# Testimony to the Subcommittee on Energy and Power entitled "Climate Science and EPA's Greenhouse Gas Regulation

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I have worked throughout my career to improve environmental conditions, including air quality, by conducting research, teaching, and also by providing scientifically rigorous information to policymakers.

For example, at the local level, I worked with the National Wildlife Federation to prevent a ski area from building in a pristine area of southwest Colorado. I also served on a local board of the Nature Conservancy and was on a committee in Fort Collins, Colorado that mandated that the permit to construct and operate a brewery near the city require the burning of natural gas rather than coal.

At the state level, I served two terms on the Colorado Air Quality Control Commission where we developed the oxygenated fuels program to reduce atmospheric CO emissions from vehicles, promulgated regulations to mandate strict controls on wood and coal burning in residential fireplaces and stoves, and on asbestos concentrations in the air. I also served on Governor Romer's Blue Ribbon Committee to develop approaches to reduce diesel emissions into the atmosphere. I was also a member of a National Research Council committee that recommended rejecting an attempt to exempt certain locations such as Fairbanks Alaska from the national CO health standard.[1] I also served on a National Research Council to communicate major concerns related to overgrazing, which includes an increase in dust emissions into the atmosphere.[2]

I have taught graduate classes and advised numerous graduate students in air pollution, modeling, weather and forecasting and climate at the University of Virginia, Colorado State University, the University of Arizona, and the University of Colorado in Boulder. My full academic record is available a: http://cires.colorado.edu/science/groups/pielke/

In my testimony today I have four main points:

1. **Research has shown that a focus on just carbon dioxide and a few other greenhouse gases as the dominant human influence on climate is too narrow, and misses other important human influences.**

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[1]National Research Council, 2003: Managing carbon monoxide pollution in meteorological and topographical problem areas. The National Academies Press, Washington, DC, 196 pp.

[2]Committee on Scholarly Communication with the People's Republic of China, 1992: Grasslands and grassland sciences in Northern China, Office of International Affairs, National Research Council, National Academy Press, Washington, D.C., 214 pp.

2. **The phrases “global warming” and “climate change” are not the same. Global warming is a subset of climate change.**

3. **The prediction (or projection) of regional weather, including extremes, decades into the future is far more difficult than commonly assumed. In addition, the attribution of extreme events to a particular subset of climate forcings is scientifically incomplete if the research ignores other relevant human and natural causes of extreme weather events.**

4. **The climate science assessments of the IPCC and CCSP, as well as the various statements issued by the AGU, AMS, and NRC, are completed by a small subset of climate scientists who are often the same individuals in each case.**

Decisions about government regulation are ultimately legal, administrative, legislative, and political decisions. As such they can be informed by scientific considerations, but they are not determined by them. In my testimony, I seek to share my perspectives on the science of climate based on my work in this field over the past four decades.

I elaborate on each of the four conclusions below.

The production of multi-decadal climate predictions of regional impacts, whose skill cannot be verified until decades from now, is not a robust scientific approach**.** Models themselves are hypotheses. The steps of hypothesis written with respect to climate predictions are

1. *Make a Prediction*
2. *Quantitatively Compare the Prediction With Real World Observations [i.e. Test the Hypothesis]*
3. *Communicate The Assessment of the Skill of the Prediction*

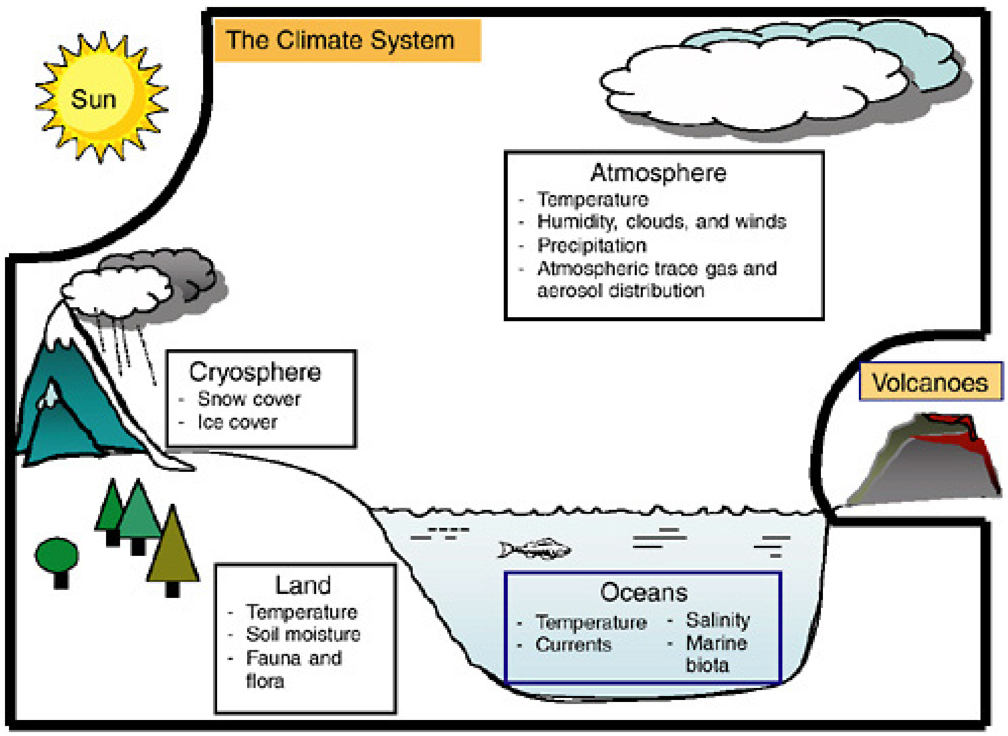
There is no way to test hypotheses with the multi-decadal global climate model forecasts for decades from now, as step 2 as a verification of the skill of these forecasts, is not possible until the decades pass.

There has also been a misunderstanding of the relationship between global warming and climate variability and longer-term change.

**Global Warming** is typically defined as an increase in the global average surface temperature. A better metric is the global annual average heat content measured in Joules. Global warming involves the accumulation of heat in Joules within the components of the climate system. This accumulation is dominated by the heating and cooling within the upper layers of the oceans.

**<u>Climate Change</u> is any multi-decadal or longer alteration in one or more physical, chemical and/or biological component of the climate system.**

The climate system is illustrated in the figure below from the NRC (2005).




<u>Figure caption</u>: The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes to the land surface are considered external to the climate system. Source: National Research Council, 2005: Radiative forcing of climate change: Expanding the concept and addressing uncertainties. Committee on Radiative Forcing Effects on Climate Change, Climate Research Committee, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C., 208 pp

Climate change includes, for example, changes in fauna and flora, snow cover, etc. which persist for decades and longer. Climate variability can then be defined as changes which occur on shorter time periods.

The use of a global annual average surface temperature anomaly as the metric to diagnose global warming is inaccurate and contains significant uncertainties and several systematic biases.[3]

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[3]Pielke Sr., R.A., C. Davey, D. Niyogi, S. Fall, J. Steinweg-Woods, K. Hubbard, X. Lin, M. Cai, Y.-K. Lim, H. Li, J. Nielsen-Gammon, K. Gallo, R. Hale, R. Mahmood, S. Foster, R.T. McNider, and P. Blanken,

The current best estimate of the rate of global warming from 2005 to mid-2010 is **a rate 0f 0.425** of that reported by Jim Hansen which he based on a multi-decadal climate model prediction for the period 1993 to 2003 (and presumably would be an even higher rate now).[4] This is still a relatively short time period and fits within the variability of the multi-decadal global model prediction, but it is a primary global warming metric that should be elevated in its prominence.

With respect to climate change, in 2009, 18 Fellows of the American Geophysical Union accepted an invitation to join me in a paper where we discussed three different mutually exclusive hypotheses with respect to the climate system:[5]

> **Hypothesis 1**: Human influence on climate variability and change is of minimal importance, and natural causes dominate climate variations and changes on all time scales. In coming decades, the human influence will continue to be minimal.
>
> **Hypothesis 2a:** Although the natural causes of climate variations and changes are undoubtedly important, the human influences are significant and involve a diverse range of first-order climate forcings, including, but not limited to, the human input of carbon dioxide ($CO_2$). Most, if not all, of these human influences on regional and global climate will continue to be of concern during the coming decades.
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> **Hypothesis 2b:** Although the natural causes of climate variations and changes are undoubtedly important, the human influences are significant and are dominated by the emissions into the atmosphere of greenhouse gases, the most important of which is $CO_2$. The adverse impact of these gases on regional and global climate constitutes the primary climate issue for the coming decades.
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> **Hypothesis 2b** is the IPCC perspective. In our EOS paper, we concluded that only **Hypothesis 2a** has not been refuted. **Hypotheses 1 and 2b** are inaccurate characterizations of the climate system.

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2007: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Res., 112, D24S08, doi:10.1029/2006JD008229. Klotzbach, P.J., R.A. Pielke Sr., R.A. Pielke Jr., J.R. Christy, and R.T. McNider, 2009: An alternative explanation for differential temperature trends at the surface and in the lower troposphere. J. Geophys. Res., 114, D21102, doi:10.1029/2009JD011841.

[4]Expressed as a global annual average in heat content change in Joules – from Update Of Preliminary Upper Ocean Heat Data Analysis By Josh Willis – "An Unpublished Update" - http://pielkeclimatesci.wordpress.com/2011/02/13/update-of-preliminary-upper-ocean-heat-data-analysis-by-josh-willis-%e2%80%93-%e2%80%9can-unpublished-update%e2%80%9d/

[5]Pielke Sr., R., K. Beven, G. Brasseur, J. Calvert, M. Chahine, R. Dickerson, D. Entekhabi, E. Foufoula-Georgiou, H. Gupta, V. Gupta, W. Krajewski, E. Philip Krider, W. K.M. Lau, J. McDonnell, W. Rossow, J. Schaake, J. Smith, S. Sorooshian, and E. Wood, 2009: Climate change: The need to consider human forcings besides greenhouse gases. Eos, Vol. 90, No. 45, 10 November 2009, 413. Copyright (2009) American Geophysical Union

In our 2009 paper we wrote

> *"In addition to greenhouse gas emissions, other first-order human climate forcings are important to understanding the future behavior of Earth's climate. These forcings are spatially heterogeneous and include the effect of aerosols on clouds and associated precipitation [e.g., Rosenfeld et al., 2008], the influence of aerosol deposition (e.g., black carbon (soot) [Flanner et al. 2007] and reactive nitrogen [Galloway et al., 2004]), and the role of changes in land use/land cover [e.g., Takata et al., 2009]. Among their effects is their role in altering atmospheric and ocean circulation features away from what they would be in the natural climate system [NRC, 2005]. As with CO2, the lengths of time that they affect the climate are estimated to be on multidecadal time scales and longer."*

We concluded that

> *"Therefore, the cost- benefit analyses regarding the mitigation of CO2 and other greenhouse gases need to be considered along with the other human climate forcings in a broader environmental context, as well as with respect to their role in the climate system"*

and

> *"The evidence predominantly suggests that humans are significantly altering the global environment, and thus climate, in a variety of diverse ways beyond the effects of human emissions of greenhouse gases, including CO2. Unfortunately, the 2007 Intergovernmental Panel on Climate Change (IPCC) assessment did not sufficiently acknowledge the importance of these other human climate forcings in altering regional and global climate and their effects on predictability at the regional scale."*

This broader view is supported by several broad-based multi-author assessments.[6]

In 2005 the National Research Council concluded,

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[6]Kabat, P., Claussen, M., Dirmeyer, P.A., J.H.C. Gash, L. Bravo de Guenni, M. Meybeck, R.A. Pielke Sr., C.J. Vorosmarty, R.W.A. Hutjes, and S. Lutkemeier, Editors, 2004: Vegetation, water, humans and the climate: A new perspective on an interactive system. Springer, Berlin, Global Change - The IGBP Series, 566 pp.

McAlpine, C.A., W.F. Laurance, J.G. Ryan, L. Seabrook, J.I. Syktus, A.E. Etter, P.M. Fearnside, P. Dargusch, and R.A. Pielke Sr. 2010: More than CO2: A broader picture for managing climate change and variability to avoid ecosystem collapse. Current Opinion in Environmental Sustainability, 2:334-336, DOI10.1016/j.cosust.2010.10.001.

National Research Council, 2005: Radiative forcing of climate change: Expanding the concept and addressing uncertainties. Committee on Radiative Forcing Effects on Climate Change, Climate Research Committee, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C., 208 pp.

*"….the traditional global mean TOA radiative forcing concept has some important limitations, which have come increasingly to light over the past decade. The concept is inadequate for some forcing agents, such as absorbing aerosols and land-use changes, that may have regional climate impacts much greater than would be predicted from TOA radiative forcing. Also, it diagnoses only one measure of climate change—global mean surface temperature response—while offering little information on regional climate change or precipitation."*

*"Regional variations in radiative forcing may have important regional and global climatic implications that are not resolved by the concept of global mean radiative forcing. Tropospheric aerosols and landscape changes have particularly heterogeneous forcings. To date, there have been only limited studies of regional radiative forcing and response. Indeed, it is not clear how best to diagnose a regional forcing and response in the observational record; regional forcings can lead to global climate responses, while global forcings can be associated with regional climate responses. Regional diabatic heating can also cause atmospheric teleconnections that influence regional climate thousands of kilometers away from the point of forcing. Improving societally relevant projections of regional climate impacts will require a better understanding of the magnitudes of regional forcings and the associated climate responses."*

*"Several types of forcings—most notably aerosols, land-use and land-cover change, and modifications to biogeochemistry—impact the climate system in nonradiative ways, in particular by modifying the hydrological cycle and vegetation dynamics. Aerosols exert a forcing on the hydrological cycle by modifying cloud condensation nuclei, ice nuclei, precipitation efficiency, and the ratio between solar direct and diffuse radiation received. Other nonradiative forcings modify the biological components of the climate system by changing the fluxes of trace gases and heat between vegetation, soils, and the atmosphere and by modifying the amount and types of vegetation. No metrics for quantifying such nonradiative forcings have been accepted. Nonradiative forcings have eventual radiative impacts, so one option would be to quantify these radiative impacts. However, this approach may not convey appropriately the impacts of nonradiative forcings on societally relevant climate variables such as precipitation or ecosystem function. Any new metrics must also be able to characterize the regional structure in nonradiative forcing and climate response."*

In an invited multi-authored paper to an American Geophysical Union Monograph on "Complexity and Extreme Events in Geosciences. we report,[7]

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[7]Roger A. Pielke Sr., Rob Wilby, Dev Niyogi, Faisal Hossain, Koji Dairuku , Jimmy Adegoke, George Kallos Tim Seastedt and Katie Suding, 2011: Dealing with Complexity and Extreme Events Using a Bottom-up, Resource-based Vulnerability perspective. Surja Sharma Editor, under review.

*"...that global multi-decadal predictions are unable to skillfully simulate major atmospheric circulation features such the Pacific Decadal Oscillation [PDO], the North Atlantic Oscillation [NAO], El Niño and La Niña, and the South Asian monsoon (Pielke, 2010; Annamalai et al., 2007). However, these large scale atmospheric/ocean climate features determine the particular weather pattern for a region (e.g. Otterman et al 2002; Chase et al 2006 ). Proposed decadal prediction efforts seek to address some of these deficiencies but are still under development (Hurrell et al 2010)."*

It is these regional atmospheric and ocean circulation features which produce extreme weather events, not a global annual average surface temperature anomaly. We also concluded that

*"There is sometimes an incorrect assumption that although global climate models cannot predict future climate change as an initial value problem, they can predict future climate statistics as a boundary value problem (Palmer et al 2008). With respect to weather patterns, for the downscaling regional (and global) models to add value over and beyond what is available from the historical, recent paleo-record, and worse case sequence of days, however, they must be able to skillfully predict the changes in the regional weather statistics. There is only value for predicting climate change if they could skillfully predict the changes in the statistics of the weather and other aspects of the climate system. There is no evidence, however, that the models can predict changes in these climate statistics even in hindcast. As highlighted in Dessai et al. (2009) the finer and time space based downscaled information can be "misconstrued as accurate", but the ability to get this finer scale information does not necessarily translate into increased confidence in the downscaled scenario (Wilby 2010)."*

As just one example, we have published recently on the role of land use change, by itself, as a possible explanation of an increase in extreme precipitation in certain regions.[8] Recent studies reported in Nature ignored this possibility.[9]

As we wrote in Pielke Sr. et al (2011) [cited earlier],

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[8] Our papers on this subject, under the leadership of Faisal Hossain, include
Hossain, F., I. Jeyachandran, and R.A. Pielke Sr., 2009: Have large dams altered extreme precipitation patterns during the last Century? Eos, Vol. 90, No. 48, 453-454. Copyright (2009) American Geophysical Union.
Degu, A. M., F. Hossain, D. Niyogi, R. Pielke Sr., J. M. Shepherd, N. Voisin, and T. Chronis, 2011: The influence of large dams on surrounding climate and precipitation patterns. Geophys. Res. Lett., 38, doi:10.1029/2010GL046482, in press.
Hossain, F., I. Jeyachandran, and R.A. Pielke Sr., 2010: Dam safety effects due to human alteration of extreme precipitation. Water Resources Research, 46, W03301, doi:10.1029/2009WR007704.

[9] Na Seung-Ki Min, Xuebin Zhang, Francis W. Zwiers and Gabriele C. Hegerl: 2011: Human contribution to more-intense precipitation extremes. Nature. 17 February 2011.
Pardeep Pall, ToluAina, Dáithí A. Stone, Peter A. Stott, Toru Nozawa, Arno G. J. Hilberts, Dag Lohmann, Myles R. Allen Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000 Nature470, 382-385 (16 February 2011) doi:10.1038/nature09762 Letter

*"Quantitative predictions of extremes by climate models are highly uncertainty due to: the choice of model(s); unknown future changes in radiative and other climate forcing (by anthropogenic emissions, land-surface modifications and natural (e.g. solar, volcanoes); and random, internal variability of climate.*

*When taking all of these factors into account it is hardly surprising that detection of robust anthropogenic signals in regional climate predictions is seldom possible within decision-making time-scales of a few decades. For example, Ziegler et al. (2005) find that time-series of 50-350 years are required to detect plausible trends in annual precipitation, evaporation and discharge in the Missouri, Ohio, and Upper Mississippi River basins. Likewise, Wilby (2006) showed that, under widely assumed climate change scenarios, expected trends in UK summer river flows are seldom detectable within typical planning horizons (i.e., by the 2020s). Again, depending on the climate model and underlying uncertainty of the regional projections, emergence time-scales for US tropical cyclone losses range between 120 and 550 years (Crompton et al., 2011)."*

Policymakers and the public rarely encounter this broader view of the climate system, in part due to the limited number of scientists who are leading climate assessments. As just one example, I present my experiences with the first CCSP report, from which I resigned with my experiences documented in a public comment[10]

In the executive summary of that report, I wrote

*"The process for completing the CCSP Report excluded valid scientific perspectives under the charge of the Committee. The Editor of the Report systematically excluded a range of views on the issue of understanding and reconciling lower atmospheric temperature trends.*

*The Executive Summary of the CCSP Report ignores critical scientific issues and makes unbalanced conclusions concerning our current understanding of temperature trends.*

*The CCSP Report entitled, "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences", therefore, while containing useful new information on temperature trends failed to adequately evaluate the diversity of scientific issues as tasked in the charge to the Committee. Instead, the Editor and the majority of the members of the Committee intended to focus almost exclusively on seeking to remove the discrepancy noted in the NRC (2000) report between surface and tropospheric temperature trends.*

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[10]Pielke Sr., Roger A., 2005: Public Comment on CCSP Report "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences". 88 pp including appendices

*The process that produced the report was highly political, with the Editor taking the lead in suppressing my perspectives, most egregiously demonstrated by the last-minute substitution of a new Chapter 6 for the one I had carefully led preparation of and on which I was close to reaching a final consensus. Anyone interested in the production of comprehensive assessments of climate science should be troubled by the process which I document below in great detail that led to the replacement of the Chapter that I was serving as Convening Lead Author.*

*Future assessment Committees need to appoint members with a diversity of views and who do not have a significant conflict of interest with respect to their own work. Such Committees should be chaired by individuals committed to the presentation of a diversity of perspectives and unwilling to engage in strong-arm tactics to enforce a narrow perspective. Any such committee should be charged with summarizing all relevant literature, even if inconvenient, or which presents a view not held by certain members of the Committee.*"

Finally, I have proposed a new approach in the climate community based on a bottom-up, resource-based perspective. There are five broad areas that we can use to define the need for these vulnerability assessments: *water, food, energy, human health* and *ecosystem function*. Each sector is critical to societal well-being. The vulnerability concept requires the determination of the major threats to these resources from extreme events including climate, but also from other social and environmental pressures. After these threats are identified for each resource, relative risks can be compared in order to shape the preferred mitigation/adaptation strategy. The questions to be asked for each key resource are:

1. Why is this resource important? How is it used? To what stakeholders is it valuable?

2. What are the key environmental and social variables that influence this resource?

3. What is the sensitivity of this resource to changes in each of these key variables? (This may include but is not limited to, the sensitivity of the resource to climate variations and change on short (days), medium (seasons), and long (multi-decadal) time scales).

4. What changes (thresholds) in these key variables would have to occur to result in a negative (or positive) outcome for this resource?

5. What are the best estimates of the probabilities for these changes to occur? What tools are available to quantify the effect of these changes? Can these estimates be skillfully predicted?

6. What actions (adaptation/mitigation) can be undertaken in order to minimize or eliminate the negative consequences of these changes (or to optimize a positive response)?

7. What are specific recommendations for policymakers and other stakeholders?