ASA Statement on Climate Change

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The American Statistical Association (ASA) recently convened a workshop of leading atmospheric scientists and statisticians involved in climate change research. The goal of this workshop was to identify a consensus on the role of statistical science in current assessments of global warming and its impacts. Of particular interest to this workshop was the recently published Fourth Assessment Report of the United Nations' Intergovernmental Panel on Climate Change (IPCC), endorsed by more than 100 governments and drawing on the expertise of a large portion of the climate science community.

Through a series of meetings spanning several years, IPCC drew in leading experts and assessed the relevant literature in the geosciences and related disciplines as it relates to climate change. The Fourth Assessment Report finds that "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising mean sea level. … 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. … Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes, and wind patterns **The ASA endorses the IPCC conclusions.**

Over the course of four assessment reports, a small number of statisticians have served as authors or reviewers. Although this involvement is encouraging, it does not represent the full range of statistical expertise available. **ASA recommends that more statisticians should become part of the IPCC process. Such participation would be mutually beneficial to the assessment of climate change and its impacts and also to the statistical community.**

The US government's Climate Change Science Program (CCSP) is in the process of producing a set of 21 Synthesis and Assessment reports on many different aspects of climate change. Some statisticians have been appointed members of CCSP committees or reviewers through the National Research Council. **ASA recommends that there should be greater involvement by statisticians in future reviews of the state of climate science conducted by the CCSP.**

Although there are numerous opportunities for increasing the participation of the statistical community in the IPCC, CCSP, and other assessment processes, the ASA notes that there is already extensive and healthy collaboration between statisticians and climate scientists in basic research on climate change. Furthermore, climate science continues to offer many statistical challenges that are currently not being tackled and many opportunities for collaboration with geoscientists. **The ASA strongly urges statisticians to collaborate with other scientists in order to advance our understanding of the nature, causes, and impacts of climate change.**

The workshop convened by ASA identified several specific areas where statistical science can make a contribution. Besides the obvious benefit to the geosciences these topics may well push the boundaries of statistics and suggest new methods, algorithms, and theory.

Interpreting and synthesizing climate observations. Observational data from different measurement platforms and sensors, such as satellites, weather balloons, surface stations, or ocean drifter buoys often represent climate processes at very different spatial or temporal scales. Moreover, observational records from earlier parts of the 20th century are sparse, particularly in southern oceans and in the developing parts of the world. Even in the satellite era – the best observed period in Earth's climate history – there are significant uncertainties in key observational datasets. Reduction of these uncertainties will be crucial for evaluating and better constraining climate models. Statisticians can advise on how best to *combine data from different sources, how to identify and adjust for biases in different measurement systems, and how to deal with changes in the spatial and temporal coverage of measurements*. The climate science community often requires regular fields of geophysical variables, such as surface temperature, which must be derived from irregular and heterogeneous observations. Evaluating the advantages and disadvantages of different interpolation approaches (referred to as infilling in climate applications) could be very helpful. This research area contains many opportunities for the development and fitting of sophisticated *space-time models to sparse data.*

Climate models. Complex computer models based on physical laws are used to simulate the dynamics of the Earth's atmosphere, ocean, and sea ice. These models provide a basis for exploring the physical relationship among different components of the climate system and also for making projections of future climate states. *The design and analysis of computer experiments* is an area of statistics that is appropriate for aiding the development and use of climate models. Statistically based experimental designs, not currently used in this field, could be more powerful. It is also important to understand how to combine the results of experiments performed with different climate models. Despite their sophistication, climate models remain approximations of a very complex system and systematic model errors must be identified and characterized. Model evaluation is an area of active research, with many opportunities for informed statistical input. Finally, assessing the many *sources of uncertainty* in climate projections requires innovative techniques for better quantifying and, where possible, reducing these uncertainties. Quantifying uncertainty and formal assessment of confidence intervals on observations and model projections are core activities of statistical science, and become particularly appropriate when climate models are used to identify human effects on climate or to estimate climate-change impacts.

Regional and local effects of climate change. There is great need for taking coarse-resolution projections from global and regional climate models down to*estimates for small areas*. Indeed, translating the large scale understanding of climate processes to changes at a local level is a grand challenge in climate research. Statisticians can provide valuable input to this problem of downscaling climate-model results to the much finer levels of detail required for policy makers.

High dimensional data analysis. The results of climate models and current observational data sets are extremely multi-dimensional and difficult to visualize and analyze. A commonly-used technique is principal components analysis (often known as empirical orthogonal functions analysis in the geophysical sciences). This standard method can miss the nonlinear and non-Gaussian attributes often associated with geophysical processes. Statisticians have the opportunity to contribute improved analytic techniques for interpreting geophysical data. It is very difficult to present all of the information concisely in a manner that can be understood by decision makers. *Dimension reduction and data presentation techniques* are needed for comparing spatial maps, explaining what is being presented, and determining how to describe the confidence levels associated with projections obtained from noisy and spatially incomplete data.

Human health effects of climate change. The available evidence suggests that certain extreme events with the potential to impact human health may be increasing in frequency as a result of global warming. For example, the IPCC concluded that there have been more intense and longer droughts, and an increase in the frequency of hot days, hot nights, heat waves, and heavy precipitation events. Climate change can also impact human health through its effects on the vectors carrying diseases, or through the complex interplay between large-scale warming and local air pollution. Links between local air pollution and human mortality are already well-established. One issue that has emerged in recent research is the extent to which individual extreme events, such as the 2003 European heat wave, can be attributed to global warming as opposed to other possible explanations, including natural causes. A fruitful line of research is to explore how concepts borrowed from epidemiology, such as *relative risk*, are potentially valuable in this context. Papers along these lines have started to appear in the climate literature, but there is much scope for further development.