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Chairman Boucher, Ranking Member Hastert and committee members, I am John Christy, professor of Atmospheric Science and Director of the Earth System Science Center at the University of Alabama in Huntsville. I am also Alabama's State Climatologist. I served as a Lead Author of the IPCC 2001 report and as a Contributing Author of the 2007 report.

SUMMARY

I will be reporting today on research that has appeared recently or that will be published shortly.

In the following testimony I will first describe how a carefully reconstructed time series of temperatures in the Central Valley of California indicate that changes since 1910 are more consistent with the impacts of land-use changes than the effects currently expected from the enhanced greenhouse theory. This and other research points to the need for a better temperature index than what is used now over land: *daytime* temperatures, rather than the *average daily* temperatures (used now), are more directly representative of the layer in the atmosphere affected by greenhouse gases. Secondly, I will describe results from two papers which examine our knowledge of atmospheric temperatures as they relate to the surface. The results point to a more modest atmospheric warming than anticipated from our current understanding of the enhanced greenhouse theory. Further, I argue for an independent program with significant funding to evaluate climate model simulations and projections with a healthy, objective eye.

I then include comments on my view of the unfortunate and incorrect attempt to demonize energy and its by-products. Without energy, life is brutal and short. The option of ethanol as a substitute for petroleum is addressed pointing out that though there are serious concerns, there is indeed a way to achieve a significant increase in production in the U.S. if that is the course the country deems necessary.

The meaning of my climate research for policy makers is two-fold. First, it is apparent that we have little skill at reproducing and predicting changes on regional scales of the size up to a region like conterminous U.S. Secondly, it is therefore far more difficult to predict the climate effect of a particular policy aimed at altering current emissions of greenhouse gases (by small amounts) and thus somehow "hold back global warming". In other words, we are unable with any confidence to predict or detect climate outcomes from Kyoto-like policy options, especially on the scale where our citizens live.

[Many of the statements below will use the terminology “consistent with” rather than “proof of”. This is the way science works in the field of climate because we basically cannot give “proof” of the type found in laboratory experimentation.]

CENTRAL CALIFORNIA TEMPERATURES

Last year I and 3 coauthors published a paper on temperature trends in Central California since 1910 (Christy et al. 2006). This was actually a follow-on of work I did as a teenager growing up in the San Joaquin Valley some 40 years ago when all I had was a pencil, graph paper, a slide rule and a fascination with climate. In this new work, sponsored by the National Science Foundation, we set out to collect all available information on surface temperatures in the Valley and nearby Sierra Nevada foothills and mountains and then develop a means to generate temperature trends with defined levels of confidence.

What drew my attention to this problem was the apparent rapid rise in nighttime temperatures in the Valley, temperatures that appeared to be much above those I remember recording as a teenager. We eventually produced a dataset with many observations never before utilized (we performed the manual digitization of many of those records.) In addition, we examined all of the ancillary information to document changes experienced by stations that could affect the overall trends. This involved reading and digitizing over 1600 pages of information about the stations and instruments. This has not been done before in California.

We then developed a method which takes into account the various events that affected each station, i.e. a move, a change of instruments, a change in procedure, etc. We discovered that on average, a station experienced about 6 events that could produce a change in the surface temperature. After adjusting for these changes, we combined the stations in the Valley to see what went on the last 100 years and did the same for the Sierras as a control experiment. Our work uses literally 10 times the amount of data of previous attempts at creating such temperature records.

We discovered that indeed the nighttime temperatures in the 18 Valley stations were warming rapidly, about 6°F in summer and fall, while the same daytime temperatures fell about 3°F. This is consistent with the effects of urbanization and the massive growth in irrigation in the Valley.

The real surprise was the composite temperature record of the 23 stations in the central Sierra foothills and mountains. Here, there was no change in temperature. Irrigation and urbanization have not affected the foothills and mountains to any large extent. Evidently, nothing else had influenced the Sierra temperatures either.

These results did not match the results given by climate models specifically downscaled for California where the Sierra’s were expected to have warmed more than the Valley over this period (e.g. Snyder et al. 2002).

Because these results were provocative, we performed four different means of determining the error characteristics of these trends and determined that nighttime warming in the Valley was indeed significant but that changes in the Sierras, either day or night, were not. Models suggest that the Sierra's are the place where clear impacts of greenhouse warming should be found, but the records we produced did not agree with that hypothesis. For policymakers in California this result is revealing. It suggests that to "do something" about warming in central California means removing agricultural and urban development rather than reducing greenhouse gas emissions.

[Note: as a follow-up to Christy (2002) on Alabama temperature trends, we examined the output from 10 climate models. All models showed a warming trend for 1900 to 2000 in the SE U.S. However, observations show a cooling trend (common throughout the SE U.S.) Additionally, Kunkel et al. 2006 perform a similar analysis for the central U.S. where temperatures have not experience a warming trend while model simulations of the same period do. Kunkel et al. identified this feature in the central U.S. as a "warming hole".]

The bottom line here is that models can have serious shortcomings when reproducing the type of regional changes that have occurred. This also implies that they would be ineffective at projecting future regional changes with confidence, especially as a test of the effectiveness for specific policies. In other words it will be almost impossible to say with high confidence that a specific policy will have a predictable or measurable impact on climate.

We are nearing the end of an extensive study of surface temperatures in East Africa, a place I had lived and monitored the weather in the mid-1970s. Our preliminary results are similar to those from Central California in that daytime temperatures are not changing at all, while nighttime temperatures appear to be rising. This particular area is of great interest because two of Africa's ice-capped mountains, Mt. Kilimanjaro and Mt. Kenya, reside in this region. There is clearly no doubt that these East African ice fields are shrinking. However if general warming is the reason, it should be due to the rise of daytime temperatures, because nighttime temperatures are well below freezing already. However, we find little if any warming in daytime temperatures, suggesting these ice fields are disappearing for reasons unrelated to a general warming … perhaps to decreasing cloudiness and precipitation.

A soon-to-be published paper focuses on surface temperature issues in general (Pielke et al. 2007). It strongly suggests that a new surface temperature index is needed for monitoring the climate system for global change. To date, the typical land surface temperature record is an *average* of the daytime high and the nighttime low. However, this research, our own research and that of others indicate that the nighttime low (more so than the daytime high) is affected by numerous local changes that are unrelated to the global climate concerns. These influences include increasing the surface roughness by adding orchards or buildings, changing natural cover to heat-soaking surfaces like asphalt, putting aerosols and dust in the lowest layer, heavy irrigation, etc.

The nighttime temperature over land occurs in a relatively shallow layer near the surface and thus is more strongly affected by changes in the properties at or near the surface as described above, be they land-use changes or atmospheric concentrations of aerosols. This implies that the more reasonable index to use for monitoring the global climate is the *daytime* maximum temperature which occurs at a time of day when a deeper layer of air is mixing down to the surface, mitigating the non-climate effects of those local changes. The daytime temperature then represents more closely what is happening in the deep atmosphere where changes due to such drivers as greenhouse gases occur. This idea will be mentioned later.

ATMOSPHERIC TEMPERATURE TRENDS

There was considerable media attention given to the Climate Change Science Program's 2006 report about temperature trends in the atmosphere, about 0 – 35,000 ft, versus those of the surface for the period since 1979. The basic task of the CCSP was to look at the various datasets of atmospheric and surface temperature and draw conclusions about their relative trends. Several atmospheric datasets revealed trends less than or the same as the surface, which is at odds with greenhouse theory as embodied in present-day climate models which anticipate a faster rate of warming in the upper air.

The key statement regarding GLOBAL trends in the report claimed, "This significant discrepancy no longer exists." It would have been more accurate in my view to have said, "The magnitude of these global discrepancies is not significant." This is a subtle but important difference because it not only acknowledges that discrepancies still exist but that the differences between the global surface and atmospheric trends are within the uncertainty bounds of our various measurements at this time. In other words, rather than being a statement claiming certainty of the measurements (and models) it should have been a statement claiming the uncertainty of our knowledge. I had proposed the second rendition, but was unsuccessful in seeing it implemented.

Be that as it may, the more interesting issue is found in the tropical region. Here we have significant discrepancies between surface and atmospheric trends for nearly all datasets. The tropical region is not trivial, constituting 1/3 of the global area.

The report acknowledged that reasons for this discrepancy were an "open question" but came to a "consensus" statement that the reason for the discrepancy was (a) errors common to models (b) errors in most observational datasets or (c) a combination of the two. The report says that the authors "favored" the second reason, i.e. observational error. The word "favored" was used to allow a sense of a majority view, since I did not agree with that assessment. I preferred the third option, that models and observations have roughly the same amount of error.

I was fairly happy with choosing option (c) because I knew of the two papers that were going to appear soon based on research sponsored by the Dept. of Energy, the Dept. of

Transportation and the National Oceanic and Atmospheric Administration (Christy and Norris 2006, Christy et al. 2007). In these papers I dealt specifically with atmospheric trends and the information we have to assess errors and uncertainties. In both papers we show that atmospheric trends from our UAH datasets are most consistent with independent measurements and thus imply that the discrepancy between the tropical surface and upper air trends is quite differently expressed in observations versus model output.

In the second of the papers, we examined eight upper air datasets in the tropics. All but one revealed less cooling aloft than at the surface. And, in all cases, these seven differed from the one "warming" dataset in the same way, something that would be highly improbable by chance if the one "warming" dataset was accurate. The conclusion of the paper was that there is very likely a difference between the surface and atmospheric tropical trends, with the atmosphere being cooler. This is significant because model simulations indicate the atmosphere should be warming faster than the surface by a factor of about 1.3 if greenhouse influences are correctly included in climate models. Thus, while all datasets indicate a warming trend in atmospheric temperatures, and therefore perhaps a consistency with some level of greenhouse forcing, the rate of the warming is (a) more modest than expected and (b) occurs in a different relationship to the surface than expressed by climate models.

PANEL QUESTIONS

Given the above information I would answer the questions posed to the panel as follows:

(1) Are global temperatures increasing?

> Averaged over the surface, over land and ocean, using both day and night temperatures together, the answer is yes. Over land, using *daytime* temperatures as a likely better indicator of overall climate change, the answer is yes, but at a small rate. In the lower atmosphere since 1979, the answer is yes, but at a rate nearly all datasets show is lower than projected from climate models relative to the surface.

(2) If global temperatures are increasing, to what extent is the increase attributable to greenhouse gas emissions from human activity as opposed to natural variability or other causes?

> No one knows. Estimates today are given by climate model simulations made against a backdrop of uncertain natural variability, assumptions about how greenhouse gases affect the climate, and model shortcomings in general. The evidence from our work (and others) is that the way the observed temperatures are changing in many important aspects is not consistent with model simulations. However, with extra greenhouse gases in the atmosphere there should be some impact on global surface and atmospheric temperatures, but the exact extent is unknown. Since 1950, the IPCC indicates from model simulations that "most" of

the 0.5 °C surface warming (perhaps 0.3?) is due to the way models incorporate the effects of extra greenhouse gases.

(3) How do you expect future global temperatures to be affected by greenhouse gas emissions from human activity.

If the simpler aspects of physics prevail in this complicated system, the surface temperature of the planet should rise. How much? The current rate is about 0.15 °C/decade, part of which is very likely due to extra greenhouse gas concentrations, and that rate seems fairly steady. Other questions related are: Will it be possible to detect in the global temperature the consequence of various legislated actions? (Almost certainly no.) What are the consequences of putting more of the basic building block of life, i.e. CO_2, into the air? (An invigorated biosphere.) How much is human life going to be improved by the fact energy will be used to enhance human existence? (A great deal, see below under Energy Policy)

MODEL EVALUATION

The inconsistencies between model output and observational data should raise concerns about model confidence. Frankly, I am surprised that so many in our climate community grant high confidence to model output while knowing the crudeness of the assumptions which characterize their construction relative to the complexity of the real world. But testing models is a considerable enterprise dominated now by those who are in some way associated with the modeling enterprise itself. It may be no surprise that many publications conclude that model output is valuable today for policymakers.

I am reminded, from my experience in the CCSP report, that model evaluation is often a restricted venture. It was a requirement in the CCSP that all observational datasets used in the report be publicly available in easy-to-access format. Some of us thought the same requirement should be applied to the global and tropical temperature averages from the climate model simulations, especially since those results had already been published the year before and the information was prominently displayed in the report.

In a curious email debate, those who did not want public access given to the climate model averages prevailed. I've encountered this asymmetry before in the field of climate science in which it has typically been very difficult to obtain climate model output in a useful format if at all. Progress has been made with the archiving of the "Climate of the 20th Century" model output at the Dept. of Energy's Lawrence Livermore Laboratory, but the effort required to retrieve specialized climate variables from scores of climate models is still Herculean. Most investigators do not have the infrastructure and personnel to spend time acquiring the huge raw datafiles for particular analyses and then climb a steep learning curve to process those files into the something useful.

This type of careful evaluation requires significant computational resources and personnel. However, such costs would represent a fraction of the millions allocated each year to modeling groups today. Having a series of significantly-funded, independent and rigorous evaluation projects to test models is absolutely essential for policymakers and represents good scientific principles. This is the path model evaluation must go for model output to be thoroughly assessed, documented and for progress to result.

More generally, there is a vital need for our nation to investigate "climate change" from all points of view. I submit that there should be a robust program to rigorously investigate outcomes of the climate change field that are not typically supported because they may not be seen as resulting in some alarming consequence or which have found a significant discrepancy that needs further study.

Using the best of all available datasets these studies would seek to characterize phenomena in the real world that may, for example, show a less sensitive climate system than currently represented in climate models. Such phenomena may lead to an understanding of a climate system that is more (or less) resistant to change than current models indicate. These studies would be done in the rigorous framework of hypothesis testing and peer-reviewed publication. As part of this effort, a thorough examination of climate indices, such as the daytime maximum versus the daily mean temperature, for their utility in understanding global changes vs. local changes would be enlightening. Because of the emotion surrounding the global warming issue, such proposals to investigate a potentially benign climate have a steep, uphill battle for funding opportunities as it struggles with the group-think that is encroaching into our profession. Yet a specific effort should be fostered to test and understand the many assumptions that underlie the current opinions of climate change that may lead to smaller changes than believed.

IPCC 2007

At this time, all we have are the "bullet points" of the IPCC *Summary for Policymakers*. As one of the contributing authors of the scientific text, I must wait until the full publication is released to understand more of the reasoning behind some of the points made in the IPCC. Contributing authors essentially are asked to contribute a little text at the beginning and to review the first two drafts. We have no control over editing decisions. Even less influence is granted the 2,000 or so reviewers. Thus, to say that 800 contributing authors or 2,000 reviewers reached consensus on anything describes a situation that is not reality.

I will comment on two of the bullet points, the first being one of the signature claims (paraphrasing for clarity) of the SPM: *we are 90% certain that most of the global surface warming since 1950 is due to humans* (actual statement is "Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations".) The reason for the not-so-certain "*very likely*" (i.e. 90%) confidence of the IPCC authors is that there are nagging problems related to the imperfections in the models' ability to reproduce many of the natural fluctuations found in the observed climate system. Had I had the opportunity to craft that statement, I would have wanted to include the idea of its origins. Perhaps something like this is more useful to policy makers, "Our current climate models are incapable of reproducing the surface temperature changes since 1950 without an extra push from the way these models incorporate the effects of extra greenhouse gases."

Another quote from the SPM that is over-interpreted is the phrase, "Warming of the climate system is unequivocal…" This statement seems designed to grant powerful confidence to a very simple idea that the observing systems we now have are able to tell us the earth's surface temperature is warmer now than it was 100 years ago and not colder (certainly a benefit). It says absolutely nothing about the cause of the warming. This becomes a problem of communication when the "unequivocal" bleeds into other claims as the media interprets the report.

All in all, the reductions in the scariest realizations is a welcomed change, i.e. reduction of the increases in sea level and average temperatures.

ENERGY POLICY

Discussions of climate for policy makers inevitably lead to questions about energy use. This leads me to discuss my perspective on energy use about which members have expressed gratitude in other hearings.

In 1900, the global energy technology supported 56 billion human-life-years (i.e. 35 yr life expectancy x 1.6 billion people – it's an index). Today, energy technology supports 426 billion human-life-years ... an eight-fold increase. Some of those human-life-years are mine. I've been allowed to become a grandparent, a situation which is now the rule, not the exception. An eight-fold increase in the global experience of human life is a spectacular achievement delivered by affordable energy.

It disturbs me when I hear that energy and its byproducts such as CO2 are being demonized when in fact they represent the greatest achievement of our society. Where there is no energy, life is brutal and short. When you think about that extra CO2 in the air, think also about an 8-fold increase in the experience of human life.

While preparing this testimony, I was reminded of my missionary experience in Africa. As you know, African women collect firewood each day and carry it home for heating and cooking. This source of energy, inefficient and toxic as it is, kills about 1.6 million women and children every year. When an African woman, carrying 50 pounds of firewood on her back, *risks her life* by jumping out in front of my van in an attempt to force me to give her a lift, I understand the value of energy. You see, what I had in my school van, in terms of the amount of gasoline I could hold in my cupped hands, could move her and her 50 pounds of firewood 2 or 3 miles down the road to her home. I now know what an astounding benefit and blessing energy is … and to what extent she and her people would go to acquire it. Energy demand will grow because it makes life less brutal and less short.

The continuing struggle of the EU and other countries to achieve their self-imposed Kyoto targets, indeed falling behind the U.S. in the slowing of emissions growth, implies a lot of things, but two that stand out to me are (1) underestimating people's demand for energy and (2) the well-known tendency for countries and industries to "game the system" for their own benefits without contributing any real results to emissions reduction. An example of this second point is found in the recent announcement by some U.S. electric power producers who are promoting limits on CO2 emissions. These producers are heavily reliant on natural gas which is more costly than competing coal (and nuclear) power generators, but emits less CO2 than coal. By promoting an extra cost (i.e. tax) on coal-fired generation these groups hope to create a government-mandated competitive advantage (and an increase in public energy costs.)

This body is being encouraged to quote "do something" about global warming. The dilemma begins with the fact energy demand will grow because the benefits of affordable energy to human life are ubiquitous and innumerable. The dilemma turns to this question, "How can emissions be reduced in a way that doesn't raise energy costs, (especially for the many poor people of my state)?"

There are several new initiatives on emissions controls being proposed. It is difficult at this point to determine what impact each hopes to have on CO2 emissions. Much of the proposed reductions apparently deal with reducing non-CO2 greenhouse gases that may not be directly related to energy production. As a benchmark, for those which are in the ballpark of the Kyoto-like reductions, their relatively small effect on emissions implies a very small impact on whatever the climate does.

I've written a number of papers about the precision of our climate records. The impact of Kyoto-like proposals will be too small for we scientists to measure due to the natural variations of climate and the lack of precision in our observing system. In other words we will not be able to tell lawmakers with high confidence that specific regulations achieve anything in terms of climate in this country or the world. Additionally, the climate system is immensely complicated and really cannot be tweaked for a predictable outcome.

Humanity uses energy at a rate between 10 and 14 terawatts, 80% of which comes from sources which emit CO2. To have a 10% impact globally on CO2 emissions requires about 1,000 nuclear power plants now. Other options such as solar and wind are comparatively minuscule and troublesome as you will hear in future hearings (though they should be studied carefully) because of their current low intensity, intermittency, cost, transmission length (and losses), environmental impact and the problems of integrating a variable power supply into a baseload grid. So, to have even a minuscule impact on the climate system by 2050 or 2100, there would need to be a massive infrastructure change, the cost of which would be tremendous, both monetarily and socially (baring an innovation that is spectacular.) I recommend Robert Samuelson's *Washington Post* column from 7 Feb 2007 on this subject.

BIOFUELS

If the nation decides to make a strong commitment to invest in biofuels as a source of energy, there are some hurdles to overcome. The physics of ethanol, as a biofuel example, are not very attractive in terms of "energy in" vs. " energy out". There are also economic concerns regarding, specifically, ethanol expansion that deal with the specter of reduced production of other crops leading to price increases, and competition for corn within the corn market. However, the more agreeable means to accommodate a major expansion in corn production, is simply to grow more corn using land currently fallow. The brief discussion which follows addresses the point that *logistically*, it is possible to significantly increase corn (or other biofuel feedstock) production without distorting other markets.

It takes about 1000 gallons of water to grow enough corn to produce 1 gallon of ethanol on a 10ft by 10ft square. That's not sensible to do in a desert, but in Alabama, we receive on average 4,000 gallons of rain on that square every year. This suggests a sustainable production system is possible where water is plentiful. However, though the numbers demonstrate we have an abundance of rain to support biofuel feedstock, that rain often does not fall at the right time when crops are maturing in the hot summer.

To produce enough ethanol to make a dent in our liquid fuel requirements would require millions of acres of sustainable production in wet places. In Alabama, like other southeastern states, we've lost over 10 million acres of row-crop production because of lack of investment in irrigation - the kind of investment the federal government has been making for over 75 years in the West. A fraction of those billions, if spent on irrigation infrastructure in states like Alabama, would provide a way to dramatically increase acreage in production. If just one million acres of the 10 million Alabama has lost were reinvigorated with low-cost and environmentally sustainable irrigation systems, we would displace 10 million barrels of Middle Eastern oil per year. 2 million acres would produce 20 million barrels. Such volumes from Alabama alone (not to mention the other SE states) amounts to a significant contribution to U.S. energy needs. (Similar results would occur for other forms of biofuel feedstocks such as switchgrass if cellulose ethanol becomes feasible).

There are some benefits to this approach. (1) An area of our nation that is terribly economically depressed would be recharged – there are a lot of poor people in my state in these areas that would experience economic growth. (2) The U.S. balance of trade would be improved. (3) The stated congressional goal of energy security would be enhanced. And, (4) a measurable impact could be assessed on the regional and national economy as dollars are retained within the U.S. economy. Though ethanol is not without its concerns, one of those should not be a *logistical* barrier due to the perceived unavailability of land and water.

Though biofuels may provide a relatively small portion of the world's energy needs, the economic and security considerations may be the more forceful drivers which argue for increased production. The goal of reducing CO_2 emissions by an appreciable amount will occur through innovation in other ways of energy production that lead to generation of high volume, baseload energy with reduced (or zero) emissions.

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