F.5 Future Investigators in NASA Earth and Space Science and Technology

SOLICITATION: NNH21ZDA001N-FINESST

The Science Mission Directorate (SMD) reviewed a total of 927 proposals that were submitted to the
F.5 Future Investigators in NASA Earth and Space Science and Technology (FINESST)
competition within the NASA Research Announcement entitled “Research Opportunities in Space and
Earth Sciences” (ROSES-2021). Six SMD divisions at NASA Headquarters conducted/provided
oversight for the review and selection process: Astrophysics, Biological and Physical Sciences, Earth

FINESST accepts proposals for graduate student-designed research projects that contribute to SMD's
science, technology, and exploration goals. The maximum, three-year total FINESST award amount is
$150,000. FINESST grants are limited cost awards. For example, SMD suggests a student stipend of
$40,000 per 12 months. Not all projects, however, require the maximum amount available in the period
of performance.

FINESST is similar to what 2 CFR200.1 Definitions calls a "Fixed Amount Award". “Fixed amount
awards means a type of grant or cooperative agreement under which the Federal awarding agency or
pass-through entity provides a specific level of support without regard to actual costs incurred under the
Federal award. This type of Federal award reduces some of the administrative burden and record-
keeping requirements for both the non-Federal entity and Federal awarding agency or pass-through
entity. Accountability is based primarily on performance and results.”

SMD’s estimated timeframe to communicate the selection or intent-to-award decisions is late May
through late July. Selection documents are released first, followed by non-selections. Non-selections
may not be available until August 15, 2022, or later. The NASA Solicitation and Proposal Integrated
Review and Evaluation System (NSPIRES) will announce decisions via a system generated email to
the PI and AOR. NSPIRES makes detailed documentation of the selection and non-selection decisions
available for each reviewed proposal to both the Principal Investigator (PI) and Authorized Organization
Representative (AOR). Access to proposal-specific documentation requires logging in to NSPIRES and
navigating to the submitted proposal, and not just visiting the web page. FIs, however, cannot receive
or access FINESST decisions or review results directly via NSPIRES. If by August 15, the PI or AOR
have not contacted the FI, then the FI should ask them to log in to NSPIRES to see if the proposal
status has changed and download and share the results.

For assistance with NSPIRES log in, please contact the NSPIRES Help Desk at (202) 479-9376
Monday – Friday, excluding Federal Holidays, (e.g., Juneteenth National Independence observed for
2022 on June 20, July 4, i.e., Independence Day, etc.) 8 AM to 6 PM Eastern Time or by email at
nspires-help@nasaprs.com.

Table 1: FINESST-21 Proposal Data

<table>
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<th>Division</th>
<th>Proposals Reviewed</th>
<th>Proposals Selected (Estimated)</th>
<th>NSPIRES Publication Date</th>
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NOTE For Selected PI-FI Teams: Once SMD receives selection acceptance, the FINESST proposal will be transferred to the NASA Shared Services Center (NSSC). NSPIRES cannot track the NSSC grant processing activities. A grant’s status may be tracked via a web search on the PI’s name (do not use the FI name or NSPIRES proposal number) at: https://www.nasa.gov/centers/nssc/forms/grant-status-form, telephoning the NSSC at 1-877-NSSC123, or e-mailing nssc-contactcenter@nasa.gov.

Any pre-award costs incurred are at the proposer’s risk. All new awards receive an automatic 90 days of pre-award spending approval on award, meaning that NASA has waived the requirement for FINESST award recipients to obtain written approval prior to incurring project costs up to 90 calendar days before NASA issues an award. However, expenses incurred more than 90 calendar days before the award require prior written (i.e., email) approval from a Grants Office at the NSSC.

NOTE for Non-Selected PI-FI Teams: SMD received a far greater number of proposals than available funds can support. NASA plans to publish the next FINESST solicitation as a cross-divisional appendix to the NASA Research Announcement entitled “Research Opportunities in Space and Earth Science (ROSES-2022).”

A non-selected 2021 FINESST proposal may be eligible to be revised and resubmitted to the 2022 competition. Entirely new, eligible proposals also are welcome. When the new FINESST solicitation (F.5) is published in final form it will be available at https://go.nasa.gov/FINESST22. Proposal intake will continue for an approximate minimum of 60 days from the release barring any unforeseen circumstances. In the interim, SMD’s Cross Division FINESST team welcome general comments, questions, and FINESST-improvement suggestions via email at: HQ-FINESST@mail.nasa.gov.

*Technical Note: The Planetary Science Division (PSD) will make all notifications (selections and declines) available on NSPIRES at the same time in order to be consistent with other PSD program practices.

**This total may be different than what a selection letter may indicate due to administrative adjustments.

EARTH SCIENCE DIVISION SELECTION (62, Alphabetical by PI Last Name)

Stephen Ackley (PI)/Mansi Joshi (FI)
University of Texas, San Antonio
21-EARTH21-0298, Analyzing Sea Ice Formation, Growth and Deformation in the Weddell Sea, Antarctica Using IceSAT-2

The Southern ocean sea ice plays an important role in the elements of the earth system which include oceans, atmosphere and the stability of the Antarctic ice sheet. Sea ice provides an essential habitat for many species, including seabirds, seals, and krill. When sea ice freezes, it rejects brine that densifies the underlying water mass causing it to sink to lower depths. It therefore also plays a vital role in the thermohaline circulation and global climate system. The decadal changes in salinity in the Antarctic Bottom Water (AABW) may affect the strength of the deep thermohaline circulation. The Weddell Sea is the largest source of AABW, the southern limb of the global thermohaline circulation, as it plays a significant role in sea ice formation. Sea ice formation in the Weddell Sea accounts for 5 %-10% of annual ice production around Antarctica, making the region a significant source of AABW. The sea ice in the Weddell Sea was observed to have an increasing trend since the satellite period of 1978, however, the sea ice extent started to decrease from 2016-2017. Thus, it becomes important to measure seasonal and interannual sea ice variability over the Weddell Sea to understand its role in global climate on longer temporal scales.

In this project we have proposed three objectives. First, estimation of sea ice thickness using ICESat-2. This objective will allow us to estimate the sea ice thickness using photon-level point cloud data from
NASA’s ICESat-2 laser altimetry mission which will provide us with unique capabilities to analyze changes in ice thickness at a finer spatial scale (10m). Second, to compute the combined thermodynamic and dynamic ice growth from ICESat-2 thickness distributions and compare it with the thickness computed from 1D thermodynamic growth model. The results from the first objective and the results from a 1D model called CICE-Icepack will be used for comparison to better understand the contributions of different processes such as snow ice contributions. Third, the results from the first and second research objectives will be compared interannually and seasonally to understand the recent trends and changes in the thickness and, with the sea ice extent, the sea ice volume over the Weddell Sea sector.

The proposed research broadly addresses NASA’s strategic objective 1.1, to understand the sun, earth, solar system, and universe and earth science research program overarching objectives i.e., to improve the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land and ice in the climate system. As the work will be based on ICESat-2 data, it is directly relevant to one of the principal ICESat-2 science objectives i.e., estimate the thickness of sea ice and monitor any changes. The analysis in this project will help us understand the changes in sea ice processes in recent years, especially after a decrease in sea ice in 2016-2017 and provide the basis for estimating interannual changes in water mass transformation in the Weddell Sea from sea ice variability.

George Allen (PI)/Emily Ellis (FI)
Texas A&M, College Station
21-EARTH21-0358, Remote Sensing of River Temperature and Discharge: Defining Connections and Assessing Changes

The goal of this proposed project is to understand the connections between river discharge and temperature in order to determine how water quality and water quantity can be combined within the field of remote sensing. This central goal will be addressed through three main study objectives. Objective 1 will seek to integrate remotely sensed river discharge and temperature data in order to better estimate river temperatures. Objective 2 will quantify the spatial patterns and determine the drivers of short-term (subdaily) river temperature variability. Objective 3 will map the spatial patterns and determine the drivers of long-term (daily-annual) river temperature changes.

This project will use a combination of remote sensing and machine learning techniques to accomplish the proposed study objectives. The first objective will extract surface temperature and river discharge from optical imagery and satellite altimetry at USGS river gage locations to create a machine learning and remote sensing-based means of estimating river temperature. The results of the first objective will inform the final two objectives by providing a method for estimating river temperatures via remote sensing. These temperature estimates will be used to address what factors impact river temperature changes over time. The second objective will employ the concept of hysteresis loops to determine what drives subdaily river temperature variability by using upstream and downstream Landsat imagery to assess changes in river temperature in a space-for-time substitution framework. The third objective will assess long-term changes in river temperature by identifying trends in river temperature, air temperature, and river discharge.

This proposed research would contribute to several categories of the Earth Science Division SMD science goals (e.g. water and energy cycle, carbon cycle and ecosystems, societal benefit). Additionally, the project relates to objectives H-2 and H-3 in NASA’s most recent Decadal Survey. These objectives center around freshwater availability, the impact of environmental changes on earth cycles, ecosystems, and society, and the development of methods for monitoring water quality for both human and ecosystem health. As proposed, this project would make novel contributions to the study of water quality. This project also has the ability to incorporate river discharge data from the Surface Water and Ocean Topography (SWOT) mission when it becomes available. Satellite imagery from the
Landsat program will also be used for all optical remote sensing portions of the project, which will contribute to Landsat missions’ legacy of monitoring, investigating, and understanding changes to the environment and resources.

Sridhar Anandakrishnan (PI)/Amanda Willet (FI)
Pennsylvania State University
21-EARTH21-0243, Fracture and Crevassing of Greenland Glaciers from ICESat-2 Data

Climate change poses an acute global threat, with large uncertainties depending especially on the success of mitigation efforts, but also on the response of the Earth system to human emissions. As assessed by the IPCC, warming drives widespread ice loss, including loss of sea ice, snow cover, glacier mass, and other ice. Increasing ice loss is contributing to global sea level rise, which will have significant and perhaps catastrophic effects on coastal communities and ecosystems (Meredith, et al., 2019). Significantly, the sum of glacier and ice sheet contributions is now the dominant source of global mean sea level rise (Oppenheimer, et al., 2019). Thus, improved understanding of glacier and ice sheet dynamics is of critical importance for determining and mitigating the risks of a warming climate.

The large uncertainty in projections of future sea-level rise for specified warming arises especially from imperfectly modeled ice sheet processes and unpredictable climate variability (Robel et al., 2019). The work proposed here seeks to reduce these uncertainties by better understanding important controls on ice-sheet stability at marine terminating glaciers, which discharge ice from inland to the sea and are currently responsible for up to 50% of Greenland’s mass loss through iceberg calving (Melton et al., 2022). Specifically, this study proposes to use the dense and high-resolution surface elevation measurements collected by the Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2), together with supporting data sets including Landsat 8 imaging and offset tracking from SAR, to characterize the statistical distribution of crevasse morphology on marine terminating outlet glaciers on Greenland and the relationship with calving, velocity, surface hydrology, and mélange structure. A major goal is to understand the origins of damage that speeds calving, and the possibility of changing damage in a warming climate. Research addressing this goal will include comparing the timing of forcings (calving events, surface meltwater drainage, mélange breakout) to the timing of observed changes in damage (as observed in 2-D from Landsat and 3-D from the sparser-time ICESat-2 data) to test hypotheses for the causes of damage.

Within the Earth Science Division, this study specifically focuses on research and analysis (R&A), with an emphasis on the development of new scientific knowledge using the analysis of data from NASA’s ICESat-2 satellite mission. Using the associated science data products to improve complex ice sheet models, I will be able to improve the current predictive capabilities of sea level rise projections. Climate change is one of the major themes guiding Earth System Science today. NASA is at the forefront of quantifying forcings and feedbacks of recent and future climate change, for which studying cryosphere dynamics is of critical importance. This study seeks to address the challenging questions associated with climate variability and change as related to cryosphere dynamics and associated sea-level rise. The work proposed in this study is directly relevant to NASA’s Earth Science mission directorate and will utilize high-resolution observations and data assimilation to determine what changes are occurring in the mass and extent of Earth’s ice cover, and what drives them. To successfully accomplish this ultimate objective of NASA, which is to enable a predictive capability of climate change on time scales ranging from seasonal to multidecadal, this work is necessary to better constrain the controls on fracture features that control the instability of ice sheets.

Ashley Ballantyne (PI)/Marie Johnson (FI)
University of Montana, Missoula
21-EARTH21-0407, An Open Source, Multiplatform Framework to Estimate Ecosystem Resilience to Forest Fire (EARTH21)
Fire and other climate driven disturbances are shaping the future of our forests. Given the vital ecosystem services provided by forests, it is crucial that we manage forests for their continued existence under changing climate conditions. This requires the immediate investigation of forest resilience, the ability of an ecosystem to withstand a disturbance by regaining its function, structure, and composition before a threshold is crossed and an ecosystem transitions to a new state. It has been widely recognized in ecology that resilience should be the primary goal of forest restoration and management, however, few studies have been designed to comprehensively examine forest resilience to wildfire across broad ecoregions. The objective of this project is to gain a comprehensive understanding of forest resilience and the important environmental drivers across the western US. To advance our understanding of forest resilience to fire we have developed the OpenRes project to combine multiple metrics of ecosystem recovery into a forest ecosystem resilience framework. We will use several different remote sensing platforms available to examine the functional, structural and compositional recovery of forest ecosystems following wildfire. Specifically, our project is designed to address the following research hypotheses: (H1) Ecosystem function will recover much faster than structure and/ or composition and that topographic diversity will be the most important environmental driver of ecosystem functional recovery, especially in drier ecoregions of the southwest. (H2) Ecosystem structure will recover slower than function but faster than composition and that burn severity will be the most important environmental driver of ecosystem structural recovery, regardless of ecoregion. (H3) Ecosystem composition will recover the slowest, compared to function and structure and that topographic diversity will be the most important environmental driver to predict the recovery of composition. To test these hypotheses we will rely on both conventional and novel remote sensing platforms.

Advances in remote sensing technologies and analyses now allow scientists to characterize many different forest properties and how they are changing simultaneously from landscape to regional scales. Specifically, to estimate the recovery of ecosystem function (H1) we will use recently derived high resolution (30m) estimates of net primary productivity and evapotranspiration that have been derived from MODIS and LandSat data products. To estimate structural recovery of forest ecosystems (H2) we will rely on GEDI data of gridded canopy height and interpolated biomass. Lastly to evaluate the recovery of forest composition (H3) we will utilize a recently developed vegetation change detection algorithm and validate it against the National landcover database and a recently derived map of tree cover for the western US.

This project will contribute directly to NASA’s earth science mission to advance our understanding of interactions among major processes in the Earth system. Our research will utilize both conventional and novel remote sensing data to detect changes in ecological resilience to forest fire. This research will result in high resolution analyses of how fires are transforming the function, structure, and composition of fires across the Western US. This research will also directly benefit society by producing actionable science, such as maps of integrated forest resilience across the Western US that will be useful for management and policymakers.

Gil Bohrer (PI)/Theresia Yazbeck (FI)
Ohio State University
21-EARTH21-0004, Improve Methane Estimation in Earth System Models Using HLS-Derived Within-Wetland Ecohydrological Patch Types

Our goal is to reduce earth system models’ prediction errors of wetland fluxes by incorporating model-resolved within-wetland vegetation patch types as classified from NASA’s HLS surface reflectance observations. The large uncertainty in wetlands’ methane budget is mainly attributed to the small-scale temporal and spatial heterogeneity of wetland hydrological and ecological structure that drives highly variable methane flux rate. Spatial heterogeneity is typically at a scale of tens of meters and associated with alternating vegetation patch types within a wetland. Temporal variability is typically at a scale of
An ongoing Department of Energy (DOE) funded project at Bohrer’s lab has recently updated the DOE’s Exascale Earth System Model (E3SM) Land Model (ELM) to be able to resolve within-wetland ecological patch types. However, to apply this model development for simulations of wetlands, prior knowledge of patch-type distribution within the wetland sites must be available. Such information could be provided by high resolution satellite imagery. NASA’s HLS product provides medium-high resolution surface reflectance (~30m) with short (few days) return time, which can be used to classify within-wetland patch-types. While the 30m resolution of HLS leads to more mixed pixels as compared to much higher resolution multi-spectral products, the frequent return time guarantees the availability of a full growing season timeseries of NDVI every year. This is a clear advantage over higher-resolution images because cloud-free high-resolution multi-spectral images may not be available at all for many sites in most years. In a previous project in our lab, conducted at a coastal wetland in Ohio, it has been demonstrated that seasonal HLS NDVI timeseries for a few ground-truth or expert classified “pure” pixels constitute a seasonal temporal fingerprint that can be used to accurately classify each HLS pixel within a wetland to its dominant vegetation patch types.

The proposed project will start by producing classified within-wetland patch type maps from HLS NDVI time series for NDVI time series for three wetland sites in Louisiana for each year during the last decade, 2015-2025. Site-level eddy covariance flux and patch-level chamber flux observations of CO2 and methane fluxes are conducted in these 3 Louisiana sites and the Ohio site. Next, we will develop functions to incorporate the information from these patch-type maps into ELM initialization, thus providing the model with the required patch-type coverage, which are needed for applying its new within-wetland patch resolution capabilities. ELM updates will be validated with flux measurements in the four study sites using the PEcAn workflow comparing patch-level and whole-site model and observed CO2 and methane fluxes. Lastly, we will contact the PIs of wetland sites from the FLUXNET-CH4 dataset and request for minimal ground-truth information needed to define the patch types relevant to their sites. We will use these data to produce HLS-based annual patch-type classification maps for 20-30 of the FLUXNET-CH4 sites within the conterminous US and regions surrounding them with wetlands of similar types. We will conduct long-term sensitivity analyses of the regions represented by these sites. We will compare modeled and observed site-level fluxes of the original single-patch simulations with simulations using the HLS-classified multi-patch approach and quantify the reduction of uncertainty in model prediction gained by implementing remote-sensing based, within-wetland, patch types.

Camrin Braun (PI)/Emmett Culhane (FI)
Woods Hole Oceanographic Institution
21-EARTH21-0403, Integrating Ships and Satellites to Understand the Global Biogeography and Biophysical Coupling of Surface and Deep Ocean Ecosystems (EARTH21)

Recent research has revealed that the ocean twilight zone (OTZ; 200-1000m) hosts the highest vertebrate biomass on Earth (7-10 billion metric tons) and provides vital ecosystem services. This region houses the largest portion of the biome that is invisible to satellites, thus estimates of animal biomass in the deep ocean are primarily based on remote observations made by shipboard echosounders (SIMRAD EK60) from the surface. In contrast to synoptic global observations of many of the physical, chemical and biological components of the Earth system, the limited spatial and temporal extent of echosounder data has prevented the development of a global-scale understanding of the OTZ.

Acoustic Doppler Current Profilers (ADCPs) have been routinely used on research cruises since the late 1980’s and contain signals that can be used to observe the relative density and distribution of mesopelagic scattering communities. Recent studies have used large archival datasets of ADCP backscattering to characterize patterns in the diel vertical migrations (DVM) of OTZ communities at a quasi-global scale. These studies have used ADCP raw received signal strength (RSSI), which can be
used to detect relative day-night differences in backscattering (and thus DVMs) though does not provide a standard metric that can be compared across ADCP instruments and frequencies. This has prevented ADCP-based analyses from describing properties of deep scattering layers themselves such as density and distribution, which are critical to understanding the structure and function of OTZ biology. An alternative approach is to use uncalibrated ADCP data to calculate mean volumetric backscattering (MVBS), though the process requires the estimation of instrument-specific calibration parameters and environmental variables, which is labor-intensive and introduces complex error that is not well described. This proposal will outline a process for the calculation of MVBS from archival ADCP data and provide a quantitative description of the associated parametric error. The derived MVBS will then be integrated with a suite of remotely sensed observations of ocean components to 1) investigate the biophysical drivers of variability in the density, depth and thickness of deep scattering layers; 2) estimate a novel global biogeography of mesopelagic biology for use in more directed studies; and 3) provide forecasts for the time-evolution of deep scattering layers in response to climate warming and anthropogenic disturbance.

The goal of this research is to improve our understanding of the structure, function and distribution of deep ocean communities through the development of a novel, large-scale dataset of mesopelagic scattering measurements and a synergistic analysis of remotely sensed observations of oceanic components. These efforts leverage NASA capabilities to expand our understanding of the pelagic ocean and the biophysical interactions that modulate the connectivity between the surface and deep-ocean. The project is directly aligned with the Earth System Science Division’s commitment to utilizing NASA’s unique capabilities to measure a comprehensive suite of Earth system components and specifically exploits these for an interdisciplinary project grounded in understanding enigmatic ecosystems that have proven particularly difficult to study with other approaches. The analysis provides a key link between the deep ocean and surface properties that can be measured by satellites, thus extending the observational capabilities of NASA into this critical, understudied and currently ‘invisible’ habitat.

Joern Callies (PI)/Scott Conn (FI)
California Institute of Technology
21-EARTH21-0154, NIW–Current Interactions in Observations of Sea Surface Height and Velocities

Near-inertial waves (NIWs) in the ocean are excited by passing storms. The ocean is resonant at the inertial frequency, making this ringing in response to wind forcing a ubiquitous feature in surface currents. But when the ocean circulation is observed from space, which is currently done using satellite altimeters that measure the sea surface elevation, NIWs are invisible. Altimeters only pick up on mesoscale eddies, turbulent currents with length scales of order a hundred kilometers, which are in what is known as geostrophic balance; a force balance between the pressure gradients produced by a tilting sea surface and the Coriolis force due to the Earth’s rotation. Altimeters measure tilts in the sea surface, and geostrophic currents can be inferred. Despite producing currents of similar magnitude in many regions of the world ocean, NIWs have no comparable signature in the sea surface elevation, and so we lack global observations of them. This may be about to change, however, because the proposed Winds and Current Mission (WaCM) would measure surface currents directly and thus give access to a global view of NIWs. This proposal aims to anticipate the advances made possible by such a mission by improving our dynamical understanding of how NIWs evolve, particularly by interacting with mesoscale eddies and fronts at the edges of such eddies.

This proposal has three objectives: (1) Assess where and when NIWs modify the geostrophic balance that has been at the core of the interpretation of decades of altimetry data. This will be done by estimating the wave effect from surface drifters and comparing it to sea surface elevation observations from altimetry. (2) Extend existing theory describing the dynamical interaction between NIWs and mesoscale eddies to account for the effects that occur at strong fronts. (3) Identify NIW–front interactions in observations collected as part of NASA’s S-MODE project, which includes aircraft
measurements using the instrument proposed to be employed in WaCM. The developed theory and numerical simulations will be used to guide the interpretation of these observations. Evidence of NIW–current interactions will also be sought in data collected by the Surface Water and Ocean Topography (SWOT) mission that is scheduled to launch later this year.

This proposal has relevance to a number of current and proposed NASA missions. WaCM would make simultaneous measurements of the surface currents and the winds. Its surface current observations would have a strong NIW signal, affording a global view of NIWs and their entanglement with mesoscale eddies and sharp fronts. The proposed work would both clarify the dynamics of NIWs and provide guidance on the interpretation of concurrent WaCM and altimetry data, including SWOT data that will offer unprecedented resolution of the sea surface elevation field. The work would highlight how a future WaCM may be used to constrain small scale dynamics that is currently not simulated in numerical climate models. The proposal would also make direct use of data collected as part of S-MODE. Investigating the interaction between NIWs and fronts would aid in S-MODE’s goal to understand the evolution of the observed fronts.

Jui-Yuan Chiu (PI)/Chen-Kuang Yang (Fl)
Colorado State University
21-EARTH21-0354, Assessing the Role of Near-Cloud Aerosols in Radiation Budget Using Retrievals from 3D Radiative Transfer and Machine Learning

The presence of aerosols can heat or cool the atmosphere, depending on their interactions with clouds and radiation. These interactions remain one of the primary sources of uncertainty in climate change predictions. To understand the role of aerosols in climate and their interactions with clouds, the observational constraints for aerosol properties and radiative forcing have largely relied on satellite observations. Specifically, shortwave reflectance measurements have been widely used to provide information on the aerosol type, particle size, and optical thickness.

While aerosol retrievals over oceans in regions far from clouds are robust, properties of aerosols in the vicinity of clouds remain challenging to retrieve and yet, are scientifically important. The retrieval challenge arises because the reflectance near clouds is enhanced by aerosol property changes due to the high humidity environment and other chemical processes and by 3D cloud radiative effects that the existing retrieval methods cannot account for. As a result, many near-cloud observations are discarded, which significantly affects the current aerosol radiative forcing estimates.

The proposed project aims to address the lack of near-cloud aerosol retrievals, fill the critical gap in the existing aerosol products, and assess the direct radiative effect of near-cloud aerosols. The proposed project will use MODIS observations over oceans, focusing on aerosol types that are most sensitive to humidity and on cumulus regimes where 3D cloud radiative effects are expected to be most significant. To achieve our goal, the following objectives will be pursued:

• Develop a machine-learning-based method that incorporates 3D cloud radiative effects and aerosol hygroscopic growth for retrieving near-cloud aerosol properties, using shortwave reflectance observations from MODIS
• Quantify the global impacts of near-cloud aerosols on clear-sky and all-sky direct radiative effects over oceans, and contrast two years that have significant changes in emission
• Exploit the new aerosol retrievals to study the variability of aerosol direct radiative effects with organizations of marine shallow cumulus and to understand the implication for a warmer climate

The proposed project is expected to provide new global and regional estimates of aerosol direct radiative effects that include near-cloud aerosols for the first time and directly contribute to enhancing the current MODIS operational aerosol retrieval algorithm. Given the importance of satellite-based
aerosol retrievals, results from this project will be of considerable interest to both climate modeling and observational communities for studying aerosols and their interactions with clouds and radiation.

Winnie Chu (PI)/Angelo Tarzona (FI)
Georgia Tech Research Corporation
21-EARTH21-0083, Analyzing Multi-Decadal Changes at Ross Ice Shelf Through Historical SPRI-NSF-TUD and Modern NASA/NSF Operation IceBridge and ROSETTA-Ice Radar Sounding Data

Embayed ice shelves like Ross Ice Shelf (RIS) restrict or “buttresses” the seaward movement of inland grounded ice. The aim of this research is to assess whether RIS basal melt rate were underestimated due to lack of observations that dates back before 2000s. This proposal will focus on using historic radar sounding data from the historical 1974 campaign of Scott Polar Research Institute (SPRI), National Science Foundation (NSF), and the Technical University of Denmark (TUD) at RIS. I will directly compare these historic data with modern radar sounding observations from the NASA/NSF Operation IceBridge (OIB) (2011, 2013, and 2017) and NSF ROSETTA-Ice (2015-2017) to quantify multi-decadal changes in RIS ice shelf thickness and derive basal melt rate estimates. The results from this proposal contributes to the long-term understanding of RIS vulnerability with respect to atmospheric and ocean warming.

Belay Demoz (PI)/Maurice Roots (FI)
University of Maryland Baltimore County
21-EARTH21-0268, Facilitating the Next Generation of Air Quality Science: Synergy of NASA’s Ground-Based Observation Networks

Ozone is an important gas throughout Earth’s atmosphere. Prolonged exposure to ozone is associated with respiratory illness and degradation of land and marine ecosystems. Policymakers have imposed regulation on the emissions that produce ozone [nitrogen oxides (NOx: NO & NO2) and volatile organic compounds (VOCs)] in the atmosphere, however high ozone episodes continue to be observed, especially in domains of complex surface terrain like coastal areas. The processes that contribute to the production and dispersion of pollutants in the air we breathe are more complex in coastal regimes, especially within the Chesapeake Bay airshed. The effect of variable topography in the mid-Atlantic region generates three distinct mesoscale features in wind patterns: Nocturnal Low-Level Jets (NLLJ) which have to enhance pollutant transport and vertical mixing, Downslope Winds (DWS) which enhance dispersion and lofting, and Bay-Breeze which causes recirculation of polluted air mass. Previous data gaps have left these three mechanisms lesser studied phenomena than their counterparts in other parts of the U.S. (i.e. the Great Plains LLJ, the Denver DSW, or the Houston Bay-Breeze). These mechanisms are strong dynamic drivers of atmospheric chemistry which are able to inhibit or enhance ozone production and alter chemical budgets and thus constitute a need for further study. To facilitate this, networks of routine high-resolution observations are needed to capture the full temporal and spatial evolution of air quality episodes. Ground-based remote-sensing instruments like advanced lidars (wind, ozone, water vapor, and aerosol profiling), ceilometers, and spectral radiometers (Pandora, AERONET), as well as in-situ samplers like sondes (meteorology and ozone) and surface analyzers (VOCs, NO2, and O3), are needed at sub-hourly timescales (high temporal resolution) with stations in major terrain differences (i.e. urban, suburban, rural, mountainous, marine) for effective four-dimensional (4D, space and time) characterization of coupled chemistry and dynamics. The proposed work will combine these observations of winds, aerosols, and trace-gas pollutants to complement and extract new science from NASA’s existing networks of ozone lidars (Tropospheric Ozone Lidar Network, TOLNet) and Pandora spectrometers. Two overarching questions will be addressed: Q1) Can the high-resolution observations from TOLNet and Pandora be harmonized with regional surface air pollution observations and dispersion models, like the NOAA HYSPLIT, to capture and quantify the evolution and regional impact of air quality episodes? Q2) To what extent are

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vertical profile observations of ozone from TOLNet and radio-sondes as well as column integrated values from Pandora properly represented by large-scale chemical transport models? Do the results show relevance and a good comparison with planned retrievals from space? This work will rely on datasets from recent NASA coastal air-quality campaigns conducted in the Chesapeake Bay, Galveston Bay, and Long Island Sound. The results of this work will serve to foster new process-level science on the coupling of chemistry and dynamics coastal area, facilitate the improvement of NASA’s chemical transport models with observational validation, and meet a data gap within the agency for validation of planned ozone retrievals from space. The synergistic approach to air quality episode analysis will directly address the 2017 NASA Decadal Survey Questions: (W-5) What processes determine the spatiotemporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?; (W-7) what processes determine observed tropospheric ozone variations and trends, and what are the concomitant impacts of these changes on atmospheric composition/chemistry and climate?

Belay Demoz (PI)/Kylie Hoffman (FI)
University of Maryland Baltimore County
21-EARTH21-0269, Understanding Dynamic Convection Organization Using Passive and Active Profiling

The planetary boundary layer (PBL) is a turbulent, well-mixed layer in the lower troposphere which plays an essential role in mesoscale dynamic processes and the transport of chemical species, aerosols, and water vapor. For decades, forecasting skill for afternoon thunderstorms driven by synoptic scale forcings and high values of convective available potential energy (CAPE) have steadily improved, while skill in predicting nocturnal thunderstorms driven by more nuanced forcings such as bore waves and converging boundaries in the PBL have not made the same appreciable advances. In the Southern Great Plains (SGP) where agriculture is a vital component of the economy and precipitation has a direct impact on soil fertility, forecast accuracy is critical both from an economic and public safety perspective.

This project will address uncertainties of observing PBL moisture and temperature organization relevant to the initiation of convection in the SGP in two major ways. First, passive and active remote sensing observations will be used to expand theories based on idealized simulations (thermodynamic and dynamic aspects) and second, comparisons between observing systems, algorithms, and instrument resolution will be conducted to identify optimal patterns for capturing observations of PBL mesoscale organization. Preliminary work based on a SGP symmetric convergence case study event demonstrates that CAPE, Convective Inhibition (CIN), and Vorticity can be calculated from remote sensing observations and results from this case study have revealed correlations between moisture and temperature observations with elevated CAPE hours before the arrival of a surface-based convergence boundary.

Future research aims to extended analyses from the case study to additional events observed during the 2015 Plains Elevated Convection At Night (PECAN) field campaign which took place over the same region, the SGP. Incorporating new events into this research will enhance or modify our early theories of the skillfulness surrounding ground-based remote sensing in early detection of parameters relevant to convection initiation. Analyses from the preliminary case study (CAPE, CIN, Vorticity calculations) will be extended to PECAN events where substantial LASE water vapor Differential Absorption Lidar (DIAL) measurements are available. Airborne DIAL observations will be incorporated into future research to allow for more rigorous analyses of how convection forms across a more expansive domain of observation. We believe that a more rigorous investigation of LASE DIAL data from PECAN and its integration with models will inform future suborbital and space-based instruments for PBL profiling, as well as lay the foundation for similar analyses with the High Altitude Lidar Observatory (HALO) water vapor DIAL.
Forecasting nocturnal convection has remained a challenge in the atmospheric science research community for decades, largely hindered by a lack of observations at night. This research aims to provide a unique perspective of the PBL by merging observations, theory, and modeling. Methods tested on a single case study will be extended to additional events of interest to expand theories surrounding convection initiation. Additionally, observation systems, retrieval algorithms, and resolution will be cross examined to identify the most ideal systems for resolving features of convection at night. Finally, many of the methods and areas of motivation within this project align with goals outlined in NASA’s Decadal Survey and PBL Incubation Report. Most notably, one of the key science topics, “The interactions between the mesoscale and PBL thermodynamic structure” is labeled as “critical”, recommending a global PBL observing system.

Chunyuan Diao (PI)/Yilun Zhao (FI)
University of Illinois, Urbana-Champaign
21-EARTH21-0378, Evaluating the Influence of Biocontrol Program on the Colorado River Biodiversity with Multi-Source Time Series Imagery

Biodiversity is essential to maintain ecosystem health, lower greenhouse gas emissions, and provide commercial, agricultural, and recreational values. Based on current studies, the Sixth Mass Extinction is arriving, and more than 20,000 species have been extinct or endangered in the past few decades. Invasive species is the second most common driver that leads to the extinction of native species. One important way to control invasive species is to introduce their predators to decrease the population size and dispersion range. However, it is critical to monitor the effects of biocontrol programs on biodiversity in case that the introduced predators threaten native species. The invasive species Tamarix, together with its biocontrol program using Diorhabda, will be studied in this project. The advances in multi-source satellite remote sensing, in combination with drone and in-situ observations, provide new opportunities to investigate the plant biodiversity change in the context of Tamarix biocontrol at both local and landscape scales.

This study aims to investigate the effects of a long-term and large-scale Tamarix biocontrol program on riparian plant biodiversity of the Colorado River in Arizona using multi-source remote sensing imagery. This overarching goal will be achieved through three objectives: 1) detect Tamarix defoliation and vegetation regrowth timing at Diorhabda observed and surrounding areas with the COntinuous monitoring of Land Disturbance (COLD) model; 2) evaluate local and landscape biodiversity change caused by the biocontrol program with convolutional autoencoder (CAE)-based time series clustering, and 3) investigate the effects of pre-biocontrol biodiversity, soil water content, and soil salinity on biodiversity change.

This study will generate the most thorough analysis of the effects of the Tamarix biocontrol program on riparian plant biodiversity at both local and landscape scales, and thus will be instrumental for evaluating the success of the Tamarix biocontrol program from the biodiversity aspect to inform the conservation agencies of enhanced riparian restoration strategies. This study will also explore the potential of using multi-source time series data with in-situ observations to study the biodiversity change. A novel deep learning method (CAE-based time series clustering) will be employed to quantify the species richness and distributions, and can be generalized to study the biodiversity change across scales. This study will advance the understanding of the theoretical and operational implications of how biodiversity changes after the biocontrol program over space and time.

Ralph Dubayah (PI)/Tiago De Conto (FI)
University of Maryland, College Park
21-EARTH21-0321, Characterizing Structural Complexity of the Earth’s Forests with GEDI
Forest structural complexity is a metric that aims to summarize the amount, variability and 3D spatial arrangement of structural attributes. Forest structure is widely recognized for having strong relationships to ecosystem function and composition, as well as an effective surrogate to measure restoration effectiveness. However, measuring forest structural complexity is a hard task since it requires extensive surveys that account for several components of structure in order to generate reliable estimates. LiDAR technology is the gold standard for quantifying forest structure, as it provides 3D measurements that enable complementary structural assessments in high detail from above or below the forest canopy - using terrestrial laser scanning (TLS) and airborne laser scanning (ALS), respectively. The NASA Global Ecosystem Dynamics Investigation (GEDI) is a spaceborne LiDAR mission that was designed to map the structure of Earth’s tropical and temperate forests, minimizing measurement and sampling limitations for mapping forest structural complexity comprehensively. This proposal aims at characterizing the current structural complexity of the Earth’s forests using GEDI and other remote sensing data to advance our understanding of how environmental factors and disturbance affect its variability. It is subdivided into three objectives: (1) refine and validate a GEDI Waveform Structural Complexity Index (WSCI) suitable for global application by linking TLS, ALS and GEDI observations of forest structure; (2) create a global map of WSCI and characterize observed complexity as a function of edaphic, climatic and topographic factors; and (3) explore the role of disturbance history on deviations between potential and actual complexity at fine spatial resolution using fusion with Landsat and Synthetic Aperture Radar (SAR) imagery. Rigorous validation and refinement of the GEDI-WSCI will be performed using a robust forest Stand Structural Complexity Index (SSCI) designed for TLS point clouds and upscaled through ALS, thus providing a mechanism to quantify the dominant controls of WSCI and define limits on retrieval of forest structural complexity. The refined WSCI will then be applied to map the actual state of forest structural complexity globally, subsequently used to identify the geographical factors that control it on a large scale. Further wall-to-wall mapping of WSCI will be done at high spatial resolution through SAR-GEDI data fusion, generating regional maps for assessing the relationship between current levels and spatial patterns of structural complexity against the disturbance history in regions where environmental factors do not explain structural complexity. That work will provide invaluable information on the current state of structural complexity of the Earth’s forests and help in expanding our understanding on how it develops in face of environmental controls and disturbance regimes. Furthermore, the outputs of the proposed work will be useful to guide future management and policy making initiatives related to nature conservation and ecosystem restoration from a strong quantitative standpoint.

Bethany Ehlmann (PI)/Abigail Keebler (FI)
California Institute of Technology
21-EARTH21-0362, From Spectra to Mineralogy: A Remote Sensing Approach to Understanding Arid Dust Source Regions

As Earth’s climate changes, our need to understand the complex processes controlling climate and Earth’s biogeochemical cycles increases. Major Earth systems models consider the role of atmospheric mineral dust, which is known to have a net radiative forcing effect in the atmosphere, influence cloud formation, and alter ocean biogeochemistry, among other roles. However, the nature and extent of mineral dust aerosols’ impacts on climate cycles depends on its mineralogy and grain size and is currently unclear, including whether dust has a warming or cooling effect and how it influences cloud formation. Characterizing the mineralogical composition and grain size distribution of dust source regions on Earth’s surface will provide a key perspective on the role of arid landscapes and dust on biogeochemical cycles.

Dust mineralogy can be inferred directly from dust source region mineralogy; currently, models rely on mineralogical atlases derived from agricultural soil databases. However, such databases overrepresent agricultural soils, excluding some of the most important dust source regions. Additionally,
Existing mineralogical soil atlases are constructed by inferring mineralogy from literature reviews of soil descriptions and are thus subject to inconsistencies. Thus, there is a need for more comprehensive, representative maps of arid dust source region soil mineralogy.

Remote sensing in the visible/near infrared (VNIR) wavelength range can provide valuable information about mineralogical composition and is an ideal method for collecting data which spans a large percentage of dust source region land area; the Jet Propulsion Laboratory will be sending the NASA Earth surface Mineral dust source InvesTigation (EMIT) infrared imaging spectrometer to the International Space Station in 2022 for this purpose. Presently, mineralogy is characterized from spectra through optical properties-based methods like the Tetracorder algorithm by Clark et al. or through various implementations of the Hapke radiative transfer model. However, inferring direct mineralogy from spectra presents a challenge, and current methods have associated uncertainties of tens of percent in some relevant cases.

Given the limitations of current soil databases and the challenges associated with extracting mineralogical composition from spectra, the proposed project seeks to improve our understanding of current methods for spectral analysis of arid soil mineralogy and explore a potential new method. We will develop a unique database of samples of natural soils from arid dust source regions which represent key global dust sources, composed of in situ VNIR spectra, XRD analysis for mineralogical composition, grain size distribution, and laboratory VNIR spectra on bulk samples and grain size separates. Our dataset will include soils previously excluded from agricultural-leaning atlases and directly link natural soil spectra to exact, known mineral composition and grain size distribution. Then, we will use our novel database to test existing physics-based modeling methods and constrain associated uncertainties and limitations with the current state-of-the-art as it relates to natural soil surfaces. We anticipate nontrivial errors, as have been documented for these methods already. So, we will trial an empirical modeling approach supported by computation and machine learning to classify mineralogy and grain size distribution from our spectral database.

The proposed work supports the Science Mission Directorate’s Earth Science Research Program’s mission to “seek to characterize [Earth’s] properties on a broad range of spatial... scales” by establishing a database characterizing the span of dust source regions’ local and global compositional diversity. Furthermore, the project will “improve our capability for predicting [Earth’s] future evolution” by providing a critical assessment of modeling techniques which play an integral role in Earth systems modeling.

Emily Fischer (PI)/Kimberley Corwin (PI)
Colorado State University
21-EARTH21-0300, Historical and Forecasted Impact of Wildfire Smoke on U.S. Solar Energy Resources Due to Aerosol-Driven Changes in Surface-Level Solar Radiation

Between 2020 and 2050, the U.S. plans to shift from 3% solar energy to 45% as climate change motivates a rapid transition to renewable energy. Understanding the impact of wildfire smoke and solar photovoltaic (PV) generation is essential for ensuring the U.S. meets renewable energy goals. Previous studies document sizeable PV generation losses on smoke-impacted days but are limited to single fire events or seasons, small numbers of PV plants, and narrow geographical areas. I propose the first longitudinal study (2006-2020) of past wildfire smoke impacts on solar resource potential and utility-scale PV output across the CONUS. I also propose to isolate and quantify how fire emissions may affect solar resources and development potential in the mid- and late 21st century. I will leverage data from multiple NASA products to conduct this research, including MAIAC, MERRA-2, AERONET, and GEOS-Chem. Data from the NOAA/NESDIS HMS and NREL NSRDB, which are derived from NASA satellite observations and model simulations, will also be incorporated in the proposed analyses. These Earth observation datasets will be integrated with solar energy records from the EIA operational reports as well as solar capacity and cost projections from the NREL reV model.
To understand the historical impact of smoke on PV resources from 2006-2020, I will 1) analyze the spatial overlap between smoke and solar potential (i.e., irradiance), and 2) develop a regression model to quantify smoke-driven changes in PV generation at existing solar plants. I will use the HMS smoke plume and MAIAC 550 nm aerosol optical depth (AOD) data to characterize smoke frequency and plume thickness. These datasets will be merged with the NSRDB global horizontal irradiance (GHI) data to characterize seasonal and annual smoke exposure across GHI zones. I will then use the SHDOM radiative transfer model to simulate surface shortwave irradiance with and without smoke based on MAIAC AODs, MERRA-2 cloud optical depths, and regional smoke optical properties. Results will be validated with AERONET. After calculating the change in irradiance due to smoke, I will integrate the EIA plant-level data and develop a regression model to determine smoke’s impact on PV generation. The regression model will estimate a plant’s capacity factor (ratio of capacity to generation) as a function of smoke-driven changes in irradiance and account for panel material, location, month, and year. I hypothesize that PV generation will decline more substantially in the western U.S. due to the more absorbing and optically thicker nature of western smoke plumes.

To predict the impact of smoke on future PV resources, I will use GEOS-Chem with RRTMG to simulate surface shortwave irradiance under variable smoke conditions and compare results to PV capacity and cost projections from the reV model. GEOS-Chem simulations for present-day (2017-2021) will be run with and without QFED emissions. Present-day fire emissions will be scaled using fire emission projections for the mid- and late 21st century that account for RCP and SSP scenarios. I will calculate the change in irradiance due to smoke for the present-day, midcentury, and late century scenarios and compare the results to the reV model’s PV capacity and cost forecasts. I will use the GEOS-Chem results in the proposed CF regression model to scale the reV capacity and quantify the impact of smoke on future PV generation.

In the 2021 Solar Futures Study, the DOE highlights the need for “evaluation of the effects of wildfires on PV generation” to strengthen solar forecasting. The proposed research leverages NASA observations and models to provide a foundation for understanding smoke’s impact on solar energy. In doing so, this project supports the NASA Earth Science Division’s science goal to “further the use of Earth system science research to inform decisions and provide benefits to society.”

Qiang Fu (PI)/Aodhan Sweeney (FI)
University of Washington, Seattle
21-EARTH21-0072, Investigating 21st Century Land-Sea Warming Contrast in Observations and Model Simulations

A robust feature of climate change simulations is enhanced warming over land compared to over oceans. This phenomenon is referred to as the Land-Sea Warming Contrast (LSWC). Due to its robust signal, the LSWC has been used as a metric for climate change and for pattern scaling approaches of climate change prediction. The LSWC has also been shown to have large impacts on both the climate system and society. Previous investigations of the LSWC use in-situ surface temperature data, which suffers from gaps in spatial coverage and inconsistent land and sea surface temperature (SST) measurements. These biases in the in-situ data degrade our ability to validate model simulations of LSWC and limit what we can learn from observations. Comparisons of simulated and observed LSWC show discrepancies in the latitudinal structure, yet it is unclear whether these differences are caused by deficiencies in the models, observations, or both. Another less studied aspect of the LSWC is its vertical structure, which in the tropics will be affected by both the vertical temperature amplification and weak horizontal tropospheric temperature gradient. Investigating the interaction of the LSWC and vertical temperature amplification could provide new perspectives on climate change in the tropics. Recent studies have also questioned the relative importance of SST trends versus local radiative effects in controlling continental warming, and thus the LSWC. To investigate these aspects of the LSWC, studies using both observations and model simulations are critically important.
The objective of this proposal is to address current gaps in documentation and understanding of the LSWC by using observations and model simulations. Key to this proposal is the use of data from the Atmospheric Infrared Sounder (AIRS). The AIRS instrument measures both land and sea surface skin temperature (and atmospheric temperature profiles) using the same instrument with global coverage, and thus it does not suffer from biases present in the in-situ products. This proposal will be completed in three phases. In Phase I observational estimates of the LSWC will be obtained globally, latitudinally, and vertically by using data from AIRS and in-situ products when applicable. Phase II will quantify uncertainty in observations by comparison to the highly accurate Advanced Microwave Sounding Unit (AMSU) and Advanced Technology Microwave Sounder (ATMS) measurements from the AQUA, MetOp-A, Suomi-NPP, and JPSS-1 satellites. Phase III will evaluate whether observational estimates of the LSWC with quantified uncertainty fall within the coupled atmosphere-ocean and prescribed SST model estimates from the Coupled Model Intercomparison Project Phase 6 (CMIP6). Experiments will also be run with the Whole Atmosphere Community Climate Model version 6 (WACCM6) using prescribed SSTs with fixed and time-varying external radiative forcings. These simulations will help quantify the relative control of continental warming (and thus the LSWC) by SST changes versus local radiative effects.

By using high quality AIRS observations with quantified uncertainties this proposal will help reconcile differences between the LSWC in observations and simulations. Observations obtained in this study will provide an opportunity to validate LSWC in CMIP6 simulations. Experiments using the WACCM6 will help elucidate the importance of SSTs in controlling the LSWC. The proposed investigation of the LSWC using observations and model simulations will significantly escalate our understanding of one of the most salient and high-impact features of climate change. This proposal will directly contribute to the Exploration and Scientific Discovery priority in the NASA 2020-2024 Science Plan through its focus on “reducing climate uncertainty and informing societal response.”

Colin Gleason (PI)/Jonathan Flores (FI)
University of Massachusetts, Amherst
21-EARTH21-0069, Monitoring the Flow of Proglacial Rivers in High Mountain Asia

Proglacial rivers play a crucial role in the hydrologic processes and water resource management in cold regions, such as High Mountain Asia (HMA). Direct monitoring of these rivers can be used to quantify the volume of glacial melt, and remote sensing is ideal to track these rivers due to logistical difficulties. However, glacial outflow streams are typically narrower than the resolution of satellite platforms such as Landsat (30 m) and Sentinel (10 m). I will leverage the use of multitemporal high-resolution Planet imagery to map smaller streams (<15m wide) and their changes over time across HMA from 2016–2022. Previous work has shown that repeated satellite widths can be used to estimate discharge, and therefore this mapping enables river discharge and therefore glacial monitoring. Traditional remote sensing techniques struggle to classify these small rivers due to geophysical constraints (e.g., shallow and muddy waters, wet glacial outwash sediment, and mountain shadows) and the lack of information further into the infrared spectrum (for Planet imagery). Given these issues, I hypothesize that the use of computer vision algorithms from the computer science literature can address these constraints and accurately classify these small rivers, and thus retrieve accurate river width variation measurements and ultimately Bayesian discharge inference solely from satellite imagery. High frequency Planet imagery will therefore augment almost nonexistent in situ gauging of HMA proglacial rivers and improve our understanding of the past, present and future hydrology of “Asia’s Water Tower”. Specifically, I propose the following science goals to develop a novel approach to monitor how much water is flowing in proglacial rivers of HMA based on remotely sensed observations: 1) develop a computer vision algorithm to accurately map the proglacial rivers in HMA using high resolution satellite imagery; 2) use established Bayesian techniques for reach-scale discharge inference from the classified images; and 3) validate the estimated discharge and quantify the discharge of every individual proglacial river in HMA to better understand this cryospheric input to the hydrologic cycle. This research will address one the of highest priorities of 2017 NASA Earth Science Decadal Survey (Objective H-1a) by accurately quantifying a component of the water cycle and offering relevant information to close the water balance.
in HMA. Overall, this research will principally contribute to the Earth Science Division’s objective to advance knowledge of Earth as a system in order to meet the challenges of environmental change and to improve life on our planet.

Nancy Glenn (PI)/Brenton Wilder (FI)
Boise State University

NASA’s study of the Surface Biology and Geology (SBG) Designated Observable has significant potential to lead to a mission that will provide critical data for global mapping of snow properties, like snow surface albedo. Prior to a SBG mission, uncertainty analysis of prototype SBG data will enable the scientific community to identify key uses of SBG data for quicker adoption in the snow and vegetation communities. The central objectives of this study are to A) Ground validate precursor SBG data and assess uncertainties of snow albedo for mid-high latitude sites; B) Quantify changes in snowmelt timing for mid-high latitude wildfires and characterize the physical processes that drive these changes to better inform modeling; and C) Use land surface model(s) with SBG snow surface albedo forcing data to analyze parameter sensitivity and reduce uncertainties in energy balance snowmelt modeling. To accomplish the first objective, in-situ measurements via the Analytical Spectral Devices (ASD) FieldSpec4 spectroradiometer and imaging spectroscopy (hyperspectral) data via satellite PRISMA and airborne AVIRIS-NG instruments, as precursor SBG data, will be analyzed and statistically compared for snow-on conditions in Alaska and Idaho. To accomplish the second research objective, NDSI (normalized difference in snow index) via multispectral satellite imagery, as well as ancillary lidar and climactic data, will be analyzed for fires across the northern hemisphere to quantify and characterize relative changes in date of disappearance of snow for a variety of burn and climate conditions. Finally, a land surface model (Crocus coupled to Noah-MP forced with WRF) will be calibrated with SBG snow surface albedo (precursor) data inputs and validated with in-situ data for the Caribou-Poker Creeks Research Watershed in Alaska. The outcomes of the research will include quantifying uncertainties in (precursor) SBG snow albedo data, identifying disturbance impacts on snowmelt processes, and sensitivity quantification of SBG snow albedo in a physics-based land surface model. The proposed work has significant implications for the SBG mission, NASA SnowEx community science, and NASA’s Earth Science Water and Energy Cycle and Carbon Cycle & Ecosystems. The work will also contribute to NASA’s Arctic-Boreal Vulnerability Experiment (ABoVE) science.

Scott Goetz (PI)/Shelby Sundquist (FI)
Northern Arizona University
21-EARTH21-0275, Characterizing Immediate and Mid-Term Climate Effects on Boreal Forest Dynamics to Model Long-Term Forest Dynamics and Management Outcomes

Boreal forests of Alaska and western Canada are experiencing rapid climate change characterized by higher temperatures, more extreme droughts, and changing disturbance regimes, resulting in forest mortality and composition changes. Black spruce, a dominant boreal forest species that stores vast amounts of carbon in deep organic soils, is not resilient to today’s droughts and fire regime. As deciduous species like aspen and birch, which grow taller and form more open forests, expand into new locations, complex interactions between vegetation, soil, and disturbance contribute to considerable uncertainty about future carbon fluxes in the boreal region. Here, I propose to address this gap by 1) characterizing climate and drought legacy effects on tree growth using tree-ring measurements, 2) incorporating these findings in a state-of-the-art model for the boreal forest, 3) verifying the forest model’s performance with site-level and remote sensing data, and 4) predicting future forest composition under various climate and management scenarios. My research objectives seek to answer the questions, will the future boreal forest be a carbon source or sink, what will the boreal forest look
like in a century, and what are the short- and long-term impacts of common forest management practices. The answers to these questions are vital for informing climate and earth system models, conservation decisions, and forest management strategies for the 21st century.

Jonathan Greenberg (PI)/Theodore Hartsook (FI)
University of Nevada, Reno
21-EARTH21-0236, Augmenting Landscape Level Remote Sensing with 3D Reconstructions of Forest Plots

The goal of this study is to evaluate a methodology by which I can "archive" forest stands in three dimensions for the purposes of post-hoc forestry measurements and to provide rapidly-collected baseline information to examine changes in vegetation over time with enough fidelity and precision to be able to measure length, area, and volume, as well as more complex characteristics such as species, all within a virtual environment. To accomplish this, I plan to use first person view (FPV) video to collect sets of imagery of forest stands, and adapt structure from motion (SfM) techniques using machine learning to reconstruct the three-dimensional structure of the stands. From this, I will evaluate the capability of these datasets to 1) capture forest stands with enough fidelity such that classic and advanced forest measurements can be collected within a virtual environment, 2) simulate three-dimensional remotely sensed datasets such as those collected from airborne and terrestrial LiDAR, as well as UAV-based SfM, 3) demonstrate how these data can be used to calibrate/validate landscape scale remote sensing of vegetation as well as vegetation change, and 4) the archiving of a research and teaching forest.

Kevin Grise (PI)/Xinhuiyu Liu (FI)
University of Virginia, Charlottesville
21-EARTH21-0071, Regional Characteristics of the Jet Streams and the Role of Moist Processes

Jet streams are relatively narrow bands of strong west-to-east winds in the upper troposphere and are important characteristics of the atmospheric circulation. Averaging over all longitudes, there are two jet streams, the subtropical jet (STJ) and polar front jet (PFJ), located in both the Northern and Southern Hemispheres. Understanding variability in the position and strength of the jet streams is important, as they directly influence impactful surface weather events, such as heatwaves, cold air outbreaks, and extratropical storm tracks and their associated heavy precipitation events. However, the dominant physical mechanisms controlling the mean-state jet streams and their variations in position and/or strength remain an area of active research.

Some recent studies have hypothesized that moist processes have significant impact on the jet streams in the current climate and in response to climate change. However, the separate influence of latent heating and cloud radiative heating on the jet streams and their relative importance has not been examined in detail yet. In addition, previous studies, which focused on vertically-integrated latent heating/cloud radiative heating or zonal-mean jets, may fail to capture some significant relationships at individual longitudes and at specific vertical levels. This study will examine the regional characteristics of the jet streams and the role of moist processes in modulating the mean-state and variability of their positions and strengths.

The proposed project has two parts. The first part of the project will examine how the mean-state jet streams are influenced by moist processes in two ways: latent heat release and cloud radiative effects. Latent heating and cloud radiative effects will be defined from MERRA-2 reanalysis and NASA satellite products from the GPM and CloudSat missions. Experiments will be conducted using a stationary wave model to partition the influence of latent heating and cloud radiative heating on the mean-state jet streams. A series of experiments will be conducted with the stationary wave model, with different
latitudes or vertical levels of latent heating or cloud radiative heating absent as perturbation experiments. The second part of the project will examine the relationship between jet variability and latent heating/cloud radiative heating in observations and try to understand the direction of causality between them using various regression techniques.

This study, which will contribute to the Ph.D. dissertation and career development of the future investigator (FI), will use multiple NASA satellite and reanalysis datasets along with conducting experiments in a stationary wave model to fill a knowledge gap of how moist processes influence the mean-state jet streams and their variabilities in the current climate. The proposed work will support the research interests of multiple NASA programs within the Earth Science Division. By investigating the role of latent heating/cloud radiative heating on the jet streams and their variabilities, the project will directly support the goal to “better understand the overall state of Earth’s climate and the physical processes that affect it (Modeling, Analysis, and Prediction Program, Climate Variability and Change Focus Area)”. By using the satellite observations to validate MERRA2 reanalysis products, the project will also support the “Reducing climate uncertainty” focus area for NASA Earth Science division in the “SCIENCE 2020-2024: A Vision for Scientific Excellence”.

Kaiyu Guan (PI)/Qu Zhou (FI)
University of Illinois, Urbana-Champaign
21-EARTH21-0316, Quantifying Field-Level over Cropping Across the U.S. Midwest Using Multi-Source Satellite Data

The corn and soybean crop system in the U.S. Midwest, contributing to one-third of the world’s production, faces grand environmental challenges related to excessive use of fertilization, soil carbon loss, and water quality degradation. Planting cover crops has been considered an essential solution to these environmental issues. To stimulate more widespread adoption of cover crops, the government has invested huge resources and efforts in cover crop programs. However, accurate quantification of large-scale cover crop adoption in the U.S. Midwest remains vastly understudied, which is critical for benchmarking historical patterns, enabling sustainable agriculture, evaluating outcomes of cover crop policies, and designing effective agricultural practices.

Remote sensing provides cost-effective and scalable approaches to detect cover crops, while traditional surveys are time-consuming, labor-intensive, and cost-prohibitive to scale up to large regions and long periods. However, remote sensing-based cover cropping remains in early stages and is limited to small regions and short periods. To fill the big gap in using remote sensing to quantify cover crop adoption at field scales across large spatial and temporal extents, this project proposes to integrate knowledge in satellite remote sensing, large-scale computation, plant phenology, and artificial intelligence, for developments of cover crop quantification framework, based on multi-source satellite observations, densely collected ground truth of cover crop adoption, and supercomputing systems. Ultimately, this project will provide field-level cover crop maps of the U.S. Midwest for the first time and enhance our understanding of cover crop adoption under climate change and government management.

To accomplish this goal, this project will produce annual field-level cover crop maps by leveraging multi-source satellite data, densely collected field-based cover crop data, environmental driver data (climate and soil), and knowledge-guided machine learning models. Specifically, this project will (1) evaluate multi-source satellite data, i.e. daily 250 m NASA’s MODIS, ~3-day 30 m NASA’s HLS, daily 30 m PI Lab’s STAIR fusion, and daily 3 m Planet’s PlanetScope for detecting cover crop fields from multiple spatial and temporal scales; (2) quantify cover crop adoption in the U.S. Midwest at field level using plant phenology to remove bare soil and cash crop signals and extract cover crop features from satellite data, and using machine learning and environmental factors to determine thresholds of cover crop features; and (3) investigate how cover crop adoption responds to climate conditions and agricultural policies by analyzing cover crop adoption under extreme climate conditions and cover crop...
spatiotemporal patterns along with cover crop policies. Our overarching science question is: what are the variations of cover crop adoption over space and time from a remote sensing perspective, and how is cover crop adoption affected by climate change and anthropogenic management?

This project will support the NASA Earth Science Research Program and NASEM 2017 Decadal Survey for Earth Observation from Space by expanding our knowledge on how cover crops are affected by natural and anthropogenic factors from multiple spatial and temporal scales utilizing NASA’s multisatellite datasets. The solicitation “highly encouraged” the use of remote sensing to understand our Earth’s surface, which is the focus of our work. Furthermore, by characterizing the dynamics of cover crops, information will be provided to policymakers and farmers for more effective policymaking and agricultural management, which is an essential element of NASA’s Earth Science Program to inform decisions and provide benefits to society.

Jennifer Haase (PI)/Harriet Yin (FI)
University of California, San Diego
21-EARTH21-0133, Using InSAR from the Recent Haiti Earthquakes to Investigate Post-Seismic Creep and Evolving Hazard on Adjacent Faults

Earthquakes pose a major threat to Haiti, as illustrated by the catastrophic M7.0, 2010 earthquake (USGS, 2010), and more recently by the M7.2 earthquake on Aug 14, 2021 (USGS, 2021). These events both occurred within the Enriquillo Plantain Garden Fault Zone (EPGFZ), a strike-slip fault zone which runs through the southern peninsula of Haiti and is a primary source of seismic hazard in the region. Neither earthquake ruptured the intervening Miragoâne segment between the two event rupture planes, raising the question of whether this segment is seismically loaded and therefore hazardous or if it’s accommodating strain in some other way. Further study of this complex rupture sequence is therefore highly relevant for both developing resilience to future earthquakes in Haiti and for improving our understanding of seismic hazard in strike-slip margins in general. Satellite-based geodetic techniques such as InSAR (Interferometric Synthetic Aperture Radar) are critical for this analysis due to the scarcity of field observations in Haiti.

Preliminary InSAR analysis of the 2021 event shows post-seismic shallow creep migrating on the EPGFZ, directly east of the rupture in the segment that was skipped. In this work I aim to answer the questions: What characteristics of the EPGFZ led to the 2021 rupture skipping over the portion of the Miragoâne segment adjacent to the 2010 Haiti earthquake and could explain the migrating creep? What are the implications of these behaviors for future seismic hazard in Haiti and other oblique strike-slip margins? To interrogate these questions, I propose to 1) process and analyze comprehensive InSAR datasets from Sentinel-1, ALOS-2 and eventually NISAR to measure the deformation field during and after the 2021 earthquake; 2) determine the coseismic slip distribution of the 2021 event using a static slip inversion and estimate the resulting static stress changes on surrounding fault segments; 3) investigate the driving mechanism of observed post-seismic creep; and 4) prepare my processing methods for the availability of NISAR data, to exploit the unique advantages of NISAR in this densely vegetated area. Results from this work will not only advance understanding of the strike-slip margin in Haiti but can also be generalized to other strike-slip boundaries, allowing for improved decision-making and broad benefits to society. This work will also develop InSAR tools and methods for NISAR which will benefit the community.

Xianglei Huang (PI)/Chongxing Fan (FI)
University of Michigan, Ann Arbor
21-EARTH21-0011, Impacts of Solar Farming on Surface Energy Budget and Climate from Long-Term NASA Satellite Observations
Motivation: To reduce carbon emissions from thermal power plants and approach the state of net-zero carbon dioxide emissions (i.e., carbon neutrality), many countries are paving the way to support the renewable energy industry. One important source of renewable energy is the radiating Sun. Converting solar energy to electricity by solar panels, commonly referred to as solar farming, becomes increasingly popular due to easy accessibility and relatively mature technology. While solar farming can reduce carbon emissions in the power production sector, dark solar panels also reduce surface shortwave reflectance and absorb more solar radiation, which is especially significant when they are deployed on highly reflective deserts. Solar panels also have different surface longwave emissivity and thermodynamic properties, affecting surface skin temperature and upward longwave radiative flux. We have analyzed MODIS observations over six solar farms in the Southwestern U.S to successfully quantify changes in surface spectral reflectances, spectral emissivities, and temperature. Similar analyses can be done in solar farms around the globe. Due to the small size of current operational solar farms, the radiative effects due to solar farming are localized. However, with solar panels covering a larger area, these effects can accumulate and propagate to a larger extent and even remote regions. It is imperative to carry out climate model simulations to predict the climatic impacts of solar farms to better inform decision makers.

Methods: I propose extending our previous work on six solar farms to other representative solar farms and, aided by climate models, investigating the radiative and dynamical response of the climate system due to large-scale solar farming activities. Specifically, I will continue to use MODIS observations in selected solar farms around the world to obtain the differences in surface spectral reflectances, spectral emissivities, and temperature before and after the installation of solar farms. This will provide a more robust estimation of the surface energy budget in a typical solar farm. Constrained by satellite observations, I will then modify the land model step by step to include the solar farm as a land type. By applying the new land type to the model grid points, I can simulate putting solar farms in different places at different scales. I will use CESM as an example due to its public accessibility and popularity, while similar treatment can be applied to other models. Finally, I will carry out sensitivity experiments to test how different scales and locations of solar farming activities could induce different responses in the climate system.

Relevance: This investigation uses NASA observations and reanalysis to provide a critical understanding of surface energy balance by surface type change. It directly relates to the water and energy cycle as well as applied science programs in NASA. The expected outcome of this study can improve our knowledge of the potential environmental impacts of large-scale solar farming, which can be used to guide future development. The discussion of attributing observed changes to physics or artifacts could also suggest the correction of satellite retrieval algorithms. All of them ultimately align with NASA’s Strategic Objectives.

Matthew Huber (PI)/Qinqin Kong (FI)
Purdue University

The lethality of moist heat stress (MHS) jointly depends on temperature and humidity. To predict extreme MHS events entails a better understanding of the controls on atmospheric boundary layer (ABL) temperature and moisture. Soil moisture (SM) in particular can substantially affect both parameters by regulating the partitioning between surface latent and sensible heat flux. It is well established that a wet soil reduces ABL temperature due to a reallocation of surface available energy from sensible to latent heat flux. But soil moistening also raises ABL humidity making the collective effects on MHS unclear. Recent modeling studies reported a modest net detrimental impact of irrigation on MHS. Such studies use either coarse-resolution GCM or regional climate models at ~30km spatial
resolution with convection parameterized. However, MHS depends critically on the build-up of hot-
humid air near the surface, and ventilation into the free troposphere, which are processes handled in an
ad hoc fashion by convection schemes. In addition, a good understanding of the physical mechanisms
that link SM to MHS is important for improving prediction of extreme MHS events. Despite a qualitative
sketch of the physical pathways by previous studies, a comprehensive and quantitative examination of
the SM-MHS process chain has proven elusive potentially due to the complex nonlinear land-
 atmosphere interaction and ABL dynamics.

Motivated by this, the objectives of this proposal is to: (1) provide a more reliable estimate of the sign
and magnitude of SM’s effects on MHS by modeling at sufficiently high resolutions that can explicitly
resolve convection; (2) decipher the physic processes governing the SM-MHS link in a quantitative
manner.

To accomplish the objectives, we will: (1) diagnose SM-MHS relation using multi-source observational
data; (2) develop a process-level understanding of the SM-MHS link using a one-dimensional ABL
model; (3) examine SM's contribution to real-world MHS events using the Weather Research and
Forecasting (WRF) model coupled with NASA’s Land Information System (LIS) at convection-permitting
scale.

This project will improve our understanding of the physical processes that govern SM-MHS link. The
outcome of this project will benefit both the early-warning and future climate change projection of
extreme MHS events. It is directly aligned with the NASA Science Mission Directorate Earth Science
Research goal to “improve the capability to predict weather and extreme weather events” and to
“improve the ability to predict climate changes by better understanding the roles and interactions of the
oceans, atmosphere, land, and ice in the climate system”.

Walter Jetz (PI)/Diego Ellis Soto (FI)
Yale University
21-EARTH21-0163, Using Detailed Human Activity and Remote Sensing Data to Assess Wildlife
Responses to Altered Human Behavior During the COVID-19 Pandemic

Most of the Earth’s surface has been substantially altered by human activities driving severe declines in
wildlife abundance, behavioral changes, restrictions in movement, and extinction of species. Despite
the clear, negative consequences for biodiversity as a whole, behavioral plasticity and evolution may
enable adaptation to a changing world, allowing some species to thrive in the Anthropocene. The
contradictory and variable responses of wildlife to anthropogenic drivers indicate that the mechanisms
that govern human-wildlife interactions and coexistence are complex; and in some cases, may be of
benefit for a subset of species. A large body of research suggests that animals respond to both the built
infrastructure of humans, as well as the direct presence and activities of humans. Much less research
has focused on assessing how the movements of humans’ impact wildlife and a more synthetic,
comparative view across multiple species is necessary to understand current and future abrupt
changes of human activities. The ongoing COVID-19 pandemic has led to an unprecedented period of
reduced human activity. While brought under the most unfortunate of circumstances, these changes in
human activity offer a unique opportunity to disentangle the effects of biotic and abiotic elements from
anthropogenic disturbances. I propose to evaluate how animals across 59 species of terrestrial birds
and mammals altered their (1) space use and (2) niche breadth across the United States before,
during, and after COVID-19 induced lockdowns in 2020. By integrating remotely sensed products with
animal tracking data and auxiliary information on human mobility data, I will investigate whether there
are key correlates of particular response types (body size, generalist vs specialist, urban tolerance).
Given the unfortunate likelihood of future drastic reductions of human activity in response to
pandemics, understanding the mechanisms underlying human impacts on animal behavior and
archiving animal tracking of the ongoing COVID-19 pandemic will be crucial. Finally (3) I plan to create
a COVID-19 animal telemetry repository that future researchers can access will lead to a wider
understanding of human-wildlife dynamics. Expected results of this research will provide a first national scale understanding of wildlife responses to changes in human activity during the anthropause. Specifically, we will be able to distinguish the effect between static infrastructure and human mobility. This work is relevant to NASA Earth Science Division and the 2020-2024 vision exploration and scientific discovery, innovation, and interconnectivity and partners (Priority 1-3) and also supports the NASA Carbon Cycle and Ecosystems Earth science goal to detect and predict changes in ecological and biogeochemical cycles, such as land cover and biodiversity.

Jennifer Kay (PI)/Jonah Shaw (FI)
University of Colorado, Boulder
21-EARTH21-0371, Can Spectral Observations from AIRS Enhance the Detection of Recent and Future Arctic Climate Change?

Spectrally-resolved observations of infrared radiation such as those made by NASA’s Atmospheric Infrared Sounder (AIRS) instrument provide valuable information about the Earth’s climate and energy budget. Yet, spectral observations are rarely used in climate change detection research. One central reason for this omission is that climate models do not produce and save spectral output. Without such model output, it is challenging to compare modeled and observed spectral radiation and to determine if observed spectral changes can be explained by natural variability alone.

Our proposed research will assess how and when forced climate change (i.e., changes driven by increased greenhouse gases) can be detected in spectral infrared measurements. In particular, we will assess if less time is needed to detect a forced change when using narrow spectral bands such as those observed by NASA’s AIRS instrument than when using broadband fluxes. To accomplish these goals, we will build a tool to simulate spectrally-resolved infrared radiances akin to AIRS observations within climate models. Using this tool, we will answer two research questions: 1) What are the spectral responses to greenhouse gas forcing and surface warming in the Arctic and can they be identified in observations from AIRS?, 2) Where in the infrared spectrum are changes in the Arctic climate first detected and what climate processes are responsible for these signals? To answer the first research question, we will perform targeted climate model experiments to isolate the spectral responses to increased carbon dioxide and surface warming. Using simulated AIRS observations, we will then investigate if these spectral responses can be identified in the AIRS record. To answer the second research question, we will perform fully-coupled climate model experiments to estimate spectral outgoing infrared fluxes under a constant climate and in response to increasing carbon dioxide. Using our constant climate benchmark, we will determine where in the infrared spectrum Arctic climate change is first detected as carbon dioxide increases. In summary, our proposed research develops a valuable tool for linking spectral observations and climate models, and applies it to study Arctic climate change. Central to NASA’s core mission, this work applies spectral satellite observations to better understand and quantify Earth’s changing climate.

Trevor Keenan (PI)/Sophie Ruehr (FI)
University of California, Berkeley
21-EARTH21-0241, Quantifying Ecosystem Reliance on Groundwater

Climate change is causing our planet to experience increasingly extreme droughts. Dry surface conditions often limit plant growth, thereby diminishing the strength of the terrestrial carbon sink and resulting in a positive feedback to climate change. Many terrestrial ecosystems rely on groundwater during drought. However, groundwater-vegetation dynamics are challenging to quantify across spatial scales and therefore are largely excluded from land surface models. Leveraging both in situ and NASA products to estimate ecosystem function and groundwater availability, this work will improve understanding of the regions, ecosystems, and processes that influence vegetation dependence on
groundwater. In turn, this research will also improve our ability to manage groundwater-dependent ecosystems in a changing world.

Chris Limbach (PI)/Robert Randolph (FI)
Texas A&M Engineering Experiment Station
21-EARTH21-0307, Active Sub-Doppler Atomic Filters for Adaptive High Sensitivity Wind Measurements

Improvements in spatially and temporally resolved wind velocimetry are essential to more accurately initialize numerical weather forecasts, improve models, predict aerosol circulation, and identify wind shear, among other uses. This project aims to improve the accuracy and precision of LIDAR wind velocity profiling through the development of an optically controlled velocity selective vapor filter. The proposed approach will take advantage of hot rubidium vapor and the phenomena of spectral hole burning. In this process, rubidium particles in the spectral vicinity of a pump laser are transferred to a trapping state, vastly reducing light transmission at this frequency and creating a spectral hole. Modulating the frequency of the pump beam shifts the spectral location of the hole. This filter will be used to analyze backscattered light from an atmospheric LIDAR, creating a filter transmission related to the line of sight wind velocity. Due to the large spectral slope from the narrow transmission hole, the precise frequency of the Doppler shifted light may be determined, providing measurement sensitivity an order of magnitude beyond state-of-the-art thermally broadened absorption lines and etalon filters.

Investigation of this concept will proceed in three distinct steps. First, table-top experiments will be used to characterize the spectral hole, its dependence on the pump laser properties, and to quantitatively observe how the pump laser frequency modulation alters the location and depth of the spectral hole. Next, Rayleigh scattering experiments in a small-scale laminar jet will be used to validate the measurement technique against existing approaches such as particle doppler anemometry and hot wire probes. In the final step, atmospheric measurements will be obtained at the remote sensing facility at the Aerospace Laboratory for Lasers, Electromagnetics and Optics at Texas A&M University. This facility contains a fiber-coupled three-channel LIDAR detection system integrated with a 16-inch diameter Ritchey-Cretien receiver telescope. The optimal configuration of the rubidium filter parameters will be chosen based on bench-top and small-scale testing.

The project outcome will include valuable data characterizing the spectral hole creation in rubidium vapor; data and modeling relating to dynamic modulation of the spectral hole location, width, and amplitude; and proof-of-principle demonstrations of wind measurements in the lab and field, including quantification of error sources. If successful, this work could lead to technology transfer and commercial development of new LIDAR systems for ground, air, and space-based monitoring of earth’s atmosphere.

Eric Lindsey (PI)/Jeng Hann Chong (FI)
University of New Mexico
21-EARTH21-0148, Investigating the Mechanics of Strain Partitioning with L-band InSAR Timeseries: A Study of the Rakhine-Bangladesh Megathrust and Crustal Faults in South and Southeast Asia

This proposal aims to develop L-band InSAR processing strategies and improved numerical methods to study the earthquake hazards represented by subduction zones. Our primary region of interest is the heavily sedimented Rakhine-Bangladesh megathrust in western Myanmar and Bangladesh. This region is densely populated and tectonically active but has been historically under-studied compared to similarly active regions worldwide, and the hazard represented by the megathrust and related faults remains debated. The availability of geodetic observations such as the Global Navigation Satellite
System (GNSS) and Interferometric Synthetic Aperture Radar (InSAR) have greatly improved our ability to map tectonic strain accumulation, but difficulties remain in remote and densely vegetated areas such as our proposed study area, which are not suitable for C-band imaging and lack dense GNSS networks.

Here, we propose to optimize the processing of 5 years’ worth of L-band ALOS-2 InSAR imagery to generate timeseries and an average line-of-sight velocity map across the Indoburman range on the overriding plate. The results will allow us to precisely map strain accumulation across the plate boundary zone as well as any transient features related to creep processes that could influence the earthquake hazard in the region. We will then combine the processed interseismic velocities with existing GNSS data to generate a regional interseismic velocity map and develop an improved block modeling framework that incorporates vertical rates to examine more accurately how strain is partitioned between the Rakhine-Bangladesh megathrust and crustal faults.

The research proposes the development of an improved set of processing strategies for L-band InSAR timeseries in a densely vegetated region, and a new block modeling framework for analysis of tectonic velocities that correctly accounts for vertical motion on dipping faults. The expected outcomes are an improved understanding of tectonic deformation of subduction zones, particularly close to the trench, an examination of the interaction between the megathrust and crustal faults, and will inform processing strategies for the upcoming NASA-ISRO Synthetic Aperture Radar (NISAR) L-band InSAR mission.

Lori Magruder (PI)/Jonathan Markel (FI)
University of Texas, Austin
21-EARTH21-0374, Investigating Arctic Coastal Erosion Through Satellite-Derived Elevation Modeling and Scalable ICESat-2 Bathymetric Data Fusion

The rapid erosion of Arctic coastlines is threatening coastal communities, ecosystems, and infrastructure. Arctic permafrost coastal erosion is irreversible, and the rate of erosion will quicken as sea ice continues to decrease. There is a critical environmental need to determine the rates of coastal erosion throughout the Arctic, better model the processes driving shoreline retreat, and predict erosion rates into the future.

Coastal digital elevation models (DEMs) which combine terrain height (topography) and seafloor depth (bathymetry) into a seamless elevation map are a one solution to this need if they can be developed with sufficient spatial extent, resolution, and vertical accuracy. This research will develop satellite derived Arctic coastal DEMs by fusing ICESat-2 coastal profiles, satellite imagery, and topographic elevation.

First, we will focus on improving satellite derived and ICESat-2 bathymetry in the Arctic. We will quantify impacts of the optically complex Arctic coastal environment (e.g., turbidity, cloud cover, and sea ice) on ICESat-2’s bathymetric capabilities. We will then derive bathymetric DEMs from satellite data and assess the accuracy of different methods at study sites along the Alaskan coast. This will help establish a comprehensive understanding of spaceborne bathymetric performance in the high latitudes. Second, despite ICESat-2 producing approximately 1 TB of data per day, with much of that the Arctic/Antarctic, there are currently no bathymetric signal finding techniques that have been validated outside of temperate climates. We will design a robust algorithm for bathymetric signal finding and classification in turbid and icy coastal environments. We will then develop techniques to fuse bathymetric classifications and with land and vegetation data products, creating unique topobathymetric profiles from ICESat-2 in an automated manner. Lastly, we will generate satellite derived, coastal DEMs through multi-source and multi-temporal data fusion. By using ICESat-2 profiles for registration and quality assessment, we will combine topographic and bathymetric models to create coastal DEMs. Ultimately, this research will result in the creation and validation of satellite-derived three-dimensional coastal models throughout the Arctic.
This research will make progress towards several Earth Science Program Objectives. Principally, it significantly improves the coverage, frequency, and vertical uncertainty of Arctic coastal DEMs derived from public satellite data. This elevation data is useful for improving flood predictions in areas facing increased storm activity and rising relative sea level, for modeling coastal sediment transport, erosion, and deposition, and for measuring the rate of Arctic coastal erosion caused by anthropogenic climate change.

Matthew Mazloff (PI)/Youran Li (Fl)
University of California, San Diego
21-EARTH21-0026, Southern Ocean Tidally Driven Mixing: Tracking Lateral Energy Transport via SWOT

Turbulence from breaking internal ocean waves drives vertical transport of water, heat, carbon, and other important tracers, influencing the ocean general circulation and climate. The past decades have seen an increased interest and success in mapping global internal tides to better understand tidally driven mixing (Dushaw et al., 2011; Zhao et al., 2016; Carrere et al., 2021). However, mapping internal tides in the energetic Southern Ocean (poleward of 35S degree) has been problematic due to signal contamination by Antarctic Circumpolar Current (ACC) jets and eddies, resulting in weak and uncertain derived amplitudes. This proposal aims to track the lateral propagation of low-mode internal tides that can travel thousands of kilometers and act as a huge remote energy source from the Southern Ocean. Quantifying this energy is essential for determining tidally driven mixing and helping improve studies focusing on internal-wave-eddy-topography interactions in the Southern Hemisphere oceans.

The proposed tools include an eddy and tide resolving 1/48 degree resolution model simulation LLC4320 from NASA and the unprecedented fine-scale Sea Surface Height (SSH) data from SWOT, which is being developed jointly by NASA and CNES and scheduled to launch later this year. Being the first swath altimeter, and thus the first altimeter able to provide across-track information, will enable SWOT to provide an excellent opportunity to better track the internal tides and study the pathways of energy cascades by providing ocean measurements with a resolution 2 km (Morrow et al., 2019).

A plane-wave fitting method, which can provide information on internal tide propagation direction, phase, and interference pattern, is proposed to resolve the full lateral picture of trajectories of low mode internal tides. Internal tidal waves are extracted by fitting plane waves using SSH measurements in moving fitting windows. In the window, the amplitude and phase of one single plane wave are determined by the least-squares fitting method in each compass direction. The technique was initially developed by Zhao et al. (2016) and has been modified to increase computational efficiency by the Fl, with help from the PI and Dr. Cornuelle (UCSD) so that it can successfully analyze the unprecedented large dataset with a high spatial resolution of both LLC4320 and SWOT. To resolve multiple internal tides, the second largest internal tide is extracted by removing the largest component from the initial SSH measurements. This process can be repeated to extract an arbitrary number of internal tides. Via extraction of M2 internal tides with both spatial and temporal coherence, the method greatly suppresses mesoscale contamination, which is essential in the Southern Ocean.

In summary, the proposal will complement the global maps of internal tides developed by Zhao, with attention being paid to the previously unresolved internal tides and to tracking lateral energy transport in the Southern Ocean via SWOT. We will first develop our methods and hypotheses via model analysis, and then aim to apply our methods to SWOT observations. With the help of NASA’s LLC4320 and SWOT and the proposed methods, we believe that the signatures of the internal waves and mesoscale eddies, and the tidally driven mixing can be better understood. The proposal is also a good match with a subset of SWOT mission goals - measuring fine-scale feature at scales as small as 20 km and improving ocean circulation models to make better future climate projections.
Particulate matter is one of the six criteria air pollutants that the United States Environmental Protection Agency (EPA) has established national ambient air quality standards (NAAQS) for under the Clean Air Act. Particles with aerodynamic diameter less than 2.5 μm (PM2.5) have been found to have the most serious adverse effect on human health and the environment. While the importance of measuring PM2.5 has been clearly demonstrated, doing so remotely remains challenging. We have developed a methodology for using High Spectral Resolution Lidar (HSRL) retrieved information about aerosol extinction and types to derive model-independent estimates of surface PM2.5 concentration and chemical speciation. We showed that for the DISCOVER-AQ BW campaign the results from the new methodology compared with the ground measurements better than the EPA CMAQ model predictions. Recently we have tested the methodology using the KORUS-AQ campaign. Our preliminary data analysis shows the method did not perform as well on retrievals from Korea as it did for the aerosols from the eastern US. We hypothesize, that this is due to two main factors: (1) particularly low mixed layer heights encountered during KORUS-AQ and (2) differences in the chemical composition and optical properties for Asian aerosols versus eastern American. For shallow mixed layer heights below ~300 m, decoupling between the surface and the air aloft makes aerosol retrievals through HSRL (and subsequent characterization by our methodology) particularly intractable. It has been shown previously that the chemical composition of aerosols (e.g., more black carbon) affects their optical properties and subsequently their type-resolved characterization (e.g., for urban aerosols).

In this work, we intend to test/improve our methodology for remotely estimating PM2.5 concentration and chemical speciation in east Asia using HSRL retrievals. This will include an introduction of a threshold for retaining the data using the HSRL derived mixed layer heights. We also plan on retraining the CATCH algorithm for east Asian aerosols using a small portion of the KORUS-AQ campaign data. Retraining will “teach” the CATCH algorithm how to treat aerosol types that may have different optical properties from the ones observed in the North American domain. Once these two steps are successfully achieved the method validation will be conducted by comparing estimated PM2.5 concentrations and chemical speciation with data from National Institute of Environmental Research (NIER) ground sites. The successful completion of this project will mean that a new methodology has been developed and validated which can be used to estimate PM2.5 concentration and chemical speciation in both North America and Asia with region-specific chemical speciation. Since the method developed in this study is designed for the NASA Langley HSRL sensor, this work will lay the groundwork for PM2.5 concentrations and chemical speciation retrievals from space a part of the NASA Atmosphere Observing System (AOS).
Therefore, this study proposes to develop a more generalized understanding of urban effects on extreme precipitation under the mountain, inland, and coastal environments. The work is highly aligned with three Science Mission Directorate (SMD) Earth Science Focus Areas of i) Water and Energy Cycle, ii) Climate Variability and Change, and iii) Weather and Atmospheric Dynamics.

The research will be guided by three science questions/tasks.

I) Where are the urban rainfall hotspots across the globe? Task I will analyze the precipitation over global urban and corresponding non-urban grids to assess urban precipitation hotspots. A map of global urban rainfall anomalies will be identified and investigated with IMERG, 3km NASA GEOS DYAMONDv2 output, and other precipitation datasets in Task I by comparing the urban and rural areas (2001 – 2020).

II) What is the influence of geography (coastal, inland, terrain complex) on urbanization rainfall anomaly? Focusing on the hotspots, Task II will target 10 to 20 cities covering the mountain, inland, and coastal environments and conduct an in-depth analysis of urban rainfall trends and distribution changes to understand the different processes. The target cities will preferably be in local clusters that are representative of coastal, inland, and complex terrain (topography) along a transect (e.g. Houston – Austin/San Antonio – Dallas; Lagos – Ibadan in Nigeria; Mumbai – Pune – Bangalore), so as to have relatively similar weather patterns affecting the rainfall.

III) What do causal/statistical approaches reveal about urban impacts on extreme precipitation? Task III will further focus on 3 to 5 cities within the hotspot locales and study the urban effects on extreme precipitation around these cities with statistical and data-driven causal analysis methods. We will assess the urban impacts on extreme precipitation using the long-term series of urban (built-up condition, impervious percentage, population, and nighttime light) and environmental factors (column water vapor, evapotranspiration, temperature, humidity, and wind). Quantitative relationships between the extreme precipitation data and urbanization variables will be developed.

This study will utilize seven satellite and reanalysis precipitation datasets with high spatial and temporal resolutions. It aims to develop a robust assessment to ensure that results are not influenced by the biases in individual precipitation datasets.

Among these seven products, four satellite and reanalysis datasets were developed or sponsored by NASA, such as IMERG, GSMaP, MERRA-2. These products will be compared and evaluated with other high quality products such as ERA5-Land and CHIRPS. Uniquely, the high-resolution (3 km) GCM output, GEOS DYAMOND Phase II dataset (provided by NASA GSFC collaborators) will be used for a fine resolution analysis of the meteorological evolution of precipitation events. This study will also use land surface and other environmental variables retrieved from NASA satellite platforms such as MODIS, Landsat, and SRTM. The utilization of NASA remote sensing data and model outputs will advance our understanding of the performance of NASA products and be helpful in assessing where improvements are needed.

Jessica O’Connell (PI)/Kyle Runion (FI)
University of Texas, Austin
21-EARTH21-0185, BERM, a Geospatial Informatics Approach for Estimating Coastal Marsh Blue Carbon and Vulnerability to Sea Level Rise

Coastal wetlands are key ecosystems for soil carbon sequestration because of high primary production. Wetland soil organic material accumulates due to reduced decomposition in water-logged anoxic soils. This encourages vertical soil accretion and resilience to sea level rise and other stressors. However, broad-scale remote sensing of productivity in existing earth system models does not accurately capture coastal wetland dynamics. The Belowground Ecosystem Resiliency Model (BERM) is a recently developed geospatial informatics tool to characterize salt marsh productivity and resilience, and is
informed by aboveground biophysical metrics. The purpose of this study is to improve BERM in order to assess broad-scale salt marsh productivity, ecosystem resilience, and soil carbon sequestration potential.

For this effort, we will expand the BERM calibration dataset through field data collection, calibrate BERM to apply to additional marsh vegetation species, and update the modeling framework to include information from both Landsat and Sentinel missions as well as other technical improvements. A main BERM output is spatially-explicit belowground biomass, a key aspect of marsh resilience, on a monthly timescale. But BERM also produces a suite of additional biophysical products, such as aboveground biomass, foliar nitrogen variation, flooding intensity, and soil temperature. Once the updated model is built, we will characterize marsh resilience trajectories by evaluating relationships between marsh productivity, water quality, drought, and flooding through place-based case studies. This will allow us to understand how changing conditions influence tidal marsh dynamics, with consequences for the societal benefits wetlands provide, such as flood control, shoreline stabilization, wildlife habitat, and water purification.

To expand BERM, we will collect ground-truth data for model calibration that cover additional wetland vegetation types, hydrodynamic, and biogeochemical conditions. We will also broaden the model and associated workflows to include additional remote sensing data products, and interrogate the model results against complementary environmental data from project partners. The goal will be to identify environmental drivers of marsh resilience. This effort will expand the applicability of BERM from the East Coast, where it is currently calibrated to model one widespread salt marsh plant species, to tidal marshes on the Gulf Coast, where vulnerable low elevation areas have higher vegetation diversity as a consequence of regional differences in tide, precipitation, and water quality. This proposal will also improve the spatial, temporal, and spectral resolution of BERM remote sensing predictor variables. BERM currently relies only on Landsat-8, but this proposal will lay the ground work for including Landsat-8, -9, Sentinel-2, and combined data products.

NASA’s Earth Science Division aims to better understand and forecast changes in the global earth system, as well as to identify causes of change and provide societal benefits. Products from this project will directly address these priorities in salt marshes by creating a tool to assess ecosystem response to naturally occurring and human-induced processes. Results will be delivered to coastal managers and decision-makers as quantitative assessments that can highlight priority areas for conservation and restoration activities. BERM will be made available to the scientific community as an open-source tool, and showcased through two place-based case studies, conference presentations, and publications in peer-reviewed journals. The continued development of BERM will generate a deeper understanding of salt marsh biophysical interactions and set the stage for the inclusion of BERM-derived algorithms in earth system models. Finally, BERM will provide a critical tool for preserving and maximizing the societal benefits these ecosystems provide.

Kiona Ogle (PI)/Emma Reich (FI)
Northern Arizona University
21-EARTH21-0132, Evapotranspiration Partitioning in Drylands Using ECOSTRESS and Eddy Covariance Fluxes

Drylands are experiencing higher rates of drought under climate change, so it is increasingly important to understand the timescales over which water fluxes (i.e., evapotranspiration [ET]) respond to changing climatic and biotic drivers. Partitioning ET into its components (evaporation [E] and transpiration [T]) can help us understand how and when climatic and biotic variables drive ET across different water-limited biomes, which will inform management practices and help predict how the hydrology of ecosystems could respond to climate change. Because drylands experience rapid environmental events and are spatially heterogeneous, it is important to be able to partition ET over short time periods in different ecosystem types to better understand the processes giving rise to
temporal and spatial variation in these fluxes. This study will integrate eddy covariance flux tower data, ECOSTRESS data, and semi-mechanistic models within a nonlinear Bayesian framework to partition ET into T and E using a new ET partitioning method that builds on previous approaches. This framework constrains water-use efficiency (WUE) with novel methods to incorporate satellite remote sensing data and constrains E with process-based algorithms. Then, this study will implement the stochastic antecedent modeling (SAM) mixed-effects Bayesian framework to quantify the drivers of T, E, WUE and their timescales of influence. Finally, it will evaluate the spatiotemporal variability in ET, T, E, and WUE along an elevation and aridity gradient to develop a better understanding of the water cycle and relative contribution of biologically mediated processes (T) to ET. This integration of ECOSTRESS data and flux-based ET partition modeling will produce a replicable method to partition ET across flux tower sites, and result in temporally fine-scale, long-term timeseries data for T, E, and WUE.

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**Paola Passalacqua (PI)/Matthew Preisser (FI)**  
**University of Texas, Austin**  
**21-EARTH21-0264, Application of Earth Observation Data in Multi-Layer Network Analysis of Flood Hazards, Social Vulnerability, and Risk**

The frequency of major flooding events continues to increase, fueling the already growing concern in numerous fields about quantifying the inequitable distribution of flood hazards. We are therefore proposing a near-real time multi-layer network model of urban flooding and social vulnerability built on survey, hydrologic point, and remotely sensed satellite data to create a comprehensive tool for impact assessments. While remotely sensed satellite data has a higher spatial coverage, point measurements can fill in gaps due to data latency and resolution challenges. Data fusion methods will integrate all available and relevant information from broad sources to provide end users with a multi-faceted picture of hazard, vulnerability, and impact of single (e.g., flood) and multiple (e.g., flood and heat) threats. Through this project, we will create a fused satellite and survey data picture of multiple hazard social vulnerability at the household level. This work will be accomplished in conjunction with existing partnerships in multiple cities to increase the adoption of scientific data for community impact.

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**Tamlin Pavelsky (PI)/Marissa Dudek (FI)**  
**University of North Carolina, Chapel Hill**  
**21-EARTH21-0263, Estimating Streamflow Gains and Losses Using In-Situ, Airborne, and SWOT Satellite Measurements**

Rivers and shallow aquifers are intricately connected hydrologic systems that are vital sources of water for communities and habitats around the world. Understanding when and where rivers gain and lose streamflow to aquifers is crucial for monitoring and maintaining these valuable resources. In the United States, nearly 64% of well water levels (within 1 km of a river) lie below the river’s water table, allowing more streamflow to potentially be lost to groundwater rather than gained. With a global increase in groundwater depletion and abstraction for agricultural and community use, regions with losing streams run the risk of withdrawing more groundwater than can be recharged. Over time, these losses can negatively impact local and downstream communities; aquatic, wetland, and riparian ecosystems; and infrastructure due to land subsidence. While extensively studied at local scales, we currently do not have a clear understanding of the patterns of streamflow gains and losses to aquifers for the majority of the world’s rivers.

With the proposed project, I aim to provide an improved understanding and methodology to detect the net water exchange (gains and losses) of river systems on a global scale. To achieve this objective, I propose to assess whether measurements from the NASA and CNES Surface Water and Ocean Topography (SWOT) satellite, when constrained with in-situ and airborne observations (collected during
a two-month field campaign), can estimate streamflow net water exchange between the Waimakariri River in New Zealand and its surrounding aquifer. With launch planned for November 2022, SWOT will enter a 90-day fast-sampling calibration and validation phase covering a nominal percentage of the Earth’s surface with a daily repeat orbit. A high-priority hydrologic validation site is the Waimakariri River which will be extensively studied with in-situ and airborne observations during this time. While this data will be collected for the purpose of validating SWOT water surface elevation, width, and slope observations, there are currently no plans to use it for scientific analysis. SWOT’s fast-sampling phase provides a unique opportunity to constrain high spatiotemporal resolution SWOT measurements using multitemporal in-situ and airborne observations over multiple river reaches, it will be possible to estimate changes in discharge using inverse and data assimilation methods.

I hypothesize that this highly constrained estimation method will yield suitable estimates of spatiotemporal variations in discharge, from which we can infer streamflow gains and losses. I also hypothesize that this method can be transferable to other river systems where some in situ data are available. In conjunction with previous studies of potential widespread streamflow losses and groundwater depletion, this time-critical assessment of SWOT’s capability to accurately detect net water exchanges will improve our understanding of the effects on river systems to climate change and the depletion/abstractions of groundwater. This new tool will provide a quantified investigation into the connectivity for the majority of the world’s rivers and their surrounding aquifers. Thus, the information gathered from this proposed research will improve our assessment, management, and decision-making regarding water quantity in rivers and aquifers on a global scale.

Robert Pierce (PI)/Juanito Jerrold Acdan (Fl)
University of Wisconsin, Madison
21-EARTH21-0024, Urban-Scale Air Quality Modeling in Coastal Environments

This proposed research will utilize an optimized, high-resolution WRF-CMAQ modeling configuration developed under previous NASA Health and Air Quality (HAQ) Applied Science Program funding for studying ozone production in urban coastal regions. The main goal is to investigate the impact of utilizing high horizontal spatial resolution modeling to simulate meso-beta scale meteorological and chemical processes in coastal urban environments. This proposed research also seeks to: 1) study the relationship between column and surface concentrations of O3 and its precursors and how the relationship varies during the day, and 2) examine potential differences in weekday and weekend VOC-NOx chemistry. The studies will utilize data collected from recent and planned field campaigns to assess the model performance. This research project supports the air quality community and the TEMPO science mission by developing high-resolution modeling capabilities needed for State Implementation Plan (SIP) development and the interpretation of diurnally resolved, high-resolution TEMPO measurements.

Andrew Richardson (PI)/Jen Diehl (Fl)
Northern Arizona University
21-EARTH21-0348, Impacts of Extreme Heat and Drought Events on Forest Productivity Assessed Using OCO-3, ECOSTRESS, DESIS, and GEDI

Climate change is causing the frequency and severity of extreme heat and drought events to increase dramatically in comparison to historical norms, which is having major impacts on forest health and productivity. Because of the major role that forests play in the global carbon cycle, it is more important than ever to understand the timescales (i.e., immediate and lagged) over which these effects occur. Technological advances in spatial resolution, temporal resolution, and precise measurements of forest health allow for novel approaches to this problem.
In late June to early July 2021 a record-breaking heat wave, commonly referred to as the “2021 Heat Dome”, shocked the Pacific Northwest, and we have yet to fully understand its impact on regional forests. This recent event provides a case study to utilize advancements in remote sensing to research and quantify the effects on forest productivity. I will use data from several NASA instruments onboard the space station (OCO-3, ECOSTRESS, GEDI, and DESIS) in my analyses. These instruments measure key attributes of ecosystem function (proxies for photosynthesis and water use), composition and structure (estimates of biomass and canopy height), and ultimately overall health (hyperspectral canopy reflectance). To quantify the effects of the Heat Dome on forest productivity and health, I will establish an analysis framework that will allow multivariate regression and account for the spatial nature of the data.

The overall goal of this project is to leverage the unique opportunity to combine advanced remote sensing to investigate the 2021 Heat Dome and its effects as a timely example of heat stress on forest productivity, creating a possible model for better understanding of the impact of future events. The following sub-questions and corresponding hypotheses are proposed to achieve this goal:

1. What were the immediate, short-term, and lagged effects of the 2021 Heat Dome on forest productivity?
   H1: As temperature increases and water availability decreases and forest exceed their critical level, forest productivity metrics will initially decrease (days). Productivity will rebound to a slightly lower steady state (weeks) as the heat dome is a pulse overlain on the more gradual press of climate change.

2. Which instrument measurement or combination of measurements most clearly captures the impact of heat-stress at short and long-term timescales?
   H2: The strongest indicator of heat-stress is a fluorescence-based measurement followed by greenness metrics. (Finding any strong indicator of stress will enhance understanding of pulse effects on the press of climate change).

3. How does forest structure influence forest recovery?
   H3: Higher biomass and closed canopied forests will show larger changes in the forest productivity metrics than thinner forests under heat-stress. (Discovering any differences in stress effects based on forest structure will enhance understanding of pulse effects on the press of climate change).

The outcome of the proposed work will represent an important contribution to NASA’s Earth Science Division’s goal of detecting and predicting changes in Earth’s ecological and biogeochemical cycles by analysis of the 2021 Heat Dome case study. The proposed research also supports NASA’s Earth Science Division’s goal to further the use of Earth system science research to inform decisions and provide benefits to society by investigating short/long term effects and forest structure benefits. With a strong remote sensing component, the proposed research will improve predictive capability for heat stress in the context of forested ecosystems and climate change.

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Dar Roberts (PI)/Clare Saiki (FI)
University of California, Santa Barbara
21-EARTH21-0194, Bridging the Gap Between Land and Atmosphere by Quantifying Wildfire Fuels and Emissions

Globally, wildfires are a significant source of greenhouse gasses and aerosol emissions that impact climate, air quality, and human health. Wildfire smoke is a complex mixture of particle pollutants that have a variety of adverse health effects such as increased susceptibility to respiratory diseases and increased risk of heart attack or failure. Because wildfires are projected to increase in frequency, severity, and extent, so too will the effects of fire emissions on the climate and human populations. The source of wildfire emissions are fire fuels, or the vegetation and biomass that burns in a fire. Fire fuels contribute to a large portion of the uncertainty in fire emissions estimates due to errors in the representations of fuel properties and their variability. Some studies have found as much as 80% of the error of calculating source emissions may be attributed to errors in estimating fuel characteristics. Fuels influence the type of combustion that occurs and subsequently the chemical composition of smoke.
Remote sensing, specifically imaging spectroscopy, allows for improved representations of fire fuels due to detailed spectral data that detect small variations between fuel types. NASA’s planned Surface Biology and Geology (SBG) mission would significantly advance our ability to map the spatial and temporal variability of fire fuel type and condition. Methods to accurately quantify fuel characteristics for fire effects modeling and estimates using imaging spectroscopy data have not been fully explored; especially methods that appropriately capture spatial and temporal variability. This proposal aims to quantify the role and impact of fire fuels in wildfire emissions from a selection of fires with a range of satellite, airborne, and ground data. The proposed research first seeks to address whether detailed biochemical and structural remote sensing data can be used to accurately map characteristics of pre-fire fuels on the ground. To do this, imaging spectroscopy, LiDAR, and multispectral spaceborne remote sensing data will be used to develop relationships with measured ground fuels data to map fuel characteristics for each fire. Burn severity will be quantified to relate the amount of fuels burned to emissions. This proposal will also address whether the same type of remote sensing data and the resulting fire fuel models can be generalized to other wildfires and regions to successfully map fire fuels. This will be done by applying the same remote sensing analysis to similar data at locations of other wildfires and statistically analyzing the resulting models and maps of fire fuels to determine if they are consistent. To quantify the influence of fire fuels on fire emissions, direct comparisons will be made between fire emissions estimated using fuels mapped with remote sensing data to the commonly used homogenous fuel inputs that contribute to uncertainty. The proposed research is relevant to the Earth Science Division’s Carbon Cycle Science and Terrestrial Ecology (CC&E) focus area as it seeks to address and improve our understanding of how vegetation and biomass impact the atmosphere. By doing so, we can better understand the role of wildfire in our earth system and the role it plays in climate change and carbon cycling. This study will specifically address the CC&E questions of “How do ecosystems, land cover, and biogeochemical cycles respond to and affect global environmental change?” and “What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?” Additionally, the proposed research addresses one of the most important ecosystems priorities from the SBG study of, “Quantify the distribution of the functional traits, functional types, and composition of vegetation and marine biomass, spatially and over time.” Through NASA sensors, this study will constrain the role of fire fuels in fire emissions with methods capable of global application.

Summer Rupper (PI)/Emma Marshall (Fl)
University of Utah, Salt Lake City
21-EARTH21-0226, A Surface Velocity Investigation of Lake-Terminating Glaciers in High Mountain Asia

Glaciers in High Mountain Asia (HMA) are important seasonal water resources as well as sources of potential hazard for millions of people living throughout downstream catchment areas. Understanding the trajectory of these land-ice bodies in a warming climate is critical to the development of robust and effective climate change adaptation and mitigation strategies. Lake-terminating glaciers appear to be a particularly important part of the overall picture of glaciers in HMA. Lake-terminating glaciers are subject to additional mass loss mechanisms (sub-aqueous melt, thermal undercutting, and calving) related to their connection to a water body that do not affect land-terminating glaciers, which lose mass dominantly through melt and sublimation. Several studies observe that these additional mass loss mechanisms seem to have consequential impacts: in recent decades, lake-terminating glaciers in many sub-regions across HMA have displayed greater terminus retreat and more negative mass balances relative to land-terminating glaciers. Coupled with projections of increases in the number and area of lake-terminating glaciers in the region in coming decades, the more negative mass balances of this group of glaciers as a whole carries important implications for the future of HMA glaciers in the 21st century.

This proposed research will improve scientific understandings of lake-terminating glaciers and the dynamics shaping their observed behavior. Beginning from the starting point of recent observations of
distinct surface velocity patterns between glaciers of different terminus types, we use surface velocity as a lens through which to examine the sub-annual glacier dynamics that contribute to observations of distinct mass balances, geometric changes and surface velocities related to terminus type on annual and interannual timescales. We focus on glacier surface velocities because they offer important information about glacier dynamics and can be collected at higher temporal frequencies than other metrics such as mass balance and thickness, facilitating our focus on events and variability that drive longer-term trends. Previous results show distinct velocity patterns between lake-terminating and land-terminating glaciers on seasonal timescales. We will use a number of surface velocity datasets to develop and validate medium-to-high temporal resolution glacier surface velocity time series. These include Global Land Ice Velocity Extraction from Landsat (GoLIVE), Inter-mission Time Series of Land Ice Velocity and Elevation (ITS_LIVE), and glacier surface velocity observations derived from synthetic aperture radar (SAR) datasets such as Sentinel1 and ALOS-PALSAR (1&2). Physical glacier models will be used to assess the various physical parameters that explain the observed glacier surface velocity variability as well as the sensitivity of surface velocities to varying physical and environmental conditions. Workflows developed in this research will contribute to the future use of NASA-ISRO Synthetic Aperture Radar mission (NISAR) products to examine glacier surface velocities on sub-annual and intra-seasonal timescales in settings where L-band is more appropriate for this analysis than C-band radar. This research serves the NASA Earth Science Research Program objective to ‘improve the ability to predict climate changes by better understanding the roles and interactions of the oceans, atmosphere, land and ice in the climate system.’ With the proposed research, we will exploit the large availability of satellite imagery over the HMA region as well as glacier modeling techniques and recent advancements in computational resources in order to better understand physical systems in an area that is highly sensitive to climate change as well as where the largest density of glaciated terrain outside of the polar regions coexists in relatively close proximity with millions of people living in downstream communities.

Oscar Schofield (PI)/Michael Chen (FI)
Rutgers University, New Brunswick
21-EARTH21-0260, Biogeochemical Cycling in the Southern Ocean: Quantifying Deep Ocean and Coastal System Dynamics in a Region of Rapid Change

The Southern Ocean plays a critical role in regulating global climate, contributing to large amounts of the ocean’s uptake of anthropogenic CO2 emissions. However, there still remain large uncertainties in our understanding of biogeochemical cycles here, largely due to the extreme difficulty in sampling this remote, hostile ocean. Satellites have provided enormous insights into the dynamics of the Southern Ocean, although they face many limitations such as the cloud-cover, lack of data during the dark polar night, and an inability to see past the surface ocean. Here, we seek to better understand biogeochemical cycling in the Southern Ocean, specifically in the rapidly warming western sector. Our first aim is to leverage autonomous profiling floats to study the dynamics and drivers of carbon export (which sequesters carbon into the deep ocean) in the deep ocean in this sector. Using the biogeochemical sensors on these floats, we will relate export to phytoplankton bloom dynamics and broad climate gradients. Our second aim is to use a long-term ecological research program to study a coastal region in this sector, the West Antarctic Peninsula. By collecting in situ optical data, we will enhance our understanding of the distribution of planktonic particle size in this coastal region, which is an important indicator of ecological community composition and how much carbon it might be able to sequester. The proposed work aligns with the Earth Science mission of NASA, and will help refine the large uncertainties in biogeochemical cycling in this rapidly changing, globally important region. Ultimately, it will help us better constrain global carbon budgets and predict regional and global change as the climate continues to warm.

Dustin Schroeder (PI)/Thomas Teisberg (FI)
Stanford University
21-EARTH21-0021, Development of a UAV-Based Integrated Ice-Penetrating Radar System for Ice Shelf Monitoring

Airborne ice-penetrating radar (IPR) is the primary geophysical tool for large-scale measurements of the geometry and internal structure of ice sheets and ice shelves. The cost and logistical complexity of collecting airborne IPR data has limited the spatial extent of measurements and has made repeat temporal monitoring exceedingly rare. The flow of most of the fastest-flowing Antarctic glaciers is buttressed by floating ice shelves. Rapid changes in these ice shelves, as has already been seen in some instances, could lead to dramatic increases in the mass loss from the Antarctic Ice Sheet. As such, temporal monitoring of ice shelves is critically important to both improving our understanding of the dynamics of ice shelves and predicting their future evolution. Due to the prohibitive cost of conventional airborne IPR, temporal monitoring is primarily done using surface observations and applying hydrostatic equilibrium assumptions to infer the ice-water interface. This approach, however, relies on multiple assumptions that are difficult to verify and likely not satisfied in many cases, especially on smaller ice shelves. We propose the development of an uncrewed aerial vehicle (UAV) with an integrated ice-penetrating radar system capable of repeat pass monitoring of ice shelves at a fraction of the cost and logistical complexity of conventional airborne IPR. This UAV-based IPR system will be capable of surveying ice shelves roughly the size of Totten Ice Shelf with a two person science field team, making it feasible to collect annual IPR surveys to monitor ice shelf changes. We have already demonstrated the feasibility of the instrument using a smaller-scale UAV and basic integration testing. Here we propose to tackle the remaining challenges of improving the radar system and integrating the instrument with a larger and more capable UAV platform. We would make this capability available to the other field teams to be used in a wide range of applications.

Nathan Senner (PI)/Jennifer Linscott (FI)
University of South Carolina
21-EARTH21-0404, Multi-Source Detection and Monitoring of Ephemeral Shorebird Habitats in an Agricultural Prairie System (EARTH21)

The North American midcontinent contains a mosaic of glacially-formed depressional wetlands that vary in depth and permanence. This variation draws migratory birds with diverse wetland habitat preferences from across the Western Hemisphere, including birds that require shallow, ephemeral wetlands. However, intensive row crop production in this region is reducing mosaic heterogeneity, disproportionately removing the shallow wetlands that many migratory species need to rest and refuel. Because shallow wetlands are often small and dynamic, little is known about how many remain in the region or how they respond to climatological cycles and landuse policies. Even less is known about how migratory birds respond to their absence. We propose an effort to map these habitats over large scales using a combination of Landsat 8 and 9 multispectral imagery, Sentinel-1 Synthetic Aperture Radar data, lidar, and the movements of shorebirds, which are indicators of shallow wetlands. With this data, we will: 1.) map the spatiotemporal distribution of shallow wetlands across the region; 2.) investigate associations between their distribution, climatic fluctuations, and land-use policies, and 3.) determine the optimal spatial network to support the migratory birds that need them.

The proposed research aligns with the NASA Earth Science Division’s key aim to monitor ecosystem changes tied to biodiversity. Results will directly inform efforts to restore wetland heterogeneity and ecosystem functioning to agricultural lands in the midcontinent. Results can also provide actionable information for shorebird conservation, informing placement of conservation easements and dynamic wetland management projects for maximal impact on migrating birds during their migratory window. Finally, we offer a framework for the growing number of wildlife biologists who are capturing animal movement data to use NASA remote sensing projects to identify ephemeral habitats and trace their effects on biodiversity.
Central Objectives: The climate-driven rapid expansion of tall shrub species into northern high-latitude tundra has important implications for Arctic ecosystem water, carbon, and energy cycling, as well as feedbacks to the global carbon cycle and climate system. However, our ability to understand the location and drivers of shrub expansion in the Arctic has been limited by its remote location and high level of biotic and abiotic heterogeneity. Increased temperatures and permafrost thaw have been generally linked to the increased shrub cover in the Arctic, but shrub distribution is also likely limited by other biotic or abiotic factors that do not favor their growth. Changes in these limiting factors could have larger or more direct impacts on shrub expansion than non-limiting factors. Therefore, a better understanding of the primary constraints on Arctic shrub distribution and growth would improve our mechanistic forecasts of their future expansion. However, current research has focused primarily on the impacts of shrub expansion on above and belowground processes, including albedo, snow, permafrost thaw, nutrient cycling, and hydrology. Far less attention has been placed on quantifying the factors that foster or limit the expansion of tall shrubs, including the species-specific and spatial and temporal variation in these limiting factors. This lack of research is further complicated by the limited availability of higher resolution datasets capable of quantifying the spatial variability in shrub biophysical properties and micro-environmental conditions. Methods/Techniques: I propose a novel, multi-scale approach to integrate field observations, unoccupied aerial systems, and NASA ABoVE airborne data to investigate the environmental limits of two tall shrub genera in the Arctic, i.e., alder and willow. I will carry out this research in three steps: 1) mapping alder and willow shrub cover from AVIRIS-NG using a scaling method that I have developed; 2) combining high-resolution maps of shrub cover, topography, climate, and soil properties to determine the environmental limits of alder and willow distribution using through environmental limiting factor (ELF) modeling; 3) identifying key biotic factors linked to these ELFs by measuring and linking maps of key plant functional traits with shrub ELFs. Three low-Arctic tundra field sites located on the Seward Peninsula, western Alaska will be used as testbeds for the training of ELF models. Once constructed, the ELF models will be applied to map the ELFs of alder and willow across this region. Existing trait measurements collected at these field sites, in combination with trait maps produced with AVIRIS-NG, will be used to examine the trait differences between alder and willow to identify biotic factors that differentiate shrub ELFs. The goals of this project are: 1) generate robust tall shrub cover maps from AVIRIS-NG across the Seward Peninsula, 2) determine the primary ELFs for alder and willow across the Seward Peninsula to understand environmental controls on tall shrub distribution, 3) compare the ELFs between alder and willow and link these with factors to underlying biotic controls through the connection with canopy functional traits. Significance: This study directly relates to NASA’s SMD “Earth Science Research Program” and within the scope of the strategic goal “How will the Earth system change in the future”. The outcome of the scaling work will provide important parameters to Earth System Modeling and new methods to the use of imaging spectroscopy for monitoring high-latitude ecosystems, which is also directly related to other NASA missions, like SBG and ABoVE. The determination of ELFs will provide new insights into the environmental limits of tall shrub expansion in the Arctic. The constructed ELF models can also be applied to future climate scenarios to provide valuable process model benchmarks to evaluate mechanistic predictions of plant distribution in the Arctic.
Recent NASA research on the climate change impact on the major crop production shows that agriculture productivity changes will be noticeable much earlier than previously anticipated. The recent state-of-the-art crop growth models report that a temperature increase of 1 to 2° C can reduce the wheat productivity by 4.7% and between 2069 and 2099, there is an expected 15.3% drop in productivity. The changes in agriculture productivity are relative to the latitude of locations. Low latitude territories would have highest decline of wheat yield and cropland extend, meanwhile for high latitude areas agro-climatic conditions can became more efficient for the wheat growth and a lead to yield increases and redistribution of cropland area. To fully understand these changes, we need to conduct a fundamental research of trends in the global extent changes that already can be observed. For this purpose, we will use the new spatial-temporal redistribution indicator – agriculture velocity that is developed based on the climate velocity concept. To improve climate velocity estimation as well as to develop robust and efficient in terms of accuracy methodology for agriculture velocity estimation, we will use optical flow model of computer vision. Agriculture velocity indicator will give us possibility to map trends of winter wheat cropland structure for 11 countries that are main wheat producers in the world, explore relationships between climate change and cropland redistribution and estimate future projection of global winter wheat fraction change based on the climate change scenarios. This research objectives can be achieved by addressing the following research questions:

i. What is the magnitude of winter wheat agriculture velocity in major wheat producing countries in the past 20 years?
ii. What are the relationships between agricultural velocity and climate change?
iii. What are the future projections of winter wheat cropland extent with regard to agriculture velocity and climate change scenarios projections?

To conduct this research, we will build winter wheat classification maps based on the MODIS satellite products, establish analysis of global agro-climatic parameters change based on the NASA Power data and produce future projections of agriculture velocity and winter wheat fraction with use of NASA NEX-GDDP and NEX-DCP30 climate change scenarios.

During this project we will produce:
1. Winter wheat maps for 11 countries which are largest producers of winter wheat in the world.
2. Collection of climate velocity maps and climate velocity maps created with the new optical flow based approach, maps of future projections of winter wheat fraction.
3. Future projection of winter wheat fraction based on the climate change scenarios.
4. Three scientific papers in the peer-reviewed journals.

This project is directly addressing the NASA’s strategic objective “Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet”, objectives of NASA’s “The Climate Variability and Change” focus area and UN Sustainable Development Goals. Outputs of this project can contribute in the conductance of Federal climate adaptation plans, agreements between NASA and USDA “to Improve Agricultural, Earth Science Research” and can be valuable for NASA Harvest, USDA’s Foreign Agriculture Service (FAS), Global Agriculture Monitoring (GEOGLAM), FAO and Global Partnership for Sustainable Development Data.

Allison Steiner (PI)/Yingxiao Zhang (FI)
University of Michigan, Ann Arbor
21-EARTH21-0014, Using Satellite Data to Understand Primary Biological Aerosols Emissions from Forest Ecosystems and Their Impacts on Cloud Properties

Primary biological aerosol particles (PBAP) are directly emitted from the Earth’s biosphere, including pollen, fungal spores, viruses, bacteria, leaf litter, and other plant fragments. They can readily take up water and act as effective cloud condensation nuclei (CCN) and ice nucleating particles (INP), and therefore have significant impacts on cloud formation and reflectivity. Compared to other aerosols, PBAP can serve as INP at warmer temperatures and thereby can dominate the ice nucleation process.
over forest ecosystems. However, current observations of PBAP are limited by small spatial and temporal regions and this leads to large uncertainties in understanding PBAP and its atmospheric effects. Satellite observations provide a new possibility to detect PBAP continuously on a large scale using optical properties. In this study, we propose to use a suite of NASA satellite products (including CALIPSO, MODIS, and AIRIBRAD) to detect PBAP in boreal-temperate forest ecosystems over North America. Ground observations (including AERONET, MPENET, ARM SGP, and NAB AAAAI) will constrain the uncertainties of satellite-derived results. We will conduct the analysis over a relatively long period (2010-2020) to understand the seasonal and interannual variations in PBAP. In addition, we will use the observed cloud properties and precipitation from CALIPSO, CloudSat, and MODIS to investigate the role of PBAP on cloud formation and lifetime. Model simulations of pollen will be conducted to understand the role of PBAP on cloud formation, and this will be evaluated with observed cloud and precipitation processes.

Overall, this study combines satellite and ground-based observation data with model simulations to develop novel tools to identify PBAP and investigate their role in cloud and precipitation. The application of this study will provide new insight into biosphere-atmosphere interactions and the associated effects on atmospheric composition and regional cloud and precipitation. Through model simulations and an understanding of the role of PBAP in the Earth system, the work will further develop Earth system modeling and weather forecasting.

Dariusz Stramski (PI)/Anjali Narayanan (FI)
University of California, San Diego
21-EARTH21-0035, Examining Responses of Phytoplankton Community Composition to Climate-Related Changes in the Arctic Ocean Using Multiyear Observations from Multiple Satellite Missions

The Arctic Ocean (AO) is experiencing drastic environmental change such as amplified warming and sea ice loss. Such changes directly impact phytoplankton biodiversity, and recent studies have reported climate-related shifts in Arctic phytoplankton community composition. Relating these shifts to climate-related changes can help better understand the current and future implications for biogeochemical cycling and upper trophic levels. Optical remote sensing offers the capability to monitor phytoplankton communities over broad spatiotemporal scales. However, most remote sensing algorithms for assessing phytoplankton community composition are developed for lower latitudes and not well-suited for immediate application in the AO. This project will address this gap by developing an optical classification algorithm for discriminating Arctic phytoplankton assemblages and applying it to ~25 years of satellite observations within the western AO in the late spring-early fall seasons from multiple satellite missions (1997-present). Major research objectives are to: (1) Develop an optical approach to partition Arctic phytoplankton communities into cell size-based classes; (2) Demonstrate and test an optical algorithm for identifying these size classes with satellite data in the Chukchi and Beaufort Seas (CBS); (3) Apply an optical algorithm to ocean color satellite imagery from the past ~25 years to conduct a times series analysis of spatial changes in phytoplankton community composition within this region; and (4) Correlate these results with changes in satellite-derived biogeoophysical parameters over this time period.

The proposed algorithms will be developed using a quality-controlled dataset comprising concurrent measurements of phytoplankton pigments, inherent optical properties (IOPs) including spectral phytoplankton absorption, and remote-sensing reflectance (Rrs) from surface waters of the CBS. The algorithms will be based on relating the optical properties to phytoplankton size-based classes calculated from pigment composition and will provide a tool to identify and discriminate pico-, nano-, and microphytoplankton-dominated assemblages from ocean color remote sensing. The ocean color algorithms based on Rrs or a combination of Rrs and IOPs will be first demonstrated and tested with satellite-in situ data matchups. Algorithms will then be applied to a time series analysis of satellite ocean color data in the CBS to determine changes and trends in phytoplankton community composition.
over the past ~25 years. Time series of satellite-derived biogeophysical data (e.g., sea surface temperature, sea ice concentration, chlorophyll-a concentration, water turbidity) will also be analyzed to understand the responses of Arctic phytoplankton communities to climate-related environmental changes.

This proposed work will produce an optical approach applicable to remote sensing that will allow monitoring of changes in Arctic phytoplankton communities over broad spatiotemporal scales and assessment of subsequent impacts to the AO ecosystem and biogeochemical cycles. This research will benefit ecological, biogeochemical, and climate models of the AO by adding satellite-derivable phytoplankton data products. The open-source deliverables of this project will help users understand the utility of optical remote sensing methods in studying Arctic climate change and empower them to use such scientific tools in management, education, and policy. This work contributes to key goals of NASA’s Earth Science program including (1) Detect and predict changes in Earth’s ecosystems and biogeochemical cycles and (2) Improve the ability to predict climate changes by better understanding the roles and interactions of the oceans, atmosphere, land, and ice in the climate system, and addresses the “Arctic Systems Interactions” and “Community Resilience and Health” priority areas of the Interagency Arctic Research Policy Committee’s 2022–2026 Arctic Research Plan.

Elizabeth Tellman (PI)/Hannah Friedrich (FI)
University of Arizona
21-EARTH21-0129, Beyond Surface Water Mapping: Satellite-Based Estimates of Coastal Storm and Flood Exposure for the United States Gulf Coast

More than half of the population in the United States lives along the coast where increased development, tropical storms, and flooding have increased the exposure of population and infrastructure to hazards. Repeat floods impact human lives and infrastructure, pressing communities to recover as quickly as possible before the next storm or flood arrives. Accurate estimates of population and infrastructure exposure to flooding are critical to mitigate future damage, inform land-use planning or potential relocation of communities, and identify post-disaster delivery of assistance.

Satellite-based observation provides a unique perspective to monitor extreme events. Yet, current satellite-based methods for measuring flood inundation and rapid damage assessments often fail in capturing the maximum flood extent or spatial detail of urban damage. The under detection results in omitted human lives and infrastructure estimated as exposed and prompts improved methods for detecting floods and their impact. Research is needed to compare post-event urban damage to detected surface water, and understand how observed damage can improve existing exposure assessments. This research hypothesizes that detected urban damage following a major storm and flood event is a more accurate metric of exposure compared to the standalone inundated area.

This proposal leverages advances in the spatial and temporal resolution of remotely sensed satellite imagery and deep learning techniques to tackle the methodological gap of under detection of urban damage and inundation. The first objective is to detect coastal storm urban damage as proxied by the blue roof and building damage by training a deep learning model on labeled structures on 3-meter spatial resolution PlanetScope imagery. The second objective is to generate a 30-meter flood inundation probability using deep learning methods to fuse observations from multiple optical, and active and passive microwave sensors. Lastly, the third objective is to validate both satellite-based estimates of coastal storm damage exposure by regressing georeferenced FEMA Individual Housing Program (IHP) claims at the census block scale against the i) estimated number of buildings damaged (Objective 1), ii) estimated number of buildings inundated (Objective 2), and iii) estimated number of buildings either damaged or inundated. The FEMA IHP data are used to validate the damage and inundation models and elucidate their respective fitness of use for estimating exposure. These research objectives are applied to three Gulf Coast study areas of Hurricane Harvey in Southeast Texas, Hurricane Michael in North Florida, and Hurricane Ida which made landfall on Coastal Louisiana in
August 2021. The frequency of Gulf Coast storm events underpins the urgency of this research to understand the potential of satellite-based observation to document hazard exposure and inform disaster management for future events.

The scientific impact of this proposed research will reveal how well satellite-based information and deep learning models can aid in understanding the impacts of floods on post-event damage and exposure. We expect the results of this research to contribute insights on the advantages and challenges of satellite imagery to detect urban damage and fill gaps in current flood mapping methods. This proposal uses NASA earth observation data, including MODIS, Landsat, AMSR-2, and CSDA Program data (PlanetScope) for a novel approach to detect exposure. This proposal is relevant to NASA’s Earth Science and Applied Sciences Programs aims to use Earth science and satellite observation to inform decision-making related to hazards and extreme events. Aligned with NASA’s commitment to connect scientific impact to equity and environmental justice, this research aims to create methods that generate more inclusive estimates of exposure given the increasing flood impacts that affect the most marginalized populations in the United States.

Mingfang Ting (PI)/Samuel Bartusek (FI)
Columbia University
21-EARTH21-0134, Causal Mechanisms of Dry and Humid Heat Extremes

Heat extremes are among the deadliest climate extremes, with wide-ranging effects on health, agriculture, and ecosystems. They have been robustly observed and projected to worsen due to global warming. However, the regional characteristics of temperature variability and extremes are less understood than global or regional mean temperature, and given their growing societal relevance and environmental justice implications it is crucial to understand them better.

Despite increasing attention, a comprehensive mechanistic understanding of the causal drivers of heat extremes, and how their drivers may change in the future, is lacking. For example, contributions to Northern Hemisphere midlatitude heat extremes from atmospheric circulation patterns and land-atmosphere interaction—and how such processes may be linked to Arctic Amplification—are difficult to untangle, and directions of causality between processes are debated. Additionally, humid heat extremes with dire health impacts are projected to increase severely in the tropics but are understudied, partly due to underreported impacts. Lacking analysis of many of the questions applied to dry heat extremes, their mechanisms and potential distinctions from dry heat extremes are poorly constrained. Finally, despite projections that heat extreme frequency, magnitude, and duration will increase, it is unclear how changes in their causal drivers may contribute to such changes. Climate model fidelity in representing the networks of heat extremes’ casual drivers is unknown and can constrain projections. Our objective is to address these critical knowledge gaps by determining the causal mechanisms of dry and humid heat extremes, at a global scale, and how they may change due to warming.

We will pursue three questions: 1) What are the causal relationships and directions between heat extremes and atmospheric, land, and oceanic conditions, both dynamic and thermodynamic? 2) What are the causal drivers of humid heat extremes and how are they distinct from those of dry heat extremes? 3) How might the identified causal drivers change in the future, and how can future heat extreme projections be better understood or constrained?

To determine heat extremes’ causal drivers, in addition to standard Earth-science methods we will construct Causal Effect Networks (CEN), a novel analysis tool harnessing graphical models to identify the strength and direction of causal connections among multiple variables. This method has recently been applied in climate science to uncover casual linkages previously inaccessible via correlation-based analysis (which may be confounded by common drivers, indirect linkages, and autocorrelations) or other standard causality tools (such as Granger causality). We have demonstrated proficiency through a proof-of-concept CEN and conducted a case-study analysis of the 2021 Pacific Northwest
heatwave. We will construct CENs for dry and humid heat extremes throughout the globe using weather-station temperature and humidity observations (HadISD), NASA high-resolution reanalysis (MERRA-2) and satellite land-surface observations (SMAP, GRACE) supplemented by other reanalysis data (ERA5). We will further test our hypotheses in historical and future runs of the Coupled Model Intercomparison Project Phase 6 (CMIP6), Polar Amplification MIP (PAMIP), and Land Surface, Snow, and Soil Moisture MIP (LS3MIP) models to characterize the effect of complex processes like Arctic Amplification and land-atmosphere interaction on current and future heat extremes.

Our work addresses NASA’s Science Mission Directorate Earth Science Division goals to “improve the capability to predict weather and extreme weather events,” “improve the ability to predict climate changes by better understanding the roles and interactions of the oceans, atmosphere, land, and ice in the climate system,” and “further the use of Earth system science research to inform decisions and provide benefits to society.”

Morgan Tingley (PI)/Ben Tonelli (FI)
University of California, Los Angeles
21-EARTH21-0030, Linking Emerging Threats to Wildlife and Human Health to Climate Change Effects on Boreal Forest Ecosystems

Emergent disease outbreaks in human and wildlife populations are a well-established threat of ongoing climate change and habitat degradation (Sutherst 2004; Brooks and Hoberg 2013). As a result, research initiatives to better integrate knowledge from across disciplines are increasingly being employed as a means to protect the health of human and wildlife (Bidaisee and Macpherson 2014; Destomieux-Garzón et al. 2018; Harrison et al. 2019). At the center of this research are zoonotic diseases, pathogens transmitted between animals and humans, which account for over 60% of all infectious diseases (Taylor et al. 2001). Because zoonotic diseases originate in wildlife populations, the distribution, abundance, and movement of these populations is critical in understanding risks to human populations and society.

One compelling and under-researched avian disease vector is the Pine Siskin (Spinus pinus), a species often central to Salmonellosis outbreaks in the United States and Canada (Hernandez et al. 2012). The Pine Siskin is a boreal songbird found across North America that exhibits dramatic “irruptive” migratory behaviors, during which millions of birds are found at abnormal concentrations beyond their normal range (Dawson 2020). Irruptions are affected by climatic variables (Strong et al. 2015), and occur more often following periods when conditions are poor for their main food source, conifer seeds, and when winter temperatures are more extreme (Strong et al. 2015).

Due to their innate susceptibility to Salmonella and their observed associations with large-scale Salmonellosis outbreaks (Hernandez et al. 2012), Pine Siskins may disproportionately contribute to increased rates of disease transmission among avian communities during irruption years. Dense siskin populations in a given area likely act as a source of Salmonella that then spills over into populations of susceptible species (Hernandez et al. 2012). Presently, the linkage between climatic factors, migratory dynamics and subsequent disease outbreaks is unknown.

Here, I propose a two-tiered approach using NASA-enabled remote sensing data to investigate the nature of a climate-driven source of increased disease risk to wildlife and human populations. Using Bayesian statistical techniques, I plan to 1) create a working model to predict the frequency and strength of irruptions of the Pine Siskin from MODIS-derived climate and fire products, and then 2) use land cover maps to analyze how the strength of irruptions modulates disease risk across habitat types. The emergent risks to human health are increasingly being recognized as the result of the downstream effects of anthropogenic changes to the Earth system. This proposal fits into NASA’s goals to understand earth as a system and will broadly address how global ecosystems are changing. This proposal also seeks to uncover how land cover and land use change lead to consequences to human
societies and ecosystem sustainability through the incursion of disease-susceptible birds into human-associated habitats. The results of this proposal will lead to a better understanding of human health risks, and thus advance NASA’s goals of safeguarding and improving life on earth.

Philip Townsend (PI)/Natalie Queally (Fl)
University of Wisconsin, Madison
21-EARTH21-0067, Detecting Disturbance Legacy Effects in Functional Trait Phenology Using Imaging Spectroscopy Data from the SHIFT Campaign

Disturbances drive ecosystem function and variability across space and time. Long-standing patterns of disturbance can influence plants to express certain functional traits—measurable characteristics linked to ecosystem function—that allow them to resist and/or recover from the disturbance. In the context of global change, it is crucial to understand how ecosystems change in response to different levels of disturbance, since disturbance patterns are likely to change with climate change and pressures from human development.

Although functional traits change in space and time in response to disturbance, field-based studies that measure traits are typically restricted to focusing on one factor (large spatial extent/diversity of plant types sampled) or the other (many time points sampled). Remote sensing allows us to study both. Using remotely sensed imaging spectroscopy data (many spectral bands measured at fine wavelength intervals) and short time intervals between image acquisitions over a growing season from the upcoming SHIFT field and imaging campaign in California, I will investigate how plant functional traits vary in space and time in response to two key disturbances in the study area: grazing and wildfire.

The SHIFT campaign will collect imagery from weekly flights over Santa Barbara County, CA over three months in 2022, covering a period of spring vegetation growth. As part of this campaign, I will help conduct fieldwork in two research reserves and a national forest in concert with the SHIFT image flights. The sample plots will represent many vegetation types, topographic positions, and soil types, among other environmental gradients over the full growing season and will be used to map 12 plant functional traits based on foliar samples collected from the plots. Using disturbance data provided by reserve managers and government agencies, I will assign trait map pixels to different classes based on disturbance history (grazing intensity or burn severity) and assess the effects of grazing and wildfire separately using generalized additive mixed models, statistical models that are useful for analyzing curvilinear trends that occur with time series data. I will interpret the model outputs to assess how each trait responds to different levels of disturbance across the growing period, while incorporating the influence of environmental gradients and also testing differences among vegetation types. I expect that the changes in traits across space and time in response to different disturbance levels will represent different adaptive strategies that help plants avoid or tolerate disturbance.

This study is of great relevance to the NASA Earth Science Division’s goal of characterizing the ways that ecosystems are changing, and will be the first study of functional trait response to disturbance on this spatial and temporal scale. Specifically, my study will directly address phenological variation in trait expression, including its drivers. It will serve as a framework for future ecosystem function-disturbance analyses with time series data, and is a prototype application for future hyperspectral satellite missions, including NASA’s Surface Biology and Geology (SBG).

Robert Trapp (PI)/Melinda Berman (Fl)
University of Illinois, Urbana-Champaign
21-EARTH21-0363, Understanding the Impact of the Lower Stratospheric Thermodynamic Environment on Observed Overshooting Top Characteristics
Overshooting tops (OTs) are manifestations of deep convective updrafts that overshoot the tropopause. OTs irreversibly transport aerosols, water vapor, mass, and other tracers into the stratosphere and occur in all latitudes and seasons. OTs have also been linked to ground-based hazards like intense rainfall, tornadoes and hail. Understanding key OT characteristics such as area (OTA), depth above the tropopause (OTD) and duration (OTT) is critical for understanding this global stratospheric transport mechanism as well as the dynamical connection to hazardous weather. Although recent work has demonstrated that OTs are positively correlated to midtropospheric updraft cores, gaps remain in understanding how the thermodynamic conditions in the lowermost stratosphere impact observed overshooting top characteristics, and initial overshooting tops alter tropopause conditions such that overshooting top characteristics in subsequent storms are different from earlier storms. To address these gaps, quantifications of thermodynamic environments using MERRA-2 will be related to key OT attributes determined from Geostationary Operational Environmental Satellite (GOES)-R series satellites. Experiments with idealized modeling simulations will be used to understand the relationships between OT attributes and the thermodynamic environment and how OTs modify the tropopause, impacting subsequent OTs.

Konstantinos Tsigaridis (PI)/Maegan DeLessio (FI)
Columbia University
21-EARTH21-0112, Global Climate Role of Biomass Burning Aerosols and Brown Carbon

As biomass burning events increase in frequency and intensity, the climate role of biomass burning aerosols like brown carbon (BrC) will become more important. However, more work is needed to reduce the uncertainty such species bring to Earth system models. Using the GISS ModelE Earth system model, the proposed project will evaluate ModelE’s representation of BrC and biomass burning aerosols. Model output will be compared to in-situ measurements of BrC from the ATom flight campaigns, as well as aerosol optical properties from remote sensing and ground-based datasets, including MODIS, OMI and AERONET. The evaluated aerosol scheme will then be used to predict future radiative forcing, and therefore the climate role, of biomass burning aerosols with both prescribed (from biomass burning inventories) and interactive (from the ModelE pyrE interactive fire module) emissions. This work will increase the predictive capability of ModelE by improving biomass burning aerosol representation. Additionally, predictions of future biomass burning climate effects will better equip scientists and policymakers with knowledge in climate change mitigation efforts.

Alexander Turner (PI)/Nikhil Dadheech (FI)
University of Washington, Seattle
21-EARTH21-0093, Emulating Atmospheric Transport for Dense Observing Systems

Carbon dioxide and methane are the two strongest anthropogenic greenhouse gases (GHGs) and account for more than 85% of the GHG forcing since pre-industrial times. As such, their current and future emissions can have a profound impact on the future state of our climate. Quantifying their emissions is critically important for both projecting future climate and assessing the impact of environmental policy. Previous work has shown that point sources for CO2 and methane account for a disproportionate percent of the total budget. This means that a handful of “super emitters” are responsible for a large percent of the total emissions. However, these point sources only represent a small physical area. As such, studying these point sources necessitates densely spaced measurements. Fortunately, there has been a proliferation of dense observing systems for GHGs over the past decade such as geostationary satellites.
Constructing the source-receptor relationship (also known as the “footprint” of a measurement) that allows researchers to quantify GHG fluxes requires researchers to run computationally expensive atmospheric transport models. For example, researchers will often use Lagrangian Particle Dispersion Models (LPDMs) to construct the footprint. However, constructing (and even storing) these footprints becomes computationally intractable as the number of measurements increases, as is the case for the next generation of space-borne GHG observing systems. Further, there is often a decoupling of the meteorology from the chemical transport modeling. Typically, researchers will run a mesoscale meteorological model that is, in turn, used to drive LPDM. Because of this, latent biases in the meteorology can propagate into the GHG flux estimation. It is presently computationally intractable to incorporate meteorological parameters into the GHG flux estimation. Similarly, researchers are often restricted to assuming Gaussian errors in the inverse problem to reduce computational expense.

Here we identify four major computational challenges in the use of dense observing systems for high-resolution data: (1) high computational cost of computing footprints for dense observing systems, (2) high storage cost of footprints for dense observing systems, (3) accounting for errors in the simulation of meteorology while estimating emissions is infeasible, and (4) assumption of Gaussian errors while inferring emissions.

We propose to develop a deep learning and stochastic based algorithm to efficiently interpret high-resolution atmospheric observations and quantify the emissions of GHG point sources. The neural network will serve as a surrogate model that is trained on outputs from the traditional, physics-based atmospheric transport models. This approach will exploit similarities in large-scale patterns that govern the source-receptor relationship for densely packed observations. This model, once trained, will be able to compute the source-receptor relationship of atmospheric observations (footprints) in near-real-time, meaning that researchers can reduce the storage costs associated with the footprints. Additionally, a computationally efficient representation of the forward model will open the door for stochastic methods of solving the inverse problem and incorporation of non-Gaussian errors as well as trans-dimensional MCMC methods (i.e., reversible jump MCMC) that allow for jointly solving the model selection and GHG flux estimation problems. An example of this would be to jointly constrain meteorological parameters in the GHG flux inversion.

The next generation of GHG observing systems are providing unprecedented spatial coverage yet utilizing them to estimate GHG fluxes is becoming computationally intractable. Our work will advance the tools needed to interpret these dense observations and infer GHG emission fluxes that are critically important for projecting future climate and assessing the impact of environmental policy.

Christopher Uejio (PI)/Elaina Gonsoroski (FI)
Florida State University
21-EARTH21-0287, Assessing the Impact of Hurricanes on Infrastructure and Mental Health with Satellite-Derived Measures of Disaster Exposure

Mental health conditions such as major depressive disorder and posttraumatic stress disorder place a heavy burden on the U.S. healthcare system. These conditions are also the most commonly reported after a disaster such as a hurricane, however, mental health outcomes after these events remain understudied. In response to these research gaps, experts have called for studies to cover a wider geography and more diverse outcomes under dual exposures. One such cumulative exposure includes large power outages which are frequently attributed to hurricanes and disproportionately affect those of lower socioeconomic status. In response to these research needs, this study will answer three research questions: First, to what extent can satellite derived data detect power outages? Second, are there sociodemographic disparities in power outages and restorations? And third, are dual exposures associated with adverse mental health outcomes?
To address these questions, the FI will first use NASA’s Black Marble product to map power outages across the United States. Currently, there is not a centralized database of electrical disruptions. The creation of this database will serve to answer how well Black Marble can quantify power outages and how these data can be used to examine disparities in outage restoration and their impact on health. To relate the database from Research Question 1, the FI will examine the relationship between power outages and different indices through spatial regression models. These ancillary datasets include the Centers for Disease Control and Prevention’s Social Vulnerability Index and the Environmental Protection Agency’s Environmental Justice (EJ) Screen. Lastly, the FI will analyze the association between disaster exposure and mental health outcomes. Exposure to the storm will be determined through remotely sensed data including power outages (Research Question One) along with damage, precipitation, flooding, wind gusts, and storm path quantified by remotely sense data from NASA and other ancillary datasets. Mental health outcomes of interest include major depressive disorder, anxiety, posttraumatic stress disorder, substance use disorders, and suicide coded in state vital statistics and Medicaid records. The FI will use Difference-in-Differences analyses to examine these relationships. Ensuring power grid resilience is critical to ensuring equitable recovery especially in the aftermath of disasters. NASA’s satellite derived data products are ideal to examine disparities in power restoration. NASA’s remotely sensed data can also play a critical role in understanding disaster exposures and their impact on mental health. This project also meets Goal 1 of the NASA Applied Sciences Program’s Strategic Plan 2021-2026 by integrating NASA Earth Science into the health community’s value chain. It also meets Goal 2 by providing training to an early career scientist and building capacity in community stakeholders to understand and utilize NASA data. This project will also provide insight into economic, health and quality of life benefits to communities affected by disasters and these insights will aid project stakeholders in making informed decisions to decrease the burden of disasters.

Susan van den Heever (PI)/Gabrielle Leung (FI)
Colorado State University
21-EARTH21-0156, Impacts of Changes to Land Cover and Aerosols on Convection in the Maritime Continent

The atmosphere and land surface are strongly coupled through exchanges of heat, moisture, and momentum. Land cover changes (LCC) such as deforestation or urbanization can thus modify the atmosphere on both local and global scales. However, disagreements exist about the impact of LCC on clouds and subsequently on precipitation and radiative forcing. Furthermore, LCC often occur alongside perturbations to aerosol loadings, which confounds the influence of land surface properties on the atmosphere. Disentangling the combined effects of aerosols and LCC is difficult, and these aerosol-land surface-cloud interactions remain understudied.

This proposal aims to describe how land surface changes and concurrent aerosol perturbations impact tropical convection, particularly in the Maritime Continent (MC). Our approach combines satellite observations, realistic region-scale modeling, and idealized large eddy simulations (LES) to quantify the magnitude of aerosol-land surface impacts on convection and to describe the mechanisms behind those changes. We will address three science questions: (1) How have past land use changes impacted convection in the MC, and how will convection change under future land use scenarios? (2) Which individual or combined land surface properties are the primary drivers of land surface-cloud interactions? (3) How does the aerosol loading modulate land surface impacts on convection?

First, we will use two decades of satellite data from MODIS Aqua and Terra to compare cloudiness over deforested areas to nearby pristine forest at relatively high spatial resolution. We will further quantify trends in cloudiness as a function of aerosol optical depth (AOD) in order to assess the combined impacts of deforestation and aerosol loading on cloudiness in the MC.

Second, we will conduct high-resolution and long-duration simulations using Landsat-derived past, present-day, and future land cover maps. We will simulate the entire Philippine basin using the
Regional Atmospheric Modeling System (RAMS), a cloud-resolving model with bin-emulating microphysics and dynamic two-way surface fluxes. This will allow us to realistically estimate the impact of LCC on convection over a large domain.

Third, we will conduct a suite of idealized LES aimed at describing the mechanisms by which individual land surface properties influence clouds. We will use an advanced statistical framework to systematically perturb land surface properties and aerosol loading, then emulate model response to the full parameter space. We will estimate the impact of each input parameter and interactions on convective properties, thereby allowing us to establish processes behind aerosol-land surface-cloud interactions, which are still highly understudied and difficult to represent in climate models.

Apart from making extensive use of NASA satellite datasets, this proposal supports multiple NASA Earth Science Division focus areas. We will quantify the impact of changes to land surface properties on cloudiness and precipitation, as well as describe the mechanisms by which LCC influences the hydrological cycle (Water and Energy Cycle). In analyzing subsequent changes to the radiative budget and regional circulation, we will quantify a potentially important control on local and regional climate, which will help to separate LCC-induced changes in convection from those driven by other climate forcers (Climate Variability and Change). Finally, we will examine how those land surface impacts on convection, precipitation, and radiative forcing are exacerbated or opposed by increases to aerosol loading (Atmospheric Composition). We anticipate that this integrated observation-modeling approach will offer novel insights into the impact of land surface and aerosols on clouds in the MC, as well as into our fundamental understanding of the combined roles of aerosols, land surface, and convection within the Earth System.

Kimberly Van Meter (PI)/Shuyu Chang (FI)
Pennsylvania State University

The frequency of algal blooms is increasing in inland waters due to increased nutrient loads from heavy fertilizer use, intensive livestock production, and increasing human population. Elevated nutrient inputs to water reservoirs, especially inputs of phosphorus (P) and nitrogen (N), commonly leads to excessive growth of algae. In some cases, these eutrophic conditions lead to the development of harmful algal blooms (HABs), which we define here as algal blooms that contain species of harmful, toxic algae that can harm fish, benthic animals, and bottom vegetation as well as humans and their pets. The development of algal blooms in the many thousands of human-constructed water reservoirs is of particular concern not only from the perspective of aquatic habitat but also due to the frequent use of these reservoirs as both drinking water sources and recreational spaces. Under a warming climate, it is likely that reservoir Chla concentrations and the incidence of HABs will increase, especially in the Northeastern U.S.

The Non-Tidal Chesapeake Bay Watershed (NTCBW), is home to 1475 dams and reservoirs, from small mill dams to the large Conowingo Dam and on the lower Susquehanna River. Most large-scale nutrient modelling efforts and remote sensing approaches have been used to monitor water quality in the bay itself, but there is less understanding of the spatial and temporal extent of algal blooms in reservoirs across the NTCBW. With warmer temperatures, an intensified water cycle, and an increased frequency of extreme weather events, there is an incomplete understanding of how these changes, together with changes in reservoir nutrient cycling, will affect the timing and frequency of HABs in water bodies that are heavily relied upon as recreational spaces and sources of drinking water. The overarching goal of the proposed work is to better our understanding of the historical occurrence of algal blooms in Chesapeake Bay Watershed reservoirs, and to predict future changes in the timing, frequency, and magnitude of large algal blooms and potential HAB events under changing climate and
management. The specific objectives of the proposed work are as follows: (1) Quantification of the spatially and temporally varying extent and magnitude of algal blooms, as measured via remote-sensing of chlorophyll-a (Chla) concentrations, in 1475 Chesapeake Bay Watershed reservoirs, and identification of historical hotspots for algal blooms (1999-present); (2) Linkage of a range of watershed and climate predictors to the occurrence of historical algal blooms. These quantitative linkages will then be used to predict the occurrence of algal blooms and potential HAB events in Chesapeake Bay Watershed reservoirs under a range of future climate scenarios as well as under simulations of future water quality. Better understanding of the role of dams in controlling both current and future water quality will help the Chesapeake Bay communities adaptively manage the landscape, to protect and restore the habitat and ecosystem.

Adam Wymore (PI)/Desneiges Murray (FI)
University of New Hampshire, Durham
21-EARTH21-0104, The Response of Atmospheric Nitrogen Deposition to Global Change: Effects on Terrestrial and Aquatic Ecosystems

Total dissolved nitrogen (TDN) in wet deposition is declining, accompanied by shifts in the ratio of oxidized to reduced forms of N. The cascading effects of these global trends on watershed N biogeochemistry remains unclear, as does the spatial and temporal variability in atmospheric TDN ratios (e.g., stoichiometry). Significant knowledge gaps also remain for long-term trends in dissolved organic N (DON) deposition, its physical origins, and geographical sources. The objective of my proposal is to quantify and characterize the response of atmospheric inorganic and organic N deposition to global change, and its effects on terrestrial and aquatic ecosystems. By leveraging NASA remote sensing data, this research will advance understanding of biogeochemical feedbacks within the Earth System and improve forecasting of N deposition across the U.S. I will address my objective through three goals:

1. Synchronize land class and terrestrial N status, with meteorology, wet deposition chemistry, and stream chemistry timeseries:
N cycling between the atmosphere and hydrosphere is largely regulated by N processing in terrestrial environments. Terrestrial ecosystem N status (e.g., %canopy N, soil C:N) is strongly correlated with near infrared (NIR) reflectance, which is collected by NASA’s MODIS satellite. I will construct a data pipeline to harmonize NIR timeseries with N flux data from other proprietary organizations (e.g., NOAA, NADP, USGS) spanning the atmosphere-biosphere-hydrosphere. Developing and disseminating this data pipeline is directly relevant to NASA’s Earth Science Climate Variability and Change Focus Area because it will lead to further understanding of feedbacks across the Earth System and provide a means for forecasting how the N cycle may respond to shifting and ever-present global change.

2. Address three questions regarding system-level variables driving trends in N deposition and the degree of atmospheric-watershed N coupling:
a) Is atmospheric deposition N load and stoichiometry changing at inter-annual or seasonal time scales, and are patterns consistent across the U.S.?
b) How do climate anomalies (e.g., warmer winters, drought) influence the composition of depositional N?
c) To what degree are atmospheric, terrestrial, and river N cycling coupled?
I will use the data pipeline product described in (1) to address these questions. I will apply novel statistical methods such as mixed-effects modeling, information theoretic, and counterfactual multiple linear regression. Results will provide insight on the trajectory of deposition N across the U.S. and how system-level processes (e.g., climate change and terrestrial productivity) influence N cycling. This will support NASA’s 2020-2024 Vision for Science Excellence by addressing the interplay among the atmospheric, ocean, land, and ice systems.
3. Quantify long-term trends in DON wet deposition and model how global change influences DON chemical properties and source:
DON is not monitored in many deposition programs leading to knowledge gaps in its trends and response to global change. Anomalies in atmospheric DON may be explained by climate-change induced disturbance processes operating at multiple scales. My third research goal leverages a unique wet deposition DON record in the Lamprey River watershed of New Hampshire. I will report on DON trends over the past two-decades and test two mechanisms that may explain changes in DON wet deposition: (a) the lengthening of the growing season in the Lamprey River watershed and (b) increased frequency of wildfire smoke transport to the northeastern U.S. I will combine DON chemical composition data, NASA fire emission and NIR reflectance data, and meteorological models from NOAA with a novel application of aircraft hyperspectral imagery data. My project will connect hyperspectral imagery to ecosystem processes which is a priority for NASA’s future Surface Biology and Geology Designated Observable satellite.

Shang-Ping Xie (PI)/Matthew Luongo (FI)
University of California, San Diego
21-EARTH21-0022, Low Clouds as a Driver of Climate Variability: Synthesizing Climate Models and Satellite Observations

It is well-known that El Nino-Southern Oscillation (ENSO) in the tropical Pacific affects global and extratropical climate via atmospheric teleconnections. However, extratropical atmospheric variability can also affect ENSO via coupled ocean-atmosphere processes. Two such processes are the Wind-Evaporation-SST (WES) and the low cloud-SST positive feedbacks. In the Northern Hemisphere WES feedback, wind forcing affects local sea surface temperature (SST) anomalies via evaporative cooling. In the Northeast Pacific's marine stratocumulus deck, low clouds reflect incoming solar radiation and cool SSTs below. Both processes locally affect subtropical SST variability; this variability may then be propagated by WES southwestward in a pattern referred to as the Pacific Meridional Mode (PMM). By affecting the tropics, these processes may affect ENSO evolution and the global climate. However, the coupled nature of these ocean-atmosphere feedback processes makes parsing out their influence on the climate system a complicated chicken-and-egg problem.

The primary goal of this work is to explore the relationship between the subtropical low cloud feedback and the Pacific Meridional Mode. While the PMM is known to be a dynamic conduit by which extratropical variability can influence the tropics, the role of the low cloud feedback in initiating and amplifying the PMM, and thus remotely impacting the equatorial Pacific, has largely been ignored. This work investigates the hypothesis that the subtropical low cloud feedback has played an important and overlooked role in shaping Pacific variability by locally amplifying SST anomalies and triggering coupled ocean-atmosphere interactions with both tropical and global impacts.

I will leverage NASA and partners’ rich, global network of space-borne and terrestrial-based observations of cloud radiative effects, surface winds, and SST to perform a suite of global climate model (GCM) observational overriding simulations that seek to address the following two primary research questions:

1. To what extent has observed low cloud cover controlled the strength and timing of observed PMM events?
2. How have observed surface winds communicated changes in subtropical cloud cover to the equatorial Pacific and ENSO?

These objectives fall clearly under NASA’s Science Mission Directorate Earth Science Division’s key goal of “improv[ing] the ability to predict climate changes by better understanding the roles and interactions of the oceans, atmosphere, land, and ice in the climate system.” More specifically, this proposal is directly relevant to the Climate Variability and Change Focus Area within the Earth Science
Division and is pertinent to the following three overarching questions: “What is the role of atmospheric composition and clouds in the climate system?”, “How can predictions of climate variability and change be improved?”, and “How does the global ocean circulation vary on a variety of temporal and spatial scales in response to climate variations?”

Xi Yang (PI)/Rong Li (FI)
University of Virginia, Charlottesville
21-EARTH21-0331, Diurnal and Day-to-Day Variations of Vegetation Photosynthesis from Novel Remote Sensing Measurements

Terrestrial photosynthesis is the largest CO2 flux in the global carbon cycle and affects the fluxes of water and energy between the land surface and the atmosphere. However, the estimation of gross primary productivity (GPP), particularly its temporal variation and response to environment, remains highly uncertain at the global scale. Solar-induced chlorophyll fluorescence (SIF) is radiation emitted by chlorophyll as a byproduct of photosynthesis and has recently been shown to correlate better with GPP than the traditional remote sensing products. Satellite observations have recently become available for analyzing both the diurnal (OCO-3) and day-to-day variations (TROPOMI) of SIF. However, SIF is jointly controlled by illumination, physiology, canopy structure, and sun-sensor geometry, and its interpretation is still an active area of research. To fully exploit the available SIF observations from different platforms, I will investigate how the combination of remotely sensed SIF and canopy reflectance can be used to understand the temporal variations of vegetation photosynthesis, particularly how photosynthesis responds to environmental stresses such as high temperature and water stress using both site-level and satellite-level remote sensing products. Below are the specific aims of this project:

1. Quantify the controls of the diurnal and day-to-day variations of SIF: I propose to decompose SIF signal by combining SIF and vegetation reflectance measurements. SIF signal will be decomposed into three components: 1) illumination, 2) physiology, and 3) structure and geometry. I will apply this approach for SIF measurements at a mixed forest and at the global scale from OCO-3 and TROPOMI. The diurnal and day-to-day variations of each component and their contribution to SIF variations will be investigated. I will test the hypothesis: The illumination component explains most of the diurnal variation of SIF, while the physiological component explains more day-to-day variation of SIF for clear days at short time scales. And I will analyze if results from satellite observation conform with that from site-level observations, and if the patterns are the same for different plant functional types (PFTs).

2. Investigate the response of the fluorescence yield (physiological component of SIF) to environmental factor: I will obtain fluorescence yield indices based on site-level, OCO-3, and TROPOMI observations and environmental variables of illumination, temperature, and water stress from tower meteorological data, thermal camera, satellite products, and reanalysis data. I will analyze the relationship between the proxy of fluorescence yield and the environmental variables and test if the relationships are the same for different PFTs and from different observations. I will test if the fluorescence yield index based on SIF and vegetation reflectance can indicate plants’ heat and drought stress conditions under diurnal and seasonal scales.

The proposed work directly links to the goal Carbon Cycle and Ecosystems of the Earth Science division of SMD: Detect and predict changes in Earth’s ecological and chemical cycles, including land cover, biodiversity, and the global carbon cycle. My work will facilitate the interpretation of remotely sensed SIF at multiple temporal scales, corresponding to observations from platforms, thereby contributing to improving the quantification of terrestrial photosynthesis and understanding of plants’ response to environment. The project will use NASA’s satellite products from OCO-3, ECOSTRESS, SMAP, MODIS and GOES, and MERRA-2 reanalysis data. TROPOMI and VIIRS products will also be used. The study also brings insight into NASA’s planned missions of GEOCARB and TEMPO, which has the potential to provide continuous diurnal variations of SIF from geostationary platforms.