Chaos implies effective controllability of extreme weather

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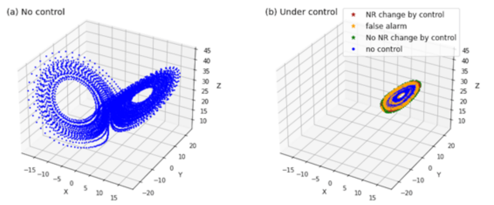
The Observing Systems Simulation Experiment (OSSE) is a very powerful approach to evaluate observing systems and data assimilation methods in numerical weather prediction (NWP). In the OSSE, we generate a nature run (NR) using a model and simulate observations by sampling the NR. An independent model run with data assimilation of the simulated observations mimics an NWP system, and we compare it with the NR to evaluate the observations and data assimilation method. In this study, we extend the OSSE and design the Control Simulation Experiment (CSE), in which we add perturbations to the NR and try to modify it to a desired state. Investigating what perturbations are effective to avoid a high-impact weather event would be useful to understand the controllability of such an event. Since the weather system is chaotic, and even more so for disturbances, small differences generally lead to big differences, particularly for high-impact weather events. This suggests potentially effective control, i.e., small interventions would lead to big differences for high-impact weather events. Chaos control has been studied extensively in the field of dynamical systems theory, but taking advantage of dynamical instability to avoid certain trajectories has not been a main focus to the best of the authors' knowledge. We first tested this idea with the Lorenz-63 3-variable model and performed an OSSE with an ensemble Kalman filter (EnKF). We extended the OSSE by adding very small perturbations (only 3% of the observation error) to the NR and found an effective approach to control the trajectory to stay in one side of the Lorenz's butterfly attractor without shifting to the other. Following the implications and understandings from the Lorenz-63 model experiments, we tested with the Lorenz-96 40-variable model to avoid the occurrences of extreme values, mimicking to avoid extreme events in NWP. Finally, we further extended the idea to test with realistic global and regional NWP models for a typhoon case and a local heavy rainfall case, respectively. This presentation will summarize the concept and methodology of CSE with some proof-of-concept demonstrations with the toy models and realistic NWP models. This is an attempt to a potential paradigm change of NWP research from decades of predictability to the new era of controllability.



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Bio-sketch of T. Miyoshi

Dr. Takemasa Miyoshi received his B.S. (2000) in theoretical physics on nonlinear dynamics from Kyoto University, and M.S. (2004) and Ph.D. (2005) in meteorology on ensemble data assimilation from the University of Maryland (UMD). Dr. Takemasa Miyoshi started his professional career as a civil servant at the Japan Meteorological Agency (JMA) in 2000. He was a tenure-track Assistant Professor at UMD in 2011. Since 2012 Dr. Miyoshi has been leading the Data Assimilation Research Team in RIKEN Center for Computational Science (R-CCS) and became Chief Scientist of RIKEN Cluster for Pioneering Research (CPR) and Deputy Director of RIKEN interdisciplinary Theoretical and Mathematical Sciences Program (iTHEMS) in 2018. Dr. Miyoshi's scientific achievements include more than 140 peer-reviewed publications and more than 180 invited conference presentations including the Core Science Keynote at the American Meteorological Society Annual Meeting (2015). Dr. Miyoshi has been recognized by several prestigious awards such as the Japan Geosciences Union Nishida Prize (2015), the Meteorological Society of Japan Award (2016), the Yomiuri Gold Medal Prize (2018), the Commendation by the Prime Minister for Disaster Prevention (2020), and the Award for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology (2022).