Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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“Initializing Sea Ice Thickness and Quantifying Uncertainty in Seasonal Forecasts of Arctic Sea Ice”

School of Earth and Ocean Sciences

Thursday, November 16, 2017
10:00 A.M.
Bob Wright Centre
Room A319

Supervisory Committee:
Dr. William J. Merryfield, School of Earth and Ocean Sciences, University of Victoria (Co-Supervisor)
Dr. Adam Monahan, School of Earth and Ocean Sciences, University of Victoria (Co-Supervisor)
Dr. Michael Sigmond, School of Earth and Ocean Sciences, UVic (Member)
Dr. Slava Kharin, Research Scientist, Canadian Centre for Climate Modelling and Analysis (Outside Member)

External Examiner:
Dr. Edward Blanchard-Wrigglesworth, Department of Atmospheric Sciences, University of Washington

Chair of Oral Examination:
Dr. Yi Yi, Department of Geography, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies
Abstract

Arctic sea ice has undergone a dramatic transformation in recent decades, including a substantial reduction in sea ice extent in summer months. Such changes, combined with relatively recent advancements in seasonal (1-12 months) to decadal forecasting, have prompted a rapidly-growing body of research on forecasting Arctic sea ice on seasonal timescales. These forecasts are anticipated to benefit a vast array of endusers whose activities are dependent on Arctic sea ice conditions. The research goal of this thesis is to address fundamental challenges pertaining to seasonal forecasts of Arctic sea ice, with a particular focus placed on improving operational sea ice forecasts in the Canadian Seasonal to Interannual Prediction System (CanSIPS).

Seasonal forecasts are strongly dependent on the accuracy of observations used as initial condition inputs. A key challenge initializing Arctic sea ice is the sparse availability of Arctic sea ice thickness (SIT) observations. I present on the development of three statistical models that can be used for estimating Arctic SIT in real time for sea ice forecast initialization. The three statistical models are shown to vary in their ability to capture the recent thinning of sea ice, as well as their ability to capture interannual variations in SIT anomalies; however, each of the models is shown to dramatically improve the representation of SIT compared to the climatological SIT estimates used to initialize CanSIPS.

I conduct a thorough assessment of sea ice hindcast skill using the Canadian Climate Model, version 3 (one of two models used in CanSIPS), in which the dependence of hindcast skill on SIT initialization is investigated. From this assessment, it can be concluded that all three statistical models are able to estimate SIT sufficiently to improve hindcast skill relative to the climatological initialization. However, the accuracy with which the initialization fields represent both the thinning of the ice pack over time and interannual variability impacts predictive skill for pan-Arctic sea ice area (SIA) and regional sea ice concentration (SIC), with the most robust improvements obtained with two statistical models that adequately represent both processes.

The final goal of this thesis is to improve the quantification of uncertainty in seasonal forecasts of regional Arctic sea ice coverage. Information regarding forecast uncertainty is crucial for end-users who want to quantify the risk associated with trusting a particular forecast. I develop statistical post-processing methodology for improving probabilistic forecasts of Arctic SIC. The first of these improvements is intended to reduce sampling
uncertainty by fitting ensemble SIC forecasts to a parametric probability distribution, namely the zero- and one- inflated beta (BEINF) distribution. It is shown that overall, probabilistic forecast skill is improved using the parametric distribution relative to a simpler count-based approach; however, model biases can degrade this skill improvement. The second of these improvements is the introduction of a novel calibration method, called trend-adjusted quantile mapping (TAQM), that explicitly accounts for SIC trends and is specifically designed for the BEINF distribution. It is shown that applying TAQM greatly reduces model errors, and results in probabilistic forecast skill that generally surpasses that of a climatological reference forecast, and to some degree that of a trend-adjusted climatological reference forecast, particularly at shorter lead times.