 to October 16, 2003.

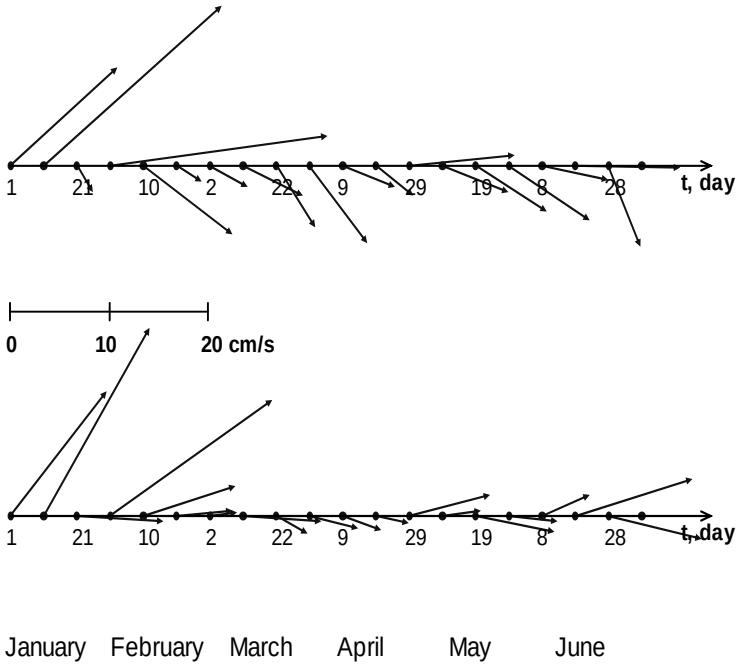


**Fig. 7** Ten-day mean vectors of residual currents at a depth 48 m (middle layer and 120 m (near-bottom) on the Kunashir shelf (Leya-3 mooring) from January 1 to June 30, 2005.

East and north-directed current components on the shelf of Tanfilieva Island (Shalila mooring) are shown in Figure 8. Diurnal tidal currents strongly dominate, in both east and north-directed components. Tidal currents are almost rectilinear (the larger axis of tidal ellipses has a southwest–northeast orientation) and steady until August. A well-expressed fortnightly modulation of tides was found from May–July and some instability occurred in August–October. The amplitude of the main diurnal constituent $O_1$ measured 15 cm/s, and that of the main semidiurnal wave $M_2$ was 4 cm/s. Small residual currents were found, with an average velocity of about 2–3 cm/s.

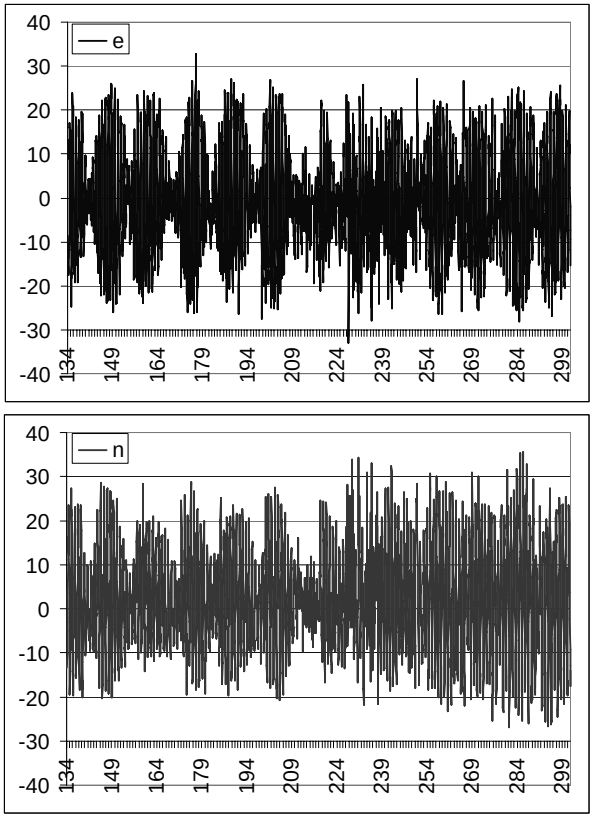


**Fig. 8** East-directed and north-directed current components (cm/s), Shalila mooring. Bottom axis is time (2005, Julian days).

## Conclusions

- Long-term observations of currents near the South Kuril Islands revealed strong diurnal tidal currents, which significantly dominate all other types of motions in this region;
- Amplification of northeasterly currents on the Okhotsk Sea shelf of the South Kuril Islands was found in October–January. This amplification is probably induced by a baroclinic gradient ;
- Outflow through Urup Strait to the Pacific Ocean was observed from March until September;
- The outflow through Ekaterina Strait to the Pacific Ocean was observed from February to mid-September, especially in the middle layer;
- Small residual currents were found near Tanfilieva Island.

## References

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