International Workshop on
Antarctic Sea Ice Thickness

Hobart, Australia

5-7 July 2006

Sponsored by:

Scientific Committee on Antarctic Research
Climate and Cryosphere Program
Australian Antarctic Division
Antarctic Climate & Ecosystems Cooperative Research Centre
Tasmanian Government – Antarctic Tasmania
European Space Agency
US National Science Foundation
International Glaciological Society

Scientific Committee:

Tony Worby & Steve Ackley (Conveners)
Robert Massom, Victoria Lytle, Christian Haas

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Friday 7th July – Afternoon

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Chair: Tony Worby

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Chair: Steve Ackley; Rapporteur: Tony Worby

16:00	Final discussion *Summary of proceedings, formal recommendations, future planning* *Establish working groups as necessary for ongoing work*
18:00	Close
18:30	Dinner at Siscos restaurant (Murray St Pier, Hobart)

International Workshop on Antarctic Sea Ice Thickness

Oral Presentations

---- in order of presentation ----

ANTARCTIC SEA ICE THICKNESS FROM SPACE

Seymour Laxon (1)

ABSTRACT

Estimates of sea ice thickness around Antarctica are particularly sparse due to the difficulty of accessing the continent (particularly during winter) and the lack of submarine data. However recent measurements of ice or snow freeboard, from both space-borne radar and laser, have demonstrated the potential to provide estimates of sea ice thickness in the Arctic. In the Antarctic, however, additional uncertainties, particularly related to snow loading, are present. We will describe both techniques and describe qualitatively the uncertainties in their retrievals. We also show initial comparisons of radar altimeter thickness estimates with ULS measurements of ice draft and thickness from the ASPeCt project. We then describe briefly the future schedule of space-borne observations and the opportunities for dedicated validation activities.

(1) Centre for Polar Observation and Modelling, University College London, England.

VALIDATING SATELLITE ESTIMATES OF ANTARCTIC SEA ICE THICKNESS

Katharine Giles [(1)]

ABSTRACT

Techniques to calculate sea ice thickness from measurements of sea ice freeboard from spaceborne radar and laser altimeters in the Arctic have the potential to be used in the Antarctic. The conversion of freeboard, measured by the altimeter, to thickness uses estimates of snow depth and density, and water and ice density, from a climatology. In order to use these estimates of sea ice thickness we must understand the errors associated with the conversion of ice freeboard to ice thickness and in particular how the errors of each of the constituent parameters co-vary. In particular the data must be averaged in space and time to reduce the errors in the freeboard measurement, and in the parameters involved in the conversion to thickness. Knowledge of how these parameters co-vary in space and time and with each other is essential in properly calculating an error in the retrieval. Therefore, ground truth measurements must be carefully designed to validate estimates of ice thickness and in particular to analyse covariance of the errors. We describe the principles of the error evaluation of estimates of sea ice thickness from satellite measurements of ice freeboard and outline the in-situ measurements required to validate such estimates.

[(1)] Centre for Polar Observation and Modelling, University College London, England.

VARIATIONS IN ANTARCTIC SEA ICE FREEBOARD AND THICKNESS DISTRIBUTIONS FROM ICESat DATA

H. Jay Zwally [1], Donghui Yi [2], Ron Kwok [3], and Seymour W. Laxon [4]

ABSTRACT

Sea ice freeboard distributions are determined from ICESat measurements of mean surface elevations with a range precision of ~2 cm over 70 m footprints spaced by 170 m along track. Freeboard (snow cover plus sea ice) distributions are constructed from elevation measurements within ± 50 km of each measurement point, from which the lowest 1% of the points are selected as the ocean reference level (i.e., open water or very thin ice). Reiterative mapping of the ocean reference level, and averaging over different time periods, is used to reduce the effect of errors in the initial estimate of the geoid. Sea-ice thickness is derived from the freeboard measurements using estimates of snow and sea-ice densities, combined with snow-depth estimated from passive microwave data from AMSR-E. Along track sea-ice freeboard and thickness values are then mapped onto 50 x 50 km grids. Since 2003, measurements have been made for about 33-day periods three times a year (February/March, May/June, and September/October). The distributions show the seasonal growth/decay cycle, regional variations, and interannual variations of the sea-ice pack.

(1) NASA Goddard Space Flight Center, USA.
(2) SGT Inc., NASA Goddard Space Flight Center, USA.
(3) NASA Jet Propulsion Laboratory, USA.
(4) University College London, England.

WIDEBAND RADARS FOR SEA ICE AND SNOW THICKNESS MEASUREMENTS

Sivaprasad Gogineni [(1)], Pannir Kanagaratnam [(1)], Ben Holt [(2)], Thorsten Markus [(3)]

and Victoria Lytle [(4)]

ABSTRACT

Thicknesses of sea ice and snow are key variables in ice-ocean-atmosphere interactions. Sea ice insulates the warm ocean from polar air and controls the heat exchange, which is determined by its thickness. Also, sea ice thicknesses, together with sea ice extent, are considered proxy indicators of polar climate change. Snow cover on sea ice modifies its thermal and mechanical properties. Because of its very low thermal conductivity and high albedo even a thin snow cover exerts a strong influence on the heat exchange between the atmosphere and the ocean. Furthermore, thick snow acts as a mechanical load and depresses sea ice surface below its freeboard. This can result in flooding of the snow-ice interface and the conversion of snow to ice. Thus, an accurate knowledge of snow thickness is essential for determining the overall heat and mass budget in the polar regions. The information on the thickness of snow cover is also required to estimate ice thickness from freeboard measurements. Satellites that can measure sea ice freeboard for estimating its thickness have been and are scheduled to be launched in the next years.

The application of radars to measure sea ice and snow thickness has been investigated with mixed results. This is partly because of inadequate signal processing capability of radars used in early investigations. The advances in digital and RF technologies, fuelled by the wireless industry, offer an opportunity to develop optimized wideband radars for sea ice and snow thickness measurements. In this paper we will summarize the status of radar sounding of sea ice and snow, show sample results from recent experiments in the Antarctic and the Arctic, and discuss the design and application of surface-based and airborne radars for sea ice and snow thickness measurements.

[(1)] Center for Remote Sensing of Ice Sheets, University of Kansas, USA.
[(2)] Jet Propulsion Laboratory, USA.
[(3)] NASA Goddard Space Flight Center, USA.
[(4)] CliC Project Office, Norway.

GPR PROFILES OF SEA ICE IN McMURDO SOUND, ANTARCTICA

Steven A. Arcone (1)

ABSTRACT

I discuss 300−400 MHz ground-penetrating radar (GPR) profiles of sea ice in McMurdo Sound, Antarctica. I recorded them in mid October, 2005 when ice temperature could have eliminated most brine in the ice and allowed the bottom to be profiled. The transects total 8 km and extend from near McMurdo Station to the transition onto the ice shelf. Horizons showing continuous and intermittent stratification occur throughout the ice. Their phases indicate both relatively low and high permittivity layers, which are probably caused by variations in porosity and brine volume. The deepest horizon consistently occurs at about 2.5−3 m depth, which is the thickness expected for this ice, but it is of the wrong polarity and too weak to be from seawater. Consequently, this depth may be a minimum value. A profile segment over the transition to the glacial ice of the McMurdo Ice Shelf shows the onset of the well known brine layer, and it has the correct strength and polarity. The brine layer within the glacial firn appears to be directly fed from a layer within the sea ice and not from the bottom. However, this seems unlikely because of such a limited supply of brine needed to feed the immense extent of the brine layer. Therefore, it may be either an intermittent connection until the sea ice is released, or there may have been a separation between the glacial and the sea ice that allowed sea water to rise to this layer.

(1) U.S. Army ERDC-Cold Regions Research and Engineering Laboratory, USA.

THEORETICAL MODELLING OF SEA ICE AS AN ELECTRICALLY DENSE MEDIUM FOR ACTIVE MICROWAVE REMOTE SENSING

Mohan Albert [(1)], Hong Tat Ewe [(1)] and H. T. Chuah [(1)]

ABSTRACT

Microwave remote sensing has been a useful tool to monitor the conditions of sea ice and ice extent in the polar regions. The study of the scattering mechanisms involved between the microwave and the sea ice medium is of interest to the researchers for understanding the important physical parameters affecting the radar returns received by the remote sensing satellite. The analysis carried out, and the knowledge gained, shall assist in the interpretation of the satellite images of the polar regions. In this paper, a theoretical model of a two layer medium is constructed consisting of a sea ice layer with a snow layer on top of it, and an ocean halfspace beneath it. In consideration of the number and density of the scatterers (brine inclusions and air bubbles) in the sea ice medium for the frequency range studied, it is regarded as an electrically dense medium as there is more than one scatterer within a wavelength. Unlike the conventional approach where sparse medium with independent scatterers is considered, the modeling of the electrically dense medium requires the consideration of coherent effects of the scatterers to be incorporated in the computation. An iterative solution with up to second order terms of the radiative transfer equation, which describes the energy propagation in the medium, is produced. The measurement data of the physical parameters of the sea ice area in Ross Island collected from 2001-2005 are applied to the model and the analysis of the results for various conditions and matching with Radarsat data is carried out. The effect of the sea ice thickness and the scattering mechanisms between the layers involved are studied to give a better understanding of the range of radar returns collected from the sea ice areas. With the snow layer on top of the sea ice, the wicking effect of the brine up to the snow-sea ice interface is also analysed. A study of the changes of the backscattering returns across frequency is also carried out to provide better understanding of the suitable frequency range to be considered for the monitoring of sea ice in polar regions.

[(1)] Multimedia University, Malaysia.

MODELLING ANTARCTIC SEA ICE THICKNESS

William H. Lipscomb (1)

ABSTRACT

I will review current efforts to model the Antarctic ice pack. Sea ice models in GCMs have become more sophisticated in recent years; state-of-the-art models now include viscous-plastic dynamics, second-order-accurate advection, multilayer thermodynamics, and multi-category thickness distributions. However, these models generally do not have realistic treatments of snow-ice formation, lateral melting, or sea ice biology. I will focus on one such model, CICE, which is used in the Community Climate System Model (CCSM). In ice-only runs using CICE, the broad features of the Antarctic ice pack can be reproduced well if the deep-ocean heat flux is tuned to limit wintertime ice growth. In coupled runs with CCSM, the ice pack is realistic overall, although the ice is too extensive in the South Atlantic and probably too thick in the Weddell Sea. Validation of ice thickness is difficult because of the sparseness of data. In greenhouse scenarios, Antarctic ice volume decreases more rapidly than ice extent, suggesting that thickness may be a better climate change indicator. The most important positive feedback is increased solar absorption in open water; the ocean heat flux convergence does not increase in most regions.

(1) Los Alamos National Laboratory, USA.

SEASONAL FORECASTING OF ANTARCTIC SEA ICE

Xiaojun Yuan [(1)] *and Dake Chen* [(1)]

ABSTRACT

Long-range forecasts of Antarctic sea ice are very much in demand, not only because of the potential importance of sea ice in global climate, but also for the practical purpose of exploring the Antarctic continent. Unfortunately, such forecasts are not yet feasible with any state-of-the-art general circulation models, because the complex air-sea-ice interaction processes on long timescales are still not well understood and are by no means well simulated by these models. An alternative is to apply statistical methods to Antarctic sea ice prediction. The linear Markov model used in this study represents one of the first attempts in this direction.

The variability of Antarctic sea ice is likely to be controlled by both remote and local processes. The atmospheric anomalies from low latitudes could excite certain modes of the Antarctic climate system, which then could be amplified and sustained by the local air-sea-ice interaction. Here we explore the possibility of forecasting Antarctic sea ice anomalies using a technique combining multivariate empirical orthogonal function (MEOF) analysis and linear Markov prediction. Seven atmospheric variables along with sea ice were chosen to define the state of the Antarctic climate, and the MEOF of these variables were used as the building blocks of the model. The predictive skill of the model was evaluated in a cross-validated fashion, and a series of sensitivity experiments were carried out. In both hindcast and forecast experiments, the model showed considerable skill in predicting the anomalous Antarctic sea ice concentration a few seasons in advance, especially in austral winter and in the Antarctic dipole regions. The success of the model is attributed to the domination of the Antarctic climate variability by a few distinctive modes in the coupled air-sea-ice system, and to the model's ability to pick up these modes.

[(1)] Lamont-Doherty Earth Observatory of Columbia University, USA.

SIMULATION OF THE Ku-BAND RADAR ALTIMETER SEA ICE EFFECTIVE SCATTERING SURFACE

Rasmus Tonboe [(1)], Søren Andersen [(1)] and Christian Haas [(2)]

ABSTRACT

Deriving ice thickness from altimeter returns depends on ice and snow density as well as knowledge of the effective scattering surface. Usually, the latter is assumed to be at the ice-snow interface. A radiative transfer model is used to simulate the sea ice radar altimeter effective scattering surface variability as a function of snow depth and density. Under dry snow conditions without layering these are the primary snow parameters affecting the scattering surface variability. The model is initialised with dry in situ snow profiles collected during the *Polarstern* ISPOL cruise in November 2004 in the Weddell Sea.

Our results show that the snow cover is important, not only due to its effect on buoyancy, but also by modification of the effective scattering surface, which is shown to be above the ice-snow interface. The resulting combined errors in ice thickness estimates are assessed.

(1) Danish Meteorological Institute, Denmark.
(2) Alfred Wegener Institute, Germany.

SOUTHERN OCEAN PRECIPITATION, SNOW DEPTH, AND SNOW TO SEA ICE CONVERSION: SPATIAL AND TEMPORAL VARIABILITY

Thorsten Markus [(1)]

ABSTRACT

Snow depth on sea ice plays a critical role in the heat exchange between ocean and atmosphere because of its thermal insulation, which is almost an order of magnitude greater than the thermal insulation of sea ice. Furthermore, a heavy snow load on the relatively thin Southern Ocean sea ice cover frequently submerges the ice floes below sea level, causing snow-to-ice conversion and thus an increase of sea ice thickness. As a matter of fact, the snow to ice conversion may significantly moderate snow depth variability so that inter-annual variations in precipitation are not fully reflected in snow depth data. The talk will present an analysis of the inter-annual and regional variability of snow depth on sea ice using an almost 30-year record of satellite passive microwave data and will compare the results with variations in the sea ice cover and with re-analysis precipitation data.

[(1)] NASA Goddard Space Flight Center, USA.

ANALYSIS OF SNOW DEPTH AND COVERAGE ON SEA ICE IN ANTARCTICA USING AMSR-E DATA PRODUCTS

Michael J. Lewis [(1)] and Hongjie Xie [(1)]

ABSTRACT

A study of the variation in snow cover and depth over the Antarctic sea ice zone was performed using AMSR-E/Aqua snow depth and sea ice temperature products of approximate 5-day intervals from June 2002 through December 2005. Time series statistic analyses of mean and maximum snow depth, snow area coverage, as well as the spatiotemporal distribution analysis of areas of minimum (less than 5 cm) and maximum (mean + 2 σ) snow depth were performed. The areas of maximum snow depth were compared with sea ice temperature data to observe potential patterns of occurrence. Results of the study indicated that the minimum snow coverage area showed a consistent decrease from 2003 to 2005 in February (later summer season), while the maximum snow coverage area showed a consistent increase from 2002 to 2005 in late September (early spring season). The mean snow depth peaks in summer months and shows a generally increasing trend from 2003 to 2005, while total snow volume (from mean snow depth multiplied by snow coverage) on sea ice generally decreased from 2003 to 2005 in both peak and low seasons. A comparison of mean snow depth to the area of snow coverage shows that a decrease in the area of thin sea ice (and hence thin snow cover) occurs in summer months and tends to bias the mean values toward thicker remaining snow cover. This is supported by maximum snow depth values that do not show a corresponding increase in summer months as shown in the mean values. Images compared from 2002 to 2005 show the occurrence of maximum areas of snow depth coincide well with previously reported areas of sea ice increases in the Weddell Sea, Ross, Sea, and Pacific Ocean. One exception is the Amundsen Sea, which shows areas of maximum snow depth in the Spring and Winter months however, was reported with decreasing sea ice trends and therefore may represent greater precipitation in these areas. Seasonal comparisons of maximum areas show changes in location that appear to correspond with ice circulation patterns in the Weddell Sea. Areas with minimum snow depth generally occur in east Antarctica, north along the Atlantic Ocean, and over thin sea ice at the edge of the ice pack. Limited comparison of sea ice temperature with maximum snow depth occurrence generally showed a consistent positive correlation between temperature minimums and snow depth maximum for all seasons.

[(1)] Laboratory for Remote Sensing and Geoinformatics, University of Texas at San Antonio, USA.

CliC: THE CRYSOSPHERE AND CLIMATE PROJECT

Victoria Lytle [(1)]

ABSTRACT

The Cryosphere and Climate Project (CliC) co-ordinates climate activities related to all parts of the earth's cryosphere. This includes sea ice, snow, ice shelves, ice bergs, lake ice, and permafrost. This talk will give a brief overview of the CliC project, and how it fits within the other international climate related projects. Although CliC is not a funding body, it is able to provide some small support for workshops and conferences. The project research consolidates terrestrial (permafrost, frozen soils, lake and river ice, snow, glaciers, ice caps and ice sheets) and marine (sea-ice, ice-shelves) cryosphere. Through cooperation with professional societies, partners programmes, focused projects and campaigns, such as the International Polar Year 2007/2008, CliC strives to develop cryospheric observations, modelling and data assimilation, as contributions to climate prediction systems. Outcomes from CliC research will contribute to seasonal forecasting, estimates of sea-level prediction, water management, energy production and many other application areas.

For sea ice, CliC is particularly interested in the question: "What will be the nature of changes in sea-ice distribution and mass balance in both polar regions in response to climate change and variability?' It is hoped that this presentation can lead to discussions of how ASPeCt might contribute to initiatives such as polar reanalysis, IPY coordination, data collection and climate related data sets, and improved representation of the cryosphere in models.

[(1)] CliC International Project Office, Norwegian Polar Institute, Norway.

PLANNED ACTIVITIES ON SEA ICE WITHIN THE GCOS SST&SI WORKING GROUP

Søren Andersen [(1)]

ABSTRACT

In autumn 2005, the GCOS Working Group on SST and Sea Ice (GCOS SST&SI WG) was redefined. The working group had been in existence, but inactive, for some 5 years, however it was concluded that there is a need for its activities. In short, the working group shall stimulate the creation of long-term homogeneous SST and sea ice concentration data sets with quantified uncertainties through intercomparison of several near real-time and historical SST and sea ice analyses. The activities on sea ice were kicked off at the first meeting of an initial core group in Boulder in late March 2006. In the present phase, a crucial activity of the initial group is to oversee the take up of relevant groups and scientists in the sea ice subgroup.

Previous long term studies have to some extent been limited by the fact that no error estimates exist for present day ice concentration analyses. Hence, an important short term objective is to promote and develop ice concentration analyses with attached error estimates. In the longer term, the working group shall work to reconcile passive microwave, ice chart and paleo ice analyses to help the formation of consistent and homogeneous long term data sets and a possible extension to sea ice thickness is also envisaged. The data recovery and standardisation activities within ASPeCt are of primary relevance to the activities of the GCOS SST&SI WG. The talk/poster will concentrate particularly on Antarctic conditions in the presentation of working group remit, planned activities and some problems of special concern.

[(1)] Danish Meteorological Institute, Denmark.

THE ASPeCt DATA SET – RECENT ANALYSIS AND APPLICATIONS

Anthony Worby [(1)], Cathleen Geiger [(2)], Matthew Paget [(3)], Michael van Woert [(4)], Stephen Ackley [(5)] and Tracy DeLiberty [(6)]

ABSTRACT

Ship-based observations of sea ice conditions have been collated from 89 voyages to the Antarctic pack ice, between 1980 and 2005. These data were collected primarily by Russian, Australia, US, German and British vessels engaged in scientific and logistic activities as part of their national Antarctic programs. The data from each voyage has been quality controlled, digitised and converted to a standard format as defined by the Antarctic Sea Ice Processes and Climate (ASPeCt) program, which was established in 1997.

The data have been analysed to assess the regional and seasonal variability in the ice thickness distribution and snow cover around Antarctica. While there are still a number of significant gaps in some regions and seasons, we have sufficient data to broadly characterise the character of the pack and to identify important regional and seasonal differences. We use a curve fitting routine to provide a numerical description of the ice thickness distribution and also provide a suite of standard statistics including the mean ice and snow thickness, standard deviation and decorrelation length scales.

A brief summary of recent applications of the ASPeCt data archive will also be presented, including comparisons with model output and the development of a climatology of sea ice albedo. The ASPeCt data files will be available online via the Tasmanian Partnership for Advanced Computing (TPAC) Digital Data Library that will facilitate spatial and temporal queries on the data archive. Visit: http://digitallibrary.tpac.org.au.

[(1)] Australian Antarctic Division and ACE CRC, Australia.
[(2)] Cold Regions Research and Engineering Laboratory, USA.
[(3)] CSIRO, Australia.
[(4)] National Science Foundation, USA.
[(5)] Clarkson University, USA.
[(6)] University of Delaware, USA.

TECHNIQUES FOR ANALYZING AIRBORNE VIDEO OVER ANTARCTIC SEA ICE

Margaret A. Knuth [(1)] *and Stephen F. Ackley* [(2)]

ABSTRACT

Sea ice observations are difficult to obtain in sufficient temporal and spatial resolution. Several observational techniques have been used to build a sea ice record of ice concentration, ice extent, and ice thickness among other things. Satellite measurements are varied in their capabilities (e.g. resolution in pixel size and timing of passes) and in how genuine the results are. Ship observations have become a standard procedure to build a database but are limited by scheduled tracks (often in ice free or ice limited areas) and the small amount of coverage they are capable of. On the other hand, helicopter video observations are able to cover much larger regions and still have the benefit of a comparatively high resolution visual observation.

The ASPeCt process has been used for some time now to characterize ice conditions during cruises. This process has been extended to helicopter video data and the technique is presented here. While there are limitations to using helicopter video data to determine floe size or ice thickness, there are methods using nearby ship observations as a tie point that can be used to provide a reliable estimate. While a significant amount of time is needed to manually process the videos using the ASPeCt method of sampling along a transect, reliable estimates of the complete set of ASPeCt parameters have been made and it has proved to be much less labor intensive than digital processing of the entire tape for ice concentration only. There is also good agreement between the estimate of ice concentration by ASPeCt sampling and the concentration obtained by objective image processing of the same tapes. The two methods have proven to give very close results (a standard deviation of ±3.3%). Two sets of observation data from helicopters have been placed in the ASPeCt data base to date. With workshop discussion, we hope to show this type of analysis is sufficient for processing helicopter photography or videos, and start to catalog data sets that may already exist to provide expansion of the existing data base. For any future filming, we will review the particulars necessary to gather data for input into the database in future.

[(1)] National Science Foundation, USA.
[(2)] Clarkson University and University of Texas, San Antonio, USA.

RECENT ACTIVITIES OF SEA ICE THICKNESS OBSERVATIONS BY THE JAPANESE ANTARCTIC RESEARCH EXPEDITION

Shotaro Uto [(1)], Haruhito Shimoda [(1)], Shuki Ushio [(2)] and Kazuki Nakamura [(2)]

ABSTRACT

This paper introduces the recent activities of sea ice thickness observation around Syowa station (40ºE), East Antarctica, conducted by the Japanese Antarctic Research Expedition (JARE). Ship-borne video observations were conducted on 12 voyages from December 1987. Ship-borne observations of ice plus snow thickness using the electro-magnetic inductive instrument were conducted on 5 voyages from December 2000. These observations were mostly conducted in December and February when the icebreaker *Shirase* sails to and from Syowa station, respectively. These data revealed the inter-annual variability of the spatial distribution of the summer landfast ice in Lutzow-holm Bukta. In January 2006, JARE started the sledge-borne observations of sea ice thickness using the electro-magnetic inductive instrument to collect the landfast ice thickness data throughout a year. Some preliminary results are described in this paper. ENVISAT/ASAR images were acquired synchronously with the ship-based observations. A preliminary analysis showed the high correlation between ice thickness and the ratio of HH and VV backscatter coefficient.

[(1)] National Maritime Research Institute, Japan.
[(2)] National Institute of Polar Research, Japan.

TECHNIQUES FOR SEA ICE PHOTOGRAMMETRY

Nicholas Hughes [(1)]

ABSTRACT

The IceCam is an automated sea ice observing and environmental data logging system developed jointly by the Scottish Association for Marine Science (SAMS) and the Norwegian Polar Institute (NPI). Photographs from the IceCam can be processed for sea ice parameters using supporting data from other onboard sensors which include GPS time and position, heading from digital compass and camera attitude from a tiltmeter. These and an assessment of the camera lense during the construction process allow sophisticated ortho-rectification of images to allow ice floe mapping. The use of colour photography and, in the future, thermal imaging provides scope for a range of analysis techniques including the possibility of floe freeboard and ridge height estimation, melt pond area calculation and ice albedo.

[(1)] Scottish Association for Marine Science, Scotland.

NATIONAL ICE CENTER SEA ICE CHARTING AND ICE THICKNESS ACTIVITIES

Pablo Clemente-Colón (1)

ABSTRACT

The National Ice Center (NIC) is a United States government tri-agency operational center comprised of components from the US Navy, the National Oceanic and Atmospheric Administration (NOAA), and the US Coast Guard (USCG). The mission of the NIC is to provide the highest quality strategic and tactical ice services tailored to meet operational requirements of US national interests. This includes broad responsibilities to monitor all frozen ocean regions of the world in support of coastal and marine sea ice operations and research. Sea ice conditions are routinely monitored using satellite imagery along with ancillary model and in situ data. Active microwave observations are the choice for NIC analysts to produce high spatial resolution products geared toward tactical support as well as regional charts. Observations presently used include RADARSAT-1 Synthetic Aperture Radar (SAR), Envisat Advanced SAR (ASAR), and the SeaWinds scatterometer on QuikSCAT. In addition, passive microwave observations such as those from the Special Sensor Microwave/Imager (SSM/I) and WindSat provide useful temporal and synoptic view of the Polar Regions but at a significantly reduced spatial resolution compared to that of active sensors. For example, automated SSM/I algorithms provide for near-real time production of a series of sea ice parameters including concentration and multiyear fraction in the Arctic Ocean and around Antarctica. These microwave observations are complemented by several other visible and infrared (IR) satellite data that are also essential to producing accurate sea ice characterization and monitoring of changes in the ice conditions. Visible and IR observations routinely used include those from the Defense Meteorological Satellites Program (DMSP) Operational Linescan System (OLS), NASA Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS), and the NOAA Advance Very High Resolution Radiometer (AVHRR). The combined use of these data is essential to produce accurate and routine ice type and stages of development analyses.

From ice type and stages of development information, rough estimates of the distribution of sea ice thickness can be produced. Sea ice type and stages of development analyses are presently done operationally for the full Arctic region. Although they have also been done around the full Antarctic region, analysis in Antarctica is presently limited to the Ross Sea due to manpower requirements. Another approach to estimating and following the distribution of sea ice thickness that has been used in the Arctic relies on following the dynamic history of the ice pack through the tracking of drifting buoys. This approach requires a well distributed buoy array and essentially applies to multi-year ice in part due to the lack of seasonal ice buoys. Ice thickness estimates can be produced for young to first year ice through relatively simple thermal models. The proper validation of all of these approaches to estimating ice thickness is critical but the availability of validation datasets, although diverse, is limited in temporal and spatial coverage at present. Some of these diverse sources of validation data available include ice mass balance buoys, electromagnetic induction sensors, radar and laser altimeters, and upward looking sonar. A review of ongoing and planned activities relating the estimation and validation of sea ice thickness will be presented.

(1) US National Ice Center, USA.

AN EVALUATION OF SEA ICE THICKNESS AS ESTIMATED FROM ICE CHARTS FOR THE SOUTHERN OCEAN

Tracy L. DeLiberty [(1)], Cathleen A. Geiger [(2)], Michael Van Woert [(3)], Anthony Worby [(4)], and Stephen Ackley [(5)]

ABSTRACT

The weekly National Ice Center (NIC) ice chart dataset is compared with in situ sea-ice thickness observations from the AsPeCT program during five cruises for 1995 to 2000 time period in the Ross Sea to discern their quality for use in monitoring sea ice thickness and mass balance changes. Sea ice thickness calculations from both datasets are temporally joined with spatially averaged in situ observations matching their respective NIC ice chart using a Geographic Information System (GIS). The uncertainties of total ice thickness for both in situ observations and NIC ice charts are propagated through individual calculations and the GIS processing. Graphical tools, as well as quantitative measures, are used in this assessment. In general, the NIC ice chart thickness estimates correlate reasonably well with in situ observations. A temporal comparison of the NIC ice chart data along an individual ship track reveal insight into the differences, and these discrepancies are further investigated. Along with this evaluation of the ice chart dataset in the Ross Sea, the comparison is extended across the entire Southern Ocean.

[(1)] Department of Geography, University of Delaware, USA.
[(2)] Cold Regions Research and Engineering Laboratory, USA.
[(3)] National Science Foundation, USA.
[(4)] Australian Antarctic Division and ACE CRC, Australia .
[(5)] University of Texas at San Antonio, USA.

ESTIMATION OF THIN ICE THICKNESS AND DETECTION OF FAST ICE FROM SSM/I DATA IN THE ANTARCTIC OCEAN

Takeshi Tamura [(1)], *Kay I. Ohshima* [(2)], *Thorsten Markus* [(3)], *Donald J. Cavalieri* [(3)], *Sohey Nihashi* [(2)] *and Naohiko Hirasawa* [(4)]

ABSTRACT

Antarctic coastal polynyas are important areas of high sea ice production and dense water formation, and thus their detection including an estimate of thin ice thickness is essential. We propose an algorithm that estimates thin ice thickness and detects fast ice using SSM/I data in the Antarctic Ocean. Detection and estimation of sea ice thicknesses of <0.2 m are based on the SSM/I PR85 and PR37 through a comparison with sea ice thicknesses estimated from the AVHRR data. Exclusion of the data affected by atmospheric water vapor is discussed. We also detect fast ice (ice shelves, glacier tongues, icebergs, and landfast ice) by using the relationship between the 85-GHz vertical and horizontal brightness temperatures. This algorithm clearly distinguishes fast ice from thin ice in coastal areas where both coexist. The probability that the algorithm correctly distinguishes thin ice from thick ice and from fast ice is ~95 %, relative to the ice thicknesses estimated from AVHRR. Although the standard deviation of the difference between the thin ice thicknesses estimated from the SSM/I algorithm and AVHRR is ~0.05 m and thus not small, the estimated ice thicknesses from the microwave algorithm have no biases and the accuracies are independent of region and season.

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[(2)] Institute of Low Temperature Science, Hokkaido University, Japan.
[(3)] NASA/Goddard Space Flight Center, USA.
[(4)] National Institute of Polar Research, Japan.

A NOVEL QUIKSCAT DUAL POLARIZATION σ^0 BASED ALGORITHM FOR DELINEATION OF SEA ICE AND SEA ICE EDGE OVER THE SOUTHERN POLAR OCEAN

S.M. Bhandari [(1)], M. K. Dash [(2)], N. Khare [(2)] and N. K. Vyas [(1)]

ABSTRACT

Fan-Beam and Pencil-Beam Radar Scaterrometers on many satellites in polar orbits, e.g. ERS-1/2, ADEOS-1/2 and QuikSCAT, have been designed primarily for estimation of vector winds over the global oceans. However, these scatterometers, due to their reasonably high resolutions and precise backscatter measurements in different polarizations, have emerged as powerful tools to map and study the ice in the polar region. Dual polarization $\boldsymbol{\sigma}^0$ (HH and VV) measurements provided by these scatterometers have been exploited to successfully delineate the presence of sea ice. Algorithms and procedures have been developed to locate the boundary between open sea and sea ice regions i.e. the sea ice edge, for flagging the ice corrupted oceanic wind retrievals as well as for providing sea ice advisories for navigation.

In the past, India launched its first passive microwave radiometer in polar orbit i.e. MSMR onboard Oceansat-1 during 1999. MSMR data have been used extensively by us for the study of spatio-temporal variability of sea ice over the Antarctic region and to examine its role in climate change.

Currently, India is planning to launch a Ku-band Pencil-Beam Scatterometer onboard Oceansat-2 in near future, coinciding with the IPY (2007-2008) period. To give boost to applications of Oceansat-2 Scatterometer in polar ice studies, we have undertaken the development of algorithms for delineation and study of sea ice based on QuikSCAT data.

In this paper, we have made use of the dual polarization measurements from QuikSCAT by using the polarization difference ($\boldsymbol{\sigma}^0$VV- $\boldsymbol{\sigma}^0$HH) and the polarization ratio ($\boldsymbol{\sigma}^0$ VV/ $\boldsymbol{\sigma}^0$ HH) in a synergistic manner to develop a new physically based algorithm for unambiguous sea ice detection over the Southern Ocean around Antarctica. The resulting sea ice maps have been used to locate the sea ice edge with high accuracy, as evidenced by comparison with simultaneous sea ice concentration images from SSM/I NASA team Algorithm. The sea ice edge located by the present algorithm is found to correspond well to the 10% sea ice concentration contour in the SSM/I images, during both the summer and winter conditions. The PR+PD based sea ice edge algorithm developed by us is found to be robust and, unlike the other QuikSCAT based algorithms published in literature, does not require any a priori information and statistics related to history of sea ice presence in the region.

The paper presents the details of the new algorithm and discusses the comparison and validation of sea ice maps generated using QuikSCAT data with those from SSM/I and other QuikSCAT based algorithms. An attempt is also being made to develop techniques to categorize sea ice regions into different classes (FY/MY, thick/thin, low/high concentration) based on the use of PR and PD as the discriminating parameters.

(1) Meteorology & Oceanography Group, Space Applications Centre (ISRO), India.
(2) Polar Remote Sensing Group, National Centre for Antarctic and Ocean Research, India.

EXTREME ATMOSPHERIC AND SEA ICE CONDITIONS IN THE WEST ANTARCTIC PENINSULA REGION – ICE THICKNESS IMPLICATIONS

Rob Massom [(1)], Sharon Stammerjohn [(2)], Ray Smith [(3)], Neil Adams [(4)], Wouter LeFebvre [(5)] and Mike Pook [(6)]

ABSTRACT

This work presents case studies of extreme sea ice conditions in the West Antarctic Peninsula (WAP) region resulting from large-scale anomalies in atmospheric circulation patterns. In 2001/2, one such anomaly persisted over a 5-6 month period i.e., virtually the entire spring-summer, to exert a profound and complex impact on sea ice thickness, distribution and conditions. Here, we combine in situ observations, satellite data, atmospheric analyses and model output to analyse these impacts. Paradoxically, extensive ice melt and dynamic thickening occurred simultaneously, both driven by winds with a dominant northerly/northwesterly component. The latter resulted in a sea ice cover up to 20 m thick. Moreover, above-average snowfall combined with enhanced deformation to cause significant snow-ice formation. In 2001/2, extreme ice compaction resulted in an unusually early and rapid (short) retreat season (negative ice-extent anomaly) in the Bellingshausen Sea – a region that underwent considerable change over the satellite era. Major ice convergence, deformation and thickening in turn led to the atypical persistence of highly-compact coastal ice through summer. This work underlines the difficulties involved in measuring such extreme thicknesses using conventional methods. It also challenges the use of ice extent information alone as a proxy indicator of climate change/variability, at least in the WAP region i.e., ice extent alone fails to account for changes in sea ice volume. In so doing, this study underlines the key need for accurate ice thickness and compactness/deformation information to more fully characterize the sea ice cover. A comparison is made with conditions in 2005/06.

[(1)] Australian Antarctic Division and ACE CRC, Australia.
[(2)] NASA Goddard Institute for Space Studies, USA.
[(3)] University of California, Santa Barbara, USA.
[(4)] Australian Bureau of Meteorology and ACE CRC, Australia.
[(5)] Université Catholique de Louvain, Belgium.
[(6)] CSIRO Division of Marine and Atmospheric Research, Australia.

EMPLOYMENT OF UPWARD-LOOKING SONAR FOR ICE THICKNESS MEASUREMENTS IN THE WEDDELL SEA

Wolfgang Dierking [(1)], Hannelore Witte [(1)] and Mario Hoppema [(1)]

Presented by Christian Haas [(1)]

ABSTRACT

Since 1990, the Alfred Wegener Institute for Polar and Marine Research (AWI) in Germany has deployed upward-looking sonar (ULS) instruments on moorings in the Weddell Sea. The ULS measurement sites are located along two profiles, the first from Kapp Norvegia to the tip of the Antarctic Peninsula, and the second along the Greenwich meridian. Measurements on the former were interrupted in 1998 but have recently been started again. On most positions of the Greenwich meridian profile, continuous data series have been gathered since 1996. The major goal is to monitor long-term changes of ice thickness and ice coverage. ULS data were used to identify different ice regimes, to estimate the relative contributions of thermodynamic growth and rafting/ridging to the effective ice thickness, and to calculate the ice mass and freshwater transport in the Weddell Sea.

The ULS records the two-way travel time of an acoustic pulse between the sensor and the ice from which the distance to the ice-water interface is calculated. At the same time, the pressure is measured which is converted into the ULS depth. In theory, the difference between the ULS depth relative to the water level and the distance to the ice equals the ice draft. For converting travel time to distance, however, the speed of sound along the path of the acoustic pulse needs to be known which usually cannot be measured simultaneously over the whole data acquisition period. Therefore, patches of open water or thin ice have to be identified in the data series which are used as “zero-draft” reference level to which the distance measurements are related. The identification of open water areas is the most critical point of the data processing which influences the accuracy of the ice draft measurements. At the AWI, two specialists on ULS data analysis determine the reference level independently from one another. Largest deviations occur during ice formation in fall and melt-onset in spring.

Recently, ULS instruments with higher sampling rates are used which may alleviate the problem of open-water identification to a certain degree. In addition, ADCP-instruments were deployed together with ULS at a few positions so that the temporal ULS draft series can be converted into spatial domain. An important item is to link ULS measurements and complementary data. For example, ULS data may serve for validating ice thickness measurements from radar altimetry. They are also a useful complement for analyses of radar imagery and of ice thickness measurements by means of electromagnetic sounding. The presentation will provide an overview about the AWI-ULS data acquisition and archiving. Examples of problems occurring in data analysis and estimates of the accuracy of measured ice drafts are discussed. An example of recent applications of ULS data in a research project at the AWI is given.

[(1)] Alfred Wegener Institute, Germany.

ADVANCES IN AUV TECHNOLOGY FOR ANTARCTIC UNDER-ICE OPERATIONS

PART I: NATURE OF SONAR DATA

Peter Wadhams [(1)] *and Jeremy Wilkinson* [(2)]

ABSTRACT

We describe the datasets on ice draft that have been collected under sea ice by AUVs, comprising experiments with single-beam and sidescan sonars and the more recent multibeam sonar data collected by Autosub off NE Greenland. To date, the highest quality data (multibeam) comes from the Arctic. In the light of what is known about the nature of Antarctic sea ice and Antarctic pressure ridge structure from drilling, photography and other data sources, we discuss how multibeam sonar can best be used to map the nature of Antarctic sea ice and what might be expected to be observed. We recommend strategies for AUV ice profiling operations in different parts of the Antarctic.

[(1)] Dept. of Applied Mathematics and Theoretical Physics, University of Cambridge, England.
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ADVANCES IN AUV TECHNOLOGY FOR ANTARCTIC UNDER-ICE OPERATIONS

PART II: MULTIDISCIPLINARY AND MULTISENSOR OPERATIONS WITH AN AUV

Jeremy Wilkinson [(1)] *and Peter Wadhams* [(2)]

ABSTRACT

The polar oceans are an ideal home for AUV technology as the sea ice cover prevents the use of most autonomous oceanographic platforms. At present under-ice investigations have been limited to military submarine operations in the Arctic and ROVs, divers and ULS in the Antarctic. AUVs offer scientists the flexibility to determine the location as well as timing from which scientifically controlled and directed missions can occur as well as being able to sail close to the ice bottom or work in areas of shallow bathymetry. More importantly the AUV can be viewed as a multidisciplinary, multisensor tool which enhances partnership between scientists from different disciplines. We present results of ice thickness monitoring that has been performed with the Autosub AUV in the Arctic, its relevance to the Antarctic, and how the ice thickness results when combined with information from other sensors onboard Autosub are of significance to a number of scientific disciplines.

[(1)] Scottish Association for Marine Science, Scotland.
[(2)] Dept. of Applied Mathematics and Theoretical Physics, University of Cambridge, England.

MEASUREMENT OF SEA ICE DRAFT USING AN UPWARD LOOKING ADCP ON AUTOSUB AUV

Christopher J. Banks [(1)], Mark A. Brandon [(1)] and Paul H. Garthwaite [(2)]

ABSTRACT

During March 2003 Autosub, the autonomous underwater vehicle (AUV) operated by the UK National Oceanography Centre in Southampton, performed a number of missions below sea ice close to Thurston Island. This talk will provide details of using on-board instrumentation to provide values for the sea ice draft in the region. The onboard instrumentation involved is an upward looking acoustic Doppler current profiler (ADCP), consisting of four beams each with a value for range to surface. The other instrument is a conductivity-temperature-depth sensor (CTD) and provided values of vehicle depth. Following a novel methodology to correct for, amongst other factors, vehicle orientation and sound speed, these values of range can be used to measure ice draft. The talk will outline these processing steps and present probability density functions for each of the missions. The impact of a geostatistical examination of the data will be provided to account for the variable density of sample points across the study regions.

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EM SEA ICE THICKNESS MEASUREMENTS – POTENTIAL AND REQUIREMENTS FOR SYSTEMATIC THICKNESS MONITORING IN THE SOUTHERN OCEAN

Christian Haas (1)

ABSTRACT

Electromagnetic induction (EM) sounding has become an operational tool for sea ice thickness profiling; on the ice, from ships, and from helicopters. While level total (ice plus snow) thickness can be determined very accurately in most seasons, the maximum thickness of pressure ridges is highly underestimated. However, the amount and distribution of ridges can be determined and the relative thickness of different ice regimes can be differentiated.

Level ice thickness estimates are biased in the events of thick slush layers due to flooding mainly during the warm season, and by the existence of gap layers during the summer. Future development has to address these issues, e.g. by improved instrumentation using multiple signal frequencies, and subsequent numerical inversion, or by obtaining information about the occurrence of slush and gap layers by other means. In this context, extensive coincident in-situ observations of ice and snow properties are still desirable. Extensive in-situ sampling of ridge morphology, block structure, and porosity, and coincident EM profiles with 3D modelling of the EM response are required to improve EM thickness estimates over ridges. The envelope shape of ice keels can best be determined by underice sonar profiling, and coincident EM and scanning upward-looking-sonar (ULS) surveys are highly desirable, e.g. using an autonomous underwater vehicle (AUV).

The paper will summarize German activities and results of EM thickness sounding in the Southern Ocean, and will present operations of a unique helicopter-borne EM thickness sensor. The so-called EM-Bird is easy and inexpensive to use and operable from ice breakers and by any helicopter. Therefore, it can also be used by other research groups to extend the observational basis in the Southern Ocean. We suggest forming a group of key scientists possessing the required logistic background to initiate a systematic monitoring program of Southern Ocean sea ice thickness, based on repeated ship cruises and our EM equipment and experience.

Independent snow thickness measurements are still required for the important differentiation between snow and ice. We will present an approach to snow thickness measurements based on the simultaneous use of EM thickness and laser/DGPS freeboard measurements, and on efforts to integrate a ground penetrating radar system into an EM Bird.

(1) Alfred Wegener Institute, Germany.

CROSS VALIDATION OF IN SITU, AIRBORNE AND REMOTE SENSING DATA FROM EAST ANTARCTICA

Andreas Pfaffling [(1)], Anthony Worby [(2)] and Rob Massom [(2)]

ABSTRACT

Remote sensing of sea ice parameters plays a key role in polar research and climate change investigations. New sensors such as high resolution passive microwave scanners (AMSR-E) and visible/infrared radiometers (MODIS) provide new information from which, given appropriate algorithms, products including sea ice extent and concentration, snow thickness or ice temperature can be derived. These algorithms depend on approximations and assumptions, which have to be assessed in situ for quality control and/or to readjust the algorithm's parameters. An Australian sea ice dedicated expedition in (austral) early spring 2003 to the East Antarctic marginal sea ice zone (RSV *Aurora Australis*, Voyage 1 - 2003/04) offered the opportunity for cross validation of diverse geophysical tools such as the AWI's helicopter-borne EM ice thickness profiler, as well as a helicopter-borne system containing a digital nadir looking camera combined with a thermal infrared radiometer, and remote sensing data from AMSR-E, SSM/I, MODIS, AVHRR, MISR, SAR, etc. satellite sensors. The airborne platforms could be precisely validated against ground truth data acquired on 13 ice stations and consequently could be used to validate remote sensing data.

On two days during the expedition exceptionally good weather conditions with clear sky along several hundred kilometres provided a superb dataset. Flight tracks of altogether more than 500 km were profiled synoptically with the EM ice thickness platform and the aerial photography + IR radiometer system. Photography flights were carried out at 5000 feet altitude while EM bird was usually flown at around 100 ft allowing the EM operators to document the general ice conditions and take detailed geocoded digital pictures of the ice and snow conditions along the track, giving a ground truth dataset for the high altitude photos as well as structures found in satellite pictures.

On both days near real time MODIS scenes containing the flight tracks were acquired and provide an excellent overview of the general ice conditions in the area. Along 109.3°E in the vicinity of the Australian Antarctic research station Casey, a 155 km long meridional flight transect from 65.75°S to 64.4°S passes a variety of different ice classes varying from a freshly refrozen polynya west of an iceberg grounding line along Peterson Bank to vast, snow - covered drifting floes at 65°S. Accounting for the different footprints and spatial resolutions of the systems, statistical properties are compared such as HEM derived ice thickness distribution with ice/snow surface temperature distributions from the helicopter IR radiometer and MODIS IR channel. Huge structures at the mentioned polynya extending for almost 10 km along the flight track, or the biggest drift floe measuring roughly 15 x 7 km can be described by the HEM thickness distribution computed from profile subsets with length equal to the highest spatial resolution for the AMSR-E (6x4 km @ 89 GHz) resulting in an average snow + ice thickness of 0.06 m with standard deviation 0.09 m and 3.49 m thickness (1.17 m SD) respectively, corresponding to a brightness of 2% and 80% in the visual MODIS channel. HEM thickness distributions from this 155 km long transect (including open water) were compared to AMSR-E ice concentrations.

[(1)] Pfaffling Geophysics, Germany.
[(2)] Australian Antarctic Division and ACE CRC, Australia.

DEVELOPMENT OF 1-D MULTI-LAYER MODEL FOR DEFORMED SEA ICE THICKNESS IN THE ANTARCTIC SEA USING THE ELECTROMAGNETIC INDUCTION DEVICE

Kazu Tateyama [(1)], Hiro Enomoto [(1)], K. Shirasawa [(2)], Takeshi Tamura [(2)], Atsu Muto [(3)], Shotaro Uto [(4)], Shuki Ushio [(5)], Ian Allison [(6)], Anthony Worby [(6)], Robert Massom [(6)] and Victoria Lytle [(7)]

ABSTRACT

Indirect ice and snow thickness measurements were carried out for the spring Antarctic sea ice in the area of 110-120^{o}E and 64-65^{o}S between September and October of 2003 by using the ground-based Electro-Magnetic inductive (EM) device during the Antarctic Remote Ice Sensing Experiment 2003 (ARISE-03). Measurements of EM, ice drilling and snow thickness were made at 1 to 2 m intervals along 13 transects (50 to 500m long) on 10 different ice floes. The ice thickness and snow depth ranged from 0.2 to 5 m and from 0.04 to 1m, respectively. This study investigated the effect of the saline slush snow layer over the sea ice and seawater-filled gap on the snow and sea ice thickness measured by EM. Results showed that for relatively smooth surface and thinner ice <2 m, the simple 1-D three layers model (which is using snow layer, single ice floe layer and seawater layer) showed good agreement within an accuracy of ±10% of in-situ thickness. For thicker ice >3.5 m, with seawater-filled gaps between deformed ice floes, the simple model showed a large underestimating error over 50%. By developing the 1-D multi-layer deformed ice model considering slush snow and seawater-filled gaps, the error was decreased to below 30%.

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(3) National Snow and Ice Data Centre, USA.
(4) National Maritime Research Institute, Japan.
(5) National Institute of Polar Research, Japan.
(6) Australian Antarctic Division and ACE CRC, Australia.
(7) CliC International Project Office, Norwegian Polar Institute, Tromsø, Norway.

FLUID AND ELECTRICAL TRANSPORT IN SEA ICE

Ken M. Golden [(1)], Amy L. Heaton [(1)], Jingvi Zhu [(1)], Ali Jabini [(1)], Megan Morris [(1)], Adam Gully [(1)], Hajo Eicken [(2)], Jeremy Miner [(2)] and Lars Backstrom [(2)]

ABSTRACT

Sea ice is a porous composite of ice with brine, air, and salt inclusions, whose microstructural properties depend strongly on temperature. The transport of brine, which carries salt, heat, and nutrients through sea ice, controls a broad range of geophysical, oceanographic, and biological processes. However, measurements of the fluid permeability of sea ice are sparse and little is known theoretically. We give mathematical formulations of the two key problems of fluid transport in sea ice, bulk flow of brine, and diffusion of dissolved substances such as pollutants or bacterial enzymes. We present a comprehensive theory for the fluid permeability of sea ice, based on rigorous bounds, continuum percolation theory, hierarchical models, network simulation, and microstructural analysis. Our theoretical results closely capture laboratory and Arctic field data. The related problem of finding the effective complex permittivity of sea ice at low frequencies, a central issue in estimating sea ice thickness, is also addressed. Our results indicate a percolation threshold around 5% brine volume fraction, in agreement with the behavior of fluid transport.

[(1)] University of Utah, Department of Mathematics, USA.
[(2)] Geophysical Institute, University of Alaska Fairbanks, USA.

ANTARCTIC FAST ICE MONITORING DURING IPY 2007/2008 AND BEYOND

Petra Heil [(1)]

ABSTRACT

Ice thickness is an important descriptor of the sea-ice state. The thickness evolution of pack ice is influenced by thermodynamic as well as by dynamic processes. A multitude of interactions between ocean, sea ice and atmosphere take place. Although these interactions make it difficult to directly link variability in ice characteristics to changes in thermodynamics or dynamics, causal links have been identified between changes in atmosphere and pack ice (e.g., Simmonds, 1996). On the other hand, the growth and melt of fast ice can generally be described by thermodynamic processes alone.

In late winter, the contribution of fast ice to the overall ice-mass balance is not negligible: e.g., fast ice may contribute as much as 14% by area to the East Antarctic sea ice (Fedotov *et al*., 1998). Furthermore, its immobility makes it an ideal tool to study ocean, ice and atmosphere interactions with a focus on thermodynamic processes. As part of the IPY submission “Sea Ice Mass Balance in Antarctica” (SIMBA), an “Antarctic Fast-Ice Network” (AFIN) has been proposed to concurrently monitor the thickness evolution of fast ice at several coastal Antarctic sites. So far, various sites for the deployment of fast-ice observing stations have been identified, including sites on glacial ice sheets.

In addition to the fast-ice data, meteorological and some oceanographic observations from nearby stations will be available for the analysis of forcing relationships between the media. For some of the network sites historical data on the fast ice are also available. Together these will allow us to study the spatio-temporal changes in the Antarctic fast ice and to identify the dominant linkages within the ocean-ice-atmosphere system.

[(1)] Australian Antarctic Division and ACE CRC, Australia.

JAPANESE MOORING PLAN IN THE CAPE DARNLEY POLYNYA DURING THE IPY

Yasushi Fukamachi [(1)], *Kay I. Ohshima* [(1)], *Shigeru Aoki* [(1)], *Shuki Ushio* [(2)] *and Masaaki Wakatsuchi* [(1)]

ABSTRACT

Historical (Jacobs and Georgi, 1977) and recent hydrographic surveys (Klepikov and Antipov, 2005), and recent satellite-data analysis (Tamura *et al*., in preparation) suggest that the Cape Darnley Polynya, located west of the Amery Ice Shelf, as a potentially important source region of the Antarctic Bottom Water (AABW). In order to estimate sea ice production in this polynya, we are planning to deploy ice-profiling sonars, ADCPs, and conductivity-temperature (CT) recorders for a year during the IPY period. In addition, in order to capture the resultant bottom-water transport, we are also planning to deploy ADCPs, current meters, and CT recorders in the downstream region northwest of the polynya. The resultant data should clarify whether this polynya is actually an important source region of the AABW in a quantitative manner. Furthermore, the resultant data will be valuable sea-truth data for the satellite-data analysis to estimate sea ice thickness, hence sea ice production.

[(1)] Hokkaido University, Japan.
[(2)] National Institute of Polar Research, Japan.

REMOTE SENSING OF THIN ICE WITH SPACE- AND HELICOPTER-BORNE MULTI-FREQUENCY RADAR DURING IPY

Stefan Kern [(1)]*, Martin Gade* [(1)]*, Detlef Stammer* [(1)] *and Rasmus Tonboe* [(2)]

ABSTRACT

Investigating the ocean-atmosphere heat exchange and water-mass transformation in regions covered by sea ice requires knowledge of its thickness – among other parameters. Remote sensing of the thickness of sea ice, particularly when it is thin, is still a challenge. Attempts to resolve this parameter are based on AVHRR imagery (which requires clear-sky conditions, e.g. Drucker *et al*., 2003), on microwave radiometry (only suitable for large thin-ice areas, e.g. Cavalieri, 1994), or on radar data (e.g. Kwok *et al*., 1995; Wakabayashi et al., 2004). Different methods have been applied to radar data to obtain the thickness of thin ice e.g. in leads, yielding quite different results concerning the maximum thickness to be obtained however. The upcoming possibility to combine space-borne radar data acquired at different frequencies and polarizations justifies further investigations of the potential of such data.

We propose to analyse thin ice using a combination of helicopter- and space-borne multi-frequency radar measurements (HH-, VV-, and HV-polarization), IR-temperature observations and video imagery, detailed in-situ measurements, and modelling of the radar backscatter of thin sea ice for at least two field campaigns. Space-borne observations will concentrate on data acquired at L-Band (ALOS-Palsar), C-Band (Envisat ASAR), and X-Band (TerraSAR-X); helicopter-borne data will include in addition observations at Ku-Band. After data processing and calibration, sea ice is discriminated from open water by its radar-backscatter co-polarization ratio being close to zero decibels already at an ice thickness of a few centimeters at a (high) frequency (X- or Ku-Band). Subsequently, the radar-backscatter co-polarization ratio at a lower frequency (L-Band) can be used to estimate the thickness of thin (30-50 cm) sea ice (e.g. Kern *et al*., 2006). Alternatives may emerge from experience gathered during the field campaigns. The ultimate goal of our investigations during IPY is to optimize and evaluate our approach for the retrieval of the thickness of thin sea ice based on helicopter-borne scatterometry (which includes an assessment of the influence of snow, slush, and/or frost flowers), and to modify this approach for its use with appropriate satellite radar imagery.

The presentation will focus on the results obtained from observations made during the cruise ARK XIX/1 of the R/V *Polarstern* in March/April 2003, and on our concept for IPY for 2008 with regard to observations of thin ice in the Southern Ocean.

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International Workshop on
Antarctic Sea Ice Thickness

Poster Presentations

---- alphabetical by first author ----

SURFACE SURVEYS OF SNOW DEPTH, ICE ELEVATION AND SEA ICE THICKNESS AND THEIR USE IN DEVELOPING ICE THICKNESS ALGORITHMS FROM LASER AND RADAR SATELLITE ALTIMETRY

Stephen F. Ackley (1)

ABSTRACT

Submarine-based ice thickness measurements have shown decreases in Arctic ice thicknesses of up to 40% (~10%/decade) over the past 30-40 years. Without submarines traversing the Antarctic sea ice zone however, there are no similar estimates of ice thickness change, or even circumpolar mean sea ice thickness for the Antarctic region. Using radar and/or laser satellite altimeters, it is postulated that the measurement of snow and ice surface elevations over sea ice, or both, can be made with sufficient accuracy and used to derive the sea ice thickness using an isostatic relationship between the above and below sea level portions of the ice cover. From Arctic ground surveys of snow depth, ice elevation and ice thickness, we compare predictions of ice thickness to measured values using elevations with various assumptions on ice density and averaging lengths in the conversion algorithm. Errors on the predicted mean thicknesses are quantified for these assumptions. Over the short lengths comparable to a single satellite laser return pulse, these calculations suggest the errors from an isostatic relationship with a constant ice density assumption may be larger than if a more realistic assumption of variable ice density is used.

For Antarctic sea ice, however, work on computing ice thicknesses from satellite algorithms, either laser or radar, are still in a developmental and/or unvalidated state. Some examples from ground-based surveys of ice thickness and surface elevation (combined snow depth and ice elevation) have indicated an even more complex relationship between elevation and thickness than suggested for the Arctic. The presence of significant areas of flooded ice with sea water at the ice surface-snow interface in the Antarctic differs from the Arctic surface case, and affects the density used to compute ice thickness from snow elevation. Radar algorithms based on positive ice elevation may also need adjustment for the Antarctic flooded condition with negative ice elevation.

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SEA ICE RESEARCH WITHIN THE INTERNATIONAL POLAR YEAR 2007-2008

Ian Allison [(1)]*, Michel Béland and David Carlson*

ABSTRACT

The International Polar Year 2007 - 2008, co-sponsored by the International Council for Science and the World Meteorological Organisation, will be an intensive and internationally coordianted campaign of high quality research and observations in the polar regions. It will have an interdisciplinary emphasis that will include social sciences as well as natural science. The IPY 2007-2008 is intended to lay the foundation for major scientific advances in knowledge and understanding of the polar regions and their role in the functioning of the planet. Nearly 900 potential IPY activities were submitted to an ICSU-WMO call for Expressions of Intent (EoI) in January 2005. A considerable number of these EoIs were proposal involving research into sea ice and its role in air-sea interaction, ocean structure and circulation, climate and ecosystems in both polar regions. Full IPY program submission, which in many cases will be larger collaborative inititatives formed from clusters of the initial EoIs, were due at the end of June 2005. This poster provides an overview of the major sea ice research that is developing under the IPY 2007-2008 vision.

[(1)] Australian Antarctic Division and ACE CRC, Australia.

ICE THICKNESS RETRIEVAL USING VISIBLE AND INFRA-RED SATELLITE OBSERVATIONS

Igor Appel [(1)]

ABSTRACT

Ice of different thickness exhibits both different albedo and different surface temperature. This is used as a physical basis to retrieve ice thickness for relatively thin ice cover. Input data for the developed algorithm deriving ice thickness consist of 2-dimensional swath images of top-of–the-atmosphere reflectances and surface temperature. The application of a sliding search window to the swath images allows one to find locally-specific ice and water tie points. Preliminary preprocessing uses those regionally-specific tie points to determine ice concentration for each pixel of satellite observations. The information on pixel concentration lets us calculate reflectance and surface temperature corresponding to ice itself (different from pixel temperature and reflectance).The algorithm further uses two different methods: (1) nighttime retrieval of ice thickness from surface temperature, achieved by using energy balance and (2) daytime retrieval from reflectance, based on radiative transfer models.

Reflectance and surface temperature are influenced by snow cover accumulated on ice. Therefore, the description of snow effects on reflectance and surface temperature is included in the algorithm. Snow depth on ice is modeled as a function of ice thickness, using data in the climatic Snow Depth/Ice Thickness look up table or the snowfall history. Ice thickness is computed from an energy balance equation transformed to express ice thickness as a function of surface temperature and snow depth. The algorithms determining ice thickness includes the analytical description of ice growth without assumptions on surface temperature considered as an internal parameter of the model. An ice BRDF look up table created on the basis of DISORT and 6S radiative transfer models is used to get the reflectance and narrow band albedo corresponding to pixel solar/viewing angles, ice thickness, and snow depth. The model directional reflectance is compared to the observed ice reflectance to obtain ice thickness.

The proposed approach can be used to develop operational algorithms to derive sea ice thickness on a global basis. This capability will be of great value to operational ice centers.

[(1)] No affiliation.

UNDER SEA ICE MEASUREMENTS IN THE NORTHWESTERN WEDDELL SEA USING THE AUTONOMOUS UNDERWATER VEHICLE AUTOSUB II

Mark A. Brandon [(1)], Christopher J. Banks [(1)] and Andrew S. Brierley [(2)]

ABSTRACT

The AUV Autosub 2 was first used under sea ice in February 2001 at the northern edge of the Weddell Sea (~63°S, 50°W) in a combined physical and biological study. The AUV was equipped with a single beam upward looking scientific echo sounder operating at two frequencies that provided data on both sea ice draft and the quantitative distribution of zooplankton. The AUV was also equipped with several other sensors including high-resolution CTDs, upward and downward looking ADCPs, a chlorophyll sensor, a dissolved oxygen sensor and a photosynthetically active radiation (PAR) sensor. For this experiment the AUV was sent on two types of completely autonomous missions, one being under sea ice and up to 80 km length at depths of 150 to 250 m and the other ~10 km and under specifically targeted individual icebergs. In total we collected over 130 km of under sea-ice data from which, after making various corrections, we derive an ice draft for each mission and then a synoptic ice draft distribution. As well as comparing the distribution with upward looking sonar data collected just to the south, the sensors have given a unique view of the ice edge under different conditions.

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ELEVATION AND FREEBOARD CHANGES OF ROSS SEA ICE AND ICE SHELF USING ICESAT

Burcu Cicek [(1)] and Hongjie Xie [(1)]

ABSTRACT

In this paper, ICESat (Ice, Cloud, and land Elevation Satellite)-based estimates of sea ice and ice shelf elevation change and the sea ice freeboard changes in the Ross Sea Region of west Antarctic were studied. To process the data, a GIS-based procedure was developed and includes three steps. First, the raw binary ICESat data was converted into a text file using a provided IDL script from The National Snow and Ice Data Center (NSIDC). Then, a custom code was developed and used to automatically extract the data for the ROSS region and to convert data according to the Geographic Information Systems (GIS) coordinate system so that the data is recognized by the commonly used GIS software. Finally, the data was imported into the GIS for further analysis. ICESat datasets of three releases were used for the study: two (laser 1 and laser 2A) in 2003 and one (laser 3D) in 2005. It was found that all of them have suspect elevation data and extensive quality control was needed to remove the suspect points before a bias-free surface could be generated. Also obtained sea-ice freeboard from ICESat elevation data showed unusual negative results. Simple, universe, and ordinary kriging interpolations as well as inverse distance weights interpolation were tested and evaluated. It was found that the ordinary kriging method based on an unknown mean performed the best and achieved the smallest RMS prediction error (<1 m) based on cross-validation technique. Seasonal elevation changes of the two complete datasets (fall to spring 2003) have been analysed and results indicate that (1) the mean elevation of sea ice increased about 0.89 m, with a mean increase of 0.55 m for the sea ice/ice shelf transition zone; (2) the mean elevation of the ice sheet decreased about 0.17 m; (3) maximum elevation of sea ice increased 1.13 m; (4) maximum elevation of ice shelf increased 5.36 m; (5) the transitional region has the largest elevation change: ~60 % of the region shown 48 to 20 m decreases, only small portions shown 20-40 m increases. Inter-annual elevation changes obtained from laser 3D and laser 2A for sea ice indicate that (1) minimum surface elevation has decreased as 5.27 m with increase of mean surface about 0.12 m; (2) maximum surface elevation from Australia spring 2003 to spring 2005 has decreased as 12.69 m. It is suggested that the freeboard derived directly from ICESat data has large negative values and needs better geoid or mean sea surface from other sources for better determination of freeboard or real elevation.

[(1)] University of Texas at San Antonio (UTSA), USA.

LAND-FAST SEA ICE THICKNESS IN McMURDO SOUND, ANTARCTICA: THE ROLE OF PLATELET ICE

Tim Haskell [(1)] and Pat Langhorne [(2)]

ABSTRACT

In some circumstances, over 50% of the thickness of Antarctic, land-fast sea ice is platelet ice. Unlike columnar ice, the formation of platelet ice is not well understood and appears to be controlled by the oceanic heat flux. In McMurdo Sound, evidence from the 1980s and 1990s implied that platelet ice appeared in the water column about the middle of winter, increasing the growth rate at this time, and disappeared in the summer. However, our field programme over the last five years has suggested that the platelet ice is more prevalent than in these previous two decades. The question now is whether the presence of several large icebergs immediately north of Ross Island has perturbed the McMurdo Sound oceanography, enhancing platelet ice growth. In this poster we present existing data and describe our plans for the future now that most of the icebergs have moved away from the Ross Island area. If we find significant differences in the contribution of platelet ice with and without the presence of large masses of glacial ice (in this case icebergs), then we may improve our understanding of the importance of this ice in the Antarctic sea ice system.

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ICECAM: SEA ICE DATA COLLECTION ON VESSELS OF OPPORTUNITY IN IPY 2007-2008

Nicholas E. Hughes [(1)] and Richard Hall

ABSTRACT

The IceCam is an automated sea ice and environmental data logging system developed jointly by the Scottish Association for Marine Science (SAMS) and the Norwegian Polar Institute (NPI). The concept for IceCam is that it can be used on non-scientific vessels to gather sea ice observation information independent of observers and if necessary transmit this via satellite to allow timely incorporation into satellite image analysis and ice chart production.

The system has been successfully used by scientific expeditions to the Arctic and Antarctic, even when no dedicated sea ice observers have been on board. The datasets produced include large numbers of photographs supported with positional, camera attitude and environmental metadata. These can then be used to develop advanced photogrammetry techniques for extracting sea ice parameters and improved understanding of satellite images. In the forthcoming International Polar Year it is planned to use IceCam in a number of expeditions operating in the Arctic and Antarctic. A pool of IceCams for use on Vessels Of Opportunity (VOO) will be established. These will be used to increase sea ice data collection during IPY and beyond by deployment on other vessels including tourist cruises and ship escort icebreakers.

(1) Scottish Association for Marine Science (Sea Ice Research Group), Scotland.

COMBINING SUB-DAILY POLYNYA SIGNATURE SIMULATION METHOD (PSSM) POLYNYA AREA ESTIMATES WITH AMSR-E SEA ICE CONCENTRATIONS AND ICE THICKNESS DERIVED FROM AVHRR DATA

Stefan Kern [(1)], Lars Kaleschke [(2)], Gunnar Spreen [(1)], Sara de la Rosa Hoehn [(1)], Georg Heygster [(2)] and Detlef Stammer [(1)]

ABSTRACT

Investigating the ocean-atmosphere heat exchange and water-mass transformation in regions covered by sea ice, requires knowledge of its distribution and thickness. Of particular interest in this context are the coastal and flaw polynyas of the Southern Ocean: windows for the ocean-atmosphere heat exchange and ice-production factories. We present multi-sensor analysis of selected Southern Ocean coastal polynyas carried out with respect to their winter time dynamics and associated thin-ice thickness. The polynya area is estimated with the Polynya Signature Simulation Method (PSSM, Markus and Burns, 1995) using orbital Special Sensor Microwave/Imager (SSM/I) brightness temperature observations at 37 and 85 GHz from two DMSP spacecraft (F13 and F15, see http://www.ifm.zmaw.de/_wwwrs/RS RossSeaPolynyaMaps.html). This area is combined with the ice concentration obtained by applying the ARTIST sea ice concentration (ASI) algorithm (Kaleschke *et al*., 2001; see http://www.seaice.de) to brightness temperature observations of the 89 GHz channels of the Advanced Microwave Scanning Radiometer (AMSR-E) and with the thin-ice thickness derived with a heat-flux method (Drucker *et al*., 2003) using optimally interpolated meteorological data from ECMWF re-analyses and operational analyses and AWS observations. Additionally, mean and variance of the sea-ice concentration derived from low-frequency SSM/I data (19 and 37 GHz) are employed to mask out fast ice which is shown to exhibit a similar passive microwave signature as the thin ice in polynyas. With this method we obtain information about the sub-daily polynya area dynamics, and the associated ice production from satellite observations and obtain estimates of the amount of salt released into the ocean. Time series of two regions, the Ross Sea and the Mertz Glacier Polynya will be presented.

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THE INTEGRATED GLOBAL OBSERVING STRATEGY FOR THE CRYOSPHERE: IGOS-Cryo

Jeff Key [(1)] *and Victoria Lytle* [(2)]

ABSTRACT

The IGOS Cryosphere Theme is a combined initiative of the World Climate Research Programme (WCRP) Climate and Cryosphere (CliC) Project and the Scientific Committee on Antarctic Research (SCAR). The Theme intends to create a framework for improved coordination of cryospheric observations conducted by research, long-term scientific monitoring, and operational programmes, and to generate the data and information needed for both operational services and research.

The principal objectives of the Integrated Global Observing Strategy (IGOS) are to address how well user requirements are being met by the existing mix of observations, including those of the global observing systems, and how they could be met in the future through better integration and optimization of remote sensing (especially space-based) and in situ systems. IGOS serves as guidance to those responsible for defining and implementing individual observing systems. Implementation of the Strategy, i.e., the establishment and maintenance of the components of an integrated global observing system, lies with those governments and organizations that have made relevant commitments, for example, within the governing councils of the observing systems' sponsors.

For sea ice, the draft recommendations include observations required to describe and monitor the distribution, properties and state of the global sea ice cover including ice concentration and extent, ice-type classification, ice thickness distribution, surface albedo and temperature, ice temperature, ice motion, snowcover thickness, floe-size distribution and the onset and geographical progression of seasonal patterns of ice melt onset and freeze-up. The sea ice thickness distribution is emphasized. The recovery, collation, digitization and analysis of historical sea ice data is also recommended.

Get involved! This is the mechanism to get our requirements for sea ice observations into a global and international context. We want the broadest possible participation. If you are interested in participating but are not already part of the team, contact us. http://stratus.ssec.wisc.edu/igos-cryo/ , clic@npolar.no or jkey@ssec.wisc.edu .

(1) NOAA/NESDIS, USA.
(2) Climate and Cryosphere (CliC) Project Office, Norway.

A MODEL OF WAVE ATTENUATION IN THE MARGINAL SEA ICE ZONE

Alison Kohout [(1)]

ABSTRACT

The sea-ice which forms in the polar oceans plays an important role in the world's climatic system. It is therefore important to understand the processes which influence the extent of this sea-ice. Ocean waves play a major role in the fracturing of ice-covered seas. The analysis of this phenomena involves many complicated variables and considerable idealisation is required. One aspect which is critical to understand is the decay of wave energy through the Marginal Ice Zone (MIZ).

The MIZ is an interfacial region which forms at the boundary of open and frozen oceans. It consists of a vast field of ice floes and is subject to considerable wave action due to its proximity to the open ocean. Unfortunately, few experiments measuring wave propagation through a MIZ have been reported. The most important of experiments were carried out by the Scott Polar Research Institute which allowed the wave attenuation coefficients to be calculated. These experiments have suggested that wave energy decays exponentially with distance of propagation into a MIZ and that this rate of decay is highly dependent on the wave period.

To simulate an idealised MIZ, we derive a two dimensional solution for multiple floating elastic plates. This leads to a solution which is based on the elastic bending of the floes and does not allow for any other physics such as viscosity and floe collisions. The actual model is found by a statistical averaging over multiple solutions for various random arrangements of ice floe lengths and thickness (distributed about some mean). Once this averaging is done, we find that the model predicts the exponential decay of wave energy exactly as is measured. We also find that the decay is proportional to floe number and is independent of floe length. This leads us to produce a simple empirical relationship between the attenuation coefficients and wave period for various ice floe thickness.

We compare our model to the series of field experiments carried out by the Scott Polar Research Institute which measured wave energy attenuation rates in the MIZ of the Greenland and Bering Seas. These field experiments are the only available ones of their kind and unfortunately there are a number of problems with the measured results. For example, we have been unable to retrieve some of the information, such as the average floe lengths, thickness and concentrations, which is required to make a comparison with our model. Also the quality of the field data that is available is questionable due to technical and logistical restrictions. Without doubt, our research would be strengthened by more extensive experimental data. Nevertheless, our simple model show good agreement with the measured data leading us to cautiously believe that we have developed a practical and effective model for wave attenuation in the MIZ.

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SIMULATION AND EXPERIMENTATION OF COMPLEMENTARY-CODED PULSE RADAR FOR ICE MEASUREMENT

Jilu Li [1], Sivaprasad Gogineni [1], Glenn Prescott [1], Pannir Kanagaratnam [1] and Torry Lee Akins [1]

ABSTRACT

Airborne complementary-coded pulse radar is proposed to map the internal layers near the ice bed of Antarctic and Greenland ice sheets. Information of these layers is required to understand the ice sheet dynamics, and will help to make accurate calculation of ice sheet mass balance that is essential to accurate sea level rise estimation. The challenges in mapping the ice layers near the ice bed are twofold. First, the radar signals are very weak because of the enormous attenuation when they reach the ice bottom and return to the receiver. Secondly, ice bed echoes are much stronger compared to those from the layers near the interface, so their sidelobes usually mask the returns from the target ice layers near the ice bed. In the proposed radar, pulse compression technique is used to compensate for the signal attenuation and complementary coding is employed to cancel the sidelobes from the ice bed.

Computer simulation and laboratory experimentation have been conducted to study the sidelobe cancellation. Complete sidelobe cancellation has been verified for ideal case and the effects of signal waveform phase shift and amplitude imbalance that may be caused by hardware on sidelobe level have been studied by simulations. As low as a sidelobe level of -60dB has been achieved in the laboratory, with complementary coded pulses generated by the waveform generator of an ice depth sounder. It has been found that sidelobe level may rise to -35dB after modulation and demodulation because of the amplitude imbalance introduced into the signal waveforms by these stages.

Based on computer simulation and laboratory experiment results, the amplitude imbalance of signal waveform caused by hardware would be the challenge in the radar development. A prototype of complementary-coded radar is suggested to be built. By careful hardware design to reduce the amplitude imbalance, and developing calibration algorithms in signal processing, it is expected to be able to design a radar capable of mapping the ice layers near the ice bed with sidelobe level 60dB below the main lobe.

[1] University of Kansas, USA.

ON THE LARGE-SCALE DISTRIBUTION OF SEA ICE ALGAE OFF EAST ANTARCTICA AND THE IMPORTANCE OF SEA ICE THICKNESS AND SNOW COVER

Klaus Meiners [(1)] Benedict Pasquer [(1)] and Ben Raymond [(2)]

ABSTRACT

Sea ice is an important structuring element of Antarctic marine ecosystems and provides a vast habitat for ice-associated algae forming communities in different horizons of the ice floes. Sea ice algae contribute significantly to overall primary production in ice-covered waters of the Southern Ocean. During spring and summer when the ice melts phytoplankton blooms develop at retreating ice-edges. It has been hypothesized that increased stratification, seeding of the water column by ice algae and the release of iron from snow accumulated on the ice cover facilitate these blooms.

In this poster we present a relatively simple model on the large-scale distribution of ice algae off East Antarctica (30-160°E). The model is based on the assumption that sea-ice algae are primarily light limited. We use ice drift and solar irradiance data to estimate the cumulative light exposure of ice floes, thus providing an indicator of potential ice algal development. The model outputs are compared to the occurrence of ice-edge blooms and we explore future developments of the model informed by ice-thickness and snow-thickness distribution.

[(1)] ACE CRC, University of Tasmania, Australia.
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ESTIMATING SEA ICE THICKNESS USING PASSIVE MICROWAVE BRIGHTNESS TEMPERATURE

Kazuhiro Naoki (1)

ABSTRACT

For newly formed sea ice, brightness temperature has dependence on surface salinity. When an empirical relationship between surface salinity and sea-ice thickness is established for a class of sea ice, e.g. for a chosen region, brightness temperature can be used to estimate sea ice thickness. The purpose of the study is to evaluate the extent to which this method is valid for thin sea ice over the Sea of Okhotsk.

A pilot study was conducted using PSR measurements and ship's observations for the region. A comparison between brightness temperature and observed sea-ice thickness based on recorded scenes of broken and turned sea ice at the side of an icebreaker reveals a positive relationship between brightness temperature and thickness for a thin (app <30 cm) category. The relationship appears stronger for a lower frequency band with horizontal polarization. On the basis of these results, an algorithm is developed to estimate sea ice thickness (<30 cm). We present the results from an application of the method to AMSR data taken from the Sea of Okhotsk during the winter of 2003, and further discuss the degree to which this methodology is applicable for other regions.

(1) Centre for Environmental Remote Sensing, Chiba University, Japan.

THE ASPeCt SEA ICE OBSERVATIONS ARCHIVE: QUALITY CONTROL, PROCESSING AND MANAGEMENT

Matt Paget [(1)] *and Tony Worby* [(2)]

ABSTRACT

The ASPeCt sea ice data archive now contains data from 83 voyages to Antarctica between 1980 and 2005, totalling more than 25,000 individual observations. The observation system was formally implemented under the auspices of the ASPeCt program in 1997 and since then has been widely adopted by scientific and operational groups operating in Antarctica.

This poster presents information on the quality control process for ASPeCt ship data when it arrives at the data archive in Hobart. Each data set undergoes an extensive suite of quality assessments and processing steps, including:

- a manual assessment of observer error, and consistency between observers
- an automated scan to assess consistency between observations and data entry codes
- inspection of maps to ensure position accuracy and continuity of observations
- ensuring appropriate detail for each of the primary, secondary and tertiary ice types
- ensuring there is no ambiguity between "no observation" and "no ice" or "no snow cover"
- removing observations that are within 6 nautical miles of the previous observation, to ensure the data are not biased towards regions of thicker ice.

We have developed and implemented a stable and expandable data processing system for the data archive which is currently implemented on a Unix platform. A current initiative is to upgrade the processing system and wholly implement it in Perl, enabling it to be platform independent in future. The final quality controlled data sets are then archived as an individual file, and contributed to the archive which is available online at the Tasmanian Partnership for Advanced Computing (TPAC) Digital Data Library.

It is important to note that in addition to the 83 voyages that are archived, data from 17 other voyages have been deemed unsuitable for inclusion in the data archive. The reasons for this are highly variable but include:

- data from old log books being too descriptive rather than quantitative
- inconsistencies between observers
- ice thickness information not properly recorded
- insufficient (or no) detail in ridging estimates
- ship suffered an engine failure and operating on half power

[(1)] CSIRO Marine and Atmospheric Research, Australia.
[(2)] Australian Antarctic Division and ACE CRC, Australia.

TOWARD AN OPERATIONAL SEA ICE ANALYSIS FROM AVHRR IMAGES

Phillip Reid (1)

ABSTRACT

The Australian Bureau of Meteorology currently analyse Advanced Very High Resolution Radiometer (AVHRR) images by hand at the meteorological centre at Casey in Antarctica. These images are used to derive sea ice analyses in order to give advice to the Antarctic Division and others on ice disposition around Antarctic stations.

In Williams et al. (2002) a system is described for classifying an AVHRR image based on various albedo and brightness temperature values. This system implements a set of rules which distinguishes sea ice from other physical features. In this poster I present initial results from an attempt at implementing this system using McIDAS to analyse the image and graphically present the results. Used in the operational environment of Casey's meteorological centre this would easily provide a first guess ice analysis.

(1) ACE CRC and Bureau of Meteorology, Australia.

TEXTURAL ANALYSIS OF AERIAL PHOTOGRAPHS OVER SEA ICE TO DETERMINE SURFACE ROUGHNESS AND SNOW COVER CHARACTERISTICS

Tony Worby [(1)] and Adam Steer [(2)]

ABSTRACT

Most Antarctic sea ice more than a few days old has a snow cover. When viewed from above, the snow cover has distinctly different textures that are largely dependent on the smoothness of the underlying ice. Snow on deformed ice looks rough, with shadows, pits and other surface features, whereas snow on undeformed ice is generally smooth - unless it is severely wind-affected. With this in mind, we have investigated the use of texture information in aerial photographs over Antarctic sea ice to derive information about the relative areas of deformed and undeformed ice, and to use in situ measurements of snow cover properties to derive large-scale statistics of the snow cover in the region.

Several approaches to texture analysis have been developed, but few have been applied to sea ice images. We used an adaptation of the Local Binary Pattern operator (LBP) combined with greyscale variance (VARc) to extract texture information from sea ice images, combined with a recursive image splitting procedure to identify blocks of homogeneous texture within an image. The method was chosen for its computational simplicity and robustness, with encouraging results. To use the derived texture information we generated a simple classification system which uses preset grey-level thresholds and a texture-based rough/smooth threshold, giving six overall classes of texture and brightness within an image. Estimates of deformed and undeformed ice are then derived by calculating the image area occupied by the two classes which represent rough and smooth ice.

The application of this image analysis will be to assess the snow thickness fields from AMSR-E data collected over the ARISE study region, off East Antarctica in Spring 2003. The aerial photography data was collected over a buoy array which drifted for a 30 day period, during which time detailed in situ measurements of snow cover thickness were collected over rough and smooth ice surfaces at many random locations accessed by helicopter.

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International Workshop on
Antarctic Sea Ice Thickness

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Notes