Wind jets through the straits near the Japanese coast: Case of the Tsushima Strait

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Abstract
We have investigated the northeasterly/southwesterly wind jets blowing through the Tsushima Strait from two case studies. Using high-resolution winds derived from SAR, we have presented the detailed structure of wind in the strait. The general flow is generally close to geostrophic wind in the strait, inferring from the seal level pressure fields. Wind jets are induced by two channels and by the terrestrial gap at the center of the Tsushima. The wind jets are clearly separated from the coastlines.

Keywords: Ocean surface wind, the Tsushima Strait, and Gap wind.

1. INTRODUCTION

The Tsushima Strait is a generic term indicating the sea area between the Korean Peninsula and the Japanese archipelago, with the Japanese islands of Honshu to the east, Kyushu to the south and the Goto Islands to the southeast (Figure 1). In the center of the strait, a slender island, the Tsushima Island is located along the strait. This island principally consists of two mountainous islands. The Tsushima Island divide the strait into eastern and western channels; the width and maximum depth are 140 km and 110 m in the eastern channel, and 40 km and 200 m in the western channel, respectively. Both channels connect the East China Sea and the Japan Sea.

From these geographical conditions, the Tsushima Strait is one of the most important sea areas where the continuous and intense monitoring researches are required from oceanographic and meteorological point of views as well as marine security point of view. Extensive previous studies investigate the Tsushima Strait hydrography by considering wind effects on it. However, higher-resolution and wider-area wind observations are required for better understanding of the oceanographic and meteorological environment because of the complex coastal topography of the region. This is because few studies pay attention to the formation of wind jets in the strait, wind jet structures, and the role of the Tsushima Island on the formation of the wind jets. These are open issues at the present stage.

The purpose of this paper is to investigate the wind blowing through the Tsushima Strait by using high-resolution satellite wind measurements. We look into the evolution and distribution of the wind jets during representative time periods and illustrate the contribution of the Tsushima Island to the wind jet formation. Specific questions we would like to address are: First question is typical structures of the wind jets found in the Tsushima Strait. When the wind blows through the Tsushima Strait in southwest-northeast direction, strong winds are formed. Second, what are the roles of the Tsushima Island on the formation of the wind jets?

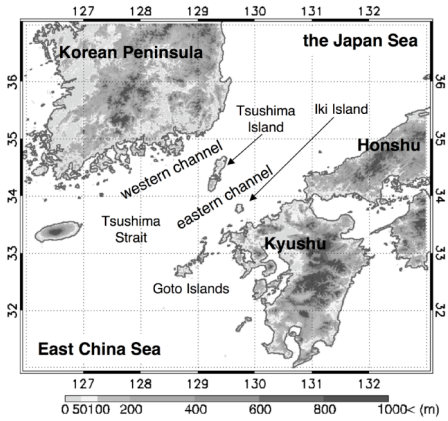

Figure 1 Map of the study area. The color scale indicates the terrain elevation. Geographical locations referred to in this paper are also shown.

2. DATA

We analyze wind fields derived from two SARs. They are the European Space Agency (ESA) Environmental Satellite (ENVISAT) Advanced Synthetic Aperture Radar (ASAR) and the Canadian RADARSAT-1. Both SARs operate at C-band (5.3 GHz). While RADARSAT operates in horizontal (HH) polarization, ENVISAT/ASAR operates in HH or vertical (VV) polarization. In this study, we use wide-swath or ScanSAR mode products. That is, the ENVISAT/ASAR Wide-swath mode images covers an area of approximately 500×500 km, with a pixel size of 75 m. The RADARSAT ScanSAR Narrow mode image covers an area of approximately 300×300 km, with a pixel size of 25 m.

Wind speed maps are derived from the ENVISAT/ASAR and RADARSAT images by applying SAR wind retrieval by using CMOD IFR2 scatterometer model function [1] and wind direction from objective

analysis data (GPV: Grid Point Data). In cases of HH polarization images, a polarization ratio conversion factor (e.g. [2]) is applied. While the C-band geophysical model function is originally developed for VV polarized radar cross section, the polarization ratio conversion factor enables to convert it to HH polarized radar cross section. It has been show by numerous studies that wind speeds can be retrieved from ENVISAT/ASAR (e.g. [3]) and RADARSAT-1 (e.g. [4]) with a root mean square error of less than 2 m/s and with negligible bias.

3. Case Study: Northeasterly wind

Figure 2 (a) shows sea level pressure and surface wind fields of NCEP reanalyses at 00:00 UTC 18 Dec. 2002. After a cyclone has passed the south of Japan, a strong anticyclone develops over the Eurasia continent and starts to generate a surge of northerly winds. This is a typical situation associated with East Asian winter monsoon. Surface winds over the Japan Sea are northeasterly. It is suggested that the wind blow toward the Tsushima Strait with converging. The isobars do not cross the strait. The isobars run west-southwest and east-northeast and align with the strait at an angle. This suggests that geostrophic balance is satisfied on some level.

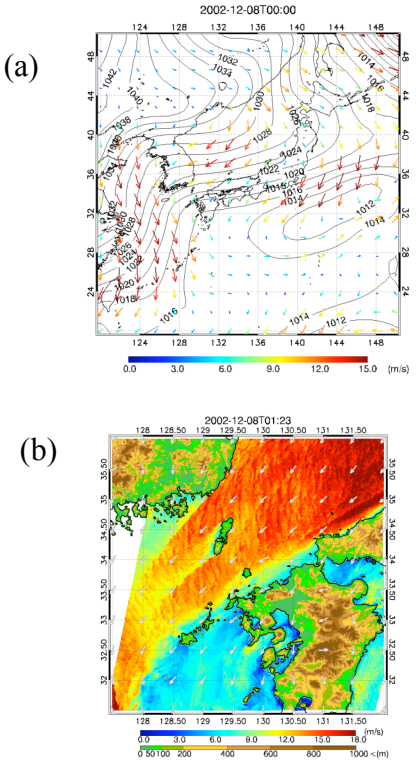

Figure 2 (a) Sea level pressure and 10-m winds from the NCEP reanalyses at 00:00 UTC 8 December 2002. (b) High-resolution wind field derived from ENVISAT/ASR at 01:23 UTC 8 December 2002. Arrows indicate wind directions derived from GPV data.

Let us now look into the wind fields in detail using SAR-derived wind field. Figure 2 (b) shows the wind field derived from an ENVISAT/ASAR image. The image is acquired at 0123 UTC 8 December 2002. The arrows indicate wind direction from the GPV data. Wind speeds are high (~18 m/s) at the Japan Sea side because of wind convergence. The open coastlines of the Korean Peninsula and the Japanese archipelago may help the convergence. The winds are detached at the promontories of the Korean Peninsula and the Japanese archipelago and weak wind regions exist along the both sides of the strait. It is noteworthy that we can not obtain any signs of the wind jet from land observations. It is apparent that two wind jets are formed at the western and eastern channels. Along the streamlines, wind speed maximum (~15 m/s) are observed just after passing through the Tsushima. In contrast, a weak wind region extends southwestward in the lee of the Tsushima. The wind speed differences (~3 m/s) keeps over the 200-km downwind.

4. Case Studies: Southwesterly wind

Figure 3 (a) shows sea level pressure and surface wind fields of NCEP reanalyses at 18:00 UTC 3 June 2001. A high-pressure system located in the East China Sea. Southwesterly and westerly winds are observed on the northwest of the high-pressure systems, and it should be noted that the winds are generated just near the Tsushima Strait. Thus, the winds blow into the strait.

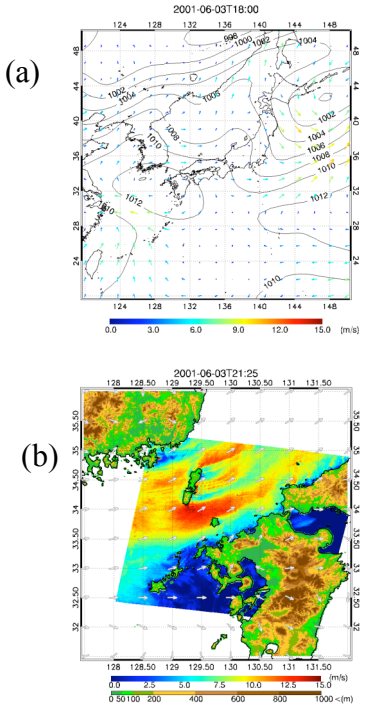

Figure 3 (a) Sea level pressure and 10-m winds from the NCEP reanalyses at 18:00 UTC 3 June 2001.
(b) High-resolution wind field derived from RADARSAT at 21:25 UTC 3 June 2001. Arrows indicate wind directions derived from GPV data.

Figure 3 (b) shows the wind field derived from a RADARSAT image. The image is acquired at 2125 UTC 3 June 2001. The arrows indicate the GPV wind direction.

Westerly winds blow into the Tsushima Strait. In this case, three wind jets are apparent on the eastern side of the Tsushima. The westerly winds rush through the northern and southern tips of the Tsushima and forms two jets in the western and eastern channels. It should be noted that the wind jets are completely within the channels and that they do not blow cross the coast. Wind speeds maximum are observed near the tips of the Tsushima. Another remarkable character is a strong winds extending from the terrestrial gap of the center of Tsushima. In the lee of northern and southern mountains of the Tsushima, weak wind regions with speeds less than 8 m/s are apparent. This wind field is also relatively close to the geostrophic winds. It is not so clear in the sea level field from the 2.5°-gridded NCEP reanalyses because of its low spatial resolution. However, it is confirmed from 10-km-gridded sea level field from the GPV data (not shown).

5. CONCLUSIONS

We have investigated the northeasterly/southwesterly wind jets blowing through the Tsushima Strait from two case studies. Using high-resolution winds derived from SAR, we have presented the detailed structure of wind in the strait. The general flow is generally close to geostrophic wind, inferring from the seal level pressure fields. Wind jets are induced by two channels and by the terrestrial gap at the center of the Tsushima. The wind jets are clearly separated from the coastlines. Using the model simulations, we investigate the atmospheric structures of these cases.

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