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COMPARISON OF GROUND BASED AND TOMS MEASUREMENTS OF SO_2 FROM VOLCANIC EMISSIONS

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The Brewer Ozone Spectrophotometer is being used in the World Ozone Network to monitor ozone and SO_2. SO_2 from both natural as well as anthropogenic sources are measured. It has been demonstrated that SO_2 interferes with total ozone values as measured by the Dobson Spectrophotometer and TOMS. A small amount of manmade SO_2 is difficult to detect and quantify by TOMS because it is located near the surface. However, larger amounts of SO_2 injected into the stratosphere from volcanic emissions are detected by TOMS.

There have been some instances when the Brewer instrument was measuring SO_2 from the ground at the same time TOMS was measuring it from space. Results of these comparative measurements are presented.

Introduction

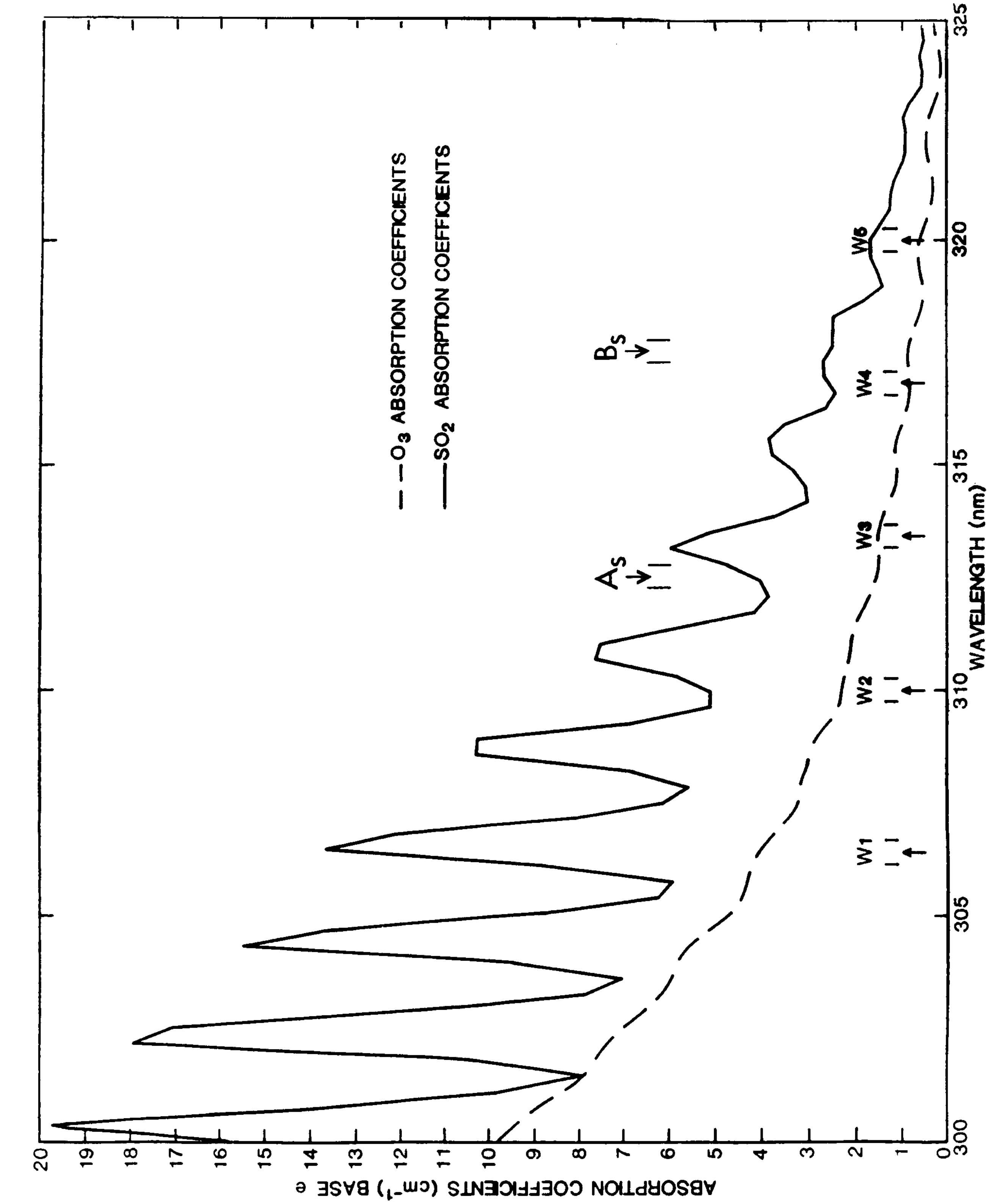
The Brewer Ozone Spectrophotometer and TOMS measure column amounts of ozone and SO_2 by ultraviolet spectroscopy. The Brewer measures both natural and anthropogenically produced SO_2 to a precision of about 1 matmcm and TOMS measures stratospheric SO_2 which usually results from volcanic emissions.

There have been three instances when TOMS detected SO_2 from space on the same day that the Brewer was measuring it from below. These three occasions were after SO_2 was injected into the stratosphere as a result of volcanic emissions. The three eruptions were Mount St. Helen's on May 18, 1980, El Chichon on March 28 - April 3, 1982 and Krafla, Iceland on September 5, 1984. Results of the SO_2 measured in these three volcanic clouds are presented here.

Method

Both ozone and SO_2 have strong absorption bands at wavelengths in the ultraviolet. The absorption spectra for these gases between 300 and 325 nm at a resolution of .5 nm is shown in Figure 1. The A and B short wavelengths for TOMS as well as the five operational wavelengths for the Brewer are indicated.

The method to measure SO_2 and ozone using the direct sun absorption technique with the Brewer Spectrophotometer has been described by Kerr et al. (1980). In this method,the absorption spectra of each gas have been carefully considered prior to selecting the five operational wavelengths. The measured solar



O3 ABSORPTION COEFFICIENTS
SO2 ABSORPTION COEFFICIENTS
As
Bs
W1
W2
W3
W4
W5
ABSORPTION COEFFICIENTS (cm-1) BASE e
WAVELENGTH (nm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
300
305
310
315
320
325

Figure 1.

light intensities at the five wavelengths are used in two algorithms: one is insensitive to absorption by SO_2 and the other is insensitive to ozone. Kerr et al. (1984) have demonstrated that total ozone as measured by the Brewer is indeed unaffected by the presence of SO_2 during pollution events at Toronto.

It is evident from Figure 1 that the absorption by SO_2 at the TOMS A and B short wavelengths is about 2.5 times that of ozone. Therefore, the presence of 1 matmcm of atmospheric SO_2 causes an apparent increase of 2.5 matmcm ozone for both the A and B measurement. Because ozone and SO_2 affect the A and B pairs in a similar manner, it is difficult to discriminate between the two gases using the standard ozone inversion algorithms. Following the technique which is used to measure SO_2 by the Brewer, an algorithm has been developed for discriminating between SO_2 and ozone has been successfully used to extract stratospheric SO_2 amounts from the TOMS irradiance data.

Results

There have been two occasions when significantly large SO_2 amounts from volcanic emissions were measured by the Brewer from the ground on the same days as TOMS measurements were made from space. Figure 2 shows the TOMS SO_2 measurements for May 19-20, 1980. Here the SO_2 which was emitted by the May 18 eruption of Mount St. Helen's is clearly evident. SO_2 values as large as 100 matmcm were observed on May 20 with typical values of about 60 to 70 matmcm. The leading edge of the cloud was located about 300 km southwest of Toronto (indicated by x) at about 17:00 GMT when the TOMS map was made. The ground based Brewer SO_2 measurements for May 20-23, 1980 are shown in Figure 3. At about 19:00 GMT on May 20 the SO_2 readings began increasing and peaked about 70 matmcm at 23:00 GMT. The following day SO_2 values remained between 30 and 40 matmcm before returning to near normal values near the end of the day. In general, the results of the TOMS and Brewer SO_2 measurements are in good agreement with regard to both the measured time of arrival of the cloud in the Toronto area as well as the measured values of SO_2 within the cloud.

The second occasion when both the Brewer and TOMS measured significant values of SO_2 on the same day was on September 7, 1984 over Norrkoeping, Sweden. This was two days after an eruption of the Krafla volcano in Iceland. Figure 4 shows the drift of the SO_2 cloud from September 5 to 7 as measured by TOMS. This map suggests that the cloud passed over Norrkoeping (indicated by N) sometime between September 6 and 7. SO_2 values within the cloud are typically between 30 and 40 matmcm.

The SO_2 values as measured by the Brewer for September 7 are shown in Figure 5. Observing conditions on this day were very good with a clear sky all day. For comparison SO_2 on September 6 was typically .4 matmcm and on September 8 it was about 1.0

MOUNT ST. HELENS MAY 1980

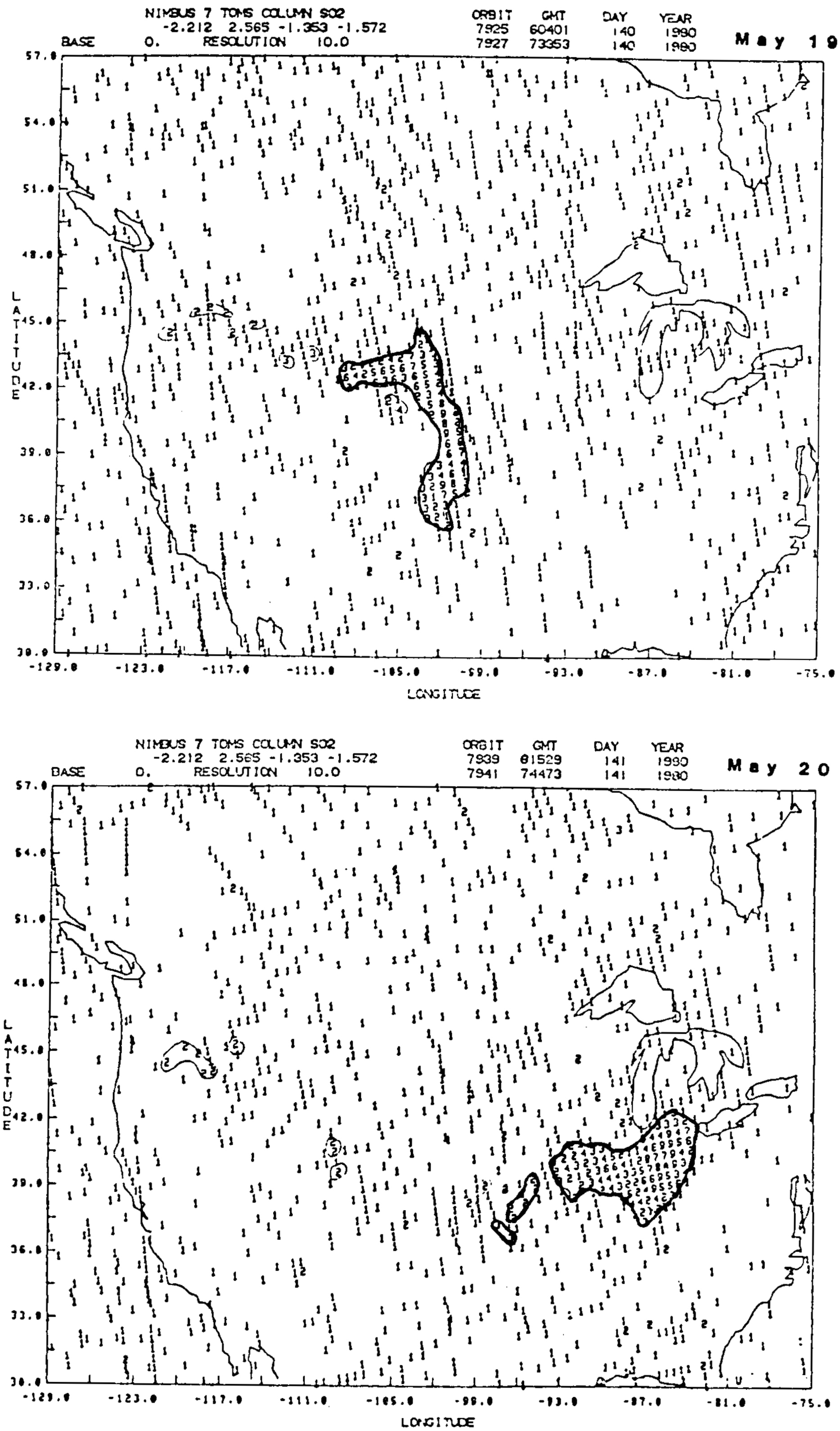


Figure 2.

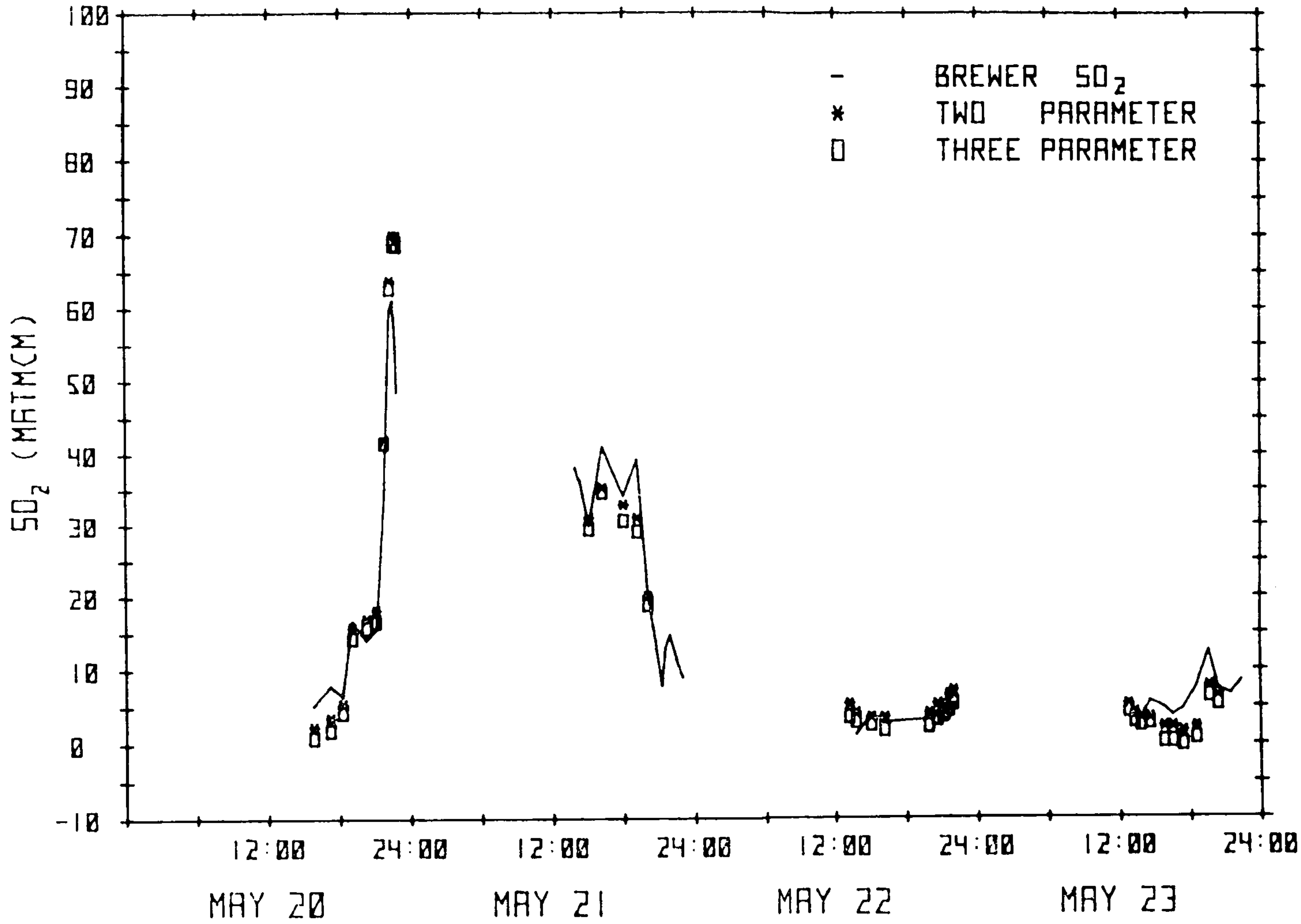

100
90
80
70
60
50
40
30
20
10
0
-10
SO2 (MATMCM)
- BREWER SO2
* TWO PARAMETER
□ THREE PARAMETER
12:00
24:00
12:00
24:00
12:00
24:00
12:00
24:00
MAY 20
MAY 21
MAY 22
MAY 23

Figure 3.

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Drift of the 5 Sept 1984 Krafla Eruption Cloud

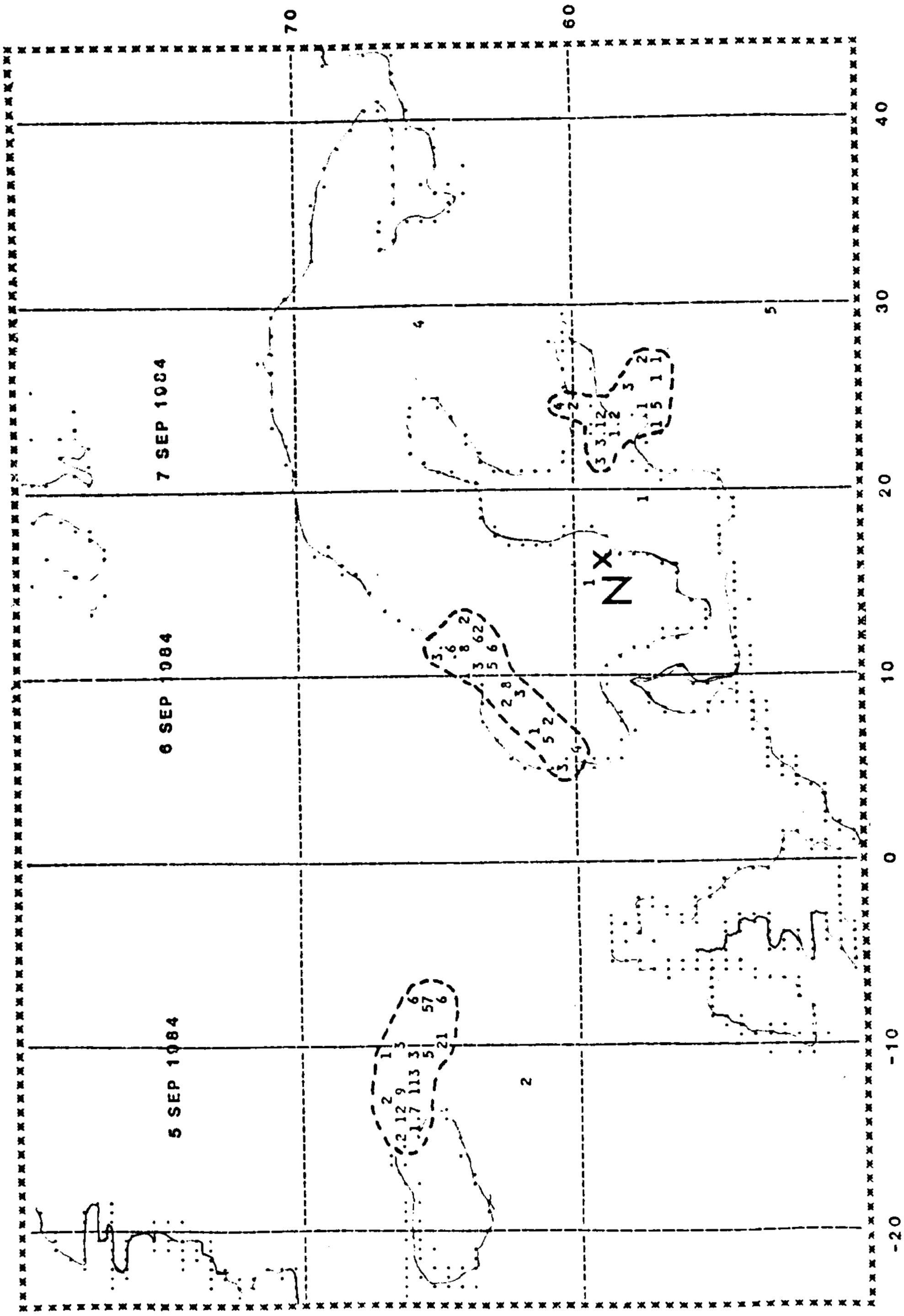
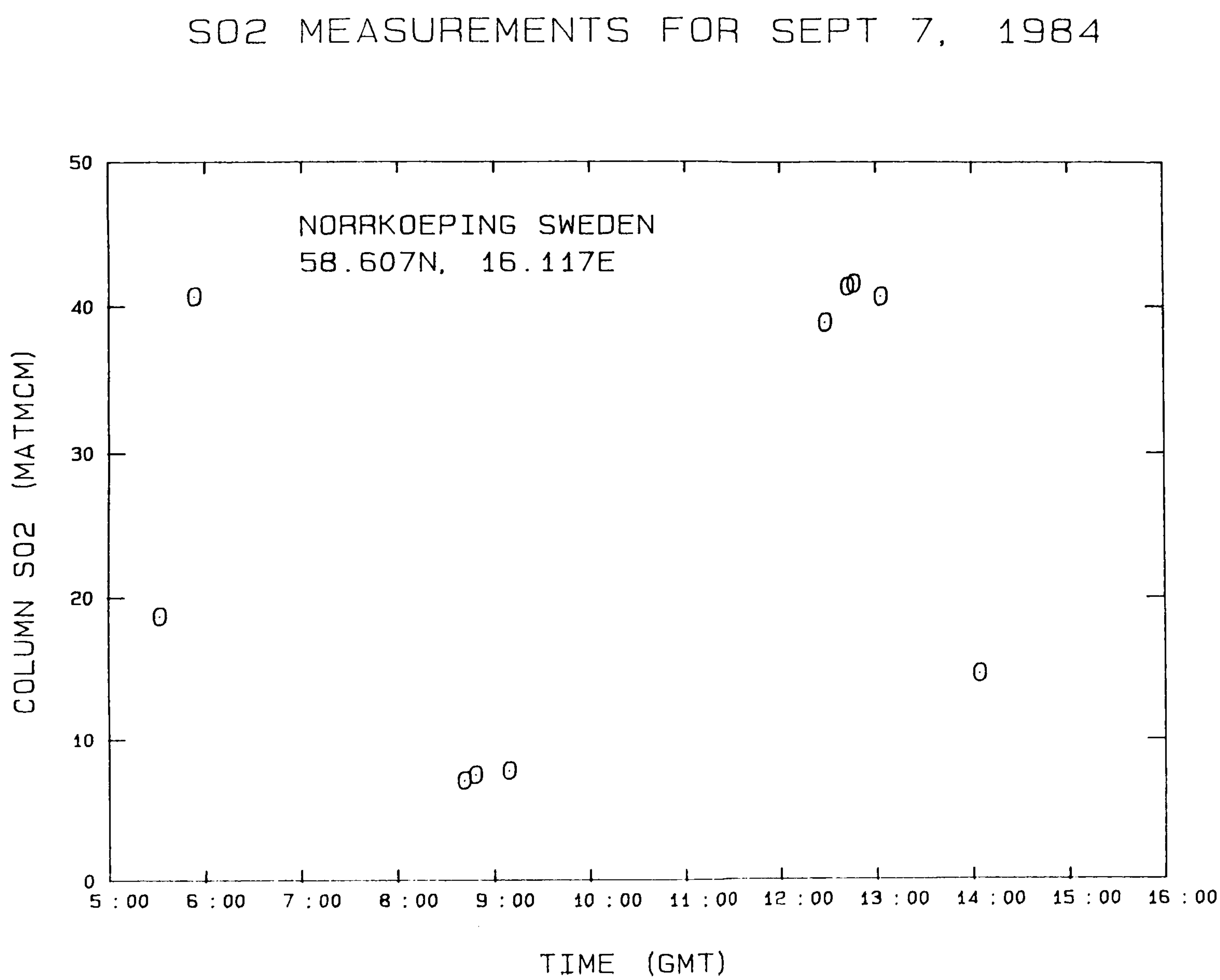


Figure 4.



SO2 MEASUREMENTS FOR SEPT 7, 1984
NORRKOEPING SWEDEN
58.607N, 16.117E
COLUMN SO2 (MATMCM)
0
10
20
30
40
50
5 : 00
6 : 00
7 : 00
8 : 00
9 : 00
10 : 00
11 : 00
12 : 00
13 : 00
14 : 00
15 : 00
16 : 00
TIME (GMT)

Figure 5.

matmcm. The values in excess on 40 matmcm on September 7 are attributable to the Krafla eruption. The ground based measurements suggest that there are at least two times during the day that the SO_2 column exceeded 40 matmcm: once in the early morning and later in the mid afternoon. When the ground based record is compared with the TOMS measurements, the early morning large values are consistent with the passage of the cloud as measured by TOMS. However, there is no evidence of the second (mid afternoon) cloud on the TOMS record. Airmass trajectory studies suggest that the SO_2 in the later cloud is at pressures between 500 and 700 mb in the troposphere. It is quite likely that the early morning peak is the stratospheric SO_2 which arrived over Norrkoeping a few hours ahead of the tropospheric SO_2. Also, it appears that the lower level SO_2 was "hiding" and was not detected by TOMS.

Following the eruption of El Chichon, measurements were made of SO_2 in the remnants of the volcanic cloud. Measurements were made five weeks after the initial eruption when the SO_2 had dispersed significantly. On this occasion, the Brewer made measurements from a NASA CV-990 aircraft which flew under the volcanic debris between 20° and 50° N latitude at a longitude of about 125° W. Figure 6 shows the TOMS measurements for May 6, 1982 with the flight path of the Brewer indicated. There is evidence of slight traces of SO_2, however, for the most part, the measurements are within the noise of TOMS measurements. Figure 7 shows the underpass measurements made from an altitude of 35,000 ft. There was an abrupt increase from background values of SO_2 to about 5 matmcm at 35° N. The value of matmcm SO_2 is quite likely to be below the detection limit of TOMS.

The TOMS figures were provided by Arlin J. Krueger, GSFC.

References

J.B. Kerr, C.T. McElroy and R.A. Olafson, Measurements of ozone with the Brewer ozone spectrophotometer, Proceedings of the International Ozone Symposium, Boulder, CO, pp 74-79, 1980.

J.B. Kerr, C.T. McElroy, D.I. Wardle, R.A. Olafson and W.J. Evans, The automated Brewer ozone spectrophotometer, Proceedings of the Quadrennial Ozone Symposium, pp 396-401, Halkidiki, Greece, 1984.

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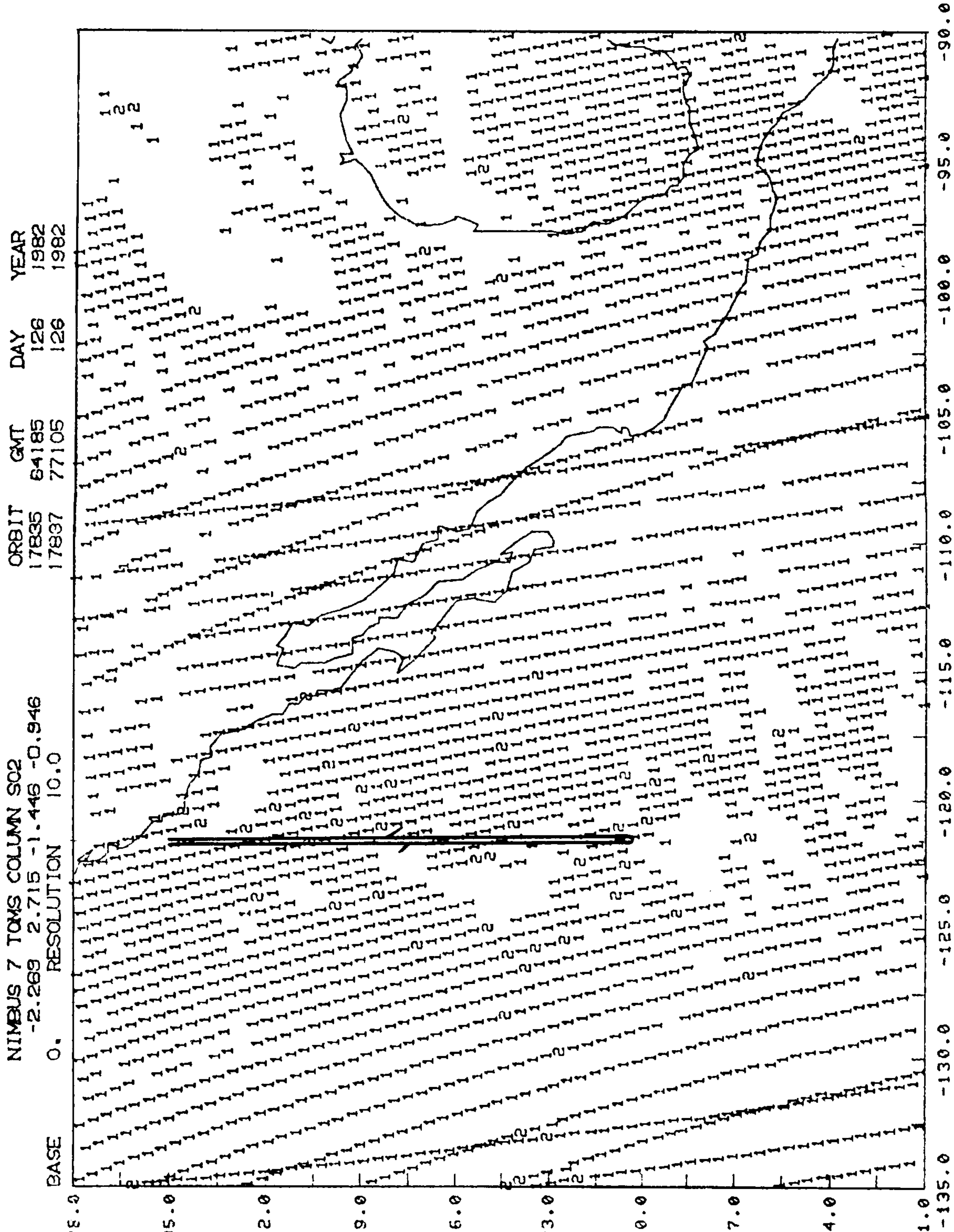

Figure 6.

SO_2 MEASUREMENTS FROM NASA CV990 OVERBURDEN OF SO_2 ABOVE AIRCRAFT

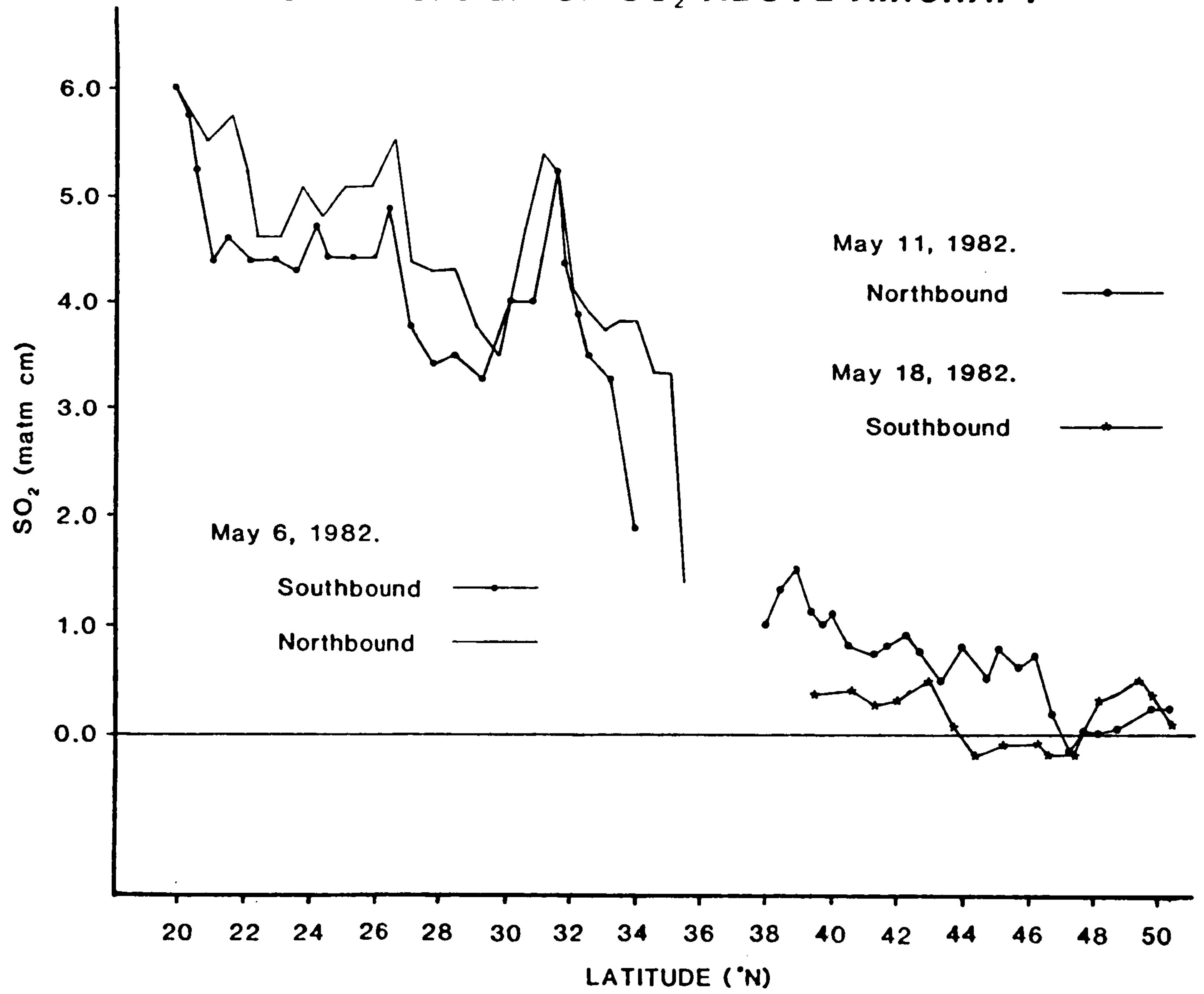

Figure 7.