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The Tartar (Mamiya) Strait Currents
타타르(間宮) 海峽의 海流

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Abstract □ The Tartar Strait currents of different scales are analysed using results of observations and modeling. The paper focuses on tidal phenomena and general circulation features. It is shown that the areas of maximal tidal currents are located in the regions of stable boundary streams. The stability of the streams under different meteorological conditions and energy concentration in the small areas may be explained by non-linear effects of tide over rough bottom topography.

要 旨 : 관측치와 모형 계산결과를 이용하여 Tartar 해협에서의 해류를 흐름 규모별로 분석하였으며, 조석현상과 일반적인 순환특성에 주안점을 두었다. 최대조류의 발생지점은 안정된 경계 흐름지역내에 위치함을 알 수 있었다. 다양한 기상조건 하에서의 흐름의 안정성과 소역에서의 에너지 집중은 바닥이 거친 지역에서 발생하는 조류의 비선형 효과로서 설명될 수 있다.

1. INTRODUCTION

Different kinds of waves, cyclonic and anticyclonic eddies, downwelling and upwelling phenomena, strong tidal, wind-driven and gradient currents are important features of the Tartar Strait hydrodynamics. Semidiurnal standing, principally, and progressiveless tidal waves dominate in daily variability in the most strait area. The standing wave has the length of about 150 miles. Its front, solid line S-L in Fig. 1, is oriented from Syurkum Cape 50°N, point S in Fig. 1a, in the western coast to Lomanon Cape 48°45'N, point L in Fig. 1a, in the eastern one (Yurasov, Yarichin, 1991). General modes M_2 and S_2 of the progressive tidal wave propagate counterclockwise relatively to the point which lies to the west from strait axis on latitude about 48°N (Ogura, 1993; Atlas, 1967; Yurasov and Yarichin, 1991; Atlas, 1991). At that incomplete stanting coastal rejection of the tidal waves and shelf trapped tidal waves formation occur near the Syurcum Cape (Necrasov, 1975; Yurasov and Yarichin, 1991). It is one of the specific points in the Tartar Strait. The trapped tidal waves propagate southward off Syurkum Cape over the gently sloping external part of the western shelf.

The diurnal tidal waves propagating through the Laperus (Soya) Strait have an effect on tidal currents mainly in the southern part of the Tartar Strait and also in the small region to the north north west from the Syurkum Cape. The maximal effect of the diurnal tide occurs in the area adjacent to the south-western Sakhalin coast and the Laperus (Soya) Strait.

2. TIDAL CURRENTS

Despite of the distributions of tidal velocity and sea level being complicated, the largest axis of tidal ellipse is approximately oriented along the axis of the strait trench and tidal amplitude rises to the north with the depth decreasing. In the south eastern part of the strait the direction of maximal tidal current velocity is NNE, in the northern and wes-

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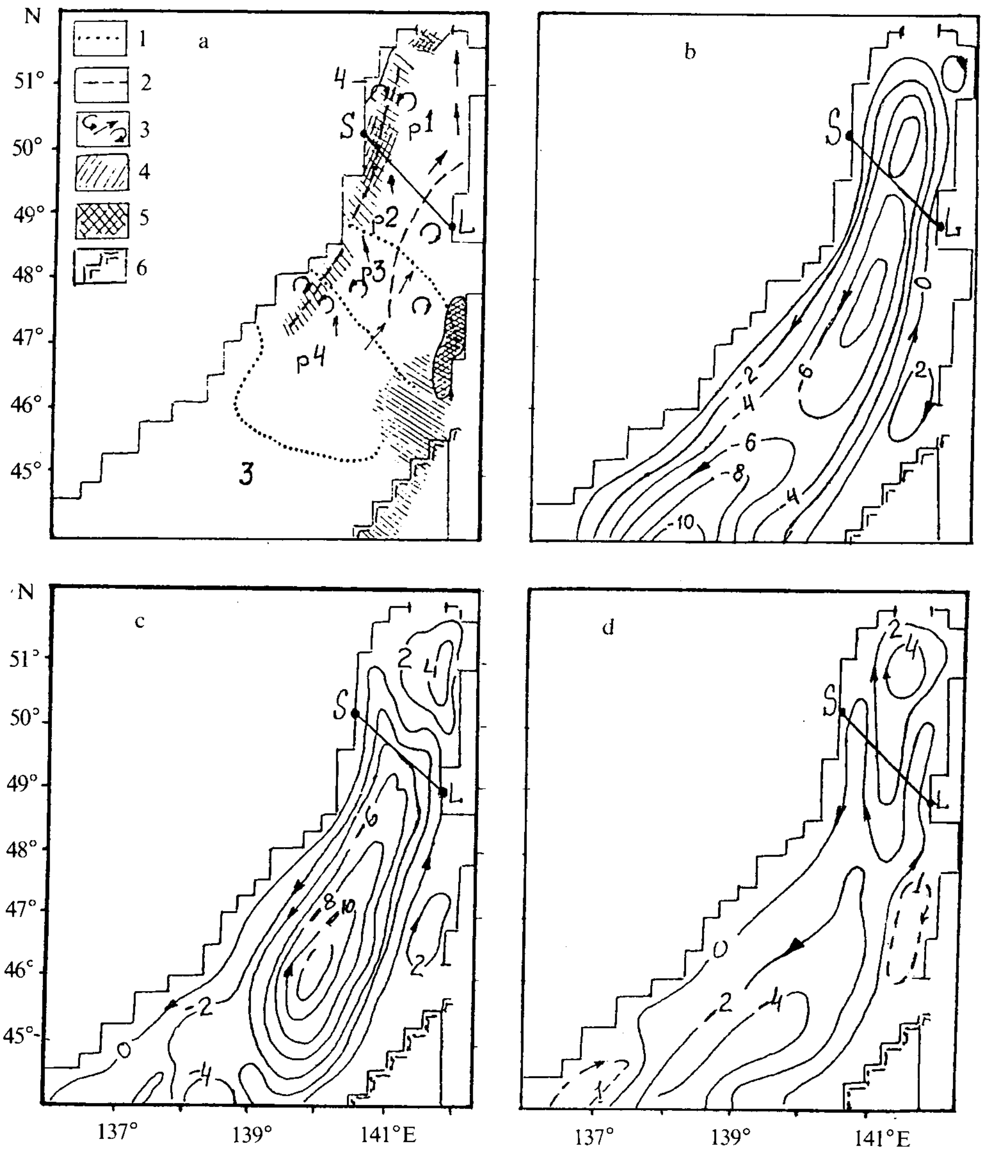

Fig. 1. Features of tides and tidal/gradient currents: line shown on pattern 1 of the legend separates areas of semidiurnal (p1), irregular semidiurnal (p2), irregular diurnal (p3) and diurnal tides (p4); line shown on pattern 2 indicates the reversal tidal current zone locations; pattern 3 shows maximum tidal velocity direction as well as counterclockwise/clockwise tidal current rotation; pattern 4 and 5 correspond to steady gradient current areas, with pattern 5 showing maximum velocity areas, pattern 6 shows the Polar front positions; b, c, d-Steady-state solutions for stream functions, $\Psi \cdot 10^{-6}$ m^3/sec.

tern part it is NNW, marked by arrows in Fig. 1a. The rotation of the current velocity vector during tidal cycle obtained by Yarichin is counterclockwise in the most of the strait area while clockwise in the south-eastern and north-western regions adjacent to the coasts (Fig [illegible] thin zone of reversal tidal currents lied between the regions of the opposite velocity vector rotation is outlined along the western shelf slope near 50 m isobath, another one is outlined from the Sakhalin coast at latitude about 49°N to the south-south-west (it is shown with dashed lines in Fig. 1a).

3. LONG-TERM CURRENTS AND GENERAL CIRCULATION

Fig. 1a is reproduced from Yurasov and Yarichin (1991) to illustrate the main features of tidal currents which are in agreement with general circulation patterns. The observations, data analysis, diagnostic methods and modeling show the cyclonic circulation to dominate both in the northern part of the Japan Basin and in the most part of the Tartar Strait area (Uda, 1931, 1934; Leonov, 1948; Pavlova, 1958; Sizova, 1962; Atlas, 1967; Kozlov, 1971; Pokudov and Tunegolovets, 1975; Yarichin, 1980, 1982; Budaeva *et al.*, 1981; Vasiliev and Makashin, 1991; Ponomarev *et al.*, 1991; Yurasov and Yarichin, 1991) Nevertheless, the Tartar Strait circulation is considered in detail only in few works: Atlas, 1967; Yarichin, 1980, 1982; Budaeva. *et al.*, 1981; Yurasov and Yarichin, 1991).

According to long-term current observations the main outflow associated with southward cold water transport occurs in the western part of the strait. Inflow associated with northward surface warm water transport is frequently observed near the strait axis in the southern zone and along the Sakhalin coast in the entral latitude zone (Atlas, 1967; Yurasov and Yarichin, 1991). The bottom currents are directed to the south-west in the northern zone of the strait and to the west-west-south from the Sakhalin coast to the continental shelf slope in the central latitude zone (Yursov and Yarichin, 1991). These are the major features of vertical circulation between centers of convergence and divergence zones in the upper layer associated with downwelling and upwelling areas accordingly.

Fig. 1a shows that only two currents in the Tartar Strait are stable under different synoptic situations. One of them, Shrank boundary current, streams southward along the western shelf slope from De-Castry Bay (51° 5N) to the latitude 47°N, being a source of the Primorskoe (Liman) cold current in the Northern Japan Sea. It is observed in all seasons. The maximum current velocity is observed on the sea surface in the northern and central latitude zones of the stream. More complicated velocity profile occurs in the southern zone of the Shrank current. It is characterized by three subsurface local maxima which are located at the depth of 10, 50 and 200 m over the steep shelf slope (Yurasov and Yarichin, 1991). Note that the southern zone of the stream is situated in the area of the mixed tidal currents.

The other stable current is the Western Sakhalin boundary stream. Being the eastern part of the anticyclonic gyre it flows southward along the southern Sakhalin shelf slope. The gyre is formed over the bottom raising and around Moneron island. Vertical distribution of the current velocity is almost homogeneous, with a small maximum at the depth of 150 m over the isobath of 200 m (Yurasov and Yarichin, 1991). The Sakhalin current manifests seasonal changes to more extent than it is specific for the Shrank stream. It is intensified during warm season, as a rule. Other currents with the inflow streams involved are those of the path variable.

It is interesting that the areas of tidal currents maxima are usually located in the regions of the stable boundary streams. According to Yurasov and Yarichin (1991) and Supranovich (1989) the maximal tidal current velocity, over 1.5~2 knots, is observed in the areas mentioned which are adjacent to the Syurcum Cape and Southern Sakhalin. The tidal current maxima occur also in the Neveiskoy and Laperus (Soya) Straits where the strong gradient streams are observed.

4. NUMERICAL EXPERIMENTS

The stream function distributions (Fig. 1b, c, d) calculated by use of barotropic circulation model with regard to detailed bottom topography (Ponomarev *et al.*, 1991) show total inflow, outflow currents and cyclonic circulation to be generally considered. The steady-state solutions for the Northern Japan Sea are obtained by Ponomarev and Voitko at the given synoptic situations typical of winter season, when the cyclonic circulation is intensified. The Polar front position is fixed as a liquid boundary of the Northern Japan basin. The no-slip boundary condition is specified and the nonlinear [illegible] tom friction is use [illegible] t [illegible]

Strait due to ice destruction by tidal and other waves. Therefore, the wind stress curl causes the ice drift and water circulation. Besides, the influence of wind on the ice free water area results in the ice drift and currents in the adjacent ice covered region as well.

The three solutions shown in the Fig.1 (b, c, d) demonstrate both the effect of strong atmospheric cyclone over the Tartar Strait area (b) and effects of strong (c) or weak (d) monsoon winds over the Northern Japan Sea. In case (b) we obtained the alternating local maxima of the cyclonic vorticity in the northern part of Japan basin and small anticyclonic eddies in the north eastern and southeastern parts of the strait. In case (c) the strong cyclonic gyre occurs in the most part of the region and significant anticyclonic eddies appear in the northeastern and south-eastern parts of the strait. In case (d) the similar cyclonic circulation takes place in the northern part of the Japan Basin while alternating vortices of the opposite signs are shown in the Tartar Strait.

When considered in detail the strong atmospheric cyclone over the Tartar Strait in case (b) results in large scale disturbances oriented along the trench axis. In case (d) the disturbances of smaller scale oriented across the strait in zonal direction are displayed under the condition of weak monsoon. In this case inflow and ourflow currents alternate across the strait. It should be noted that in all cases the given atmospneric pressure fields are sufficiently smooth and wind stress curl calculated in only cyclonic over the northern part of the Japan Basin. The mentioned features of the vorticity distribution obtained from our model are mainly conditioned by the bottom topography and coastilne effects. Despite of different models, boundary and external conditions, general patterns of the calculated steady-state solutions specified by meteorological situation are similar to those obtained by Budaeva (1981), where the seasonal atmospheric pressure fields are used.

Non stationary solutions include topographic Rossby [illegible] Kelvin waves generated by synoptic forcing [illegible] topographic Rossby waves [illegible] [illegible] rthward along the eastern slope. Numerical experiments with the low dissipative barotropic model show that the synoptic scale vorticity produced in the Tartar Strait and adjacent area moves counterclockwise around the Japan Basin (Ponomarev *et al.* 1991; Smirnov and Ponomarev, 1991). We suppose that the topographic Rossby and Kelvin waves may cause inter-daily or more long variations of currents in the Tartar Strait. The substantial inter-daily current velocity variations within the total water layer have been observed along 49°N latitude in July, 1978 under the stable atmospheric condition (Yurasov and Yarichin, 1991).

5. CONCLUDING REMARKS

Numerical experiments show that the currents in the most part of the Tartar Strait area are more variable than the Shrank and Sakhalin boundary currents. The stability of the streams observed under different meteorological conditions and energy concentration in small areas may be explained by nonlinear tidal effect since the tidal currents have the specifics in those areas (Fig. 1a). The sea level free oscilation periods may be close to the tidal/shelf wave periods, that is the condition for resonance phenomena (Proshutinsky and Polyakov, 1992). Therefore, the eigen oscillation modes of the Japan basin and the Tartar Strait should be studied with detailed bottom topography.

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