Evaluation of Arctic Sea Ice Simulations Across Timescales using Global Coupled Models

Abstract:

The Arctic is warming faster than any other region on Earth, and the accelerating loss of its sea ice has raised both the scientific and the operational stakes of simulating and predicting the ice cover across timescales. This thesis evaluates how Arctic sea ice is represented and forecast in global coupled models, examining its systematic biases and regime dependent predictability at sub-seasonal to seasonal (S2S) scales across regional and seasonal domains, using observational and reanalysis datasets, a subset of CMIP6 simulations, and the global coupled S2S reforecast system at the National Centre for Medium Range Weather Forecasting (NCMRWF), India. A multi-model assessment of historical and SSP585 simulations in the sixth phase of the Coupled Model Intercomparison Project (CMIP6), with model skill evaluated against observed present-day sea ice concentration, shows that projected twenty-first century changes in sea ice concentration, thickness, and sea surface temperature under SSP585 far exceed historical variability, are strongest in September, and proceed at distinct regional rates, with the Barents Sea warming earliest in association with Atlantification and the first ice-free September emerging near mid-century. In the operational S2S reforecast system, a basin-wide underestimation of summer sea ice concentration is identified and traced to an excessive net surface heat flux, in which a dry low-level moisture bias enhances downwelling shortwave radiation and reinforces the ice-albedo feedback. Stratifying forecasts by the atmospheric regime at initialisation reveals that sub-seasonal predictability over the Barents-Kara and Greenland Sea is regime and season dependent. In particular, Ural Blocking reverses its influence over the Barents-Kara Sea between early and late winter, degrading skill in autumn but opening a window of opportunity in late winter. Finally, the thesis demonstrates the translation of the model forecast-based guidance into operational situational awareness support for an Indian scientific expedition to the Arctic, emphasizing the better utilisation of forecast for informed decision making and practical applications across scales.