National Aeronautics and Space Administration

Building the foundations of a global plant disease surveillance system: Detecting plant-microbe interactions through integrated proximal and remote imaging spectroscopy

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Program: FY22 SURP

Strategic Focus Area: Water and carbon cycles

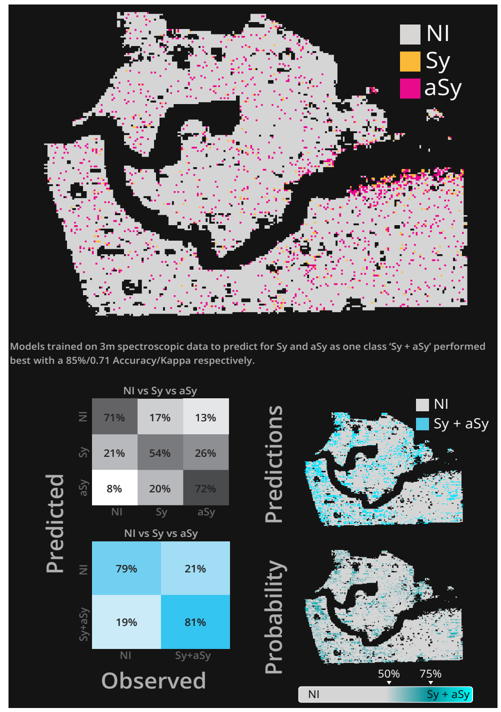
Objectives:

The goal of this project is to develop both a specific application and a general framework for crop disease detection with imaging spectroscopy. To do this, we are using airborne imaging spectroscopy data collected in September 2020 by NASA's Airborne Visible/Infrared Imaging Spectrometer Next Generation (AVIRIS-NG) and Grape Leaf Roll Virus in red grapevines in Lodi, CA as a model system. Understanding how disease detection scales from the ground to airborne to spaceborne scale is an essential first step toward building global disease surveillance systems with forthcoming imaging spectroscopy satellite missions.

Background: Viral diseases, including that caused by Grapevine Leafroll Virus Complex 3 (GLRV), cause $3 billion in damages and losses to the US wine and grape industry annually. GLRV has a long latent period in which vines are infectious but do not yet display visible symptoms, making it an ideal model pathosystem to evaluate both symptomatic and asymptomatic remote-sensing based disease detection. The ability to detect disease during the latent period at scale would greatly reduce management costs, as current detection methods are labor intensive, expensive, and non-scalable.

Approach and Results:

Using external funding, the team conducted an airborne AVIRIS-NG imaging spectroscopy campaign in September 2020. This campaign yielded high spatial and spectral resolution data of 37,317 acres of California vineyards at the peak of the growing season. In this SURP project, to ground-truth our campaign, we collaborated with grape growers to scout a subset of flown vineyards on a vine-by-vine basis for Grapevine Leafroll Virus Complex 3 (GLRV) rating for both disease incidence and severity, to provide us with detailed disease validation maps. A subset of these vines was sent for viral testing to identify asymptomatic infections (~500 total). We have standardized these datasets to a GIS friendly format for ease of analysis using our recently developed pipeline and tool suite, "QScout," (Evans, Romero Galvan, et al. in prep). We also mined historical AVIRIS acquisitions over California that opportunistically captured vineyards yielding a total dataset of 883,772 acres. We used these to develop an accurate Random Forest model for mapping California grape varieties.



This fiscal year, we finalized a workflow for detecting GLRV in Cabarnet Sauvignon grapes using AVIRIS-NG spectral imagery (Romero Galvan, Pavlick, et al, submitted). e combined random forest with synthetic minority oversampling technique (SMOTE) to train a spectral model able to distinguish between non-infected and GLRV-infected grapevines. We observed clear spectral differences that allowed for differentiation between non-infected and GLRV infected vines regardless of foliar-symptoms visually identifiable by human scouts at 1m through 5m resolution. Our two best performing models had 87% accuracy and 0.73 kappa score between non-infected (NI) vs. asymptomatic (aSy) and 85% accuracy and 0.71 kappa score between NI vs. (aSy + symptomatic [Sy]) respectively. We hypothesize these spectral differences are linked to changes in overall plant physiology induced by disease, as visible foliar symptoms were restricted to the lower canopy.

In September 2022, we conducted a field campaign at a vineyard in Santa Barbara timed to coincide with a NASA Surface Biology and Geology SHIFT AVIRIS-NG flight. We visually scouted and geotagged five acres of multiple red grape varieties for GLRV. We collected tissue samples from 50 vines to do lab-based confirmation of the presence of GLRV. We used the autonomous Cornell PhyloPathoBot to collect high-resolution RGB and multi-spectral geotagged images of every vine. These data will be used in the coming fiscal year to validate our existing algorithm and to develop a new deep learning model that incorporates both the airborne spectra and the robotic ground-based imagery for improved disease detection.

Significance/Benefits to JPL and NASA: The use of remote sensing to advance plant disease detection represents an innovative opportunity to further the use of Earth system science research to benefit society and inform decision making while advancing applications-focused research in precision agriculture, one of the priorities outlined for Surface Biology and Geology in the 2018 Earth Science NASA Decadal Survey and strategic priorities. The ability to non-destructively sense plant disease would greatly benefit modern agriculture and food security. Early intervention is key to successful disease mitigation. Farmers can apply systemic fungicides to stop disease before it spirals out of control, but these are only effective when applied early during the infection process. Worldwide, plant disease research and early intervention efforts are often constrained by a lack of local expertise to devote to prevention, a lack of resources to devote to monitoring and/or remediation, and a lack of qualified personnel to allocate to both these tasks. The use of remote sensing to advance plant disease research represents an opportunity to avoid these challenges and make a difference in the lives of farmers worldwide while advancing applications focused research on precision agriculture, one of the goals outlined in the NASA Earth Science Decadal Survey.

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Publications:

Evans, J. R., Romero Galvan, F. E., Kanaley, K., Cadle-Davidson, L., & Gold, K. M. (2022). QScout: A QGIS plugin tool suite for georeferencing and analysis of field-scouted and remote sensing data. *The Plant Phenome Journal*, *5*(1), e20031.

Trolley, G., Romero Galvan, F., Pavlick, R., Starr, C., & Gold, K. (2021, December). Grapevine variety discrimination using airborne hyperspectral imagery. In *AGU Fall Meeting Abstracts* (Vol. 2021, pp. B55K-1322)

Romero-Galvan, F.E., Pavlick, R., Trolley, G., Aggarwal, S., Sousa, D., Forrestel, B., Starr, C., Bolton, S., del Mar Alsina Marti, M., Dokoozlian, N., and Gold, K.M. (submitted) Scalable early detection of grapevine virus infection with airborne imaging spectroscopy.

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