[*N.B. This version of the report does not include Appendices.*]

Canadian Sea Ice and Snow Evolution: The CanSISE Network: Second Annual Progress Report

SECTION 1. INTRODUCTION, PROGRESS ON PROJECTS AND DELIVERABLES

The CanSISE Network is a partnership between Canadian Universities, Environment Canada (EC), the Pacific Climate Impacts Consortium (PCIC), and NSERC. The Research Areas/aims of CanSISE aim to (A) significantly improve EC's capacity to forecast seasonal snow cover and sea ice (S/SI) and related hydroclimate variables on timescales ranging from seasonal to the decadal; to (B) support EC's and PCIC's efforts to quantitatively attribute the impacts of human influence on S/SI related process; and to (C) improve scientific understanding of S/SI processes and their coupling to atmosphere-ocean circulation. Through the research undertaken, CanSISE also aims to produce Deliverables in which (1) EC's S/SI prediction systems are evaluated, (2) an assessment of S/SI variability in the near-term (next 10-20 years) is produced, (3) human influence on S/SI and related impacts is analyzed, and (4) key aspects of future observational network design are developed. CaanSISE is unique in cryospheric research Canada in its emphasis on collaborative research involving rigorous comparison of a large suite of currently available observations to models in the context of model uncertainty, observational uncertainty, and climate variability. Its activity comprises a focus on EC numerical prediction systems in an international context involving the activities of modeling centres worldwide. The Network's resources are devoted almost entirely to salaries and training of student and postdoctoral researchers (highly qualified personnel or HQP).

In this Annual Report, we were asked to summarize progress and also address referee comments and concerns from last year. These comments were constructive and expressed relatively few concerns about our research progress or plans, but some important points about our organization and communications. We will try to address many of them through comments in the text or in footnotes. We summarize and highlight some key points: Project Year 1 (2013-2014) focused on setup of the Network, particularly HQP hiring, and culminated in a productive all-network Workshop 1 in Victoria. During this Project Year 2, the CanSISE network became much better established. Project Year 2 featured (1) recruitment of new HQP to fill most available positions[1], (2) noteworthy research progress on the 20+ Network projects and subprojects, (3) initial applications that are anticipated to lead to improvements in the EC seasonal prediction systems and benefits for our PCIC partners[2], (4) the initiation and half completion of a major new computational project – the CanSISE "Large Ensemble" in support of Research Area B and C, with resources committed to serve the data as a legacy of the project[3], (5) a series of four regional meetings of the Network for Network PIs and enhanced participation by HQP to share results[4], (6) new Canadian and international partnerships culminating in a proposal submitted to the Belmont Forum's Arctic Call whose Canadian contribution was lead by the CanSISE team, and (7) improved web presence[5] and visibility of the Network's activities in international meetings. Our simple management approach, which comprises regular contact with the Network membership, the Steering Committee, Advisory Panel, and NSERC through monthly telecons and videocons, has run smoothly. Our overall budget expenditures also align better with our original plans: while in the startup Project Year 1, we

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[1] Note to referees: HQP recruitment delays, a significant concern for CanSISE and for the referees, were primarily caused by a frustratingly slow visa process for non-Canadian HQP. Some PIs also faced difficulty in recruiting qualified candidates, a situation that is improving now.

[2] Referees noted knowledge transfer as an issue of interest: in this report we highlight good examples of our results being immediately useful for our partners in EC and PCIC.

[3] Data management was another referee concern, which we will partially address this year.

[4] Referees commented on apparently low levels of participation by HQP in research and its dissemination. The research and its dissemination this Project Year is largely driven by HQP.

[5] These improvements were in part in response to the referees' indication that our website did not meet expectations as of December 2013.

spent only 40% of allocated funds and needed to reprofile our entire budget, in this Project Year 2 we spent well over 85% of our budget and will propose a relatively modest carry forward. In Project Year 3 we will continue to pursue research in most of our projects; hold CanSISE Workshop 2, which is centred on Theme B; make progress on our Deliverables by completing most of Deliverable 1, gathering the principal input for Deliverable 2; and beginning the work for Deliverable 3.

As in last year's report, we next describe progress in the CanSISE projects and Deliverables (rest of Section 1). We then discuss the budget, spending, and resource plans (Section 2 and Appendix A); the operation of the Network including interaction with partners and HQP (Section 3); and conclude with a few points of focus and a summary (Section 4). We append to this report a membership list for CanSISE (Appendix B), and a list of presentations and publications (Appendix C).

Projects and Deliverables

1. For **Research Area A (***S/SI Prediction and Projection***)**, **Project A1** (*Improved observational datasets for initialization and verification of S/SI predictions***)** includes work to compile and improve existing retrieval methods and data records, and to quantify inter-dataset consistency. In **Project Year 2** co-PI Derksen and other EC collaborators in CanSISE completed their contributions to the European Space Agency 'GlobSnow' project, focusing on evaluation of the GlobSnow SWE microwave snow modeling component across the Arctic and subarctic. For modelling applications in CanSISE, the GlobSnow data record was compared to a number of gridded SWE analyses (land surface models driven by meteorology from NASA MERRA; ERA-interim and GLDAS), in order to determine the amount of spread between independent SWE products. CanSISE support of RA Mudryk was critical to this effort. On the sea ice side, York University's activities, under the supervision of co-PI Haas, in support of Project A1 included 1) compilation of data from snow on sea ice and drift velocities from ice mass balance buoys (IMBs), 2) compilation of data from new airborne ice thickness surveys in the Beaufort Sea, north of Ellesmere Island and Greenland, and 3) improved data processing and validation of CryoSat ice freeboard and thickness retrievals. York's related research contributions to projects will be described below. *Project A1 is largely complete as scheduled,* although our set of data products will be updated as new versions become available through the life of the project. Applications of these datasets are described throughout the text[6].
2. For **Project A2.1** (*Assessment of prediction skill for S/SI and related variables*), in the area of snow, Merryfield (CCCma, co-PI) and Kharin (CCCma, collaborator) identified appropriate datasets for verification of CanSIPS seasonal predictions of snow water equivalent (SWE) for several SWE reanalyses (ERA-Interim, MERRA-Land, MERRA). They found that skill scores are highly dependent on the dataset used for verification, with MERRA providing much higher scores than ERA-Interim and MERRA-Land. When verified against MERRA, CanSIPS skills for monthly and seasonal prediction of SWE are surprisingly high (higher than for temperature) within a given snow season. This is believed to be a result of the realistic initialization of SWE by CanSIPS, together with the tendency of SWE anomalies to persist through the snow season. By contrast, the skill of SWE predictions initialized before the snow season, though generally positive, is far more modest. In the area of sea ice model representation, current work falling under Project C1.2 will be applied to CanSIPS model output in Project Year 3.
3. **Project A2.2** (*Improved CanSIPS snow/land surface initialization*), continued on three fronts. First, Guelph PDF Thomas and Guelph co-PI Berg have been collaborating with Merryfield to evaluate the influences of snow and soil moisture initialization of the Canadian Climate Model version 3 on prediction of the springtime (April-May) near surface air temperature. Comparison of forecasts

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[6] Regarding referee comments about data management and dissemination: CanSISE observational data has been gathered under projects separate from CanSISE and thus cannot be easily managed by CanSISE for general distribution. This is not the case for model output originating from the project as will be discussed below.

using a “realistic” initialization vs. scrambled land surface initialization linked forecast noise to the wrong initialization of SWE and frozen component of the soil. A manuscript on this analysis was completed and recently submitted for publication; *this represents effective knowledge transfer of University research to EC CanSIPS initialization development*. CCCma PDF Sospedra-Alfonso continued his work on assessing the realism with which SWE is initialized in the CanSIPS hindcasts, using in situ measurements from Canadian stations and gridded analysis and reanalysis products for comparison. A paper co-authored with Toronto PDF/RA Mudryk, Merryfield and Derksen was submitted in November 2014. Based on previous undergraduate work Guelph M.Sc. student Williamson wrote a manuscript that examines the potential for observational networks used for soil moisture monitoring to capture freeze thaw processes. In Project Year 3 and beyond Williamson's research will focus on the development of soil freeze thaw observation network for comparison with satellite data from the upcoming Soil Moisture Active Passive Satellite and with land surface models.

4. The complement to the previous project on the sea ice prediction side is **Project A2.3** (*Improved CanSIPS sea ice initialization*), which advanced well ahead of schedule. First year UVic Graduate student Arlan Dirkson has developed a statistical method based on singular value decomposition that estimates the Arctic sea ice thickness distribution using past statistical relationships between ice thickness and variables that are observable in real time, such as sea ice concentration and sea level pressure. This method already improves considerably on the method currently used to initialize sea ice thickness in CanSIPS seasonal predictions, and *thus represents another practical contribution of CanSISE research to improvements of EC's operational prediction*.
5. The objective of **Project A2.4** (*Streamflow predictions/Western Cordillera*) is to bring CanSIPS forecasts to the regional scale using statistical/dynamical downscaling for predicting the Fraser River Basin's streamflow on seasonal timescales. Identification and evaluation of the best performing snow water equivalent (SWE) gridded products over British Columbia is key to creating a high-resolution model for this purpose. In Project Year 2, ERA-Interim/Land, MERRA and MERRA-Land reanalyses have been added to previous datasets by UBC PhD student Andrew Snauffer. The analysis indicates overall large negative biases relative to snow concourse measurements by the BC Snow Survey Program, with the largest biases typically occuring in the Coast Mountains. All evaluated products underestimate SWE in both the Coast Mountains and the Interior Plateau except for ERA-Interim/Land. MERRA and the CMC Snow Analysis had lowest relative biases in the Northern Plateaus and Great Plains, respectively. Overall ERA-Interim/Land performed the best of the evaluated products in BC. For Project Year 3, results of the SWE gridded product evaluation in British Columbia will be written up for journal submission. In the UNBC group, an evaluation of the EcoHydRology SnowMelt model found significant potential for estimating interannual variability relative to other evaluated gridded products. Driven by ERA-Interim temperature and precipitation values, the model achieved an average correlation of 0.7 when averaged over all stations and survey months, whereas the best preforming gridded products were found to average 0.5 over all of BC. Further improvements in the representation of end of season snowmelt may be possible using a multi-layer snow model. Project Year 3 for this group will focus on modification and testing of the EcoHydRology SnowMelt model in a two-layer design to help create a high-resolution SWE dataset for BC, which will then be adapted to downscale CanSIPS forecasts.
6. **Project A3** (*Analysis of interannual to multidecadal S/SI predictions and projections*) complements the focus on EC models; it analyzes CMIP5 output and climate simulations generated by University scientists. In Project Year 2, Mudryk and Toronto PDF Bichet analyzed snow cover extent trends in the NCAR CESM Initial Condition Large Ensemble in comparison to their previous work on NCAR CCSM4. Disagreement among models on the trends, internal variability among trends, and observational uncertainty among the trends were all comparable; extracting robust trends to compare with observations therefore proves challenging. In Project Year 3, work comparing the

CESM Large Ensemble and the CanSISE Ensemble (see Project B4) snow trend response will continue.

7. For **Project A4** (*Assessing limits to S/SI predictability*) Sospedra-Alfonso, Merryfield and Kharin examined the potential predictability (PP) of snow in CanSIPS as a function of location, forecast initialization date and lead time. PP was found to be largest in midwinter in regions having substantial snow accumulation, with much smaller values being found in early and late in the snow season and in locations with occasional or intermittent snow cover. Because the onset of the melt season acts as a PP "barrier", PP time scales tend to be largest after the start of the snow season, but well prior to peak snow accumulation.
8. For **Research Area B (***Attributing change in S/SI and modelling its impacts*), **Project B1** (*Drivers of S/SI change: High latitude temperature and precipitation*), CanSISE researchers led by PCIC PDF Najafi under co-PI Zwiers quantified the separate contributions to observed Arctic temperature change from well-mixed greenhouse gases, other anthropogenic forcing agents (which are dominated by aerosols) and natural forcing agents. *This high-profile CanSISE-supported work is now accepted in* Nature Climate Change. Long-term trends in hydroclimate have also been analysed. Warming is observed across Canada in the instrumental records. Precipitation has also generally increased. Changes in stream flow, snow cover etc., are consistent with what would be expected from changes in temperature and precipitation (Vincent et al. 2014). Decadal variability in the climate system contributes to uneven distribution of trend, i.e., stronger warming in the west and weaker warming in the east. In addition, an updated analysis of high latitude precipitation changes has been submitted, which uses CMIP5 simulations and an observational dataset that has been extensively updated with recent observations and having larger spatial coverage. The group is now able to more confidently attribute the observed increase in high-latitude precipitation to human influence (Wan et al. 2014). This work represents a key contribution to EC's climate analysis and assessment activities. In Project Year 3, a separate detection and attribution analysis for Canadian temperatures will be undertaken.
9. Also in the PCIC group, in **Project B2** (*Detection and attribution of northern hemisphere SCE changes*), causes of the decline in Northern Hemisphere SCE are investigated using CMIP5 simulations from models that performed the full complement of historical forcing experiments. A range of observational SCE data products including the NOAA Northern Hemisphere climate data record (CDR) for snow cover extent, GLDAS, ERAInterim and MERRA reanalyses are considered. NOAA and GLDAS have been identified as the relatively more reliable observational records. Formal detection and attribution analysis has been performed which suggest further investigation of the uncertainties pertained to observational records in Project Year 3.
10. For **Project B3** (*Implications of precipitation and snow cover changes on water resources*), UNBC PDF Kang under co-PI Déry performed retrospective simulations of the Variable Infiltration Capacity (VIC) model for the hydrology of the Fraser River Basin (FRB) for 1948-2006, over 11 major sub-watersheds. From 1948 to 2006, the ratio of spatially averaged maximum SWE to runoff (RSR) exhibits a significant declining trend in 9 of the 11 sub-watersheds. RSR is found in a separate analysis to decreases significantly in response to recent warming trends, when these are imposed in isolation from precipitation trends. Results were compared to those from the PCIC group and published by Kang et al. in J. Hydrometeorology. The PCIC group is undertaking a broader study on detection and attribution of hydrologic changes for the Fraser, Peace, Upper Columbia, and Campbell basins, for CMIP5 simulations with different forcings. For this component of Project B3, in Project Year 2, hydrological indicators have been selected and a statistical emulator of the VIC model is being tested. The PCIC group is also comparing hydrological responses to climate change in the hydrologically distinct regimes of western Canada and the western United States, employing long-term stream-flow observations and high resolution PRISM climate data. In Project Year 3 they are updating the analysis for Western Canada watersheds. Also in Project Year 3, the UNBC group's new PDF Siraj ul Islam will conduct further VIC model

simulations focusing on recent trends, test the VIC model's sensitivity to various forcing datasets, and carry out simulations of the FRB for various future climate scenarios. PCIC and UNBC will collaborate on detection attribution studies for Western Canada. *This project provides an important example of how CanSISE is contributing to PCIC's regional hydroclimate prediction mandate.*

11. For **Project B4** (*Detection and attribution of Arctic sea ice and snow cover extreme* events), work has begun on event attribution analysis using the *CanSISE Large Ensemble* (LE), which is an initial-condition ensemble of coupled simulations from CanESM2 (CCCma) and CESM1 (U of Toronto and NCAR). An important milestone achieved for this project is the completion of a large ensemble of 50 historical and 50 NAT simulations for the 1951-2020 period for the CanSISE network and collaborators by CCCma. *This contribution represents an important example of productive interaction between EC scientists and the broader Canadian modeling community*; the main design discussion for these experiments took place within CanSISE meetings, while the timely completion of this represents an important legacy for CCCma's current CMIP5 project effort. This data was immediately shared with the CanSISE and Changing Cold Regions Networks (see Section 3) on completion of the integrations via an external server set up by EC, and being in standard CMIP5 format can be easily shared with the international community. *This dataset is thus an important legacy of the CanSISE project*[7]. In Project Year 3, a companion ensemble with NCAR CESM led by Toronto PDF Bichet and Toronto RA Mudryk is being undertaken by the University of Toronto group, whose completion depends in part on Compute Canada resource allocations for 2015. This dataset will also be documented and made publicly available on completion using a storage server that will be purchased this project year (see footnote 7).

    Besides this effort, this year UVic Ph.D. candidate Mueller under Zwiers will update previous detection and attribution studies on SIE using recent data and CMIP5 simulations. A study on the roles of internal variability and forced responses in Hydroclimatic Extremes in high latitude regions, and a comparison with high and midlatitudes, has also been undertaken by the UVic/PCIC group. The effects of internal variability and forced responses on hydroclimatic extremes are quantified using CMIP5 and CanESM2/CESM1 large ensemble data. This year, the group has analyzed the CMIP5 ensemble for hydroclimatic extremes and compared it with observations, and a refined regional division of North America into 9 geographic regions has been designed. In Project Year 3, the sea ice and hydroclimate event attribution analysis on the current CanSISE LE will be pursued.

12. For **Research Area C** (*Snow and sea ice processes and climate interactions*), for Project Year 2 we have broadened **Project C1.1-i** from *Snow-albedo feedback* to *Snow-albedo feedback and other climate interactions*. In snow-albedo feedback work, Waterloo PhD student Thackeray under co-PI Fletcher has demonstrated the impact that snow parameterizations have on snow albedo feedback in (SAF) forested areas in the NCAR CLM4 land model. The group will shortly submit a follow-up publication examining the impact of canopy snow on the seasonal evolution of albedo in the full suite of CMIP5 models including CanESM2. In collaboration with Lawrence (NCAR), Thackeray is also producing a diagnostic quantifying biases in simulated snow and albedo, for the International Land Model Benchmarking (ILAMB) Project. CanSISE UG Intern Woerthle, at Waterloo, documented and improved code to compute SAF from model output; this code has now been released to the community. He then analysed links between black carbon (BC) deposition and SAF in multiple model simulations. In the broader area of snow-climate interactions, Sospedra-Alfonso, Merryfield and CCCma Visiting Fellow Joe Melton compared the impact of temperature and precipitation on snowpack variability as a function of altitude at a large set of measurement sites in the US Rocky Mountains. (Data records from mountain sites in western Canada were found to be too incomplete for such an analysis to be performed.) It was found that a threshold "effective" altitude exists near 1500 m, below which interannual snowpack variability is mainly controlled by

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[7] This emphasis is in response to referee comments on data management and dissemination.

temperature anomalies, and above which snowpack variability is mainly controlled by precipitation. These results bear on understanding the dynamics, predictability, and sensitivity to climate change of Western Cordillera snowpack. Finally, former Toronto UG student Mohajerani (now a Ph.D. student at UC Irvine) submitted and will submit a revised version of a paper with Kushner, Brown, and Derksen that shows that the proposed connection between October Eurasian snow variability and wintertime Northern Hemisphere climate variability is strongly dataset dependent. The observational study is important because simulating this connection has been used as a benchmark performance metric for climate prediction systems.

13. **Project C1.1-ii** (*Sea-ice albedo feedback*) is slated to begin in **Year 3**. In preparation for this project, in Project Year 2 NSERC summer undergraduate student Lee worked with Kushner to continue last year's project of NSERC summer UG Machemy on simplified dynamical representations of sea ice concentration and thickness trends in the CMIP5 models following the approach of Massonnet and others.
14. **Project C1.2** (*Changes of wind-driven ice drift and deformation in relation to ice thickness variations in observations and GCMs*) CanSISE Intern UG summer student Pittana at York compared observations of seasonal variations of snow on sea ice from IMBs (see Project A1) with reanalyses and simulations from NCEP, ERA-40, and CanCM3 and 4. Results showed that seasonal snow accumulation partially compares well in reanalyses and models with observations, considering that the IMB measurements represent measurements through space and time along the drift path of the ice, and that they observe local conditions at the buoy site rather than average snow conditions in a larger region corresponding to a model grid cell. In some cases, individual snow fall events were represented both in the observations and reanalyses. However, overall there were differences of more than 100% between total amount of snow accumulated over a year, and with the timing of snow melt onset. The latter was particularly pronounced with the CanCM model results, which showed the seasonal disappearance of snow a month before it started to melt in reality. The identified differences are large enough to likely impact the winter mass balance and evolution of ice mass balance into the summer. Initial comparisons of Arctic and Antarctic sea ice observations with CCSM4 model simulations has shown large differences with respect to ice concentration, ice thickness, and ice drift. In Project Year 3, the gained results and experiences will be applied to CanCM and CanSIPS model output.
15. For **Project C1.3** (*Towards improved sea ice physics and dynamics in the Canadian GCMs*) in Project Year 2, the McGill group's work led by PDF Slavin under co-PI Tremblay will submit a paper on vertical ocean heat fluxes beneath Linear Kinematic Features as a potential mechanism for rapid sea-ice decline in the Arctic. The paper will quantify, using in-situ observations, the impact of large ocean heat fluxes beneath active sea ice leads on the Beaufort Sea ice mass balance. It was found that lateral advection of heat from Pacific summer and winter waters in the Beaufort Sea, at depth just beneath the Near Surface Temperature Maximum, is too important (and not well constrained enough) to assess the temporal changes of the top 120 m heat content of the Arctic Ocean and to quantify the vertical ocean heat fluxes into the mixed layer, beneath active sea ice leads. Idealized simulations were used to back out estimated vertical ocean heat fluxes beneath active LKFs. The McGilll group's Ph.D. student Desjardins examined the fate of ocean heat as it enters the Arctic Ocean from the Fram Strait, the Bering Strait, and Barents Sea, in NCAR CCSM3 and CCSM4, which have a widely differently different response in future climate change scenarios. The two versions provide distinct physical mechanisms and rates of projected sea ice loss strongly influenced by heat through the main Arctic Ocean gates. In Project Year 3 this work will be completed and manuscripts submitted.
16. **Project C2.1** (*Changes in sea ice extent and impacts on circulation*) is a topic of considerable interest and has proceeded in three areas. 1) In a CCCma project led by PDF McCusker, supervised by co-PI Fyfe, the effects of historical sea-ice loss on remote climatic changes have been isolated by prescribing Arctic sea ice loss from two different observational datasets to an atmosphere-land

model (CanAM4, the atmospheric component of CanCM4). These simulations have allowed for the separation of the climate effects of forced (human-induced) sea ice loss and the climate effects of (random) sea ice changes induced by internal variability. While all scenarios exhibit a robust, shallow Arctic warming and a tendency for lower Arctic sea level pressure in autumn and winter, the pattern and magnitude of circulation change outside the Arctic and at upper levels varies widely across simulations. The results suggest that mid-latitude changes to observed Arctic sea ice loss are dominated by internal variability in the sea ice loss patterns. The work will be written up for publication in Project Year 3. 2) The Toronto group's Ph.D. student Blackport also led a modeling study on the teleconnected response to sea ice loss driven by an imposed change in sea ice albedo in multicentury integrations of the coupled CCSM4, carried out with Compute Canada resources. In the coupled simulation, oceanic adjustment drives a reduction in sea ice thickness throughout the year, but as in the McCusker study the atmospheric mean circulation response is only pronounced in the Arctic boundary layer. In particular it is found that the temperature response to sea ice loss is subject to strong internal variability over the Eurasian continent. A very robust result is a pronounced reduction in temperature variability in response to sea ice loss, which is centred over the Arctic Ocean but extends into North America. In Project Year 3, this work will be extended to sea ice loss experiments in CESM1. 3) The McGill group's Ph.D. student Gervais is seeking to identify the role of sea-ice loss on air masses and high- or mid-latitude atmospheric circulation using Self-Organizing Maps (SOM) that extract dominant patterns of equivalent potential temperature at 850hPa in the Community Earth System Model (CESM) Large Ensemble RCP8.5 (2006-2100). The focus is on the seasonal transitional period when large inter-annual variability (from ice covered to mostly ice free) is simulated in the Pacific sector or the Arctic. Results show a reduction in the frequency of a particular low equivalent potential temperature pattern and an increase in the frequency of patterns of warm/cold anomalies over the North American continent. In Project Year 3, preliminary results suggesting a relationship between January-February sea ice concentration in the Chukchi sea, and equivalent potential temperature over North America, hypothesized to involve a downstream teleconnection through equivalent potential temperature patterns, will be further investigated.

17. **Project C2.2** (S/SI response to teleconnected forcing) is scheduled to start in Project Year 3, but has advanced for the last two years with Toronto PDF Bichet in collaboration with Terray (CERFACS) and Fyfe (CCCma). Bichet has derived an improved methodology to estimate the forced component of climate change in sea surface temperature and sea ice, in a paper now in revision for Climate Dynamics. A preliminary project undertaken by Toronto graduate student PHD01 for this project was discontinued as the results were not promising. Efforts for Project Year 3 will focus on assessment of how the estimated patterns can drive regional climate anomalies in snow and high latitude temperatures, using the NCAR CAM5 atmosphere/land model.
18. For **Project C3.1** (*Declining SCE: Characteristics and causes*), work by Research Assistant Hernández-Henriquez (UNBC) focused on identifying the mechanisms contributing to recent springtime SCE reductions in North America and Eurasia (Brown et al. 2010; Derksen and Brown 2012), including determining the role of latitude and elevation on observed snow cover trends, and establishing that snow-albedo feedback plays a critical role in observed SCE trends. Work on this will be submitted this Project Year. In Project Year 3, the UNBC group will establish Northern Hemisphere SCE trends at the grid point scale to determine which regions are undergoing significant reductions or increases in SCE, continue to identify mechanisms contributing to recent springtime SCE reductions in North America and Eurasia, and further explore the role of the snow-albedo feedback on other climatic variables such as air temperature and precipitation phase.
19. Last year, we reported on some progress in **Project C3.2-i** (*Changes in sea ice area and type in the Canadian Arctic Archipelago*) and **Project C3.2-ii** (*Changes in pan-Arctic SIE, thickness and snow on ice*), although these were originally envisioned as beginning in Project Year 4 (2016-2017). The York group's sea ice thickness work reported in A1 and A2.3 is related to this, and Howell has

continued investigations of Canadian Arctic Archipelago (CAA) sea ice exchange, as reported in CanSISE regional meetings this year; we will report on these projects further in subsequent years.

20. For the CanSISE Network Deliverables, regarding **Deliverable 1** (*Assessment of S/SI Biases, Projections, and Predictions in the Canadian GCMs*) we reported on preliminary results from diagnostic Projects in Research Areas A and C on CanSIPS, CanCM3, CanCM4, and CanESM2 and committed to writing up these results as a brief report this Project Year. We instead decided not to create the Deliverable 1 report yet because it is only after this Project Year that we have enough new and interesting results that stem from CanSISE activities to merit a synthesis. *We will thus produce the report on Deliverable 1 in Project Year 3.* This report will be posted on the CanSISE website, and highlighted to EC management. Depending on the outcome of the report, other publication plans will be considered. Progress on Deliverable 2 (*Assessment of Canadian Snow and Sea Ice for the next decade*) will be reported at the CanSISE Workshop 2 in March 2015. In Project Year 3, now that the CCCma contribution to the CanSISE Large Ensemble is underway, project B4 can begin to provide input on Deliverable 3 (*ACRE – Attribution of Cryospheric Events*). All Deliverables continue to proceed as scheduled.

SECTION 2. BUDGET AND PLANS

Table 1 (after Section 4) summarizes budgeting and spending in Project Year 2, anticipated carryover into Project Year 3, and Project Year 3 planned expenditures. Shown in the table are Project Year 2 award amounts, actual expenditures from 01/02/14-30/09/14, projected expenditures from 01/10/14-31/01/15, and the estimated carryforward for Project Year 3. Project Year 2 spending was about $690K of the original $790K awarded, resulting in about 12% carry forward. This carry forward reflects delays in hiring of students and technical/professional assistants for Project Year 2 and a shift of the salary of L. Mudryk from CanSISE to Environment Canada where he is currently on a term contract. These factors led to about a $90K underspend. In addition, lower than anticipated Project Year 2 spending on dissemination costs added another few thousand dollars. The large majority of the Project Year 2 carry forward is expected to be spent in Project Year 3 with additional hiring.

Other relatively minor budget points: in Project Year 2, we spent $7K more then planned to cover the salary adjustments for R.Christensen (Climate Research Project support) for Project Years 1 and 2, and spent about $17K more than planned to cover the cost of regional meetings, and a higher than anticipated demand for HQP conference travel funds towards the end of Project Year 2. Because we have a net carry forward it was easy to absorb these changes with our current funds.

In Table 2 we list the carryover for each category into Project Year 3, the budget associated with the funds awarded by NSERC, the Project Year 3 Planned Expenditures, accounting for adjustments (Column 4) that increase travel budget and R. Christensen's salary by drawing from unspent HQP salary, publication cost, and outreach/communications. (Note that the drawdown in HQP salary is about $14K of $800K or ~2% of the HQP budget.)

We request from NSERC this year Project Year 3 funds in the amount of $774,979, as planned.

Section 3. INTERACTION WITH PARTNERS, RESEARCH TEAM AND TRAINING

The CanSISE Network management and partnership model hinges on regular communication via regional meetings and monthly telecons. These telecons continue to alternate between entire-Network and steering committee (SC) meetings, with every other SC meeting including the Advisory Panel (AP). Often, NSERC staff have also attended. The telecons cover primarily the business of the network such as HQP recruitment, funding issues, and workshop planning. Minutes for these meetings are posted for members on the CanSISE website www.cansise.ca which was initially set up in February 2013. This year we held regional meetings with our partners at the Canadian Ice Service in Ottawa, at the University of Victoria, and at the University of Toronto. All meetings are run with Go To Meeting software and slide sharing capability and most meetings have involved remote presentations. The regional meetings have continued to highlight HQP contributions and are available at http://www.cansise.ca/events-and-meetings[8], which were dominated by HQP presentations.

Most of our Projects and Deliverables involve growing collaborative interactions for research projects and for ongoing planning. EC's contribution to the Canadian modeling community through the CanSISE Large Ensemble, particularly from Scinocca, Kharin, and Fyfe, is especially noteworthy. The University teams in Ontario have interacted very successfully with EC observational and prediction scientists. As for last year, we list key collaborations between partners: Berg/Merryfield/Kharin, Haas/Howell/Derksen, Kushner/Derksen/Brown, Kushner/Fyfe, Fletcher/Derksen/Brown, Zwiers/Zhang/Gillett, Déry/Brown/Derksen, Déry/Zwiers.

Encouraged by NSERC, Kushner led a CanSISE contribution proposal to the Belmont Forum's Arctic Call and engaged EC scientists inside and outside of CanSISE including G. Smith (MRD), A. Tivy (CIS), and S. Howell and X. Wang (CRD). The focus of this proposal, led internationally by CanSISE AP member Bitz (U. Washington), is on collaborative research related to prediction of sea ice on subseasonal timescales, which represents a new direction for CanSISE research related to similar research being undertaken in EC.

Our current understanding is that EC management continues to be aware of and is satisfied with our rate of progress. Significant evidence for this is that EC management has provided considerable support for our activities — the CanESM contribution to the CanSISE LE is a signature example of in kind support. EC personnel attend almost all our telecons as appropriate to their roles. We are meeting the challenge set in the last report for the network as a whole to become more familiar with the EC model output that has now been provided from CMIP5 and CanSISE LE output datasets.

After two years, CanSISE has begun to build an international profile and broader connections. Kushner has been asked to represent CanSISE at the NOAA Arctic Research Planning Workshop (Boulder), the International Astronautical Conference (Toronto), the Transatlantic Science Conference (Toronto), the WWRP-PPP/WCRP-PCPI polar-lower latitude linkages workshop (Barcelona), and upcoming polar climate workshops/meetings in Reading and Paris. Interactions with the CanSISE in her role as Advisory Panel member encouraged Bitz to lead the application for the international Belmont Arctic Call with partners from Norway, Germany, and Russia. This is part of an effort to build outreach and stakeholder connections beyond EC and PCIC. The CCAR Changing Cold Regions Network and CanSISE are also connecting through a Memorandum of Understanding on data sharing and exchange that has been agreed to informally and that is awaiting formal approval by the Universities of Saskatchewan and Toronto.

We have been working to improve our outreach and public visibility within the available resources of the Network. Christensen and Kushner focused on improving our website with a more in depth description of our research activities, research updates, archived notes from meetings, etc.[9] Kushner represented CanSISE research as a Canadian Association of Physicists Undergraduate Lecture Tour speaker, and in interactions with GTA high schools. The UNBC research group's work has been featured in *International Innovation* magazine, and the York group's work in First Air's in-flight magazine. In addition, the Belmont Proposal includes specific plans and a request for additional resources for Christensen to assist the international group in building connections with sea ice forecasters and the end users of sea ice forecasts. We have attempted but have only had mixed success with a social media presence via Twitter (@CanSISE), and will evaluate the effectiveness of this at the end of Project Year 3.

We are now at a stage of recruitment of HQP that most open positions from last year have been filled. Following feedback from last year's Victoria workshop, we have been working to improve HQP

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[8] We followed referees recommendations that the website be updated to allow open access to meeting materials.

[9] Again, this effort was in part stimulated by referee comments.

connections and linkages through enhanced engagement at regional workshops, website contributions, and participation in network and smaller telecons. Anecdotally, HQP tell us that they now have a better understanding of the scope of the network's activities, especially in light of the regional meetings. The CanSISE membership in BC held a successful "CanSISE West" regional workshop that served to bring HQP in that region together for the first time this project year. We have extended the running time of the CanSISE Workshop 2 in Toronto to allow all attending HQP to present their work and for SC and AP members present to evaluate the status of education and training in the Network. Encouragingly, opportunities for CanSISE HQP at EC have started to open up and will be detailed in next year's report should positions be confirmed.

Section 4. CONCLUSION

The idea of CanSISE since its establishment in February 2013 has been to bring together relatively isolated Canadian efforts in climate prediction system development and observational dataset development. CanSISE brings researchers across the University and Government sectors together to focus on process understanding and practical improvements in the area of snow and sea ice and related climate parameters for Canada and the Arctic. Our active research, largely led by HQP, and growing publication record suggest that we are fulfilling our mandate as originally proposed. Throughout this report, in the main text or through footnotes, we have tried to respond to external referee comments on the first annual report. These comment are appreciated by the Steering Committee and the Advisory Panel, and we look forward to receiving your feedback again this year. Highlights for us this year included getting a first glimpse at how snow on drifting sea ice from Arctic ice mass balance buoys compared to contemporaneous reanalysis datasets, the development of practical improvements in sea ice initialization, new insights into the snow albedo feedback process in observations and models, and a major effort by CCCma to enhance its database of scientifically valuable climate simulations for CanSISE and related communities. We are starting to work in more frontier areas not reported here, such as the transition to finer resolution in global models, the analysis of snow and sea ice in new ocean-atmosphere-sea ice models in EC, and the exploration of the subseasonal timescale and its potential utility for forecast stakeholders, and look forward to reporting on results of such new activities in the coming years. Importantly, we are beginning to educate and train a generation of Canadian researchers who will be easily able to bridge the model/observational divide in snow and sea ice research and potentially lead climate prediction system development and research in the future.