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Implementation Plan for a NRT global ASCAT soil moisture product for NWP

Part 5: Implementation Plan for a Soil Moisture Product for NWP

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ASCAT Soil Moisture Report Series No. 5

Implementation Plan for a Soil Moisture Product for NWP

VIENNA UNIVERSITY OF TECHNOLOGY
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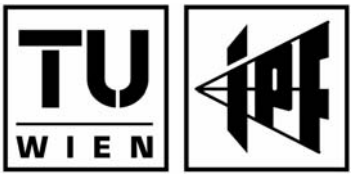

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Executive Summary

This report presents an implementation plan for a global 25 km surface soil moisture product for Numerical Weather Prediction (NWP) applications. The surface soil moisture data can be derived directly from orbit data acquired by the Advanced Scatterometer (ASCAT) onboard of METOP and distributed in near-real-time over EUMETCast. If the Level 2 processor is installed at EUMETSAT's central Product Processing Facility then Level 2 processing can take place immediately after ASCAT Level 1b processing. In this way, the Level 2 surface soil moisture products could reach the NWP users within about 135 minutes after sensing. Considering the present launch window for METOP (July 2006) and the planning for reprocessing ERS-1/2 data to 25 km at the European Space Agency (ESA) the Level 2 processor could be ready by December 2007, to start production of global ASCAT Level 2 products in 2008.

The present study was funded by the NWP SAF (http://www.metoffice.com/research/interproj/nwpsaf).

Acronyms

ASAR	Advanced Synthetic Aperture Radar (ESA)
ASCAT	Advanced Scatterometer
CDA	Command and Data Acquisition
EARS	EUMETSAT's Advanced Retransmission Service
ECMWF	European Centre for Medium-Range Weather Forecasting
EPS	EUMETSAT Polar System
ESA	European Space Agency
EUMETCast	EUMETSAT's Data Distribution System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAO	Food and Agriculture Organization
FWF	Austrian Science Fund
GMES	Global Monitoring for Environment and Security (European Commission)
IDL	Interactive Data Language
IPF	Institute of Photogrammetry and Remote Sensing
IPR	Intellectual Property Rights
JRC	Joint Research Centre (European Commission)
METOP	Meteorological Operational satellite
MSG	Meteosat Second Generation
NRT	Near Real Time
NWP	Numerical Weather Prediction
PPF	Product Processing Facility
SAF	Satellite Application Facility
SMOS	Soil Moisture and Ocean Salinity
SWI	Soil Water Index
TU WIEN	Vienna University of Technology
USDA	U.S. Department of Agriculture
WARP	WAter Retrieval Package
ZAMG	Austrian Institute for Meteorology and Geodynamics

Contents

1 Introduction

This implementation plan is the outcome of a study carried out from 1/12/2004 to 30/11/2005 in the framework of an Associate Scientist mission funded by the Satellite Application Facility (SAF) for Numerical Weather Prediction (NWP). The objective of the study was to develop an implementation plan for a near-real-time (NRT) global surface soil moisture product for NWP to be retrieved from Advanced Scatterometer (ASCAT) data. The feasibility for an implementation at EUMETSAT's central Product Processing Facility (PPF) was to be investigated. The ASCAT is a C-band scatterometer flown on-board of the three Meteorological Operational (METOP) satellites, which are part of the EUMETSAT Polar System (EPS). As input to the implementation plan, following activities were carried out:

1. Dialogue with the NWP community to specify their requirements for an optimum ASCAT soil moisture product [1]
2. Review potential data streams and data formats [2]
3. Define a global grid for processing ASCAT and ERS-1/2 time series in agreement with NWP requirements for the NRT product [3]
4. Strategies for cross-calibration of ERS-1/2 and METOP [4]
5. Study of azimuthal effects [5]

The study also considered results and lessons learned from other projects, most importantly the EUMETSAT funded project "Processor for ERS-SCAT based soil moisture" (Contract EUM/CO/05/1421/HGB), which has been carried out in the period 1/6/2005 to 30/11/2005. This latter project has been concerned with developing a C prototype software for NRT processing of ERS-2 SCAT data. It addressed mostly technical issues such as resampling procedures, quality flag definition, and data input and output routines. Also more general discussions about mission design, system architecture, and set up of operational remote sensing capacities have had an important impact on this implementation plan. The most important inputs came from the two Science Advisory Groups for the METOP ASCAT and the Soil Moisture and Ocean Salinity Mission (SMOS), the working groups in preparation of the Hydrology SAF, the project "geoland" funded by the Global Monitoring for Environment and Security (GMES) programme of the European Commission, and finally from the Land SAF.

2 Operational Scenario

2.1 ASCAT Processing Chain

Processing of earth observation data is done in a series of processing steps to convert the satellite measured signal into geophysical products of different complexity. It is common usage to use the term "Level" to indicate the sequence of the processing: Level 0 data are the data recorded at the satellite and processed to some extent in the ground segment, Level 1 data are calibrated measurement quantities, Level 2 data are retrieved geophysical products, and Level 3 or higher are value-added data products obtained by integrating data from other sources as well. We will use this notation here to simplify the discussion of the generation of ASCAT soil moisture data. For Level 0 and Level 1 ASCAT data specifications are fixed; for Level 2 and Level 3 soil moisture products let us make the following definitions:

- Level 0 are the backscattered radar echoes recorded at the satellite.
- Level 1 data are the calibrated backscattering coefficient data in orbit geometry, given in decibels, with a spatial resolution of 25 km and appended geolocation information.
- Level 2 data are the retrieved surface soil moisture data in orbit geometry, expressed in degree of saturation, i.e. in relative units (0-1), with a spatial resolution of 25 km and appended geolocation information.
- Level 3 data are value-added soil moisture data of different thematic content, representing different soil layers at different temporal and spatial resolution, obtained by merging Level 2 data with data from other sources.

The main data downlink for the ASCAT Level 0 data occurs via the Global Data dump (Figure 2-1). All data acquired and accumulated onboard over the last orbit are dumped within 5 minutes to the Command and Data Acquisition (CDA) station. The age of the oldest data at this stage is about 102 minutes, worst case being 117 minutes. Then the data are transferred to EUMETSAT in a progressive manner. The progressive transfer continues throughout the processing of the data

and the dissemination to the users, meaning that the users receive data of relatively constant "age". At EUMETSAT's central Product Processing Facility (PPF) the ASCAT Level 0 data are converted to calibrated Level 1 backscatter data. The time from sensing at this stage is about 135 minutes. For European coverage, the processing of the ASCAT data can be sped up by making use of EUMETSAT's Advanced Retransmission Service (EARS). This service collects data received by a network of ground stations around the Atlantic and Artic Oceans, which forward the data to EUMETSAT immediately after reception. In this way, Level 1 processing can be completed within 30 minutes after data reception. Immediately after processing at the PPF, the ASCAT Level 1 data are distributed in near real time via EUMETSAT's Data Distribution System (EUMETCast). EUMETCast utilizes the services of telecommunication satellites to distribute data to users in Europe, Africa and America.

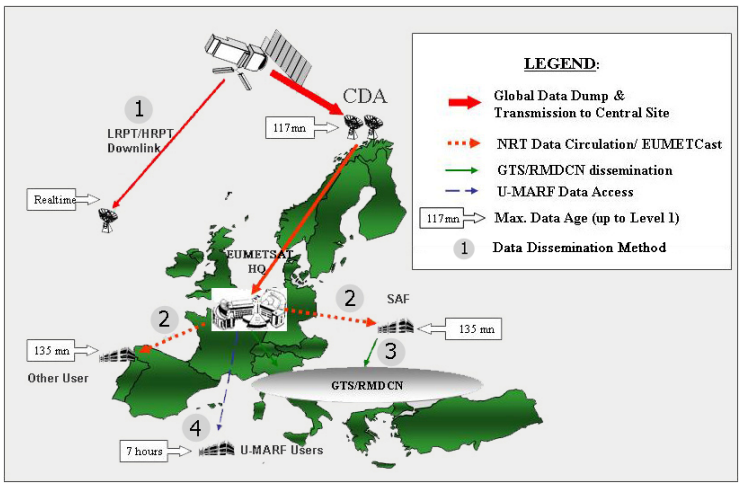

Figure 2-1: *EPS data distribution scheme © EUMETSAT.*

The Level 2 soil moisture data, as defined here, are still "close" to the satellite. The sampling is irregular both in space and time. They are expressed in degree of saturation, which is a physical quantity ranging between 0 (no water in the soil) and 1 (all the soil pores are filled with water). The depth of the remotely sensed soil layer is relatively shallow and depends on wetness conditions, from a few millimetres when wet to few centimetres when dry. Because it is a relatively complex product it is expected that only advanced users will be capable of using the Level 2 soil moisture data directly. Before suggesting the architecture for Level 2 and Level 3 processing, let us address user requirements in the next chapter.

2.2 User Requirements

Even though this study was in principle only concerned with NWP requirements, we took on a larger perspective, including other potential user groups as well. Let us consider following prospective user groups:

- **Numerical Weather Prediction:** The pilot users are the consortium members of the NWP SAF. A survey of their requirements carried out as part of this study showed that they are principally interested in soil moisture data that are as "close" as possible to the satellite measurements [1]. In our notation these are the Level 2 soil moisture data. The data must be provided with quality indicators in NRT.
- **Hydrology:** Prospective operational pilot users are the Joint Research Centre (JRC) of the European Commission and partners/users of the Hydrology SAF. Our current understanding is that operational hydrological users require surface soil moisture products in a very timely fashion particularly in the case of flooding, but only for specific regions/catchments. Hydrologists are also interested in profile soil moisture data. The 25 km spatial resolution of the ASCAT is considered to be a serious limitation of the data for hydrologic applications.
- **Agrometeorology:** Operational agrometeorological users such as the UN Food and Agricultural Organisation (FAO) or the US Department of Agriculture (USDA) are interested in weekly/decadal profile soil moisture products of all crop growing areas worldwide. In addition, for determination of drought conditions or excessive wetness they want to have soil moisture anomalies compared to long-term means.
- **Scientific community:** Other than the operational user communities above, the scientific community has no need for operational soil moisture products. Also, timeliness is normally not an issue. Their main interest is in long-term, consistent data sets for both surface and profile soil moisture. Equally important is that the method and data are well documented in the peer-reviewed literature.

An important lesson learned from these considerations is that, for the time being, only the NWP community requests global near-real-time Level 2 surface soil moisture data in orbit geometry. All other user groups have a preference for obtaining regularly sampled, value-added Level 3 soil moisture product. The specific requirements can differ strongly with respect to spatial resolution, spatial extent, temporal

sampling rate, timeliness, product cycle, data availability, layer depth, accuracy, and thematic content of the remotely sensed soil moisture data (e.g. absolute versus relative soil moisture values). As a result, there is not one single method for converting the Level 2 surface soil moisture data into Level 3 soil moisture data, but many. Accordingly, several specific Level 3 product lines and data distribution chains have to be built up in order to meet the requirements of different user communities (Figure 2-2). This becomes even more apparent when the requirements of other potential user groups such as fire brigades, locust fighting organizations, water resource managers, etc. are considered.

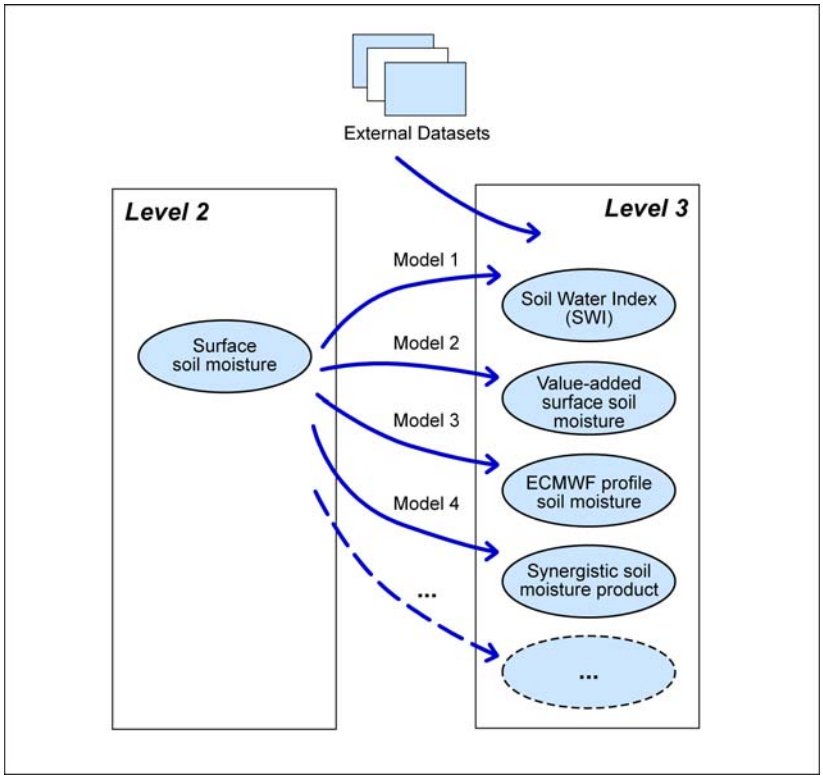

Figure 2-2: *Level 2 and Level 3 processing architecture for meeting variable user requirements.*

The conclusion is that the Level 2 processing architecture should be designed to meet the requirements of NWP, utilizing the best technical performance offered by the METOP ASCAT and the EPS system architecture. To meet the requirements of the other user communities dedicated Level 3 processing lines have to be developed, building upon the Level 2 processing architecture. The architecture for the Level 2 processor is discussed in the next section, followed by a short description of prospective Level 3 processing lines.

2.3 Level 2 Soil Moisture Processor

The solution which best meets the requirements of the NWP community is to install the Level 2 soil moisture processor centrally at EUMETSAT's PPF. This is because at the PPF the Level 2 processing could be performed directly after the Level 1 processing. As we demonstrated under contract EUM/CO/05/1421/HGB, the Level 2 soil moisture processor is computationally inexpensive. Complete ASCAT orbits can be processed in a matter of seconds using the near-real-time software developed by TU Wien, called WARP^{NRT}. In this way, practically no time is lost for retrieving the soil moisture data. The Level 2 soil moisture data could be collocated to the Level 1 backscatter data and distributed immediately over EUMETCast. As a result, NWP centres can receive global soil moisture information about 135 minutes after sensing, European data within about 30 minutes (Figure 2-3). This is deemed very important for NWP applications because timeliness is critical for accepting the ASCAT data as input into the NWP assimilation schemes.

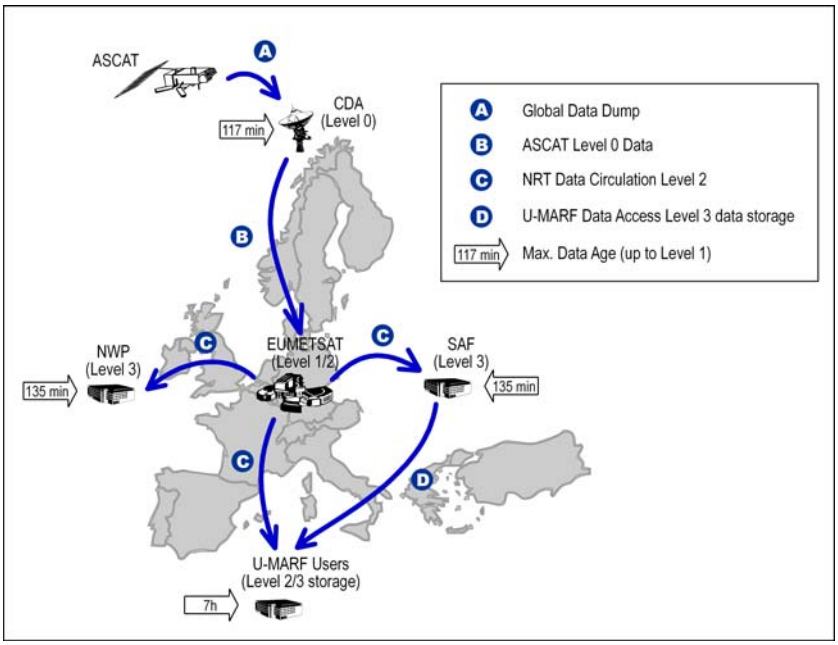

Figure 2-3:
Global Level 2 processing architecture.

The implementation of the Level 2 processor at other locations may in principle be justifiable because of the moderate processing and maintenance efforts. However, valuable time would be lost by transmitting the data to the remote location, processing it there and uploading the data to EUMETCast.

2.4 Level 3 Soil Moisture Processing Lines

Because the NWP centres only require Level 2 surface soil moisture data this implementation plan does not address the generation of value-added Level 3 soil moisture products. However, prospective Level 3 products are mentioned here to show linkages to other on-going activities, most importantly the Hydrology SAF and the Land SAF. Level 3 products are obtained by some kind of modelling approach using the ASCAT Level 2 and other data sources as input. A typical Level 3 product is an estimate of the soil moisture content for different soil layers and different temporal and spatial sampling characteristics. Prospective ASCAT Level 3 products are:

- **Soil Water Index (SWI)**: This index is obtained by filtering the surface soil moisture time series with an exponential function to produce a red-noise like profile soil moisture time series. This is the current standard ERS-1/2 soil moisture product distributed to users.
- **Disaggregated surface soil moisture**: The 25 km spatial resolution of Level 2 surface soil moisture products is not sufficient for many hydrologic applications. Therefore, a method for disaggregating the Level 2 data to a finer grid is an important development goal. This subject will have to be taken up by the Hydrology SAF which aims to address the needs of operational hydrologic users in Europe.
- **ECMWF profile soil moisture**: Also within the framework of the Hydrology SAF it is planned that ECMWF develops a method for assimilating ASCAT Level 2 surface soil moisture products into their models for obtaining more physically-based profile soil moisture estimates.
- **Synergistic soil moisture product**: There have been discussions with the Land SAF of how to utilize the complementary information content of microwave and thermal infrared data. While the microwave data provide rather direct information about the surface soil moisture content at 25 km independent of atmospheric conditions, optical and infrared imagery as provided by Meteosat Second Generation (MSG) provides indirect information about the profile soil moisture content at a much higher spatial resolution, albeit only at clear-sky conditions. Therefore the idea is to use the ASCAT Level 2 soil moisture and surface temperature and albedo data produced by the Land SAF to produce a synergetic profile soil moisture product (0-100 cm layer) with a temporal resolution of 1-2 days and a spatial resolution of 2-5 km.

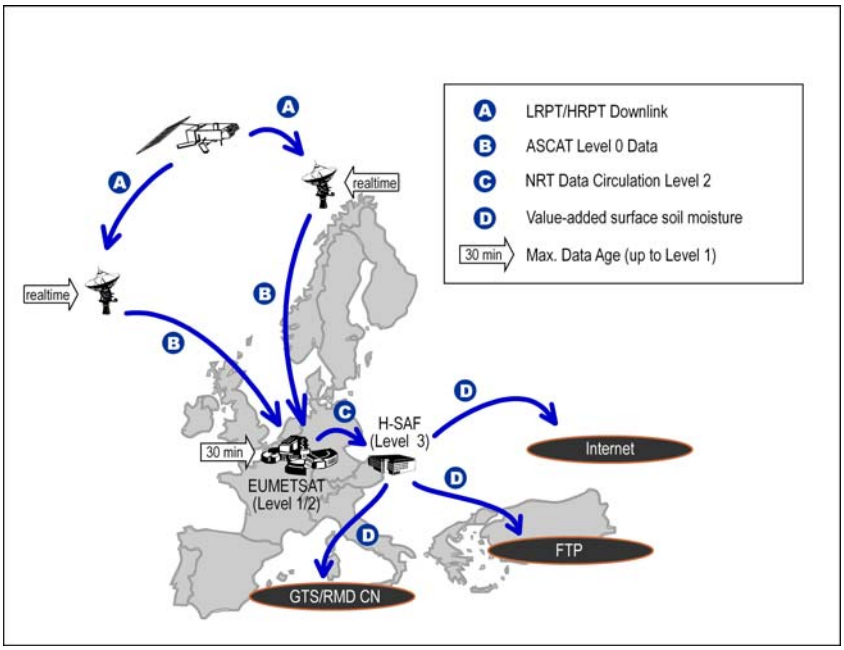

Figure 2-4:
Potential Level 2 and Level 3 processing architecture for surface soil moisture products in orbit geometry and value-added surface products.

As an example, a potential system architecture for the H-SAF surface soil moisture product is shown in Figure 2-4. The H-SAF receives EARS Level 2 surface soil moisture products over EUMETCast within about 30 minutes, performs several processing steps for producing a Level 3 product most suited for hydrologic users, and distributes the data immediately afterwards over different channels to reach the various hydrologic user groups. Level 3 processing could e.g. include a projection of the orbit data into national coordinate systems (taking the topography into account), disaggregation of the 25 km pixels to a finer grid (e.g. 1 km), and by adding various quality information layers. The disaggregation method could e.g. be based upon land cover information or C-band backscatter data acquired with the Global Monitoring Mode of the ENVISAT Advanced Synthetic Aperture Radar (ASAR), where recent research findings indicate that a useful downscaling layer can be computed.

3 State of the Art

3.1 Pre-Existing Know-How

The Institute of Photogrammetry and Remote Sensing (I.P.F.) of the Vienna University of Technology (TU Wien) has been developing algorithms and software for producing soil moisture data from ERS-1/2 scatterometer data since 1994, starting with the master thesis of Wagner in 1995 [6]. The initial algorithm developments up to the year 1998 have become possible thanks to a number of fellowships to support the Ph.D. work of Wagner and have been carried out in collaboration the European Space Agency (ESA) and the Joint Research Center of the European Commission (JRC). After that funding came from the Austrian Science Fund (FWF) and the European Space Agency (ESA Data User Programme and Market Development Programme) which supported the Ph.D. study of K. Scipal and the application and testing of the soil moisture retrieval algorithms at a global scale. Within the ESA funded projects the focus was on drought monitoring and yield estimation using the scatterometer derived soil moisture data as input. TU Wien was only responsible for the soil moisture retrieval. The agrometeorological developments were carried out by the project coordinator NEO (http://www.neo.nl/) in collaboration with Alterra and the University of Leuven. The company NEO also coordinated the ESA funded CLIMSCAT project, which was the first project to analyse the potential value of scatterometer derived soil moisture for climate and meteorology applications [7].

The scientific basis and algorithms for the TU Wien method have been fully published in a series of conference and journal papers, most important of which are [7-13]. The most complete descriptions of the algorithms can be found in the Ph.D. thesis of Wagner [14] and Scipal [15].

The software for processing the scatterometer data is called WARP (soil WAter Retrieval Package) and is written entirely in the software language IDL (Interactive Data Language). It currently comprises 745 IDL procedures/functions, all written by the staff of the TU Wien. It has evolved in several versions from a command-line software package

for processing of small data sets only to a global processing system with graphical user interfaces.

- Version 1 was ready in 1995 and included the routines for the normalization of the backscatter measurements and error models.
- Version 2 included an improved data base concept and allowed the application of the then existing algorithms to different regions. Instead of IDL it was written in the programming language PV-Wave. Since this version was developed during a fellowship term at ESA, ESA has had the source code of this software version. There has been no discussion about setting up a formal agreement with respect to the future use of the software.
- Version 3 was developed within the framework of an European Ph.D. fellowship programme at the JRC in Ispra. Consequently, JRC had version 3 of the software package. It already included all crucial processing steps and algorithms, but was only applicable to small regions due to limitations in the underlying data base concept. Also, this version was written in PV-Wave. Issues of intellectual property right (IPR) were shortly discussed between JRC and Wagner, but never lead to any written agreement.
- Version 4 was developed completely from the scratch since it employed new data base concepts and new data formats for global processing. Also, it was decided to move back to IDL. It is the current version and was used to produce the "Global Soil Moisture Archive 1992-2000 from ERS Scatterometer Data" http://www.ipf.tuwien.ac.at/radar/ers-scat/home.htm.

The most distinct feature of WARP is that all processing is done in the time domain. Since scatterometer data arrive in image format the data need to be reorganized from an image to a time series format in the first processing step. Only for display and representation data are transformed back to the spatial domain.

3.2 Near-Real-Time Level 2 Processor

Because in WARP all processing is done in the time domain it cannot be used straight away for NRT processing of ASCAT orbit data. The solution is to develop a stand-alone software package for NRT processing, which uses as input the global parameter data base derived using WARP to retrieve surface soil moisture directly from the orbit data. We refer to this software package as WARP^{NRT}. The first version of WARP^{NRT} was developed as part of contract EUM/CO/05/1421/HGB for use with 50 km ERS-2 scatterometer data and builds

upon the algorithms and data bases of WARP 4.0. The general characteristics of WARP and WARP^{NRT} are compared in Table 3-1. While WARP is an extensive, relatively complex software system, WARP^{NRT} is a comparably small software programme which can be run in a batch-mode as part of an automatic processing chain. In WARP^{NRT} following processing steps are carried out:

1. reading the incoming backscatter images
2. re-sampling of the global parameter data base to the orbit grid
3. application of the algorithms to retrieve surface soil moisture values (and other products such as the normalised backscattering coefficient and a number of quality parameters)
4. storing the output image files

Strictly speaking, both WARP and WARP^{NRT} form the Level 2 soil moisture processor. However, for operational applications only WARP^{NRT} needs to be considered.

	WARP	WARP^{NRT}
Purpose	Processing of scatterometer data archives	Operational NRT processing
Programming language	IDL	C
Processing strategy	Algorithms are applied to long-term time-series for a predefined global grid	Algorithms are applied to scatterometer orbit data
Inputs	Complete ERS-1/2 and METOP data archives	• NRT scatterometer data in satellite geometry • Global parameter data base
Outputs	• Long-term surface soil moisture time series • Global parameter data base	Surface soil moisture maps in satellite geometry

Table 3-1: *Comparison of software packages WARP and WARP^{NRT}.*

3.3 Intellectual Property Rights

The property rights concerning the software packages WARP 4.0 and WARP^{NRT} 1.0 for processing 50 km ERS-1/2 data were discussed in preparation of the contract EUM/CO/05/1421/HGB. To ensure that EUMETSAT can run and improve the Level 2 soil moisture processor on its own it was agreed that:

Article 8.2. All intellectual property rights developed in the performance of this contract, including any exercised option, shall belong to EUMETSAT in their entirety. EUMETSAT shall own WARP^{NRT} 1.0 in C and WARP^{NRT} prototype in IDL. In case certain intellectual property rights by law are not transferable in their entirety, EUMETSAT

shall receive an exclusive irrevocable licence to all rights making up the intellectual property rights in question. This shall include the right to grant sub-licenses. With respect to WARP^{NRT} prototype in IDL the Contractor [TU Wien] shall receive a non-exclusive, irrevocable, world-wide license to use, copy and modify WARP^{NRT} prototype in IDL for TU Wien's purposes.

Article 8.3. With respect to the software WARP 4.0, and any other software furnished under this contract, including any exercised option, but developed prior and independently of this contract (hereafter 'Licensed Reused Software'), EUMETSAT, including EUMETSAT's on-site Consultancy, shall have a royalty-free, perpetual, non-exclusive, irrevocable world-wide license to use, copy and modify the Licensed Reused Software for EUMETSAT purposes.

These agreements will equally apply to the next software generation to process 25 km ASCAT data and reprocessed ERS-1/2 scatterometer data (WARP 5.0 and WARP^{NRT} 2.0).

4 Research & Development Plan

4.1 Tasks

Significant research and development work is required to build up the operational ASCAT Level 2 processor. Firstly, WARP 5.0 needs to be developed from the scratch because of a number of major improvements and new features which affect all parts of the processing:

- New global grid definition
- Updated data base structure
- Moving from 50 km to 25 km
- Improved algorithms (modelling of azimuthal effects, improved slope model, better correction of dry/wet reference values, volume scattering in dry sandy soils, land cover changes, etc.)
- Improved error modelling and quality flags
- Improved handling of data re-analysis procedures to produce consistent long term data sets and updating of the global parameter data base
- New modules for independent checking of ASCAT calibration (consistency with ERS-1/2 scatterometer calibration)

These improvements will flow directly into WARP^{NRT} 2.0. In addition to developing the software packages, following research efforts and activities are important:

- Critical analysis of algorithms compared to other retrieval methods
- Error propagation modelling
- Continued development of methods to use external data sets to indicate problems in the soil moisture retrieval due to snow, freezing, topography, inundation and wetland dynamics
- Continued validation of ERS-1/2 and METOP soil moisture products
- Joint research activities with pilot users from the different user communities (NWP, hydrology, agrometeorology, etc.)

- Collaboration on data assimilation techniques
- Cooperation with SMOS and HYDROS science teams
- Investigation of scaling issues, e.g. using ENVISAT ASAR
- Analysis of long-term trends in ERS-1/2 and METOP soil moisture data
- Publications in peer-reviewed journals and conferences

4.2 Milestones

The overall goal is to deliver the operational version of the Level 2 soil moisture processor to EUMETSAT in December 2007 to start NRT production of 25 km ASCAT soil moisture products in 2008. For testing pre-operational versions of the WARP^{NRT} software will be delivered to EUMETSAT beforehand. The foreseen WARP^{NRT} versions are listed in Table 4-1. Table 4-2 provides information about the databases. Please note in particular that WARP^{NRT} 2.0 uses a global parameter database at the 12.5 km grid, but still derived from historic 50 km ERS-1/2 data. The main motivation for this planning is that sufficiently long time series of 25 km ERS-2 and ASCAT data are expected to become available only in 2007. Therefore, for testing of WARP 5.0 and WARP^{NRT} 2.0 the readily available 50 km data from ERS-1 and ERS-2 from the years 1992-2000 will be used.

The milestones of the project, including the development deadlines for the WARP software versions, are presented in Table 4-3.

Table 4-1: *WARP^{NRT} Versions*

Date	WARP^{NRT}	Algorithms as in WARP	Database Identification	To be used for	Comments
12/2005	1.0	4.0	1.0	50 km ERS-2	
9/2006	1.1	4.0	1.0	50 km ASCAT & ERS-2	Cross-calibration of ASCAT and ERS not checked
1/2007	2.0	5.0	2.0	25 km ASCAT	Resolution of NRT data (25 km) and database (50 km) does not match
12/2007	2.1	5.1	3.0	25 km ASCAT	**Operational version**

Date	Data-base ID	Sensor/ Resolution	Years	Processed with WARP @ Grid	Comments
2002	1.0	ERS-1/2 50 km	08/1991-01/2001	4.0 @ 25 km Grid	Current version
12/2006	2.0	ERS-1/2 50 km	08/1991-01/2001	5.0 @ 12.5 km Grid	50 km data sampled to 12.5 km grid
12/2007	3.0	ERS-2 and ASCAT 25 km	3-5 years ERS-2 & 1 year ASCAT	5.1 @ 12.5 km Grid	Availability of 25 km ERS-2 data depends on ESA

Table 4-2: *Database Identification*

Date	Milestones
09/2006	WARP^{NRT} 1.1 ready
10/2006	WARP 5.0 ready
12/2006	Database 2.0 ready
01/2007	Delivery of WARP^{NRT} 2.0 to EUMETSAT
09/2007	WARP 5.1 ready
11/2007	Database 3.0 ready
12/2007	Delivery of WARP^{NRT} 2.1 to EUMETSAT

Table 4-3: *Milestones*

4.3 Major Work Packages

Due Date	Description
03/2006	Implementation of 12.5 km Discrete Global Grid
04/2006	Report on new azimuthal model
06/2006	Report on new slope and curvature models (seasonal behaviour)
06/2006	Advisory flag fields for 12.5 km grid
08/2006	Report on new dry/wet correction
09/2006	Implementation and testing of WARP^{NRT} 1.1 for 50 km ASCAT data
10/2006	Implementation and testing of WARP 5.0 with 50 km ERS-1/2 data
12/2006	Global application of WARP 5.0 to 50 km 1992-2000 ERS-1/2 data to produce test data base 2.0 at 12.5 km grid
01/2007	Implementation and testing of WARP^{NRT} 2.0 for 25 km ASCAT data
01/2007	Demonstration and on-site support for implementation of WARP^{NRT} 2.0 at EUMETSAT
03/2007	Improved error model for use with WARP 5.1
05/2007	Report on errors and problems of WARP 5.0 used with 25 km ERS-2 and ASCAT data
07/2007	Report on cross-calibration of ERS-2 and ASCAT
09/2007	Implementation and testing of WARP 5.1 for 25 km ERS-2 and ASCAT data
10/2007	Report on WARP 5.1 algorithms
11/2007	Global application of WARP 5.1 to 25 km ERS-2 and ASCAT data to produce global parameter data base 3.0 at 12.5 km grid
11/2007	Implementation and testing of WARP^{NRT} 2.1 for 25 km ASCAT data
12/2007	Demonstration and on-site support for implementation of WARP^{NRT} 2.1 at EUMETSAT

Table 4-4: *Major Work Packages for implementation of Level 2 ASCAT soil moisture processor (Lists does not include scientific activities, e.g., validation, nor Level 3 specific work).*

4.4 Risks

There are a number of risks which may delay the completion of the work:

- **Reprocessing of ERS-1/2 data**: ESA plans to reprocess the entire ERS-1/2 data archive to 25 km. This new data set is needed as input to WARP 5.0 to calculate the global parameter data base necessary for the NRT processing of ASCAT 25 km image products. According to our latest information ERS-2 reproduction should start in the beginning of 2006. One year of data is processed in about 3 months. This means that for the first 25 km Level 2 soil moisture processor it is expected that three to five years of ERS-2 data and initial ASCAT data are available to calculate the global 25 km parameter data base. This is sufficient for a robust parameter estimation. However, a delay in the reprocessing activities at ESA would directly cause a corresponding delay of our activities.
- **Transition from ERS-2 to METOP**: In order to check the cross-calibration from ERS-2 to METOP at least one year of overlapping data would be extremely valuable. This is because already relatively small differences in the absolute calibration of the backscattering values can introduce a noticeable bias in the surface soil moisture data. Therefore a further delay of the launch of METOP or a discontinuation/failure of ERS-2 before METOP launch may delay our assessment of the ASCAT calibration (with respect to ERS-1/2).
- **Changes in instrument design**: In [16] we discussed the potential impact of the slight changes in instrument design from the ERS-1/2 scatterometer to the METOP ASCAT. Even though this does not appear to be a critical factor, it cannot be excluded with 100 % certainty that one or the other problem arises.

5 Funding

If no major problems are encountered then the funding should be sufficient to successfully complete the implementation of the Level 2 processor. Table 5-1 gives an overview of all relevant projects, including the specific tasks and objectives of each project.

Project	Funded by	Duration	Objectives and Tasks of TU Wien
geoland (coordinated by InfoTerra)	GMES, 6. Frame-work Programme of the EC	2004-2006	• Reanalysis of ERS data • Validation and cross-comparison with other geoland products • Cooperation with agrometeorological modellers and users • Extensive reporting and user training
GLOBESCAT (coordinated by K. Scipal, TU Wien)	Translational Programme, Austrian Science Fund	2005-2007	• Develop WARP 5.0 • Produce global, long-term 25 km soil moisture data for the period 1991-2007 • Distribute soil moisture data to operational pilot users (ECMWF, FAO, JRC) for demonstration • Validation and scientific publications
Soil Moisture in Ungauged Basins (coordinated by G. Blöschl, TU Wien)	Austrian Academy of Sciences	2004-2006	• Assimilation of ERS scatterometer soil moisture in soil moisture accounting scheme over Austria • Investigate problems in soil moisture retrieval for the difficult environment of Austria (mountains, snow, dense forest, etc.) • Re-processing of scatterometer data over Austria with improved algorithms
NWP SAF Associated Scientist Mission	Met Office/NWP SAF	2005	• NWP SAF User Requirement Study • Data streams and data formats • Define a new global grid • Develop strategies to cross-compare the calibration of ERS-1/2 and METOP • Investigate azimuthal effects • Implementation plan for Level 2 processor
ERS SCAT soil moisture processor	EUMETSAT	2005	• Develop WARP^{NRT} 1.0 for 50 km ERS-2 data
METOP ASCAT soil moisture processor	EUMETSAT *currently under review*	2006-2007	• Generation of global parameter data base required for ASCAT • Develop WARP^{NRT} 2.0 for 25 km ASCAT data

Hydrology SAF (Soil moisture cluster coordinated by ZAMG)	EUMETSAT	2005-2010	• Develop surface soil moisture products which meet the needs of operational hydrologic users (Level 3) • Cooperation with ECMWF to produce profile soil moisture from assimilated ASCAT surface soil moisture products (Level 3) • Participation in hydrologic pilot studies and validation
Synergistic soil moisture product	Land SAF *currently under review*	2005-2007	• Study the feasibility of developing a synergistic Level 3 soil moisture product using ASCAT Level 2 data and Land SAF surface temperature and albedo as input

Table 5-1: *Projects at TU Wien.*

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