

# Report from IICWG workshop on sea ice modeling and data assimilation, Oslo 14-16 May 2007

## **Data types**

There were several presentations discussing the use of satellite data for sea ice and sea ice modeling. The discussion and conclusions are summarized below for various data types.

## **Passive microwave – ice concentration**

The most common large scale satellite derived parameter to assimilate in ice models is ice concentration. This is natural due to the relatively easy access to these data and the direct link to the model variable. Today the Canadian Ice Service and met.no both use this parameter operationally. So is also the case for the TOPAZ system run at NERSC and the PIPS system at NIC. CIS is also working with direct use of Tb measurements (as gradient and polarization ratios) in 3D VAR.

Leif Pedersen / Søren Andersen presented the status of the OSI SAF ice concentration product. This is currently based on SSM/I but will be upgraded this year to use AMSR-E. In the presented work the performance of various algorithms has been tested and measures of std and biases for the different algorithms were derived. The different sources of errors have been studied, (atmosphere, emissivity resolution). The choice of the OSI SAF ice concentration algorithm is made based on this study. A hybrid algorithm has been established as a smooth combination of two of the tested algorithms, the Bristol algorithm and the Bootstrap frequency mode algorithm. To ensure an optimum performance over both marginal and consolidated ice, and to retain the virtues of each algorithm, the Bristol algorithm is given little weight at low concentrations, while the opposite is the case over high ice concentrations.

CIS expressed interests in evaluating the operational OSI SAF ice concentrations. Daily operational products and archived products back to 2005 are found on <http://saf.met.no>. CIS also expressed interest in applying the atmospheric correction of Tb as done in the OSI SAF.

## **Ice drift**

Examples of ice drift assimilation were given by Knut Lisæter and Katja Rollenhagen. Ice drift responds quickly to the atmospheric forcing. A simple drift correction has little impact on the forecast. Multivariate update of the model field, ice thickness/volume is therefore important to get impact on the model forecast.

Ice drift can be derived from various satellite data. All methods build on recognition of a pattern based on cross correlations in the satellite derived signals. In the presented examples of assimilation CERSAT data based on AMSR were used. SSM/I, scatterometer, SAR and also AVHRR (and similar) can also be used in a similar way. It is common to derive the drift from composite of data. The CERSAT product is based on three days of daily gridded AMSR data.

Various aspects concerning resolution, both temporal and spatial were discussed.

Leif Pedersen presented ice drift information derived from SAR. A variety of time intervals for correlations were presented (from less than 1 day up to a week). Shorter intervals generally yields better correlation and thus better coverage (less gaps) but if the resolution is low, quantization effects were encountered. In particular if sub-pixel accuracies were not obtained.

Longer time intervals require also larger search areas in order to accommodate the longer expected drifts. This increases computation time. This problem can be partly overcome by a hierarchical resolution approach.

In Leifs' examples of use of ASAR data overlapping swath data where used directly without creating averaged mosaics of several passages. This gives better information of when the data is valid and thereby reduces the uncertainty in the observation.

The following recommendations were proposed:

- Specify accurate start and end times of displacement vectors
- Specify elaborate error statistics (Gaussian?, are u and v errors correlated?)
- Specify accurately the size of correlation windows and search areas
- Do NOT generate additional displacements by interpolation in order to complete the grid

## **High resolution data**

Currently SAR data are utilized in data assimilation after being manually analyzed. E.g. at met.no gridded ice concentration fields on high resolution are created from the subjective analysis provided by the operational sea ice service. All available SAR and AVHRR / MODIS are exploited. This dataset is then assimilated by nudging into a limited area ice model with relatively high resolution. The intention of this is to produce a 1-2 day forecast based on local ice conditions. This is a pragmatic indirect way of utilizing high resolution satellite data.

Richard Hall presented SAR products from KSAT. SAR data clearly gives the most accurate ice edge observation. New examples of ice classification based on Dual Polarization single bands were presented. These are still promising, however reliable automatic classification methods for operational use are still missing. It will be suggested to focus on this issue at the science workshop at the IICWG meeting which will be held at ESA (ESRIN, Frascati) in November.

L-A Breivik presented use of AVHRR data in the OSI SAF. Using Bayesian approach the probability of ice, open water and clouds can be calculated from combinations of AVHRR channels. The method is based on having a large dataset for training the algorithm. One need reliable estimates of the probabilities of measuring the AVHRR parameter given known surface type: ice, water or cloud. Using the channel 3b (1,6  $\mu\text{m}$ ) gives very good results. It is important to include clouds as a separate class in the analysis and not rely on pre-run cloud-masks. The results will be utilized in regional OSI SAF products (1-2 km resolution).

A similar approach could be applied for SAR data. One will then need to build up a training data set with SAR derived parameters and known ice quantities.

The Bayesian approach calculating probability of ice can be a good starting point for direct assimilation of high resolution satellite data in models. The sea ice probability can be assigned to an ice edge or concentration estimate.

### **Relative value of various observation data types**

As an initial guide to the value of different observation types, a series of hindcast simulations were made using the Canadian prototype system for the period January through April of 2003. The verification results shown below compare the 24 hour forecast to CIS daily ice charts. In each case, only the indicated observation data type was assimilated. The actual numbers are only relevant for this particular system and application and verification using daily ice charts is not ideal. However, one can make some general conclusions. It is clear that assimilating any of the data types improves the model results. At this stage AMSR data provides a significant improvement in concentration bias over SSMI and further improvements are expected with improved land masking schemes. Image analysis charts derived from satellite SAR offer a significant improvement in terms of concentration RMS over PM data despite the fact that they only provide complete coverage every three days or so at this latitude. Overall, the run using daily ice charts has the lowest concentration errors. This is not surprising since they are prepared by experienced forecasters who incorporate all available data.

24 Hr	Avg Edge Error	Edge Bias	Concentration Bias	Concentration Abs Error	Concentration RMS Error
No Data	22.7	-18.5	-28.0	40.7	50.6
SSMI NT2	13.3	-1.4	-14.7	30.2	38.5
AMSR NT2	14.1	0.6	-1.2	28.8	38.2
Daily Ice Charts	13.1	-2.3	-0.1	22.5	31.2
Image Analysis Charts	12.3	-1.1	-2.6	24.7	33.5

### ***Assimilation techniques***

Several different techniques are currently being used by various groups for the assimilation of sea-ice data. These include the variational approach, the ensemble Kalman filter (EnKF), a reduced-rank Kalman filter called the Singular Evolutive Interpolated Kalman filter (SEIK), nudging, and Bayesian estimation. Firstly, the use of each approach, as described in the presentations, is summarized. Then, some common issues related to all assimilation techniques are discussed.

### **Specific techniques**

Two presentations described the work underway in Canada to develop an operational ice data assimilation system based on the variational approach. The first presentation, by Mark Buehner, summarized the general approach and gave some reasons for choosing the variational approach, including:

- ability to assimilate observations indirectly or nonlinearly related to the model variables,
- flexibility in specifying background error covariances,

- ability to account for non-Gaussian errors,
- benefit from NWP experience, and
- to facilitate eventual coupling with variational NWP assimilation systems.

Next, the importance and challenge of specifying the background error covariances for a coupled ice-ocean analysis were discussed. Background error covariances are especially important for unobserved variables that are related to observed variables (e.g. ice thickness and under-ice ocean variables) and when the horizontal coverage of ice observations is not complete over the analysis domain (e.g. SAR or AVHRR data). Ignoring important spatial and multivariate covariances can lead to imbalances or artificial spatial discontinuities in the analysed model state. However, the standard approach of prescribing a homogeneous and isotropic correlation function may not be appropriate for the ice concentration field since it would lead to smoothing out the ice edge. A possible alternative approach was presented in which the ice concentration errors are parameterized in terms of displacement errors. Therefore, the background state is corrected by advecting the ice concentration field to bring it in better agreement with concentration observations. In this way, sharp spatial gradients in the background field (such as the ice edge) are maintained in the analysis. This approach would only be effective if the main source of error in the background ice concentrations was actually related to displacement errors caused by, for example, atmospheric or oceanic forcing errors.

The second presentation, by Alain Caya, provided additional information on the Canadian system, currently based on a coupled ice-ocean model for the east coast of Canada and a three-dimensional variational approach with the background state evaluated at the appropriate time (3D-FGAT= first guess at the appropriate time). The current approach for computing the background error covariances was described. Since the variational approach does not include an approach for obtaining the background error covariances, an EnKF was run over an entire ice season (January-April) and the background error covariances computed by temporally and horizontally averaging the vertical and multi-variate ensemble covariances. The only sources of uncertainty represented in the EnKF are due to initial condition error, observation error and atmospheric forcing error. The atmospheric forcing error is incorporated by using output from the Canadian atmospheric ensemble prediction system to supply 16 different wind forcing fields for the different ice-ocean ensemble members. It was shown that the atmospheric forcing uncertainty accounts for the majority of the ice concentration background error variance in the ensemble Kalman filter experiment. The resulting covariances between ice concentration and both ocean temperature and salinity profiles were shown. The use of these covariances to update the under-ice ocean fields from assimilating ice concentration observations was shown to improve the ice concentration forecasts, but to slightly degrade forecasts of the ice edge. The accuracy of the EnKF 24-hour forecast ensemble mean was also compared to the 24-hour forecasts from the 3D-FGAT analyses. It was found that some ice in the southern portion of the domain appeared in the forecasts from the 3D-FGAT analyses and the observations, but not in the EnKF forecasts. This was due to the differences in the background error covariances in the 3D-FGAT and EnKF. The 3D-FGAT uses error covariances from the EnKF after averaging temporally and over the entire model domain.

Knut Lisaeter presented results from implementing an EnKF with the TOPAZ ice-ocean system over the Arctic ocean. The EnKF includes uncertainties from observation error and atmospheric wind forcing. The ensemble covariances are estimated by applying horizontal localization with a radius of 500km. Results from assimilating ice

concentration observations (SSM/I retrievals) show that the ensemble spread is larger for ice volume than for Ice extent and larger during the summer than during the winter. Results were also shown from ongoing experiments of assimilating 3-day ice drift. From the ensemble members, the covariances between 3-day drift and the instantaneous model variables were computed and used to compute the corrections to the model variables. Corrections to the ice concentration are small and only occur near the ice edge. On the other hand, corrections to the ice thickness field are more wide-spread throughout the domain.

The final presentation in the “techniques” section was given by Ingunn Burud on the SEIK filter, as applied at met.no. This technique is being developed to replace the currently operational system in which ice concentration and SST observations are assimilated with a nudging approach. Results from twin experiments were shown where several different combinations of ocean observations were assimilated. Experiments with either 15 or 30 members were performed. A version of this approach in which the covariances are spatially localized was mentioned as something that will be explored. This will likely be important when assimilating ice concentration which is typically a much less smooth field than the ocean fields.

## **Common issues**

### Computing background error covariances

Ensemble approaches are a convenient approach for computing error covariances. This can be done either as in the EnKF, where the ensemble forecasts are part of the assimilation approach itself, or by running a separate set of ensemble forecasts that begin from the same state but include perturbations to represent model and/or forcing uncertainties (as planned by Paul Meyers). Depending on the type of model and the spatial/temporal scales of interest, the dominant sources of uncertainty need to be identified and an approach for incorporating these uncertainties into the ensemble integrations found. Due to the availability of output from operational atmospheric ensemble prediction systems, incorporating uncertainties from wind forcing is quite straightforward. Also, the EnKF technique allows for including the influence of error in the assimilated observations. However, less straightforward is the influence of model error on background error which is likely to be model dependent. It was mentioned in a couple presentations, but no attempts have been made yet to try to incorporate model error in the calculation of background error covariances.

### Non-Gaussian errors

Some discussion took place on the problem of non-Gaussian errors, especially for ice concentration which is bounded between 0 and 100%. Both variational and EnKF techniques are based on the assumptions that the errors are Gaussian and unbiased. Because models are probably not able to handle values of ice concentration outside the range 0 to 100%, such values must be truncated to 0 or 100%. Consequently, high ice concentrations will likely have a negative bias and low concentrations a positive bias.

## Ice concentration spatial correlations

The horizontal correlations of background error for ice concentration are likely to be complex, especially near the ice edge. The EnKF technique uses the instantaneous spread among of the ensemble members to estimate these correlations independently for each grid-point. However, the necessity of using a small ensemble size causes the correlations to be noisy. This problem is partially solved by applying spatial localization to damp spurious long-range correlations. Variational approaches often use horizontal correlations that are homogeneous and isotropic, which are clearly inappropriate for ice concentration. The approach presented by Mark on correcting ice concentration through the estimation of displacement errors is one possibility for obtaining more physically realistic error correlations for ice concentration.

## **Models**

The focus of the workshop was to a less degree directed toward the ice models themselves than to the interaction of them with the assimilation techniques. The different talks reflected that each group has their own model system and that the details of the methods chosen has to be more or less tailored to that specific model system.

All sea ice models presented at the workshop are relying on a two-dimensional continuum hypothesis for description of the ice, and uses versions of the Viscous-Plastic rheology, where the most common is the EVP-formulation. None of the groups are using discrete element models, or other Lagrangian types of models, despite that some of the forecast systems are operating with a few km horizontal resolution. Most of the models used has been developed with climate applications as a main constraint. Although the question of how these climate types of models behaves as operational forecast models at high resolution was raised, no conclusive answers was given at the workshop. Careful validation of model forecasts to observations is the best way to evaluate this.

There are larger variations in the thermodynamic formulation of the models, ranging from so called zero-layer, two category formulations to full thickness and enthalpy distribution models. In addition, FIMR has a pure thermodynamic, one-dimensional ice and snow model with high vertical resolution, used for ice-thickness growth and snow condition estimates.

Several of the groups are using the CICE (Community Ice CodE) model (CIS, NIC, DMI, Australia). This model is also considered for use in climate projects in Norway, where the met.no-group is involved. This opens up the possibility that the model can be used for operational forecasts in Norway too in the future.

The ocean models used by the groups are different local versions of POM, HYCOM, NCOM, NEMO(OPA), MOM-4, FESIM (finite elements), Although the ocean state might have a large impact on the sea ice forecast, little focus was dedicated to discussions of the different ocean models and their strengths and weaknesses.

There where some discussions on how complex a model system must be for the ice forecasts (uncoupled ice, coupled ice-ocean, fully coupled atmosphere-ice-ocean, or a hybrid in between those). The general answer is that this depends on the type and length of the forecast, and on what kind of physical processes that are the most

important for that specific case. For example, an uncoupled high-resolution ice model, forced with an ensemble of atmospheric wind products, could be one such simplified system giving valuable information about the uncertainty in the ice edge position. However, the system will rely on a good analysis of ocean fields, and these would preferably come from a coupled ice-ocean model with assimilation. How successful such a ensemble system would be, will depend on the specific synoptic situation. Rapid varying temperature fronts in the ocean is one situation that will limit the score of such a simplified uncoupled system.

## ***Operational and research Systems***

Several operational data assimilation systems were described. These include systems from Canada, Norway, Denmark, Finland and USA. The assimilation techniques range from simple insertion to more complex techniques such as 3DFGAT and EnKF. Some systems use models to provide a first guess or background field while others do not rely on first guess fields. The emphasis of these systems ranges from purely focusing on the analysis, the forecast or a mix of both. A more detailed description of these systems follows.

*Canada:* The Canadian prototype system has been developed through a collaboration of government labs and consists of a coupled ice-ocean model and a 3-dimensional first guess at appropriate time (3DFGAT) variational data assimilation system. The coupled model is composed of a viscous plastic dynamic thermodynamic ice module coupled to the Princeton Ocean Model (POM). The system currently has about a 15 km resolution and assimilates daily ice charts and image analysis ice charts with a 12 hour window. The prototype system has been compared with the operational system which uses a nudging technique for daily ice charts. Initial results are roughly comparable with the operational system slightly in the lead. Further testing is required before additional observations (passive microwave) are used.

*OSI-SAF* provide daily global ice analysis (edge and concentration) from SSM/I on 10 km grids. It will be upgraded to also use AMSR for ice concentration and scatterometer for ice edge. This operational system is analysis based and does not include a sea ice model or a trial field. Passive microwave data from the SSMI sensor is corrected for atmospheric humidity and surface wind effects. The system is regularly validated against Danish and Norwegian ice charts and will be compared with Canadian ice charts in the near future.

*Met.No* operational coupled ice ocean model is today assimilating the OSI SAF ice concentration and SST products, using a nudging technique. This forecast and analysis system is composed of a locally developed 2 category sea ice model, using the EVP rheology, coupled to a local version of POM over the Arctic Ocean. A semi-operational version of the system at 4 km horizontal resolution is running daily for the Svalbard area, and the resolution for this area will increase to 2 km during the year. Adaptation of the SEIK filter for sea ice is under way. The Arctic domain is at present producing daily 120 hour forecasts at 20 km resolution, while the high resolution models give 60 hour forecasts.

*TOPAZ, NERSC:* This analysis and forecasts system is composed of HYCOM coupled to a 2 category dynamic/thermodynamic EVP sea ice model over the Arctic Ocean. The system assimilates ice drift data passive microwave ice concentration data and ice drift data using EnKF techniques.

*PIPS 3:* This US Navy (NRL) forecast system consists of the LANL CICE model loosely coupled to US Navy operational ocean forecast model NCOM for the Arctic Ocean and marginal seas. Direct insertion of SSM/I derived NT2 ice concentrations is used for model ice initialization. Ice thicknesses are determined by ... Forecasts for up to ... days are issued on a daily basis. The model has approximately a 9 km resolution. Output is available on a rotated lat-lon grid in netcdf format...

*Finland :* This forecast system uses at the University of Helsinki developed multicategory dynamic/thermodynamic sea ice model, which is implemented at FIMR and used operatively in a resolution of 1 nm for the Baltic Sea. The model allows for the separation of level, rafted and ridged ice. Sea ice variables are fully prognostic, but SST is prescribed by the ice chart provided by the Finnish Ice Service. The model provides 56 hour forecasts on a daily basis. The forecasts are available through the Polar View web-page [polarview.fimr.fi](http://polarview.fimr.fi).

In the Baltic Sea the development of the data assimilation scheme will begin in the autumn 2007. From the successive SAR image pairs derived displacement fields will be used to adjust the sea ice model parameters. In the first phase the validation data set consists of the EM based ice thickness measurements collected in winter 2005. The total length of the EM profiles is about 1500 km.

*Australia* In co-operation with Australian Antarctic Division, Institute for Antarctic and Southern Ocean Studies, CSIRO Hobart, and Bureau of Meteorology (BoM) a system for sea ice analysis and forecasting is under development at Antarctic Climate and Ecosystem Cooperative Research Center, Hobart, Tasmania. This system comprises of a remote sensing data base and a numerical model to predict future evolution of sea ice conditions for up to ten days for the whole Southern Ocean. Special attention, i.e. high resolution analysis and modeling, will be paid on the East Antarctic to provide guiding information for ships operating in this region. With the installation of a new X-Band receiving facility at Casey Station a wide range of near real time satellite data will be available for a best possible analysis of the current condition of the sea ice cover. Such an analysis will comprise information on fractional coverage of sea ice, surface temperature, sea ice velocity, location of the pack ice edge as well as fast ice distribution, and location of icebergs. For a short term prediction of sea ice conditions a numerical model will be run together with data assimilation. The CICE (Community Ice CodE) model is implemented on the AUSCOM grid and coupled to MOM-4 ocean code. Test runs are successfully conducted. As a first step the model will be assimilated to sea ice concentration remote sensing data applying an Ensemble Optimal Interpolation technique, which will be transferred from the Bluelink Ocean Data Assimilation System (BODAS). BODAS is operational at CSIRO/BoM predicting ocean state around Australia for up to a week.

*Germany, AWI, research system;* The Arctic research system developed at AWI is a Hibler-type finite-element sea-ice model applying the EVP approach. This sea-ice model

usually is coupled to the finite-element ocean model. To reduce computational costs the uncoupled version FESIM is applied for data assimilation with the SEIK Filter. The challenge in the assimilation of the sea-ice drift so far has been that – compared to the ice thickness or concentration – the drift changes very frequently, depending on wind, ocean and internal ice stress. Since inertia of sea ice is small compared to stresses, the system has very little memory beyond each assimilation step, making corrections by the filter very short lived. Even a perfectly corrected drift field has very little effect on the model state in the next model integration step. However, ice-drift history is stored in the sea-ice thickness and concentration distributions. By considering covariance of sea-ice thickness and drift as well as covariance of sea-ice concentration and drift, the SEIK filter is able to modify the more conservative state variables “ice thickness” and “ice concentration” during the course of assimilation.

First results of sea-ice drift assimilation show mainly modifications in the sea-ice thickness rather than in the sea-ice drift itself or concentration. The modification of the sea-ice thickness leads to different sea-ice drift during the model integration than in a model run without assimilation; and could result in a better performance of sea-ice drift compared to buoy drift observations, especially in regions of thick sea ice. A comparison with ULS-derived sea-ice thickness data from October 2000 proves the improvement of sea-ice thickness distribution by assimilation of ice drift. Simulated ice thickness after the assimilation procedure appears to be overestimated; the qualitative distribution of thickness minima and maxima, however, is far better represented than in a model-only run. Sea-ice drift assimilation is still work in progress and issues related to filter stabilisation and mass conservation have to be solved. It seems that the drift assimilation with FESIM utilizing the SEIK Filter is applicable for sea-ice forecast providing reliable sea-ice thickness distributions in the central Arctic within a few assimilation steps for a time period of a few weeks. An additional assimilation of sea-ice concentration data is expected to improve results esp. for the location of the ice edge.

## ***Verification***

There are many reasons for using verification within any analysis and forecast system. In particular, it is desirable to determine whether changes to the system provide a measurable improvement to an analysis or forecast. Examples of changes that will arise include: new or revised models; new or revised data assimilation techniques; additional observations; or revisions to observation processing. The difficulty in the sea ice domain is that none of the desired quantities are measured directly in a routine manner. Even the two most basic quantities, ice concentration and ice edge location must be derived from observations of backscatter, reflectance, etc. The information derived from each source has intrinsic limitations that must be considered when used for verification. While there may be considerable merit to use any and all observations for verification, it is recommended that ice charts be used as one source for ice concentration and ice edge. This is because ice charts incorporate many types of observations and are prepared by experienced analysts. Moreover, one of the goals of the data assimilation effort to provide a good first guess ice chart product.

## Ice Concentration and Ice Edge

Initial verification measures such as bias and root mean square error should be used for ice concentration. Skill scores can also be used to compare the model forecast with some reference forecast such as persistence or climatology. It is recommended to map from the model grid to the observation points in order to calculate statistics.

Ice edge errors are determined by comparing the distance between the forecast and the observed edge location. One relatively simple technique to calculate this is by taking the area between the forecast and observed edge and dividing by the length of the observed edge. This can provide both an average error and the bias. Persistence is a good reference to use for calculating shorter forecast skill scores.

## Ice Drift

Ice drift is another important quantity that can be used for verification. The simplest error measures can consider the distance between a forecast and observed trajectory as a function of time. More sophisticated measures can use complex correlation techniques. A reasonable reference for calculating skill scores could be a free drift model or basically 2% of the wind.

## Other quantities

It would be highly desirable to validate additional quantities such as Ice thickness, ice pressure and ice strength. However, these are not observed directly nor routinely. Ice charts provide general information about ice thickness through the inferred stage of development. Some satellite based sensors provide ice freeboard in particular conditions. Airborne EM sensors provide ice-snow thickness for particular experiments. Ice pressure is reported by ships when it is encountered but not in areas away from the shipping lanes. Subjective impressions of ice strength are even less frequently reported. As a result, it is expected that verification of these additional quantities will be less conclusive and care will be required to interpret the results.

## ***Actions and Collaborations***

The meeting was generally considered by the participants to have been very useful. Specific concrete action that were proposed follow

- Carrieres will compare the OSISAF products to CIS ice charts and provide a report to Breivik
- Breivik and Toudal will share with CIS their radiative transfer code (OSI SAF) for correcting passive microwave brightness temperatures and for AVHRR cloud masking, SST and ice retrieval
- Breivik recommends everybody to attend the next OSI SAF users meeting to be held in conjunction with Eumetsat Conference in Amsterdam on Sept 24-28, 2007.
- The next workshop is recommended to be held in about 1 years time at DMI

IICWG Workshop on Sea Ice Data Assimilation  
Norwegian Meteorological Institute, Oslo  
14-16 May 2007  
9:00 to 5:00 each day  
Day 1

09:30 Introduction (Lars-Anders Breivik/Tom Carrieres)

**Assimilation Techniques**

- 09:40 Assimilation of sea-ice data using a variational approach: Concepts and theory (Mark Buehner)  
10:10 Assimilating sea-ice data in a coupled ice-ocean prediction system: Results and diagnostics (Alain Caya)  
10:40 Coffee  
11:00 An implementation of sea-ice drift assimilation in an ice-ocean model (Knut Lisæter)  
11:30 Seik (Ingunn Burud)  
12:00 Discussion
- 12:45 Lunch

**Data**

- 13:30 Mapping sea ice state variables to AMSR-E observations for a 3D variational data assimilation system (Mingrui Dai)  
14:00 Ice drift and reanalysis (Leif Toudal)  
14:30 OSI SAF, operational met. Satellites (Lars-Anders Breivik)  
15:00 Coffee  
15:30 Active Radar (Richard Hall)  
16:00 Sea ice and Arctic observations in International Polar year (Cecilie Mauritzen)  
16:30 Discussion

Day 2

**Operational Systems**

- 09:00 Met.no (Jens Debernard)  
09:30 The CIS/EC prototype sea ice data assimilation system (Tom Carrieres)  
10:00 Towards a sea ice analysis and forecast system for the Southern Ocean (Jan Lieser)  
10:30 Coffee  
11:00 Towards an operational sea ice model for the waters around Greenland (Nicolai Kliem)  
11:30 Sea Ice modeling and assimilation in Finland (Markku Simila)  
12:00 Discussion
- 12:45 Lunch

**Research Systems**

- 13:30 Climate and Cryosphere project (Victoria Lytle)  
14:00 Sea Ice Representation in the NATL4 Configuration of the NEMO System and Assimilation (Paul Myers)

14:30 Arctic sea ice drift assimilation in a Finite Element Sea Ice Model using the Singular Evolutive Interpolated Kalman Filter (Katja Rollenhagen)  
15:00 Coffee  
15:30 Discussion

### Day 3

Review and Discussions -> report

Presentation by Leif Toudal

Data Types (Lars-Anders Breivik)

- Summary of work being done
- Consensus on data priority
- Retrievals vs direct assimilation
- Data/product access
- Areas for future research and collaboration

Assimilation techniques (Mark Buehner)

- Summary of work being done
- Advantages & disadvantages for sea ice applications

NIC update – presented by Tom Carrieres

Models (Jens Debernard)

- Summary of work being done
- Simple vs complex
- Importance of ocean dynamics and thermodynamics
- Atmospheric coupling/effects

Operational Systems (Tom Carrieres)

- Summary of work being done
- Verification
- Usage

Future Plans and Collaborations