Table S1. Hydrographic sections with $\Delta^{14}C$ data from WOCE/SAVE and CLIVAR. The principal investigators for radiocarbon measurements in WOCE and CLIVAR are R. Key and A. McNichol. Data are available at http://cchdo.ucsd.edu

	Location	WOCE/SAVE year	CLIVAR year	Chief Scientists	References
P16	150°W	1991-92	2005-06	J. Reid, L. Talley, J. Bullister, J. Swift, R. Feely, B. Sloyan	Key et al. 1996; R. Key and A. McNichol, unpublished data
P6	32°S	1992	2003	M. McCartney, H. Bryden, J. Toole, S. Watanabe, M. Fukasawa	Key et al. 1996; Kumamoto et al. 2011a
A16S	30°W	1988-89	2005	W. Smethie, L. Talley, R. Wanninkhof, S. Doney	Oceanographic Data Facility 1992ab; R. Key and A. McNichol, unpublished data
I8S	90°E	1994-95	2007	M. McCartney, J. Swift	Key and Quay 2002; R. Key and A. McNichol, unpublished data
P17N	135°W	1993	2001	D. Musgrave, M. Fukasawa	Key et al. 1996; Kumamoto et al. 2011b

Table S2. Surface area and volume of the total ocean and shallow ocean reservoirs in the CCSM and ECCO models.

	CCSM	**ECCO**
Total		
Surface area	$3.6\cdot10^{14}$ m^2	$3.5\cdot10^{14}$ m^2
Volume	$1.3\cdot10^{18}$ m^3	$1.3\cdot10^{18}$ m^3
σ_θ<26.5		
Surface area	87.4 %	82.9 %
Volume	6.6 %	6.4 %

Table S3. Atmospheric CO_2 mole ratio and $\Delta^{14}C$ histories used in model forcing

	$\Delta^{14}C$ SH	$\Delta^{14}C$ EQ	$\Delta^{14}C$ NH	CO_2
1765	0.0	0.0	0.0	277.7
1766	0.0	0.0	0.0	277.8
1767	0.0	0.0	0.0	277.9
1768	0.0	0.0	0.0	278.0
1769	0.0	0.0	0.0	278.1
1770	0.0	0.0	0.0	278.2
1771	0.0	0.0	0.0	278.3
1772	0.0	0.0	0.0	278.5
1773	0.0	0.0	0.0	278.6
1774	0.0	0.0	0.0	278.7
1775	0.0	0.0	0.0	278.8
1776	0.0	0.0	0.0	279.0
1777	0.0	0.0	0.0	279.1
1778	0.0	0.0	0.0	279.3
1779	0.0	0.0	0.0	279.4
1780	0.0	0.0	0.0	279.5
1781	0.0	0.0	0.0	279.7
1782	0.0	0.0	0.0	279.8
1783	0.0	0.0	0.0	280.0
1784	0.0	0.0	0.0	280.1
1785	0.0	0.0	0.0	280.3
1786	0.0	0.0	0.0	280.4
1787	0.0	0.0	0.0	280.6
1788	0.0	0.0	0.0	280.7
1789	0.0	0.0	0.0	280.8
1790	0.0	0.0	0.0	281.0
1791	0.0	0.0	0.0	281.1
1792	0.0	0.0	0.0	281.3
1793	0.0	0.0	0.0	281.4
1794	0.0	0.0	0.0	281.6
1795	0.0	0.0	0.0	281.7
1796	0.0	0.0	0.0	281.9
1797	0.0	0.0	0.0	282.0
1798	0.0	0.0	0.0	282.1
1799	0.0	0.0	0.0	282.2
1800	0.0	0.0	0.0	282.4
1801	0.0	0.0	0.0	282.5
1802	0.0	0.0	0.0	282.6
1803	0.0	0.0	0.0	282.7
1804	0.0	0.0	0.0	282.8
1805	0.0	0.0	0.0	282.9
1806	0.0	0.0	0.0	283.0
1807	0.0	0.0	0.0	283.1
1808	0.0	0.0	0.0	283.2
1809	0.0	0.0	0.0	283.3
1810	0.0	0.0	0.0	283.4
1811	0.0	0.0	0.0	283.4
1812	0.0	0.0	0.0	283.5
1813	0.0	0.0	0.0	283.6
1814	0.0	0.0	0.0	283.6
1815	0.0	0.0	0.0	283.7
1816	0.0	0.0	0.0	283.8
1817	0.0	0.0	0.0	283.8
1818	0.0	0.0	0.0	283.9
1819	0.0	0.0	0.0	284.0
1820	0.0	0.0	0.0	284.0
1821	0.0	0.0	0.0	284.1
1822	0.0	0.0	0.0	284.1
1823	0.0	0.0	0.0	284.2
1824	0.0	0.0	0.0	284.2
1825	0.0	0.0	0.0	284.2
1826	0.0	0.0	0.0	284.3
1827	0.0	0.0	0.0	284.3
1828	0.0	0.0	0.0	284.4
1829	0.0	0.0	0.0	284.4
1830	0.0	0.0	0.0	284.5
1831	0.0	0.0	0.0	284.5
1832	0.0	0.0	0.0	284.5
1833	0.0	0.0	0.0	284.6
1834	0.0	0.0	0.0	284.6
1835	0.0	0.0	0.0	284.7
1836	0.0	0.0	0.0	284.7
1837	0.0	0.0	0.0	284.8
1838	0.0	0.0	0.0	284.9
1839	0.0	0.0	0.0	284.9
1840	-0.9	-0.9	-0.9	285.0
1841	-1.0	-1.0	-1.0	285.1
1842	-1.2	-1.2	-1.2	285.2
1843	-1.3	-1.3	-1.3	285.3
1844	-1.5	-1.5	-1.5	285.4
1845	-1.6	-1.6	-1.6	285.5

1846	-1.7	-1.7	-1.7	285.5	1889	-4.5	-4.5	-4.5	293.2
1847	-1.9	-1.9	-1.9	285.6	1890	-4.3	-4.3	-4.3	293.5
1848	-2.0	-2.0	-2.0	285.7	1891	-4.1	-4.1	-4.1	293.8
1849	-2.2	-2.2	-2.2	285.8	1892	-4.0	-4.0	-4.0	294.0
1850	-2.3	-2.3	-2.3	285.9	1893	-3.8	-3.8	-3.8	294.3
1851	-2.5	-2.5	-2.5	286.0	1894	-3.7	-3.7	-3.7	294.5
1852	-2.6	-2.6	-2.6	286.1	1895	-3.5	-3.5	-3.5	294.8
1853	-2.8	-2.8	-2.8	286.2	1896	-3.5	-3.5	-3.5	295.1
1854	-3.0	-3.0	-3.0	286.3	1897	-3.6	-3.6	-3.6	295.3
1855	-3.1	-3.1	-3.1	286.4	1898	-3.7	-3.7	-3.7	295.6
1856	-3.3	-3.3	-3.3	286.5	1899	-3.7	-3.7	-3.7	295.9
1857	-3.6	-3.6	-3.6	286.7	1900	-3.7	-3.7	-3.7	296.2
1858	-3.8	-3.8	-3.8	286.8	1901	-3.8	-3.8	-3.8	296.5
1859	-4.0	-4.0	-4.0	286.9	1902	-3.8	-3.8	-3.8	296.8
1860	-4.2	-4.2	-4.2	287.0	1903	-3.9	-3.9	-3.9	297.1
1861	-4.5	-4.5	-4.5	287.2	1904	-4.0	-4.0	-4.0	297.4
1862	-4.7	-4.7	-4.7	287.3	1905	-4.0	-4.0	-4.0	297.7
1863	-4.9	-4.9	-4.9	287.5	1906	-4.3	-4.3	-4.3	298.0
1864	-5.2	-5.2	-5.2	287.6	1907	-4.6	-4.6	-4.6	298.3
1865	-5.4	-5.4	-5.4	287.8	1908	-4.9	-4.9	-4.9	298.7
1866	-5.4	-5.4	-5.4	287.9	1909	-5.2	-5.2	-5.2	299.0
1867	-5.4	-5.4	-5.4	288.1	1910	-5.5	-5.5	-5.5	299.3
1868	-5.4	-5.4	-5.4	288.3	1911	-5.8	-5.8	-5.8	299.7
1869	-5.4	-5.4	-5.4	288.5	1912	-6.1	-6.1	-6.1	300.0
1870	-5.4	-5.4	-5.4	288.7	1913	-6.4	-6.4	-6.4	300.3
1871	-5.3	-5.3	-5.3	288.9	1914	-6.7	-6.7	-6.7	300.7
1872	-5.3	-5.3	-5.3	289.1	1915	-7.0	-7.0	-7.0	301.0
1873	-5.3	-5.3	-5.3	289.3	1916	-7.1	-7.1	-7.1	301.4
1874	-5.3	-5.3	-5.3	289.5	1917	-7.2	-7.2	-7.2	301.7
1875	-5.3	-5.3	-5.3	289.7	1918	-7.3	-7.3	-7.3	302.0
1876	-5.3	-5.3	-5.3	289.9	1919	-7.4	-7.4	-7.4	302.4
1877	-5.3	-5.3	-5.3	290.2	1920	-7.5	-7.5	-7.5	302.7
1878	-5.2	-5.2	-5.2	290.4	1921	-7.6	-7.6	-7.6	303.1
1879	-5.2	-5.2	-5.2	290.7	1922	-7.7	-7.7	-7.7	303.4
1880	-5.2	-5.2	-5.2	290.9	1923	-7.8	-7.8	-7.8	303.8
1881	-5.2	-5.2	-5.2	291.2	1924	-7.9	-7.9	-7.9	304.1
1882	-5.2	-5.2	-5.2	291.4	1925	-8.0	-8.0	-8.0	304.4
1883	-5.1	-5.1	-5.1	291.7	1926	-8.6	-8.6	-8.6	304.8
1884	-5.1	-5.1	-5.1	291.9	1927	-9.2	-9.2	-9.2	305.1
1885	-5.1	-5.1	-5.1	292.2	1928	-9.8	-9.8	-9.8	305.4
1886	-4.9	-4.9	-4.9	292.4	1929	-10.4	-10.4	-10.4	305.8
1887	-4.8	-4.8	-4.8	292.7	1930	-11.0	-11.0	-11.0	306.1
1888	-4.6	-4.6	-4.6	293.0	1931	-11.6	-11.6	-11.6	306.4

1932	-12.2	-12.2	-12.2	306.7
1933	-12.8	-12.8	-12.8	307.0
1934	-13.4	-13.4	-13.4	307.3
1935	-14.0	-14.0	-14.0	307.6
1936	-14.6	-14.6	-14.6	307.9
1937	-15.2	-15.2	-15.2	308.1
1938	-15.8	-15.8	-15.8	308.4
1939	-16.4	-16.4	-16.4	308.7
1940	-17.0	-17.0	-17.0	308.9
1941	-17.6	-17.6	-17.6	309.2
1942	-18.2	-18.2	-18.2	309.4
1943	-18.8	-18.8	-18.8	309.7
1944	-19.4	-19.4	-19.4	310.0
1945	-20.0	-20.0	-20.0	310.2
1946	-20.5	-20.5	-20.5	310.5
1947	-21.0	-21.0	-21.0	310.8
1948	-21.5	-21.5	-21.5	311.1
1949	-22.0	-22.0	-22.0	311.5
1950	-22.5	-22.5	-22.5	311.8
1951	-23.0	-23.0	-23.0	312.2
1952	-23.5	-23.5	-23.5	312.6
1953	-24.0	-24.0	-24.0	313.0
1954	-24.5	-24.5	-24.5	313.5
1955	5.0	7.0	10.0	314.0
1956	20.0	35.0	55.0	314.5
1957	50.0	70.0	90.0	315.0
1958	100.0	120.0	150.0	315.6
1959	160.0	185.0	210.0	316.2
1960	195.0	210.0	220.0	316.8
1961	205.0	215.0	230.0	317.5
1962	230.0	310.0	370.0	318.2
1963	360.0	600.0	753.0	318.9
1964	565.0	720.0	852.0	319.7
1965	640.0	720.0	764.0	320.5
1966	625.0	660.0	698.0	321.3
1967	590.0	629.0	629.0	322.3
1968	565.0	571.0	571.0	323.3
1969	550.0	550.0	550.0	324.3
1970	536.0	536.0	536.0	325.4

1971	508.0	508.0	508.0	326.5
1972	474.0	474.0	474.0	327.7
1973	428.0	428.0	428.0	328.9
1974	397.0	397.0	397.0	330.1
1975	380.0	380.0	380.0	331.4
1976	362.0	362.0	362.0	332.6
1977	347.0	347.0	347.0	334.0
1978	336.0	336.0	336.0	335.4
1979	318.0	318.0	318.0	336.9
1980	298.0	298.0	298.0	338.3
1981	280.0	280.0	280.0	339.8
1982	255.0	255.0	255.0	341.3
1983	225.0	225.0	225.0	342.9
1984	210.0	210.0	210.0	344.4
1985	205.0	205.0	205.0	346.0
1986	198.0	198.0	198.0	347.6
1987	185.0	185.0	185.0	349.2
1988	168.0	168.0	168.0	350.8
1989	160.0	160.0	160.0	352.3
1990	150.0	150.0	150.0	353.8
1991	140.5	140.5	140.5	355.2
1992	133.7	133.7	133.7	356.5
1993	127.4	127.4	127.4	357.9
1994	120.1	120.1	120.1	359.3
1995	115.1	115.1	115.1	360.9
1996	109.0	109.0	109.0	362.5
1997	104.1	104.1	104.1	364.3
1998	99.7	99.7	99.7	366.0
1999	94.2	94.2	94.2	367.8
2000	88.1	88.1	88.1	369.6
2001	82.3	82.3	82.3	371.5
2002	77.3	77.3	77.3	373.4
2003	71.7	71.7	71.7	375.4
2004	66.8	66.8	66.8	377.5
2005	62.3	62.3	62.3	379.5
2006	58.9	58.9	58.9	381.5
2007	52.9	52.9	52.9	383.5
2008	47.0	47.0	47.0	385.5

Table S4. Configuration of NCAR CCSM Model. Except the non-default parameter values listed, default parameter values were used (CCSM3.0 User Guide http://www.cesm.ucar.edu/models/ccsm3.0/pop/doc/POPusers_main.html).

Model Version	CCSM3.0 (POP 2.0.1)
Grid	T62_gx3v5
Vertical Spacing	25 levels
Horizontal Spacing	0.9-1.9° lat. by 3.6° lon.
Vertical Mixing	KPP (Large et al. 1994)
Horizontal Mixing of Momentum	Anisotropic lvariable_hmix_aniso = .true. lsmag_aniso = .false.
Horizontal Mixing of Tracers	Gent and McWilliams (1990) gm_bolus = .true.
Tracer Advection	Centered differences
Sea ice model	Inactive, Sea ice coverage given by Hurrell et al. (2008) lactive_ice = .false.
Surface Heat Flux Forcing	CORE-CNYF (Large and Yeager, 2004) shf_formulation = 'partially-coupled' shf_data_type = 'monthly' shf_data_inc = 24. shf_interp_freq = 'every-timestep' shf_interp_type = 'linear' shf_interp_inc = 72. shf_restore_tau = 30. shf_data_renorm(3) = 0.94 shf_weak_restore = 0. shf_strong_restore = 0. luse_cpl_ifrac = .true. shf_strong_restore_ms = 92.64
Surface Fresh Water Flux Forcing	CORE-CNYF (Large and Yeager, 2004) sfwf_formulation = 'partially-coupled' sfwf_data_type = 'monthly' sfwf_data_inc = 24. sfwf_interp_freq = 'every-timestep' sfwf_interp_type = 'linear' sfwf_interp_inc = 72. sfwf_restore_tau = 30. sfwf_data_renorm(1) = 0.001 sfwf_weak_restore = 0.0115 sfwf_strong_restore = 0.0 sfwf_strong_restore_ms = 0.6648 ladjust_precip = .true. lms_balance = .false. lsend_precip_fact = .true.

References:

Gent, P. R., J. C. Mcwilliams (1990), Isopycnal Mixing in Ocean Circulation Models. *J. Phys. Oceanogr.*, 20, 150–155.

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Large, W., J. McWilliams, and S. Doney (1994), Oceanic vertical mixing: A review and a model with a nonlocal boundary layer parameterization. *Rev. Geophys.,* **32,** 363–403.
Large, W. and S. Yeager (2004), Diurnal to decadal global forcing for ocean and sea-ice models: the datasets and flux climatologies. NCAR Technical Note: NCAR/TN-460+STR, CGD Division of the National Centre for Atmospheric Research.

Table S5. Configuration of MIT GCM used to compute the ECCO state estimate (ECCO-GODAE iteration 2.199). Note that unlike CCSM, there is no standard or default version of the MIT model and hence no default grid or parameter values. For details see: http://mitgcm.org.

Model Version	MITgcm checkpoint58d_post
Vertical Spacing	23 levels
Horizontal Spacing	1° lat. by 1° lon.
Vertical Mixing	KPP (Large et al. 1994)
Horizontal Mixing of Momentum	Isotropic
Horizontal Mixing of Tracers	Gent and McWilliams (1990)
Tracer Advection	3d order direct-space time
Sea ice model	None
Surface Heat Flux Forcing	Adjusted NCEP
Surface Fresh Water Flux Forcing	Adjusted NCEP