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CASE STUDIES AND CURRENT STATUS OF H SAF METOP/AVHRR AND MSG/SEVIRI SNOW EXTENT PRODUCTS

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Abstract

In this work, we describe the current status of the meteorological H SAF MSG/SEVIRI (H31) and Metop/AVHRR (H32) snow extent products. H SAF MSG/SEVIRI based snow extent product has been operational since 2008. It provides daily snow extent in MSG/SEVIRI disk. H SAF Metop/AVHRR snow extent product reached operational status 2018 and the product is available since 2015. It provides global daily snow extent data in high spatial resolution.

These H SAF snow extent products have been developed for meteorological and hydrological applications, such as an additional data source for numerical weather prediction. Recent validation results using the surface observations show that both products exceed the required target accuracy.

We will present case studies of snow episodes in Europe during the winter 2017-2018 to illustrate the potential of these products.

Both products are available from the LSA SAF website (http://landsaf.ipma.pt/).

H SAF MSG/SEVIRI AND METOP/AVHRR SNOW EXTENT PRODUCTS

Snow is significant factor in the northern weather and ecosystems. Snow cover changes the heat and water flow between soil and atmosphere and changes the radiative properties of the surface.

Currently there are two operational meteorological snow extent products in the H SAF. These products are aimed for meteorological applications, such as numerical weather prediction. Meteorological products emphasize the effects of snow to the radiative properties of the surface where even this layer of snow has significant effect while hydrological products are more concerned about the water content and effects on water cycle. Our discussions with members of the NWP community suggest that accuracy is more important than high spatial coverage and for this reason these products prefer unclassified pixels over classified if the snow coverage status is uncertain.

The MSG/SEVIRI snow extent product (H SAF H31) is daily full disk product which covers Europe, Africa and parts of Asia and South America. This product is based on intermediate products generated every 15 minutes to produce reliable daily snow extent product. The product has been operational and is available from 2008.

The Metop/AVHRR snow extent product (H SAF H32) is high resolution global daily product, which provide better coverage and resolution in high latitudes. However, the temporal coverage is limited and AVHRR is a rather old instrument with limited capabilities, for example only 5 channels compared to the channels available in newer instruments. The Metop/AVHRR product is has been operational since 2018 and is available since 2015. Examples of both products are shown in Figures 1 and 2.

MSG/SEVIRI product covers full SEVIRI disk, Metop/AVHRR product is a global product in 0.01° grid. The snow cover is well presented in the cloud free regions in the Northern Hemisphere in the Metop/AVHRR product. Some data are missing in South America, Australia and mid-Atlantic. Extreme polar regions are covered but unclassified due to polar night and low viewing and sun angles.

In comparison to Metop/AVHRR product, the MSG/SEVIRI product has smaller geographical coverage, lower resolution, but much better temporal coverage. In the daily product, the effect of cloudiness in the MSG/SEVIRI product is reduced because the instrument covers the same area every 15 minutes and the algorithm can determine the surface status if there is a reasonably number of cloud free scenes during the day. However, the instrument resolution and viewing angle are not optimal near the edges of the viewing disk, e.g., Nordic countries and the Antarctic

SURFACE VALIDATION

Without validation even the best products are useless. Although there are other high quality satellite snow products which provide good data for comparison, the best option is to validate the product with large number of surface observations. Unfortunately, the challenge in the satellite snow product development is the lack of reliable validation data, i.e. surface observations. Even when there are excellent snow cover measurements, quite often they have limitations which prevent large scale validation. The highest quality observations may be available for short periods of time in limited areas (e.g. campaign data), have poor temporal coverage (e.g. twice a month) or are limited to single countries.

However, there are two types of operational observations available from weather stations: snow depth and the state of the ground. Snow depth is easy to measure with simple instruments and can be automated quite reliably except in cases when the snow cover is very thin or patchy. Complementary are the state of the ground observations which provide limited information about the snow coverage which can be converted to simple four point scale (no snow, less than half snow covered, more than half snow covered and full snow cover) These observations are currently made manually, but it is possible that in the future at least limited observations of the snow coverage can be made automatically using e.g. fixed cameras.

For this work we have used snow depth and the state of the ground observations available in the FMI observations database. The database does not have complete global coverage, but there are observations from several thousand stations which cover most of the world.

The data set created can be used to calculate different validation statistics. Daily contingency tables require binary data and therefore partial snow cover class must be either excluded or converted to snow free or snow covered classes. For this analysis partially snow covered pixels has been treated as snow free. This time series of contingency tables have been used to calculate validation measure time series for Metop/AVHRR and MSG/SEVIRI snow products which are presented in figure 3.

In general, this time series plots show that both product detect snow and snow free reliably which is important for the NWP users. The global snow cover has some features which can be seen in the time series plots. First, these are primarily optical products which require sun light to work. Polar night and low sun elevations prevent the classification. Secondly, uneven land distribution between the hemispheres means that most of the season snow is in the northern hemisphere and this produces season cycle in the snow cover which can be seen in the images. It should be noted that many validation measures can behave erratically when the distribution of classifications is highly uneven i.e. during the northern summer. These days are marked in orange in the plots.

The plots in figure 3 show that both products are highly accurate from November to April. In other months the hit rate is very high and false alarms rare, but there are still some misclassifications which can be seen as erratic behaviour in some of the validation measures. Based on these results and overall statistics both products exceed the target accuracy (hit rate 80%, false alarms 15%) and almost reach the optimal requirements (hit rate 90%, false alarms 5%).

EXAMPLE CASES: WINTER 2017–2018

Statistical validation results show that both products work well in areas where adequate day light is available during the satellite overpass. To get a more detailed view of the products, we show some examples of these products vs MODIS images.

During the winter 2017 – 2018 British Isles had significant snow cover couple of times. The snow fall of the December 10, 2017 covered large areas in England and Wales and had significant effects on traffic. Schools were closed in large areas and daily life of the people was heavily affected. One day after the event sky was clear over much of the area (see the surface view in figure 4) and satellite products could be expected to detect the snow on ground.

Figure 5 show both of our daily snow extent products in British Isles December 11, 2017. The MSG/SEVIRI products does detect snow very well, but Metop/AVHRR product struggles to show anything. MSG/SEVIRI product benefits of the full day coverage of the MSG/SEVIRI instrument because there are images (and snow product) every 15 minutes and this covers also the moments around the midday.

Our first guess was that British Isles were in difficult position during the Metop satellite overpass in the morning of December 11. Figure 6 shows that this is indeed the case. RGB image shows that the area is poorly lit and sun is still quite low. In the middle panel we present the first phase snow extent analysis (before merging to global product), which shows that the algorithm struggles to detect snow and snow free surface although the snow free detection improves slightly in areas south of the UK. The right panel gives even more details about algorithm behaviour. Light blue colour shows that the algorithm manages to detect the cloud covered region in the eastern part of the UK, but white colour tells that it fails to classify practically all of the snow free surface of the western part of England and Wales. Dark red pixels nearby show that this area is quite near the edge of the classification limits of the sun and satellite angles.

Higher sun elevation and better light conditions mean that the Metop/AVHRR algorithm manages much better in late winter (February 23, 2018, figure 7) and spring (April 14, 2018, figure 8). Both algorithms (MSG/SEVIRI and Metop/AVHRR) succeeds in snow cover detection and manage to produce very realistic snow extent maps.

The example case of February 23, 2018 (figure 7) shows clearly the most significant differences of the Metop/AVHRR and MSG/SEVIRI snow extent products. Although both products do detect snow extent well, in the MSG/SEVIRI product which employs the 15 minute cycle of the images the unclassified area is much smaller. The main reason is that usually there are cloud free periods during the day which allow the algorithm to detect surface even when the sky is mostly cloud covered. In the Metop/AVHRR product have some overlap in the images in the North, but usually there is only one image per day. Thus, even temporarily cloud covered areas cannot be classified. However, Metop/AVHRR has much better resolution in high latitudes where geostationary MSG/SEVIRI has poor resolution and the algorithms struggles to detect snow (especially in forests) due to low viewing angle.

The same features can be seen in the second case of April 14, 2018. Cloud cover is not as extensive as in the February case and both products cover most of the Europe. In this case, however, the

resolution and viewing angle differences of Metop/AVHRR and MSG/SEVIRI can be seen quite well. In this case MSG/SEVIRI product has a narrow strip of unclassified pixels between snow covered and snow free regions, which we believe is mostly related to low viewing angle in forest covered areas.

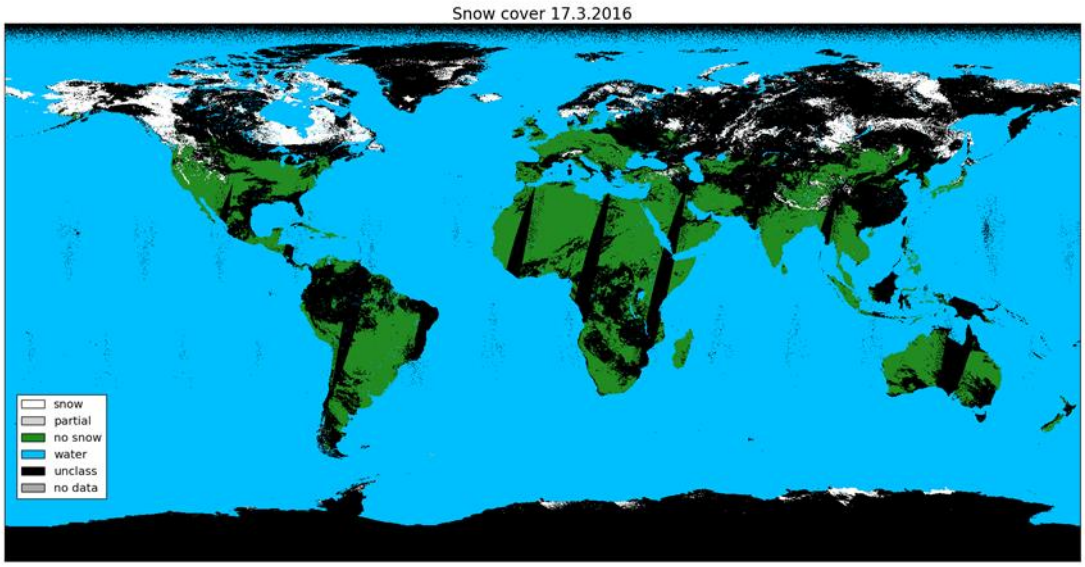

Figure 1: **Example of the H SAF Metop/AVHRR snow extent product (H32), March 17, 2016. Note the gaps between swaths of the Metop/AVHRR near the equator.**

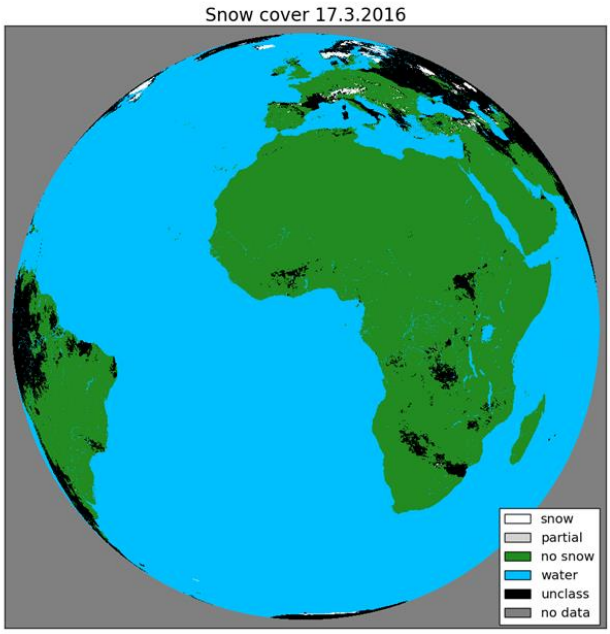

Figure 2: **Example of the H SAF MSG/SEVIRI snow extent product (H31) March 17, 2016. Note the location of typically snow covered regions near the northern edge of the SEVIRI disk.**

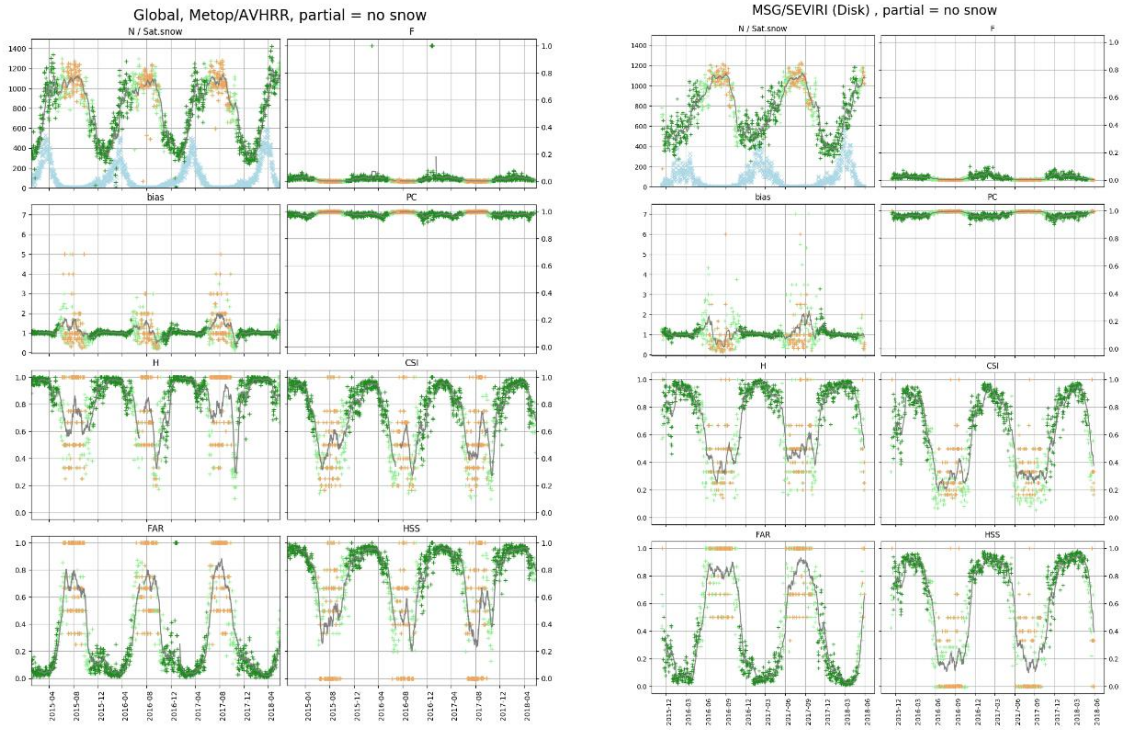

Figure 3: **Time series of global validation measures for Metop/AVHRR (left) and MSG/SEVIRI (right) snow extent. All subplots use the same colour coding. On top left panel green and orange colour shows the total number of observation pairs and blue colour shows the number of satellite snow pixels in observation pairs. When the correct rejections exceed the other classes by more than 20 (200) times light green (orange) marker is used. In these days the highly skewed distribution of pixels emphasize the misclassifications of very rare snow covered pixels.**

Figure 4: **Fully snow covered surface in Great Malvern, UK, December 11, 2017. Snow fall during the previous day covered large areas in England and Wales.**

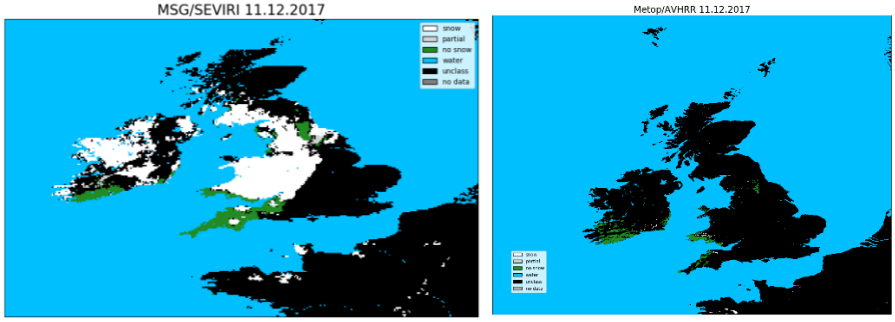

Figure 5: **MSG/SEVIRI and Metop/AVHRR snow extent in British Isles December 11, 2017. Good detection can be seen in the MSG/SEVIRI product which benefits of the full coverage every 15 minutes, but Metop/AVHRR fail to detect snow. See figure 6 for more details.**

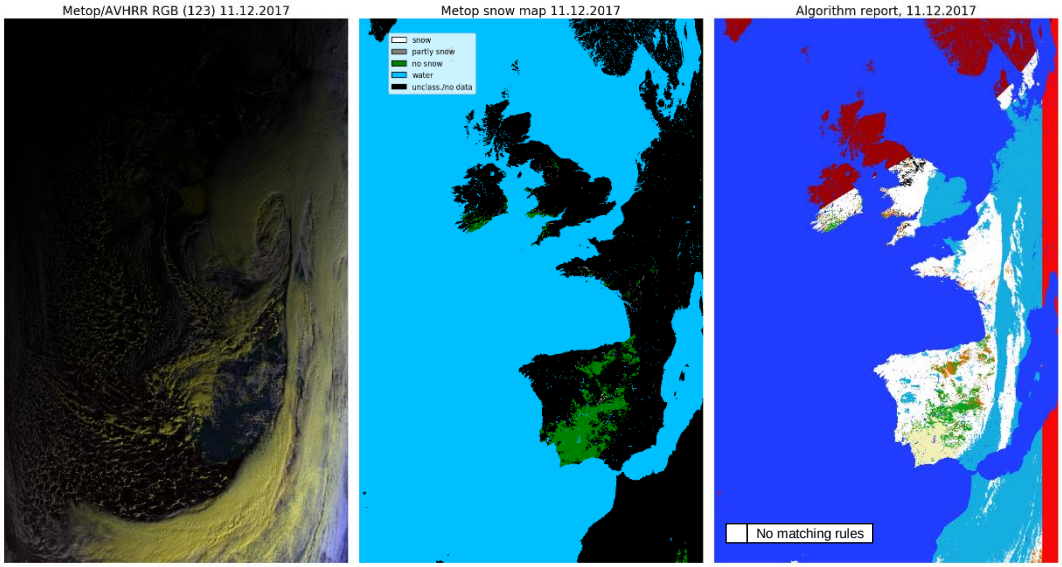

Figure 6: **Detailed intermediate Metop/AVHRR algorithm analysis reveals more details of the snow detection in December 11, 2017. The only daylight RGB image on left shows that in the British Isles the sun elevation is quite low and the algorithm fails to detect snow in these conditions as we can see in the middle panel. On the right is the algorithm analysis where different colours indicate different reasons for classification. Here white colour shows that none of the classification rules match and these pixels are unclassified by default. In the UK, some of the clouds have been detected (light blue colour) and these pixels are classified as unclassified, but most of the cloud free area in the UK cannot be classified (white colour). Higher sun elevation (i.e. more light) would help the classification as can be seen in the Iberian Peninsula where snow free surface have been detected by several different classification rules.**

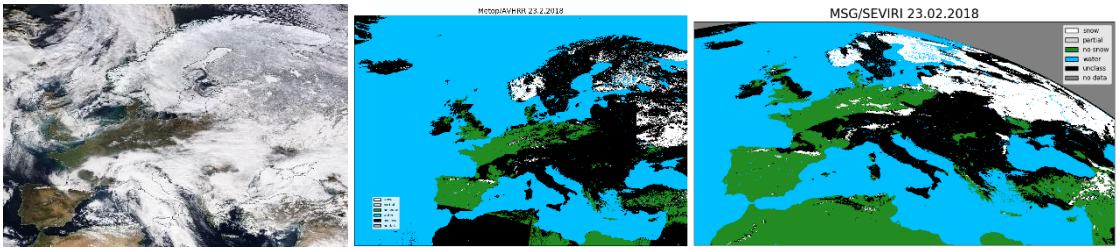

Figure 7: **MODIS image of the Europe February 23, 2018 on the left and both H SAF snow extent products (Metop/AVHRR and MSG/SEVIRI) on the middle and on the right. Better light conditions than in December help the Metop/AVHRR algorithm to detect snow quite well, but merging of the 15 minute imagery of the MSG/SEVIRI improves the snow detection in cloudy conditions. Metop/AVHRR provides better resolution in the polar region.**

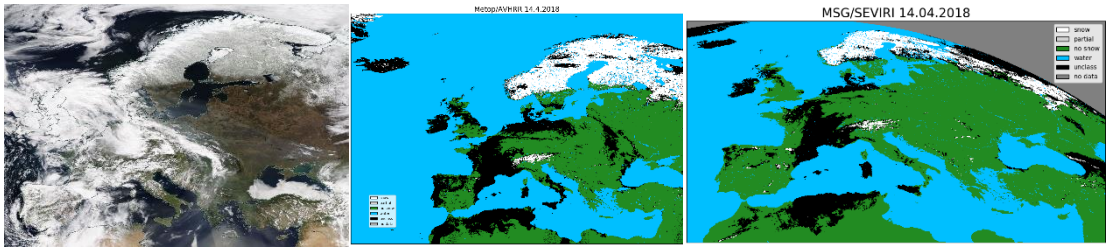

Figure 8: **The MSG/SEVIRI and Metop/AVHRR snow detection vs MODIS RGB image in April 14, 2018. High temporal coverage of the MSG/SEVIRI instrument help to provide nearly full coverage of the Europe. Cloud free day and good light conditions mean that the Metop/AVHRR product has good high resolution coverage of the Nordic countries and rather good coverage even in Central Europe.**

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