

Christopher Marsh

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Education

- 2012–2019 **Ph.D.** Physical Geography
University of Saskatchewan, Saskatoon, SK
Supervisors: Dr. John Pomeroy, Dr. Howard Wheeler
Multi-Scale Modelling of Cold Regions Hydrology
- 2009–2012 **M.Sc.** Physical Geography
University of Saskatchewan, Saskatoon, SK
Supervisors: Dr. John Pomeroy, Dr. Raymond Spiteri
Implication Of Mountain Shading And Topographic Scaling On Energy For Snowmelt
- 2005–2009 **B.Sc. Honours** Physical Geography, Minors: Math and Comp. Sci.
University of Saskatchewan, Saskatoon, SK
High Resolution Radiation Modelling In Complex Terrain

Awards & Grants

- 2021 **STIC SREDA finalist**
Saskatoon Regional Economic Development Authority
- 2020 **Graduate Thesis Award for PhD**
University of Saskatchewan
- 2016 **AGU Flash Freeze competition**
American Geophysical Union
- 2016 **AGU Outstanding Student Paper Award in Cryosphere**
American Geophysical Union, student presentation
- 2014–2016 **NSERC Alexander Graham Bell**
Natural Sciences and Engineering Research Council of Canada (NSERC)
- 2014 **CGU Stan Patterson award in Glaciology**
Canadian Geophysical Union
- 2014 **Saskatchewan Innovation and Opportunity**
University of Saskatchewan and Gov. Saskatchewan research in a signature area
- 2013 **J.H. Richards Graduate Award**
University of Saskatchewan, highest average
- 2012 **AGU Outstanding Student Paper Award in Cryosphere**
American Geophysical Union, student presentation
- 2011 **D.M. Gray Hydrology Award**
CGU-HS, top student paper and presentation
- 2009–2012 **Graduate Student Scholarship**
University of Saskatchewan, academic performance
- 2009 **Canadian Association of Geographers**
Most distinguished geography undergraduate
- 2008 **Honours scholarship**
University of Saskatchewan, academic performance

Research Experience

2024–	Research Scientist (Hydro-Climate Analysis) Intersection of freshwater and climate change in Canada. Climate Processes Section, Climate Research Division, Environment and Climate Change Canada
2024–	Adjunct Professor Dept. Geography and Planning University of Saskatchewan, Canada
2023–2023	Research Associate Development of the Canadian Hydrological Model (CHM) to meet the needs to the next-generation hydrological modelling group with Global Water Futures. University of Saskatchewan, Canada
2019–2023	Postdoctoral Fellow Development of the Canadian Hydrological Model (CHM) to meet the needs to the next-generation hydrological modelling group with Global Water Futures. University of Saskatchewan, Canada
2012–2023	Lab Assistant Coordinated purchases, configuration, and on-going support of the shared workstations used for numerical simulations at the Centre for Hydrology Center for Hydrology, University of Saskatchewan, Canada
2012–2019	PhD. Field work Canmore, AB; Whitehorse, YK Snow surveys, meteorological site maintenance, ground control of historical sites
2012	CRHM Tools developer Supervisor: John Pomeroy Lead developer on the Cold Regions Hydrological Model (CRHM) Tools project at the University of Saskatchewan
2009–2012	Field work for M.Sc. Canmore, AB Installing radiometers and time lapse cameras, snow surveys, and meteorological site maintenance
2009	MITACS summer employment with Environment and Climate Change Canada Supervisor: Bruce Davison and Raymond Spiteri Improved MESH efficiency via parallelization and code optimization
2008	Modelling with the Cold Regions Hydrological Model (CRHM) for work in ungauged basins Supervisor: John Pomeroy
Spring 2008	International Polar Year Supervisor: Stephan Pohl & Cuyler Onclin Field assistant for instrument installation (water level recorders, snow surveys, vegetation surveys, and surveying (Total Station) at Trail Valley Creek, Inuvik, NWT
Spring 2006	Environment Canada Supervisor: Cuyler Onclin Field assistant for instrument installation of water level recorders and surveying at Trail Valley Creek, Inuvik, NWT

Teaching experience

2024	Lecturer Computer Science 851, University of Saskatchewan Lecture on high performance computing for research code
2023	Lecturer Geography 825, University of Saskatchewan Lecture on high performance computing for hydrological modelling
2023	Lecturer Computer Science 851, University of Saskatchewan Lecture on high performance computing for research code
2023	Lecturer Geography 825, University of Saskatchewan Lecture on hydrological modelling and code design
2022	Lecturer Geography 825, University of Saskatchewan Lecture on hydrological modelling and high performance computing paradigms
2021	Lecturer Computer Science 851, University of Saskatchewan Lecture on high performance computing for research code
2016–2019	Lecturer Geography 290, University of Saskatchewan Lectures for two weeks on remote sensing and GIS. Prepared material and taught the associated labs, as well as providing 1-on-1 teaching
2016	Teaching assistant Geography 225, University of Saskatchewan 2nd year general hydrological course. Lead labs and provided 1-on-1 teaching
2016	Teaching assistant Geography 290, University of Saskatchewan 2nd year introduction to field methods. Assisted in the field with students
2014	Teaching assistant Geography 225, University of Saskatchewan 2nd year general hydrological course. Lead labs and provided 1-on-1 teaching

Scientific service

2021–present	CRYOLIST.org Owner and manager of the listserv
2016–2017	Young Hydrologic Society (YHS) Canada branch Chair and founding member
2010–2021	CRYOLIST.org Co-manager of the listserv
2012–2018	Global Institute for Water Security (GIWS) student group Founding member and committee member University of Saskatchewan

Peer review

- Atmosphere-Ocean
- Big Earth Data
- Computers and Geoscience
- Remote Sensing of Environment
- Environmental Processes
- Geoscientific Model Development (GMD)
- Hydrological Processes
- Hydrology and Earth System Sciences (HESS)
- JGR: Atmospheres
- Journal of Glaciology
- Journal of Hydrology
- The Cryosphere
- Water Resources Research (WRR)

Skills**Languages**

- Native English
- French immersion (Grade 12)

Technical skills

- Languages: C, C++, R, Python, Matlab, FORTRAN, Bash
- Code development: git, conan, easy build, Github Actions, Read the docs
- Key libraries: xarray, pandas, dplyr, ggplot2, esmf, dask
- High Performance Computing (HPC): OpenMP, MPI, SLURM, Paraview, Totalview
- GIS: ArcGIS, SAGA GIS, QGIS, GDAL
- Office: MS Office, Photoshop, \LaTeX
- OS: Linux (Fedora, Ubuntu, CentOS), MacOS, Windows

Field work

- Datalogger
- Site maintenance
- Meteorological site installation and operation
- Snow surveys

Instruction

- CRCA Canoe Moving Water Level 1 and 2
- CRCA Canoe Moving Water 1 Instructors
- CSIA Downhill Skiing Level 1 Instructors

Safety

- Rescue 3 International SwiftWater Rescue Technician Unit 1
- OHS Standard Level First Aid and CPR Level C
- Over 20 years of extensive remote outdoor experience such as wilderness camping and canoeing

Computational hydrology

The Canadian Hydrological Model (CHM)

Lead developer of Canadian Hydrological Model (CHM), a novel modular unstructured mesh based approach for hydrological modelling. It can move between spatial scale, temporal scale, and spatial extents. It is designed for developing and testing process representations for hydrological models. It is written in C++ and uses OpenMP and MPI to utilize hundreds to thousands of CPUs.

<https://github.com/Chrismarsh/CHM>

Mesher

Lead developer of Mesher, a novel multi-objective unstructured mesh generation software that allows mesh generation to be generated from an arbitrary number of hydrologically important features while maintaining a variable spatial resolution. It is written in Python and C++ and uses MPI to utilize hundreds of CPUs.

<https://github.com/Chrismarsh/mesher>

Windmapper

Lead developer of Windmapper, a python tool and a set of algorithms for producing and using pre-computed libraries of wind field used for wind downscaling. It is written in Python and uses MPI to utilize hundreds of CPUs.

<https://github.com/Chrismarsh/Windmapper>

pyCHM

Lead developer of pyCHM, a python library to work with the output of CHM. It makes extensive use of xarray, pandas, and ESMPy.

<https://github.com/Chrismarsh/pyCHM>

SnowCast

Lead developer of SnowCast, an experimental Canadian Hydrological Model (CHM) data product that downscales the Global Environmental Multiscale (GEM) model forecasts from Environment and Climate Change Canada (ECCC) to provide high resolution snowpack forecasts that take into account variable windflow, solar radiation, precipitation, and temperature over complex terrain. It is written in Python and makes extensive use of the xarray and pandas libraries.

www.snowcast.ca

Publications

- Liu, Hongli, Martyn P. Clark, Shervan Gharari, Razi Sheikholeslami, Jim Freer, Wouter J. M. Knoben, **Marsh, Christopher B.**, and Simon Michael Papalexiou (2024), An Improved Copula-Based Framework for Efficient Global Sensitivity Analysis, *Water Resources Research* 60(1), DOI: 10.1029/2022wr033808.
- Marsh, C. B.**, P. Harder, and J. W. Pomeroy (2023), Validation of FABDEM, a global bare-earth elevation model, against UAV-lidar derived elevation in a complex forested mountain catchment, *Environmental Research Communications*, DOI: 10.1088/2515-7620/acc56d.
- Marsh, C. B.**, V. Vionnet, and J. W. Pomeroy (2023), Windmapper: An Efficient Wind Downscaling Method for Hydrological Models, *Water Resources Research* 59(3), DOI: 10.1029/2022wr032683.
- Knoben, W. J. M., M. P. Clark, J. Bales, A. Bennett, S. Gharari, **Marsh, C. B.**, B. Nijssen, A. Pietroniro, R. J. Spiteri, G. Tang, D. G. Tarboton, and A. W. Wood (2022), Community Workflows to Advance Reproducibility in Hydrologic Modeling: Separating Model-Agnostic and Model-Specific Configuration Steps in Applications of Large-Domain Hydrologic Models, *Water Resources Research* 58(11), DOI: 10.1029/2021wr031753.
- Marsh, C. B.**, V. Vionnet, and J.W. Pomeroy (2022), The Canadian Hydrological Model: A New Way to Estimate Snowpacks in the Canadian Rockies, *The Avalanche Journal*, Winter (2022-23).
- Pomeroy, J.W., T. Brown, X. Fang, K.R. Shook, D. Pradhananga, R. Armstrong, P. Harder, **Marsh, C. B.**, D. Costa, S.A. Krogh, C. Aubry-Wake, H. Annand, P. Lawford, Z. He, M. Kompanizare, and J.I. Lopez Moreno (2022), The cold regions hydrological modelling platform for hydrological diagnosis and prediction based on process understanding, *Journal of Hydrology* 615(Hydrology and Earth System Science 26 21 2022), p. 128711, DOI: 10.1016/j.jhydro1.2022.128711.
- Marsh, C.B.**, K. R. Green, B. Wang, and R. J. Spiteri (2021a), Performance improvements to modern hydrological models via lookup table optimizations, *Environmental Modelling & Software*, p. 105018, DOI: 10.1016/j.envsoft.2021.105018.
- Vionnet, V., **Marsh, C.B.**, B. Menounos, S. Gascoin, N.E. Wayand, J. Shea, K. Mukherjee, and J.W. Pomeroy (2021), Multi-scale snowdrift-permitting modelling of mountain snowpack, *The Cryosphere* 15, pp. 743–769, DOI: 10.5194/tc-15-743-2021.
- Leroux, N.R., **Marsh, C.B.**, and J.W. Pomeroy (2020), Simulation of Preferential Flow in Snow with a 2D Non-Equilibrium Richards Model and Evaluation against Laboratory Data, *Water Resources Research* 56.
- Marsh, C.B.**, J.W. Pomeroy, R.J. Spiteri, and H.S. Wheeler (2020a), A Finite Volume Blowing Snow Model for Use With Variable Resolution Meshes, *Water Resources Research* 56(2), DOI: 10.1029/2019wr025307.
- Marsh, C.B.**, J.W. Pomeroy, and H.S. Wheeler (2020), The Canadian Hydrological Model (CHM) v1.0: a multi-scale, multi-extent, variable-complexity hydrological model – design and overview, *Geoscientific Model Development* 13(1), pp. 225–247, DOI: 10.5194/gmd-13-225-2020.
- Marsh, C.B.**, R.J. Spiteri, J.W. Pomeroy, and H.S. Wheeler (2018), Multi-objective unstructured triangular mesh generation for use in hydrological and land surface models, *Computers & Geosciences* 119, pp. 49–67, DOI: 10.1016/j.cageo.2018.06.009.
- Wayand, N.E., **Marsh, C.B.**, J.M. Shea, and J.W. Pomeroy (2018), Globally scalable alpine snow metrics, *Remote Sensing of Environment* 213, pp. 61–72, DOI: 10.1016/j.rse.2018.05.012.
- Marsh, C.B.**, J.W. Pomeroy, and R.J. Spiteri (2012b), Implications of mountain shading on calculating energy for snowmelt using unstructured triangular meshes, *Hydrological Processes* 26(12), pp. 1767–1778, DOI: 10.1002/hyp.9329, URL: <http://doi.wiley.com/10.1002/hyp.9329>.

Thesis

- Marsh, C.B.** (2019), Multi-Scale Modelling of Cold Regions Hydrology, Ph.D, University of Saskatchewan.
- (2012), Implications of mountain shading on calculating energy for snowmelt using unstructured triangular meshes, M.Sc. University of Saskatchewan.
- (2009), Application and comparison of high resolution radiation models in complex terrain, Undergraduate, University of Saskatchewan.

Book Chapters

Marsh, C. B. (2023a), Contributing Author, Canadian Mountain Assessment, ed. by Graham McDowell, University of Calgary Press, chap. Mountains Under Pressure.

Conferences (Oral presentation)

Marsh, C.B. (2023b), Changing Water Budgets, Cryosphere and Rivers Panel contribution, Global Water Futures (GWF) Final Open Science Meeting (invited speaker); May 14–17; Saskatoon, Saskatchewan, Canada).

Marsh, C.B., Lv. Z., Vincent Vionnet, P. Harder, Raymond J. Spiteri, and John W. Pomeroy (2023b), Forecasting seasonal snow with million km² large-extent snowdrift-permitting simulations, International Network for Alpine Research Catchment Hydrology (INARCH); October 9–11; Stanley, Idaho, USA).

Marsh, C.B., Kevin Green, Raymond J. Spiteri, Zhibang Lv, Vincent Vionnet, and John W. Pomeroy (2022a), New developments in the Canadian Hydrological Model (CHM) and large-extent simulations, International Network for Alpine Research Catchment Hydrology (INARCH; October 18–20; Baños de Panticosa, Spain).

Marsh, C.B., Zhibang Lv, Kevin Green, Raymond J. Spiteri, Vincent Vionnet, and John W. Pomeroy (2022b), Large Extent Snowdrift-resolving Snowpack Simulations Across the Canadian Cordillera, American Geophysical Union (AGU; Dec 12–16; Chicago, USA).

Marsh, C.B., V. Vionnet, K. Green, R. J. Spiteri, Z. Lv, and John W. Pomeroy (2022c), Large extent snowdrift-resolving snowpack simulations across the Canadian Cordillera, Global Water Futures (GWF) Annual Open Science Meeting; May 16–18; Online).

Marsh, C.B., Vincent Vionnet, Kevin Green, Raymond J. Spiteri, Zhibang Lv, and John W. Pomeroy (2022d), SnowCast: Daily forecasts of mountain snowpack using a snowdrift-permitting model, Canadian Water Resources Association (CWRA); June 5–8; Canmore, Alberta, Canada).

Marsh, C.B., Kevin Green, R. Zolfaghari, V. Vionnet, R. J. Spiteri, Martyn P. Clark, and John W. Pomeroy (2021b), Simulating multi-scale hydrological processes with the Canadian Hydrological Model (CHM), Global Water Futures (GWF) Annual Open Science Meeting; May 17–19; Online).

Marsh, C.B., Vincent Vionnet, Kevin Green, Raymond J. Spiteri, Martyn P. Clark, and John W. Pomeroy (2021c), Development of the Canadian Hydrological Model (CHM) for multi-scale snow simulations, International Network for Alpine Research Catchment Hydrology (INARCH; October 18–20; Online).

Pomeroy, J.W., V. Vionnet, **Marsh, C.B.**, B. Menounos, K. Green, R.J. Spiteri, and P. Harder (2020), Evaluating a multi-scale, multi-physics snow redistribution and ablation model in the Canadian Rockies using Airborne LiDAR, Airborne Snow Observatories (ASO); Oct 26–29; Online.

Marsh, C.B., V. Vionnet, K. Green, R. Spiteri, N. Wayand, H. Wheeler, and J.W. Pomeroy (2019a), Multiscale snow hydrology modelling, IUGG-CGU (invited speaker); July 8–18; Montreal, Quebec, Canada.

– (2019b), Segment 5 intervention for: Diagnostic, coupled atmospheric-cryospheric-hydrological models operating at “snowdrift resolving scales” are needed in mountains in order to resolve the processes forming avalanches, glaciers and snow patches that control mountain streamflow generation, cryospheric features and hazards. WMO High Mountain Summit (invited speaker); Oct 29–31; Geneva, Switzerland.

Marsh, C.B. (2017), Simulating Complex, Cold-region Process Interactions Using a Multi-scale, Variable-complexity Hydrological Model (OSPA Invited), AGU; Dec 11–15; New Orleans, LA, USA.

Marsh, C.B., J.W. Pomeroy, H. Wheeler, N. Wayand, and R. Spiteri (2017a), Simulating blowing snow with the Canadian Hydrological Model, AGU; Dec 11–15; New Orleans, LA, USA.

– (2017b), Simulating steady-state blowing snow with the Canadian Hydrological Model, CGU-HS; May 29–31; Vancouver, BC, Canada.

Marsh, C.B., N. Wayand, R. Spiteri, J.W. Pomeroy, and H. Wheeler (2017c), Towards Large-Scale Simulations in the Yukon with the Canadian Hydrological Model, Wolf Creek Research Basin 25th Anniversary Science Summit; September 28–29; Whitehorse, Yukon, Canada.

Marsh, C.B., J.W. Pomeroy, and H. Wheeler (2016), Testing warranted model complexity using a multi-scale, variable-complexity hydrological model, CGU-HS; May 29–June 2; Fredericton, NB, Canada.

Marsh, C.B., N. Wayand, J.W. Pomeroy, and H. Wheeler (2016a), The Canadian Hydrological Model: a Multiscale, Multiphysics, Variable Resolution Mesh Simulation System for Cold Regions, AGU; Dec 12–16; San Francisco, CA, USA.

- Marsh, C.B.**, N. Wayand, J.W. Pomeroy, and H. Wheeler (2016b), The Canadian Hydrological Model: a Multiscale, Multiphysics, Variable Resolution Mesh Simulation System for Cold Regions, AGU Flash Freeze; Dec 12-16; San Francisco, CA, USA.
- Marsh, C.B.**, J.W. Pomeroy, and H. Wheeler (2015), Robustness in the spring surface energy balance in a mountain basin, CGU-HS; May 3-7; Montreal, QC, Canada.
- (2014), Impacts of spatial scaling of unstructured meshes on calculating surface irradiance, CGU-HS; May 4-8; Banf, AB, Canada.
- Marsh, C.B.**, J.W. Pomeroy, R.J. Spiteri, D. Marks, M. Hayashi, S. Munro, M. Demuth, and H. Wheeler (2013), Impacts of spatial scaling of unstructured meshes on calculating surface irradiance, CGU-HS; May 27-30; Saskatoon, SK, Canada.
- Marsh, C.B.**, J.W. Pomeroy, and R.J. Spiteri (2012a), Implication of mountain shading and topographic scaling on energy for snowmelt, AGU Dec 3-7 (invited speaker); San. Francisco, Calif. , USA.
- (2011a), Implication of mountain shading and topographic scaling on energy for snowmelt, CGU-HS student conference Jan 29; Calgary, Alberta, Canada.
 - (2011b), Implication of mountain shading and topographic scaling on energy for snowmelt, CGU-HS May 15-18; Banff, Alberta, Canada.

Conferences (Posters)

Harder, P., **Marsh, C.B.**, and John W. Pomeroy (2023), Distributed modelling of the Canadian Prairie snowpack: model evaluation and demonstration, CGU-HS; May 7-10; Banff, Alberta, Canada.

Marsh, C.B., Z. Lv, K. Green, V. Vionnet, P. Harder, R. J. Spiteri, and John W. Pomeroy (2023a), Million km² large-extent snowdrift-permitting snowpack predictions, Global Water Futures (GWF) Final Open Science Meeting; May 14–17; Saskatoon, Saskatchewan.

Marsh, C.B., Vincent Vionnet, Kevin Green, Raymond J. Spiteri, and John W. Pomeroy (2021d), Daily forecasts of mountain snowpack using a snowdrift-permitting model, Eastern Snow Conference; 9 June; Online.

Marsh, C.B., Vincent Vionnet, Kevin Green, Raymond J. Spiteri, Brian Menounos, and John W. Pomeroy (2020b), Multi-objective unstructured meshes for improved mountain snow hydrology with the Canadian Hydrological Model (CHM), AGU Dec 1-17 2020; San Francisco, California, USA.

Marsh, C.B. and J.W. Pomeroy (2018), PBSM3D: A complex terrain blowing snow model for use with variable resolution meshes, International Network for Alpine Research Catchment Hydrology (INARCH) February 8-9; Environmental Research Station Schneesfernerhaus, Germany.

Headstrom, N., R. Granger, S. Miller, M. Marsh, and **Marsh, C.B.** (2013), Effect of Buoy Motion on Eddy Flux Measurements over Lakes, CGU-HS May 27-30; Saskatoon, SK, Canada.

Marsh, C.B., J.W. Pomeroy, and R.J. Spiteri (2011c), Implication of mountain shading and topographic scaling on energy for snowmelt, CGU-HS Student conference, Jan 29; Calgary, Alberta, Canada.

Marsh, P., S. Endrizzi, C. Derksen, M. Russell, C. Onclin, H. Wilson, J. Pomeroy, and **Marsh, C.B.** (2010), Factors controlling the spatial variability in end of winter snowcover and spring melt at an arctic tundra site, AGU Dec 13-17; San Francisco, California, USA.

Marsh, C.B., R.J. Spiteri, and B. Davison (2009a), Improved MESH efficiency via parallelization and code optimization, P3/WC2N Annual conference, Oct 14-17; Lake Louise, Alberta, Canada.

Marsh, C.B., S. Pohl, and G.E. Liston (2007), Impact of increased shrub density on snow accumulation and melt in the Arctic tundra, IUGG; Perugia, Italy.

Session convenor

Modelling and measuring snow processes across scales. (2024), European Geophysical Union (EGU); April 14-19; Vienna, Austria.

Observation and modelling of snow and glacier processes (2023), Canadian Geophysical Union (CGU); May 7-10; Banff, Alberta, Canada.

Emphasizing F, I, and R in FAIR Hydrology: Bottlenecks and Solutions to Making Hydrologic Science More Reproducible I Hybrid Panel (2022a), Frontiers in Hydrology Meeting 2022; June 19-24 2022; San Juan, Puerto Rico + Online.

Observation and modelling of snow processes: integrating legacy and new tools to advance snow science (2022b), Canadian Geophysical Union (CGU); 1-3 June and 6-8 June.; Online.

Cold regions hydrology (2021), Canadian Geophysical Union (CGU); June 24th; Online.

A Call to Action for FAIR, Reproducible, and Transparent Science: Analytical Code, Workflows, Services, Models, and Conclusions eLightning (2020), American Geophysical Union (AGU); Online.

Canadian Geophysical Union Hydrology Section (CGU-HS) student conference (2012), University of Saskatchewan, Saskatoon, Canada.

Technical report

Marsh, C.B., R.J. Spiteri, and B. Davison (2009b), Improved MESH efficiency via parallelization and code optimization, tech. rep., Department of Computer Science, The University of Saskatchewan.