Supporting Information for

Diurnal heating of the lower atmosphere over land determines the Vapor Pressure Deficit (VPD)

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Text S1: Modeling surface water limitation

Equilibrium evaporation is derived from well-known micrometeorological partitioning commonly referred as equilibrium partitioning (Slatyer & McIlroy, 1961; Priestley and Taylor, 1972; Kleidon and Renner, 2013). This framework assumes that the land surface is fully saturated and therefore not constrained by water supply. Under this assumption, the air close to the surface remains near saturation as it is heated. The partitioning of energy between sensible and latent heat is then governed by the heat capacity of air and the rate at which saturation vapor pressure changes with temperature. While the heat capacity is relatively constant, saturation vapor pressure increases exponentially as temperature rises. Based on this, equilibrium evaporation (LE_{pot}, in W m^{-2}) can be expressed as:

$$LE_{pot} = \frac{s}{s+\gamma} R_{net} \qquad \text{(S1)}$$

In this expression, s (Pa K^{-1}) represents the slope of the saturation vapor pressure curve, γ is the psychrometric constant (65 Pa K^{-1}) and R_{net} is the net radiation at the surface. The term $\frac{s}{s+\gamma}$ was further refered as the evaporative fraction at equilibrium

$$f_{eq} = \frac{s}{s+\gamma} \qquad \text{(S2)}$$

Equilibrium evaporation therefore represents the upper limit of evaporation driven by available surface energy. In terrestrial environments, however, evaporation is often limited by water availability, as surfaces are rarely fully saturated. To account for this, a water availability factor (f_w) is introduced (Conte et al., 2019; Ghausi et al., 2025). It is defined as the ratio between actual and potential evaporation:

$$f_w = \frac{LE_{act}}{LE_{pot}} \qquad \text{(S3)}$$

The actual evaporation (LE_{act}) (Wm^{-2}) is derived using the observations from GLEAM, while potential evaporation is estimated using Equation S1.

Figure S1

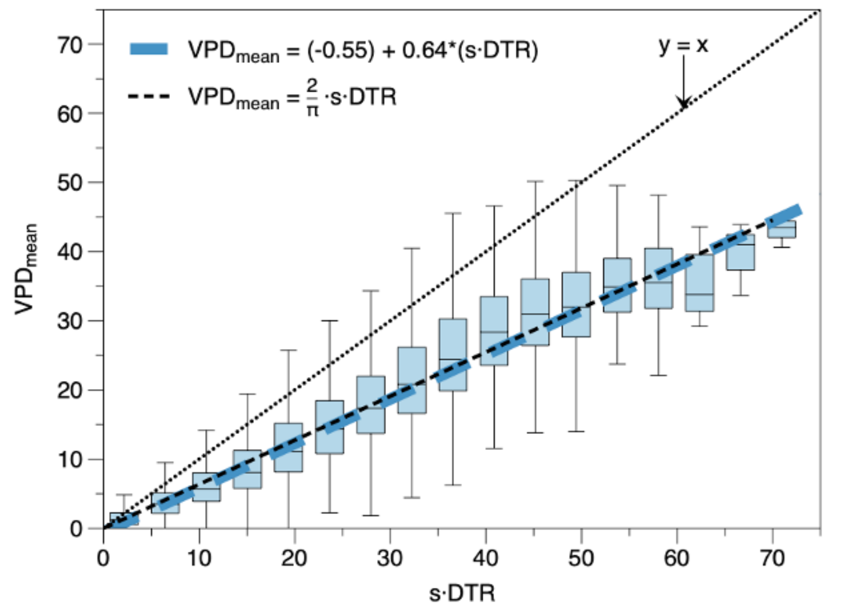

Figure S1: *Relation between mean daily VPD and s*DTR. Blue dashed line is the regression between mean daily VPD and s*DTR. Black dashed line represents the estimate of mean daily VPD from s*DTR considering average over sinusoidal cycle.*

Figure S2

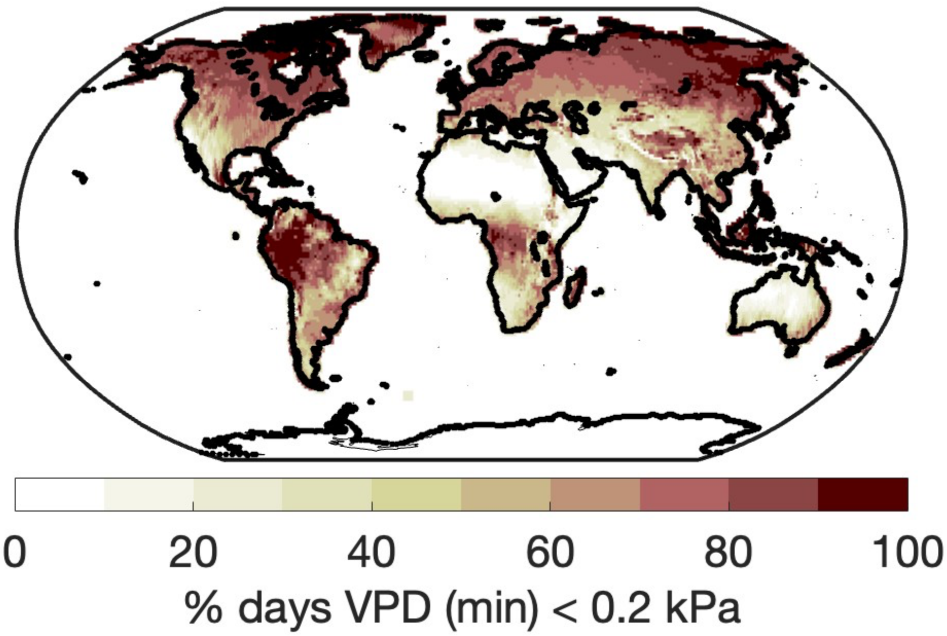

Figure S2: *Global map showing the number of days (in % fraction of total days) with daily minimum VPD (VPD min < 0.2kPa) for each grid.*

Figure S3

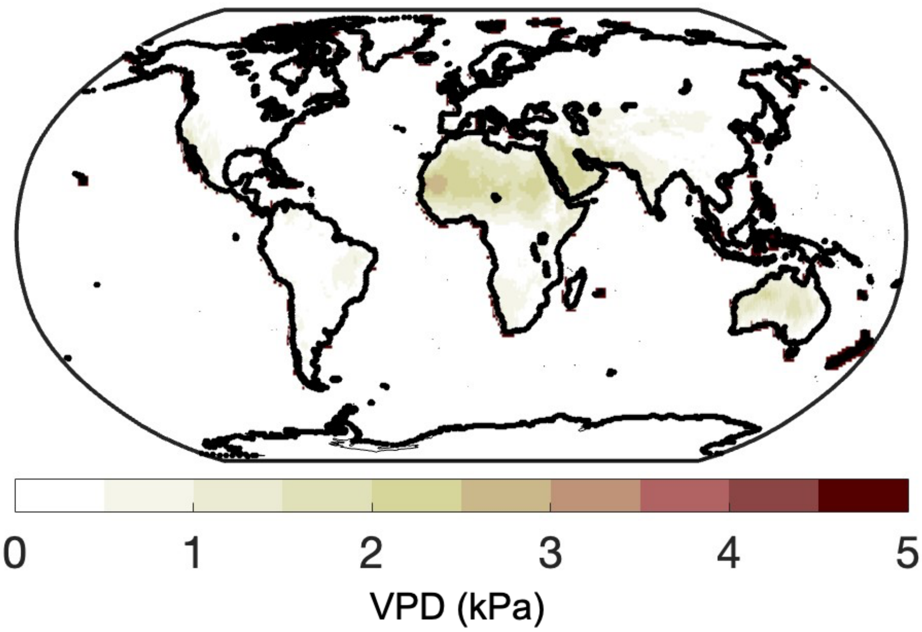

Figure S3: *Global map showing root mean squared error (RMSE) between observed and estimated diurnal changes in VPD (kPa).*

SI References:

1. Kleidon, A., and M. Renner (2013), Thermodynamic limits of hydrologic cycling within the Earth system: Concepts, estimates, and implications, *Hydrol. Earth Syst. Sci.,* 17(7), 2873– 2892, doi:10.5194/hess-17-2873-2013.

2. Priestley, C. H. B., & Taylor, R. J. (1972). On the assessment of surface heat flux and evaporation using large-scale parameters. Monthly Weather Review, 100, 81–92. https://doi.org/10.1175/1520-0493(1972)100<0081:OTAOSH>2.3.CO;2

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5. Ghausi, S. A., McColl, K., Zehe, E., & Kleidon, A. (2025). Explaining observed daily variations and decadal trends in the diurnal air temperature range. Geophysical Research Letters, 52, e2024GL113595. DOI: https://doi.org/10.1029/2024GL113595