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Phenological controls on inter-annual variability in ozone dry deposition velocity

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Our understanding of ozone removal by northern mid-latitude temperate deciduous forests is largely based on short-term observational studies, and thus year-to-year variations of this sink have received little attention. The specific pathways for ozone dry deposition include stomatal uptake and other non-stomatal processes that are poorly understood. Given the importance of ozone dry deposition to model accurately the tropospheric ozone budget and regional air quality, an improved mechanistic understanding of this ozone sink is needed. We investigate here the physical and biological controls on inter-annual variations in seasonal and diurnal cycles of ozone dry deposition velocity using nine years of hourly observations of eddy covariance ozone flux and concentration measurements at Harvard Forest, a northern mid-latitude temperate deciduous forest. We also use coincident eddy covariance water vapor flux and sensible heat flux and other micrometeorological measurements to infer stomatal conductance in order to separate the impacts of stomatal versus non-stomatal pathways on ozone deposition.

There is a difference of approximately a factor of two between minimum and maximum monthly daytime mean ozone dry deposition velocities at Harvard Forest. The highest summertime mean ozone dry deposition velocities occur during 1998 and 1999 (0.72 cm/s), and similar seasonal and diurnal cycles occur in both years. The similar dry deposition velocities during these two years, however, may reflect compensation between different processes as mean daytime summertime stomatal conductance during 1998 is roughly 1.5 times higher than for 1999, suggesting large year-to-year variations in non-stomatal as well as stomatal uptake of ozone.

We partition the onset and decline of the growing season each year into different periods using spring and fall phenology observations at Harvard Forest. Combining the dry deposition velocities across years during each phenological period, we find that differences emerge in the shape of the mean diurnal cycles. We conclude that neglecting year-to-year differences in the timing of different periods in the the onset and decline of the growing season (as defined by the phenology observations) will lead to biases in mean ozone dry deposition velocity as represented in models. We further demonstrate the potential for these transitional periods, as defined by phenological measurements, to be represented with backwards two-week running means of gross primary productivity, a variable which should be readily available from dynamic vegetation models and thus could be used to parameterize dry deposition in earth system models that include atmospheric chemistry.