

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.

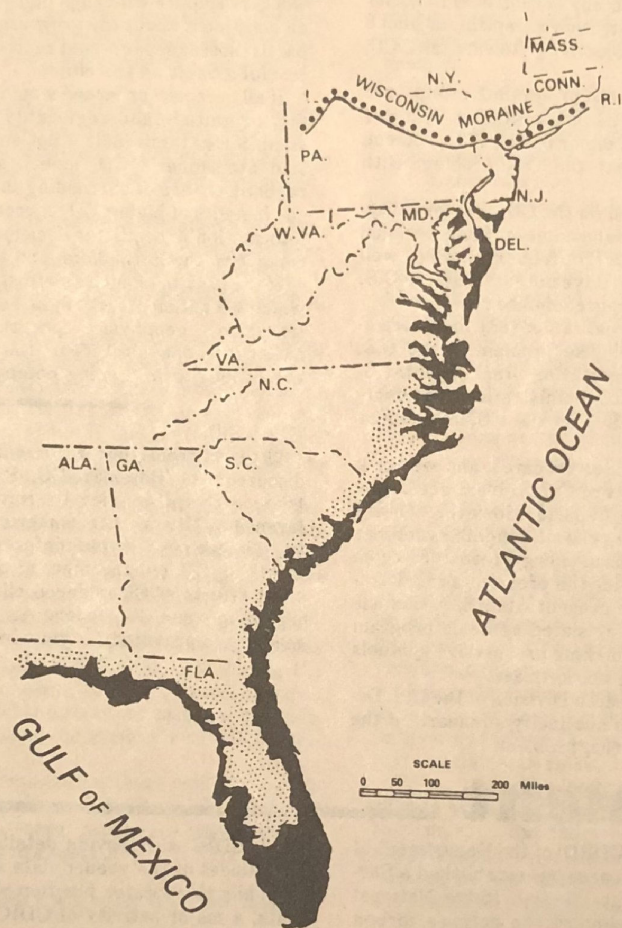
CO₂ Newsletter

Volume 3, Number 3

Mar.-Apr., 1982

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

Shorelines during slightly warmer times:



Map shows interglacial shorelines of submergence attained when global temperatures were only a few degrees warmer than present, as presented by Jerry S. Olson in a pre-print to the AAAS-DoE. Workshop on Environmental and Societal Consequences of a Possible CO₂-Induced Climate Change, April 1979. (Published October 1980 in DoE's CONF-7904143).

Solid area was submerged by Pamlico or Princess Anne shore about 8 m higher than present in Sangamon? time. The Sangamonian Age (equivalent to the Eemian Age of Europe) occurred 100,000-300,000 years ago, with greatest warmth and highest sea level occurring about 125,000 years ago.

Dotted area was submerged by Wicomico shore (Yarmouth?) about 30 m higher than present. The term Yarmouthian Age has been applied in North America to the interglacial time interval of about 800,000-1,300,000 years ago based on descriptions of deposits from Yarmouth in southeast Iowa around 1900. Recognition of environments of

continental interglacial deposits is still somewhat unclear, however, as a research team from Iowa Geological Survey and Iowa State University has shown recently that these deposits at Yarmouth "represent a cold environment rather than a warm environment."

Olson reported that "Evidence derived from the biological indicators of [Sangamon or Eem interglacial time] for the Alps, Netherlands, Czechoslovakia, Southeastern Europe, and Toronto implies temperatures up to 2° to 3° warmer than present climates." He noted from climate-model studies of others that a world-average warming of 3° C at sea level corresponds to a 9° C mean warming in high latitudes. Olson concluded that substantial flooding (+ 8 m) could result from less than 200 years of such warmth—although that amount of sea level rise could take much longer—due to an expected irreversible reduction in the altitude of the Greenland icecap. Such an altitude reduction would preclude the rebuilding of the icecap "even if temperatures instantly changed to their recent levels".

CO₂ 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.

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"The scientific discipline is one way in which . . . insight . . . is brought down to earth and into direct and decisive contact with the concerns of mankind."

- Walter Lippman

Editorial

The present administration in Washington inherited a CO₂-greenhouse problem which had not been accorded any seriousness in either action or policy under the previous administration except in its final 8 days of office. Even then, a lack of objectivity toward anti-CO₂ strategies left a taint of political ploy.

Presently no self-proclaimed environmental-protection groups are clamoring for increased funding for CO₂-greenhouse studies. Not one scientific organization has issued a position paper on the CO₂ problem, and scientific magazines have yet to treat the CO₂ problem with genuine concern, especially in editorials.

The news media frequently have reported on the CO₂ problem in articles, but with no real continuity or editorial comment. Congressional hearings on the CO₂ problem have been brief, infrequent and not well attended by lawmakers. Other governments have not matched the U.S. government in a substantive fashion in CO₂-greenhouse research.

With such a perspective, and with the realization that many scientists presently working on the CO₂-greenhouse problem in the U.S. have not expressed any urgency toward instituting practical anti-CO₂ measures, one can understand the current administration's rationale for reducing the budget for scientific studies on the CO₂-greenhouse problem.

We deplore any cut in funds for CO₂-related research, and we see a need for much greater funding for all facets of the problem due to the overwhelming magnitude of the expected impacts. However, we are heartened by the quickness with which the present administration has restored the funding advantage to non-fossil-energy research which had been lost to fossil-energy research under the previous administration. We also admire the way in which the present administration has lessened the subsidies of the previously legislated synfuels program (which is highly pro-CO₂) and the way it is making prospective synfuels producers face some of the realities of the marketplace.

The Director of the Carbon Dioxide Research Division of the U.S. Department of Energy, Fred Koomanoff, has succinctly summarized the major unknowns and uncertainties of the CO₂ problem:

- The timing, magnitude, and regionality of climate change.
- The future consumption of fossil fuels.
- The level of CO₂ that is acceptable in terms of minimum impact.
- Possible mitigation strategies.
- The costs and benefits of higher CO₂ concentrations."

A tendency in the past has been for individual scientific workers to concern themselves with a narrow aspect of the CO₂ problem. Consequently, our overall understanding of these major unknowns has not really advanced in recent years.

We continue to be awed by the imaginative insights which scientific workers acquire with such limited funding, but at the same time we feel an emptiness about the progress of the CO₂ program as a whole. An impartial scorekeeper would record many brilliant skirmishes but no successful assault on the citadel.

If all persons concerned would make an extra effort to assess the timing, magnitude and regionality of climate change, the potential consumption of fossil fuels if not supplanted, the potential impacts at certain atmospheric CO₂ levels, all mitigation strategies that have a realistic chance of succeeding in the practical world, and the costs versus benefits of higher CO₂ concentrations, not only would DoE have the information it needs for decision-making, but so would the public, the reporters, the lawmakers, and leaders of foreign governments.

If the results of such an effort illustrate the seriousness and urgency which we anticipate, it might be possible to generate a well-funded, international geophysical program comparable to that of the International Geophysical Year (the 'International Carbon Dioxide Year'), with a long-term funding potential for critical programs.

"Dear Bill

"I noted from your Volume 3(2) Newsletter (Jan-Feb, 1982) a brief discussion of 'Potential CO₂ Problems of U.S. Agriculture'. You introduce this discussion by referencing the forthcoming Athens conference on 'Rising Atmospheric Carbon Dioxide and Plant Productivity'. The purpose of this conference is to examine potentially beneficial effects of CO₂ enhancement of photosynthesis. The conference will **not** treat effects of CO₂-induced climate change on agriculture as you indicate in your discussion. An abstract of the scope of the Athens meeting is provided for your information. . ."

"Sincerely,
(Fred)

Frederick A. Koomanoff, Director
Carbon Dioxide Research Division
Office of Energy Research

Announcement

The Carbon Dioxide Research Division (CDRD) of the Department of Energy's (DOE) Office of Basic Energy Sciences has established a Carbon Dioxide Information Center (CDIC) at the Oak Ridge National Laboratory. The purpose of CDIC is to support the nation's carbon dioxide-climate research effort by providing a focal point for the compilation and distribution of CO₂-related information under systematic quality control.

CDIC is working with DOE/CDRD area and program managers and researchers to compile a list of needs for CO₂-related data and information. This list is dynamic and will change as new issues become identified. The procedures to identify data needs and inventory sources are:

- (1) determine the needs for data and assess how the data are to be used
- (2) locate, evaluate, and obtain (when necessary) the important numeric data files and relevant documentation
- (3) provide consensus guidelines for format, documentation, coding, computer software, and quality assurance of the data
- (4) compile the "best available" data and determine the extent to which uncertainties associated with these data are documented.

One of the primary functions of the center will be to serve as a networking mechanism between the user community and the large number of established national and international data centers containing relevant data to the CO₂-climate issue (such as atmospheric CO₂ measurements, fossil fuel utilization, forest conversion, characterization of ocean properties, historical records from ice cores, tree rings,

etc.). CDIC will provide details on content, accessibility, format, and usefulness of the needed data sets.

While this locator function will serve users' needs for experimental data, a major activity of CDIC will be to provide a clearinghouse for evaluated information. The intent of the evaluation process will be to choose a "best" estimate (confirmed by a consensus of scientists) from a collection of data from the same subject area. Final data sets should have a quantitative estimate of the uncertainty in the data and traceability to the primary sources of the information. The data sets and supporting documentation will be stored in a computer-searchable format.

The specialized bibliographic data base on carbon dioxide and climate has been in development for several years and currently contains over 3000 citations. Emphasis has been placed on studies relating to the carbon cycle, atmospheric modeling, agriculture and forestry, energy climates. Literature selected for inclusion in bibliographic files is keyed with appropriate identifiers, abstracted and entered into an on-base may be made, preferably in writing, to the following address:

CARBON DIOXIDE INFORMATION CENTER
OAK RIDGE NATIONAL LABORATORY
P.O. BOX X, BLDG. 6025/13-
OAK RIDGE, TENNESSEE 37830
TELEPHONE: 615/574-6181 or FTS 624-6181

Excerpts from recent reports

From 'Warming Warning', transcript of a television program written and directed by Richard Broad and broadcast by Thames Television Limited (England) 8th December 1981:

"**Narration:** Great technology bestrides the planet. But the need for energy, so central to our society, is threatening to alter the climate of the globe.

"**Gus Speth:** It's possible that we could have very, very serious changes in global climate, in precipitation patterns, in wind patterns, effects on agriculture, effects on societies. . .

"**David Burns:** We're talking about a fundamental alteration of . . . the globe we inhabit—caused by man himself. And one which is essentially irreversible in the normal human time-scale.

"**Dr. Walter Orr Roberts:** By the year 2000, we expect we would be in an unprecedented new climatic regime. Different from anything in the recorded history of mankind.

"**Narration:** The Ecology—the system of complex cycles sustaining life—has only looked vulnerable in the past two decades . . . pollution seemed controllable. . . But the Carbon Dioxide question is different. . . Carbon Dioxide is made by man's most basic economic activity. The production of energy itself. . .

"Over the millennia, a great reservoir of coal, oil, and natural gas—fossil fuel—has built up in the earth's crust. Without this, the industrial revolution could never have happened. For it is this locked-up carbon that has enabled us to meet the energy demands necessary to industrial society.

"**Dr. William Kellogg:** As a result of our need for energy we have been taking carbon out of the earth in the form of fossil fuels and burning it. . . since the turn of the century, we have been using so much of this fossil fuel that the carbon dioxide in the atmosphere has gone up about 20%. . .

"**Narration:** . . . One trans-Atlantic flight uses the equivalent energy it took an acre of forest a century to lay down. The coal we now take from the earth in a year . . . took 400,000 years for nature to lay down. . .

" . . . half the Carbon Dioxide man has put in the air has been put there in the last 20 years. . . It is now thought that by the first half of the next century, energy consumption will be up four-fold. And that the amount of CO₂ in the atmosphere could have doubled.

"A slower release of CO₂ into the atmosphere might not have mattered. By no means all of the CO₂ remains in the air. About half is absorbed by the oceans. But this is a slow and poorly understood process. It was, in fact, the sea's capacity to absorb CO₂ that made scientists sceptical that it would ever present a serious problem.

"**Dr. Lester Machta:** Up until about 1960 the prevailing scientific view was that the oceans could soak up all the CO₂ that might come from the combustion of fossil fuel. But in 1957 and 1958 during the International Geophysical Year, two observatories were set up. One on the side of Mauna Loa at about 11,000 feet, and one at the south pole. And we began to make measurements of the atmospheric CO₂ there.

"**Dr. Stephen Schneider:** . . . (W)e expect that there could be significant warming of the planet should this trend continue. We also know that the greenhouse effect is not just a theory but a very strong reality. Because Venus, with its temperatures in excess of 700° at the surface is a largely carbon dioxide atmosphere.

"**Narration:** . . . Real evidence of such a warming, it is now thought, has been detected.

"**Dr. Stephen Schneider:** Right now there are a number of scientists who are beginning to argue that the CO₂ signal, if you will, is already detected. For example, if you look at the mean temperature of the globe in the last 30 years, it's something like . . . three-tenths of a degree or so warmer than the mean temperature of the globe perhaps a century ago. That's consistent with the CO₂ theory.

"**Dr. Lester Machta:** We believe that there is some suggested evidence now that the atmosphere is indeed warming. The lower atmosphere is indeed warming due to the greenhouse effect. . .

"**Dr. George Woodwell:** And there is a reasonable consensus among meteorologists that the warming will continue and will be significant and measurable, easily measurable, roughly by the end of this century.

"**Narration:** Most scientists involved in this problem agree that the temperature will rise on average some 2-degrees centigrade in the next century. . . If that doesn't sound like much, remember there was a time when the world was only 5°C colder during the ice age, when the ice sheet reached Bristol. . .

"**Dr. William Kellogg:** By the middle of the next century, when we might have twice as much carbon dioxide as we had in 1900, . . . in the

polar regions it could be 5 or 10 degrees centigrade [warmer], which becomes a very large change and one that's going to change the whole character of the polar regions.

"**Narration:** There is some tentative evidence that the poles have begun to warm. In the extremely unlikely event of them melting altogether, it would have the calamitous effect of raising sea levels worldwide 200 ft. But warming in the [West] Antarctic region might present a different problem . . .

"**Dr. Stephen Schneider:** . . . if the climate warms up a few degrees, there are a number of glaciologists who believe these [ice] shelves would break up . . . it would lose the buttressing effect and there might be a surge of the land . . . ice, raising the sea level something like five to eight metres.

"**Narration:** Glaciologists disagree whether this melting is likely in decades or centuries. However, a rise of up to 20 feet would make the new Thames barrier, designed to meet surge tides of 11 feet, redundant. More than two million people in London would be at risk. Half a million homes, factories, and shops permanently under water. The Isle of Dogs and Canvey Island would disappear. So would the Underground.

"Most of the world's great cities are ports, and all would suffer. Leningrad and New York: Venice and Bangkok. Around the world, large areas of lowland would be submerged—the fens, Florida, and Holland, are examples.

"Up the river, the new shore line would reach Piccadilly. . . The House of Commons under 18 feet, and Buckingham Palace under 7 feet of water.

"Such a rise in sea levels would be disastrous. But changes in the climate caused by global warming might be overwhelming. . . North-East Africa it is suggested - now often drought-stricken might get more rain and even become a grain producer. In India - The possibility of increased rainfall suggests that in some areas an extra crop of rice might be grown. The United Kingdom - could have a significant temperature rise with changes in rainfall. It might well be like the Middle-Ages when vineyards flourished here. In the central plains of Russia - increased temperatures might lengthen the growing season by a fortnight or so, promising increased yields if the water could be found.

"But the picture would be very different in North America . . . A drop in the rainfall of 10% and a temperature rise of one degree centigrade would reduce yields by 20% in wheat producing areas. The hot dry summer of 1980, when there were unusually high temperatures here, and rainfall fell by 19% proved that. . . However, climatic change in this region would not only be disastrous for the farmers. . . Over a hundred countries now have to import grain and almost all of it, 80%, comes from here. . . A 10% fall in yields here would cut off at a stroke the surplus now available to other countries in the world. . .

"**Lester Brown:** It would mean a lot of people would be eating less food. It could mean, for those . . . billion and a half lower income people in the world where the margin of survival is very thin . . . as food prices rise - so do death rates. . .

"The . . . world's food production system . . . is keyed to a particular climate system. If that system changes, then the agriculture will have to change. . . But there will also be uncertainty, because this will be happening in a way, and in a rate which may not be very predictable. So farmers will be reluctant to change because they're not sure how far the change is going to go, or when it's going to stop. . .

"**Narration:** And for similar reasons, uncertainty will permeate energy policy. If only because such a policy needs to be introduced before there is irrefutable evidence that it is needed. . .

"International agreement will be needed to control the use of fossil fuels. But with the Third World likely to benefit from climatic changes—and while Russia and China have vast reserves of coal, that seems unlikely. Alternatives to fossil fuels, like nuclear power, have their own dangers. Or in the case of solar energy, present technical problems.

"Yet a serious policy of fuel conservation, which makes good sense for other reasons, becomes imperative as a result of the CO₂ problem. . .

"Man has demonstrated he has the capacity to change one of the great natural systems of the world. The sheer weight of our presence is altering the planet. Our industry has now become part of the climate. A new intruder disturbing an old system.

"Most of the small group of scientists who really understand the interactions of the climate have now warned us in measured language of the prospects that we face."

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From 'Global Sea Level Trend in the Past Century', by V. Gornitz, S. Lebedeff and J. Hansen, *SCIENCE* 26 March 1982:

"... We used tide-gauge measurements to estimate global sea level change in the past century. ...

"We reduced the individual station records to a common reference point by fitting a least-squares regression line to sea level as a function of time and by defining the zero point to be the value of the regression curve for 1940. The annual mean sea level curves for stations within a geographical region were then averaged to yield a mean sea level curve for each region. We obtained the global mean sea level curve by averaging the regional mean sea level curves, weighting each region equally (excluding the isostatically uplifting region of Scandinavia). ...

"We also attempted to remove the long-term (usually 6000-year) sea level trends from the data. ... The cause of the long term trend is uncertain. It has been argued that as much as 90 percent of it is residual isostatic uplift of continents due to the removal of the Wisconsin ice sheets(*). However, the long-term trend may contain a eustatic component ... due to a change in volume of the Antarctic and Greenland ice sheets. ...

"The raw global sea level trend that we obtain for the past century is a rise of about 12 cm per century. After subtraction of the long-term trend, the result is a rise of 10 cm per century or 1 mm/year. ...

The global sea level trend for the past century has some similarity to the trend in global surface air temperature (*). ... Most of the positive correlation arises from the general increase in both sea level and temperature. ...

"... (It is interesting that the time lag of 18 years [calculated to minimize the variance between the sea level curve and global temperature trend] is of the order of the thermal relaxation time for the upper layers of the ocean, that is, the layers that are mixed in a time less than or comparable to the thermal relaxation time. This result suggests that part of the sea level rise may be attributable to thermal expansion. ... With the commonly accepted value for [equilibrium sensitivity] $\sim 3^{\circ}\text{C}$, about half the observed sea level change is accounted for in terms of the thermal expansion of seawater. ...

"The magnitude of the global sea level rise therefore suggests that there has been a net melting of the ice sheets. ...

"... With the 10-cm rise of the past century, sea level must now be at or near its highest level since the earlier interglacial, the Eemian 100,000 years ago (*). ...

"Continued rise of sea level is likely in the near future, if predictions of global warming (*) are correct. The thermal expansion of sea water may raise sea level about 20 to 30 cm in the next 70 years (*); if slow ice sheet melting increases this by the same factor as in the past 100 years, a sea level rise of about 40 to 60 cm would occur by 2050. Thus we believe that substantial change may occur even without rapid collapse of the West Antarctic ice sheet.

"... A sharp global warming trend has been under way since the mid-1960's (*), and the current growth of atmospheric CO_2 and trace gases virtually assures that this trend will continue (*). The sea level response to this warming should be carefully determined to aid our understanding of the processes and to allow early detection of any nonlinear response."

From 'Letters', *GEOTIMES*, April 1982:

"The December issue of *Geotimes* contains an article ... titled 'old solutions fail to solve beach problem'. This article is stated to be a shortened version of a fuller report.

"If I read the article correctly, it is based on the assumption that coastal erosion can be set in a one-to-one relationship with sea-level rise, which is stated to be going on today. This highly simplistic view poses problems at 2 levels. In dealing with the public, the signers of the longer document may wish to use a simplistic view, one which is not correct, on the assumption that the public could not understand the correct version. ...

"However, *Geotimes* is widely read in the professional community, and many geologists may be led to believe that this modified version actually represents the best available thinking on the subject.

"That sea level has made many changes in the past 20,000 years, and has even changed in recent centuries, seems quite clear. ... However, the relationship between sea-level change ... and changes in coastal erosion rates ... is not a simple and direct one. ... (B)each ridge plains, where sharply defined, are ... all of middle to late Holocene age. ... Some of these beach ridge plains passed to a state of erosion some centuries ago, some are passing to such a condition now, and in some cases, this transition has not been made yet. If there is a direct immediate correlation between sea-level rise, and the shift to erosion, then one must conclude that sea level has not risen in all parts of the world at the same time.

"A better inference would be that ... a system of intervening steps

causes a lag or delay (in some of the erosive effects), which has different lengths in different areas. ...

"It seems clear ... that the coasts of the world are now passing into an almost-global erosion crisis. It further seems clear that this crisis will get worse in the near future (decades, perhaps centuries). I am in sympathy with the aims of the people who drew up the longer document which was not condensed ... I do not wish to go back to the simplistic statement that mankind is responsible for that crisis. ...

"This is not a plea that development of the coast should stop, but rather a call for a more nearly solid foundation of fact and inference on which to base our plans for future development."

-W.F. Tanner
Department of Geology
Florida State University

"The ... beach 'position paper' asserts: 'Many factors are responsible for coastal erosion, but it is so widespread that sea-level rise appears to be a primary cause.' This, and subsequent statements in the paper, do not in any way imply a one-to-one relationship of sea-level rise to coastal erosion. ...

"Our conclusion that man causes erosion is sociological, not geological. It is a fact where man and his accoutrements hug the shore we have an erosion problem. Where man is absent, we have no erosion problem, no matter what the shoreline is doing.

"I would like to comment further on the position paper. It was the project of a 10-person conference held at, and funded by, the Skidaway Institute of Oceanography, University of Georgia, Savannah. ... The document was signed by 110 people, the majority of the coastal geological research community. It was released to the press in October 1981 and was reported in most of America's coastal newspapers. ...

"The position paper is having far more impact than we dared hope for. ... On the other hand, the document would have had even more impact had it emanated from under the sponsorship of a national geological society. We discussed the document with committee members and officer of several groups, and all agreed that it was highly unlikely that we could have obtained such sponsorship. Our national societies tend toward caution and conservatism in controversial situations. ...

"In defense of GSA [the Geological Society of America], they at least have tried to face societal issues in the past. A few years back, the GSA organized a panel to consider a position paper on barrier-island environment ... 3 of the Skidaway attendees were involved in the GSA effort. In a well-meaning attempt to be totally objective, the GSA panel included a developer, a coastal engineer, and other non-geologists. The resulting document had a lot of compromise in it, and as a consequence has had limited impact, if any. The GSA panel made an attempt to view all sides of the shoreline problem and come up with the 'truth'. As geologists, however, we are best qualified to find the 'geologic truth', which should then be thrown into our societies' economic and political maelstrom.

"I urge other geologists concerned with problems important to society to pursue the same independent route followed for the coastal position paper. I believe that society has a great deal to benefit from the geological view, especially since we tend to take a longer time-range viewpoint than most politicians and public officials. I hope that the success of the Skidaway coastal position paper will spur such initiatives from other segments of the geological community."

-Orrin H. Pilkey
Department of Geology
Duke University

From 'Recent trends in Antarctic temperature', by P.R. Mayes, *CLIMATE MONITOR* (published by Climate Research Unit, University of East Anglia, Norwich UK) September-November 1981:

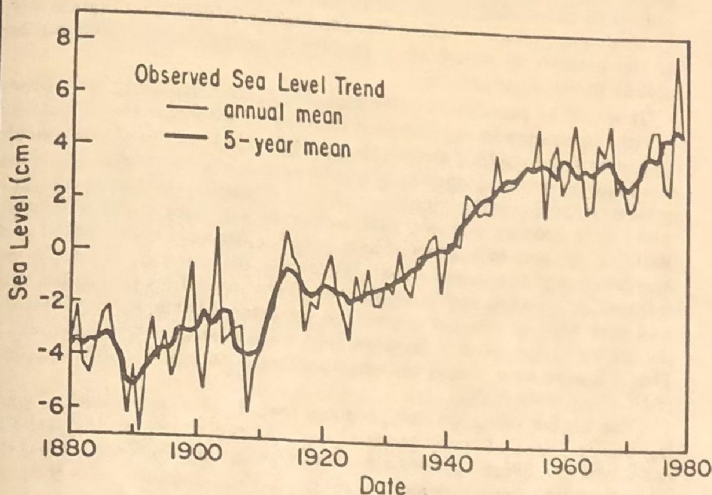
"... Recent work ... has emphasized the importance of the polar regions in determining hemispheric and larger-scale temperature trends: yet many previously documented 'global' temperature rises have tended to ignore the higher southern latitudes. ...

"In this paper, the results for mean annual temperature for two regions of the Antarctic, East and West, are presented ... Average temperatures for each region were calculated simply by averaging the individual station anomalies [from the 1957-1981 mean]: no attempt was made to weight these individual values in any way ... Apart from the temperature record at Orcadas, which begins in 1903, no other long-term record exists south of 60°S

"The West Antarctic annual temperature series (Figure 2) shows a steady warming from 1958 to 1874, followed by a decrease in temperatures to date. These two trends, accounting for 13% of the total variance, resemble those for sea-ice data from the Weddell Sea region. ...

"Figure 3 shows the mean annual temperature time series for East Antarctic stations. This does not exhibit such a clear trend as that

Right: From 'Recent trends in Antarctic temperature,' by P.R. Mayes, CLIMATE MONITOR September-November 1981.



Global mean sea level trend based on tide gauge measurements.

From Global sea level trend in the past century, by V. Gornitz, S. Lebedeff and J. Hansen SCIENCE 26 March 1982.

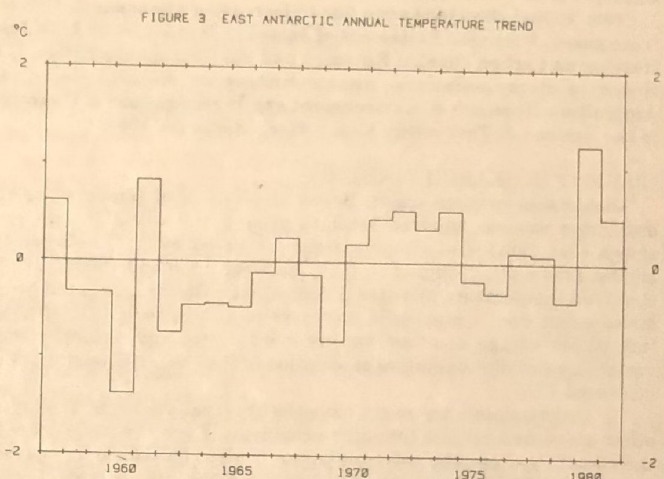
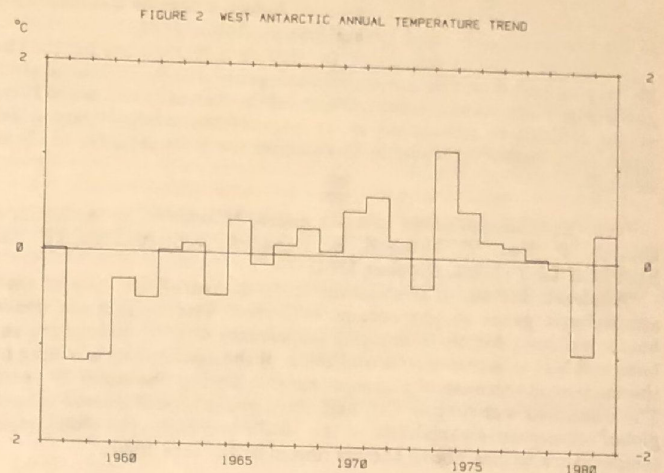
shown by the West Antarctic series, although a slight warming is suggested between 1960 and 1980. The greater year-to-year variability of this series, together with the shortness of the data record, may well mask any significant warming. Although the two time series show a similar slight warming trend overall, they are not significantly correlated ($r = 0.05$). It is thus clear that temperature variations over the Antarctic are regional in nature (confirming the work of Budd, 1975) and some care is needed when comparing Antarctic regions to those of other regions. . .

"Although the two times series show a slight warming trend, the data record is too short for its significance to be evaluated, particularly with regard to the effect of increasing carbon dioxide levels. Kukla and Gavin (1981) have attempted to relate a decrease in Antarctic sea ice extent to the expected effect of increasing atmospheric CO₂. However, both the sea-ice and temperature records from the Antarctic are short in climatological terms, and as Kukla and Gavin point out, the natural variability of these elements has not yet been established. Any conclusions about a relation between observed departures and a CO₂ increase must be, at present, highly tentative.

"The warming trend at high southern latitudes is out of phase with the cooling trend from 1940 until the mid-1960s in the Northern Hemisphere (Jones and Wigley, 1980). . ."

From 'Carbon dioxide', by Kirby J. Hanson, WEATHERWISE, December 1980:

"The principal 'refuse' of all the crude oil, natural gas and coal that has been extracted from the Earth, carbon dioxide remains in the atmosphere for many years. Who must take responsibility for setting pol-



icy for this unwanted refuse of our energy appetite? . . .

"... In particular the added carbon dioxide is expected to modify the natural flow of infrared radiation in the atmosphere on a global scale. That, in turn, is expected to change paths of storms and the associated temperature, precipitation and other weather conditions over the entire earth. . .

"Yet the very nature of the carbon dioxide issue invites public apathy and political indifference. . .

"Carbon dioxide is not a visible pollution like smog, and many people are unaware of its presence. . .

"The carbon dioxide buildup and its consequences are an exceedingly long-range problem compared to many environmental threats. . . How does one in political office prioritize a problem such as carbon dioxide in relation to the many more visible and more short-term needs of one's constituency? . . .

"At present time predictions of future climate change attributed to a carbon dioxide increase are neither credible enough nor regionally specific enough to tell us exactly how a carbon dioxide enriched world will impact our lives. . .

"Unconcern and inaction, today, cost less than concern and action. . .

"Today there are no internationally agreed-upon ground rules placing upper limits on the amount of carbon dioxide allowable in the global atmosphere. Thus, nations are free to dispose of the 'refuse' in the atmosphere as they wish, and, until such rules are in place, nations likely will continue to do so.

"The scientific community is now in a period of 'morning twilight' in its knowledge of the probable effects of future atmospheric carbon dioxide increases. They foresee that major global changes in climate may occur, but they are not yet able to make credible, realistic

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estimates of expected changes in specific areas of the world, such as within national boundaries. . .

"Could it be that our present 'twilight' era is . . . the best possible time to reach international agreement before scientific understanding of the carbon dioxide issue crystallizes sufficiently) . . .

"A United Nations resolution to provide a framework for limiting global pollution would be somewhat analogous to an international poker game where the rules are spelled out before the cards are dealt. If this seems difficult to accomplish in an international arena, imagine how much more difficult it would be to establish the rules after the cards are dealt."

From 'Greenhouse effect of trace gases, 1970-1980', by A. Lacis, J. Hansen, P. Lee, T. Mitchell, S. Labadoff, GEOPHYSICAL RESEARCH LETTERS, October 1981:

Abstract. Increased abundances were measured for several trace atmospheric gases in the decade 1970-1980. The equilibrium greenhouse warming for the measured increments of CH₄, chlorofluorocarbons and N₂O is between 50% and 100% of the equilibrium warming for the measured increase of atmospheric CO₂ during the same 10 years. The combined warming of CO₂ and trace gases should exceed natural global temperature variability in the 1980's and cause the global mean temperature to rise above the maximum of the late 1930's."

Excerpts from recent reports

From 'Global climate change due to increasing atmospheric CO₂ and trace gases', Prepared Statement of James E. Hansen (NASA) to Joint Hearing on Carbon Dioxide Research and the Greenhouse Effect, U.S. House of Representatives, Subcommittees on Natural Resources, Agriculture Research & Environment and Investigations & Oversight of the Science & Technology Committee, March 25, 1982:

"RECENT RESEARCH FINDINGS

"Global temperature trend. Based on analysis of temperature records from several hundred stations around the world (*), we have shown that global mean temperature increased by 0.2°C between the middle 1960's and 1980 and by 0.4°C between 1880 and 1980 . . . (T)his observed temperature increase is consistent with the calculated greenhouse effect due to measured increases of atmospheric CO₂, although lack of knowledge of other forcing mechanisms and natural climate variability prohibit definitive association of the observed warming with increased CO₂ . . .

" . . . Unfortunately we do not have the observations needed to specify other suspected climate forcing mechanisms. Even the basic drive for the climate system, the solar radiation incident on the earth, has been measured with sufficient accuracy only for the past 2 years (by the NASA Solar Maximum Mission) . . .

"Trace gas trends. Increased abundances have been measured recently for several trace atmospheric gases including CH₄, N₂O and the chlorofluorocarbons (CFC's). The growth of these trace gases has not been measured as accurately as it has been for CO₂. However, it is clear that the trace gases have recently been increasing at a rate large enough that they provide a significant addition to the greenhouse effect caused by CO₂ . . .

"Substantial growth of these trace gases has probably been a more recent phenomenon than the growth of CO₂. The CFC's, for example, are entirely man-made and they have been produced in large amounts only during the past two decades. The effect of these trace gases can be thought of as reducing the amount of CO₂ required to reach a given level of climate impact: 200 ppm of added CO₂ plus trace gases may be approximately equivalent to 300 ppm of CO₂ . . .

"Global sea level trend . . . mean sea level rose by about 12 cm in the past century, and by about 10 cm after correction is made for long-term vertical movements of shorelines . . . This sea level change is highly correlated with the trend of global surface air temperature in the past century. Approximately half of the sea level rise can be accounted for by thermal expansion of the upper layers of the ocean. The remainder of the sea level rise is inferred to be a result of slow net melting of the polar ice sheets.

" . . . Concern has been expressed (*) that global warming could cause disintegration and melting of [the West Antarctic ice sheet] to occur relatively rapidly, on a time scale of perhaps a few centuries. Rising sea level will contribute to destabilization of this marine ice sheet, and sea level is now apparently at or near its highest level in the past 100,000 years (*). . .

"Significant sea level change is likely to occur in coming decades, even without rapid collapse of the West Antarctic ice sheet. Thermal expansion of sea water will raise sea level 15-30 cm in the next 70 years (*), if the global climate sensitivity is approximately 3°C for doubled

CO₂ . . . If slow ice sheet melting increases this sea level rise by the same factor as in the past 100 years, a sea level rise of at least 30-60 cm (1-2 feet) would occur by 2050. . .

"Global climate sensitivity. There is a large degree of uncertainty in the sensitivity of global climate to change of atmospheric composition. Recent simulations with a three-dimensional global climate model by Dr. Manabe at Princeton University (*) suggest a mean global warming of about 2°C (4°F) for a doubling of atmospheric CO₂, while our studies (*) at the NASA Goddard Institute for Space Studies indicate a mean warming of about 4°C (7°F) . . .

" . . . The Goddard result suggests that 300 ppm of added CO₂ (or 200 ppm of CO₂ plus moderate trace gas increases), an abundance likely to occur in the coming century, will cause a warming of 4°C globally, and about 10°C in late summer in the vicinity of the West Antarctic ice sheet. The Princeton result suggests that 900 ppm of added CO₂ is required to cause that degree of global warming. . .

"A primary cause of the different sensitivities of the climate models is the manner in which they specify or compute the distribution of clouds in the atmosphere. . .

"It would be possible to infer global climate sensitivity from observed climate change in say the past century, if we knew the climate forcings which were acting during that period and the rate of heat penetration into the ocean (assuming that the natural noise level in the climate system is sufficiently small). . . (T)he observed global temperature trend is in good agreement with a climate sensitivity of 2.8°C for doubled CO₂, if the penetration of heat into the ocean is represented as diffusion beneath the mixed ocean layer with diffusion coefficient $k \sim 1 \text{ cm}^2 \text{ sec}^{-1}$. . . Based partly on measured ocean profiles of tritium, which was sprinkled on the ocean surface by atmospheric atomic testing in the 1960's, it has been estimated that k may be closer to $2 \text{ cm}^2 \text{ sec}^{-1}$. This diffusion rate would be consistent with an equilibrium sensitivity of 5°C for doubled CO₂.

"[The higher diffusion rate] implies that most of the eventual warming due to CO₂ and trace gases already added to the atmosphere has not appeared. Thus we may already have 'in the pipeline' a great deal more warming than is generally realized. Furthermore, as warming at the surface continues this will tend to stabilize the upper layers of the ocean, which could reduce future exchange with deep layers. If that occurs, the ocean will be a less effective sink for both heat and atmospheric CO₂ in the future; these positive feedbacks would hasten and enhance the global climate change. . .

"The largest effects of increasing CO₂ and trace gases are likely to be regional climate changes, the shifting of climatic zones. . .

"RECOMMENDED RESEARCH

"Solar Monitoring and Analysis. . . (I)t is essential to know the extent to which the basic solar drive of the climate system is changing.

" . . . The total solar irradiance is being monitored with sufficient accuracy for the first time from the Solar Maximum Mission.

"I believe that high priority should be given to establishing a program of total and spectral solar irradiance. . .

"Trace Gas Monitoring. The CO₂ greenhouse effect is only a part of a broader environmental issue: man's total impact on atmospheric composition and climate. . .

"I believe that highest priority in this area should be given to accurately measuring trace gas trends. It is also important to try to reconstruct past trace gas histories, for example, by measuring trace gas atmospheric absorption profiles in astronomical plates and by measuring the composition of air bubbles trapped in ice sheets.

"Clouds. Clouds, and how their properties depend upon climate and climate change, are perhaps the greatest source of uncertainty in our attempts to understand climate sensitivity. . .

"The World Climate Research Program (WCRP) has in advanced planning stages an International Satellite Cloud Climatology Project which would extract a 5-year-cloud data set from meteorological satellite observations. I believe that this project warrants high priority.

"Ocean mixing and heat storage. Horizontal ocean heat transports play a major role in establishing climatic patterns; practically nothing is known about how these transports will respond to a forced climate change such as CO₂ warming. . .

"Long-term measurements of heat storage and transport in the ocean and crucial to understanding the CO₂ climate impact. . .

"Ice sheets. . . In order to make reliable predictions it is necessary to deduce the past behavior of the Antarctic ice sheet, as well as its present state and the nature of current trends.

"Key ice sheet studies depend on monitoring of the ice sheet topography, which will require observations by altimeter from a satellite in polar orbit. It will also be essential to have field work on the ground in selected locations and substantial modeling and theoretical analyses. . .

SUMMARY

Mr. Chairman, it is becoming increasingly clear that we should anticipate climate change during the next several decades as a result of man's impact on the composition of the atmosphere. This conclusion is based in part on the fact that climate models . . . continue to indicate a large climate impact for increased atmospheric CO₂ and trace gases. Also the findings from spacecraft investigations of planetary environments, ranging from the thin CO₂ atmosphere of Mars to the thick greenhouse effect. And, perhaps most important, the circumstantial evidence contained in trends of global mean temperature, sea level and sea ice coverage all reveal long range changes which are consistent with expectations from the greenhouse theory.

"... In order for decision makers to have better information available when it is needed a variety of research efforts must be adequately funded now. . ."

(* References are deleted here for brevity.)

From 'Recent changes in the snow and ice marginal belt', Prepared Statement of George J. Kukla (Lamont-Doherty Geological Observatory), presented to Joint Hearing on Carbon Dioxide Research and the Greenhouse Effect, March 25, 1982:

"... My statement will summarize the results which I obtained during the last year together with J. Gavin and which were published in more detail in the journals Monthly Weather Review (*) and Science (*). ... Our results show that the recent summer pack-ice area around Antarctica is less extensive than in the 1930s. We found that the zonal mean surface air temperatures at the time when the seasonal snow and ice cover melts in the high latitudes of the northern hemisphere are higher than in the 1930s. . .

Findings

"(1) We found that in late spring and early summer the sea ice along a large segment of Antarctica between 60°W and 100°E longitude is less extensive in recent years than it was in the 1930's. About fourth fifths of all the summer ice edge positions reported in the 1930's are north of the corresponding recent average lines and about one third of the reported positions are further north than the maximum extent registered since 1973.

"(2) We also found that, while in the mid 1970's the zonal mean surface air temperatures of the northern hemisphere were cooler throughout most of the year than in the mid 1930's, they were warmer at the time when the seasonal snow and ice cover in corresponding zones dissipates in spring and summer. . .

"(3) We therefore tentatively concluded that the cooling which occurred elsewhere since the 1940's did not occur in spring and summer along the snow and ice margins. This is a geographic zone in which the so-called snow-albedo feedback takes place.

Links with the CO₂ rise

"(4) The above findings have implications for the detection of a CO₂ climate impact. This is because several numerical climate models predict that the strongest increase in the short wave energy absorption resulting from the doubling of CO₂ will occur in the snow and ice marginal belt during spring and summer. The energy balance model of Ramanathan, Lian and Cess (*) predicts the strongest CO₂ warming in the northern hemisphere to take place at the time and in the latitudes where the recent warm anomaly was observed. . . Our findings on the southern hemisphere sea ice are in line with earlier published reports on the recent increase in surface air temperatures at many southern ground stations (*) and with the warmer post-war sea surface temperatures around Antarctica as compared to the 1930's. Some of these observations were previously correlated with the CO₂ rise (*).

"(5) We therefore concluded that the recent changes in the snow and

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ice marginal belt in spring and summer indicate a warming trend which may be the result of increasing CO₂. . .

"(6) What I believe is established beyond reasonable doubt is that the climate did change within the last 40 years and that the change was not uniform geographically or seasonally (*). While most data supporting this statement refer to the annually and seasonally averaged surface air temperatures, the precipitation patterns and other aspects of climate changed as well(*).

"(7) . . . Based on what we know of the physical behavior of carbon dioxide and based on results of climate models, it is probable that CO₂ is one of the important factors in recent climate change. Nevertheless, in the middle and high latitudes of the northern hemisphere, the CO₂ increase did not reverse the cooling trend observed in the annual mean temperatures of the last 40 years.

"(8) Some other variables suspected of influencing recent climate on different time and space scales are:

- "- dust and gases released by volcanic explosions,
- "- dust and gases released by industry,
- "- industrial and urban heat,
- "- land use related changes of surface albedo and evaporation rates,
- "- variations in solar activity.

Limitations

"(9) The changes observed along the snow and ice margin can not yet be linked to the CO₂ increase with certainty because of the following problems:

"a. Other natural and man-made variables unrelated to CO₂ . . . can influence the climate in the snow and ice marginal belts and produce the observed changes . . .

"b. There are large year-to-year and decade to decade variations in the extent of the sea-ice which some climatologists believe result from the shifts in oceanic circulation. For example the recent decrease in the summer sea ice around Antarctica between 1973 and 1980 by 2.5 mill sq. km., which followed an episode of sea ice growth between 1968-1972, may be to a large degree due to such a short term variability. . .

"(10) I mention these limitations to underline the difficulties of documenting, that any climatic change is due to increase of CO₂. Such proof is extremely important, but very difficult to substantiate. At the same time, what we have learned so far about the seasonal and geographic aspects of the recent climate anomalies is in my opinion highly suggestive of the CO₂ impact. A significant climate change due to the continuing increase of the atmospheric carbon dioxide in the coming decades is a real possibility.

"(11) Currently our observations cover a relatively short time span and are geographically limited. . .

Projections of the Future CO₂ Impact on Climate

"(12) In my opinion a reliable prediction of the future CO₂ climatic impact is not yet possible. This is because we still do not understand the background of variations against which the carbon dioxide induced climate change is to be measured. . . Our predictions of climate 100 years ahead would be more reliable if we first accurately explained the climatic developments of the last 50 or so years.

"(13) This situation dictates the priorities of the CO₂ impact research program, which I see as follows:

"-First to identify all significant variables which are responsible for the climate variations of the past 50 years on regional as well as global scales and to determine the degree to which they affected climate. . .

"-Second, to project the future changes of the variables identified as influencing climate.

"-Third, to predict the CO₂ impact as an integral part of the composite climate system, where the . . . variables unrelated to CO₂ also change.

"(14) Some previous strategies placed strong emphasis on the research of the CO₂ impact only . . .

"Arguments were also made, that other contaminants released by

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burning of fossil fuels, reside in the atmosphere for a relatively short time, have as yet only regional distribution, and therefore have no climatic impact. I disagree since the global climate is a composite of regional climates . . . Since most of the world's population happens to live and raise food in the regions of industrial pollutants, we should pay more attention to the regional aspects of climate change.

"15) By approaching our principal objective, the prediction of future climate, we also will necessarily bring a considerable improvement in the season-to-season and year-to-year forecasts. . .

"In summary we found that the cooling which affected the middle and high latitudes of the northern hemisphere since 1940's is not present along the melting snow and ice margins, where some climate models predict the strongest impact of CO₂ on the surface energy exchange. This finding is an indication that the increased concentration of carbon dioxide at present levels is already influencing the climate system. . ."

'Summary of (prepared) Testimony of Dr. Melvin Calvin' submitted to the Joint Hearing on Carbon Dioxide and the Greenhouse Effect, March 25, 1982:

"Dr. Calvin was awarded the Nobel Prize in 1961 for studies in photosynthesis which included CO₂. He is a member of the Energy Research Advisory Board (ERAB), an independent panel that provides advice to the Department of Energy on research matters.

"The Board studied Federal energy R&D priorities and made recommendations regarding the relative importance of each program. They ranked the various programs as higher, medium, or lower priority as well as recommending funding level changes.

"The final report ranked Climate and CO₂ research as the second highest priority program and indicated that the funding should be increased. The report stated, 'ERAB members are in strong agreement on the importance of this program due to its long-term significance for public policy toward the use of fossil fuels. Although the predicted effects of increased CO₂ in the atmosphere occur well in the future, an intensified research effort is needed now in order to ensure that better information will be available for future decision making. The Federal

Government clearly has the principal responsibility for research in this area; an increased effort is recommended."

'Summary of (prepared) Testimony of Frederick Koomanoff (Director, Carbon Dioxide Research Division, U.S. Department of Energy) submitted to the Joint Hearing on Carbon Dioxide and the Greenhouse Effect, March 25, 1982:

"Known information

"Global atmospheric CO₂ has increased from 315 to 338 parts per million in the past 22 years. The major cause of the increase is man's energy activities.

"List of unknown issues

"The level of CO₂ that is acceptable in terms of minimum impact.

"Possible mitigating strategies.

"The costs and benefits of higher CO₂ concentration.

"Research efforts

"It may never be possible to attribute climate change directly to an increase in atmospheric CO₂. Currently, temperature changes predicted by general circulation models cannot be identified unambiguously because the natural year-to-year variability of the global average temperature is greater than that expected from the approximately 14% increase in CO₂ since the turn of the century.

"Agricultural impact

"Increased atmospheric CO₂ may benefit vegetation and crops because it is an essential ingredient for plant growth.

"Carbon emissions

"The growth rate of carbon emissions, which averaged over 4.5 percent per year throughout the third quarter of this century, has dropped to less than 2.5 percent per year since 1973.

"Future CO₂ emissions

"Land use changes will not produce a significant fraction of Man's total future releases of CO₂. Future CO₂ problems would be dominated by the burning of fossil fuels, not the burning of forests.

"Research needs

"Continual research is mandatory to ensure a sound quantitative knowledge base to aid in decision making."

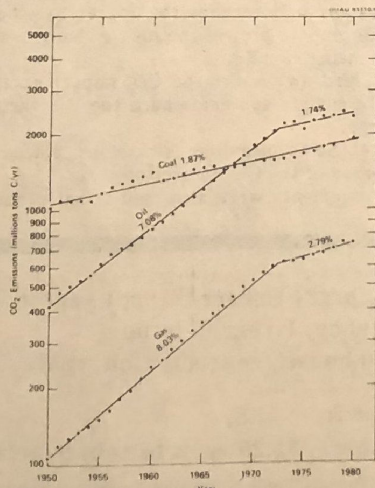
How much CO₂ from future oil?

In recent years the standard reference for annual production of CO₂ from fossil fuel consumption has been Ralph M. Rotty's compilations based primarily on data from the U.N. Statistical Office energy section, and which generally follows the methodology of Keeling (1973).

In an update of February 1982, Rotty has demonstrated a significant change in the rate of fossil CO₂ release from a steady 4.3% exponential growth 1860-1973 (except for periods of reduced CO₂ production during two world wars and the great economic depression) to a post-1973 growth rate of 2.25%.

This overall change is attributed to a decrease from the very rapid growth rates of oil (7%) and gas (8%) for 1950-1973 to nearly 2% and 3%, respectively, beginning about 1973. Rotty suggests that the reduced growth rates since 1973 may not be temporary excursions, "but are perhaps first signs of things to come".

Annual CO₂ emissions from each type of fossil fuel with growth rates.



The measured exponential buildup of CO₂ in the atmosphere has failed to track this rate change in fossil fuel consumption. An apparent

divergence of fossil-fuel growth rate and CO₂-buildup rate has some disconcerting implications.

Based on carbon-13 tree-ring studies, Pieter Tans (1980) interpreted the net change in the world's biotic carbon. He showed a very rapid decline from a large net-carbon-input situation in 1960 to a neutral situation in the mid-1970s, and—if projected—the biota may have crossed over rapidly to a net-carbon-output situation at about the same time that the exponential rate of fossil-fuel growth suddenly changed slope.

If Tans's analysis truly represents biotic change, then a disproportionately large amount of CO₂ produced from the rapidly growing fossil-fuel use in the 1960s and early 1970s may have been taken up by net biotic growth in that period, and a much lower biotic take-up rate or reinforcement by net biotic output of CO₂ could represent what may be expected in future decades. The possibility exists, of course, that the rate of oceanic uptake of CO₂ decreased in the last decade due to global temperature rise, but such a positive feedback would offer no future relief.

If the current ratio of atmospheric CO₂ increase to increase of fossil-fuel consumption is applicable to future decades, then it becomes important to re-examine the world's potential for sustained fossil-fuel growth into the next century. A very methodical analysis by K.E. Rosing and P.R. Odell of Erasmus University, Rotterdam, published in GEOJOURNAL, 1981 (Akademische Verlagsgesellschaft, Wiesbaden) offers no solace that early exhaustion of the world's oil supplies will soon help slow the CO₂ buildup:

"Abstract: There is currently a generally accepted view that world oil resources are so limited that they are unable to sustain the growth of industry beyond the next decade or so. This pessimistic forecast is contrasted with somewhat earlier optimism of the oil industry concerning its future.

"Based on a wide range of values for each variable the contemporary accepted view on the future of oil is shown to be one of the least likely. It is also shown that the current view has a dangerous feedback effect on energy policy making. More likely futures for oil are considered and it is concluded that there is a 90% probability for growth until the year 2009; a 50% probability for growth until 2037 and a 10% chance that the industry need not reach its peak until 2077. Over the remainder of the industry's growth period the worldwide use of oil could increase to at least twice and up to 3.5 times its present size."

—W.N.B.