From Houghton (2004)

Figure 4.5 Variations in the Earth’s orbit (a), in its eccentricity, the orientation of its spin axis (between 21.6° and 24.5°) and the longitude of perihelion (i.e. the time of year when the Earth is closest to the Sun, see also Figure 5.19), cause changes in the average amount of summer sunshine (in millions of joules per square metre per day) near the poles (b). These changes appear as cycles in the climate record in terms of the volume of ice in the ice caps (c).

Figure 5.19 Changes in the Earth’s elliptical orbit from the present configuration to 9000 years ago and (right hand side) changes in the average solar radiation during the year over the northern hemisphere.
Figure 6.12 The change in temperature derived from the measurement of the hydrogen isotope ratio (H/D) in an ice-core drilled at Vostok in Antarctica, showing how the ice core record extends back 260,000 years covering the last two glacial and interglacial periods (data from NOAA WDC-A).

From Burroughs (2001)
Nature 411:546-547

From Sturm et al. (2001)
Nature 411:546-547
From Burroughs (2001)

![Graph showing ring widths over time](image1.png)

*Figure 1.8* Ring widths (twenty-year averages) from bristlecone pines growing high in the White Mountains, California, from AD 470. The variations in tree-ring width at this altitude are an indication of summer warmth and/or duration of growing season (data from Tree-ring Laboratory, University of Arizona).


![Graph showing surface elevation change](image2.png)

*Figure 2* Measured changes in surface elevation between 1954 and 1995. Dashed-dotted lines indicate maximum errors. Letters denote longitude bands used in the data analysis.
From Burroughs (2001)

Figure 4.23: Combined annual land-surface air and sea-surface temperature anomalies (a) Northern Hemisphere; (b) Southern Hemisphere; (c) Globe. The dashed smoothed curves are corresponding results from IPCC (1992), adjusted to be relative to 1861–90 (IPCC, 1995).


Figure 3. Trends in monthly mean temperature anomalies. a, MOS channel 2 (brightness temperature) anomalies relative to 1961–90; b, Northern Hemisphere; c, Southern Hemisphere; d, tropical. The error bars represent the 95% confidence intervals of the slopes, using the standard calculation for ordinary least squares.
Figure 2.7 The Earth’s radiation and energy balance. The net incoming solar radiation of 342 W m\(^{-2}\) is partially reflected by clouds and the atmosphere, or at the surface, but 49\% is absorbed by the surface. Some of that heat is returned to the atmosphere as sensible heating and considerably more as evapotranspiration that is released as latent heat in precipitation. The amount of energy emitted as thermal infrared radiation from the surface depends on how much is absorbed by the atmosphere which in turn emits radiation both up and down, as part of the greenhouse effect. The net terrestrial radiation lost to space from the surface, from cloud tops and from throughout the atmosphere balances out the total amount of absorbed incoming solar radiation (IPCC, 1995, Fig. 1.3).

From Keeling & Whorf (2004) CDIAC web site
From Burroughs (2001)

Figure 8.9 CO₂ concentrations over the last 1,000 years from ice-core records (D47, D57, Siple and South Pole – all in Antarctica) and (since 1958) Mauna Loa, Hawaii, measurement site. The smooth curve is based on a 100-year running mean. The rapid increase in CO₂ concentration since the onset of industrialisation is evident and has followed closely the increase in CO₂ emissions from fossil fuels (see inset of period from 1850 onwards) (IPCC, 1995, Fig. 1(a)).

From Houghton (2004)

Figure 3.3 (a) Fossil carbon emissions (based on statistics of fossil fuel and cement production) and estimates of global reservoir changes: atmosphere (deduced from direct observations and ice core measurements), ocean (calculated with the Geophysical Fluid Dynamics Laboratory (GFDL), University of Princeton, ocean carbon model) and net terrestrial biosphere (calculated as remaining imbalance) from 1840 to 1990. The calculation implies that the terrestrial biosphere was a net source to the atmosphere prior to 1940 (negative values) and has been a net sink since about 1960. (b) Estimates of contributions to the carbon balance of the terrestrial biosphere. The curve showing the terrestrial reservoir changes is taken from (a). Emissions from land-use changes (including tropical deforestation) are plotted negatively because they represent a loss of biospheric carbon. These estimates are subject to large uncertainties (see uncertainty estimates in Table 3.1).
From Houghton (2004)

Figure 3.1 The global carbon cycle, showing the carbon stocks in reservoirs (in Gt) and carbon flows (in Gt year\(^{-1}\)) relevant to the anthropogenic perturbation as annual averages over the decade from 1989 to 1998. Net ocean uptake of the anthropogenic perturbation equals the net air/sea input plus run-off minus sediment. The units are thousand millions of tonnes or gigatones (Gt).


Table 1 Global carbon budgets for the 1980s and 1990s (Pg C yr\(^{-1}\))

<table>
<thead>
<tr>
<th></th>
<th>1980s</th>
<th>1990s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil fuel emissions(^*)</td>
<td>5.4 ± 0.3</td>
<td>6.3 ± 0.4</td>
</tr>
<tr>
<td>Atmospheric increase(^*)</td>
<td>3.3 ± 0.1</td>
<td>3.2 ± 0.2</td>
</tr>
<tr>
<td>Oceanic uptake(^†)</td>
<td>-1.7 ± 0.6</td>
<td>-2.4 ± 0.7</td>
</tr>
<tr>
<td>Net terrestrial flux(^‡)</td>
<td>-0.4 ± 0.7</td>
<td>-0.7 ± 0.8</td>
</tr>
<tr>
<td>Land-use change(^‡)</td>
<td>2.0 ± 0.8</td>
<td>2.2 ± 0.8</td>
</tr>
<tr>
<td>Residual ‘terrestrial’ flux</td>
<td>-2.4 ± 1.1</td>
<td>-2.9 ± 1.1</td>
</tr>
</tbody>
</table>

Negative values indicate a withdrawal of CO\(_2\) from the atmosphere.

*from Prentice et al. (2001).
†from Plattner et al. (2002).
‡from Houghton (in press).


Fig. 4. Comparison of model response (blue) using all forcing terms (with a sensitivity of 2.0°C) against (A) the CL (12) data set spliced into the 11-point smoothed Jones et al. (16) Northern Hemisphere instrumental record, with rescaling as discussed in the text and in the Fig. 1 caption; and (B) the smoothed Mann et al. (11) reconstruction. Both panels include the Jones et al. instrumental record for reference. To illustrate variations in the modeled response, the $^{13}$C calculation from Bard et al. (30) has been used in (A) and the $^{10}$Be estimates from (30) have been used in (B).

![Graph showing temperature variations over time](image)

**Fig. 6.** Comparison of the GHG forcing response (from Fig. 3) with six residuals determined by removing all forcing except GHG from the two different temperature reconstructions in Fig. 1. As in Fig. 5, the three different estimates of solar variability were used to get one estimate of the uncertainty in the response. This figure illustrates that GHG changes can explain the 20th-century rise in the residuals; ±2 standard deviation lines (horizontal dashed lines) refer to maximum variability of residuals from Fig. 5A (inner dashes) and maximum variability (outer dashes) of the original pre-1850 time series (Fig. 1). The projected 21st-century temperature increase (heavy dashed line at right) uses the IPCC BAU scenario (the “so-called IS92a forcing”) for both GHG and aerosols (sulfate and biomass burning, including indirect effects), and the model simulation was run at the same sensitivity (2.0°C for a doubling of CO₂) as other model simulations in this article. The IS92a scenario is from (39).

From Stott et al. (2000) Science 290:2133-2137

![Graph showing temperature anomalies](image)

**Fig. 1.** Annual-mean global mean near-surface (1.5 m) temperature anomalies (relative to 1981–1990) for the NATURAL, ANTHRO, and ALL ensembles. Ensemble members are shown as colored lines, and observations [updated versions of surface temperature data set of Parker et al. (39) are shown as a black line. All model data up to November 1999 are masked by the observational missing data mask and expressed, like the observations, as anomalies relative to 1961–1990. Future model data are masked by observational mask for year December 1998 to November 1999. Global means are then calculated and expressed as anomalies relative to 1981–1990.

Table 1. Comparison of the heat balance of the climate system.

<table>
<thead>
<tr>
<th>Component of the climate system and source of data</th>
<th>Time period of change</th>
<th>Observed or estimated change</th>
<th>Assumption made in this calculation</th>
<th>Heat content increase or total heat of fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>World ocean (5)</td>
<td>1955–1996</td>
<td>Observed temperature increase</td>
<td>–</td>
<td>$18.2 \times 10^{22}$ J</td>
</tr>
<tr>
<td>Global atmosphere (6)</td>
<td>1955–1996</td>
<td>Observed temperature increase</td>
<td>–</td>
<td>$6.6 \times 10^{21}$ J</td>
</tr>
<tr>
<td>Decrease in Antarctic sea ice extent (78)</td>
<td>1950s–1970s</td>
<td>Estimated 311-km reduction in sea ice edge</td>
<td>Assumed 1.8 mm per year increase in sea level</td>
<td>$3.2 \times 10^{21}$ J</td>
</tr>
<tr>
<td>Mountain glacier decrease (74)</td>
<td>1961–1997</td>
<td>$3.7 \times 10^5$ km$^3$ decrease in mountain glacier ice volume</td>
<td>$\rho_i = 9.17 \times 10^3$ kg m$^{-3}$ $\lambda_i = 3.34 \times 10^{5}$ J kg$^{-1}$ m$^{-1}$ 100% ice coverage of 2-m thickness</td>
<td>$1.1 \times 10^{21}$ J</td>
</tr>
<tr>
<td>Decrease in Northern Hemisphere sea ice extent (77)</td>
<td>1978–1996</td>
<td>Areal change based on satellite measurements</td>
<td>$\rho_i = 9.17 \times 10^3$ kg m$^{-3}$ $\lambda_i = 3.34 \times 10^{5}$ J kg$^{-1}$ m$^{-1}$ 100% ice coverage of 2-m thickness</td>
<td>$4.6 \times 10^{19}$ J</td>
</tr>
<tr>
<td>Decrease in Arctic perennial sea ice volume (76)</td>
<td>1950s–1980s</td>
<td>40% decrease in sea ice thickness</td>
<td>Thickness of the melted sea ice 1.3 m</td>
<td>$2.4 \times 10^{19}$ J</td>
</tr>
</tbody>
</table>


Fig. 1. Decadal values of anomalous heat content ($10^{22}$ J) in various ocean basins. The heavy dashed line is from observations (74), and the solid line is the average from five realizations of the PCM (76–79) forced by observed and estimated anthropogenic forcing. Both curves show significant warming in all basins since the 1950s. The shaded bands denote one (heavy shading) and two (light shading) standard deviations above the model mean signal estimated from the standard deviation in the scatter of the five-member ensemble. The heat content is computed over the upper 3000 m of the water column. The space/time sampling was identical for both model and observations. Basin averages for the northern oceans are defined between 60$^\circ$N and the equator. The southern ocean averages are between the equator and 77$^\circ$S.
Figure 1 Examples of IRIS and IMG observed and simulated spectra for a three-month average (April–June) over selected regions. a, Observed IRIS and IMG clear sky brightness temperature spectra for the central Pacific (10°N–10°S, 130°W–180°W). b, Top, observed difference spectrum taken from a, middle, simulated central Pacific difference spectrum, displaced by −5 K; bottom, observed difference spectrum for “near-global” case (60°N–60°S), displaced by −10 K. c, Component of simulated spectrum due to trace-gas changes only. ‘Brightness temperature’ on the ordinate indicates equivalent blackbody brightness temperature.