Eric E. Small

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Current Research

Remote sensing and modeling of the terrestrial water cycle

Mapping snow water equivalent in mountains and forecasting seasonal water supply using remote sensing, physical-based models, data assimilation, and machine learning

Quantifying forest canopy effects on snow and hydrology of mountain drainage basins

Using ground- and satellite-based GNSS reflections to monitor the water cycle

Validation and application of soil moisture retrievals from SMAP, SMOS, and CYGNSS

Education

Ph.D., Earth Sciences Department, University of California Santa Cruz, June 1998.

B.A., Geology, Williams College, June 1993.

Academic Appointments

2023 to present, Executive Director, College of Arts and Sciences Residential Academic Program, University of Colorado, Boulder.

2022 to 2023, Director, Environment and Natural Sciences Residential Academic Program, University of Colorado, Boulder.

2016 to 2021, Associate Chair for Undergraduate Studies, Geological Sciences, University of Colorado, Boulder.

2011 to present, Professor, Geological Sciences, University of Colorado, Boulder.

2006 to 2011, Associate Professor, Geological Sciences, University of Colorado, Boulder.

2002 to 2006, Assistant Professor, Geological Sciences, University of Colorado, Boulder.

2000 to 2003, Adjunct Professor, Biology, University of New Mexico, Albuquerque, NM.

1999 to 2002, Assistant Professor of Hydrology, Earth and Environmental Science, New Mexico Tech, Socorro, New Mexico.

1998, Postdoctoral Research Associate, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts.

1998, Postdoctoral Research Associate, Climate and Global Dynamics Division, National Center for Atmospheric Research, Boulder, Colorado.

Awards and Fellowships

AGU Editors' Citation for Excellence in Refereeing - Geophysical Research Letters, 2019

Colorado Governor's Award for High-Impact Research, 2017.

Creativity Award, Prince Sultan Bin Abdulaziz International Prize for Water, 2014.

"Professor of the Month Award", University of Colorado, October 2004.

Academic Life Teaching Award, University of Colorado, Fall 2003.

Department of Energy, Alexander Hollaender Distinguished Postdoctoral Fellowship, 1998.

Earth Science Dissertation Year Fellowship, University of California Santa Cruz, 1998.

Outstanding Student Paper Award, AGU Hydrology Section, 1997.

Horton Research Grant, AGU Hydrology Section, 1996.

Univ. California Institute on Global Conflict and Cooperation Dissertation Fellowship, 1996.

Geological Society of America Graduate Research Grant, 1996.

University of California White Mountain Research Station Fellowship, 1995.

National Defense Science and Engineering Graduate Fellowship, 1993-1996.

National Science Foundation Graduate Fellowship, 1993.

Current and Past Research Funding

Current Funding

Toward Improved SWE Mapping in Mid-Latitude Mountains Through the Integration of Snow Depth from Multiple Spaceborne LiDAR Instruments (PI)

NASA Terrestrial Hydrology Program, $200,00 (CU Portion).
June 2025 – May 2028.

The utility of aerial LiDAR snow surveys to improve water supply forecasts across the western U.S.: comparing the relative importance of current snow conditions and future weather (CoI)

Bureau of Reclamation Snow Water Supply Forecast Program, $130,000 (CU Portion).
October 2024 – September 2026.

Does integration of airborne lidar with existing snow monitoring technologies improve water supply forecasts in the western United States? (PI)

Bureau of Reclamation Snow Water Supply Forecast Program, $625,388.
October 2023 – September 2026.

Development of a Colorado-Wide Data Assimilation System to Provide Snow Water Equivalent Data and Water Supply Forecasts to Water Managers (PI)

NASA Water Resources, $468,000.
June 2022 – May 2025.

Advancing the mapping of snow water equivalent with space ready remote sensing through snow model integration (CoI)

NASA Terrestrial Hydrology, $467,000.
January 2022 – December 2024.

Past Funding

Water-mediated coupling of natural-human systems: drought and water allocation across spatial scales (coI)

NSF Coupled Human-Natural Systems $743,000.
September 2020 – August 2023.

Enhancing community and exploring diversity through A&S RAP Monthly Cultural Heritage Celebrations

CU Boulder Impact Grant, $22,876
August 2023 – July 2024

Merging CYGNSS reflectivity observations with SMAP brightness temperatures to produce downscaled soil moisture retrievals (coI)

NASA Terrestrial Hydrology, SMAP Science Team $337,000 (CU portion only).
September 2020 – August 2023.

Improving in situ snowpack sampling strategies for constraining modeled density and SWE from Lidar-based snow depth across landscapes in SnowEx (CoI).

NASA Terrestrial Hydrology Program $560,000.
Feb 2017 – May 2023.

High resolution mapping of surface water dynamics using CyGNSS L-band bistatic radar observations (PI).

NASA Terrestrial Hydrology Program $430,000.
Jan 2018 – Dec 2020.

Improved process understanding of snow density and SWE across forested mountain landscapes from coordinated field observations and model analyses

NSF Hydrologic Sciences $531,000.

March 2018 – February 2021.

Monitoring soil evaporation using SMAP surface soil moisture in a water balance framework (Co-PI)

NASA Terrestrial Hydrology Program $292,000.
August 2016 – July 2018.

GPS-based terrestrial water storage anomalies during hydrologic extremes: linking hydrologic process, solid-earth response, and monitoring networks (PI)

NSF Hydrologic Sciences $293,000.
August 2015 – July 2018.

PBO H_2O: GPS Reflection-Based Climate Products for 2007-2017 (Co-PI)

NSF AGS $512,000
June 2015 – May 2018.

AMIGHO: Automated Metadata Ingest for GNSS Hydrology within OODT (Co-I)

NASA Advanced Information Systems Technology (AIST) $949,000.
May 2015 – April 2017.

Validation of SMOS and SMAP soil moisture and vegetation products using ground-based GPS reflections data (PI)

NASA Terrestrial Hydrology Program $522,000.
Jan 2013 – Dec 2016.

GPS Ground Networks: An International Resource for Earth System Science Studies (CoI)

NASA Earth Science Division $554,185.
May 2012 – April 2015.

PBO H2O: Using EarthScope GPS Data to Generate Water Cycle Products (CoI)

NSF Earthscope Program, $442,336.
March 2012 – February 2015.

Developing and testing a new microwave radar sensor designed to monitor plant growth (PI).

University of Colorado Innovative Grant Program, $48,000.
June 2013-July 2014.

Validation of AMSR-E Soil Moisture and Snow Data Products Using Co-Located GPS and in situ Observations (PI)

NASA Terra/Aqua, $91,935.
April 2011 – March 2014.

Development of GPS as a Snow Sensor (CoI)

NSF EAR, $380,051
January 2010 – December 2012.

Development of GPS as an Instrument for a Continental-Scale Soil Moisture Network (CoI)
NSF Atmospheric Sciences, $631,258,
January 2010 – December 2012.

GPS-hydrology installation at SMAP in situ sensor test bed site (PI)
NASA Terrestrial Hydrology, $108,356.
June 2010 – May 2012.

The effects of weathering on bedrock channel erosion and form (PI)
NSF Geomorphology and Land Use Dynamics, $282,710
September 2009 – August 2012.

Ecosystem consequences of precipitation extremes in semiarid grassland and shrubland (CoI)
DOE National Institute for Climate Change Research, $150,000
January 2008-December 2010.

Sustainability of semiArid Hydrology and Riparian Areas (SAHRA).
NSF Science and Technology Center, $238,590 to E. Small at CU Boulder
January 2004-December 2009.

Development of GPS as a Soil Moisture Instrument (CoI)
NSF Atmospheric Sciences, $170,000
January 2008 – June 2009.

Groundtruth of soil moisture estimates from GPS SNR data (CoI)
University of Colorado Innovative Grant Program, $41,676,
July 2007-December 2008.

Impact of pine-beetle tree death on water quantity and quality in Colorado (PI)
University of Colorado Innovative Grant Program, $48,000,
July 2007-December 2008.

Modeling the influence of plant cover on water and energy cycling at the land-atmosphere interface: constraints from satellite and ground data (PI)
NASA IDS, $350,000
January 2004-December 2006.

Use of soil moisture observations for improved prediction of the North American Monsoon Precipitation (PI)
NOAA CPPA, $165,000
May 2004-June 2007.

Impact of rainfall variability and woody encroachment on productivity in a semiarid grassland in New Mexico (CoI)
DOE-NIGEC, $289,498
January 2004-December 2006.

Sevilleta Long Term Ecological Research (LTER) III: Long term ecological research in a biome transition zone (CoI)
NSF Environmental Biology
November 2002 – October 2006

Hydrological applications of remote sensing: Natural resource analysis and management in New Mexico (PI)
NSF EPSCoR, $710,000 to New Mexico Tech Hydrology Program
January 2002-December 2005

Influence of shrub invasion on water and nutrient cycling (PI)
NSF Hydrology, $173,000 to NMT
January 2001-December 2003.

The influence of land-atmosphere interactions on variability of the North American Monsoon (PI)
NASA IDS, $245,000
May 2000-April 2003.

Estimation of regional soil moisture and evapotranspiration using Landsat TM (CoI)
Los Alamos National Laboratory NUCOR program, $165,000.
Aug 1999 - July 2002.

The influence of land surface forcing on variability of the North American Monsoon (PI)
NOAA OGP, $157,500
June 2000-May 2003.

Undergraduate research opportunities in semiarid hydrology (PI)
NSF REU via SAHRA STC. $15,500.
June 2001-December 2001.

Cosmogenic dating of old, high pluvial shorelines in the western Great Basin (CoI)
NSF Geology and Paleontology Program. $149,961.
June 2000-May 2002.

Soil moisture-rainfall feedbacks in New Mexico (PI)
New Mexico Water Resources Research Institute, $25,000.
June 1999-May 2000.

Datasets *graduate student supervised

*Wernicke, L. J., Chew, C. C. & Small, E. E. (2024). *SMAP/CYGNSS EASE-Grid Soil Moisture*. (NSIDC-0797, Version 1). Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/8OODMTVR6RT9. Date Accessed 12-04-2024.

*Bonner, H. M., Smyth, E., Raleigh, M. S., & Small, E. E. (2022). A meteorology and snow dataset from adjacent forested and meadow sites at Crested Butte, CO, USA (1.3). Zenodo. https://doi.org/10.5281/zenodo.6618553

Publications

Google scholar metrics as of Feb 2025: total citations = 17,005; h-index = 62.

Refereed

*graduate student supervised; ** postdoc supervised

*Wernicke, L. J., Chew, C. C., & Small, E. E. (2024). Spatially Interpolated CYGNSS Data Improve Downscaled 3 km SMAP/CYGNSS Soil Moisture. *Remote Sensing*, *16*(16), 2924. doi:10.3390/rs16162924

*Herbert, J. N., Raleigh, M. S., & Small, E. E. (2024). Reanalyzing the spatial representativeness of snow depth at automated monitoring stations using airborne lidar data. *The Cryosphere*, *18*(8), 3495-3512. doi:10.5194/tc-18-3495-2024

*Modi, P. A., Jennings, K. S., Kasprzyk, J. R., Small, E. E., Wobus, C. W., & Livneh, B. (2024). Using Deep Learning in Ensemble Streamflow Forecasting: Exploring the Predictive Value of Explicit Snowpack Information. doi:10.22541/essoar.172222576.62134567/v1

Bjarke, N. R., Livneh, B., Barsugli, J. J., Pendergrass, A. G., & Small, E. E. (2024). Evaluating Large-Storm Dominance in High-Resolution GCMs and Observations Across the Western Contiguous United States. *Earth's Future*, *12*(6). doi:10.1029/2023ef004289

Steele, H., Small, E. E., & Raleigh, M. S. (2024). Demonstrating a Hybrid Machine Learning Approach for Snow Characteristic Estimation Throughout the Western United States. *Water Resources Research*, *60*(6). doi:10.1029/2023wr035805

Clara Chew, Eric Small, Hannah Huelsing, (2023). Flooding and inundation maps using interpolated CYGNSS reflectivity observations, *Remote Sensing of Environment*, Volume 293, 113598, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2023.113598.

*Modi, P. A., E. E. Small, J. Kasprzyk, and B. Livneh, (2022). Investigating the Role of Snow Water Equivalent on Streamflow Predictability during Drought. *J. Hydrometeor.*, 23, 1607–1625, https://doi.org/10.1175/JHM-D-21-0229.1.

Wobus C, Small E. E., Carbone J. C., *Modi P., Kamen H., Szafranski W., Livneh B. (2022).Water Allocation, Return Flows, and Economic Value in Water-Scarce Environments: Results from a Coupled Natural-Human System Model. *Water*. 14 (20) (October 01, 2022): ARTN 3280.

*Wernicke L.J., Chew C.C., Small E. E., Das N.N. (2022). Downscaling SMAP Brightness Temperatures to 3 km Using CYGNSS Reflectivity Observations: Factors That Affect Spatial Heterogeneity. *Remote Sensing*. 14 (20) (October 01, 2022): ARTN 5262.

*Bonner H.M., *Smyth E., Raleigh M.S., Small E.E.. (2022). A Meteorology and Snow Data Set From Adjacent Forested and Meadow Sites at Crested Butte, CO, USA. *Water Resources Research*. 58 (9) (September 01, 2022): ARTN e2022WR033006.

*Smyth, E. J., Raleigh, M. S., & Small, E. E. (2022). The Challenges of Simulating SWE Beneath Forest Canopies are Reduced by Data Assimilation of Snow Depth. *Water Resources Research*, https://doi.org/10.1029/2021WR030563

*Bonner, H. M., Raleigh, M. S., & Small, E. E. (2022). Isolating forest process effects on modelled snowpack density and snow water equivalent. *Hydrological Processes*, 36(1), e14475. https://doi.org/10.1002/hyp.14475

Raleigh, M. S., Gutmann, E. D., Van Stan, J. T., Burns, S. P., Blanken, P. D., & Small, E. E. (2022). Challenges and capabilities in estimating snow mass intercepted in conifer canopies with tree sway monitoring. *Water Resources Research*, 58, e2021WR030972. https://doi.org/10.1029/2021WR030972

*Abolafia-Rosenzweig, R., Badger, A. Livneh B., & Small, E. E. (2020). A continental-scale soil evaporation dataset derived from Soil Moisture Active Passive satellite drying rates. Scientific Data 7 (1), 1-10.

Chew, C. and Small, E. (2020) Description of the UCAR/CU Soil Moisture Product. *Remote Sensing*, *12*, 1558, https://doi.org/10.3390/rs12101558.

Chew, C. and Small, E. (2020). Estimating inundation extent using CYGNSS data: A conceptual modeling study, *Remote Sensing of Environment*, 246, https://doi.org/10.1016/j.rse.2020.111869.

*Smyth, E. J., Raleigh, M. S., & Small, E. E. (2020). Improving SWE estimation with data assimilation: The influence of snow depth observation timing and uncertainty. *Water Resources Research*, 56, e2019WR026853. https://doi.org/10.1029/2019WR026853

*Abolafia-Rosenzweig, R., Livneh B., & Small, E. E. (2019). Soil Moisture Data Assimilation to Estimate Irrigation Water Use. *Journal of Advances in Modeling Earth Systems*, 11, 3670-3690. https://doi.org/10.1029/2019MS001797.

*Enzminger, T. L., Small, E. E., & Borsa, A. A. (2019). Subsurface water dominates Sierra Nevada seasonal hydrologic storage. *Geophysical Research Letters*, 46, 11993-12001, doi.org/10.1029/2019GL084589.

*Smyth, E. J., Raleigh, M. S., & Small, E. E. (2019). Particle filter data assimilation of monthly snow depth observations improves estimation of snow density and SWE. *Water Resources Research*, 55. doi:10.1029/2018WR023400.

Small, E. E., Badger, A. M., *Abolafia-Rosenzweig, R. & Livneh, B. (2018). Estimating soil evaporation using drying rates determined from satellite-based soil moisture records. *Remote Sensing*, 10(12). doi:10.3390/rs10121945.

Chew, C., Reager, J. T., & Small, E. (2018). CYGNSS data map flood inundation during the 2017 Atlantic hurricane season. *Scientific Reports*, *8*(1). doi:10.1038/s41598-018-27673-x

*Fairfax, E., & Small, E. E. (2018). Using remote sensing to assess the impact of beaver damming on riparian evapotranspiration in an arid landscape. *Ecohydrology*, *11*(7), 14 pages. doi:10.1002/eco.1993

Chew, C. C., & Small, E. E. (2018). Soil Moisture Sensing Using Spaceborne GNSS Reflections: Comparison of CYGNSS Reflectivity to SMAP Soil Moisture. *GEOPHYSICAL RESEARCH LETTERS*, *45*(9), 4049-4057. doi:10.1029/2018GL077905

Murphy, B. P., Johnson, J. P. L., Gasparini, N. M., Hancock, G. S., & Small, E. E. (2018). Weathering and abrasion of bedrock streambed topography. *GEOLOGY*, *46*(5), 459-462. doi:10.1130/G40186.1

Small, E. E., Roesler, C. J., & Larson, K. M. (2018). Vegetation Response to the 2012-2014 California Drought from GPS and Optical Measurements. *REMOTE SENSING*, *10*(4), 16 pages. doi:10.3390/rs10040630.

*Enzminger, T. L., Small, E. E., & Borsa, A. A. (2018). Accuracy of snowwater equivalent estimated from GPS vertical displacements: A synthetic loading case study for western U.S. mountains. *Water Resources Research*, 54, 581–599. https://doi.org/10.1002/ 2017WR021521.

*Shellito, P. J., Small, E. E., and Livneh, B.: Controls on surface soil drying rates observed by SMAP and simulated by the Noah land surface model, *Hydrol. Earth Syst. Sci*., 22, 1649-1663, https://doi.org/10.5194/hess-22-1649-2018, 2018.

S.K. Chan, R. Bindlish, P. O'Neill, T. Jackson, E. Njoku, S. Dunbar, J. Chaubell, J. Piepmeier, S. Yueh, D. Entekhabi, A. Colliander, F. Chen, M.H. Cosh, T. Caldwell, J. Walker, A. Berg, H. McNairn, M. Thibeault, J. Martínez-Fernández, F. Uldall, M. Seyfried, D. Bosch, P. Starks, C. Holifield Collins, J. Prueger, R. van der Velde, J. Asanuma, M. Palecki, E.E. Small, M. Zreda, J. Calvet, W.T. Crow, Y. Kerr, Development and assessment of the SMAP enhanced passive soil moisture product*, Remote Sensing of Environment*, Volume 204, 2018, Pages 931-941, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2017.08.025.

Shobe, C. M., Hancock, G. S., Eppes, M. C., & Small, E. E. (2017). Field evidence for the influence of weathering on rock erodibility and channel form in bedrock rivers. *Earth Surface Processes and Landforms*, *42*(13), 1997-2012. doi:10.1002/esp.4163.

Wobus, C., Small, E. E., Hosterman, H., Mills, D., Stein, J., Rissing, M., . . . Martinich, J. (2017). Projected climate change impacts on skiing and snowmobiling: A case study of the United States. *Global Environmental Change-Human and Policy Dimensions*, *45*, 1-14. doi:10.1016/j.gloenvha.2017.04.006.

**Raleigh, M. S., and Small, E. E. (2017), Snowpack density modeling is the primary source of uncertainty when mapping basin-wide SWE with lidar, *Geophys. Res. Lett*., 44, 3700–3709, doi:10.1002/2016GL071999.

*Shellito, P. J., Small, E. E., and others (2016) SMAP soil moisture drying more rapid than observed in situ following rainfall events, *Geophysical Research Letters*, 10.1002/2016GL069946.

*Shellito, P. J., Small, E. E., and Cosh, M. H. (2016) Calibration of Noah Soil Hydraulic Property Parameters Using Surface Soil Moisture from SMOS and Basinwide In Situ Observations, Journal of Hydrometeorology, 10.1175/JHM-D-15-0153.1

Cosh, M. H., T. E. Ochsner, L. McKee, J. Dong, J. B. Basara, S. R. Evett, C. E.Hatch, E. E. Small, S. C. Steele-Dunne, M. Zreda, C. Sayde (2016) The Soil Moisture Active Passive Marena, Oklahoma, In Situ Sensor Testbed (SMAP-MOISST): Testbed Design and Evaluation of In Situ Sensors, *Vadose Zone Journal*, DOI: 10.2136/vzj2015.09.0122.

Small, E. E., K. M. Larson, *C. C. Chew, J. Dong and T. E. Ochsner, (2016) Validation of GPS-IR Soil Moisture Retrievals: Comparison of Different Algorithms to Remove Vegetation Effects, *IEEE JSTARS*, doi: 10.1109/JSTARS.2015.2504527

K. M. Larson and E. E. Small, (2016) Estimation of Snow Depth Using L1 GPS Signal-to-Noise Ratio Data, *IEEE JSTARS*, doi: 10.1109/JSTARS.2015.2508673.

*Q. Chen, D. Won, D. M. Akos, E. E. Small, (2016) Vegetation Sensing Using GPS Interferometric Reflectometry: Experimental Results With a Horizontally Polarized Antenna, *IEEE JSTARS*, doi: 10.1109/JSTARS.2016.2565687

*Q. Chen, D. Won, E. E. Small, D. M. Akos, K. M. Larson , (2016) Signal Polarization Selection for GPS-IR Remote Sensing-Theoretical Analysis and Experimental Results, PROCEEDINGS OF THE 28TH INTERNATIONAL TECHNICAL MEETING OF THE SATELLITE DIVISION OF THE INSTITUTE OF NAVIGATION (ION GNSS+ 2015) Pages: 3958-3968.

S. K. Chan *et al*., (2016) Assessment of the SMAP Passive Soil Moisture Product, *IEEE Transactions on Geoscience and Remote Sensing*, doi: 10.1109/TGRS.2016.2561938.

Small, E. E., *T. Blom, G. S. Hancock, B. M. Hynek, and C. W. Wobus, (2015) Variability of rock erodibility in bedrock-floored stream channels based on abrasion mill experiments, J. Geophys. Res. Earth Surf., 120, doi:10.1002/2015JF003506.

*Chew, C.C., E. E. Small, K.M. Larson, (2015) An algorithm for soil moisture estimation using GPS-interferometric reflectometry for bare and vegetated soil, *GPS Solutions*, doi: 10.1007/s10291-015-0462-4.

*Chew, C.C., E. E. Small, K.M. Larson, V.U. Zavorotny, (2015) Vegetation Sensing Using GPS-Interferometric Reflectometry: Theoretical Effects of Canopy Parameters on Signal-to-Noise Ratio Data, Geoscience and Remote Sensing, *IEEE Transactions on Geoscience and Remote Sensing*, doi: 10.1109/TGRS.2014.2364513.

*Wei, W., K. M. Larson, E. E. Small, *C. C. Chew, J. J. Braun (2015) Using geodetic GPS receivers to measure vegetation water content, *GPS Solutions*, DOI 10.1007/s10291-014-0383-7.

*Chew, C. C., and E. E. Small (2014), Terrestrial water storage response to the 2012 drought estimated from GPS vertical position anomalies, *Geophys. Res. Lett.*, 41,

doi:10.1002/2014GL061206.

**McCreight, J. L., E. E. Small, and K. M. Larson (2014), Snow depth, density, and SWE estimates derived from GPS reflection data: Validation in the western U. S., *Water Resour. Res*., 50, 6892–6909, doi:10.1002/ 2014WR015561.

*Evans, S.G., E.E. Small, and K.M. Larson (2014), Comparison of vegetation phenology in the western United States from reflected GPS microwave signals and NDVI, *Int. Journal Remote Sensing,* Vol. 35(9), 2996-3017, doi:10.1080/01431161.2014.894660

Larson, K.M. and E.E. Small (2014), Normalized Microwave Reflection Index, I: A Vegetation Measurement Derived from GPS Data, *IEEE JSTARS,* doi*:*10.1109/JSTARS.2014.3200116.

Small, E.E., K.M. Larson, and *W. Smith (2014), Normalized Microwave Reflection Index, II: Validation of Vegetation Water Content Estimates at Montana Grasslands, *IEEE JSTARS*, 10.1109/JSTARS.2014.2320597.

*Huda, S.A. and Small, E.E. (2014) Modeling the Effects of Bed Topography on Fluvial Bedrock Erosion by Saltating Bed Load, JGR Earth Surface, doi: 10.1002/2013JF002872.

Larson, K.M. and Small, E.E. (2013), Using GPS to Study the Terrestrial Water Cycle. Eos, Transactions, American Geophysical Union 94(52): 505-506. doi: 10.1002/2013EO520001.

Ochsner, T.E., Cosh, M.H., Cuenca, R.H., Dorigo, W.A., Draper, C.S., Hagimoto, Y., Kerr, Y.H., Larson, K.M., Njoku, E.G., Small, E.E., Zreda, M. (2013), The state of the art in large-scale soil moisture monitoring, *Soil Science Society of America Journal* doi:10.2136/sssaj2013.03.0093.

Jones, M.O., Kimball, J.S., Small, E.E., Larson, K.M. (2013), Comparing land surface phenology derived from satellite and GPS network microwave remote sensing, *International Journal of Biometeorology* doi: 10.1007/s00484-013-0726-z.

**McCreight, J.L. and Small, E.E. (2013), Modeling bulk density and snow water equivalent using daily snow depth observations. The Cryosphere Discussions 7: 5007-5049. doi: 10.5194/tcd-7-5007-2013.

*Chew, C.C., Small, E.E., Larson, K.M., Zavorotny, V. (2013) Effects of near-surface soil moisture on GPS SNR data: Development of a retrieval algorithm for volumetric soil moisture, *IEEE Transactions on Geoscience and Remote Sensing* doi: 10.1109/TGRS.2013.2242332.

*Pugh, E. T. and Small, E. E. (2013), The impact of beetle-induced conifer death on stand-scale canopy snow interception, *Hydrology Research*, 44 (4): doi: 10.1109/TGRS.2013.2242332.

Báez, S., Collins, S.L., Pockman, W.T., Johnson, J.E., and Small, E.E. (2012), Effects of experimental rainfall manipulations on Chihuahuan Desert grassland and shrubland plant communities. *Oecologia* doi: 10.1007/s00442-012-2552-0.

*Pugh, E.T. and Small, E.E. (2012), The impact of pine beetle infestation on snow accumulation and melt in the headwaters of the Colorado River. *Ecohydrology* 4: n/a. doi: 10.1002/eco.239

Hancock, G., Small, E.E., and Wobus, C. (2011), Modeling the effects of weathering on bedrock-floored channel geometry. Journal of Geophysical Research 16: n/a. doi: 10.1029/2010JF001908

Lakshmi, V., *Hong, S., Small, E.E., and F. Chen (2011), The influence of the land surface on hydrometeorology and ecology: new advances from modeling and satellite remote sensing. *Hydrology Research*, 42(2-3): 95-112.

Small, E. E., K. M. Larson, and J. J. Braun (2010), Sensing vegetation growth with reflected GPS signals. *Geophysical Research Letters,* L12401, doi:10.1029/2010GL042951.

*Gutmann, E. D., and E. E. Small (2010), A Method for the Determination of the Hydraulic Properties of Soil from MODIS Surface Temperature for use in Land Surface Models. *Water Resources Research,* doi:10.1029/2009WR008203.

Pockman, W. T. and E. E. Small (2010), The influence of spatial patterns of soil moisture on the grass and shrub responses to a summer rainstorm in a Chihuahuan Desert ecotone. *Ecosystems*, 13(4), 511-525.

Larson, K. M., J. J. Braun, E. E. Small, V. U. Zavorotny, E. D. Gutmann, and A. L. Bilich (2010), GPS Multipath and Its Relation to Near-Surface Soil Moisture Content, *Ieee Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *3*(1), 91-99.

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Other Publications

Larson, K. M., E. E. Small, J. J. Braun, and V. U. Zavorotny (2014), Environmental Sensing: A Revolution in GNSS Applications, *Inside GNSS*, July/August, 2014.

Larson, K. M., E. E. Small, J. J. Braun, and V. U. Zavorotny (2011), Using GPS to measure soil moisture, snow depth and vegetation growth, *inSights the EarthScope Newsletter*, Fall 2010.

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Small, E. E. and Kurc, S., 2001. The influence of soil moisture on the surface energy balance in semiarid environments. New Mexico Water Resources Research Institute Technical Completion Report No. 318.

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Seminars and Invited Talks

2024 September, NASA Applied Sciences Water Resources Annual Meeting, Cambridge, MA.

2024 November, Bureau of Reclamation, Snow Water Supply Forecast Forum, remote.

2023 September, NASA Applied Sciences Water Resources Annual Meeting, Huntsville, AL.

2023 March, NASA SnowEx Working Group, Remote.

2022 November, Presentation (virtual) at Colorado River Climate and Hydrology Work Group Annual Meeting

2022 August, NASA Applied Sciences Water Resources Annual Meeting, Salt Lake City, Utah.

2021 August, NASA SMAP Science Team

2018 October, NSF Earthscope HydroGeodesy meeting, UCSD.

2017 May, GNSS Reflections Workshop, Univ. Michigan.

2016 March, UNAVCO annual science meeting, Broomfield, CO.s

2015 June, Panelist: Chapman Conference on the California Drought

2014 September, The future of PBO after Earthscope, Breckenridge, CO

2014 September, GNSS-R Colloquium, NCAR, Boulder, CO

2014 September, SMAP Cal/Val meeting, Pasadena, CA

2013 December, AGU Fall Meeting

2013 November, SMAP Cal/Val meeting, Pasadena, CA

2013 May, NASA MOISST meeting, Stillwater, OK

2013 April, CU Hydrology and Water Resources Seminar

2012 November, SMAP Cal/Val meeting, Oxnard, CA

2012 September, Phenology 2012 Meeting, Milwaukee, WI

2012 May, SMAP *in situ* Sensor Test Bed meeting, Oklahoma State University, OK

2012 January, NSF Earthscope Meeting, Boulder, CO

2011 October, Soil Science Society of America Meeting, Austin, TX

2011 July, NASA JPL working group on GPS reflections

2010 June, National Ecological Observatory Network (NEON), Boulder, CO

2010 May SMAP Cal/Val meeting, Oxnard, CA

2010 October, Geological Sciences Seminar, Boulder, CO

Teaching

Courses Taught

Machine Learning in the Hydrologic Sciences, CU Boulder (graduate class)
Water, Energy, and Environment CU Boulder (undergraduate class)
Planet Earth CU Boulder (undergraduate class)
Field Hydrology CU Boulder (upper-division undergraduate class)
The Terrestrial Water Cycle CU Boulder (graduate class)
Numerical Simulation of Earth Surface Processes, CU Boulder (graduate class)
Vadose Zone Hydrology, CU Boulder (graduate class)
Writing in the Geosciences, CU Boulder (undergraduate)
Physical Geology, CU Boulder (undergraduate)
Surface Hydrology, New Mexico Tech (undergraduate)
Desert Vadose Zone Hydrology, New Mexico Tech (graduate)
Hydroclimatology, New Mexico Tech (graduate)
Plant-Water Interactions, New Mexico Tech (graduate)

Graduate and undergraduate students supervised

Current students: Jordan Herbert, Spencer Shaw, Lena Nyblade, Olivia Stanley

Completed Ph.D.: Liza Wernike (2024), Eric Smyth (2022), Hannah Bonner (2022), Tom, Enzminger (2019), Emily Fairfax (2019), Peter Shellito (2017), Clara Chew (2015), Evan Pugh (2011), Shirley Kurc (2007), Ethan Gutmann (2008), David Bedford (2008), Laure Montandon (2009)

Completed M.S.: Emily Carbone (2017), Shahen Huda (2013), Sarah Evans (2013), Tevis Blom (2012), Phillip Jacobson (2007), Andrew Schmidt (2005), James Elliott (2004, New Mexico Tech), Douglas McGee (2002, New Mexico Tech), John Boulanger (2001, New Mexico Tech), Eric Bhark (2001, New Mexico Tech)

Postdocs supervised: Mark Raleigh, James McCreight, Karen Boniface, Cheney Shreve, Hongjie Xi, Janjun Xu

Undergraduates advised: Reilly Kaczmarek, Paloma Siegal, Forrest Becker, Jacklyn Florman, Simon Bantugan, Will Gallon, Evan Posdamer, David Yin, Natalie Burris, Ronn Friedlander, Isaac Vimont, Andrew Hattel, Tevis Blom, Jason Sauer, Maria Rocco, Jerri Tebbits, Caitlin Collins, Ann Marie Prue

Other Teaching Activities

2022-2024: Curriculum Development: Economics of Water Use and Trade in western U.S., funded by NSF Coupled Human Natural Systems.

2017-2018: Member of Department Action Team (DAT) working to develop an assessment plan and tool for the Department of Geological Sciences.

2014-2016: Co-author on NSF-funded Curriculum Development: Geodesy Tools for Societal Issues (GETSI). GETSI develops teaching materials for engaging undergraduate students in addressing societally important Earth science questions through the use of geodetic data.
2015: Revision of Geol1010 teaching materials to flip the classroom, with G. Tucker.

2010-2011: Lead effort to revise format and curriculum of the Geological Sciences senior writing class.

2006-2007**:** Participation in CU Boulder's SEI program: Working with other geology faculty and postdocs to develop learning goals and clicker-questions for Physical Geology intro course.

2004: I quantified the impact of clickers on student attendance, in-class participation, and overall performance by comparing two sections of Physical Geology: one with clickers and the other without.

2003**:** Implementation of "clicker" technology into geology classes at CU Boulder. I led an effort to enhance interactive learning in large lecture classes using personal infrared transmitters.

Service

Geological Sciences Department

Associate Chair for Undergraduate Studies (Fall 2016 – 2021)

Executive Committee (2003-2004, 2011-2012, 2014-2015)

Graduate curriculum committee (2007, 2014)

Undergraduate curriculum committee (2015-2022)

Graduate admissions committee (2009-2011)

Ph.D. entry interview committee (2009, 2013)

Tenure and Promotion Committee: various

Space committee (2006, 2009)

Hydrogeochemistry search committee (2005)

Biogeochemistry search committee (2002)

PRP research subcommittee (2004) and teaching subcommittee (2010)

College and University

First Year Executive Advisory Board, member.

Dean's DEI Advisory Board

Executive Director, College of Arts and Sciences Residential Academic Program, University of Colorado, Boulder

Director, Environment and Natural Sciences Residential Academic Program, University of Colorado, Boulder

ARPAC Internal Review for Department of Civil, Environmental, and Architectural Engineering (2017-2018).

Hydrologic Sciences Program, Geological Sciences faculty representative (2008 – 2021): Coordinate hydrology-related graduate courses across campus, review graduate student applications to the program, plan activities such as the annual symposium.

CU's Innovative Seed Grant Program Panel Reviewer (2010 – 2018): Review of more than 10 proposals per year; panel meeting with IGP coordinator to rank proposals for funding.

College Curriculum Committee; Writing Sub-committee (2011-2012): This 7-member committee drafted documents regarding (1) rules for classes being considered 'writing intensive'; (2) use of graduate student resources in writing classes (GPTIs).

Dean's Fund for Excellence committee member (2009 – 2012): The four member committee meets monthly to select proposals to fund, between 15 and 30 proposals a month.

Boulder Faculty Assembly (BFA), including participation in BFA Technology Committee (2005 – 2007).

Steering committee to form a Hydrology Graduate Program at CU Boulder (2002)

Profession

NASA review panels: including Energy and Water Cycle, Terrestrial Hydrology, SMAP Science Team, CyGNSS Science Team, New Investigator Program, Remote Sensing Theory

NSF review panels: Hydrological Sciences

NASA SMAP Science Team Member (2019-2024)

NASA SnowEx Participant (2018-present)

NASA SMAP Cal/Val Team Member (2013-2018)

GNSS-R Mission Planning Team (2012-2014)

NASA Soil Moisture *in-situ* sensor testbed participant (2011-2021)

AGU Outstanding Student Paper judge

Member of working group to develop NSF CUASHI hydrologic observatory (2004)

Member of NCEAS working group on precipitation and ecosystem change (2002-2003)

Steering committee: NSF EPSCoR New Mexico Institute for Natural Resource Analysis and Management.

Review of manuscripts and proposals for the following journals and funding agencies

Journals: *Water Resources Research, Geophysical Research Letters, Journal of Climate, Remote Sensing of Environment, Ecosystems*, *Journal of Geophysical Research*, *Geology*, and many others.

Funding Agencies: NSF (EAR/IF, Hydrological Sciences, Geomorphology and Land Use Dynamics), NASA (Water and Energy Cycle, Interdisciplinary Science, Terrestrial Hydrology), NOAA