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Modeling Effective Albedo as a Function of Land Cover Type and Snow Type

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Abstract: The Center for Environmental Radioactivity (CERAD) project UV- maps aims to obtain geographically distributed time-series of solar ultraviolet (UV) radiation in Norway. Since UV-measurements are limited to a few monitoring stations, a full representation of the spatial and temporal distribution needs to be based on a radiative transfer model (RTM). A key parameter is the regional albedo distribution. The albedo model developed here use a gridded set of local albedo values to derive the regional, effective albedo at any given point. In Norway there is a UV-monitoring network that has been operating since 1996, de- livering almost continuous 20-years time series of UV data, and the stations are used as reference points for the model. The albedo model uses land cover information and snow dispersion data from 11 years. Land cover classifications combined with snow classifica- tions constitute a matrix of albedo values, with one albedo value for each combination of land cover type and snow type, under the hypothesis that the snow albedo is affected by the underlying land type.

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1. Introduction

Solar radiation is a primary factor for all life on earth. Organisms have developed strategies to take advantage of sunlight and at the same time manage harmful effects from UV-radiation. Disturbance in the solar radiation climate and climate induced changes in land cover, might lead to different species composition in the environment (Bjørn 2015).

Solar radiation has a temporal variation during the day and throughout the year and is influenced by many factors from topography and vegetation, to atmosphere and weather conditions. In many cases, like solar energy applications, climate, health and environmental studies, knowledge of geographically and yearly distribution of solar radiation will be relevant and important.

The reflecting power of a surface, albedo, is measured as the ratio of upwelling reflected radiation from the ground to the downwelling radiation hitting the ground, integrated for all angles of incidence (Feister and Grewe 1995). The albedo of a surface is generally spectrally dependent and in the following, only the UV part will be considered. Different surfaces have different albedo values and typical values are 0.02-0.05 for soil and vegetation (Feister and Grewe 1995), while for glaciated regions with homogeneous snow surfaces, such as Antarctica and Greenland, the surface UV albedo could be nearly 1.0 (Wuttke and Seckmeyer 2006). A part of the upwelling radiation from the ground is backscattered by molecules and particles in the atmosphere, resulting in an enhanced downwelling irradiance from the sky. We refer to this multiply scattered radiation as the diffuse contribution. If the albedo value is high, the diffuse contribution could be as high as 40 % for clear sky conditions (Wuttke and Seckmeyer 2006) , whereas in combination with clouds, enhancement values of up to 63 % have been observed of the total UV irradiation (Kylling et al. 2000). Knowledge of snow cover and snow quality is therefore of great importance.

Based on different land cover (sea, lakes, fjords, mountains, vegetation and urban environment), where we know the areal cover within a circle around each point, together with a time series of categorized snow dispersion, we hypothesize that the effective albedo, which is the sum off all influence from surrounding surfaces at a point, can be determined as a weighted function of area type, areal cover and distance to point. This hypotheses assumes that the aldedo value is known for all combinations of land cover and snow conditions.

2. Methods

2.1. UV network

In Norway there is a UV monitoring network of nine stations with 5-channel ground based UV radiometer (GUV) instruments (Johnsen et al. 2012). Since they have 2 channels in the UVB (280-315 nm) and 3 channels in the UVA (315-390 nm), it is possible to study different parts of the UV-spectrum. The stations have been working since 1996 — delivering a unique 20-year time-series of UV-data (Johnsen et al. 2012). They are spread across the country in order to give the best geographical and topographical representation of the UV radiation climate in Norway. One of the stations is located at Finse, a mountainous plateau in the south of Norway (60.6 degrees North and 7.5 degrees East). At about 1200 meter above sea level, Finse is snow covered from late October to mid May. The land covers here are a mix of open mountain, lakes and glaciers. When these areas are covered with snow, the area is quite homogeneous and is therefore suited for studies of how snow affects the effective albedo at the station. This study is therefore limited to Finse, but will later be extend to other stations.

2.2. Clear weather

Based on the observations at the UV-stations an algorithm for estimating the clearness index for all days was applied. The shape of the irradiation distribution over the day gave the UV-profile for that day, and python's scipy.optimize.curve_fit (Jones et al. 2001–) function was used to fit this curve. If the fit was good, the fitted values was used for comparison with the modeled values. Throughout this study only almost clear days were used. The choice of clear days is merely chosen as an instrument to estimate the albedo. Atmospheric conditions where the radiation can be scattered several times, in for example clouds, are not suitable for this type of calculation. Days with clouds are therefore discarded from the data.

2.3. From UV to albedo

The 380 nm GUV channel is sensitive to cloud interference, but not affected by ozone, and is therefor used to find cloud free days. If most of the day is clear, the clear-weather-UV-function fit is good. The Libradtran software (Mayer and Kylling 2005) performs radiative transfer calculations and is used to calculate a dummy 380 nm channel day-profile. In this calculation, the albedo was set to 0. The difference between the dummy profile and observations are due to the effective albedo, and the mode of the fraction and the relation between effective albedo and UV irradiation was used to obtain the observed effective albedo estimate.

2.4. Snow dispersion data

The Norwegian Water Resources and Energy Directorate (NVE) produces daily estimates of the snow situation in Norway, and has modeled snow conditions for at the last decade. NVE has a variety of snow dispersion data available and the chosen data that has four categories; "no snow", "some snow", "wet snow" and "dry snow", with spatial resolution of 1x1 km (Saloranta 2014).

2.5. Land cover

The N1000 area cover map from The Norwegian Mapping Authority (NMA) provides a categorical land cover vector map with key land cover surfaces. NMA share this map as a PostGIS dump file (Holl and Plum 2009), which also is our format of choice.

Table 1: The parameter matrix with albedo values to be determined

Land cover	No snow	Some snow	Wet snow	Dry snow
Glacier	a_{11}	a_{12}	a_{13}	a_{14}
Open	a_{21}	a_{22}	a_{23}	a_{24}
Water	a_{31}	a_{32}	a_{33}	a_{34}
Forest	a_{41}	a_{42}	a_{43}	a_{44}
Settlement	a_{51}	a_{52}	a_{53}	a_{54}

The format is downloaded as a zip-file and imported to local PostGIS server, and some of the categories are listed in table 1. This vector map covers all of Norway, but this study is focused on Finse, and therefore a 60 km x 60 km area around the Finse station is extracted by PostGIS's ST_Intersection and ST_MakeEnvelope functions.

A part from the great speed and possible command line interface, PostGIS access is implemented in a large number of GIS-softwares and programming languages. QGIS (QGIS Development Team 2009) is our chosen GIS-software to access our PosGIS database and convert the extracted vector map to a 100 m x 100 m raster map with the ”Rasterize” function. The raster map is stored as a GeoTIFF file, because they are easily imported into python with the use of GDAL (GDAL Development Team 201x).

2.6. Albedo model

The albedo model aims to estimates the effective albedo at any given point in Norway. The model uses gridded, component surface albedo values. In table 1 the parameters that are relevant for the Finse area are listed. The parameter values are set for a raster map covering 60 km by 60 km area around the central point. Based on Walker 2009 the apriori assumption that the backscattered sky irradiance resulting from distant patches of snow, or snow free ground, is Gaussian declining from the point, a Gaussian distance weighting over that raster is applied. Summing the contributions from the surrounding areas gives the effective albedo in the central point. This method is illustrated in figure 1 and gives an effective albedo estimate which changes daily according to snow-conditions. Using the Finse station as central point means that a comparison of the model results with observations is possible.

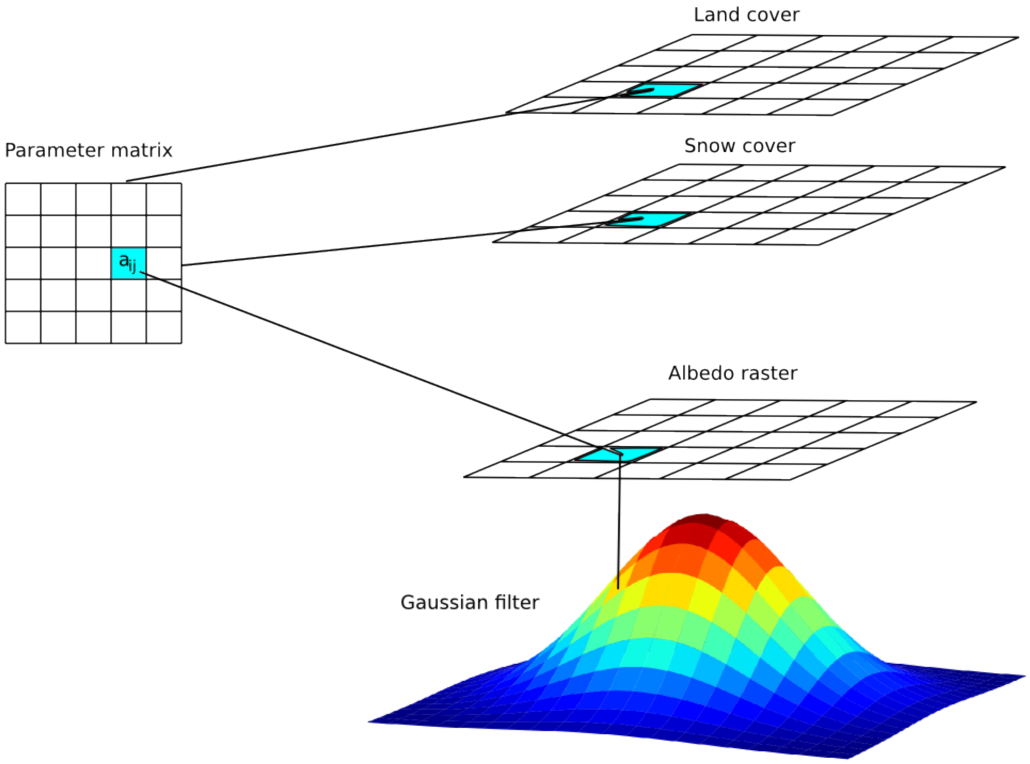

Figure 1: Illustration of the albedo model. Land cover and snow cover are used to find the aldedo value for each raster cell in an albedo map. A Gaussian filter is applied before summing the contributions to the effective albedo in the center.

2.7. Effective albedo equation

The effective albedo at point P can also be calculated as the sum

$$Albedo_{eff} = \sum_{i,j} a_{ij} x_{ij} \tag{1}$$

Here a_{ij} is the albedo parameter for land cover type i with snow type j, while x_{ij} is the effective area for land cover type i with snow type j. The effective area for each combination ij is calculated like this:

$$x_{ij} = \int s_{ij}(\vec{r}) g(\vec{r}) dA \tag{2}$$

where $\vec{r}$ is radius vector from P, and $s_{ij}(\vec{r})$ is 1 if position $\vec{r}$ is of type ij, and 0 otherwise, and $g(\vec{r})$ is a central symmetric Gaussian weighting function centered at P. The effective areas are all normalized so that their sum is 1.

3. Results

3.1. Parameter determination

The problem of determining the parameter values a_{ij} is solved by least squares regression using python's scipy.optimize least squares (Jones et al. 2001–) method. The bounds $min = 0$ and $max = 1$ was applied and the equation was solved with three different loss functions (linear, soft_l1 and cauchy).

The Finse area mainly consists of open mountain area, glaciers and lakes. At 20-30 km from the Finse station there are some forest areas, but the contributions to the effective albedo are assumed to be too small to be determined. Forests were therefore excluded and glacier's and lake's contributions where combined. Now there is four parameters to determine: Wet snow on open areas, dry snow on open areas, wet snow on lakes and glaciers, and dry snow on lakes and glaciers. The results are given in table 2.

Table 2: Albedo parameter regression results for Finse

Land cover	Wet snow	Dry snow
Glacier and lakes	0.93	1.0
Open	0.45	0.68

Table 3: Albedo parameter regression results for Finse, ignoring underlying land cover

Land cover	Wet snow	Dry snow
Finse area	0.52	0.72

As seen from table 2, the albedo parameter for dry snow with glacier or lake cover is pushed to the limit value 1. This is not a good estimate and the result is not physically rooted. The value for wet snow with glacier or lake cover is also higher than plausible. This discrepancy is probably because of the relatively small areas in combination with long distance to the center, resulting in a too low influence to be determined properly by the parameter regression method.

By ignoring the underlying land cover for Finse and only look at areas with different snow cover, wet or dry, the regression gives values shown in table 3.

The results seen in table 3 clearly distinguish between wet and dry snow and agrees with values found in literature (Feister and Grewe 1995). For glaciers and snow covered water, thees values may be too low and for open areas with rough stone formations these values seems too high. The vales found in table 2 is more in accordance to what would be expect for open mountain areas.

3.2. Model and observations comparison

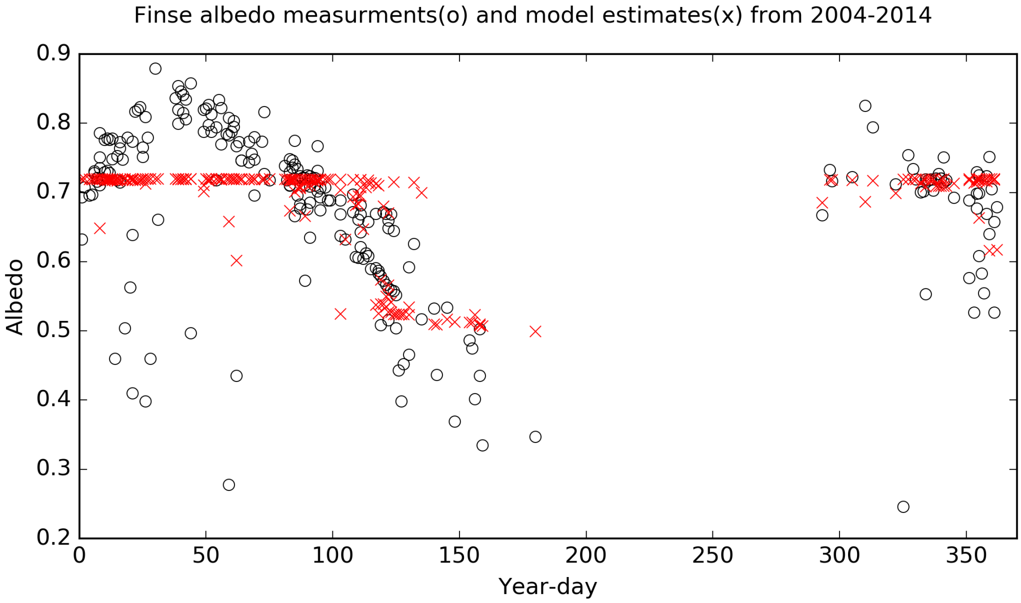

Figure 2: Clear weather effective albedo and model estimates at Finse UV-station.

The modeled effective albedo estimates, using the parameters found in table 3, are plotted in figure 2 where the circles are station observations and the crosses are model estimates. Only days when wet and dry snow covers more than 95% of the area are included in the figure. There is a systematic underestimation of the effective albedo from January to March, with a minimum at late January. From March to summer the differences are more spread, but with a mean closer to zero. The large differences seen between day 0 and day 50 are probably due to some random error or because of uncertainties in the effective albedo algorithm, which is highest during winter when the sun is low in the sky. The model captures some of the variation of the measured data, but there is clearly room for improvement.

4. Discussion

A description of a model for clear weather effective albedo calculations based on snow dispersion data and land cover has been presented together with an eleven year period of measured effective albedos at the Finse research station. Also, a methodology to determine the albedo parameters on which the model is based has been described. The current results from this parameter determination show that there are some issues that need to be addressed. Land covers which are not in the direct vicinity of the station tend to influence the effective albedo so little, that parameter determination is not possible and so these should be excluded from the analysis.

Figure 2 shows how the modeled effective albedos fits the observations at Finse UV-station. The modeled values follow the snow melting in April-May fairly well, although the modeled values seem a bit time lagged. In January and February, when the Finse area usually is covered with dry snow, the model is pushed to the upper albedo limit. Still, in late January/beginning of February, the model clearly undershoots the observation. This result shows that there are periods with albedo levels outside the bounds of the model. The reason for this might be because these periods have high abundance of snow and possibly also lower temperatures than at other times of the year. These are possible correlations which will be investigate in future studies. Deeper snow would make a better cover for the underlying rocky terrain and lower temperature would mean smaller snow grain size which have higher albedo. Also, this period is suspected to have more days with new snow, which would also increase the albedo levels.

The snow data used in this work have limitations, with only four categories and a resolution of 1 km x 1 km. More detailed snow data might make the albedo model more dynamic, but will also increase the number of parameters which need to be determined. The Gaussian distance weighting might also be a source of error, and it will in the extension of this work be developed a distance function based on the seasonal snow variation and effective albedo observation.

When albedo values are known, the influence of clouds on UV irradiance can also be included in the model. The modeled UV-irradianse can also be weighted by different types of action-spectra like the spectrum for erythema (de lEclairage 1999). It would also be possible to investigate the energy production of solar panels at different angels by applying spectral data of solar cells.

Although this project is ongoing and the results are preliminary, the methodology shows how FOSS4G technology can be applied in scientific research, to exploit the vast amount of spatial data which contributes to new and better scientific understanding.

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References

Bjørn, L. O., 2015. Photobiology - The science of light and life. Springer.

de lEclairage, C. I., 1999. Joint iso cie standard: Erythema reference action spectrum and standard erythema dose. iso 17166 cie s007 e-1999.

Feister, U., Grewe, R., 1995. Spectral albedo measurements in the uv and visible region over different types of surfaces. Photochem. Photobiol. 62 (4), 736–744.

GDAL Development Team, 201x. GDAL - Geospatial Data Abstraction Library, Version 2.1.0. Open Source Geospatial Foundation.
URL `http://www.gdal.org`

Holl, S., Plum, H., Apr. 2009. PostGIS. GeoInformatics 03/2009, 34–36.
URL `http://fluidbook.microdesign.nl/geoinformatics/03-2009/?page=34`

Johnsen, B., Nilsen, L. T., Dahlback, A., Edvardsen, K., Myhre, C. L., 2012. The norwegian uv-monitoring network: Qc and results for the period 1996-2011. AIP Conf. Proc. 1531 (1), 784–787.
URL `http://adsabs.harvard.edu/abs/2013AIPC.1531..784J`

Jones, E., Oliphant, T., Peterson, P., et al., 2001–. SciPy: Open source scientific tools for Python.
URL `http://www.scipy.org`

Kylling, A., Dahlback, A., Mayer, B., 2000. The effect of clouds and surface albedo on uv irradiances at a high latitude site. Geophysical Research Letters 27, 1411–1414.
URL `http://dx.doi.org/10.1029/1999GL011015`

Mayer, B., Kylling, A., 2005. Technical note: The libRadtran software package for radiative transfer calculations - description and examples of use. Atmospheric Chemistry and Physics 5, 1855–1877.

QGIS Development Team, 2009. QGIS Geographic Information System. Open Source Geospatial Foundation.
URL `http://qgis.osgeo.org`

Saloranta, T., 2014. New version (v.1.1.1) of the senorge snow model and snow maps for norway. Report no. 6.
URL `http://publikasjoner.nve.no/rapport/2014/rapport2014_06.pdf`

Walker, D., 2009. Cloud effects on erythemal uv radiation in a complex topography. Ph.D. thesis.

Wuttke, S., Seckmeyer, G., 2006. Spectral radiance and sky luminance in antarctica: a case study. Theor. Appl. Climatol. 85 (3), 131–148.