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

Prof. Matthew McCabe
Biological and Environmental Sciences and Engineering Division
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


Water quality sampling

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

Agricultural monitoring
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

FalconVIZ Quad-Copter

QuestUAV Fixed Wing
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
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
Development of high-resolution Digital Elevation Models
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

UAVs in the Hydrological Sciences

Flood mapping and monitoring - hydrological forecasting

[UPDATE] UAV Provides Colorado Flooding Assistance Until FEMA Freaks Out

Flood mapping and erosion monitoring

UAVs in the Hydrological Sciences

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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
Agricultural monitoring and vegetation health assessment

- Capacity to retrieve plant health, stress and physiological response
- Incorporate metrics into modeling system to constrain coupled H$_2$O & C

Vegetation parameters inform crop health + water use
UAVs also allow for spatially and spectrally equivalent validation.
Feature identification and field-scale heterogeneity

Maximizing the information content from multi-resolution systems

LandSat 30 m, 17 days
RapidEye 5 m, daily
UAV 10 cm, on-demand
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
Feature identification and field-scale heterogeneity

- 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 ✔
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

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Clockwise rotation of center-pivot

Cooler and more dense

Warmer and more sparse

Coupled with coincident mapping of vegetation information, the thermal data allow estimation of plant water use (i.e. evaporation)
Retrieval of Crop Thermal Signatures

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

Center-pivot wheel lines

Calibration Targets
High resolution retrievals present unique problems

Impacts of dust on atmosphere and vegetation
High resolution retrievals present unique problems

**Local Challenges – Atmospheric**

Impacts of dust on atmosphere and vegetation
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)
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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