ANTARCTIC CRC

COOPERATIVE RESEARCH CENTRE FOR THE ANTARCTIC AND SOUTHERN OCEAN ENVIRONMENT

A Technique for Making Ship-Based Observations of Antarctic Sea Ice Thickness and Characteristics

PART I Observational Technique and Results

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PART II User Operating Manual

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ABSTRACT

This report details a technique for making systematic and quantifiable observations of sea ice thickness and characteristics from ships transiting the Antarctic pack ice. This observation protocol has been endorsed by the SCAR ASPeCt (Antarctic Sea ice Processes and Climate) program as the preferred method for conducting ship-based observations of sea ice characteristics.

Part I is a complete description of the observational method. It presents the codes used for quantifying the ice and snow parameters such as thickness, floe size and topography, and provides guidelines for observers to follow when making the observations. Results from observations made in the East Antarctic pack are shown, including the observed seasonal cycle of sea ice and snow thickness distribution for the period 1986–1996. A set of blank observation sheets are provided in Appendix 1. Examples of completed observation sheets are presented in Appendix 2.

Part II is the user operating manual for the purpose-designed computer program for entering, quality controlling and processing the ship-based observations on PC. The software proformas have a similar layout to the hand-written observation sheets. The software runs on PC under Windows 3.11 or higher, and is written in microsoft visual C++ version 1.5.2.

This report should be read in conjunction with the CD-ROM “Observing Antarctic Sea Ice: A Practical Guide for Conducting Sea Ice Observations from Vessels Operating in the Antarctic Pack Ice” [Worby, 1999] which provides an interactive tutorial and instructions for conducting ship-based sea ice observations in the Antarctic. The CD-ROM also contains an image library and bibliography of sea ice types and general information on the role of sea ice in the global climate system.

ACCESS TO SOFTWARE AND RELATED FILES

The software and related files described below have been specifically designed for conducting ship-based observations of Antarctic sea ice, and for entering, quality controlling and processing the data. The files are available via the ASPeCt (Antarctic Sea Ice Processes and Climate program) web site or on CD-ROM [*Worby,* 1999]. At the time of publication version 2.22 of the software was released. Future upgrades will be available via the ASPECT web site at:

http://www.antcrc.utas.edu.au/aspect.

From this site follow the SEA ICE OBSERVATIONS link and follow the instructions.

The CD-ROM, which also contains an interactive tutorial for conducting sea ice observations and an image library and bibliography of sea ice terms, is available from:

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To install the ice observation software, download the following three files to a new directory on your PC. Run the executable file (seaice.exe) from Windows by double clicking the icon. When you run the executable a new file (seaice.cfg) will be created, which stores the software configuration information. This file is automatically updated when the user changes any default settings. It is important to remember to delete this file before installing future upgrades of the seaice.exe software.

(i)	seaice.exe	This is the executable version of the software.
(ii)	grid.vbx	This is a system file that must be copied to enable the executable to run.
(iii)	landmask.map	This is a file of latitude and longitude points around the Antarctic coastline and is used for plotting purposes.

The following four files contain the blank observation spreadsheets and codes used for recording the ship-based sea ice observations. The completed forms should kept as a hard copy record of your observations:

(i)	iceobs.pdf	Ice and meteorological observation log sheets
(ii)	comm.xls.pdf	Comments log sheet
(iii)	icecodes.pdf	Ice observation codes
(iv)	metcodes.pdf	Meteorological observation codes

Parts I and II of this report are contained in the file:

(i)	report.pdf	Parts I and II of this report (Antarctic CRC Research Report 14),

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PART I

OBSERVATIONAL TECHNIQUE AND RESULTS

1.0 INTRODUCTION

The sea ice thickness distribution is a fundamental parameter for defining the extent of ocean-atmosphere interaction within the sea ice zone as well as the extent of mechanical deformation within the ice field. Combined with sea ice extent it also defines the total ice volume and possible response of sea ice to climatic change; combined with ice velocity it defines the mass flux of ice; and combined with the multi-year ice fraction, ice structural composition, and ice temperature and salinity, it defines the mechanical strength of the ice cover. However, sea ice thickness is one of the most difficult geophysical parameters to measure over large spatial and temporal scales. It can not be measured remotely; hence the need for *in situ* measurements to determine the distribution and thickness of different ice types within the pack ice zone.

In the Antarctic over the past several decades, numerous field investigations have employed different techniques for measuring sea ice thickness. These include drilled measurements [*Ackley*, 1979; *Allison and Worby*, 1994; *Eicken et al.*, 1994; *Jeffries and Weeks*, 1992; *Lange*, 1991; *Wadhams et al.*, 1987], upward looking sonar [*Bush et al.*, 1996; *Strass* and Fahrbach, 1998], impulse radar [*Wadhams et al.*, 1987], electromagnetic induction techniques [*Haas, 1998; Worby et al., in press*], satellite remote sensing [e.g., *Comiso and Zwally*, 1984; *Gloersen and Cavalieri*, 1986], and ship-based observations [e.g., *Worby et al.*, 1996b; *Worby et al.*, 1998]. Each of these observational techniques has acknowledged biases, and therefore different techniques are useful for identifying different thickness categories within the pack ice [*Worby*, 1998]. The ship-based observations are particularly useful for providing localised information on sea ice thickness and characteristics, which over the duration of a voyage, amount to semi-synoptic coverage of the pack. The ship-based observations also discriminate thin sea ice types which are not represented in the drilled thickness data, and are problematic for the interpretation of SSM/I data from satellites [*Comiso et al.*, 1989].

One of the problems faced by observers making ship-based observations of sea ice thickness and other ice characteristics has been the lack of a standardised system for making and recording the observations. Observations of e.g., sea ice type, concentration, thickness and surface topography have been maintained on many voyages over the past two decades; however these have often been in the form of written notes, and in many instances there has been no quantitative analysis of the data. Furthermore, individual data sets are rarely in a format comparable with others from different voyages, making regional or seasonal comparisons impossible. The ship-based observing scheme presented in this report provides a consistent and quantifiable method for estimating the thickness and distribution of sea ice along a ship's track through the pack ice. The scheme involves making hourly observations from the ship's bridge, entered using a series of classification codes for each parameter. Information on snow cover type and thickness are also recorded. Software for PC is available for entering, quality controlling and conducting preliminary analyses of the data while in the field.

The observations may be made by a trained observer from any ice-capable vessel operating within the Antarctic pack ice zone. Frequently repeated shipping routes to Antarctic coastal stations provide an opportunity to obtain data which may identify seasonal and, possibly, inter-annual changes in ice conditions. Observations from multiple voyages within the pack ice may enable the identification of regional differences.

2.0 OBSERVATIONAL TECHNIQUE

A standard set of observations are made hourly by an observer on the ship's bridge. These include the ship's position and total ice concentration, and an estimate of the areal coverage, thickness, floe size, topography and snow cover of the three dominant ice thickness categories within a radius of approximately 1 km of the ship. The three dominant ice categories are defined as those with the greatest areal concentration, and the thickest of these is defined as the primary ice type. There may be times when only one or two different ice categories are present in which case only the primary, or primary and secondary, classifications are defined. The observations are entered on log sheets using a standard set of codes based on the WMO [1970] nomenclature and designed exclusively for Antarctic sea ice. A set of blank proformas is located in Appendix 1 and on the CD-ROM described on page ii. Examples of completed proformas are shown in Appendix 2.

2.1 Ice Concentration (c)

Total ice concentration is an estimate of the total area covered by all types of ice, expressed in tenths, and entered as an integer between 0 and 10. In regions of very high ice concentration (95–99%) where only very small cracks are present, the recorded value should be 10 and the open water classification should be 1 (small cracks). Regions of complete ice cover (100%) will be distinguished by recording an open water classification of 0 (no openings). An estimate of the concentration of each of the three dominant ice thickness categories is also made. These values are also expressed in tenths and should sum to the value of the total ice concentration. It is sometimes difficult to divide the pack into three distinct categories, and it may be necessary to group some categories together to ensure their representation.

2.2 Ice Type (ty)

The different ice categories, together with the codes used to record the observations, are shown in Table 2.1. The ice categories are based on the [*WMO*, 1970] sea ice classifications. First year ice greater than approximately 0.1 m thick is classified by its thickness (e.g., young grey ice 0.1–0.15 m; first year ice 0.7–1.2 m), while thinner ice is generally classified by type (e.g., frazil, shuga, grease and nilas). A single category is defined for multi-year ice. There is also a category for brash, which is common between floes in areas affected by swell and where pressure ridging has collapsed. Books by e.g., *Armstrong et al.* [1973] and *Steffan* [1986], and the CD-ROM described on page ii [*Worby*, 1999] provide illustrated examples of different sea ice types.

2.3 Ice Thickness (z)

Ice thickness is estimated for each of the three dominant ice types. It is helpful to the observer to suspend an inflatable buoy of known diameter (or other gauge) over the side of the ship, approximately 1 m above the ice, to provide a scaled reference against which floe thickness can be estimated. The ice thickness can then be determined quite accurately as floes turn sideways along the ship's hull. Only the thickness of level floes, or the level ice between ridges, is estimated. This is because ridges tend to break apart into their component blocks when hit by the ship, making it impossible to estimate their thickness. In order to determine the thickness of ridged floes, observations of the areal extent and mean sail height of the ridges are made (see Section 2.5) and combined with the level ice thickness data into a simple model (see Section 3.3).

Table 2.1 Ice thickness classifications used for the ship-based observations

Ice Type Classification		Ice Thickness, m	Code
New ice	Frazil	<0.1	10
	Shuga		11
	Grease		12
	Nilas		20
Pancakes		<0.2*	30
Young grey ice		0.10–0.15	40
Young grey-white ice		0.15–0.3	50
First year ice		0.3–0.7	60
First year ice		0.7–1.2	70
First year ice		>1.2	80
Multi-year ice		<20*	85
Brash		<0.5*	90
Fast ice		<3*	95

*Range is a guide only and may be exceeded

Thinner, snow-free ice categories, which are particularly important for ocean-atmosphere heat exchange, can be reliably classified by a trained observer from their apparent albedo, while the thickness of very thick floes may be estimated by their freeboard. The accuracy of careful observations will be within 10–20% of the actual thickness, and a large sample of observations can be expected to provide a good statistical description of the characteristics of the pack. This is particularly true at the thin end of the thickness distribution where changes are most important for both radiant and turbulent heat transfer [e.g., *Worby and Allison*, 1991].

On dedicated scientific voyages, it is usually possible to make regular *in situ* measurements of ice and snow thickness, both on level ice and across ridges, to "calibrate" the ship-based observations. *Worby et al.* [1996b] demonstrated a technique for combining *in situ* and ship-based observations to estimate the ice thickness distribution in the Bellingshausen Sea. Dedicated scientific voyages also usually provide the opportunity to follow specific routes to optimise data quality, which may be compromised if the ship follows the most easily navigable routes. It is the observer's responsibility to clearly indicate on the observation sheet when the ship is preferentially following leads so that this may be considered during data processing.

2.4 Floe size (f)

Floe size can be difficult to determine because it is not always clear where the boundary of a floe is located. Cracks and leads delineate floe boundaries whereas ridges do not. Where smaller floes have been cemented together to form larger floes, the larger dimension is recorded, but usually with a comment to indicate that smaller floes are visible. Where two floes have converged and ridged, the floe size is taken as the combined size of the two. A good rule of thumb is: if you could walk from point A to point B, then both points are on the same floe. This guide can be helpful when trying to determine floe size. The length of the ship (about 100 m for most ice breakers) can act as a good guide for estimating floe size. The ship's radar can be useful for determining the size of very large floes.

Floe size is recorded using a code between 100 and 700. New sheet ice (code 200) is normally used for nilas. This code does not specify a floe size, but is a descriptor for refrozen leads and polynyas. It is often used in conjunction with topography codes 100 (level ice) and 400 (finger rafting).

2.5 Topography (t)

As discussed above, the ice thickness estimates are only made of the level ice in a floe. This is because the thickness of ridges can not reliably be estimated from a ship, since they tend to break up in to their component blocks when hit by the ship, rather than turning sideways so that their thickness can be estimated. However, drilled transects across ridged ice floes indicate that the mass of ice in ridges is a major contributor to the total ice mass of the pack, hence it is important to quantify the extent of ridging within the pack. To do this, the areal extent and mean sail height of ridges is recorded for each ice type within the pack. The extent of surface ridging is estimated to the nearest 10%. It is important that observers not look too far from the ship when estimating the areal extent of ridges, otherwise only the ridge peaks are seen and not the level ice between them. This gives a false impression of more heavily deformed ice than is actually present. The mean sail height is estimated to the nearest half metre below 2 m, and to the nearest metre above 2 m. It is important to remember that it is the *mean* sail height that is recorded. This can be difficult to estimate, particularly in flat light when the sky is overcast. Our experience has shown that ridge height is generally underestimated due to the vertical perspective from the bridge.

Ridges are classified using a three digit code between 500 and 897. The first digit (5–8) is a description of the type of ridge, which may be unconsolidated, consolidated or weathered. This is determined from the appearance of the ridge and is useful for estimating ridge sail density. The second digit (0–9) describes the areal coverage of ridges, and the third digit (0–7) records the mean sail height to the nearest 0.5 m. These observations are probably the most subjective of those made from the ship, and it is particularly important to standardise them between observers.

The observations of surface ridging are input to a model formulation as described in section 3.3, to estimate the mass of ice in ridges.

2.6 Snow type (s)

This is a descriptor for the state of the snow cover on sea ice floes. It is important for estimating the area-averaged albedo of the pack as discussed in Section 3.4. The snow classification is an integer between 0 and 10. For accurate surface albedo calculations, the snow cover classification describes the surface snow. Hence, in a case where fresh snow has fallen over older wind-packed snow, the classification code should describe the freshly fallen snow cover. However, it is very important that the total snow cover thickness is still recorded.

2.7 Snow thickness (sz)

An estimate of the snow cover thickness is made for each of the three dominant ice thickness categories. Snow thickness is relatively straight forward to estimate for floes turned sideways along the ship's hull, although at times the ice/snow interface is difficult to distinguish, particularly when the base of the snow layer has been flooded and snow-ice has formed.

2.8 Open water (o/w)

The codes for open water are descriptors for the size of the cracks or leads between floes, not a concentration value (in tenths). As discussed above, the length and breadth of the ship can act as a useful guide when estimating lead dimensions. The ship's radar can also be useful, particularly at night.

2.9 Meteorological Observations

Instantaneous conditions are usually recorded hourly, but this may be reduced to three hourly. The standard set of observations include water temperature, air temperature, true wind speed and direction, total cloud cover, visibility, and current weather. On most research vessels, water temperature, air temperature and wind speed and direction will be displayed on the bridge, and may even be logged for the duration of the voyage. Cloud cover can be estimated by the observer in eighths, and visibility is estimated in kilometres from the ship. Wind speed is recorded in ms^{-1} and wind direction relative to north (°T). The current weather is recorded using the Australian meteorological observer's two digit codes that are provided in appendix 3 [*Australian Bureau of Meteorology*]. Only a subset of these codes, pertinent to Antarctic conditions, has been included in the software.

2.10 Photographic Records

During daylight hours a photographic record of ice conditions can be kept. Slides are usually taken from the bridge at the time of each observation, and the log book has a column for recording film and frame numbers. There is also scope for recording the frame number for a time lapse video recorder which the authors have mounted on the ship's rail. This captures a single video frame every 8 seconds, providing a comprehensive visual record of ice conditions on a single video tape for each 30 day period. This photographic archive is not generally used for quantitative analyses, but provides an excellent reference that can be used in conjunction with the ship-based observations. At night the camera is angled closer to the ship to view an area that can be adequately lit by flood lights mounted on the ship's rail.

2.11 Comments

In addition to the hourly observations entered by code, there is scope for additional comments to be recorded. These usually include a brief description of the characteristics of the pack, in particular features which are not covered by the observation codes, such as frost flowers on dark nilas or swell penetrating the pack. Brief details of sampling sites, buoy deployments or other 'on ice' activities may also be recorded and, if necessary, a comment on how typical the ice along the ship's route is of the surrounding region. The *Ref. no.* column enables the observer to easily reference comments made on the *Additional Comments* proforma.

3.0 DATA ENTRY AND PROCESSING

Software has been written to enable the ship-based observations to be entered and processed on a PC. A comprehensive user operating manual for this software is presented in Part II of this report. A summary of the main features is presented below.

3.1 Quality control

Checks are made to identify errors and inconsistencies in the data. These include, but are not limited to:

- snow thicker than ice
- thin ice types greater than 0.1 m thick
- total concentration greater than 10/10, or not adding up to the sum of the concentrations of the three dominant categories

- ice thickness categories not matching assigned thickness values
- topography or floe size codes incompatible with ice type (e.g., consolidated ridges on nilas)
- primary ice category thinner than secondary or tertiary categories
- distance between consecutive hourly observations greater than 20 km.

The program checks the data for each hourly entry, and prompts the user when erroneous or anomalous data are entered. When entries are clearly wrong, the quality control software will insist that the correct data be entered, and will not accept the record until corrections are made. In cases when the data appear to be wrong but in fact represent unusual ice conditions (e.g., unusually thick snow on thin nilas), the quality control software will accept the entry after it has been flagged and checked. See Part II, Sections 2.6 and 3.4 for more details on data quality control.

3.2 Editing data

The data set may be edited to exclude observations within a prescribed distance of the previous observation. This is to prevent biasing in areas of heavy ice where the ship's speed is reduced. The distance is usually set to 6 nautical miles, corresponding to a straight line speed of 6 knots which most ice breakers are capable of maintaining in moderate pack ice. The processing software enables the user to specify this distance, or to use all observations regardless of spacing.

Observations are also removed when there is obvious biasing caused by the ship following easily navigable routes. The most common example of this is near the ice edge, when the ship may constantly pick its way through leads. This is usually avoidable on voyages dedicated to sea ice research, but may otherwise prove to be a problem. It is at the discretion of the observer to either note that the data may be biased, or not record data under such circumstances.

3.3 Estimating the area-averaged ice and snow thicknesses

Estimates of the area-averaged ice and snow thicknesses may be made over the ice covered region of the pack only, or for the total pack ice zone including the open water fraction. Each observation is equally weighted unless eliminated by the minimum distance rule described above. For each hourly observation, the estimated ice thickness values for each of the three dominant ice thickness categories are weighted by the ice concentration. This provides a mean thickness of the level ice within the pack.

To account for the mass of ice in ridges, the observations described in section 2.5 are used in conjunction with a simple model to calculate a corrected mean floe thickness (z_r). The model takes the undeformed floe thickness (z_u), average sail height (S) and an estimate of the areal extent of surface ridging (R) as input parameters, and calculates the mean thickness of the floe (z_r), assuming a triangular sail, isostasy and a ratio of ice and snow above sea level to ice below sea level as 5:1. The assumption of a triangular sail cross section is consistent with the formulation of *Hibler et al.* [1974] for calculating the effective thickness of ridged ice. Their formulation used a fixed slope angle of 26°; however the present study uses an implied variable slope angle which is dependent upon the areal coverage of ridges and the average sail height. In this way broader ridges are flatter which is consistent with the theory that ridges should build laterally once the limiting height is reached [*Tucker and Govoni*, 1981]. The assumption of a triangular ridge is therefore not likely to induce large errors. Published literature on sea ice density is sparse; however *Buynitskiy* [1967] presented mean densities from East Antarctic sea ice for summer and winter ice of 875 kg m^{-3} and 920 kg m^{-3} respectively, and these are consistent with the value of 900 kg m^{-3} used in the model formulation. The assumption of hydrostatic equilibrium must also hold on the large scale; however the effect of snow drifts around ridges may induce errors in both the observations and the model. In particular, observers may not be able to differentiate ridge sails from adjoining snow drifts, hence the observations of the areal coverage (and to a lesser extent, height) of ridging will include the fraction covered by snow. This will affect the value r defined as the ratio of ice thickness below sea level to the combined thickness of ice and snow above sea level. Hence, the assumption that ridge sails are solid ice with a density of 900 kg m^{-3} is incorrect, and this is accounted for in the model.

To determine r in the vicinity of ridges, data from drilled thickness transects that intersected ridges were examined. Only transects, or parts thereof, with peaks in freeboard >0.5 m were considered, and the mean ice and snow thicknesses were calculated. A total of 339 drill holes from 9 thickness transects had mean ice and snow thicknesses of 1.18 m and 0.16 m respectively. By assuming densities of 900 kg m^{-3} and 360 kg m^{-3} for ice and snow respectively the mean draft was calculated to be 1.12 m. Hence, $r = 5$ in areas of ridged ice. The snow density value was derived from data collected on two voyages to the East Antarctic pack (V9 92/93 and V1 95/96), with a mean value of 360 ± 110 kg m^{-3} over the range 120–760 kg m^{-3}.

In order to calculate only the thickness of ice in ridges it is necessary to remove the snow from the calculation. The ratio of ice below sea level:ice above, r', is defined as:

$$r' = [1-(0.16/1.18)]r = 4.3 \tag{3.1}$$

based on the mean ice and snow thicknesses given above. The value r'= 4.3 compares well with the value of 4 used by *Dierking* [1995], which was based on drilled transect measurements by *Lange and Eicken* [1991a] and *Wadhams et al.* [1987].

The model formulation to calculate the average thickness of ridged floes (z_r) can now be written as:

$$z_r = (r'+1)(0.5RS) + z_u \tag{3.2}$$

where R is the areal extent of surface ridging, S is the average sail height of ridges, and z_u is the thickness of level (undeformed) ice in the floe.

3.4 Calculating area-averaged albedo

The area-averaged albedo is computed from the ice concentration and allwave albedo for each ice type. The allwave albedo values for different ice and snow thickness categories were originally taken from *Allison et al.* [1993]; however these have recently been updated [*Warren*, personal communication, 1998]. The average albedo is calculated over the entire pack, including the open water fraction. A value is calculated at each hourly observation site, from which zonal averages may also be calculated.

4.0 TYPICAL RESULTS

A summary of the results from ship-based observations collected in the East Antarctic pack ice is presented, to indicate the usefulness of the data. For a complete presentation of results readers are referred to *Allison et al.* [1993], *Allison and Worby* [1994], and *Worby et al.* [1998]. Results from work conducted in the Bellingshausen and Amundsen Seas are presented in *Worby et al.* [1996b].

In the East Antarctic, ship-based sea ice observations have been collected on 18 voyages between October 1986 and August 1995. The voyage tracks are shown in Figure 4.1, and a summary of the seasonal coverage of the data are presented in Table 4.1. The combined data set from all voyages have been used to describe the seasonal cycle of the sea ice thickness distribution around East Antarctica. The complete data set (1986–1995) comprises 2419 observations, with the highest

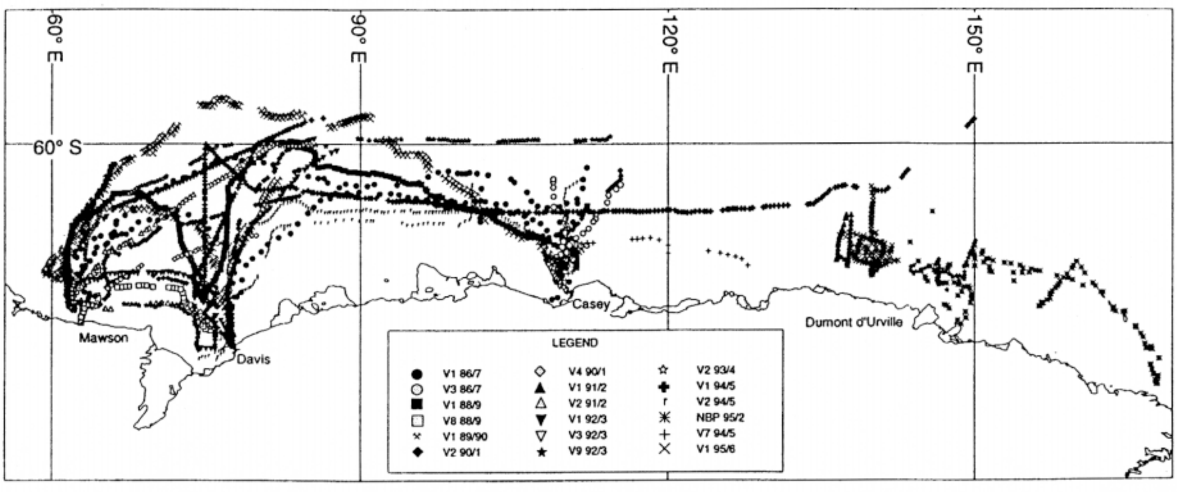

Figure 4.1. Voyage tracks for 18 voyages to the East Antarctic pack ice between 1986 and 1996 on which ship-based observations have been collected.

concentration of observations en route to, and in the location of, the three Australian Antarctic stations. The majority of the data have been collected during spring, and most years have observations in October and November. There are also observations in March, April, May, September and December in some years. The data have been categorised by month, and binned into 0.2 m thickness categories. The mean monthly ice and snow thickness distribution curves are shown in Figures 4.2 (a) and (b).

There are sufficient data in seven months (March–April and August–December) to draw statistically meaningful conclusions about the thickness distribution of the sea ice and snow cover in this region of the Antarctic ice pack. Currently there is still a large gap in the data set during the early winter months, with very little or no data in May, June and July. By far the greatest seasonal changes in the ice thickness distribution are in the open water and thin ice categories. The amount of open water decreases from almost 60% in December to little more than 10% in August, and the thinnest ice thickness category (0–0.2 m) shows a 30% seasonal change between December and March. In contrast, the amount of ice greater than 1.0 m shows very little seasonal variability.

Table 4.1. Summary of the mean ice concentration, and undeformed ice and snow thickness values from ship-based observations

Month	Number of Voyages	Number of Observations	Mean Ice Concentration	Mean Ice Thickness (m)	Mean Snow Thickness (m)
March	3	92	76	0.36	0.02
April	3	129	83	0.48	0.11
August	1	165	93	0.52	0.11
September	1	246	82	0.47	0.12
October	10	595	75	0.35	0.07
November	8	1129	64	0.36	0.07
December	4	63	43	0.31	0.07

The mean values are calculated over the entire pack ice, including the open water fraction. Note that the mean ice and snow thickness values for March exclude the anomalously thick multi-year floes (shown in Figure 12) observed on the March 1995 voyage near 150°E.

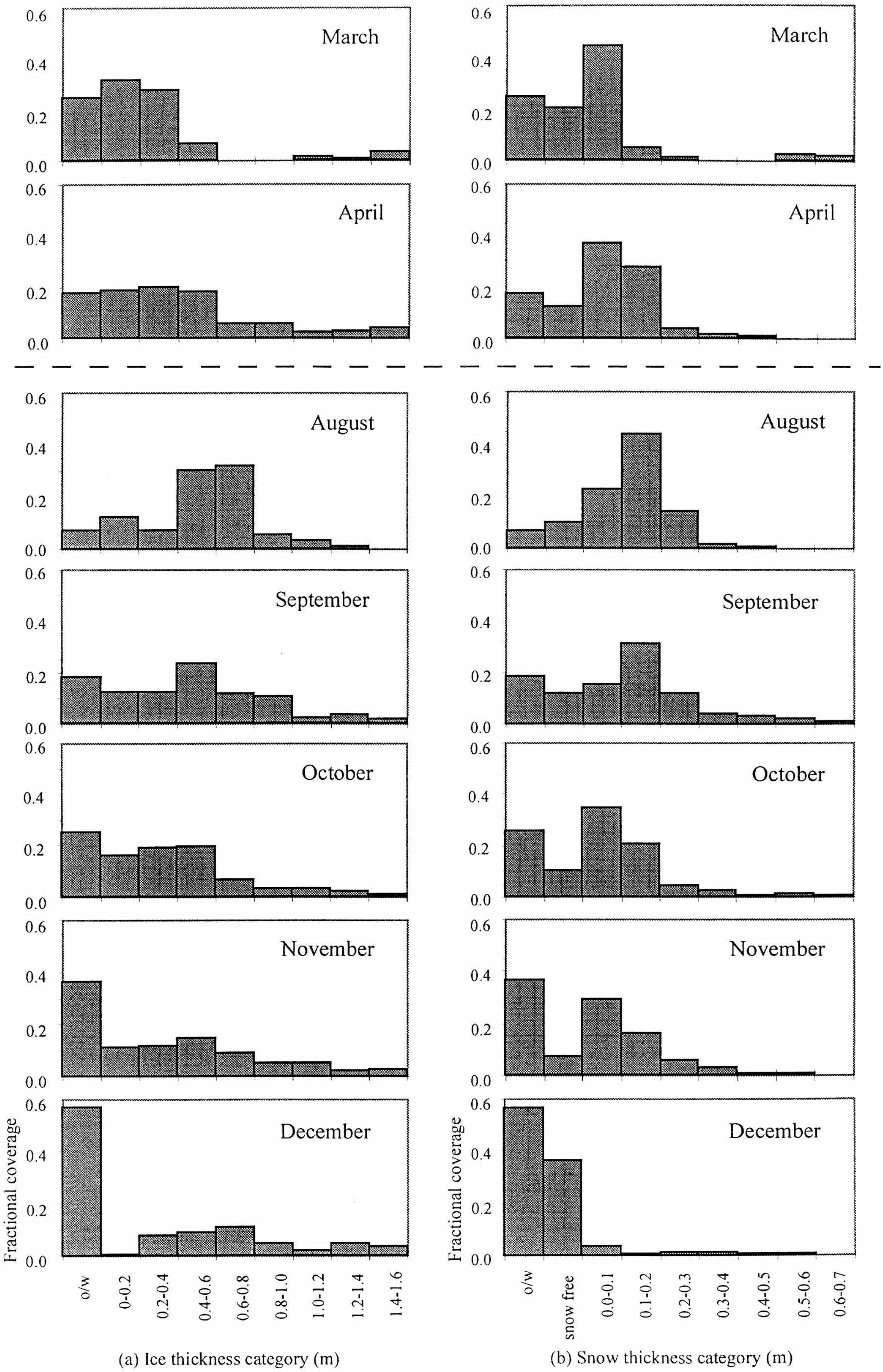

Figure 4.2. Monthly ice and snow thickness distributions determined from all available ship-based sea ice observations.

The discussion of Figures 4.2(a) and (b) focuses on the months of March, August, October and December. In March, there is approximately 25% open water and an additional 60% of ice less than 0.4 m, indicative of rapid new ice growth over large areas of the Southern Ocean. Most of this ice has a thin snow cover with less than 10% greater than 0.1 m. In August, the pack is quite consolidated, and the open water fraction averages only 12%. There is only a small percentage of ice less than 0.4 m thick due to cold air temperatures at this time of year quickly refreezing leads to greater than 0.4 m, and also due to the effects of deformation. This is supported by observations in the winter pack showing that ice may quickly grow to more than 0.4 m [*Worby et al.*, 1996a]. Hence, only a small fraction of the pack is comprised of open water and thin ice, the opposite of the March distribution, but the snow cover is predominantly less than 0.2 m.

By October, two changes in the ice growth regime contribute to the flattening of the thickness distribution curve. First, leads do not refreeze as quickly as observed in August, increasing the amount of ice less than 0.7 m thick. Second, the ice does not grow to the same thickness, primarily because of increased radiation and warmer air temperatures. As a result, there is more open water and thin ice within the pack, typically with a thinner snow cover. As the pack diverges, ice is slower to form, leading to an increase in the open water fraction, and a subsequent warming of the surface ocean water. This is a positive feedback which further limits ice production, and may result in some ice melt. The distribution curve for December reflects this, showing the greatest open water fraction, no ice thinner than 0.2 m, and a considerable decrease in the ice types thinner than 0.6 m.

The ice thickness distribution curves for the intervening months are consistent with the discussion above. April shows a flatter distribution than March, which is indicative of less new ice growth over large areas, and the formation of thicker ice by dynamical processes. The September curve flattens between the thinnest category and the 0.4–0.6 m category, which is consistent with the trend between August and October. November, in turn, shows an increase in open water fraction and further flattening of the distribution curve in response to the divergence of the pack and limited new ice growth.

The surface topography observations used as input to the ridging model described in section 3.3 have been collected on voyages to the East Antarctic pack since 1992. These data show that by incorporating the ridged ice, the mean thickness increases by, on average, 1.7 times the observed mean undeformed ice thickness. Individual voyages show increases of between 1.3–2.3 times.

5.0 ACKNOWLEDGEMENTS

The authors are grateful to Vicky Lytle and Rob Massom for their comments and input to the ice observation scheme. Thanks also to Steve Ackley, Martin Jeffries, Christian Haas and Steve Warren who have trialed the observation scheme on numerous Antarctic voyages and provided valuable feedback. Individual observers who have contributed to the success of the program over the past decade are too numerous to name individually; the authors are grateful for the contributions of each one. This publication has been produced in conjunction with the SCAR Global Change and the Antarctic (GLOCHANT) Antarctic Sea Ice Processes and Climate (ASPeCt) program.

6.0 REFERENCES

Ackley, S. F., Mass-balance aspects of Weddell Sea pack ice, *J. Glaciol.*, *24* (90), 391-405, 1979.

Allison, I., R. E. Brandt, and S. G. Warren, East Antarctic sea ice: albedo, thickness distribution, and snow cover, *J. Geophys. Res.*, *98* (C7), 12,417-12,429, 1993.

Allison, I., and A. P. Worby, Seasonal changes of sea-ice characteristics off East Antarctica, *Ann. Glaciol.*, *20*, 195-201, 1994.

Armstrong, T., B. Roberts, and C. Swithinbank, *Illustrated Glossary of Snow and Ice*, Special Publication, 4, 60 pp., Scott Polar Research Institute, 1973.

Australian Bureau of Meteorology, *Recording and encoding weather observations*. Publication B 220, Catalogue No. 216610, 38 pp.

Bush, G., A. J. Duncan, J. D. Penrose, and I. Allison, Acoustic reflectivity of Antarctic sea ice at 300 kHz, in *Proceedings of the 3rd European conference on underwater acoustics*, pp. 883-888, Heraklion, Crete, Greece, 1996.

Buynitskiy, V. K., Structure, principal properties, and strength of Antarctic sea ice, *Sov. Antarct. Exped. Inform. Bull.*, *65*, 504-510, 1967.

Comiso, J., T. Grenfell, D. Bell, M. Lange, and S. Ackley, Passive microwave observations of winter Weddell Sea ice, *J. Geophys. Res.*, *95* (8), 10,891-10,905, 1989.

Comiso, J. C., and H. J. Zwally, Concentration gradients and growth/decay characteristics of the seasonal sea ice cover, *J. Geophys. Res.*, *89* (C5), 8081-8103, 1984.

Eicken, H., M. A. Lange, H.-W. Hubberten, and P. Wadhams, Characteristics and distribution patterns of snow and meteoric ice in the Weddell Sea and their contribution to the mass balance of sea ice, *Ann. Geophys.*, *12* (1), 80-93, 1994.

Haas, C., Evaluation of ship-based electromagnetic-inductive thickness measurements of summer sea ice in the Bellingshausen and Amundsen Seas, Antarctica, *Cold Regions Sci. Technol., 27*, 1-16, 1998.

Gloersen, P., and D. J. Cavalieri, Reduction of weather effects in the calculation of sea ice concentration from microwave radiances, *J. Geophys. Res.*, *91* (C3), 3913-3919, 1986.

Hibler, W. D., III, S. J. Mock, and W. B. Tucker, III, Classification and variation of sea ice ridging in the western Arctic Basin, *J. Geophys. Res.*, *79* (18), 2735-2743, 1974.

Jeffries, M. O., and W. F. Weeks, Structural characteristics and development of sea ice in the western Ross Sea, *Antarct. Sci.*, *5* (1), 63-75, 1992.

Lange, M. A., Antarctic sea ice: its development and basic properties, in *Proceedings of the International Conference on the Role of the Polar Regions in Global Change*, pp. 275-283, University of Alaska Fairbanks, Fairbanks, Alaska (June 1990), 1991.

Parkinson, C. L., *Sea ice in the polar regions*, a module in the CD-ROM *Sea ice in the polar regions and the Arctic observatory*, Consortium for International Earth Science Information (CIESIN), University Center, Michigan, 1996.

Steffan, K., *Atlas of the sea ice types. Deformation processes and openings in the ice. North Water project*, *Zürcher Geographische Schriften, 20*, 55 pp., Geographisches Institut, Eidgenössische Technische Hochschule, Zürich, 1986.

Strass, V. H., and E. Fahrbach, Temporal and regional variation of sea ice draft and coverage in the Weddell Sea obtained from upward looking sonars, in Jeffries, M. O. (ed) *Antarctic Sea Ice: Physical Processes, Interactions and Variability, Antarctic Research Series, 74*, 123-139, 1998.

Tucker, W. B., III, and J. W. Govoni, Morphological investigations of first-year sea ice pressure ridge sails, *Cold Reg. Sci. Technol.*, *5*, 1-12, 1981.

Wadhams, P., M. A. Lange, and S. F. Ackley, The ice thickness distribution across the Atlantic sector of the Antarctic Ocean in midwinter, *J. Geophys. Res.*, *92* (C13), 14,535-14,552, 1987.

WMO, World Meteorological Organisation Sea-Ice Nomenclature: Terminology, Codes and Illustrated Glossary, *WMO/OMM/BMO 259, TP 145*, World Meteorological Organisation, Geneva, Switzerland, 1970.

Worby, A. P. *Seasonal variations in the thickness distribution and snow cover of Antarctic sea ice in the region 60°-150°E*, PhD thesis, 195 pp., University of Tasmania, Hobart, Tasmania, Australia, 1998.

Worby, A. P. *Observing Antarctic Sea Ice: A practical guide for conducting sea ice observations from vessels operating in the Antarctic pack ice*. A CD-ROM produced for the Antarctic Sea Ice Processes and Climate (ASPeCt) program of the Scientific Committee for Antarctic Research (SCAR) Global Change and the Antarctic (GLOCHANT) program, Hobart, Australia, 1999.

Worby, A. P., and I. Allison, Ocean-atmosphere energy exchange over thin, variable concentration Antarctic pack-ice, *Ann. Glaciol.*, *15*, 184-190, 1991.

Worby, A. P., N. L. Bindoff, V. I. Lytle, I. Allison, and R. A. Massom, Winter sea ice/ocean interactions studied in the East Antarctic, *EOS Trans. AGU*, *77* (46), 453, 456-457, 1996a.

Worby, A. P., P. Griffen, V. I. Lytle and R. A. Massom, On the use of electromagnetic induction sounding to determine winter and spring sea ice thickness in the Antarctic, *Cold Regions Sci. Technol.*, in press.

Worby, A. P., M. O. Jeffries, W. F. Weeks, K. Morris, and R. Jaña, The thickness distribution of sea ice and snow cover during late winter in the Bellingshausen and Amundsen Seas, Antarctica, *J. Geophys. Res.*, *101* (C12), 28,441-28,455, 1996b.

Worby, A. P., R. A. Massom, I. Allison, V. I. Lytle, and P. Heil, East Antarctic sea ice: A review of its structure, properties and drift, in *Antarctic sea ice physical processes, interactions and variability, Antarct. Res. Ser., 74*, edited by M. O. Jeffries, pp. 41-67, American Geophysical Union, Washington, D.C., 1998.

7.0 APPENDIX 1

BLANK OBSERVATION SHEETS AND CODES

Day/Date (Z):

hr (Z)	POSITION Lat (°S) dd mm	Long (°E/W) ddd mm	SEA ICE OBSERVATIONS Conc. (tenths)	PRIMARY c ty z f t s sz	SECONDARY c ty z f t s sz	TERTIARY c ty z f t s sz	O/W	hr (Z)
0								0
1								1
2								2
3								3
4								4
5								5
6								6
7								7
8								8
9								9
10								10
11								11
12								12
13								13
14								14
15								15
16								16
17								17
18								18
19								19
20								20
21								21
22								22
23								23

NOTES:
* PRIMARY SEA ICE IS OF GREATEST THICKNESS. HENCE ty1 > ty2 > ty3

Day/Date (Z):

	METEOROLOGICAL OBSERVATIONS						PHOTO	VIDEO	COMMENTS		OBSERVER	
hr (Z)	Twater (°C)	Tair (°C)	Wind (sp/d)	Cloud (oktas)	Visib (v)	Weath (ww)	Film/ Frame	Tape No./ Reading	Text	Ref. no.	Name	hr (Z)
0												0
1												1
2												2
3												3
4												4
5												5
6												6
7												7
8												8
9												9
10												10
11												11
12												12
13												13
14												14
15												15
16												16
17												17
18												18
19												19
20												20
21												21
22												22
23												23

NOTES:
* ADDITIONAL COMMENTS MAY BE MADE ON THE FOLLOWING PAGE, PROVIDING DUE REFERENCE IS GIVEN

ADDITIONAL COMMENTS

Ref.	Comment	Ref.	Comment

ICE TYPE (ty)

10	Frazil
11	Shuga
12	Grease
20	Nilas
30	Pancakes
40	Young grey ice, 0.1-0.15 m
50	Young grey-white ice, 0.15-0.3 m
60	First year, 0.3-0.7 m
70	First year, 0.7-1.2 m
80	First year, >1.2 m
85	Multiyear floes
90	Brash
95	Fast ice

ICE CONC^{n} (c)
to be expressed in tenths

SEA ICE (z) AND SNOW THICKNESS (sz)
to be expressed in centimetres

FLOE SIZE (f)

100	Pancakes
200	New sheet ice
300	Brash/broken ice
400	Cake ice, <20 m
500	Small floes, 20-100 m
600	Medium floes, 100-500 m
700	Large floes, 500-2000 m
800	Vast floes, >2000 m

TOPOGRAPHY (t)

100	Level ice
200	Rafted pancakes
300	Cemented pancakes
400	Finger rafting
5xy	New, unconsolidated ridges (no snow)
6xy	New ridges filled with snow or a snow cover
7xy	Consolidated ridges (no weathering)
8xy	Older, weathered ridges

x values:

0	0-10% areal coverage
1	10-20%
2	20-30%
3	30-40%
4	40-50%
5	50-60%
6	60-70%
7	70-80%
8	80-90%
9	90-100%

y values:

1	0.5 m av. sail height
2	1.0 m
3	1.5 m
4	2.0 m
5	3.0 m
6	4.0 m
7	5.0 m

SNOW TYPE (s)

0	No snow observation
1	No snow, no ice or brash
2	Cold new snow, <1 day old
3	Cold old snow
4	Cold wind-packed snow
5	New melting snow (wet new snow)
6	Old melting snow
7	Glaze
8	Melt slush
9	Melt puddles
10	Saturated snow (waves)
11	Sastrugi

OPEN WATER

0	No openings
1	Small cracks
2	Very narrow breaks, <50m
3	Narrow breaks, 50-200 m
4	Wide breaks, 200-500 m
5	Very wide breaks, >500 m
6	Lead/coastal lead
7	Polynya/coastal polynya
8	Water broken only by small scattered floes
9	Open sea

Meteorological Observation Codes

The meteorology codes are used to describe the weather conditions at the time of the sea ice observations. They are taken from the Australian Bureau of Meteorology Observers Handbook. Only those conditions pertinent to Antarctic conditions are reproduced here.

Cloud Development During Past Hour Codes (00–03)

00: Cloud development not observed or not observable
01: Clouds dissolving or becoming less developed
02: State of sky on the whole unchanged
03: Clouds forming or developing

Fog/Precipitation During Past Hour But Not At Time Of Obs (20–28)

20: Drizzle not freezing or snow grains
21: Rain not freezing or snow grains
22: Snow not freezing or snow grains
23: Rain and snow, or ice pellets
24: Drizzle or rain, freezing
25: Showers of rain
26: Showers or snow or of rain and snow
27: Showers of hail or of hail and rain
28: Fog in the past hour, not at present

Blowing or Drifting Snow (36–39)

36: Drifting snow, below eye level, slight/moderate
37: Drifting snow, below eye level, heavy
38: Blowing snow, above eye level, slight/moderate
39: Blowing snow, above eye level, heavy

Fog/ Mist (41–49)

41: Fog in patches, visibility <1000 m
42: Fog thinning in last hour, sky discernible, visibility <1000 m
43: Fog thinning in last hour, sky not discernible, visibility <1000 m
44: Fog unchanged in last hour, sky discernible, visibility <1000 m
45: Fog unchanged in last hour, sky not discernible, visibility <1000 m
46: Fog beginning/thickening in last hour, sky discernible, visibility <1000 m
47: Fog beginning/thickening in last hour, sky not discernible, visibility <1000 m
48: Fog depositing rime, sky discernible, visibility <1000 m
49: Fog depositing rime, sky not discernible, visibility <1000 m

Precipitation As Drizzle (50–59)

50: Slight drizzle, intermittent
51: Slight drizzle, continuous
52: Moderate drizzle, intermittent
53: Moderate drizzle, continuous
54: Dense drizzle, intermittent
55: Dense drizzle, continuous
56: Freezing drizzle, slight
57: Freezing drizzle, moderate or dense
58: Drizzle and rain, slight
59: Drizzle and rain, moderate or dense

Precipitation As Rain, Not Showers (60–69)

60: Slight rain, intermittent
61: Slight rain, continuous
62: Moderate rain, intermittent

63: Moderate rain, continuous
64: Heavy rain, intermittent
65: Heavy rain, continuous
66: Freezing rain, slight
67: Freezing rain, moderate or heavy
68: Rain or drizzle and snow, slight
69: Rain or drizzle and snow, moderate/heavy

Frozen Precipitation, Not Showers (70–79)

70: Slight fall of snow flakes, intermittent
71: Slight fall of snow flakes, continuous
72: Moderate fall of snow flakes, intermittent
73: Moderate fall of snow flakes, continuous
74: Heavy fall of snow flakes, intermittent
75: Heavy fall of snow flakes, continuous
76: Ice prisms, with/without fog
77: Snow grains, with/without fog
78: Isolated starlike snow crystals
79: Ice pellets

Precipitation As Showers (80–90)

80: Slight rain showers
81: Moderate or heavy rain showers
82: Violent rain showers
83: Slight showers of rain and snow
84: Moderate/heavy showers of rain and snow
85: Slight snow showers
86: Moderate or heavy snow showers
87: Slight showers of soft or small hail
88: Moderate/heavy showers of soft/small hail
89: Slight showers of hail
90: Moderate or heavy showers of hail

Visibility Codes

The visibility codes are used to estimate how far an observer can see from the ship's bridge.

90: <50 m
91: 50–200 m
92: 200–500 m
93: 500–1000 m
94: 1–2 km
95: 2–4 km
96: 4–10 km
97: >10 km
-1: Not available

8.0 APPENDIX 2

EXAMPLES OF COMPLETED OBSERVATION SHEETS

Day/Date (Z): 31 July 1995 DAY 212

	POSITION					SEA ICE OBSERVATIONS																						
hr	Lat (°S)		Long (°E/W)		Conc.	PRIMARY							SECONDARY							TERTIARY							O/W	hr
(Z)	dd	mm	ddd	mm	(tenths)	c	ty	z	f	t	s	sz	c	ty	z	f	t	s	sz	c	ty	z	f	t	s	sz		(Z)
0																												0
1	63	22	139	47	8	1	80	150	500	833	4	15	5	60	50	400	601	3	10	2	10	2	-	-	-	-	2	1
2	63	39	139	50	9	3	60	50	400	621	4	10	6	50	30	500	100	2	5								1	2
3	63	39	139	51	9	4	70	80	500	621	4	15	5	60	60	500	611	3	10								1	3
4	63	46	139	52	8	2	70	100	400	641	4	10	6	60	70	500	100	3	5								1	4
5	63	50	140	09	0																						7	5
6																												6
7																												7
8																												8
9	63	56	140	11	9	1	80	120	500	642	4	60	5	70	80	400	621	4	30	3	90	20	300	-	1	0	4	9
10	64	02	140	06	9	3	80	150	500	642	4	30	3	70	90	400	611	4	20	3	60	50	400	100	3	10	1	10
11	64	08	140	03	9	3	80	140	500	642	4	30	5	70	70	500	100	4	15	1	90	30	300	-	1	0	1	11
12	64	13	140	00	9	3	80	160	500	632	4	30	3	70	80	500	611	4	20	3	60	50	400	100	4	10	1	12
13	64	17	139	53	9	3	80	140	500	632	4	25	5	70	90	500	611	4	15	1	60	50	500	100	3	10	1	13
14	64	17	140	04	10	2	80	120	500	612	4	30	8	60	60	500	611	4	10								1	14
15	64	17	140	14	9	3	70	70	500	621	4	20	6	60	60	500	601	4	10								1	15
16	64	21	140	20	9	4	70	100	500	621	1	20	5	60	60	600	601	2	10								1	16
17	64	25	140	20	10	10	60	70	700	632	1	10															1	17
18																												18
19																												19
20	64	26	140	20	9	9	60	40	700	100	3	5															2	20
21																												21
22	64	33	140	20	9	1	70	90	600	721	3	15	5	60	50	700	601	2	7	3	50	20	600	100	2	2	2	22
23	64	37	140	20	10	4	70	70	800	100	2	12	6	60	50	800	100	2	7								0	23

NOTES:
* PRIMARY SEA ICE IS OF GREATEST THICKNESS. HENCE ty1 > ty2 > ty3

Day/Date (Z): 31 JULY 1995 DAY 212

hr (Z)	METEOROLOGICAL OBSERVATIONS: Twater (°C)	Tair (°C)	Wind (sp/d)	Cloud (oktas)	Visib (v)	Weath (ww)	PHOTO: Film/ Frame	VIDEO: Tape No./ Reading	COMMENTS: Text	Ref. no.	OBSERVER: Name	hr (Z)
0									CTD station		Anton	0
1	-1.68	-0.7	24/020	8	93	73	-	0:01:27		1	Anton	1
2	-1.67	-0.5	27/037	8	93	73	1/3	0:01:42		2	Petra	2
3	-1.71	-0.4	30/030	8	93	73	1/4	0:01:57		3	Rob	3
4	-1.67	-0.6	21/346	8	96	02	1/5	0:02:12		4	Petra	4
5	-1.65	-0.8	16/342	7	94	01	-	0:02:28	Approaching polynya for CTD.	5	Petra	5
6												6
7									CTD Station			7
8												8
9	-1.80	-1.8	16/003	8	96	71	-	0:03:25			Tony	9
10	-1.80	-2.2	16/009	8	96	71	-	0:03:41			Tony	10
11	-1.81	-1.8	9/027	8	96	71	-	0:03:56	Turned video off - dark	6	Tony	11
12	-1.79	-1.9	9/031	8	96	71	-	-			Tony	12
13	-1.80	-2.3	16/057	8	96	71	-	-		7	Tony	13
14	-1.80	-4.2	13/078	8	96	71	-	-		8	Vicky	14
15	-1.78	-4.4	9/087	8	96	71	-	-		9	Vicky	15
16	-1.80	-5.9	10/110	8	96	71	-	-		10	Vicky	16
17	-1.78	-6.4	9/120	8	94	46	-	-		11	Vicky	17
18									CTD Station			18
19												19
20	-1.8	-1.9	12/124	8	94	73	-	-		12	Anton	20
21										13	Anton	21
22	-1.65	-0.9	15/100	8	94	73	-	-			Ian	22
23	-1.77	-0.5	18/090	8	93	70	-	0:03:56	Turned video on.	14	Anton	23

NOTES:
* ADDITIONAL COMMENTS MAY BE MADE ON THE FOLLOWING PAGE, PROVIDING DUE REFERENCE IS GIVEN

ADDITIONAL COMMENTS

Ref.	Comment
1	Just departed CTD Station
2	Snow accumulating on floes. Many floes overwashed with sea water. Swell ~1.5m, 7s period
3.	Swell ~1m. Large expanses of flat, fragmented grey-white ice interspersed with older rubble floes. Wind blowing snow across floes to form dune features.
4.	Nearly no swell. Large open water areas within pack in this region. Photo from port side.
5.	Ship moving toward a polynya for CTD. No swell.
6.	Some very thick floes >2m freeboard. Swell increased to ~2m, $\lambda \sim 200m$, moving through pack from NW. Very little thin ice, but brash between thicker floes. Heavy snow cover on most floes.
7.	Have been moving through alternate bands of heavy ridged ice and thinner ice/open water. Swell diminished.
8.	Heading E to locate suitable CTD site. Floes mostly broken (<100m) but not much ridging.
9.	Swell barely perceptible.
10.	Heading South again.
11.	Floe size increased significantly shortly after last observation. Large, vast floes all appear to have same origin + thickness. Some flooding on the edges of ridges. Visibility decreased.
12.	On station
13.	Moving off station
14.	Have turned video camera on again.

PART II

USER OPERATING MANUAL FOR SOFTWARE

1.0 INTRODUCTION

1.1 General Description

This program seaice.exe facilitates the digitising, quality control and processing of ship-based observations of Antarctic sea ice characteristics. It is designed for use in conjunction with, but not to replace, the handwritten sea ice observation log sheets. The program allows the user to supply and verify all observation data via a dialog box user interface. The advantages of this are:

- The data are entered and quality controlled during the voyage. All data quality checking is performed at the time the data are entered, enabling any errors or ambiguities to be identified and fixed at the time of the observation. The data quality checks are described in section 6.1.
- Data entry is via a series of dialog boxes, thus reducing the possibility of input errors by the user.
- Initial data processing can be completed during the voyage. Calculations include mean ice and snow thicknesses and the fraction of different ice types within the pack. These can be calculated on the entire data set or any subset of it defined by a range of dates, or latitude and longitude. Furthermore the statistics may be calculated on multiple data files.
- The program can plot sea ice and meteorological observations on an XY Cartesian graph, and geographical plots (to show ship tracks) on a polar stereographic map (south only). Geographical plots may include the Antarctic coastline and station locations.

1.2 Data File Format

The program stores observation records to a disk file in binary format. Thus the files cannot be viewed or printed directly. The reason for using a binary file format is to simplify reading and writing complex data records to disk reliably and rapidly. The program provides a facility to create text file listings from binary data files. These text files can be viewed and printed. The minimum hardware configuration to run the program is:

- IBM-PC or compatible with 4MB of memory.
- Windows 3.11 or higher.
- Colour graphics display with pixel resolution better than 800 x 600, 16 colours. Screens with a lower resolution (e.g., 640 x 480) will work but are not as practical.
- 400 kbytes of disk space is required for the program, as well as sufficient disk space for the data files. Each hourly observation requires approximately 550 bytes of disk space.

1.3 Installation

To install the program, create a subdirectory on the hard disk where the program will reside. Then copy all the required files as described at the front of this report. The program should be run from Windows.

2.0 USER MANUAL

2.1 The main Screen Layout

Running the program will produce a main screen which displays a table of daily sea ice observations. The screen has a spreadsheet format similar to the proforma for the hand-written observations. This is illustrated in Figure 2.1. Note that all the fields are initially empty, and that a log file must be loaded before it can be displayed. The screen is divided into the following sections:

- **Menu Bar** — The individual menus are described in the next section.
- **Main titles** — Log file name, Date and Julian Day fields.

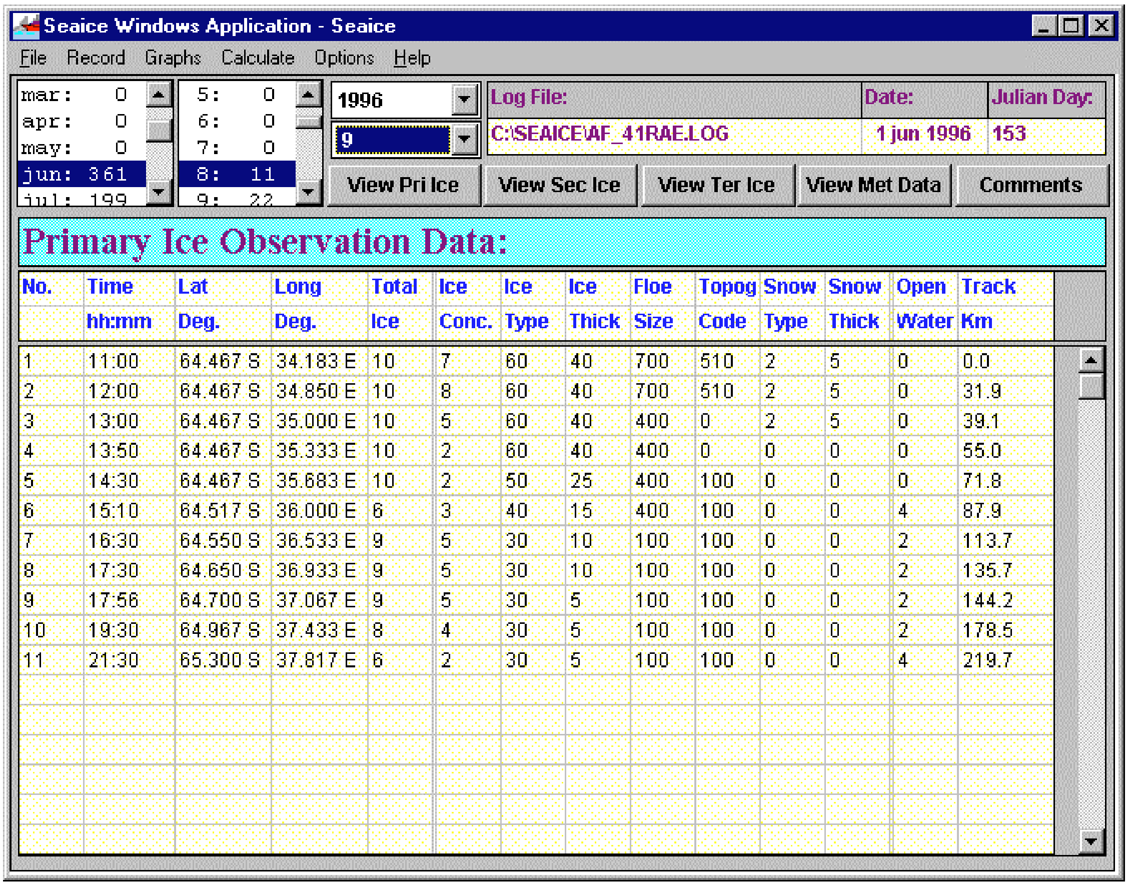

Figure 2.1. The main window

- **Five buttons** — View Primary Ice, View Secondary Ice, View Tertiary Ice, View Met Record and View Comments. These buttons are used to display individual parts of the record.

- **Title for data** — This is shown in blue. It indicates which field is currently displayed, i.e., Primary Ice Observation Data, Secondary Ice Observation Data, Tertiary Ice Observation Data, Meteorological Observation Data, or Ice Observation Comments depending on which of the five buttons above is selected.

- **Table header** — *Primary/Secondary/Tertiary ice*: Displays the record number, time, latitude, longitude and total ice concentration. Additionally, the ice concentration, ice type and thickness, floe size, topography, snow type, snow thickness, distance along track from the first observation, and open water codes are displayed for each of the primary, secondary and tertiary ice types. The ice and snow thickness values are in units of cm. All other entries are in the specified codes.

  Meteorological Data: Displays the record number, time, latitude, longitude, sea temperature, air temperature, wind speed, wind direction, photo-film, photo-frame numbers, video counter, visibility, cloud cover, and current weather codes.

  Comments: Displays the record number, time, latitude, longitude, and comments from the ice observation record.

- **Months List box** — To display the data for a different month, click on the month, and the list box to the right (Day:) will display the number of daily records for that particular month. Click on one of the days listed to display the contents on screen.
- **Day List box** — To display the data for a different day, click on the day number, and the program will display the daily records for that particular day.
- **Year List box** — To the right of the day list box, the year(s) is listed. The database may span more than one year e.g., Nov 97 – Jan 98, hence the appropriate year must be selected.
- **Font Size box** — To change the size of the font used to list the data on the main screen, simply choose a different font. The font size box is located just below the year list box.

2.2 The FILE Menu

2.2.1 Open Observation Log

This menu function allows the user to open an existing observation log file or to create a new observation log file. From the ***File*** menu, choose the ***Open Observation Log*** option. The file browser dialog box (Figure 2.2) appears on the screen.

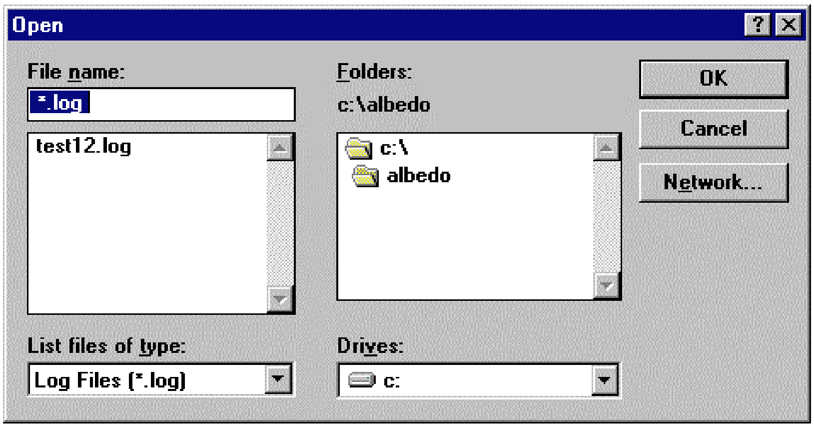

Figure 2.2. Open Observation Log Dialog Box

All log file names must have the extension *.log*. If the log file exists, it will be loaded and the contents displayed on screen. If the file does not exist, an empty file will be created. The daily records of the first day containing data are displayed. The log file name will appear on the top left corner of the main window, the month list box will display the number of records for each month, and the day list box will display the number of records for each day of that particular month. By clicking on the day list box you can display the records for the particular day that is selected. To view specific sections of the record, click on any of the five buttons: ***View Pri, View Sec, View Ter, View Met***, or ***Comments***.

2.2.2 Convert To Text File

From the ***File*** menu, choose the ***Convert to Text File*** option. The dialog box shown in Figure 2.3 appears on the screen. This function is used to generate printable text files from binary database log files.

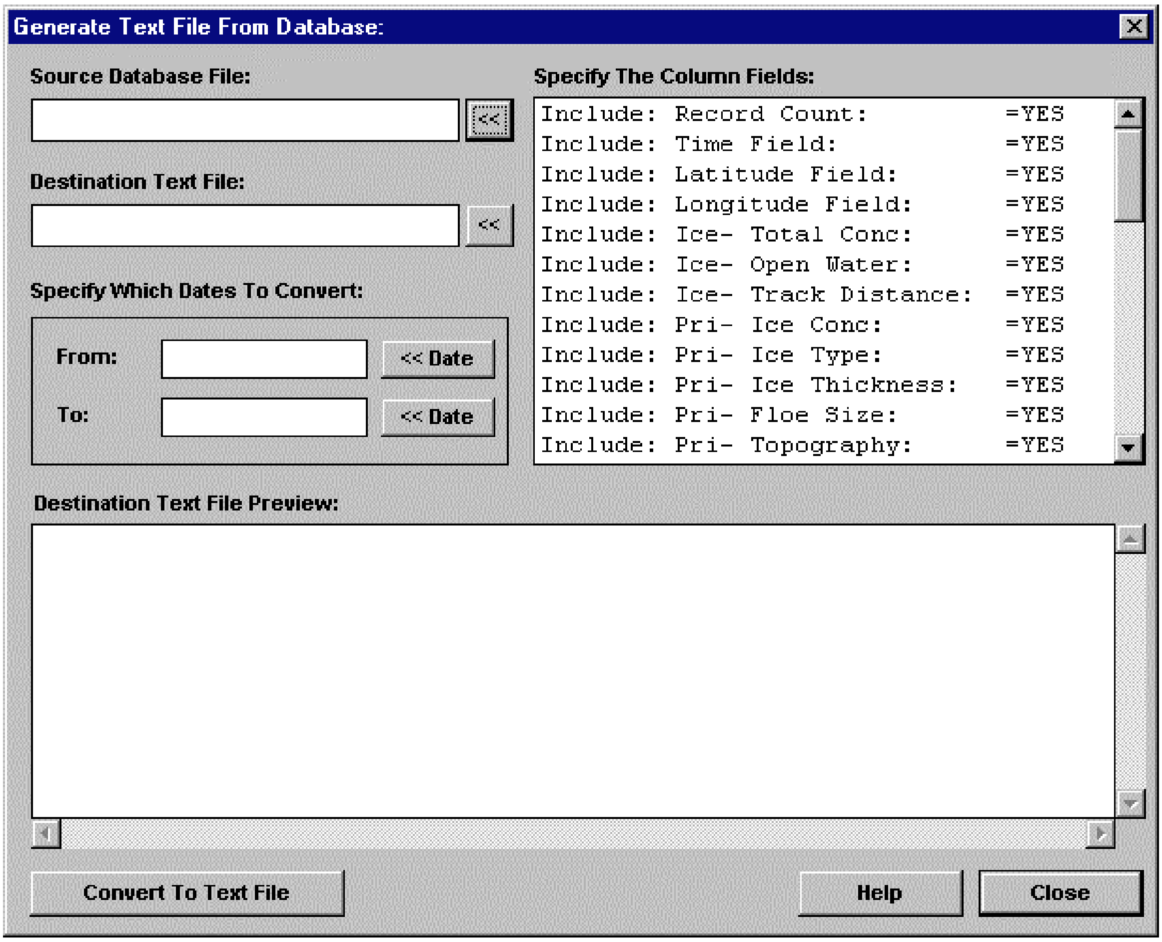

Figure 2.3. Convert To Text File

- **Source Database File name** This box displays the name of the database log file to convert from. It will initially be blank. Click on the **<<** button to select a log file. A file browser box will appear, similar to that shown in Figure 2.2. Select a file with the extension .log. When the file is loaded, the Dates From/To will default to the first and last record in the file.

- **Destination Text File** This is the name of the destination text file. The default file name will be identical to the log file but with the extension .txt. Click on the **<<** button to change the name of the destination file.

- **Date >> (From)** This specifies the first record of the file to be converted to text. Pressing this button will display a dialog box with a list of records in the file. Select the required record. Refer to Figure 2.4.

- **Date >> (To)** This specifies the last record of the file to be converted to text. Pressing this button will display a dialog box with a list of records in the file. Select the required record. Refer to figure 2.4.

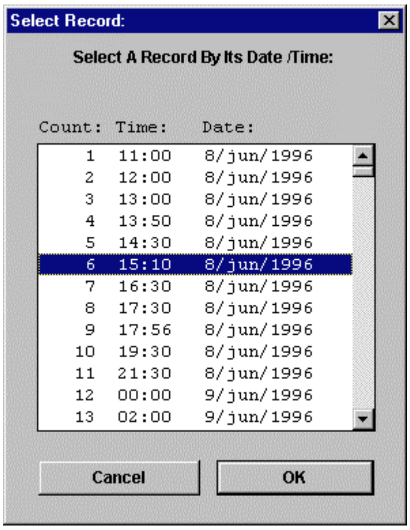

Figure 2.4. Select Date From/To

- **Column Fields** — These are the fields that may be included in the destination text file. To toggle between YES and NO click on the item.
- **Text File Preview** — After the text file is created it is displayed in this edit box. A sample output is shown below.
- **Convert To Text File** — Pressing this button will generate the text file.
- **Help** — Currently not implemented.

When you exit the dialog box, the program will prompt you to save the setup configuration to the disk file seaice.cfg. This setup configuration is loaded each time the user opens the ***Convert to text file*** dialog box. A typical text file is shown below, showing the time, date, latitude, longitude, and primary ice conditions only.

Typical sample file output:

Rec	Date	Time	Lat	Long	Conc	OW	Track	c1	ty1	iz1	f1	t1	s1	sz1
1	4-aug-1997	13:00	-64.933	140.683	10	0	1.9	10	60	30	800	100	3	7
2	4-aug-1997	20:00	-65.033	140.617	10	0	13.7	10	60	50	700	502	3	10
3	4-aug-1997	21:00	-65.067	140.583	10	0	17.8	10	60	65	800	702	3	10
4	4-aug-1997	22:00	-65.100	140.567	10	0	21.6	10	60	65	800	713	3	15
5	4-aug-1997	23:00	-65.117	140.550	10	0	23.7	10	60	60	800	713	3	10
6	5-aug-1997	01:00	-65.150	140.500	10	0	52.0	9	70	70	800	713	3	20
7	5-aug-1997	02:00	-65.150	140.317	10	0	43.3	2	70	75	800	711	4	15

Abbreviations used in the text file listing:

Lat: Latitude
Long: Longitude
OW: Open water
Conc: Ice concentration
Track: Distance of observation along ship's route from first observation of voyage

Primary Ice
c1: primary ice conc
ty1: primary ice type
iz1: primary ice thickness
f1: primary floe size
t1: primary topography
s1: primary snow type
sz1: primary snow thickness

Secondary Ice
c2: secondary ice conc
ty2: secondary ice type
iz2: secondary ice thickness
f2: secondary floe size
t2: secondary topography
s2: secondary snow type
sz2: secondary snow thickness

Tertiary Ice
c3: tertiary ice conc
ty3: tertiary ice type
iz3: tertiary ice thickness
f3: tertiary floe size
t3: tertiary topography
s3: tertiary snow type
sz3: tertiary snow thickness

Meteorological:

Sea T:	Sea temperature in degrees C.
Air T:	Air temperature in degrees C.
W Vel:	Wind velocity in m/sec
W Dir:	Wind direction in degrees 0–359
Film:	Film counter
Frame:	Frame counter for the film
Video:	Video recorder counter hh:mm:ss
Visib:	Visibility code
Cloud:	Cloud in oktas
Weath:	Weather code

2.2.3 Import Old Database File

From the ***File*** menu, select the ***Import Old Database Files*** option. The dialog box in Figure 2.5 will appear. This option is used to convert database files from older versions of the sea ice software to the new version of the sea ice software, and **will not be required by the vast majority of users**.

Older versions of the sea ice software used data base files in text format. Two separate data base files were used: one containing the sea ice observations and the other containing meteorological observations. The current version of seaice.exe uses a single binary data base format which combines the ice and met data into a single record. The file extension used is .log.

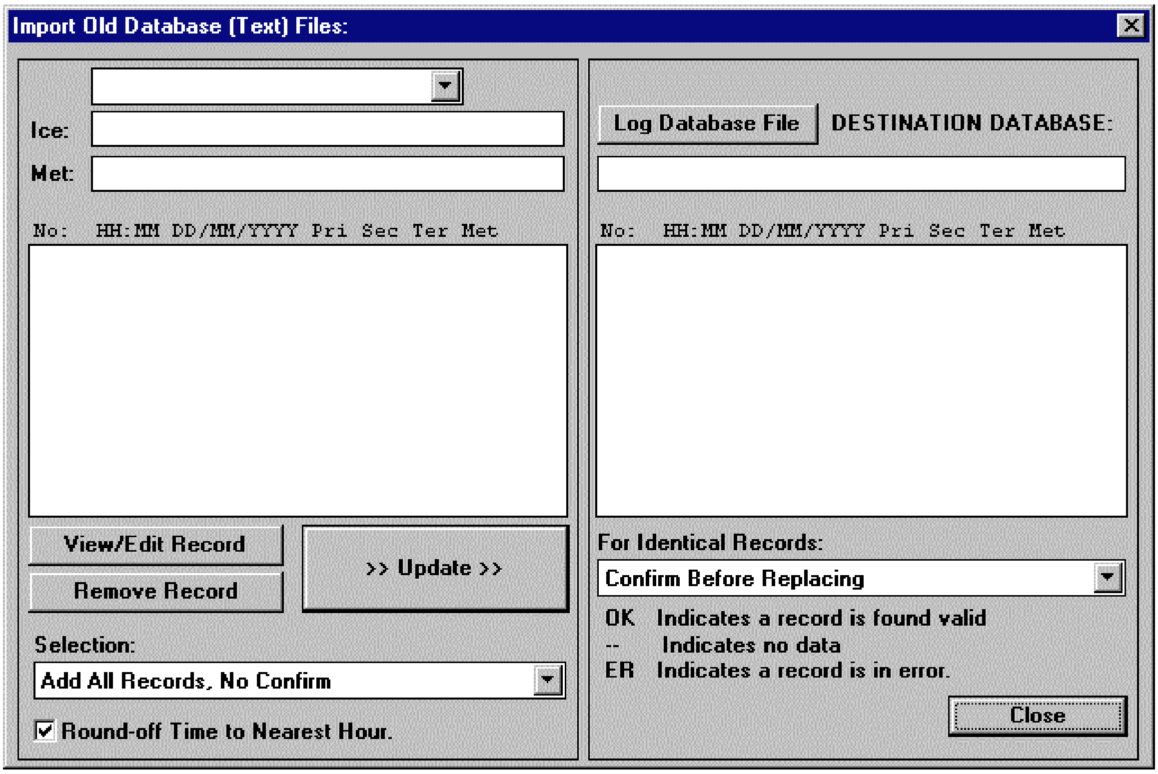

Figure 2.5. Import Old Database Files Dialog Box

Figure 2.5 shows the dialog box used to convert old version database files to the new version files. On the left of the dialog box, the user specifies the file names of the old met and ice data files, and on the right the file name of the destination log file is specified. If the log file exists, the new records are appended to it or replace any existing records. The fields are as follows:

- **Import** — This pull-down combo box allows the file name of either the met or ice database files (old format) to be specified, it has five different selections as shown below. Once the file is imported, the file name is displayed and the contents are listed in the list-box below the file name. This is a read-only edit box.

  - **(i) Import V1.X Albedo .FIN Ice File** — The database file is an old V1.X (ice obs) of the seaice windows program preceding this version, created by V. Dirita.
  - **(ii) Import V1.X Albedo .MET Met File** — The database file is an old V1.X (met obs) of the seaice windows program preceding this version, created by V. Dirita.
  - **(iii) Import Unix .FI3 Ice file** — The database file contains ice obs and was created via the unix version of the program by A. Worby.
  - **(iv) Import Unix .OLD Met (1986–1991)** — The database file contains met obs and was created via the unix version of the program by A. Worby.
  - **(v) Import Unix .OLD Met (1992–1995)** — The database file contains met obs and was created via the unix version of the program by A. Worby.

- **Ice** — This box contains the file name of the ice obs data which has been loaded using the import button above. This is a read-only edit box.
- **Met** — This box contains the file name of the met obs data which has been loaded using the import button above. This is a read-only edit box.
- **View/Edit Record** — You can manually edit individual records in the old database file before updating the new log file. Select (highlight) one of the records in the list box on the left and then click this button. The record is edited in the same way as described in section 3.2. Note that the original data base text file is not affected, only the data in the list box is changed.
- **Remove Record** — A record can be removed from the list of records in the left list box by first highlighting the record and then pressing this button. The program will prompt to confirm before deleting the record. The old data base is not affected.
- **Selection** — This drop list box is used to specify the records from the old database fin file that are to be added to the new log file. There are three options:

  - **(i) Add All Records, No Confirm** — Each record from the fin file is added to the log file without confirmation.
  - **(ii) Add All Records, Confirm** — The user is asked to confirm each record before adding it to the log file.
  - **(iii) Add Valid Records Only** — Some records from the old database fin file may not be valid, hence these records may not be added if this is chosen.

- **Round off to Hour** — This check box is used to round off the time from the imported files to the nearest hour. The time is stored as a decimal fraction in the form: ddd.dd i.e., ddd=day and .dd=fraction of day, hence when converting back to hours:minutes, the minutes will be rounded off. i.e., the times 11:58 and 12:01 will be rounded off to 12:00.

- **Log Database File** — This is the output file with the extension .log. Note that if the file already exists, the program will add the new records into the file. Records are inserted into the file in chronological order. If the file does not exist, it will be created and will contain only the new records.

- **For Identical Records** — This drop list box is used to select from one of three update options. If the destination log file already contains records with the same time and date as the old text file, the user is given three options:

  - **(i) Replace** — Replace all identical records found in the log file with the records from the fin and met files.
  - **(ii) Don't Replace** — Don't replace the records.
  - **(iii) Confirm Before Replacing** — Prompt before replacing each identical record.

- **Update** — Press this button to update the log file with the records from the fin and met files. After completing, the log file is shown in the list box. All track distances are re-calculated for the new log file.

2.3 The RECORD Menu

2.3.1 Add New Record

From the ***Record*** menu, select the ***Add New Record*** function. This menu function is used to add new observation records to the database log file, and consists of three pages, or sections, of data: ***General, Ice Observation*** and ***Met Observation***. The dialog boxes for each section are shown in Figures 2.6, 2.7 and 2.8 respectively. When a new record is added to the file, the record is inserted in chronological order (by date and time). All track distances are then automatically recalculated.

- **General** — This page must be completed in order to uniquely identify a record using the time and date fields. When a new record is added to the file, the record is inserted into the file in chronological order, not necessarily at the end of the file. The track distances are recalculated for the entire file when this occurs.

- **Ice Observation** — This page is used to record the hourly ice observations. Data entry is via a series of dialog boxes. Note that it is not essential to enter ice data to create a valid record, but if no ice data are available the ***No Ice Observation*** box must be checked.

- **Met Observation** — This page is used to record the meteorological data. Note that met data may be recorded in the absence of ice data if necessary. Note that it is not essential to enter met data to create a valid record, but if no met data are available the ***No Met Observation*** box must be checked.

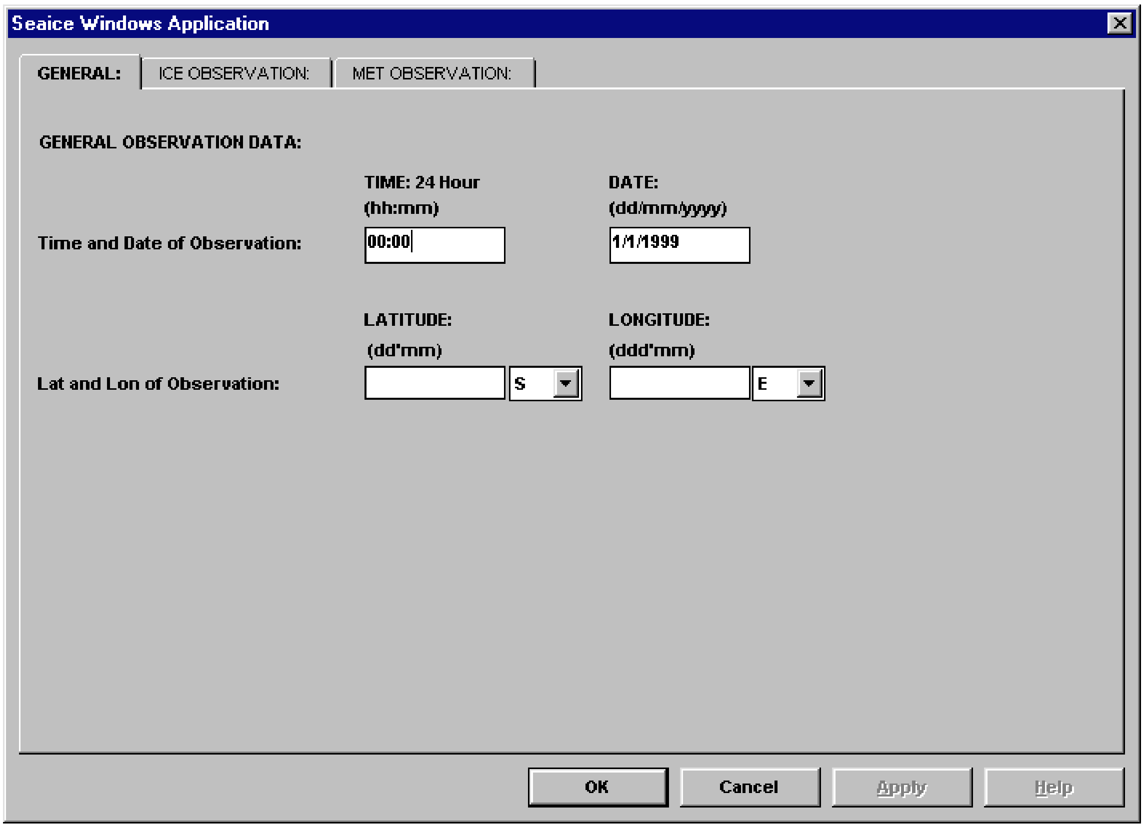

Figure 2.6. General Information Page

- **Hour:Minute** — The time of the observation is in hours and minutes, and entered in 24 hour clock time, e.g., 06:15, 17:23 etc.
- **Day/month/year** — The date of the observation is entered as day/month/year, eg: 1/1/1997, 30/12/2001. The year must be entered as a four digit number between 1900 and 2100. The date and time are used to uniquely identify each record.
- **Lat dd'mm** — The latitude is entered in degrees'minutes. The range is 0–89 degrees, 0–59 minutes. North and south can be specified using the check box. The latitude may also be entered in decimal degrees, i.e., dd.ddd (see section 2.6.3). A warning message will appear if the latitude and longitude occur elsewhere in the data base.
- **Lon ddd'mm** — The longitude is entered in degrees'minutes. The range is 0–179 degrees, 0–59 minutes. East and west can be specified using the check box. The longitude may also be entered in decimal degrees, i.e., ddd.ddd (see section 2.6.3). A warning message will appear if the latitude and longitude occur elsewhere in the data base.

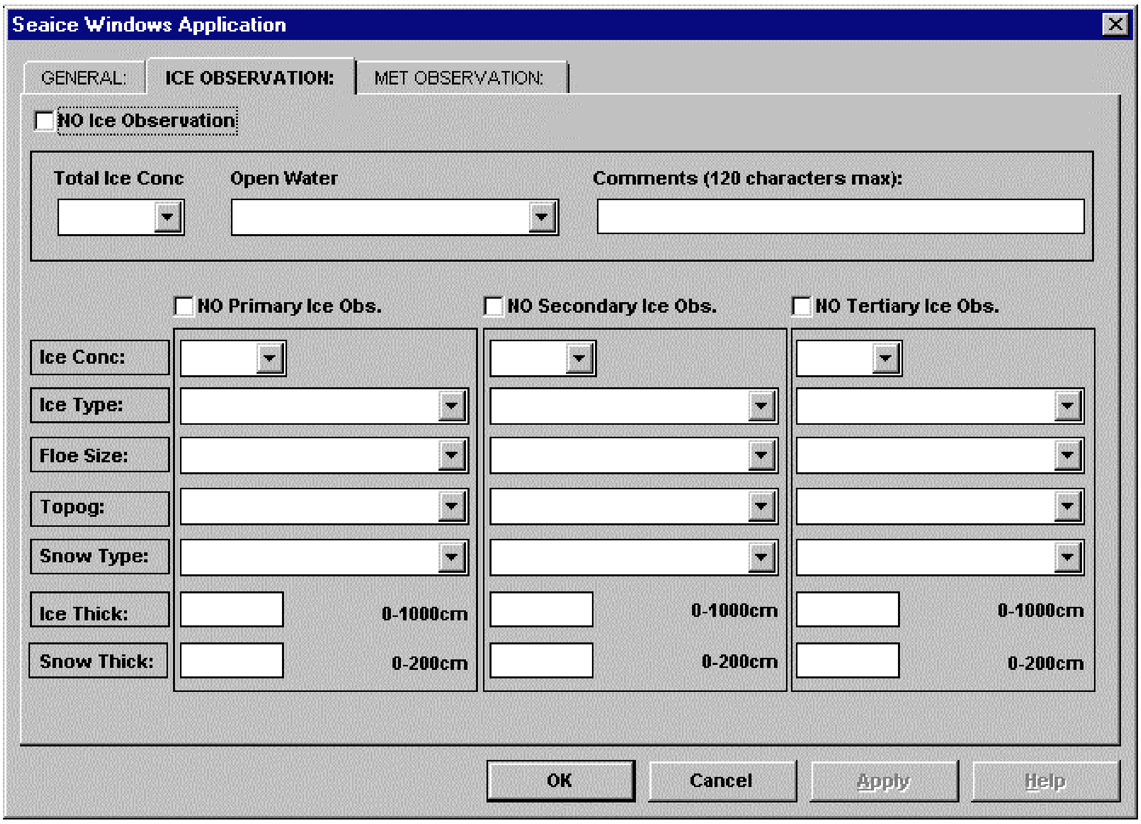

Figure 2.7. Ice Observation Page

Note that the codes for all ice types, floe sizes, topography, snow type, and open water are listed in the appendix.

- **No Ice Observation** — If there is no ice observation (as distinct from no ice at the time of the observation), then this box should be checked.
- **Total Ice Conc** — Drop list box to select the total ice concentration between 0 and 10. This value must equal the sum of the primary + secondary + tertiary ice concentrations.
- **Open Water** — Drop list box to select open water code: 0 to 9.
- **Comments** — Comments for this ice observation to a maximum of 120 characters.
- **Ice Conc** — Drop list box to select ice concentration for primary or secondary or tertiary ice: 0 to 10.
- **Ice Type** — Drop list box to select ice type code for primary or secondary or tertiary ice: 10 to 95. Code '0' identifies no data.
- **Floe Size** — Drop list box to select floe size code for primary or secondary or tertiary ice: 100 to 800. Code '0' identifies no data.
- **Topog** — Drop list box to select topography code for primary or secondary or tertiary ice: 100 to 897. If topography >=500 it will prompt for the x and y components (x = areal coverage, y = mean sail height). Code '0' identifies no data.
- **Snow Type** — Drop list box to select snow type code for primary or secondary or tertiary ice: 0 to 10. Code '0' identifies no data.

- **Ice Thick** — Ice thickness in cm for primary or secondary or tertiary ice drop list box: 0 to 2000 cm.
- **Snow Thick** — Snow thickness in cm for primary or secondary or tertiary ice drop list box: 0 to 300 cm.
- **No Primary Ice Obs** — If no primary ice observation is available, click on this check box. All primary ice input fields will be disabled. Note that in this case the *No ice observation* box should be checked.
- **No Secondary Ice Obs** — If no secondary ice observation is available, click on this check box. All secondary ice input fields will be disabled.
- **No Tertiary Ice Obs** — If no tertiary ice observation is available, click on this check box. All tertiary ice input fields will be disabled.

After completing the required input fields for the ice observation, you must proceed to the met observation page to enter any meteorological data, or to specify that none are available. At this point the program will check that all the required ice data are supplied and valid. It will then apply the check rules described in Sections 2.6 and 3.4, and prompt the user if incorrect or anomalous entries are found.

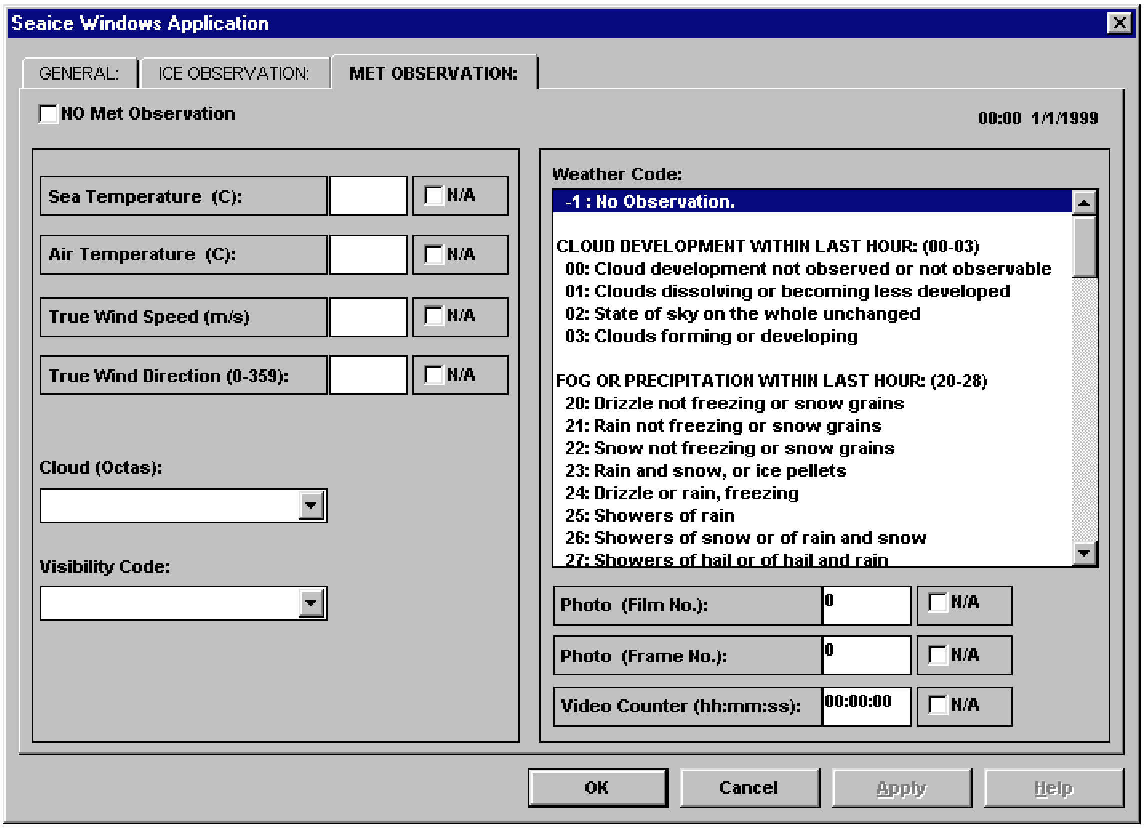

Figure 2.8. Met Observation Page

- **No Met Observation** — If no met data are available, simply click this check box. All other controls become invisible. This means that the record will not contain any met data.
- **Air Temp C** — The air temperature in °C. If no data are available, click on the check box to the right of the air temperature input box. This check box may be disabled by default, refer to section 2.6.3. A warning message appears if the air temperature is >5°C
- **Sea Temp C** — The sea temperature in °C. If no data are available, click on the check box to the right of the sea temperature input box. This check box may be disabled by default, refer to section 2.6.3. A warning message appears if the sea temperature is outside the range -2 – 2°C.
- **Wind Speed (m/s)** — The wind speed in meters/second. If no data are available, click on the check box to the right of the wind speed input box. This check box may be disabled by default, refer to section 2.6.3. A warning message appears if the wind speed is >25 m/s.
- **Wind Direction (0–359)** — The wind direction in metres/second. The range is 0 to 359 degrees relative to north (i.e., °T) entered as an integer. If no data are available, click on the check box to the right of the wind direction input box. This check box may be disabled by default, refer to section 2.6.3.
- **Photo (Film No)** — The photo film number. Any integer is allowed. If no data are available, click on the check box to the right of the photo film number input box. This check box may be disabled by default, refer to section 2.6.3.
- **Photo (Frame No)** — The photo frame number. Any integer is allowed. If no data are available, click on the check box to the right of the photo frame number input box. This check box may be disabled by default, refer to section 2.6.3.
- **Video Tape Counter** — The video tape counter. This must have the format: hh:mm:ss. If no data are available, click on the check box to the right of the video tape counter input box. This check box may be disabled by default, refer to section 2.6.3.
- **Visibility Code** — Visibility code: 90–97. A value of -1 indicates no data. This is a drop list box from which the required code is selected.
- **Cloud (Oktas)** — Cloud in oktas code: 0–8. A value of -1 indicates no data. This is a drop list box from which the required code is selected.
- **Weather Code** — The weather code is a two digit code from the Australian Meteorological Observers handbook. The codes normally range from 00–99; however only the codes for weather conditions likely to be encountered in Antarctica are listed (i.e., codes for unlikely events such as dust storms are not listed).

2.3.2 Delete Record

From the ***Record*** menu, select the ***Delete Record*** option. This allows an observation record to be deleted from the log file. The dialog box shown in Figure 2.9 appears on the screen.

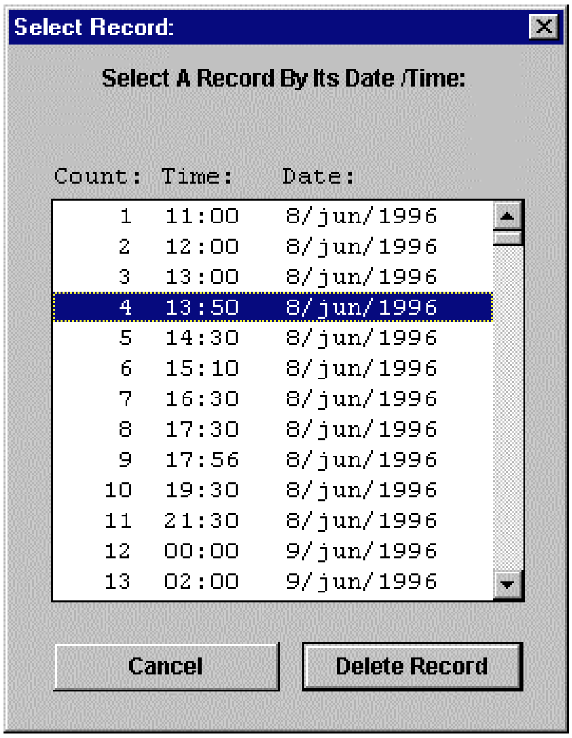

Figure 2.9. Delete Record Dialog Box

To delete a record, select it by highlighting the appropriate time and date in the list box, and then click the ***Delete Record*** button. The program will prompt for confirmation before the record is removed from the database log file. After the record is deleted, the program will re-calculate all track distances for the remaining records in the log file.

- **Record** Click on the date-time list box to select the record to be deleted.
- **Delete Record** This button is used to delete the selected record.

2.3.3 Edit Record

From the ***Record*** menu, select the ***Edit Record*** option. This allows an observation record to be individually edited from the log file. The dialog box shown in Figure 2.10 appears on the screen.

To edit a record, select it by highlighting the appropriate time and date in the list box, and then click on the ***Edit Record*** button. The record is edited in the same manner as described in section 2.3.1 (Add New Record) except that all the fields in the record are initialised with the contents of the record in the log file. Once the record is edited, the program will re-calculate all track distances for all the records in the log file. Note that the record is identified by the time/date fields, changing these fields will delete the original record specified and add a new record with a new time/date.

- **Record** Click on the date-time list box to select the record to be edited.
- **Edit Record** This button enables the selected record to be edited.

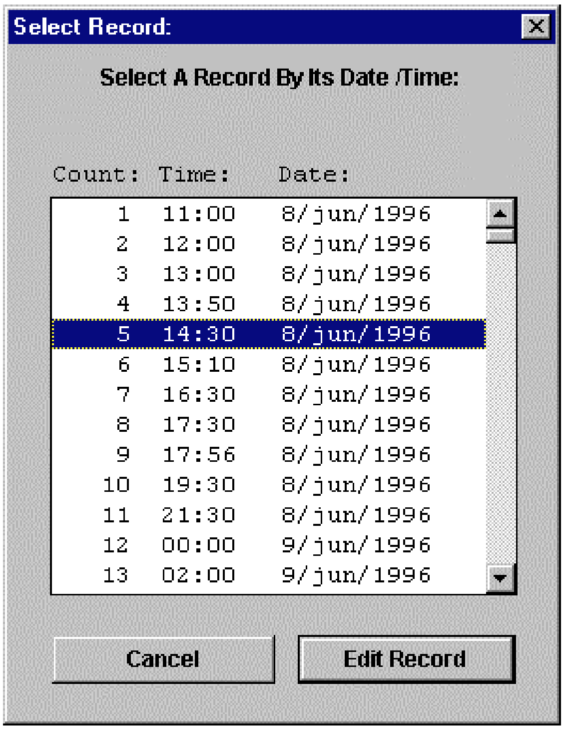

Figure 2.10. Edit Record Dialog Box

2.4 The GRAPHS Menu

2.4.1 Plot Ship Route

Database files can be plotted on a geographic map, generally used for plotting the observation locations. From the ***Graphs*** menu, select the ***Plot Ship Route*** option. The dialog box shown in Figure 2.11 will appear on the screen.

The display consists of a polar stereographic projection of the south pole. The latitude circles are labelled along the vertical and horizontal axes, the longitude lines are labelled at the edges of the rectangular display region. When the cursor is inside the plot region, its coordinates are given in decimal latitude and longitude on the right of the scree. Mapping and projection algorithms are given in the appendix. Any part of the plot may be zoomed by clicking and dragging the mouse over the region to be enlarged. The resulting enclosed area will be zoomed when the mouse is released. You may also resize the dialog box simply by dragging the corners of the dialog box. The dialog box contains the following controls:

- **Full Zoom Button** — Pressing this button will zoom out fully, displaying the entire south polar region. This is illustrated in Figure 2.11.
- **Zoom Previous Button** — Adjusts plot to previous zoom coordinates.
- **Grid Button** — This controls the grid display, i.e., the number of grid lines, latitude and longitude increments, colour etc. A dialog box (Figure 2.12) appears on the screen. The grid can be turned on/off, and the latitude and longitude step size, and colour can be changed.

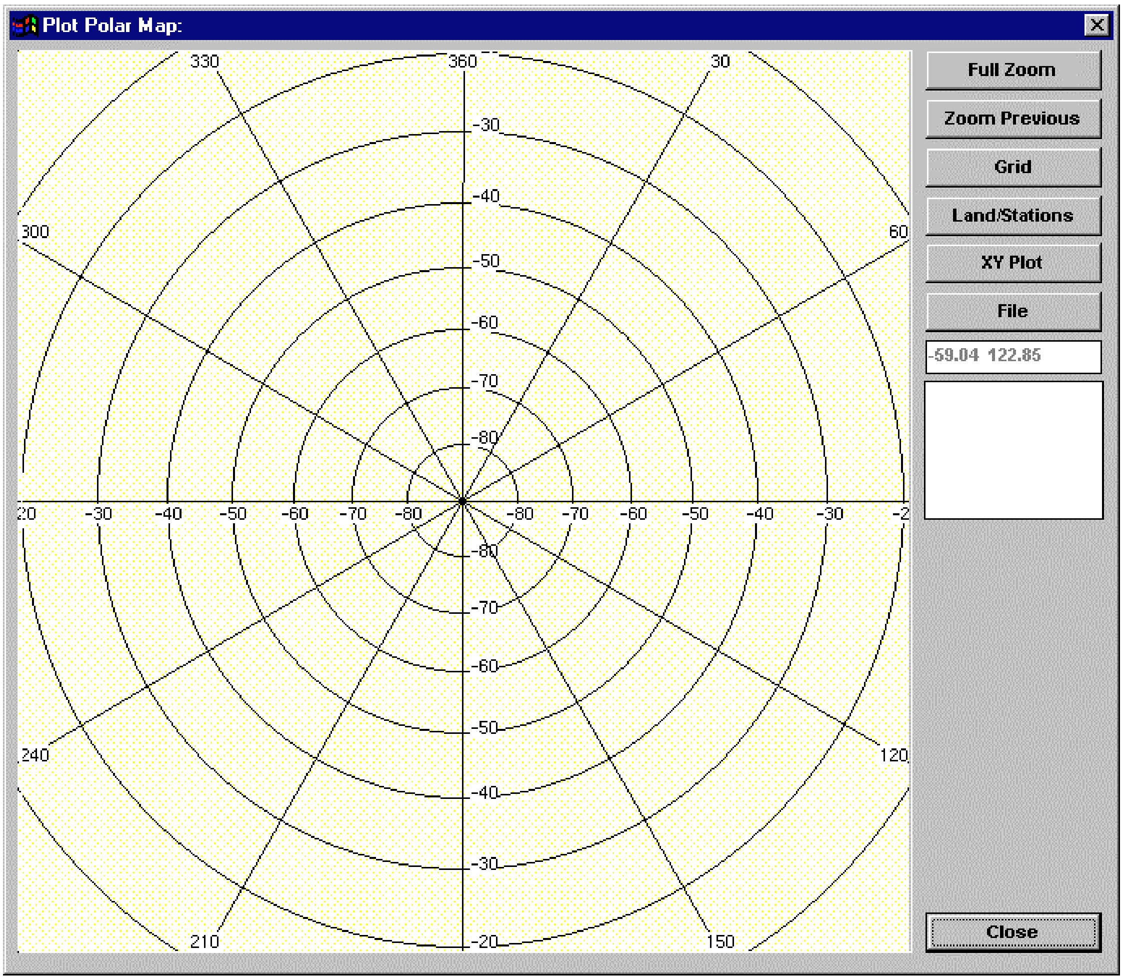

Figure 2.11. Graph Plot: Plot Ship Route Display

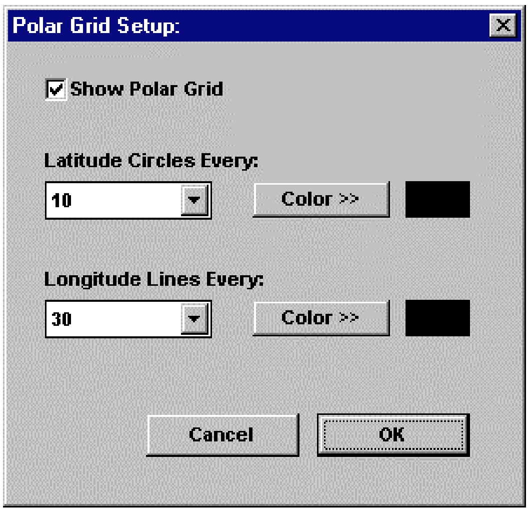

Figure 2.12. Grid Options

- **XY Plot Button**

Currently not implemented.

- **Land/Stations Button**

A map of the Antarctic coastline can be plotted. The dialog box in Figure 2.13 appears on the screen. A file of 2000 latitude and longitude points called landmask.map is supplied for this purpose. Alternatively, users may plot their own coastline data provided the input file consists of a series of latitude and longitude points in decimal degrees. Adjacent points can be connected to produce a solid coastline by clicking on the ***Draw Solid Outline*** check box (provided the data points are continuous around the continent, which is not the case for the supplied landmask.map file). The location of most Antarctic stations may also be plotted on the map by clicking on the ***Show Stations*** check box.

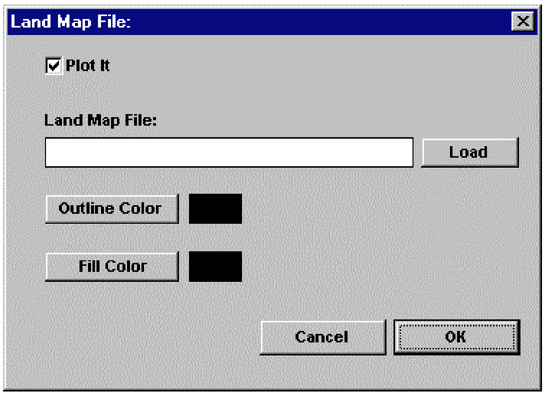

Figure 2.13. Land Mask Options

- **File Button**

This button is used to load and plot a database log file. The latitude and longitude of each observation will be plotted on the map. The dialog box shown in Figure 2.14 will appear on the screen. Clicking on the ***<<File*** button will enable the user to load a log file. Each observation record in the file is listed along with the date, time, latitude and longitude of the observation. To plot the entire file, click on the ***Plot Entire File*** button, and the entire list will be highlighted. If you wish to plot a subset of the file, simply highlight the required observations in the list. The marker style, line thickness and line colour for a plot may be specified. Note that there is an option to place a latitude and longitude marker at each observation point using the ***Mark each Location*** check box.

- **Lat Lon Box**

This box displays the latitude and longitude of the cursor in decimal degrees when the cursor is placed inside the plot region. The cursor also changes to + when inside the plot region.

- **File List Box**

This is a list box which displays the file name of all the database log files being plotted. Each time a file is selected for plotting (see the ***File*** button above), the file name appears in this box. Up to five log files may be plotted simultaneously. If you click on a file name inside this list box, that file and its plot options will appear on the screen, and may be modified as described above.

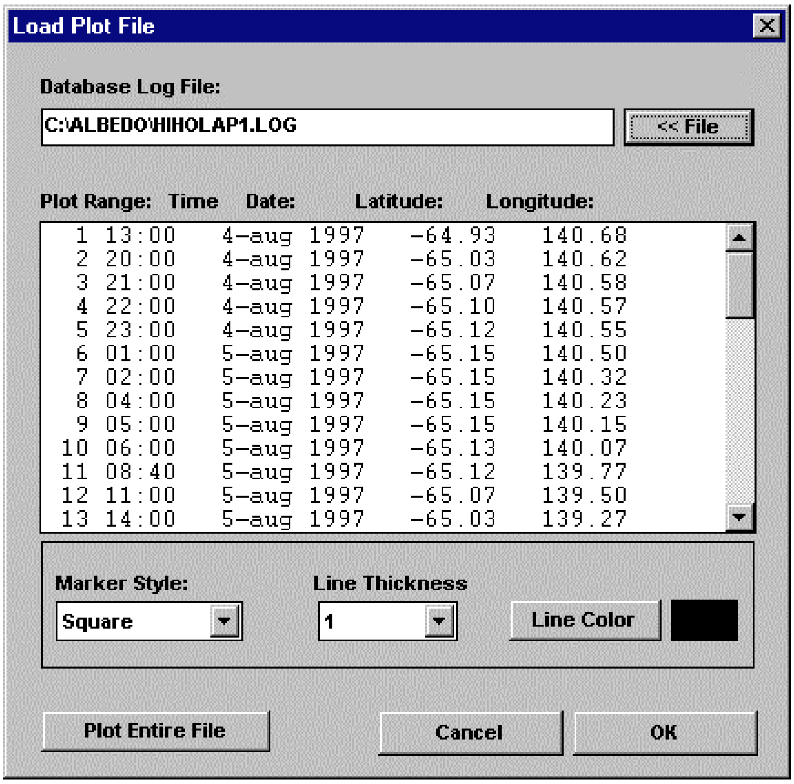

Figure 2.14. Load /File Options

2.4.2 Plot Sea Ice Data

Database files can be plotted as a time series plot. From the ***Graphs*** menu, select the ***Plot Sea Ice Data*** option, and a blank graph will appear on the screen. This plot facility allows any data (either met or ice observation) to be plotted versus time. It also allows multiple y-axis plots as shown in Figure 2.16. Note that only .log files may be plotted.

To plot a graph, follow the procedure below:

- **Load** Click on this button to select the log file to plot. The file browser dialog box shown in Figure 2.15 will appear on the screen, select the log file you wish to plot. The file will initially be loaded but not plotted until the x-axis is specified.

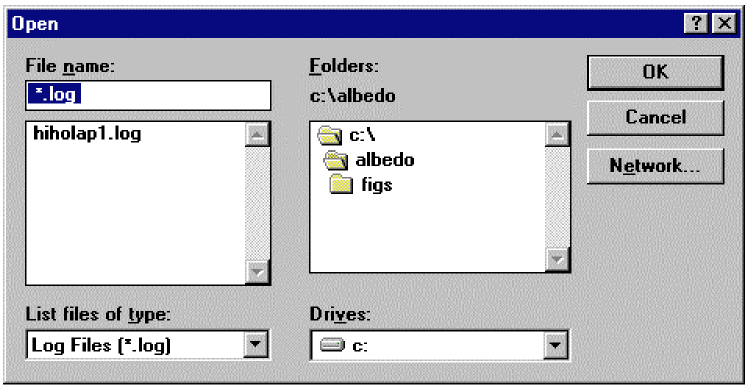

Figure 2.15. Select a .log file to plot

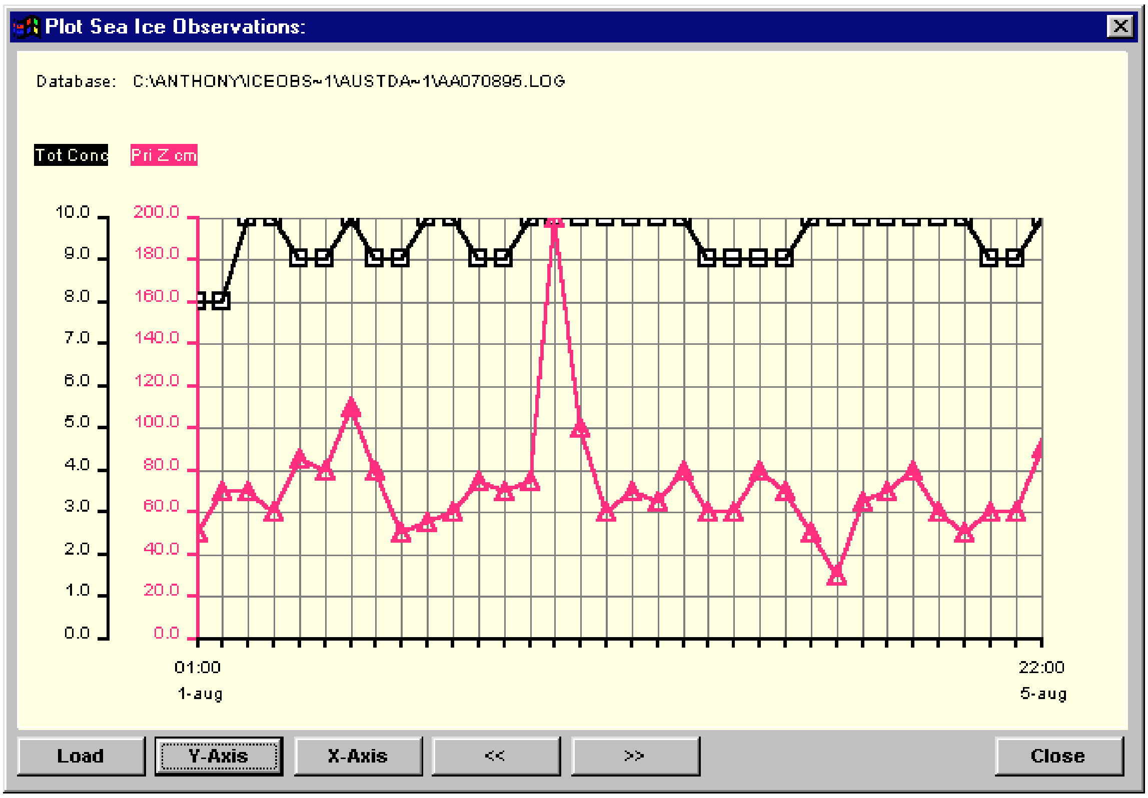

Figure 2.16. Plot sea ice data

• **X-Axis**

If you wish to plot the entire file (i.e., a particular parameter/s from every record in the file) click on "Plot Entire File". Otherwise, you may highlight a subset of the data (by time and date) as shown in Figure 2.17.

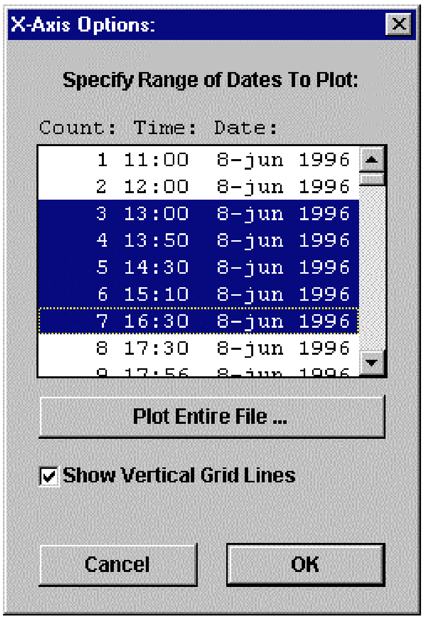

Figure 2.17. X-Axis Dialog Box

• Y-Axis

Any of the ice or met data may be plotted on the y-axis. The following dialog box displays the y-axis set up and contains a list of items which may be plotted along the y-axis. More than one item may be plotted at any time.

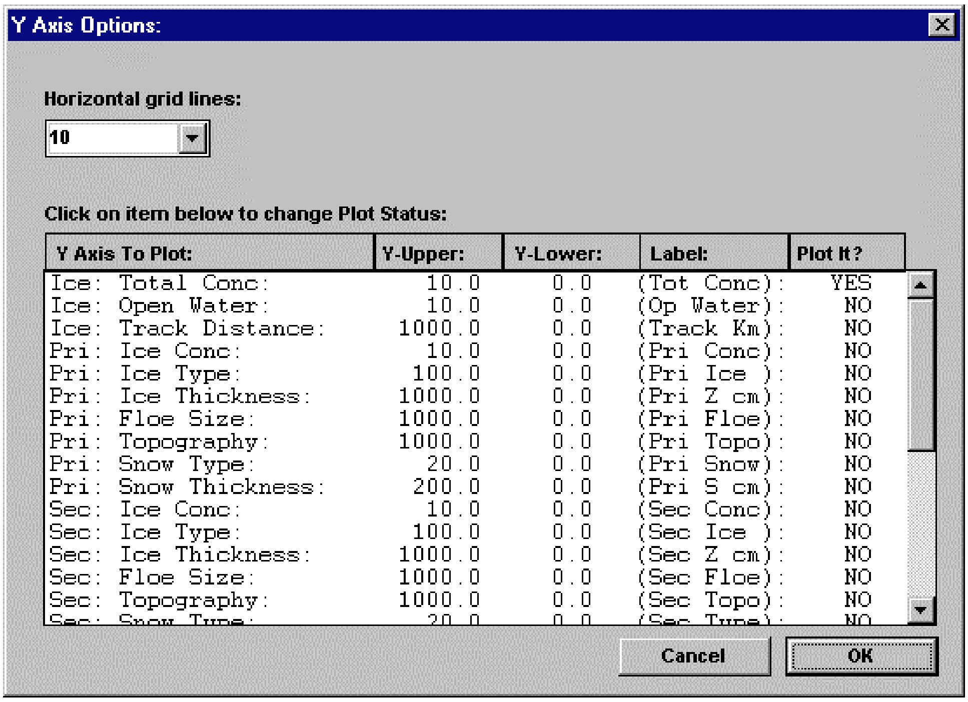

Figure 2.18. Y-Axis Dialog Box

• Horizontal Grid Lines

The number of grid lines may be selected from the combo box or a number can be typed in.

• Click an item to change plot status

Highlighting any one of the parameters in this list box will display the dialog box shown in Figure 2.19. The dialog box has a range of options. To plot the selected parameter check the "Plot it?" box. The upper and lower plot ranges may be specified as well as the line colour and thickness, and marker style. Different marker shapes can be used to better display plots on lower quality monitors. On monitors that do not support more than 16 colours, some colours will not be displayed correctly.

• << Button

This is a scroll left button, if you are plotting a large file, and viewing only a small section of that file, it is possible to scroll backward and forward using this button and the **>>** Button. The graph will scroll by one page, where one page is equal to the number of points plotted on the x-axis.

• >> Button

Scroll right button. See description above.

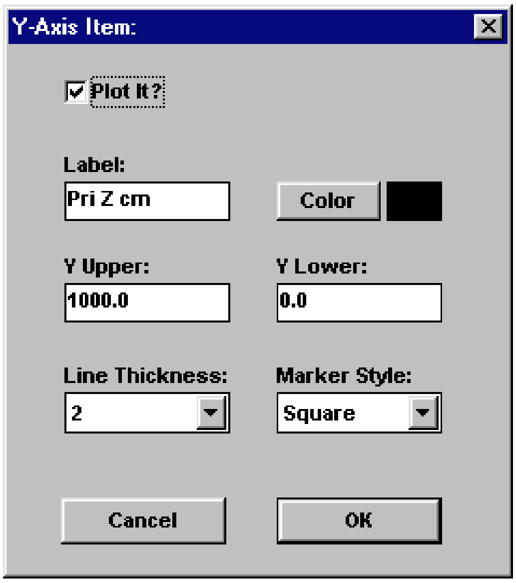

Figure 2.19. Single Y Plot Item Dialog Box

2.5. The CALCULATE Menu

2.5.1 Sea Ice Statistics

From the ***Calculate*** menu, choose the ***Sea Ice Statistics*** option. The dialog box shown in Figure 2.20 will appear on the screen. The details of all the sea ice calculations are described in the appendix.

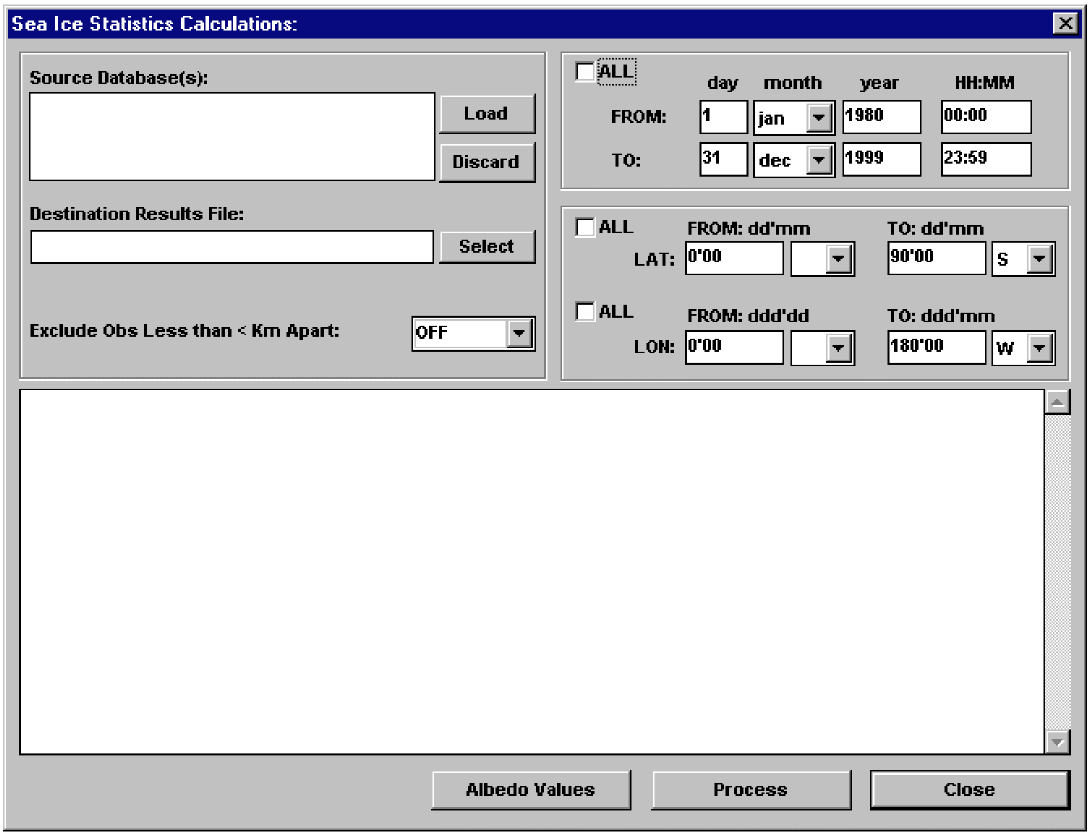

Figure 2.20. Sea Ice Statistics

- **Load** Specify the name of the database log file to process. A file browser will appear on the screen (similar to Figure 2.15). The file is loaded and the file name is displayed in the box to the left. Note that multiple database files may be loaded and combined to give an overall statistical output.
- **Discard** To exclude a file from processing (when multiple files are selected for processing) simply click on the file name in the box to the left and hit the Discard button. The file is then removed from the list of files to process.
- **Select** The destination file name default is the same as the input file but with the extension .sta. The user may specify a different destination file name by clicking the *Select* button.
- **ALL** If this box is checked, then the time and date is ignored in the processing. If this box is not checked, then the user must specify the subset of records to be processed (defined by a range of times and dates).
- **Date FROM** To specify the starting date of a subset of records for processing.
- **Date TO** To specify the finishing date of a subset of records for processing.
- **Lat ALL** If this box is checked then the latitude range is ignored. If this box is not checked, then the user must specify a subset of records to be processed (defined by a range of latitude).
- **LAT From/To** This is used to specify a subset of the data file by latitude. All observations outside this range will not be processed. You may specify the From and To values in any order, i.e., From 60°S to 65°S will produce the same result as From 65°S to 60°S. The specified range can not be greater than 90 degrees.
- **Lon ALL** If this box is checked, then the longitude range is ignored. If this box is not checked, then the user must specify a subset of records to be processed (defined by a range of longitude).
- **LONG From/To** This is used to specify a subset of the data file by longitude. All observations outside this range will not be processed. You may specify the From and To values in any order, i.e., From 170°E to 165°W will produce the same result as From 165°W to 170°E. The specified range can not be greater than 180 degrees.
- **Exclude Observations <** Records less than a specified distance from the previous record may be excluded from the data analysis. This is to prevent biasing when there is an uneven spatial distribution of observations. To turn this option off, select the OFF option. You may also type a number rather than selecting from the list provided (see Figure 2.20).
- **Sea Ice Statistics** Displays the results of the calculations, i.e., the destination file contents. A sample result file is shown in the appendix.

Table 2.1. Sample Output from ***"Calculate Statistics"*** for Voyage Data from RSV *Aurora Australis,* 2–26 October 1997.

TOTAL OBSERVED AREA:

==

DATABASE:
C:\SEAICE\ICEOBS\AA101097.LOG 113
OUTPUT:
C:\SEAICE\ICEOBS\AA101097.STA

Date From:	ALL
Date To:	ALL
Latitude From:	ALL
Latitude To:	ALL
Longitude From:	ALL
Longitude To:	ALL
Exclude observations <:	11.0 km
number of observations:	113

==

Total ice concentration:	80.09
Open water within pack:	19.91
Av level ice thickness (total area) cm:	27.49
Av level ice thickness (ice area) cm:	34.32
Fraction of surface area ridged:	0.06
Av ridged ice thickness (total area) cm:	52.18
Av ridged ice thickness (ice area) cm:	65.16
Av snow thickness (total area) cm:	6.13
Av snow thickness (ice area) cm:	7.65
Av snow thickness (snow covered area) cm:	11.16
Snow covered ice within pack (total area):	54.87
Snow free ice within pack (total area):	25.31
Percent ice with snow cover:	68.43
Percent ice with no snow:	31.57
Av albedo (total area):	0.46

Level Ice:

snow cover	0cm	0-3cm:	>3cm:
Water:	19.91	0.00	0.00
New Ice (=<10 cm):	3.45	0.00	0.00
Nilas (=<10 cm):	19.03	0.00	0.00
Grey Ice (10-15 cm):	1.59	6.55	2.92
Grey-White Ice(15-30 cm):	0.80	5.31	9.38
1st Year(30-70 cm):	0.00	0.18	18.67
1st Year (70-120 cm):	0.00	0.00	7.08
1st Year (>120 cm):	0.00	0.00	4.69
Multiyear Ice:	0.00	0.00	0.09
Brash:	0.44	0.00	0.00
Fast Ice:	0.00	0.00	0.00

Ridged Ice:

snow cover	0cm	0-3cm:	>3cm:
Water:	19.91	0.00	0.00
New Ice (=<10 cm):	3.45	0.00	0.00
Nilas (=<10 cm):	19.03	0.00	0.00
Grey Ice (10-15 cm):	1.59	3.81	0.71
Grey-White Ice(15-30 cm):	0.80	5.22	9.47
1st Year(30-70 cm):	0.00	2.12	11.50
1st Year (70-120 cm):	0.00	0.88	9.20
1st Year (>120 cm):	0.00	0.00	11.86
Multiyear Ice:	0.00	0.00	0.09
Brash:	0.44	0.00	0.00
Fast Ice:	0.00	0.00	0.00

- **Coefficients** — To calculate the area-averaged albedo from the observed sea ice types and thicknesses, a table of albedo coefficients is specified. The coefficients can be displayed and changed. Refer to section 2.6.2, or Part I of this report for more information.
- **Process** — Pressing this button will process the log file. The results are saved to the destination file and displayed in the sea ice statistics box.

A full description of all calculations is given in Appendix I. Algorithms and software are also included. A sample output file is shown in Table 2.1.

2.6. The OPTIONS Menu

2.6.1 Input Validation Control

From the ***Options*** menu, select the ***Input Validation Control*** option. This menu function is used to enable or disable various validation checks when the user is entering a new observation record. The dialog box shown in Figure 2.21 will appear. Each validation check has three settings:

- **YES** (enabled) — Forces the user to provide input data consistent with the prescribed checks
- **NO** (disabled) — Ignores the validation check
- **WARNING ONLY** — Identifies data inconsistent with the prescribed checks but enables the user to overwrite them.

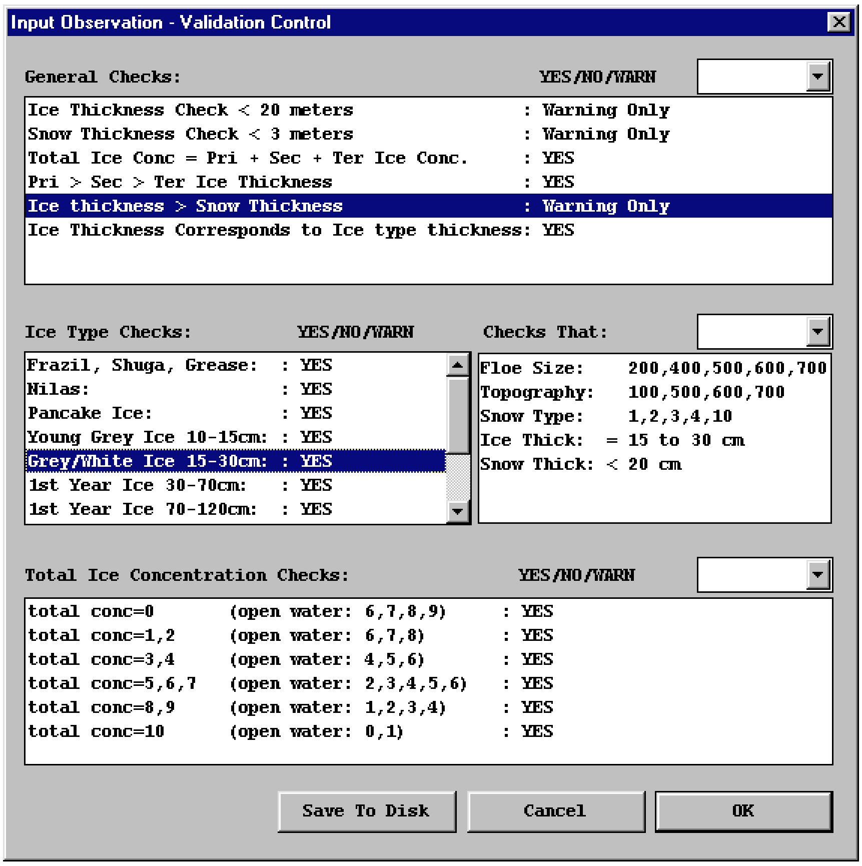

Figure 2.21. Input Validation Dialog Box

All the validation checks are described in detail in Appendix I. They are also described briefly here. To change the setting between YES, NO and WARNING ONLY for a particular parameter, simply click on the line containing the validation rule.

To change the validation check settings for all the parameters in ***General Checks, Ice Type Checks*** or ***Total Concentration Checks*** click on the **All YES, All NO,** or **All WARNING ONLY** buttons.

General Checks

• **Ice Thickness <2000 cm**	The ice thickness must be less than 2000 cm.
• **Snow Thickness <300 cm**	The snow thickness must be less than 300 cm
• **Total Ice Conc=Sum Pri+Sec+Ter**	The total ice concentration must equal the sum of individual ice concentrations. When no tertiary ice is specified, sum=pri+sec. When no secondary ice is specified, sum=pri.
• **Ice Thickness pri > sec >ter**	The ice thickness values must be in order of primary > secondary > tertiary
• **Ice Thickness > snow thickness**	The ice thickness must be > snow thickness
• **Ice thickness matches ice type**	The ice thickness must be consistent with the ice type specified. For example, if the ice type selected is young grey ice, the ice thickness must be 10–15 cm.

Ice Type Checks

For each ice type there is a corresponding set of ice parameters, each of which has a defined range of values. When you click on each of the ice types, the acceptable range of values of each corresponding parameter are displayed. Clicking on the ice type will switch the validation controls between YES, NO and WARNING ONLY.

For example:

Ice type is:	***Check that:***	
nilas	floe size:	200
	topography:	100, 400, 500, 600
	snow type:	1, 2, 3
	ice thickness:	<0 cm
	snow thickness:	<3 cm

Total ice concentration checks

For each value of total ice concentration there is a corresponding range of values for open water. When you click on the total concentration list, the acceptable range of values for open water are displayed. Clicking on the ice type will switch the validation controls between YES, NO and WARNING ONLY.

For example:

Total ice conc is:	***Check that:***
4/10	Open water value 4,5,6

Note that the configuration of validation controls may be stored so that next time the program runs the set up information is the same. This information is stored on the disk file seaice.cfg. Click on the ***Save to Disk*** button to save the configuration.

2.6.2 Albedo Values

From the ***Options*** menu, select the ***Albedo Values*** option. This menu function is used to view or change the sea ice albedo coefficients specified for each ice type and snow thickness. These values are shown in Figure 2.22.

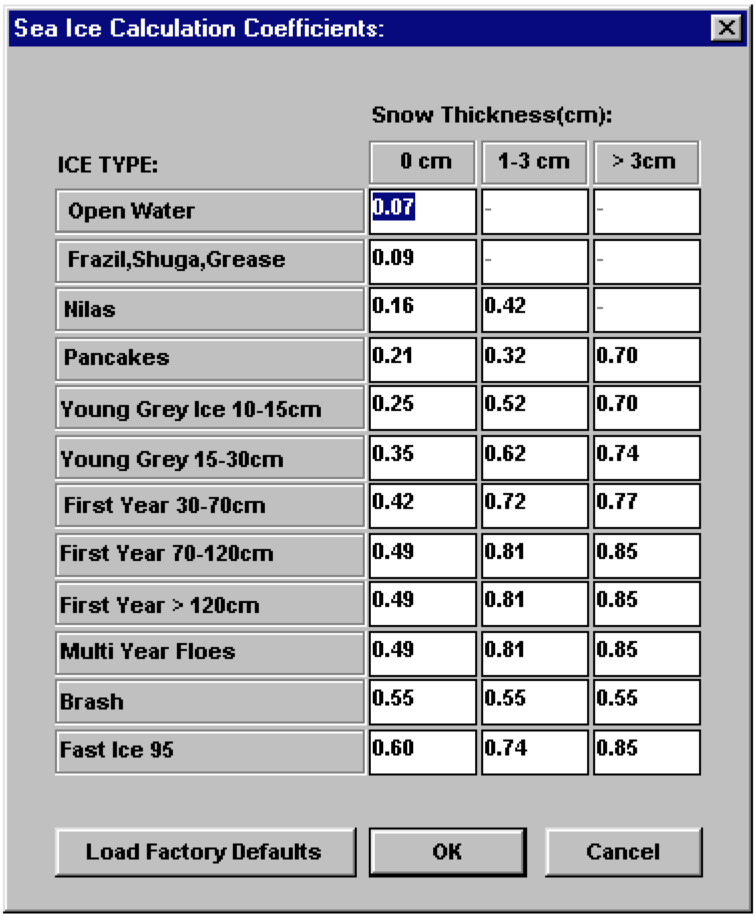

Figure 2.22. Sea Ice Albedo Coefficients

Any of the values may be changed; however users should be aware that these values are based on results available from field experiments [*Allison et al.,* 1993; *S. Warren*, personal communication, 1998]. The coefficients are used to calculate the area-averaged albedo based on the observed distribution of ice types, snow cover and open water within the pack ice. The calculations are described in the appendix.

The coefficients are loaded from disk, and stored on the disk file seaice.cfg when changed. The standard defaults are shown in Figure 2.22. The ***Load Factory Defaults*** button will change all the coefficients back to the original values.

Values are not specified for ice conditions that either do not occur or are unlikely to be observed. These boxes are disabled and values can not be specified.

2.6.3 Observation Record Defaults

From the ***Options*** menu, select the ***Observation Record Defaults*** option. This menu function is used to initialise the observation record with some default values. The dialog box shown in Figure 2.23 appears on the screen.

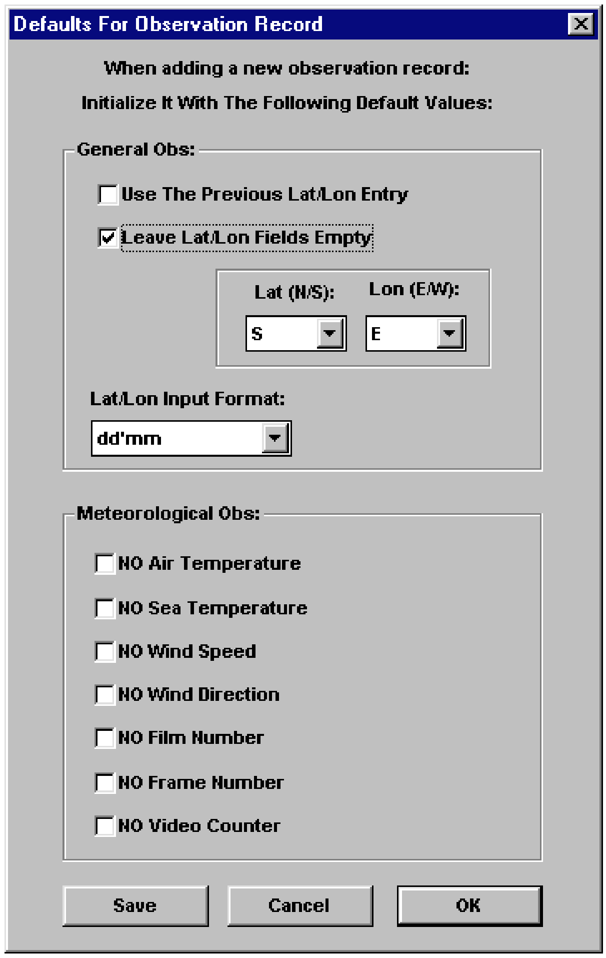

Figure 2.23. Observation Record Defaults

Use The Previous Lat/Lon Entry
When a new record is being added to the log file the latitude and longitude fields will be shown as that of the previous record entry if this box is checked.

Leave Lat/Lon Fields Empty
When a new record is being added to the log file the latitude and longitude fields will be blank if this box is checked.

Lat (N/S)
This is used to set the hemisphere default for latitude to either north or south if the *Leave Lat/Lon Fields Empty* check box is selected.

Lon (E/W)
This is used to set the hemisphere default for longitude to either east or west if the *Leave Lat/Lon Fields Empty* check box is selected.

.

Lat/Lon Input Format
The default latitude and longitude may be specified as either decimal degrees or degrees and minutes. The default setting applies to all aspects of the program including data entry, plotting and display. The default setting may be changed at any time.

No Air Temperature	Check this box to set the default no air temperature to “no data”. This means that when entering a new record, the air temperature in the met observation dialog box has a default value of N/A (not available). Note that when entering a new record the user may override this default setting by unchecking the N/A box and entering a value.
No Sea Temperature	Check this box to set the default for the sea temperature field to N/A.
No Wind Speed	Check this box to set the default for the wind speed field to N/A.
No Wind Direction	Check this box to set the default for the wind direction field to N/A.
No Photo (Film No)	Check this box to set the default for photographic film number to N/A.
No Photo (Frame No)	Check this box to set the default for photographic frame number to N/A.
No Video Counter	Check this box to set the default for the video counter to N/A.

3.0 APPENDIX I

3.0 SOFTWARE ALGORITHMS AND CHECK CODES

3.1 Calculating sea ice statistics

3.1.1 Notation

The equations for calculating the sea ice statistics assume that all the input data are correct. The following notation is used in all equations:

c_j	ice concentration: j=1 primary, 2 secondary, 3 tertiary ice
z_j	ice thickness in metres: j=1 primary, 2 secondary, 3 tertiary ice
sz_j	snow thickness in metres: j=1 primary, 2 secondary, 3 tertiary ice
x	areal coverage parameter, x/100%
ty_j	ice type classification: j=1 primary, 2 secondary, 3 tertiary ice
N	total number of observations
cc	total ice concentration for an observation

3.1.2 Type Concentration Matrix

Calculate the Type Concentration matrix, this is a matrix of [10][3] dimensions, 10 = ice types, 3 = snow thicknesses (0 cm, 0–3 cm, >3 cm). The table of albedo coefficients for each of the 10 ice types and 3 snow thicknesses is shown in the previous section (see Figure 2.22).

Coeff(sz_j, ty_j)	Table of albedo coefficients depending on the snow thickness (sz_j) and the ice type (ty_j) classification. Note that the function Coeff() returns 3 values; the row: 1–10 (ice type, ty), the column: 1–3 (snow thickness 0 cm, 0–3cm, >3cm), and the albedo coefficient: coeff.
TypeCon[10][3]	Type concentration matrix, this is used for output to a file, and for the calculation of the other parameters. Refer to algorithm A.

3.1.3 Algorithms

From the TypeCon [10][3] matrix we can calculate all remaining parameters as described in algorithm B.

Algorithm-A: Calculate The TypeCon[10][3] Matrix

```
SumAvIceThickTot=0;
SumAvSnoThickTot=0;
SumAvAlbedo=0;
SumPerAreaRidged=0;

Repeat (for each observation)
{
        Read from the log file (sz_j, ty_j, c_j, cc)
        TypeCon[1][1] = TypeCon[1][1] + (10 - cc)
        SumAvAlbedo = SumAvAlbedo + (10 - cc)*0.07

        for (j=1 to 3)
        {
                coeff,row,col = Coeff(sz_j, ty_j);
                TypeCon[row][col] = TypeCon[row][col] + c_j
                SumAvIceThickTot = SumAvIceThickTot + c_j*z_j
                SumAvSnoThickTot = SumAvSnoThickTot + c_j*sz_j
                SumAvAlbedo = SumAvAlbedo + c_j*coeff
                SumPerAreaRidged = SumPerAreaRidged + c_j*x
        }
}
```

Algorithm-B: Calculate The Albedo and averages

sumcol1 = $\sum$ TypeCon[k][1]	• calculate column 1 sum k=1 to 10
sumcol2 = $\sum$ TypeCon[k][2]	• calculate column 2 sum k=1 to 10
sumcol3 = $\sum$ TypeCon[k][3]	• calculate column 3 sum k=1 to 10

sum = sumcol1 + sumcol2 + sumcol3

Average Ice Thickness (total area)	= SumAvIceThickTot/(10*N)
Average Snow Thickness total area	= SumAvSnoThickTot/(10*N)
Average Albedo	= SumAvAlbedo/(10*N)
Total Ice Concentration:	= 100 - TypeCon[1][1]
Snow covered ice within pack:	= sumcol2 + sumcol3
Snow free ice within pack:	= sumcol1 - TypeCon[1][1]
Open water within pack:	= TypeCon[1][1]
Percent snow covered ice:	=100*(sumcol2 + sumcol3)/(sum - TypeCon[1][1])
Percent snow free ice:	= 100 - Percent snow covered ice
Average ice thickness (ice only):	= 100*Average Ice Thickness/Total Ice Conc.
Average snow thickness (ice only):	= 100*Average Snow Thickness/Total Ice Conc.
Percent surface area ridged:	= SumPerAreaRidged/(100*N)
Average snow thickness (snow only):	= Average Snow Thickness/((sumcol2+sumcol3)/100)

3.2 Database (.log file) Structure

The database log file consists of binary records. Each record consists of an ice observation record and met observation record. The total size is 544 bytes per record. When records are added to the log file, they are inserted into the file chronologically, and not necessarily appended to the end of the file.

Single Ice Classification (primary/secondary/tertiary ice):

```
struct ICEOBS
{
        BOOL         isValid;        //if the ice classification is valid
        short int    iceConc;        //the ice concentration 0-10
        short int    iceType;        //ice type code
        short int    floeSize;       //floe size code
        short int    topography;     //topography code
        short int    snowType;       //snow type code
        float        iceThick;       //ice thickness in cm
        float        snowThick;      //snow thickness in cm
};
```

Single Ice observation:

```
struct ICERECORD
{
        BOOL         isValid;        //if the observation was made
        TIMEDATE     Tobs;           //the time and date when the observation was made
        float        lat;            //the latitude in degrees
        float     l  on;             //the longitude in degrees
        float        distTrack;      //distance since start of log (first observation)
        float        distEdge;       //distance from the edge of ice
        short int    totalIce;       //total ice concentration
        short int    openWater;      //open water code
        char         comments[120];  //comments field
        ICEOBS       pri;            //primary sea ice data
        ICEOBS       sec;            //secondary sea ice data
        ICEOBS       ter;            //tertiary sea ice data
        char         spare[50];      //spare fields for future use
};
```

Single Met observation:

```
struct METRECORD
{
	BOOL		isValid;		//if the observation was made
	TIMEDATE	Tobs;			//met observation time and date
	float		lat;			//latitude of the observation
	float		on;			//longitude of the observation
	float		seaTemp;		//sea temperature in C
	BOOL		isValidSeaTemp;		//valid-invalid sea temp data
	float		airTemp;		//air temperature in C
	BOOL		isValidAirTemp;		//valid-invalid air temp data
	short int	windVel;		//wind velocity in m/s
	BOOL		isValidWindVel;		//valid-invalid wind velocity
	short int	windDir;		//wind direction in degrees
	BOOL		isValidWindDir;		//valid-invalid wind direction
	short int	photoFilm;		//film (roll) number
	BOOL		isValidPhotoFilm;	//valid-invalid photo film
	short int	photoFrame;		//film frame counter;
	BOOL		isValidPhotoFrame;	//valid-invalid photo frame
	short int	video;			//video recorder counter
	BOOL		isValidVideo;		//valid-invalid video counter
	short int	visibility;		//visibility code
	short int	cloud;			//cloud cover code
	short int	weatherCode;		//weather code
	char		comments[200];		//comments field
	char		spare[50];		//spare fields for future use
};
```

The complete observation record written to disk file:

```
struct LOGRECORD
{
	ICERECORD icerecord;
	METRECORD metrecord;
};
```

3.3 Config File Structure

The config file comprises the individual records written to a single file called **seaice.cfg**. The following records are stored in the same sequence as listed:

Data validation record:

```
struct VALRECORD
{							//GENERAL CHECKS::
	VALIDATION_STYLE iceThick2000;			//check for ice thickness <2000 cm
	VALIDATION_STYLE snowThick300;			//check for snow thickness <300 cm
	VALIDATION_STYLE totIceIsSum;			//check total ice=sum pri+sec+ter
	VALIDATION_STYLE priSecTerThick;		//check pri > sec > ter thickness
	VALIDATION_STYLE snowIceThick;			//snow thickness > ice thickness
	VALIDATION_STYLE iceThickIceType;		//ice thick corresponds to ice type thick
							//SPECIFIC ICE TYPE CHECKING::
	VALIDATION_STYLE iceTypeChecks[10];		//see list of ice type checks below
							//TOTAL ICE CONCENTRATION CHECKS::
	VALIDATION_STYLE totalConcChecks[6];		//see list of total conc/open water checks
};
```

Coefficients record:

```
struct COEFFRECORD
{
	BOOL   isValid[10][4];
	double coeff[10][4];
	char   comments[100];
	har   spare[50];
};
```

Factory Default coefficients, values:

```
static double COEFF_FACTORY_COEFF[12][3] =
{
	{0.07,   ... ,   ...  },
	{0.09,   ... ,   ...  },
	{0.17, 0.24,   ...  },
	{0.21, 0.32, 0.70},
	{0.21, 0.32, 0.70},
	{0.35, 0.50, 0.74},
	{0.50, 0.65, 0.77},
	{0.60, 0.74, 0.85},
	{0.60, 0.74, 0.85},
	{0.60, 0.74, 0.85},
	{0.55, 0.55, 0.55},
	{0.60, 0.74, 0.85},
};
```

Convert to text file record:

```
struct TEXTRECORD
{
	char		srcFile[80];		//the name of the source database file
	char		desFile[80];		//the name of the destination text file
	BOOL		entireFile;		//TRUE if entire file is to be converted
	short int	selectedMonth;		//currently selected month 1..12
	BOOL		selectedDays[31];	//currently selected days to convert
	BOOL		fields[TEXTFIELDS];	//which of the fields below to convert
};
```

3.4 Check and Validation Rules

As described in section 2.6.1, the ***Input Validation Control*** dialog box can be used to enable or disable various validation checks that are performed on the data when a new observation record is entered. If enabled, the following checks apply.

3.4.1 General Checks

- All the required data are supplied. An error message is displayed if any data field has not been specified.
- All the supplied data are within their specified range. Thus the time must be <= 23:59, the day <= 31, month <=12 etc. The ice thickness must be <=2000 cm and the snow thickness <=300 cm. An error message is displayed if any entry is not specified correctly.
- The total ice concentration must equal the sum of the individual ice concentrations thus primary+secondary+tertiary = total.
- The primary ice thickness > secondary ice thickness > tertiary ice thickness.
- The ice thickness should normally be greater than the snow thickness. A warning message is displayed if this is not the case; however the user can choose to ignore the warning message if the observation is correct.
- The specified ice thickness must be consistent with the specified ice type category. Thus if the ice type is 40 (Young grey ice 10–15 cm) then the ice thickness must be in the range 10–15 cm.

3.4.2 Ice Type Checks

Frazil, Shuga, Grease	Floe size	= 0
	Topography	= 0
	snow type	= 1
	ice thickness	< 10 cm
	snow thickness	= 0 cm
Nilas	Floe size	= 200
	Topography	= 100, 400, 500, 600
	snow type	= 1, 2, 3
	ice thickness	< 10 cm
	snow thickness	< 3 cm
Pancakes	Floe size	= 100, 400
	Topography	= 100, 200
	snow type	= 1, 2, 3, 4, 10
	ice thickness	< 20 cm
	snow thickness	< 10 cm
Young grey 10–15cm	Floe size	= 200, 400–700
	Topography	= 100, 500–700
	snow type	= 1, 2, 3, 4, 10
	ice thickness	= 10–15 cm
	snow thickness	< 10 cm
Grey/white 15–30cm	Floe size	= 200, 400–700
	Topography	= 100, 500–700
	snow type	= 1, 2, 3, 4, 10
	ice thickness	= 15–30 cm
	snow thickness	< 20 cm
1st Year ice 30–70cm	Floe size	= 200, 400–800
	Topography	= 100, 500–800
	snow type	= 1, 2, 3, 4, 10, 11
	ice thickness	= 30–70 cm
	snow thickness	< 40 cm
1st Year ice 70–120cm	Floe size	= 400–800
	Topography	= 100, 500–800
	snow type	= 2, 3, 4, 10, 11
	ice thickness	= 70–120 cm
	snow thickness	< 60 cm
1st Year ice >120cm	Floe size	= 400–800
	Topography	= 500–800
	snow type	= 2, 3, 4, 10, 11
	ice thickness	= 120–300 cm
	snow thickness	< 100 cm
Multi Year ice (85)	Floe size	= 400–800
	Topography	= 100, 500–800
	snow type	= 2–11
	ice thickness	< 2000 cm
	snow thickness	< 300 cm

Brash ice (90)	Floe size	= 300
	Topography	= 0
	snow type	= 1
	ice thickness	< 50 cm
	snow thickness	= 0 cm
Fast ice (95)	Floe size	= 800
	Topography	= 100, 500–800
	snow type	= 2–11
	ice thickness	< 300 cm
	snow thickness	< 60 cm

3.4.3 Total Ice Concentration

0:	Check open water 6–9
1, 2:	Check open water 6–8
3, 4:	Check open water 4–6
5, 6, 7:	Check open water 2–6
8, 9:	Check open water 1–4
10:	Check open water 0–1

3.5 Ice Observation Codes

3.5.1 Ice Type Codes (ty)

0:	No data
10:	Frazil
11:	Shuga
12:	Grease
20:	Nilas
30:	Pancakes
40:	Young Grey ice 0.1–0.15 m
50:	Young grey white ice 0.15–0.3 m
60:	First year 0.3–0.7 m
70:	First year 0.7–1.2 m
80:	First year >1.2 m
85:	Multi Year floes
90:	Brash
95:	Fast Ice

3.5.2 Floe Size Codes (f)

0:	No data
100:	Pancakes
200:	New sheet ice
300:	Brash/broken ice
400:	Cake ice <20 m
500:	Small floes 20–100 m
600:	Medium floes 100–500 m
700:	Large floes 500–2000 m
800:	Vast floes >2000 m

3.5.3 Topography Codes (t)

0:	No Data
100:	Level ice
200:	Rafted pancakes
300:	Cemented pancakes
400:	Finger rafting
5xy:	New unconsolidated ridges (no snow)
6xy:	New ridges filled with snow/snow cover
7xy:	Consolidated ridges (no weathering)
8xy:	Older weathered ridges

where:

X : Areal Coverage	
0:	0-10%
1:	10-20%
2:	20-30%
3:	30-40%
4:	40-50%
5:	50-60%
6:	60-70%
7:	70-80%
8:	80-90%
9:	90-100%

Y : Sail Height	
0	No ob
1	0.5m
2	1.0m
3	1.5m
4	2.0m
5	3.0m
6	4.0m
7	5.0m

3.5.4 Snow Type Codes (s)

0:	No observation
1:	No snow, no ice or brash
2:	Cold new snow <1 day old
3:	Cold old snow
4:	Cold wind packed snow
5:	New melting snow, wet new snow
6:	Old melting snow
7:	Glaze
8:	Melt slush
9:	Melt puddles
10:	Saturated snow (waves)
11:	Sastrugi

3.5.5 Open Water Codes (OW)

0:	No openings
1:	Small cracks
2:	Very narrow breaks <50 m
3:	Narrow breaks 50–200 m
4:	Wide breaks 200–500 m
5:	Very wide breaks >500 m
6:	Lead/coastal lead
7:	Polynya/coastal polynya
8:	Water broken only by small scattered floes
9:	Open sea

3.6 Meteorological Observation Codes

3.6.1 Cloud Development During Past Hour Codes (00–03)

00:	Cloud development not observed or not observable
01:	Clouds dissolving or becoming less developed
02:	State of sky on the whole unchanged
03:	Clouds forming or developing

3.6.2 Fog/Precipitation During Past Hour But Not At Time Of Obs (20–28)

20:	Drizzle not freezing or snow grains
21:	Rain not freezing or snow grains
22:	Snow not freezing or snow grains
23:	Rain and snow, or ice pellets
24:	Drizzle or rain, freezing
25:	Showers of rain
26:	Showers or snow or of rain and snow
27:	Showers of hail or of hail and rain
28:	Fog in the past hour, not at present

3.6.3 Blowing or Drifting Snow (36–39)

36:	Drifting snow, below eye level, slight/moderate
37:	Drifting snow, below eye level, heavy
38:	Blowing snow, above eye level, slight/moderate
39:	Blowing snow, above eye level, heavy

3.6.4 Fog/ Mist (41–49)

41:	Fog in patches, visibility <1000 m
42:	Fog thinning in last hour, sky discernible, visibility <1000 m
43:	Fog thinning in last hour, sky not discernible, visibility <1000 m
44:	Fog unchanged in last hour, sky discernible, visibility <1000 m
45:	Fog unchanged in last hour, sky not discernible, visibility <1000 m
46:	Fog beginning/thickening in last hour, sky discernible, visibility <1000 m
47:	Fog beginning/thickening in last hour, sky not discernible, visibility <1000 m
48:	Fog depositing rime, sky discernible, visibility <1000 m
49:	Fog depositing rime, sky not discernible, visibility <1000 m

3.6.5 Precipitation As Drizzle (50–59)

50:	Slight drizzle, intermittent
51:	Slight drizzle, continuous
52:	Moderate drizzle, intermittent
53:	Moderate drizzle, continuous
54:	Dense drizzle, intermittent
55:	Dense drizzle, continuous
56:	Freezing drizzle, slight
57:	Freezing drizzle, moderate or dense
58:	Drizzle and rain, slight

59:	Drizzle and rain, moderate or dense

3.6.6 Precipitation As Rain, Not Showers (60–69)

60:	Slight rain, intermittent
61:	Slight rain, continuous
62:	Moderate rain, intermittent
63:	Moderate rain, continuous
64:	Heavy rain, intermittent
65:	Heavy rain, continuous
66:	Freezing rain, slight
67:	Freezing rain, moderate or heavy
68:	Rain or drizzle and snow, slight
69:	Rain or drizzle and snow, moderate/heavy

3.6.7 Frozen Precipitation, Not Showers (70–79)

70:	Slight fall of snow flakes, intermittent
71:	Slight fall of snow flakes, continuous
72:	Moderate fall of snow flakes, intermittent
73:	Moderate fall of snow flakes, continuous
74:	Heavy fall of snow flakes, intermittent
75:	Heavy fall of snow flakes, continuous
76:	Ice prisms, with/without fog
77:	Snow grains, with/without fog
78:	Isolated starlike snow crystals
79:	Ice pellets

3.6.8 Precipitation As Showers (80–90)

80:	Slight rain showers
81:	Moderate or heavy rain showers
82:	Violent rain showers
83:	Slight showers of rain and snow
84:	Moderate/heavy showers of rain and snow
85:	Slight snow showers
86:	Moderate or heavy snow showers
87:	Slight showers of soft or small hail
88:	Moderate/heavy showers of soft/small hail
89:	Slight showers of hail
90:	Moderate or heavy showers of hail

3.6.9 Visibility Codes

90:	<50 m
91:	50–200 m
92:	200–500 m
93:	500–1000 m
94:	1–2 km
95:	2–4 km
96:	4–10 km
97:	>10 km
-1:	Not available

3.7 Map Plotting Coordinate Transformation

The map plotting facility described in section 2.4.1 (Plot Ship Route) is used to plot geographical maps, and the location of the ship-based ice observations, on a polar stereographic plot of the southern hemisphere. The latitude and longitude coordinates are mapped to pixel coordinates using the geodetic to polar stereographic projection. Details of this algorithm can be found in:

Snyder, J. P. 1982. Map projections used by the US Geological Survey. *US Geological Survey Bulletin* 1532.

The notation used is:

R_e	earth radius
S_{lat}	standard latitude 70.00
e	earth eccentricity 0.081816154
G_x,G_y	polar stereographic coordinates
lat,lon	geodetic coordinates
Sign	-1=south pole
ρ	radius of latitude circle on polar azimuthal projection, or radius from centre on any azimuthal projection
C_m	elipsoid correction factor

3.7.1 North or South Pole

For the southern hemisphere a constant of 180 degrees (XLAM) is specified. For the northern hemisphere this value is -45.

```
if (lat <0)
{
        Sign = -1
        XLAM=180
        lat = -1×lat
        lon = -1×lon
}
else
{
        Sign = +1
        XLAM=-45
}
```

3.7.2 Calculate polar stereographic coordinates

This conversion produces no distortion at latitudes of 70 degrees south (or north), hence there is minimal distortion within the Antarctic sea ice zone. The earth is assumed to be an ellipsoid with a radius of 6378.273 km and eccentricity e of 0.081816153.

$$\text{if}(lat \,?\, 90)$$

$$t_1 = \frac{\tan(\pi/4 - lat/2)}{\left[(1 - e \times \sin(lat))/(1 + e \times \sin(lat))\right]^{e/2}}$$

$$t_2 = \frac{\tan(\pi/4 - S_{lat}/2)}{\left[(1 - e \times \sin(S_{lat}))/(1 + e \times \sin(S_{lat}))\right]^{e/2}}$$

$$Cm = \frac{\cos(S_{lat})}{\sqrt{(1 - e^2 \cdot \sin^2(S_{lat}))}}$$

$$\rho = \frac{R_e \cdot Cm \cdot t_1}{t_2}$$

$$G_x = \rho \cdot Sign \cdot \sin(lon - XLAM)$$
$$G_y = \rho \cdot \cos(lon - XLAM)$$

$$if(lat = 90)$$
$$G_x = 0$$
$$G_y = 0$$

3.8 Track Distance Calculations

To calculate the distance between two points (lat1, lon1) and (lat2, lon2) on the earth, we use the following equations. It is assumed that the points are close to each other. The notation used is:

R_e:	earth radius 6378.273 km
e:	earth eccentricity 0.081816154
lat, lon:	geodetic coordinates

3.8.1 Latitude distance

$$dS_1 = \frac{R_e . \sqrt{1 - e^2}}{\sqrt{1 - e^2 . \cos^2\theta}} d\theta$$

where:

$$\theta = lat_1$$
$$d\theta = |lat_2 - lat_1|$$

all values are in radians.

3.8.2 Longitude distance

$$dS_2 = \frac{R_e . \sqrt{1 - e^2} \cos\theta}{\sqrt{1 - e^2 . \cos^2\theta}} d\phi$$

where:

$$\theta = lat_1$$
$$d\phi = |lon_2 - lon_1|$$

3.8.3 Track distance

$$dS = \sqrt{dS_2^2 + dS_1^2}$$