Spatiotemporal variability in plant community phenology revealed from decadal phenocam timeseries on the north slope of Alaska

ITEX-AON
Understanding Tundra Ecosystem Change

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Arctic Phenocam Synthesis Website

Abstract

Climate change is pronounced at high northern latitudes where the ensuing impacts on ecosystems caused by climate change has become a well-recognized research priority. Plant phenology is sensitive to climate variability and has the potential to elucidate climate-ecosystem coupling over multiple spatial and temporal scales. **This study is a component of the US International Tundra Experiment - Arctic Observing Network (ITEX-AON) and assesses the effectiveness of hourly plot and landscape-level time lapse images acquired from phenocams to derive measures of phenological variability (e.g., slope of productivity, slope of senescence and end of season) for dominant vegetation communities near Utqiaġvik (formerly Barrow) and Atqasuk, Alaska.**
Ten growing seasons of environmental data (e.g., soil moisture, soil temperature, and active layer thaw depth) along with digital imagery were assessed by extracting time series of the green chromatic coordinate (GCC) index, derived from Red-Green-Blue digital numbers. **Seasonal and inter-annual variability in GCC were greatest in low arctic and wet plant communities, while high arctic and dry plant communities showed less variability. Overall, findings suggest that sometimes strong seasonal and inter-annual variability in arctic landscapes are likely driven by moist to wet land cover types**. Future work will extend cross-scale analyses to a variety of satellite platforms (e.g., WorldView, Landsat, MODIS) to understand how such patterns transcend sensor platforms and sampling at different spatial scales.

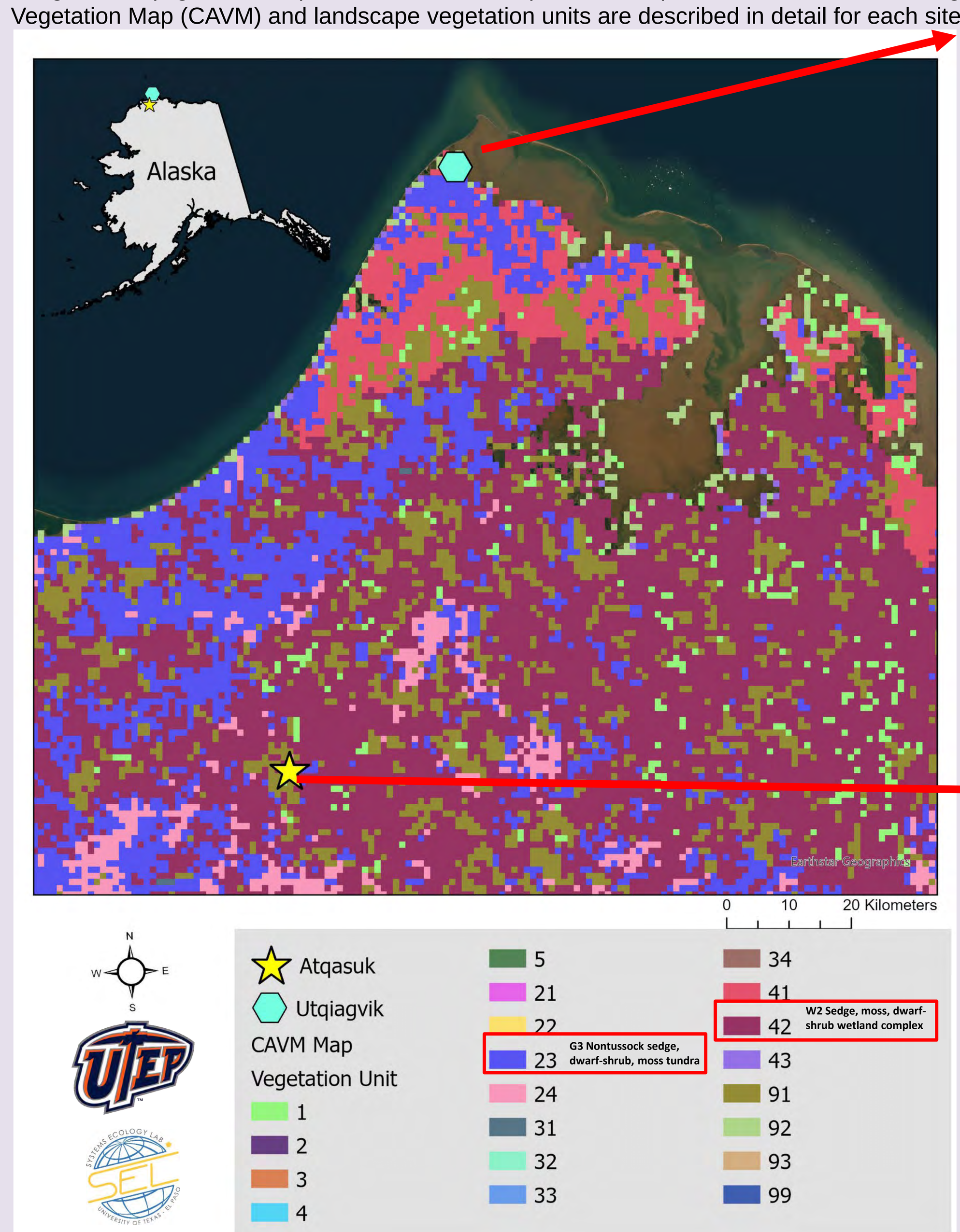
Introduction

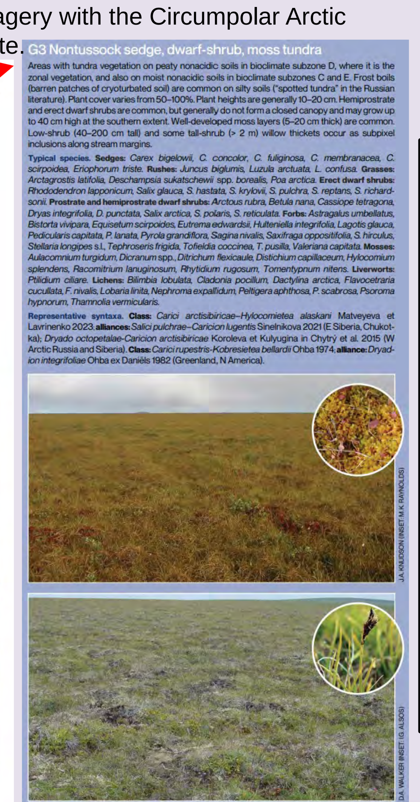
Satellite remote sensing has a proven capacity to detect change in arctic landscapes. However, image capture, interpretation (e.g., greening vs. browning) and ultimately change detection can be compromised by factors such as coarse spatial resolutions, cloud cover, the presence of standing water, low sun angles and a limited ability for temporal acquisitions. Networks of low-cost sensors and other ground-based sensing platforms have the capacity to complement satellite derived measurements by filling in the spatial and temporal scale gaps if deployed in an extensible manner (*Andresen et al. 2017; Beamish et al. 2016; Brown et al. 2016; Healey et al. 2014; Ide et al. 2013; Sonnentag et al. 2012,; Westergaard-Nielsen et al. 2013*). **The objective of this study was to utilize inexpensive sensors to document how long-term phenological trends differ between locations and plant communities. Key research questions:**

1. **How do phenological trends vary by location, vegetation type and year?**
2. **Can we observe evidence of greening and/or browning trends over time?**
3. **What environmental parameters control phenological differences between sites and across years?**
4. **Does vegetation type predict landscape phenological dynamics?**

Study Sites

Fig. 1. Map showing Mobile Instrumented Sensor Platform (MISP) phenocam study sites located near the native Alaskan villages of Utqiagvik and Atqasuk on the North Slope. Base map shows visible satellite imagery with the Circumpolar Arctic Vegetation Map (CAVM) and landscape vegetation units are described in detail for each site.





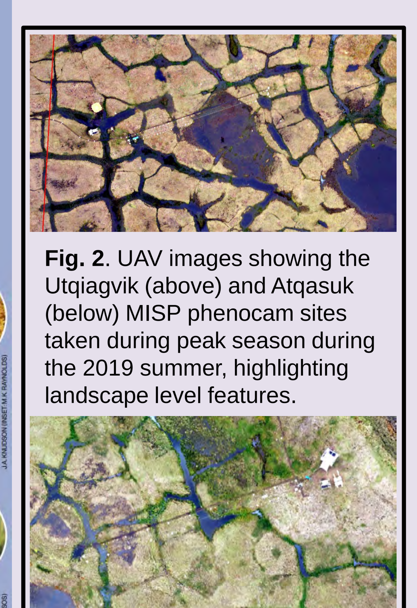


Fig. 2. UAV images showing the Utqiagvik (above) and Atqasuk (below) MISP phenocam sites taken during peak season during the 2019 summer, highlighting landscape level features.

The Circumpolar Arctic Vegetation Map (CAVM) shows the types of vegetation that occur across the Arctic at 1km spatial resolutions—between the Arctic Ocean to the north and the northern limit of forests ("treeline") to the south. Here, environmental and climatic conditions are extreme, with a short growing season and low summer temperatures.

Data Collection

Fig. 3. Phenocams were installed on top of the MISP transect towers at both Utqiagvik and Atqasuk, Alaska during summer of 2011 and 2016. The Wingscapes Birdcam and UTEP proprietary camera models were used and programmed to capture hourly images throughout each growing season.

Workflow

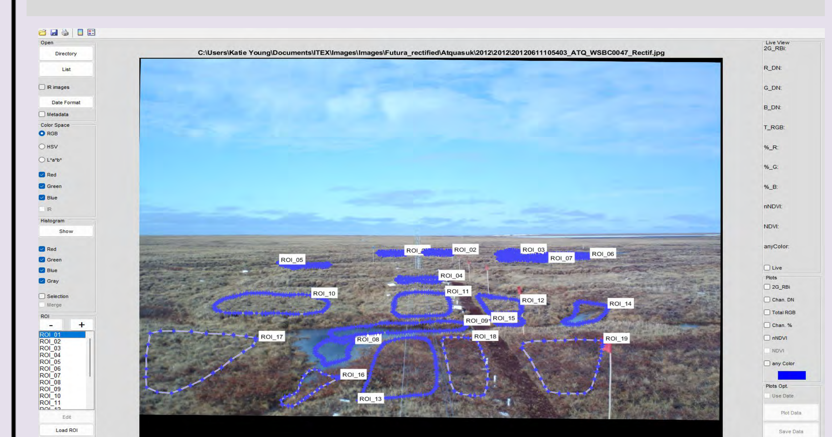
1) Image Processing

1A) **Horizon Leveling** – Correct drift in camera

1B) **Image Alignment –** Correct image correspondence

2) Data Extraction

2A) **Vegetation specific ROIs**



ROI Delineation

ROI ID	Vegetation class	Scale
ROI_01 – ROI_03	Dry	Landscape
ROI_04 – ROI_06	Moist	Landscape
ROI_07	Wet	Landscape
ROI_08 – ROI_09	Wet	Local
ROI_10 – ROI_12, ROI_17	Dry	Local
ROI_13, ROI_18 – ROI_19	Dry shrub	Local
ROI_14 – ROI_16	Moist	Local

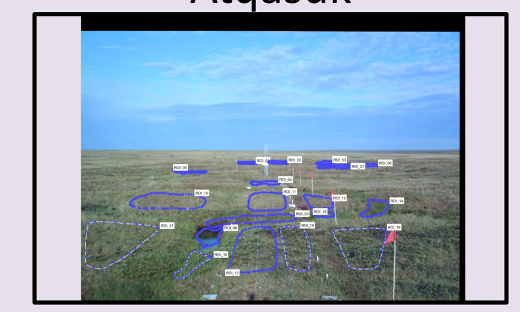
2B) **Data Extraction (RGB/HSV Indices)**

Figure 4. Conceptual workflow for image processing and extraction of vegetation greenness indices as proxies of vegetation phenology: 1A) Images are corrected for drift in camera level (Python code). 1B) Images are aligned to correct image correspondence (Camera Futura Software). 2A) ROIs are manually delineated using high resolution vegetation maps and expert knowledge. 2B) Greenness indices are extracted for individual ROIs (custom image analysis software Phenoanalyzer).

Results

Veg class ROIs

Atqasuk



Utqiagvik

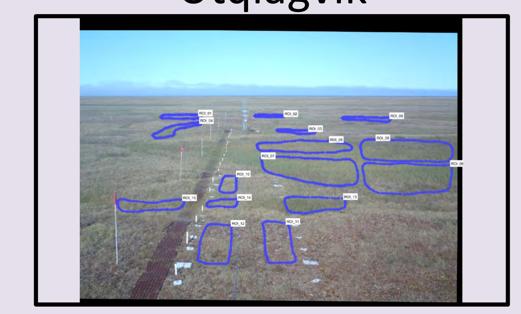
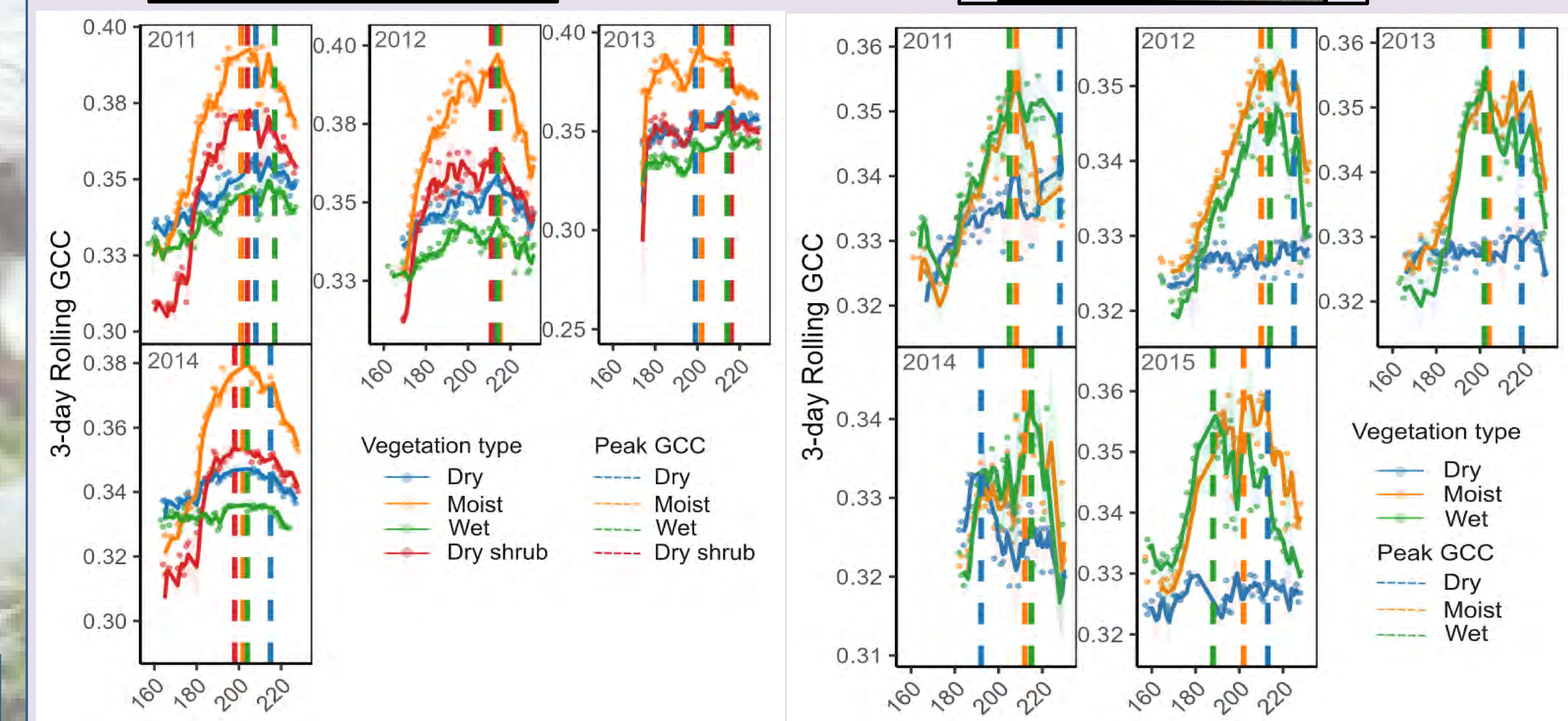


Fig. 5 Plots showing Atqasuk and Utqiagvik phenocam-derived GCC 3-day rolling means for veg class ROIs by year between 2011-2015.



Landscape ROI

Atqasuk

Utqiagvik

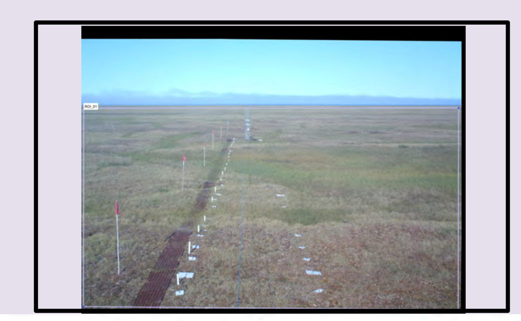
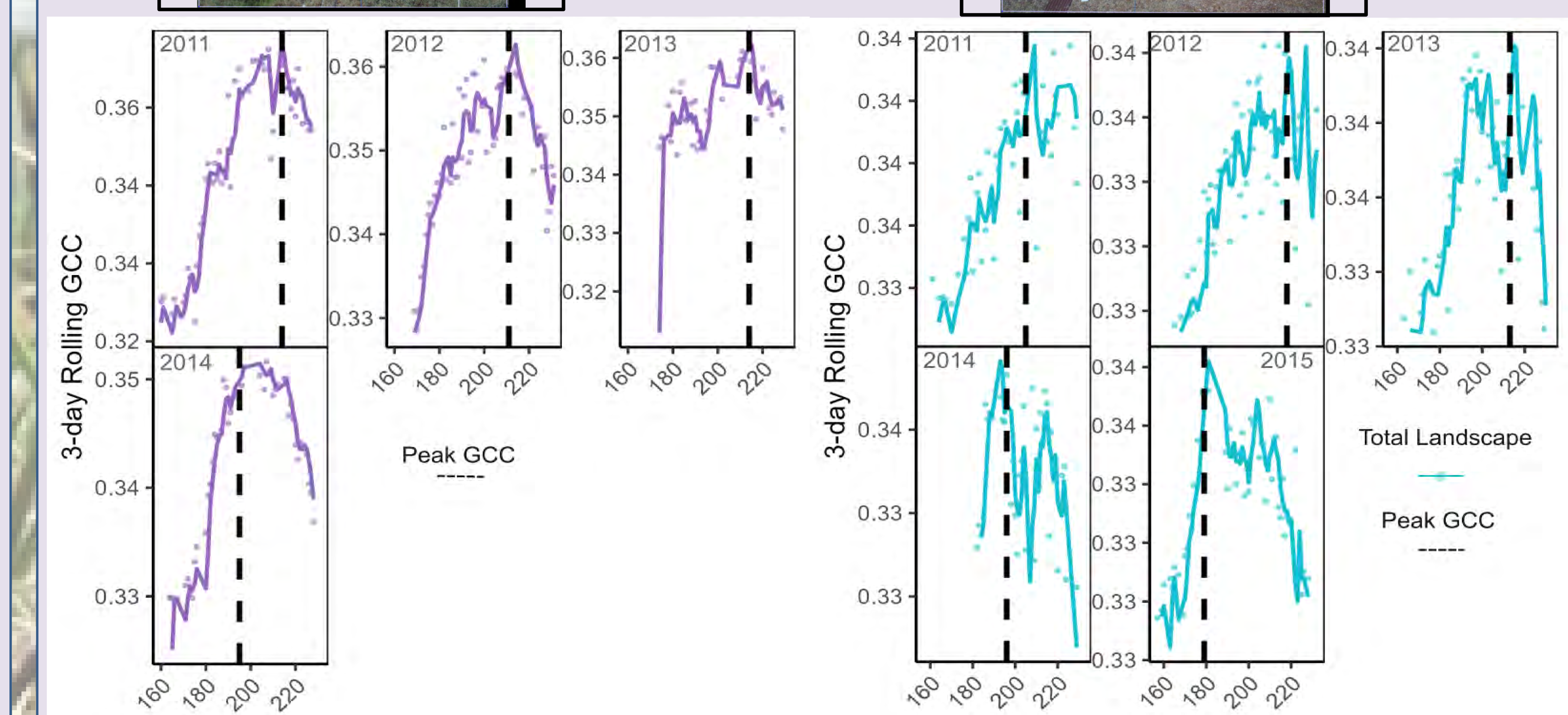


Fig. 6 Plots showing Atqasuk and Utqiagvik phenocam-derived GCC 3-day rolling means for total tundra landscape ROIs by year between 2011-2015.



Conclusions/ Next Steps

- The preliminary findings of this study show that these approaches have the capacity to document key phenological trends occurring at local to landscape scales (e.g., meters to squared kilometers) and over short-temporal frequencies (e.g., hours to days) that previous studies have not been able to describe
- Drier plant communities and those located in Utqiagvik show stable seasonal phenological trends (steady GCC) while moist to wet plant communities and those present in Atqasuk are more variable and, in most cases, display higher greening signals as detected from GCC
- Change documented in studies using low resolution satellite imagery is likely driven by changes to moist and wet plant communities (graminoids) versus those with drier soil moisture contents (forbs, mosses and lichens)
- Implications of this work suggest that large scale change in greening of the Arctic indicates the capacity for ongoing and large scale ecohydrological change to which moist and wet land cover types are responding
- **Ongoing research is focused on:**
  - **Assessing what environmental parameters control phenological differences between sites and across vegetation types**
  - **Exploring how GCC phenological trends from phenocams scale to satellite trends**
  - **Quantify pheno-phases for each vegetation type to explore changes in green-up and senescence rates over time**

Acknowledgements

This project was funded through support from the National Science Foundation (AON grant no.0856710). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. This work would not have been possible without the help of the following Stephen Escarzaga, Mayra Melendez, Marianna Orejel, Tabatha Fuson, Grand Valley State University and Florida International University field crews.

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