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Discussions

Interactive comment on "Global patterns of annual actual evapotranspiration with land-cover type: knowledge gained from a new observation-based database" *by* S. M. Ambrose and S. M. Sterling

S. M. Ambrose and S. M. Sterling

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We are pleased to submit the revised manuscript "Global patterns of annual actual evapotranspiration with land-cover type: knowledge gained from a new observation-based database" by S.M. Ambrose and S.M. Sterling.

We thank both referees for their insightful and helpful comments. We have addressed all comments, through revisions to the manuscript and figures, additional analyses and new supplementary information. A point-by-point response to each of the referee comments is included table format, with embedded figures, in the supplement to this response. We have numbered the comments and cross-referenced the comment numbers in inserted comments in the revised manuscript.

Below we inventory each referee comment and our response and actions taken.

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Comment #1 Referee #1 “It uses a new observation based database (GETA 2.0) and applies the “linear effective mixed model” methodology to estimate point information to unobserved locations at a global scale and 5’-spatial resolution.”

Response #1 To clarify, we use a “linear mixed effect model” (LMM) instead of a “linear effective mixed model” - We describe this model in more detail in response (#5), clarifying the definition and strengths of ET_LMM.

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Comment #2 Referee #1 Results and subsequent analysis reveal interesting insight into LC specific patterns and changes that are in my opinion an interesting and relevant topic that could be of importance for potential HESS readers and should be published.

Response #2. No response required.

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Comment #3 Referee #1 I have one comment about the issue of spatial resolution: The GETA 2.0 database provides point information, the climate forcings and therefore predictor variables from NCC are available at 1° resolution. The LC rasters have a 5’ resolution. So in fact the LMMing is in principle providing 1° estimates, but that are disaggregated by the 5’ LC rasters (with the problem described at p12110 L16-27, but that is o.k.). I think this aspect is important (as is stated by the authors,) but I feel it should be included as a statement/information more dominantly also in the abstract and conclusion part.

Response #3. We agree and have added a corresponding statement in the abstract

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(Page 1, L17-20) which now reads: “We derive one-degree resolution global fields for each LC using linear mixed effect models (LMM) that use geographical and meteorological variables as possible independent regression variables; the fields are disaggregated by five-minute LC rasters.” And we have added a statement in the conclusion (Page 15, L21-25) which now reads: “However, to the extent that the ET_LMM generated here represents only a single climate within a grid cell, and that the ET_LMM was generated by 1-degree results disaggregated to 5 minutes by LC rasters, the. . .”

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Comment #4 Referee #1 In the model development of LMM it is said (p12110 L14ff), that the BIC is chosen as a “goodness-of –fit” criteria. Should this be done in a cross-validation framework as well? Have you compared LMM with other techniques (again I would do this in a cross validation framework)?

Response #4 We have completed a cross validation of the GETA 2.0 ET_LMM, also recommended by Referee #2, comment #22. We describe the results on page 6 (L 15-20) in the following new sentences: “To assess the robustness of the model predictions, we performed “leave one out cross validation” (LOOCV) (Hastie et al., 2001). We iterated the LOOCV algorithm 200 times and assessed predictive skill explicitly by LC type. The mean cross validation error showed a root mean squared error of 0.44 [lnET], but ranged nearly threefold between LCs (.339-.803 [lnET]). Histograms of the cross validation error are symmetric, indicating that the model predictions are unbiased despite high variance for some LCs”

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Comment #5 Referee #1 From my knowledge LMM (at least as it is implemented in R) will estimate all coefficient of the model (equation 1) simultaneously, so why are you deviding ET_obs values into groups of LC types, again at least in the R implementation you just provide a dataset where locations/measurements have a certain LC (hope we talk about the same technique!).

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Response #5 We divide ET_OBS values into groups of LC types because linear mixed effect modelling (LMM) allows for the statistical analysis of grouped data (here LC) with a spatial dependence structure. We use the LMM approach to test whether empirical rates of ET vary significantly by LC type by determining if LC may be used as a predictor of ET. In particular, our LMM quantifies the variability in ET across and within LC type, while also controlling for meteorological and environmental variables that may affect this relationship. We have addressed this comment by adding a more detailed description of LMMs here, which may be included in a new Supplementary Information Section, following the discretion of the editor. LMMs are an extension of classical regression models and are specifically designed for grouped data. Instead of fitting a single coefficient (a 'fixed' effect) to relate a response variable and predictor, the mixed model allows coefficients to vary by group where each group-specific effect is derived from a probability distribution (a 'random' effect). The term 'mixed' refers to a model which has both fixed and random effects. LCs create a natural grouping of ET measurements that are ideally suited for mixed effect regression models. The LMM analysis is used to examine whether climate variable predict ET and how does this relationship varies by land cover. Statistically, this scientific hypothesis reduces to fitting a mixed model and determining whether a fixed or random effect fits the data best. If the variable predicts ET but does not vary by LC, we would expect the fixed effect to fit the data; however, if the relationship varies by LC we would expect a random effect to fit best, and the fitted numerical values for the random coefficients would describe how the relationships vary. The LMM modelling technique determines the drivers of ET, and the level of the effect. To select the variables to include in the LMM, we will use the Bayesian Information Criterion (BIC) which is a statistical measure determining goodness-of-fit (Kadane and Lazar 2004). The BIC is calculated as [1] $BIC = -2*\ln(L)+l*\ln(n)$, where L is the value of the statistical likelihood function for a fitted model (which in first approximation, is the cumulative probability of the model parameters given the data), l is the number of model parameters, and n is the number of data points. To choose the variables to be included, one finds the variable combination which gives the lowest possible BIC value. When investigating a relatively small number of predictors as in the ET data, it is possible to fit all combinations of fixed and random effects to rank the best fitting models. After the best model was determined, the results were generated by using the model equation in R to output a raster of the predicted values and determining the climate drivers for each LC. LMMs are useful because of the explicit interest in the covariate relationships between and among LC groups. Although this is not a new statistical technique, LMMs are rarely applied to the geosciences. Instead it is more common to fit individual fixed effect regressions to each LC subset of the data; if the researcher were interested in 'overall' effects then the individual coefficients could be averaged post-hoc. The main advantage of a LMM over this more common approach is greater statistical power, which reduces the standard errors on the individual effects. By using all the available data and assuming a common probability distribution among all the random effects, the individual estimates 'borrow' information from other groups (land-covers) and reduce uncertainties in individual estimates (McCulloch and Searle 2001). McCulloch, C. E. and Searle, S. R.: Genealized, linear and mixed models, John Wiley & Sons, Inc, USA., 2001.

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Comment #6 Referee #1 Will the GETA 2.0 database be available after publication?

Response #6 GETA 2.0 will be freely available after publication and will be freely available on the Dalhousie University Repository website (http://dalspace.library.dal.ca/).

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Comment #7 Referee #1 Also, are there sources where the NCC data and the LC raster are avail from? Would be excellent if yes and good to know what the sources are.

Response #7 The LC raster maps used will be freely available on the Dalhousie University Repository website (http://dalspace.library.dal.ca/). The NCC dataset is available at http://hydro.iis.u-tokyo.ac.jp/∼thanh/wiki/index.php?n=Main.NCCDataset

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Comment #8 Referee #1 At p12113 L22 you mention the discrepancies between the Jung etal. (2010) and your findings concerning wetland and surrounding tropical forest ET. I have no exact numbers but I cannot fully follow your arguments. Tropical forest as well evaporate large amounts of interception water that are not captured by NEE either. What are the number of concrete stations in tropical forest and wetland from where these findings are derived?

Response #8 The referee raises some excellent comments with regards to comparison of ET between tropical wetland and forests. We have removed the discussion of the discrepancies between the Jung et al. (2010) ET and our ET estimates of wetland and tropical forest in the text for reasons explained in comment/response #36, below.

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Comment #9 Referee #1 Concerning the discussion of ET change with change in LC – is there any station in GETA 2.0 where a concrete LC has occurred and where that change might actually be seen?

Response #9 The GETA 2.0 database does not contain information on changes in ET with LC changes at a point, as this question is beyond the scope of this paper. We agree that this is an important question to be investigated by future research. To address this comment, we have modified statements with regards to changes in ET with LC change to make them better reflect the scope and approach of this study, as described in comment #25.

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Comment #10 Referee #1 P12105 L23f: LC changes alter water availability. I would agree with the first three ways but irrigation is only an indirect consequence!?

Response #10 We have reorganized the sentence to make it clearer to the reader. The sentence now reads (Pg. 2, L. 28-31) “LC change alters water availability at the land surface by changing rooting depth, changing soil properties that retain moisture, and by directly removing or adding water to the surface through inundation, draining and indirectly through irrigation."

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Comment #11 Referee #1 P12107 L03ff: Is there a reference and/or Web-Site for the GETA 2.0 database (except supplement B)?

Response #11 The GETA 2.0 database will be freely available on the Dalhousie Dalhousie University Repository (http://dalspace.library.dal.ca/).

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Comment #12 Referee #1 P12107 L19ff: Raster maps of LC are mentioned, are they publicly available to individual researchers/institutions? Or is there only the Sterling & Ducharne (2008) reference?

Response #12 The LC raster maps used will be freely available on the Dalhousie Dalhousie University Repository (http://dalspace.library.dal.ca/).

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Comment #13 Referee #1 P12108 L12ff: Authors mention the problem of dominant grassland location of meteorological stations in the NCC data base. Very good to mention this, but with regard to the analysis that follows, is this a problem? An additional comment here would be very helpful

Response #13 The uniform land cover type for meteorological stations does not pose a problem. We have made an additional comment describing this point on Page 4 L24-30: "It should be noted, however, that these atmospheric forcing datasets are based upon data from meteorological stations located on the surface that are typically situated on grass plots, so the atmospheric forcing data would be representative more of grass plots than any other LC type. In theory, the difference in LC type between the grass plot and the actual LC should impact Tair, Qair and wind most directly. As is not realistic to have situate meteorological stations in all the land covers for the areas that they are to represent this problem is not avoidable; however, having meteorological stations located in uniform land surface types makes it easier to interpret possible effects than would be the case if they were situated in varying land cover types."

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Comment #14 Referee #1 P12111L17ff: What is "sufficient spatial coverage"?

Response #14 We have removed the reference to "sufficient spatial coverage" to address this comment.

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Comment #15 Referee #1 P12129Fig.1: axis labels!?

Response #15 We have added axis labels to Figure 1.

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Comment #16 Referee #1 P12130Fig.2: please add labels and the scaling factor *10-4 to the axis!

Response #16 We have added labels and scaling factor to axes in Figure 2.

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Comment #17 Referee #1 P12133Fig.5: what is A what B?

Response #17 We have removed part B from Figure 5. Figure 5 now consists solely of "Part A", and the new Supplementary Information section E now contains Part "B".

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Comment #18 Referee #1 Sup_A: Abbreviation used in Supplement A should be explained in the caption, independent of its usage in the text.

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Response #18 We have modified the caption of the figure in Supplement A to explain the abbreviations, as follows: “Pathways through which land cover (LC) change affects evapotranspiration (ET). LC changes that alter ET are in green boxes. Light blue boxes indicate main drivers of ET. Purple box represents ET. Solid line indicates a direct effect. Dashed line indicates an indirect effect. Blue arrows indicate positive relationship. Red arrows indicate a negative relationship. Abbreviations used in the figure are as follows: Ts indicates surface temperature; LW indicates long-wave radiation; P indicates precipitation; and GHG indicates greenhouse gas.”

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Comment #19 Referee #1 Sup_B: In Supplement B it is not clear which year the mean yearly ET rate is related to, an additional column for this information should be provided.

Response #19 In our assembly of the GETA database we did not include the date of measurement because we were not examining changes with ET over time. We agree that this information may be useful for those who may use GETA 2.0, and this could be found by going the original source cited in the database.

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Comment #20 Referee #2 This manuscript aims to analyze the variability of annual mean evapotranspiration ET with respect to land cover (LC) types on a global scale. The authors use a ET dataset which comprises estimates from different methods.

Response #20 No response required.

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Comment #21 Referee #2 This incoherent dataset is then extrapolated with a statistical model using global average meteorological data at a spatial scale of 1âŮę and land cover type data at a smaller resolution of 5 min.

Response #21 No response required.

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Comment #22 Referee #2 Although the authors report max, range, mean and sd of model and observations for each LC, however, no model performance evaluation is shown (model performance such as explained variance, model error, etc) and more important, no cross validation analysis is presented.

Response #22 We have completed cross validation of the GETA 2.0 ET_LMM, also recommended by Referee #1, comment #4. We describe the results on page 6 (L 15-20) in the following new sentences: “To assess the robustness of the model predictions, we performed “leave one out cross validation” (LOOCV) (Hastie et al., 2001). We iterated the LOOCV algorithm 200 times and assessed predictive skill explicitly by LC type. The mean cross validation error showed a root mean squared error 0.44 [lnET], but ranged nearly threefold between LCs (.339-.803 [lnET]). Histograms of the cross validation error are symmetric, indicating that the model predictions are unbiased despite high variance for some LCs.” With regards to model performance evaluation, we use bootstrapping to generate confidence intervals to represent the model error; the results are shown in Figure 7. To address this comment, we have also added the following section on page 12 (L16-21): “The bootstrapping results are consistent with those from cross-validation and indicate that the parameter estimates are relatively insensitive to error in the data. Again, the bootstrap distributions showed good symmetry which indicates that the fitted relationships are unbiased. Taken together, the two model diagnostics indicate relatively high variance (largely due to sparse sampling), but unbiased parameter estimates and predictions which indicate a robust underlying physical signal.”

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Comment #23 Referee #2 The model performance is also not compared to other global ET studies such as Jung et al. (2010) or Mueller et al. (2013).

Response #23 To address this comment we have compared our ET_LMM with the ET

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fields generated by Jung et al. (2010). We have added a description of the results to Page 9 L 19-23, as follows: "We found a 9.57% median cell specific difference between results generated by a multi-tree ensemble (Jung et al., 2010) and ET_LMM, calculated at a half-degree resolution; the largest differences occurred at locations with wetlands, which was included in ET_LMM but not in Jung et al. (2010), and in these locations the ET_LMM was greater than the ET prediction in Jung et al (2010)."

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Comment #24 Referee #2 Further the model is not compared against the physical constraints of ET: precipitation and evaporative demand (net radiation or potential evaporation).

Response #24 We compared the model against the mean annual precipitation for 1948-2000 from the NCC dataset, at the one-degree cell resolution, summing the ET for all the LC types in the cell. The majority of cells had precip < ET as one would expect. Some cells did have ET > precip, but most were in wetlands, so this was not surprising as water supply should not be limiting to ET in these locations. However, there were some cells with other land cover types that had cells in which ET > precipitation; these tended to be dry land covers, such as barren land and shrubland; causes of this may be due to the ET_OBS being made in a wetter year, to the precipitation data being incorrect, or to the LMM over-estimating ET in this location, or to a combination of all three.

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Comment #25 Referee #2 Nevertheless the authors extrapolate the empirical model for each LC type to the global land. These extrapolations are then being used to qualitatively discuss the sensitivity of ET to land cover change. This is done by simply comparing the extrapolations for the different LC. Here I would wish that the author would be more careful with the conclusions of different sensitivity of ET along different latitudes given the lack of sufficient data for their zonal evaluation and the uncertainties of their model in these regions. So in particular I am wondering why the zonal averages e.g. for grass and grazing LC are so different in the tropics. Reported coefficients seem to be quite similar

Response #25 We have made the following changes to make the language more careful with regards to the conclusions of different sensitivity of ET along different latitudes: We have changed the abstract to read (Pg 1, L28ff): “Furthermore, zonal ET means among LCs reveal new patterns: LCs with a higher evaporation component show higher variability of ET at the global scale; and LCs with dispersed rather than contiguous global locations have a higher variability of ET at the global scale. The zonal means also suggest that ET rates in low-latitudinal bands may be more sensitive to change than in higher latitude bands.” We have changed the results and discussion section pertaining to Figure 6 to read (Page 10, L 17-30): “The zonal plots suggest that the expected response of ET to a particular LC change is not the same across all latitudinal bands. For example, results suggest that conversion of wetlands to grazing land may decrease annual ET at the mid- and lower latitudes and the difference is most significant in the mid-latitudes (Figure 6). Results suggest that a change from evergreen broadleaf forest to urban lands may cause the greatest reductions in ET nearer the equator as compared with higher latitude bands. Similarly, results suggest that a change from shrub land to lakes would cause the greatest increases in ET in the low latitudes. While the zonal plots suggest likely changes to ET resulting from a variety of LC changes in particular latitude bands, given the lack of sufficient data in some latitudes and uncertainties of the ET_LMM model in these regions, further investigation is needed to verify these observations.” We have changed the conclusion section pertaining to Figure 6 to read (Page 14, L 19-25): “Results suggest that ET may be more sensitive to LC change in some latitude bands than others. Changes to ET from LC change appear to be largest in the tropical latitude bands, particularly associated with differences between ET inLCs with high water availability and low water variability. This finding suggests that land use planning should be particularly careful in the tropics because of the possibility of heightened impacts to the Earth system in these

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latitude bands; further study into these observations is recommended.” Regarding why the zonal averages for grass and grazing are so different in the tropics, the difference can be explained as a result of differences in intercepts and t_air values, as shown here: Value GRS GRZ

int -0.62 -0.42

t_air 0.099 0.15

precip 0.27 0.26

SW 0.13 0.13

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Comment #26 Referee #2 My greatest concern with the approach taken in the manuscript is that spatial scales of observations (ecosystem to watershed), model (5 min) and explanatory variables (1âŮę) are inconsistent. The variability of climate can be large within 1 geographical degree and also land cover can be quite heterogeneous. This problem is especially true for anthropogenic LC. Hence the large variability found for these types may be due to the inappropriate choice of spatial scales.

Response #26 To clarify, the spatial scales we use are the point-scale ET_OBS estimates and the 1° resolution climate forcing predictor variables. The land surface modelling uses this information to generate 1° ET estimates that are masked by 5-minute LC rasters. Our model is not run at 5 minutes. In response to the comment, the high variability in ET estimates is not due to the inappropriate choice of spatial scales. The scales are intrinsic to the research questions and aim of the study and are unavoidable. First, it is not possible have the original ET_OBS data at a coarser scale. Ground-based ET estimates of a single land cover type are constrained to the point-scale as they rely using energy balance, soil water balance, micrometeorological or flux tower approaches at a site or at the mouth of a small catchment where the catchment water balance approach was used. Second, global scale climate data

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are only available at coarse scales (the one-degree NCC dataset resolution is quite good compared to other datasets, often at 2.5 degree). To address this comment, we have modified the text to make explicit that any use of these data should bear in mind the one-degree resolution of the ET fields, and that the rasters should not be used to predict ET or ET changes at resolutions finer than one-degree. 1) We have added a note of the one-degree resolution of the ET rasters to the abstract (P. 1 L 17); to the methods (P. 6 L27ff); and to the conclusions (P. 14, L. 20 and P. 14, L. 29-30). It should be noted that the one-degree ET rasters may be masked by other land cover maps apart from the ones used for this study. Other studies that may want to compare, for example, global land surface model output of ET may use the map used in their global land surface model to mask the ET_LMM, remaining cognisant that the ET_LMM raster is at a one-degree resolution.

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Comment #27 Referee #2 So given these inconsistencies I am not sure what we can learn from the global extrapolations. I would rather recommend to study the important LC effect at the scale where the observations have been done. Here an evaluation of LC effects on ET (see Williams et al. (2012) for a good example using FLUXNET data) using sophisticated statistical models may be more informative than the attempt to upscale to global ET fields.

Response #27 Our global one-degree ET_LMM fields of provide a new observation-based estimate of ET for a wide range of land cover types that are independent of model and process-based assumptions, and form a valuable contribution for global water cycle applications. It is important for users of the dataset to keep in mind the one-degree resolution of the data, and we have emphasized this resolution in several locations in the manuscript. A key advantage of our study is that we are able to include a larger number of ET observations in more land cover types. We are able to include ET observations with sparse climate information by drawing upon one-degree climate means, than would be possible by relying upon FLUXNET data alone (as was in Williams et al (2012) approach, a great study as well, and one that generates normalized ET estimates). Despite the high variability in the ET estimates, the statistical power of the larger sample size reveals significant differences and clear patterns between land cover types that emerge at the one-degree resolution.

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Comment #28 Referee #2 P12107L22: What is the source of the LC rasters?

Response #28 We have addressed this comment by clarifying the source of the LC rasters on Page 6, L29-32, that now states: “The 5-minute presence/absence LC rasters used to mask ET_LMM were derived potential and anthropogenic vegetation rasters from Ramankutty and Foley (1999) and Sterling and Ducharne (2008), except for tree plantations which was derived from Erb et al. (2007). We converted percent cover to presence/absence at the 5-minute resolution of tree plantations by preserving the area (Kröger, 2012), assuming a linear tree plantation expansion rate between 1990 and 2010, with an estimate of 221.1955 million hectares of tree plantations globally.”

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Comment #29 Referee #2 P12108L2: NCC is not defined

Response #29 We have added the following acronym definition on Page 4 (L17): “We used predictors from the NCC (NCEP/NCAR Corrected by CRU) 53-year (1948-2000)...”

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Comment #30 Referee #2 P12109L20: how is spatial correlation represented in the model?

Response #30 The spatial correlation in the LMM is represented using a correlation structure based upon the haversine distance between points. To address this comment

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in the text, we have added a reference (Pinhiero and Bates, 2000): Pinheiro, J.C., and Bates, D.M. (2000) "Mixed-Effects Models in S and S-PLUS", Springer.

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Comment #31 Referee #2 P12110L6: which statistical model assumptions have been tested?

Response #31 LMMs assumes that residuals are normally distributed; we checked this assumption for all residuals as well as individual LC residuals. To address this comment in the text, we added the following sentence (Pg. 6, L. 4-6) : "We verified there was no violation of model assumptions by checking both the homogeneity of the variance as well as the normality of the residuals within LC."

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Comment #32 Referee #2 P12110L24: 58% of unaligned LC types of observations and LC raster. How does this influence your results? Please discuss this in the discussion.

Response #32 We have addressed this point by adding the following statement to the discussion that describes how this influences our results (pg 13, line: 7-12) . "As mentioned earlier, the LC type of 58% of the ET_OBS points did not align with the dominant LC type in the LC raster. This discrepancy will not add error to the ET_LMM estimates, because the true LC type is considered to be the one linked with the ET_OBS and is the one used in the LMM; however, this discrepancy affects the ET_LMM results in that the masked ET_LMM cells will not extend over all the cells in which the land cover occurs, to address this, the unmasked ET_LMM raster may be masked to a different LC raster."

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Comment #33 Referee #2 first two paragraphs of section 3.1 are a data set description rather than results. Whereas the last paragraphs does not link to the section heading.

Response #33 Our first research question is “what are the patterns in available information from ET observations among LC types?”. The paragraphs in section 3.1 (the beginning of the Results and Discussion section) address this research question. The first paragraph in section 3.1 describes the patterns and gaps in ET data by land cover type, as visualized in Figure 2. The second paragraph in section 3.1 describes patterns and gaps in the spatial distribution of ET data as visualized in Figure 3. The third paragraph in section 3.1 discusses the results by comparing the spatial pattern in ET data with global hotspots. We agree that the last paragraph does not follow smoothly the previous paragraph as it contains a discussion of the statistical model and proposes an explanation of why the model results are as they are. We avoided putting this paragraph in the methods, because it contains discussion points, but are willing to move it up to section 2.2.2 as an alternative arrangement.

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Comment #34 Referee #2 section on global means for LC: here ET of land cover types are compared without taking climate effects into account. As climate shapes ET in the first place, a comparison of ET between land cover types should be conditional on the respective climate. One way to do that is by binning the data with the aridity index.

Response #34 We agree that it would be useful to have reliable estimates of ET for climate sub-types of the land covers presented here, in particular for anthropogenic land covers, as the referee notes in Comment #26. However, we have chosen not to sub-divide the land cover classes by climate-sub-types because there are not enough ET_OBS in the climate-subzones of each land cover type to be able to generate meaningful global mean summaries. To address this comment, we recommend that future research would target additional ET_OBS measurements so that all climate sub-types of LCs would be represented (Page 14, L 4-5).

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Comment #35 Referee #2 P12112L26 wrong reference to table

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Response #35 Thank you for catching this. We have fixed this issue by removing the reference to Table 2 (p 8 L 25).

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Comment #36 Referee #2 P12113L24-26: comparison to Jung et al. (2010) at Amazon is unclear to me. I can not see this from Fig 5.

Response #36 We based our original comparison on Figure 1a in the Jung et al. (2010) paper in which the amazon river appears to have a lower ET than the surrounding forest, as shown in the supplement table, or in Jung et al., 2010, Recent decline in the global land evapotranspiration trend due to limited moisture supply, Nature 467, 951-954, Figure 1a. In response to this comment, we have requested the original data for Figure 1 a in Jung et al. (2010) for both 1982-2008 and 1981-2011, and this data does not show the tropical wetlands as having a lower ET than the surrounding forests (see generated figure in the supplement table).

Because of the discrepancy between the data we received and that shown in Figure 1a, we removed this comparison of ET in the Amazon from the paper (page 9, L 24-31)
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Comment #37 Referee #2 P12114L3-4: I do not fully understand how Fig 5a is being computed. How is natural vegetation defined and what do you mean be overlying with wetlands?

Response #37 We have addressed this comment by changing “natural vegetation” in the caption in Figures 5 and 6 to the more precise term “potential vegetation”. We also replaced “natural vegetation” with “potential vegetation” in the text and added the distinction (P 6 L 28) that the land cover maps represent potential and anthropogenic vegetation. To address the comment on overlying wetlands, we changed the text from: “Global ET_LMM fields project a cumulative total ET (TET) of 70,600 km3/yr for a globe

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covered with natural vegetation (Figure 5a, b), including and the overlying wetlands." to "Global ET_LMM fields project a cumulative total ET (TET) of 70,600 km3/yr for a globe covered with potential vegetation and wetlands (Figure 5)."

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Comment #38 Referee #2 P12115L17 "more jagged curves" is not a quantitative assessment of variability

Response #38 We have addressed this comment by changing the text to read (P. 11 L. 14-15): "...have higher variability in mean zonal ET in adjacent latitude bands (Figure 6)."

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Comment #39 Referee #2 P12117L20-25: unclear

Response #39 We have clarified this text to read (P. 113, L 20-27) the text to: "For example, lakes and barren lands have a relatively high uncertainty in ET predictions compared with other LCs and this may be explained by three things: 1) lakes and barren lands have greater decoupling of LC location from climate variables (i.e., these two LCs can occur in a greater range of possible climates than can tropical evergreen forest, for example), 2) lakes in particular have a spatial pattern that is comprised of disparate sub-units (i.e., more patchy) which would increase the range of climate drivers that affect the LC, and 3) lakes and barren lands have more extensive extrapolation of ET_LMM beyond range of predictor variables compared with other LCs, due to absence of measurements in key climate locations (such as the arctic barren lands), as shown in (Supplementary Information D)."

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Comment #40 Referee #2 P12118L5: "powerful" / also in the abstract "robust" global ET patterns. The robustness of these extrapolated patterns has not been assessed. Hence this should not be claimed

Response #40 We have addressed this comment by removing “powerful” and “robust” from both the conclusions and the abstract.

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Comment #41 Referee #2 P12122: reference of Jung et al. (2010) missing

Response #41 Thank you for spotting this! It is a very important reference and has been added.

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Comment #42 Referee #2 P12127: Table 3, here deviations of the estimated coefficients should be reported.

Response #42 We agree that it is important to communicate the deviations of the estimated coefficients for the model. Because the deviations for each LC vary with location, it would be too complex to include them all in Table 3 and so we have displayed the coefficient deviations through the bootstrapping map (Figure 7) which shows the confidence interval generated by bootstrapping.

-

Comment #43 Referee #2 P12129: Fig.1 increase the scale for SW

Response #43 To address this comment we have done two things: 1) we have moved SW to the top of Figure 1 so it does not blend in with the x-axis and 2) we have increased the y-axis scale for SW.

-

Comment #44 Referee #2 P12131: Fig.3 unit is missing. Why do we see circle shapes? Maps should have a coordinate system plotted.

Response #44 To address this comment we have added the following to Figure 3 caption: “Circles represent the density of ET_OBS where “Highest” represents 1.26 points

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per 7.5 degree search radius and “None” represents zero data points per 7.5 degree search radius.” Circles are used because they represent the density of ET measurements in a fixed radius from a given point. We have also added coordinate systems for all the maps in this manuscript.

-

Comment #45 Referee #2 P12133: Fig.5 I can not really see much in this figure due to the low resolution of the color scale. Also the subpanels in Fig. 5b do not reveal much information.

Response #45 To address this comment we have increased the colour resolution in Figure 5, and we have moved the subpanels from Figure 5b to a new Supplementary Information (E), and have noted this reference in the caption for Figure 5.

-

Comment #46 Referee #2 P12134: Fig 6. could you plot the data points as well?

Response #46 We agree that a plot of the GETA points would be useful for the reader. Because we felt it would be too crowded to plot the data points in Figure 6 (as you can see from the right hand column - there can be >30 points at one location), to address this comment we have done two things: 1) we have added a map of the data points to Supplement B, and 2) in the caption of Figure 6 we have added a reference to Supplementary Information C which contains additional plots of data points.

-

Comment #47 Referee #2 P12135: Fig.7: unit is missing. Color scale does not reveal much information for must of the globe.

Response #47 Thank you for this observation. To address this comment, we have lengthened the colour scale and added the units to Figure 7.

- -

Thank you for your consideration of the revised manuscript.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/11/C6654/2015/hessd-11-C6654-2015-supplement.zip

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 12103, 2014.

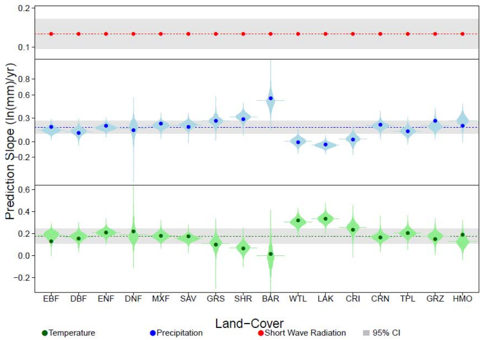

Figure 1: Linear mixed effect modelling slope by predictor. Slopes of two random effects (air temperature (green) and precipitation (blue)) and fixed slope (shortwave radiation (red)). The fixed effect is displayed by the dotted line, with the additional random effect shown by the dot. Lighter shading indicates the bootstrapped distribution, where the horizontal line is the mean of the bootstrapped distribution.

Fig. 1.

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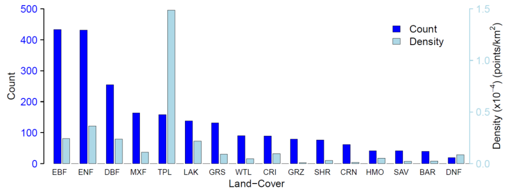

Figure 2: Count and density of ET measurements (ET_OBS) by LC. Count of points in the GETA database for each LC shown in dark blue using the left axis, and the density of points for each land-cover (light blue) calculated per km^2 on the right axis (x $10^{\wedge-4}$).

Fig. 2.

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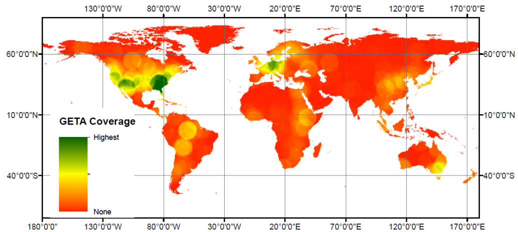

Figure 3: Global patterns of ET_OBS density for all LCs, as derived from the GETA 2.0 database. Circles represent the density of ET_OBS where "Highest" represents 1.26 points per 7.5 degree search radius and "None" represents zero data points per 7.5 degree search radius.

Fig. 3.

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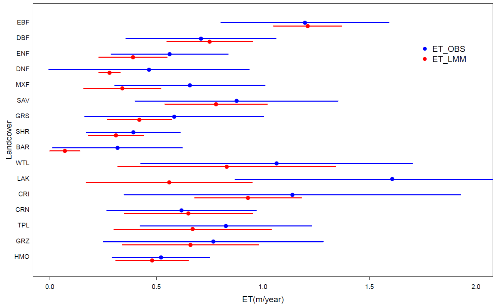

Figure 4: Mean (point) and standard deviation (line) of annual ET values by land-cover. ET_OBS represent point observations of ET from the GETA 2.0 database and ET_LMM represents ET of global fields generated by a statistical model from ET_OBS.

Fig. 4.

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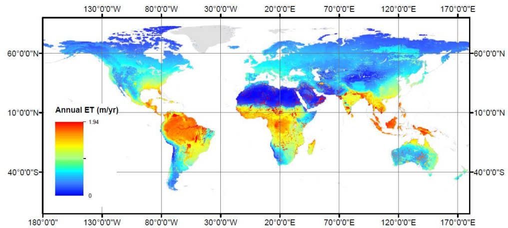

Figure 5. ET_LMM (m/yr) global annual actual ET projections. Potential vegetation with wetland overlay. Grey indicates areas permanently covered by ice or large lakes. ET_LMM maps for individual anthropogenic land covers are presented in Supplementary Information E.

Fig. 5.

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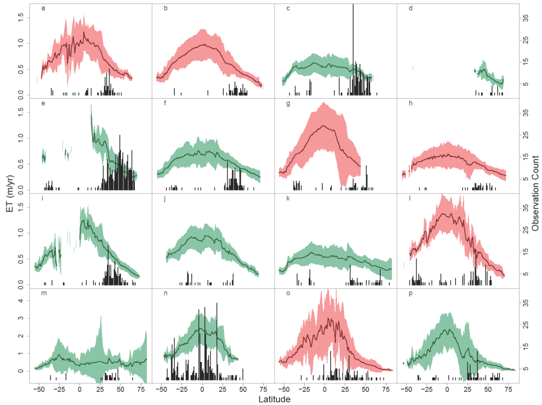

Figure 6: Zonal patterns of ET_LMM for LC types. The line represents the zonal mean, and the lighter area represents the 95% confidence interval derived from bootstrapped data. Green represents potential vegetation (DBF, DNF, ENF, GRS, MXF, SAV, SHR, EBF, and WTL), and red represents anthropogenic vegetation (CRI, CRN, GRZ, HMO, TPL, BAR and LAK, (here classified as anthropogenic although it is a mix of natural lakes and anthropogenic reservoirs)), See Table 1 for abbreviations). The black line plots represent the number of observations at that latitude. LC types are ordered alphabetically, except for the last row, which contains the LCs with the largest spread for ease of labelling (a. CRI, b. CRN, c. DBF, d. DNF, e. ENF, f. GRS, g. GRZ, h. HMO, i. MXF, j. SAV, k. SHR, l. TPL, m. BAR, n. EBF, o. LAK, p. WTL). For more detail on the ET data points see Supplementary Information C.

Fig. 6.

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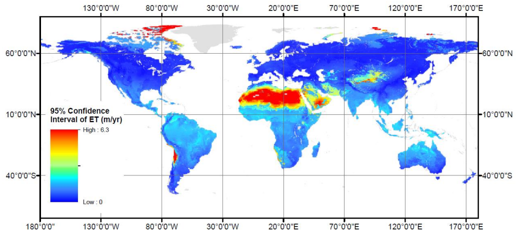

Figure 7: Confidence interval size for ET_LMM generated from 1000 bootstrapped datasets.

Fig. 7.