# Ice Thickness Distribution Test

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## LONG-TERM GOAL

Our long term goal is to understand the composition of the arctic sea ice cover in terms of its ice thickness distribution. This distribution is observed by submarine and moored upward-looking sonars and is modeled in a range of guises in ice, ice-ocean, and climate models. We pursue a common understanding of ice thickness that encompasses both observations and modeling.

## OBJECTIVES

The objective of this work is to determine the sampling errors that occur when one tries to estimate mean thickness or the ice thickness distribution from one or more profiles of ice draft. That is, we want to put error bars on observations of ice thickness. These error bars are needed if one is to use observations to test ice model simulations of thickness distribution.

## APPROACH

We densely surveyed an area of sea ice by submarine sonar during SCICEX'96 along a set of ten diameters of a circle about 200 km in diameter. With this "oversampled" region we can see how the estimate of mean thickness or of thickness distribution is affected by including all or only portions of the data. How much lower is the error if we use a 200 km sample than if we had only a 100 km or a 25 km sample? Such tests allow us to calculate error bars for surveys of a given size, and allow us to design future experiments that test ice models. A suitable test must contain a signal—a regional or temporal

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thickness variation—large enough to be measured without question above the noise—small scale "sampling" variations in ice thickness.

## WORK COMPLETED

With the 1996 SCICEX data we have been investigating how the variance of an estimate drops off with increasing sample size and find that the drop-off is less rapid than the usual reciprocal of sample size. A paper on this behavior is in preparation.

We have worked with the 1993, 1996 and 1997 SCICEX ice draft data from transects of the whole Arctic. We compared these data with model output, testing how much of the variations of ice draft seen in the data showed up in the model. This work is preliminary and awaits more extensive submarine data, hopefully from the historical record from the 1970's and 1980's. We have reported this work at the Ice Thickness Workshop in Monterey in April 1997 and at the SCICEX 2000 Workshop in Warrenton in October 1998.

## RESULTS

We have found unexpected behavior of ice draft profile data which shows that the decrease in variance of ice draft statistics with increasing sample size is slower than for more common data sets in which the data points are independent. The properties are seen in the autocorrelation function at long (spatial) lags and in the spectra at small wavenumbers. This decline in sample variance with increasing sample size is slower for long linear (profile) samples than for area samples. We find sample variance is reduced more effectively by sampling larger areas rather than by sampling longer profiles.

## IMPACT/APPLICATION

Forecast models and climate models need validation with ice draft data. The data sets with the greatest potential for such validation tests are SCICEX ice draft data and the historical record of ice draft data being prepared for release by the Environmental Working Group.

The statistical behavior of sea ice is similar to other geophysical processes and should be more commonly taken into account when estimating statistics (means, interannual variability, trends, etc.) of geophysical importance.

## TRANSITIONS

none

## RELATED PROJECTS

1. Our follow-on SCICEX work, "Ice Thickness Distribution Test -- Stage 2" is funded by the National Science Foundation and is aimed at using sequential submarine ice surveys to test how well an ice thickness distribution model can describe the change observed for a patch of ice over periods of a month to a year.

2. Ice modeling work under a NASA funded Interdisciplinary Investigation "POLar Exchange at the Sea Surface" is using these data to test model performance.

3. We have plans to collaborate with colleagues at the Mullard Space Science Laboratory to compare submarine ice draft data with ice thickness estimated from satellite-borne altimeters.

4. With separate ONR and NSF support, we have organized and convened a workshop on the status of SCICEX, its accomplishments, and its outlook for the future. A workshop report will contain recommendations for future utilization of submarines for arctic marine science.

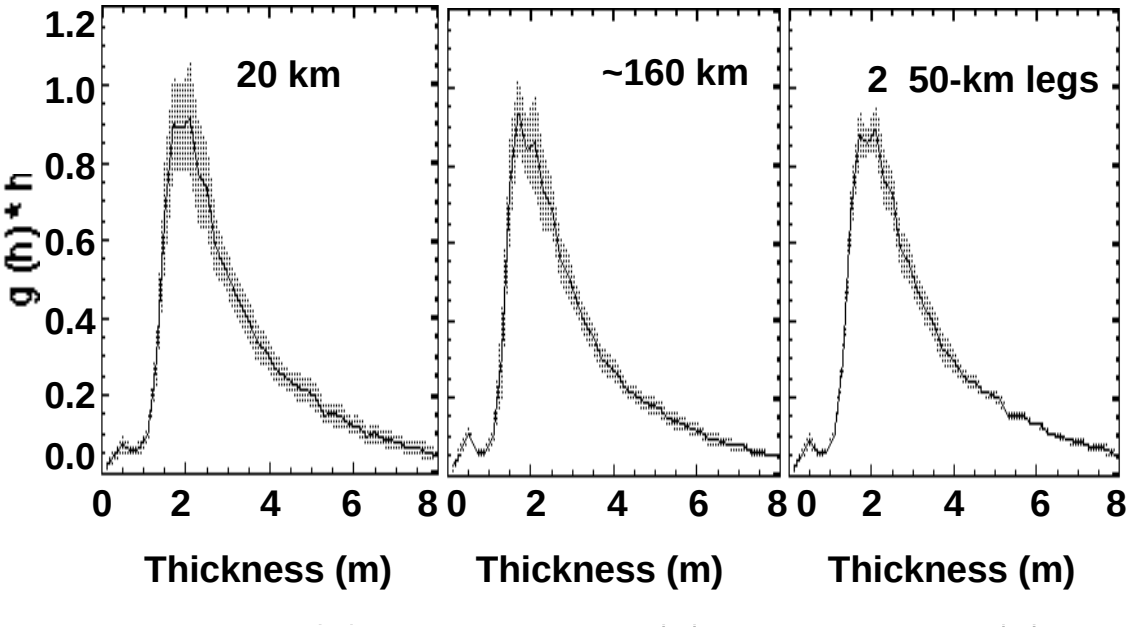


***Figure 1. The grey areas are the 90% confidence intervals for thickness distribution estimated (left) from a 20 km profile, (center) a 160 km profile, and (right) a cross of 2 50-km profiles. To minimize sampling errors with a given sample size, it is more efficient to sample in two dimensions than in one.***