Introduction to special section: Oceanography of the Okhotsk Sea

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[1] The Okhotsk Sea is a 1.5×10^6 km^2 marginal sea adjacent to the Pacific Ocean in the Northern Hemisphere. Its defining boundaries are Hokkaido, Japan, Sakhalin Island, the Russian mainland, the Kamchatka Peninsula, and the Kuril Islands. In the Northern Hemisphere the Okhotsk is the southernmost sea with a sizable seasonal ice cover, which experiences large interannual variations in extent. Because of the coupling of this ice cover with the Okhotsk oceanography, the ice can be considered as a sensitive indicator of climate change. Despite the recent realization of the importance of the Okhotsk Sea, because of severe weather conditions and the presence of sea ice, in situ observations have been limited, especially in winter.

[2] Part of the importance of the Okhotsk is that the North Pacific Intermediate Water (NPIW) is believed to be ventilated in and around it, both from hydrographic data [*Talley*, 1991] and chlorofluorocarbons (CFCs) observations [*Warner et al.*, 1996]. Specifically, the Okhotsk is regarded as the only site where the atmosphere can directly exchange the heat and material (including CO_2) with the NPIW. Ventilation of this water is an important component of the global overturning circulation. There are two ventilation sites for the intermediate water in the Okhotsk Sea. The first is the northwest shelf, which has large active coastal polynyas that are regarded as the primary area of dense shelf water (DSW) formation [*Kitani*, 1973; *Wong et al.*, 1998; *Martin et al.*, 1998; *Gladyshev et al.*, 2000]. The second is the area in and around the straits in the Kuril Islands, where strong tidal currents generate diapycnal mixing [*Talley*, 1991].

[3] As part of a joint Japanese-Russian-U.S. study of the Okhotsk, four international joint cruises were carried out in the Okhotsk during 1998–2001 on the R/V *Professor Khromov*. These were supported by U.S. National Science Foundation and the Core Research for Evolutional Science and Technology of Japan Science and Technology Corporation. The participants consisted of representatives from the Russian Far Eastern Regional Hydrometeorological Research Institute, the U.S. Scripps Institution of Oceanography and the University of Washington, and the Japanese Hokkaido University and Japan Agency for Marine-Earth Science and Technology (JAMSTEC, previously Japan Marine Science and Technology Center). The main focus of the study was the ventilation of the NPIW by the Okhotsk Sea. This divides into three parts: the northwest Okhotsk shelf, where brine rejection generates the DSW; the East Sakhalin Current, which is the western Okhotsk boundary current and DSW pathway to the southern Okhotsk [*Mizuta et al.*, 2003]; and the Bussol Strait, which is the main exchange between the Okhotsk and the Pacific and a site of diapycnal mixing.

[4] As the accompanying papers show, the project was an interdisciplinary one, consisting of studies of physical oceanography, sea ice, biogeochemistry, paleo-oceanography, and atmospheric sciences. The field methods consisted of hydrographical and chemical observations, moorings, bottom lander observations, Lagrangian float measurements, lowered acoustic Doppler current profiler (ADCP) measurements, and sediment corings. At the Ocean Sciences Meeting at Honolulu in 2002 a meeting of the Okhotsk participants showed that there were sufficient potential papers and new results to justify a *Journal of Geophysical* special section. In this special section, eight papers of the thirteen papers are based on the field results; others are based on numerical and satellite studies.

[5] As the papers derived from these field experiments describe, direct measurements on the northwest shelf of brine rejection and formation of DSW were carried out for the first time using bottom landers [*Shcherbina et al.*, 2003, 2004a]. These landers directly observed the ventilation of the intermediate water and also suggest that baroclinic instabilities occur on the density front at the

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polynya edge. The transport of the DSW south and its modification were observed by moorings in the East Sakhalin Current [*Fukamachi et al.*, 2004], which also observed offshore eddy transport of the cold water, suggesting baroclinic instabilities.

[6] Within the DSW outflow a large amount of dissolved and particulate organic carbon is transported from the shelf into the intermediate layer, characterizing the biogeochemical cycle in the Okhotsk Sea [*Nakatsuka et al.*, 2004a]. The outflow of cold and turbid DSW intensified the lithogenic particle fluxes into the deep basin, where these fluxes regulate the Okhotsk sedimentation process [*Nakatsuka et al.*, 2004b]. These are important to the understanding of material cycling in the Okhotsk Sea and past oceanographic conditions from the sediment cores. Relatively high-density observations of CFCs [*Yamamoto-Kawai et al.*, 2004] and methane [*Yoshida et al.*, 2004] were carried out over the Okhotsk Sea. The behavior of the DSW can also be traced by CFCs and methane distributions, suggesting that DSW is transported into the Kuril Basin through the cyclonic gyre [*Ohshima et al.*, 2004].

[7] The NPIW is also ventilated by the diapycnal mixing associated with the strong tidal currents in and around the Kuril Straits, where the water exchange also occurs with the Pacific. Because of the strong tides, conventional geostrophic calculations cannot be used to estimate the current structure [*Riser*, 1996]. Under the project, direct current measurements were performed at the Bussol Strait, the largest and deepest strait, with moorings [*Riser*, 2001] and with repeated lowered ADCP measurements [*Katsumata et al.*, 2004]. Both observations revealed extremely strong diurnal tidal currents in the strait. The measurements by *Katsumata et al.* [2004] provide the first direct estimation of the mean inflow and outflow in the Kuril Straits. In a related topic, *Nakamura and Awaji* [2004] use a three-dimensional nonhydrostatic numerical model to examine the tide-induced diapycnal mixing in the Kuril Straits and its role in water transformation and transport. Their results of tidal residual flow structure are consistent with the *Katsumata et al.* [2004] direct observations. CFCs observations [*Yamamoto-Kawai et al.*, 2004] also suggest the importance of the ventilating process in and around Bussol Strait.

[8] The formation of the DSW is closely related to sea ice production. For the northwest shelf, *Shcherbina et al.* [2004b] estimate the formation rate of DSW from a combination of the direct measurements and satellite observations. *Kimura and Wakatsuchi* [2004] also examine the sea ice production in the coastal polynyas through the analyses of ice drift data derived from the satellite images. The Kashevarov Bank polynya is the prominent open ocean polynya in this sea. *Martin et al.* [2004] use a combination of satellite observations and a coupled ice-ocean numerical model to show that the polynya area depends on the fortnightly and diurnal tides. For the entire Okhotsk, *Watanabe et al.* [2004] use a coupled ice-ocean numerical model to examine the role of sea ice in the heat and salt balance.

[9] At longer timescales, *Minobe and Nakamura* [2004] examine for the first time the interannual-to-decadal variability of the upper layer temperature of the Okhotsk Sea. They show that the anomalies of the Okhotsk exhibit a prominent quasi-decadal variability that is closely related to the wintertime sea surface temperature anomalies over the North Pacific subarctic front and to the changes in strength of the Asian winter monsoon.

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