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Interactive comment on "WRFv3.2-SPAv2: development and validation of a coupled ecosystem-atmosphere model, scaling from surface fluxes of CO$_2$ and energy to atmospheric profiles" *by* T. L. Smallman et al.

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- Reviewer comments

* Indicates authors reply

Final response of authors

Response to anonymous Referee #1

We thank referee #1 for their comments on our paper and agree that the paper should

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be of interest to researchers in a range of disciplines. We accommodate the majority of recommendations through the following changes in the text.

- p. 1573, second line ' sensible heat flux is based on the temperature difference ...' then on the same page following equation (24) we have 'sensible heat () is calculated based on the difference ...'

* Repeated declaration of sensible heat flux will be removed such that pg1573 line 19 "H_{leaf} is sensible heat (W m^{-2}), $\Theta _{leaf}$ and $\Theta _{air}$ are potential leaf and air temperatures respectively.".

- p.1573, last line 'The P-M equation is used to calculate the potential evaporation or dew formation i.e.' and then after equation (25) for Epot we have ' Epot () is potential evaporation or dew formation ..'

* second declaration of Epot will be removed so pg 1574 line 3 reads "δe is the vapour pressure deficit (Pa)".

- Equations 26 and 27 can be folded into one: Ewet lambda = Cstor/Cmax Epot lambda – Eleaf lambda The sentence 'Note that potential evaporation is first converted to Wm-2 by multiplying by lambda' can be omitted.

* Equations 26 and 27 will be merged into one and specified sentence will be removed. The text will also be updated to make reference to Eq. 26 only.

- There is repeated description of some constants i.e. specific heat capacity, air density.

* Repeated declarations will be removed

* pg 1572 line 15 "z height above soil removed".

* pg 1573 line 15-17 removed declaration of g$_{wv}$, line 19-21 will remove repeated declaration of specific heat capacity and air density.

* pg 1574 line 7 redeclaration of transpiration will be removed.

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- The net radiation 'n symbol can be replaced with Rn as ' is already used for stability correction term.

* The net radiation and isothermal net radiation symbols will be changed to Rn and Rni respectively.

* Changes will be on

* pg 1573 line 5, 6, 7, 10, 11.

* pg 1574 line 1, 6.

- Given the complexity of the SPA model, it would be of interest to see the complete list of model parameters used for these simulations.

* SPA requires 63 parameters which would use several pages in the article to name and appropriately describe each parameter. We do not believe that this is an appropriate use of journal space as this information is available in other papers involved in SPA's development. Therefore we would prefer not to include a complete parameter list in this paper. However, we would be happy add a table detailing the model parameters which are specifically mentioned in the model description, while also altering the text to direct readers to the previous SPA publications for detailed information on SPA parameters. We could also place additional information in a suplimentary section.

- The roughness length for the soil used in SPA is 0.01m; is this value decreased for soil under canopy with large LAI?

* The roughness length of the soil is constant at 0.01 m under all conditions. The sentence on pg 1571 line 11 will now state "The soil surface roughness length z_{soil}; m), is assumed to be equal to $0.01\,\unit{m}$ both when under a canopy and as bare ground" to reflect this.

- p. 1577, second paragraph, second line: 'Air samples were (not where) corrected.'

* the specified correction will be made.

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- p. 1575, last paragraph, 'the mass of surface litter mass ....

* the line will be corrected to read "..the mass of surface litter present."

- p. 1577, section 5.1, '(analysed in R2...)' proper reference required

* The reference has been corrected to "..analysed in R v2.15.2, R Core Team, 2012.." as specified in the bibtex reference provided with the R software.

- p. 1581, last paragraph, 'Further, there (is) presence...'

* the specified correction will be made.

- p. 1594, figure caption, observations (of) the surface ...'

* the specified correction will be made.

Response to anonymous Referee #2

We acknowledge that the recommendations made by referee #2 are needed to improve the readability of the paper and to improve clarity. We will make the following corrections to address the issues highlighted.

- 'extensively validated' in line 8 of the abstract could be replaced with more concrete findings and/or statistics. The entire abstract could benefit from some specific results to make the paper more citable.

* The 'extensively validated' sentence will be followed by an example of statistical metric from the paper to illustrate the performance of WRF-SPA. The abstract will now read

'The Weather Research \& Forecasting meteorological (WRF) model has been coupled to the Soil Plant Atmosphere (SPA) terrestrial ecosystem model, to produce WRF-SPA. SPA generates realistic land-atmosphere exchanges through fully coupled hydrological, carbon and energy cycles. The addition of a~land surface model (SPA) capable of modelling biospheric CO_2 exchange allows WRF-SPA to be used for investigating the feedbacks between biosphere carbon balance, meteorology, and land use and

land cover change. We have extensively validated WRF-SPA using multi-annual observations of air temperature, turbulent fluxes, net radiation and net ecosystem exchange of CO$_2$ at three sites, representing the dominant vegetation types in Scotland (forest, managed grassland and arable agriculture). For example air temperature is well simulated across all sites (forest R2 = 0.92, rmse = 1.7C, bias = 0.88C; managed grassland R2 = 0.73, rmse = 2.7C, bias = -0.30C; arable agriculture R2 = 0.82, rmse = 2.2C, bias = 0.46C). WRF-SPA generates more realistic seasonal behaviour at the site level compared to an unmodified version of WRF, such as improved simulation of seasonal transitions in latent heat flux in arable systems. WRF-SPA also generates realistic seasonal CO2 exchanges across all sites. WRF-SPA is also able to realistically model atmospheric profiles of CO2 over Scotland, spanning 3 year period (2004–2006), capturing both profile structure, indicating realistic transport, and magnitude (model-data residual +/- 4 ppm) indicating appropriate source sink distribution and CO2 exchange. WRF-SPA makes use of CO2 tracer pools and can therefore identify and quantify land surface contributions to the modelled atmospheric CO2 signal at a specified location.'

- 'Land use and land use change' between pages 1560 and 1561 is usually referred to as land use and land cover change (LULCC)

* The specified phrase will been altered to read "land use and land cover change".

- Page 1563 line 24 still may strike some as subjective despite rigorous tests. The passage 'often considered.' can be deleted without compromising the meaning of the sentence.

* The phrase "often considered" will been removed.

- I have a question about the use of CarbonTracker. It's just a model product itself whose prior is just a multi-model estimate. Is it being used here for prior data or as a validation product?

* CarbonTracker optimised 3D mixing ratio CO2 product is used as an input into the

WRF-SPA model, it is not as a validation dataset. The text will be updated to make this explicit. Pg 1565 line 8 will read "...CTE CO2 fields were used to provide WRF-SPA initial ..."

- What does 'example Scottish meteorology' mean on page 1566?

* Example Scottish meteorology was Griffin Forest observations (1998-2000), which provided meteorology that is broadly representative of the Scottish average for years which were not simulated for in this study. pg 1566 line 25 will be changed to make this explicit. "C pools (foliage, structural/wood carbon, fine roots, labile, soil organic matter (SOM) and surface litter) were "spun-up", in an offline SPA simulation (except for crops) using 3 years of meteorology (1998–2000) from Griffin Forest. These observations are broadly representative of the Scottish average and are from a period not simulated here. The observations were obtained from the CarboEurope network (www.carboeurope.org) and looped for a 30 year period. "

- 'Reduced emissivity' on page 1567 was a bit confusing to me because whereas building materials often have lower emissivities than natural vegetation, this isn't always the case (see e.g. http://www.monarchserver.com/TableofEmissivity.pdf). Albedo and roughness are also often different. Have these properties been changed in the model as well?

* Emissivity was reduced to be the same value as that used in the NOAH LSM. Canopy height and albedo parameters were left unchanged from the default evergreen forest. We expect that the urban parametrisation has only a small impact on the simulation as urban areas cover < 1 % of the model domain. The text will be altered on pg 1567 line 8 to read "...constructed materials. WRF-SPA used the same emissivity value for urban as used the default WRF LSM, NOAH. However, we expect this parametrisation to have little impact as urban cover represents <1 % of the modelled..."

- There are unnecessary parentheses in equation 13.

* Parenthesis will be removed from equation 13.

- Eddy diffusivity within the canopy follows dynamics that are a bit more complicated than exponential decay (e.g. http://www.nicholas.duke.edu/people/faculty/katul/blm_poggi_2004_1.pdf), but for the present study this should be sufficient; it is not the major theme of the investigation.

* We acknowledge the simplification of exponential decay of eddy diffusivity in the canopy is not realistic, this is a simplification which is widely used in land surface models so we believe it is reasonable to include here. However future SPA development will likely include an updated representation of the roughness sub-layer and processes within the canopy impacting on exchange of scalars.

- Spell out 'two' on page 1576.

* 'Two' will be spelt out

- On page 1578, improving ground heat flux seems like an easy thing to do for a model with a multi-layer canopy where radiation attenuation by the canopy is (hopefully) represented quite well. Are soil heat flux observations available for any of the sites? This could be an easy fix.

* Soil heat flux data are available for Griffin Forest, however correction is unlikely to be a quick fix. In SPA ground heat flux calculated to balance soil surface net radiation and partitioning to ground heat, soil surface latent and soil surface sensible heat fluxes. Therefore soil water availability, soil boundary layer conductance and soil thermal conductance properties each play an important role in determining soil surface fluxes. However we do recognise that this is an area which needs to be addressed and will be the subject of future model development work.

- On page 1579, the underestimation of fluxes could just as likely be overestimation by the flux measurements due to the night time (low ustar) flux observation challenge. Likewise for the overestimation of latent heat flux by the model. . .this may be under-

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estimation by the measurements due to the energy balance closure problem.

* The carboeurope datasets are quality controlled to remove highly uncertain observations such as low ustar values, for consistency these time steps were also removed from the WRF-SPA and WRFv3.2 outputs used to create the monthly mean values used in the seasonal comparison. Therefore we cannot confidently attribute underestimates seen in WRFv3.2 to this cause. However we do accept that overestimates by WRF-SPA may be due to underestimation in observations of turbulent fluxes due to failure to close the surface energy balance. Stoy et al 2013 found evidence that non-closure is greater in agricultural systems which is consistent with the greater underestimation seen here at East Saltoun compared to the grassland and forest site. Therefore on pg 1582 line 6 a new paragraph will be added to discuss this possibility

"WRF-SPA overestimates latent heat at all three sites compared to observations (Fig. 3). However the model-data mismatch may be due to an underestimate of turbulent fluxes in observations due to non-closure of the surface energy balance (Stoy et al 2013). Stoy et al (2013) also found evidence that non-closure of the energy balance is greater in crop systems, which is consistent with the greatest model-data mismatch seen as East Saltoun."

- The last sentence on page 1580 is a fragment. On that note, should a different MODIS land cover map (UMD, PFT, etc.) be used?

* The sentence fragment has been corrected and an explicit statement is made for the need to replace the MODIS land cover map. The sentence will now read "This issue could be rectified through replacement of the MODIS map with a more realistic representation of UK land covers (e.g. LCM 2007, http://www.ceh.ac.uk/LandCoverMap2007.html).

- The sentence on line 10 of page 1581 is subjective. By what metrics is it comparable?

* We acknowledge that the line is subjective and now provide examples with references

of WRF's performance in comparison to other mesoscale models. The sentence will now read ". WRF is considered to be one of the best mesoscale models available in terms of simulating vertical profiles of temperature (Steeneveld et al., 2011) and surface meteorological variables (Sarrat et al., 2007). Therefore, we can infer that WRF-SPA is also comparable to many other models that are currently used in regional scale research. ..."

- Griffin Forest should be capitalized in the last sentence of page 1581.

* Griffin Forest will be capitalized and made consistent throughout the manuscript.

- On that note, did it only take a year for Griffin Forest to recover following the harvest?)

* Thinning of Griffin Forest occurred in June 2004, by 2006 the forest has recovered to NEE levels which exceed the fluxes prior to the thinning.

- Sentence fragments are also present in the Acknowledgements.

* Sentence fragments will be corrected so that Acknowledgements now read "The authors would like to thank the PhD project funding body, the National Centre for Earth Observation, a UK Natural Environment Research Council research centre. Christoph Gerbig of the Max Plank Institute is thanked for providing the original CO_2 tracer modifications for WRF. John Finnigan of CSIRO is thanked for help in implementing a new canopy momentum decay parametrisation within SPA. The aircraft observations were funded by the AEROCARB project of the EU Framework Programme 5."

- In Table 3, is NEE in umol C or umol CO2? Either one is ok as long as it's consistent, the flux literature usually uses umol CO2, but that's just convention.

* NEE units will be corrected to umol CO2 and made consistent throughout the manuscript.

- Grassland is one word in Figure 1.

* The figure will be updated to make grassland one word.

Interactive comment on Geosci. Model Dev. Discuss., 6, 1559, 2013.

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