Atmospheric Forcing And Its Spatial Variability Over The Japan Sea

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LONG-TERM GOALS

The long-term goal of this study is to improve our understanding of the marine atmospheric boundary layer (MABL), its spatial structure and variability, and the resultant ocean surface forcing over the Japan/East Sea (JES).

OBJECTIVES

The main objectives are (1) to determine the structure and variability of the MABL over the JES on synoptic and seasonal time scales, (2) to estimate surface wind stress and heat flux time series during summer and winter conditions, and (3) to examine the role of the coastal mountain ranges along the western perimeter of the JES on the low-level air flow and surface forcing during winter, with special emphasis on cold-air outbreak events.

APPROACH

This study is part of the ONR Japan/East Sea Directed Research Initiative to examine frontal processes, circulation, and water property evolution in the Japan/East Sea during 1999–2000. Our approach is to (1) make ship and fixed-point meteorological measurements on selected JES cruises to investigate MABL structure and surface forcing variability during summer (1999) and winter (2000) conditions, (2) collect and analyze JMA buoy weather data, regional WMO surface and upper-air data, stationary weather satellite imagery, and ECMWF surface fields to determine the synoptic setting during our *in-situ* measurement periods, and (3) conduct a process-oriented model study to gain dynamical understanding of the wintertime orographically modified flow, and to compare these model flows to observations and to results from more complex models.

WORK COMPLETED

Meteorological data were collected on three R/V *Revelle* and two R/V *Professor Khromov* cruises during summer 1999 and winter 2000 in the JES. These measurements included (a) basic shipboard measurements of surface variables (wind, air temperature, relative humidity, air pressure, incident short- and long-wave radiation, precipitation, and sea surface temperature) on all five cruises, (b) balloon soundings (winds, air temperature, relative humidity, and air pressure) to 10 km on the two *Revelle* SeaSoar cruises, and (c) high-frequency sonic measurements of wind velocity, temperature and relative humidity on the winter *Revelle* cruise. Additional meteorological data were obtained from an automatic weather station installed in Vladivostok in late 1999, other fixed surface stations including Japanese Meteorological Agency buoy 21002, and the WMO upper air sounding stations surrounding the JES. Weather satellite imagery and SST data were also collected and archived.

The JES shipboard meteorological data have been processed and time series of the surface measurements and computed surface wind stress and heat flux components are available at ftp://ftp.whoi.edu/pub/users/mcaruso/jes. A manuscript describing the marine weather conditions and surface forcing over the JES during winter 2000 has been completed. The idealized model study of the influence of the Vladivostok “gap” in the coastal mountain range on “channeling” the eastward flow of cold surface air during cold-air outbreaks has begun, with initial results available at http://www.unc.edu/~ascotti/jes. See http://www.whoi.edu/science/PO/japan_sea for an updated project description.

RESULTS

Icing Conditions Over the JES During Cold-Air Outbreaks

Cold-air outbreaks, a distinctive feature of the winter weather over the JES, typically last a few days and occur several times a month. Our winter 1999–2000 measurements provide quantitative details about cold-air outbreaks that are essential for understanding the local meteorology and surface forcing of the JES. Cold-air outbreaks are also of operational interest to the ships that can develop significant icing such as covered the *Revelle* ship’s bell (Figure 1) during the January 24–26, 2000 cold-air event. After the icing ended, the ship’s captain ordered the crew to chip the larger pieces off forward portions of the ship.

Cloud Sheets Over the JES

A cold-air outbreak sets up a unique cloud sheet formation in the marine boundary layer. One example occurred on January 26, 2000. The stationary satellite visual image shows a nearly uniform cloud sheet covering most of the JES (Figure 2). The individually distinguishable rolls, lined with the sea-surface wind, can be followed from near Russia to Japan. These cloud sheets require nearly uniform conditions over the sea, which are (1) a sea minus air temperature difference >10°C, (2) wind speeds >5 m/s, and (3) a moist marine layer ~1-km deep that is capped by very dry air. The SST difference across the sea is large, from 0°C next to the Russian coast to 12°C at the Japanese coast. Air parcels taking one-half day to cross the sea during a cold-air outbreak warm at a rate that matches that at which it is advected over the SST gradient. Thus, the air–sea temperature difference experienced by an air parcel traversing the sea is uniform, which is an important condition for the cloud sheet formation.

Figure 1.
Ice buildup on the Revelle ship's bell after the January 24–26, 2000 cold-air outbreak.

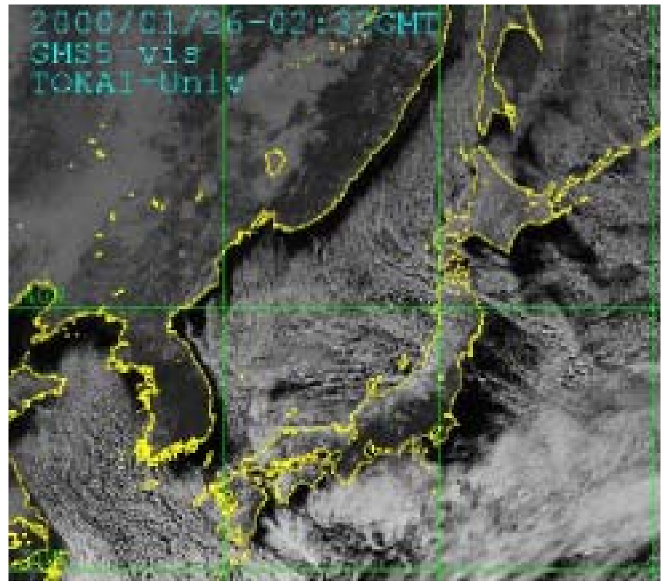

Figure 2.
Marine cloud sheet over the JES during a cold-air outbreak on January 26, 2000.

Conditions During the Winter Revelle SeaSoar Cruise

The *Revelle* spent much of the winter SeaSoar cruise in the central portion of the JES between January 17 and February 3, 2000. Four characteristic events occurred during this period. February 3 was a fairly typical cold Asian air day with routine conditions and air temperatures above freezing over the JES. In contrast was January 24–26, with a very cold Siberian air outbreak with sub-zero air extending to Japan and further. A mixed event occurred on January 19–21, which began with a weak surface low moving across the JES followed by a brief cold-air outbreak on January 21. A strong southeastward flow of very cold Asian air occurred on January 31.

The surface heat flux measured by the *Revelle* in the center of the JES reflects these events (Figure 3). February 3 had modest peaks in sensible and latent heat losses that mirror the increased winds and clear sky, so that the net surface heat loss for the last half of the day averaged about 400 Wm^{-2}. The largest sensible and latent heat losses occurred on January 20–21, with sustained winds in excess of 15 ms^{-1} and a sea–air temperature difference of 10 to 15°C. The mean net heat loss during 18 GMT January 20–06 GMT January 21 was ~715 Wm^{-2}. Large sustained sensible and latent heat losses also occurred on January 24–25 during the very cold Siberian air outbreak. While the largest air–sea temperature differences occurred during this period, winds were somewhat weaker, resulting in a mean net loss of ~600 Wm^{-2} on January 24. The strong southeastward flow of very cold Asian air on January 30–31 produced a short period of net heat loss exceeding 700 Wm^{-2} prior to sunrise on January 31.

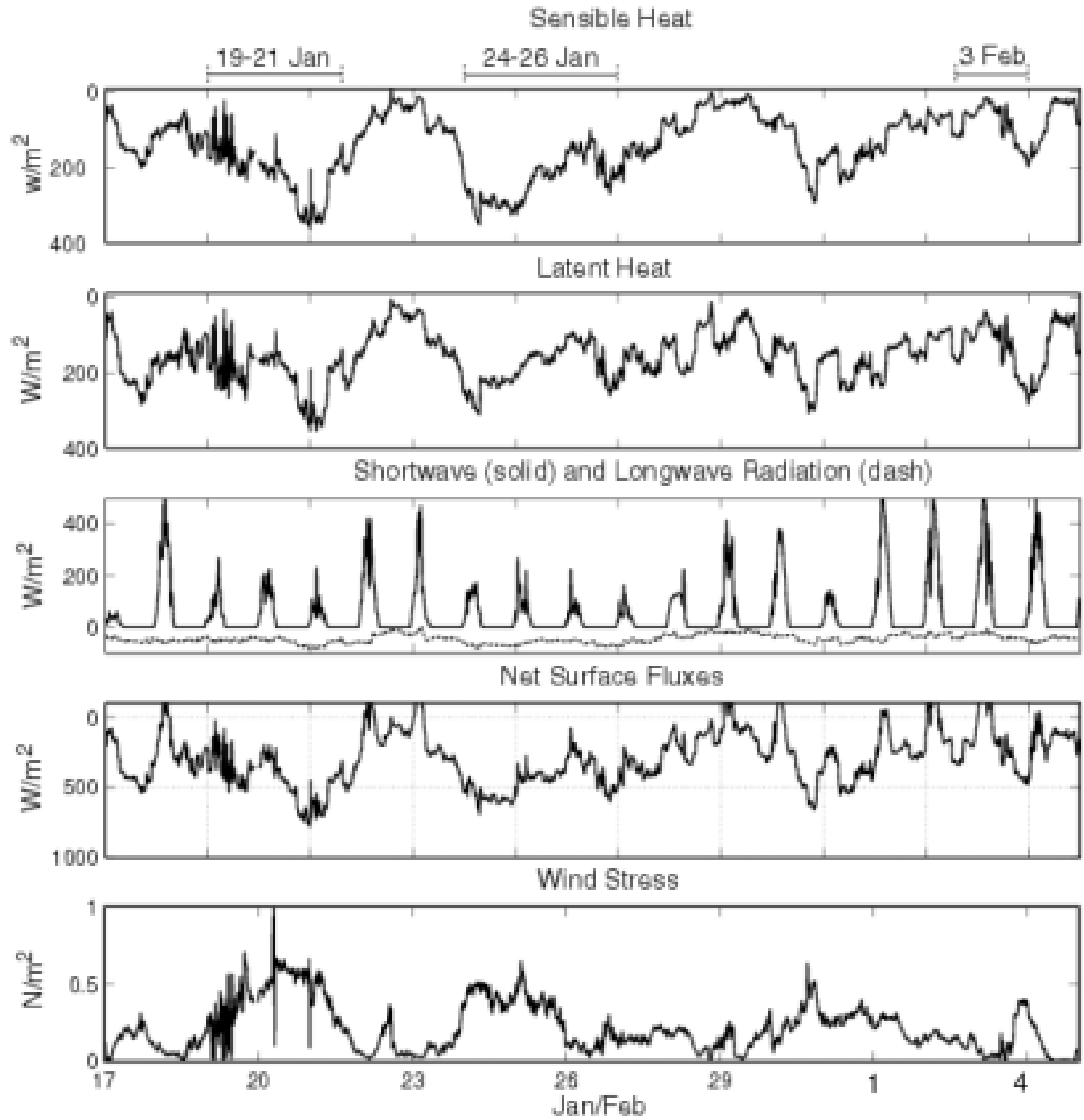

Figure 3.
Revelle wind stress and heat flux during January 17–February 4, 2001

Air Mass Movement Over the JES

There are two basic flow regimes over the JES in winter. Both move cold dry continental air over the Russian coast toward the south. The dominant regime moves cold Asian air (CAA) that originates over China/Mongolia and then over eastern Russia. The air around 1 km passes over the Russian coastal mountains, subsides to sea level and then moves to the south over the JES. The surface air temperature on the northwestern side of the coastal mountains is –15°C to –10°C, but it does not get over the coastal mountain ridge. The strong surface inversion is capped by a deep isothermal layer (measured at Vladivostok), and the weak northerly winds suggest that the surface air is blocked by the Russian coastal mountains. Less frequent are very cold Siberian air outbreaks (VCSAO). This air mass forms farther to the north in the Siberian High and then moves to the south. Both the surface and lower level air temperatures over the Russian continental interior decrease to –20°C to –30°C, greatly reducing the stability and even eliminating the surface inversion. The result is that this air, originating from 500–1000-m elevation inland, moves over the Russian coastal range and down to the ocean surface where it is much colder than that observed during CAA conditions. The combination of greater wind speeds and colder air temperatures associated with these VCSAO events cause much greater heat fluxes, surface evaporation and boundary layer mixing, which is required to generate cloud sheets extending across the JES.

IMPACT / APPLICATIONS

None.

TRANSITIONS

None.

RELATED PROJECTS

This study is part of the ONR Japan/East Sea DRI. The atmospheric measurements, compiled observational and model products, and the idealized model results are relevant to many of the other projects in the DRI. The surface forcing fields for the summer 1999 and winter 2000 *Revelle* cruises have been supplied to C. Lee (UWash) and L. Talley (SIO) for use in analysis of the SeaSoar and shipboard ADCP measurements made during those cruises. Comparisons of our estimates of wind stress and heat flux with NOGAPS and ECMWF analysis values will provide important clues about the accuracy of these model fields and their usefulness in JES ocean circulation simulations made by R. Preller (NRL) and other investigators. Comparison of our results with the aircraft measurements made by C. Friehe (UCI) will help us interpret our shipboard sonic measurements of wind stress, plus provide additional tests of the accuracy of the NOGAPS and ECMWF and other model fields to be used in the JES ocean modeling effort.

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None.

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