How (small) unmanned aerial vehicles can provide data at appropriate spatial, temporal, and spectral scales to monitor fine-scale ecological patterns and processes.

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2014 UAS Workshop Argonne National Labs
CMU Center for GIScience

- Research and Service Center
- Expertise:
  - UAS Remote Sensing
  - GeoSpatial Modeling
  - Cartography/Custom Mapping, GeoDatabase Development
  - Work closely with Institute for Great Lakes Research at CMU
- Clients:
  - Academic
  - Government
  - Non-Profit
  - Corporate
Outline

- Why sUAS? A Personal Perspective
- The Three Scales in Remote Sensing
  - Temporal
  - Spatial
  - Spectral
- UAS Remote Sensing Opportunities
- Conclusions
“Explain the impact of scale in remote sensing” – a doctoral comprehensive exam question
# Why UAS?

## (B) Worldview-2

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Scales of Remote Sensing

Scales of Detection: Extent and Resolution

- Temporal Scale
  - Revisit Time
  - Timing of Phenomenon

- Spatial Scale
  - Areal Extent
  - Pixel Size (Resolution)

- Spectral Scale
  - Color vs. Wavelength
Photography vs. Spectroscopy

Spectroscopy
- How light interacts with matter
- Consistent, Robust, scientific measurement
- % Reflectance or Radiance – watts/sq m.
- Quantitative Analysis
- Requires advanced training and equipment

Photography
- Picture (can be NIR)
- Difficult to directly compare images
- CANNOT easily use vegetation indices or other quantitative analysis
- Existing expertise and equipment

Jones and Vaughan, 2010
Phenology

Canopy

Nutrients*

Structure / Biomass

Fire

10cm

2m

30m

250m

1km

50km

200km

500km

2000km

Spatial Resolution

Spatial Extent

Temporal Resolution

After Chambers et al. 2007

MODIS

Landsat / HYPERION*

Quickbird / Worldview-2

Airborne*

Small Unmanned*
Non-Imaging remote sensing

- sUAS can be a tool to collect samples in difficult terrain
- Example: Hyperspectral measurements of plants in wetlands using handheld spectroradiometer
  - **On the ground**
    - Sensitivity of equipment
    - Travel Time
    - Navigation Issues
    - Disturbance of field site
  - **In the air**
    - Predetermined sampling
    - Equipment is safe
    - Sampling is quick

Non-imaging sensors often less than 1/10th cost of imaging sensors
Opportunities for UAS Remote Sensing: Spatial

- Object of interest < pixel size
- Satellite & Manned Aircraft: Forests, Agriculture, Shrublands
- What about herbaceous vegetation?
  - Tundra / Alpine
  - Grasslands
  - Wetlands
    - Peatlands
    - Marshes

Photo credit: Smith, R.W.

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Opportunities for UAS Remote Sensing: Spatial

- Fine-scale Patterns and Variability
  - Field Plots
  - Farm Field
  - Flux Towers

Barr et al. 2010
Opportunities for UAS Remote Sensing: Temporal

- Phenology
  - Leaf burst
  - Leaf senescence
  - Flowering
  - Fruiting
  - Insect Hatch

- Flexible and Rapid Deployment
  - Plant Pathogens
  - Invasive Species
  - Drought, Floods, Extreme Events

Fine Spatial Scale Phenology:
- Detection of individual flowers, leaves, fruits

7/29/2014
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Opportunities for UAS Remote Sensing: Precision Agriculture

Bratney and Whelan, 2001

Zarco-Tejada et al. 2008
Opportunities for UAS Remote Sensing: Multi-Dimensional Analysis

- Spectral-Temporal Signatures
  - Repeated image acquisition over the growing season
- Spectral-Spatial Classification
  - Object-based Image Analysis
- 4-D Analysis (X,Y,Time,Spectral)
- Scaling with larger-footprint imagery
  - Local → Regional → Global
  - Integrate UAS remote sensing with other platforms
Challenges for UAS Remote Sensing: Undiscovered Country

- New Methods and Platforms $\rightarrow$ Research Opportunity
- BUT $\rightarrow$ can be inconsistent with long-established protocols
- More proof-of-concept required for:
  - Sensors
  - Sensor Integration
  - Data Quality and Accuracy
Challenges for UAS Remote Sensing: Sensor Integration

Source: Leptron Industrial Robotic Helicopters

Source: Headwall Phonics
Challenges for UAS Remote Sensing: Platform Stability

- Airborne Platforms are constantly adjusting Pitch, Roll, Yaw

- For 2-D imagers, post-processing can adjust.

- For 1-D imagers (most hyperspectral), post-processing is not possible and requires complicated corrections.

- Vibration isolation is also critical

Jones and Vaughan, 2010
Challenges for UAS Remote Sensing: Sensor Calibration and Processing

Accurate Reflectance Measurements Require:

- In-Situ Calibration with multiple Calibration Tiles

- AND/OR

- Continuous Readings of Incoming Radiation (variable light conditions)

Jones and Vaughan, 2010
Current UAS Research Projects at CMU

Mapping Wetland Biodiversity
Location: Washtenaw County, MI

Mapping Pitcher’s Thistle
Location: Wilderness State Park, MI

Collaborators: Chicago Botanic Gardens, East Carolina University, Charleston College

Funded in-part by USFWS
Conclusions

- Remote sensing requires careful consideration of spatial, temporal, and spectral scales.

- UAS as a new platform provides new opportunities for flexible deployment (temporal scale) and low altitude image collection (fine-spatial scale).

- Type of spectral data has considerable tradeoffs between potential benefits and costs/efforts to achieve results.
Thank You – Questions?

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