The National Aeronautics and Space Administration (NASA) Science Mission Directorate solicited proposals supporting the implementation of selected targets under the United Nations Sustainable Development Goals 14 (Life Below Water) and 15 (Life on Land) within the context of climate variability and change. The solicitation requested investigations using biological and climatic data alongside ecological modelling that addressed issues in both the NASA Research and Analysis and Applied Sciences Programs. NASA received a total of 63 proposals and has selected 17 for funding at this time. The total funding to be provided for these investigations is approximately $13 million over thirty-six months. The investigations selected are listed below. The Principal Investigator, institution, investigation title, and project summary are provided. Co-investigators are not listed here.

**Grant Ballard/Point Reyes Bird Observatory**  
**Opening the Black Box - Integrating Wintering Ecology into the Management of the Ross Sea Region Marine Protected Area**  
18-SLSCVC18-0061

As one of the harshest and most remote regions on the planet, the Ross Sea, Antarctica, has proved difficult to study, especially during winter. Challenging environmental conditions have also contributed to this region being among the last remaining large, intact marine ecosystems, with globally significant populations of apex predators including seals, whales, and penguins. Due to its importance, much of the region was designated for protection as the Ross Sea Region Marine Protected Area (RSRMPA) in 2016 by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). It is the largest marine protected area in the world, with a central goal of protecting the marine ecosystem and strengthening resilience to the impacts of climate change.

Adélie penguins breeding on Ross Island in the Southwest Ross Sea are known to migrate and winter over an area that includes the vast majority of the Ross Sea region. This fact, along with their position near the top of the food chain, makes Adélies ideal sentinels for monitoring ecosystem change at broad scales throughout the year. Indeed, Adélie penguins are considered a key indicator species by the CCAMLR Ecosystem Monitoring Program. The winter period encompasses nearly two-thirds of the Adelie penguin annual cycle, yet very little is known about their ecological needs during the winter “black box.” This lack of information means that winter habitat use of Adélie penguins and other predators was largely unaccounted for during the development of the RSRMPA. However, recent advances in animal-borne bio-loggers as well as in NASA’s remote sensing data products means opening up the winter black-box in the Ross Sea is now within reach.
Our primary research objectives are to: 1) Assess the dependence of Ross Sea Adélie penguin migration on sea ice movements and the strength of ocean currents (the Ross Gyre); 2) Identify important foraging areas and characteristics for Ross Sea Adélie penguins during the austral winter; and 3) Assess whether the RSRMPA General Protection Zone (which will be unfished) includes important penguin winter foraging habitat boundaries and zones, especially compared with adjacent areas that will receive differing degrees of fishing intensity. Leveraging existing efforts tracking wintering Adélie penguins, this proposed research project will connect penguin location and diving data with NASA-derived remotely-sensed characteristics of the Ross Gyre, sea ice movement, location of polynyas (areas of persistent open water) and other sea ice and ocean habitat characteristics. These data will be used to develop ecological models of winter habitat use and assess how penguins may adjust their migration and foraging patterns to cope with environmental and climatic variability.

Our project addresses two targets under the U.N. Sustainable Development Goals (SDG): Target 14.2: to “sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience (...) to achieve healthy and productive oceans,” and Target 14.5: to “conserve at least 10 percent of coastal and marine areas (...) based on the best available scientific information.” By filling key ecological knowledge gaps for an important indicator species, this project will inform more effective ecosystem management of the RSRMPA (SDG indicator 14.2.1), improving efficacy of the whole system, including for other top predators like seals and whales. Our project meets NASA interests in utilizing remotely sensed data to increase national capabilities to predict natural hazards, to manage resources using remote sensing technologies, and to develop knowledge from these data to inform environmental policy.

Charlene DiMiceli/University of Maryland, College Park

Modeling Edge Influence on Forest Structure
18-SLSCVC18-0020

As global forests become more fragmented, edge influences become increasingly important. Haddad et al. (2015) estimate that 70% of world forests are now within 1 km of an edge. Forest edges receive more sunlight and are typically drier and warmer. They are at higher risk of damage from fires, storms, and impacts from adjacent land uses, including exposure to agricultural chemicals, non-native plants and insects, soil compaction and changes in hydrology and soil chemistry. As a result, forest edges typically form a different habitat and are home to a different suite of species than interior forests. Many species find edge environments inimical, others benefit from proximity to varied habitat. In order to accurately plan and monitor conservation efforts to protect forest communities, it is vital that we gain a richer understanding of the impacts of edges on forest structure.

With few exceptions, past studies of the influence of edges on forest structure have been done at the plot level. There is little consensus among these studies as to the magnitude of
edge effects or even the sign of the change when moving from the forest interior to the edge (Harper et al. 2005). Differences in plot study results are likely due to high variability in forest edge composition and to small sample size. To provide a more robust description of forest edge structure, therefore, an increased sample size is necessary. In addition, distance from forest edge, the most commonly used variable in forest edge studies, is not sufficient to predict edge impacts. The addition of spatial variables describing forest topology, such as patch size and shape, has been shown to provide more accurate characterizations of forest edge effects. We also hypothesize that the addition of variables describing climate, adjacent land use, and time from forest edge creation, not yet widely studied, will improve forest edge modeling.

In the case of forest structure, modeling forest edge influences can best be done using remote sensing data. We propose, under the research activity of this funding announcement, to use Landsat and Landsat-derived data at 30 m resolution, supported by ancillary Lidar data to perform the following tasks in support of the ecology community:

1. Define forest edges using a threshold approach. Map global forest edges at 30m. Map independent forest structure variables: tree cover, greenness and forest height. Test and select spatial variables best correlated with edge influences on forest structure variables.
2. Research the effect of climate (temperature, precipitation, drought and wind speed) on forest edges. How do forest edges differ in varied climates? How will climate change, especially increased temperature and drought, change forest edges?
3. Analyze the evolution of forest edges. Do effects expand into interior forest? Do edges heal over time?
4. Determine the influence of adjacent land uses on forest edges. How do agricultural activities, roads, logging and other human enterprises differ in their impacts on nearby forests?
5. Develop a model relating climate, time from edge creation, adjacent land use, and forest patch topology to forest structure variables (tree height, greenness, and canopy cover).
6. Apply this model as an extension to a forest landscape model (LANDIS-II) and demonstrate its use in a species distribution model (MAXENT).

In light of increasing forest fragmentation, models of forest edge structure are expected to provide significant benefit to conservation researchers and managers dedicated to preserving biodiversity. Conservationists and ecologists need better tools to predict habitat suitability, changes in fragmented forests over time, and the success of corridors and preserves. The proposed effort has the additional benefit of improving biomass estimation for carbon accounting.

Solomon Dobrowski/University of Montana, Missoula
Resource managers within the western U.S. and elsewhere have begun to see recruitment failures in semi-arid forests in recent decades. Increased fire frequency, size and severity, along with drought and extreme temperature events have dramatically increased reforestation needs. These needs are out-paceing the ability of managers to respond and this trend is expected to continue and/or accelerate. The primary goal of this project is to model the likelihood of recruitment failure in semi-arid forests of the western US - an important precursor to the loss of forest ecosystems. The proposed work integrates earth observation data, in-situ data, and a coupled ecohydrologic/plant hydraulics model to simulate loss of hydraulic function and lethal surface temperatures for conifer seedlings. We focus on these indicators because they are critical drivers of seedling mortality in semi-arid regions globally. Our work flow will allow us to estimate the capacity of semi-arid forests to naturally regenerate given projected future climate variability. Further, our project addresses sustainable development goal (SDG) 15, targets 15.1 and 15.2, focusing specifically on indicators 15.1.1 (Forest area as a proportion of total land area) and 15.2.1 (progress towards sustainable forest management).

We propose a model-data assimilation framework that will support reforestation planning by enabling the USFS to prioritize and develop more targeted and efficient planting efforts. We build capacity in an area that the agency is currently lacking; identifying sites and conditions which will no longer support natural regeneration. We will develop a suite of high resolution (30 m) gridded products for the western United States that quantify plant hydrologic and physiological stress, the likelihood of seedling mortality, and integrate these products into an existing reforestation Decision Support System (DSS) developed by the USFS. This work will leverage existing research of the PIs funded by NASA and the National Science Foundation and will allow for investments in basic science to be translated to operational tools for decision making.

Christopher Doughty/Northern Arizona University
Adding Space-Based Vegetation Structure Measurements to a Global Ecosystem Model to Simulate Tropical Forest Animal Communities and Their Role in Ecosystem Function
18-SLSCVC18-0032

Tropical forest animals provide valuable ecosystem services that are generally unrecognized because they are difficult to quantify at the macroscale. This makes them more vulnerable to extinction pressures because they are often undervalued. Here we propose to address the role of animals in tropical forests by adding space-based forest structure measurements to an ecosystem model with complex animal ecology (the Madingley model). Currently Madingley does not explicitly incorporate 3D forest structure so it cannot make useful predictions for tropical forests. If we are successful, the Madingley model will bridge several Essential Biodiversity Variables (EBVs) addressing traits, composition and ecosystem function, combining remotely sensed observations with data constrained modelling.
We propose to run Madingley using satellite derived MODIS Net and Gross Primary Production (GPP, NPP) products, partitioning NPP into four canopy layers based on the gridded LAI products from the upcoming GEDI (Global Ecosystem Dynamics Investigation) LiDAR mission. Since running Madingley for individual species at the global level is infeasible, not least because of inadequate parameterizations (only 10-20% of species have been described) and computational demands, Madingley uses cohorts or groups of animals that share similar categorical and continuous traits. In addition to adding forest structure, we propose to add two new functional traits to the model. First, we will add a trait that determines the capacity for organisms to use vertical structure, e.g. for habitat and forage. We will parameterize this for larger bodied organisms (e.g. monkeys or birds) based on existing literature and a wealth of GPS animal data, including 3D accelerometer data, whilst for invertebrates, we will make use of a new insect leaf herbivory datasets. Second, we will incorporate a trait that determines the capacity for organisms to engineer or modify ecosystem structure (e.g. forest elephants). We will parameterize this cohort based on detailed Gabon elephant tracking and abundance data, combined with high-resolution aircraft LiDAR, and published literature on how forest elephants impact forest structure.

We will initially run and parametrize Madingley for three tropical field sites where we have an abundance of data (Gabon for ecosystem engineering, Peru for the leaf herbivory, and the Atlantic Forest in Brazil for the vertical use propensity). Once we have confidence at these three sites, we will run simulations for the broader tropics. With these results, we can model how scenarios of faunal exploitation, forest fragmentation, or climate change may affect key EBVs (spanning traits, composition, function and structure) as well as ecosystem services at the macroscale. For example, we will estimate the impact of the loss of threatened insectivores on trophic cascades (with associated impacts on insect abundance) and on ecosystem services (increased insect herbivory reduces leaf area and carbon uptake).

A recent global study shows that animal movement is a function of the human footprint. We will incorporate this study, plus structure information from GEDI to better parameterize how animals move laterally in Madingley. This will help better understand key ecosystem services, such as nutrient and seed dispersal. Ultimately, we will use NCAR’s CESM land model outputs to predict tropical forest NPP and run Madingley under various future climate change scenarios. Overall, Madingley is a unique tool that can inform EBVs such as traits (e.g. body mass distributions), composition (functional diversity), structure (size and trophic distributions) and ecosystem function. However, without forest structure it is unrealistic in tropical forests, the most data limited but biodiversity rich biome on the planet. With this proposal, we aim to address this shortcoming and create a model combining satellite data and predictive biodiversity modelling.

Robert Griffin/University of Alabama, Huntsville
Climate-Influenced Nutrient Flows and Threats to the Biodiversity of the Belize Barrier Reef Reserve System
Background: Coral reef ecosystems are critically important to communities living around and dependent upon them, particularly by providing ecosystem services through aquatic biodiversity, recreation, and touristic value. Countries in Central America face great challenges in properly monitoring and sustainably managing these vast and disparate environments, especially in the context of climate-induced threats such as through increased nutrient runoff and load. The Belize Barrier Reef Reserve System (BBRRS), the world’s second longest barrier reef system, and a UNESCO World Heritage Site, is a critically important area in this regard, and therefore an appropriate case study on the impacts of nutrient flows on algal growth and coral reef biodiversity. A 2009 study led by the World Resources Institute, for instance, indicated that the BBRRS was responsible for 12-15% of Belize’s gross domestic product. In that context, earth observations from NASA multispectral imagers provide a viable solution to complement current efforts to monitor coral reefs in the region and assess the impact of policies and actions implemented.

Major Goals: The main objective of this proposal is to study the impacts of eroded sediments and nutrients from Belize’s sixteen major watersheds on the coral reef health and biodiversity within the broader Belize Barrier Reef Lagoon system. We will use a time series approach for studying moderate resolution NASA optical datasets, atmospheric correction algorithms developed by this research team for high accuracy over water bodies, and in situ measurements of both coral reef extent and water quality and nutrient load. While similar activities have been attempted in piecemeal fashion previously, this proposed effort seeks both to leverage earth observation data in a way they have not previously been used, but also to develop sustained local capacity to utilize such data for decision-making. The project will leverage strong existing networks within the country of Belize, including through a network of NGOs and governmental agencies focused on sustainable coastal zone management. Finally, the proposed work will entail capacity building of key institutions in Belize in the theme of NASA Earth Observations for aquatic ecosystem monitoring.

Specific Tasks: 1) Historical assessment – While there are now almost two decades of ocean color data from NASA’s multispectral imagers, this data has not been analyzed specifically with regard to the impacts of sediments and nutrients on the Belize Barrier Reef. Thus, a major effort will be to analyze the time series of data to better understand water quality dynamics within the Belize Barrier Reef Lagoon system, including seasonal changes in nutrients, temperature, and occasional algal blooms. 2) Forecasting – Building on earlier efforts looking at the transport of sediments and nutrients, UAH and its partners will develop a country-specific model for estimating the quantities of nutrients being discharged from the major rivers and being transported out to the Belize Barrier Reef complex. Such a model will help local decision-makers to guide efforts to reduce nutrient loads. 3) Field calibration / validation – WCS and partners will conduct physical and ecological monitoring activities to assess impact of nutrients on coral reef systems across Belize, in order to confirm / validate data gathered via satellite remote sensing, and calibrate the models, as necessary. 4) Capacity building – UAH will work closely with GIS staff from local organizations (WCS and Coastal Zone Management Authority & Institute) to increase capacity in remote assessment of aquatic ecosystem monitoring. 5)
Information dissemination – Data analysis will be synthesized for presentation to national authorities for recommendations, as needed, to inform for improved coral reef management in Belize, given anthropogenic threats increasing vulnerability to the impacts of climate change.

Andrew Hansen/Montana State University, Bozeman
Maintaining Life on Land (SDG 15) Under Scenarios of Land Use and Climate Change in Colombia, Ecuador, and Peru
18-SLSCVC18-0051

Countries within the United Nations recently adapted 17 Sustainable Development Goals (SDGs) to end poverty, protect the planet, and ensure prosperity for all by 2030. The targets for SDG 15, Life on Land, include sustainably managing forests, combating desertification, halting and reversing land degradation, and halting biodiversity loss. The United Nations Development Program (UNDP) is the leading agency in the UN system in assisting governments to integrate the SDGs into their national development plans and policies. This assistance requires access to spatial data, thus UNDP is a partner in a current NASA applications project designed to provide decision support for countries in the humid tropics meeting the Convention on Biodiversity 2020 targets. The goal of the proposed project is to develop and implement in collaboration with Colombia, Ecuador, and Peru, a decision support system for scenario planning, forecasting, policy development, and reporting on SDG 15. Project objectives include:
1. Assess the collaborating countries’ needs for decision support regarding SDG 15 under climate change and variability;
2. Project change to 2100 in ecosystem structure and composition, vertebrate habitats, and water risk under scenarios of climate socioeconomics, and policy.
3. Analyze trends and spatial patterns in the results to inform reporting and policy making for SDG 15.
4. Develop an SDG decision support system (DSS) for sustained use by the collaborating countries.

Our approach follows the framework of the Group on Earth Observations Biodiversity Observatory Network (GEO BON) for integrating research and assessment to inform policy. Consistent with the principles of co-learning, the national collaborators, UNDP, and the science team will be involved in all phases from proposal writing to project completion. We will begin the project by refining user needs of the collaborating countries relative to SDG 15. Earth observations will then be integrated with biological data to produce higher-order indicators of driving variables and “Essential Biodiversity Variables” (EBVs) relating to ecosystem composition and structure, vertebrate habitat suitability, and risk to water yield. We will develop statistical models relating the EBVs to land use and climate change during 1970-2015. These models will be used to forecast EBVs under scenarios of climate, socioeconomic, and policy change. The resulting trends and spatial patterns of EBVs will be compared among scenarios and interpretations drawn for effectiveness of policy in meeting the SDG 15 targets.

The methods and results of the project will be incorporated into an existing decision support system (DSS) that is being developed through direct collaboration with countries.
to ensures uptake by pilot countries and streamlining of reporting. The DSS was created using the MapX geospatial platform, a UN-backed, geo-spatial information platform that aims to map and monitor natural resources and environmental risks in real time using best available data and emerging digital technologies. The expanded DSS will be designed for interoperability with the DSS being developed within Colombia BON.

The proposed work will be the first to project land-use change and to forecast the interactive effects of land use change and climate change on EBVs in the study area. The project will also be among the first efforts to integrate monitoring, assessment, forecasting and policy under the new GEO BON framework and thus serve as a demonstration for broader applications to the up to 170 countries served by UNDP.

Robert Jones/Nature Conservancy
Earth Observations for Climate-Ready Aquaculture Management and Siting to Improve Food Security and Ocean Health in Palau, a Small Island Developing State 18-SLSCVC18-0064

We propose to work with the Government of Palau to utilize NASA Earth observations in concert with best international practices to sustainably site (locate) and manage climate-ready aquaculture farms in Palau. Palau is a small island developing state whose citizens consume more wild fish per capita than nearly any country on earth. Wild fish stocks in Palau have declined, and continue to decline at an accelerating rate. Climate change impacts are projected to further decrease catches by 25% in Palau, creating an impending food security crisis. With a land area 2.5 times the size of Washington D.C., marine aquaculture—the practice of farming aquatic organisms—has been identified by the Government of Palau, The Nature Conservancy and partners as a primary way to meet food production needs. However, Palau does not have the existing technical capacity to utilize Earth observations to inform the spatial planning needed to manage an aquaculture sector sustainably without the potential for environmental harm.

This proposal advances SDG 14.A, 14.2, and 14.7 by building capacity and support for effective regulatory processes in Palau to sustainably manage and protect marine resources under the threat of climate change. Specifically, we propose to build technical capacity within the Palau Bureau of Marine Resources to conduct spatial planning for aquaculture in alignment with best international practices. The Nature Conservancy has partnered with the Government of Palau for over 28 years, and has worked to address ocean conservation challenges to benefit people and nature. Leveraging this strong partnership, we will work directly with the Government of Palau and key stakeholders to: (1) identify and develop aquaculture siting guidelines, (2) conduct in-country training modules and provide direct mentorship to transfer knowledge of technical aquaculture spatial planning approaches to representatives of the Palau Bureau of Marine Resources, (3) collaboratively develop spatial planning analyses and products that utilize NASA remotely-sensed Earth observations data products (i.e., identify locations associated with major space use constraints and biophysical ecological forecasting to identify climate resilient locations for aquaculture) for 3-5 identified priority regions (~ 10% of Palau's Exclusive Economic Zone that is usable for aquaculture), and (4) develop an online
spatial decision support tool that hosts these products to ensure their long-term utility and value to the Government of Palau.

Peter Kalmus/ Jet Propulsion Laboratory

Identifying Coral Refugia from Observationally Weighted Climate Model Ensembles
18-SLSCVC18-0049

Reef-building corals face a variety of mounting anthropogenic stressors originating both at the global scale (increasing sea surface temperatures (SSTs), rising sea levels, and ocean acidification) and the local scale (such as destructive fishing, overfishing, sedimentation, invasive species, nutrient over-enrichment, and chemical pollutants). We propose producing more accurate, better validated, and locally resolved projections of likely 21st century refugia from global stressors (with robust uncertainty estimates) using the best available scientific information, to guide conservation management at local scales. Working with reef conservation managers, we will synthesize information from remote sensing data sets, global climate models, in situ time series, and ecological models to identify likely refugia. Prioritizing these refugia for conservation could increase the likelihood of preserving biodiversity.

We hypothesize that rising SST will continue to be the most severe global stressor. Corals are mortally vulnerable to ocean heat waves – elevated temperatures accumulated over periods of weeks – which are increasing in frequency and severity due to global warming. We begin by assigning skill-based weights to CMIP5 model projections of SST by comparing historical model runs (hindcasts) to gridded instrumental SST records at all reef locations. Our novel weighting method decomposes the model and observational time series into climate (low frequency) and weather (high frequency) components, and measures the similarity between the two time series with the p-value of a test of the null hypothesis that the wavelet coefficients describing the climate signals (observed and modeled) are the same. There is no requirement that the time series themselves match up at individual time points. At each location, we produce a time series of weighted probability distributions of the forecast projections from the entire model ensemble.

Environmental conditions affecting reef populations vary at kilometer (and finer) spatial scales, and higher resolution data will better inform local reef health and vulnerability. We will statistically downscale the weighted SST projections using high resolution (1 km) satellite observations, at locations with shallow-water coral reefs throughout the globe. We will perform all operations on both hindcasts and projections under three CMIP5 emissions scenarios (low, medium, and high).

Our Year 1 Goal is to use weighted projections to estimate the year after which SST conditions annually exceed a severe bleaching threshold of 8°C-weeks (degree heating weeks) at global reef locations at 1 km resolution. We next will use time series of bleaching and mortality events to build a marked point process model predicting quantitative regional bleaching and mortality thresholds based on cumulative
anomalously high SSTs. Our Year 2 Goal is to estimate the year after which SST conditions annually exceed the modeled SST thresholds at global reef locations, including uncertainty estimates. Sites crossing at later times are global refugia. Turning our attention to the Great Barrier Reef (GBR), we next use observational sea level anomaly data from remote sensing and modeled ocean acidification data (aragonite saturation state) to build a multivariate marked point process model to predict regional bleaching and mortality thresholds in the global stressor space. Our Year 3 Goal is to use downscaled ESM projections of sea level and aragonite saturation state to estimate the year that the CMIP5 projections of SST, sea-level rise, and aragonite saturation state cross these multivariate threshold surfaces every year thereafter, in the GBR. Sites crossing at later times are refugia in the GBR.

Patrick Keys/Colorado State University
Cross-Scale Impacts of SDG 15 Achievement: Household Decisions, Ecosystem Change, and Atmospheric Water Recycling
18-SLSCVC18-0006

Sustainable development in East Africa is acutely related to land and water resources - societies are densely populated throughout rural areas, and many are reliant on subsistence livelihood strategies. As civil society works to achieve the Sustainable Development Goals (SDGs) related to land and water resources, and SDG#15 specifically, activities at different scales of space and time may lead to cross-scale interactions and feedbacks. SDG#15 addresses ‘Life on Land’, and targets 15.1 and 15.2 aim to reverse forest loss and land degradation, as well as improve sustainable forest management. Recent work by the PI has demonstrated a significant impact of human land-use change on atmospheric water recycling - the process of water evaporating from land, traveling through the atmosphere, then falling back to Earth as precipitation. Specifically, land-use change in one place can have tele-connected impacts on downwind precipitation, via the atmospheric water cycle, significantly impacting human societies and ecosystems that are spatially distant. This insight, combined with advances in understanding behavioral drivers of land-use change in East African pastoralist systems, offers a unique opportunity to examine how human behavior, land-use, and atmospheric water recycling may couple to enable or hinder achievement of the forest and land-related targets of SDG#15. Notably, in East Africa’s forests and woody savannas, forest management often overlaps directly with rangeland management, and when considering ecological conservation it is equally important to consider the societies that dwell in these landscapes.

For this work, we propose to investigate achievement of SDG#15, specifically Target 15.1 and 15.2, within Kenya. Our first objective is to develop a first-of-its-kind, cross-scale coupled modeling system that captures household decisions (DECUMA model), ecosystem change (G-Range model), and atmospheric water recycling (WAM-2layer model). This coupled modeling system will be developed using NASA remote sensing products (i.e., Landsat Forest Cover Change, MODIS Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI), TRMM precipitation, GPM
precipitation), gridded population and population growth scenarios, and the most recent NASA reanalysis (MERRA-2). Our second objective is to simulate scenarios of how SDG#15 may be achieved in Kenya using this modeling framework, with a particular focus on the analysis of feedbacks, interactions, and system thresholds across scales. The scenarios of achievement of SDG#15 will allow us to explore Targets 15.1 and 15.2 explicitly, and will reflect different configurations of forest area coverage (i.e., area) and composition (i.e., wildlife habitat suitability). Our third objective is to leverage our coupled-modeling research as a basis for stakeholder engagement with our in-country partners.

This research advances the knowledge necessary to address SDG#15 within the context of ongoing climate variability and change, by illustrating how cross-scale interactions directly driven by SDG achievement relate to biodiversity within Kenya, and more generally in East Africa. Furthermore, we anticipate that our cross-scale approach can act as a framework for similar studies in other parts of the world. The integration of NASA remote-sensing and modeling products into the coupled framework pushes the boundaries of SDG-oriented science and is a significant leap towards more integrated thinking regarding long-term achievement of sustainability in East Africa.

Rebecca Lewison/San Diego State University
Climate-Ready and Resilient Fisheries: Using Satellite Data to Conserve and Manage Life in the Ocean and Support Sustainable Fisheries
18-SLSCVC18-0052

With billions of people relying on fish as their primary source of animal protein, healthy and productive oceans are more important now than ever. Sustainable Development Goal (SDG) 14 aims to support sustainable, resilient fisheries using ecosystem-based management approaches. By harnessing the power of satellite earth observations, in situ biological data, and climate models, we propose to increase our understanding of the linked physical and biological ocean, meet specified targets and indicators associated with SDG 14, and help the U.S. and other stakeholders make science-based decisions that can promote fisheries sustainability in the context of climate variability and change.

The objective of our proposed project is to harness satellite data to develop applications that support sustainable management and protection of marine systems (Target 14.2), increase the proportion of exclusive economic zones (EEZ) managed using an ecosystem-based approach (Indicator 14.2.1) and support effective fishery regulation and harvest regulation based on science-based management (Target 14.4 and Indicator 14.4.1). Working with fisheries on the East and West coast of the U.S., we will develop dynamic ocean management applications that integrate satellite data, species distribution information, predictive modelling, and fishery effort to provide fisheries managers and resource users with information to support climate-ready, resilient fisheries.

This project will use NASA remote-sensing, in situ biological and fishery-based data streams to support sustainable fisheries, primarily by providing directly applicable tools
to inform fishery decision-making processes for pelagic species within the U.S. EEZ. This approach will synthesize remote-sensing and modeled oceanographic data with available data on marine species from scientific surveys and fishery data collection efforts. This project leverages and builds on recent innovations in integrated sustainable fisheries analyses and data delivery methods from funded NASA and NOAA research. Our project will develop online products and applications that will allow fisheries managers to track dynamic distributions of species of interest, identify fishery-relevant climate anomalies, monitor fishery interaction and exploitation hotspots and integrate climate projections into strategic planning fisheries management. These deliverables will directly inform management of pelagic species in the U.S. EEZ as well as fisheries management mandates of international Regional Fisheries Management Organization (RFMO) partners who share high seas resources with the U.S., including the International Commission for the Conservation of Atlantic Tunas (ICCAT). Our products and their integration into an accessible toolkit for end users will directly inform fisheries management and provide the basis to track progress towards SDG 14 using the designated metrics and indicators.

Gordon Luikart/University of Montana, Missoula
Projecting the Spread of Aquatic Invasive Species Using Remote Sensing, Genetics, and Climate Modeling
18-SLSCVC18-0050

Aquatic invasive species (AIS) are nonnative (exotic) species that spread rapidly into new ecosystems. AIS are the second greatest threat to biodiversity after habitat fragmentation. Spread of AIS causes billions of dollars of economic losses annually to agriculture, hydroelectric facilities, commercial fisheries, and eco-tourism. Our overall objective is to support the United Nations “Target 15.8” goal to help “prevent the spread of invasive alien species in water ecosystems.” Climate and land use change are major drivers of the spread of AIS by lowering the resilience of native ecosystems to AIS. Managers need decision support web tools, and spatio-temporal models to better map, visualize, and predict occurrence and spread of AIS. We will help managers predict and prevent spread of AIS by providing novel combinations of three recent advances; these are (1) increased availability of regionally consistent environmental data from satellite remote sensing, (2) time-series data on AIS spread across varying habitats, and (3) environmental DNA (eDNA) monitoring of AIS. eDNA is the DNA that is continuously shed into the environment by all organisms (in feces, urine, slime, sloughed cells). eDNA can be reliably distinguished at very low levels in natural landscapes and efficiently collected and processed at relatively low cost, which has led to widespread use of eDNA sampling to help track AIS spread. We will integrate these three datatype advances by leveraging database resources from multiple state and federal databases on AIS presence/absence, and by enhancing an existing environmental (remotely-sensed) database and support system to provide tools for AIS managers to visualize, map, and forecast the spread of AIS across the entire Columbia and Missouri River Basins (CRB, MRB) in western North America. The database frameworks and tools can be extended nationally and globally to other
countries. This work will benefit from two crowdsourcing initiatives (1) to collect novel
eDNA samples, and (2) to acquire existing AIS occurrence data from multiple state and
federal management agencies. This will improve AIS tracking, and establish a national
eDNA database.

Our web-based tools (main deliverables) will combine existing AIS occurrence data with
eDNA detection data, and remotely-sensed environmental databases to create modeling
tools to help forecast (map) geographic areas susceptible to AIS spread and colonization.
Importantly, AIS “presence/absence” (occurrence) is the main “essential biological
variable” (EBV) recommended by multiple organizations for monitoring of invasive
species (GEOBON, McGeoch and Squires 2015). Finally, this application will be
integrated into a developing USGS framework for monitoring the spread of AIS.

Our software applications will use time-series data on five key AIS that pose the
greatest economic and ecological threats in the CRB, MRB, and nationwide. These
include zebra and quagga mussels, Eurasian watermilfoil, smallmouth bass, and rainbow
tROUT. These AIS inhabit a range of environmental conditions (water temperature and flow
regimes, physical habitat), with different mechanisms of spread or invasion (human and
animal vectors, and dispersal), and types of risk to native species and habitats (e.g.,
predation, competition, habitat modification, hybridization).

This project will build on our past experience with an online decision support
system (RAP) that provides riverscape-focused remotely-sensed environmental data and
tools to predict climate change effects on native endangered fish. We can synergistically
use the RAP (www.ntsg.umt.edu/rap/) environmental database to build user-friendly tools
necessary for managing both AIS and native fish (salmonids). These tools and the eDNA
database will be housed and used by the USGS and state agencies to help transform
biodiversity conservation and decision making while addressing the sustainable
development goals (Target 15.8) of the United Nations.

Anna Pidgeon/University of Wisconsin, Madison
Modeling Endangered Species' Forest Habitats, And Updating Forest Land Use
Plans in Argentina In Support of the UN Sustainable Development Goals
18-SLSCVC18-0019

The UN’s sustainable development goal No. 15 is to “protect, restore, and promote
sustainable use of terrestrial ecosystems, sustainably manage forests, … and halt
biodiversity loss.” Achieving this goal requires land use plans that are based on state-of-
the art forest monitoring and species’ habitat models. Many countries have developed
such land use plans. However, especially developing countries often lack the capacity to
employ remote sensing technology and advanced models in their planning efforts.

Argentina is a perfect example of a developing country that established regional forest
land use plans in 2007 (National Forest Law N 26 331), but whose provincial
governments lacked the know-how to use biodiversity information when zoning their
forests. However, our team recently developed and implemented a straightforward
approach to enhancing the land-use plans for the Southern Yungas forest of northern
Argentina based on maps of endangered species’ habitats and conservation threats
(Martinuzzi et al. 2017). Both Salta and Jujuy provinces are now using our results in the latest of the mandated 5-year plan updates.

We propose here to A) develop new remote sensing indices to characterize and map forest habitats and their phenology throughout Argentina (Indicator 15.1.1), B) model the habitat of threatened forest species (Indicator 15.5.1), and C) model the human footprint and assess conservation threats, and levels of protection (Indicator 15.1.2), in order to integrate ecosystem and biodiversity values in national and local planning (Target 15.9), halt the loss of biodiversity (Target 15.5) and progress towards sustainable forest management (Target 15.2).

Forests habitats are highly diverse, but typically classified into broad classes, or vegetation continuous fields, because species-level classifications are challenging. To characterize forest habitats, we propose to assess a) their phenology, and b) their texture, based on 30-m Landsat and Sentinel-2 data, and to cluster forests into types. Furthermore, we will characterize annual phenology and land surface temperature curves from MODIS/VIIRS.

We will test our new indices characterizing forest habitats in ecological models of threatened and endangered species for each province in Argentina. Occurrence data will be provided by GBIF, eBird, and local collaborators. We will predict suitable habitat for each species, and integrate these maps with the existing forest plans to identify important habitat zoned for extractive activities or even development.

To assess conservation threats and protection, we will model the human footprint based on land cover, settlements, and infrastructure (following Martinuzzi et al., 2017), and assess current levels of protection. Furthermore, we will assess forest connectivity using GUIDOS’ Morphological Spatial Pattern Analysis both under current forest zoning, and assuming deforestation of the areas designated as low-conservation-value-forests.

Ultimately, we will provide a key set of remotely-sensed indicators of forest habitats and biodiversity potential for all forests of Argentina. Our project will make substantial contributions to Target 15.1, ensuring sustainable use in particular forests and mountains, Target 15.5, halting the loss of biodiversity, and Target 15.9, integrating ecosystem and biodiversity values into national and local planning. Because Argentina’s forest land-use plans are updated every 5 years our newly generated data will be readily integrated into the existing land use planning process.

Our proposed project will have broad societal relevance given widespread biodiversity declines, and the methods that we are developing will be applicable in many developing countries with similar land use plans. We will make strong use of NASA assets, especially Landsat and MODIS/VIIRS, as well as Sentinel-2 data to contribute to NASA’s mission and the UNs Sustainable Development Goals.

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Erika Podest/Jet Propulsion Laboratory
The objective of the proposed study is to develop a Sustainable Forest Management and Information System (SFMIS) for addressing SDG 15.2.1 “progress towards sustainable forest management”, which consists in tracking net forest area change. This will be done in the context of climate variability and change over the country of Panama.

The proposed Type B application study will be conducted with the Climate Change Unit of the Ministry of the Environment in Panama. This entity is responsible for reporting progress on SDG 15.2 to Panama’s Ministry of Foreign Affairs, which then officially reports the results to the United Nations on behalf of the country. The Ministry of the Environment has informed on this target for years 2005, 2010 and 2015. Forest cover statistics for the years reported were based on interpolation/extrapolation of forest loss/gain statistics using landcover maps from 1992, 2000 and 2012. However, landcover statistics between the two satellites varied and they have not informed since then, justifying the need for an established tool that can systematically calculate landcover and determine net forest change rate to address this SDG.

Panama has been working towards this goal through two efforts. The first one consisted in generating annual forest/nonforest maps of the country using Landsat-5 from 1990-2015. The second effort is ongoing and consists in developing Landsat-7 based landcover maps annually from 2000-present that includes 7 landcover classes. This new product is expected to be completed by December 2018. It will be an improvement to the previous product because it will characterize more landcover classes including secondary regrowth which is often misclassified as forest.

One of the major shortcomings in the generation of this dataset is cloud cover, with approximately 10% of each annual mosaic covered by clouds. The other shortcoming is validation of the dataset especially given limited in situ data collection. Our SFMIS will address both of these shortcomings by filling cloud covered gaps with other land cover products and by allowing for a thorough comparison and validation with in situ measurements and these land cover products. Tools will be available to generate a new enhanced product by using information from other better performing products in places where the Climate Change Unit’s landcover classes have low accuracy. SFMIS will also allow for exploring correlations between spatial patterns in net forest change area and climate variables such as air temperature and precipitation.

The SFMIS tool will address all five sub-indicators defined under target 15.2.1. We will follow the concepts and definitions for each sub-indicator as provided by the U.N. and report parameters specified by the SDG 15.2.1 protocol.

The SFMIS tool will utilize time-series forest cover products derived from satellite and radar sensors. We will integrate information provided by the Ministry of the Environment on in situ measurements for validation and vectors files delineating protected areas under different management plans. We will address the impact of climate change on this indicator by determining if net forest change is related to modeled derived indicators of precipitation and air temperature. In addition, the tool will allow exploration of seasonal to interannual variations of the indicator in different ecoregions in Panama characterized according to topography. We will work with the Ministry of the Environment to tailor SFMIS tools and products for their specific policy and decision making needs.
The study will be based on integration of open source data products and techniques readily available. We will work in close collaboration and coordination with the Climate Change Unit to develop the tool according to their needs. At the end of the project we will transition the SFMIS to the end user organization. The methodology and SFMIS system developed in this study will be adaptable to other regions.

ERIC SANDERSON/Wildlife Conservation Society
A Near-Real Time Integrated Mapping and Reporting System for Critical Biodiversity Sites Under Sustainable Development Goal 15: The Tiger as Model
18-SLSCVC18-0031

The goal of the proposed applications research is to advance knowledge of data integration with NASA Earth observations, climate data, field-collected biodiversity data, and ecological models to help nations report in an accurate and timely way on Sustainable Development Goal 15 (“Life on Land.”) Specifically we seek to develop, test, and demonstrate to governments a “near-real-time” integrated mapping and reporting system that produces regional results about sites important for biodiversity as described in SDG Indicator 15.1.2. By “near-real-time” we mean repeating analyses as often the underlying satellite or field data change. Our proposal focuses on tigers (Panthera tigris) as an example, implementing well-established models on a cloud-based geospatial computing platform (e.g. Google Earth Engine) and serving data by web portal. We propose to compute integrative models of tiger conservation landscapes (TCLs; Dinerstein et al. 2007, Sanderson et al. 2006) and source sites (SSs; Walston et al. 2010) in time series and analyze these critical sites in relation to protected areas and ecosystems on a country-by-country basis, looking back to the year 2000 and forward through at least 2030. We will also compute new 1 km2 resolution human footprint maps (sensu Sanderson et al. 2002; see Venter et al. 2016) on an annual basis globally. What tigers need is analogous to what many wildlife species need: intact patches of ecosystems with suitable structural characteristics of ecosystems, some of which are remotely sensible; freedom from too much human influence, as measured by the human footprint; and interconnected blocks of undiminished habitat large enough to support a population. Climate change impacts all these factors, and new satellite observations such as the Fire Information for Resource Management System (FIRMS) and annualized land cover products from MODIS allow us to detect significant changes in landscape characteristics. Structured if asynchronous field data collections across 10 countries in Asia will enable us to calibrate models, generate up-to-date findings, and validate the results. Countries need time-series, not snapshots, to show change and respond effectively to their international commitments and national goals. Here they will receive them whenever observations change through their Internet browser, as both top-level indicators (e.g. area of TCLs and SSs protected) and as downloadable geospatial layers with 1 km2 minimum map units. Although tigers are only one of the millions of species that live in Southern and Eastern Asia, this Type B Applications Proposal will provide a high-profile, working example of scientific fusion of NASA satellite data collections with the efforts of governments and non-governmental organizations to observe, document, and conserve endangered species of many kinds as the climate changes.
Summary: There is an urgent challenge to identifying when and where illegal unreported and unregulated (IUU) fishing, and by whom. It is a global challenge, with IUU activities happening worldwide, and one that is difficult to solve because any vessel committing illegal activities often goes dark, that is vessels turn off their GPS transponders. Our inability to know where fishing occurs and why, and to track vessels in real- to near-real time makes precise short and long-term forecasts of illegal fishing presently impossible. This is a direct challenge to the UN’s Sustainable Development Goal 14 to conserve and sustainably use the oceans, and disproportionately harms coastal communities with livelihoods and economies based on legal fishing. Our proposed research offers a promising way forward for measuring SDG indicator 14.4.1 (the proportion of fish stocks within biologically sustainable levels) by improved monitoring of illegal fishing through early-warning signals of anomalous spatial behavior of observed fleets. This project will improve estimates through a synthesis and advanced analysis of new global datasets based on NASA satellite data.

Proposed Research: The overarching goal of this project is to improve estimates of SDG Indicator 14.4.1 predicting legal and illegal fishing effort. We will make significant advances through a synthesis of new datasets, including recently created data on global vessel locations, analyzed with new Big Data algorithms. These data alone have limited value, and this proposed research will expand that value through a synthesis with other important (global) data products:

1) Synthesize global geospatial datasets – daily estimates of biophysical drivers of fishing effort based on global remote sensing time series data (2012-2018), global AIS maritime vessel location data collected every 5 minutes (2012-2018), global daily raster fishing effort derived from AIS location data at 0.01degree spatial resolution (2012-2018).
2) Improve monitoring of fishing vessels using NASA’s Black Marble nighttime lights product and AIS data (globally, 2012-2018, see Figure 2).
3) Develop statistical and Machine Learning models to explain and predict patterns of fishing based on biophysical variables.
4) Use methods from behavioral ecology, geospatial statistics and complex systems science to predict illegal fishing from the anomalous spatial behavior of observed fleets. Focus on areas of high vessel density: the Patagonia Shelf, off South Africa and the South China Sea and Indonesia.
5) Identify past trends in anomalous spatial behavior, and project patterns of fishing effort into the future using CMIP5 data; Compare against fisheries metrics (e.g. multispecies Maximum Sustainable Yield) to inform SDG indicator 14.4.1.
Broader Impacts: This is a Type A: Research Proposal as the tools available to estimate legal and illegal fishing at global scales (in near real-time) need significant basic advances before application by user organizations. Our basic research directly addresses the Sustainable Development Goal 14, its target and indicator. In quantifying illegal (and legal) fishing, this work will also inform indicator 14.2.1 (proportion of national exclusive economic zones managed using ecosystem-based approach) and indicator 14.5.1 (coverage of protected areas in relation to marine areas). Furthermore, our work will have impacts beyond a focus only on monitoring progress. Many individual countries, seafood supplying companies, intergovernmental (e.g. Interpol) and quasigovernmental organizations (e.g. Regional Fisheries Management Organizations), and NGOs are also all keenly interested in tracking, apprehending, deterring illegal fishing. Hence, while our core objective is to inform SDG 14, our results have utility to a much broader group of constituents and in service of enforcement and deterrence, not just monitoring the progress of SDG 14.

Danielle Wood/Massachusetts Institute of Technology
Designing Applications to Foster the Health of Terrestrial and Wetland Ecosystems in the Coastal Zone of West Africa
18-SLSCVC18-0022

This project pursues four objectives that contribute to efforts within the countries of Benin and Ghana to reach Sustainable Development Goal 15.
• Objective #1 is to co-design, evaluate and recommend an improved capability within the government of Ghana to use satellite-based remote sensing data to monitor illegal gold mining and resulting deforestation and forest degradation.
• Objective #2 is to co-design, evaluate and recommend an improved capability within the government of Benin to use satellite-based remote sensing to monitor and manage terrestrial forests and mangroves.
• Objective #3 is to deploy and evaluate an operational information system that provides a regional Observatory of Invasive Plant Species for Southern Benin Republic in conjunction with the environmental firm called Green Keeper Africa, based in Benin.
• Objective #4 is to develop and evaluate methods that teams from the governments of Ghana and Benin can use to include climate variability and vulnerability analysis in forest and invasive species management, focusing on variability in sea level. This work contributes to SDG Targets 15.1, 15.2 and 15.8. The project contributes to measurement and management of Indicators 15.1.1 (forest area), 15.2.1 (forest management) and 15.8.1 (control of invasive species). This proposal is designed in response to management challenges facing government and private sector organizations in Benin and Ghana.

In Ghana, the national government prioritizes ending illegal gold mining and remediating the degradation it causes in forests, soil and terrestrial waterways. In Benin, the government seeks to improve management of terrestrial and coastal forests; they identified a need to improve their techniques for land use mapping and fire monitoring to inform forest management policies. We are collaborating with the Benin National Center
for Remote Sensing and Ecological Monitoring to enhance techniques for forest mapping and fire monitoring. We are also collaborating with a private social enterprise called Green Keeper Africa (GKA) that seeks to improve the management of invasive water hyacinth that endanger the livelihood and transportation of low-income villagers. We are collaborating with Green Keeper Africa to design and implement an Observatory of Invasive Species that maps the location of the invasive water hyacinth and publishes this information for government and public users. Green Keeper Africa helps control the infestation of water hyacinth by harvesting it and converting it into a product that absorbs oil-based industrial waste.

Ecological forecasting methods, including land use, land cover analysis, forest biomass estimation, forest health monitoring, vegetated wetland mapping, and fire mapping using satellite data all play a role to meet the needs facing these organizations in Ghana and Benin. This proposed project harnesses previous research methods developed by the NASA Goddard Co-Investigators (Fatoyinbo and Lagomasino) to use remote sensing data from a suite of spaceborne sources such as Landsat, Digital Globe, Sentinel 1 and 2, TanDEM-X and the upcoming GEDI mission to monitor forests and invasive water plants.

The government and private teams in Ghana and Benin are also aware that the challenges they face with ending illegal gold mining, managing terrestrial forests and controlling invasive species will be impacted by climate variability. Thus, the work under Objective #4 examines the effect of sea level rise on coastal forests and invasive plant species; this project component also considers how land cover and climate shifts will influence the prevalence of fires and the health of forests.

Benjamin Zuckerberg/University of Wisconsin, Madison

Applying Sustainable Development Goals to the Conservation of Winter Environments and Cold-Adapted Species in a Warming World

18-SLSCVC18-0001

The climate is changing rapidly especially during the winter months of the Northern Hemisphere, causing rapid declines in the extent and duration of snowpack across the quarter of the planet that experiences seasonal snow cover. Indeed, since the onset of satellite monitoring in the 1960s, snow cover extent has declined every decade by an area larger than the state of Texas. This loss of snow cover is a form of widespread habitat loss for winter plants and animals that have adapted to living in, under, or on top of a protective blanket of snow. With a shortening winter season, tree root systems are losing the insulation of snow that protects them from extreme cold, forest fires are more common in areas of reduced snowmelt, and animals dependent on snow are retreating northward or up in elevation. Regions experiencing the largest changes in seasonal snow cover will likely exhibit losses in winter biodiversity and require future protection and conservation. Sustainable Development Goals (SGDs) are an ambitious global effort of setting benchmarks for the protection of the planet by focusing on the conservation and sustainability of Earth’s biodiversity. One of the objectives of SDG 15 is to ensure the conservation and sustainable use of terrestrial ecosystems. In the United States, the primary indicator for achieving this goal is the representation of important sites for
terrestrial biodiversity in the current network of protected areas. While agencies invest substantial resources in mapping biodiversity hotspots, these initiatives do not incorporate climate variability and are highly biased towards equatorial regions. As a result, winter is a current blind spot in biodiversity assessment, especially in regions characterized by seasonal snow cover. Our goal is to provide a national assessment of winter biodiversity for the U.S. based on dynamic snow cover conditions as captured by NASA satellite observations, and evaluate the potential for such assessments to inform protected area planning and climate adaptation science. To do so, we will combine time series of satellite-based estimates of snow cover and frozen ground with biological observations from citizen science programs and state agency monitoring efforts. We will take advantage of two recent remote sensing datasets: the MODIS Snow Cover product and the NASA MEaSUREs Global Record of Daily Landscape Freeze/Thaw Status dataset derived from SSM/I and SSMIS. We have previously used these datasets to develop a new global 500-m resolution dataset depicting the duration of snow-covered ground and the duration of snow-free frozen ground. Currently, we are mapping the same variables based on 30-m Landsat data as part of a USGS Landsat Science Team project. We will use both MODIS- and Landsat-based data to develop novel indices capturing the extent, duration, and variability of seasonal snow cover across the U.S. at an unprecedented resolution. We will then identify regions where snow cover dynamics are changing rapidly and use these estimates to develop species distribution models predicting the occurrence of cold-adapted birds and mammals. Our biological data will come from citizen science programs and snow track and furbearer surveys conducted by state agencies. Using these data, we will identify regions of high biodiversity and hotspots of vulnerable populations, and estimate the representation of these areas within the network of protected areas. Finally, we will collaborate with the National Climate Adaptation Science Center and their network of managers to identify areas threatened by declining and variable snow cover and explore the management of cold-adapted species.

Our proposed research fulfills the missions of NASA’s Earth Science division because the sustainability and conservation of winter environments presents a novel and unexplored conservation challenge during an era of rapid climate change and a new frontier for the application of NASA satellite and data products.