Behind the scenes of streamflow model performance

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EGU 2020

Currently open discussion HESSD

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Review status
This preprint is currently under review for the journal HESS.

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Received: 17 Apr 2020 – Accepted for review: 26 Apr 2020 – Discussion started: 28 Apr 2020

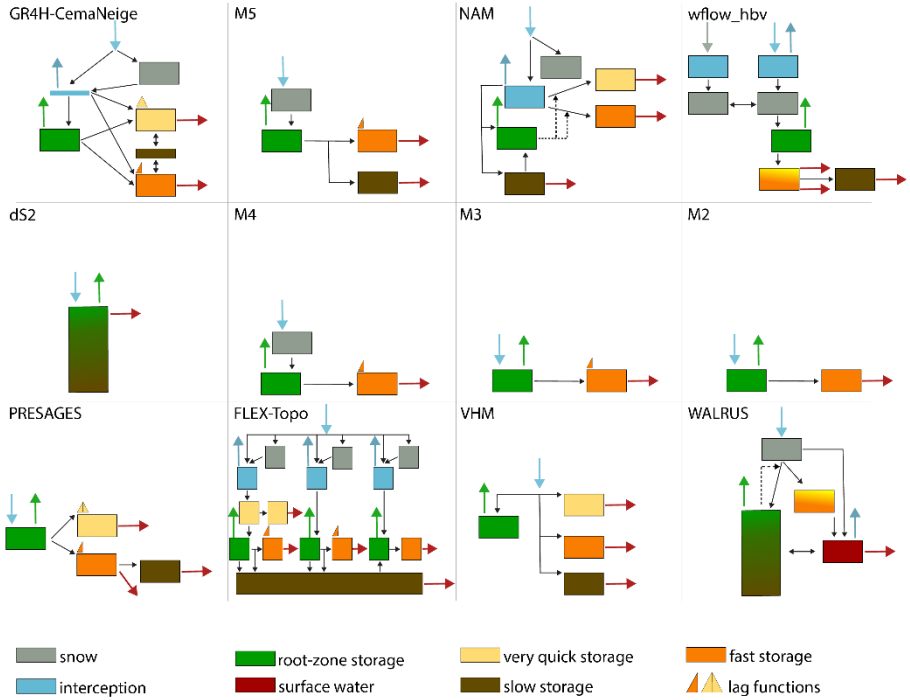
https://www.hydrol-earth-syst-sci-discuss.net/hess-2020-176/

Introduction

- Streamflow often the only variable used to constrain hydrological models

- Do models with similar streamflow performance have similar representations of internal states and fluxes?

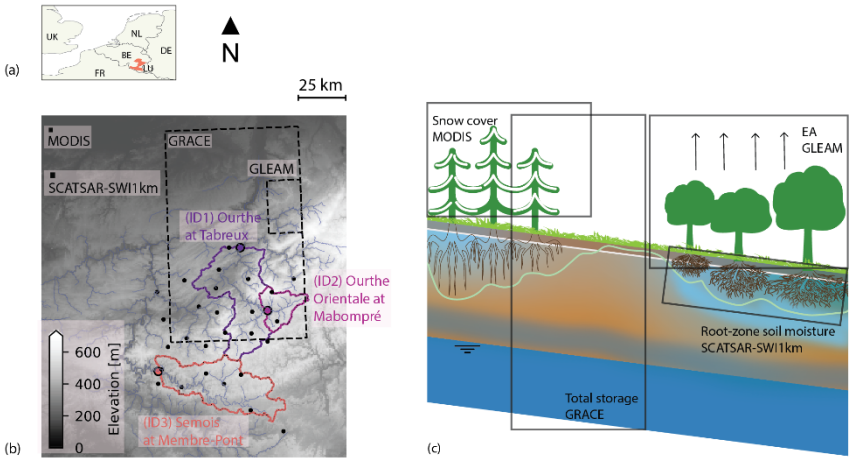
Methods



- 12 process-based models calibrated following an identical protocol by several research institutes (de Boer-Euser et al. 2017)
- Similar streamflow performance
- Compare internal state and flux variables between models and evaluate them against remotely-sensed observations of evaporation, snow, soil moisture and total storage anomalies.

de Boer-Euser, T., Bouaziz, L., De Niel, J., Brauer, C., Dewals, B., Drogue, G., Fenicia, F., Grelier, B., Nossent, J., Pereira, F., Savenije, H., Thirel, G., and Willems, P.: Looking beyond general metrics for model comparison – lessons from an international model intercomparison study, Hydrol. Earth Syst. Sci., 21, 423–440, https://doi.org/10.5194/hess-21-423-2017, 2017.

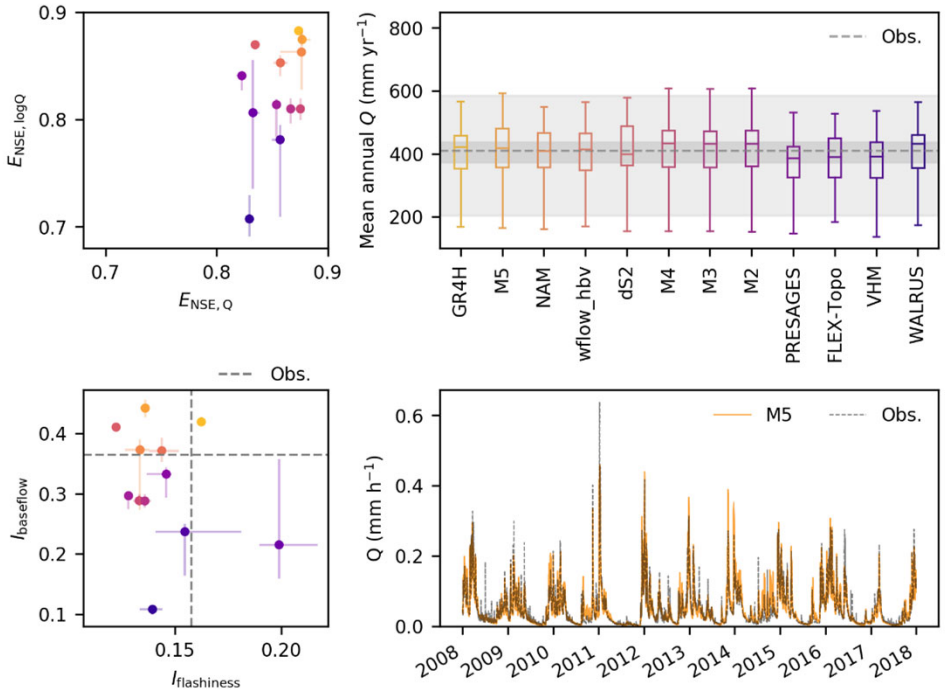
Study area and data



- Catchments within the Meuse River Basin in North-West Europe
- Remotely-sensed estimates of snow cover (MODIS), evaporation (GLEAM), soil moisture (SCATSAR-SWI1km) and total storage anomalies (GRACE)

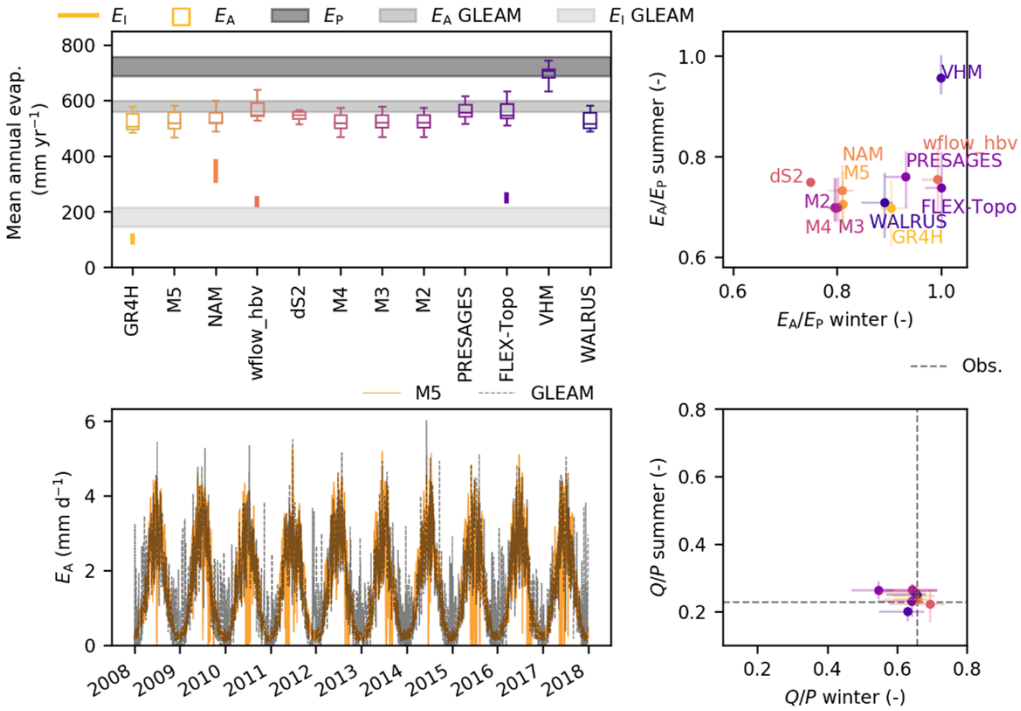
Precipitation and streamflow data was provided by the Service Public de Wallonie (Direction générale opérationnelle de la Mobilité et des Voies hydrauliques, Département des Etudes et de l'Appui à la Gestion, Direction de la Gestion hydrologique intégrée (Bld du Nord 8-5000 Namur, Belgium))
Evaporation estimates from the Global Land Evaporation Amsterdam Model (GLEAM) (Miralles et al. 2011, Martens et al. 2017).
MODIS Snow cover fractions (Hall and Riggs 2016).
Soil Water Index SCATSAR-SWI1km (Bauer-Marschallinger et al. 2018).
GRACE land data (Swenson et al. 2006, Swenson et al. 2012), supported by the NASA MEaSUREs Program.
Digital elevation model from the Shuttle Radar Topography Mission (SRTM)

Results - Streamflow



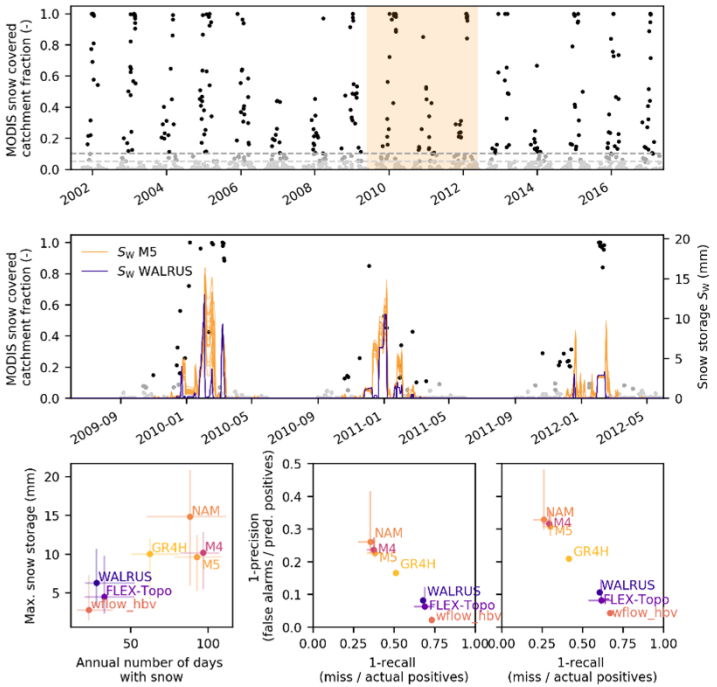
- High Nash-Sutcliffe Efficiencies for the streamflow and the logarithm of the streamflow ($E_{NSE,Q}$ and $E_{NSE,logQ}$)
- Similar mean annual streamflow
- However, differences in the partitioning of low and high flows as suggested by flashiness and baseflow indices.

Results - Evaporation



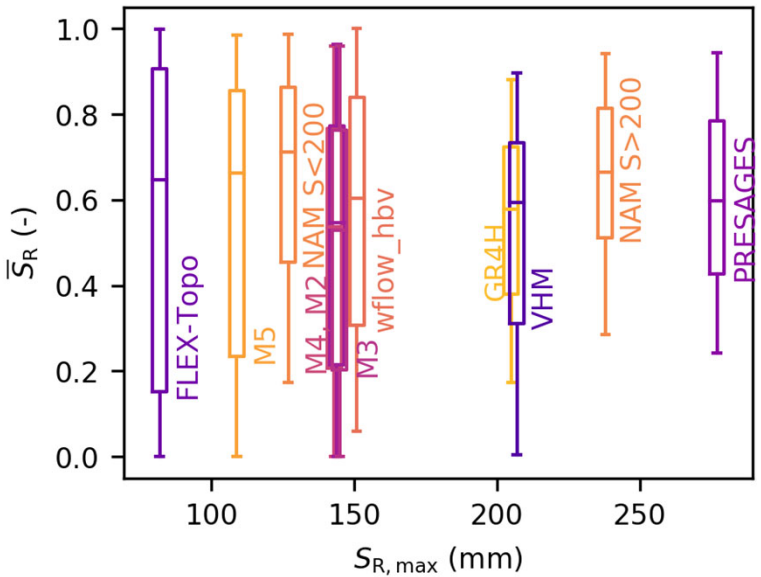
- Differences in mean annual evaporation and interception
- Differences in seasonal ratio between actual and potential evaporation
- Reduced evaporation in summer for some models
- Similarity in seasonal runoff coefficients

Results - Snow storage



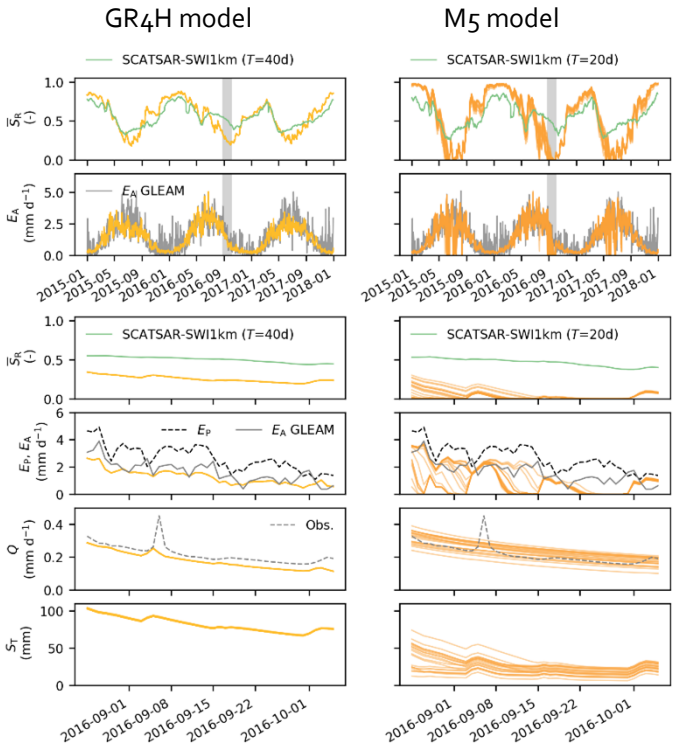
- Compare occurrence of modeled days with snow with MODIS snow cover product
- Substantial differences between models in the maximum annual snow storage and annual number of days with snow

Results - Root-zone soil moisture



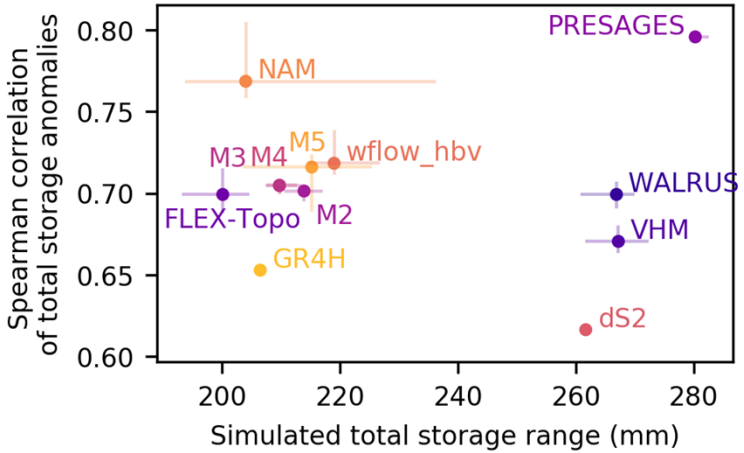
- Differences in the maximum root-zone storage capacity ($S_{r,max}$) and utilization of available root-zone storage

Results – Drying out during summer



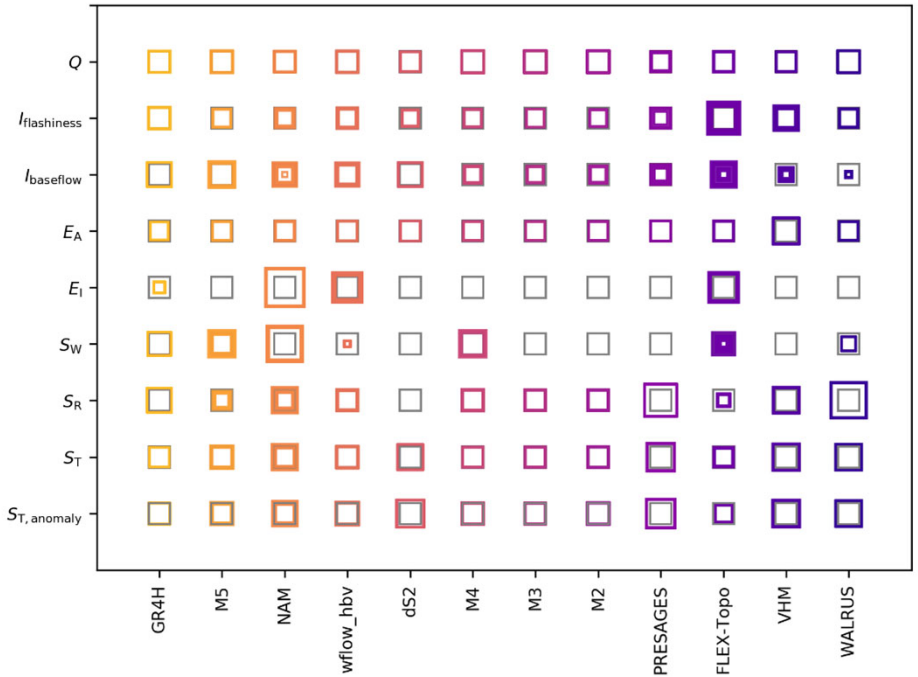
- Two best performing models in terms of Nash-Sutcliffe Efficiencies for the streamflow and the logarithm of the streamflow show distinct summer response
- Drying-out of root-zone soil moisture in model M5 with smaller root-zone storage capacity $S_{r,max}$ leads to a reduction of actual evaporation in spite of a relatively similar streamflow response during the summer of 2016.

Results – Total storage



- Comparison of total storage anomalies with GRACE estimates shows relatively high similarity (Spearman rank correlations)
- Differences in total storage range between models
- This suggests similar *change* of total storage amongst models in spite of different total storage ranges

Summary



- Summary of over- and underestimations of mean annual streamflow (Q), flashiness and baseflow indices, actual evaporation, interception, snow storage, root-zone storage and total storage for all models

Conclusions

- Dissimilarities in internal process representation imply that these models cannot all simultaneously be close to reality

- Differences may exacerbate for more extreme conditions or climate change scenarios

- Lack of knowledge and observation data to evaluate all internal processes

Implications

- More experimental research to evaluate internal states and fluxes
- Evaluate models using multiple variables (remote sensing and in situ observations)
- Multi-model & multi-parameter studies to reveal uncertainty in model selection

HESSD Discussion https://www.hydrol-earth-syst-sci-discuss.net/hess-2020-176/