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CO_2 EXCHANGE OVER SHORTGRASS SODS

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ABSTRACT

Progress to October 1970 consisted mainly of improving the experimental design of an instrumentation system for monitoring carbon dioxide exchange in plants under field conditions. Initial results are presented for both the open flow and compensating systems. Ambient carbon dioxide concentrations are presented as a seasonal decline from a high of 328 ppm CO_2 in April to 322 ppm in September.

INITIAL RESULTS OF 1970 SEASON

The 1970 field season proved to be one of additional instrumentation problems which continued to make interpretations of biological responses difficult. Original plans were for the unit to function as a mobile laboratory with its own power source in the form of a 2.5 kw generator (see Technical Report 31). Two problems encountered were the varying frequencies produced by the generator and the high surges required upon starting by a 7 ampere compressor. The frequency problem was mastered, but the generator could not produce enough wattage to handle all of the equipment.

The trailer was then moved to an area which had commercial power, but was still in an infrequently traveled area. The same general procedure was followed as that outlined in Technical Report 31 (Moir et al, 1969).

The unit was capable of sensing slight changes in CO_2 concentrations (±2 ppm), but this was the only factor which was being continuously recorded. It became apparent that in order to interpret photosynthetic responses of the vegetation, other parameters would have to be monitored and recorded.

Even though humidity, light, and temperature were not continuously recorded, some interesting output was obtained. The temperatures recorded were those manually read from paired thermistors, one located at an exit from the dome, and another sensing ambient temperature in the shade. The same two thermistors were controlling a "feedback" system which maintained dome temperatures relatively the same as ambient temperature. The greatest deviation observed between the two was a 4°C warmer atmosphere within the dome. Observations of short-term cloud cover were logged by the operator.

Ambient CO_2 concentrations were recorded for various periods beginning in late March and continuing to mid-September. Neither ambient nor dome concentrations were obtained in August.[1/] The ambient concentrations recorded for April averaged 327-328 ppm CO_2. This dropped to a low in July of 321-322 ppm, and in September, the ambient concentration was still around 322 ppm.

The results presented are those from both compensation and open flow procedures for determining CO_2 exchange. Fig. 1 represents the results of initial attempts to maintain ambient concentrations of CO_2. This approach is the compensation or "anti-plant" system as used by Koller (1970) with a modified Siemen's unit. Point 1 of Fig. 1 indicates when the dome was placed over the sod, and photosynthetic activity was sufficient to drop the CO_2 concentration almost 70 ppm in about five minutes. The addition of CO_2 rapidly increased the concentration toward ambient levels. Ideally, a fluctuation around 320 ppm should be maintained. The fact that one can't predict the physiological activity ahead of time produces conditions such that the operator must make intuitive "guesses" on what flow rate should suffice without exceeding some desired range of concentration. For example, in Fig. 1, the area between points 4 and 6 represents an error in judgement in halting the supply of the concentrated sample. At point 4 the reduction in CO_2 flow rate indicated that assimilation would draw down the concentration, but for some reason, there was an increase in the period from 0951 to 1000 hours. To reduce the increase in concentration, the bottled source was cut off and outside air of about 320 ppm CO_2 was allowed to replace the sample withdrawn from under the dome. The results were manifested by the depletion of CO_2 concentration to below 270 ppm. After this point, the amplitude of

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[1/] On July 29 the chopper motor assembly failed to function. This is pointed out in order to emphasize that complete backup systems, or a supply of spare parts, are an absolute necessity in order to guarantee data acquisition throughout the season.

the fluctuations was too great to be of much significance in determining assimilation rates, but it may show some of the insensitivity inherent with a system of such large volume at relatively slow flushing rates. The switch over in the relative positions of surface temperature was observed by sensing temperatures from paired thermistors placed on the surface, both inside and outside. Around 0955 hours, the outside surface temperature was 42°C, while the surface temperature in the chamber was 44°C. At 1005, the surface temperatures were equal at 44°C, and at 1015 the outside surface temperature was 48°C, four degrees higher than the surface temperature under the dome.

The averaged results from July 27 are presented in Fig. 2. This represents the open system, where accurate flow rates are of primary importance. The procedure is to adjust flow rates so that there is a detectable depletion or enrichment of CO_2. Normally, the procedure is to allow no more than a 10% differential between inside and outside concentrations. The period from 0900 to 0912 in Fig. 2 represents apparently true fluctuations in activity, i.e., no mechanical changes. Commencing at 0922, the system was flushed for 2.5 minutes in an attempt to reach ambient concentrations. Probably the assimilation rates were great enough that ambient concentrations could not quite be reached at these flow rates due to the high activity. The drop in concentration around point 6 occurred almost immediately after cessation of the rapid flushing. The plateau from 0925 to 0927 may actually be the result of a log in the circulation of the air stream as well as a result of the approximately 40 seconds required for a sample to pass into the analyzer sample cell and for the analyzer to respond. The actual response might be better represented by a smooth curve from 322 ppm down to about 275 ppm. The short-term flushing periods returned CO_2 concentration toward 320 ppm, but upon closing the system each time, the concentration was drawn down again. At 0940, the concentration was being depleted as in preceeding "cycles," but suddenly the concentration began to rise. There were no adjustments to flow rates nor additions of concentrated CO_2 to account for the change. There was an apparent drastic plant response. Probably this was the mid-morning or mid-day closure of stomata due to high moisture stress or high foliage temperature. The rest of that morning, there was net evolution of CO_2 (intense respiration), and therefore rather regularly spaced flushing periods to reduce the concentration. This procedure caused an "overshoot" of the analyzer, producing the swing below ambient levels. Perhaps other reasons may be responsible for some of the apparent depletion of CO_2 below ambient levels, but their discovery will have to come at a later time.

The trace in Fig. 3 is a copy of the actual chart data. Note reversal of scale on vertical axis. It serves to show the sensitivity of the grasses to decreases in incoming radiation. Yet, the bulk volume of the system seems to be so great that, when active assimilation starts again, the high concentration of CO_2 requires too long a "drawn down" time. If the concentration had been allowed to continue to increase, then in time the photosynthetic activity might have reduced the concentration to below ambient. Following the addition of bottled CO_2 at point 5, there were apparently no more significant rates of assimilation.

Calibration of Standard Gases

We now have nine cylinders (size A) of known concentrations of CO_2 prepared by Matheson Gas Products. The accuracy of these concentrations may vary somewhat, but two were checked against standards of the National Oceanic Atmospheric Administration (NOAA) in Boulder, Colorado.[2/] The rest were then calibrated from these concentrations. Our bottles contain the following range of concentrations: 290, 297, 299, 337, 340, 344, 451, and two cylinders greater than 455 ppm.

Proposed Modifications

Most CO_2 exchange systems require elaborate sensing and monitoring systems to maintain the environment within the chamber according to some predetermined schedule (Mooney et al, in press). We are preparing to sense and record the following:

(i) inside and outside ambient temperature,

(ii) incoming visible radiation under the dome,

(iii) vapor pressure under the dome,

(iv) soil temperature, upper 2 cm, under dome and outside of dome.

The recording of variations in the above parameters in conjunction with CO_2 variations will provide the necessary correlations for the assimilation of an empirical mode.

The open flow system may be the better choice between the two systems described above for work in the short grass prairie. Accordingly, next year's experimental procedure will follow a fairly constant open flow system. We want to reduce the complexity of interpretations in such a manner that only rates of biological activity need explanation.

[2/] We sincerely appreciate the efforts of Tom Harris of NOAA in verifying the concentrations of our CO_2 samples.

FIGURE TITLES

Fig. 1. Initial results of CO_2 fluctuations over Buffalograss sod utilizing a compensating or "make-up" procedure. July 16, 1970.

Fig. 2. Averaged results of CO_2 fluctuations over Buffalograss sod using an open flow system with rapid flushing rates. July 27, 1970.

Fig. 3. Actual trace of CO_2 fluctuations over Buffalograss sod. July 17, 1970.

Log of Fig. 1: Averaged Fluctuations
of CO_2 Exchange Over Buffalograss
July 16, 1970

1. Air sample from under dome connected to sample cell of analyzer. Outside air replacing sample withdrawn for analyzing.

2. Sample replacement air now originates from a cylinder of 1000 ppm CO_2 at flow rate of 1 l/min.

3. Rate of concentrated CO_2 input cut to 0.47 l/min.

4. Additional reduction of CO_2 input to rate of 0.13 l/min. Outside ambient temperature 30°C. Surface temperature 42°C outside and 44°C under dome.

5. Input from cylinder cut off, and outside air (319 ppm CO_2) is now replacing sample pulled out for analyzer. Soil surface temperature is 44°C for both outside and inside surfaces.

6. CO_2 added from cylinder at 0.62 l/min.

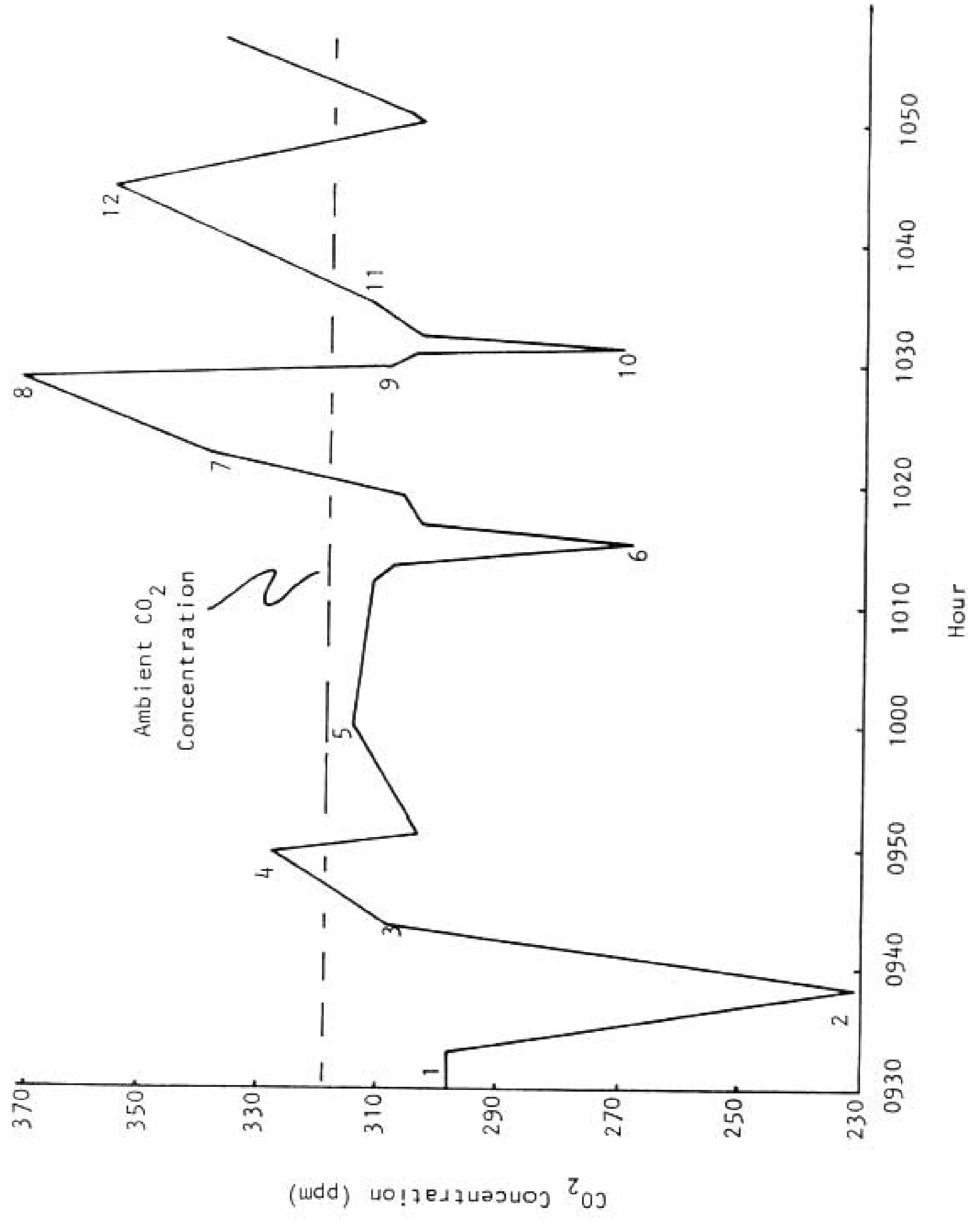
7. Source flushed to reduce build-up of CO_2. Flushing accomplished by breaking connection in coaling loop where flow rates are high.

9. Outside air replacing sample.

10. Bottled CO_2 added at rate of 0.52 l/min.

11. Concentrated source disconnected and outside air admitted.

12. System flushed to reduce CO_2 concentration.



Ambient CO_2 Concentration
CO_2 Concentration (ppm)
370
350
330
310
290
270
250
230
0930
0940
0950
1000
1010
1020
1030
1040
1050
Hour
1
2
3
4
5
6
7
8
9
10
11
12

Fig. 1.

Log of Fig. 2: Averaged Gas Exchanges
Over Buffalograss Sod, July 27, 1970

1. Sample connected from dome to gas analyzer.

2. No concentrated CO_2 input, fluctuations observed reflect the initial biological responses within the dome system.

3-4. System rapidly flushed with outside air.

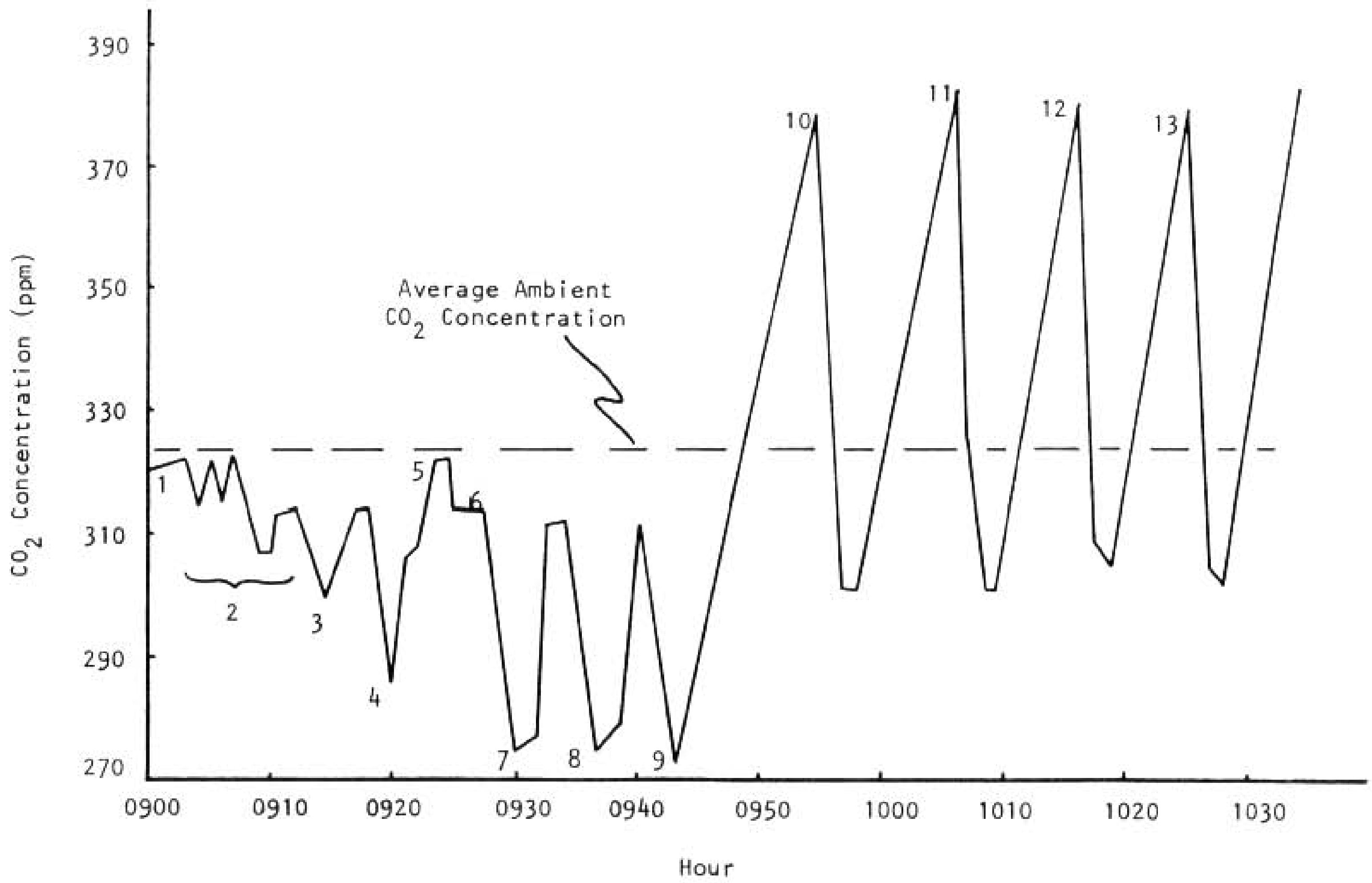
5. System flushed for 2.5 minutes to approach ambient conditions.

6. Sample from under dome shows response time of 0.5 minutes after halting rapid flush.

7-8. System flushed with outside air.

9. No mechanical changes were made from 0940 to 0954 hours.

10-14. System flushed repeatedly to maintain near ambient conditions.



Average Ambient
CO_2 Concentration
CO_2 Concentration (ppm)
390
370
350
330
310
290
270
0900
0910
0920
0930
0940
0950
1000
1010
1020
1030
Hour
1
2
3
4
5
6
7
8
9
10
11
12
13

Fig. 2.

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Log of Fig. 3: Results of Actual Trace of
CO_2 Exchange Over Buffalograss Sod, July 17, 1970

1. Intake sample from dome channeled through analyzer. Full sunlight, temperature under dome, 26°C. Outside air replacing sample.

2. Sun hidden behind cloud.

3. Full sunlight.

4. System flushed for 2.5 minutes by disconnecting hose in coaling loop.

5. Input now from bottled gas of 1000 ppm CO_2 at flow rate of 1.3 l/min.

6. CO_2 input cut to 1.0 l/min. Surface temperature under dome, 42°C.

7. Bottled CO_2 input cut off and outside air replacing sample.

8. System flushed for 2 minutes.

9. System flushed for 1 minute. Surface temperature under dome, 45.5°C and air temperature under dome, 31°C.

10. System flushed 0.75 minutes.

11. System flushed 1.75 minutes.

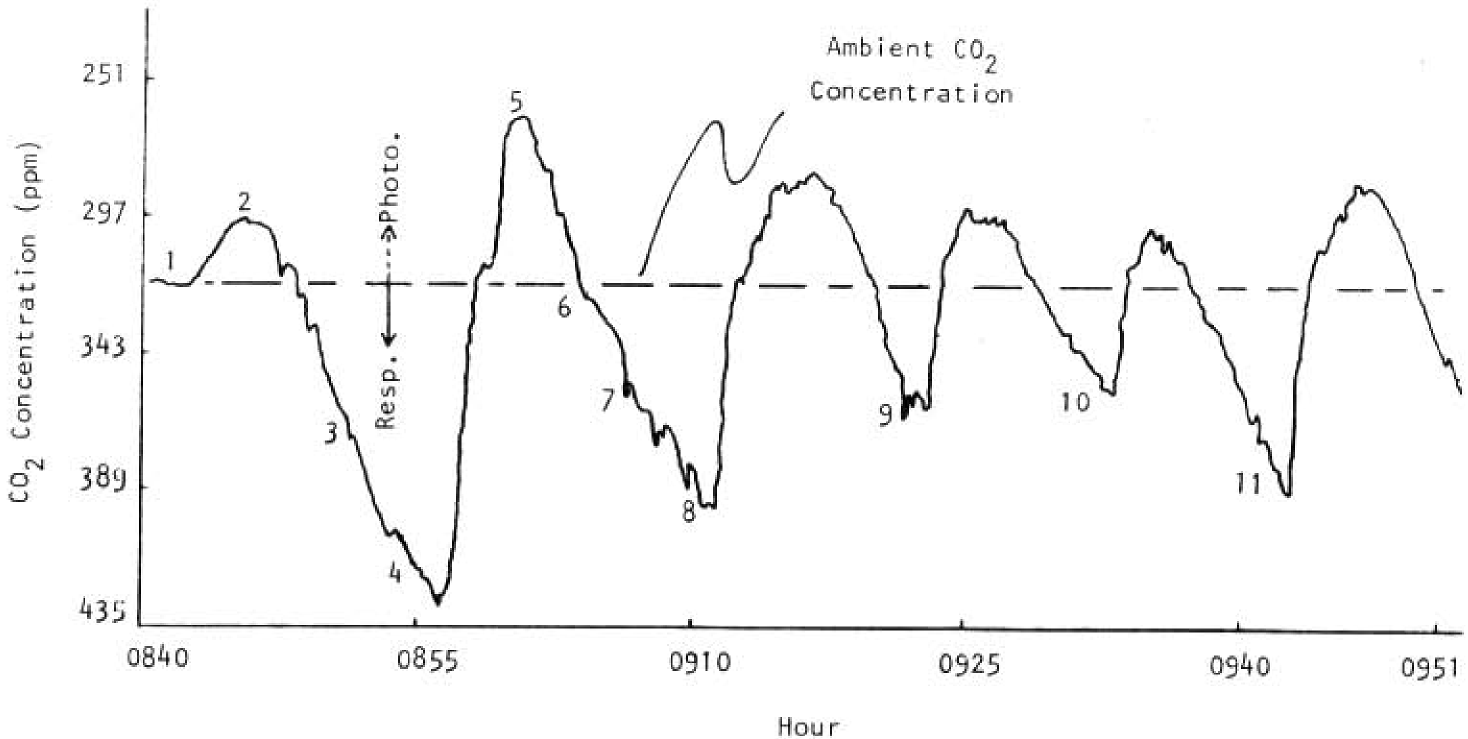
Ambient CO_2
Concentration
Photo.
Resp.
CO_2 Concentration (ppm)
251
297
343
389
435
1
2
3
4
5
6
7
8
9
10
11
0840
0855
0910
0925
0940
0951
Hour

Fig. 3.

LITERATURE CITED

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