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Extended seasonal forecast of Antarctic Sea Ice using ANTSIC-UNet

Ziying Yang[1,2,3], Jiping Liu[4], and Rune Grand Graversen[3,5]
[1]Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
[2]University of Chinese Academy of Sciences, Beijing, China
[3]Department of Physics and Technology, Arctic University of Norway, Tromsø, Norway
[4]Sun Yat-sen University, and Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai, China
[5]Norwegian Meteorological Institute, Tromsø, Norway

Antarctic sea-ice variability affects the ocean and atmosphere both locally through thermodynamic processes and beyond the Antarctic regions remotely through dynamic processes, which may all change due to global warming. In this study, we develop the ANTSIC-UNet, a deep-learning model trained on physically enriched climate variables, to predict the extended seasonal Antarctic sea ice concentration of up to 6 months in advance. We assess the predictive skill of ANTSIC-UNet as regards linear trend prediction and anomaly persistence prediction in the Pan- and regional Antarctic areas using comparative analyses with two baseline models. Our results exhibit superior performance of ANTSIC-UNet for the extended seasonal Antarctic forecast. The predictive skill of ANTSIC-UNet is notably season-dependent, showing distinct variations across regions. Optimal prediction accuracy is found in winter, while diminished skill found during the summer can be largely attributed to the ice-edge error. High predictive skills are found in the Weddell Sea throughout the year, which suggests that regional Antarctic sea-ice predictions beyond 6 months are possible. We further quantify variable importance through a post-hoc interpretation method which indicates that ANTSIC-UNet has learned the relationships between SIC and other climate variables and the method therefore provides information on the physics of the model. At short lead times, on timescales of up to two months, ANTSIC-UNet predictions exhibit heightened sensitivity to sea surface temperature, radiation conditions and vertical atmospheric circulation conditions in addition to the sea-ice itself. At longer lead times, predictions are dependent on stratospheric circulation patterns at 7-8 months lead in addition to sea-ice. Furthermore, we discuss the potential of implementing physical constraints to enhance sea-ice-edge predictability.