opinion

A broader view of the role of humans in the climate system

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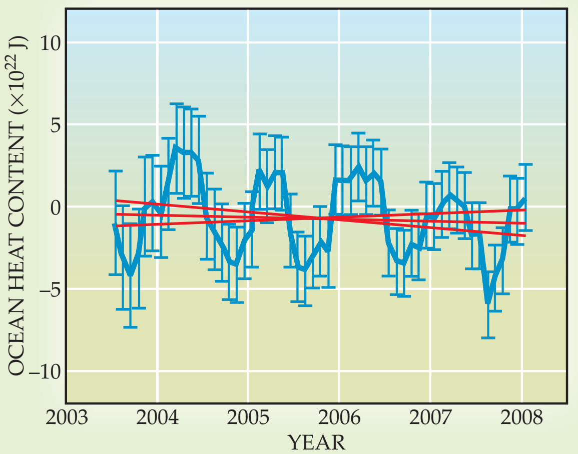
The 2007 report from the Intergovernmental Panel on Climate Change Working Group I presents a narrow view of the state of climate science.[1] Attempts to significantly influence regional and local-scale climate based on controlling carbon dioxide emissions alone cannot succeed since humans are significantly altering the global climate in a variety of diverse ways beyond the radiative effect of CO_2. The IPCC assessments have been too conservative in recognizing the importance of these human climate forcings as they alter regional and global climate. When the IPCC focuses its policy attention on CO_2, it neglects other important aspects of the impact of human activities on climate.



Four-year rate of the global upper 700 m of ocean heat changes in joules at monthly time intervals. One standard error value is also shown. (Figure adapted from ref. 5, courtesy of Joshua Willis of NASA's Jet Propulsion Laboratory.)

Definition of climate

For many, the term "climate" refers to long-term weather statistics. However, more broadly and more accurately, the definition of climate is a system consisting of the atmosphere, hydrosphere, lithosphere, and biosphere. Physical, chemical, and biological processes are involved in interactions among the components of the climate system. Vegetation, soil moisture, and glaciers, for example, are as much a part of the climate system as are temperature and precipitation.

Human actions that influence the climate system include the radiative forcing from added atmospheric CO_2 but also include the biogeochemical influence of CO_2, and a variety of atmospheric aerosol forcings, nitrogen deposition onto land and the oceans, and land-cover changes.[2] Each of these factors influence long-term weather statistics as well as other aspects of the climate. The IPCC assessment process focused mainly on the effects of CO_2 and devoted less attention to the effect of the other human climate forcings in altering the global climate system. The United Nations Framework on Climate Change specifically ignores the other climate forcings.

Climate system heat changes

Not only did the 2007 IPCC report focus primarily on CO_2 and other well-mixed greenhouse gases, even within that focus the panel used global average surface-temperature changes as the primary metric to quantify the effects of human-caused climate changes. However, my collaborators and I have shown that global average surface-temperature changes are not particularly useful for assessing the broad range of human influences on climate.[3]

Global warming (or global cooling) can be more accurately quantified in terms of the accumulation (or loss) of heat in the Earth system as measured in joules. The 2007 IPCC report estimated that global average total net anthropogenic radiative forcing in 2005 was 1.6 (+0.8, −1.0) W m^{-2} with 0.12 (+0.18, −0.06) from solar irradiance. This estimate corresponds to a heat accumulation in the climate system of 2.8 (+1.6, −1.7) × 10^{22} joules per year.

The ocean, of course, is the largest reservoir of this heat change. Thus, the Earth's heat budget observations, within the limits of their representativeness and accuracy, provide an observational constraint on the actual global average radiative forcing. The value of ocean heat content at any time documents the accumulated heat content and its change since the last assessment.[4]

Unlike temperature at some specific depth in the ocean or height in the atmosphere, where there is a time lag in its response to radiative forcing, no time lags are associated with heat changes, since the actual amount of heat present at any time is accounted for. Moreover, because the surface temperature is a massless two-dimensional global field while heat content involves mass, the use of surface temperature as a monitor of climate change is not accurate for evaluating heat storage changes.

The figure presents the latest estimate of change in global average heat storage in the upper 700 meters of the ocean; it was provided by Joshua Willis of NASA's Jet Propulsion Laboratory. The year-to-year variations can be seen along with the average four-year rate of ocean heat change with plus or minus one standard error. Willis's estimate of the four-year rate is -0.076 ± 0.214 W m^{-2} or $0.12 \pm 0.35 \times 10^{22}$ joules per year but with additional uncertainty associated with heating and cooling in the deeper ocean and under sea ice. His estimate is, of course, in agreement with the value of the contributions from heat to sea-level change published by Willis and his collaborators.[5]

Even with the uncertainty, this value of upper ocean heat change is clearly much smaller than that given by James Hansen and his collaborators,[6] who reported a planetary heating rate of 0.85 W m^{-2} or 1.39×10^{22} joules per year for 10 years prior to 2003. The Willis value is also much smaller than the total global average radiative forcing estimates in 2005 of 1.72 W m^{-2} (+0.98, −1.06) presented in the 2007 IPCC Summary for Policymakers.[1] Thus there is an error in the IPCC net radiative forcing, or the radiative feedbacks are negative, or both.

Although four years is a relatively short period of analysis, the absence of heating of the magnitude reported by Hansen and his collaborators and the 2007 IPCC report should raise issues with respect to our level of understanding of the climate system, since the global climate model projections used by the IPCC predict more or less monotonic accumulation of heat in the Earth system.

Regional forcings and feedbacks

The concept of a global average radiative forcing is generally a poor metric for assessing the impact of diverse climate forcings and feedbacks. Weather events such as drought, floods, and hurricanes are regional events and are essentially independent of the global average radiative imbalance.

Regional diabatic heating patterns (the warming and cooling of the atmosphere) can lead to climate variability and change that are influenced both by such natural atmospheric circulation features as El Niño southern oscillation events (ENSO), North Pacific decadal oscillation (PDO), and North Atlantic oscillation (NAO) and by human alterations in atmospheric composition, land cover, and aerosols. The resulting changes in regional diabatic heating produce temperature increases or decreases in the layer-averaged regional troposphere. The changes necessarily alter the regional pressure fields and thus the wind pattern. Important weather patterns such as drought, floods, and intensity and path of tropical cyclones are also consequently altered. Atmosphere and ocean circulations respond to regional forcings, not to a global average.

There is debate, however, regarding whether the magnitude of human-caused regional diabatic forcing is large enough to result in long-distance effects on weather patterns (teleconnections). Research indicates that observed multidecadal trends in tropospheric-averaged temperatures are large enough to result in large-scale circulation trends. Multidecadal global model simulations similarly show large effects due to landscape changes[7] and the wide-ranging effects of aerosols that produce regional tropospheric-temperature anomalies of a similar or larger magnitude as associated with ENSO, the NAO, and the PDO. Aerosols also alter cloud and precipitation processes that will subsequently change weather patterns far from where the aerosols entered the atmosphere.

Other human disturbances that are regional in spatial scale but can subsequently alter climate processes include aerosol deposition onto the surface—such as nitrogen deposition that will alter vegetation growth in the region—and the biogeochemical effect of added CO_2 on vegetation transpiration and growth.

Such regional climate forcings due to human activities represent a major but underrecognized climate forcing on long-term global weather patterns. Indeed, heterogeneous climate forcing may be more important with respect to our weather than changes in weather patterns associated with the more spatially homogeneous radiative forcing of the well-mixed greenhouse gases.[8] The magnitude of natural climate variations and change have also been underestimated (and are only poorly understood) based on examination of the historical and paleo-climate record. Although the radiative effect of CO_2 cannot be ignored, the science of climate change is far more complex than presented by the IPCC.

Conclusions

Humans are significantly altering the global climate, but in a variety of diverse ways beyond the radiative effect of CO_2. Significant, societally important climate change on the regional and local scales, due to both natural and human climate forcings, can occur due to these diverse influences. The result of the more complex interference of humans in the climate system is that attempts to significantly influence regional and local-scale climate based on controlling CO_2 emissions alone is an inadequate policy for this purpose. There is a need to minimize the human disturbance of the climate by limiting the amount of CO_2 that is emitted into the atmosphere by human activities, but the diversity of human climate forcings should not be ignored.

References

1. IPCC Summary for Policymakers (2007), http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf.
2. National Research Council, Committee on Radiative Forcing Effects on Climate Change and Climate Research Committee, *Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties*, National Academies Press, Washington, DC (2005).
3. R. A. Pielke Sr et al., *J. Geophys. Res.* **112**, D24S08 (2007).
4. R. A. Pielke Sr, *Bull. Am. Meteorol. Soc.* **84**, 331 (2003).
5. J. K. Willis, D. P. Chambers, R. S. Nerem, *J. Geophys. Res. (Oceans)* **113**, C06015 (2008).
6. J. Hansen et al., *Science* **308**, 1431 (2005).
7. R. A. Pielke Sr, *Science* **310**, 1625 (2005).
8. T. Matsui, R. A. Pielke Sr, *Geophys. Res. Lett.* **33**, L11813 (2006). ■