Investigating Climate Change using Ice Core Database

IB CORE

Introduction

Snow falling in the polar regions of the earth (e.g. Greenland and Antarctica) sometimes is preserved as annual layers within the ice sheets, provided that they are not destroyed by flow of the ice. These annual layers provide a record of the earth's climate that reaches back as much as 200,000 years.

Several different climate indicators can be measured from samples of the ice:

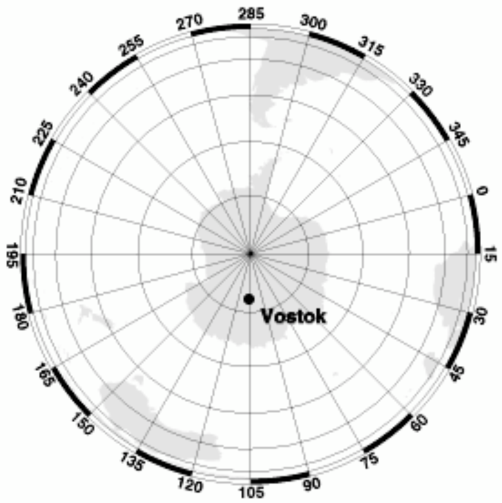
The amount of dust in each annual layer is indicative of the environment at the time that the dust was deposited. Various kinds of fallout from the atmosphere, including airborne continental dust and biological material, volcanic debris, sea salts, cosmic particles, and isotopes produced by cosmic radiation, are deposited on the ice sheet surface along with the snow, thus mixing with the snow and also acting as a distinctive barrier between different ice layers.

The composition of bubbles of air trapped in the ice is a measure of the composition of the atmosphere in ancient times. With increasing pressure from subsequent snow deposition on an ice cap or glacier, the snow becomes compacted and, consequently, air is trapped within the deposited layer. This entrapment of air occurs essentially with no differentiation of the atmospheric gas components. However, carbon dioxide has different chemical properties from other atmospheric gases, thus, the carbon dioxide concentration in the air-filled spaces might be affected by interaction with the ice itself or with trapped impurities.

The isotopic composition of water, and in particular the concentration of the heavy isotope of oxygen, ^{18}O, relative to ^{16}O, as well as ^{2}H (deuterium) relative to ^{1}H, is indicative of the temperatures of the environment. During cold periods, the concentration of less volatile ^{2}H (^{18}O) in the ice is lower than during warm periods. The reason for this is that at lower temperature, the moisture has been removed from the atmosphere to a larger degree resulting in an increased depletion of the heavier isotopes.

The Vostok core was drilled in East Antarctica, at the Soviet station Vostok from an altitude of 3488 m, and has a total length of 2083 m. Ice samples have been analyzed with respect to isotopic content in ^{2}H, dust, and methane and carbon dioxide trapped in air bubbles. The profiles of ^{2}H, methane, and carbon dioxide concentrations behave in a similar way with respect to depth in the core, showing a short interglacial stage, the Holocene, at the top, a long glacial stage below, and the last interglacial stage near the bottom of the core. The record goes back in time about 160,000 years.

(Pfirman, 2007)



Vostok, Antarctica
78°28' S, 106°48'E
3488 m above MSL

Aim

The aim of this investigation is to use the National Climatic Database (NCD) of the *U.S Department of Commerce* to investigate changes in atmospheric CO_2 concentration and Climate temperature.

Using the ice core database

TASK 1: Analysing global temperature relative to atmospheric CO_2 concentration.

1. Obtain the data from Vostok Ice Core Data from Columbia University:

   http://eesc.columbia.edu/courses/ees/climate/labs/vostok/data/vos_data.tsv

   (if you are having problems with the internet it can be found in Appendix 1)

2. Copy this data into Microsoft Excel to produce a graph of; Atmospheric CO_2 concentration relative to time. Note (1 ka = 1000 years).

   (HINT: A X-Y scatter graph is the best graph to use as it will allow you to compare temperature on the same graph.)

4. Converting deuterium values to temperature values:

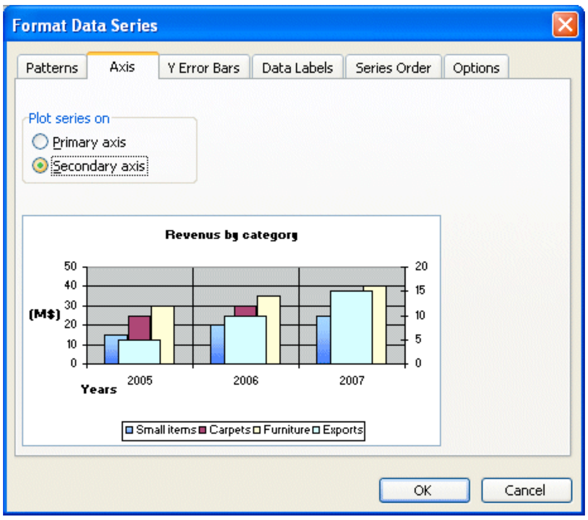
   The temperature value from deuterium can be approximately achieved using the following formula:

$$\text{Temperature (deg-C)} = -55.5 + (\delta D + 440) / 6$$

5. Use this formula to form a 'temperature column' in your Microsoft Excel spreadsheet

6. Graph the Temperature on your graph to compare temperature with atmospheric CO_2 concentration.

   (HINT: You will need to add this as a second series, then you will need to add a secondary *y* axis. This can be done by right clicking your temperature data series on your graph and choosing **Format data series...** then select the **Selected Data Series** tab.)



6. Print your graph and compare your two data sets (*series*), describe any patterns or trends.

TASK 2: Analysing recent changes in atmospheric CO_2 concentration.

1. Obtain the data from Law Ice Core Data Site (Also in Antartica) from the National Climatic Database (NCD) of the U.S Department of Commerce:

   ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/law/law_co2.txt

   (if you are having problems with the internet it can be found in Appendix 1)

   Details of the collection method and process can be found here:

   ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/law/readme_law_co2.txt

3. Copy this data into Microsoft Excel to produce a graph of; Atmospheric CO_2 concentration relative to time.

   HINT: You may need to separate the data in separate columns using **Text to columns…** from the **Data** menu.

4. Print your graph and mark the beginning of the industrial revolution on your graph (Late 1800s)

5. Describe any significant patterns on the back of your graph.

6. Compare this to the concentration of atmospheric CO_2 for the last 160 thousand years. What do you notice?

7. What is your prediction about the level of CO_2 in today's atmosphere.

8. What implications will this have for the future?

Read the following article:

Positive Feedback

Ocean warming provides a good example of a potential positive feedback mechanism. The oceans are an important sink for CO2 through absorption of the gas into the water surface. As CO2 increases it increases the warming potential of the atmosphere. If air temperatures warm it should warm the oceans. The ability of the ocean to remove CO2 from the atmosphere decreases with increasing temperature. Hence increasing CO2 in the atmosphere could have effects that exacerbate the increase in CO2 in the atmosphere.

(Carpenter)

8. Explain the relationship between the ocean and atmospheric carbon dioxide levels.

References

Carpenter, M. (n.d.). *Feedback Mechanisms In Climate*. Retrieved 10 7, 2008, from The University of Michigan's Global Change: http://globalchange.umich.edu/globalchange1/current/lectures/samson/feedback_mechanisms/

Pfirman, S. (2007, 10 2). *The Climate System*. Retrieved 10 6, 2008, from Columbia University: http://eesc.columbia.edu/courses/ees/climate/labs/vostok/

Wikipedia. (2008, 10 5). *Ice core*. Retrieved 10 5, 2008, from http://en.wikipedia.org/wiki/Ice_core

APPENDIX 1 – Raw ice core data from the Vostok site, Antarctica

depth	ice_age	delta D	dust	gas_age	CO2	CH4
m	ka	permille	10-9cm3g-1	ka	ppmv	ppbv
140	4.66	-435.94	12.42	2.28	273.07	
150	5.06	-439.72	11	2.66	272.14	666.93
160	5.45	-441.88	7.47	3.04	271.22	653.54
170	5.85	-434.77	6.13	3.41	270.29	640.15
180	6.27	-440.36	11.57	3.82	268.39	594.65
190	6.7	-441.26	10.33	4.25	266.06	593.28
200	7.14	-423.85	15	4.67	263.73	591.92
210	7.57	-438.79	15.48	5.09	261.4	590.55
220	8.01	-438.94	15.95	5.52	259.06	589.19
230	8.44	-435.7	16.75	5.94	256.73	585.64
240	8.87	-434.32	10.25	6.36	254.4	579.11
250	9.31	-439.38	12	6.79	252.07	593.3
260	9.76	-435.64	16.75	7.23	255.09	607.49
270	10.24	-443.25	19.29	7.68	257.22	621.4
280	10.74	-454.11	12	8.13	257.77	634.89
290	11.24	-460.28	30	8.58	258.31	648.38
300	11.74	-458.56	16	9.02	258.86	661.87
310	12.32	-451.23	13	9.52	257.58	650.61
320	12.94	-461.94	34	10.04	255.66	624.17
330	13.55	-470.88	68	10.56	253.75	500.31
340	14.17	-476.82	161.5	11.08	251.83	496.15
350	14.78	-483.99	255	11.6	249.91	592.5
360	15.39	-489.57	325.91	12.12	247.99	640.33
370	16.01	-494.94	247.55	12.64	246.07	593.7
380	16.69	-488.96	484	13.22	240.5	466.61
390	17.48	-496.59	436.5	13.87	230.26	435.7
400	18.26	-493.46	389	14.52	220.02	424.48
410	19.05	-493.2	522.14	15.18	209.79	413.27
420	19.83	-498.63	347.86	15.83	199.55	402.06
430	20.63	-494.72	603.33	16.54	193.11	388.12
440	21.45	-495.59	668.43	17.34	193.43	369.51
450	22.28	-487.49	267	18.15	193.74	356.85
460	23.11	-490.4	364	18.95	194.05	353.02

470	23.93	-491.81	518.79	19.75	194.37	376.64
480	24.76	-496.94	461.71	20.58	195.13	365.26
490	25.6	-489.53	263.47	21.42	196.21	349.99
500	26.43	-484.69	166	22.27	197.29	381.42
510	27.27	-494.34	303.45	23.11	198.37	403.16
520	28.1	-488.52	289.82	23.96	199.45	395.28
530	28.93	-492.44	266	24.81	199.81	387.39
540	29.74	-485.11	232	25.66	199.41	391.67
550	30.56	-489.15	198	26.51	199.02	407.48
560	31.38	-483.53	133.2	27.36	198.63	416.47
570	32.19	-474.11	68.4	28.21	198.24	419
580	33	-476.61	71.26	29.05	201.8	421.53
590	33.79	-486.59	136.91	29.89	211.31	425.3
600	34.59	-484.11	241	30.72	220.81	430.79
610	35.37	-481.41	104.48	31.53	217.71	488.22
620	36.16	-483.57	88.83	32.35	210.85	536.7
630	36.94	-479.8	85.83	33.15	207.51	508.13
640	37.71	-481.06	80.42	33.95	208.66	476.62
650	38.48	-480.87	75	34.74	209.82	474.92
660	39.24	-471.56	88.13	35.52	209.48	481.14
670	40.01	-477.47	92.71	36.3	208.87	473.2
680	40.77	-475.69	74.35	37.08	208.25	453.2
690	41.53	-484.76	75.22	37.86	207.63	433.2
700	42.3	-483.23	187	38.64	207.02	427.04
710	43.06	-485.28	135.75	39.4	201.24	432.67
720	43.82	-483.45	119.92	40.16	195.3	438.3
730	44.58	-481.96	99.8	40.92	189.37	436.13
740	45.34	-478.73	75.4	41.68	183.43	426.77
750	46.1	-477.7	51	42.44	179.86	417.3
760	46.85	-476.01	62.75	43.2	187.85	407.3
770	47.61	-478.26	40.25	43.96	195.84	415.14
780	48.36	-475.4	114.18	44.71	201.49	443.08
790	49.1	-479.26	95.09	45.47	204.6	468.87
800	49.85	-474.86	76	46.22	207.7	484.84
810	50.6	-483.58	78.33	46.97	206.42	500.81
820	51.34	-480.83	101.67	47.72	205.15	495.58
830	52.09	-472.77	82.42	48.47	203.87	485.05
840	52.84	-468.12	83.25	49.21	202.6	486.85

850	53.58	-464.16	58	49.96	201.32	500.03
860	54.35	-471.32	172.58	50.71	201	513.21
870	55.12	-475.98	287.17	51.45	201	519.33
880	55.9	-475.27	187.63	52.2	204.78	525
890	56.69	-480.92	188.88	52.95	211.41	512.51
900	57.49	-484.89	151	53.7	218.04	479.56
910	58.3	-488.53	251.42	54.47	217.91	446.61
920	59.11	-480.97	351.83	55.25	215.88	431.71
930	59.94	-490.14	315.71	56.04	213.48	419.74
940	60.78	-491.61	381.13	56.84	210.29	411.32
950	61.63	-493.53	299	57.65	207.11	412.52
960	62.5	-487.73	246.44	58.47	204.63	413.71
970	63.38	-489.51	437.56	59.3	202.32	414.32
980	64.26	-479.63	237.5	60.14	199.56	414.74
990	65.13	-483.98	126	61	196.2	417.81
1000	66.01	-483.4	25	61.86	192.84	425.41
1010	66.88	-477.96	36	62.75	192.36	433.01
1020	67.74	-483.63	50.5	63.65	192.83	430.68
1030	68.59	-485.65	48.5	64.54	195.81	426.86
1040	69.43	-484.76	80.29	65.43	200.14	427.44
1050	70.27	-477.23	41	66.33	204.46	441.21
1060	71.1	-469.15	36	67.2	212.63	454.97
1070	71.93	-476.41	31	68.07	222	449.26
1080	72.75	-486.42	38.54	68.94	229.73	438.06
1090	73.57	-477.34	55.63	69.79	235.93	433.53
1100	74.39	-481.76	93	70.65	242.13	446.13
1110	75.19	-476.22	100.92	71.49	239.98	458.72
1120	75.99	-467.38	108.83	72.34	236.47	444.31
1130	76.79	-465.7	65.5	73.17	233.93	420.41
1140	77.58	-461.74	42.5	74	232.1	405.39
1150	78.37	-466.86	89	74.83	229.95	420.15
1160	79.15	-462.17	63.17	75.64	225.77	434.9
1170	79.93	-466.88	37.33	76.45	221.59	457.1
1180	80.7	-462.45	23.63	77.26	219.8	481.28
1190	81.47	-455.84	24.88	78.06	220.39	504.24
1200	82.24	-461.33	31	78.85	220.98	524.93
1210	83.01	-465.61	33.08	79.65	221.57	545.53
1220	83.78	-468.4	35.17	80.45	222.16	563.35

1230	84.55	-468.79	44.33	81.22	224.42	581.17
1240	85.33	-466.15	61	81.96	228.88	586.42
1250	86.1	-473.96	83	82.71	233.33	559.33
1260	86.88	-479.73	67.17	83.52	228.31	532.25
1270	87.65	-477.95	51.33	84.35	221.61	496.31
1280	88.43	-470.28	60.5	85.16	216.76	459.17
1290	89.21	-475.39	85.5	85.95	213.26	424.68
1300	89.99	-471.17	95	86.74	210.35	420.68
1310	90.78	-464.77	67.08	87.53	215.3	418.02
1320	91.56	-471.4	39.17	88.32	220.26	430.78
1330	92.35	-469.84	36.42	89.12	222.77	443.54
1340	93.15	-466.57	27.25	89.91	224.47	453.22
1350	93.94	-468.47	17	90.71	226.31	448.91
1360	94.73	-472	24.52	91.51	229.41	444.6
1370	95.53	-470.42	28.43	92.31	232.51	433.08
1380	96.33	-464.69	13.48	93.12	232.59	417.34
1390	97.13	-465.83	42.17	93.93	229.88	406.11
1400	97.93	-465.48	56	94.74	227.18	406.5
1410	98.74	-463.17	54.75	95.55	229.6	406.88
1420	99.55	-459.69	53.5	96.36	233.73	423.21
1430	100.38	-457.24	55.46	97.18	234.1	446.36
1440	101.23	-460.89	78.38	98	229.87	469.52
1450	102.08	-468.1	72	98.83	225.63	479.35
1460	102.97	-466.45	73.91	99.67	226.38	509.63
1470	103.87	-469.43	37.55	100.52	228.01	506.34
1480	104.78	-466.93	27.87	101.39	230.58	501.91
1490	105.71	-468.74	40.04	102.28	234.62	524.74
1500	106.65	-469.11	39	103.17	238.44	547.58
1510	107.64	-484.17	35.17	104.1	236.94	566.55
1520	108.62	-481.53	36.48	105.03	235.44	581.64
1530	109.6	-479.63	26.35	105.98	236.2	573.31
1540	110.57	-476.4	27.22	106.96	240.79	463.41
1550	111.53	-478.78	17	107.95	242.88	444.23
1560	112.45	-480.79	10.26	108.97	239.16	452.74
1570	113.37	-479.64	17.22	109.98	235.43	459.43
1580	114.27	-473.94	22.71	110.97	234.87	466.13
1590	115.15	-468.3	23.89	111.93	237.72	463.5
1600	116.02	-468.07	32	112.88	242.53	457.25

1610	116.85	-460.36	13.4	113.79	255.16	451
1620	117.68	-458.29	16.43	114.7	267.79	445.98
1630	118.5	-451.61	27.86	115.59	275.36	453.58
1640	119.29	-452.02	10	116.46	273.52	490.88
1650	120.09	-448.9	23	117.32	271.68	499.06
1660	120.85	-447.81	33.6	118.15	274.51	507.23
1670	121.61	-448.1	17	118.97	277.86	515.59
1680	122.36	-447.17	24.43	119.78	278.75	527.43
1690	123.1	-441.91	30.1	120.57	275.28	539.27
1700	123.83	-442.83	5	121.36	271.81	547.55
1710	124.54	-436.6	7	122.12	269.32	553.45
1720	125.25	-438.57	58	122.87	266.93	557.96
1730	125.95	-443.29	22.88	123.61	265.96	560.37
1740	126.65	-439.33	16	124.33	268.01	564.12
1750	127.34	-434.71	48	125.04	270.06	570.75
1760	128.04	-436.55	17.8	125.76	272.11	577.37
1770	128.74	-435.07	12.33	126.48	274.16	584
1780	129.44	-437.07	25.67	127.19	273.23	585.04
1790	130.15	-435.33	26.2	127.9	270.22	586.6
1800	130.86	-430.06	24	128.61	267.22	594.07
1810	131.57	-425.54	55.06	129.33	269.27	601.54
1820	132.29	-427.15	14.43	130.05	272.92	609.02
1830	133.01	-420.98	9.2	130.78	273.44	616.49
1840	133.74	-428.51	30.5	131.51	269.81	629.03
1850	134.47	-440.89	46	132.24	266.18	646.08
1860	135.24	-430.44	11.38	132.99	277.41	649.35
1870	136	-437.21	10	133.73	289.42	693.41
1880	136.8	-442.66	18	134.48	291.71	600.31
1890	137.64	-454.55	8.25	135.25	280.02	532.7
1900	138.49	-456.74	18	136.02	268.34	527.77
1910	139.43	-464.04	24	136.86	260	509.61
1920	140.4	-473.68	42	137.72	252.5	483.99
1930	141.39	-484.07	92.38	138.61	245	458.38
1940	142.49	-486.84	60.33	139.58	237.51	445.28
1950	143.61	-485.33	344	140.57	230.31	435.5
1960	144.89	-496.7	96.33	141.68	225.05	419.71
1970	146.18	-496.39	156.5	142.78	219.79	398.54
1980	147.58	-490.49	162	143.98	211.62	352.91

1990	149.11	-492	98	145.29	200.16	363.05
2000	150.67	-490.51	301	146.65	191.69	369.66
2010	152.35	-495.73	296	148.23	195.12	337.2
2020	154.02	-490.8	297.89	149.8	198.55	318.25
2030	155.7	-495.07	247	151.45	198.89	318.94
2040	157.38	-492.08	184.27	153.18	195.15	339.4
2050	159.05	-496.54	308	154.92	191.41	348.54
2060	160.73	-492.25	90.36	156.65	192.8	353.25

APPENDIX 2 – Raw ice core data from the Law Dome Site, Antartica

Historical CO2 record from the Law Dome DE08, DE08-2, and DSS ice cores

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Ice Sample Code	Analysis Date	Mean Ice Depth, m	Ice Age, year A.D.	Mean Air Age, year A.D.	CO2 Mixing Ratio, ppm
DE08 205	20-Aug-92	83.10	1939	1969	323.2
DE08 235	12-Aug-93	83.98	1938	1968	323.7
DE08 225	2-Aug-93	89.15	1935	1965	319.5
DE08 226	2-Aug-93	89.00	1935	1965	318.8
DE08 203	5-Aug-92	91.95	1933	1963	318.2
DE08 212	14-Jul-93	93.00	1932	1962	318.7
DE08 213	14-Jul-93	93.15	1932	1962	317.0
DE08 214	15-Jul-93	92.68	1932	1962	319.4
DE08 215	15-Jul-93	92.84	1932	1962	317.0
DE08 201	27-Jul-92	104.44	1923	1953	311.9
DE08 208	13-Nov-92	104.61	1923	1953	311.0
DE08 236	12-Aug-93	104.29	1923	1953	

312.7

DE08 227	2-Aug-93	115.66	1914	1944	309.7
DE08 243	8-Oct-93	121.80	1909	1939	311.0
DE08 240	19-Aug-93	121.90	1908	1938	310.5
DE08 238	13-Aug-93	130.27	1902	1932	307.8
DE08 231	10-Aug-93	138.79	1894	1924	304.8
DE08 237	13-Aug-93	138.79	1894	1924	304.1
DE08 233	11-Aug-93	149.86	1885	1915	301.3
DE08 239	17-Aug-93	153.00	1882	1912	300.7
DE08 253	19-Jul-95	160.70	1875	1905	296.9
DE08 254	3-Aug-95	160.90	1875	1905	298.5
DE08 230	10-Aug-93	167.86	1868	1898	294.7
DE08 241	19-Aug-93	174.39	1862	1892	294.6
DE08 252	19-Jul-95	179.50	1856	1886	293.7
DE08 229	10-Aug-93	184.31	1852	1882	291.9
DE08 255	3-Aug-95	190.30	1847	1877	288.8
DE08 228	6-Aug-93	197.54	1839	1869	287.4
DE08 232	11-Aug-93	206.09	1831	1861	286.6
DE08 234	12-Aug-93	214.10	1824	1854	284.9
DE08 200	26-Jun-92	218.02	1820	1850	285.2
DE08 222	29-Jul-93	228.74	1810	1840	283.0

Ice Sample Code	Analysis Date	Mean Ice Depth, m	Ice Age, year A.D.	Mean Air Age, year A.D.	CO2 Mixing Ratio ppm
DE08-2 008	9-Dec-93	81.11	1948	1978	335.2
DE08-2 012	15-Dec-93	81.30	1948	1978	332.0

DE08-2 003	17-Aug-93	85.05	1945	1975	331.2
DE08-2 002	6-Aug-93	87.96	1943	1973	328.1
DE08-2 005	24-Aug-93	90.55	1941	1971	324.1
DE08-2 015	3-Aug-95	91.69	1940.2	1970	325.2
DE08-2 016	3-Aug-95	92.30	1939.7	1970	324.7
DE08-2 009	15-Dec-93	120.27	1918	1948	309.9
DE08-2 007	9-Dec-93	128.79	1910	1940	310.5
DE08-2 011	15-Dec-93	135.82	1904	1934	309.2
DE08-2 006	9-Dec-93	242.81	1802	1832	284.5

Ice Sample Code	Analysis Date	Mean Ice Depth, m	Ice Age, year A.D.	Mean Air Age, year A.D.	CO2 Mixing Ratio, ppm
DSS 004	13-Nov-92	78.02	1901	1959	315.7
DSS 001	20-Aug-92	81.82	1896	1954	313.6
DSS 002	21-Aug-92	81.82	1896	1954	314.7
DSS 003	21-Aug-92	81.82	1896	1954	314.1
DSS 029	24-Nov-93	86.19	1890	1948	311.4
DSS 037	7-Jun-95	92.86	1881	1939	309.2
DSS 027	18-Nov-93	94.13	1878	1936	307.9
DSS 041	15-Jun-95	99.82	1871	1929	305.2
DSS 008	13-Aug-93	100.32	1868	1926	305.0
DSS 033	2-Jun-95	114.45	1847	1905	299.0
DSS 007	11-Aug-93	116.89	1841	1899	296.5
DSS 030	24-Nov-93	122.82	1833	1891	294.7
DSS 009	20-Aug-93	151.56	1787	1845	286.1
DSS 010	20-Aug-93	163.51	1767	1825	

					285.1
DSS 015	8-Oct-93	179.97	1738	1796	283.7
DSS 016	14-Oct-93	181.34	1736	1794	281.6
DSS 017	14-Oct-93	190.88	1719	1777	279.5
DSS 031	2-Jun-95	200.64	1702	1760	276.7
DSS 014	23-Aug-93	206.50	1691	1749	277.2
DSS 025	10-Nov-93	207.58	1689	1747	276.9
DSS 019	21-Oct-93	223.01	1662	1720	277.5
DSS 011	20-Aug-93	238.00	1634	1692	276.5
DSS 020	21-Oct-93	245.63	1621	1679	275.9
DSS 013	23-Aug-93	263.35	1589	1647	277.2
DSS 012	23-Aug-93	285.20	1546	1604	274.3
DSS 021	28-Oct-93	293.20	1531	1589	278.7
DSS 032	2-Jun-95	302.14	1512	1570	281.9
DSS 018	21-Oct-93	313.93	1489	1547	282.8
DSS 035	7-Jun-95	323.84	1469	1527	283.2
DSS 023	10-Nov-93	336.73	1441	1499	282.4
DSS 044	30-Jun-95	351.30	1407	1465	279.6
DSS 022	28-Oct-93	360.64	1388	1446	281.7
DSS 024	10-Nov-93	387.13	1329	1387	280.0
DSS 026	18-Nov-93	387.20	1329	1387	280.4
DSS 034	5-Jun-95	414.22	1269	1327	283.4
DSS 039	14-Jun-95	447.34	1188	1246	281.7
DSS 036	9-Jun-95	467.85	1138	1196	283.9
DSS 043	30-Jun-95	488.46	1088	1146	283.8
DSS 042	15-Jun-95	506.03	1038	1096	282.4
DSS 040	14-Jun-95	523.56	988	1046	

280.3

DSS 038	12-Jun-95	534.27	948	1006

279.4

Mean Air Age, year A.D.	CO2, 20 Year Smoothed, ppm
1832	284.3
1833	284.1
1834	284.0
1835	283.8
1836	283.7
1837	283.5
1838	283.4
1839	283.4
1840	283.4
1841	283.4
1842	283.5
1843	283.6
1844	283.7
1845	283.9
1846	284.1
1847	284.2
1848	284.4
1849	284.6
1850	284.7
1851	284.9
1852	285.0
1853	285.1
1854	285.3
1855	285.4
1856	285.6
1857	285.7
1858	285.9
1859	286.1
1860	286.2
1861	286.4
1862	286.5
1863	286.6
1864	286.8
1865	286.9
1866	287.0
1867	287.1
1868	287.2
1869	287.4
1870	287.5
1871	287.7
1872	287.9
1873	288.1
1874	288.4
1875	288.7

1876	289.0
1877	289.4
1878	289.8
1879	290.2
1880	290.7
1881	291.2
1882	291.7
1883	292.1
1884	292.6
1885	293.0
1886	293.3
1887	293.6
1888	293.8
1889	294.0
1890	294.2
1891	294.3
1892	294.5
1893	294.6
1894	294.7
1895	294.8
1896	294.9
1897	295.0
1898	295.2
1899	295.5
1900	295.8
1901	296.1
1902	296.5
1903	296.8
1904	297.2
1905	297.6
1906	298.1
1907	298.5
1908	298.9
1909	299.3
1910	299.7
1911	300.1
1912	300.4
1913	300.8
1914	301.1
1915	301.4
1916	301.7
1917	302.1
1918	302.4
1919	302.7
1920	303.0
1921	303.4
1922	303.8
1923	304.1
1924	304.5
1925	305.0
1926	305.4
1927	305.8

1928	306.3
1929	306.8
1930	307.2
1931	307.7
1932	308.2
1933	308.6
1934	309.0
1935	309.4
1936	309.8
1937	310.0
1938	310.2
1939	310.3
1940	310.4
1941	310.4
1942	310.3
1943	310.2
1944	310.1
1945	310.1
1946	310.1
1947	310.2
1948	310.3
1949	310.5
1950	310.7
1951	311.1
1952	311.5
1953	311.9
1954	312.4
1955	313.0
1956	313.6
1957	314.2
1958	314.9
1959	315.6
1960	316.3
1961	317.0
1962	317.7
1963	318.4
1964	319.2
1965	320.0
1966	320.8
1967	321.8
1968	322.8
1969	323.8
1970	324.8
1971	325.8
1972	326.9
1973	328.0
1974	329.2
1975	330.3
1976	331.5
1977	332.6
1978	333.7

Mean Air Age, year A.D.	CO2, 75 Year Smoothed, ppm
1010	279.5
1015	279.6
1020	279.7
1025	279.8
1030	279.9
1035	280.0
1040	280.2
1045	280.3
1050	280.5
1055	280.7
1060	280.9
1065	281.1
1070	281.3
1075	281.5
1080	281.7
1085	281.9
1090	282.1
1095	282.3
1100	282.5
1105	282.7
1110	282.9
1115	283.0
1120	283.2
1125	283.3
1130	283.5
1135	283.6
1140	283.7
1145	283.8
1150	283.9
1155	284.0
1160	284.0
1165	284.1
1170	284.1
1175	284.1
1180	284.0
1185	284.0
1190	283.9
1195	283.8
1200	283.6
1205	283.4
1210	283.2
1215	283.0
1220	282.8
1225	282.5
1230	282.3
1235	282.2
1240	282.0
1245	281.9

1250	281.9
1255	281.9
1260	282.0
1265	282.1
1270	282.2
1275	282.3
1280	282.5
1285	282.6
1290	282.8
1295	282.9
1300	283.0
1305	283.1
1310	283.2
1315	283.3
1320	283.3
1325	283.2
1330	283.1
1335	282.9
1340	282.7
1345	282.4
1350	282.1
1355	281.8
1360	281.5
1365	281.2
1370	281.0
1375	280.7
1380	280.5
1385	280.4
1390	280.3
1395	280.3
1400	280.3
1405	280.4
1410	280.5
1415	280.6
1420	280.7
1425	280.8
1430	280.9
1435	280.9
1440	280.9
1445	280.9
1450	280.8
1455	280.7
1460	280.6
1465	280.6
1470	280.6
1475	280.8
1480	281.0
1485	281.3
1490	281.6
1495	281.9
1500	282.2
1505	282.5

1510	282.7
1515	282.9
1520	283.1
1525	283.2
1530	283.2
1535	283.2
1540	283.1
1545	283.0
1550	282.8
1555	282.6
1560	282.2
1565	281.8
1570	281.2
1575	280.5
1580	279.7
1585	278.8
1590	278.0
1595	277.1
1600	276.4
1605	275.8
1610	275.5
1615	275.3
1620	275.3
1625	275.4
1630	275.6
1635	275.9
1640	276.1
1645	276.3
1650	276.4
1655	276.5
1660	276.5
1665	276.5
1670	276.4
1675	276.4
1680	276.4
1685	276.4
1690	276.5
1695	276.6
1700	276.7
1705	276.8
1710	276.9
1715	277.0
1720	277.0
1725	277.0
1730	277.0
1735	276.9
1740	276.9
1745	276.9
1750	277.0
1755	277.2
1760	277.6
1765	278.0

1770	278.6
1775	279.3
1780	280.1
1785	280.8
1790	281.6
1795	282.3
1800	282.9
1805	283.4
1810	283.8
1815	284.0
1820	284.2
1825	284.3
1830	284.4
1835	284.5
1840	284.6
1845	284.8
1850	285.2
1855	285.7
1860	286.3
1865	287.2
1870	288.2
1875	289.4
1880	290.8
1885	292.3
1890	293.7
1895	295.2
1900	296.7
1905	298.2
1910	299.9
1915	301.5
1920	303.2
1925	304.9
1930	306.5
1935	308.0
1940	309.3
1945	310.5
1950	312.0
1955	314.1
1960	316.9
1965	320.5
1970	324.7
1975	329.4