MONITORING OF SPRING SNOWMELT WITH ENVISAT ASAR WS IN THE EASTERN ALPS BY COMBINATION OF ASCENDING AND DESCENDING ORBITS

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ABSTRACT

ENVISAT ASAR Wide Swath data from ascending and descending orbit have been normalized and combined in the eastern Alps in order to increase the covered area from 60-70% to up to 78%. Band rationing was applied for the identification of wet snow surface. Although that probability maps of thawing snow can be derived, combinations of morning and evening orbits are difficult to interpret in late spring. Wet snow could be identified for forested as well as un-forested regions. Areas, which have either thawed completely, only at the surface or such which have not yet undergone thawing, can be distinguished with the use of optical data such as SPOT acquired shortly after the ASAR images. ENVISAT Global mode data can also be used to detect snowmelt patters over large areas. Good temporal resolution allows the determination of snowmelt at altitudes above 2000 m in the study area.

Key words: ScanSAR; snow melt; time series.

1. INTRODUCTION

The Austrian Alps are often covered by clouds. This limits the use of optical sensors such as MERIS or MODIS for monitoring snow cover in the Austrian Alps. Even though snow is rather difficult to identify using Synthetic Aperture Radar (SAR) data, SAR satellites represent the only data source which could, in principle, guarantee frequent coverage at an acceptable spatial resolution. Previous studies have demonstrated that wet snow can be mapped using SAR data of high spatial resolution [1, 2]. To improve the temporal coverage - which is important for snow-melt models - SAR operated in ScanSAR represents an attractive alternative. Therefore the purpose of this study was to investigate the potential of ENVISAT ASAR ScanSAR to map wet snow in the eastern Austrian Alps. ENVISAT modes which have already been investigated for snow mapping are the Image Mode [3] and APP mode [4]. The ScanSAR modes which have been analysed in this study are Wide Swath (WS) and Global Mode (GM). Wide Swath has already successfully applied in Norway [5] but terrain is moderate compared to the Alps. Information cannot be retrieved from many areas due to layover. Therefore, ascending and descending ENVISAT ASAR wide swath acquisitions from the same day have been combined for the analyses of spring snowmelt for this study. The objective was to access how much information can be gained by such a combination of normalized ScanSAR data from varying frames. The results are compared to SPOT data. Additionally, a time series of coarse resolution GM images was established and investigated with special emphasis on spring season.

Table 1. ENVISAT ASAR WS data base

Date	**Descending Orbit (9:15)**	**Ascending Orbit (20:35)**
12.03.2005	X	X
31.03.2005	X	X
21.05.2005	X	X
04.04.2006	X	X
25.05.2006	X	X
13.06.2006	X	X

The study area is located in the eastern Alps, Austria (15–16 E, 47.3–48 N). It comprises 6.400 km^2 including Hochschwab (2277m), Rax (2007m) and Schneeberg (2076m). Many of the drinking water springs for the water supply system of Vienna are located in these Karst areas south of Vienna. Snow plays an important role as water storage and especially during spring time the melting snow feeds the springs rather directly. Therefore knowledge about the current condition of the snow cover and the process of snow melt is important in order to be able to guarantee sufficient water supply of high quality.

2. METHODS

Altogether 10 ENVISAT ASAR WS scenes are available for March to June 2005 and 8 scenes for April to June 2006 (Table 1). Three ascending/descending pairs are

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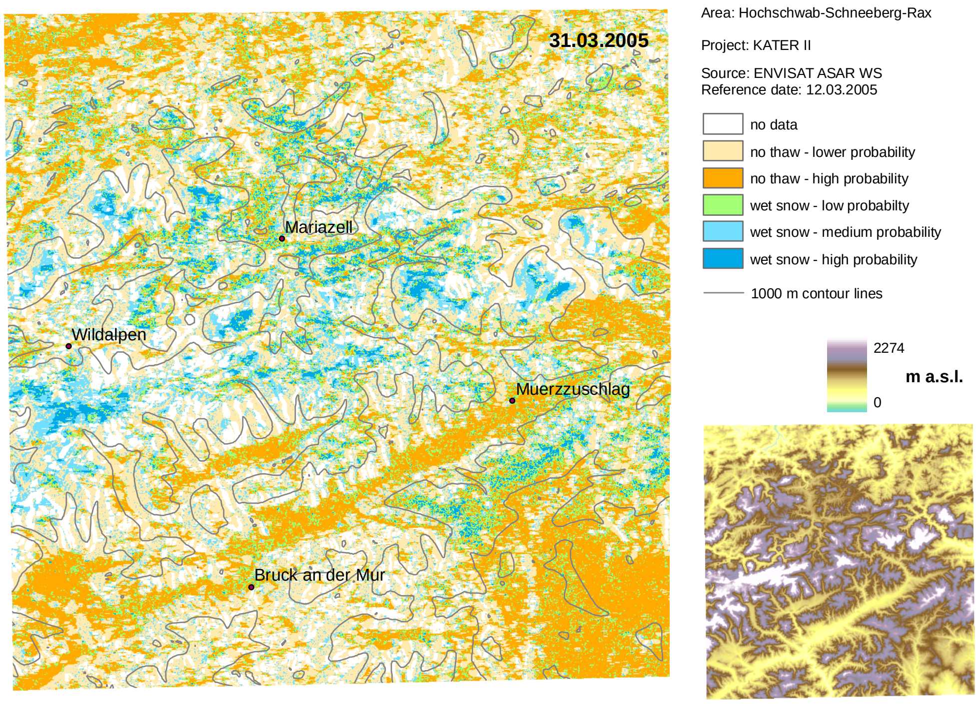

Figure 1. Snow probability classes from ASAR WS, 31.03.2005; plus DEM (lower right)

available for each year 2005 and 2006. An inter-annual comparison, however, is only possible for two dates: end of March/beginning of April and middle of May. A spatial shift of orbits between the years influences comparability as well. The first data pair from March 2005 has been used as reference data set since it features complete snow cover under dry/cold conditions. It serves as base for all ratio calculations which allow the identification of wet snow areas [1].

ASAR Global Mode data are an alternative source. Pixel spacing is only 500 m but the temporal sampling rate is higher and data are more accessible. A high temporal resolution is advantageous for processes such as spring snow melt.

All ENVISAT ASAR WS scenes have been preprocessed using the in-house software ESCAPE. It enables operational processing of Scansar data with the use of modules of the commercial software Sarscape (Sarmap)[6]. In a first step data are tested for errors and then radiometrically corrected and georeferenced using a photogrammetrically derived elevation model (25 m). ASAR GM data are preprocessed similarly but a 100 m SRTM (USGS) elevation model is used.

All results are available in UTM projection. WS data have also been normalized using a polynomial function for each image using the local incidence image what allows use of global classification methods. A location depended pixel based normalization approach is used for time series analyses of Global Mode data. Further on, a layover and shadow mask has been derived for WS what is crucial in the study region since elevation ranges between 320 m and 2277 m over short distances. Linear values served as input for the ratio calculation.

Eventually, the WS classification results of the same day were combined. The final mosaic is reclassified into classes of snowmelt probability. After pre-processing the following products are available: backscatter in linear units, backscatter in dB, a classification of layover and shadow. A further analysis takes place in five steps:

1. Reclassification of layover and shadow for each acquisition in order to provide a binary image (data/no data) for masking.
2. Calculation of backscatter ratio (linear) separate for ascending and descending orbit: reference image (12.03.2005)/ image of interest
3. Masking of ratio images (step 2) using the result of step (1)
4. Reclassification of masked ratio images. Areas with strong reduction of backscatter compared to the reference date are identified. The threshold is ratio value less than 1 for morning acquisitions at the beginning of snow melt. All further images are classified using a value of 2, what means that at least a reduction to half of backscatter is assumed.
5. Combination of results from descending (morning) and ascending (evening) orbits with deriva-

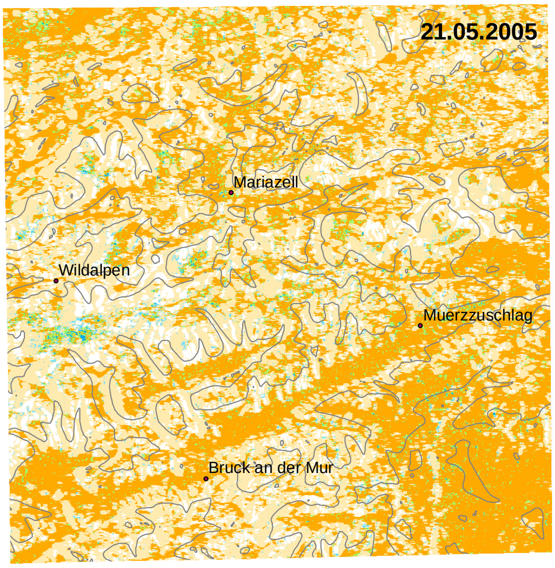

Figure 2. Snow probability classes from ASAR WS, 21.05.2006; for legend see Figure 1

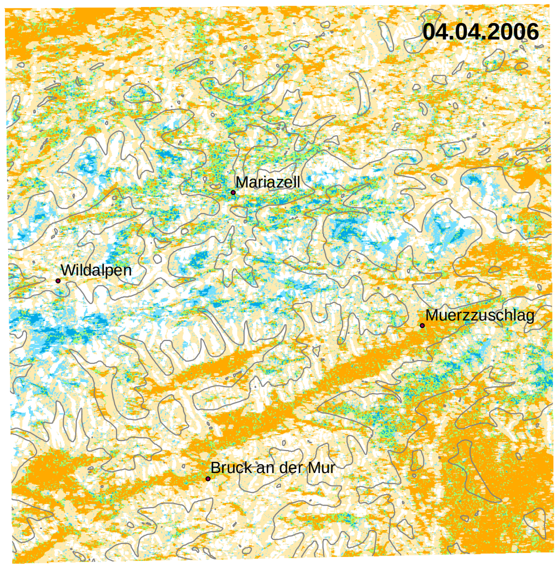

Figure 3. Snow probability classes from ASAR WS, 04.04.2006; for legend see Figure 1

tion of probability classes (Figures 1–3): 'Thawing snow with high probability' is assumed if sufficient backscatter decrease could be recorded in the morning and evening image. Medium probability corresponds to thawing snow either in the morning or on the evening, if no data could be derived due to layover or shadow effects in the corresponding image. If the backscatter change was too low for either the morning or evening image but high enough in the corresponding image, a low probability is assumed. Thawing snow is unlikely in case of negative results for both acquisitions or a combination of negative and no data. It should be noted that thawing snow can only be derived from both orbits during the major snowmelt period. In early summer, only morning data can be used to identify perennial and late lying snow patches.

ASAR Global Mode (1km) time series have been compared to the ASAR Wide Swath (150m) and SPOT (20m) results. Approximately 30 ENVISAT ASAR Global Mode acquisitions are available for Hochschwab by July 2006 (Figure 9). Mostly, dates are limited to the period September 2005 - February 2006. Pixel spacing of ASAR Global Mode is 500 m (resolution 1km). Two acquisitions over the study area exist for spring snow melt 2006.

Two SPOT images from 2005 (4th of April and 27th of May) have been orthorectified and classified for deriving snow cover and landuse maps. The images have been taken four days after the WS images. Snow cover information from SPOT was used to validate and also refine ASAR WS results.

3. RESULTS

3.1. Wide Swath

The ENVISAR ASAR WS data are acquired on descending orbit in the morning (9:15) and ascending orbit in the evening (20:35). Temperatures may vary extremely during some days due to specific weather conditions. Additionally, the temperature difference between morning and evening varies differently for varying altitudes. This affects both thaw processes and comparability of the two orbits. The latter is important for the reduction of layover and shadow effects, which impede data analyses. They could be reduced by combination of the different orbits (different viewing direction). Affected regions can be identified by reconstruction of acquisition geometry (sensor position, digital elevation model) for each scene. The different orbits complement one another to some degree.

The proportion of masked area increases by terrain slope and decreases with distance to sensor nadir. The latter causes differences between orbits. The western parts of covered areas are negatively affected during ascending orbit and the eastern parts during descending orbit. The ascending/descending constellation of a day differs between 2005 and 2005. This impacts the comparability between years. The proportion of masked area is lowest for ascending (evening) acquisitions of 2006. Data for 75% of the area of interest can be gained. Scenes from descending orbit are better for 2005 with 70%. Proportions from corresponding orbits are always 11-12 % lower. The combination of ascending and descending data provides a 78% data coverage.

Band rationing of the reference data (31.03.2005) with

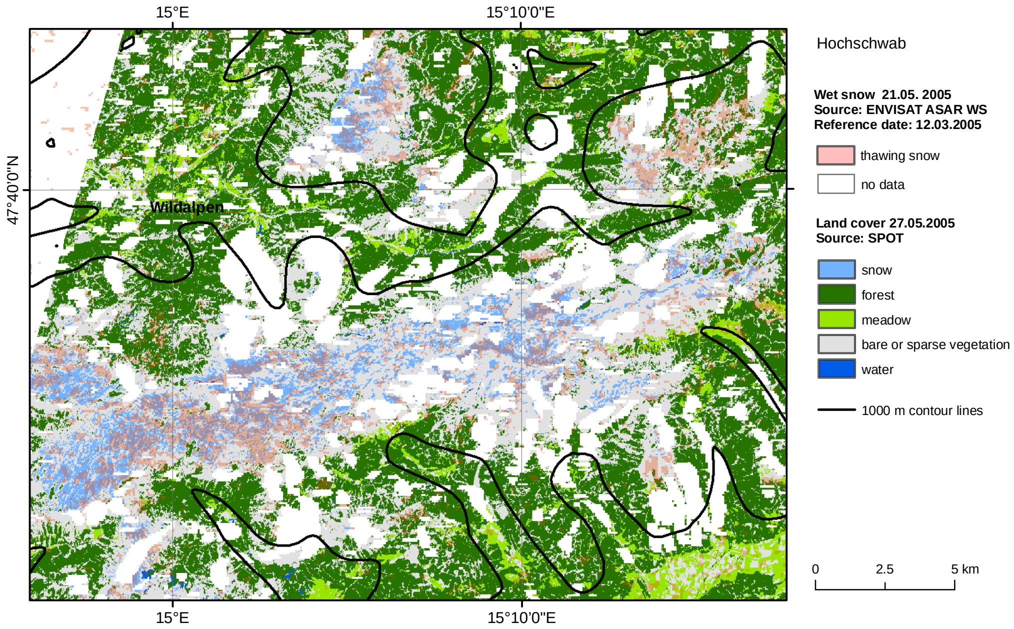

Figure 4. Comparison of snow areas with wet surface (ASAR WS 21.05.2005, transparent) with snow cover derived from SPOT data (27.05.2005). Overlaying regions appear purple.

each pair allows the identification of snow surface thaw since, in the Alps, backscatter usually drops when the surface turns wet. Due to differing acquisition times and thus weather conditions for ascending and descending orbit (9:15am and 8:35pm), classification thresholds needed to be determined differently.

The area lost due to layover effects (category 'no data') is larger for 04.04.2006 with 22% than for 31.03.2005 with 16.5%. This restricts a direct comparison. 1550 km^2 of wet snow surface could be detected in 2005, whereas only 1160 km^2 have been determined in April 2006 with 818 km^2 overlap. 45% of non-overlap regions correspond to no data' and 45% to no snow surface thaw. Anthropogenic impacts and natural patterns from vegetation and soil surface cause misclassifications along the valleys later in the season. Differing coverage causes again problems for comparison. The result from the 21.05.2005 has 12% no data' and from 25.05.2006 16.5%. In both years 340 km^2 have been classified as wet snow surface, but only 50% overlap. The other 50% are mostly found in valleys and caused by misclassification. For interpretation of the final snow melt phase a mask should be used which excludes regions below a specific altitude.

3.2. Comparison with SPOT

The ASAR WS results from 31.03. and 21.05. 2005 have been compared with SPOT based snow cover classification results. The SPOT images have been acquired 4 days after ASAR in both cases. Regions where snowmelt took place on the days before (as identified from ASAR WS) can be divided up into parts where the process has been completed (no snow cover in SPOT) and where some snow still remains (Figure 4). The latter were located at a mean altitude of 1300 m a.s.l. (standard deviation 290 m), whereas snowmelt had finished within the four days at 950 m a.s.l. (standard deviation 250 m). The SPOT image from May has also been used to derive a forest mask. This allows testing the suitability of C-Band for the detection of snow surface thaw in forested mountainous areas which represents 60% of the land cover. Thaw areas could be identified for forested as well as un-forested regions. On 31st of March 2005, 40% of the thaw area (of area not masked due to layover etc.) was located in forested area.

3.3. Global Mode

The entire Eastern Alps are still covered with snow in 16.03.2006 (Figure 6) and therefore backscatter is comparably high with values above -5 dB. Only the surrounding lowlands and larger valleys show lower backscatter. This situation is reversed approximately two weeks later (01.04.2006, Figure 7). Snow starts to thaw all over the mountain range and backscatter drops on mountain plateaux above 2000 m a.s.l. (e.g. Hochschwab, Figure 9). At the same time in the previous year, snow was only left at higher altitude (Figure 5).

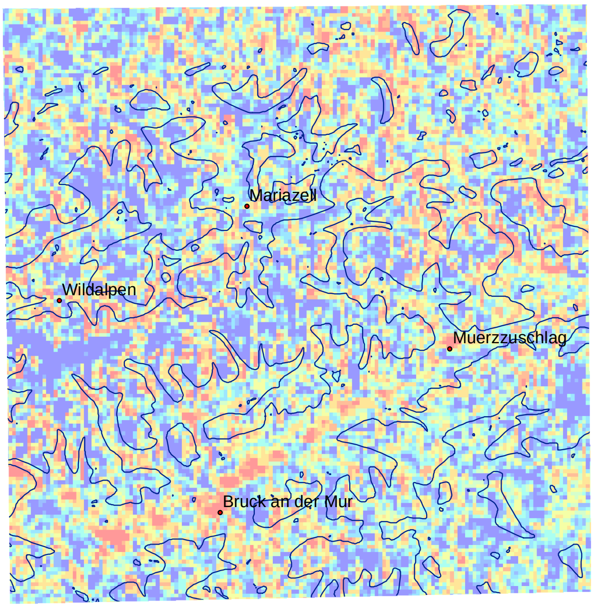

Figure 5. Global mode backscatter 03.04.2005

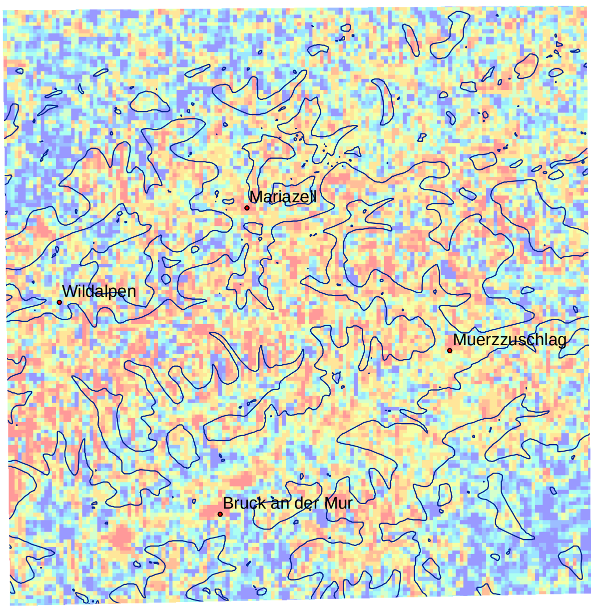

Figure 6. Global mode backscatter 16.03.2006

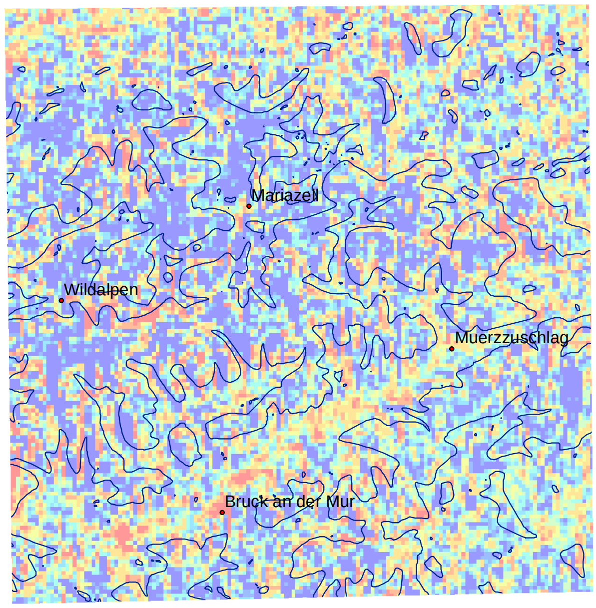

Figure 7. Global mode backscatter 01.04.2006

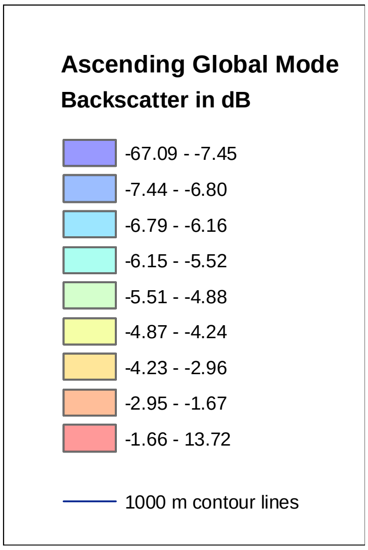

Figure 8. Legend for Global mode backscatter images

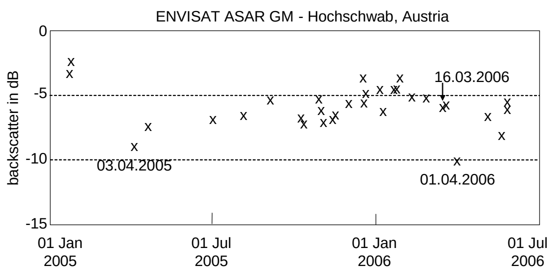

Figure 9. Global mode time series, 15.005 E 47.59 N

4. CONCLUSIONS

ASAR WS data are suitable for the identification of wet snow surfaces during the major snow melt period which occurs usually end of March/ beginning of April in the area of interest. Snow covered areas which are affected by snowmelt over a longer time period and regions where snow has disappeared more rapidly can be distinguished by comparison with optical data such as SPOT. Forest induced effects of identification of snow surface thaw cannot be shown with the available optical data. On the contrary, for thaw characteristic backscatter values can be derived for forested regions. Problems are caused by the differing acquisition times between ascending and descending orbit, and spatial shift of the track from date to date. Both impede comparability and the use of combined orbits. Beside ASAR Wide Swath, Global Mode can be used for snow monitoring as well. A general trend of thaw over larger regions can be determined. An advantage is the easier data access, but so far no data are available for western Austria and Europe.

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