



**Proceedings of the
76th ANNUAL**

EASTERN SNOW CONFERENCE
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Fairlee, Vermont, USA

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FOREWORD

This proceedings volume contains papers presented at the 76th Eastern Snow Conference (ESC) held 4-6 June 2019 in Fairlee, Vermont, USA. The meeting featured oral and poster sessions on recent advances in remote sensing, remote sensing theory, applications of remote sensing ranging from the ice sheets to the tropics, snow and ice processes, and hydroclimatology. The meeting also included a panel discussion on the future of snow satellite missions.

The ESC is a joint United States and Canadian forum for discussing recent work on operational, applied and scientific issues related to snow and ice. It also retains an increasing interest as a symposium where novel approaches to cryospheric science of international significance are presented. The ESC has published an annual series of proceedings since 1952. Typical topics include studies of snow and ice as materials, snow removal, meteorological forecasting, river ice control, snow hydrology, snow chemistry, glaciology, remote sensing of snow and ice, and snow ecology. Membership in the ESC is open to all interested individuals and corporations. Additional copies of the current proceedings and all back issues can be obtained from the Secretary. Additional information about the Eastern Snow Conference may be found at: <http://www.easternsnow.org/>.

We thank members of the ESC executive committee for their continued work toward making each annual meeting a success. This includes, but is not limited to, the work of the Research Committee who evaluate all student presentations and recommend awardees for the three student prizes.

Logistical support for the 2019 Eastern Snow Conference was provided by the Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH. Special thanks to Renee Melendy, CRREL program specialist, for assisting with the meeting.

The 2019 meeting of the Eastern Snow Conference and these Proceedings were made possible in part by Corporate membership from Campbell Scientific Canada, Geonor, Gradient Wind Engineering, and Hoskin Scientific Ltd.

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We look forward to seeing you at the 77th Eastern Snow Conference meeting to be held 9–11 June 2020 at York University in Toronto, Ontario, Canada.

Krystopher Chutko and Eli Deeb
ESC Proceedings Co-Editors
University of Saskatchewan and CRREL

STATEMENT OF PURPOSE

The Eastern Snow Conference (ESC) is a joint Canadian/US organization founded in the 1940s, originally with members primarily from eastern North America. Our current members are scientists, snow surveyors, engineers, technicians, professors, students, and operational and maintenance professionals from North America, the United Kingdom, Japan, and Germany. There is a western counterpart to the ESC, the Western Snow Conference (WSC), which also is a joint Canadian/US organization. Every fifth year, the ESC and the WSC hold joint meetings.

The Eastern Snow Conference is a forum that brings the research and operations communities together to discuss recent work on scientific, applied, and operational issues related to snow and ice. The location of the conference alternates yearly between the United States and Canada, and attendees present their work by either giving a talk or presenting a poster. Most resulting papers are reviewed, edited, and published in our yearly *Proceedings of the Eastern Snow Conference*. In recent years, the ESC meetings have included sessions on snow physics, winter survival of animals, snow and ice loads on structures, river ice, remote sensing of snow and ice, and glacier processes. Volumes of the *Proceedings* can be found in libraries throughout North America and Europe, and the papers are also available through the National Technical Information Service (NTIS) in the United States and CISTI in Canada.

* * * * *

Le Colloque sur la neige région Est (ESC) est une organisation américaine-canadienne fondée dans les années '40 et dont les membres provenaient à l'origine principalement de l'est de l'Amérique-du-Nord. Actuellement, les membres, qu'ils soient chercheurs, techniciens, ingénieurs, professeurs, étudiants, et spécialistes des services d'exploitation et d'entretien, viennent non seulement d'Amérique-du-Nord, mais aussi du Royaume-Uni, du Japon, et d'Allemagne. Le Colloque sur la neige-région Ouest (WSC), aussi une organisation américaine-canadienne, est l'homologue de l'ESC pour l'ouest nord-américain. Tous les cinq ans, l'ESC et la WSC organisent des réunions en commun.

L'ESC est un forum qui rassemble chercheurs et responsables des services d'exploitation pour discuter des travaux récents sur les problèmes scientifiques, opérationnels, ou autres dus à la neige et à la glace. Le site de cette réunion annuelle alterne entre les États Unis et le Canada. Les participants y présentent les résultats de leurs travaux par des communications orales ou au moyen d'affiches. Ces communications, une fois revues et éditées, sont publiées dans les *Annales de l'ESC*. Dans les années récentes, les réunions de l'ESC ont inclus des sessions sur la physique de la neige, la survie hivernale de la faune, les forces exercées par la neige et la glace sur les structures et les bâtiments, la glace de rivière, la télédétection de la neige et de la glace, et les processus glaciaires. Les *Annales de l'ESC* sont accessibles dans la plupart des bibliothèques scientifiques d'Amérique-du-Nord et d'Europe. Des copies d'articles peuvent être obtenues du National Technical Information Service (NTIS) aux États Unis et son équivalent au Canada, le CISTI.

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THE PRESIDENT'S PAGE

The 76th annual meeting of the Eastern Snow Conference was held at the Lake Morey Resort in Fairlee, VT, on 4-6 June 2019. A serene country setting compared to the urban bustle of College Park, MD where last year's ESC was held. It was enjoyable to watch loons diving in the lake and to hear them calling at night. Lake Morey Resort was chosen because it is just up the road from Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH.

The scientific program included 25 oral presentations, 36 poster presentations and a town hall/panel session on future snow satellite missions moderated by Edward Kim, and Michael Durand, with panelists, Carrie Vuyovich and Joshua King. The town hall/panel session, which was a first for an ESC that I'm aware of, had excellent participation and was a great exchange of ideas and plans between US and Canadian scientists. A wide range of research and applications concerning snow and ice were presented by ESC participants. A large number of students attended and presented their research. The ESC had a social media presence, Twitter, with many posts made by participants. The Research Committee at the Banquet recognized the following students for exemplary achievement:

- Zhibang Lv of the University of Saskatchewan, was awarded the Wiesnet Medal for best student presentation for "Assimilation of snow interception information into a cold regions hydrological model".
- Gaohong Yin of the University of Maryland, College Park, was awarded the David Hewitt Miller Best Student Poster Award for "Characterizing Snow Water Equivalent from Ground-based Observations of GPS Vertical Displacement and Model-based Hydrologic Loading Estimates".
- Alex Mavrovic of the Université de Sherbrooke, was presented the Campbell Scientific Canada prize for "Development of an open-ended coaxial probe (OECF) for snow liquid water content measurement".

We were greatly pleased to have Dr. Don Perovich, Professor of Engineering, Dartmouth College and former research scientist at CRREL deliver the Banquet Address.

Barry Goodison gave a preamble on the history and significance of the coveted Sno-foo Award. Alexandre Langlois presented the coveted Sno-foo Award to Alexandre Roy for letting slide the solemn duty of attaching award winner names to the Award.

Special thanks to Eli Deeb the Vice-President and Program Chair and his local arrangements team of Joan Ramage, Carrie Vuyovich and CRREL volunteers. Thanks to ESC Executive Committee Members Krys Chutko, Derrill Cowing and Ken Rancourt, who continue to provide outstanding leadership and were instrumental to the success of the 76th meeting. The efforts of webmaster Vincent Sasseville, and members of the steering and research committees, notably Barton Forman for revising the Wiesnet Medal guidelines to increase student interest, are also greatly appreciated. Likewise, the meeting would not have been a success without the participation and continued support of our corporate members: Campbell Scientific Canada, Geonor, Hoskin Scientific and new corporate member Gradient Wind Engineering.

Please plan to attend the 77th ESC in Toronto, Canada, early June 2020. Krys Chutko, University of Saskatchewan, is the Vice-President and Program Chair. Check the ESC website for updates and students should review the guidelines for the Wiesnet Medal, the David Hewitt Miller Best Student Poster Award and Campbell Scientific Canada prize.

Thank you for your participation and support of the Eastern Snow Conference. Best wishes for success in your field work, model development, research or whatever your contribution is to better understanding the cryosphere. When the chill of winter comes, remember to pull on your ESC hat.

George Riggs
76th President, Eastern Snow Conference

LIFE MEMBERS OF THE EASTERN SNOW CONFERENCE

The Eastern Snow Conference gratefully recognizes individuals who have made lifelong contributions to the study of snow and for their support of this organization.

JAMES FOSTER

BARRY GOODISON

GERRY JONES

JOHN METCALFE

HILDA SNELLING

DONALD WIESNET

Wiesnet Medal

The Eastern Snow Conference encourages student research through its Wiesnet Medal. This medal is presented annually to the best student paper presented at the conference.

Year	Winner	Affiliation
2019	Zhibang Lv	University of Saskatchewan
2018	Jiyue Zhu	University of Michigan
2017	Caroline Dolant	Université de Sherbrooke
2016	Syed Mousavi	University of Michigan
2015	Nicolas Leroux	University of Saskatchewan
2014	Justin Hartnett	Syracuse University
2013	Andreas Dietz	Earth Observation Center/DFD, Germany
2012	Elizabeth Burakowski	University of New Hampshire
2011	Kathryn Semmens	Lehigh University
2010	Simon von de Wall	University of Victoria
2009	Si Chen	Dartmouth College
2008	Chris Fuhrmann	University of North Carolina at Chapel Hill
2007	<i>Not awarded</i>	
2006	Y.C. Chung	University of Michigan
2005	M. Javan-Mashmool	Université du Québec à Chicoutimi
2004	J. Farzaneh-Dehkordi	Université du Québec à Chicoutimi
2003	Alexandre Langlois	Université de Sherbrooke
2002	Patrick Ménard	Université de Laval
2001	C. Tavakoli	Université du Québec à Chicoutimi
2000	<i>Not awarded</i>	
1999	S. Brettschnieder	Université du Québec à Chicoutimi
1998	Andrew Grundstein	University of Delaware
1997	Newell Hedstrom	University of Saskatchewan
1996	Suzanne Hartley	University of Denver
1995	Paul Wolfe	Wilfred Laurier University
1994	G.E. Mann	University of Michigan
1993	G. Devarenes	Université du Québec à Québec
1992	D.W. Cline	University of Colorado
1991	D. Samelson	Cornell University
1990	A.K. Abdel-Zaher	University of New Brunswick
1989	A. Giguere	McGill University
1988	Mauri Peltó	University of Maine
1987	Cameron Wake	Wilfred Laurier University
1986	Craig Allan	Trent University
1985	Robert Speck	Rensselaer Polytechnic Institute
1984	N.K. Kalliomaki	Laurentian University
1983	David Beresford	Trent University
1982	<i>Not awarded</i>	
1981	Jeffrey Patch	University of New Brunswick
1980	Bryan Wolfe	Trent University
1979	Margaret Leech	McGill University
1978	Michael English	Trent University
1977	Don McLaughlin & George Duggan	Rensselaer Polytechnic Institute
1976	Dwayne McMurter	Trent University
1975	Nigel Allan	Syracuse University
1974	<i>Not awarded</i>	
1973	Stan Mathewson	Trent University

David Miller Award

The David Miller Award is presented to the best student poster at the annual Conference.

Year	Winner	Affiliation
2019	Gaohong Yin	University of Maryland
2018	Justin Pflug	University of Washington
2017	Elizabeth Ryan	University of Maryland
2016	Oliver Wigmore	The Ohio State University
2015	Charles Papasodoro	Université de Sherbrooke
2014	Laura Thomson	University of Ottawa
2013	Nastaran Saberi	University of Waterloo
2012	Johnathan Sugg	Appalachian State University
2011	<i>Not awarded</i>	
2010	Nicolas Svacina	University of Waterloo
2009	Iliyana Dobрева	Texas A&M University
2008	Christopher Karmosky	Pennsylvania State University

Campbell Scientific Canada Prize

The Campbell Scientific Canada prize is awarded to student research showing the most innovative use of technology in the gathering of data.

Year	Winner	Affiliation
2019	Alex Mavrovic	Université de Sherbrooke
2018	<i>Not awarded</i>	
2017	Abigail Dalton	University of Ottawa
2016	<i>Not awarded</i>	
2015	<i>Not awarded</i>	
2014	Aaron Campbell	University of Waterloo
2013	<i>Not awarded</i>	
2012	Andrew Kasurak	University of Waterloo
2011	Mathieu Beaulieu	University of British Columbia
2010	<i>Not awarded</i>	
2009	<i>Not awarded</i>	
2008	Nicholas Kinar	University of Saskatchewan
2007	Gro Lilbaek	University of Saskatchewan
2006	Gernot Koboltschnig	University of Natural Resources and Applied Life Sciences, Vienna
2005	Warren Helgason	University of Saskatchewan