2nd Periodic Report

IOMASA

Contract Number EVK-CT-2002-00067

Reporting Period:

Project Month 13–24,

1 November, 2003 – 31 October, 2004

Sections 1 – 4

Coordinator: Klaus Künzi, Georg Heygster

http://www.uni-bremen.de/~pharos/iomasa

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Participants Information

N°	Institution/ Organization	Street name/ number	Post Code	Town/City, Country		Title	Family Name	First Name	Telephone N°	Fax N°	E-mail
1	IUP, UB	Otto-Hahn-Allee 1	28359	Bremen	DE	Prof.	Künzi	Klaus	+49-421-218-3909	+49-421-2184555	kunzi@uni-bremen.de
2	IUP, UB	Otto-Hahn-Allee 1	28359	Bremen	DE	Dr.	Heygster	Georg	+49-421-218-3910	+49-421-218-4555	heygster@uni-bremen.de
3	IUP, UB	Otto-Hahn-Allee 1	28359	Bremen	DE	Dr.	Melsheimer	Christian	+49-421-218-2584	+49-421-218-4555	melsheimer@uni-bremen.de
4	Ørsted*DTU, DTU		2800	Lyngby	DK	Dr.	Toudal Pedersen	Leif	+45-4525-3791	+45-4593-1634	ltp@oersted.dtu.dk
5	Ørsted*DTU, DTU		2800	Lyngby	DK		Saldo	Roberto	+45-4525-3790	+45-4593-1634	rs@oersted.dtu.dk
6	DMI	Lyngbyvej 100	2100	København Ø	DK	Dr.	Gill	Rashpal S.	+45-3915-7500	+45-3915-7300	rsg@dmi.dk
7	DMI	Lyngbyvej 100	2100	København Ø	DK	Dr.	Andersen	Søren	+45-3915-7346	+45-3915-7300	san@dmi.dk
8	DMI	Lyngbyvej 100	2100	København Ø	DK		Bøvith	Thomas	+45-3915-7500	+45-3915-7300	thb@dmi.dk
9	DMI	Lyngbyvej 100	2100	København Ø	DK	Dr.	Tonboe	Rasmus	+45-3915-7349	+45-3915-7300	rtt@dmi.dk
10	met.no	P.O. Box 43, Blindern	0313	Oslo	NO	Dr.	Schyberg	Harald	+47 22 96 33 28	+47 22 96 30 50	h.schyberg@met.no
11	met.no	P.O. Box 43, Blindern	0313	Oslo	NO	Dr.	Breivik	Lars-Anders	+47 22 96 33 33	+47 22 96 30 50	l.a.breivik@met.no
12	met.no	P.O. Box 43, Blindern	0313	Oslo	NO		Tveter	Frank Thomas	+47 22 96 33 57	+47 22 96 30 50	f.t.tveter@met.no
13	SMHI		60176	Norrköping	SE	Dr.	Landelius	Tomas	+46 11 495 81 80	+46 11 495 80 01	Tomas.Landelius@smhi.se
14	SMHI		60176	Norrköping	SE	Dr.	Gustafsson	Nils	+46 11 495	+46 11 495 80 01	Nils.Gustafsson@smhi.se
15	SMHI		60176	Norrköping	SE		Dahlgren	Per	+46 11 495 83 12	+46 11 495 80 01	Per.Dahlgren@smhi.se
16	SMHI		60176	Norrköping	SE	Dr.	Perov	Veniamin	+46 11 495 84 53	+46 11 495 80 01	venjamin.perov@smhi.se

IUP: Institut für Umweltphysik; UB: University of Bremen; DTU: Technical University of Denmark; DMI: Danish Meteorological Institute, met.no: The Norwegian Meteorological Institute; SMHI: Swedish Meteorological and Hydrological Institute

SECTION 1

Management and Resource Usage Summary

1.1 Objectives of the reporting period

The reporting period is entirely in phase 2 of the project, the development phase that ends in March 2005 (project month 28).

1.2 Scientific/Technical progress made in different work packages according to the planned time schedule

Until the end of the reporting period (project month 18), all work packages, i.e., work packages 1.2, 2.2, 3.2, and 4.2, have been on schedule. work package 3.2 has been successfully completed at the end of project month 20, and the subsequent work package 3.3 is on schedule so far.
Table 1.1 gives an overview of the situation. The triple vertical line marks the end of the reporting period.
Table 1.2 shows a comparison between planned and used manpower and financial resources.

1.2.1 Partner 1: IUP

WP 1.2 The procedure to calibrate the TWV retrieval algorithm with radiosonde is now adapted to AMSU-B data, TWV data of the Arctic for much of the offline investigation period (2000/2001) have been calculated. The TWV algorithm has also been implemented into the IOMASA processor and web interface by DTU (http://www.seaice.dk/iomasa). The work on determining the sea ice emissivity at temperature sounding frequencies is ongoing and has produced first results.

1.2.2 Partner 2: DTU

WP 3.2 and 3.3 Forward models relating relevant geophysical parameters for the atmosphere, ocean and sea ice to measured brightness temperatures for the new AMSR microwave radiometer have been implemented. The model will be expanded to include snow parameters, and the snow/ice surface model will be used in conjunction with DTU's optimal parameter estimation method. A study of the prospects of using data from NASA's new microwave radiometer AMSR-E for ice/ocean/atmosphere parameter retrieval has been performed. An on-line database of AMSR swath data covering more than 15 months data has been established and is continuously being expanded as new data become available. These data are automatically transferred to partner DMI. An on-line database of all 20 channels of AMSU-A and

Table 1.1: **IOMASA Project Planning and Time Table.** The triple vertical line marks the end of the reporting period.

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			⇓ 18					⇓ 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-res. NWP				■	■	■	■	■	■	■	■	■	■	■				
2.3: Prepare real time assimilation															■	■		
2.4: NWP Production and validation																	■	■
Part 3: Empirical model for emissivity and backscatter of sea ice (Partner 2)																		
3.1: Prepare sea ice modelling	■	■	■															
3.2: Sea ice forward models				■	■	■	■	■	■	■								
3.3: Influence of snow											■	■	■	■	■	■		
3.4: Validate sea ice forward models																	■	■
Part 4: Sea ice concentration retrieval (Partner 3)																		
4.1: Prepare sea ice retrieval	■	■	■															
4.2: 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																	■	■

AMSU-B is being established. It now covers more than a year. Time series of data at selected locations are being extracted for further analysis, and for model comparison. ENVISAT ASAR data for the validation experiments have been ordered and received under DTU's ENVISAT AO.

The database has been expanded by a multitude of AMSR products being produced in near-real-time by the IOMASA processor (http://ww\w.seaice.dk/iomasa). In addition, ENVISAT ASAR Global Mapping Mode data are being received and archived since April 2004.

1.2.3 Partner 3: DMI

WP 4.2 A book chapter (see reported refereed publications in queue: *Tonboe et al.*) has been drafted, thermodynamic models for the snow cover on sea ice have been implemented and their use in ice concentration analysis will be tested. Accuracy of the SAR classification technique has been assessed and shows a dependence on the analyst of 2-3%. Operational AMSR data have been acquired from NOAA/NESDIS and are an important component of an operational processing chain.

Table 1.2: Comparison between planned and used manpower and financial resources by Work Packages (WP) and partners

WP	Partner	Person-Months		Financial Resources [€]	
		planned	used	planned	used
0	IUP	0.5	0.5	2,509	2,512
1.2	IUP	8.5	7	46,912[a]	37,364[a]
2.2	met.no	5.35	5.5	71,084[b]	69,679[b]
	SMHI	3.4	2.6	28,951+ 3,500[c]	22,151+ 5527[c]
3.2	DTU	1	1	4,254	4,254
3.3	DTU	6	6	42,867	42,867
4.2	DMI	6	9.75	230,563 DKK	374,664 DKK + 8,900 DKK[d]
	met.no	2.5	3	30,958	38,042

[a] incl. travel and consumables
[b] incl. travel
[c] travel
[d] travel

1.2.4 Partner 4: met.no

WP 2.2 and 4.2 An SSM/I processing chain has been set up for daily sea ice input for AMSU sounding channel sea ice emissivity estimations. Assimilation of AMSU-A data into HIRLAM with an interface to daily emissivity estimate grid files has been coded and set up.

1.2.5 Partner 5: SMHI

WP 2.2 A 1DVAR (One-Dimensional Variational Analysis) code has been developed which provides a powerful tool for testing new assimilation techniques.

For AMSU-B over open sea a large data set has been obtained. Quality control algorithms from the AAPP (AVHRR and AMSU Processing Package) system has been used to clear out contaminated observations. Via RTTOV-7 and collocation code from met.no, innovation vectors were calculated and a bias reduction strategy determined.

Experiments for determining observation error covariances have begun. This includes 'reflection of background errors into observation space', called BGOS, with the HIRVDA (HIRLAM variational data assimilation) system (HIRLAM 3DVar).

For AMSU-B over ice a cloud mask from the OSI-SAF, which covers parts of the arctic region, has been obtained. Code that collocates HIRLAM NWP fields and emissivities determined from OSI-SAF data and AMSU observations is obtained from met.no. This will be used to calculate innovation vectors.

The HIRLAM system has been set up at the computer facilities at ECMWF for test runs with modified surface fluxes.

1.3 Milestones and deliverables obtained

See Table 1.3 and Table 1.4.

Table 1.3: Overview of Deliverables Obtained. All dates are in project months.

Deliverable	Date	
	planned	actual
1.2.1	20	20
3.2.1	22	22
3.2.2	22	22

Table 1.4: Overview of Milestones Reached. DL denotes “Deliverable”; all dates are in project months.

Milestone	Date	
	planned	actual
DL 1.2.1	20	20
DL 3.2.1	22	22
DL 3.2.2	22	22

1.4 Co-ordination of the information between partners, communication activities

IOMASA project meetings

Mid-Term Review, 10-11 May, met.no, Oslo, Norway: project partners

Co-operation with other projects/networks

SMHI: Cooperation with the HIRLAM project concerning the work on including new variables in the control vector during the data assimilation and on an improved snow formulation.

SMHI: Cooperation with the EU project CLOUDMAP2 concerning the use of a new humidity variable in the assimilation process.

SMHI Cooperation with the national SWECLIM project concerning surface heat flux modelling.

SMHI: AMSU-A and AMSU-B data received at SMHI via the EARS service (Eumetsat ATOVS Retransmission Service)

SMHI: Ice concentration estimates are provided by the OSI SAF.

SECTION 2

Executive Publishable Summary

Contract n°	EVK-CT-2002-00067	Reporting period:	Nov. 2003 – Oct. 2004
Title	IOMASA – Integrated Observation and Modeling of Arctic Sea ice and Atmosphere		

Objectives: The overall objective of IOMASA is to improve our knowledge about the Arctic atmosphere and ocean by using satellite information which is continuously available, but currently not exploited. This progress will be achieved through an integrated approach involving

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.

The reporting period is entirely within phase 2 of the project, the development phase, ending in March 2005 (project month 28). It is devoted to developing and improving algorithms.

Scientific achievements: The following data are now available to all project partners: SMMR and SSM/I (25 years), AMSU-A and -B (since 2000), QuikSCAT (2001-2002), global radiosonde data (1996-2002), relevant HIRLAM numerical weather prediction fields like total cloud liquid water or 2 m temperature. Data streams for the direct measurements of AMSU-B radiances, redistributed by EUMETSAT, as well as for the OSI SAF (Satellite Application Facility on Ocean and Sea Ice) ice concentration measurements have been set up. A near-real-time data stream for providing co-located AMSU measurements and interpolated HIRLAM profiles and surface data has been set up. The assimilation system for HIRLAM has been extended and prepared for the assimilation of humidity and temperature information from AMSU data. The near real time data distribution system set up to present IOMASA results to interested parties (http://www.seaice.dk/iomasa), provides maps of ice concentration, multi-year ice fraction, ice temperature, sea surface temperature, wind speed, total water vapour and cloud liquid water, based on AMSR(-E) data. The algorithm to retrieve total water vapour (TWV) from AMSU-B data has been completed. It is also implemented in the above-mentioned data distribution system. A new heat flux scheme has been implemented in HIRLAM. Development of the sea ice emissivity model and of the algorithms to retrieve cloud liquid water, temperature profile, and sea ice concentration from the remote sensing data is progressing.

Socio-economic relevance and policy implications: If brought to operational application the results should improve operational weather forecasts in Northern Europe, helping to improve the living conditions in Northern Europe and especially human off-shore activities in the Arctic region, such as navigation, fisheries, tourism, and exploitation of marine mineral resources. In addition, reliable forecasts are the first step in risk management and disaster control whether in the marine environment, the atmosphere or on land. It is important in making decisions on capital expenditure regarding investments in industry and infrastructure. The assimilation of AMSU-B data will also enhance value of data of meteorological European satellites because sensors similar to AMSU-B are planned on future METOP satellites. The new surface heat flux scheme should lead to improved weather forecasts for Northern Europe and especially of clouds in the Arctic.

Keywords: Numerical Weather Prediction, Arctic, Remote Sensing Data, Microwave Sounding, Assimilation, Sea Ice Concentration, Surface Emissivity, Total Water Vapour, Cloud Liquid Water

Publications (cumulative list)

Peer-Reviewed Articles:

Authors	Date	Title	Journal	Reference
S. Sukoriansky, V. Perov, B. Galperin	2003	Application of a new spectral theory of turbulence to a stably stratified atmospheric boundary layer	Geophysical Research Abstracts	Vol. 5, 07037, 2003
S. Sukoriansky, V. Perov, B. Galperin	2004	A spectral closure model for turbulent flows with stable stratification - Theory and a test case of atmospheric SBL over ice	Boundary Layer Meteorology	in press

Non-refereed Literature:

Authors / Editors	Date	Title	Event	Reference	Type[1]
G. Heygster, S. Andersen, N. Gustafsson, K. Kunzi, T. Landelius, H. Schyberg, L. Toudal	Dec 2002	IOMASA – Integrated Observation and Modeling of Arctic Sea ice and Atmosphere	3rd EuroGOOS conference	Proceedings of the 3rd EuroGOOS conference, Athens, 3-6 Dec. 2002	paper
P. Dahlgren	Nov 2003	Ongoing and planned activities in the usage of ATOVS AMSU A/B in the HIRLAM 3DVar system at SMHI	ITSC XIII	Proceedings of ITSC XIII, Montreal, Canada, Nov. 2003	paper
R. Tonboe, S. Andersen, L. Toudal	2003	Anomalous winter sea ice backscatter and brightness temperatures		DMI Techn. Rep. 03-13, 62 pp.	techn. report
D. Hofman-Bang	2003	Microwave remote sensing of sea ice	Master Thesis		thesis
R. Tonboe, S. Andersen	2004	Modelled radiometer algorithm ice concentration sensitivity to emissivity variations of the Arctic sea ice snow cover		DMI Scient. Rep. 04-03, 62 pp.	tech. report

Articles submitted to peer-reviewed journals:

Authors	Date	Title	Submitted to
N. Selbach, T.J. Hewison, G. Heygster	2003	Emissivity of sea ice at 89 GHz, 157 GHz and 183 GHz in the Arctic winter	IEEE Trans. Geosci. Remote Sens.
R. Tonboe, S. Andersen, L. Toudal	2003	Anomalous winter sea ice backscatter and brightness temperatures	Remote Sensing of Environment
R. Tonboe, S. Andersen, L. Toudal, G. Heygster	2004	Sea ice emission modelling	chapter in book *Radiative transfer models for microwave*, edited by C. Mätzler.

Planning of future publications:

Author(s)	Date	Title	Target	Type
T. Bøvith, S. Andersen, L. Kaleschke	2004	Sea ice concentration from Single polarised SAR data using Second-Order Grey level Statistics and Learning Vector Quantisation	DMI	techn. report
D. Hofman-Bang, L. Toudal Pedersen	2003	Retrieval of geophysical parameters from AMSR data	DTU	report
G. Hong, J. Miao, G. Heygster, K. Künzi	2004	Simultaneous retrieval of cloud liquid water and precipitable water vapour over open ocean and sea ice using AMSR-E data	IEEE Trans. Geosci. Remote Sens.	paper

SECTION 3

Detailed Report by Work Package

3.1 Work Package 1.2 (IUP)

3.1.1 Objectives

Development of algorithms for retrieval of atmospheric parameters.

3.1.2 Methodology and scientific achievements

Total water vapour (TWV)

The algorithm to retrieve TWV from AMSU-B data has been fully reimplemented and is being used to retrieve TWV fields of the Arctic for the offline investigation period (2001-2002).
The algorithm does the following steps:

- Use AMSU-B Brightness temperatures (T_b) at three different frequencies (AMSU-B channels) i, j, k at which ground emissivity ϵ_s is similar but water vapor absorption different; $\kappa_i < \kappa_j < \kappa_k$:

$$TWV \sec\theta = C_0 + C_1 \log\left(\frac{T_{b,i} - T_{b,j} - F_{ij}}{T_{b,j} - T_{b,k} - F_{jk}}\right)$$

- Determine two sets of calibration parameters C_0, C_1, F_{ij}, and F_{jk} from regressions with radiosonde data and simulated T_bs: one set for $(i,j,k) = (20,19,18)$ and one set for $(i,j,k) = (17,20,19)$ (see Table 3.1.2 for the frequencies)
- Use AMSU-B channels 20, 19, and 18 for low TWV ($<$ 1.5 kg/m^2)
- Use AMSU-B channels 17,20, and 19 for higher TWV ($<$ 6 to 7 kg/m^2)

Table 3.1: AMSU-B channels and frequencies

Freq. [GHz]	89.0	150.0	182.31±7	182.31±3	182.31±1
AMSU channel	16	17	20	19	18

When the TWV exceeds about 6 kg/m^2, channels 20 and 19 are both saturated and the algorithm fails. Careful mathematical and physical analysis showed that:

- Condition when algorithm is not applied any more (saturation) can be relaxed from
  $T_{20} - T_{19} \geq 0$ ("saturation cut-off" = 0)
  to

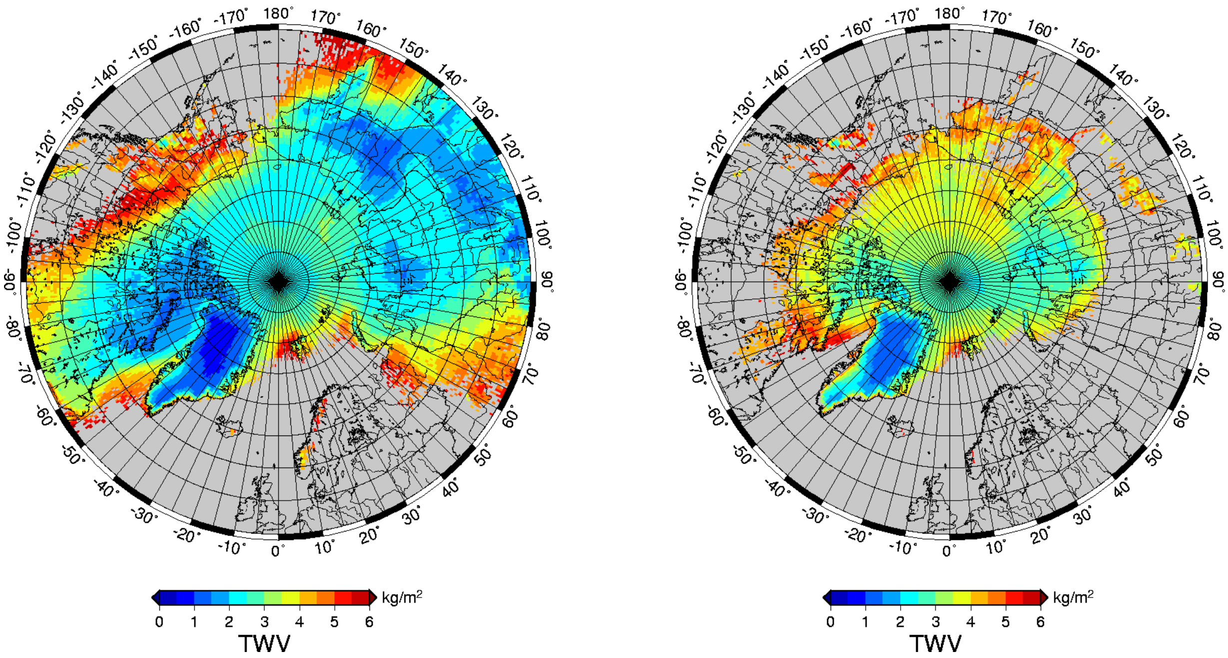

Figure 3.1: Maps of monthly mean TWV derived from AMSU-B data for January 2001 (left) and April 2001 (right).

$T_{20} - T_{19} \geq F_{20,19}$ ("saturation cut-off" = $F_{20,19}$)
where the focal point coordinate $F_{20,19}$ is typically a few K

- As long as both numerator and denominator of the log argument are negative, the algorithm works.

$$\log \frac{T_{b,i} - T_{b,j} - F_{ij}}{T_{b,j} - T_{b,k} - F_{jk}}$$

TWV can now be calculated from AMSU-B swath data in form of

- swath data (ASCII or binary), i.e., table with three columns (longitude, latitude, TWV), one value for each AMSU "pixel"
- daily averages, monthly averages (see example in Figure 3.1) in the following formats
  - maps (i.e., images: PostScript, PNG)
  - grid files (GMT output in NetCDF format),
  - more standard NetCDF (can be read, e.g., by GrADS)

A comparison with NCEP reanalysis data was done and showed overall agreement, with a few localized "hot spots" where there is a deviation of several kg/m^2. Since the TWV data derived from AMSU-B have much higher resolution than NCEP data, they show much more detail.

Surface emissivities at temperature sounding frequencies

The work on determining the sea ice emissivity at temperature sounding frequencies is ongoing. The basics of the algorithm can be summarised as follows:

- The total brightness temperature measured by satellite sensor like AMSU-A (viewing angle θ, frequency ν) is:

$$T_b(\theta, \nu) = c_1 + c_2 \varepsilon_s T_s + (1 - \varepsilon_s) c_3$$

where

$c_1 = T_u(\nu, \theta)$, upwelling radiation from atmosphere
$c_2 = \mathrm{e}^{-\tau(0)\sec\theta}$, $\tau(0) =$ opacity of atmosphere
$c_3 = T_d(\nu, \theta)\mathrm{e}^{-\tau(0)\sec\theta}$, downwelling radiation from atmosphere
$T_s =$ physical temperature of the surface
$\epsilon_s =$emissivity of the surface

$\Rightarrow \quad \epsilon_s = (T_b - c_1 - c_3)/(c_2 T_s - c_3)$

- $\epsilon_s = (T_b - c_1 - c_3)/(c_2 T_s - c_3)$
- For $\epsilon_s = 0$:
  $$T_b(\epsilon_s = 0) = c_1 + c_3$$
- For $\epsilon_s = 1$:
  $$T_b(\epsilon_s = 1) = c_1 + c_2 T_s$$

$\Rightarrow \quad \epsilon_s = [T_b - T_b(\varepsilon_s = 0)] \,/\, [T_b(\varepsilon_s = 1) - T_b(\varepsilon_s = 0)]$

- This means: Emissivity at given ν can be determined from measured (AMSU-A) T_b if we simulate $T_b(\epsilon_s = 0)$ and $T_b(\epsilon_s = 1)$ for ν
- Here: MWMOD (MicroWave radiative transfer MODel). Input: Atmospheric profile from
  - Measurements during Polarstern cruises; Problem: only in summer
  - ECMWF model profiles

As an example result, Figure 3.2 shows the seasonal variation of the emissivity of an area in the Arctic. The low emissivity of open water in late summer and the very high emissivity of new ice in winter is clearly visible.

3.1.3 Socio-economic relevance and policy implication

The development of the total water vapour, the cloud liquid water and the surface emissivity retrieval algorithm is economically attractive because it aims at better exploitation of existing data; no new sensors need to be developed and brought to space.

3.1.4 Discussion and conclusion

The work package is in good progress: The TWV algorithm has been completed, and first results of the emissivity algorithm have been produced.

3.1.5 Plan and objectives for the next period

For the TWV algorithm plans and objectives are

- Comparison with ECMWF reanalysis data
- Validation with radiosonde data
- Extension to higher TWV values (started)

The algorithm development for emissivity at temperature sounding frequencies and for cloud liquid water is ongoing and should be concluded soon.

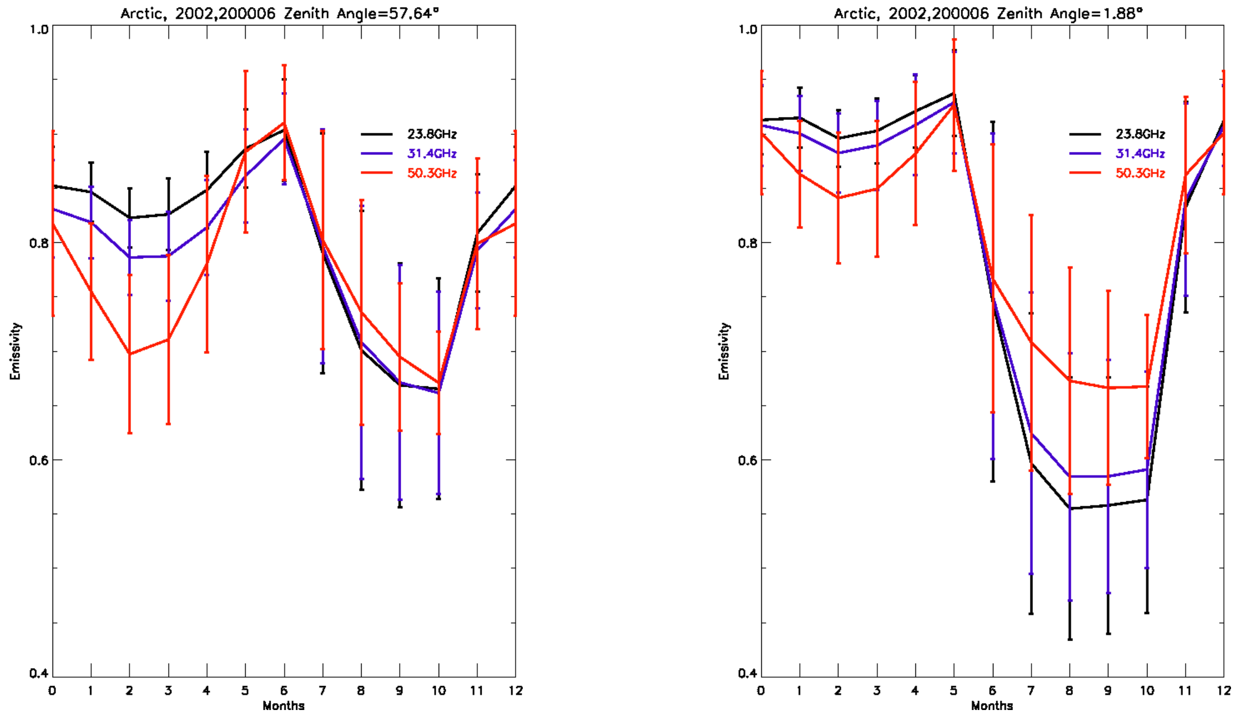

Figure 3.2: Seasonal variation of emissivity in the Arctic at different frequencies. Zenith angle 1.88°(left) and 57.64°(right).

3.2 Work Package 2.2 (SMHI, met.no)

3.2.1 Objectives

Improve high-resolution Arctic NWP

3.2.2 Methodology and scientific achievements

Met.no has set up an SSM/I processing chain for daily sea ice input for AMSU sounding channel sea ice emissivity estimations. We have defined data formats and the design of the interface with the HIRLAM data assimilation system and with data in AMSU-A footprints in order to build a colocation data set that also contains HIRLAM profile data.

A study of AMSU-A observations versus corresponding modelled AMSU-A observations from NWP profiles with an emissivity estimate and a radiative transfer model is ongoing. This will be used to assess various formulations for emissivity estimates.

The HIRLAM variational data assimilation system has been prepared for AMSU-A-data over sea ice. Assimilation of AMSU-A data with an interface to daily emissivity estimate grid files has been coded and set up. Preparations for parallel experiments with and without AMSU-A assimilation over sea ice to assess the impact are ongoing. A report describing the code and changes done in HIRVDA for assimilation of AMSU-A over ice is under preparation.

Output of OSI-SAF (Ocean and Sea Ice Satellite Application Facility) cloud mask product from the met.no processing chain has been set up for delivery to SMHI for tests of AMSU-B cloud masking.

Humidity over sea

Following the recommendation from UAG member Steven English (The Met Office) we focus on assimilation of raw radiances instead of TWV products. The former are more probable to have Gaussian statistics and this is a requirement for a successful assimilation.
The natural start for using AMSU-B HIRLAM 3DVar is to implement AMSU-B assimilation over open sea before tackling the much more challenging task of assimilation over ice. AMSU-B over sea is already used in operations at many centres in the world, e.g., ECMWF and the MetOffice. Algorithms in the AAPP code that detect observations contaminated by scattering processes from rain and cirrus clouds have been used to get a big data sample free of contaminated observations. AAPP processed data is collected at SMHI via EARS (EumetsAt Retransmission Service). Collocation code from met.no was used to calculate innovation vectors with the RTTOV-7 model. The bias of the observations compared to the NWP model is corrected with a linear regression using three predictors. Determination of which weight to give the observations in the analysis is ongoing. The HIRVDA (HIRLAM 3DVar) system system offers the possibility to calculate 'background errors in observation space', or BGOS, for conventional data and also for AMSU-A using RTTOV-5. That code has now been extended to use RTTOV-7 and AMSU-B. BGOS can be a very good tool for determining the weight for different observations. With that it is possible to determine how much weight to give the AMSU-B observations compared to other sources of information, e.g., TEMPS. Coding for the use of AMSU-B over sea in HIRVDA has begun.

Humidity over ice

If we want to use AMSU-B over ice it is very important to get an accurate description of the surface emissivity and temperature. In order to do any assimilation experiments at all we need, as for the case over open sea, a data set where radiances affected by scattering processes have been removed. With such a data set innovation vectors can be calculated and the biases studied. After finding a way to correct them, observation error covariances can be estimated.
The indexes used to clear out contaminated observations over sea can not be used over ice. Therefore we will use the OSI-SAF cloud mask for which we have data from the spring of 2004. Met.no has provided code that collocates NWP fields with AMSU observations as well as estimates of surface emissivities calculated from OSI-SAF data. With that as input to RTTOV-7 we can begin to calculate innovation vectors. The thing that remains to do is to find AMSU data for the same period and location as the OSI-SAF cloud mask.

Surface fluxes

It is sometimes almost forgotten that the NWP models themselves are not perfect. If we want to improve NWP simulations over the Arctic the surface fluxes must be better described. At SMHI there are plans to do some experiments with the vertical diffusion scheme.
The conventional Monin-Obukhov (MO) similarity theory has been extended to the stably stratified atmospheric surface layer. New correction functions to the neutral drag were introduced depending, besides the bulk Richardson number, on one more stability parameter involving the Brunt-Väisälä frequency in the free atmosphere and on roughness lengths for wind and temperature (humidity). Results show close agreement between potential temperature and wind profiles in 1D HIRLAM and LES (large eddy simulation) models. Tests show significant influence of the new parameterisation in winter time at northern latitudes.
The HIRLAM system has been set up on the ECMWF computer facilities to do test runs on one month of data.

3.2.3 Socio-economic relevance and policy implication

If brought to operational application, the results should increase prosperity and strengthen security in Northern Europe by boosting operational weather forecasts, helping to improve the living conditions in Northern Europe and especially human off-shore activities in the Arctic region, such as navigation, fisheries, tourism, and exploitation of marine mineral resources.

Greater confidence in short and medium term weather predictions which benefits the entire population of this region, and also the environment through improved risk management possibilities and better disaster control. Reliable forecasts are the first step in risk management and disaster control whether in the marine environment, the atmosphere or on land, and for all economic activities and developments. It is important in making decisions on capital expenditure regarding investments in industry and infrastructure.

The assimilation of AMSU-B should lead to improved weather forecasts for Northern Europe - especially for precipitation. It will also enhance value of data of meteorological European satellites because sensors similar to AMSU-B are planned on future METOP satellites.

The new surface heat flux scheme should lead to improved weather forecasts for Northern Europe and especially of clouds in the Arctic.

3.2.4 Discussion and conclusion

Even if assimilation of TWV products is not a priority at this time it would still be interesting to compare the result from assimilating raw radiances with that of assimilating TWV. Code for assimilation of TWV in HIRLAM is already available and this option could also be used as a fall-back strategy in case severe problems occur with the raw radiance approach.

We have a clear picture of what to do concerning AMSU-B over sea, and Per Dahlgren's visit to the MetOffice was very useful. One thing that is yet a bit uncertain is what to do with observations in places where the atmosphere is very dry and the surface contributes a lot to the observation value. If the model does not have an accurate description of the surface temperature, false signals may be sent into the analysis. If this becomes a problem there are two possible ways to deal with it:

1. Let T_{skin} be a part of the control vector inside HIRVDA and let it adjust during minimization.
2. Adjust T_{skin} separately before entering the analysis. This can be done using our 1DVar code.

3.2.5 Plan and objectives for the next period

AMSU-B over sea

- Further tuning of observation error covariances
- Coding of AMSU-B into HIRVDA
- Impact studies
- Maybe implement $T\mathrm{skin}$ in the control variable in HIRVDA or stand-alone using 1DVar

AMSU-B over ice

- Get AMSU data for the same period and time as the OSI-SAF cloud mask.
- Calculate innovation vectors using emissivities estimated from OSI-SAF data as input to RTTOV-7.
- Study how to do bias correction over ice. Maybe it can be done the same way as over sea?
- Assimilation experiments using 1DVar.

Surface fluxes

Do test runs with three different setups:

1. Use modified surface fluxes (Zilitikevich/Perov/King)
2. 1. + the whole turbulence scheme, CBR, modified. (Galperkin/Sukoriansky/Perov)
3. 2. + OSI-SAF sea ice information as the lower boundary condition.

3.3 Work Packages 3.2 and 3.3 (DTU)

3.3.1 Objectives

Construction of sea ice forward model.

3.3.2 Methodology and scientific achievements

Radiative transfer theory provides the relationship between the observed brightness temperatures T_B and some geophysical parameters. A model describing this relationship is known as a forward model, and here an ocean/atmosphere forward model described by *Wentz* [2000][1] has been used as the starting point. The model describes the connection between four geophysical parameters (wind, water vapour, liquid water and sea surface temperature) and the brightness temperatures measured by the AMSR. The model described by *Wentz* [2000] is only valid for water surfaces, so the model has to be expanded to take ice-covered surfaces into account.

Inclusion of ice in the Forward Model In the model by *Wentz* [2000], the upwelling brightness temperature at the top of the atmosphere - the brightness temperature measured by the AMSR satellite - is written in equation (10) as:

$$T_{B\uparrow} = T_{BU} + \tau \left[ET_S + T_{B\Omega}\right]$$

where T_{BU} is the contribution of the upwelling atmospheric emission, τ is the total transmittance from the surface to the top of the atmosphere, E is the Earth surface emissivity and $T_{B\Omega}$ is the surface scattering integral.
A change in the surface content from open water to ice only has an influence on the following parts of the model: ET_S (the brightness temperature close to the sea surface) and $T_{B\Omega}$.
In order to be able to include ice in the model for the brightness temperature close to the sea surface, one has to consider the difference between the emissivity of an open water sea surface and an ice-covered sea surface.
The brightness temperature, $T_{B,ice}$, at the ice surface can be written as:

$$T_{B,ice} = T_{P,ice} E_{ice}$$

where $T_{P,ice}$ is the physical temperature of the ice surface and E_{ice} is the emissivity of the ice surface. The emissivity of an ice-covered surface depends on the type of ice cover, the polarisation and the frequency. The preliminary sea ice emissivities used to calculate the brightness temperatures of the different channels of the AMSR are given in Table 3.2.
During the year the ice signatures have been adjusted using time series analysis of areas of first-year and areas of multi-year ice, they are summarised in Table 3.3, Table 3.4, Table 3.5.

[1] Wentz, F., T. Meissner, Algorithm Theoretical Basis Document, version 2: AMSR Ocean Algorithm, *RSS Tech. Proposal 121599A-1*, Nov. 2000; http://www.seaice.dk/iomasa/documents/Wentz_AMSR_Ocean_Algorithm_Version_2.pdf

Table 3.2: Emissivities at AMSR frequencies for the First Year (FY) and Multi Year (MY) ice used in the forward model for autumn.

	Frequency	6 GHz	10 GHz	18 GHz	23 GHz	37 GHz
FY	Vertical	0.9204	0.9127	0.9373	0.9409	0.9347
	Horizontal	0.7502	0.7738	0.8314	0.8490	0.8600
MY	Vertical	0.9692	0.9284	0.8843	0.8554	0.7813
	Horizontal	0.8651	0.8356	0.7917	0.7792	0.7248

Table 3.3: Emissivities for the First Year (FY) and Multi Year (MY) ice used in the forward model for early summer.

	Frequency	6 GHz	10 GHz	18 GHz	23 GHz	37 GHz
FY	Vertical	0.9187	0.9168	0.9437	0.9415	0.8975
	Horizontal	0.7963	0.8046	0.8274	0.8580	0.8170
MY	Vertical	0.8956	0.8898	0.9204	0.9364	0.9233
	Horizontal	0.7697	0.7803	0.8169	0.8504	0.8356

Table 3.4: Emissivities for the First Year (FY) and Multi Year (MY) ice used in the forward model for late summer.

	Frequency	6 GHz	10 GHz	18 GHz	23 GHz	37 GHz
FY	Vertical	0.9678	0.9531	0.9722	0.9763	0.9639
	Horizontal	0.9271	0.9206	0.9170	0.9334	0.9639
MY	Vertical	0.9994	0.9841	0.9963	0.9927	0.9796
	Horizontal	0.9541	0.9608	0.9753	0.9763	0.9567

Table 3.5: Emissivities for the First Year (FY) and Multi Year (MY) ice used in the forward model for winter.

	Frequency	6 GHz	10 GHz	18 GHz	23 GHz	37 GHz
FY	Vertical	0.9905	0.9718	0.9817	0.9773	0.9567
	Horizontal	0.9097	0.9007	0.9072	0.9075	0.8927
MY	Vertical	0.9870	0.9487	0.8933	0.8494	0.8927
	Horizontal	0.8866	0.8627	0.8163	0.7871	0.7011

Now, the brightness temperature close to a surface mixed of open water, first-year (FY) and multi-year (MY) ice can be written as:

$$T_{B,S} = ET_S = C_{ow}T_{B,ow} + C_{FY}T_{B,FY} + C_{MY}T_{B,MY}$$

where C_{ow}, C_{FY} and C_{MY} and are the concentrations (= surface fractions) of open water, FY and MY year sea ice, respectively, and $T_{B,ow}$, $T_{B,FY}$ and $T_{B,MY}$ are the respective brightness temperatures of the three different surface types.
The surface scattering integral is given by *Wentz* [2000], equation (61) as:

$$T_{B\Omega} = [(1+\Omega)(1-\tau)(T_D - T_C) + T_C]\, R$$

where T_D is the downwelling brightness Temperature, T_C is the cosmic background, and Ω is a fit parameter. In this equation it is only the sea-surface reflectivity, R, which is influenced by the ice. An effective reflectivity for a mixed surface can be written as:

$$R_{eff,mix} = 1 - E_{eff,mix} = 1 - (C_{ow}E_{ow} + C_{FY}E_{FY} + C_{MY}E_{MY})$$

where C_{ow}, C_{FY} and C_{MY} are the concentrations of the three surface types and E_{ow}, E_{FY} and E_{MY} are the emissivities of the surface types.
The last thing one has to take in to consideration when including ice in the model is that the forward model described by *Wentz* [2000] has a surface temperature included. This temperature has to take the temperature of the ice into account and therefore the surface temperature used in the ice model has to be calculated by:

$$T_{S,mix} = C_{ow}T_{P,ow} + C_{ice}T_{P,ice}$$

where C_{ow} and C_{ice} are the concentrations of open water and sea ice, respectively, and $T_{P,ow}$ and $T_{P,ice}$ are the respective physical surface temperatures. This mixed surface temperature only has to be used in the part of the model concerning the atmosphere, not in the parts concerning the dielectric constant of sea-water and the wind-roughened sea surface.

3.3.3 Discussion and conclusion

Work package 3.2 has been successfully completed, work package 3.3 is ongoing.

3.3.4 Plan and objectives for the next period

The development activities will be continued.

3.4 Work Package 4.2 (DMI. met.no)

3.4.1 Objectives

Construction of algorithm for ice concentration retrieval.

3.4.2 Methodology and scientific achievements

Ice concentration retrieval algorithms using SSM/I are well known and have been used for the last 20 years. Work in recent years has concentrated on the optimisation of tie-points, which are fundamental for sea ice concentration retrievals, as well as on the correction for the atmospheric influence. 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 polynyas within the consolidated ice cover. This in turn affects the performance of NWP models with regard 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 polynyas. 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 tie-points, that span the scale of ice concentrations. This will be obtained in mainly from WP3 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. 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 at most 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. 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 in order 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.
The routine analysis of SAR data has been initiated by skilled ice analysts at the DMI Ice Service, investigations to optimise the selection and computation of features have taken place. They indicate that the final output based on training by two independent analysts results in differences of only 2-3% of the pixels. The MEMLS radiative transfer model for snow has been augmented with a sea ice module and in spite of a lack of sufficient validation data the model is consistent with the qualitative behaviour of snow and ice layers. It is found that the snow layer on the ice is the dominant factor for the correct retrieval of ice concentration and type information. This has been further documented in a book chapter (see reported refereed publications in queue: *Tonboe et al.*). Recently a thermodynamic snow and ice model has been implemented to better describe the metamorphosis and state of the snow layer on the ice as a result of meteorological forcing. Ifremer ice drift data have been analysed in order to test their consistency. Integration over an ice season gave a consistent age and thickness distribution and consequently this data source will be taken into account in the continued development and testing of ice concentration algorithms.

3.4.3 Socio-economic relevance and policy implication

Better knowledge of sea ice properties allows improved weather forecasting in Arctic areas. This in turn benefits directly key activities in the region such as shipping and fisheries.

3.4.4 Discussion and conclusion

The work package is in good progress and first results have already emerged. Two publications have already been completed and three more are in queue.

3.4.5 Plan and objectives for the next period

The work package continues through the next period. The development strategy has been fixed to make better use of the information hidden in the history of the snow pack and ice through thermodynamic models driven by NWP model output and ice drift from remote sensing techniques. Finally different prototype techniques will be assessed based on their performance relative to analysed SAR data. An operational processing chain will be set up as an experimental OSI SAF (SAF on Ocean and Sea Ice) subsystem.

3.5 Work Package 5.1 (DTU, DMI, IUP, met.no)

3.5.1 Objectives

Prepare real time processing and user interface.

3.5.2 Methodology and scientific achievements

Data exchange formats Data exchange formats for the most relevant data types have been defined as binary GRIB format for gridded data and plain ASCII format for more simple data.

Near real time data distribution to end-users The AMSR-E parameter retrieval suite using optimal estimation techniques has been operationalized, and now runs in near real time with AMSR-E data from the National Snow and Ice Data Center (NSIDC). Data are distributed via the IOMASA web pages at DTU (http://www.seaice.dk/iomasa) The retrievals are based on the atmosphere/ice/ocean forward emissivity/radiative transfer model of work package 3. Figure 3.3 shows a suite of parameters as retrieved.

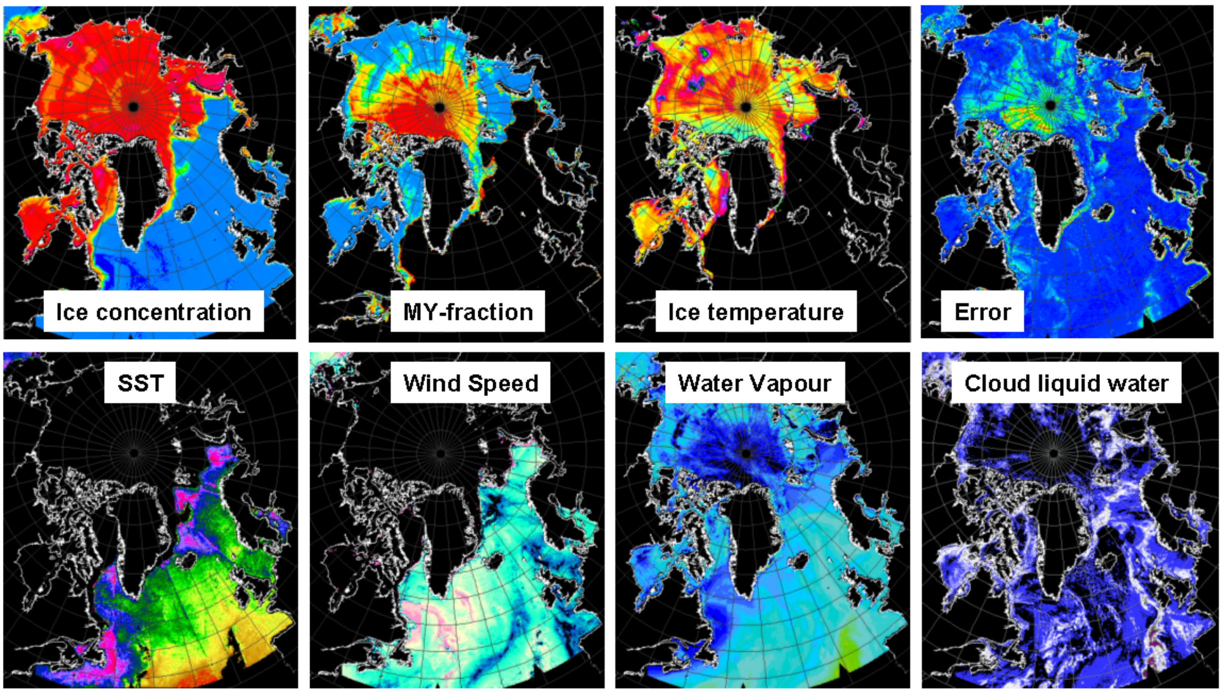

Figure 3.3: All parameters retrieved using the optimal parameter estimation technique. Input AMSR-E swath data from NSIDC, output the 7 parameters presented above. The plot titled 'Error' shows the mismatch between the modeled and the measured antenna temperatures. Blue indicates very small errors, red large errors.

The University of Bremen total water vapour algorithm has been implemented to run in near real time with the AMSU-B data stream at DTU as well. An example of the DTU water vapour retrieval from AMSR-E data is shown in Figure 3.4 and the corresponding IUP water vapour from AMSU-B (algorithm from work package 1.2) in Figure 3.5.
Daily SST composites are now being combined into a 7-day mean SST image for the northern hemisphere (Figure 3.6).

3.5.3 Socio-economic relevance and policy implication

Socio-economic relevance and policy implication: The On-line near real time data distribution system has quite a number of users worldwide.

3.5.4 Discussion and conclusion

The data distribution system can be accessed at http://www.seaice.dk/iomasa

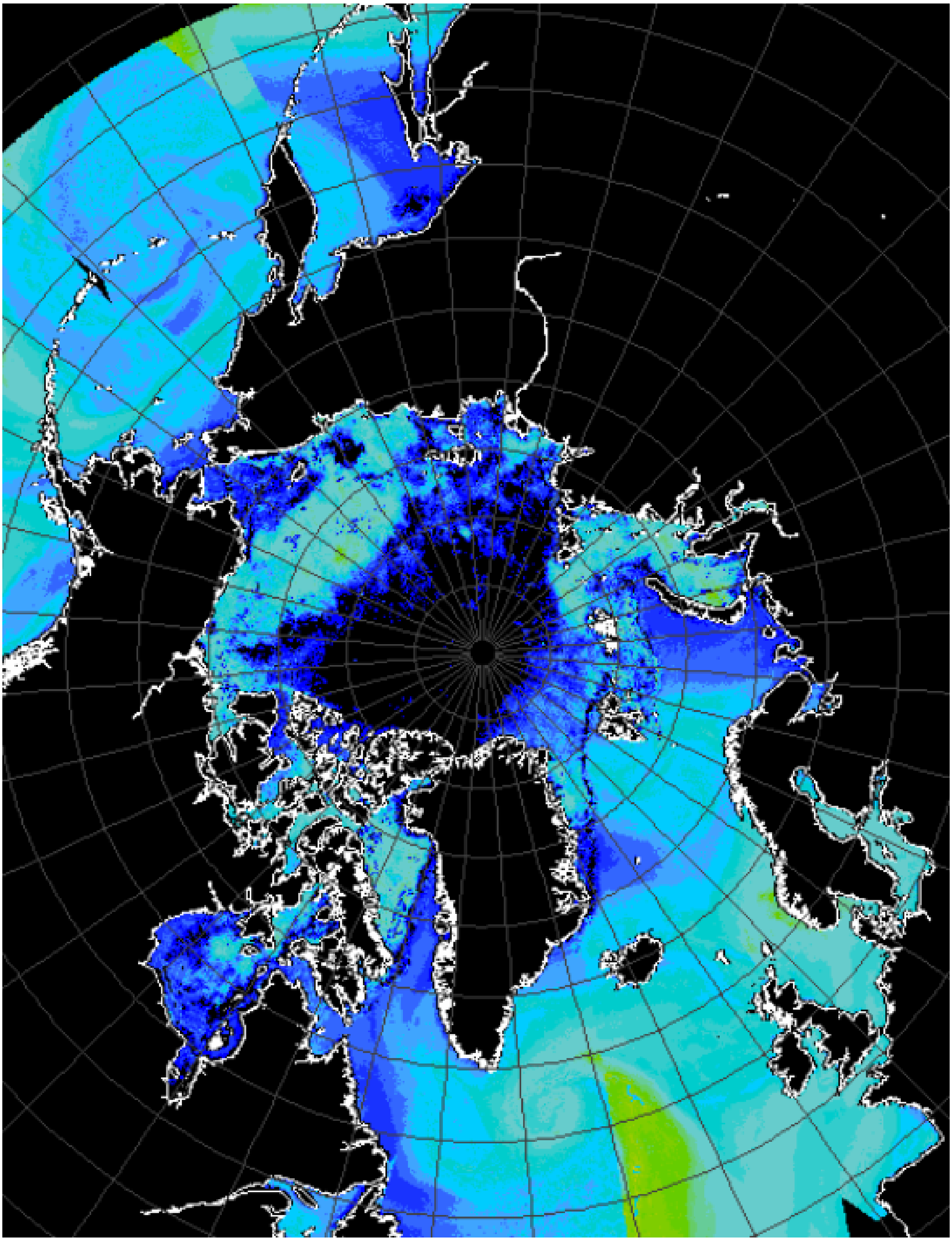

Figure 3.4: Retrieval of integrated water vapour using forward model from work package 3.2. AMSR data from National Snow and Ice Data Center, December 5, 2004.

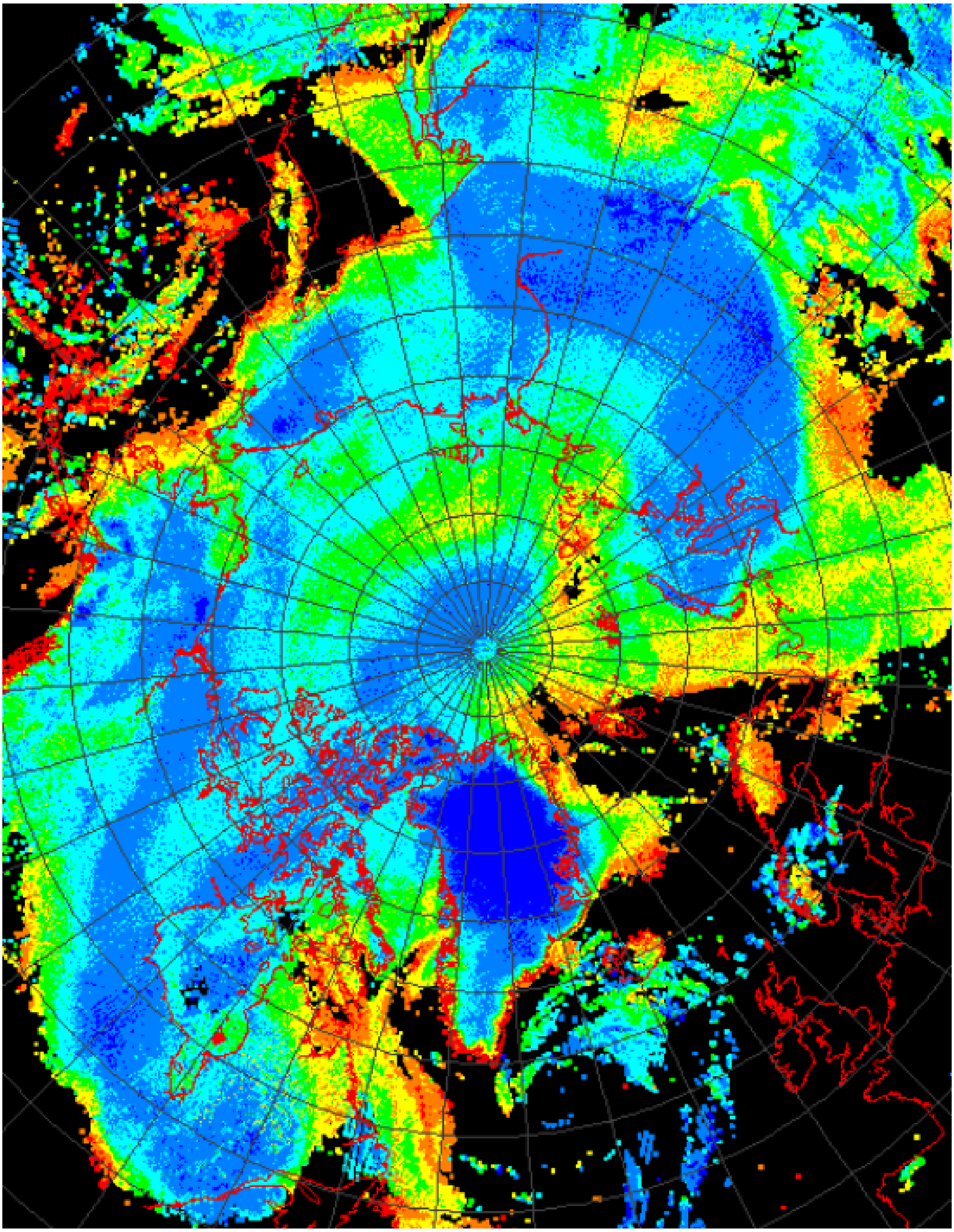

Figure 3.5: Retrieval of total atmospheric water vapor from AMSU-B data using algorithm from from work package 1.2. AMSU-B data from Cooperative Institute for Research in the Atmosphere, Colorado State University, December 5, 2004.

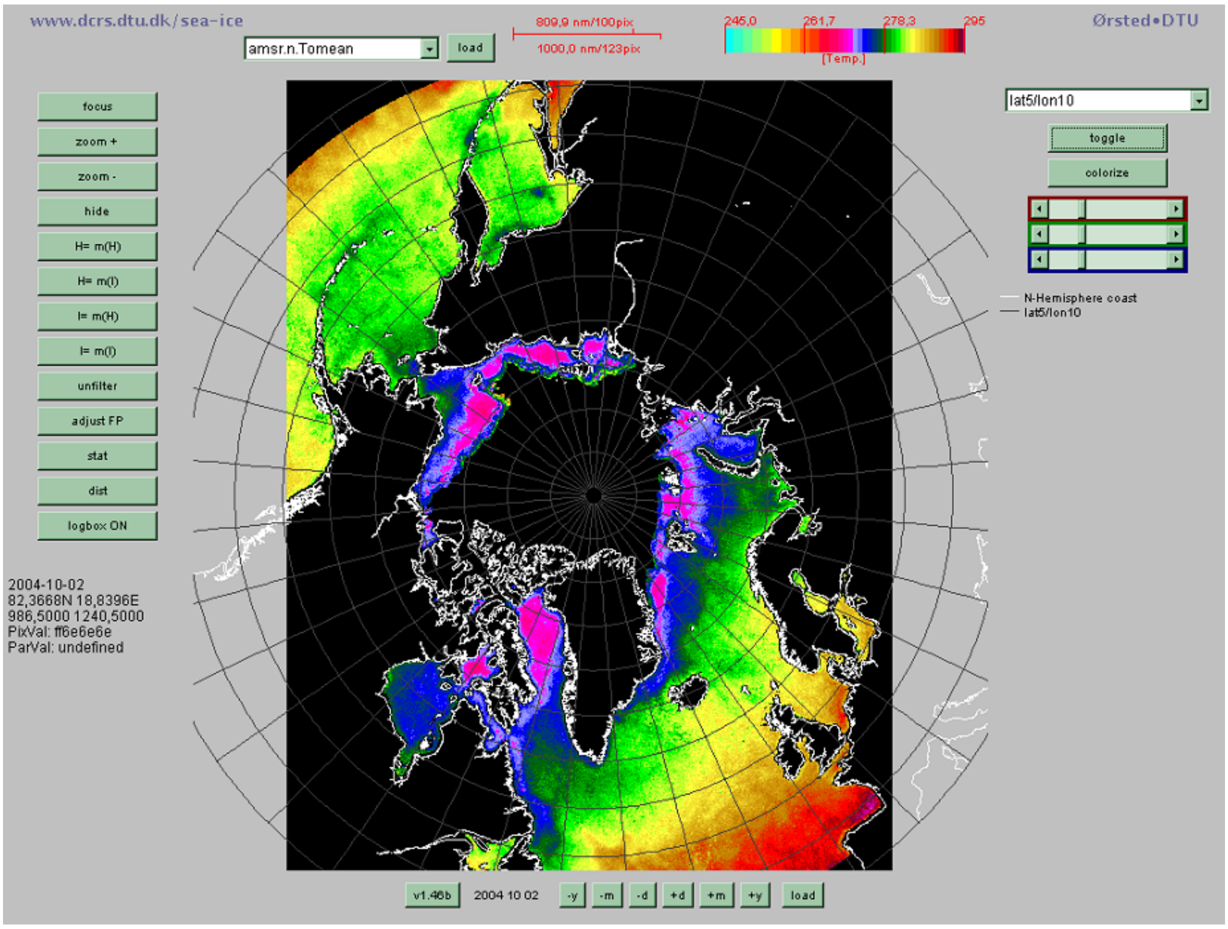

Figure 3.6: SST seven-day mean.

SECTION 4

Technological Implementation Plan (Cumulative)

[See eTIP on http://www.cordis.lu/fp5/tip.htm (EVK3-CT-2002-00067)]

ANNEX A

Meeting reports

A.1 Mid-Term Review, 10–11 May, 2004, met.no, Oslo

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                    Minutes of the IOMASA Mid-term Review,
                              12-11 May, 2004
                         held at met.no, Oslo, Norway

   Start of meeting: 10 May, 13:30
   End of meeting: 11 May, 12:30

Participants:


IUP:
Georg Heygster                    GH
Christian Melsheimer              CM

DTU-DCRS:
Leif Toudal Pedersen              LTP
Roberto Saldo                     RS

DMI:
Søren Andersen                    SA
Rasmus Tonboe                     RT

met.no:
Harald Schyberg                   HS
Frank Thomas Tveter               FT
Steinar Eastwood                  SE

SMHI:
Per Dahlgren                      PD
Tomas Landelius                   TL

1. Introductory items:

     * Welcome address.
     * Overview  of  project  schedule:  We  are  amidst  Phase  2, i.e.,
       algorithm development.

2. Progress of Phase 2: Status and Results of Phase 2 of each Partner:

  2.1 Part 1 (IUP): WP 2.1: Atmospheric remote sensing algorithms
```

```
   (C. Melsheimer):

    Total water vapour (TWV) from AMSU-B:

     * J.   Miao' algorithm (using ratios of brightness temperature
       differences of 3 frequencies).
  Freq. [GHz]:  89 150  183.31+/-7  183.31+/-3  183.31+/-1
  channel no.:  1   2       3          4           5
  Channel 1, 2: Window channels,
  Channel 3,4,5: around water vapour line.
     * Using  radiosonde data to get the "calibration parameters" C0, C1,
       F_ij, F_jk for the algorithm:
       TWV = ( C0 + C1 * log [(Ti-Tj/F_ij)/(Tj-Tk/F_jk)] ) * cos(theta),
     * Use  different  channel  combinations  (i,j,k  =  3,4,5, or 2,3,4)
       depending on saturation of channel 5
     * Status:  Can  derive  the  4  calibration  parameters for spatial,
       seasonal,  temporal  subsets  of radiosonde data and for given TWV
       ranges.
     * Results: TWV maps compare well with NCEP reanalysis TWV maps.
     * But:  Condition  T3-T4>0  too strict. The logarithm gets undefined
       only when T3-T4>F_34, and F_34 is of the order of 5 to 7 K.
     * Therefore:   relaxing   saturation   condition   to   T3-T4  >  S,
       S="saturation threshold", result shows extension of the area where
       the algorithm can be successfully applied.
     * Further refinement: Calibration parameters for TWV subrange:
         1. Determine preliminary. TWV with algorithm as is.
         2. Based  on  preliminary.  TWV,  use  algorithm for appropriate
            subrange

//    TL: Areas of no retrieval because of too high TWV will cause a
//       bias in the model since only TWV data from dry area will be
//       assimilated.
//    HS: Merge with TWV over water from AMSU-A? (emissivity of sea
//       with FASTEM model?)
//    SA: TWV over ice is also very interesting for sea ice part, for
//       the atmospheric correction
//    HS: Does the algorithm work over land as well?
//    CM: Yes, provided TWV is not too high.

   (G. Heygster):

    Surface emissivity at AMSU-A frequencies

     * Purpose:
          + Improve  assimilation  of  AMSU-A  radiances  into NWP models
            (IOMASA)
          + Improve temperature profile retrieval near surface
     * Method: Use
          + AMSU-A data,
          + colocated radiosonde profiles, and
          + ice concentrations from SSM/I
     * Method: 3 steps:
         1. Determine  bulk emissivity within one AMSU-A footprint (Using
            RTE for horizontally homogeneous atmosphere)
         2. Determine  contributions from different surface types MY ice,
            FY ice, OW (open water); surface types from SSM/I data
         3. Determine  emissivities  e[k]  of  surface types k by solving
            linear equation system:
```

```
          Sum[i,j] Sum[k] A[i,j] P[i,j,k] e[k]
          for many measurements at each incidence angle and frequency.
     * Results:
          + AMSU-A data 1998-2003 (except 1999) in house
          + Radiosonde profiles of R/V Polarstern 1984-2003 provided
          + Tool  to  extract  colocations, adjustable tolerances in time
            (5h) and space (600 km)
          + Example  plot:  Emissivity  at 50.4 GHz, 2 surface types (OW,
            ice)

    Daily AMSR ice charts

     * Using ARTIST Sea Ice (ASI)algorithm
     * Northern and Southern hemisphere: Resolution 6.25 km
     * Selected regions: Resolution 3 km:
          + North West Passage, Greenland Sea
          + Baltic Sea, Caspian Sea, Sea of Okhotsk
          + Antarctic Peninsula, Ross Sea, Scotia Sea

//
//    LT: Have you corrected for the difference in AMSR A-scan and B-scan?
//    GH: Not yet.
//    LT: What do the red spots in cloud signature image mean?
//    GH: NaN (not a number), caused by negative argument of the logarithm.
//

  2.2 Part 2 (met.no/SMHI): WP 2.2 Improve Arctic high-resolution NWP

   (H. Schyberg):

    temperature data assimilation (AMSU-A)

     * completed activities:
          + NWP  fields  for  use  by  project  partners:  code/script to
            extract   2  years  (2003-2004)  NWP  data  implemented,  see
            Deliverable  Report  2.2.1;  extraction of data to be done as
            soon as possible
          + OSI  SAF  chain including experimental products (e.g., MY ice
            fraction) running
          + near-real-time  collocation  chain:  collocation  fields with
            AMSU-A level 1c, HIRLAM and SAF sea ice data
//
//    LT: How about the AMSU-A asymmetry?
//    HS: Not considered so far.
//
     * (present and future activities:)
          + Operational delivery chain HIRLAM NWP data GRIB fields
          + SAF experimental. chain running further development:
               o set  up  AMSU  collocation  of ice from SAF experimental
                 chain
               o improved  experimental  ice  analysis method: correlated
                 satellite passes
          + Experimentation with emissivity predictors

   (T. Landelius):

    Humidity Assimilation (AMSU-B):

     * done:
```

```
          + P. Dahlgren has visited Met Office
          + Stand-alone 1D-Var
          + T_skin and emissivity in 1D var and 3D var
          + Bias correction scheme for AMSU-B
     * ongoing:
          + New  humidity  variable  (not log(hum) as usual since that is
            not Gaussian)
          + Cloud mask
     * planned:
          + AMSU-B into HIRVDA
          + AMSU-B into HIRVDA (= HIRLAM variational data assimilation)

   (P. Dahlgren):

    Quality control

     * Have a clear picture of how to get AMSU-B over sea
     * But: Neither Met Office nor ECMWF use AMSU-B over ice
     * Approach:  put  Ts  and emissivity in control vector and let VarQC
       decide what to accept
     * this can be tested in the 1D-VAR
     * Before,  AMSU-B  needs  bias correction (mainly because of clouds,
       specifically we need cloud clearing (clouds cause most bias))
//
//    GH: How to do that?
//    TL: Bias correction where you have RS data
//
     * NWC-SAF cloud mask? Cloud mask: over sea ice.

   (T. Landelius):

    Improved modeling of surface heat flux

     * done:
          + HIRLAM snow scheme and ice scheme
          + flux formulation for stable conditions
     * ongoing:
          + Flux implementation
     * planned:
          + validation of new flux and snow
          + validation of new ice scheme

  2.3 Part 3 (DTU): WP 3.2: Construction of sea ice emissivity forward model:

   (L.Toudal):

    Advanced statistical retrieval

     * SST, WS, WV, CWV, C, F, T_ice
     * Color representation
     * near real time processing
     * Example images/data, 27 April, 2004
          + SST map: Rhine outflow = warm plume
          + TWV map: some areas with values above 20 kg/m2
          + Sea  ice  concentration  (IC):  erroneous  low IC in areas of
            probably refrozen ice
          + CLW vs. R-factor (SSM/I): looks o.K. => calibrate R-factor?!
          + Check of IC: IC vs. NT1 IC w/o weather filter
               o ice free area: o.K., DTU algorithm better
```

o area with 100% IC: DTU-algorithm: 100%; NT: 80-90%; similar standard deviation
Problem: Changing emissivities (tie-points)

//
// SA: How are the different AMSR channels weighted? You might see
// more variation in the H-pol channels
// LT: Maybe we should adjust the error covariance matrix to give
// the H-pol channels less weight
// GH: Validation with SAR
// LT: Yes, RADARSAT and Envisat, but with Envisat data there are
// ordering problems...
//

Time series analysis (AMSR-E, AMSU)

* Time Series AMSR MY ice: more variation in H-polarisation channel (later: comparison with data from some ice camp)
* Time Series AMSR FY ice: almost independent of frequency, as expected
* AMSU-A vs. AMSR: produce emissivity. maps from AMSR data (37H, 23H): compare with AMSU

//
// GH: AMSU-A: theta-dependence?!
// LT: First try without. Then see if theta makes much difference
// GH: Penetration depth?
// LT: Not considered yet - might be cause of some errors.
// GH: Are varying penetration depth (with freq. and time) and
// varying footprint size the main problems?
// LT: Not necessarily.
//

2.4 Part 4 (DMI): WP 4.2: Construction of algorithm for sea ice concentration retrieval:

Activities focussed on:
* ice/snow emission
* concentration algorithm evaluation
* extending the toolbox (drift data)
* routine SAR classification

(R. Tonboe):

Emission modeling

* MEMLS (snow emissivity model by C. Mätzler)
-> added sea ice (MEMLSI)
* 1st try: simulating MSR measurements w/ MEMLSI and in-situ measurements (23.3.03, 76.26N, 23.28E)
* difficult: point measurement <-> large-scale satellite footprint
-> use specific profile (sea ice, hoar, snow, thin ice layers) and do sensitivity study.
=>
+ NT algorithm: sensitive to layer contrast
+ Comiso bootstrap (frequency mode) algorithm: moderately sensitive to scattering in ice/snow
+ Near-90-GHz (Svendsen) algorithm: moderately sensitive to deep scattering, sensitive to layer contrast

```
   (S. Andersen):

    Time series analysis

   (R. Tonboe):

    Sea ice (satellite data assimilation) model

     * Input:
          + Ice drift from SeaWinds scatterometer data
          + Ice concentration from SSM/I, Bootstrap (frequency mode)
     * Output:
          + ice age (and thickness)
          + deformation (ridges)
          + new ice forming
          + brine flux
          + melt rate
     * Algorithm Pros and Cons
  | 90 GHz (pol) | Bootstrap   |     NT       |     NT2
--+--------------+-------------+--------------+--------------
+ | resolution   | weather     | temperature  |  surface
  |              | insensitive | insensitive  |  insensitive
--+--------------+-------------+--------------+--------------
- | weather,     | temperature | surface/snow |  weather in
  | surface/snow |             |              |  MIZ?

   (S. Andersen):

    Plans

     * Continue ice model and ice time series analyses
     * Run Sealion algorithm
     * New Wentz radiative transfer model
     * Experimental SAF chain
     * Explore 6 GHz and 19 GHz channels and 37GHz-89GHz gradient
     * More and better in-situ data.

    SAR classification

     * classification by ice analysts started; mixed results
     * Ice   and   turbulent   water  confusion:  Turbulent  water  class
       discarded, smooth water class optimised.
     * problem:  range  effect (darker on one side, brighter on the other
       side): ENVISAT data not range-corrected (unlike RADARSAT) => large
       uncertainties
//
//    LT: Envisat data have some parameters in header for a range
//        correction (there is an ESA report on that)
//    GH: There is also the Master's Thesis by Arash Houshangpour at
//        IUP Bremen.
//

     * Effect of texture:
          + accuracy  of  classification  raised  by  using  texture, but
            classified image sometimes seems noisy
          + some tuning planned
     * Plans for SAR classification
          + Process DMI data backlog for Baffin Bay
```

```
          + In view of poor Envisat supply, buy RADARSAT data
               o less temporal and spatial coverage
               o May alleviate planning of manpower for classification
          + Verify positive influence of range correction
          + Investigate texture computation parameters

3. Review of Phase 2:

   We  are right in the middle of phase 2 (development phase), thus it is
   not  easy  to judge if everything is exactly on time. In any case, all
   partners  are  ready  now to provide new data to others and to use and
   apply new data from others. Details in the next section.

4. Inter-task communication and exchange

  Part 1, Atmospheric algorithms (IUP)

     * TWV data produced from AMSU-B
          + Who: DMI, DTU, SMHI
          + What: Swath data, i.e.:
               o lat, lon, TWV, scan position,
               o AMSU-A WV over water,
               o meta-data, namely the saturation cut-off
          + Where: link to ftp server on IOMASA member web site
     * R-factor data from SSM/I:
          + Who: met.no
          + Where: link to data on member web site
     * day-0  algorithms  for  TWV  and  R-factor  are on member web site
       already
//
//    HS: SSM/I 89GHz channel has different resolution from 37 GHZ
//        channel?
//    SA: There is an easy way to deal with that (have dealt with that
//        before: [-> offline discussion]
//    FT: For AMSR products: what is the delay between acquisition
//        and availability?
//    GH: A few hours.
//    FT: For nowcasting people it mustn't be more than 1 hour...
//    GH: Yes, but AMSR is an experimental sensor, not an operational one.
//
     * Emissivities: should be ready by next meeting.
//
//    TL: How about emissivity at 182 +/-1,3,7 GHz? We would need a
//        first  guess only (in dry atmosphere, sometimes ground
//        shines through even at 182 GHz)
//

  Part 2, Data Assimilation Activities (met.no/SMHI):

//
//    GH: Progress/Results?
//    TL/HS: Had to get quality control ready.
//
     * Now toolbox ready for experimentation
     * Crucial: Clouds. <= AMSU-A CLW? <= emissivity?
     * => emissivity crucial

    Part 3 Sea ice emissivity forward model (DTU):
```

```
   AMSR emissivity maps (AMSU-A frequencies) and SST
//
//    TL: AMSU-B emissivities?
//    LT: We have only 89 GHz (highest AMSR channel)
//    TL: Good enough.
//    GH: Time series?
//    LT: Using for validation/checking
//

5. Project Management

  5.1 Management and resource usage report:

     * Identical to Section 1 of Annual report, but for the period from 1
       Nov, 2003 till 30 Apr, 2004
     * due end of June,
     * input from partners by end of May
     * needed input:
          + Resources  (financial  &  person months) planned/used, just a
            table  with  numbers  and  explanation if deviation from plan
            substantial
          + Progress: About 1 sentence per work package.
     * C.  Melsheimer  will  write and explicit e-mail to all, requesting
       input.

  Location and Venue of next meetings

     * Additional   Meeting   (PM  3-delta)?  -  All  partners  think  an
       additional coordination meeting in early December is needed.
          + Venue: Bremen?
          + Time:  week  6-10  December, 2004, either Mon/Tue or Thu/Fri,
            depending on flight schedules
          + all  partners please check until end of May if there would be
            enough travel funds
          + if meeting not possible, try to "meet" at least virtually, by
            preparing  presentations  and  exchanging  the files? At that
            time,  we'll  be  collecting  the  input for the 2nd Periodic
            Report anyway.
     * Next regular meeting: PM3 (Progress Meeting 3)
          + With UAG
          + Venue: DTU, Copenhagen
          + Time:  week  14-18 Feb, 2005, Mon/Tue or Thu/Fri depending on
            flight schedules.
     * PM4, June 2005: Copenhagen or Norrköping
     * Final Presentation
          + Venue: IUP, Bremen
          + better 1 month before end of project, i.e., Sep 2005

6. Action items for MTR

  6.1 Discuss upcoming Deliverables

     * Del. 1.2.1 (AMSU-B TWV algorithm): see section 4. above
     * Del.  2.2.1  (report  and  programme code on humidity assimilation
       into  NWP):  Should be due at the end of project month 29, not 20,
       i.e., March, 2005

  6.2 Discuss input for next Management Report (covering period Nov 2003 till
  April 2004), due at the end of June, 2004
```

```
   See section 4. above

7. Any Other Business

  7.1. Review of User Advisory Group comments from PM1, one year ago

   Main statements:
     * Carl  Fortelius:  Analysis of increments to learn about physics of
       model.
//
//     TL/HS: Too big an issue to be addressed within IOMASA: We need
//         to pr... our improved humidity assimilation; we'll make
//         sure about communication with HIRLAM model physics people
//         (Colin  Jones, SMHI)
  //
     * Markku  Rummukainen:  Needed: Data and error statistics. Sometimes
       results show more than one has expected.
     * Helge  Tangen:  Benefit  of  IOMASA  can only be measured if users
       actually use it.
//
//    CM: This could be helped by the TIP. Everybody should look at
//        the TIP results.
//

  THE FUTURE: Follow on projects?

     * all partners agree there should be a follow-on project
     * scope of follow-on:
          + Emissivity (of sea ice): Forward model etc.
          + Accuracy / error assessment
          + New  sensors  (e.g.,  new  NPOESS:  CMIS, i.e. combination of
            SSM/I and AMSU, consistently conically scanning)
     * possible frameworks:
          + IPY-CARE  (IPY:  International  Polar  Year, 2007-2008; CARE:
            Climate  of  the  Arctic  and  its  Role for Europe) has been
            unsuccessfully  submitted to EU FP6, modified version will be
            resubmitted
          + ICEMON (Sea ice monitoring in the polar regions), (GMES, ESA)
//
//    LT: There is probably no funding for IPY CARE since there are no
//        international funds for IPY.There might be national funding
//        for IPY, put we have to put together a joint project
//        independent of IPY CARE to have access to national IPY
//        funds. IPY proposals should appeal to the integration of
//        polar activities in IPY.
//
//    LT: Instead of ICEMON, maybe we can just start a new GMES project?
//    GH: GMES is very much focused on operational issues, there is
//        no money for development.
//
//    LT: How about the "Data User Programme/Elements" (DUE?) of ESA?
//    SA/LT: Since that is funded by ESA, they might expect us to rely
//        mainly on ESA data, not AMSU, AMSR, SSM/I...
//
//    SA: We might check EU calls, e.g. Ocean Modelling (no funds for
//        development)
//
//    SA: EUMETSAT (only for meteorological institutions)?
```

```
//
//    LT: Network  of Excellence? 1 person-month per partner. Check
//        calls
//

     * Who checks what:
          + L.Toudal: DUE (ESA)
          + G.  Heygster:  ask  CARE  people  where  they  get (national)
            funding
          + S. Andersen et al.: Check FP6 calls
          + all: IPY national funding
          + all: EU Network of Excellence calls
     * Compile  info  on  member  web-site; remind all partners once in a
       while

  7.3 IOMASA Brochure

     * is  finally out, be distributed at each partners institute, and at
       conferences or meetings of the relevant communities.
     * Coordinator sends 200 copies to each partner.

  7.4. MTR presentations

   Electronic  files  of  the presentations of this meeting to be sent to
   Christian as soon as possible, as usual.
```

GLOSSARY/ACRONYMS:

ASI	ARTIST sea ice algorithm
CARE	Climate of the Arctic and its Role for Europe
CLW	cloud liquid water
CMIS	Conical-Scanning Microwave Imager/Sounder
CWV	column water vapour (= TWV = PWV)
DMI	Danish Meteorological Institute
DTU-DCRS	Technical Univ. of Denmark, Danish Center for Remote Sensing
EuroClim	European climate change (http://euroclim.nr.no)
GMES	Global Monitoring of Environment and Security
FP	Framework Programme
FY	first-year (ice)
HIRVDA	HIRLAM variational data assimilation)
IC	ice concentration
ICEMON	Sea ice monitoring in the polar regions
IPY	International Polar Year
IR	infra-red
IUP	Institut für Umweltphysik (Environm. Physics), Univ. Bremen
LWC	liquid water content
met.no	Norwegian Meteorological Institute
MIZ	marginal ice zone
MY	multi-year (ice)
NCEP	National Centers for Environmental Prediction
NSIDC	National Snow and Ice Data Center
NT	NASA TEAM (algorithm for sea ice concentration retrieval)
NT2	NASA TEAM 2 (algorithm for sea ice concentration retrieval)
NWC SAF	SAF in Support to Nowcasting and Very Short Range Forecasting
NWP	numerical weather prediction
OEM	optimal estimation method
OSI SAF	SAF on Ocean and Sea Ice
OW	open water

PWV	precipitable water vapour (= TWV = CWV)
RTE	radiative transfer equation
SAF	Satellite Application Facility
SMHI	Swedish Meteorological and Hydrological Institute
SST	sea surface temperature
T	temperature
Tb	brightness temperature
TCW	total cloud water
TWV	total water vapour (= CWV = PWV)
WV	water vapour

Minutes prepared by Christian Melsheimer

Abbreviations/Acronyms

1DVar	One-Dimensional Variational Analysis
3DVar	Three-Dimensional Variational Analysis
AAPP	ATOVS and AVHRR Processing Package
AHVRR	Advanced Very High Resolution Radiometer
AMSR	Advanced Microwave Scanning Radiometer; on satellite ADEOS-2 (Midori)
AMSR-E	Advanced Microwave Scanning Radiometer for EOS; on satellite Aqua
AMSU	Advanced Microwave Sounding Unit; on NOAA satellites
CLW	cloud liquid water
DMI	Danish Meteorological Institute
DMSP	Defence Meteorological Satellite Program
DTU-DCRS	Technical University of Denmark
ECMWF	European Centre for Medium-Range Weather Forecast
FY	first-year (ice)
GRIB	gridded binary (format)
HIRLAM	High Resolution Limited Area Model
HIRVDA	HIRLAM variational data assimilation
Ifremer	Institut Français pour la Recherche et l'Exploitation de la Mer
IUP	Institut für Umweltphysik (Institute of Environmental Physics)
LES	large eddy simulation
MEMLS	Microwave Emission Model for Layered Snow-packs
met.no	The Norwegian Meteorological Institute
MY	multi-year (ice)
NWP	numerical weather prediction
NWP SAF	Satellite Application Facility (SAF) on Numerical Weather Prediction
OSI SAF	Satellite Application Facility (SAF) on Ocean and Sea Ice
SAR	synthetic aperture radar
SMHI	Swedish Meteorological and Hydrological Institute
SSM/I	Special Sensor Microwave/Imager on DMSP satellites
SSM/T	Special Sensor Microwave/Temperature sounder
SST	sea surface temperature
TWV	total water vapour
UAG	User Advisory Group
DTU	Technical University of Denmark
DMI	Danish Meteorological Institute
UB	University of Bremen