The Canadian Sea Ice and Snow Evolution Network (CanSISE): Fourth Annual Progress Report

SECTION 1. INTRODUCTION, PROGRESS ON PROJECTS AND DELIVERABLES

The CanSISE Network is a government-academic research partnership that seeks to advance Canada's sea ice and snow prediction capacity on seasonal and longer timescales; enhance process understanding and quantitative attribution of snow and sea ice related climate extremes and associated impacts; and better of integrate state of the art snow and sea ice observations into climate prediction systems. Since its inception in February 2013, the CanSISE Network has enhanced Canadian leadership in these areas through careful analysis of snow and sea ice processes in earth systems models and in observations in the context of climate variability arising from natural and anthropogenic forcing and of observational uncertainty.[i] During Project Year 1 (2013-2014) the network established new collaborations and partnerships. Project Years 2 and 3 (2014-2015, 2015-2016) featured considerable progress on research, spurred by two concrete outputs led by the CanSISE Network: the *CanESM Large Ensemble* of climate simulations and the *Blended-5 snow water equivalent* (*B5 SWE*) observational dataset. Project Year 4 (February 2016 to January 2017) has seen the completion of Deliverable 1 (assessment of snow and sea ice prediction in CanESM) and has set the stage for a clearer definition and completion of the remaining three Deliverables, a continuing record of high quality and high impact publications, advancement of HQP, and the development of two new projects building upon our research activities in response to NSERC's "CCAR Network Enhancement Initiative (NEI)" call. Communication and collaboration in the network has continued through regional and network-wide workshops, as well as with regular telecons/webinars. We will briefly discuss our budget in Section 2 (see budget tables in Appendix A), the proposed NEI activities and management/partnership topics in Section 3. Updated membership list and presentations/publications are presented in Appendix B and Appendix C.

Projects and Deliverables

1. For **Research Area A (***S/SI Prediction and Projection***)**, **Project A1's** (*Improved observational datasets for initialization and verification***)** scope was expanded and clarified in Year 3 to target collation of datasets involving multiple sources of observations of selected parameters for forecast system verification and initialization, and for additional climate analysis. The creation and maintenance of multi-source datasets for sea ice and snow is a key recommendation of the Deliverable 1 report (see item 19 below). The multisource *Blended-5 SWE* (Mudryk et al. 2015; data available at the National Snow and Ice Data Center at http://nsidc.org/data/NSIDC-0668) snow water equivalent dataset, which was published last year and described in the Project Year 3 report, continues to find application in several areas (described below). In Project Year 4, we have begun a project to produce multisource datasets of recent (post Year 2000) sea ice observational data that will be started with available resources from CanSISE. This *CanSISE Legacy Data Project* as envisioned extends beyond the lifetime of the CanSISE Network but the short-term products of this effort are expected to be immediately useful. Year 4 activity involved developing a gridded multi-sourced sea ice thickness dataset using a similar approach to the B-5 SWE but focusing on post-2000 to accommodate recent satellite and airborne sensors (e.g. Cryosat-2, ICESat, Operation IceBridge) in addition to reanalysis products. All datasets are currently being placed on a common grid for subsequent comparison (regional and pan-Arctic) and determination of uncertainty and bias. This work is being led by M-E Gagné in collaboration with Howell, Mudryk, and Kushner. For snow, the B5 SWE dataset and extensions to it

represented part of CanSISE's leadership in the evaluation of northern hemisphere snow water equivalent (SWE) datasets for the European Space Agency (ESA) Satellite Snow Product Inter-comparison Experiment (SnowPEx), which will conclude in early 2017. The consistency of seven daily, gridded Northern Hemisphere snow water equivalent (SWE) datasets (satellite, reanalysis driven land models) has been assessed and compared to in situ reference datasets. The B5-SWE dataset is available to support CMIP6 analysis through the Obs4MIPS program.

2. For **Project A2.1** *(Assessment of prediction skill for S/SI and related variables in CanSIPS hindcasts based on current and enhanced verification datasets)*, working with Merryfield and Kharin, former CanSISE PDF Reinel Sospedra-Alfonso (now an NSERC Visiting Fellow at CCCma) has extended previous work that examined potential predictability and actual skill or snow water equivalent (SWE) in CanSIPS hindcasts and has found that (i) soil moisture potential predictability has a rich and complicated behaviour apparently related to the seasonal freeze/thaw cycle and to ENSO; (ii) higher actual skill is achieved when blends of several analyses are used for verification data than when individual analyses are considered, thus demonstrating the potential value of the multisource approach (Sospreda-Alfonso et al. 2016 a,b).
3. For **Project A2.2** (*Improved CanSIPS snow/land surface initialization*), CanSISE PDF Jaison Ambadan (Guelph) working with Berg and Merryfield analysed lagged influences of snowmelt on soil moisture memory and near-surface air temperatures in four reanalysis products and two CanSIPS seasonal forecast models. A considerable diversity of behaviour was found, likely relating to differing biases and land surface physics schemes in the various models. In addition, Ambadan and new CanSISE University of Guelph PDF Manoj Kizhakkeniyil have begun to develop procedures for mapping the values of variables in the ISBA and SVS land surface models used in ECCC's land surface assimilation and weather prediction models into the variable set of the Canadian land surface scheme (CLASS), which is the land model employed by ECCC's seasonal forecast models. This should enable more realistic land initialization in seasonal forecasts through incorporation of information from ECCC's Canadian Land Data Assimilation System (CaLDAS) and a 30-year land reanalysis now being developed by ECCC (collaboration with Dr. Bélair). Williamson (Guelph MSc. 2016) finished a thesis on evaluation of soil freeze thaw products for validation of freeze thaw products from the Soil Moisture Active Passive Satellite (SMAP) and for land surface models with ground data. Guelph Ph.D. student Renato Pardo will develop methods for soil freeze thaw observations from satellites for assimilation into land surface models.
4. In **Project A2.3** (*Improved CanSIPS sea ice initialization*), CanSISE PhD student Arlan Dirkson, co-supervised by Merryfield and UVic faculty member Adam Monahan, completed an analysis of CanSIPS hindcasts that use different statistical and dynamical methods for sea ice thickness initialization. Marked improvements in CanSIPS forecasts of sea ice concentration were found when ice thickness fields from the statistical models and PIOMAS are employed for initialization, except in the Nordic Seas where improved sea ice thickness amplifies an existing model bias (Dirkson et al. in press). In addition, this project was extended to improve, relative to current operational practice, methods for probabilistic sea ice forecasting (for example probabilities that sea ice concentration will exceed some threshold value during the forecast period).
5. For **Project A2.4** (*Streamflow predictions/Western Cordillera*), a comparison of six gridded snow water equivalent (SWE) products with snow station measurements over BC has been

completed and published (Snauffer et al., 2016 a and b). Performance of gridded products over BC was assessed and informed a follow-up effort to develop a SWE data fusion product. Based on the products' relative performance, various combinations of the products were averaged and also used as predictors in artificial neural networks (ANNs) and multiple linear regressions (MLRs). A base set of relevant station covariates used as predictors in the ANNs and MLRs including position, survey date, etc. was developed. Improvements were also found across the province and in most regions when comparing the ANN with the Variable Infiltration Capacity (VIC) hydrologic model run over BC by the Pacific Climate Impacts Consortium (PCIC).

6. For **Project A3** (*Analysis of interannual to multidecadal S/SI predictions and projections*) CanSISE investigators are contributing to the development of coupled climate model experiments within the World Meteorological Organization/Climate and Cryosphere (WMO-CliC) Earth System Model Snow Model Intercomparson Project (ESM-SnowMIP) and the CMIP6 endorsed Land Surface, Snow, and Soil Moisture Model Intercomparson Project (LS3MIP). A paper summarizing the LS3MIP experimental approach was completed (van den Hurk et al., 2016) and ESM-SnowMIP test simulations using prescribed and/or perturbed snow physics are underway. Large initial condition ensembles from CanESM2 and CESM were combined with a multi-model CMIP5 ensemble and an observational ensemble of snow datasets (related to the B5-SWE product, Project A1) to assess historical and future trends in continental scale snow cover (Thackeray et al., in press) and quantify snow cover sensitivity to temperature forcing (Mudryk et al., in revision). Work on **Project A4** (*Assessing limits to S/SI predictability*) was largely completed in Year 3.
7. 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*) is complete. For **Project B2** (*Detection and attribution of northern hemisphere SCE changes*), a formal detection and attribution (DA) analysis of SCE changes based on several different observational datasets with different structural characteristics was undertaken. Early spring (March-April) and late spring (May-June) NH SCE changes using climate simulations of the responses to anthropogenic and natural forcings combined (ALL) and to natural forcings alone (NAT) from the Coupled Model Intercomparison Project Phase 5 (CMIP5) were analyzed. Results considerably strengthen the available body of evidence showing that human influence on the climate systems has contributed to the observed snow cover extent declines on hemispheric and continental scales (Najafi et al, 2016a).
8. The subprojects of **Project B3** (*Implications of precipitation and snow cover changes on water resources*) deal with impacts of large-scale climate change to snow on hydrological characteristics in the Western Cordillera:
    a. A DA analysis on attribution of the regional SWE/summer runoff decline in Western Canada was carried out at PCIC, focusing on the multi-decadal trend in SWE and in summer runoff of four BC river basins with distinct hydro-climatic characteristics. A suite of ten CMIP5 models were used including ALL, NAT, and preindustrial control simulations (CTL). These simulations were downscaled to daily time series at 1/16° spatial resolution to drive the VIC hydrologic model. Manual snow survey, and VIC reconstructed SWE were projected onto the multi-model ensemble means of the VIC simulated SWE based on the responses to different forcings using the optimal fingerprinting approach. Results indicate a detectable influence of human induced climate change on normalized SWE across the four basins and in three of the four

basins individually. These findings complement an earlier study that detected human influence on the hydrology of the western USA (a water limited region) and demonstrates the impact of human influence in a region with an energy limited (as opposed to water limited) hydrologic regime (Najafi et al., 2016b, under review). A similar analysis was performed considering summer stream flow changes in these basins. Summer stream flow has declined, which is an expected consequence of reduced winter snow storage. The study confirms that human induced climate change is a factor contributing to the observed stream flow changes (Najafi et al., 2016c, under review).

b. At PCIC and UNBC, an assessment of whether human induced climate change has changed the risk of extreme annual maximum discharge (flooding) events on the Fraser River was carried out. The hydrology of the FRB is dominated by snow accumulation and melt processes, leading to a prominent annual peak daily streamflow (APDF) invariably occurring in June-July. Historically, some of these APDFs have resulted in damaging floods. However, as not all are associated with an unusually large spring snowpack, it is unclear exactly what climatic conditions contributed to these extreme events. Recently hired Research Associate Charles Curry has been using hydrological model output to examine the sensitivity of APDFs to a set of predictors characterizing the magnitude and timing of rainfall, SWE and temperature, using a regression framework. The PCIC and UNBC implementations of VIC, with complementary gridding approaches, are being compared.

c. The UNBC group focused on evaluating predictive uncertainties in the snow hydrology of the Fraser River Basin (FRB) of British Columbia (BC), Canada, using the VIC model forced with several high-resolution gridded climate datasets (Canadian Precipitation Analysis, ANUSPLIN, NARR, etc.). Uncertainties at different stages of the VIC implementation were analysed focusing on driving datasets, optimization of model parameters, and model calibration during cool and warm phases of the Pacific Decadal Oscillation (PDO). The forcing datasets (precipitation and air temperature) and their VIC simulations (SWE) and runoff reveal widespread differences over the FRB especially in mountainous regions. The analysis shows that the parameter choices and choice of calibration period is less important in influencing the response than the choice of forcing datasets. Further analyses of VIC forced with CMIP projections provide evidence of increasing variability (and hence less predictability) in daily flows for the main stem Fraser River at Hope. Thus in a warmer climate, streamflow for the Fraser River may be more variable, either on a day-to-day basis or from year-to-year, implying potentially less predictability in that system.

9. For **Project B4** (*Detection and attribution of Arctic sea ice and snow cover extreme* events), U Vic Ph.D. student Bennit Mueller carried out a DA analysis of anthropogenic and natural influences on observed trends in Arctic sea ice. Using updated records of Arctic sea ice extent covering 1953 onwards, it has been possible to detect, for the first time, the separate contributions of greenhouse gas forcing (GHG), other anthropogenic forcing (OANT; notably aerosols) and natural external forcing from solar and volcanic activity (NAT) to observed sea-ice extent changes. The results demonstrate that the effect of OANT has helped to offset a substantial fraction of the sea ice loss that would have occurred if only GHGs had influenced the Arctic. This has policy implications, since actions to curb aerosol and aerosol precursor emissions may exacerbate sea-ice loss if greenhouse gas emissions are not

curtailed at the same time. U Vic PDF Megan Kirchmeier-Young led an event attribution study for extremes in Arctic sea ice extent, demonstrating that extreme minimum events such as the current records in both the September annual minimum and March annual maximum extent would not have occurred without the inclusion of anthropogenic forcings. This analysis also first confirmed that an anthropogenic signal was detected in the long-term annual and September time series of Arctic sea-ice extent through a formal detection and attribution assessment (Kirchmeier-Young et al., 2016, J. Climate, in press). The detection of a natural forcing signal in the September time series using the multi-model CMIP5 ensemble was further explored in a paper by Gagne et al. (2016) investigating the influence of major volcanic eruptions on Arctic sea ice.

As an important extension beyond the original proposal in 2016, the event attribution methodology applied to sea ice extent extremes is being utilized for an analysis of extreme wildfire/fire weather events in western Canada. The connections with and relevance for CanSISE are twofold. First, and most directly, the study uses the CanSISE-sponsored CanESM2 large ensemble. Secondly, it was motivated by the Fort McMurray wildfire that burned 590,000 ha and extended from May to early July. Fire indices that inform wildfire risk are affected by a number of climate variables, including antecedent moisture, which in cold climates, is affected by snow storage. The CanESM2 and CESM large ensembles, plus additional CMIP5 simulations, were downscaled before the calculation of indices from the Canadian Forest Fire Weather Index (FWI) System. A major challenge for this project involves defining the region(s) and specific events of interest, which includes considerations of the signal-to-noise ratio for the various metrics/variables, the usefulness of the results, and representing fire risk and/or occurrence using only output from an ESM that does not include a fire model or human behaviours for ignition/suppression. Furthermore, snow data from the ESM will be used/downscaled to determine appropriate start dates for the fire season.

10. For **Research Area C Project C1.1-i** (*Snow-albedo feedback and other climate interactions*) Chad Thackeray (PhD student at UWaterloo) investigated biases in simulated snow cover and albedo, and their role in climate. Thackeray et al. (2016) evaluated the uncertainty in historical and future simulations of Northern Hemisphere spring snow cover using data from two climate model ensembles and seven observation-based snow products. This study utilized the CanESM Large Ensemble to illustrate the role that internal climate variability plays in simulated spring snow cover trends. A synthesis/review paper was also published on snow albedo feedback (Thackeray and Fletcher, 2016). Extensive progress has also been made with new offline land model simulations with the NCAR CESM model. These simulations incorporate prescribed observation-based albedo measurements, and can be used to quantify the impact on climate from previously-documented biases in simulated albedo. Markus Todt (PhD student at Northumbria, co-supervised by Fletcher at Waterloo) has made considerable progress toward implementing a new longwave canopy radiation parameterization in the NCAR CLM model. He is currently diagnosing a simplified version of the parameterization, and has now begun to test this code in CLM. Tyler Herrington (PhD student at UWaterloo) and Kevin Nagtegaal (NSERC USRA recipient at UWaterloo) investigated the role of internal variability in the wintertime snow-AO teleconnection. Herrington's PhD thesis work will examine the role of Cloud Radiative Effects in Snow Albedo Feedback. Bakr Badawy (PDF at UWaterloo) has ported the latest version (v3.6) of

the CLASS to SciNet. He has begun an uncertainty quantification analysis using offline global simulations with CLASS, where the impact on climate from combinations of uncertain model snow parameters, constrained by observational data, will be assessed.

11. **Project C1.1-ii** (*Sea-ice albedo feedback and related feedback processes*). In Project Year 4, CanSISE PDF Tandon continued his investigation of regional Arctic feedbacks between sea ice and atmospheric circulation in the context of Arctic decadal variability. Previous work characterizing the coupled sea ice drift process, which involves feedbacks between wind driving and sea ice fluxes have characterized GCM behaviour in this area as very poorly simulated. Tandon has found in fact that this is an artefact of the sampling used to relate ice drift to wind variability, and this work suggests that the wind-driven sea ice drift feedback has not played as important a role in long-term sea ice trends as previously thought. This work was spurred in part by the participation of Kushner in the WCRP Polar Climate Prediction Initiative's focus study on polar feedbacks (Section 3).
12. For **Project C1.2** (*Changes of wind-driven ice drift and deformation in relation to ice thickness variations in observations and GCMs*) PDF Bajish, with Haas at York, finalized his analysis of gridded snow-on-sea ice data, which is a critical parameter for the retrieval of sea ice thickness from satellite remote sensing, in comparison to CanSIPS and CanESM (ms in prep).
13. For **Project C1.3** (*Towards improved sea ice physics and dynamics in the Canadian GCMs*), McGill Ph.D. student James Williams is running a viscous-plastic sea-ice model at increasingly high spatial and temporal resolution. An idealized domain is being used to study the dependence of sea-ice export (a metric for the amount of internal dissipation) as a function of the spatial resolution of the model. Results show that a decrease in the mechanical compressive strength of sea ice is required as spatial resolution is increased to maintain the same ice export. The results were anticipated by theoretical analysis but are inconsistent with laboratory experiments, suggesting that sea ice in natural floes has weaknesses that reduces its mechanical strength to values that are well below that of isolated, undamaged floes. McGill Ph.D. student G. Auclair is carrying out a numerical study of a solver for the sea ice momentum equation to improve convergence as higher resolution is achieved. The analytical Jacobian of the 1D sea ice momentum equation is derived. Preliminary results show promise in terms of computational efficiency. Although robustness remains an issue for some test cases, it is improved compared to the Jacobian free approach. In order to make use of the strong points of both the new and Jacobian free methods, a new hybrid pre- conditioner is also introduced, which combines robustness and computational efficiency when solving the sea ice momentum equation.
14. For **Project C2.1** (*Changes in sea ice extent and impacts on circulation*) U Vic/U Washington research associate, Kelly McCusker completed analysis and publication of the effect of Barents-Kara sea ice loss on Eurasian winter temperatures. This work showed that the multi-decadal decline of Barents-Kara sea ice concentration is unlikely to be the cause of the trend toward cooler winters in central Eurasia since about 1980, and instead is likely due to an internally-generated persistent high pressure over the Barents-Kara Seas and downstream trough. McCusker also completed execution and analysis of a suite of CanESM2 nudging simulations that isolate the effect of sea ice loss and increased CO2 concentrations in a coupled model. Toronto Ph.D. student Russell Blackport has submitted a study on the response to imposed sea ice loss in the NCAR coupled models CESM1 and CCSM4. He applied a two-parameter pattern scaling technique to separate the response of

the atmospheric circulation from sea ice loss from that of low-latitude warming. This allows atmospheric circulation responses over the North Pacific and the Eurasian continent in winter to be separately attributed to sea ice loss and tropical warming separately (Blackport and Kushner, in press). This work has continued with Toronto Ph.D. student Stephanie Hay, who is collaborating with McCusker to compare the NCAR model responses to those found in McCusker's experiments with CanESM. At McGill, the work described in Year 3 for Tremblay's group on how patterns of Arctic air masses will be affected by sea ice loss and polar amplification has been published (Gervais et al. 2016).

15. For **Project C2.2** (*S/SI response to teleconnected forcing*) work has continued from that reported in Year 3 (Bichet et al. 2015, Bichet et al. J. Climate, in press) to estimate responses in land-surface temperature, precipitation, and snow cover associated with greenhouse warming, using a modelling approach that is tightly constrained by observed trends in sea surface temperatures and sea ice. Year 4 focused on revising the Bichet et al. paper (J. Climate, in press), which concerned on past trends, and completing analysis of projected snow and land surface temperature trends.
16. For **Project C3.1** (*Declining SCE: Characteristics and causes*), work by Allchin at UNBC has continued on 1) establishing Northern Hemisphere SCE trends at the grid point scale to determine which regions are undergoing significant reductions or increases in SCE and their relationships to vegetation cover and large-scale teleconnections such as the Arctic Oscillation, 2) continuing to identify mechanisms contributing to recent springtime SCE reductions in North America and Eurasia, 3) exploring the role of the snow-albedo feedback on other climatic variables such as air temperature and precipitation phase and 4) preparing an article that presents long-term (up to 10 years) hydrometeorological data collected from BC's Cariboo Mountains.
17. For **Project C3.2-i** (*Changes in sea ice area and type in the Canadian Arctic Archipelago*) Observed and modelled landfast ice thickness variability and trends spanning more than 5 decades within the Canadian Arctic Archipelago (CAA) were summarized. The observed sites (Cambridge Bay, Resolute, Eureka and Alert) represent some of the Arctic's longest records of landfast ice thickness. Observed end-of-winter (maximum) declining trends of landfast ice thickness (1957–2014) were statistically significant at all sites except Resolute. Snow depth was found to be strongly associated with the negative ice thickness trends. Comparison with multi-model simulations from CMIP5, Ocean Reanalysis Intercomparison (ORA-IP) and Pan-Arctic Ice-Ocean Modeling and Assimilation System (PIOMAS) show that although a subset of current generation models have a "reasonable" climatological representation of landfast ice thickness and distribution within the CAA, trends are unrealistic.
18. Finally, for **Project C3.2ii** (*Changes in pan-Arctic SIE, thickness and snow on ice*) sea ice area flux using RADARSAT from 1997 to 2014 was analyzed at three gates in Beaufort Sea: the Canadian Basin (entrance), mid-Beaufort (midpoint), and Chukchi (exit). The majority of ice transport in Beaufort Sea was found to occur from October to May providing replenishment for ice lost during the summer months. The cross-strait gradient in sea level pressure explains ~40% of the variance in the ice area flux at the gates. Remarkably, the mean July–October net sea ice area flux at the Chukchi gate decreased by ~80% from 2008 to 2014 relative to 1997–2007 and became virtually ice-free every year since 2008. This reduction was associated with younger (thinner) ice that was unable to survive the summer melt season when either being sequestered from the Canadian Basin and transported through

Beaufort Sea during the melt season (2008–2011) or remaining immobile and present in the vicinity of the Chukchi gate during the melt season (2012–2014).

19. The **CanSISE Network Deliverables** represent the synthesis of our research, geared towards summarizing its broader implications. The **Deliverable 1 Report** (*Assessment of S/SI Biases, Projections, and Predictions in the Canadian GCMs*) was posted in spring 2016 and shared with Environment Canada management. The report concluded that the quality of the CanESM2 simulation of snow-related climate parameters, such as cold-region temperature and precipitation, lies well within the range of currently available international models. Accounting for the considerable disagreement among satellite-era observational datasets on the distribution of snow water equivalent, CanESM2 has too much snow cover and an unrealistic spatial distribution of SWE in the spring over the Canadian land mass and has too much springtime snow over the Northern Hemisphere as a whole. CanESM2 exhibits springtime retreat of snow in the satellite era that is generally greater than observational estimates. Sea ice is biased low in the Canadian arctic and subarctic, and the amount of snow on floating wintertime sea ice is probably also biased low, although observational estimates of snow on sea ice are uncertain. The report discusses tradeoffs in having a model system that is sufficiently computationally inexpensive to afford operational seasonal prediction and multiple realizations under different forcings, but of high enough resolution to capture key geographical features for simulating snow and sea ice. Improvements in climate prediction systems like CanSIPS relies not just on simulation quality but on being able to take advantage of novel observational constraints and being able to transfer research to an operational setting. Research results from CanSISE suggest potential improvements in seasonal forecasting practice using CanSIPS, including the impact of accurate initialization of the state of snow and frozen soil, properly accounting for observational uncertainty in forecast verification, and operational implementation of sea ice thickness initialization using statistical predictors available in real time. The report concludes with recommendations and areas of interest for future collaborative research; these cover benefits of entraining a network of researchers bridging observational and modelling communities and bridging the government and academic sector, benefits of multi-source observational datasets, and the availability of large initial condition simulation ensembles.

The CanSISE Network is now well positioned to produce the remaining Deliverables of the project. Derksen is leading the **Deliverable 2 Report** [*Assessment of Canadian snow and sea ice trends (1981-2016) and projections (2020-2050)*] which will be submitted for publication as part of ECCC's contribution to the Canadian National Climate Assessment 2020's foundational report *Canada's Changing Climate*. Figures for Deliverable 2 have been produced and a draft of the report will be discussed at a CanSISE East regional network meeting in February 2016. A related session will be held at CMOS in Toronto in June 2016. A network-wide call for contributions to the **Deliverable 3 Report** (Snow and sea ice related climate event attribution and impacts) will be the subject of a CanSISE West regional workshop in April 2016. Preliminary results for **Deliverable 4** (*CanSISE Legacy Multisource Snow and Sea Ice Data Project*) will be reported at a CanSISE East Regional workshop in June (coincident with the Toronto CMOS meeting) and this Deliverable will be finalized in Year 6.

SECTION 2. BUDGET

Table 1 (after Section 4) summarizes budgeting and spending in Project Year 4 (including estimated spending estimated from October 2016 to January 2017). We anticipate no significant carry forward apart from the Year 4 Network Enhancement Initiative funds ($43K) that will be spent on the March 2017 *North2Warm* workshop (see below); the remaining carry forward is <$20K and CanSISE operating budgets for Year 5-6 remain essentially unchanged.

SECTION 3. INTERACTION WITH PARTNERS, RESEARCH TEAM AND TRAINING

A significant change in CanSISE leadership is that Prof. Christian Haas, who has joined the Alfred Wegener Institute in Bremerhaven, Germany in September 2016, is no longer active in the Network as an investigator but remains as a member of our Advisory Panel. In response to this change in leadership we have asked Dr. Steven Howell (ECCC) and Prof. Chris Fletcher (Waterloo) to join the Steering Committee. Deliberation by the Steering Committee has been of critical importance for several decisions involving personnel, the response to the CCAR NEI call and review process, and ensuring that our four deliverables are completed in a timely manner. We continue our successful partnership and management model with monthly to bimonthly telecons with the steering committee, advisory panel, and entire network, as well as the CanSISE Research Report from selected HQP at the end of the Network telecons.

We held CanSISE regional meetings in January, May, and June 2016 (two in Toronto and one in Victoria) and our All-Network Workshop in November 2017. These meetings, particularly the all-network Workshop in March, provided important opportunities for interaction and collaboration. The regional workshops will in Years 5 and 6 be increasingly focused on finalizing project deliverables.

Our active partnerships were described in last year's report. Almost every project described above involves a partnership between University and Environment Canada or PCIC researchers. The generation of the CanESM Large Ensemble and the B5-SWE product has represented a great example of resource commitment of EC to the benefit of the Canadian modeling community. As in previous years, we list key collaborations between partners: Berg/Merryfield/Kharin, Howell/Kushner/Derksen, Kushner/Derksen, Kushner/Fyfe, Fletcher/Derksen/Kushner, Fletcher/Kushner/Howell, Zwiers/Zhang/Gillett, Déry/Brown/Derksen, Déry/Zwiers.

Regarding new partnership opportunities, Kushner and Fyfe took part in EU Horizon 2020 proposals related to polar research (one of which, APPLICATE, in which Fyfe is involved, was successful); the U. Bergen proposal submitted in CanSISE Year 3 on the Dynamics of Midlatitude-Arctic Teleconnections was successful and has led to partnership opportunities with that institution; and Fletcher, Kushner and Howell submitted a proposal on calibration, validation, and modelling of satellite-derived snow/sea ice/weather processes for the Canadian Space Agency's Earth System Data Analysis call. Kushner helped represent Canada's efforts in these areas at the WCRP/PCPI Polar Feedbacks workshop in Louvain-la-Neuve, Belgium (May 2016).

In response to NSERC's CCAR NEI call, two project activities that build upon CanSISE's original proposal were accepted by NSERC. The first, entitled *North2Warm: The impact of 1.5-2.0 degrees Celsius warming on Canada's North*, is designed to respond to the UNFCC's COP21 call to the IPCC to produce a special report on the anticipated impacts of 1.5°C or greater global warming above pre-industrial levels. An organizing committee consisting of Flato, Howell, D. Lemmen of NRCan, and Kushner, are convening a workshop in March 2017 that will focus on climate change impacts on Canada's North and that will contribute to the material that will be available for assessment in the IPCC Special Report. This activity is intended to integrate Canadian research in these areas into a high profile international endeavour, and to provide invaluable information to the Canadian public, policy makers, and the scientific and broader research community concerned with this critical topic. The primary aim of our activity is to submit and publish a peer-reviewed paper on this topic that, we hope, will provide highly relevant reference material for the IPCC Special Report.

The second NEI project activity, *First look at the next generation Canadian Earth System Model CanESM5*, will comprise a workshop and report that will coincide with the release to the international research community of output of ECCC/CCCma's new model, CanESM5, for WCRP CMIP6. The workshop will involve a Canada-wide call for analyses of the new model (including but not limited to snow and sea ice processes) to build a community of researchers who are vested in the ongoing development of Canada's climate prediction systems.

The enthusiasm and support for the NEI initiatives described above, which involve considerable in-kind resources from ECCC, is emblematic of our continued strong partnership with ECCC. In addition to this partnership, we continue to partner with other CCAR networks in various ways: CanSISE, CCRN, and CNRCWP co-convened sessions at the 2016 CMOS meeting; CNRCWP and CCRN participation has been sought in the North2Warm activity; L. Sushama of CNRCWP presented an overview of that network's activity at the CanSISE West meeting in May 2016; Kushner presented a CanSISE Deliverable 1 report overview at the CNRCWP workshop in May 2016; and all the CCAR Networks will be invited to participate in the *First Look CanESM5* workshop in 2018.

We continue to report success of HQP who have advanced professionally with the help of CanSISE Network suppor. Former CanSISE PDF Reza Najafi will start a new faculty position at UWO in January 2017, former CanSISE Research Associate Lawrence Mudryk has obtained a term physical scientist position at ECCC/CRD, former CanSISE PDF Neil Tandon has obtained a Visiting Scientist PDF at ECCC/CRD, and Ph.D. student Russell Blackport has completed his Ph.D. under CanSISE and is starting a postdoctoral position at U. Exeter.

Section 4. CONCLUSION

This concludes the penultimate report of the CanSISE Network. We now look forward to the successful completion of the Network's activities in September 2018 that we will be able to summarize in our Final Report in 2018. In particular, alongside our regular research output in the form of high quality and high impact peer-reviewed literature, we look forward to providing:

1) An important update since IPY of recent and projected snow and sea ice trends over Canada (Deliverable 2 report, input into the Canada National Climate Assessment 2020);
2) A broad survey of the role of human activity in recent climate extremes and impacts related to sea ice and snow, including the hydroclimate of the Western Cordillera and wildfires that are influenced by snow processes (Deliverable 3 report)
3) Production of a new multisource observational dataset for sea ice thickness for initialization, validation, and analysis, to complement the B5-SWE dataset (CanSISE Legacy Data Project and Deliverable 4 report)
4) An assessment involving climate scientists, social scientists, and stakeholders on the impacts of the 1.5-degree target on Canada's North as input to the IPCC assessment process (North2Warm CCAR NEI Activity and related publication); and
5) The engagement of a broad scientific community on Canada's next generation climate prediction system based on CanESM5 (*First Look at CanESM5* CCAR NEI Activity and related report).

Endnote:

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[i] *Review of the CanSISE Project's organization*: CanSISE partners seven Universities (British Columbia, Guelph, McGill, Northern British Columbia, Toronto, Victoria, and Waterloo); Environment Canada (Climate Research Division in Downsview, CCCma in Victoria, CIS in Ottawa); the Pacific Climate Impacts Consortium (PCIC), and NSERC. The Research Areas of CanSISE aim to (A) improve EC's capacity to forecast seasonal snow cover and sea ice and related hydroclimate variables on timescales ranging from seasonal to the decadal; (B) support efforts to quantitatively attribute the impacts of human influence on snow/sea-ice related process; and (C) improve scientific understanding of snow/sea-ice processes and their coupling to atmosphere-ocean circulation. Through the research undertaken, CanSISE also aims to produce Deliverables in which, with respect to snow/sea-ice and related processes, (1) EC's prediction systems are evaluated, (2) an assessment of variability in the near-term (next 10-20 years) is produced, (3) human influence and related impacts is analyzed, and (4) key aspects of future observational network design are developed. Originally funded from February 2013 – January 2018, the CanSISE Network has received a no-cost extension into Year 6 with an end date of September 30, 2018.

Omitted Budget Pages. Membership, presentations, publications included below.

Please contact us with any updates/ omissions for Project Year 4.

Jaison Ambadan	Post-Doctoral Fellow	University of Guelph
Michael Allchin	PhD Student	University of Northern British Columbia
G. Auclair	MSc Student	McGill University
Bakr Badawy	Post-Doctoral Fellow	University of Waterloo
Stephan Belair	Collaborator	Environment Canada, MRD
Aaron Berg	Funded Collaborator	University of Guelph
Adeline Bichet	Post-Doctoral Fellow	University of Toronto
N. Bimochan	Undergraduate Student	McGill University
Cecilia Bitz	Steering Committee	University of Washington
C. Brunette	PhD Student	McGill University
Russell Blackport	PhD Student	University of Toronto
George Boer	Collaborator	Environment Canada, CCCma
Ross Brown	Collaborator	Environment Canada, CRD
Travis Burns	MSc Student	University of Guelph
Alex Cannon	Collaborator	University of Victoria
Marco Carrera	Collaborator	Environment Canada, MRD
Tom Carrieres	Advisory Panel	Environment Canada, CIS
Bob Christensen	Project Support	University of Toronto
Charles Curry	Research Associate	University of Victoria
Chris Derksen	Steering Committee, Funded Collaborator	Environment Canada, CRD
Stephen Déry	Steering Committee, Funded Collaborator	University of Northern British Columbia
Louis-Renaud Desjardins	PhD Student	McGill University
Patricia DeRepentigny	MSc Student	McGill University
Arlan Dirkson	Post-Doctoral Fellow	University of Victoria
Greg Flato	Steering Committee	Environment Canada, CCCma
Chris Fletcher	Steering Committee, Funded Collaborator	University of Waterloo
John Fyfe	Steering Committee, Funded Collaborator	Environment Canada, CCCma
Marie-Ève Gagne	Research Associate	University of Victoria
Nathan Gillett	Funded Collaborator	Environment Canada, CCCma
Christian Haas	Steering Committee, Advisory Panel, Funded Collaborator	York University
Marco Harnandez-Henriquez	Research Assistant	University of Northern British Columbia
Yuki Hata	PhD Student	McGill University
Stephanie Hay	PhD Student	University of Toronto
Tyler Herrington	Post-Doctoral Fellow	University of Waterloo
Stephen Howell	Steering Committee	Environment Canada, CRD
William Hsieh	Funded Collaborator	University of British Columbia
Siraj Islam	Post-Doctoral Fellow	University of Northern British Columbia
Euan Joly-Smith	Undergraduate Student	University of Toronto
Do Hyuk Kang	Post-Doctoral Fellow	University of Northern British Columbia
Mark Kazakevic	Undergraduate Student	University of Toronto
Slava Kharin	Collaborator	Environment Canada, CCCma

Megan Kirchmeier-Young	PhD Student	University of Victoria
Sanjiv Kumar	Post-Doctoral Fellow	University of Toronto
Paul Kushner	Primary Investigator, Steering Committee	University of Toronto
Frederic Laliberte	Research Associate	Environment Canada, CRD
Dennis Lettenmaier	Advisory Panel	University of Washington
Camille Li	International Collaborator	University of Bergen
Kelly McCusker	Post-Doctoral Fellow	University of Victoria
Humfrey Melling	Advisory Panel	Fisheries and Oceans Canada
Bill Merryfield	Steering Committee, Funded Collaborator	Environment Canada, CCCma
Lawrence Mudryk	Post-Doctoral Fellow	University of Toronto
Bennit Mueller	Post-Doctoral Fellow	University of Victoria
Nagtegaal, N	Undergraduate Student	McGill University
David Pierce	Advisory Panel	Scripps Institution of Oceanography
Markus Schnorbus	Collaborator	Environment Canada, CCCma
John Scinocca	Collaborator	Environment Canada, CCCma
James Screen	International Collaborator	University of Exeter
Michael Sigmond	Collaborator	Environment Canada, CCCma
Alexandar Slavin	Post-Doctoral Fellow	McGill University
Doug Smith	Advisory Panel	UK Met Office
Andrew Snauffer	PhD Student	University of British Columbia
Seok-Woo Son	International Collaborator	Seoul University
Reinel Sospedra-Alfonso	Collaborator	University of Victoria
Neil Tandon	Post-Doctoral Fellow	University of Toronto
Laurent Terray	International Collaborator	CERFACS, France
Chad Thackery	PhD Student	University of Waterloo
Adrienne Tivy	Collaborator	Environment Canada, CIS
Markus Todt	PhD Student	University of Waterloo
Bruno Tremblay	Funded Collaborator	McGill University
Knut von Salzen	Collaborator	Environment Canada, CCCma
Libo Wang	Collaborator	Environment Canada, CRD
James Williams	PhD Student	McGill University
Matthew Williamson	MSc Student	University of Guelph
Younas Waqar	Research Associate	University of Northern British Columbia
Xuebin Zhang	Collaborator	Environment Canada, CRD
Xuesong Zhang	PhD Student	University of Toronto
Francis Zwiers	Steering Committee, Funded Collaborator	Pacific Climate Impacts Consortium

Appendix C: Publications and Presentations in Year 4

Published, in press, and accepted articles directly supported by CanSISE[2]

1. Bichet, A., P.J. Kushner, and L.R. Mudryk, 2016: Estimating the Continental Response to Global Warming Using Pattern-Scaled Sea Surface Temperatures and Sea Ice. J. Climate, doi: 10.1175/JCLI-D-16-0032.1.
2. Blackport, R., and P. J. Kushner, 2016: The Transient and Equilibrium Climate Response to Rapid Summertime Sea Ice Loss in CCSM4. J. Climate, 29, 401–417, doi:10.1175/JCLI-D-15-0284.1.
3. Dirkson, A., W. J. Merryfield, and A. Monahan, 2016: Impacts of sea ice thickness initialization on seasonal Arctic sea ice predictions. J. Climate, doi:10.1175/JCLI-D-16-0437.1. http://dx.doi.org/10.1175/JCLI-D-16-0437.1 (Accessed December 6, 2016).
4. Gervais, M., E. Atallah, J. R. Gyakum, and L. B. Tremblay, 2016: Arctic Air Masses in a Warming World. J. Climate, doi:10.1175/JCLI-D-15-0499.1.
5. Kang, D. H., H. Gao, X. Shi, S. ul Islam, and S. J. Déry, 2016: Impacts of a Rapidly Declining Mountain Snowpack on Streamflow Timing in Canada's Fraser River Basin. Scientific Reports, 6, 19299.
6. Kirchmeier-Young, M. C., F. W. Zwiers, and N. P. Gillett, 2016: Attribution of Extreme Events in Arctic Sea Ice Extent. J. Climate, doi: 10.1175/JCLI-D-16-0412.1
7. Kumar, S., F. Zwiers, P. A. Dirmeyer, D. M. Lawrence, R. Shrestha, and A. T. Werner (2016), Terrestrial contribution to the heterogeneity in hydrological changes under global warming, Water Resour. Res., 52, 3127–3142, doi:10.1002/2016WR018607.
8. Kumar, S., J. L. Kinter III, Z. Pan, and J. Sheffiled (2016). Twentieth century temperature trends in CMIP3, CMIP5, and CESM-LE climate simulations – spatial-temporal uncertainties, differences and their potential sources, Journal of Geophysical Research-Atmospheres, accepted, doi: 10.1002/2015JD024382
9. Laliberté, F., S. E. L. Howell, and P. J. Kushner, 2016: Regional variability of a projected sea ice-free Arctic during the summer months. Geophys. Res. Lett., 43, 2015GL066855, doi:10.1002/2015GL066855.
10. McCusker, K. E., J. C. Fyfe, and M. Sigmond, 2016: Twenty-five winters of unexpected Eurasian cooling unlikely due to Arctic sea-ice loss. Nature Geosci, advance online publication. http://dx.doi.org/10.1038/ngeo2820.

11. Najafi, M. R., F. W. Zwiers, and N. P. Gillett, 2016: Attribution of the spring snow cover extent decline in the Northern Hemisphere, Eurasia and North America to anthropogenic influence. Climatic Change, 1–16, doi:10.1007/s10584-016-1632-2.
12. Snauffer, A.M., A.J. Cannon, and W.W. Hsieh, 2016: Comparison of gridded snow water equivalent products with in situ measurements in British Columbia, Canada, Journal of Hydrology, 541, 714-726, doi:10.1016/j.jhydrol.2016.07.027
13. Sospedra-Alfonso, R., L. Mudryk, W. J. Merryfield, and C. Derksen, 2016a: Representation of Snow in the Canadian Seasonal to Interannual Prediction System. Part I: Initialization. J. Hydrometeor, 17, 1467–1488, doi:10.1175/JHM-D-14-0223.1.
14. Sospedra-Alfonso, R., W. J. Merryfield, and V. V. Kharin, 2016b: Representation of Snow in the Canadian Seasonal to Interannual Prediction System. Part II: Potential Predictability and Hindcast Skill. J. Hydrometeor., 17, 2511–2535, doi:10.1175/JHM-D-16-0027.1.
15. Thackeray, C.W., & Fletcher, C. G. (2016). Snow albedo feedback: Current knowledge, importance, outstanding issues and future directions. Progress in Physical Geography. doi:10.1177/0309133315620999
16. Thackeray, C. W., C. G. Fletcher, L. R. Mudryk, and C. Derksen, 2016: Quantifying the uncertainty in historical and future simulations of Northern Hemisphere spring snow cover. J. Climate, doi:10.1175/JCLI-D-16-0341.1. http://dx.doi.org/10.1175/JCLI-D-16-0341.1
17. Williams, J., Tremblay, B., Newton, R., and R. Allard (2016): Dynamic Preconditioning of the Minimum September Sea-Ice Extent. J. Climate, doi:10.1175/JCLI-D-15-0515.1

Published Articles related to CanSISE Science[3]

1. Schwaizer, G., E. Ripper, T. Nagler, R. Fernandes, S. Metsämäki, R. Solberg, K.Luojus, C. Derksen, L. Mudryk, and R. Brown. 2016. Snow Product Intercomparison and Validation Report. The Satellite Snow Product Intercomparison and Evaluation Exercise Deliverable 13. https://earth.esa.int/web/sppa/activities/qa4eo/snowpex
2. Wang, L., J. N.S. Cole, P. Bartlett, D. Verseghy, C. Derksen, R. Brown, and K. von Salzen (2016), Investigating the spread in surface albedo for snow-covered forests in CMIP5 models, J. Geophys. Res. Atmos., 121, 1104–1119, doi:10.1002/2015JD023824.
3. Wang, L., M. MacKay, R. Brown, P. Bartlett, R. Harvey, and A. Langlois (2014), Application of satellite data for evaluating the cold climate performance of the Canadian Regional Climate model over Québec, Canada, Journal of Hydrometeorology, 15, 614-630.

4. Williams, J., L.B. Tremblay, R. Newton, R. Allard, 2016: Dynamic preconditioning of the September sea-ice extent minimum, Journal of Climate, 5879-5891, August, doi: 10.1175/JCLI-D-15-0515.1.

Submitted

1. Blackport, R., and P. Kushner. Isolating the atmospheric circulation response to Arctic sea-ice loss in the coupled climate system. Submitted to J. Climate, April 2016.
2. Fyfe, J.C. & 10 co-authors. Large near-term projected snowpack loss over the western United States. Submitted to Nature Comms. (2016).
3. Gagne, M.-E., M.C. Kirchmeier-Young, N.P. Gillett & J.C. Fyfe. Arctic sea ice response to the eruptions of Agung, El Chichon and Pinatubo. Submitted to Geophys. Res. Lett. (2016).
4. Islam S and Déry S J (2016), Evaluating uncertainties in modelling the snow hydrology of the Fraser River Basin, British Columbia, Canada, Hydrology and Earth System Sciences Discussion, doi:10.5194/hess-2016-469, in review (directly supported by CanSISE).
5. Islam S., Déry S.J. and Werner A.T., 2015: Future climate change impacts on snow and water resources of the Fraser River Basin, British Columbia, Submitted to Journal of Hydrometeorology
6. Sospedra-Alfonso, R., and W. J. Merryfield, 2016: Influence of temperature and precipitation on historical and future snowpack variability over the Northern Hemisphere in the Second-Generation Canadian Earth System Model. Submitted to Journal of Climate, August 2016
7. Sigmond, M., M. C. Reader, G. M. Flato, W. J. Merryfield and A. Tivy, 2016: Skillful seasonal forecasts of Arctic sea ice retreat and advance dates in a dynamical forecasting system. Geophysical Research Letters, submitted.

Presentations

1. Allchin, M., Stephen Déry. (2016). Spatio-Temporal Patterns in Trends of Northern Hemisphere Snow Extent and Duration, 1971-2014. Joint CMOS/CGU congress, Fredericton, Canada
2. Ambadan-Thomas, J., A. Berg, W. Merryfield. 2016. Effects of snow-melt on soil moisture memory and on Land-Atmosphere interaction. Canadian Geophysical Union and Canadian Meteorological and Oceanographic Society. Fredericton NB. Canada.
3. Bouchat, A., Tremblay, B., 2016, Can we improve the deformation distributions of viscous-plastic sea-ice models?, Ocean Science Meeting, New Orleans (LA).
4. Bouchat, A., Tremblay, B., 2016, Using RGPS deformation fields to constrain sea-ice mechanical strength parameters, FAMOS Meeting, Woods Hole (MA).

5. Bouchat, A., Tremblay, B., 2016, Using RGPS deformation fields to constrain sea-ice mechanical strength parameters, Quebec-Ocean General Assembly, Rimouski (QC).
6. Bourdages L., Tremblay, B., 2016, Spatial and temporal variability of Arctic atmospheric inversions, Rimouski.
7. Brunette C., Williams J, Tremblay B, Newton R, Pfirman S, 2016, Regional forecast of the minimum sea ice extent: A Lagrangian approach, New Orleans.
8. Brunette C., Tremblay B., Williams J., Newton R., 2016, Coastal divergence as a Predictor for the minimum sea ice extent, Polar Prediction Workshop, LDEO, Palisafes.
9. Derksen, C., L. Mudryk, R. Brown, K. Luojus, P. Marsh, C. Smith, and R. Sospedra-Alphonso. Linking snow on the ground and snowfall. 5th International Workshop on Space-based Snowfall Measurement, Bologna, Italy, October 2016.
10. Derksen, C., L. Mudryk, R. Brown, and K. Luojus. The role of remotely sensed datasets in the characterization of northern hemisphere snow water equivalent. ESA Living Planet Symposium, Prague, Czech Republic, May 2016.
11. Dirkson A, 2016: Skilful probabilistic forecasts of Arctic sea ice, AGU Fall Meeting, 12-16 Dec 2016, San Francisco
12. Hata Y., Tremblay B., Dupont F., 2016, The forces acting on sea ice in the Canadian Arctic Archipelago, Woods Hole - the FAMOS meeting.
13. Hata Y., Tremblay B., 2016, Mechanical sea-ice strength parameterized as a function of ice temperature, Vienna - he EGU General Assembly.
14. Hata Y., Tremblay B., 2016, Estimating the landfast sea ice strength in the Canadian Arctic Archipelago, Banff - ArcTrain Meeting, related to CanSISE.
15. Herrington, T. and Fletcher, C. (2016) "Lucky" Realizations of the AO-Snow Relationship. Canadian Association of Geographers - Ontario Division 2016, Waterloo, ON, 28 Oct 2016. Poster.
16. Islam S. and Déry S.J. (2016) Quantification of uncertainties in modelling the present and projected hydrology of the Fraser River Basin, British Columbia, 50th CMOS Congress & joint CGU Annual Meeting, May 29- June 02, 2016, Fredericton, NB, Canada.
17. Kumar, S., R. Allan, F. Zwiers, D. Lawrence, and P. Dirmeyer (2016). Revisiting Trends in Wetness and Dryness in the Presence of Internal Climate Variability. AMS 96th Annual Meeting, New Orleans, 10-14 January 2016.

18. Kushner, P.J., Mudryk, L.R., Derksen, C., Brown, R., and Thackeray, C.W., 2016: Relationship between snow cover and temperature trends in observational and earth-system model ensembles. American Geophysical Union Fall Meeting, San Francisco.
19. Merryfield W J, 2016: Current and emerging seasonal and longer range ECCC forecasting capabilities relevant to hydrological prediction, Ouranos sub-seasonal to seasonal workshop, Montreal
20. Mudryk, L.R., P.J. Kushner, C. Derksen, C. Thackeray, "Snow cover response to temperature in observational and climate model ensembles", CESM Workshop 2016, Bolder, CO, June 2016.
21. Sospedra-Alfonso R, Merryfield W J, 2016: Potential and actual predictability of snow water equivalent in the Canadian Seasonal to Interannual Prediction System (CanSIPS), 50th CMOS Congress, Fredericton
22. Sospedra-Alfonso R, 2016: Skill of snow water equivalent forecasts in CanSIPS, ECCC Climate Research Division seminar, Toronto
23. Sospedra-Alfonso R, 2016: Skill of snow water equivalent forecasts in CanSIPS, ECCC Recherche en prévision numérique seminar, Montreal
24. Sospedra-Alfonso R, 2016: Potential predictability and actual skill for snow water equivalentand soil moisture in CanSIPS, Ouranos sub-seasonal to seasonal workshop, Montreal
25. Thackeray, C.W., Fletcher C.G., Mudryk, L.R., and Derksen C., 2016: Quantifying the uncertainty in historical and future simulations of Northern Hemisphere spring snow cover. American Geophysical Union Fall Meeting, San Francisco.
26. Thackeray, C.W., Fletcher C.G., and Derksen, C., 2016: The impact of simulated albedo biases on climate in CLM. CanSISE Network Workshop 2016, Toronto.
27. Tremblay B, 2016: Rapid sea ice decline in the Arctic: an ocean mechanism, Reykjavik (Iceland).
28. Tremblay B, Williams J, Brunette C, Newton R, Pfirman S, 2016: Regional forecast of the minimum sea ice extent a Lagrangian approach, 2016 Polar Prediction Workshop, Palisades (NY).
29. Tremblay B, 2016: Rapid sea ice decline in the Arctic: an ocean mechanism, Bologna (Italy).
30. Tremblay B, 2016: Regional forecast of the minimum sea ice extent: a Lagrangian approach, Atelier sur la prévision saisonnière et décénnale – Ouranos, Montreal.
31. Tremblay B, 2016: Review of the state of the Art in ice modeling, 17th Meeting of the International Ice Charting Working Group, Ottawa.

32. Williams, J., Tremblay, B., Newton, R., Allard, R., 2016, Dynamic preconditioning of the minimum September Sea-ice extent, Eurpoean Geophysics Union, Vienna, Austria.
33. Williams, J., Tremblay, B., and Lemieux, J-F., 2016, The effects of elastic and plastic waves on the numerical convergence of the Elastic-Viscous-Plastic and Viscous-Plastic sea-ice models, Alfred Wegener Institute, Bremerhaven, Germany.
34. Williams, J., Tremblay, B., and Lemieux, J-F., 2016, Resolving plastic deformation in a Viscous-Plastic sea-ice model, AGU Ocean Sciences, New Orleans, USA.
35. Williams, J., Tremblay, B., and Lemieux, J-F., 2016, Resolving plastic deformation in a Viscous-Plastic sea-ice model, NASA Stennis Space Center, USA.

Endnotes

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[2] We have grouped these papers together to clearly indicate which publications have come out in the reporting period that are directly supported by funds from the Network. There are 17 published, in press, and accepted papers.

[3] In the following lists are papers that involve CanSISE researchers or collaborators but that are not directly supported by CanSISE, as well as papers that are not yet accepted (submitted/in revision) whether or not supported by CanSISE.

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