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A NEWSLETTER ON CLIMATE SCIENCE AND PRODUCTS FOR USERS

Michael A Fortune*
Climate Science Forum, Silver Spring, Maryland

Reliable News and Analysis in Climate Science

http://climate-science.org

1. INTRODUCTION

In 2002 a quarterly newsletter for the non-specialist public interested in climate science, climate variations and climate change and was launched. *Climate Science Forum* reports on climate products, analyzes significant new findings in the science of climate, and presents diverse viewpoints by investigators. We expect that readers use the information to shape their decisions on climate-related strategies.

The newsletter does not assume editorial positions on matters of "good science" or good policy. It does, though, host a "Forum" in which various viewpoints are solicited from climate scientists. Each issue also has news; reports from meetings and conferences; a "Climate Science Classroom; Letters to the Editor; and illustration of products such as the Seasonal Climate Highlights.

The online *Climate Science Forum* uses active links to original articles or documents in its citations.

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2. WE SOLICIT YOUR SUPPORT

★ to inform us of your products, publications, and work in progress;

★ to clarify your need for specific climate information that the community does not now provide;

★ as associates who will work with us to produce the newsletter. We are eager to associate with state climatologists, regional climate centers, trade associations, Universities, and others who may wish to assist in producing a professional publication with appeal to multiple sectors of society;

★ as Editorial Board members.

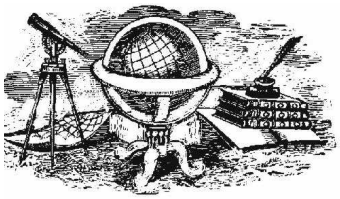
3. NEWSLETTER EXAMPLES FOLLOW

Below are two complete issues of Climate Science Forum from 2002. Past issues like these are available at http://climate-science.org . A recent issue from 2003 is also included in this CD under the 14th Conference on Applied Climatology (Fortune, 2004, below).

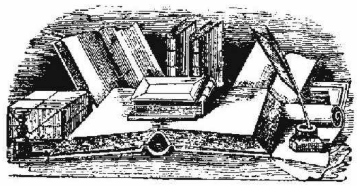
4. Reference

Fortune, M.A., 2004: A newsletter forum on climate science for non–specialists. Preprint P3.3, 14th Conf. on Applied Climatology, Seattle WA, American Meteorological Society, Boston MA.

CLIMATE SCIENCE FORUM



Reliable News and Information on Climate Change



Summer 2002 **http://climate-science.org** **Vol. 1 No. 2**

Unprecedented Breakup of Antarctic Ice Sheets

Not All Breakups due to Climate Change

We had just gone to press in March when huge pieces of Antarctica's floating ice shelf had detached from the mainland and disintegrated in the sea. In 2000 and 2001 at least three sections of ice sheets, each one the size of Connecticut, cast off to become floating islands. This year, between January 31 and March 7, a large section of the Larsen B ice shelf on the Antarctic Peninsula (near South America, see map on page 3) disintegrated in only 35 days. The satellite photos before and after this breakup are also on page 3. The Larsen ice shelf lost 60% of its former summertime extent in the last five years.

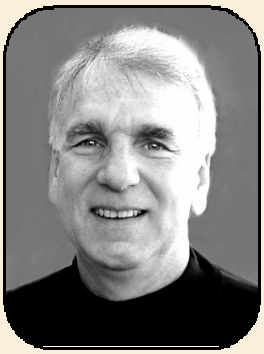
Has a changing climate contributed to the unusual breakup? "Yes" for some events, "No" for others. While many saw this as evidence of a warming planet, the observations show that most of the Antarctic continent is, in fact, cooling. Peter T. Doran and coworkers wrote

Antarctica *continues on page 3*

INTERVIEW

What Climate Prediction Models Still Cannot Do: An Expert Speaks Out

Dr. Robert Livezey questions ability to get regional climate trends right



by Michael A. Fortune

Dr. Robert E. Livezey takes personal pride in two bold climate forecasts that the Climate Prediction Center put out. One was their confident prediction (six months in advance) that El Niño would cause unusual winter conditions in 1997–98, and the largely correct pattern of specific impacts in different parts of the country. "Our forecasts were unprecedented, and the scores for their accuracy set new records." The other was a bold prediction made during the coldest deep freeze in Washingtonian memory when the Potomac River froze over in December 1989. In front of top policy makers, he stood firm on their earlier forecast that the winter as a whole would be warm. Two months later, he was seen to be right.

But developing an effective office of climate services, his next job after he moved on from the Climate Prediction Center in 1999, was all too often an uphill effort. Finding qualified staff and appropriations was slow. Moreover, it was an effort to convince climate scientists that the National Weather Service (NWS) was serious in wanting to foster cutting-edge climate predictions for the US.

> "There should be no debate that this country has undergone a climate change."

Today, the NWS Climate Prediction Center, which produces the services his office now oversees, routinely makes predictions as far as one year in advance. Seasonal predic-

Interview *continues on page 6*

From the Editors

Pity the Poor Policy Planners

As we put the finishing touches on this second issue of *Climate Science Forum,* we began to realize that all too few of the questions on which we report have clear answers. Sometimes the facts are contradictory; sometimes our leading scientists reach opposite conclusions about the same data. With this heated debate among the experts, how can our non-scientist legislators establish climate policies?

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A few years ago, a friend of mine in Los Angeles was opening a new office and consulted a *feng shui* master to make sure that the office space and its furnishings arrangement would bring good fortune. Unfortunately, the venerable master concluded that everything — from the walls to the very compass direction of the office — was wrong and should be started anew. However, having put out a great deal of money on office construction that could not be recovered, my friend consulted a reportedly even greater master than the first, paid him quite a bit, and received a comforting assurance that the original space and furniture placement were absolutely perfect.

At times, a course of least resistance might certainly be best. Certainly, a cynic might suggest that, where climate change is involved, a decision-maker under stress could just as well follow the advice that seems most comfortable at the time.

Nevertheless, we have created *Climate Science Forum* as a means to present unvarnished issues and as clear a picture as possible of current scientific opinion, including different sides of disputed issues. History shows us that the truth is sometimes obscured by popular consensus, and the ghosts of Galileo's detractors might be embarrassed to know that the world is not really flat.

Thus, our "open" forum may present ideas from legitimate climate researchers that are out of step with prevailing scientific opinion. Until we are certain what is happening with global warming or cooling, we cannot afford to dismiss any serious theories.

Michael A. Fortune

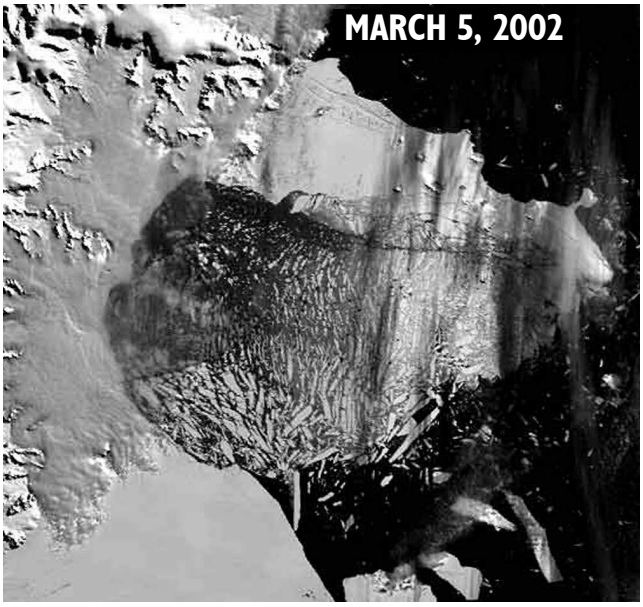
Robert Wang

Religious Organizations Enter Climate Change Debate

Speaking for the leaders of more than 25 Pennsylvania church organizations, the Rev. Dr. Thomas M. Johnson recently stated that "People of faith can no longer sit by while we destroy God's good earth. We must educate, motivate and activate our congregations to ensure that global climate change be halted, and then reversed. People of faith have an obligation to act on their religious and spiritual responsibilities and help create the political consensus for our nation and all nations to be good stewards of the earth."

On another front, it has been widely reported that the Cleona School Board of Anneville, Pennsylvania, recently voted to ban books discussing global warming and other "controversial topics," which is not precisely correct. For whatever reason, the board deferred to the wishes of one of the nine members about a relatively minor textbook intended to teach reading comprehension, and removed those ideas that offended her religious convictions.

Dr. Marsha Zehner, Superintendent of Schools in the district did not mask her irritation about this, telling *Climate Science Forum* that the teaching of science in their schools was not at issue. Like all Pennsylvania state schools, those in Anneville follow the state guidelines, which encourage schools to teach a balance of scientific theories.



A satellite recorded the extraordinarily rapid disintegration of most of the Larsen B ice shelf early this year. Black scratches and dots in the earlier picture are ponds of meltwater, which may have initiated the breakup.

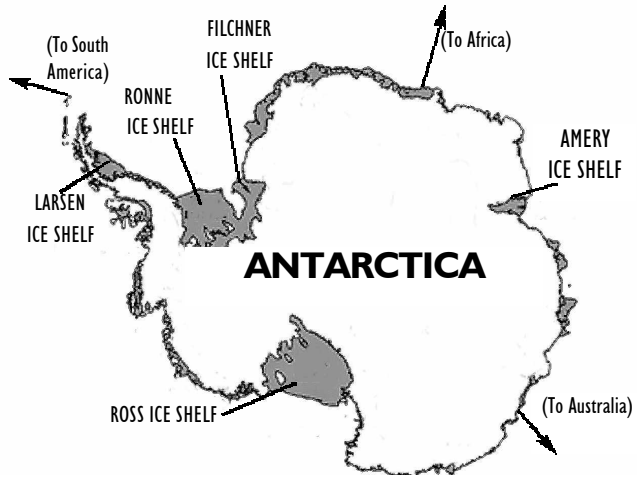
Antarctica, *continued from page 1*

in *Nature*[1] that average temperatures have fallen over the last 35 years and that summer temperatures have fallen the most. The few living creatures that call Antarctica their home are sensitive to summer temperatures, because summer is when their body temperature can reach 0°C, the melting point of water.

The breakups of ice shelves on the Antarctic Peninsula and other ice shelves farther south are caused by different factors. The Peninsula region, including the Larsen shelf, is warming, with temperatures now 3°C warmer than in the 1940s when the trend began. A theory put forth by Ted Scambos of the National Snow and Ice Data Center *[http://nsidc.org]*, University of Colorado, now has the support of observations during this year's catastrophic breakup.

Scambos thinks that meltwater ponds on the surface of the ice introduce water into deep cracks or crevasses, which forces them apart. The more that water sinks into these fissures, the more pressure it exerts on the walls, until the crack extends all the way through the ice shelf, about 700 feet thick. What is different is that the top surface now remains above freezing for 60 to 70 days each summer, long enough for the ponds to grow large. You can see meltwater ponds in the picture from January, above, as numerous black scratches and dots on the white ice. This region disintegrated into the sea over the 35 days following this picture. Scambos thinks the recent warming is a principal cause of the sudden ice breakups on the Antarctic Peninsula.

Farther south, the four largest ice shelves (Ross, Ronne, Filchner, and Amery) around the margins of the continent almost never reach melting temperatures even in the summer. Scambos credits different factors for causing the breakups in 2000 and 2001: ocean currents, tides, and katabatic (hurricane force) winds off the continent. Even so, these ice shelves had extended farther out than ever before observed and were ready to be broken off. After the recent breakup, the margins of the Ross Ice shelf were whittled back to where they were in the 1960s.



[1] Nature, *10 January 2002. www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v415/n6871/abs/nature710_fs.html*

CLIMATE BRIEFS

Sea Ice Melts Away in the North While It Expands in the South

Satellite observations of the extent of sea ice over the last 20 years show that Arctic ice has decreased for every day of the 365 days of the year. The retreat of the ice has been greater in the summer than in the winter; therefore, the summer-to-winter change has become sharper. At the same time, sea ice in the Southern Hemisphere has increased. Down there, the winter ice has increased but the summer ice extent has not. This behavior agrees with a 1997 satellite observation using microwave data.

The new finding is by Vinnikov and three others in *Geophysical Research Letters*, v. 29, 24-1, on 8 May 2002.*

Yet Another Gas Having Climatic Effects

Antarctic ice cores have yielded yet more clues about the history of the atmosphere, this time for a sulfur compound that acts not only to cool the earth but also to destroy ozone. The gas is carbonyl sulfide, the most abundant sulfurous gas in the atmosphere, one that is produced naturally as well as by industrial processes. By crushing ice cores having ages from 385 to 310 years old, Murat Aydin and colleagues have reported that the air trapped in the ice during the 1600s held only three-fourths as much carbonyl sulfide as the present atmosphere does. They infer that industrial emissions may be responsible for one-fourth of the current amounts of this gas.

Murat Aydin's work appeared in *Geophysical Research Letters*, v. 29, 15 May 2002.*

Amazon Wetlands May Be a Source, Not a Sink, of CO_2

Another morsel in the stew of carbon sequestration: Ground-based studies suggested that tropical forests were absorbing more CO_2 from the air than deforestation elsewhere was releasing into the air. However, a new study by Jeffrey Richey and co-workers has identified a new source of CO_2: outgassing from rivers and wetlands. It appears that rivers transport a load of organic debris from upland forests, which is then decomposed in the rivers, thus releasing CO_2 into the air. The authors suggest that the overall budget of carbon in rain forests is closer to balance than earlier studies had suggested.

Their report appears in *Nature*, v. 417, 617–620, April 2002; online at *www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v416/n6881/full/416617a_fs.html.*

US Vegetation Absorbing a Lot of Carbon

The reason? There's more rain!

Certain human activities offset a healthy part of the emissions of greenhouse gases from other activities. Planting and growth of new trees and vegetation absorbs or "sequesters" CO_2, converting it into wood, vegetation and organic matter. As long as more vegetation is created than destroyed during a time period, then CO_2 is removed from the atmosphere. Deforestation, then, enhances the greenhouse effect by adding CO_2, while "afforestation" can be one viable solution to greenhouse effects, and is part of the climate policies of many nations, including the US.

The US land mass has been absorbing more CO_2 through the years, with a 14% increase in total vegetation over some 43 years, but the reasons have not been clear. A simple explanation comes from R. Nemani and co-workers at the School of Forestry of the University of Montana, who found that increases in rainfall may account for two-thirds of the increase in vegetation growth. Although the explanation is simple, it has been overlooked.

The study appeared in the *Geophysical Research Letters* of 28 May 2002.*

No Trend Found in Climate Variability

Although many climate indices exhibit a trend when their average is computed over a long period of time, Vinnikov and Robock (2002) report that the so-called variance of five common indices did not show any trends at all. The variance or the standard deviation are used to measure the variability of climate. The five indices are:

- Average sea level at New York City rose 30 cm (one foot) in 100 years, but its year-to-year variability remained the same.
- U.S. mean annual precipitation increased about 8% over 100 years, which was statistically significant, but its variability did not change appreciably.
- The other three indices showed no change in the average and also no change in variability: (a) the Palmer Drought Index, (b) the strength of the Indian Monsoon, and (c) El Niño.

Their work, "Trends in moments of climatic indices" appeared in *Geophysical Research Letters*, v. 29, 14-1, on 29 Jan 2002.*

* *www.agu.org/pubs/toc2002/gl.shtml*

Volcanic Eruption in 1991 Sheds Light on Sensitivity of Climate to Water Vapor

Theory and computer models strongly suggest that water vapor amplifies the response of Earth's atmosphere to any warming or cooling that may occur, including warming caused by greenhouse gases. While carbon dioxide is expected to cause a warming, volcanic eruptions cool the planet, because the global plumes of fine ash particles reduce the amount of visible sunlight that reaches the ground. In the presence of water vapor, the cooling is expected to be even greater. Water vapor amplifies a small warming or small cooling.

Brian J Soden and others at Princeton and Rutgers Universities investigated the cooling of Earth after the eruption of Mount Pinatubo in the Philippines in 1991. They compared the actual cooling with simulated coolings, both with and without the effect of water vapor. They conclude that the global plume of ash and aerosols plus the water vapor feedback cooled the Earth 60% more than the aerosol plume alone would have done. The observed cooling and its regional pattern resembled the cooling in a model simulation that included the water vapor effect. It was possible to remove the water vapor effect in the simulation by removing its influence on thermal radiation, and when the effect was removed, the cooling of the Earth was 60% less than it was in the standard simulation.

Looking back to June 15, 1991: After being dormant for 500 years, Mount Pinatubo suddenly exploded with the second largest eruption of the century. 50,000 people were forced to evacuate, two military bases were effectively shut down, and hundreds of people lost their lives. The impact of this natural disaster continues even today.

The effect of water vapor on the sensitivity of climate – even whether the feedback is positive or negative – is in dispute. Some have argued that water vapor or resulting clouds suppress any temperature changes and, thus, have a negative feedback on temperature changes. R. Lindzen takes this position when he proposed an "Iris Effect," as described in our first issue of *Climate Science Forum*. Soden's team believes it has made a strong case that water vapor amplifies any temperature change.

Their article is in *Science*, v. 296, 26 April 2002, 727–730 *[www.sciencemag.org/cgi/content/abstract/296/5568/727].*

Forests That Now Absorb Carbon Dioxide May Not Do So in Future

Many policies for limiting future levels of greenhouse gases depend on the ability of forests, grasslands, and organic soil to absorb and "sequester" atmospheric carbon dioxide, as these ecosystems convert the carbon to wood and organic matter. A report in *Nature** by Richard A Gill and others dashes such hopes.

In a field experiment in a Texas grassland, the authors modified the concentration of CO_2 in the ambient air from 200 parts per million (ppm) – well below the concentration observed in the pre-industrial age before 1800 – to 550 ppm, a level that some expect the atmosphere to reach by 2100. The ability of the grassland to absorb more carbon from the atmosphere depended on the availability of nutrients. The grassland apparently grew faster when CO_2 levels were lower than when they were higher. Researchers found that carbon storage in soil and cycling of nitrogen "are much more responsive to past atmospheric CO_2 concentration than those forecast for the coming century." They suggest that sequestration of carbon in soils "may have been important historically, but the ability of soils to continue as sinks is limited."

* *Nature*, v. 417, 16 May 2002, *[www.nature.com/nature]*

Interview, *continued from page 1*

tions even farther in advance are expected, although Livezey thinks that two years ahead may be a limit.

Many climate predictions are based on what meteorologists casually refer to as a "model," a simulation of the atmosphere in evolution, whether in the past or looking to the future. But Livezey points out that models have serious pitfalls in representing the real physics that goes on in the air in clouds – in rainfall, in the balance of energy and water, in chemical reactions. Predictions of just the atmosphere are difficult to "get right," but to get correct simulations of climate years into the future, requires joining atmospheric models with models of the ocean, of the ice, of the land surface, of chemical reactions and, perhaps, even of the biosphere – the world of living creatures. These "coupled models" are still experimental, with accuracy often untested.

When asked how confident he is that the current climate models can simulate climate trends and variations in the US, he said, "I have no confidence at all, especially if we want to use the models for future projections for the US. The models have to be able to reproduce the season-to-season and region-to-region differences in climate and the trends observed over the last 30 years or so. So far, the models have not."

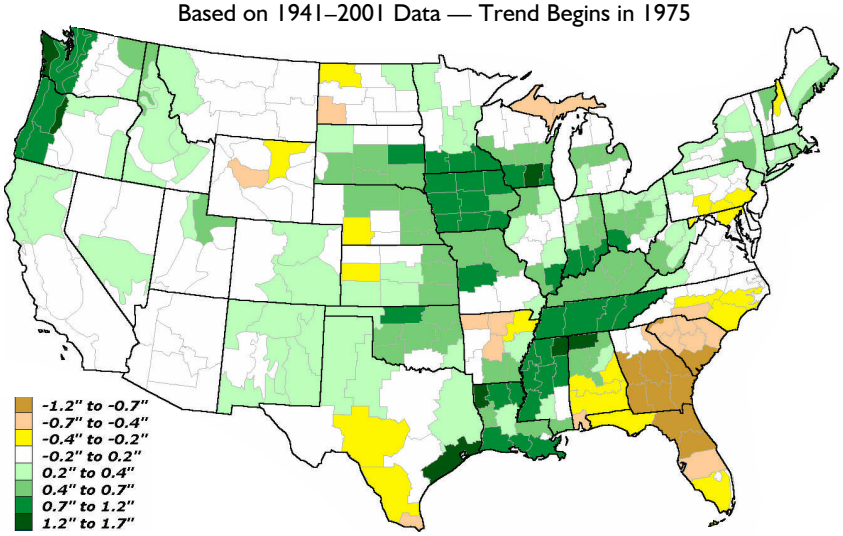
> "I have no confidence at all, if we want to use the models for future projections."

As an example, Livezey discusses the risk that the Great Plains might suffer a future drought as devastating as the dust bowl of the 1930s: before we can assess that risk, we have to be able to accurately simulate the region's past. But as far as he knows, the current models used to make such predictions fail to reproduce the trend toward wetter conditions in the last 25 years, especially in the growing season.

Livezey's research shows that, since 1976, the country has actually been getting wetter, not drier – especially in the Great Plains in the spring and summer and the Lower Mississippi in the fall. Figure 1 shows the regional trend of Spring rainfall over the last 26 years. The Mississippi valley has definitely become wetter, but even the Plains from Oklahoma to the Dakotas have become wetter, not drier. Also in Fig. 1, there has been drying in the Southeastern states, especially Florida and Georgia. That dry trend extends along the Gulf Coast for the summer period, but again, the Plains from Oklahoma north have had wetter summers. The US as a whole has been getting wetter at the rate of 0.6 inches (1.5 cm) of rainfall every ten years in all seasons.

Livezey asserts, "There should be no debate that this country has undergone a climate change." His work demonstrates that the nation as a whole has seen warming over the last 25 years, but the seasonal patterns are different, and the trends vary from region to region. The warming has primarily been in the winter, at least in the United States. Livezey and colleagues have updated their results to Spring 2002 and fitted the data since 1940 to a line with two parts: no trend before 1976 and an upward trend since 1976. We are pleased to share their latest results in these pages. Figure 2 strikingly depicts the national temperature change in each season. The winter has warmed 1°F per decade (2.5°F in the years since 1976) which far exceeds the change in other seasons – while the summer warming trend

Figure 1. Precipitation Trend (inches per decade) — Spring
Based on 1941–2001 Data — Trend Begins in 1975



Dr. Robert E. Livezey is Chief of the Climate Services Division, Office of Climate, Water and Weather Services, National Weather Service; formerly Senior Scientist at the Climate Prediction Center. He is author of more than 50 refereed papers in climate journals, several book chapters, and more than 60 articles in non-refereed publications. All viewpoints are his own. Nothing in this article is an official statement of the National Weather Service or NOAA.

is only one-fourth as much and the autumn has had no trend at all. Livezey adds that "east of the Rocky Mountains, there is no evidence yet of warmer summers in the US."

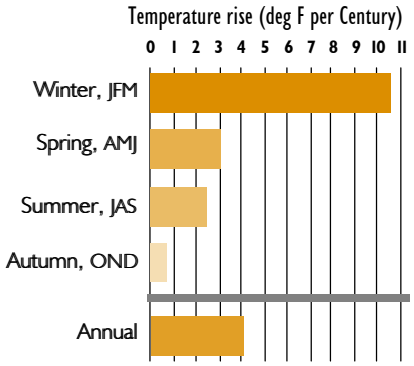
Figure 3 depicts the geography of the Winter temperature change: the nation as a whole has warmed in winter since 1976, but the Northern Plains near the border with Canada have warmed the most, 6°F during those years, while Alabama and east Texas warmed not at all. Also, the Western states have warmed in all seasons except autumn.

The autumn trend is different: there is either no temperature change, or a slight cooling, everywhere east of the Rockies and the Rio Grande. The summer pattern is similar, with little change in the East and Midwest over 30 years.

> "We don't have yet a credible regional climate forecast system."

"Global climate models", he says, "get the warming of the last 30 years right – the global annual average. *But they don't get the seasonal and regional details right.*" He sees no evidence that these models can make credible projections of a region's climate. A serious weakness is that no single model correctly reproduces the patterns of the three most important atmospheric oscillations that affect the climate variations over North America from month to month and year to year. These three phenomena are the El Niño/Southern Oscillation (ENSO); the North Atlantic Oscillation (NAO), and the Madden-Julian Oscillation (MJO). These phenomena control weather patterns, especially the differences from one continental region to another. Some

Figure 2. US Temperature Trend by Season



Temperature trend based on 1941–2001 data with trend beginning in 1975. Winter = January, February, March, and so forth.

models handle one or two of these phenomena well, but none (that he knows of) handles all three well.

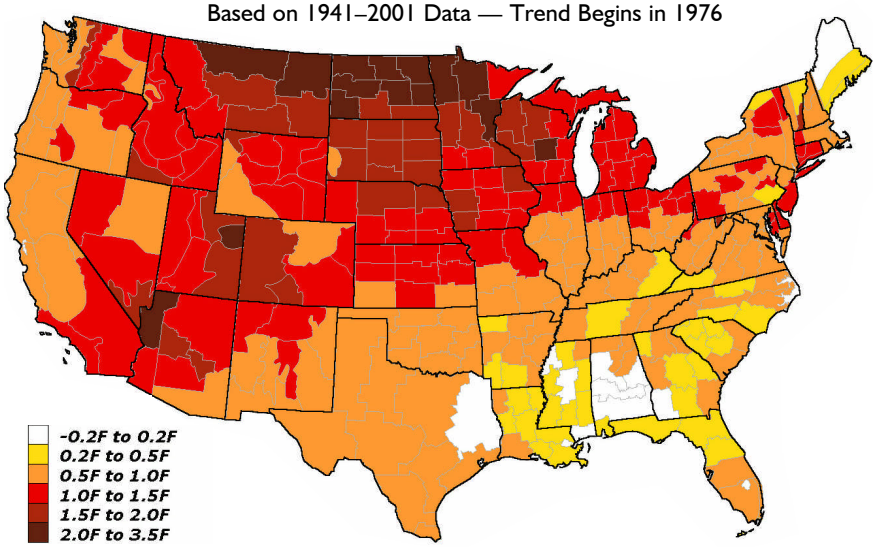
"It's worse than that. Because the climate is changing . . . The rules we go by are changing." He explains that the basic state of the atmosphere will change, which can affect the nature and number of the planetary waves. In turn, these waves will affect weather patterns in new ways. "We may need different rules to forecast climate 50 years into the future. "

Livezey is saying that the computer models used to predict the future mean little if they do not accurately replicate the variations of the past. He explains that they do not yet even simulate properly the tropical patterns of rain and thunderstorms that are so important to North American weather, and concludes, "We have not completed Step One yet, to get the meteorology and oceanography right!"

What would it take to build his confidence in models as tools for climate prediction? Before we can take them seriously, he avers, developers must prove that their models can reproduce the trends over the last 30 years, especially for major regions of continents; that they correctly show the observed variation from one region to another; and most importantly, that they properly depict the three phenomena mentioned (El Niño, NAO, and MJO) – which for him means that the climatic variations from region to region, the changes through the seasons, and the trends since 1970 all have to be correct.

> "We have not completed Step One yet, to get the meteorology and oceanography right!"

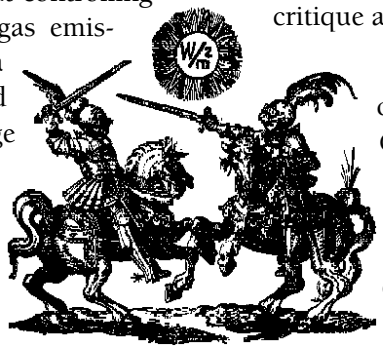
Figure 3. Temperature Trend (degrees F per decade) — Winter
Based on 1941–2001 Data — Trend Begins in 1976



FORUM Should We Deal with Air Pollutants First and Carbon Dioxide Later ?

JAMES E. HANSEN: Attack both health and climate threats by focusing on non–CO_2 air pollution first.

James E. Hansen, prominent climate scientist at the NASA Goddard Institute for Space Studies, proposed an "alternative scenario" for handling the impact of greenhouse gases and human pollutants on climate in a controversial paper in the *Proceedings of the National Academy of Sciences*.[1] His goal was to put forth a companion to the "Business-as-Usual" scenario, which assumes no special efforts at controlling the greenhouse effect of human gas emissions. He intended to propose a "plausible set of actions" that would have a modest rather than a large effect on climate.



Hansen proposed that it is possible to limit the extra climate forcing to 1 Watt per square meter (1 W/m^2) beyond what now exists, due to additional CO_2. He also asserts that it is possible to have no additional climate forcing from all other gases and pollutants, including greenhouse gases, soot, and aerosols. The effect is shown as "Alternativve Scenario" in the exhibit below. It is like illuminating a one-watt Christmas tree light bulb above every square meter of the Earth's surface.

In contrast, the "Business-as-Usual" scenario, below would allow 3 W/m^2 of climate forcing beyond what now exists, of which two units are due to the effects of additional CO_2. Hansen's alternative would have only one-third the direct effect on climate as the business-as-usual scenario, which would be similar to hanging three light bulbs over every square meter of Earth. Hansen prefers quick action on non-CO_2 gases and slow, deliberate action to reduce CO_2.

Hansen *continues on page 9*

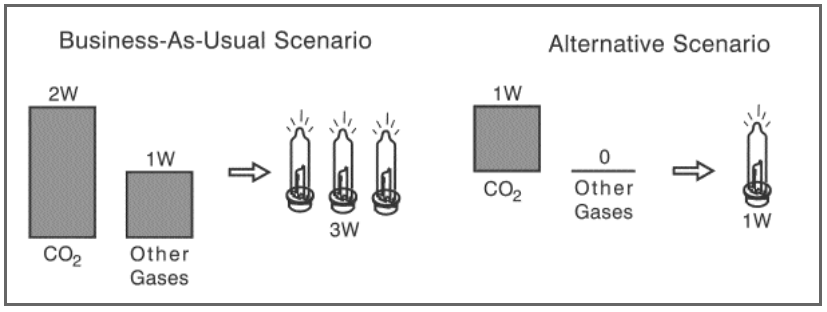
DONALD J. WUEBBLES: Hansens's scenario is too simple to be a strategy.

Donald J. Wuebbles, a professor of atmospheric sciences at the University of Illinois, criticized the paper by James Hansen's scenario (at left) because it overlooks other careful studies of emissions and strategies in the future. Thus, it is inadequate to serve as a strategy. He also underlines that Hansen's paper has been widely misunderstood by the press, as Hansen himself took pains to document. Wuebbles critique appears in this years's *Climatic Change*.[3]

Noting that Hansen "seems to suggest that one can balance off the warming effects of CO_2 and the cooling effects of aerosols", Wuebbles added that the net effect of aerosols can either be a warming or a cooling effect in different regions, because of the extremely inhomogeneous way that the particles are distributed. Also, there has been little change in the radiative effects of aerosols over the last 30 years, while the effects of CO_2 have been increasing; "clearly there is no balancing of the radiative effect of CO_2 and aerosols."

According to Wuebbles, Hansen did not compare his "optimistic" scenario with the many published scenarios for managing greenhouse gas effects. Further, he says that Hansen's proposed increase of $1Wm^2$ in "climate forcing" is smaller than any proposed in IPCC scenarios and that a zero increase in methane emissions is achievable but difficult.

Climate Forcing from 2000 to 2050 in the "Business-As-Usual" and "Alternative" Scenarios, from Hansen (2000), see footnote 2



Hansen, *continued from page 8*

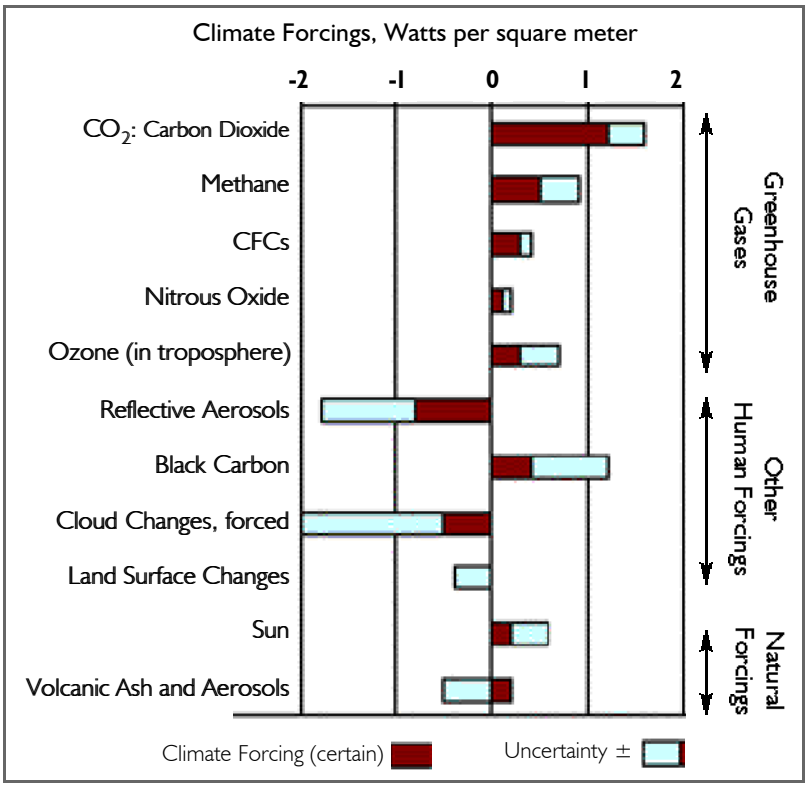
CO_2 gases and slow, deliberate action to reduce CO_2. Referring to non--CO_2 greenhouse gases, he says, "These gases are probably the main cause of observed global warming, with methane causing the largest net climate forcing [after CO_2]."

The exhibit below, adapted from Hansen's papers, compares the total climate forcing of all greenhouse gases, dust, aerosols, human effects on land surfaces and cloud cover, and natural changes in the strength of the sun and amount of volcanic ash. While carbon dioxide exerts the largest forcing, notice that the other four types of greenhouse gases together cause a forcing that is equal to or greater than CO_2.

While black soot and methane are larger problems than the Intergovernmental Panel on Climate Change (IPCC) has indicated, he says their emissions are easily controlled. Hansen asserts that the warming effect of black carbon soot is 1 W/m^2, ten times greater than IPCC calculated. On the exhibit below, notice that black carbon has a climatic warming effect roughly equal to that of methane, and these two together have an effect as large as CO_2. Quick action to reduce soot pollution from black carbon should lead to quick results. Of the other air pollutants, ozone has a warming effect on climate, while aerosol particles have a cooling effect – but the Kyoto protocol addresses neither. Methane, a large part of the problem, forces a climate change one-half as large as that caused by CO_2 but has received little attention.

Hansen would like to see immediate action to reduce air pollutants, both to reduce human impacts on climate and to improve human health. Developing nations, particularly, could enlist support for dealing with climate change and air pollution together.

Hansen's strategy is published on the Web by *Natural Science* (footnote 2), while his rebuttal to Wuebbles' arguments appears in *Climatic Change* (footnote 4).



Estimated Climate Forcings from 1850 to 2000, Hansen (2000), see footnote 1.

Glossary

Climate Forcing is a phrase often used in place of "radiative forcing." Both phrases refer to the change of net energy entering the Earth and atmosphere, due to some imposed change, such as an increased amount of a greenhouse gas or reduced amounts of dust. However, the temperatures of the Earth and atmosphere are considered to be fixed during this measurement. We consider only the change in radiation energy, including visible light, infrared, and microwave radiation. "Net" energy means the incoming energy minus the outgoing energy. We measure the change in net energy at jet-stream level and above the lowest, well-mixed layer of the atmosphere, which is called the troposphere.

1. *Proceedings of the National Academy of Sciences*, vol 97, 9875–9889, Aug. 2000.
2. *Natural Science* on the Web at *http://naturalscience.com/ns_let25.html*.
3. *Climatic Change*, vol. 52, p. 431–434.
4. Hansen's rebuttal to Wuebbles' arguments appears in *Climatic Change*, v. 52, 435–440, 2002.

New US Statement on Its Role in Climate Change

White House agrees temperature change "likely due mostly to human activity"

Although the United States refused to sign the Kyoto Protocol, it had earlier signed the 1992 U.N. Framework Convention on Climate Change. Each member nation of the Framework Convention is required to report its greenhouse gas emissions and trends over time. The White House just submitted the *Third US National Communication on Climate Change* covering the 1990s; it is available through the Environmental Protection Agency at *www.epa.gov/globalwarming/publications/car/*.

Climate Change Science

The Administration let stand the conclusion of the National Research Council in its 2001 report, *Climate Change Science*. As we reported in our March issue, the Council said,

"Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing global mean surface air temperature and subsurface ocean temperature to rise. *While the changes observed* over the last several decades *are likely due mostly to human activities,* we cannot rule out that some significant part is also a reflection of natural variability." *(Emphasis ours)*

Trends in Emissions

The report covered the period 1990–1999, but we have updated the figures to 2000 with data from EPA. The US economy emitted **14%** more Greenhouse gases at the end of the decade than at the start, an increase of 1.3% per year. Carbon dioxide accounted for 83% of these emissions and grew at **17%** per decade. The overwhelming source of CO2 (96% of it) was the combustion of fossil fuels.

Other greenhouse gases are compared with carbon dioxide by converting their emissions from tons into tons of "equivalent CO_2". Each gas has a unique factor (a "global warming potential") indicating how much one kilogram of gas can affect the heat balance of Earth. Methane has a factor 21 times larger than CO_2 because methane is so much more active as a greenhouse gas.

As measured in equivalent CO_2, methane now contributes to **9%** of the greenhouse gas emissions, but these emissions have fallen by 6% over the decade. The largest source of methane is landfill gases. Nitrous oxide now amounts to **6%** of the emissions and its contribution has increased 10% over the ten years. Most of the gas results from the application of nitrogen fertilizers to soils.

An increase of forest area and other changes in land use have removed some carbon dioxide from the atmosphere. This report treats these so-called "carbon sinks" as a **credit** amounting to **13%** of the gross total emissions. Because of the credit, the report speaks of gross emissions and net emissions of greenhouse gases.

Policy Actions

Policies center around a continuation of existing programs plus new, primarily **voluntary** efforts:

- Standards for efficiency of residential appliances. Four new standards (for central air conditioners, water heaters, fluorescent lights, and washing machines) are now pending
- Continuing the Energy STAR program for homes and office buildings
- Federal/Industry partnerships have reduced the emissions of methane, the number-two greenhouse gas. These will hold down the emissions below 1990 levels through the year 2010
- Other programs focus on reducing the emissions of those greenhouse gases with the highest "global warming potential" (these are *not* CO_2)
- More partnerships with State and local governments. To date, there are 41 state inventories of greenhouse gases, 27 state action plans, and 110 cities and counties with either one or the other.

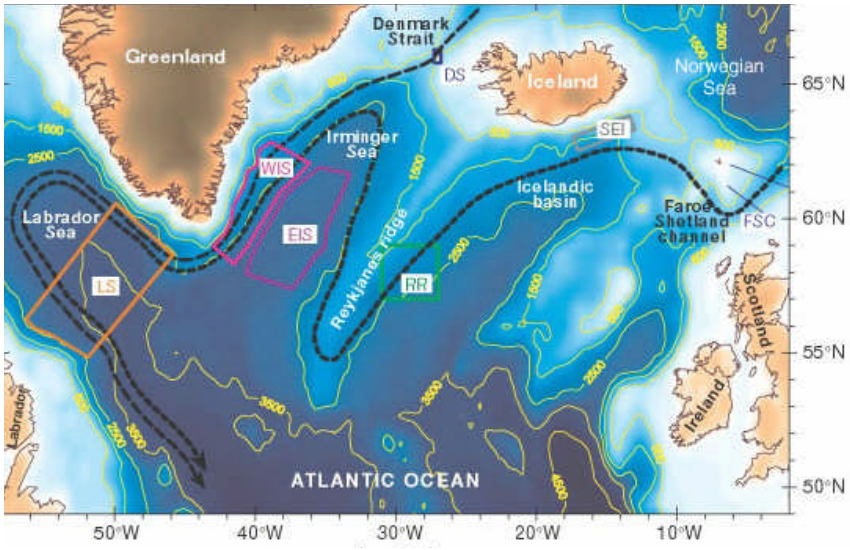
CLIMATE SCIENCE CLASSROOM

FAIR WARNING?

How Arctic Climate Change Has Rapidly Freshened Deep Atlantic Waters

In the last Climate Science Forum, we explained how the entire circulation of Atlantic Ocean water was forced by cold air over Arctic waters. Large amounts of fresh water in the Arctic could inhibit this process that mixes the shallow water with the deep Atlantic water. Since our last issue, Bob Dickson and others have announced that the deep waters of the North Atlantic Ocean have become notably more fresh (less salty) as a result of observed freshening of surface water in the Arctic Ocean ("Rapid freshening of the deep North Atlantic Ocean over the past four decades," *Nature*).[2]

To reach the Atlantic, cold subsurface water in the Arctic regions must flow over submerged "ledges" 800 meters deep, before it sinks into the deep Atlantic. One ledge is the Faroe-Shetland Channel between Scotland and Iceland (see map), and the other ledge is in the Denmark Strait between Iceland and Greenland. The path that the cold water follows is shown by dark dashed lines. In the last 40 years, observations show this overflow water has become noticeably less salty.



Topography of the bottom of the North Atlantic ocean and the cold currents flowing over ledges between Greenland and Scotland, and their subsequent pathways to and through the Labrador Sea (heavy dashed lines).
Reprinted by permission from *Nature*, 25 April 2002, © 2002 Macmillan Publishers Ltd.

The Labrador Sea – comprising Atlantic waters east of Labrador and south of Greenland – plays a pivotal role in the Earth's climate. Through its deep layers passes all water that circulates in the deep Atlantic; through its surface layers passes the main flow of fresh water from the Arctic to the Atlantic. The authors write that "over the last 3 to 4 decades, the entire water column of the Labrador Sea has undergone radical change."

The explanation: Water upstream has become much more fresh in the top one kilometer of the Norwegian Sea. The far northern waters must pass through two channels and over the two ledges mentioned above. Dickson assembled observations from many locations along this "conveyor belt" of sinking water that show the water has steadily freshened at roughly the same rate over 25 years. They claim to have found a way that Arctic climate change has affected the deep abyssal water of the Atlantic Ocean. The stage is set for a possible slowdown of the entire thermohaline circulation of this Ocean (discussed in our last issue).

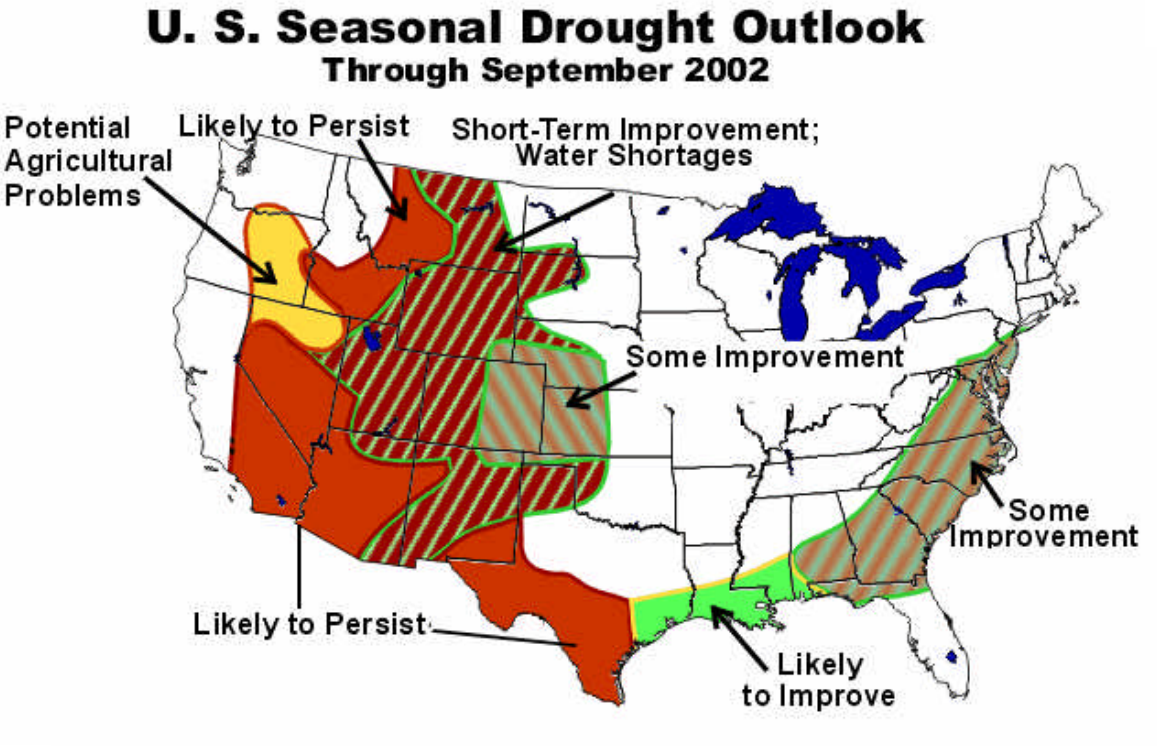
Although it's clear that the water of the far northern Atlantic is now less salty than it was 40 years ago, a number of factors could have caused the change, as Dickson points out. For example, the Arctic Ocean is exporting more ice to the Atlantic; precipitation has increased over northern Europe; and the East Icelandic current is bringing in more fresh water – all of which are tied to the North Atlantic Oscillation, an atmospheric see-saw that has amplified in these same years. Whether this is a natural or a human-induced change remains to be seen.

[2] *"Rapid freshening of the deep North Atlantic Ocean over the past four decades,"* Nature *v. 416, 832–837, 25 April 2002. Online at www.nature.com/cgi-taf/DynaPage.taf?file= /nature/journal/v416/n6883/abs/416832a_fs.html.*

El Niño Effects on US to Begin in Autumn

The El Niño that began to develop last January is developing slowly. According to the US Climate Prediction Center, the effects will be felt this autumn and winter in the same states that bore the brunt of El Niño in 1998. The Northern Plains and Canadian Prairies are expected to have a very warm winter and to suffer continued drought; Montana, especially, will have a drought. Meanwhile, the South, from Texas to the Carolinas, is predicted to have a wet, cool winter and spring. There is one promising note: California and Arizona tend to have wet winters during strong El Niños; but because this El Niño is weak, the Climate Prediction Center is predicting a normal winter in these states.

See predictions at www.cpc.ncep.noaa.gov/products/predictions.



This map shows likely seasonal changes through September 2002. Only major trends are predicted, as short-term events, such as individual storms, cannot be accurately forecast more than a few days in advance. Source: US Climate Prediction Center

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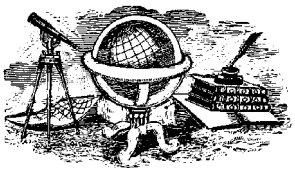
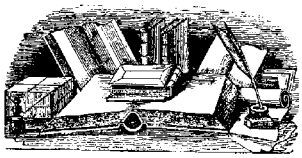


Reliable News and Information on Climate Change



Vol. 1 No. 1 March 2002

http://climate-science.org

FROM THE EDITOR'S DESK

Our Purpose

Welcome to ***Climate Science Forum***, a newsletter that will provide credible and easily understood information in a matter of great world significance.

The newsletter assumes no editorial position in any matter of science or policy. Rather, our intention is to report the results of investigations in climate science, and their interpretations, that may be used to shape decisions on climate-related policies and strategies. Many prominent investigators have reached contradictory conclusions on whether and how the climate of Earth has changed, is changing or will change. This is frustrating to people making decisions that could affect the future of the planet. It also obscures the possible pathways that societies can take to deal with worldwide changes.

We are atmospheric scientists acting on a responsibility to transmit evidence of a possible alteration of the Earth itself, and the effects that may follow. Through this printed newsletter and its Web page equivalent, we will provide you with concise evidence of climate change and various interpretations of how climate has changed in the past, whether it is changing now, and what may be expected in the future. We shall not filter or censor the interpretations; rather we strive to balance hypotheses and interpretations as we present a range of evidence. This is a young and active science, very much in transition!

Each issue will include:

– Results of investigations in climate science, with citations and active links to the original articles. This issue focuses on the theme of abrupt climate transitions, past and present.

– Reports from conferences and meetings. This issue summarizes highlights of the American Meteorological Society annual meeting in Orlando, Florida.

(Continued on Page Two)

National Research Council Asserts Past Climate Change Speed 'Startling'

A December 10 report concludes that past changes of climate have occurred remarkably abruptly, and proposes a research agenda for determining the mechanisms of sudden change and their consequences. The National Research Council (NRC) report stated that "major and widespread climate changes have occurred with startling speed." As an example, one half of the temperature rise of the North Atlantic Ocean since the last Ice Age occurred over approximately 10 years.

"Abrupt climate changes were...common when the climate system was being forced to change most rapidly." Thus, the NRC suggests, if human alteration of the climate is taking place, the possibility of large and unwelcome climatic events is increased.

The report concludes, moreover, that "future abrupt changes cannot be predicted with confidence, and climate surprises are to be expected," because our knowledge of the nature of such abrupt changes is so limited.

In this issue of *Climate Science Forum*, a British climatologist has reviewed a wide range of work on this very issue of abrupt climate change (page 5). And our Climate Science Classroom explains the link between loss of ice in the Arctic, the circulation of deep water in the Atlantic, and sudden climate changes in Europe (page 7).

[The 205 page NRC report is available on line through the National Academy of Sciences: *http://www.nap.edu/catalog/10136.html?onpi_topnews_121101*].

QUOTE WITHOUT COMMENT

"The Kyoto-Bonn accord will make little progress in slowing global warming...if the Kyoto-Bonn Accord is implemented as designed, there is trouble ahead." — William D. Nordhaus, *Professor of Economics, Yale University*

(Our Purpose, from Page One)

The Conference on Global Change and Climate Variations was an important part of that meeting.

– A summary of policy initiatives under review in Congress, the executive branch, in the states, and in international bodies.

– A Climate Science Classroom. While the issues in climate science may be complex and involve many disciplines, it is vitally important that decision makers comprehend the basic points of agreement or the lack of agreement in the science. As an example, we explain in this issue how some believe that a warmer Arctic Ocean may stop the flow of warm water of the Gulf Stream to Europe.

– A Climate Forum, in which we invite two or more leading scientists to write contrasting viewpoints on a current issue in climate science

– Letters and commentary on information presented earlier.

Please browse this first issue, covering the period November 2001—February 2002. Let us know what information you need to see for your decision-making, and what you find that is, or is not, valuable.

We welcome your letters by mail or e-mail at *editor@climate-science.org* .

Michael A Fortune

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Submissions will be welcomed by ***Climate Science Forum***, at our web site:
http://climate-science.org
The Internet version provides links to all studies and articles cited in this newsletter.

OF SPECIAL INTEREST

from the American Meteorological Society Annual Meeting, Orlando, FL, Jan. 2002

First Signs of El Niño in 2002: NOAA's Climate Prediction Center officially announced that warming is being observed over the Tropical Pacific, which could lead to an El Niño by early Spring. The U.S. is not expected to see its potential impacts until late summer, through the fall and into next winter. Read the story at *www.noaanews.noaa. gov/stories/s849.htm.*

(Continued on Page 3)

Does the Earth have an "Adaptive Iris"?

The American Meteorological Society (AMS) published a paper in which it was argued that the Atmosphere has a mechanism that resists any warming that may occur at the surface of the tropical Oceans. [See R.S. Lindzen, M.D. Chou, and A.Y. Hou, 2001: "Does the Earth have an adaptive Infrared Iris?", *Bulletin of the AMS*, v. 82, no.3, 417-433; online at *http://ams.allenpress.com/amsonline*]. It was dubbed the "Iris effect" in analogy with the iris of an eye, which opens to admit more light when illumination is dim, and closes to restrict light when illumination is strong. For the Earth, the "iris" is the high level "anvil" clouds of thunderstorms and the surrounding regions moistened by the ice from anvil clouds. These moist regions diminish the exodus of infrared radiation from the warm surface of Earth out to space; conversely, clear and dry skies allow the surface to cool rapidly.

For the Iris effect to occur, the moist area associated with anvil clouds must decrease in area when the sea surface becomes warmer. Lindzen and colleagues presented some evidence that higher amounts of cloudiness were associated with lower sea surface temperatures in their study area in the Pacific Ocean.

D.L. Hartmann and M.L. Michelsen (2002) have just published a critique ["No evidence for Iris", *Bulletin of the AMS*, v. 83, no. 2, 249-254], in which they disagree that the evidence provided by Lindzen really supports an Iris effect. They assert that the observed changes in cloudiness were far removed from the deep tropical "hot towers" of thunderstorms, and that there was no cause-and-effect connection.

Climate Science Forum will visit the evidence for and against the Iris effect in a forthcoming issue.

(OF SPECIAL INTEREST, Continued from page 2)

NOAA confirmed its assessment that El Niño conditions will appear within 3 months in a press release on Feb. 5. They also predict a warming of the sea surface off the coasts of Peru and Ecuador over the next few weeks.

Uncertainty in Temperature Projections: C.E. Forest and colleagues took a closer look at the probabilities of various outcomes in climate projections. They were able to reduce the range of uncertainty in one area – the cooling effect of aerosols – but broadened the range of uncertainty in "climate sensitivity", to a range of 1.4° to 7.7°C, for a doubling of atmospheric carbon dioxide. The upper limit in the IPCC 2001 Report is 4.5°C. Climate sensitivity is the expected temperature change on Earth for a given increase in a greenhouse gas. *Science*, v. 295, 113, 4 Jan 2002, (on line at *www.Sciencemag.org)*

100 Year floods more frequent in 20th century: In a recent report in *Nature*, v. 415, 514 (31 Jan 2002) (on line at *www.nature.com*), Princeton researchers found that great floods have increased in frequency in the last century. The record, which relies on measurements of river flow, is consistent with a positive trend they identified in simulations with a climate model.

Below: American Meteorogical Society (AMS) Policy Forum: What can the AMS do to better foster scientific services for society's needs? Panel (Left to right): Bryan Hannegan (Senate Committee on Energy and Natural Rerources), Jerry Skees (Professor of Agricultural Economics, University of Kentucky), Michael Crow (Professor of Science and Technology Policy, Columbia University), Ann Kellan (Science Correspondent, CNN)

Climate has Changed Rapidly Even in Warm Regimes

The old belief that climate is stable and relatively unchanging in the absence of human forcing is being evermore discarded. A new paradigm is emerging: that climates have shifted abruptly many times, and that the present climate may be expected to shift in any number of ways. "Surprises" are to be expected.

Most of the support for this new thinking comes from evidence of changes during the ice ages, or of sudden changes at the onset or termination of the ice ages (so-called "glacial events").

In this vein, J. Overpeck and R. Webb (2000) documented ways that the recent climate since the last ice age has shifted abruptly. Rather than cite evidence from the ice ages, they looked at recent changes during the "warm regime" of the last 10,000 years — which may be more relevant to today's situation.

The Pacific and El Niño: From studies of growth bands in coral, they note that the tropical Pacific climate was very different 7000 to 5000 years ago. For one thing, the El Niño phenomenon may have been totally absent. More recently, the variability of Pacific climate suddenly changed in the mid-1970's, so that, for example, El Niño variations have become more frequent since then.

Monsoons in Asia and Africa: Wet regimes have shifted to dry in a matter of a couple of years. Such changes in moisture have occurred multiple times. The demise of the Indus Valley civilization has been attributed to such a change.

North American drought: Persistent droughts left evidence of sand dunes and active sheets of sand in the High Plains of the U.S. The record suggests that the current climate is relatively wet and free of severe drought. Before 1200, droughts were severe and frequent.

Their article, "Nonglacial Rapid Climate Events: Past and Future," is found in *Proceedings of the National Academy of Sciences* (Feb 15, 2000), v. 97, no. 4, p. 1335; on line at:
www.pnas.org/cgi/content/full/97/4/1335 .

Book Shelf

The Skeptical Environmentalist

by Bjorn Lomborg

Excerpts from *The Skeptical Environmentalist*: *Measuring the Real State of the World* (Cambridge University Press, 2001): Chapter 24, Global Warming. Bjorn Lomborg is professor of Statistics, University of Aarhus, Denmark. Reprinted with permission.

"It is true that temperature has increased, although mainly at night, in the winter, and in cold places. Such reduction in cold extremes without increasing heat extremes has in many respects been beneficial, but if the warming continues, eventually heat extremes will also take their toll.

"To sum up, **the IPCC business-as-usual scenario …leads to overestimates in the speed of global warming.** We will still use predominantly fossil fuel at the end of the century. Yet such a scenario is unlikely … Rather more plausible assumptions point to almost complete fossil fuel substitution over the 21st century, drastically limiting global carbon emissions, and restricting temperature increases . . .

"We will undoubtedly still use fossil fuels for many years to come. In order to handle global warming, we need not necessarily phase out fossil fuels rapidly. Instead we need to make sure that . . . sun, wind, and fusion will become competitive energy sources before or by mid-century. This will cost much less and give rise to only a smaller temperature increase.

"However, global warming will have serious costs – the total cost is about $5 trillion. The consequences will hit the developing countries hardest, whereas the industrialized countries may actually benefit from a warming lower than 2° – 3°C. Economic analyses clearly show that it will be far more expensive to cut CO_2 emissions radically than to pay the costs of adaptation to increased temperatures. . . A key conclusion of all economic modelers was: 'Current assessments determine that **the optimal policy calls for a relatively modest level of control of CO_2.**' "

CRITIQUE

by Stephen H. Schneider, editor of *Climatic Change* and Professor of Biological Science, Stanford University (Reprinted from "Global Warming: Neglecting the Complexities," *Scientific American,* January 2002 [*www.sciamarchive.org*]. Copyright © 2001 Scientific American Inc. All rights reserved).

On cost-benefit calculations: "Lomborg cites only one value for climate damages - $5 trillion - even though the same papers he refers to for costs of climate policy generally acknowledge that climate damages can vary from benefits up to catastrophic losses.

"It is precisely because the responsible scientific community cannot rule out such catastrophic outcomes at a high level of confidence that climate mitigation strategies are seriously proposed. And to give one number - rather than a broad range - for climate damages defies explanation, especially when he does give a range for climate policy costs.

On emission scenarios: "Lomborg asserts that over the next several decades new, improved solar machines and other renewable technologies will crowd fossil fuels off the market. This will be done so efficiently that the IPCC scenarios vastly overestimate the chance for major increases in carbon dioxide. How I wish this would turn out to be true! But wishes aren't analysis. One study is cited; ignored is the huge body of economics work he later accepts to estimate a range of costs if we were to implement emissions controls. In fact, most of these economists strongly believe high emissions are quite likely: they usually project carbon dioxide doubling to tripling (or more) as 'optimal' economic policy. I have attacked this literature for failing to point out that climate policies that raise the price of conventional fuels spur investments in alternative energy systems. But such incentives need policies first, and Lomborg opposes those very policies."

To conclude: "So what then is 'the real state of the world'? Clearly, it isn't knowable in traditional statistical terms, even though subjective estimates can be responsibly offered. The ranges presented by the IPCC in its peer-reviewed reports give the best snapshot of the real state of climate change: *we could be lucky and see a mild effect or unlucky and get the catastrophic outcomes*. The IPCC frames the issue as a risk management decision about hedging. It is not the everything-will-turn-out-fine affair that Lomborg would have us believe."

Abrupt Climate Transitions Regarded as Frequent, Unpredictable

Major Review of Past Climates Challenges Assumption that Climate System is Stable

The Royal Meteorological Society recently published a review of work on "Sudden and Abrupt Climatic Transitions and Fluctuations" [J.G. Lockwood, 2001: *International Journal of Climatology*, v. 21, p. 1153-1179; on line at *www.royal-metsoc.org.uk/ijc01.html*]. Lockwood's review is worth highlighting in these pages for its breadth of vision.

His basic tenet is that climate is an unstable system which is not, and never was, at equilibrium. Using "systems theory", he explores the behavior of unstable systems as they evolve. At a "bifurcation point" the system may "choose" among various regimes, and the fluctuations become large. In other words, it shifts away from its previous climate state to a new state in which properties take on new average values. Even the range of values, and the variability, can change.

This is more than a mere academic exercise. Lockwood has assembled a wide range of evidence from the historical period, the Holocene (the warm era from the last Ice Age up to the present), and the last Ice Age itself, to show that climate has shifted abruptly in numerous ways, a number of times.

Understanding is growing that the climate is not stable, but switches from one state to another in a matter of years or decades. Climate changes abruptly on every time scale. On seasonal (very short) scales, the whole circulation of the Asian monsoon begins on a matter of a day or days. On century scales, sudden advances of glaciers occurred every 200 to 400 years. On scales of a millenium, both the onset and the termination of the so-called "Little Ice Age" were sudden, judging from an analysis of ice cores –- the shift was as sudden as the ice core can possibly show.

The last glacial period ("Ice Age") lasted from 115,000 to 10,000 years ago, but it included at least 24 "sudden warmings" in an otherwise cold climate, according to several investigators of the Greenland ice core. The sudden warmings occurred over "a few decades or less." Extreme and short-lived cold episodes, or "Heinrich events," also recurred in the glacial period. Lockwood attributes these events to complete shutdowns of the North Atlantic deep water circulation. See the Climate Science Classroom (page 7) for an explanation of the thermohaline circulation.

In the 20th century, the Arctic region warmed 3 times since 1970, with the strongest warming in the 1990's. The spatial pattern of temperature of Arctic Ocean waters also underwent a change. In the Tropics, a shift in the behavior of El Niño occurred in 1976. Before then, the frequency of El Niños was like it was 124,000 years ago; since 1976, the frequency has been "distinctly different."

Lockwood is saying that climatic "equilibrium" is difficult to find anywhere, even in the tropics, for any time period. We have new evidence of sudden shifts and oscillations in periods previously regarded as stable. Computer simulations of a world with CO_2 levels from 2 to 4 times the present level suggest that at some point, the thermohaline circulation shuts down, as it has done in the distant past.

"Climate changes in the past have not always taken place in a slow, smooth manner. It is most unlikely that future changes associated with present . . . warming will be smooth. We could, therefore, be in for some climatological surprises!"

Below: French, Russian, and American scientists of the Greenland Ice Sheet Project-2 (GISP-2) hold ice cores containing a "frozen record" of global changes over the past 110,000 years. The Project is managed by the University of New Hampshire and funded by the National Science Foundation. (Photo: Todd Sowers, Columbia University, and the NOAA Paleoclimatology program.)

Bush Administration Outlines Climate Policy

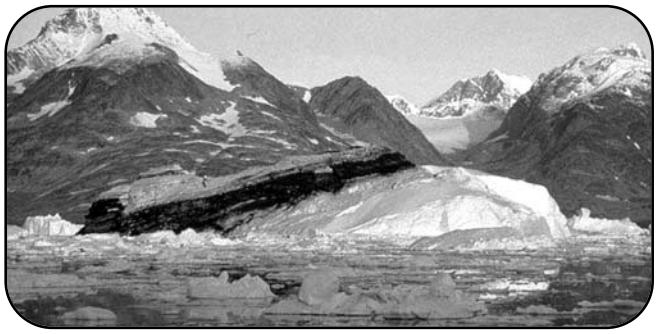
The Bush administration outlined its first policy package for dealing with greenhouse gasses and future climate change, in a speech the President delivered to NOAA on Feb. 14. The policies emphasize voluntary agreements with industries, tax incentives, more resources for renewable energy sources, and a new measure of greenhouse gas impact. The climate policy is summarized in the box at the right.

At the same time, the President delivered a policy initiative for limiting emissions of three traditional air pollutants emitted by power plants: sulfur dioxide (SO_2), nitrogen oxides (NOx), and mercury.

The two policies were quite different. Mandatory emission limits are proposed for the three traditional pollutants by the years 2010 and 2018, with at least a two-thirds reduction from this year's emissions required by 2018. The proposal only addresses power plant emissions.

Under the climate policy, the Administration does not mandate fixed ceilings on greenhouse gas emissions; rather it proposes limits which are tied to economic growth. In order to measure progress, the President proposed a new measure: *greenhouse gas* (GHG) *intensity.* The goal is to reduce this GHG intensity by 18% from 2002 to 2012.

Whether emissions are actually reduced will depend on the level of economic activity. With a fixed goal of greenhouse gas (GHG) intensity, allowable emissions of CO_2 may be greater when the GDP is greater. In order to attain a targeted rate of emissions (which is not what the Administration proposes; but the Kyoto protocol does), the GHG intensity goal would have to be set lower when the GDP is higher, when the economy is strong. The intensity goal could be higher (a more relaxed, easier policy) when the economy is weak.



Highlights of Climate Policy Initiative

Both policies are described on line at:
www.whitehouse.gov/infocus/environment/

Goal for Greenhouse Gases: Sets a goal for Greenouse Gas emissions, relative to economic output. Proposes a new measure of compliance : the greenhouse gas intensity, defined as the ratio of emissions of equivalent greenhouse gas in tons, to the gross domestic product (GDP) in dollars.

The goal is *an 18% reduction over 10 years* from 2002 greenhouse gas intensity levels.

Fuel Economy: Directs Dept.of Transportation (DOT) to reform the Corporate Average Fuel Efficiency (CAFÉ) program, and to propose new standards; seeks $3 billion in tax credits over 11 years for purchase of new hybrid or fuel cell vehicles. “Freedom car” initiative, a program to promote hydrogen as the primary fuel for cars and trucks.

Tax Incentives for “Clean Energy” Sources:

Proposed tax credits of $555 million in FY 2003, and $4.6 billion over 5 years:

◆ to spur investments in renewable energy (solar, wind, and biomass), hybrid and fuel cell vehicles,co-generation of space heat and electricity, ethanol fuel, and landfill gas recovery.

◆ tax credit for residential use of solar power.

◆ tax credits to individuals of $4000 for a new hybrid vehicle and $8000 for a fuel-cell vehicle.

“Methane First” Strategy for lowering emissions of greenhouse gasses, because methane is more active than CO_2 in the atmosphere

Carbon Storage: Requests $1 billion more than the $3 billion baseline for the land conservation program of the Dept. of Agriulture

Science and Engineering Funding: Seeks a $700 million increase (an 18% increase) in climate science and technology funding (a total of $4.5 billion).

◆ a new science effort, the "Climate Change Research Initiative" will receive $40 Million, to address major gaps in understanding of:

The natural carbon cycle
The role of black soot in climate change
The role of aerosols in climate change

◆ a new engineering effort will receive $40 million for development of the most promising "breakthrough" technologies in renewable energy.

(Left) Melting glacier in Greenland may affect the thermohaline circulation of the Atlantic

Climate Science Classroom

Warm Gulf Stream and Arctic Sea Ice: *what's the connection ?* The Thermohaline Circulation

Earth science is constantly finding surprising connections between distant parts of the globe. A good example is the mutual influence of warm tropical ocean currents, such as the Gulf Stream flowing by the East coast, and the frozen Arctic Ocean. Their influence on each other may have played a role in causing the abrupt climate changes that have plagued Europe and North America.

The best example of a major change is the advance and retreat of the massive ice sheets that covered Canada and part of the United States, as well as Europe and Russia, five separate times during the era when humans lived on Earth. The Little Ice Age from 1350 to 1850 is another example of a cool period that began and ended rather quickly. We have included several articles on the theme of abrupt climate change in this issue.

So what do the Gulf Stream and the Arctic ice sheet have to do with climate change? Let's cover some basics:

The tropics warm up a great deal. The excess heat in the tropics naturally flows into colder regions around the Poles. The oceans transport about a half of this energy, while the Atmosphere carries the rest. If we look at a globe, we see that the Indian Ocean has no connection with the Arctic, and the Pacific Ocean connects with the Arctic only at the narrow Bering Strait. This Strait is quite shallow; it is believed that Asian peoples walked across it to Alaska when the sea level was lower, and begat Native American peoples. Only insignificant amounts of water get through the Bering Strait. That leaves the Atlantic Ocean as the only ocean with a broad, deep channel to the Arctic.

Warm water is lighter than cold water, so it floats on top. Fresh water is lighter than salty water, so it also floats on top of brine. Very warm water in the tropics (85°F) spreads northward to the polar latitudes. In the Atlantic, this warm current is the Gulf Stream, which provides northern Europe with a milder climate than that of Canada. While releasing its warmth to the atmosphere, the waters of the North Atlantic are chilled by frigid air in the region between Norway, Greenland, Iceland, and the Arctic ice pack. The chilled water sinks and fills the deep basin of the Atlantic, flowing over the bottom all the way to the tropics and even farther, into the South Atlantic. "And so the cycle is complete." This cycle is called the thermohaline circulation.

If the chilled water is salty, it will sink because salty water becomes heavier as it cools to the freezing point. BUT fresh water is different: as it cools to 4°C (39°F), it becomes heavier; but when it cools even more, it starts to become lighter – until it freezes into ice, when it becomes lighter still. This is why ice floats. Fresh water that is colder than 4° C floats on top of water right at 4° C; and the two layers do not mix easily.

When ice forms from fresh water, the ice layer cuts off almost all the heat flow from the ocean to the air. Salty water, though, would rather sink than freeze. So where the cold ocean is salty, the sinking of cold water drives the thermohaline circulation; but where the cold ocean is not-so-salty, ice forms, and little or no circulation ensues in the ocean.

Four large rivers drain from the Russian mainland into the Arctic Ocean, and the Mackenzie River drains from Canada. All this fresh water spreads over the top of the Arctic sea water, and readily freezes into the Arctic ice pack. A large fraction of the ice melts every summer. It does not require much atmospheric warming to melt the ice pack and reduce its area significantly.

A large amount of melt water, or fresh water from rivers, is thought to inhibit the thermohaline circulation in the Oceans, because it tends to remain on the surface of the Arctic Ocean instead of sinking, as salty water does.

There is evidence that a complete shutdown of the circulation has happened in the past. Model simulations give circumstantial evidence that it might be possible in the future, with some of the larger projected temperature increases. The National Research Council concluded that a complete shutdown of the thermohaline circulation was "unlikely" in the next 100 years, but could not rule out the possibility.

Year 2001 Climate in review: Warm

The National Climate Data Center (NCDC), in Asheville NC, reported that last year was the second warmest ever observed. The only year warmer than 2001 was 1998, when a strong El Niño boosted Pacific sea surface temperatures.

The temperature trend itself has accelerated. Over the 20th century, the temperature of Earth was observed to increase at 0.6°C per century, but the rate has been 2.0°C per century since 1976. There were two periods of rapid rise, the first in 1910 – 1945, and the second over the last 25 years.

There is still a large difference between the rate of warming on the surface of the Earth and in the lowest layer of the atmosphere (from 0 to 8 km). This difference has been the source of controversy. The lower atmospheric has warmed only +0.3°C per century over the last 20 years, a rate that is 6 times slower than the warming rate at the surface.

In May and August last year, more than one-fourth of the nation was "very warm", while in November two-thirds of the US was "very warm." The phrase "very warm" is used to refer to the warmest 10% of all temperatures observed in the climatic record.

The portion of the country experiencing severe to extreme long-term drought increased to 20% of the nation by October, while the portion experiencing a severe to extreme wet spell was only 4%.

The drought last year really began in 1999 in the Pacific Northwest and the Atlantic coast. Washington, Oregon, and Idaho declared drought emergencies, and record numbers of wildfires were fought in those States. In the Northeast, nine months of the year were dry. Maine had the driest year on record; the Appalachians had the worst wildfire season in 10 years. Full details can be viewed on their web site: *http://lwf.ncdc.noaa.gov/oa/climate/research/2001/perspectives.html*

The NCDC also reported that the three-month season from November 2001 through January 2002 was the warmest such period ever observed in the United States, in records going back to 1895. The most pronounced departure from previous conditions was observed from Minnesota to New England. Details can be viewed at:

http://lwf.ncdc.noaa.gov/oa/climate/research/2002/jan/national.html#3month .

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