Hydrol. Earth Syst. Sci. Discuss., 9, C4502–C4511, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C4502/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Applying a time-lapse camera network to observe snow processes in mountainous catchments" *by* J. Garvelmann et al.

J. G. Corripio (Referee)

jgc@meteoexploration.com

Received and published: 1 October 2012

This paper presents an interesting monitoring experiment in three catchments of the Black Forest in Germany. The authors investigate the potential of time lapse photography to derive information on snow depth, snow canopy intersection, precipitation phase and snow albedo. They employ an impressive array of 45 cameras and an undisclosed number of meteorological stations. The potential for acquiring useful distributed data at the catchment scale is very good and the continuation of this type of work should be encouraged.

However, the data analysis is very poor, there are too many unnecessary simplifications of complex processes, information is lacking and replicability nearly impossible. In the evaluation criteria of papers submitted to HESS, point number six states:

6- Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

The answer is no.

Section **Image analysis** says:

“We used IDL image processing software to extract information about snow depth, albedo and the interception of snow in the forest canopy from the digital images.”

Yet no further information is given on which tools, techniques or procedures are used. IDL has hundreds of image processing routines, all of them well documented and in many cases with clear code provided. If the reader is going to trust this study and benefit from its application, the algorithms used should be clearly stated.

Equation 1 for albedo derivation comes from an online secondary school exercise. The “Albedo project” is a very commendable enterprise, but it is not a rigorous study and therefore that equation should be tested carefully. Even more when the source referred indicates that “this is approximate; final analysis is not yet complet”. According to Equation 1 the albedo of a section of the image (ROI) is directly proportional to the ratio of reflectance between the ROI and a reference target. How do you know that the response of the camera sensor is directly proportional to illumination intensity? We have used many different types of cameras to derive snow albedo (35 mm slides, CCDs, CMOS) and found that in most cases the response of the digital sensor to illuminance is nearly logarithmic. It is affected not only by the sensor but also by the lens and the camera internal image processing. The final result is better approximated by a polynomial function, a 3rd order is usually sufficient, as shown in Figure 1, below. It is clear from this figure that the linear fit is the least appropriate, while the polynomial fit is a much better representation of the relationship between DN (digital number, your $\overline{RGB}$) values in the photographic image and actual reflectance values in the real pho-

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tographed scene. Figure 1 is for a different camera, but deriving the relationship for the cameras used in this work should be straightforward.

Using a reference board on the photographic scene is perfectly valid, but we need to know the actual albedo of the reference and its illumination conditions. Unless you have used a Spectralon panel as a reference, it can not be called a “perfect white” (10691, 27). What is the albedo of this reference board and how was it calculated? If you don’t have this value, the result of Equation 1 cannot be called albedo.

Even if we know the exact albedo of the reference board, the RGB pixel values collected by the camera will depend on the intensity of the illumination of the panel. If the relationship between ground surface and reference board illumination changes, then Equation 1 is not valid anymore. As the board has a different orientation than the ground, their ratio of illumination intensity will change over the season. Equation 1 needs to be corrected for this variation. If not corrected the errors can be very large, as appreciated on Figures 1 and 2. There is also need to correct for the ratio of direct to diffuse insolation in cloudy days. These corrections can be implemented using any solar radiation software, I used the R package insol (http://cran.r-project.org/web/packages/insol/).

We are told that the albedo derivation is supported by a high correlation between the photography-derived albedo and that measured by an AWS. Yet, out of a very impressive set of images from 45 cameras during two winter seasons, we are presented with the correlation values for a mere seven days. Why such a short series?

That single week of albedo correlation includes a strong melt event, and there is a synchronous large drop of albedo values both from the camera and at the AWS to reach low values that do not correspond to snow. This results in a high correlation that does not necessarily represents that of the whole season. Please provide longer time series that are representative of the full study.

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The digital image analysis was also applied to:

- snow depth
- state of precipitation
- snow canopy interception

The procedure was executed in a batch mode, but there is no further information on how this was done, what precise analysis was performed, how was it automated, what problems did you encounter and how did you solve them.

For example, for snow depth, how were the pixels in the scale bar counted? How did you correct for the viewing angle and distance to the camera? Did image distortion alter the readings?

For state of precipitation, how did you identified separately snow and rain? Which shutter speed did you used (they are fast moving targets)? Did low light affected the measurements?

And for snow canopy interception, what thresholds for vegetation and snow did you use? What error analysis was applied? What was the difference between low branches and high branches estimated (surely the viewing angle of the camera has an important effect)?

Without this additional information the technique described is of little use to other researchers.

There is a detailed discussion of the problems with the camera, storage and batteries which, although lengthy, is useful for researcher looking into implementing this technique.

Additional comments

Page 10689, lines 10, 11. It looks to me that Jost et. al (2009) evaluated one single model, it is not possible to generalize from here that all albedo models respond in the same manner. I will suggest checking the output of the SNOWMIP inter-comparison exercise or the albedo simulations in models such as CROCUS or SNOWPACK. Other simpler implementations may perform better than the model studied by Jost et al. See for example: Brock et al. (2000); Brun et al. (1989); Etchevers et al. (2004); Lehning et al. (2002); Oerlemans and Knapp (1998).

P. 10690, l. 7. What is a “vegetational situation”?

P. 10690, l. 12. I doubt that there is such a thing as a “typical mid latitude mountain range”. Please provide some broad description of the forest, such as composition (deciduous, conifer, mixed,...), size, density, etc.

P.10692, l. 2. The term white balance and white/black balance is confusing, as in photography it refers to an adjustment of the temperature of the light to get realistic colours. It is not used in the same sense here, please be more specific.

P. 10693, l. 4. CCDs and CMOS are actually sensitive to NIR radiation, which is an advantage for albedo estimation. In fact, this property is used by many digital camera applications in astronomy and vegetation studies. Usually manufacturers filter the NIR component and do not provide full information of the sensitivity range due commercial confidentiality, but the sensor can measure beyond the visible spectrum.

P. 10695. Spatial SWE distribution was derived from a linear regression model. How does the model compares with measured values of SWE?

P. 10699, l. 10 “A high density meteorological observation network”. How many stations were installed? Please provide a list or table with the instrumentation, sensor type and measuring range and precision.

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P. 10699, l. 23. Some snow models calculate the snow/rain threshold from atmospheric profiles, dew point or other parameters, and it is not unusual to set the threshold at a positive temperature, see for example Lundquist et al. (2008) and references therein.

Figure 1. The color scale makes no sense, as different colors indicate overlapping altitude ranges. Please provide coordinates and which way is north.

Figure 11. On day 2012-01-05 measured albedo drops to zero. That is rather unusual for a partially snow covered grass surface. Do you have any explanation?

Figure 12. Is there any direct measurement of albedo with an albedometer to validate these results under the canopy?

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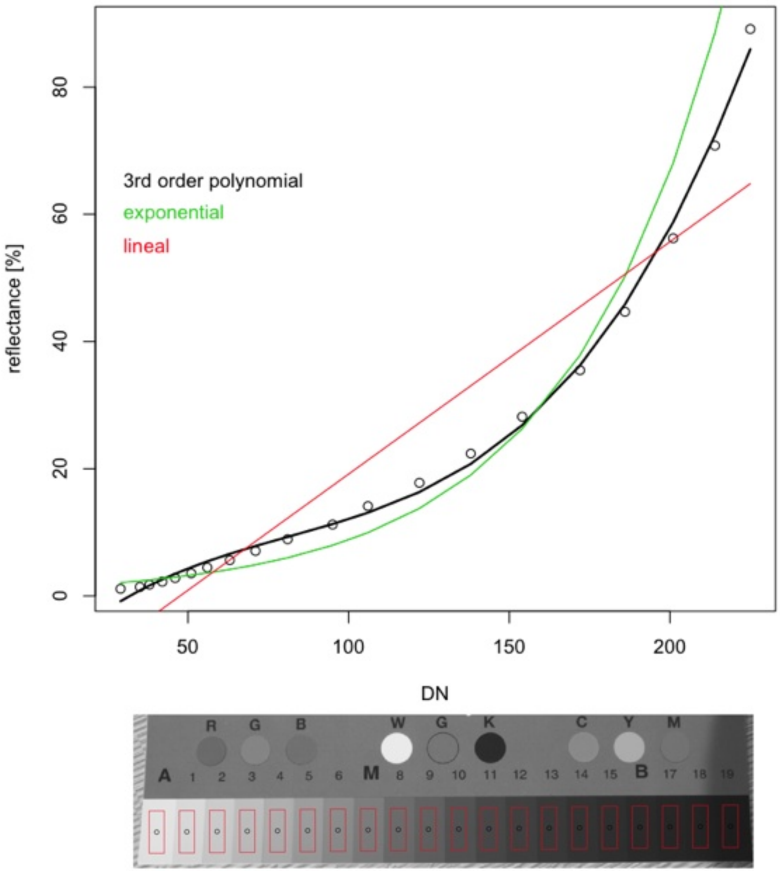

Fig. 1. Relationship between photographic pixel DN value and reflectance in a 35 mm reflex camera, derived from a Kodak Grayscale Q13 calibration card.

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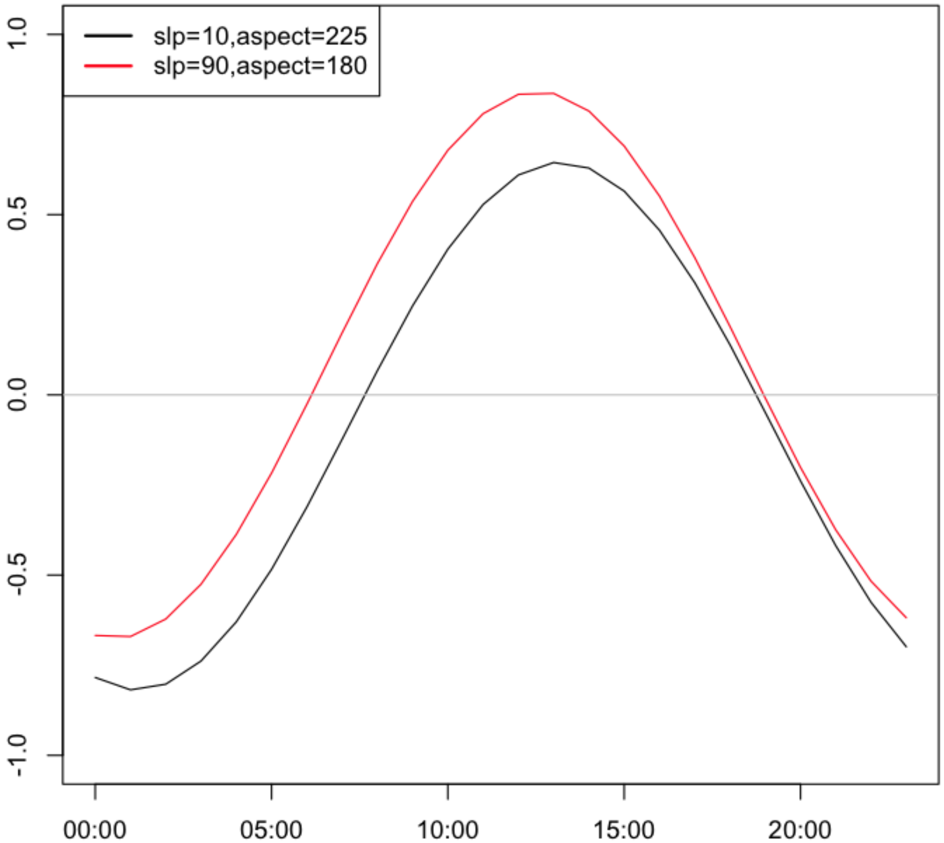

Fig. 2. Hourly variation of the cosine of the angle between sun and vector normal to surface for a given ground surface and a vertical reference board looking south on the 1st of March at 50 degrees of latitu

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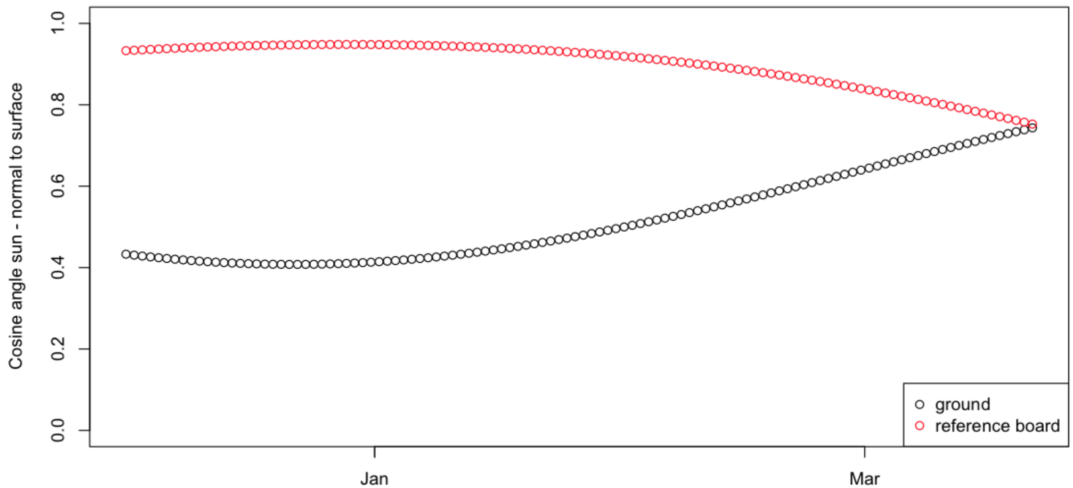

Fig. 3. Cosine of the angle between sun and vector normal to surface for a given ground surface and a vertical reference board looking south at mid day from December to March at 50 degrees of latitude North

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