NATIONAL ECOLOGICAL OBSERVATORY NETWORK (NEON) AIRBORNE REMOTE MEASUREMENTS OF VEGETATION CANOPY BIOCHEMISTRY AND STRUCTURE

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1. INTRODUCTION

The design strategy for the National Ecological Observatory Network (NEON) is based on a multi-scaled sampling strategy, employing systematically deployed ground-based sensors, field sampling, high-resolution airborne sensors and integration with national geospatial information. Important to this strategy is the capability to extrapolate relationships between the ecosystem drivers (climate change, land-use change and biological invasions) and the ecological consequences to areas not sampled by the NEON facilities, but where partial, extensively sampled or gridded information is available. Adequately capturing drivers and responses, which occur over a considerable range of spatial and temporal scales, requires a multiplicity of integrated measurement approaches [2].

The NEON airborne capability, referred to as the Airborne Observation Platform (AOP), will consist of a suite of remote sensors designed to bridge scales from organism and stand scales capture in field samples and automated ground sensor measurements to the scale of satellite based remote sensing. The AOP will require sub-meter spatial resolution that will allow measurements at the level of individual organisms or small groups of organisms. The remote sensing data will be used to measure the effects of land use change, changes in vegetation state and performance, including the presence and effects of invasive species. The optimum available instrumentation to implement these capabilities is a high-fidelity spectrometer measuring surface reflectance over the visible to shortwave infrared and a waveform-recording LiDAR providing spatially-explicit information on regional vegetation canopy biochemistry and structure, respectively. A high-resolution digital camera is included in the suite to support land cover and land use identification at sub-meter resolution.

2. NEON SITES

In order to collect ecological data in a strategic manner, NEON has partitioned the U.S., including Alaska, Hawaii and Puerto Rico, into 20 eco-climatic domains, each of which represents different regions of vegetation, landforms, climate, and ecosystem performance. Division of the U.S. into domains ensures that NEON is able to systematically sample the U.S. in a design objectively representing environmental variability. In contrast to earlier maps based on expert knowledge, NEON has designed a set of domains based on a new statistically rigorous analysis using national data sets for eco-climatic variables. The statistical design is based upon algorithms for Multivariate Geographic Clustering [3,4]. Each domain contains one core site selected to represent unmanaged wildland conditions within each domain. Each domain also contains two relocatable sites to collect data that will focus on human land management effects on ecosystems. These comparisons at both the domain and national levels will provide critical information that can be used to test ecological models and to identify the impacts of land use change and invasive species on ecology.

The high cost of aircraft operations will limit the frequency of standard AOP observations to individual NEON sites once per year to detect interannual trends. To minimize the phenological contribution to the signal, flights will be planned to reach each site during a period of peak greenness. Annual observations inevitably miss important site level signals such as phenology. Higher frequency data on vegetation function is available from satellite measurements at a coarser resolution. A sufficiently large area must be flown by AOP for reliable comparison to satellite measurements. Currently we estimate that each AOP site mission will cover approximately 300 km^2, a compromise between area coverage and cost. The AOP will also be deployed in response to extreme events to monitor the forcing (e.g., hurricane damage) and the response (regrowth after fire) as well as other directed requests (e.g., regional surveys of invasive species or phenology). The deployment requirements requires three identical AOP systems be available for NEON.

3. ADVANCING AIRBORNE REMOTE SENSING FOR REGIONAL ECOLOGICAL STUDIES

The capabilities of AOP represent a significant advancement in the study of regional ecology. The NEON AOP instrumentation is designed to support research on a range of important themes in ecology in response to grand challenges in the study of biodiversity, biogeochemistry, climate change, ecohydrology, infectious disease, invasive species, and land use change [5]. Detection of invasive plant species, ecosystem productivity and climate feedback and ecosystem response to climate change in the Arctic present science use cases that illustrate how NEON and the AOP as a system can be used to address specific aspects of the grand challenges in environmental science [6,7,8].

The AOP science goals require observational data of a wide range of ecosystem attributes from plant functional types, biochemical and biophysical properties, canopy structure to ecosystem functioning and response (NOD, 2009). Waveform Light Detection and Ranging (wLiDAR) can provide quantitative information on vegetation cover, height, shape and vertical structure and underlying terrain [9]. Imaging spectroscopy provides quantitative information on vegetation cover, abundance, and biophysical and chemical properties [10,11].

The fusion of hyperspectral and wLiDAR technologies pioneered by Carnegie Airborne Observatory [12] has demonstrated the power of combing data from these sensors. Spectral reflectance signatures of vegetation are affected by canopy structure and shadows between canopies. By using coincident wLiDAR data, structural information can be obtained. The wLiDAR alone, however, provides little information to distinguish plant species and plant functional types. This latter information must come from spectroscopy and is necessary to accurately convert structural information into above ground biomass estimates. Co-location of the wLiDAR and spectrometer is necessary to achieve a high degree of registration of data on the ground. Even small offsets in ground pixel registration cause significant errors because typical ecosystem distributions are extremely heterogeneous.

The AOP remote sensing instrument suite was developed to provide synergistic hyperspectral and waveform LiDAR measurements to facilitate the fusion of the two data types. The optical sensors will be mounted to a common mechanical structure to maintain optical alignment, provide vibration isolation and facilitate rapid integration and de-integration into and out of an aircraft. The sensors will be configured to view through an open port located in the floor of the aircraft cabin, providing a clear view to the ground during flight. An integrated Global Positioning System (GPS) and inertial measurement unit (IMU) sensor to be mounted on the payload structure is a critical component to enable high accuracy geolocation of the science data. Data collected over each site will be stored on removable hard drives and sent to the NEON Headquarters for input to the Observatory cyber-infrastructure for processing, archival and distribution.

4. SUMMARY

The capability of fully integrated NEON AOP will be well beyond existing systems in its ability to produce quantitative information about the ecosystem response to climate change, land use change and invasive species. The AOP will provide detailed measurements of vertical and horizontal vegetation structure (canopy height, leaf area distribution, patchiness), vegetation function (photosynthesis, water use, forage quality for herbivores), topography and built structures. These data will be at sub-meter to meter spatial scales over 300 km^2 per day bridging the scales from organism and stand scales to the scale of satellite based remote sensing. There are no similar facilities regularly available to the US scientific community.

5. REFERENCES

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