USE OF SATELLITE INFORMATION IN THE HUNGARIAN NOWCASTING SYSTEM

Mária Putsay, Zsófia Kocsis and Ildikó Szenyán

Hungarian Meteorological Service, Kitaibel Pál u. 1, H-1024, Budapest, Hungary

Abstract

The Hungarian Nowcasting System uses regularly three types of satellite retrieved parameters as input data. Application of other satellite derived parameters is planned. This paper discusses the preparation phase of using satellite retrieved snow cover maps. The LSA Snow Cover daily maps were compared to the daily snow maps derived from the NWC SAF Cloud Type product. The comparison was made qualitatively by studying case studies and quantitatively by verifying both satellite retrieved snow maps against Hungarian surface snow depth observations. We found that the accuracy of snow detection is good for both products. 6-hourly snow cover maps were created from the 15-minute NWC SAF Cloud Type product to assimilate it into the NWP model the Nowcasting system is based on. The previous day LSA SAF Snow Cover daily product was also used as a background of the merged maps.

The results of the cross-verification are also used in the 'Drought Management Centre for South Eastern Europe' project of South East Europe Transnational Cooperation Program'.

INTRODUCTION

The Hungarian Nowcasting System (Mesoscale Analysis, Nowcasting and DEcision Routines, MEANDER) and the automatic warning system based on MEANDER have been using the following satellite information regularly since 2005:

- **Cloud Mask** (CMa) and **Cloud Type** (CT) for deriving cloud amount,
- CT for filtering radar noises on cloud-free areas and regions covered by very thin cirrus clouds,
- CT for sending warning for potential foggy areas (used together with relative humidity field analyses and derived low visibility),
- **Cloud Top Height** (CTTH) for estimating the maximum wind speed in the thunderstorm outflow (together with the radar derived cloud top height and many other parameters).

The CMa, CT and CTTH products are routinely calculated at the Hungarian Meteorological Service with the SAFNWC/MSG software developed by the 'Satellite Application Facility on support to Nowcasting and Very Short Range Forecasting' (NWC SAF) international working group founded by EUMETSAT.

From 2010 application of other satellite products in MEANDER and in the warning system are planned:

- to improve the **fog** module applying the algorithm of Guidard and Tzanos (2007). This algorithm uses detailed surface relative humidity, wind and precipitation fields together with the Cloud Type product.
- to use the **Rapid Developing Thunderstorm** (RDT) product of NWC SAF together with radar cell tracking algorithm.
- to use **Land Surface Temperature** (LST) product of Land Surface Analysis Satellite Applications Facility (LSA SAF).
- to use 6-hourly **snow cover** maps (derived from **CT** and LSA SAF Snow Cover product) to assimilate it into WRF model, which is the basic NWP model of MEANDER.

This paper discusses the preparation phase of using satellite retrieved snow cover information in MEANDER. As the developers of the MEANDER ask 6-hourly snow maps, we cannot use snow maps of LSA SAF or H-SAF (Satellite Application Facility on support to Operational Hydrology and Water Management), which are daily products. So we decided to create the 6-hourly snow map from the 15-minute NWCSAF Cloud Type product, which contains snow class. However, we use 'as background' the previous day Snow Cover (SC) product of LSA SAF (see below).

The different snow cover map products were studied and compared also because we plan to use them in the 'Drought Management Centre for South Eastern Europe project' of South East Europe Transnational Cooperation Program. The main aim of this project is to improve drought preparedness and help to reduce drought impacts.

COMPARISON OF SNOW DETECTION PERFORMANCE OF LSA AND NWC SAFS' PRODUCTS

The LSA SC is a daily product, while NWC SAF CT is a 15-minute product. To compare them we created daily map from CT as well. Note, that snow is detectable only in cloud-free areas (as these methods work with SEVIRI channels, without microwave information). Snow detection is available in CT only if the sun elevation is greater than 5 degree. In LSA SC this threshold is 10 degree. As a consequence, we can get snow information only at daytime. For example in the winter months, in Hungary the sun is high enough only during 7-10 hours.

A method was developed to create daily maps from NWCSAF CT. This method was discussed with the CT developers.

- Daily map pixel is set to snowy, if CT detects snow at least in 3 slots.
- Daily map pixel is set to snow-free, if it is not set to snowy and CT detects snow-free at least in 3 slots. Here we use only those slots where the sun elevation for the given pixel is greater than 10 degree.
- Other pixels are set to unclassified.

Case studies

This chapter summarizes the typical features found studying the satellite imagery of 14 days in February and March 2010.

The ***partly snowy pixels*** are handled in different way in the two products. They are classified as snow-free in NWC SAF CT product (Le Gleau and Derrien, 2009). The detection of the partly snowy pixels was not a requirement of this product. The primary goal of this product is the cloud classification. LSA SC aims to detect both the snowy and the partly snowy area in two separate classes (Siljamo and Hyvärinen, 2009). However, we have seen very few partly covered pixels.

The ***forest often behaves like partly snowy area*** from the 'satellite point of view', due to the shadows and snow-free branches. LSA SC made effort to detect the snowy forests. In the beginning of February there was deep snow all around in Central-Europe. So we supposed the forests were also snowy. The 'Daily Northern Hemisphere Snow and Ice Analysis' product of IMS (Interactive Multisensor Snow and Ice Mapping System, NOAA, NESDIS) also confirms that the Carpathian mountains in Romania were covered by snow (see Fig. 1). Note that IMS uses microwave information as well, so it has no cloudy class.

We have found that LSA SC detected quite well the snowy forest in that period (see for example Fig. 2). Fig 2 shows the LSA and the NWC SAF CT derived daily snow maps (left top and below). For comparison we show for 09:40 UTC the NWC SAF CT classification image (rose, green, black colors indicating snowy land, snow-free land and snow-ice-free sea areas) and the 'day and night RGB' image, where reddish color indicates snowy land, while greenish and dark bluish colors indicate snow-free land and snow-ice-free sea).

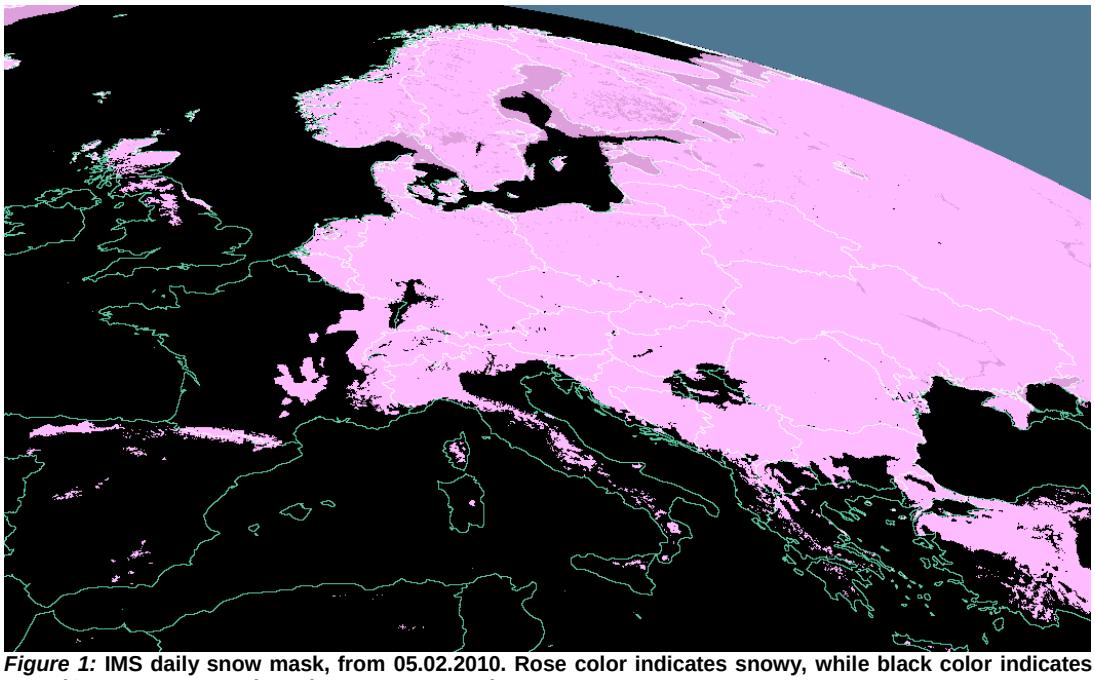

Figure 1: **IMS daily snow mask, from 05.02.2010. Rose color indicates snowy, while black color indicates snow –free area. (Courtesy to Marcel Derrien, Meteo-France)**

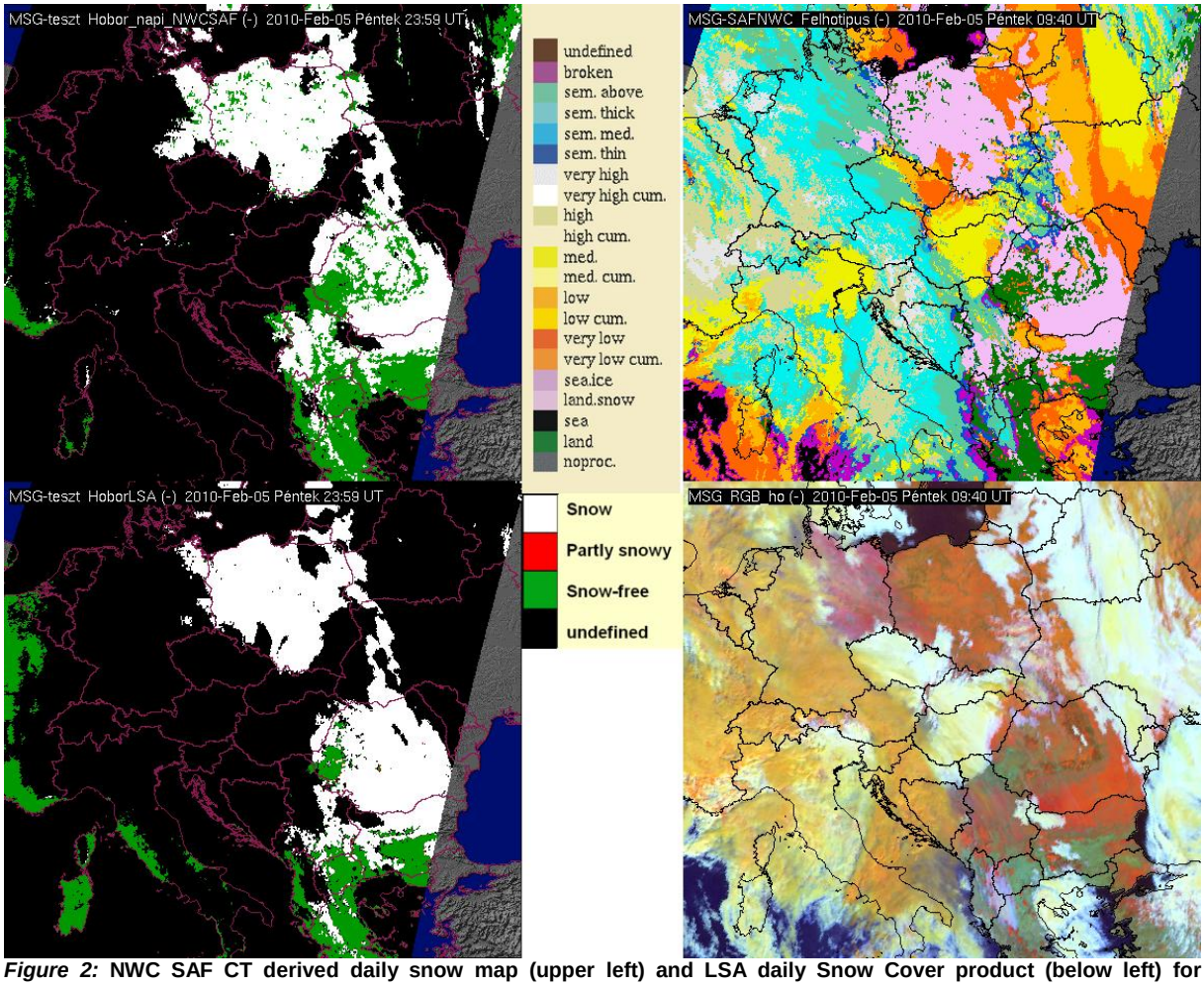

Figure 2: **NWC SAF CT derived daily snow map (upper left) and LSA daily Snow Cover product (below left) for 05.02.2010. NWC SAF Cloud Type (upper right) and 'day and night RGB' (below right) images for 05.02.2010 09:40 UTC. The color scales for the cloud type classes and LSA snow cover maps are presented in the middle. Note, that for the NWC SAF CT derived daily map there is no partly snowy class.**

In most of the cases **different extent of the snowy areas** were found in the two products.

- Larger snowy areas in LSA SC than in the NWCSAF CT-derived daily snow map was often found in the beginning of March, when the snow started to melt in Central Europe, and the weather was often cloud-free. The reason for this might be that LSA SC often detects the partly snowy area as totally snow covered, while NWCSAF CT indicates it as snow-free.
- The NWCSAF CT-derived daily snow map provided information for larger area than LSA SC in the beginning of February, when there was deep snow all around in Central-Europe, with cold and cloudy weather (see Fig 3).

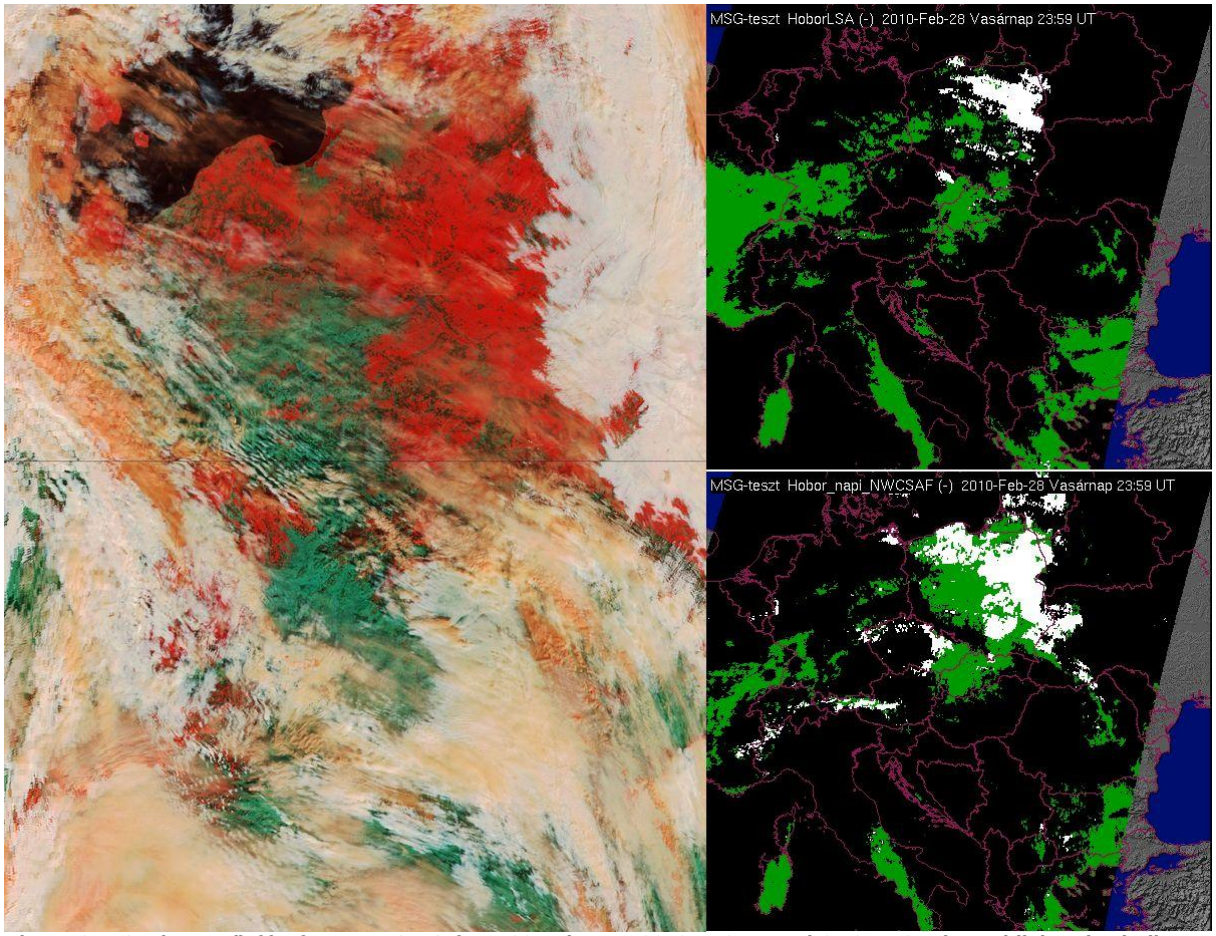

Figure 3: **RGB image (left) of Terra MODIS from 28 February 2010 at 9:45 and 9:50 UTC. The reddish color indicates snow covered cloud-free area, while the greenish color indicates snow-free area. LSA daily Snow Cover product (upper right) and NWC SAF CT derived daily snow map (below right) for 28 February 2010 (white, green and black colors indicate snowy, snow-free and not classified areas, respectively).**

In the snow maps the black color indicates the area with no information (cloudy pixels or uncertainty whether the cloud-free pixel is snowy or snow-free). The black area is often much larger in LSA SC than in NWCSAF CT derived daily snow map. LSA SC seemed to be more cautious. In some cases it might be 'too cautious' (the algorithm needs more than 5(!) cloud-free hours to set the pixel as snowy).

In some cases NWCSAF CT detects snow under very thin cirrus as well. In a few cases it confuses clouds with snow covered cloud-free pixels. Note that CT has to decide for all pixels to which class it belongs. LSA SC can more easily include the ambiguous pixels into the 'black category'.

Verification of the satellite retrieved snow maps with Hungarian snow depth observations

To calculate statistics we used data of stations with observer and 4 automatic stations with ultrasonic equipment. In Hungary snow depth observations are done only once a day at 6 UTC (usually in dark or twilight condition). Thus we had to compare instantaneous observations with daily maps. To solve

this problem we selected for each stations only those days when the observer measured more than 2 cm deep snow both the actual and the next mornings. We supposed that in these cases the snow was during the whole day present and deep enough. We took into account only deep snow to avoid patchy snow cover. We intended to make a statistics of totally covered satellite pixels. For these selected cases 'snowy' and 'snow-free' pixels (around the station) were counted and the probability of detection (POD) was calculated (see Table 1). We found that POD was high for both products (see the 3rd column of Table 1). It is higher for LSA SC, maybe because of the better detection of snowy forests.

		POD Snow depth >= 2cm	Sum of the numbers of snowy and snow-free pixels	Sum of the numbers of snowy and snow-free pixels divided by all pixels	NWC/LSA
December 2009	LSA	0,94	963	32%	
	NWC	0,78	1328	44%	1.38
January 2010	LSA	0,93	682	11%	
	NWC	0,71	1508	25%	2,21
February 2010	LSA	0,91	1390	18%	
	NWC	0,85	2241	29%	1,61
Dec-Febr 2009-2010	LSA	**0,93**	3035	**18%**	
	NWC	**0,79**	5077	**30%**	**1,67**

Table 1: **Probability of snow detection (POD) of LSA and NWC SAF products in Hungary in the 2009-2010 winter period and the winter months separately (3rd column). The 5th column shows the ratio of the pixels with information (snow or snow-free) to all pixels.**

For the selected pixels – containing the meteorological station with snow depths observation greater or equal than 2 cm both on the actual and next mornings - **the pixels with information (snow or snow-free) were divided by the number of all pixels. It was found that the NWC CT derived daily map gave information for 67% larger area that LSA SC** (see the 5th and 6th column of Table 1).

To calculate FAR (false alarm rate) we had to work with a much smaller database (~ 120-150 cases). In this dataset **we did not found any false alarms**, neither in LSA SC nor in NWCSAF CT derived daily snow maps.

Summarizing the statistics reflect the same features as the case studies.

MERGING THE LSA SAF AND NWC SAF SNOW COVER INFORMATION

The MEANDER developers considered that the snow cover information of the **previous day is too old** for assimilation. They asked actual 6-hourly snow maps. For this we could not use the daily LSA SAF product. We decided to use the 15-minute NWCSAF CT data. However, realizing that CT does not detect the snowy forest, we decided **to merge the two products taking the advantages of both.**

In the merged product we introduced 5 classes: snowy, maybe snowy, snow-free, maybe snow-free and undefined. Our snow maps are not really 6-hourly, they contain information coming from:

- the last 6 hours - providing the 'snowy', 'snow-free' pixels, and
- the previous day and the actual day, but older than 6 hours information - providing the 'maybe snowy' or 'maybe snow-free' pixels.

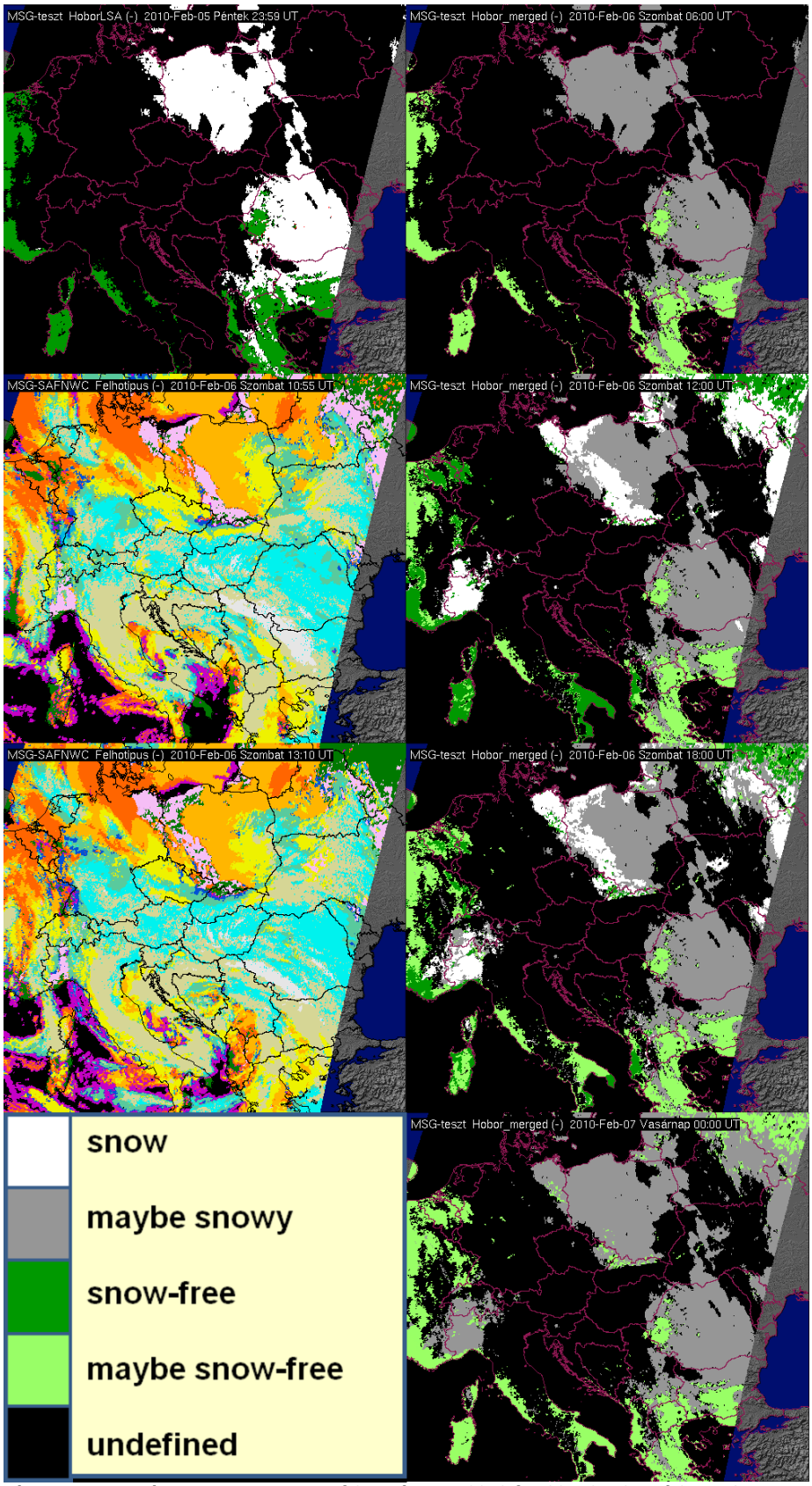

Figure 4: **Merged snow cover maps of 07 February 2010 for 06, 12, 18 and 24 UTC are presented in the right panels of the 1st, 2nd, 3rd and 4th rows, respectively. The left panel in the first row shows the LSA SC map of the previous day (06 February 2010). The left panels in the 2nd and 3rd rows show the NWC SAF CT product at 10:55 and 13:10 UTC of the actual day. The color scale of the NWC SAF CT product is presented in Fig.2. Rose color indicates snow.**

In Fig. 4 an example of the merged '6-hourly' snow map is presented. The merged maps are created in the following way:

- At 6 UTC the previous day LSA SC is used by replacing 'snow' class with 'maybe snow' and 'snow-free' class with 'maybe snow-free'. This map is used as 'background' to create the 12 UTC snow map.
- We merge the CT information between 6-12 UTC with the background map. A pixel will belong to snowy or snow-free classes if CT indicated snow
    - minimum in 3 slots, or
    - minimum in 2 slots and according to the background map it was "maybe snowy".
- For 18 UTC merged map we make the same, with the 12 UTC merged map as background.
- The midnight UTC merged map is created from the 18 UTC map by converting to snowy/snow-free pixels to maybe snowy/snow-free ones.

CONCLUSIONS AND FUTURE PLANS

The statistics are good for both the LSA SC and the NWC SAF CT derived daily snow cover maps. LSA SC seems to be a bit more reliable first of all in forested area, however, it gives information for much smaller area. It would be useful to have shorter range Snow Cover products in LSA SAF, not only daily ones. It would be extremely useful to create snow maps using microwave information as well, like in the IMS snow maps, not to have the large undefined class, where we presently have no information because of the cloudiness.

We plan

- to perform statistics for a longer period,
- to include surface snow observations into the merged snow maps for possible corrections,
- to study the H-SAF snow cover product,
- to test and use other snow parameters of H-SAF,
- to use other snow parameters both in MEANDER and in the 'Drought Management Centre for South East Europe' project,
- to test the performance of the future 15-minute LSA SC product.

ACKNOWLEDGEMENTS

Part of this research was supported by the Operational Program of Environment and Energy (KEOP-630/2F/09-2009-004), the DMCSEE (Drought Management Centre for South East Europe) project of South East Europe Transnational Cooperation Program and the Hungarian Scientific Research Fund (OTKA68277). The authors wish to thank to the developers of the NWC and LSA SAF for their discussion and help.

REFERENCES

Derrien, M. and Le Gléau, H. (2005) MSG/SEVIRI cloud mask and type from SAFNWC. International Journal of Remote Sensing, **Vol. 26**, No. 21, pp 4707-4732.

Le Gléau, H. & M. Derrien (2009) Algorithm Theoretical Basis Document for "Cloud Products" (CMa-PGE01 v2.0, CT-PGE02 v1.5 & CTTH-PGE03 v2.0) Meteo-France, CMS (available from http://www.meteorologie.eu.org/safnwc)

Le Gléau, H. & M. Derrien (2009) Product User Manual for "Cloud Products" (CMa-PGE01 v2.0, CT-PGE02 v1.5 & CTTH-PGE03 v2.0) Meteo-France, CMS (available from http://www.meteorologie.eu.org/safnwc)

Guidard, V. and Tzanos, D., (2007) Analysis of Fog Probability from a Combination of Satellite and Ground Observation Data, Pure Appl. Geophys. DOI 10.1007/s00024-007-0215-6

Siljamo, N. and Hyvärinen, O. (2009) SAF for Land Surface Analysis (Land SAF), Algorithm Theoretical Basis Document, Snow Cover. Finnish Meteorological Institute, FMI (available from http://landsaf.meteo.pt)

Siljamo, N. and Hyvärinen, O. (2009) SAF for Land Surface Analysis (Land SAF), Product Output Format Document, Version 2.3, Snow Cover. Finnish Meteorological Institute, FMI (available from http://landsaf.meteo.pt/)