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The Forest-Atmospheric Carbon Transfer and Storage-II (FACTS-II): Aspen FACE Project

NCASI Project Report (January 1998)

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Environmental Biology and Instrumentation Division

DISCLAIMER

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The Forest-Atmospheric Carbon Transfer and Storage-II (FACTS II): Aspen FACE Project

NCASI Project Report (January 26, 1998)

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Summary

The FACTS II (ASPEN FACE) infrastructure including 12 FACE rings, a central control facility, a central CO_2 and O_2 receiving and storage area, a central O_3 generation system, and a dispensing system for CO_2 and O_3 was completed in 1997. The FACE rings were planted with over 10,000 plants (aspen, birch and maple). The entire system was thoroughly tested for both CO_2 and O_3 and was shown to be effective in delivering elevated CO_2 and/or O_3 on demand and at predetermined set points. The NCASI support to date has been extremely helpful in matching support for federal grants.

This research was performed under the auspices of the U.S. Department of Energy under contract No. DE-AC02-76CH00016.

The Free-Air CO_2 Enrichment (Aspen FACE) facility at the Harshaw farm site (USFS land) near Rhinelander, Wisconsin, has been established to examine the influence of greenhouse gases (CO_2, O_3) on a northern forest ecosystem. We have constructed twelve 30-m diameter FACE rings (3 controls, 3 with elevated O_3 [O_3 to be administered according to a modified ambient profile from southern Michigan and with a target total summer dose of 100 ppm-hr], 3 with elevated CO_2 [ambient + 200 ppm], and 3 with elevated O_3 + CO_2 (Figure 1). A central gas distribution center has been constructed with a central receiver CO_2 tank and its associated ambient air vaporizer unit and an oxygen receiver tank and ambient air vaporizer unit (Figure 2). Ozone is generated in a central building adjacent to the O_2 tank. Then O_3 and CO_2 are piped out to the rings. Gas dispensing and monitoring is done from a monitoring shed at each ring and is controlled from a central computer facility that is interfaced to the sheds via a double loop fiber optic system.

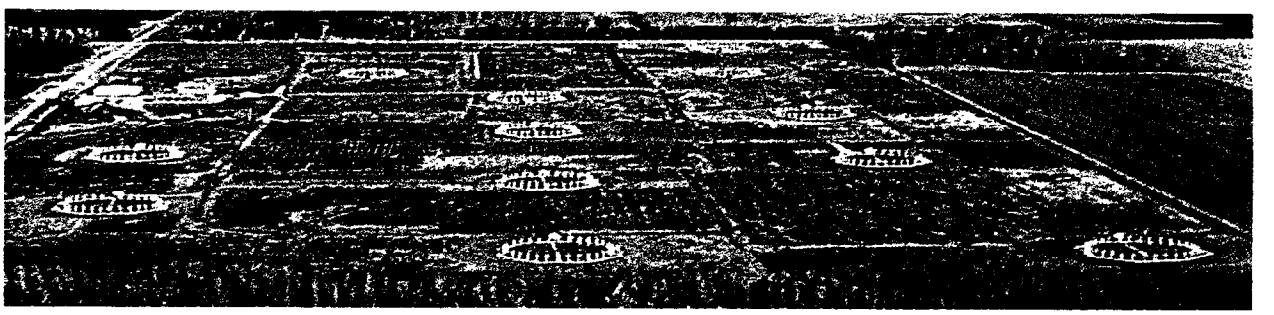


Figure 1. The twelve 30-m diameter Free-Air CO_2 Exposure (FACE) rings making up the FACTS II (Aspen FACE) experiment in northern Wisconsin. There are 3 rings each of controls, elevated CO_2, elevated O_3, and elevated CO_2 + O_3. The gases are dispensed and monitored from a central control facility (top left corner of the 20 ha site which is entirely enclosed in a deer fence).

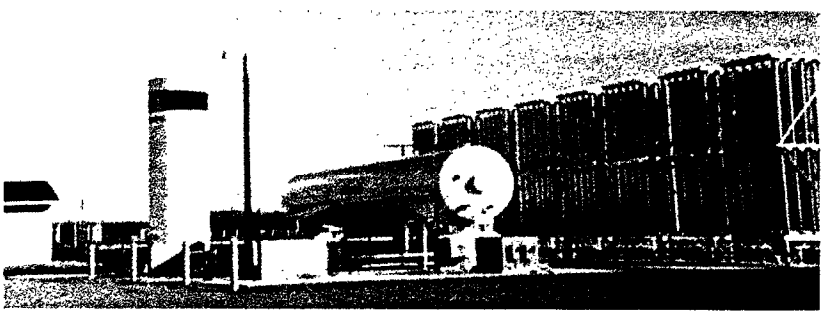


Figure 2. The central gas distribution system for the FACTS II (Aspen FACE) experiment. The horizontal receiver is for storage of CO_2 and the steel columns to its right are the ambient air vaporizers for vaporizing CO_2. The vertical receiver is for oxygen which is used for generating O_3 from a large capacity O_3 generator in the building on the left. Gaseous O_3 and CO_2 are piped to the various FACE rings.

Each FACE ring is divided into three parts by a central walk-way (Figure 3). One-half of the ring is planted at 1 m x 1 m spacing to 1-year-old plants of 5 trembling aspen clones differing in their O_3 or CO_2 responsiveness (Figure 4). The other one-half of the ring is divided into two sections: one planted with aspen clone 216 (tolerant) and sugar maple seedlings (1-year-old) intermixed at 1 m x 1 m. There are 5 border rows of aspen around each FACE ring. An irrigation system was constructed for all 12 rings and used to supplement rain events during the first growing season.

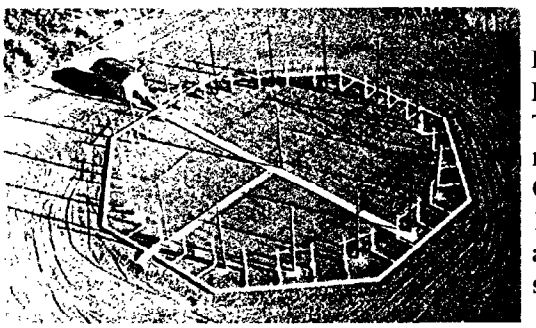


Figure 3. Each 30-m diameter FACE ring in the FACTS II (Aspen FACE) experiment is divided into 3 parts by the walkways shown. The area above the walkway is planted at 1 m x 1 m spacing with ramets of trembling aspen clones varying in their responsiveness to CO_2 or O_3. The bottom left and bottom right sections are planted at 1m x 1m spacing with an alternating sugar maple and trembling aspen or paper birch and trembling aspen, respectively, to allow for study of species competition.

Figure 4. A typical trembling aspen plant in the FACTS II (Aspen FACE) project.

In order to accommodate dispensing of both CO_2 and O_3 from our vertical vent pipes, we modified our gas injection system (Figure 5) in two ways as compared to that system used at the FACTS I (DUKE) experiment. First to accommodate a larger flow rate to dilute O_3 concentrations coming out of the vertical vent pipe (so we would not have extremely high O_3 concentrations near the vertical vent pipes), we changed from a hole configuration to a slot (Figure 6). We oriented the vertical vent pipe so it was pointed away from the center of the ring and placed a set of baffles to redirect air coming from the vertical vent pipes into the FACE ring. Finally, we added a flashing on top of the baffles to direct air down and into the ring. Together, these modifications improved the stability and distribution of both CO_2 and O_3 in our FACE rings. CO_2 and O_3 are dispensed from the upwind side of each ring and monitored at plot centers (Figure 7).

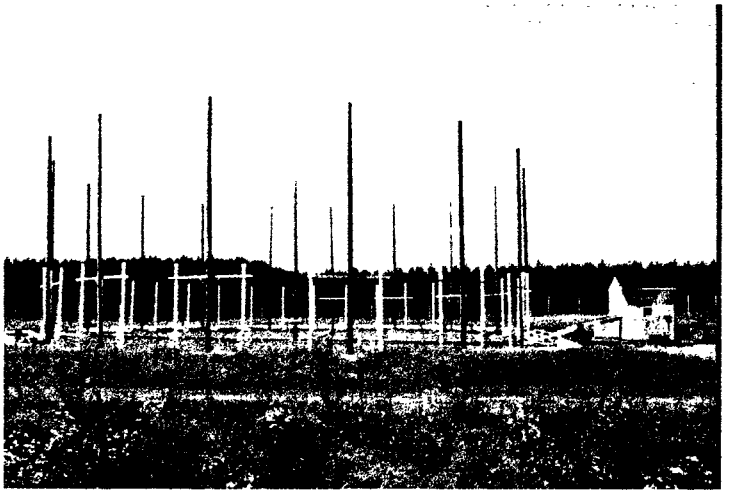


Figure 5. A typical FACE ring in the FACTS II (Aspen FACE) experiment and its associated control shed.

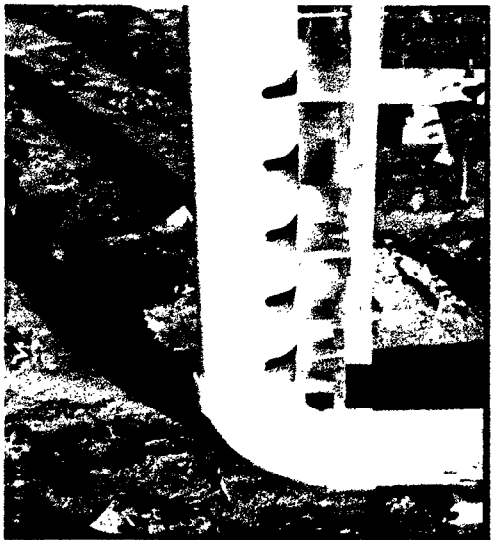


Figure 6. The CO_2 injection system in the FACTS II (Aspen FACE) experiment utilizes slots, baffles, and flashing as shown here. The vertical vent pipe is oriented with the slots and baffles facing out from the center of each ring.

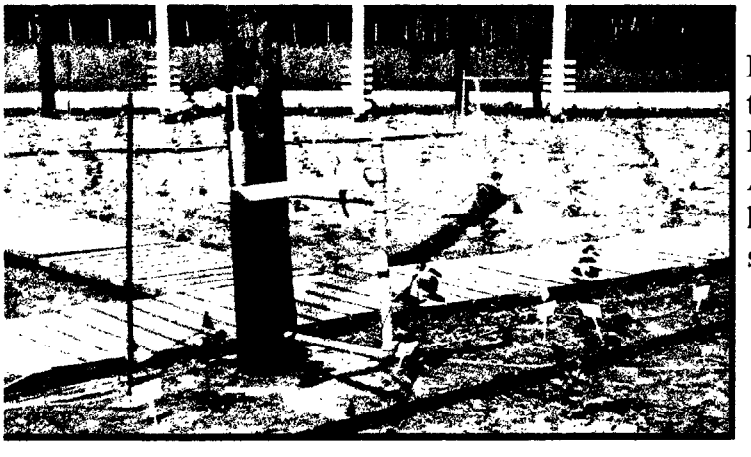


Figure 7. CO_2 and O_3 are monitored in the center of each FACE ring at the FACTS II (Aspen FACE) experiment. Also shown here are the micrometeorological equipment for determining wind speed and direction.

The CO_2 system was run for 40 days beginning on August 21 to test the system and to examine plant responses to daylight-only versus 24-hour CO_2 exposures. The O_3 system was run for approximately 25 days in October (after leaf drop) to test the system. Simultaneous CO_2 and O_3 exposures were run for several days in October. Control of both CO_2 and O_3 was excellent under winds from 0.5 m/sec to 5.0 m/sec which are typical of daylight wind conditions at our site. During these conditions, we were able to maintain CO_2 and O_3 concentrations within 10% of our target value 90% of the time and within 20% of our target value nearly 98% of the time (Figures 8 and 9). Multiport systems were established at two FACE rings to allow for a thorough characterization of gas distribution. These pointed out the hot spots near the upwind vertical vent pipes where our border row trees are located but indicated an excellent gas distribution across the experimental trees.

We have thoroughly characterized all trees and all plots in the experiment. Heights, diameters, and leaf numbers of all trees were taken at the time of planting. Baseline leaf epicuticular wax chemical composition, particulate chemical composition using SEM-EDAX, and wax structure using SEM was completed in 1997. Soil samples from multiple points and various depths were taken from each ring for characterization of soil properties and soil microbiology. Leaves from all rings and all species were taken for foliar nutrient analysis and to characterize antioxidants. Our first year of our experiment will commence with bud break in 1998.

We view the FACTS II (Aspen FACE) site as a user facility and we encourage participation by interested scientists. Currently, we have over 30 U.S. collaborators and 8 foreign scientists involved in our site. We have garnered support from several other sources including the U.S. Department of Energy, the USFS Global Change Program, the National Science Foundation (Biology and Academic Infrastructure Programs), Brookhaven National Lab, the Finnish Academy of Sciences, the University of Wisconsin Foundation, Natural Resources Canada - Canadian Forest Service, and Michigan Technological University.

Presentations and Publications

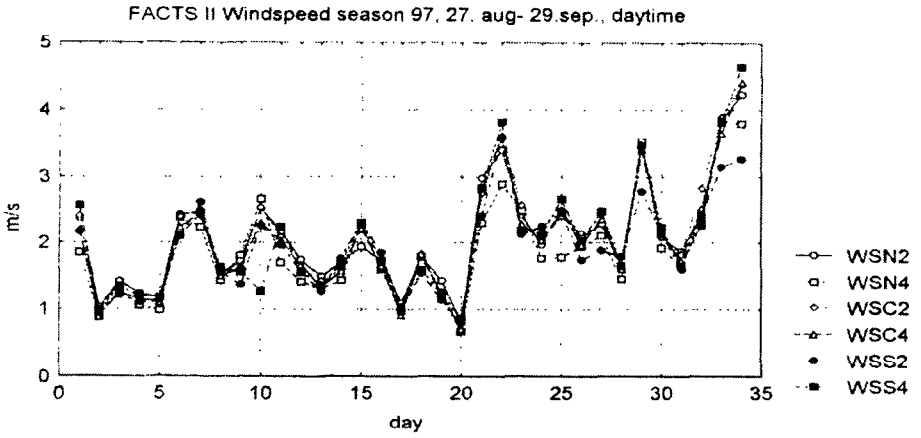
Coleman, M., E. Kruger, J. Vogel, G. Hendrey, J. Nagy, K. Lewin, R. Dickson, J. Isebrands, J. Sober, M. Kubiske, G. Host, W. Heilman, K. Pregitzer, and D.F. Karnosky. 1997. Daily CO_2 exposure regimes, daytime-only versus 24-hour: Results from FACTS II (Aspen FACE) experiment. Third International IGBP-GCTE Workshop. Raleigh, N.C. (Submitted to *Tree Physiology*).

Karnosky, D.F. 1997. Early progress and results from the FACTS II (Aspen FACE) experiment. DOE Science Team Meeting. Raleigh, N.C.

Hendrey, G., M. Coleman, K. Lewin, J. Nagy, J.G. Isebrands, R. E. Dickson, J. Sober, and D. F. Karnosky. 1997. Advances in the CO_2 injection system in the FACTS II (Aspen FACE) experiment. Third International IGBP-GCTE Workshop. Raleigh, N.C.

Isebrands, J.G., G. Hendrey, M. Coleman, K. Lewin, J. Nagy, J. Sober, E. Kruger, K. Pregitzer, and D.F. Karnosky. 1998. Experimental design and early performance of FACTS II (Aspen FACE) in Wisconsin, USA. GCTE/LUCC Open Science Conference on Global Change. Barcelona.

Isebrands, J.G., J. Rebbick, R.E. Dickson, and D.F. Karnosky. 1998. The interacting effects of multiple stresses on the growth and physiological processes in northern forest trees. In: J. Hom, R. Birdsey, and R.A. Mickler (Eds.). Responses of Northern U.S. Forests to Environmental Changes. Springer Verlag (In Press).



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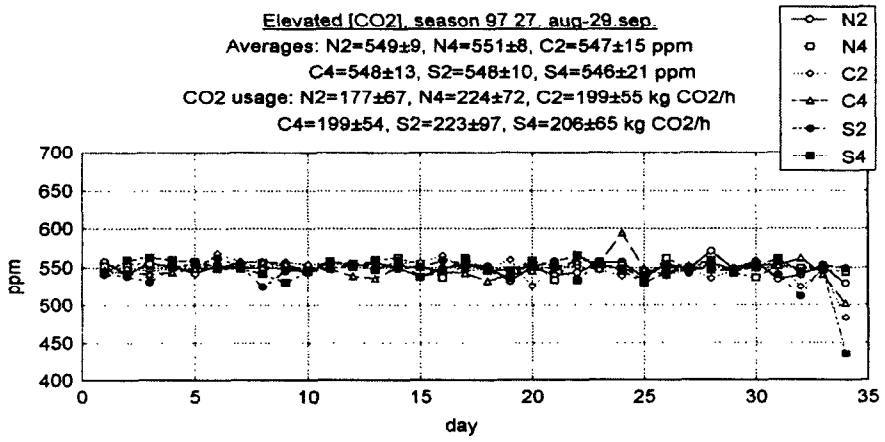

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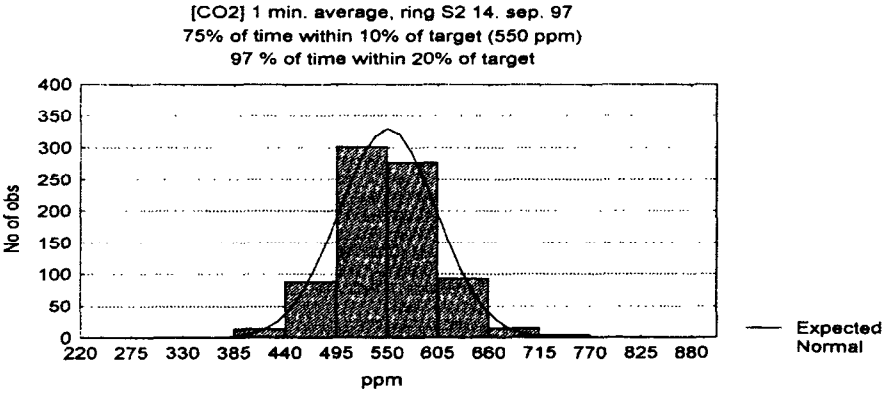
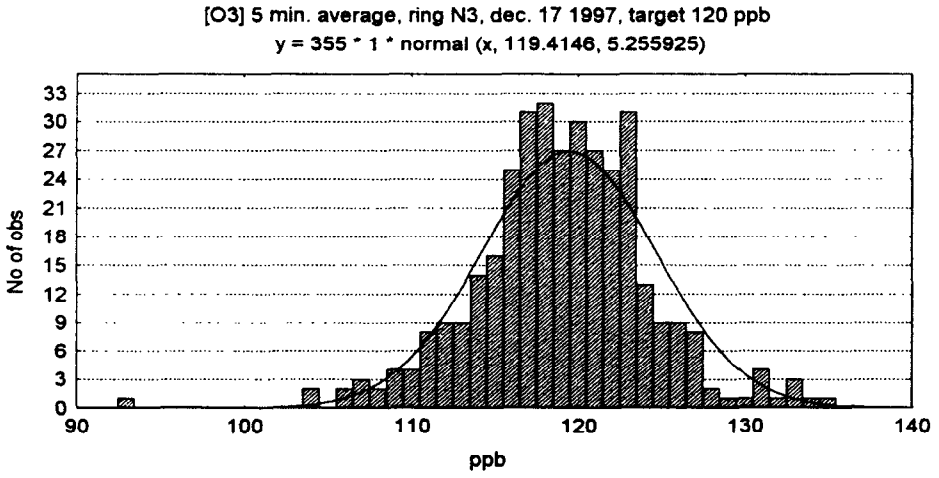


C

Figure 8. The CO_2 control in the FACTS II (Aspen FACE) experiment is illustrated here. During highly variable wind conditions (A), we still maintained very uniform CO_2 concentrations at ambient plus 200 ppm (B). Only at the highest wind conditions (day 34) did we lose CO_2 control. The distribution of CO_2 around our set point (550 ppm) for a single ring and single day is shown in (C) above.



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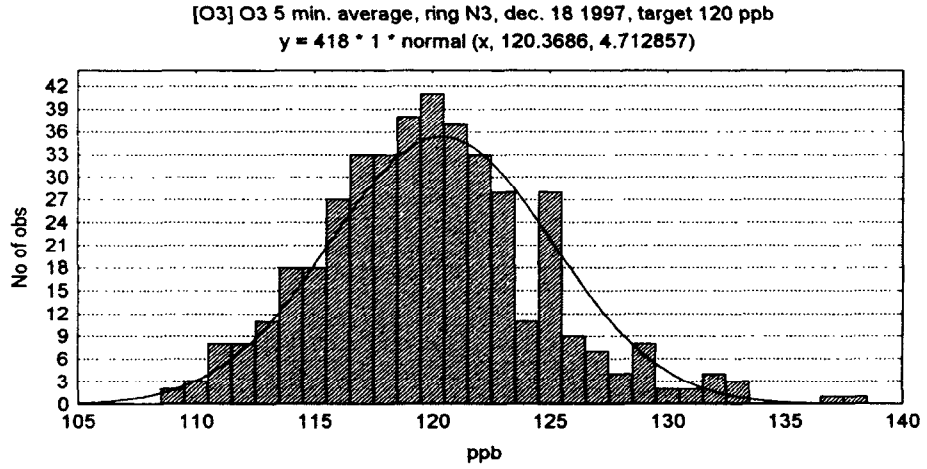

B.

Figure 9. Ozone (O_3) concentrations in the center of a FACE ring in the FACTS II (Aspen FACE) experiment on two different days.