P1.23 INVESTIGATION OF SEASONAL SEA-ICE THICKNESS VARIABILITY IN THE ROSS SEA

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1. INTRODUCTION

A number of studies suggest a connections between sea-ice variability and climate sensitivity (Ledley, 1991; Rind et al., 1995; Simmonds and Jacka, 1995; Geiger et al., 1997 and others). The fact that sea ice covers about 7% of the earth's surface at any one time and varies seasonally in extent, emphasizes the importance of monitoring and understanding sea ice. This is especially true in the Southern Ocean where sea ice varies in extent by almost 80% and is considerably thinner than its Arctic counterpart (average of 1m in the Antarctic versus 3m in the Arctic). Antarctic sea ice is an important feature of the global climate system because it exists as a thin layer at the air-ocean interface and is a very sensitive controlling parameter for heat, mass, and momentum fluxes between the ocean and atmosphere.

Changes in sea-ice cover due to global temperature changes can be monitored through accurate estimates of sea-ice mass balance. This requires knowledge of the ice extent, compactness, and thickness. Remote sensing provides considerable information on the ice extent and compactness. However, there is currently no space-borne platform which can resolve sea-ice thickness. Hence, of the three variables needed, thickness is the least known.

Using proxy information, such as ice type acquired from remotely sensed data, it is possible to infer a range of ice thicknesses from which one can estimate the variability of thickness distribution on a regional basis. The World Meteorological Organization (WMO) recognizes 16 distinct ice thickness categories or stages of develeopement (WMO, 1970) ranging from ice-free regions through various types of first-year ice to multi-year ice. The National Ice Center (NIC) has routinely produced weekly ice charts since the 1970's. From the period of 1995 to 2000, classification by stage-of-development (i.e. ice type) has been incorporated into these charts using aircraft reconnaissance, visual and infrared AVHRR (advanced very high resolution radiometer) and OLS (operational line scanner) imagery, and simple models based on "freezing-degree days". Currently, these charts represent the only continential-scale estimates of Antarctic ice type with the potential to resolve interannual sea-ice thickness variability.

To date, there have been no comparison studies of these charts with *in-situ* measurements. Since 1997, the Antarctic Sea Ice Processes and Climate (ASPeCt) program under the Scientific Committee on Antarctic Research (SCAR) has had as one of its main objectives the compilation of a comprehensive archive of *in-situ* Antarctic sea-ice data. The data for this archive have been obtained from ship-based observations by numerous national Antarctic programs, including the U.S., Australia, Russia, U.K., and Germany. The current archive consists of over 20,000 records over the Antarctic pack ice between 1980 and the present.

The goal of a recently funded 3-year NSF project is to compare the Antarctic NIC ice charts with the ship-based observations from 1995 to 2000 in order to ascertain their quality for use in monitoring ice mass balance changes on a climatological scale. In this paper, we will present preliminary results based on a small subset of the data in the Ross Sea during 1995. We will report on a spatial-temporal GIS database developed for comparison of the NIC ice charts and ship-based observations along with analysis of the seasonal (and eventually interannual) variability in these data.

2. DATA PROCESSING

Each of these data sets breaks down sea-ice classification into three ice groups (thickest, middle, and thinnest) within each observation area in accordance with the WMO criteria for sea-ice classification. Details of each of these data sets is given below followed by a description of the temporal-spatial data merge process. The geographic information system (GIS) called ArcGIS 8.1 developed by the Environmental Systems Research Institute (ESRI) is used in the data conversion, management, analysis of these data, and the visualization of the results.

2.1 Ship-Based Measurements

The ship-based observations were imported into the

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Table 1: **Selected Data from Ross Sea in 1995**

Time	Points	Polygons	Common
05/05 - 05/11	38	21	5
05/12 - 05/18	89	24	4
05/19 - 05/25	114	26	5
05/26 - 06/01	80	28	5
06/02 - 06/08	96	32	5
06/09 - 06/15	75	34	6
07/28 - 08/03	5	39	2
08/04 - 08/10	105	35	7
08/11 - 08/17	120	30	3
08/18 - 08/24	85	42	3

Points are the number of *in-situ* ship observations during each week, polygons are the total number of polygons found on the NIC charts within the Ross Sea, while common are the number of NIC chart polygons with ship measurements.

GIS and spatially referenced through a geodatabase which catalogued the observed ice concentration for each of three ice groups for properties of ice thickness, type, topography, amounts of ridged ice and ridge sail heights, and snow depth as well as overall open water fraction. Estimates of sea-ice thickness were calculated in centimeters for the level ice, ridged ice and snow thicknesses. Each of these were computed for each ice group (thickest, middle, and thinnest) and weighted by the concentration of ice.

2.2 NIC Ice Charts

A combined effort by the NIC, Naval Research Lab (NRL), and the University of Delaware (UD) digitized and defined the attributes for the ice charts from 1995. As with the ship-based observations, the ice charts are comprised of three ice groups defined for each area. However, unlike the ship-based measurements, the NIC charts contain properties about ice characteristics as described in localized areas denoted by polygons on these charts, hence providing large regional estimates of ice attributes. Since ice thickness can not be directly computed using current remote sensing platforms, these charts contain a proxy for thickness known as the "stage-of-development" over which a range of ice thickness is described within a named ice type as defined through WMO standards. Once the mean thickness for each ice type was determined, an average ice thickness was computed and then weighted with the appropriate concentration for each ice type over each polygon.

2.3 Merging of Data Sets

Both datasets were reprojected into a common equal area projection for analysis and then combined. Using

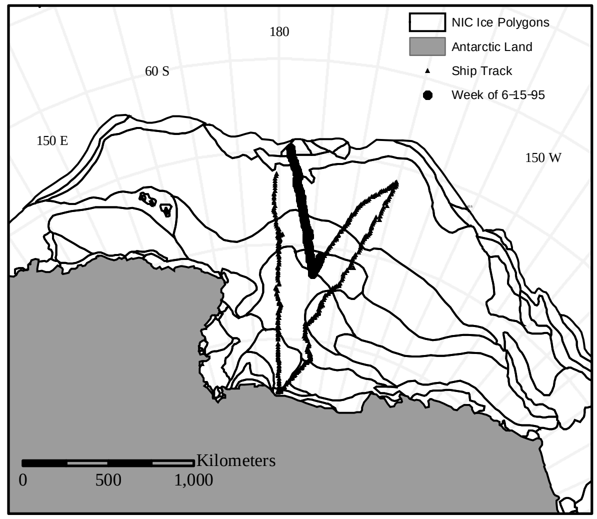

Figure 1: Example of merged data product between NIC chart and ship-based observations for the week of June 9-15 (in bold) and the entire ship track for the May-June in 1995.

the GIS, the ship observations were temporally merged to the weekly NIC sea ice charts. This procedure resulted in a joined table of spatially coincident points overlayed on the weekly NIC polygons (Figure 1). The ship observation points were then averaged within each NIC polygon to obtain a single ship average thickness observation for each respective polygon (Table 1). The resultant merged table was used to produce the scatter plots and histograms shown below.

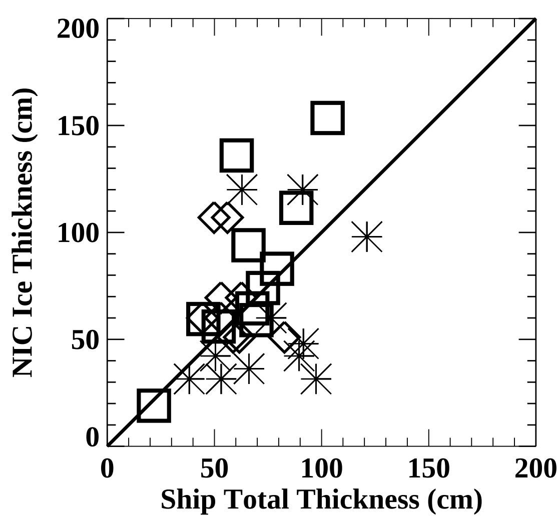

Figure 2: Scatter plot comparing the average ice thickness from the NIC ice chart polygons and ship-based measurements of level and ridged ice and snow thickness. Asterisk symbol used for the month of May, diamonds for June, and squares for August.

3. RESULTS

A comparison of ice thickness between ship-based observations and NIC ice charts is shown in Figure 2. The ship-based observations include the sum of ridged ice, level ice and snow thicknesses while the NIC ice charts are based on the interpretation and analysis of remotely sensed data as described earlier. As seen from this figure, the NIC ice charts underestimate ice thickness early in the growth season but overestimates ice thickness for the thicker ice categories (i.e. during August). Otherwise, the two data sets show good correspondance.

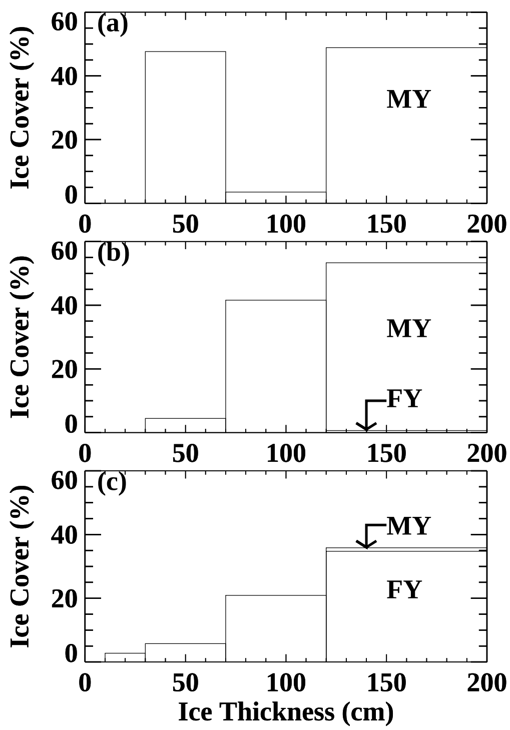

Figure 3: Distribution of the thickest ice category are shown based on NIC ice charts for the week of (a) May 5-11, (b) June 9-15, and (c) August 18-24. Ice covereage is shown as a percentage of total ice area for this ice category. Labels FY and MY indicate first-year and multi-year ice types, respectively.

A description of the seasonal variability seen in ship-based observations is presented in Worby et al. (1998) and clearly shows that the ship-based data, when carefully observed and quality controlled, provide a unique and highly variable source of Antarctic sea-ice thickness data. Complementary to their results, the weekly NIC chart-derived thickness distribution also demonstrates the seasonal changes in thickness categories (Figure 3). Figure 3a shows the majority of the thickest ice category is bi-modally distributed at the beginning of the season between 30-70 cm with residual multi-year (>120cm) ice from the previous year. Then in June (Figure 3b), there is a shift in ice thickness distribution represented by the increase in the 70-120 cm range, together with the first indications of new first-year ice greater than 120cm. By August (Figure 3c), there is a progressive shift of ice to the thickest values with a notable increase in first-year ice greater than 120 cm.

4. SUMMARY

Based on a preliminary subset using one season of data for 1995 in the Ross Sea, this analysis shows that there is a strong correspondance between ship-based observations and remotely sensed ice charts. Additionally, results reveal a notable change in the thickness distribution through the growth season in the NIC charts, as well as the already established seasonal signal from ship-based observations. These encouraging results will be further investigated to validate the NIC charts and to make use of both data sets to monitor the variability and long-term climate changes detectable in the Southern Ocean.

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