Japan/East Sea Air-Sea Interaction and Meteorology: Boundary-Layer Structure and Model Validation

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LONG-TERM GOALS

The long-terms goals of the research are to understand and parameterize the physics of air-sea interaction and the marine boundary layer over a wide spectrum of weather and ocean conditions.

OBJECTIVES

The main objectives of this effort are to study the air-sea interaction under the extreme conditions of cold-air outbreaks over the Japan/East Sea (JES) during winter. We are primarily interested in *(i)* the determination of boundary-layer structure *(ii)* the measurement of momentum, heat and water vapor (latent heat) air-sea fluxes and their spatial variability *(iii)* parameterization of these fluxes and *(iv)* model validation using observations.

APPROACH

We instrumented the Navy CIRPAS Twin Otter research aircraft with wind, temperature, humidity, IR sea temperature and aircraft motion and navigation sensors. High quality turbulence and meteorological measurements from thirteen aircraft flights over the JES in February 2000 were obtained. The bulk of the measurements were made inside the "Flux Center" (41-42.5N, 131.5-133.5E, Kawamura and Wu, 1998) an area off of Vladivostok characterized by enhanced winds and surface fluxes due to the flow of cold and dry Siberian air channeled through the orographic gap near Vladivostok. Three basic research goals were addressed with different flight patterns: *(i)* Flux Mapping: after transit to the ``Flux Center" south of Vladivostok, the surface-layer fluxes were mapped in a grid pattern at 100 feet with soundings to 5000 feet; *(ii)* Internal Boundary-Layer Growth: after transit to the "Flux Center" south of Vladivostok, a line of soundings from 100 to 3000-5000 feet was flown following an approximate streamline across the JES (five-minutes flux legs were flown at 100 feet between soundings); and *(iii)* Flux Divergence: after transit to the ``Flux Center" south of Vladivostok, a vertical stack pattern was flown to determine the flux divergence profile in the boundary layer.

WORK COMPLETED

We have concentrated our analysis on the internal boundary-layer growth over the Japan/East Sea as measured from multi-profile flights across the JES. We have submitted a manuscript, together with

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The long-terms goals of the research are to understand and parameterize the physics of air-sea interaction and the marine boundary layer over a wide spectrum of weather and ocean conditions.

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Professor Qing Wang of the Naval Postgraduate School, to the special issue of *Deep Sea Research* on the JES experiment. We are continuing to analyze the vertical structure of the boundary layer measured in the flux divergence flights, where many levels were flown in the boundary layer.

RESULTS

An internal boundary layer develops across the JES in cold-air outbreak conditions. Such development is shown in Figure 1, where profiles of potential temperature from30 to 1400 m are shown at increasing fetch from Vladivostok. The boundary-layer height, marked by the sharp inversion, initially drops and then increases. This is due to the initial topographical effect of the airflow out of the Vladivostok gap, where the boundary layer thins as the flow expands seaward under the strong inversion. This feature is predicted by the model of Scotti (2002) for the JES. Downstream of the gap, the boundary layer grows due to interaction with the sea as the square root of fetch.

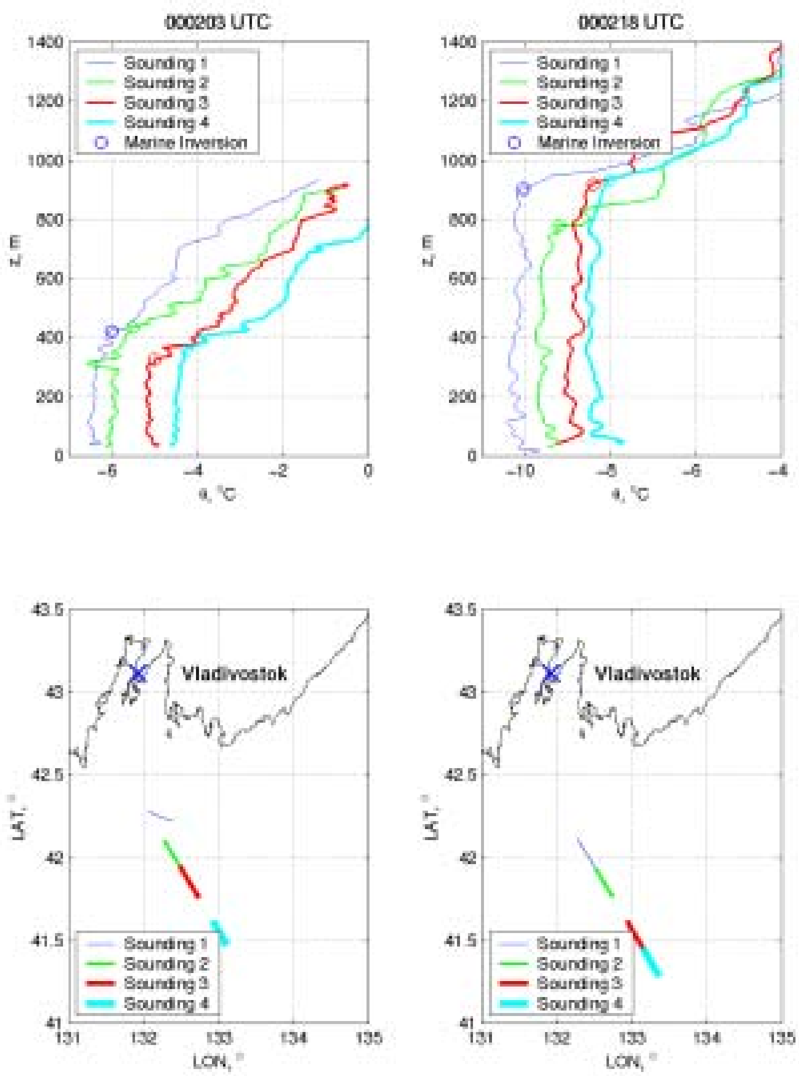

Figure 1: Aircraft soundings of potential temperature downstream of the Vladivostok gap for Feb 03 and 18 2000 from the CIRPAS Twin Otter. The height of the inversion initially decreases by 50m due to gap flow topographical effects, then increases due to air-sea interaction.

The growth of the internal boundary layer over the entire JES is shown in Figure 2. After the initial decrease, an approximate square-root dependence is found, in accord with simple theory. Professor Qing Wang applied the Navy COAMPS mesoscale model to the JES aircraft data with supporting meteorological data for initialization. The comparisons of the model and the aircraft data are shown in Figure 3 for the two days of Figure 2. COAMPS underestimates the height of the internal boundary layer, although the growth rate is approximately correct. The model runs extended closer to the landmass of Honshu Island than the flight data, and perhaps reflect orographic influence.

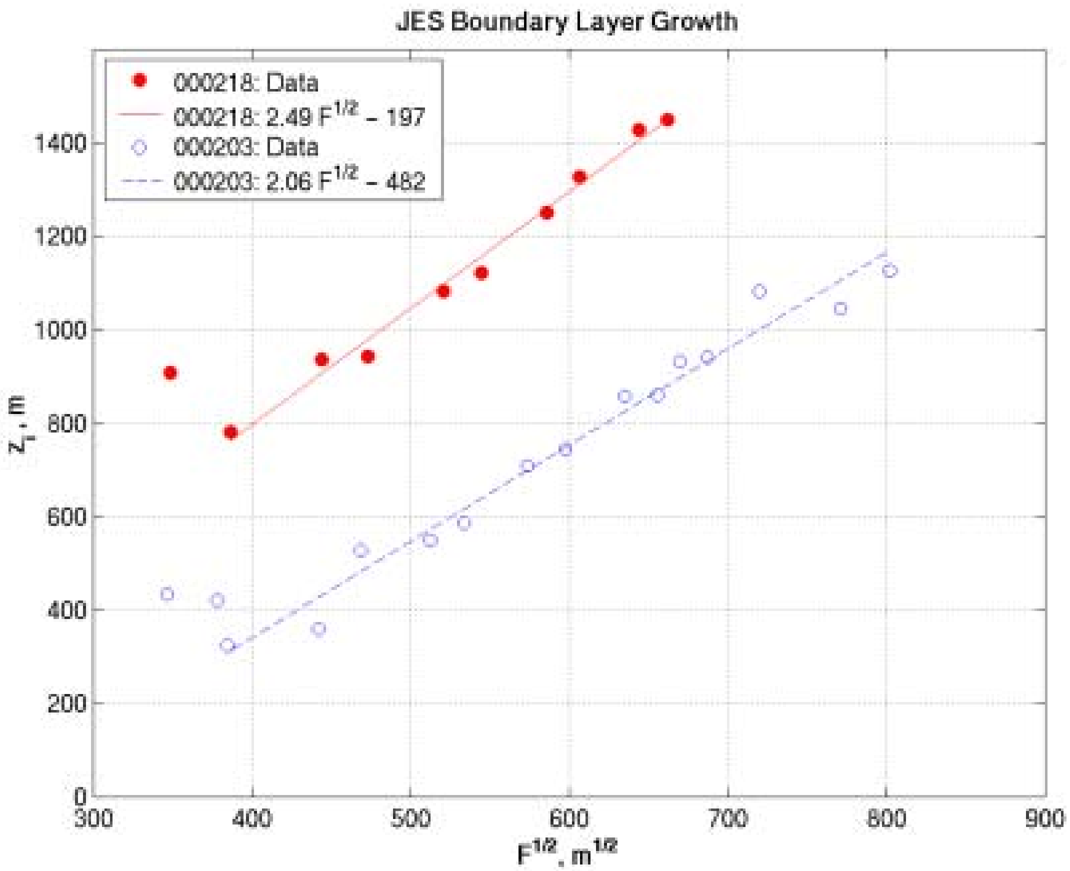

Figure2: Internal boundary layer growth across the Japan/East Sea for Feb 03 and 18 2000. After an initial decrease near the Vladivostok gap, the boundary layer height increases as approximately the square root of fetch across the JES.

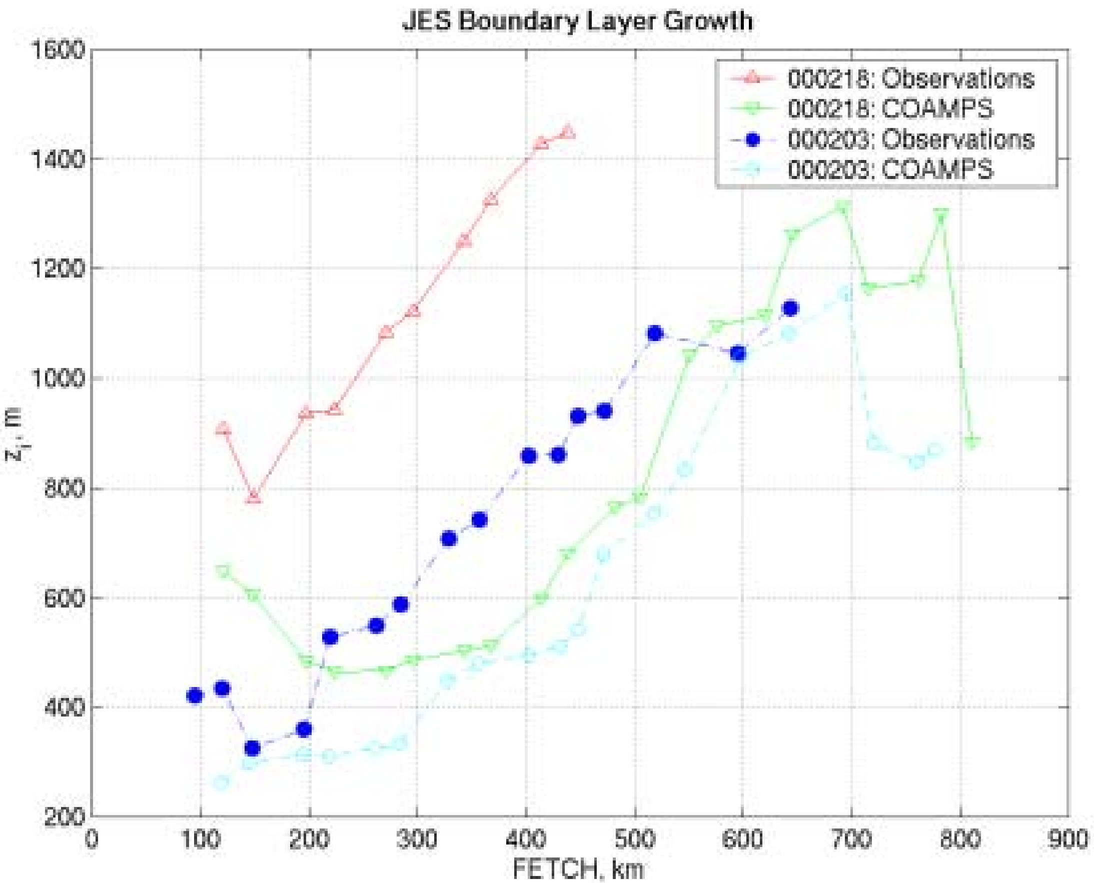

Figure 3: Comparison of the internal boundary-layer growth from the CIRPAS Twin Otter and the COAMPS model (Prof. Qing Wang, NPS) for Feb 03 and 18 2000. While the functional growth rates are similar, COAMPS underestimates the absolute height of the boundary layer.

IMPACT/APPLICATIONS

The high-quality turbulence and meteorological aircraft data are the first measurements to provide good spatial (both horizontal and vertical) coverage of the boundary layer over the JES in cold-air outbreak conditions. Their impact is to improve our understanding and parameterizations of air-sea fluxes and boundary-layer structure in extreme weather conditions. Their use as input and validation of JES mesoscale models such as COAMPS and MM5 will enhance the accuracy of these models.

TRANSITIONS

The same instrumentation we developed for the JES experiment has been used on the CIRPAS Twin Otter in the Rough Evaporation Duct (RED) experiment we just completed. The calibration maneuvers performed on each RED research flight will allow us to obtain an even better calibration of the wind measurement system. We are planning to use the new calibration results on our upcoming reprocessing the JES data set. Other recent Twin Otter projects where our instrumentation was used are DEC (1999), SHOWEX (1999) and HALO (2001).

RELATED PROJECT

A supplement to this grant was obtained from ONR Marine Meteorology to participate in the CARMA-I experiment in August – September 2002 with the same instrumentation on the CIRPAS Twin Otter with Dr. Dean Hegg of the University of Washington.

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PUBLICATIONS

Journal Articles:

Khelif, D., C. A. Friehe, Q. Wang, 2002: Wintertime Boundary-Layer Structure and Air-Sea Interaction over the Japan/East Sea. *Deep Sea Research*, submitted.

Abstracts:

Rados, K., et al., 2002: Evaluation of Marine Boundary-Layer Parameterizations in COAMPS Using the JES Experiment Data Set, 15th Symp. On Boundary Layers and Turbulence, Amer. Met. Soc., 15-19 July 2002,Wageninen, The Netherlands, pp. 632-635.