FOREST MICROMETEOROLOGICAL RESPONSES TO INCREASED CO_2 AND O_3 CONCENTRATIONS

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ABSTRACT
The Forest-Atmosphere Carbon Transfer and Storage (FACTS-II) Project in northern Wisconsin is examining the interacting effects of elevated carbon dioxide (CO_2) and ozone (O_3) concentrations on the productivity, sustainability, and competitive interactions in a regenerating northern hardwood ecosystem. A key component of this project involves an examination of the micrometeorological feedback mechanisms that can alter atmospheric environments within and above vegetation layers exposed to elevated CO_2 and O_3 concentrations. This paper provides a brief summary of some of the observed forest micrometeorological responses to elevated CO_2 and O_3 concentrations at the FACTS-II study site over the 1999-2004 period.

INTRODUCTION
Large-scale (as opposed to laboratory) experiments are usually needed for examining all the potential interactions and feedbacks involved in total ecosystem responses to increasing concentrations of CO_2, O_3, and other atmospheric greenhouse gases associated with global climate change. In response to this need and specifically for addressing temperate forest responses to increasing CO_2 and O_3 concentrations, the Forest-Atmosphere Carbon Transfer and Storage (FACTS-II) Project in northern Wisconsin was established in 1998 [*Dickson et al*. 2000]. The FACTS-II Project incorporates free-air carbon dioxide enrichment (FACE) system technology applied to field plots of trembling aspen (*Populus tremuloides* Michx.), paper birch (*Betula papyrifera* Marsh.), and sugar maple (*Acer saccharum* Marsh.), three species common to forests in the Great Lakes region of the U.S.

A core component of the FACTS-II Project is an assessment of the small-scale feedback mechanisms responsible for further altering atmospheric environments within and above vegetation layers exposed to elevated CO_2 and O_3 concentrations. To that end, a micrometeorological monitoring network was established at the FACTS-II study site in 1999 to gather continuous, long-term data for examining (1) near-surface atmospheric changes induced by aspen, birch, and maple vegetation responses to elevated CO_2 (560 ppm) and O_3 (1.5 x ambient) concentrations and (2) the secondary effects of these induced micrometeorological changes on forest ecosystems.

MICROMETEOROLOGICAL OBSERVATIONS
Micrometeorological observations are presented for four 30-m diameter treatment plots, each containing plantings of aspen, maple, and birch established in 1998. Using the FACE system technology, one plot has been fumigated with CO_2 to produce an inner plot concentration of ~560 ppm throughout each growing season. Another plot has been fumigated with O_3 to produce an inner plot concentration of ~1.5 times the ambient O_3 concentration at the study site location throughout each growing season. A third plot has been fumigated with both CO_2 and O_3 to assess the combined effects of both gases on the vegetation. The fourth plot serves as a control plot, with no CO_2 or O_3 fumigation.

After seven years (1998-2004), the individual treatment plots have exhibited significant variations in those micrometeorological conditions that govern the turbulent transport of heat, moisture, and chemicals through the vegetation layers. Fig. 1 shows the 1999-2004 April-September trends in the number of days each month when the mid-afternoon (1500 LT) gradient Richardson number (Ri) (calculated from wind and temperature observations within and above each treatment plot) was less than -0.03, the threshold for free convection flow. The increased vegetation growth in the CO_2-fumigated plot over the seven-year period resulted in a substantial reduction in the number of days each month during the growing season when the daytime atmospheric turbulence structure within and above the plot was dominated by buoyancy. In effect, the CO_2 fumigation decreased the instability of the atmospheric environment within and just above the treatment plot, thereby decreasing the amount of vertical turbulent transport of heat, moisture, and chemicals through the vegetation layers. Fig. 1 also suggests that increased CO_2 concentrations in the presence of increased O_3 concentrations do not result in a similar instability decrease; buoyancy plays a significant role in governing the overall turbulence structure in the CO_2+O_3 treatment plot, just as it does for the O_3 and control plots. At night, the vegetation responses to the different fumigation treatments did not result in substantial differences among the plots in the number of occurrences of Ri exceeding 0.25, the threshold for the complete suppression of atmospheric turbulence by buoyancy.

Observed near-surface net radiation values among the different treatment plots were consistent with the Ri behavior in the plots, with average mid-afternoon net radiation values in the CO_2 treatment plot generally lower than the values observed in the other plots. During the nighttime, net radiation differences among the plots were minimal. The variation of Ri with near-surface net radiation in each plot indicates that the threshold for free convective flow (Ri < -0.03) was more likely to be exceeded for net radiation values in the 100-400 W m^{-2} range in the O_3, CO_2+O_3, and control plots than in the CO_2 plot. Furthermore, net radiation values in the 0-100 W m^{-2} range were more likely to be associated with positive Ri values between 0 and 0.25 (stable wind-shear dominated turbulence regime) in the CO_2 plot than in the other plots.

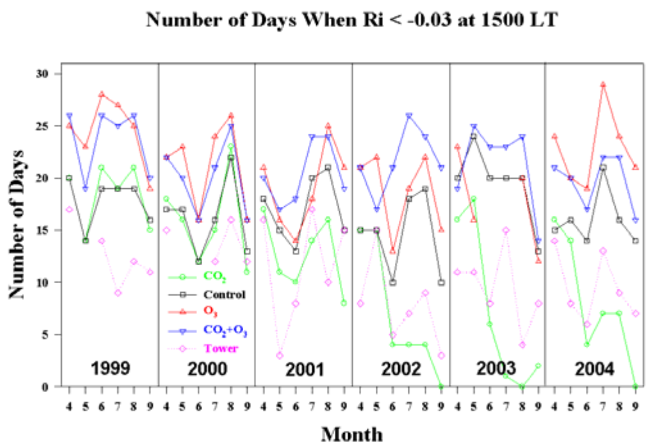

Fig. 1. Number of days each month (April-September) for years 1999-2004 when the near-surface Ri < -0.03 at 1500 LT in the CO_2, O_3, CO_2+O_3, and control plots, and at a tower site outside the treatment plots at the FACTS-II study site.

Collectively, these findings suggest that (1) while increased CO_2 concentrations in the atmosphere can have a warming effect on the global atmosphere, the response of forest vegetation to greenhouse gases may lead to a more stable near-surface atmosphere with fewer days dominated by very unstable free-convection conditions for certain types of forest-atmosphere environments, and (2) elevated CO_2 concentrations in the presence of elevated O_3 concentrations may not result in the same stability enhancements within forest-atmosphere environments that are suggested when only CO_2 concentrations are elevated. It is this near-surface atmospheric stability condition that governs the amount of vertical transport and diffusion of moisture and chemicals through forest vegetation layers and into the atmospheric boundary layer above.

REFERENCES

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