Statement on Research

I joined the Department of Atmospheric Sciences, College of Geosciences at Texas A&M University in August 2016 as an Assistant Professor. Over the past five years here, I have developed an independent research program with a primary focus on the historical attribution, present impact, and future mitigation of climate change, arguably a defining issue for our world in the 21st century. I have made a considerable intellectual contribution to this rapidly developing research field by producing a solid record of peer-reviewed publications in leading disciplinary journals and high-profile multidisciplinary journals.

My current research activities center around climate variability and change at a decadal to centennial time scale using Earth system modeling. We have made a considerable contribution towards understanding past changes, assessing present and future impacts, and identifying and promoting possible solutions. In the past few years, my group published extensively on the interaction of climate and aerosols, decadal variability due to internal ocean-atmosphere processes, and also the long-term projection of the climate system including extreme weather behaviors. I have also started to develop interdisciplinary collaborations on topics related to climate impacts and adaptations.

The first line of investigation is on **climate change attribution to various anthropogenic forcing mechanisms and natural variabilities.** A better understanding of the relative contribution of these entangled factors will help explain the recently observed trends and also enable a more robust prediction of near-term climate change in the next 10-30 years. A series of model-based studies by my student (Diao) and other collaborators have shown industrial activities related to aerosols are a dominant driving force for changes observed in the last few decades, which have temporarily "masked" global warming due to greenhouse gases. We consistently show a more significant impact due to anthropogenic aerosols for changes in precipitation extremes (Lin et al., 2018GRL, 2016GRL), latitudinal temperature gradient (Wang et al., 2017SP; Diao and Xu, 2020CD; Diao et al., 2020ACPD), various drought indices (Xu and Lin, 2017CC; Lin et al., 2016CC) and snow cover (Xu et al., 2016ACP). Because of the relatively stronger masking effect in the past, we show that future clean-up of aerosols, due to air quality concerns or decarbonization efforts, will undesirably lead to stronger and faster warming (Xu et al., 2018Nature; Xu et al., 2015CC; Wang et al., 2020npjClim). We have also studied the fractional contribution and competing mechanisms due to cooling and heating aerosols (Wang et al., 2017ACP; Lin et al., 2016JGR; Xu and Xie, 2015ACP).

The contribution of all these various forcing mechanisms and natural variability deserves a thorough investigation, especially given the emerging opportunities of super-ensemble climate modeling simulation. With support from NSF, we are now looking deeper into the natural variability aspect of the problem including contribution from various climate modes (Xu and Hu, 2019JC; Diao et al., 2021CD; Yao et al., 2021CD; Lee et al., in prep.).

The focused aspect on the role of non-CO2 in climate change has received wide attention from both academic communities and the general public. Our precipitation attribution work (Lin et al., 2016GRL) was featured in *Nature*, and the study on snow cover response to various forcing mechanisms (especially black carbon; Xu et al., 2016ACP; Gul et al., 2021EP) also led to a follow-on project on the Himalayas organized by World Bank, for which I participated as an advisory committee member. A holistic understanding of past changes also enables us to provide recommendations on climate change mitigation solutions beyond decarbonization (i.e., cutting fossil fuel use), particularly aiming at limiting warming below 1.5ºC. My collaborative work with various groups explicitly addressed a full suite of options of limiting the use of methane, hydrofluorocarbons, scaling up of carbon capture, stratospheric aerosol geoengineering (Ocko et al., 2021ERL; UNEP 2020; Hanna et al., 2021NC; Xu et al.,2020ESD).

Another line of investigation is **on climate change impact**. My recent work focused on the discernable difference between 1.5ºC and 2ºC global warming, primarily related to the intensification of heat and rainfall extremes (Wang et al., 2017EF). I was also the main contributor to a large-scale community modeling activity in support of the IPCC 1.5ºC Special Report (Sanderson Xu et al., 2018ESD). My student has also published on the convolution of meteorological extremes and air pollution episodes (Wu et al., 2019JGR; Xu et al., 2020 AGUadv). One advantage of working in a major research university is that I can engage more actively in interdisciplinary work. I have received an Energy Institute seed grant (split evenly between me and Dr. McCarl at Agricultural economics) to study extreme weather statistics and regional impact, and am a co-PI of a NASA-funded interdisciplinary study on climate extremes and air pollution impact in urban environments.

Providing knowledge-based solutions to climate problems will be my lifetime pursuit. In close collaboration with TAMU colleagues from public health, agriculture, engineering, and urban planning, I have started the process of developing data products specifically geared for hyper-local extreme weather quantifications, with anticipated wide applications in risk assessment of various fields. I plan to initiate an integrative approach of combining physics-based Earth system modeling (with balanced chemistry and dynamical processes for computational efficiency) and machine learning (ML)-based statistical modeling. Efforts are ongoing to develop an ML-based prototype of downscaling climate extreme data to community-scale (with a "stacking" ensemble learning approach of merging neural network and decision tree-based methods). This rich data product and the ML approach of accounting for "hidden" features/contributors will also aid a deeper fundamental understanding of physical drivers at regional to local levels as elucidated above. In the next five years, I plan to scale up this ML-based approach to further downscale air quality data, in addition to the physical extremes as conventionally focused on, which is much more spatially heterogeneous. Preliminary analysis suggests that beyond spatial inference, additional constraints from the remote sensing data set and land/societal/economic data can be highly valuable.

Impact of Research Activities. Since the year 2016, I have published more than 30 papers (with a dozen more in various stages of the review process), including 9 first-authored and 4 student first-authored articles (published or in review). The total funding received is 850K from external agencies and about 90K from internal programs. Among the papers that are multi-disciplinary and multi-authored, I was the main author (first or corresponding) in 7 of them, played a major role in 9 of them (second or third author), and played a supporting role in 7 of them. The total citations according to Google Scholar are close to 2000 with an H-index of 21, and most of them were collected in the past three years.

Overall, my research activities in the past few years have generated a wide impact on the climate research community. As an example, my modeling paper (Sanderson, Xu, et al., 2017ESD) on community modeling activities in support of the Intergovernmental Panel on Climate Change's 1.5ºC Special Report was widely adopted and referenced by researchers globally with more than 100 citations. I was selected for the Global and Environment Change Early Career Award from the American Geophysical Union in 2019, which recognizes "outstanding contributions in research, educational, or societal impacts in the area of global environmental change".

My work related to the role of non-CO2 species has been well recognized as an important element to the solution package of climate change and has started to raise greater awareness of an "all hands on deck" approach to climate problems. My previous study working with integrated assessment modelers and policy advocates quantified the magnitude of warming due to uncontrolled use of HFC-based coolants/refrigerants, which can in itself consists of a surprising major chunk of projected warming despite a relatively small share in the economy. This alarming number of 0.5ºC warming has been quoted in numerous settings, including Secretary John Kerry's final remarks at Kigali, and thus contributed to the swift adoption of the Kigali Amendment to Montreal Protocol (adopted in 2016 and entered into force in 2019).