Response to comments from Zachary Zubin

We wish to thank the reviewer for his positive review and the useful comments and suggestions on our manuscript. We have modified the manuscript accordingly and detailed corrections are listed below. In the following the reviewer's comments are given in italics and our replies in regular font.

Short comment by Zachary Zubin

Based on an initial reading, this manuscript seems thorough and represents an important contribution to the literature. I glossed over some areas beyond my expertise (e.g., the river parameterization). Below are some minor comments / suggestions:

The methods should explain briefly (in addition to the references) how the surface fluxes / vegetation / atmospheric boundary conditions in the PCR-GLOBWB are determined. Is this a full land-surface model like that found in a global climate model?

We explain the used land-surface model into more detail and added the paragraph below in section *2.1.1:*

"For a detailed description of the model PCR-GLOBWB we refer to van Beek et al.(2011), and a summarized model description is given here. PCR-GLOBWB was run at 6' resolution using a daily time step. Monthly climate data were taken from the CRU TS2.1 (Mitchell and Jones, 2005) with a spatial resolution of 0.5^{o} and downscaled using the ERA-Interim reanalysis (Dee et al., 2011) to obtain a daily climatic forcing (see de Graaf et al., 2014 for a more detailed description of this forcing dataset). Each grid-cell contains a land surface that is represented by a vertically structured soil column comprising two soil layers (maximum depth 0.3 m and 1.2 m respectively), an underlying groundwater reservoir, and the overlying canopy. Sub-grid variability is included with regards to land cover (in this case using fractions of short and tall vegetation), soil conditions, and topography. The model employs the improved Arno Scheme (Todini, 1996; Hageman and Gates, 2003) to simulate variations in the fraction of saturated soil in order to quantify direct surface runoff. Each time step, for every grid cell the water balance of the soil column is calculated on the basis of the climatic forcing that imposes precipitation, potential reference evaporation, and temperature. Actual evapotranspiration is calculated from potential evaporation and soil moisture conditions. Vertical exchange between the soil and groundwater occurs through percolation and capillary rise. Specific runoff from the soil column, comprising direct surface runoff, interflow and baseflow, is accumulated along the drainage network that consists of laterally connected surface water elements representing river channels, lakes or reservoirs. The accumulated runoff is routed to obtain discharge using the kinematic wave approximation of the Saint-Venant equations at a sub-daily time step."

Eq. 3-5 are a bit hard to follow and may need some additional explanation.

According to the reviewer's suggestion, we will rewrite point 3 and 4 of section 2.2 in the manuscript to explain the used equations more extensively.

Eq. 6 seems to be mixing the concept of near-surface permeability with the deep-groundwater permeability as determined by Gleeson et al 2011. Is it realistic to decay to zero below the depth alpha, or should there be a minimum bedrock permeability for the thickness of the aquifer? Give some idea of the range of alpha. Is alpha the soil depth, the regolith depth, or the depth to impermeable bedrock?

To estimate aquifer permeability at greater depth we combined the concept of exponentially decreasing permeability of the continental crust with depth (e.g. Ingebritsen and Manning (1999)) with data on near surface permeability from Miguez-Macho et al. (2008).

The near surface permeability is prescribed by the sediment-bedrock profile at a location, which depends strongly on terrain slope; the steeper the land, the thinner the regolith and the sharper the decrease in permeability with depth. This is expressed through the e-folding depth. The range of the e-folding depth (alpha) is given in the graph below, and its spatial distribution in the map below.
Both figures we will added in the extra material of our manuscript, and we will extend the description of the usage of the e-folding depth to explain this better.

The permeability diminishes exponentially with depth from a known value of near surface permeability (k_0). The transmissivity can then be calculated with the presented integral of Eq 6 (p. 5226). As Eq 6. is an exponential function, permeabilities will approximate zero at infinite depth. This implies, that for thick aquifers (i.e. thickness extending e-folding depth) permeabilities at greater depth are contributing to aquifer transmissivities, whereas, for more shallow aquifers, the higher permeabilities of the regolith are more important.

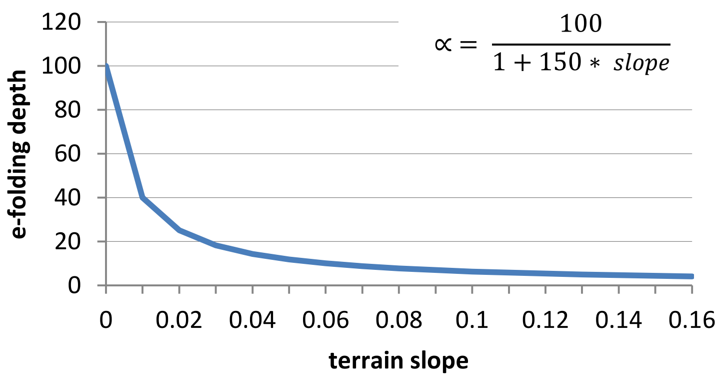

Fig A-1: e-folding depth as a function of terrain slope, using constants of Miguez-Macho et al. (2008)

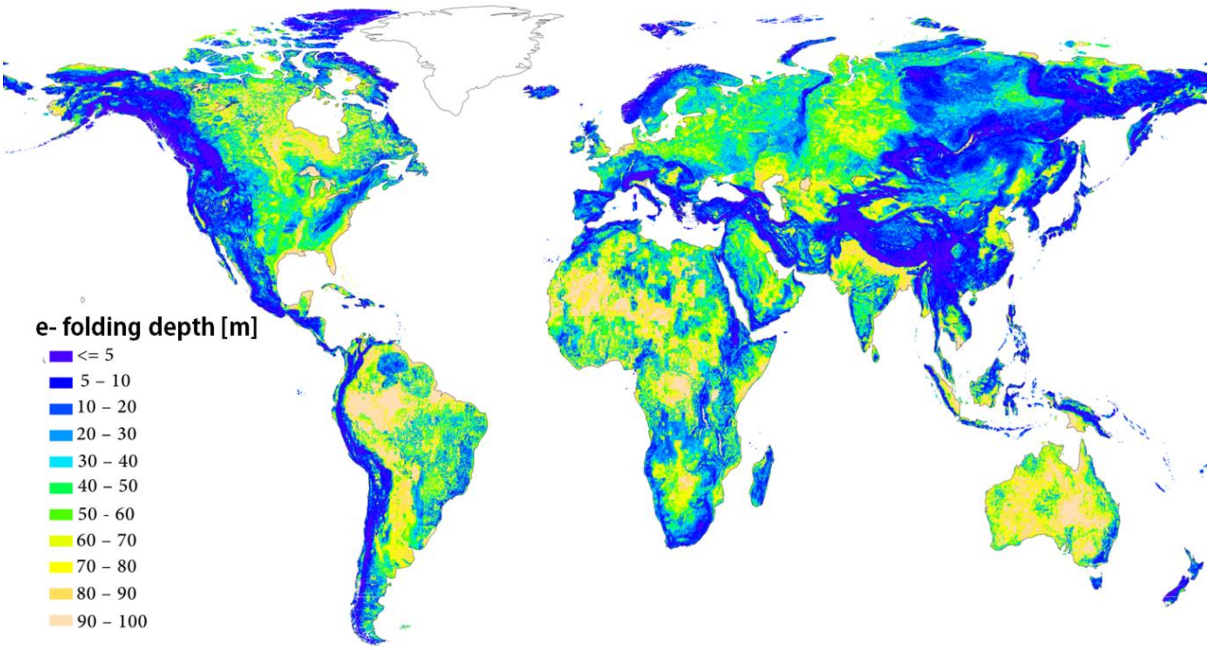

Fig A-2: e-folding depth

In the determination of the 6' gridcell properties, I'm not sure if it is done at 30" and aggregated up, or if the 30" data is only used to calculate the floodplain depth for the 6' cell and the average depth is used in determining that 6' cell's properties.

We used the 30" data to determine the floodplain elevation at 6'as follows: Within each 6'cell and using the Hydrosheds dataset, we identified the lowest elevation at 30'' (maximum 144 values for a cell comprising only land area), and assigned this as the floodplain elevation for the entire cell.
We will clarify this into more detail in the manuscript in section 2.2.

What is the difference between the "true" and "apparent" MODFLOW grid cell area?

By naming the cells 'true' and 'apparent' we wanted to clarify the difference between the lat-lon cell area used by PCR-GLOBWB and the cell area used by MODLFOW, as the latter assumes rectangular grid cells. This means there is a difference in area, for which we should correct (as done in Eq 7). We will explain this more clearly in the manuscript in section 2.3.

The Figure 6 caption needs correction.

As suggested, we have corrected the caption to read: "Scatter plots of observed groundwater heads in (red) sediment basins, and (blue) mountain ranges. A) best performing run, and B) best performing run when observations outside the sediment basins are excluded in determining the parameter set to used. "

Figure 8 caption: where are the white areas referred to?

The white areas are no-data values. This is added to the figure caption now.

Good luck on a productive review and publication.

Thank you for your kind wishes.