**Basic Information**

Project No. and Title: W3188: Soil, Water, and Environmental Physics Across Scales

Period Covered: 10/01/2017 to 09/30/2018

Date of Report: 06/03/2019

Annual Meeting Dates: 01/10/2019 to 01/11/2019

**Participants**

Majdi Abou Najm, UC Davis; Hoori Ajami, UC Riverside; Emmanuel Arthur, Aarhus University; Ebrahim Babaeian, University of Arizona; Todd Caldwell, University of Texas at Austin; Karletta Chief, University of Arizona; Maria Dragila, Oregon State University; Markus Flury, Washington State University; Shmulik Friedman, Institute of Soil, Water and Environmental Sciences; Alex Furman, Israel Institute of Technology; Horst H. Gerke, Leibniz Centre for Agricultural Landscape Research; Teamrat Ghezzehei, UC Merced; Amir Haghverdi, UC Riverside; Shoichiro Hamamoto, The University of Tokyo; Thomas Harter, UC Davis; Robert Heinse, University of Idaho; Robert Horton, Iowa State University; Jingyi Huang, University of Wisconsin Madison; Yan Jin, University of Delware; Scott Jones, Utah State University; Tamir Kamai, The Volcani Center; Thijs Kelleners, University of Wyoming; Naftali Lazarovitch, Ben-Gurion University of the Negev; Yili Lu, China Agricultural University; David Mulla, University of Minnesota; Attila Nemes, Norwegian Institute of Bioeconomy Research; John Nieber, University of Minnesota; Carlos Ochoa, Oregon State University; Tyson Ochsner, Oklahoma Statee University; Hanna Ouaknin, UC Davis; David Robinson, Centre for Ecology & Hydrology; Morteza Sadeghi, Utah State University; Elia Scudiero, UC Riverside; Manoj Shukla, New Mexico State University; Jiri Simunek, UC Riverside; Ryan Stewart, Virginia Tech; Christine Stockert, UC Riverside; Paul Stoy, Montana State University; Markus Tuller, University of Arizona; Ole Wendroth , University of Kentucky; Laosheng Wu, UC Riverside; Michael Young, University of Texas at Austin; Wei Zhang, Michigan State University; Jie Zhuang, The University of Tennessee; Jan Hopman, UC Davis.

**Brief Summary of Minutes of Annual Meeting**

2018 Annual Meeting of the W-3188 Multi-State Research Project:

Soil, Water, and Environmental Physics across Scales

January 10-11, 2018, University of California Riverside, Riverside, CA

Hoori Ajami (Chair) and Wei Zhang (Secretary)

January 10, 2019. Chair brought the house to order on 9:00 AM.

Steve Loring (Administrative Advisor, New Mexico State University) joined the meeting through video conferencing. He provided USDA update, and discussed preparation and submission of annual report as well as project renewal proposal.

John Nieber (University of Minnesota) led proposal discussion.

Jiangyi Huang (University of Wisconsin) discussed high-resolution mapping of soil moisture in cropland using remote sensing and soil moisture probes and the role of soil moisture at various scale on digital agriculture.

One-hour poster session was held.

Thijs Kelleners (University of Wyoming) presented research on coupled water, heat and solute transport in a rangeland soil, above and below-canopy turbulent fluxes in a mountain forest, and geological impact on streamflow generation in the Rocky mountains. It was found that solute transport in semi-arid rangeland soil is limited, except perhaps during spring snowmelt.

Business meeting on 12:00-13:00 PM. Next annual meeting will be held on January 2-3, 2020 at Las Vegas. Ryan Stewart (Virginia Tech) was elected as Secretary.

Michael Young and Todd Caldwell (The University of Texas at Austin) reported work on regional scale landscape impacts in Texas from energy development, assessment of Arctic tundra permafrost, structure from motion photogrammetry of desert ecosystems, integrated assessment modeling of natural/human environments, calibration and validation activities for NASA SMAP satellite, and sensor evaluation.

Robert Horton (Iowa State University) presented sensor research for measurement of bulk density, soil water content, thermal properties, and hydraulic properties. Particular attention was made on in situ correction of heat pulse sensor spacing.

Ryan Stewart (Virginia Tech) discussed dynamic controls on soil preferential flows, specifically the role of soil structure on transport of neonicotinoid pesticide and the simulation of preferential flow, infiltration, and overland flow in shrink-swell soils.

Thomas Harter’s group (University of California Davis) reported their work on the irrigation demand calculator (IDC) validation. IDC is sensitive to soil type, soil parameterization choice, and climate scenario. Irrigation and nitrogen management on almond production was discussed.

Karletta Chief (University of Arizona) discussed the extension programs on water management and policy, mining and environmental impacts, and tribal watershed hydrology. NSF NRT INDIGE-FEWS: Indigenous food, energy & water systems, and arsenic and lead in sediment and agricultural soil along the San Juan River on the Navajo Nation one year after the Cold King Mine Spill were discussed.

Hoori Ajami’s group (University of California Riverside) reported the progress on development of a semi-distributed hydrologic modeling framework for catchment scale simulations, and showed that the Soil Moisture and Runoff Simulation Toolkit (SMART) is computationally efficient. They also used multiple approaches for disaggregating soil moisture to finer spatial resolutions, and quantified uncertainty of semi-distributed hydrologic model simulations. Groundwater recharge through the critical zone to the groundwater was also discussed.

Scott Jones’s group (Utah State University) reported work on soil sensing depth disparity, sensor development, the need for soil moisture sensor standards, soil parametrization in land surface models, and soil moisture monitoring and forecast network for improved water resource management. An analytical approach to calculate surface water flux from near-surface soil moisture data was presented.

Markus Tuller and Ebrahim Babaeian’s group (The University of Arizona) discussed project on hydraulic and aeration properties of soilless greenhouse substrate mixtures, and unmanned aircraft system (UAS) for high resolution mapping of soil moisture for precision agriculture applications.

Ole Wendroth (University of Kentucky) reported their work on exploring spatial variability of soil properties for water management, including co-regionalizing soil clay content, mapping zone delineation, pedo-transfer functions at the field scale, and scale decomposition of soil hydraulic conductivity.

Meeting closed for the day at 5:30 PM.

January 11 2019. Chair brought the house to order at 9:00 AM.

Wei Zhang (Michigan State University) discussed research on emerging contaminants in soil, water and plant systems, including internalization mechanisms of silver nanoparticles by plants, and antibiotic resistance genes and microbiome in soils exposed to antibiotics load.

Markus Flury and Joan Wu (Washington State University) reported work on stormwater and land use management, colloid and surface properties of biochar, interfacial dynamics at aqueous-NAPL interfaces, habitability of Martian environments by Atcadama Desert Experiment, and microplastics and biodegradable mulch in soil environment.

Yan Jin (University of Delaware) discussed research on quantification of colloids and colloidal carbon in environmental systems, coupling of colloid/organic carbon behaviors and redox oscillations, preferential flow paths as biological hotspots, biophysical processes in the rhizosphere, and colloid/bacteria attachment/detachment on/from rough surfaces.

Manoj Shukla’s group (New Mexico State University) reported their work on data logger machine learning algorithms, ground water salinity, and brackish water for sustainable use.

Maria Dragila and Carlos Ochoa (Oregon State University) discussed work on sandy soil hydrology, soil solarization for pathogen and weed disinfection, soil aeration, and land use-environment relationships in rangeland and agriculture systems.

Jirka Simunek (University of California Riverside) reported on research and activities on HYDRUS including 6th HYDRUS Conference in Japan and 5 short courses, hydrological applications using HYDRUS (e.g., freshwater, freshwater recharge and salt/fresh water interfaces, and HYDRUS Package for MODFLOW), fate and transport of various substances (carbon nanotubes, viruses, and explosives), agricultural (irrigation) applications, and new HYDRUS development.

Laosheng Wu (University of California Riverside) discussed leaching requirements in irrigated crop lands, how to determine leaching fraction for deficit, drip, micro-sprinkler and alternative row irrigation methods. A web tool for soil salinity and leaching management was also presented.

Tyson Ochsner (Oklahoma State University) reported research on groundwater recharge, large-scale soil moisture monitoring, and new applications for soil moisture information. New open educational resource was also presented.

Naftali Lazarovitch (Ben-Gurion University of the Negev) discussed water and solute balances for irrigation using lysimeters, and found that the lysimeter lower boundary condition affects the solute distribution in the soil, suction cup can be used for soil solution chemistry measurement and a need for transient and spatial sampling of soil and plants.

Tamir Kamai (Institute of Soil, Water, and Environmental Sciences) reported novel methods of using pressure waves in porous media for increasing flow and transport by creating significant local pressure gradients and abrupt pressure changes in soil water.

Teamrat Ghezzehei (University of California Merced) discussed the role of soil water retention characteristics on aerobic microbial respiration, and introduced a model that can predict moisture-sensitivity function without the need for measured respiration rates over wide range of moisture status.

Elia Scudiero (University of California) presented work on precision agriculture research including dynamic management zones to improve irrigation scheduling and integrating soil and plant spatial information for time-specific precision agriculture.

Meeting closed at 5:00 pm

**Accomplishments**

**Short-term Outcomes**

University of Arizona (Markus Tuller and Ebrahim Babaeian): Modified the ParSWMS parallelized code for solving 3-D water and solute transport, resolved computational issues and adapted the code for “Ocelote”, the University of Arizona’s high-performance computing cluster, and the modified code will be made available pending additional testing; Developed a framework for delineation of dust emission source zones based on satellite remote sensing observations; Developed approach to quantify soil vapor sorption hysteresis in collaboration with Aarhus University (Emmanuel Arthur); Conducted extensive field experiments with a one-of-a-kind robotic phenotyping scanner to develop physical relationships between SWIR reflectance and actual evapotranspiration in collaboration with Utah State University (Morteza Sadeghi and Scott Jones); Developed a framework to generate high-resolution plant available moisture maps from unmanned aircraft system (UAS) observations and ground soil moisture measurements to aid precision irrigation management in collaboration with Utah State University (Morteza Sadeghi and Scott Jones); Collaborated with Utah State University (Morteza Sadeghi and Scott Jones) to develop a new analytical model for estimation of land surface net water flux from near-surface soil moisture observations.

University of California-Riverside (Hoori Ajami): Extended the functionality of the semi-distributed model (SMART) model to the catchment scale; Developed a new approach for disaggregating sub-basin scale soil moisture to fine resolution; Performing multi-objective assessment of SMART simulations across a range of catchments in Australia using discharge and remotely sensed evapotranspiration and soil moisture products, in collaboration with Ashish Sharma University of New South Wales; Developed new approaches for quantifying uncertainty of conceptual ecohydrologic models using remotely sensed vegetation products, in collaboration with Lucy Marshall University of New South Wales.

University of California-Riverside (Jirka Simunek): Continued to expand the capabilities of the HYDRUS modeling environment by developing specialized modules for more complex applications that cannot be solved using its standard versions. A range of applications published in 2018 included: hydrological applications, the use of HYDRUS models to evaluate various irrigation and fertigation problems in agricultural applications, and fate and transport of various substances (carbon nanotubes, viruses, explosives).

University of California-Riverside (Laoshen Wu): Developed numerical and data analysis methods for predicting gas, water and solute transport in porous media and in groundwater; Evaluated management practices to maximize salinity leaching and minimize nitrate leaching in irrigated croplands.

University of Delaware (Yan Jin): Continued progress on quantifying the effects of rhizobacteria on water physical and hydrological properties using novel experimental techniques and new modeling approaches; Demonstrated that small colloids (< 0.45 µm), which are conventionally considered as part of the dissolved fraction, are quantitatively significant in water samples from multiple field sites as well as in laboratory studies; Demonstrated that soil organic carbon has size-dependent properties and biological activity; Designed and used a two-dimensional setup to study preferential flow pathways as biological hotspots; Measured flow and colloid/bacteria deposition behaviors on surfaces of varied roughness via sessile drop evaporation.

Iowa State University (Robert Horton) and North Carolina State University (Joshua Heitman): Developed an empirical model to determine soil thermal diffusivity from texture, bulk density and degree of water saturation; Developed a heat pulse probe method to estimate water content and bulk density simultaneously; Determined in-situ unsaturated soil hydraulic conductivity at a fine depth scale with heat pulse and water potential sensors; Demonstrated that an in situ probe‐spacing‐correcting thermo‐TDR sensor can measure soil water content accurately; Demonstrated that accounting for soil porosity improves a thermal inertia model for estimating surface soil water content.

New Mexico State University (Manoj Shukla): Demonstrated that irrigation with brackish groundwater and desalination concentrate increases number of flowers but continued irrigation decreases chile pepper yields; Demonstrated that desalinated brackish groundwater and RO concentrate can be used to grow halophytes; Demonstrated that RO irrigation will increase soil salinity, therefore, RO irrigation should only be applied until vegetation establishment and in non-agricultural areas; Water and nitrogen management can be improved using numerical models; Shared results with stakeholders.

Oklahoma State University (Tyson Ochsner). Key outcomes of this project during this reporting period were advances in scientific knowledge on estimating drainage rates and nutrient leaching from the root zone under crops using two methods: 1) soil water balance calculations and suction cup samplers and 2) automated equilibrium tension lysimeters. This new knowledge was generated by the project team and shared with audiences of researchers and stakeholders through peer-reviewed journal publications.

Oregon State University (Maria Dragila): For sandy soil water cycle study, completed field experiments to assess irrigation efficiency, initiated data analysis, graduated 2 MS students, and discussed with potential co-PIs for a project on deep drainage nitrate transport from sandy soil agricultural fields; for vadose zone aeration, completed two manuscripts associated with soil and vadose zone aeration; completed field work and initiated data analysis for soil solarization study.

Oregon State University (Carlos Ochoa): Installed three additional stations to monitor soil moisture, temperature, and conductivity fluctuations in under-canopy and inter-canopy locations in juniper woodlands of central Oregon; Installed one station to monitor soil moisture, temperature, and conductivity fluctuations in a sage steppe rangeland location in eastern Oregon; Installed instrumentation to monitor soil moisture, temperature, and conductivity fluctuations in a riparian area, a meadow pasture, a non-irrigated pasture, and an irrigated pasture in western, Oregon; Performed data collection and analyses of soil physical properties from the three sites mentioned above.

Nevada, Desert Research Institute (Markus Berli): Developed a model to describe the relationship between soil hydrophobicity and infiltration; Developed a model to describe water infiltration, redistribution and evaporation for arid soil; Developed a model to simulate post-fire stream and debris flow.

North Dakota State University (Aaron Daigh and Francis Casey): Evaluated the temporal response of soil microbial communities to natural cycles of water and heat transfer in agricultural fields of varying soil disturbance levels; Evaluated a thermal-desorption method, used for remediating oil-contaminated soils, effects on soil physical properties and partitioning of the surface energy balance; Evaluated hydrophobic capillary barriers to limit resalinization of remediated brine-spill soil; Developed new in-situ methods to harvest brine spill salts from the soil surface using engineered wicking materials. Limitations of the method were defined and long-term effects to crop health and soil microbial communities quantified; Evaluated the fate of halogenated 17β-estradiol and estrone in the environment.

Washington State University (Markus Flury and Joan Wu): Demonstrated that in the driest places on earth there lives a metabolically active, microbial community; Showed the biodegradable plastic mulches have no negative impacts on soil quality; Showed that earthworms will pull plastic mulch into their burrows, thereby distributing plastic in the soil profile; Tested methods to extract nano- and microplastics from soils, and showed that currently used methods are ineffective in quantitatively extracting nano- and microplastics from soils; Through a simulation study, we evaluated fuel reduction treatment effects in a national forest, and showed that fuel reduction treatments, such as thinning and prescribed burns to treated hillslopes, may lead to an increase in water yield and significant alterations in hydrological processes.

University of Texas at Austin (Todd Caldwell and Michael Young): Created new conceptual models for evolution of ice-wedge polygons in thermokarst environments in the Alaskan tundra, near Prudhoe Bay; Develop numerical models to simulate temperature changes in ice-wedge polygons through a year of simulation period. The results closely matched field data collected at the site, indicating that our conceptual understanding of thermal build up is reasonable representation of natural site conditions; The CS655 soil water content sensor was tested at a soil observation network in Texas; data were used for the NASA SMAP satellite mission. Calibration of the sensor reduced the error of calibration to below RMSE of 0.02 m3 m-3; Creation of soil moisture validation data sets at multiple scales (1, 3, 9 and 36 km) for integration in real time into algorithm development and retrieval validation with NASA, the European Space Agency, The Japan Aerospace Exploration Agency. The development of upscaling and downscaling routines using both simple (spatial averaging) and advanced machine learn techniques; Different observation networks and watersheds are being used in US to understand landscape and biome scale processes. A broad survey of researchers and end users indicate several challenges in ensuring that data being collected at these sites are used in Earth system models and that the models are incorporating the multiple lines of data being collected; Significant energy development in Texas (and elsewhere) is leading to degraded landscapes and species habitats. Using the Eagle Ford energy region of South Texas as a test site, we assessed landscape changes with time from 2006-2014, when hydraulic fracturing technologies were applied for oil and gas exploration. Results indicate an increased area of landscape impact from ~95 km2 to 225 km2 during the study period. Some revegetation occurred during the study period.

University of Wyoming (Thijs Kelleners). Above- and below-canopy eddy covariance data from forest ecosystems were used to validate calculated canopy and surface energy balances generated by the GEOtop watershed model; Progress was made towards determining hillslope subsurface hydraulic parameters using time-lapse electrical resistivity tomography data; Soil solute transport was added to an existing soil-plant-atmosphere numerical model describing coupled water flow and heat transport in snow and soil.

Texas A&M University (Binayak Mohanty). Research effort has summarized available soil moisture and soil hydraulic property estimation using in situ and satellite-based sensors (Mohanty et al., 2017; Mohanty, 2013). We developed the new concept of watershed-scale subsurface connectivity (Kim and Mohanty, 2016, 2017) using probabilistic soil moisture thresholds between adjacent pixels to describe the spatial patterns of soil moisture as well as Bayesian model averaging for addressing water balance (including stream flow, ET, recharge, and root zone moisture) across hydrologic watersheds. We investigated land surface physical controls for multi-scale soil moisture distribution (Gaur and Mohanty, 2016, 2018) in various landscapes and hydroclimates and developed new physical control based scaling algorithms to downscale satellite soil moisture data (Gaur and Mohanty, 2018). Our team developed novel space-time modeling for soil moisture (Chen et al., 2017) as well as non-parametric modeling scheme (Shin et al., 2018) for linking precipitation and soil moisture spatio-temporal distributions. We formulated first-of-its-kind nonstationary geostatistical framework for fusing multi-platform (insitu, air-borne, and space-borne) soil moisture estimates and generating more reliable multi-scale soil moisture products (Kathuria et al., 2019a,b). In addition, we have developed a two-stage machine learning scheme for gap filling in satellite soil moisture data in space and time (Mao et al., 2019). Using Soil Moisture Active Passive (SMAP) satellite, we discovered the time stable features and minimum number of soil moisture ground samples necessary for calibration/validation at satellite footprint-scale as well as estimating watershed-mean soil moisture with high accuracy (Singh et al., 2019 a,b). We have investigated local-scale coupled hydraulic and thermally-driven unsaturated flow processes in the shallow subsurface and developed novel upscaling scheme to describe field-scale land-atmosphere phenomenon across diurnal to longer time scales (Sviercoski et al., 2018). Using field campaign data from Southern Great Plains region, our study showed new ways to derive transfer functions for soil water retention properties using landscape features and soil thermal properties (Bayat et al., 2019). In addition to these experimental, modeling, scaling, data fusion and conceptual soil moisture and hydraulic parameter development efforts, we participated in national and international review, synthesis, and writing vision papers, setting the stage for next-generation soil hydrologic research leading to its applications in land surface modeling leading to earth systems modeling (Rahmati et al., 2018, Fan et al., 2019).

Montana State University (Paul C. Stoy): Measured the surface-atmosphere exchange of water, energy, and CO2 using the eddy covariance system at a montane grassland and organized existing eddy covariance observations from flood and pivot-irrigated and dryland cropping sequences; Developed approaches to simulate the impacts of large-scale transitions away from baresoil toward alternate cropping sequences on regional climate processes in the Northern Plains using 4 km convection-permitting Weather Research and Forecasting (WRF) model runs; Demonstrated that the 2017 Northern Plains drought was preceded by anomalously low likelihood of convective precipitation but convective precipitation itself has become far more likely over the past four decades – by up to 40% during May and June; Derived a simple model for the partitioning of solar radiation into direct and diffuse components.

Virginia Tech (Ryan Stewart): Developed a new conceptual model to mechanistically describe how mineral water repellency regulates water vapor sorption and exchange in soils; Demonstrated that wildfires in southern Appalachian Mountain forests can induce soil water repellency and reduce infiltration rates for at least one year; Developed new low-cost and open-source methods (using Arduino-based sensors) to characterize water turbidity and soil microbial respiration and activity; Developed a numerical model to describe the effects of installation of permeable porous tree pit coverings on water fluxes within urban environments; Developed an analytical model that differentiates between overland flow mechanisms that is applicable to urban and reference soil profiles.

University of Wisconsin Madison (Jingyi Huang): We worked with farms in Central Sands, Wisconsin on monitoring and mapping the soil water dynamics over the growing seasons from 2016 to 2018. We demonstrated that irrigation management can be improved by using soil moisture probes and remote sensing platforms; We worked with NRCS, Wisconsin on monitoring and mapping soil organic carbon stock dynamics across the whole Wisconsin from 1850 to 2050. We demonstrated that land use change, improved agricultural management and climate change are the main drivers that affect the soil organic carbon stocks; We mapped the within-field variation of soil water dynamics in Central Sands, and identified areas of irrigation inefficiencies for future improvement; We shared results with stakeholders.

Michigan State University (Wei Zhang): Investigated the plant uptake and in-plant transformation of pharmaceuticals; Investigated the effect of overhead and soil surface irrigation on pharmaceutical residue levels in greenhouse lettuce, showing that overhead irrigation resulted in greater pharmaceutical residue levels in lettuce shoot; Assessed whether pharmaceutical exposure through soils and irrigation water could influence the survival of human pathogens in vegetables, due to competition between native bacteria and invading pathogens; Investigated the role of stomata to the internalization of silver nanoparticles into plant leaves, using Arabidopsis thaliana as model plants; Investigated novel ZnO nanowires as catalysts for photodegradation of cephalexin; Investigated metal-organic frameworks materials for sorption of Se(IV) and Se(VI); Investigated the effect of biochar amendment in soils on zinc uptake by wheat and rice; Continued collaboration with researchers in China.

**Outputs**

University of Arizona (Markus Tuller and Ebrahim Babaeian): Research results were disseminated in collaboration with various involved groups through 8 peer-refereed international journal publications and book chapters, and 4 conference contributions.

University of California-Riverside (Hoori Ajami): Published 4 journal articles related to groundwater recharge processes, quantifying uncertainty in ecohydrologic models, catchment scale application of the new semi-distributed modeling framework, and development of a new hybrid approach for disaggregation of coarse resolution soil moisture to fine resolution; Wrote the hydrologic assessment section of California’s Fourth Climate Change Assessment report for the Desert inlands region (<http://www.climateassessment.ca.gov/regions/docs/20180827-InlandDeserts.pdf>); journal article is currently under review and 5 conference abstracts were published in 2018; 3 invited public presentations as part of California’s Fourth Climate Change Assessment report and Riverside County Ag Expo; Taught 2 upper division undergraduate course regarding principles of Groundwater science (4 units), and Spatial analysis and remote sensing for environmental sciences (4 units); Served on 2 PhD dissertation committee and 2 PhD qualifying exams; Served as Associate Editor of California Agriculture and Hydrological Sciences Journals.

University of California-Riverside (Jirka Simunek). Research findings were disseminated via refereed journal publications, conference proceedings, and a number of presentations at national and international meetings (see the publication section below). HYDRUS models have been updated with several new capabilities and options that have been developed for various research projects, which in turn have been published in peer-reviewed journals.

University of California-Riverside (Laosheng Wu): Research results were disseminated through peer-refereed international journal publications, presentations, and classroom teaching.

University of Delaware (Yan Jin): Research results were disseminated in collaboration with various involved groups through 6 peer-refereed international journal publications and 21 invited and volunteered conference contributions.

Iowa State University (Robert Horton) and North Carolina State University (Joshua Heitman): Research results were disseminated in collaboration with various involved groups through peer-refereed publications.

University of Kentucky (Ole Wendroth): Research results were disseminated in 6 scientific peer-reviewed journal articles, during field days, and commodity group meetings, in 1 extension publication, and to audiences at scientific meetings (Kentucky Water Resources Research Institute Meeting, Congress of the International Union of soil Science Congress, and American Society of Agronomy meeting).

New Mexico State University (Manoj Shukla): Seven peer-reviewed manuscripts were published or accepted for publication; Two invited talks to China Agricultural University, Beijing, China in June 2018; Four manuscripts submitted for publication to peer reviewed Journals; Mentored 2 MS and 5 PhD students as chair and 5 other graduate students as committee member; Graduated 1 MS student.

Oklahoma State University (Tyson Ochsher): Paper describing soil water dynamics and nitrate leaching under corn–soybean rotation, continuous corn, and kura clover was published in Vadose Zone J.; Paper describing nitrate leaching in soybean rotations without nitrogen fertilizer was published in the journal Plant and Soil.

Oregon State University (Maria Dragila): Presented results to growers at Columbia Basin Soil Health Potato Commission Conference for the sandy soil water cycle study; Published two manuscripts for the vadose zone aeration study; Presented results to growers and extension agents at North Willamette Research and Extension Center Solarization Workshop and published article in The Organic Farmer Magazine (west coast publication) for the soil solarization study.

Oregon State University (Carlos Ochoa): Conference contribution presenting findings related to soil moisture differences at different depth in under-canopy and inter-canopy locations in juniper dominated landscapes; Conference contribution presenting soil moisture monitoring in three long-term, watershed-scale, study sites being established in western, central, and eastern OR locations.

Nevada, Desert Research Institute (Markus Berli): Our publications focused on developing and validating models to describe the water dynamics of arid soils and their impact on desert hydrology.

North Dakota State University (Aaron Daigh and Francis Casey): Research findings were disseminated via 12 publications in peer-reviewed journals, 11 research reports and 7 conference abstracts and presentations.

Washington State University (Markus Flury and Joan Wu): Published our research results in peer-reviewed journals and presented the research results in national and international conferences (Soil Science Society Annual Meeting; European Geoscience Union), and invited talks in China and Germany. The highlight was a publication in the Proceedings of the National Academy of Sciences, which has led to comprehensive news coverage in Europe, USA, and South America.

University of Texas at Austin (Todd Caldwell and Michael Young): Research findings were disseminated via refereed journal publications and presentations at local, national and international meetings.

University of Wyoming (Thijs Kelleners): 5 journal articles were published in 2018; 5 courses were taught: Soil Physics Lecture (3 credits), Soil Physics Laboratory (2 credits), Agroecology Capstone (1.5 credits), Modeling Flow and Transport (4 credits), and Forest and Range Soils (3 credits).

Montana State University (Paul C. Stoy): Published 14 manuscripts (two in open review) on topics including snow and environmental physics including the role of landcover change away from bare soil (summer fallow) on the regional climate of the Northern Plains; Gave 4 conference presentations and 6 invited presentations and contributed to eight conference presentations by postdoctoral research scientists and graduate students; Provided input to popular press articles in Science, Massive Science and The Furrow by John Deere.

Virginia Tech (Ryan Stewart): Research findings were disseminated via 2 publications in peer-reviewed journals and 5 conference abstracts and presentations.

University of Wisconsin Madison (Jingyi Huang): Two peer-reviewed manuscripts published or accepted for publication; Two oral presentations (one invited) in World Soil Congress, Rio de Janeiro, Brazil, 2018; Three manuscripts submitted for publication to peer-reviewed journals; 1 PhD as main advisor and 1 PhD as committee member.

Michigan State University (Wei Zhang): Published 12 journal articles, gave 8 presentations (5 invited) in national and international conferences, delivered 8 invited seminars, edited a special issue “Advancing soil physics for securing food, water, soil and ecosystem services” in Vadose Zone Journal, and served as Secretary General for International Symposium on Agro-Environmental Quality, Nanjing, China, November 2-5, 2018.

**Activities**

University of Arizona (Markus Tuller and Ebrahim Babaeian)

(1) Adoption and Modification of ParSWMS (Mohammad Gohardoust, Horst Hardelauf, Asher Bar-Tal, and Markus Tuller). Simulation of three-dimensional water flow and solute transport in containerized variably saturated soilless substrates with complex hydraulic properties and boundary conditions necessitates high-resolution discretization of the spatial domain, which commonly leads to several million nodes requiring numerical evaluation. Even today’s computational power of workstations is not adequate to tackle such problems within a reasonable timeframe. Hence, parallelization of the numerical code and utilization of supercomputers are required. The previous version of ParSWMS (Hardelauf et al., 2007), which is the parallelized version of SWMS-3D (Simunek et al., 1995) solves porous media water flow and solute transport equations considering one solute at a time and a linear adsorption isotherm. The code was modified to accommodate nonlinear solute adsorption and to support multi-species solute simulations. Computational issues were resolved and the code was adapted to run on high-performance computing clusters.

(2) Remote Sensing of Earth Surface Processes. In collaboration with Utah State University (Morteza Sadeghi and Scott Jones) we continued to extensively work on the development of novel measurement and remote sensing techniques for characterization of largescale near surface processes and basic soil properties. Below are a few research highlights accomplished in 2018.

(3) Application of Satellite Remote Sensing for Delineation of Dust Source Zones (Mohaddese Effati, Mohammad Gohardoust, Ebrahim Babaeian and Markus Tuller): Saline playas in arid and semiarid regions of the world are significant sources of unconsolidated sediments susceptible to aeolian transport. This causes ecosystem degradation, accelerated desertification and frequent dust storms, causing respiratory diseases and other health problems. We developed a framework for delineation of dust source zones and estimation of dust storm occurrence probability based on remotely sensed land surface properties (i.e., soil moisture and vegetation cover), soil texture, climate characteristics (i.e., wind speed) and ground visibility measurements to inform possible remediation measures. Observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) are utilized to determine the Normalized Difference Vegetation Index (NDVI) and to estimate surface soil moisture with a recently introduced optical trapezoid model. The soil textures extracted from the SoilGrids database and wind speeds obtained from local weather stations together with the estimated surface soil moisture where found to be highly correlated with dust emission probability.

(3) Unmanned Aircraft System Observations for Estimation and Monitoring of Soil Moisture Variability for Agricultural Water Management (Ebrahim Babaeian, Richard Ward, Maria S. Newcomb, Morteza Sadeghi, Scott Jones, and Markus Tuller): Knowledge about the variability of soil moisture (SM) and plant available water (PAW) is crucial for precision agricultural water management. Recent advances in unmanned aircraft system (UAS) and electromagnetic in situ soil moisture sensing technology provide powerful means for irrigation management. We developed a new framework combining remote UAS and satellite observations with ground-based soil moisture measurements and numerical modeling to provide decision support for farm-scale precision irrigation management. We introduced a new trapezoidal space confined by remotely-sensed near infrared transformed reflectance (NTR) and normalized difference vegetation index (NDVI) data for estimation and mapping of SM and PAW variability.

(4) A New Analytical Model for Estimation of Land Surface Net Water Flux from Near-Surface Soil Moisture Observations (Morteza Sadeghi⁠, Markus Tuller, Arthur W. Warrick⁠, Ebrahim Babaeian, Kshitij Parajuli, Mohammad R. Gohardoust, and Scott B. Jones): The accurate determination of land surface water fluxes at various spatiotemporal scales remains a challenge in hydrological sciences. It is intuitive that land surface net water flux (i.e., infiltration minus evapotranspiration) directly affects near-surface soil moisture. However, there exists no hydrological model suitable to calculate net water flux based on measured near-surface soil moisture data. This is a consequence of the mathematical structure of existing models that use ‘boundary conditions’ to determine ‘internal conditions’, whereas what is needed is a model amenable to use near-surface soil moisture data (an internal condition) to determine the surface water flux (a boundary condition). To pursue the idea of utilizing remotely-sensed or in situ (i.e., sensor networks) near surface soil moisture data for estimation of net water flux, we derived an analytical model via inversion of Warrick’s 1975 analytical solution to the linearized Richards’ equation for arbitrary time-varying surface flux boundary conditions. A major advantage of the new model is that it does not require calibration, which provides an unprecedented opportunity for large scale estimation of land surface net water flux using remotely sensed near-surface soil moisture observations.

University of California-Riverside (Hoori Ajami): Continue on development of the SMART model by adding new functionalities; Adding new uncertainty quantification framework to SMART, in collaboration with Mojtaba Sadegh Boise State University.

University of California-Riverside (Jirka Simunek): In 2018, we offered two- or three-day short courses on how to use HYDRUS models at a) Czech University of Life Sciences, Prague, Czech Republic, b) Colorado School of Mines, Golden, CO, c) the Research Center for Eco-Environmental Sciences, Chinese Academy of Science, Beijing, Peoples Republic of China, d) Tokyo University of Agriculture and Technology, Department of Ecoregion Science, Tokyo, Japan, e) WASCAL Headquarters, Accra, Ghana, NC. About 150 students participated in these short courses.

University of California-Riverside (Laosheng Wu): Gave presentations to various academic and on-academic groups. Working on the following on-going projects.

Decision Support for Water Stressed FEW Nexus Decisions (DS-WSND). NSF INFEWS. Collaborator. 01/01/2018 to 12/30/2020.

Hispanic-Serving Institutions (HSI) Education Grants Program. USDA/NIFA. Co-PI. 10/01/2016 to 08/01/2020.

Optimizing Water Management Practices to Minimize Soil Salinity and Nitrate Leaching in California Irrigated Cropland. UC Division of Agri. & Natural Res. PI. 03/2017-02/2019.

Enhancing site-specific turf irrigation management and developing turf deficit irrigation strategies using soil moisture sensors, smart ET-based irrigation controllers, and remote sensing. US Golf Association. Co-PI. 01/2018-12/31/2019.

University of Delaware (Yan Jin)

(1) We conducted measurements of water retention in several sand/soils to quantify the effects of rhizobacteria influence on water retention and evaporation using Hyprop with and with salt presence. The goal is to further evaluate the potential of this strain of bacteria in potentially alleviating drought and salt stresses on plants and to elucidate relevant mechanisms.

(2) Sampling and analyzing water and soil samples from a fresh water wetland, including three zones (upper land, transition zone, and wetland zone) for size fractionated colloid and OC concentrations, stable isotope values of C, N, and H, as well as multiple elements and environmental parameters (pH, Eh, EC, temperature, precipitation, water table depth…). The goal is to evaluate the effects of wetland hydrology (or hydroperiods) on colloid and carbon fate and transport in this redox-dynamic ecosystem.

(3) Conducted a laboratory study using syringe columns to measure the dynamic changes in colloid and OC concentration and composition as influenced by redox conditions.

(4) Conducted laboratory experiments using 2D chambers to demonstrate that preferential flow paths are biological hotspots where nutrients and microbial biomass tend to accumulate so that microbial activities are more intense at the interface of preferential flow paths and soil matrix.

(5) We examined wetting and de-wetting patterns of water and surfactant solution on both hydrophilic and hydrophobic surfaces and surfaces with regular and irregular roughness features; we also measured colloid attachment and detachment on these surfaces.

Iowa State University (Robert Horton) and North Carolina State University (Joshua Heitman):

(1) Soil thermal diffusivity k is an essential parameter for studying surface and subsurface heat transfer and temperature changes. It is well understood that k mainly varies with soil texture, water content, and bulk density BD, but few models are available to accurately quantify the relationship. In this study, an empirical model is developed for estimating k from soil particle size distribution, BD, and degree of water saturation S. The model parameters are determined by fitting the proposed equations to heat-pulse k data for eight soils covering wide ranges of texture, BD, and S. Independent evaluations with published k data show that the new model describes the k(S) relationship accurately, with root-mean-square errors less than 0.75 x 10-7 m2 s-1. The proposed k(S) model also describes the responses of k to BD changes accurately in both laboratory and field conditions. The new model is also used successfully for predicting near-surface soil temperature dynamics using the harmonic method. The results suggest that the model provides useful estimates of k from S, BD, and soil texture.

(2) Soil bulk density (ρb) and volumetric water content (θ) determine the volume fractions of soil solids, water and air, and influence mass and energy transfer in soils. It is desirable to monitor ρb and θ concurrently and nondestructively. We present a heat pulse-based method for simultaneous determination of ρb and θ from soil thermal properties. The method employs equations that relate ρb and θ to soil volumetric heat capacity (C) and to soil thermal conductivity (λ). Knowing soil texture and specific heat of soil solids a priori, a three-step calculation procedure is used to solve for ρb and θ from heat-pulse sensor measured C and λ. Laboratory evaluation on soil samples of various textures showed that the three-step method provided reliable ρb and θ estimates at θ values greater than the critical water content when λ started to respond significantly to θ change.This method provides a new way for simultaneous determination of ρb and θ with a heat pulse sensor.

(3) Unsaturated hydraulic conductivity (K) of surface soil changes substantially with space and time, and it is of great importance for many ecological, agricultural, and hydrological applications. In general, K is measured in the laboratory, or more commonly, predicted using soil water retention curve and saturated hydraulic conductivity. In the field, K can be estimated through infiltration experiments. However, none of these approaches are capable of continuously monitoring K in-situ at fine depth scale. In this study, we propose and investigate an approach to continuously estimate fine depth-scale K dynamics under field conditions. Evaporation rate and change in water storage in a near-surface soil layer are measured with the heat pulse method. Then, water flux density at the lower boundary of the soil layer is estimated from evaporation rate, change in water storage, and rainfall or irrigation rate using a simple water balance approach. Finally, K values at different soil depths are derived using the Buckingham-Darcy equation from water flux densities and measured water potential gradients. A field experiment is performed to evaluate the performance of the proposed approach. K values at 2-, 4-, 7.5-, and 12.5-cm depths are estimated with the new approach. The results show that in-situ K estimates vary with time following changes in soil water content. The K-water content relationship is affected by depth due to the difference in bulk density. In-situ estimated K-matric potential curves agree well with those measured in the laboratory. In-situ K estimates also show good agreement with the Mualem-van Genuchten model predictions, with an average root mean square error in log10 (K, mm h-1) of 0.54 and an average bias of 0.17. The new approach provides reasonable in-situ K estimates and has potential to reveal the influences of natural soil conditions on hydraulic properties as they change with depth and time.

(4) To reduce the possibility of probe deflections, conventional thermo-time domain reflectometry (T-TDR) sensors have relatively short probe lengths (≤4 cm). However, short probes lead to large errors in TDR-estimated soil water content (θv). In this study, two new 6-cm-long probe-spacing-correcting T-TDR (CT-TDR) sensors are investigated. Compared to conventional 4-cm-long T-TDR sensors, the 6-cm-long CT-TDR sensors reduce errors in TDR-estimated θv. Errors in HP-estimated θv due to probe deflections are reduced when linear or nonlinear probe spacing correcting algorithms are implemented. The new 6-cm-long CT-TDR sensors provide more accurate θv estimations than do the conventional 4-cm-long T-TDR sensors.

Soil thermal inertia (P), a property that controls the temporal variation of near-surface temperature, has been used to estimate surface water content (θ) in remote sensing studies. The accuracy of θ estimates, however, is affected by surface soil porosity (*n*). We hypothesize that *n* can be derived using a simple linear *n*-P relationship of a dry surface soil layer, and that accounting for *n* improves the accuracy of θ estimation using a P(θ) model. The P of a surface layer was measured by using the heat pulse method during a drying period, and the feasibility of estimating θ with a P(θ) model that included *n* was explored. The approach was also tested with published P values derived from meteorological data and MODIS data against *in situ* θ measurements at two field sites in Arizona, USA. The results on a partially vegetated shrubland indicated that by using the P-derived *n*, the P(θ) model provided more accurate θ estimates than by using the literature *n* values. Discrepancies between modeled θ and *in situ* θ measurements were observed at small θ values, which were caused in part by the fact that the modeled θ represented soil layers a few millimeters thick, while the *in situ* measurements represented θ at the 5-cm depth. The new *n*-P function has potential for estimating surface θ accurately using multi-scale P data on bare soils or on sparsely vegetated lands.

University of Kentucky (Ole Wendroth): Mapping Zone delineation: Manuscript submitted and accepted (part of dissertation Javier Reyes); Resubmitted CAP grant research proposal to the Water in Agriculture Challenge Area was again turned down; Continued to use RZWQM2 to simulate crop growth of different crops, nitrogen management (part of dissertation Saadi Shahadha); Ongoing a four-state research project on irrigation management between Kentucky, Georgia, Alabama, and Tennessee.

New Mexico State University (Shukla Manoj): Taught soil physics, advanced soil physics and environmental soil science classes; Taught a class on Natural Resources in Northwest A&F University, China; Taught at summer school in Qi City, China Agriculture University; Hosted one faculty members from Jiangxi Agriculture University, one student from China Agriculture University, and another graduate student from China agriculture University started from November 2018; Field and greenhouse trips were organized to collect soil and water samples, soil moisture content, soil temperature, and other meteorological data; Experiments were planned on use of brackish groundwater and RO concentrate for looking at influence of irrigation water salinity on soil microbiological properties; Soil and plant samples were collected from Pecan orchards from New Mexico orchards to evaluate salinity induced changes in pecan physiology; Proposals were written and submitted to various Funding Agencies.

Oklahoma State University (Tyson Ochsner): Objective 2 of this multi-state project was to develop and evaluate new instruments and analytical methods to connect our understanding of mass and energy transport in the vadose zone at different scales and environmental transformations. During this project period, we have analyzed, interpreted, and published new findings on the effectiveness of lysimeters and water balance approaches for understanding water and solute transport in agricultural ecosystems in the US and Brazil.

Oregon State University (Maria Dragila): Investigating soil water relations in sandy agricultural soil to improve irrigation efficiency (Collaboration with M. Kleber and R. Qin, OSU) and continuing field and laboratory investigations associated with the evolutionary development of micro-aggregation in sandy soil; Investigating the biophysical mechanisms associated with the evolution of water repellency to uncover an effective remediation strategy (Collaboration with M. Kleber, OSU), and continuing laboratory investigations of water repellency development; Investigating the erosional evolution of microfractures in the epikarst and performing data analysis; Investigating the efficacy of using soil solarization for pest and weed disinfectation in the Pacific Northwest. (Collaboration with J. Parke and C. Mallory-Smith, OSU, and S. Dollen, Grower) and completed third and last-year of field trials and begun data analysis; Investigated how various mechanisms impact gas exchange across the interface between vadose zone and atmosphere. (Collaboration with N. Weisbrod, Ben Gurion, IL), completed data analysis and published 2 manuscripts; Investigating film flow below the detection limit of CT scans (Collaboration with PI Dorthe Wildenschild), preparing manuscript in progress and begun new set of experiments.

Oregon State University (Carlos Ochoa): (1) Investigate soil water relations in irrigated pastures to assess water transport through the vadose zone and into the shallow aquifer (Collaboration with D. Godwin and S. Ates, OSU), including field and laboratory work related with soil physical properties and water transport through the unsaturated zone; (2) Investigate soil water relations in juniper-sage steppe landscapes to assess water transport through the vadose zone and into the shallow aquifer (Collaboration with T. Deboodt, OSU), including automated field data collection at multiple locations in one watershed with juniper and one where juniper was removed 13 years ago.

Nevada, Desert Research Institute (Markus Berli): Developed a physically-based model to describe the relationship between soil hydrophobicity (expressed as apparent contact angle or water penetration time) and infiltration through sorptivity; Evaluated methods to measure sorptivity in the field; Worked on an improved understanding of water infiltration, redistribution and evaporation from arid soils; Validated the hydrology model KINEROS2 as a potential tool to simulate post-fire stream flow and sediment transport from watersheds in the US Southwest; Reviewed the state of knowledge on engineered nanomaterials (ENM) in soil environments.

North Dakota State University (Aaron Daigh and Francis Casey). Soil temperatures, water contents, and the responses of soil microbial communities were monitored in a silty clay field plant to soybeans and subject to various levels of mechanical soil disturbance (tillage). This experiment is designed to improve our understanding of soil heat and water processes across spatial and temporal scales in agricultural fields and subsequent effects on soil biology. Surface energy balance partitioning was performed on field plots, remediated by thermal desorption, using micro bowen ratio. Water and salt transport across a hydrophobic leonardite was evaluated in the laboratory using large soil columns instrumented with three needle heat pulse probes and MPS-6 matric potential sensors. Continued to develop new methods to harvest brine spill salts from the soil surface. The use of a crystallization inhibitor ferric hexacyanoferrate and various wicking media were evaluated in the laboratory and greenhouse. The effects of soil ferric hexacyanoferrate contents on soybean and wheat plant health and soil microbial community structures were evaluated in a greenhouse study. Field-scale fate and transport of brominated estradiols as surrogates for native 17ß-estradiol.

Washington State University (Markus Flury and Joan Wu): Worked on water activities and water contents along an east-west transect in the Atacama desert; Worked on determining water contents in microhabitats in the Atacama desert; Conducted long-term field experiments to determine suitability of biodegradable plastic mulch; Evaluated soil quality as affected by long-term use of biodegradable plastic mulch; Conducted laboratory experiment to evaluate how earthworms interact with biodegradable plastic mulch; Tested whether earthworms will ingest biodegradable plastic mulch; Evaluated how freezing and drying cycles affect the leaching of metals from biosolids; Worked on quantifying interfacial convections at NAPL-water interfaces; Measured contact angles on colloidal biochar. Characterized colloidal properties of a variety biochar samples; Lead new group Hatch project on "Soil and Rhizosphere Processes"; Published a special section on “Lysimeters in Vadose Zone Research” in the Vadose Zone Journal; Organized symposium on “Nanoparticle Fate and Transport in Soil and Groundwater Systems” at the European Geoscience Union Annual meeting.

University of Texas at Austin (Todd Caldwell and Michael Young). A numerical model is presented to test whether a hillslope diffusion approach can simulate the topographic evolution of some recently developed high-centered ice-wedge polygons south of Prudhoe Bay, Alaska. The polygons are adjacent to a highway whose construction appears to have triggered their geomorphic transition. The model is calibrated using a light detection and ranging data-set that captures both the high-centered polygons and some neighboring low-centered polygons that appear to be unaffected by thermokarst. The latter are used to represent initial conditions. Model simulations are analyzed to estimate potential fluxes of soil from polygon edges into troughs and the loss of depressional water storage during development of the high-centered polygons. Overall, a match between the topography of simulated and observed high-centered polygons suggests that diffusive hillslope processes represent a feasible mechanism driving polygon transition. Rates of soil displacement inferred from optimized simulations, moreover, are within the range previously observed in permafrost terrain with a similar climate. Direct observations of the soil velocity profile in actively transitioning polygons would help resolve whether and to what extent hillslope processes, as opposed to pure thaw-related subsidence at the polygon edges, drive the development of high-centered forms in natural systems.

The goal of this research is to constrain the influence of ice wedge polygon microtopography on near-surface ground temperatures. Ice wedge polygon microtopography is prone to rapid deformation in a changing climate, and cracking in the ice wedge depends on thermal conditions at the top of the permafrost; therefore, feedbacks between microtopography and ground temperature can shed light on the potential for future ice wedge cracking in the Arctic. We first report on a year of sub-daily ground temperature observations at 5 depths and 9 locations throughout a cluster of low-centered polygons near Prudhoe Bay, Alaska, and demonstrate that the rims become the coldest zone of the polygon during winter, due to thinner snowpack. We then calibrate a polygon-scale numerical model of coupled thermal and hydrologic processes against this dataset, achieving an RMSE of less than 1.1 C between observed and simulated ground temperature. Finally, we conduct a sensitivity analysis of the model by systematically manipulating the height of the rims and the depth of the troughs and tracking the effects on ice wedge temperature. The results indicate that winter temperatures in the ice wedge are sensitive to both rim height and trough depth, but more sensitive to rim height. Rims act as preferential outlets of subsurface heat; increasing rim size decreases winter temperatures in the ice wedge. Deeper troughs lead to increased snow entrapment, promoting insulation of the ice wedge. The potential for ice wedge cracking is therefore reduced if rims are destroyed or if troughs subside, due to warmer conditions in the ice wedge. These findings can help explain the origins of secondary ice wedges in modern and ancient polygons. The findings also imply that the potential for re-establishing rims in modern thermokarst-affected terrain will be limited by reduced cracking activity in the ice wedges, even if regional air temperatures stabilize.

Soil moisture sensors infer volumetric soil water content (SWC) from other properties of the bulk porous media. The CS655 water content reflectometer is a relatively new, low-frequency electromagnetic sensor that determines relative permittivity (Ka) using the two-way travel period and voltage attenuation of the applied signal along two 12-cm rods. This measured attenuation is quadratically related to bulk electrical conductivity (EC). Along with an onboard thermistor, the CS655 allows a more robust correction of propagation time and Ka, which its predecessors, the CS615 and CS616, lacked. However, with new sensors it is necessary to quantify their practical accuracy in the field. Here, we present an overview of the CS655 sensor and an evaluation under both laboratory and field conditions, using five surface soils (0–10-cm depth) in the laboratory and gravimetric samples collected in the field. Overall, a site-specific calibration using a two-term linearization of the SWC–Ka function reduced the root mean square error (RMSE) of the factory-derived SWC of 0.073 and 0.043 m3 m−3 during batch and infiltration experiments, respectively, to 0.025 and 0.028 m3 m−3. Results further indicate that a soil-specific calibration additionally reduced the RMSE to < 0.02 m3 m−3. Field evaluation across the Texas Soil Observation Network found that calibration reduced the variance across the network but did not affect the arithmetic mean or the RMSE against gravimetric sampling, which remained ~0.05 m3 m−3 regardless of the SWC–Ka–EC function applied. At the regional scale, a global calibration is sufficient.

Accurate soil moisture is critical to predict regional weather patterns, ecosystem status, and water resources. Many gridded products have emerged from land surface models and satellite data; however, validating such data is particular challenging. Soil moisture, for example, is highly variable in both time and space complicating our ability to upscale point measurements to satellite footprints. To this end, I built and maintain the Texas Soil Observation Network (TxSON, <http://www.beg.utexas.edu/research/programs/txson>) to serve as an on-ground data product with replicated soil moisture at 1, 3, 9, and 36 km scales. This data and collaboration with NASA and the SMAP Science Team has moved soil moisture to the forefront of global hydrologic cycle.

Advancing our understanding of Earth system dynamics (ESD) depends on the development of models and other analytical tools that apply physical, biological, and chemical data. This ambition to increase understanding and develop models of ESD based on site observations was the stimulus for creating the networks of Long-Term Ecological Research (LTER), Critical Zone Observatories (CZOs), and others. We organized a survey, the results of which identified pressing gaps in data availability from these networks, in particular for the future development and evaluation of models that represent ESD processes, and provide insights for improvement in both data collection and model integration. From this survey overview of data applications in the context of LTER and CZO research, we identified three challenges: (1) widen application of terrestrial observation network data in Earth system modelling, (2) develop integrated Earth system models that incorporate process representation and data of multiple disciplines, and (3) identify complementarity in measured variables and spatial extent, and promoting synergies in the existing observational networks. These challenges lead to perspectives and recommendations for an improved dialogue between the observation networks and the ESD modelling community, including co-location of sites in the existing networks and further formalizing these recommendations among these communities. Developing these synergies will enable cross-site and cross-network comparison and synthesis studies, which will help produce insights around organizing principles, classifications, and general rules of coupling processes with environmental conditions.

Spatio-temporal trends in infrastructure footprints, energy production, and landscape alteration were assessed for the Eagle Ford Shale of Texas. The period of analysis was over four 2-year periods (2006–2014). Analyses used high-resolution imagery, as well as pipeline data to map EF infrastructure. Landscape conditions from 2006 were used as baseline. Results indicate that infrastructure footprints varied from 94.5 km2 in 2008 to 225.0 km2 in 2014. By 2014, decreased land-use intensities (ratio of land alteration to energy production) were noted play-wide. Core-area alteration by period was highest (3331.6 km2) in 2008 at the onset of play development, and increased from 582.3 to 3913.9 km2 by 2014, though substantial revegetation of localized core areas was observed throughout the study (i.e., alteration improved in some areas and worsened in others). Land-use intensity in the eastern portion of the play was consistently lower than that in the western portion, while core alteration remained relatively constant east to west. Land alteration from pipeline construction was ~65 km2 for all time periods, except in 2010 when alteration was recorded at 47 km2. Percent of total alteration from well-pad construction increased from 27.3% in 2008 to 71.5% in 2014. The average number of wells per pad across all 27 counties increased from 1.15 to 1.7. This study presents a framework for mapping landscape alteration from oil and gas infrastructure development. However, the framework could be applied to other energy development programs, such as wind or solar fields, or any other regional infrastructure development program.

University of Wyoming (Thijs Kelleners). We continue to maintain a state-wide soil moisture network for drought monitoring in rangelands (consisting of 17 sites). This is a collaboration with Ginger Paige, a hydrologist at the University of Wyoming. We are monitoring five snow-dominated experimental catchments in the Rocky Mountains. The focus is on the role of the subsurface in transforming snowmelt into streamflow. Geophysical measurements are combined with hydrological monitoring and hydrological modeling. A sixth site will be added in 2019. This is a collaboration with Andrew Parsekian, a hydro-geophysicist at the University of Wyoming.

Texas A&M University (Binayak Mohanty): Develop fundamental understanding of spatio-temporal variability and multi-scale soil hydrologic processes in various hydroclimatic conditions; Collect multi-scale field data on soil moisture and soil hydraulic properties using insitu and remote sensing tools; Design new data analysis, modeling, and data assimilation/ fusion platforms at multiple space-time scales; Develop adaptive upscaling and downscaling tools to generate multi-scale data products for various hydrologic and environmental applications.

Montana State University (Paul C. Stoy): Synthesized observations of sensible and latent heat flux during snowmelt events to simplify the treatment of these processes in snowmelt models; Synthesized observations of climate extremes in the southeastern U.S. and observations of mean climate and extreme climate events in the Northern Plains to provide a baseline for regional climate modeling activities; Synthesized observations of carbon dioxide fluxes from tropical ecosystems including approaches for understanding the reasons that the surface energy balance as measured by eddy covariance remains unclosed and approaches to measure and estimate the flux of isoprene and methane from tropical ecosystems to the atmosphere; Described the means by which ongoing land cover changes in the Northern Plains interact with different elements of the food-energy-water nexus.

Virginia Tech (Ryan Stewart). We performed and completed a laboratory experiment in which water repellency was induced to varying degrees in two model minerals (kaolinite and montmorillonite). We then quantified vapor sorption isotherms for the treatments, allowing us to quantify water repellency effects on water vapor sorption and exchange in soils. We collected and analyzed data from two field sites in southern Appalachian Mountain forests that were burned by wildfires in November 2016. Over a fourteen month period, we collected repeated measurements of soil water content, infiltration rates, and water drop penetration times, allowing us to quantify relationships between soil water content, repellency and infiltration. We performed a series of modeling exercises to understand the effects of urbanization on soil properties. In one study, we examined the role of permeable pavements on water fluxes within urban environments. We are also developing a modeling framework to compare hydrological processes (e.g., runoff, infiltration, drainage) in urban versus reference soil profiles. We collected samples and data to evaluate whether low-intensity prescribed fires affect soil aggregate stability, soil nutrient status, or water quality (e.g., dissolved organic carbon, turbidity) in a first-order forested watershed.

University of Wisconsin Madison (Jingyi Huang): Taught soil physics at the graduate level at University of Wisconsin-Madison; Soil samples, soil and geophysical surveys conducted in various regions in Wisconsin to characterize the spatial and temporal variations in soil water and other properties; Meetings with various growers in Wisconsin on the application of proximal and remote sensing technologies in soil and land resources management.

Michigan State University (Wei Zhang): Fundamental research on environmental processes and impacts of emerging contaminants (including pharmaceuticals such as antibiotics, engineered nanoparticles, and antibiotic resistance genes) in soil, water and plant systems; International collaboration in basic agricultural and environmental sciences.

**Milestones**

University of Arizona (Markus Tuller and Ebrahim Babaeian): Modified ParSWMS parallelized code to include simulation capabilities for nonlinear solute adsorption and multi-species solute simulations for optimization of soilless greenhouse substrates; Developed a framework for delineation of dust emission source zones based on satellite remote sensing observations; Developed approach to quantify soil vapor sorption hysteresis; Developed a framework to generate high-resolution plant available moisture maps from unmanned aircraft system (UAS) observations and ground soil moisture measurements to aid precision irrigation management; Developed a new analytical model for estimation of land surface net water flux from near-surface soil moisture observations.

University of California-Riverside (Hoori Ajami): Improving runoff simulations in SMART modeling framework.

University of California-Riverside (Jirka Simunek): Various novel applications of the models were implemented, and published 6 refereed articles in hydrological applications, 14 refereed articles in agricultural applications, 5 refereed papers on fate and transport of various substances, and 2 review manuscripts. Additional capabilities to rigorously consider soil processes to other models such as MODFLOW and DSSAT.

University of California-Riverside (Laosheng Wu): Improve our fundamental understanding of vadose zone physical properties and processes, and how they interact with other environmental and biogeochemical processes across various spatial and temporal scales; Apply our knowledge of scale-appropriate methodologies to enhance the management of vadose zone resources that benefit agricultural systems, natural resources and environmental sustainability. Developed a model for pentachlorophenol dissipation; performed inverse modeling of hydrologic system; Evaluate salt tolerance and growth of Avocado rootstocks; Assessing salinity leaching efficiency in three Soils by the HYDRUS 1D and 2D Simulations.

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University of Delaware (Yan Jin)

(1) We improved understanding on how rhizobacteria may cause soil structural change through EPS production and biofilm formation, which affects soil water retention.

(2) We tested the feasibility of imaging water retention and evaporation of control and bacteria-inoculated columns with x-ray tomography and neutron tomography simultaneously. Coupling the two powerful imaging equipment has the potential to give unprecedented resolution of all phases (solid, water, and air).

(3) We continue to expand our collection of data to demonstrate the importance of separating small colloidal fractions from conventionally defined dissolved phase.

(4) We demonstrated preferential pathways can be biological hotspots.

Iowa State University (Robert Horton) and North Carolina State University (Joshua Heitman): Developed an empirical model to estimate soil thermal diffusivity; Developed a heat pulse sensor method to determine soil water content and soil bulk density simultaneously; Developed a method to determine soil hydraulic conductivity in situ; Developed an in situ heat pulse probe spacing correction method that enabled accurate determination of soil water content; Developed a way to account for soil porosity in order to improve a thermal inertia model for estimating surface soil water content.

University of Kentucky (Ole Wendroth): Successfully linked remote sensing information and simply-observable soil state variables in a farmer’s field for functional soil mapping. The soil property maps are relevant for the next step in our work, i.e. decision support. (dissertation Javier Reyes); Progress in developing pedo-transfer functions for computing soil hydraulic properties and their spatial variability at the field-scale in a farmer’s field. Current pedo-transfer functions tend to overestimate soil hydraulic conductivity and do not represent the spatial variability of soil hydraulic conductivity. Ongoing. (part of dissertation Xi Zhang); Completed a 3-year research project on improving irrigation management in Kentucky.

New Mexico State University (Manoj Shukla): Quantified impacts of irrigation water salinity induced changes to evapotranspiration and yields of several chile pepper cultivars, tomato, and pecans; Quantified impacts of irrigation water salinity induced changes to evapotranspiration and yields of some halophytes; Quantified increases in soil salinity and ion concentrations in soil with continued irrigation with brackish groundwater and RO concentrate; Developed a new low cost data logger for soil moisture monitoring; Calibration for three soil moisture sensors (Hydra probe, 5TE, and TEROS 12 sensors) is underway; Tested a low cost data logger with wireless capability to collect data and directly transmit to a central storage; Studied water and nutrient dynamics that would be useful for management of Pecan orchards in the valley; Quantified ion accumulation in soil and plant (chile, tomatoes, some halophytes) that would be a helpful for designing improved irrigation strategies for using RO for agriculture.

Oregon State University (Maria Dragila): Continuing work on water motion within sandy soils is leading to a more mature conceptual pore and field-scale model for the role of biofilms on water storage within the upper-soil water cycle.

Oregon State University (Carlos Ochoa): Expanded a soil moisture-monitoring network in riparian areas and pastures in the Oak Creek watershed in Corvallis, OR; Expanded a soil moisture-monitoring network in rangeland juniper-dominated systems in central Oregon; Began establishing a new sensor network in a new study site in eastern Oregon.

Nevada, Desert Research Institute (Markus Berli): Model developed and validated for water infiltration into hydrophobic soil; Improved model to simulate water infiltration, redistribution and evaporation for arid soils.

North Dakota State University (Aaron Daigh and Francis Casey). We were able to successfully remove salts from brine contaminated soils using engineered wicking media. During a five week period, two engineered paper-based humidifier wicks and two non-engineered wicks (wheat straw and hydromulch) placed on the surface of brine-contaminated soils reduced the total soil Na concentrations by 65-88% and 5-80%, respectively. Capillary rise of water and soluble salts were substantially limited across a raw, hydrophobic leonardite layer, with liquid water and salt penetrating only 1 cm into a 10 cm thick layer over 50 days. The leonardite layer also reduced appearent soil evaporative loss rates by 63% during the first 10 days and then by 92% during the following 40 days. A decrease in hydrophobicity was evidence after repeated cyclical infiltration and drying cycles. However, this decrease was observed after the infiltrating water exceeded the total annual precipitation of western North Dakota by several times. Soil disturbance induced consistent differences in soil moisture and temperature as expected throughout soybean and wheat cropping systems in North Dakota. Soil microbial community structures appeared to display some evidence of cyclical characteristics based on spectral density analysis of their temporal patterns. Notably, soil microbial biomass appeared to have cyclical patterns at 15 and 30 day periods. These cycles were more pronounced when microbial biomass was spatially detrended using corresponding total organic carbon data. However, no substantial fluctuations or shifts due to precipitation events were observed for fungal:bacteria ratios, rhizosphere bacteria (gram -), or a rhizosphere stress index (i.e., ratio cyclopropane to monounsaturated phospholipid fatty acids), which varied by 50%, 12%, and 12%, respectively. Remediation of oil contaminated soils via thermo-desorption in the Bakken region of North Dakota did not alter the surface energy balance. When net radiation, ground, sensible, and latent heat fluxes were compared to native topsoil, the cumulative daytime fluxes were within 6, 20, 8, and 7 MJ m-2 d-1 over an 18 day period.

Washington State University (Markus Flury and Joan Wu): Demonstrated that even in the driest places on Earth, microbial communities not only survive, but can form thriving in situ microbial communities; Showed that interfacial processes can lead to convective flow; Showed that colloidal biochar can form stable suspensions in typical soil solutions; Showed that freezing and drying do not necessarily accelerate the leaching of metals from biosolids. Application of biosolids in fall should therefore not cause enhanced leaching of metals out of land-applied biosolids; Tested several bioretention media for optimal removal of nitrate, copper, and phosphorus from stormwater; Our results of the microplastic experiments indicate that flotation generally works to separate plastic nano- and microbeads in a solution, with the challenge being to quantitatively extract nano- and microbeads from a biosolids or soil matrix. Samples high in organic matter content require removal of the organic matter, but the common method of H2O2 oxidation leads to poor extraction efficiencies for nano- and microbeads; Developed methods to test ingestion and translocation of plastic by earthworms. Petri dish and mesocosms methods were developed and tested; Completed a fourth field seasons evaluating the effects of biodegradable plastic mulches on soil quality; Developed a GIS-based, landscape-scale decision-support system for determining the placement of GSI (green stormwater infrastructure) and selecting the most suitable types of GSI that will maximize their functions in pollution- and flood control.

University of Wyoming (Thijs Kelleners). Hydrology PhD student Andrew Fullhart successfully defended his dissertation entitled: Modeling of water and energy fluxes in snow-dominated mountain ecosystems. One paper was published in Soil Science Society of America Journal. Two papers are in review with Hydrological Processes. Andrew is currently working as a postdoc at the USDA-ARS Southwest Watershed Research Center.

Montana State University (Paul C. Stoy): We have now collected or contributed to the collection of 15 site-years of eddy covariance observations across different agricultural treatments in Montana including bare soil (summer fallow), dryland spring and winter wheat, flood irrigated barley, and pivot irrigated canola and wheat.

Virginia Tech (Ryan Stewart): Quantified effects of mineral water repellency on vapor sorption and exchange; Quantified effects of the water repellent layers (including severity, persistence, and layer depth) on infiltration rates in soils after wildfire; Quantified changes in soil aggregate stability, soil nutrient availability, and water quality (e.g., dissolved organic carbon, turbidity) due to prescribed fire in a first-order forested watershed; Quantified water fluxes in urban settings by comparing tree pits with and without trees and with and without permeable pavement covers; Developed and tested Arduino-based sensors to measure: 1) water turbidity, including within stream systems and under laboratory conditions; and 2) soil respiration and activity using a modified “burst test” and a low-cost infrared gas analyzer; Identified feedbacks between infiltration and soil water repellency that can be useful for forest managers while assessing and alleviating post-fire effects on hydrological processes in forested catchments; Demonstrated that soil water repellency can reduce vapor sorption and enhance evaporative losses; this information can be important to agricultural producers working in semi-arid regions, that may wish to use techniques to ameliorate water repellency in their soils (e.g., using surfactants).

University of Wisconsin Madison (Jingyi Huang): Mapped soil organic carbon stock dynamics across the whole Wisconsin from 1850 to 2050 and demonstrated that land use change, improved agricultural management and climate change were the main drivers that affected the soil organic carbon stocks. The work has been submitted to peer-reviewed journals for publication; Mapped soil water dynamics over the growing seasons from 2016 to 2018 and demonstrated that soil texture, climate and irrigation practices played different roles in determining the spatial and temporal variations in soil water content at the field, farm and catchment scales. The work has been submitted to peer-reviewed journals for publication; Developing a method to use remote sensing technology (Sentinel-1) for monitoring and mapping soil water dynamics across 2,660 ha in the croplands of Central Sands, Wisconsin. The work has been submitted to peer-reviewed journals for publication; Developing a method to use digital camera and image analysis for quantifying coarse fragments and the shape characteristics in soil samples. The work has been accepted for publication in Eurasian Soil Science.

Michigan State University (Wei Zhang): Completed the project on physiochemical controls of pharmaceutical transport in soil and water environment; Completed the project on physical mechanisms of water film-mediated microbial pathogen attachment and detachment on fresh vegetable surfaces; Participated the science exchange and cooperation with the Chinese delegation on ecological and circulatory agricultural technologies.

**Impacts**

University of Arizona (Markus Tuller and Ebrahim Babaeian): In 2018 our advanced X-Ray CT segmentation algorithms that we developed in past years have aided numerous other researchers with projects that utilize X-Ray CT for soil and porous media research.

University of California-Riverside (Hoori Ajami): This research provides a set of numerical model codes for understanding and quantifying surface water-groundwater exchange at large catchment scales. The numerical models will allow assessment of climate variability and management decisions on catchment water balance. This information will be valuable for sustainable water resource management in California and elsewhere.

University of California-Riverside (Jirka Simunek): The HYDRUS models are being constantly updated based on the basic research carried out by the W3188 group. The HYDRUS-1D model was downloaded more than ten thousand times in 2018 and over twenty five thousand HYDRUS users from all over the world registered at the HYDRUS website. We continue supporting all these HYDRUS users from USA and around the world at the HYDRUS website using various tools, such as Discussion forums, FAQ sections, and by continuously updating and expanding a library of HYDRUS projects. Additionally, we have added capabilities to rigorously consider processes in the soil to the very widely used modeling tools, such as MODFLOW and DSSAT. These two tools are used by thousands of users to simulate flow in the groundwater and the growth of multiple agricultural crops, respectively. Finally, in 2018 we have offered short courses on how to use HYDRUS models at a) Czech University of Life Sciences, Prague, Czech Republic, b) Colorado School of Mines, Golden, CO, c) the Research Center for Eco-Environmental Sciences, Chinese Academy of Science, Beijing, Peoples Republic of China, d) Tokyo University of Agriculture and Technology, Department of Ecoregion Science, Tokyo, Japan, e) WASCAL Headquarters, Accra, Ghana, NC. About 150 students participated in these short courses.

University of California-Riverside (Laoshen Wu): The new models allow to more accurately predict gas, water and solute transport in porous media; Assessment of best management practices improves water use efficiency and protects water quality.

University of Delaware (Yan Jin): The long-term goals of the rhizosphere study include: 1) to provide a more complete understanding of plant-soil-microbe interactions in the root zone and their influence on water retention and hydraulic properties and 2) to learn the fundamentals of the important feedback among plants, microbes and soil; and 3) to explore the application potential of using PGPR as an alternative (to plant genetic engineering and breeding) for reducing plant drought stress tolerance and meeting the challenge of producing adequate food for the growing world population under the changing climate. Couple neutron and x-ray tomography investigation has the potential to yield high resolution, real-time images of multiphase systems thus a powerful tool for studying multiphase flow problems. Colloid and colloidal OC study at both field and laboratory scales have important implications on C cycling and contaminate transport. Identifying preferential flow paths as biological hotspots may lead to more complete understanding on the role of preferential flow in not only water and contaminate transport but also in biogeochemical interactions in porous media.

Iowa State University (Robert Horton) and North Carolina State University (Joshua Heitman): The development of new sensors and methods able to determine soil water content, bulk density, hydraulic conductivity, and thermal diffusivity will aid numerous modelers and experimentalists studying soil water, heat, and solute transport.

University of Kentucky (Ole Wendroth): We helped a farmer to irrigate more efficiently by lowering the irrigation rate and avoiding surface water runoff in parts of his field.

New Mexico State University (Manoj Shukla): The availability of surface water for irrigation is not sufficient for sustaining agriculture in the southern New Mexico. Increasingly saline groundwater is used for irrigation, which can have severe consequences on the soil quality and sustainability of agriculture. My research groups work on the use of brackish groundwater and RO concentrate for growing chile peppers and halophytes has identified the potential problems and opportunities. This has generated a lot of interest in the state and has been widely published by various Newspapers. Our strategy towards developing new irrigation scheduling protocols for low cost reuse of RO concentrate for agriculture in marginal lands, greenhouses, and along desert margins can be a key for sustaining agriculture in water starved southern New Mexico as well as other similar arid areas. These efforts showed the potential of low cost reuse of RO concentrate locally for ensuring food security as well as desertification control.

Oregon State University (Maria Dragila): Understanding bio-water-dynamics of sandy soil will provide the mechanistic foundation for improved irrigation methods that can reduce water usage and costs; reduce the transfer of contaminants to the water table; reduce water runoff and its associated erosion; and improve overall crop success in irrigated semi-arid land agriculture; Understanding the erosional evolution of microfractures into larger conduit-carbonate-units

provides a basis for the theoretical framework of Karst land evolution. Karst geological units extend across terrain associated with ~40% of the world’s aquifers. Where these lands are associated with agricultural activity or underlie populated areas, they present serious challenges for water quality management; Determining the feasibility and practicality of solarization in the Pacific Northwest could offer growers an important alternative for crop protection against weed and pest invasion where pesticides/herbicides are not available or allowed. Solarization also provides alternatives to chemical use by methods that are less harmful to the overall ecosystem.

Oregon State University (Carlos Ochoa): Understanding the dynamics of soil water transport through the vadose zone and into the shallow aquifer in rangeland ecosystems provides critical information regarding the potential for shallow groundwater recharge in arid and semiarid landscapes of the Pacific North West; Understanding the dynamics of soil water transport through the vadose zone and into the shallow aquifer in agroecosystems connected to riparian areas helps understanding potential hydrologic flow paths that may affect water quality in the stream.

Nevada, Desert Research Institute (Markus Berli): Improved our understanding of the water dynamics of desert soils and their impact on desert hydrology. In particular with respect to soils of reduced wettability and structural stability.

North Dakota State University (Aaron Daigh and Francis Casey). The development and evaluation of methods to efficiently remediate brine and oil spills and then return those soils back to an ecologically and economically productive state is of critical importance in regions with oil and gas extraction. The research program at North Dakota State University provides evidence-based knowledge and information transfer to stakeholders of such methods to better inform land managers and legislature. Basic knowledge of salt, estrogen, water, and heat transport, some coupled with soil microbial response, was produced and new knowledge transferred to stakeholders in numerous formats. These works will increase stakeholder’s ability to successfully ameliorate and remove contaminants from sensitive or working landscapes.

Washington State University (Markus Flury and Joan Wu): It was an unresolved question whether microorganisms in the most arid environments on Earth are thriving under such extreme conditions or they are just dead or dying remains of blown in microorganisms. Our findings demonstrated that microorganisms indeed form thriving communities. This indicates that life on other planetary bodies like Mars likely can survive in harsh environments.

University of Wyoming (Thijs Kelleners): Snow-dominated ecosystems in the Rocky Mountains are an important source of water in the western US, supporting agriculture, cities, and industry. Increasingly, numerical computer simulation models describing water flow and heat transport are used at the plot, hillslope, and catchment scales to better understand streamflow generation, and to predict changes in streamflow under future scenarios. Past, current, and future work at the University of Wyoming Soil Physics Laboratory is focused on improving the description of cold region processes such as snow accumulation/melt and soil water freeze/thaw in these models. This is accomplished by developing and testing new algorithms using long-term monitoring data from federal agencies as well as data collected by the University of Wyoming, including the Soil Physics Laboratory.

Texas A&M University (Binayak Mohanty): Research efforts have shed new light in soil moisture, temperature, and hydrologic flux dynamics at multiple space-time scales. Our fundamental discoveries, new modeling and scaling tools, and advanced satellite platforms will play key role in more accurate agricultural resource management, improved hydrologic predictions, strategic field monitoring schemes, better adoption to climate change, and long-term soil and water security and sustainability.

Montana State University (Paul C. Stoy): We have studied the role of agricultural changes on water and energy fluxes that impact the regional climate of the U.S. Northern Plains and Canadian Prairie Provinces – a region that we call the ‘Northern North American Great Plains’. Results demonstrate that convective precipitation is now more likely as the transition from wheat / summer fallow (bare soil) rotations to alternate cropping sequences across millions of hectares have increased water flux to the atmosphere and decreased sensible heat flux.

Virginia Tech (Ryan Stewart): The incidence, frequency, and duration of large wildfires have increased in recent years, and are projected to continue increasing during the coming decades. In coordination with the United States Forest Service and North Carolina State Parks, we performed two studies related to fire effects on soil properties and hydrological processes. The results from this study, now being summarized in four manuscripts in development, provide new understanding of interactions between fire severity, soil water repellency, soil water content, and infiltration dynamics.

Limited funding resources and critical deficiencies in environmental sensing necessitates the development of low-cost sensors capable of high-resolution measurements. To this end, we have been working on integrating sensors into the Arduino processing platform to provide accurate yet affordable measurements. We have developed and tested turbidity sensors to measure in-stream turbidity as well as dispersed soil particle characteristics, and have created a new methodology to analyze microbial respiration and activity in soils using an infrared gas analyzer. These results are now being compiled into publications and presentations, and will be made available to the scientific community and public via a project website.

University of Wisconsin Madison (Jingyi Huang): The spatial and temporal variation in soil water and organic carbon contents are important to farmers and land managers in Wisconsin. The nature of sandy aquafer in Central Wisconsin and the heterogeneity of soil and landscape across the entire Wisconsin hinder the agricultural production and soil and water resources management. My research group works on the use of various proximal and remote sensor technologies, soil and hydrological models, and spatial and temporal analysis to characterize the spatial and temporal variations in soil properties and address various problems related to soil and water management. This has led to a number of meetings/talks held between the local growers (e.g. Wisconsin Potato & Vegetable Growers Association) and our teams at University of Wisconsin-Madison. These efforts showed the potential of sustainable management of soil water and carbon from the field to catchment scales.

Michigan State University (Wei Zhang): Knowledge gained will improve knowledge on fate and risks of contaminants in soil, water and food crops, and contribute to better strategies for protecting ecosystem and human health.

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