LETTERS TO THE EDITOR


Dear Editor:
In an article published in Agronomy Journal, Campbell (2003) proposed a set of uncoupled equations to deal with latent and sensible heat flux. The fluxes proposed are enthalpy (H) and isothermal latent heat (λEi) and the new driving forces are equivalent temperature and vapor pressure deficit. In the derivation method, however, there was an error in the mathematical manipulation of one of the equations. The objective of this letter is to correct that error and to show the correct set of uncoupled equations.

Campbell (2003) defined latent heat flux as (Eq. [3] in the original paper)

\[ \lambda E = - \frac{\rho \lambda K_s h \, de_s}{p \, dz} - \frac{\rho \lambda K_v e_s \, dh}{p \, dz} \]  

[1]

where \( \lambda \) (J mol\(^{-1}\)) is the water latent heat of vaporization, \( E \) (mol m\(^{-2}\)s\(^{-1}\)) is the water vapor flux density, \( \rho \) is the air molar density (mol m\(^{-3}\)), \( K_v \) (m\(^2\)s\(^{-1}\)) is the vapor diffusivity, \( h \) is relative humidity, \( e_s \) (kPa) is the saturation vapor pressure at air temperature, \( p \) (kPa) is the atmospheric pressure, and \( z \) (m) is distance.

Campbell substituted \( \Delta dT/dz \) for \( de_s/dz \) where \( \Delta \) is the slope of the saturation vapor pressure function (kPa °C\(^{-1}\)) and \( T \) is temperature (°C). He also proposed that since the vapor pressure deficit \( D \) (kPa) is defined as \( D = e_s(1 - h) \), differentiating and rearranging terms appropriately provides a substitution for the derivative term \( dh/dz \). However, there was an error in the derivation, where Campbell obtained \( dh/dz = 1/e_s \times dD/dz \). Substituting in Eq. [1] he obtained (Eq. [4] in the original paper)

\[ \lambda E = - \frac{\rho \lambda K_s h \Delta dT}{p \, dz} + \frac{\rho \lambda K_v D}{p \, dz} \]  

[2]

The correct differentiation of \( D \) yields \( \frac{dh}{dz} = \frac{1}{e_s} \left[ \frac{de_s}{dz} - h \frac{de_s}{dz} - \frac{dD}{dz} \right] \) since both \( e_s \) and \( D \) vary with \( z \). Equation [2] (Eq. [4] in the original paper) therefore becomes

\[ \lambda E = - \frac{\rho \lambda K_s \Delta dT}{p \, dz} + \frac{\rho \lambda K_v D}{p \, dz} \]  

[3]

Equation [3] expresses that the latent heat flux depends on the vapor pressure deficit (or \( \lambda E_i \), the second term on the right of the equation) and temperature gradients, without any involvement of \( h \). This correction changes the decoupled Eq. [8] (latent heat flux) and Eq. [9] (sensible heat flux) of Campbell (2003) to the standard Penman–Monteith forms:

\[ \lambda E = \frac{sH + \gamma^* \lambda E_i}{s + \gamma^*} \]  

[4]

\[ C = \frac{\gamma^*(H - \lambda E_i)}{s + \gamma^*} \]  

[5]

where \( s = \frac{\Delta}{p} \) (K\(^{-1}\)), \( \gamma^* = \frac{c_p K_h}{K_v} \) and where \( c_p \) is the specific heat of air (J mol\(^{-1}\) K).

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References


Editor’s note: Through a series of events, Valipuram S. Manoranjan, Armen R. Kemanian, and Ryan L. Orozco discovered an error in the mathematical manipulation of one of the equations in the article by Campbell (2003). Dr. Kemanian subsequently contacted Dr. Campbell regarding this error and the correct derivation. These authors and Dr. Campbell have jointly prepared this Letter to the Editor. All authors have agreed on the content of the letter so there is no separate reply from Dr. Campbell.