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THE LATITUDINAL DISTRIBUTION OF OZONE TO 35 KM ALTITUDE FROM ECC OZONESONDE OBSERVATIONS, 1982-1990

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ABSTRACT

Electrochemical concentration cell (ECC) ozonesonde observations, made in recent years at ten stations whose locations range from the Arctic to Antarctica, have yielded a self-consistent ozone data base from which mean seasonal and annual latitudinal ozone vertical distributions to 35 km have been derived. Ozone measurement uncertainties are estimated, and results are presented in the Bass-Paur [1985] ozone absorption coefficient scale adopted for use with Dobson ozone spectrophotometers January 1, 1992, [Komhyr et al., 1992a]. The data should be useful for comparison with model calculations of the global distribution of atmospheric ozone, for serving as àpriori statistical information in deriving ozone vertical distributions from satellite and Umkehr observations, and for improving the satellite and Umkehr ozone inversion algorithms. Attention is drawn to similar results based on a less comprehensive data set published in *Ozone in the Atmosphere*, Proceedings of the 1988 Quadrennial Ozone Symposium [Komhyr et al., 1989] where errors in data tabulations occurred for three of the stations due to inadvertent transposition of ozone partial pressure and air temperature values.

1. INTRODUCTION

Mean seasonal and annual ozone vertical distribution data are presented for Alert, Canada (ALT, 83°N, 62°W); Resolute, Canada (RES, 74°N, 95°W); Point Barrow, Alaska (BRW, 71°N, 156°W); Edmonton, Canada (EDM, 53°N, 114°W); Boulder, Colorado (BLD, 40°N, 105°W); Hilo, Hawaii (HILO, 19°N, 155°W); American Samoa, South Pacific (SMO, 14°S, 170°W); Lauder, New Zealand (LDR, 45°S, 170°E); Syowa, Antarctica (SYO, 69°S, 39°E); and South Pole, Antarctica (SPO, 90°S, 25°W). Most of the observational data used in the analysis were obtained during 1985-1990. Table 1 shows the actual period of record for each station from which the mean data were derived and the number of soundings made at each station.

Except at SYO, the ozone observations were made with ECC ozonesondes [Komhyr, 1969]. At SYO, Carbon Iodine (CI) ozonesondes were used that are predecessors of the ECC sondes [Komhyr, 1964], and that have performance characteristics similar to those of the ECC instruments.

2. DATA PRECISION AND ACCURACY

The stoichiometry of reactions occurring within the ECC ozone sensor cathode depends on the concentration of the cathode's KI electrolyte. Use of a 1% electrolyte has yielded ECC sonde total ozone amounts in the past that agreed well with Dobson

TABLE 1. Periods of record and number of ECC ozonesonde soundings used in deriving average seasonal and annual ozone profiles at 10 stations.

		Number of Soundings				
Station	Period of Record	DJF	MAM	JJA	SON	ANN
ALT	Dec 1987-Dec 1990	77	44	31	28	180
RES	Jan 1982-Dec 1990	67	71	56	48	242
BRW	Feb 1986-Apr 1988	16	35	14	17	82
EDM	Jan 1985-Dec 1990	38	43	43	38	162
BLD	Jan 1985-Feb 1990	59	62	48	57	226
HIL	Jan 1985-Dec 1990	62	67	68	68	265
SMO	Apr 1986-Jan 1990	26	23	31	31	111
LDR	Aug 1986-Dec 1990	63	51	73	87	274
SYO	Jan 1982-Dec 1986	13	3	3	26	45
SPO	Jan 1986-Dec 1990	59	50	58	128	295

spectrophotometer ozone values derived from observations on AD wavelengths using ozone absorption coefficients of Vigroux [1953]. For example, for 525 soundings made within the NOAA ozonesonde network during 1984-1988 over a wide range of operating conditions from the tropics to the poles, the mean ECC sonde Dobson instrument total ozone normalization factor was found to be 1.009 ± 0.054 (σ). On January 1, 1992, new improved Bass-Paur ozone absorption coefficients were adopted for use with the Dobson instruments [Komhyr et al., 1992a]. These new coefficients, including the use of improved Rayleigh molecular scattering coefficients, yield total ozone amounts 2.6% smaller than those obtained in the past. ECC ozonesonde data presented herein have been adjusted to the new scale by multiplying all previous values by 0.9743.

Except for SYO, ozonesonde profiles used in the analysis had Dobson spectrophotometer normalization factors ranging from 0.85-1.15. At SYO, this data selection criterion was relaxed to 0.80-1.20, to avoid excessive data loss.

Improved sonde air pump efficiency corrections are incorporated in the ECC sonde data presented here. These were derived in 1989 by a novel technique [Komhyr et al., 1992b] based on the observation that the pumping efficiency of constant displacement type pumps is 1.0 for pumps working against zero back pressure. The new measurements yielded sonde pump efficiencies that were near 1.000 at ambient pressures greater than 200 mbar, but that decreased to 0.990, 0.982, 0.961, 0.938, 0.920, 0.889, and 0.806 at pressures of 100, 50, 20, 10, 7, 5, and 3 mbar, respectively. These efficiencies were lower by 10.1%, 3.4%, 1.2%, and 0.9 % than values determined in the past at 3, 5, 7, and 10 mbar, respectively.

Estimates of ECC ozonesonde ozone measurement precision and accuracy are given in Table 2. They were derived from comparison NOAA and NASA ECC ozonesonde soundings conducted at the Jet Propulsion Laboratory's Table Mountain Observatory in California in 1989 [Komhyr et al., 1992b], taking into account, also, results of other laboratory and field tests conducted on the instruments in the past [Torres et al., 1981; Hilsenrath et al., 1986].

TABLE 2. ECC Ozonesonde Ozone Measurement Precision and Accuracy in Percent Ozone*

Measurement Errors	775-200 (mb)	200-100 (mb)	100-10 (mb)	10-4 (mb)
Precision	±4 - ±12	±12 - ±3	±3	±3 - ±10
O_3 Abs. Coeff.	±2	±2	±2	±2
Abs.Coeff.Transfer	±2	±2	±2	±2
Pump Efficiency	±0	±1	±2	±2 - ±8
Backgrd. Current	±2 - ±5	±4	±3	±3 - ±8
Pump Temp.	±1	±1	±1	±1
Atmos. Pollution	±2	±0	±0	±0
Accuracy	±6 - ±13	±13 - ±6	±6	±6 - ±15

*From Komhyr et al., [1992b]

Accuracy estimates at each altitude range were computed by combining the errors in lines 1-7 of the table using the root-mean-square method.

3. RESULTS AND DISCUSSION

Average December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), September-October-November (SON), and annual (ANN) ozone profiles for the ten stations are plotted in Figure 1. Mean seasonal and annual ozone partial pressure data, mainly for mandatory pressure levels, are given in Tables 3 and 4. Three factors affecting the quality of the profiles and data are worth noting: First, because the MAM and JJA average ozone partial pressures for SYO were derived only from three ozonesonde soundings each, they are most likely not highly representative of true conditions during the spring and summer seasons. Also, while the southern hemisphere data at SMO, LDR, and SPO were obtained during approximately 1986-1990, the SYO data are representative of an earlier time interval (1982-1986) when ozone depletion in Antarctica was not as severe as it was toward the end of the 1980s. Second, because of variable balloon-burst altitudes, the seasonal and annual ozone means at the higher altitudes are generally derived from fewer ozonesonde sounding than indicated in Table 1. Finally, SMO data were not normalized to Dobson spectrophotometer total ozone because the assumption of constant ozone mixing ratio at above balloon-burst altitudes could not be satisfactorily invoked for many of the soundings at this tropical station. Calculated seasonal and annual ozone averages should, however, not be

TABLE 3. Average seasonal and annual ozone partial pressures in nanobars from ECC ozonesonde soundings at South Pole, Antarctica.

Pressure (mb)	DJF	MAM	JJA	SON	ANN
Surface	13.6	17.0	21.8	18.9	17.8
600	11.7	15.9	20.2	17.5	16.3
500	12.0	14.6	17.5	16.1	15.1
300	34.2	20.9	14.5	14.2	21.1
200	62.3	52.6	38.7	37.7	47.9
150	67.6	67.5	64.4	53.1	63.2
100	100.4	115.4	107.8	49.8	94.0
70	135.5	147.1	141.2	56.9	120.5
50	140.8	131.9	134.6	61.4	117.0
30	109.6	88.8	86.2	74.7	89.1
20	76.1	56.1	62.4	74.3	66.5
15	59.5	42.1	53.7	61.6	53.8
10	43.4	30.8	41.1	44.2	39.5
8.5	39.7	26.7	37.1	38.6	35.6
7	36.0	21.3	31.8	35.4	30.9
5	24.2	10.5	21.1	24.2	20.2

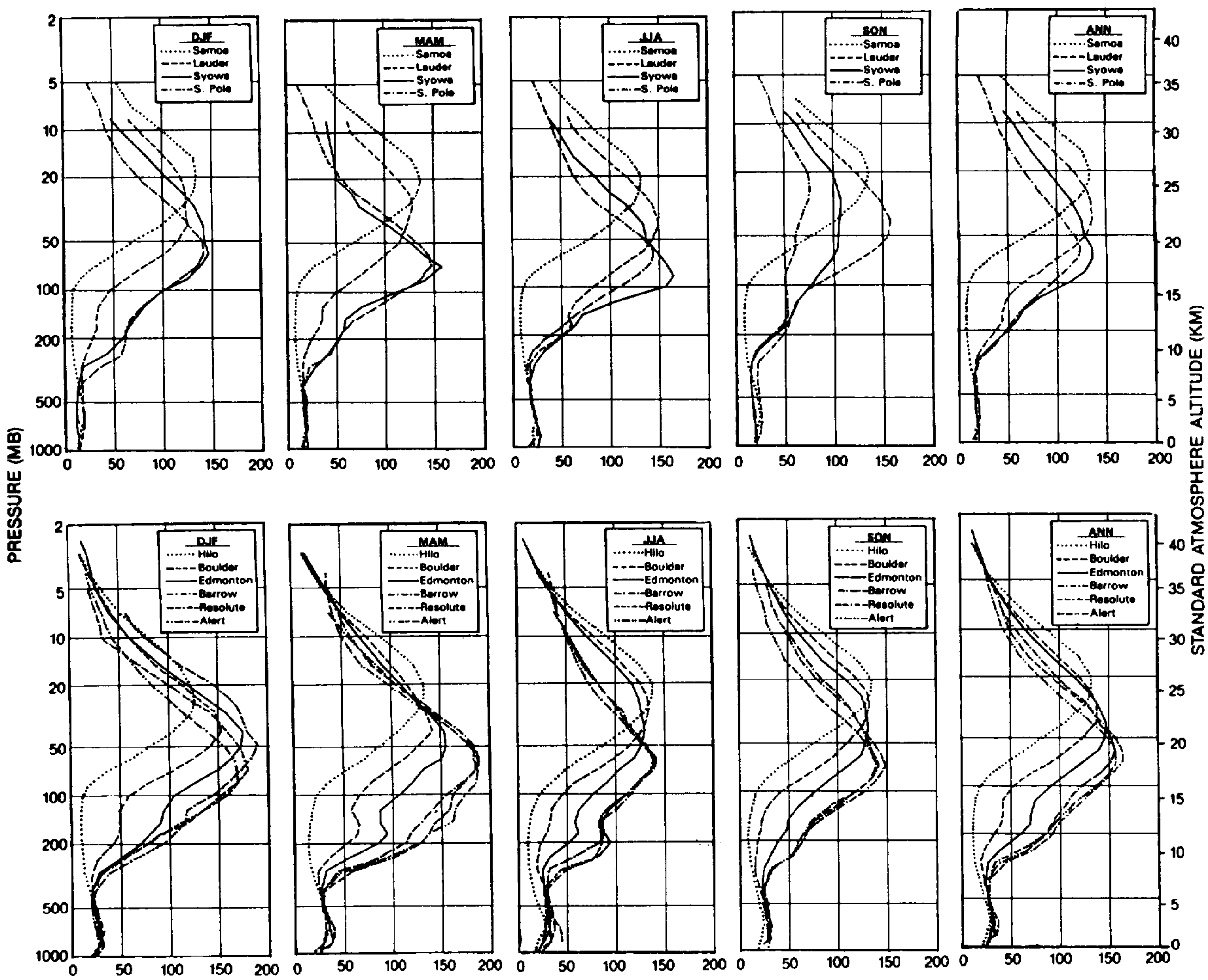

Fig. 1. Average seasonal and annual ozone profiles derived at ten stations, from observation made with ECC ozonesondes during time periods indicated in Table 1.

adversely affected, since as indicated earlier, the average normalization factor for the ECC ozonesondes (Vigroux 1953 ozone absorption coefficient scale) is approximately 1.0.

ACKNOWLEDGMENTS

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TABLE 4. Average seasonal and annual ozone partial pressures in nanobars from ECC ozonesonde soundings at stations located between 83°N - 70°S latitude.

Pressure (mb)	DJF	MAM	JJA	SON	ANN	DJF	MAM	JJA	SON	ANN	DJF	MAM	JJA	SON	ANN
	Alert					Resolute					Point Barrow				
Surface	26.4	18.2	19.9	26.4	22.6	23.1	15.6	19.4	27.1	21.2	24.7	19.9	22.1	27.0	23.1
850	28.1	28.3	24.9	29.9	28.0	26.5	30.7	26.7	27.7	28.0	31.3	37.1	31.8	30.4	32.6
700	26.1	30.3	27.7	28.7	28.6	24.6	31.8	31.2	27.2	28.6	28.8	35.8	35.9	29.7	32.8
500	21.8	25.9	27.0	26.5	25.6	20.1	28.8	29.1	22.7	25.1	22.7	29.3	32.2	24.8	27.5
300	27.2	46.9	41.7	33.0	37.8	30.9	59.3	48.6	34.6	43.0	36.8	43.6	30.2	30.2	33.9
200	75.7	127.8	85.3	59.6	86.9	76.9	129.2	94.7	63.9	91.1	93.0	113.4	84.2	64.7	86.4
150	109.4	160.7	82.1	73.1	104.6	116.8	143.7	85.7	82.7	107.2	115.6	129.8	82.8	76.5	97.9
100	159.9	174.3	110.6	120.4	138.8	152.8	162.1	111.2	126.5	138.3	145.4	155.5	114.4	117.8	122.6
70	169.6	187.2	139.0	140.0	157.3	179.8	183.9	137.2	148.0	163.2	173.9	187.6	136.2	141.4	152.7
50	156.0	183.3	131.6	128.4	148.7	171.2	180.7	132.0	135.9	156.5	190.5	185.0	128.1	132.0	152.8
30	113.9	135.3	97.3	93.9	109.7	141.8	138.9	103.5	112.2	125.1	172.0	144.6	107.7	112.0	128.5
20	84.0	96.6	71.7	68.5	79.4	100.2	103.8	80.7	80.2	90.8	145.0	105.4	81.5	85.1	96.8
15	66.5	69.8	61.7	48.0	60.7	70.6	80.1	66.3	62.9	69.3	112.3	85.5	68.7	69.8	79.2
10	42.8	49.8	49.9	34.1	43.1	32.4	59.2	52.0	47.7	49.0	75.7	56.6	52.9	50.6	55.7
7	32.7	40.4	41.8	26.4	33.8	26.6	46.1	40.6	34.4	40.4	57.3	36.3	37.2	35.5	39.6
5	21.7	35.6	36.4	17.7	26.5	18.5	35.7	33.3	27.8	29.5	-----	-----	-----	-----	-----
4	17.0	35.5	32.8	14.8	23.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	Edmonton					Boulder					Hilo				
Surface	22.5	32.7	25.6	22.8	25.8	27.6	37.8	44.4	29.4	34.7	18.9	25.6	17.1	17.2	19.7
850	29.4	37.5	32.6	29.2	32.2	-----	-----	----	-----	-----	27.4	29.3	19.6	21.0	24.3
700	29.3	35.0	31.8	30.7	31.7	31.6	39.7	42.5	32.2	36.4	27.7	34.8	28.1	23.9	28.5
500	22.2	29.2	29.2	25.3	26.5	24.0	28.9	30.3	24.1	26.7	21.7	28.2	20.2	18.8	22.2
300	27.3	31.4	24.6	24.1	26.1	20.2	22.6	19.5	14.1	19.1	13.1	17.2	11.0	10.7	13.0
200	70.1	84.8	52.0	39.3	59.9	41.4	52.8	23.0	17.7	33.4	11.1	13.7	9.4	7.6	10.4
150	90.3	86.8	58.0	49.3	70.3	49.2	65.2	31.9	22.1	41.6	10.0	15.9	12.1	9.0	11.7
100	105.2	107.4	77.2	77.3	91.1	58.8	66.6	45.5	41.9	53.1	12.3	23.1	22.2	17.0	18.5
70	150.0	132.0	105.0	110.4	124.4	104.8	97.5	81.8	80.8	91.1	37.6	54.4	48.8	43.4	46.0
50	173.2	155.5	126.2	128.4	146.0	142.1	127.3	113.8	109.6	123.2	78.4	87.2	85.9	76.5	81.9
30	157.8	137.3	126.0	128.5	138.1	146.8	135.3	134.7	131.7	137.3	122.6	127.4	130.4	125.5	126.5
20	119.6	110.0	116.5	108.6	114.5	113.2	116.7	126.4	120.4	119.2	121.7	133.4	138.0	135.1	131.9
15	92.8	90.7	99.3	85.1	92.4	86.1	100.3	107.9	98.6	98.1	110.2	123.1	123.1	120.7	119.3
10	60.2	67.8	71.0	60.9	65.0	59.8	75.1	78.6	69.9	70.6	80.0	89.0	88.9	86.2	85.9
7	39.9	48.9	49.6	43.8	45.3	42.3	49.8	51.4	47.2	47.5	51.7	56.0	58.0	55.7	55.3
5	26.7	34.0	31.4	31.2	30.4	28.4	30.7	32.0	30.9	30.4	31.8	33.3	34.9	32.5	33.0
4	23.1	24.7	23.8	24.2	24.1	20.2	20.5	21.4	22.3	21.1	21.2	21.8	24.5	21.8	22.3
3	18.6	13.4	13.5	15.5	16.0	10.6	10.2	13.1	14.5	12.0	11.9	11.0	12.9	10.0	11.1
	Samoa					Lauder					Syowa				
Surface	11.0	15.0	21.3	17.8	16.3	13.8	12.1	14.3	19.5	14.6	13.9	19.8	25.0	20.4	19.9
850	12.5	14.7	19.6	18.7	16.3	15.8	18.2	23.7	23.8	20.1	13.1	18.5	27.4	19.5	19.9
700	16.6	17.9	21.8	23.2	19.6	19.3	18.6	23.8	25.7	21.6	10.7	16.9	23.4	17.7	17.5
500	16.4	15.2	18.0	20.6	17.3	17.8	16.5	19.0	22.9	18.9	11.6	19.5	18.5	15.7	16.7
300	9.5	8.8	11.4	11.4	10.2	16.6	14.8	17.5	21.7	17.5	18.5	27.3	22.1	15.1	19.5
200	6.8	6.7	8.4	8.4	7.5	28.5	24.2	52.2	48.2	37.9	59.2	51.6	51.9	40.2	49.8
150	7.1	6.5	7.9	7.4	7.1	31.9	35.4	57.0	55.7	44.6	71.3	58.8	71.1	57.4	64.6
100	8.5	9.1	11.1	12.3	10.0	46.5	50.1	82.7	78.9	63.9	100.1	111.4	156.2	76.8	110.9
70	32.2	26.2	35.6	39.2	33.1	83.2	85.2	115.1	125.2	101.3	138.9	157.2	156.2	97.4	135.7
50	70.4	66.9	78.2	76.6	72.8	115.6	113.2	142.9	155.3	130.4	142.1	126.0	136.7	104.5	127.4
30	122.5	121.4	123.6	124.9	123.0	122.8	128.0	143.6	147.1	134.6	131.5	74.0	115.6	107.7	114.0
20	134.9	136.2	131.5	136.5	135.0	118.0	112.7	116.6	122.7	117.3	103.5	50.7	84.5	99.3	90.5
15	131.9	127.0	118.2	129.7	126.7	103.7	93.3	92.6	100.6	97.1	85.6	48.2	62.9	81.2	74.6
10	101.2	93.4	82.7	92.4	93.1	76.0	66.0	62.5	71.1	68.9	58.4	42.4	46.3	62.5	56.0
8.5	85.8	79.7	72.2	77.8	79.4	64.7	61.9	57.1	62.5	61.0	47.8	40.9	36.8	51.2	46.1
7	68.7	62.6	57.6	62.6	64.3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
5	53.6	38.3	37.7	-----	43.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

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