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LETTERS

Global Warming

William Dozier (July 1992) asserts that global warming is a "chimera" invented by people who "hate free enterprise." Apparently he believes that these people have brainwashed the community of atmospheric scientists, the overwhelming majority of whom (70% in a recent poll) say that it would be unwise to continue increasing atmospheric carbon dioxide when we know that the effects could be disastrous.

Dozier explains that any action in this direction would be "oppressive," that people "want the personal freedom that comes from driving their own car." Yet he does not give a single example of a proposed oppressive action. I have heard no proposal that private autos should be confiscated, but it has been proposed that the gasoline tax be raised by anywhere from 25 cents to a dollar per gallon, thereby raising the cost of operating a car by as much as 10%. Imagine the tragic consequences:

- Some people might choose to drive less and walk more.
- Some might demand more energy-efficient autos, which they don't demand now because fuel costs are such an insignificant part of driving costs.
- The government would receive roughly $100 billion. Forty billion of that could cover the cost of maintaining naval forces in the Middle East, to end this hidden subsidy for oil. Some could be spent to improve the wretched quality of our streets and highways, and to remove the burden of repairs from financially strapped cities. Some could finance measures to alleviate air pollution, to which autos and trucks are main contributors. Some could make public transportation and rail travel far more readily available.

The net effect would be to reduce pollution, conserve oil, provide a more balanced transportation system, and reduce the number of highway deaths and injuries. How oppressive!

Is it fair to drivers? I am a driver, and I think it is fairer to do this than to spend my gas tax money for more highways when I would rather take a train which is faster, more efficient, less polluting, safer, and more comfortable. Why subsidize drivers when we have so many other budgetary problems? Consider the fact that a toll road costs 3 or 4 cents a mile, or about $1 per gallon. Clearly that figure, not the current federal tax of 14 cents per gallon, represents the actual cost of interstate "freeways." The difference is covered by money diverted from funding of other roads.

This is not an extremist view. The extremists are the small minority who agree with Dozier, and who preach freedom while supporting the conditions that take our freedom away.

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Charles Dale (July 1992) calls for discussion in these pages of "scientific pricing of nonrenewable resources." This is important because pricing greatly affects our individual and national behavior.

Let's start by evaluating an investment in a more efficient refrigerator, which saves energy and can be considered a type of renewable resource. For example, let us compare $100-200 invested to improve a refrigerator to save 1000 kWh/year (comparing 1974 to 1990 refrigerators) with electricity at 7 cents/kWh. The annual cost of the investment would be the annual cost of the refrigerator that lasts (say) 20 years, plus the annual cost of borrowing the money. In constant dollars, this would be about 10% per year, or $10-20 per year for a $100-200 investment. Dividing this annual cost by the annual savings of 1000 kWh gives 1-2 cents/kWh — much less than the price of electricity. See Reference 1 for details.

The pricing of nonrenewable resources is much more difficult, and in fact economists don't seem to know how to incorporate the finite resource issue. If markets are working, price is typically cost plus profit, and profit is minimized with competition. This isn't a bad approach , but it does little about the finite resource. The usual argument is that the price rises as we run out of oil, allowing drillers to go to more costly, lower-quality resources. But life is more complicated than that. In one of my first assignments in the Senate a year after the 1974 oil embargo, I did the staff work on setting the US oil "price" for three years. It was a political compromise.

In the first reference below, the equations are developed to take care of old oil, new oil, stripper oil and enhanced recovery oil. But when push came to shove, the Senate conferee vote was 12 to 12, and the analysis of the 25th Senator prevailed. Around 1974, excess profits from oil that went from $1.5 per barrel oil to $12 per barrel oil were somewhat obscene. Nevertheless, it is clear that higher prices do yield some conservation as well as other benefits. With good market forces, changes in prices affect purchasing. When these forces are weaker (or inelastic), changes in price won't much affect demand. It is generally felt that gasoline is somewhat inelastic in the near term since you must buy gas to commute to work, but that elasticity rises with time as you adjust to higher prices.

We have a $400 billion budget deficit that could be reduced with taxation rates at European levels of $4/gallon. Since the US burns about 5 million barrels a day on its roadways, this would give revenues of some $75 billion a year. If applied to all uses of petroleum, revenues would be some three times higher, or about half of the current budget deficit. Of course this isn't a new idea, but I can tell you that it is not very popular if you are running for office. However, the $75-225 benefit would be accompanied by reduced future consumption, reduced dependence on the Middle East with consequent reduced need for encounters like the Gulf

War, improved air quality, and reduced environmental damage caused by energy production.

We are usually told that Price = Cost + Profit, but this equation doesn't take all of the above into account.

1. D. Hafemeister, Am. J. Physics **47**, 670 (1979); **50**, 29 (1982); **55**, 307 (1987).

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Suggestion for a Forum Study: The Hydrogen Energy Economy

The oil crisis of 1973 rudely awakened America to its vulnerability to the whims of Arab dictators. For a while, this led to some hard thinking about reducing our growing dependence on foreign petrochemicals, particularly as energy sources. Unfortunately many hopeful approaches like the one discussed here were examined and more or less abandoned. Expensive programs were started and discontinued before they could bear fruit. The Arabs seem to have aborted our programs by a temporary reduction in oil prices.

Our consumption of foreign oil has since greatly increased, the resulting problems of pollution and anxieties about greenhouse effects have grown ever more acute, and brown-outs are increasingly frequent. Nuclear energy is stuck in the politics of irrationality, coal-burning power plants are bad polluters and coal mining despoils landscapes, and biomass fuel has severe, perhaps prohibitive, economic handicaps. Solar and wind energy are enjoying continuing significant progress in conversion efficiencies. However they still have, in addition to the economic cost of building the needed infrastructure, problems like unavailability at times most needed, inadequate means of energy storage, and remoteness of the most desirable sites for energy production from areas of high consumption.

Hydrogen is a highly desireable fuel, for burning it produces pure H_2O. Used in fuel cells, it produces electric power far more efficiently than any heat engine. It is a fine energy storage medium and can be efficiently manufactured electrolytically from sea-water using solar, wind, geothermal, or any other source of electrical energy. It is readily transportable by pipeline, in high pressure tanks, in the form of stable hydrides, or as a cryogenic liquid. It can be used, not only for fuel or in fuel cells, but as a chemical feedstock, e.g. to manufacture methane from coal, to derive liquid fuels from the same source, or to upgrade tar sands or oil shale. It can be added, at least up to 10%, to natural gas used as fuel, with no modifications needed on home furnaces etc. Problems in handling hydrogen (its explosive nature) are well understood, and techniques are in hand for handling it on an industrial scale.

Much progress has been made in all of the above since the 1970s, and the time now appears ripe to reexamine the hydrogen route to energy self-sufficiency using renewable non-polluting ultimate energy sources (solar, wind), and producing useable products in place of pollutants and greenhouse gases. All the problems of intermittancy, remoteness, and storage, seem minor. There are useful by-products of hydrogen production and consumption such as pure oxygen and concentrated brine (for extracting Mg, and other brine-based industrial products, or as the basis of concentration-cell electric power) and pure water. Fuel-cell-powered autos, trucks, buses and locomotives can be developed over time. An important consideration is that the transition to a hydrogen energy economy can be evolutionary, so that the economic return from products continuously supports construction of a growing infrastructure.

A Forum Study is suggested to examine what drawbacks and difficulties might hinder realization of the rosy scenario sketched above.

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ARTICLES

Symposium on Global Warming: Physical Basis, Present Data and Future Measurements

Physics and Society presents here articles based on the three talks given at an invited session sponsored by the Forum on Physics and Society at the April 1992 APS meeting in Washington, DC. The first talk by Bruce Barkstrom of the NASA Langley Research Center described the basic interactions and conservation laws that are used to establish the equations that are used in modeling. The forcing terms that affect the global temperature balance were examined, including that of trace gases, such as carbon dioxide, and that of clouds. Due to space limitations, most of the mathematical details have had to be left out of the article printed below, but these details are available upon request from the author. The second paper by George Maul of the NOAA Miami Meteorological Laboratory examines the temperature trends for surface temperatures over the past century, as well as the data on the rise of ocean levels. The third paper by James Baker of the Joint Oceanographic Institution of Washington, DC, examines the various space platforms that are being planned for Mission to Planet Earth. The meeting was a lively one, with lots of questions. This session is a continuation of the Forum's effort to look at global warming issues, following its 1991 short course and book *Global Warming: Physics and Facts* (AIP, New York, 1991). The session was chaired by D. Hafemeister.

The Physical Basis for Global Change

Bruce R. Barkstrom

In trying to understand global change, there seem to be three major components that concern us: first, changes in Earth's climate; second, changes in the chemistry of the atmosphere, oceans, and land systems; and third, changes in the ecological systems that contain and support life.

Changes in the greenhouse effect certainly play a large role in discussions of climate change. We have measured increases in CO_2 and other trace constituents that we believe increase the opacity of the atmosphere to the emission of infrared radiation to space. Our current models of the effect of these changes makes it clear that there is every reason to expect that this increase will lead to an increase in the surface temperature of Earth. In this paper, we want to explore our understanding of the energy flows that lead to this conclusion.

Although we will not explore the chemical and ecological bases for global change in any detail here, there are certainly legitimate grounds for concern over these facets of change. We have recently measured unexpected changes in stratospheric ozone. We also know that numerous ecosystems are being changed by man's activities. As we will comment toward the end of this discussion, the changes in the chemical and ecological components of Earth's environment are coupled with the energy flows that govern the climate component. As we move into a new ear of observing Earth, we are constantly reminded of the need to think of these components as part of systems that interact.

Energy flows and climate — a simple model

An atmosphere that does not interact with sunlight, but that absorbs and emits infrared radiation provides a simple metaphor for the energy balance of Earth's climate. The simplest way to treat the atmosphere's effect on heat transfer is to assume that the atmosphere is an isothermal slab. The slab's temperature is T_a, and its emissivity is ε. We assume that all energy fluxes are radiative. Figure 1 illustrates these flows. We must simultaneously find both surface and atmospheric temperature, T_s and T_a.

We have carried out a mathematical analysis of this model, and of several time-dependent perturbations to it. Due to space limitations, the details are omitted from this article; they are available from the author upon request. The model demonstrates the following conclusions:

1. For climate time scales, imbalances in the radiation budget force the surface temperature to change. The imbalance moves the system to a new equilibrium. The fact that radiative imbalances force the temperature to change is the reason we call such imbalances climate forcings.

2. The final equilibrium does not depend on how rapidly the climate forcing is turned on. Solar constant perturbations have the same footing as emissivity perturbations.

3. The relationship between the forcing and the final climate perturbation does not depend upon how the forcing is applied. The climate system only knows that there is an imbalance in the radiation budget. It will adjust its internal state until the radiation budget is back in balance.

4. Different models have different sensitivity.

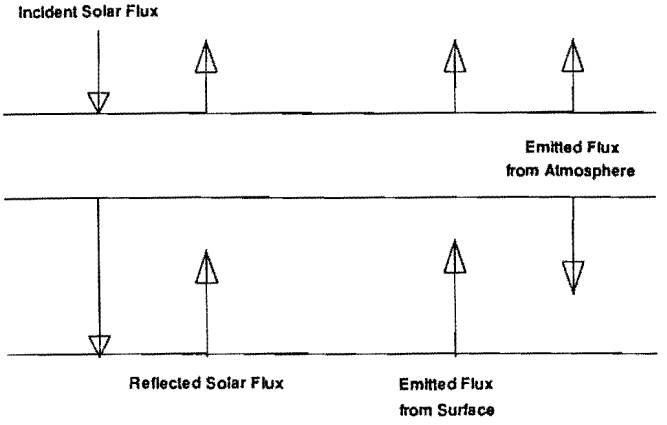

Figure 1. Energy balance of a climate model with a simple atmosphere. The atmosphere has no effect on solar radiation, but does absorb, transmit, and emit infrared radiation.

Cloud-radiative forcing observations

We can now place the effect of clouds on the radiation balance in the context of climate forcings and feedbacks. Clouds reflect sunlight and decrease the emission from the surface to space because the atmosphere is colder than the surface. Thus, if we could instantaneously remove clouds from the system, we could perform the same kind of experiment as we did in changing the emissivity, or the atmospheric reflectivity.

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Such an experiment was long considered as interesting by the modeling community. However, the Earth Radiation Budget Experiment (ERBE) made this experiment directly. ERBE observed the Earth from three satellites with two different instrument packages on each satellite. For measuring the cloud-radiative forcing, the ERBE scanner observations were fundamental. After the ERBE processing system converted the instrument data to calibrated radiances, the system categorized the scene within each pixel into cloudiness categories: clear, partly-cloudy, mostly-cloudy, and overcast.

To describe the effect of clouds on the radiation balance, we simply define the forcing:

$$C = F_{\text{all sky}} - F_{\text{clear}}$$

Because ERBE separated the fluxes into reflected solar and emitted terrestrial wavelength bands, we could obtain cloud forcings for all each band independently. At the same time, by computing the total forcing, we could look at the net effect of clouds.

The initial results reported by Ramanathan et al (1, 2) showed that the longwave cloud-radiative forcing was about 30 W/m^2, while the shortwave cloud-radiative forcing was about -45 W/m^2. The net forcing, over the entire globe was about -15 W/m^2. In other words, clouds cool the current climate. It is interesting that this cooling effect is about four times the size of the expected forcing from a CO_2 doubling. As Harrison et al (3) showed, ERBE observed cloud-radiative forcings of about this value for all seasons.

We had not expected to obtain such a clear picture of the influence of clouds. In the tropics, the modeling community had long debated whether clouds heated the climate, because of the infrared blocking from high cirrus clouds, or whether they cooled the climate because of the substantial increase in solar reflectivity. The ERBE observations strongly suggest that these two effects nearly cancel each other out there. What was surprising was that the strongest effects of clouds were over the mid-latitude storm systems. There, clouds low in the atmosphere markedly increase the reflected sunlight, but are low enough in the atmosphere that they do not block an equivalent amount of infrared flux.

The climate modeling community has taken the ERBE observations and has begun the massive task of intercomparing the behavior of various models against the observations. A preliminary study which included nineteen General Circulation Models (GCMs) showed a substantial disagreement in predictions of cloud-radiative forcing for model months of January and July. Indeed, the disagreement was as large as the cloud forcing itself. Furthermore, in trying to understand cloud feedback, the models showed reasonable agreement in their predictions of clear-sky responses, but differed by almost an order of magnitude in their prediction of cloud feedback.

The Earth-observing system as an example of systematic measurements

The disagreement between the observations of cloud-radiative forcing and model predictions of this quantity and the large discrepancies has created an interesting situation in the climate modeling community. At present, the disagreements are large enough that the community will have a substantial amount of work to do to bring them into reasonable bounds. However, the disagreement in cloud feedback predictions is more difficult to anchor to observations. As the theoretical treatment shows, cloud forcing is the result of an "instantaneous" change in the atmosphere. The feedback is the derivative of the forcing. Thus, the ERBE observations do not complete the work of understanding the role of clouds in climate.

A preliminary study which included nineteen General Circulation Models showed a substantial disagreement in predictions of cloud-radiative forcing. Indeed, the disagreement was as large as the cloud forcing itself.

For a deeper insight into this problem, it is important to remember that the climate system is constantly being perturbed. For example, in July 1991 Mount Pinatubo exploded and sent sulfur-containing gases into the stratosphere. Over the ensuing months, this gas created sulfate aerosol in the stratosphere, which created a substantial perturbation to the radiation balance of the Earth. Over the next few years, this perturbation will die out as the aerosols are removed. Hansen and others have computed the radiative perturbation, and show that they expect a net cooling which peaks about one-half year after the eruption, and then decays over the next two to three years. Thus, although the perturbation from the eruption started quickly enough, it will not remain, and so the surface temperature will not be forced to respond to a permanent perturbation. Rather, the Earth's surface was struck by a transient change in fluxes. We also know from observations of the solar "constant" that the sun's output varies over the sunspot cycle. In this case, there is a quasi-periodic perturbation in the incident flux. There are also internal perturbations, such as the El Niño changes in the storm systems in the western Pacific. Here, the clouds and precipitation move from a location near Indonesia out over the central Pacific. We now have a partial record of how this affects the radiation balance.

Given this situation, it has become clear that we need to be able to separate out the response of the climate system to the internal and external perturbations that excite modes of response that are different from the response to longer and more global perturbations. This is not easy for clouds. We can imagine a variety of ways clouds can respond to climate forcings. We might get more cloud cover or create more high cirrus clouds in tropical thunderstorms. We might decrease the pole-to-equator gradient in temperature and thereby replace low-level frontal clouds with higher thunderstorms. We need to obtain a clearer picture of the mechanisms by which different climate models respond to changed conditions.

It is also true that we need longer term and better observations. ERBE obtained only a five year record of cloud forcing. In the meantime, the El Niño perturbation to the clouds over the Pacific is causing changes to the atmospheric and oceanic circulation systems. We need observations of the sun, of volcanic aerosols, and of the cloud radiative forcing. We also need better information on the physical properties of the clouds themselves. A low spatial resolution sensor, such as the ERBE scanner, even though of very high radiatiometric accuracy, cannot do as well at observing cloud properties as can instruments with higher spatial and spectral resolution.

Furthermore — the models showed reasonable agreement in their predictions of clear-sky responses, but differed by almost an order of magnitude in their prediction of cloud feedback.

As we have observe cloud-radiative forcing from ERBE, it has become clear that clouds are not random objects scattered over the Earth. Rather, they are components of systems that move and act as objects. Cloud systems are born, move, and die over time and space scales that are larger than their component clouds. Some of these systems seem to be nearly stationary, such as the low stratus decks off the Western coasts of South America, California, and Africa. Some of these systems form over continents and persist in the cloud-forcing record for more than a month and over thousands of kilometers. One particularly interesting example can be seen in the ERBE monthly average data. It is not at all obvious why systems made of such transient entities as water droplets and turbulent vertical motions should form in the same place and persist as systems that influence the energy fluxes over a month or more. Thus, it may be useful to think of these cloud systems as entities in their own right.

From this standpoint, we may begin to think of Earth's environment as made up of interacting systems on spatial and temporal scales that we cannot readily experience in our normal modes of existence. Cloud systems certainly influence the energy flows to and from Earth's surface, and thereby change the environmental regime of the surface ecosystems. The response is mutual, since the ecological regimes also play a substantial role in the transfer of heat and water from and to the surface. Our old ways of thinking about this kind of system interaction are probably no longer appropriate for understanding how the climate system works. We need observations that treat extended entities, such as cloud systems and ecological regions, on a common, long-term basis.

The Earth Observing System (EOS) is an example of the kind of system we need to provide data for this kind of understanding. We need to go beyond the view of single instruments and single satellites to a more "systematic" view of the Earth. For example, with EOS, we will have the CERES instruments that come directly from the ERBE heritage. We will also have improved cloud property retrievals from the MODIS-N instrument and improved temperatures and humidities from the AIRS, AMSU, and MHS instruments. These instruments will provide data that can produce a synergism that will give us a much deeper understanding of how the climate system works.

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Global Temperature and Sea Level Change

*George A. Maul**

Both the scientific and popular press have had numerous articles of late discussing global climatic change. The debate seems endless. Reports from the Intergovernmental Panel on Climate Change (IPCC) (1) assure us that both observations and models show a consistent pattern of anthropogenic warming. At another end of the debate are assurances from the Marshall Institute (2) that the models do not reproduce the observed global temperature rise and that solar activity is probably forcing the changes. The one thing we are not assured of however is that the observations per se represent a truly global indicator of climate change.

Measuring surface air or sea temperature or sea level change seemingly is a trivial exercise. Indeed, the simple measuring of these variables at a given location is not a difficult task; it also is not the issue. The issue is: to make such measurements in a consistent manner using methods that vary considerably from country to country; to exclude effects of the local environment on the measurements; to account for a changing data base, both spatially and temporally; and to integrate the data into a global estimate. Considering that half of the 71% of Earth's surface covered by water is unsampled by conventional (non-satellite) observations, the problem becomes clearly non-trivial.

During the 1991 APS/Forum short course *Global Warming: Physics and Facts* (3), and again at the APS 1992 annual meeting, the issue of such global estimates of temperature and sea-level change were explored in depth. This note is a summary of investigations of the problem from the perspective of a physical oceanographer, as reported in the APS gatherings of the last two years. For brevity, the references will be kept to a minimum herein, but the interested reader is referred to the bibliographies in AIP Conference Proceedings 247, the IPCC (4) reports, and journals such as Nature and Science, which regularly have review articles.

Land air temperature change 1860-1990

Our most complete records of surface air temperature are over the land areas of Earth, but they are not as numerous as might be expected. In 1870 (5) the coverage of surface meteorological stations was limited to western Europe and eastern North America, with a few stations in South America, Africa, India, Australia, New Zealand, and California. As late as 1930 most of the smaller islands were without routine measurements, and the land areas of the Northern Hemisphere had a much higher density of weather stations than the Southern Hemisphere. After the International Geophysical Year in the late 1950's, Antarctica was added to the global network, and from this data base a pronounced 0.5°C "global" warming of the last century has been estimated (5).

— There does seem to have been a "global" air and sea temperature rise and sea level rise during the last 100 years — It may be more important in the next decade to make better measurements — than to concentrate on the trends.

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One clear difficulty with such estimates is that often the ocean is not included, except for some islands. A deeper investigation uncovers myriad other concerns, notably with the data base itself. Over the contiguous United States, some 6000 land air temperature stations are incorporated into a national climate network; analysis of these US data reveals no statistically significant temperature change during the last 100 years (6). Comparisons of the US network with other data sets (7) show trend differences between 0.1°C and 0.4°C since the turn of the 20th century, due to increasing urban development around the weather stations (typically at airports). Although climatologists go to great lengths to account for trends due to urban bias, it is still an issue of great concern.

Marine air and sea surface temperature 1870-1980

One can picture a sequence of marine coverage maps similar to those described for land, except that ship routes add an extra degree of complexity. The opening of the Panama Canal in 1914 markedly changed the coverage of the Southern Ocean, both around Cape Horn and the Cape of Good Hope. To this day, much of the oceanic area south of 40°S latitude is rarely sampled, as are many regions of the central Pacific and Indian Oceans. Ships too have changed over the last 100 years: steel construction instead of wood; higher navigation bridges where the air data are taken; engine cooling water intake "sea surface" temperatures instead of surface bucket samples; changed observational procedures.

Several efforts have been made to estimate the long term trend in the marine data sets (8,9) and to account for the several changes in observational environment discussed above. Both the marine air and sea surface temperatures show declining temperatures from about 1870 to 1910, an increase from 1910 to about 1940 (0.3°C or so), and steady or slightly declining values since. The marine air temperatures have larger deviations than the sea surface temperatures, but as with the land air temperatures, there is an increase in the measured temperatures since the turn of this century, but the 130 year trend is rather small.

Figure 1 summarizes some of the temperature trends discussed above (4). These data are all relative to a zero mean for the thirty year period 1861-1890, which emphasizes the uncertainty during the last few decades. Much of the interannual variability in the records shown in Figure 1 has been removed with a binomial filter that passes almost unattenuated, fluctuations having a period of greater than 20 years.

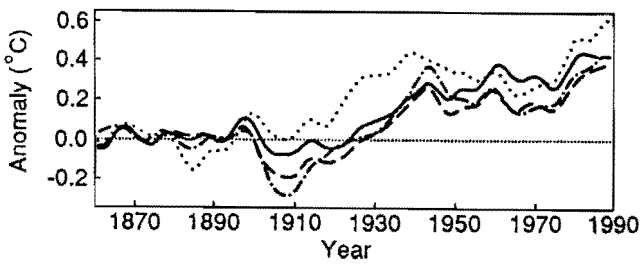

Figure 1. Estimates of global temperature change redrawn from the Intergovernmental Panel on Climate Change (4). Two sea surface temperature (SST) estimates are shown (solid, dashed); nighttime marine air temperature is illustrated using dot-dash; land air temperature is shown by dots. All four estimates are relative to the 30-year norm 1861-1890. Differences in the SST estimates are caused by different methods of treating the transition from bucket temperatures to engineroom intake temperatures. Homogenization of the marine data with land data has been affected; therefore the marine and land air data are not independent in this figure.

Satellite measurements 1980-1990

Satellite measurements of sea surface temperature have shown mixed results over the last decade, mostly due to atmospheric aerosol effects on the observations (10). These satellite temperatures are made using passive infrared multispectral observations from operational meteorological satellites, and if left uncorrected for aerosols have trends as large as +0.1°C per year. The blended satellite/ship/buoy data sets show "global" variations +0.2°C in the last decade, but the record is too short to describe trends. "Global" is in quotation marks as a reminder that these satellite data depend on in situ observations for calibration, and the in situ data are not uniformly distributed over the ocean.

Passive microwave observations of tropospheric marine and land air temperatures seem to be much better at describing the global temperatures than infrared measurements. Radiances from the Microwave Sounding Unit (MSU) onboard the NOAA polar orbiting meteorological satellites are nearly free of aerosol effects, seem to have precision at the +0.01°C level in the monthly means, and have a linear correlation coefficient r=0.9 with the land air temperatures over the contiguous US (11). As with the satellite sea surface temperatures only a decade or so are available, but these MSU data show no trend.

Sea-level measurements 1880-1990

Sea level variations are somewhat different indicators of global climate change than temperature, and are of great concern to the 60% or so of humankind living in proximity to the coasts. Sea level is measured by tide gauges, typically affixed to piers in or near major commercial harbors. The measurement is the relative difference between the motion of the sea and the motion of the land upon which the tide gauge sits; the term "relative sea level" is thus operative. Vertical land motion is to sea level change, as urbanization is to land air temperature change: The long term signal is often dominated by external causes (tectonics, subsidence, etc.).

Globally, there are only about 64 relative sea level records covering the time span 1930-1987 (3 lunar nodal cycles), and their mean latitude is 41°N; only two are in the Southern Hemisphere. A plot of the linear trend in these sixty-odd stations versus latitude shows negative values (falling relative sea level) north of about 40°N, and mostly positive values toward the equator. As a first approximation, the latitudinal distribution reflects the post-glacial rebound of an elastic earth emerging from the glaciation of the last 18,000 years (12,13).

A simple average of the linear trends in the aforementioned 64 records is +0.7 mm/yr, +2.9 mm/yr (+1 standard deviation). Several authors have applied the post-glacial rebound model of Peltier (12) and have made estimates somewhat larger than the +1.2 mm/yr accepted by the IPCC (3) in 1990 as the global trend in sea level for the last 100 years. However, along the eastern US, post-glacial rebound models (12,13) do not agree in either sign or magnitude (14). Fortunately, metrology is poised to make direct measurements of the vertical velocity of tide gauges using the space-based technologies of the global positioning system and very long baseline interferometry (15). These new astronomic-geodetic techniques are approaching +1 cm precision, and offer the promise of significant improvements in determining geocentric (absolute) sea level.

The linear trends in sea level based on data covering the last 57 years, and the skewed latitudinal distribution discussed above, are

shown in Figure 2. Geophysical earth models have not been applied to the trends in order to illustrate the nature of the problem. The linear trends range from -8.9 mm/yr at Furuogrund, Iceland, to +8.2 mm/yr at Manila, the Philippines in these 1930-1987 data.

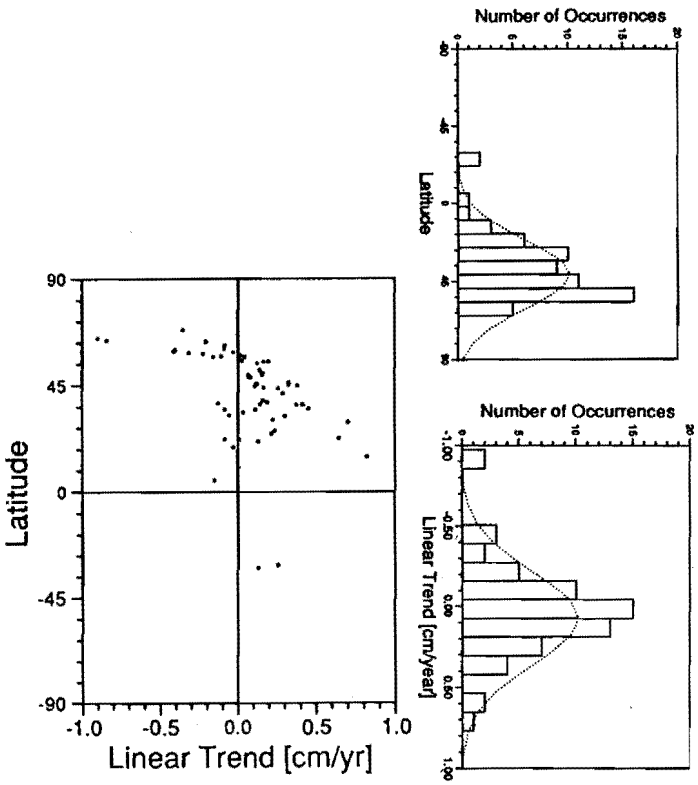

Figure 2: Linear trend in sea level as a function of latitude using data from the Permanent Service for Mean Sea Level (U.K.). All trends are calculated from the "revised local reference" subset of the PSMSL files, and all cover the three lunar nodal cycles (18.61 cpy) since 1930. The histogram on the upper right emphasizes the latitudinal distribution of the "global" data, and the histogram on the lower right illustrates the spread of the linear trends; dashed line on each histogram is the best fit Gaussian Distribution.

Conclusions

A summary such as this often leaves one with more questions than answers; indeed that is the point. In spite of the uncertainties, there does seem to have been a "global" air and sea temperature rise and a "global" sea level rise during the last 100 years or so, but there may still be systematic errors in either or both measurements. It may be more important in the next decade to make better measurements, establish better understanding of natural variations (e.g. volcanism (16), El Nino), and make better comparisons with global climate models, than to concentrate on the trends. Physically modelling post-glacial earth rebound, and the interannual and decade-scale fluctuations in temperature and sea level, are challenging problems in geophysical fluid dynamics worthy of the attention of the best physicists among us.

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Mission to Planet Earth: Current Status

D. James Baker

The successful launches in 1991 of the European Space Agency's Earth Resources Satellite (ERS-1) and NASA's Upper Atmosphere Research Satellite and in early 1992 of the Japanese ERS-1 radar satellite mark the beginning of a new era of remote sensing of Earth. After two decades of development of sensors, platforms, and data relay and archive systems, NASA and its sister space agencies have begun a comprehensive Mission to Planet Earth. The new data are critical to understanding and predicting global change.

Today, NASA's definition of Mission to Planet Earth includes space hardware, data systems, and support or research. The space-based elements include a set of narrowly focused missions called Earth Probes, a broad multi-disciplinary program called Earth Observing System, and contributions from other space agencies. In its full configuration, the Mission will provide a constellation of satellites in a variety of orbits around Earth. The program also includes shuttle flights of instruments for test and short-term (a few days) measurements.

Mission to Planet Earth is aimed at meeting the consensus priorities of the scientific community as laid out by the US Global Change Research Program and international groups like the Intergovernmental Panel on Climate Change. In order to fully cover climate-related issues, the satellite instruments will observe processes ranging from the effect of the sun on Earth to the gravity and magnetic fields that depend on the composition and structure of Earth deep beneath the surface.

This may sound like a tall order, but in fact the technology developed over the past thirty years has provided us with the ability to make these measurements. Passive collection of electromagnetic radiation from the ultraviolet to the visible to the far infrared and microwave and active radar and lidar (laser ranging and doppler systems) provide images, soundings, and other information on the atmosphere, ocean, and land.

NASA is not the only space agency involved in providing environmental data to users. Operational weather and other environmental data is provided in the US by the National Oceanic and Atmospheric Administration (NOAA) with their continuing series of Polar Operational Environmental Satellites (POES) and the Geostationary Operational Environmental Satellites (GOES) and the Air Force with its Defense Meteorological Satellite Program (DMSP).

Outside the US, the European Space Agency and the space agencies of Russia and Japan operate operational weather satellites that provide continuing and useful data. These agencies and those of Canada, China, France, Germany, India, and Italy either operate or participate with other countries in operating a variety of remote-sensing missions. The number of countries is increasing each year, for example, Brazil and South Africa are expected to enter the field of remote sensing soon.

Near-term missions

During the first part of the 1990s, relevant satellite missions include those that are ready to fly in the next two or three years, the Earth Probes, and a number of non-US missions. The data from these missions will provide a transition from today's limited-duration research missions to the long-term and comprehensive Earth Observing System planned for the end of the 20th and the early part of the 21st century. In the paragraphs below, I will list some representative topics addressed by the upcoming missions.

Many of the major questions about our environment revolve around atmospheric chemistry. For example, what causes ozone variations? How are the chemical, radiative, and dynamic processes of the stratosphere coupled? The Upper Atmosphere Research Satellite (UARS), launched last year and still providing most of its data in spite of a recent problem with the solar panels, carries ten instruments. Data from UARS are being used to study energy input and loss, global photochemistry, the dynamics of the upper atmosphere, and the coupling between upper and lower atmosphere.

Total Ozone Mapping Spectrometers, which have already given more than a decade of information on ozone, will fly on several spacecraft in the 1990s. Several flights of the Shuttle Solar Backscatter Ultraviolet (SSBUV) Experiment are also planned for ozone measurements. A Global Ozone Monitoring Experiment (GOME) is planned for ERS-2, in 1994. NASA has arranged the Atmospheric Laboratory for Applications and Science (ATLAS) program, a set of Earth-observing instruments that fly periodically on the Space Shuttle.

Earth's radiation budget is a key element of the climate system. Up to 1990 there was a set of instruments flying which made up the Earth Radiation Budget Experiment (ERBE). Data were collected for five years. The initial information shows that clouds do in fact have a negative feedback on temperature change (that is, increasing amounts of clouds lead to cooler temperatures). However, this is only a preliminary conclusion from a small part of the data; much more work remains to be done.

A joint experiment between France and Russia will help bridge the gap between the ERBE studies and those planned for EOS later in the decade. The instrument, called Scanner Radiatsionnogo Balansa (ScaRaB), is now in a prototype phase for test this year. Full calibrated instruments are scheduled for flight in 1993 aboard two Russian Meteor spacecraft.

Precipitation is also part of the global energy budget. Direct measurement of precipitation, particularly over the oceans, has always been difficult. In the mid-1990s, the Tropical Rainfall Measurement Mission (TRMM), a joint US-Japanese initiative, will monitor rainfall with active and passive microwave instruments, together with visible and infrared to derive rainfall amount and distribution between 35 degrees north and south latitude. Radiation will be monitored by this mission with some of the same instruments that are planned for flight on the Earth Observing System.

TRMM data will be used directly in climate models that are critical to understanding global change. However, TRMM will not measure precipitation outside the tropics and subtropics, it will have relatively large sampling errors over land, and it will have a limited lifetime. These problems will be addressed with the global measurements and long lifetime proposed for the instruments of the Earth Observing System.

By the late 1990s, there will be at least one terabyte per day of raw data being collected. This daily 10^{12} bytes of information is equal to the total amount of information in the Library of Congress.

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Satellite measurements of the ocean have provided a new view of the ocean that is complementary to that gained from ships and buoys. Typically a polar-orbiting satellite will complete an orbit in about 90 minutes; the wide swath measurements of the sea surface temperature instruments can cover the ocean in one day. Narrow swath instruments, such as altimeters, take about 10 days to cover all the oceans. This is to be compared to the time it takes for ship to make one traverse of an ocean basin which is on the order of weeks. To date, it has proved feasible to measure sea surface temperature, sea surface color, the shape and distribution of waves, the large-scale shape of the sea surface and the extent of sea ice.

In the 1990s, several ocean-related satellite missions are either flying or planned for flight. The European Space Agency's ERS-1 was launched in early 1991 carrying instruments for measuring sea surface temperature, sea surface height, waves and winds, and ice concentration and extent. In August 1992, a joint US-France precision altimeter mission, TOPEX/Poseidon, will be launched on an Ariane rocket. This mission is designed for a measurement accuracy of a few centimeters, thus accurately providing measurements of global ocean currents.

At the moment, there are no precision altimetry missions currently scheduled for the late 1990s, after TOPEX/Poseidon. In making planes to remedy that gap, the ocean community has determined that at least two altimetric systems are necessary to provide continuity and optimal sampling of ocean variability in time and space. A geodetic mission to determine Earth's gravity field is also needed.

For wind and wave measurements, the next flight of a radar scatterometer is planned for 1996: NASA will have an instrument on the Japanese Advanced Earth Observation Satellite (ADEOS). After ADEOS, the next scatterometers will be carried by ERS-2 and EOS. For biological studies, an ocean color mission (Sea Star) is planned in 1993 as a joint venture between NASA and Orbital Sciences Corporation. In 1996, a Japanese ocean color instrument is scheduled for flight on ADEOS. In the late 1990s, an instrument for measuring ocean color is planned as part of NASA's Earth Observing System. Ocean color data near coasts is also provided by the land sensing systems Landsat and SPOT.

Droughts, floods, and the global hydrological cycle are strongly influenced by the water and ice distribution on land. Biogeochemical cycles of life — supporting elements such as carbon, nitrogen, phosphorus, and sulfur are all dependent on vegetation on land and in the ocean. Volcanic eruptions, earthquakes, landslides, uplift and subsidence and associated hazards in coastal areas are all of interest and importance.

Many of the processes can be measured from space. Today, the European Space Agency, France, India, the US, Russia, and Japan all operate satellites that monitor processes occurring at the land surface. France's Satellite Pour l'Observation de la Terre (SPOT), provides stereoscopic views of the land surface at high resolution. India and Japan operate systems with resolution similar to Landsat.

All of the current systems are being upgraded with more spectral and spatial resolution. At the same time, all of these systems have one major drawback: lack of time resolution. The spatial detail, in the best cases to a resolution of a few meters, is good. But even at lower resolution it takes about a month to get full global coverage. Thus rapid changes in time can easily be missed. Flying several satellites at once, as proposed by EOS, helps address this problem.

Synthetic aperture radar (SAR), as noted above, is a key measurement for land and ice processes including snow and ice extent and the shape of ice caps, ice sheets, and glaciers. In addition to the instruments now flying on ERS-1 and the Russian Almaz satellite (the first commercial radar satellite), three such instruments are planned for the mid-1990s: ERS-2, a Japanese JERS-1, and a Canadian Radarsat. Radarsat, planned for launch in late 1994 or early 1995, will carry a synthetic aperture radar designed for ice measurements. Stereoscopic SAR imagery will also point out geological structures and help identify potential mining sites. Radarsat will also monitor and map renewable resources for the agricultural and forestry industries.

Measurements of the Earth's gravity field are being discussed by NASA and ESA for a mission for the late 1990s called ARISTOTELES (Applications and Research Involving Space Technologies Observing the Earth's Field from Low Earth Orbiting Satellites). This mission involves flying a proof mass inside a satellite and then tracking its detailed movements as it is affected by the gravity field. A magnetic field measurement is also being planned as a joint US French mission, that would take place before EOS.

The Earth Observing System

Recognizing the need to take the next steps toward a long-term comprehensive space measurement system and the long lead times necessary for such planning, NASA and the scientific community began planning the next stage of Mission to Planet Earth, the Earth Observing System (EOS), in the early 1980s. The initial conception of EOS was that it would pull together the many strands of disciplinary measurements into one long-term program that was as comprehensive as possible. In this way the scientific community would benefit by having long-term data, and NASA would have a focused program that could be supported as a single unit. This initial general conception has held up.

The plans for EOS are to put into space the next generation of instruments for remote sensing, starting in 1998, for flight of a period of at least 15 years. This time period, to be achieved by using missions end-to-end, is more than three times the normal span of a single mission. This initial phase covers the time over which major environmental change can occur. For example, in 15 years we can expect to see several atmospheric biennial oscillations, three to five El Ninos, and an entire solar cycle. Although in the long-term we will need a commitment to such measurements for an indefinite period, the agreement to fund a series of satellites to make such measurements is an important new step for Earth sciences.

The set of instruments proposed for EOS includes a variety of visible, infrared, and microwave imagers and sounders, active radar altimeters and scatterometers, radiation and chemical sensors, particle and aerosol detectors, and geodetic positioning and ranging. In addition, new techniques are being developed for direct measurements of, for example, winds by doppler shift observed by laser techniques (lidar) and water vapor multifrequency lasers.

The EOS program involves NOAA and non-U.S. agencies as well. The European Space Agency plans a series of Polar Orbiting Earth Observation Missions (POEM) with two series, one focused on meteorology, ocean and ice processes and the other with a focus on land resources and related atmospheric processes. The Japanese plan at least two platforms, one in polar orbit and one in an inclined orbit, for that time period. Starting in the early 21st century, NOAA satellites will be part of the program.

The amount of data coming down from satellites and being collected by Earth-bound sensors is increasing rapidly. By the late 1990s, with the many satellites in place that we have discussed above, there will be at least one terabyte per day of raw data being collected. This daily 10^{12} pieces of information is equal to the total amount of information in the Library of Congress. Each day this amount of information must be processed, archived, and made

available for distribution. This is an enormous task, the largest data and information task that any government agency has yet faced.

In recognition of the magnitude of the problem, NASA has put a major emphasis on the EOS Data and Information System. EOSDIS is planned to acquire and maximize the utility of a comprehensive, global, 15-year data set. To show the commitment of NASA to the data system, NASA will allocate only 40% of the EOS funding to spacecraft hardware and 60% to ground-based activities, including EOSDIS and related science. This contrasts with the usual mission, where about 70% goes to spacecraft hardware and 30% to ground-based activities. The initial phase of EOSDIS, called Pathfinder, is to develop a system that will work with existing satellite data.

Issues for the future

In the long-term, the major problem is making the transition from these research measurements to an operational system that will provide the data we need into the indefinite future. NASA and its sister agencies have been successful in getting attention and funding for the elements of Mission to Planet Earth, but at the same time the US civil operational system has been starved. The operational environmental satellite system operated by NOAA, which must be the backbone of any long-term US contribution to a global climate observing system, is showing the strain of budget neglect. Without a robust operational system, we will not have the long-term data sets we need.

The above points to a real problem of coordination in our government. The operational systems the US has, including Landsat, the NOAA operational polar and geostationary satellites, the Department of Defense Meteorological Satellite Program, and EOS are not integrated in any coherent way: Each agency tends to go its own way. The classified technical developments useful for remote sensing do not get over into the civil side. Data collected by classified instruments is not made available to users even after its strategic importance has diminished. The existence of an uncoordinated, piecemeal approach has been recognized by the Department of Commerce Inspector General in a report on coordination of remote sensing across the government. A coordinated approach would lead to a more cost effective operation. If we do not have such an approach, then we will lose the opportunity to apply this technology for a common good.

REVIEWS

Recent Journal Publications

In the April *Ambio*, architect Wolf Hilbertz discusses a variety of ways in which choices of building materials affect the quantity of carbon in the environment. Major building materials (cement and steel, for example) are fossil-fuel intensive, and some release CO_2 in processing. Alternatives include solar-powered generation of building materials from sea water ("earth's largest continuous ore-carrying body"), and natural and artificial biomineralization (e.g. coral reefs).

Ambio's February issue presents a set of papers on population, natural resources, environment, and development. Much here has been said before, and none of the articles are extensive or deep, but the issue as a whole provides a valuable overview of scientific thinking on the eve of the disappointing UN Conference in June.

With the end of the Soviet-American nuclear arms race, attention in the arms control literature shifts to conventional weapons, chemical and biological weapons, and ballistic missiles. In the May/June *Public Interest Report* (Federation of American Scientists), FAS President Jeremy Stone argues for ballistic missile disarmament leading to a ban, and presents a schematic draft treaty for that purpose. Also given are excerpts from a "hearing," covering pros and cons of such a ban. For data consult the "Factfile" in the April issue of *Arms Control Today*, a complete list of Third World ballistic missile systems. In the March *Arms Control Today*, John R. Harvey and Uzi Rubin argue that ballistic missiles should not be singled out for controls; rather, that advanced strike aircraft pose a similar threat and should be included in a variety of steps aimed at controlling proliferation of long-range weapons.

The June *Bulletin of the Atomic Scientists* contains a thorough and balanced history of the Shoreham Nuclear Power Station. The Long Island plant, now decommissioned, "fell victim to nearly every affliction that has haunted the US nuclear power industry," and will wind up costing about $6.5 billion.

In the same issue of the *Bulletin*, George Perkovich discusses the politics of a ban on nuclear testing. His point, one not widely discussed, is that the influence of the US nuclear establishment in opposing a test ban is mirrored in the Russian nuclear establishment's opposition to a test ban, and works against the democratic constituency in Russia.

WorldWatch, journal of the Worldwatch Institute, presents sometimes slanted but often informative studies dealing with energy, environment, and natural resources. The March/April issue has an interesting article on aluminum, a material high in energy and environmental costs, and at the same time extremely important in making energy-saving products.

Michael Sobel
Brooklyn College

Unauthorized Overview

The Forum on Physics and Society cosponsored a Symposium on "Science to Shape the Future of America" with the Committee on Applications of Physics at the March 1992 APS meeting in Indianapolis. The session was interesting and successful. However, in the APS Bulletin abstracts, Vol. 37, No. 1 (1992), pp. 526-7, an "Overview" of the Symposium was published which appeared to have the endorsement of the Forum on Physics and Society. It did not. The overview had a strong political coloration, implying full endorsement of the Gulf War and apparently considering the results to be unqualified technical successes. No member of the Forum on Physics and Society was given an advance copy of this text or gave the right to use the Forum's name as an apparent sponsor of this text. This was an error. The Forum on Physics and Society emphasizes that it does not endorse the sentiments therein.

Minutes of the Forum's Executive Committee Meeting

We met at the Ramada Renaissance Hotel, Washington DC, on 21 April 1992. Members present were R. Howes (chair), A. Fainberg (vice-chair), H. Barschall (secretary-treasurer), B. Levi (Forum councilor), M. Sobel, J.A. Thompson. Members absent: L. Badash, G. Garvey, T. Moss, C. Schwartz, R. Scribner, A. Sweedler. Members of the 1992/93 executive committee present: E. Gronlund, A. Nero, J. Wittels. APS Officers present: M. Gray (controller), H. Lustig (treasurer), N.R. Werthamer (executive secretary). Guests: A Hobson (newsletter editor), N. Chonacky, D. Hafemeister, P. Lindenfeld, A. Saperstein, D. Schroeer.

Howes called the meeting to order at 9:15 a.m. The minutes of the 1991 Meeting were approved.

The Treasurer's report (Table 1.) shows an increased balance due to several factors: Some outstanding commitments have not yet been charged; the amount authorized for a new study has not yet been used; one of last year's winners had no travel expenses; the Forum sessions brought in more revenue than previously. The transfer of $5000 from the income fund to the award fund was approved. The treasurer's report was approved.

Fainberg presented the report of the program committee. He reported a problem with a session organizer who put an inappropriate description of a session into BAPS. The program chair needs to watch both what session organizers put into BAPS, and travel expenses of invited speakers, especially when sessions are organized jointly with other subunits.

Levi presented the report of the Forum councilor. Several issues raised in the report were discussed:

- Although the Forum strongly supports a "truly general" meeting, the obstacles against such a meeting are difficult to overcome. As to timing, the Forum favors the fall. As to location, Washington or accessibility from Washington is strongly favored because of the availability of speakers from the Washington area who might not wish to travel to other locations.
- The European Physical Society has a counterpart to the Forum on Physics and Society. Although the overlap of interests may not be great, Howes appointed Schwartz last summer as a contact with EPS.
- The draft report of the task force on APS awards and prizes was distributed. (The report was adopted by Council after the executive committee meeting). The use of Forum funds for monetary awards is no longer permitted, but Forum funds may be used for travel and other expenses. Since the executive committee decided in 1991 not to make monetary awards to winners of the Forum and Szilard Awards after 1992, the new rule causes no problems. On the other hand, a renewed effort to endow at least one of the awards should be undertaken. Lustig suggested that the Task force to create a Burton Award be reactivated. The previous efforts of the Task Force were unsuccessful, in part because of disagreements between members of the Task Force.

Table 1. Treasurer's report:

Balance 4/1/91		$12,946
Income:		
Dues	+	11,813
Registration fees	+	10,631
Interest	+	1,884
Contributions	+	140
Short course	+	4,570
Expenses:		
Awards	-	585
Ballots	-	1,613
Executive committee	-	250
Newsletter	-	10,642
Speakers	-	350
Short course	-	4,050
Balance 4/1/92		$24,494
Proposed 1992/93 Budget:		
Income	+	20,000
Expenses:		
Newsletter	-	11,000
Awards	-	3,000
Ballots	-	1,200
Executive committee	-	1,200
Short course	-	2,500
Speakers	-	1,000
Study	-	3,000
Expenses total	-	21,700
Award account:		
Balance		2,194
Interest income	+	133
Scrolls	-	410
Bal (award acct) 3/31/92		1,917

Hobson presented a report of the editor of *Physics and Society*. Hobson urged that the program committee chair inform speakers in advance that their talks are expected to be published. Speakers might also be asked whether they would like to have their talks taped to facilitate the preparation of manuscripts. The question of printing *Physics and Society* on recycled paper was referred to a subcommittee consisting of Hobson, Howes, and Gronlund.

The revision of the Forum Bylaws has been approved by the membership. The new Bylaws prescribe different terms of office for the elected persons. The executive committee decided that all terms of office should be those to which the candidates were originally elected. That means that Moss's term on the executive committee goes through 1993, and Howes's through 1994. It was suggested that two provisions of the new Bylaws should be changed.

The program committee, which under the provisions of the new Bylaws has five members, was considered to be too small. The name of the Editorial Board Committee was felt to be misleading. No action was taken to initiate these changes. (Procedures for changes in the Bylaws are described in Article XII of the Bylaws). (At the April Council meeting two changes in all subunit Bylaws were approved; one of them increases the membership of the fellowship committee from three to five and modifies the description of the responsibilities of the committee).

Sobel reported that the fellowship committee had received eight nominations of which seven were approved by the committee and subsequently by Council. With the establishment of the new Forum on Education some candidates previously considered by the Forum on Physics and Society will in the future be more appropriately considered by the Forum on Education.

Howes's proposal for a study on conventional weapons had been approved by the executive committee by mail ballot. About ten volunteers for the study have been found, but no progress was reported. There will be a need for reviewers who have security clearance.

Suggestions for other studies should be sent to Fainberg, preferably before June 30. Studies require approval by the executive committee and will then be announced in *Physics and Society*. A suggested topic was the job situation in physics.

The establishment of an Electronic Bulletin Board for the Forum was discussed, possibly on PINET. Fainberg and Chonacky will follow up on this. The relationship with the other APS Fora was discussed. Fainberg was authorized to appoint liaison members. Ross asked for discussion of a project to help physicists find research topics and/or jobs relating to the environment. An announcement in *Physics and Society* might be appropriate. Howes suggested that an effort be made to get enough contributed papers for a session a the next April meeting. Saperstein suggested the establishment of a speakers bureau. This suggestion was referred to a subcommittee consisting of Saperstein, Sobel, and Gronlund.

The meeting adjourned at 1 p.m.

Heinz Barschall
Outgoing Secretary-Treasurer of the Forum

Forum Councilor's Report

The first meeting of the APS Council that I attended as Forum Councilor was held on Saturday, 25 April. The following are some of the issues discussed at that meeting that should be of interest to Forum members.

APS Spring Meeting. The APS committee on meetings is considering a recommendation to rotate the spring meeting among different cities, due to the high expense of the DC location. The committee on meetings is also wondering whether to make the APS/AAPT meeting a "truly general" meeting (not just in name only) and, if so, whether it ought then to be held in the fall, with other divisional meetings spread throughout the year. The APS Executive Board decided to hold the April meeting in the Washington area for 1993-95, and to work toward having one annual meeting in which all divisions and topical groups would participate.

Crisis for science in the FSU. An ad hoc task force chaired by Bill Blanpied has made several recommendations to help the crisis in basic science in the former Soviet Union. The stress was on helping young physicists stay where they were so that they could help rebuild physics. Two short-range actions have already been taken: distribution of surplus issues of Physical Review Letters and an appeal for donations of money and/or equipment. The Council approved the task force report, which included a plan to approach funding agencies for support of the following programs:

- Development of international schools and workshops in the republics of the FSU;
- Support of young physicists in the republics of the FSU;
- Distribution of APS research journals to physicists in the republics of the FSU.

Liaisons between EPS and APS. The office of international scientific affairs reported that the president of the European Physical Society suggested that subunits of EPS establish liaisons with corresponding subunits of APS. I suggest that the Forum find out whether EPS has a corresponding entity and, if so, consider seeking a liason.

Task force on APS prizes and awards. The Council approved the guidelines of this task force, which include a proscription on using subunit dues to fund awards and prizes. (See the discussion of this issue in the minutes of the Forum Executive Committee.

Education Forum. The Forum on Education now has about 1000 members and is preparing for an election of candidates for its executive committee.

APS Treasurer's Report. In FY91 APS realized a net surplus in its unrestricted fund operations amounting to $3.8 M, on total revenues of $24.1 M and expenses of $20.3 M. Most of that results from switching a sizable portion of the Society's portfolio and thereby realizing, on this year's revenue report and balance sheet, a previous appreciation in market values. In the next few years the Society still expects tight finances because of the growing size of publications and shrinking library subscriptions.

Intersociety initiative on physics teaching. The Council approved APS participation in a joint effort of APS, AAPT, and AIP to improve science education in the US.

POPA. The Panel on Public Affairs is considering a study on energy and, after surveying what had already been done, was considering three possible topics for possible POPA study: advanced reactors, nuclear waste, and renewable energy sources.

International freedom of scientists. The Council passed one resolution expressing concern about the harsh treatment of Chinese students and another affirming the importance of assuring that all international scientific meetings allow free entry, exit and circulation of all participants.

Barbara Levi
Forum Councilor

Conference Report on Engineering Ethics

The Center for the Study of Ethics in the Professions (CSEP) at Illinois Institute of Technology announces publication of *Engineering Ethics in Engineering Education: Report of a Conference June 12-13, 1990.* Produced in May, 1992 under a grant from the NSF Ethics and Values Studies Program and written by Vivian Weil, Director of CSEP, the report summarizes points agreed to by conference participants. It discusses avenues for introducing engineering ethics in the studies of engineering students as well as concepts and content, methods, and qualifications for teaching.

The conference brought together leaders in engineering education and in engineering ethics. The report should interest educators looking for ways to incorporate engineering ethics into the education of engineering students. It should also be useful to educators concerned with introducing ethics in other fields, to graduate students as well as undergraduates. The 14 page report is available without charge from CSEP, IIT, 3101 S. Dearborn St., Rm. 166 LS, Chicago, IL, 60616-3793, phone 312-567-3017!

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COMMENT

From the Incoming Chair

I welcome the membership of the Forum on Physics and Society to a new year, one which I hope will be as successful for us as the last. We have been fortunate in that our retiring chair, Ruth Howes, and our retiring secretary-treasurer, Heinz Barschall, were extremely hard-working, activist officers. As a result our financial situation is now relatively solid, our bylaws have been brought up to date, and our last year saw the appearance of two new Forum books and a series of well-attended sessions at both the March and April meetings. And, as had been the case for several years, our newsletter, *Physics and Society*, has steadily improved and become more widely respected and read under the excellent guidance of editor Art Hobson (although he generally uses more exclamation marks than I would!). A book review editor has just been added, Kenneth Krane of Oregon State University. Ken's experience will be very helpful in making the book review section a major part of the newsletter.

To address the current and future as effectively as we have in the past, our Forum will have to refocus its attention on the new issues of the day. It is trite but necessary to refer to the major changes that have occurred in the world during the past three years. Previous emphases of areas of interest, for example, on arms control agreements between the US and the USSR must be changed. Future important international issues involving physics and society will be topics such as global climate change, international cooperation on major projects (e.g., space research, next-generation accelerators, nuclear fusion), energy sources, nuclear proliferation, conventional arms technologies and restrictions, partition of world resources, and, believe it or not, tactical missile defense. On the domestic level, the principal topic of interest to the physics community will be one I mentioned as looming on the horizon in this publication when I ran for executive committee member several years ago: limits on federal research funding. The current national fiscal crisis, developed by the progression of the federal deficit (now apparently in free fall) over 11 years, is already having severe repercussions on scientific research and will have worse ones. Another major domestic topic is the sorry state of math and science education at the secondary level, reflected in the scientific illiteracy of the general public.

So, in spite of some positive international developments there are many subjects that our Forum needs to deal with; our relevance is not at an end! We need to continue to work hard on the above and other problems, as we have in the past: By talking about them, interacting with the media, organizing workshops, forming study groups that produce useful books, and, not least, by holding sessions at APS meetings.

I hasten to add that I welcome suggestions both for topics for action and for innovative approaches for dealing with them. Upcoming is, I hope, an electronic bulletin board for our Forum, being organized by Norm Chancy of Bowfin. Also on the way is a membership drive, led by membership committee chair Lisbeth Gronlund. We need both to extend our membership within APS and to raise more activists from among our membership. Regarding future projects, at least two subjects are being considered for study groups: conventional arms and employment for physicists.

Please communicate with me or with the newsletter with any comments or suggestions you may have. You will have noticed that there is a rather wide range of viewpoints characteristically presented in letters to the editor. Let's widen that range even further and perhaps make the level of commentary even more profound, as well!

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Physics and Cancer — Taking the War to the Enemy

On 24 April 1992, *The New York Times* reported the deaths by cancer of two eminent physicists — Gian Carlo Wick at age 81 and Gerald Feinberg at 58. The coincidence recalled the cancer deaths at age 53 of Enrico Fermi in 1954 and of John Von Neumann in 1957. In 1961 Percy Bridgman chose suicide.

Cancer is not an occupational hazard of physics, but when such scientifically versatile men as Fermi and Von Neumann are struck down by a disease as deadly and as little understood as cancer, one might wonder if they would have turned their minds to the study of cancer if they had had timely warning of their disease. My purpose here is to call attention to the neglected work of physicist Louis Henry Gray (1,2), a former student of Ernest Rutherford. During World War II when Fermi, Von Neumann and other physicists generally were fighting Hitler, Gray pursued fundamental research on the radiobiology of neutrons (2) and launched his personal war on cancer with proposals for using fast neutrons for cancer treatment.

Despite Gray's early initiative in fundamental radiobiology (2), the role of physicists in the war on cancer has been a limited one as helpers in the delivery and use of various particles in the radiation treatment of cancer. On 23 April 1992, at the American Physical Society meeting in Washington DC, for example, there was a session of invited papers on accelerators in medicine partly devoted to the radiation treatment of cancer.

At that session my unscheduled paper "Neutron Therapy —

Whose Failure?" was the only one on neutron treatment of cancer. It noted the deep pessimism about this mode of therapy among health officials in Britain and America (3), but pointed to flourishing treatment centers at the Universities of Washington and Hamburg — the latter in its 20th year. I also noted recent negative clinical results in the literature (4), and some of the failures of efforts to produce neutron generators for hospital use (5).

My contention that the negative results both in clinical trials and in accelerator development have been inconclusive has already been published (6) and need not be repeated here. My purpose here is to call attention to the almost-forgotten pioneering work of Gray (1). His fundamental results in support of neutron therapy have never been directly challenged, while his criticisms (1) of the use of cyclotron neutrons in the first neutron therapy trials apply as well to the most recent trials (4).

The broader purpose of this article, however, is to encourage the interest of physicists in the study of cancer — its causes and its treatment. The dynamics of cell development present the kind of scientific challenge that should be congenial to physicists. The late Leo Szilard in his last years was fascinated by the problems of cell aging. Physicians themselves recognize the medical role of physics by requiring a course in physics for admission to medical school, and by collegial relations with radiological physicists.

Physics gives pre-medical students an obviously important technical basis for medical diagnosis and treatment. More importantly, physics history and methodology condition one to think freshly about fundamentals, and to bring a fresh viewpoint to bear where it is needed — a case in my own experience being clinical trial methodology (7).

One could make an even more impressive case for the usefulness of physics to medicine and the war on cancer if one could point to more examples such as that of Gray. Yet with the notable exception of Gray, physicists have merely been tutors and aids to physicians and suppliers of hardware. Despite their major contributions to basic biological science, as in the unraveling of the structure of DNA, they have contributed little to basic understanding of cancer or to rationales for its treatment.

One of the fondest boasts of physicists is the versatility and power of physics as a scientific discipline. Cancer strikes at them as frequently and fatally as at the rest of us. Does it not behoove them to strike back with some of their best minds and best theoretical and experimental weapons, and take the 20-year war on cancer to the enemy?

References:

1. L.H. Gray, J. Read, Treatment of cancer with fast neutrons, Nature 1943, 152: 53.
2. Vide supra. The 24 footnotes to this article are an invaluable bibliography of the early work on neutron radiobiology.
3. P.J. Bourdillon, British Health Services, 30 November, 1990; M.A. Friedman, National Cancer Institute, Jan. 2, 1992, private communications.
4. Errington et al., High energy neutron treatment for pelvic cancers: study stopped because of increased mortality, BMJ 1991, 302, 1045-51, Stafford et al., Fast neutron treatment for squamous cell carcinoma, BMJ 1991, 302, 48-49.
5. DeLuca et al., Phys. Med. Biol. k978, 23, 876-887.
6. L. Cranberg, Fast neutron treatment for squamous cell carcinoma, BMJ 1991, 302, 349.
7. L. Cranberg, Do retrospective controls make clinical trials "inherently fallacious"?, BMJ 1979, 2, 1265, and editorial, Randomised controlled trials?, 1244.

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Editorial: An Exchange of Ideas

A "Forum" is a place for the exchange of ideas. This newsletter is devoted to the exchange of worthy ideas between physicists concerning physics-related societal matters.

Physics and Society has had a slight case of schizophrenia, at least since I came on board in 1987, because it tries to play three rather different roles. First, and most obviously, it functions as a newsletter, publishing such items as reports of meetings, announcements, and reviews. Unsolicited news items are encouraged. If you want to publicize a workshop, call for volunteers, describe a new program, etc., send us a news item or a letter to the editor.

Second, it functions as an informal journal of serious science-based articles. The main goal here is publication of articles based on the Forum's invited symposiums at APS meetings, although individually-contributed articles may also be accepted following refereeing. Recently-published symposiums have included, for instance, the effects of low-level electromagnetic radiation on living systems, the Forum's energy study, protecting the space environment, pseudoscience (an AAPT-sponsored symposium), and international safeguards on highly-enriched uranium and plutonium. Publication has the effect of amplifying these symposiums beyond the tens or hundreds of physicists who attended the meeting session, to the 5000 physicists who receive *Physics and Society*. And publication creates a permanent record of the symposiums.

Third, through the letters and commentary articles, and to some extent through the reviews, *Physics and Society* functions as a journal of opinion for physicists. This can become controversial. Our criterion here is that letters and articles be reasonably well-informed, and worth the time of socially-aware physicists. *All* points of view, from right to left, from atheist to fundamentalist, from pro-science to anti-science, are enthusiastically encouraged! The newsletter itself, and the Forum itself, supports no particular point of view, although the editor reserves the right to express his own personal point of view in editorials. If you feel that any particular point of view is receiving too much support in the newsletter, please write and correct the balance with your own comments on the other side. Controversy is one of the spices of life, and an important path to knowledge.

This newsletter, and indeed the Forum itself, thrives on the open and direct exchange of differing views. If you read something in the newsletter with which you disagree (or agree) strongly, if you have thoughts about how the Forum or the APS or the physics community should conduct itself, or if you have ideas about physics-related political or social or cultural matters, put your thoughts down on paper and send them to *Physics and Society*. Scientists know, or should know, better than anyone else that nobody has a direct pipeline to "truth." Especially in matters relating to physics and society, it is in the dynamic interplay of differing ideas that some reasonable approximation to the "truth" is more likely to be found.

So write to us. You will find guidelines for contributors on page two.

Art Hobson