

**NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences -2018
NNH18ZDA001N-ECOSTRESS
A.7 ECOSTRESS 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 73 proposals and has selected 15 for team membership at this time. The total funding to be provided for these investigations is approximately \$5 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.

**Dennis Baldocchi/University of California, Berkeley
How Much Water is Evaporated Across California?: An Assessment Using a
MesoNetwork of Eddy Covariance Sites, a Biophysical Model Forced with Satellite
Remote Sensing and ECOSTRESS Data
18-ECOSTRES18-0009**

California experiences high spatial-temporal variability in evaporation. Spatial variations are associated with the north-south gradients in rain fall that affect the type of native vegetation, its leaf area index, how roots tap ground water and its physiological response to seasonal drought. Temporally, evaporation of native vegetation experiences strong seasonal dynamics in evaporation due to the wet, cool, winters and the hot dry summers. Accurate evaporation products, derived from ECOSTRESS, must consider spatial and seasonal changes in meteorology and plant structure and function. Consequently, California is an ideal, yet challenging test case for applying ECOSTRESS products. In short, if ECOSTRESS products work well across California, we have confidence they will work well across most other portions of the United States.

We propose a project that will involve operating a network of Ameriflux sites across agricultural and native vegetation of central California; these sites include an oak savanna, annual grassland, corn, alfalfa, pasture and restored wetlands. At these sites we will make eddy covariance measurements of carbon, water and energy fluxes, measure site characteristic, meteorology and soil conditions. We will use these direct measurements of evaporation, carbon dioxide fluxes and energy exchange to validate and parameterize ECOSTRESS products. We will evaluate the performance of ECOSTRESS products with the biophysical CanVeg and Breathing Earth System Simulator (BESS) models; these models couple energy balance, photosynthesis and stomatal conductance algorithms that are evaluated for the sun and shade fractions of the canopy and operates with inputs from satellite remote sensing, including many products from MODIS.

Key questions and objectives include

- 1) what is the amount of water evaporated across the diverse climates and ecosystems of the State of California, as evaluated with high resolution ECOSTRESS ET products and a mechanistic model, BESS, that couples energy balance, water, carbon and operates at 1 km resolution with MODIS data;
- 2) how much water is evaporated across major climatic/ecological/agricultural regions of the state as compared between ECOSTRESS ET products and eddy covariance measurements across a meso-network of stations across California?; and
- 3) how does the spatially integrated evaporation vary seasonally over extremely dry and wet conditions, as compared to eddy covariance measurements over managed and natural ecosystems?

Kerry Cawse-Nicholson/Jet Propulsion Laboratory
Evaluating a CONUS-Wide disALEXI Evapotranspiration Product
18-ECOSTRES18-0022

DisALEXI is an agriculture-specific evapotranspiration (ET) product that is currently produced by the USDA over six target zones (each 90km x 90km). The proposed work will provide an extension to the current ECOSTRESS disALEXI evapotranspiration product, by producing it over CONUS. An optimal ET product will have a significant impact on water and ecosystem applications, including a global view of water and energy balance, drought monitoring, water resource management, input to precision agriculture, and species richness determination. DisALEXI is known to be an ET model significantly dependent on LST input, which is appropriate for an ECOSTRESS model. It provides ET at sub-hectare level, which significantly improves accuracy when compared to ALEXI (4 km), since small-scale fluctuations and changes in landcover are captured.

This proposal leverages support from other efforts, in order to produce and evaluate the disALEXI ET algorithm over all of CONUS, focusing on agricultural regions. Our disALEXI ET data directly address the ECOSTRESS science objective “Measure agricultural water consumptive use over CONUS at spatiotemporal scales applicable to improve drought estimation accuracy.” The evaluation of a crop-specific algorithm even across a wider spatial region of managed landscapes will also provide valuable input into the research of agricultural water consumptive use. In addition, the production of a statistically appropriate uncertainty quantification will greatly enhance the current state of practice, and provide precision agriculture and other water management users with a more relevant decision making tool.

Our main goal is to develop, validate and evaluate disALEXI ET products. To achieve this objective, we will develop a 70m resolution disALEXI evapotranspiration product based on daytime ECOSTRESS observations for the entire CONUS, and evaluate it over agricultural field validation sites. In addition, we will assess the value of the algorithm over non-agricultural regions, and make the data available through the Land Processes Data Active Archive Center (LP DAAC).

The investigators are uniquely qualified to produce this product, since the disALEXI algorithm is already in place, the appropriate resources for production will be available, and the expertise of the algorithm's developers will be leveraged.

Nicholas DeFelice/ICAHN School of Medicine at Mount Sinai
Developing Spatial Real-Time Forecasts of Mosquito-Borne Diseases
18-ECOSTRES18-0046

We are at an exciting juncture in infectious disease modeling: the point at which forecasting of disease outbreak characteristics has evolved from an idea to an achievable reality. West Nile virus (WNV) is the leading domestically acquired arbovirus and ecologically-informed forecast applications hold promise to help improve management decisions for abatement and public health. We propose to expand our current research of developing a WNV forecast system, by integrating some of the most detailed ecological images of the earth's surface ever acquired from space. ECOSystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) data will be used to develop spatial risk predictions of WNV for mosquito management decisions. This unique remote sensing instrument provides the fine spatial resolution needed to capture variability in physical environmental factors (e.g., temperature and hydrology), all of which influence mosquito development, WNV transmission dynamics, and the potential risk of human spillover infections. Such high-resolution monitoring at the watershed level will enable a more comprehensive depiction of the small-scale hydrologic variability associated with focal and sporadic WNV amplification and transmission, potentially allowing such events to be detected. The inclusion of ECOSTRESS' high spatial (70m) and temporal (revisit every 4 day) resolution data will allow us to capture changes in the micro-ecosystem, giving public health and vector abatement districts additional data to understand the process of how arboviruses amplify at a fine spatial scale. Highly resolved maps will further allow for appropriately timed interventions, such as public health warnings, or more intense mosquito control efforts in the region of concern. The objectives of this proposal align with the NASA mission of developing and introducing next-generation methodologies for public health management.

We have targeted WNV because of its public health relevance and the potential to better understand how highly resolved temporal and spatial satellite data can be used to characterize, monitor, and predict mosquito-borne disease outbreaks. This project will also provide a foundation for how highly-resolved thermal remote sensing products from future missions like HypIRI can be integrated into vectorborne disease (VBD) monitoring. Informed by remote sensing, applications will guide interventions accurately in space and time to the scale of the problem. Benefits from these risk maps will include improved allocation and timing of two key mosquito control interventions, larviciding and adulticiding, which are critical for reducing the impact of VBD on humans. To develop this product, we have assembled a multi-disciplinary team that includes specialists in remote sensing, VBD, ecology, and public health, as well as collaborators familiar with the local mosquito-disease dynamics in Suffolk County, New York, a suburban county with nearly 1.5 million residents on Long Island.

This is a very important and timely project and will be a significant step towards global efforts for improving, monitoring, and reducing the health effects of VBD. Suffolk County Department of Health will be involved as end-users. Continuous communication with the end-users is important for the success of the project; we will provide them with an enhanced web-based tool that will predict areas of VBD risk. These objectives align with the NASA goals by conducting new research using ECOSTRESS data products in combination with data products from other gridded hydrological parameters (e.g., HRRR) that advance the understanding of the mosquito ecosystems and their biodiversity. In developing these WNV risk predictions using a simple generalizable framework based off mosquito monitoring and the unique ECOSTRESS high-resolution space-time products, we will develop and introduce next-generation applications for public health management that can be applied elsewhere.

Christopher Doughty/Northern Arizona University
Merging ECOSTRESS with Field Data in the Highest Uncertainty Water Use
Efficiency Regions in the World
18-ECOSTRES18-0071

Understanding the thresholds for plant water use and water use efficiency (WUE) across tropical transition zones is critical for predicting how these key regions, which are high in biodiversity and provide significant ecosystem services, may respond to climate change. A primary goal of ECOSTRESS is to reduce the uncertainty in estimates of water use and WUE; when combined with ground-based data, this information can provide both a means of validation and an unprecedented opportunity to test novel hypotheses that provide predictive insights into plant, ecosystem and landscape function and feedbacks to Earth systems.

We will leverage a large and unique existing leaf trait (morphology, photosynthesis, albedo, chemistry, and stable isotopes) dataset from 89 species sampled along 11, 1 ha plots along tropical vegetation transition zones in Ghana and Brazil. Our sites are within two of the ECOSTRESS ‘hotspot’ regions identified as having high uncertainty in WUE. Because we collected samples from all of the species in each plot that composed 80% of the stand basal area, we are able to compare ECOSTRESS pixels to similarly sized plot-level community weighted means of WUE and canopy temperature derived from gas exchange measurements and leaf isotopes. We will establish the level of agreement between ECOSTRESS and field data to provide a measure of accuracy for ECOSTRESS data. In doing so, we will provide critical insights into how plant WUE and leaf temperature vary across tropical transition zones and test the extent to which there is evidence for thresholds associated with vegetation characteristics.

We will then use ECOSTRESS evapotranspiration (ET) and canopy temperature capabilities to test a novel hypothesis regarding how predicted changes in leaf albedo (darker leaves – Doughty et al. 2018) in tropical transition zones might push leaves past a critical water threshold by closing stomata and increasing leaf temperatures. ECOSTRESS will provide surface temperature and ET estimates at higher spatiotemporal

resolution than previous remote sensing products, allowing us to understand how slight spatial variations in surface albedo impact diurnal canopy temperature and ET. We will first combine ECOSTRESS data with our ground-based data to establish how canopy temperature and ET vary with leaf albedo and photosynthesis. We will then compare Landsat surface albedo to ECOSTRESS canopy temp and ET across transition zones in Ghana and Brazil. Thus, we will exchange space for time and use our spatial understanding to predict whether future darker leaves will heat the canopy or lead to greater evapotranspiration. Finally, we will determine how changing albedo affects Earth systems. Current models predict that decreased albedo will increase ET, but this has never been empirically validated and studies suggest the models are inaccurate. Whether canopies heat up or evaporate more water could impact both regional (ecosystem shifts) and global (air temperature) processes.

Our research team has >10 years expertise working in these transition zones (Doughty, Goldsmith, Oliveras, and Malhi), extensive knowledge of ECOSTRESS (Fisher – ECOSTRESS science PI), and expertise in the necessary field, remote sensed, and modeling methods. The proposed research has minimal risk and presents the opportunity for a significant return on investment because the field data has already been collected; funds will almost exclusively be used to interpret and compare the data to ECOSTRESS. Overall, we are uniquely positioned to directly address the first and second science objectives of ECOSTRESS within two of the key climate sensitive regions delineated by the ECOSTRESS ‘hotspots.’

Joshua Fisher/Jet Propulsion Laboratory
Improvements to ECOSTRESS Data for Science and Applications
18-ECOSTRES18-0066

ECOSTRESS was one of the fastest to launch and most cost-effective NASA Earth Science missions ever, having been selected in 2014 and launched in 2018 at a cost cap of \$30M (Class D). Data from ECOSTRESS provide unprecedented spatial and temporal resolution for science and applications with a primary focus on plant water use and stress (e.g., evapotranspiration, water use efficiency) [Fisher et al., 2017]. In the International Space Station (ISS) orbit, data are produced at 70 m spatial resolution every 3-5 days.

The high spatial resolution of the L3 ET data is primarily the result of the 70 m L2 land surface temperature and emissivity (LSTE) data in conjunction with corresponding ancillary VNIR data from Landsat 8, the latter of which is necessary to convert L2_LSTE to L3_ET. However, the Landsat data are provided on a much lower temporal resolution (16 days) than the ECOSTRESS L2 data (3-5 days). As such, we hypothesize that major phenological changes, including agricultural planting and harvest, in between Landsat acquisitions introduce significant uncertainties for ECOSTRESS during these times. High spatial (10 m) and temporal (5 day) resolution Sentinel 2AB VNIR data became available just prior to ECOSTRESS launch. We propose to incorporate Sentinel 2AB VNIR data into the L3 ET operational data processing. Our science objective is to quantify

uncertainty reductions during major phenological changes across spatial domains.
[Objective 1]

Currently, ECOSTRESS ingests the gross primary productivity (GPP) product from MODIS, which is combined with the ECOSTRESS L3 ET to produce the L4 WUE product. The MODIS GPP product is substantially coarser (500 m) than the 70 m ECOSTRESS L3 ET, and has also been reported to have large errors in some biomes. We hypothesize that WUE uncertainty can be significantly improved through replacement of the GPP product through incorporation of a GPP algorithm directly into the ECOSTRESS data processing system at 70 m. We propose to incorporate the state-of-the-art Breathing Earth System Simulator (BESS) GPP algorithm, enabling a consistent 70 m WUE product with improved accuracy. [Objective 2]

As a result of these data improvements and new production, we will provide a major service to the selected project teams and to the larger ECOSTRESS data user community. ECOSTRESS data production is currently very much bare-bones, and not very user-friendly. We propose to produce and deliver the new ECOSTRESS L2-4 data gridded in GeoTIFF, enabling AppEEARS and other tools for analysis. We will grid the data directly onto that used by Sentinel for ready comparisons, as already compatible with multiple data archives such as Landsat. [Objective 3]

In summary, our objectives include:

1. Improve the accuracy of the L3 product through incorporation of Sentinel 2AB;
2. Improve the spatial resolution and accuracy of the L4 Water Use Efficiency product through incorporation of the BESS GPP algorithm;
3. Produce and deliver gridded ECOSTRESS L2-4 data in GeoTIFF.

The overarching science goal of this proposal is to significantly improve the science investigation of ET and WUE over phenological changes at field scale. We will also substantially strengthen the data quality and usability beyond what was feasible under ECOSTRESS project cost cap. Finally, Dr. Fisher proposes to continue in his role as the ECOSTRESS Science Lead, providing overall science leadership, support, integration, and synthesis to the selected ECOSTRESS Science Team. ECOSTRESS has led to a ground-swell of interest and demand from multiple science and applications communities; it is imperative now that the data are produced to best advance the science and applications enabled by ECOSTRESS.

Christian Frankenberg/California Institute of Technology
Exploiting Diurnal Cycles to Evaluate Vegetation Responses to Heat and Drought Stress
18-ECOSTRES18-0056

Global warming is expected to increase the frequency and intensity of droughts. Understanding how ecosystems respond to heat and drought stress is critical for projecting the fate of the terrestrial biosphere in the advent of climate change. It is

equally important to understand how emergent ecosystem properties contribute to the development of heat waves and prolonged droughts through exchanges of water and energy between the biosphere and atmosphere.

Diurnal cycles can provide a window into the drivers of water stress as they exhibit strong hysteresis effects. To study the diurnal and seasonal cycle of energy, water, and carbon fluxes under unstressed and stressed conditions, we propose to link land surface temperature (LST) and evapotranspiration (ET) retrievals from ECOSTRESS with collocated solar-induced fluorescence (SIF) measurements from TROPOMI, OCO-2, and OCO-3, and at selected flux towers with temporally dense time-series.

Our primary objectives are as follows:

At the regional level, classify each of the major land cover types into a range of stress levels based on meteorological data and estimate how LST, ET, and GPP (derived from SIF) evolve differently, how corresponding water use efficiency change in time, and how different land cover types respond to a certain level of evaporative demand.

At the site level, we will select representative flux sites for the major land cover types that have temporally dense time-series to represent the diurnal cycles, which will then be used to interpolate ECOSTRESS measurements to full diurnal cycles to allow the analysis of how diurnal changes in energy, water, and carbon fluxes differ between unstressed and stressed conditions and whether these can be explained by land surface models.

Lastly, we will use leaf-level measurements of SIF and carbon/water fluxes to better understand the mechanisms underpinning these behaviors. Typical diurnal cycles observed at the various flux towers can be simulated using our leaf level gas exchange system.

Our proposed work directly responds to the NASA ECOSTRESS science team call by providing “evaluation and improvement of existing ECOSTRESS data products” and “using ECOSTRESS data products 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.” Our team will provide a mechanistic interpretation of the integrated observations made at multiple scales to answer critical science questions of “how ecosystem respond and contribute to drought and heat stress”, which strongly supports the mission’s overarching goal.

Christoph Hecker/Universiteit Twente
Investigating Dynamic Thermal Processes to Optimize Geothermal Hotspot
Detection

18-ECOSTRESS18-0014

The ECOSTRESS mission was designed to measure evaporative plant stress on a near-global scale. This research proposes to use data from the same ECOSTRESS mission in a unique and novel way by investigating temperature hotspots in soils and rocks at the Earth's surface. These thermal anomalies are important in the reconnaissance of new geothermal resources, a vital source in the global energy transition towards a more sustainable energy supply.

Geothermal anomalies can only be detected from satellite data if their temperatures are sufficiently elevated above the natural temperature variations of the surrounding areas (the "background"). During the day, background temperatures vary extensively due to the absorbed sunlight, while during the night, these affects are subdued but still present. Looking at a single image (or a daytime/nighttime pair) has the disadvantage that we are only looking time slices and we cannot understand and reproduce the dynamic behavior of the geologic substrate as it cools down.

The aim of this proposed work is to optimize the geothermal temperature anomaly detection from space by using a different and novel approach. We will look at the nighttime temperature decay rates in time series, rather than temperatures in individual time slices. This approach will provide hypothetical stabilization temperatures at the end of cooling, even if that stable temperature is not reached at the end of the night for a given pixel. The proposed approach will side-step two issues that current state-of-the-art methodologies are struggling to handle:

- 1) the effect of solar heating and starting temperature at the beginning of the night are inconsequential for our result, as our focus is on decay rates rather than on absolute temperatures, and
- 2) variations of thermal inertia in the geologic substrate are controlled by looking at the stable end temperature which are inertia independent.

In order to reconstruct the nighttime cooling patterns for each image pixel, we propose to merge data from the precessing ECOSTRESS orbit (different acquisition times on different overpass days) with data from geostationary weather satellites. This merged product will provide a super-temporal resolution time series, with the high spatial details from ECOSTRESS and the high temporal details from the weather satellites.

This research makes full use of the specifications and orbit characteristics of ECOSTRESS and its ISS platform. The research has a strong link with Sustainable Energy Resources and dovetails with the NASA focus areas on innovative analyses, carbon cycle and sustainable resource use. Results from this research will assist in the global energy transition by providing input to future missions in terms of optimal user requirements on orbits, overpass time, pixel size and minimum signal-to-noise levels required for geothermal anomaly detection. This study will analyze for the first time the nighttime cooling dynamics of the geologic substrate in ECOSTRESS images, and will provide an assessment of its potential for improved near-global geothermal anomaly detection.

Chuanmin Hu/University of South Florida, Tampa
Thermal Stress in South Florida Estuaries: A Multi-Sensor Assessment
18-ECOSTRES18-0038

South Florida estuaries have been under ecological stress, as evidenced by frequent and recurrent algae blooms (mostly cyanobacterial blooms of *Microcystis* and *Synechococcus*) and seagrass dieoffs. These blooms and seagrass dieoffs mainly occur in the St. Lucie Estuary (SLE), Caloosahatchee River Estuary (CRE), and Florida Bay (FB), all located downstream of Lake Okeechobee (LO, the largest lake in Florida). Most water quality monitoring and management programs emphasize on freshwater and nutrient discharges, while potential thermal stress has been neglected. This is mainly because of lack of data – in situ data are scattered in both space and time while satellite remote sensing often lacks spatial resolution to resolve the temperature changes in the relatively small estuaries. Are these ecosystems thermally stressed and, if so, what's the role of thermal stress in cyanobacterial blooms and seagrass dieoffs?

The availability of the high-resolution (40 m by 70 m) ECOSTRESS thermal infrared (TIR) data from the International Space Station makes it possible to combine with other remote sensing data to establish a long-term temperature record to assess potential thermal stress in these ecologically important estuaries. The ECOSTRESS TIR data alone are not sufficient for this purpose because they were only collected recently after July 2018, but their resolution, accuracy, and precision will be used to calibrate and validate long-term time-series of Landsat thermal data. The Landsat series provide the longest thermal data ever since the 1980s with resolutions ranging between 120 (earlier sensors) and 60 m (new sensors). However, Landsat sensors are restricted to only 1 or 2 thermal bands, making it difficult to estimate surface temperature accurately. The combination of the ISS thermal data and Landsat thermal data is hopefully to provide a validated long-term temperature record for major South Florida estuaries, while the approach may be extendable to other estuaries. The existing field work from different agencies also provides ground truth data to this multi-sensor effort.

Currently, the official agency of Florida to manage water discharge in South Florida is the South Florida Water Management District (SFWMD), which works with the U.S. Army Corps of Engineers (USACE) to make water discharge decisions. How is water temperature potentially impacted by the discharge? The established long-term thermal data record will be used to answer this question, with results passed to SFWMD to help make water discharge decisions.

The project is a collaboration between researchers and a leading water management agency, with the following expected outcome: 1, Accuracy assessment of the ECOSTRESS thermal data for South Florida estuaries and all major GulfCoast estuaries; 2) Cross-sensor calibration algorithms to estimate surface temperature of the targeted estuaries from Landsat measurements; 3) Long-term temperature record to evaluate temperature anomaly events and potential thermal stress; 4) Potential impacts of water discharge management on temperature anomaly and/or thermal stress. The ultimate

outcome of the project, with SFWMD being the end user, is an improved and integrated Decision Support Information System (DSIS) for water management, with ARL7 (from the current ARL2) projected for the remote-sensing component in the DSIS. The deliverables include: 1) approaches to evaluate, calibrate, and validate both ECOSTRESS and Landsat thermal data, which may be extendable to many other estuaries around the nation; 2) long-term ST data products and improved understanding of the thermal environment for South Florida estuaries; and 3) improved decision support tool (i.e., improved DSIS) to help water management in South Florida.

Christine Lee/Jet Propulsion Laboratory

Evaluation of ECOSTRESS Surface Temperature over Inland Waters for Aquatic Ecosystem Applications

18-ECOSTRES18-0075

Challenge. The San Francisco Bay and Delta (Bay Delta) is critical to the world's biodiversity as well as California's water supply, draining 40% of California's water to support a \$50B agricultural industry and drinking water supply for 35 million people. This system's sustainability is under continued threat from anthropogenic activity and development as well as from climate change. Water temperature is arguably the most critical factor governing habitat suitability in aquatic and estuarine systems. In the Bay Delta, higher water temperatures are associated with increased mortality and stress for various fish species and is expected to worsen under climate change projections. To balance these resource needs, federal, state, and regional mandates and agencies work to meet co-equal goals of water supply reliability and management and protection of ecosystems. Water temperature is one water quality variable that is used to manage towards these goals.

Opportunity. ECOSTRESS represents a unique opportunity to leverage space-based observations to support resource agency goals for improved water and ecosystems management in the Bay Delta (Letters of Support: Metropolitan Water District, CA Department of Fish and Wildlife, 34North). This project will leverage existing data infrastructure, partnerships, water agency investments, as well as other NASA investments, to evaluate and prepare ECOSTRESS surface temperature data for management applications. In addition, this project will apply ECOSTRESS data to applications use cases in the Bay Delta and transition ECOSTRESS surface temperature data products to Bay Delta Live (baydeltalive.com) to support decision-making, long term availability and use.

Soe Myint/Arizona State University

Changing Landscapes, Urban Heat Island and the Effects on City Water Conservation Policy

18-ECOSTRES18-0067

Evidence suggests that human-induced climate changes, variations, and extremes will create a warmer and drier future for the Southwestern United States and, indeed, that the turn to more intense climatic conditions has already started. In Phoenix, urban heat island (UHI) effect has increased summer nighttime temperatures by as much as 6°C, consistent with some climate models. Urban vegetation as a mitigation and adaptation strategy to urban warming has been documented by extensive studies. Yet, during periods of drought, a desert city, such as Phoenix, must require consumers to reduce water use. Outdoor water uses are likely to be among the first to be targeted for reduction, which can have an enormous impact on urban greening, energy use, and food security. Without altering key urban design features, outdoor water conservation would elevate daytime warming effects and reduce or delay nighttime cooling effects during early evening hours, especially in industrial and downtown neighborhoods.

According to the City of Phoenix's Water Services Department, one of the main areas in which they have an information deficiency involves outdoor water uses. With a tremendous range of landscapes and a high incidence of pool ownership, Phoenix poses unique challenges for outdoor water use. To date, national studies have focused on only a few variables, such as total turf and expected irrigation requirements using evapotranspiration rates, when analyzing water use. However, in Phoenix, where the majority of homes are partially or mostly surrounded by desert vegetation, studies must employ more sophisticated approaches to understanding how outdoor landscape types affect water use. With the future of the city's water supply being largely unknown, estimates of outdoor water use must be improved so that Phoenix can proactively prepare for drought management and water conservation while mitigating UHI effect.

While water managers and planners recognize the relationship between urban vegetation and cooling, they question how much water is necessary to cool Phoenix and even whether cooling is realistic and achievable. These decision makers understand that some areas of the city are warmer or dryer than others, and that it is important to understand the customers' needs concerning aesthetics, recreation, HOAs, landscape watering recommendations, and health and wellness. In this study, we will identify specific parts of Phoenix that would benefit from: (a) tree-beautification programs to decrease surface temperatures, or (b) water-conservation strategies to reduce water use. In some cases, we may need to plant additional trees, grass, and shrubs to counter UHI, but in other areas it may be more beneficial to replace high-water-using vegetation with desert adapted landscape.

The goal of this proposed study is to identify areas where water use could be lowered (i.e., single family, commercial, on/off project, etc.), while considering hot-spot areas where land-surface temperatures need to be reduced by adding appropriate vegetation cover. This will allow Phoenix's City Managers to identify areas of concern and make informed decisions for effective water conservation practices across Phoenix that can lower heat stress and improve the health and wellness of city customers. The City of Phoenix has agreed to partner with the PI in the School of Geographical Sciences and

Urban Planning at Arizona State University to generate a series of maps that can identify microclimate areas and to learn how different landscape patterns and composition, new developments, and redevelopment construction projects within Phoenix contribute to UHI and water conservation.

Daniel Otis/University of South Florida, Tampa
Examining the Relation Between Biodiversity and Surface Temperature Regimes in Localized Coastal Upwelling Zones Using ECOSTRESS
18-ECOSTRES18-0037

This project will take advantage of the unique opportunity that the ECOsystem Spaceborne Thermal Radiometer Experiment on Space (ECOSTRESS), installed the International Space Station (ISS), affords to make frequent thermal infrared observations of coastal areas of the United States at a high spatial resolution. We plan to utilize two types of ECOSTRESS data to investigate fine-scale patterns of surface temperatures over water and land as well as at the interface between the two. First, we will apply a split-window sea-surface temperature algorithm to the Level-1B mapped radiance to create a product comparable to data from other thermal infrared sensors that provide daily coverage but at much coarser spatial resolution. Specifically, the Moderate Resolution Imaging Spectroradiometer (MODIS), Visible Infrared Imaging Radiometer Suite (VIIRS), and Sentinel-3 observations will be used to validate and to assess uncertainties of ECOSTRESS temperature retrievals over water. Second, Level-2 Land Surface Temperature data will be extracted from short transects running perpendicular to the shoreline (Shore Temperature Profiles). The novelty of this proposed work relies on the fact that we can collect high spatial resolution surface temperature data of sensitive coastal environments at different times of day with near-daily coverage. This study focuses on U.S. coastlines in ecologically important National Marine Sanctuaries, such as the Channel Islands off the California coast and along the Florida Keys reef tract. These have been the focus of the NASA/NOAA-supported Marine Biodiversity Observation Network (MBON) efforts. This project provides a pathfinder for the NASA Surface Biology and Geology (SBG) mission concept that emerged from the National Academies' 2018 Decadal Survey on Earth Observation from Space, and builds on the HypsIRI combined visible and thermal infrared science questions. The results of the study will inform such future satellite missions that measure temperature in the coastal zone in several ways: by developing a strategy to generate useful and accurate thermal infrared maps, including calibration and correction of coherent noise, applying and validating sea-surface temperature algorithms, and establishing a strategy for baselines of fine-scale temperature patterns. The products of this ECOSTRESS project will be of use in documenting patterns in habitat variability of interest to ecological studies in the Channel Islands and Florida Keys against which we can assess future changes.

Objectives:

This proposal aims to:

1. Calibrate and flat field ECOSTRESS thermal infrared data and apply a split-window sea-surface temperature (SST) algorithm to data collected over coastal waters. These

retrievals will be validated using data from existing sensors such as MODIS, VIIRS and Sentinel-3.

2. Investigate spatial and temporal patterns of surface temperature at the land-water interface using the ECOSTRESS Level-2 land-surface temperature (LST) product.
3. Investigate SST patterns in upwelling areas along the coast of the Continental U.S. and in the Florida Keys.
4. Provide a pathfinder for thermal infrared studies and applications of SST for the Surface Biology and Geology (SBG) pilot studies that have evolved from HysPIRI.
5. Fully participate in ECOSTRESS Science Team efforts and in the planning for requirements for the NASA SBG mission concept as appropriate.

Helen Poulos/Wesleyan University

Evaluating the Potential of ECOSTRESS for Predicting Wildfire Effects on Plant Community Structure and Water Relations in an Arizona Sky Island Pine-Oak Forest

18-ECOSTRES18-0047

Wildfires trigger a range of changes to forest ecosystems that vary with fire-severity. Low-severity wildfires reorganize forest structure and plant community composition by killing small, short-statured trees and understory plants, while high-severity fires result in total topkill of above-ground vegetation. This variation in wildfire effects can have major impacts on post-fire vegetation composition, plant transpiration and water stress, and site evapotranspiration (ET). The new NASA ECOSTRESS remotely sensed ET and evaporative Stress Index (ESI) data products offer the opportunity to scale wildfire effects on plant and site-scale water balance from the plant- to the landscape-scales. We propose to evaluate the utility of the ECOSTRESS sensor for predicting how wildfires influence post-fire plant and site water balance and forest successional trajectories. First, we propose to install a network of field ET and plant water potential sensors in the wake of the 2011 Horseshoe Two Fire in southeastern Arizona to quantify diurnal, monthly, and seasonal variation in post-fire plant transpiration and water potential and site ET in Rhyolite Canyon of the Chiricahua Mountains. Then, we will use these data to validate ECOSTRESS for wildfire applications by relating field measurements to ECOSTRESS imagery from a range of times of day over each month of the year. We will then compare the performance of ECOSTRESS and other similar remotely sensed ET and ESI products. Finally, we will use data from this effort, along with post-fire vegetation data from our network of 270 permanent forest monitoring plots and Landsat-derived fire severity data (i.e. relative difference burn ratio (dNBR) data) to model the relationships among fire severity, plant water status, and vegetation response. The results from this study provide a first test of ECOSTRESS data products for wildfire-related applications. Such information is directly relevant forest management and biodiversity conservation due to recent, widespread increases in the prevalence of wildfire throughout the West. Moreover, products from this work would validate the use of ECOSTRESS both at the proposed study site and elsewhere as a critical tool for predicting wildfire effects on plant and site water balance and their cascading effects on plant community structure and function.

David Wethey/University of South Carolina
ECOSTRESS- Heat and Desiccation Risk Prediction in Intertidal Shellfisheries
18-ECOSTRES18-0005

The intertidal zone between the high and low tide marks on ocean shores is the miner's canary for the effects of extreme events on the distribution, abundance and ecological success of organisms. The organisms that live in this zone are of marine origin but they experience the stress of terrestrial conditions (high temperatures and desiccation) every day during low tide. The European Atlantic coast is especially interesting because it is a mosaic of warm and cold regions (UK and English Channel cold, Bay of Biscay hot, NW Spain cold, Portugal hot). In this region there are extensive commercial mussel, oyster and clam harvesting and grow-out operations worth millions of dollars to local and regional economies. Extreme weather events cause stunting, death, reproductive failure and reduced productivity and pose enormous risks to the sustainability of these fisheries.

We plan to determine the utility and accuracy of the ECOSTRESS land surface temperature (LST) product for estimation and forecasting the risk of high temperature in the intertidal, at spatial scales relevant to the organisms. We propose modifications of the ECOSTRESS land surface temperature algorithm to take into account the fact that the intertidal zone remains wet during some of each low tide, so conditions are intermediate between land and water. We will collaborate with existing continental-scale networks of intertidal temperature sensors deployed by our European collaborators, to test the accuracy of ECOSTRESS L2 LST and of the alternative intertidal surface temperature algorithms that we propose.

The ECOSTRESS L3 Priestly-Taylor Evaporative Stress Index (ESI) product, since it estimates evaporation rate, is a potential proxy for desiccation risk to intertidal organisms, but the intertidal zone is masked out so it is not available. We propose two ways to derive an intertidal evaporative stress index. First we propose methods for generating an intertidal mask where the ESI can be produced. Second, we propose to use ECOSTRESS intertidal temperatures and ground level humidity from Numerical Weather Prediction, to calculate the water vapor pressure deficit between shellfish and the air, as a measure of desiccation risk.

We will use relationships between physiological performance and temperature and desiccation to predict the consequences of the temperature and desiccation conditions estimated from ECOSTRESS imagery. We will compare our risk estimates to reports from aquaculture operators.

This project addresses the call for new research and innovative analyses using ECOSTRESS products in combination with data products from other sensors (NASA, US entities or international providers) that advance the understanding of ecosystems and their biodiversity and extreme weather events. This project also expands the ECOSTRESS user community from exclusively terrestrial to including the shallow water zone between the tides. This increases the number of critical biomes served by the data products, and

broadens the agricultural applications to the economically important global aquaculture community.

Mary Whelan/Rutgers University, New Brunswick

New Estimates of Terrestrial Carbon and Water Fluxes by Combining the Carbonyl Sulfide Stomatal Conductance Tracer Framework and High Resolution Surface Data

18-ECOSTRES18-0036

Climbing ambient carbon dioxide (CO₂) levels are expected to increase plant water use efficiency (WUE) and plant photosynthetic rates, but neither of these effects are readily observed on scales larger than a leaf. CO₂ and water are exchanged through leaf stomata, where stomatal control regulates carbon uptake at the expense of evaporating water. On regional and global scales, photosynthetic carbon uptake or gross primary productivity (GPP) continues to harbor the greatest amount of uncertainty within the carbon cycle, with estimates varying by a factor of 2 (Anav et al., 2015; Beer et al., 2010). Similarly, global evapotranspiration appears to be the most difficult flux in the water cycle to measure, with estimates disagreeing by 20% (Badgley et al., 2015). The persistence of this problem mirrors the continued challenge of linking smaller-scale, process-driven evidence and large-scale earth system models. Carbonyl sulfide (OCS) is an emerging stomatal conductance tracer that can provide robust, large scale constraints on leaf gas exchange. OCS and CO₂ are simultaneously consumed within leaves at a ratio between 1 and 2. Where OCS and CO₂ concentrations are known and OCS ecosystem fluxes observed, an estimate of stomatal conductance can be made, side-stepping the uncertainties in other methods (Hilton et al., 2017; Mary E. Whelan et al., 2018). The largest global sink for OCS is destruction in plant leaves, and typically OCS production is geographically isolated from this consumption term. However, when the surface is hot and dry, soil OCS production can lead to a 25% underestimate of stomatal conductance using the OCS tracer (Mary E. Whelan et al., 2016). While OCS soil interactions appear to be straightforward to both measure and model on the site level, high resolution data is necessary to capture these “hot spots” over regional spatial scales. Here we propose to leverage the high resolution ECOSTRESS surface temperature (Level 2) observations to resolve two outstanding questions: (1) where and when are surface temperatures high enough to warrant soil OCS production corrections and (2) how does this new information change our OCS-based estimates of plant water and CO₂ exchange on regional scales? The first task will rely on an empirical model of soil OCS exchange (Mary E. Whelan et al., 2016), then calculating the geographic distribution of anticipated soil fluxes at unprecedented resolution using SMAP and ECOSTRESS data. We will use GEOS-Chem to calculate the influence of hot spots on the atmospheric concentrations, comparing the results to atmospheric observations collected by the NOAA Global Monitoring and ACT-America programs. We can then demonstrate the possible necessity of such high resolution data by comparing to OCS exchange modeled by CLM5, which includes a process-based plant OCS model. These efforts will result in a CONUS map of surface OCS fluxes that will be used to create new estimates of stomatal conductance, a critical parameter for leaf gas exchange.

Jingfeng Xiao/University of New Hampshire, Durham
Understanding Diurnal Cycles of Plant Water Use and Carbon Uptake with
Existing and New Products Based on ECOSTRESS, MODIS, and FLUXNET
18-ECOSTRES18-0049

Understanding plant water use and carbon uptake is critical for assessing ecosystem productivity, agricultural production and management practices, hydrologic cycle, carbon dynamics, and feedbacks to the climate system. Diurnal cycles of evapotranspiration (ET), water stress, and carbon uptake are of significant scientific importance for better understanding plant water use and the regulation of water stress on plant carbon uptake. Sub-daily (e.g., hourly) data of ET, water stress, and GPP are essential for understanding the diurnal patterns of plant water use and carbon uptake. The ECOSystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) can to some extent capture the trajectory of the daily ET cycling as plants open and close their stomata over the course of a day with its diurnal sampling, and provides a great opportunity to assess diurnal cycles of plant water use. The overarching goal of the proposed project is to understand the diurnal cycles of plant water use and carbon uptake using existing and new data products based on ECOSTRESS, MODIS, and FLUXNET.

Our proposed work will make use of existing and new ECOSTRESS data products in combination with data products based on other sensors (e.g., MODIS) and in-situ measurements (FLUXNET) to advance our understanding of plant water use, water stress, and carbon uptake over the course of the diurnal cycle. We plan to make use of ECOSTRESS data, MODIS data, FLUXNET observations, and meteorological reanalysis data to develop an instantaneous ECOSTRESS GPP product (a Level 3 product), and will also combine this GPP product and the existing ECOSTRESS ET product (L3_ET_PT-JPL) to develop an instantaneous WUE product (a Level 4 product). We will combine these instantaneous products with the existing ECOSTRESS ET and ESI products to explore the diurnal cycles of plant water use and photosynthesis at regional scales. These findings will be compared against those we will achieve at the ecosystem level using FLUXNET data. We will also generate temporally continuous, hourly GPP, ET, and WUE products. These temporally continuous, hourly products along with the temporally discrete, finer-resolution (both existing and new) ECOSTRESS products will be combined to assess the full diurnal cycles of ET, water stress, and carbon uptake. Our findings can shed light on how plants use water and how ET and photosynthesis vary over the course of the diurnal cycle and inform future improvement of terrestrial biosphere/land surface models.

Our proposal extensively uses the existing ECOSTRESS Level 3 (ET) and Level 4 (ESI) data products and will also develop new Level 3 (GPP) and Level 4 (WUE) products based on ECOSTRESS, MODIS, and FLUXNET data and temporally continuous, hourly GPP, ET, and WUE products. These products along with FLUXNET data will be used to assess diurnal cycles of plant water use and carbon uptake, basic research of importance to Earth system science and agricultural production. Our effort will advance the

ECOSTRESS science objectives, evaluate and improve existing ECOSTRESS data products, conduct new research and innovative analyses using ECOSTRESS data in combination with data from Terra/Aqua MODIS and in-situ measurements (FLUXNET) that advance our understanding of the carbon and water cycles and ecosystem functioning. Therefore, our proposed work is highly responsive to the ECOSTRESS solicitation. Our new ECOSTRESS GPP and WUE products and temporally continuous, hourly products (GPP, ET, and WUE) will be shared with the research community and the public in a timely fashion.
