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Hydrology and Earth System Sciences Discussions

Interactive comment on "Topographic effects on solar radiation distribution in mountainous watersheds and their influence on reference evapotranspiration estimates at watershed scale" *by* C. Aguilar et al.

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The authors deeply appreciate the work done by the reviewer. Answers to the review comments are given below, where the original reviewer's comments are highlighted in quotation marks. Some paragraphs have been added in order to clarify certain statements. Please find attached the revised version as well as figure 3.

"1.There are two topics in the manuscript; one is about modeling the complex processes of solar radiation on topography, and the other is about their influence on evapotranspiration computing. Which one did the authors concerned mainly? I noticed that the most part of the manuscript was about the solar radiation computing, however, there are no creative and new points beyond the previous studies. Maybe they considered more about potential influence of topography on evapotranspiration, but the introduction part has not included detailed review about it."

The main topic of the manuscript is the spatial and temporal interpolation of solar radiation for distributed energy and water balance models, specifically evapotranspiration, in mountainous terrain. Here the combination of extreme gradients in the spatial distribution, together with the lack of measurements at detailed spatial and temporal scales, calls for the need to integrate algorithms simple enough to be run with common measurements. The main effort was to couple the different existing algorithms and corrections for each component of the final variable at its proper temporal and spatial scales for its use in the computation of a crucial term of the hydrological water balance, the evapotranspiration. This final step of applying corrected meteorological terms in the spatial computation of hydrological variables is often missed in most distributed hydrological models and therefore may constitute a considerable source of error, especially in rough terrain and arid environments. In this way, following the comment of the reviewer, the aims of the study have been rewritten as below (line 15 in page 5 in the revised text): The aim of this study is to address the importance of incorporating in hydrological models the effects of topography on the spatial distribution of global solar radiation at watershed scale. To this purpose, different topographic algorithms have been coupled in order to estimate series of distributed solar radiation values and calculations have been made to quantify such influence on evapotranspiration estimates in mountainous areas in Mediterranean locations. Thus, an algorithm was derived from Dozier (1980) and Jacovides et al. (1996) to take into account the lack of meteorological stations at high altitudes. To be exact, it should estimate hourly global values as well as the separation between its beam and diffuse components from the common measurements obtained on horizontal surfaces. The resulting algorithm was imple-

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mented on a GIS-based routine and applied to data from a mountainous watershed on the south coast of Spain. The distributed results were compared to those obtained from simpler interpolating methods and experimental data. Finally, in order to address the hydrologic importance of using topographically corrected solar radiation fields over uniform values, a simple evaluation in terms of their influence in the computation of reference evapotranspiration fields is carried out.

"2.On page 2378, the authors mentioned 'these approaches are not commonly included in GIS-based hydrological models.' That argument does not carry conviction, please give more support."

The explanation of this argument comes in the following paragraphs giving examples of well-known GIS-based distributed hydrological models that do not consider topographic corrections in the spatial interpolation of solar radiation. Instead, a constant value for each hydrological unit or subwatershed is applied (e.g. SWAT), or just simple corrective terms for the inclusion of altitude or atmospheric factors but disregarding the effects of shadows cast by the surrounding terrain (e.g. AnnAGNPS). For a better comprehension, the paragraph could be rewritten as: "Despite the availability of topographically corrected models for the estimation of solar radiation fields as Dozier and Frew (1980), Dubayah (1992, 1994), etc., these approaches are not commonly included in GIS-based hydrological models, which usually adopt simple approaches to estimate the incident radiation throughout the watershed, as explained in the following. In AnnAGNPS..." (line 22 in page 4 in the revised version).

"3.On page 2382, "Thus, a simpler approach is proposed so that once the daily values of each component are obtained for each cell, the hourly values (rb and rd), are computed by distributing the daily amounts along the day following the temporal pattern of extraterrestrial hourly radiation during the day." It's difficult to understand that the components of radiation can be computed by this method. Any facts or references support this argument? Please give more proofs."

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The lack of information to properly compute the hourly fractions of the global radiation leads to this approach. The application of hourly relations between hourly CI and hourly diffuse radiation values was initially considered following previous studies in the literature (Orgill and Hollands, 1977; Bugler, 1977; Erbs et al., 1982). However, the aim of this work was to provide a feasible method to include topographic effects on radiation at watershed scale, and the size and heterogeneity of the study site together with the lack of meteorological stations, which unfortunately are usual circumstances in many locations, make it unreasonable to spatially interpolate hourly CI values as the spatial distribution of diffuse and direct radiation shows a better correlation at a daily scale. Then, for the temporal downscaling of the variable we took as a first approximation the hourly behaviour of extraterrestrial radiation as we assume that four stations in the watershed are not able to provide a reliable framework for the spatial distribution of hourly values in the whole area. This argument has been included in the text (line 18 in page 8 in the revised version) in order to support the reason for such simplification: The application of hourly relations between hourly CI and hourly diffuse radiation values was initially considered following previous work in the literature (Orgill and Hollands, 1977; Bugler, 1977; Erbs et al., 1982). However, the aim of this work was to provide a feasible method to include topographic effects on radiation at watershed scale, and the size and heterogeneity of the study site together with the lack of meteorological stations, which unfortunately are usual circumstances in many locations, make it unreasonable to spatially interpolate hourly CI values as the spatial distribution of diffuse and direct radiation shows a better correlation at a daily scale. Besides, the application of hourly correlations would require the availability of some other variables such as solar altitude or air mass (González and Calbó, 1999). However, as pointed out by Zaksek et al. (2005), the use of more sophisticated models depends on the scale and purpose of the study, so that under certain circumstances it would be better to use a less complex model. Thus, a simpler approach is proposed so that once the daily values of each component are obtained for each cell, the hourly values (rb and rd), are computed by distributing the daily amounts along the day following the temporal pattern of extraterrestrial hourly radiation during the day. The hourly values of beam and diffuse radiation on horizontal surfaces can then be transposed to give hourly radiation on tilted surfaces, since hourly methods of computing radiation on inclined planes, when available, should give slightly more accurate results than those obtained by the daily methods (Iqbal, 1978).

"4.On page 2385, ‘Shading cast by the nearby terrain’, this point is the key in computing solar radiation. And the albedo from RS images is important also. It is better to describe them in more details. On the other hand, it is better to describe some methods more briefly which are fully developed in many previous studies, such as ‘2.3.2 diffuse radiation’."

Section 2.3. ’Modelling topographic effects’ introduces the computation of the shading of direct sunlight by surrounding terrain from the idea of local horizon for each cell proposed by Dozier (1980). Then, subsection 2.3.1 specifies the two different situations that may modify beam radiation reaching a cell and so, brief descriptions with a reference for each one is provided where more detail concerning the methods can be found (Dozier et al., 1981; Dubayah, 1992). Nevertheless, following the comment of the reviewer the figure 3 (page 30 in the revised text) is proposed to be included after the point ‘Shading cast by the nearby terrain’ for a better comprehension and so, the following figures as well as their references in the text had to be renumbered (revised text). Caption of figure 3 would be the following: Figure 3. Shading cast by the nearby terrain by comparison between the horizon angle (HΦ) and the illumination angle (θ) As for the albedo estimation from RS techniques, it was developed for the particular conditions of the study site by Díaz et al. (2007) so just a short description of the procedure (origin of the images and applied algorithm) and the reference, were this study is fully developed, is provided.

"5.Equation 11, please check the subscript."

Subscripts are correct. Reflected solar radiation is calculated as an average radiation reflected from the surrounding terrain corrected by a terrain configuration factor. To calculate reflected radiation, it is necessary to make some generalizations about the surrounding terrain. Here, the assumption of an infinitely long slope needs to be applied, as numerous authors have already proposed (Dozier and Frew, 1980; Dubayah et al., 1990), to simplify the procedure; otherwise, it would be necessary to calculate every single terrain facet visible from each cell in the DEM.

"6.On page 2395, the last paragraph which gives some technological information about computer programs can be neglected, or moved to METHOD part."

The paragraph has been reallocated in the materials and method's section (line 22 in page 12 in the revised version).

References

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Hadjioannou, L., Pashiardis, S., and Stefanou, L.: On the diffuse fraction of daily and monthly global radiation for the island of Cyprus, Sol. Energy, 56, 565-572, 1996.
Zaksek, K., Podobnikar, T., and Ostia, K.: Solar radiation modelling, Comp. Geosci., 31, 233-240, 2005.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/7/C1119/2010/hessd-7-C1119-2010-supplement.zip

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 2373, 2010.

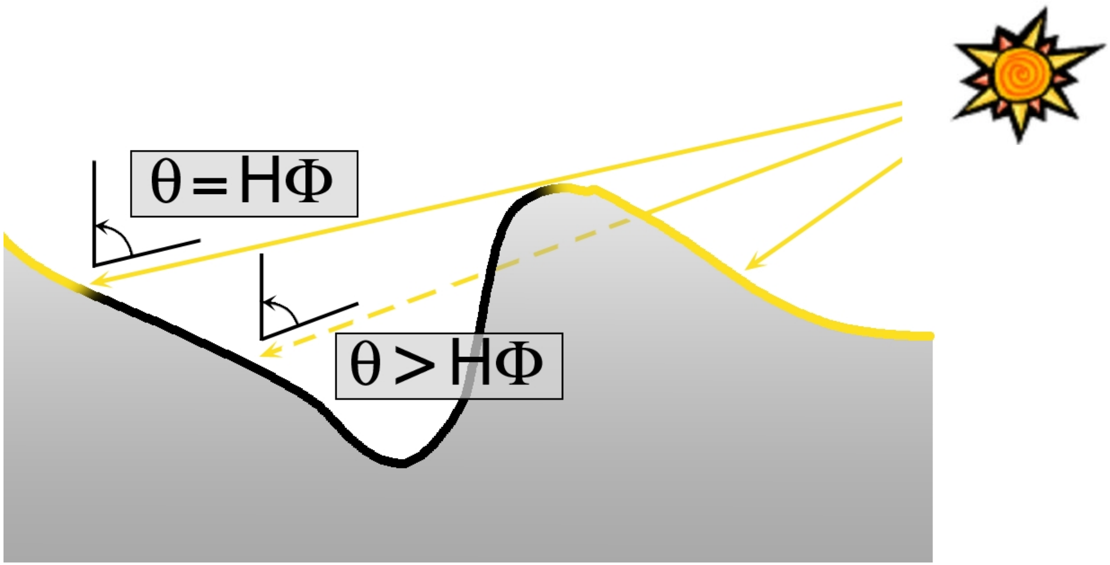

Fig. 1. Figure 3. Shading cast by the nearby terrain by comparison between the horizon angle (HΦ) and the illumination angle (θ)

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