SATELLITE BASED NEAR REAL-TIME MULTI-TEMPORAL AND MULTI-SENSOR RETRIEVAL OF SNOW PARAMETERS IN MOUNTAINUS AREAS

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Envisnow is an EU FP5 project focusing its attention on retrieving snow parameters and soil moisture using multisensor earth observation satellites. The project will demonstrate a near real-time retrieval system for snow covered area and snow wetness in the spring 2004. Assimilation og snow parameters with hydrological models and use in run-off forecast will also be demonstrated pre-operationally. In this paper snow detection algorithms for synthetic aperture radar (SAR) imagery will be discussed. In addition examples of SAR and optical SCA data combined in a scalable multi-sensor processing system will also be demonstrated.

The project has shown that wide swath SAR data can be used to produce snow cover maps with 100 m resolution and 500 km by 500 km coverage. This allows operational use of SAR data for snow mapping. The applied wet snow detection algorithm (Nagler and Rott, 2000) has been complimented with a dry snow algorithm, predicting dry snow above medium wet snow line. Results from a campaign in southern Norway 2003 using Envisat ASAR and MODIS data combined with aerial SAR imagery and in-situ measurements will be shown. The results demonstrates that a close integration of snow parameter data from several sensors (both radar and optical) may be used to improve temporal resolution and coverage, avoid problems with clouds and improve the overall classification accuracy.

Introduction

Retrieval of snow and soil parameters such as Snow Covered Area (SCA), Snow Water Equivalent (SWE), Snow Surface Wetness (SSW) and Soil Wetness (SW) from satellite sensors is of great importance for hydrological and climatological applications. In the project Envisnow, sponsored by the EC FP5 EESD program, assimilation of SCA in hydrological models has improved run-off forecast and flood warning in Norwegian catchments (Engeset et al, 2003). A multisensor and multitemporal algorithm for fusion of SAR and optical SCA data has improved the spatial and temporal coverage of SCA data.

SCA monitoring with Synthetic Aperture Radar (SAR)

Synthetic Aperture Radar (SAR) has the advantage that it is weather and light independent. A semi-operational processing line for SAR data has been implemented in an ENVI/IDL framework. The first step in the process is to geocode the data. This is facilitated with in-house automatical software that first reads a SAR scene from ftp or CD-ROM and then automatically geolocates the scene based on orbital parameters and a DEM. Data from ESA PAFs are usually sufficiently accurate to eliminate the need for manual selection of control points.

Several papers have demonstrated the potential of SAR for wet snow detection (Nagler and Rott, 2000, Koskinen et al., 1997 and Guneriussen et al., 2002) using ERS and Radarsat standard mode (100 km coverage and 30 m resolution). Wet snow was detected by utilizing the high absorption and therefore low backscatter of wet snow pixels and then comparing the backscatter with the corresponding pixel of a reference scene taken during dry snow or snow free conditions. All these methods show high performance for detection of wet snow. Recently, dry snow has also been inferred by using digital elevation models (DEM) and the wet snow line to postulate dry snow pixels above the wet snow (Malnes and Guneriussen, 2002). For wide swath imagery the method was improved (see Storvold and Malnes, 2004) by using a sliding window technique (10km by 10km) to take into account variable snow line height over the imagery. The methodology has been further improved by taking into account in-situ air temperature measurements and deriving interpolated temperature fields based on standard 6ºC/km height laps rate. Pixels with positive postulated temperature are hence filtered out.

The accuracy of the SCA algorithm has been evaluated by comparing the SAR snow classification with EOS Modis data; classification accuracies around 90% were observed.

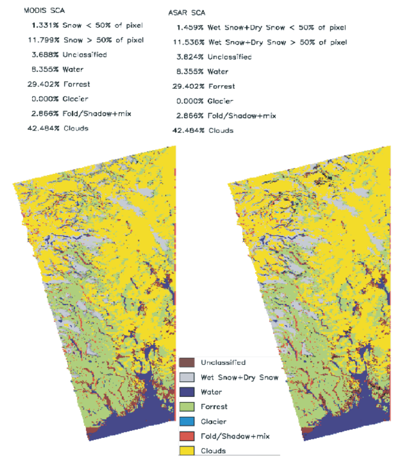

Figure 1. Comparison of SCA from MODIS (left) ASAR WS (right). The ASAR image was averaged into the same resolution as the MODIS image. Further we compared pixels having more and less than 50% snow cover. The agreement is quite good with 0.1% difference in total area with less than 50% (10% relative difference) and 0.3% difference in total area with more than 50% snow cover (2.5% relative difference). Cloud mask from the MOD35 product. MODIS image is from May 2nd and ASAR from May 1st. The image covers most of Southern Norway.

SCA monitoring with optical sensors

The Norwegian Computing Centre has operated a processing line for optical imagery (NOAH AVHRR and EOS MODIS) for several years. The 250 m resolution MODIS are used for snow cover classification (corresponding to NASA MOD02QKM), and 1 km resolution MODIS data are used for cloud classification (corresponding to NASA MOD021KM). From the 1 km MODIS data, a cloud mask is produced from radiometrically calibrated data. The reason for using the 1km MODIS product for the cloud classification, is that this product contains more spectral bands than the 250m product. The cloud classification is performed using a multispectral KNN classification scheme. The resulting cloud mask is resampled to 250m to match the 250m MODIS image used for the snow cover classification.

In order to obtain snow cover maps geometric correction of the images are performed. The correction is based on the lat/long coordinate information which follows the MODIS data. Then the snow cover classification is performed based on the 250 m MODIS image, also using the generated cloud mask in addition to a land mask and a calibration mask. The processing is performed on radiometrically calibrated data, and is based on a snow fraction algorithm that calibrates the classification by assuming a linear relationship between the snow covered area at the sub-pixel level and the radiance measured. The resulting snow cover product, gives the percentage of snow covered area (0-100%) estimated for each pixel in the image.

Confidence maps

In addition to the snow cover map, each single sensor algorithm also produces a confidence map. The confidence map gives a model-based confidence to each pixel in the SCA map based on the classification and the geometry. Areas with cloud coverage is set to 0 % confidence. Areas which are classified as dry snow from the SAR algorithm is set to a low confidence (30 %).Snow covered areas from optical sensors and wet snow areas from SAR is set to 100%, but then modified depending on the incidence angle. Particularly optical sensors have degradation in the classification accuracy for low incidence angles.

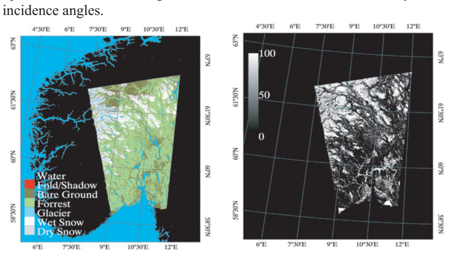

Figure 2. Left: Envisat ASAR snow covered area map from May 5, 2003. Right: Corresponding confidence map.

Multisensor and multitemporal SCA algorithm

By combining optical and SAR imagery it is possible to remove cloud covered areas and areas erroneously classified as dry snow by the SAR algorithm.

The multisensor process works in the way that it updates a multi SCA product, as new images are processed and new single SCA products are computed. Hence, the multisensor fusion works with one input image at the time and integrates this with a multi product resulting from several images from previous images from this or other sensors. In that way this step performs both a multisensor and a multitemporal fusion of single SCA products into a multi SCA product.

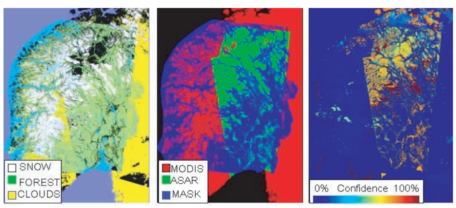

Figure 3. Left: Example of ASAR and MODIS multisensor/multitemporal Snow Cover Area product for Norway from May 1, 2003. Imagery has been accumulated over 7 days. Middle: Mask showing which sensors that contributes to the image. Right: Confidence is set according to the time since last update and other parameters such as incidence angle and vicinity to clouds that

The multisensor fusion algorithm takes the single product SCA maps, fusing it together with the current accumulated map by comparing the confidence of each pixel, and using the pixel having the highest confidence. The current map is accumulated over a certain period (typically 1 week), and the confidence in each pixel is degraded depending on the age.

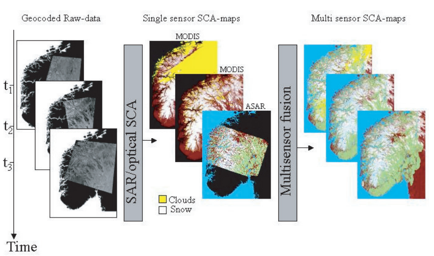

Figure 4. Processing scheme for multisensor SCA-mapping.

Near real-time demonstrations of the Envisnow system

The Norwegian partners of Envisnow NORUT IT, NR, NVE and KSAT will in the of spring 2004 demonstrate a prototype snow information system in full use. The system uses near real-time satellite data (Envisat ASAR and EOS Modis) to derive snow cover area data. Snow cover maps from individual sensors are fused together in a multisensor and multitemporal SCA product to obtain the best possible coverage and mapping quality. The classifications accuracy in each pixel is also assessed. The SCA product is subsequently used by the operational hydrological models from NVE to derive run off from 8 snow magazines in southern Norway.

Improved runoff simulations

Improved methods for earth observation of snow parameters are used in hydrological models to improve the runoff forecast. The Norwegian Water and Energy Authority (NVE) operates hydrological HBV models in several Norwegian basins on operational basis. The HBV model has been improved by assimilating snow cover area from EO data. The improvement is particularly important for rapid flood prediction and hydropower production planning. In 2004 the system will be tested in combination with the Envisnow SCA map system in a semi-real time environment.

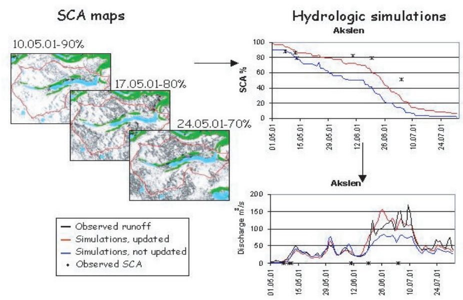

Figure 5. Hydrologic simulations in the Akslen catchment area in Norway. HBV simulations with updated Snow Covered Area data improve runoff estimates, and catch potential flood peaks.

Validation

The optical and SAR algorithms are tested and validated by using in-situ snow measurements and by using alternative similar sensors operated on planes. In 2003 a airborne SAR campaign was carried out using the ESAR platform. A field crew operated differential GPS and corner reflectors in addition to performing snow profiling.

ESAR performed polarimetric C.band measurements of the partial snow covered area. The results are used to study the feasibility of using polarimetrical data for snow studies.

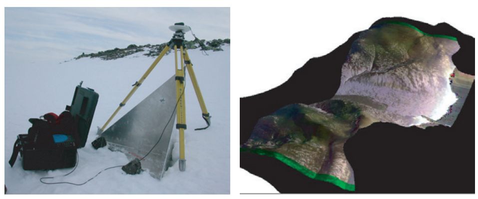

Figure 6. Left: Differential GPS measurements and corner reflectors for accurate calibration and geocoding of ESAR imagery. Right: HH,HV and VV polarization in an RGB-composite draped on the DEM of the area.

Conclusions

We have presented the work in the EC FP5 project Envisnow. The project deals with retrieval of snow and soil parameters using optical and synthetic aperture radar (SAR) satellites and multisensor/multitemporal fusion algorithms. In 2004 the project will demonstrate a near real-time retrieval system for snow cover area and snow surface wetness in the spring 2004. Assimilation of theses parameters into hydrological models and in run-off forecast will also be demonstrated pre-operationally. The paper describes the components in the system.

In particular we describe how Envisat ASAR wide swath imagery is used to find SCA in Norwegian mountainous areas where cloud coverage often prohibits optical retrieval of SCA. SCA maps with 100 m resolution and 500 km by 500 km coverage allows operationalisation of ASAR data. We also show that comparisons with optical data give high classification accuracies. Validation is also supported by in-situ and aerial measurements by the ESAR platform.

Acknowledgement

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