Seasonal and interannual changes of atmospheric pressure, air and water temperatures in the area of the Kuril Ridge

George V. SHEVCHENKO[1] **and Akie Kato**[2]

[1] Institute of Marine Geology and Geophysics, Russian Academy of Sciences, Yuzhno-Sakhalinsk, Russia

[2] Sakhalin Regional Hydrometeorological Agency, Yuzhno-Sakhalinsk, Russia

Introduction

Poezzhalova and Shevchenko (1997a, b) found significant seasonal and interannual sea level changes in the area of the Kuril Ridge. They also detected strong sea level trends probably associated with vertical ground motions. The purpose of the present paper is to verify these findings and to investigate long-term variations of some other meteorological parameters which probably influence sea level changes. It was also interesting to estimate possible effect of the 1997 El Niño on the northwestern part of the Pacific Ocean. The series of monthly means of atmospheric pressure, air and water temperatures from 4 meteorological stations were analyzed to estimate various statistical characteristics (mean and extreme values, standard errors, etc.) for every month and for all stations. The stations were located in the area of Kuril Ridge: Shumshu (Shumshu Island), Simushir (Simushir Island), Kurilsk (Iturup Island), and Yuzhno-Kurilsk (Kunashir Island) (Fig. 1).

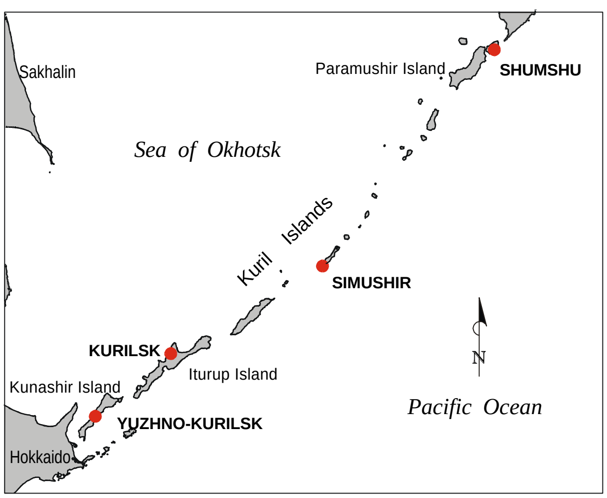

Fig. 1 Location of the meteorological stations in the area of the Kuril Islands.

Seasonal oscillations

The seasonal variations of oceanographic and meteorological parameters may be described as

$$y(t) = A_1 \cos(w\,t - j_1) + A_2 \cos(2w\,t - j_2) + e(t),$$

where $w = 2\pi/12$ is the annual frequency, t is the time (in months), A_1 and A_2 are the amplitudes of annual (Sa) and semiannual (Ssa) harmonics, j_1 and j_2 are their phases ($j_1 = 0$ corresponds to January 15), e are the residual background oscillations. We used the least square method to calculate the amplitudes and phases of these harmonics. The results of this analysis are presented in Table 1.

The amplitudes of the annual oscillations of the atmospheric pressure are rather small in the area of the South Kuril Islands but quite significant in the area of the North Kuril Islands. These results are in good agreement with the results of sea level analysis made by Poezzhalova and Shevchenko (1997a, b): The sea level amplitudes of the Sa harmonic for the former region were considerably smaller than for the latter (5 and 10 cm, respectively).

Seasonal sea level and atmospheric pressure oscillations are approximately in antiphase, maximum sea level heights correspond to minimum atmospheric pressure, and vice versa. Normally, these maximum sea levels and minimum pressure are observed in December or January and are associated with influence of the Aleutian Low. However, these seasonal variations of sea level cannot be described by the simple “inverted barometer law”. The Sa sea level amplitudes are approximately twice as large as those of the atmospheric pressure. We may assume that there are some additional oceanic and atmospheric factors influencing seasonal sea level variations.

The Sa (annual) harmonic strongly dominates in the variations of air and sea surface temperatures (95–98% of the total variance). Maximum amplitudes of this harmonic, both for air (AT) and sea surface (SST) temperatures, occur near Kunashir Island (southern part of the Kuril Ridge) and minimum amplitudes are observed in the vicinity of Simushir Island (central part of the Kuril Ridge). In general, the seasonal changes of SST are relatively small, apparently due to the suppressing influence of the Pacific Ocean water masses. The annual changes of SST and sea level are in antiphase. Probably, rather strong seasonal sea level oscillations in the area of the Kuril Ridge are determined by the changes in ocean circulation in the Northwest Pacific induced by the large-scale atmospheric fluctuations (such effect is well known for the Northeast Pacific (cf. Emery and Hamilton, (1985))).

Table 1 Parameters (amplitude and phase) of annual and semiannual harmonics and their contribution to the total variance. The multiyear mean values are presented in brackets.

I. Atmospheric pressure

Period (month)	Amplitude (mBar)	Phase (deg)	Relative contribution (%)
Yuzhno-Kurilsk (1006.8 mBar)			
12 6	0.9 1.8	274.1 177.1	17.0 73.1
Kurilsk (1007.2 mBar)			
12 6	1.0 2.0	231.7 175.6	19.9 71.1
Simushir (1007.2 mBar)			
12 6	3.1 2.1	201.6 179.9	65.9 31.0
Shumshu (1004.8 mBar)			
12 6	4.8 2.0	185.1 178.3	83.3 14.9

II. Air temperature

Period (month)	Amplitude (°C)	Phase (deg)	Relative contribution (%)
Yuzhno-Kurilsk (4.8°C)			
12 6	10.2 1.4	208.2 144.0	98.0 1.6
Kurilsk (4.5°C)			
12 6	10.3 0.5	204.4 149.6	99.1 0.7
Simushir (2.8°C)			
12 6	7.4 1.0	207.8 148.1	97.8 1.7
Shumshu (1.7°C)			
12 6	8.1 0.8	205.9 92.6	98.8 1.0

III. Sea surface temperature (SST)

Period (month)	Amplitude (°C)	Phase (deg)	Relative contribution (%)
Yuzhno-Kurilsk (6.7°C)			
12	8.7	223.0	98.1
6	1.1	125.6	1.8
Kurilsk (5.6°C)			
12	7.0	226.9	97.5
6	1.1	117.2	2.2
Simushir (2.3°C)			
12	2.0	225.7	99.1
6	0.2	171.6	0.6
Shumshu (3.4°C)			
12	5.7	210.9	98.3
6	0.7	81.5	1.6

Interannual changes

The mean annual values of meteorological parameters were used to estimate respective multiyear averaged values and linear trends. The coefficients of the linear trends were calculated by the least square method. These coefficients for the atmospheric pressure are –0.030 and 0.022 mbar/yr at stations Yuzhno-Kurilsk and Kurilsk, and negligibly small at Shumshu and Simushir (Fig. 2). This means that the interannual changes of the atmospheric pressure cannot induce sea level drift with coefficients of about 0.4–0.6 cm/yr observed in the area of the Kuril Islands (Yakushko et al., 1982; Poezzhalova and Shevchenko, 1997b).

The air temperature increased slowly with time (except Shumshu), the regressional coefficients ranged from 0.0055°C/yr (Yuzhno-Kurilsk) to 0.019°C/yr (Kurilsk). The multiyear mean values were from 1.8°C (Shumshu) to 4.8°C (Yuzhno-Kurilsk) (Fig. 3.).

The sea surface temperature had the opposite tendency, the linear trend coefficients ranged from –0.001°C/yr (Simushir) to –0.0078°C/yr (Yuzhno-Kurilsk); the mean values at these stations were 2.3 and 6.7°C, respectively. The coldest month weather was observed in 1967, the warmest in 1990–1991. The direct effects of the 1982 or 1997 El Niño are not evident in the area of the Kuril Islands.

We calculated also the coefficients of the linear trends for different seasons using seasonal (3-month) averaged values of air temperature (Table 2). In this way we got more interesting results. Thus, the air temperature for all stations (also, except Shumshu) relatively fast increased for winter seasons with the coefficients of about 0.02–0.034°C/yr and somewhat weaker for fall seasons (0.015–0.02°C/yr). Probably, this effect is the result of the global climate warming. In contrast, sea surface temperature for some stations noticeably decreased from year to year: at Yuzhno-Kurilsk for summer seasons (for about 1.5°C during the period of observations), and at Kurilsk for fall seasons (Fig. 4). Unfortunately, we could not calculate SST linear trends at Simushir and Shumshu because the corresponding data had too many gaps.

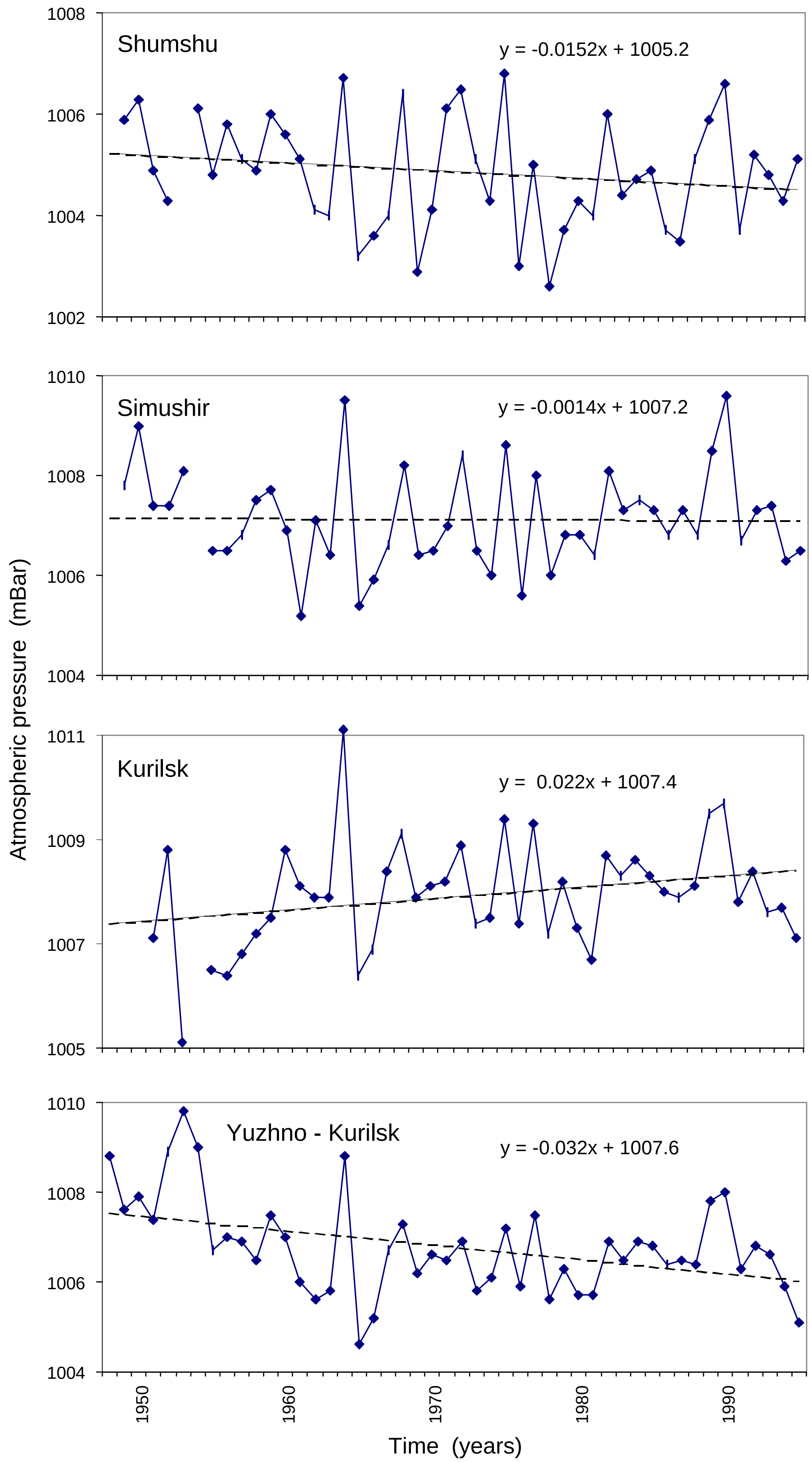

Fig. 2 Mean annual values of atmospheric pressure (solid lines) and linear trends (dashed lines) calculated by the least square method for various stations of the Kuril Islands.

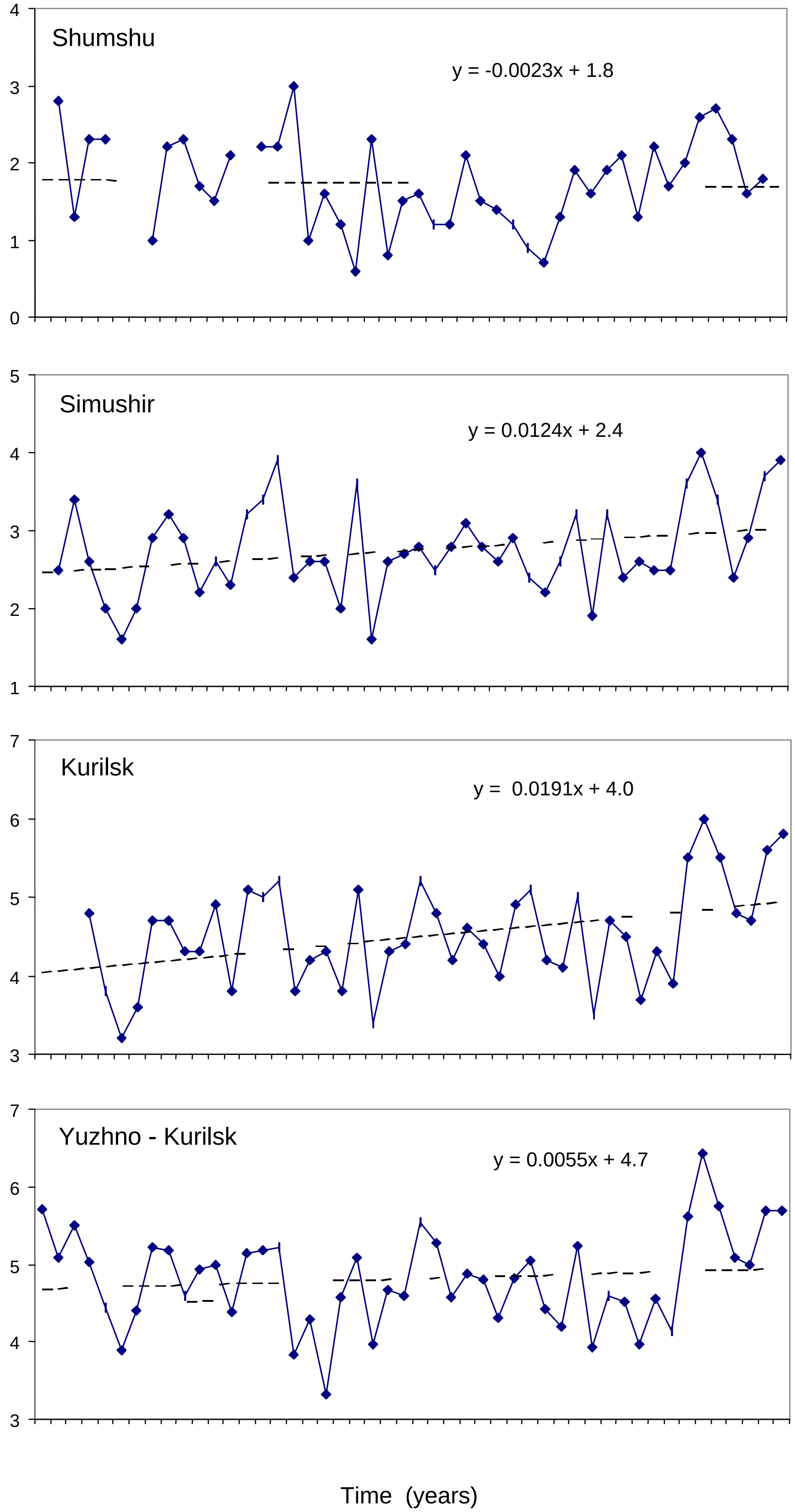

Fig. 3 Mean annual values of air temperature (solid line) and linear trend (dashed line) for various stations.

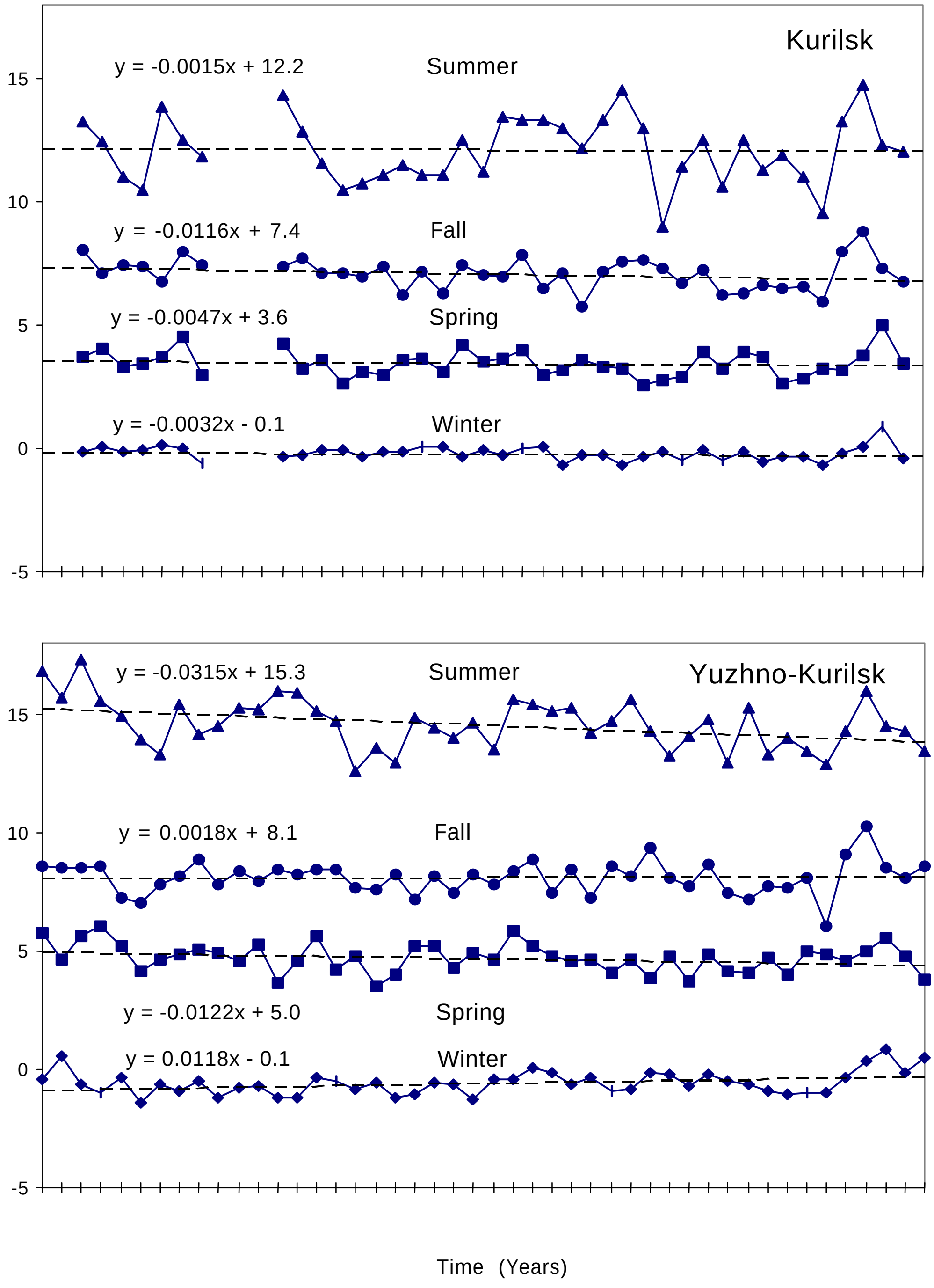

Fig. 4 Seasonally (3-month) averaged values of sea surface temperature and parameters of linear trend for different seasons at Kurilsk and Yuzhno-Kurilsk.

Table 2 The coefficients of linear trend (°C/yr) based on 3-month averaged values of air temperature for different seasons at various Kuril stations.

Station	Winter	Spring	Summer	Fall
Shumshu	0.0029	0.0068	–0.0075	0.0001
Simushir	0.0256	0.0089	0.0021	0.0157
Kurilsk	0.0338	0.0088	0.0124	0.0173
Y-Kurilsk	0.0196	–0.0035	–0.0111	0.0203

Acknowledgments

We wish to thank Dr. Alexander Rabinovich of the Shirshov Institute of Oceanology, Moscow for his constructive criticism and valuable comments, and to Willie Rapatz for help with English.

References

Emery, W.J. and Hamilton, K. 1985**.** Atmospheric forcing of interannual variability in the Northeast Pacific Ocean: Connections with El Niño, *J. Geophys. Res., 90*(C1), 857–868.

Poezzhalova, O.S. and Shevchenko, G.V. 1997a. Seasonal oscillations of sea level in the Sea of Okhotsk, *Twelfth Intl. Symp. on Okhotsk Sea and Sea Ice*, *Abstracts*, Mombetsu, Japan.

Poezzhalova, O.S. and Shevchenko, G.V. 1997b. The Okhotsk Sea mean level variations. pp. 131–144. In *Tsunami and Accompanying Phenomena*, Institute of Marine Geology and Geophysics, Yuzhno-Sakhalinsk. (in Russian)

Yakushko, G.G., Nikonov, A.A. and Yurkevich, N.E. 1982. Modern vertical motions of the Kuril Islands. *Trans. (Doklady) USSR Acad. Sci.*, *265*(2), 444–449. (in Russian)