NASA Contractor Report 165356

ANALYSIS OF GASP CARBON MONOXIDE DATA

Mao-Fou Wu
Institute for Atmospheric Optics and Remote Sensing
Hampton, Virginia 23666

August 1981

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lewis Research Center
Under Contract NAS3-22541

Page intentionally left blank

TABLE OF CONTENTS

1. INTRODUCTION

This report summarizes an analysis of carbon monoxide data from the Global Atmospheric Sampling Program (GASP). The objective of this study, as described in the original proposal, is to try to improve our understanding of the cycle of this trace species in the atmosphere. To date, the sources, sinks, and transports of CO are still not yet fully identified and understood. While some of the previous figures and/or ideas on its production are under revision, new thoughts are being proposed. For example, Crutzen et al. (1979) have recently suggested that the burning of biomass is another possible source. The high values of CO found over Africa during October 1977 PAN AM round-the-world flight were first explained by Newell and Gauntner (1979) as the result of interhemispheric transport, but Pratt and Falconer (1979) attribute them as originating from vegetation in the tropical regions. A good summary of our current understanding of the carbon monoxide budget has been given recently by Marenco and Delaunay (1980). This report provides more information about the distribution and variation of CO and presents our new findings.

2. DATA

2.1 General Description

All carbon monoxide data used in the analysis are from GASP measurements. GASP was a multiyear program beginning in 1972 to measure atmospheric ozone, carbon monoxide, water vapor, condensation nuclei, and clouds, and related meteorological parameters with instruments aboard four commercial airlines (a United Airlines B-747, two Pan American World Airways B-747's, a Qantas Airways of Australia B-747) and the NASA CV-990 research aircraft. The in situ CO measurement is made with an infrared absorption analyzer using dual isotope fluorescence as described by Dudzinski (1979). For each flight, data acquisition begins on ascent through the 6 km altitude flight level, and terminates at descent through 6 km, with most observations taken between 10- and 12-km altitude. A complete GASP sampling cycle is 1 hour, divided into twelve 5-minute sampling segments. Six of these segments were data segments during which measurements were made. Interspersed between these data segments were six 5-minute calibration segments during which the systems are under checking and adjustment. Details on instrumentation, routes, and other information can be found in data reports by Holdeman et al. (1978, 1979, 1980) and Briehl et al. (1980).

2.2 Availability

The CO data are stored on tapes VL0009 through VL0020, which cover the period March 1977 through October 1978; the content of each tape is described in the above mentioned "Data Reports." A summary of carbon monoxide observations and flights is given in Tables 2.1 and 2.2. Although data are taken in all flights above 6 km altitude, the bulk of observations fall between about 9 km and 12.5 km. Furthermore, the data are scattered unevenly over the globe. Beside the GASP data, the tapes also contain the tropopause heights (both in pressure and in meters) obtained from time and space interpolation of National Meteorological Center (NMC) archived data for the dates of the flights.

2.3 Data Check

All CO data used in the analysis were checked for obvious errors. Unexplained anomalies, such as very high values (reaching to 200 ppbv) in the stratosphere, were not included in the climatological presentation of carbon monoxide distribution over the globe. Other checks, including zero shift, variability, tagged values, extremely low and high readings, were carried out for all flights made by all aircraft for the period March 1977 through October 1978. If the zero is shifting rapidly, as indicated by inspection and by the number of values tagged "C," an indicator used to denote zero shifts of more than 100 mv but less than 200 mv between successive zero reading, then the data is classified as poor. Also, if the data is tagged "F," an indicator used to denote full scale data readings (COV = 5000 mv), then the data is classified as poor. Likewise, negative readings, again an indication of zero setting problems, would receive this classification. A method by which CO concentration is computed from the instrument voltage is outlined in "Data Reports" mentioned previously. A good guide to possible zero setting problems seems to be available in the mean stratospheric concentrations. If these are close to 50 ppbv as found earlier by Seiler (1974), then, in general, the remainder of the data in a given file seems to be problem free. This cannot be an absolute rule, otherwise we would be producing a prejudiced climatology, but it is a good guide that seems to fit in with other tests. Several measurements of very low CO (10-20 ppbv) did appear in the stratosphere and these were retained in the analysis, when the mean values were close to 50 ppbv. In fact, each of the observations has been scanned visually by both the author and Professor Newell. After some experience, it is possible to pick out anomalies rather easily. Almost all the very low CO values are characteristic of the stratosphere and are associated with high ozone. Sometimes these values are found below the nominal tropopause; more examples are given later. A more sophisticated approach could be devised to divide the data between troposphere and stratosphere now that this experience has been gained, but for the present report the division is based on the nominal height of the tropopause as given in the data tapes.

Very high point-to-point variabilty can also sometimes be used as an indicator that the instrument is not working properly, particularly if this occurs throughout the tape. Some studies of the autocorrelation distance (not included here) based on data we considered excellent by other criteria yielded values of several hundred kilometers. Occasionaly, sizeable patches of very high or very low CO will occur and these could be studied further as we suggest by trajectory analysis. At this time they are thought to be real.

The quality of each tape or the performance by individual aircraft is rated based on the above mentioned check items, and indicated in Table 2.1 with a short explanation in the remarks. Consequently, tape 10, tape 18, file 2 of tape 19, files 1 and 2 of tape 20, the first 1.5 hours of measurements by QANTAS contained in tape 11, and the winter CO data in file 1 of tape 14 are omitted in the final composite presentations on an aircraft basis. Some of the data are treated separately for a comparison purpose. Note that the full scale data readings (COV = 5000 mv) identified with an "F" were also discarded. A substantial amount of data had already been removed before the tapes were made available by means of the criteria that the zero shift between readings exceeded 200 mv.

TABLE 2.1. Summary of GASP Carbon Monoxide Data

Tape no.	Aircraft	File	Dates	Total flights	Quality	Remarks
9	PAN AM-N533 PA	1-4	10/28-31/77	4	Very good	Round-the-world
10	PAN AM-N533 PA	1	01/21/77-04/03/77	66	--	No CO data
		2	04/06/77-05/31-77	99	Poor	High variability, suspect zero drift
		3	06/01/77-06/02-77	2	Poor	therefore, not included in the
		4	06/03/77-08/12/77	96	Poor	analysis
		5	08/13/77-10/04/77	73	Poor	
11	QANTAS VH-EBE	1	01/10/77-02/28/77	127	--	No CO data
		2	03/15/77-04/23/77	120	OK	Low readings of CO occur often during
		3	04/24/77-06/18/77	144	OK	the first 1- to 2-hour flights owing
		4	06/18/77-08/12/77	131	OK	to the water vapor contamination
		5	08/15/77-10/02/77	124	OK	effect on the desiccator
12	UAL-N4711U	1	01/03/77-03/25/77	49	--	No CO data
		2	03/26/77-06/13/77	102	OK	Flight route is limited between
		3	06/14/77-07/26/77	93	OK	21°N-46°N and 74°W-157°W
		4	07/27/77-09/20/77	110	--	No CO data
13	PAN AM-N655 PA	1	02/22/77-04/09/77	84	--	No CO data
		2	04/15/77-06/14/77	126	OK	--
		3-5	06/01/77-10/05/77	266	--	No CO data
14	PAN AM-N533 PA	1	10/04/77-01/03/78	109	Fair	CO values are OK in fall, but too high in winter
	UAL-N4711U	2	11/06/77-01/05/78	138	OK	--
	PAN AM- N655 PA	3	10/05/77-12/18/78	99	OK	--
	QANTAS VH-EBE	4	10/03/77-11/19/77	96	OK	--
	QANTAS VH-EBE	5	11/20/77-01/04/78	120	OK	CO values are too high in winter stratosphere

TABLE 2.1. Continued

Tape no.	Aircraft	File	Dates	Total flights	Quality	Remarks
15	PAN AM-N533 PA	1	01/08/78-03/01/78	81	Excellent	Good for case studies
		2	03/02/78-05/03/78	81	Excellent	
		3	05/04/78-06/21/78	84	--	No CO data
16	PAN AM-N533 PA	1	06/22/78-08/14/78	111	Good O_3	No CO data
		2	08/01/78-10/05/78	102	data	
17	UAL-N4711U	1	01/05/78-03/20/78	160	Good	
		2	03/22/78-05/08/78	79	Good	
		3	05/08/78-06/23/78	103	Good	
18	UAL-N4711U	1	06/23/78-08/11/78	123	Poor	Many CO data with tag C;
		2	08/11/78-10/06/78	70	Poor	Summer values are unreasonably high; not included in the analysis
19	QANTAS VH-EBE	1	01/05/78-03/04/78	70	Poor/fair	Treated separately, high variability
	PAN AM-N655 PA	2	01/09/78-03/06/78	160	Fair	Treated separately
	PAN AM-N655 PA	3	03/06/78-05/02/78	82	Poor	Many CO data with tag F; CO values are too high; not included in the analysis
20	PAN AM-N655 PA	1	05/16/78-06/12-78	67	Poor	Many CO data with tag F;
		2	06/13/78-07/27/78	134	Poor	not included in the analysis
		3	07/28/78-10/09/78	162	OK	Treated separately

TABLE 2.2. Summary of CO Measurements by Aircraft

Aircraft	Period	No. of month
PAN AM-N533 PA	04/06/77-10/04/77 10/28/77-10/31/77 10/04/77-12/21/77 01/08/78-06/21/78	15
PAN AM-N655 PA	04/14/77-05/07/77 10/05/77-12/18/78 01/09/78-10/09/78	14
UAL-N4711U	03/26/77-07/26/77 11/17/77-01/05/78 01/05/78-10/06/78	15
QANTAS VH-EBE	03/22/77-10/02/77 10/03/77-12/04/77 01/05/78-03/04/78	11

3. RESULTS AND DISCUSSIONS

3.1 Analysis Procedures

The analysis procedures involved tabulating and analyzing the CO data on a tape basis first. For those tapes which contain CO measurements by more than one aircraft, we have followed the same processes on a file basis. Finally, the composite results from four airliners, namely, PAN AM-533PA, PAN AM-N655 PA, UAL-N4711U and QUANTAS VH-EBE, are given in tabular as well as in graphical forms. In the presentations, mean values of CO and their standard devitations have been summarized on a 10° latitude by 20° longitude grid basis with subdivision into troposphere and stratosphere using reported tropopause heights with a further subdivision into seasons. In the computations of cross correlation coefficients among carbon monoxide, ozone, temperature, and zonal and north-south winds, we require that all the variables must be measured simultaneously and that the ozone data with an "L" tag is excluded. Special treatment of tape 9 has been made. Since all the data are local measurements, they were averaged by one degree in latitude and then used for plotting. However, both local and averaged values were used in the study (see Figures 3.1-2). For the other tapes, we used 128 second average values throughout.

Data were divided into four seasons: December-February, March-May, June-August and September-November. As abbreviations in the figures we have termed these winter (WI), spring (SP), summer (SU) and fall (FA) even though the basic division is calendar months regardless of hemisphere, and seasons is not an appropriate term for the tropics.

3.2 Distribution and Variations of Carbon Monoxide

3.2.1 On tape and aircraft basis

The distribution and variations of carbon monoxide as a function of latitude and longitude in the troposphere and stratosphere for different seasons are shown in Tables 3.1 through 3.10. Zonal mean values of CO mixing ratio are plotted in Figures 3.3a-d. The purpose of presenting the data based on tape or file is to enable us to make a good comparison among all observations conducted by different aircraft during their flights. Hopefully, we can select a good data set to be used for representation of the CO background values for a significant fraction of the world. Since to date there are no substantial statistics of this gas available, the GASP data can actually be considered as the largest collection in the world, and should provide useful information on the CO climatology. The earlier reports by Seiler (1974,1975) and Dianov-Klokov et al. (1978) in USSR contain far fewer values than the present report.

3.2.2 Composite results on an aircraft basis

After careful study we have selected data from the tapes and constructed four sets of CO climatological pictures based on four aircraft. The key to the data used in each set is shown in Table 3.11 in which Tables 3.12 and 3.13 are mentioned.

Figure 3.4 presents the composite results of zonal mean mixing ratio of carbon monoxide. The UAL flights of the summer of 1978 on tape 18 have been omitted from the overall summary because of zero drift.

problems. But a summary of these data is included in Table 3.8 for information as it illustrates one of the problems arising in the type of analysis. It will be noted that there is a sharp discontinuity at the west coast of the United States with values over the land much higher than values over the ocean. Further examination showed that this came from time variations of the zero setting rather than spacial variations of carbon monoxide. Flights from Chicago to Honolulu and return showed no such discontinuity at the coast.

We should point out the fact that the averaged values of CO mixing ratio for each grid area are derived from four aircraft whose flight routes are irregular in time and space.

3.2.3 Findings

Several findings are noted.

1. Measurements of CO made by different aircraft are generally consistent. Summaries of zonal mean values collected by the four aircraft are shown by season in Table 3.14. Note that for the spring troposphere there is very good agreement between data from three aircraft. For the fall and winter troposphere agreements is not so good and we use the stratosphere data as a guide at this time. Values in the general range of CO of 50-70 ppbv are considered acceptable. On this basis all three aircraft provide good data in the spring, while the UAL data in the summer is suspect. Inspection of the individual QANTAS results for the fall showed many cases of high ozone and CO values in the 50-70 ppbv range, hence these data were accepted. PAN AM-655 data is suspect in the fall. Both PAN AM-655 and QANTAS data are suspect in the

winter as they appear too high. Present climatology may be obtained from PAN AM-533 data with the addition of PAN AM-655 plus UAL in the spring, with QANTAS and UAL in the fall, and with UAL in the winter. Having this experience with the data set it would now be possible to go back and devise a different set of criteria for data selection; however, funds are exhausted so this is not possible.

2. The overall acceptable results shown in Table 3.14 indicate that northern hemisphere values are higher than those in the southern hemisphere and troposphere values are larger than those in the stratosphere, as found by Seiler (1974).

3. A new item is tentative evidence of a seasonal cycle with northern hemisphere spring values exceeding those of summer and fall. This finding confirms the conclusion of Dianov-Klokov et al. (1978) based on measurements of total CO in the atmospheric column.

4. There is no reliable data to evaluate the seasonal cycle in the southern hemisphere. Further work with this data set on this topic is recommended.

3.3 Relationship of Carbon Monoxide with Ozone, Temperature and Winds

3.3.1 On tape or aircraft basis

We first computed linear bivariate correlation coefficients among five variables: carbon monoxide (CO), ozone (O_3), air temperature (T), zonal wind (U) and north-south wind (V) on a tape or aircraft basis using the same division as in section 3.2. We anticipate that CO should correlate negatively with O_3 in the vicinity of the tropopause. The agreement is based on the fact that O_3 is mainly produced in the stratosphere, while CO has its source on the ground and, therefore, the vertical gradients are oppositely directed. An upward motion will bring more CO and less O_3 to the tropopause region. A downward motion would act in an opposite way.

In view of the difference in the production rates of CO and O_3 over an annual cycle, we have divided the data into seasons. A special treatment of tape 9 has been made. The correlation coefficients (R's) were computed separately for individual flights, for the troposphere and stratosphere and for the averaged values over 1° latitude. The results are presented in Table 3.15a-c. The R's for other tapes are given in Tables 3.16-3.22. It is noted that the data on tape 9 have been studied by Holdeman et al. (1978), Gauntner et al. (1979), Newell and Gauntner (1979,1980), and Pratt and Falconer (1979).

3.3.2 Composite results on an aircraft basis

Computations of correlation coefficients (R's) were performed on an aircraft basis (see Table 3.11 and Tables 3.23-3.26). In view of the dramatic decrease in CO mixing ratio in the stratosphere, which suggests that the chemical reactions of CO with other minor species become active in that region, and since the ozone mixing ratio shows almost constant and low values in the upper troposphere within about 20 degrees in either side of the equator from all observations (see Fig. A.1), we further divide the data into four categories, namely, troposphere, stratosphere, regions below and above 20° latitude. The R-values calculated in this arrangement are presented in Tables 3.23-3.26. Note that part of these correlations is contributed by the overall variation of carbon monoxide and other variables as a function of position and it would be desirable to eliminate this contribution to the variance. However, limited funds and time did not permit this differentiation.

3.3.3. Findings

1. On individual tape basis

Except the data on tape 11 which yield very low values of correlation coefficient between CO and O_3, $R(CO,O_3)$, possibly due to water vapor contamination on the instruments, the other 9 tapes provide us with 23 $R(CO,O_3)$'s of which 21 cases show minus signs and 2 show positive signs. Using a student-t test, we have found that none of the positive $R(CO,O_3)$'s are significant. For negative $R(CO,O_3)$'s, 19 out of 21 are significant at the 1% level or higher.

2. On aircraft basis

a. Above 20^o latitude

Twenty-two $R(CO,O_3)$ values have been obtained. All of them indicate the anticorrelation between CO and O_3. Three $R(CO,O_3)$'s are insignificant with the rest, 19 values of R, having significant levels higher than 1%.

b. Below 20^o latitude

There are only seven R values. Interestingly enough, all but one have positive signs. However, most of them are insignificant; only one has significance at the 1% level and two at about the 3% level. In general, the lowest correlations occur for aircraft and season which were rejected in our consideration of Table 3.14.

3.4 Case Studies

We have made several case studies examining how the CO mixing ratio changes in response to the variations of O_3 concentrations. Records of flight level, tropopause altitude, air temperature, ozone and carbon monoxide mixing ratios are plotted in Figure 3.5 through Figure 3.11. It is seen clearly in these figures that in the stratosphere the O_3 mixing ratio and the air temperature are high and the CO mixing ratio is low, and that the picture is reversed when the aircraft is flying in the troposphere. However, two interesting points are worthy of note.

1. At times when the aircraft was supposed to be in the troposphere according to the tropopause altitude indication, occasionally one finds that the mixing ratio of CO decreases sharply and the O_3 and T increase at the same time. Such incidences can be found in Figure 3.5 (by the arrow at 0115 GMT) and Figure 3.9 (by the arrow at 1050 GMT).

2. On the other hand, when the aircraft was indicated as flying in the stratosphere, the instruments suddenly recorded high CO, low O_3 and T values as shown in Figure 3.8 by the arrow at 1245 GMT and in Figure 3.10 by the arrow at 1900 GMT.

The former cases can be explained by the downward motion of the stratospheric air into the troposphere at those times, while the latter cases are thought to be due to an upward intrusion of the tropospheric air into the stratosphere. These examples lead us to suggest that the O_3 concentrations, the air temperature and the CO mixing ratio should be analyzed simultaneously and that the numerical height of the tropopause is not always a good indicator to be used for dividing the CO values. This approach could be used in future analysis.

3.5 Ozone Data

In view of the relationships found in section 3.3.3 between ozone and carbon monoxide, we include a summary of the ozone data itself in Appendix A. It may be seen from Figure A.1 that ozone in the upper tropical troposphere has an almost constant and low mixing ratio (~ 20 ppbv). These values are similar to those reported by Routhier et al. (1980) in the GAMETAG experiment. The negative correlation between the two species at high latitudes can no doubt be explained by vertical motion processes as illustrated in section 3.4. The positive correlation at low latitudes may partly arise from photochemical interactions between the species as have been described recently by Fishman et al. (1980). There may also be a contribution to the positive correlation from the process of advection. Northern hemisphere middle latitude air moving into the tropics will be traveling down the gradient of both ozone and carbon monoxide, as may be seen from a comparison of Figure 3.4 and Figure A.1.

There are some unexplained very low ozone concentrations (16-30 ppbv) in the middle latitudes as may be seen from Table A.9. These originate from the tape 20 record for May 1978. The instrument measured up to 600 ppbv when the aircraft was definitely in the stratosphere so these measurements are not evident instrument problems.

(text continues on page 113)

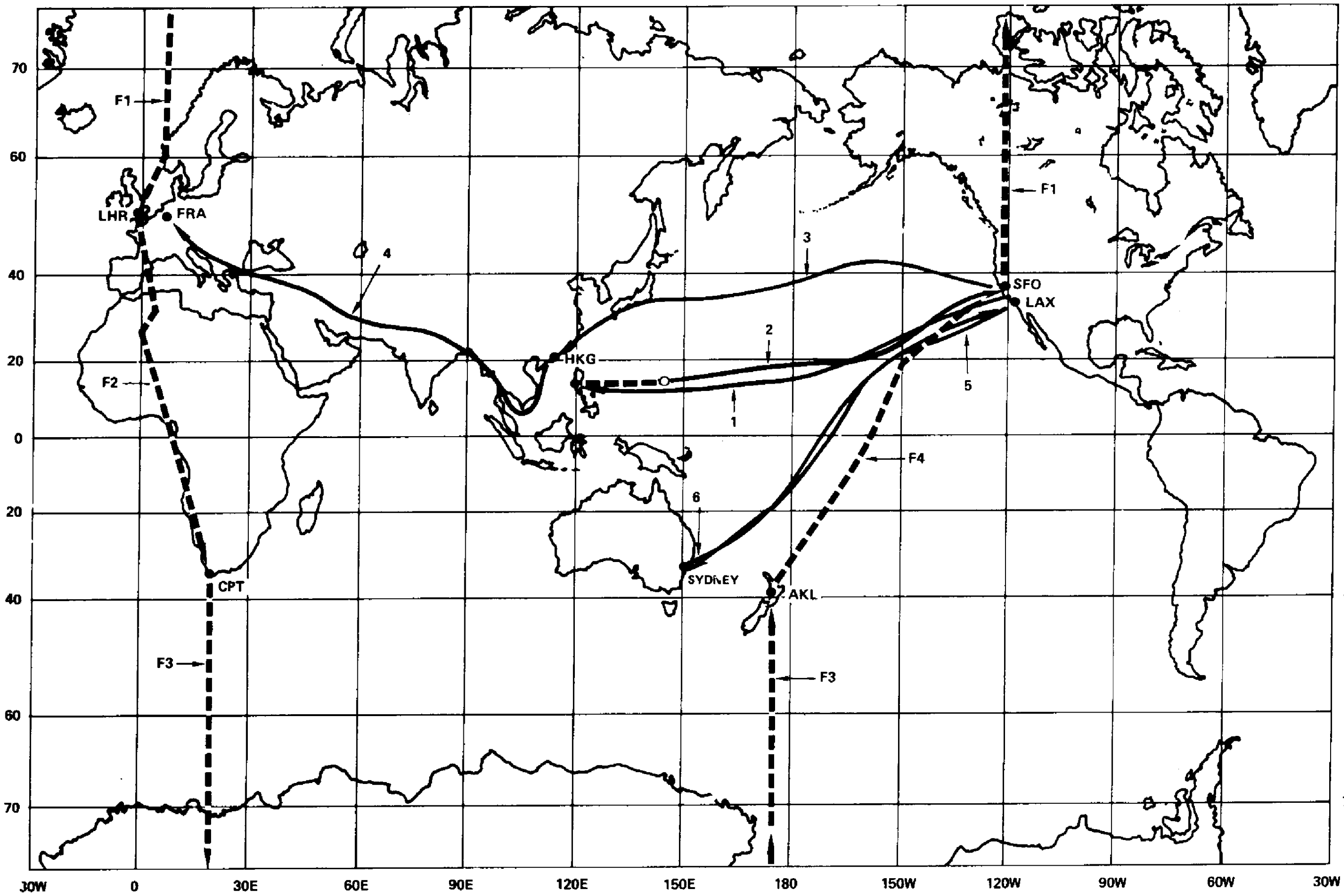

FIGURE 3.1. Flight path of the PAN AM B-747SP aircraft, 28-31 October 1977. F1 is from San Francisco (SFO) to London (LHR); F2 is from LHR to Capetown (CPT); F3 is from CPT to Auckland (AKL); F4 is from AKL to SFO. The other routes indicated by 1 through 6 are the paths of the PAN AM-N655 aircraft.

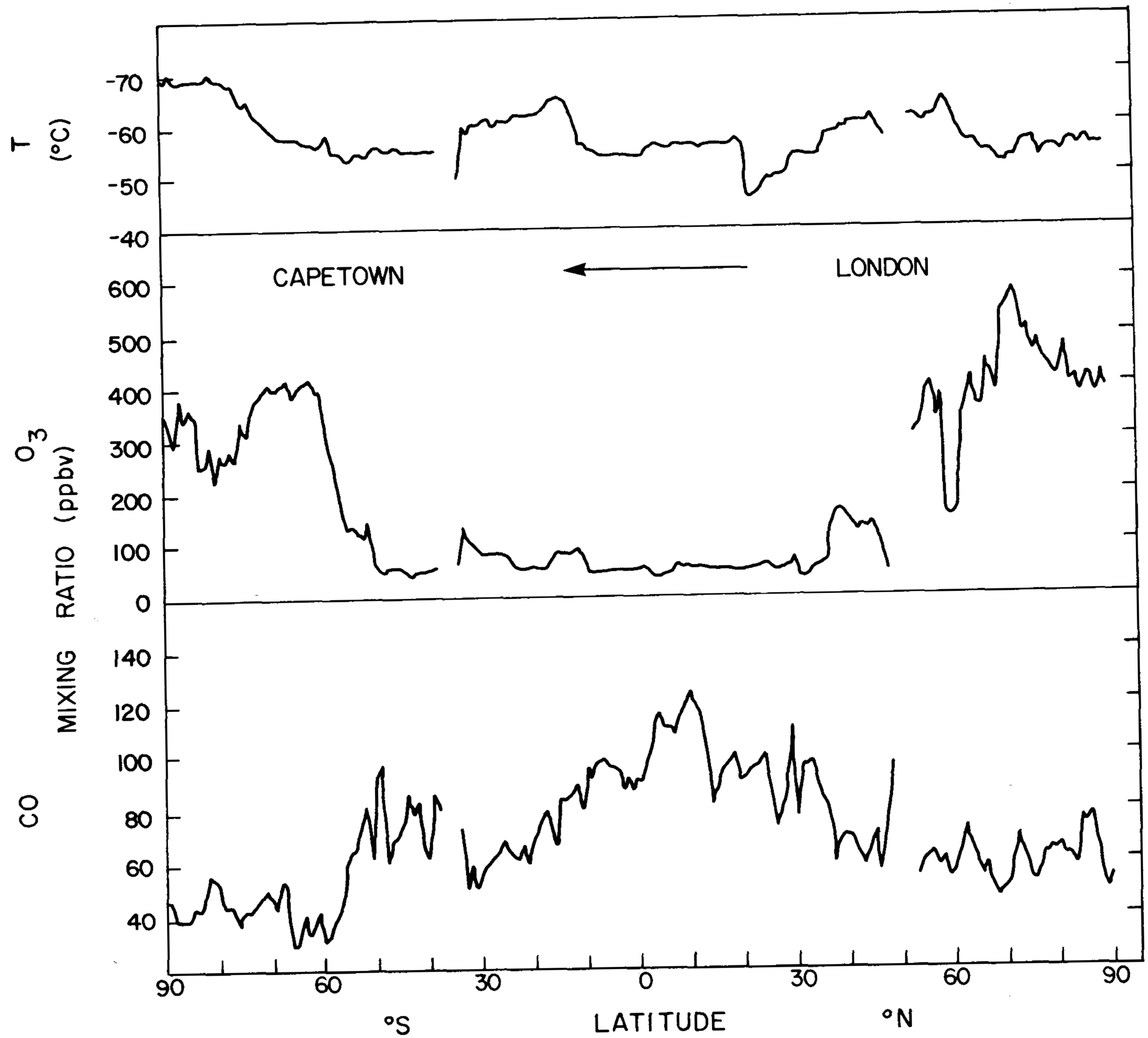

FIGURE 3.2a. Carbon monoxide, ozone and air temperature (T) on the PAN AM flights from north pole to south pole.

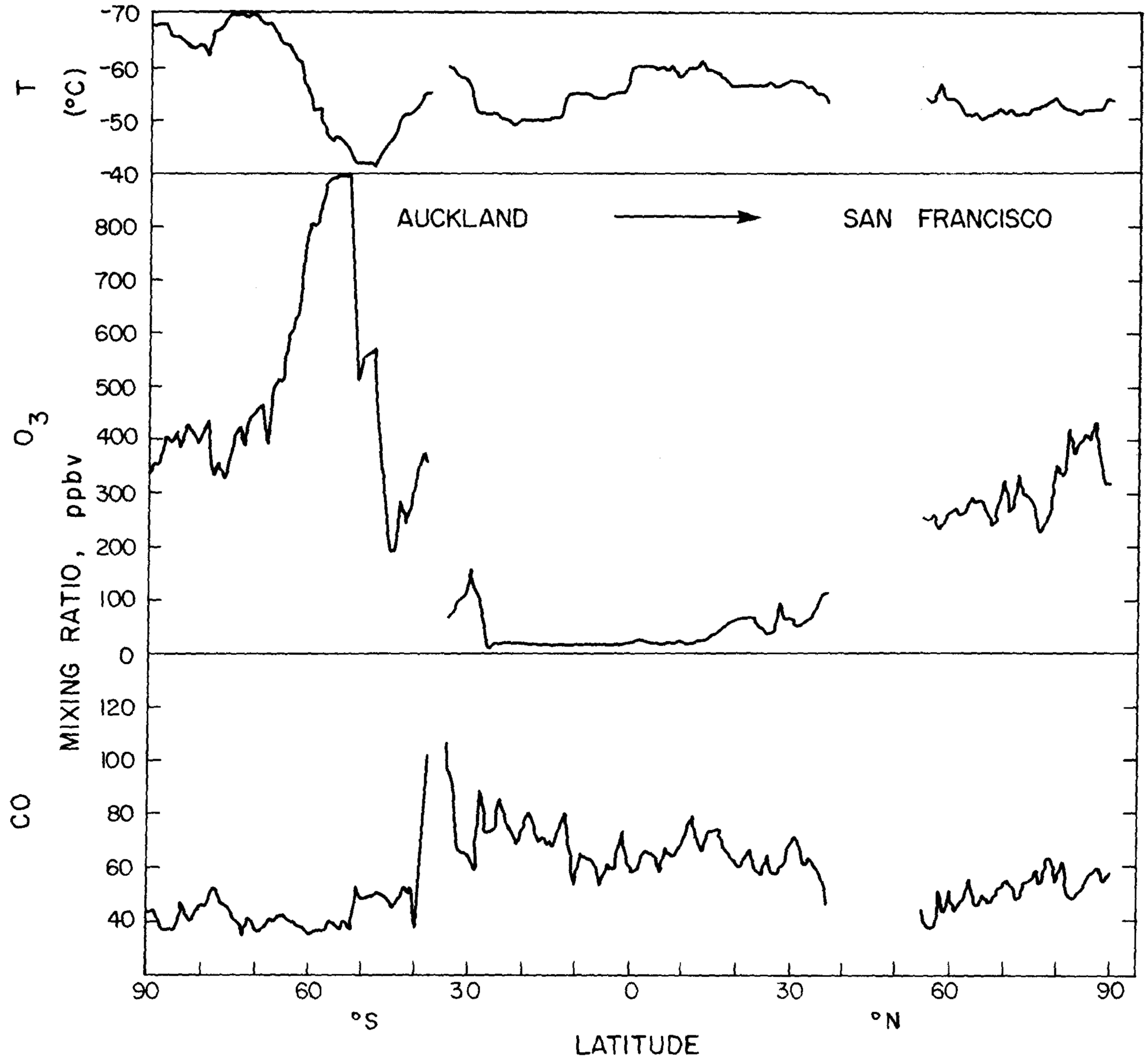

FIGURE 3.2b. Similar to Figure 3.2a, but from south pole to north pole.

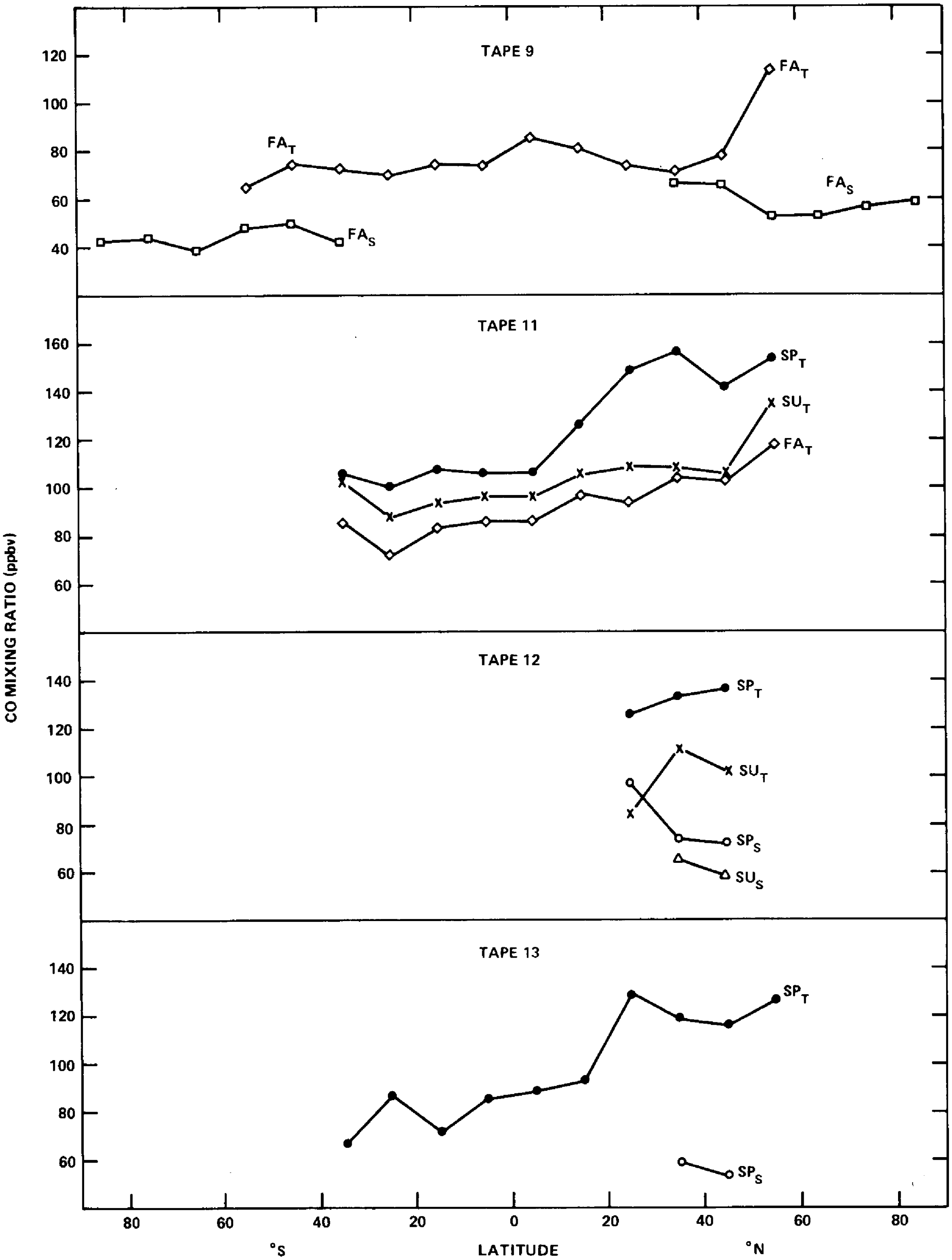

FIGURE 3.3a. Zonal means of carbon monoxide mixing ratio. SP, SU, FA and WI stand for spring, summer, fall and winter, while subscripts T and S are for troposphere and stratosphere, respectively.

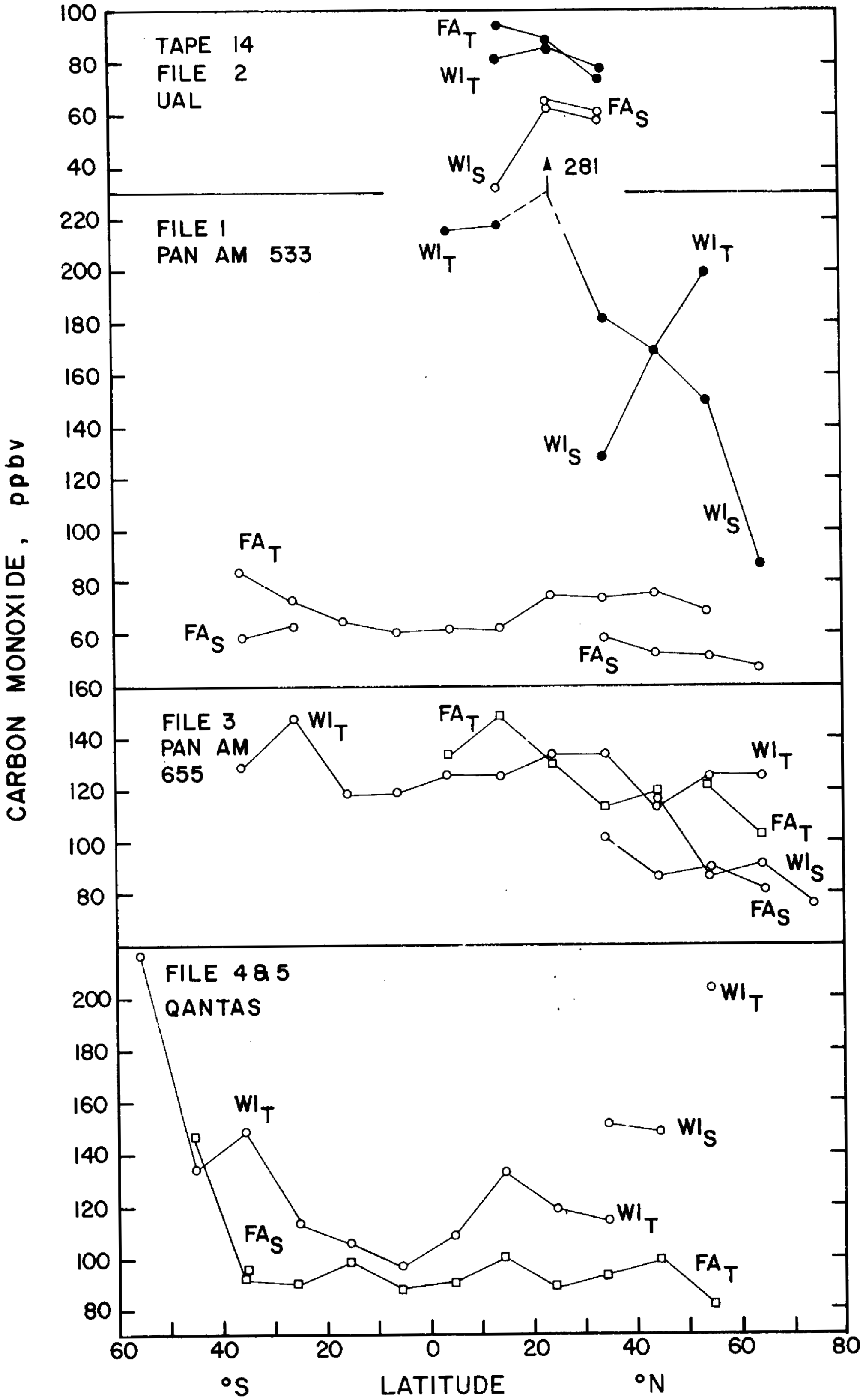

FIGURE 3.3b. Similar to Figure 3.3a except that the data are taken from different tapes or obtained by different aircraft.

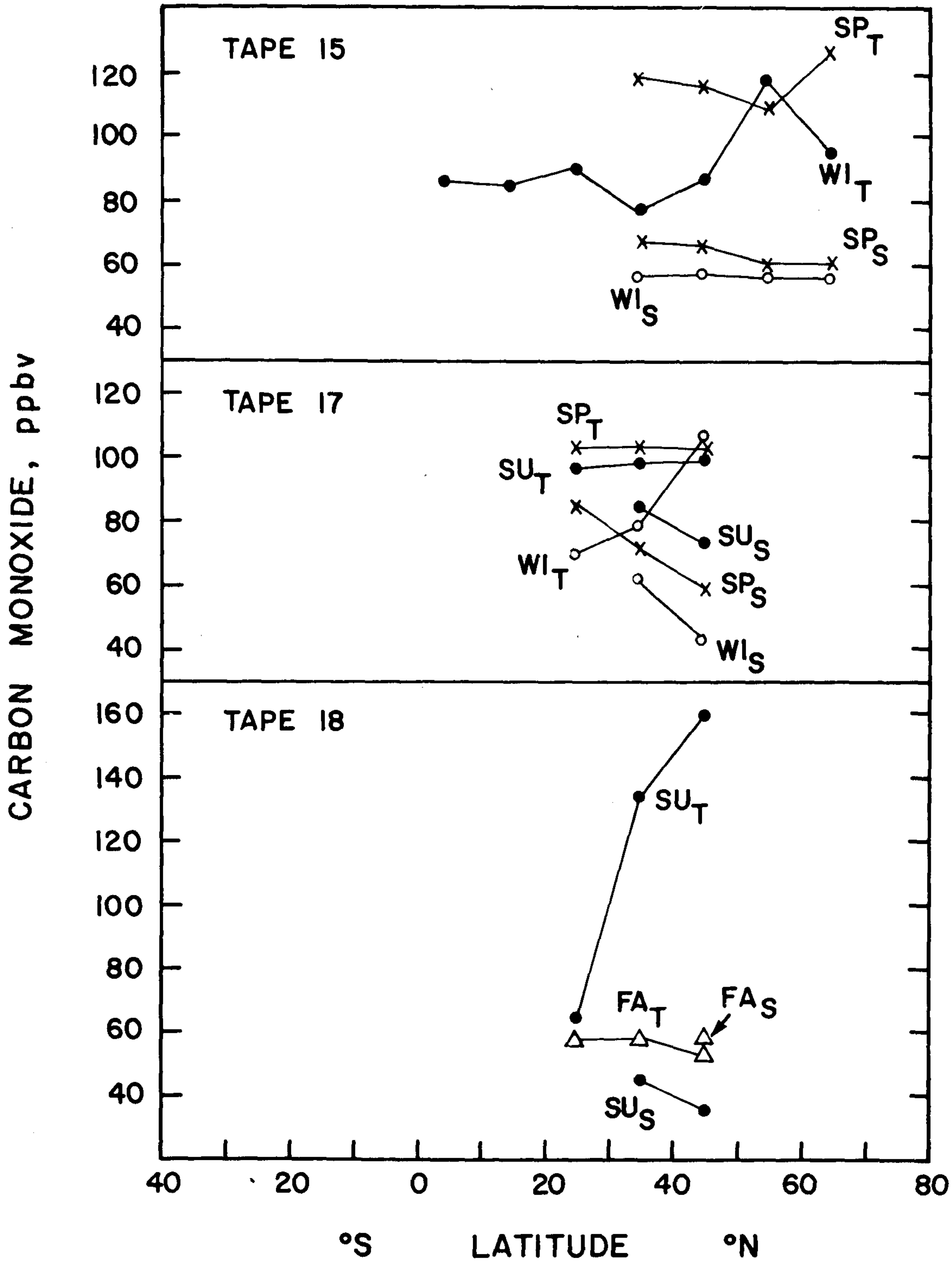

FIGURE 3.3c. Similar to Figure 3.3b.

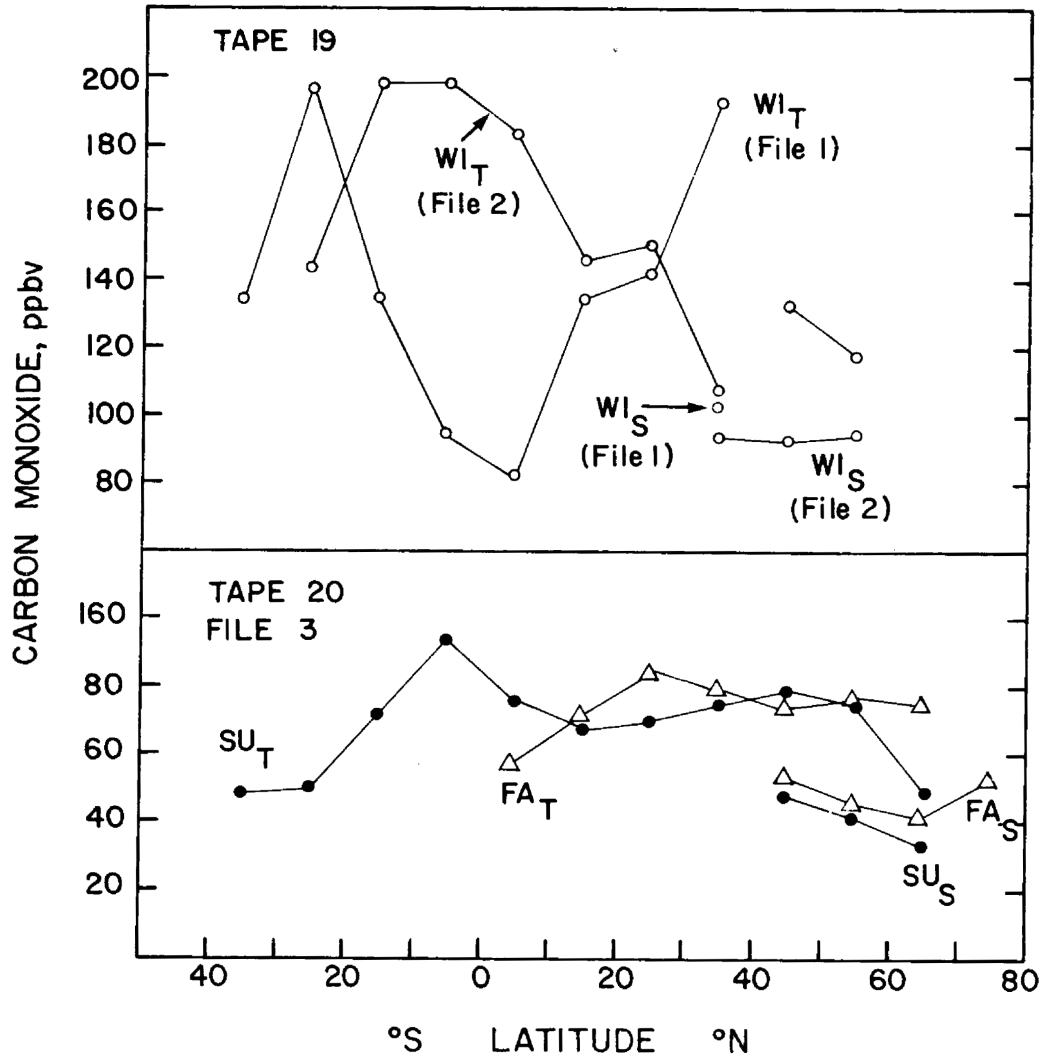

FIGURE 3.3d. Similar to Figure 3.3b.

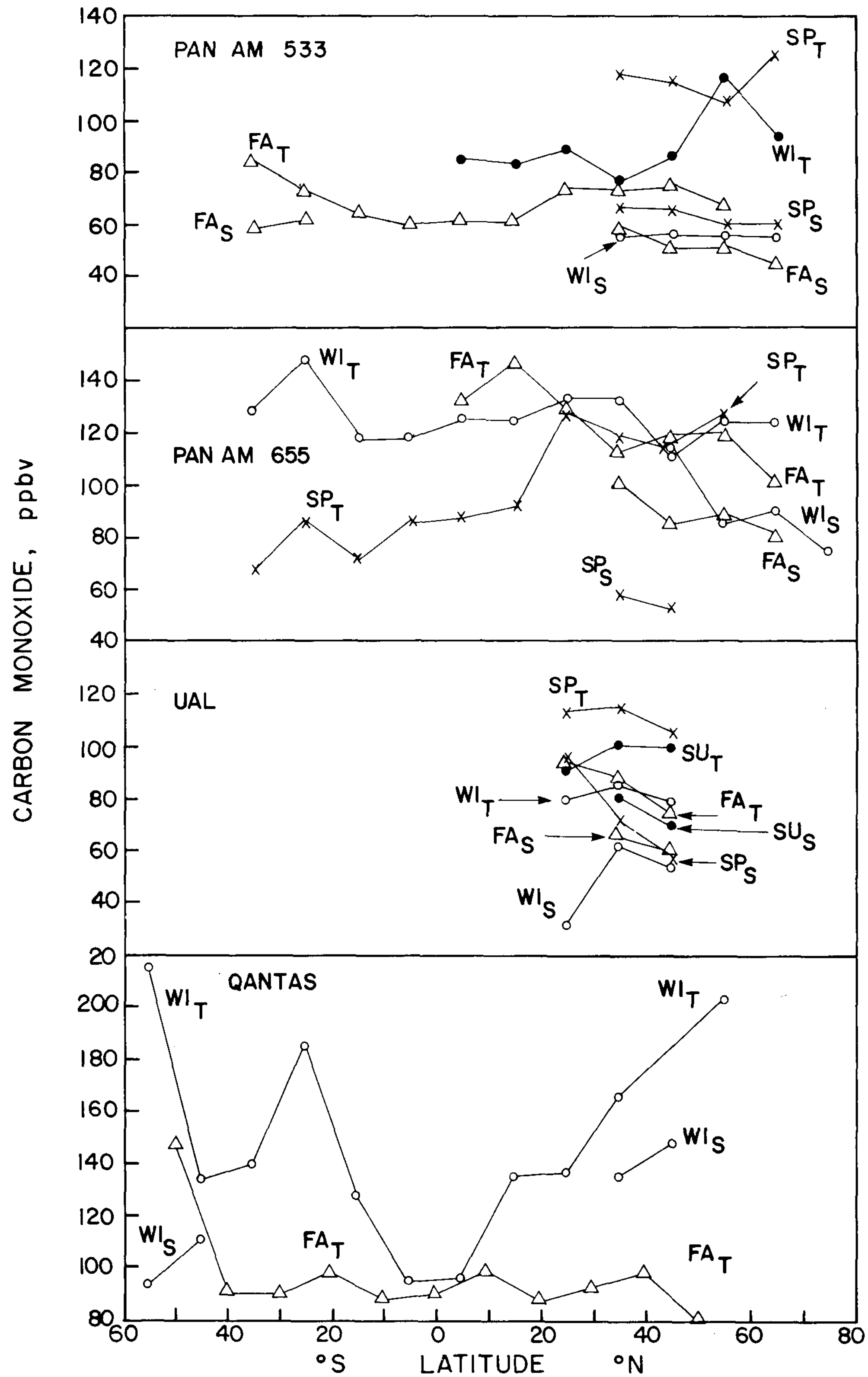

FIGURE 3.4. Composite results of zonal mean mixing ratio of CO derived from four airlines. SP, SU, FA and WI stand for spring, summer, fall and winter, while subscripts T and S are for troposphere and stratosphere, respectively.

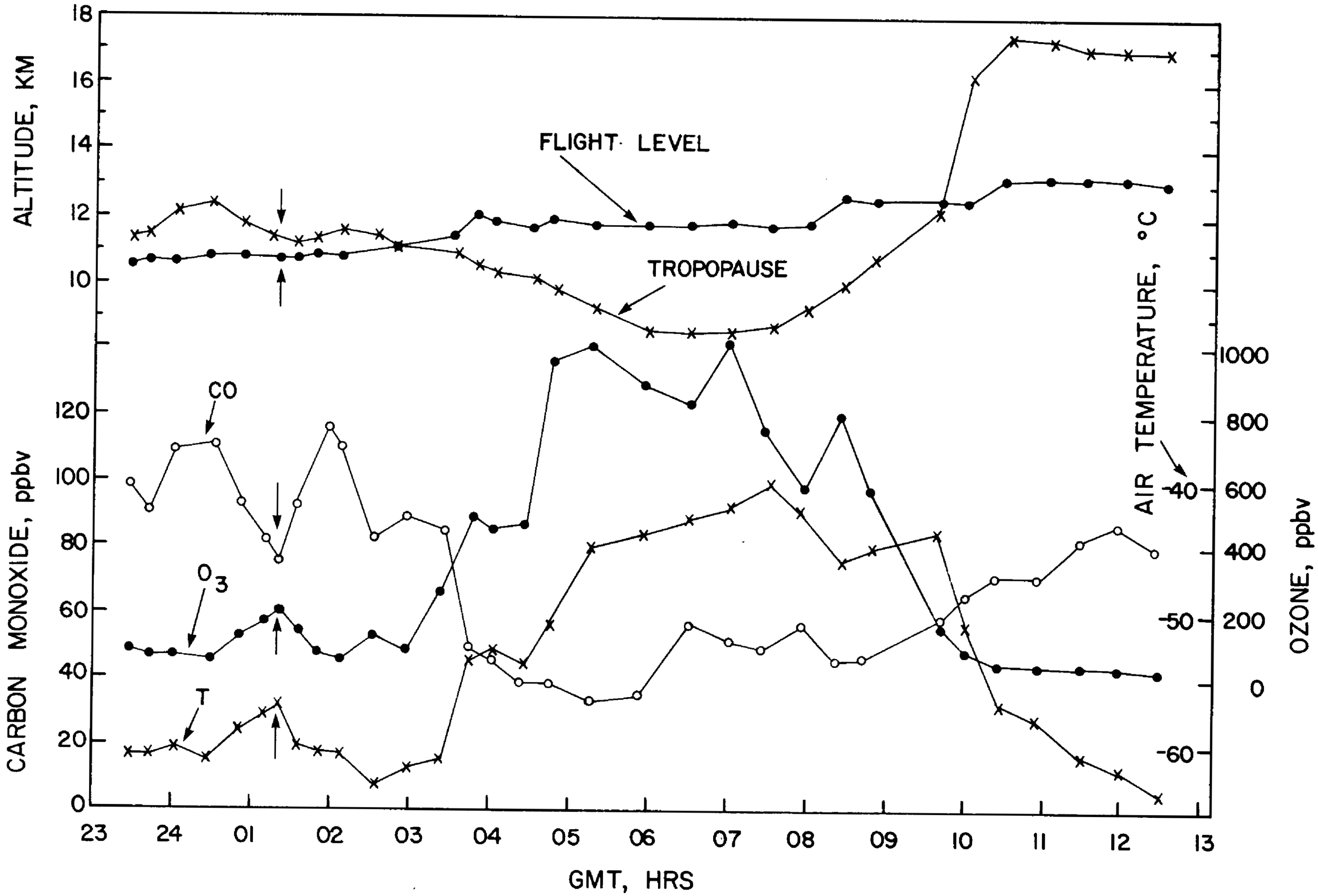

FIGURE 3.5. Measurements of ozone (O_3) and carbon monoxide (CO) mixing ratios and temperature (T) during the flight of the PAN AM-N533PA from San Francisco to Hong Kong 1 February 1978.

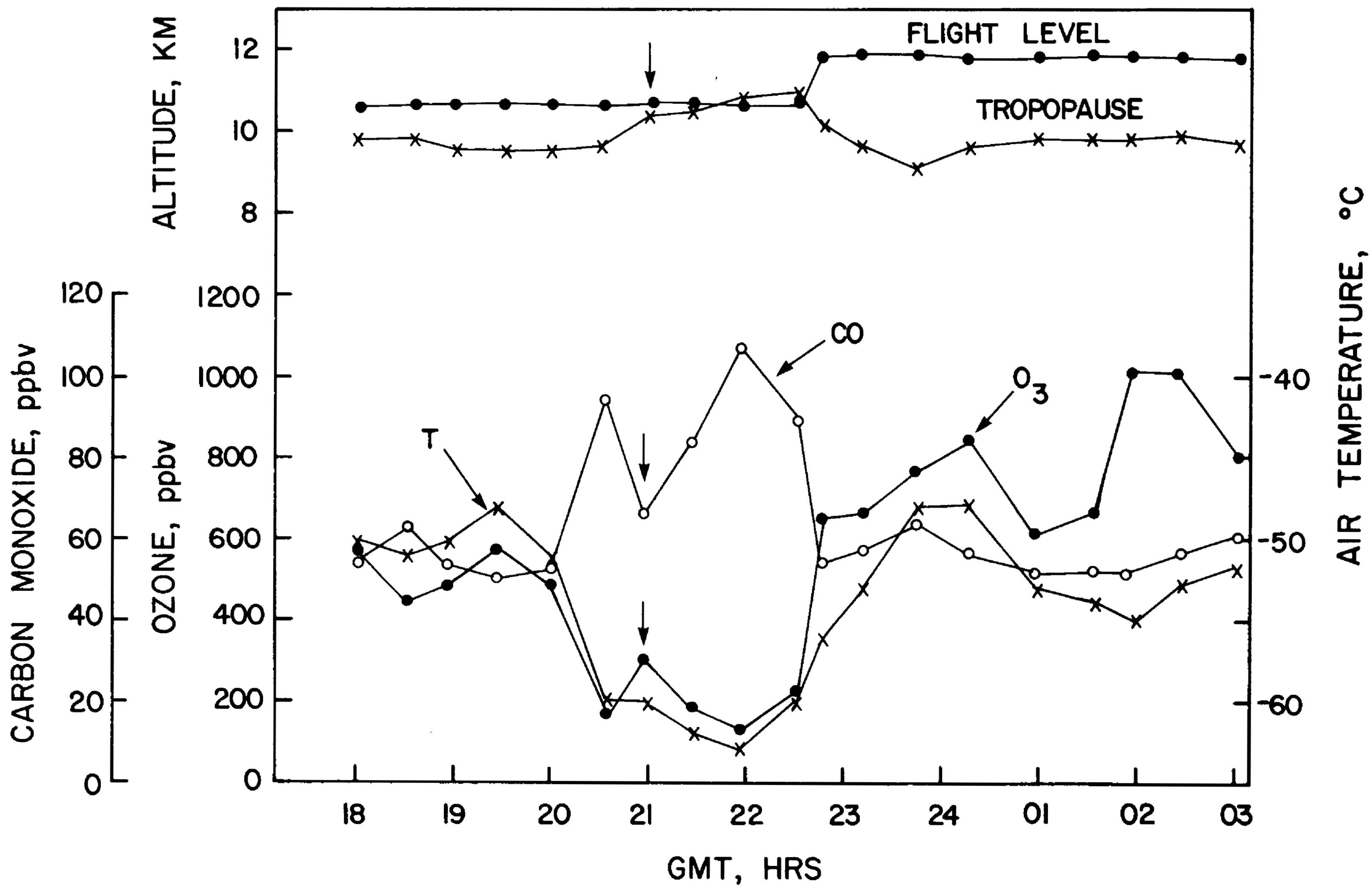

FIGURE 3.6. Measurements of ozone (O_3) and carbon monoxide (CO) mixing ratios and temperature (T) during the flight of the PAN AM-N533PA from JFK (40.67°N, 73.78°W) to HND (35.53°N, 139.71°E) on 24 February 1978.

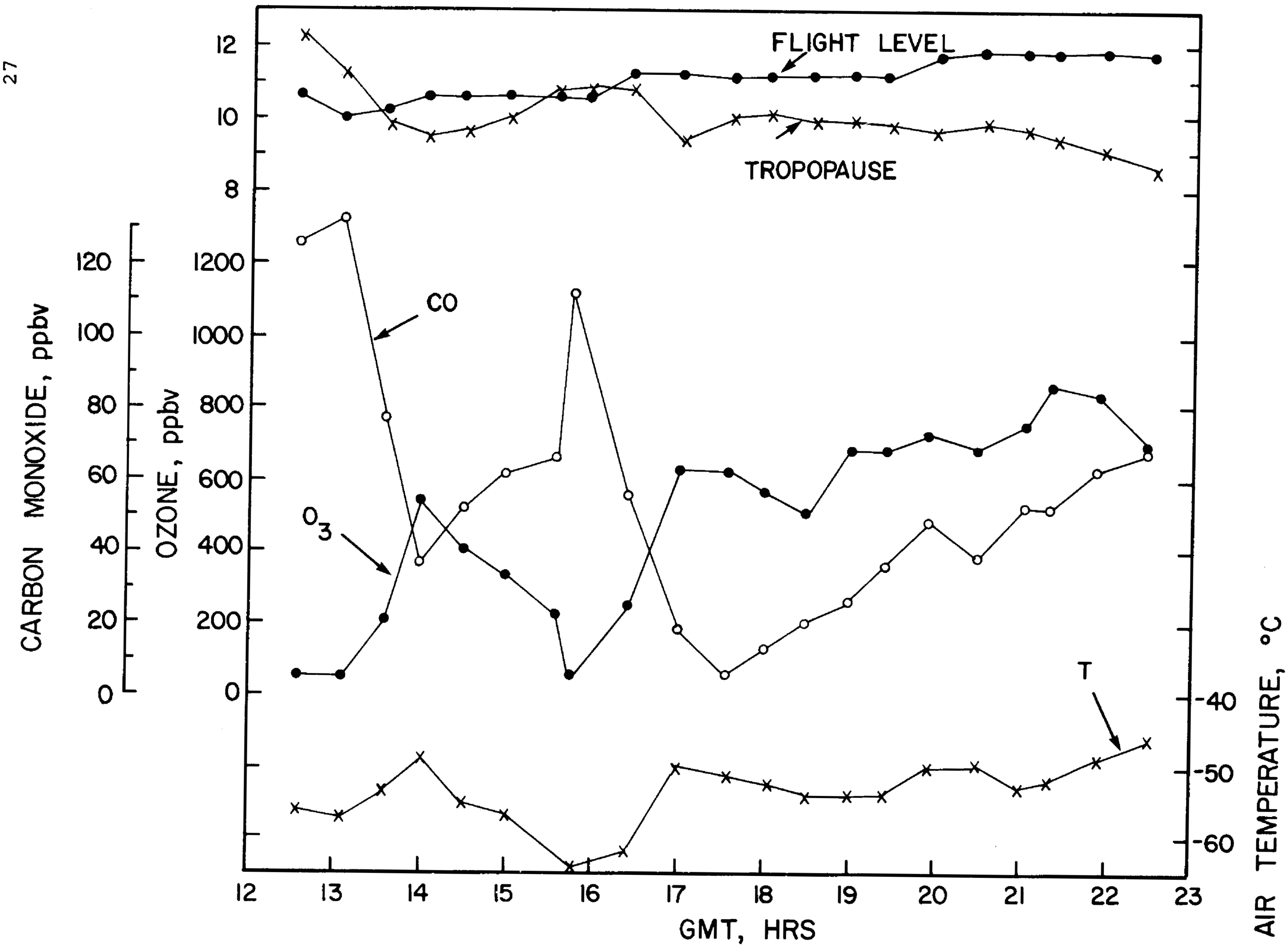

FIGURE 3.7. Similar to Figure 3.5 but from HND to JFK and on 4 March 1978.

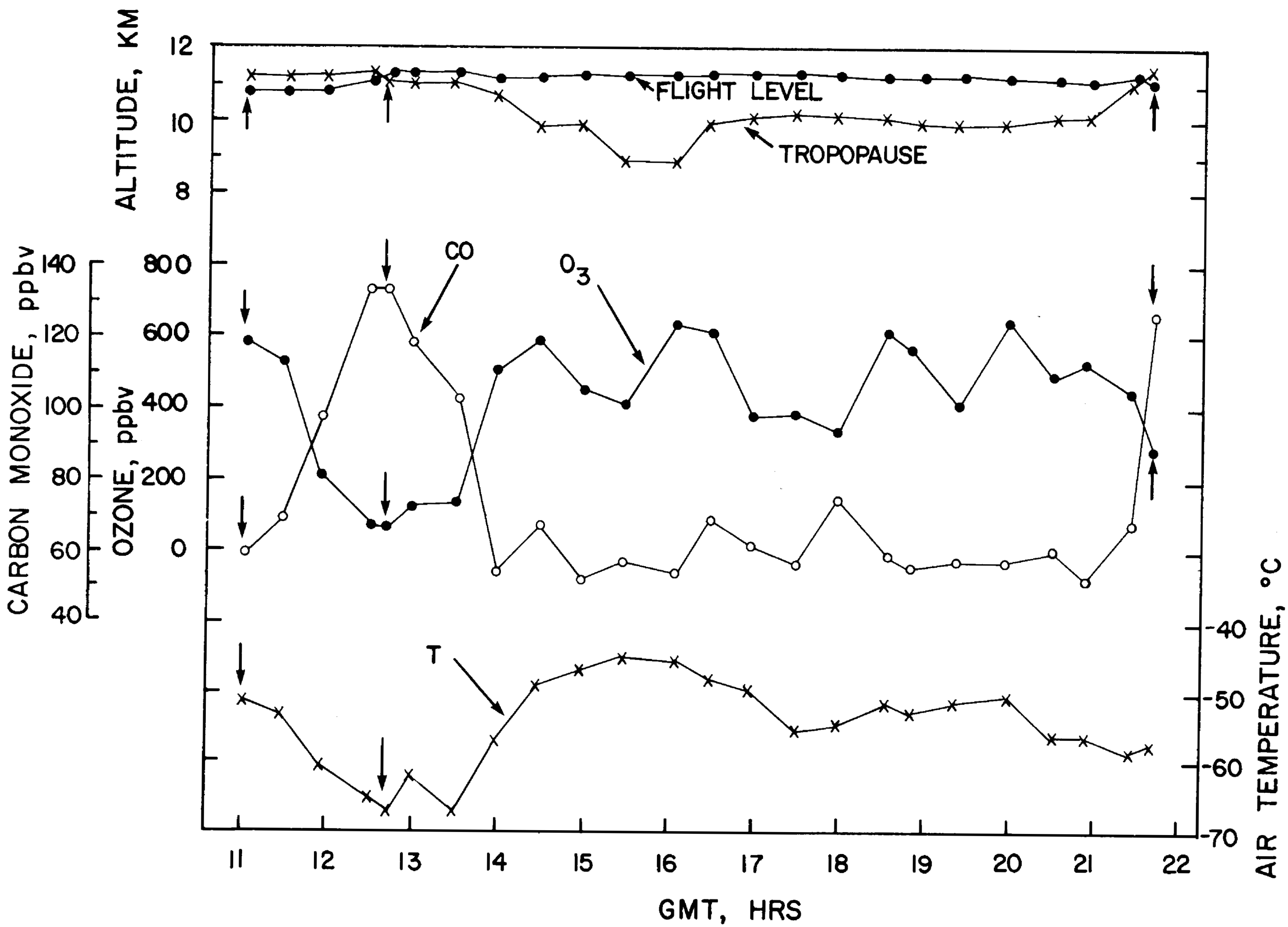

FIGURE 3.8. Similar to Figure 3.5 but from HND to JFK and on 13 March 1978.

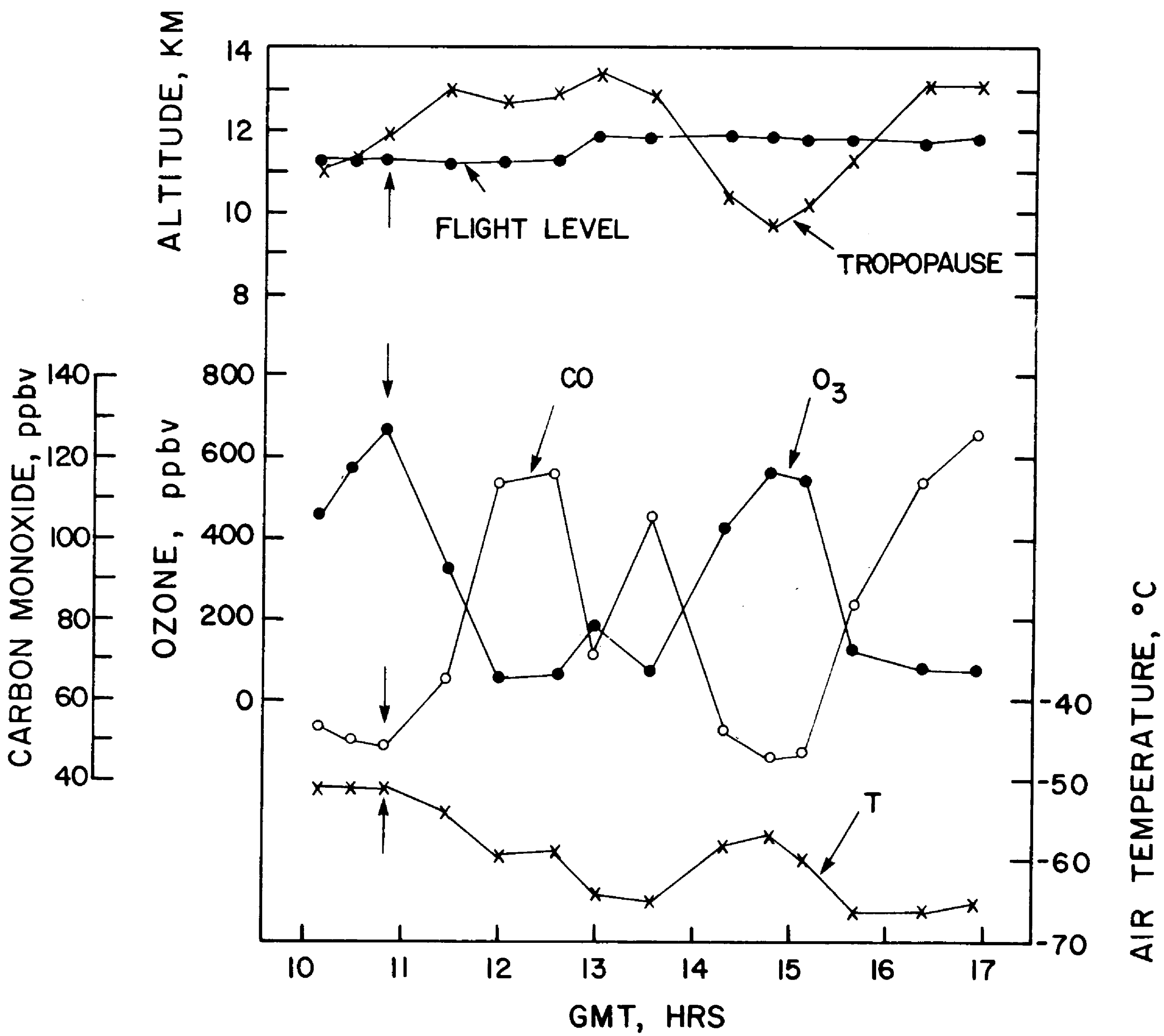

FIGURE 3.9. Similar to Figure 3.5 but from HND (35.53°N, 139.71°E) to LAX (33.86°N, 118.34°W) and on 15 March 1978.

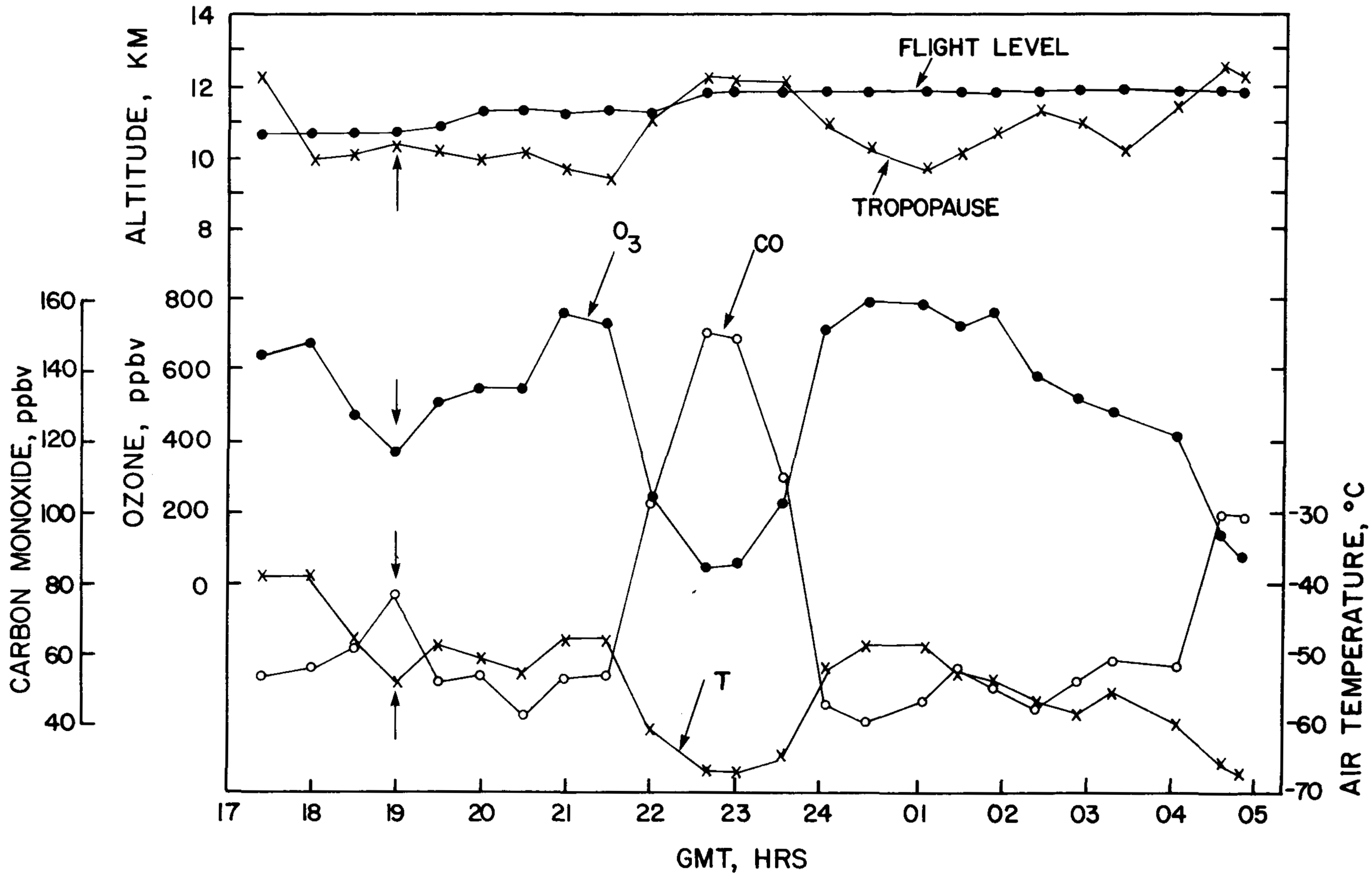

FIGURE 3.10. Similar to Figure 3.5 but on 1 April 1978.

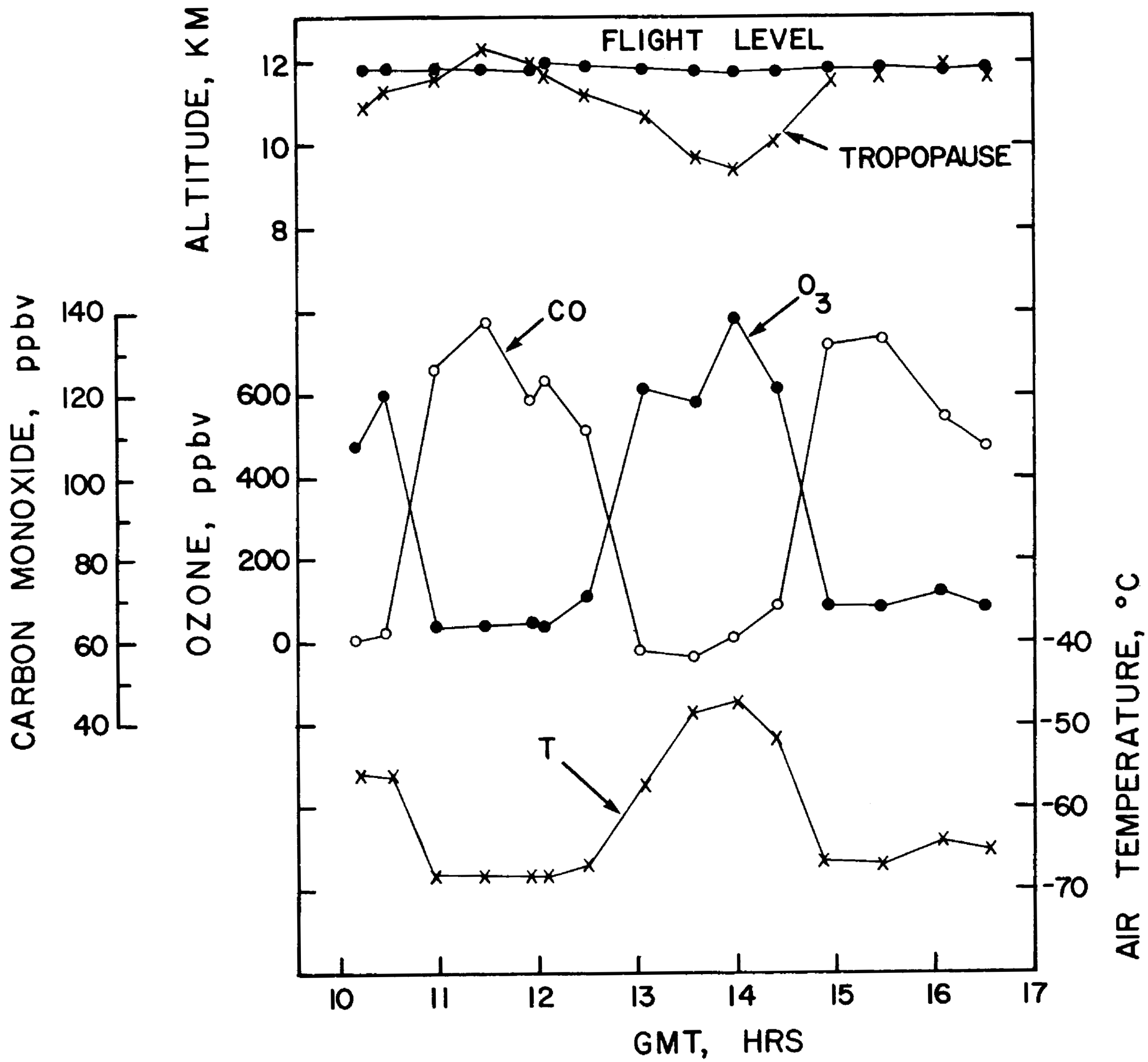

FIGURE 3.11. Similar to Figure 3.5 but from HND (35.53°N, 139.71°E) to LAX (33.86°N, 118.34°W) and on 23 April 1978.

LATITUDE	160E–180	180–160W	160W–140W	140W–120W	0–20E	MEAN
60–50 °N					114 1 10	114 (10)
50–40 °N					78 22 87	78 (87)
40–30 °N				61 8 291	84 14 215	71 (506)
30–20 °N				61 5 408	90 12 344	74 (752)
20–10 °N			71 5 347	62 3 43	96 11 307	81 (697)
10–0 °N			64 5 442		111 10 375	86 (817)
0–10 °S		59 5 264	66 7 132		91 5 288	74 (684)
10–20 °S		72 6 398			78 8 300	75 (698)
20–30 °S	67 4 40	78 9 271			63 4 262	70 (573)
30–40 °S	87 18 149				62 13 185	73 (334)
40–50 °S					75 11 308	75 (308)
50–60 °S					65 6 48	65 (48)

LONGITUDE

TABLE 3.1a. Fall tropospheric CO data taken from tape 9 as a function of latitude and longitude. The mean mixing ratio (ppbv) and standard deviation for each grid are given at the left and right corner, and the number of points is indicated at the bottom of the box. The zonal mean and the total observations are shown at the right-hand column.

LATITUDE	160E–180	180–160W	160W–140W	140W–120W	0–20E	MEAN
°N 90–80				55 6 265	61 10 396	59 (661)
80–70				55 5 308	59 6 228	57 (536)
70–60				49 5 297	57 9 303	53 (600)
60–50				45 6 176	58 4 259	53 (435)
50–40					66 5 172	66 (172)
40–30					68 3 86	68 (86)
°S 30–40	41 2 43					41 (43)
40–50	50 4 308					50 (308)
50–60	42 7 313				56 13 267	48 (580)
60–70	38 3 307				40 9 313	39 (620)
70–80	44 6 353				45 3 335	44 (688)
80–90	42 4 368	45 1 44	44 – 2		44 5 352	43 (766)

LONGITUDE

TABLE 3.1b. Similar to Table 3.1a but for the stratosphere.

LATITUDE	0–20E	20E–40E	40E–60E	60E–80E	80E–100E	100E–120E	120E–140E	140E–160E	160E–180	180–160W	160W–140W	140W–120W	MEAN
60–50 N	154 19 6												154 (6)
50–40 N	155 19 29	144 19 70											147 (99)
40–30 N		154 31 60	145 33 138								182 51 14	190 40 76	161 (288)
30–20 N			125 28 45	154 29 119	138 30 36	187 - 1					182 46 91		156 (292)
20–10 N				141 25 59	147 26 35	159 27 10				135 34 35	167 26 13		144 (152)
10–0 N				120 38 12	129 23 61	150 26 23	89 36 16			95 36 106			111 (218)
0–10 S					123 15 68	125 22 70	98 27 22		90 27 8	93 23 86			110 (254)
10–20 S					116 13 44	111 24 54	117 29 66		102 30 69	91 14 29			109 (262)
20–30 S		138 16 7	119 29 13	108 18 16	116 20 16	105 19 46	106 33 44	110 19 32	112 29 104				111 (278)
30–40 S					128 40 7	120 17 16	120 45 52	122 33 94	115 25 14				121 (183)

LONGITUDE

TABLE 3.2a. Spring tropospheric CO data taken from tape 11 as a function of latitude and longitude. The plotting code is the same as described in Table 3.1a. The first one and one-half hours of each flight data are excluded.

LATITUDE \ LONGITUDE	0–20E	20E–40E	40E–60E	60E–80E	80E–100E	100E–120E	120E–140E	140E–160E	160E–180	180–160W	160W–140W	140W–120W	MEAN
60–50 °N	139 27 8												139 (8)
50–40 °N	103 27 22	121 44 9											108 (31)
40–30 °N		85 - 1	99 - 1										92 (2)
30–20 °N													
20–10 °N													
10–0 °N													
0–10 °S													
10–20 °S													
20–30 °S													
30–40 °S							114 5 5						114 (5)

TABLE 3.2b. Similar to Table 3.2a but for the stratosphere.

LATITUDE	0–20E	20E–40E	40E–60E	60E–80E	80E–100E	100E–120E	120E–140E	140E–160E	160E–180	180–160W	160W–140W	140W–120W	MEAN
60–50 N	136 24 12												136 (12)
50–40 N	139 22 24	116 31 69											122 (93)
40–30 N		94 30 50	112 21 100								140 28 7	155 18 24	144 (181)
30–20 N			98 29 33	115 16 78	124 20 17	113 - 1					145 16 28		118 (157)
20–10 N				111 27 61	115 17 38	106 7 6	114 - 1			115 17 17	129 10 8		114 (131)
10–0 N				104 20 9	105 14 47	121 18 13	108 7 7			91 22 26			104 (102)
0–10 S					105 15 41	114 22 42	98 19 12		83 12 7	88 25 29			102 (131)
10–20 S			103 - 1	123 12 8	96 17 26	97 20 67	89 24 48		88 28 23	91 19 11			94 (184)
20–30 S		63 3 3				93 16 33	101 18 80	96 15 13	85 30 19				96 (148)
30–40 S					107 - 1	105 21 16	114 21 38	101 18 24	102 11 6				108 (85)

LONGITUDE

TABLE 3.2c. Similar to Table 3.2a but for summer troposphere.

LATITUDE \ LONGITUDE	0–20E	20E–40E	40E–60E	60E–80E	80E–100E	100E–120E	120E–140E	140E–160E	160E–180	180–160W	160W–140W	140W–120W	MEAN
60–50 °N	109 0 / 1												109 (1)
50–40 °N	113 16 / 2												113 (2)
40–30 °N													
30–20 °N													
20–10 °N													
10–0 °N													
0–10 °S													
10–20 °S													
20–30 °S													
30–40 °S							85 24 / 11	93 9 / 10	89 16 / 4				89 (25)

TABLE 3.2d. Similar to Table 3.2c but for the stratosphere.

LATITUDE	0–20E	20E–40E	40E–60E	60E–80E	80E–100E	100E–120E	120E–140E	140E–160E	160E–180	180–160W	160W–140W	140W–120W	MEAN
60–50 °N	120 12 4												120 (4)
50–40 °N	128 18 7	111 18 14											117 (21)
40–30 °N		113 11 8	108 10 26								88 19 4	117 27 15	110 (53)
30–20 °N			122 6 2	117 18 14							82 14 17		99 (33)
20–10 °N				110 25 15	120 4 6					99 25 18	78 31 7		102 (46)
10–0 °N				121 1 2	100 22 19	113 2 3				83 23 33			92 (57)
0–10 °S					115 9 19				70 20 11	80 16 24			90 (54)
10–20 °S					104 11 12	110 7 8	15 - 1		82 13 18	80 11 3			92 (42)
20–30 °S						95 24 13	57 21 8	64 16 11	82 17 11				77 (43)
30–40 °S						71 14 3		86 23 12					83 (15)

LONGITUDE

TABLE 3.2e. Similar to Table 3.2a but for fall troposphere.

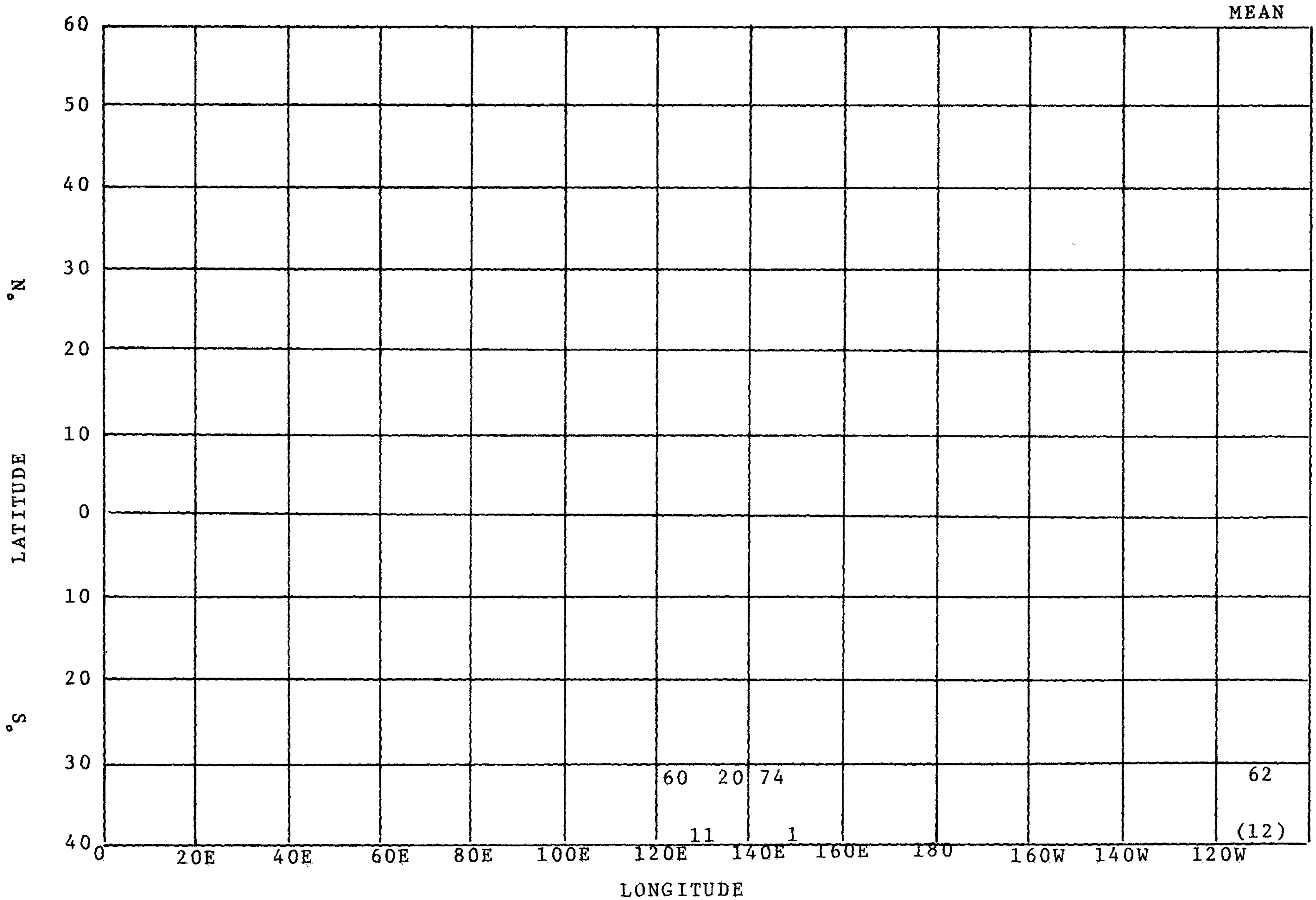

TABLE 3.2f. Similar to Table 3.2e but for the stratosphere.

LATITUDE (°N) / LONGITUDE

Latitude	160W–140W	140W–120W	120W–100W	100W–80W	80W–60W	MEAN
40–50			55 22 20	81 33 28	92 49 4	72 (52)
30–40			72 24 44	83 13 9		74 (63)
20–30	99 11 9					99 (9)

(a) Spring Stratosphere

Latitude	160W–140W	140W–120W	120W–100W	100W–80W	80W–60W	MEAN
40–50				136 30 9		136 (9)
30–40	131 – 1	124 29 12	142 18 9		145 18 2	133 (24)
20–30	126 31 31	136 6 2				127 (33)

(b) Spring Troposphere

Latitude	160W–140W	140W–120W	120W–100W	100W–80W	80W–60W	MEAN
40–50			58 7 8			58 (8)
30–40		65 6 5				65 (5)
20–30						

(c) Summer Stratosphere

Latitude	160W–140W	140W–120W	120W–100W	100W–80W	80W–60W	MEAN
40–50			97 20 16	105 17 20	101 – 1	101 (37)
30–40	106 16 11	126 86 42	92 17 33	129 17 5		111 (91)
20–30	84 15 96	107 1				84 (97)

(d) Summer Troposphere

TABLE 3.3. CO data taken from tape 12 as a function of latitude and longitude. The plotting code is the same as described in Table 3.1a.

LATITUDE	20W–0	0–20E	20E–40E	40E–60E	60E–80E	80E–100E	100E–120E	120E–140E	140E–160E	160E–180	180–160W	160W–140W	140W–120W	MEAN
60–50 °N	127 13 5													127 (5)
50–40 °N			86 13 6								130 23 13	119 31 11		117 (30)
40–30 °N				135 10 7				81 26 6	91 17 14	122 27 12		141 8 3	128 30 41	119 (83)
30–20 °N					96 30 8	93 11 11	175 44 5	242 141 8			98 13 9	119 22 51	148 12 17	129 (109)
20–10 °N						96 16 6	108 35 12	88 9 13	94 12 20	86 7 26	92 8 23	98 24 5		93 (105)
10–0 °N							100 10 4				86 9 16			89 (20)
0–10 °S											86 9 15			86 (15)
10–20 °S										89 8 4	61 13 7			71 (11)
20–30 °S										87 16 23				87 (23)
30–40 °S									65 27 5	72 22 2				67 (7)

LONGITUDE

TABLE 3.4a. Spring tropospheric CO data taken from tape 13 as a function of latitude and longitude. The plotting code is the same as described in Table 3.1a.

LATITUDE	20W–0	0–20E	20E–40E	40E–60E	60E–80E	80E–100E	100E–120E	120E–140E	140E–160E	160E–180	180–160W	160W–140W	140W–120W	MEAN
60–50 °N														
50–40 °N		44 8 5	69 3 3											53 (8)
40–30 °N			62 11 4	72 4 3									46 15 4	59 (11)
30–20 °N														
20–10 °N														
10–0 °N														
0–10 °S														
10–20 °S														
20–30 °S														
30–40 °S														

LONGITUDE

TABLE 3.4b. Similar to Table 3.4a but for the stratosphere.

LONGITUDE \ LATITUDE	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
MEAN	84 / 14	73 / 25	65 / 29	61 / 24	62 / 25	62 / 28	75 / 25	74 / 132	76 / 160	69 / 43	
100–120 °E											
120–140 °E											
140–160 °E	87 38 / 10	80 – / 1						76 25 / 41	81 20 / 23		
160–180 °E	77 47 / 4	78 16 / 8	69 5 / 7	61 – / 3				90 14 / 5	84 22 / 19		
180–160 °W		70 15 / 16	64 9 / 22	62 5 / 15	62 5 / 9	59 6 / 6		63 10 / 9	58 8 / 15	58 5 / 4	
160–140 °W				60 6 / 6	62 6 / 16	63 2 / 21	70 8 / 8	77 12 / 11	63 15 / 8	59 12 / 7	

TABLE 3.5a. Fall tropospheric CO data taken from tape 14, file 1. The plotting code is the same as described in Table 3.1a except that the zonal mean values are shown at top row of the table.

140						59 – 1	78 8 17	75 27 56	61 14 11		
120								60 19 10	65 18 9		
100									71 22 14	68 – 1	
80									86 45 47	63 – 1	
60									70 7 13	66 55 11	
40									55 – 1		
20										78 34 19	
0											

LONGITUDE °W

40 20 0 20 40 60

°S °N

LATITUDE

TABLE 3.5a. Continued.

LONGITUDE											
MEAN	58 33	63 2						59 5	53 245	52 276	46 31
100–120 °E											
120–140 °E											
140–160 °E	43 6 5								53 8 28		
160–180	61 35 28	58 – 1						60 5 2	61 5 5	46 6 29	
180–160 °W		67 – 1						60 4 2	50 6 6	47 5 22	47 8 6
160–140 °W									51 7 22	44 8 12	42 6 7
LATITUDE	40 °S		20 °S		0		20 °N		40 °N		60 °N

TABLE 3.5b. Similar to Table 3.5a but for the stratosphere.

LONGITUDE °W \ LATITUDE	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
140–120								57 – 1	51 8 28	43 3 4	43 4 6
120–100									46 6 15	47 8 8	46 – 1
100–80									53 13 30	54 17 6	
80–60									56 23 55	59 12 5	
60–40									54 8 26	49 9 64	
40–20									51 8 25	52 9 61	46 2 7
20–0									58 5 5	63 27 65	57 2 4

LATITUDE

TABLE 3.5b. Continued.

LONGITUDE \ LATITUDE	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
MEAN					216 10	218 14	281 15	182 38	172 24	200 33	
100–120 °E					216 36 10	218 30 14	271 72 6				
120–140 °E							289 97 9	195 51 7			
140–160 °E							268 72 7				
160–180 °E								239 75 8	132 48 8	276 64 10	
180–160 °W								114 33 4		250 69 10	
160–140 °W								90 17 2	193 70 4		

TABLE 3.5c. Similar to Table 3.5a but for winter troposphere.

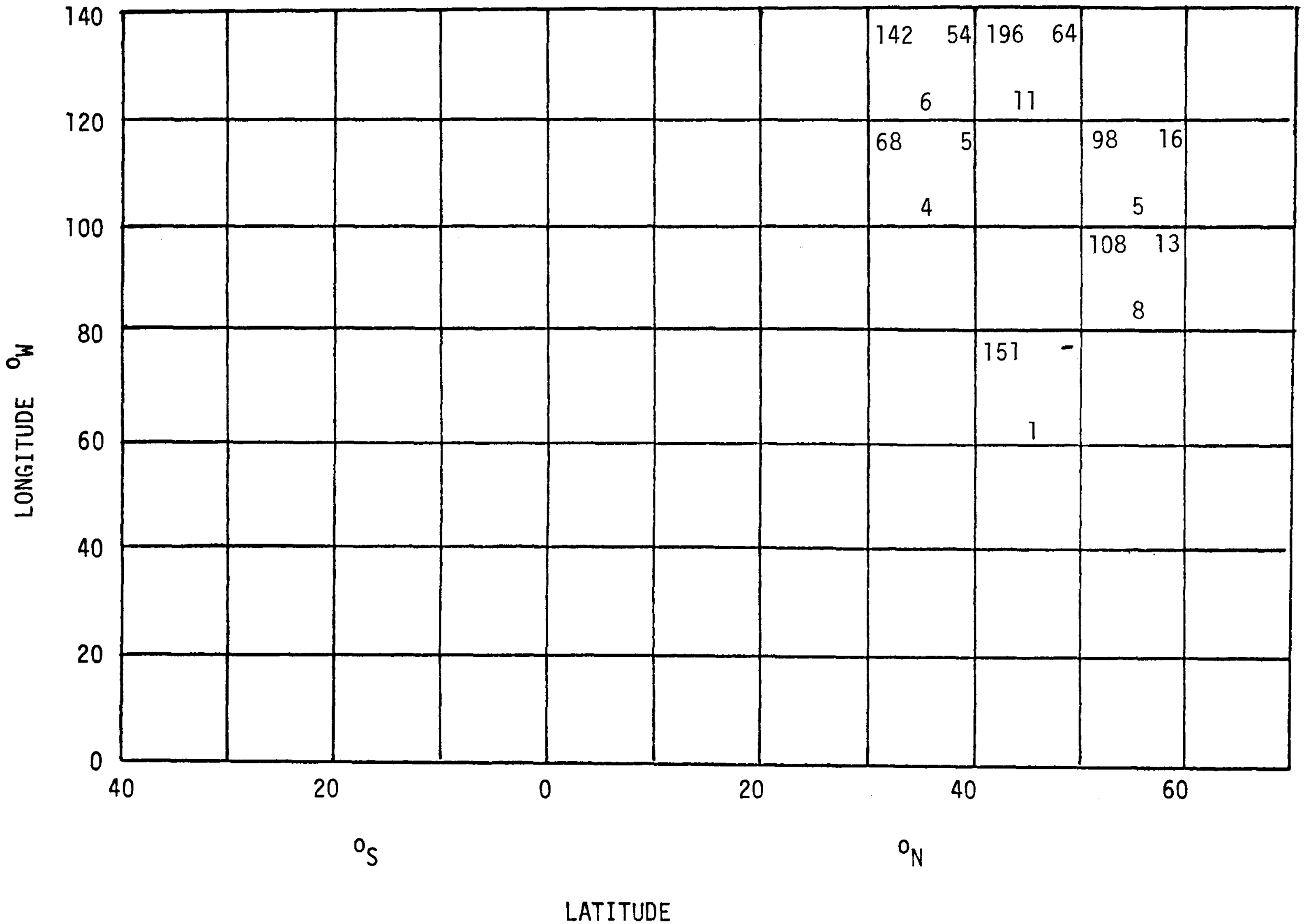

TABLE 3.5c. Continued.

LONGITUDE											
MEAN								128 68	172 119	150 86	86 23
100–120 °E											
120–140 °E								138 26 5			
140–160 °E								188 98 17	184 75 54		
160–180								168 - 1	91 19 9	137 59 37	
180–160 °W								194 28 8	99 21 7	164 62 22	
160–140 °W								83 23 15	115 31 6	170 47 20	77 17 6

40 20 0 20 40 60

°S °N

LATITUDE

TABLE 3.5d. Similar to Table 3.5c but for the stratosphere.

LONGITUDE °W \ LATITUDE	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
140–120								105 37 11	175 25 16	141 31 2	74 33 7
120–100								59 6 4	206 18 10		94 17 4
100–80								65 7 7	199 105 14	113 23 5	
80–60									227 132 3		
60–40											
40–20											
20–0											

TABLE 3.5d. Continued.

LONGITUDE °W	20–30	30–40	40–50
MEAN	95 125	89 104	75 12
160–140	90 20 92	88 14 5	
140–120	110 33 33	90 28 64	64 35 4
120–100		93 30 26	103 25 4
100–80		76 23 5	79 – 1
80–60		59 2 4	49 21 3

LONGITUDE °W	20–30	30–40	40–50
MEAN		66 4	61 66
160–140			
140–120			
120–100		66 24 4	69 36 20
100–80			59 21 44
80–60			44 14 2

LATITUDE °N

TABLE 3.5e. Fall tropospheric (left) and stratospheric (right) CO data taken from tape 14, file 2. The plotting code is the same as described in Table 3.1a.

LONGITUDE °W	20–30	30–40	40–50
MEAN	82 223	87 182	78 28
160–140	80 21 171	88 31 9	
140–120	89 26 52	95 25 110	97 9 3
120–100		72 27 57	100 19 12
100–80		88 23 6	51 17 11
80–60			77 7 2

LONGITUDE °W	20–30	30–40	40–50
MEAN	32 3	63 90	59 48
160–140	32 2 3	50 17 10	
140–120		72 33 15	
120–100		63 27 57	75 48 6
100–80		60 40 8	56 21 40
80–60			76 12 2

LATITUDE °N

TABLE 3.5f. Similar to Table 3.5e but for winter.

LONGITUDE (^{O}E) \ LATITUDE ^{O}N	0–10	10–20	20–30	30–40	40–50	50–60	60–70
MEAN	134 25	148 114	130 163	114 202	118 268	122 129	102 4
0–20					115 19 18	213 - 1	
20–40				126 19 13	128 22 23		
40–60				118 24 52			
60–80			126 15 50	151 - 1			
80–100		144 23 28	139 19 38				
100–120	134 23 25	146 27 58	139 14 14				
120–140		172 22 9	135 20 38	130 42 37			
140–160		175 52 8		103 23 42	116 47 26		
160–180		125 15 11	111 - 1	101 18 19	135 19 20		

TABLE 3.5g. Fall tropospheric CO data taken from tape 14, file 3. The plotting code is the same as described in Table 3.1a.

LONGITUDE (°W) \ LATITUDE °N	0–10	10–20	20–30	30–40	40–50	50–60	60–70
160–180			101 12 / 12	115 12 / 6	114 24 / 43		
140–160			123 22 / 10	107 8 / 6	117 29 / 43	157 23 / 4	
120–140				107 26 / 26	126 39 / 41	155 14 / 5	
100–120							
80–100							
60–80					111 24 / 39	124 – / 1	
40–60					112 17 / 9	115 22 / 29	
20–40					83 10 / 6	130 24 / 41	
0–20						112 26 / 48	102 13 / 3

TABLE 3.5g. Continued.

MEAN			
101 16	86 100	88 122	81 20

LONGITUDE (^{o}E) \ LATITUDE ^{o}N		40		60
0–20		96 20 11		
20–40	101 19 9	104 27 23		
40–60	101 24 7			
60–80				
80–100				
100–120				
120–140				
140–160		69 14 20		
160–180			75 13 34	

LONGITUDE ^{o}W \ LATITUDE ^{o}N	40		60
180–160	70 8 4	78 17 25	
160–140	72 4 6	95 23 16	
140–120	82 6 3		
120–100			
100–80			85 7 4
80–60	78 14 15	106 9 2	68 5 5
60–40	93 22 15	108 29 23	79 17 5
40–20	78 8 2	110 26 12	92 13 5
20–0	50 - 1	77 24 10	79 - 1

TABLE 3.5h. Similar to Table 3.5g but for the stratosphere.

LONGITUDE	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
MEAN	129 9	148 21	118 32	119 39	126 44	125 39	134 80	134 48	112 10	104 8	125 3
140–160 °E	117 20 7										
160–180 °E	171 3 2	148 27 21	116 1 2								
180–160 °W			108 16 15	120 18 23	135 19 27	126 14 18					
160–140 °W			127 42 15	116 30 16		123 6 5	123 25 42	130 24 12			
140–120 °W					112 12 17	124 14 16	145 25 38	136 15 35	112 14 10	99 9 5	
120–100 °W								114 - 1		208 - 1	
20–0										65 4 2	125 8 3

LATITUDE

TABLE 3.5i. Similar to Table 3.5g but for winter troposphere.

LONGITUDE °W \ LATITUDE °N	40–50	50–60	60–70	70–80
MEAN	116 13	86 73	91 78	76 4
160–140			88 7 3	
140–120	116 33 13	89 21 10	89 1	
120–100		91 38 25	73 4 2	
100–80		104 7 6	80 16 21	
80–60			84 15 17	76 8 4
60–40		78 11 2	83 17 22	
40–20		85 20 12	142 22 12	
20–0		75 27 17		

TABLE 3.5j. Similar to Table 3.5i but for the stratosphere.

LONGITUDE (°E) \ LATITUDE	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N
MEAN	147 2	91 64	90 140	98 137	88 120	90 108	100 112	89 88	92 113	99 30	80 4
0–20									104 8 6	92 20 14	80 11 4
20–40									103 19 112	106 14 16	
40–60								88 19 28	58 18 9		
60–80							109 22 47	101 19 22			
80–100						110 21 42	106 22 25				
100–120		96 18 2	104 23 9	98 15 29	102 41 42	125 27 3	114 18 13	102 4 2			

TABLE 3.5k. Fall tropospheric CO data taken from tape 14, files 4 and 5. The plotting code is the same as described in Table 3.1a.

LATITUDE (°E / °W)											
–140 °E		87 15 / 9	107 24 / 49	109 12 / 67	97 13 / 34	76 17 / 23	75 - / 1				
140–160 °E	147 61 / 2	92 29 / 45	80 25 / 41								
160–180		93 32 / 8	77 27 / 41	85 21 / 30	71 8 / 7						
180–160				69 13 / 11	67 16 / 34	75 14 / 40	73 20 / 20				
160–140 °W							69 10 / 6	81 18 / 36	97 17 / 10		
140–120 °W									87 18 / 46		

40 20 0 20 40 60

°S °N

LATITUDE

TABLE 3.5k. Continued.

LONGITUDE (^oE) \ LATITUDE	60–50 ^oS	50–40 ^oS	40–30 ^oS	30–20 ^oS	20–10 ^oS	10–0 ^oS	0–10 ^oN	10–20 ^oN	20–30 ^oN	30–40 ^oN	40–50 ^oN	50–60 ^oN
MEAN	217 7	134 7	149 7	113 5	106 14	97 18	109 16	133 5	118 11	114 18		203 3
0–20												203 67 3
20–40										123 9 3		
40–60										112 13 15		
60–80							113 11 4	133 17 5	118 9 11			
80–100					103 10 11	97 16 18	108 20 12					
100–120			113 8 2	113 40 5	118 39 3							
120–140			117 4 3									
140–160	217 51 7	134 35 7	233 58 2									

TABLE 3.5l. Similar to Table 3.5k but for winter troposphere.

LONGITUDE (°E)	60–50 °S	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N
MEAN			95 9								
100–120			54 - 1								
120–140			100 32 8								

LONGITUDE (°E)	60–50 °S	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N
MEAN	94 3	111 6								151 2	148 16
0–20											137 35 8
20–40										151 17 2	160 62 8

LATITUDE

TABLE 3.5m. Similar to Tables 3.5k and 3.5l but for fall stratosphere (top) and winter stratosphere (bottom).

LONGITUDE \ LATITUDE °N	0–10	10–20	20–30	30–40	40–50	50–60	60–70
MEAN	86 24	85 22	90 105	78 290	86 62	118 11	95 7
100–120 °E	86 12 24	85 10 22	98 30 27				
120–140 °E			87 13 76	70 16 39			
140–160 °E			82 3 2	95 43 86	48 2 11		
160–180 °E				72 21 67	84 11 9	109 6 4	
180–160 °W				61 9 44	51 – 1		
160–140 °W				61 9 33	82 19 5	113 4 4	85 23 3
140–120 °W				107 58 20	95 23 34		101 6 3
120–100 °W				74 – 1		136 40 3	
100–80 °W							
80–60 °W					174 30 2		

TABLE 3.6a. Winter tropospheric CO data taken from tape 15 as a function of latitude and longitude. The plotting code is the same as described in Table 3.1a.

LONGITUDE	0–10	10–20	20–30	30–40	40–50	50–60	60–70
MEAN				56 230	57 387	57 387	56 169
100–120 °E							
120–140 °E				53 9 17			
140–160 °E				60 22 47	55 7 146		
160–180 °E				61 7 13	53 5 18	52 12 135	
180–160 °W				57 8 23	53 7 24	56 13 82	55 7 37
160–140 °W				53 10 47	56 11 41	55 11 49	56 9 49
140–120 °W				54 14 82	59 11 52	56 8 9	54 9 49
120–100 °W				131 - 1	51 5 17	63 19 38	61 20 34
100–80 °W					57 12 49	62 17 74	
80–60 °W					66 23 40		

LATITUDE °N

TABLE 3.6b. Similar to Table 3.6a but for the stratosphere.

LONGITUDE							
MEAN				119 273	116 369	109 58	125 17
100–120 °E							
120–140 °E							
140–160 °E				115 56 114	97 41 63		
160–180 °E				91 33 18	122 55 39	72 16 5	
180–160 °W				98 36 18	105 25 38	103 15 9	114 16 7
160–140 °W				63 4 3	109 40 45	102 32 14	138 16 7
140–120 °W				133 48 118	125 34 88		115 0 1
120–100 °W				167 58 5	102 45 9	128 27 13	121 8 2
100–80 °W					115 31 31	114 18 17	
80–60 °W					135 56 56		

0 20 40 60

LATITUDE °N

TABLE 3.6c. Similar to Table 3.6a but for spring troposphere.

LONGITUDE \ LATITUDE °N	0–10	10–20	20–30	30–40	40–50	50–60	60–70
MEAN				66 / 217	66 / 758	60 / 925	60 / 368
100–120 °E							
120–140 °E							
140–160 °E				66 36 / 136	59 10 / 287	53 9 / 2	
160–180 °E				64 11 / 27	66 24 / 118	59 12 / 286	
180–160 °W				76 19 / 6	75 26 / 58	59 11 / 196	63 14 / 75
160–140 °W				69 28 / 20	72 29 / 79	60 19 / 128	58 17 / 104
140–120 °W				64 24 / 26	69 45 / 71	57 10 / 58	60 20 / 96
120–100 °W				76 19 / 2	89 49 / 8	60 15 / 91	58 15 / 91
100–80 °W					65 25 / 87	64 15 / 164	59 8 / 2
80–60 °W					76 30 / 50		

LATITUDE °N

TABLE 3.6d. Similar to Table 3.6c but for the stratosphere.

LONGITUDE °W \ LATITUDE °N	20–30	30–40	40–50
MEAN	70 42	79 40	106 1
160–140	70 18 42	55 24 5	
140–120		76 32 19	
120–100		89 57 13	
100–80		96 18 3	106 - 1
80–60			

LONGITUDE °W \ LATITUDE °N	20–30	30–40	40–50
MEAN		62 12	42 20
160–140			
140–120		59 4 2	
120–100			37 2 2
100–80		67 17 7	41 24 16
80–60		52 4 3	52 18 2

TABLE 3.7a. Winter tropospheric (left) and stratospheric (right) CO data taken from tape 17 as a function of latitude and longitude. The plotting code is the same as described in Table 3.1a.

LONGITUDE ^{o}W	LATITUDE ^{o}N 20–30	30–40	40–50
MEAN	113 / 569	117 / 613	108 / 247
160–140	112 29 / 469	112 33 / 53	
140–120	119 31 / 100	117 32 / 399	
120–100		115 37 / 158	108 17 / 82
100–80		105 15 / 3	106 32 / 148
80–60			130 41 / 17

LONGITUDE ^{o}W	LATITUDE ^{o}N 20–30	30–40	40–50
MEAN	85 / 3	72 / 171	59 / 228
160–140	85 9 / 3	98 37 / 10	
140–120		83 37 / 53	
120–100		64 26 / 99	60 24 / 100
100–80		63 34 / 9	56 24 / 119
80–60			90 86 / 9

TABLE 3.7b. Similar to Table 3.7a but for spring 1978.

LONGITUDE °W \ LATITUDE °N	20–30	30–40	40–50		20–30	30–40	40–50
MEAN	95 258	98 410	100 164			84 31	73 39
160–140	95 16 210	107 12 48				105 1	
140–120	94 12 48	98 16 194	107 16 21			94 12 4	74 11 4
120–100		94 18 118	93 18 65			84 20 24	75 15 15
100–80		100 22 49	105 16 74			58 7 2	70 18 19
80–60		108 3 3	99 34 4				78 - 1

TABLE 3.7c. Similar to Table 3.7a but for summer 1978.

Tropospheric (left)

LONGITUDE °W \ LATITUDE °N	20–30	30–40	40–50
MEAN	65 180	133 296	179 213
160–140	65 13 174	62 14 33	
140–120	68 20 6	68 38 97	26 15 4
120–100		183 164 151	170 127 72
100–80		205 168 15	178 134 126
80–60			314 132 11

Stratospheric (right)

LONGITUDE °W \ LATITUDE °N	20–30	30–40	40–50
MEAN		44 11	35 5
160–140			
140–120		54 14 4	35 7 5
120–100		38 13 7	
100–80			
80–60			

LATITUDE °N

TABLE 3.8a. Summer tropospheric (left) and stratospheric (right) CO data taken from tape 18 as a function of latitude and longitude. The plotting code is the same as described in Table 3.1a.

LONGITUDE °W	LATITUDE °N 20–30	30–40	40–50
MEAN	58 126	58 117	54 64
160–140	58 12 125	62 11 11	
140–120	53 – 1	59 11 78	
120–100		58 26 28	51 13 23
100–80			56 27 38
80–60			42 3 3

LONGITUDE °W	LATITUDE °N 20–30	30–40	40–50
MEAN			56 5
160–140			
140–120			
120–100			84 – 1
100–80			49 3 4
80–60			

TABLE 3.8b. Similar to Table 3.8a but for fall 1978.

MEAN	134 11	198 29	136 42	95 52	92 50	135 47	142 40	193 34		
140–160	134 61 10	299 – 1								
160–180	99 – 1	194 107 26	140 86 33	85 23 8						
180–160			119 31 9	97 44 44	92 43 50	130 71 40				
160–140						162 38 7	142 66 40	230 58 4		
140–120								188 62 30		
120–100										
100–80										
80–60										
60–40										
40–20										
20–0										

40 20 0 20 40 60

°S °N

LATITUDE

TABLE 3.9a. Winter tropospheric CO data taken from tape 19, file 1. The plotting code is the same as described in Table 3.1a.

LONGITUDE										
MEAN		143 1	199 29	199 33	183 23	146 69	150 81	109 54	134 32	118 77
140–160 °E								99 11 7		
160 °E–180								114 11 5		
180–160 °W								131 3 2		
160–140 °W								106 12 8		
140–120 °W								107 16 13	128 25 6	109 - 1
120–100 °W							153 28 65	113 41 19	179 29 2	136 32 2
100–80 °W					145 - 1	143 21 51	136 18 16			
80–60 °W				220 51 11	186 68 20	153 31 18			127 16 16	137 17 6
60–40 °W		143 - 1	199 54 29	188 22 22	168 3 2				141 19 8	102 22 24
40–20 °W										110 26 20
20–0 °W										136 28 24

LATITUDE: 40 °S — 20 — 0 — 20 — 40 — 60 °N

TABLE 3.9b. Winter tropospheric CO data taken from tape 19, file 2.

MEAN								94 18	93 18	94 60
140								78 7 3	83 5 10	
160										91 16 10
180								104 13 7		100 14 7
160								111 5 2		82 16 9
140								88 – 1		
120								85 11 5		103 2 2
100									110 11 6	116 12 4
80									91 2 2	88 16 11
60										90 17 7
40										102 32 10
20										
0	40		20		0		20		40	60

°S °N

LATITUDE

TABLE 3.9c. Similar to Table 3.9b but for the stratosphere.

LONGITUDE (^oE)												
MEAN	49 19	51 36	72 103	94 124	76 110	68 198	70 303	75 216	79 265	75 294	49 6	
0									65 30 25	68 34 14		
20								75 10 16	97 34 26			
40								96 28 35				
60							83 15 31	67 – 1				
80						58 20 8	124 14 5					
100					34 12 8	52 11 16	84 33 3					
120						69 17 25	84 19 8	79 12 11				
140	57 36 9					66 31 54						
160	44 1 2	50 15 26	42 9 6			65 19 22	57 15 45		65 20 3			
180												

LATITUDE: 40, 20 (^oS), 0, 20, 40, 60, 80 (^oN)

TABLE 3.10a. Summer tropospheric CO data taken from tape 20, file 3.

LONGITUDE (°W) \ LATITUDE	40–30°S	30–20°S	20–10°S	10–0°S	0–10°N	10–20°N	20–30°N	30–40°N	40–50°N	50–60°N	60–70°N	70–80°N
180–160			49 9 / 10	51 10 / 22	55 16 / 20	55 11 / 11	64 25 / 49		63 23 / 4			
160–140						48 5 / 3	61 15 / 72	81 25 / 12	52 12 / 5			
140–120							67 12 / 16	71 24 / 93	52 – / 1			
120–100						84 10 / 4	81 30 / 62	65 28 / 14		78 9 / 7		
100–80					42 12 / 2	79 38 / 27	153 10 / 2	62 37 / 15		81 17 / 9		
80–60				110 67 / 43	88 43 / 57	81 38 / 21	61 16 / 10	69 21 / 19	77 32 / 69	48 – / 1	50 6 / 5	
60–40	42 22 / 8	55 35 / 10	76 41 / 87	97 56 / 59	81 13 / 23	76 16 / 7			83 36 / 79	75 34 / 38		
40–20									94 34 / 27	74 27 / 111	41 – / 1	
20–0									64 26 / 26	76 25 / 114		

TABLE 3.10a. Continued.

LATITUDE

LONGITUDE (°E)	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N	70–80 °N
MEAN									49 58	42 90	33 17	
0–20									50 — 1	23 10 3		
20–40												
40–60												
60–80												
80–100												
100–120												
120–140												
140–160												
160–180												

TABLE 3.10b. Similar to Table 3.10a but for the stratosphere.

LONGITUDE (°W) \ LATITUDE	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N	70–80 °N
180–160									65 16 10			
160–140									53 7 8			
140–120									33 5 4			
120–100												
100–80												
80–60									34 14 9	27 6 6	38 18 3	
60–40	21 1								55 13 17	35 18 34	25 7 9	
40–20									34 5 3	55 27 26	45 18 5	
20–0									41 8 6	43 19 21		

TABLE 3.10b. Continued.

LONGITUDE (^oE) \ LATITUDE	40–30 ^oS	30–20 ^oS	20–10 ^oS	10–0 ^oS	0–10 ^oN	10–20 ^oN	20–30 ^oN	30–40 ^oN	40–50 ^oN	50–60 ^oN	60–70 ^oN	70–80 ^oN
MEAN					59 13	72 42	85 43	80 53	75 432	77 359	76 71	
0–20									76 12 3	57 13 14		
20–40								70 18 4	66 – 1			
40–60								77 28 17				
60–80							84 19 17					
80–100						78 15 18	98 12 17					
100–120					59 14 13	67 11 24	71 17 2					
120–140							47 14 4	64 17 6				
140–160								119 13 6	91 20 4			
160–180									83 20 3			

TABLE 3.10c. Similar to Table 3.10a but for fall troposphere.

TABLE 3.10c. Continued.

LONGITUDE (^oW)	30–40 ^oN	40–50 ^oN	50–60 ^oN	60–70 ^oN
180–160				
160–140		64 12 6		
140–120	83 39 14	63 9 12		
120–100	36 - 1	42 11 9	58 18 17	64 15 7
100–80	94 23 2		93 22 4	62 11 6
80–60	51 11 3	75 36 144	73 22 10	
60–40		76 24 156	84 29 65	73 20 25
40–20		76 18 61	78 29 120	87 24 25
20–0		85 39 33	79 30 129	73 22 8

LATITUDE: 40 ^oS – 80 ^oN

MEAN									53 39	44 73	42 73	53 5
0										22 10 4		
20												
40												
60												
80												
100												
120												
140												
160									102 11 2			
180												

LONGITUDE (^oE)

40 20 ^oS 0 20 40 ^oN 60 80

LATITUDE

TABLE 3.10d. Similar to Table 3.10c but for the stratosphere.

LONGITUDE (°W)	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N	70–80 °N
180–160									82 16 / 11			
160–140									45 12 / 5			
140–120												
120–100									56 19 / 3	45 14 / 13	43 2 / 3	
100–80											42 15 / 26	
80–60									33 16 / 12	47 - / 1	41 19 / 25	53 14 / 5
60–40									26 9 / 6	56 13 / 15	41 26 / 6	
40–20										44 13 / 29	57 6 / 5	
20–0										34 18 / 11	38 9 / 8	

LATITUDE

TABLE 3.10d. Continued.

TABLE 3.11 CO Climatology

Set	Aircraft	Tape no.	File no.	Table no.	Remark
1	PAN AM-N533 PA	14	1	3.5a-b	Fall data only
		15	1-3	3.6a-d	
2	PAN AM-N655 PA	13	2	3.4a-b	
		14	3	3.5g-j	
3	UAL-N4711U	12	2,3	3.12a-b	
		14	2	3.12a-b	
		17	1-3	3.12a-b	
4	QANTAS VH-EBE	14	4,5	3.5k,3.5m	Fall data only
		19	1	3.13a-b	

(a)

LATITUDE °N \ LONGITUDE °W	160–140	140–120	120–100	100–80	80–60	Mean
50–40			100 25 98	106 32 169	131 39 19	106 286
40–30	122 33 54	117 32 409	113 38 183	86 15 11	146 19 2	116 659
30–20	133 29 500	119 31 102				114 602

(b)

LATITUDE °N \ LONGITUDE °W	160–140	140–120	120–100	100–80	80–60	Mean
50–40			59 24 104	56 23 132	81 80 11	59 247
40–30	98 37 10	83 37 53	66 26 126	68 36 10		72 199
30–20	96 12 12					96 12

(c)

LATITUDE °N \ LONGITUDE °W	160–140	140–120	120–100	100–80	80–60	Mean
50–40		107 16 21	94 18 81	105 16 92	99 30 5	100 199
40–30	106 13 59	103 41 234	93 18 147	103 23 52	108 3 3	101 495
30–20	92 16 304	94 12 49				92 353

(d)

LATITUDE °N \ LONGITUDE °W	160–140	140–120	120–100	100–80	80–60	Mean
50–40		74 11 4	69 15 23	70 18 19	78 - 1	70 47
40–30	105 0 1	78 17 9	84 20 24	58 7 2		82 36
30–20						

LONGITUDE °W

TABLE 3.12a. Composite results of carbon monoxide measurements made by United Airlines B-747 aircraft. The data are taken from tape 12, tape 14 (file 2 only) and tape 17. The plotting code is the same as described in Table 3.1a. (a) Spring troposphere. (b) Spring stratosphere. (c) Summer troposphere. (d) Summer stratosphere.

(a)

LATITUDE °N \ LONGITUDE °W	160–140	140–120	120–100	100–80	80–60	Mean
50–40		64 35 / 4	103 25 / 4	79 / 1	49 21 / 3	75 / 12
40–30	88 14 / 5	90 28 / 64	93 30 / 26	76 23 / 5	59 2 / 4	89 / 104
30–20	90 20 / 92	110 33 / 33				95 / 125

(b)

LATITUDE °N \ LONGITUDE °W	160–140	140–120	120–100	100–80	80–60	Mean
50–40			69 36 / 20	59 21 / 44	44 14 / 2	61 / 66
40–30			66 24 / 4			66 / 4
30–20						

(c)

LATITUDE °N \ LONGITUDE °W	160–140	140–120	120–100	100–80	80–60	Mean
50–40		97 9 / 3	100 19 / 12	55 22 / 12	61 17 / 2	79 / 29
40–30	76 33 / 14	92 27 / 129	75 35 / 70	91 22 / 9		86 / 222
30–20	78 21 / 213	89 26 / 52				80 / 265

(d)

LATITUDE °N \ LONGITUDE °W	160–140	140–120	120–100	100–80	80–60	Mean
50–40			66 45 / 8	52 23 / 56	64 19 / 4	54 / 68
40–30	50 17 / 10	71 31 / 17	63 27 / 57	63 27 / 15	52 4 / 3	63 / 102
30–20	32 2 / 3					32 / 3

TABLE 3.12b. Similar to Table 3.12a but (a) for fall troposphere, (b) for fall stratosphere, (c) for winter troposphere, and (d) for winter stratosphere.

LONGITUDE °E \ LATITUDE	60–40 °S		40–20 °S		20–0 °S		0–20 °N		20–40 °N		40–60 °N	
Mean	217 7	134 7	140 18	185 32	128 56	95 70	96 66	135 52	137 51	166 52		203 3
0–20												203 7 3
20–40										123 9 3		
40–60										112 13 15		
60–80							113 11 4	133 17 5	118 9 11			
80–100					103 10 11	97 16 18	108 20 12					
100–120			113 8 2	113 40 5	118 39 3							

TABLE 3.13a. Composite results of carbon monoxide measurements made by QANTAS Airways during winter (December 1977-February 1978) in the troposphere. The data are taken from tape 14 (files 4 and 5) and tape 19 (file 1 only). The plotting code is the same as described in Table 3.1a.

LONGITUDE \ LATITUDE	60–50 °S	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N
120–140 °E			117 4 / 3									
140–160 °E	217 51 / 7	134 35 / 7	153 70 / 12	299 - / 1								
160 °E–180			99 0 / 1	194 108 / 26	140 86 / 33	85 23 / 8						
180–160 °W					119 31 / 9	97 44 / 44	92 43 / 50	130 71 / 40				
160–140 °W								162 38 / 7	142 66 / 40	230 58 / 4		
140–120 °W										188 62 / 30		

TABLE 3.13a. Continued.

LONGITUDE °E												
Mean	94 3	111 6								135 3	148 16	
0											137 35 8	
20										151 17 2	160 62 8	
40												
60												
80												
100												
120												

60 40 20 0 20 40 60

°S LATITUDE °N

TABLE 3.13b. Similar to Table 3.13a but for winter stratosphere.

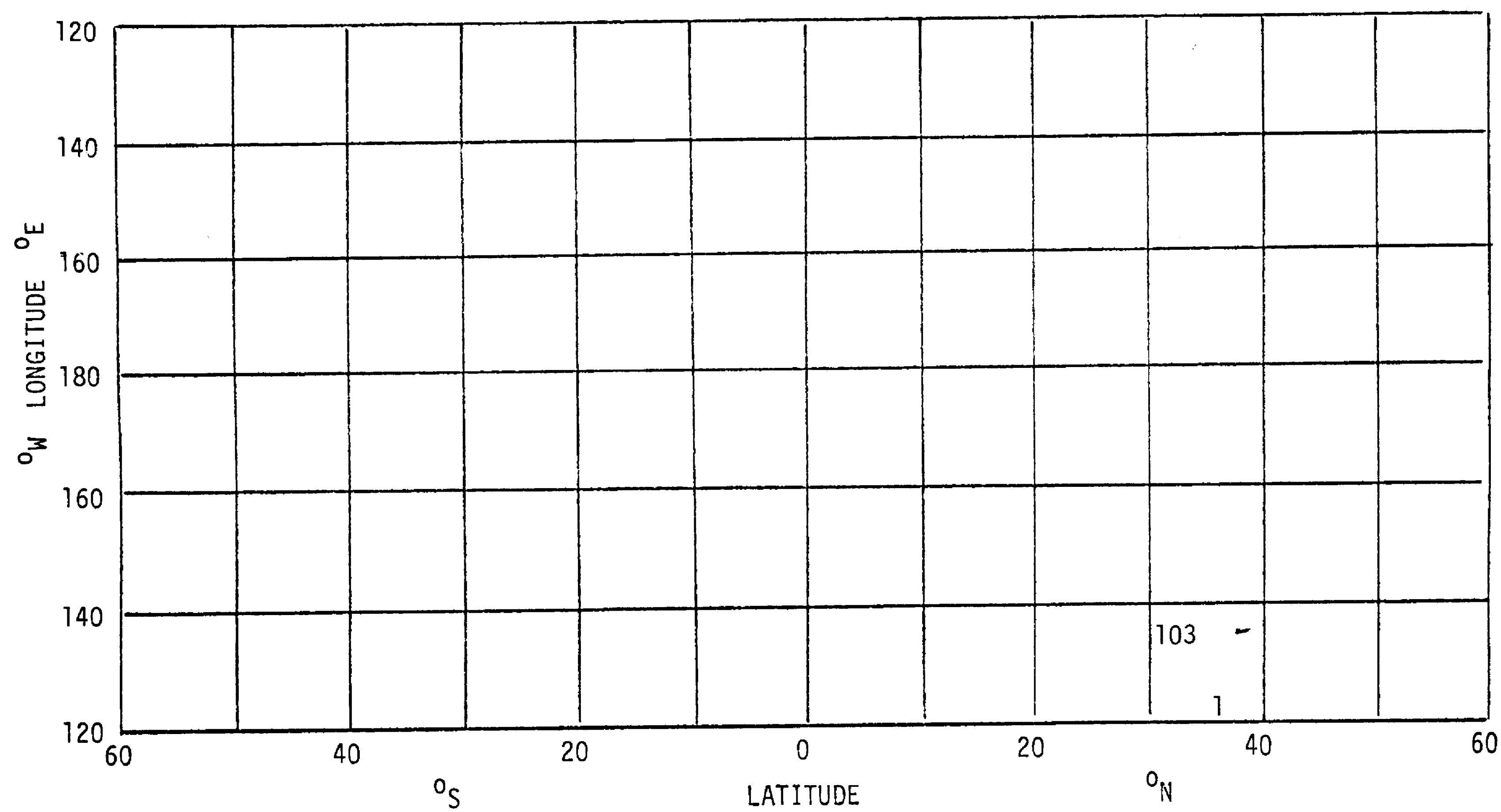

TABLE 3.13b. Continued.

TABLE 3.14a. Summary of Zonal Mean Mixing Ratios of CO for the Troposphere

Latitude belt	°S ←				| → °N						
	30-40	20-30	10-20	0-10	0-10	10-20	20-30	30-40	40-50	50-60	60-70
<u>Spring</u>:											
PAN AM-533								119 (273)	116 (369)	109 (58)	125 (17)
PAN AM-655		87 (23)	71 (11)	86 (15)	89 (20)	93 (105)	129 (109)	119 (83)	117 (30)		
UAL							114 (602)	116 (659)	106 (286)		
MEAN		87 (23)	71 (11)	86 (15)	89 (20)	93 (105)	116 (711)	117 (1015)	112 (685)	109 (58)	125 (17)
<u>Summer</u>:											
UAL							92 (353)	101 (495)	100 (199)		
<u>Fall</u>:											
PAN AM-533	84 (14)	73 (25)	65 (29)	61 (24)	62 (25)	62 (28)	75 (28)	74 (132)	76 (160)	69 (43)	
PAN AM-655*					134 (25)	148 (114)	130 (163)	114 (202)	118 (268)	122 (129)	
QANTAS	91 (64)	90 (140)	98 (137)	88 (120)	90 (108)	100 (112)	89 (88)	92 (113)	99 (30)		
UAL							95 (28)	89 (104)	75 (12)		
MEAN	90 (78)	87 (165)	92 (166)	84 (144)	85 (133)	92 (140)	91 (244)	84 (349)	79 (202)	69 (43)	

TABLE 3.14a. Continued

Latitude belt	°S ← 30-40	20-30	10-20	0-10	→ °N 0-10	10-20	20-30	30-40	40-50	50-60	60-70
<u>Winter</u>:											
PAN AM-533					86 (24)	85 (22)	90 (105)	78 (290)	86 (62)	118 (11)	
PAN AM-655*		148 (21)	118 (32)	119 (39)	126 (44)	126 (39)	134 (80)	134 (48)	112 (10)		
QANTAS*	140 (18)	185 (32)	128 (56)	95 (70)	96 (66)	135 (52)	137 (51)	166 (52)			
UAL							80 (265)	86 (222)	79 (29)		
MEAN					86 (24)	85 (22)	83 (370)	81 (512)	84 (91)	118 (11)	

* indicates that the data are not included in the calculations of the means.
Number of observations in parentheses.

TABLE 3.14b. Summary of Zonal Mean Mixing Ratios of CO for Stratosphere

Latitude belt	Northern Hemisphere 20-30	30-40	40-50	50-60	60-70
Spring:					
PAN AM-533		66 (217)	66 (758)	60 (925)	60 (368)
PAN AM-655				59 (11)	
UAL	96 (12)	72 (199)	59 (247)		
MEAN	96 (12)	69 (416)	64 (1005)	60 (936)	60 (368)
Summer:					
UAL		82 (36)	70 (47)		
Fall:					
PAN AM-533			53 (245)	52 (276)	46 (31)
PAN AM-655*		101 (16)	86 (100)	88 (122)	81 (20)
UAL			61 (66)		
MEAN		88 (52)	63 (458)	63 (398)	60 (51)
Winter:					
PAN AM-533		56 (230)	57 (387)	57 (387)	56 (169)
PAN AM-655*			116 (13)	86 (73)	91 (78)
QANTAS*			148 (16)		
UAL		63 (102)	54 (68)		
MEAN		58 (332)	57 (455)	57 (387)	56 (169)

* indicates that the data are not included in the calculations of the means.
Number of observations in parentheses.
No data in southern hemisphere.

TAPE 9

FLIGHT 1 (2312)

FLIGHT 2 (2523)

	CO	O_3	T	U	V
CO		0.144	-0.016	-0.167	-0.456
O_3	-0.640		0.133	-0.366	-0.372
T	0.382	-0.368		-0.195	0.279
U	-0.471	0.159	0.170		-0.037
V	0.629	-0.212	0.622	-0.739	

FLIGHT 3 (3472)

FLIGHT 4 (2755)

	CO	O_3	T	U	V
CO		-0.627	0.328	0.530	0.362
O_3	-0.069		0.189	-0.302	-0.467
T	0.096	-0.060		0.692	-0.212
U	0.498	0.251	0.486		0.257
V	0.230	-0.257	-0.072	0.091	

TABLE 3.15a. Linear bivariate correlation coefficients among five variables. CO = carbon monoxide; O_3 = ozone; T = air temperature; U = zonal wind, V = N-S wind. Number of data pairs in parenthesis.

TAPE 9	TROPOSPHERE (5481)				
STRATOSPHERE (5536)	CO	O_3	T	U	V
CO		-0.064	0.196	-0.056	0.560
O_3	-0.352		-0.141	0.291	-0.085
T	0.245	0.302		0.260	0.317
U	0.110	-0.056	0.547		0.077
V	0.056	-0.308	0.102	-0.054	

TABLE 3.15b. Similar to Table 3.15a except that the data are grouped based on whether they are obtained in the troposphere or stratosphere instead of on flight basis.

TAPE 9 — FLIGHT 1 (74) / FLIGHT 2 (80)

	CO	O_3	T
CO		0.366	-0.322
O_3	-0.652		0.307
T	0.265	-0.279	

FLIGHT 3 (105) / FLIGHT 4 (70)

	CO	O_3	T
CO		-0.648	0.266
O_3	-0.210		0.228
T	0.256	-0.067	

TAPE 9 — TROPOSPHERE (150) / STRATOSPHERE (179)

	CO	O_3	T
CO		-0.176	0.191
O_3	-0.486		-0.207
T	0.255	0.205	

TABLE 3.15c. Similar to Table 3.15a but using averaged values of CO, O_3 and T over 1^{o} latitude.

TAPE 11 FALL (350)

SPRING (1370)

	CO	O_3	T	U	V
CO		-0.066	0.123	-0.244	0.175
O_3	0.062		-0.110	0.376	0.174
T	-0.471	-0.294		-0.125	-0.046
U	-0.004	0.100	-0.069		0.027
V	-0.199	-0.174	0.215	0.030	

TAPE 11 SUMMER (1171)

	CO	O_3	T	U	V
CO		0.018	-0.200	-0.064	0.052
O_3			-0.187	0.290	0.134
T				-0.156	0.073
U					-0.105
V					

TABLE 3.16. Similar to Table 3.15a but for tape 11 and on seasonal basis.

TAPE 12 — SUMMER (177) / SPRING (130)

	CO	O_3	T	U	V
CO		-0.678	-0.118	0.101	-0.376
O_3	-0.717		-0.064	-0.042	0.284
T	-0.153	0.185		-0.368	-0.197
U	-0.283	0.214	0.319		-0.125
V	-0.145	0.156	0.118	0.572	

TAPE 13 — SPRING (115)

	CO	O_3	T	U	V
CO		-0.335	-0.485	-0.377	-0.216
O_3			-0.095	-0.022	-0.298
T				0.157	0.212
U					0.464
V					

TABLE 3.17. Similar to Table 3.16 but for tape 12.

TAPE 14 (FILE 1) FALL (1109)

WINTER (429)

	CO	O_3	T	U	V
CO		-0.457	0.051	0.096	0.039
O_3	-0.343		0.188	-0.025	0.019
T	-0.088	0.273		-0.115	0.124
U	0.090	-0.226	0.014		0.193
V	0.233	-0.226	0.022	-0.005	

TAPE 14 (FILE 3) FALL (407)

WINTER (503)

	CO	O_3	T	U	V
CO		-0.592	-0.009	-0.222	-0.264
O_3	-0.609		0.074	0.079	0.183
T	0.246	-0.320		0.021	0.202
U	0.166	-0.180	-0.176		0.289
V	-0.180	0.222	-0.066	-0.083	

TABLE 3.18. Similar to Table 3.16 but for tape 14, file 1 and file 3 only.

TAPE 14 (FILE 4 & 5) FALL (883)

WINTER (168)

	CO	O_3	T	U	V
CO		-0.088	0.054	-0.009	0.009
O_3	0.014		-0.328	0.316	0.066
T	-0.241	-0.395		-0.127	0.085
U	-0.012	-0.035	-0.337		-0.029
V	-0.025	-0.203	0.102	0.153	

TAPE 15 WINTER (1675)

SPRING (2133)

	CO	O_3	T	U	V
CO		-0.530	-0.193	0.250	0.106
O_3	-0.700		0.241	-0.491	-0.029
T	-0.469	0.720		0.327	-0.015
U	0.345	-0.421	-0.323		-0.024
V	-0.062	0.043	0.101	0.059	

TABLE 3.19. Similar to Table 3.16 but for tape 14 (file 4 and 5) and for tape 15.

TAPE 17 WINTER (117)

SPRING (1874)

	CO	O_3	T	U	V
CO		-0.538	-0.020	0.121	0.113
O_3	-0.654		-0.369	-0.552	0.080
T	0.016	0.060		0.371	-0.299
U	-0.085	0.036	-0.158		-0.152
V	-0.080	0.054	0.081	0.169	

SUMMER (920)

	CO	O_3	T	U	V
CO		-0.443	-0.066	-0.024	-0.016
O_3			-0.108	0.003	-0.035
T				-0.002	0.068
U					0.349
V					

TABLE 3.20. Similar to Table 3.16 but for tape 17.

TAPE 18 — FALL (277); rows: SUMMER (471)

	CO	O_3	T	U	V
CO		-0.281	0.151	-0.151	-0.118
O_3	-0.244		0.253	0.048	-0.242
T	-0.195	-0.023		-0.137	0.125
U	-0.110	-0.131	-0.088		0.303
V	-0.098	0.136	-0.116	0.151	

TAPE 19 (FILE 2) — WINTER (498)

	CO	O_3	T	U	V
CO		-0.608	0.211	-0.301	-0.081
O_3			-0.101	0.061	-0.001
T				0.057	-0.061
U					-0.121
V					

TABLE 3.21. Similar to Table 3.16 but for tape 18 and tape 19 (file 2).

TAPE 20 (FILE 3) FALL (1133)

SUMMER (1739)

	CO	O_3	T	U	V
CO		-0.435	0.295	-0.049	-0.053
O_3	-0.272		-0.093	0.067	-0.007
T	0.263	-0.126		-0.222	-0.022
U	-0.068	0.238	-0.129		0.032
V	-0.031	0.016	0.036	0.041	

	CO	O_3	T	U	V
CO					
O_3					
T					
U					
V					

TABLE 3.22. Similar to Table 3.16 but for tape 20 (file 3).

WINTER TROPOSPHERE $\leq 20^{0}$ LATITUDE (36)

$> 20^{0}$ LATITUDE (442)

	CO	O_3	T	U	V
CO		0.326	0.050	0.053	0.041
O_3	-0.309		-0.113	-0.413	0.148
T	-0.145	-0.060		0.106	-0.283
U	-0.264	-0.213	0.401		-0.568
V	0.208	-0.099	-0.097	0.022	

WINTER STRATOSPHERE $\leq 20^{0}$ LATITUDE (0)

$> 20^{0}$ LATITUDE (1159)

	CO	O_3	T	U	V
CO					
O_3	-0.371				
T	-0.368	0.489			
U	0.059	-0.226	0.181		
V	-0.154	0.146	0.116	-0.133	

TABLE 3.23a. Similar to Table 3.15 except that the data are grouped based on latitude and the region below and above the tropopause. The data used in the computations were collected by PAN AM-N533 aircraft.

SPRING TROPOSPHERE $\leq 20^0$ LATITUDE (0)

$> 20^0$ LATITUDE (532)

	CO	O_3	T	U	V
CO					
O_3	-0.670				
T	-0.159	0.422			
U	-0.001	-0.047	0.055		
V	-0.157	0.187	0.121	0.161	

SPRING STRATOSPHERE $\leq 20^0$ LATITUDE (0)

$> 20^0$ LATITUDE (1616)

	CO	O_3	T	U	V
CO					
O_3	-0.489				
T	-0.341	0.669			
U	0.226	-0.269	-0.292		
V	-0.106	0.089	0.128	- 0.032	

TABLE 3.23b. Similar to Table 3.23a but for spring season.

FALL TROPOSPHERE $\leq 20^0$ LATITUDE (106)

$> 20^0$ LATITUDE (414)

	CO	O_3	T	U	V
CO		0.191	0.290	0.219	0.123
O_3	-0.418		-0.272	0.418	-0.208
T	0.159	-0.041		-0.173	0.541
U	0.058	0.045	0.017		-0.346
V	0.058	-0.034	0.150	0.240	

FALL STRATOSPHERE $\leq 20^0$ LATITUDE (0)

$> 20^0$ LATITUDE (589)

	CO	O_3	T	U	V
CO					
O_3	-0.298				
T	-0.097	0.575			
U	-0.040	-0.102	-0.317		
V	-0.002	0.007	0.062	0.118	

TABLE 3.23c. Similar to Table 3.23a but for fall season.

WINTER TROPOSPHERE $\leq 20^{o}$ LATITUDE (152)

$> 20^{o}$ LATITUDE (187)

	CO	O_3	T	U	V
CO		0.125	0.352	-.001	0.083
O_3	-0.183		0.067	0.253	-0.089
T	0.184	-0.083		-0.044	-0.060
U	-0.098	-0.252	-0.301		0.481
V	-0.136	0.391	0.019	0.027	

WINTER STRATOSPHERE $\leq 20^{o}$ LATITUDE (0)

$> 20^{o}$ LATITUDE (164)

	CO	O_3	T	U	V
CO					
O_3	-0.611				
T	-0.425	0.394			
U	0.086	-0.179	-0.068		
V	-0.059	-0.116	0.129	-0.353	

TABLE 3.24a. Similar to Table 3.23a except that the data used in the computations were obtained by PAN AM-N655 aircraft.

SPRING TROPOSPHERE $\leq 20°$ LATITUDE (22)

$> 20°$ LATITUDE (89)

	CO	O_3	T	U	V
CO		0.349	0.131	0.265	0.205
O_3	-0.280		-0.083	0.397	0.289
T	-0.521	-0.036		-0.199	-0.692
U	-0.567	-0.080	0.567		0.292
V	-0.249	-0.455	-0.489	0.494	

$\leq 20°$ LATITUDE (0)

$> 20°$ LATITUDE (4)

	CO	O_3	T	U	V
CO					
O_3	-0.904				
T	-0.877	0.615			
U	0.789	-0.968	-0.480		
V	0.557	-0.842	-0.099	0.874	

TABLE 3.24b. Similar to Table 3.24a but for spring season.

FALL TROPOSPHERE $\leq 20^{o}$ LATITUDE (22)

$> 20^{o}$ LATITUDE (238)

	CO	O_3	T	U	V
CO		0.213	0.246	0.037	0.255
O_3	-0.367		-0.161	0.585	-0.491
T	-0.002	0.011		-0.121	0.153
U	-0.035	-0.031	0.016		-0.528
V	-0.174	0.041	0.179	0.191	

FALL STRATOSPHERE $\leq 20^{o}$ LATITUDE (0)

$> 20^{o}$ LATITUDE (147)

	CO	O_3	T	U	V
CO					
O_3	-0.404				
T	-0.427	0.539			
U	-0.227	-0.221	0.234		
V	-0.187	0.031	0.399	0.396	

TABLE 3.24c. Similar to Table 3.24a but for fall season.

WINTER TROPOSPHERE $\leq 20^{o}$ LATITUDE (0)

$> 20^{o}$ LATITUDE (86)

	CO	O_3	T	U	V
CO					
O_3	-0.429				
T	-0.169	-0.312			
U	-0.073	-0.565	0.359		
V	0.125	0.252	-0.467	-0.290	

WINTER STRATOSPHERE $\leq 20^{o}$ LATITUDE (0)

$> 20^{o}$ LATITUDE (32)

	CO	O_3	T	U	V
CO					
O_3	-0.613				
T	-0.549	0.781			
U	0.350	-0.479	-0.225		
V	-0.053	0.096	0.322	0.299	

TABLE 3.25a. Similar to Table 3.23a except that the data used in the computations were obtained by United Airlines B-747 aircraft.

SPRING TROPOSPHERE — $\leq 20^o$ LATITUDE (0); $> 20^o$ LATITUDE (1544)

	CO	O_3	T	U	V
CO					
O_3	-0.372				
T	0.048	-0.055			
U	-0.064	0.043	-0.140		
V	-0.080	0.061	0.058	0.185	

SPRING STRATOSPHERE — $\leq 20^o$ LATITUDE (0); $> 20^o$ LATITUDE (450)

	CO	O_3	T	U	V
CO					
O_3	-0.699				
T	-0.529	0.689			
U	-0.079	-0.067	-0.029		
V	-0.056	0.050	0.205	0.194	

TABLE 3.25b. Similar to Table 3.25a but for spring season.

SUMMER TROPOSPHERE — $\leq 20^{o}$ LATITUDE (0)

Rows: $> 20^{o}$ LATITUDE (890)

	CO	O_3	T	U	V
CO					
O_3	-0.299				
T	-0.090	-0.090			
U	-0.041	0.031	-0.031		
V	-0.066	0.020	0.040	0.314	

SUMMER STRATOSPHERE — $\leq 20^{o}$ LATITUDE (0)

Rows: $> 20^{o}$ LATITUDE (75)

	CO	O_3	T	U	V
CO					
O_3	-0.840				
T	-0.480	0.562			
U	-0.031	-0.089	0.001		
V	-0.186	0.241	0.055	0.309	

TABLE 3.25c. Similar to Table 3.25a but for summer season.

WINTER TROPOSPHERE $\leq 20^{o}$ LATITUDE (95)

$> 20^{o}$ LATITUDE (95)

	CO	O_3	T	U	V
CO		-0.004	-0.676	-0.308	0.089
O_3	-0.036		-0.106	0.586	-0.456
T	-0.117	-0.433		0.022	-0.081
U	-0.288	0.003	-0.127		-0.286
V	-0.059	-0.149	0.056	0.151	

$\leq 20^{o}$ LATITUDE (0)

$> 20^{o}$ LATITUDE (26)

	CO	O_3	T	U	V
CO					
O_3	-0.246				
T	-0.161	0.453			
U	-0.201	-0.005	-0.513		
V	0.249	0.076	-0.336	0.417	

TABLE 3.26a. Similar to Table 3.23a except that the data used in the computations were obtained by QANTAS Airways VH-EBE aircraft.

FALL TROPOSPHERE $\leq 20^{o}$ LATITUDE (431)

$> 20^{o}$ LATITUDE (443)

	CO	O_3	T	U	V
CO		0.363	0.067	0.082	0.157
O_3	-0.279		0.030	0.071	0.211
T	0.048	-0.178		-0.024	0.025
U	-0.037	0.046	0.224		-0.191
V	-0.090	0.163	0.068	0.088	

FALL STRATOSPHERE $\leq 20^{o}$ LATITUDE (0)

$> 20^{o}$ LATITUDE (9)

	CO	O_3	T	U	V
CO					
O_3	-0.934				
T	-0.874	0.951			
U	-0.044	0.236	0.414		
V	0.527	-0.501	-0.534	-0.053	

TABLE 3.26b. Similar to Table 3.26a but for fall season.

4. SUMMARY AND CONCLUDING REMARKS

The GASP observations of carbon monoxide are plentiful and can be claimed as the largest collection in the world. Our studies reported in this document can only represent an overall look at this material; much remains to be investigated in more detail. Unfortunately, due to instrumental problems, about one-half or more of the data has been found questionable. Hence, great care was exercised when we examined these data. We believe that the final results presented in this report are reasonably good and can be used by modelers in validating their theoretical calculations. The following conclusions are reached.

1. Based on the final data recommended in Table 3.14, we note that carbon monoxide is higher in middle latitudes of both hemispheres than in low latitudes with the largest values in the northern hemisphere.

2. Also, based on the data of Table 3.14, there is preliminary evidence of a seasonal cycle in the northern hemisphere with maximum values in the spring season. Because so much of the data from the southern hemisphere was discarded, it is not possible to establish a seasonal cycle there.

3. Carbon monoxide and ozone are negatively correlated for latitude polewards of 20°, a circumstance we ascribe to vertical motion. Ozone-rich carbon monoxide poor air descends from higher levels in the stratosphere often through the tropopause while ozone poor carbon monoxide rich air ascends from lower levels in the troposphere to flight levels.

4. Carbon monoxide and ozone are positively correlated for latitudes equatorwards of 20°, a circumstance that may be related to photochemical interactions between the gases as observed by Fishman et al. (1980).

5. Variability of CO in the stratosphere is small. Because we used the stratosphere as a calibration device we partly forced this conclusions. But as long as the instrument was able to measure down to about 50 ppbv and simultaneously registered high ozone ($> \simeq 120$ ppbv) the data was accepted. There were a few measurements of very low carbon monoxide ($\simeq$ 10-20 ppbv) whose origin is unknown. Again, they could be examined by trajectory analysis.

REFERENCES

Briehl, D., T. J. Dudzinski, and D. C. Liu, 1980: NASA Global Atmospheric Sampling Program (GASP) Data Report for Tape VL0014, NASA TM-81579.

Crutzen, P. J., L. E. Heidt, J. P. Krasnec, W. H. Pollock, and W. Seiler, 1979: Biomass burning as source of the atmospheric gases CO, H_2, N_2O, NO, CH_3CL, and COS, paper presented at CACGP Symposium on the Budget and Cycles of Trace Gases and Aerosols in the Atmosphere, 12-18 August 1979, University of Colorado, Boulder, p. 17.

Dianov-Klokov, V. T., Y. V. Kokeyeve, and L. N. Yurganov, 1978: A study of the carbon monoxide content of the atmosphere, *Izvestiya, Atmos. and Oceanic Phys. 14(4)*, 263-270.

Dudzinski, T. J., 1979: Carbon monoxide measurement in the global atmospheric sampling program, NASA Technical Paper 1526.

Fishman, J., W. Seiler, and P. Haagenson, 1980: Simultaneous presence of O_3 and CO bands in the troposphere, *Tellus*, *32*, 456-463.

Gauntner, D. J., T. W. Nyland, M. W. Tieferman, and T. J. Dudzinski, 1979: Measurements of carbon monoxide, condensation nuclei, and ozone on a B-747SP aircraft flight around the world, *Geophys. Res. Lett. 6*, 167-170.

Holdeman, J. D., T. J. Dudzinski, T. W. Nyland, and M. W. Tieferman, 1978: NASA Global Atmospheric Sampling Program (GASP) data report for tape VL0009, NASA TM-79058.

Holdeman, J. D., T. J. Dudzinski, T. W. Nyland, and M. W. Tieferman, 1979: NASA Global Atmospheric Sampling Program (GASP) data report for tapes VL0010 and VL0012, NASA TM-79061.

Holdeman, J. D., T. J. Dudzinski, and M. W. Tieferman, 1980: NASA Global Atmospheric Sampling Program (GASP) data report for tapes VL0011 and VL0013, NASA TM-81462.

Papathakos, L. C., and D. Briehl, 1981: NASA Global Atmospheric Sampling Program (GASP) data report for Tape VL0015, Vl0016, VL0017, VL0018, VL0019, and VL0020, NASA TM-81661.

Marenco, A., and J. C. Delaunay, 1981: Experimental evidence of natural sources of CO from measurements in the troposphere, *J. Geophys. Res. 85*, 5599-5613.

Newell, R. E., and D. J. Gauntner, 1979: Experimental evidence of interhemispheric transport from airborne carbon monoxide measurements, *J. Appl. Meteor.* *18*, 696-699.

Newell, R. E., and D. J. Gauntner, 1980: Reply, *J. Appl. Meteor.* *19*, 339-340.

Pratt, R. W., and P. D. Falconer, 1979: Circumpolar measurements of ozone, particles, and carbon monoxide from the flight of a Pan American Airliner, paper presented at CACGP Symposium on the Budget and Cycles of Trace Gases and Aerosols in the Atmosphere, 12-18 August 1979, University of Colorado, Boulder, p. 15.

Routhier, F., and D. D. Davis, 1980: Free tropospheric/boundary-layer airborne measurements of H_2O over the latitude range of 58°S to 70°N: Comparison with simultaneous ozone and carbon monoxide measurements, *J. Geophys. Res.* *85*, 7293-7306.

Seiler, W., 1974: The cycle of atmospheric CO, *Tellus*, *26*, 116-135.

Seiler, W., 1975: The cycle of carbon monoxide in the atmosphere, paper presented at International Conference on Environmental Sensing and Assessment, 14-19 September 1975, Las Vegas, Nevada, Vol. 2, p. 35-4.

APPENDIX

Summary of GASP ozone data as a function of latitude and longitude for the period March 1977 to December 1978. In each box the value at the upper left corner represents the mean value of ozone mixing ratio (ppbv) for that grid area, the figure at the upper right corner is the standard deviation, and the number of observations is indicated at the bottom. The zonal mean and the corresponding total data points for the latitudinal belt are given at the top row in each table. The data are taken from tapes 11 through 20. Note that the ozone data with an "L" tag are not included in the statistics and that the 128 second average ozone values are used only.

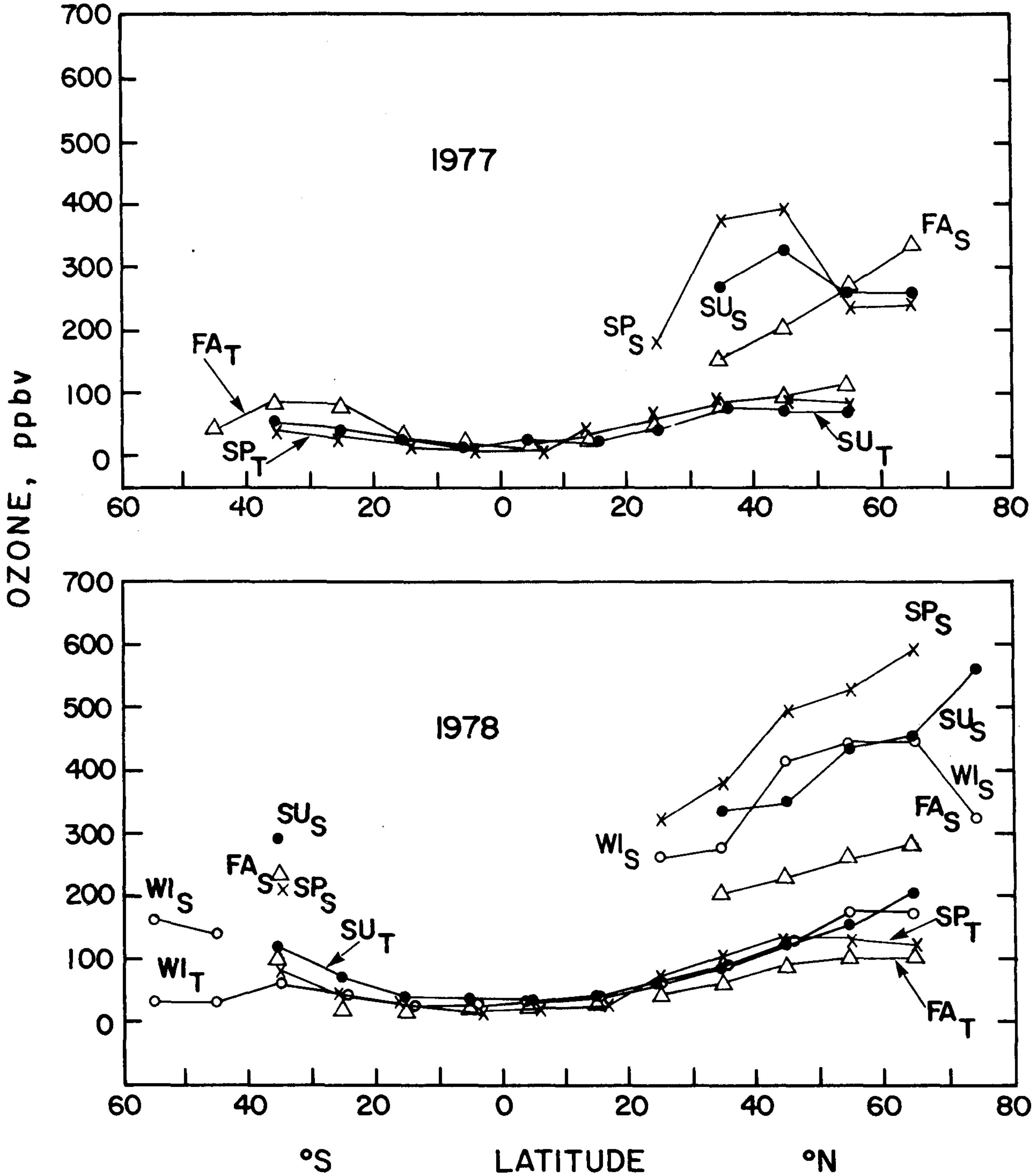

FIGURE A-1. Composite results of zonal mean ozone mixing ratio derived from all available data taken from tapes 11 through 20. SP, SU, FA and WI stand for spring, summer, fall and winter, while subscripts T and S are for troposphere and stratosphere.

LONGITUDE °E	50–40 °S	40–30	30–20	20–10	10–0	0–10	10–20	20–30	30–40	40–50	50–60	60–70 °N
MEAN		46 183	32 302	24 189	20 182	18 174	29 146	60 309	79 263	89 72	73 6	
0–20										45 8 22	73 28 6	
20–40			42 17 9						71 30 34	103 85 39		
40–60			38 19 16					40 6 23	66 40 83			
60–80			47 18 19			17 4 10	37 13 35	51 18 75				
80–100		47 9 10	65 31 16	29 7 22	25 5 34	23 8 38	31 8 18	45 19 27				
100–120		42 17 11	32 8 31	32 7 32	23 6 44	25 9 16	41 12 14	43 -- 1				
120–140		43 25 55	32 8 30	28 8 43	22 6 19	18 4 15	24 -- 1					
140–160		43 21 74	29 9 27									
160–180		58 43 33	27 13 154	19 6 63	17 4 7							

°S LATITUDE °N

TABLE A.1. March, April, May 1977 in troposphere. See appendix.

LONGITUDE °W \ LATITUDE	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
180–160				19 8 29	15 5 78	15 5 95	18 10 61					
160–140							40 12 17	71 40 164	106 109 14			
140–120								46 11 19	85 79 121	90 5 2		
120–100									116 54 9			
100–80										138 115 9		
80–60									70 8 2			
60–40												
40–20												
20–0												

TABLE A.1. Continued.

LONGITUDE °E										
MEAN			59 3		184 14	379 182	391 321	240 224	246 11	
0–20							324 46 4			
20–40										
40–60										
60–80										
80–100										
100–120										
120–140										
140–160										
160–180			59 2 3							

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.2. March, April, May 1977 in stratosphere. See appendix.

LONGITUDE °W										
180–160										
160–140					184 55 14				250 90 8	
140–120						318 127 17	517 190 18	278 89 24	237 91 3	
120–100						391 244 145	497 216 83			
100–80						347 195 20	378 240 121			
80–60							339 128 46	306 58 5		
60–40							266 94 32	385 64 73		
40–20							203 86 14	201 99 76		
20–0							340 51 3	205 72 46		

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.2. Continued.

LONGITUDE °E \ LATITUDE	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
MEAN		54 103	41 194	25 189	19 153	20 128	26 136	46 196	76 246	71 113	69 12	
0–20										60 17 36	69 40 12	
20–40			58 10 4						86 65 63	76 43 74		
40–60			53 2 3	28 – 1				46 16 39	51 17 112			
60–80				76 2 7		21 1 10	23 4 60	43 14 90				
80–100		37 1 2	29 – 1	24 6 26	21 4 43	20 5 57	27 13 40	51 12 20				
100–120		54 32 14	36 11 43	29 12 74	18 5 54	19 5 13	19 2 6	29 – 1				
120–140		51 15 48	45 18 89	19 6 45	13 6 10	17 6 10	27 – 1					
140–160		61 35 24	38 17 21									
160–180		56 24 15	34 17 33	25 8 23	20 2 7							

TABLE A.3. June, July, August 1977 in troposphere. See appendix.

LONGITUDE °W \ LATITUDE	20°S–10°S	10°S–0	0–10°N	10°N–20°N	20°N–30°N	30°N–40°N	40°N–50°N
180–160	26 7 / 13	20 3 / 39	21 3 / 38	29 14 / 21			
160–140				38 13 / 8	50 18 / 45	69 74 / 11	
140–120					13 -- / 1	98 91 / 44	
120–100						167 73 / 11	325 -- / 1
100–80						114 15 / 5	84 24 / 6
80–60							120 -- / 1

TABLE A.3. Continued.

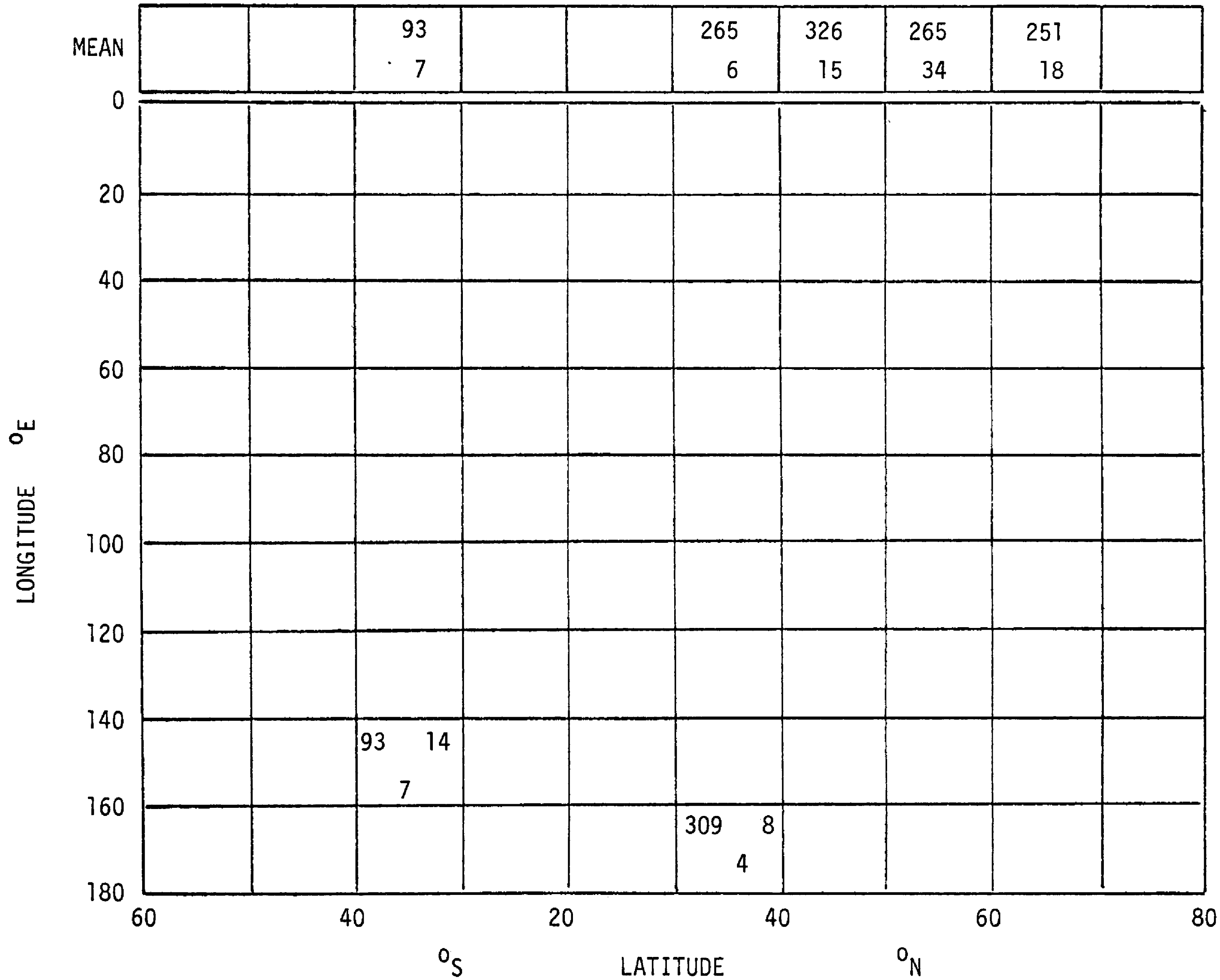

TABLE A.4. June, July, August 1977 in stratosphere. See appendix.

180–160										
160–140						176 6 2	227 12 3		252 40 11	
140–120							230 57 4	265 60 34	251 57 7	
120–100							411 119 8			
100–80										
80–60										
60–40										
40–20										
20–0										

LONGITUDE °W

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.4. Continued.

LONGITUDE °E \ LATITUDE	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
MEAN	49 4	89 188	81 348	36 230	24 232	19 215	27 243	50 261	78 664	93 426	115 40	
0–20									92 49 6	65 28 51	51 15 10	
20–40									66 28 85	43 32 59		
40–60								62 22 40	77 40 41			
60–80						20 2 5	31 12 62	43 16 47				
80–100				22 4 12	18 1 19	20 11 59	35 18 41	83 13 18				
100–120		99 59 6	56 14 32	50 26 40	42 23 42	26 13 11	35 12 35	40 13 11				
120–140		83 65 24	72 35 85	44 28 76	22 14 41	17 7 24	38 8 6	51 24 12	152 16 7			
140–160	49 14 4	82 32 120	95 51 95				16 8 2		88 77 91	88 41 49		
160–180		112 62 38	82 61 113	25 17 54	16 6 20				82 22 23	91 52 36	151 20 7	

TABLE A.5. September, October, November 1977 in troposphere. See appendix.

LONGITUDE °W \ LATITUDE	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
180–160			85 46 23	26 22 48	21 8 103	17 7 95	16 8 58	81 36 11	61 24 10	156 90 31	164 43 5	
160–140					76 10 7	19 2 18	22 11 38	36 12 102	59 28 31	113 69 16	143 92 13	
140–120							20 – 1	75 20 20	76 42 181	67 31 46	73 53 5	
120–100									90 32 17	107 45 14		
100–80									70 36 37	50 17 7		
80–60									81 43 107	180 4 2		
60–40									88 45 20	126 71 26		
40–20									122 29 8	96 41 35		
20–0										110 52 54		

TABLE A.5. Continued.

LONGITUDE °E										
MEAN			258 73	107 2		151 14	205 499	263 539	333 75	
0–20							216 77 12			
20–40						111 7 2	146 63 19			
40–60						177 19 5				
60–80										
80–100										
100–120			283 41 2							
120–140			209 145 24							
140–160			333 120 10				232 112 77			
160–180			268 166 37	106 – 1		182 43 3	135 35 14	309 114 84		

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.6. September, October, November 1977 in stratosphere. See appendix.

LONGITUDE °W										
160–180				107 -- 1		107 18 2	176 69 27	322 72 61	379 76 16	
140–160							189 69 50	251 91 44	366 69 18	
120–140						124 -- 1	185 84 42	313 81 15	300 71 17	
100–120						119 -- 1	227 91 28	212 57 24	279 28 9	
80–100							199 97 46	160 87 16		
60–80							231 99 82	210 68 5		
40–60							222 105 58	257 79 105		
20–40							185 76 36	250 100 92	352 41 10	
0–20							211 11 8	231 81 93	243 19 5	

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.6. Continued.

LONGITUDE °E \ LATITUDE	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
MEAN	35 / 19	63 / 472	45 / 417	27 / 464	23 / 442	25 / 475	32 / 434	63 / 1397	97 / 1575	137 / 311	127 / 183	171 / 11
0–20											26 11 / 5	
20–40										61 2 / 4		
40–60									24 – / 1	39 15 / 27		
60–80						36 6 / 5	43 9 / 6	20 4 / 13				
80–100				29 14 / 13	20 11 / 22	33 6 / 16						
100–120		61 6 / 3	23 12 / 3		32 7 / 27	25 12 / 61	21 8 / 47	28 12 / 44				
120–140		54 9 / 19	50 4 / 3	41 9 / 20	36 9 / 12			38 18 / 121	128 173 / 56			
140–160	41 18 / 8	59 40 / 296	53 22 / 63	26 7 / 19	21 2 / 18	19 1 / 18	21 2 / 21	45 16 / 18	124 158 / 153	768 360 / 16		
160–180	32 6 / 11	71 41 / 154	44 23 / 344	26 12 / 349	23 7 / 26				94 89 / 111	112 72 / 24	37 22 / 19	

TABLE A.7. December 1977 through January and February 1978 in troposphere. See appendix.

LONGITUDE (^oW) \ LATITUDE	50–40 ^oS	40–30 ^oS	30–20 ^oS	20–10 ^oS	10–0 ^oS	0–10 ^oN	10–20 ^oN	20–30 ^oN	30–40 ^oN	40–50 ^oN	50–60 ^oN	60–70 ^oN
160–180				23 9 97	22 12 267	24 14 315	29 15 170	72 -- 1	113 61 70	429 23 3	34 14 14	
140–160				29 10 28	24 3 21		31 13 43	70 65 948	134 137 163	122 61 13	57 10 5	237 138 3
120–140						23 5 22	30 11 21	68 46 134	79 72 776	114 104 130	183 37 10	134 26 5
100–120								46 19 96	115 107 190	103 70 20	115 63 14	153 -- 1
80–100						50 2 2	43 17 93	46 33 21	88 49 25	91 45 43	70 19 11	
60–80					20 8 17	29 13 33	40 7 33			65 56 52	36 5 7	
40–60			35 24 4	35 17 48	27 9 32	21 4 3				62 38 10	234 90 29	
20–40											192 52 32	
0–20											117 63 37	172 3 2

TABLE A.7. Continued.

LONGITUDE °E										
MEAN	165 7	144 8			261 40	271 850	411 1150	448 817	449 354	319 9
0–20							122 50 10			
20–40						100 13 2	123 24 11			
40–60										
60–80										
80–100										
100–120										
120–140						267 217 33				
140–160						359 268 76	531 300 296			
160–180						135 81 21	414 258 36	613 328 237		

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.8. December 1977 through January and February 1978 in stratosphere. See appendix.

LONGITUDE °W										
180–160						255 180 48	383 218 41	462 296 153	579 255 55	
160–140					269 152 26	364 241 98	374 209 66	366 202 104	501 199 82	
140–120					246 97 14	238 167 296	283 178 136	341 200 30	524 229 74	
120–100						236 144 193	379 223 114	359 177 85	474 228 52	
100–80						307 186 75	395 263 342	420 219 128	288 61 26	
80–60						532 98 8	423 238 98	286 69 14	276 43 19	319 35 9
60–40								227 38 10	250 62 30	
40–20								185 91 30	154 48 16	
20–0								223 56 26		

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.8. Continued.

LONGITUDE ^{o}E												
MEAN		86 114	45 97	38 143	29 136	31 179	33 296	79 1392	108 1837	136 1456	133 317	118 24
0–20										27 1 7	81 84 10	
20–40										16 9 7		
40–60									33 14 14			
60–80								34 10 29	23 -- 1			
80–100								24 1 11				
100–120						40 9 29	52 15 50	66 9 23				
120–140			54 3 3	50 9 23	35 6 19	27 2 24	65 29 65	125 95 54				
140–160		73 47 49	73 13 20				24 2 39		143 166 257	192 174 174		
160–180		97 74 65	32 15 27	26 3 8			24 1 33	27 2 18	119 131 66	149 155 121	330 206 35	

50 40 20 0 20 40 60 70

^{o}S LATITUDE ^{o}N

TABLE A.9. March, April, May 1978 in troposphere. See appendix.

LONGITUDE °W												
180–160			40 29 46	37 17 77	29 8 66	29 6 33	27 4 32	26 2 50	78 61 27	179 178 118	269 212 23	125 70 10
160–140				14 9 14	25 7 29	26 5 54	28 7 42	85 51 908	77 110 126	102 116 134	71 90 39	100 56 10
140–120						79 3 11	33 10 26	94 72 229	106 104 937	94 116 256	41 23 21	143 9 2
120–100								38 17 39	103 87 327	101 67 135	150 57 21	149 4 2
100–80							42 19 28	24 1 16	81 55 26	147 128 308	98 60 23	
80–60						36 11 16	43 16 13	38 2 4	77 9 2	170 148 149		
60–40			65 -- 1	52 11 21	29 6 22	43 10 12	47 1 4			97 113 33	81 84 29	
40–20										59 7 14	119 151 51	
20–0											97 111 65	
LATITUDE	50 °S	40		20		0		20		40 °N		60 70

TABLE A.9. Continued.

LONGITUDE °E	60–50 °S	50–40 °S	40–30 °S	30–20 °S	20 °S–	–40 °N	40–50 °N	50–60 °N	60–70 °N	70–80 °N
MEAN			211 45		340 9	381 517	495 1458	527 1461	596 448	
0–20								115 99 6		
20–40						50 4 4	36 23 6			
40–60										
60–80										
80–100										
100–120										
120–140										
140–160			228 65 15			442 201 129	615 187 356	664 171 2		
160–180			303 62 30			389 177 15	464 199 127	593 232 411		

°S LATITUDE °N

TABLE A.10. March, April, May 1978 in stratosphere. See appendix.

LONGITUDE °W										
160–180						450 250 6	443 210 100	547 211 294	607 220 82	
140–160					279 128 6	361 262 33	450 214 129	521 205 187	630 181 140	
120–140					461 150 3	373 233 151	414 230 140	435 227 87	582 175 131	
100–120						351 195 167	448 187 150	541 192 122	553 125 94	
80–100						379 192 12	488 204 287	548 159 185	648 -- 1	
60–80							149 234 149	11 296 11		
40–60							516 181 16	409 179 56		
20–40								285 183 62		
0–20								403 253 38		

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.10. Continued.

LONGITUDE °E \ LATITUDE	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
MEAN		121 208	75 338	44 394	42 423	37 504	40 1178	61 2315	91 2690	127 3365	152 1689	205 291
0–20									118 74 10	142 106 123	151 88 42	
20–40									135 115 76	150 84 99		
40–60								73 17 20	91 68 149			
60–80							46 7 4	61 23 124	44 -- 1			
80–100							41 12 59	59 22 75				
100–120						24 9 101	30 13 164	55 25 56				
120–140							36 14 117	49 21 204	60 34 96			
140–160		124 69 75	132 98 5				27 9 164	46 17 12	82 74 452	113 93 478		
160–180		103 90 123	70 43 147	37 12 43	29 9 7		40 26 126	51 31 117	67 55 192	132 106 360	204 171 131	

TABLE A.11. June, July, August 1978 in troposphere. See appendix.

LONGITUDE °W \ LATITUDE	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
160–180			64 37 169	37 15 250	35 12 235	35 11 84	43 19 65	57 29 285	75 65 96	139 107 212	198 162 116	215 144 30
140–160					36 17 79	38 16 225	38 16 196	62 37 848	81 13 246	112 94 198	180 134 59	238 178 39
120–140							47 17 70	62 31 413	94 87 985	157 113 251	141 127 66	208 185 37
100–120							65 1 3	90 32 130	109 80 485	134 91 315	184 179 37	275 193 19
80–100						54 16 6	61 16 136	65 17 15	97 60 132	133 97 365	180 133 123	254 151 4
60–80					65 14 45	44 13 65	57 17 68	81 19 16	86 20 30	114 78 529	137 73 24	228 69 14
40–60		312 106 10	212 175 17	63 13 101	63 13 57	58 11 23	43 11 6			117 96 285	164 123 180	235 149 19
20–40										112 81 84	135 117 393	170 127 87
0–20										147 107 66	128 92 518	42 167 42

TABLE A.11. Continued.

LONGITUDE °E										
MEAN			294 207	165 4		335 104	350 935	431 1775	459 938	560 54
0–20							367 178 26	398 126 14		
20–40						512 156 9	444 208 6			
40–60						361 -- 1				
60–80										
80–100										
100–120										
120–140										
140–160			255 143 71			477 -- 1	425 187 60			
160–180			315 151 135	149 39 2		349 167 28	445 162 173			

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.12. June, July, August 1978 in stratosphere. See appendix.

LONGITUDE °W										
180–160			182 2 2			289 178 85	452 177 169	481 139 72		
160–140					93 -- 1	314 173 132	469 132 98	418 146 104		
140–120					320 161 27	328 138 171	451 152 94	424 146 96		
120–100					307 154 54	383 164 94	457 151 262	486 134 144		
100–80					377 86 9	386 142 128	403 160 299	522 99 120	586 66 9	
80–60					364 3 2	350 167 69	449 138 156	493 111 96	555 90 30	
60–40			383 -- 1			337 154 75	394 137 136	444 146 148	546 103 12	
40–20						230 165 17	430 143 160	419 150 122	591 6 3	
20–0						414 177 34	395 151 216	408 175 36		

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.12. Continued.

LONGITUDE °E \ LATITUDE	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
MEAN		105 9	23 32	21 37	30 43	28 123	33 181	46 618	68 1153	90 1401	103 599	107 110
0–20									102 12 7	77 19 15	81 34 15	
20–40									100 35 31	119 27 6		
40–60								71 17 23	68 20 40			
60–80							50 15 4	70 17 38				
80–100							38 6 18	52 6 17				
100–120						25 8 77	28 11 113	48 25 35				
120–140								50 22 97	69 26 40			
140–160		39 -- 1						39 15 52	76 43 178	98 56 120		
160–180		150 150 5	12 4 3					44 16 41	122 98 41	100 79 111	122 66 6	

TABLE A.13. September, October, November 1978 in troposphere. See appendix.

Longitude (°W)	50–40 °S	40–30 °S	30–20 °S	20–10 °S	10–0 °S	0–10 °N	10–20 °N	20–30 °N	30–40 °N	40–50 °N	50–60 °N	60–70 °N
160–180			8 7 20	7 2 26	9 2 17			37 -- 1	60 23 78	96 64 55	195 107 22	76 12 3
140–160					13 6 8	15 5 26	20 9 18	41 16 234	62 18 102	96 77 70	193 104 25	185 109 10
120–140							47 26 8	38 20 60	60 39 383	99 69 107	223 69 3	226 63 6
100–120									61 36 185	76 45 189	67 29 42	75 24 9
80–100									95 15 37	89 49 196	102 62 48	49 5 7
60–80					61 5 6	58 11 20	61 14 61	61 12 20	85 24 31	87 32 237	144 75 17	
40–60		54 10 3	60 23 9	56 16 11	57 4 12					98 60 168	104 67 81	111 74 23
20–40										81 38 76	102 67 141	65 28 39
0–20										76 20 51	86 53 201	172 103 13

LONGITUDE °W — LATITUDE °S / °N

TABLE A.13. Continued.

LONGITUDE °E										
MEAN			235 35	37 1	66 6	209 8	234 464	267 665	283 337	178 4
0–20							186 85 14	243 79 7		
20–40							217 30 6			
40–60										
60–80										
80–100										
100–120										
120–140										
140–160			128 49 9				288 123 94			
160–180			272 145 26	37 – 1			192 83 46	313 125 133		

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.14. September, October, November 1978 in stratosphere. See appendix.

LONGITUDE °W										
180							203 95 74	285 87 97	284 110 31	
160							276 102 70	263 81 41	230 104 48	
140					66 7 6	206 168 7	233 100 32	259 89 20	256 89 44	
120						223 – 1	267 137 29	196 88 58	271 65 32	
100							206 75 47	217 100 99	311 89 34	
80							163 68 39	298 103 48	335 94 50	178 87 4
60							245 92 13	285 126 48	297 103 44	
40								279 11 62	273 96 31	
20								246 94 52	279 70 23	
0										

60 40 20 40 60 80

°S LATITUDE °N

TABLE A.14. Continued.

1. Report No. NASA CR-165356	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle ANALYSIS OF GASP CARBON MONOXIDE DATA		5. Report Date August 1981
		6. Performing Organization Code
7. Author(s) Mao-Fou Wu		8. Performing Organization Report No. IFAORS-175
		10. Work Unit No.
9. Performing Organization Name and Address Institute for Atmospheric Optics and Remote Sensing P.O. Box P Hampton, Virginia 23666		11. Contract or Grant No. NAS3-22541
		13. Type of Report and Period Covered Contractor Report
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington D.C. 20546		14. Sponsoring Agency Code 505-32-32

15. Supplementary Notes

Final report. Project Manager, Erwin A. Lezberg, Aerothermodynamics and Fuels Division, NASA Lewis Research Center, Cleveland, Ohio 44135.

16. Abstract

Atmospheric carbon monoxide in the upper troposphere and lower stratosphere for the period March 1977 through October 1978 was analyzed. This trace constituent was measured as part of the Global Atmospheric Sampling Program (GASP) by the four Boeing 747 aircraft. This report summarizes the CO data and presents the distribution and variations in space and time of this gas. The data show that the CO mixing ratios are higher in the troposphere than those in the stratosphere. In the northern hemisphere the highest value of CO mixing ratio occurs in spring, although more data are needed to verify these findings. Correlation coefficients among CO, O_3, air temperature (T) and winds were calculated for different regions under different seasons. It has been found that the CO correlates negatively with O_3 above 20 degrees latitude and positively below that latitude. Case studies using the data of CO, O_3, and T measured simultaneously were performed. Discussions and suggestions are made. A summary of ozone data on seasonal basis is given in an appendix.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Aeronomy; Atmospheric transport; Carbon monoxide distribution; Atmospheric gases; Atmospheric pollution	Unclassified - unlimited STAR Category 47

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	150	

* For sale by the National Technical Information Service, Springfield, Virginia 22161