Supplement of Hydrol. Earth Syst. Sci., 18, 4839–4859, 2014
http://www.hydrol-earth-syst-sci.net/18/4839/2014/
doi:10.5194/hess-18-4839-2014-supplement

Hydrology and Earth System Sciences
Open Access

Supplement of

Using expert knowledge to increase realism in environmental system models can dramatically reduce the need for calibration

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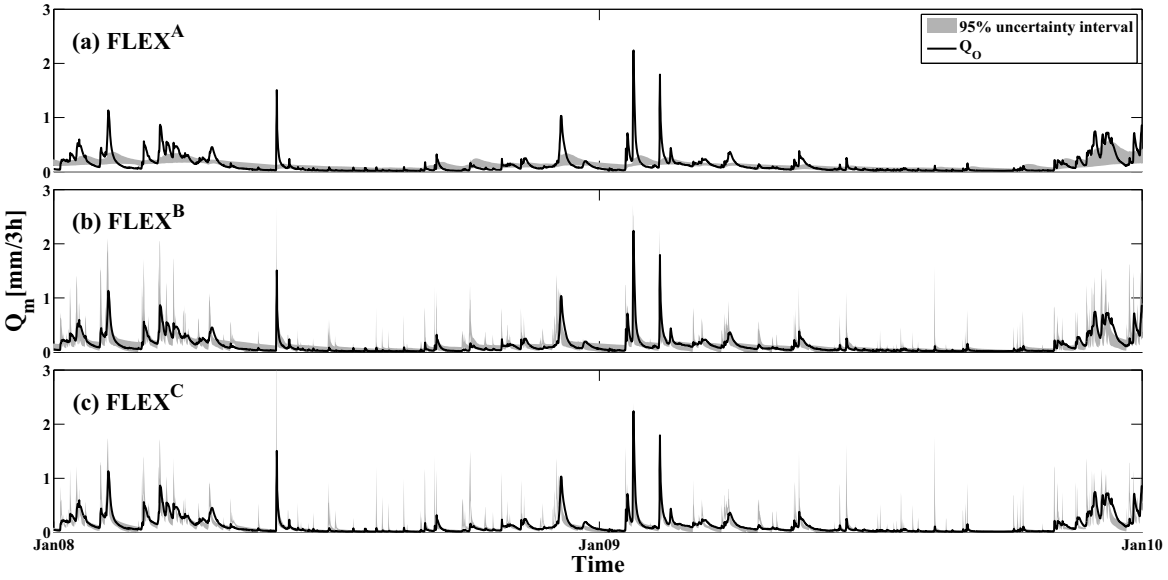

Fig. 1. The observed hydrograph and the 95% uncertainty interval of the modeled hydrograph derived from the complete set of *constrained but uncalibrated* parameter sets for the three different model set-ups **(a)** FLEX$^{\mathrm{A}}$, **(b)** FLEX$^{\mathrm{B}}$ and **(c)** FLEX$^{\mathrm{C}}$ for 2 years (2008-2009) of calibration.

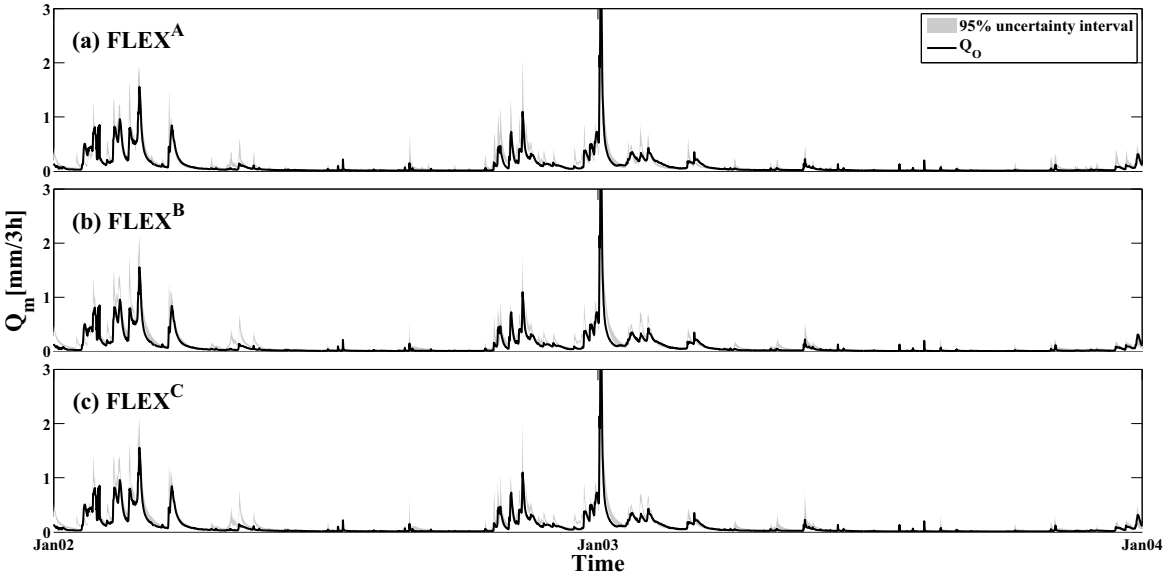

Fig. 2. The observed hydrograph and the 95% Pareto uncertainty interval of the modeled hydrograph for *constrained and calibrated* parameter sets for the three different model set-ups **(a)** FLEX$^{\mathrm{A}}$, **(b)** FLEX$^{\mathrm{B}}$ and **(c)** FLEX$^{\mathrm{C}}$ for the 2 years (2002–2003) of validation period.

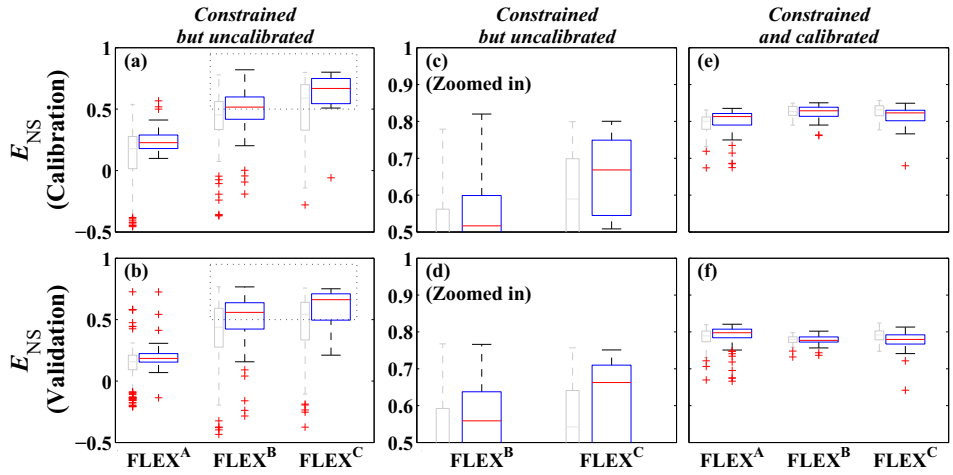

Fig. 3. Model performance (E_{NS}) based on *constrained but uncalibrated* **(a-d)** and *constrained and calibrated* **(e-f)** parameter sets for calibration (2006–2009) and validation (2002–2005) periods for the three different model set-ups FLEX^A, FLEX^B and FLEX^C. Note that **(c)** and **(d)** are zoom-ins of **(a)** and **(b)** and the gray box-plots represent the benchmark models. . The box plots indicate the median value in red and 25 and 75% quartile. Whiskers represent the 1.5 times the interquartile range (IQR) and the red crosses show outliers.

Table 1. The median model performances (in brackets their corresponding 95% uncertainty intervals) and the area spanned by the 95% uncertainty interval of hydrograph derived from uncalibrated parameter sets which satisfy the complete set of constraints for the three model set-ups FLEX$^{\mathrm{A}}$, FLEX$^{\mathrm{B}}$ and FLEX$^{\mathrm{C}}$, for the three modeling objectives (E_{NS}, $E_{\mathrm{NS,log}}$, $E_{\mathrm{NS,FDC}}$) in the calibration (2006–2009) and validation (2002–2005) periods. The italic values indicate performance and 95% uncertainty interval of hydrograph for the unconstrained benchmark models.

		E_{NS}	$E_{\mathrm{NS,log}}$	$E_{\mathrm{NS,FDC}}$	95 % uncertainty area [mm]
FLEX$^{\mathrm{A}}$	Calibration	0.23 [0.12 0.39]	0.29 [-0.02 0.59]	0.45 [0.28 0.76]	1243
		0.18 [-0.37 0.39]	*0.29 [-2.53 0.56]*	*0.38 [-0.35 0.76]*	*1888*
	Validation	0.18 [0.09 0.29]	0.05 [-0.40 0.49]	0.39 [0.25 0.69]	1325
		0.16 [-0.16 0.30]	*0.10 [-1.11 0.51]*	*0.35 [-0.12 0.67]*	*1814*
FLEX$^{\mathrm{B}}$	Calibration	0.52 [-0.06 0.77]	0.45 [-1.15 0.73]	0.89 [0.62 0.99]	2042
		0.45 [-1.44 0.76]	*0.30 [-3.50 0.73]*	*0.81 [0.08 0.97]*	*2993*
	Validation	0.56 [0.00 0.73]	0.33 [-1.36 0.65]	0.87 [0.66 0.95]	1827
		0.44 [-1.03 0.72]	*0.07 [-3.06 0.60]*	*0.77 [0.05 0.93]*	*2615*
FLEX$^{\mathrm{C}}$	Calibration	0.67 [-0.06 0.80]	0.50 [-0.33 0.74]	0.95 [0.88 0.99]	1294
		0.59 [-0.11 0.79]	*0.58 [-2.89 0.75]*	*0.93 [0.65 0.99]*	*2287*
	Validation	0.66 [0.22 0.75]	0.36 [-2.37 0.70]	0.93 [0.82 0.96]	1274
		0.54 [-0.24 0.75]	*0.34 [-2.30 0.69]*	*0.86 [0.60 0.94]*	*2015*

Table 2. The median model performances (in brackets their corresponding Pareto uncertainty intervals) and the area spanned by the uncertainty interval of the hydrograph derived from the Pareto optimal solutions of the *constrained and calibrated* model set-ups FLEX$^{\mathrm{A}}$, FLEX$^{\mathrm{B}}$ and FLEX$^{\mathrm{C}}$ for the three modeling objectives (E_{NS}, $E_{\mathrm{NS,log}}$, $E_{\mathrm{NS,FDC}}$) in the calibration (2006–2009) and validation (2002–2005) periods. The italic values indicate performance and 95% uncertainty interval of hydrograph for the benchmark models (without any constraints).

		E_{NS}	$E_{\mathrm{NS,log}}$	$E_{\mathrm{NS,FDC}}$	95 % uncertainty area [mm]
FLEX$^{\mathrm{A}}$	Calibration	0.81 [0.69 0.83]	0.84 [0.72 0.88]	0.98 [0.92 1.00]	661
		0.80 [0.72 0.83]	*0.84 [0.74 0.88]*	*0.99 [0.92 0.99]*	*683*
	Validation	0.80 [0.68 0.82]	0.76 [0.63 0.80]	0.93 [0.90 0.95]	574
		0.79 [0.71 0.82]	*0.75 [0.65 0.80]*	*0.93 [0.89 0.95]*	*593*
FLEX$^{\mathrm{B}}$	Calibration	0.83 [0.76 0.85]	0.83 [0.59 0.86]	0.99 [0.98 1.00]	600
		0.83 [0.79 0.85]	*0.84 [0.62 0.87]*	*0.99 [0.98 1.00]*	*561*
	Validation	0.78 [0.74 0.80]	0.70 [0.48 0.79]	0.92 [0.90 0.93]	526
		0.78 [0.75 0.80]	*0.71 [0.48 0.79]*	*0.92 [0.89 0.93]*	*489*
FLEX$^{\mathrm{C}}$	Calibration	0.82 [0.73 0.85]	0.83 [0.59 0.88]	0.99 [0.97 1.00]	709
		0.83 [0.78 0.85]	*0.84 [0.64 0.88]*	*0.99 [0.98 1.00]*	*621*
	Validation	0.78 [0.69 0.81]	0.70 [0.47 0.78]	0.92 [0.88 0.94]	570
		0.79 [0.76 0.82]	*0.73 [0.51 0.80]*	*0.92 [0.90 0.94]*	*535*