جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

UAVs in hydrology: opportunities (and challenges) from a novices perspective

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Unmanned Autonomous Vehicles

Development of a New Observational Capacity

UAVs offer an unprecedented opportunity in Earth Observation

- Emergency and disaster management and response
- Engineering and project management
- Environmental monitoring and sampling
- Applications in the hydrological and related sciences

Fire mapping

http://www.iuavs.com/en/pages/aplicaciones_y_usos

Water quality sampling

http://research.unl.edu/annualreport/2014/

Agricultural monitoring

Earth Observation with UAVs

Low-Altitude Unmanned Autonomous Vehicle Sensing

UAVs are poised to deliver an information revolution in E-O science

- Availability of off-the-shelf and custom-designed systems and software
- Sensor miniaturization allows purpose specific payloads
- Targeted acquisition for high-resolution near real-time data collection
- Retrieval across a range of Earth system processes

Unmanned Autonomous Vehicles

UAV based Earth Observing Instrumentation

Advancing traditional satellite based EO-analysis

- Options for both fixed wing and quad-copter UAV solutions
- Comprehensive sensor package with interchangeable pay-loads

SONY NEX-7 Digital Camera

- 24MP
- interchangeable lens
- 560 grams

Tetracam MiniMCA 6 bands

- 490,560,665,705,740,865 nm
- Replicate Senintel 2/Landsat
- 700 grams

HeadWall Nano-Hyperspec

- 270 spectral bands
- 400-1000nm & 640 spatial
- 600 grams

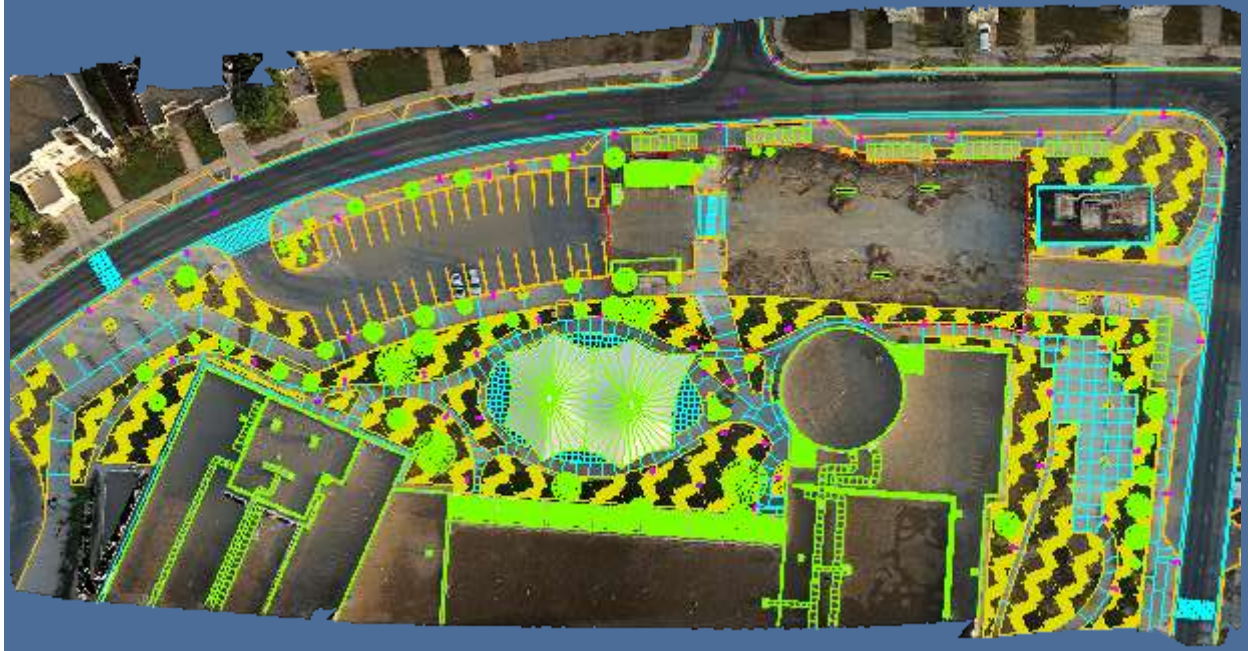
Optris Pi-450 Thermal Sensor

- 7.5-13 µm (broadband)
- 382 x 288 pixel
- 320 grams

UAVs in the Hydrological Sciences

Development of high-resolution Digital Elevation Models

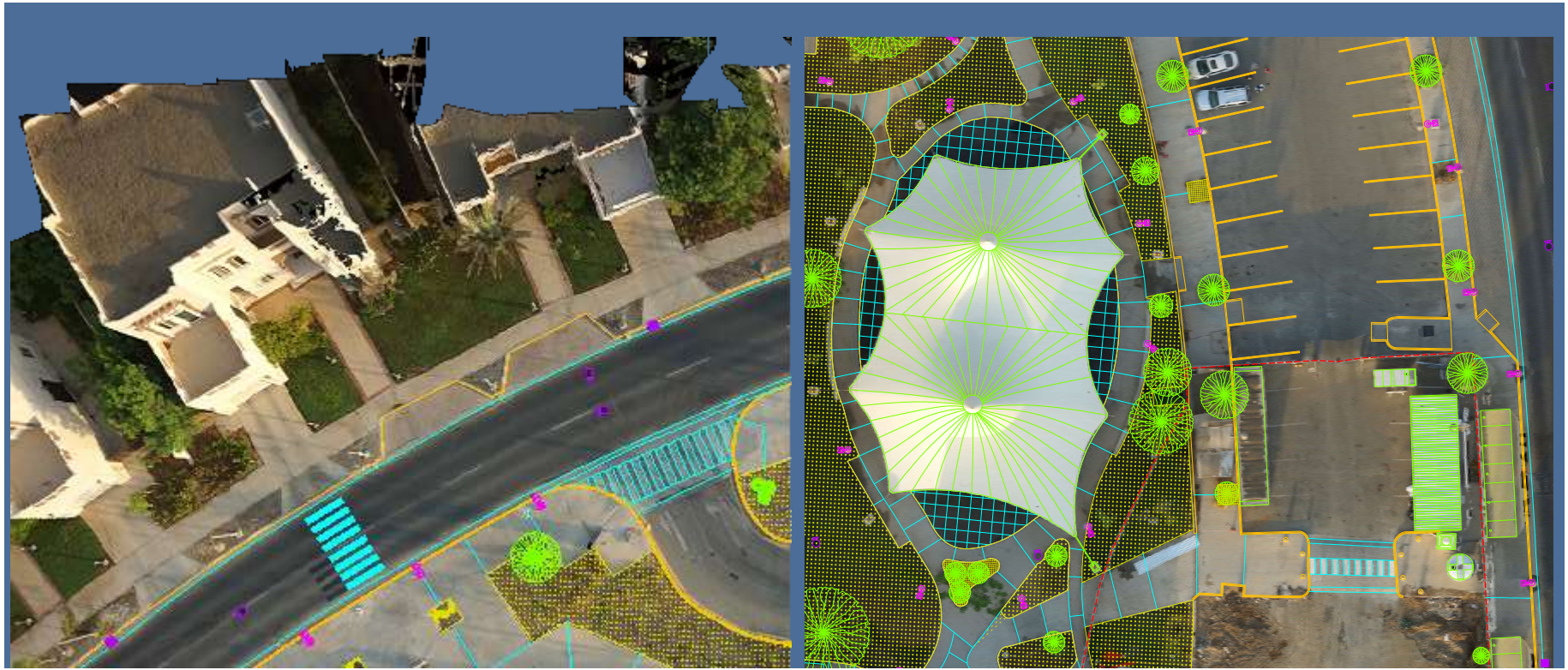
Digitizing the KAUST campus for engineering and utilities planning



- Structure from Motion for DEM development
- Ground control point for geo-rectification
- Ultra-fine resolution (decimeter scale)
- 3D walk-throughs

UAVs in the Hydrological Sciences

Development of high-resolution Digital Elevation Models



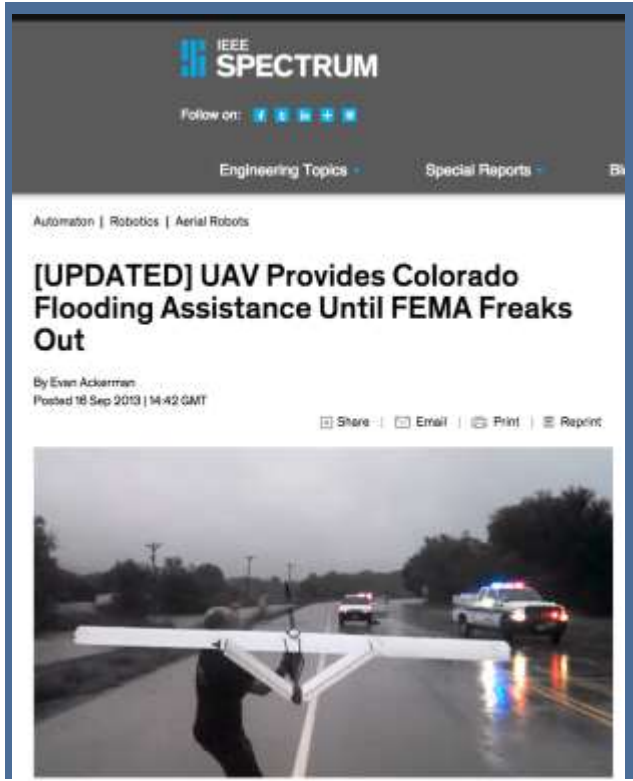
UAVs in the Hydrological Sciences

Development of high-resolution Digital Elevation Models

Feature extraction and vegetation modeling using UAVs and LiDAR

UAVs in the Hydrological Sciences

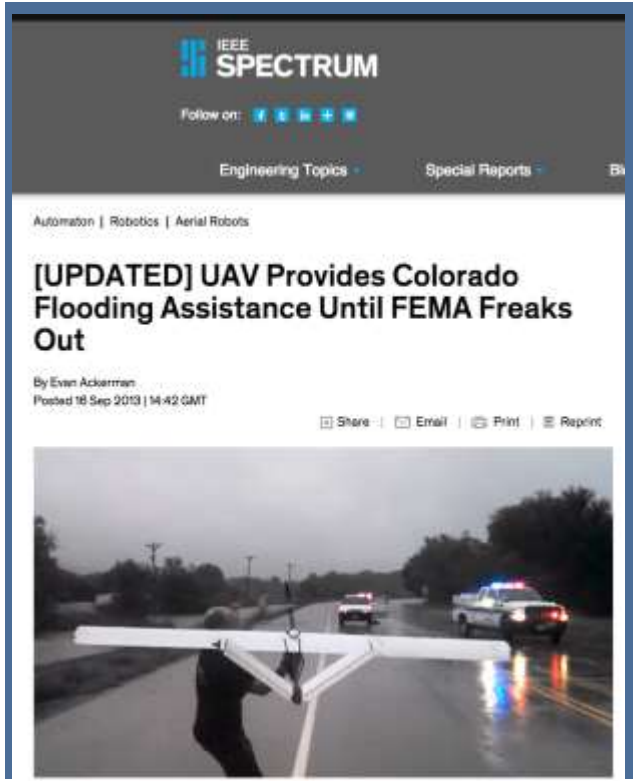
Flood mapping and monitoring - hydrological forecasting



http://spectrum.ieee.org/automaton/robotics/aerial-robots/falcon-uav-provides-colorado-flooding-assistance-until-fema-freaks-out

UAVs in the Hydrological Sciences

Flood mapping and monitoring - hydrological forecasting



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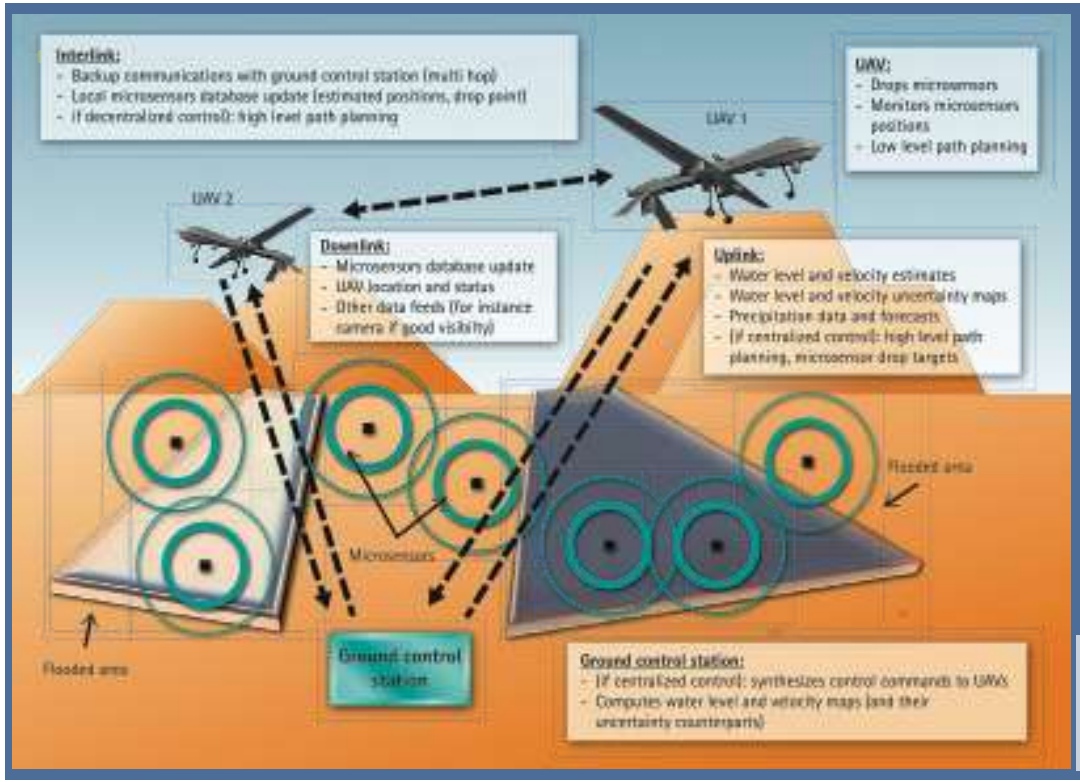
UAVs in the Hydrological Sciences

Flood mapping and erosion monitoring



d'Oleire-Oltmanns et al. (2012) "Unmanned Aerial Vehicle (UAV) for Monitoring Soil Erosion in Morocco", Remote Sensing, 4(11), 3390-3416

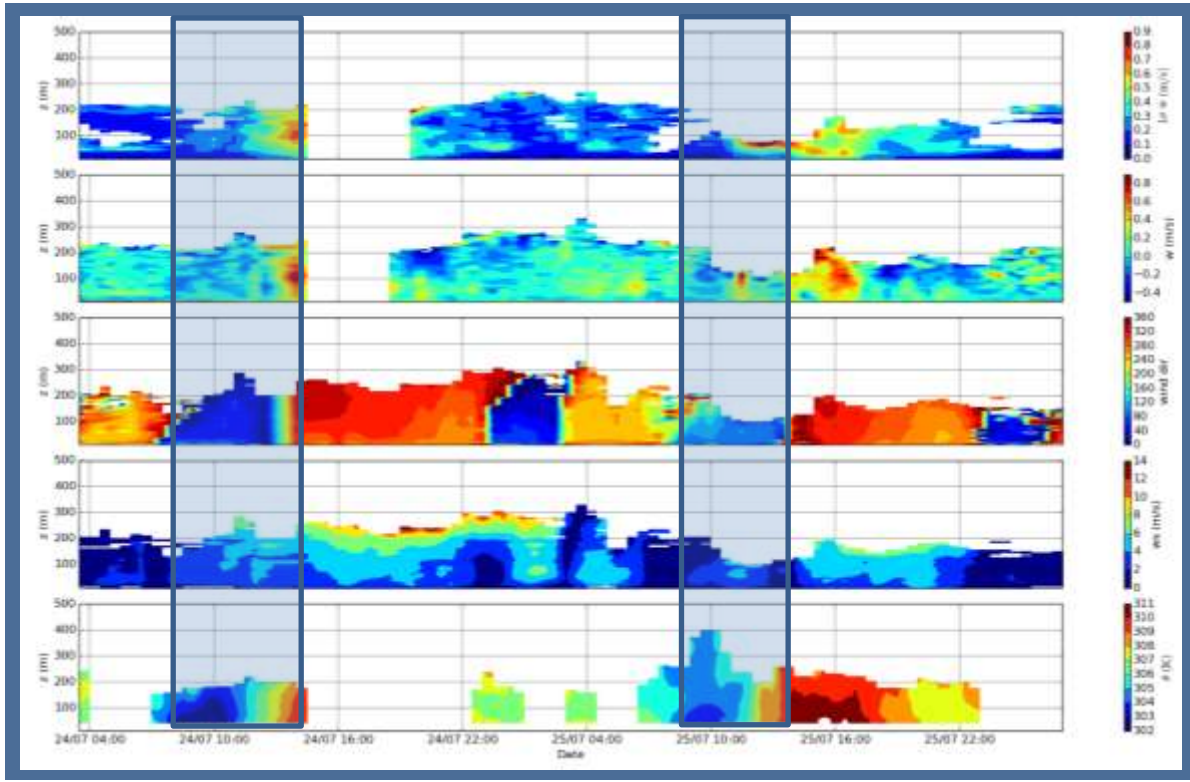
UAVs in the Hydrological Sciences

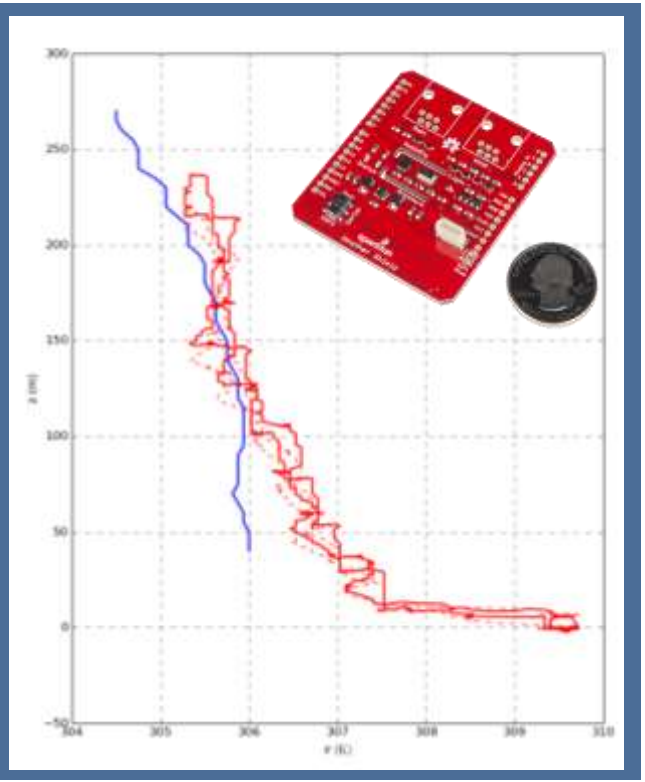
Monitoring rainfall variability and spatial patterns

Research being led by Prof. Greg Mariethoz at Uni Lausanne

UAVs in the Hydrological Sciences

Atmospheric profile retrievals and aerosol monitoring



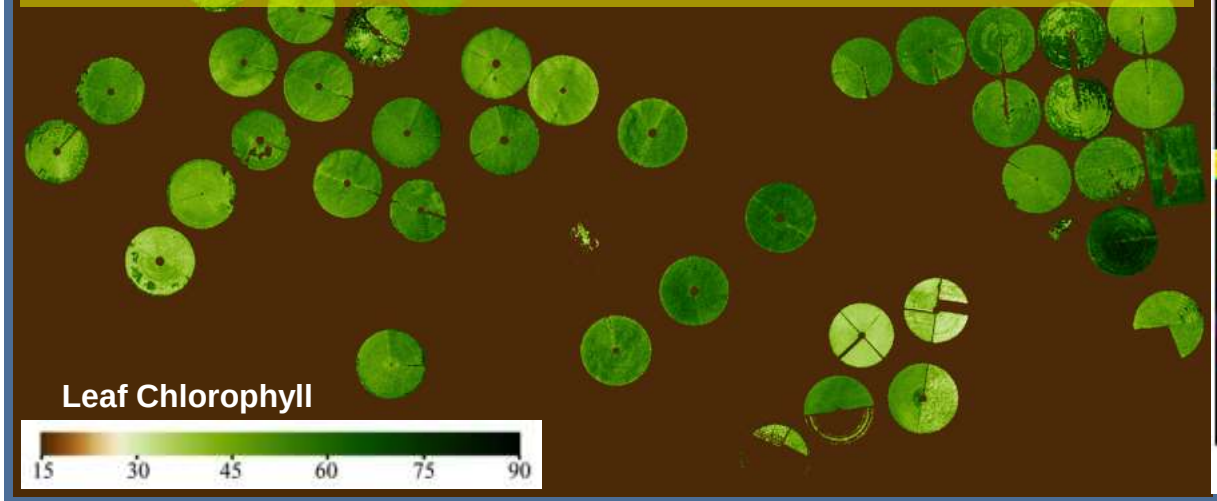


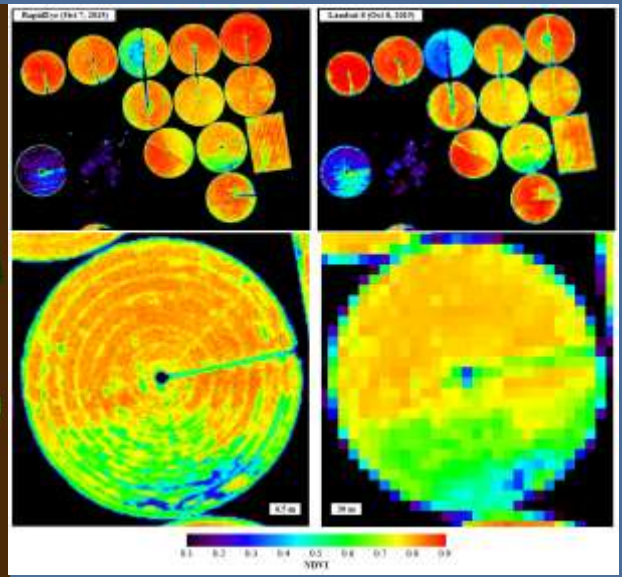
UAVs in the Hydrological Sciences

Agricultural monitoring and vegetation health assessment

- Capacity to retrieve plant health, stress and physiological response
- Incorporate metrics into modeling system to constrain coupled H_2O & C

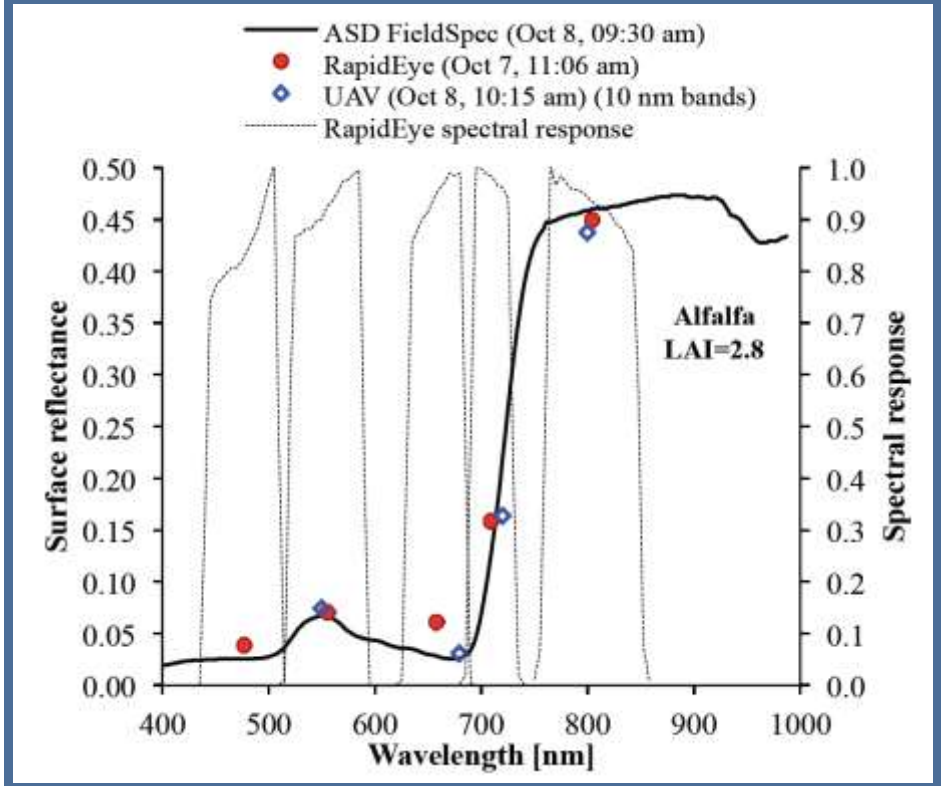
Vegetation parameters inform crop health + water use

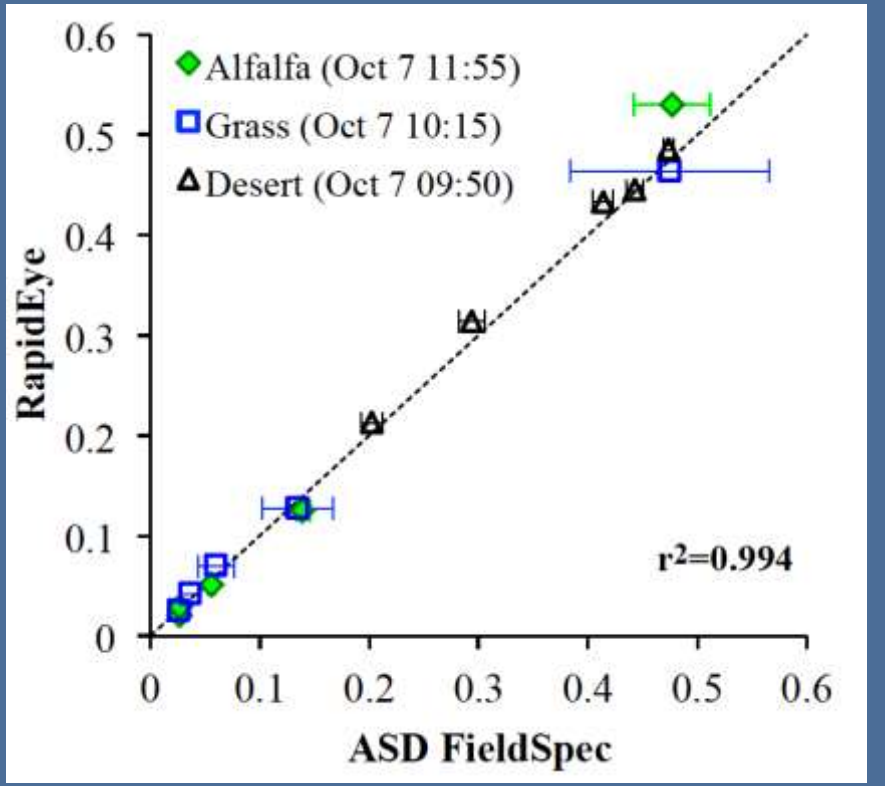




Transcending the Point-to-Pixel Divide

UAVs also allow for spatially and spectrally equivalent validation.

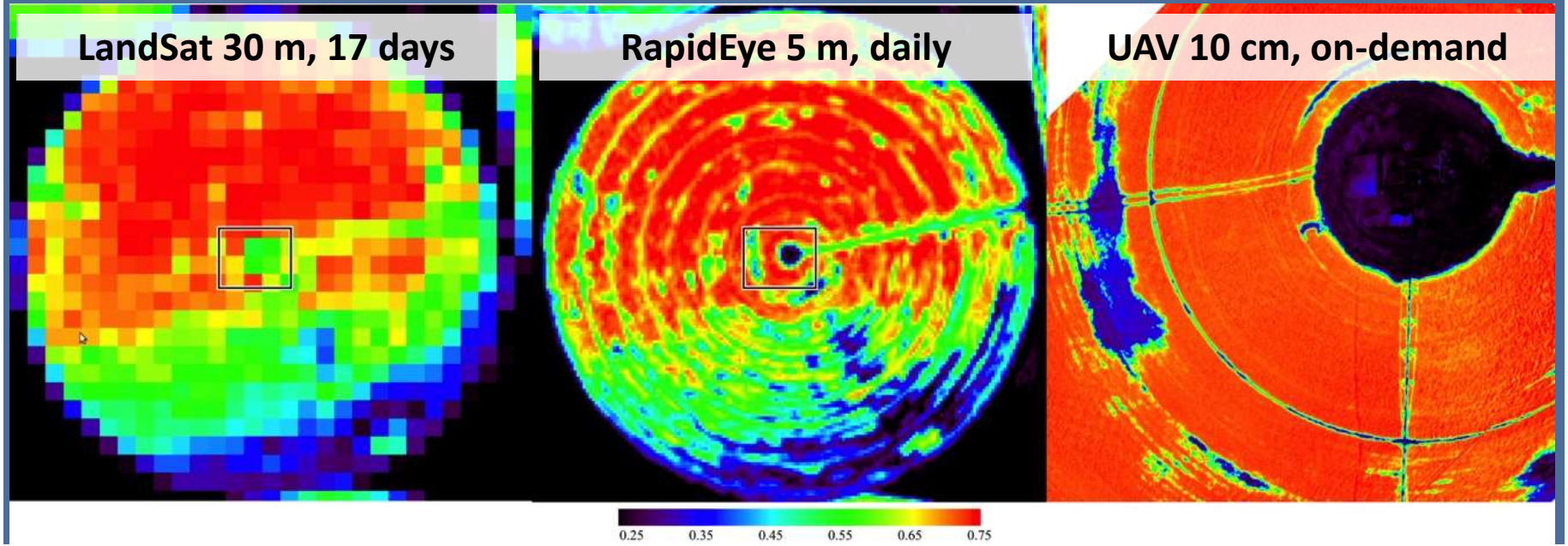




The Spectral and Spatial Advantage

Feature identification and field-scale heterogeneity

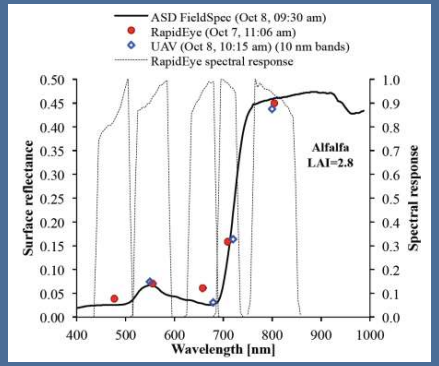
Maximizing the information content from multi-resolution systems

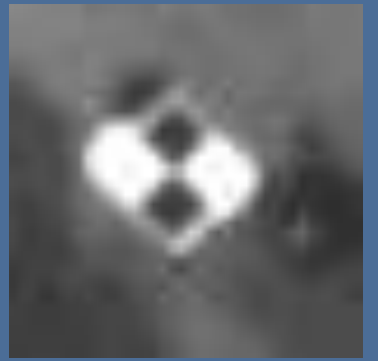


Vegetation Retrievals from UAVs

Translating UAV-based reflectances to crop data

- Employ empirical line correction method using Fieldspec targets (i.e. UAV based digital counts to spectral surface reflectances)
- Develop a multi-variate linear regression via CUBIST regression tree
- Regression based on range of RapidEye spectral indices and in-situ LAI
- Applied derived relationship to the same UAV based spectral indices





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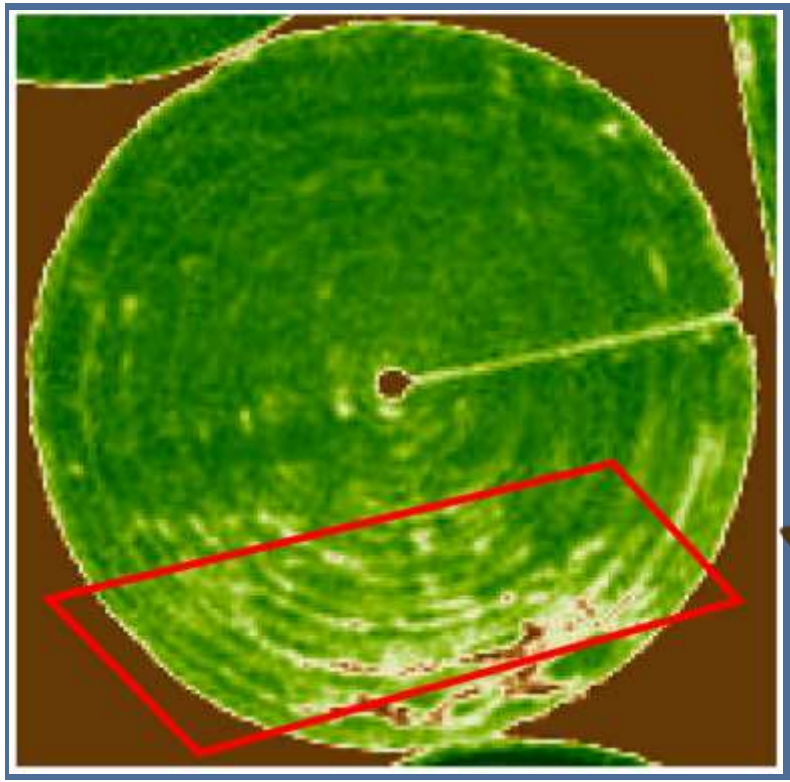
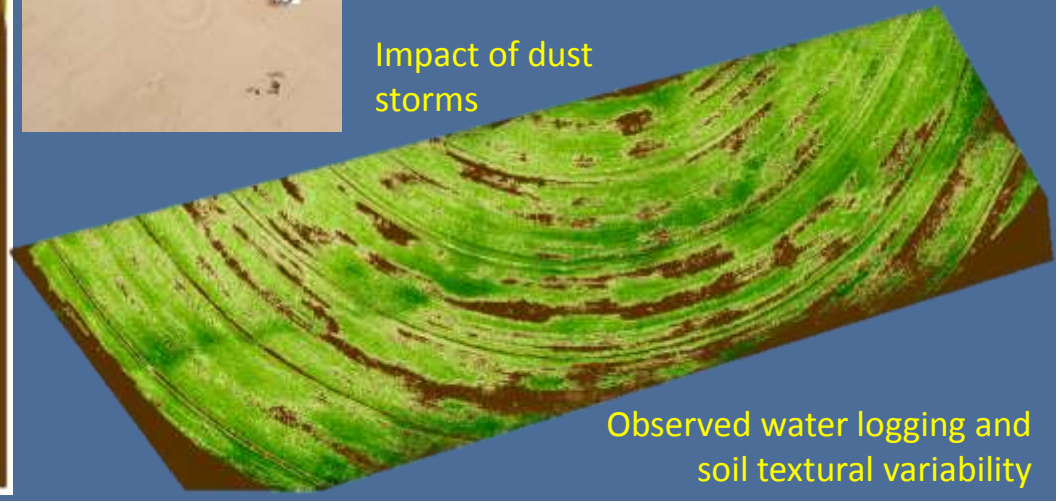


- Hyper-resolution (10 cm)
- 25-min flight time
- 500 foot flight ceiling

Impact of dust storms

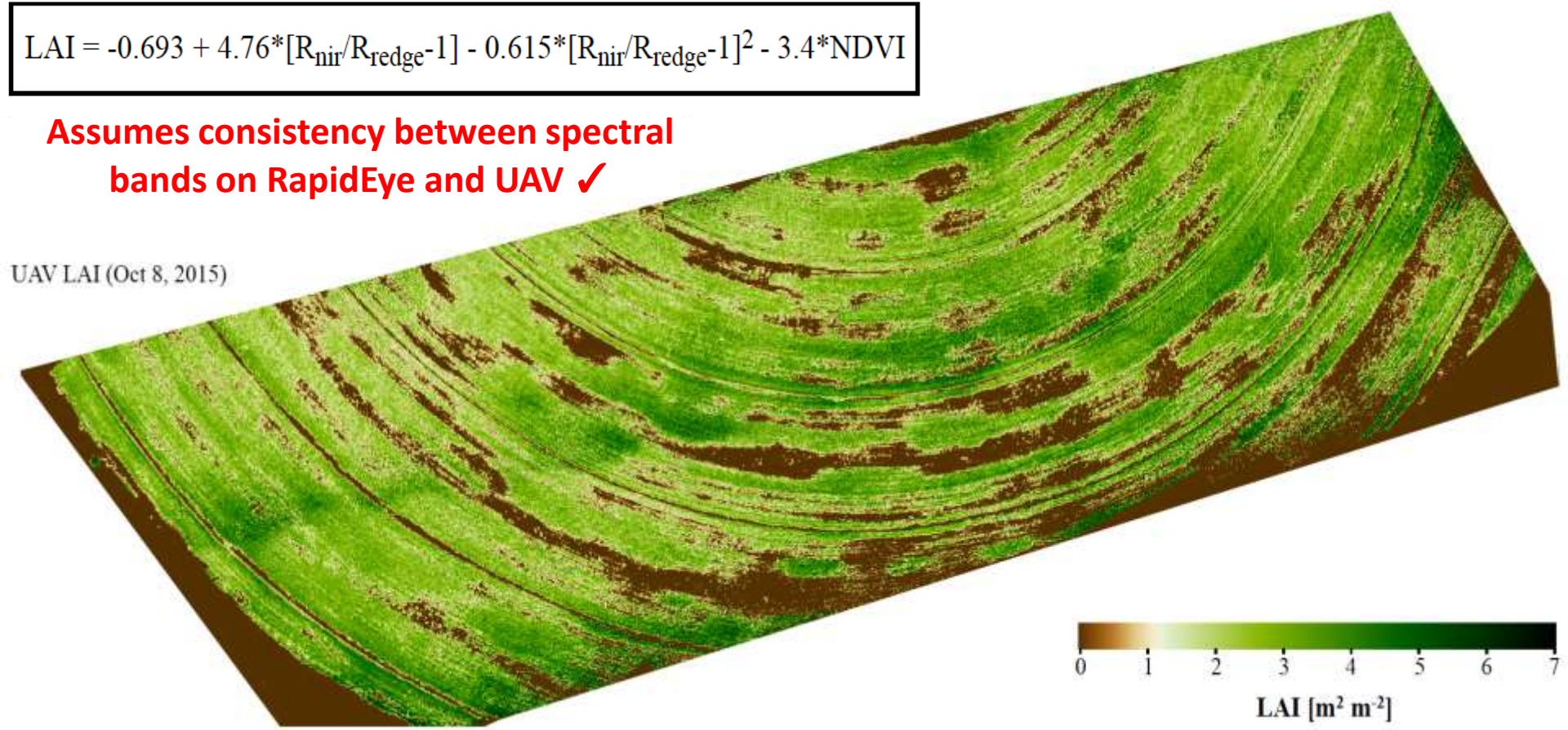


Observed water logging and soil textural variability

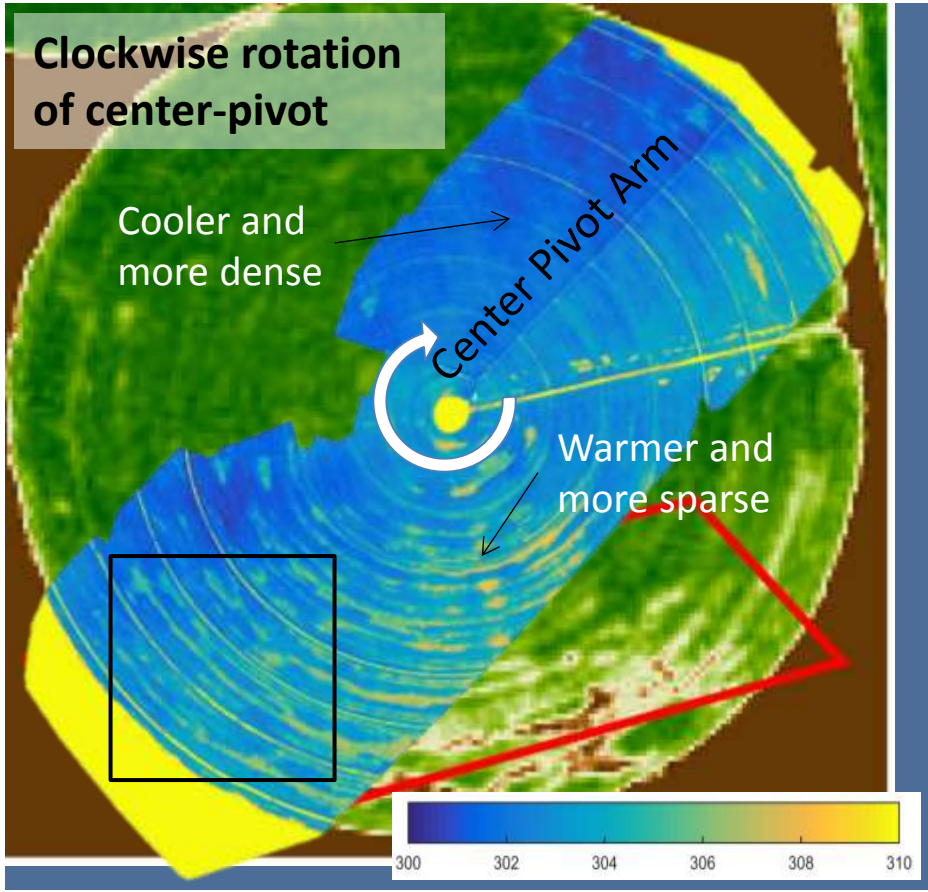
Vegetation Retrievals from UAVs

$$LAI = -0.693 + 4.76*[R_{nir}/R_{redge}-1] - 0.615*[R_{nir}/R_{redge}-1]^2 - 3.4*NDVI$$

Assumes consistency between spectral bands on RapidEye and UAV ✓



Retrieval of Crop Thermal Signatures



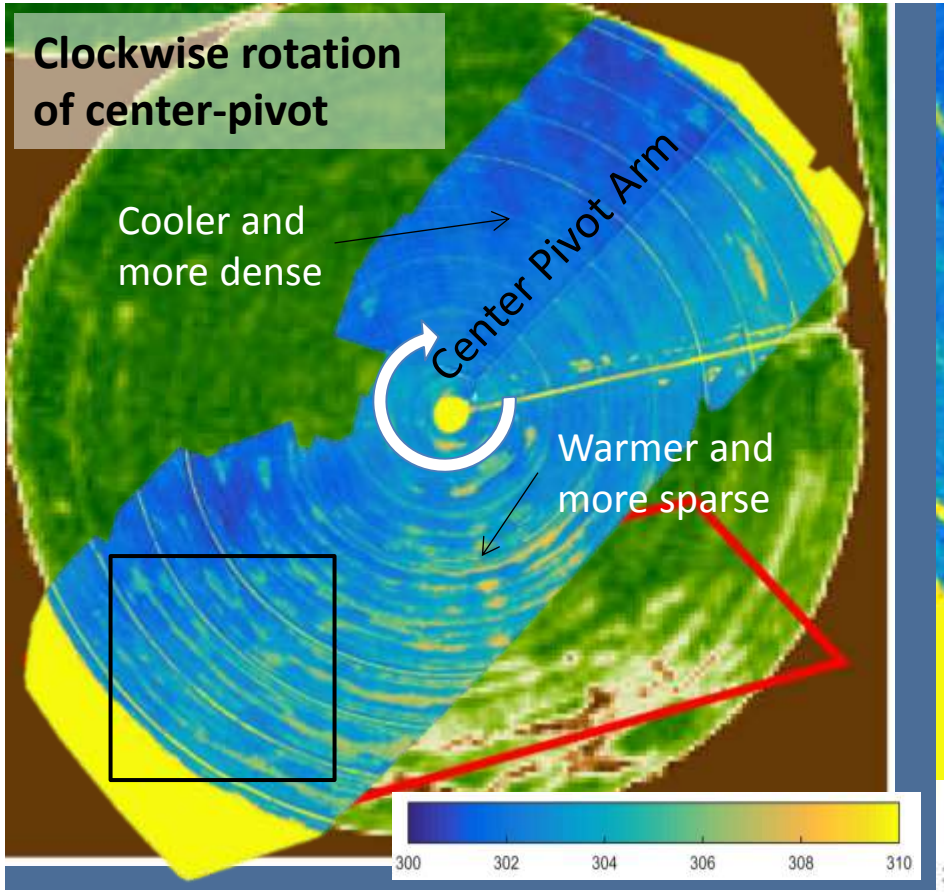
Estimation of Land Surface Temperature from UAV systems

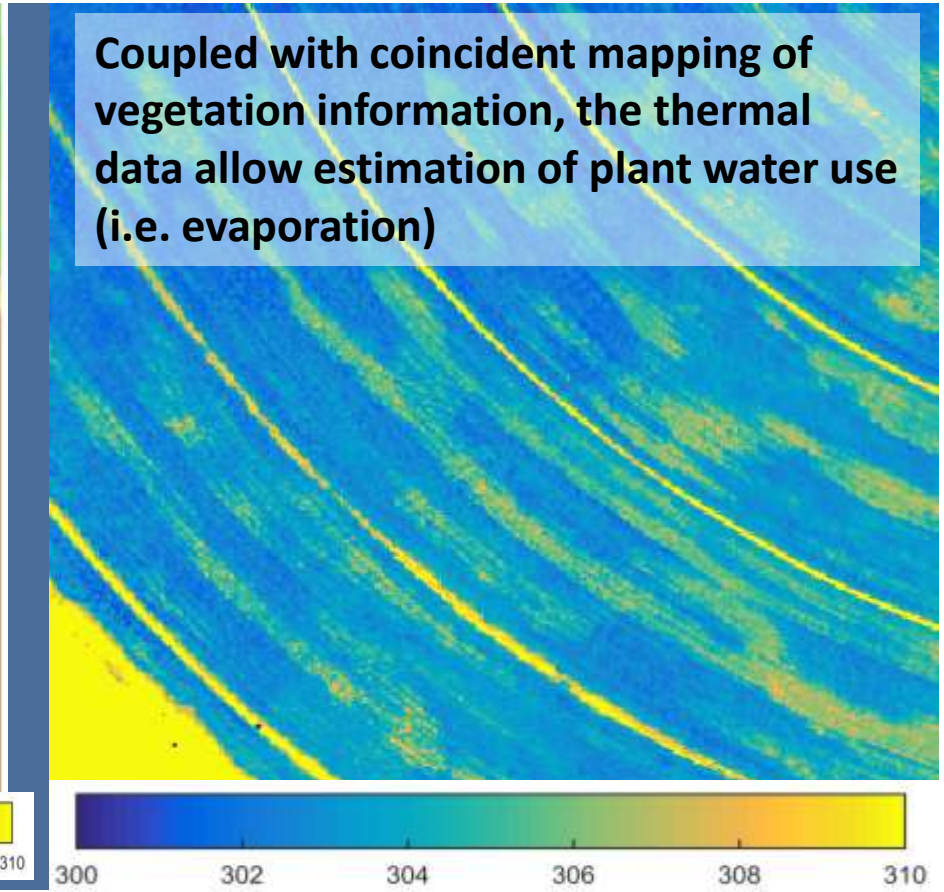
- Serves as a proxy of crop stress
- On-board thermal sensor
- Sensitivity and accuracy (environmental constraints)
- Expected within-field variability

Optris Pi-450 Thermal Sensor

- 7.5-13 µm (broadband)
- 382 x 288 pixel
- 320 grams

Retrieval of Crop Thermal Signatures





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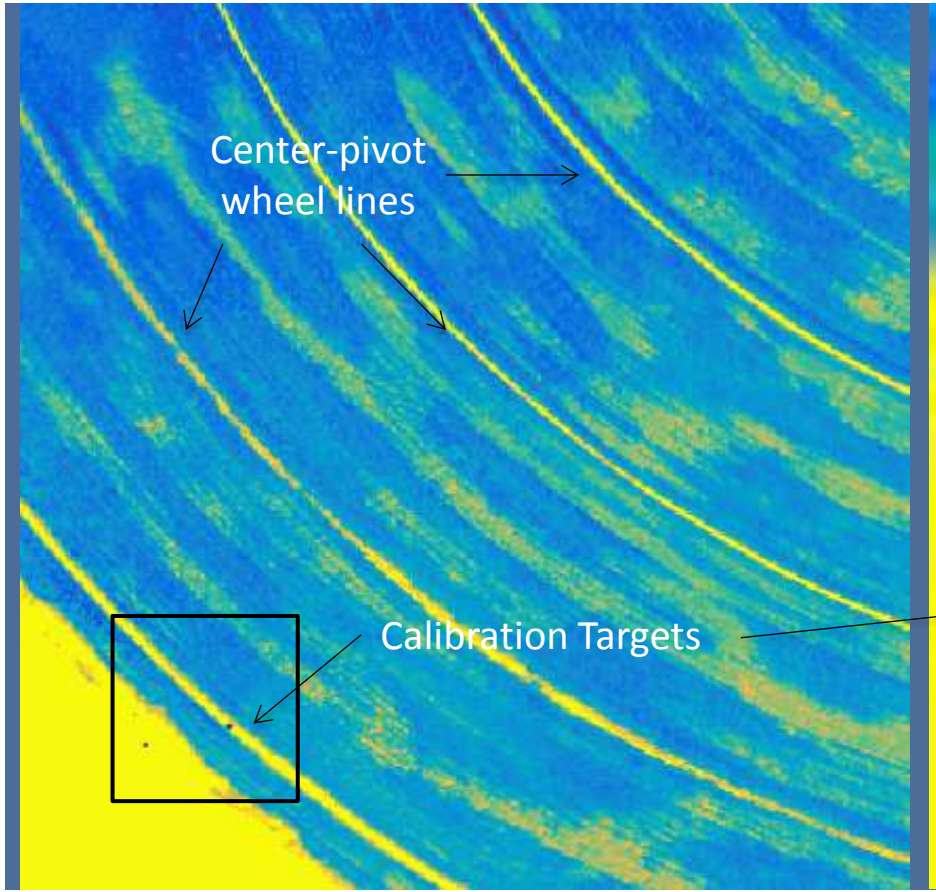
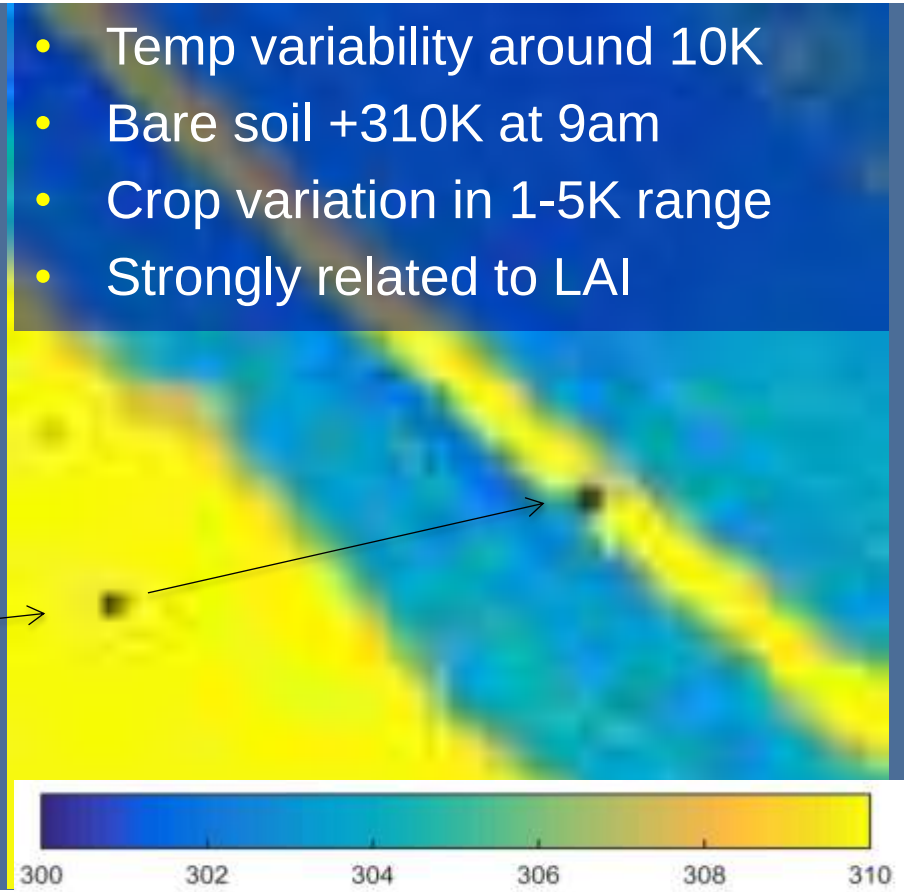
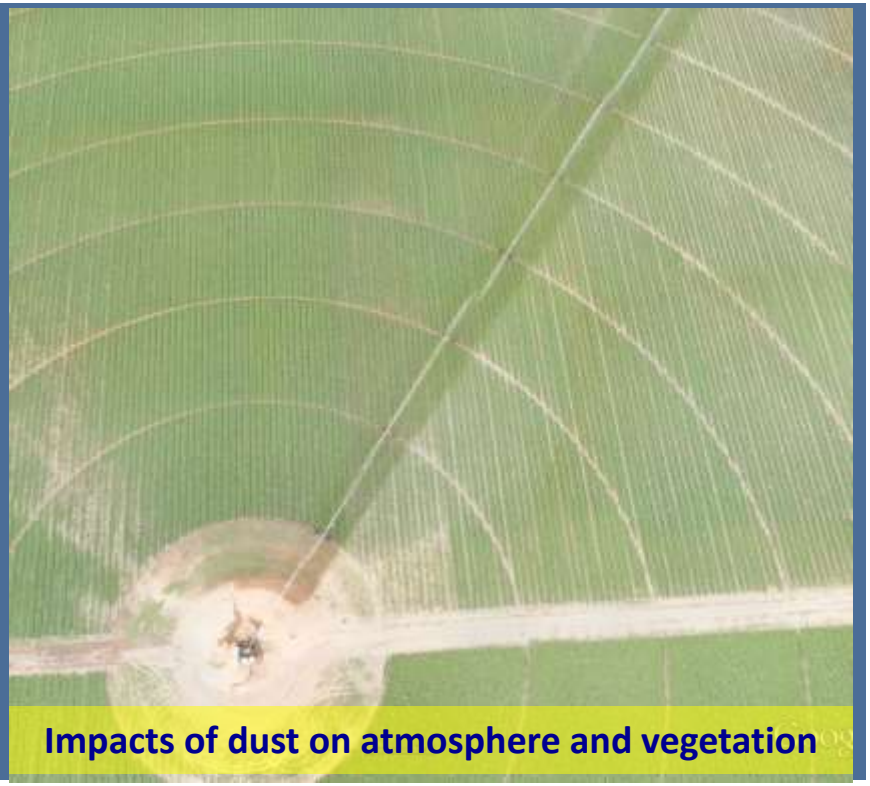


- Temp variability around 10K
- Bare soil +310K at 9am
- Crop variation in 1-5K range
- Strongly related to LAI



Local Challenges – Atmospheric

High resolution retrievals present unique problems



Impacts of dust on atmosphere and vegetation

Local Challenges – Atmospheric

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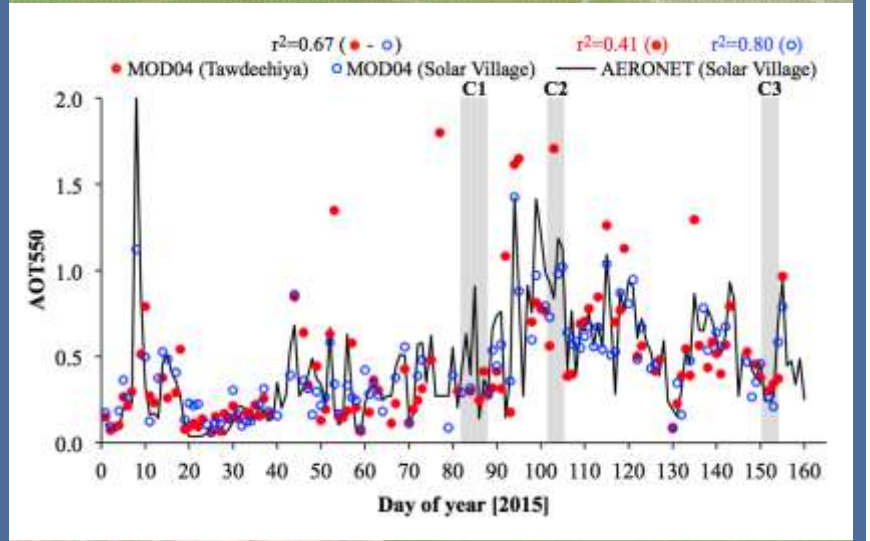

Impacts of dust on atmosphere and vegetation

Challenges and Other Issues

UAVs represent an exciting frontier in Earth observation

However, they are not without their challenges:

- spatial geo-referencing and image stitching
- mapping different sensors into the same image space
- spectral calibration and validation (particularly for thermal)
- sensor sensitivities to environmental conditions (wind, temperature)
- flight time limitations (area of acquisition – satellite coincidence)
- too much information i.e. how do we use the data appropriately?
- steep learning curve with potential dangers
- replacement cost of mistakes (crashes are inevitable)

Summary and Discussion Points

Unmanned Autonomous Vehicles offer great opportunity in EO studies

- Potential to drive a new era of information technology in agriculture
- Replacement to high-resolution satellite missions ($$$)??
- Need for streamlined processing to deliver products
  i.e. potential constraint on user uptake
- The science is lagging the technology: community playing catch-up
- Sensors not always fit for purpose – more advances being made
- Present **new modeling challenges** that need to be addressed

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