

Karl Rittger

Associate Research Scientist, University of Colorado Boulder (UCB)
Research Scientist III, Institute of Arctic and Alpine Research (INSTAAR)
Phone: (303) 735-3433 | Email: Karl.Rittger@colorado.edu

EDUCATION

PhD, Environmental Science and Management (July 2012)

Bren School of Environmental Science & Management
University of California, Santa Barbara (UCSB)

MESM (Master of Environmental Science and Management) (May 2006)

Water Resource Management Specialization
Bren School of Environmental Science & Management
University of California, Santa Barbara (UCSB)

ScB (Bachelor of Science), Geology-Physics/Mathematics (June 2002)

Brown University, Providence, RI

AREAS OF RESEARCH EXPERTISE

Remote sensing, snow hydrology, ice and snow, Earth surface energy and water balance, the cryosphere's melt sources, large-scale data modeling, data fusion super computing

RESEARCH APPOINTMENTS

University of Colorado, Boulder

Associate Research Scientist – Research Scientist III (January 2022-Present)

INSTAAR, UCB, Boulder, Colorado

Coordinate intra-institutional and inter-institutional snow research at CU Boulder including coordination with NASA, SERVIR, ICIMOD, the USGS, NOAA, and the NSIDC DAAC. Plan, direct, and lead projects in remote sensing, snow hydrology, snow physical processes. In charge of technological, scientific, and budgetary aspects. Proposal conceptualization and writing; code development for remote sensing of snow and earth energy balance; analysis and validation of remotely sensed snow properties and snow water equivalent; publication and presentation; teaching and training in developing countries, formal and informal student guidance.

Associate Research Scientist – Research Scientist II (October 2018-December 2021)

INSTAAR, UCB, Boulder, Colorado

Plan, direct, and lead projects in remote sensing, snow hydrology, snow physical processes. In charge of technological, scientific, and budgetary aspects. Proposal conceptualization and writing; code development for remote sensing of snow and earth energy balance; analysis and validation of remotely sensed snow properties and snow water equivalent; publication and presentation; teaching and training in developing countries, formal and informal student guidance.

Research Scientist I & II (January 2014 - September 2018)

National Snow and Ice Data Center, UCB, Boulder, Colorado

Proposal conceptualization and writing; International training in developing countries; code development for remote sensing of snow and earth energy balance, analysis and validation of remotely sensed snow properties and snow water equivalent; publication and presentation.

RESEARCH APPOINTMENTS (Continued)

University of California, Santa Barbara (part time remote)

Associate Research Scientist II (August 2022 -present)

Earth Research Institute, UCSB, Santa Barbara, CA

Associate Research Scientist I (July 2020-July 2022)

Earth Research Institute, UCSB, Santa Barbara, CA

Assistant Research Scientist II-IV (July 2012-June 2020)

Earth Research Institute, UCSB, Santa Barbara, CA

Previous positions

Postdoctoral Researcher (July 2012-December 2013)

Jet Propulsion Laboratory, Pasadena, California

Graduate Student Researcher (July 2005-June 2012)

Earth Research Institute, UCSB, Santa Barbara, California

Awards: Jeff and Linda Dozier Fellowship, Bren School of Environmental Science & Management, UCSB (September 2005-June 2006)

ACTIVE COMMITTEES AND ADVISORY BOARDS

Member, NSIDC Communications Liaison for internal & external strategy (April 2022-present)

Member, NASA MODIS/VIIRS Land Team (April 2022-present)

Member, NASA Surf. Biology & Geology Cal/Val Working Group (June 2021-present)

Lead, **NASA Snow-Today website**, NSIDC - INSTAAR collaboration, (February 2020-present)

Member, NASA Surf. Biology & Geology Applications Working Group (August 2020-present)

Member, NASA Surf. Biology & Geology Algorithms Working Group (June 2020-present)

Executive Committee (elected), International Snow Working Group, (2019-present)

Member (volunteer), Snow Albedo Working Group, NASA Hydrology (2019-present)

Science Board Advisor (selected), National Center Ecological Analysis (2016-present)

Member, European Geophysical Union (EGU) (2014-present)

Member, JPL Snow Data System (2012-present)

Member, American Geophysical Union (AGU) (2004-present)

DIVERSITY, EQUITY, AND INCLUSION ROLES

Member, **INSTAAR Justice Equity Diversity & Inclusiveness** (April 2020-July 2021)

Participate in monthly meetings and subgroups to foster inclusiveness at INSTAAR

INSTAAR, University of Colorado, Boulder, Colorado

Hollaback training (July 2020-present)

Participate in trainings to learn how to respond to and intervene in instances of harassment. Trainings include Conflict de-escalation, bystander intervention training, and undoing implicit bias training.

INSTAAR, University of Colorado, Boulder, Colorado

USAID and NASA SERVIR training (2012-2021)

Training of >180 students & faculty in 8 developing countries for USAID and NASA SERVIR
NSIDC and INSTAAR, University of Colorado, Boulder, Colorado

PUBLICATIONS (Page 1 of 5)

Planned

Rittger, K., Brodzik, M.J., Racoviteanu, A., Bair, E.H., Stilling, T.C., Armstrong, R.L., Painter, T.H., The fate of perennial snow and ice in mountain ranges and river basins of High Mountain Asia. *Geophysical Research Letters*.

Rittger, K., Abegg, S., Kleiber, W., Brodzik, M.J., Bair, E.H., Fusion of remotely sensed snow cover and snow albedo. *Frontiers in Remote Sensing*.

In preparation (likely mid 2023 to early 2024)

Rittger, K., Stilling, T., Bair, E.H., Skiles, S.M., (*in preparation*). Assessment of snow albedo mapping from MODIS. *Frontiers in Remote Sensing*.

Rittger, K., Bair, E.H., Racoviteanu A.E., Armstrong, R.L., Painter, T.H., (*in preparation*). Quantifying the individual contributions of melt from snow and glaciers in High Mountain Asia: Indus River basin. *Water Resources Research*.

Mahanthege, S., Kleiber, W., **Rittger, K.**, Rajagopalan, B.R., Brodzik, M.J., Bair, E.H., A (*in preparation*). Spatially-Distributed Machine Learning Approach for Fractional Snow Covered Area Estimation. *Water Resources Research*.

Feldman, D.R., Aiken, A.C., Boos, W.R., Carroll, R.,...**Rittger, K.** (*in preparation*). The Surface Atmosphere Integrated Field Laboratory (SAIL) Campaign. *Bulletin of the American Meteorological Society*.

Bair, E.H., Dozier, J., Rittger, K., Stilling, T., Kleiber, W., Davis, R.E., (*in preparation*). Does higher spatial resolution improve snow estimates? *The Cryosphere*.

In review (likely late 2022 to early 2023)

Yang, K., **Rittger, K.**, Musselman, K.N., Bair, E.H., Dozier, J., Margulis, S.A., Painter, T.H., Molotch, N.P. (*submitted*), Intercomparison of snow water equivalent products in the Sierra Nevada California using Airborne Snow Observatory data and ground observations; *Journal of Hydrology: Regional Studies*.

McGrath, D., Zeller, L., Bonnell, R., Reis, W., Kampf, S., Williams, K., Okal, M., Olsoen-Mikitowic, A., Bump, E., Sears, M., **Rittger, K.**, (*submitted*), Losses exceed gains: impact of the Cameron Peak wildfire on high-elevation seasonal snowpack, *Geophysical Research Letters*.

Hachett, B., Koshkin, B., Guirguis, K., **Rittger, K.**, Rhoades, A.M., Noline, A., Heggli, A., East, A., Siirila-Woodburn, E.R., Brandt, W.T., Gershunov, A., Haleakala, K. Midwinter dry spells amplify post-fire snowpack decline, *Geophysical Research Letters*.

Hao, D., Bisht, G., **Rittger, K.**, Stilling, T., Bair, E., Gu, Y., Leung, L.R. (*in review*), Evaluation of snow processes over the Western United States in E3SM land model, *The Cryosphere*.

Stilling, **Rittger, K.**, T., Bair, E.H., Raleigh, M., Davis, B. (*in review*) Landsat, MODIS, and VIIRS performance as validated by airborne lidar datasets, *The Cryosphere*.

Publications (Continued, Page 2 of 5)

2022

Hao, D., Bisht, G., He, C., Bair, E., Huang, H., Dang, C., **Rittger, K.**, Gu, H., Wang, H., Qian, Y., Leung, R. (2022) Improving snow albedo modeling in E3SM land model (version 2.0) and assessing its impacts on snow and surface fluxes over the Tibetan Plateau.

Geoscientific Model Development. 2022, 1-31, doi: 10.5194/gmd-2022-67.

Huang, H., Qian, Y., He, C., Bair, E.H., **Rittger, K.** (2022), Snow albedo feedbacks enhance snow impurity-induced radiative forcing in the Sierra Nevada. *Geophysical Research Letters*. 9, e2022GL098102, doi: 10.1029/2022GL098102.

Bair, E. H., Dozier, J., Stern, C., LeWinter, **Rittger, K.**, A., B Savagian, A., Stillinger, T., & Davis, R. E. (2022). Divergence of apparent and intrinsic snow albedo over a season at a sub-alpine site with implications for remote sensing. *The Cryosphere*, 16, 1765-1778. doi: 10.5194/tc-16-1765-2022

2021

Rittger, K., Krock, M., Kleiber, W., Bair, E.H., Brodzik, M.J., Stephenson, T.R., Rajagopalan, B., Bormann, K.J., Painter, T.H., 2021. Multi-sensor fusion using random forests for daily fractional snow cover at 30 m. *Remote Sensing of Environment* 264:112608. doi:10.1016/j.rse.2021.112608.

Rittger, K., Bormann, K.J., Bair, E.H., Dozier, J., Painter, T.H., (2021). Evaluation of VIIRS and MODIS snow cover Fraction in High-Mountain Asia using Landsat 8 OLI. *Frontiers in Remote Sensing*, 2. doi: 10.3389/frsen.2021.657154.

Ackroyd, C., Skiles, S.M., **Rittger, K.**, & Meyer, J. (2021). Trends in Snow Cover Duration Across River Basins in High Mountain Asia From Daily Gap-Filled MODIS Fractional Snow Covered Area. *Frontiers in Earth Science*, 9, doi: 10.3389/feart.2021.713145.

Yang, K., Musselman, K.N., **Rittger, K.**, Margulis, S.A., Painter, T.H., & Molotch, N.P. (2021). Combining ground-based and remotely sensed snow data in a linear regression model for real-time estimation of snow water equivalent. *Advances in Water Resources*, 104075, doi: <https://doi.org/10.1016/j.advwatres.2021.104075>.

Micheletty, P., Perrot, D., Day, G., & **Rittger, K.** (2021) Assimilation of Ground and Satellite Snow Observations in a Distributed Hydrologic Model for Water Supply Forecasting. *JAWRA Journal of the American Water Resources Association*, n/a, doi: <https://doi.org/10.1111/1752-1688.12975>.

Bair, E., Stillinger, T., **Rittger, K.** and Skiles, M., (2021). COVID-19 lockdowns show reduced pollution on snow and ice in the Indus River Basin. *Proceedings of the National Academy of Sciences* 118, e2201174118. doi: 10.1073/pnas.2101174118.

Mishra, S.K., Rupper, S., Kapnick, S., Casey, K., Chan, H.G., Ciraci', E., Haritashya, U., Hayse, J., Kargel, J.S., Kayastha, R.B., Krakauer, N.Y., Kumar, S.V., Lammers, R.B., Maggioni, V., Margulis, S.A., Olson, M., Osmanoglu, B., Qian, Y., McLarty, S., Rittger, K., Rounce, D.R., Shean, D., Velicogna, I., Veselka, T.D., & Arendt, A. (2021). Grand Challenges of Hydrologic Modeling for Food-Energy-Water Nexus Security in High Mountain Asia. *Frontiers in Water*, 3, doi: 10.3389/frwa.2021.728156.

2020

Khan, A., **Rittger, K.**, Xian, P., Katich, J.J., Armstrong, R.L., Kayastha, R., Dana, J. McKnight, D.M., (2020). Biofuel Burning Influences Refractory Black Carbon Concentrations in Seasonal Snow at Lower Elevation of the Dudh Koshi River basin of Nepal. *Frontiers, Earth Science*. doi: 10.3389/feart.2020.00371.

Sarangi, C., Qian, Y., **Rittger, K.**, Leung R., Chand, D., Bormann, K., Painter, T.H., (2020), Dust dominates high-altitude snow darkening and melt over high-mountain Asia, *Nature-Climate Change*. doi:10.1038/s41558-020-00909-3.

Hill, A. F., **Rittger, K.**, Dendup, T., Tshering, D., & Painter, T. H. (2020). How Important Is Meltwater to the Chamkhar Chhu Headwaters of the Brahmaputra River? *Frontiers in Earth Science*, 8(81). doi:10.3389/feart.2020.0008.

Bair, E.H., **Rittger, K.**, Ahmad, J.A., & Chabot, D. (2020): Comparison of modeled snow properties in Afghanistan, Pakistan, and Tajikistan, *The Cryosphere*, 14, 331-347, doi: 10.5194/tc-14-311-2020.

Rittger, K., Raleigh, M.S., Dozier, J., Hill, A.F., Lutz, J.A., Painter, T.H., (2020) Canopy adjustment of time-smoothed daily snow cover from MODIS. *Water Resources Research*, 55. doi:10.1029/2019WR024914.

2019

Bair, E. H., **Rittger, K.**, Skiles, S. M. K., & Dozier, J. (2019). An examination of snow albedo estimates from MODIS and their impact on snow water equivalent reconstruction. *Water Resources Research*, 55. doi: 10.1029/2019WR024810

Racoviteanu A.E., **Rittger K** and Armstrong R (2019) An Automated Approach for Estimating Snowline Altitudes in the Karakoram and Eastern Himalaya From Remote Sensing. *Front. Earth Sci.* 7:220. doi: 10.3389/feart.2019.00220

Sarangi, C., Qian, Y., **Rittger, K.**, Bormann, K. J., Liu, Y., Wang, H., Wan, H., Lin, G., and Painter, T. H. (2019) Impact of light-absorbing particles on snow albedo darkening and associated radiative forcing over high-mountain Asia: high-resolution WRF-Chem modeling and new satellite observations, *Atmos. Chem. Phys.*, 19, 7105–7128, doi:10.5194/acp-19-7105-2019.

2018

Armstrong, R.L., **Rittger, K.**, Brodzik, M.J., Racoviteanu, A., Barrett, A.P., Khalsa, S.J.S, Raup, B., Hill, A.F., Khan, A.L., Wilson, A.M., Kayastha, R.B., Fetterer, F., Armstrong, B., (2018) Contributions to High Asia runoff from glacier ice and seasonal snow: separating melt water sources in river flow. *Regional Environmental Change*. doi:10.1007/s10113-018-1429-0.

Hill, A.F., Stallard, R.F., **Rittger, K.**, (2018), Clarifying regional hydrologic controls of the Marañon River, Peru through rapid assessment to inform system-wide basin planning approaches. *Elementa: Science of the Anthropocene*, 6, Art. No 37, doi: 10.1525/elementa.290.

Publications (Continued, Page 4 of 5)

2018 (continued)

Bair, E. H., Abreu Calfa, A., **Rittger, K.**, and Dozier, J. (2018), Using machine learning for real-time estimates of snow water equivalent in the watersheds of Afghanistan, *The Cryosphere*, 12(5), 1579-1594, doi:10.5194/tc-12-1579-2018.

2000-2018

Rittger, K., Bair, E., Kahl, A., Dozier, J. (2016), Spatial estimates of snow water equivalent from reconstruction, *Advances in Water Resources*, 94, 345-363, doi:10.1016/j.advwatres.2016.05.015.

Bair, E.H., **Rittger, K.**, Davis, R.E., Painter, T.H., & Dozier, J. (2016). Validating reconstruction of snow water equivalent in California's Sierra Nevada using measurements from the NASA Airborne Snow Observatory. *Water Resources Research*, 52, 8437-8460. 10.1002/2016WR018704.

Seidel, F.C., **Rittger, K.**, Skiles, S.M., Molotch, N.P., Painter, T.H. (2016), Case study of spatial and temporal variability of snow cover, grain size, albedo and radiative forcing in the Sierra Nevada and Rocky Mountain snowpack derived from imaging spectroscopy, *The Cryosphere*, 10, 1229-1244, doi:10.5194/tc-10-1229-2016.

Pearson, C, Schumer, R., Trustman, B.D., **Rittger, K.**, Johnson, D.W., Obrist, D. (2015), Nutrient and mercury deposition and storage in an alpine snowpack of the Sierra Nevada, USA, *Biogeosciences*, 12 (12) 3665-3680, doi:10.5194/bg-12-3665-2015.

Painter, T.H., Seidel, F.C., Bryant, A.C., Skiles, M., **Rittger, K.** (2013), Imaging spectroscopy of albedo and radiative forcing by light-absorbing impurities in mountain snow, *Journal of Geophysical Research: Atmospheres*, 118, 1-13, doi:10.1002/jgrd.50520.

Sproles, E.A., Nolin, A.W., **Rittger, K.**, Painter, T.H. (2013), Climate change impacts on maritime mountain snowpack in the Oregon Cascades, *Hydrology and Earth Systems Science*, 17, 2581-2597, doi:10.5194/hess-17-2581-2013.

Welch, S.C., Kerkez, B., Bales, R.C., Glaser, S.D., **Rittger, K.**, Rice, R. (2013), Sensor placement strategies for snow water equivalent (SWE) estimation in the American River basin, *Water Resources Research*, 49, 891-903, doi:10.1002/wrcr.20100.

Raleigh, M. S., **Rittger, K.**, Moore, C.E., Henn, B., Lutz, J.A., Lundquist, J.D. (2013), Ground-based testing of MODIS fractional snow cover in subalpine meadows and forests of the Sierra Nevada, *Remote Sensing of Environment*, 128, 44-57, doi:10.1016/j.rse.2012.09.016.

Rittger K., Painter, T. H., Dozier, J. (2013), Assessment of methods for mapping snow cover from MODIS, *Advances in Water Resources*, 51, 367-380, doi:10.1016/j.advwatres.2012.03.002.

Jepsen, S.M., Molotch, N.P., Williams, M.W., **Rittger, K.**, Sickman, J.O. (2012), Interannual variability of snowmelt in the Sierra Nevada and Rocky Mountains, United States: Examples from two alpine watersheds, *Water Resources Research*, 48, doi: 10.1029/2011wr011006.

Publications (Continued, Page 5 of 5)

2000-2018 (continued)

- Rittger, K.**, Kahl, A., Dozier, J. (2011), Topographic distribution of snow water equivalent in the Sierra Nevada, *Proceedings, Western Snow Conference*, 79, 37-46.
- Painter, T. H., **Rittger, K.**, McKenzie, C., Davis, R.E., Dozier, J. (2009), Retrieval of subpixel snow-covered area, grain size, and albedo from MODIS, *Remote Sensing of Environment*, 113, 868-879, doi:10.1016/j.rse.2009.01.001.
- Dozier, J., Painter, T.H., **Rittger, K.**, Frew, J.E. (2008), Time-space continuity of daily maps of fractional snow cover and albedo from MODIS, *Advances in Water Resources*, 31(11), 1515-1526, doi:10.1016/j.advwatres.2008.08.011.
- Adams, N., Allen, H., Burgard, A., Dietz, C., Fung, P.C. & **Rittger, K.** (2006). Analysis of water resources management strategies for the Santa Ana River watershed region: Water reuse, recharge and use efficiency. *MESM Thesis*, University of California, Santa Barbara, 204 pp.
- Thurber, C., Roecker, S. Roberts, K., Gold, M., Powell, L., **Rittger, K.** (2003). Earthquake locations and three-dimensional fault zone structure along the creeping section of the San Andreas fault near Parkfield, CA: Preparing for SAFOD. *Geophysical Research Letters*, 30. doi:10.1029/2002gl016004.

COMPETITIVE AND UNSOLICITED GRANTS (Page 1 of 7)

Selected (Principal Investigator unless otherwise noted)

Total: \$9,297,748; **PI:** \$6,133,428; **Co-I:** \$3,164,271

Awaiting funding (likely 2023)

NASA Earth Science U.S. Participating Investigator

\$749,976 (3/1/2023-02/28/2028)

Title: *TRISHNA mission preparation and operation: fusion of optical and thermal data for snow fraction, albedo, and melt state*

Roles and Responsibilities: The upcoming Thermal infrared Imaging Satellite for High-resolution Natural resource Assessment (TRISHNA) mission will provide optical and thermal infrared data with spatial/temporal resolutions not represented by existing satellites. I will investigate the application of physically based models to produce snow surface properties from TRISHNA. During mission preparation (i.e., pre-launch) I will rely on hyperspectral data from the Environmental Mapping and Analysis Program (EnMAP), from the Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra, and the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) on Landsat 8/9 as surrogates for coincident optical and thermal observations. I will develop an algorithm that uses grain sizes and snow cover derived from spectral mixture analyses combined with surface temperature to classify melt conditions for diverse applications, from snowmelt modeling and streamflow forecasting to characterizing snow for coarse-resolution passive microwave SWE retrievals. In the operational phase of the mission (i.e., post-launch), I will test and finalize the algorithms based on spectral mixture analyses and our new melt state algorithm. I will validate and compare the products to coincident observations and to in situ observations and provide feedback to French and Indian teams on thermal and optical products, respectively. I will fuse the new TRISHNA observations with other satellite data using a machine learning approach to produce snow-surface observation datasets with a spatiotemporal resolution previously unachievable.

Awarded in 2022

NASA Earth Science Applications: Water Resources

\$1,199,995 (1/1/2022-12/31/2024)

Title: *Advancing domestic and international water management capabilities with a global daily snow cover and albedo product*

Roles and Responsibilities: I will lead a team to complete the transition of the data processing, archiving, and distribution of snow cover and snow albedo to that National Snow and Ice Data Center for VIIRS replacing existing global snow products. I will work with snow remote sensing end users who serve diverse needs of national and international water resource decision makers. These collaborators are globally distributed in North America, New Zealand, the Andes, High-Mountain Asia, and the European Alps. The historical and near real-time snow and albedo products will enhance decision-making processes to better inform stakeholders in a range of applications, including streamflow forecasting, agriculture, and water futures planning. The products account for off-nadir views, snow under the forest canopy, and use cloud filtering techniques not employed in existing products. I will work with the team at NSIDC to produce these products with sub-daily latency.

COMPETITIVE AND UNSOLICITED GRANTS (Continued, Page 2 of 7)

Awarded in 2022 (continued)

NASA Terrestrial Hydrology: Snow Cover and Albedo

\$335,000 (6/1/2022-12/31/2023)

Title: *Snow cover and albedo in near real time from MODIS*

Roles and Responsibilities: I will lead a team at the National Snow and Ice Data Center to process the global record of snow cover and albedo from MODIS Terra. I will work with the team to ensure consistent, reliable, repeatable data output through comparison to existing datasets in regions previously processed in research projects and compare data to higher spatial resolution data in new regions. I will supervise a programmer and develop code for the programmer to implement in a scalable fashion to achieve the global production required to process the historical record of data from March 2000 to present.

NASA Terrestrial Hydrology

\$474,864 (7/1/2021-6/30/2024)

Title: *Bridging MODIS to SBG: Improving the historical remotely sensed snow albedo record and preparing for satellite imaging spectroscopy via multi-sensor fusion*

Principal Investigator: McKenzie Skiles; Co-Investigator: Karl Rittger

Roles and Responsibilities: I will collaborate with PI Skiles to improve the historical snow albedo record from MODIS by 1) assigning uncertainty to values through comparison with higher resolution observations of snow albedo, 2) extending the processing domain to all mountains regions globally and adapting the processing workflow to VIIRS for continuity, and 3) downscaling to 30 m using Landsat-8 OLI/Sentinel-2 in select regions where hydrology is snow dominated. The outcomes of the project will be an open-access quality assessed multispectral snow albedo record spanning 20+ years, and in situ and airborne imaging spectrometer-based snow albedo validation datasets. We will also prepare for the future satellite missions by developing a workflow to fuse multispectral and imaging spectrometer retrievals of snow albedo. Many of the limitations of current multispectral platforms will be addressed by the SBG mission, with its planned higher spectral and spatial resolution.

NASA The Science of Terra, Aqua, and Suomi-NPP

\$713,075, (9/1/2021-8/31/2024)

Title: *Co-production of snow cover and snow albedo at sub-pixel scale with analysis, uncertainty, and data distribution in near real-time*

Roles and Responsibilities: I will lead a team of scientists, a programmer, operations, web developers, and writers to create snow cover and snow albedo data using a new algorithm we developed to replace the current NASA global snow products from MODIS and VIIRS. Using snow and snow albedo we will produce in near real-time over 48 tiles, the Snow Today at the National Snow and Ice Data Center will be expanded to include automated error estimation to support users' independent analysis and allow for ease of use in data assimilation. In addition to new, multivariate gridded data sets, daily analysis and monthly synthesis articles will provide meaningful interpretation of the data for researchers, policymakers and the general public.

COMPETITIVE AND UNSOLICITED GRANTS (Continued, Page 3 of 7)

Awarded in 2020

NASA SERVIR Training

\$36,000, (12/01/2020-05/31/2020)

Title: *SERVIR Subject Matter providing training on Snow Water Equivalent (SWE) to the SERVIR Hindu Kush Himalaya Hub*

Roles and Responsibilities: Based on previous experience training in Nepal, Kazakhstan, and India, I planned a lecture and hands on training for estimating SWE for the SERVIR Hindu-Kush Hub with Dr. Timbo Stillinger. I will prepare lecture and hands-on training materials and deliver the training to approximately 30-50 students in the Hindu-Kush region. Use cases in the training include a techniques that 1) could be accomplished with current resources 2) could be accomplished with slightly more resources or 3) a near-real time approach that requires substantially more resources. This approach will engage a range of student abilities. [Link](#)

NASA Interdisciplinary Research in Earth Science

\$1,018,842, (12/01/2020-11/31/2023)

Title: *The lifecycle of snow in the Sierra Nevada USA: from snowfall to snowmelt and effects on endangered bighorn sheep*

Principal Investigator: Edward Bair; Co-Investigator: Karl Rittger

Roles and Responsibilities: Along with Dr. Edward Bair, I conceptualized the idea to examine the Life Cycle of Snow investigating historical accumulation, melt, and sublimation, acquiring funding from the NASA Interdisciplinary Research (IDS) in Earth Science Program. My focus on this project will be to create the high-resolution snow-surface properties at a daily temporal resolution. I will use these to analyze historical snow properties, drive energy balance modeling used to estimate snow water equivalent. This data will be used to validate a regional climate model to forecast future snowpack run by Dr. Yun Qian of Pacific Northwest National Laboratory. To make this truly interdisciplinary, we will also work with Mary Conner of Utah State University and Tom Stephenson at the California Department of Fish and Wildlife who will use habitat modeling to choose the best areas for reintroduction of Sierra Bighorn Sheep.

University of Colorado Research and Innovation Seed Grant Program

\$50,000, (7/01/2020-06/30/2021)

Title: *Does snow persistence control rates of soil development & carbon storage?*

Roles and Responsibilities: In another cross-disciplinary effort, I joined efforts with Dr. Schmidt, a professor in Ecology and Evolutionary Biology at the University of Colorado, to better understand how snow persistence affects microbial succession and carbon accumulation in soil. I will develop snow-persistence maps using a record of data from Landsat and MODIS. The data will be used to direct sampling locations in a well-studied region near Ny-Alesund, Svalbard. The results, while relevant to the community studying this site, will also serve as preliminary data to inform more research proposals to expand this combination of remote sensing and soil development study in chronosequences where glaciers are retreating at other sites in the Arctic and high Alpine. This cross-department research that I lead strengthens INSTAARs ties to other disciplines.

COMPETITIVE AND UNSOLICITED GRANTS (Continued, Page 4 of 7)

Awarded in 2020

NASA Rapid Response and Novel Research in Earth Science

\$105,920, (7/28/2020-7/27/2021)

Title: *Satellite-based snowpack information to inform water resource management during the COVID-19 pandemic*

Principal Investigator: Noah Molotch; Co-Investigator: Karl Rittger

Roles and Responsibilities: Along with my current supervisor, Professor Molotch, we propose to address challenges to society, notably agricultural production, which in the semi-arid western U.S. relies heavily on forecasts of water supply that are anchored by measurements on the ground that are not currently available due to COVID-19 impacts. I will work with Professor Molotch to improve snow water equivalent (SWE) estimates using MODIS snow-cover maps to determine which ground-based snow observations are the most valuable for constraining SWE and how water management decisions can use satellite-based snow estimates. I will work closely with Dr. Molotch's team to integrate satellite remote sensing that provide spatially and temporally complete maps of snow-surface properties.

Awarded in 2019

NASA Understanding Changes in High Mountain Asia

\$1,079,662 (8/1/2019-7/31/2022)

Title: *Snow water equivalent and partitioned snow and glacier melt for 1985 to present, a 35+ year record for climate modelers*

Roles and Responsibilities: I conceptualized and acquired funding from the NASA High Mountain Asia II program to quantify the temporal and spatial variability of snow and ice in High Mountain Asia. For this project, I will lead a team consisting of researchers from CU Boulder, UCSB, and the University of Aberystwyth use satellite remote sensing data from 1985 to present to create a 35+ year record of snow/ice surface properties and mass estimates that include snow water equivalent, snow/ice melt, and sublimation, all at 500 m spatial resolution. A daily record of this length is useful for regional climate models (RCMs) as it captures both oceanic and atmospheric oscillations that occur on decadal or longer time scales, in addition to inter-annual variability. Our approach does not rely on total precipitation estimates from reanalysis or observational datasets, making it a unique calibration and validation tool.

Awarded in 2018

Directed funding from NASA Hydrology Program

\$380,534 (8/1/2018-7/31/2021)

Title: *NASA/INSTAAR/NSIDC near real time snow analyses*

Roles and Responsibilities: In order to obtain this programmatically directed funding from NASA Terrestrial Hydrology, I had to solicit support from the community including snow researchers like Dorothy Hall at NASA Goddard that are direct competitors for funding. With the community behind me, I was able to show the value of the proposed near-real-time snow analyses now available at: <https://nsidc.org/snow-today>. This project also builds collaboration between institutions at CU Boulder, bringing together teams from NSIDC and INSTAAR. The project has the potential to become a cornerstone of NSIDC web traffic as it broadens the expertise to include seasonal snow, in addition to their already strong sea-ice work.

COMPETITIVE AND UNSOLICITED GRANTS (Continued, Page 5 of 7)

Awarded in 2018 (continued)

Directed funding from NASA Cryosphere Program, Commercial Small Sat Pilot

\$120,317 (3/1/2019-2/28/2021)

Title: *Commercial satellite data for validation of snow-surface properties*

Roles and Responsibilities: Through close contact with the NASA Cryosphere Program Manager, I obtained funding to augment and extend work on one of my NASA projects on the Indus River basin. The work aims to better understand the accuracy of Essential Water Variables (EWVs) identified by the Group on Earth Observations (GEO). In this work, I lead a team including Dr. Keith Musselman and Leanne Lestak at INSTAAR to use commercial satellite data to improve our understanding of uncertainty in the EWVs. A major outcome was that a summary of our work was included in a report to Congress for decision making regarding the utility of commercial data and funding further acquisitions.

NASA Group on Earth Observations Work Program

\$545,302 (3/1/2018-2/28/2021)

Title: *Optimizing the Indus Basin Irrigation System and reservoir operations using remotely-sensed snow-surface properties in the ParBal model*

Roles and Responsibilities: In response to a solicitation from the NASA Applied Science program, I proposed creating a suite of Essential Water Variables to be analyzed as indicators to long-term trends in the Indus River basin that spans the countries of Pakistan, Afghanistan, India, and China. These variables are fundamental to forecasting short-term water supply and understanding long-term changes of water sources and subsequent impacts in the Indus River basin to minimize basin and regional risk. This collaboration with the U.S. Army Corps of Engineers (USACE) has already enabled research to applications using the USACE Hydrologic Modeling System (HEC-HMS) Model and HEC-ResSim Model reservoir simulation, which is specifically designed to duplicate and improve on the existing water management system comprising the Tarbela and Mangla Reservoirs, two major water resources in Pakistan.

NOAA JTTI Improving water prediction capabilities

\$418,384 (10/1/2018-9/30/2020)

Title: *Improving sub-seasonal water supply prediction across the Western United States through assimilation of remotely-sensed snow cover, snow albedo, and snow water equivalent in the NOAA National Water Model*

Roles and Responsibilities: Broadening my funding from NASA, here, I lead a team of six researchers at INSTAAR, UC Santa Barbara, and the National Center for Atmospheric Research (NCAR) to improve the NOAA National Water Model's (NWM) sub-seasonal (30-day, aka "long-range") forecast product. The product is underutilized by water managers and resource planners due to lack of grounding in observational datasets, high uncertainties, and unfamiliarity with the system. I developed a 20-year historical dataset of snow-surface properties and snow water equivalent covering the Western U.S. I provided this to NCAR to test an ensemble particle-filter assimilation method to winnow the long-range forecast ensemble set to "optimal" combinations of model parameters and forecasts that best replicate the snow observations, inserting uncertainty consistent with the observations back into the long-range analysis.

COMPETITIVE AND UNSOLICITED GRANTS (Continued, Page 6 of 7)

Awarded in 2018 (continued)

California Department of Fish and Wildlife

\$331,196 (1/1/2018-12/31/2020)

Title: *Daily snow-cover maps for use in understanding habitat and carrying capacity of Bighorn Sheep in the Sierra Nevada*

Roles and Responsibilities: In my first attempt to expand from studying snow for water resources and climate change effects on the cryosphere, I built upon a relationship with the California Department of Fish and Wildlife's (CDFW) Tom Stephenson from my time as a PhD student. Aware of the need for daily high-resolution snow mapping for habitat modeling, I successfully solicited funding from CDFW and completed a 20-year daily 30 m snow-cover dataset for a region that covers both the Sierra Bighorn sheep range and potential reintroduction areas for the sheep and for other wildlife like pronghorn. The work led to a manuscript on a method for data fusion. The effort also led to further funding by NASA Interdisciplinary Research (IDS), a grant previously described. In this project, I again created ties to other departments and centers working with Applied Math and NSIDC.

NASA The Science of Terra, Aqua, and Suomi NPP

\$823,336 (12/1/2018-11/30/2021)

Title: *Fusion of MODIS, VIIRS, and Landsat snow-cover data to create high spatial and temporal resolution estimates of snow water equivalent in a well-instrumented and austere basin*
Principal Investigator: Edward Bair; Co-Investigator: Karl Rittger

Roles and Responsibilities: While my colleague Dr. Bair leads this project, the impetuous behind our proposal was my previous fusion work for CA-DFW. The project further develops fusion of satellite data for snow-surface properties, specifically, snow albedo. In addition, we use these data to estimate SWE at 30 m. This work brings remote sensing and modeling techniques closer to the scale needed for understanding snow accumulation and melt processes.

U.S. Army Engineering and Development Center

\$741,309 (9/1/2018-9/30/2020)

Title: *Using enhanced-resolution passive microwave data to improve spatially distributed near-real-time snow water equivalent estimates*

Principal Investigator: Mary J. Brodzik; Co-Investigator: Karl Rittger

Roles and Responsibilities: This project focused on using a historical passive microwave (PM) dataset to estimate snow water equivalent for the entire world over the last approximately 50 years, moving from data at a 25 km spatial resolution to ~3 km. My role in the project was to produce SWE maps from independent methods based on the ParBal model and use these to estimate errors and uncertainty in the PM datasets.

COMPETITIVE AND UNSOLICITED GRANTS (Continued, Page 7 of 7)

Awarded in 2017 or earlier

Jet Propulsion Laboratory

\$179,987 (10/1/2017-9/30/2019)

Title: *Gap-filled snow-surface properties for High Mountain Asia and the Colorado River basin*

Roles and Responsibilities: For this work, I investigated the impact of light absorbing particles (LAPs) on snow and glaciers principally in High Mountain Asia. My contribution to the work included estimating snow albedo and the reduction of snow albedo from LAPs. In collaboration with Pacific Northwest National Laboratory, we analyzed RCM and GCM accuracy using remote sensing observations and published 2 papers.

United States Geological Survey

\$30,000 (7/1/2014-2/28/2015)

Title: *Development of a Landsat-MODIS snow-covered area essential climate variable product*

Roles and Responsibilities: I assisted the USGS in assessing surface reflectance products and implementing a spectral mixture analysis algorithm for fractional snow cover. The work resulted in a massive archive of Landsat data processing for CONUS that continues to this day.
<https://www.usgs.gov/core-science-systems/nli/landsat/landsat-fractional-snow-covered-area>

NASA Earth and Space Science Fellowship

\$30,000 (7/1/2009-6/30/2012)

Title: *Improving Runoff Forecasting in the Sierra Nevada with Enhanced Estimates of Snow Cover Properties*

Roles and Responsibilities: I applied for and received funding to pursue my PhD research. I created models to account for errors in remote sensing data which I used to drive an energy balance model I created to estimate the spatial distribution of snow water equivalent. Unlike many models, it did not rely on uncertain in-situ or reanalysis precipitation estimates.

PENDING GRANTS (Page 1 of 1)

Submitted 2022

NASA Making Earth System Data Records for Use in Research Environments

\$2,999,819 (1/1/2023-12/31/2027)

Title: *A global 40-year record of minimum annual snow and ice with uncertainty from spaceborne optical multispectral sensors*

Roles and Responsibilities: Global snow and ice are decreasing in extent and volume, but no systematic algorithm is currently available to map annual minimum snow and ice fraction (SIFmin) or to estimate associated uncertainties. To produce systematically derived maps of SIFmin, I will instead employ a mature algorithm adopted by the NASA and the USGS called the Snow-Covered Area and Grain size algorithm (SCAG), a physically-based spectral mixture analysis model. This eliminates subjectivity in current glacier mapping methods and facilitates consistent global mapping. From 2000 to 2023, using daily observations in the VIS, NIR, and SWIR from MODIS at 463 m, we will apply the MODIS Persistent Ice (MODICE) algorithm to SCAG outputs to produce consistently derived maps of SIFmin, pixelwise Date of annual Minimum (DOM), and uncertainty forming our first ESDR. While daily observations from MODIS can precisely capture the DOM, the 16-day cycle of Landsat will introduce temporal uncertainty. We will use DOM range from the MODIS era to estimate temporal uncertainty based on the date of observation from Landsat. From the 40+ -year record of Landsat (1985-2027), we will create global 30 m maps of SIFmin and uncertainty. As the first global, systematic record of minimum snow and ice measurements from the recent past, our ESDRs will provide a critical, evidence-based perspective in planning for an uncertain future.

ORAL PRESENTATIONS (since 2014) (Page 1 of 5)

2022

- (Invited) **Rittger, K.**, 2022-11-17. Global snow cover and albedo. Colorado River Climate and Hydrology Work Group, Salt Lake City, United States.
- (Invited) **Rittger, K.**, Snow Today at the National Snow and Ice Data Center, 2022-10-15. Association of Environmental Science Students, Portland, Oregon, United States.
- (Contributed) **Rittger, K.**, Stillinger, T., Bair, E.H., Skiles, Raleigh, M.S., M., Musselman, K., Brodzik, M.J., 2022-09-30. In pursuit of Open Access Accurate Global Snow Albedo Observations. International Symposium on Snow, Davos, Switzerland.
- (Contributed) **Rittger, K.**, Musselman, K., Skiles, Stillinger, T., Bair, E.H., M., Brodzik, M.J. Serreze, M., 2022-09-13. Advancing domestic and international water management capabilities with a global daily snow cover and albedo product. International Mountain Conference, Innsbruck, Austria.
- (Contributed) **Rittger, K.**, Stillinger, T., Bair, E.H., Skiles, Raleigh, M.S., M., Musselman, K., Brodzik, M.J. Serreze, M., 2022-06-30. In pursuit of Open Access Accurate Global Snow Albedo Observations. American Meteorological Society, Salt Lake City, United States.
- (Contributed) **Rittger, K.**, Musselman, Stillinger, T., Bair, E.H., Skiles, Raleigh, M.S., M., Musselman, K., Brodzik, M.J. Serreze, M., In pursuit of Open Access Accurate Global Snow Albedo Observations. Frontiers in Hydrology, San Juan, Puerto Rico.
- (Contributed) **Rittger, K.**, Musselman, K., Brodzik, M.J. Brodzik, Serreze, M., Abegg, S., Kleiber, W., Skiles, M., Bair, N., Stillinger, T., 2022-06-08. An accurate global daily snow cover and albedo product from MODIS and VIIRS. Eastern Snow Conference, Online.
- (Invited) **Rittger, K.**, Stillinger, T., Bair, E.H., Brodzik, M.J., 2022-04-12. Co-production of snow cover and snow albedo at sub-pixel scale with analysis, uncertainty, and data distribution in near real-time, NASA Land Surface Team Meeting. Zoom, United States.

2021

- (Contributed) **Rittger, K.**, Raleigh, M., Serreze, M., Musselman, K., Brodzik, M.J., Stillinger, T., Bair, E.H., Skiles, M., Snow Today at the National Snow and Ice Data Center. American Geophysical Union. New Orleans, LA, United States.
- (Contributed) **Rittger, K.**, Bair, E.H., Doan, W.P., Brodzik, M.J. 2021-10-07. Optimizing the Indus River Basin Irrigation System and reservoir operations using remotely sensed snow surface properties in the ParBal model, NASA Applied Sciences meeting. Zoom, United States.
- (Contributed) **Rittger, K.**, 2021-07-21, Snow Today. Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. CUAHSI Virtual Biennial 2021 Virtual, United States.
- (Invited) **Rittger, K.**, 2021-05-07, Multi-platform, multi-sensor snow surface properties for energy balance, model validation, and snow water equivalent. NASA Jet Propulsion Laboratory Seminar. Pasadena, CA, United States.

ORAL PRESENTATIONS (since 2014) (Continued, Page 2 of 5)

2021 (continued)

- (Contributed) **Rittger, K.**, Brodzik, M.J., Painter, T.H., 2021-04-21, Snow covered area and grain size for high resolution satellites. Satellite Snow Product Intercomparison and Evaluation Exercise, ENVEO, Austria via Zoom.
- (Contributed) **Rittger, K.**, Raleigh, M., Serreze, M., Musselman, K., Brodzik, M.J., Bair, E.H., Painter, T.H., 2021-04-12, Snow Today. 88th Western Snow Conference, Virtual, United States.
- (Invited) **Rittger, K.**, 2021-03-22. Multi-platform, multi-sensor snow surface properties for energy balance and model validation. INSTAAR Seminar, Online, United States.
- (Contributed) **Rittger, K.**, Dozier, J., Painter, T.H., 2021-02-23., Snow covered area and grain size for moderate resolution satellites. Satellite Snow Product Intercomparison and Evaluation Exercise, Zoom, Austria.

2020

- (Contributed) **Rittger, K.**, Krock, W. Kleiber, W., Bair, E.H., Brodzik, M.J., Stephenson, T., Rajagopalan, B., Bormann, K.J., Painter, T.H. 2020-09-04. Fusion of Landsat and MODIS for daily 30 m snow surface properties, SnowEx meeting, Zoom, United States.
- (Contributed) **Rittger, K.**, Bair, E.H., Doan, W.P., Brodzik, M.J. 2020-07-21. Optimizing the Indus River Basin Irrigation System and reservoir operations using remotely sensed snow surface properties in the ParBal model, NASA Applied Sciences meeting. Zoom, United States.
- (Invited) **Rittger, K.**, 2020-06-25. Multi-platform, multi-sensor snow surface properties for energy balance and model validation. Surface Biology and Geology Applications Working Group meeting, Pasadena, California, United States.
- (Contributed) **Rittger, K.**, 2020-02-04. [Multi-platform, multi-sensor snow surface properties for energy balance and model validation](#). SnowHydro, 2020, Bozen, Italy.
- (Contributed) **Rittger, K.**, 2020-01-28. [Multi-platform, multi-sensor snow surface properties](#). 9th EARSeL workshop on Land Ice and Snow, 2020, Bern Switzerland.

2014-2019

- (Contributed) **Rittger, K.**, Bair, E., Kleiber, W., Musselman, K., Bormann, K., Dugger, A., Chan, V., Brodzik, M., Doan, W., Rajagopalan, B., Painter, T., 2019-12-12. [Multi-platform, multi-sensor snow surface properties for energy balance and model validation](#). American Geophysical Fall Meeting, 2019, San Francisco, CA, United States.
- (Contributed) **Rittger, K.**, Bair, E., Doan, W.P., Brodzik, M.J., 2019-07-19. [Historical and real time snow product suite for the Indus River basin](#). 2019 NASA Applied Sciences Program, WWAO & Water Resources Team Meeting. Portland Oregon.
- (Contributed) **Rittger, K.**, Kleiber, W., Rajogopalan, B., Musselman, K., Bair, E., Bormann, K., Brodzik, M.J., 2019-07-09. [Fusion of Sentinel 2, Landsat, MODIS, and VIIRS Snow Surface Properties](#). 27th IUGG General Assembly, Montreal, Canada.

ORAL PRESENTATIONS (since 2014) (Continued, Page 3 of 5)

2014-2019 (continued)

- (Contributed) **Rittger, K.**, Bair, E., Painter, T.H., Bormann, K., Dozier, J., Raleigh, M., Serreze, M. 2019-04-16. [Near real time and historical trends of snow surface properties based on MODIS for the western U.S.](#) 87th Annual Western Snow Conference, Reno, Nevada, United States.
- (Contributed) **Rittger, K.**, Bair, E., Doan, W.P., Brodzik, M.J., 2018-12-14. [Historical and real-time snow product suite for the Indus River basin.](#) American Geophysical Union Fall Meeting 2018, Washington DC, United States
- (Invited) **Rittger, K.**, 2018-12-17. [High Mountain Asia snow trends](#), Securing the Third Pole: Glaciers, Snowpacks, and Water Vulnerability in High Asia. Wilson Center, Washington DC, United States.
- (Invited) **Rittger, K.** 2018-11-20. Remote sensing of snow surface properties from Landsat, MODIS, and VIIRS and applications for snow water equivalent and streamflow. SLF, Davos, Switzerland
- (Invited) **Rittger, K.**, Sarangi C., Bormann, K., Qian, Y., Painter, T.H., 2018-10-16. [High Mountain Asia Snow Surface Properties from MODIS/VIIRS and Comparison with High Resolution WRF-CHEM-SNICAR modeling.](#) Snow Products Small Group Meeting, Salt Lake City, UT, United States
- (Invited) **Rittger, K.**, Bormann, K.J., Bair, E., Painter, T.H., Raleigh, M., Serreze, M., 2018-09-11: [Integration of the Airborne Snow Observatory with daily observations and forecasts.](#) 3rd Annual Airborne Snow Observatory Meeting, Mammoth Lakes, CA, United States
- (Invited) **Rittger, K.**, Bair, E., Doan, B., 2018-6-26: [Optimizing the Indus Basin Irrigation System and reservoir operations using remotely sensed snow surface properties in the ParBal model.](#) 2018 NASA Applied Sciences Program Water Resources Team Meeting, Boulder, Colorado, United States
- (Invited) **Rittger, K.**, Bair, E., Doan, B., 2018-6-18: Optimizing the Indus Basin Irrigation System and reservoir operations using remotely sensed snow surface properties in the ParBal model. United States State Department, Washington D.C., CO, United States
- (Contributed) **Rittger, K.**, Armstrong, A.L., Bair, E., Brodzik, M.J., Racoviteanu A., Hill, A.F., Wilson, A.M., Khan, A.L., Khalsa, S.J.S., Barrett, A.P., Raup, B.H., Painter, T.H., 2018-4-8: [The Contribution to High Asia Runoff from Ice and Snow \(CHARIS\): Understanding the source and trends of cryospheric contributions to the water balance.](#) European Geoscience Union General Assembly, 2018, Vienna, Austria
- (Contributed) Racoviteanu, A., **Rittger, K.**, Armstrong, R., Brodzik, M.J., Hill, A., Khan, A., Wilson, A., 2017-4-8: [Estimating snowline altitudes across High Mountain Asia for melt modeling: challenges in using remote sensing.](#) European Geoscience Union General Assembly, 2018, Vienna, Austria

ORAL PRESENTATIONS (since 2014) (Continued, Page 4 of 5)

2014-2019 (continued)

- (Contributed) **Rittger, K.**, Armstrong, A.L., Bair, E., Racoviteanu A., Brodzik, M.J., Hill, A.F., Wilson, A.M., Khan, A.L., Ramage, J.M., Khalsa, S.J.S., Barrett, A.P., Raup, B.H., Painter, T.H., 2017-12-11: [The Contribution to High Asia Runoff from Ice and Snow \(CHARIS\): Understanding the source and trends of cryospheric contributions to the water balance](#). American Geophysical Union Fall Meeting 2017, New Orleans, Louisiana, United States
- (Contributed) Bair N., **Rittger, K.**, Dozier, J., 2017-12-11: [Using machine learning to predict snow water equivalent in the Sierra Nevada USA and Afghanistan](#). American Geophysical Union Fall Meeting 2017, New Orleans, Louisiana, United States
- (Contributed) **Rittger, K.**, Bair, E., Racoviteanu, A., Brodzik, M.J., Armstrong, R.L., Khalsa, S.J.S., Painter, T.H., Dozier, J., 2017-4-27: [Quantifying the individual contributions of melt from snow and glaciers in High Mountain Asia river basins: Syr Darya, Amu Darya, Indus, Ganges, and Brahmaputra](#). European Geoscience Union General Assembly, 2017, Vienna, Austria
- (Invited) **Rittger, K.**, Brodzik, M.J., Painter, T.H., Armstrong, R.L., Dozier, J., 2016-4-27: [Development and application of improved snow cover algorithms](#). The Eighteenth Session of the Terrestrial Observation Panel for Climate (TOPC-18), Boulder, Colorado, United States, pp. 12
- (Invited) **Rittger, K.**, Brodzik, M.J., Bair, E., Racoviteanu, A., Barrett, A., Khalsa, S.J., Painter, T.H., Dozier, J., 2016-4-18: [Distinguishing snow and glacier ice melt in High Asia using MODIS](#). European Geoscience Union General Assembly, 2016, Vienna, Austria
- (Contributed) **Rittger, K.**, Brodzik, M.J., Painter, T.H., Racoviteanu, Raup, B., Armstrong, R.L., Dozier, J., 2016-4-18: [Trends in annual minimum exposed snow and ice cover in High Mountain Asia from MODIS](#). European Geoscience Union General Assembly, 2016, Vienna, Austria
- (Invited) **Rittger, K.**, 2016-3-14: The geographic extent of High Mountain Asia. 3rd CAS-NASA Workshop on Earth Observation for Global Change in High Mountain Asia, Sanya, China
- (Contributed) **Rittger, K.**, Brodzik, M.J., Bair, E., Racoviteanu, A., Barret, A., Khalsa S.J., Armstrong, A., 2015-12-14: [Distinguishing snow and glacier ice melt in High Asia using MODIS](#). AGU Fall Meeting, San Francisco, California, United States
- (Invited) **Rittger, K.**, Brodzik, M.J., Racoviteanu, Bair, E., A., Barret, A., Khalsa S.J., Raup, B., Armstrong, A., Dozier, J., Painter, T.H., Davis, R., 2015-9-9: [Distinguishing snow and glacier ice melt in High Asia using MODIS](#). 2nd CAS-NASA Workshop on Snow and Glacier Ice Change and Related Natural Disasters in High Mountain Asia, Mammoth Lakes, California, United States

ORAL PRESENTATIONS (since 2014) (Continued, Page 5 of 5)

2014-2019 (continued)

- (Contributed) **Rittger, K.**, Brodzik, M.J., Racoviteanu, A., Barret, A., Khalsa S.J., Raup, B., Armstrong, A., Bair, E., Dozier, J., Davis, R., 2015-6-22: [Snow and ice melt contributions from a temperature index model and an energy balance model in the Hunza River basin](#). 26th International Union of Geodesy and Geophysics, Prague, Austria
- (Invited) **Rittger, K.**, Brodzik, M.J., Racoviteanu, A., Barrett, A., Armstrong, 2015-4-2: [Determining Snow And Ice Melt Contributions Using MODIS And A Temperature Index Melt Model In The Hunza River Basin](#). 10th Annual Hydrologic Sciences Research Symposium, Boulder, Colorado, United States

POSTER PRESENTATIONS (since 2014) (Page 1 of 2)

- (Contributed) **Rittger, K.**, Bair, E., Stillinger, T., Racoviteanu A., Brodzik, Rounce, D, Kleiber, W, Snow Water Equivalent and partitioned snow and glacier melt in basins of High Mountain Asia, a record for climate modelers. American Geophysical Union. New Orleans, LA, United States.
- (Contributed) **Rittger, K.**, Krock, W. Kleiber, W., Bair, E.H., Brodzik, M.J., Stephenson, T., Rajagopalan, B., Bormann, K.J., Painter, T.H. 2020-09-04. Fusion of high spatial and high temporal snow surface properties, American Geophysical Union Fall Meeting, December 1 to 17, 2020, Online, United States.
- (Contributed) **Rittger, K.**, Armstrong, A.L., Bair, E., Racoviteanu A., Brodzik, M.J., Hill, A.F., Wilson, A.M., Khan, A.L., Ramage, J.M., Khalsa, S.J.S., Barrett, A.P., Raup, B.H., Painter, T.H., 2017-12-11: [The Contribution to High Asia Runoff from Ice and Snow \(CHARIS\): Understanding the source and trends of cryospheric contributions to the water balance](#). CIRES Rendezvous, Boulder, Colorado, United States
- (Contributed) Horn, J., Painter, T.H., Bormann, K.J., **Rittger, K.**, Brodzik, M.J., Skiles, M., Burgess, A.B., Mattmann, C.A., Ramirez, P., Joyce, M., Goodale, C.E., McGibbney, L.J., Zimdars, P., Yaghoobi, R., 2017-12-11: [The Snow Data System at NASA JPL](#). American Geophysical Union Fall Meeting 2017, New Orleans, Louisiana, United States
- (Contributed) Wilson, A.M., Armstrong, A.L., Armstrong, B.R., Barrett, A.P., Brodzik, Fetterer, F.M., Fluri, J.L., M.J., Hill, A.F., Kayastha, R.B., Khalsa, S.J.S., Khan, A.L, Miller, H.A., Minbaeva, C., Racoviteanu A., Raup, B.H., **Rittger, K.**, 2017-12-11: [International cryospheric science capacity building and its role in policy and management](#). American Geophysical Union Fall Meeting 2017, New Orleans, Louisiana, United States
- (Contributed) Armstrong, R.L., Brodzik, M.J., Armstrong, B., Barrett, A., Fetterer, F., Hill, A., Khalsa, S.J., Raup, B. **Rittger, K.**, Williams, M. Wilson, A., Ye, Q., 2017-4-27: [Improving Understanding of Glacier Melt Contribution to High Asian River Discharge through Collaboration and Capacity Building with High Asian CHARIS Partner Institutions](#). European Geoscience Union General Assembly, 2017, Vienna, Austria
- (Contributed) **Rittger, K.**, Brodzik, M.J., Bair, E., Racoviteanu, A., Barrett, A., Khalsa, S.J., Painter, T.H., Dozier, J., 2016-12-12: [Quantifying the Individual Contributions of Snow and Glaciers in High Mountain Asia River Basins](#). AGU fall meeting
- (Contributed) **Rittger, K.**, Bormann, K., Brodzik, M.J., Armstrong, R.L., Painter, T.H., Dozier, J., 2016-5-13: Fractional snow cover for Landsat OLI, MODIS, and VIIRS from spectral mixture analysis. CIRES Rendezvous, Boulder, Colorado, US
- (Invited) **Rittger, K.**, Bormann, K., Armstrong, R., Painter, T.H., Dozier, J., 2015-9-16: [Fractional snow cover for Landsat OLI, MODIS, and VIIRS from spectral mixture analysis](#). 2nd International Satellite Snow Products Intercomparison Workshop, Boulder, Colorado, USA

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- (Contributed) **Rittger, K.**, Brodzik, M.J., Racoviteanu, A., Barret, A., Khalsa S.J., Armstrong, A., 2015-5-1: [Distinguishing snow and ice melt contributions using daily MODIS and a temperature index melt model in the Hunza River basin](#). CIRES Rendezvous 2015, Boulder, Colorado, USA
- (Contributed) **Rittger, K.**, Brodzik, M.J., Racoviteanu, A., Barret, A., Khalsa S.J., Armstrong, A., 2015-4-12: [Distinguishing snow and ice melt contributions using daily MODIS and a temperature index melt model in the Hunza River basin](#). European Geoscience Union, General Assembly, Vienna, Austria
- (Contributed) **Rittger, K.**, Brodzik, M.J., Racoviteanu, A., Barrett, A., Khalsa, S.J., Painter, T.H., Armstrong, R., Burgess, A., 2014-12-16: [Distinguishing ice from snow for melt modeling using daily observations from MODIS](#). AGU Fall Meeting, San Francisco, California, USA
- (Contributed) **Rittger, K.**, Painter, T.H., Selkowitz, D., Dozier, J., Burgess, A.B., Skiles, M., 2014-7-21: [Fractional Snow Covered Area From Landsat TM and ETM+, A Validation and Application](#). 1st International Satellite Snow Products Intercomparison Workshop , College Park, Maryland, USA
- (Contributed) **Rittger, K.**, Brodzik, M.J., Burgess, Anne, C., Burgess, E., Painter, T.H., Armstrong, R., 2014-4-27: [Distinguishing ice from snow for melt modeling using daily observations from MODIS](#). European Geoscience Union, General Assembly, Vienna, Austria

TEACHING, MENTORING, & ADVISING (Page 1 of 4)

My role with individual students is followed by my history of teaching in developing countries with large groups of diverse students.

Committee Member (PhD candidate)

Patrick Naples

Geography, University of Utah

Title: Understanding Trends in Dust Radiative Forcing in Snow in the Upper Colorado River basin

Patrick's work focuses on understanding the impact of dust on snow and snowmelt in the Colorado River basin using satellite remote sensing data. Work includes analyzing trends in dust on snow over the last 22 years including impacts on drought as well as analyzing the controls on changes perhaps related to vegetation and surface roughness as well as seasonal variations in meteorology.

Environmental Data Science Capstone Project (Masters completed)

Ryan Munnikhuis, Julia Parish, Marie Rivers

Title: Snow Today: Delivering Impactful Information on Snow Cover and Albedo to Diverse Global Users Through Web Based Big Data Visualizations [Link](#)

In an effort to improve my website at NSIDC, called Snow Today and simultaneously train students to work with big data, UCSB researcher Timbo Stillinger and I proposed this project to the Bren School of Environmental Science & Management. Three students selected the project. I worked with the students to help them understand snow data and users. I coordinated meeting with NSIDC staff to help them understand web design and visualizations.

Mentor and funder (Masters completed)

Stephanie Abegg (September 2020– 2022)

University of Colorado, Boulder

Title: Fusion of snow cover, snow grain size, and the impact of light absorbing particles

I began working with Ms. Abegg through my collaboration with CU Boulder Applied Math Professor William Kleiber who is also funded on the NASA TAS project described earlier in this CV. Ms. Abegg extended work begun by two master's students, Mr. Krock and Ms. Mahanthege. We focused on fusing moderate and fine scale snow grain sizes and meet weekly. This work is centered on the important field of snow albedo. I shared code and data with Ms. Abegg and meet weekly to guide her research.

TEACHING, MENTORING, & ADVISING (Page 2 of 4)

MA and PhD student interactions

Mentor and collaborator (PhD completed)

Kehan Yang (July 2018 – 2022)

INSTAAR, University of Colorado, Boulder

Dissertation title: Estimating the spatial distribution of snow water equivalent using in situ and remote sensing observations

I began working informally with Ms. Yang when she requested spatially gridded snow water equivalent data from another project. I helped guide her analysis of the SWE data and also began sharing other remotely sensed data. After joining Ms. Yang's research group led by Professor Noah Molotch, I have met with Ms. Yang in monthly meetings for the Mountain Hydrology Group since joining in October of 2018. Our work together recently culminated a manuscript that will be submitted in late November of 2020.

Mentor and funder (Masters completed)

Mitchell Louis Krock (January 2019 – September 2020)

Applied Math, University of Colorado, Boulder

Thesis title: Some models for large spatial data

Along with Mr. Krock, Professor Kleiber (his advisor), and CIRES fellow Professor Balaji Rajogopalan, we developed a new method for fusing remotely-sensed satellite data using random forests. I advised Mr. Krock on snow cover datasets from multispectral satellites for his work on the fusion process. Though well explored in other fields, little work had been done for snow. Our work resulted in a submitted publication.

Committee Member (Masters completed)

Chelsea Seutatia Ackroyd (January 2018 - May 2019)

University of Utah

Thesis title: Snow cover trends over high mountain Asia from MODSCAG

I worked with Ms. Ackroyd and Professor Mckenzie Skiles at the University of Utah to produce and analyze snow cover trends over 10 countries and 5 large rivers basins that serve billions of people in High Mountain Asia. I guided Ms. Ackroyd on analyzing snow cover datasets in High Mountain Asia. I worked with her to discover the best variable for trend analysis and how to perform the trend analysis for a publication that will be submitted to Remote Sensing of the Environment by the end of 2020.

Mentor (PhD completed)

Dr. Theo Masson (April 2016 - April 2018)

Institute of Engineering, University Grenoble Alpes, CNRS

I worked with Dr. Masson in analyzing competing methods for retrieving snow cover. Dr. Masson's publication advanced the understanding of the remote sensing of snow and acknowledged my contribution.

TEACHING, MENTORING, & ADVISING (Page 3 of 4)

Mentor (PhD completed)

Dr. Alice Hill (March 2015 – March 2017)

University of Colorado, Boulder - Geography

Thesis Title: Clarifying Hydrologic Controls of Remote Mountain Water Resources Across Varying Scales Through Development of a Rapid Hydrologic Assessment Methodology

I worked with Dr. Hill during her PhD on the USAID funded CHARIS project. Through our collaboration, we were able to connect remote sensing of snow and ice to in situ observations of discharge. The work was a step forward in understanding the sources of discharge from snowmelt, ice melt, rainfall, and groundwater.

Training and group teaching activities

Contributor for training in Modeling Melt from Snow and Ice (June 2018)

NSIDC, UCB, CHARIS, Thimphu, Bhutan

In preparation for the CHARIS team training lead by Dr. Richard Armstrong, I prepared datasets, programs, and lecture materials. There were 43 participants (31 internationals & 12 Bhutanese, including 3 female participants and 3 female participants from the U.S. government) from nine different countries. The participants were research scientists, PhD scholars, U.S. government employees (USAID & U.S. State Department), and water managers.

Contributor for training in Modeling Melt from Snow and Ice (April 2017)

NSIDC, UCB, CHARIS, Kathmandu, Nepal

In preparation for the CHARIS team training lead by Dr. Richard Armstrong, I prepared datasets, programs, and lecture materials. The two-day workshop and training were attended by 11 partner institutions each with three to four participants from nine countries.

Instructor for training in Modeling Melt from Snow and Ice (March 2016)

NSIDC, UCB, CHARIS, Almaty, Kazakhstan

I co-led this workshop and training and prepared datasets, programs and lecture material. I presented the material and led hands on training activities on hydrologic modeling and glacier mapping. We used the python programming language to perform and analyze snow and ice melt modeling. Our workshop had 36 participants and representation from eight partner countries.

Instructor for training in Remote Sensing and Energy Balance (March 2014)

NSIDC, UCB, CHARIS, Dehra Dun, India

I helped lead this 4-day workshop and training that consisted of both lectures and hands on training on elevation models, delineating basins, and mapping snow and glaciers with remote sensing. The 31 attendees represented the partner countries of Afghanistan, Bhutan, Kazakhstan, Kyrgyzstan, India, Nepal and Tajikistan.

TEACHING, MENTORING, & ADVISING (Page 4 of 4)

NASA SERVIR Training on Snow Water Equivalent

NASA, Online - students in Afghanistan, Bhutan and Nepal

Lectures and delivered to approximately 30-50 students in in the Hindu-Kush region. Use cases in the training include techniques that 1) could be accomplished with current resources 2) could be accomplished with slightly more resources or 3) a near-real time approach that requires substantially more resources. [Link](#)

[YouTube recordings](#)

[Lecture 1: Snow hydrology, Optical and Passive remote sensing of microwave remote sensing of snow](#)

[Lecture 2: Energy balance of snow and reconstruction of snow water equivalent](#)

[Lecture 3: Snow Water Equivalent Reconstruction at mountain range scales, contextualizing SWE information & climatology](#)

[Lecture 4: Snow Water Equivalent machine learning, snow covered area fusion, HiMAT-2 SWE products, operational data visualization of seasonal snow](#)

Instructor for Applied Remote Sensing Training (ARSET) (November 2014)

NASA, Fresno, CA

I lead presentations and discussions with water managers from the California Department of Water Resources and local water districts on how remote sensing can be used to inform water and reservoir management.

Instructor for Snow Products Training for SERVIR-Himalaya/ICIMOD (October 2012)

Jet Propulsion Laboratory, Kathmandu, Nepal

I lectured and taught hands on training for three full days by myself. The workshop drew 32 participants from 10 partner institutions in Bhutan, China, India, Pakistan, and Nepal. Attendees represented a mix of mid-level professionals, students, and university professors.

Teaching Assistant for Remote Sensing of the Environment (January 2007-May 2007)

ERI, UCSB, Santa Barbara

I taught the laboratory portion of this class for Professor Jeff Dozier. I lead 10 classes using ENVI software that lead to individual student projects. Labs were using ENVI software. In addition to regular lessons I assisted student in their individual projects.

Teaching Assistant and Speaker for Watershed Management (January 2007-May 2007)

ERI, UCSB, Santa Barbara

I assisted by contributing lectures to this master's level class while working on my PhD.

Math Teacher and Tutor (January 2003-June 2004)

The Learning Center; Avon, CO

Kip McGrath Education Centers, Avon, CO

Prior to continuing research as a graduate student, I helped K-12 children to learn all levels of math and science. Through this experience, I also worked for the state of Colorado and helped a mentally disabled individual transition from school to work.

OTHER SERVICE TO PROFESSIONAL/SCIENTIFIC COMMUNITY

Science Panel Member, Securing the Third Pole: Glaciers, Snowpacks, and Water Vulnerability in High Asia (Wilson Center/USAID) (December 2018)

Chair, High Mountain Asia's Cryosphere, AGU Meeting (December 2016)

Participant, NASA inter SNOWEX field campaign (February 2015)

Participant, Snow Product Intercomparison & Evaluation, ESA (July 2014)

Participant, 2nd Workshop on Snow Rem. Sensing, NASA Working Group (January 2014)

Participant, Airborne Snow Observatory field survey, NASA (April 2013)

Participant, Tokopah basin snow survey, UCLA (April 2012)

Participant, Sierra snow survey (April 2011)

SKILLS

Programming Languages: MATLAB, Python, BASH

High Performance Computing Software: Slurm, Torque, Sun Grid Engine

GIS Software: ArcGIS, QGIS, GRASS

OTHER RESEARCH EXPERIENCE

Oceanographic Seismic Researcher (October 2001-May 2002)

Brown University, Providence, RI & Columbia University, New York City, NY

Seismology Intern (May 2001-August 2001)

Rensselaer Polytechnic Institute, Troy, NY

Lamont – Doherty Earth Observatory Intern (May 2000-August 2000)

Columbia University, New York City, NY

Geology Department Teaching Assistant (January 2000-May 2000)

Brown University, Providence, RI

Field Analyst and GIS Operator (September 1999-May 2000)

Brown University, Providence, RI

OTHER ACTIVITIES

Division 1 NCAA Athlete, Wrestling (September 1997-March 2002)

Division 1 NCAA Qualifier, Wrestling, 184lbs (March 2001)

Division 1 Eastern Intercollegiate Wrestling Association Runner-up, 184lbs (March 2001)

The Ivy Group All-Ivy Team, Wrestling (September 1999-June 2000)