



Supplement of

Integration of the vegetation phenology module improves ecohydrological simulation by the SWAT-Carbon model

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2 Figure S1: Temporal variability in the LAI during the calibration (2007–2011) and

3 validation (2012–2014) periods. The 8-day LAI time series were observed by satellite and

4 simulated by the original SWAT-Carbon model with an adjustment of non-growing season

5 LAI for forest (a) and grassland (b).





7 Figure S2: Projection of future runoff during 2030–2100 using the original SWAT-

8 **Carbon.** Colored lines and shading in the left subplot represent the mean and one standard

9 deviation across the four Coupled Model Intercomparison Project Phase 6 (CMIP6) models.

10 The scenarios SSP1-2.6, SSP2-4.5, and SSP5-8.5 refer to low emissions, moderate emissions,

11 and high emissions, respectively. The cross symbol represents the outliers.



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13 Figure S3: Projection of average future runoff from 2030 to 2100 under each emission

14 scenario by the modified SWAT-Carbon model and CMIP6.



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- 16 Figure S4: Precipitation, simulated water yield, and ET by modified SWAT-Carbon
- 17 model from 2030 to 2100 under each emission scenario.

Table S1: Summary of the LAI-related parameters controlling vegetation growth and

| D (| | Calibrat | ion values |
|------------|---|----------|------------|
| Parameter | Definition (unit) | FRST | PAST |
| ALAI_MIN | Minimum leaf area index (m ² /m ²) | 1.099 | 0.287 |
| BLAI | Maximum potential leaf area index (m ² /m ²) | 4.012 | 4 |
| DLAI | Fraction of PHU when LAI beings to decline | 0.850 | 0.839 |
| FRGRW1 | Fraction of PHU corresponding to the 1st point on the leaf area development curve | 0.166 | 0.161 |
| FRGRW2 | Fraction of PHU corresponding to the 2nd point on the leaf area development curve | 0.809 | 0.408 |
| LAIMX1 | Fraction of BLAI corresponding to the 1st point on the optimal leaf area development curve | 0.296 | 0.636 |
| LAIMX2 | Fraction of BLAI corresponding to the 2nd point on the optimal leaf area development curve | 0.472 | 0.984 |
| T_BASE | Minimum temperature for plant growth (°C) | 0.855 | 0.006 |

19 calibrated values for forest (FRST) and grassland (PAST).

Table S2: Summary of the original and modified SWAT-Carbon models' parameters

22 controlling runoff with their calibrated values.

| Parameter | Definition (unit) | Scaling type | Range | Original model | | Modified | Modified model | |
|-----------|---|-----------------|-------------|----------------|------|----------|----------------|--|
| | | | | Value | Rank | Value | Rank | |
| CN2 | Initial SCS runoff curve number for moisture condition II | multiple | -0.5 - 0.5 | 0.01 | 1 | -0.12 | 3 | |
| SFTMP | Snowfall temperature (°C) | replace | -5 - 5 | 1.56 | 20 | 1.89 | 5 | |
| SMTMP | Snow melt base temperature (°C) | replace | -5 - 5 | -0.18 | 15 | -4.28 | 17 | |
| TIMP | Snow pack temperature lag factor (°C) | relative | 0 – 1 | 0.30 | 14 | 0.79 | 9 | |
| ALPHA_BF | Baseflow alpha factor (days) | replace | 0 - 1 | 0.72 | 8 | 0.34 | 7 | |
| GW_DELAY | Groundwater delay time (days) | replace | 0 - 500 | 16.60 | 9 | 6.09 | 8 | |
| GWQMN | Threshold depth of water in the shallow aquifer required for return flow to occur (mm H ₂ 0) | replace | 0 - 5000 | 1142.72 | 5 | 2882.59 | 10 | |
| GW_REVAP | Groundwater "revap" coefficient | relative | 0.02 - 0.2 | 0.03 | 12 | 0.08 | 21 | |
| RCHRG_DP | Deep aquifer percolation fraction | replace | 0 - 0.5 | 0.44 | 7 | 0.42 | 4 | |
| CH_N2 | Manning's "n" value for the main channel | replace | 0.25 - 0.14 | 0.05 | 19 | 0.05 | 14 | |
| SOL_K | Saturated hydraulic conductivity (mm/hr) | multiple | -0.5 - 0.5 | -0.38 | 3 | -0.31 | 6 | |
| SOL_AWC | Available water capacity of the soil layer (mm H ₂ O/mm soil) | multiple | -0.5 - 0.5 | -0.003 | 10 | -0.05 | 16 | |
| SOL_BD | Moist bulk density (g cm ⁻³) | multiple | -0.5 - 0.5 | 0.25 | 2 | 0.19 | 1 | |
| SOL_Z | Depth from soil surface to bottom of layer (mm) | multiple | -0.5 - 0.5 | -0.38 | 13 | 0.19 | 18 | |
| HRU_SLP | Average slope steepness | multiple | -0.5 - 0.5 | 0.23 | 4 | 0.50 | 2 | |
| SLSUBBSN | Average slope length (m) | multiple | -0.5 - 0.5 | 0.04 | 11 | -0.39 | 12 | |
| CANMX | Maximum canopy storage | replace | 0 - 15 | 7.86 | 22 | 13.0 | 13 | |
| ESCO | Soil evaporation compensation factor | replace | 0 - 1 | 0.97 | 6 | 0.89 | 11 | |

Table S3: Performance of runoff simulation in different months using the original and

25 modified SWAT-Carbon models.

| Month | | R ² | N | NSE | | |
|--------------------|----------|----------------|----------|----------|--|--|
| Month | Original | Modified | Original | Modified | | |
| June | 0.45 | 0.58 | 0 | 0.39 | | |
| October | 0.49 | 0.79 | 0.31 | 0.78 | | |
| Non-growing season | 0.72 | 0.73 | 0.19 | 0.54 | | |