



Supplement of

A single-point modeling approach for the intercomparison and evaluation of ozone dry deposition across chemical transport models (Activity 2 of AQMEII4)

Olivia E. Clifton et al.

Correspondence to: Olivia E. Clifton (olivia.e.clifton@nasa.gov)

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Table S1: Aerodynamic resistance parameterizations for the single-point models.

| Model | Aerodynamic resistance (r_a) | Reference |
|---|---|---|
| WRF-Chem Wesely | $r_a = \begin{cases} \frac{1}{k u^*} \left(0.74 \ln \left(\frac{z_r}{z_0} \right) + 4.7 \frac{z_r - z_0}{L} \right), & 1/L > 0 \\ \frac{1}{k u^*} 0.74 \left(\ln \left(\frac{\sqrt{1 - 9 \frac{z_r}{L}} - 1}{\sqrt{1 - 9 \frac{z_r}{L}} + 1} \right) - \ln \left(\frac{\sqrt{1 - 9 \frac{z_0}{L}} - 1}{\sqrt{1 - 9 \frac{z_0}{L}} + 1} \right) \right), & 1/L < 0 \end{cases}$ | McRae (1981) |
| GEOS-Chem Wesely, IFS, TEMIR models | <p>In aerodynamically smooth conditions ($Re_r < 0.1 r_a$) where roughness Reynolds number ($Re_r = u^* z_0 / \nu$) then r_a equals 10^4 s m^{-1}. Otherwise,</p> $r_a = \begin{cases} \frac{1}{k u^*} \left(5 \ln \left(\frac{z_r - d}{z_0} \right) + \frac{z_r - d - z_0}{L} \right), & (z_r - d)/L > 1 \\ \frac{1}{k u^*} \left(\ln \left(\frac{z_r - d}{z_0} \right) + 5 \left(\frac{z_r - d - z_0}{L} \right) \right), & 0 \leq (z_r - d)/L \leq 1 \\ \frac{1}{k u^*} \left(\ln \left \frac{\sqrt{1 - 15 \frac{z_r - d}{L}} - 1}{\sqrt{1 - 15 \frac{z_r - d}{L}} + 1} \right - \ln \left \frac{\sqrt{1 - 15 \frac{z_0}{L}} - 1}{\sqrt{1 - 15 \frac{z_0}{L}} + 1} \right \right), & (z_r - d)/L < 0 \end{cases}$ | |
| GEM-MACH Wesely | $r_a = \frac{1}{k u^*} \left(\ln \left(\frac{z_r - d + z_0}{z_0} \right) - \psi_{heat} \right)$ $\psi_{heat} = \begin{cases} -5 \left(\frac{z_r - d - z_0}{L} \right), & \frac{z_r - d}{L} > 0.01 \\ e^{0.598 + 0.39 \ln \left(-\frac{z_r - d}{L} \right) - 0.18 \ln \left(-\frac{z_r - d}{L} \right)}, & \frac{z_r - d}{L} < -0.01 \\ -e^{0.598 + 0.39 \ln \left(-\frac{z_0}{L} \right) - 0.18 \ln \left(-\frac{z_0}{L} \right)}, & \\ 0, & -0.01 \leq \frac{z_r - d}{L} \leq 0.01 \end{cases}$ | Voldner et al. (1986); Makar et al. (2018) |
| GEM-MACH Zhang | $r_a = \frac{1}{k u^*} \left(0.74 \ln \left(\frac{z_r}{z_0} \right) - \psi_{heat} \right)$ $\psi_{heat} = \begin{cases} -4.7 \frac{z_r}{L}, & \frac{z_r}{L} \geq 0 \\ 2 \ln \left(0.5 \left(1 + \sqrt{1 - 9 \frac{z_r}{L}} \right) \right), & \frac{z_r}{L} < 0 \end{cases}$ <p>The variable r_a is set to a maximum of 10 s m^{-1}.</p> | |
| CMAQ M3Dry models | $r_a = \frac{1}{k u^*} 0.95 \left(\ln \left(\frac{z_r - d}{z_0} \right) - \psi_{heat} \right)$ $\psi_{heat} = \begin{cases} 1 - 8.21 \frac{z_r - d + z_0}{L}, & \frac{z_r - d}{L} - \frac{z_0}{L} > 1 \\ -8.21 \left(\frac{z_r - d}{L} - \frac{z_0}{L} \right), & 0 < \frac{z_r - d}{L} - \frac{z_0}{L} \leq 1 \\ 2 \ln \left(\frac{\left(1 - 11.6 \frac{z_r - d}{L} \right)^{0.5} + 1}{\left(1 - 11.6 \frac{z_0}{L} \right)^{0.5} + 1} \right), & \frac{z_r}{L} < 0 \end{cases}$ | Högström (1988) for ψ_{heat} |
| CMAQ STAGE | $r_a = 0.95 \frac{u}{(u^*)^2}$ | Knauer et al. (2018); Young et al. (2021) |
| DO ₃ SE models | $r_a = \frac{1}{k u^*} \ln \left(\frac{z_r - d}{z_0} \right)$ | Garratt (1992) |

| | |
|-----------------|---|
| MLC-CHEM | $r_a = \begin{cases} \frac{1}{k u^*} \left(0.74 \ln \left(\frac{z_r}{z_0} \right) + 4.7 \frac{z_r}{L} \right), & 1/L > 0 \\ \frac{1}{k u^*} 0.74 \left(\ln \left(\frac{\sqrt{1 - 9 \frac{z_r}{L}} - 1}{\sqrt{1 - 9 \frac{z_r}{L}} + 1} \right) - \ln \left(\frac{\sqrt{1 - 9 \frac{z_0}{L}} - 1}{\sqrt{1 - 9 \frac{z_0}{L}} + 1} \right) \right), & 1/L < 0 \end{cases}$ |
|-----------------|---|

The parameter k is the von Kármán constant [0.4]; ν [$\text{m}^2 \text{s}^{-1}$] is kinematic viscosity of air. Otherwise, variables and parameters are defined in Table 1.

Table S2: Obukhov length parameterizations for the single-point models.

| Model | Obukhov length (L) |
|--|---|
| WRF-Chem Wesely, GEOS-Chem Wesely, IFS models | $L = - \frac{u^{*3} \rho c_p (T_a + 273.15)}{k g SH}$ <p>The variable L is restricted to the range from -1×10^4 to 1×10^4 m.</p> |
| GEM-MACH Wesely, TEMIR models | $L = - \frac{u^{*3} \rho c_p (T_v + 273.15)}{k g SH}$ <p>The variable T_v is the virtual temperature [$^{\circ}\text{C}$]. The variable L is restricted to the range between 1×10^5 and 1×10^{-1} m if L is positive, and -1×10^5 to -1×10^{-1} m if L is negative.</p> |
| GEM-MACH Zhang | $L = \min \left\{ \frac{\theta_v (7.5 \times 10^{-4} + 6.7 \times 10^{-5} u)^{1.5} u^2}{5.09 \times 10^{-3} (\theta_v - \theta_{v,s})}, 5 \right\}$ <p>The variable θ_v [K] is potential temperature. The near-surface potential temperature $\theta_{v,s}$ [K] is approximated from a linear interpolation between the air and ground to a height of 1.5 m. If $\theta_v - \theta_{v,s}$ is less than or equal to 10^{-6} then $L = 10^4$.</p> |
| CMAQ M3Dry models | $L = - \frac{u^{*3} \rho c_p (T_v + 273.15)}{k g SH}$ <p>The variable T_v is the virtual temperature [$^{\circ}\text{C}$].</p> |

The parameter c_p is specific heat capacity of air [$\text{J kg}^{-1} \text{K}^{-1}$]; g [m s^{-2}] is acceleration due to gravity. Otherwise, variables and parameters are defined in Table 1.

Table S3: Quasi-laminar boundary layer resistance parameterizations for the single-point models.

| Model | Quasi-laminar boundary layer resistance |
|---|--|
| WRF-Chem Wesely, GEOS- Chem Wesely, TEMIR models, IFS models, GEM- MACH Zhang, GEM-MACH Wesely, CMAQ M3Dry models, DO₃SE models | $r_b = \frac{2}{k u^*} (R_{diff,b})^{\frac{2}{3}}$ |
| CMAQ STAGE | <p>The vegetation quasi-laminar boundary layer resistance ($r_{b,v}$) follows Massad et al. (2010) and Jensen and Hummelshøj (1995, 1997):</p> $r_{b,v} = \frac{\nu}{D_{O_3}} \left(\frac{l u^*}{LAI^2 \nu} \right)^{\frac{1}{3}} \frac{1}{u_*}$ <p>The parameter l [m] is the leaf width (Table B13).</p> <p>The ground quasi-laminar boundary layer resistance ($r_{b,g}$) follows Schuepp (1977), Nemitz et al. (2001), and Massad et al. (2010):</p> $r_{b,g} = \frac{\nu}{D_{O_3}} - \ln \left(\frac{u_{*,g}}{z_1 k D_{O_3}} \right)$ <p>The parameter z_1 [0.1 m] follows Nemitz et al. (2001); $u_{*,g}$ [m s^{-1}] is friction velocity under the canopy elements following Yi (2008):</p> $u_{*,g} = u^* e^{-\frac{LAI}{2}}$ |
| MLC-CHEM | <p>The leaf-level quasi-laminar boundary layer resistance ($r_{b,leaf}$) is calculated according to Meyers et al. (1987):</p> |

| | |
|--|--|
| | $r_{b,leaf} = 180 (R_{diff,b})^{\frac{2}{3}} \sqrt{\frac{l}{u}}$ |
| The parameter l is a characteristic leaf dimension [0.07 m]. | |

The parameter k is the von Kármán constant [0.4]; ν [$\text{m}^2 \text{s}^{-1}$] is kinematic viscosity of air; $R_{diff,b}$ is defined in Table S4. Otherwise, variables and parameters are defined in Table 1.

Table S4: Ozone-specific dry deposition parameters in the single-point models.

| Model | $\frac{R_{diff,st}}{D_w} = \frac{D_w}{D_{O_3}}$ | $R_{diff,b} = \frac{Sc}{Pr}$ | D_{O_3} | f_0 | H |
|-------------------------|---|--|--|-------|------------------------------------|
| WRF-Chem Wesely | 1.6 | $\frac{\kappa}{D_{O_3}}$ $\kappa = 2.08 \times 10^{-5}$ | 1.7×10^{-5} | 1 | 0.015 |
| GEOS-Chem Wesely, TEMIR | ~1.3 | $\frac{\kappa}{D_{O_3}}$ $\kappa = 2 \times 10^{-5}$ | $D_x = \frac{3\pi}{32} \left(1 + \frac{M_x}{M_{air}}\right) \left(\frac{1}{\pi \left(1 + \frac{M_x}{M_{air}}\right)^{1/2} n_{air} d_x^2}\right) \left(\frac{8R(T_a + 273.15)}{\frac{\pi M_x}{1000}}\right)^{1/2}$ <p>The parameter M_x is the molar mass of diffusing gas X; R is the universal gas constant [$\text{J mol}^{-1} \text{K}^{-1}$]; $n_{air} = \frac{A_v p_a}{R(T_a + 273.15)}$ is the number density of air [molecules m^{-3}]; A_v is Avogadro's number [molecules mol^{-1}]; $d_x = 2.7 \times 10^{-10}$ m is the assumed collision diameter for the gas in air.</p> | 1 | 0.01 |
| IFS SUMO Wesely | 1.6 | $\frac{\kappa}{D_{O_3}}$ | $D_{O_3} = \frac{D_w}{\sqrt{\frac{M_{O_3}}{M_w}}}$ <p>$D_w = 2.5 \times 10^{-5}$</p> | 1 | 0.01 at 298 K, varies with T_a |
| IFS GEOS-Chem Wesely | ~1.3 | $\frac{\kappa}{D_{O_3}}$ | $D_x = \frac{3\pi}{32} \left(1 + \frac{M_x}{M_{air}}\right) \left(\frac{1}{\pi \sqrt{\left(1 + \frac{M_x}{M_{air}}\right)} n_{air} d_x^2}\right) \sqrt{\frac{8R(T_a + 273.15)}{\frac{\pi M_x}{1000}}}$ <p>The parameter M_x is the molar mass of diffusing gas X; R is the universal gas constant [$\text{J mol}^{-1} \text{K}^{-1}$]; $n_{air} = \frac{A_v p_a}{R(T_a + 273.15)}$ is the number density of air [molecules m^{-3}]; A_v is Avogadro's number [molecules mol^{-1}]; $d_x = 2.7 \times 10^{-10}$ m is the assumed collision diameter for the gas in air.</p> | 1 | 0.01 |
| GEM-MACH Wesely | 1.23 | $1.135 \frac{D_w}{D_{O_3}}$ | $D_{O_3} = \frac{D_w}{\sqrt{\frac{2.608}{1 + \frac{M_{air}}{M_{O_3}}}}}$ | 1 | 0.01 |
| GEM-MACH Zhang | ~1.6 | $\frac{\kappa}{D_{O_3}}$ | $D_{O_3} = \frac{1.0 \times 10^{-3} T_s^{1.75} \sqrt{\frac{M_{air} + M_{O_3}}{M_{air} M_{O_3}}}}{\frac{p_a}{1.01325 \times 10^5} \left[(0.369 M_{O_3} + 6.29)^{\frac{1}{3}} + (0.369 M_{air} + 6.29)^{\frac{1}{3}} \right]^2}$ <p>Equation follows Perry and Green (1984) with the calculation of the molar volume from the mass following Li et al. (1993). The near-surface air temperature T_s [K] is approximated from a linear interpolation between T_a and T_g to a height of 1.5 m.</p> | n/a | n/a |
| CMAQ M3Dry models | 1.51 | $\frac{\kappa}{D_{O_3}}$ $\kappa = 1.86 \times 10^{-5}$ | 1.444×10^{-5} | n/a | n/a |
| CMAQ STAGE | ~1.6 | n/a | $D_{O_3} = \frac{10^{-7} (T_a + 273.15)^{1.75} \sqrt{M_{air}^{-1} + M_{O_3}^{-1}}}{\left(\frac{1}{V_{m,air}^{\frac{1}{3}}} + \frac{1}{V_{m,O_3}^{\frac{1}{3}}} \right)^2}$ <p>The parameter $V_{m,air}$ is molar volume of air [22.41 L mol^{-1}]; V_{m,O_3} is molar volume of ozone [21.0 L mol^{-1}]. Equation follows Fuller et al. (1966).</p> | 1 | 0.0114 at 298 K, varies with T_a |

| | | | | | | |
|---------------------------|------|--|-----------------------------|--|-----|-----|
| MLC-CHEM | 1.28 | $\frac{\kappa}{D_{O_3}}$ $\kappa = 1.89 \times 10^{-5}$ | $D_w = 2.12 \times 10^{-5}$ | $D_{O_3} = \frac{D_w}{\sqrt{\frac{M_{O_3}}{M_w}}}$ | n/a | n/a |
| DO ₃ SE models | 1.66 | $\frac{\kappa}{D_{O_3}}$ $\kappa = 2.08 \times 10^{-5}$ | 1.5×10^{-5} | | n/a | n/a |

The parameter M_{O_3} [g mol⁻¹] is molar mass of ozone; M_w [g mol⁻¹] is molar mass of water. Otherwise, variables and parameters are defined in Table 1.

Table S5: Site- and season-specific^a parameters for WRF-Chem Wesely.

| Site | r_i | r_{lu} | r_{ac} | r_{cl} | r_g |
|------------------|-----------------------|------------|------------|------------|----------|
| Auchencorth Moss | 120, 10 ¹⁰ | 2000, 9000 | 100, 100 | 1000, 400 | 200, 200 |
| Borden Forest | 100, 500 | 2000, 8000 | 2000, 1700 | 1000, 600 | 300, 300 |
| Bugacpuszta | 120, 10 ¹⁰ | 2000, 9000 | 100, 100 | 1000, 400 | 200, 200 |
| Easter Bush | 120, 10 ¹⁰ | 2000, 9000 | 100, 100 | 1000, 400 | 200, 200 |
| Ispra | 70, 10 ¹⁰ | 2000, 9000 | 2000, 1500 | 1000, 400 | 200, 200 |
| Harvard Forest | 70, 10 ¹⁰ | 2000, 9000 | 2000, 1500 | 1000, 400 | 200, 200 |
| Hyytiälä | 130, 250 | 2000, 4000 | 2000, 2000 | 1000, 1000 | 200, 200 |
| Ramat Hanadiv | 120, 10 ¹⁰ | 2000, 9000 | 100, 100 | 1000, 400 | 200, 200 |

^aMidsummer with lush vegetation, Autumn with unharvested croplands

Table S6: Site-specific parameters for GEOS-Chem Wesely.

| Site | r_i | r_{lu} | r_{ac} | $r_{cl,S}$ | $r_{cl,O}$ | $r_{g,S}$ | $r_{g,O}$ |
|------------------|------------------|-----------------|----------|------------------|------------|-----------|-----------|
| Auchencorth Moss | 200 | 9000 | 300 | 2500 | 1000 | 0 | 1000 |
| Borden Forest | 200 | 9000 | 2000 | 2000 | 1000 | 500 | 200 |
| Bugacpuszta | 200 | 9000 | 100 | 2000 | 1000 | 350 | 200 |
| Easter Bush | 200 | 9000 | 100 | 2000 | 1000 | 350 | 200 |
| Ispra | 200 | 9000 | 2000 | 2000 | 1000 | 500 | 200 |
| Harvard Forest | 200 | 9000 | 2000 | 2000 | 1000 | 500 | 200 |
| Hyytiälä | 200 | 9000 | 2000 | 2000 | 1000 | 500 | 200 |
| Ramat Hanadiv | 200 | 9000 | 100 | 2000 | 1000 | 350 | 200 |
| Snow | 10 ¹² | 10 ⁶ | 1 | 10 ¹² | 1000 | 100 | 3500 |

Table S7: Site- and season-specific^a parameters for IFS SUMO Wesely.

| Site | r_i | r_{lu} | r_{ac} | r_{cl} | r_g |
|------------------|-------|------------------------------|------------------------------|------------------------------|--------------------------|
| Auchencorth Moss | 100 | 2000, 9000, 9000, 9999, 4000 | 100, 100, 100, 10, 80 | 1000, 400, 400, 1000, 500 | 200, 200, 200, 3500, 200 |
| Borden Forest | 250 | 2000, 9000, 9000, 9999, 4000 | 2000, 1500, 1000, 1000, 1200 | 1000, 400, 400, 400, 500 | 200, 200, 200, 3500, 200 |
| Bugacpuszta | 100 | 2000, 9000, 9000, 9999, 4000 | 100, 100, 100, 10, 80 | 1000, 400, 400, 1000, 500 | 200, 200, 200, 3500, 200 |
| Easter Bush | 100 | 2000, 9000, 9000, 9999, 4000 | 100, 100, 100, 10, 80 | 1000, 400, 400, 1000, 500 | 200, 200, 200, 3500, 200 |
| Ispra | 250 | 2000, 9000, 9000, 9999, 4000 | 2000, 1500, 1000, 1000, 1200 | 1000, 400, 400, 400, 500 | 200, 200, 200, 3500, 200 |
| Harvard Forest | 250 | 2000, 9000, 9000, 9999, 4000 | 2000, 1500, 1000, 1000, 1200 | 1000, 400, 400, 400, 500 | 200, 200, 200, 3500, 200 |
| Hyytiälä | 250 | 2000, 4000, 4000, 6000, 2000 | 2000 | 1000, 1000, 1000, 1500, 1500 | 200, 200, 200, 3500, 200 |
| Ramat Hanadiv | 225 | 2000, 9000, 9000, 9999, 4000 | 100, 100, 100, 10, 80 | 1000, 400, 400, 400, 500 | 200, 200, 200, 3500, 200 |

^aMidsummer, Autumn, Late Autumn, Winter/snow, Transitional spring. When one value is given, only one value is used for all seasons.

Table S8: Site-specific parameters for IFS GEOS-Chem Wesely.

| Site | r_i | r_{lu} | r_{ac} | r_{cl} | r_g |
|------------------|-------|----------|----------|----------|-------|
| Auchencorth Moss | 200 | 9000 | 100 | 1000 | 200 |
| Borden Forest | 200 | 9000 | 2000 | 1000 | 200 |
| Bugacpuszta | 200 | 9000 | 100 | 1000 | 200 |
| Easter Bush | 200 | 9000 | 100 | 1000 | 200 |
| Ispra | 200 | 9000 | 2000 | 1000 | 200 |
| Harvard Forest | 200 | 9000 | 2000 | 1000 | 200 |
| Hyytiälä | 400 | 9000 | 2000 | 1000 | 200 |
| Ramat Hanadiv | 200 | 9000 | 100 | 1000 | 200 |

Table S9: Site- and season-specific^a parameters for GEM-MACH Wesely.

| Site | r_i | r_{ac} | r_{tu} | r_g | r_{cls} | r_{cl0} | T_{max} | T_{min} | T_{opt} |
|-------------------------|----------------------------|-------------------------|------------------------------|-----------------------------|------------------------------|------------------------------|-----------|-----------|-----------|
| Auchencorth Moss | 80, 9999, 9999, 9999, 160 | 20, 20, 20, 20, 20 | 6000, 6000, 9000, 9999, 6000 | 1000, 800, 1000, 3500, 1000 | 2500, 9000, 400, 400, 3000 | 1000, 600, 600, 600, 600 | 45 | 5 | 25 |
| Borden Forest | 100, 800, 800, 800, 190 | 190, 150, 110, 100, 100 | 1000, 1500, 2000, 2000, 1000 | 300, 300, 300, 3500, 300 | 2000, 4000, 6000, 400, 3000 | 1000, 600, 1000, 600, 700 | 42 | -3 | 21 |
| Bugacpuszta | 120, 9999, 9999, 9999, 240 | 40, 40, 40, 10, 30 | 1500, 2000, 3000, 6000, 1500 | 200, 200, 200, 3500, 200 | 2000, 9000, 9000, 9999, 4000 | 1000, 400, 400, 1000, 500 | 45 | 5 | 27 |
| Easter Bush | 120, 9999, 9999, 9999, 240 | 40, 40, 40, 10, 30 | 1500, 2000, 3000, 6000, 1500 | 200, 200, 200, 3500, 200 | 2000, 9000, 9000, 9999, 4000 | 1000, 400, 400, 1000, 500 | 45 | 5 | 27 |
| Ispra | 70, 9999, 9999, 9999, 140 | 250, 190, 115, 100, 100 | 1200, 2000, 9000, 9999, 2000 | 200, 200, 200, 3500, 200 | 2000, 9000, 9000, 9000, 4000 | 1000, 400, 400, 400, 500 | 45 | 0 | 27 |
| Harvard Forest | 100, 800, 800, 800, 190 | 190, 150, 110, 100, 100 | 1000, 1500, 2000, 2000, 1000 | 300, 300, 300, 3500, 300 | 2000, 4000, 6000, 400, 3000 | 1000, 600, 1000, 600, 700 | 42 | -3 | 21 |
| Hyytiälä | 130, 250, 250, 400, 250 | 100, 100, 100, 100, 100 | 1000, 1500, 2000, 2000, 1000 | 200, 200, 200, 3500, 200 | 2000, 2000, 3000, 200, 2000 | 1000, 1000, 1000, 1500, 1500 | 40 | -5 | 15 |
| Ramat Hanadiv | 70, 9999, 9999, 9999, 140 | 60, 60, 30, 20, 30 | 4000, 1500, 2000, 3000, 4000 | 150, 150, 150, 3500, 150 | 2000, 9000, 9000, 9000, 4000 | 1000, 400, 400, 400, 500 | 43 | 0 | 21.5 |

^aMidsummer, Autumn, Late Autumn, Winter, Spring. When one value is given, only one value is used for all seasons.

Table S10: Seasonal dependence as a function of month and latitude in GEM-MACH Wesely.

| Latitude [° N] | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | | |
|----------------|------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0 | Sum ^a | Sum | Sum | Sum | Sum | Sum | Sum | Sum | Sum | Sum | Sum | Sum | | |
| 30 | TrS | TrS | | | | | | | | | | | | |
| 35 | Win | Win | TrS | TrS | TrS | TrS | TrS | Aut | Aut | LaA | Win | Win | | |
| 40 | | | TrS | | | | | | | | | | | |
| 45 | | | TrS | TrS | TrS | TrS | TrS | TrS | Aut | Aut | LaA | Win | Win | |
| 50 | | | | | | | | | | | | | | TrS |
| 55 | | | TrS | TrS | TrS | TrS | TrS | TrS | Aut | Aut | LaA | Win | Win | |
| 60 | | | | | | | | | | | | | | TrS |
| 65 | | | TrS | TrS | TrS | TrS | TrS | TrS | Aut | Aut | LaA | Win | Win | |
| 70 | | | | | | | | | | | | | | TrS |
| 80 | | | TrS | TrS | TrS | TrS | TrS | TrS | Aut | Aut | LaA | Win | Win | Win |
| 85 | | | | | | | | | | | | | | |
| 90 | TrS | TrS | TrS | TrS | TrS | TrS | Aut | Aut | LaA | Win | Win | Win | | |

^a“Sum” = Midsummer, “TrS” = Transitional Spring, “Win” = Winter, “Aut” = Autumn, “LaA” = Late Autumn after frost.

Table S11: Site-specific parameters for GEM-MACH Zhang.

| Site | r_i | b_{rs} | T_{min} | T_{max} | T_{opt} | b_{vpd} | $\psi_{leaf,1}$ | $\psi_{leaf,2}$ | $c_{cut,dry}$ | $c_{cut,wet}$ | $r_{ac0,min}$ | $r_{ac0,max}$ | r_g | SD_{max} |
|-------------------------|-------|----------|-----------|-----------|-----------|-----------|-----------------|-----------------|---------------|---------------|---------------|---------------|-------|------------|
| Auchencorth Moss | 150 | 40 | 0 | 45 | 20 | 0.27 | -1.5 | -2.5 | 1000 | 200 | 10 | 40 | 200 | 20 |
| Borden Forest | 150 | 44 | -3 | 42 | 21 | 0.34 | -2.0 | -2.5 | 1500 | 300 | 20 | 20 | 500 | 10 |
| Bugacpuszta | 100 | 20 | 5 | 45 | 25 | 0.00 | -1.5 | -2.5 | 2000 | 300 | 20 | 60 | 200 | 50 |
| Easter Bush | 100 | 20 | 5 | 45 | 25 | 0.00 | -1.5 | -2.5 | 2000 | 300 | 20 | 60 | 200 | 50 |
| Ispra | 150 | 43 | 0 | 45 | 27 | 0.36 | -1.9 | -2.5 | 2500 | 200 | 100 | 250 | 200 | 200 |
| Harvard Forest | 150 | 44 | -3 | 42 | 21 | 0.34 | -2.0 | -2.5 | 1500 | 300 | 20 | 20 | 500 | 10 |
| Hyytiälä | 250 | 44 | -5 | 40 | 15 | 0.31 | -2.0 | -2.5 | 2000 | 200 | 100 | 100 | 200 | 200 |
| Ramat Hanadiv | 150 | 40 | 0 | 45 | 30 | 0.27 | -2.0 | -4.0 | 2000 | 400 | 60 | 60 | 200 | 50 |

Table S12: Site-specific parameters for CMAQ M3Dry and M3Dry-psn.

| Site | f_{veg} | r_i | α | V_{cmax} at 25°C |
|------------------|-----------|-------|----------|---|
| Auchencorth Moss | 1 | 100 | 0.07 | 71.1 (Oleson et al., 2013) |
| Borden Forest | 0.95 | 195 | 0.02 | 57.7 (Kattge et al., 2009) |
| Bugacpuszta | 0.95 | 100 | 0.07 | 71.1 (Oleson et al., 2013) |
| Easter Bush | 0.9 | 100 | 0.07 | 71.1 (Oleson et al., 2013) |
| Ispra | 0.95 | 200 | 0.02 | 57.7 (Kattge et al., 2009; Oleson et al., 2013) |
| Harvard Forest | 0.95 | 200 | 0.02 | 30 (Slevin et al., 2015; Ran et al., 2017) |
| Hyytiälä | 0.8 | 175 | 0.02 | 60 (Slevin et al., 2015) |
| Ramat Hanadiv | 0.7 | 200 | 0.02 | 55 (Oleson et al., 2013) |

Table S13: Site-specific parameters for CMAQ STAGE.

| Site | r_i | l |
|------------------|-------|-------|
| Auchencorth Moss | 100 | 0.01 |
| Bugacpuszta | 100 | 0.01 |
| Easter Bush | 100 | 0.01 |
| Ispra | 200 | 0.05 |
| Harvard Forest | 200 | 0.05 |
| Hyytiälä | 175 | 0.005 |
| Ramat Hanadiv | 200 | 0.02 |

Table S14: Site-specific parameters for TEMIR Zhang.

| Site | r_i | b_{rs} | T_{min} | T_{max} | T_{opt} | b_{VPD} | $\psi_{leaf,1}$ | $\psi_{leaf,2}$ | $c_{cut,dry}$ | $c_{cut,wet}$ | $r_{ac0,min}$ | $r_{ac0,max}$ | SD_{max} |
|------------------|-------|----------|-----------|-----------|-----------|-----------|-----------------|-----------------|---------------|---------------|---------------|---------------|------------|
| Auchencorth Moss | 150 | 40 | 0 | 45 | 20 | 0.27 | -1.5 | -2.5 | 5000 | 300 | 20 | 20 | 10 |
| Borden Forest | 150 | 43 | 0 | 45 | 27 | 0.36 | -1.9 | -2.5 | 6000 | 400 | 100 | 250 | 200 |
| Bugacpuszta | 150 | 50 | 5 | 40 | 30 | 0 | -1.5 | -2.5 | 4000 | 200 | 20 | 20 | 20 |
| Easter Bush | 150 | 50 | 5 | 40 | 30 | 0 | -1.5 | -2.5 | 4000 | 200 | 20 | 20 | 20 |
| Ispra | 150 | 43 | 0 | 45 | 27 | 0.36 | -1.9 | -2.5 | 6000 | 400 | 100 | 250 | 200 |
| Harvard Forest | 150 | 43 | 0 | 45 | 27 | 0.36 | -1.9 | -2.5 | 6000 | 400 | 100 | 250 | 200 |
| Hyytiälä | 250 | 44 | -5 | 40 | 15 | 0.31 | -2 | -2.5 | 4000 | 200 | 100 | 100 | 200 |
| Ramat Hanadiv | 150 | 50 | 5 | 40 | 30 | 0 | -1.5 | -2.5 | 4000 | 200 | 20 | 20 | 20 |

Table S15: Site-specific parameters for TEMIR photosynthesis-based approaches.

| Site | CLM4.5 plant functional type | g_{IM} | $V_{cmax,25}$ |
|------------------|------------------------------|----------|--------------------------|
| Auchencorth Moss | C ₃ grass | 5.25 | 78.19 x 10 ⁻⁶ |
| Borden Forest | broadleaf deciduous tree | 4.45 | 57.68 x 10 ⁻⁶ |
| Bugacpuszta | C ₃ grass | 5.25 | 78.19 x 10 ⁻⁶ |
| Easter Bush | C ₃ grass | 5.25 | 78.19 x 10 ⁻⁶ |
| Ispra | broadleaf deciduous tree | 4.45 | 57.68 x 10 ⁻⁶ |
| Harvard Forest | broadleaf deciduous tree | 4.45 | 57.68 x 10 ⁻⁶ |
| Hyytiälä | needleleaf evergreen tree | 2.35 | 62.48 x 10 ⁻⁶ |
| Ramat Hanadiv | C ₃ grass | 5.25 | 78.19 x 10 ⁻⁶ |

Table S16: Site-specific parameters for DO₃SE models.

| Site | g_{max} | f_{min} | T_{min} | T_{max} | T_{opt} | VPD_{min} | VPD_{max} | ϕ_a | ϕ_b | ϕ_c | ϕ_d | ϕ_e | α | g_0 | g_1 | D_0 | $V_{cmax,25}$ |
|------------------|-----------|-----------|-----------|-----------|-----------|-------------|-------------|----------|----------|----------|----------|----------|----------|---------------------------|-------|-------|-------------------------|
| Auchencorth Moss | 0.00146 | 0.01 | 1 | 36 | 18 | 1.0 | 3.0 | 1.0 | 1.0 | 1.0 | 0 | 0 | 0.009 | 0.006 x 10 ⁻⁶ | 10 | 2.15 | 10 x 10 ⁻⁶ |
| Borden Forest | 0.00549 | 0.06 | 0 | 35 | 20 | 1.0 | 3.0 | 0.4 | 1.0 | 0.4 | 20 | 40 | 0.003 | 0.0209 x 10 ⁻⁶ | 8.17 | 2.42 | 36.8 x 10 ⁻⁶ |
| Bugacpuszta | 0.00659 | 0.01 | 12 | 40 | 26 | 1.3 | 3.0 | 1.0 | 1.0 | 1.0 | 0 | 0 | 0.009 | 0.028 x 10 ⁻⁶ | 8.17 | 2.15 | 40 x 10 ⁻⁶ |
| Easter Bush | 0.00659 | 0.01 | 12 | 40 | 26 | 1.3 | 3.0 | 1.0 | 1.0 | 1.0 | 0 | 0 | 0.009 | 0.028 x 10 ⁻⁶ | 8.17 | 2.15 | 40 x 10 ⁻⁶ |
| Ispra | 0.00549 | 0.06 | 0 | 35 | 20 | 1.0 | 3.25 | 0.0 | 1.0 | 0.0 | 15 | 30 | 0.003 | 0.0209 x 10 ⁻⁶ | 8.17 | 2.42 | 36.8 x 10 ⁻⁶ |
| Harvard Forest | 0.00549 | 0.1 | 0 | 35 | 20 | 0.8 | 3.0 | 0.4 | 1.0 | 0.4 | 20 | 40 | 0.0045 | 0.0209 x 10 ⁻⁶ | 8.17 | 2.42 | 36.8 x 10 ⁻⁶ |
| Hyytiälä | 0.00463 | 0.1 | 5 | 33 | 16 | 1.0 | 3.1 | 0.8 | 1.0 | 0.8 | 20 | 40 | 0.006 | 0.0209 x 10 ⁻⁶ | 6.355 | 2.55 | 26.4 x 10 ⁻⁶ |
| Ramat Hanadiv | 0.00475 | 0.02 | 1 | 39 | 23 | 2.2 | 4.0 | 1.0 | 1.0 | 1.0 | 0 | 0 | 0.012 | 0.0021 x 10 ⁻⁶ | 8.17 | 2.25 | 32 x 10 ⁻⁶ |

Table S17: Ozone flux measurements at the sites.

| Site | Time period and temporal frequency of data | Measurement type for ozone flux | Fast ozone analyzer | More details on ozone fluxes ^a | Measurement height for ozone fluxes | References for ozone fluxes | AQMEII4 processing of hourly/half-hourly ozone deposition velocities ^b |
|-------------------------|---|---------------------------------|--|--|-------------------------------------|------------------------------------|---|
| Auchencorth Moss | 1 January 2016 00:00 – 1 January 2018 00:00 LT (UTC+0) Half hourly | Eddy covariance | Gesellschaft Für Angewandte Systemtechnik (Güsten et al., 1992; Güsten and Heinrich, 1996) clone (Coyle, 2006) | Data processing and quality control and assurance follow Muller et al. (2010) for Easter Bush. Absolute ozone fluxes are calculated via the Ratio Offset Method (Muller et al., 2010). | 4.15 m | | Values discarded at beginning of the time series until 6 July 2016 because observed ozone fluxes were roughly a factor of 5–10 lower during this measurement period than for the rest of the observational record and were therefore considered to be unrealistic |
| Borden Forest | 31 December 2007 19:00 – 30 May 2013 15:00 LT (UTC-5) Half hourly | Gradient | N/A | Data are flagged if $[O_3] < 1.0$ ppbv, $u < 1.0$ m s ⁻¹ , $v_d > 1.5$ x the deposition velocity estimated with only aerodynamic and quasi-laminar boundary layer resistances (Wu et al., 2016), or the vertical ozone gradient < 0 | 33 m | Wu et al. (2016, 2018) | flag < 0 removed |
| Bugacpuszta | 1 August 2012 00:30 – 13 January 2014 23:30 LT (UTC+1) Half hourly | Eddy covariance | Dry chemiluminescence (Zahn et al., 2012) | High frequency (10 Hz) data are processed on the basis of the methodology of TK3 software (Mauder and Foken, 2015). The final spectral correction was calculated based on the averaged values from methodology of Ammann et al. (2006) and Mauder and Foken (2015). The random flux error was estimated in Horváth et al. (2018) | 4 m | Horváth et al. (2018) | |
| Easter Bush | 18 May 2001 16:00 – 1 January 2013 00:00 LT (UTC+0) Half hourly | Gradient | N/A | | 2.1 m | Coyle (2006); Muller et al. (2009) | |

| | | | | | | | |
|-----------------------|---|-----------------|--|---|-------|--|--|
| Ispra | 1 January 2013 00:30 – 31 December 2015 23:30 LT (UTC+1) Half hourly | Eddy covariance | Sextant (New Zealand) FOS dry chemiluminescence | High frequency (10 Hz) data are processed with EdiRe software (Mauder et al., 2008). Quality tests are performed on ozone fluxes following Foken et al. (2004). Results of quality tests are combined into three quality flags as described in Sabbatini et al. (2018): good quality (flag 0), acceptable quality (flag 1), and bad quality (flag 2). | 38 m | Visser et al. (2021) | flag = 2 removed and when $[O_3] < 0$ because there are a substantial number of negative $[O_3]$ |
| Harvard Forest | 28 October 1991 00:00 – 12 December 2000 23:00 LT (UTC-5) Hourly | Eddy covariance | Ethene chemiluminescence | | 29 m | Munger et al. (1996); Clifton et al. (2017, 2019) Other meteorological datasets (Munger and Wofsy, 1999; Fitzjarrald and Sakai, 2009) | |
| Hyytiälä | 1 January 2002 00:00 – 31 December 2012 23:30 UTC+2 Half hourly | Eddy covariance | Unisearch Associates Inc. (Concord, Ontario, Canada) LOZ-3 wet chemiluminescence | | 23 m | Keronen et al. (2003); Altimir et al. (2006); Launiainen et al. (2013); Rannik et al. (2009, 2012) | |
| Ramat Hanadiv | 31 July 2015 10:30 - 30 June 2017 21:00 LT (UTC+2) Half hourly | Eddy covariance | Sextant (New Zealand) FOS V2.0.1 dry chemiluminescence | | 6.3 m | Li et al. (2018, 2019) | |

^aDetails are only included here when they are missing from the peer-reviewed literature referenced in the last column, or when flagging for unreliable ozone fluxes.

^bIn addition to Hubert and Vandervieren (2008). When there is additional post-processing, the Hubert and Vandervieren (2008) step comes last.

Table S18: Meteorological and biophysical variables input to the single-point models.

| Site | LAI and <i>h</i> | Snow | Canopy wetness | Other details ^b |
|-------------------------|---|--|--|------------------------------------|
| Auchencorth Moss | Both variables estimated from approximately monthly measurements during 1995 and 1996; a five parameter Pseudo-Voigt peak function is fitted to the measurements using nonlinear regression | Snow depth measured (missing for around half the period) | Measured with a Campbell Scientific Inc. (Utah, USA) Model 237, which indicates whether the surface is wet or dry but may only detect periods of substantial wetness. Thus, values represent the average of measured values within the averaging interval. Values greater than 0 were set to 1 because the site operator | Excluded wind sectors are 60–170°N |

| | | | | |
|-----------------------|---|--|---|---|
| | | | indicates that the instrument cannot reliably provide fractional values. | |
| Borden Forest | <p>h is assumed to be constant throughout the measurement period [22 m]</p> <p>LAI is measured for several tree species, measured approximately weekly during the growing season, and composited to develop a canopy value (Wu et al., 2018)</p> | Not observed, but snow depth measurements from the nearby (15 km) Canadian Air and Precipitation Monitoring Network Egbert site (Wu et al., 2016) are used | Measured with a Campbell Scientific Inc. (Utah, USA) Model 237, which indicates whether the surface is wet or dry but may only detect periods of substantial wetness. Thus, values represent the average of measured values within the averaging interval. Values between 0.2 and 0.6 are considered unreliable by the site operator and are set to missing in this study. | |
| Bugacpuszta | <p>h is measured in each quadrant of the tower every 1 to 2 weeks during summer, fall, and spring, and monthly during winter</p> <p>LAI is measured approximately weekly with light interception measurements (Horváth et al., 2018)</p> | Snow depth measured | Measured with a Campbell Scientific Inc. (Utah, USA) Model 237, which indicates whether the surface is wet or dry but may only detect periods of substantial wetness. Thus, values represent the average of measured values within the averaging interval. | |
| Easter Bush | <p>h measurements are daily to monthly frequency at ten locations in each wind sector</p> <p>LAI measured in 1999 (Milford, 2004) and estimated for other times based on an empirical relationship with h</p> | Not observed | Measured with a Campbell Scientific Inc. (Utah, USA) Model 237, which indicates whether the surface is wet or dry but may only detect periods of substantial wetness. Thus, values represent the average of measured values within the averaging interval. Values greater than 0 were set to 1 because the site operator indicates that the instrument cannot reliably provide fractional values. | Excluded wind sectors are 130–150°N and 305–315°N, leaving the sectors that represent the two fields |
| Ispra | <p>h assumed constant [26 m]</p> <p>LAI has been estimated using a network of 22 PAR sensors deployed below and above the canopy with the Xin et al. (2019) method. During winter when there are no LAI measurements, LAI is gap-filled using linear interpolation. We also fill LAI at the beginning and end of the time series. At the end of the time series, constant values of 3.6 were replaced with multiyear daily average values for 9 November–31 December 2015. At the beginning of the time series, missing values for 1 January – 23 April 2013 were replaced with multiyear daily averages.</p> | Not observed | Measured with S. W. & W. S. Burrage (Kent, UK) SW120, a low power electronic leaf sealed in waterproof resin. The SW120 measures wet or dry and is not sensitive to changes in atmospheric humidity. Half-hourly values are given as 0 or 1. For the last nine months of the time series at Ispra, observed values were always reported as 0 and the CMAQ estimate ^a was used instead | |
| Harvard Forest | <p>h is constant through the period [24 m]</p> <p>Measurements of LAI are available from 1998, 1999 and 2005–2014 (Barford et al., 2001; Munger and Wofsy, 2021) at weekly to biweekly</p> | Not observed | Not observed; modeled ^a | Daily total precipitation measurements are from the nearby Shaler Meteorological Station (Boose and Gould, 1999) and are distributed evenly across the hours of the day in the forcing dataset. |

| | | | | |
|-----------------|---|----------------------------|--|---|
| | <p>intervals through the growing season using a LICOR 2000 plant canopy analyzer across an array of plots extending to 500 m from the tower in the dominant northwest (NW) and southwest (SW) wind sectors of the flux tower. We average across three plots in each sector, interpolate to daily resolution and average across years. The variable <i>LAI</i> differs between these sectors on average by $0.9 \text{ m}^2 \text{ m}^{-2}$. To capture the <i>LAI</i> of the flux footprint, we use NW <i>LAI</i> when wind comes from the NW and SW <i>LAI</i> when wind comes from the SW. When wind comes from the east, we use <i>LAI</i> from the SW. Across years except 1998 and 1999 when we have yearly <i>LAI</i> constraints, we use the average across years with <i>LAI</i> data (1998, 1999 and 2005–2014). During winter except 1999, <i>LAI</i> is set as the minimum observed value. For 1999, we linearly interpolate between the last fall measurement and first spring value of 2000 for a smoother transition. Otherwise, when wind direction data are missing, we interpolate between <i>LAI</i> with non-missing wind direction data.</p> | | | |
| Hyttiälä | <p><i>h</i> based on biomass inventories within 200 m of the tower in 2003, 2008, 2011 and 2015 (Ilvesniemi et al., 2009); at the end of the inventory years, <i>h</i> is calculated as the mean height of overstory trees; in other years <i>h</i> is estimated by linear interpolation</p> <p>Seasonal maximum <i>LAI</i> in the inventory years is estimated with allometric equations (Repola, 2009). Seasonal maximum <i>LAI</i> is then interpolated yearly, with <i>LAI</i> estimated from below-canopy photosynthetic photon flux density measurements to capture the decrease in winter 2009–2010 when crowns of many big trees were brought down by heavy snow. The timing of canopy height and <i>LAI</i> growth is derived from manual measurements of pine shoot and needle elongation 2–3x per week during May–July. The variables <i>h</i> and <i>LAI</i> are assumed to increase linearly during shoot and needle elongation. Seasonal <i>LAI</i> minimum is 75% of maximum <i>LAI</i> based on average needle longevity. The decline of <i>LAI</i> during leaf fall is assumed to be linear from September–October. The first and last months of the year are filled with the seasonal minimum values.</p> | <p>Snow depth measured</p> | <p>Measured with a Vaisala DRD 11-A rain detector, with measured values greater than or equal to 920 indicating dry conditions and values below 920 indicating increasingly wet conditions. The raw values were converted to binary dry versus wet values based on the threshold value of 920.</p> <p>Because the time series suggests almost permanently wet after the start of May 2008, we use the measured values to infer wet/dry conditions through 3 May 2008 but use the CMAQ estimate^a</p> | <p>For soil temperature, no measurements were available for the first four years of the time series between 1 January 2002 and 31 December 2005. These missing data were filled in with multiyear daily average soil temperature values calculated using all non-missing values present in the rest of the time series.</p> |

| | | | | |
|----------------------|---|--|------------------------------------|--|
| Ramat Hanadiv | <i>LAI</i> and <i>h</i> measured in November 2015 and are considered constant otherwise | Not measured but no snow during period | Not observed; modeled ^a | Excluded wind sectors are 233°N to 33°N. Incoming solar radiation data are missing during some periods at this site, so estimates are provided when there is missing data. The reconstruction of the downward solar radiation (DSR) is based on the National Centers for Environmental Prediction/U.S. Department of Energy (NCEP/DOE) Atmospheric Model Intercomparison Project (AMIP)-II Reanalysis-2 data (Kanamitsu et al., 2002) and in-situ global solar radiation (GSR) measurements. The noontime re-analysis data is used to scale DSR. The GSR measurement is used to determine local clouds (clear sky is defined as less than 10% difference between GSR and DSR). For a clear sky day, the DSR reconstruction of that day is based on the ratio between noontime DSR and GSR. For a cloudy day, a virtual noontime GSR peak is reconstructed using Gaussian fitting based on other GSR data points on the same day, which is followed by reconstruction based on the ratio between noontime DSR and GSR. |
|----------------------|---|--|------------------------------------|--|

^aThe CMAQ estimate for fractional canopy wetness (f_{wet}) is based on precipitation (P), relative humidity (RH) and wind speed (u): if $P \geq 0.005 \text{ mm hr}^{-1}$, f_{wet} is set to 1, if $P < 0.005 \text{ mm hr}^{-1}$ and $(0.6 + u)(1 - RH) < 0.19$, f_{wet} is set to 0.5, and if $P < 0.005 \text{ mm hr}^{-1}$ and $(0.6 + u)(1 - RH) \geq 0.19$, f_{wet} is set to 0.

^bThis column contains information as to whether there are excluded wind sectors of the flux datasets, and if assumptions are made in a given input driving variable. If a variable (other than the variables described in other columns of this table, or soil moisture (see Table S17)) has not been described in this column, the variable can be assumed to be measured using standard techniques. We also do the following for all datasets: (1) Sometimes there are small negative observed solar radiation (G) at night in some datasets. Because some models would fail upon input of negative G ; we changed all negative values to missing data except when solar zenith angle $< 70^\circ$ for which we changed negative values to zero. We also fill missing or negative PAR [$\mu\text{mol m}^{-2} \text{ s}^{-1}$] when G is positive and non-missing with: $PAR = 4.566 * 0.45 * G$. The 4.566 is a unit conversion from W m^{-2} to $\mu\text{mol m}^{-2} \text{ s}^{-1}$ and the 0.45 is the assumed PAR fraction of G . (2) Ambient mixing ratios of carbon dioxide ($[CO_2]$) are required for some single-point models. Values at all sites were filled to maximize the number of hours for model prediction. Missing values were filled with the last valid data in the time series. If no previous valid data were available (i.e., the first value of the dataset is missing), the global background value at Mauna Loa (NOAA Global Monitoring Laboratory, 2022) for first year of the time series was used for gap filling.

Table S19: Soil moisture input to the single-point models.

| Site | Value used for w | Value used for w_2 | Measurement depth(s) | Spatial heterogeneity and related measurements | Location of roots | Details regarding gap-filling | Temporal frequency of measurements & any related interpolation | References for soil moisture data |
|-------------------------|-----------------------|-----------------------|---|--|-------------------|--|--|-----------------------------------|
| Auchencorth Moss | Average across depths | Average across depths | 6, 18, 30, and 34 cm below moss layer where peat dominates soil (average peat depth is 50 cm) | Average of four probes used | | | Measured continuously | |
| Borden Forest | 2 cm | 50 cm | 2 and 50 cm depth | Measurements from two sites; Site B is more representative and thus used, except when there is more missing data | | Site A values have been substituted for missing values at Site B | Measured continuously | |

| | | | | | | | | |
|-----------------------|------------------------------|-------------------------------|-----------------------------|---|--|--|---|---|
| | | | | (Site A is a bit lower and closer to a creek) | | | | |
| Bugacpuszta | 3 cm | 30 cm | 3 and 30 cm depth | | Most of the root mass between soil surface and 30 cm (Papp et al., 2018) | | Measured continuously | |
| Easter Bush | constant (0.40) | constant (0.40) | | | Primary rooting zone extends to 31-cm depth (Jones et al., 2017) | Soil moisture measurements were not provided for this site. Given that soil moisture averages about 40–45%, we employ a constant soil moisture value throughout the period. | | |
| Ispra | 10 cm | 30 cm | 10 and 30 cm depth | | About 50% of the root biomass at 0–15 cm depth (Ferréa et al., 2012) | | Measured continuously | |
| Harvard Forest | 15 cm | 15 cm | 15 cm depth | Measurements from three plots in each transect of NW and SW quadrants of tower Soil drainage is heterogenous within tower footprint and varies from nearly saturated surface soils in low areas to moderately well drained high points | Root biomass concentrated in top 15 cm of soil (Abramoff and Finzi, 2019) Large trees access shallow groundwater and are only limited by drought in late summer of the driest years (Urbanski et al., 2007) | Soil moisture for 1991–1994 in the forcing dataset is the 1995–2000 average ^a | Measured approximately weekly during 1995 to 2000 Linearly interpolate values from approximately weekly to daily | Davidson and Savage, (1999); Savage and Davidson (2001) |
| Hyytiälä | Average across 2-5 cm depths | Average across 9-14 cm depths | Measured at multiple depths | Average across five locations | | Any missing soil moisture values from 1 January 2002 – 13 April 2004 were filled using preceding non-missing values (as described for carbon dioxide). In many cases, the missing values for this period were measurements at the bottom of the hour when only measurements at the top of the hour were available. | Measured continuously | |

| | | | | | | | | |
|----------------------|---------------------------|---------------------------|---------------------------------|--|---|---|---|-------------------------|
| | | | | | | Between 14 April 2004 and 12 January 2005, missing soil moisture data was more prevalent, and any missing data for this period was filled in with day-of-year average soil moisture values calculated using all non-missing values present in the unfilled time series. | | |
| Ramat Hanadiv | Average across 0 to 20 cm | Average across 0 to 20 cm | Average across 0 to 20 cm depth | | About 50% of the roots expected between 10 to 40 cm depth | Inferred using observed values for evergreen shrubs for January 2008 to July 2010 | Measured at a frequency of approximately at few weeks to a few months Values are linearly interpolated to daily for 2008 to 2010. Daily values are then averaged across years and months to create multiyear monthly averages. Multiyear monthly averages are placed as each month's 15th day. Values are then linearly interpolated to daily frequency. | Grünzweig et al. (2010) |

^aSoil moisture from one plot is missing in 2000 because the site was flooded. Because this plot, which is adjacent to a wetland, strongly influences the site-level average, we substituted the 1995-1999 mean for this plot's missing data in creating the site-level average.

Table S20: Soil hydraulic properties.^a

| Site | w_{fc} | w_{wlt} | w_{sat} | B | $\psi_{soil,sat}$ |
|-------------------------|----------|-----------|-----------|-------|-------------------|
| Auchencorth Moss | 0.75 | 0.114 | 0.86 | 2.66 | -7 |
| Borden Forest | 0.24 | 0.078 | 0.402 | 4.46 | -1.00 |
| Bugacpuszta | 0.225 | 0.081 | 0.389 | 4.9 | -0.69 |
| Easter Bush | 0.297 | 0.138 | 0.411 | 6.53 | -1.19 |
| Ispra | 0.209 | 0.059 | 0.393 | 3.97 | -0.811 |
| Harvard Forest | 0.29 | 0.0954 | 0.425 | 4.508 | -1.79 |
| Hyttiälä | 0.205 | 0.0522 | 0.397 | 3.66 | -0.899 |
| Ramat Hanadiv | 0.304 | 0.1 | 0.43 | 4.52 | -4.98 |

^aSoil hydraulic properties are estimated from soil texture when the silt, sand and clay fraction (Table 2) are reported following Clapp and Hornberger (1978) using Colorado State University's Soil Hydraulic Properties (2022) calculator. This tool assumes a field capacity ($\psi_{soil,fc}$) and wilting point ($\psi_{soil,wlt}$) soil matric potentials of -10 kPa and -1500 kPa, respectively. When soil texture information is not completely available, qualitative soil description (e.g., course, sandy loam, fine), and the USDA Soil Texture Calculator (2022) is used to constrain textural estimates. Because the Clapp and Hornberger (1978) relationships do not consider soil organic matter, soil hydraulic properties at Auchencorth Moss are estimated from observed soil moisture data and resulted in values that are similar to undecomposed sphagnum estimated by Verry et al. (2011).

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