Methodology for the processing of ASAR-wide swath data for the derivation of land surface properties of the Mosel catchment

Appel, F. (1), Bach, H. (1), Demuth, N. (2), Loew, A. (3), Ludwig, R. (3), Mauser W. (3), Waske, B. (3)

(1) VISTA Geowissenschaftliche Fernerkundung GmbH
Gabelsbergerstr. 51, D-80333 München, Germany
appel@vista-geo.de, bach@vista-geo.de
(2) Landesamt für Umwelt, Wasserwirtschaft und Gewerbeaufsicht, Rheinland-Pfalz
Amtsgerichtsplatz 1, D-55276 Oppenheim, Germany
norbert.demuth@wwv.rlp.de
(3) Department of Earth and Environmental Sciences
Section Geography, University of Munich
Luisenstr.37, D-80333 München, Germany
a.loew@lmu.de, r.ludwig@lmu.de, w.mauser@iggf.geo.uni-muenchen.de

1. ABSTRACT

Operational application of remote sensing data for hydrologic tasks in meso- to large scale watersheds requires frequent observations with wide swath imagery. The challenge for the derivation of operational products from heterogeneous image geometries is caused by the large spatial extent of WideSwath data and the related diversity of incidence angles.
The study describes the geometric and radiometric methods and techniques that were developed and applied to process ENVISAT-Wide swath data. For the operational application of Near-Real-Time (NRT) datasets provided by ESRIN/ESA, a fully automatic software for autonomous product generation was developed and tested sucessfully. Relevant parts of the developed and adapted methodology are the automatic geocoding of the WSM_1P datasets using orbit information, individual fine correction based on ground control areas and the correction of incidence angle influences.

2. PROJECT

The developments presented in this paper were achieved in the context of the Inferno+ project, funded by the German Aerospace Center DLR and led by the HVZ Karlsruhe. Within this project the integration of remote sensing information in operational water balance and flood forecasting models is performed. The project studies the potential of ENVISAT data for the operational flood forecast. The processed ASAR-WSM data are used to derive information on the spatial distributed and highly variable landsurface parameters snow properties and soil moisture. This information will be assimilated in the water balance model LARSIM, applied by the water authorities and flood protection agencies of Rhineland-Palatinate and Baden-Württemberg in order to improve flood forecast. More information on the project [1] and data assimilation [2] is given in dedicated publications.

3. METHODOLOGY

The derivation of land surface properties from ASAR imagery for larger scale areas firstly necessitates practicable and automated methods for data homogenisation. For an intended operational application of ENVISAT data in hydrological modelling, instant and accurate processing of the data is essential.
In order to allow for a sufficient temporal and spatial coverage of the area of interest, datasets from ascending and descending paths and various orbits need to be allocated and processed homogeneously.

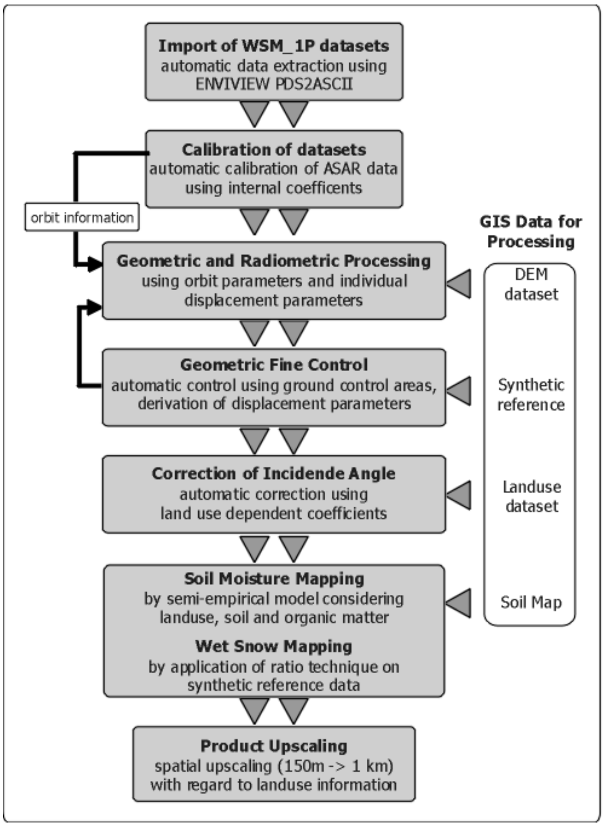

Fig. 1. Methodologies of automatic geometric and radiometric processing of ASAR WSM data

The application of remote sensing products in a continuously running water balance and flood forecasting model requires a fully automatic treatment of all available datasets. A methodology of processing incoming WSM_1P datasets towards soil moisture and wet snow products was developed by VISTA GmbH, in cooperation with the University of Munich, Dept. of Earth and Environmental Sciences, using ASAR datasets and the experience from previous methods of derivation of snow cover maps [3][4]. All parts of the schema (see figure 1) are enhanced for automatic processing with regard to the near-real-time availability of the ENVISAT ASAR data. For a automatic generation of products, all necessary datasets of the test site (450 km x 450 km), comprising the catchments of the Mosel (28000 km^2) and the Neckar (14000 km^2), are provided in GIS datasets.

3.1. Incoming Data and Import

All incoming ASAR WSM datasets, preferable in V/V polarisation, were imported using the ENVIVIEW routines (PDS2ASCII) provided by ESA. Within this fundamental step of the processing chain, the measurement datasets and the major processing parameters, including the orbit state vectors are extracted from the ASAR medium resolution images. Due to previous format errors miscellaneous importing tools were developed. These tools make it possible to extract single datasets from files containing multiple scenes or enable the analysis of faulty products. In case of multiple products an extraction of all contained single scenes and the determination of the spatial overlap with the test area is performed. Datasets matching largely with the test area are provided as binary raster files (internal format) and accompanying header file. For the online (via FTP) available NRT datasets the importing module is running autonomously.

3.2. Geometric and radiometric processing

The geometric and radiometric properties of any SAR images are influenced by terrain influences. For the generation of unaffected datasets a precise pre-processing, consisting on parametric geometric and detailed radiometric corrections of the WSM data, based on orbit and DEM information of the area is performed. The sophisticated processing (algorithm detailed described in [5]) is carried out for the investigation area of 450 km x 450 km (see Fig. 2). This processing step is carried out two times. First using the orbit information extracted from the orbit state vectors, enclosed in the main processing parameters of each WSM product, and a slightly smoothed DEM dataset to get approximate, incorrected position of the scene. After this step the displacement parameters are obtained automatically from the fine control (see 3.3). In a second pass of the geometry process, these additional parameters, together with the orbit parameters and a high resolution DEM are considered. As interim result, the backscatter coefficients of each processed 150 x 150 m^2 pixel, only affected by the surface characteristics and the wide ranging incidence angle, are stored.

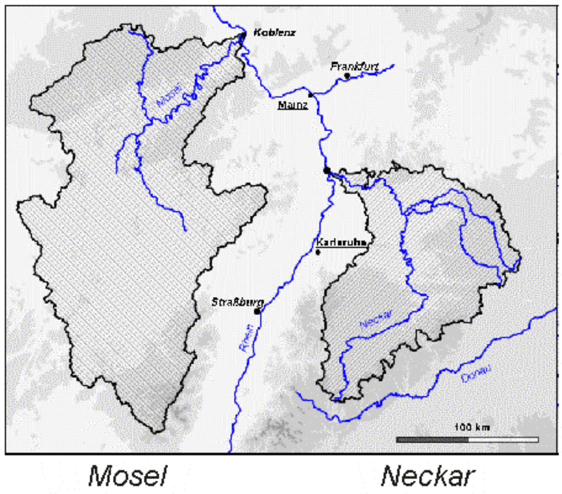

Fig. 2. Investigated catchments of the Mosel and Neckar in the South West of Germany and part of France

3.3. Geometric fine control

Due to sparse density of orbit information (only every 10-15 sec) and (ordinary) inaccuracies of the predicted orbit points a slightly deviation of the parametric geocoding can be observed. In practice, a spatially varying shift of several pixels (up to +- 10) relating to the simulated ASAR image can be detected. These divergences are ascertained on 48 ground control areas using automatic cross-correlation with a simulated ASAR reference dataset. The detected shift parameters for the scene are finally computed to 6 individual displacement parameters, using a multiple linear regression model. By considering this correction, applied on the image ground geometry, the orbit is indirectly rectified. Using the adjusted orbit parameters and the high resolution DEM (on approval from SRTM), a very precise geocoding of the ASAR WSM scene is performed. Remaining deviations after the second navigation run are in average less than 1 pixel (150m).

3.4. Correction of incidence angle

After the previous geometric processing the single image data is still influenced by the large (15-49°)

incidence angle variability. To manage the comparability of every dataset, a correction of this complex effect is essential. Based on the available image data (more than 50 datasets), the angular and annual characteristics of different land uses of the investigated area were analysed. This knowledge was summarized in different correction terms for an angular normalisation of the datasets [6]. A comparison between an uncorrected section of area and the result after incidence angle correction is shown in Fig. 3. The corrected images now allow a direct, independent analysis of the surface parameters.

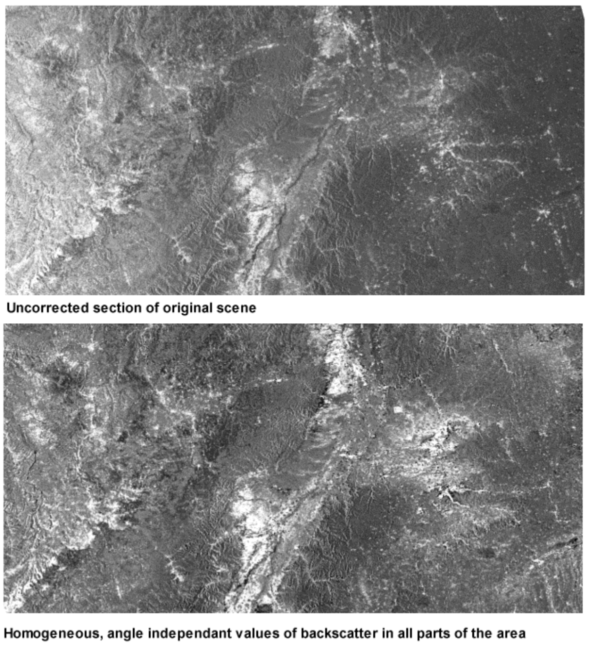

Fig. 3. Result of the WSM incidence angle compensation top: before correction; bottom: after correction

3.5. Soil moisture and wet snow mapping

In order to derive soil moisture information from ASAR data an adapted method, primary developed by the University of Munich using ERS data, is used [7][8]. It is based on an empirical compensation of the different terms (vegetation, biomass) affecting the backscatter coefficient. The soil moisture is finally calculated using the relationship between backscatter and the dielectric constant with help of soil texture information and subpixel information of the different land uses. The retrieved soil moisture values (of 150 x 150 m^2 image pixel) show high accuracy with field measurements. The ascertained rms error (less than 6 Vol%) is very close to the range of inner field variability (+- 5%) observed from point measurements [7].

The detection of wet snow is performed using a simple rationing approach, using a reference image, without snow cover and recorded under similar surface (vegetation) conditions. Wet snow pixels can be estimated using a threshold (-3.0 to -2.5 dB) for the difference between reference and snow image [4][6]. In case of ASAR WSM images (large incidence angle variability) an adequate pre-processing of the image data is important for snow detection. A synthetic reference image, generated from backscatter statistics of different land uses on the numerous available ASAR datasets, permits an uninfluenced, precise characterisation of the snow property conditions of the area.

3.6. Upscaling of products

Image processing and parameter retrieval is performed with a spatial resolution of 150m. For the comparison of surface parameters (snow, soil) from current ASAR data with results from operational water balance modelling and the imminent data assimilation, an adaption of the spatial resolution is needful. Therefore an upscaling algorithm is added to the processing chain. With this step, a final soil moisture / wet snow product is calculated using the information of the overlapping 150m cells. Since none of the intended information of surface parameters (relevant for hydrology) from cells dominated by settlements or forest can be derived, land use information (from additional GIS layers) is taken into account. Each resulting 1km^2 pixel contains the normalised information of arable land and grassland.

4. PERFORMANCE

For the spatial estimation of land surface parameters and their integration in operational modelling, the time offset between data recording / satellite pass and incoming product must be minimized. As the provision of snow cover information using NOAA-AVHRR can be realized within less than 1 hour after data reception [3][4], an immediate assimilation can be executed. SAR datasets from ERS and ENVISAT for application were only available after days or weeks so far. The previous datasets for the development of the algorithms were distributed on CD by mail and arrived with a delay up to several weeks. Within the first provided scenes several errors in the format and data occurred. For this datasets (in case of presents of all metadata) a manual treatment was necessary.
Since June 2004 the ordered ASAR WSM datasets were increasingly provided on a custom FTP directory.
With the availability of the first NRT datasets the software of autonomous product generation was tested

and the performance of processing logged. For the time span between sensing and delivery of final product several steps are important:

- Time from sensing to data processing at ESA (including downlink to acquisition station)
- Time between processing and presence of data file on FTP directory
- Time of FTP transfer
- Processing at VISTA's facilities

The experiences from the first three tests of NRT datasets (including automatic download) showed different delays on the way from sensing to final soil moisture map (see Fig. 4). As the processing from obtained data set can be done equable / regular in about 1.5 to 2 hours, the periods for the antecedent steps were quite different (see Tab. 1). Probable some improvements can be expected with increasing data distributions.

Tab. 1 Time delay in ESAs ASAR WSM processing

Date	*Sensing End [UTC]*	Delay1 'Transf' [min]	*Processing Start [UTC]*	Delay2 'Proc' [min]	*File on FTP-Dir [UTC]*
28.7.2004	*21:12*	38	*21:50*	26	*22:16*
13.8.2004	*09:46*	211	*13:17*	26	*13:44*
1.9.2004	*21:13*	54	*22:07*	120	*00:07*
Minimum		**38**		**26**	

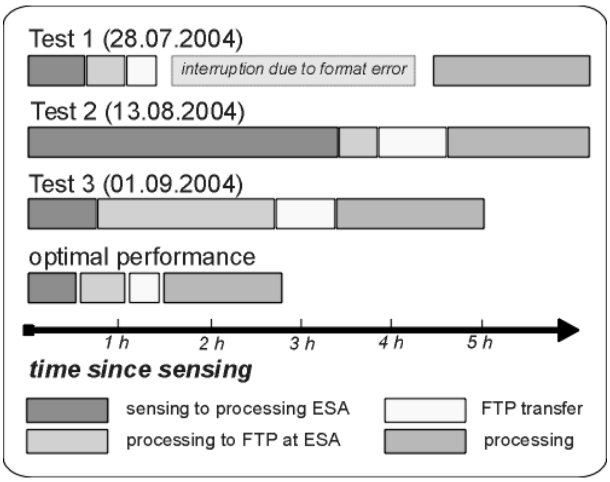

Fig. 4. Performance of ASAR NRT transfer and processing

During the first test run (overnight) an unexpected format error occurs, the following runs could be processed without any manual editing. Observed delays were enclosed in different parts in the data chain.
Processing of the online provided datasets (nominal 65MB per WSM_1P dataset) is carried out at VISTA's facilities using the in house developed software on standard PC hardware. Referring to this part of the process chain further improvements are possible. Summarized, in case of optimal performance of all steps a timeframe of less than 3 hours will be realistic.

5. RESULTS

With the presented methodologies and the developed software a rapid, precise and automatic processing of ENVISAT ASAR WSM data for assimilation into the models is at our disposal. During the test runs of the online available datasets, time series of the surface soil moisture patterns covering the Mosel and Neckar test area were derived. Figure 5 (next page) is showing the part of the Mosel catchment, after a period of almost dry weather (left) and intense rainfall (right). The partly increased surface soil moisture at the scene of 28.07.2004 can easily be detected by blue colour. Parts of the area densely covered by forest or settlements remain as 'no data'.

6. OUTLOOK

During the next winter routinely product provisions of soil moisture and wet snow cover are planned. The SAR based land-surface properties will further be combined with product of optical data. Both types of products together shall help to improve the performance of hydrological model used to predict runoff and allow flood forecast.
One problem of our approach is that acquisition of WSM data is often in conflict with the wishes of other ASAR users in Central Europe, who mostly prefer high resolutions. Switching from high to medium resolution requires a certain time span without possible acquisition. We are however looking forward to planned improvements at ESA, who recognised this problem ad try to reduce this time span for switching in the next future.

7. ACKNOWLEDGEMENTS

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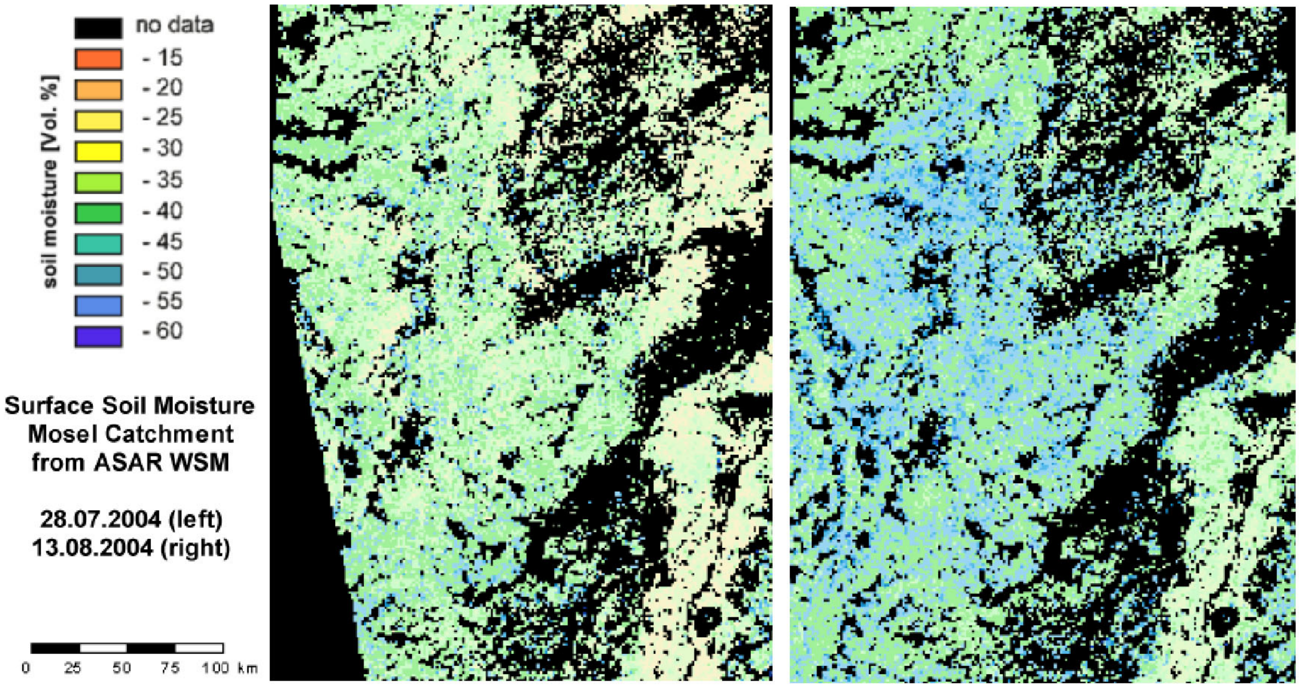

Fig. 5. Surface soil moisture of the Mosel catchment from ASAR NRT test during summer 2004 (1km spatial resolution)

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