IOMASA –

Integrated Observing and Modeling of the Arctic Sea ice and Atmosphere

An RTD project of the European Comission
in the Fifth Framework Programme
under the specific programme on
Energy, environment and sustainable development,
Part A: 'Environment and Sustainable Development'
of the European Comission
Key Action 3, RTD priority 3.4,
Project Number EVK3-2001-00116

Description of Work (DoW)

May 2002

Contents

1 Summary of Project IOMASA – Integrated Observing and Modeling of the Arctic Sea ice and Atmosphere

1.1 Problems to be solved

At present, the polar regions belong to the regions of which the least information is available about the current and predicted states of surface and atmosphere. Because of sparse observations, we only have at a rough quality weather forecasts for northern Europe, and ice charts for the ice frequented waters of the European Arctic.

1.2 Scientific objectives and approach

The objective of IOMASA is to improve our knowledge about the Arctic atmosphere by using satellite information which is continously available, but currently not exploited. This progress will be achieved through an integrated approach involving, the outcomes of each of these three points serving to improve the two other ones:

1. remote sensing of atmospheric parameters temperature, humidity and cloud liquid water over sea and land ice,
2. improved remote sensing of sea ice with more accurate and higher resolved ice concentrations (percentage of ice covered sea surface), and
3. improving numerical atmospheric models by assimilating the results of the points 1 and 2.

1.3 Expected impacts

We expect impacts for the following problems:

- obtain knowledge to improve weather forecasts for northern Europe,
- obtain knowledge to improve ice charts for the ice frequented waters of the European Arctic,
- obtain knowledge to improve estimation of the fraction of open water in the higher Arctic which is very important for the total heat budget of the region, affecting both local and regional weather and climate. The heat exchange between the ocean and the atmosphere is about two orders of magnitude larger when no ice is present.

The improved knowledge about the Arctic environment will be available to users of many kinds. On a large scale, the models can be embedded in large-scale GCMs to predict global climate change, while on a smaller space scale and shorter time scales they will be used to improve operational forecasting of weather, ice and ocean conditions, helping to improve the living conditions of all members of the Arcitic population.

2 Scientific/technical objectives and innovation

2.1 General objectives

At present, the polar regions belong to the regions of which the least information is available about the current and predicted states of surface and atmosphere. The objective of IOMASA is to improve our knowledge about the Arctic atmosphere by using satellite information which is continously available, but currently not exploited. This progress will be achieved through an integrated approach involving, the outcomes of each of these three points serving to improve the two other ones:

1. remote sensing of atmospheric parameters temperature, humidity and cloud liquid water over sea and land ice,
2. improved remote sensing of sea ice with more accurate and higher resolved ice concentrations (percentage of ice covered sea surface), and
3. improving numerical atmospheric models by assimilating the results of the points 1 and 2.

2.2 Scientific objectives and approach

Remote sensing of atmospheric parameters over sea ice A recently proposed procedure to retrieve the total water vapour in the range of 0 to 6 kg/m^2 over Antarctic sea and land ice from data of the microwave humidity sounder SSM/T2 will be transferred (1) to the similar sensor AMSU-B (part of ATOVS aboard the NOAA satellites) and (2) to Arctic conditions.

Fields of the cloud signature (roghly the cloud liquid water) will be derived from SSM/I (Special Sensor Microwave/Imager) data after transferring the method originally derived for the Antarctic to Arctic conditions.

A method to improve the retrieval of temperature profiles from microwave sounders working in the oxygene absorption band near 60 GHz (e.g. AMSU-A, SSM/T1) by including surface emissivity information in regions (partially) covered by sea ice will be adapted to direct assimilation and Arctic conditions.

Improving numerical atmospheric models

(1) Assimilation of atmospheric parameters into NWPs. A significant part of the forecast errors in numerical weather prediction comes from errors in the initial state, and in particular from the lack of observations of the atmospheric state in remote areas over the oceans and polar ice caps.

The use of satellite sounding data from microwave and infrared channels from the ATOVS sensor package (including AMSU-A and AMSU-B) has contributed to relieving this problem over open ocean. Radiances measured by these instruments play an important role in the meteorological observing system. They are intensively used by many NWP centres. Over sea and land ice, however the use of ATOVS channels has been limited.

A main goal in this project is to improve atmospheric models over and near the Arctic by enhanced use of AMSU-A temperature sounding observations and by taking AMSU-B moisture sounding data into use over ice. When SSMIS will become available (scheduled for launch in november 2001), the extension of the methods to that sensor will be considered, offering the advantage of simultaneous soundings of temperature and humidity, and sea ice detection. An optimal treatment of the AMSU-A and AMSU-B data in assimilation will be found, which applies estimates of ice concentration and surface emissivity. This will lead to more efficient data assimilation of sounding data over ice in general, and will in this project be used in a near-real time framework for improving weather forecasts over the Arctic when applied in a high-resolution limited-area model.

(2) Improved surface heat flux modeling. A closed sea ice cover reduces the heat flux up to two orders of magnitude, with small openings contributing significantly to the atmospheric heat budget. The effect of a surface heat flux parametrization using ice concentrations from a SSM/I or multi-sensor retrieval in terms of the effect on forecast quality will be studied.

For both types of improvements, special emphasis will be put on obtaining impact of the data in high-resolution limited-area models, here with horiontal resolution of 20 km or better. Limited area models are continously forced by the lateral boundary conditions (with values usually taken from a coarser, typically global, NWP model). There is a potential for improving the (especially short-range) forecast skill by better estimates of the initial state. In particular the higher density of satellite passages at the high latitudes will be exploited, where the gaps between the conventional observations are large . The results will be validated in parallel forecast cycle experiments.

Remote sensing of sea ice. For large-scale remote sensing of sea ice, passive microwave sensors offer the unique features of independence of darkness (polar night), nearly independence of cloud cover and daily global coverage. Current operational products mainly rely on the SSM/I with data available since over 20 years. The combined use of active and passive microwave sensors has been little explored, mainly due to the narrow swath of the ERS scatterometers and the early failure of NSCAT aboard ADEOS. However with the advent of Quikscat (1999), scatterometry-based sea ice detection has gained momentum and obvious synergies with passive microwave instruments particularly regarding ice type detection have emerged. A nearly indentical instrument in planned for launch in 2002 aboard ADEOS-2.

This project will develop and test a set of improved algorithms to derive ice concentration from active and passive microwave satellite data with high temporal repetition using the best available information from other sources to correct for the unwanted/unknown parts of the signals (in parenthesis the source of correction information): (1) cloud liquid water (cloud signature from SSM/I), (2) atmospheric water vapour (improved NWP short term predictions), (3) wind speed over open ocean (NWP, SSM/I and scatterometers), (4) ice surface temperature (short term NWP results plus relaxation for surface temperature changes), and (5) ice surface emissivity (empirical ice evolution models).

Past attempts to derive ice concentrations have primarily relied on the microwave radiometer signals itself to correct for these effects, the remaining uncertainty being in the order of 5...10%, sometimes up to 30%. We will reduce these numbers substantially using auxiliary information from short term numerical weather prediction, supplementary satellite sensors and algorithms, and an improved knowledge of the temporal and spatial variability of the ice surface signatures.

The skill achieved by this study will be validated using a combination of high resolution satellite data from visible/infrared and Synthetic aperture radar sensors.

2.3 Innovation

Although both temporal development and remote sensing of sea ice and polar atmosphere are intimately interrelated through many processes, both components of the Arctic climate system are currently treated separately for sea ice analysis and weather forecast.

The overall innovative aspect of the project is to develop tools suitable for an integrated retrieval and forecast of atmosphere and sea ice from both satellite and model data.

Moreover, each of the components sea ice retrieval, atmospheric remote sensing and atmospheric modeling will benefit from specific innovations described below:

2.3.1 Remote sensing of Arctic atmosphere

Until recently, only very little information about the polar atmosphere over sea and land ice could be obtained by remote sensing methods. Now, three methods

1. to detect the total water vapour over sea and land ice from data of the microwave humidity sounder working near the 183 GHz absorption line sounders (e.g. SSM/T2, AMSU-B),
2. to detect the total cloud liquid water over sea ice from SSM/I data,
3. and to improve the temperature profile sounding over sea ice and in the marginal ice zone from microwave temperature sounder data (e.g. SSM/T1, AMSU-A), improved by ice concentration data from SSM/I and surface temperature data from an infrared sensor (e.g. OLS, AVHRR) ,

respectively, have been devised. Methods 1 and 2 are completely new, no such informations was available before. All three methods have been derived and validated for Antarctic conditions. They will be

- adapted and validated for Arctic conditions, and
- demonstrated in a near-real time experiment.

2.3.2 Modeling

Unlike over ocean, ATOVS data have been in use only to a limited extent over sea ice, and only by a few weather prediction centres running global models. The main source of problems here is the inability to account for the surface contribution to the measured radiances. This has been circumvented by only using AMSU-A channels responding on the upper troposphere over the Arctic icecap or by introducing a very strict quality control which rejects observations where the discrepency between the measurement and that simulated using NWP forecasts is too large, causing only a fraction of the observations to be used.

IOMASA will improve our ability to use these data over ice accounting for the surface contribution by exploiting information about the ice concentration and emissivity. This will be done by implementing the algorithms for ice concentration and sounding channel ice emissivity referred to above for near-real time processing. This will be interfaced to a fast radiative transfer model to allow forward computation of AMSU-A and AMSU-B sounding channel radiances for use in a data assimilation system. This shall enable us to use surface channels over ice and get benefit from a much larger fraction of the AMSU-A observations than before.

To our knowledge satellite sounding channels have not been used in high-resolution limited area forecast models over Arctic sea ice. The observations will be assimilated into such a model using a three-dimensional variational data assimilation system (3D-Var). This will also lay a foundation for possible future use in a four-dimensional variational scheme.

The NWP surface heat flux formulation in the Arctic will be improved by replacing the assumption of full ice coverage with more realistic ice concentration estimates as derived in this project.

The extended use of sounding data over sea ice and the better parameterization of the surface heat flux are expected to give a positive impact on the forecasts.

2.3.3 Sea ice

Past attempts to derive ice concentrations have primarily relied on multichannel microwave radiometer observations solely. Under such circumstances the ice concentration may be estimated with uncertainties between 6 and 10% using atmospherically corrected passive microwave observations and monthly tiepoints. Some work already exists on the combined exploitation of passive and active microwave observations for sea ice retrieval but these methods either do not handle ice concentration or take into account atmospheric and surface effects. A halving of the uncertainty of ice concentration retrievals to between 3 and 5% is expected through the following novel approaches to the retrieval problem:

- Use of short term weather foreoasts and analysis data to correct both active and passive microwave data prior to the retrieval of ice parameters.
- Use of synergies between active and passive microwave observations to better account for surface effects and previously unhandled ice types such as thin ice in areas where multi year ice shall be encountered.
- The use of simultaneous retrievals of cloud signature to correct for the influence of cloud liquid water.
- Higher resolved ice edge and ice concentrations with high reliability through the compensation methods mentioned above.

2.3.4 User interface

The results of the above three fields of activity will be brought directly to all interested users. This interface will also serve to evaluate the usefulness of the products for operational forecasters in the Arctic.

3 Project workplan

3.1 Introduction: structure and methodology of the work

3.1.1 Structure

The aim of the IOMASA project is to develop methods to improve our knowledge and ability on

1. remote sensing of atmospheric parameters over sea and land ice,
2. the retrieval and of the properties of the Arctic sea ice, of which the most important is the sea ice concentration, and
3. the numeric modeling and forecast of the Arctic atmosphere.

According to these objectives, IOMASA is structured into five parts and four phases. The parts are:

Part 1: Remote sensing of atmospheric parameters,
Part 2: Improving numerical weather prediction models,
Part 3: Empirical model for emissisivity and backscatter of sea ice,
Part 4: Sea ice concentration retrieval,
Part 5: Demonstration of real time processing and user interface.

Each part extends over several or all phases. The phases are:

Phase 1, Months 1-6: Preparation phase: Provide data, day 0 algorithms and data sets, perform literature studies,
Phase 2, Months 7-28: Development of algorithms for retrieval and assimilation,
Phase 3, Months 29-32: Production experiment on 2-year historic data set,
Phase 4, Months 33-36: Validation and real time experiment: Demonstrate operational use and online data distribution.

3.1.2 Methodology

Though the parts of the project are inter-related, they will be described separately for reasons of clarity of the proposal.

The following parameters of all data and investigations have to be agreed upon during the kick off meeting:

- Period of offline investigation: 2 years, probably 1999 and 2000
- Region of investigation: Most parts of the Arctic as covered by the operational model of Partner 4, see Figure 1.
- Geographic projection grid of all data and deliverables.

Part 1: Remote sensing of atmospheric parameters

Phase 1, WP 1.1: Provide data of investigation period and day 0 algorithms

The following data, sources of data sets, or day 0 algorithms are to be provided:

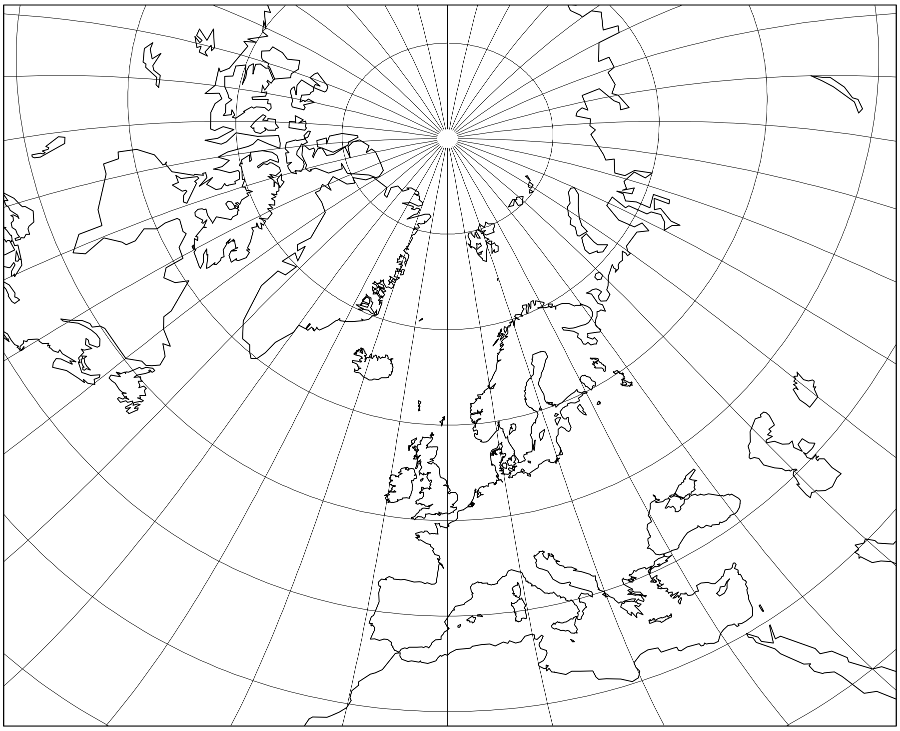

Figure 1: Region covered by the numerical weather prediction model

– 2 years of AMSU-B, AMSU-A and SSM/I data covering investigation period, fallback option for sounder data: SSM/T1 and SSM/T2 data,
– Gather radiosonde data of investigation period for calibration and validation. Potential sources are operational coastal stations, research vessels, and projects, e.g. SHEBA.
– Day 0 algorithms for total water vapour and cloud liquid water over sea ice.
– literature data for sea ice emissivity at temperature sounding frequencies and incidence angles

Phase 2, WP 1.2: Development of algorithms for retrieval and assimilation

(1) Atmosperic total water vapor

Over open water the atmospheric total water vapor (TWV) is routinely retrieved from SSM/I data since many years. However, over sea and land ice, satellite microwave radiometry has not been successful in measuring the TWV. The difficulties faced in these regions arise from the very low water vapor burden of the atmosphere and the large and highly variable emissivities of ice surfaces in the microwave frequency range. By exploiting the advantages of the Special Sensor Microwave/Temperature 2 (SSM/T2) working near the water vapour absorption line near 183 GHz, a method has been developed to retrieve TWV over Antarctica from satellite data (Miao et al., 2001). This

method shows very low sensitivities to the change of surface emissivity and to the presence of water clouds. However, ice clouds may have considerable effects. Results of radiative transfer model simulation show that they may cause one to underestimate TWV using the proposed method and that the amount of underestimation is proportional to the ice water path of the ice cloud. Validations using radiosonde measurements and numerical model analyzes suggest that SSM/T2 retrievals have a high accuracy (maximum error $< 10\%$) as long as TWV is $<4.0\,\mathrm{kg\,m^{-2}}$. Above this value, retrievals show a systematic overestimation. Presumably, this is a result of the seasonal difference between the validation and the training radiosonde data sets.
With slightly higher error margins, values up to 6 $\mathrm{kg/m^2}$ can be retrieved. Although even higher values may occur over sea ice, even this range of retrieved values allows to cover the sea ice up to the ice edge in most cases. A single day's (20 Apr 1995) case study of the Antarctic sea and land ice has shown that the TWV could be retrieved over about 95% of the ice covered surface.
Currently, partner 1 is performing investigations to extend the range of retrieved TWV values up to 10. . .12 $\mathrm{kg/m^2}$ by including the 92 Ghz channel of the SSM/T2 into the retrieval.
The procedure will be transferred (1) to the humidity sounder AMSU-B with channels similar, but not identic to SSM/T2 aboard the NOAA satellites and (2) to Arctic conditions and will be calibrated with a set of radiosonde data to be collected at the beginning of the project. A second means of calibration will be the TWV retrieval over open water in the cases where it does not exceed the upper limit allowed by the AMUS-B procedure.

(2) Cloud liquid water

A method to detect the cloud signature (mainly the cloud liquid water) over the sea ice covered Weddell Sea in the Austral summer season has recently be proposed (Miao et al., 2000). By using the polarization differences at the two high frequency channels (*i.e.* 37 and 85 GHz) of the SSM/I, a new quantity called R-factor is defined. Using the R-factor, the atmospheric signal can be separated from the surface signal and, more importantly, the surface signal and its variation can be strongly reduced, especially in regions with low ice concentrations. In regions with high ice concentrations, other sea ice parameters like snow cover play an important role as indicated by atmospheric radiative transfer simulations using *in situ* measured sea ice emissivities and SSM/I observations. Under the assumption that the sea ice parameters remain sufficiently stable within a short period (*e.g.* 10 days), a method has been proposed to determine the background term from SSM/I measurements, allowing the detection of the cloud signature. A comparison with a known SSM/I cloud liquid water algorithm over the open ocean shows a high degree of correlation (0.958) of the cloud signatures detected by the two algorithms. In a case study over the sea ice covered Weddell Sea the cloud signature detected using the R-

factor method compares well with coincident observations from both visible and infrared sensors.

During this project, the method has to be transferred to Arctic conditions in two respects, namely of calibrating and validating it to the conditions (1) of the Arctic atmosphere with possibly different cloud microphysical and climatological properties and (2) of the Arctic sea ice emissivity.

The adaptation to the *Arctic atmospheric conditions* shall be achieved by calibrating the method with the set of Arctic radiosonde profile data. A specific problem is the lack of directly measured cloud liquid water data. It will be solved by using the radiosonde profiles of temperature and humidity to selcet parameter settings representing clouds. Several methods have been suggested for this procedure (Chernykh and Eskridge, 1996; Karstens et al., 1994). These simulated liquid water profiles, together with those of temperature and humidity, will then be used as input for a radiative transfer model to simulate the brightness temperature observed from the satellite. The thus obtained dataset of brightness temperatures and known atmospheric conditions will be divided into two parts, one for calibration and one for validation.

The remaining problem of unknown *Arctic sea ice emissivity* will initially be treated using experiences from the published literature (cit??). During the course of the project, the emissivity values will be refined by using the additional knowledge about the ice types, their temporal evolution and emissivities according to the outcomes of Part 3.

(3) Surface emissivity at temperature sounding frequencies

Knowledge of the atmospheric temperature profile is of critical importance for meteorological and climatological studies. For the polar regions where in situ measurements from radiosondes are sparse, only satellite measurements can provide this information with good spatial coverage. The temperature sounder AMSU-A aboard the NOAA satellites is well suited to derive temperature profiles continously. Operationally used retrieval methods accound for the influence of the surface only by utilizing the surface channel, and significant retrieval errors can occur in the lower troposphere. In polar regions, the surface conditions are complex with mixtures of open water and different ice types, all posessing different emissivities and coverages in the footprints of AMSU-A. Recently, Miao et al. (1995) have proposed a procedure to combine temperature sounding data with coincident measurements of (1) SSM/I for sea ice concentration and type and (2) IR radiometer data for surface temperature measurements. For an example, see Fig. 2

In order to combine this method, originally derived for Antarctic conditions and for the sounder SSM/T1, with the assimilation schemes currently used for AMSU-A, the procedure to determine the surface emissivity at the frequencies and incidence angles of the sounder will be transferred to Arctic conditions and to the scan geometry of AMSU-A.

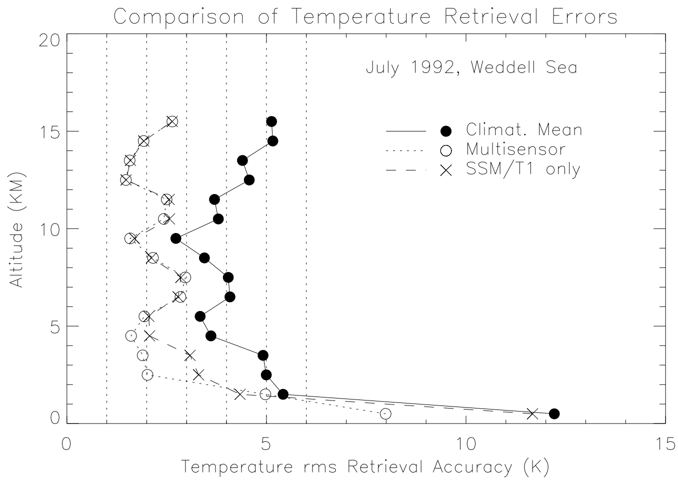

Figure 2: Improvement of temperature profile retrieval by including surface information (Miao et al., 1995).

Phase 3, WP 1.3: Produce fields of TWV and cloud signature for investigation period
Phase 4, WP 1.4: Validation and operational evaluation of atmospheric products

The real time remote sensing products of TWV and cloud signature as well as the TWV fields of the NWP with TWV assimilation will validated using operatinal radiosonde data. A quantitiative validation of the cloud signature product is difficult due to the lack of direct measurements. It will be replaced by qualitative comparisons with synoptic observations and visible and infrared imagery.

The validated cloud signature product will be made available to operational weather forecasting over the Arctic enabling on-duty forecasters at Partner 4 to evalate the usefulness of the cloud signature images in monitoring the Arctic.

Part 2: Improving numerical weather prediction models (NWPs)

Phase 1, WP 2.1: Prepare NWP activities

This work package comprises two activities:

– set up the data stream for an experimental NWP to be driven parallel to the operational environment of a weather service. Moreover, the continous provision of the humidity sounder data (planned: AMSU-B) and of the temperature sounding data (AMSU-A) will be achieved. Extension to the planned operational sensor SSMIS (combined sucessor of SSM/I, SSM/T1 and SSM/T2)will be considered later on in the project.
– Start extracting the NWP output fields for the two years of offline investigations. The quantities to be extracted are: Wind, TWV, liquid water path, surface temperature.

Phase 2, WP 2.2: Development of assimilation procedures

met.no (Partner 4) and SMHI (Partner 5) will be running high-resolution models covering large parts of the Arctic area. These models will be versions of the HIRLAM model (Källén, 1996) implemented on different domains at these two operational centers. The HIRLAM model is also run by the national meteorological services in Denmark, Finland, Iceland, Ireland, The Netherlands and Spain.
The domain and resolution of the HIRLAM model versions can be defined by the user, and it is a hydrostatic grid-point model. The resolutions presently in use are 55 to 5 km horizontally and 16 to 31 levels in the vertical. The coordinate systems used are a rotated lat-long grid horizontally and a hybrid p-sigma system in the vertical. The time stepping is semi-implicit, Eulerian and a fourth order, linear horizontal diffusion is used. The radiation scheme has been developed in the HIRLAM project, vertical diffusion is formulated through a one-and-a-half order closure scheme ('CBR') and condensational processes are handled by the Sundqvist scheme (with 'STRACO', a Smooth-TRAnsition Kuo type COnvection). Surface processes are handled in a two layer scheme with snow, ice and soil moisture included. A new surface scheme ('ISBA'), applied with surface tiles, is being tested and is like to replace the present surface scheme during 2002. This new scheme is, for example, treating fluxes from open water and ice surfaces separately in a consistent way. Furthermore, new schemes for condensation (Rasch-Kristjanson) and convection (Kain-Fritsch, based on mass-flux) are also likely to be introduced during 2002 and will improve model performance, in particular at model resolutions around 20 km.
The models will probably have a horizontal resolution of 20 km when the work is undertaken, but there is also possibility that NWP models with even higher resolution are available for parts of the Arctic. The models are typically run up to 48 hours with a short cut-off time for observations, and are used operationally to produce forecasts with fast availability for operational forecasters.
A 3-Dimensional variational assimilation scheme (3D-Var) will be used for assimilation in these models, see Courtier et al, 1998 for 3D-Var methods in global models and Lorenc et al, 2000, and Gustafsson et al, 2001, for application in limited-area modelling. Initial experiments with extension to a 4-Dimensional variational assimilation system (4D-Var, see Klinker et al, 2000) has also been undertaken for the limited-area models. The 4D-Var scheme is expected to enable us to exploit further the potential for impact of added observations over the Arctic. AMSU data from a planned EUMETSAT retransmission service will ensure that observations from a large part of the Arctic will be available within the strict timeliness requirements for such limited-area modelling.
Model forecast inaccuracies are either due to inaccuracies in the forecast model used for making predictions from an initial state or due to inaccuracies in the initial state itself. The development of assimilation procedures assesses the latter issue. In general improved model forecasts means improvements of several parameters which can be derived from the forecast, such as for instance surface wind, surface temperature, cloud cover or precipitation.

Several methods exist for verification of NWP model results. One approach is to compare forecasts to observations from the meteorological observation system and compute statistics from that. In this project we will for instance compare the forecast results to radiosonde measurements. The disadvantage with such statistical approaches is that the statistics has no weighting with the ‘importance’ of each sample. It is for instance acknowledged as more important to predict well rapid changes and severe weather than calm and stable weather situations. Therefore case studies of for instance situations of severe weather impact are also used in the assessment. In this project we will assess the model improvements obtained both with statistical comparisons with observations and with case studies.
The present project is focused on the assimilation of atmospheric moisture. It is expected that this will results in improved forecasts of clouds and precipitation in the Arctic and surrounding areas. It is furthermore likely that the proposed utilization of an improved lower boundary condition (fractions of sea ice and open water) in the Arctic will have a more general positive impact on the forecasts quality, also on larger horizontal scales.

Humidity.

Two assimiltion procedures will be compared:

- direct assimilation of radiances. 3-dimensional as well as 4-dimensional variational assimilation will be applied. It is expected that an optimal utilization of humidity information will only be achieved by application of 4-dimensional variational data assimilation. Emphasis will also be devoted to the lower boundary condition, e.g. the surface emissivity formulation.
- assimilation of a simple expression of radiances nearly proportional to the TWV according to the retrieval procedure of Miao et al. (2001). The advantage of this procedure is that the assimilated quantity has a nearly linear tangent to the assimilated quantity.

Temperature sounder data.

A known problem of the assimilation temperature sounder data over sea ice is the surface contribution present in several channels. Output from a method for estimating ice surface emissivity (see Part 1) as well as ice concentration estimates will be interfaced to a fast radiative transfer model (Saunders et al, 1999) for forward modelling of AMSU-A brightness temperatures. Statistics for deviations between brightness temperatures modelled from a NWP background and the observations will be investigated. Optimal bias correction algorithms and quality control procedures will be developed and implemented to enable direct assimilation of the AMSU-A channels over ice surfaces in 3D- or 4D-variational assimilation schemes. Extensions to SSMIS will be considered on a later stage.

Surface flux modelling

In present operational set-ups of operational NWP models running over areas covered with sea ice in the Arctic, only information on the ice edge is applied, assuming that areas within the ice edge are completely covered with ice. This can lead to large errors in surface fluxes in areas where open water is present, degrading the quality of Arctic forecasts. More advanced coupling to the sea and ice surfaces, including use of ice concentrations fields as well as ocean and ice models, are applied in the Baltic Sea (Gustafsson et al., 1998). We will exploit the potential of replacing the assumption of full ice coverage with more realistic ice concentration estimates also in the Arctic area.

We will interface the surface flux computation in an atmospheric model suitable for operational application with output from SSM/I or multi-sensor ice concentration algorithms. A near-real time data flow will be set up to make recent ice concentration estimates available at the start of each high-resolution NWP model run. The concentration estimation procedure will be updated when improved algorithms become available in the project.

The effect of using concentration estimates as opposed to assuming full ice coverage will be investigated in parallell forecast cycle experiments.

Phase 3, WP 2.3: Prepare near-real time assimilation

Set up real time assimilation of TWV and temperature, provide NWP fields for user interface and ice analysis (TWV and near-surface temperature)

Phase 4, WP 2.4: Validation of NWP fields including assimilation

The improvement in the performance of the NWP under various changes will be evaluated by running parrallel forecast cycles with and without the changes. The forecast quality will be assesed by comparison with conventional observations near or in the Arctic area. The validation will both use average statistics for a time period of the order of one to several months and by investigating cases and weather situations of particular interest.

Part 3: Empirical model for emissisivity and backscatter of sea ice

Phase 1, WP 3.1: Preparation of surface model work

The following data will be provided:

- Day 0 model of emissivity of sea ice,
- 20 years of daily satellite passive microwave data from SSM/I and SMMR for time series analysis. SMMR data from 1978-1987 will allow assesment of lower frequency channels in preparation for AMSR,
- 2 years of swath data for diurnal variability and snow effect studies,
- Numerous datasets from airborne field campaigns,
- Snow data from National Snow and Ice data Center,
- Precipitation and temperature data from European Arctic from HIRLAM model (to be collected during the first model year from the operational model).

Phase 2, WP 3.2: Construction of sea ice forward model

All algorithms to quantitatively derive ice concentrations from satellite passive microwave observations of the polar oceans rely on so-called tie points that are the expected signatures of 100% pure surface types. The most common algorithm, developed at the NASA Goddard space flight center in the USA, utilizes the signatures of ice free water, first-year ice and multi-year ice in order to calculate the relative amounts of these three surface types within the resolotion cell. Unfortunately these signatures (tie points) are not constant in space and time. The microwave signature of the ice free water depends on the roughness and whitecapping of the water surface, and thus on the local surface winds. Similarly, the signatures of the ice surfaces depend on ice surface properties such as snow cover, deformation (roughness) salinity, snow cover etc. In addition, at lower salinities microwaves penetrate into the ice volume, and volume effects such as particle size and salinity become important as well.

We will apply time series analysis of satellite data to establish an empirical model that relates the temporal evolution of the brightness temperatures to sea ice parameters.

Ultimately, a physical model relating known or unknown sea ice parameters to microwave brightness temperatures will be used in derivation of ice, atmosphere and ocean parameters from the satellite measurements. The model will be based on the microphysical snow and ice emissivity model of Fuhrhop et al. (1998), in combination with the empirical model from above.

In 2001 and 2002, the two passive microwave sensors AMSR-E and AMSR are scheduled for launch aboard the AQUA (NASA) and ADEOS-2 (NASDA) platforms, respectivey. In comparison to SSM/I, they will both have similar channels, but the spatial resolution will be increase two to three times. Moreover, there will be additional channels at 6.9 and 10.6 GHz. The potential of improvement to be expected when shifting from the passive microwave sensors SSM/I(S) to AMSR(-E) will be assessed.

Phase 3, WP 3.3: Influence of snow on emissivity and backscatter.

The influence of snow on microwave brightness temperatures has been summarized by Garrity, 1992. We will use a combination of snow cover data from the Arctic to establish an empirical relationship. In 1998, Markus and Cavalieri published the first algorithm for deriving the depth of snow on sea ice from satellite passive microwave data. The algorithm was developed and tuned for Antarctic conditions, and we will investigate the applicability to the Arctic region in this project

Time series of brightness temperatures will be compared with HIRLAM precipitation and temperature data to find empirical relationships between snowfall/snowcover and ice signatures.

Phase 4, WP 3.4: Validation sea ice emissivity and backscatter models

For the validation of the ice model, three studies will be performed:

- Validate snow cover algorithm with available snow data from the Arctic region (Russian and Canadian data available from NSIDC (National Snow and Ice Data Center)).
- Validate ice emissivity models with available airborne data.
- Validate empirical model of seasonal variations of sea ice signatures by comparison to independent data not used in the time series analysis.

Part 4: Sea ice concentration retrieval

Phase 1, WP 4.1: Preparation

Provide

- SSM/I swath and Quikscat data of 2 year investigation period from archive of Partner 3,
- Day 0 models and algorithms:
  - Microwave radiative transfer models,
  - Ku-band wind model function,
  - Sea ice concentration algorithms from SSM/I,
  - Ice type algorithms from Quikscat,
  - Synergistic SSM/I-Quikscat ice concentration algorithm.
- Validation strategy and data:
  - Collection of suitable SAR data and ice analyses from the archives of Partner 3,
  - Additional collection and analysis of SAR data obtained from relevant areas.

Phase 2, WP 4.2: Algorithm development

Ice concentration retrieval algorithms using SSM/I are wellknown and have been used for the last 20 years (e.g. Comiso et al. 1998). Work in recent years has concentrated on the optimisation of tiepoints, which are fundamental for sea ice concentration retrievals as well as correction for the atmospheric influence (Andersen, 1998; Andersen, 2000; Kern and Heygster, 2001; Breivik et al., 2001). Current SSM/I based algorithms are capable of retrieving sea ice concentration with an accuracy of only ±5-10%, which results in corresponding inaccuracies in ocean/atmosphere fluxes. These fluxes vary dramatically with the addition of even small areas of open water in the form of leads and polynias within the consolidated ice cover. This in turn affects the performance of NWP models with regards to e.g. humidity, winds and temperature estimates. Thus it is crucial that the sea ice cover is represented correctly.
The primary objective in this work package will thus be to improve the ice concentration retrieval in regions infested with the above mentioned leads and polynias. This will be carried out by way of improved:

1. accounting for the atmospheric contribution to the satellite measured radiances and backscatter values,
2. knowledge of the ice surface type enabling more accurate specification of reference radiative properties, also known as tiepoints, that span the scale of ice concentrations. This will be obtained in mainly from WP 3 in combination with synergies between Quikscat and SSM/I.

The sea ice concentration algorithm developed is envisaged to take into account relevant parameters describing the radiative transfer in the atmosphere and ice/ ocean surface. In connection with the development of the EUMETSAT Satellite

Application Facility (SAF) on Ocean and Sea Ice, correction methods for SSM/I brightness temperatures based on NWP model output have been applied with good results and are being used operationally (Andersen, 2000; Breivik et al., 2001). More specifically, using NWP model estimates of surface wind and integrated water vapour content it has proved possible to reduce the standard deviation of the SSM/I derived sea ice concentration estimates by 5-15%, while reducing the bias to max. ± 2%. This method will be adopted and possibly improved, e.g. by a more accurate specification of surface emissivity in the radiative transfer calculations.

The important sea ice information obtained from Quikscat is the differentiation of various ice surface types (Ezraty and Cavanie, 1999 ; Grandell, 1999; Tonboe, 2001). However, a major problem for ice retrieval from scatterometer is the influence of the surface wind not least in mixtures of sea ice and open water. It is planned to use the knowledge gained from atmospheric correction of SSM/I data to improve the reliability of ice type retrievals by correcting them for the influence of winds as obtained from NWP model and current Ku-band wind model functions.

Subsequently emissivity and backscatter models developed in Part 3 will be combined with sea ice type information using state of-the-art synergetic data combination techniques to further improve the sea ice concentration estimates.

Phase 3, WP 4.3: Produce sea ice data for investigation period

Phase 4, WP 4.4: Validate sea ice algorithm

The sea ice algorithm will be validated against manually interpreted SAR data from ENVISAT and RADARSAT. Considering the objective of better concentration estimations within ice of high concentration, particular weight will be given to such areas. However also the sea ice edge will be validated against analysed SAR data obtained around Greenland.

Part 5: Demonstration of real-time processing and user interface

Phase 1, WP 5.1: Preparation

The near-real time production system will be a distributed processing system. The NWP model will be run at Partners 4 and 5, sea ice retrieval will be performed at Partner 3 with input of cloud liquid water, integrated water vapour, wind and surface temperature fields from Partner 4. The data will be presented by Partner 2. This presentation system will be the entry point for any external users and will hold near-real time data (during the one month near the end of the project) as well as the 2 year demonstration time series. The activities during the preparations phase will be to

- define software interfaces and schedules for real time production of atmospheric parameters and sea ice,
- define data formats for atmospheric and sea ice parameters. To facilitate the use of the IOMASA data, output formats should be open and well documented,

such as HDF, CDF, GRIB and BUFR. Likewise for the internal exchange of data, special care must be taken to ensure platform independence. A baseline candidate format is GRIB because it is the standard exchange format between the meteorological services.

Phase 2, WP 5.2: –

Phase 3, WP 5.3: Setup and integration of real time production and distribution system

According to the plans made during phase 1 the software modules of the entire production system are configured and interfaced for real time production and dissemination.

The baseline candidate format for the near real time user interface/visualisation will be the standard JAVA to enable end users interactive access to the data. This system was originally developed in EC project IWICOS (IST programme 2000-2002) and will be utilized after some enhancements to accomodate the new datatypes. The IWICOS system uses metadata descriptions in XML format along with the GRIB format for gridded data, and BSQ format for image data.

Phase 4, WP 5.4: Demonstration and validation of real time system

The 2 years of demonstration data will be added to the presentation system. Real time production and dissemination takes place for at least one month near the end of the project.

While the dissemination method of the real time system is the internet, the data of the one month demonstration period will equally be documented on CD-ROM.

References

Andersen, H. S., Hansen, K. Q., Gill, R. S., Tonboe, R., Rosengren, M. and Valeur, H. H., 2000: The Greenland case: Operational sea ice monitoring based on satellite images – Experience and prospects. In *Proc. Workshop on Mapping and archiving of sea ice data – The expanding role of RADAR, Ottawa, Canada, May 2–4, 2000*, WMO/CIS/CIWG, WMO/TD-No. 1027.

Andersen, S., 1998: *Monthly Arctic sea ice signatures for use in passive microwave algorithms*. DMI Technical Report 98-18, Danish Meteorological Institute, Copenhagen, DK.

Andersen, S., 2000: *Evaluation of SSM/I sea ice algorithms for use in the SAF on Ocean and Sea Ice*. DMI Scientific Report 00-10, Danish Meteorological Institute, Copenhagen, DK.

Breivik, L.-A., Eastwood, S., Godøy, Ø., Schyberg, H., Andersen, S. and Tonboe, R. T., 2001: Sea Ice Products for EUMETSAT Satellite Application Facility. *Can. J. Rem. Sensing*.

Comiso, J. C., Cavalieri, D. J., Parkinson, C. L. and Gloersen, P., 1997: Passive microwave algorithms for sea ice concentration – A comparison of two techniques. *Rem. Sens. Environ.*, **12**, 60, 357–384.

Ezraty, R. and Cavainé, A., 1999: Intercomparison of backscatter maps over Artic sea ice from NSCAT and the ERS scatterometer. *J. Geophys. Res.*, **104**, C5, 11 471–11 483.

Fuhrhop, R., Grenfell, T. C., Heygster, G., Johnsen, K.-P., Schlüssel, P., Schrader, M. and Simmer, C., 1998: A combined radiative transfer model for sea ice, open ocean, and atmosphere. *Radio Sci.*, **33**, 2, 303–316.

Garrity, C., 1992: Characterization of snow on floating ice and case studies of brightness temperature change during the onset of melt. In *Microwave remote sensing of sea ice*, Carsey, F. D., ed., AGU Monograph, 68, pp. 313–328, Washington, D.C.: Am. Geophys. Union.

Grandell, J., Johannessen, J. A. and Hallikainen, M. T., 1999: Development of a Synergetic Sea Ice Retrieval Method for the ERS-1 AMI Wind Scatterometer and SSM/I Radiometer. *IEEE Trans. Geosci. Rem. Sens.*, **37**, 2, 668–679.

Gustafsson, N., Berre, L., Hornquist, S., Huang, X.-Y., Lindskog, M., Navasues, B., Mogensen, K. S. and Thorstseinsson, S., 2001: Three-dimensional variational data assimilation for a limited area model. Part I: General formulation and the background error constraint. *Tellus, Series A – Dynamic Meteorology and Oceanography*, **53**, 4, 425–446.

Källén, E. (Ed.), 1996: *HIRMLAM Documentation Manual, System 2.5*. Norkopping, Sweden: SMHI.

Kern, S. and Heygster, G., 2001: Sea ice concentration retrieval in the Antarctic based on the SSM/I 85 GHz polarization. *Ann. Glac.*, **33**, 109–114.

Klinker, E., Rabier, F. and Mahfouf, J.-F., 2000: The ECMWF operational implementaion of four-dimensioan variational assimilation. III: Experimetal results and diagnostics with operational configuration. *Quarterly Journal of the Royal Meteorological Society*, **126**, 1191.

Lorenc, A. C., Ballard, S., Bel, R. S., Ingleby, N. B., Andrews, P. L. F., Barker, D. M., Bray, J. R., Claytion, A. M., Dalby, T. and Li, D., 2000: The Met. Office Global three-dimensional variational data assimilation scheme. *Quarterly Journal of the Royal Meteorological Society*, **126**, 570, 2991–3012.

Markus, T. and Cavalieri, D. J., 1998: Snow depth distribution over sea ice in the Southern Ocean from satellite passive microwave data. In *Antarctic Sea Ice: Physical processes, interactions and variability*, Jeffries, M. O., ed., Antarctic Research Series, 74, pp. 19–39, Washington, D.C.: Am. Geophys. Union.

Miao, J., Künzi, K. F., Heygster, G., Lachlan-Cope, T. A. and Turner, J., 2001: Atmospheric water vapor over Antarctica derived from SSM/T2 data. *J. Geophys. Res.*, **??**, D?, accepted.

Miao, J., Johnsen, K.-P., Kern, S., Heygster, G. and Kunzi, K., 2000: Signature of Clouds over Antarctic Sea Ice Detected by the Special Sensor Microwave/Imager. *IEEE Trans. Geosci.*

Rem. Sens., **38**, 5, 2333–2345.

Miao, J., Markus, T. and Burns, B., 1995: Retrieval of Temperature Profiles over Sea Ice with Multi-sensor Analysis: Combination of the DMSP's SSM/I, OLS, SSM/T1 sensors. In *Proc. IGARSS'95, 10–14 July 1995, Firenze, Italy*, IEEE Catalog No.95CH35770.

Saunders, M. M., R. and Brunel, P., 1999: An improved fast radiative transfer model for assimilation of satellite radiance observations. *Quarterly Journal of the Royal Meteorological Society*, **125**, 1407.

Tonboe, R., 2001: QuikScat – SeaWinds scatterometer observations of sea ice types around Greenland. In *8th International symposium on Remote Sensing, Toulouse, 17–21 September 2001*, vol. 4544 of *Proceedings of SPIE*.

3.2 Project tables

This section contains the tables on Project planning and schedule, the flowchart, the workpackage list, the deliverables list, and the workpackage description tables.

Table 1: IOMASA Project Planning and Time Table

Project Month	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35
Meeting months	⇓ 1		⇓ 6			⇓ 12					⇓ 22			⇓ 28		⇓ 32		⇓ 36
Management	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Part 1: Remote sensing of atmospheric parameters (Partner 1)																		
1.1: Data and day 0 algorithms	■	■	■															
1.2: Atmospheric algorithms				■	■	■	■	■	■	■	■	■	■	■				
1.3: Produce retrieved fields															■	■		
1.4: Validation																	■	■
Part 2: Improving numerical weather prediction models (Partners 4,5)																		
2.1: Prepare NWP activities	■	■	■															
2.2: Improve Arctic high-resolution NWP				■	■	■	■	■	■	■	■	■	■	■				
2.3: Prepare real time assimilation															■	■		
2.4: NWP Production and validation																	■	■
Part 3: Empirical model for emissisivity and backscatter of sea ice (Partner 2)																		
3.1: Prepare sea ice modeling	■	■	■															
3.2: Sea ice foreward models				■	■	■	■	■	■	■								
3.3: Influence of snow											■	■	■	■	■	■		
3.4: Validate sea ice foreward models																	■	■
Part 4: Sea ice concentration retrieval (Partner 3)																		
4.1: Prepare sea ice retrieval	■	■	■															
4.3: Sea ice retrieval algorithm				■	■	■	■	■	■	■	■	■	■	■				
4.3: Produce sea ice fields															■	■		
4.4: Validate sea ice algorithm																	■	■
Part 5: Real time processing and user interface (Partner 2)																		
5.1: Define interfaces and formats	■	■	■															
5.2: —																		
5.3: Setup of production and interface															■			
5.4: Validate production and interface																	■	■

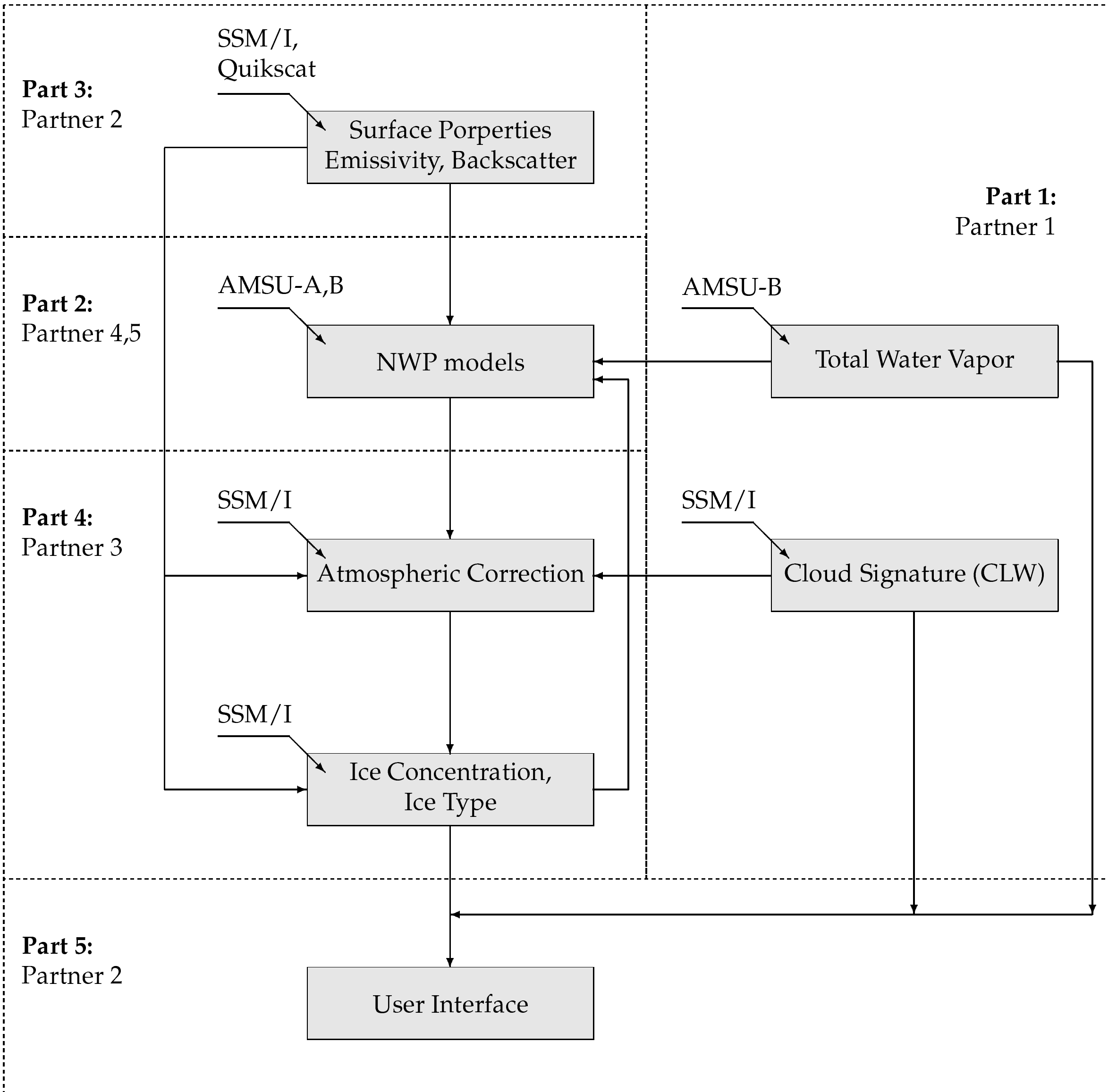

Figure 3: Task interdependencies of IOMASA

WPL Workpackage list

WP No.	WP title	Lead Partner	Person-months	Start month	End month	Del. No
0	Management	1	5	1	36	0
Part 1: Remote sensing of atmospheric parameters (Partner 1)						
1.1	Data and day 0 algorithms	1	6	1	6	1.1
1.2	Atm. remote sensing algorithms	1	36	7	28	1.2.1, 1.2.2, 1.2.3
1.3	Produce retrieved fields	1	8	29	32	1.3.1, 1.3.2, 1.3.3
1.4	Validate atmospheric algs.	1	11	32	36	1.4
Part 2: Improving numerical weather prediction models (Partners 4,5)						
2.1	Prepare NWP activities	4	8	1	6	2.1.1, 2.1.2
2.2	Improve Arctic high-resolution NWP	4	38	7	28	2.2.1, 2.2.2, 2.2.3
2.3	Prepare real time assimilation	4	9	29	32	2.3
2.4	NWP Production and validation	4	8	33	36	2.4
Part 3: Empirical model for emissisivity and backscatter of sea ice (Partner 2)						
3.1	Prepare sea ice modeling	2	7	1	6	3.1.1, 3.1.2
3.2	Sea ice foreward models	2	14	7	20	3.2.1, 3.2.2
3.3	Influence of snow	2	12	21	32	3.3
3.4	Validation of sea ice foreward model	2	4	1	6	1.1
Part 4: Sea ice concentration retrieval (Partner 3)						
4.1	Prepare sea ice retrieval	3	12	1	6	4.1
4.2	Sea ice retrieval algorithm	3	30	7	28	4.2
4.3	Produce sea ice fields	3	4	29	32	4.3
4.4	Validate sea ice algorithm	3	8	33	36	4.4
Part 5: Real time processing and user interface (Partner 2)						
5.1	Define interfaces and formats	2	7	1	6	5.1
5.2	—	–	–	–	–	–
5.3	Setup of production and interface	2	12	29	32	5.3
5.4	Validatate production and interface	2	8	33	36	5.4

DL Deliverable List				
Del. No.	Deliverable title	Del. date	Nature	Diss. level
0	Interim and final reports, financial reports	12,24,26	Re	PU
Part 1: Remote sensing of atmospheric parameters (Partner 1)				
1.1	Baseline data and algorithms for atmospheric remote sensing	6	Re, Da, Me	PU
1.2.1	Retrieval algorithm for TWV from AMSU-B data	20	Re, Da, Me	PU
1.2.2	Retrieval algorithm for coud signature from SSM/I-B data	29	Re, Da, Me	PU
1.2.3	Retrieval algorithm for surface emissivity at AMSU-A frequencies	29	Re, Da, Me	PU
1.3.1	Fields of TWV of investigation period	32	Da	PU
1.3.2	Fields of cloud signature of investigation period	32	Da	PU
1.3.3	Operational processing chain for cloud signature	32	Re, Da	PU
1.4	Validation report for TWV and cloud signature	36	Re	PU
Part 2: Improving numerical weather prediction models (Partners 4,5)				
2.1.1	Report on setup of operational data stream	6	Re	PU
2.1.2	2 data years of NWP fields: Wind, TWV,liquid water path, and surface temperature	6	Da	PU
2.2.1	Report and programme code on humidity assmilation into NWP	20	Re, Me	PU
2.2.2	Report and programme code on temperature assmilation into NWP	29	Re, Me	PU
2.2.3	Report and programme code on interface implementation (sea ice)	29	Re, Me	PU
2.3	Report on real time assimilation system for TWV and improved temperature assimilation	32	Re, Da	PU
2.4	Validation report on assimiltion impact	36	Re	PU
(Contiuation see next page)				

Nature: Re = Report, Da = Data, Me = Method

DL Deliverable List (Cont'd)				
Del. No.	Deliverable title	Del. date	Nature	Diss. level
Part 3: Empirical model for emissisivity and backscatter of sea ice (Partner 2)				
3.1.1	Offline data and day 0 algorithms for Part 3	6	Re, Da, Me	PU
3.1.2	HIRLAM data of project year 1	12	Da	PU
3.2.1	Report and programme code for emissivity and backscatter model of sea ice	22	Re, Me	PU
3.2.2	Report on improvement potential with sensors AMSR(-E)	22	Re	PU
3.3	Report and programme code for influence of snow	32	Re, Da	PU
3.4	Validation report for sea ice model	36	Re	PU
Part 4: Sea ice concentration retrieval (Partner 3)				
4.1	Data sets and day 0 algorithms for sea ice retrieval	6	Re, Da	PU
4.2	Report and programme for retrieval of sea ice concentration	29	Re, Me	PU
4.3	Sea ice concentration data set of investigation period	32	Da	PU
4.4	Validation report for sea ice retrieval	36	Re	PU
Part 5: Real time processing and user interface (Partner 2)				
5.1	Data formats and software interfaces for real time production	12	Re	PU
5.3	Real time production and distribution system	32	Re, Da	PU
5.4	Demonstration report and data	36	Re, Da	PU

Nature: Re = Report, Da = Data, Me = Method

Deliverables: Project Reports for the Commission	
Month	Report description
6	Managment Report.
12	Managment Report, Annual Scientfic and Technical Report, Draft of TIP, periodic cost statements.
18	Managment Report.
24	Managment Report, Annual Scientfic and Technical Report, Draft of TIP, periodic cost statements.
30	Managment Report.
36	Managment Report, Final Report, actual TIP, final cost statements.

DWP	**Workpackage description**
Workpackage number: 0 **Start project month: / event** 1 (Kick Off Meeting) **Participant codes:** **1** 2 3 4 5 **Person-months per participant:** **5**	
1	**Objectives;** Coordination of the project Financial control Reporting to the EC
2	**Methodology / work description;** *Contracts:* Supervision of all contractual requirements, supervision and coordination of all activities, *Documentation:* Dissemination of project results, preparation of minutes of meetings, progress reports, including technical, financial and management aspects of the project, based on input from the participating partners. *Meetings and workshops:* Preparation, coordination of attendance, distribution of minutes.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *0:* Interim and final reports, financial reports (2 %)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** Months 12, 24, 36: Providing the EC with offical reports of the project activities and financial statements (2%)

<table>
<tr><th colspan="2">DWP Workpackage description</th></tr>
<tr><td colspan="2">Workpackage number: 1.1
Start project month: / event 1 (Kick Off Meeting)
Participant codes: 1 2 3 4 5
Person-months per participant: 7</td></tr>
<tr><td>1</td><td>Objectives;
Provide sensor data of historic investigtion period and day 0 algorithms for atmospherice remote sensing</td></tr>
<tr><td>2</td><td>Methodology / work description;
Provide items of the deliverables list from project participants, data centers and literature</td></tr>
<tr><td>3</td><td>Deliverables including cost of deliverable as percentage of total cost of the proposed project;
The following items are combined into the deliverable 1.1: (cost: 2%)
1. provide 2 years of AMSU-B, AMSU-A and SSM/I data covering investigation period, fallback option: for sounder data: SSM/T1 and SSM/T2 data,
2. Gather radiosonde data of investigation period for calibration and validation. Potential sources are operational coastal stations, research vessels, and projects, e.g. SHEBA.
3. Day 0 algorithms for total water vapour and cloud liquid water over sea ice.
4. literature data for sea ice emissivity at temperature sounding frequencies and incidence angles</td></tr>
<tr><td>4</td><td>Milestones including cost of the Milestone as percentage of total cost of the proposed project;
Month 6: Distribute deliverables to project partners during progress meeting 1 (2%).</td></tr>
</table>

DWP	**Workpackage description**
Workpackage number:	1.2
Start project month / event:	7 (Progress meeting 1)
Participant codes:	**1** 2 3 4 5
Person-months per participant:	36

1	**Objectives;** Development of algorithms for retrieval of atmospheric parameters
2	**Methodology / work description;** 1. Atmospheric water vapour: transfer procedure (1) to the humidity sounder AMSU-B aboard the NOAA satellites and (2) to Arctic conditions. Calibrate with a set of radiosonde data to be collected at the beginning of the project. A second means of calibration will be the TWV retrieval over open water in the cases where it does not exceed the upper limit allowed by the AMUS-B procedure. Support work to extend retrieval range of the procedure to 10. . .12 kg/m^2 by including the 92 Ghz channel of the SSM/T2 into the retrieval. 2. Cloud liquid water: Transfer porecdure developed for Antarctic conditions to the conditions (1) of the Arctic atmosphere with possibly different cloud microphysical and climatological properties and (2) of the Arctic sea ice emissivity. 3. Surface emissivity at temperature sounding frequencies: Determine the surface emissivity at the frequencies and incidence angles of AMSU-A under Arctic ice conditions and at the scan geometry of AMSU-A.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *1.2.1:* Retrieval algorithm for TWV from AMSU-B data (5%) *1.2.2:* Retrieval algorithm for coud signature from SSM/I-B data (4%) *1.2.3:* Retrieval algorithm for surface emissivity at AMSU-A frequencies (3%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 20 (Progress meeting 2):* Deliverable 1.2.1 completed (5%) *Month 29 (Progress meeting 3):* Deliverables 1.2.2 and 1.2.3 completed (7%)

DWP	**Workpackage description**				
Workpackage number:	1.3				
Start project month / event:	29 (Progress meeting 3)				
Participant codes:	**1**	2	3	4	5
Person-months per participant:	**7**			1	

1	**Objectives;** 1. Produce fields of TWV and cloud signature for investigation period 2. Make the validated cloud signature product available for operational weather forecasting over the Arctic by setting up an operational processing chain which enables on-duty forecasters at Partner 4 to use the cloud signature images in monitoring the Arctic.
2	**Methodology / work description;** Apply retrieval algorthms of WP 1.2.2 to fields of WP 1.1 (2 data years).
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *1.3.1:* Fields of TWV of investigation period (1%) *1.3.2:* Fields of cloud signature of investigation period (1%) *1.3.3:* Operational processing chain for cloud signature (1%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 32 (Progress meeting 4):* Deliverables 1.3.1, 1.3.2, and 1.3.3 completed (3%)

DWP	**Workpackage description**				
Workpackage number:	1.4				
Start project month / event:	33 (Progress meeting 4)				
Participant codes:	**1**	2	3	4	5
Person-months per participant:	**7**			4	

1	**Objectives;** Validation and operational evaluation of atmospheric products
2	**Methodology / work description;** The real time remote sensing products of TWV and cloud signature as well as the TWV fields of the NWP with TWV assimilation will validated using operatinal radiosonde data. A quantitative validation of the cloud signature product is difficult due to the lack of direct measurements. It will be replaced by qualitative comparisons with synoptic observations and visible and infrared imagery.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *1.4:* Validation report for TWV and cloud signature (5%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 36 (Final Presentation):* Deliverable 1.4 completed (5%)

DWP	**Workpackage description**					
Workpackage number:	2.1					
Start project month / event:	1 (Kick Off Meeting)					
Participant codes:	1	2	3	**4**	5	
Person-months per participant:				4	4	

1	**Objectives;** Prepare NWP activities
2	**Methodology / work description;** This work package comprises two activities: – set up the operational data stream for an experimental NWP to be driven in the operational environment of an national weather service. Moreover, the operational provision of the humidity sounder data (planned: AMSU-B) and of the temperature sounding data (AMSU-A) will be achieved. – Start extracting the NWP output fields for the two years of offline investigations. The quantities to be extracted are: wind, TWV, liquid water path, surface temperature.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *2.1.1:* Report on setup of operational data stream (3%) *2.1.2:* 2 years of NWP fields: Wind, TWV, liquid water path, and surface temperature (3%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 6 (Progress meeting 1):* Deliverable 2.1.1 completed (3%) *Month 29 (Progress meeting 3):* Deliverable 2.1.2 completed (3%)

DWP Workpackage description

Workpackage number:	2.2				
Start project month / even:t	7 (Progress meeting 1)				
Participant codes:	1	2	3	**4**	5
Person-months per participant:				16	22

1 Objectives;

Improve high-resolution Arctic NWP

2 Methodology / work description;

Humidity. Two assimilation procedures will be compared:

– direct assimilation of radiances,
– assimilation of a simple expression of radiances nearly proportional to the TWV according to the retrieval procedure of Miao et al. (2001). The advantage of this procedure is that the assimilated quantity has a nearly linear tangent to the assimilated quantity.

Temperature Sounder data. A known problem of the assimilation temperature sounder data over sea ice is the surface contribution present in several channels. The method suggested by Miao et al. (1996) will be used to retrieve surface-corrected temperature profiles which will be assimilated into the NWP.

Improved surface flux modelling using ice concentration estimates. An operational processing chain computing daily SSM/I or multi-sensor sea ice concentration estimate will be available from partner 4. An interface will be made in the operational setup of the NWP model to allow use of these concentrations in the surface flux computations instead of only using ice edge information.

3 Deliverables including cost of deliverable as percentage of total cost of the proposed project;

2.2.1: Report and programme code on humidity assmilation into NWP (7%)
2.2.2: Report and programme code on temperature assmilation into NWP (7%)
2.2.3: Report and programme code on interface implementation NWP–ice concentration estimates (5%)

4 Milestones including cost of the Milestone as percentage of total cost of the proposed project;

Month 20 (Progress meeting 2): Deliverable 2.2.1 completed (7%)
Month 29 (Progress meeting 3): Deliverables 2.2.2 and 2.2.3 completed (12%)

DWP	**Workpackage description**				
Workpackage number:	2.3				
Start project month / event:	29 (Progress meeting 3)				
Participant codes:	1	2	3	**4**	5
Person-months per participant:			1	4	4

1	**Objectives;** Prepare real time assimilation
2	**Methodology / work description;** Set up real time assimilation of TWV and temperature, provide NWP fields for user interface and ice analysis (TWV and near-surface temperature)
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *2.3:* Report on real time assimilation system for TWV and improved temperature assimilation (7%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 32 (Progress meeting 4):* Deliverable 2.3 completed (7%)

DWP	**Workpackage description**				
Workpackage number:	2.4				
Start project month: / event	33 (Progress meeting 4)				
Participant codes:	1	2	3	**4**	5
Person-months per participant:				4	4

1	**Objectives;** Validation of NWP fields including assimilation
2	**Methodology / work description;** The improvement in the performance of the NWP under various changes will be evaluated by running parrallel forecast cycles with and without the changes. The forecast quality will be assesed by comparison with conventional observations near or in the Arctic area. The validation will both use average statistics for a time period of the order of one to several months and by investigating cases and weather situations of particular interest.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *2.4:* Validation report on assimiltion impact (6%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 36 (Final Presentation):* Deliverable 2.4 completed (6%)

DWP	**Workpackage description**	
Workpackage number:		3.1
Start project month / event:		1 (Kick Off Meeting)
Participant codes:		1 **2** 3 4 5
Person-months per participant:		7 (participant **2**)
1	**Objectives;** Prepare sea ice modeling activities	
2	**Methodology / work description;** The following data will be provided: 1. Day 0 model of emissivity of sea ice, 2. 20 years of daily satellite passive microwave data from SSM/I and SMMR for time series analysis. SMMR data from 1978-1987 will allow assesment of lower frequency channels in preparation for AMSR, 3. 2 years of swath data for diurnal variability and snow effect studies, 4. Numerous datasets from airborne field campaigns, 5. Snow data from National Snow and Ice data Center, 6. Precipitation and temperature data from European Arctic from HIRLAM model (to be collected during the first model year from the operational model).	
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *3.1.1:* Data sets 1-5 from above list (1%) *3.1.2:* Data set 6 from above list (1%)	
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 6 (Progress meeting 1):* Deliverable 3.1.1 completed (1%) *Month 12 (Progress meeting 2):* Deliverable 3.1.2 completed (1%)	

DWP	Workpackage description
Workpackage number:	3.2
Start project month / even:t	7 (Progress meeting 1)
Participant codes:	1 **2** 3 4 5
Person-months per participant:	14
1	**Objectives;** Construction of sea ice forward model
2	**Methodology / work description;** Construct model according to description in introduction of project workplan.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *3.2.1:* Report and programme code for emissivity and backscatter model of sea ice (3%) *3.2.2:* Report on improvement potential with sensors AMSR(-E) (0.4%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 22 (Midterm Review):* Deliverables 3.2.1 and 3.2.2 completed (4%)

DWP	**Workpackage description**	
Workpackage number:		3.3
Start project month / event:		21 (Progress meeting 3)
Participant codes:		1 **2** 3 4 5
Person-months per participant:		12
1	**Objectives;** Influence of snow on emissivity and backscatter	
2	**Methodology / work description;** Compare time series of brightness temperatures with HIRLAM precipitation and temperature data to find empirical relationships between snowfall/snowcover and ice signatures.	
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *3.3:* Report and programme code for influence of snow (3%)	
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 32 (Progress meeting 4):* Deliverable 3.3 completed (3%)	

DWP	**Workpackage description**
Workpackage number:	3.4
Start project month: / event	33 (Progress meeting 4)
Participant codes:	1 **2** 3 4 5
Person-months per participant:	4
1	**Objectives;** Validation sea ice emissivity and backscatter models
2	**Methodology / work description;** For the validation of the ice model, three studies will be performed: 1. Validate snow cover algorithm with available snow data from the Arctic region (Russian and Canadian data available from NSIDC (National Snow and Ice Data Center)). 2. Validate ice emissivity models with available airborne data. 3. Validate empirical model of seasonal variations of sea ice signatures by comparison to independent data not used in the time series analysis.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *3.4:* Validation report (1%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 36 (Final Presentation):* Deliverable 3.4 completed (1%)

DWP Workpackage description

Workpackage number: 4.1

Start project month / event: 1 (Kick Off Meeting)

Participant codes:	1	2	**3**	4	5
Person-months per participant:			10	2	

1 Objectives;

Prepare activities on sea ice concentration retrieval

2 Methodology / work description;

The following data will be provided:

1. SSM/I swath and Quikscat data of 2 year investigation period from archive of Partner 3,
2. Collection of suitable SAR data and ice analyses from the archives of Partner 3,
3. Additional collection and analysis of SAR data obtained from relevant areas.
4. Day 0 models and algorithms:
   - Microwave radiative transfer models,
   - Ku-band wind model function,
   - Sea ice concentration algorithms from SSM/I,
   - Ice type algorithms from Quikscat,
   - Synergistic SSM/I-Quikscat ice concentration algorithm.
5. Collection of suitable SAR data and ice analyses from the archives of Partner 3,
6. Additional collection and analysis of SAR data obtained from relevant areas.

3 Deliverables including cost of deliverable as percentage of total cost of the proposed project;

4.1: Data sets 1-5 from above list (3%)

4 Milestones including cost of the Milestone as percentage of total cost of the proposed project;

Month 6 (Progress meeting 1): Deliverable 4.1 completed (3%)

DWP	**Workpackage description**					
Workpackage number:	4.2					
Start project month / even:t	7 (Progress meeting 1)					
Participant codes:	1	2	**3**	4	5	
Person-months per participant:			22	8		

1	**Objectives;** Construction algorithm for ice concentration retrieval
2	**Methodology / work description;** Construct model according to description in introduction of project workplan.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *4.2:* Report and programme for retrieval of sea ice concentration (12%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 29 (Progress meeting 3):* Deliverable 4.2.1 completed (12%)

DWP	**Workpackage description**
Workpackage number:	4.3
Start project month / event:	29 (Progress meeting 3)
Participant codes:	1 2 **3** 4 5
Person-months per participant:	4 (participant 3)
1	**Objectives;** Produce sea ice data for investigation period
2	**Methodology / work description;** Apply ice concentration algorithm to data set of investigation period
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *4.3:* Sea ice concentration data set of investigation period (1%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 32 (Progress meeting 4):* Deliverable 3.3 completed (1%)

DWP	**Workpackage description**
Workpackage number:	4.4
Start project month: / event	33 (Progress meeting 4)
Participant codes:	1 2 **3** 4 5
Person-months per participant:	7 (participant 3), 1 (participant 4)
1	**Objectives;** Validate sea ice algorithm
2	**Methodology / work description;** Validate against manually interpreted SAR data from ENVISAT and RADARSAT
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *4.4:* Validation report (2%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 36 (Final Presentation):* Deliverable 4.4 completed (2%)

DWP	**Workpackage description**					
Workpackage number:	5.1					
Start project month / event:	1 (Kick Off Meeting)					
Participant codes:	1	**2**	3	4	5	
Person-months per participant:	1	3	1	1	1	

1	**Objectives;** prepare real time processing and user interface
2	**Methodology / work description;** 1. define software interfaces and schedules for real time production of atmospheric parameters and sea ice, 2. define data formats for atmospheric and sea ice parameters.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *5.1:* Data formats and software interfaces for real time production (2%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 12 (Progress meeting 2):* Deliverable 5.1 completed (2%)

DWP	**Workpackage description**
Workpackage number:	5.3
Start project month / event:	29 (Progress meeting 3)
Participant codes:	1 **2** 3 4 5
Person-months per participant:	7 2 1 2
1	**Objectives;** Setup and integration of real time production and distribution system
2	**Methodology / work description;** According to the plans made during phase 1 the software modules of the entire production system are configured and interfaced for real time production and dissemination.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *5.3:* Real time production and distribution system (3%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 32 (Progress meeting 4):* Deliverable 5.3 completed (3%)

DWP	**Workpackage description**
Workpackage number:	5.4
Start project month: / event	33 (Progress meeting 4)
Participant codes:	1 2 **3** 4 5
Person-months per participant:	2 3 1 2
1	**Objectives;** Demonstration and validation of real time system
2	**Methodology / work description;** 1. Add the 2 years of demonstration data will be added to the presentation system. 2. Run real time production and dissemination for at least the last month of the project.
3	**Deliverables including cost of deliverable as percentage of total cost of the proposed project;** *5.4:* Demonstration report and data (3%)
4	**Milestones including cost of the Milestone as percentage of total cost of the proposed project;** *Month 36 (Final Presentation):* Deliverable 5.4 completed (3%)

4 Contribution to objectives of programme/call

This project addresses directly the main elements of Key Action 3.4 by contributing to an integrated marine and atmospheric observing and forecasting (atmosphere) system on a regional, nearly hemispheric scale (see figure on model region). The feasibility will be demonstrated in the demonstration phase of the project and in an near real time environment. If brought to operational application (which is beyond the scope of this project), the deliverables of improved sea ice charts and weather predictions for the European Arctic will facilitate the human offshore activities such as navigation, fisheries, tourism, and exploitation of marine mineral resources. In accordance with the RTD priorities, the project comprises the full sequence of operations:

- optimized selection of parameters: the parameters described in the last section are the most important ones for sea ice analysis and numerical weather forecast,
- the remote sensing and NWP fields will be archived in a standardized format and retrievable on request,
- a system for real time use of the data and user interface will be demonstrated,
- assimilation of remote sensing fields of atmospheric temperature profiles, integrated water vapor and sea ice concentrations into a numerical model will be demonstrated,
- dissemination of the results to the users through an interactive interface will be demonstrated.

Through these features, the project contributes to the requirements of Key Action 3, an integrated management of the European Arctic seas in the open ocean, as requested for projects of Key Action 3. It integrates the interrelated processes in the atmosphere and ocean leading, if brought to application, to both better sea ice analysis and forecast of weather.

5 Community added value and contribution to EU policies

5.1 European dimension

The programme brings together very different areas of expertise that, however, are necessary to achieve our objectives. The proposed combination of

1. improved remote sensing of the polar surface above sea ice and open water,
2. improved atmospheric model results by assimilating the outcomes of point 1,
3. surface emissivity and backscatter models
4. improving the remote sensing of sea ice using the results of these 3 points

goes beyond the facilities of the involved individual nations and will help to increase our understanding of the Arctic environment. IOMASA will result in improved weather forecasts and sea ice analyses.

This project complements in an interdisciplinary way expertise and work being done nationally in the fields of

– remote sensing of the polar atmosphere (see description of Partner 1 in section 8),
– modeling and assimilation of the polar atmosphere (see description of Partners 4 and 5 in section 8), and
– modeling and retrieval of sea ice (see description of Partners 2 and 3 in section 8).

By these means, the project helps to improve the coordination of a number of European national projects and helps to fuse these into a Community-wide RTD programme. Finally the project promotes the scientific cooperation and integration between European universities and research institutes and contributes to transfer new technologies from research institutes (Partners 1 and 2) to operational services (Partners 3 to 5).

The addressed geophysical processes and the used remote sensing, analysis and forecasting techniques cover regions much larger than the regions of interest of the involved countries. Therefore it appears natural and efficient to bundle the mutual resources to achieve the best possible progress. The effort necessary to achieve the objectives of IOMASA exceeds by far the means and expertise of each of the involved countries.

5.2 Contribution to Northern Dimension of the EU

The Northern Dimension is part of the EU's external and cross-border policies with a specific aim to raise the Union's profile in Northern Europe. The Northern Dimension builds upon the existing framework of contractual relationships, financial instruments and regional organisations without needing additional financial instruments in the EU.

If the methods developed in this project are brought to application in the operational environments of the weather services, this project will efficiently improve the weather forecasting infrastructure of countries throughout the Arctic hence optimising the cost/benefit ratio of such services. It is in line with the policies of the Northern Dimension and contributes to their goals by various aspects:

– It promotes the cooperation between the involved countries on environmental subjects affecting the complete Northern Europe.
– The improved weather forecasts and sea ice analyses will help to increase prosperity and strengthen security in Northern Europe.
– These goals will be achieved by addressing the challenges of the project objectives by embracing the opportunities that exist in these regions.
– The project identifies the interests of the EU in the North and establishes a consistent line of action.
– The project relies on the existing financial instruments of the EU (5th Framework Programme) and regional organisations, namely the national weather services and environmental research institutes of the involved countries.
– IOMASA intensifies the cooperation and increases the interaction between the actors of the region, EU member states and the Comission.
– The project improves the interoperability of EU programmes (5th FP, Northern Dimension) as well as national research programmes with a view to creating synergies between them.

5.3 Widening of European scientific expertise

The project will broaden considerably the European expertise in the following fields, as described in detail in Part B of the proposal:

Remote sensing of the polar atmosphere
Atmospheric modeling and assimilation
Remote sensing and modeling of sea ice

The datasets of Arctic ice and atmospheric conditions are expected to be the best in the world at the time of production.

Interrelations to ESA and EUMETSAT programmes

In addition to the objectives described in Part B, IOMASA contributes by using SAR scenes for remote sensing of sea ice and evaluation of retrieval procedures to the approved ENVISAT projects AO-170 (Partners 2, 4), 287 (Partner 3), 311 (Partner 3), and 556 (Partner 1).

The proposed research will take advantage and enhance the value of data of meteorological European satellites because sensors similar to the sounders AMSU-A and -B are planned on the future METOP satellites. Therefore the project is also in line with the EUMETSAT policies, see attached letter of recommendation from EUMESAT.

6 Contribution to Community social objectives

We expect impacts for the following problems we are concerned to resolve:

- obtain knowledge to improve weather forecasts for northern Europe,
- obtain knowledge to improve ice charts for the ice frequented waters of the European Arctic,
- obtain knowledge to improve estimation of the fraction of open water in the higher Arctic which is very important for the total heat budget of the region, affecting both local and regional weather and climate. The heat exchange between the ocean and the atmosphere is about two orders of magnitude larger when no ice is present.

  The benefits to be gained from applying this additional knowledge will include

- greater confidence in short and medium term weather predictions which will benefit
  - the entire population of this region,
  - the environment through improved risk management possibilities and better disaster control. Reliable weather forecasts are the first step in risk management and disaster control whether in the marine environment, the atmosphere or on land, and
  - all ecomonic activities and developments. It is important in making decisions on capital expenditure regarding investments in industry and infrastructure.
- greater confidence in mapping of ice conditions in the European Arctic, with impacts on safety in navigation as well as decisions regarding transportation of goods within and between Europe and Asia. This applies to the development of navigation in the Northern Sea Route (Europe - Far East trade) and Northwest Passage, the exploitation of offshore oil and gas in Arctic regions by European contractors (e.g. off East Greenland, in the Barents Sea and Russian shelves), and the improvement of port and harbour facilities and urban infrastructure in Arctic coastal communities affected by sea ice.

The improved knowledge about the Arctic environment will be available to users of many kinds. On a large scale, the models can be embedded in large-scale GCMs to predict global climate change, while on a smaller space scale and shorter time scales they will be used to improve operational forecasting of weather, ice and ocean conditions, helping to improve the living conditions of all members of the Arcitic population.

The European sector of the Arctic Ocean has regional impacts which influence northern parts of Norway, Sweden and Finland as well as Russia. The hydrocarbon potential of this region is the greatest in Europe. As mentioned already, the region also has substantial fisheries, which until recently yielded 10 million tons per year and which are the chief means of support for many coastal communities which will benefit from increased knowledge of ocean and weather conditions. The Arctic Monitoring and Assessment Programme (AMAP) of the International Arctic Science Committee has identified sources of pollution which endanger the vulnerable ecosystem; in particular, long range transport of halogenated hydrocarbons and local sources of nuclear waste. Changing pathways of pollutants will alter the needs for pollution control and coastal management of the European North. In order to establish viable strategies for combating future adverse effects, good knowledge of the entire system and its most recent transformations with potential climate change must be obtained.

7 Economic development and S&T prospects

The strategic impact of the project is to improve the knowledge of Arctic weather and sea ice conditions by better exploiting remote sensing data in a region where only very little other data are available. By developing appropriate remote sensing, assimilation and modified NWP techniques, the entire population and economics of the region can benefit from these progresses if they will be brought to operational application, which is beyond the direct scope of this project. Because exploiting of atmospheric remote sensing data over sea ice for weather forecast and sea ice analysis are only little developed today, the outcomes of the project will represent the leading edge in their scientific fields at the time of delivery thus strengthening the competitiveness of the project partners.

The project is economically attractive because it will reach its aims by better exploitation of existing data; no new sensors need to be developed and brought to space.

The results of this project will include methods, algorithm and data. During the latter part of the project itself, and during the years after the end of the project, the partners will seek to ensure that the results of this work are properly disseminated and applied.

7.1 Dissemination

Regarding dissemination the project final scientific report will also be written up in such a way by the partners (the chapters reading like a set of interlinked papers) that it can also be published as a special issue of a journal of environmental research.

Dissemination of the data will be achieved by extending the interactive internet-based user interface which relies on advances made in the previous EU project IWICOS (Integrated Weather, Sea Ice and Ocean Service System, EU contract IST-1999-11129). This system funded under the IST (Information society technologies) initiative of the 5th Framework Programme allows easily to add new products to the distribution facilities. >From the visitors to the IWICOS home page, the following groups of users of sea ice and atmospheric data have been identified:

– ship navigation, planning and administration of ship traffic
– export and import companies, producers and manufacturers
– exploration and expedition logistics
– oil, gas and offshore industry
– weather services and geophysical research
– consulting and service companies
– all groups of weather prediction users

All these groups, and in addition to those mentioned in section 6 will benefit from the bringing the results of IOMASA to application, both directly using the data of the internet interface or indirectly by improved weather predictions.

Among the deliverables planned for the internet interface (Deliverable 5.4) are the remote sensing fields of atmospheric total water vapour (1.2.1), cloud signature (1.2.2), ice concentration (4.2) and various NWP output fields as the will be produced using the new assimilations schemes (2.2).

7.2 Applications

As already mentioned in section 5, the proposed research will take advantage and enhance the value of data from operaional meteorological and European satellites. This will pave the way for optimum use of the future METOP satellites, as is confirmed by EUMETSAT, see attached letter of support.

It is an integral part of the project to shape the its research in a way that future applications of the methodologic progress achieved in the fields of remote sensing of polar atmosphere and surface and numerical weather prediction are made easy because these procedures will be developed and implemented to run in parallel to the operational environments of the project partners which at the same time are national weather services (DMI, met.no, SMHI).

Moreover, all weather services involved use the same NWP model (HIRLAM) for the project as well as for their operational forecasts. HIRLAM (High Resolution Local Area Model) is an international cooperation of the following meteorologic institutes:

- Danish Meteorological Institute (DMI) (Denmark)
- Finnish Meteorological Institute (FMI) (Finland)
- Icelandic Meteorological Office (VI) (Iceland)
- Irish Meteorological Service (IMS) (Ireland)
- Royal Netherlands Meteorological Institute (KNMI) (The Netherlands)
- The Norwegian Meteorological Institute (met.no) (Norway)
- Spanish Meteorological Institute (INM) (Spain)
- Swedish Meteorological and Hydrological Institute (SMHI) (Sweden)
- Meteo-France (France, research cooperation)

A reference version of HIRLAM is maintained at the European Centre for Medium range Weather Forecasts (ECMWF), and all changes to HIRLAM are introduced via the reference system.

If after completion of the project the new assimilation schemes are brought to the HIRLAM reference system, the progress achieved in the IOMASA can easily benefit to all HIRLAM member institutions. Candidate deliverables suitable for this kind of exploitation within the HIRLAM community are those of work package 2.2 (Assimilation procedures). Because remote sensing procedures are not covered by HIRLAM, the atmospheric remote sensing procedures (deliverables of work package 1.2) which are intimately related to the assimilation, will be made available in a similar way, but not formally in the HIRLAM package.

During the cours of the project, a HIRLAM representative, probably the member of the HIRLAM management group responsible for data assimilation, will be invited to attend some project meetings thus ensuring a continous dialogue with the HIRLAM community.

7.3 Operational Forecasting Cluster

The aim of the Operational Forecasting (OF) Cluster of European Research Framework Programme funded projects is to further the development of the operational forecasting methods, tools and systems required in Europe. As a consequence, an intensive exchange of information and increased co- ordination and co-operation is foreseen between the projects participating in the OFăCluster.

The 5th Framework Programme Project IOMASA (EVK3-2001-00116) will participate in the Operational Forecasting Cluster outlined in the paragraph above.

The IOMASA partners agree to participate in Workshops of the OF Cluster that take place during the period of the IOMASA contract. The European Commission will convene these Workshops after consultation with the respective Project Co-ordinators and only after obtaining the agreement of the respective Project Co-ordinators to holding the said Workshops. Any expenses incurred by the IOMASA partners in relation to the Workshops set out in this paragraph can be charged to the project's budget.

The Co-ordinators of the projects in the OF Cluster, or their nominated representatives, furthermore agree to participate in up to 2 meetings per year whenever the European Commission believes that such a meeting is necessary to enhance further co-ordination. When such meetings are called in Brussels, the European Commission will cover the travel costs related to attending such meetings. When such meetings are called elsewhere, for example during the proceedings of another conference, then any expenses incurred in relation to this meeting by the IOMASA Co-ordinator or his nominated representative can be charged to the project's budget.

8 Description of consortium

The partners cooperating in the project and the persons planned to be involvedare

1. *University of Bremen, Institute of environmental physics (IUP)* (Co-ordinator), Bibliothekstrasse, D-28334 Bremen.

   Responsible: Dr. Klaus Künzi.
   Tel.: +49 421 219 3909
   Fax: +49 421 218 4555
   email: kunzi@physik.uni-bremen.de

   Second Point of Contact: Dr. Georg Heygster
   Tel.: +49 421 219 3910
   Fax: +49 421 218 4555
   email: heygster@uni-bremen.de

2. *Danish Centre for Remote Sensing, Ørsted*DTU, Technical University of Denmark (DTU-DCRS),*
   Lyngby, DK-2800 Denmark.

   Responsible: Dr Leif Toudal.
   Tel. +45-4525-3791
   Fax: +45-4593-1634
   email: ltp@oersted.dtu.dk

3. *Danish Meteorological Institute (DMI),*
   Lyngbyvej 100, DK-2300 København Ø, Denmark.

   Responsible: Dr. Rashpal S. Gill
   Tel.: +45 39157500
   Fax: +45 39157300
   email: rsg@dmi.dk

   Second Point of Contact: Søren Andersen
   Tel.: +45 39157346
   Fax: +45 39157300
   email: san@dmi.dk

4. *The Norwegian Meteorological Institute (met.no),*
   P.O. Box 43, Blindern, N-0313 Oslo.

   Responsible: Dr. Harald Schyberg
   Tel.: +47 22 96 33 33
   Fax: +47 22 69 63 55
   email: h.schyberg@dnmi.no

   Second Point of Contact: Dr. Lars-Anders Breivik
   Tel.: +47 22 96 33 33
   Fax: +47 22 69 3050
   email: l.a.breivik@dnmi.no

5. *Swedish Meterological and Hydrological Institute (SMHI),*
S-60176 Norrköping.

Responsible: Dr. Tomas Landelius
Phone: 46 11 495 8180
Fax: 46 11- 495 80 01
email: Tomas.Landelius@smhi.se

Second Point of Contact: Dr. Nils Gustafsson
Phone: 46 11- 495 80 00
Fax: 46 11- 495 80 01
email: Nils.Gustafsson@smhi.se

Roles and contributions

Partner 1: University of Bremen

The University of Bremen will contribute to IOMASA the atmospheric remote sensing procedures for total water vapour, cloud signature and temperature profile over sea ice. in which field there is a large amount of experience in the institute (Miao et al., 1995; 1997; 2000; 2001; Schlüter and Heygster, 2000, see reference list in description of participants).

The expertise in the fields of remote sensing of sea ice with passive (Hunewinkel et al., 1998, Kern and Heygster, 2001) and active microwave sensors (Kaleschke et al., 2001, Schmidt and Heygster, 1998) will be helpful for the sea ice retrieval activities at Partner 3 (DMI).

The experience in microphysical emissivity modeling of sea ice and snow (Fuhrhop et al., 1998) will be contributing to the sea ice emissivity and backscatter forward model of Partner 2 (DTU).

The IUP will serve for the coordination and technical management of the project.

Partner 2: Danish Technical University

DTU will lead the programme for the development of an empirical emissivity and backscatter model for the ice including the sea ice cover. Temporal analysis of the satellite data will be carried out in collaboration with DMI.

In collaboration with IUP, existing field data will be utilized for understanding the regional differences in the temporal evolution of the ice signatures. DTU will assist DMI in the development of the weather correction sea ice concentration algorithm.

As interactive user interface for the real time data the IWOCOS (Integrated Weather, Sea Ice and Ocean Service System) software will be used, under the responsibility of DTU where this software is currently in use. The experience of DTU with IWICOS will directly benefit to the user interface of IOMASA which in fact is planned as an extension of the IWICOS software.

Support is sought for the salary of Dr Toudal and a Ph.D. student or postdoc.

Partner 3: Danish Meteorologic Institute

DMI will be responsible for the development of sea ice retrieval algorithms. DMI has a long experience in sea ice retrieval using optical as well as active and passive microwave sensors through its operational obligations and in addition has participated in a number recent projects in the field.

Having observed the ice around Greenland systematically since 1959, DMI is in possession of considerable expertise and observations in the fields of ice properties and processes and will assist DTU in the development of the sea ice emissivity and backscatter model. DMI's archive of remote sensing data spans several years of SSM/I, ERS scatterometer and SAR, Quikscat, Radarsat and AVHRR data. These data as well as real time observations and remote sensing data will be at the projects disposal.

DMI will participate in the work on improving surface flux modelling to help optimise the use of the developed ice concentration algorithm.

Partner 4: Norwegian Meteorologic Institute

met.no will be responsible for assimilation of temperature. met.no has been working in this field for many years.

Additionally, met.no will contribute to the sea ice retrieval activities with its experience gained during the activites for EUMETSAT's Satellite Application Facility (SAF) on Oceans and Sea Ice.Here, met.no is responsible for the multisensor sea ice product.

Moreover, it will contribute similar to DMI with its archived and real time observing data to the validation data base for the atmospheric and sea ice remote sensing algorithms, the assimilation and modeling deliverables.

Partner 5: Swedish Meteorological and Hydrological Institute

SMHI will be responsible for the development of techniques for assimilation of moisture information from satellite radiance data and for the testing of the impact of these data on the quality of numerical weather prediction in the Arctic area. SMHI will further participate in the validation of the impact of using ice concentration information for numerical weather prediction in the Arctic area.

Description of resources

Table 2 shows the allocation of the manpower to the work packages. For the Partners working on Additional Cost basis, the manpower allocated to IOMASA is split up into temporary staff funded by the EC and permanent staff funded by the institution.

In addition, many key resources are made available without additional cost by the involved institutions, *e.g.*

IUP: Archive of remote sensing data with sensors SSM/I (swath and CD-ROM data format), ERS-SAR, AVHRR, OLS, etc., emissivity model of the combined system sea ice-atmosphere, relevant ENVISAT scenes from the approved AO proposal 556,

DTU: Use of the interactive internet data presentation system for Part 5, originally developed under the EU project IWICOS (see description of DTU for details), relevant ENVISAT scenes from the approved AO proposal 170,

DMI: relevant RADARSAT scenes from the Greenland area purchased for operation ice charting, relevant ENVISAT scenes from the approved AO proposals 287 and 311,

met.no and SMHI: environment for running experimental atmospheric models in near-real time, relevant ENVISAT scenes from the approved AO proposal 170 (met.no).

Moreover, each partner contributes considerable facilites of their own to the project. Among these are computing power, maintenance, peripheral devices such as tape drives, printers, etc.

Table 2: IOMASA Workload Table. All figures in workmonths. $x + y$ for the AC partners means x months temporary staff, y months permanent staff.

Work Package	IUP	DTU	DMI	mi.no	SMHI	Sum
0	4+1					5
1.1	6+1					7
1.2	30+5					35
1.3	6+1			1		8
1.4	6+1			4		11
2.1				4	4	8
2.2				16	22	38
2.3			1	4	4	9
2.4				4	4	8
3.1		6+1				7
3.2		14				14
3.3		12				12
3.4		4				4
4.1			6+4	2		12
4.2			22	8		30
4.3			4			4
4.4			4+3	1		8
5.1	1	1+2	1	1	1	7
5.3		2+5	2	1	2	12
5.4		2	2+1	1	2	8
Sum	54+9	41+8	42+8	47	39	247

9 Project management

9.1 Steering commitee

The partners cooperating in this project are shown in section 8.

For each project part, one or two scientists are responsible for subcoordination and surveillance of milestones and deliverables. The members of this steering committee planned at the time of writing are listed in the Table 3. Among the tasks of the steering committee are

– to provide advice to the Co-ordinator on the execution of the project,
– to assess the fulfilment of the tasks and deliverables,
– to summarise and synthesise the scientific results,
– to decide on regulations to ensure that the work of the partners is performed according to this Description of Work.

Table 3: Members of the steering committee

Project Part	Responsible	Project Part	Responsible
1	K. Kunzi, IUP	3	L. Toudal, DTU
2	H. Schyberg, met.no and	4	R. Gill, DMI
	Nils Gustafsson, SMHI	5	L. Toudal, DTU

9.2 Project co-ordinator

The project will be coordinated by the Institute of Environmental Physics, University of Bremen, with at the time of writing Klaus Kunzi serving as Coordinator. It is planned that he will be assisted in the technical and data management by Georg Heygster, of the same institute. Both will have full administrative support from the University, which is experienced in dealing with EU projects.

The project co-ordinator is responsible for the day-to-day co-ordination of the project. He acts as the main interface between the partnership and DG RTD. He must oversee the project planning and complete the progress reports, milestone reports, cost statements and budgetary overviews using inputs from the other partners. He must ensure that target dates are met and, if any major deviations occur from research or publication plans, he must aim to resolve the problems through interaction with the relevant partners and/or DG RTD. He is also responsible for data management.

9.3 Milestone reviews

The course of the project can be seen from the flow chart and from the schedule in section 3.2. The latter and the Table 4 show the list of planned project meetings. The milestone reviews, mainly the mid-term and final reviews, will assess the progress of the project and the ability of the programme to accomplish the tasks specified and achieve the desired results. Any changes in the work plan that are suggested by these reviews will be discussed by the steering committee, and special review meetings will be held regarding the mid-term and final reviews in which a representative from DG RTD will be present.

Table 4: Project Meetings

Month	Acronym	Name
1	KOM	Kick off Meeting
6	PM1	Progress Meeting 1
12	PM2	Progress Meeting 2
22	MR	Midterm Review
28	PM3	Progress Meeting 3
32	PM4	Progress Meeting 4
36	FP	Final Presentation

9.4 User advisory group

In order to guarantee a continous dialogue with potential end users, a user advisory grouup (UAG) will be invited to the major meetings (kick off, mid term review and final presentation). It is planned to invite one representative of each of the following institutions

– the European Centre of Medium-range Weather Forecast (ECMWF),
– the HIRLAM initiative (see section C.8),
– the EUMETSAT Satellite Application Facility on Numerical Weather Prediction.

The EUMETSAT Satellite Application Facility on Ocean and Sea ice will be represented by members of the project. Few more members can be invited if the necessity should emerge during the kick off meeting.

Other roles of the UAG will be

– to contribute to the evaluation of likely product performances and of their impact,
– to link with other projects on the subject,
– to contribute to disseminate information on the IOMASA project in the appropriate environments.

The mission expenses will be supported by the the project, if not supported by the institute the UAG member belongs to.

9.5 Communication strategy

All partners will be kept fully informed about the status of all activities, and will have access to all minutes of meetings, visit reports, task reports and publications.

This will be achieved by all such material being channelled to the Co-ordinator, who is then responsible for passing it on to all other partners. Mechanisms to achieve this will include a project home page on a World Wide Web (WWW) server accessible via the Internet, to be established during the first 6 months of the project. In an area restricted to project partners and the European Commission (password protected), it will provide:

– the Description of Work document for the contract;
– work schedules and logistics information;
– updates on deliverables, news and project reports;
– a forum for scientific exchange and discussion;
– data inventories and data handling guidelines;
– issues regarding dissemination of results, also including abstracts of papers and presentations.

The WWW server will also have a "home page" to provide non-confidential information on the project for outsiders (e.g., project summary, published papers, products for users).

9.6 Monitoring and reporting

The table 'Deliverables: Project Reports for the Commission' in section 3.1.2 gives an overview of the deliverable reports.

Every 6 months the project will submit a Management Progress Report. This report, which describes the actual progress of the project in comparison with what was anticipated in this Description of Work, will be sent to the Commission within one (1) month of the end of the period covered by the report.

Every 12 months the project will submit a Scientific and Technical Progress Report in addition to the management report referred to above. The Scientific and Technical Report will describe the scientific and technical progress made in the project during the previous 12 months. Each Scientific and Technical Report will include a draft Technological Implementation Plan (TIP).

The periodic Cost Statements for the previous 12 months will also be sent to the Commission at the same time as the Scientific and Technical Progress Report. The Scientific and Technical Progress Report and the Cost Statements will be submitted within two (2) months of the end of the period covered by the report.

Within two (2) months of the end of the project a Final Report and Integrated Cost Statements will be sent to the Commission. Within two (2) months of the end of the project a Technological Implementation Plan (TIP) will be sent to the Commission. The format for these reports will follow those guidelines that are issued by the Commission. Three (3) copies of each report, written in the English language, will be delivered to the Commission.