

# SEA ICE EDGE FORECAST VERIFICATION PROGRAM FOR THE BERING SEA

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## Abstract

*The Navy/NOAA Joint Ice Center issues 7-Day forecasts of changes in the position of the sea ice edge over the Bering Sea each week. These forecasts are used by marine interests, especially crab fishing fleets, to aid in safe and efficient operations. The Center undertook the verification of these forecasts, despite observational difficulties, in order to assess their merits and to explore ways to make them more accurate. Ice forecasts for the ice seasons of 1987–88 and 1988–89 were compared to climatologically derived changes in ice edge position and comparative statistics were developed. The mean error of the Center's 7-Day forecasts was about 23 n mi and 25 n mi for 1987–88 and 1988–89, respectively. The Center's forecasts outperformed climatology in both years by about 25%. Persistence forecasts proved poor since the ice edge rarely remained in the same location from week to week. A modified persistence forecast (using the prior week's ice edge motion) also proved far less accurate than climatological or Center forecasts. The Joint Ice Center's requirements for forecast accuracy were shown to be met, on average, but individual forecast errors highlight the Ice Center's dependence upon accurate medium range predictions by both NMC and the European Center for Medium Range Forecasting (ECMWF).*

## 1. Introduction

The Navy/NOAA Joint Ice Center (JIC) is engaged in global sea ice analysis and forecasting. This paper describes a program to verify the accuracy of the JIC's routinely produced 7-Day ice edge forecasts for the Bering Sea. The ice edge changes in response to environmental conditions and is normally located using satellite remote sensing. Ice forecast user requirements are determined by the application and vary over a wide range. Fixed platform operations and some research applications call for accuracies exceeding the resolution of the best operational sensors, 0.6 n mi. At the other extreme, most operational Global Circulation Models call for ice edge accuracies of about  $\pm 60$  n mi. The majority of JIC's users are either commercial operators or Navy fleet elements who require ice edge information with an accuracy of between 10 and 60 n mi as an aid to navigation. As a compromise to the users and a concession to ice edge detection accuracy, the JIC ice forecasters established 7-Day forecast accuracy goals of  $\pm 20$  n mi under clear sky (good observation) conditions and  $\pm 60$  n mi under other, less favorable conditions.

Sea ice forecasting remains a subjective skill with few quantitative aids. State of the art sea ice models are incapable of accurately forecasting changes in the position of the ice edge, due in part, to our relatively poor knowledge of ice rheology (mechanical properties/interactions between ice floes) and the ocean environment. Empirical models relating ice drift and wind velocity often provide the best guidance.

Since many of the inputs are subject to substantial errors in the observation-sparse high latitudes and model outputs have their own errors, the ice forecaster's primary method to improve skill is to accumulate experience.

In the past JIC forecasters made little attempt to quantitatively verify their products. The accepted procedure called for the forecaster to subjectively compare last week's forecast with the current ice analysis. Little feedback was gathered from users because there was no mechanism to permit an exchange of information. Forecast accuracy was, and remains, dependent upon analysis accuracy. Unlike various meteorological and oceanographic measurements, sea ice edge location remains a subjectively determined parameter. Several data sources, with a wide range of resolutions, are blended in order to obtain the ice edge location. These data sources, discussed in more detail below, have improved in recent years, as have the JIC's tools for interpretation. In addition, the proliferation of marine satellite telefax communications has enabled the JIC to better serve the users and to solicit comments on the analyses and forecasts provided.

In producing ice edge forecasts, meteorological forecast products from the National Meteorological Center (NMC), the European Center for Medium Range Forecasting (ECMWF) and Fleet Numerical Oceanography Center (FNOC) are routinely employed by JIC ice forecasters. NMC and FNOC also provide specialized ice forecasting products requested by the JIC. NMC creates three special products; a Bering Sea model for the winter season (simple dynamics and thermodynamics), an empirical wind driven/ice drift model for selected locations and an alphanumeric listing of surface wind speed, wind direction and temperature for selected points in the Bering Sea derived from the Medium Range Forecast model. FNOC provides two special types of forecasts, a dynamic/thermodynamic model for the polar regions (north of the Bering Sea) and an empirical wind driven/ice drift model (different from NMC's) for selected locations. Ice forecasters at the JIC use common, empirically derived ice forecasting relationships, such as the 2% wind driven/ice drift relationship developed by Zubov (1945). They also make use of sea ice edge climatologies and climatological trends derived from an eleven year database of weekly ice analyses. Oceanographic parameters also strongly influence ice edge position but routine ocean products are limited to sea surface temperature charts whose resolution and accuracy are insufficient for most forecast situations. Forecasters use average ocean current data from several sources and derive some knowledge of sea surface temperatures from infrared satellite imagery when available.

A verification program was initiated at the JIC in order to obtain some degree of confidence in the accuracy of ice forecasts. Practical experience in supporting operations near the ice edge has shown that extreme and/or unusual changes in position are difficult but not impossible to forecast. This verification program was designed to establish a quantitative



measure of forecast accuracy and to identify those conditions leading to large forecast errors. The study area, in the Bering Sea, is shown in Figure 1.

**2. JIC Sea Ice Analysis**

An understanding of the analysis procedures employed at JIC is necessary in order to assess the forecast verification program, because forecasts are based upon current analyses and verified from the following week's analyses. Desired forecast accuracy and verification procedures are intimately related to analysis accuracy.

The JIC's weekly ice charts show the position of the ice edge and ice concentrations for ocean areas covered by ice. The accuracy of JIC's ice analyses is primarily dependent upon satellite sensors. Under clear sky conditions the Advanced Very High Resolution Radiometer (AVHRR) sensor aboard the NOAA polar orbiting satellites enables the

JIC ice edge analysis to be within about 10 n mi of its true position. However the AVHRR sensor does not image the surface through clouds. The JIC receives visual band images from the Defense Meteorological Satellite Program's (DMSP) Operational Linescan System (OLS) from the U.S. Air Force. The OLS resolution is only about 0.6 km but these images are delivered to JIC some 48 to 96 hours after imaging and are also cloud limited. Currently, the only all-weather sensor applicable to sea ice analysis is the Special Sensor Microwave Imager (SSM/I) carried on board the DMSP "morning" satellite. SSM/I brightness temperatures are entered into a sea ice algorithm developed by the Navy expressly for the JIC. Output consists of global sea ice concentration amounts for 50 km square "pixels." It is known that several sources of error exist in the SSM/I data so that in practice the ice edge derived solely from SSM/I data may be one to three pixels in error depending upon ice conditions. Through experience, including comparing SSM/I data with

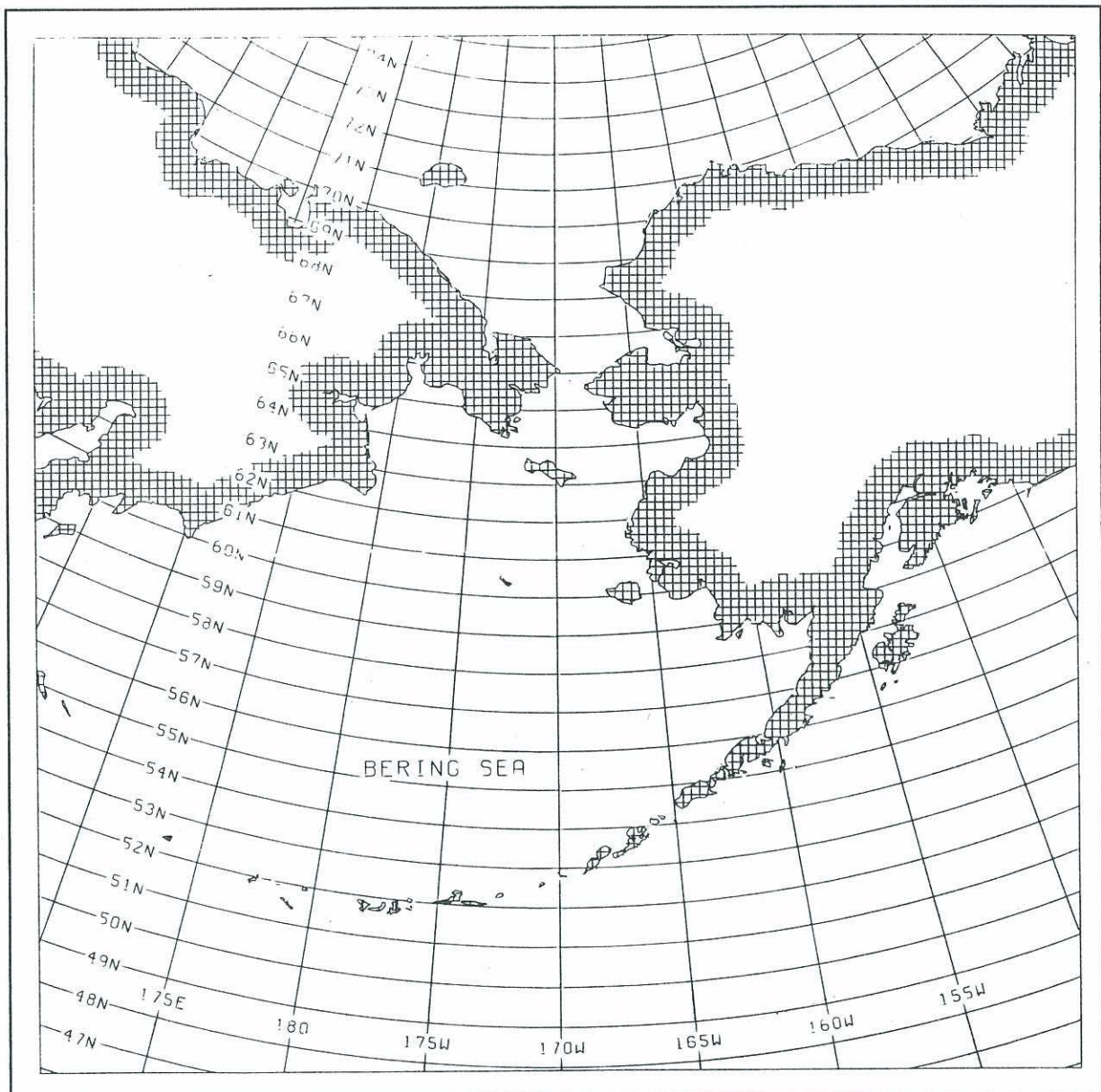


Fig. 1. Study Area.