Supplement of

Can atmospheric chemistry deposition schemes reliably simulate stomatal ozone flux across global land covers and climates?

S1. Total dry deposition velocity calculation

The total dry deposition velocity of O3 (v_d) is calculated by the standard formula including the aerodynamic resistance (R_a), quasi-laminar boundary layer resistance (R_b), and surface resistance (R_c).

$$v_d = \frac{1}{(R_a + R_b + R_c)} \quad (1)$$

The formula for R_a and R_b are essentially the same among different models that follow earlier literature (e.g., Padro, 1996; Wesely et al., 2002). R_c is calculated as follows.

$$R_c = \frac{1}{\left(\frac{1}{R_s + R_m} + \frac{1}{R_{ext}} + \frac{1}{R_{inc} + R_{soil}}\right)} \quad (2)$$

Where R_s, R_m, R_{ext}, R_{inc}, and R_{soil} are resistances due to stomata, mesophyll, cuticle, in-canopy (aerodynamic), and soil resistance to deposition. R_m= 0 for O_3 in all models used in this study. Equations for R_{ext}, R_{inc}, and R_{soil} can be found in the respective literature of each of the models. Equations for R_s is different for each model and are discussed in section S3.

S2. Effective conductance calculation

The effective conductance of O_3 through a given pathway indicates the relative importance of the pathway to the total deposition (Clifton et al., 2023; Galmarini et al., 2021). There are three deposition branches for the models used in the current study, i.e., the effective conductance through ground ($G_{ground,eff}$), Cuticle ($G_{cut,eff}$), and Stomata ($G_{st,eff}$), and their formulae are as follows.

$$G_{ground,eff} = \frac{\frac{1}{R_{inc} + R_{soil}}}{\frac{1}{R_s} + \frac{1}{R_{ext}} + \frac{1}{R_{inc} + R_{soil}}} * V_d \quad (3)$$

$$G_{cut,eff} = \frac{\frac{1}{R_{ext}}}{\frac{1}{R_s} + \frac{1}{R_{ext}} + \frac{1}{R_{inc} + R_{soil}}} * V_d \quad (4)$$

$$G_{st,eff} = \frac{\frac{1}{R_s}}{\frac{1}{R_s} + \frac{1}{R_{ext}} + \frac{1}{R_{inc} + R_{soil}}} * V_d \quad (5)$$

Where R_s, R_{ext} , R_{inc} , and R_{soil} are resistances due to stomata, cuticle, in-canopy aerodynamic resistance, and soil resistance to deposition. V_d is the deposition velocity of O3.

S3. Stomatal Ozone Flux (F_{st}) calculation using the Stomatal resistance (R_s)

The canopy level stomatal ozone flux (F_{st}) was calculated from the canopy level total stomatal resistance by the following equation:

$$F_{st} = \frac{C_0}{R_s + R_m} \qquad (6)$$

Where, C_0 is the ozone concentration at the top of the canopy. As the O3 concentrations at the top of the canopy are typically not available and the O3 measurement heights across our study sites were mostly below 10 m (Table 1), C_0 were assumed to be the same as the O3 concentrations above the canopy and such assumptions are very reasonable (Zhang et al., 2006). R_s and R_m are the stomatal and mesophyll resistance, respectively; the latter of which is assumed to be 0 for O_3. Calculations of R_s are described in the following sections.

S3.1. R_s calculation by the Zhang et al. (2003) model

The stomatal resistance (R_s) calculation by Zhang et al. (2003) uses the Jarvis-style approach, where the R_s is calculated from minimum stomatal resistance (maximum stomatal conductance) and a series of empirical functions as stress functions. The equation for R_s:

$$R_s = 1/\left[G_s(PAR)f(T)f(D)f(\psi) \times D_i/D_v\right] \qquad (7)$$

where $G_s(PAR)$ is the unstressed leaf stomatal conductance, which is a function of photosynthetically active radiation (PAR). The dimensionless stress functions $f(T)$, $f(D)$, and $f(\psi)$ represent the conductance-reducing effects of air temperature T, water vapour pressure deficit D, and water stress (leaf water potential) ψ, respectively, on leaf stomatal conductance. D_v and D_i are the molecular diffusivities for water vapour and ozone, respectively. The sunlit/shade stomatal conductance model (two-big leaf model) is used for calculating $G_s(PAR)$:

$$G_s(PAR) = \frac{L_{sun}}{r_s(PAR_{sun})} + \frac{L_{shade}}{r_s(PAR_{shade})} \qquad (8)$$

$$r_s(PAR) = r_{s,min}(1 + b_{rs}/PAR) \qquad (9)$$

where L_{sun} and L_{shade} are the total sunlit and shaded leaf area indexes, respectively. r_s is the unstressed leaf stomatal resistance calculated for PAR_{sun} and PAR_{shade} (PAR received by sunlit and shaded leaves, respectively). $r_{s,min}$ is the minimum leaf stomatal resistance and b_{rs} is an empirical constant. Details of the calculations of these parameters as well as those for *f(T)*, *f(D)*, and *f(ψ)* can be found in Zhang et al. (2002).

S3.2. R_s calculation in the Noah-GEM model

The Noah-GEM model uses the semi-empirical Ball-Berry type approach where the stomatal resistance is calculated from the plant photosynthesis rates (Niyogi et al., 2009; Wu et al., 2011):

$$R_s = 1/[LAI(mA_n h_s P/C_s + b)] \qquad (10)$$

Where LAI, A_n, h_s, P, C_s are leaf area index, net photosynthesis rate, relative humidity at leaf surface, atmospheric pressure, and CO_2 partial pressure at the leaf surface, respectively. m and b are linear coefficients obtained through gas exchange experiments. The Noah-GEM model for $R_s$calculation requires several submodels for calculating the $A_n$and are described in Wu et al. (2011) and Niyogi et al. (2009).

S3.3. R_s calculation in the CMAQ model

The CMAQ model has the options of both Jarvis-style and Ball-Berry type approaches to calculate the stomatal resistance. Current study used both approaches of the model. In the Jarvis-style approach, the canopy is treated as a single leaf (one-big leaf model) and the stomatal resistance is calculated as follows (Pleim and Ran, 2011; Pleim and Xiu, 2003; Xiu and Pleim, 2001):

$$R_s = r_{s,min}\, LAI/(f_{PAR} f_T f_{vpd} f_w) \qquad (11)$$

Where $r_{s,min}$ is the minimum stomatal resistance (maximum conductance of a leaf under unstressed conditions), which is specified according to the vegetation type (Xiu and Pleim, 2001). LAI is the leaf area index of the canopy. $f_{PAR,}$ $f_{T,}$ f_{vpd}, and f_w are the dimensionless stress functions, which represent the fractions of stomatal closure (0 to 1) associated with the photosynthetically active radiation PAR, air temperature in the canopy, relative humidity at the leaf surface, and root-depth soil moisture, respectively. Equations of the four stress functions are given in Xiu and Pleim (2001).

Ran et al. (2017) implemented the Ball-Berry type stomatal resistance calculations in the CMAQ model:

$$R_s = 1/(m_g A_{net} e_s P_a / C_s \, e_i + g_0) \qquad (12)$$

Where A_{net} is the net photosynthesis rate, C_s is the CO_2 partial pressure at leaf surface, e_s is the water vapor partial pressures at leaf surface, e_i is the saturation vapor pressure inside the leaf, and P_a is the atmospheric pressure. g_0 is set to 0.01 mol/m^{-2}s^{-1} for C_3 plants and 0.04 mol/m^{-2}s^{-1} for C_4 plants, m_g is a plant-type parameter which is 9 for C_3 plants and 4 for C_4 plants. Detailed discussion on A_{net} calculations can be found in Ran et al. (2017).

S3.4. R_s calculation in the TEMIR model

The Terrestrial Ecosystem Model in R (TEMIR) (Sun et al., 2022; Tai et al., 2023) has two Jarvis-style stomatal conductance schemes adopted from the Wesley scheme (Wesely, 1989) and the Zhang et al. (2003) scheme, as well as two photosynthesis-based schemes: Farquhar–Ball–Berry (Ball et al., 1987; Farquhar et al., 1980) and Medlyn (Medlyn et al., 2011) schemes. In the current study, the FBB scheme was used. The equation for the stomatal resistance is as follows:

$$R_s = 1\Big/\left[\left(\frac{L_{sun}}{r_b + r_{sun}} + \frac{L_{shade}}{r_b + r_{shade}}\right)\frac{D_i}{D_v}\right] \qquad (13)$$

Where L_{sun} and L_{shade} are the sunlit and shaded LAI respectively, r_b is the leaf boundary resistance, r_{sun} and r_{shade} are the leaf level sunlit and shaded stomatal resistances for water vapor, respectively, and D_v and D_i are the molecular diffusivities for water vapour and ozone, respectively. r_{sun} and r_{shade} in the FBB scheme are calculated from the stomatal conductance (g_s) according to the following equation.

$$r_s = 1/g_s = 1\Bigg/\left[\alpha\left(\frac{mA_n\left(\frac{e_s}{e_{sat}}\right)}{\left(\frac{C_s}{P_{atm}}\right)} + b\right)\right] \qquad (14)$$

Where α is the unit conversion factor (μmol H_2O m^{-2} s^{-1} to m s^{-1}) that is dependent on atmospheric temperature and pressure, m and b are linear coefficients, which are dependent on the plant types, and the values are given in Oleson et al. (2013), A_n is the photosynthesis rate calculated separately for sunlit and shaded leaves. C_s is the CO_2 partial pressure at leaf surface, P_{atm} is the atmospheric pressure e_s is the water vapor partial pressure at the leaf surface, and e_{sat} is the saturation vapor pressure inside the leaf.

S3.5. R_s calculation in the ECHAM-MESSy model

The ECHAM-MESSy model uses Jarvis-style approach for the stomatal resistance calculations (Emmerichs et al., 2021) and the formula is very similar to that in Zhang et al. (2003):

$$R_s = [r_s(PAR, LAI)/f_T f_{vpd} f_w)] \times D_v/D_i \tag{15}$$

$$r_s(PAR, LAI) = \frac{kc}{[\frac{b}{d\ PAR} \ln\left(\frac{d\exp(kLAI)+1}{d+1}\right) - \ln\left(\frac{d\exp(-kLAI)}{d+1}\right)]} \tag{16}$$

Where $r_s(PAR, LAI)$ is the optimal stomatal resistance which depends on the photosynthetically active radiation (PAR) and the leaf area index (LAI). $f_{T,}$ f_{vpd}, and f_w are the dimensionless stress functions associated with air temperature in the canopy, relative humidity at the leaf surface, and root-depth soil moisture, respectively. D_v and D_i are the molecular diffusivities of water vapour and ozone, respectively. k is the extinction coefficient (= 0.9), c is the minimum stomatal resistance (= 100 sm^{-1}), and a = 5000 J m^{-3}, b = 10 W m^{-2} and d = $\frac{a+bc}{c\ PAR}$ are fitting parameters. Stress function equations are given in Emmerichs et al. (2021).

S3.6. R_s calculation in the DO3SE model

The DO3SE model calculates the Rs from the by stomatal conductance that is obtained by the following formulas (Emberson et al., 2000):

$$R_s = r_s/LAI \tag{17}$$

$$r_s = g_{max}\ max\{(f_{min}, f_{temp}, f_{VPD}, f_{SWC})\} \times f_{phen} \times f_{light} \tag{18}$$

Where LAI is the leaf area index, g_{max} is the maximum stomatal conductance (prescribed) that is modified by several stress functions to account for the conductance change by the variations of leaf/needle age over the growing period (f_{phen}), solar radiation (f_{light}), temperature (f_{temp}), vapor pressure deposit (f_{VPD}), and soil water (f_{SWC}). f_{min} is the minimum daytime stomatal conductance under field conditions (expressed as the fraction of g_{max})

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