AGU100 ADVANCING EARTH AND SPACE SCIENCE

Space Weather

EDITORIAL

10.1029/2018SW002083

Communicating Uncertainty and Reliability in Space Weather Data, Models, and Applications

Delores J. Knipp[1], Michael A. Hapgood[2], and Daniel Welling[3]

[1]Smead Aerospace Engineering Science Department, University of Colorado Boulder, Boulder, CO, USA, [2]RAL Space, STFC Rutherford Appleton Laboratory, Harwell Campus, Oxfordshire, UK, [3]Physics Department, University of Texas at Arlington, Arlington, TX, USA

Key Points:

- The SWE editorial board is strongly committed to having uncertainty and reliability quantified in future manuscripts
- We highlight relevant examples from recent space weather publications

Citation:
Knipp, D. J., Hapgood, M. A., & Welling, D. (2018). Communicating uncertainty and reliability in space weather data, models, and applications. *Space Weather*, *16*, 1453–1454. https://doi.org/10.1029/2018SW002083

Received 18 SEP 2018
Accepted 21 SEP 2018
Accepted article online 12 OCT 2018
Published online 27 OCT 2018

Abstract Space Weather Journal editors advocate for discussion of uncertainty and reliability in future journal manuscripts and throughout the space weather enterprise.

The US National Research Council (2006) noted that "All prediction is inherently uncertain and effective communication of uncertainty information in weather, seasonal climate, and hydrological forecasts benefits users' decisions …." Though no mention was made of space weather, the modern era of space weather observing, forecasting, and applications demands that modelers and practitioners provide estimates of uncertainties. To advance the discussion of uncertainty and reliability in the space weather enterprise, the Space Weather (SWE) editorial board has commissioned an AGU Grand-Challenge Manuscript on "Embedding uncertainty in space weather products and forecasts: Challenges now and in the future." We anticipate this forward-looking article will be a guide for future space weather studies and SWE manuscripts.

Background: As in terrestrial weather, the science behind space weather models and applications has limits: (1) We do not have a full understanding of magneto-electrodynamics, chemistry, or physics underpinning most space weather processes; (2) In many cases, to represent complex processes, we have to make approximations—essentially nesting models inside of models; and (3) Computer processing has limits, as do grids for representing the domains and subdomains for space weather. Perhaps more so for space weather than for terrestrial weather, there are observational constraints: In addition to the random and systematic biases in observations, much of the space weather regime is data-sparse or data starved. Space weather relies on a great deal of remotely sensed data—and some of the observations can be in conflict due to indirect or differing measurement techniques.

Where we are: A growing number of SWE Journal submissions have included discussions of uncertainty and/or reliability. Here are a few highlights. Cash et al. (2015) addressed the variability in predicted ejecta arrival time with varying input parameters for the ensemble modeling of the 23 July 2012 coronal mass ejection. Savani et al. (2017) noted that the uncertainty range on ejecta magnetic field magnitude provides a useful solution for predicting the uncertainty in geomagnetic storm strength. Subsequently, Scolini et al. (2018) quantified the influence of ejecta radius, ejecta opening angle, and other factors in predicting in situ plasma properties at 1 AU. Camporeale et al. (2016) addressed the propagation of uncertainties in radiation belt simulations and Riley and Love (2017) provided confidence intervals for a two types of probability distributions for a future extreme geomagnetic event comparable to the Carrington event. Murray et al. (2017) quantified (with error bars) that flare forecasts by the UK Met Office Space Weather Operations Center with humans in the loop were better than using raw model output alone. Recently, the SWE special collection Low Earth Orbit Satellite Drag: Science and Operational Impact (Zhang et al., 2018) included numerous papers discussing and showing uncertainty in their analyses. For example, Hejduk and Snow (2018) found that a priori knowledge of the approximate density-estimation error greatly aided satellite conjunction analysis (CA), even if the CA model itself is unaltered. Similarly, Bussy-Virat et al. (2018) presented an algorithm that accounted for atmospheric density uncertainties to more accurately assess collision risk. Regarding the role of ensembles, Owens and Riley (2017) showed how simple models of solar wind propagation can support the use of large ensembles (many hundreds of members) to provide an accurate measure of forecast uncertainty, an approach that would be computationally prohibitive using a three-dimensional Magnetohydrodynamic model. Further, Morley et al. (2018) reported that after accounting for uncertainty in the data driving, it is possible to determine where incorrect forecasts are due to the uncertainty, as well as where they are due to inadequacies in the model itself.

In most cases, uncertainty analysis is hard, nontrivial work. The efforts are well worth doing, as they markedly strengthen the manuscript and broaden understanding of our capabilities and limitations. This is being highlighted in multiple manuscripts from the developing Special Collection on Space Weather Capabilities Assessment: https://agupubs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1542-7390.SW_CASS. Going forward, the SWE editorial board is strongly committed to having uncertainty and reliability quantified in future manuscripts. To that end, SWE editors will be encouraging authors to include discussion of these topics at a level appropriate to the existing content of the paper. We will also ask that all proposers for SWE Special Collections agree to make uncertainty/reliability an integral part of some, if not all, manuscript submissions.

Acknowledgments
No new data were produced for this editorial.

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