Earth Syst. Dynam. Discuss., 5, C166–C173, 2014
www.earth-syst-dynam-discuss.net/5/C166/2014/

Earth System Dynamics Discussions Open Access

Interactive comment on "Contrasting roles of interception and transpiration in the hydrological cycle – Part 2: Moisture recycling" *by* R. J. van der Ent et al.

R. J. van der Ent et al.

r.j.vanderent@tudelft.nl

Received and published: 22 May 2014

Comments by the referee are in *italic* and our answers are in upright text.

The paper is very well written and contains a lot of meaningful information which might be useful for many different subjects. The results are presented in a clear and comprehensible way which made it easy to follow the author's findings. However, there are (amongst others) some issues which typically arise from such single-model analyses (–> general comments).

We thank referee 3 for the kind words about our manuscript and useful suggestions for its improvement.

General comments

All results in the paper are based on a single model. Therefore, it would be interesting how "reliable" these numbers are. In section 4, the authors conclude that 60 % (56 %) of intercepted (transpirated) evaporation returns to the land surface. When we take into account all the uncertainties from the moisture tracking model, STEAM, and ERA Interim, I wonder if e.g. the difference of 4 % between intercepted and transpirated evaporation is "realistic" or simply due to errors or simplifications in the model and driving data. It would be very interesting to see some "ensemble" analyses and how the results change if e.g. the driving data is slightly modified (! stability). I know that this would go far beyond the scope of the paper but the authors might consider this for future investigations.

The 4 % at first sight could possibly be seen as small in relation to potential model errors, but we are sure that the existence of a difference is real. No matter what the conceptualization and parameterization of the input model (STEAM in this case) is, it very improbable that one would find transpiration to be more likely to return to the continent than interception. This is simply the case because transpiration is more dominant in the dry season compared to interception. Hence, it is less likely for transpiration to return locally. The exact numbers are indeed uncertain, but we still think that continental evaporation recycling efficiency for interception > continental evaporation recycling efficiency for transpiration is a robust finding. We will include this type of reasoning in the revised manuscript.

In advance, as the authors provide absolute numbers of the different partitions of evapotranspiration (and other water cycle quantities), I think it is absolutely necessary to give at least some rough uncertainty estimates of these values.

Although we understand the referee's call for uncertainty estimates, we do not think that anybody reads our numbers as the absolute truth. Given the tremendous amount of discussion about evaporation partitioning going on at the moment (e.g., Coenders-

Gerrits et al., 2014; Schlesinger and Jasechko, 2014; Sutanto et al., 2014), including the discussion belonging to the companion paper (Wang-Erlandsson et al., 2014), we do not think this paper (Part 2) is the right place to have this discussion. In the revised version, we will make more clear, however, that while the interception vs. transpiration recycling results are robust in our opinion, the absolute numbers are indeed dependent on the input data and more studies should repeat our partitioned recycling calculations to learn more about their uncertainty.

In section 2.2, the authors present some new metrics which allow a much more detailed analysis of moisture recycling. It could help the reader a lot if the authors summarize these metrics (together with a short description) in a table.

This is an excellent suggestion. We will include this in the revised version.

Section 3.6: I somehow have the feeling that this section is a bit "out of topic". It further does not add a lot to the authors' main findings. That being said, it would make more sense if the authors remove the West Africa section completely and add a more detailed analysis on the seasonality of their results. It would be very interesting to see e.g. how their recycling metrics change over time.

On the one hand, we agree with the referee that it is a big switch from the global results to a specific case study. On the other hand, we considered the West Africa section an informative case study that illustrates how interception and transpiration have different roles in moisture recycling throughout the year in a specific area. In fact it is an analysis of the seasonality of our results, on which also referee Helge Goessling would like to see more emphasize. We think that a specific case study is the most appropriate way to try to analyse the yearly cycle of recycling.

Specific comments

Page 283, line 25: Could you give a short explanation what you mean by "recycled" evapotranspiration?

We will add this in the revised version.

Page 285, line 27: We aim at ... I think this is a bit too far reaching. You're not presenting a completely new image, but a more detailed look at the global water cycle.

We agree with the referee and will rephrase this sentence to "We aim to present a new (i.e., more detailed) image of the global hydrological cycle . . . "

Section 2.1: The terminology in the formulas is a bit mis-leading. It is common practice to call evapotranspiration ET (or even ETa for actual evapotranspiration). Here, you're using the term E_t for transpiration only.

As explained in a previous comment (Van der Ent et al., 2014), the word evapotranspiration is actually not as common as some might think, and moreover it is in our opinion not a very good term either.

Page 287, line 5: Using oceanic precipitation and evaporation estimates from reanalyses is dangerous!!! We know that the analysis increments in reanalysis models can significantly distort the water budgets. This can be observed especially over the oceans. As you directly use oceanic values from ERA Interim in your analysis, it might be necessary to comment on the reliability of these estimates (e.g. use GPCP, HOAPS, TRMM, ...).

We have experimented with other data, which did not yield significantly different results (e.g., Van der Ent, 2009; Van der Ent et al., 2010; Keys et al., 2014; Zemp et al., 2014). Moreover, these products are not the truth either and there are often practical problems, such as different time and spatial resolution that have to be overcome before such a product can be used in a global study as this one.

Page 287, lines 10 – 11: Why don't you use the full resolution product ($0.75° \times 0.75°$)?

To be honest, this is mainly a practical reason. The amount of data handling and computation time would be tremendously increased, while we already know from previous research with ERA-40 on a $2.5° \times 2.5°$ scale that the results do not differ significantly from those obtained with ERA-Interim (Van der Ent, 2009). Therefore, we do not think it is worth the effort to go to $0.75° \times 0.75°$.

Page 289, Equations 12, 13, 14: What exactly do you mean by $\tau_{\rho,c} = N\,(P_c \leftarrow E_c)$? In the current version, this indicates that N is a function of $(P_c \leftarrow E_c)$. As you do not use $(P_c \leftarrow E_c)$ in the following, I think these formulas can be easily changed.

We mean the time that has been spent in the atmosphere by the continentally recycled part of the precipitation (P_c), counted from the moment it evaporated (E_c). We will clarify this in the revised version.

Page 289, line 25 "The lifetime of continental …" The authors explain that $\tau_{\rho,c}$ is the "average age" of a water particle. I don't know if I might miss the point here but what does this imply if precipitation in a pixel is a combination of recycled (from the pixel itself, short lifetime) and advected (from a remote location, long lifetime) moisture? As $\tau_{\rho,c}$ is an average, it could be that this value does not even occur in reality. Can you comment on this?

This is true. We will clarify in the revised version that $\tau_{\rho,c}$ is the average age of the recycled precipitation fraction only, and that it does not say anything about the distribution.

Pages 291 – 292: Think about re-arranging the formulas. It might be more convenient to start with λ_ρ, .. and then explain what ρ_{X_1}, .. is.

As λ_ρ is immediately explained below, we do not think rearranging is necessary.

Page 294, Section 3.1: Are these numbers on ERA Interim (ocean) and STEAM (land)?

Yes, we will add this in the caption of Fig. 1.

Page 294, Lines 297 – 298: How do you compute Q? Is this an output from the STEAM model? Do you somehow account for trends in the continental water storage?

This is indeed $P - E$ from STEAM. We will also clarify this in the caption of Fig. 1.

Page 294, Line 10: A portion of this land evaporation (E_o) is advected to the oceans ...

It seems that the referee suggests a different placement of E_o, however E_o refers to the portion of evaporation that is advected to the oceans only.

Page 294, From line 12: I think you should add some comments about the reliability of these numbers (see second general comment).

See previous response.

Page 295, Lines 16 – 19: How does this explain the location of the "hot spot" of interception?

Unfortunately, we do not exactly see which point the referee is missing here.

Page 296, Lines 10 – 15: Even if this sounds like a reasonable explanation, the difference between interception and transpiration is only about 5 % in these regions! I fear that such differences can also be explained with errors in the model or driving data... In that sense, a different model might give totally different numbers (see first general comment).

See previous response

Figure 1: This figure needs much more detailed explanation. Especially, F_{in} and F_{out} are not explicitly mentioned in the text. This makes it rather difficult to understand what is going on.

We got the same comment from referee #1 and we will clarify this in the revised version.

Figure 2: Consider using equal color bars (at least for 2b and 2c).

As explained in the caption of Fig. 2 we chose a different colour scale on purpose. This is done as to be able to visually inspect their relative importance in different regions better.

Global Maps (Fig. 2 – 6, A1, A2) Consider using only a single colorbar for maps which share the same color map. This gives you more space for the figure.

As several panels have different colour scale we think it is clearest of all figures have a separate colour bar.

References

Coenders-Gerrits, A. M. J., van der Ent, R. J., Bogaard, T. A., Wang-Erlandsson, L., Hrachowitz, M., and Savenije, H. H. G.: Uncertainties in transpiration estimates, Nature, 506, E1-E2, doi:10.1038/nature12925. 2014.

Keys, P. W., Barnes, E. A., van der Ent, R. J., and Gordon, L. J.: Variability of moisture recycling using a precipitationshed framework, Hydrol. Earth Syst. Sci. Discuss., 11, 5143-5178, doi:10.5194/hessd-11-5143-2014. 2014.

Schlesinger, W. H., and Jasechko, S.: Transpiration in the global water cycle, Agricultural and Forest Meteorology, 189–190, 115-117, doi:10.1016/j.agrformet.2014.01.011. 2014.

Sutanto, S. J., van den Hurk, B., Hoffmann, G., Wenninger, J., Dirmeyer, P. A., Seneviratne, S. I., Röckmann, T., Trenberth, K. E., and Blyth, E. M.: HESS Opinions: A perspective on different approaches to determine the contribution of transpiration to the surface moisture fluxes, Hydrol. Earth Syst. Sci. Discuss., 11, 2583-2612, doi:10.5194/hessd-11-2583-2014. 2014.

Van der Ent, R., Savenije, H., Kunstmann, H., and Knoche, R.: Shifts in continental moisture cycling patterns, Geophysical Research Abstracts, 12, EGU General Assem-

bly 2010 - Oral. 2010.

Van der Ent, R. J.: A new perspective on continental moisture recycling, MSc thesis, Water Management, Delft University of Technology, Delft, 2009.

Wang-Erlandsson, L., van der Ent, R. J., Gordon, L., and Savenije, H. H. G.: Contrasting roles of interception and transpiration in the hydrological cycle - Part 1: Simple Terrestrial Evaporation to Atmosphere Model, Earth System Dynamics Discussions, 5, 203-279, doi:10.5194/esdd-5-203-2014. 2014.

Zemp, D. C., Schleussner, C.-F., Barbosa, H. M. J., Van der Ent, R. J., Donges, J. F., Heinke, J., Sampaio, G., and Rammig, A.: On the importance of cascading moisture recycling in South America, Atmos. Chem. Phys. Discuss., submitted. 2014.

Interactive comment on Earth Syst. Dynam. Discuss., 5, 281, 2014.