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

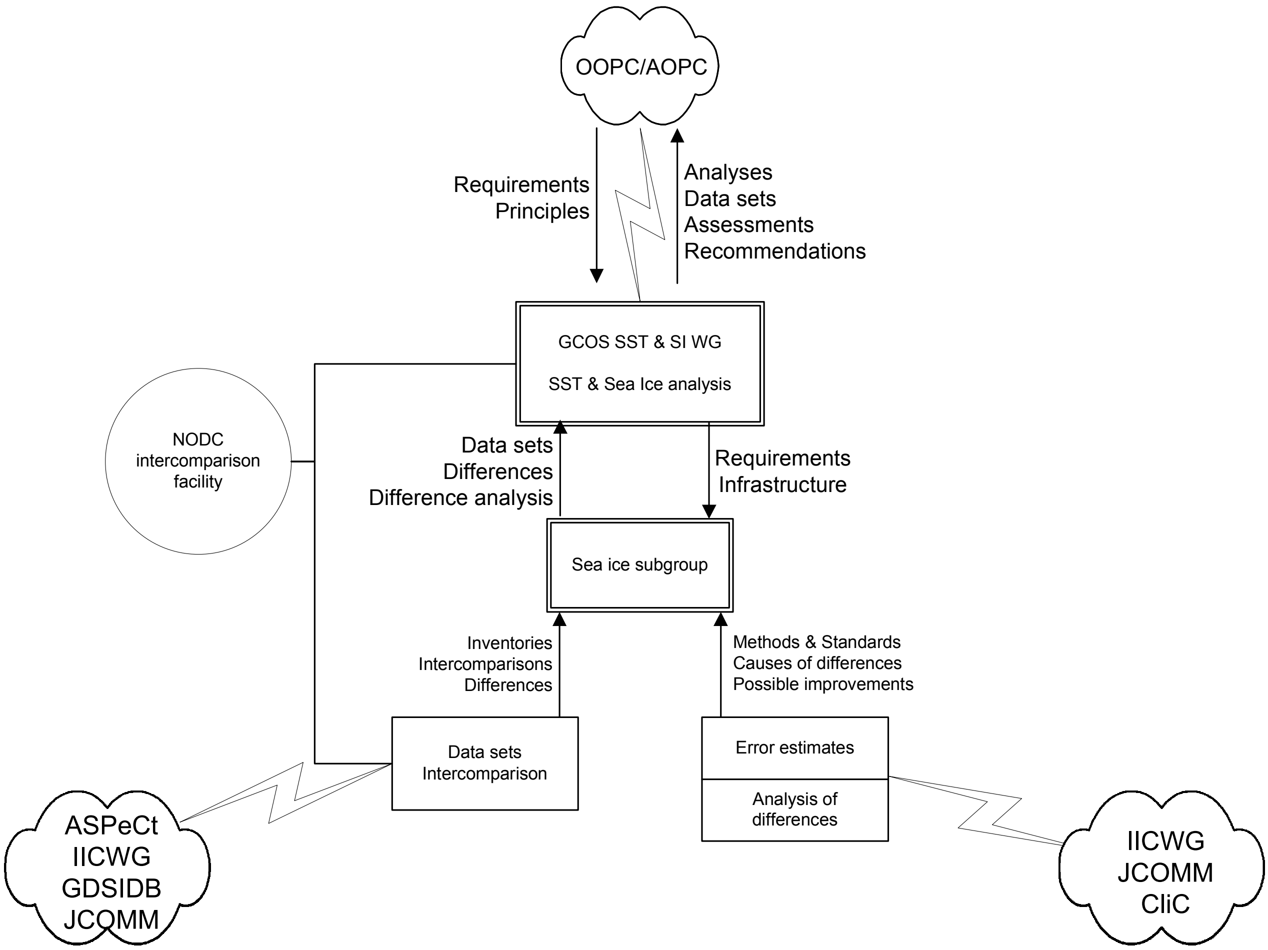

Figure 1 Proposed organisation and foreseen relationships outside the group.

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 tis 2006 meeting in Helsinki. Activities of great importance are to identify and record changes in ics 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

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