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Thermal Safety Margin for Plant Photosynthesis Constrained by Temperature Variability at Most Locations Across the Globe

Kumarathunge, D.[a], Jiang, M.[b], and Huntingford, C.[c]

[a]*Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Sri Lanka*

[b]*College of Life Sciences, Zhejiang University, Hangzhou, China*

[c]*UK Centre for Ecology and Hydrology, Wallingford, Oxfordshire, U.K.*

Abstract

The search for globally applicable features of the terrestrial responses to climate change, amenable to numerical representation in the land part of Earth system models, underpins our ability to accurately predict the ecological consequences associated with different potential future trajectories of climate change. Here we present an example of near "universality" by introducing the concept of a data-based unified thermal safety margin for plant photosynthesis (TSM). We use the global gridded (0.75° latitude x 0.75° longitude) historic 6-hourly temperature output from the ECMWF reanalysis product to perform the analysis. We calculated TSM as T_{optA} (optimum temperature for photosynthesis) - T_{growth} (mean air temperature of the months where T_{air} is > 0 °C). We derive the standard deviation of the 6-hourly temperature dataset (using only times when T_{growth} > 0 °C) to represent temperature variability at each grid point over the 40-year period. Our analysis provides strong evidence to support the notion that the TSM for plant photosynthesis is proportionally related to growth temperature variability at the global scale. We capture this correlation with a statistic named normalised TSM, which is the TSM divided by growth temperature standard deviation, TSD. We illustrated that in many terrestrial ecosystems around the globe, the probability of growth-season temperature exceeding the optimum temperature for photosynthesis is small and, critically, takes a geographically near-invariant value. This finding of a globally applicable level of risk relates plant physiology to meteorological conditions and their fluctuations that prevail during their growth phases. As such, statistics of near-surface temperature can be utilised to determine locally applicable values of optimal temperature for photosynthesis, which in turn is available for parameterisation of the land surface components of Earth system models. Our findings provide a useful mathematical interpretation of how plant photosynthesis responds to different levels of temperature variability across the globe.

Keywords: *Climate Variability, Earth System Models, Global Warming, Photosynthesis, Universal Parameters.*

Corresponding Author: *dushank@agri.ruh.ac.lk*