Derivation and validation of a sigmoid generalized complementary function with physical constraints

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The generalized complementary function to estimate actual evaporation, namely, the ratio of actual evaporation \( E \) to Penman potential evaporation \( E/E_{\text{Pen}} \) as a function of the proportion of the radiation term in \( E_{\text{Pen}} \), \( E/E_{\text{Pen}} = f(\text{Erad}/E_{\text{Pen}}) \), has been increasingly recognized. Existing analytical forms of the generalized complementary function can be classified into three types: linear (advection–aridity model of [Brutsaert and Stricker, 1979]), approximately concave (Brutsaert, 2015), and sigmoid (Han et al., 2012). These functions are limited by improper boundary conditions resulting from inadequate understanding of physical constraints.

In this study, its zero- and first-order boundary conditions were rigorously derived by adopting the physical constraints for \( E \) in Penman’s combination theory, and a sigmoid feature of relationship between \( E/E_{\text{Pen}} \) and \( \text{Erad}/E_{\text{Pen}} \) was derived. Minimum and maximum limits of \( \text{Erad}/E_{\text{Pen}} \) were introduced based on the derived boundary conditions, and accordingly a new sigmoid function was developed. By restricting it to be approximately equivalent to the linear advection–aridity [Brutsaert and Stricker, 1979] function under normal environments, the new sigmoid function satisfied the upper limits of Penman’s open water evaporation and Priestley–Taylor’s minimal advection evaporation in parallel. The sigmoid feature and the new sigmoid function were validated by tower based data from FLUXNET. This work improves our understanding of the complementary principle, and the new function demonstrates a favorable potential for use in evaporation estimation.

References: