

# GCOS SST&SI Working Group sessions at 7'th International Ice Charting Working Group Meeting

25 - 28 September 2006

## Attendance

Søren Andersen, Florence Fetterer, Cathleen Geiger, Tony Worby, Vasily Smolyanitsky, Pablo Clemente-Colon, Per Gloersen, Stefan Kern

## Overall summary and actions

The participation of the GCOS SST&SI Working Group in the IICWG meeting took place in response to the decision at the inaugural meeting in Boulder to engage the ice charting community. The IICWG generously allocated the Monday morning session to various presentations representing the total cross-section of the group's activities from satellite data, through ice charts to ship and field observations. In addition, a number of side meetings were held the following days to discuss details and general coordination issues. Overall, the following issues were discussed:

- Monday: During the summary session, following presentations, discussions took place on common areas of interest and support, for example: Uncertainty estimates in ice charts and satellite data, intercomparison of ice charts, use and management of ship and field observations.
- Tuesday: Review of activities whitepaper, input to upcoming GCOS SC meeting
- Wednesday: Brainstorming of ideas for funding error estimation in historical ice charts including a proposal to NSF for December call.
- Thursday: Coordination with JCOMM, concerning a possible ice analyst workshop, policy issues and future communication between the GCOS SST&SI Working Group and the ice charting community via ETSI and IICWG.

In particular, a mutual interest in the Group's activities on error assessments and documentation of the ice chart data record was evident. Even though ice charts were never specifically created for climate monitoring purposes, they have a unique role as a data source that spans multiple decades prior to the satellite record. The Ice Charting community has invested considerably in digitization of old charts and has a profound interest in seeing the data records being used. The chart based ice thickness analyses of the ASPeCt project were seen as an example of the possible innovative applications based on ice chart data and as a good demonstration of how error estimates can be assigned and propagated through an analysis. It was thought that the addition of suitable error estimates could be a catalyst to increase the significance of analyses based on ice charts. It is evident that the error properties of the ice charts vary with time and the Ice Services could assist by recording a timeline of changes in practice and input data availability. In Russia, the input data can be traced via systematic remarks on the individual ice chart. Several other ice services may have adhered more or less to a similar practice. The Canadian Ice Service (CIS) has published a specific report including a timeline of important changes in practice and capabilities. This was recognised as a good model for other Ice Services to follow. A number of actions on the GCOS SST&SI Working Group were decided to aid in the progress of the partnership with the Ice Charting community.

**Action 1 (Geiger):** In cooperation with IICWG Science Working Group, contact NSF indicating the importance of rigorous error estimates in sea ice data sets. Discuss mechanisms to achieve this.

**Action 2 (Andersen):** Draft letter to Ice Charting Community through JCOMM Expert Team on Sea Ice (ETSI) to 1) promote the completion and publication of timeline information concerning practice and capabilities; 2) promote the possible automatic tagging of polygons in future ice charting software with information relevant to error estimation (e.g. active data layer content); 3) urge the community to take steps to facilitate that important knowledge of retiring and/or retired members of staff is identified and preserved.

The Group discussed the activities whitepaper, circulated before the meeting, enclosed in Annex A. In general, the Working Group now has a good composition to take up the initial steps required to start activities. It was agreed, with a few modifications, to adopt this document as a baseline for the activities to take up in the coming time. The Global Digital Sea Ice Data Bank (GDSIDB) at the Arctic and Antarctic Research Institute (AARI) volunteered to update holdings with recent data. This will greatly benefit the intercomparison efforts, between ice charts as well as between ice charts and satellite data. Much data resides in different grid projections and some concerns were expressed concerning the effects of reprojection. It was decided to make an investigation of these effects on ice extent, area and related linear trends, with the EASE grid (equal area), GSFC polar stereographic and the SIGRID (0.25 degree geographical) grids. Concerning intercomparisons, activities will start up based on both vector and gridded data sets.

**Action 3 (Smolyanitsky):** Update GDSIDB holdings with recent data

**Action 4 (Andersen):** Document effects of reprojecting data sets.

**Action 5 (Geiger):** Start up comparisons of vector based data. Initially, focus on ice edge estimation.

**Action 6 (Andersen):** Implement first intercomparison products based on raster data sets. Initially, use NASA/TEAM and Bootstrap datasets. Consider also HadISST, ERSST and GDSIDB.

Error estimates of both ice charts and satellite data sets will be pursued but any progress is dependent on funding. A short term activity would be to stage relevant background documents on the Working Group website. The CRREL report on ice chart error propagation is the first contribution; other possible contributions would document the intercomparison products and methodology, definitions of pertinent statistical tools, outcome of the analysis of data reprojection, etc. This would essentially form a toolbox and common reference for the working group. The same could be done for reference observations from ice breaker and field stations.

**Action 7 (Andersen + group):** Publish “toolbox” documents and list reference observations on Working Group website; group to consider possible contributions.

At several points during the meetings, the issue of ship (including ice breakers) and field data management in the Arctic was raised. At present, observations are generally residing in numerous institutions and probably neither in common format nor with systematic documentation. There was agreement that a consolidated data base of Arctic field and ship observations would be useful. This is illustrated by the ASPeCt data base that is now a useful independent resource on ice edge and thickness. However, some questioned if the benefit would outweigh the costs. There are proposed activities during IPY that target data rescue and consolidation. The working group should monitor these activities. No plans towards an active engagement by the Working Group were made.

Finally, the Working Group discussed relations with JCOMM ETSI, focusing on 1) a possible JCOMM ice analysis workshop; and 2) the relationship between the GCOS SST&SI Working Group and ETSI. The possible JCOMM ice analysis workshop is intended to address intercalibration and standardisation of ice charts. These objectives are at the crux of the SST&SI Working Group and a considerable mutual interest is evident. A number of items were proposed and forwarded through ETSI chairman Vasily Smolyanitsky to be considered at the upcoming JCOMM Services meeting. Vasily Smolyanitsky, on behalf of ETSI, expressed support to the activities of the GCOS SST&SI Working Group and proposed that ETSI constitute the formal point of contact for recommendations and requests to the operational ice charting community. The more informal exchanges in the frame of the International Ice Charting Working Group are considered extremely relevant for the activities of the Working Group. A representation at future meetings to follow up and report on issues and activities should be pursued.

## Summary of science session presentations and discussion

Monday 25 September 2006

*Agenda:*

9:00	Introduction to working group and the session	Søren Andersen:
9:20	Passive Microwave Climate Data Set Development and A New Chart-Based Gridded Sea Ice Data Set	Florence Fetterer
9:40	Perspective on error analysis	Cathleen Geiger
10:00	Inter-calibration and comparison of ice charts.	Seymour/Falkingham
<b>10:20</b>	Break	
<b>10:50</b>	<i>Session I continue</i>	
10:50	Lessons learnt from "data fusion" between ship, ice charts and passive microwave data	Tony Worby
11:10	Ongoing sea ice data processing at NASA Goddard Space Flight Center	Per Gloersen
11:30	Error sources and error propagation in passive microwave sea ice retrieval	Stefan Kern
16:10	Summary session, discussions	Plenary

Søren Andersen gave an introduction to the GCOS SST&SI Working Group and presented the reasoning behind the decision to engage the ice charting community. The overall objective of the session and subsequent meetings was 1) to make the ice charting community aware of issues identified in the climate monitoring community; 2) to obtain expert input on ice chart related issues, such as best practices in intercomparison of ice charts and changes in practice and capabilities. The possible positive relationship with operational issues of standardisation and intercalibration was stressed. Finally, the presentations of the remaining session, representing a broad cross-section of the disciplines featured in the working group were introduced .

Florence Fetterer introduced the status of NSIDC activities in developing sea ice climate data sets from satellites as well as from ice chart data. Different applications make different and possibly contradicting requirements. An example was given of how the requirement from the SST community for a sea ice mask could favour the selection of a product that would not form an optimal sea ice climate data record. It was mentioned that differences in available sea ice records were large enough to significantly impact modelling applications. Ice chart and satellite records

were used synergistically in the HadISST data set to correct biases in the satellite record in summer. Comparisons and literature suggest that several products offer the consistency necessary for trend detection, however their accuracy is not sufficient for modelling applications. A number of requirements to passive microwave climate data record were explained and some recent NSIDC initiatives were introduced. The consolidation of the many existing passive microwave data sets is already in progress. At present there are multiple data streams for each algorithm product. This is reduced by consolidating the processing at NSIDC, harmonizing the near real time production with the climate data production, such that these only differ in the level of quality control. In parallel NSIDC, in cooperation with the international climate community, is pursuing a number of promising techniques for the next generation of climate data products.

Florence Fetterer then reported on the development of a gridded climatology data set based on NIC ice charts from 1972 through 2004. The product is a follow-on to the Environmental Working Group joint US/Russian data sets. A number of derived products and applications were presented, before turning to some issues encountered in the processing. For example, the pack ice was classified as 10 tenths concentration during the years from 1976-1986 and 9-10 tenths before and after this period. Different processing is also likely to result in information loss in some cases. In particular the charts from 1972-1994 were digitised from paper, gridded in SIGRID format and reprojected on the EASE grid. From 1995 on, the conversion from vector format to EASE grid was accomplished in one step. Similarly, two different land masks were used over the duration of the data set, which may impact some coastal applications such as land ice studies. The introduction of modern ice charting terminals, GIS and digital imagery in 1996 and 1997 is evident in the record that was very similar to the passive microwave record prior to that.

Cathleen Geiger presented an analysis of Antarctic ice charts from NIC and comparison to ship observations of sea ice thickness. These are two high quality operational products that, with care, can be used in a scientific analysis of the sea ice mass balance. The realisation that the data are noisy is fundamental and a meaningful synthesis of the ship and chart records requires that their errors are quantified and accounted for. However, the first step was to align the code used for the ship measurements with the code used for the ice chart estimates. The WMO code was used as the basis in both cases and constitutes a consistent standard over the time period. Errors based partly on the ranges represented in the WMO codes were propagated through the analysis of both the ice chart and ship observations. This resulted in two ice thickness records with uncertainties that allowed qualifying the relationship with better confidence. This constitutes an important demonstration of the benefit to more rigorous error characterisation. There are interesting perspectives in the adaptation to long time series of ice chart concentrations and edges, facilitating a more meaningful combination with other data sets.

Paul Seymour and John Falkingham gave a very relevant presentation, introducing some of the underlying assumptions and techniques that are employed in the production of ice charts as well as a historical perspective on their evolution. Over time the ice chart content and quality has been affected by 1) the observational basis, from reconnaissance to analysis of imagery and model output with ever increasing resolution; 2) changes in staff and management priorities; and 3) the evolution of analysis systems from pencils and mylar through early computerized systems to the GIS based systems of the present. These developments are crucial inputs to the possible extension of the work presented by Cathleen Geiger. An introduction to the NIC and CIS ice chart data bases was given along with important milestones. A number of cautions were given on specific issues such as the

use of the “9+” concentration classification, the lack of reliability in multi-year and second-year ice classification and base map changes.

In a related talk, given during a side meeting, Paul Seymour presented the intercalibration of NIC and CIS products in the development of the North American Ice Service. The particular overlap and experimental area was the Great Lakes and numerous differences practice and coding were mentioned. It is beyond the scope of this summary to repeat all this information, suffice it to say the information was very timely and relevant for both the GCOS SST&SI working group as well as the ASPeCt applications presented by Cathleen Geiger and Tony Worby. It underlined the importance of keeping close relations to the operational ice charting community.

Further due to time constraints during the Monday session, Vasily Smolyanitsky also presented the activities and holdings of the GDSIDB in a side meeting. The current holdings have been collected from Russia, US, Canada, Japan and the Baltic. The Russian data set covered the period back to 1950 for the Eurasian sector of the Arctic Ocean, most other services go back to the 1960's or 1970's. A blended data set based on the holdings has been produced recently. A range of statistical analyses were presented, on hemispheric as well as local scales, demonstrating the usefulness of the compilation. Over the coming 6 months, the holdings will be updated with more recent data.

Tony Worby gave a presentation related to the one presented by Cathleen Geiger, however with some more emphasis on the scientific interpretation of data and with a broader emphasis on the relationship between ship observations and remote sensing data. The analysis of the ice chart and ship based ice thickness records seemed to indicate that the ice chart stage of development reflected the level ice thickness, i.e. it did not include the contribution to ice mass balance by ridges and snow. The ice chart derived thicknesses seemed to give a consistent development of the ice thickness spectrum over different seasons. Some periods and regions had been identified where the ship and ice chart records corresponded less well. The reason is as yet unexplained. Ice edge positions determined from where a given ship first encounters sea ice in the ASPeCt ship observation data base was compared to passive microwave ice edge positions. During winter the correspondence was fairly good, however in the melting season there was an average southward shift in the passive microwave ice edge relative to ship observations of  $1.6^\circ$ . This discrepancy was sufficient to explain the difference between ice edges in a 1925-1952 monthly climatology and a more recent passive microwave dataset. Finally, with the ARISE validation efforts as an example, it was illustrated how a hierarchy of scales must be considered when trying to relate satellite based observations to field observations. The study bridged the gap between field observations and coarse resolution passive microwave observations with airborne camera and high resolution satellite data. The outcome seemed to suggest that the snow thicknesses retrieved from AMSR-E satellite data was representative of level ice snow thickness, i.e. biased low. The analysis involved several intricate decisions concerning the spatial averaging between different scales, however many of these decisions were specific and it is difficult to give general recommendations independent of the application.

Per Gloersen introduced the activities taking place at Goddard Space Flight Center (GSFC), where the group has been working with sea ice retrieval from passive microwave observations since the 1970's. The group has lately updated the SMMR and SSM/I merged ice concentration time series with data through the end of 2005. The data set is available from NSIDC and a similar multiyear sea ice concentration time series is available from GSFC. With the advent of AMSR-E, the operational algorithm is now the NASA/TEAM2 and a range of new products such as snow depth and sea ice

temperature have been introduced. In parallel, the AMSR time series is processed with the Bootstrap algorithms too and, as the other products, available from NSIDC. The group has also processed visible/infrared radiances into sea and ice surface temperatures as well as albedo. An analysis of local temporal minima (LTM, the time of minimum ice concentration per pixel) showed that the sea ice area at LTM was more consistent with multi-year sea ice area the following season. The sea ice area at LTM showed a decreasing linear trend. However, a caveat on the interpretation of linear trends was given based on analysis of modes of the time series of the total Arctic ice area; the residual mode is a U-shaped curve, decreasing from 1978 to 1992, and then increasing to a value higher than the initial one by the end of 2005. This occurrence contradicts the notion of an ever-decreasing Arctic ice canopy.

Stefan Kern presented the theoretical background on errors in passive microwave sea ice concentration retrievals. He gave 4 main classes of uncertainty: Sensor noise, Sampling/field-of-view errors, ice/snow conditions and weather influence. As to the sampling errors, it is interesting to note that 9 SSM/I FOV's contribute to one 25x25 km grid cell at 19 GHz. He then showed examples of how ice and snow as well as atmospheric parameters affect the retrieved ice concentrations. Finally examples of error propagation through the ASI and Sealion algorithms were shown. The presentation was concluded with concluding that we have a good knowledge of error sources and the way they propagate through the retrieval algorithms, however we lack information on the spatio-temporal distribution of uncertainties, i.e. on seasonal to annual and local to global scales.

The session was reviewed during the summary at the end of the day. The following points were captured:

1. There was a discussion concerning the possibilities of automatically recording information useful for error estimation during the ice charting process. As a complicating factor, it was mentioned that most ice services make ice charts valid at a time, which can be before or after the time stamp of the imagery and information being used. However, it is possible, for example, to record information of the type of imagery on which polygon vertices are being drawn. CIS are in the process of designing a new ice charting system and could build in such a capability. At NIC, polygon vertices are already labelled with image type. It might be considered to reflect these thoughts in the on-going work related to the ice objects catalogue and modernisation of SIGRID.
2. Concerning intercomparison of ice charts, it was suggested to make a comparison of the CIS climatology to the NIC record. For a limited period in 1970's, CIS reanalysed all ice charts of the season, however for budget reasons this practice was abandoned.
3. It is important to decide beforehand what scales the comparison should deal with. In particular, ship observations are often not representative of larger scales and field reports on ice concentration are therefore typically given little weight. Some warned that general intercomparison could quickly become very complicated and so it would be important to limit the scope, at least initially.
4. On the same token, there was some scepticism concerning the use of ship observations in comparisons. However, there was a clear distinction between regular ships and ice breakers, where the latter would be more likely to deliver useful observations. In the Arctic there is currently no systematic collection of field and ice breaker observations, such as what the ASPeCt project has implemented for the Antarctic. However, on the Russian side, the compilation of observations was routinely taking place, although on an informal basis. It was mentioned that there are IPY projects that will work on collecting field station and

possibly ice breaker data. It was suggested that, as an intermediate action, the GCOS SST&SI Working Group should work to assemble a list of possible reference data on the website.

### **Current membership**

The membership of the Sea Ice subgroup currently consists of the following:

Steve Ackley (ASPeCt),  
Søren Andersen (Danish Meteorological Institute),  
Florence Fetterer (NSIDC),  
Pablo Clemente-Colon (NIC),  
Mark Drinkwater (ESA),  
Cathleen Geiger (CRREL/University of Delaware),  
Per Gloersen (NASA GSFC),  
Stefan Kern (University of Hamburg)  
Walt Meier (NSIDC),  
Vasily Smolyanitsky (AARI/JCOMM ETSI/GDSIDB),  
John Stark (UK Met Office),  
Tony Worby (ASPeCt)

## GCOS SST&Sea Ice Working Group activities on sea ice

### 1. Introduction

The GCOS SST & Sea Ice (SI) Working Group is tasked to monitor, recommend and implement improvements in the homogeneity of Sea Surface Temperature (SST) and Sea Ice time series. The working group is composed of a main group working on both SST and Sea Ice and a subgroup working specifically with Sea Ice issues. The present document concentrates on the activities of the sea ice group and is intended to define the overall direction and organisation of the group's activities. It is based on the working group terms of reference as well as the outcome of the first meeting on Sea Ice in Boulder in March 2006 and input from various groups.

### 2. Working group terms of reference

The Terms of Reference define the core activities of the SST&SI working group as follows:

1. To record and evaluate the differences among historical and near real time SST and SST/SI analyses
  - a. Identify a standard data set for the intercomparisons of different products, e.g., COADS [*for SST*].
  - b. Select several standard difference products as a minimum comparison set (i.e., define regions and time periods; compute biases, standard deviations, and RMS differences)
  - c. Oversee standards for intercomparisons
2. To identify the sources of differences in the analyses
3. On the basis of comparison of those differences with the expected climate signals in the SST patterns, to recommend actions needed to ensure the quality and consistency of the SST and SST/SI analyses
4. To establish criteria to be satisfied by SST and SST/SI analyses to ensure the quality and consistency required by the Global Climate Observing System (GCOS)
5. Liaise with all appropriate bodies
6. To report annually to AOPC and OOPC on progress and recommendations

The main focus with regard to sea ice is the creation of homogeneous multi-decadal data sets of sea ice concentration with quantified uncertainties and intercomparison is seen as an appropriate tool to help achieve these objectives. It should be noted how, from point 4, the GCOS Climate Monitoring Principles (GCMP) provide the baseline requirements to data sets [WMO, 2004]. This means that the analysis will also assess such aspects as overlap between old and new systems, documentation of changes, etc. In addition the building of a systematic intercomparison capability links directly to GCMP requirement for “a capacity to routinely assess the quality and homogeneity of data on extreme events”.

The need to consider ice thickness is acknowledged from the perspective of its importance in monitoring and modelling the high latitude climate systems. However, an operational observing capability is in its infancy and the sparse coverage of existing measurements makes it difficult to evaluate in a systematic intercomparison framework. The recent IceSAT and the coming CryoSat-II missions should remedy this situation and evaluations of uncertainties and compliance to climate

monitoring principles will be required. The issue is kept open within the Working Group to be considered and assessed at regular meetings.

### 3. Overview of approach

Intercomparison of sea ice estimates is not a new concept [e.g. Steffen et al., 1992; Comiso et al., 1997; Hanna and Bamber, 2001; Belchansky et al., 2002; Agnew and Howell, 2003; Meier, 2005]. However, it has never been applied as systematically and across both in-situ, ice charting and satellite retrieval communities as it is intended here. Similarly, the theoretical concepts for deriving error estimates in sea ice analyses are established but consistent standards are lacking and current operational sea ice analyses rarely contain error estimates at all. A major initial task of the sea ice subgroup is therefore to create a foundation in terms of a membership that represents these communities sufficiently to facilitate the necessary exchange of knowledge and results. This wide engagement across communities, on the other hand, represents the risk that the working group activities loose focus. The central objectives defined in the Terms of Reference are to record differences and promote error estimates in sea ice concentration data sets. It is essential in the founding process, to concentrate on these objectives and avoid too much divergence in the group's activities. Once these central activities are established, it is a natural next step to consider deeper relations with groups of algorithm and sea ice analysis providers to determine the cause of differences and to improve algorithms and products.

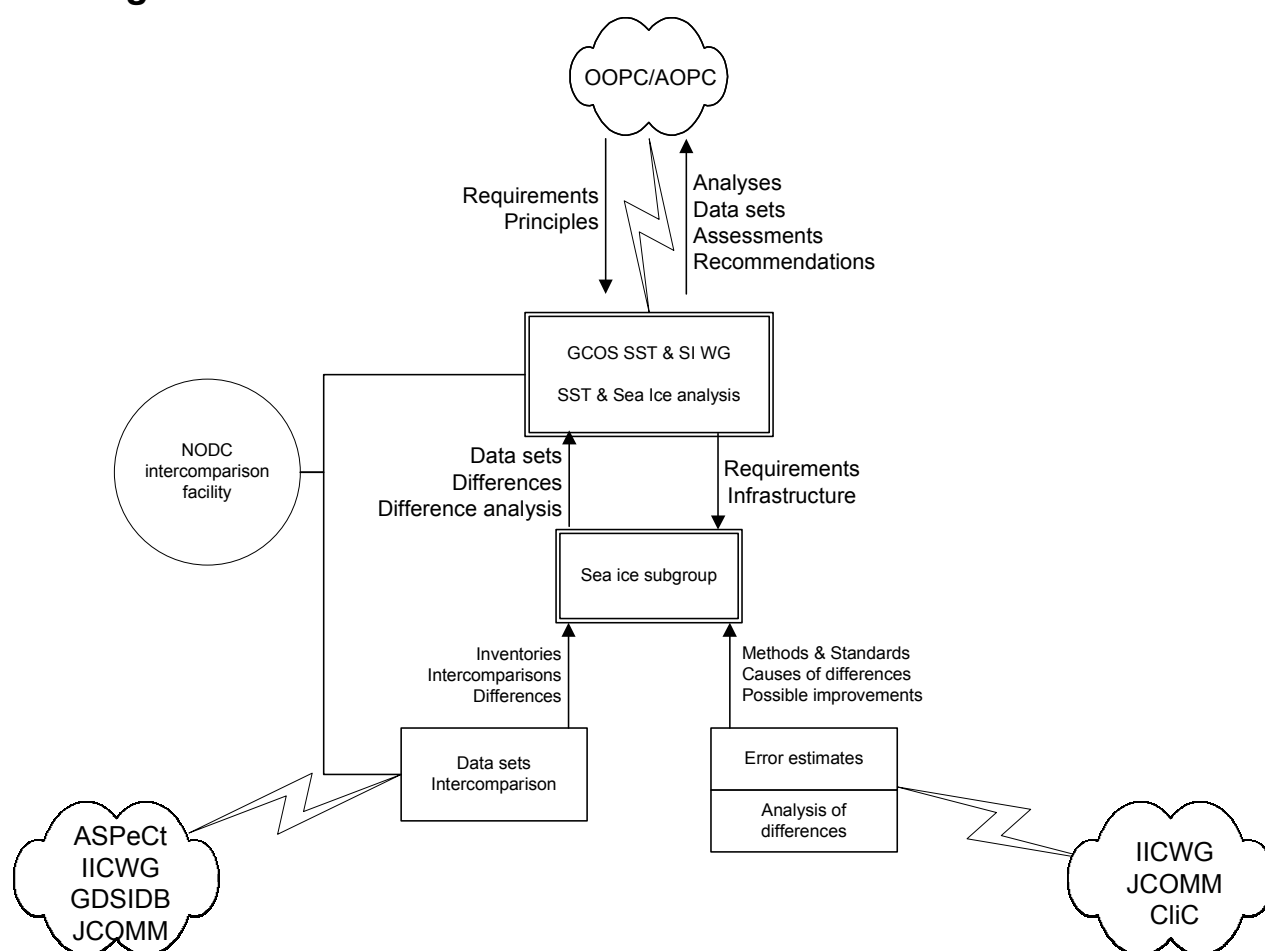
The sea ice observations that will be taken into account belong to the following categories:

1. Sea ice concentration analyses from passive microwave observations. Mostly available as daily gridded data sets. Such data sets extend back to 1972 with some gaps in the late seventies.
2. Ice charts. Available in digital vector format and/or as gridded compilation data sets. Ice charts are a synthesis of observations from sources including ship and coastal observations, aerial reconnaissance and satellite data.
3. Field observations, mainly from ships. Available as direct observations as well as compilations in a variety of formats and from numerous sources.
4. High level multi-input SST & Sea Ice analyses, such as HadISST [Rayner et al., 2003], ERSST [Smith & Reynolds, 2004] and OISST [Reynolds et al., 2002] analyses. These datasets synthesize information from the above sources to achieve long term homogeneous records. The sea ice fields are mainly used to simulate SST.

The observations above have widely differing spatial and temporal characteristics and are based on techniques ranging from manual/subjective assessment to inversion of satellite observed radiances. No single observation type offers an optimal combination of detail and temporal/historical coverage. The production of long time series therefore requires the combination of datasets across categories and in turn a good understanding of their differences and uncertainties. However, even within each category, sources of inconsistency exist that must be recorded and analyzed to fully understand differences between categories. Such differences are, for example, the increase in detail in ice charts over time or, for satellite data, instrument drift, inter-sensor/inter-satellite differences and geophysical crosstalk (changes in for example atmospheric or surface properties that mimic ice concentration changes). Yet, even without a full understanding of the errors in the fundamental data sets, examination of differences between high level analyses (category 4) is useful to analyze the effects of assumptions in analysis procedures and to better understand the propagation of errors in the analysis.

*Error estimates are lacking in practically all the fundamental sea ice data sets available today. It is therefore a priority to develop and standardize methods to compute consistent and comparable error estimates. In the short term, it is particularly important for passive microwave and ice chart data sets as the meaningful combination and assessment of these data in higher level products and studies requires realistic estimates of uncertainty.* Intercomparison in this context is a useful way to evaluate the realism of the theoretical uncertainty estimates. The development of error estimates, like the analysis of differences, will naturally seek to include the input or feedback from algorithm developers and product providers.

### 3.1. Organisation



**Figure 1** Proposed organisation and foreseen relationships outside the group.

The organisation of the working group's activities is sketched in Fig. 1. An important attribute of this organisation is the shared use of the NODC (National Oceanographic Data Center) intercomparison facility. This facility is best viewed as a data repository with a common data model that facilitates access and manipulation of a large number of gridded data sets of SST as well as sea ice. The data model is best suited to represent data sets with homogeneous increments in time and space, excluding some types of ice chart data and most field observations. While it is envisaged that this facility will be a central driver towards the initial routine production of intercomparisons, parallel activities must take place to cover the observations that fall outside the data model. The

organisation further reflects the perceived commonalities of the error estimate and difference analysis activities. These both require deep theoretical knowledge of algorithms and procedures on which the sea ice records are based.

The sea ice subgroup has a mandate that responds to the needs of the larger SST&SI working group. Activities are primarily driven by the requirements of this group. However, it is in the best interest of the group to liaise and cooperate openly with other groups and organisations that share similar interests.

## **4. Proposed activities and schedule**

In the following, a set of proposed activities is given along with pertinent background information. At this stage, it is difficult to define a detailed schedule; however the activities will be listed sequentially in order of priority. For some activities funding is prerequisite and the first activity would therefore be to examine the possibilities and organise accordingly. Other activities depend on initiatives in external groups and are therefore fundamentally uncertain. The addition of sea ice data to the NODC intercomparison facility is a key activity and at least the initial actions are considered certain.

### **4.1. Data sets and Intercomparison**

#### **4.1.1. Gridded analyses**

The activities on gridded data sets will leverage the frameworks developed in the larger SST&SI working group, in particular the SST intercomparison facility at NODC. Initially a limited selection of satellite and possibly gridded ice chart products will be ingested into the intercomparison server to facilitate the development of comparison standards and relative difference products. It is most likely efficient to form a set of derived products such as monthly sea ice extent and area.

Subsequently, a larger number of products will be included to reflect a representative cross-section of available products. It will be useful to consider the definition of one or more products that may serve as comparison standard. This is not a trivial task as, in general, all sea ice concentration observations are affected by error that is difficult to quantify. In contrast to SST, which can be measured objectively with well defined accuracies in the laboratory, no simple setup allows a similar concept for sea ice concentration. This leaves the examination of indirect and relative evidence and must be identified as a major point of discussion within the group as well as through cooperation with external groups that may view the problem from other perspectives.

Some gridded fields, in particular those based on ice charts, exist that are too local and/or irregular in time to be imported into the NODC system. Still these data are applicable in local studies and combined they might sum up to represent a useful data set. Other institutions and initiatives such as NSIDC and the CliC Data and Information Service already hold large searchable inventories of this type of data and it is not the intention to duplicate these facilities. However, it is simple to make these data available in a web page to ease the use of these data in subsequent analyses. A possible challenge that must be analysed in this respect, is differences in grid geometries – it is thought that an overview of the products must be formed before this analysis can be made.

#### **Activities**

1. Initial activities

- a. Define a limited set of products for initial ingestion into the NODC intercomparison facility
  - b. Define a set of initial intercomparison products
  - c. Make inventory of available and *useful* gridded sea ice analyses
  - d. Select a common grid and develop resampling methods
  - e. Provide access to local and irregular data sets via web page
2. Operational activities
    - a. Ingest additional sea ice products
    - b. Revise intercomparison products to support interpretation of differences

#### 4.1.2. Ice charts

Ice charts usually cover only a limited geographical area and, except for the global service at NIC, different authorities are in charge of different areas. Ice charts are produced mainly for navigational needs and areas less frequented by ships are therefore often mapped in less detail. The ice edge can be biased due to most navigators' preference for avoiding sea ice. Even if there are standards for many of the processes involved in making an ice chart, differences exist due to local practices, local customer requirements and, over time, improved mapping capabilities. Ice charts of different origin constitute the bulk of sea ice information prior to the satellite passive microwave era. They are typically stored in SIGRID formats. This format is available in 3 revisions, where the most recent (SIGRID-3) is a vector format while the preceding versions are defined on a fixed 0.25 degree resolution geographical grid. The Global Digital Sea Ice Data Bank (GDSIDB) web site at the Arctic and Antarctic Research Institute (<http://www.aari.nw.ru/gdsidb>) includes documentation of these formats. It is noted that ice charts are inherently vector based and the gridded SIGRID-1 and SIGRID-2 formats therefore cannot represent the full information content of the original ice chart. There have been a few compilations into atlases or data bases, such as the data sets by Walsh, EWG, ACSYS and GDSIDB.

Mainly due to uncertainties in best practice ice chart data manipulation and the complications of representing vector information in a raster based intercomparison framework, it was decided to initially keep ice chart information separate from the NODC data repository. However, several existing projects, such as GDSIDB, ASPeCt, IICWG and CliC have developed systems and standards to deal with this type of observation. In the operational community, JCOMM is in the process of defining activities to inter-calibrate and compare operational ice charts from the different ice charting agencies. The most efficient way forward is therefore to interact with these groups.

We are seeking active participation in the working group by the ice charting community by engaging IICWG at its 2006 meeting in Helsinki. Activities of great importance are to identify and record changes in ice charting practice and data availability over time as well as to promote consistent error estimates in climate data based on ice charts. In addition, planning of activities and coordination with the operational community should assure that intercomparison and calibration activities in the operational community may be leveraged. How the activities of the GDSIDB can be of use should be identified, as well as if and how the GCOS SST&SI working group may contribute to GDSIDB objectives.

#### Activities

1. Initial activities
  - a. Determine possibilities of routine intercomparison of ice charts in liaison with the ice charting community (IICWG, JCOMM ETSI, etc.)

- b. Determine an initial set of possible intercomparison products and objectives
  - c. Analyse the compliance of available ice chart data sets with respect to GCMP's.
2. Operational activities
- a. Take part in intercomparison activities and revise outputs to support interpretation of differences

### 4.1.3. Field and ship observations

Ship observations are important as the only source of information on the period before systematic ice chart and satellite observations; and, in recent periods, as a possible reference. The objectives are mainly efficiency in terms of standards for data formats and access as well as data rescue to extend the observations back in time. The ASPeCt group has been successful in establishing a systematic recording of ship observations covering the entire Antarctic. In the Arctic, resources are numerous but tend to be more heterogeneous as coordination seems to have been lacking. Even though some of the ASPeCt procedures can probably not be transferred directly to Arctic conditions, the idea of adopting a standardized ice observation protocol and format is valuable. Measurements of sea ice thickness, until the satellite remote sensing capability is developed, consist exclusively of field and ship observations. It is therefore natural that possible activities on ice thickness could arise from the discussions in this theme.

#### Activities

1. Analyse the availability of ship observations and their management with special regard to GCMP's. Recommend a global standard for representation and management of ship observations.
2. Examine data gaps and provide recommendations for possible mitigation.
3. Examine the possible use of ship observations as a reference to determine absolute differences.

## 4.2. Error estimates and interpretation of differences

The activities on development of standards for error estimates in ice charts and daily gridded ice analyses share many aspects of the theoretical framework. However, the application calls for specialized knowledge of the processes and measurements on which the different sea ice observations depend. For now, this is taken as justification for dividing the activities in two themes rather than one.

### 4.2.1. Gridded satellite analyses

The interpretation of differences in gridded satellite analyses requires specialised knowledge of algorithms and radiative processes in the atmosphere as well as in the snow and sea ice. The activities will take input from intercomparison differences and make recommendations for new intercomparison experiments to help in making conclusions. Error models as well as their inputs (e.g. uncertainties in tie points, atmospheric variability, etc.) should be assessed to propose a consistent standard that allows users to make more informed decisions and model the performance of their specific application. Both activities are highly related and most likely require specific liaisons with the product developer/provider community. These activities, in particular the development of error estimates, very likely require funding in order to achieve the momentum necessary to engage the developer community in an efficient manner.

#### Activities

1. Interpret intercomparison results in cooperation with product developers
  - a. Propose new intercomparison products
  - c. Recommend further investigation of selected differences and suggest methods
2. Promote the inclusion of error information in sea ice products
  - a. Assess different error models and assumptions to recommend a consistent standard to aid in the user task of selecting a data set for a given application
  - b. Evaluate output of error models against intercomparison differences

#### 4.2.2. Ice charts

With ice charts, the recording of changes in analysis procedures, technical capabilities and data availability at the analysis center is crucial to the interpretation of the derived climate data record as well as to the estimation of errors. These activities could initially take input from intercomparison of rasterised ice chart (such as the EWG and NIC atlas compilations available from NSIDC) and satellite data sets to detect and quantify changes in error characteristics that may be due to changes in practice and capabilities. The NODC intercomparison facility could be a useful tool. Results from such analysis could form a valuable input to the estimation of error in ice chart analyses. We recall that regular intercomparison of ice charts of different origin should depend on activities in several existing projects. With the possible inception of routine ice chart intercomparisons, the activities could further be extended to analyse the results and provide recommendations, analogous to similar activities for gridded satellite analyses.

#### Activities

1. Record changes in analysis procedures, technical capabilities and data availability. Initially, this could take input from intercomparison of rasterized ice chart time series with satellite data.
2. Promote error estimate frameworks in the analysis of ice charts
  - a. Engage ice charting community via IICWG.
  - b. Determine possible organisation and funding for developing the actual framework.

#### Acronyms

<b>ACSYS</b>	Arctic Climate System Study	<b>JCOMM</b>	Joint WMO-IOC technical Commission on Oceanography and Marine Meteorology
<b>AOPC</b>	Atmospheric Observation Panel on Climate	<b>NIC</b>	National Ice Center
<b>ASPeCt</b>	Antarctic Sea ice Processes and Climate	<b>NOAA</b>	National Oceanic and Atmospheric Administration
<b>CliC</b>	Climate and Cryosphere	<b>NODC</b>	National Oceanographic Data Center
<b>COADS</b>	Comprehensive Ocean Atmosphere Data Set	<b>NSIDC</b>	National Snow and Ice Data Center
<b>ETSI</b>	Expert Team on Sea Ice	<b>OI</b>	Optimal Interpolation
<b>EWG</b>	Environmental Working Group	<b>OOPC</b>	Ocean Observation Panel on Climate
<b>GCMP</b>	GCOS Climate Monitoring Principles	<b>SI</b>	Sea Ice
<b>GCOS</b>	Global Climate Observing System	<b>SIGRID</b>	Sea Ice GRID
<b>GDSIDB</b>	Global Digital Sea Ice Data Bank	<b>SST</b>	Sea Surface Temperature
<b>IICWG</b>	International Ice Charting Working Group		

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## Appendix 1: Provisional intercomparison products

NSIDC has a useful set of diagnostics products known as the sea ice index [Fetterer & Knowles, 2004; [http://nsidc.org/data/seaice\\_index/](http://nsidc.org/data/seaice_index/)]. Comparison of these quantities derived from different

algorithms and observation types would be interesting. In addition the following products might be useful to compare:

- Linear trends on monthly mean values of sea ice extent and area results in a measure of the spread in estimated retreat or increase in the sea ice cover. Taking one product as reference can be useful.
- Maps of linear trend in concentration or sea ice persistence provide the spatial structure of differences in estimated sea ice trends.
- Per pixel range of concentration based on several products or maps of anomaly with respect to wintertime average ice concentration provide spatial structure of single algorithm results.
- Maps of differences between algorithms on various time scales provide the spatial structure of inter-algorithm differences.