An Energy Partitioning Perspective on Lake Evaporation Variations to Climate Change

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Introduction

- Lake evaporation, nexus between the lake hydrological cycle and its surface energy balance, is very sensitive to climate change.
- Two hypotheses have been proposed to explain interannual variations in lake evaporation: **Hypothesis I** – the lake evaporation rate will increase as air temperature rises, at a rate of about 7% K^{-1} predicted by the Clausius-Clapeyron equation; **Hypothesis II** – lake evaporation variabilities are controlled by variabilities in the surface solar radiation.

Objective

- To investigate the mechanisms underlying the response of lake evaporation variations to climate change (RCP8.5), using NCAR's CLM4.5 model.

Surface energy balance and the Priestley-Taylor model

$$\beta = \frac{H}{\lambda E}$$

$$R_n - G = \lambda E + H$$

$$\lambda E = \alpha \frac{\Delta}{\Delta + \gamma}(R_n - G)$$

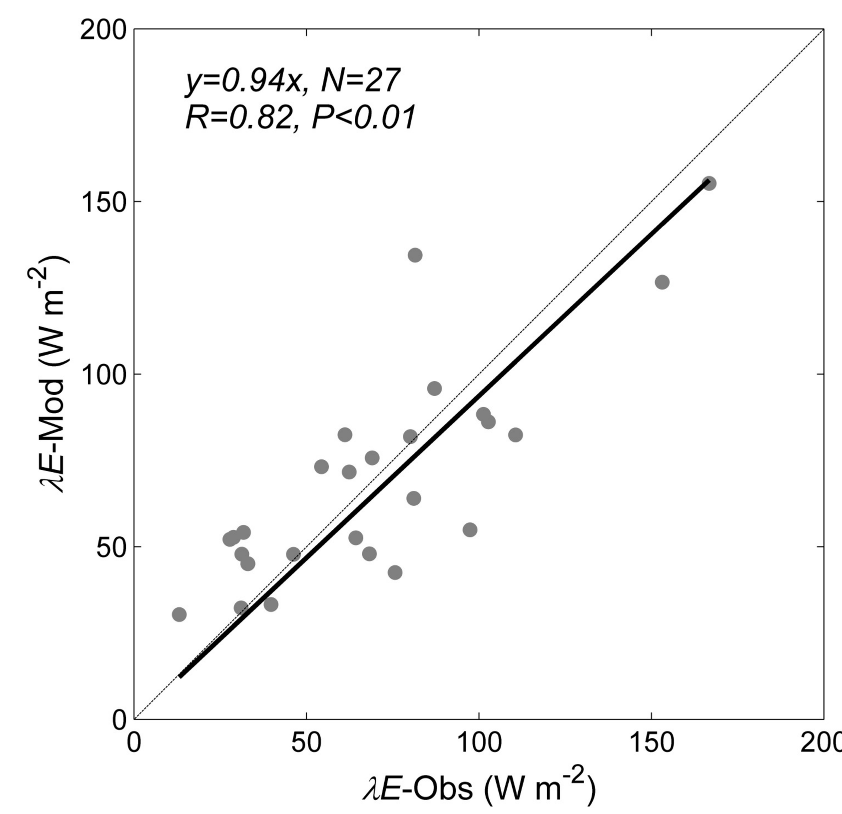
⇨

$$\beta = \frac{1}{\alpha}\frac{\gamma}{\Delta} + \frac{1}{\alpha} - 1$$

$$EF = \frac{1}{1+\beta}$$

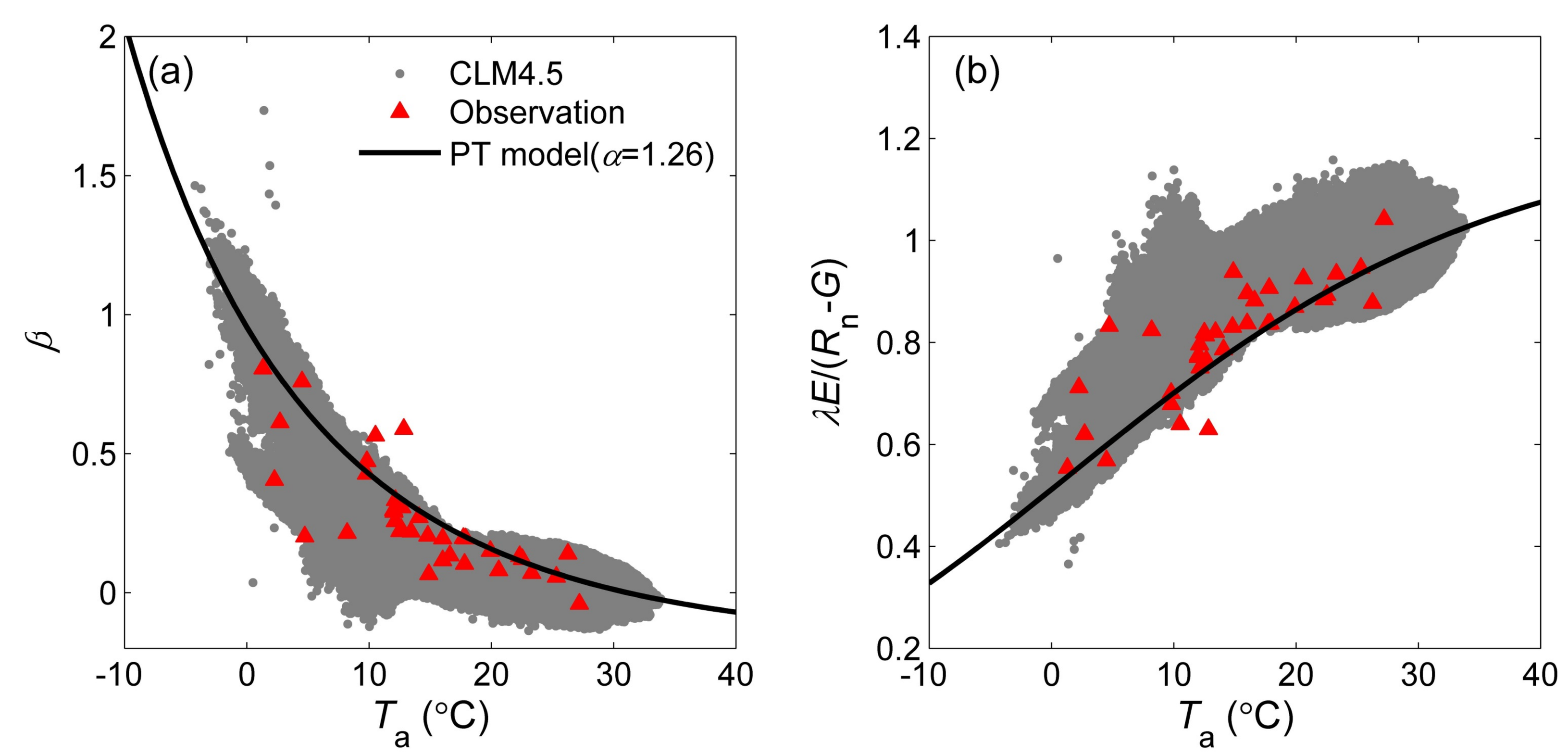
- β – Bowen ratio (dimensionless)
- H – sensible heat flux (W m^{-2})
- λE – latent heat flux (W m^{-2})
- R_n – net radiation (W m^{-2})
- G – heat flux into lake (W m^{-2})
- α – Priestley-Taylor coefficient with a standard value of 1.26 (dimensionless)
- Δ – slope of the saturated vapor pressure curve relative to temperature (Pa K^{-1}), increasing nonlinearly with air temperature.
- γ – psychrometer constant (Pa K^{-1})
- EF – λE / (R_n-G) evaporative fraction (dimensionless)

Validation of lake evaporation simulation



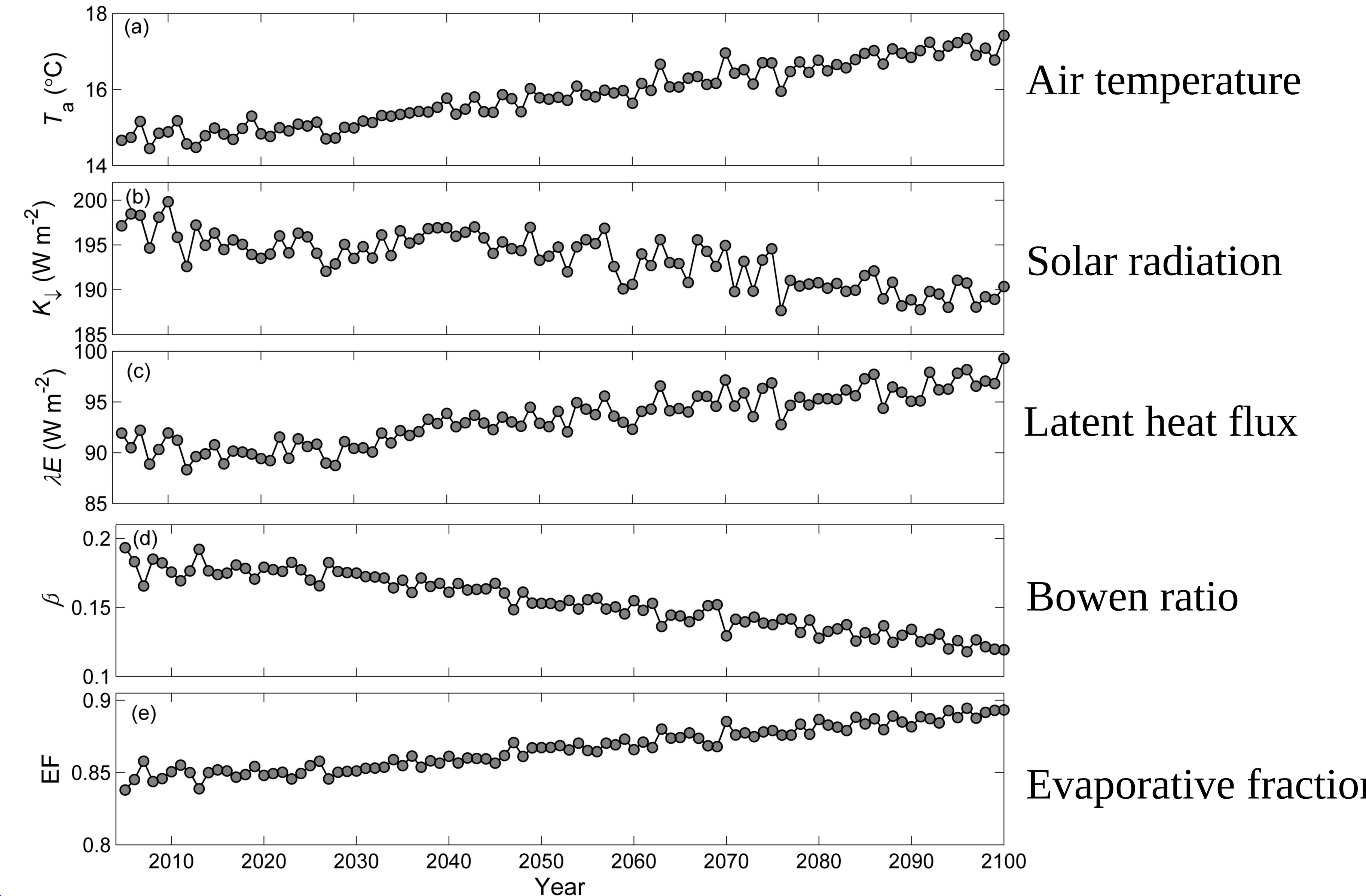
Validation of lake evaporation simulation of NCAR's CLM4.5-LISSS (Lake, Ice, Snow, and Sediment Simulator). Each datapoint represents the annual mean for one lake during ice-free periods.

Energy partitioning vs. air temperature



Lake annual mean Bowen ratio (β) decreases with air temperature (T_a), while evaporative fraction (EF) increases with air temperature. Each gray dot represents one lake annual mean during the open water period from 2005 to 2100 under RCP8.5. Red triangles denote observations found in the literature. The black line is the Priestley-Taylor (PT) model with the standard Priestley-Taylor coefficient (α=1.26).

Interannual variations in global lake mean



Spatial variations