The role of climate-ecosystem interactions on summer time ground level ozone pollution

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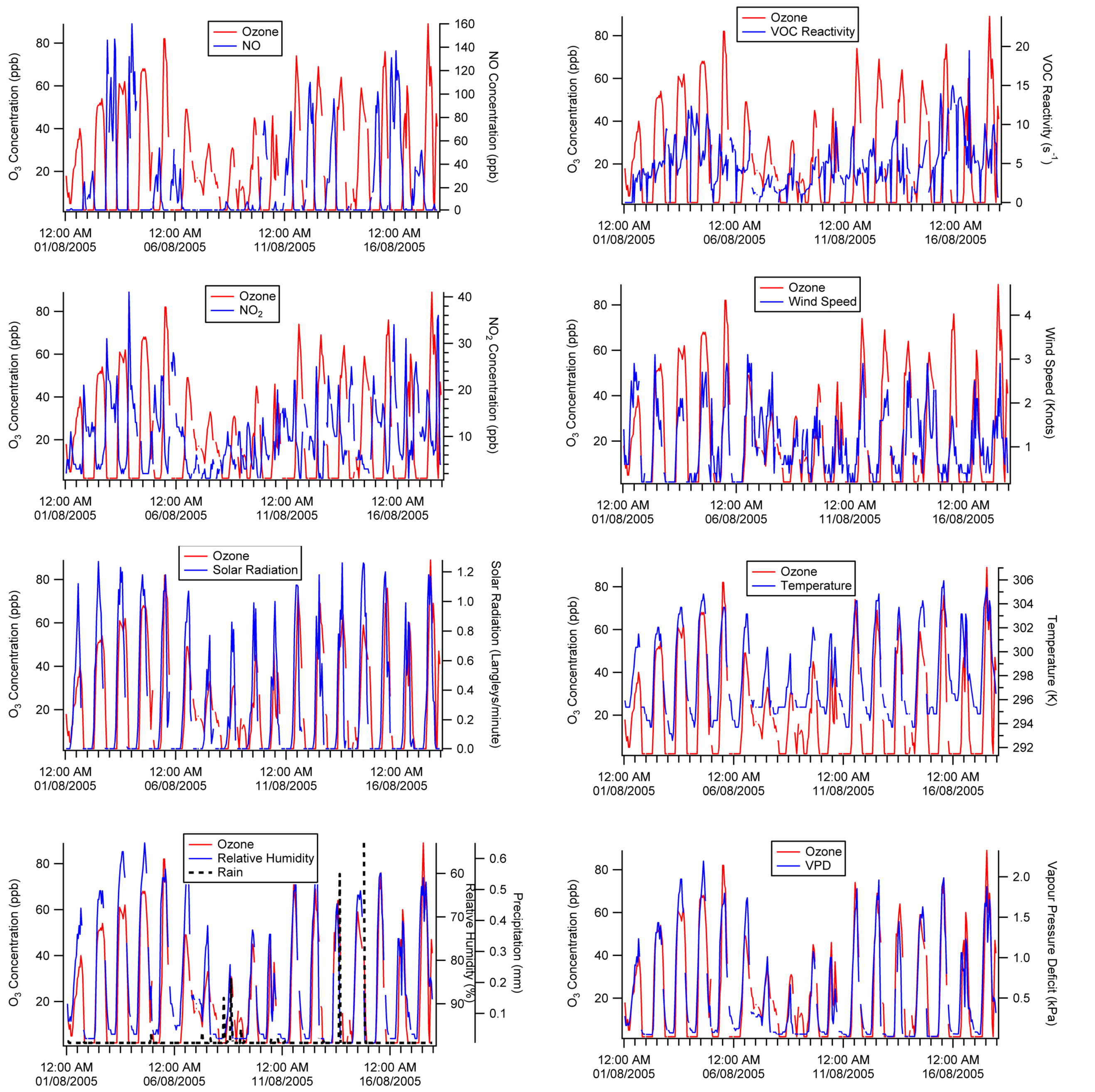
Ozone-Meteorology Correlations

Temperature and relative humidity are known to be the dominant predictors for summer-time ozone concentration in much of the United States[1,2,3], but a full explanation for the spatial patterns seen in ozone-meteorology correlations has been lacking.

We want to know: **What controls the day-to-day variability seen in ground level ozone concentrations?**

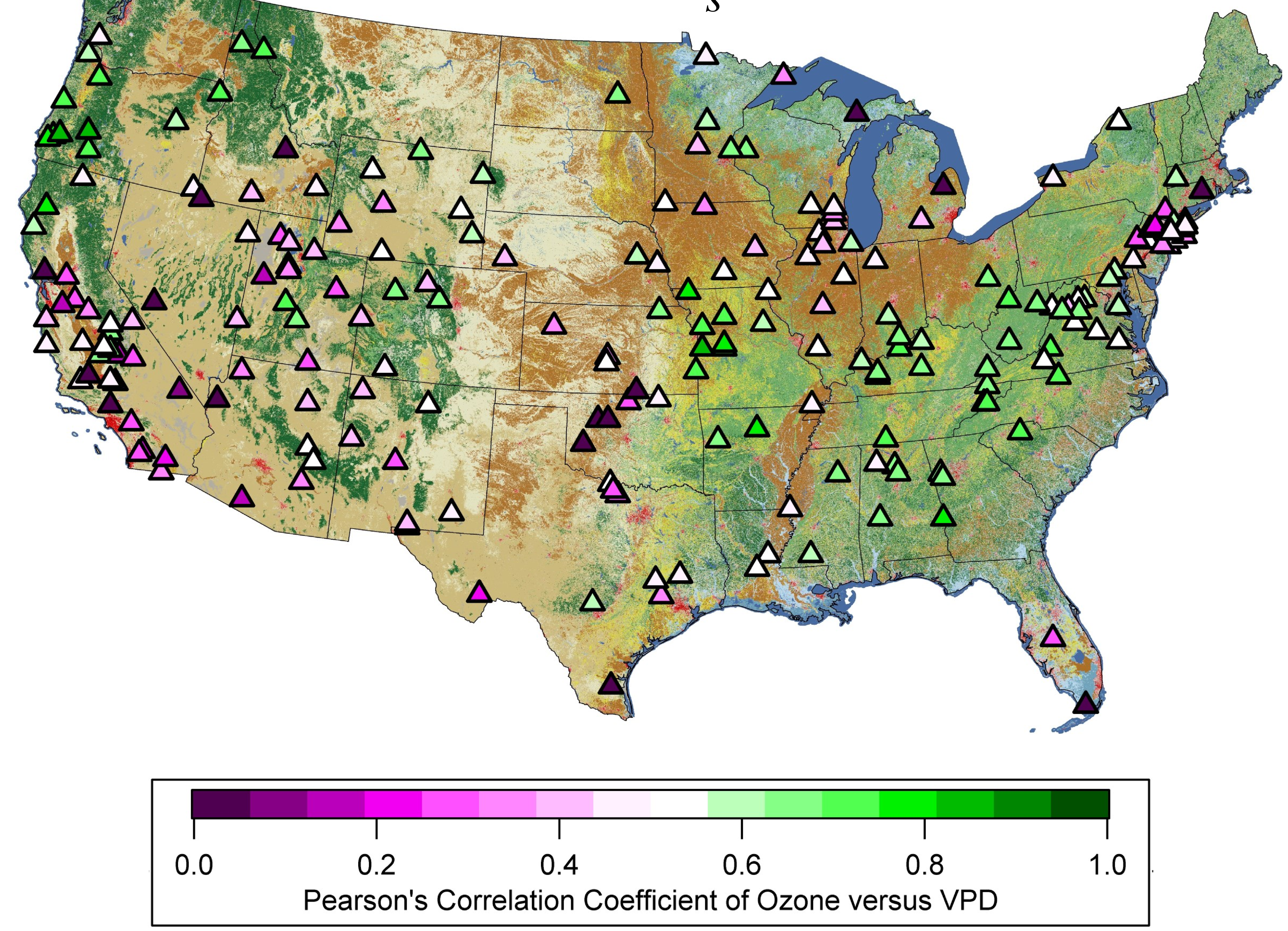


Surface measurements from EPA-AQS and PAMS station 13-089-002 located in Atlanta, Georgia.

At numerous urban and rural sites in the South-East and North-West, vapour pressure deficit is the primary predictor for peak daily summer time ozone concentration.

Correlation Between Ozone and Vapor Pressure Deficit

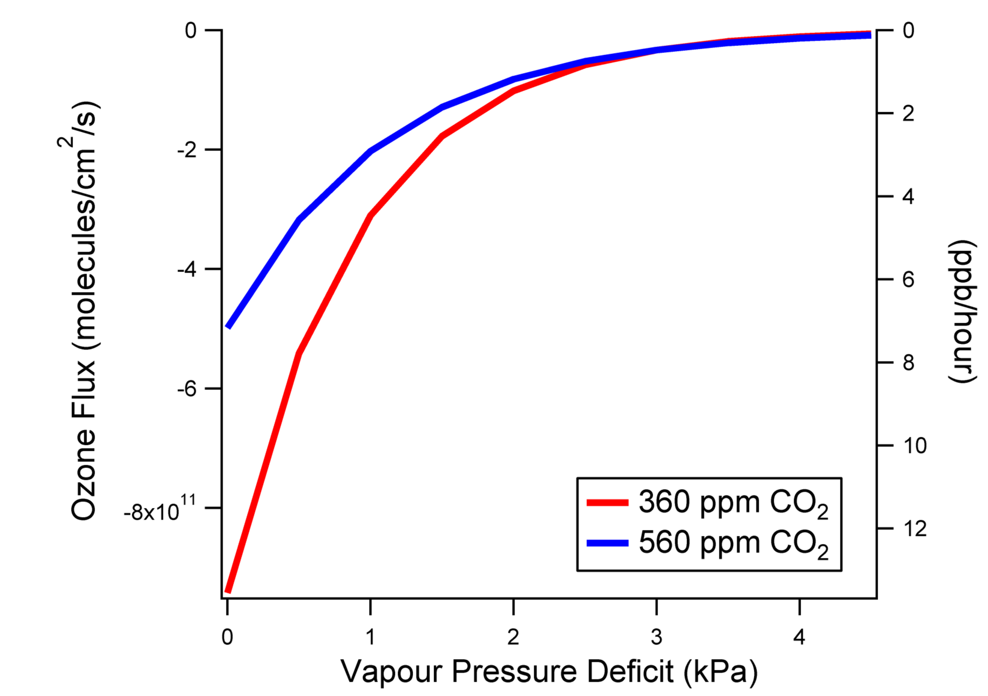
$$VPD = e_s - e$$



Pearson's correlation coefficient (R) between observed surface ozone concentration and vapour pressure deficit between 12:00 and 16:00 at EPA-AQS stations for the month of August 1994-2013.

Consequences for Urban Air Quality

The importance of ozone dry deposition in forests is well known, but numerous cities, with elevated ozone levels, have LAI comparable to that of naturally vegetated spaces .

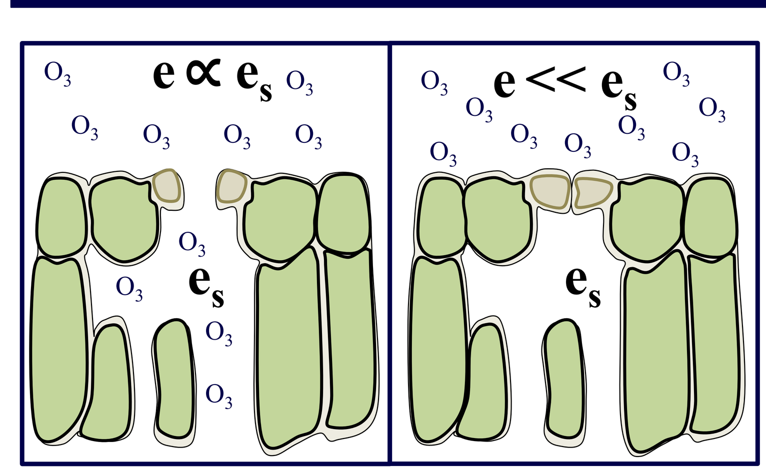


Above is an inferred O_3 flux-VPD relationship for Atlanta, Georgia (LAI 2.2 m^2/m^2) based on the stomatal resistance-VPD relationship for *Liquidambar styraciflua*, the most prevalent tree species in Atlanta, Georgia, obtained by [6]. Flux assumes 65ppb ozone, loss rate assumes 1km mixing height**. Significant changes to the ozone loss rate are apparent over the range of observable VPDs**, suggesting the observed meteorological correlation may have mechanistic significance

Conclusions

Afternoon ozone concentrations in the summer are strongly coupled with VPD in non-drought stressed regions of large LAI suggesting that **VPD-dependent enhanced stomatal resistance is a significant factor in summer time ozone episodes**. The stomatal resistance-VPD relationship may explain spatial patterns seen in O_3-temperature and O_3-humidity correlations.

Stomatal Uptake of Ozone



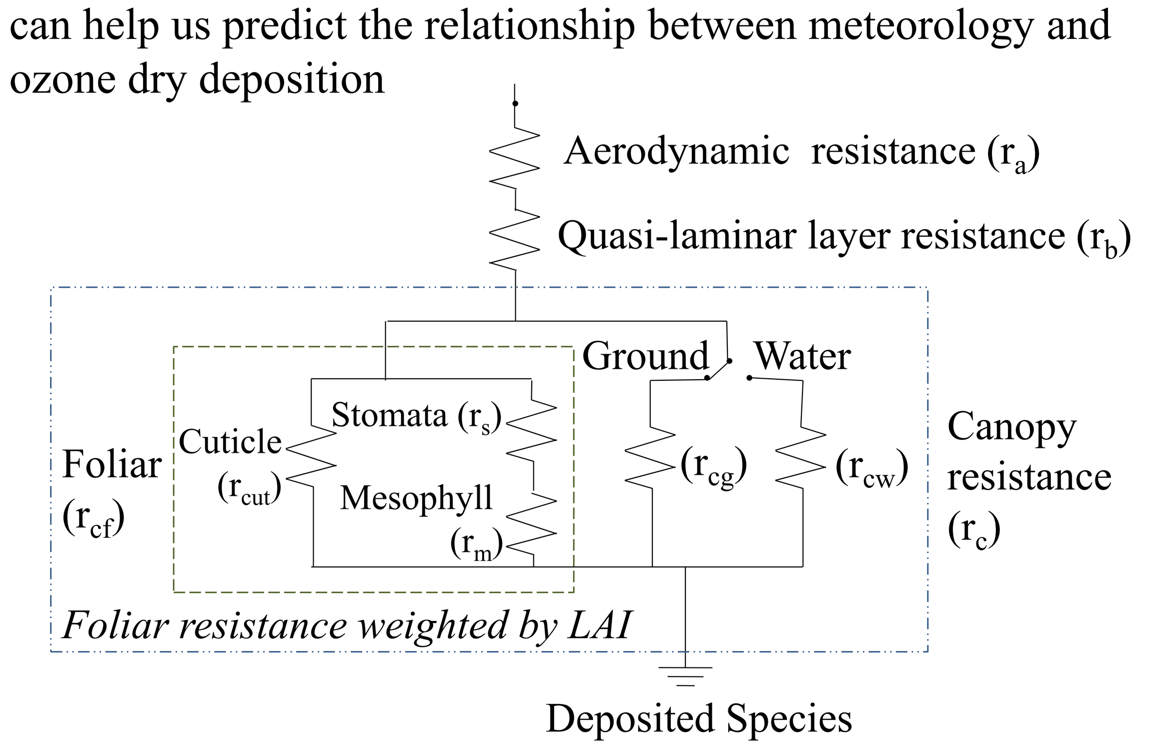
In non-drought stressed plants, stomatal resistance is controlled by response to sunlight , CO_2, temperature, and vapour pressure deficit (VPD). **VPD is the difference between ambient vapour pressure, e, and saturated vapour pressure, e_s** and is thus coupled with humidity and temperature.

Dry deposition is the main removal process for boundary layer O_3, and stomatal uptake can account for up to 90% of that sink[4,5]. During most afternoons in the growing season, stomatal resistance, r_s, is the primary factor controlling the dry deposition of ozone in regions with high leaf area indices (LAI).

Stomatal resistance-vapour pressure deficit relationships have been derived for many species of plants at various CO_2 concentrations. Many tree species common to the US show a strong correlation between stomatal resistance and VPD.

Resistance Scheme for Dry Deposition

Coupled with a scheme for modelling dry deposition, these experimentally determined resistance-meteorology relationships can help us predict the relationship between meteorology and ozone dry deposition



The flux of ozone, F, is proportional to the concentration, C, at some height.

$$F = -v_d C$$

Where the proportionality constant, v_d, is called the deposition velocity , and given by,

$$v_d = \frac{1}{r_a + r_b + r_c}$$

Implications for Modeling

Numerous chemical transport models use the Wesely parameterization for stomatal resistance to gaseous pollutants:

$$r_s = r_{s\,min}\{1+[200(G+0.1)^{-1}]^2\}\{400[T(40-T)]^{-1}\}$$

This parameterization does not account for response to vapour pressure deficit, which may explain observed biases and difficulty capturing day-to-day variability of ozone.

References

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Acknowledgments

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