TOPOGRAPHY CORRECTION OF THE CM-SAF SURFACE ALBEDO PRODUCT SAL

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Abstract

A topography correction method for reflectance values is developed using high resolution DEMs, such as SRTM or ASTER DEM. The calculation is carried out only for pixels having slope angles larger than 5 degrees in the GTOPO30 resolution. The method is based on calculating slope and aspect angle distributions for each satellite pixel and correcting the bidirectional reflectance distribution function (BRDF) using local incidence angles instead of the global ones. In rugged terrain the topographically corrected albedo values deviate from the uncorrected ones easily more than 10%.

INTRODUCTION

Surface albedo is one of the dominating factors of the Earth's radiation budget (Dickinson, 1983). Over the recent years, scientific and political concern over climate change has focused increased attention to the Earth's climate system. There is a significant difference between the historical reflected flux data of the Earth Radiation Budget Experiment (ERBE) and the Clouds and the Earth's Radiant Energy System (CERES), and a large imbalance in the amount of incoming and outgoing radiation derived from the CERES measurements (Bender *et al*., 2006). The modelled albedos are almost consistently closer to ERBE data and higher than the satellite based values. The causes of these discrepancies are unknown and they call for independent high-quality albedo data.

From the point of view of global albedo products the effect of rugged terrain can't be neglected. If the satellite would observe the Earth from the same zenith and azimuth angles as the Sun, it would completely measure the direct reflection of the incoming illumination. As the satellite typically observes the terrain from a different direction than the Sun, some slopes of the terrain are visible for the Sun, but not for the satellite and vice versa. This easily leads to underestimation of the albedo, as some of the reflected direct illumination does not contribute to the satellite measurement. Therefore, the surface albedo product SAL (Riihelä, 2009; Riihelä et al., 2010) processed by the CM-SAF project (Schulz et al., 2009) is provided with topography correction (Manninen, 2003; Manninen, 2006).

METHOD

The topography affects the AVHRR image in first order in two ways: 1) the altitude difference with respect to sea level will cause the geolocation of the pixel to be shifted (***Figure** 1*) and 2) the direction and inclination of the slopes of the terrain within a pixel will alter its reflectance value. As the BRDF calculations are based on the horizontal plane assumption, erroneous values will be obtained for inclined slopes. In addition, the slope distribution of the terrain covered by the pixel may contain slopes that are not seen at all by the Sun or the satellite (Manninen 2003; Manninen 2006). These kinds of situations will cause even larger errors than small inclinations of slopes.

Multiple reflections from slope to slope would be a second order effect, but already the first order correction involves so many time consuming calculations that the second order effect is not studied here at all.

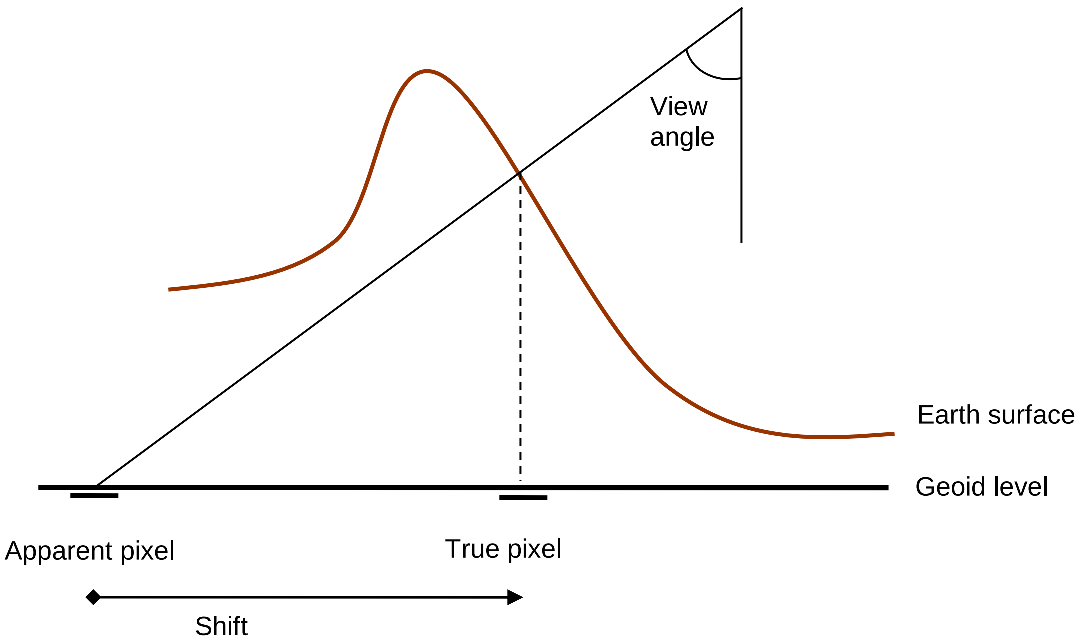

Figure 1. **The error in geolocation of a pixel due to altitude.**

The geolocation of the AVHRR pixels is corrected taking into account GTOPO30 DEM and the satellite viewing and azimuth angles. The radiometric correction for each AVHRR pixel is carried out using the SRTM DEM (Rodriguez et al., 2006). In latitudes outside the SRTM coverage the GlobASTER DEM (Toutin, 2008) is used instead. The reason for not using GTOPO30 for the radiometric correction is that the slope information obtained from that is in far too coarse resolution. Thus each pixel can't be described using just one slope and aspect angle value like in high resolution images (Riaño et al., 2003). Instead one has to determine the slope and aspect angle distributions for each pixel separately. Since the satellite overpasses do not overlap precisely, these slope and aspect angle distributions have to calculated for every image separately. This is a heavy computation task, therefore the topography correction is limited to areas where the slope is on the average larger than 5 degrees, when calculated using the GTOPO30 DEM in it's original arc 30 sec resolution.

The slopes are a divided in three groups: 1) slopes for which the illumination and viewing angles are sufficiently small to permit the determination of the BRDF model (n_{BRDF}), 2) slopes for which the illumination and/or viewing angles are too large to permit the determination of the BRDF (n_{extr}) and 3) slopes which are not seen by the Sun or the satellite at all (n_{shade}). The average value of reflectance for each AVHRR pixel $\langle R \rangle$ is taken to depend on the reflectance values of the individual slopes (subpixels) R_i as follows

$$\langle R \rangle = \frac{n_{BRDF} + n_{extr} + n_{shade}}{n_{BRDF} + n_{extr}} \frac{1}{n_{BRDF}} \sum_{i=0}^{n_{BRDF}} R_i \qquad (1)$$

If all subpixels had zero slopes, the full pixel reflectance would equal the mean of the subpixel reflectances. The subpixel slope reflectances R_i are assumed to differ only due to different viewing geometry. They are calculated substituting the global illumination and viewing angles with the local ones (valid for the particular slopes). The shaded subpixels present a special problem, since they should contribute to the topographically corrected pixel albedo even though they are not visible for that particular satellite image. As the viewing and illumination geometry of any pixel changes from AVHRR image to another, the distribution of shaded subpixels also changes. We assume that the shaded subpixels have reflectances equal to the visible subpixels in all AVHRR pixels. Since the end products are weekly/pentad and monthly means, this assumption is expected to be reasonable for most regions and times of year.

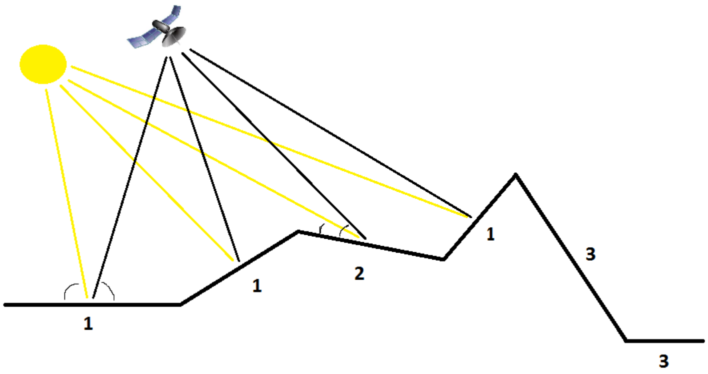

Figure 2. **An example of the slope classification in an AVHRR pixel**.

DATA

In order to study the effect of topography correction, a relatively cloudfree AVHRR image covering the Alps in April 15, 2009 at 10:04 am was processed to surface albedo using the new SAL algorithm (Riihelä, 2009), but excluding the topography correction and using the new algorithm in the normal way including the topography correction. The image used in the study corresponds to typical satellite and Sun zenith angle values. When the sun elevation is low and the satellite and Sun are viewing the terrain from opposite directions, the effect is largest (Manninen, 2006). It was so difficult to find cloud free images in the areas of interest, that no extreme case could be demonstrated here.

RESULTS

The ratio of the topographically corrected and uncorrected surface albedo in the Alp region is shown in ***Figure 3***. Details of this image are shown in ***Figure 4*** and for comparison the calculated corrected and uncorrected albedo values. As the Alps are snow covered the albedo is high. Due to the steep slopes the corrections are in the mountains practically everywhere larger than 10% and in a large fraction of areas larger than 20% (***Figure 5***), whereas in the valleys the correction is within 5%.

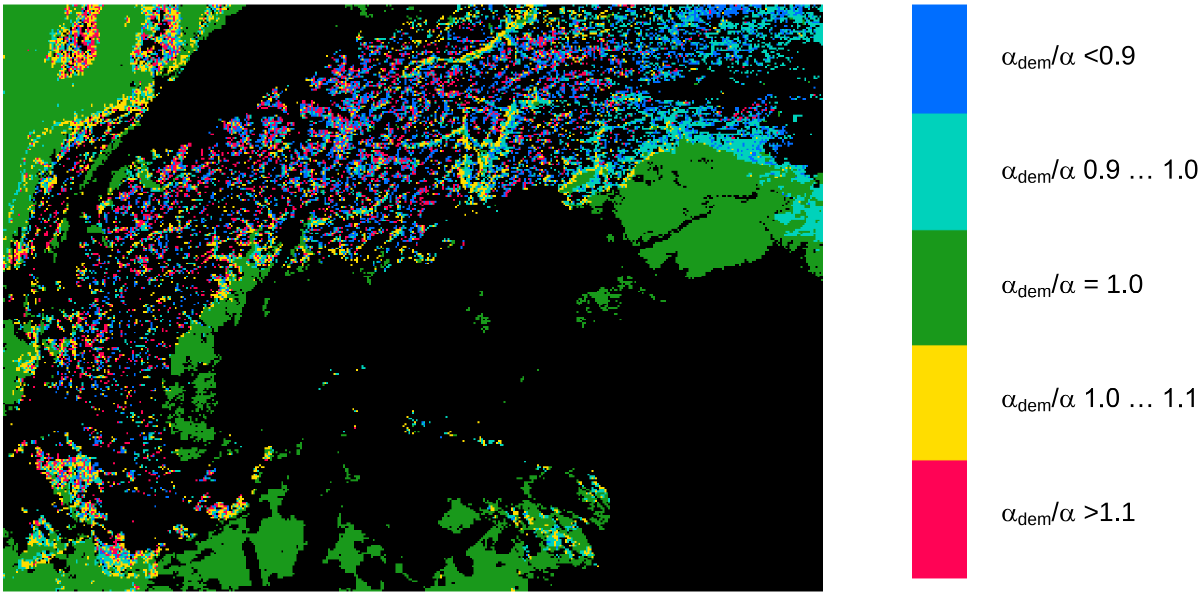

Figure 3. **Ratio of the topographically corrected and uncorrected surface albedo values in the Alps. The black area is masked clouds or gaps caused by pixels shifting of the topography correction.**

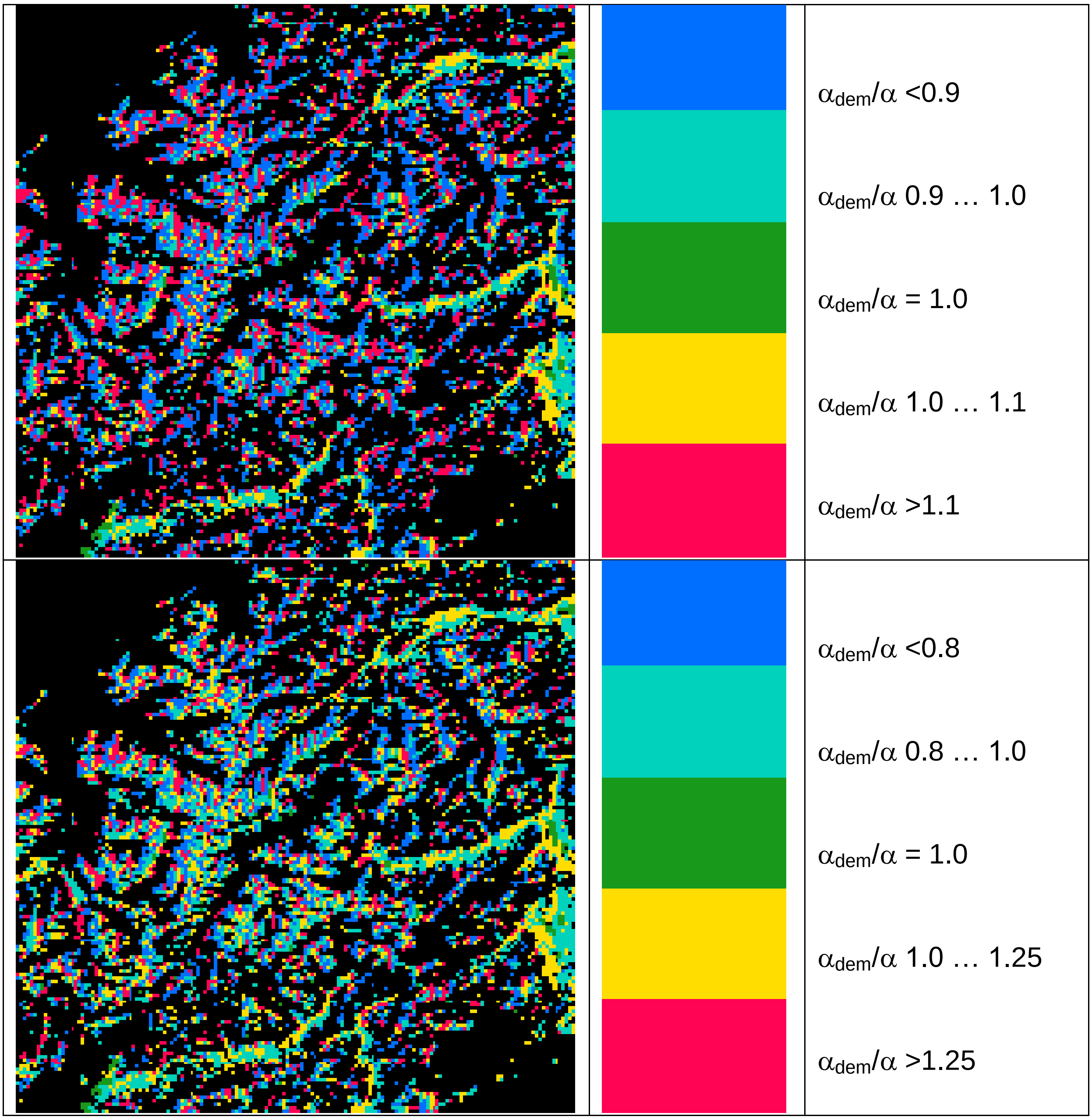

Figure 4. **The ratio of the corrected and uncorrected surface albedo with 10% (top) and 20% (bottom) error scale. The black area is masked clouds or gaps caused by pixels shifting of the topography correction.**

A relative difference between the corrected and uncorrected albedo values can also be quite large in areas, where the albedo value is relatively small (***Figure 6*** and ***Figure 7***). In addition, a marked topography correction may also be needed at lower altitudes than the Alps (***Figure 8*** and ***Figure 9***).

In all areas also the number of masked pixels increases due to the topography correction. This is caused by the geometrical distortion related to high altitudes. When pixels are moved to correct the altitude effect on the reflectance (*Figure 1*), it is possible that the shift is sometimes larger than one pixel, so that somewhere there a gap is left behind. It is considered better to not multiply pixels to cover shaded areas, because those might have reflectance values that are different from the shifted pixel reflectance values.

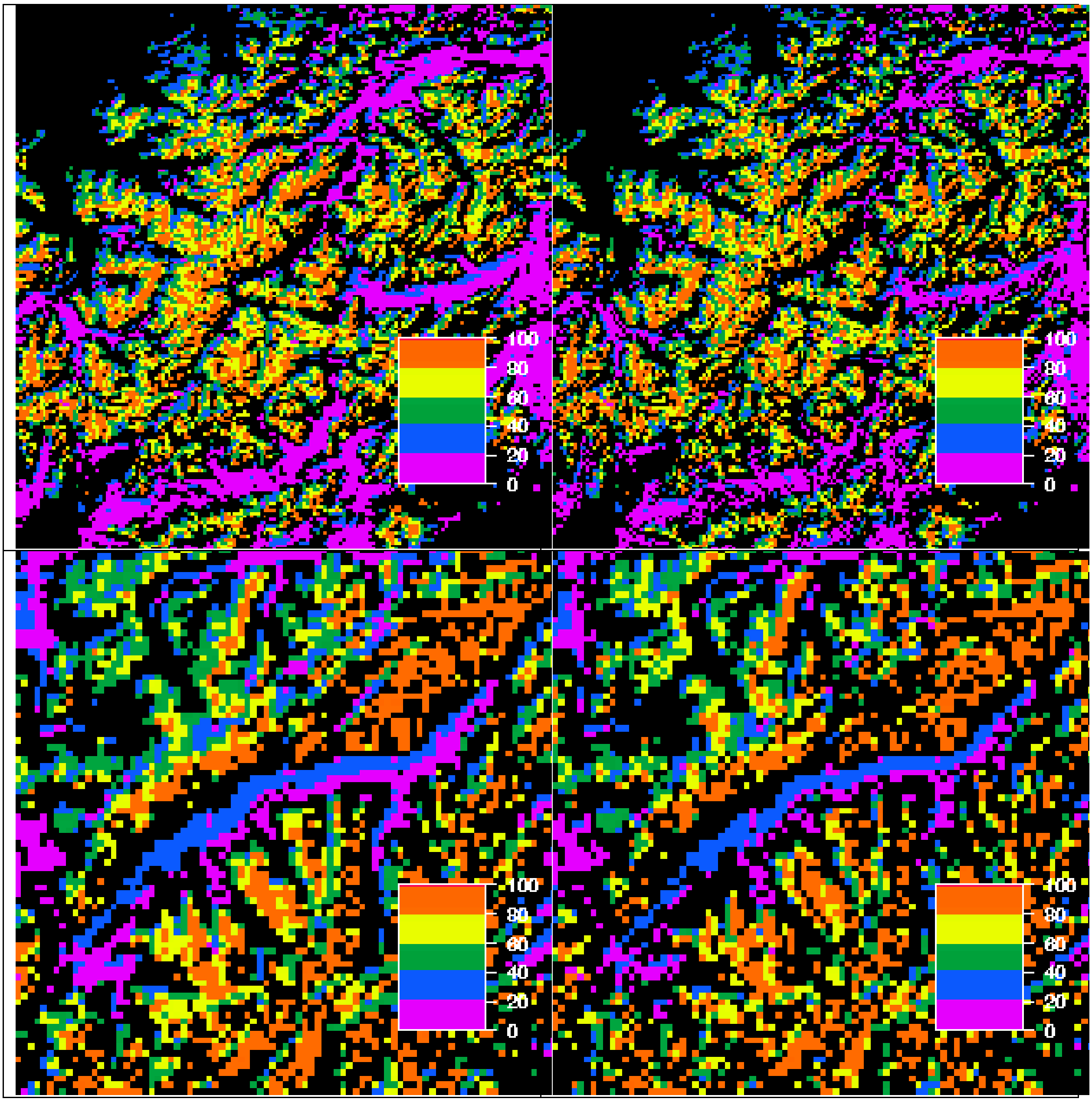

Figure 5. **Surface albedo of the Alp region without (left) and with (b) topography correction. The images are in the original swath projection. The black area is either clouds or gaps caused by the altitude related pixel shifting of the topography correction.**

DISCUSSION

The calculation of the BRDF for the inclined slopes just assuming that the local incidence and viewing angles have to be used instead of global is a good assumption for many land cover classes, such as snow and sand. For forests one should basically take into account that the tree trunks are often essentially vertical even when the ground is tilted. However, the BRDF model used for forests (Roujean et al. 1992) treats the canopy as a layer of random scatterers without any special attention to tree trunks. Yet the grouping of the trees will affect the radiation characteristics of a canopy. Probably this effect will just average out in coarse resolution images. Hence it is considered justified to use the BRDF model also for forests on inclined slopes.

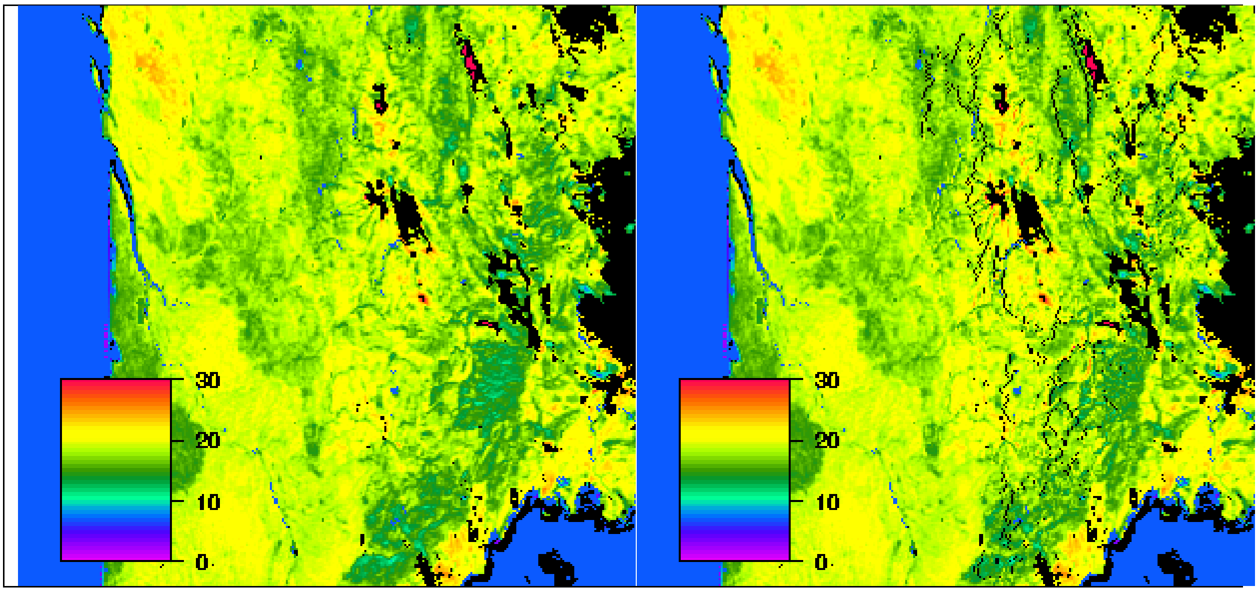

Figure 6. **Surface albedo of Southern France west of the Alps without (left) and with (b) topography correction. The image is in the original swath projection. The black area is masked clouds or gaps caused by pixels shifting of the topography correction.**

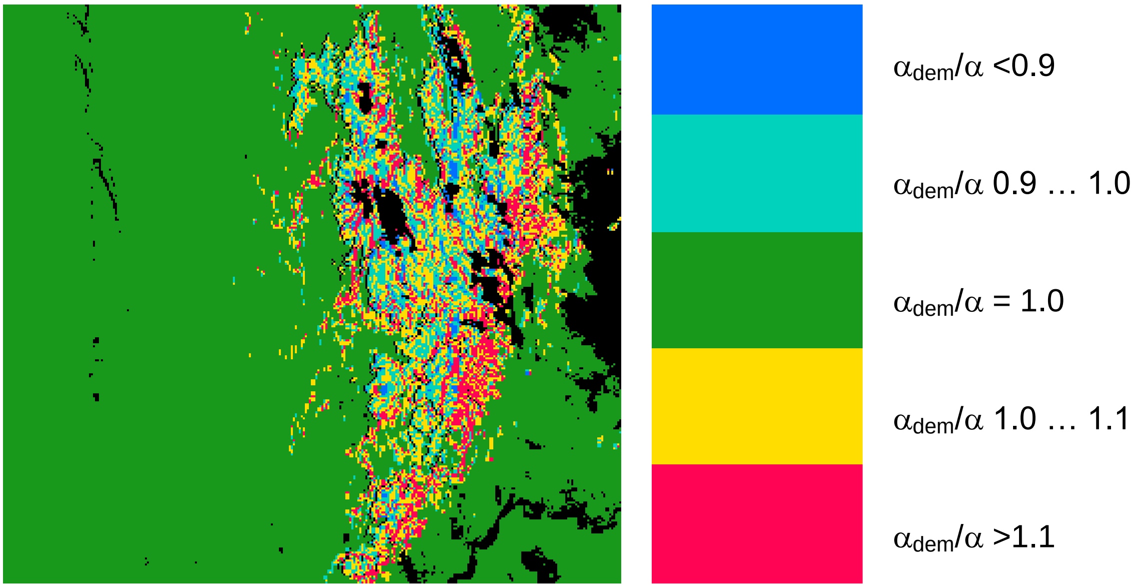

Figure 7. **Ratio of the topographically corrected and uncorrected surface albedo values in Southern France, west of the Alps. The black area is masked clouds or gaps caused by pixels shifting of the topography correction.**

CONCLUSIONS

The topography correction is clearly larger in mountainous areas, but also rugged terrain at lower altitudes may have a marked difference in the corrected and uncorrected albedo values. The topography correction in the mountains exceeds 10% practically everywhere and even errors larger than 20% are common for typical Sun and satellite zenith angle values.

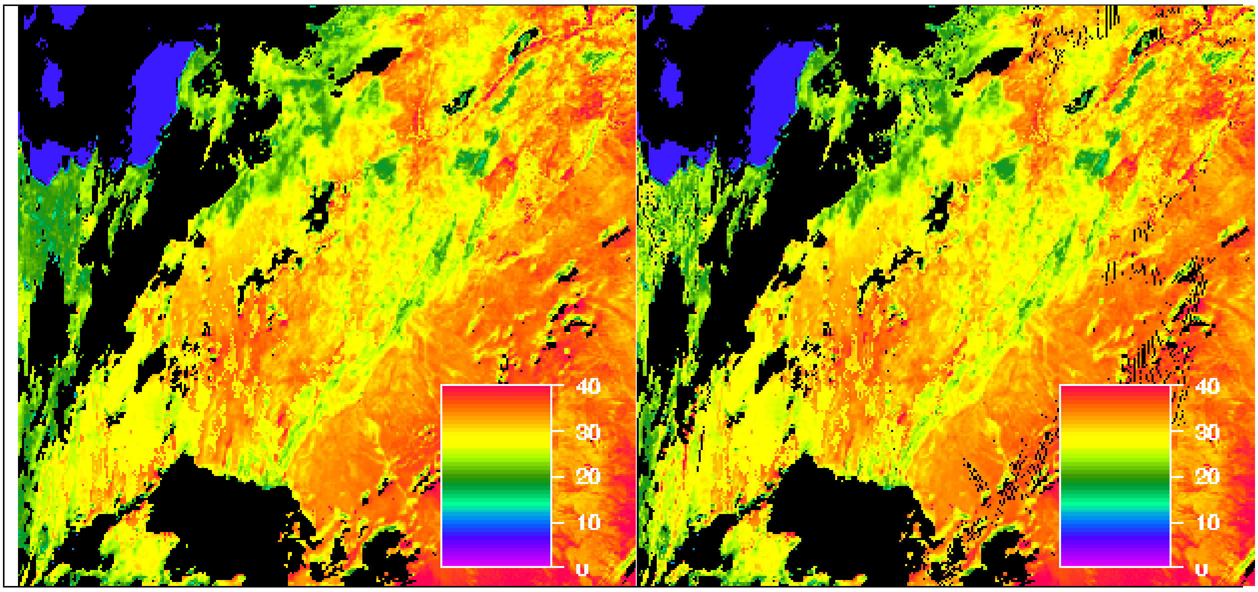

Figure 8. **Surface albedo of the coast of Morocco East of Gibraltar without (left) and with (b) topography correction. The image is in the original swath projection. The black area is masked clouds or gaps caused by pixel shifting of the topography correction.**

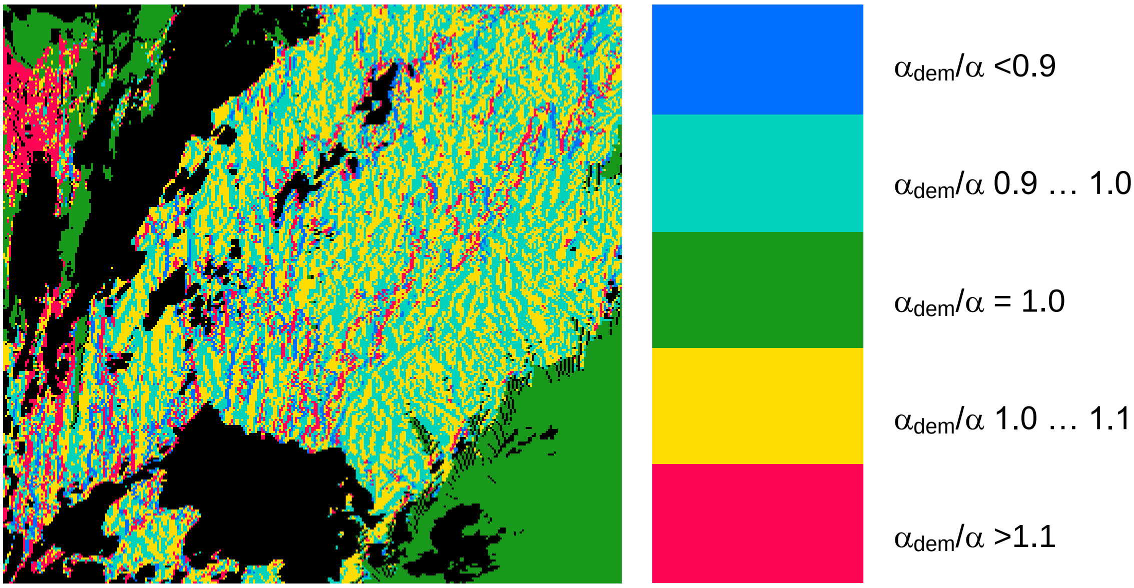

Figure 9. **Ratio of the topographically corrected and uncorrected surface albedo values in Morocco, East of Gibraltar. The black area is masked clouds or gaps caused by pixel shifting of the topography correction.**

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