

Keith N. Musselman, Ph.D.

CONTACT INFORMATION

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Boulder, Colorado 80305

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EDUCATION

University of California Los Angeles Los Angeles, California
Doctor of Philosophy in Civil Engineering 2012

- Minor in Atmospheric Sciences
- Emphasis in Hydrology & Water Resources
- NASA Earth System Science Fellowship Recipient

University of Arizona Tucson, Arizona
Master of Science in Hydrology & Water Resources 2006

- Emphasis in Surface Hydrology

University of Vermont Burlington, Vermont
Bachelor of Science in Geology 2003

- Emphasis in Surface Hydrology

PROFESSIONAL EXPERIENCE.

Institute of Arctic and Alpine Research,
University of Colorado Boulder

Boulder, Colorado

Research Associate

October 2017 – Present

- Lead Principle Investigator on \$3M project with NCAR and USGS scientists to the National Science Foundation Navigating the New Arctic program to strengthen understanding of terrestrial hydrologic change in the Arctic and the potential impacts on rivers, fisheries, and Indigenous communities. Lead PI on a NOAA Climate Program Office project with NCAR to downscale CMIP6 runs for assessment of projected changes in precipitation, snowpack, soil moisture and flood risk.
- Analyze the agricultural water supply-demand imbalance during the California drought using novel NASA satellite data, snow models, lidar, and GPS data. Oversee operational reports to California DWR and stakeholders. Reanalysis of 2017 Oroville Dam flood disaster using diverse gridded historical weather and climate data. Supervise and mentor three graduate and two undergraduate students.
- Published high impact paper in *Nature Climate Change* on future rain-on-snow flood risk in western North America. A second paper in revision at *Nature Climate Change* introduces winter snowmelt as an indicator of warming robust to natural variability.

National Center for Atmospheric Research

Boulder, Colorado

Advanced Study Program Fellowship - Postdoctoral

October 2015 – October 2017

- Independently pursued research that collaboratively leveraged NCAR's world-class climate modeling capacity and multidisciplinary hydrologic team expertise. Analyzed high-res RCM output and led a high-impact paper in *Nature Climate Change* that alters conventional thought of how water resources may respond to climate change.
- Advanced the capability of hydrologic models to simulate dominant cold region processes in Alaska. As a member of a collaborative team, built propensity for research techniques using a model to achieve the Mission's goal of advancing hydrological model capacity and uncertainty characterization.

University of Saskatchewan

Kananaskis, Alberta

Postdoctoral Fellow

October 2012 – October 2015

40 Hours/Week

- Developed new parsimonious model capacity of snow and forest hydrology to evaluate cold region process sensitivity to changes in land cover and climate. Creative use of technology (computational fluid dynamics, ray tracing) in solutions of challenging problems related to fine-scale numerical modeling of Earth System processes.
- Designed and supervised a large field campaign to evaluate how forest vegetation structure and disturbances influence water and energy availability. Mentored and developed graduate students, student interns, and supervised two technicians.

University of California Los Angeles

Los Angeles, California

NASA Earth System Science Graduate Fellow

September 2008 – September 2012

- Conduct independent research using field measurements and numerical modeling to analyze snow accumulation and melt dynamics in the Sierra Nevada.
- Designed and supervised ten basin-scale snow surveys with five or more researchers including undergraduate and graduate students in the remote Sierra Nevada, California.
- Build future capabilities leveraging state-of-the-art lidar technology to estimate high-resolution solar radiation beneath a forest canopy in Sequoia National Park with a novel approach that remains an example of technical excellence.

CLASSROOM

TEACHING EXPERIENCE

University of Colorado Boulder

Boulder, Colorado

Lecturer

Spring and Fall Semesters, 2019

- Lecture three days per week a class of 160 undergraduates in Geography course *Environmental Systems: Landscapes and Water*; plan field excursions, design lectures, homework, and exams. Supervise three teaching assistants who held weekly labs.

University of California Los Angeles

Los Angeles, California

Teaching Assistant (TA)

Fall Semester, 2009

- Lead weekly discussion sessions, designed homework and held office hours for class of 100+ in Civil Engineering course 150 *Introduction to Hydrology*. Prof. S. Margulis

WORKSHOPS &
FIELD COURSES

TAUGHT

UCB Science Discovery, Family Engineering Day; 1000+ attendees (2020)
NSF-funded workshop LiDAR Applications in Critical Zone Sciences (2014)
TA for *Advanced Field Methods in Snow Science*, Prof. Noah Molotch (2011)
TA for *Snow Hydrology and Field Camp*, Prof. Paul Brooks (2006)

FUNDING

- (Pending) **NSF, Growing Convergence Research** 2021-2026
“Collaborative Research: GCR: Co-defining climate refugia to inform the management of mountain headwater systems” (role: PI, \$3.6M)
- (Pending) **NSF, Hydrological Sciences** 2021-2024
“Estimating the “time of emergence” of the anthropogenic warming signal in snow water resource metrics for western US headwaters” (role: PI, \$700K)
- (Pending) **NASA, Commercial Small-Satellite Data Analysis** 2021-2022
“Towards improved representation of snow in forests for NASA global snow mapping” (role: co-PI, \$50K)
- (Pending) **Department of Energy, Subsurface BioGeoChem Research** 2021-2023
“Consequences of winter perturbations on hydro-biogeochemical connectivity in contrasting ecosystems” (role: co-I, \$60K)
- (Awarded) **NASA, Applied Sciences** 2021-2022
“Satellite-based Snowpack Information to address COVID-19 impacts on water resources” (role: co-PI, \$21K)
- (Awarded) **NSF, Navigating the New Arctic Program** 2020-2024
“The climate impacts on Alaskan and Yukon rivers, fish, and communities as told through co-produced scenarios” (role: PI, \$3M)
- (Awarded) **NOAA, Climate Program Office** 2019-2021
“Assessing the predictability and probability of 21st century rain-on-snow flood risk for the conterminous U.S.” (role: PI, \$200K)
- (Awarded) **NASA, GEO, supplemental funding** 2019
“Optimizing the Indus Basin Irrigation System and reservoir operations using remotely sensed snow surface properties in the ParBal model” (role: co-I, \$22K)
- (Awarded) **National Science Foundation, Hydrologic Sciences** 2018-2020
“Extending the vadose zone: characterizing the role of snow for liquid water storage and transmission in streamflow generation” (role: co-PI, \$142K)
- (Awarded) **University of Colorado Outreach Award** 2019-2020
“Past, Present, Future: Exploring Boulder’s Natural Environment” (role: co-I, \$24K)
- (Past Award) **NCAR Advanced Study Program Fellowship** 2015-2017
“Slower snowmelt in a warmer world” (\$136K)
- (Past Award) **NASA Earth and Space Science Fellowship Program** 2008-2012
“Remote Sensing and Ground Data Assimilation Using A Basin-Scale Snow Water Equivalent Reconstruction Method” (\$90K)

STUDENT
MENTORSHIP

Graduate Student co-Advisor

Dylan Blaskey, Ph.D. Student, Civil Engineering, CU Boulder

Ph.D. Committee Member

Kehan Yang, University of Colorado, Boulder

Hamideh Safa, University of Nevada, Reno

Dylan Blaskey, University of Colorado, Boulder

John Bryan Curtis, University of Colorado, Boulder

Undergraduate Research Mentor

Siobhan Ciafone, University of Colorado, Boulder

Ella Hall, University of Colorado, Boulder

AWARDS
RECEIVED

Best Presentation

Western Snow Conference Annual Meeting, Reno, NV 2019

Best Student Poster Presentation

Eastern Snow Conference Annual Meeting, Montreal, Quebec 2010

Graduate College Fellowship Award (merit-based)

University of Arizona 2005 and 2006

David Hawley Undergraduate Research Scholarship

University of Vermont 2003

REFEREED
PUBLICATIONS

24+ Peer-reviewed publications | *H*-index of 18+

In Review | In Press **Musselman, K.N.**, N. Addor, J.A. Vano, and N.P. Molotch, Melt trends protend widespread declines in snow water resources. In Press, *Nature Climate Change*.

Seybold, E.C., R. Dwivedi, **K.N. Musselman**, D.W. Kincaid, A.W. Schroth, J.N. Perdrial, A.T. Classen, and E.C. Adair, Changing winter dynamics pose threat to water quality. Submitted to *Science Advances*.

Rasmussen, R., K. Ikeda, C. Liu, F. Chen, M. Barlage, A.J. Newman, E. Gutmann, J. Dudhia, D. Gochis, A. Dai, C. Luce and **K.N. Musselman**, Projected future changes in snowfall and snowpack in the western U.S. as captured by a convection resolving climate simulation: mesoscale and microphysical factors. In Review at *Journal of Climate*.

Published

[25] Mendoza, P.A., T.E. Shaw, J. McPhee, **K.N. Musselman**, J.R. Revuelto, and S. MacDonell, Seasonal and annual variability of snow depth fractal behavior in a sub-alpine catchment. *Water Resources Research*. 56(7), e2020WR027343

[24] Ueher, T.M., S.D. Kaspari, **K.N. Musselman** and S.M. Skiles, and (2020), The post-wildfire impact of burn severity and age on black carbon snow deposition and implications for snow water resources, Cascade Range, Washington, USA. *Journal of Hydrometeorology*. 21(8), 1777-1792.

[23] Henn, B., **K.N. Musselman**, L. Lestak, F.M. Ralph, and N.P. Molotch (2020), Extreme runoff generation from atmospheric river driven snowmelt during the 2017 Oroville Dam spillways incident. *Geophysical Research Letters*, 47(14).

[22] Mendoza, P.A., **K.N. Musselman**, J.S. Deems, J.R. Revuelto, I. Lopez-Moreno, and J. McPhee (2020), Seasonal and annual variability of snow depth

fractal behavior in a sub-alpine catchment. *Water Resources Research*, 55(7).

[21] Giroto, M., **Musselman, K.N.**, and Essery, R.L. (2020), Data Assimilation Improves Estimates of Climate-Sensitive Seasonal Snow. *Current Climate Change Reports*, 6, 81–94.

[20] **Musselman, K.N.**, F. Lehner, K. Ikeda, M.P. Clark, A.F. Prein, C. Liu, M. Barlage and R. Rasmussen (2018), Projected increases and shifts in rain-on-snow flood risk over western North America. *Nature Climate Change*, 8, 808-812.

[19] Isabelle, P.E., D.F. Nadeau, M.H. Asselin, R. Harvey, **K.N. Musselman**, A.N. Rousseau, F. Anctil (2018), Solar radiation transmittance of a boreal balsam fir canopy: Spatiotemporal variability and impacts on growing season hydrology, *Agricultural and Forest Meteorology*, 263, 1-14.

[18] **Musselman, K.N.**, M. P. Clark, C. Liu, K. Ikeda and R. Rasmussen (2017), Slower snowmelt in a warmer world. *Nature Climate Change*, 7(3), 214-219.

[17] **Musselman, K.N.**, N.P. Molotch, and S.A. Margulis, Snowmelt response to simulated warming across a large elevation gradient, southern Sierra Nevada, California. (2017) *The Cryosphere*, 11(6) 2847-2866.

[16] López-Moreno, I., S. Gascoin, J. Herrero, E. Spoles, M. Pons, E. Alonso, J. Sickman, **K.N. Musselman**, A. Boudhar, L. Hanich, N. Molotch, J. Pomeroy (2017), Different sensitivities of snowpack to warming in Mediterranean climate mountain areas. *Environmental Research Letters*, 12(7), 074006.

[15] **Musselman, K.N.** and J.W. Pomeroy (2017), Estimation of needleleaf canopy and trunk temperatures and longwave contribution to melting snow. *Journal of Hydrometeorology*. 18, 555-572.

[14] **Musselman, K.N.**, J.W. Pomeroy, R. Essery, and N. Leroux (2015), Impact of windflow calculations on simulations of alpine snow accumulation, redistribution and ablation. *Hydrological Processes*, 29(18), 3983-3999.

[13] **Musselman, K.N.**, J.W. Pomeroy, and T.E. Link (2015), Variability in shortwave irradiance caused by forest gaps: Measurements, modelling, and implications for snow energetics. *Agricultural and Forest Meteorology*, 207, 69:82.

[12] Harpold, A.A., J.A. Marshall, S.W. Lyon, T.B. Barnhart, B. Fisher, M. Donovan, K.M. Brubaker, C.J. Crosby, N.F. Glenn, C.L. Glennie, P.B. Kirchner, N. Lam, K.D. Mankoff, J.L. McCreight, N.P. Molotch, **K.N. Musselman**, J. Pelletier, T. Russo, H. Sangireddy, Y. Sjöberg, T. Swetnam, and N. West (2015), Laser Vision: LiDAR as a Transformative Tool to Advance Critical Zone Science. *Hydrology and Earth System Sciences*. 19, 2881–2897.

[11] Meromy, L., N.P. Molotch, M. Williams, **K.N. Musselman**, and L. Kueppers (2015), Snowpack-climate manipulation using infrared heaters in subalpine forests of the Southern Rocky Mountains, USA. *Agricultural and Forest Meteorology*, 203, 142-157.

[10] Harpold, A.A., N.P. Molotch, **K.N. Musselman**, R.C. Bales, P.B. Kirchner, M. Litvak, and P.D. Brooks (2015), Snowmelt infiltration in mixed conifer subalpine forests. *Hydrological Processes*, 29(12), 2782-2798.

[9] Harpold, A.A., Q. Guo., N. Molotch, P.D. Brooks, R. Bales, J.C. Fernandez-Diaz, **K.N. Musselman**, T.L. Swetnam, P. Kirchner, M. Meadows, J. Flanagan, and R. Lucas (2014), LiDAR-derived snowpack datasets from mixed conifer forests

across the Western U.S., *Water Resources Research*. 50(3), 2749-2755.

[8] Perrot, D.O., N.P. Molotch, **K.N. Musselman**, and E.T. Pugh (2014), Modeling the effects of the Mountain Pine Beetle on snowmelt rates in a subalpine forest. *Ecohydrology*. 7(2), 226-241.

[7] **Musselman, K.N.**, S.A. Margulis, and N.P. Molotch (2013), Estimation of solar direct beam transmittance of conifer canopies from airborne LiDAR. *Remote Sensing of Environment*. 136, 402-415.

[6] Huang, C., S.A. Margulis, M.T. Durand, and **K.N. Musselman** (2012), Assessment of snow grain-size model and stratigraphy representation impacts on snow radiance assimilation: Forward Modeling Evaluation, *IEEE Transactions on Geoscience and Remote Sensing*. 50(11) 4551 – 4564.

[5] López-Moreno, J.I., S.R. Fassnacht, J.T. Heath, **K.N. Musselman**, J. Revuelto, J. Latron, E. Morán-Tejeda, T. Jonas (2012), Small scale spatial variability of snow density and depth over complex alpine terrain: Implications for estimating snow water equivalent, *Advances in Water Resources*, 55, 40-52.

[4] **Musselman, K.N.**, N.P. Molotch, S.A. Margulis, M. Lehning, and D. Gustafsson (2012), Improved snowmelt simulations with a canopy model forced with photo-derived direct beam canopy transmissivity, *Water Resources Research*, 48(10).

[3] **Musselman, K.N.**, N.P. Molotch, S.A. Margulis, P.B. Kirchner, and R.C. Bales (2012), Influence of canopy structure and direct beam solar irradiance on snowmelt rates in a mixed conifer forest. *Agricultural and Forest Meteorology*, 161, 46 – 56.

[2] Molotch, N.P., P.D. Brooks, S.P. Burns, M. Litvak, R.K. Monson, J.R. McConnell, and **K.N. Musselman** (2009), Ecohydrological controls on snowmelt partitioning in mixed-conifer sub-alpine forests, *Ecohydrology*, 2, 129–142.

[1] **Musselman, K.N.**, N.P. Molotch, and P.D. Brooks, (2008), Effects of vegetation on snow accumulation and ablation in a mid-latitude sub-alpine forest, *Hydrological Processes*, Vol 22 (15), 2767-2776.

CONFERENCE

PROCEEDINGS Presented extensively (>60 led and co-authored talks and posters) in Europe and North America

PROFESSIONAL AFFILIATIONS & SERVICE ACTIVITIES

Peer Review Panelist

- NASA Terrestrial Hydrology
- NASA Applied Sciences Program

Journal Peer Review

- *Advances in Water Resources*
- *Agricultural and Forest Meteorology*
- *Arctic, Antarctic, and Alpine Research*
- *Bulletin of the American Meteorological Society*
- *Earth System Science Data*
- *Ecohydrology*
- *Frontiers of Earth Science*
- *Geophysical Research Letters*
- *Hydrological Processes*
- *Hydrology Research*
- *J. of Applied Met. and Climatology*
- *J. Advances Modeling Earth Systems*
- *JGR – Atmospheres*
- *Journal of Hydrology*
- *Journal of Hydrometeorology*
- *Nature Climate Change*
- *Remote Sensing of Environment*
- *Science Advances*
- *The Cryosphere*
- *Water Resources Research*

Society Member:

- American Geophysical Union (2006-present)
- Canadian Geophysical Union (2013-2015)
- European Geophysical Union (2017)
- American Meteorological Society (2017)
- USGS Rocky Mountain Hydrologic Research Center
- Sigma Gamma Epsilon Earth Sciences Honor Society
- Changing Cold Regions Network

Committee Member:

- Executive Board Member, Western Snow Conference
- NOAA CMIP6 Climate Change Task Force

FIELDWORK EXPERIENCE

- 2019 - 2020 NASA SnowEx field campaign, Niwot Ridge, Colorado
- 2019 Snow distribution in a forested South American Catchment, Valle Hermoso, Chile
- 2019 Snowmelt pathway study, Niwot Ridge Long Term Ecological Observatory, Colorado
- 2017 NASA SnowEx field campaign, Grand Mesa, Colorado
- 2016 Photogrammetric monitoring of SNOTEL sites snow depth dynamics, Colorado
- 2013 - 2015 Terrestrial laser survey of 4-D snowpack dynamics, Rocky Mountains, Canada
- 2012 - 2015 Hydrometeorological impacts of forest clearings, Kananaskis, Alberta, Canada
- 2011 NASA Goddard grain size measurement campaign, Steamboat Springs, Colorado
- 2010 NASA JPL vegetation biomass survey, Grand Mesa, Colorado
- 2010 Basin scale variability of snow properties, Pyrenees, Spain and France
- 2007 - 2009 Plot and basin scale snow surveys, Sequoia National Park, California
- 2005 - 2006 Snow-vegetation interactions, Valles Caldera, NM
- 2002 - 2003 Precipitation gauge deployment and maintenance, Stowe, VT

GUEST LECTURES (Selected from >10 last three years)

Title: Snow water resources in a warmer American West

Department of Civil Engineering, July, 2019

Universidad de Chile, Santiago, Chile

Title: Climate change impacts on snow water resources

Mountain Meteorology, ATOC 4550, Fall 2018

Department of Atmospheric & Oceanic Sciences

University of Colorado, Boulder, CO

Title: Snow water resources in a warmer American West

Rocky Mountain Association of Professional Geologists, Fall 2018

Denver, Colorado

Title: The Feb. 2017 Oroville Dam Atmospheric River Event: the role of rain-on-snow.

Earth System Research Laboratory, Spring 2018

NOAA, Physical Sciences Division, Boulder, Colorado

Title: The science of snow and snow-cover persistence

Cross Country Ski Area Association, Spring 2018

Snow Mountain Ranch, Granby, Colorado