The CO2 Newsletter, created, published, and edited by William N. Barbat, ran from 1979 to 1982.

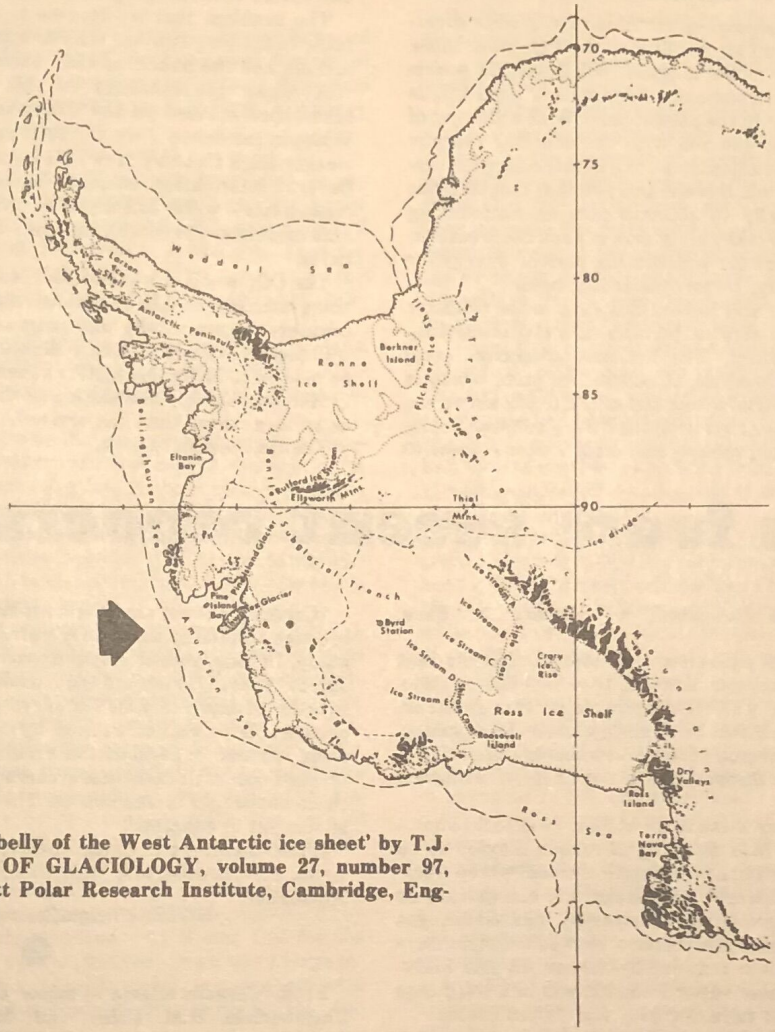
In 2025, the family of Mr. Barbat donated an original set of all issues to Dr. Marc Hudson, and agreed that these could be digitised and placed online as a resource for anyone who wants to understand how long we've known about the carbon dioxide and global warming problem.

CO_2 Newsletter©

Volume 3, Number 5 **July-August, 1982**

A bimonthly summary of advances in knowledge of the CO2-greenhouse problem, and of the social, political, and economic implications.

'Weak underbelly' of Antarctic ice described



From 'The weak underbelly of the West Antarctic ice sheet' by T.J. Hughes in JOURNAL OF GLACIOLOGY, volume 27, number 97, 1981, published by Scott Polar Research Institute, Cambridge, England.

Possible collapse of the West Antarctic ice sheet led by surges of the Thwaites and Pine Island Glaciers into the ice-free Pine Island Bay of the Amundsen Sea may come as the result of CO_2-induced climatic warming. Such destructive tendencies have been described in papers by C.S. Lingle, J.A. Clark, R.H. Thomas, G.H. Denton, and T.J. Hughes in the Journal of Glaciology in 1979.

The Thwaites Glacier presently terminates as a huge floating ice tongue 200 km long, thought to be near the beginning of a surge, and Pine Island Glacier terminates in a calving bay extending 30 km into the ice stream, which may be toward the end of a surge.

In 1981 in this journal, Hughes drew together many observations and published mathematical models to formulate a plausible scenario for West Antarctic ice-sheet collapse. Grounding-line retreat of that major body may be initiated by accelerated surge of these unstable glaciers. Drawdown of ice by such surge at the present divides between the Pine Island-Thwaites glacial basin and the Ronne and Ross glacial basins is expected to hasten retreat of the grounding lines in the latter basins by reducing the input of their ice streams. Hughes also has outlined preliminary tests of this concept, of which some criteria reportedly have been confirmed.

Many glaciologists remain skeptical that the West Antarctic ice sheet could be destroyed as rapidly as the Hudson's Bay remnant of the great Laurentide ice sheet was apparently destroyed (in 200 years), but none has so far expressed an assurance that such rapid destruction will not happen.

A comprehensive description of the original CLIMAP project and the resulting elaboration on the vulnerability of the West Antarctic ice sheet is presented in **The last great ice sheets (Wiley-Interscience, 1981, $95).**

CO_2 Newsletter is published bimonthly by Wm. N. Barbat Associates (Energy Consultants), P.O. Box 24, Teton Village, Wyoming 83025. Deadlines for contributed articles and letters are Jan. 1, March 1, May 1, July 1, Sept. 1, and Nov. 1. U.S. subscription rates: Companies, institutions, or agencies $40 per year, which allows for unlimited 'in-house' reproduction rights; individuals and university libraries $20 per year (6 issues). Back issues $2.50 each to non-subscribers; $1.25 each to subscribers. Foreign airmail, if sent from the U.S., add $4.

European subscription rate inclusive of postage: Swiss francs 48.—per year (6 issues).

Telephone: News or subscription information [307] 739-9799.

For all European subscriptions and for issues of back copies, contact Rudolf Trüb, CUMULUS FACHBUCHHANDLUNG, 5000 Aarau, Switzerland, Telephones 064 22 50 20 or 22 37 98.

©1982 by William N. Barbat

"Knowledge increases one's responsibility." —Victor Hugo

Editorial

Three recent articles in the popular press illustrate a wide divergence of views on the gravity and tractability of the CO_2-greenhouse problem. Roger Revelle's article in the August 1982 **Scientific American** anticipates no profound environmental degradation until CO_2 is doubled over pre-industrial levels in the atmosphere. With a slowing of the CO_2 buildup expected by Revelle and with the doubling thereby deferred sufficiently, agricultural adjustment to climatic change is considered within the reach of research. Revelle also feel that coastal cities can gradually shift geographically to accommodate an encroaching shoreline, provided sea level rise takes place slower than the worst expected case. No need is expressed for substituting nuclear energy for fossil fuels, particularly petroleum, on an accelerated basis.

An article by William Kellogg and Robert Schware in the Summer 1982 **Foreign Affairs** brings the serious impacts of a continued CO_2-buildup very close to the present. The authors anticipate levels reaching the 'first stage' of seriousness at 360 to 370 ppm, which is about 25 to 30% above pre-industrial levels and **only 6 to 9% above the present level**, which "even if concerted programs were adopted immediately, this scale of change would probably still occur within at most 40 years." The authors are to be commended for greatly upgrading the knowledge that policy planners need by quantifying potential agricultural and industrial productivity changes.

Kellogg and Schware help foster social action further by suggesting strategies to help slow the CO_2 increase: "energy conservation, adoption of renewable (non-fossil fuel) energy sources, increased use of nuclear energy, and reforestation . . ." However, they talk only of **postponing** the 'second stage' (doubling) through concerted international action rather than bringing the CO_2 buildup to a halt at some target level.

The problem that we foresee is that treating countermeasures as futile in the long run will tend to make them futile in the eyes of policy makers and the public, as they become self-fulfilling prohpecies.

A major breakthrough in this matter is represented in well-researched articles on the CO_2 problem by Betsy Bernfeld and Dan Whipple published July 23, 1982 in the environmentally-oriented bi-weekly **High Country News** ($15 per year, Box K, Lander, Wyoming). Several information sources—including all past issues of the **CO_2 Newsletter**—were consulted in great depth for material, and the unfavorable and favorable outlooks were all aired in highly readable articles.

The CO_2 problem was not addressed as being hopeless, but rather as being understandable by rational analysis and—while very difficult to counteract—not wholly unmanageable. In our estimation, only a few well-placed articles of such enlightenment in the popular press would be needed to bring this matter squarely into the public forum in a timely fashion. Possibly the halting of the CO_2 buildup may then be viewed as an idea whose time has arrived.

Thanks, Betsy and Dan.

Excerpts from recent reports

From **'CO_2-Climate Models Defended', by Richard A. Kerr, SCIENCE 13 August 1982:**

"A National Research Council panel has concluded (*) that the best estimate of the long-term, global warming due to a doubling of atmospheric carbon dioxide is still 3° ± 1.5°C, despite claims that global climate models of the greenhouse effect have exaggerated the warming. The panel enters the fray in the side of the overwhelming majority of specialists in the field, but the dissenters are not likely to withdraw soon.

"The center of the controversy is the work of Sherwood Idso (who) . . . calculated the warming due to a doubling of carbon dioxide to be 0.26°C . . . Rather than constructing a mathematical model whose workings would mimic the physical world, Idso based his calculations on measurements of the temperature effects of naturally induced changes in radiation . . . Idso determined the relation between temperature changes and changes in radiation induced by carbon dioxide surrogates—in two cases dust or water vapor Phoenix, and in a third case the seasonal changes in incident radiation over the United States.

". . . In support of his calculations, Idso cites equally small carbon dioxide response by tropical ocean temperatures in a model by Reginald Newell . . . and T.G. Dopplick . . .

"In public at least, climate model specialists have, without exception, criticized these conclusions . . . (O)bservations from a single site, a single country, or one part of the ocean cannot suffice to verify what is a global process. A major failing, they say, is the omission of the ocean from Idso's natural experiments, as he calls them. Those experiments extend over only a few months, while the surface layer of the ocean requires 6 to 8 years to respond significantly to a change in radiation. A part of the response is to send more water vapor into the atmosphere, which traps even more radiant energy, just as carbon dioxide does. Without this and other feedback mechanisms to amplify the carbon dioxide warming, an apparently small response is inevitable, critics say. Researchers make similar complaints about Newell and Dopplick's model, pointing out that the allowed increase in humidity is unrealistically small.

"Critics point out that their sophisticated, global climate models can produce a similarly small effect, given unrealistic conditions for a global study. In independent model experiments, Stephen Schneider . . . and James Hansen. . . limited their models geographically and temporarily in order to duplicate Idso's observations. Their models' responses were comparable to that calculated by Idso. V. Ramanthan . . . has in the same manner duplicated the results of Newell and Dopplick for the tropical ocean. Climate researchers believe that their evidence against these challenges is undeniable. The dissenting minority, as small as it is, has yet to concede."

(Panel members: J. Smagorinsky, chairman; K. Bryan; S. Manabe; L. Armi; F.P. Bretherton; R.D. Cess; W.L. Gates; J. Hansen; and J.E. Kutzbach.)

NOTE: (*) signifies references deleted here for brevity.

●

From **'Climate effects of minor atmospheric constituents', by J.W. Chamberlain, H.M. Foley, G.J. MacDonald, and M.A. Ruderman, JASON Technical Report SJR-81-27 (SRI International), August 1981:**

". . . The average temperature of the earth's atmosphere is controlled by the amount of the sun's energy that is trapped within the atmosphere. If the earth had no atmosphere the average temperature of the surface would be about -20°C rather than the 15°C observed. Small quantities of water vapor, carbon dioxide, ozone, and a variety of other compounds influence the thermal structure of the atmosphere . . . Water vapor strongly absorbs radiation except for the 8 to 12 μm region. Ozone, which makes up only 0.41 x 10^{-6} of the atmosphere, accounts for one degree of warming, indicating the potential of minor atmospheric constituents to alter the thermal regime of the atmosphere . . . The blanketing effect of the trace gases leads to the observed warming of the earth's surface of about 35°C . . .

"Two relatively recent discoveries have focused attention on constituents other than water vapor, carbon dioxide, and ozone. The first is that trace species, even at exceedingly low concentrations, can have significant effects on the thermal structure of the atmosphere if their

long wave absorption characteristics in the 8 to 12 μm region. The second discovery is that man in a variety of ways is altering the chemical composition of the atmosphere and thus changing its absorption characteristics in the 8 to 12 μm region.

"... While the anthropogenic increase in carbon dioxide has received the greatest attention both in the scientific and popular literature, major advances in atmospheric chemistry in the past decade have revealed that other man-made substances can affect the atmosphere's thermal structure...

"Total Effect. Leaving aside O_3, and taking the results in Table 2 at face value, we would find a total contribution from these 'minor constituents' of $T = 1.8°K$ if all were doubled from present concentrations (O_3 adds about 1.3°K). While there is no reason to suppose that all these constituents might increase (or decrease) together, it is evident that significant changes in the amount of these constituents would induce climatic effects of the same order as might the well known CO_2 'threat.' Note that a major part of this effect comes from the two badly calculated cases—N_2O and CH_4. Our results are in agreement, however, with those of Donner and Ramanthan.(*) ..."

●

From **'Global Dynamics of Biospheric Carbon', Proceedings of symposium held at the Annual Meeting of the Ecological Society of America Under the Auspices of the American Institute of Biological Sciences, August 17, 1981, Bloomington, Indiana, U.S. Dept. of Energy Report #** CONF-8108131, issued July 1982:

"Introduction and Summary, (by Sandra Brown)

"The problem of atmospheric buildup is not new to science. In the 1910's Clarke, the famous geomorphologist, was already calculating the global implications of the increase in atmospheric CO_2 as a result of charcoal burning in cities as Paris. However, it is the data base collected by Keeling and colleagues that has brought the issue to its full modern focus by documenting about a 30 ppm CO_2 increase in the atmosphere since the early 1950's.

"... (M)any of the more accepted global carbon models emphasize physical phenomena but contain few ecological attributes ... This symposium was called to attention on the ecological aspects of the carbon issue ...

"Speakers discussed five aspects of the global carbon cycle: 1) analyses of atmospheric CO_2 data to determine the role of ecosystems in the regulation of atmospheric CO_2 concentration, 2) the response of plants to CO_2 enrichment, 3) state of knowledge of the magnitude of net carbon fluxes between the major terrestrial biomes, 4) state of knowledge of the magnitude of net carbon fluxes between the major terrestrial biomes and the atmosphere, and 5)model simulations of the role of the terrestrial biota in the global carbon cycle ...

"... Brown et al ... found that apparent annual uptake rates of CO_2 were not correlated to fossil fuel inputs but that apparent release rates were significantly correlated. If the biosphere was not responding to the increase in atmospheric CO_2, they hypothesized that apparent annual uptake rates should decrease with increasing inputs of CO_2. Because they found that apparent uptake rates were not decreasing, but rather remaining fairly constant, they suggested that actual uptake rates were keeping pace with the increased CO_2 inputs through processes such as increased uptake by the present biota, net rate of revegetation of the landscape, greater oceanic uptake in the summer than in the winter, or any combination.

"Bacastow et al. considered the amplitude in the seasonal oscillation of the Mauna Loa data as a measure of net ecosystem production. They found that the slope of the yearly amplitudes at Mauna Loa for the period of record increased at 0.02 ppm/yr, but that there was a large error associated with this value. This trend, however, is consistent with results from oceanic models and fossil release data indicates that the biosphere is a net sink of CO_2.

"The results from both of these analyses must be viewed with caution because the Mauna Loa data are currently being reviewed to ensure that they contain no computational errors that could bias any trends found in the annual cycle.

" The response of plants to long-term CO_2 enrichment is summarized in the paper by Roger et al ...:

"—net photosynthesis increased in soybean and sweetgum but not in corn. This difference in response was attributed to differences in the plant's CO_2 fixation pathway (C_3 versus C_4);

"—water use efficiency of the plants increased sharply;

"—changes in plant anatomy occurred;

"—the rate of nitrogen fixation in soybeans increased; and

"—increases in total dry weight occurred in all plants, with increases in the marketable yield of the two crops.

". .. However, Strain points out that although organisms respond directly and indirectly to changing atmospheric CO_2 concentrations, the response will be specific to each type of organism. He suggested that the differential response by species could cause ecosystems to change structurally and functionally.

"The round table discussion on this subject concluded that research is needed at the ecosystem level to determine how ecosystems, as units, will respond to the increasing atmospheric CO_2.

"Revised estimates of the storage of organic carbon in the tundra and taiga ecosystems are presented in the paper by Miller and in tropical forest ecosystems by Lugo and Brown. In both cases the new estimates are lower than previous ones ... These revised estimates are approximately one-third to one-half lower than previous ones ... [The revised estimate for storage of carbon in tropical ecosystems] is approximately half the earlier densities. The greatest uncertainty in this estimate is the area currently occupied by tropical forests. Northern ecosystems and tropical forests combined, account for approximately 40% of the total terrestrial carbon pool.

"A revised estimate of the soil carbon pool ... by Post et al ... found that:

"—the mean soil carbon density for each [Holdridge] life zone produced a clear pattern in relationship to climate,

"—the size of soil carbon pool in tropical forests ... was similar to that reported in the paper by Lugo and Brown, and

"—an estimate of the global soil carbon pool ... was close to other widely accepted values.

"... Recent analyses of temperate forests suggested that they were a carbon sink of approximately 1.0-1.2 Gt C/yr in the present century because of the regrowth of secondary forests that replaced abandoned farmland and logged forests. The paper by Johnson and Sharpe suggests that this carbon sink may be larger, approximately 1.6-1.9 Gt C/yr, because the ratio used to convert merchantable biomass to total forest biomass in the earlier analyses by have been too small. Neither the earlier or present analysis included the accumulation of carbon in the soils of these regrowing forests which would, if considered, make the carbon sink in temperate forests larger.

"Regardless of which value more closely represents the actual magnitude of the carbon sink, the paper by Armentano and Loucks suggests that increased forest utilization for fiber and energy may cause temperate forests to become a source in future decades. For example, their analysis suggested that the net carbon accumulation in North American forests could be eliminated in 20-30 years if an annual harvest rate of wood equivalent to 10 quads of energy (about 13% of current U.S. consumption) prevails.

"It was generally agreed at the round table discussions that temperate zone forests in North America and Europe during last century have been a sink of atmospheric carbon. There was some disagreement about the role of forests in Russia, with some suggesting that they were sinks while others suggested that they were a large source of carbon because of recent exploitation. Clearly more information on the status of forest areas in Russia is needed.

"Other carbon sinks were reported for northern ecosystems (Miller). He estimated that these ecosystems accumulate carbon at the rate of 0.2 Gt C/yr, most of which occurs in the taiga peatlands. He also suggested that this rate will increase with CO_2-induced climate change due to increases in CO_2 concentration.

"The results from the papers by Armento and Loucks, Johnson and Sharpe, and Miller clearly indicate that there are large areas of the terrestrial biota that are presently sequestering carbon.

"... It is clear from the results of (carbon flux models by Detweiler et al. and Shaver et al.) ... That the estimates of the net flux of carbon to the atmosphere due to land use changes have been lowered from previously published results.

"... (B)oth of these models are concerned only with carbon fluxes that arise from land use changes, they do not consider the role of the so-called undisturbed, mature ecosystems ...

"The three compartmental global model (atmosphere, oceans and terrestrial biota, including the kinetics of ^{13}C and ^{14}C) of Emanuel et al, included sufficient detail in the terrestrial compartment to allow for estimates of carbon pools and fluxes usually measured in ecological studies. Using ^{13}C; ^{14}C time series data determined from tree rings as the reference data, forest clearing rates were adjusted to produce good agreement between ^{13}C and ^{14}C ratios obtained by model and the data obtained from tree rings. This produced carbon fluxes from the terrestrial biota to the atmosphere that increased steadily from 1850 to the 1930's to a peak value of about 4.2 Gt C/yr, and then decreased steadily until 1950. From 1950 to the early 1960's the terrestrial biota acted as a sink of atmospheric carbon, after which time it became a source again of about 1 Gt C/yr. These results depend upon the interpretation of tree ring data in which a number of difficulties have been documented in the literature.

"Common to all models that include the terrestrial biota is the critical need for more information in the area of tropical ecology, particularly on rates of land use change and role of mature forests, if continued progress is to be made in understanding the issues associated with the global carbon budget.

". . .New analyses of terrestrial systems have produced estimates of carbon pools and net fluxes that are lower than previously published ones. Improved understanding of the global carbon cycle and a refinement of the data base used in models is clearly defining where better information is needed and is reducing the magnitude of the source of carbon to the atmosphere from the terrestrial biota and soils."

●

From **'How climate change could affect food production patterns', by Robert Schware and William W. Kellogg, published in CERES, FAO Review on Agriculture and Developmenet, March-April 1982:**

"Most climatologists agree that continued burning of fossil fuels will raise the concentration of carbon dioxide in the atmosphere and cause a 'greenhouse effect' that will warm the surface of the earth in the decades ahead. (*) Our purpose here is to present one scenario of a global climatic change and its impact on regional food production. Policy makers should assess how a long-term climate change could affect the productivity of agricultural areas, the availability of food supplies, and the continued viability of long-term food import and export agreements.

"We should first describe possible long-term changes in patterns of temperature and rainfall. Climatologists are not yet prepared to make such detailed predictions, however, we are obliged to illustrate a range of possible conditions using climate scenarios . . . (O)ne such scenario shows the regions that may become wetter or drier in a future warmer climate. Combining this information with data on world food productivity shows some kinds of crops that could be affected by climate-induced changes in soil moisture.

". . . All of these [paleoclimatic, historic and model climate] sources were consulted, and areas of agreement and disagreement were noted . . . Although it is reasonable to assume that in these areas of general agreement, the specified change will probably occur, this climate scenario should be considered not a prediction of things to come but an illustration of the regional patterns of change in soil moisture that could take place. Furthermore, it is impossible at this stage to quantify the changes.

"We next looked at current patterns of world food production and considered how they might be altered. World food production data published by FAO (*) are given for the five largest crops—wheat, rice, maize, potato and barley . . . The percentage of each crop that may be affected by wetter or drier soil moisture conditions is shown in the top portions of every figure.

"Areas that produced roughly half the world's wheat and 55 percent of the world's maize in 1978 could become warmer and drier. On the other hand, wetter soil conditions would affect approximately 86 percent of the world's rice, 60 percent of the world's potatoes and 50 percent of the world's barley . . . Ordinarily, drier and hotter conditions in the grain-producing countries will be detrimental, but not invariably. Furthermore we should expect the higher level of carbon dioxide that will have brought about the climatic change in the first place to encourage photosynthesis and improve the water utilization of crops (*).

"A drier and hotter US

"It is especially important to consider which countries' food production could be modified by a change in soil moisture and temperature conditions. For example, the US accounted for nearly half the world production of maize in 1978. According to the scenario, a large portion of its current production areas could become drier and hotter. The USSR produced almost one-third of the world's wheat, potatoes and barley in 1978, and practically all of these could face drier soil conditions. China and India, which accounted for over half of the world production of rice in 1978, could get wetter soil.

". . . (T)he longer growing season that would accompany generally warmer and wetter weather could increase rice yields in the major producing countries, namely, China, India, Indonesia, Bangladesh, Thailand and Japan.

". . . (B)oth China and the USSR import a significant fraction of their domestic wheat consumption; the same applies to Brazil, China and the USSR with respect to maize. Eastern European countries in turn rely heavily on the USSR for their grain supplies. Major shifts in the production of any of these countries would require adjustments in the patterns of international food trade and renegotiation of existing import and commodity agreements.(*)

". . . Large wheat exporting countries, for example, such as Canada, France and the US, may have to reduce exports and resort more to feeding themselves.

"Hence it is against this background of climatological uncertainty and prospects of possible shifts in patterns of food production, that the development of strategies to cope with or to avert climate change must be seen. If strategies are developed and implemented to decrease our vulnerability to the inevitable year-to-year fluctuations of climate and crop production—strategies that make sense now—then we will be better equipped to cope with a more gradual climate change if and when it occurs. (*)"

●

From **'Carbon Dioxide and World Climate', by Roger Revelle, SCIENTIFIC AMERICAN, August 1982:**

". . . In 1957 Hans Suess and I showed that a rather small change in the amount of free carbon dioxide dissolved in seawater corresponds to a relatively large change in the pressure of carbon dioxide at which the oceans and the atmosphere are in equilibrium. From this finding it followed that the rate at which the oceans can absorb the gas is much lower than had been thought.

"Gases are readily exchanged between the oceans and the atmosphere only in a wellmixed surface layer some 80 meters deep on the average. If absorbed carbon dioxide is confined to this layer, a given change in the amount of carbon dioxide in the atmosphere would change the content of the surface water by only about a ninth as much. We called this 9:1 ratio the 'buffer factor' and showed that it increases with increasing atmospheric carbon dioxide. Downward diffusion, advection or convection between the well-mixed layer and the deeper water would increase the amount of carbon dioxide taken up by the ocean and thereby reduce the amount remaining in the atmosphere, but we believed these processes are relatively slow. Hence, it seemed likely that much of the carbon dioxide released by the combustion of coal, oil and natural gas would stay in the atmosphere for a considerable time, possibly with profound effects on the world's climate.

". . . Projects for the measurement of atmospheric carbon dioxide were incorporated into the program of the International Geophysical Year in 1957-58 . . . When the measurements began, the concentration was rising at a rate of about .7 part per million per year; by the late 1970's the rate had reached 1.4 parts per million per year.

"Keeling and his colleague Robert Bacastow concluded that the average concentration at Mauna Loa increased from 315.8 parts per million in early 1959 to 334.6 parts per million in January, 1978—a rise of 6 percent . . .

". . . The general agreement between modeled and observed trends in temperature strongly suggests that carbon dioxide and volcanic aerosols are responsible for much of the global variation in temperature in the past 100 years. It must be said, however, that so far the warming trend has not risen above the 'noise level' of yearly fluctuations in temperature, which amount to plus or minus .2 degree C. Confidence in the carbon dioxide hypothesis will be much firmer if a warming trend exceeding the noise level becomes evident. Almost any reasonable estimate of how much fossil fuel will be burned in the coming years suggests that if carbon dioxide is indeed altering climate, an unmistakable warming trend should appear in the 1990's. . .

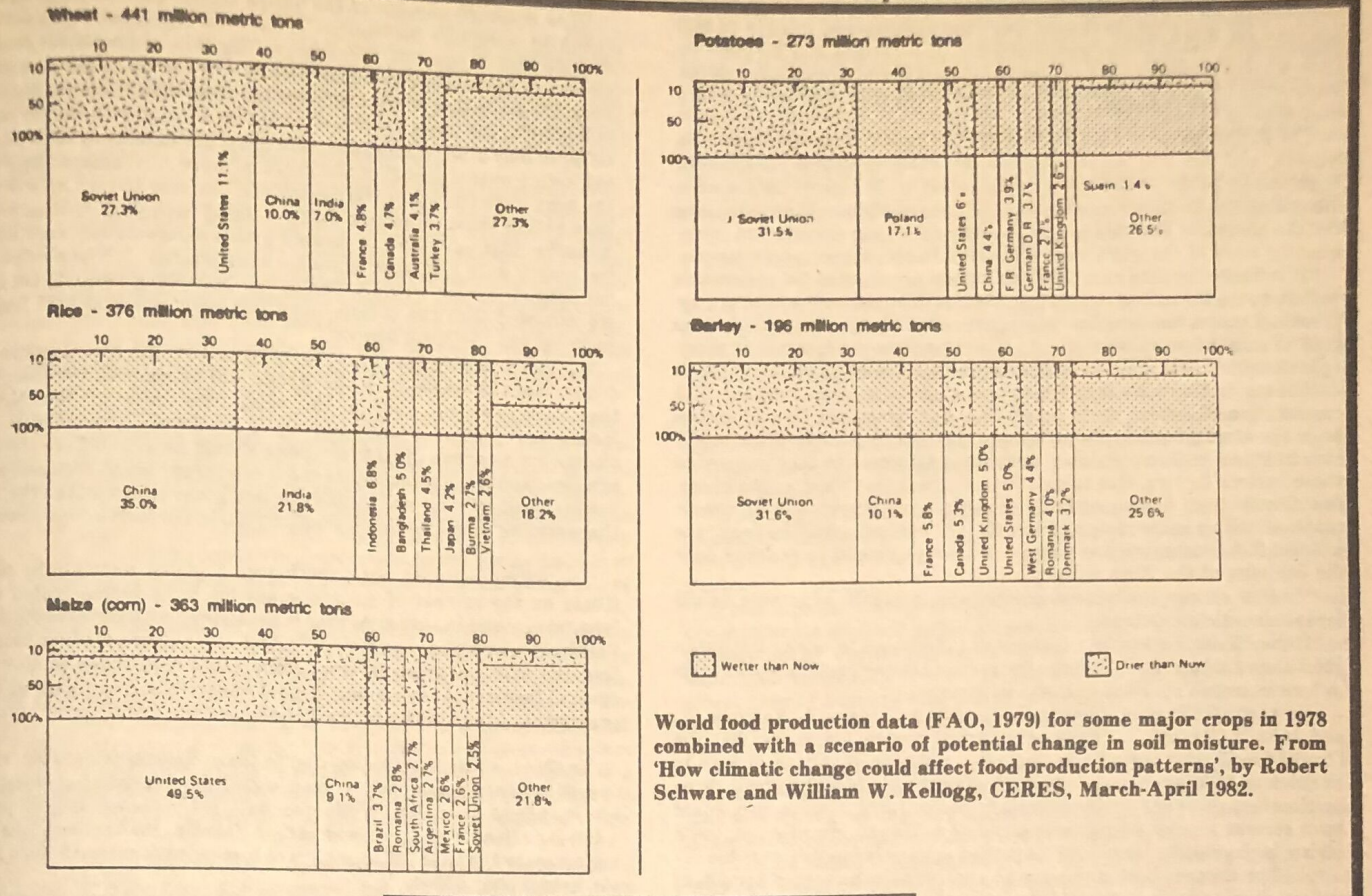
"Syukuro Manabe, Richard T. Wetherald and Ronald Stouffer . . . have devised a mathematical model to explore the geographic distribution of probable climatic changes resulting from a doubling or quadrupling of atmospheric carbon dioxide. The model shows a markedly different climatic response at different latitudes. . .

"The model shows a large increase in the rates of precipitation and runoff at high northern latitudes. Between 35 and 45 degrees North, however, there is a significant decrease in the difference between precipitation and evaporation, which could result in a marked decline in runoff . . . Global temperatures [for a doubling] might be warmer than civilized man has ever experienced. The high temperatures would persist for hundreds of years until slow absorption by the oceans removed excess carbon dioxide from the atmosphere.

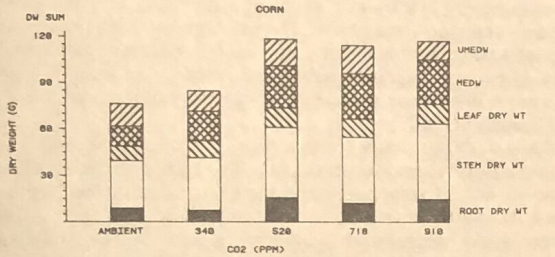
"Models of the type employed by Manabe and his colleagues entail many uncertainties . . .

"All these uncertainties suggest that the mathematical modeling of changes in climate should be evaluated and controlled by studies of past warm periods . . .

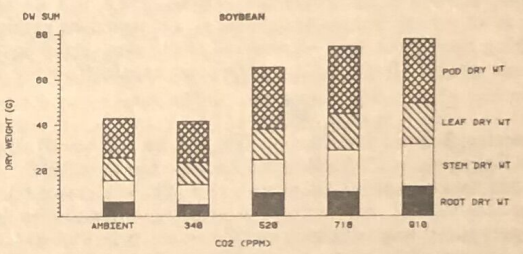
"Flohn's analysis of the historical record suggests there could be appreciable decreases in precipitation and increases in temperature (and hence in evaporation) in bands of latitude centered on 40 degrees North and 10 degrees South. Precipitation would be greater, on the other hand, between 10 and 20 degrees North and in the regions north of 50 degrees North and south of 30 degrees South. These changes could have profound effects on the distribution of the world's water resources . . . With a rise of several degrees C. in air temperature and a 10 to 15 percent decline in precipitation the average flow of the Colorado [River] could diminish by 50 percent or more . . .



World food production data (FAO, 1979) for some major crops in 1978 combined with a scenario of potential change in soil moisture. From 'How climatic change could affect food production patterns', by Robert Schware and William W. Kellogg, CERES, March-April 1982.



Corn: CO_2 concentration during growth versus dry weight components roots, stems, leaves, and marketable (MEDW) and unmarketable ears (UMEDW).



Soybean: CO_2 versus total dry weight components roots, stems, leaves, and pods.

From 'Effects of long-term CO_2 concentrations on field-grown crops and trees,' by H.H. Rogers, et al, 1982 (USDOE CONF 8108131).

"Major changes in surface and underground water supplies would be likely in other parts of the world. In northern Africa the average flow of the Niger, Chari, Senegal, Volta, and Blue Nile rivers could increase substantially because their basins would receive from 10 to 20 percent more precipitation while temperatures at the surface would rise only slightly. In many other rivers the flow could greatly decrease: the Hwang Ho in China, the Amu Darya and Syr Darya in one of the prime agricultural areas of the USSR, the Tigris-Euphrates system in Turkey, Syria and Iraq, the Zambezi in Zimbabwe and Zambia and the São Francisco in Brazil. Somewhat smaller runoff and underground storage cold be expected in the Congo River in Africa, the Rhone and the Po in western Europe, the Yangtze in China and the Rio Grande in the U.S. Many of these form the basis of extensive and highly productive irrigated-agriculture systems, and the projected slackening of their flow could have grave consequences. At the same time large increases in the flow of the Mekong and the Brahmaputra rivers could lead to frequent destructive floods over wide areas of Thailand, Laos, Cambodia, Vietnam, India and Bangladesh.

". . . (A) higher concentration of carbon dioxide promotes photosynthesis and gives rise to faster growth. Other things being equal, a higher atmospheric content of carbon dioxide should lead to increased production of such crops as rice, wheat, alfalfa and soybeans.

"Or perhaps of equal importance is the fact that many plants tend to partly close their stomata, or leaf pores, in an environment high in carbon dioxide, with a resulting reduction in the transpiration of water. Hence with marginal rainfall maize, sugarcane and sorghum, as well as the crops already named, are likely to be less affected by water stress as the atmospheric content of carbon dioxide increases. At high latitudes the higher temperatures induced by carbon dioxide may lengthen the growing season, making it possible to expand rainfed agricultural areas.

"A possible consequence of climatic warming that has been widely discussed is the disintegration of the West Antarctic ice sheet, which many glaciologists think is unstable because much of it is below sea level. The volume of ice above sea level is about two million cubic kilometers. If it were all carried into the ocean, the sea would rise by five to six meters, inundating many coastal cities and much farmland in the Netherlands, Bangladesh, the coastal lowlands of the southern U.S. and populated river deltas throughout the world. Half of the state of Florida would be covered by seawater.

"Although such changes in the map of the world may seem to be the most dramatic potential consequence of climatic warming, social and economic adaptation might not be difficult, at least for the cities, if the change were sufficiently slow. Except for historical monuments, cities are constantly being rebuilt even without the impetus of changing coastlines. The 'half-life' of city buildings—the period after which half of the buildings erected in a given year have been destroyed or replaced—seems to be between 50 and 100 years. Thus the disrup-

tiveness of climatic change will depend strongly on the rate of change.

". . . With the present fuel proportions and rates of growth in fuel consumption, most of the petroleum and natural gas will be gone by 2050, whereas from 90 to 95 percent of the recoverable coal will remain. The carbon dioxide problem is thus fundamentally related to the future consumption of coal . . .

". . The buffer factor should become larger as atmospheric dioxide increases, and this will reduce the rate at which carbon is transferred from the air to the ocean. On the other hand, if the rate of carbon emissions diminishes, as it has in the past few years, there will be more time for the oceans to absorb a given quantity of carbon dioxide and consequently more of the gas can be dispersed in the deeper ocean layers.

"It is likely that the rate at which forests are cleared for agriculture will decrease in coming decades as the limits of cultivable land are approached and as improved technology results in larger crop yields from land already under cultivation. At the same time the increase in atmospheric carbon dioxide may bring about an increase in photosynthesis and hence in the quantity of biomass, at least in some regions. The combination of factors could result in a significant net flow of carbon from the atmosphere to the biosphere. In 1977 Walter H. Munk and I constructed a rather primitive model that attempts to take account of these various factors. Our calculations suggest that the fraction of carbon dioxide from human activities remaining in the air will be almost constant, with a value ranging from 40 to 50 percent, until the peak rate of fossil-fuel consumption is passed. This peak should be reached near the begining of the 22nd century.

"Modern research-intensive agriculture is highly adaptable to different climatic conditions . . .

"If the (West Antarctic) ice sheet did disintegrate in the last interglacial, an attempt to determine the rate of its destruction would seem to be a research problem of great importance . . .

"Terrence J. Hughes, George H. Denton and James L. Fastook . . . and John H. Mercer . . . have constructed models indicating that the flow of the West Antarctic ice shelves could conceivably accelerate to as much as 20 kilometers per year, raising the sea level by about three centimeters per year or three meters per century. Such a rise would have serious reprecussions for coastal areas. Many glaciologists think such a high velocity is unlikely, but they acknowledge it is possible . . .

". . . The changes that may come as a result of an increased amount of carbon dioxide in the atmosphere, however, will not be events. They will be slow, pervasive environmental shifts. They will be imperceptible to most people from year to year . . . It would be prudent to begin thinking now about how humankind might best avoid or ameliorate the unfavorable effects and gain the most benefit from the favorable ones."

●

From 'Society, Science and Climate Change', by William W. Kellogg and Robert Schware, in FOREIGN AFFAIRS, Summer 1982:

. . . "Within roughly the last 50 years a new [climatic] factor has been added—the activities of man himself. A growing accumulation of evidence has persuaded most of the scientific community that human activity may be contributing to a substantial change in the Earth's climate on a global scale. In particular, large-scale consumption of fossil fuels (caol, petroleum and natural gas) is leading to an accumulation of carbon dioxide in the atmosphere, which is continued appears likely to increase the average temperature of the Earth by several degrees over the next 50 to 70 years. And the release into the atmosphere of other gases arising from human activity may add significantly to this overall 'greenhouse effect.'

". . . Since the prospective global change is the result of human activities, we could in principle avert or at least defer it if we decided that the likely consequences were 'unacceptable.' or we could accept their onset and take measures to mitigate the adverse effects of the change and to capitalize on its beneficial effects.

". . . There remains an important need for more organized and systematic analysis, especially in translating overall global trends into a more precise picture of what can be expected for the climate of specific regions of the world. But the trend itself is now so unmistakable that it is time to broaden the analysis and to unite the research and judgment not only of physical scientists, but of a whole range of disciplines including history, geography, political science and economics. . .

". . . Since 1900 the release of additional carbon dioxide from fossil fuel burning has risen inexorably . . . Even if there should be no further increases, present levels of release are bound to deposit a large fraction of the new carbon dioxide in the atmosphere. In aggregate terms, the world was releasing 1.6 billion tons of carbon per year (in the form of carbon dioxide) in 1950, and 5.3 billion tons in 1980(*). The resulting increase in atmospheric carbon dioxide during that period has averaged one part per million per year. Comparing the additional amount that can be accounted for in the atmosphere to the amount released, the airborne fraction has averaged about 60 percent of the total.

"The other 40 percent of the added carbon dioxide must have been taken up mostly by the oceans. The oceans represent a sink for carbon dioxide that is some 60 times larger than the atmosphere; **eventually** almost all of the added carbon dioxide will end up in the oceans. However, the processes of removal from the atmosphere, limited by the rate of mixing of the large volume of deep ocean water with the surface mixed layer only a few hundred meters deep, are extremely slow and gradual, acting over a period of 500 years or more . . . it seems likely that in the next 50 to 100 years the oceans will continue to take up a little less than half of the new carbon dioxide added each year.(*) It now seems, however, that estimates of current global deforestation were based on too scanty data and were probably exaggerated . .. The matter is still not settled, but we would probably not be making a significant error if we assumed that the oceans were the main sink and that fossil fuel burning was the main source. .

". . . Both model results and experience with the real atmosphere indicate that the warming in the Arctic will be some three times larger than the average, and in the temperate zone of the Northern Hemisphere, where a large number of the developed countries lie, the change for a carbon dioxide doubling should be 4° to 6°C. In the Southern Hemisphere, because of its relatively larger ocean area and an Antarctic Continent that will initially be much less affected than the Arctic, the warming trend would be smaller than in the Northern Hemisphere. . .

". . . (W)hy have we not experienced a global warming by now? . . (D)ata on the retreat of Antarctic sea ice have demonstrated a clear long-term trend in that area that is consistent with the expectation of a Southern Hemisphere warming.(*) And . . . analyses of other natural influences on global mean surface temperature have revealed sporadic or cyclical factors whose cooling impact apparently more than offset the greenhouse effect in the years that showed the overall cooling trend.(*) . . .

"In short, as the fluctuation due to these natural factors (or 'climatic noise') has been sorted out, a clear 'signal' from increasing carbon dioxide is indeed revealed. While the data do not conclusively prove a warming effect from increased carbon dioxide, the temperature observations over the past 100 years are at least consistent with the notion of the greenhouse effect.

". . . The message is fairly clear: possibly before the year 2000 and in any case before 2020—well short of a doubling of atmospheric carbon dioxide—the world may be on the average warmer than at any time in the past 1,000 years or more—that is, 1°C warmer than now. This 'first stage' of climate change would stem from a rise from the present 340 parts per million to an atmospheric carbon dioxide fraction of about 360 to 370 parts per million . . .

"While a 1°C average change does not appear at first glance to be very significant, consider first that this change wil be amplified toward the poles, and at temperate and high latitudes in the Northern Hemisphere it may be 2° to 3°C. In the temperate zone such a temperature change would correspond to roughly a four degree difference of latitude, or the present mean temperature difference between such pairs of cities as Copenhagen and Paris or Boston and Washington. As the trend continues to a doubling of the pre-1900 level of carbon dioxide—in what might be called a 'second stage' of climate change—Boston would approach the same mean temperature as Miami has at present, while the southern parts of the United States and Europe would become truly tropical . . .

"Changes in solar activity in this interval could hasten the warming, according to a theory based on solar cycles;(*) conversely a period of intense volcanic activity (or a major nuclear war could reduce the effect. And recall that the addition of other infrared-absorbing gases would add another 0.5°C in the first stage of change alone.

". . . The oceans have a large thermal capacity, and a lag of about a decade is likely as the upper layers of the world's oceans gradually warm up.(*) This oceanic lag is expected to be somewhat shorter in the tropics than at high latitudes; and the central parts of the major continents, far removed from the moderating effect of the oceans, should be less affected by the delay than places along the coasts.

". . . There is, as noted, good evidence that the change is already taking place, but has been partly disguised by natural fluctuations, so that we are not yet generally aware of it. There will be little doubt about its reality when the change becomes larger than the fluctuations, and this should be by the turn of the century, perhaps sooner.

". . . (T)emperature is of course only one feature of weather and climate. **Rainfall** and **evaporation**, together determining **soil moisture** are even more crucial, especially for growing food.

". . . We can gain some . . . hints [about expected changes] by looking at reconstructions of the Altithermal Period when the climate was generally warmer.(*) Then the Sahara was not a desert, but a kind of

savannah able to support nomadic tribes with their cattle; North Africa and the Middle East were generally more favorable for agriculture; and the present Rajasthan Desert in northwest India was a region where several large cities prospered (cities now swallowed by sand). Still another set of useful hints comes from studies of particularly warm years or seasons during this century, for which good meteorological records of temperature and rainfall have been kept.(*)

". . . These sources have been used in construction of (a map of possible soil moisture patterns on a warmer earth). The process was somewhat subjective and also relied on some general reasoning based on concepts of how the large-scale circulation patterns would change with a global warming and a decrease in the temperature difference between the equator and the poles. (For example, it is fairly clear that the monsoon circulation that determines so much of the climate of Asia would be stronger and more regular, and that the storm tracks would on the average move poleward.) The resulting map . . . (is) a scenario of the future climate describing what **could** happen.

". . . It suggests that large areas of Africa, the Middle East and India, as well as a substantial portion of central China, might cease to be water-deficient areas, or at least be much less water-deficient. On the other hand, there would probably be much drier conditions in the central section of the North American continent, and drier conditions virtually throughout the central and northern areas of the Soviet Union, so that it would be harder to grow wheat, corn, barley and other major food crops in parts of what are now the 'food basket' areas of North America and the Soviet Union.

". . .Finally, a discussion of the many aspects of a global warming would not be complete without mentioning the possibility of a future rise in sea level—which has been prominently featured by the media. Studies have suggested that the ice sheets of Greenland and the Antarctic have been shrinking slightly in the past 100 years as the Earth grew slightly warmer, contributing to a rise of five to ten centimeters in sea level. In the case of the West Antarctic ice sheet, there is a possibility that it could actually begin to partially disintegrate with the much greater prospective warming of the Polar regions and the neighboring areas.

"While a straightforward melting of these enormous masses of ice would probably take many thousands of years, it has been pointed out that most of the West Antarctic ice sheet (and portions of the larger one of the East Antarctic) rests on bedrock well below sea level. Thus, warmer ocean water could work its way under the ice sheet, causing it to relinquish its frozen hold on the bedrock, and to begin sliding toward the ocean, gradually disintegrating and then melting much more rapidly through fuller exposure to the water.

". .. Whether the West Antarctic ice sheet would disintegrate in a matter of centuries or millenia following a major warming is still being debated, but in any case few, if any, experts now claim that the time involved could be less than about 200 years.(*). . .

"Agricultural Production

". .. Broadly speaking, it would appear that hotter and drier conditions in key growing areas of the temperate zone would have a negative effect (or at least require drastic adjustments), while in the more tropical areas that may become less arid, the effect would be favorable. But such generalizations are too simple: much would depend on the pace of change, specific offsetting effects, opportunities for agricultural migration within a given region, and new technology to cushion the impact.

"The primary cause of the global warming, increasing carbon dioxide, is of itself an asset to plants. Operators of greenhouses have known for years that raising the level of carbon dioxide in the air of a greenhouse will cause most plants to grow faster and larger (provided they are not limited by water or nutrients . . . "As a longer growing season opened up new areas, might present patterns of agriculture simply migrate? One careful study estimates that the U.S. corn belt would shift 175 kilometes northeastward for each degree (centigrade) of increase in temperature, if precipitation remained unchanged.(*) This is due to the fact that a peculiar situation exists in our Midwest wherein the gradient of summertime temperature is northward and the gradient of rainfall is westward . . .

". . . (R)ainfall and soil moisture patterns would often change as well—the predicted drying of the American Middle West, for example—so that a given pattern of agriculture could no longer be practiced even by moving poleward within a region.

". . . The best agricultural soils are those with just enough leaching to remove the excess basic salts but not enough to remove the essential minerals from the clay. An example if the prairie soil of the midwestern United States, among the best in the world.(*)

"Thus, in Canada the scope for northward migration of grain production with warmer temperatures is limited to the Peace River Valley of northern Alberta and a few other scattered localities where good soils exist but the growing season is currently too short. Longer growing seasons in Alaska could greatly increase its agricultural potential. In the Soviet Union there may be opportunities to extend agriculture northward, particularly in the alluvial soils of the Yakutian plain along the Lena River—provided that rainfall or irrigation water is adequate. The same opportunities apparently do not exist in Scandinavia because of poor soils.(*) . . .

"Weighing all these conflicting factors, it appears likely that the net impact of climate change would still be negative in some important producing areas of the Soviet Union, China, Canada and the United States . . .

"From a global standpoint, future drier and warmer conditions could occur in areas where roughly 50 percent of the world's wheat and 55 percent of the world's maize (corn) was grown in 1978. On the other hand, approximately 86 percent of the world's rice and 50 percent of the world's barley could be affected by wetter soil conditions . . . rice yields may increase in the major rice-producing countries of China, India, Indonesia, Bangladesh, Thailand and Japan . . .

"Equally important to food production may be the changing climate's effects upon the frequency and severity of pest outbreaks . . . With a global warming we can also expect changes in the frequency and geographical distribution of plant disease epidemics.(*)

". . . On balance, it appears that the world's total ability to grow food may not suffer in the long run, provided the appropriate agricultural technology is applied and planning for improved water resource management can keep ahead of the change. But the long-range challenge must be recognized and faced now.

"Global Ecology

". . . An obvious historical example is the transition in northern Africa from a grassland that sustained wild animals, and perhaps herds of cattle, to what is now the Sahara Desert—a change that seems to have occurred rather rapidly around 5,000 years ago.(*)

". . . The untouched tropical forests will be affected chiefly by new rainfall patterns, while the Arctic tundra biome will be influenced by both precipitation and temperature.

". . . In the semiarid areas, where water is precious . . ., trees are extremely susceptible to small decreases in precipitation . . .

"For the frozen tundra of the Arctic Basin, a warming induced by increased carbon dioxide would also have a very large influence. This biome is characterized by permafrost, which accounts for its low-growing vegetation, lack of trees, and poor drainage in summer. If a warming trend occurred in the tundra, the permafrost would slowly retreat, allowing trees to grow further poleward, as occurred during the Altithermal Period in Canada.

"Human Health and Disease

". . . About all that can be said with assurance is that the climate changes . . . will probably complicate substantially the task of bringing under control the major diseases that still ravage millions in the poorer countries of the world.

"A more general question is how effectively human beings will perform in changed climatic conditions . . . (I)n the present temperate

For subscriptions mail to:
William N. Barbat Associates
P. O. Box 24
Teton Village, WY 83025

Subscription Rates:
☐ Individual or University Library Subscription, 1 year (6 issues) $20
☐ Company/Institutional/Agency, 1 year (6 issues)
which allows for unlimited "in-house" reproduction rights $40

Foreign Airmail add $4 if sent from U.S.

Copies of back issues $2.50 each to non-subscribers, $1.25 each to subscribers.

Subscriptions are now available in Europe exclusively through Rudolf Trüb, Cumulus Fachbuchhandlung, 5000 Aarau, Switzerland (Tel. 064-22-50-20 or 22-37-98). The price for one year (6 issues) inclusive of postage is Swiss franks 48.—.

zones, especially in the cooler areas that would experience a sharp warming trend—for example, Boston becoming like Washington, and eventually like Miami—there is a real possibility that labor productivity will be affected, not to mention leisure activities or, at a more basic if intangible level, those behavior characteristics that distinguish 'northerners' from 'southerners' in almost every temperate zone country, from China to Italy to the United States. Studies lend support to the common belief that very high or very low temperature and humidity can negatively influence the capacity for physical performance, personal motivation and social behavior.(*)

". .. (O)ver a period of time (decades to centuries) we might see the most thriving societies appearing further from the equator.

"... Most of the industrialized countries are located in temperate latitudes, and the greatest use of energy in these areas is for space heating and cooling. Although only 18 percent of the total U.S. annual energy demand is for space heating, in Canada the figure is 29 percent and Denmark 50 percent.(*) . . .

"Roughly speaking, demand for space heating is greatest in areas of the world with mean annual temperatures between 2° and 18°C, and this includes most of the industrial areas of the world . . .

"Climate change may also affect energy demand by creating additional needs to pump water for irrigation . . . (T)here is a recent U.S. example from the 1976-77 experience, when the rainy season in California was much drier than usual and water allotments to agriculture were reduced by 60 percent. (In a normal year 80 percent of the developed fresh water supply in California is used for crops.) Consequently, farmers were forced to replace the deficit by pumping up more ground water for irrigation, and the additional energy required for this operation was about one billion kilowatt hours in California alone.(*)

"... To summarize, a global warming will ease the requirements for space heating in temperate latitudes in winter by increasing requirements for cooling, shifting the demand from the direct use of fuel to electricity. Patterns of energy use will shift but not move uniformly poleward; there will be marked regional differences in the temperature and precipitation changes due to related changes in atmospheric circulation . . . (T)he move to conservation and use of renewable energy resources, especially solar heating, would have to be taken into account, as well as future attitudes regarding nuclear energy.

"... Even if the future could be predicted and precise estimates of future carbon dioxide-induced damage could be made, efforts to control fossil fuel use and carbon dioxide emissions on a worldwide basis would face extremely tough political opposition. Both consumers and powerful vested interests in fossil fuel production and use industry would oppose any moves to curtail the availability of this conventional source of energy. . .

"What then, ought we to do? Three types of strategies seem to make clear sense:

"—Strategies that lead to improved choices . . .

"—Strategies that help to slow the increase of carbon dioxide . . .

"—Strategies that increase resilience to climate change . . .

"... (A) crucial element of the problem is that a small number of industrialized countries are likely to remain the principal sources of the additional carbon dioxide . . . Between 1950 and 1976 the United States, the Soviet Union, China, the United Kingdom, West Germany and Japan were the largest carbon dioxide-producing countries.(*) These and similar nations are likely to continue for many decades to be the major cumulative contributers of carbon dioxide to the atmosphere, and this fact alone suggests that developed nations will bear much of the responsibility for the new climatic regions, should they occur . . .

"(T)he time is almost bound to come—if not in the next decade, then surely by the turn of the century—when it will be both possible and necessary to take a much harder look at potential national and international measures to reduce fossil fuel consumption . . . (I)f programs were adopted immediately, this scale of change would probably still occur within at most 40 years.

"But the pace of change to a . . . doubling of the carbon dioxide fraction . . . —producing an average global change of 2 to 3°C (with a change of 4 to 6°C in temperate zones and even greater at the Poles)—is something the world may see strong reason to at least postpone for as long as possible.

"... (M)any of the adverse effects of the kind of climate change that appears likely would be felt most seriously in such countries as the United States, the Soviet Union and China, particularly in terms of their food-growing capabilities. These three countries happen to be those with the largest reserves of coal, as well as being major users of energy.(*). . ."

On quantification of risk

Public debates on the risks and acceptability of nuclear energy bear directly on the speed at which nuclear energy might supplant fossil energy to halt the CO_2 buildup. An article by Peter G. Groer in Summer 1982 **Institute for Energy Analysis Newsletter** provides a graphic scientific foundation for estimating chance and analyzing risk that might successfully end arguments through rational quantification.

Groer notes that the combined techniques derived from Thomas Bayes (1791) and Daniel Bernoulli (1760) could mitigate the present schism of the Committee on Biological Effects of Ionizing Radiation (BEIR). He states, "Bayes asks the scientist to quantify his personal knowledge or lack of it in the form of a prior distribution of characteristic parameters . . . Bernoulli was concerned with the question, How would the eradication of smallpox, through mandatory vaccinations, change the mortality experience of a population? He assumed that each individual is exposed to two risks: death from smallpox and death from all other causes. The two risks are competing for each life. His calculations . . . showed a beneficial effect of vaccinations through a gain in life expectancy."

Figure 1 from Groer shows a simple example of the flat prior distribution on expectation of core damage accidents in nuclear reactors and bell-shaped posterior distribution based on the Three Mile Island event of March 28, 1979. He notes that this distribution continues to change minute by minute with new operational data, but that experience can be mapped into a sequence of distributions concerning uncertainty.

The 1980 BEIR report states, "A significant number of committee members believed that the somatic effects section of the report did not adequately reflect the full range of committee opinion."

In 1980, D.V. Lindley combined Bernoulli's life tables with the Bayesian concept of a prior distribution. Also in 1980, R.E. Barlow and F. Proschan have shown how the judgment of independence influences the survival analysis of technical components and therefore, by analogy, also of persons at risk.

Thus Groer notes that the methodology is advanced enough to permit BEIR committee members to express the full range of their opinions—as a democratic expression of individuality—through the range of a prior distribution. Groer's Fig. 2, for example, based on information from the followup study of the survivors of Hiroshima, shows that the survival rate will converge in a manner dictated by the mathematical algorithm, "washing out initial individual differences . . . This single distribution thus represents a consensus of opinion and characterizes the remaining uncertainty unequivocally."

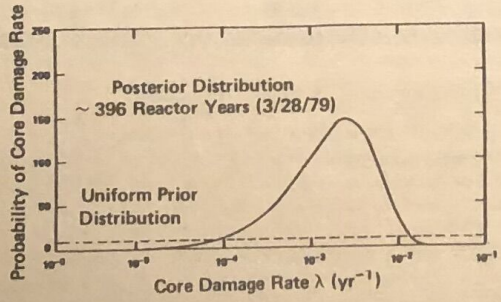


Figure 1: Posterior Distribution for Core Damage Rates Based on Diffuse Prior Knowledge

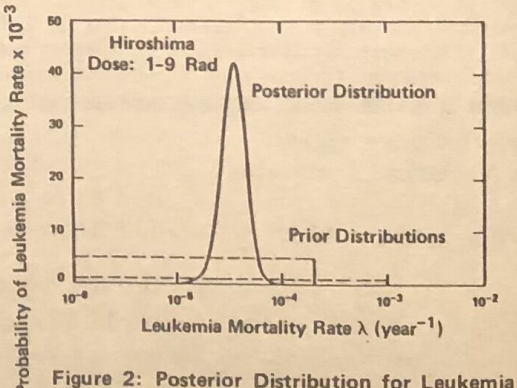


Figure 2: Posterior Distribution for Leukemia Mortality Rate in Survivors of the Hiroshima Bomb