Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

A study on implementing catchment-scale rootzone water storage capacities, derived from climatic parameters, in the HTESSEL land surface scheme

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EGU 2020 - CL4.21 Land-atmosphere interactions and climate extremes

Introduction

Research background

Vegetation's roots drive water fluxes from the subsurface to the atmosphere. The water storage capacity in the vegetation's rootzone is a key parameter in predicting evaporation fluxes, in particular during dry periods.

Problem

The vegetation's rootzone is inadequately described in land surface models, causing difficulties in evaporation predictions by these models.

Whereas climate is the main controller of root development [1,2], the land surface model HTESSEL describes the vegetation's rootzone only as a function of soil type and model soil depth.

Research goal

Implementation of rootzone water storage capacities derived from climatic parameters in the HTESSEL land surface model and analysis of the effects of the modified root parameterisation on simulated water and energy fluxes.

1. *Guswa, A. J. The influence of climate on root depth: A carbon cost-benefit analysis. Water Resour. Res.* ***44****, 1–11 (2008)*
2. *Kleidon, A. Global datasets and rooting zone depth inferred from inverse methods. J. Clim.* ***17****, 2714–2722 (2004)*

Methodology – *Mass balance approach*

Study area: 15 Australian river catchments
Climatic regions: Temperate, Mediterranean and tropical regions
Data:
- River discharge (observations Bureau of Meteorology)
- Precipitation (GSWP-3)
- Potential evaporation (Hargreaves and Samani)

Estimation of catchment scale rootzone water storage capacities with climate-based mass balance approach [3]

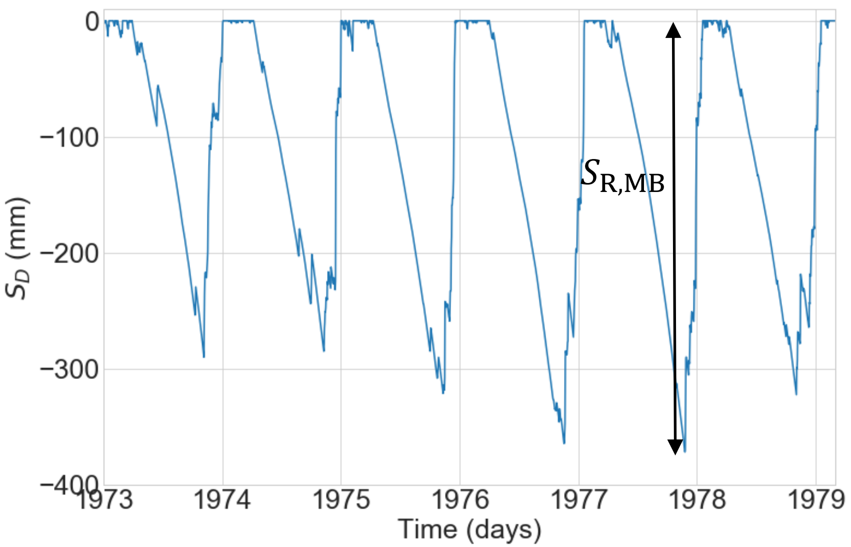
- Root development is controlled by the climate
- Vegetation adapts in a way it overcomes droughts

$$S_D = \int P_e - E_t \, dt$$

$$S_{\mathrm{R,MB}} = \max(S_D)$$

S_{D}: Soil water storage deficit
P_{e}: Effective precipitation
E_{t}: Transpiration (derived from potential evaporation and long term mean actual evaporation)
$S_{\mathrm{R,MB}}$: Total rootzone storage capacity applying mass balance approach

Figure 1: Example of soil water storage deficit in a river catchment from 1973-1979. The maximum storage deficit in this period corresponds to the total rootzone water storage capacity ($S_{\mathrm{R,MB}}$)



3. Gao, H., Hrachowitz, M., Schymanski, S. J., Fenicia, F., Sriwongsitanon, N., & Savenije, H. H. Climate controls how ecosystems size the root zone storage capacity at catchment scale. Geophysical Research Letters, 41 (22) (2014)

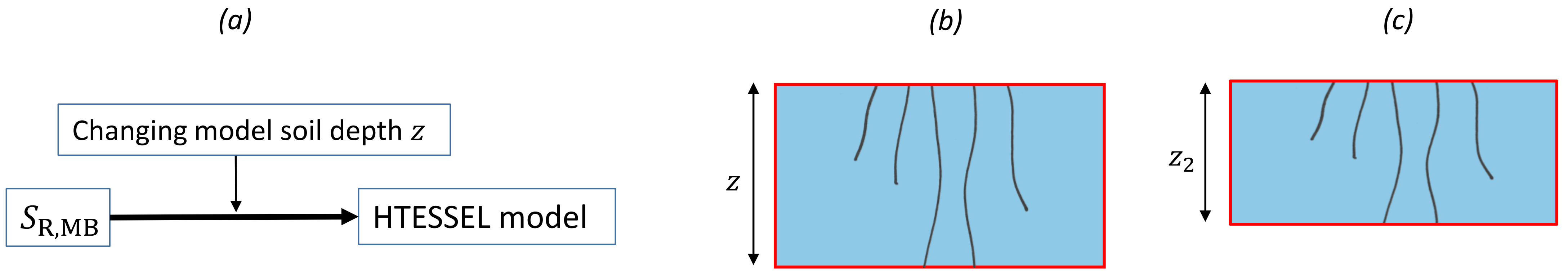
Methodology – *HTESSEL model*

Implementation of mass balance derived rootzone storage capacity estimates in the HTESSEL model

$$\boldsymbol{S_{\mathrm{R,HTESSEL}} = z(\theta_{\mathrm{FC}} - \theta_{\mathrm{WP}})}$$

$S_{\mathrm{R,HTESSEL}}$:	Total rootzone storage capacity HTESSEL
$S_{\mathrm{R,MB}}$:	Total rootzone storage capacity estimate from mass balance
z:	Model soil depth
$\theta_{\mathrm{FC}} - \theta_{\mathrm{WP}}$:	Root available soil moisture (vegetation specific)

Figure 2: Implementation of $S_{\mathrm{R,MB}}$ in HTESSEL by changing the model soil depth z (a). Water bucket representation of model soil layer with vegetation roots in the current HTESSEL model (b) and the HTESSEL model with modified layer depth (MD) (c). The red box represents total available water for root extraction.

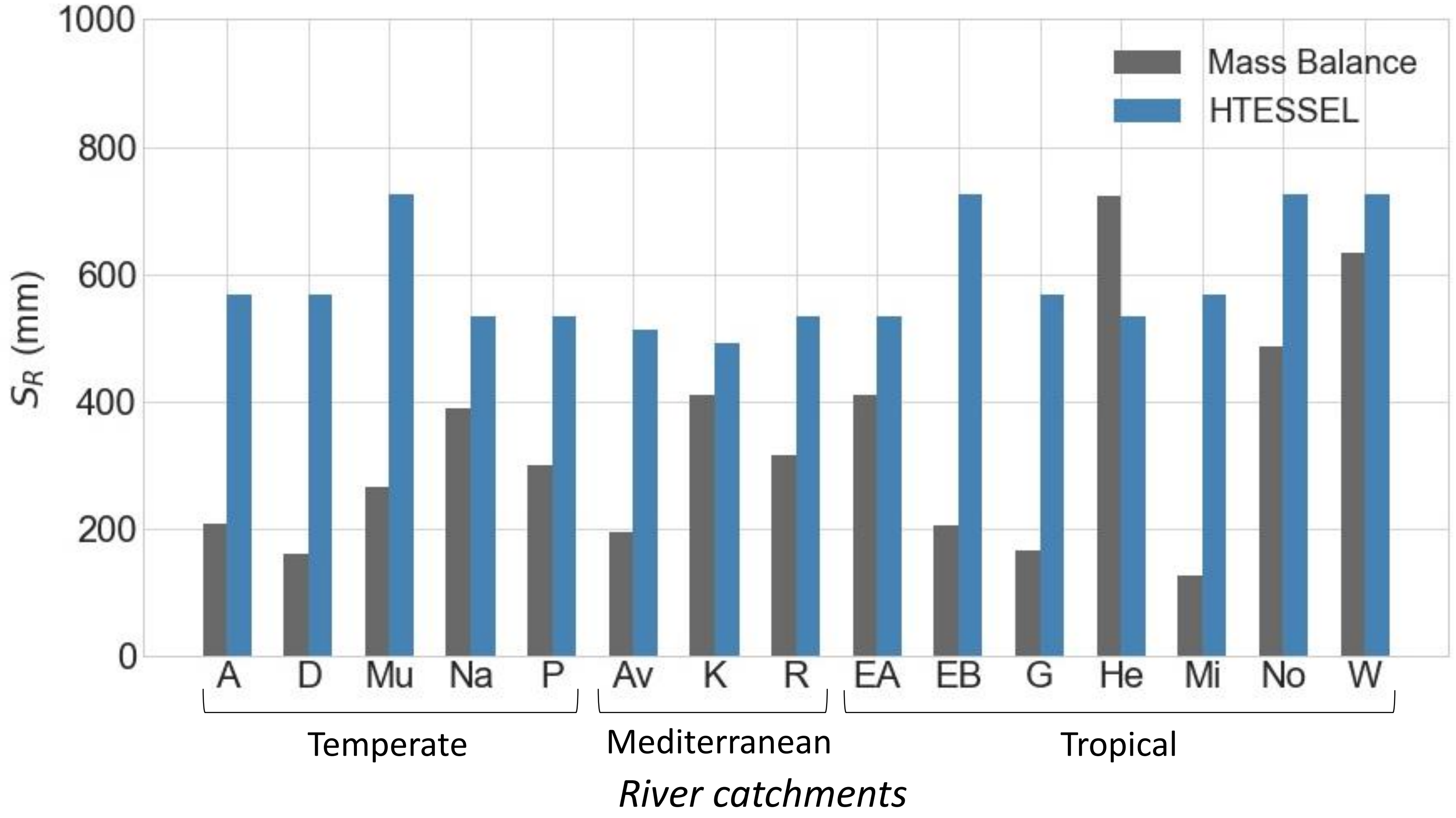


$S_{\mathrm{R,HTESSEL}} = z(\theta_{FC} - \theta_{WP})$

$S_{\mathrm{R,HTESSEL,MD}} = z_2(\theta_{FC} - \theta_{WP})$

Results – *Rootzone storage capacities*

Figure 3: Total rootzone water storage capacities (S_R) in 15 Australian river catchments clustered in three climatic regions estimated with the Mass Balance approach and derived from the current HTESSEL model



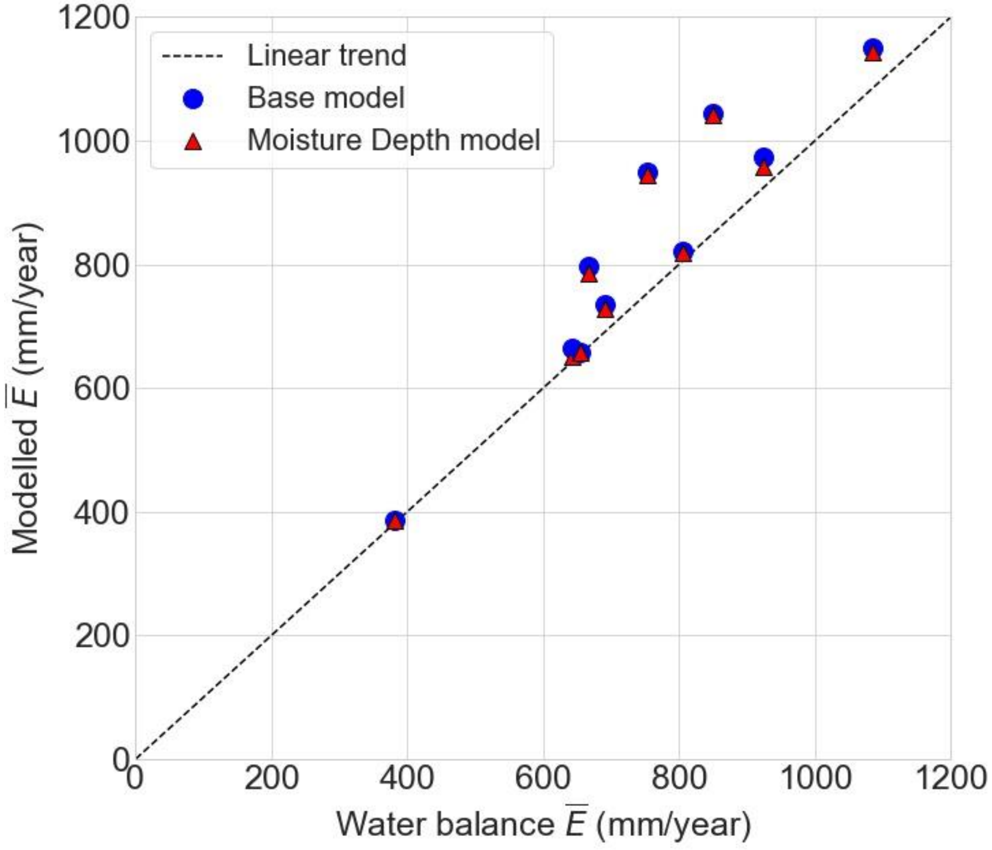
$S_{R,\mathrm{HTESSEL}} > S_{R,\mathrm{Mass\ Balance}}$

Overestimation of evaporation fluxes by HTESSEL

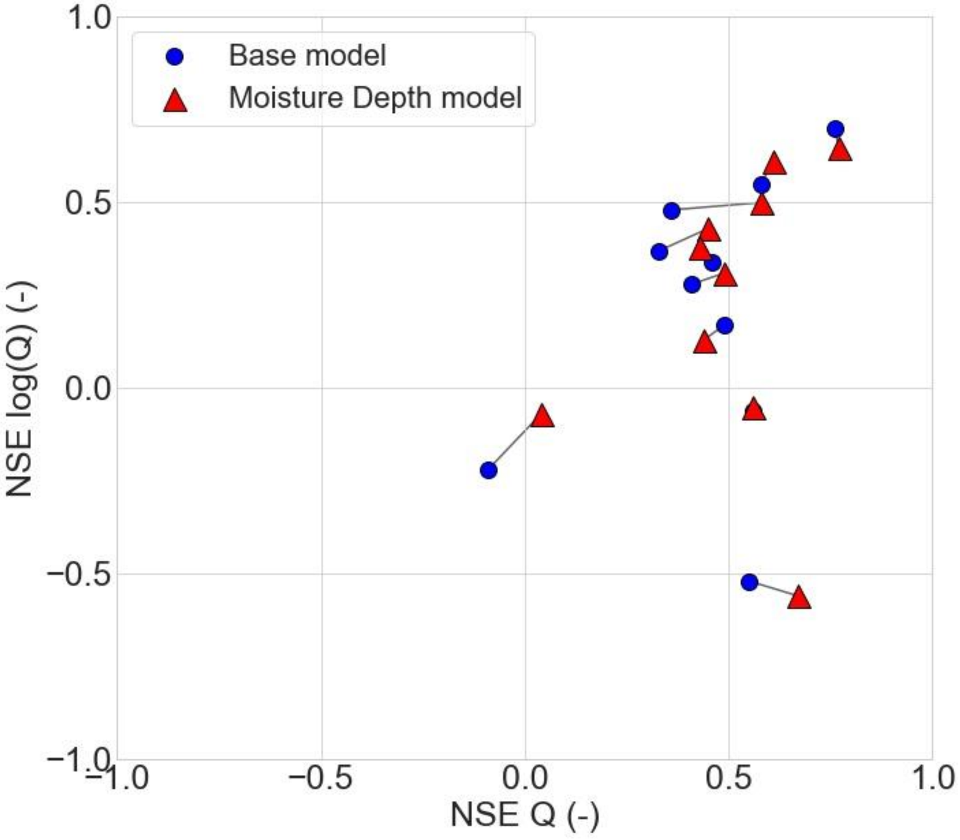
Results – *HTESSEL simulations*

Figure 4: Model performance of the current HTESSEL model (Base model) and the HTESSEL model with modified moisture soil depths based on implementation of mass balance rootzone storage capacity estimates (Moisture Depth Model). The lines connect corresponding study catchments.

a) Modelled and water balance-derived long term mean actual evaporation



b) Nash Sutcliffe Efficiency (NSE) based on modelled and observed monthly river discharges



$$\text{NSE} = 1 - \frac{\sum_{i=1}^{n}(Q_{o,i}-Q_{m,i})^2}{\sum_{i=1}^{n}(Q_{o,i}-\overline{Q_o})^2}$$

Q_o: Observed monthly discharge
Q_m: Modelled monthly discharge

NSE-log: NSE of logarithmic flows, is an indication for model performance regarding low flows.

NSE = 1 → model perfectly simulates observations

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Conclusions

- Rootzone water storage capacities in HTESSEL consistently larger than mass balance derived estimates
  → HTESSEL overestimates long term mean evaporation fluxes

- Mass balance rootzone water storage capacities improve water flux simulations by HTESSEL
  - Small but consistent effect on modelled long term mean evaporation
  - Consistent improvements of NSE-values of the river discharges

Table 1: NSE and NSE-log of monthly modelled discharge (Q) in the current HTESSEL model (Base model) and the HTESSEL model with implementation of mass balance derived rootzone water storage capacities

	Base model	**Moisture depth model**
NSE Q (-)	0.44	0.51
NSE log(Q) (-)	0.21	0.23

- Model parameterisations of other hydrological processes than the rootzone also result in modelling biases

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