Improvement of the modelled infiltration and surface runoff for flash floods events with the JULES land surface model

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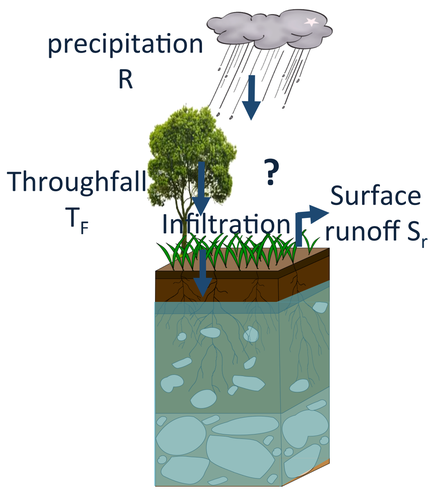
Introduction

Intense rainfall can lead to flash flooding and may cause disruption, damage and loss of life. Since flooding from intense rainfall occurs ususally during a short duration and in a limited area, these events are generally poorly predicted by numerical weather prediction models. The hydrological processes descriptions of land surface models are not necessarily suitable to deal with cases of intense rainfall. In these cases, the rate of rainfall is faster than the ability of the soil to infiltrate all the water. The infiltration rate must be considered in the model to generate surface runoff during excess of infiltration as well as saturation excess.

This work is funded by NERC's Flooding From Intense Rainfall (FFIR) programme, project TENDERLY. We improved the representation of the infiltration of the soil in JULES by introducing a variable maximum infiltration to better predict the amount of surface runoff which is related to the river discharge.

Infiltration processes in the JULES model



Actual infiltration depends on value of T_F and maximum infiltration I_{max}

If $T_F > I_{max}$: Surface runoff $= T_F - I_{max}$
If $T_F < I_{max}$: Infiltration $= T_F$

Actual Infiltration:

$$I = \Sigma_{i=1}^{n_{PFT}} (T_{fall} + M - S_{runoff})$$

Maximum Infiltration:

- Standard Scheme is fixed: $I_{max} = \beta K_{sat}$
- New Variable scheme: $I_{max} = \beta K_{top}$

Methods

We have compared the modelled surface runoff and the river flow at the outlet of 8 catchments in UK with the standard scheme and the new variable scheme of infiltration. The modelled river flows are compared to the observations from the National River Flow Archive (*https://nrfa.ceh.ac.uk/*). We have compared the modelled river flow with (PDM) and without PDM (NO PDM)(Probability Distribution Model, *Moore and Bell, 2002*) for the small Ure catchment. The comparison between the different scheme of infiltration has been made with using PDM.

10 years period: 1991-2000

meteorological forcing used: CHESS (CEH)

- 1 km^2 spatial resolution
- daily precipitation
- using RFM for each simulation

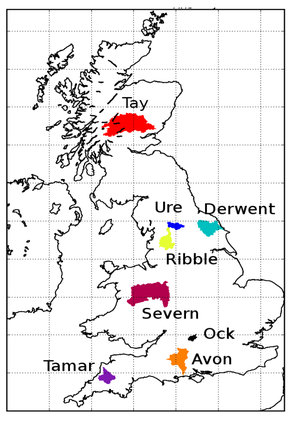


Fig. 1: UK catchments

Evaluation of the model based with the Kling-Gupta Efficiency (*Gupta et al, 2009*):

$$KGE = 1 - \sqrt{\underbrace{(\frac{Cov_{sim,obs}}{\sigma_{simu}\sigma_{obs}} - 1)^2}_{\rho \text{ Correlation}} + \underbrace{(\frac{\sigma_{sim}}{\sigma_{obs}} - 1)^2}_{a \text{ Variability}} + \underbrace{(\frac{\mu_{sim}}{\mu_{obs}} - 1)^2}_{b \text{ Volume}}}$$

Results

The results show that the new scheme of maximum infiltration enhance a better estimation of the riverflow at the outlet of UK catchments when high precipitation occurs, especially for the Ure, Tamar and Ribble catchment. However, this scheme overestimate the variability and the mean value of the modelled riverflow.

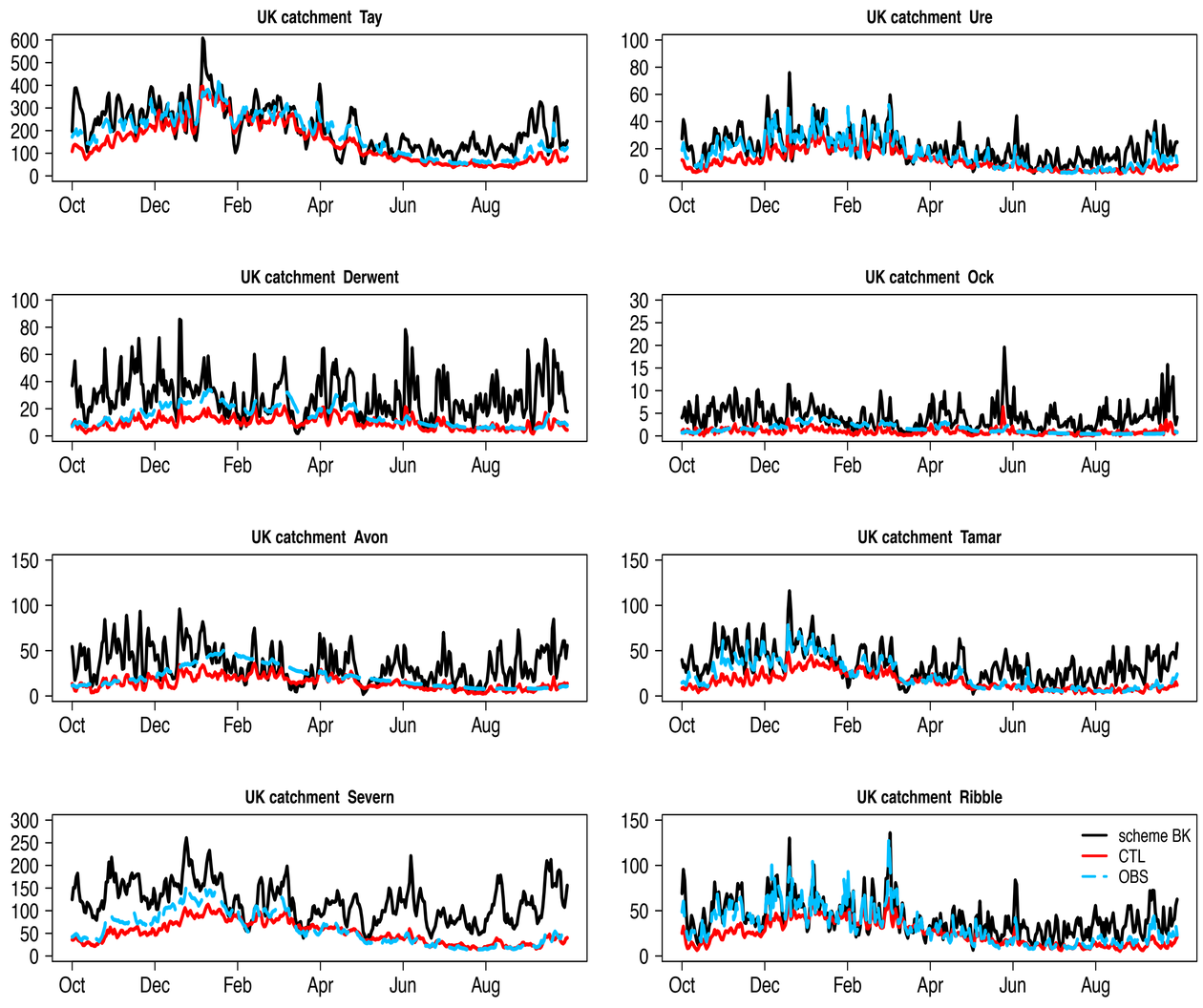


Fig. 2: Daily modelled (black and red) and observed (blue) riverflow of the annual mean of 1991-2000 period of 8 catchments in UK.

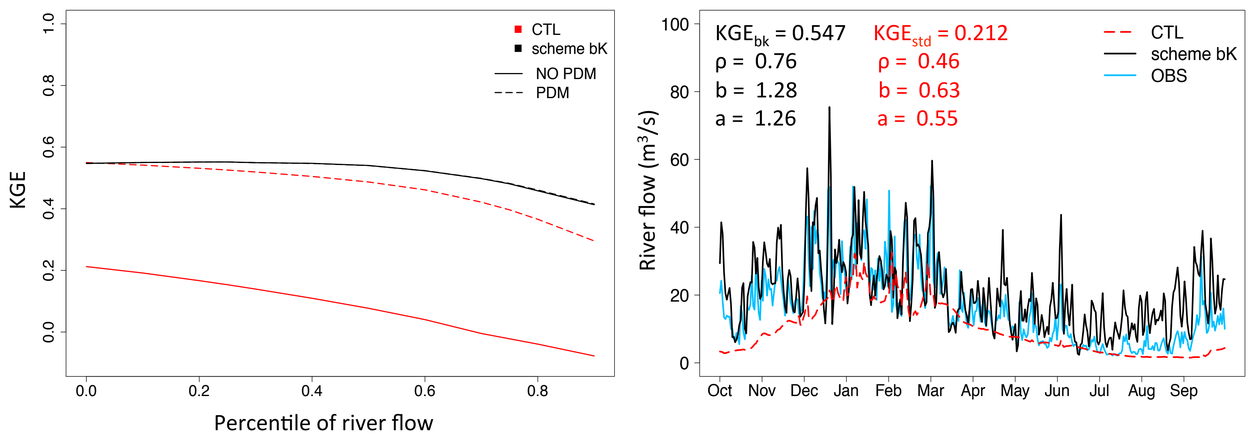


Fig. 3: Left: KGE efficiency in function of the percentile of the modelled riverflow of the outlet of Ure catchment. Right: Annual mean value of riverflow at the outlet of Ure when PDM is not activated.

Conclusions

Introduction of a variable maximum infiltration scheme: $I_{max} = \beta K_{top}$

This new scheme enhances an increase of the surface runoff and improves the river flow in small catchment, especially during high rate of precipitation.

Outlook

Reduce the overestimation of the mean river flow (parameter b) and the variability (parameter a). Comparison of river flow in a case study of flash floods with precipitation data every 15min.

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