Coupling Models and Observations to Probe Fundamental Physical Processes. B. Tremblay[1,2], K. Reardon[2], M. Rast [1] and M.D. Kazachenko [1,2]. [1]Laboratory for Atmospheric and Space Physics (3665 Discovery Drive, Boulder, Colorado, USA), [2]National Solar Observatory (3665 Discovery Drive, Boulder, Colorado, USA).

The Sun's atmosphere represents a unique testbed for deciphering fundamental plasma processes in regimes not accessible by laboratory experiments, as well as a template for a multitude of astrophysical settings. We here advocate that we can best enhance our understanding of this system through an integrative, data-driven approach that necessarily intertwines the interpretive power of state-of-the-art numerical simulations and the physical touchstone of cutting-edge, highly-resolved solar observations. The desired goal is a deep knowledge of how the solar atmosphere behaves across a range of temporal and spatial scales, and the ability to make projections about its dynamic behavior. From a broader perspective, these results will inform on very general phenomena such as magnetic reconnection, shocks, turbulence, multi-species plasmas, and, crucially, their interconnections.

We argue here for the importance of the coupling of observational efforts and numerical models throughout the lifecycle of research studies – from determining the signatures of physical processes, to designing observational strategies to best tease out key properties from the received signals, to the effective interpretation of the data grounded in the underlying physics. Future evolution of model and computational capacities will allow more robust data-assimilation techniques to be employed, allowing more direct and predictive comparisons to be made. We suggest that closer coordination with the terrestrial weather community, where such techniques have reached a much higher level of maturity, would be valuable in guiding the development of these tools in solar physics.

Such an approach will play an increasing role in the scientific exploitation of the 4-meter-diameter Daniel K. Inouye Solar Telescope (DKIST; Rimmele et al., 2020), funded by the National Science Foundation (NSF), revealing new details on the physical properties of the solar atmosphere. Such methods will likely become an essential component of future facilities such as ngGONG, FASR, and COSMO. It will also be an integral in multi-messenger heliophysics, combining Earth- and space-based facilities, enabling a holistic understanding of the heliosphere.