

# Carbon Flux to the Atmosphere from Land-Use Changes

[Graphics](#)[Digital Data](#)

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## Period of Record

1850-1990

## Methods

The methods used to derive this time series of flux estimates are described fully in Houghton (1999) and other publications (Houghton et al. 1983, 1987; Houghton and Hackler 1995, 1999). In summary, this database provides estimates of regional and global net carbon fluxes, on a year-by-year basis from 1850 through 1990, resulting from changes in land use (such as harvesting of forest products and clearing for agriculture), taking into account not only the initial removal and oxidation of the carbon in the vegetation, but also subsequent regrowth and changes in soil carbon. The net flux of carbon to the atmosphere from changes in land use from 1850 to 1990 was modeled as a function of documented land-use change and changes in aboveground and belowground carbon following changes in land use. The changes in carbon, with time, following land-use change are specified by region and ecosystem type.

The approach uses a bookkeeping model to track, on an annual basis, changes in aboveground and belowground carbon in different kinds of ecosystems following changes in land use. Annual rates of expansion and contraction of agricultural area (for cropland, pasture, and shifting cultivation) and of wood harvest were used to estimate the types of ecosystem affected, and the change in area of each affected ecosystem type. Then, response curves were generated, to estimate the changes in carbon, for years to decades, that follow each type of land management or land-use change. All carbon in the affected area is accounted for: live vegetation, soil, slash (woody debris produced during disturbance), and wood products. However, this procedure does *not* account for all processes that affect ecosystem carbon storage and fluxes (e.g., natural disturbances, fire suppression, and environmental factors such as CO<sub>2</sub> and climate that affect vegetation). Furthermore, the analysis ignores fluxes of carbon to or from ecosystems not directly affected by land-use change. Data on land-use change, wood harvest, and carbon in ecosystems were obtained from a number of sources, detailed in Houghton (1999).

The bookkeeping model partitioned the vegetation after land-use change into three pools: standing live vegetation, dead material left on-site, and woody material removed from the site. The model tracked the return of carbon in the remaining live vegetation to pre-disturbance values. Dead material left on-site, and woody material removed from the site, decayed at specified rates. Changes in soil carbon included both post-disturbance losses and eventual recoveries. The coefficients and time constants were specified by region, ecosystem type, and land-use type. Finally, changes in on-site carbon pools and carbon in off-site wood products were used to estimate fluxes to and from the atmosphere.

## Trends

The estimated global total net flux of carbon from changes in land use increased from 397 Tg C (1 teragram =  $10^{12}$  gram) in 1850 to 2187 Tg C or 2.2 Pg C (1 petagram =  $10^{15}$  gram) in 1989 and then decreased slightly to 2103 Tg C or 2.1 Pg C in 1990. The global net flux during the period 1850-1990 was 124 Pg C. During this period, the greatest regional flux was from South and Southeast Asia (39 Pg C), while the smallest regional flux was from North Africa and Middle East (3 Pg C).

The estimates of annual net carbon flux, on a global total basis, reported by Houghton (1999) vary somewhat from estimates reported previously (Houghton et al. 1983, Houghton and Skole 1990, Houghton and Hackler 1995), as shown in Figure 6 of Houghton (1999).

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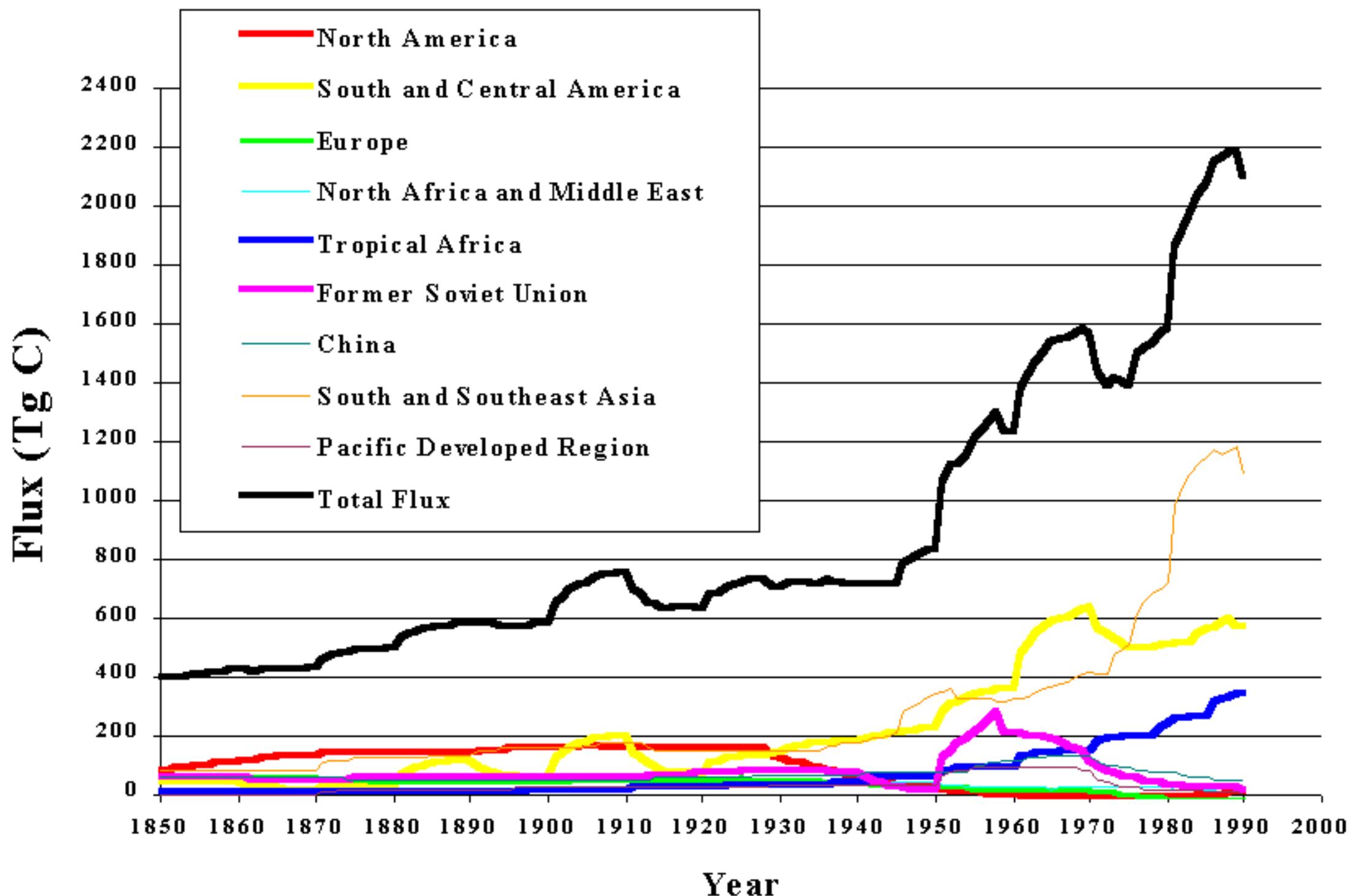
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## Annual Net Flux of Carbon to the Atmosphere from Land-Use Change: 1850-1990 (Houghton and Hackler)



Annual Net flux of Carbon to the Atmosphere from Land-Use Change: 1850-1990  
 Version corresponding to R.A. Houghton, 1999, Tellus 51B:298-313

Units = Tg C (1 teragram = 10<sup>12</sup> g)

Year	North America	South and Central America	Europe	North Africa and Middle East	Tropical Africa	Former Soviet Union	China	South and Southeast Asia	Pacific Developed Region	TOTAL FLUX
1850	87.28	42.48	55.04	3.98	5.61	58.56	56.52	85.63	2.05	397.145
1851	87.22	42.18	55.02	3.98	6.47	58.55	56.50	85.20	2.04	397.164
1852	90.37	41.90	54.99	3.98	6.60	58.88	56.48	85.25	2.04	400.492
1853	93.38	41.66	54.96	3.98	6.69	59.22	56.47	85.33	2.03	403.713
1854	96.28	41.44	54.93	3.98	6.77	59.58	56.45	85.42	2.03	406.877
1855	99.12	41.24	54.90	3.98	6.82	59.96	56.43	85.53	2.03	410.017
1856	101.93	41.06	54.87	3.98	6.86	60.34	56.42	85.65	2.02	413.137
1857	104.72	40.91	54.84	3.98	6.88	60.72	56.40	85.77	2.02	416.250
1858	107.50	40.77	54.81	3.98	6.90	61.10	56.39	85.90	2.01	419.363
1859	110.27	40.64	54.78	3.98	6.92	61.48	56.37	86.02	2.01	422.481
1860	113.06	38.09	54.75	3.98	6.93	61.85	56.36	86.14	2.01	423.171
1861	116.34	32.46	54.79	9.01	8.02	62.22	56.25	86.26	2.08	427.422
1862	119.70	29.66	54.86	9.96	8.18	53.69	56.13	86.38	2.18	420.740
1863	123.16	26.89	54.96	10.82	8.31	53.75	55.99	86.49	2.30	422.672
1864	126.70	24.20	55.06	11.25	8.41	53.80	55.85	86.61	2.43	424.303
1865	130.31	21.57	55.18	11.64	8.49	53.86	55.71	86.71	2.56	426.033
1866	131.46	20.62	55.31	11.99	8.53	53.74	55.55	86.82	2.70	426.713
1867	132.67	19.74	55.46	12.31	8.57	53.62	55.39	86.91	2.83	427.495
1868	133.95	18.90	55.61	12.61	8.59	53.51	55.23	87.01	2.96	428.377
1869	135.30	18.11	55.78	12.89	8.62	53.41	55.06	87.10	3.09	429.350
1870	136.72	19.79	55.95	13.15	8.64	53.32	54.88	87.18	3.21	432.843
1871	138.16	23.97	50.48	13.40	8.66	53.23	54.70	108.79	9.87	461.264
1872	139.64	25.66	49.60	13.64	8.67	53.49	54.53	113.96	11.93	471.118
1873	141.14	27.32	48.75	13.87	8.69	53.75	54.35	117.71	13.66	479.236
1874	142.67	28.92	47.95	14.09	8.70	54.01	51.69	120.51	14.33	482.862
1875	144.23	30.47	47.17	14.30	8.71	54.27	51.15	122.69	14.87	487.850
1876	144.64	30.66	46.53	14.47	9.79	54.94	50.74	124.08	15.35	491.204
1877	144.91	31.36	45.94	14.63	9.96	55.04	50.41	125.23	15.76	493.231
1878	145.05	32.02	45.39	14.79	10.08	55.13	50.11	126.23	16.12	494.901
1879	145.06	32.63	44.87	14.93	10.18	55.21	49.84	127.11	16.44	496.273
1880	144.94	33.22	44.39	15.07	10.26	55.30	49.59	127.91	16.75	497.425
1881	144.70	70.55	43.94	15.21	10.30	55.40	49.35	128.27	17.05	534.771
1882	144.34	82.30	43.52	15.35	10.33	55.51	49.14	128.59	17.34	546.421
1883	143.86	92.24	43.12	15.49	10.36	55.63	48.94	128.87	17.64	556.158
1884	143.27	100.88	42.74	15.63	10.39	55.76	48.75	129.13	17.94	564.499
1885	142.58	108.58	42.39	15.77	10.41	55.90	48.58	129.37	18.24	571.807
1886	141.82	112.04	42.56	15.90	11.71	56.03	48.42	129.59	18.54	576.593
1887	141.00	114.43	42.73	16.03	11.91	56.17	48.26	129.79	18.83	579.162
1888	140.14	116.44	42.92	16.16	12.06	56.30	48.11	129.98	19.12	581.235
1889	139.21	118.15	43.11	16.29	12.18	56.44	48.04	130.16	19.36	582.940
1890	138.09	119.63	43.31	16.42	12.28	56.57	47.97	130.32	19.60	584.180
1891	148.45	92.35	43.51	16.54	12.34	56.70	47.90	146.76	19.83	584.388
1892	150.16	84.19	43.72	16.66	12.38	56.83	47.84	150.78	20.06	582.620
1893	151.73	77.09	43.91	16.78	12.42	56.96	47.79	153.67	20.28	580.630
1894	153.18	70.78	44.11	16.90	12.45	57.08	47.75	155.83	20.50	578.581
1895	154.55	65.05	44.31	17.01	12.47	57.21	47.70	157.53	20.72	576.549
1896	155.52	63.60	44.50	17.12	12.50	57.33	47.66	158.61	20.93	577.764
1897	156.43	62.47	44.68	17.23	12.52	57.45	47.63	159.49	21.14	579.038
1898	157.30	61.59	44.86	17.34	12.53	57.57	47.60	160.22	21.35	580.364
1899	158.14	60.90	45.03	17.45	12.55	57.68	47.57	160.87	21.55	581.740
1900	158.92	60.36	45.19	17.55	12.56	57.79	47.54	161.44	21.75	583.112
1901	159.83	124.92	45.44	20.07	15.57	57.90	47.62	161.69	22.03	655.075
1902	160.75	144.42	45.70	20.58	16.02	58.05	47.72	161.98	22.34	677.559
1903	161.70	160.67	45.98	21.04	16.35	58.19	47.84	162.24	22.65	696.656
1904	162.67	174.59	46.28	21.29	16.61	58.33	47.96	162.47	22.97	713.179
1905	163.67	186.84	46.60	21.52	16.82	58.47	48.11	162.67	23.30	727.993
1906	163.10	191.39	46.93	21.72	16.93	58.59	48.25	170.77	23.62	741.299
1907	162.56	195.05	47.27	21.89	17.02	58.59	48.40	172.83	23.94	747.540
1908	162.04	198.06	47.62	22.05	17.10	58.58	48.55	174.30	24.25	752.540
1909	161.56	200.56	47.98	22.20	17.16	58.56	48.70	175.40	24.56	756.671
1910	161.10	202.27	48.35	22.33	17.21	58.54	48.85	176.27	24.87	759.791
1911	160.68	140.60	48.72	22.48	21.53	58.53	49.01	176.84	25.15	703.522

1912	160.30	122.37	49.10	22.59	22.20	58.51	49.16	177.30	25.41	686.940
1913	159.97	107.21	49.47	22.69	22.69	63.68	49.30	156.93	25.67	657.631
1914	159.68	94.19	49.85	22.79	23.08	65.23	55.07	152.36	25.91	648.173
1915	159.44	82.67	50.23	22.88	23.40	66.59	56.06	149.05	26.16	636.474
1916	159.22	78.80	50.66	22.93	23.57	67.89	56.94	153.45	26.39	639.850
1917	159.03	75.71	51.09	22.97	23.71	69.21	57.66	153.09	26.62	639.076
1918	158.88	73.19	51.51	23.01	23.82	70.49	58.32	152.93	26.84	638.978
1919	158.76	71.09	51.92	23.03	23.92	71.76	58.95	152.69	27.05	639.181
1920	158.68	66.46	52.32	23.05	24.00	73.06	59.55	152.43	27.26	636.822
1921	158.64	104.94	52.77	23.06	28.35	74.38	60.11	152.08	27.57	681.924
1922	158.64	114.93	53.20	23.07	29.04	75.75	60.66	151.74	27.79	694.822
1923	158.67	122.76	53.62	23.08	29.56	77.06	61.17	151.80	28.00	705.725
1924	158.75	129.12	54.03	23.09	29.97	78.40	61.61	151.87	28.18	715.011
1925	158.85	134.47	54.42	23.09	30.30	79.78	62.10	151.96	28.35	723.319
1926	158.29	135.88	54.08	31.70	30.49	81.20	62.42	147.46	28.57	730.099
1927	157.65	136.87	53.62	33.63	30.64	82.53	62.72	146.83	28.81	733.300
1928	157.22	137.47	53.05	35.36	30.77	83.10	62.98	146.53	29.05	735.537
1929	131.20	137.78	52.36	35.79	30.87	83.70	63.09	146.44	29.30	710.527
1930	124.19	141.11	51.56	36.12	30.97	84.30	63.17	146.47	29.54	707.444
1931	117.44	157.80	50.66	36.74	35.33	84.91	63.25	146.66	29.79	722.578
1932	110.89	163.27	49.66	37.31	36.02	85.52	63.31	146.89	30.04	722.897
1933	104.46	167.92	48.56	37.82	36.55	86.15	63.36	147.15	30.28	722.256
1934	98.14	171.97	47.36	38.30	36.96	84.55	67.10	147.42	30.53	722.339
1935	91.89	175.55	46.08	38.75	37.30	82.80	67.92	147.70	30.78	718.768
1936	85.51	177.38	44.76	39.18	37.49	80.90	68.63	165.10	31.02	729.964
1937	79.19	179.58	43.40	39.59	37.65	78.84	69.19	169.48	31.26	728.172
1938	72.92	181.57	42.01	39.98	37.78	76.69	69.70	172.75	31.50	724.900
1939	66.67	183.40	40.59	40.35	37.89	74.51	70.17	175.29	31.73	720.611
1940	60.51	185.09	39.15	40.71	37.99	71.15	70.61	177.32	31.96	714.481
1941	54.31	194.01	37.69	41.03	53.04	54.42	71.04	182.27	32.19	719.998
1942	48.15	198.34	36.23	41.35	55.30	47.51	71.44	187.87	32.41	718.624
1943	42.05	202.54	34.77	41.65	56.99	40.84	71.84	193.64	32.63	716.943
1944	39.63	206.70	33.31	41.89	58.30	34.35	72.21	199.44	32.84	718.664
1945	37.25	210.70	31.86	42.13	59.36	28.04	72.58	205.19	33.04	720.135
1946	34.91	214.35	30.40	42.35	59.93	24.03	72.93	281.30	33.24	793.441
1947	32.61	217.62	28.96	42.56	60.38	20.43	73.28	302.11	33.44	811.378
1948	30.35	221.01	27.52	42.77	60.75	17.18	73.62	318.01	33.63	824.833
1949	28.13	224.51	26.08	42.97	61.06	14.31	73.67	329.78	33.82	834.320
1950	25.97	229.84	24.66	43.16	61.33	13.08	73.72	340.01	34.00	845.773
1951	18.23	286.38	23.53	34.40	82.95	126.91	74.65	349.78	67.51	1064.327
1952	15.04	304.72	22.55	32.64	86.28	149.64	75.60	362.04	76.88	1125.376
1953	12.12	319.58	21.71	30.83	88.76	171.48	76.56	322.62	84.52	1128.181
1954	9.44	331.78	21.01	28.61	90.71	192.67	77.52	323.13	86.59	1161.448
1955	6.97	342.05	20.44	26.39	92.29	213.75	97.76	326.78	87.92	1214.345
1956	4.71	348.10	20.00	25.71	93.16	236.15	102.65	326.49	88.76	1245.711
1957	2.63	353.04	19.68	25.04	93.86	258.25	107.01	326.34	89.26	1275.109
1958	0.72	357.15	19.48	24.41	94.43	279.95	110.54	320.70	89.52	1296.919
1959	-1.02	362.41	19.40	23.79	94.92	208.34	113.79	320.51	89.62	1231.770
1960	-2.61	366.65	19.44	23.21	95.34	210.89	116.84	321.34	89.59	1240.677
1961	-4.09	481.93	16.70	22.64	129.92	205.22	119.69	325.96	89.48	1387.432
1962	-5.48	517.55	16.32	22.08	135.24	201.87	122.35	332.01	89.30	1431.247
1963	-6.76	546.07	16.01	21.55	139.22	198.82	124.84	347.12	89.09	1475.961
1964	-7.96	572.04	15.78	21.03	142.32	196.18	127.34	356.56	88.83	1512.116
1965	-9.08	593.94	15.61	20.52	144.85	192.92	129.51	365.27	88.56	1542.088
1966	-9.07	603.87	15.48	21.63	146.24	181.17	129.61	374.12	88.25	1551.292
1967	-9.03	612.03	15.39	21.82	147.36	169.52	130.71	382.93	87.94	1558.677
1968	-8.97	619.05	15.35	21.96	148.28	157.92	131.78	397.51	87.61	1570.492
1969	-8.87	629.61	15.33	21.73	149.06	147.84	132.89	407.46	87.04	1582.089
1970	-9.26	638.01	13.57	21.48	149.73	114.46	132.78	416.75	86.46	1563.981
1971	-9.53	567.12	11.18	21.52	184.52	100.10	104.98	407.73	50.23	1437.845
1972	-9.76	547.71	8.64	21.57	190.04	85.37	101.07	410.06	39.11	1393.820
1973	-9.93	531.05	5.96	21.62	194.18	71.25	97.25	474.68	29.74	1415.799
1974	-9.56	516.35	3.15	21.66	197.43	64.85	93.70	492.08	26.12	1405.787
1975	-9.15	503.09	0.21	21.71	200.09	58.78	90.12	505.73	23.24	1393.830
1976	-8.74	501.64	-2.64	21.75	201.60	55.92	86.52	619.65	20.85	1496.554
1977	-8.32	500.90	-5.64	21.78	202.82	50.36	82.85	655.90	18.78	1519.441
1978	-7.99	500.34	-8.79	21.81	203.84	44.82	79.10	682.44	16.94	1532.511
1979	-7.48	507.58	-12.08	21.84	233.70	39.50	75.22	703.56	15.26	1577.084
1980	-7.09	511.59	-14.09	21.85	238.69	35.44	73.78	721.19	13.69	1595.045
1981	-7.01	516.39	-15.34	17.00	256.24	33.41	73.42	979.87	15.58	1869.544
1982	-5.80	517.03	-16.39	16.56	261.24	30.73	63.74	1046.49	14.94	1928.539

1983	-4.30	516.74	-17.23	16.44	265.19	28.82	60.42	1092.35	14.13	1972.563
1984	-2.55	552.39	-17.88	18.04	267.79	27.16	57.65	1126.06	12.75	2041.413
1985	-0.55	563.87	-18.34	19.80	269.92	25.77	55.55	1152.18	11.29	2079.482
1986	1.67	567.57	-18.62	20.37	318.45	23.36	53.90	1173.82	9.77	2150.284
1987	4.08	592.06	-18.72	21.02	326.58	22.57	52.43	1154.87	8.22	2163.104
1988	6.69	596.17	-18.65	21.72	332.71	21.85	51.09	1166.73	6.65	2184.948
1989	9.47	579.12	-18.42	22.47	337.54	21.19	49.85	1180.05	5.29	2186.550
1990	12.42	577.16	-18.08	23.24	341.50	20.11	48.69	1094.39	3.92	2103.342