H08: Snow Level and Precipitation: Trends, Extremes and Impacts

Conveners: Mindy Brugman[1], and Ron Stewart [2]

Co-chairs: Mindy Brugman[1], and Ron Stewart [2]

[1] Coastal and Mountain Meteorology National Lab West, MSC, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5, Phone: 604-713-9518, E-mail: mindy.brugman@canada.ca

Session Description

Snow Level is closely tied to Precipitation Intensity, and both factors change dramatically with individual weather systems and climate change. Modeling of the melting snow transition layer, through which precipitation melts from snow into rain is critical for accurate snow level forecasting. Also, the heavier the precipitation rate, the greater the cooling required in the atmosphere to melt the snow, and the lower the snow level. A series of interrelated processes occur in the melting snow transition layer that can be observed with a variety of instruments, and can be tracked with time. The intensity of precipitation is expected to increase with global warming, and there already is some suggestion that convective precipitation is increasing on earth. In recent years we have been experiencing repeated record breaking precipitation events, and impactful snow level changes. How more frequent will extreme events now occur? The impacts caused by more intense precipitation with or without rapidly varying snow levels, can be extreme. The current trends are for the snow level to rise, however with more intense precipitation it is possible deep snow will still accumulate at the highest elevations. All papers related to snow level and precipitation, from observations to modeling, past present and future are invited. Studies that provide new insight into remote sensing of melting snow layer properties and the physics controlling precipitation and snow level variations are invited. Innovative new methods are welcome, including isotopic applications. Studies that focus on precipitation intensity and detection of shifts and extremes are also welcome. Investigations on the impacts of past snow level and precipitation intensity changes are needed, to improve our understanding of current trends and extremes, so we can accurately warn and effectively prepare for change. In addition, related regional impact studies such as flooding, avalanche and water supply changes are welcome.

Primary Affiliation: Joint cgu/CSAFM/ Meteorology/ Hydrology/ Earth Surface Processes / Glaciology

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NOTE: THIS DOCUMENT CONTAINS INFORMATION FOR ALL SESSION SUB-SECTIONS. PRESENTER ABSTRACTS ARE FOUND AT THE END OF THE DOCUMENT.

SCHEDULE MAY BE SUBJECT TO CHANGE.

ORAL SESSION H08a

Chairs: M. Brugman & R. Stewart **Room: GEOG 200**

Tuesday, May 30th

TIME	AUTHORS	TITLE
16:00 INVITED	Julie M. Thériault	Formation mechanisms and evolution of winter precipitation types
16:15	M.M. Brugman, T. Smith, C. Emond, A. Coldwells, M. Loney & A. Chen	Snow level forecasting using precipitation feedbacks within the melting snow transition layer
16:30	A.M. Snauffer, W. Hsieh & A. Cannon	High-resolution mapping of snow water equivalent in British Columbia by artificial neural networks
16:45	R. E. Stewart, M.M. Brugman, R. Mo, G. Bramwell, J. Bau, M. MacDonald & J. Goosen	Recent high impact freezing rain events in BC
17:00	J. Almonte & R.E. Stewart	On the changing snow-rain transition regions of the south-western Canadian Cordillera under a warmer climate
17:15	P. Odon, G. West & R. Stull	Extreme levels of temperatures, wind speeds, and precipitation over British Columbia, Canada

POSTER SESSION H08

Chairs: M. Brugman & R. Stewart **Room: ESB Atrium**

Wednesday, May 31st

Poster No.	AUTHORS	TITLE
P01-H08	J.H. Sherwood, S.J. Ketcheson, & J.S. Price	Landform controls on snow dynamics in a fen watershed in the Western Boreal Plains, Canada
P02- H08	M.M. Brugman, T. Smith, R. Mo, J. Goosen, G. Pearce, J. Bau, A. Besson, J. Hay, C. Yu, L. West, M. Loney & D. Simpson	Precipitation forecasting during major winter storms in Pacific and Yukon region
P03- H08	T. Atkinson, M.M. Brugman, C. Emond, J. Goosen & T. Smith	Validation of a new snow level algorithm for the winter of 2016/2017

SUBMITTED ABSTRACTS

H08-01 INVITED: Formation mechanisms and evolution of winter precipitation types

Julie M. Thériault[1]

[1] Department of Earth and Atmospheric Sciences, Université du Québec à Montréal, Montréal, QC, H2X 3Y7

Abstract
Winter storms often lead to major inconveniences and the different types of precipitation are often the key factor. In particular, many types of precipitation such as freezing rain, ice pellets and wet snow may occur when the temperature is near 0°C. Their formation mechanisms are complex because they are composed of both liquid and ice. For instance, only a small change in temperature can affect dramatically the severity of the storm by producing freezing rain instead of ice pellets. Each winter storm occurring contributes directly to the climatology of a region. Some efforts are being made currently to better understand their formation mechanisms, atmospheric conditions and their accurate detection at the surface. These are critical to assess their variation with climate change. This presentation will discuss different aspects of winter precipitation. First, the many processes involved in the formation of winter precipitation are investigated and it is shown, for example, that a small change in the temperature (~1°C) can affect the type of precipitation reaching the surface. Second, historical and climate projections of freezing precipitation using a regional climate model will be discussed. Third, the problem of precipitation under catch will be put in perspective of the validation of solid precipitation produced by regional climate models. Overall, this is a step towards a better understanding of the evolution of precipitation types during individual storms and from a climate perspective.

Presentation type: Invited Oral Presentation

H08-02: Snow level forecasting using precipitation feedbacks within the melting snow transition layer

Melinda M. Brugman[1], Trevor Smith[2], Chris Emond[2], Al Coldwells[2], Matt Loney[2], Aaron Chen[3]

[1] Coastal and Mountain Meteorology National Lab, Prediction Services and Operations West, MSC, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5,
Phone: 604-713-9518, E-mail: mindy.brugman@canada.ca

[2] Pacific Storm Prediction Centre, PSO-W, MSC, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5

[3] Weather Operations Support, Shared Services Canada, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5

Abstract

The snow level elevation is closely tied to precipitation intensity, and both factors change dramatically with individual weather systems and climate. For this study, a new snow level forecast was developed using physically based principles applied to operational numerical models, and validated over western Canada. The Snow Level (SL) forecasts were improved by considering precipitation rate and condensation using a post processing SL algorithm based on the wet bulb freezing temperature. Adiabatic processes due to vertical and horizontal motions, were handled by numerical model profile updates, with diabatic latent heat exchanges the focus here. The latent heat exchanges considered in this study were caused by hydrometeor phase transformation. This study developed what is called the Enhanced Wet Bulb freeZing (EWBZ) algorithm. CMC operational numerical model profiles were adjusted using this post processing EWBZ SL algorithm. This algorithm uses the rate precipitation falling through the upper freezing level and the surrounding air remains isothermal at the freezing point until the all the snow is melted. Snow level forecasts at points are next transferred into gridded snow level forecasts. As precipitation rate intensifies, the snow level lowers until the integrated heat available equals the latent heat required for melting. This SL algorithm includes condensation to avoid super-saturation. The Melting Snow Transition Layer (MSTL) is the "bright band" zone where falling snow melts into rain. The MSTL is assumed to remain at wet bulb freezing temperature throughout. This algorithm was validated using surface observations and vertical profiles, including air motion adjusted RASS profiles. An intriguing new result is convective precipitation is likely enhanced by feedbacks near the snow level in strong upslope flows. This EWBZ SL algorithm improves snow level forecasts, when model precipitation and atmospheric vertical profiles are accurate. Results imply precipitation feedbacks enhance intensities near the snow level.

Presentation type: Oral Presentation

H08-03: High-resolution mapping of snow water equivalent in British Columbia by artificial neural networks

Andrew M. Snauffer[1*], William Hsieh[2], and Alex Cannon[3]

[1] Department of Earth, Ocean and Atmospheric Sciences, The University of British Columbia, Vancouver, BC V6T 1Z4, Phone: 778-986-3319, E-mail: asnauffer@eoas.ubc.ca
[2] Department of Earth, Ocean and Atmospheric Sciences, The University of British Columbia, Vancouver, BC V6T 1Z4
[3] Environment and Climate Change Canada, Victoria, BC V8W 2Y2

Abstract
Accurate estimates of regional snow water equivalent (SWE) are critical for hydrologic planning, particularly areas with hydrologic regimes dominated by spring melt. While numerous gridded data products provide such estimates, accurate representations are particularly challenging under conditions of mountainous terrain, heavy forest cover and large snow accumulations, contexts which in many ways define the province of British Columbia (BC), Canada. One promising avenue of improving SWE estimates is a data fusion approach which combines field observations with gridded SWE products and relevant covariates. A base artificial neural network (ANN) was constructed using three of the best performing gridded SWE products over BC (ERA-Interim/Land, MERRA and GLDAS-2) and simple location and time covariates. This base ANN was then enhanced to include terrain covariates (slope, aspect and Terrain Roughness Index, TRI) as well as a simple 1-layer energy balance snow model driven by gridded bias-corrected ANUSPLIN temperature and precipitation values. While the ANN enhanced with all these covariates did perform better than the base ANN, it was found that slope and aspect did not contribute to skill improvement in a meaningful way. The enhanced ANN improved station mean absolute error (MAE) by 55% relative to the composing gridded products over the province. Interannual peak SWE correlation coefficient was found to be 0.74, an improvement of 0.06 to 0.17 over the composing products. This nonlinear approach outperformed a comparable multiple linear regression (MLR) model by 20% in MAE and 0.05 in interannual correlation. The enhanced ANN has also been shown to estimate better than the Variable Infiltration Capacity (VIC) hydrologic model calibrated and run for four BC watersheds, improving MAE by 29% and correlation by 0.06. The performance improvements of the enhanced ANN are statistically significant at the 95% level across the province and in most of its five physiographic regions.

Presentation type: Oral Presentation

H08-04: Recent high impact freezing rain events in BC

Ronald E. Stewart[1], Melinda M. Brugman[2], Ruping Mo[2], Giselle Bramwell[3], J. Bau[4], M. MacDonald[4] and Jim Goosen[4]

[1] Environment and Geography Dept., University of Manitoba, Winnipeg, MB, R3T 2N2, Phone: (204) 480-1052, E-mail: Ronald.Stewart@umanitoba.ca
[2] Coastal and Mountain Meteorology National Lab West, Prediction Services Operations West, MSC, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5
[3] Applied Climatology, Client Services and Outreach, Prediction Services Operations West, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5
[4] Pacific Storm Prediction Centre, PSO-W, MSC, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5

Abstract
Several unusual high impact freezing rain events have occurred in British Columbia during the last 3 years. Could these major events suggest a climate shift to a new normal? These major recent events were unusual because they lasted several days and created unexpectedly severe impacts. The severe impacts included major power outages, with many travelers stranded on highways due to icy conditions, widespread tree fall and vehicle accidents. Many citizens were imprisoned in their houses for days, with supplies running short. Significant economic impacts and inconveniences prevailed especially for the two biggest storms of Jan. 4-7, 2015 and Feb. 9-10, 2017. These produced heavy snow and freezing rain that crippled lower Fraser Valley and nearby mountain highways, causing the Coquihalla Summit route to be closed for days. The recent Feb. 9-10, 2017 storm trapped many travelers in risky situations when the mountain highways became suddenly impassable between the coastal mainland and the Okanagan regions. The freezing rain events occurred when entrenched arctic air over the BC interior was overrun by a warm moist storm air stream (called an “Atmospheric River” or AR). Intense wintertime AR storm events occurred during the worst recent freezing rain episodes in BC. For both events, a long or severe cold snap provided the optimal situation for freezing rain to eventually happen. The unusually long cold spell from Dec. 2016 to Feb. 2017 caused the Shuswap Lake in the southern BC interior to freeze over completely, which locals had not witnessed for more than 60 years. Results show that intense storm systems with unusually strong warm moist jets aloft overriding entrenched cold air at the surface produced the major freezing rain events in BC during 2015-17. For perspective, the available freezing rain records for BC are summarized and compared to freezing rain records from across Canada.

Presentation type: Oral Presentation

H08-05: On the changing snow-rain transition regions of the south-western Canadian Cordillera under a warmer climate

Juris Almonte* and Ronald E. Stewart

Environment and Geography Dept., University of Manitoba, Winnipeg, MB, R3T 2N2
Phone: 204-510-5779, E-mail: umalmonj@myumanitoba.ca

Abstract
Snow-rain transition regions have major implications for those in the transportation, power, and tourism industries, as they are often associated with hazardous weather conditions. They commonly occur within mountainous regions, as the 2010 Vancouver Winter Olympics exemplified. Given their importance, this presentation will discuss the analyses of changing snow-rain transition regions over the south-western portion of the Canadian Cordillera (49 to 53°N and -114 to -125°W) during the winter and spring months (JFMA) of 2010. The Weather Research and Forecasting (WRF) model Version 3.4.1 was used to conduct a pseudo-global warming (PGW) experiment, in which the past climate is perturbed using CMIP5 RCP8.5 and its projections at the end of the 21st century (Liu et al. 2016). Overall, under a PGW climate, there is a 2.8°C average increase in temperature and a 4% decrease in total precipitation over this domain, resulting in a 38% reduction in snow, along with 16 and 15% increases in rain and graupel, respectively. Important transition region changes are evident through the examination of specific days. For example on 11-12 January the PGW information indicates 64% fewer snow-rain transitions, with a mean elevation gain of almost 300 m. Visual inspection of precipitation patterns indicates a northern movement in the locations of transition regions along the Coastal Mountains and new occurrences over the Canadian Rockies along the northern edge of the domain. Both the historical and PGW runs indicate that transition regions were predominantly occurring within downslope conditions. Continuing analysis is focusing on changes in precipitation intensity and the composition of associated articles including their degree of accretion. This presentation will illustrate a comprehensive summary of these and other findings.

Presentation type: Oral Presentation

H08-06: Extreme levels of temperatures, wind speeds and precipitation over British Columbia, Canada

Pedro Odon[1*], Gregory West[2], and Roland Stull[2]

[1] Dept. of Earth, Ocean and Atmospheric Sciences, 2020 – 2207 Main Mall, Vancouver, BC, V6T 1Z4, Phone: 778-918-1712, E-mail: podon@eoas.ubc.ca

[2] Dept. of Earth, Ocean and Atmospheric Sciences, 2020 – 2207 Main Mall, Vancouver, BC, V6T 1Z4

Abstract

The extreme weather events of greatest concern in British Columbia include heavy precipitation, drought, unseasonably hot and cold periods, and wind storms. These weather events directly impact the general population as well as British Columbia's primary utility company, BC Hydro. To gauge the severity of an extreme weather event, a historical dataset is needed. However, weather station data over British Columbia is sparse outside of far southwestern BC. This paucity of data motivates research to determine the best reanalysis, and how well it represents extreme weather events. Seasonal bias and spread of extreme values of 2-m temperatures, 10-m wind speeds and precipitation are evaluated at daily time scales over the complex terrain of British Columbia for the period 1980–2010, from the ERA-Interim, the Climate Forecast System Reanalysis (CFSR), the 55-year Japanese Reanalysis (JRA-55), and the latest Modern-Era Retrospective Analysis for Research and Applications (MERRA-2). Reanalysis data are compared with observations at 27 meteorological stations in disparate climatological zones. They cover the vast majority of BC's population centers as well as mountainous terrain to the extent possible. Finally, changes in extreme temperatures, wind speeds and precipitation due to non-stationarity are evaluated over the same period. For temperature, JRA-55 and ERA-Interim are the better reanalyses. They represent well the distributions of daily maximum and minimum temperatures, and of extreme values. There is, however, significant bias for valley stations, likely due to poor terrain representation.

Presentation type: Oral Presentation

H08-07: Landform controls on snow dynamics in a fen watershed in the Western Boreal Plains, Canada.

James H. Sherwood, Scott J. Ketcheson, and Jonathan S. Price

Dept. of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1, Phone: 519-888-4567 x 35397, E-mail: jsherwoo@uwaterloo.ca

Abstract:
In the Western Boreal Plains (WBP) region of Northern Alberta, snow represents ~25% of annual precipitation and is, therefore, a potential recharge water source for landforms (e.g. coarse textured hillslopes) during spring thaw. Influences on snow accumulation and redistribution during winter include canopy openness, tree-stem density and wind fetch. These are not consistent across landform/peatland types in the WBP, where contrasting tree density, size and species may influence accumulation, redistribution and ablation dynamics. Inclusion of snow dynamics is essential for understanding water availability in the sub-humid WBP climate. Few studies focus on snow dynamics in the WBP and distribution of over-winter precipitation stores across upland-peatland systems remains unclear.

Controls on snow distribution, accumulation, snow water equivalent and melt dynamics, were investigated for a poor fen watershed basin. Field measurements, taken March-May, 2012-2014 and in 2016, found snow depth lowest in the open fen, and highest in the densely treed fen and at changes in gradient (i.e. slope margins, lower areas of hillslopes). Multiple linear regression analysis suggests wind speed to be the dominant snow accumulation control, followed by tree density and canopy openness. Tree height correlated with slower pack ablation within dense treed fen areas, greater stem densities and dense canopy leading to negligible wind speeds 1m above the snow pack, making aeolian redistribution negligible in densely treed areas.

Beyond developing a better understanding of snow dynamics in natural basin-fen systems, it is also of particular relevance to landscape reclamation design in the WBP, given basin features on post-mine landscapes are targeted for wetland and hydrologically integrated conveyor features within mine closure plans.

Presentation type: Poster

H08-08: Precipitation forecasting during major winter storms in the Pacific and Yukon region

Melinda M. Brugman[2], Trevor Smith[1], Ruping Mo[2], Jim Goosen[1], Greg Pearce[1], Jonathan Bau[1], Andre Besson[1], Jennifer Hay[1], Cindy Yu[1], Lisa West[1], Matt Loney[1] and Doug Simpson[1]

[1] Pacific Storm Prediction Centre, PSO-W, MSC, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5, Phone: 604-664-9385, E-Mail: Trevor.Smith@canada.ca
[2] Coastal and Mountain Meteorology National Lab West, PSO-W, MSC, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5

Abstract
During recent winters the forecast guidance has indicated record breaking storms in terms of precipitation amounts and also snowfall for British Columbia. Often on the forecast desk the guidance presented to forecasters differs by orders of magnitude depending on the model choice. Recently record breaking precipitation has been forecast by guidance for multiple storms, and in some cases this has occurred, but not all. Although numerical and statistical model methods are improving, model resolutions are finer and more ensemble forecast choices are available, the models can show disparate precipitation forecasts across the complex terrain of western Canada. Forecasters on the desk keep model differences in mind (such as differences in hydrometeor "spillover" in strong flows, terrain blocking or boundary layer physics), but still need to make accurate timely decisions by comparing all the best numerical model, statistical guidance and observational data sets available. During the past several years, this decision making has become much more challenging, because the new models sometimes differ too much, especially during the most intense storms. With global warming, there is a real and current need to anticipate record breaking storms and related precipitation events with greater confidence. This is because the weather impacts based on climate warming projections would greatly affect Canada, and the western regions are the first hit by the most intense Pacific storms. In this paper, recent storms are examined from a weather forecasters perspective with focus on events with difficult decision making requirements related to precipitation intensity, amount and type. How Pacific Storm Prediction Centre meteorologists make critical decisions to give the best forecasts and warnings possible is discussed, with lessons learned from the 2016-17 winter season.

Presentation type: Poster

H08-09: Validation of a new snow level algorithm for the winter of 2016/2017

Tim Atkinson[1*], Melinda M. Brugman[2], Chris Emond[3], Jim Goosen[3] and Trevor Smith[3]

[1] University of British Columbia, Vancouver, BC, V6T 2P6, E-mail: Tim.Atkinson@canada.ca
[2] Coastal and Mountain Meteorology National Lab West, Prediction Services Operations West, MSC, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5, Phone: 604-713-9518; E-mail: Mindy.Brugman@canada.ca
[3] Pacific Storm Prediction Centre, PSO-W, MSC, Environment and Climate Change Canada, Vancouver, BC, V6C 3S5

Abstract
A new experimental Snow Level (SL) algorithm was developed by the Coastal and Mountain Meteorology National Lab with Pacific Storm Prediction Centre of Meteorological Services of Canada (MSC). This SL algorithm was validated with direct observations to assess the diabatic cooling caused by snow melting as it falls. For this study, 0-48 hr SL forecasts were produced by computing the Enhanced Wet Bulb Freezing Level (EWBZ) from CMC operational models at grid scales between 2.5 to 10 km (or more). In this study, we developed a procedure to obtain a Critical Success Index for forecasts such as over the Coquihalla Highway, which is the main transportation route crossing between the BC coast and interior. During winter months this highway is often referred to as the "highway through hell" because of its world renowned difficult conditions due to heavy snow, heavy rain and variable snow levels. Web cameras and surface observations were the focus of validation used in this study, supported by radar and vertical profilers. Radiosonde data was also compared to the vertical profiles before and after transformation from the numerical model to the actual terrain surface, and EWBZ adjustments. Significance testing being carried out on the results is discussed. New multi-dimensional methods were developed to compare disparate data sets where forecast snow levels are strongly dependent on model temperature and humidity profiles as well as precipitation intensities, and for numerical models which sometimes varied by orders of magnitude between different forecast precipitation amounts and also observed values. The methodology for comparing the SL observations to the new EWBZ forecasts will be discussed. Finally, the validation results are applied to determine if the EWBZ SL algorithm provides better forecasts than the currently operational guidance.

Presentation type: Poster