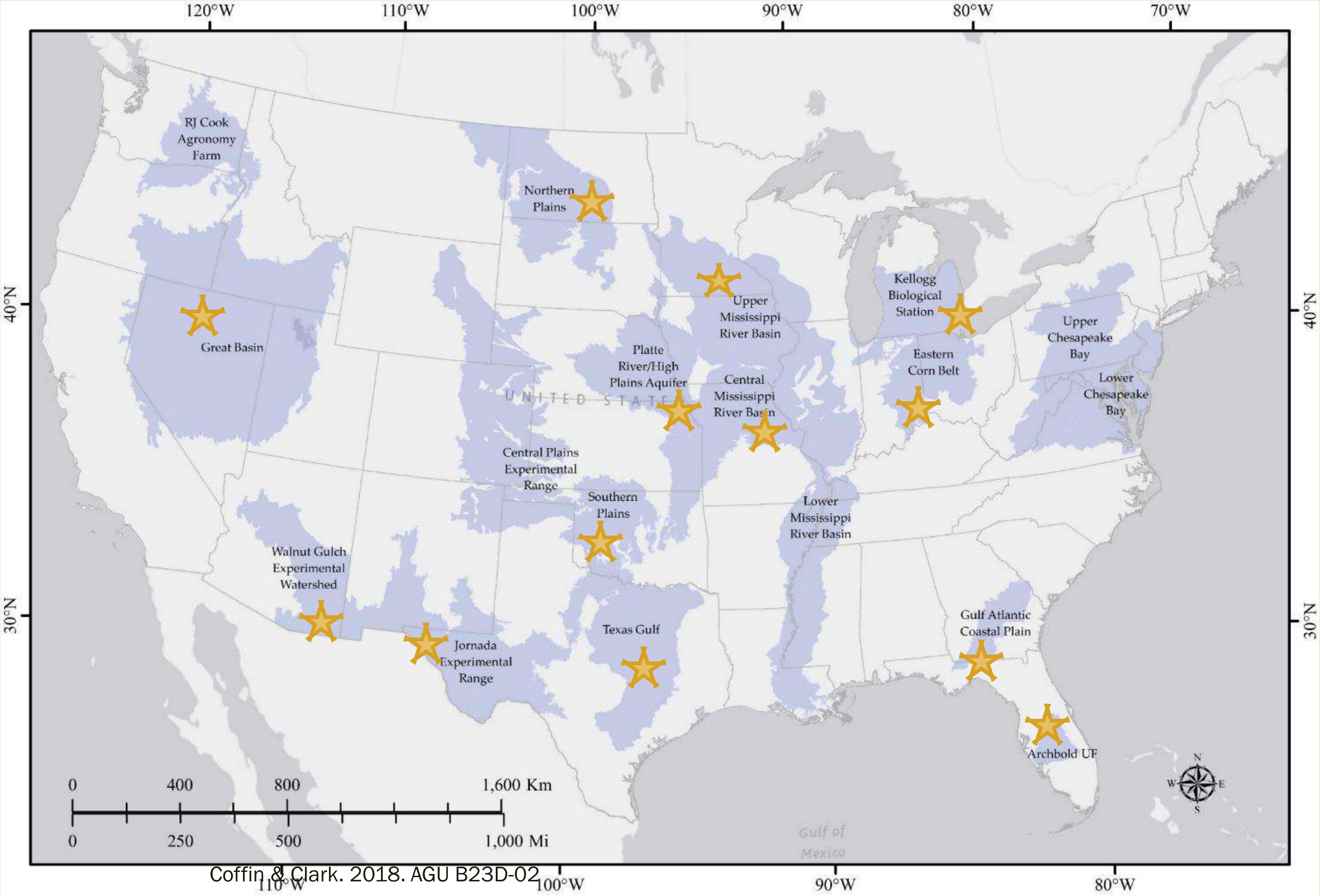
The Promise and Challenges of Small Unmanned Aerial Systems (sUAS) for Agricultural Research in the Long-term Agroecosystem Research (LTAR) network

Alisa Coffin, Pat Clark
USDA – Agricultural Research Service

B23D-02
2018 AGU Meeting, Washington, D.C.
11 December 2018, 13:55-14:10

LTAR: Long-Term Agroecosystem Research Network



Coffin & Clark. 2018. AGU B23D-02

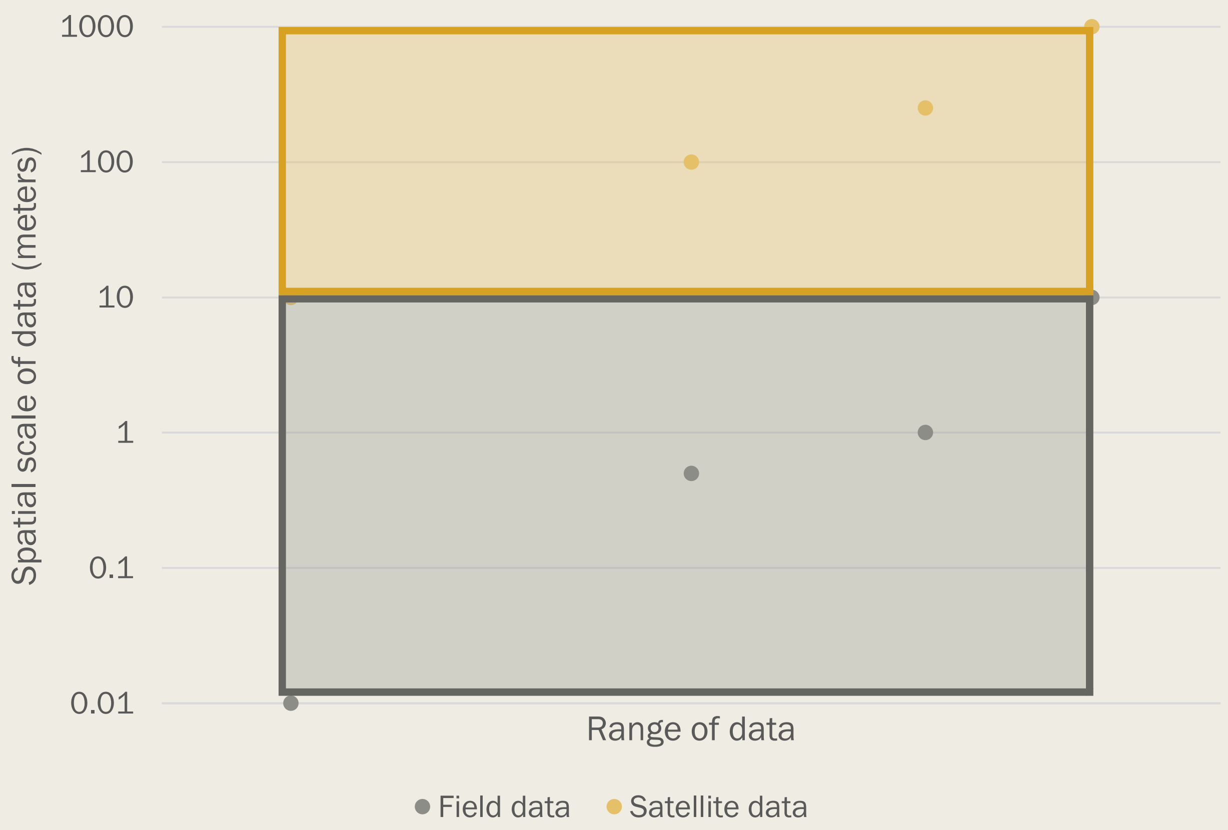
The promise of sUAS for agricultural research

- Tools to monitor crop conditions with fine resolution and low latency.
- Rangelands are also benefiting from the increased resolution and frequency of sUAS vegetation monitoring systems.
- For producers: low-cost solutions promise high-performance decision tools.
  - *Adequate data quality to quickly spot problems, such as pest and disease outbreaks.*
- For researchers: the promise of filling gaps where satellite data are poor quality or non-existent
  - *UAVs complement proximal and remote sensing programs*

What do we want to know from remote sensing?

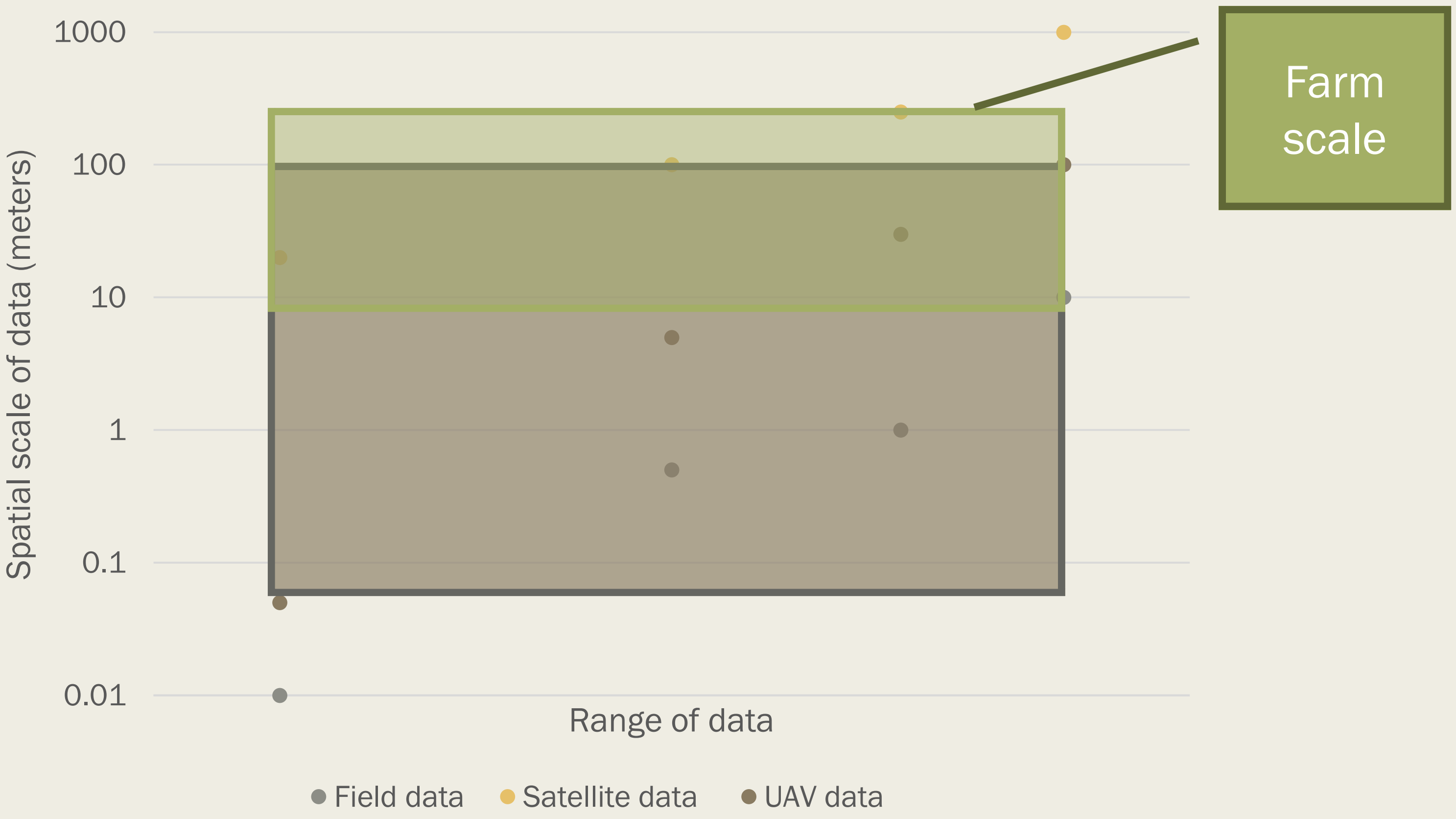
- What kind - classification
- How big - total biomass or yield, net primary productivity
- How fast - growth rates
- How healthy - stressed from water, nutrients, pests
  - *(Hatfield and Prueger, “Remote Sensing in Agriculture: Achieving the potential from this technology for agriculture” 2018 ASA meeting, Baltimore, MD)*

Field data and Satellite data



Coffin & Clark. 2018. AGU B23D-02

UAV data and Farm scale



Coffin & Clark. 2018. AGU B23D-02

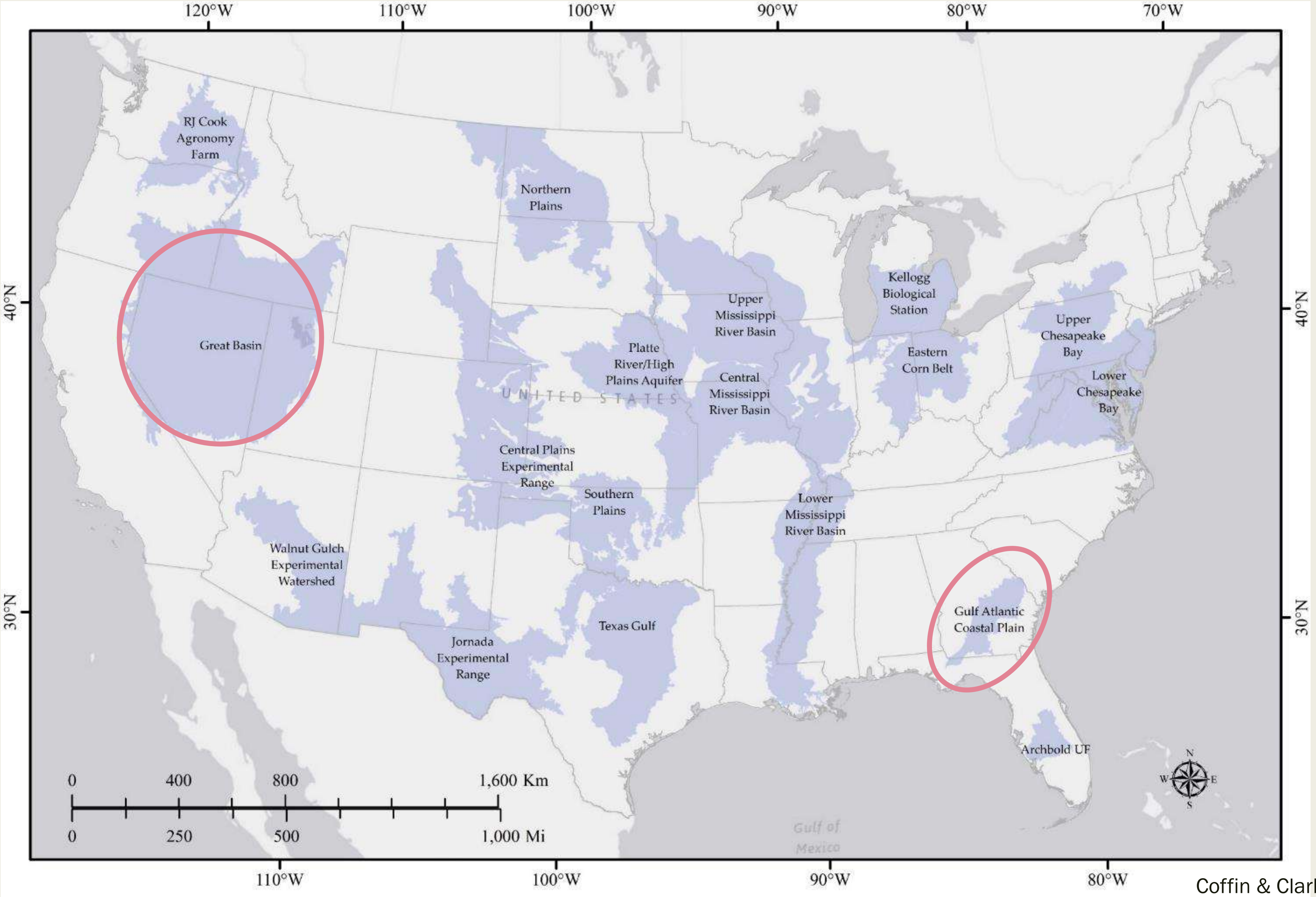
What do we need to use UAVs?

- Appropriate equipment specification
- Mission planning and preparation
- Resources for data handling, processing and storage
- Sufficient data quality to extract necessary information
  - *e.g. is it a warm body? is it burnt or unburnt? Is the plant healthy?*

But, scientific research with small UAVs also requires

- Particular attention to final data quality and documentation
- Evaluation of instruments for adequacy to the science
- Proper use of instrumentation to produce sound measurements using repeatable protocols
- Outputs with known accuracies and uncertainties
  - *e.g. what are the spectral characteristics? How does this compare to other multi-frequency rs images?*

Long-Term Agroecosystem Research Network



Coffin & Clark. 2018. AGU B23D-02

GACP LTAR
Tifton, GA

- Research objectives 2017-2022:
  - *Quantify and assess the effects of…*
    - Runoff, erosion and sediment properties on contaminant transport
    - Agricultural conservation practices at multiple spatial and temporal scales
    - Interactions among agroecosystems and landscape components on water supply, water quality and other ecosystem services
- Collection efforts include extensive monitoring of stream flow and water quality
- But,
  - *Scale and availability of rs datasets limit quantification at the field scale*
  - *High costs to carry out intensive ground-based collection*
- Therefore, sUAS program is supporting this with
  - *Fine scale surface measurements*
  - *Supplement to traditional field data collection*
  - *Filling gaps of satellite data at whole field scales*

GACP UAV program elements

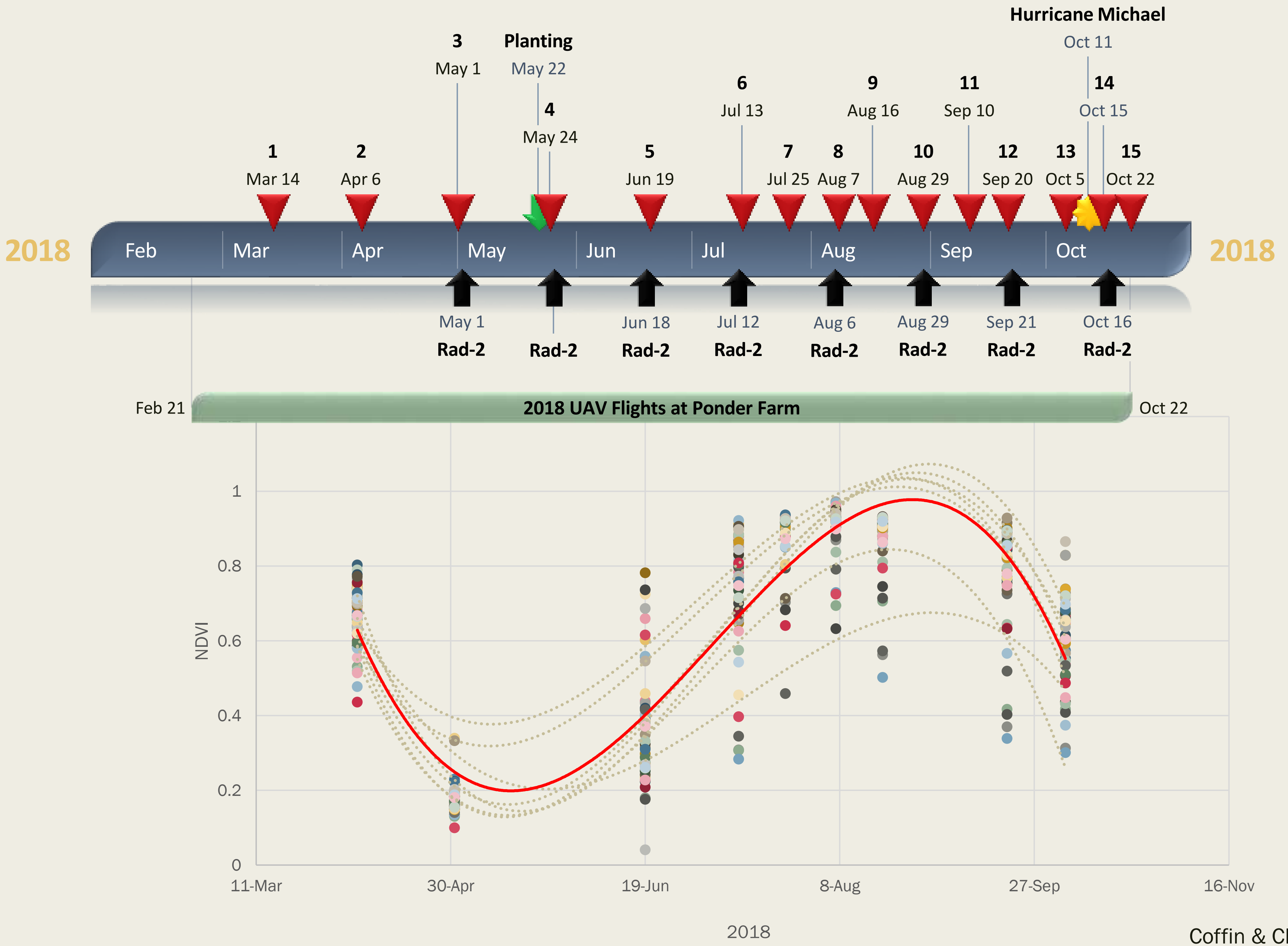
- Aircraft
  - *DJI Matrice100*
  - *DJI Matrice 210 RTK*
  - *DJI Spark*
- Sensors
  - *Navigation cameras*
  - *High resolution RGB cameras*
  - *MicaSense RedEdge*
  - *FLIR XTr*
- Computing system
  - *High performance rack mounted PC*
    - 2 quad-core 3.6 GHz processors
    - 256 Gb RAM
    - 7 Tb storage
  - *File server 9 Tb storage*
- People
  - *2 Part 107 certified pilots*
  - *IT support*
  - *Farmers (cooperators)*

DJI Matrice 100 w/ RedEdge

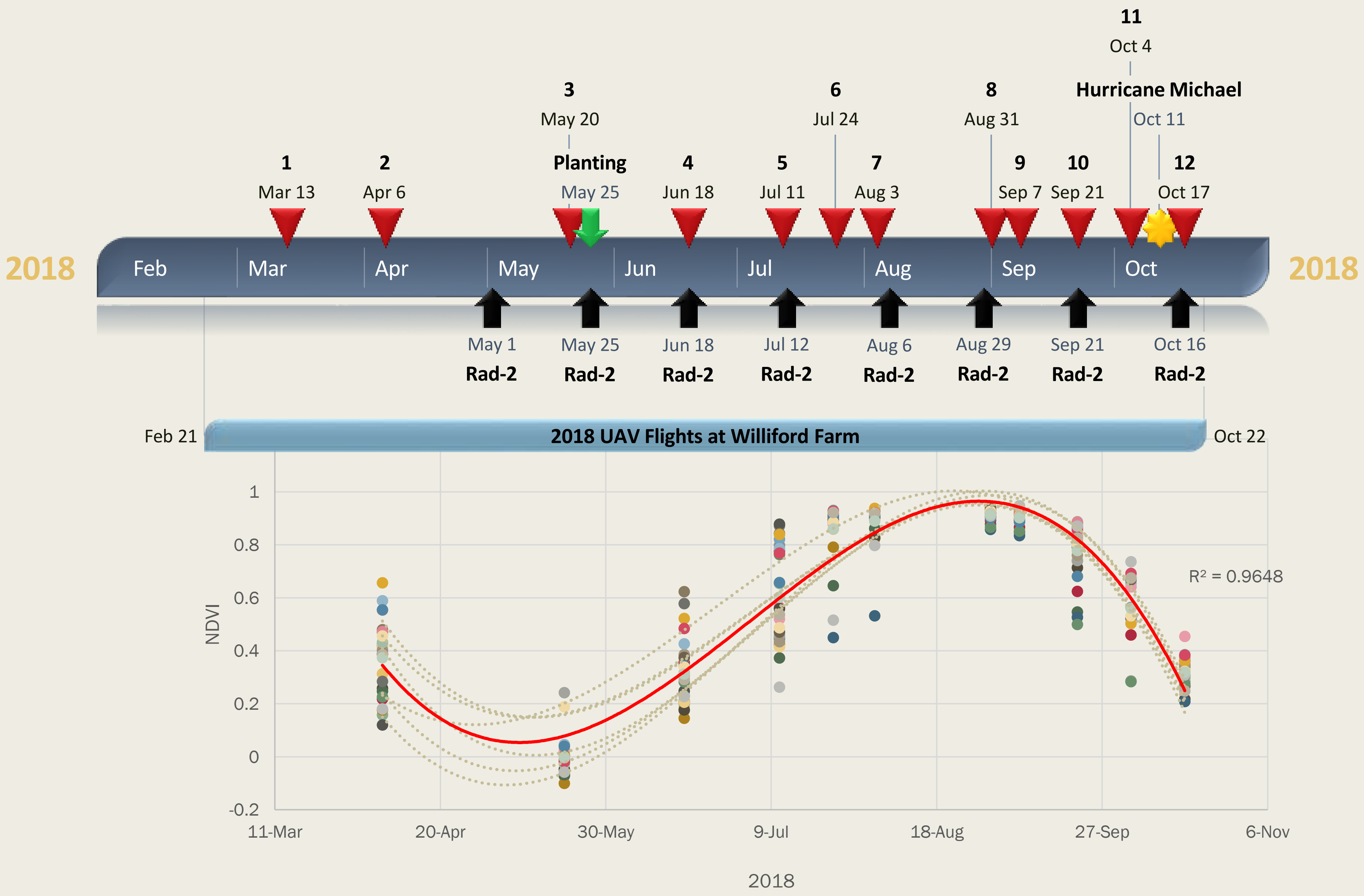
Coffin & Clark. 2018. AGU B23D-02

Flights to date

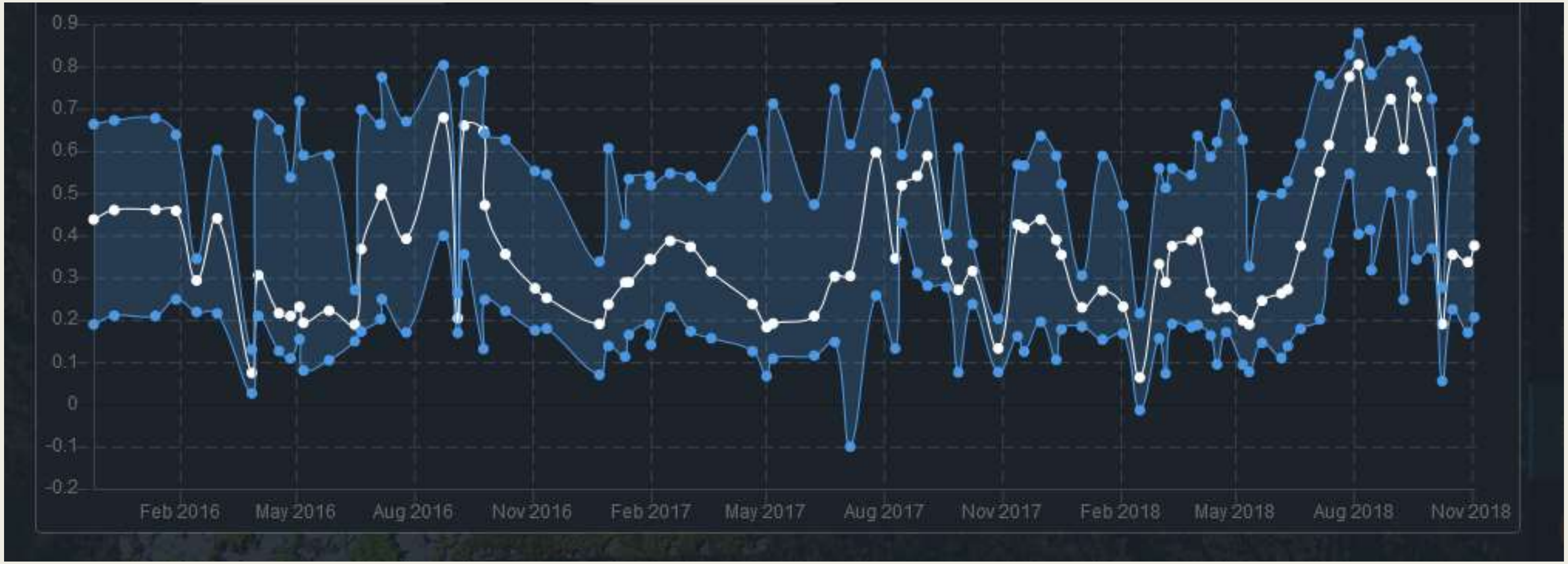
- 2017
  - *69 missions*
  - *5 farms: Ogletree,* ***Ponder (7), Williford (7)****, Wilson, Gibbs*
- 2018
  - *64 missions*
  - *5 farms: Gibbs, Wilson,* ***Ponder (15), Williford (12)****, Belflower*



Coffin & Clark. 2018. AGU B23D-02

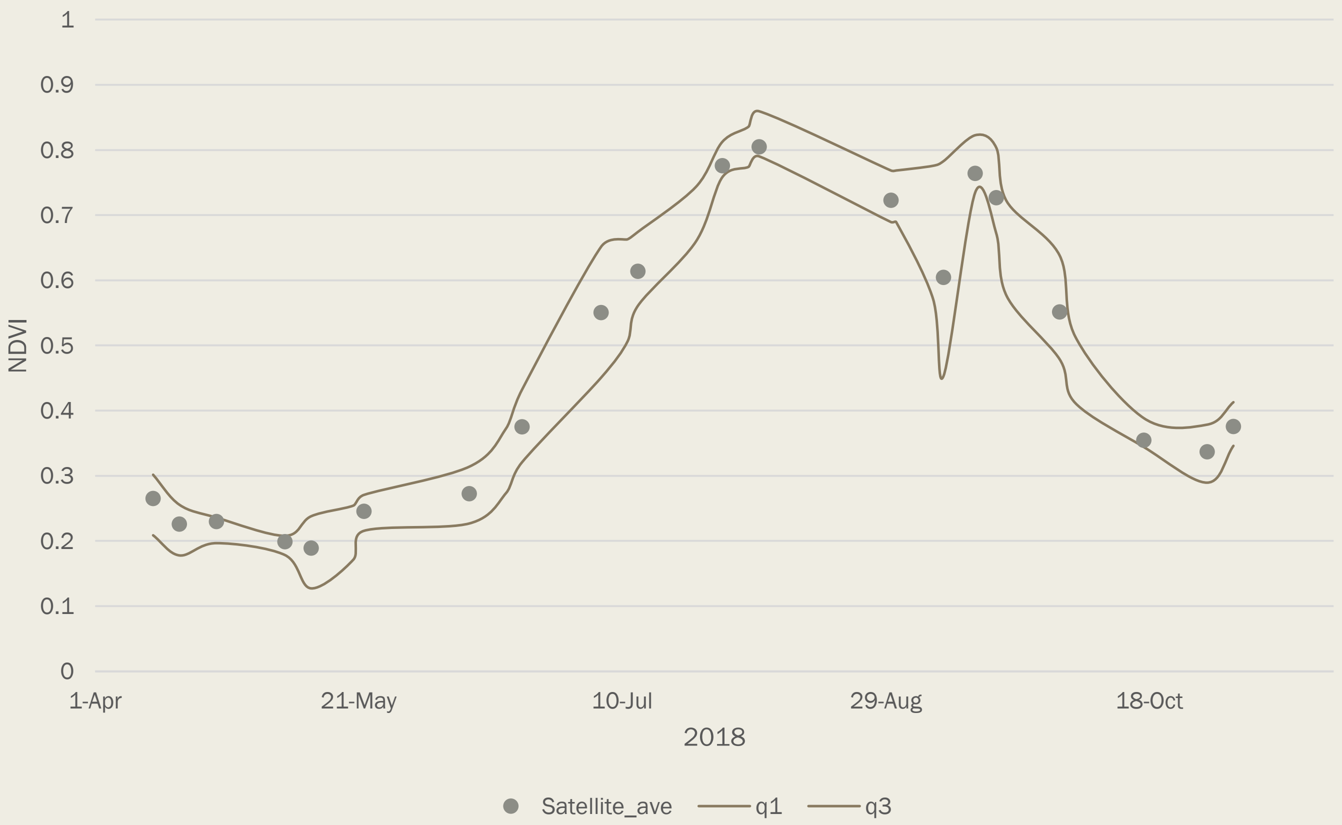


11
Oct 4
Hurricane Michael
Oct 11
3
May 20
Planting
May 25
6
Jul 24
8
Aug 31
1
Mar 13
2
Apr 6
4
Jun 18
5
Jul 11
7
Aug 3
9
Sep 7
10
Sep 21
12
Oct 17
2018
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
2018
May 1
Rad-2
May 25
Rad-2
Jun 18
Rad-2
Jul 12
Rad-2
Aug 6
Rad-2
Aug 29
Rad-2
Sep 21
Rad-2
Oct 16
Rad-2
Feb 21
2018 UAV Flights at Williford Farm
Oct 22
NDVI
1
0.8
0.6
0.4
0.2
0
-0.2
R² = 0.9648
11-Mar
20-Apr
30-May
9-Jul
18-Aug
27-Sep
6-Nov
2018

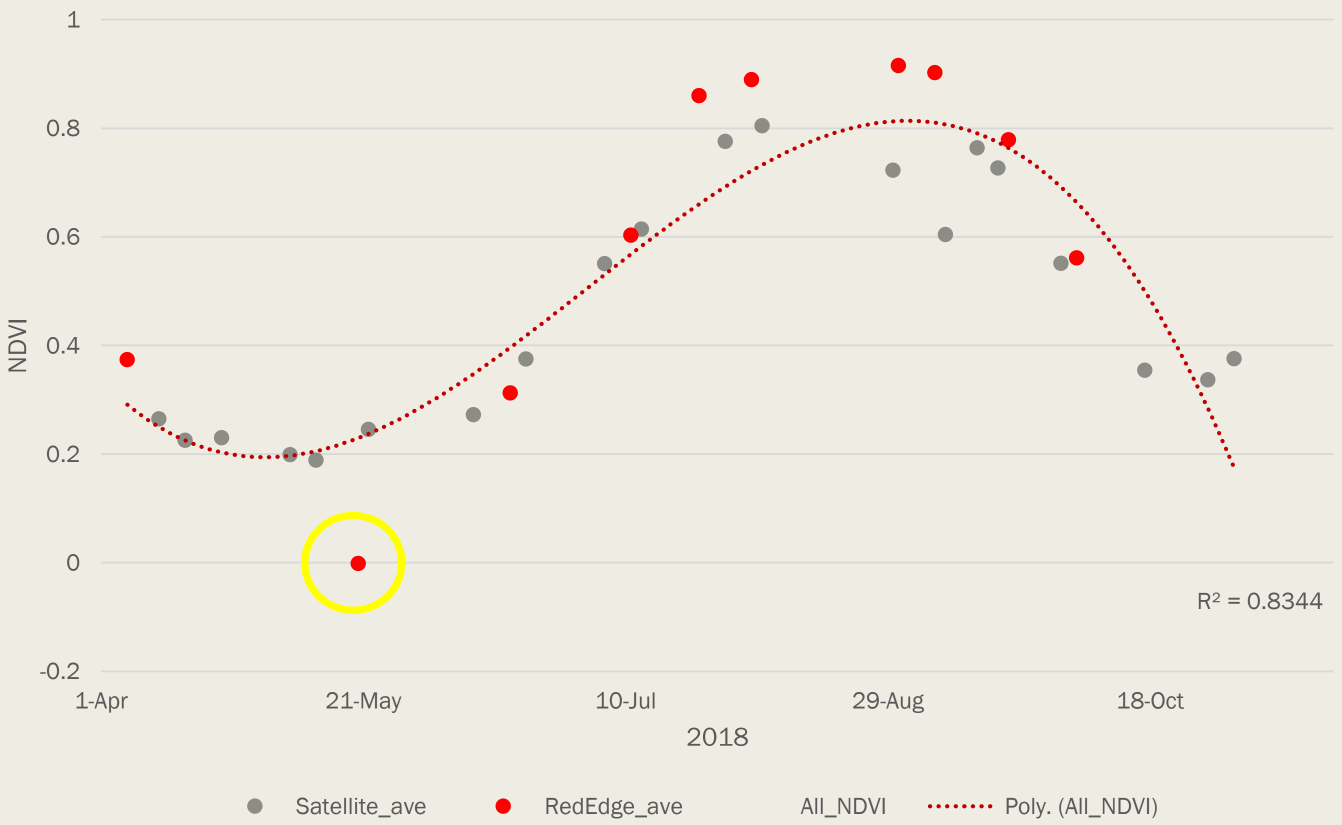


NDVI 11/2015 – 11/2018 – Williford Farm
Landsat 8 & Sentinel 2

eos.com/landviewer



Coffin & Clark. 2018. AGU B23D-02



Coffin & Clark. 2018. AGU B23D-02

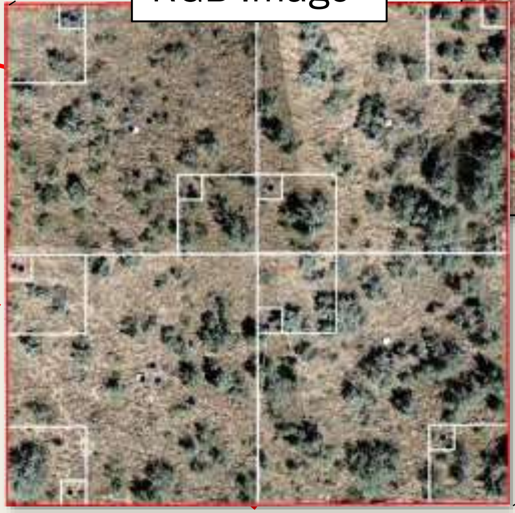
Great Basin LTAR
Boise, ID

- Western rangeland monitoring and assessment efforts face different set of challenges.
- Ground-based field techniques are typically used to assess rangeland
- But
  - *extensive spatial scope and spatiotemporal variability*
  - *huge time and material costs*
  - *data collections tend to be localized and sparsely distributed*
  - *difficult to adequately sample vegetation parameters,*
- Therefore, UAVs can greatly enhance data collection and inform assessment efforts

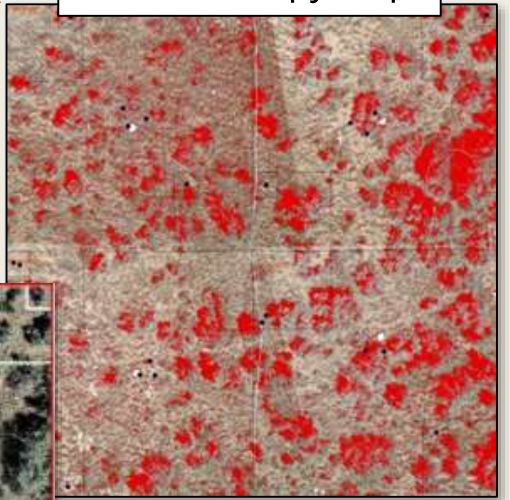
Quantifying Fine-Scale Vegetation Dynamics across Time and Space

Low-Cost UAV

RGB Image



Shrub Canopy Gap



Parameters

- Cover (Abundance)
- Canopy Gap (Fuel Connectivity)
- Basal Gap (Bare Ground Connectivity)
- Vegetation Structure
- Biomass (Productivity)
- Greenness (Vigor/Phenology)

Fire Behavior

Habitat Quality

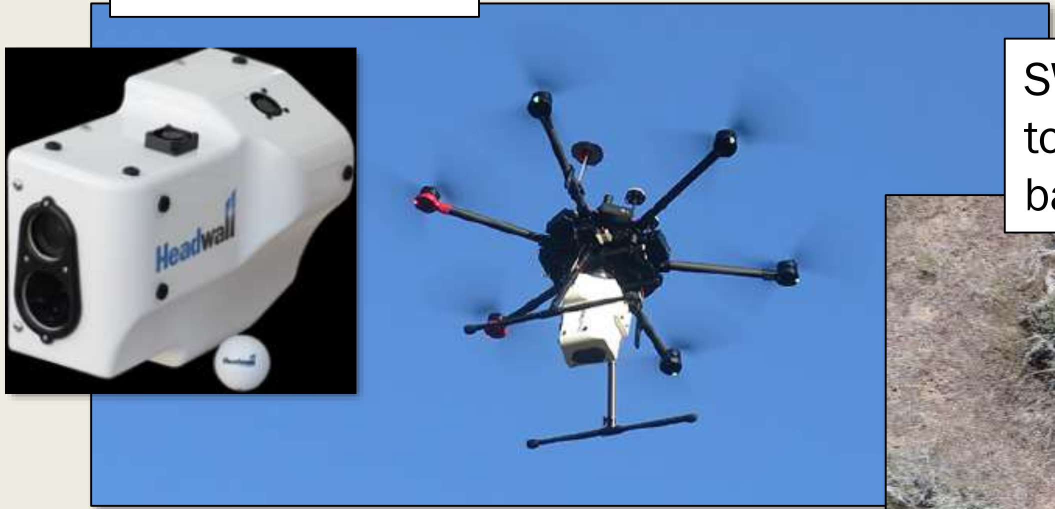
Applications

- Runoff and Erosion Prediction
- Fire Behavior (Next-Gen Fuel Models)
- ANPP, Ecosystem Health, and Forages
- Habitat Quality Assessment (sage-grouse)

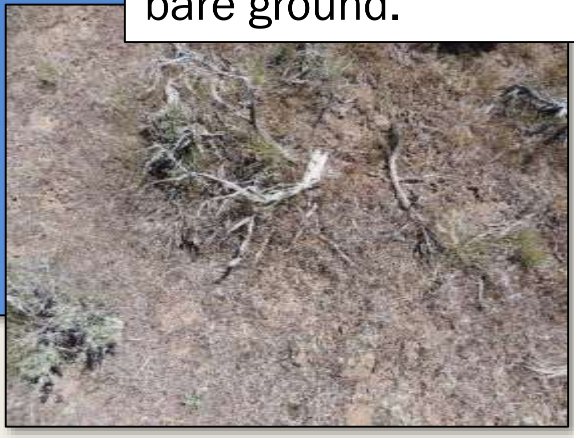
Coffin & Clark. 2018. AGU B23D-02

Challenges Potentially Requiring Advanced Sensor Technologies

VNIR-SWIR Sensor



SWIR Imagery needed to tease apart litter from bare ground.



High spectral & spatial resolution needed to identify separate species.

Parameters

- Bare Ground
- Litter Cover
- Plant Species Composition
- Invasive Plant Species

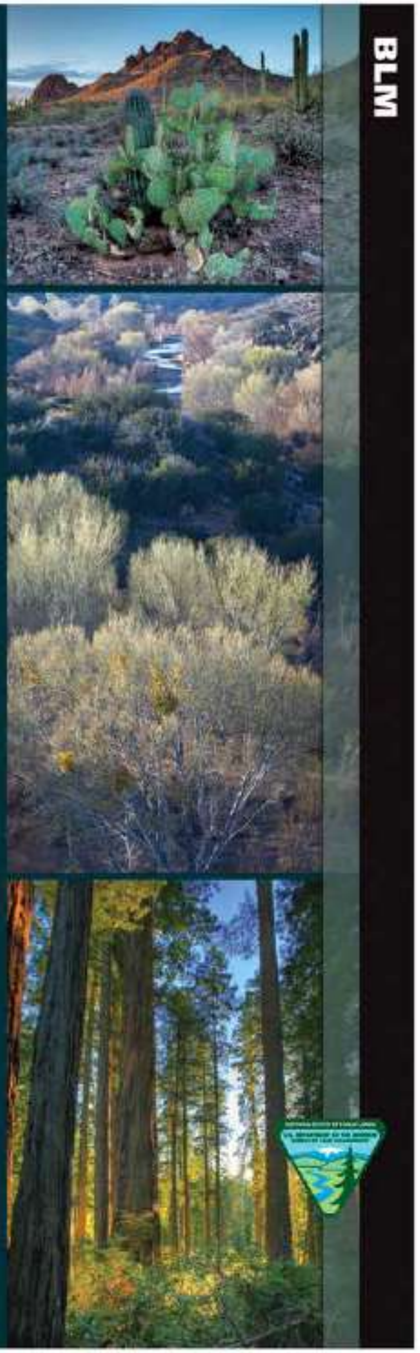
Applications

- Runoff and Erosion Prediction
- Nutrient/Carbon Cycling Quantification
- Biodiversity Measurement
- Integrated Pest Management

Coffin & Clark. 2018. AGU B23D-02

AIM-Monitoring:

A Component of the BLM Assessment, Inventory, and Monitoring Strategy



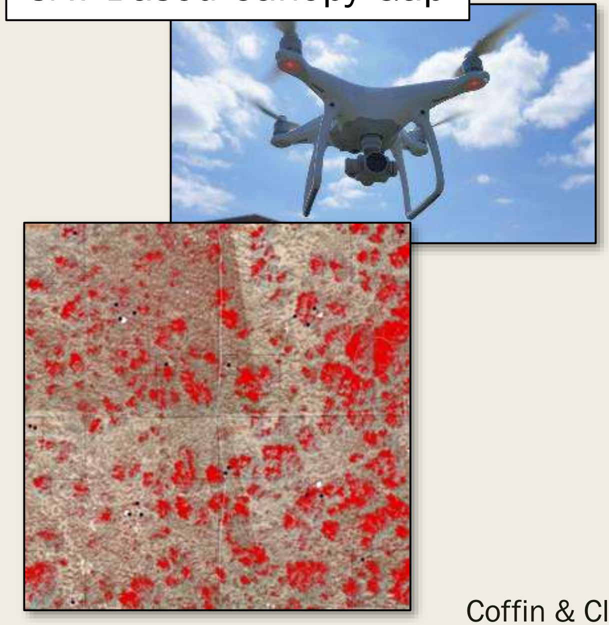
Terrestrial Core Indicators

- Bare Ground
- Non-Native Invasive Sp.
- Plant Species of Concern
- Plant Canopy Gap
- Vegetation Composition
- Vegetation Structure

AIM Transect Sampling

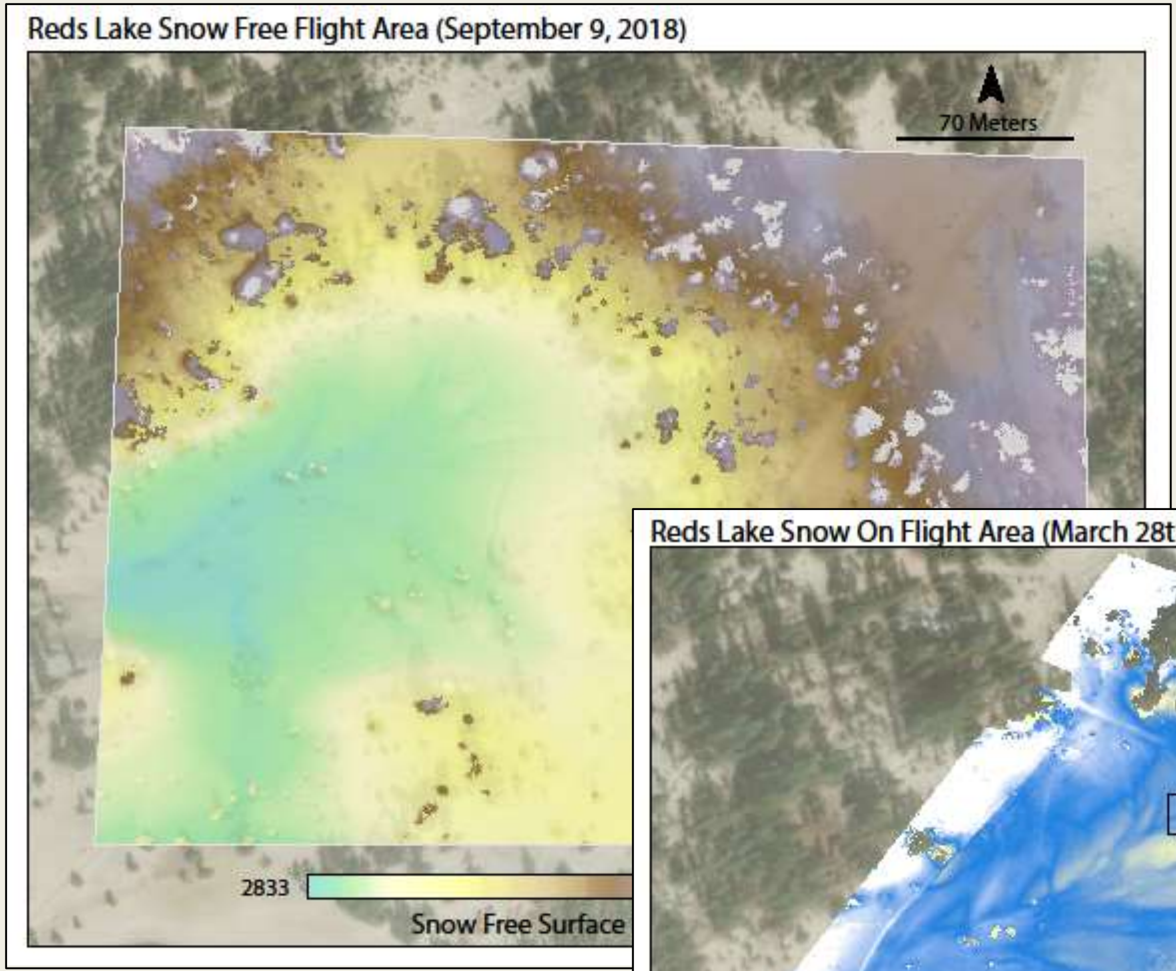
Goal:
Extend, scale and/or replace ground-based measurements with those acquired with UAVs.

UAV-Based Canopy Gap

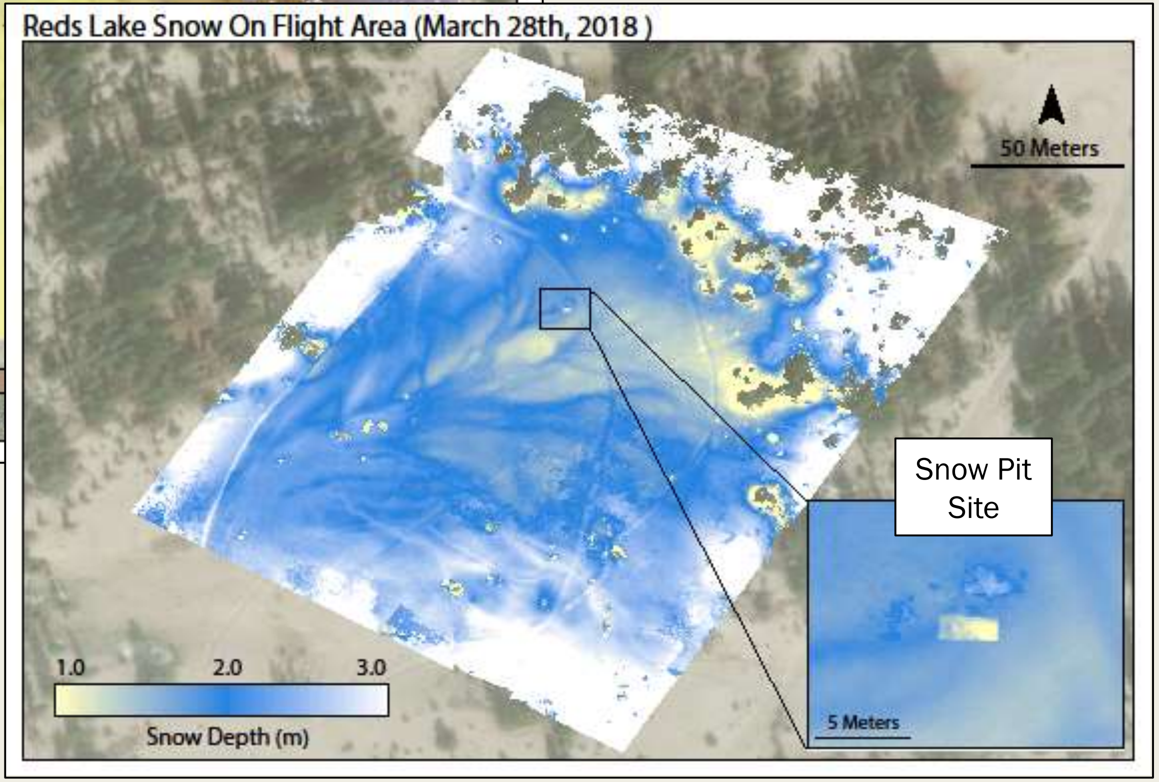


Coffin & Clark. 2018. AGU B23D-02

Quantifying Snow Depth using UAV imagery and Structure-from-Motion for Water Supply Forecasting.



Differencing of Snow-Off and Snow-On DSMs yields Snow Depth.



Coffin & Clark. 2018. AGU B23D-02

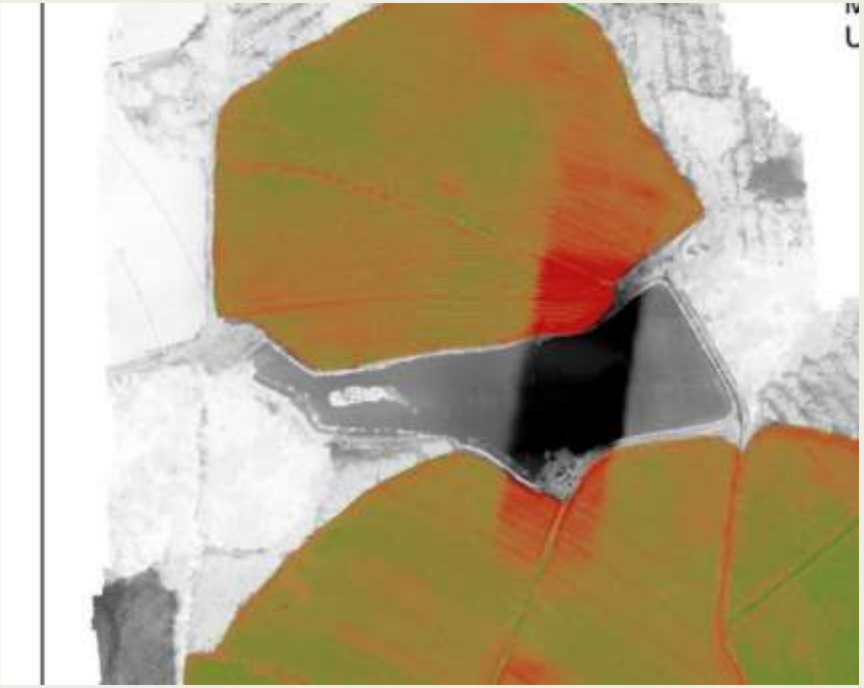
The challenges of sUAS for agricultural research

Data type	Precision	Accuracy	Frequency	Cost
Field data	Very high	Very high	Low	High
Satellite data	High	High	Variable	Low
UAV data	Very high	Variable	Moderate	Moderate

- Satellites – high overpass frequency, but clouds may obscure the view, so data frequency can be low for optical imagery
- UAVs –
  - in south Georgia lighting conditions change very quickly;
  - in the Western US, haze in the afternoons; dealing with smoke and shadows;
- Need to quantify impacts for sUAS data.

Coffin & Clark. 2018. AGU B23D-02

Working on these:



Coffin & Clark. 2018. AGU B23D-02

UAVs can be very useful IF…

1. We can manage for and correct data quality problems due to uneven illumination
2. We can quickly evaluate issues of spectral data quality in post-processing
3. We can show a linkage between our field data and drone imagery
   1. *Which parameters are better with drone vs. field data?*
   2. *In the Western US, potential benefit is high due to cost and sparcity of field data.*
4. We can downscale satellite imagery to our fields
5. We can manage UAV data at the network level

LTAR UAV data management planning

- Main features of this plan, when it is fully developed, will include:
  - *best practices for mission planning,*
  - *data collection,*
  - *storage protocols,*
  - *metadata collection,*
  - *and a transfer mechanism for archiving and network-wide research use.*

What is required for coordinated network level research using UAVs?

- Across LTAR, sUAS data provide a means of “bridging the gap” between low repeat, high resolution, and high repeat, low resolution satellite imagery.
- Scientists in LTAR are integrating sUAS datasets as inputs to models that characterize and forecast agroecosystem dynamics.
- Further steps are required to curate sUAS data that is incorporated into research projects.

Thank you

ANY QUESTIONS?

ALISA.COFFIN@USDA.GOV

PAT.CLARK@USDA.GOV

Special thanks to Ponder Farms, Williford Farm, Coby Smith, Wiley Griffin, Thoris Green, Tim Strickland, Lorine Lewis, Josh Moore, Rex Blanchet, Dinku Endale, John Davis, Bryant Luke