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DRY DEPOSITION OF SULPHUR DIOXIDE IN THE ATHABASCA OIL SANDS AREA

by

A.H. Jamal, D.S. Chadder, W.A. Murray and R.D. Brymer

Promet Environmental Group Ltd.

1338P-36 Avenue NE

CALGARY, Alberta T2E 6T6

Telephone: (403) 276 9123

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ABSTRACT

A field study has been undertaken at the Sandalta lease near Fort McMurray to determine the sulphur dioxide dry deposition velocities above and within a tree canopy. The concentration gradient method has been used to compute fluxes and dry deposition velocities. The covariance of temperature and vertical wind velocity was measured with a sonic anemometer. The eddy diffusivity for heat was calculated from the ratio of the coveriance to the potential temperature gradient. A flame photometric analyzer was utilized to measure sulphur dioxide concentrations. Most calculations were performed in real time using a digital datalogger. An average daytime dry deposition velocity of 0.8 ± 0.7 cm/s was calculated for the September 26, 1983 episode. Sulphur dioxide was observed on nine other occasions during the operational period but because of equipment limitations, it was not possible to calibrate the SO_2 analyzer on the sampling range.

1. INTRODUCTION

Promet Environmental Group Ltd. was contracted by Alberta Environment, Research Management Division, to carry out sulphur dioxide flux measurements above and within a tree canopy at Sandalta near Fort McMurray. The tree canopy consisted of a stand of jack pine, poplar and spruce trees. The project is a specific component of an integrated research effort to assess the impact of total acid deposition on terrestrial ecosystems. The experiment required measurements of ambient concentrations of sulphur dioxide and collection of integrated data on the quality and quantity of SO_2 dry deposition. The subsequent field study was also a step toward establishing improved measurement techniques and ensuring stable and consistent operation of all equipment. The raw data were further utilized in the derivation of dry deposition velocities and other flux parameters using the gradient technique. The characteristics and requirements along with comments on the type of results obtained for this and other methods have been presented by Hunt et al (1981). Only the data obtained on September 26, 1983 above the primary tree canopy have been analyzed. The remaining data are presented in raw form in the Appendix.

The field season for the project was to run for four consecutive months commencing 1983 June 01 and ending 1983 September 30. However, due to the developmental nature of the project and the need to devise a sophisticated instrumentation system capable of reliable and accurate data acquisition, the start up of the project was delayed till August. All sensors were operational at this time and a complete set of data was collected on August 26. Thereafter, data for ten days with SO_2 episodes were obtained.

2. METHODS

2.1 SITE SELECTION

The following criteria were necessary for the conditions to be conducive to flux measurements.

1. Site should be downwind of an SO_2 source;
2. A fetch of uniform surface should extend upwind at least 100 to 200 times the height for which constant flux is assumed;
3. The vegetation should be in an actively growing state; and
4. Line power should be available.

Figure 1 shows the location of the site for the field study. The SO_2 sources were the Suncor and Syncrude oil sand extraction plants which are licensed for 354 tonnes/day and 292 tonnes/day of sulphur, respectively. The site was situated approximately 25 km to the northeast of the two plants.

An air quality trailer that houses 24 hour continuous ambient monitoring analyzers is located in a 200 square m clearing which is 80 m west of the flux tower. The Monitor Labs analyzers in the trailer measure ambient levels of O_3, SO_2 and NO_2. All four pollutants are measured at two levels, 4 m and 22 m. A weather station situated next to the trailer monitors the following meteorological parameters:

1. Precipitation;
2. Horizontal wind speed and direction at the 10 and 46 m levels;
3. Vertical wind speed at the 46 m level;
4. Incoming solar radiation;
5. Surface temperature at 1.5 m;
6. Surface relative humidity at 1.5 m; and
7. Temperature difference between the 10 and 46 m levels.

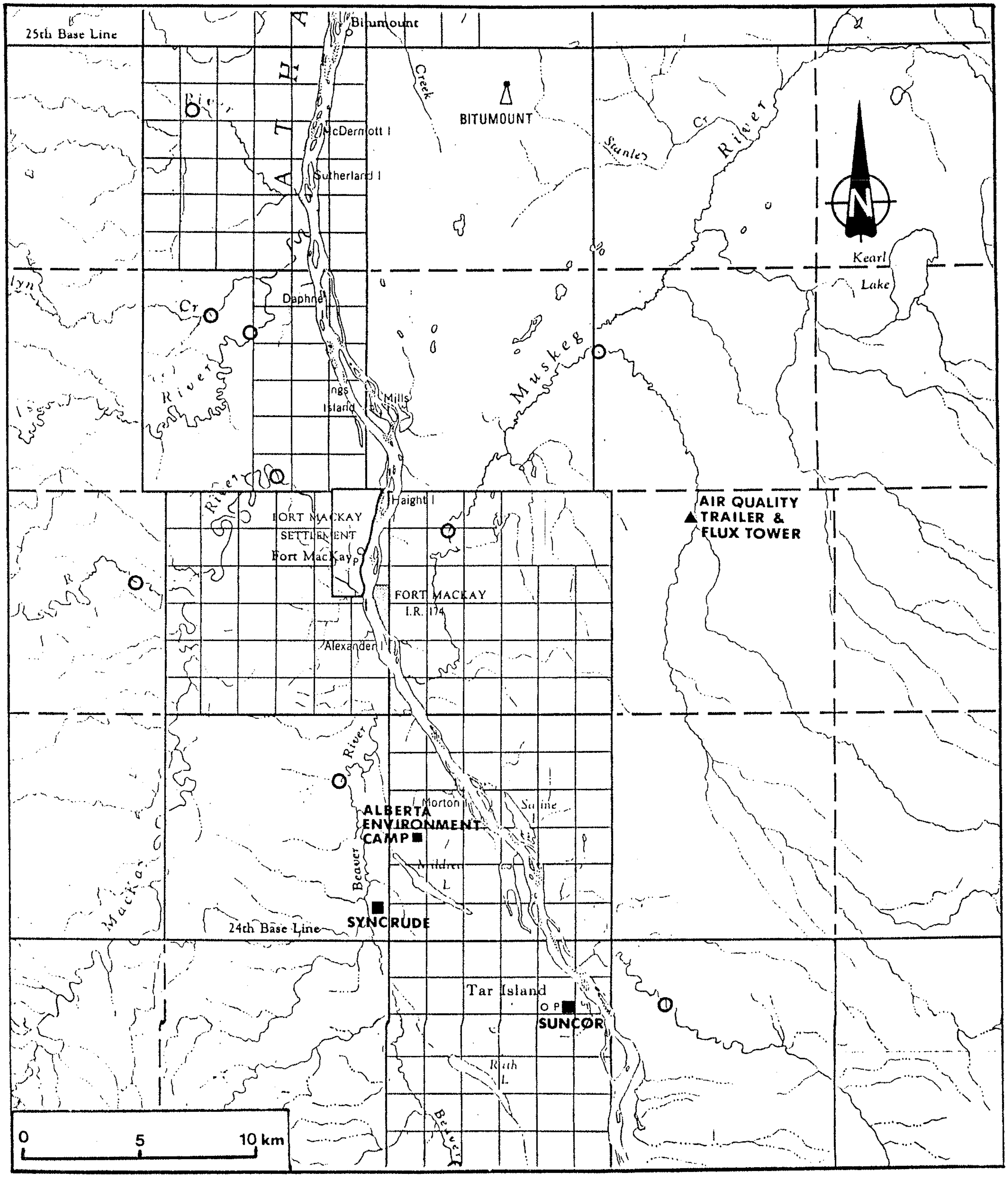

Figure 1. Topographical map showing project study area.

2.2 EQUIPMENT

There were ten variables recorded continuously during the field experiment at the flux tower. These included:

1. Temperature difference over a 3 m height interval at 0.5 m above the primary tree canopy (19 m above ground);
2. Temperature difference over a 3 m height interval at 5 m above ground;
3. Vertical winds at 8 m and 21 m above ground;
4. Ambient SO_2 concentration at heights of 5 m, 10 m, 19 m and 22 m above ground;
5. Air temperature at approximately 1 m above ground;
6. Relative humidity at about 1 m above ground.

A 24 m tower was used to mount the sensors for items 1 to 4. Copper-constantan thermocouple junctions were used to measure the temperature differences within and above the tree canopy.

A reversing arm mechanism was built to rotate every 15 minutes to help remove any systematic errors associated with the thermocouple sensors. Although based on an original design of Black and MacNaughton (1971), two reversing arm improvements were made by Promet. The first involved the prevention of the booms from over- or under-shooting because of strong winds. This was accomplished by a reversing motor with worm gear drive. Also, special radiation shields were constructed under the direction of T. Gillespie (personal communication), of the University of Guelph, to shield the sensors from radiation influences.

A Campbell Scientific sonic anemometer with a fine wire thermocouple junction (0.01 mm) constructed from chromel-constantan was used for generation of heat flux and eddy correlation data. The fine thermocouple wire measures very minute temperature fluctuations between the ambient air and a reference junction housed inside the anemometer's "thermal mass". The orientation of instrumentation on the tower with respect to the tree canopies is shown in Figure 2. The reversing arm was mounted facing northwest to reduce the radiative effects of direct solar radiation. The sonic anemometers were directed away from any mechanical air movement caused by the air flow into the sample lines and the reversing of the boom. The sample lines faced southwest, toward the SO_2 sources (i.e., Syncrude and Suncor).

The SO_2 analyser, datalogger and recorders were housed at ground level in a 4 m x 2 m tent. This non-rigid structure was used to minimize the effects of turbulence and radiation which would interfere with the readings of the sensors at the lower level.

A Meloy SA285E flame photometric detection (FPD) analyzer was used to measure SO_2 concentration at four heights. Ambient air was drawn into 6 mm teflon lines continuously by vacuum pumps that provided approximately 1.5 L/m of flow through each of the four sampling lines. All sample lines were of equal length to minimize inconsistencies in the readings due to adsorption, moisture, and contamination. The sample lines were placed in a 19 mm plastic pipe which was heat traced to prevent condensation in the lines. Four manually operated solenoid zero/span valves were also placed in the pipe. The valves were used to control conditioning of the teflon lines. All four sample lines were conditioned with SO_2 which was delivered under pressure from a cylinder for an average time of 4 minutes for each height, twice a day.

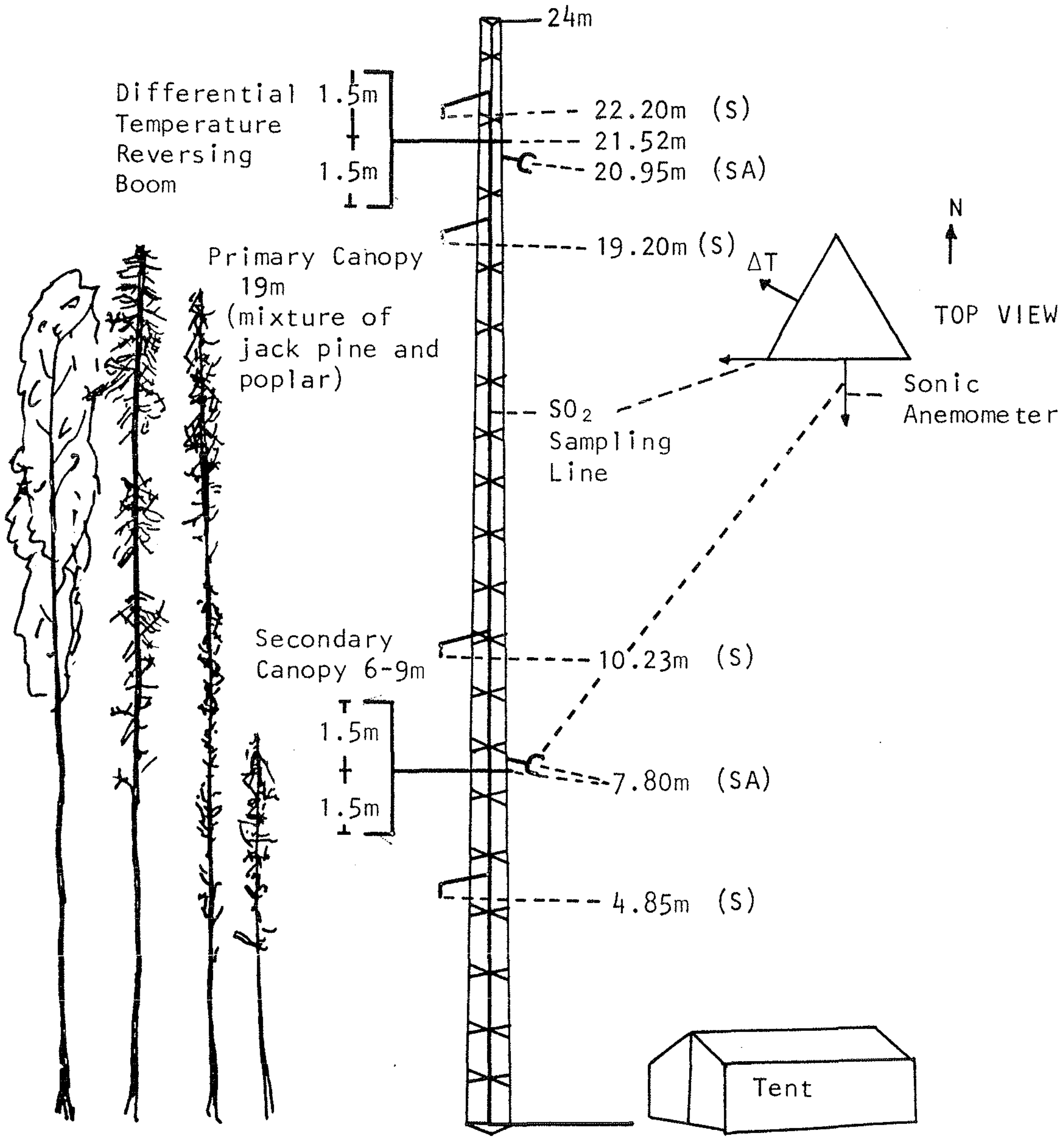

Figure 2 . Schematic showing equipment location on the flux tower. Ambient S02 was sampled at those four levels marked (S), whereas vertical wind speed levels are marked as (SA).

2.3 DATA ACQUISITION

Datalogging and sampling system control were performed using the Campbell Scientific CR7 datalogger. Data were processed in real time by the CR7 and then recorded on magnetic tape. A printer was also used to display the data. All input processing was done over a 15 minute period. That is, every 15 minutes averages and other statistics for each variable were computed and output to the printer and magnetic tape.

Three different scan rates were used to sample the data. Each sensor was scanned at a rate appropriate to its individual response characteristics.

The two sonic anemometers were sampled twice every second. Software in the CR7 computed the eddy correlation of the temperature and vertical winds in real time. The eddy correlation software package in the CR7 contains a subaveraging interval of 180 seconds. Acting like a high band pass filter, eddy frequencies lower than 0.006 Hz are filtered out. SO_2 laden eddies above the forest canopy generally will have frequencies much above this limit (telephone communication with B. Tanner, designer of the sonic anemometer, 1983 June 03).

The CR7 datalogger scanned the output of the SO_2 analyzer once every second. The Meloy SO_2 analyzer attained 95 percent of the SO_2 response in approximately 5 seconds. Only the last five seconds of the 15 second scanning duration were used for computations to ensure that enough time had been allowed for the analyser to respond. Fifteen seconds were spent at each of the four SO_2 sample heights, in succession, before solenoid valves were activated and a new height was sampled. Hence, every minute four 5 second conditional averages were computed and stored in memory. Every 15 minutes, these conditional averages were summed and divided by 15 to provide the average SO_2 concentrations for each of the four heights.

The following variables were scanned once every ten seconds: relative humidity, temperature and temperature difference for two levels below and above the tree canopy. Temperature differences were recorded only after the lapse of a five minute sensor equilibrating period following the boom reversal. The boom reversal mechanism and the solenoid valves which select the sample level of ambient air at any one time were controlled by the CR7 datalogger.

The data accumulated in the CR7 memory were averaged over a 15 minute interval and the output was printed and also recorded on cassette tape. The SO_2 concentrations were also recorded on a Soltec chart recorder. The temperatures of the burner and detector ovens of the SO_2 analyzer were monitored to ensure that the temperatures remained within the recommended operating range. Deviations from this range would result in baseline drift and erratic SO_2 readings.

2.4 CALIBRATION

A two point (zero and span) calibration was performed through each sample line twice a day. Bottled SO_2 gas with a concentration of 79.9 ppbv (210 ug/m^3) traceable to a National Bureau of Standards reference was used.

In addition, multi-point calibrations were performed directly on the analyzers (not through the sampling lines) at least once a day. A Monitor Labs #8550 calibrator with a permeation tube with a permeation rate of 1021 ng/min was used. Five points were used between concentrations of 0 to 1309 ug/m^3 (0 to 500 ppbv). To calibrate on the ranges used for sampling (0 to 50 and 0 to 100 ppbv) a permeation tube with a lower permeation rate would have to be used. Unfortunately, a low concentration permeation tube (123 ng/min) was not obtained until September 28, near the end of the study. Summaries of the calibration data are given in the appendix, Section 7.

The two point calibration rather than the multipoints were used in processing the data as there were consistent differences in response between sampling lines, and the two point calibration was on the range (0 to 100 ppbv) actually used for sampling.

2.5 OPERATIONAL PROBLEMS

Once the apparatus was operational, all instruments, with the exception of the sonic anemometer, functioned well for the duration of the project. The sonic anemometer contains two dishes placed 10 cm apart that emit and receive sound waves. Any moisture accumulation on the dishes distorts the signal. This characteristic restricted use of the instrument to the daylight hours as condensation was prevalent at night. The sonic instrument was covered each night to avoid dew or rain on the sensor. The constant handling of the sonic anemometer increased the risk of distorting the alignment of the dishes. A slightly misaligned dish would cause erroneous values for vertical wind speeds. The sonic anemometer mounted at the lower level was not functioning 50 percent of the time due to the above mentioned problems.

The static head exerted by the sampling lines and sample vacuum pump on the intake manifold disturbed the normal operating flow through the SO_2 analyzer. The Meloy analyzer is designed to maintain a constant system flow by drawing air under vacuum across a critical orifice. If the differential pressure across this orifice is changed, the analyzer will show a baseline shift. The CSI-Meloy analyzer system flow is less than 1 L/min. Originally, the sampling pump which was used to draw air into the manifold was set at 25 L/min, however because of the adverse effect it had on the analyzer the sampling flow was trimmed to 1.5 L/min.

The rotameters which were acquired for the higher flow of 25 L/min should be modified to resolve the 1.5 L/min flow better. As well, because of the uncertainty of baseline shifts while sampling ambient air as opposed to SO_2 free air, it would be prudent in the future to provide a multipoint calibration for each of the sampling levels rather than a single SO_2 level.

The equipment in the tent was subject to temperature extremes. During the study period, the temperature in the shelter ranged between -3°C and 35°C. The analyzer temperature controller had difficulty keeping up with the ambient temperature variations during this period. The oven and detector temperatures deviated as much as 5 and 10°C from the recommended operating values. The ambient temperature variations also caused changes in the resistances in the voltage divider at the output of the analyzer so that the calibrations varied. To avoid such fluctuations in the operating environment, the possibility of installing a rigid structure with temperature control rather than a tent should be examined. This might possible avoid equipment failures, excessive zero drifts, frequent calibrations and vandalism.

2.6 DATA RECOVERY

Sulphur dioxide was observed on ten days in the August 26 to September 29, 1983 operational period. Unfortunately, except for September 26, the SO_2 analyzer was not calibrated on the range used for sampling because of equipment limitations. The September 26 data were analyzed and are discussed in Section 4, below. Only the raw data are presented in the Appendix for the other episodes.

3. ANALYSIS

3.1 THEORY

Estimates of SO_2 fluxes can be produced using the following equation:

$$F = K_h(SO_2\ (z_2) - SO_2\ (z_1))/(z_2-z_1)$$

where, F = quantity of SO_2 transferred through unit area per unit time;

K_h = eddy diffusivity constant (m^2/s);

$SO_2(z)$ = mean SO_2 concentration in ug/m_3 for a specified averaging period at height Z (m);

z_1 = height of sampling level #1; and

z_2 = height of sampling level #2.

The transport mechanism for SO_2 is deemed to be analogous to that for water vapor or heat fluxes in most atmospheric conditions where turbulent eddies are the dominant means of transport. Heat flux measurements were chosen for the field trials because of the success other researchers had experienced in using fast response sensors such as sonic anemometers.

The following expression shows how $K_h(z)$ was computed:

$$K_h = Z(\overline{W'T'})/\ (\ \Delta T + \gamma\ \Delta Z)$$

where, $\overline{W'T'}$ is the covariance of vertical wind and temperature. That is, the average of the product of the deviations from the means of vertical velocity and temperature. ΔT is the temperature difference over the height interval ΔZ, and γ is the dry adiabatic lapse rate (0.0098 $^{o}C/m$).

The deposition velocity is an empirical parameter which is used to estimate SO_2 fluxes from the ambient SO_2 concentrations. Estimates of the deposition velocity (V_d) were computed using the following equation:

$$V_d = F/C$$

where C is the mean of the SO_2 concentrations at z_2 and z_1, respectively.

3.2 ERROR CALCULATIONS

The parameters that have been determined in the flux calculations are functions of several variables which are measured independently. It is possible therefore to be able to apply the theory of propagation of error to such cases (Concord 1983:18).

If P is a linear function of j independent variables:

$$P = f\ (S_1, S_2, S_3, \ldots S_j)$$

Then, the probable error of P is related to the probable errors, Q_1, $Q_2 \ldots Q_j$, of the mean values m_1, $m_2 \ldots m_n$, of the several independent measured quantities $S_1, S_2, \ldots S_j$, by the following equation:

$$Q_p = (\Sigma(dP/dS_j)^2 \cdot Q_j^2)^{1/2}$$

For example, to calculate the probable error in the deposition velocity, the independent quantities flux and concentration are used:

$$V_d = F/C$$

Hence, the probable error is:

$$Q_{V_d} = ((Q_F/C)^2 + (Q_C * F/C^2)^2)^{1/2}$$

4. RESULTS AND DISCUSSION

On September 26, winds above the tree canopy were light, from the south-southwest, the direction of the Suncor and Syncrude oil sands plants. Skies were clear in the early morning, but it clouded over and was overcast during the SO_2 episode. Sigma theta (standard deviation of azimuthal angle of the wind) values were typical of slightly unstable conditions as shown in Table 1. Air temperature was 14°C with a relative humidity of 75% at the base of the flux tower.

The average deposition velocity during the episode was 0.8 ± 0.7 cm/s. This is within the range of values determined by other dry deposition experiments over forests. Studies have been undertaken by several other workers to determine the characteristic SO_2 uptake by trees. Most field measurements for SO_2 deposition have been made over agriculture land (Chadder et al 1983, Hicks et al 1982, Garland and Bronson 1982). Various controlled laboratory measurements of SO_2 fluxes onto forest predict the deposition velocities to be between 0.1 and 0.6 cm/sec. Field studies using the eddy correlation technique (Fowler and Cape 1983) determined the rates of dry deposition onto a Scots pine forest to range from 0.05 to 1 cm/s. Similar work by Johansson et al (1982) gave values of V_d of 0.5 cm/s above a birch forest.

The estimated error in the deposition velocity is large, of the order of 0.7 cm/s. This arises from the fact that the velocity is calculated from the ratio of two small differences. Because of the pronounced roughness of the forest surface, the air tends to be well mixed in the vertical and the potential temperature gradients are small. Likewise, the concentration gradients are weak because of vertical mixing of the pollutant.

Table 1. Average deposition velocities and environmental conditions during the September 26, 1983 SO_2 episode.

Time	SO_2 Concentration ug/m^3 22 m	19 m	K_h m^2/s	SO_2 Flux ug/m^2s	Deposition Velocity cm/s	Wind Speed km/h	Wind Dir. deg
1215	202.6	202.3	1.6	0.2	0.1∓0.1	13	207
1230	238.6	237.3	1.8	0.8	0.4∓0.2	11	213
1245	191.3	190.9	2.7	0.3	0.2∓0.2	10	207
1300	116.3	116.6	2.2	-0.3	-0.2∓0.3	9	225
1315	70.8	70.9	2.6	-0.1	-0.2∓0.6	8	225
1330	45.1	44.9	2.5	0.2	0.4∓0.9	8	219
1345	30.6	30.0	1.4	0.3	0.9∓0.8	8	222
1400	27.7	26.7	1.4	0.5	1.7∓0.9	9	212
1415	30.1	29.0	2.0	0.7	2.4∓1.3	8	222
1430	25.5	24.6	2.5	0.7	2.9∓1.9	11	240
Mean	97.9	97.3	2.1	0.3	0.8∓0.7	10	219
Standard Deviation	83.4	83.4	0.5	0.4	1.1	2	10

In a few cases, upward SO_2 fluxes and negative deposition velocities were calculated. These values may in fact have been positive due to the large error of estimate.

The stand of trees in the current study was a mixture of coniferous and deciduous varieties of varying sizes and shapes. Accordingly, uptake of SO_2 will not be as consistent due to the variability of leaf shapes and types found within the canopy.

One of the constraints for the site selection was to have a fetch of uniform surface extending upwind at least 100 times the height of measurement above the tree canopy. This requirement was not met as there existed a 200 m^2 clearing 80 m upwind of the flux tower. This represents a major surface disturbance which will upset turbulent transfer into the canopy.

The calculated SO_2 fluxes underestimate the actual values because eddies with frequencies outside the range 0.006 Hz to 2 Hz are not sampled by the datalogger. McBean (1972) presents a method of correcting flux data for this effect. This would result in a six percent under estimation of flux due to the high frequency cut off and seven to twelve percent under estimation due to the low frequency cut-off. These errors are negligible when compared to the estimated error of up to 100 percent and they therefore have not been taken into account in the calculations.

5. CONCLUSIONS AND RECOMMENDATIONS

The instrumentation performed satisfactorily with the exception of the sonic anemometers. They could only be used during daylight hours since condensation at night distorted the output signal. It is recommended that a more durable vertical wind measuring instrument be used as backup in future studies. so that data can be obtained at night and when it rains.

The requirement of uniform fetch was not met and may have resulted in apparent upward SO_2 fluxes. Other anomalous results may have been due to horizontal penetration of SO_2 into the canopy.

The average computed dry deposition velocity during the daytime on September 26 was 0.8 ± 0.7 cm/s. Due to the small SO_2 and potential temperature gradients between 19 and 22 m, the probable error in the deposition velocity was relatively high.

Since the study took place during daytime hours, only a small range of meteorological conditions were encountered and no deductions were possible regarding the relationship between deposition velocities and the meteorological conditions.

It is evident that the gradient method for measurements of SO_2 dry deposition velocities and fluxes is limited in accuracy because of the small differences in SO_2 concentration over a tree canopy. Other forest research workers have concentrated on direct eddy measuring techniques rather than gradient methods. However, difficult technical modifications are required to achieve both the high sensitivity and fast response characteristics required in the eddy correlation techniques.

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7. APPENDIX

Table 2. Multipoint Calibration Summaries for August 19, 20, 21, 26, 27, 28, 29, 30 & 31, 1983

Date	Time (MDT)	Net Responses (mV) SO2 concentration 298±7 (ug/m3)	537±14 (ug/m3)	1098±37 (ug/m3)	Response to zero air (mV)	Comments
1983.08.19	0900-1057	20.7	39.6	88.0	1.0	
1983.08.20	1015-1115	18.9	36.6	83.9	0.5	
1983.08.21	0952-1045	20.5	37.0	83.3	1.6	
1983.08.26	1317-1415	20.0	40.0	86.7	0.5	
1983.08.27	1508-1615	21.5	38.7	87.2	0.5	
1983.08.28	1510-1635	20.2	36.8	84.9	0.5	
1983.08.29	0823-0916	20.2	39.5	88.2	2.0	
1983.08.29	1400-1530	20.7	36.5	83.6	2.6	SF6 carrier gas
1983.08.30	0930-1009	21.2	38.5	85.6	1.5	
1983.08.31	0820-0919	22.6	43.5	82.5	0.7	

Monitor: Meloy SA285E Serial #: CE003 Range: 0-1200 ug/m3
Recorder: Soltec Serial #: A02615 Range: 0-100 mV
Datalogger: Campbell Scientifc CR7
Permeation Rate: 1021 ng/min.
Calibrator: Monitor Labs 8500-1769

H2S carrier gas unless otherwise noted

Table 3. Multipoint Calibration Summaries for September 20 - 29, 1983

		Net Responses (mV)					
	SO2 concentration	963+31 (ug/m3)	762+21 (ug/m3)	501+13 (ug/m3)	355+9 (ug/m3)	265+6 (ug/m3)	Response to zero air (mV)
Date	Time (MDT)						
1983.09.20	0845-0915		44.5	28.3	19.2	14.1	1.0
1983.09.20	1400-1430		57.3	35.9	24.9	18.7	1.3
1983.09.21	0839-0914	68.5	54.2	35.0	23.8	17.4	1.0
1983.09.21	1455-1535	75.7	59.3	38.0	26.3	19.5	0.7
1983.09.22	0838-0907	72.5	87.7	36.4	24.8	18.5	1.0
1983.09.22	1432-1503	81.7	63.6	40.3	28.2	21.1	1.0
1983.09.23	0917-0944	77.4	61.1	39.0	27.1	20.1	1.1
1983.09.23	1250-1315	82.2	62.9	40.1	27.7	20.8	0.8
1983.09.24	0950-1015	65.2	58.4	37.4	26.1	19.2	0.7
1983.09.24	1400-1425	80.2	62.1	39.8	27.6	20.3	0.9
1983.09.25	1010-1030	77.4	60.1	39.1	27.0	19.9	1.0
1983.09.25	1350-1425	81.6	63.9	41.0	28.3	20.9	0.9
1983.09.25	1625-1645	78.7	61.9	39.4	27.5	20.7	0.8
1983.09.26	0918-0935	72.4	56.8	36.1	25.1	18.5	1.1
1983.09.26	1210-1230	77.7	60.0	37.9	26.2	19.5	0.8
1983.09.27	1110-1200	74.5	58.7	37.1	25.8	18.9	1.2
1983.09.28	0930-1005	75.0	57.7	37.0	25.7	18.7	1.4
1983.09.28	1320-1345	77.0	60.0	37.6	26.0	19.2	1.3
1983.09.29	1130-1155	74.8	58.4	37.8	26.2	19.2	1.4

Monitor: Meloy SA285E Serial #: CE003 Range: 0-1200 ug/m3
Recorder: Soltec Serial #: A02615 Range: 0-100 mV
Datalogger: Campbell Scientific CR7
Permeation Rate: 1021 ng/min.
Calibrator: Monitor Labs 8500-1769

Table 4. Multipoint Calibration Summaries for August 31 & September 1, 8, 9, 10, 11, 12, 14, 15, & 16, 1983

		Net Response (mV)					
	SO2 concentration	762+21 (ug/m3)	501+13 (ug/m3)	355+9 (ug/m3)	265+ 6 (ug/m3)	Response to Zero Air (mV)	Comments
Date	Time (MDT)						
1983.08.31	1242-1345	58.5	37.5	26.5			
1983.09.01	0825-0945	57.3	37.6	27.4	20.5	0.5	
1983.09.08	1625-1708	57.6	36.5	25.6	18.9	0.5	
1983.09.09	0940-1041	53.5	33.8	23.2	17.3	0.6	
1983.09.10	0955-1030	61.0	41.1	28.7	21.2	0.4	
1983.09.10	1943-2010	65.6	41.5	29.0	21.7	0.6	
1983.09.11	1119-1155	66.1	42.0	29.2	21.5	1.0	
1983.09.11	1618-1652	60.3	37.9	26.4	20.6	1.0	
1983.09.12	0922-0950	53.3	34.0	23.3	17.2	1.0	
1983.09.12	1422-1448	60.7	39.1	27.2	20.2	0.8	
1983.09.14	0852-0925	57.6	36.3	25.5	18.8	1.0	
1983.09.14	1348-1427	56.6	35.8	24.6	18.0	0.9	
1983.09.15	0848-0912	58.7	36.4	25.5	18.7	1.0	
1983.09.15	1311-1334	59.8	38.6	26.6	19.5	0.9	
1983.09.16	1630-1700	61.9	38.8	26.7	19.5	0.9	

Monitor: Meloy SA285E — Serial #: CE003 — Range: 0-1200 ug/m3
Recorder: Soltec — Serial #: A02615 — Range: 0-100 mV
Datalogger: Campbell Scientific CR8
Permeation Rate: 1021 ng/min.
Calibrator: Monitor Labs 8500-1769

Table 5. Multipoint Calibration Summaries for September 28-29, 1983

SO2 Concentration (ug/m3)	Net Responses (mV) Date and Time Sept. 28/83 1425-1500 MDT	Sept. 28/83 1048-1137 MDT	Sept. 29/83 1230-1305 MDT	Sept. 29/83 1412-1440 MDT
245	98.4	97.1	98.2	101.0
192	71.1		72.9	73.0
158	55.9	56.8	57.9	57.9
134	46.5		48.2	48.2
83	27.0	27.9	28.9	27.9
60	18.9	20.3	20.8	20.2
43	13.2	15.0	15.6	13.9
39	12.1	13.9	14.5	12.5
36	11.0	13.1	13.7	11.5
32	9.9	12.2	12.7	10.4

Monitor: Meloy SA285E Serial #: CE003 Range: 0-262 ug/m3
Recorder: Soltec Serial #: A02615 Range: 0-100 mV
Datalogger: Campbell Scientific CR7
Permeation Rate: 123 ng/min.
Calibrator: Monitor Labs 8500-1769

Table 6. Multipoint Calibration Summaries for September 28-29, 1983

SO2 Concentration (ug/m3)	Net Responses (mV)		
	Date and Time		
	Sept. 28/83 1145-1235 MDT	Sept. 28/83 1505-1540 MDT	Sept. 29/83 1305-1338 MDT
116	78.5	78.1	82.1
103	68.6	67.4	72.0
92	61.1	59.0	63.6
76	49.9	47.6	52.4
60	39.7	37.0	41.8
43	29.6	26.0	31.3
39	27.4	23.6	29.2
36	25.9	21.6	27.5
32	24.0	20.1	25.3

Monitor: Meloy SA285E Serial #: CE003 Range: 0-131 ug/m3
Recorder: Soltec Serial #: A02615 Range: 0-100 mV
Datalogger: Campbell Scientific CR7
Permeation Rate: 123 ng/min.
Calibrator: Monitor Labs 8500-1769

Table 7. Two point, zero and span (210 ug/m3) calibrations, responses in mV or 100 ppbv analyzers scale.

Date	Time	22m Zero	22m Span	19 m Zero	19 m Span	10 m Zero	10 m Span	5 m Zero	5 m Span
1983.09.10	1310-1421	4.5	73.5	8.0	74.8	6.2	76.2	5.0	77.5
1983.09.11	1100-1200	3.0	79.3	3.3	79.2	3.3	80.1	3.5	80.8
1983.09.11	1200-1240	3.2	78.9	3.7	78.4	3.2	80.3	3.4	81.2
1983.09.12	0900-0945	1.8	72.2	2.2	72.1	2.2	72.6		
1983.09.13	1009-1110	1.7	66.0	1.9	65.7	2.0	66.5	2.5	67.3
1983.09.14	0855-1030	2.6	57.3	3.1	58.3	3.0	59.4	3.1	60.6
1983.09.14	1248-1327	2.6	60.3	2.9	60.6	2.8	61.5	2.9	62.6
1983.09.15	0815-0834	2.1	71.4	2.1	71.3	2.1	71.9	2.2	72.7
1983.09.15	1450-1535	4.7	72.4	4.6	72.1	5.0	72.9	4.3	73.0
1983.09.20	0820-0905	4.4	57.4	4.7	58.1	4.7	59.0	5.8	59.8
1983.09.21	0819-0900	2.0	71.0	2.2	71.1	1.9	71.5	2.2	72.3
1983.09.22	0810-0845	2.2	70.4	2.3	70.8	2.2	71.4	2.6	72.4
1983.09.23	0735-0815	1.5	70.5	2.3	71.1	2.3	71.6	2.7	72.9
1983.09.24	0819-0849	2.2	70.8	2.2	71.4	2.0	72.0	2.5	73.1
1983.09.25	0830-0905	2.3	70.6	2.8	71.3	2.7	71.8	3.1	73.2
1983.09.26	0740-0813	2.2	70.2	2.3	70.8	2.5	71.4	3.2	72.8
1983.09.27	0740-0825	3.6	71.5	3.8	71.6	3.8	72.2	4.0	73.7

Table 8. SO2 Flux Data Summary for August 26, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C m/s 8 m	21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m2
1330	87.9	87.2	87.0	86.9	ND	0.050		-0.010				
1345	42.3	42.3	43.5	43.9	0.068	0.196	-0.047	-0.073	26	44	41	0.59
1400	43.9	43.1	43.5	43.8	0.053	0.160	-0.031	-0.038	26	42	32	0.46
1415	26.9	26.3	26.6	26.8	0.005	0.086	-0.063	-0.127	26	42	18	0.31
1430	12.3	11.7	11.8	11.6	0.000	-0.008	-0.029	-0.050	25	43	10	0.15
1445	20.5	20.0	20.0	19.9	0.000	-0.002	-0.013	-0.013	24	45	9	0.19
1500	25.8	26.0	25.8	25.7	0.000	0.000	-0.019	-0.021	24	46	7	0.16
1515	24.4	23.5	23.7	24.1	0.000	-0.001	0.097	-0.021				
Avg	35.5	35.0	35.2	35.3	0.018	0.060	-0.021	-0.044	25	44	19	0.31
SDev	23.7	23.6	23.6	23.6	0.029	0.080	0.051	0.040	1	2	14	0.18
Zero	5.7	6.1	6.0	6.3								

Intermittent problems with sonics.

Table 9. SO2 Flux Data Summary for August 27, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C m/s 8 m	21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3
1115	28.17	27.76	28.07	28.07		0.105	0.073	-0.211				
1130	27.56	27.50	26.83	26.65		0.148	0.103	-0.140	22	61	18	0.56
1145	100.20	100.60	100.50	99.10	O	0.127	0.085	-0.012	23	58	13	0.53
1200	128.40	128.40	128.70	129.90	F	0.150	0.133	-0.060	24	56	21	0.55
1215	101.50	101.40	101.00	101.70	F	0.194	0.182	-0.066	24	53	25	0.58
1230	54.96	54.44	54.32	56.34		0.141	0.204	-0.160	24	53	20	0.58
1245	40.14	40.07	40.19	40.89		0.073	0.163	-0.078	23	52	18	0.50
1300	33.90	33.57	34.14	34.95		0.159	0.114	-0.070				
Mean	75.46	75.40	75.26	75.76		0.139	0.145	-0.086	23	55	19	0.55
SDev	40.14	40.25	40.42	40.38		0.039	0.046	0.055	1	4	4	0.03

Table 10. SO2 Flux Data Summary for August 28, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C 8 m	Covariance m/s 21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO2] ug/m3
945	38.71	38.57	38.10	38.40	0.008	0.106	0.077	-0.093					
1000	37.59	37.79	37.60	37.60	0.003	0.115	0.050	-0.079	18	70	16	0.47	136
1015	33.29	33.39	32.98	33.47	0.008	0.120	-0.009	-0.057	19	67	12	0.49	133
1030	34.59	34.84	34.94	34.52	0.016	0.095	0.006	-0.087	20	63	13	0.49	141
1045	29.96	29.96	30.20	29.54	0.001	0.136	-0.011	-0.080	21	60	14	0.60	133
1100	35.60	35.68	35.58	35.61	0.042	0.096	-0.033	-0.118	21	58	5	0.54	145
1115	48.01	47.65	47.74	47.66	0.020	0.118	0.024	-0.056	22	54	33	0.57	171
1130	65.87	65.50	65.32	65.77	0.070	0.222	-0.017	-0.150	24	53	33	0.56	190
1145	66.93	67.17	67.07	66.65	0.027	0.185	-0.001	-0.070	25	49	9	0.56	173
1200	36.90	36.83	37.94	37.42	0.018	0.115	-0.048	-0.107	25	45	25	0.62	218
1215	34.71	34.77	34.43	34.54	0.035	0.134	0.071	-0.050	25	43	14	0.58	201
1230	33.14	32.72	32.76	32.67	0.046	0.207	-0.006	-0.125	25	44	42	0.60	229
1245	34.47	34.90	34.70	35.04	0.031	0.144	0.011	-0.119	25	43	7		
1300	35.36	35.68	35.73	35.59	0.052	0.229	-0.014	-0.103	25	42	37		
1315	42.49	42.60	42.06	42.34	0.027	0.192	0.037	-0.153	25	41	15		
1330	43.89	43.88	43.56	44.00	0.004	0.068	0.099	-0.105	26	41	12		
1345	94.90	95.70	94.60	94.50	0.004	0.039	-0.014	-0.071	25	42	5	0.24	288
1400	132.30	132.10	132.50	131.30	0.001	0.094	0.020	-0.044	25	42	17	0.33	347
1415	75.40	75.40	75.50	75.40	0.009	0.039	0.000	-0.051	25	42	13	0.33	356
1430	73.90	73.80	73.80	73.80	0.026	0.036	-0.008	-0.080	25	42	17	0.34	223
1445	18.22	18.03	19.66	18.81	0.001	0.094	0.020	-0.044	25	41	13	0.43	50
1500	3.04	2.85	2.87	2.76	0.017	0.110	-0.030	-0.070					
Mean	47.69	47.72	47.71	47.61	0.021	0.122	0.010	-0.087	23	49	18	0.48	196
SDev	27.85	27.89	27.78	27.66	0.019	0.056	0.037	0.032	2	10	11	0.12	81
Zero	0.70	1.10	1.00	1.30									

Table 11. SO2 Flux Data Summary for August 30, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C m/s 8 m	21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO2] ug/m3
0930	35.3	35.5	33.0	32.9	-0.003	0.007	0.021	-0.035					
0945	33.1	32.9	31.3	31.2	-0.001	0.008	-0.014	-0.063	17	90	5	0.11	
1000	31.7	31.7	30.9	30.3	0.001	0.031	-0.007	-0.026	18	88	10	0.20	
1015	31.0	30.6	30.2	29.8	0.004	0.030	-0.017	-0.061	19	85	6	0.12	
1030	32.8	33.1	32.6	32.0	0.002	0.015	-0.012	-0.051	19	84	7	0.15	
1045	40.4	40.5	39.8	38.8	0.000	0.016	-0.010	-0.043	19	83	11	0.12	
1100	45.9	47.3	45.8	44.9	0.000	0.030	-0.012	-0.037	19	82	15	0.21	
1115	48.9	48.3	47.0	46.5	0.013	0.078	-0.021	-0.050	20	80	13	0.28	
1130	41.7	41.4	40.2	40.0	0.009	0.094	-0.006	-0.041	21	78	22	0.36	
1145	36.2	36.0	35.6	34.9	0.072	0.238	-0.048	-0.062	23	72	20	0.57	
1200	33.7	33.4	32.7	32.2	0.078	0.209	-0.075	-0.049	25	64	14	0.56	
1215	31.5	31.1	30.9	30.4	0.008	0.217	-0.003	-0.091	25	62	14	0.53	
1230	27.1	26.8	26.8	26.3	0.025	0.150	0.039	-0.085	25	62	17	0.48	
1245	25.5	25.3	25.3	25.0	0.023	0.113	0.008	-0.100	25	61	17	0.54	
1300	24.9	24.7	24.5	24.1	0.042	0.134	-0.059	-0.119	25	58	17	0.46	
1315	26.0	25.6	25.4	24.9	0.011	0.135	0.023	-0.091	25	58	16	0.55	
1330	27.3	26.9	26.7	26.3	0.027	0.127	-0.027	-0.095	25	56	22	0.38	
1345	44.7	44.5	43.3	42.6	0.004	0.024	-0.035	-0.095	26	58	19	0.19	
1400	57.8	58.2	56.5	54.8	0.002	0.034	-0.016	-0.040	25	60	9	0.28	
1415	67.6	68.4	66.6	65.2	0.018	0.086	0.049	-0.035	24	59	15	0.42	
1430	93.4	91.5	89.9	89.0	0.074	0.204	-0.005	-0.065	25	58	16	0.19	
1445	89.7	89.5	86.6	85.2	0.011	0.038	-0.046	-0.094	25	58	21	0.19	
1500	79.2	81.7	78.9	79.3	0.010	0.028	-0.035	-0.064	26	59	15	0.34	
1515	44.9	43.7	43.2	41.9	0.051	0.137	-0.066	-0.044	25	58	15	0.34	

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SO2 Flux Data Summary (continued)
August 30, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C m/s 8 m	21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO2] ug/m3
1530	61.6	61.3	59.9	58.9	0.015	0.047	0.002	-0.101	26	56	10	0.33	
1545	66.8	67.0	65.4	63.9	0.014	0.105	0.021	-0.073	27	56	20	0.41	
1600	64.4	63.3	61.7	61.4	0.005	0.090	0.086	-0.065					
Mean	45.7	45.7	44.6	43.9	0.021	0.093	-0.015	-0.067	23	67	15	0.33	
S Dev	20.2	20.3	19.6	19.4	0.024	0.071	0.030	0.026	3	12	5	0.15	
Zero	11.2	11.6	11.5	11.8									

Table 12. SO2 Flux Data Summary for September 1, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C 8 m	Covariance m/s 21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO2] ug/m3
	on 50 ppbv scale												
1330	18.0	17.8	16.8	15.6	0.024	0.228	-0.043	-0.111					
1345	50.7	50.8	50.6	49.6	0.075	0.248	-0.134	-0.074	24	43	27	0.54	61.6
1400	43.4	43.4	41.6	41.6	0.066	0.189	-0.090	-0.080	24	43	14	0.53	39.6
1415	49.8	48.7	48.7	46.5	0.035	0.209	-0.048	-0.085	24	43	22	M	55.4
1430	55.5	53.7	53.6	53.8	0.053	0.593	-0.040	-0.081	24	42	18	S	
1445	35.8	36.1	34.7	34.2	0.039	0.146	-0.094	-0.063	24	42	16	G	
1500	16.2	16.0	15.4	14.4	0.022	0.191	-0.028	-0.102	24	44	30	0.22	39.6
1515	24.2	24.2	23.6	23.5	0.032	0.127	-0.102	-0.116					
Mean	36.7	36.3	35.6	34.9	0.043	0.241	-0.072	-0.089	24	43	21	1.72	49.0
SDev	15.5	15.2	15.4	15.5	0.019	0.148	0.038	0.019	0	1	6	0.73	11.2
Var	34	34	35	36	41	63	56	16	1	2	30	42	23
Zero	3.8	4.3	4.5	5.4									

Table 13. SO_2 Flux Data Summary for September 10, 1983

Time MST	Observed SO_2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C m/s 8 m	21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO_2] ug/m3
	on 50 ppbv scale												
1515	38.5	38.7	38.8	39.0	0.042	0.093	0.071	-0.101					
1530	30.4	30.2	30.4	30.5	0.011	0.020	-0.018	-0.127	13	66	0.8	0.30	0.00
1545	29.9	29.7	28.9	29.4	-0.000	-0.005	-0.024	-0.004	13	67	0.3	0.21	0.00
1600	14.2	13.0	13.7	13.2	0.003	0.004	-0.024	-0.004					
Mean	28.3	27.9	27.9	28.0	0.014	0.028	0.001	-0.059	13	67	0.6	0.26	0.00
SDev	10.2	10.8	10.5	10.8	0.019	0.044	0.047	0.064	0	1	0.4	0.06	
Var %	37	40	38	40	127	200	16	158	1	1	64	23	
Zero	10.1	10.3	9.7	10.7									

Table 14. SO2 Flux Data Summary for September 15, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C m/s 8 m	21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO2] ug/m3
	on 50 ppbv scale												
0900	25.9	26.0	26.1	25.0	-0.001	0.034	0.015	-0.039					
0915	31.3	31.5	31.1	29.2	0.002	0.055	0.080	-0.066	9	95	16	0.29	42
0930	43.1	44.2	43.0	40.6	-0.003	0.072	0.039	-0.041	10	94	13	0.31	64
0945	39.2	39.7	38.4	37.3	-0.002	0.090	0.012	-0.077	11	93	16	0.36	52
1000	29.6	29.9	29.1	28.3	0.002	0.101	0.000	-0.050	11	91	18	0.39	38
1015	14.4	14.4	14.3	14.0	0.010	0.133	0.059	-0.143	12	88	18	0.40	17
1030	12.5	12.4	12.3	12.0	0.018	0.115	-0.007	-0.015	12	86	21	0.43	14
1045	8.9	8.6	8.6	8.4	0.008	0.090	0.031	-0.109	13	85	20	0.36	5
1100	16.3	16.0	15.6	15.0	0.001	0.111	0.029	0.008	13	81	12	0.37	18
1115	34.9	34.8	34.2	32.5	0.014	0.100	0.022	-0.142	13	79	21	0.35	48
1130	28.8	29.1	28.6	27.4	0.013	0.067	0.027	-0.012	14	78	16	0.32	46
1145	34.8	35.0	34.6	33.6	0.012	0.064	0.015	-0.127	15	69	19	0.37	44
1200	6.3	5.9	6.0	5.8	0.015	0.074	0.038	-0.024					
Means	25.1	25.2	24.8	23.8	0.007	0.085	0.028	-0.064	12	85	17	1.44	35
SDev	12.1	12.4	12.0	11.5	0.007	0.027	0.023	0.051	2	8	3	0.16	19
Var %	44	45	44	44	105	27	90	77	14	9	17	11	53
Zero	4.1	4.3	4.1	4.5									

Table 15. SO2 Flux Data Summary for September 16, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m		Covariance deg C m/s 8 m	21 m	Temperature Difference Signal mV 8 m 21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO2] ug/m3
on 50 ppbv scale, 100 ppbv after 1415 MST													
1215	58.1	57.9	55.8	55.9	s	0.02	-0.073	-0.084					
1230	57.5	58.2	57.9	57.5	o	0.05	-0.086	-0.031	11	86	10	0.18	97
1245	108.9	107.7	103.8	107.2	n	0.08	-0.077	-0.103	11	85	18	0.22	168
1300	117.7	118.3	118.7	117.0	i	0.08	-0.082	-0.049	11	85	36	0.23	155
1315	79.7	80.7	81.5	79.0	c	0.04	-0.060	-0.129	11	85	18	0.21	104
1330	57.3	56.9	57.1	57.0		0.05	-0.057	-0.043	10	85	25	0.18	71
1345	60.6	60.1	61.1	59.8	o	0.07	-0.037	-0.079	11	85	19	0.19	81
1400	91.1	89.1	92.2	90.3	f	0.08	-0.058	-0.041	11	83	29	0.22	120
1415	128.9	129.2	129.4	128.3	f	0.06	-0.061	-0.132	11	81	18	0.22	206
1430	101.8	103.2	102.2	101.0		0.05	-0.041	-0.049	11	80	17	0.19	258
1445	66.7	66.9	66.1	66.4		0.04	-0.057	-0.095	11	81	5	0.16	176
1500	49.1	49.2	49.0	48.7		0.03	-0.068	-0.058	11	82	7	0.14	136
1515	27.1	26.7	26.3	26.9		0.02	-0.045	-0.043	11	82	9	0.11	62
1530	8.5	7.6	7.8	8.0		0.01	-0.054	-0.031					
Means	92.9	92.9	92.7	87.0			-0.060	-0.068	11	83	18	0.19	136
S Dev	47.5	48.4	47.7	46.1			0.015	0.036	0	2	9	0.04	59
Var %	42	43	42	44			27	48	3	2	52	19	43
Zero	4.8	5.1	5.1	5.9	on 50 ppbv scale								

Table 16. SO2 Flux Data Summary for September 22, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C m/s 8 m	21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO2] ug/m3
	on 50 ppbv scale												
0915	93.2	92.5	91.1	88.2	0.000	0.083	0.020	-0.056					
0930	61.6	63.0	61.9	61.2	-0.000	0.116	-0.072	-0.022	13	74	17	0.32	75
0945	26.3	26.2	25.6	25.8	0.030	0.162	0.007	-0.043	14	72	21	0.34	29
1000	16.5	16.4	16.4	16.1	0.006	0.117	0.170	-0.053	14	71	16	0.36	16
1015	14.2	14.0	14.0	13.8	0.001	0.165	-0.074	-0.059	15	69	21	0.39	15
1030	20.6	20.1	19.9	19.6	-0.000	0.159	-0.019	-0.049	16	68	18	0.40	23
1045	17.2	17.0	16.9	16.7	-0.000	0.116	0.050	-0.058	16	66	21	0.42	18
1100	22.5	22.1	22.1	21.6	-0.000	0.147	0.030	-0.089	17	64	17	0.43	27
1115	11.5	11.6	11.4	11.4	-0.000	0.145	0.091	-0.042	18	62	21	0.45	9
1130	11.5	10.9	10.4	11.3	-0.000	0.175	-0.084	-0.075	18	60	18	0.46	0
1145	5.6	5.8	6.0	5.7	-0.000	0.122	0.033	-0.088					
Means	27.3	27.2	26.9	26.5	0.003	0.137	0.014	-0.058	16	67	19	0.40	24
S Dev	26.4	26.4	26.0	25.2	0.009	0.028	0.076	0.020	2	5	2	0.05	21
Var %	97	97	97	95	281	21	552	35	12	7	11	13	90
Zero	4.5	4.6	4.4	5.2									

Table 17. SO2 Flux Data Summary for September 24, 1983

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C 8 m	Covariance m/s 21 m	Temperature Difference Signal mV 8 m	Temperature Difference Signal mV 21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO2] ug/m3
	on 50 ppbv scale												
0945	41.5	41.3	41.1	39.7		0.053	-0.035	0.328	8	76	18	0.26	84
1000	30.5	30.8	29.8	28.2		0.100	-0.036	-0.056	9	73	14	0.36	60
1015	37.6	37.9	37.3	36.0		0.125	0.127	-0.059	10	69	18	0.39	68
1030	53.9	54.6	54.3	52.5		0.152	-0.019	-0.083	11	66	17	0.40	86
1045	64.4	65.8	64.9	63.0		0.042	-0.040	-0.067	12	63	15	0.23	100
1100	90.0	91.0	88.9	89.5		0.062	0.005	-0.024	12	63	15	0.28	185
1115	72.9	73.6	72.9	70.8		0.132	0.026	-0.080	13	59	20	0.51	177
1130	53.7	53.2	53.0	50.9		0.179	0.139	-0.070	14	54	16	0.48	139
1145	55.9	54.1	53.5	51.4		0.158	0.040	-0.087	14	53	23	0.43	81
1200	38.3	38.6	37.5	36.3		0.073	-0.017	-0.083	15	50	20	0.32	57
1215	54.0	54.3	53.8	52.4		0.094	-0.040	-0.064	15	49	19	0.32	83
1230	61.0	61.8	61.5	60.6		0.082	-0.019	-0.043	15	49	20	0.37	94
1245	112.5	113.3	113.4	112.9		0.132	-0.022	-0.073	15	48	16	0.39	151
1300	59.0	60.8	60.0	58.4		0.145	-0.028	-0.067					
Means	58.9	59.4	58.7	57.3		0.109	0.006	-0.037	13	59	18	1.46	105
S Dev	21.7	22.0	22.0	22.4		0.043	0.059	0.107	2	10	3	0.08	43
Zero	4.3	4.4	4.1	4.9									

Table 18. SO2 Flux Data Summary for September 26, 1983

on 50 ppbv scale until 1215 MST, then, 100 ppbv till 1445.

Time MST	Observed SO2 Response (mV) 22 m	19 m	10 m	5 m	Covariance deg C 8 m	Covariance m/s 21 m	Temperature Difference Signal mV 8 m	21 m	T C	RH %	Sigma Theta Deg	Sol. Rad. MJ/m3	Trailer [SO2] ug/m3
1200	87.9	91.4	86.6	85.1	0.014	0.028	-0.057	-0.039					
1215	132.6	132.5	127.5	131.6	0.007	0.034	-0.051	-0.053	13	78	20	0.17	211
1230	93.5	93.8	91.2	88.6	0.011	0.032	-0.066	-0.045	13	76	16	0.14	222
1245	63.2	63.6	62.9	63.3	0.009	0.037	-0.066	-0.037	13	76	9	0.14	142
1300	35.5	36.3	35.9	35.6	0.009	0.032	-0.086	-0.041	13	76	16	0.15	89
1315	24.5	24.6	24.4	23.9	0.012	0.037	-0.099	-0.051	13	76	12	0.16	65
1330	15.6	15.8	15.7	15.5	0.018	0.048	-0.069	-0.034	14	75	17	0.21	41
1345	11.4	11.3	11.2	11.1	0.007	0.075	-0.045	-0.064	14	74	14	0.26	29
1400	9.9	9.8	9.7	9.6	0.017	0.077	-0.033	-0.062	14	73	10	0.26	28
1415	13.3	13.0	13.0	13.1	0.014	0.074	-0.034	-0.049	15	72	23	0.21	36
1430	11.1	11.1	11.0	11.0	0.015	0.046	-0.102	-0.046	15	71	18	0.19	23
1445	6.1	5.9	5.9	5.9	0.009	0.033	-0.071	-0.041					
Means	32.9	33.1	32.3	32.2	0.012	0.046	-0.065	-0.047	14	75	16	0.19	89
S Dev	28.2	28.4	27.5	27.3	0.004	0.019	0.023	0.009	1	2	4	0.05	77

Zero 2.2 2.3 2.5 3.2 on 100 ppbv scale.

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