Supplement of

Testing a maximum evaporation theory over saturated land: implications for potential evaporation estimation

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Figure S1. Validation of \( LE \) and \( T_s \) estimated using the maximum evaporation approach at the selected site-days where the energy balance closure of the flux site measurements is achieved by using the Bowen ratio approach (Twine et al., 2000). The colors represent different biome types (as provided in Figure 1). The dashed black lines indicate the 1:1 line.

Figure S2. Estimation of temperature difference between the surface and the effective radiating height of the atmosphere \( (\Delta T) \). (a) Relationship between \( \Delta T \) and atmospheric transmissivity \( (\tau) \) across all 1128 non-water-limited site-days. The thick black curve represents the \( \Delta T-\tau \) relationship obtained over global ocean surfaces in Yang and Roderick (2019) (i.e., \( \Delta T = 2.52\exp(2.38\tau) + 0.035|\text{lat}| \)) and the colored dots/lines represent different biome types (legend provided in Figure 1). (b) Comparison between observed \( \Delta T \) and estimated \( \Delta T \) using Eq. (5) in Sect. 2.2.
Figure S3. Relationships between the Bowen ratio ($\beta$) and surface temperature ($T_s$).

Figure S4. The performance of the maximum evaporation model in estimating $LE$ with varying selection criteria of unstressed evaporation observations. (a) The soil moisture criterion varies from 30% to 70%, (b) the Maximum soil moisture criterion varies from 95th to 99th percentile and (c) the evaporative fraction criterion varies from 0.5 to 0.9.
Figure S5. Estimation of LE using observed net radiation (per Eq. (1)). Comparison of estimated LE using observed net radiation with four different β-\(T_s\) relationships. (a) Generic land β-\(T_s\) relationship (\(\beta = 0.27\gamma/\Delta\)), (b) Biome-specific β-\(T_s\) relationships (per Figure 2), (c) Ocean surface β-\(T_s\) relationship (\(\beta = 0.24\gamma/\Delta\)) and (d) the Priestley-Taylor model (\(\beta = 0.79\gamma/\Delta - 0.21\)). The colors represent different biome types (legend provided in Figure 1). The dashed black lines indicate the 1:1 line.
Figure S6. Variations of energy fluxes with $T_s$ within the maximum evaporation framework with different $\beta$-$T_s$ relationships. In this calculation, the coefficient of the $\beta$-$T_s$ relationship (i.e., $m$) varies from 0.18 to 0.36 and all other forcings are the same as those in Figure 3. The solid line represents the case when $\beta = 0.27\gamma/\Delta$ and the shadows represent the range of all cases for $m$ changing between 0.18 and 0.36. The red dots show the location of $LE_{\text{max}}$ when $\beta = 0.27\gamma/\Delta$ and the short red line shows the locations of $LE_{\text{max}}$ when $m$ changes between 0.18 and 0.36.

Figure S7. Comparison of three model performance in estimating incoming longwave radiation validated against four global products under wet conditions across the globe (the wet conditions are determined following Milly and Dunne, 2016). The three compared models include the maximum evaporation model in this study, the Brutsaert model (1975) and the Shakespeare and Roderick model (2021). The four global products include ERA5 (1979-2019; Hersbach et al., 2019), CERES (2001-2016; Kato et al., 2018), the Princeton global forcing dataset (PGF, 1979-2010; Sheffield et al., 2006) and the GLDAS global forcing dataset (1979-2014; Rodell et al., 2004).
Figure S8. Estimation of $LE$ at unstressed site-days. (a) The maximum evaporation model, (b) The Priestley-Taylor model, (c) The Open Water Penman model. The colors represent different biome types (as provided in Figure 1). The dashed black lines indicate the 1:1 line.
Table S1. Descriptions of the flux sites used in this study including site number (Site Num), site identifier (Site ID), latitude (Lat), Longitude (Lon), biome type and number of selected days (Site-days).

| Site Num | Site ID | Lat (°N) | Lon (°E) | Biome Type           | Site-days |
|----------|---------|----------|----------|----------------------|-----------|
| 1        | AU-ASM  | -22.28   | 133.25   | Savanna              | 2         |
| 2        | AU-Ade  | -13.08   | 131.12   | Savanna              | 5         |
| 3        | AU-Cpr  | -34.00   | 140.59   | Savanna              | 13        |
| 4        | AU-Cum  | -33.62   | 150.72   | Broadleaf forest     | 12        |
| 5        | AU-DaP  | -14.06   | 131.32   | Grassland            | 22        |
| 6        | AU-DaS  | -14.16   | 131.39   | Savanna              | 24        |
| 7        | AU-Dry  | -15.26   | 132.37   | Savanna              | 34        |
| 8        | AU-Emr  | -23.86   | 148.47   | Grassland            | 14        |
| 9        | AU-Fog  | -12.55   | 131.31   | Wetland              | 16        |
| 10       | AU-GWW  | -30.19   | 120.65   | Savanna              | 8         |
| 11       | AU-Gin  | -31.38   | 115.71   | Savanna              | 16        |
| 12       | AU-How  | -12.49   | 131.15   | Savanna              | 28        |
| 13       | AU-Lox  | -34.47   | 140.66   | Broadleaf forest     | 6         |
| 14       | AU-RDF  | -14.56   | 132.48   | Savanna              | 4         |
| 15       | AU-Rig  | -36.65   | 145.58   | Grassland            | 4         |
| 16       | AU-Stp  | -17.15   | 133.35   | Grassland            | 4         |
| 17       | AU-TTE  | -22.29   | 133.64   | Grassland            | 1         |
| 18       | AU-Tum  | -35.66   | 148.15   | Broadleaf forest     | 12        |
| 19       | AU-Wac  | -37.43   | 145.19   | Broadleaf forest     | 3         |
| 20       | AU-Whr  | -36.67   | 145.03   | Broadleaf forest     | 12        |
| 21       | AU-Wom  | -37.42   | 144.09   | Broadleaf forest     | 3         |
| 22       | AU-Ync  | -34.99   | 146.29   | Grassland            | 13        |
| 23       | BE-Lon  | 50.55    | 4.75     | Cropland             | 5         |
| 24       | BR-SA3  | -3.02    | -54.97   | Broadleaf forest     | 12        |
| 25       | CA-Gro  | 48.22    | -82.16   | Needleleaf forest    | 1         |
| 26       | CA-Qfo  | 49.69    | -74.34   | Needleleaf forest    | 13        |
| 27       | CA-SF1  | 54.49    | -105.82  | Needleleaf forest    | 8         |
| 28       | CA-SF2  | 54.25    | -105.88  | Needleleaf forest    | 10        |
| 29       | CA-SF3  | 54.09    | -106.01  | Shrubland            | 1         |
| 30       | CA-TP4  | 42.71    | -80.36   | Needleleaf forest    | 23        |
| 31       | CA-TPD  | 42.64    | -80.56   | Broadleaf forest     | 10        |
| 32       | CH-Cha  | 47.21    | 8.41     | Grassland            | 8         |
| 33       | CH-Fru  | 47.12    | 8.54     | Grassland            | 10        |
| 34       | CN-Cng  | 44.59    | 123.51   | Grassland            | 14        |
| 35       | CZ-Cng  | 49.02    | 14.77    | Wetland              | 13        |
| 36       | DE-Geb  | 51.10    | 10.91    | Cropland             | 36        |
| 37       | DE-Hai  | 51.08    | 10.45    | Broadleaf forest     | 22        |
| 38       | DE-Kli  | 50.89    | 13.52    | Cropland             | 11        |
| 39       | DE-Lkb  | 49.10    | 13.30    | Needleleaf forest    | 2         |
| 40       | DE-Lnf  | 51.33    | 10.37    | Broadleaf forest     | 27        |
| Code  | Country | Latitude | Longitude | Land Cover Type           | Code  |
|-------|---------|----------|-----------|---------------------------|-------|
| 41    | DE-Obe  | 50.79    | 13.72     | Needleleaf forest         | 7     |
| 42    | DE-SLN  | 47.81    | 11.33     | Wetland                   | 9     |
| 43    | DE-Tha  | 50.96    | 13.57     | Needleleaf forest         | 16    |
| 44    | DE-Zrk  | 53.88    | 12.89     | Wetland                   | 13    |
| 45    | DK-Sor  | 55.49    | 11.64     | Broadleaf forest          | 7     |
| 46    | Fl-Hyy  | 61.85    | 24.29     | Needleleaf forest         | 5     |
| 47    | FR-Gri  | 48.84    | 1.95      | Cropland                  | 10    |
| 48    | FR-LBr  | 44.72    | -0.77     | Needleleaf forest         | 7     |
| 49    | IT-Mci  | 40.52    | 14.96     | Cropland                  | 11    |
| 50    | IT-CA1  | 42.38    | 12.03     | Broadleaf forest          | 10    |
| 51    | IT-CA3  | 42.38    | 12.02     | Broadleaf forest          | 12    |
| 52    | IT-Col  | 41.85    | 13.59     | Broadleaf forest          | 22    |
| 53    | IT-Isp  | 45.81    | 8.63      | Broadleaf forest          | 13    |
| 54    | IT-Lav  | 45.96    | 11.28     | Needleleaf forest         | 25    |
| 55    | IT-MBo  | 46.01    | 11.05     | Grassland                 | 21    |
| 56    | IT-Noe  | 40.61    | 8.15      | Shrubland                 | 29    |
| 57    | IT-Ren  | 46.59    | 11.43     | Needleleaf forest         | 1     |
| 58    | IT-SR2  | 43.73    | 10.29     | Needleleaf forest         | 3     |
| 59    | IT-SRo  | 43.73    | 10.28     | Needleleaf forest         | 5     |
| 60    | IT-Tor  | 45.84    | 7.58      | Grassland                 | 8     |
| 61    | MY-PSO  | 2.97     | 102.31    | Broadleaf forest          | 34    |
| 62    | NL-Hor  | 52.24    | 5.07      | Grassland                 | 3     |
| 63    | NL-Loo  | 52.17    | 5.74      | Needleleaf forest         | 14    |
| 64    | RU-Fyo  | 56.46    | 32.92     | Needleleaf forest         | 8     |
| 65    | US-AR1  | 36.43    | -99.42    | Grassland                 | 13    |
| 66    | US-AR2  | 36.64    | -99.60    | Grassland                 | 4     |
| 67    | US-ARM  | 36.61    | -97.49    | Cropland                  | 19    |
| 68    | US-CRT  | 41.63    | -83.35    | Cropland                  | 1     |
| 69    | US-GLE  | 41.37    | -106.24   | Needleleaf forest         | 2     |
| 70    | US-Goo  | 34.25    | -89.87    | Grassland                 | 17    |
| 71    | US-MMS  | 39.32    | -86.41    | Broadleaf forest          | 59    |
| 72    | US-Me2  | 44.45    | -121.56   | Needleleaf forest         | 8     |
| 73    | US-NR1  | 40.03    | -105.55   | Needleleaf forest         | 1     |
| 74    | US-Oho  | 41.55    | -83.84    | Broadleaf forest          | 29    |
| 75    | US-SRC  | 31.91    | -110.84   | Needleleaf forest         | 9     |
| 76    | US-SRG  | 31.79    | -110.83   | Grassland                 | 31    |
| 77    | US-SRM  | 31.82    | -110.87   | Savanna                   | 45    |
| 78    | US-Tw2  | 38.10    | -121.64   | Cropland                  | 13    |
| 79    | US-Tw3  | 38.12    | -121.65   | Cropland                  | 14    |
| 80    | US-Tw4  | 38.10    | -121.64   | Wetland                   | 7     |
| 81    | US-Var  | 38.41    | -120.95   | Grassland                 | 34    |
| 82    | US-WCr  | 45.81    | -90.08    | Broadleaf forest          | 10    |
| 83    | US-Whs  | 31.74    | -110.05   | Shrubland                 | 7     |
| 84    | US-Wkg  | 31.74    | -109.94   | Grassland                 | 8     |
|   |     |     |      |            |   |
|---|-----|-----|------|------------|---|
| 85| ZA-Kru | -25.02 | 31.50 | Savanna   | 8 |
| 86| ZM-Mon | -15.44 | 23.25 | Broadleaf forest | 14 |
Table S2. Worked example of applying the maximum evaporation model for $E_P$ estimation ($R_{si}$: incoming shortwave radiation at the surface; $R_{so}$: outgoing shortwave radiation at the surface; $R_{si	ext{ TOA}}$: incoming shortwave radiation at the top of the atmosphere).

| Variable          | Value          | Source/Method                        |
|-------------------|----------------|--------------------------------------|
| **Input**         |                |                                      |
| $R_{si}$          | 200.0 W m$^{-2}$ | Observed                            |
| $R_{so}$          | 40.0 W m$^{-2}$  | Observed                            |
| $R_{si	ext{ TOA}}$ | 300.0 W m$^{-2}$ | Observed                            |
| lat               | 10.0°          | Observed                            |
| $\varepsilon$     | 0.98           | MOD11A1                              |
| $T_s$             | [273.1 K, ..., 313.1 K] at 0.1 K interval | Prescribed                        |
| $P_{air}$         | 101.3 kPa      | Observed                            |
| **Calculation/Output** |            |                                      |
| $\tau$            | 0.667          | $R_{so}/R_{si	ext{ TOA}}$          |
| $\Delta T$        | 14.2 K         | Equation (5)                        |
| $R_n$             | [100.4 W m$^{-2}$, ..., 69.3 W m$^{-2}$] | Equation (4)                        |
| $\gamma$          | [66.0 Pa K$^{-1}$, ..., 68.5 Pa K$^{-1}$] | Equation (7)                        |
| $\Delta$          | [44.3 Pa K$^{-1}$, ..., 392.2 Pa K$^{-1}$] | Equation (8)                        |
| $\beta$           | [0.4168, ..., 0.0489] | $\beta = 0.28 \gamma/\Delta$            |
| $LE$              | [70.9 W m$^{-2}$, ..., 66.1 W m$^{-2}$] | $LE = R_n/ (1+\beta)$                |
| $E_P$             | 76.7 W m$^{-2}$ | Searching for the maximum $LE$ in $LE$ estimates from previous step |
| $T_s$             | 287.7 K        | Surface temperature corresponding to $LE_{\text{max}}$ (or $E_P$) |
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