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Atmosphere-Biosphere Interaction Study Field Campaign Report

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ARM

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All at Argonne National Laboratory

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
ECOR	eddy correlation flux measurement system
ESM	earth system model
GB	gigabyte
GPP	gross primary production
NDVI	Normalized Difference Vegetation Index
PRI	Photochemical Reflectance Index
RGB	red-green-blue
SGP	Southern Great Plains
TIR	thermal infrared

Contents

1.0 Summary

The objective of this campaign was to collect hyperspectral reflectance measurements and complementary optical and infrared data of land surface (i.e., vegetation and soil) throughout the growing season (i.e., from March to September) at high temporal frequency (e.g., < 30 minutes). To collect the measurements, the EcoSpec system, a tower-based sensor system housing seven optical and infrared sensors that was developed at Argonne National Laboratory, was deployed to the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility Southern Great Plains (SGP) atmospheric observatory (within the crop, south of the eddy correlation flux measurement system [ECOR] tower).

The EcoSpec system consists of a spectroradiometer having 2,151 channels (350–2,500 nm), red-green-blue (RGB) camera, diffuse radiometer, thermal infrared (TIR) sensors, albedometers, Photochemical Reflectance Index (PRI) sensors, Normalized Difference Vegetation Index (NDVI) sensors, and wetness sensor. The system is designed to collect an array of land surface measurements, including hyperspectral reflectance of plants and soils, RGB photos capturing contextual information of land surface, radiant temperature of sky and land surface, incoming and reflected shortwave radiation, and incoming radiation components (direct and diffuse) as frequent as every minute from up to 12 discrete positions around the tower. This would allow us to capture inherent heterogeneity of the terrestrial ecosystem and to obtain representative spectral signatures of the plant and soil surfaces via averaging those measurements.

The SGP site provides advanced atmospheric and other physical measurements that are essential for our investigation of ecosystem functions using hyperspectral reflectance measurements of land surfaces. Located in the mid-latitudes, the SGP site exhibits dynamic seasonality and a wide range of meteorological variability and flux properties that make it ideal for studying interactions between near-surface atmosphere and biosphere across a range of environmental conditions.

The atmosphere, plants, and soil control terrestrial carbon and water cycles. To make more accurate climate forecasts, researchers need to understand ecosystem dynamics at the biosphere–atmosphere interface. Even though our ability to forecast ecosystem dynamics and climate at both the regional and global scales has advanced significantly, we still do not know how local phenomena affecting water and carbon fluxes—such as diurnal variations—interrelate with large-scale atmospheric/climate phenomena, and vice versa. The lack of a more thorough understanding of ecosystem dynamics and climate interactions is a key knowledge gap for the improvement of earth system models (ESMs).

The spectral response of the terrestrial surface is a function of the composition, abundance, and configuration of its elements (plants, soil) and their properties. These properties determine ecosystem processes and responses to continuously changing environmental conditions, such as temperature, moisture, and light intensity. This suggests the potential for identifying meaningful relationships between plant properties, measured by spectral reflectance, and ecosystem processes, as they respond to environmental variations. Because there is only a limited understanding of the relationships between ecosystem fluxes of water and carbon and hyperspectral reflectance signatures of land surface, the research community recognizes a critical research need in this area for understanding interactions between land surface and atmosphere. Developing the capability of collecting land surface hyperspectral reflectance measurements at a high temporal frequency is an important step toward improving an understanding of atmosphere-biosphere interactions. More specifically, using the hyperspectral

reflectance and supporting measurements of land surface, we aim to retrieve terrestrial ecosystem properties and their status that indicate interactions between the near-surface atmosphere and terrestrial biosphere, particularly associated with carbon and water cycling of the Earth (e.g., photosynthesis, respiration, and transpiration).

High-temporal-frequency land surface measurement made possible by the EcoSpec system will provide independent measurements of gross primary production (GPP), ecosystem respiration, and evapotranspiration fluxes. We expect that deploying the EcoSpec measurements at the SGP site will extend the investigation of its capabilities across multiple spatial scales and vegetation types. In addition, the principals to be developed by the tower-based system will provide a foundation for imaging systems.

2.0 Results

The system was previously tested in 2015 and 2016 in an agricultural field at Fermi National Accelerator Laboratory (AmeriFlux US-IB1). The retrieval of observations representing land surface functions and processes may be possible through analyses of the measurements with the ecosystem flux measurements collected using the co-located instrument. Based on the lessons learned from the 2017 season, we identified and resolved the issues disrupting the system functionality and conducted thorough testing to perfect the system function prior to deployment for the 2018 season. We have collected a greater volume of measurements during the 2018 season than the 2017 season.

A total of approximately 7 GB of high-frequency time-series data was collected from June 13 to August 13, 2018. The data collected during the campaign include:

- Electromagnetic radiation reflected by the land surface across the spectral range from 400 nm to 2500 nm at a 1-nm interval accompanied with reference measurements that enable standardization of the measured electromagnetic radiation into reflectance values
- RGB photos containing land surface within the field of view of each electromagnetic radiation measurement
- TIR radiation of sky and land surface corresponding to each electromagnetic radiation measurement
- Direct and diffused light
- Solar broadband radiation (upwelling and downwelling).

We are currently investigating several data-cleansing techniques to produce ‘analysis-ready’ measurements using the measurements collected during the campaign and hope to test and produce preliminary ‘analysis-ready’ data in subsequent years. We plan to report as the ‘analysis-ready’ data and derived products become available.

3.0 Publications and References

We have been invited to publish a paper in *Sensors*, an open-access, peer-reviewed journal (Impact Factor: 3.031) and plan to submit a manuscript.

4.0 Lesson Learned

The campaign at the SGP was the first data collection trial for the EcoSpec system. Despite the team's best effort including thorough testing prior to the deployment and providing troubleshooting instructions to on-site technicians, the remoteness of the site was extremely challenging for any timely testing and repair. Because of the considerable inconsistency in the issues and their causes, the team is considering a different configuration of the system using new sensor components for the future. The team anticipates that the new proposed system will contain limited moving components and fewer sensors absolutely essential for observing ecosystem functions.

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