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Hydrology and Earth System Sciences
Discussions

Interactive comment on "ERA-Interim/Land: a global land water resources dataset" *by* G. Balsamo et al.

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The Authors wish to thank the Reviewer for the very helpful comments that have led to sizeable modifications to the text and Figures and which no doubt have produced a very positive effect on our manuscript. The Reviewer commented positively on the work, but pointed out mismatching statements or descriptions that were too brief in the abstract and the results sections. In the main these have been revised accordingly with new additions. However in a small number of cases, we feel for reasons of clarity that the succinct presentation is preferable as we feel strongly that as a reference paper for this new dataset, which presents only selected results, overzealous explanation would be inadvisable. The Reviewer has made 3 major and 29 minor comments. We

have provided a point-by-point response where Reviewer remarks and questions are numbered and our responses (R:) are reported below:

1. The methodology and the datasets are not presented in details. In many places (as will be seen from the minor comments), the description of technical details is very vague and not easy for readers to understand without relevant backgrounds. For example, what does it mean “09-21 h forecast intervals” or “03-12 forecast-range”? Such kind of inconsistency can be seen throughout the manuscript. It is suggested to check closely and to avoid such inconsistency, for a better demonstration of this particular study.

R: We have addressed these concerns. A new introduction that includes specific comments to clarify and add details can be found in the new version of the document. For the meteorological forcing section highlighted in the comment above, the text has been updated and most importantly a new Figure with the schematic of forecast base-time and forecast range combination that creates the ERA-Interim/Land continuous forcing time-series has been added. This is uploaded with the response. All the 12 Figures (now 13 in the revised version) have been improved for clarity and graphical rendering.

2. For the results, although many figures are presented, they are not explained enough in the text. Even though they are show cases, it is still important to analyze it in details for reader to understand why the result is demonstrating the advantage/disadvantage of using the new products. It is understood that intensive studies have been done for different components of water cycle separately. However, it is not wise to just mention the result very briefly by citing the references. More detailed explanation and analysis are highly suggested to give readers better hints why ERA-Interim/land is performing better. In this regard, the discussion on the comparison for snow cover did a good job.

R: Yes this is true and it is a shortcoming that gave us motivations for improving the paper where there was not enough description. Sentences have been added in each of the parameterisation sub-sections to describe the major factors contributing to ERA-

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Interim/Land being superior to the original ERA-Interim. It should be noted that each of the land surface modifications described in 2.2 is well documented by published papers and therefore a lean and concise description can still remain our main focus.

3. Many acronyms are given without full expression for the first time usage. And, the inconsistency in Figures and abbreviations can be seen. For example, ERA-Interim/Land sometime is expressed as ERA-I/L, but not everywhere. In figure 6, the CDF is expressed as frequency while in figure11 it is expressed as CDF. Please check carefully and make sure the consistency throughout the manuscript.

R: The acronym definition is revised for enhanced consistency particularly in the Fig.6 and Fig.11 as highlighted above and also in the comments below (e.g. SYNOP, OZNET, FLUXNET are now all defined at first occurrence). All the Figures have been re-edited to improve clarity and readability, leading to a major revision of the entire manuscript.

Minor Comments:

1. Line 9 Page 5: It would be much clear to indicate which data set belongs to supporting and which to validation.

R: This information is now added in the introduction of section 2.1: "The ERA-Interim meteorological reanalysis and the GPCP v2.1 monthly gridded precipitation are supporting datasets to the generation of ERA-Interim/Land while the other datasets are used for the validation of the water cycle components (water storage terms and fluxes)."

2. Line 24-25 Page 5: For readers not familiar with IFS, it'd be better to explain the forecast intervals a little bit more. For example, what is the difference among analyses, forecasts and accumulated forecasts? How 3 hourly surface fluxes are generated from the 09-21h forecast intervals? why 3 hourly surface fluxes can help avoiding possible spin-up effect?

R: This paragraph has been substantially revised to respond to the Reviewer questions above and it contains details also on ERA-Interim and meteorological terms such as

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analysis and spinup, with the purpose of addressing a larger audience. “The ERA-Interim atmospheric reanalysis is built upon a consistent assimilation of an extensive set of observations (typically tens of millions) distributed worldwide (from satellite remote sensing, in-situ, radio-sounding, profilers, etc.) and by the analysis step that combines observations and Earth system model a-priori information in a statistically optimal manner. In ERA-Interim two analyses per day are performed at 00 and 12 UTC times and serves as initial conditions for the subsequent forecasts. To create a continuous time series of meteorological forcing therefore an opportune combination of analyses and forecasts has been produced as detailed in the Figure. The weather forecast’s spin-up effects are typical of fields such as precipitation and radiation fluxes, for which the first hours after the analysis present some initial shock problem”. The spinup problem is explained in much more detail in Kallberg (2011) as mentioned in this section. The text above is added for the benefit of clarity.

3. Line 1 Page 6: Again, this part needs some more description for readers not familiar with ECMWF data.

R: Yes this is an important point. Details have been added (see response to point 2) and this section includes also a new Figure.

4. Line 18 Page 6: OPI, the first time occurrence requires the full expression.

R: OPI is an acronym for “Outgoing longwave radiation Precipitation Index”. This is now defined at the first occurrence in the text.

5. Line 26 Page 6: FLUXNET, the first time occurrence requires the full expression.

R: FLUXNET is a global surface energy water and CO2 FLUX observation NETwork and it is a collection of existing regional networks.

6. Line 2 Page 8: OZNET

R: OZNET is a label for the Australian hydrological network. Clarification added to the text.

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7. Line 8 Page 8: SYNOP

SYNOP is a label for the conventional meteorological observations taken at the surface at SYNOPtic time (typically 3-hourly from 0 UTC) under the coordination of the World Meteorological Organization (WMO). Clarification added to the text.

8. Line 19 Page 9: 11yrs -> From which year to which year is 11 yrs?

R: 1979 to 1989 included. Added to the text.

9. Line 20-22, Page 9: I don't understand this sentence. Don't know how this is connected with the previous and the followed sentences.

R: The sentence is clarified as follows: "The meteorological forcing described in 2.1.3 is used to drive a 11 yr spin-up run (1979 to 1989 included) that serves the purpose of generating plausible initial conditions for the 1st of January (as average of spin-up run dates in 1980-1989)."

10. Line 24 Page 11: Please check and explain, in Fig.1, how to distinguish the differences for mid-winter and mid-summer.

R: Fig. 1 shows the median of the 32-year snow and soil moisture conditions valid on the 15th of January and 15th of July respectively. The median is particularly adapted to show the typical values for those dates. For mid-January for instance the "median" is much better than the "mean" for which a single exceptional year with large snowfall will generate a snow pattern. The same argument is valid for mid-July in which a single exceptional flood will move the mean but does not affect the median. This figure serves the purpose of illustrating the potential of the multi-decadal daily land reanalysis. Similarly the 95th percentile of the distribution is shown for comparison in Figure 2 to illustrate the water resources dynamical range in the past 3 decades associated with snow and unsaturated soil layers and the extent and the magnitude of exceptional events can be appreciated.

11. Line 4 Page 12: what does the label mean on the x-axis of both Figure 3 & 4?

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R: The X-axis the label is time and those shown are dates at equal span in the 1979-2010 period. The figure has been improved for clarity in the new version of the manuscript.

12. Line 7-9 Page 12: Could you explain a bit more what kind of snow changes in Fig.4? Another point is that if you check the color bar, some colors are the same for the reduction and the increase. This will confuse readers. Could you revise it?

R: Colors are distinct although some red tones are not too far apart chromatically. The specialized plot being generated by proprietary software complicates revision of the legend. Color proximity is true only for snow red-tones (upper panel) and not for soil moisture (lower panel) we believe this revision is not critical. Howmöller plots are very well adapted to highlight the time dimension (related here to a 32-year global reanalysis available at sub-daily frequency), but this kind of plot has intrinsic limitations for geographical attribution. The latitude bands showing snow reduction are really minimal and concentrated at NH mid-latitude as commented in the text. Figure 4 is meant to illustrate that ERA-Interim and ERA-Interim/Land are significantly different throughout the 32-year period. These comments are added to the text to underline the plots merits and limitations. The plot has undergone editorial improvement for the benefit of clarity (size of labels, color scheme where inappropriate to appreciate differences).

13. Line9-10 Page 12: Why is this statement? Please detail.

R: Clarified in the response to point 11 as reported above.

14. Line 21 Page 12: It is clear that the skill of ERA-Interim/Land has been improved when compared to ERA-Interim. However, it is beneficial for readers/users to know why this improvement is, by explaining its physical mechanism, for example through mass balance or energy balance point of views. Although such kind of details can be inferred from previous publication by the author, it'd be much better to express them explicitly here to make the pare more readable.

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R: Yes we agree and for this reason the main point supporting the ERA-Interim/Land improvements have been added to the text

15. Line 15-17 Page 13: Are you saying that for the same correlation coefficient (cc) the portion of ERA-Interim/Land river discharge at this cc level are much higher than that of ERA-Interim. If it is in this case, i found the statement here is confusing. Please rephrase. Again, another point is that a detailed explanation may be needed to explain why the ERA-Interim/land is over-performing ERA-Interim all over the globe. Or even in more details, why over certain continent the skill of ERA-Interim/Land is higher than the other continents.

R: The improvements on river discharge correlation coefficients (ERA-Interim/Land to GRDC discharge observations) are averaged on all the continental rivers indicated in each panel of Fig. 6. Clarification added to the text.

16. Line 19 Page 13: 'such as this (Pappenberger). . .' please rephrase. . .

R: The sentence has been rephrased as suggested and now reads as follows: "Although there is still some way to go in effectively representing river discharge in large-scale land surface schemes, modelling cascades can enable bridging the ERA-Interim/Land with river hydrology (Pappenberger et al, 2012)."

17. Line 26 Page 13: responding to variations of what?

R: The missing word is fluxes. The sentence now reads as: "The water reservoirs verification aims at assessing the daily performance of ERA-Interim/Land in reproducing the top metre of soil water content and the snow water equivalent, which are responding to the diurnal, synoptic and seasonal fluxes variations."

18. Line 1 Page 14: Can we say slower soil layers?

R: The deeper and slowly evolving soil moisture layers

19. Line 4 Page 15: Fig8. There is no explanation for Fig.8 in this paragraph. The

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caption only is not enough to see why is there an improvement, and how this can be used to interpret the capacity of reproducing soil moisture. For example, the difference between the ERA-I/L and ERA-I are increasing with the fraction of bare soil. Does it mean ERA-I/L has a higher RMSE over ERA-I always, and such difference increases with the increasing fraction of bare soil. Does it mean both schemes are working not properly over bare soil? Please clarify with more details.

R: With the RMSD being positive definite and calculated against in-situ soil moisture observation, the differences between RMSD between ERA-Interim/Land and ERA-Interim are measuring improvements realized by ERA-Interim/Land. The RMSD difference is calculated for several vegetation fractions and the improvement is shown to be larger on points with sizeable bare soil. This is a demonstration that the enhanced match to the observed soil moisture is indeed the results of the bare soil evaporation revision as detailed in Albergel et al. (2012a). This explanation is added in the text.

20. Line 19 Page 15: USSR is the first time usage.

R: Union of Soviet Socialist Republics (USSR) is added.

21. Line 5-7 Page 16: Could you expand/detail this statement?

R: A significantly lower bias in this case is obtained without the GPCP rescaling (9.7 mm vs. 33.8 mm) confirming the general difficulties in measuring snowfall with gauges. This means that GPCP precipitation rescaling is not universally beneficial and outperforming ERA-Interim solid precipitation forecasts. In this case ERA-Interim (non rescaled) snowfall would lead to higher skill in simulating snow accumulations in the verification area. Given the difficulty in applying precipitation corrections only partially at this stage it is only possible to document this shortcoming of the bias correction method and/or the used datasets.

22. Line 11 Page 16: (SDR=1 being the best) should not be repeated.

R: The second occurrence has been removed.

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23. Line 20 Page 16: Please make sure the consistency between Figure 6 and Figure 11. The Figure 11 is much clearer than Figure 6 in presenting the better performance of ERA-I/L than that of ERA-I. Another point is that, sometime you use ERA-Interim/Land, sometime you use ERA-I/L. please make sure the consistency.

R: The consistency of labels has been improved for consistency. ERA-Interim/Land is being used throughout.

24. Line 26 Page 16: Why finally is needed here?

R: The word has been removed.

25. Line 1 Page 17: ". . . is more resilient. . .", 'more' compared to what?; ". . . in case snow abundance the SDR may favour a biased snow scheme. . .", Could you expand a bit on this? ". . . in forest areas", Is it specifically for forest areas only?

R: The paragraph has been rephrased and expanded. The FCA index is a robust indicator and is more resilient to model biases compared to SDR, which in case snow abundance may favour a biased snow scheme. The MODIS land surface albedo is used to verify the ERA-Interim/Land, particularly in the snow representation in forest areas (Fig. 13) in Northern Canada and Siberia, where conventional SYNOP observations are generally less informative.

26. ". . . reduced albedo bias . . .", Here, you assume MODIS land surface albedo is the "ground truth", Why is that? A bit more explanation would be appreciated.

R: Rephrased as mentioned above in 25 and added: Fig. 12c points to a substantially reduced albedo bias in the ERA-Interim/Land attributed to the snow scheme revision described in Dutra et al. (2010) and in particular at the snow-vegetation albedo retuning.

27. Line 4-8 Page 18: This is too brief. It is encouraged to describe more on this part, as this is in the discussion section not the section of summary.

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R: The skill of an ERA-Interim/Land variant (with no precipitation readjustment) together with other model-based and remote-sensing datasets (such as MERRA-Land and ESA-Climate Change Initiative datasets) for the detection of soil moisture climate trends in the past 30 yr is evaluated in Albergel et al. (2013). This study, using the methodology described in this paper, represents an attempt to gain insights on soil water reservoirs and its evolution in response to natural and anthropogenic forcing.

28. Line 5 Page 19: The comparison of the river discharge only is not enough to assess the water balance per se.

R: We agree and we have therefore rephrased the paragraph accordingly. The water balance is verified with the observed river discharge from the GRDC river network showing an enhanced correlation to the observations with respect to ERA-Interim as combined effect of the GPCP precipitation correction and the land surface improvements. While river discharges verification is not enough for a global water balance assessment the results from the verification of evaporation fluxes (the other main outgoing land water flux) and of the two main water reservoirs in the soil and snow-pack permit to qualify the ERA-Interim/Land enhanced accuracy as genuine. When water fluxes and water storages terms show consistent indication of improvements there are in fact good grounds to believe that the parameterization changes are real added value and not the result of compensation. Finally, the impact of adopting ERA-Interim/Land as initial condition in retrospective forecasts has also been verified with a generally positive effect of the new land initial condition, more evident in longer lead times of the forecasts.

29. Line 8-11 Page 19: I didn't see detailed or corresponding part of discussion on this point.

R: The impact on numerical weather prediction is demonstrated in Balsamo et al. (2012) and this reference is already reported in the conclusions.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 14705, 2013.

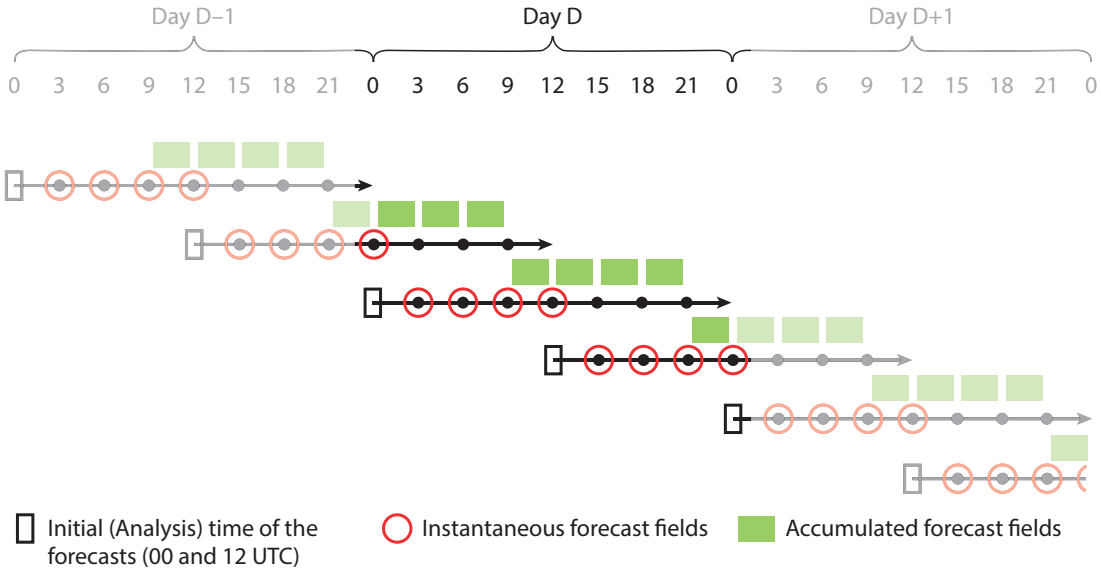

Fig. 1. Schematic representation of the ERA-Interim meteorological forecasts concatenation for the creation of the 3-hourly forcing time-series used in ERA-Interim/Land for a given day.

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