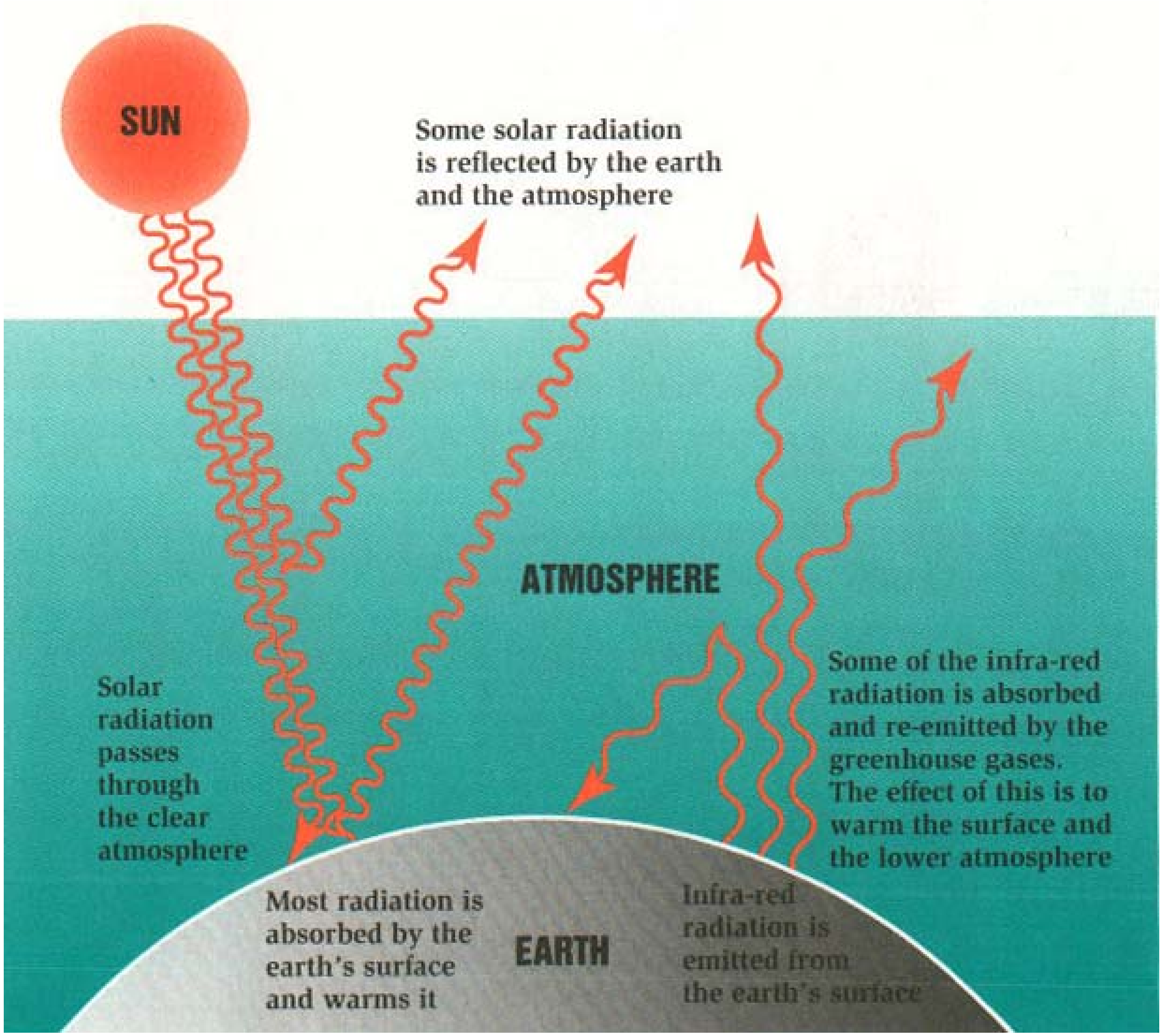

SUN
Some solar radiation is reflected by the earth and the atmosphere
ATMOSPHERE
Solar radiation passes through the clear atmosphere
Some of the infra-red radiation is absorbed and re-emitted by the greenhouse gases. The effect of this is to warm the surface and the lower atmosphere
Most radiation is absorbed by the earth's surface and warms it
EARTH
Infra-red radiation is emitted from the earth's surface

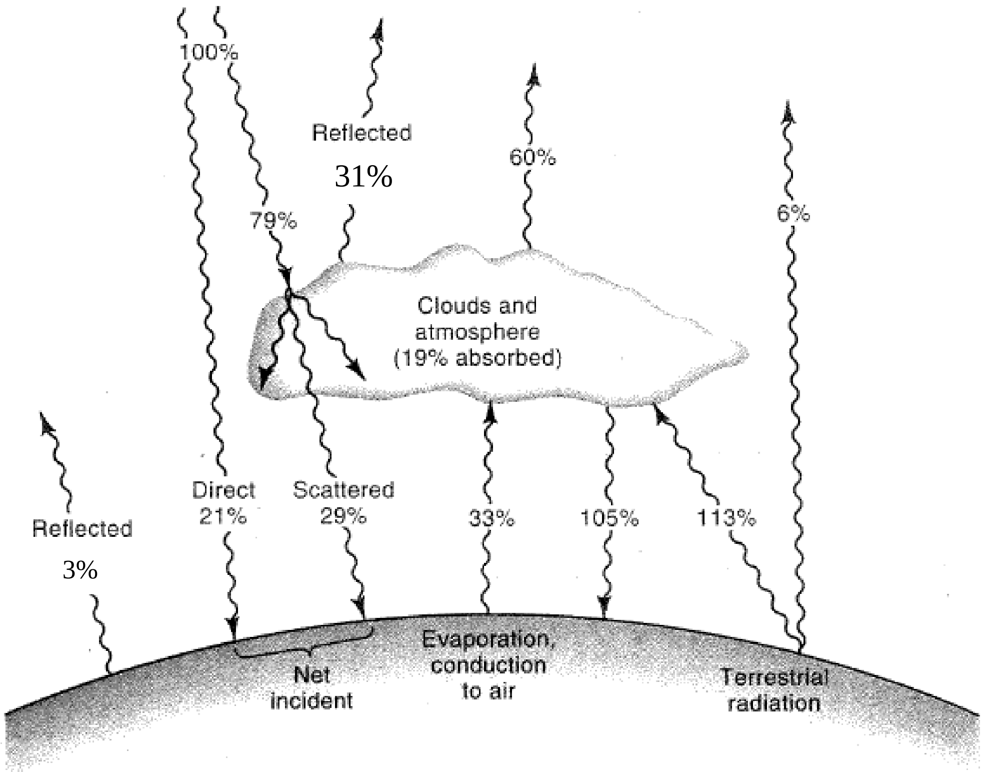


FIGURE 6.3

Energy balance for the earth. The earth receives about 50% of the incident solar radiation: 21% is from direct radiation and 29% is scattered through the clouds. The energy leaving the earth's surface comes from evaporation and conduction to the atmosphere (33%), and infrared radiation (noted here as terrestrial radiation). Most of the infrared radiation (113%) is absorbed by the atmosphere and reradiated back to the surface (the "greenhouse effect"). In order to have temperature equilibrium at the earth's surface, the energy input must equal the energy output. For this figure, 50% (incident radiation) = 3% (reflected) + 33% (evaporation) + 14% (net terrestrial radiation: 113% + 6% − 105%).

Table 9.1 GREENHOUSE GASES

Gas	Sources	U.S. Emissions (MT/y)	GWP*	Atmospheric Lifetime (y)	1995 Concentration (ppM)
CO_2	Fossil fuels, deforestation	5500	1	100	360
Methane	Rice fields, cattle, landfills	300–400	21	10	1.7
Nitrogen oxides	Fertilizers, deforestation	15	310	170	0.31
CFCs	Aerosol sprays, refrigerants	1	1300–12,000	70–100	0.003 (Cl atoms)

*GWP = Global Warming Potential, which is related to a molecule's ability to absorb thermal radiation relative to that of CO_2.

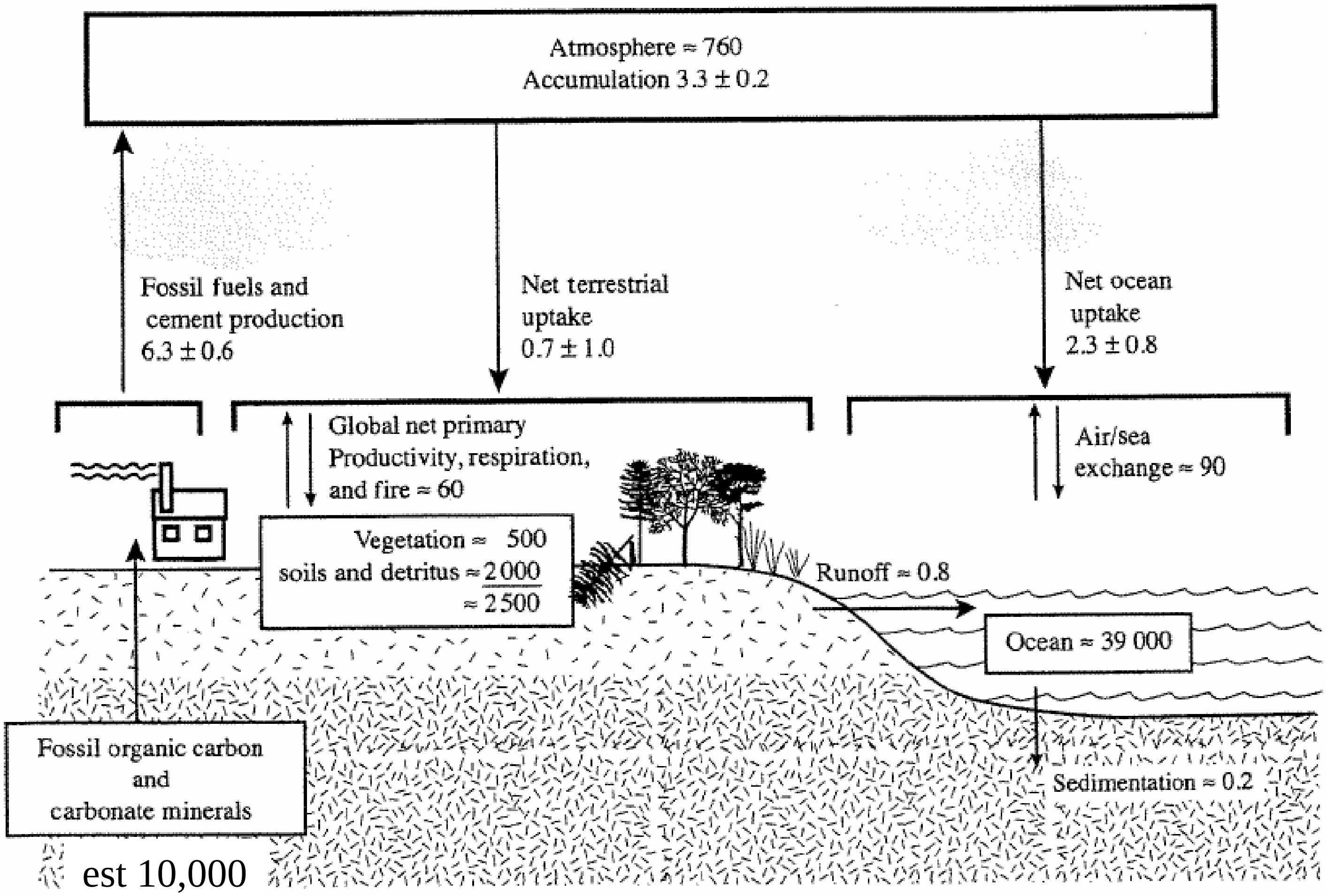
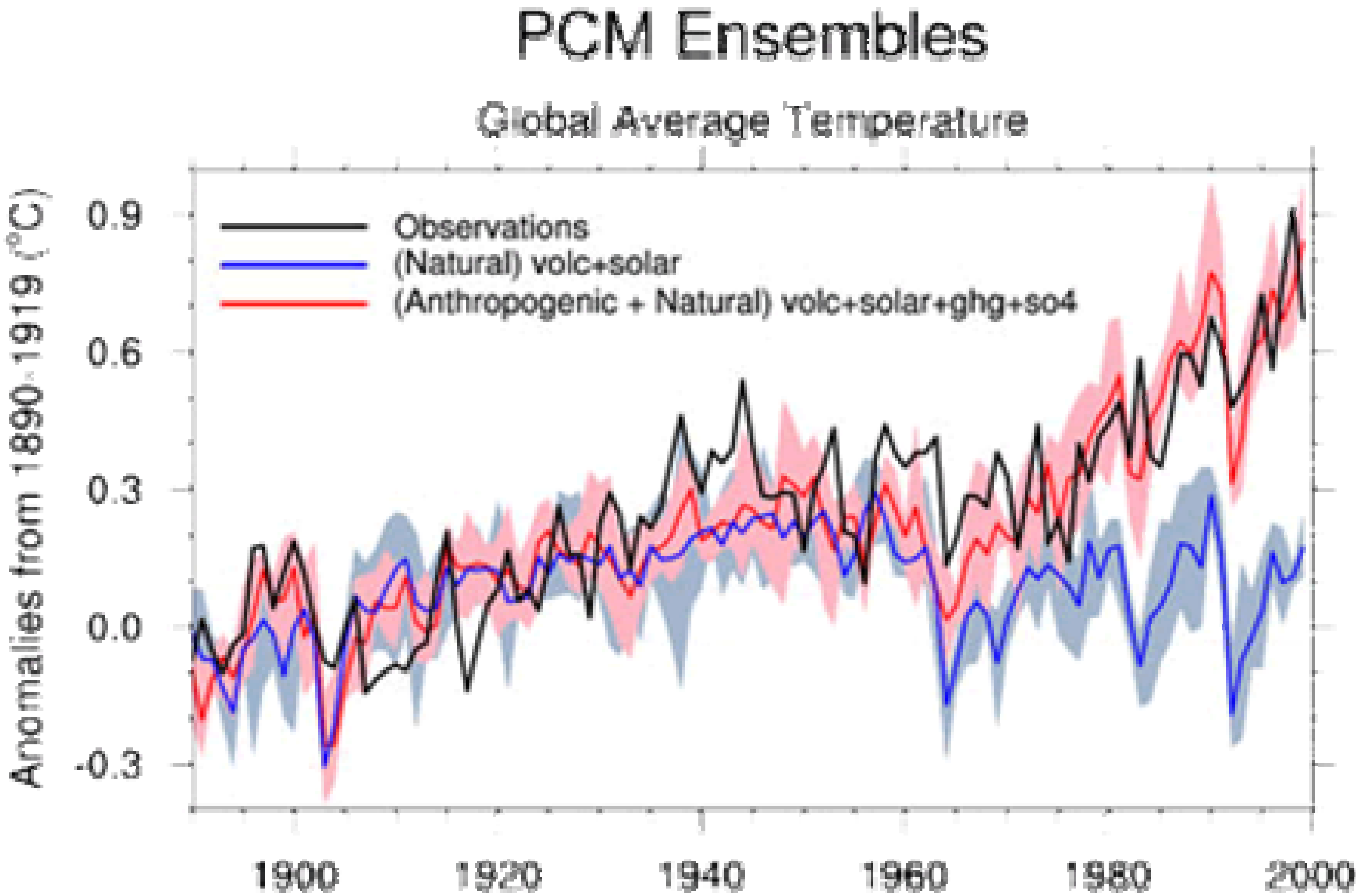
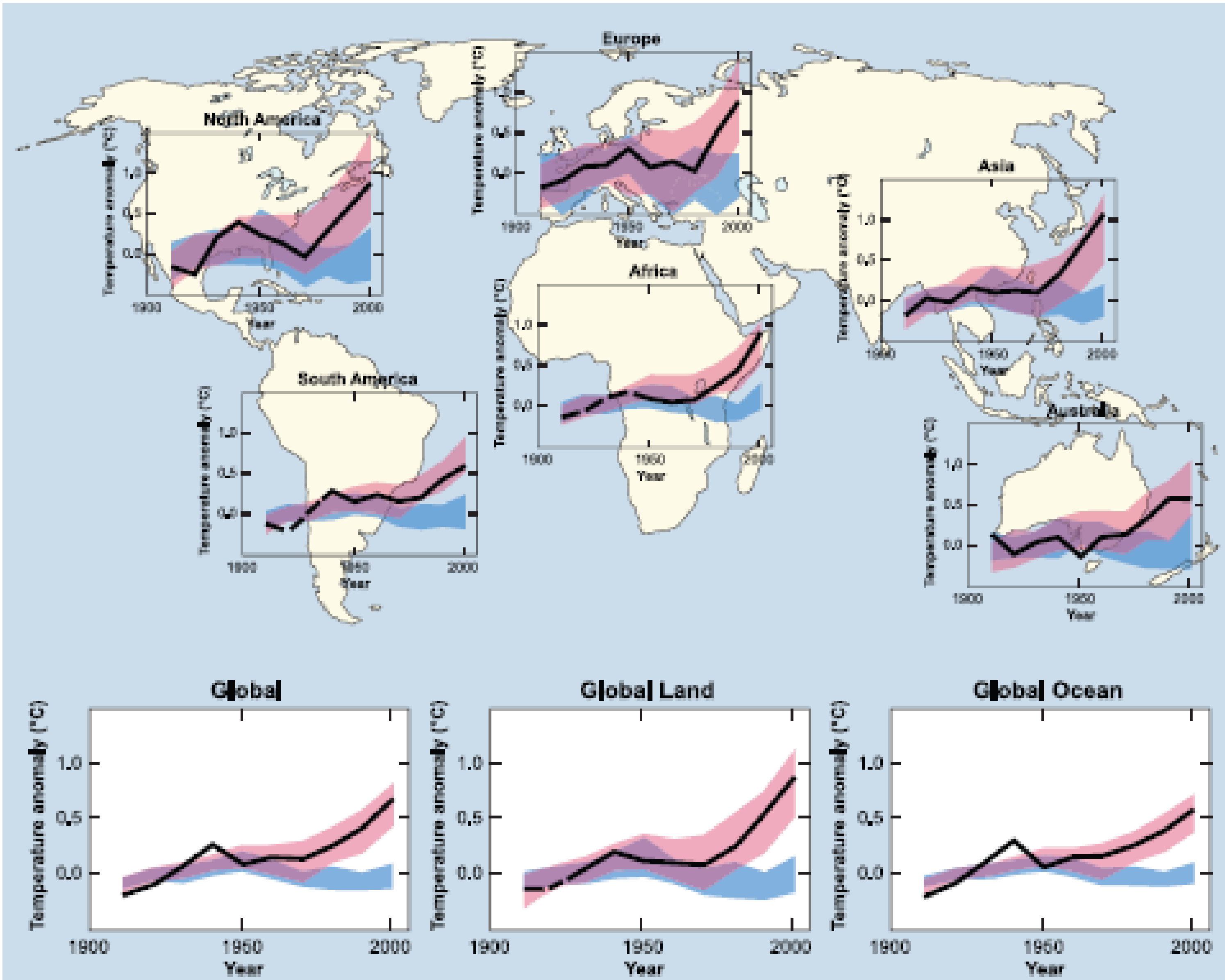


Figure 3.1 The global carbon cycle, showing the carbon stocks in reservoirs (in Gt) and carbon flows (in Gt $year^{-1}$) relevant to the anthropogenic perturbation as annual averages over the decade from 1989 to 1998. Net ocean uptake of the anthropogenic perturbation equals the net air/sea input plus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



From http://www.ucar.edu/research/climate/warming.jsp

Global and Continental Temperature Change



models using only natural forcings

models using both natural and anthropogenic forcings

observations

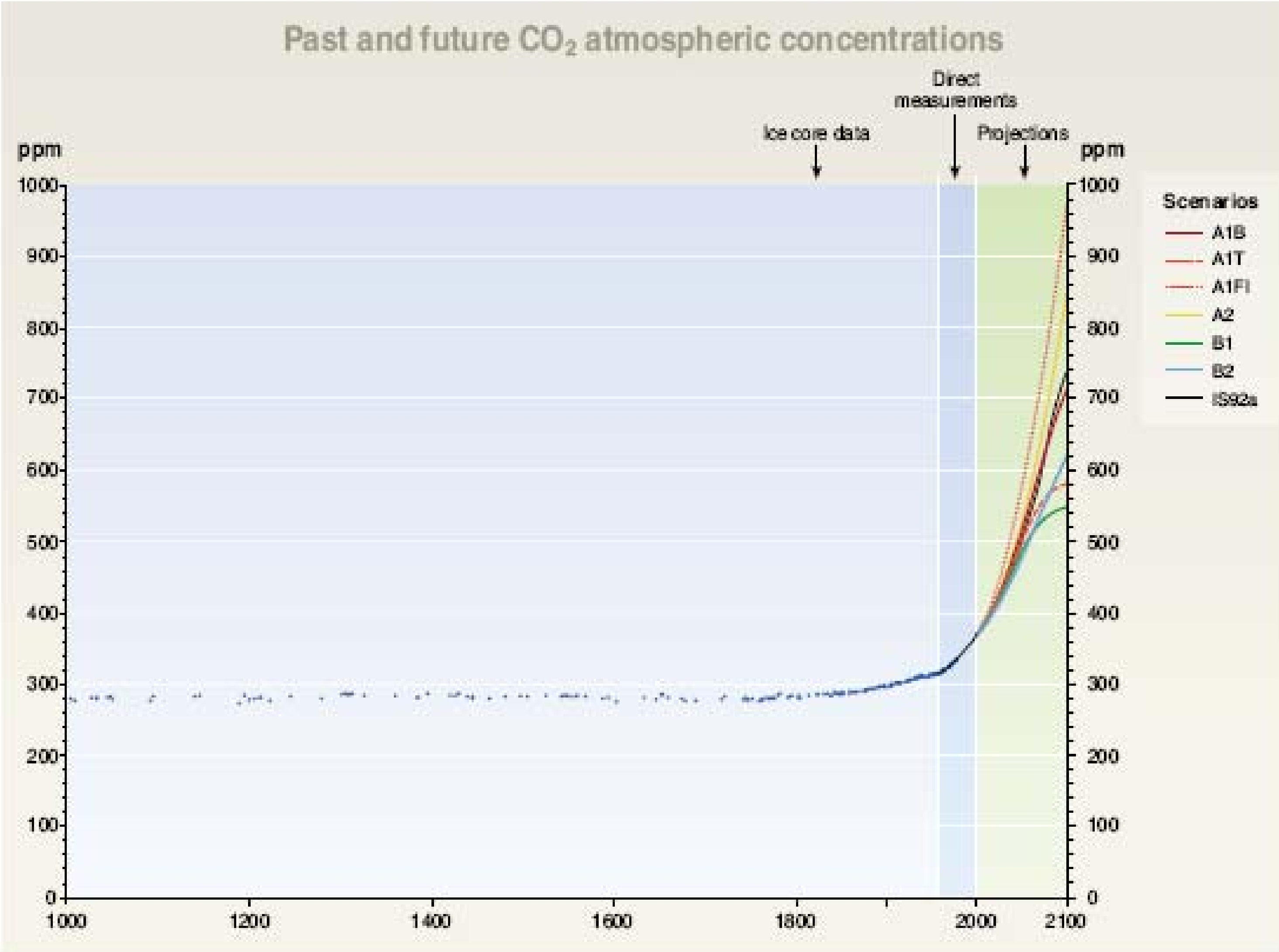


Figure SPM-10a: Atmospheric CO_2 concentration from year 1000 to year 2000 from ice core data and from direct atmospheric measurements over the past few decades. Projections of CO_2 concentrations for the period 2000 to 2100 are based on the six illustrative SRES scenarios and IS92a (for comparison with the SAR).

Q9 Figure 9-1a

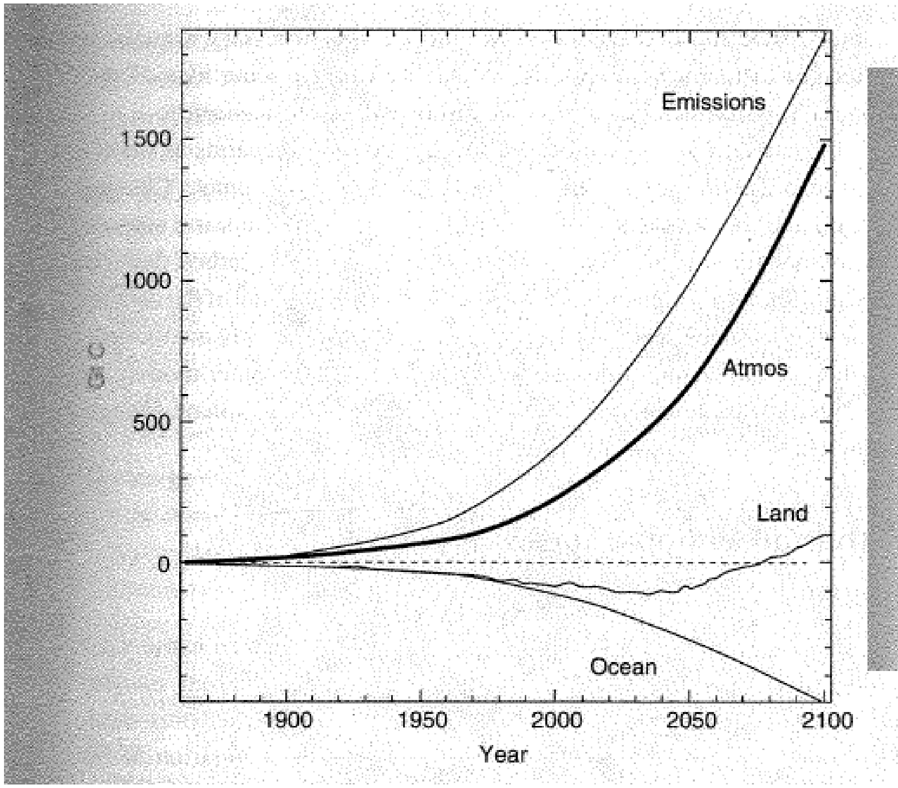


Figure 3.5 Illustrating the possible effects of climate feedbacks on the carbon cycle. Results are shown of the changing budgets of carbon (in gigatonnes of carbon) in the atmosphere, land and ocean in an ocean–atmosphere model coupled to an ocean carbon cycle model (which includes the transfer of carbon dioxide to depth through both the solubility pump and the biological pump) and a dynamic global vegetation model (which includes the exchange of carbon with the soil and with five different types of plant). The model was run with the fossil fuel carbon dioxide emissions from 1860 to the present and then projected to 2100 assuming the IS 92a scenario shown in Figure 6.1. Note that because of climate feedbacks, the terrestrial biosphere changes from being a net sink of carbon to being a net source around the middle of the twenty-first century. Note also as this source becomes stronger, by 2100 the atmospheric carbon content is increasing at about the same rate as the total emissions (i.e. the 'airborne fraction', or the fraction of fossil fuel emissions that remains in the atmosphere, has changed from being about a half in the year 2000 to being about unity in 2100). Note also that an atmospheric carbon content of 1500 Gt more than it was in 1860 is equivalent to a concentration of nearly 1000 ppm.

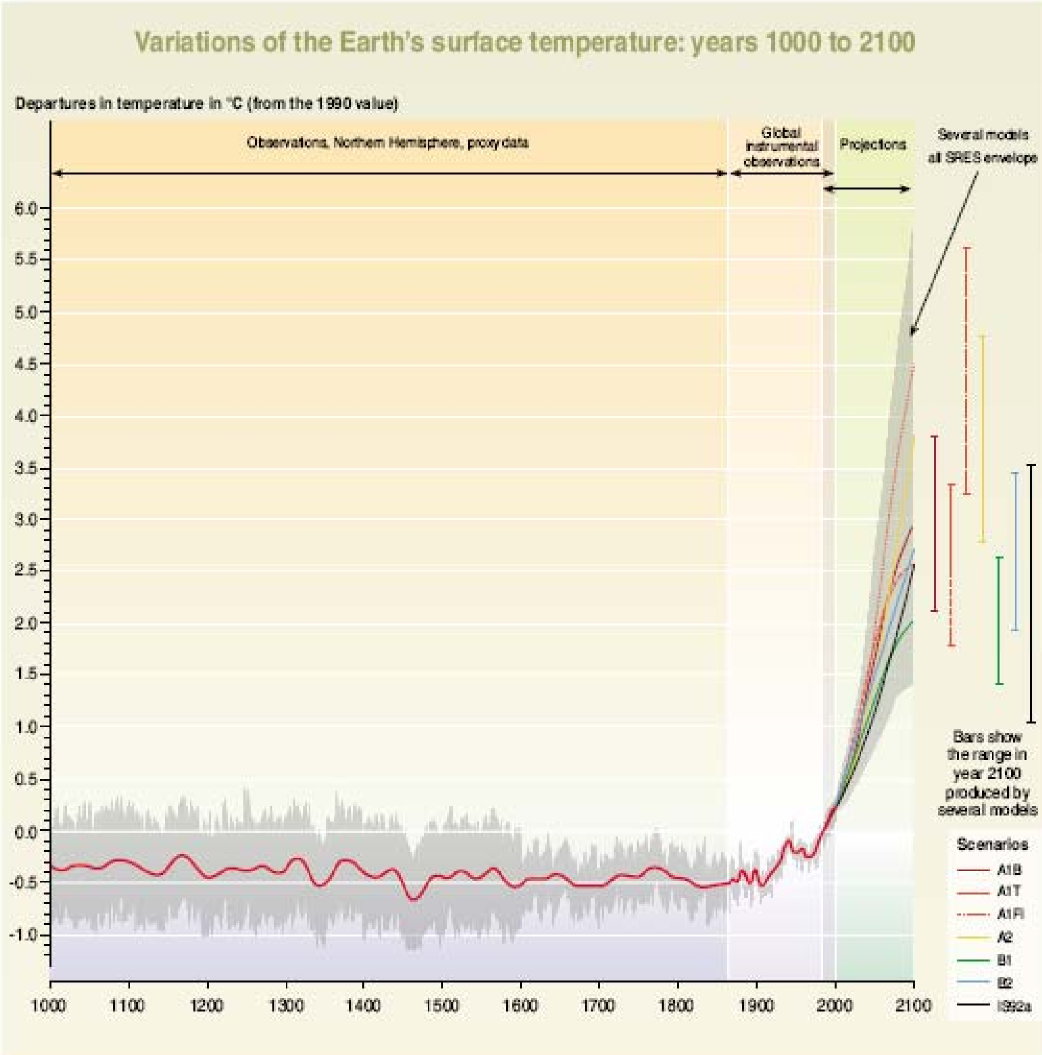


Figure SPM-10b: Variations of the Earth's surface temperature: years 1000 to 2100. From year 1000 to year 1860 variations in average surface temperature of the Northern Hemisphere are shown (corresponding data from the Southern Hemisphere not available) reconstructed from proxy data (tree rings, corals, ice cores, and historical records). The line shows the 50-year average, the grey region the 95% confidence limit in the annual data. From years 1860 to 2000 are shown variations in observations of globally and annually averaged surface temperature from the instrumental record; the line shows the decadal average. From years 2000 to 2100 projections of globally averaged surface temperature are shown for the six illustrative SRES scenarios and IS92a using a model with average climate sensitivity. The grey region marked "several models all SRES envelope" shows the range of results from the full range of 35 SRES scenarios in addition to those from a range of models with different climate sensitivities. The temperature scale is departure from the 1990 value; the scale is different from that used in Figure SPM-2.

Q9 Figure 9-1b

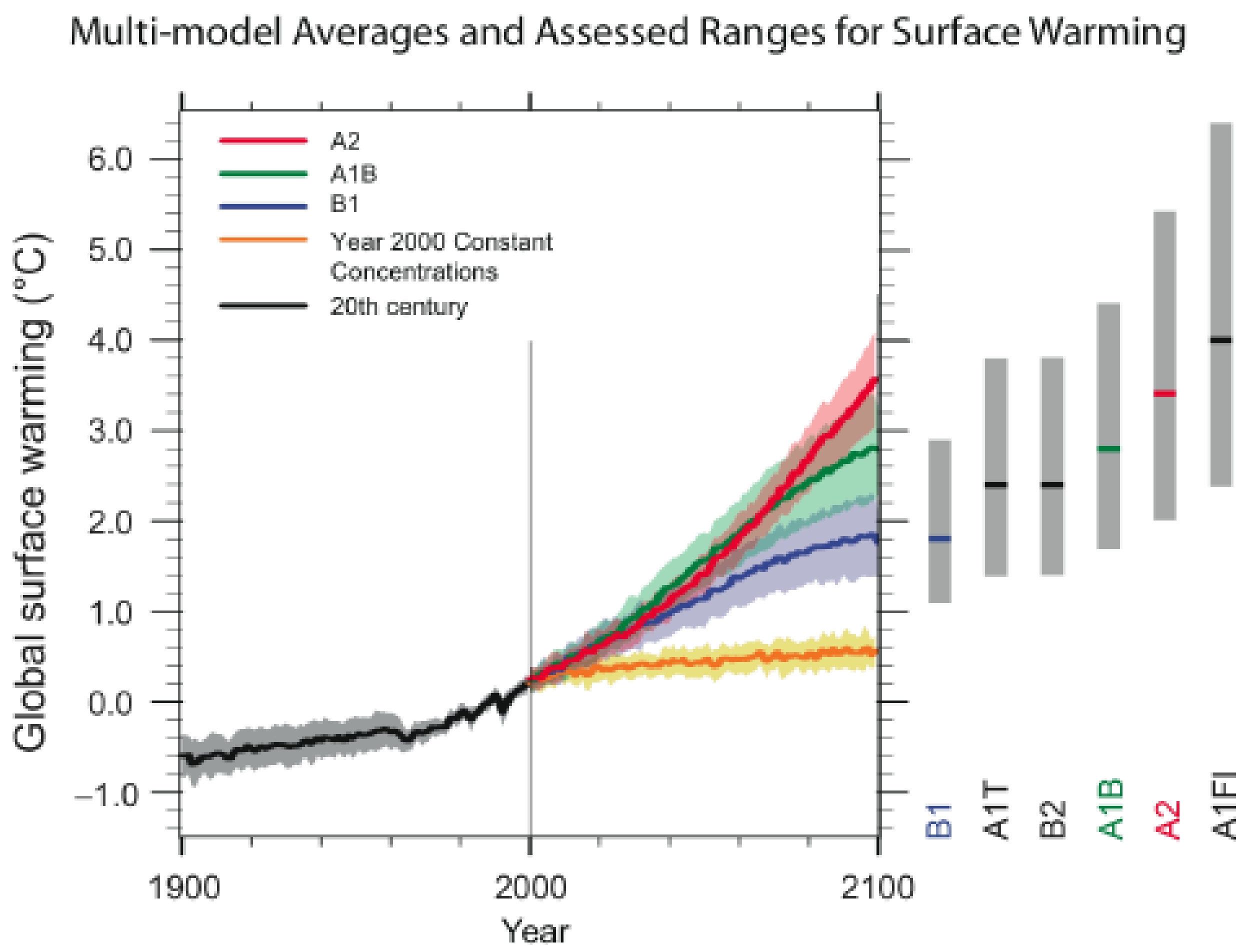


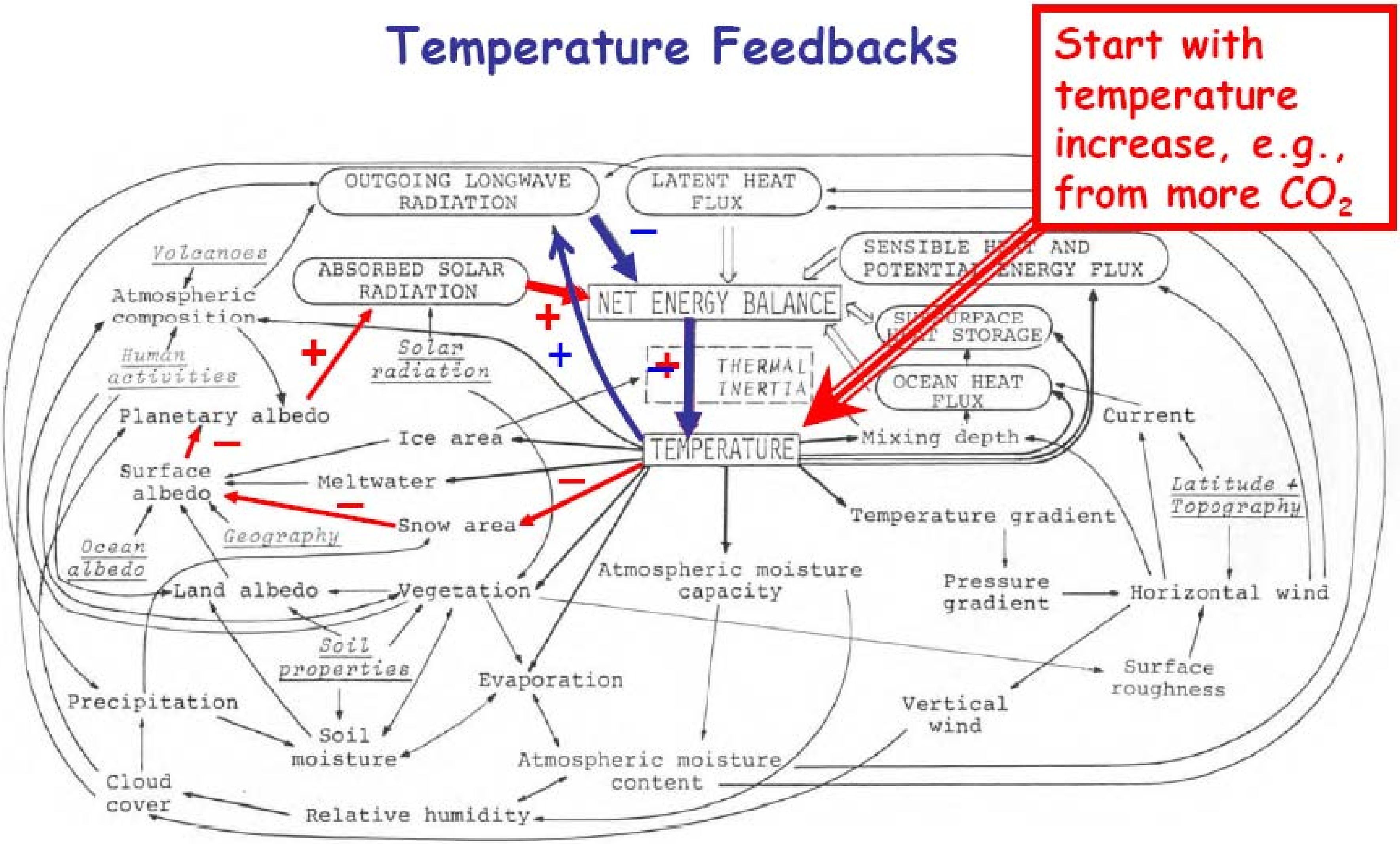
FIGURE SPM-5. Solid lines are multi-model global averages of surface warming (relative to 1980-99) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the plus/minus one standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The gray bars at right indicate the best estimate (solid line within each bar) and the *likely* range assessed for the six SRES marker scenarios. The assessment of the best estimate and *likely* ranges in the gray bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}

From IPCC 4 executive summary

Climate “sensitivity” = global average surface warming following a doubling of carbon dioxide concentrations

range is 2-4.5 C, best estimate is 3 C.

Temperature Feedbacks



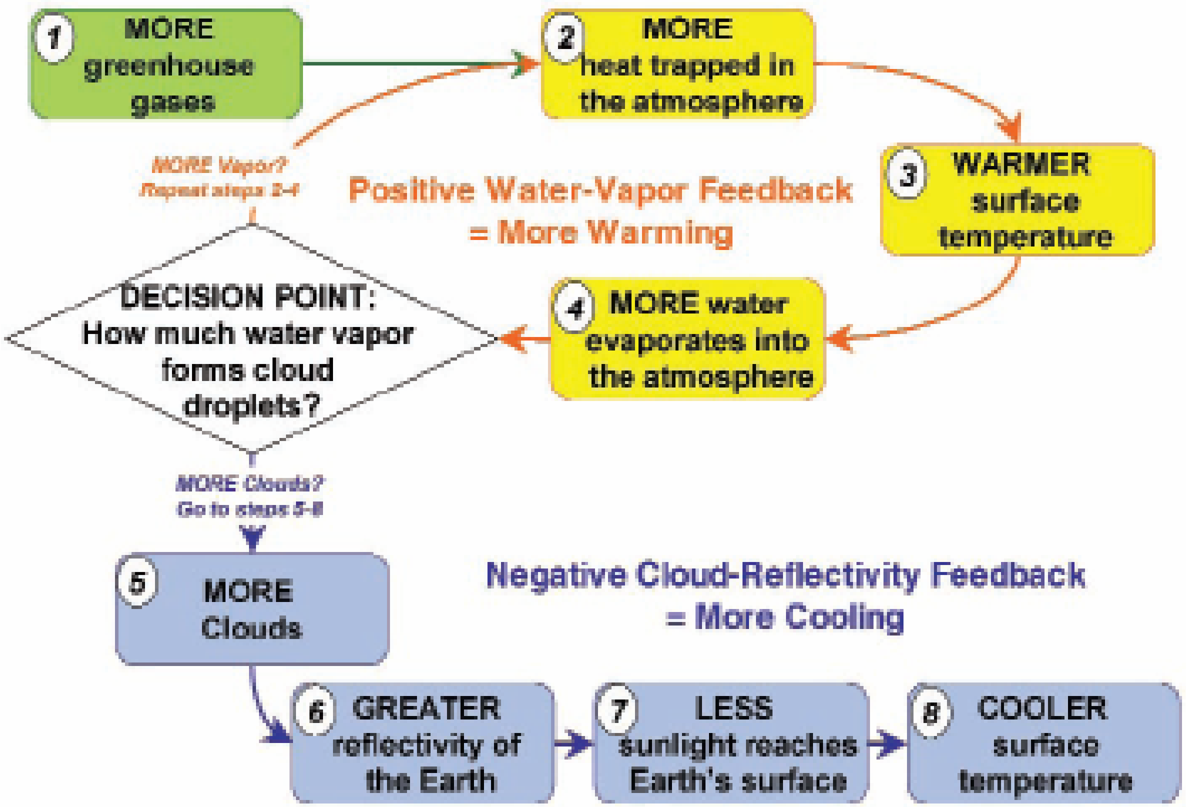


Figure 6. More vapor or more clouds? This schematic illustrates just two out of the dozens of climate feedbacks identified by scientists. The warming created by greenhouse gases leads to additional evaporation of water into the atmosphere. But water vapor itself is a greenhouse gas and can cause even more warming (steps 2-4 are repeated). Scientists call this the "positive water-vapor feedback." On the other hand, if the water vapor leads to the formation of more clouds, some warming may be counteracted because clouds reflect solar radiation (steps 5-8). Clouds also trap heat in the atmosphere. A major research question is how many and what type of clouds will form—low clouds tend to cool (reflect more energy than they trap) and high clouds tend to warm (trap more energy than they reflect).