BUSH ENERGY POLICY AT ODDS WITH EFFICIENCY

The headline of a story on the front page of the 15 December issue of the *Denver Post* said, "Bush Aides Say No to Conservation." The story reported that "White House aides, led by Chief of Staff John Sununu, have told Energy Secretary James Watkins to remove energy-conservation measures from his proposed National Energy Strategy. . . . Proposals to stiffen auto-fuel efficiency standards and to increase use of non-gasoline fuels drew particularly heavy fire. . . . Bush aides also attacked virtually all of Watkins's proposals to encourage energy conservation."

I suspect that a great majority of the members of the American community of physicists would strongly support the reported efforts of Secretary Watkins and would reject the reported position of Sununu and his allies. We note with pride that in an earlier energy crisis, a decade or two ago, the physics community responded vigorously with several pioneering studies of methods of increasing the efficiency with which energy can be used.

Much of the knowledge one needs to improve the efficiency of energy use is covered by fundamental topics: temperature and heat energy; the gas laws; the first law of thermodynamics; calorimetry; heat transfer by conduction, convection and radiation; the second law of thermodynamics; the Carnot cycle; and heat engines and refrigerators. Readers will recognize these topics as the essential contents of the traditional section on heat and thermodynamics in introductory physics texts. These topics have been an integral part of our first-year physics courses for generations.

Major efforts are currently under way to restructure introductory collegiate physics courses. The physics faculty of one (and perhaps more than one) of the nation's most prestigious technical universities is reported to have decided to omit these traditional topics of thermodynamics from its introductory physics courses. A current suggestion from a major "reform" study is to replace these topics in the curriculum with an introduction to statistical mechanics. The courses being affected are those that prepare the nation's future generations of scientists, technologists, engineers and leaders in other professional fields.

There would probably be widespread agreement in the physics community that a major priority for America throughout the foreseeable future must be to improve the efficiency with which we use energy. The White House staff apparently does not want Americans to be educated about this priority, and some leaders of the physics community want these priority topics displaced from our curricula. How odd it is that the actions of some of our tenured friends and colleagues are aiding and abetting the efforts of transient members of the White House staff in advancing policies that most of us reject.

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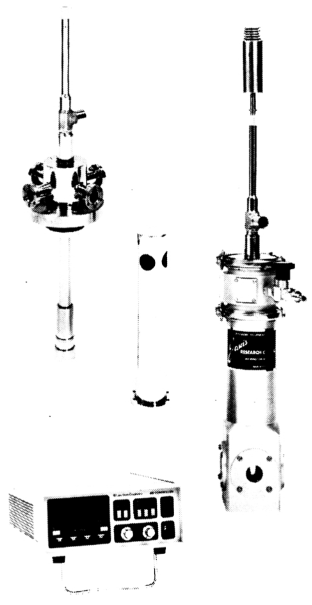
Is Greenhouse Effect in Ice of the Beholder?

Raphael Kazmann (July 1990, page 13) writes that we should not bet our scarce resources on theories predicting a rise in sea level from global warming, because some glaciers are advancing today. If Kazmann had a clearer picture of the situation, he might be less sanguine. On average, mountain glaciers are melting and contributing to a sea-level rise today.[1] We do not know whether the ice sheets of Antarctica are growing or shrinking. Portions of the ice sheet in central Greenland do seem to be thickening,[2] but possibly because of an odd dynamic situation rather than recent climatic effects.[3] (Ice-age ice in Greenland has lower viscosity than recent ice, probably because ice-age ice contains more windblown impurities. As recent ice progressively replaces the ice-age ice, the average



viscosity of the ice sheet increases, and the ice sheet must thicken and steepen to remove the snowfall on it.) Sufficient warming will begin to melt the Greenland ice sheet,[4] although in Antarctica it may increase snowfall more than it does surface melting.

The real concern is with ice flow in West Antarctica. The bed of the modern West Antarctic ice sheet is below sea level, and generally is deepest beneath the center of the ice sheet, becoming gradually more shallow toward the edge of the ice sheet and beyond, beneath marginal seas. The ice thins rapidly toward its margins until it begins to float in the marginal seas, forming extensions called ice shelves, which are hundreds of meters thick. The location of the transition from nonfloating (or grounded) to floating ice is called the grounding line.

If an ice shelf floats freely, then the rate at which its flow removes ice from the grounding line increases approximately with the cube of the water depth there. This, along with the sloping bed of West Antarctica, suggests an inherent instability: If the grounding line advances into the sea a short distance, the water depth at the grounding line will decrease, the rate of ice removal from the grounding line will be reduced below the rate of ice supply from upglacier, the ice at the grounding line will thicken, and the grounding line will advance. If, however, the grounding line retreats toward the center of the ice sheet, the water depth at the grounding line will increase, ice removal will exceed supply from upglacier, the ice will thin, and the grounding line will retreat. In this simplest model, there are only two steady grounding-line positions: advanced to the edge of the continental shelf (large ice sheet) and retreated to the center of the basin (no ice sheet).[5] Indeed, geological evidence shows that the ice sheet has oscillated between advanced and collapsed positions, and was advanced during the most recent ice age.[6]

The ice shelves around West Antarctica do not float freely everywhere, however, but run aground on local high spots in the sea floor, which thus partially "dam" ice flow and slow ice removal from the grounding line. Model results show that the grounding-line retreat triggered by the end of the last ice age would have collapsed the entire West Antarctic ice sheet thousands of years ago if this damming effect did not occur.[7]

An ice shelf is an effective dam only in cold conditions, however. Warm ocean waters circulating beneath an ice shelf can melt meters per year from its base, removing ice much faster than snow falls on its surface. A sufficiently large warming of the polar oceans is likely to increase basal melting and thin the ice shelves, reducing their damming effect until ice-sheet collapse is triggered. Such a collapse would raise global sea levels at least 6 meters (from West Antarctica alone) and as much as 80 meters (if East Antarctica and Greenland also collapsed) in as little as one or a few centuries.

What can we do about this? Research is an obvious (and obviously self-serving) answer. We can hope to reduce the uncertainties in our knowledge enough to be useful to planners with on the order of $10 million in science funding per year for a few years or decades—say, $100 million to $1 billion total, in round numbers (0.01–0.1 SSC, or 0.1–1 Stealth bomber?). This should be balanced against the potential costs of ice-sheet collapse. When a few meters of storm surge from a single hurricane can approach $10 billion in damage, even $10 trillion in total damage from ice-sheet collapse seems like a low estimate. Would a good strategic planner in the corporate world pay a few pennies per thousand dollars to know if and when a disaster was coming? I think so.

Certainly, Kazmann argues not against research but against possible active measures to reduce greenhouse-gas emissions. Here, the question is more political than scientific. Depending on the assumptions one makes within the current large error bars, abatement of greenhouse-gas emissions is either nonsensical or economically sound. However, the conclusion is hard to avoid that trace-gas emissions beyond some limit could trigger ice-sheet collapse, and that we may cross that threshold before we learn where it is. A gambler might opt for life as usual, hoping that we learn faster than we burn. As one of more conservative bent, my vote is to hedge our bets and tax our gas.

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Raphael G. Kazmann cites evidence for the growth of some glaciers as being in contradiction with the concept of climate warming from the anthropogenically enhanced greenhouse effect. From a glaciological standpoint there are two misconceptions in his discussion.

The first relates to the response times of glaciers to changes in their environment. The advances and retreats of glacier snouts cannot be directly associated with concurrent changes in atmospheric temperature; they reflect instead complex changes in the velocity distribution throughout the whole glacier. Velocity changes, whether they stem from climatic or other effects, take time because of the dynamic sluggishness of glacial systems. The response time varies from years for small glaciers through decades for large glaciers to tens of thousands of years for the large ice sheets. Thus the substantial increase in the number of advancing glaciers between 1960 and 1980 cited by Kazmann reflects changes in conditions roughly between the 1940s and 1950s on the one hand and the 1960s and 1970s on the other. What the effect of warming in the 1980s may be remains to be seen some years in the future, although there is already evidence that at least two small glaciers that were advancing in 1980 are now retreating, according to information I have received from Edwin D. Waddington of the University of Washington, Seattle.

The second error is the implicit assumption that interior growth of the ice sheets of Greenland and Antarctica is inconsistent with climatic warming. In fact, warming is a likely cause of that growth. An immediate effect of a warmer atmosphere is an increase in the saturation vapor pressure. Air masses that move from the oceans into the interiors of the ice sheets are saturated with water and, because of the high interior elevations, dump essentially all of their moisture as snowfall in the interior. Warming should increase the melt rate around the margins of the Greenland ice sheet, but the measurements cited by Kazmann were only on the interior surface above the limit of melt. Any dynamic lowering of the interior because of coastal melting will take thousands of years to appear. Antarctica is so cold that summertime melting, which occurs only in a thin band around the northernmost fringes of the ice sheet, is a negligible factor in the overall mass balance. The positive balance for Antarctica that Kazmann cites from my work[1] is based on many data too old to be relevant to anthropogenic warming, but T. H. Jacka and William F. Budd have presented data that do statistically support increases in both temperature and snow accumulation rate in Antarctica that are compatible in magnitude with those expected from greenhouse warming.[2]

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Raphael Kazmann complains that "we are supposed to spend billions of dollars to reduce the use of fossil fuels, . . . drive smaller, more dangerous cars, . . . reduce the use of power, . . . to name just a few of the expensive steps" proposed to reduce global warming. It is true that the experimental information and the results of computer models are not and probably will not be as conclusive as one would like—at least not before the consequences of doing nothing have become so obvious to all that it is too late. Given not only the uncertainties in the predictions, but also the consequences of a worst-case scenario, it would make more sense to adopt a strategy of "prudent avoidance" than to wait and do nothing. Such a strategy entails taking those actions that are relatively painless or have "tie in" benefits even if climatic changes do not materialize as forecast.

When one considers the entire system and not just small sectors, pursuing energy efficiency usually makes economic sense in the long term. Decreasing the use of fossil fuels would lessen acid rain and urban air pollution and reduce dependence on foreign producers. Relatively simple changes that mostly involve redirecting investment can make buildings more energy efficient, for possible savings of up to $50 billion per year.[1] Increased energy efficiency brings more "energy" per investment dollar than new sources of energy do.[2]

The technology for producing fuel-efficient cars and small trucks without sacrificing safety, comfort, low emission levels and affordability already exists. Volvo has produced a prototype that gets 81 mpg on the highway and 63 mpg in the city, seats four and withstands crashes better than US law requires. If such a car is ever marketed, I for one will buy it and will not buy a car that does not get this kind of mileage. Is happiness really to be equated with far more horsepower than is conceivably usable in typical heavy traffic? Kazmann seems to think it is, but reducing the horsepower of most cars would really be a totally painless way to avoid a potential increase in the greenhouse effect.

Kazmann writes that "while verifiable models are being developed, we can devote our funds to something useful, like filling potholes, repairing highway bridges or improving education." Educational improvements could be paid for with the savings that come from making buildings and appliances more efficient. As for bridge and road improvements, drivers should pay for them through drastically increased gasoline taxes. (After all, they are the beneficiaries.) This would be fully consistent with a strategy of prudent avoidance as far as global warming is concerned, and makes a good bit more sense than sticking one's head in the sand like an ostrich.

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Kazmann replies: I appreciate the comments of Richard B. Alley, Charles R. Bentley and Edith Borie. The reason that I wrote my letter in the first place was that the computer programs that predicted global warming were inadequate, unreliable and misleading—as indicated by the lack of the necessary corroborative observational evidence. None of the letters takes issue with this, and one would think the writers would join me in counseling caution and patience before we embark on expensive and probably unnecessary economic and social experiments. But this expectation would be in error, even though without a substantiated model the kinetics and direction of climate change are unpredictable and any action may be deleterious.

Borie has little confidence that we will ever have the ability to model climate properly. She argues that we ought to spend a lot of money, increase taxes and tell people what to do, even in the absence of observational data to show whether the climate is slowly getting warmer or colder. The world's people have already had enough trouble with command economies based on fallacious theories without embarking on worldwide economic changes based on a hypothetical cause and effect.

Alley suggests that more research and study would be "self-serving." I myself am retired and have no grants or proposals pending. He says we ought to tax gasoline to reduce greenhouse gases. We are already taxing gasoline heavily. Moreover, most proposals for political and economic action go much further than a simple tax on gas. We are now in a position, if we spend the money, to produce mass balances for the various ice sheets, and after we have assimilated and analyzed the data over a few decades we should have a sound basis for evaluating just when and if Alley's disaster might happen.

Bentley cites data from a paper presented after I wrote my letter. It has always proved difficult to consider unpublished information when you prepare a critique. I await Bentley's next paper with anticipation.

All of the robust observational data that I have been able to obtain indicate that the climate is getting colder, *not* warmer. The northern line of orange production in Florida has moved south over the past 20 years, not north. For those who enjoy anecdotal evidence, let me refer to chapter 39 of Mark Twain's *Life on the Mississippi*, concerning Natchez, Mississippi. Twain agreed with Mrs. Trollope's 1827 statement that "Natchez is the furthest point to the north at which oranges ripen in the open air or endure the winter without shelter." This is no longer true. Louisiana oranges were commercially grown south of New Orleans beginning in the early 1940s, but the last commercial grove was destroyed by frosts in the 1980s.

Finally there is the new "Plant Hardiness Zone Map" issued by the Department of Agriculture, which shows the low temperatures controlling plant survival: The 1990 map shows that the zones in the 1965 map are now 5–10 °F colder. At this rate, maybe we should be concerned about a new ice age and should promote the production of greenhouse gases to counteract the cooling. Let me emphasize that I do not advocate this—but we do need more research, and substantiated models, before the scientific community begins to advocate expensive restrictions on entire populations to avert a hypothetical anthropogenic climate change.

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Batting Around Ideas on Curveball Physics

Geoffrey F. Chew's review of *The Physics of Baseball* by Robert K. Adair (September 1990, page 103) led me to read and enjoy that delightful book. I was intrigued, but not entirely convinced, by Chew's reference to the mechanism of the curveball (the Magnus effect) as being "simpler than the Bernoulli effect." According to Georg Joos's *Theoretical Physics*,[1] from which I learned much of my physics, the Magnus effect is derived from the Bernoulli equation. Joos points out that this derivation assumes no separation of flow from the rotating surface, that is, it assumes no turbulence; and it follows from his discussion that *with* separation the lateral force is reduced by about half. Inclusion of turbulence, it seems to me, makes the mechanism more complex, though more realistic.

Adair expresses the Magnus effect in terms of the drag force due to flow separation and the experimentally derived drag coefficient, and he makes a point of distinguishing the Magnus and Bernoulli effects. He describes experimental results showing that the lateral (Magnus) force on a baseball varies with speed and reaches a slight maximum at about 60 miles per hour and a slight minimum at about 80 mph. The average magnitude in this speed range is roughly half of the inviscid-flow Magnus effect.

It seems to me that the inviscid-flow solution has unique conceptual and heuristic value, and that the experimental results might best be explained as departures from the inviscid-flow solution due to flow separation.

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ADAIR REPLIES: As another who learned much physics—and something of the Magnus effect—from Georg Joos's wonderful *Theoretical Physics*, I have no important disagreement with Robert G. Fleagle's physics. My use of Isaac Newton's simple description of the Magnus effect was based partially on pedagogical concerns: My book was addressed to the lay audience and the late baseball commissioner Bart Giamatti. The Bernoulli pressure–velocity relation that follows from the conservation of energy applied to irrotational laminar flows surely plays an important role in the Magnus effect, but the trailing vortices at low baseball velocities and the turbulence that follows Nolan Ryan fastballs generate effects outside of the Bernoulli conditions. And Joos's instructive calculation of the Magnus effect was derived from a model that did not account for the drag force.

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Geometric Phase's First Formulators

In an illuminating article (December 1990, page 34) Michael Berry writes about people whose work anticipated his discovery of the geometric phase. The earliest reference on his list is to the work by Sergei M. Rytov and Vassily V. Vladimirskii in the Soviet Union, to whom he attributes the discovery of the law of the parallel transport of the polarization vector in electrodynamics.

In fact, as we wrote in our paper on Berry's phase in the relativistic theory of spinning particles,[1] this discovery was made in 1926 by a mathematician, E. Bortolotti, who was working on the applications of the absolute differential calculus invented by Tullio Levi-Civita. In a very clearly written paper published in the proceedings of the Lincei Academy, Bortolotti described the propagation of linearly polarized light in an inhomogeneous refracting medium and found the correct propagation law for the polarization vector.[2] He ended his paper with the following conclusion: "The light vector of the linearly polarized ray Γ, propagating through a medium with a varying index of refraction $n(x,y,z)$, is transported along the ray Γ by a parallelism with respect to a metric connection (in the sense of Weyl) in $\mathbf{R}_3$, whose components are determined by the vector grad $\log(n^2)$."

Since B. L. Markovski and S. L. Vinitsky have already proposed the name "Rytov–Vladimirskii phase" for Berry's phase as it appears in the propagation of the polarization vectors in electromagnetism, I believe