NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences -2022
NNH22ZDA001N-ECOSTRESS
A.33 ECOSTRESSS Science and Applications Team
Abstracts of Selected Proposals

The National Aeronautics and Space Administration (NASA) Science Mission Directorate solicited proposals for membership on the science and applications team for the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) instrument on the International Space Station (ISS). This team supports basic research and analysis activities as well as applications activities associated with the production, validation, and utilization of ECOSTRESS data products. NASA received a total of 54 proposals and has selected 15 for team membership at this time. The total funding to be provided for these investigations is approximately $6 million over thirty-six months. The investigations selected are listed below. The Principal Investigator, institution, investigation title, and project summary are provided. Co-investigators are not listed here.

Scott Allen/University of Nevada, Reno
Water-Balance Succession Following Wildfires in Great-Basin Shrublands
22-ESAT22-0052

Objectives: This proposed research will enhance understanding of the progression of evapotranspiration (ET) following severe wildfires in dry, shrubland landscapes. In the western US, intensifying wildfire regimes imply that an increasing fraction of the Western US will exist in a post-fire recovery state at any given time. Recent studies have shown that ET can decrease by 40% and streamflow can increase by 150% following wildfires in western forests. We, however, lack insights on fires effects on ET and water yields in the arid shrubland ecosystems that dominate the Great Basin region of the western US. This lack is not surprising because elsewhere ET is commonly quantified by watershed water-balance closure (ET = precipitation stream discharge), but that approach is less practical in Great Basin drylands where a) flow variability challenges accurate gauging, b) the importance of subsurface flows invalidate typical water-balance-closure assumptions, and c) few gauges exist in small watersheds (where burned areas could represent a substantial proportion of the watershed). Thus, alternative methods are needed. ECOSTRESS provides a novel opportunity to estimate ET at scales that can be matched to burned areas (or to the footprint areas of flux tower ET measurements). We propose using ECOSTRESS to estimate ET across previously burned pixels to compose a post-fire chronosequence, to quantify the effect of age since fire on ET in under-studied and under-monitored Great-Basin shrubland systems.

Methods: Regions will be identified where shrublands are coincident with severe wildfires over the past 38 years (from Monitoring Trends in Burn Severity). For all pixels in those regions, ECOSTRESS ET products will be retrieved and compiled to generate time series capturing diurnal, seasonal, and annual ET variations across a range of post-fire ages. To validate ET estimates, ECOSTRESS data will be compared to measurements from existing flux towers and temporary energy-balance systems that we will deploy. Using the resulting 38-year chronosequence of post-fire ET in a space-for-time analysis will enable us to test our primary hypothesis, that ET will increase with time since fire. We expect this ET-age relationship to also depend on climate, topography, and vegetation structure, which will be evaluated as covariates using interpolated and remotely sensed data. Given that topography, climate, and vegetation structure also control productivity in water-limited ecosystems, we will test a secondary hypothesis that productivity determines the rate at which ET approaches pre-fire conditions (inferred using unburned control pixels with paired site characteristics). Lastly, we hypothesize that water stress will increasingly inhibit ET as vegetation cover increases, implying decreases in ET per vegetation amount and that vegetation structure alone will not effectively predict ET; we will test whether ET plateaus at younger ages than does productivity, and whether plant water stress becomes more frequent as cover increases.

Significance: This proposed study will yield a first quantification of long-term fire effects on ET across the Great Basin. Additionally, our evaluation of ECOSTRESS ET using ground-based measurements of ET (and of evaporation and transpiration) in sparse vegetation should improve understanding of the performance of ECOSTRESS ET in quantifying ET and its partitioning in such systems, which otherwise remains uncertain. Lastly, the testing of site- and plant-level controls over ET should yield an improved ability to predict ET in shrublands from widely available site characteristic data or other remotely sensed data that capture key structural and physiological traits. Applications of such findings could be crucially important for managing ecosystems and water resources, given hypothesized increasing water yields across the Great Basin.

Devendra Amatya/USDA Forest Service
Towards Enhancements in ECOSTRESS Products for Quantifying Ecosystem Evapotranspiration and its Partitioning for Key Southern US Forests
22-ESAT22-0056

Forests are a major land cover on the southeastern U.S., providing important ecosystem services (e.g., timber, clean water, and carbon sequestration) that support economies in the region and beyond. During the last century, most of the longleaf pine (LLP) ecosystems were replaced by highly productive loblolly (LOB) pine plantations for timber production. Recent forest management strategies aim at increasing forest resiliency to climate change impacts (e.g., drought, wildland fire, invasive species) and enhancing ecosystem services such as water supply and wildlife habitat. Forest ET is a key variable to assess not only hydrological response to climate and land use change, but also forest productivity and health and wild fire and drought risks. Although forest hydrology, including evapotranspiration (ET), has been documented well for the southern US forests, there is a lack of knowledge and availability of modeling tools to describe their interactions among energy, water, and carbon cycles for the LLP in particular. Such information are crucial for our understanding of forest ecosystem functions and evaluating the benefits of forest restoration, especially under a changing climate.
We intend to improve NASA s recent ECOSTRESS products (Levels 2, 3, and 4) to enhance the estimation of ET, and its components: tree transpiration (T), canopy interception (EI), and forest floor evaporation (FFE) over the key southern forests. We hypothesize that ECOSTRESS ET products will be able to 1) accurately quantify seasonal ET of various forest types, 2) adequately

differentiate ET between forest types, 3) detect ET response to forest management (e.g., thinning and harvesting), 4) differentiate partitioned components of ET among pine stands, and 5) detect key environmental factors controlling the seasonal ET and T that vary significantly with forest types. Within the hypotheses (1 and 2) we will also investigate if the LLP forests have lower ET than either of the LOB pine and deciduous forests, and if forest ET rates are stable during wet or drought years in the region.
The specific objectives of this study are to compare ECOSTRESS ET to eddy covariance ET measured at 15 sites representing a range of species composition, stand age, and management. We will quantify and compare the ET for various forest types and stands to test the hypotheses 1-to-3. Secondly, we will test hypothesis (4) and evaluate ECOSTRESS s partitioned T data using T estimated from sap flow measurements from two sites in South Carolina, and subsequently improve ECOSTRESS ET partitioning using an energy balance model. Thirdly, we will improve the spatiotemporal resolution of ECOSTRESS products to daily 30-m resolution with data fusion method and use the daily outputs to identify major predictive factors controlling ET, T, and FFE using the relationships of ECOSTRESS products with vegetation, soil moisture, and climatic variables (hypothesis 5). In addition, we will compare ECOSTRESS ET products to modeled ET and its components by the WaSSI ecohydrological model driven by climate, soil, and vegetation data, for additional validation.
Overall, our project will address three ECOSTRESS Research Priorities by combining ECOSTRESS products with other imagery data products, and adopting innovative data fusion approaches. The improved estimation of forest ET metrics will make significant contribution to model development and better understanding of ecosystem response related to its functions and services of Southern US Forests. In addition, the project will create data products and an optional related standalone software, to rapidly assess and respond to threats to ecosystem services, for a potential use by end-users, such as, forest managers, stakeholders, landowners, researchers, and state and federal agencies. This project will also provide unique education, training, and professional development opportunities for graduate students and post-doctoral scientists.

Joshua Fisher/Chapman University
I.C.E. C.R.E.A.M.: Integrating Communication of ECOSTRESS into Community Research, Education, Applications, and Media
22-ESAT22-0008

How do we empower the next generation to use ECOSTRESS and NASA data to engage in observing and diagnosing our planet? We present a non-traditional, science and applications-focused proposal that integrates research, education, and multimedia science communication for ECOSTRESS. One of the most effective means of growing the impact of missions such as ECOSTRESS is to conduct and communicate research directly through education using emerging current events. New and ongoing climate events such as fires, droughts, heat waves, and volcanic eruptions are challenging to study ahead of the timeline for a typical funding cycle, yet make for engaging educational opportunities, have high media salience, and result in high impact papers. Here, we turn the traditional proposal paradigm around, and propose ahead of time to capture these events through education, research, and communication.

First, we will develop a project-based learning course focused purely on ECOSTRESS. Every week, each student will be required to identify an ECOSTRESS-related event that recently occurred, download ECOSTRESS data, create a map visualizing the event, and write a media-friendly summary. These will be delivered on a weekly basis to the ECOSTRESS Applications Lead (Co-I Lee) at JPL for incorporation onto the ECOSTRESS website and to media channels as appropriate (e.g., JPL media, NASA Earth Observatory/Image of the Day). As students become particularly interested in a specific event, they pivot to research mode, conducting an in-depth analysis of the event. The research will continue to completion (i.e., journal submission) into the next term as independent research studies, resulting in multiple publications from the project.

After piloting the first year of the course, we extend it to 11 additional universities in collaboration with partners committed to adding this class in year 2. Our focus is on early career faculty at Historically Black Colleges and Universities (HBCUs), Hispanic-serving institutions, and minority-serving institutions. Ultimately, we expect to train approximately 150-200 students on ECOSTRESS. We will coordinate virtual science and applications talks across institutions from ECOSTRESS Science and Applications Team members, as well as trainings in science communication led by Mongabay (Rhett Butler), media relations led by Chapman University (Susan Paterno), and data visualization led by JPL (Scott Davidoff). All tutorials and talks will be made publicly available to become a resource for any institution. This second year of projects culminates in an ECOSTRESS student meetup for select students from each institution at the ECOSTRESS Science and Applications Team meeting, where they will present their work.

Finally, all our educational work is supported by an external assessment and evaluation by the Institute for Learning Innovation (ILI; Co-I Verbeke). ILI will carry out detailed pre- and post-course surveys and interviews throughout the project duration to inform revision of the materials, and to determine how engaging in such coursework aids in the development of science interest and identity, with particular emphasis on students from minority-serving institutions. These results will contribute to the pedagogical forefront of how we can engage remote sensing for authentic project-based learning to improve the recruitment and retention of new scientists in the field. We expect that our project will significantly advance ECOSTRESS science, applications, and research, as well as provide a framework to expand educational lessons-learned into subsequent missions.

Bo-Cai Gao/Naval Research Laboratory
Quantifying ECOSTRESS LST Errors Resulting From Unmasked Cirrus Clouds and Developing Techniques to Remove Thin Cirrus Effects In Surface Temperature Data Products
22-ESAT22-0003

Evapotranspiration (ET) is one of the key scientific data products by the ECOSTRESS mission. ET is a Level 3 product derived from a combination of Level 2 Land Surface Temperature (LST) product and data from other sources. LST and SST data products have already been evaluated by several researchers for very clear scenes. It was found that the LST and SST products were biased low by about 1 K in comparison with products from MODIS, VIIRS, and Landsat data.

When the ECOSTRESS LST products were used for generating ET products, it was found that the LST products provided useful information, but were limited by cloud contamination, mainly by the sub-visual cirrus. The ECOSTRESS bands located in IR atmospheric windows did not permit accurate cirrus masking, and resulted in much smaller retrieved LSTs. Based on our preliminary analysis, we found that, for cirrus-contaminated ECOSTRESS pixels, the LST values can be biased low by 10 K or more, which could transfer to even higher biases in ET products. Here, we propose to make a comprehensive evaluation of the ECOSTRESS LST and cloud mask products using nearly coincident MODIS, VIIRS, and Landsat OLI data, to develop an algorithm for cirrus detection and correction, and to evaluate impacts of these correction measures on ET products. Specifically, we plan to:

1) Quantify errors in ECOSTRESS LST and SST data products resulting from unmasked thin cirrus clouds. MODIS, VIIRS, and Landsat OLI instruments are all equipped with narrow bands centered near 1.38 micron for cirrus detections. The thin cirrus effects on IR bands in 8 12 micron region can be quantified using correlations between the 1.38-micron band reflectances and brightness temperatures (BTs) of IR bands.

2) Develop an algorithm for correcting LST errors for pixels contaminated by thin cirrus clouds with 1.38-micron band reflectances less than 5%. The algorithm is expected to be similar to the current operational MODIS cirrus reflectance algorithm at a NASA DAAC. The thin cirrus-corrected LST data products would be useful as input to ET algorithms and for generating more spatially contiguous ET products.

3) Develop new techniques for detecting thin cirrus contaminated pixels using not only IR bands located in atmospheric window regions, but also IR bands near 4.5 or 13.2 micron, where the bands have atmospheric CO2 absorption effects. The two CO2 bands are subsets of the CO2-slicing bands often used by the atmospheric science community for remote sensing of atmospheric temperatures. We will demonstrate that the two IR bands can be very effective in detecting thin cirrus clouds.

4) Evaluate the impacts of unmasked thin cirrus on ET products from the ALEXI/DisALEXI model. ET will be retrieved using uncorrected and corrected LST products. We will quantify the impact of cirrus detection on ET accuracy using available flux tower observation data at daily to monthly time steps. Improvement will be quantified by land-cover type and climate region within the continental U.S.

We expect that the results from the proposed task 2 will have significant ramifications for the development of new LST retrieval algorithms for missions collecting imaging data from both the visible to shortwave IR spectral region (0.4-2.5 micron) and the IR emission region (3.5-15 micron), such as Landsat Next and Surface Biology and Geology. The results from the proposed task 3 will provide reference data for possible future thermal free-flying sensor missions, using information from other satellites having both IR atmospheric window bands and some CO2-slicing bands centered near 13.2 or 4.6 micron for improved cirrus detection and masking over land. The proposed work will improve the ECOSTRESS surface temperature data quality and benefit the studies using surface temperature for socioeconomic and health applications, for vegetation stress detection, as well as for water resource management.

Kaiyu Guan/University of Illinois, Urbana-Champaign
Redefining Droughts for the U.S. Corn Belt: Quantification of the Impacts of Soil Aridity and Atmospheric Aridity on Agroecosystems Using ECOSTRESS LST and ET Products
22-ESAT22-0049

Agricultural droughts can lead to significant economic loss and food insecurity. Conventionally, agricultural droughts have been characterized by deficits in soil moisture (SM) (i.e. soil water supply), but recent studies have found that the high atmospheric water demand, characterized by vapor pressure deficit (VPD), also plays important roles. Fundamentally, agricultural drought is related to the crop responses through stomatal conductance, which then propagates to photosynthesis, water use, and crop yield. How to properly and comprehensively characterize the impacts of supply-limited and demand-limited droughts on crop stomatal conductance is the key science question to be addressed by the scientific community.

ECOSTRESS LST data and energy-balance-based ET product (e.g. ECO3ETALEXIU) provide an unprecedented opportunity to address the above question, due to the high spatial and diurnal information of thermal information, which resolves ET from the surface energy balance. We hypothesize that these new ECOSTRESS data provides an independent way to constrain as well as derive canopy stomatal conductance, which can be used to better characterize supply-limited and demand-supply droughts across space and time.

The objective of this proposal is to quantify the impacts of soil aridity and atmospheric aridity on agroecosystems in the Midwest using ECOSTRESS LST and ET products. We aim to carry out three corresponding tasks. Task 1: Estimate canopy and stomatal conductance from ECOSTRESS data in the U.S. Midwest. We will integrate ECOSTRESS LST and ET products and other satellite data (GOES-R and HLS) with a carbon-water-coupled biophysical model BESS to monitor conductance. Task 2: Assess the coupling and decoupling between SM and VPD in the U.S. Midwest. We will conduct spatially and temporally explicit statistical analysis to analyze the relationships between SM, VPD and canopy and stomatal conductance. Task 3: Assess the supply-limited and demand-limited droughts in the U.S. Midwest. We will use the biophysical model BESS to detangle the two types of water stress on canopy and stomatal conductance.

We expect the outcome from the proposed work will significantly advance the science objectives of the NASA ECOSTRESS mission. Scientifically, by answering Question 2 and 3, this proposed study will directly address two of the three ECOSTRESS Science Objectives: 1. Identify critical thresholds of water use and water stress in key climate-sensitive biomes , and 2. Detect the timing, location, and predictive factors leading to plant-water uptake decline and/or cessation over the diurnal cycle . Technically, by answering Question 1, this proposed study will directly fit the area encouraged by the solicitation: new research and innovative analyses using ECOSTRESS data products alone or in combination with data products from other sensors that advance the understanding of the climate system, the water cycle, the carbon cycle, ecosystems and their biodiversity, and/or extreme weather events . Practically, the derived new dataset, canopy and stomatal conductance in the U.S. Midwest, can be used to guide irrigation practices since we found that stomatal conductance is the most effective plant-centric metrics in improving irrigation efficacy (Zhang et al., 2021a). Finally, this proposed study will improve our capacity of modeling and monitoring of hydrological cycles, terrestrial ecosystems, climate variability and change recommended by the 2017 Decadal Strategy for Earth Observation from Space .

Gregory Halverson/Jet Propulsion Laboratory
Thermally Sensitive ECOSTRESS Evapotranspiration Model Ensemble Evaluation and Development
22-ESAT22-0012

The ECOSTRESS mission has introduced the unique remote sensing capability of observing diurnal, fine spatial resolution land surface temperature (LST) images, giving us a new opportunity to observe the mid-day thermal stress of plants in the ECOSTRESS Level 2 LSTE product. The ECOSTRESS mission processes these temperature images into the ECOSTRESS Level 3 PT-JPL Evapotranspiration (ET) product in order to support the second mission objective: detecting the timing, location, and predictive factors leading to plant-water uptake decline and cessation over the diurnal cycle. To support this objective, the ET estimate must be thermally sensitive to capture the mid-day temperature increase of heat-stressed plants closing their stomata as an ET decrease. This thermally sensitive ET estimate will facilitate the first high resolution remotely sensed maps of stomatal closure.

The PT-JPL model was selected to produce the instantaneous ET estimate for the ECOSTRESS Level 3 products due to its established accuracy compared to eddy covariance data and its capability to partition transpiration in its instantaneous ET calculation. It is this transpiration component, separate from soil evaporation and other contributing factors to ET, that should provide these maps of stomatal closure, when analyzed over the diurnal cycle. But the transpiration partitioning method utilized in PT-JPL is heavily dependent on remotely sensed normalized difference vegetation index (NDVI). Since the ECOSTRESS sensor only observes longwave infrared, these ancillary fine resolution NDVI images have to be imported from shortwave sensors, like Landsat and Sentinel. This temporal lag between NDVI and LST opens the possibility of abrupt changes in vegetation, such as harvest, logging, fire, and senescence to not be accurately reflected in the ECOSTRESS PT-JPL ET estimate. An ideal processing workflow for ECOSTRESS ET would be more sensitive to the ECOSTRESS observation of LST than to ancillary estimates of corresponding NDVI.

This project will develop an improved ECOSTRESS Level 3 ET processing workflow, leveraging the full ensemble of ET models used at the Jet Propulsion Laboratory, including PT-JPL-SM, BESS, MOD16, DisALEXI-JPL, and STIC, with the goal of producing a thermally sensitive transpiration estimate to fully support the second ECOSTRESS mission objective. Our approach to this problem will have two main objectives:
1. Sensitivity analysis of the existing JPL ET models to determine the sensitivity of changes in ET to changes in LST for each of the existing models
2. Develop a hybrid ET workflow combining the strengths of the existing models to produce a thermally sensitive ET estimate

Brian Hornbuckle/Iowa State University, Ames
Remotely Sensing Crop Stress in the U.S. Corn Belt
22-ESAT22-0023

A recent paper (https://doi.org/10.1029/2021GL097697) claims that NASA SMAP soil moisture can identify plant water stress because surface and root-zone soil moisture are hydraulically linked. We reject this general finding and argue that in the U.S. Corn Belt artificial tile drainage and shallow ground water tables break this hydraulic linkage. Consequently, the only way to anticipate and detect the occurrence of crop water stress in the Corn Belt via satellite remote sensing is to infer canopy stomatal conductance which controls transpiration and water loss. This can be done in three ways, and possibly a fourth. First, low stomatal conductance reduces actual evapotranspiration below potential evapotranspiration. Second, reduced evapotranspiration decreases latent heat flux, which necessitates higher crop temperatures that balance the land surface energy budget through increased sensible heat flux and emitted longwave radiation. This increase in temperature can be observed using thermal sensors such as those on ECOSTRESS. Third, the diurnal change in crop temperature will have a different signature when crops start to become stressed for water. ECOSTRESS is uniquely able to discover these changes. Finally, we speculate that there is in fact a way to use SMAP microwave observations to detect crop water stress, but by monitoring diurnal variations of water within crop tissue and not soil moisture.

Our long-term goal is to determine how crops (plants managed by humans to produce food, feed, fiber, or fuel) and cropping systems will be affected by global environmental change. Our objective in this proposal is to refine and develop new techniques of remotely sensing crop water stress, and its precursors, in the Corn Belt. We hypothesize that stomatal behavior associated with crop water stress results in diurnal temperature changes that can uniquely be observed by ECOSTRESS, and potentially diurnal changes in crop tissue water that can be discerned by SMAP. Our rationale for this proposal is that reliable satellite crop water stress detection techniques in the Corn Belt will enable best management of food, water, and energy systems in this important region. We are uniquely qualified to conduct this investigation. PI Hornbuckle is an expert in remote sensing of soil and vegetation. Co-I Drewry is an ecohydrologist and crop modeler. Co-I Aslan-Sungur s expertise is in measuring evapotranspiration in situ. Collaborator VanLoocke maintains a heavily-instrumented field site at which we would perform model and product validation experiments.

This proposal is innovative because we will explore new satellite detection methods of crop water stress, including whether it is possible to produce a combined ECOSTRESS and SMAP crop water stress product that would have better spatial and temporal qualities than existing products. The expected outcome of our work is a better understanding of estimates of evapotranspiration, as well as diurnal changes in both crop temperatures and crop tissue water, which could be exploited with satellite remote sensing to monitor crop water stress in the Corn Belt. Our work is important because crop water stress lowers crop yield by restricting photosynthesis, and changes the balance of sensible and latent heat flux to the atmosphere. Since plants link the water, carbon, and energy cycles, our proposal is responsive to the Decadal Survey priority "Enabling advances in the study of the water, carbon, and energy cycles, especially on those topics that deal with the intersections of these cycles." Our proposal is also responsive to the following specific types of proposals solicited: "Efforts that advance the three ECOSTRESS science objectives" (detect the timing, location, and predictive factors leading to plant water uptake decline and/or cessation over the diurnal cycle); and "New research and innovative analyses using ECOSTRESS data products alone or in combination with data products from other sensors."

Leiqiu Hu/University of Alabama, Huntsville
Harnessing ECOSTRESS to Assess the Diurnal Dynamics of the Urban Thermal Environments and Their Impacts on Heat-Related Health Risks
22-ESAT22-0032

The thermal regime is the fundamental for all forms of life, including humans, animals, and plants. Widespread and rapid urbanization and land change have transformed landscapes with consequences at local-to-global scales. Changes in the physical environment, from surface cover to morphology, reshape the local thermal patterns and alter urban ecosystems. Urban landscapes feature highly diverse and spatially complex thermal environments compared to most natural, semi-natural, and cultivated landscapes (e.g., forests and cropland). These landscapes include a mosaic of impervious hardscapes as well as lawns, shrubs, and trees that themselves can be highly dynamic based on urban forestry practices, irrigation restrictions, drought, and other factors. Regional climate and urban properties can have interactive and compounding effects on the urban thermal environment, often known as an urban heat island effect. However, most often city-scale temperature gradients (as intensity) using either land surface temperature (LST) or air temperature (Tair) are analyzed in ways that offer little direct understanding of how spatiotemporal dynamics of built environments and human activities (tree planting and irrigation) impact intra-urban thermal patterns as well as their impact on heat-related health risks. Providing both high spatial resolution and high temporal frequency due to its low-Earth orbit, ECOSTRESS offers unprecedented space-borne thermal observations to improve our current understanding of diurnal intra-urban thermal environments, and more importantly, their direct impacts on urban populations.

This proposed project is in line with the ECOSTRESS science objectives, specifically detect the timing, location, and predictive factors leading to plant-water uptake declines and/or cessation over the diurnal cycle and the science and application team s mission on application of ECOSTRESS products in combination with data products from other sensors for water management, disaster response and mitigation, public health& in highly urbanized regions. Specifically, (1) we will develop diurnal-fully-resolved ECOSTRESS-based data to characterize the intra-urban thermal environments, not limited to radiant temperature (LST), but also key biometeorological variables simultaneously, including air temperature (Tair) and humidity at the ECOSTRESS scale. (2) Leveraging the proposed new ECOSTRESS-based thermal profiles, the project aims to improve the understanding of how urban vegetation and built environments modulate the spatiotemporal variations of heat. (3) The project will then incorporate ECOSTRESS-based diurnal data to investigate urban heat exposure and risks for urban populations.

The project will focus on the Las Vegas metropolitan region which is reported as the fastest warming city in the US. The project team will also collaborate with the local nonprofit organization, Make The Road Nevada, to help understand local heat disparity and support local efforts to improve the thermal environment for vulnerable communities.

Madeleine Pascolini-Campbell/Jet Propulsion Laboratory
An Investigation of Fire-Driven Changes in Landscape Water Use: A Diurnal, Multi-Ecoregion Perspective
22-ESAT22-0027

Fire-induced ecological-type conversion can dramatically alter landscapes and in consequence local microclimates. These changes are apparent along several dimensions, including albedo, land-surface temperature, vapor-pressure deficit, and partitioning of precipitation into runoff versus evapotranspiration (ET). Wildfires affect vegetation water use and water budgets through all of these factors, which are importantly mediated by the species- and weather-dependent diurnal timing of stomatal closure - the process in which plants exchange water and carbon dioxide with the atmosphere. In a West experiencing megadrought and unprecedented heat, investigating such questions is crucial for understanding risks related to water availability, vegetation drought, and heat waves.

ECOSTRESS provides a novel diurnal view of land-surface temperatures and plant water use by leveraging the varying overpass time of the International Space Station. We propose to use this unique capability to comprehensively assess how wildfire impacts vegetation water use and evapotranspiration, including net effects on regional water budgets. In addition, we will explore calculating water use using other thermally sensitive ET algorithms (i.e. STIC) with the land-surface temperature data to complement ECOSTRESS s PT-JPL. Our analysis will focus on California, which encompasses a range of recently burned landscapes both natural and agricultural. We will focus on 7 wildfires that burned in 2020 and 2021. We will use ECOSTRESS data to compare pre- and post-fire conditions in select areas affected by these wildfires, complemented by vegetation productivity from C-SIF (OCO-2, 3), gross primary productivity (GPP) from MODIS, and in-situ measurements from the Fluxnet eddy-covariance network.

The primary objectives are to:

1. Examine changes in evapotranspiration and vegetation water use pre- and post-fire for major wildfires across ecoregions of California.
2. Determine the impact of wildfire-related vegetation change on ET by identifying changes in diurnal and seasonal patterns of ET and inferred stomatal conductance.
3. Quantify wildfire-related changes in the balance between precipitation, evapotranspiration, and streamflow across California water basins, and in the balance between temperature and atmospheric humidity that together drive heat stress.

Our proposal s novel aspects include a comparison across ecoregions (forests, grasslands, croplands), a focus on the diurnal cycle, and connections to fine-scale water, heat, and agricultural impacts. Stomatal closure is expected to reduce vegetation transpiration, presenting an opportunity to use our findings to optimize water usage on seasonal or even weather-forecast-based timescales. The proposed work also has the potential to provide information on wildfire vegetation recovery, as well as for applications in wildfire resource management. These insights are only possible by bringing together several types of NASA-sponsored space-based and ground-based products.

Benjamin Poulter/NASA Goddard Space Flight Center
Quantifying Global Ecosystem Vulnerability to Drought with ECOSTRESS
22-ESAT22-0016

Ecosystems are globally experiencing more frequent and more intense droughts, which have direct consequences for carbon uptake, crop yields, and biodiversity. With a lack of global observations of evapotranspiration (ET) and soil moisture that describe ecosystem health, it has been a challenge to understand which global ecosystems are most vulnerable to droughts. In part, this is because surface water loss does not influence each ecosystem the same, as summarized by the fundamental nonlinear relationship between evapotranspiration and soil moisture. As such, observing this relationship is key to identifying types of ecosystem vulnerability and quantifying ecosystem response to drought. Nevertheless, even with global ET and soil moisture observations becoming available, we still lack a fundamental understanding of the spatial patterns of land surface drought vulnerability. It is also unclear if global models adequately characterize these patterns, which may greatly bias their surface flux outputs and ability to represent ecosystem drought responses.

Here, we ask, where and to what degree are ecosystems vulnerable to drought across the globe? Using a fully observational framework, we will globally quantify ecosystem drought vulnerability and soil moisture stress thresholds using ET-soil moisture relationships observed from NASA ECOSTRESS diurnal temperature observations along with NASA SMAP soil moisture. We address this question with three objectives to identify hotspots of drought vulnerability (Objective 1), assess which ecosystems respond the most adversely to recent dry events (Objective 2), and identify ecosystem mechanistic drivers (i.e., stomatal and rooting strategies) that explain why some ecosystems show the most drought vulnerability (Objective 3).

The main project outcomes include (I) a global map of ecosystem vulnerability hotspots and soil moisture thresholds that delineate when water limitation occurs; (II) identification of whether global climate models capture ecosystem water stress and vulnerability patterns obtained from observations; (III) an understanding of mechanistic drivers of ecosystem drought vulnerability types and their magnitude of drought response; (IV) quantification of ecosystem soil water use depth as well as soil moisture sensing depth of the NASA SMAP satellite.

The proposed work directly addresses ECOSTRESS science questions to understand the terrestrial biosphere s response to changing water availability and its first objective to identify critical thresholds of water use and water stress in key climate-sensitive biomes. In our synergistic use with SMAP, it directly answers the call to use ECOSTRESS along with other NASA sensors to advance the understanding of the climate system. It additionally informs the 2017 Decadal Survey s very important objective to understand ecosystem change by understanding drivers of fluxes between ecosystems and the atmosphere. The work will inform algorithms for NASA s Surface Biology and Geology Designated Observable for which ECOSTRESS is a pathfinder.

Our project team consists of experts on ecosystem response to climate variability in water-limited ecosystems. It also includes experts on the use of satellite thermal remote sensing observations and satellite soil moisture retrievals, variables that are key to understanding ecosystem drought vulnerability and ecosystem soil moisture thresholds that define water-limitation.

Temuulen Sankey/Northern Arizona University
Semi-Arid Forest Restoration Treatments Improve Drought Resiliency: ECOSTRESS-Based Assessment
22-ESAT22-0013

Southwestern US forests are experiencing escalating aridity and wildfire risk as a consequence of climate change and increasing fuel loads. Federal and state government agencies are implementing large-scale forest restoration via thinning and prescribed burning treatments to reduce catastrophic wildfire risks and increase forest resiliency to environmental stressors. We propose to use extensive field measurements to evaluate the utility of ECOSTRESS land surface temperature (LST), evapotranspiration (ET), evaporative stress index (ESI), and Collection 2 Soil Moisture data for quantifying the effects of forest management treatments on drought resiliency. Specifically, we propose to validate ECOSTRESS LST, ET, ESI and Soil Moisture data at a local scale using a suite of in-situ measurements from 2018-2023 including canopy temperature and multispectral time-series images from unmanned aerial vehicles (UAV), post-thinning lidar data, hourly sapflow and Bowen ratio station evapotranspiration measurements, and hourly soil moisture data. We then propose to quantify the effects of a regional-scale forest restoration treatment across Arizona on daily, seasonal, and annual forest water balance and canopy temperatures using the ECOSTRESS products. In both the local- and regional-scale analyses, we will compare trends in forest water cycling and canopy temperature during normal precipitation years (2018-2019) versus drought years (2020-present) to determine if the restoration treatments are improving forest resiliency to drought. Our local-scale in situ instrumentation and measurements provide a unique opportunity for validating the ECOSTRESS products, while Arizona’s forest restoration treatments over 2.4 million hectares examined with ECOSTRESS data can be used as a model for other western states that are launching similar large-scale forest restoration efforts.

The proposed project is directly relevant to the ECOSTRESS mission science objectives as it quantifies the benefits of regional-scale forest restoration aimed at improving drought and fire resiliency in a water-limited, fire-prone region of the US. While this project will quantify the accuracy of ECOSTRESS products at multiple functional, spatial, and temporal scales, our ultimate goal is to use ECOSTRESS data to inform current and future forest management and climate adaptation decisions. Our results will quantify the ecohydrological benefits of regional forest management and identify specific treatment prescriptions that provide the most benefits for forest water balance. The ECOSTRESS-based results are particularly important because the US Forest Service is planning to implement forest treatments across 20 million more ha to reduce wildfire risks. We predict that ECOSTRESS data can play a key role in optimizing the designs of these forest treatments across the western US. The results of the proposed project will also provide a real-world example, verified with ECOSTRESS data, of the climate adaptation activities that integrate climate considerations into land management planning. Our interdisciplinary team of forest ecologists, biologists, and remote sensing scientists will train one postdoctoral researcher and one PhD student in ecological informatics.

Allison Steiner/University of Michigan, Ann Arbor
Using ECOSTRESS to Understand the Role of Diffuse Light on Vegetation
22-ESAT22-0002

The amount of radiation reaching the Earth s surface drives ecosystem productivity and is an important input for ECOSTRESS evapotranspiration retrievals. Within a vegetation canopy, light is attenuated depending on the canopy structure and can influence the location and magnitude of light absorption that initiates key ecosystem processes such as photosynthesis and transpiration. The presence of atmospheric aerosol particles and clouds can reduce direct incoming shortwave radiation from the Sun by absorbing or scattering radiation, and the scattering of radiation by atmospheric particles can create diffuse light. A reduction in incoming solar radiation has the potential to reduce carbon dioxide uptake in both natural vegetation and agricultural systems, modify transpiration and influence water use efficiency (WUE, defined as the amount of carbon fixed per unit of water). Prior studies have indicated that an increase in diffuse light may increase photosynthesis and total ecosystem carbon uptake, sometimes known as the diffuse fertilization effect, as diffuse light is more able to penetrate the canopy and can promote overall total canopy photosynthesis. The link between diffuse light and evapotranspiration is less distinct, and the proposed work will examine the role of changes in atmospheric composition that can affect the magnitude and quality of light reaching the surface and driving evapotranspiration processes. Additionally, aerosols have the potential to alleviate midday photosynthetic depressions by reducing leaf temperatures, thereby increasing photosynthesis and transpiration. Quantifying the magnitude of this aerosol-land surface feedback has been challenging due to limited ground-based observations, but the advent of diurnal cycle information from ECOSTRESS now provides the potential to test this theory across the globe.

We propose to use ECOSTRESS to understand the effects of atmospheric aerosols and low cloud amounts (e.g., cloud optical thickness less than 10) on WUE. We will use Level 3 ET and Level 4 WUE products in conjunction with MODIS Aerosol Optical Thickness (AOT) and Cloud Optical Thickness (COT) to address the following questions:

1. What is the relationship between WUE and atmospheric optical properties under both short-term extreme events (e.g., wildfire aerosol) and long term events (e.g., background aerosol loading and cloud type)?
2. How do diurnal cycles of WUE change under moderate and high AOT and/or COT?
3. How do aerosol and cloud effects on diffuse light moderate WUE in water-rich ecosystems (e.g., Midwest and Eastern US) versus water-stressed biomes (e.g., Western US)?

The proposed work will address the ECOSTRESS Science Objective 1 (Identify critical thresholds of water use and water stress in key climate-sensitive biomes) and Science Objective 2 (Detect the timing, location and predictive factors leading to plant-water uptake decline and/or cessation over the diurnal cycle). Our focus will link changes in atmospheric composition to surface processes to provide potential explanatory variables for both short-term and long-term changes in WUE. This work will be important for understanding how light within forest canopies especially the role of direct versus diffuse light can be used to understand the coupled water-carbon balance.

Nick Steiner/City College of New York
Remote Sensing of Urban Ecosystem Function in the Megacity: Fine Resolution Characterization of Water Stress in New York City Urban Forests with ECOSTRESS
22-ESAT22-0041

Urban forest ecosystems can mitigate the negative impacts to health and energy usage from surface urban heat island (SUHI). Urban regions in and around New York City (NYC) experience SUHI that is exacerbated by climate change and heat wave (HW) events of increased frequency. Currently, urban heatwaves are a leading cause of global weather-related fatalities. Urban vegetation content is the most important factor in regulation of SUHI as observed in all major cities. Understanding the health and mitigation potential of urban forests will become increasingly more important with time and requires urgent attention and research focus as they are a nature-based approach to mitigation of SUHI.
We will employ ECOSTRESS to (1) measure the temperature reduction in urban forests in NYC as a proxy for heat mitigation. (2) We will partition this impact by the major contributors to heat reduction, evaporative cooling, and shade, using measurements in urban forest stands, (3) allowing us to verify the capabilities of ECOSTRESS in monitoring water stress in urban forests, especially during HW events.

Using canopy surface temperatures from ECOSTRESS we will create observational models of temperature reduction by urban forests, especially during heatwave events, to estimate the strength of mitigation provided by forested areas in NYC. We will determine water stress in NYC forest communities from ECOSTRESS-based measurements of canopy surface temperature reduction relative to the forest community potential determined by forest ecosystem structure and function.

In April and May of 2022, NASA s UAVSAR instrument, a polarimetric L-Band synthetic aperture radar, collected SAR backscatter images at high resolution (2m) over NYC. We will use UAVSAR datasets combined with field portable Terrestrial Laser Scanning (TLS) instrumentation to produce a high-resolution map of forest structure in NYC parks and green spaces.
We will use observations of sap flow and precision dendrometry in urban trees to develop linkages between ECOSTRESS surface temperatures and water stress. With key environmental variables we can determine transpiration and canopy conductance, and with soil moisture, water status and stress. These, in addition to the characterization of forest structure and shade, will allow us to constrain the temperature reductions from urban forests in context with observed over

forested areas in NYC. We will use dendrochronology to determine growth rates and water stress occurrence during the ECOSTRESS observational years (2018-2023) and to assess the historical relationship between HW and growth rates. Observational models, between in-situ measurements of water use and transpiration and forest structure and forest cover, will improve estimates of these critical ecosystem services across all urban forests in NYC.

Using NYC as a test-case, we will evaluate the potential of combining the advantages of ECOSTRESS thermal infrared radiometer and UAVSAR radar datasets to monitor water stress in forests by assessing observed temperature reduction by vegetation community structure. This methodology is beneficial for the ECOSTRESS mission, it can be applied in areas of urban density, climate and ecosystems in the Northeast, a major population center, and replicated with instrumentation in other urban fabric/climate/ecosystem combinations.

David Wethey/University of South Carolina
High Resolution Sea Surface Temperature from ECOSTRESS
22-ESAT22-0006

ECOSTRESS produces the highest resolution skin temperature products currently available, but the standard products do not include sea surface temperature (SST). This is different from other instruments like VIIRS and MODIS which are used by NOAA, NASA, and other agencies to produce operational L2 SST products. This is problematic for several reasons. (1) ECOSTRESS has the potential to generate a breakthrough SST product for the oceanographic community because of the need for ultra-high resolution for understanding air-sea coupling, fronts, biodiversity and coastal dynamics. (2) ECOSTRESS is dedicated to enhancement of agriculture, but there is no product for shallow seas, where aquaculture has the same temperature challenges as agriculture on land.

Our proposal responds to the request for improvement of existing ECOSTRESS data products and for enhanced validation strategies, techniques and data products. The proposal has three goals: (1) develop a processing pipeline producing an L2 ECOSTRESS SST product, (2) validate the ECOSTRESS SST product with in-situ and satellite data, and (3) address image checkerboarding and striping, which limits ECOSTRESS utility on land and sea.

The ECOSTRESS land surface temperature (LST) product suffers from several deficiencies, hampering its acceptance by the oceanographic community: (1) it is produced with a Temperature Emissivity Separation (TES) algorithm, which is neither necessary nor recommended for SST applications because water emissivity is much more tightly constrained than land emissivity; (2) the L2 LST product has a cold bias, and a low emissivity bias; (3) the radiometric noise level is high enough that oceanographic temperature gradients are difficult to resolve; (4) there are stripe artifacts related to focal plane non uniformity; (5) the cloud mask was developed for land and does not work well over water; (6) the L2 LST product does not meet the Group for High Resolution Sea Surface Temperature (GHRSST) netcdf-4 file standard.

We will develop a processing pipeline for producing a split-window SST product, including innovative approaches to reduce the systematic biases and systematic radiometric noise. The pipeline will be derived from VIIRS SST software (OCSSW v2020) from the NASA GSFC Ocean Biology Processing Group (OBPG). We will compare operational ocean cloud mask algorithms (OBPG, NOAA, ESA) to identify the best for use with ECOSTRESS. We will validate the SST with data from the NOAA In-situ SST Quality Monitor ship and buoy measurements (2 million observations per month) and other in-situ observations including Saildrones, shipboard infrared radiometers and hull sensors. We will evaluate the quality of the new product by comparison to collocated L2 SST from VIIRS and geostationary instruments. The new L2 SST will be produced as GHRSST-compliant netcdf-4 files for distribution by the NASA Physical Oceanography Distributed Active Archive Center. To reduce the stripe and checkerboard artifacts, we will use pre-flight calibration data to make focal plane non-uniformity corrections that are more effective than the current 2-point calibrations from the on-board black bodies. We will also use NOAA-VIIRS destriping software to reduce the non-uniformity effects. The ability to detect gradients and fine-scale oceanographic features will be used as a benchmark for the corrections.

Reduction of systematic biases and systematic radiometric noise will benefit the entire ECOSTRESS community. Temperature biases, stripes and checkerboard artifacts are common in ECOSTRESS land scenes, and are inhibiting terrestrial research programs, as has been documented in two ECOSTRESS Science and Applications Team meetings.

This work is distinct from our current ECOSTRESS project which is focused on the use of ECOSTRESS data for estimating heat and evaporative stress in shellfish harvesting areas in the zone between the high and low tide levels on ocean shores.

Yun Yang/University of Maryland, College Park
Water-Use and Land-Cover Change Detection Using ECOSTRESS and OpenET
22-ESAT22-0038

Ecosystems are subject to natural and human induced change, and understanding response of ecosystem health to change is critical to better stewardship of natural resources. Both natural (e.g. drought, wildfire, pest outbreak and hurricane) and human drivers (e.g. conversion and restoration of landcover type and management practices) can impact ecosystem health in different ways and to different degrees. While there has been considerable research on using remote sensing to detect land-cover change, studies investigating the biophysical feedbacks on the ecosystem (e.g. evapotranspiration (ET) change) resulting from these changes are limited, especially at the finer scales at which anthropogenic change tends to occur. ET is an important indicator of vegetation health, and changes in ET can signal vegetation stress and irrigation needs. Automatic detection of changes in ET metrics can provide critical information about consumptive water use and land surface changes for improved irrigation planning and water and natural resource management, especially for water limited area with the projected more severe and frequent drought events in the future. However, the Landsat observations, as one of key inputs for ET models, are limited due to the relatively long revisiting time, which can impact the accuracy of daily ET estimation and change detection. The frequent thermal infrared observations provided by ECOSTRESS will benefit ET change detection at field scale through improved daily ET estimation.

This proposed project aims to 1) update the ECOSTRESS L3/L4 DisALEXI ET processing system with daily 30-m surface reflectance (SR) data; 2) prototype a land-use, water-use, and vegetation stress change detection system; and 3) implement the change detection system in Google Earth Engine (GEE). This system adapts a well-tested automatic change detection method to simultaneously mine co-aligned fine scale SR data and Evaporative Stress Index (ESI) timeseries (or datacubes) to detect land- and water-use changes.

Daily 30m SR timeseries will be produced over target sites by fusing Harmonized Landsat Sentinel (HLS) and Visible Infrared Imaging Radiometer suite (VIIRS) SR data. 30m ET will be produced with the existing ECOSTRESS L3/L4 DisALEXI system by fusing ET retrievals from ECOSTRESS, Landsat and VIIRS, upgraded to use improved albedo/vegetation inputs derived from the daily 30-m SR data. Gap-filled ESI will then be computed at daily timesteps as the ratio between actual and a reference ET estimated from gridded meteorological data. The SR and ESI datacubes will be used in an automatic change detection system to detect concomitant changes in land-cover and water-use/stress driven by natural and anthropogenic drivers. The detected changes will be evaluated in comparison with management/condition records from the target sites, drought classifications from the United States Drought Monitor, and crop and rangeland condition reports from the National Agricultural Statistics Service. This automatic change detection system will be ported into GEE and tested with available GEE assets, including ET data from OpenET generated with Landsat and ECOSTRESS data. The field-scale ESI and water-use change from 2016 to 2022 over the entire 17 western states will be estimated and analyzed on GEE. Both abrupt (e.g. due to flash drought, management, wildfire and hurricane) and long-term water use change trend (e.g. due to irrigation technology and water use policies) over the water limited western states will be explored.

This study will use the ECOSTRESS L1/L2 datasets to motivate the value of high spatiotemporal resolution TIR data for assessing ecosystem health and for monitoring regional land-cover and water-use change. The results from this study will be relevant for setting requirements for future thermal Earth observing satellite missions and will help to better understand vegetation water use for improved agricultural and water resource management.