CURRICULUM VITAE

DAVID J. GOCHIS

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1. Educational Information:

1994: B.S.	University of Kansas, Lawrence, Kansas
1998: M.S.	Oregon State University, Corvallis, Oregon: Thesis title: "Estimated plant water use and crop coefficients for drip irrigated hybrid poplars"
2002: Ph.D.	University of Arizona, Tucson, Arizona: Dissertation title: "Modeled sensitivities of the North American Monsoon"

2. Professional Experience:

2011-present:	Scientist III, National Center for Atmospheric Research, Boulder, CO
2007-2011:	Scientist II, National Center for Atmospheric Research, Boulder, CO
2004-2007:	Scientist I, National Center for Atmospheric Research, Boulder, CO
2002–2004:	Postdoctoral Fellow, National Center for Atmospheric Research, Advanced Study Program, Research Applications Program (RAP), Boulder CO, USA
1998-2002:	Research Assistant/Associate, University of Arizona, USA
1998:	Consulting Engineer, CH2M Hill, Portland, Oregon, USA
1995-1998:	Research Assistant, Oregon State University, USA

3. Scientific & Technical Accomplishments:

1. Original and continued lead developer of the community WRF-Hydro modeling system. Developed original version of WRF-Hydro while an ASP Postdoc at NCAR and have continued to lead the development and application of the model for research and forecasting since 2003. There are now dozens of research applications of WRF-Hydro around the world, and four operational official national hydrologic forecasting systems including the U.S. National Weather Service (others: Romania, Israel, United Arab Emirates-in progress). The WRF-Hydro code has been downloaded over 5,000 times by users around the world and has contributed to over 60 peer-reviewed publications.

2. Led the design, implementation, operation and analysis of a surface rainfall observing network in western Mexico in support of the CLIVAR/GEWEX endorsed North American Monsoon Experiment (NAME) for 6 years. This data contributed critical ground observations of the climatological structure of rainfall across the complex terrain of western Mexico and provided ground-truth data for radar and satellite precipitation studies in the region. (Gochis et al., 2003,

2004, 2006 and other co-authorships)

3. Lead the ground-validation and data impact modeling studies (using WRF-Hydro) for a series of gap-filling radar studies in Colorado from 2009-present that has resulted in the implementation of three new gap-filling radar installations in Alamosa, Gunnison (in progress) and Durango (in progress) (Gochis et al., 2016 Report to the Colorado Water Conservation Board).

4. Led development of the definitive paper describing the physical mechanisms and observations that characterized the 2013 Colorado flood event. (Gochis et al., 2015, BAMS)

5. Performed the first modeling study on how spatially-varying soil depths in complex impact land surface energy flux partitioning through regulation of soil water storage capacity (Gochis et al., 2011, J. Arid Environments).

6. Designed and operated first high-elevation eddy-covariance energy-balance measurement system to measure high elevation riparian evaporative fluxes (Ryken et al., 2021, manuscript under review).

7. Developed and implemented the first, real-time, seasonal water supply forecasting system that assimilates airborne lidar derived snowpack information into a hyper-resolution, physics-based hydrologic forecasting model (WRF-Hydro, 2021, manuscript in preparation).

8. Designed, deployed and operating a rapidly-deployable hydrometeorological observing network to support large-scale hydrometeorological field campaigns (RELAMPAGO-2018 and OTREC-2019). Multiple publications in print or in press.

4. Community Service:

4.1 Educational activities

- Developed and lead multiple training courses on the WRF-Hydro Modeling System (2010 – present)
- Lead science instructor for training classes associated with the NOAA National Water Model (multiple events from 2015-2020)
- Lead science lecturer on the NOAA National Water Model for the CUAHSI Summer Institute (2016-2019)
- Guest lecturer at:
    - U. California Irvine – 12 International Precipitation Conference (Short course on WRF-Hydro and the National Water Model)
    - MICMOR Helmholtz Research School (Mechanisms and Interactions of Climate Change in Mountain Regions) – Karlsruhe Institute of Technology, Germany
    - European Center for Medium Range Weather Forecasting (ECMWF-Reading U.K.)

    - Bjerknes Center for Climate Research
    - University of Texas at Austin
    - University of Nebraska-Lincoln
    - Creighton University
    - Arizona State University
    - University of Colorado
    - Colorado State University
    - University of Arizona
    - Cyprus Institute
    - Colorado School of Mines
    - University of Oklahoma
    - Universidad Autonoma Nacional de Mexico
    - Duke University
    - State University of New York (SUNY) at Albany
- Instructor for U.S. National Weather Service/UCAR COMET courses in Hydrometeorology

4.2 Mentoring Activities

- Significant Opportunities in Atmospheric Research and Science (SOARS) Science and Writing Mentor (multiple)
- NCAR HIRO program scientific advisor (2011)
- NCAR Early Career Scientist Assembly, Co-organizer, June 2003 and July 2007
- AGU Hydrology Section Outstanding Student Paper Award Committee (2008-2011)
- Supervised 4 NCAR staff technicians within NCAR
- Supervised of 3 Software Engineer within NCAR
- Supervised over 10 Scientists within NCAR

4.3 Student advisory committees

2020-present:	Yufen, Huang (PhD), University of Hawaii-Honolulu
2021:	Sujan Pan (PhD), University of Illinois, Champaing-Urbana
2021:	Anna Ryken (PhD), Colorado School of Mines, Main Advisor – Reed Maxwell

2019:	Nicholas Elmer (PhD), University Alabama-Hunstville
2018:	Anna Ryken (MS), Colorado School of Mines, Main Advisor – Reed Maxwell
2018:	Danielle Tijerina, (MS), Colorado School of Mines, Main Advisor – Reed Maxwell
2018:	Aleya Kushik, (PhD), University of Colorado, Main Advisor – David Noone
2018:	Jose Camarena, CIBNOR-Guymas, Sonora, Mexico , Main Advisor – Luis Brito-Castillo
2017:	MaryMicheal Forrester (MS), Colorado School of Mines, Main Advisor – Reed Maxwell
2016:	Francesca Viterbo (PhD), University of Savona, Italy
2016:	Tiantian Xiang (PhD), Arizona State University, Main Advisor - Enrique Vivoni
2013:	Joel Beiderman (PhD), University of Arizona, Main Advisor – Paul Brooks
2012:	Hernan Moreno (PhD), Arizona State University, Main Advisor - Enrique Vivoni
2011:	Wei Yu (PhD), U. of Colorado, Main Advisor – Weiqiu Wang
2008:	Michael Barnes, U. of Arizona, NOAA Hollingsworth Summer Fellowship
2008:	Kazungu Maitaria (PhD), U. Arizona, Main advisor – Jim Shuttleworth
2007:	Chunmei Zhu (PhD), U. Washington, Main advisor – Dennis Lettenmaier
2007:	Angela Rowe (MS), Colorado State University, Main advisor – Steve Rutledge

4.4 Editorial Activities

2021-present:	Associate Editor for the Journal of Hydrology – Regional Studies
2011-2014:	Associate Editor for the Journal of Hydrology
2011:	J. of Hydrometeorology, guest editor, Special Collection on Land Surface-Atmosphere Interactions and the role of vegetation
2010:	J. of Arid Environments, guest editor, Special Issue on land surface eco-hydrology of the North American Monsoon
2007:	J. Climate, guest editor, Special Issue on the North American Monsoon Experiment (NAME)
2002-2013:	Journal Reviewer: Science, Climate Dynamics, J. of Climate, HESS, J. Hydrometeorology, Monthly Weather Review, Geophysical Research Letters, Water Resources Research, J. of Applied Meteorology, Climate

Change, Advances in Water Resources, International Journal of Climatology, Bulletin of the American Meteorological Society, Q. Journal of the Royal Meteorological Society, J. Geophysical Research, J. Arid Environments, J. of Hydrology

4.5 Advisory Activities

2020-present	AMS Hydrological Sciences Awards Selection Committee
2020-present:	DOE-SAIL Science Steering Committee
2016-present	Advisory panel member Dept. of Energy Special Focus Area on East River Carbon-water-BGC cycling
2017-2020	American Meteorological Society-Society Council Member
2014-2018	American Meteorological Society – Committee on Hydrology
2015-2019	Advisory panel member NOAA/NCAR Development Testbed Center (DTC)
2010-2013:	Co-chair of CLIVAR Variability of American Monsoon Systems (VAMOS) Panel
2010-2012:	National Research Council (NRC) Panel Member, Assessment of the U.S. National Weather Service Modernization Program
2008-2010	NOAA Climate Change Prediction Program for the Americas (CPPA) Advisory Panel Member
2007-2011:	CLIVAR Variability of American Monsoon Systems (VAMOS) Panel member
2007-2013:	NSF-NCAR-BEACHON (Bio-hydro-atmosphere interactions of Energy Aerosols, Carbon, H2O, Organics & Nitrogen) Science Working Group
2008-2009:	Water Cycle Science Steering Group to inform the Water Cycle Inter-Agency Working Group of the U.S. Climate Change Science Program (CCSP)
2006-2010:	Chair North American Monsoon Experiment (NAME) Science Working Group
2004-2010:	Member NAME Science Working Group
2004-2006:	Member of the Consortium of Universities for the Advancement of Hydrological Sciences, Inc. (CUAHSI) Science Advisory Team

4.6 Conference/Workshop/Symposium Chair/Session convener:

2019	Annual Meeting of the American Meteorological Society, Session Chair
2018	Annual Meeting of the American Meteorological Society, Session Chair
2017	American Geophysical Union, Session Chair.
2017	Annual Meeting of the American Meteorological Society, Session Chair.

2016	Annual Meeting of the American Meteorological Society, 30th Conference on Hydrology Program co-Chair.
2016	American Geophysical Union, Session Chair.
2013	Annual Meeting of the American Geophysical Union, Session co-Chair.
2013	16th CLIVAR-VAMOS Panel Meeting, Meeting Co-Chair
2011	Annual Meeting of the American Meteorological Society, Session Chair.
2010	Annual Meeting of the American Meteorological Society, Session Chair.
2009-2016	Fall AGU Meeting, Session Chair.
2006	2nd World Weather Research Program on QPF and Hydrology, Boulder, CO, Co-Chair, July
2008	10th NAME Science Working Group Meeting, Miami, FL. Chair and lead organizer
2007	Spring Joint AGU/UGM Meeting, May 2007 Session Chair
2007	9th NAME Science Working Group Meeting, Acapulco, Mexico, Chair and lead organizer
2006	8th Science Working Group Meeting, Tucson Arizona, Chair and lead organizer
2006	NAME Monsoon Applications Workshop, Guaymas, Mexico, May, Co-chair
2006	Joint NCAR ASP/IAI Summer colloquium on climate change, climate variability in Latin America, July, Co-chair
2005	7.5th NAME Science Working Group Meeting, State College, PA, Chair, lead organizer

5. Honors and Awards:

2021	Publons Highly Cited Researcher (Multiple papers in top 1% of field)
2021	NCAR/RAL Annual Publication Award
2021	NCAR/RAL Education and Outreach Division Award for Training, Outreach and Support of the community WRF-Hydro system
2020	Publons Highly Cited Researcher (Multiple papers in top 1% of field)
2019	Publons Highly Cited Researcher (Multiple papers in top 1% of field)
2018	CUAHSI Community Service Award
2018	Fellow of the American Meteorological Society
2017	NCAR Science and Technical Achievement Award for Development and Implementation of the NOAA National Water Model
2017	RAL Science and Technical Achievement Award for Development and Implementation of the NOAA National Water Model
2016	Editor's Choice Award: Water Resources Research

2015	NCAR Publication of the year award
2011	Nominated for the AMS Horton Award for Hydrology
2001	Dept. of Hydrology and Water Resources Departmental Scholarship
1999	Institute for the Study of Planet Earth (ISPE) Fellowship, University of Arizona
1997	Recipient of the Wade Rain Scholarship, Oregon State
1996	Recipient of the Jefferson B. Rogers Scholarship, Oregon State
1994	Departmental Honors, Atmospheric Sciences, University of Kansas

6. Research Grants:

- Over 60 grants awarded since 2011
- Over $37M in grant funding acquired since 2011
- Grant success rate in excess of 70%

7. Publication List:

7.1 Theses:

Gochis, D.J., 1998: Estimated plant water use and crop coefficients for drip irrigated hybrid poplars. MS Thesis, Oregon State University, Corvallis, Oregon, USA.

Gochis, D.J., 2002: Modeled sensitivities of the North American Monsoon. PhD Dissertation, U. of Arizona, Tucson, Arizona, USA, 179 pages.

7.2 Refereed Journal Articles

1. **Gochis, D.J.** and R.H. Cuenca, 2000: Plant water use and crop curves for hybrid poplars. J. *of Irrigation and Drainage Engineering*, **126(4)**, 206-214.

2. Yang, Z.-L, **D.J. Gochis,** and W.J. Shuttleworth, 2001: Evaluation of the simulations of the North American Monsoon in the NCAR CCM3. *Geophys. Res. Lett.*, **28(7)**, April 1 2001, 1211-1214.

3. **Gochis, D.J**., W.J. Shuttleworth, and Z.-L. Yang, 2002: Sensitivity of the Modeled North American Monsoon Regional Climate to Convective Parameterization. *Monthly Weather Review*, **130**, 1282-1298.

4. Yang, Z.-L., **Gochis D.**, and Shuttleworth W.J., 2003: The impact of sea surface temperature on the North American monsoon: A GCM study. *Geophys. Res. Lett*., **30(2)**, 1033, Jan. 17, 2003.

5. **Gochis, D.J.**, W.J. Shuttleworth, and Z.-L. Yang, 2003. Hydrometeorological response of the modeled North American Monsoon to convective parameterization. *J. Hydrometeorology*, **4**, 235-250.

6. **Gochis, D.J.**, J.C., Leal, W.J. Shuttleworth, C.J. Watts and J. Garatuza-Payan, 2003: Preliminary diagnostics from a new event-based precipitation monitoring system in support of the North American monsoon experiment. *J. Hydrometeorology*, **4(5)**, 974-981.

7. **Gochis, D.J.**, A. Jimenez, C.J. Watts, J. Garatuza-Payan, and W.J. Shuttleworth, 2004: Analysis of 2002 and 2003 warm-season precipitation from the North American Monsoon Experiment (NAME) Event Rain Gauge Network (NERN). *Monthly Weather Review*, **132(12)**, 2938-2953.

8. Mapes, B., T. Warner, M. Xu, and **D. Gochis**, 2004: Comparison of cumulus parameterizations and entrainment using domain-mean wind divergence in a regional model. *J. Atmos. Sciences*, **61(11)**, 1284-1295.

9. **Gochis, D.J.** B. Anderson, and A. Barros, et al, 2005: Future Scientific Directions, Views from early career scientists, The Water Cycle Across Scales. *Bull. Am. Meteor. Soc*., **86**, 1743-1746.

10. Higgins, R.W. D. Ahijevych, and J. Amador, et al, 2006: The NAME 2004 field campaign and modeling strategy. *Bull. Amer. Meteor. Soc.*, **87(1)**, 79-94.

11. Vera, C., R.W. Higgins, J. Amador, T. Ambrizzi, R. Garreaud, **D. Gochis**, D. Gutzler, D. Lettenmaier, J. Morengo, C.R. Mechoso, J. Nogues-Peagle, P.L. Silva-Dias, and C. Zhang, 2006: Towards a unified view of the American monsoon systems. *J. Climate*, **19**, 4977-5000.

12. **Gochis, D.J.**, L. Brito-Castillo, and W.J. Shuttleworth, 2006: Hydroclimatology of the North American Monsoon Region in northwest Mexico. *J. Hydrology*, **316**, 53-70.

13. **Gochis, D.J.**, C.J. Watts, J. Garatuza-Payan, and J. Cesar-Rodriguez, 2007: Spatial and temporal patterns of precipitation intensity as observed by the NAME Event Rain Gauge Network from 2002 to 2004. *J. Climate*, **20**, 1734-1750.

14. Higgins, R.W. and **D.J. Gochis**, 2007: Synthesis of results from the North American Monsoon Experiment (NAME) Process Study. *J. Climate*, **20(9)**, 1601-1607.

15. Hong, Y., **D.J. Gochis**, J.-T. Cheng, K.-L. Hsu, and S. Sorooshian, 2007: Evaluation of satellite-based rainfall measurement using the North American Monsoon Experiment (NAME) Event Rain gauge Network (NERN). *J. Hydrometeorology*, **8**, 469-482.

16. **Gochis, D.J.**, L. Brito-Castillo, and W. J. Shuttleworth, 2007: Correlations between sea-surface temperatures and warm season streamflow in northwest Mexico. *Intl. J. Climatology*, **27**, 883-901.

17. Ray, A.J., G.M. Garfin, L. Brito-Castillo, M. Cortez-Vazquez, H.F. Diaz, J. Garatuza-Payan, **D. Gochis**, R. Lobato-Sanchez, R. Varady, and C. Watts, 2007: Monsoon region climate applications: Integrating climate science with regional planning and policy. *Bull. Amer. Meteor. Soc.*, **88(6)**, 933-935.

18. Liebmann, B., I. Blade, N.A. Bond, **D.J. Gochis,** D. Allured, and G. Bates, 2008: Characteristics of North American summertime rainfall with emphasis on the monsoon. *J. Climate*, **21**, 1277-1294.

19. Nesbitt, S., **Gochis, D.J.**, and T. Lang, 2008: The diurnal cycle of clouds and precipitation along the Sierra Madre Occidental observed during NAME-2004: Implications for warm season precipitation estimation in complex terrain. *J. Hydrometeorology*, **9**, 728-743.

20. Lyon, S., **D. Gochis**, F. Dominguez, N.A. Brunsell; C.L. Castro; F.K. Chow; Y. Fan; D. Fuka, Y. Hong; P.A. Kucera; S. W. Nesbitt; N. Salzmann; J. Schmidli; P.K. Snyder; A.J. TeuLing; T.E. Twine; S. Levis; J.D. Lundquist; G.D. Salvucci; A.M. Sealy and M.T. Walter, 2008: Coupling terrestrial and atmospheric water dynamics to improve prediction in a changing environment. *Bull. Amer. Meteor. Soc.*, Sept. 2008, 1275-1278.

21. Kursinski, E.R., R.A. Bennett, **D. Gochis**, S.I. Gutman, K.L. Holub, R. Mastaler, C.M. Sosa, I.M. Sosa, and T. van Hove, 2008: Water Vapor and surface observations in northwestern Mexico during the 2004 NAME Enhanced Observing Period. *Geophys. Res. Lett.*, **35(3)**, L03815, Feb. 14, 2008.

22. Vivoni, E.R., K. Tai, and **D.J. Gochis**, 2008: Effects of initial soil moisture on rainfall generation and subsequent hydrologic response during the North American Monsoon. *J. Hydrometeorology*, **10(3)**, 644-664.

23. **Gochis, D.J.**, W. Shi, J. Schemm, and R.W. Higgins, 2009: A forum for evaluating forecasts of the North American Monsoon: The NAME Forecast Forum. *Eos. Transactions,* **90(29)**, July 21, 2009.

24. David, C.H., **D.J. Gochis**, D.R. Maidment, W. Yu, D.N. Yates, and Z.-L. Yang, 2009: Using NHDPlus as the land base for the Noah-distributed model. *Transactions in GIS*, **13(4)**, 363-377.

25. Rosero, E., Z.-L. Yang, L.E. Gulden, G.-Y. Niu, F. Chen, K.E. Mitchell, and **D.J. Gochis**, 2009: Rethinking land-surface model development: an integrated approach to evaluating enhanced hydrological representations in the Noah-LSM. *J. Hydrometeorology*, **10**, 600-622.

26. Zhu, C., R. L. Leung, **D. Gochis**, Y. Qian, and D. P. Lettenmaier, 2009: Evaluating the influence of antecedent soil moisture on variability of the North American Monsoon precipitation in the coupled MM5/VIC modeling system, *J. Adv. Model. Earth Syst*., **1(13)**, 22 pp., doi:10.3894/JAMES.2009.1.13.

27. **Gochis, D.J.**, S. Nesbitt, W. Yu, and S.F. Williams, 2009: Assessment of quantitative precipitation estimates from space-borne platforms during the 2004 North American Monsoon Experiment. *Atmosfera*, **22**, 69-98.

28. Brito-Castillo, L., E. R. Vivoni, **D. Gochis**, A. Filonov, I. Tereschenko, and C. Monzon, 2010: An anomaly in the occurrence of the month of maximum precipitation distribution in northwest Mexico. *J. of Arid Environments*, **74**, 531-539.

29. Vivoni, E.R., C.J. Watts, and **D.J. Gochis**, 2010: Land surface eco-hydrology of the North American Monsoon. *J. Arid Environments*, **74**, 529-530.

30. **Gochis, D.J.**, E.R. Vivoni, and C.J. Watts, 2010: The impact of soil depths on land surface energy and water fluxes in the North American Monsoon region. *J. Arid Environments*, **74**, 564-

571.

31. Ikeda, K. R. Rasmussen, C. Liu, **D.J. Gochis**, D.N. Yates, F. Chen, M. Tewari, M. Barlage, J. Dudhia, K. Miller, K. Arsenault, V. Grubisic, and G. Thompson, 2010: Simulation of Seasonal Snowfall over Colorado. *Atmospheric Research*, **97**, 462-477.

32. Yucel, I., R.J. Kuligowski, and **D.J. Gochis**, 2011: Evaluating the Hydro-Estimator Satellite Rainfall Algorithm over a Mountainous Region. *Int. J. Rem. Sens. and Environ*. 32(22), 7315-7342.

33. Barlage, M., F. Chen, M. Tewari, K. Ikeda, **D. Gochis**, J. Dudhia, R. Rasmussen, B. Livneh, M. Ek, and K. Mitchell, 2010: Noah Land Surface Model Modifications to Improve Snowpack Prediction in the Colorado Rocky Mountains. *J. Geophys. Res.*, 115, DOI: 10.1029/2009JD013470.

34. Yu, W., W. Han, E. Maloney, **D. Gochis,** and S.-P. Xie, 2011: Observations of Eastward Propagation of Atmospheric Intraseasonal Oscillations from the Pacific to the Atlantic. *J. Geophys. Res*. 116, DOI: 10.1029/2010JD014336.

35. Rasmussen, R., C. Liu, K. Ikeda, **D.J. Gochis**, D. Yates, F. Chen, M. Tewari, M. Barlage, J. Dudhia, W. Yu, K. Miller, K. Arsenault, V. Grubišić, G. Thompson, E. Gutmann, 2010: High-Resolution Coupled Climate Runoff Simulations of Seasonal Snowfall over Colorado: A Process Study of Current and Warmer Climate. *J. Climate*, 24, 3015 – 3048.

36. Wood, E.F., J.K. Roundy, T.J. Troy, R. van Beek, M. Bierkens, E. Blyth, A. de Roo, P. Döll, M. Ek, J. Famiglietti, **D. Gochis**, N. van de Giesen, P. Houser, P.R. Jaffé, S. Kollet, B. Lehner, D.P. Lettenmaier, C. Peters-Lidard, M. Sivapalan, J. Sheffield, A. Wade, P. Whitehead, 2011: Hyper-Resolution Global Land Surface Modeling: Meeting a Grand Challenge for Monitoring Earth's Terrestrial Water. *Water Resources Research*. 47, DOI: 10.1029/2010WR010090.

37. Wood, E.F., J.K. Roundy, T.J. Troy, R. van Beek, M. Bierkens, E. Blyth, A. de Roo, P. Döll, M. Ek, J. Famiglietti, **D. Gochis**, N. van de Giesen, P. Houser, P.R. Jaffé, S. Kollet, B. Lehner, D.P. Lettenmaier, C. Peters-Lidard, M. Sivapalan, J. Sheffield, A. Wade, P. Whitehead, 2012: Reply to comment by Keith J. Beven and Hannah L. Cloke on "Hyperresolution global land surface modeling: Meeting a grand challenge for monitoring Earth's terrestrial water" *Water Resources Research*. 48, DOI: 10.1029/2011WR011202.

38. Moreno, H.A., E.R. Vivoni, and **D. Gochis**, 2012: Utility of quantitative precipitation estimates for high resolution hydrologic forecasts in mountain watersheds of the Colorado Front Range. *J. Hydrol.*, 438-439, 66-83.

39. Gutmann, E.D., R.Rasmussen, C. Liu, K. Ikeda, D.J. **Gochis**, M. Clark, G. Thompson, 2012: A Comparison of Statistical and Dynamical Downscaling of Winter Precipitation over Complex Terrain. *J. Climate*, 25(1), 262-288. doi:10.1175/2011JCLI4109.1.

40. Waliser, D.E. M. Moncrieff, D. Burrridge, A. Fink, **D.J. Gochis**, B. N., Goswami, B. Guan, P. Harr, J. Heming, H.-H. Hsu, R. Johnson, C. Jakob, S. Jones, P. Knippertz, J. Marengo, H. Nguyen, M. Pope, Y. Sera, C. Thorncroft, M. Wheeler, R. Wood, 2010: The "Year" of Tropical Convection (May 2008 to April 2010): Climate Variability and Weather Highlights. *Bull. of Amer. Meteorol. Soc*. 93(8), 1218 DOI: 10.1175/2011BAMS3095.1.

41. Rasmussen, R., B. Baker, J. Kochendorfer, T. Myers, S. Landolt, A. Fisher, J. Black, J. Theriault,

P. Kucera, **D.J. Gochis**, C. Smith, R. Nitu, M. Hall, S. Cristanelli and E. Gutmann, 2010: The NOAA/FAA/NCAR Winter Precipitation Test Bed: How Well Are We Measuring Snow? *Bull. of Amer. Meteorol. Soc.*, 93(6), 811-829.

42. Edburg, S.L., J.A. Hicke, P.D. Brooks, E. Pendall, B. Ewers, U. Norton, **D.J. Gochis** and E. Gutmann: Cascading Impacts of Bark Beetle-Caused Tree Mortality to Coupled Biogeophysical and Biogeochemical Processes, *Frontiers in Ecology and the Environment*., 10(8), 1416-1424.

43. Greenberg, J., D. Asensio, A. Turnipseed, A. Guenther, T. Karl, **D. Gochis**, 2012: Contribution of leaf and needle litter to whole ecosystem BVOC fluxes. *Atmospheric Environ.*, 59, 302-311.

44. Yu, W., W. Han, **D. Gochis**, 2012: Influence of the Madden-Julian Oscillation and Intraseasonal Waves on Surface Wind and Convection of the Tropical Atlantic Ocean. *J. of Climate*, 25(23), 8057-8074.

45. Duhl, T.R., **D. Gochis**, A. Guenther and S. Ferrenberg, 2012: Emissions of BVOC from Lodgepole Pine trees at two forest sites impacted differently by the Mountain Pine Beetle (MPB) following MPB attach. *Biogeosciences*., 10(1), 483-499.

46. Matrosov, S., R. Cifelli, **D.J. Gochis**, 2012: Measurements of Heavy Convective Rainfall in Flood-Prone Areas Using an X-Band Polarimetric Radar. *J. Applied Met. and Climatol.*, 52(2), 395-407.

47. Rasmussen, S.H., J. H. Christensen, M. Drews, **D. J. Gochis** and J. C. Refsgaard, 2012: Spatial scale characteristics of precipitation simulated by regional climate models and the implications for hydrological modeling. *J. of Hydrometeorology*, 13(6), 1817-1835.

48. Moreno, H. E. Vivoni and **D. Gochis**, 2013: Limits to Flood Forecasting in the Colorado Front Range for Two Summer Convection Periods Using Radar Nowcasting and a Distributed Hydrologic Model. *J. Hydrometeorology*, 4(4), 1075-1097.

49. J. A. Huffman et al., 2013: High concentrations of biological aerosol particles and ice nuclei during and after rain. *Atmos. Chem. & Phys.*, 13(13), 6151-6164.

50. Fiori, E., A. Comellas, L. Molini, N. Rebora, F. Siccardi, **D. Gochis**, S. Tanelli, A. Parodi, 2014: Analysis and hindcast simulations of an extreme event in the Mediterranean area: the Genoa 2011 case. *Atmospheric Research*, 15, 13-29.

51. Mascaro, G., E. Vivoni, **D. Gochis**, C. Watts, J. Rodriguez, 2014: Temporal downscaling and statistical analysis of rainfall across a topographic transect in northwest Mexico. *Journal of Applied Meteorology and Climatology*, 53(4), 910-927.

52. Ortega et al., 2014: Overview of the Manitou Experimental Forest Observatory: Site description and selected science results from 2008-2013. *Atmospheric Chemistry and Physics*, 14(12), 6345-6367.

53. Moreno, H.A, Vivoni, E.R., and **Gochis, D.J.**, 2014. Addressing Uncertainty in Reflectivity-Rainfall Relations in Mountain Watersheds during Summer Convection. *Hydrological Processes.* 28(3): 688-704.

54. Bukovsky, M. S., **Gochis, D.J.**, Mearns, L.O., 2013: Towards Assessing NARCCAP Regional Climate Model Credibility for the North American Monsoon: Current Climate Simulations.

Journal of Climate. 26(22), 8802-8826.

55. Berkelhammer, M., Hu, J., Bailey, A., Noone, D.C., Still, C.J., Barnard, H., **Gochis, D.**, Hsiao, G.S., Rahn, T., Turnipseed, A., 2013: The nocturnal water cycle in an open-canopy forest. *Journal of Geophysical Research-Atmospheres*, 118(17), 10225-10242.

56. Kaser, L., Karl, T., Guenther, A., Graus, M, Schnitzhofer, R., Turnipseed, A., Fischer, L., Harley, P., Madronich, M., **Gochis, D.**, Keutsch, E.N., Hansel, A., 2013: Undisturbed and disturbed above canopy ponderosa pine emissions: PTR-TOF-MS measurements and MEGAN 2.1 model results. *Atmospheric Chemistry and Physics*, 13(23), 11935-11947.

57. Xiang, T., Vivoni, E.R. and **Gochis, D.J.** 2014. Seasonal Evolution of Ecohydrological Controls on Land Surface Temperature over Complex Terrain. *Water Resources Research*. 50(5): 3852-3874.

58. Rasmussen et al., 2014: Impacts of Climate Change on the Water Balance of the Colorado Headwaters: High Resolution Regional Climate Model Simulations. *J. of Hydrometeorology*. 15(3), 1091-116.

59. Biederman, J. A., Harpold, A. A., **Gochis, D. J.**, Ewers, B.E., Reed, D.E., S.A. Papuga, Brooks, P.D, 2014: Increased evaporation following widespread tree mortality limits streamflow response. *Water Res. Research*, 50(7), 5395-5409.

60. Biederman, J. A., P.D. Brooks, Harpold, A. A., **Gochis, D. J.**, Gutmann, E., Reed, D.E., Pendall, E. Ewers, B.E., 2014: Multiscale observations of snow accumulation and peak snowpack following widespread, insect-induced lodgepole pine mortality. *Ecohydrology*, 7(1), 150-162.

61. Yucel, I., Onen, A., Yilmaz, K. and **Gochis, D.** 2015. Calibration and evaluation of a flood forecasting system: Utility of numerical weather prediction model, data assimilation and satellite-based rainfall. *J. Hydrol.* 523, 49 – 66.

62. **Gochis, D.J.**, R. Schumacher, K. Friedrich, N. Doesken, M. Kelsch, J. Sun, K. Ikeda, D. Lindsey, A. Wood, B. Dolan, S. Matrosov, A. Newman, K. Mahoney, S. Rutledge, R. Johnson, R. Kucera, P. Kennedy, D. Sempere-Torres, M. Steiner, R. Roberts, J. Wilson, W. Yu, V. Chandrasekar, R. Rasmussen, A. Anderson and B. Brown, 2016: The Great Colorado Flood of September 2013. *Bull. Amer. Meteorol. Soc.* 96(9), 1461-1487.

63. Fan, Y., Richard, S., Bristol, R. S., Peters, S. E., Ingebritsen, S. E., Moosdorf, N., Packman, A., Gleeson, T., Zaslavsky, I., Peckham, S., Murdoch, L., Fienen, M., Cardiff, M., Tarboton, D., Jones, N., Hooper, R., Arrigo, J., **Gochis D.J.**, Olson, J., Wolock, D., 2014: DigitalCrust - a 4D data system of material properties for transforming research on crustal fluid flow. *Geofluids*, 12, 1-2, 372-379.

64. Bierkens, Marc F. P., V.A Bell, P. Burek, N. Chaney, L.E. Condon, C. David, A. de Roo, P. Doell, N. Drost, J. Famiglietti, M. Floerke, **D. J. Gochis**, P. Houser, R. Hut, J. Keune, S. Kollet, R. Maxwell, J.T. Reager, L. Samaniego, E. Sudicky, E Sutanudjaja, N. van de Giesen, H. Winsemius, E.F. Wood. 2014: Hyper-resolution global hydrological modelling: what is next? "Everywhere and locally relevant". *Hydrol. Processes*, 29(2), 310-320.

65. Coe, J., J. Kean, J. Godt, R. Baum, E.S. Jones, **D. Gochis**, G.S. Anderson, 2014: New insights into debris flow hazards from an extraordinary event in the Colorado Front Range. GSA Today, v. 24, no. 10, doi: 10.1130/GSATG214A.1.

66. Bukovsky, M.S., C. M. Carrillo, **D. J. Gochis**, D. M. Hammerling, R. R. McCrary, L.O. Mearns, 2015: Towards Assessing NARCCAP Regional Climate Model Credibility for the North American Monsoon: Future Climate Simulations. *J. Climate*, 28(17), 6707-6728.

67. Hazenberg P., Y. Fang, P. Broxton, **D. Gochis**, G.-Y. Niu, J. Pelletier, P. A. Troch, X. Zeng, 2015: A hybrid-3D hillslope hydrological model for use in Earth system models. *Water Res. Research*, 8218-8239.

68. Friedrich, K., E.A. Kalina, J. Aikins, **D. Gochis**, R. Rasmussen, 2015: Precipitation and cloud structures of intense rain during the 2013 Great Colorado Flood. *J. Hydrometeorology*, 17(1), 27-52.

69. Biederman, J. A., A. J. Somor, A. A. Harpold, E. D. Gutmann, D. D. Breshears, P. A. Troch, **D. J. Gochis**, R. L. Scott, A. J. H. Meddens, and P. D. Brooks 2015: Recent tree die-off has little effect on streamflow in contrast to expected increases from historical studies, *Water Resour. Res.*, 51, doi:10.1002/2015WR017401.

70. Friedrich, K., E. Kalina, J. Aikins, M. Steiner, **D.J. Gochis**; P. Kucera, K. Ikeda, J. Sun, 2015: Raindrop size distribution and rain characteristics during the 2013 Great Colorado Flood.*J. Hydrometeorology*, 17(1), 53-72.

71. Clark, M., Y. Fan, D. Lawrence, J. Adam, D. Bolster, **D. Gochis**, R. Hooper, M. Kumar, L. Ruby Leung, D. Mackay, R. M. Maxwell, C. Shen, S. Swenson, X. Zeng, 2015: Improving the representation of hydrologic processes in Earth System Models. *Water Resources Research*, 51(8), 5929-5956.

72. Senatore, A., G. Mendicino, **D. J. Gochis**, W. Yu, D. N. Yates, and H. Kunstmann. (2015), Fully coupled atmosphere-hydrology simulations for the central Mediterranean: Impact of enhanced hydrological parameterization for short and long time scales, *J. Adv. Model. Earth Syst.*, 07, doi:10.1002/2015MS000510.

73. Fatichi, S., E.R. Vivoni, F.L. Ogden, V.Y. Ivanov, B. Mirus, **D. Gochis**, C.W. Downer, M. Camporese, J.H. Davison, B. Ebel, N. Jones, J. Kim, G. Mascaro, R. Niswonger, P. Restrepo, R. Rigon, C. Shen, M. Sulis, D. Tarboton, 2016: An overview of current applications, challenges, and future trends in distributed process-based models in hydrology. *J. Hydrology*, 537, 45-60.

74. Pelletier, J.D., P.D. Broxton, P. Hazenberg, X. Zeng, P. A. Troch, G.-Y. Niu, Z. Williams, M. Brunke, and **D. Gochis**, 2015: A gridded global data set of soil, immobile regolith, and sedimentary deposit thicknesses for regional and global land surface modeling, J. Adv. Model. Earth Syst., 8, doi:10.1002/2015MS000526.

75. Meixner, T., A. H. Manning, D. A. Stonestrom, D. M. Allen, H. Ajami, K. Blasch, A. E. Brookfield, C. L. Castro, J.F. Clark, **D.J. Gochis**, A.L. Flint, K.L. Neff, R. Niraula, M. Rodell, B.R. Scanlon, K. Singha, M.A. Walvoord, 2016: Implications of projected climate change for groundwater recharge in the western United States, *Journal of Hydrology*, 534, 124-138, ISSN 0022-1694, http://dx.doi.org/10.1016/j.jhydrol.2015.12.027.

76. Niraula, R., T. Meixner, H. Ajami, M. Rodell, **D. Gochis**, C. Castro, 2016: Comparing potential recharge estimates from three Land Surface Models across the western US. J. Hydrology, DOI: 10.1016/j.jhydrol.2016.12.028.

77. Hazenberg, P, Broxton, P, **Gochis, D.**, Niu, GY, Pangle, LA, Pelletier, JD, Troch, PA, Zeng, X.,

2016: Testing the hybrid-3-D hillslope hydrological model in a controlled environment. *Water Resources Research*. 1089-1107.

78. Brunke, M. A., P. Broxton, J. Pelletier, **D. Gochis**, P. Hazenberg, D. M. Lawrence, L. R. Leung, G.-Y. Niu, P. A. Troch, and X. Zeng, 2016: Implementing and evaluating variable soil thickness in the Community Land Model, Version 4.5 (CLM4.5). *J. Climate*, 29, 3441-3461, doi:10.1175/JCLI-D-15-0307.1.

79. Givati, A., **D. Gochis**, T. Rummler, H. Kunstmann, 2016: Comparing One-way and Two-way Coupled Hydrometeorological Forecasting Systems for Flood Forecasting in the Mediterranean Region. *Hydrology*. *3*(2), 19; doi:10.3390/hydrology3020019.

80. Xiang, T., E. Vivoni, **D. Gochis**, 2016: Soil Moisture and Vegetation Influence on North American Monsoon Precipitation. *Atmosfera*, 31(1), pp. 25-45.

81. Changhai Liu, K. Ikeda, R. Rasmussen, M. Barlage, A.J. Newman, A. F. Prein, F. Chen, L. Chen, M. Clark, A. Dai, J. Dudhia, T. Eidhammer, **D. Gochis**, E. Gutmann, S. Kurkute, Y. Li, G. Thompson, D.Yates, 2016: Continental-scale convection-permitting modeling of the current and future climate of North America. *Climate Dynamics*, DOI 10.1007/s00382-016-3327-9.

82. Niraula, R., Meixner, T., Dominguez, F., Bhattarai, N., Rodell, M., Ajami, H., **Gochis, D.**, & Castro, C. (2017). How might recharge change under projected climate change in the western U.S.?. Geophysical Research Letters, 44, 10,407–10,418. https://doi.org/10.1002/2017GL075421.

83. Xiang, T., Vivoni, E.R., **Gochis, D.J.**, and Mascaro, G. 2017. On the Diurnal Cycle of Surface Energy Fluxes in the North American Monsoon Region using the WRF-Hydro Modeling System. *Journal of Geophysical Research - Atmospheres.* 122(17): 9024-9049.

84. Li, L., **D. J. Gochis**, S. Sobolowski, and M. D. S. Mesquita, 2017: Evaluating the present annual water budget of a Himalayan headwater river basin using a high-resolution atmosphere-hydrology model. *Journal of Geophysical Research: Atmospheres*, **122**, 4786-4807, doi:10.1002/2016JD026279.

85. Camarena, J., L. Brito-Castillo, L. Farfan, **D. Gochis**, S. Diaz, 2018: Ocean-atmosphere conditions related to severe and persistent droughts in the Mexican Altiplano. *Intl. J. Climatology,* 38(2), pgs. 853-866.

86. Verri, G., N. Pinardi, **D. Gochis**, J. Tribbia, A. Navarra, G. Coppini, and T. Vukicevic, 2017: A meteo-hydrological modelling system for the reconstruction of river runoff: the case of the Ofanto river catchment. *Natural Hazards and Earth System Sciences*, 17, 1741-1761, doi:10.5194/nhess-17-1741-2017.

87. Lin, P., Z. -L. Yang, **D. J. Gochis,** W. Yu, D. R. Maidment, M. A. Somos-Valenzuela, and C. H. David, 2018: Implementation of a vector-based river network routing scheme in the community WRF-Hydro modeling framework for flood discharge simulation. *Environmental Modelling & Software*, 107, 1-11, doi:10.1016/j.envsoft.2018.05.018.

88. Friedrich, K., R. Grossman, J. Huntington, P. Blanken, J. Lentners, K. Holman, **D. Gochis**, B. Livneh, J. Prairie, E. Skeie, N. Healey, K. Dahm, C. Pearson, T. Finnessey, S. Hook, T. Kowalski, 2018: Reservoir Evaporation: Current science, challenges, and future needs. *Bull.*

American Meteorological Soc., 99(1), 167-188.

89. Powers, J.G. Klemp, J.B., Skamarock, W.C., Davis, C.A., Dudhia, J., Gill, D.O., Coen, J.L., **Gochis, D.J.**, Ahmadov, R., Peckham, S.E., Grell, G.A., Michalakes, J., Trahan, S., Benjamin, S.G., Alexander, C.R., Dimego, G.J. Wang, W., Schwartz, C.S., Romine, G.S., Liu, Z.Q., Snyder, C., Chen, F., Barlage, M.J., Yu, W., Duda, M.G., 2017: The Weather Research and Forecasting Model, Overview, System Efforts, and Future Directions. *Bulletin of the American Meteorological Society*. 98(8), pags 1717-1727. DOI: 10.1175/BAMS-D-15-00308.1.

90. Gilbert, J.R., R. Maxwell, **D. Gochis**, 2017: Effects of water table configuration on the planetary boundary layer over the San Joaquin River watershed, California. *J. Hydrometeorology,* 18(5), 1471-1488.

91. Xue, Z., **D.J. Gochis**, W. Yu, B. Klien, R. Rholi, Z. Zang, K. Sampson, A. Dugger, D. Sathiarj, Q. Ge, 2018: Modeling hydroclimatic change in southwest Louisiana rivers. Water, 10, 596, doi:10.3390/w10050596.

92. Forester, M.M., R.M. Maxwell, L. Bearup, **D. Gochis**, 2018: Forest disturbance feedbacks from bedrock to atmosphere using coupled hydrometeorological simulations over the Rocky Mountain headwaters. *J. Geophys. Res.-Atmos.*, 123, doi: 10.1029/2018JD028380.

93. Hu, H. F. Dominguez, P. Kumar, J. McDonnel, **D. Gochis**, 2018: A Numerical Water Tracer Model for Understanding Event-Scale Hydrometeorological Phenomena. *J. Hydrometeorology*, 19(6), 947-967.

94. Salas, F.R., M. Somos-Valenzuel, A. Dugger, D. Maidment, **D.J. Gochis**, C. David, W. Yu, D. Ding, E.P. Clark, 2018: Towards Real-Time Continental Scale Streamflow Simulation in Continuous and Discrete Space. *J. American Water Res. Assoc.*, 54(1), 7-27.

95. Mason, L. A., A.D. Gronewold, M. Laitta, **D.J. Gochis**, K. Sampson, L. Read, E. Klyszejko, J. Kwan, L. Fry, K. Jones, P. Steeves, A. Pietroniro, M. Major , 2019: New transboundary hydrographic data set for advancing regional hydrological modeling and water resources management. *Journal of Water Resources Planning and Management*, 145, 06019004, doi:10.1061/(ASCE)WR.1943-5452.0001073.

96. Lahmers, T. M., H. Gupta, C. L. Castro, **D. J. Gochis**, D. Yates, A. Dugger, D. Goodrich, and P. Hazenberg, 2019: Enhancing the structure of the WRF-Hydro hydrologic model for semiarid environments. *Journal of Hydrometeorology*, 20, 691-714, doi:10.1175/JHM-D-18-0064.1.

97. Rummler, T., J. Arnault, **D. J. Gochis**, and H. Kunstmann, 2019: Role of lateral terrestrial water flow on the regional water cycle in a complex terrain region: Investigation with a fully coupled model system. *Journal of Geophysical Research: Atmospheres*, 124, 507-529. doi:10.1029/2018JD029004.

98. Xu, X., F. Chen, M. Barlage, **D.J. Gochis**, S. Miao, and S. Shen, 2019: Lessons learned from modeling irrigation from field to regional scales. *J. Adv. Model. Earth Syst.*, DOI:10.1029/2018MS001595.

99. Kim, J., L. Read, L.E. Johnson, **D.J. Gochis**, R. Cifelli and H. Han, 2020: An experiment on reservoir representation schemes to improve hydrologic prediction: coupling the national water model with the HEC-ResSim, *Hydrological Sciences Journal*, DOI: 10.1080/02626667.2020.1757677

100. Viterbo, F., K. Mahoney, L. Read, F. Salas, B. Bates, J. Elliott, B. Cosgrove, **D.J. Gochis**, R. Cifelli, 2020: A Multiscale, Hydrometeorological Forecast Evaluation of National Water Model Forecasts of the May 2018 Ellicott City, Maryland, Flood. *J. Hydrometeorology*, 21, DOI: 10.1175/JHM-D-19-0125.1.

101. Viterbo, F., L. Read, Nowak, K., A.W. Wood, **D.J. Gochis**, R. Cifelli, M. Hughes, 2020: General Assessment of the Operational Utility of National Water Model Reservoir Inflows for the Bureau of Reclamation Facilities. *Water*, 12(10), DOI: 10.3390/w12102897.

102. Carroll, R.W.H., **D. Gochis**, K. Williams, 2020: Efficiency of the Summer Monsoon in Generating Streamflow Within a Snow-Dominated Headwater Basin of the Colorado River. *Geophys. Res. Lett.*, 47(23).

103. Pérez-Ruiz, E.R., E.R. Vivoni, E.A. Yepez, J.C. Rodriguez, **D.J. Gochis**, A. Robles-Morua, J. Delgado-Balbuena, D.K. Adams, 2020: Landscape Controls on Water-Energy-Carbon Fluxes Across Different Ecosystems during the North American Monsoon. In press, *J. Geophysical Research-Biogeosciences*.

104. Valayamkunnath, P., M. Barlage, F. Chen, K. Franz, **D.J. Gochis**, 2020: High-resolution mapping of tile drained croplands using a geospatial modeling approach. In Press. *Scientific Data*.

105. Yin, D., Z. G. Xue, **D.J. Gochis**, W. Yu, M. Morales, A. Rafieeinasab, 2020: WRF-Hydro-Sed: A Process-Based Soil Erosion and Sediment Transport Model. In press, *Water*, May, 2020.

106. Pal, S., F. Dominguez, M.E. Dillon, J. Alvarez, C.M. Garcia, S.W. Nesbitt, **D.J. Gochis**, 2021: Hydometeorological Modeling of an Extreme Rainfall Event using WRF and WRF-Hydro during the RELAMPAGO Field Campaign in Argentina. *J. Hydromet.* 10.1175/JHM-D-20-0133.1.

107. Eidhammer, T., A. Booth, S. Decker, L. Li, M. Barlage, **D.J. Gochis**, R. Rasmussen, K. Melvold, A. Nesje, 2021: Detailed mass balance and hydrological modeling of the Hardangerjøkulen ice cap in south-central Norway. *HESS*. 10.5194/hess-25-4275-2021

108. S. W. Nesbitt, P.V. Salio, P.V., E. Ávila, P. Bitzer, L. Carey, V. Chandrasekar, W. Deierling, F. Dominguez, M. E. Dillon, C. Marcelo Garcia, **D. Gochis**, S. Goodman, D. A. Hence, K. A. Kosiba, M. R. Kumjian, T. Lang, L. M. Luna, J. Marquis, R. Marshall, L. A. McMurdie, E. L. Nascimento, K. L. Rasmussen, R. Roberts, A. K. Rowe, J.J. Ruiz, E. F.M.T. São Sabbas, A. C. Saulo, R. S. Schumacher, Y. G. Skabar, L. A. T. Machado, R. J. Trapp, A. Varble, J. Wilson, J. Wurman, E.J. Zipser, I. Arias, H. Bechis and M.A. Grover, 2021: A storm safari in Subtropical South America: Proyecto RELAMPAGO. *BAMS*. 10.1175/BAMS-D-20-0029.1.

109. Tijerina, D., Condon, L., FitzGerald, K., Dugger, A., Forrester, M., Sampson, K., **Gochis, D.**, Maxwell, R., 2021: Continental Hydrologic Intercomparison Project (CHIP), Phase 1: A Framework for Large-Scale Hydrologic Model Comparisons, 2021. *Water Resources Research*. 10.1029/2020WR028931.

110. Ryken, A., **D.J. Gochis**, R. Maxwell, 2021: Using eddy covariance method to constrain energy and water fluxes in complex terrain regions. Accepted in *Hyd. Processes*.

111. Elmer, N., N. Pai, A. Molthan, **D. Gochis**, X. Nair, 2021: Impact of Real-time Satellite-derived Green Vegetation Fraction on National Water Model Fluxes in Humid Alabama Watersheds. Accepted. *JAWRA.*

7.3 Other Refereed Papers:

Gochis, D.J., W.J. Shuttleworth, and Z-L. Liang, 2001: North American Monsoon rainfall and flows respond to deep convection. *GEWEX News,* 11(3):12-13

Gochis, D.J., J-C. Leal, C.J. Watts, W.J. Shuttleworth, and J. Garatuza-Payan, 2003: PACS-GAPP Fills the Gap in NAME Precipitation Data. *GEWEX News*, February 2003.

Gochis, D.J. and C. Davis, 2006: Meeting report of from the 2nd World Weather Research Program Symposium on Quantitative Precipitation Forecasting and Hydrology. *Eos Transactions*, 87(36), 2006.

Gochis, D.J. and E.H. Berbery, 2010: Contributions from the North American Monsoon Experiment towards improved understanding and prediction high impact weather and climate events. Book Chapter for the WMO International Monsoon Working Group. In press.

NRC-National Research Council, 2011. The National Weather Service Modernization and Associated Restructuring: A Retrospective Assessment Committee on the Assessment of the National Weather Service's Modernization Program. Washington, D.C.: National Academies Press. 150 pages.

NRC-National Research Council, 2012. The National Weather Service Modernization and Associated Restructuring: Strategies for Making the National Weather Service Second to None. Washington, D.C.: National Academies Press.

7.4 Journal Articles in Preparation or Submitted:

112. Valayamkunnath, P., **D. Gochis**, F. Chen, M. Barlage, K. Franz, 2021: Modeling the hydrologic influence of subsurface tile drainage using the National Water Model. Submitted, *Water Resources Research*.

113. Mascaro, G., A. Houssein, A. Dugger, **D.J Gochis**, 2021: Process-Based Calibration of WRF-Hydro in a Mountainous Basin in Southwestern US. Submitted to *JAWRA.*

114. Ruddell, B.L., M.P.Clark, JM. Driscoll**, D.J. Gochis**, H. Gupta, J. Harvey, D. Huntzinger, J.W. Kirchner, L. Larsen, H. Loescher, Y. Luo, R. Maxwell, E. Moges, W.J. Riley, Z. Xu, 2021: Calling for a National Model Benchmarking Facility. Submitted, Adv. in Water Resources.

115. Lahmers, T.M., Kumar, S., Rosen, D., Dugger, A., **Gochis, D.**, Santanello, J., Gangodagamage, C., and Dunlap, R., 2021: Assimilation of NASA's Airborne Snow Observatory snow measurements for improved hydrological modeling: A case study enabled by the coupled LIS/WRF-Hydro system. Submitted to Water Resources Research.

116. Lahmers, T.M., Hazenberg, P., Gupta, H., Castro, C., **Gochis, D.**, Dugger, A., Yates, D., Read, L., Karsten, L., and Wang, Y, 2021: Evaluation of NOAA National Water Model Parameter Calibration in Semi-Arid Environments Prone to Channel Infiltration. Minor revisions. Journal of Hydrometeorology.

117. Read, L., Yates, D., McCreight, J., RafieeiNasab, A., **Gochis, D.**, Sampson, K. 2021: Development and Evaluation of the Channel Routing Model and Parameters within the National Water Model. Submitted to JAWRA.

118. **Gochis, D.J.**, M. Barlage, R. Cabell, M. Casali, A. Dugger, K. FitzGerald, M. McAllister, J. McCreight, A. RafieeiNasab, L. Read, K. Sampson, D. Yates, Y. Zhang, 2021: The WRF-Hydro Modeling System. In preparation for *Geophysical Model Development.*

119. Karsten, L., S. Tessendorf, L. Xue, R. Rasmussen, **D.J. Gochis**, 2021: A new method to assess the impacts of wintertime cloud seeding on streamflow using the WRF-Hydro modeling system. In preparation for *J. Applied Meteorol. and Climatol.*

120. Cosgrove et al., 2021: Overview and Operational Implementation of the NOAA National Water Model. In preparation for *BAMS*.

121. Kim, J., L.E. Johnson, R. Cifelli, A. Wood, **D.J. Gochis**, 2021: A Preliminary Assessment of the NOAA National Water Model: The Operational Short-Range Streamflow Forecast in the San Francisco Bay Area. In preparation.

122. Gochis, D.J., Y. Zhang, J. Deems, T. Painter, J. Grimm, R. Saddique, 2021: Real-time assimilation of airborne lidar derived snowpack estimates into a physics-based, hyper-resolution seasonal water supply forecasting system. In preparation.

123. Zhang, Y. D. Gochis, D. Jackson, M. Hughes, H. Reeves, F. Viterbo, R. Cabell, 2021: Impact of solid-liquid precipitation phase partitioning on NOAA National Water Model hydrologic simulation skill. In preparation.

124. J. Grimm, Y. Zhang, D. Gochis, 2021: Impact of gap-filling radar information on seastonal water supply forecast skill for the headwaters of the Rio Grande. In preparation.

125. Yimam, Y.T., H.L. Neely, C.L.S. Morgan, M. Barlage, A. Kishne, D. Gochis, B. Dornblaser, 2021: Evaluation of Noah-MP Performance with Available Soil Information for Vertically Heterogeneous Soils. In preparation for *Geoderma*.

7.5 Internally Refereed Publications:

Gochis, D.J. and F. Chen, 2003: Hydrological enhancements to the Community Noah land surface model: Technical Description. NCAR Science and Technical Note, TN-454+STR, Sept., 2003.

7.6 Non-Refereed Publications:

Gochis, D.J., M. Barlage, R. Cabell, M. Casali, A. Dugger, K. FitzGerald, M. McAllister, J. McCreight, A. RafieeiNasab, L. Read, K. Sampson, D. Yates, Y. Zhang (2020). The WRF-Hydro® modeling system technical description, (Version 5.1.1). NCAR Technical Note. 107 pages. Available online at: https://ral.ucar.edu/sites/default/files/public/WRFHydroV511TechnicalDescription.pdf. Source Code DOI:10.5281/zenodo.3625238

Gochis, D.J., J. Busto, K. Howard, J. Deems, N. Coombs, I. Maycumber, K. Bormann, A. Dugger, L. Karsten, N. Langley, J. Mickey, T. Painter, M. Richardson, S. Mckenzie Skiles, L. Tang, 2016: Upper Rio Grande Basin Snowfall Measurement and Streamflow (RIO-SNO-FLOW) Forecasting Improvement Project. Final project report to the Colorado Water Conservation Board.

Gochis, D.J., M. Barlage, A. Dugger, K. FitzGerald, L. Karsten, M. McAllister, J. McCreight, J. Mills, A. RafieeiNasab, L. Read, K. Sampson, D. Yates, W. Yu, (2018). The WRF-Hydro modeling system technical description, (Version 5.0). NCAR Technical Note. 107 pages. Available online at https://ral.ucar.edu/sites/default/files/public/WRF-HydroV5TechnicalDesc.... Source Code DOI:10.5065/D6J38RBJ

Gochis, D.J., W. Yu, D.N. Yates, 2015: The WRF-Hydro model technical description and user's guide, version 3.0. NCAR Technical Document. 120 pages. Available online at: http://www.ral.ucar.edu/projects/wrf_hydro/.

Gochis, D.J., 2004: NAME: A Bi-national Climate Research Program. Southwest Hydrology, Jan.-Feb. 2004, pp 6-7.

Gochis, D.J., 2007: The North America Monsoon Experiment (NAME): Warm Season Climate Research in the Mountainous Regions of Southwestern North America. CIRMOUNT Newsletter, 1(2), 19-25.

Gochis, D.J., 2008: A view from the golden years of the N. American Monsoon Experiment. CLIVAR Exchanges, 13(2) April, 2008.

Gochis, D.J. and R.W. Higgins, 2007: The path to improving predictions of the North American Monsoon. Invited contribution, U.S. CLIVAR-Variations, Newsletter of the U.S. Climate Variability and Predictability program. 5(1), 2007.

Gochis, D.J., 2008: Early review of the 2008 North American Monsoon. Border Climate Summary, Oct. 8, 2008. pp 1-6.

Gochis, D.J., 2008: The North American Monsoon Experiment: A research program for improving predictions of monsoon rainfall. Border Climate Summary, July 7, 2008. pp 3-5.

Yucel, I., R.J. Kuligowski and **D.J. Gochis**, 2010: Evaluating the Hydro-Estimator Satellite Rainfall Algorithm over a Mountainous Region. in New Approaches to Hydrological Prediction in Data Sparse Regions, IAHS Publication 333, 260-266.

Gochis, D.J., 2010: The North American Monsoon Experiment: A look back at the 2009 summer monsoon. Border Climate Summary, February 18, 2010. pp 3-5.

Huffman, J.A., Prenni, A. J., DeMott, P. J., Poehlker, C., Mason, R. H., Si, M., Schumacher, C.J., Li, J. Froehlich-Nowoisky, J., Tobo, Y., Despres, V., Schmer, B., **Gochis, D. J.**, Mueller-Germann, I., Ruzene, C., Andreae, M. O., Kreidenweis, S. M., Bertram, A. K., Poeschl, U., 2014: From the lab to the sky: Linking biological aerosol particles, atmospheric ice nuclei, and precipitation. ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY, 248th National Meeting of the American-Chemical-Society (ACS), AUG 10-14, 2014. San Francisco, CA.

Gochis, D.J., 2015: Emerging Challenges in Advancing Predictions of the North American Monsoon System. CLIVAR Exchanges, Special Issue on Monsoons. No. 66,(19), Jan. 2015.

NOAA Climate Prediction Program for the Americas (CPPA) Science Plan, 2008, contributing author

VAMOS Extremes White Paper, 2008, contributing author

VAMOS Anthropogenic Climate Change in the Americas White Paper, 2008, contributing author

Report on Climate Change to Colorado Governor Bill Ritter (2008-2009), contributor and reviewer
NAME Forecast Forum Work Plan, 2007, lead author

CUAHSI Science Plan, 2006, contributing author. Available online at:http://www.cuahsi.org/docs/dois/CUAHSI-SciencePlan-Nov2007.pdf

Gochis, D.J. and co-authors, 2005: Proposed research strategy for the NAME Hydrometeorological Working Group (NHWG). Solicited White Paper document submitted to the NAME Science Working Group and NOAA-OGP Program Directors.

CUAHSI Vision statement on advancing land surface modeling, 2004, lead author. Available online at: http://www.cuahsi.org/cyberseminars/**Gochis**-20041201-paper.pdf

1. Narrative

1.1 General

Dr. Gochis joined the National Center for Atmospheric Research (NCAR) as an Advanced Studies Program (ASP) post-doc in August 2002. He received ASP fellowship offers from both MMM and RAL with the intent of improving the representation of hydrologic and hydrometeorological processes in high resolution prediction systems such as MM5 and WRF. Prior to joining NCAR, Dr. Gochis was a research assistant/associate at the University of Arizona, where he received his PhD in Hydrology and Water Resources, focusing on observation and modeling the processes leading to deep convection and runoff generation within the North American Monsoon system in southwestern North America (primarily in Mexico and Arizona). Dr. Gochis obtained undergraduate and graduate degrees in Atmospheric Sciences and Hydrologic Engineering from the University of Kansas (BS with Honors) and Oregon State University (MS), respectively. Prior to returning to school for his PhD, Dr. Gochis worked as a consulting engineer where he conducted water resources analyses, flood inundation studies and designed irrigation systems. Throughout his academic and professional career, Dr. Gochis has worked at the joint interfaces of observation and modeling studies and of hydrology and atmospheric sciences and has consistently sought to bring science forward from basic research to clear societal application and benefit.

Dr. Gochis's primary research interests include hydrometeorology, land-atmosphere interactions, terrestrial hydrologic processes, and advancing coupled hydrometeorological predictions for societal applications. His research has included a rich combination of field observing studies and predictive model development. Dr. Gochis's field research has focused on ground-validating and improving understanding of terrestrial hydrologic processes at landscape scales that are critical for high resolution modeling of land-atmosphere exchanges. He has participated in and/or led several major international field campaign efforts, most notably the NASA BOREAS-95 project, NSF CASES-97, the GEWEX/CLIVAR North American Monsoon Experiment (NAME-'04), State of Colorado gap-filling radar program (2009-present), NSF-RELAMPAGO (2018-2019), NSF-OTREC-2019, and most recently the DOE East River Watershed Science Focus Area/SAIL program (2017-present). Dr. Gochis was the original creator and lead developer of the community WRF-Hydro modeling system which is intended to provide a multitude of multi-scale, high-resolution process enhancements to traditional land surface models running in coupled or un-coupled hydrometeorological prediction systems. A crowning achievement of his modeling contribution has been leading the NCAR team in RAL that contributed to the selection, implementation and advancement of the WRF-Hydro modeling system as the official, operational NOAA National Water Model since 2015. The WRF-Hydro team was awarded the NCAR Science and Technical Achievement award in 2017. Combined, these expansive areas of sustained contribution have embraced strong multi-disciplinary collaborations, continued development and adoption of novel observation and model formulations and a strong understanding of the Research-to-Operations and Operations-to-Research (R2O-O2R) development lifecycle. As such, Dr. Gochis's research contributions span both the hydrologic and hydrometeorological research communities and has delivered several first-in-time prediction methodologies and foundational observation datasets. His work is recognized both nationally and internationally within the hydrology and meteorology communities and his expertise has been sought by leading government agencies, both domestically and internationally, with regards to building and advancing societally-critical hydrometeorological observation and prediction systems.

Dr. Gochis has maintained a strong supervision and mentoring presence throughout his entire career at NCAR. He has participated in numerous cycles of the SOARS program, has served as an academic committee member for over 15 graduate students and has hosted dozens of visitors from academic institutions as well as domestic and international government agencies. He currently serves as a direct primary supervisor or indirect project supervisor for over 20 different RAL staff through various research projects. The core WRF-Hydro development team that Dr. Gochis co-leads supports more than 20 different scientists, software engineers and education specialists. In recognition for his impact on the hydrologic sciences community, in 2018, Dr. Gochis was awarded the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI) Community Service Award on behalf of the whole WRF-Hydro development and support team for their efforts to support the academic community in application and improvement of the community WRF-Hydro system. Dr. Gochis is a well-recognized presenter and routinely gives over 20-30 oral presentations a year at society conferences, inter-agency advisory panel meetings, project sponsor meetings, academic department seminars and WRF-Hydro model training workshops. He has also provided official briefings to elected officials at the State of Colorado statehouse, committees of the U.S. Senate and various governmental engagement forums such as the Wester Governors' Association and the Western States Water Council.

1.2 Scientific Accomplishments

Dr. Gochis's work has provided significant contributions in the areas of hydrometeorology, terrestrial hydrologic process representation, hydrometeorological observing system enhancement and hydrologic prediction system development. His work is has been published in nearly every leading journal in the hydrologic and hydrometeorological sciences as well as in many cross-disciplinary journals. He is recognized in the community as a leader in multidisciplinary research and operational prediction system development working consistently at the interface of atmospheric sciences and hydrology. He has made numerous sustained contributions over the years to large, integrated field studies in hydrometeorology and hydroclimate and has contributed multiple datasets to major data repositories such as those operated by DOE, NASA and NCAR/EOL. He is known for his work in operationalizing complex physics-based hydrologic models as real-time hydrologic prediction tools and in innovatively fusing novel datasets with prediction models to enhance hydrologic predictions. He pioneered the development one of the first major, high-resolution fully-coupled terrestrial hydrologic-numerical weather prediction systems (fully coupled WRF/WRF-Hydro) which has shed light on the value and limits of land surface model complexity in numerical weather prediction. Lastly, he is routinely called upon to translate the meaning and value of advances in hydrologic prediction and hydroclimate applications to societal impacts through his participation on multiple high level panels and in various media fora.

Dr. Gochis's research accomplishments may be grouped into the following areas: (1) Measurement and Modeling of Hydrometeorological Processes in the Complex Terrain Regions of the North American Monsoon; (2) Improvement of terrestrial hydrologic processes in uncoupled and coupled, high resolution prediction systems; (3) Development, operationalization and advancement of the first continental scale, high-resolution hydrologic forecasting system for the U.S. National Weather Service; and (4) Advancing the utility of novel observations in seasonal water supply and flash flood prediction systems.

1. Measurement and Modeling of Hydrometeorological Processes in the Complex Terrain Regions of the North American Monsoon

   Complex terrain regions of the world present some of the most significant challenges in building understanding of relevant physical processes and also in limiting prediction skill in meteorological, climate and hydrologic models. The reasons for this are manifold but include poor understanding and model representation of multi-scale interactions within the land surface and in the overlying atmosphere. There are also pervasive and long-standing deficiencies in land surface hydrologic and lower atmospheric observations in most complex terrain regions. Consistently throughout his career, Dr. Gochis has worked at the forefront of addressing these issues by designing and operating observational networks to improve understanding of hydrometeorological processes in complex terrain and also in the development of one of the first fully-coupled multi-scale hydrometeorological models (WRF/WRF-Hydro) aimed at modeling these complex processes. Dr. Gochis led the design, operation and diagnostic analysis of surface precipitation observations during the 2004 North American Monsoon experiment providing critical ground validation observations of the extreme spatial and temporal gradients in monsoon precipitation in the core region of the monsoon in mountains of Northwest Mexico (Refs. 6, 7, 10, 12, 13, 14, 18, 19, 21 and 27). Diagnostic analysis from this surface observational network along with subsequent analyses from multiple remote sensing platforms (e.g. EOL/SPol, TRMM, CMORPH, PERSIANN) provided a rigorous conceptual model for the climatological structure and evolution of deep convective precipitation over the mountains of the Sierra Madre Occidental (Refs. 13, 15 and 19) one of the primary convective generation mechanisms of the N. American Monsoon. Dr. Gochis's work linked stationary features of the landscape physiography such as terrain elevation, orientation, distance from the warm waters of the Gulf of California to background characteristics of the diurnal cycle of convective rainfall in the region. He also linked variations in this rainfall regime to multiple modes of propagating transient variability that traverse the N. American Monsoon region. At larger scales, Dr. Gochis contributed original hydroclimatic analysis work to elucidate the patterns of seasonal precipitation and runoff in western Mexico to the terrain-linked precipitation structure of the monsoon as well as to larger scale teleconnections across the intra-Americas seas and the eastern Pacific (Refs. 2, 3, 4, 5, 12, 16, 85). Through multiple domestic and international collaborations, Dr. Gochis led and/or contributed to multiple studies seeking to quantify the role of land surface hydrology, principally soil moisture and vegetation-mediated surface energy partitioning, in modulating precipitation behavior within the N. American Monsoon region (Refs. 22, 26, 29, 30, 57, 80, 83, 102, 103).

   In addition to the foundational precipitation observation diagnostic studies, one of the most significant studies to emerge from this body of land-surface process oriented work was the modeling study of Gochis et al., 2010 (Ref. 30) which combined a paired set of eddy covariance flux towers in the complex terrain region of Sonora, Mexico, with a set of 1-d land surface model studies to quantify the impact of variable soil depth structures in complex terrain on modeled land surface energy flux partitioning skill. The results highlighted the critical role soil depth plays in regulating the timescale and magnitude of latent versus sensible heat flux partitioning such that very shallow soils saturate more quickly and release water to direct evaporation and root water extraction more readily per a given precipitation input amount than do thicker soil profiles which are slower to saturate and drydown. Only through adjust of model-discretized soil layers, and associated rooting profiles, could the model achieve the appropriate general energy flux dispersion compared to what was observed by the eddy covariance towers. The implication for this model process representation is similar to what has been found in understanding the complexities of rooting depth and hydraulic root function in many climate model land surface model representations) but from a different controlling mechanism, one of soil water storage, soil water retention and the timescales associated with soil water release.

Combined these studies have progressively contributed to a broader understanding of how warm season precipitation is initiated and is organized over complex terrain, what the various roles of land surface forcing as well as larger scale synoptic transients and global scale teleconnections have on the hydroclimate of the N. American Monsoon.

2. <u>Enhancement of Terrestrial Hydrologic Processes in Uncoupled and Coupled, High Resolution Prediction Systems</u>

With little doubt the most impactful and lasting contribution of Dr. Gochis has been as the original creator and lead developer of the community WRF-Hydro modeling system. WRF-Hydro emerged from the need to enhance and improve the terrestrial hydrologic process representations, namely overland flow and groundwater flow, in traditional, column-based land surface models, particularly when land surface models are used at scales for which classical 1-d assumptions break down, typically at model grid resolutions less than ~1km, when lateral hydrologic transfer processes form a significant component of the grid-scale water budget (See Gochis and Chen, 2003 NCAR Technical Note). The WRF-Hydro modeling system enabled not only lateral transfer process representation into the WRF model but also provided one of the first truly, multi-scale, fully-coupled modeling system where there was explicit, high-resolution accounting of lateral hydrologic exchanges on a refined grid and a subset of hydrologic states and fluxes are aggregated up to the native column land surface model grid scale for calculation of land-atmosphere fluxes. The applications of the WRF-Hydro formulation gained significant use in both the traditional hydrologic modeling community and in the coupled land-atmosphere community when representations for river flow, and lakes and reservoirs were also added. The impact of these hydrologic enhancements have been documented in a long succession of works to which Dr. Gochis has made numerous contributions to since the model's inception (Refs. 36, 61, 64, 72, 73, 83, 84, 89, 92, 97, 107). The community WRF-Hydro modeling system has also been adapted for coupled implementation with WRF on every continent except Antarctica and over 40 publications have documented its use and impact on simulated meteorology and regional climate (See the WRF-Hydro community publications web page for a current full list of published applications of WRF-Hydro). The primary consistent finding that emerges from a majority of the coupled model studies, is that the lateral transfer formulations in WRF-Hydro enable a much greater dynamic range and organizational capacity in modeled soil moisture and modeled land surface energy fluxes than when the formulations are not used as well as generally broader ranges of soil moisture residence time distributions. The terrain-driven organizational patterns in soil moisture and energy fluxes feedback to the atmosphere in non-linear ways but works to date have documented slight to moderate improvements in the simulation of precipitation as well as in resulting hydrologic forecasts when the WRF-Hydro enhancements are used as opposed to when they are not used. The concepts behind the inclusion of lateral exchanges into land surface models has also proliferated into increasingly high resolution global climate models (Refs. 67, 71, 77, and more recently into CTSM). There are several factors that impact the significance of the inclusion of these processes into coupled model predictions which continue to be investigated. These factors include; the magnitude of large-scale forcing in precipitation formation and persistence, the specifics of terrain form and land cover conditions on the land surface, the fidelity of land surface parameter datasets with respect to accuracy and resolution, the overall model resolution and the scale separation and grid-scale aggregation between the principle land surface model grid and the explicit terrain routing grid.

In addition to the advances in coupled hydrometeorological process-based research enabled by WRF-Hydro, the WRF-Hydro system has been integrated into several national uncoupled hydrologic and, more recently fully-coupled prediction systems. The flagship application of WRF-Hydro which Dr. Gochis has led for the past 6 years has been the implementation of WRF-Hydro as the U.S. National Water Model in collaboration with NOAA (discussed in the next section below). WRF-Hydro is currently also being integrated into the NOAA Unified Forecasting System (UFS) as an enhanced, high-resolution land surface model formulation in addition to the existing RUC land surface model and traditional, column-based NoahMP land surface formulation that both already exist within UFS. The intent of including WRF-Hydro in UFS is to enable the explicit representation of the aforementioned lateral transfer processes and surface inundation processes on the modulation of land surface energy exchanges with the atmosphere. Additionally, there is an added motivation from NOAA to be able to be able to have a full bedrock through atmosphere, high-resolution model formulation for UFS which provides unified, mass and energy conserving hydrometeorological forecasts. Dr. Gochis currently serves as the lead PI on this NOAA-funded UFS project in collaboration with UFS/Rapid Refresh Forecast System (RRFS) scientists at NOAA/GSL.

Lastly, it is noted that since the WRF-Hydro inception in 2003, Dr. Gochis has served as the principal lead scientist who trains WRF-Hydro users and developers on the model. Prior to 2014, Dr. Gochis, along with Dr. David Yates who developed the channel routing and reservoir formulation for WRF-Hydro, performed all WRF-Hydro model training and provided all WRF-Hydro model documentation and web resources. They conducted WRF-Hydro trainings both at NCAR and in numerous locations around the work. Since 2014, the WRF-Hydro team has grown significantly and new staff members have made substantial contributions to the WRF-Hydro community support enterprise.

3. <u>Development, operationalization and advancement of uncoupled prediction applications of WRF-hydro including the first continental scale, high-resolution hydrologic forecasting system for the U.S. National Weather Service</u>

In addition to fully-coupled model applications, the WRF-Hydro system has seen prolific, high impact use as a stand-alone, uncoupled hydrologic model system since 2008. While there are a large number of hydrologic models that have been developed for a multitude of purposes, the WRF-Hydro system possesses several scientific and software attributes that distinguished it early on from other systems. These attributes include a multi-scale and multi-physics modular framework, tight process coupling between vertical and horizontal hydrologic processes, a wide range of “high” resolution scale applications from a few km down to a few meters in grid resolution, substantial utilization of parallel computing capabilities for large domain, high resolution, long duration and ensemble application, couple-ability with high resolute numerical weather prediction and regional climate model instances of WRF. These attributes, which have been designed in from the origination of WRF-Hydro (Gochis and Chen, 2003), have resulted in a flexible and readily extensible modeling system amenable to a large variety of uncoupled applications such as national scale hydrologic, flood and flash-flood prediction (Refs. 61, 79, 94, 95, 99, 100, 101, 109), investigation of semi-arid hydrologic process representations (Ref. 96), representation of tiled agricultural systems in an operational forecasting context (Ref. 104), representation riverine sediment transport (Refs. 91), coupling with estuarine and regional ocean models (Ref. 86), linkage to an active tracer formulation to diagnose flowpaths, residence times and isotopic fractionation within terrestrial hydrologic waters (Ref. 93), linkage to an alpine glacier model to represent climate impacts on glacially-modulated water resources (Ref. 107), and provision of real-time hydrologic forecasts to assist research-based flood-chasing style observations (Ref. 106).

Of these applications the selection, implementation and advancement of the WRF-Hydro model as the U.S. National Water Model (NWM) has by far been the most audacious and impactful uncoupled model application of WRF-Hydro to date. In late 2014, a research version of WRF-Hydro was selected to be the first NWM providing an unprecedented accounting of the nation's hydrology providing seamless multi-scale resolution of the land surface (1km column land surface and 250m terrain routing) and channel flow routing for over 3 million river reaches and over 6,000 lakes and reservoirs. Upon selection WRF-Hydro was to be deployed in official NOAA supercomputer operations for analysis, short- (1-day), medium- (10-day), and long-range (30-day ensemble) applications. The model was delivered on time and under budget to NOAA and went operational in August of 2016. Since then the model has gone through 5 version upgrades and has exhibited over a doubling of model simulation skill according to multiple streamflow evaluation metrics. These results are documented in NWM version upgrade briefings NCEP management. Dr. Gochis led the NCAR team in this effort, overseeing all aspects of model physics development and evolution, model calibration and model meteorological forcing data preparation. He grew the WRF-Hydro team from 3 people at the start of the project (Drs. Gochis, Yates and Yu) to a team which now consists of over 25 scientists, software engineers and community outreach specialists. The NWM implementation of WRF-Hydro has provided operational forecast guidance to the NWS and general public now for over 6 years and has provided critical emergency preparedness information for major catastrophic events such as Hurricanes Harvey, Florence, Rita, Irma, large-scale river basin flooding in the Missouri and Mississippi Rivers in 2018, widespread droughts throughout the western and countless flash flood events.

It is noted here that development and implementation of an operational model engages a very rapid research-to-operations and operations-to-research development cycle which has precluded the journal publication of many of the advances of the NWM and WRF-Hydro. For many years of this project NCAR was not allocated resources to publish these advances from its NOAA sponsors who cited development timeframes and limited resources to support publication. Nevertheless the advances in model robustness and skill provide clear quantitative evidence of rigorous scientific-based development process.

Lastly, it is also noted that the United States Geological Survey's water missionary has recently selected WRF-Hydro as a candidate model to contribute to the development of its congressionally-mandated National Water Census which is an official inventory of the Nation's water resources. NCAR will work collaboratively with the USGS on this effort and Dr. Gochis has been selected to serve as the lead WRF-Hydro scientist in this major application. Combined with its current implementation as the NWS national forecasting model, WRF-Hydro has risen to become the leading hydrologic modeling system for the assessment and prediction of the nation's waters. No other single hydrologic model has ever achieved this point of prominent use nor has had such a national scale impact on the prediction and management of one of the nation's most critical natural resources. These accomplishments speak directly to NCAR's primary mission to create actionable Earth system science that directly serves critical societal needs.

4. Advancing the utility of novel observations into hydrologic prediction systems

Dr. Gochis has built a research career on working at the interface of observations and modeling and, in particular, developing new ways to both integrate novel observations into models, as well as by utilizing models to isolate new observational priorities. Work and contributions at this interface thread throughout Dr. Gochis's research portfolio beginning first with using regional climate simulations of the N. American Monsoon to define observational needs as part of the NAME research program, and then continue through the present through sustained participation in the State of Colorado gap-filling radar and enhanced snowpack monitoring program (See Gochis et al., 2016 report to the Colorado Water Conservation Board), developing the first real-time assimilation of airborne lidar estimates of snowpack into a physics-based, seasonal water supply forecasting system (Gochis et al., 2021 AGU Conference). Dr. Gochis has also collaborated closely with other researchers in designing and deploying observational networks to help validate predictive models and provide key model optimization datasets in several large-scale field research experiments such as the North American Monsoon Experiment (provision and/or analysis of ground-based rainfall, temperature, humidity soil moisture, and eddy covariance measurements, see Refs. 6, 7, 13, 15, 19, 22, 26, 27, 29, 30, 57, 80, 83, 103), 2018 NSF-RELAMPAGO field campaign (near surface precipitation, temperature, humidity, soil moisture, soil temperature, incoming solar radiation and in situ acoustic Doppler profiler streamflow measurement, see Ref. 106, 108), 2019 NSF-OTREC field campaign (See Ref. Lintner et al., 2021, 34th Conf. on Hurricanes and Tropical Met.), and ongoing DOE-sponsored, eddy-covariance research in the East River study area (See Ref. 112). Each of these projects contained an iterative interaction between modeling studies that would be better informed by critical observations and then assessing the impact of those observations on model predictive skill.

Some of Dr. Gochis's most impactful work in this area is emerging from an ongoing series of projects which began in 2009, funded by the Colorado Water Conservation Board in partnership with multiple regional water management authorities and in collaboration with the National Severe Storms Laboratory and the Airborne Snow Observatory, Inc. This work has undertaken a series of observational enhancements around the State of Colorado to quantify the impact of gap-filling radars on hydrologic prediction skill. Limited duration programs have taken place in Gunnison (2009), Durango (2011) and the San Luis Valley (2016). Dr. Gochis provided ground-based, quality controlled precipitation validation datasets to examine the skill of the radars in these challenging mountain environments. Dr. Gochis also led WRF-Hydro based modeling studies assessing the impact of the gap-filling radar data on subsequent seasonal water supply predictions. The results of these project, summarized in a report in 2016 to the State of Colorado documenting the clear benefit of small-scale radar deployment to improve measurements of rainfall and snowfall in the headwaters of the Rio Grande river, a system currently tightly administered under a federally-decreed interstate compact agreement between multiple entities. Since 2016, Dr. Gochis as extended this real-time seasonal water supply prediction work to cover the entire state of Colorado providing forecasts for a multitude of water management entities throughout the state such as the Col. Division of Water Resources, the Conejos Water Conservation District, the Dolores Water Conservation District, the Upper Gunnison Water Conservation District, the Bureau of Reclamation and National Weather Service River Forecast Centers. Most recently, during the winter for 2020-2021 Dr. Gochis led an NCAR/WRF-Hydro modeling team in deploying the first-in-time, real-time assimilation of high resolution (50m) airborne lidar-derived snowpack observations into this seasonal water supply forecasting system, building on the published results from Lahmers et al. WRR, submitted (Ref. 113). The demonstrated benefit of this work has already accelerated State of Colorado and State of California level investments in the acquisition and utilization of additional airborne lidar snowpack missions and their ingest into real-time instances of WRF-Hydro for ensemble seasonal water supply prediction. Dr. Gochis is presenting this study at the 2021 meeting of the AGU.

Dr. Gochis is also currently engaged in a multi-year effort to improve both observations and modeling in the Upper East River branch of the Upper Gunnison River system in Colorado under support the Department of Energy Watershed Science Focus Area program. Building on Dr. Gochis's seasonal water supply forecasting work discussed above, Dr. Gochis has worked with collaborators within DoE and Princeton University (Dr. Reed Maxwell) to deploy a critical small scale eddy covariance system to quantify the impact of groundwater mediated influences on high elevation riparian evapotranspiration and compare measured energy and radiation fluxes against those estimated from a pair of hydrologic models (WRF-Hydro and PARFLOW). The results, now accepted for publication in Hydrologic Processes (See Ryken et al., 2021, Ref. 112, Dr. Gochis led the advising of Dr. Ryken during her dissertation work in the use and derivation of eddy covariance based flux measurements), demonstrated that riparian evapotranspiration is critically supported by subsurface lateral transport mechanisms and the measurements also provide an upper-envelope of ET-flux potential from high elevation regions owing to the abundant moisture supply in the perpetually wet riparian areas. As such, these new measurements provide an important benchmark for models operating in this critical water resource generation region. As an outcome of this research DOE has engaged Dr. Gochis in the deployment of 2 additional long-term eddy-covariance/energy balance measurement systems in the Upper Gunnison river basin in order to sample additional forest and land cover types.

Given this body of work in fusing novel observations into hydrologic prediction and water resources assessment models, the USGS has recently engaged Dr. Gochis to serve as the NCAR point collaborator on their Next Generation Water Observing System (NGWOS) study in the Upper Colorado River and Upper Gunnison River systems. The NGWOS program is a flagship research effort by the USGS to improve their national water observing infrastructure and ensuring the utility of these observations to simultaneously provide critical environmental monitoring capabilities and enhance water quantity and water quality prediction capabilities. This role is supported by an ongoing strategic partnership between NCAR/RAL and the USGS water missionary.

Combined, these past, current and emerging projects that operate at the interface novel observations and physics-based water prediction models directly answer NCAR strategic priority to deliver actionable science and Earth system predictive capabilities for improved real-time, operational management of critical natural resources.

1.3 Community Service

As noted above, Dr. Gochis has contributed to several major national and international field research experiments and programs including the NASA BOREAS-95 project, NSF CASES-97, the CLIVAR/GEWEX North American Monsoon Experiment (NAME-‘04), State of Colorado gap-filling radar program (2009-present), NSF-RELAMPAGO (2018-2019), NSF-OTREC-‘19, and most recently the DOE East River Watershed Science Focus Area/SAIL program (2017-present). He served as the lead for the North American Monsoon Experiment working group from 2006-2010 and the WCRP/CLIVAR/Variability of Monsoon Systems (VAMOS) working group from 2008-2011. He is currently heavily engaged in field research activities in Colorado oriented towards improving water cycle characterization and prediction capabilities in high-mountain watersheds and regularly coordinates his field research with entities from NOAA, DOE, the U.S. Bureau of Reclamation and the State of Colorado.

Dr. Gochis’s expertise has been sought by number of high-level panels and committees. Most notably Dr. Gochis served as a National Research Council panel member to a National Academies of Science panel which provide a top-to-bottom, two-phase, program review of the modernization of the U.S. National Weather Service. This strategic review and proposal resulted in several major new initiatives within the U.S. NWS including the establishment of a unified National Water Model and in the accelerated coordination of the NOAA Unified Forecasting System (UFS). Second, Dr. Gochis served two full terms each as a member of the Council of the American Meteorological Society. In addition to serving on the AMS Council he also served two full-terms on the AMS Hydrology Science and Technical Committee. Dr. Gochis currently serves on the review committee for AMS awards in hydrologic sciences. In addition to these appointments, Dr. Gochis has served on numerous ad-hoc committees and advisory panels for the U.S. Global Change Research Program (USGCRP), the NOAA National Water Center, internal NCAR programs such as the Biocomplexity, TIIMES, BEACHON and STEP research programs.

Dr. Gochis has made numerous sustained contributions to the academic literature community throughout his career. He has co-organized multiple special collections/special editions for various journals. He has served as a peer-reviewer for dozens of journal manuscripts and agency proposals. He currently resides as an Associate Editor for the Journal of Hydrology-Regional Studies (Impact Factor 5.02) and in the past has served as an Associate Editor for the J. of Hydrology (2011-2014), a flagship journal in the field of hydrology and water resources.

LIST OF ACRONYMS

ASP – NCAR Advanced Studies Program

NAME - North American Monsoon Experiment

BAMS – Bulletin of the American Meteorological Society

RELAMPAGO – Remote Sensing of Electrification, Lightning and Mesoscale/Microscale Processes with Adaptive Ground Observations

OTREC – Organization of Tropical East Pacific Convection

CUAHSI – Consortium of Universities for the Advancement of Hydrologic Sciences, Inc.

BOREAS – Boreal Ecosystem/Atmosphere Study

CASES – Cooperative Atmosphere Surface Exchange Study

DOE – Department of Energy

SAIL – Surface Atmosphere Integrated Field Laboratory

SOARS – Significant Opportunities in Atmospheric Research and Science

EOL/SPol – NCAR Earth Observing Laboratory S-band Polarimetric radar

TRMM – Tropical Rainfall Measurement Mission

CMORPH – NOAA Climate Prediction Center MORPHing technique

PERSIANN – Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks

CTSM – Community Terrestrial Systems Model

UFS – Unified Forecast System

RUC – Rapid Update Cycle

RRFS – Rapid Refresh Forecast System

NOAA/GSL – NOAA Global System Laboratory

NWM – National Water Model

NCEP – National Centers for Environmental Prediction

USGS – U.S. Geological Survey

WRR – Water Resources Research

AGU – American Geophysical Union

ParFlow – Parallel Flow hydrologic model

NGWOS – Next-Generation Water Observing System

VAMOS – CLIVAR Panel on the Variability of American Monsoon Systems

WCRP – World Climate Research Program

CLIVAR – Climate and Ocean Variability Predictability and Change panel

GEWEX – Global Energy and Water Cycle Experiment

STEP – Short Term Explicit Prediction