

The Greenhouse Effect and Man-Made Climate Changes

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Most of the material presented here originates from

- the **Scientific Assessment of Climate Change** prepared by the **Intergovernmental Panel on Climate Change (IPCC)**
- most recent research done at the Max-Planck-Institut für Meteorologie in Hamburg (Cubasch, Santer, Hasselmann)

Overview

Part 1: The Greenhouse Effect

- The physics of the greenhouse effect and the Vostok ice core
- The greenhouse gases and their observed increase

Part 2: The Assessment by the IPCC

- What the IPCC is certain of
- What the IPCC calculates with confidence
- How the IPCC judges the evolution of the last century
- The IPCC scenarios A, B, C and D

Part 3: Present Climate Research

- Tools
- Funding
- Most recent results obtained at the Max-Planck-Institut

Part 4: Aspects of Future Climate Research

- The "global/regional"-scale problem
- What information users want
- Will storms be more frequent or stronger?
- A new science: Impact of climate change of economy and ecology

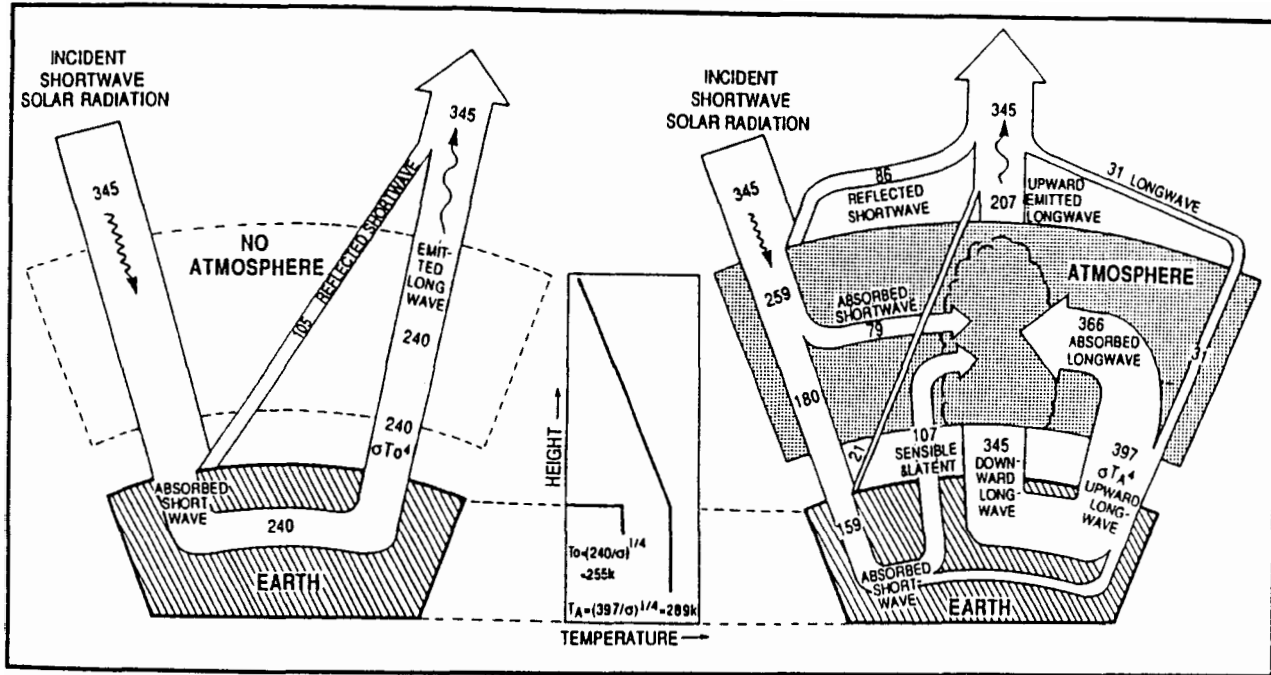
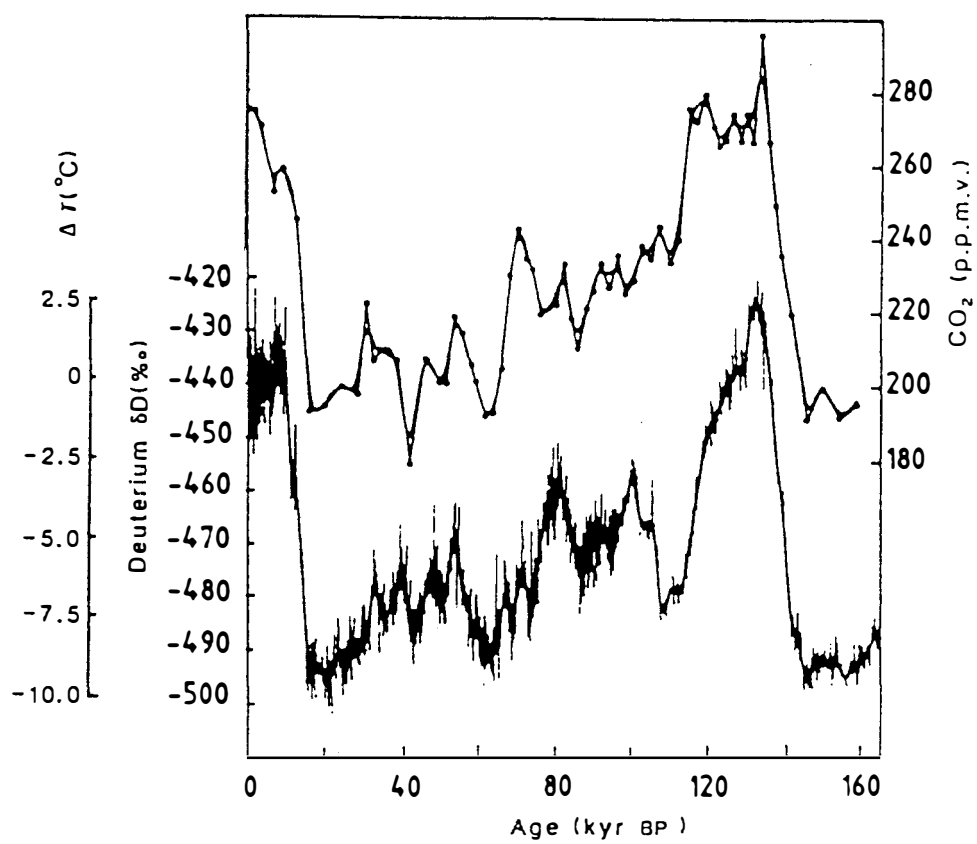
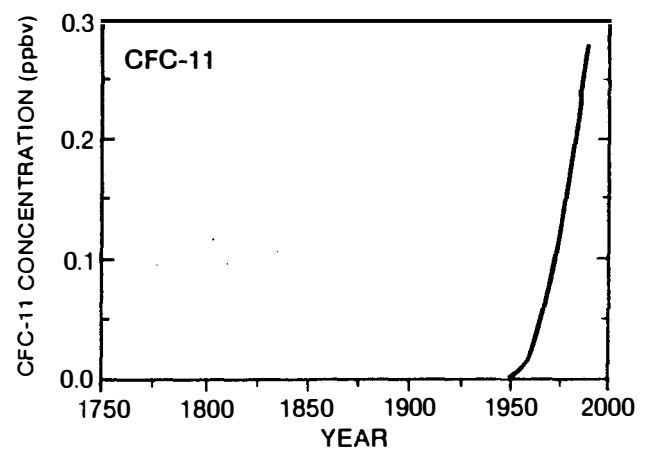
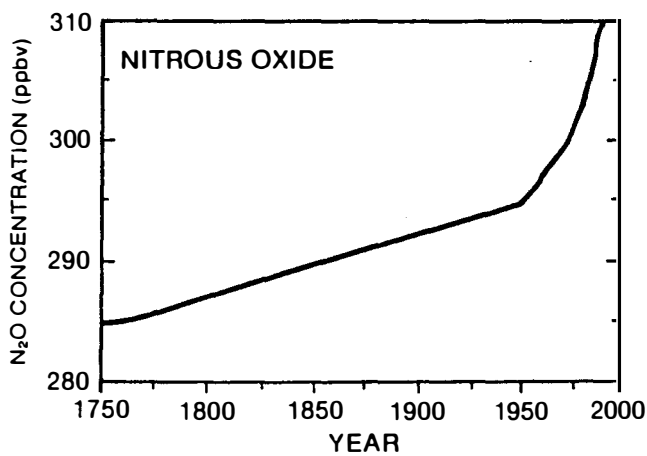
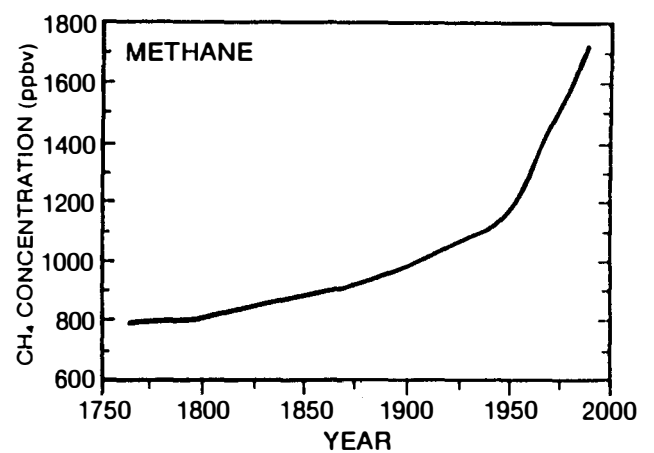
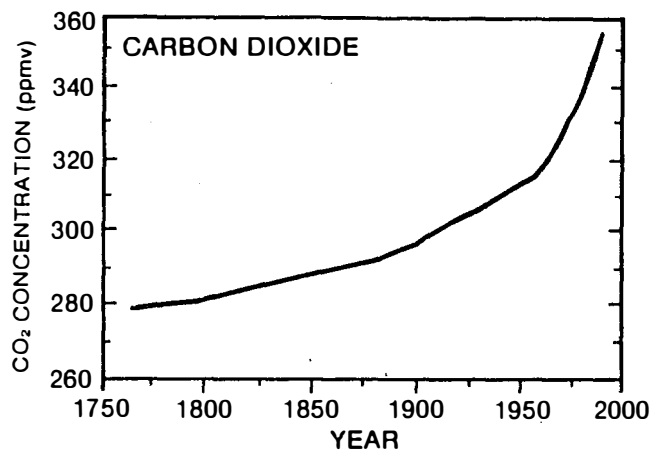
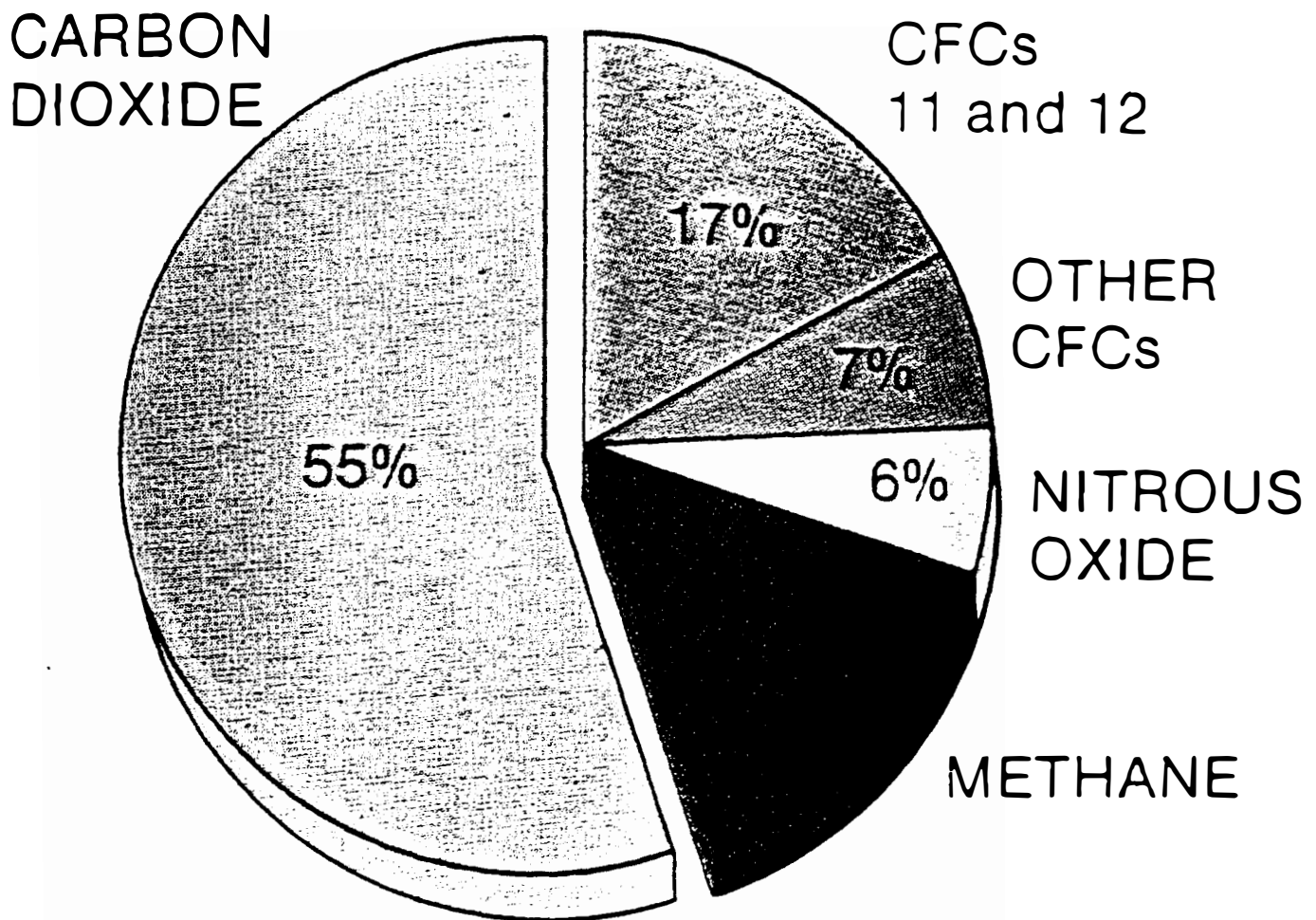


Figure 2. The greenhouse effect. In the absence of an atmosphere (left), the long-wave radiation emitted back to space will exactly equal the absorbed short-wave radiation (assuming an albedo of approximately 0.31) if the surface radiative temperature is 255K. With an atmosphere containing water vapour, carbon dioxide and other greenhouse gases (right) most of the upward radiation emitted from the surface is trapped and re-radiated downward and upward by cloud and greenhouse gases thus warming the earth's surface and cooling the upper layers of the atmosphere. The net long-wave radiative cooling of the atmospheric layer is offset by latent and sensible heat flux upward from the warmed surface. Radiative-convective equilibrium is achieved when the globally averaged surface temperature reaches 289K. In the equilibrium situation, the atmospheric temperature falls off with height to temperatures well below the planetary temperature of 255K as shown schematically above (centre). All heat fluxes are approximate global averages for the present climate and are given in Watts per square metre (Wm^{-2}).





Concentrations of carbon dioxide and methane after remaining relatively constant up to the 18th century, have risen sharply since then due to man's activities. Concentrations of nitrous oxide have increased since the mid-18th century, especially in the last few decades. CFCs were not present in the atmosphere before the 1930s.



The contribution from each of the human-made greenhouse gases to the change in radiative forcing from 1980 to 1990. The concentration from ozone may also be significant but can not be quantified at present

The IPCC is certain of the following:

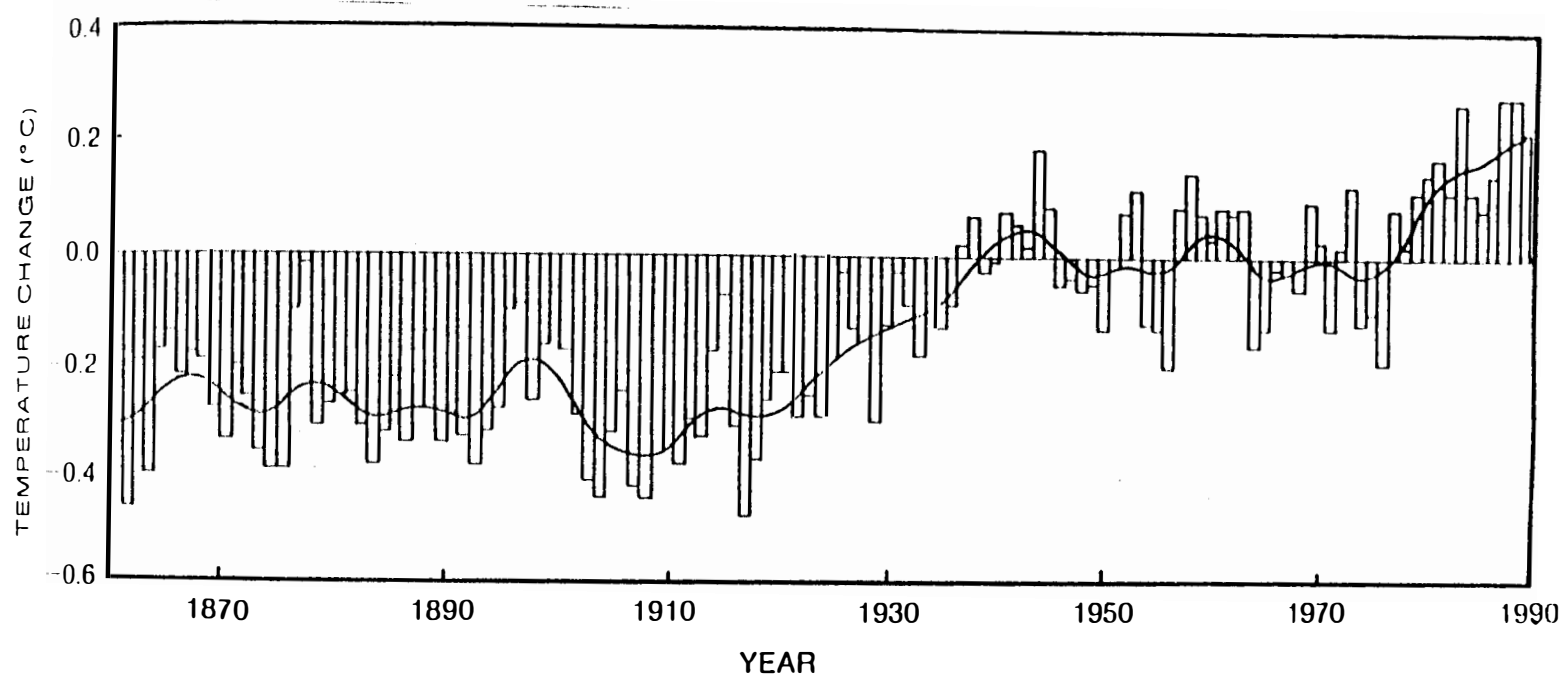
- There is a natural greenhouse effect which already keeps the Earth warmer than it would otherwise be.
- Emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide. These increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface. The main greenhouse gas, water vapour, will increase in response to global warming and further enhance it.

The IPCC calculates with confidence that:

- Some gases are potentially more effective than others at changing climate, and their relative effectiveness can be estimated. Carbon dioxide has been responsible for over half the enhanced greenhouse effect in the past, and is likely to remain so in the future.
- Atmospheric concentrations of the long-lived gases (carbon dioxide, nitrous oxide and the CFCs) adjust only slowly to changes in emissions. Continued emissions of these gases at present rates would commit us to increase concentrations for centuries ahead. The longer emissions continue to increase at present-day rates, the greater reductions would have to be for concentrations to stabilize at a given level.
- The long-lived gases would require immediate reductions in emissions from human activities of over 60% to stabilize their concentrations at today's levels; methane would require a 15-20% reduction.

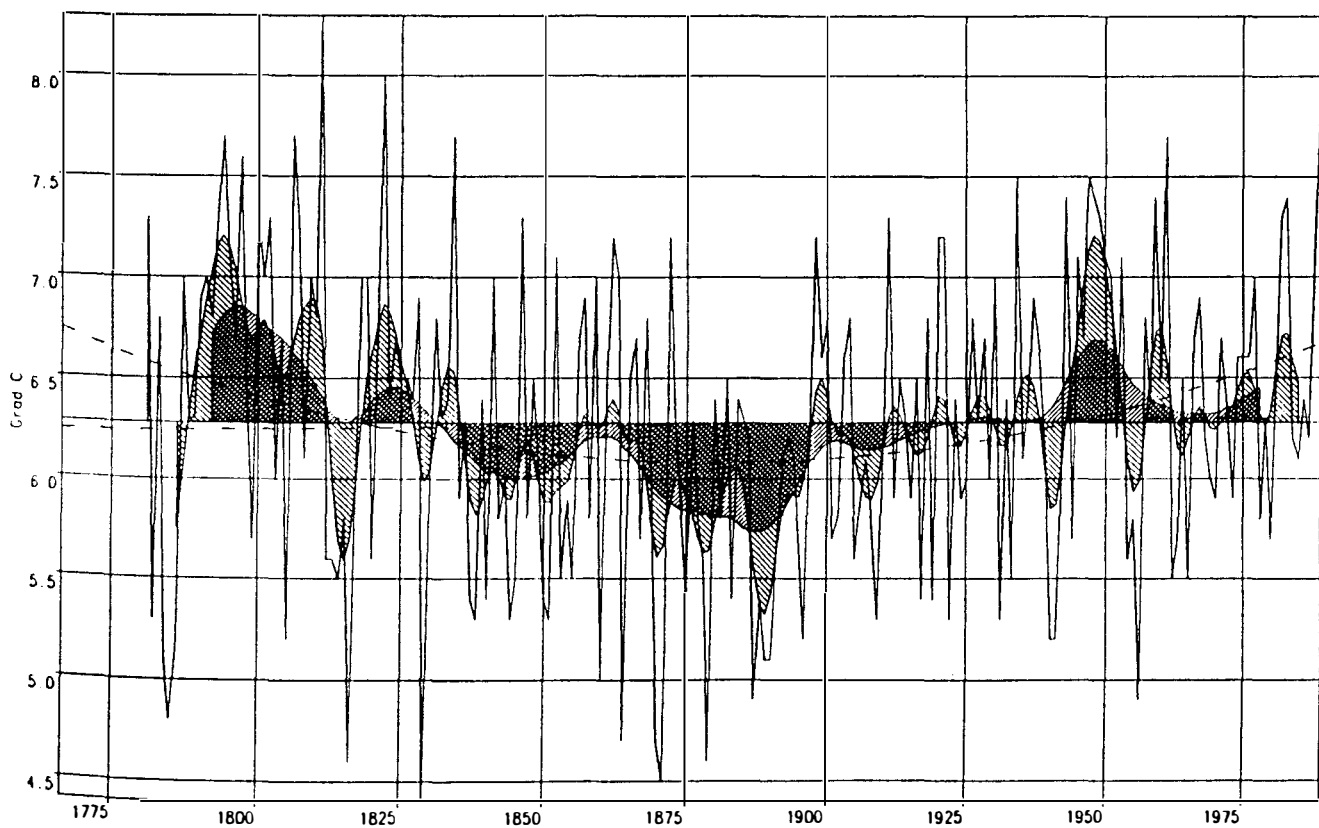
The IPCC's judgement is that:

- Global mean surface air temperature has increased by 0.3°C over the last 100 years, with the five global mean warmest years being in the 1980s. Over the same period global sea level has increased by 10-20cm. These increases have not been smooth with time, nor uniform over the globe.
- The size of this warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability. Thus the observed increase could be largely due to this natural variability; alternatively this variability and other human factors could have offset a still larger human-induced greenhouse warming. The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more.



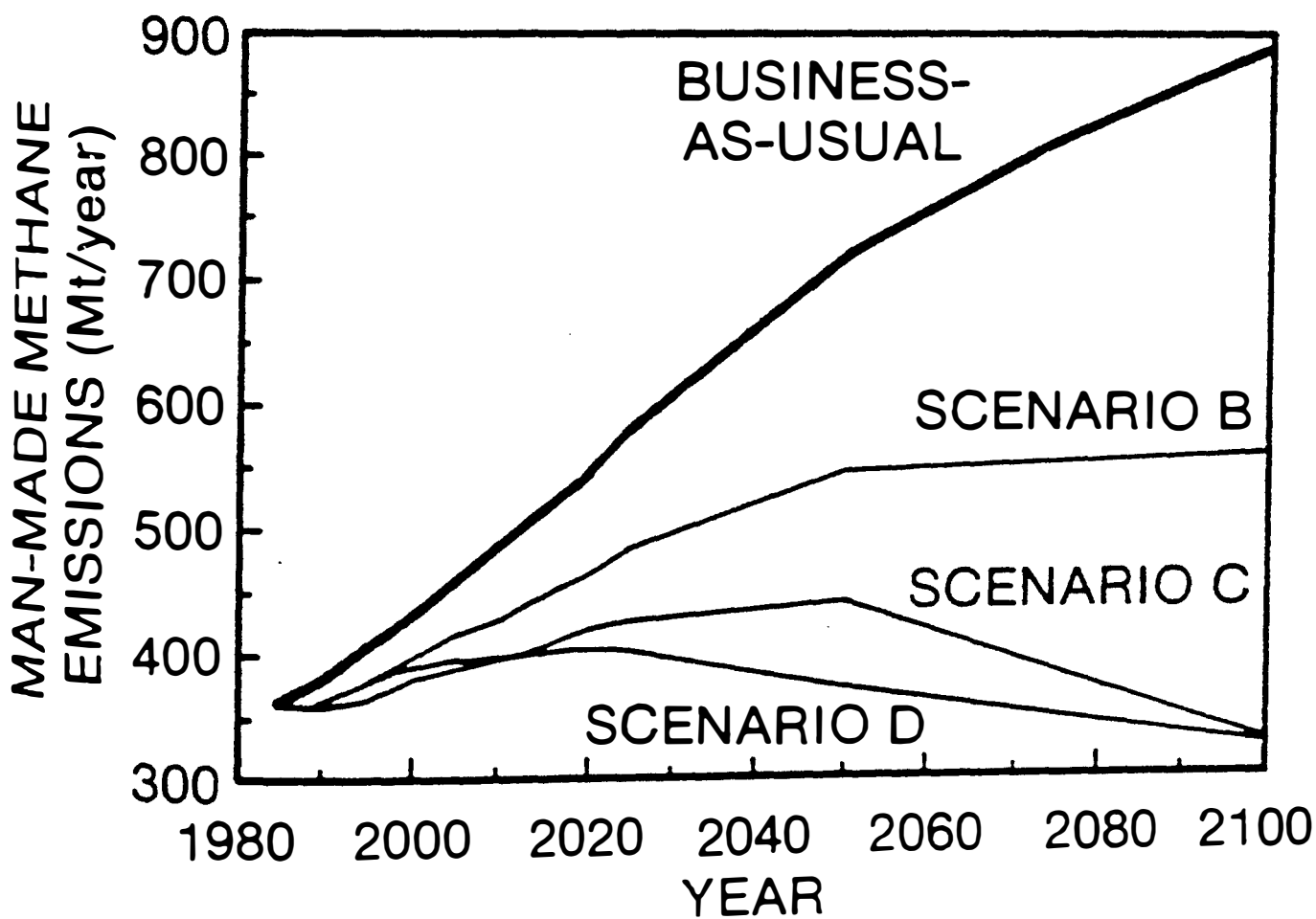
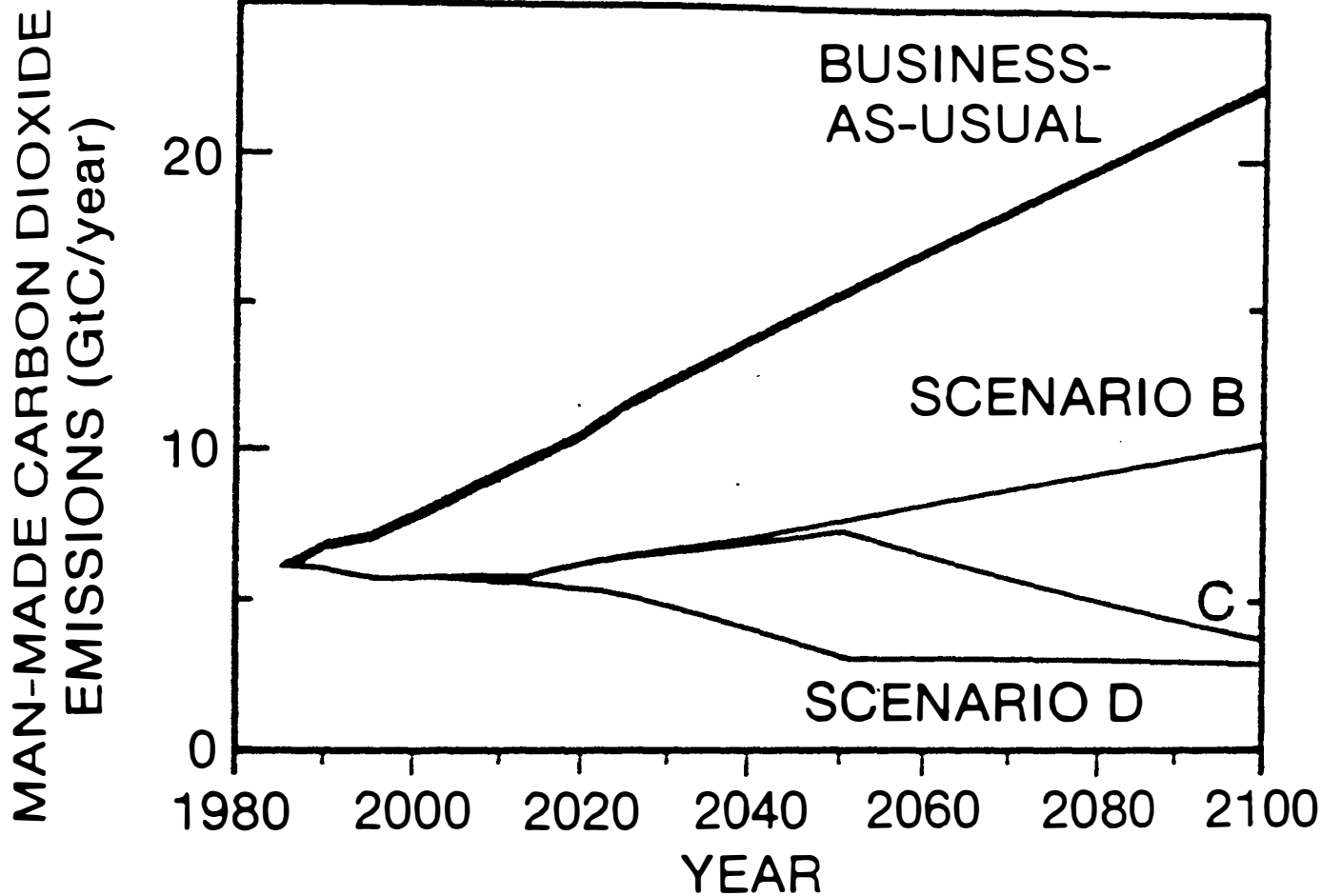
Annual deviation of global mean combined land-air and sea-surface temperature for the period 1861-1980 (shown by bars), relative to the average for 1951-1980. The curve shows the results of a smoothing filter applied to the annual values.

Hohenpeissenberg

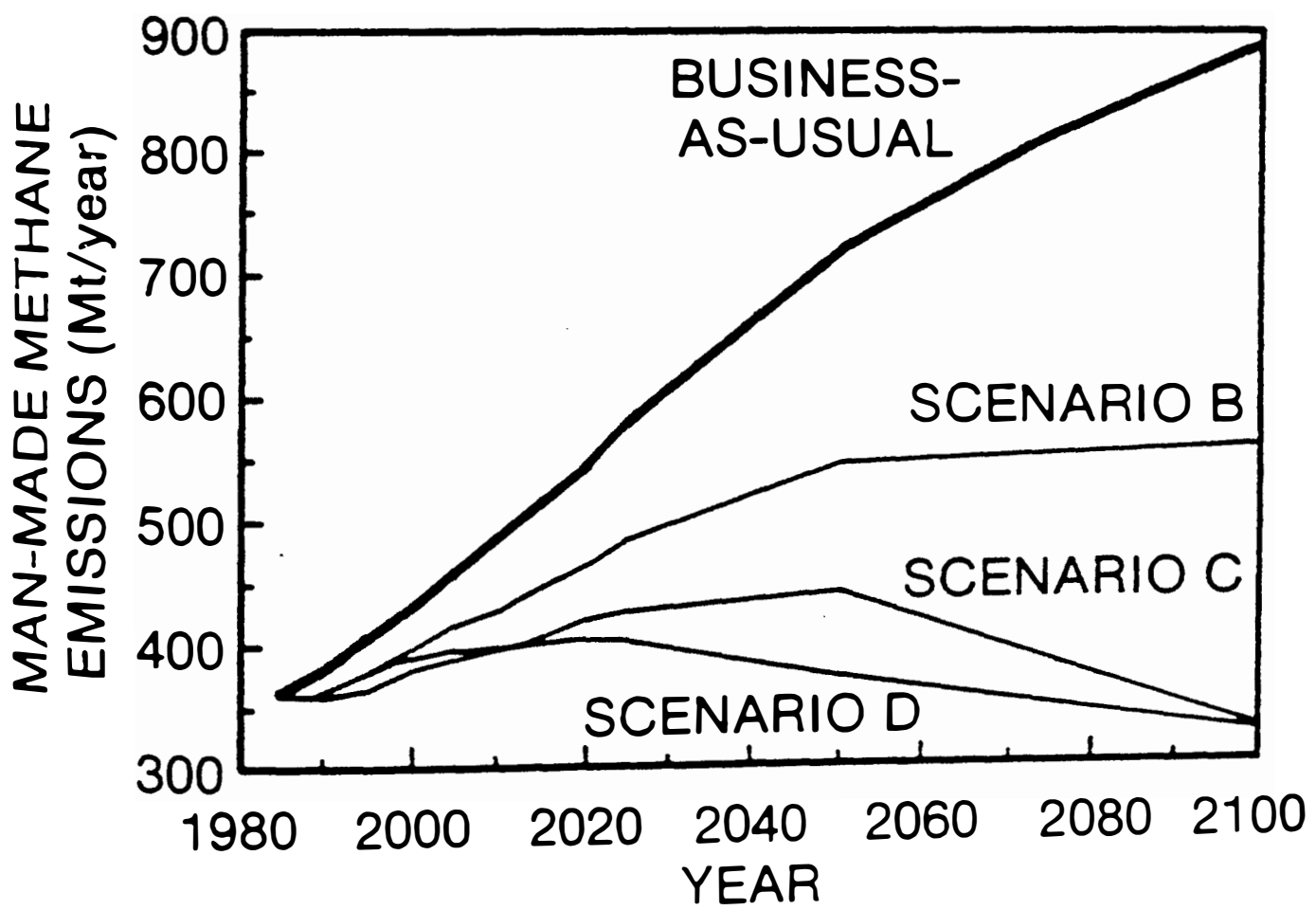
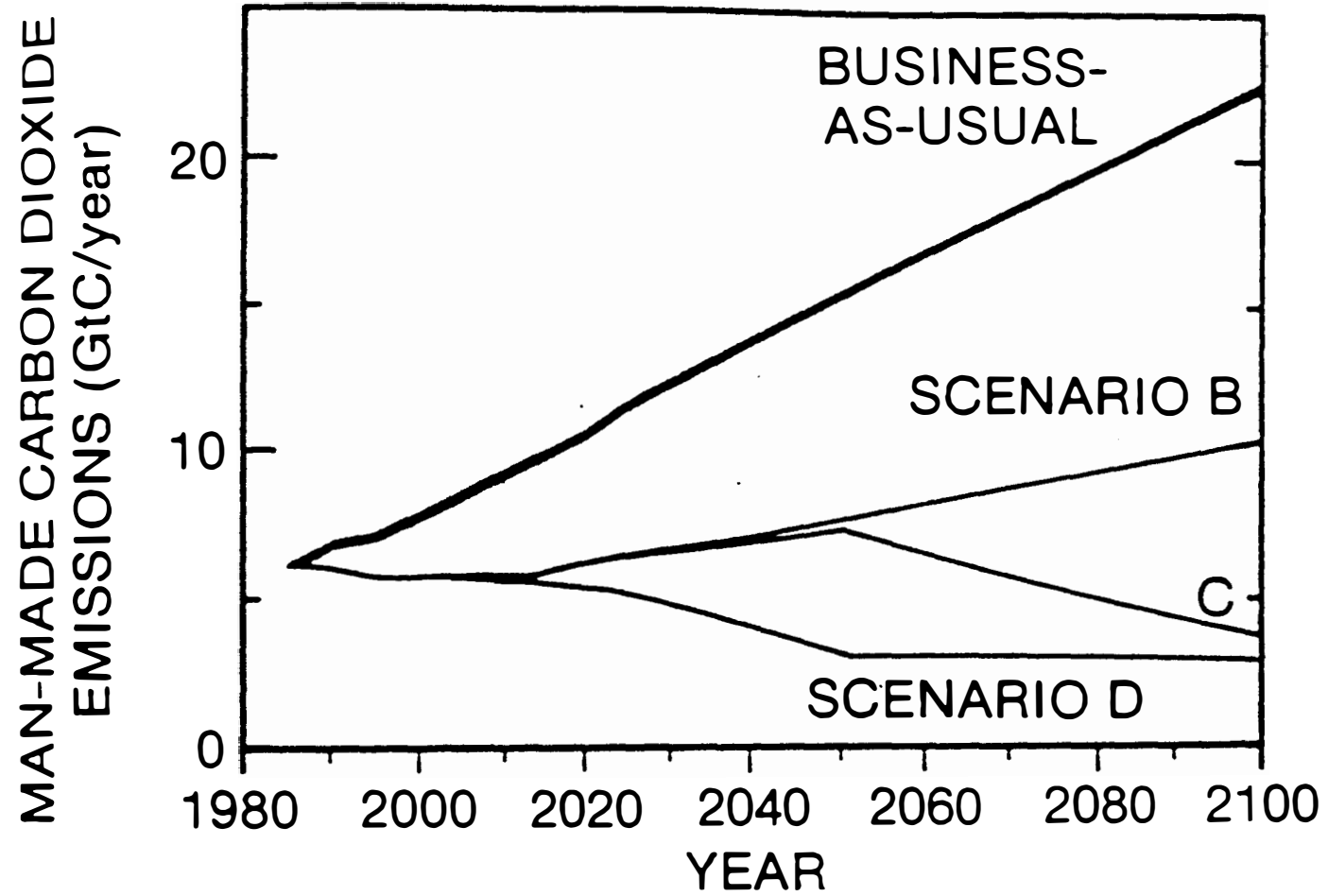


Jahresmitteltemperatur mit Tiefpassfilterung ueber 10 und 30 Jahre

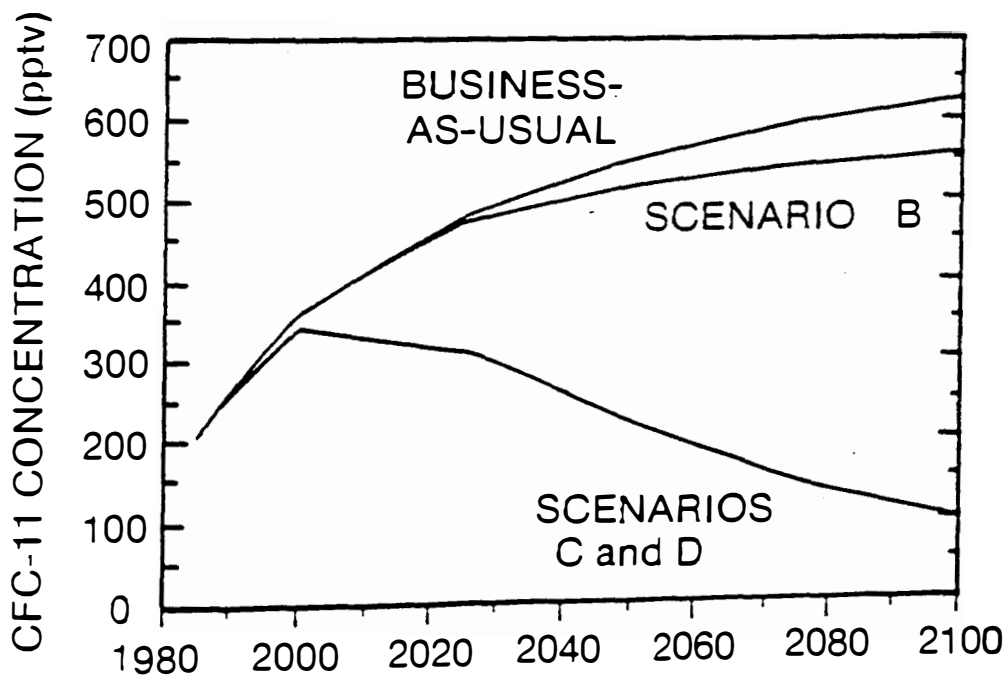
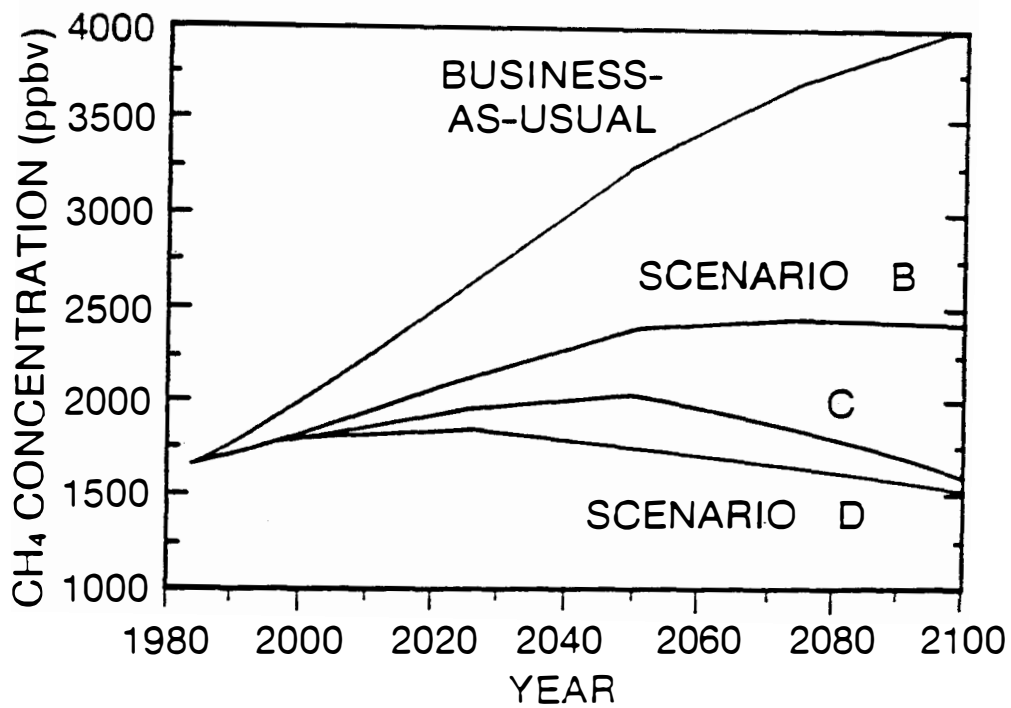
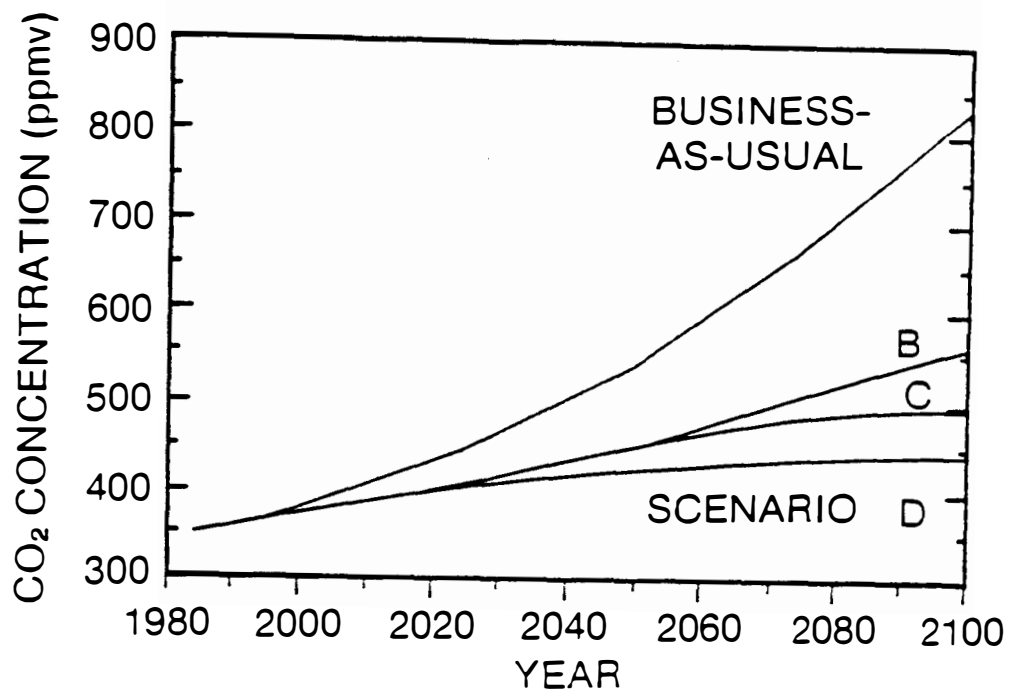
- In the **Business-as-Usual scenario (Scenario A)** the energy supply is coal intensive and on the demand side only modest efficiency increases are achieved. Carbon monoxide controls are modest, deforestation continues until the tropical forests are depleted and agricultural emissions of methane and nitrous oxide are uncontrolled. For CFCs the Montreal Protocol is implemented albeit with only partial participation.
- In **Scenario B** the energy supply mix shifts towards lower carbon fuels, notably natural gas. Large efficiency increases are achieved. Carbon monoxide controls are stringent, deforestation is reversed and the Montreal Protocol implemented with full participation.
- In **Scenario C** a shift towards renewables and nuclear energy takes place in the second half of next century. CFCs are now phased out and agricultural emissions limited.
- For **Scenario D** a shift to renewables and nuclear in the first half of the next century reduces the emissions of carbon dioxide, initially more or less stabilizing emissions in the industrialized countries. The scenario shows that stringent controls in industrialized countries combined with moderated growth of emissions in developing countries could stabilize atmospheric concentrations. Carbon dioxide emissions are reduced to 50% of 1985 levels by the middle of the next century.

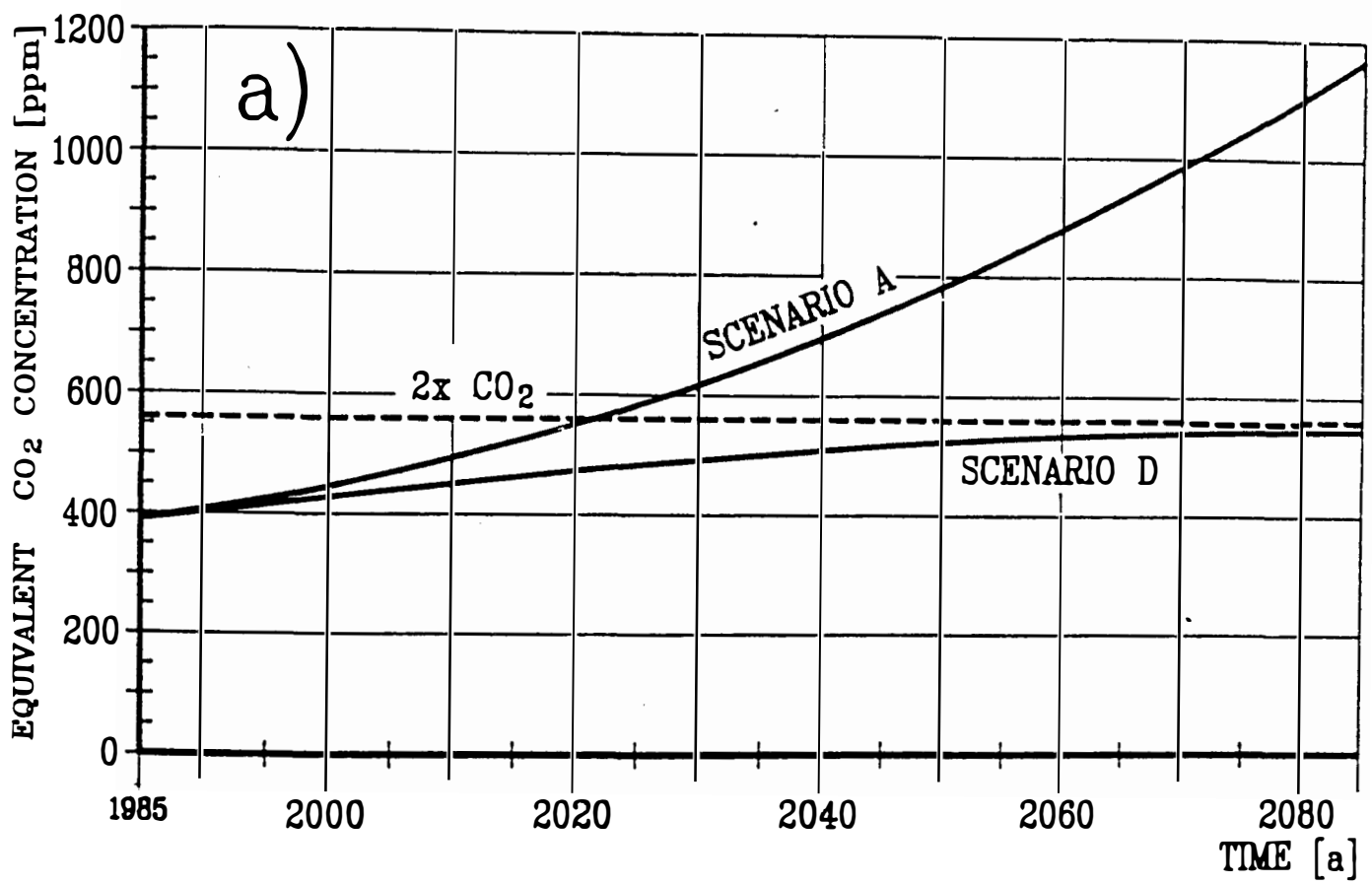


Man-made emissions of carbon dioxide and methane (as examples) to the year 2100, in the four IPCC scenarios



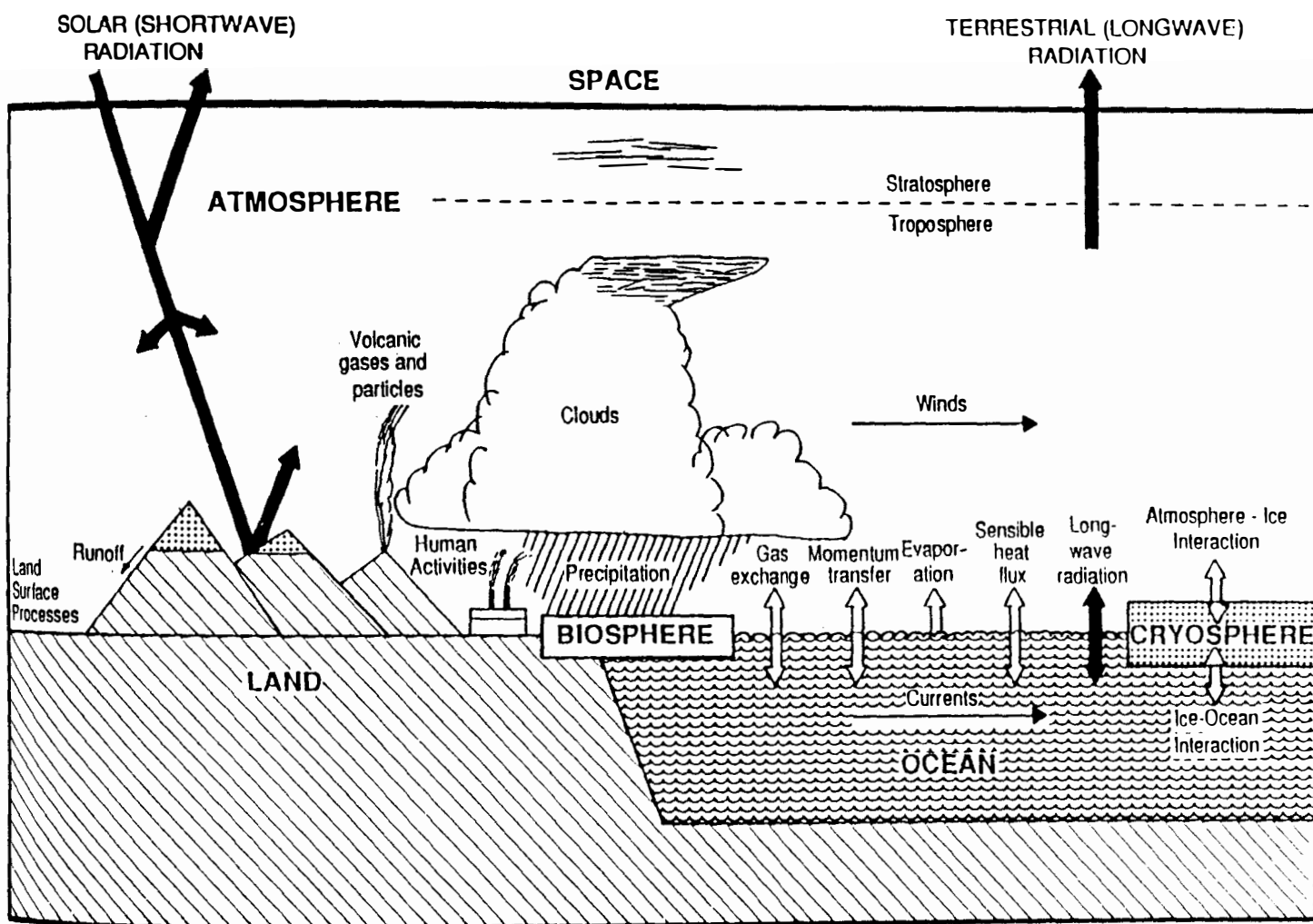
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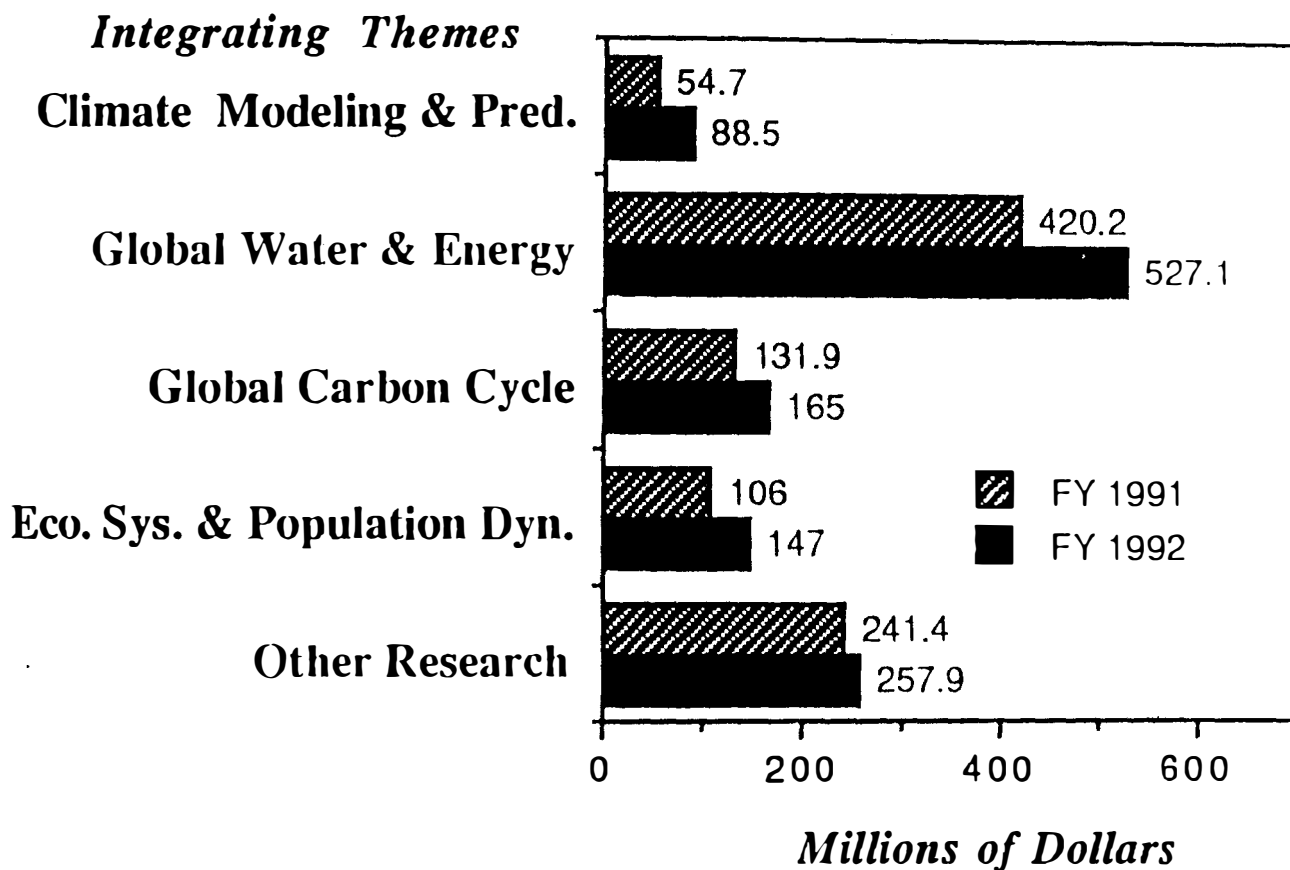


Based on current model results, the IPCC predicts:

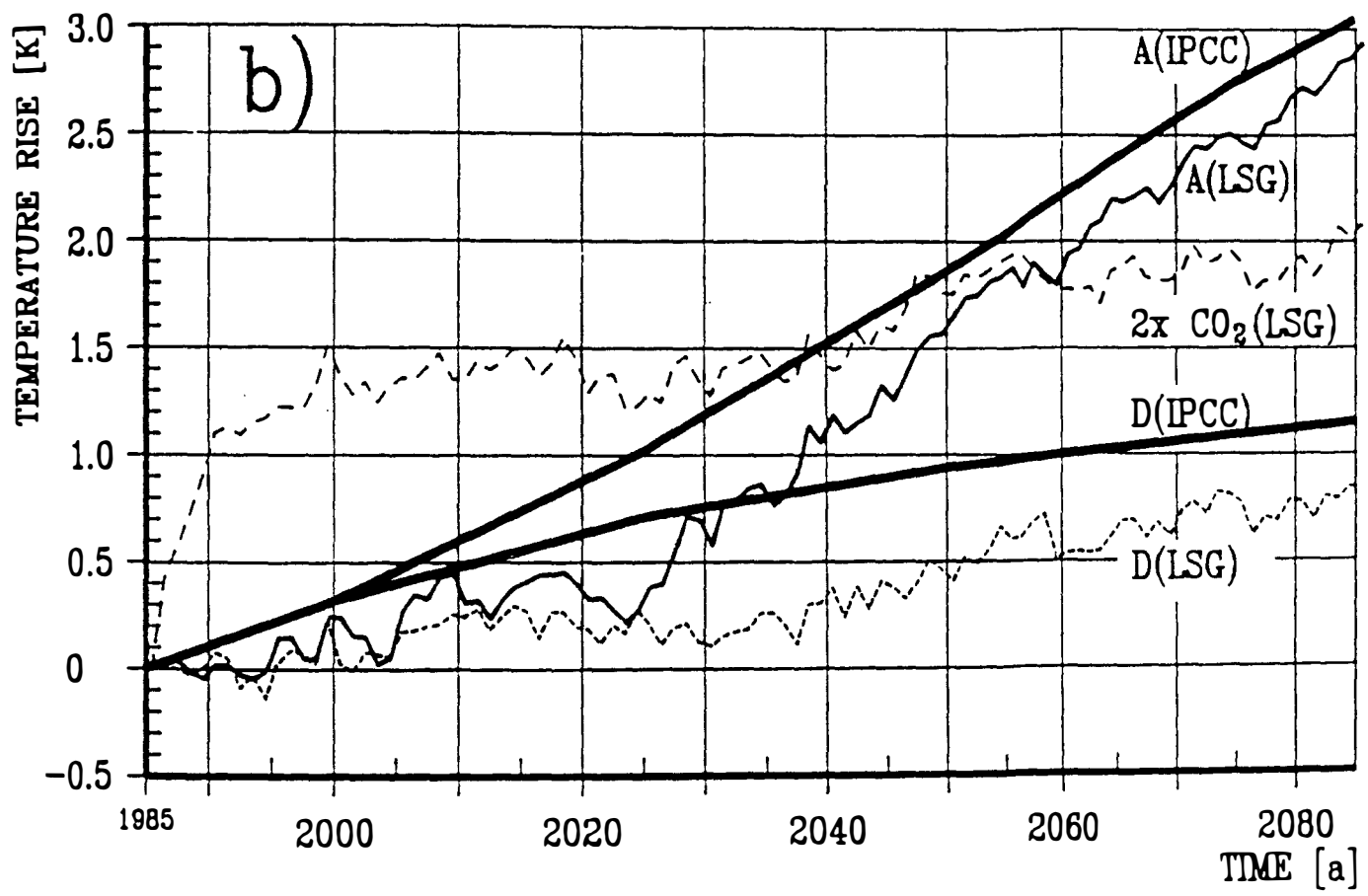
- Under the IPCC Business-as-Usual (Scenario A) emissions of greenhouse gases, a rate of increase of global mean temperature during the next century of about 0.3°C per decade (with an uncertainty range of 0.2°C to 0.5°C per decade); this is greater than that seen over the past 10,000 years. This will result in a likely increase in global mean temperature of about 1°C above the present value by 2025 and 3°C before the end of the next century. The rise will not be steady because of the influence of other factors.
- Under the other IPCC emission scenarios which assume progressively increasing levels of controls, rates of increase in global mean temperature of about 0.2°C per decade (Scenario B), just above 0.1°C per decade (Scenario C) and about 0.1°C per decade (Scenario D).
- That land surfaces warm more rapidly than the ocean, and high northern latitudes warm more than the global mean in winter.



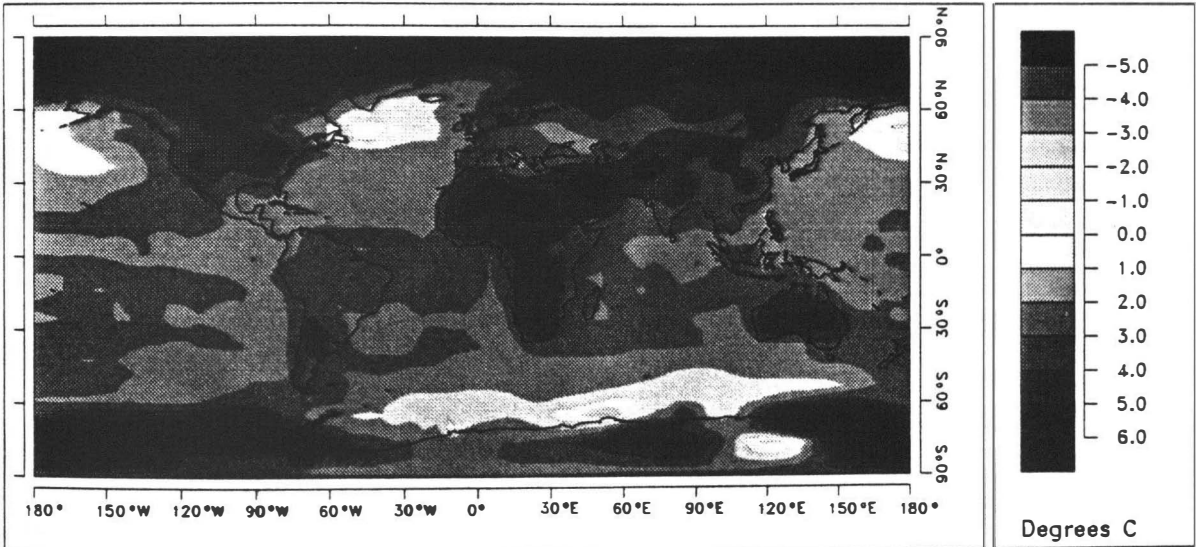
A schematic representation of the components of the global climate system.



U.S. Global change research program budget by integrating themes.

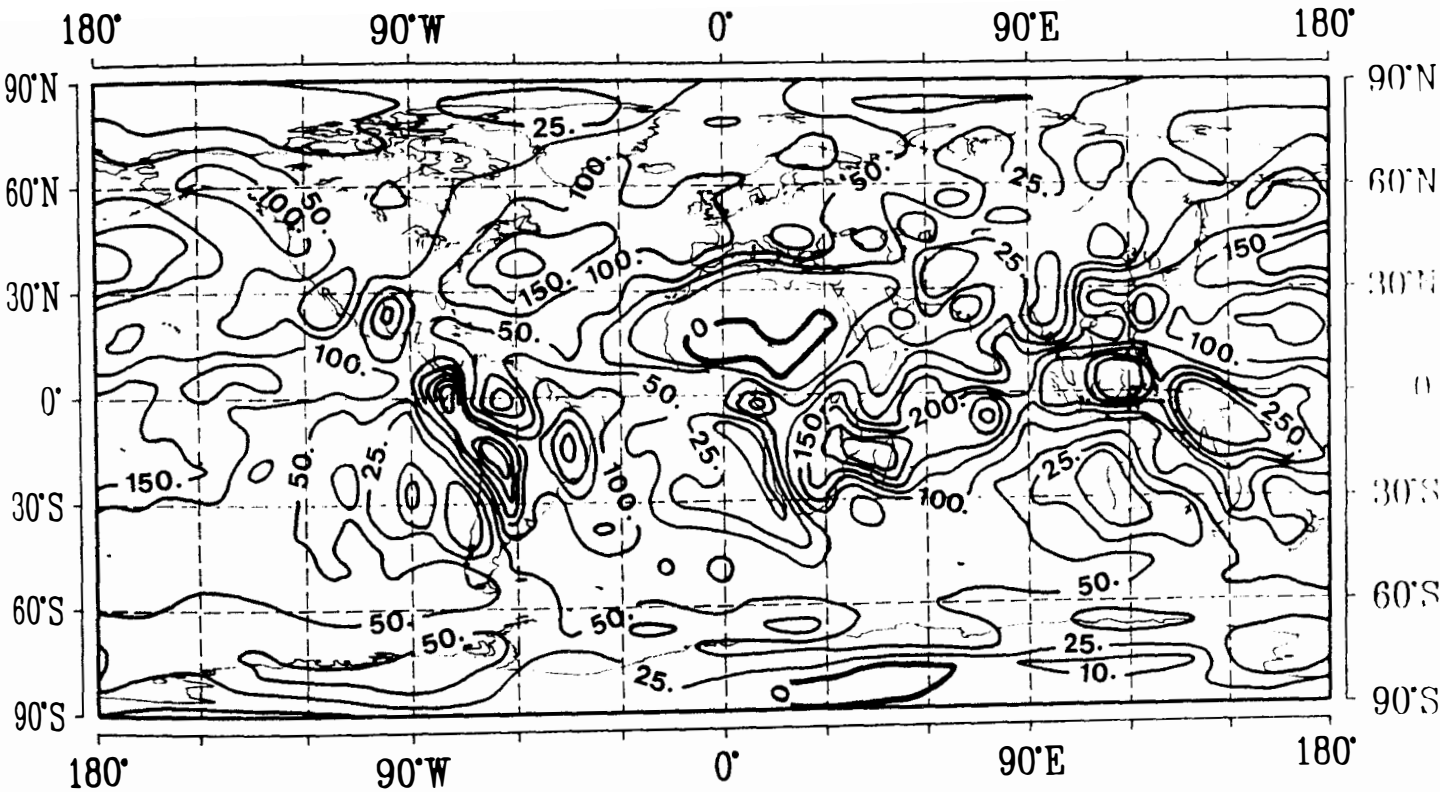


2M TEMPERATURE ECHAM LSG SZA 91-100 MINUS CTL AVE YRS 1-10



LABEL: (167) ANN B.D. Santer. MPI Hamburg. (unweighted) DATE: 06/19/91 TIME: 09:30:08

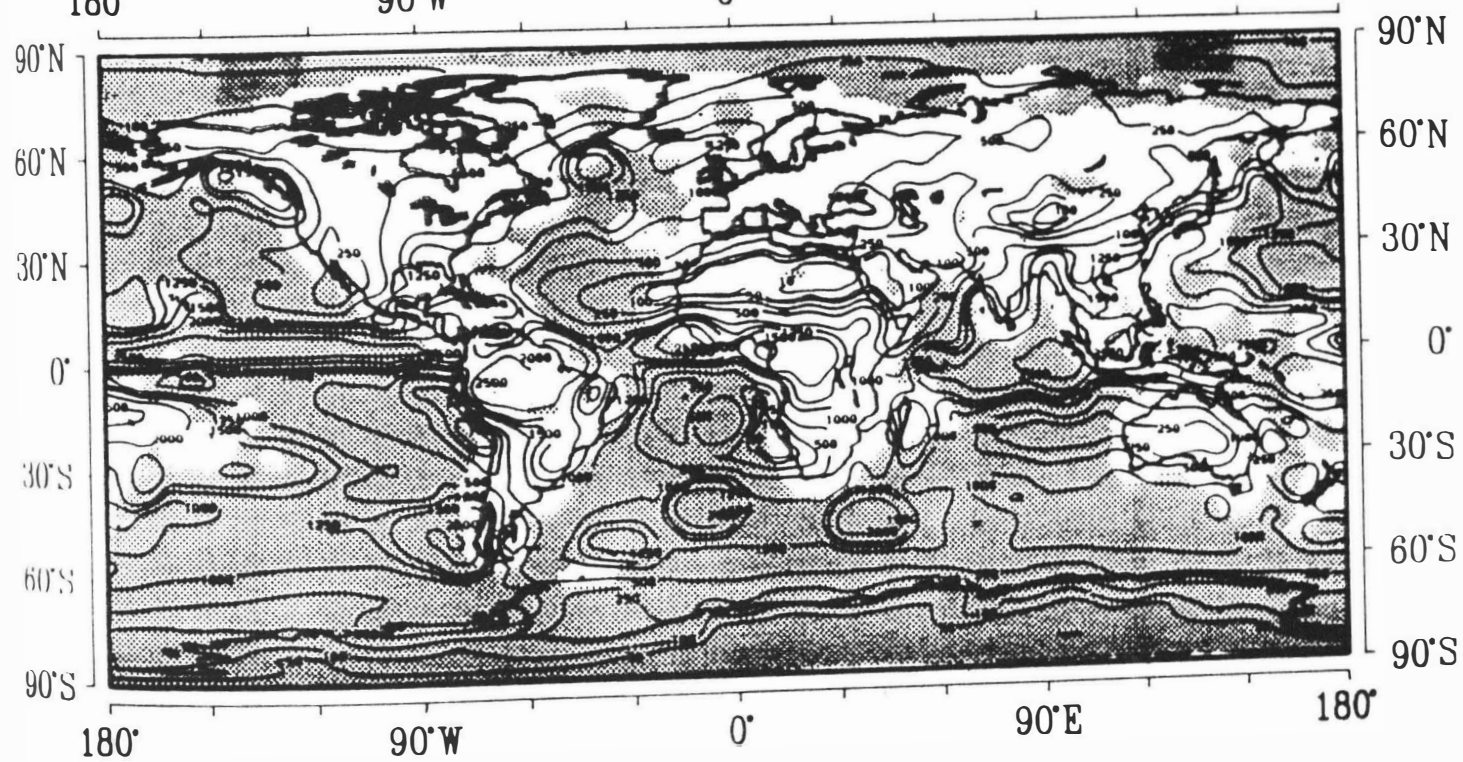
ECHAM1 / LSG



120EDZdb

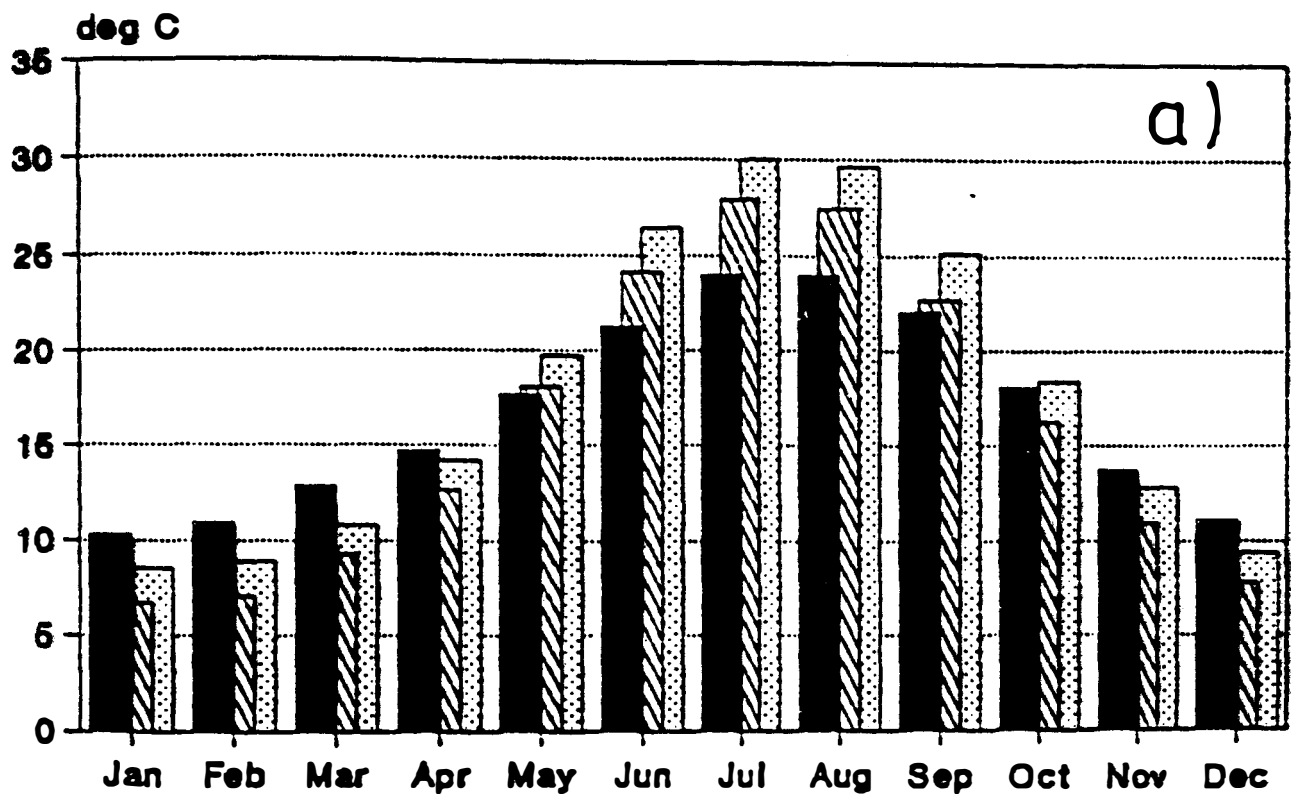
OBSERVED

180° 90°W 0° 90°E 180°

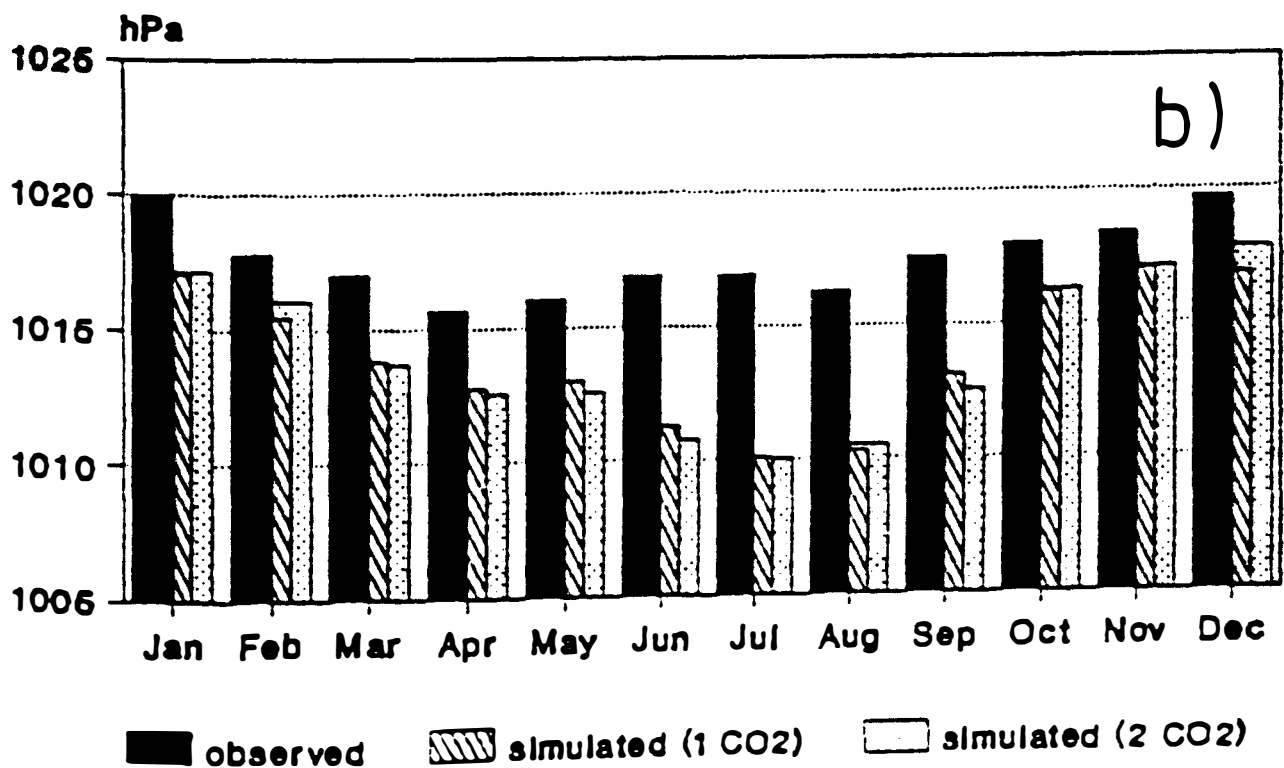


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Iberian Peninsula Area Average Temperature

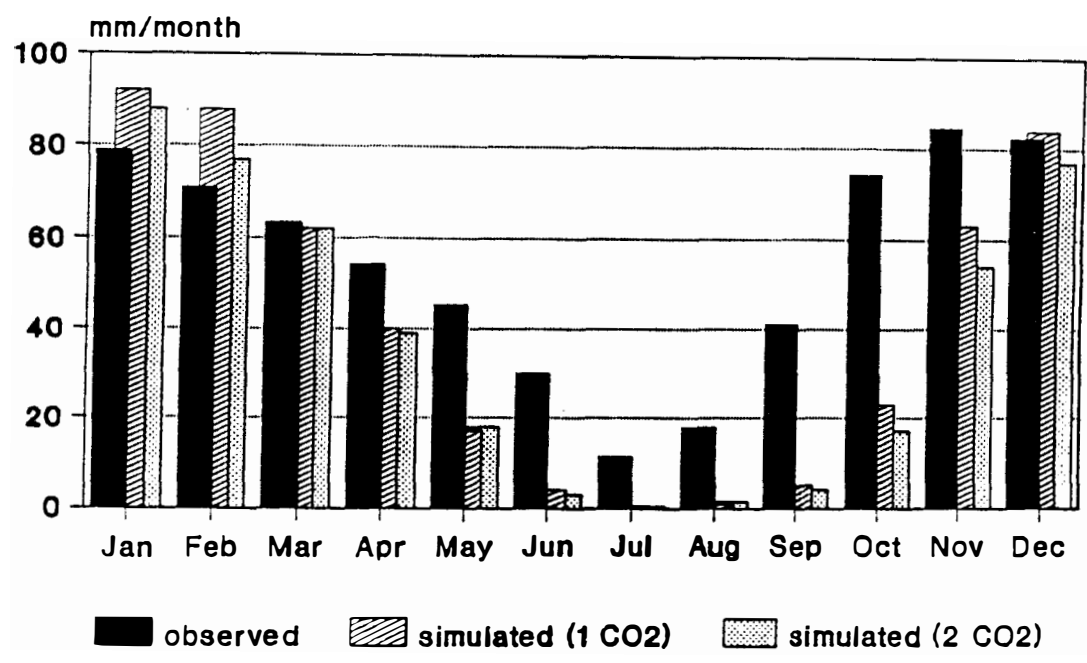


Sea-Level Pressure



Iberian Rainfall

Observed and Simulated



Summary of Major User Needs Identified from Discussions with Scenario Users

Time Scale

Daily values - not necessarily a weather stream

Space Scale

100-km x 100-km grid - specific needs highly variable

Information needed

1. Simple descriptive statistics for individual elements (means and variance, totals, extremes, etc.).
2. Climatic anomaly information, especially concerning **drought** (magnitude and persistence of events).
3. Threshold values (probability of values significant for particular impact).
4. Synoptic information, especially for **storms** (sequences of events and combinations of elements).

Will Storms Increase in a Warmer World?

Storms can have a major impact on society. Will their frequency, intensity or location increase in a warmer world?

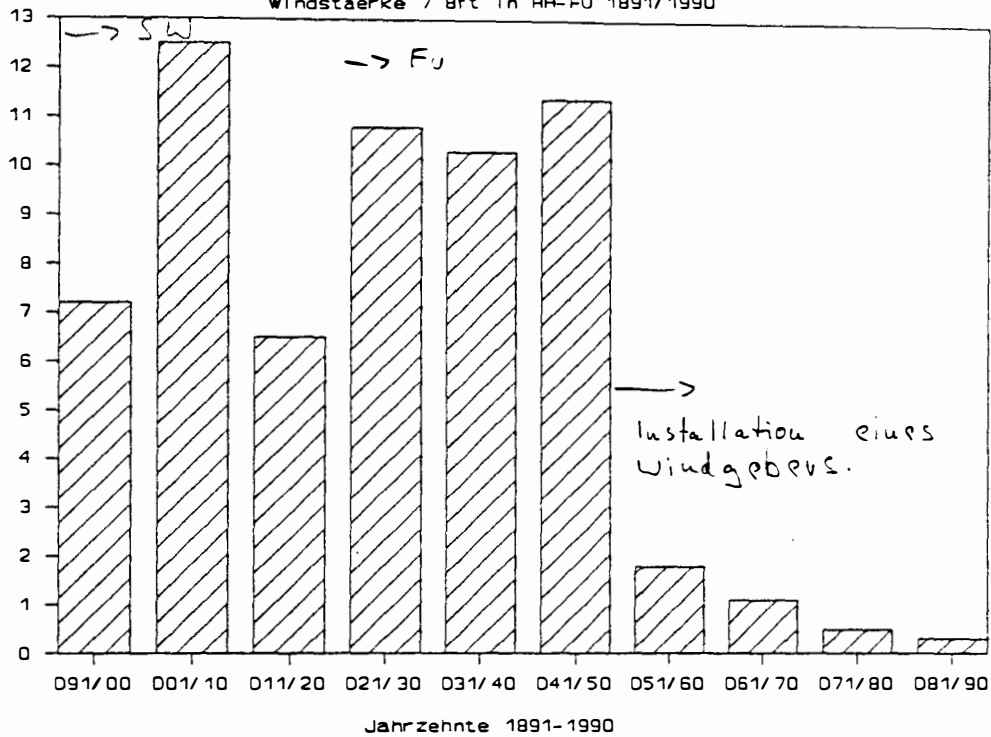
Tropical storms, such as typhoons and hurricanes, only develop at present over seas that are warmer than about 26°C. Although the area of sea having temperatures over this critical value will increase as the globe warms, the critical temperature itself may increase in a warmer world. Although the theoretical maximum intensity is expected to increase with temperature, climate models give no consistent indication whether tropical storms will increase or decrease in frequency or intensity as climate changes; neither is there any evidence that this has occurred over the past few decades.

Mid-latitude storms, such as those which track across the North Atlantic and North Pacific, are driven by the equator-to-pole temperature contrast. As this contrast will probably be weakened in a warmer world (at least in the northern hemisphere), it might be argued that mid-latitude storms will also weaken or change their tracks, and there is some indication of a general reduction in day-to-day variability in the mid-latitude storm tracks in winter in model simulations, though the pattern of changes vary from model to model. Present models do not resolve smaller-scale disturbances, so it will not be possible to assess changes in storminess until results from higher-resolution models become available in the next few years.

Mittlere Anzahl an Tagen mit

Windstaerke 7 Bft in HH-FU 1891/1990

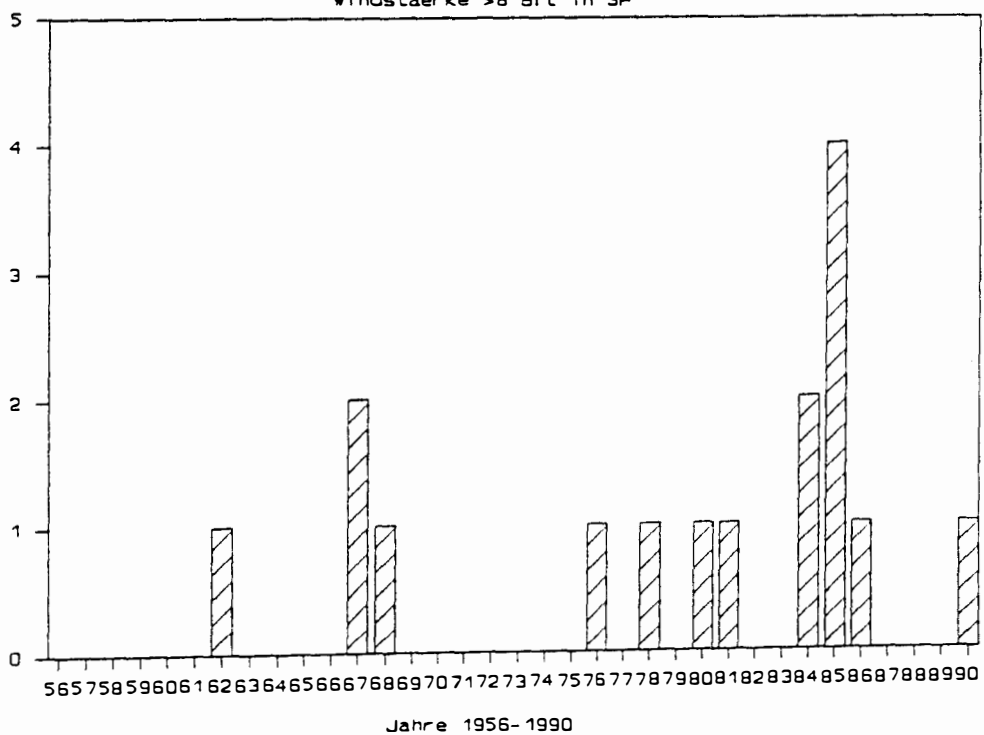
Zahl der 14-Uhr-Beob. mit 7 Bft pro Jahr



Zahl der Tage mit

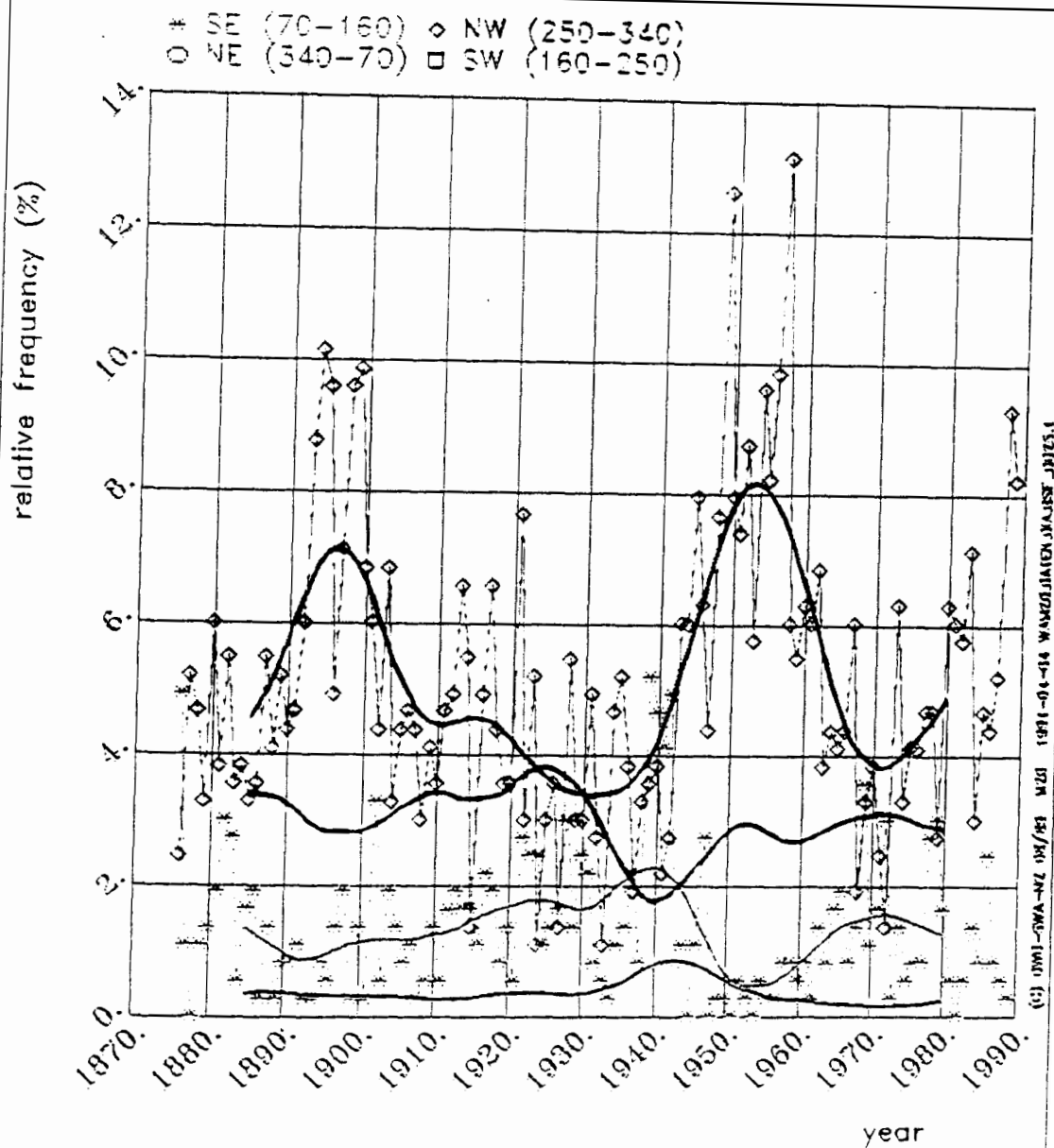
Windstaerke >8 Bft in SP

Zahl der Tage im Jahr



DEUTSCHER WETTERDIENST
-Seewetteramt Hamburg-

DWD



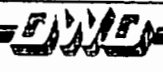
GEOSTROPHIC WIND

from pressure triangle Borkum-Hamburg-Fanoë.

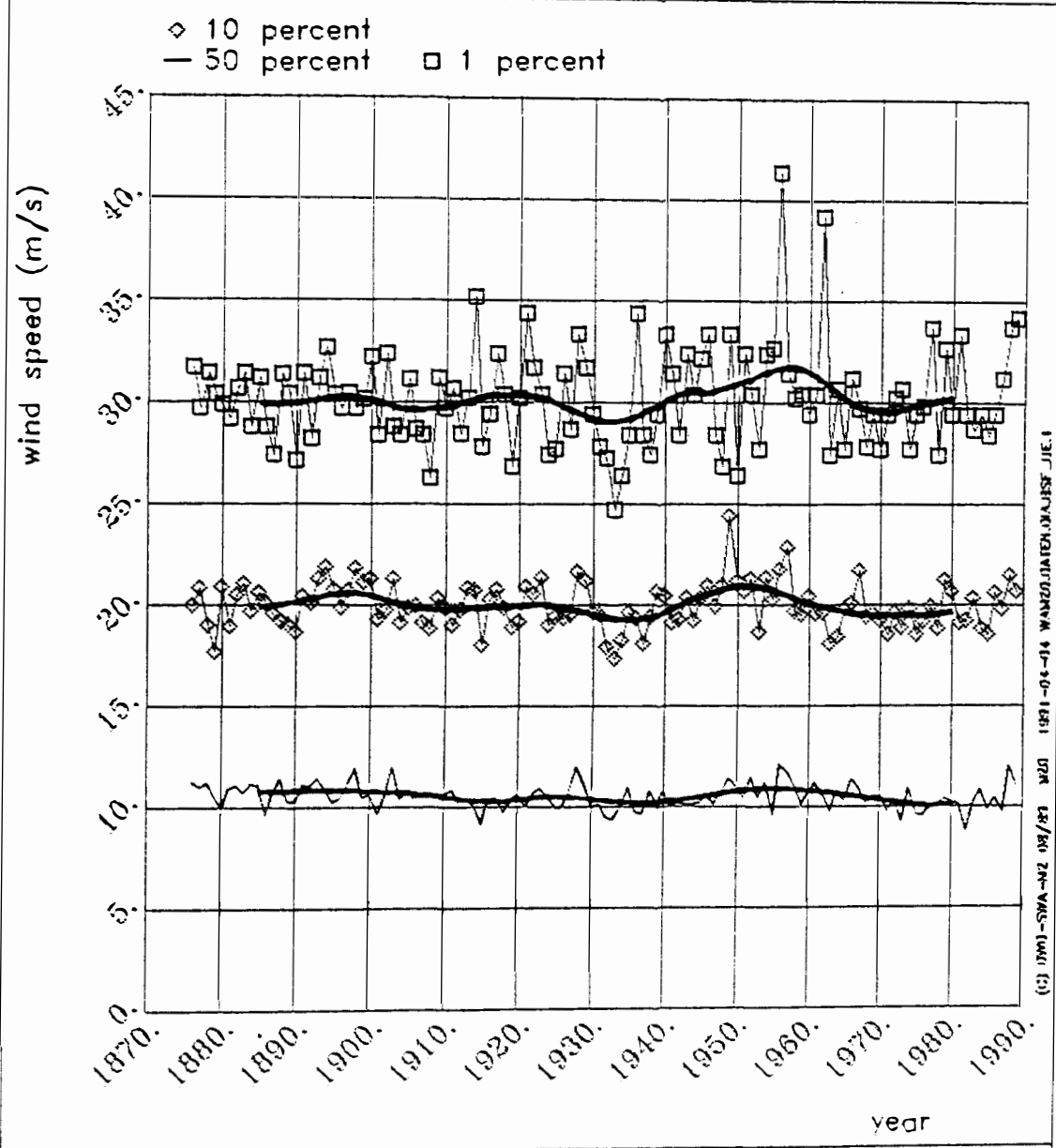
Annual frequencies of wind speeds > 20 m/s

for 4 directional sectors of 90 degrees.

Sector 250-340 are "surge enhancing" directions.



DEUTSCHER WETTERDIENST
-Seewetteramt Hamburg-



GEOSTROPHIC WIND
from pressure triangle Borkum-Hamburg-Fanoe.
Annual wind speeds for different levels
of probability of exceedance.

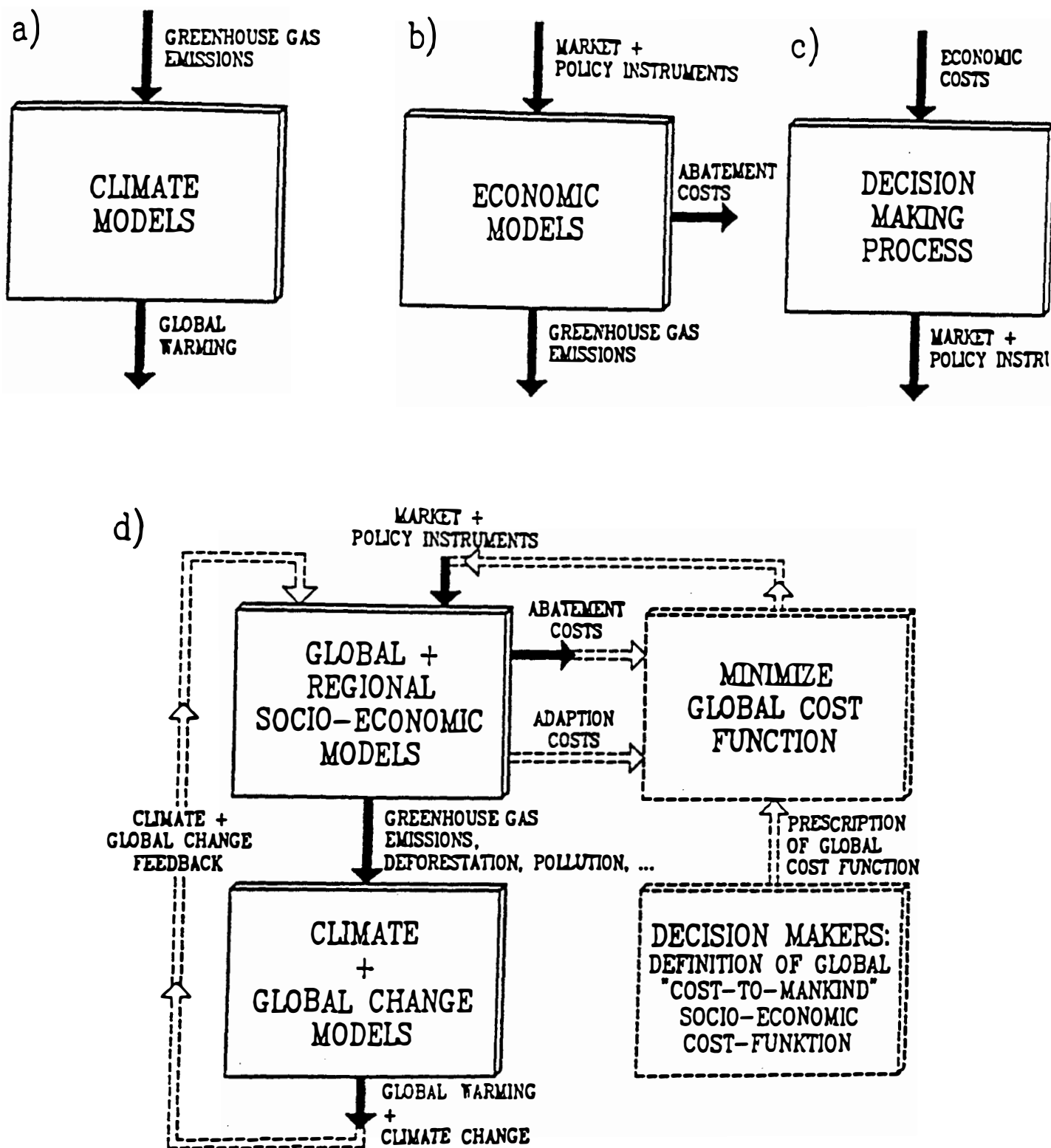


Fig. 1: Integration of climate models (panel a), economic models (panel b) and models of decision making process (panel c) in comprehensive Global Environment and Man (GEM) model (panel d).

GLOBAL WARMING POTENTIALS

The warming effect of an emission of 1 kg of each gas relative to that of carbon dioxide.
These figures are best estimates calculated on the basis of the present-day atmospheric composition

	Time Horizon		
	20 yr	100 yr	500 yr
Carbon dioxide	1	1	1
Methane (including indirect)	63	21	9
Nitrous oxide	270	290	190
CFC-11	4500	3500	1500
CFC-12	7100	7300	4500
HCFC-22	4100	1500	510

Global Warming Potentials for a range of CFCs and potential replacements are given in the full text

SUMMARY OF KEY GREENHOUSE GASES AFFECTED BY HUMAN ACTIVITIES

	Carbon Dioxide	Methane	CFC-11	CFC-12	Nitrous Oxide
Atmospheric concentration	ppmv	ppmv	pptv	pptv	ppbv
Pre-industrial (1750-1800)	280	0.8	0	0	288
Present day (1990)	353	1.72	280	484	310
Current rate of change per year	1.8 (0.5%)	0.015 (0.9%)	9.5 (4%)	17 (4%)	0.8 (0.25%)
Atmospheric lifetime (years)	(50-200)*	10	65	130	150

ppmv=parts per million by volume;

ppbv=parts per billion (thousand million) by volume;

pptv=parts per trillion (million million) by volume.

ESTIMATES FOR CHANGES BY 2030

(IPCC Business-as-Usual scenario; changes from pre-industrial)

The numbers given below are based on high-resolution models, scaled to be consistent with our best estimate of global mean warming of 1.8°C by 2030. For values consistent with other estimates of global temperature rise, the numbers below should be reduced by 30% for the low estimate or increased by 50% for the high estimate. Precipitation estimates are also scaled in a similar way.

Confidence in these regional estimates is low

Central North America (35°-50°N 85°-105°W)

The warming varies from 2 to 4°C in winter and 2 to 3°C in summer. Precipitation increases range from 0 to 15% in winter whereas there are decreases of 5 to 10% in summer. Soil moisture decreases in summer by 15 to 20%.

[Redacted]

The warming varies from 1 to 2°C throughout the year. Precipitation changes little in winter and generally increases throughout the region by 5 to 15% in summer. Summer soil moisture increases by 5 to 10%.

[Redacted]

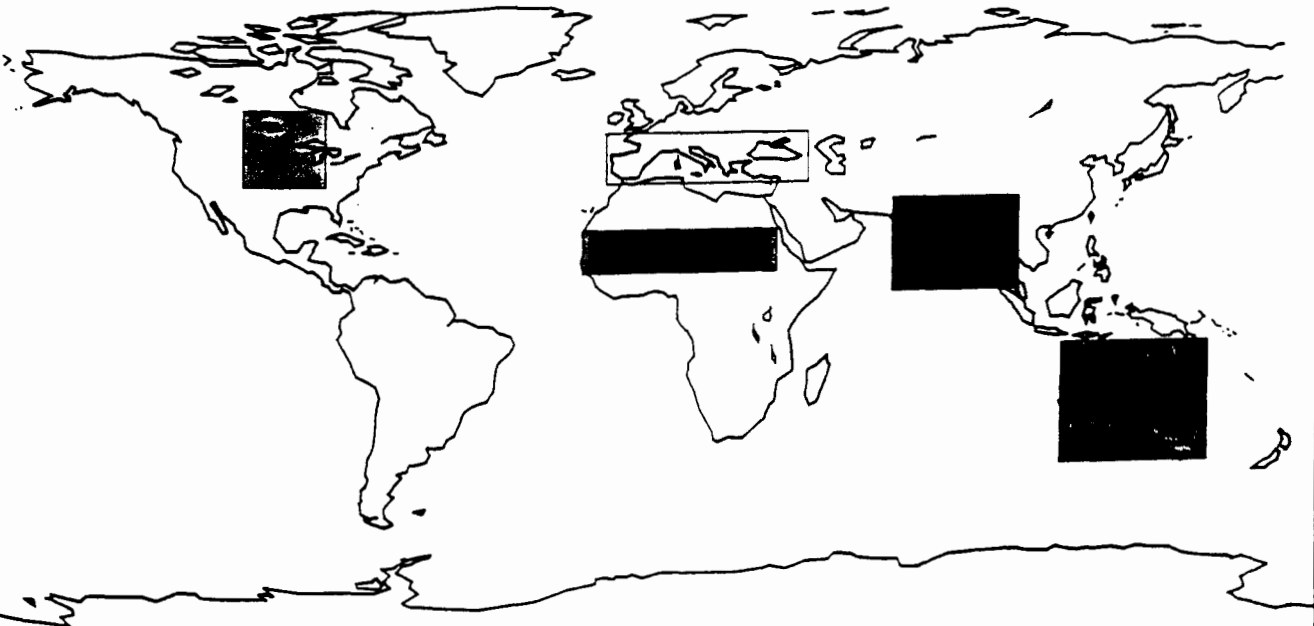
The warming ranges from 1 to 3°C. Area mean precipitation increases and area mean soil moisture decreases marginally in summer. However, throughout the region, there are areas of both increase and decrease in both parameters throughout the region.

Southern Europe (35°-50°N 10°W-15°E)

The warming is about 2°C in winter and varies from 2 to 3°C in summer. There is some indication of increased precipitation in winter, but summer precipitation decreases by 5 to 15%, and summer soil moisture by 15 to 25%.

Western India (5°-10°N 75°-85°E)

The warming ranges from 1 to 2°C in summer and is about 2°C in winter. Summer precipitation increases by around 10%, but the models do not produce consistent estimates of the changes in soil moisture. The area averages hide large variations at the sub-continental level.



Map showing the locations and extents of the five areas selected by IPCC

Wellenlänge in Mikrometern

100

20

10

8

1.0

0.5

0

— Wasserdampf

1.0

0.5

0

— Kohlendioxid

- - - Ozon

1.0

0.5

0

· — · Lachgas

..... Methan

FCKW

1.0

0.5

0

Durchlässigkeit

