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Hydrology and Earth System Sciences Discussions

Interactive comment on "Combining remote sensing and GIS climate modelling to estimate daily forest evapotranspiration in a Mediterranean mountain area" *by* J. Cristóbal et al.

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Reviewer general comments 1: This paper outlines a simple remote sensing method for estimating evapotranspiration over a scots pine stand in a mountainous terrain. In general, the paper is well written and robust techniques for mapping ET are of great importance. However, additional thought could be put into how to better distinguish this paper from ET papers that abound in the literature.

The method itself is quite simplified, and more physically sound techniques exist. It is not clear how a methodology like this will be useful in practice, given that it appears to

require intensive local calibration - this should be better motivated within the text.

Authors reply to reviewer general comments 1: In the case of the B parameter, we have chosen three ways to compute it depending on its complexity. We know that B parameter computed using a net radiation sensor needs more intensive local calibration. But, on the other hand, B computed using NDVI do not require local calibration, only realistic values of NDVI. When we compared the different B parameter methodologies, results, in Landsat case, were so close, so we can use B-NDVI in an operative way without local calibration. However, in this article we also wanted to point out not only the advantages of the methodology but also the limitations of these techniques in order to improve them in a future.

In pages 1139-1140 from lines 25 to 15 we have discussed these issues and we have mentioned this in the conclusion section. However we agree that perhaps this is not clear in the text and we have included in these sections the reviewer's suggestion.

"..Although the two B parameter approaches (B-Rn ratio local and B-NDVI) obtained similar results, the main advantage of the NDVI approach is easily implemented, when realistic values of NDVI thresholds to compute NDVI* are selected, to compute ET than B-Rn ratio local or regional because that require intensive local calibration. So, if a well-balanced regional Rn ratio is not available due to limitations in the meteorological networks, the NDVI approach is preferable for computing the B parameter at regional scales in an operative way. ..."

Reviewer general comments 2: It would have also been nice to see specific demonstrations of where the GIS/DEM based analysis of met and LST inputs to the model really made a difference compared to a more simplistic treatment. This component of the analysis is novel, and could be better promoted.

Authors reply to reviewer general comments 2: We agree with the referee that compar-

ing more complex models against simplistic treatments is an interesting idea in order to evaluate if the effort is a worthwhile. In this direction, specific demonstrations of more simplistic treatments can be found in Pons and Ninyerola, 2008, where interpolated solar radiation without taking into account relief was compared with a DEM-based solar radiation. In this comparison better result were obtained in the second case. Therefore, we understand that including DEM-based in ET modeling will improve the results. In the case of LST we do not have radisonde or thermal infrared sensor to compare with LST retrieved from Landsat or MODIS data.

In the conclusions section there is a comment about the GIS-based climate ETd input variables that ties to promote these techniques. In addition, we have also included a comment in the abstract section.

"Finally, GIS-based climate ETd input variables performed well, making possible to compute ETd at regional scales"

Specific comments

Reviewer specific comments 1: Abstract: L14: What is the “B parameter”? This has not been defined yet.

Authors reply to specific comments 1: We have included a brief description of the B parameter in the Abstract section

“.....combining three different approaches to calculate the B parameter, which represents an average bulk conductance for the daily-integrated sensible heat flux”.

Reviewer specific comments 2: L20: Give absolute and %error for MODIS at this point, so user can compare to Landsat performance. May want to state spatial resolution of

Landsat and MODIS assessments somewhere in abstract.

Authors reply to specific comments 2: This has been included in the abstract section. "..The method using Landsat data resulted in a good agreement, R2 test of 0.89, with a mean RMSE value of about 0.6 mm day-1 and an estimation error of $\pm$30%. The poor agreement obtained using TERRA/AQUA MODIS, with a mean RMSE value of 1.8 and 2.4 mm day-1 and an estimation error of about $\pm$57 and 50%, respectively, data reveals that ETd retrieval from coarse resolution remote sensing data is troublesome in these heterogeneous areas, and therefore further research is necessary on this issue.."

Reviewer specific comments 3.1:Pg 1128. L20: Expand model acronyms at first use. 30% errors in daily ET are not great. Typically errors more like 10% are being obtained routinely with LST-based energy balance models.

Authors reply to specific comments 3.1: Acronyms has been expanded in the text.

Reviewer specific comments 3.2: Errors more like 10% are being obtained routinely with LST-based energy balance models but typically over crop areas.

Authors reply to specific comments 3.2: The focus of this paper is in natural vegetation areas, specifically in Scots Pine. In page 1141 line 16, “3. Results and discussion section” we have compared our results with other references that have modeled ET in natural vegetation areas and the errors are similar. The good agreement regards to the R2 test of 0.89. This has been clarified in the abstract section.

"The method using Landsat data resulted in a good agreement, R2 test of 0.89, with a mean RMSE value of about 0.6 mm day-1 and an estimation error of $\pm$30%. "

Reviewer specific comments 4: Pg 1129. L1: Expand these acronyms as well

Authors reply to specific comments 4: This has been expanded in the text

"ET can be modelled at global scales using GIS climate-based methodologies such as Geographical Information Systems (GIS)-based Erosion-Productivity Impact Calculator -GEPIC- (Liu et al., 2007), Lund-Potsdam-Jena managed Land –LPJmL- (Rost et al., 2008) or Global Crop Water Model -GCWM- (Siebert and Döll, 2010). However, radiometric measurements provided by remote sensing added to GIS climate. . ."

Reviewer specific comments 5: L15: Use "moderate" in place of "medium"

Authors reply to specific comments 5: This has been changed in the text

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Reviewer specific comments 6: L25: Swap phrases, as "The objective of this paper is to evaluate a simple method for computing daily ET using stand-scale sap flow measurements made in Scots Pine in a heterogeneous"

Authors reply to specific comments 6: This has been changed in the text

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Reviewer specific comments 7: Pg 1130. L1: Again, use moderate instead of medium

Authors reply to specific comments 7: This has been changed in the text

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Reviewer specific comments 8: Pg 1130. L21: LST is being used for both land-surface temperature and local solar time.

Authors reply to specific comments 8: This has been changed in the text

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Reviewer specific comments 9: Pg 1132. L20: The aerodynamic resistance has a

strong dependence on wind speed. How can a single value for Ra be used?

Authors reply to specific comments 9: Effective aerodynamic resistance can be computed using the methodology proposed by Norman et al. (1995). We have not included this methodology because the sensors we need to compute it over the canopy were not present during the experiment. Sánchez et al. (2007) found a weak relationship between windspeed and effective aerodynamic resistance so they suggest using a single value of effective aerodynamic resistance to model ET.

Reviewer specific comments 10: L24: Again, where is windspeed playing a role in Equation 2, as is stated in this sentence?

Authors reply to specific comments 10: Line 24 regards to Eq. 3. In this case, B is computed trough the Carlson et al. (1995) approach in which Eq. 3 is obtained from a soil-vegetation atmosphere transfer model that integrates the main factors on which B depends, such as wind velocity and aerodynamic resistance.

Reviewer specific comments 11: Should mention somewhere in this section that the soil heat conduction flux is being neglected, and give a rationale for doing this.

Authors reply to specific comments 11: We forgot to mention this in the paper, G is not being neglected, is supposed to be close to 0 for daily periods, so Eq 1 expresses the 24-h integrated surface sensible heat flux into the atmosphere. We have included this in the paper.

Reviewer specific comments 12: P 1133. L9: "and a mean RMSE less than 15m was obtained." What does this mean? RMSE in what? This relief correction technique needs a little more explanation.

Authors reply to specific comments 12: “and a mean RMSE less than 15m was obtained.” stands for the planimetric accuracy of the geometric correction. We have improved the section.

"Landsat images were corrected using the methodology proposed by Palà and Pons, (1995) that is based on a first-degree polynomial fit that accounts for the relief using a detailed enough Digital Elevation Model (DEM) obtained from the Cartographic Institute of Catalonia (ICC). This correction also requires a set of ground control points (GCP) that were digitized on screen from 2.5 m digital orthophotos (from the ICC). A planimetric accuracy (obtained with an independent set of GCP) of less than 15 m (half pixel) was obtained."

Reviewer specific comments 13: L17: MODIS products are generated by the MODIS teams (NASA-related), not by USGS.

Authors reply to specific comments 13: The sentence has been changed in the text.

Reviewer specific comments 14: P 1134. L1-9: This air temperature analysis technique needs more explanation, since it seems to be a crucial component of this work.

Authors reply to specific comments 14: We have improved the entire section.

"Different air temperature input variables are needed to compute net radiation LST and ETd: satellite pass air temperature (Ti), daily mean air temperature (Ta) and daily minimum air temperature (Tmin). To regionalize air temperature, we applied a multiple regression analysis with spatial interpolation of residual errors of ground meteorological station data using geographical variables as predictors, such as altitude, latitude, or continentality (Cristóbal et al., 2008; Ninyerola et al., 2000; Ninyerola et al., 2007). Spatial interpolation of the residuals has been computed using the Inverse Distance Weighted interpolation because this interpolator offers better results than other

methodologies, at least in the case of air temperature modelling [Ninyerola et al., 2000].
"

Reviewer specific comments 15: L14: It yielded an RMSE of 1K in comparison with what? Ground-based LST measurements? Explain. Avoid starting sentences with “It” – too ambiguous.

Authors reply to specific comments 15: We have compared LST with radiosonde data. This has been included in the text.

"In the case of Landsat-5 TM and Landsat-7 ETM+, the LST was calculated with the methodology proposed by Cristóbal et al. (2009), which is based on the radiative transfer equation and needs air temperature and water vapour as input variables, and present a RMSE of about 1 K compared with radiosonde data."

Reviewer specific comments 16: Eq 5: Should this be Rnd, like in Eq 1? Distinguish Rs as a daily value with a d subscript as well. LST and Ta are instantaneous values, right? How does that work into the daily net radiation computation?

Authors reply to specific comments 16: Eq 5 is the equation to compute instantaneous Rn. We have changed and added some parts in this section as well as its title in order to make more understandable the text. In addition, we have changed the tile of the section 3.2. We have also added a d subscript in Rs.

See SupplementFile_1.pdf.

Reviewer specific comments 17: Pg 1137 L4: By this do you mean that the B-Rn ratio method yielded ET estimates that had an RMS error of X with respect to sapflow measurements? Be precise in your wording.

Authors reply to specific comments 17: In this section we are not comparing the ETd results (this is presented in section 3.4 Etd validation). In this section we are just showing the B parameter results.

Reviewer specific comments 18: In comparing to sapflow, are we assuming the expected soil evaporation component is negligible, or do these methods only model transpiration fluxes?

Authors reply to specific comments 18: In the study plot the understory is very sparse and measured soil evaporation during summer, when the soil is dry, was always below 0.15 mmday-1 (Poyatos et al., 2007). Applying a two-source evapotranspiration model at the same stand, typical maximum evaporation rates from the soil under wetter conditions were shown to be 0.5-0.7 mm day-1 (Poyatos et al. 2007).

Reviewer specific comments 19: Pg 1141. An LST image pair over the same study area from both MODIS and Landsat would help the reader to understand visually the relative information content provided by each sensor.

Authors reply to specific comments 19: We have included a LST image pair in figure 1. See figure 1.

Figure 1 caption: "Figure 1. Location of SMC meteorological stations and Vallcebre research catchments in Universal Transversal Mercator (UTM) projection (UTM coordinates are expressed in km). The white dots are meteorological stations from the SMC that include air temperature sensors, the black dots are meteorological stations from the SMC that include net radiation sensors, and the black triangle indicates the Vallcebre research catchments. Figure A is the Landsat-TM LST of 01/07/2003 and figure B is the TERRA MODIS LST of 10/07/2003 of the Vallcebre research catchments (black triangle). The red square represents a Landsat-TM thermal band pixel (120m)

and the yellow square represents a TERRA MODIS thermal band pixel (1000m). In A and B figures, the white dot is the Scots pine stand."

Reviewer specific comments 20: Pg 1155. Fig 2: In text, need to define what “bow-tie” effect means.

Authors reply to specific comments 20: We have included this definition “an artefact of the arrangement of sensors on the MODIS instrument, in which the scans are partially overlapping at off nadir angles” in figure 2 caption.

References

Carlson, T. N., Caphart, J., and Gillies, R. R.: A new look at the simplified method for remote sensing of daily evapotranspiration. Remote Sens. Environ., 54, 161-167, 1995.

Norman, J. M., Kustas, W. P., and Humes, K.: A two-source approach for estimating soil and vegetation energy fluxes from observations of directional radiometric surface temperature, Agr. Forest Meteorol., 77, 263−293, 1995.

Poyatos, R., Villagarcía, L., Domingo, F., Piñol, J. and Llorens, P. (2007): Modelling evapotranspiration in a Scots pine stand under Mediterranean mountain climate using the GLUE methodology. Agricultural and Forest Meteorology, 146: 13–28

Sánchez, J.M., Caselles, V., Niclós, R., Valor, E., Coll C., and Laurila, T.: Evaluation of the B-method for determining actual evapotranspiration in a boreal forest from MODIS data, Int. J. Remote Sens., 27, 1231-1250, 2007.

Please also note the supplement to this comment:

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 1125, 2011.

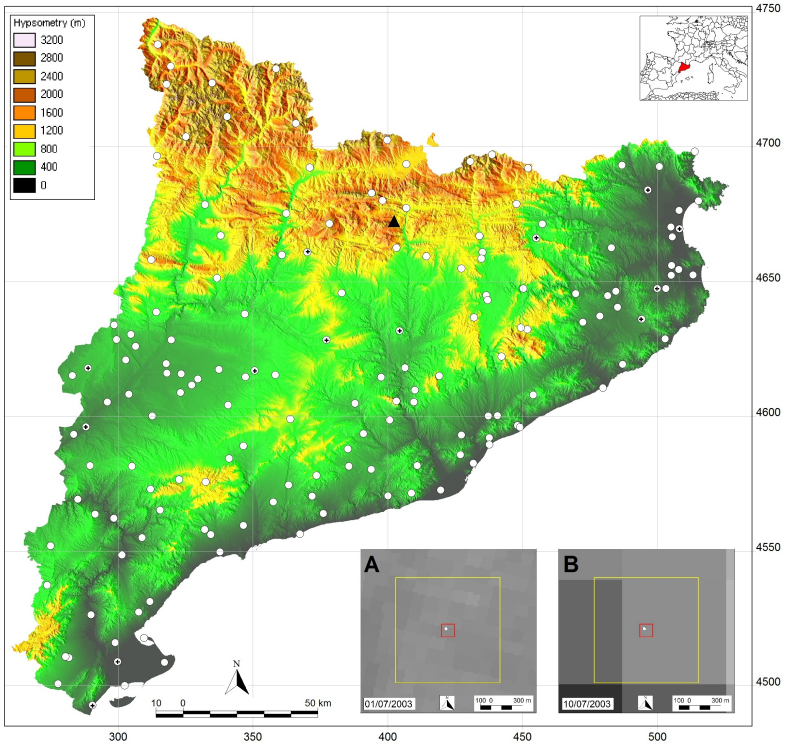

Fig. 1. Location of SMC meteorological stations and Vallcebre research catchments