# Guest Editors' Introduction to the Special Issue on "Climate and the Earth System"

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The Journal of Agricultural, Biological and Environment Statistics (JABES) special issue on the Climate and Earth System highlights recent statistical develops that aim to refine our understanding of this complex system. New methods are required to process the massive environmental data that often fuels climate analysis and to properly account for uncertainty in the results. This special issue proudly features eight papers that span a wide range of computational and methodological problems related to the climate and earth system. In this brief introduction, we identify common themes among the papers and point to areas of future research.

**Key Words:** Climate models; Computational statistics; Extreme value analysis; Spatiotemporal data.

Rapidly melting ice sheets in Greenland and the recent record-breaking heat wave in Europe are just two examples of the ever more pressing topic of climate change and its societal impacts. While the basic scientific facts of climate change are well understood and widely accepted globally, questions of *quantifying* specific expected effects, and even more so, the *uncertainties* associated with these effects, remain unsettled in many cases. The Statistical and Applied Mathematical Sciences Institute (SAMSI) held a year-long Program on Mathematical and Statistical Methods for Climate and the Earth System (CLIM) during the academic year 2017/2018 to address some of these questions and broadly advance the urgently needed collaborations between climate scientists and mathematics and statisticians. While not limited to SAMSI CLIM participants, the special issue draws primarily from projects from this successful SAMSI program highlighting advances in the area of statistical research related to the climate and earth sciences.

The papers that comprise the special issue cover a wide range of application and methodological areas. However, a few common methodological themes emerge. First, it is clear that computation plays a central role in modern statistical analyses of the climate and earth system. In particular, new methods for massive spatiotemporal datasets are sorely needed. For example, Heaton et al. (2019) compare numerous state-of-the-art spatial prediction methods

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in terms of accuracy and computational speed on simulated and real data. This paper provides an excellent overview of research in this area and summarizes the incredible progress that has been made over the past decade on this challenging problem. Turning to the temporal domain, Lewis-Beck et al. (2019) use Hamiltonian Monte Carlo to efficiently process remote sensing data to identify crop growth signatures, and Barboza et al. (2019) compare Markov chain Monte Carlo and integrated nested Laplace approximations for palaeoclimate reconstruction using multiple sources of large time-series data. In fact, all of the papers in the special issue have a large computational component, and many develop algorithms tailored to the proposed methodology.

A second theme that emerged is the power of combining advanced statistical methods with scientifically derived numerical output. For example, Edwards et al. (2019) carefully develop statistical models and computational algorithms to train a stochastic model using climate model output to produce realizations of total precipitable water, surface temperature and wind speed that preserve the spatiotemporal correlation structure and the relationships between the climate variables. Guan et al. (2019) apply statistical calibration to a sea ice deformation model to give more realistic uncertainty quantification of future change. In particular, they develop image warping methods to account for model errors in the location and direction of major changes.

Finally, three papers develop new methodology for the extreme events that often have the largest immediate impact. Hewitt et al. (2019) develop a computationally efficient spatial approach to map return levels and apply their method to extreme rainfall probabilities in Colorado. While understanding the risk of extreme events at individual locations is vital, often the extreme events that have the largest impact are those that simultaneously affect many areas such as is often the case with floods. To understand the threat posed by simultaneous extreme events, Huang et al. (2019) develop a network model for extreme value analysis. In addition to quantifying risk, the impact of extreme events can be mitigated using short-term forecasting. Towards this end, Castro-Camilo et al. (2019) develop a new model to forecast extreme wind speed, a topic of high relevance to the renewable energy community.

In summary, the manuscripts provide excellent examples of the many directions statistical research related to the climate and earth system can take. They, however, just cover a minuscule portion of the many open and interesting problems that could benefit from the skills and insights of the statistics community. As a matter of fact, one would be hard-pressed to find an area of applied statistics that would not find ample applications in the climate and earth sciences. We sincerely hope that the remarkable work presented in this special issue serves as motivation for the statistics community to more broadly engage in and contribute to this important area of research. Given the urgency and societal relevance, there is no better time to do so than now!

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