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Climate Change -- The Potential for Surprises

John S. Perry

The Earth's climate is maintained by a complex system consisting of atmosphere, ocean, land, ice, and the life they support. Many of the processes that determine climate are highly nonlinear in character. Complex systems of this nature are unpredictable and often unstable. Small and slow causes may lead to large, sudden, and unexpected effects. Indeed, history reveals numerous marked and rapid shifts in local, regional, and global climate. If similar changes are triggered by human-induced changes in the atmosphere, major consequences for human society would result. The purpose of this newsletter is to emphasize that the changes in the global atmosphere being induced by human activities carry a small but significant risk of much greater changes than are usually considered.

For well over a century, scientists have known that trace gases in the air play a major role in determining the climate of our planet through the "greenhouse effect." For almost as long, they have suspected that human activities are changing the composition of the air, and thus threatening to change our climate by enhancing this natural process. Global mean temperatures have indeed increased over the past century, and scientists project continued gradual warming over the centuries to come. Based on internationally coordinated assessments, the nations are currently striving to control and reduce emissions with the goal of stabilizing the atmosphere and averting unwanted changes in climate.

Current discussion of this difficult and challenging issue is implicitly based on the assumption that changes in the air and the climate will be slow and gradual, and may be controlled, mitigated, and adapted to in a similarly incremental fashion. Is this implicit assumption valid? Or is it possible that startling breakers lurk among the swells of a changing climate?

In actuality, climate surprises are undoubtedly possible. The climate system is a huge heat engine working by means of an array of complex and nonlinear processes, e.g., evaporation and condensation or freezing and melting. Such systems are known to exhibit complex, counterintuitive, and surprising behavior. Indeed, the history of earth's climate reveals not only ceaseless change over the millennia, but also abrupt shifts and startling events on the time scales of human life. Small and slow trends in global averages reflect changes in the workings of the complex global *system* that determines climate; local and regional manifestations of these changes may be rapid and large. Underneath the scenario of slow global warming lurks the distinct possibility of rapid and stark changes important to humankind.

Possibilities in Climate Change

This report highlights four examples of such major, rapid changes that have occurred in the past, may be developing in the present, and could certainly occur in the future. By definition, surprises cannot be predicted. But if we accept the possibility of surprises, we should consider taking out insurance. In current international parlance, this strategy is enshrined as the *precautionary principle*. As applied to the problem of climate change, the possibility for surprise significantly enhances the urgency of controlling changes in the atmosphere, and in building versatile and robust capabilities to deal with environmental surprises.

Changing Air, Changing Climate

Precise measurements have confirmed that the concentrations of a number of gases that play a role in climate and are associated with the human economy are indeed changing:

- Chlorofluorocarbons (CFCs), synthetic compounds used for refrigeration and industrial processes, increased rapidly from the late 1970s through the early 1990s. Production has ceased, and concentrations are dropping.
- Nitrous oxide, largely produced by high-temperature combustion, is up by about 25%.
- Methane, emitted from burning of fossil fuels–coal, oil, and gas–has increased over 30%.
- Carbon dioxide emitted from burning of fossil fuels -- coal, oil, and gas -- has increased over 30%.

These "greenhouse gases" -- among which water vapor is in fact the most important -- influence climate by absorbing and emitting heat radiation, reducing the loss of energy to space and increasing the flux of energy to the earth's surface and lower atmosphere. Because of this "greenhouse effect" the earth is considerably warmer than an airless planet would be.

Analyses dating back to the early 19th century

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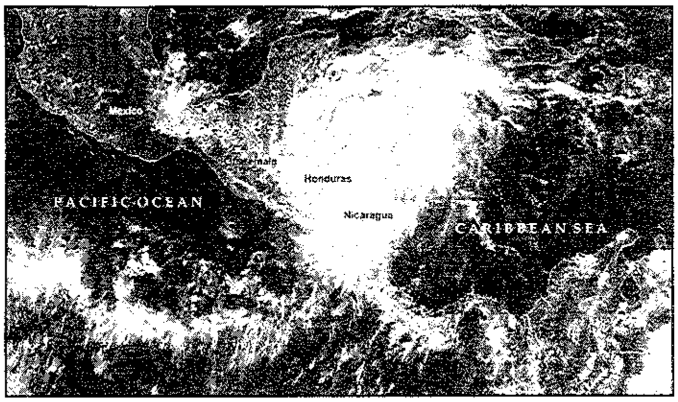
The Federation of American Scientists (FAS), founded October 31, 1945 as the Federation of Atomic Scientists by Manhattan Project scientists, engages in research and advocacy on science- and-society issues, especially global security.

Current war and peace issues range from nuclear war to ethnic conflict and from nuclear disarmament to arms sales; sustainable development issues include disease surveillance, climate modification, poverty, food security and environment. FAS also works on human rights of scientists and on reductions in secrecy.



Satellite photo of Hurricane Mitch over Latin America (NOAA/ National Climatic Data Center)

based on fundamental physics and contemporary calculations with elaborate numerical models indicate that increases in these gases will enhance the natural greenhouse, trapping more energy in the lower atmosphere. The actual amount of warming to be expected depends crucially on "feedbacks" within the system. For example, increases in water vapor (particularly at high altitudes) would add to the greenhouse effect; and increases in cloud and snow coverage would reflect more sunlight back to space. On the other hand, particles in the atmosphere such as sulfate aerosols from fossil fuel combustion can also reflect solar radiation back to space, partially offsetting the warming.

Notwithstanding these major uncertainties, numerous independent studies project future increases in global mean temperatures amounting to several degrees Celsius. The higher ranges of the projections imply almost as large a change as our planet experienced between the last glaciation and today. Temperature records around the world, laboriously corrected to account for urbanization and changes in observing technology, show that global mean temperatures have indeed increased. When aerosol effects and solar variability are taken into account, together with increasing greenhouse gases, there is reasonable agreement between observed and calculated changes. The recent assessment from the Intergovernmental Panel on Climate Change (IPCC) concluded that "[t]he balance of evidence suggests a discernible human influence on global climate."

Nations Respond to Scientific Consensus

In response to this international scientific consensus, the nations of the world set in motion a series of international negotiations aimed at forestalling damaging changes in the atmosphere and climate. These led to the agreements concluded recently at Kyoto that proposed reductions in greenhouse gas emissions. Much debate has ensued, largely centered on widely diverging assessments of the urgency of the problem and the economic consequences of implementing the Kyoto accords.

In this document, FAS takes no sides in these debates, and offers no new predictions. Our purpose is simply to highlight the possibilities for untoward climatic surprises -- surprises that perhaps pose a higher level of *risk* to our complex global society than is currently being taken into account as we consider the policies of Kyoto and beyond.□

El Niños -- Occasional Visitors or Unwanted Guests?

Cloudless sky, burning sun, vagrant breezes stirring the dust. Gaylen gazed sadly at what had once been among the most profitable cotton plantations in Texas. Sure, back when he was a boy there used to be droughts. And sometimes everything just got washed out. You could ride out the bad times, make enough in the good times to carry on. But then the dry years started coming ever more often, and seemingly worse each time. It really wasn't a big change that the city folks would notice, but in the lifelong gambling game of farming, the odds surely changed. "Give the place back to the desert," Gaylen decided. "But I wonder what went wrong?"

In 1998, farmers like Gaylen indeed began to wonder if the weather dice had turned against them. They were not alone. In Oklahoma, National Guard troops ferried in hay for starving herds. In Dallas, homeowners watched lawns revert to desert. In Peru, floods cascaded through desert landscapes. In Central America, parched hillsides launched torrents of hurricane rain, destroying towns, bridges, and lives.

All these, and more, have been linked to the great swings in atmospheric and ocean circulation over the Pacific termed the Southern Oscillation, or more popularly El Niño and La Niña. Strictly speaking, El Niño refers to an anomalous warming of surface waters of the eastern equatorial Pacific that has historically occurred about every 3 to 7 years. When the warming occurs, it begins shortly after Christmas -- the arrival of the Christ Child (El Niño).

Meteorologists, however, recognize this warming as but one symptom of a massive swing in the circulation of the Pacific Ocean and its overlying atmosphere. In "normal" and below normal years, which some term "La Niña," steady easterly trade winds feed air and warm water westward into the torrid sweatboxes of the Indonesian archipelago, while cold waters well up along the South American coast. In El Niño years, westerly winds visit the equator, the great "hot spot" moves eastward, together with its turbulent convective storms, and warm surface waters spread a blanket over the eastern ocean.

These shifts are associated with myriad local effects. In South America, the rich fisheries that depend on nutrient-rich cold waters are decimated. As ocean-cooled, dry air is replaced by warmer, more moist currents, heavy rains visit normally arid regions. In the west, much of Southeast Asia experiences drought.

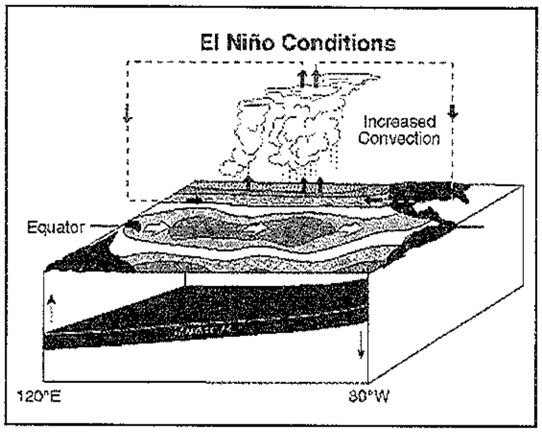


Diagram of El Niño conditions in the Pacific (courtesy of NOAA/PMEL/TAO)

Worldwide Effects of El Niño

The effects of this giant seesaw are not confined to the tropics. Consequences are felt worldwide, for example in the timing and intensity of the Indian Monsoon, and temperature changes in Alaska, western Canada, and Europe. One major influence is on the distribution of hurricanes, with more vigorous activity in the Pacific and less in the Atlantic during El Niño episodes.

Perhaps the most significant impacts are on precipitation patterns throughout the world. Areas that usually have droughts during El Niño years--Indonesia, Australia, Southeast Asia, and parts of Africa and Brazil--are likely to experience heavy rains during La Niña. In North America, El Niño events bring wetter conditions in the southeast and drier conditions in the north.

The reasons for the long-term frequency of these shifts between El Niño and La Niña conditions are not entirely understood, although numerical models now succeed in predicting individual events several seasons in advance. However, it does appear that El Niño has been behaving peculiarly in the last couple of decades. Since 1976, there have been more El Niño episodes than would be expected, and fewer occurrences of La Niña. Moreover, the two biggest El Niño events on record -- 1982-1983 and the unprecedented long 1990-1995 event -- occurred in this period.

Global Warming Induces New Trends

Might this trend be connected with increasing greenhouse gases and global warming? Certainly El Niño events export additional heat from the tropics, producing an added short-term worldwide warming. On a longer time scale, global warming may be slowly enlarging the size of the western Pacific warm pool, reducing the time needed to "recharge" the system. Climate models show changes with global warming; however, they do not simulate El Niño/La Niña swings with sufficient fidelity to justify confidence in their results.

Moreover, one would expect global warming to amplify some of the effects of El Niño. Increased downward thermal radiation should increase evaporation and thus exacerbate droughts. Globally, however, the moisture content of the atmosphere should increase. Thus, there should be a general increase in precipitation. At the same time, the increased moisture supply to storm systems of all kinds should increase their intensity. Indeed, an increase in precipitation from extreme events is actually being observed in many parts of the world.

Thus, slowly evolving changes in the atmosphere and climate may manifest themselves through increases in the frequency and intensity of El Niño/La Niña events. These, in turn, may drive unexpected and highly significant increases in the frequency and intensity of floods, droughts, and damaging storms.□

Derailing the Conveyor Belt

Trudging through the newly fallen snow, Pierre glances upward to see the Eiffel Tower dimly outlined against the September sky. Soon, he would be able to skate to school along the Seine instead of stumbling through slush and drifts. Papa worried about the barley harvests and something called the balance of trade, but Pierre looked forward to the ice fairs on the frozen river. Papa was so old-fashioned, always talking about the good old days of his childhood with wine and Riviera holidays. No grapes in France these days -- beer is better anyway! And who?d want to go to a cold and drizzly place like Nice anyway? Pierre liked the long winters from September through May. They gave him plenty of time for cross-country skiing practice...

Science fiction? Certainly. Impossible? Certainly not. Climate records contained in Greenland ice reveal that during the last 60,000 years, climate switched back and forth between intense cold and moderate cold with transitions taking a few years to a few decades. One such switch took place about 13,000 years ago, as the earth struggled out of the last major glaciation. The switch is best documented in Europe, where the climate had begun to approach today's balmy levels, and oak forests had become established. Within about 45 years, near-glacial temperatures resumed, and the forests were replaced by the tundra shrubs that give the period its name, the "Younger Dryas." In essence, the climate of Iceland invaded the south of France. Similar, though less spectacular, coolings occurred throughout the world. Once established, this mini-glacial period lasted for more than a millennium.

The Conveyor Belt

How could such a catastrophic event occur? To seek an answer, we must look at the 70% of our planet's surface that principally controls our climate -- the ocean. A complex of ocean currents on a global scale plays a major role in determining the climate of Europe, the North Atlantic, and indeed the globe as a whole. Transporting vast amounts of heat around the globe, this system has been termed "the oceanic conveyor belt."

The most prominent feature of the ocean circulation of our times is the strong northward flow of warm waters in the upper layers of the Atlantic Ocean, the core of which we call the Gulf Stream. In winter, as these waters near Iceland, they are cooled by cold air streaming off Canada and Greenland. Water arriving at a temperature of over 50°F cools to near freezing, releasing vast amounts of heat into Europe-bound winds before sinking into the ocean depths. As a result of this giant hot-water heating system, palm trees flourish at Irish seaside resorts, and Paris enjoys a climate far more comfortable than Labrador's. From a global standpoint, the most important effect of this process, in a relatively small patch of ocean, is that it is the prime mover of the heat conveyor system that spans the entire planet.

Will History Repeat Itself?

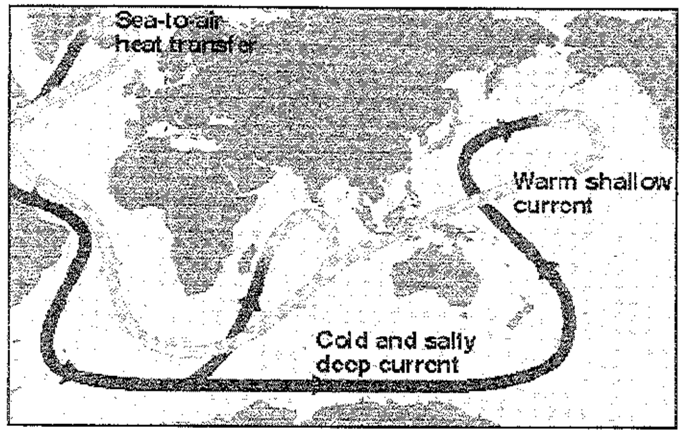
The most likely explanation of the "Younger Dryas" event is that light, fresh waters melting from the great ice sheets flooded the upper layers of the Atlantic, making the surface waters too light to sink. With this loop of the conveyer stalled, the remaining circulation adjusted itself into a different pattern, absorbing, transporting, and releasing heat and moisture differently, and thus shifting climates world-wide.

Were this to happen again, a simplistic analogy with the Younger Dryas would suggest alarming consequences. Iceland would become one large ice cap. Ireland's climate would become like Spitzbergen's. Tundra would replace forests in Scandinavia. The Baltic Sea would be permanently ice-covered. Temperatures would fall and rainfall patterns would dramatically shift throughout the world.

Model-based projections of climate changes induced by increasing greenhouse gases suggest that warming will indeed deliver more fresh water to high latitudes. The North Atlantic would then receive, not an avalanche of ice, but a torrent of light fresh water from rain, snow, and swollen rivers. Ocean models then predict that the global conveyor would gradually slow down, accompanied by marked changes in regional ocean temperatures and climate.

This complete scenario is, however, unlikely to unfold. Today's climate is vastly different from that which preceded the Younger Dryas. For example, our ice caps are far smaller. However, the comparison is illuminating: Any individual event that did happen once can happen again. More significantly, perhaps, this history demonstrates that global-scale shifts in climate may be locally triggered, and may be neither gradual nor small. Moreover, the Younger Dryas experience suggests that climate might "flicker," exhibiting short-term changes and reversals in trends.

In today's world, starting from today's climate, we might well see a global pattern of climate changes resulting from a shutdown in the global ocean conveyor belt quite different from those seen in the Younger Dryas. Such changes might be manifest in precipitation, temperature, and storm intensities, frequencies, and tracks throughout the world. If the climate "flickers," as some scientists find plausible, then regions and localities throughout the world would experience confusing and contradictory trends in climate that would make adaptation measures difficult, expensive, and perhaps counterproductive.□



The Oceanic Conveyor Belt

Flowing Ice; Rising Seas

"It's no use," Hans ter Horch morosely reported to his Minister. "We'll have to give up Gelderland for good." He recalled that after the disasters of 1953 and 1955, the massive Delta Project had been put in place to forever armor Holland's watery south against the slowly rising North Sea. But the rise was no longer slow: levels predicted for 2050 had arrived by 2010. In fine weather, it was far from a flood. But the margin of safety was gone, and not even the ruinously expensive storm barrier could guarantee safety. How many polders must be given up? Would the entire 50% of the Netherlands below sea level be returned to the sea?

Whether in Amsterdam or Adelaide, sea level depends primarily on two factors: how much of the Earth's water resides in the oceans, and the elevation of the land itself. Movements of water between ocean and land-borne ice lower sea level, while movements of the earth's crust can slowly change locally perceived sea level.

The Intergovernmental Panel on Climate Change (IPCC) currently projects that global sea level will rise about 50 cm by 2100, with a possible range of 15 to 95 cm. This rise is predicted to result from slow warming and expansion of the ocean, and melting of land-borne ice in a warming climate. Such slow changes may seem of relatively little consequence, given the constant construction and reconstruction of coastal facilities.

However, the IPCC's estimates span a disturbing range of possibilities, and leave much unsaid. A steady rise of 15 cm over a century could no doubt be readily accommodated by many countries. For others, such as Bangladesh, even a small rise would increase economic damage and human misery. A steady rise to 95 cm would present greater challenges such as marked changes in tidal patterns and penetration of storm surges perhaps hundreds of meters further inland. Although resilient and economically advanced human societies could no doubt develop plans and adaptations, less well-equipped societies would face daunting problems.

Preparation is not Security

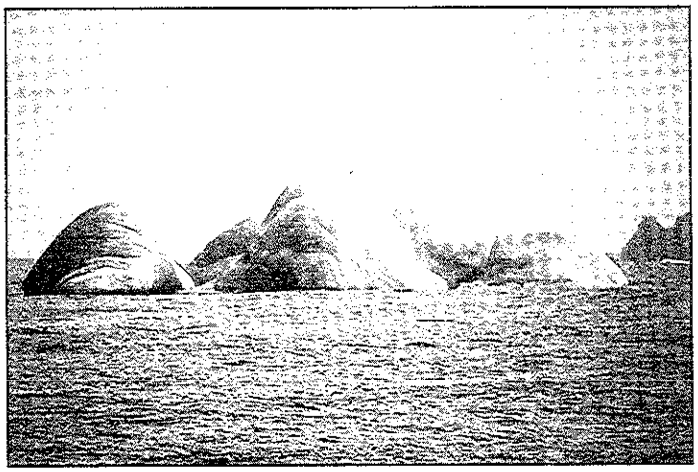
But what if these changes are far from steady? What if massive planning and construction efforts are set in motion based on plausible projections seemingly confirmed by observations -- and then are confounded by sudden changes to a radically different rate of change? What risks are hidden in the interplay of ice, climate, and water that determines global sea level?

Balancing Global Sea Level

At present, about 10% of the Earth's fresh water supply is stored in the West Antarctic Ice Sheet (WAIS), forming the largest single body of water that could conceivably add to the ocean's volume. For the most part, this vast mass rests on solid rock. As snow gradually accumulates, a few giant ice streams slowly drain it, dispersing ice into the surrounding floating ice shelves, and eventually into the world ocean. Evaporation and eventual precipitation on Antarctica withdraw water from the global ocean and therefore act to lower sea level; flow of ice from land to floating ice shelves and bergs acts to raise it.

As long as outflow balances inflow, the WAIS has no net effect on the amount of water in the world ocean. In fact, it is generally believed that the WAIS and indeed Antarctica as a whole are at present close to balance. However, changes in the rate of accumulation of ice, or the rate of export of ice into the world ocean could markedly and rapidly affect global sea level.

Since its formation some 10-20 million years ago, the WAIS has repeatedly advanced and retreated. During the last glacial maximum, 13,000 - 24,000 years ago, the "grounded" ice (ice resting on land rather than floating on the sea) extended hundreds of kilometers beyond its current limit. Accumulation of ice on land, in Antarctica but mostly in the Northern Hemisphere, lowered global sea level by about 120 meters. Conversely, during the last interglacial before our times (125,000 years ago), sea level may have been as much as 6 meters higher than today. The additional water most likely came from both Greenland and the Antarctic.



Melting icebergs, resulting in rising sea levels, may have disastrous consequences. (Australian Antarctic Division photo by Richard Priddy)

Could comparable changes occur in our times? It cannot be ruled out. Suspicion centers on the behavior of the giant, fast-moving (about .5 km per year) ice streams that slowly drain the WAIS into the world ocean, disintegrating into fleets of icebergs. The flow of the WAIS ice streams is governed by their interaction with the ground upon which they lie and the ice shelves that surround them. Possibilities for instability have been revealed through numerical studies. With global warming, retreat of floating ice sheets and rising sea level might "unpin" the ice streams from the topographical features that currently restrain them, permitting ice to flow rapidly into the ocean. In an extreme but not inconceivable scenario, much of the WAIS could be emptied into the ocean in less than a century, implying sea level rises at perhaps ten times current and projected rates. Nevertheless, the current consensus is that the risk of catastrophic increases in ice export and consequent sudden rises in sea level is low, though non-zero.

Sea Level Scenarios Shelved

These possibilities pose problems for human society. First, if decisions regarding coastal development are made on the assumption of slow and modest rises in a sea level, there is the possibility of unwanted consequences should sea level rises be greater and more rapid than anticipated. On the other hand, planning and preventive measures based on a worst-case scenario might prove unnecessarily expensive, and would divert resources that could otherwise be employed more effectively by society. Thus, the West Antarctic Ice Sheet hangs over not only the distant wastes of the Southern Ocean, but also over the coastal communities of the entire globe.□

Ill Winds from On High

Hugh watched helplessly as yet another yard of high-priced La Jolla landscaping toppled into the sea, its fall muffled by the howling wind and crashing waves. It was worse every year -- when would it end? The house would be next to go. Perhaps he should move back to the farm? But would there be any farm? There didn't seem to be much rain in Iowa these years. What's happened to the weather anyway?

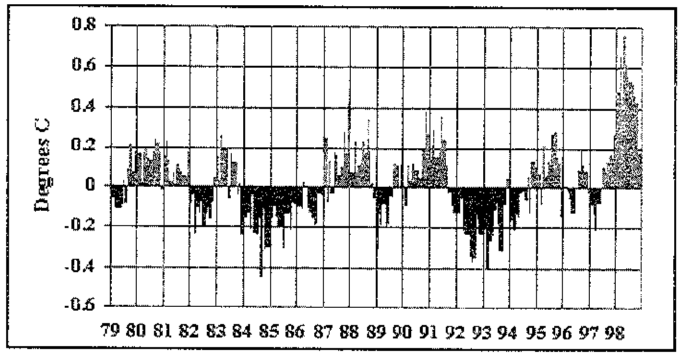
The weather that most concerns us from day to day occurs in the lower part of the troposphere. Here, the atmosphere is constantly mixed by convection and storms, and temperature steadily decreases with height. Lying above the troposphere at an altitude of about six miles, is the stratosphere, in which the temperature no longer decreases with height.

In contrast with the troposphere, the stratospheric circulation in both hemispheres is dominated by large-scale waves in a vortex roughly centered on the pole. The temperatures, pressure distribution, and winds of the stratosphere are largely determined by radiation received from sun and earth, and emitted to space. In the long night of the polar winter, the stratosphere cools strongly and the polar vortex strengthens until the pole is surrounded by a whirlwind of hurricane-force winds. As the sun returns, the vortex weakens and is replaced eventually by a summertime reversed flow pattern, sometimes through vast and vigorous overturnings termed "stratospheric warmings." These violent late-winter events have been clearly linked with anomalies in surface weather.

The strange world of the stratosphere six miles above -- certainly not earth and not quite space -- seems distant and disconnected from our daily life on the planet's surface. But are we in fact changing this part of the atmosphere as we have changed all else? Are changes in the stratosphere perhaps more significant than we might suspect?

An Atmospheric Domino Effect

The answer to the first question is unequivocally yes. It is well known that increases in CFCs in the stratosphere have led to decreases in ozone, arousing concern for weakening of the atmosphere's shield against damaging solar ultraviolet radiation. However, by absorbing solar energy, ozone also heats the stratosphere, and decreasing ozone would be expected to lower stratospheric temperatures. At the same time, increasing concentrations of CFCs, methane, carbon dioxide, and perhaps water vapor in the stratosphere radiate more thermal energy to space, again cooling the region. And indeed, observations indicate a detectable cooling, accompanied by a strengthening of the polar vortex.



Global Lower Tropospheric Temperature Variation January '79 - November '98 (Graph by NASA/MSFC)

Conversely, the winds of the stratosphere receive much impetus from the weather systems of the troposphere. As greenhouse warming changes tropospheric climate, consequent changes in the stratosphere are likely.

Thus, these two regions of our atmosphere are linked by chemistry, radiation, and dynamics -- and we are influencing all of these mechanisms.

Do changes in the stratosphere make any difference to us, six miles below? The known linkage between late-winter sudden stratospheric warmings and tropospheric weather suggests that the stratosphere can indeed make a difference on the short term. But there is a growing body of evidence that long-term changes in the stratospheric polar vortex play a role in the interannual and secular variability of climate at the earth's surface. Researchers have demonstrated a coupling between the strength of jet-stream winds in the polar vortex of the lower stratosphere and wave patterns in the troposphere that govern major shifts in surface climate. For example, changes in the stratosphere have been linked with wintertime temperature anomalies over Eurasia and enhanced westerlies across the North Atlantic.

Human Activity Plays a Role

If this deepening of the polar vortex continues into the 21st century, it could have far-reaching consequences. Changes in wind systems could combine with slow warming to radically reduce the extent and thickness of Arctic pack ice. Changes in patterns of cooling could influence large-scale ocean circulation, adding to the concerns about the "conveyor" noted above, and affecting fisheries recruitment. Changes in winter and spring precipitation patterns could affect soil moisture and agricultural productivity.

Thus, the effect of human activities on the stratosphere of our planet introduces a new "wild card" into the climate change equation.□

Surprising Futures

The most authoritative current assessment of the future course of our climate under the influence of human activities is that of the Intergovernmental Panel on Climate Change. This group reaffirms that human activities can change global climate, declares that "...the balance of evidence suggests a discernible human influence on global climate," and projects slow temperature rises over the next century.

The IPCC's projections also speak in general terms of consequent changes in sea level, precipitation, storm systems, and regional climate regimes. In sum, they depict an exceedingly broad band of uncertain consequences ever widening into the unknown and unknowable future.

A survivor looks through the debris left after a tsunami hit Papua-New Guinea last year. (courtesy of AFP)

To some extent, this uncertainty reflects the weakness of our understanding of the processes and mechanisms of climate. As understanding deepens through research, we can hope for somewhat sharper vision. However, much uncertainty stems from the complex, nonlinear, highly interlinked nature of the climate system itself -- not to mention the human system that increasingly influences it and depends upon its workings. We know from countless examples that systems such as this exhibit chaotic and unpredictable behavior. Moreover, we know from the record of the past that the climate system has in fact experienced marked and sudden changes in complex patterns over the face of the globe. *This class of uncertainty cannot be reduced; it must therefore be accepted and dealt with.*

More Uncertainty for the Future

The surprising things that *have* happened before as a consequence of natural forces *can* happen again as a consequence of human activities. Such climatic surprises must be included within the broad band of uncertainty within we must plan our common future on this complex planet. The examples of climatic surprises sketched in this paper are not presented as predictions, but simply as examples of surprising and significant events that might punctuate the course of human-induced change in our atmosphere and climate over the next century. As we develop mechanisms to deal with the problem of human-induced climate change, we should bear in mind the possibility that the stakes may be much higher and much closer to home than suggested by placid scenarios of gradual global warming.

Possible Consequences Set the Agenda

We believe that this insight has a number of implications for our approach toward dealing with human influences on climate:

1. The range of consequences, and therefore the range of risks, is far greater than suggested by the current projections of modest and gradual changes. In the complex earth system in which we live, large and sudden changes can result from small and gradual influences. Human-induced climatic changes may be the straws breaking the camel's back of climate. Thus, the issue of human influence on climate merits a continuing high place on our society's agenda of concern.

2. Although surprises cannot be predicted, they can perhaps be detected. Early warning of emerging surprises can provide valuable lead time to permit more effective mitigation and adaptation. Thus, high priority should be given to observation and monitoring systems focused on critical elements of the climate system. A suite of internationally coordinated climate-related observing networks is currently being developed by the earth science community. These systems merit strong support.

3. As we consider measures to mitigate climate change, e.g., by constraining emissions of greenhouse gases, our cost-benefit calculations should take into account the very real possibilities for unanticipated and extreme climatic excursions. Thus, we should in all likelihood be willing to incur significant near-term costs to buy a measure of insurance against the possibility of unacceptable long-term risks. As we develop means to adapt to the climatic changes that appear virtually inevitable, we should ensure that these adaptations have an ample margin of safety, so as to give us some "cushion" against the possibility of climatic surprises. The internationally accepted "precautionary principle" is amply justified. □

This issue of the *Public Interest Report* was prepared by Dr. John S. Perry.

Dr. Perry, an atmospheric scientist educated at Queens College and the University of Washington, comes to FAS after careers in the US Air Force and the National Research Council. In the Air Force, he worked as operational meteorologist, computer systems analyst, and research program manager at the Advanced Research Projects Agency, retiring in the rank of Colonel. He is a graduate of the Air Command and Staff College and the Air War College. At the NRC, he directed a variety of programs in atmospheric sciences and climate, oceanography, and sustainable development, and participated in numerous international activities of the World Meteorological Organization, the UN Environment Program, the International Council of Scientific Unions, and other organizations relating to weather and climate. He is currently writing and consulting in the Washington area, and serving on the advisory boards of environmental organizations.

This report draws heavily on the work of Professor Wallace S. Broecker, Lamont Geophysical Observatory, Columbia University; Dr. Kevin E. Trenberth, National Center for Atmospheric Research; Dr. Michael Oppenheimer, Environmental Defense Fund; and Professor John M. Wallace, University of Washington. Dr. Perry is very grateful to these scientists for their inputs, encouragement, and constructive comments.

The Hague Appeal for Peace Conference

In May 1999, The Hague Appeal for Peace Conference hosted over 9,000 delegates from over 100 countries to discuss conflict resolution, creating a "culture of peace," and human rights. Nuclear disarmament was a central theme, as were the role of women and youth in the peace movement and conventional weapons proliferation.

The International Action Network on Small Arms (IANSA) was launched at the conference to facilitate global action against the proliferation and misuse of small arms--the leading killers in today's internal wars. IANSA will help coordinate the activities of over 200 member organizations through e-mail and the world wide web. Nobel Peace laureate José Ramos-Horta and others promoted the International Code of Conduct on Arms Transfers, which would prevent arms transfers to countries that violate international humanitarian and human rights laws, as one of IANSA's key goals. The International Code would expand upon the proposed U.S. Code of Conduct, an idea FAS and other NGOs have been promoting since the early 1990s. □ *–Tamar Gabelnick*

FAS Website Proves Itself on Kosovo

John E. Pike

Although other websites implemented by government agencies, news organizations and think tanks provided coverage of the Kosovo war, no other website approached the depth and breadth of the FAS Target Kosovo website. By closely monitoring worldwide news sources, our website reported the start of the air campaign six hours before CNN [courtesy a VOA report], and reported Serbia's initial acceptance of NATO's terms before this news had reached the Pentagon [courtesy a TASS report]. Informed by this comprehensive all-source coverage, our analysis of the conduct and conclusion of the war proved remarkably prescient, an achievement highlighted by the pervasive and persistent misjudgement of the war by so many other analysts and commentators. (See May/June PIR, p. 6-7)

The utility of the FAS Target Kosovo website did not go unrecognized, as weekly usage of the FAS website quickly doubled compared to its peacetime level. Each week over 50,000 users accessed Target Kosovo, downloading nearly half a million text files and thousands of megabytes of images.

Over the past year the Defense Department has systematically removed much, if not most, of the content from military websites, and the few commercial sources of comprehensive data are priced well beyond the means of all but the most well-financed users. Consequently, the FAS website is rapidly becoming the preeminent publicly-available source of current weapon system information.□

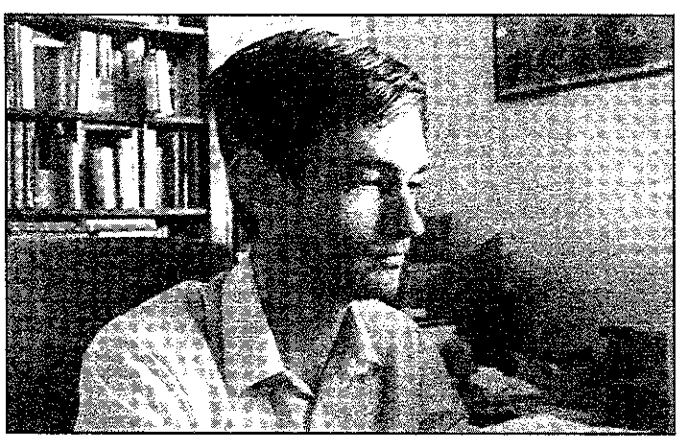
Website Kudos

"I have made regular use of your site during the whole of the Kosovo crisis and it has normally been my first stop on my regular internet search."
--Lawrence Freedman, Department of War Studies, King's College, London

"Keep up the good work, the Target Kosovo site is heavily visited by the NATO press corps in Brussels."
--Mark Laity, British Broadcasting Corporation

"What made your work so extraordinary was the timeliness with which you managed to accomplish all this ... a couple of others tried (far less successfully) to do what you did ... your Kosovo website has taken FAS to yet another plane of relevance and credibility in Washington's national security debates."
--John Barry, National Security Correspondent, Newsweek

"The FAS site on the Kosovo conflict helped me tremendously in my work providing the main coverage of developments in the International Herald Tribune. We also alerted many other people in journalism and government to the site, which we view as a truly outstanding example of the special qualities of discussion, accuracy and technological sophistication and thoroughness associated with American culture."
--Joe Fitchett, Diplomatic Correspondent. International Herald Tribune



Dr. Maxim Vadislavovich Tarasenko

Tarasenko Dies in Tragic Accident

The death of Dr. Maxim Vadislavovich Tarasenko in an automobile accident on 4 May 1999 was a profound loss to FAS and students of the Russian aerospace complex.

His monumental study of the structure of the Russian aerospace industry, hosted on the FAS website, represented a small but valuable component of his prolific and pathbreaking output. All who worked with him valued his gentle humor and generosity, and his untimely death has inflicted a major setback on the space policy community.□

–JEP

FAS Press Release Helps Spur Serbian War Crimes Investigation

On June 18th, FAS began collaborating with Human Rights Watch to uncover evidence of the alleged use of chemical weapons (CW) by the Yugoslav Army (VJ) and/or paramilitary forces under their command in Kosovo. This inquiry is in support of a larger war crimes investigation being conducted by the Hague on the use of CW in Kosovo. The Hague started this initiative, in part, due to an FAS press release through *U.S. Newswire* on April 14th.

The investigation centers around the use of the incapacitating agent BZ by VJ forces along the north western Albanian border region against the Kosovo Liberation Army (KLA) and the local Muslim population. BZ is intended to produce physiological or mental effects that prevent exposed personnel from conducting normal routines for an extended period of time. The use of BZ is illegal under the Chemical Weapons Convention; Yugoslavia is not a signatory of the Convention.□ *–Kevin Kavanaugh*

Jensen Receives Service Award

After twenty years of loyal service as the FAS Comptroller, Eleanor Jensen has retired from her position. She will still work with FAS occasionally on a volunteer basis.

On the occasion of her retirement, Jensen was awarded the first FAS Service Award with the following citation:

"For Anchoring FAS for Twenty Years With the Qualities Shown Below Thus Becoming Our Full

Patient

Adaptable

Reliable

Tenacious

Number-Crunching

Efficient

Resourceful

In All FAS Achievements of Two Decades"

–Christa J. Fanelli

The Ballots are In

The FAS Council election, concluded June 30th, ended the full terms of three dedicated Council members: Linda Gottfredson, Daniel Kammen, and Robert Socolow. The new member-elected Council members are Jean Herskovits, Michael Klare, and David Robinson.

During 1998, there were some other changes in the Council and Fund Board due to the appointment of Morton H. Halperin in the State Department and the election of Rush Holt to Congress. Sidney G. Winter, Jr. replaced Halperin in the Council. Bruce Blair and Massoud Simnad were added to the Board.

The following famous Sponsors passed away during the year: Wassily W. Leontief, Frederick Reines, Arthur Schawlow, Glenn T. Seaborg, and C.S. Wu. All of these men were nobel-prize winners.□ *–CJF*

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