

# UAVs and Ecology: Research & Technology Futures

DART Symposium  
June 21 2019

Maggi Kelly  
UC Berkeley  
UCANR

# *Successful Resource Management Always Starts with a Map*

**data**

+

data

**tools**

sensors

remote sensing

aggregators

spatial

models

**GIS**

space-time

analysis

distributed computing

participatory + crowd

platforms

field

UAV

web mapping/viz

proprietary

open

+

**people**

collaboration

impact

engagement

## Talk Outline

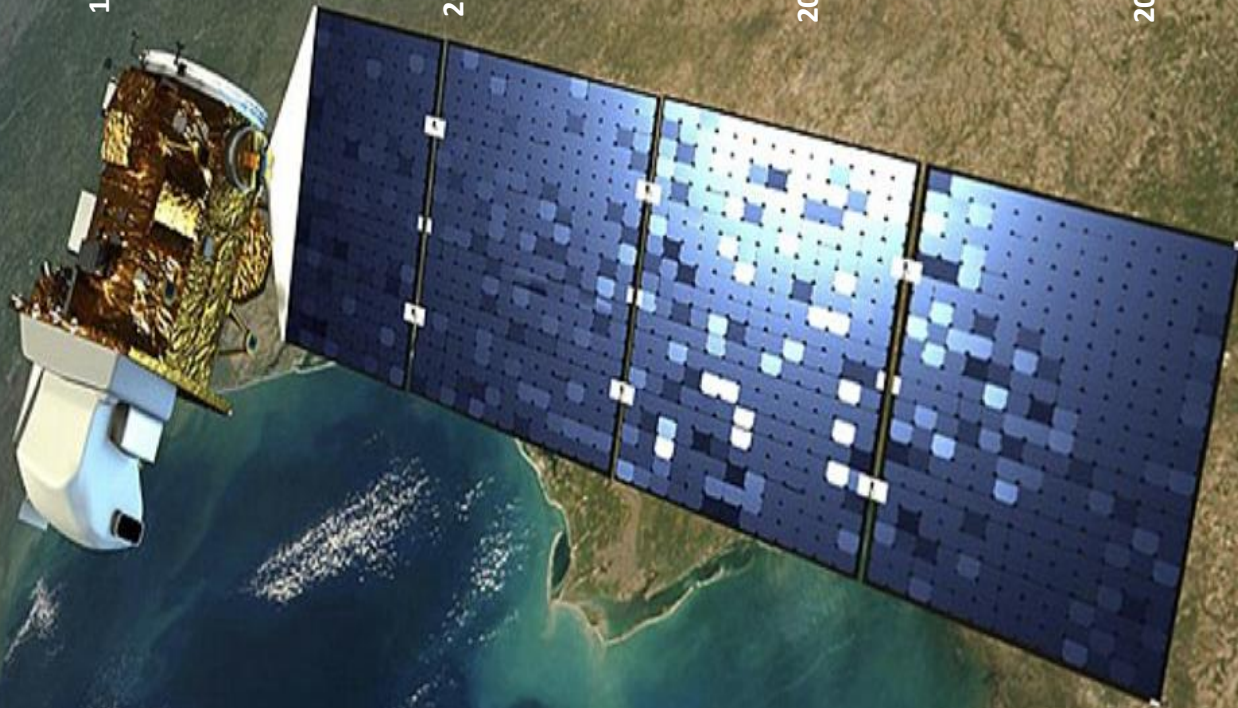
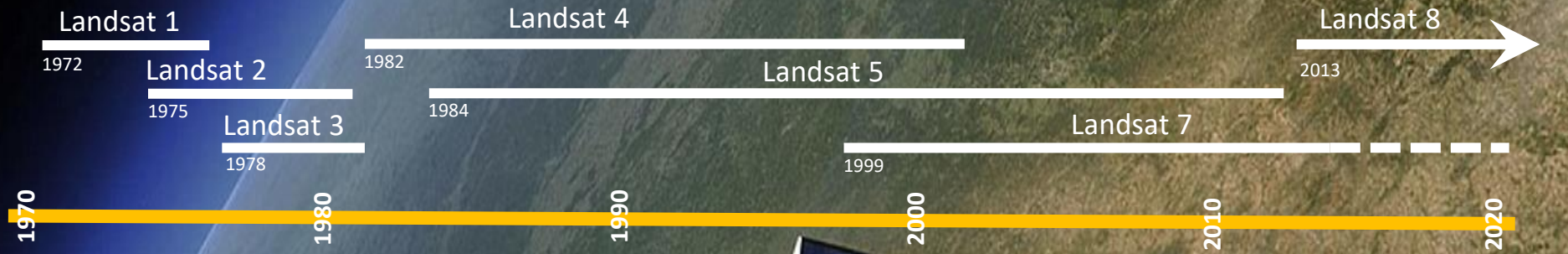
Trends in remote sensing

Advantages of UAVs

Case studies from our work in California

Technological and research futures for UAVs

# Trends in Remote Sensing: Continuity



Landsat 1 Launch 1972

Open Landsat Archive 2008

# Trends in Remote Sensing: Constellations

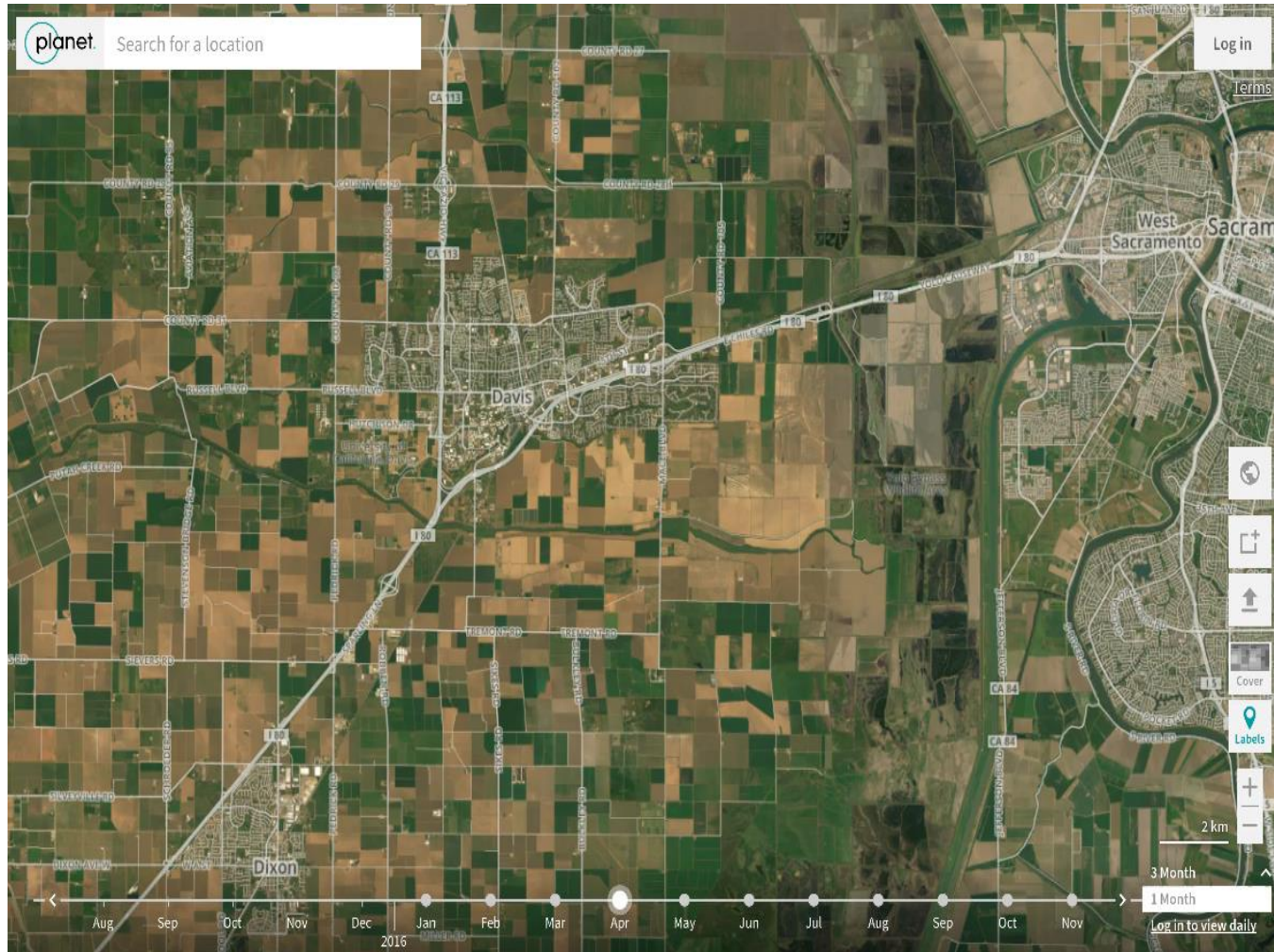
Planet  @planetlabs · Apr 25  
BRB—watching this mesmerizing, endless #cubesat deployment.

Planet Launches 88  
micro satellites  
("cubesats"), Feb 2017

Planet will image the  
entire earth, daily, at  
~3m resolution



# Trends in Remote Sensing: High Spatial & Temporal Resolution

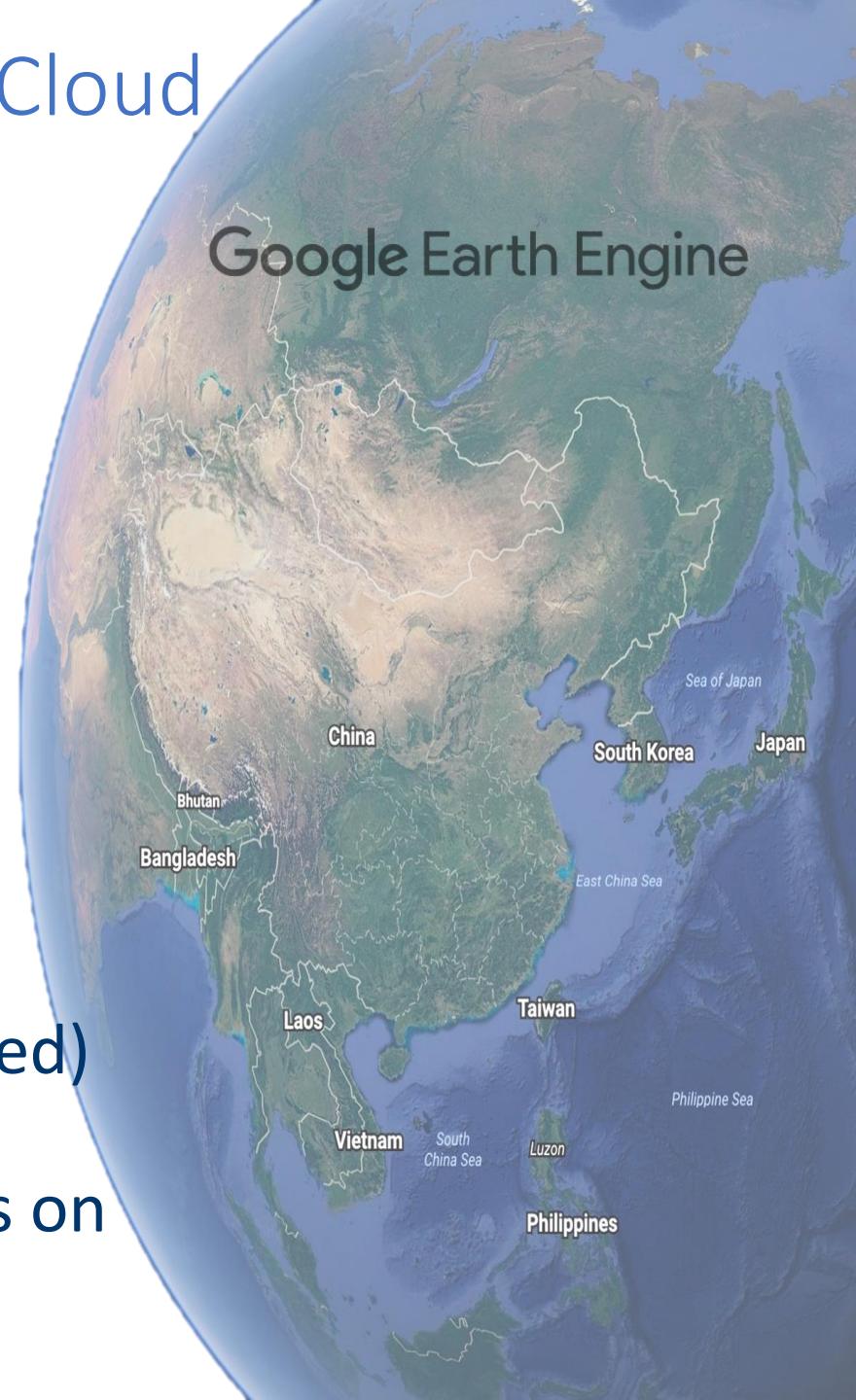


# Trends in Remote Sensing: Cloud & HPC Platforms

At the scale of Landsat (30m pixel):

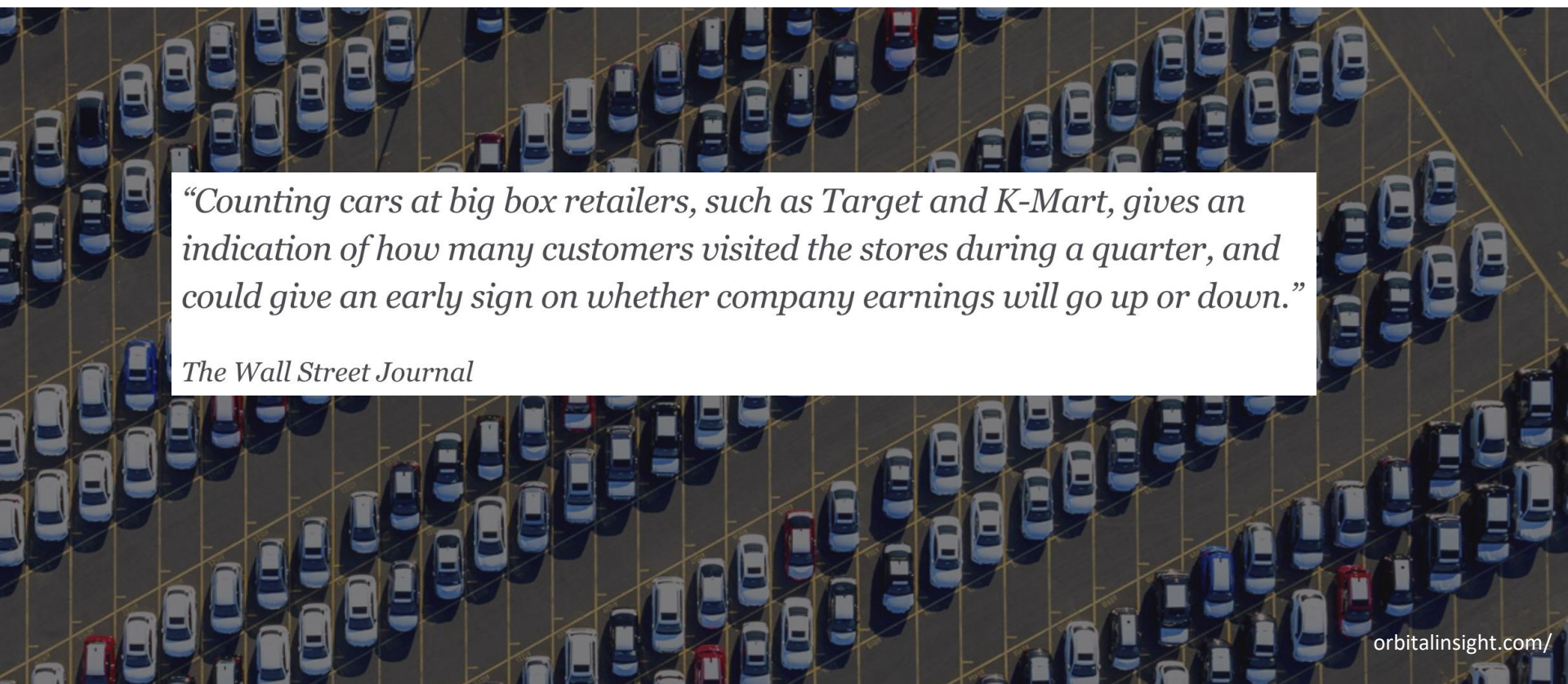
- California → 500M pixels
- China → 10B pixels
- Globe → 800B pixels

High Performance Computing (parallel / distributed / clustered) supports the applications of traditional geospatial methods on big spatial data



# Trends in Remote Sensing: AI, Machine Learning, Deep Learning

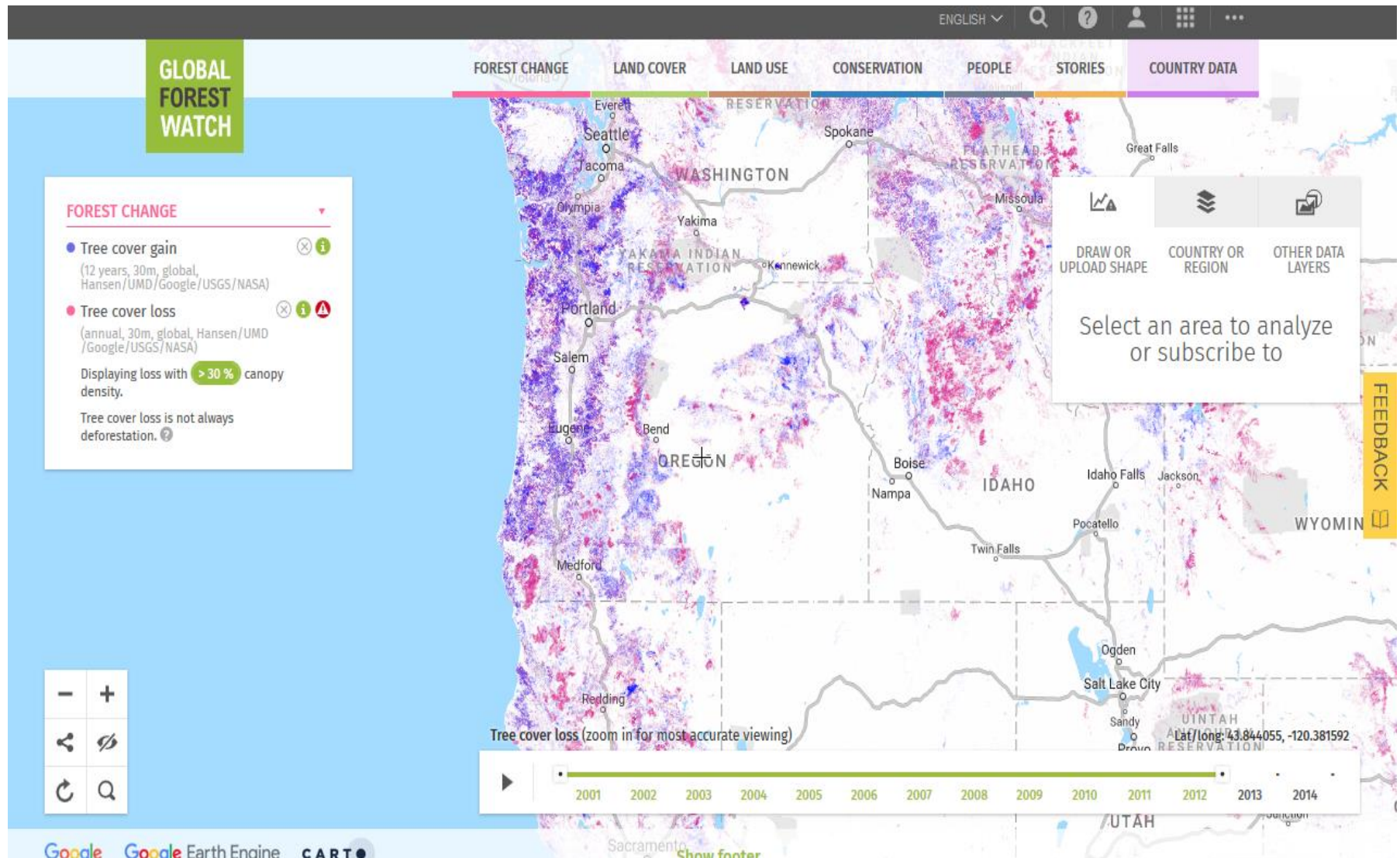
Machine Learning = algorithms to parse data, learn, and make predictions. The machine is “trained” using large amounts of data and algorithms that give it the ability to learn how to perform tasks.



*“Counting cars at big box retailers, such as Target and K-Mart, gives an indication of how many customers visited the stores during a quarter, and could give an early sign on whether company earnings will go up or down.”*

*The Wall Street Journal*

# Trends in Remote Sensing: Geo-collaboratories



# So how do these trends relate to UAVs?

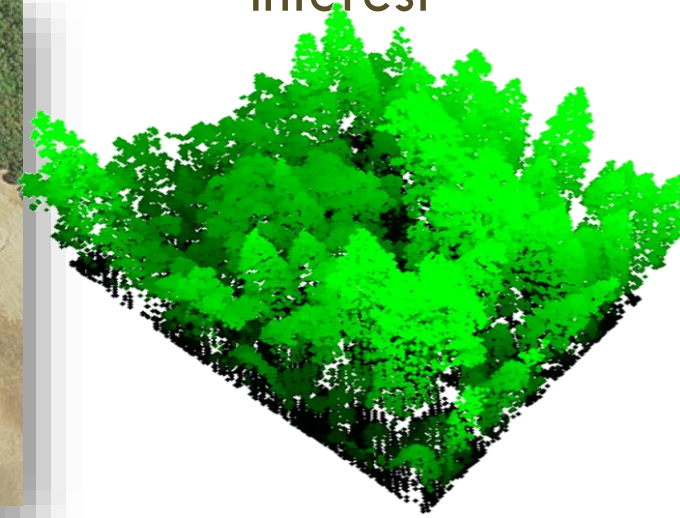
Satellite imagery  
might be too coarse



Satellite might not  
carry the sensor of  
interest



Imagery might have  
been flown at the  
wrong time of day, or  
on a cloudy day





## Advantages of UAVs:

***Flexible,  
Focused, &  
Precise Data***

Drones can deliver ***fine spatial resolution*** data at ***temporal*** resolutions defined by the end user

***Costs*** can be very reasonable

Flight can be ***controlled***: height, resolution, time of day, repeat schedule

***Camera/platform*** can be chosen by user

***Products*** include high resolution imagery, point cloud and DSM

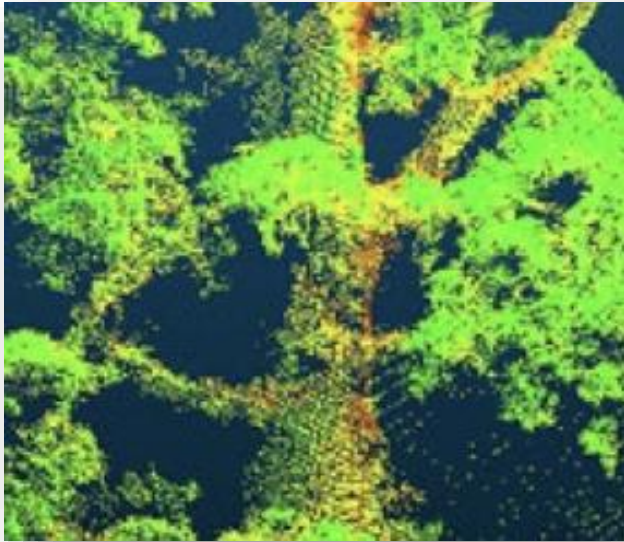
Engaging, ***hands-on*** technology

# Advantages: Spatial Resolution

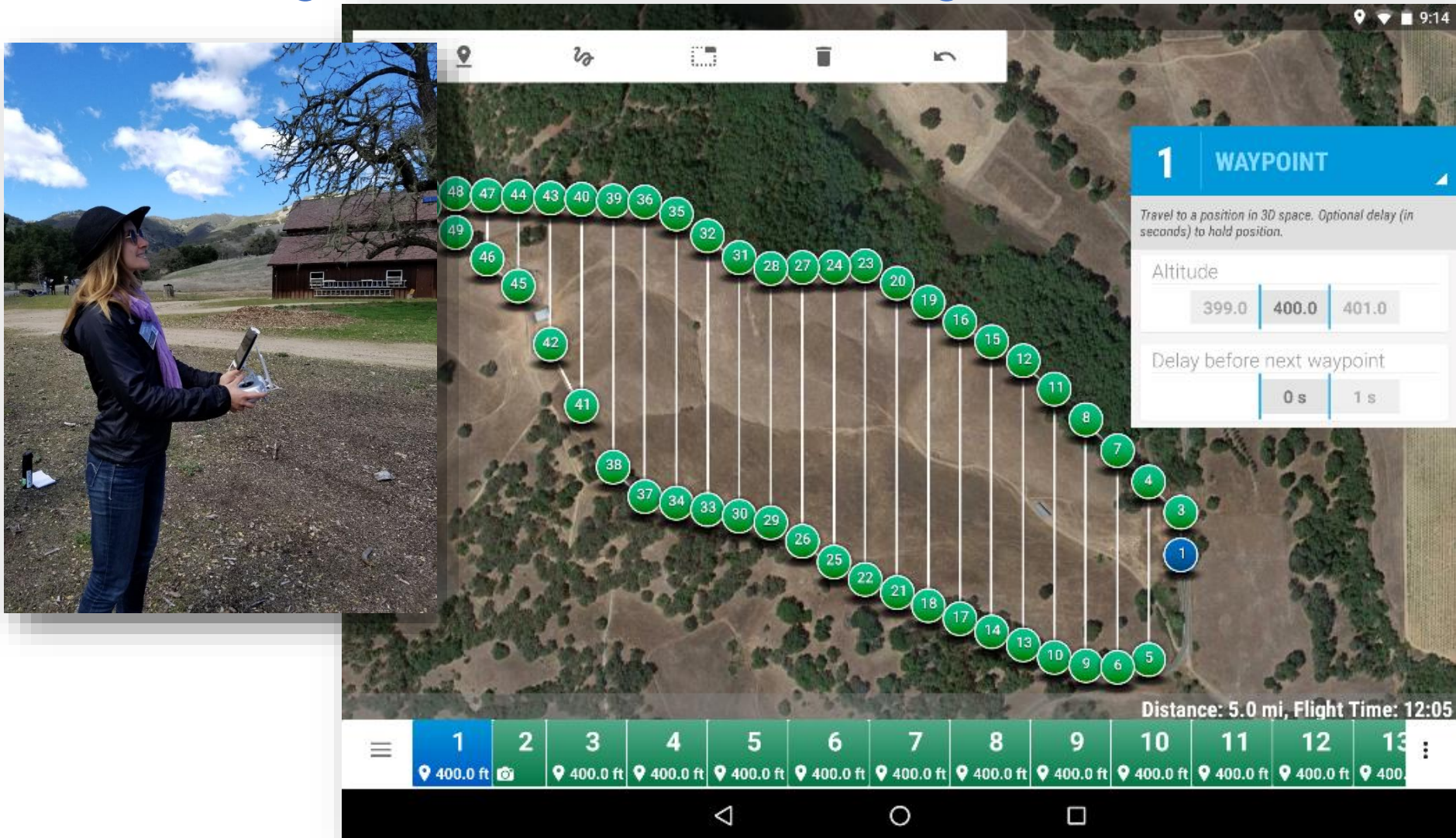
*RGB camera 2cm GSD*



*DAP: Digital Aerial  
Photogrammetry: “Leaf-  
scale resolution” Todd  
Dawson, UCB*



# Advantages: Mission Planning



Programmable flight paths are an advantage over manually piloted UASs: they allow for repeat monitoring because they collect measurements over the same configuration multiple times

# Advantages: Multiple Sensors



RGB



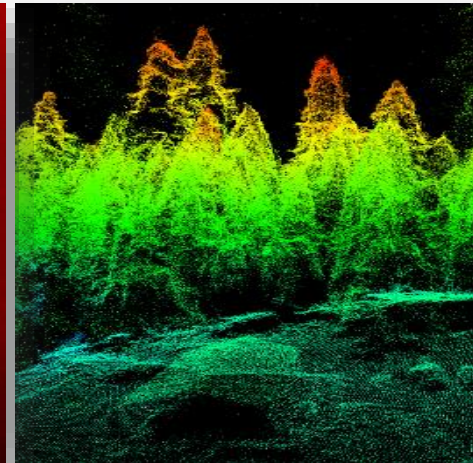
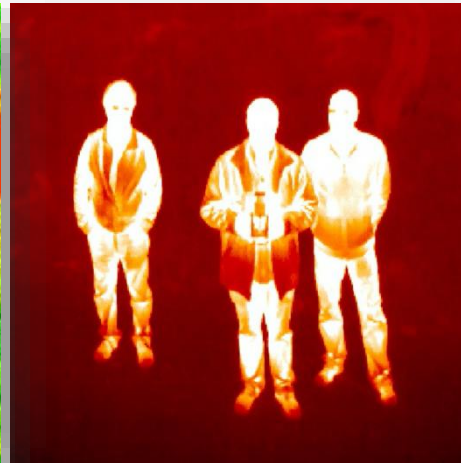
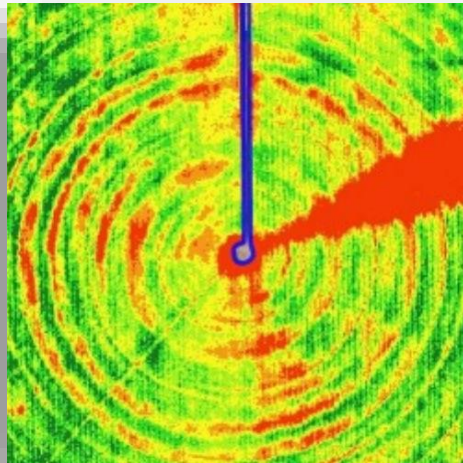
Multispectral



Thermal



Lidar



# Advantages: Costs



DJI Mavic  
\$900



DJI Phantom  
\$1,000



DJI Inspire  
\$2,000



DJI Matrice  
\$5,000



SenseFly eBee  
\$20,000



\$700  
RGB



\$3,500  
Multispectral

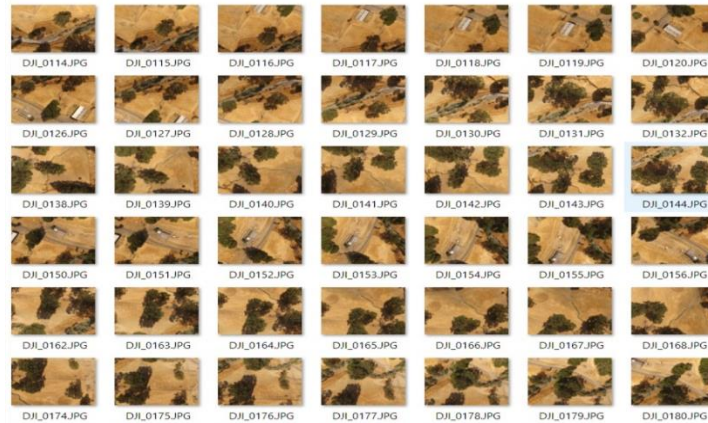


\$9,000  
Thermal

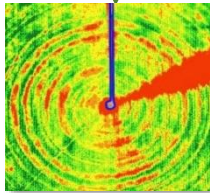


\$50,000  
Lidar

# Advantages: Multiple Products



**Orthomosaic**



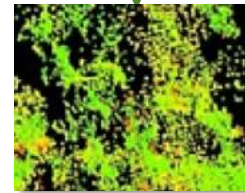
**NDVI or  
other index**



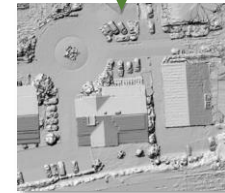
**Video**



**360°**



**Point Cloud**



**DSM**



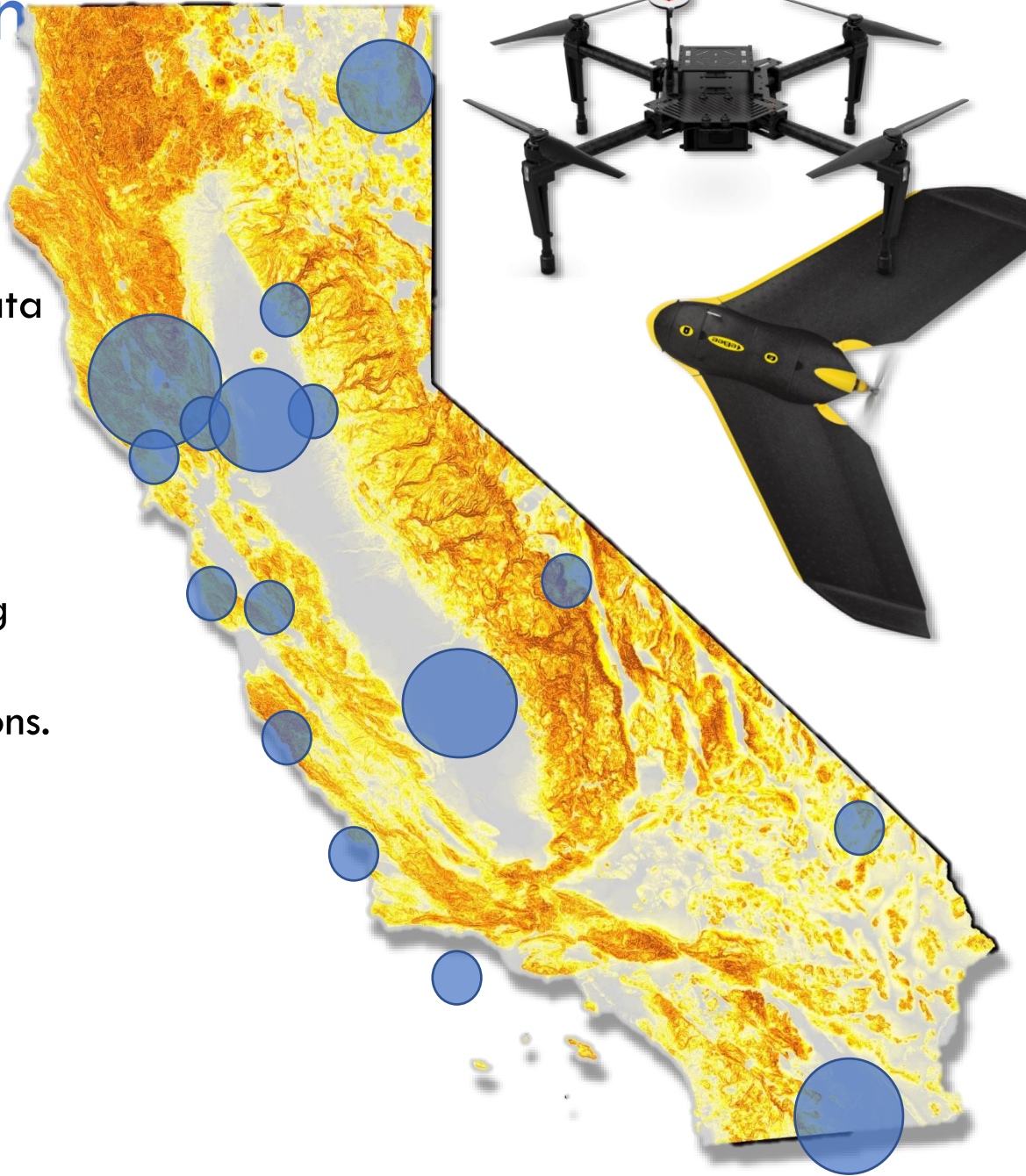
**Textured Mesh**

**Repeatable, through time**

# IGIS UAV Work in California

## Our Mission:

- Collect and analyze drone data on agricultural land to reveal and facilitate improved production practices
- Map forests, rangelands, grasslands and wetlands using drones, giving managers tools needed to make smart decisions.
- We have flown ~30 missions (total 25 km<sup>2</sup>) on and around the network of research properties in California



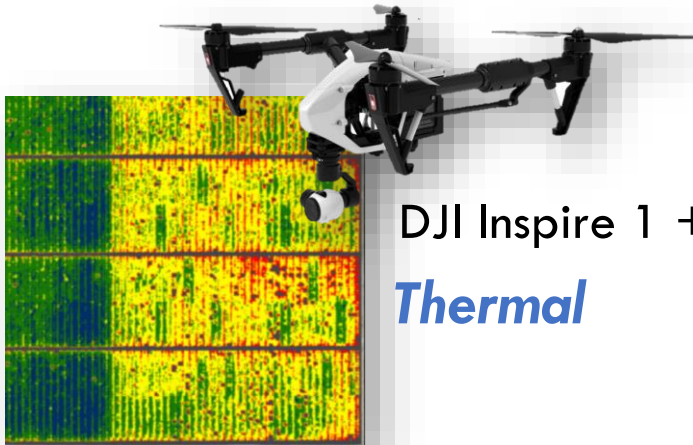
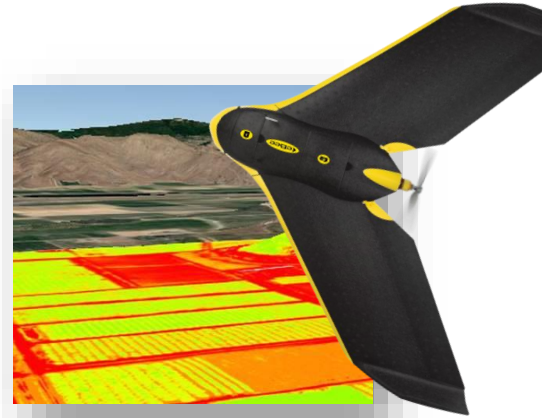


## RGB

DJI Phantom + RGB GoPro Camera + Hangar  
DJI M100 quadcopter UAV + Zenmuse X3

## MultiSpectral

SenseFly eBee + Parrot Sequoia multispectral camera



DJI Inspire 1 + Zenmuse Thermal XT

## Thermal

## LiDAR

Light Detection & Ranging  
Discrete return Optech GEMINI Airborne  
Laser Terrain Mapper (ALTM)



# *RGB Sensor:* Habitat Recovery Post Fire



Hopland Research and Extension Center  
2200 ha (5,300) near Ukiah, California  
Mediterranean-type climate, oak woodland,  
grassland, chaparral, and riparian environments.

# Example of Hangar 360° Imagery



The River Fire began 7-27-18 in Hopland. By the time it was contained (as part of the Mendocino Complex), it had burned 19,797 ha (48,920 acres). It is now the largest California wildfire in modern history.

We have been capturing the site with drone imagery: 360° imagery and RGB/Multispectral high res imagery.

# Scaling: UAV vs Planet Imagery



eBee imagery (2cm)

Planet imagery (3m)

# *Multispectral Sensor:* Mapping Individual Trees in an Agricultural Setting



Lincove Research and Extension Center  
75 ha (190 acres) in the San Joaquin Valley.  
The Center grows nearly 600 tree crop  
varieties, mostly citrus species, with trees of  
various ages and sizes.



Csillik, Kelly et al. 2018. Identification of citrus trees from UAV imagery using Convolutional Neural Networks. *Drones* 2(4), 39

# *Thermal Sensor:* Water Use Efficiency in Almond orchards

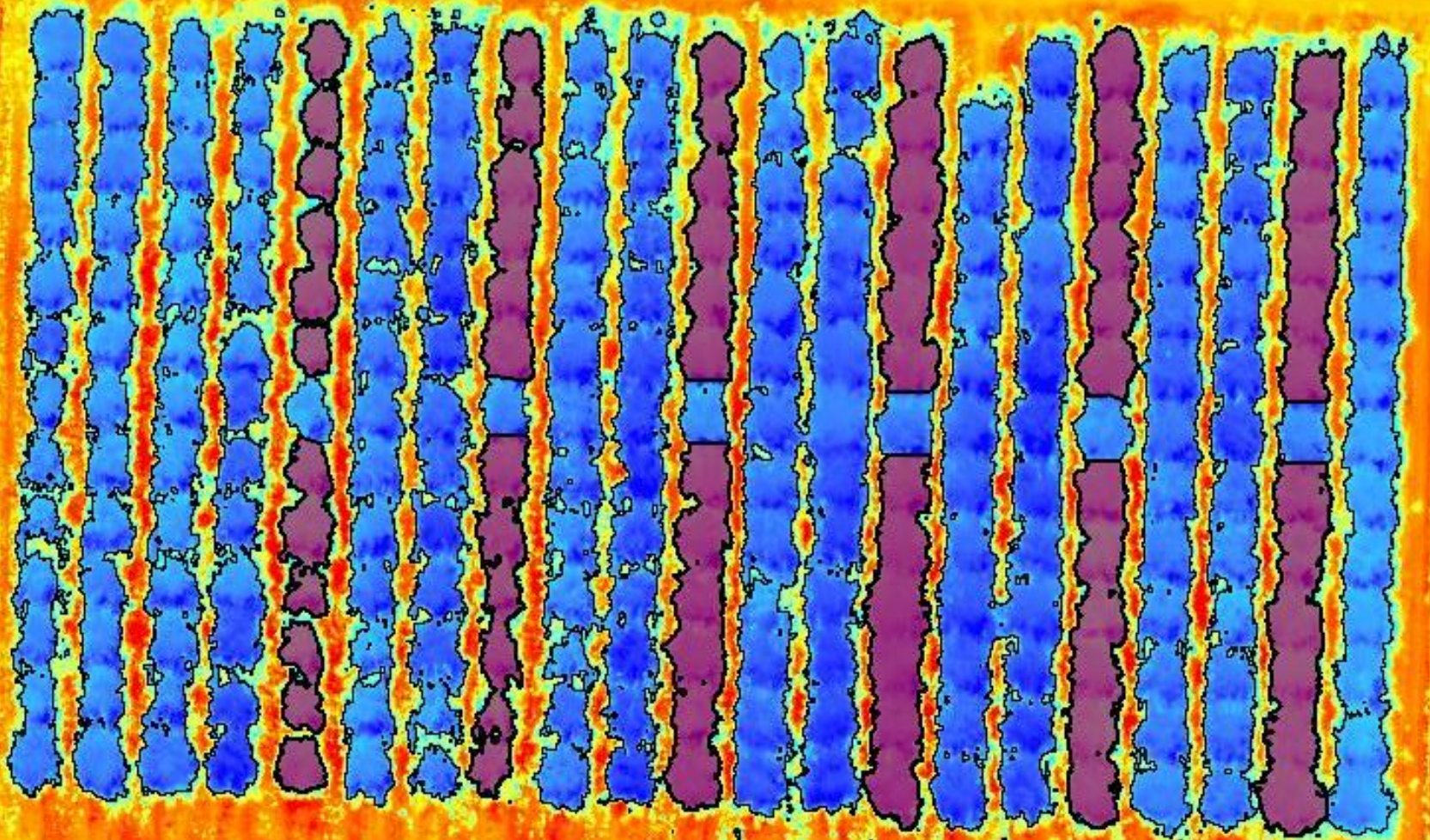


## Kearney Research and Extension Center

330 acres in the San Joaquin Valley.  
Development of new fruit, nut, and grape  
varieties, innovative cultural and irrigation  
practices, pest and disease management  
techniques.

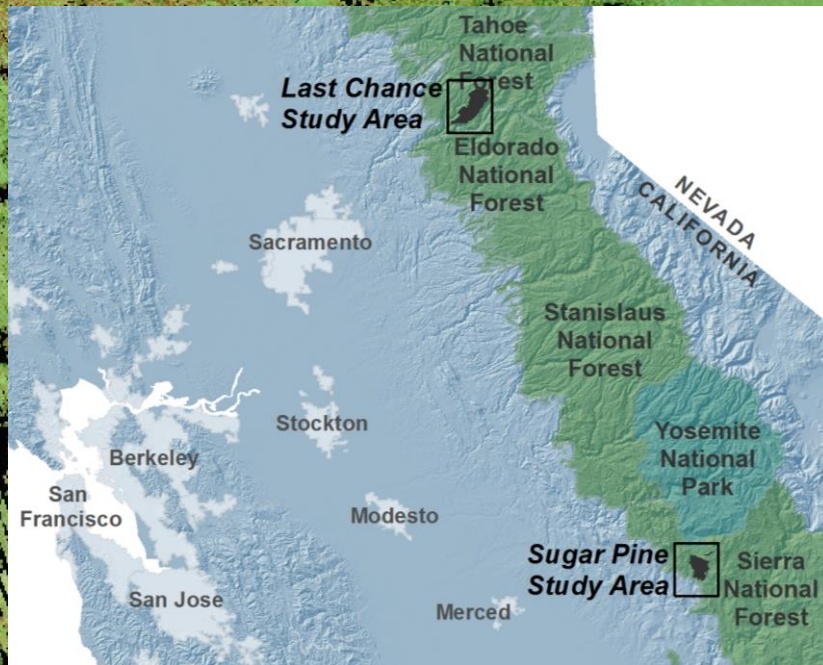


■ Full watering      ■ Water restricted



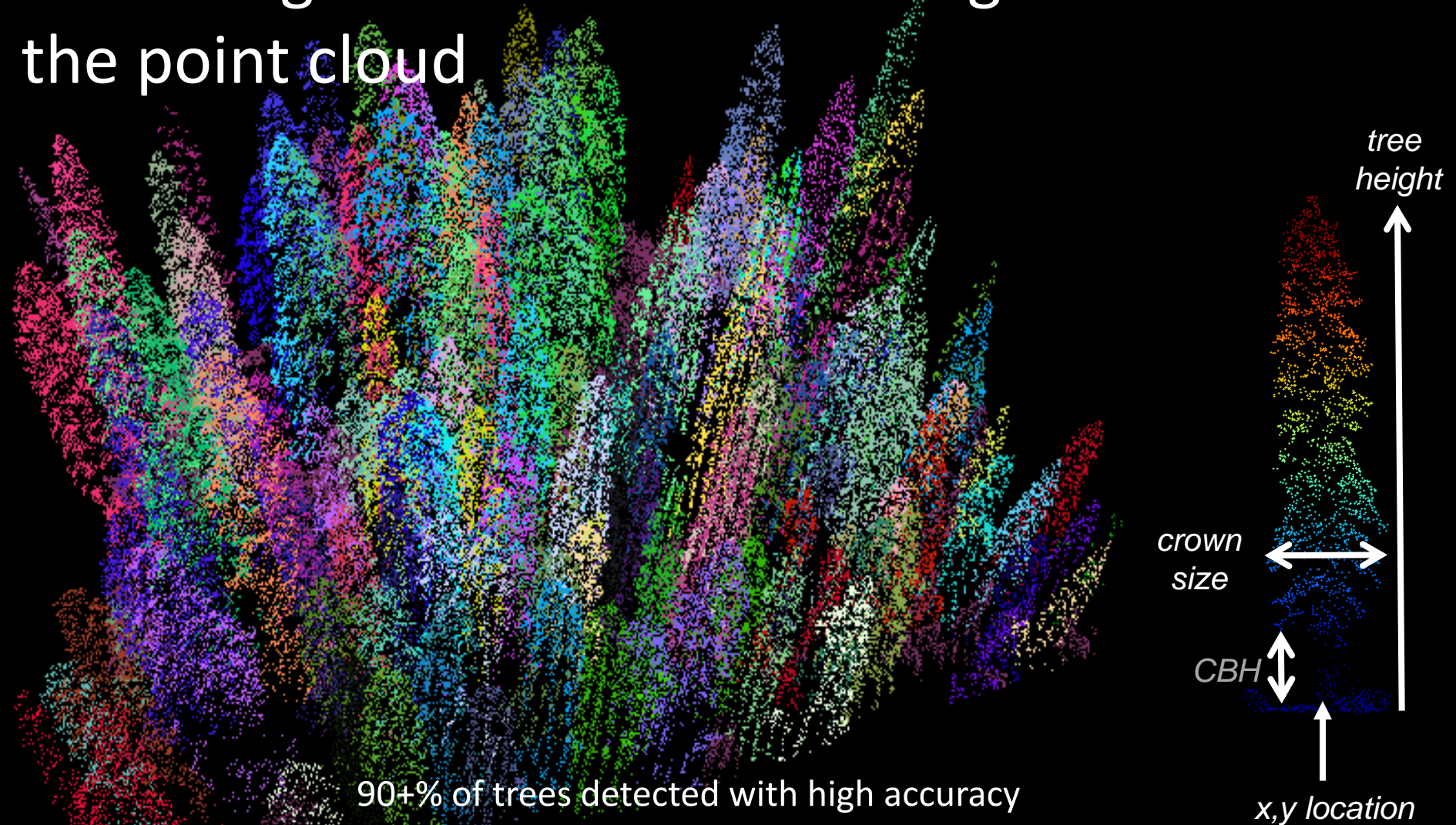
Testing the ability to differential water treatment (full watering, restricted water) on Almond orchards

# *Lidar Sensor:* Forest Structure



Lidar Point Cloud

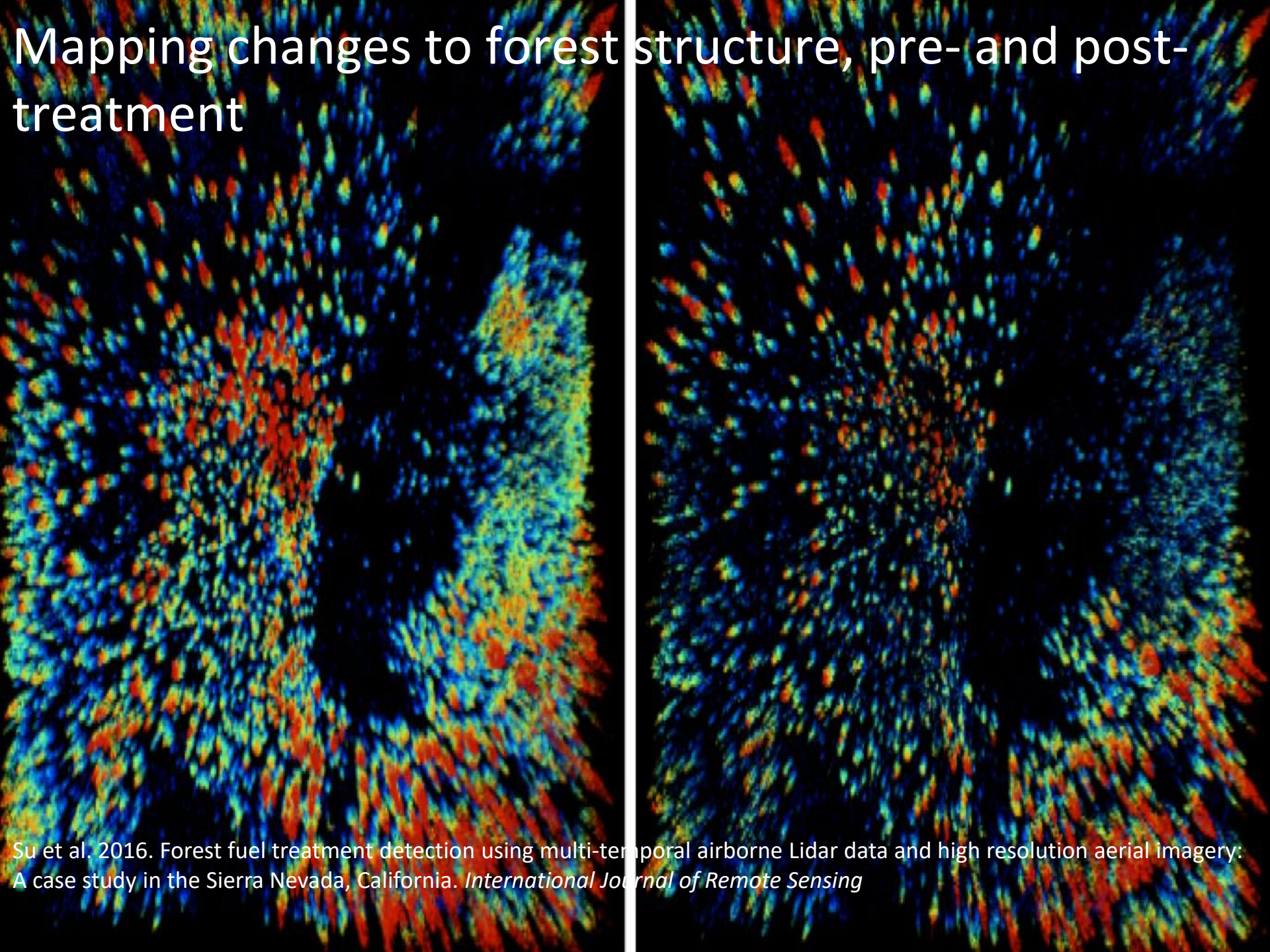
# Extracting information about single trees from the point cloud



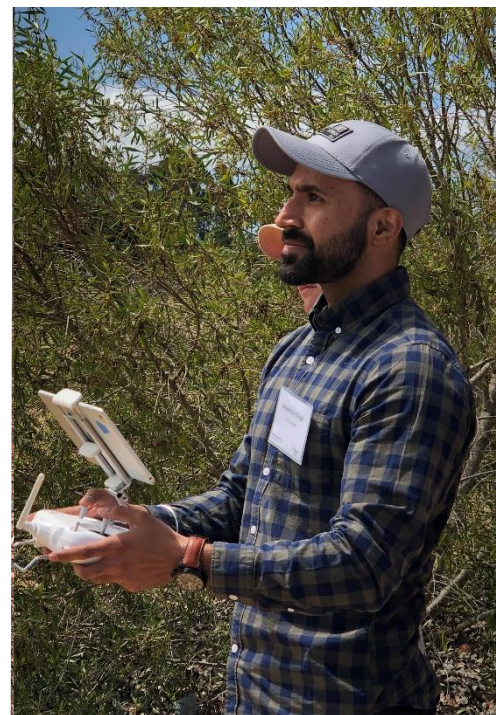
Li et al. 2012. A new method for segmenting individual trees from the lidar point cloud. *Photogrammetric Engineering and Remote Sensing*

Jakubowski et al. 2013. Delineating individual trees from lidar data: a comparison of vector- and raster-based segmentation approaches. *Remote Sensing*

# Mapping changes to forest structure, pre- and post-treatment



Su et al. 2016. Forest fuel treatment detection using multi-temporal airborne Lidar data and high resolution aerial imagery: A case study in the Sierra Nevada, California. *International Journal of Remote Sensing*



Public Engagement & STEM

# Challenges: UAV Operations

*UAVs give us flexible, focused, & precise data on demand, but there are challenges*



## Data

Geo-registration  
Storage  
Processing time  
Sharing



## Hardware & Equipment

Upkeep & Maintenance  
Connectivity  
Obsolescence  
Accidents  
Insurance



## Workflows

Software: proprietary  
& open  
Linking with other RS  
tools  
Cloud processing



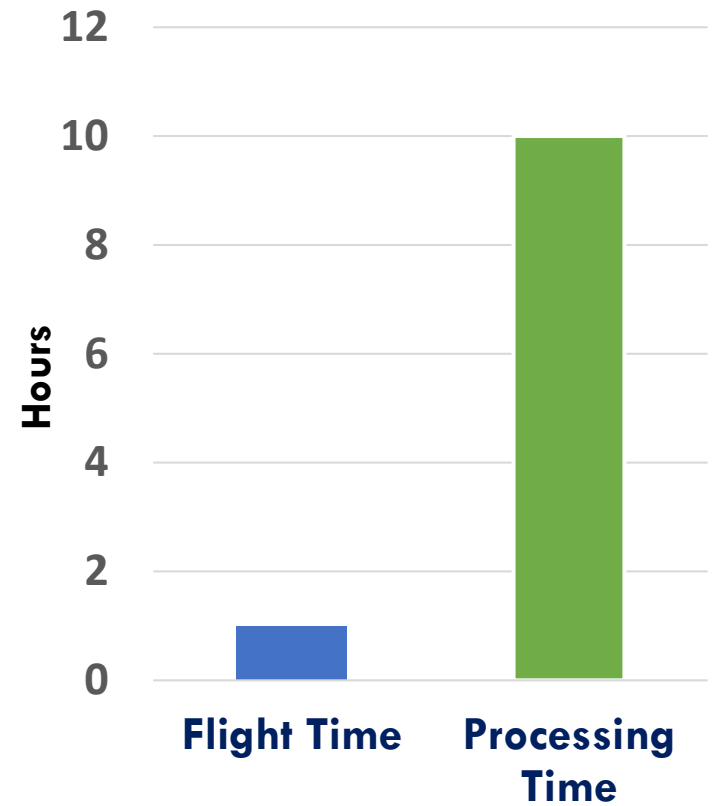
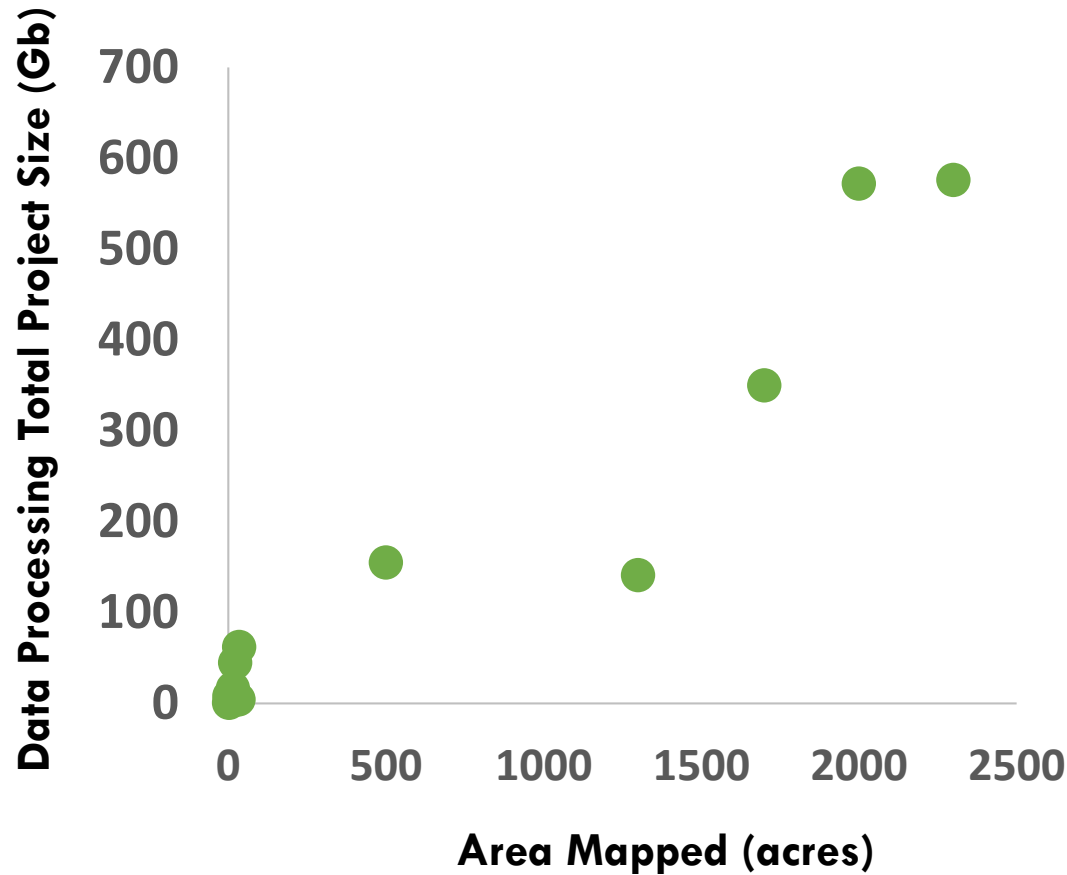
## Flight

Flight skills  
Safety  
Regulation  
Training



## Drone Mission Data Sizes & Processing Time

Data





## Hardware & Equipment

Maintaining a drone fleet requires considerable upkeep and continual maintenance; and new improved models come out all the time.

It's always good to have backups, and to plan for accidents

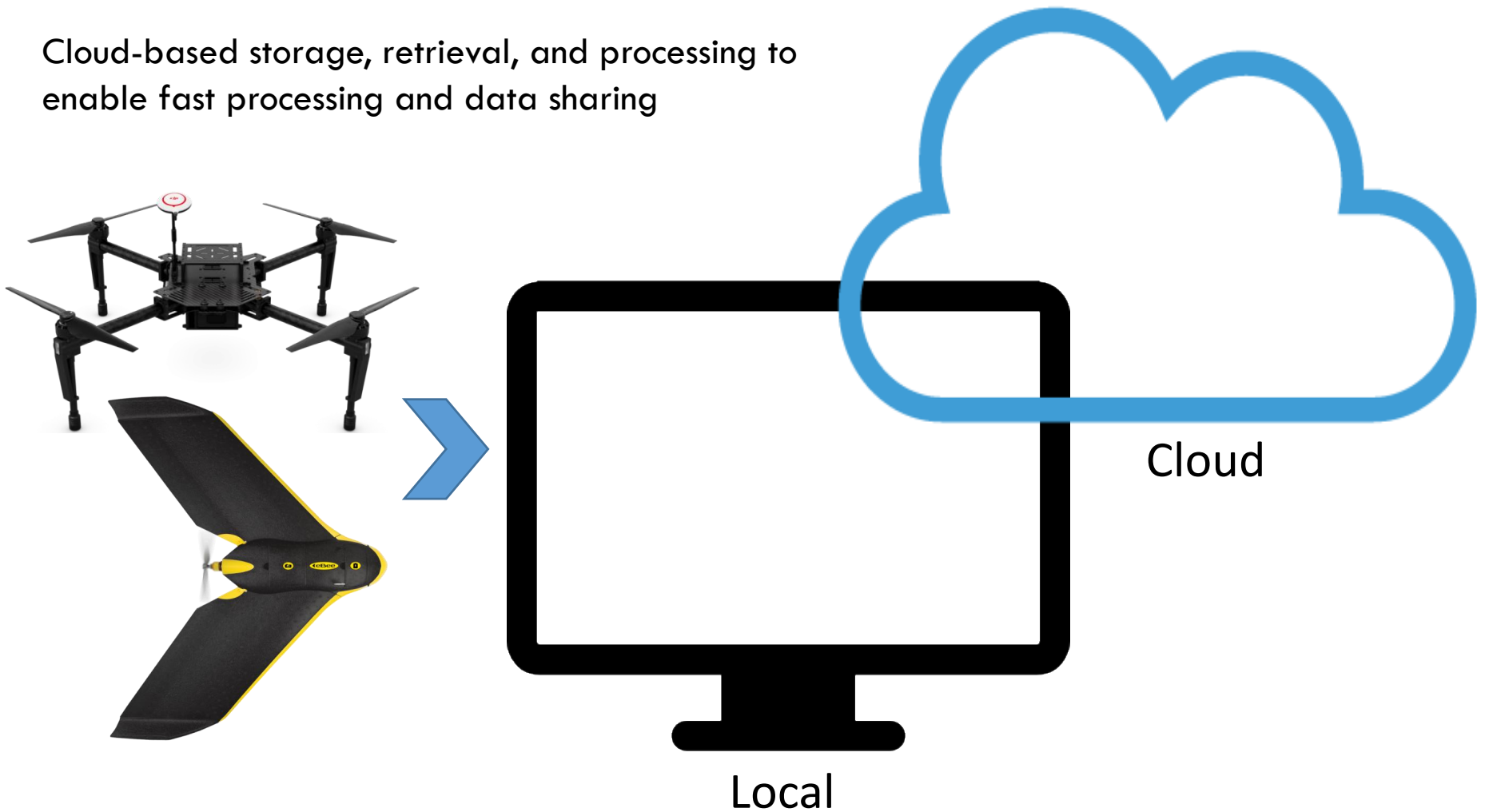




# Cloud Storage & Processing

## Workflows

Cloud-based storage, retrieval, and processing to enable fast processing and data sharing





Flight



**'My fingers were almost cut off by a drone'**

© 23 July 2017 | UK

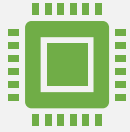
f t m e Share

<http://www.bbc.com/news/uk-40697682>

DroneCamp: Continual training for flight skills, safety and regulation



# UAV Technology Futures



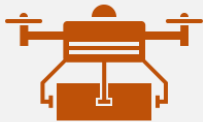
## ***Sensors***

New developments in multispectral, hyperspectral, Lidar, thermal, fluorescence sensors



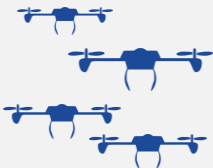
## ***Defense***

Technology to detect, track, and disrupt unwanted UAVs



## ***Payloads & Mobility***

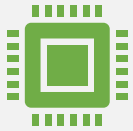
UAVs for delivery; for sampling; for application (e.g. spraying); Aquatic – Aerial UAVs



## ***Swarms***

Technology for swarm autonomy and reliability  
UAV-to-UAV communication via cellular mobile wireless infrastructure

# UAV Research Frontiers



## ***Sensor calibration and benchmarking***

*Sensor Benchmarking:* How to use, when to use, how to fuse



## ***Development of new indices and measures***

Spectral indices  
Rate of change measures  
Combination metrics  
Leaf-scale and within-canopy measures



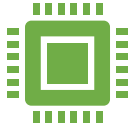
## ***Digital Aerial Photogrammetry (DAP) vs LiDAR***

Point cloud vs Lidar: across scale / across species / across density



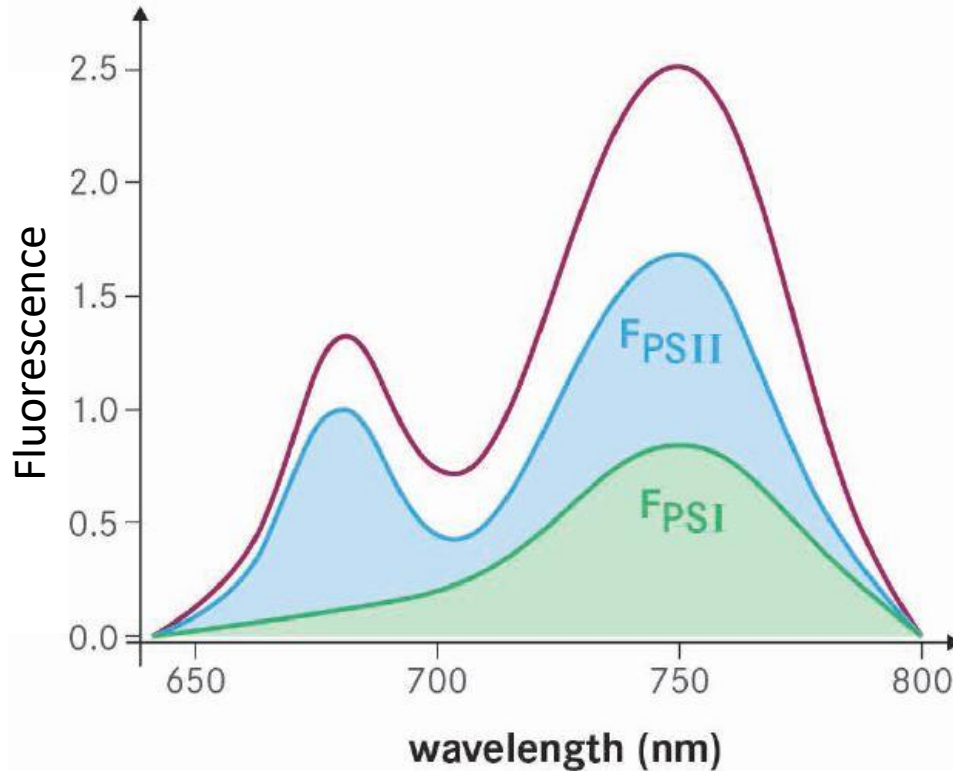
## ***Cloud-based storage, retrieval, and processing***

Enabling fast processing and data sharing



## ***Sensor calibration and benchmarking***

## ***Fluorescence***



~1% of solar energy captured by plants is re-emitted by chlorophyll as fluorescence

Requires very narrow spectral bands: ~0.02-0.05nm

When plants are exposed to sunlight, they reflect, transmit, and absorb light. In addition to R, A, T, plants re-emit light = fluorescence.

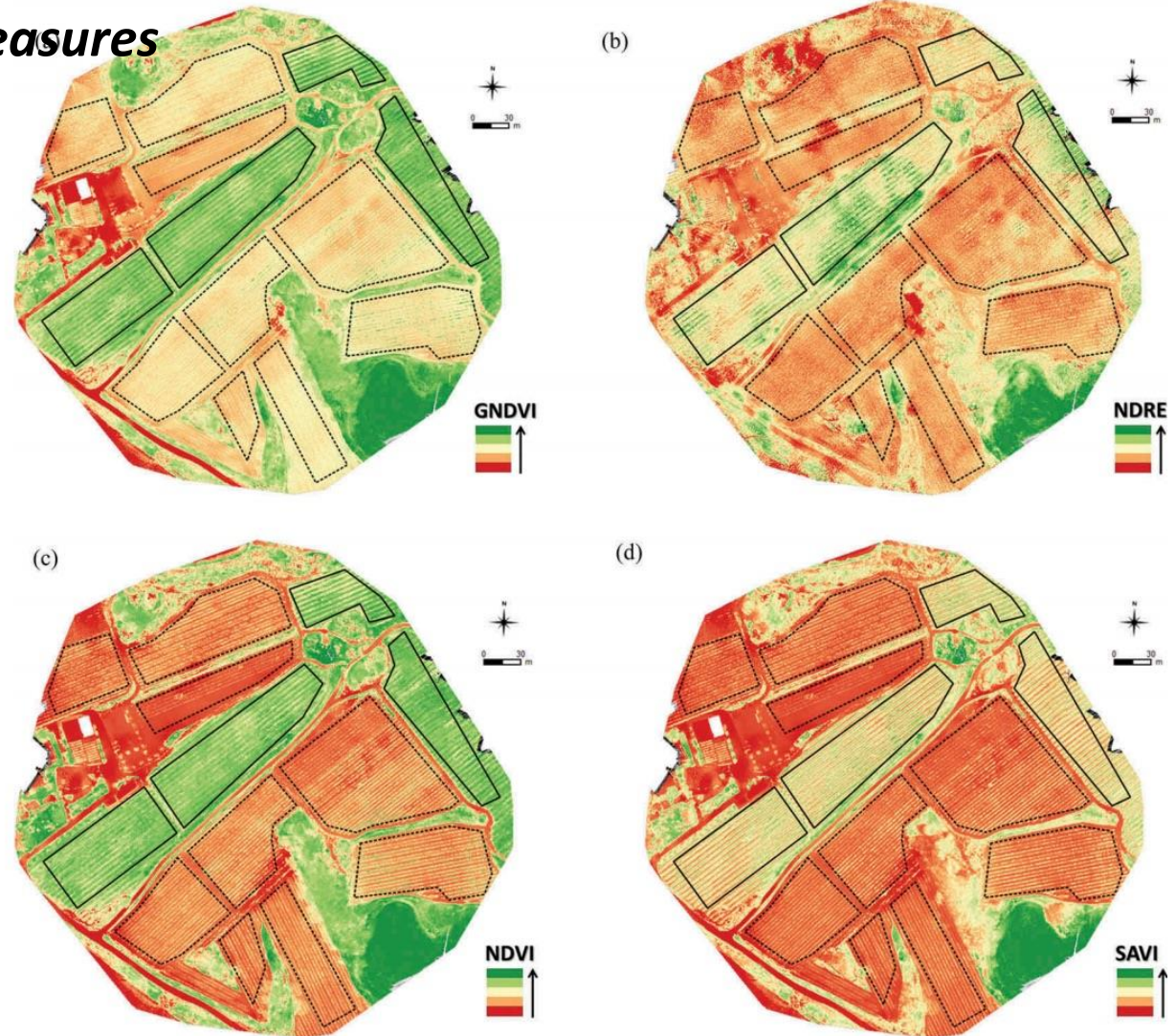
The amount of fluorescence emission is a direct indicator of the photosynthetic activity of a plant.

*Fluorescence emission from photosystems I and II (PSI, PSII)*

<http://terraluma.net>



## *Development of new indices and measures*

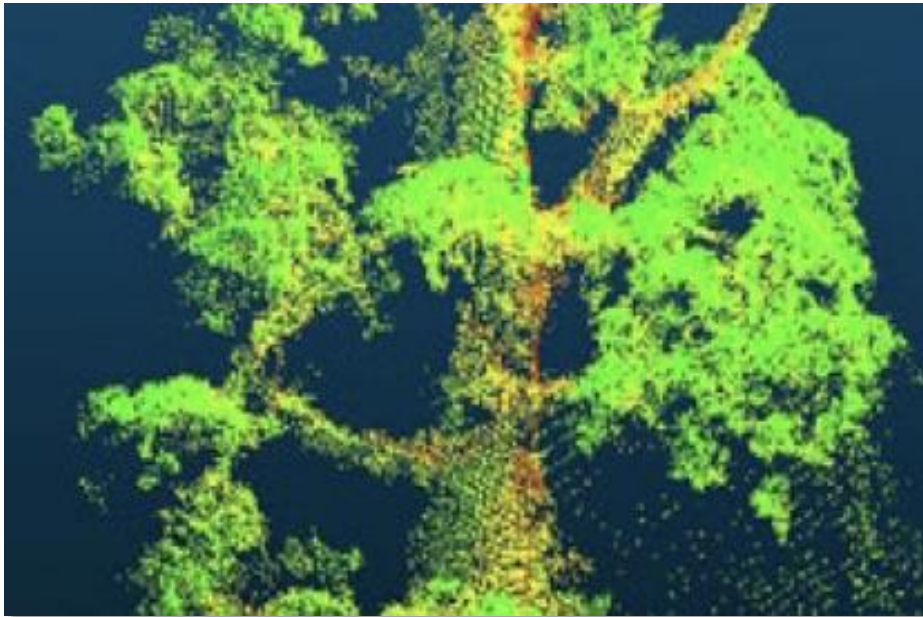


Jorge, Vallbé, and Soler. 2019. Detection of irrigation inhomogeneities in an olive grove using the NDRE vegetation index obtained from UAV images. *European Journal of Remote Sensing* 52(1): 169-177

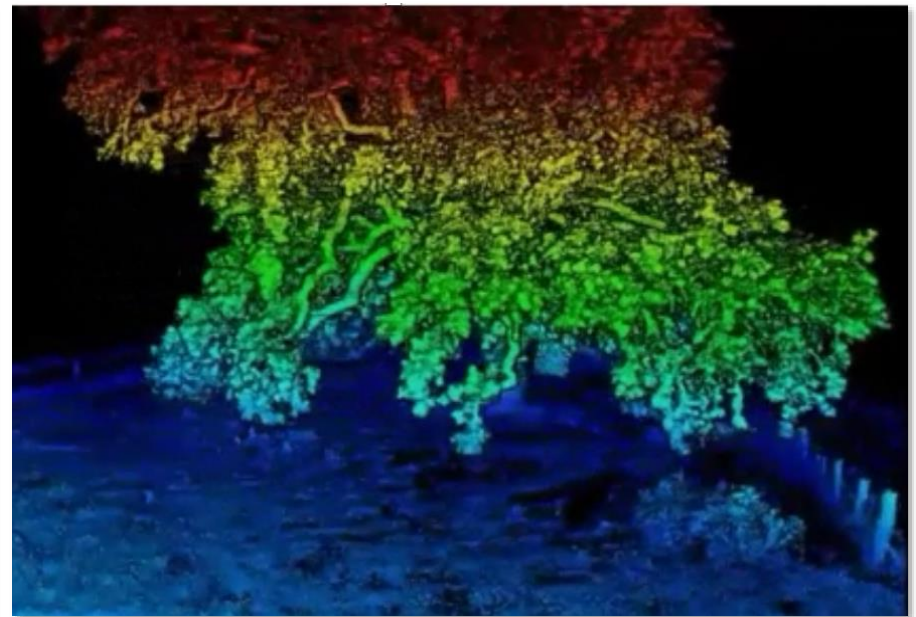


# ***Digital Aerial Photogrammetry (DAP) vs LiDAR***

## Leaf-scale Resolution



Digital Aerial Photography



Terrestrial LiDAR

# UAV Grand Challenges: The 3Ss



## Scaling

Fine to broad-scale in space and time;  
e.g. links with regional and global  
models



## Sampling

UAV as sampling tool: Strategic use of  
UAVs to help scaling research; e.g.  
Lidar for biomass



## Synergy

Cloud storage, retrieval and processing

Interoperability and sharing

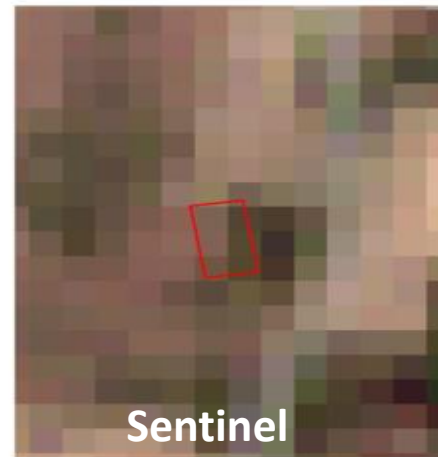
FAIR drone data (Findable, Accessible, Interoperable, Reusable)



UAV



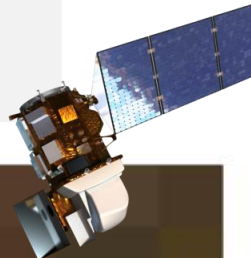
Planet



Sentinel



Landsat



# UAV Grand Challenges: The 3Ss



Scaling



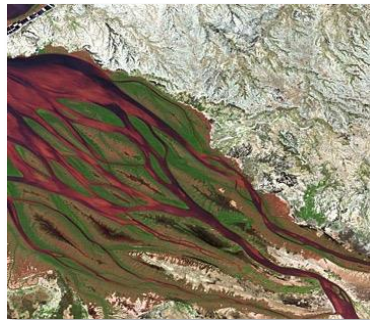
Sampling



Synergy



Landsat 30m



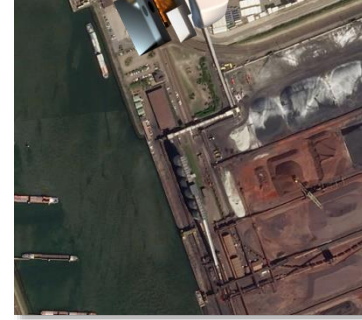
Sentinel 10-20m



WorldView3 0.3-1.2m



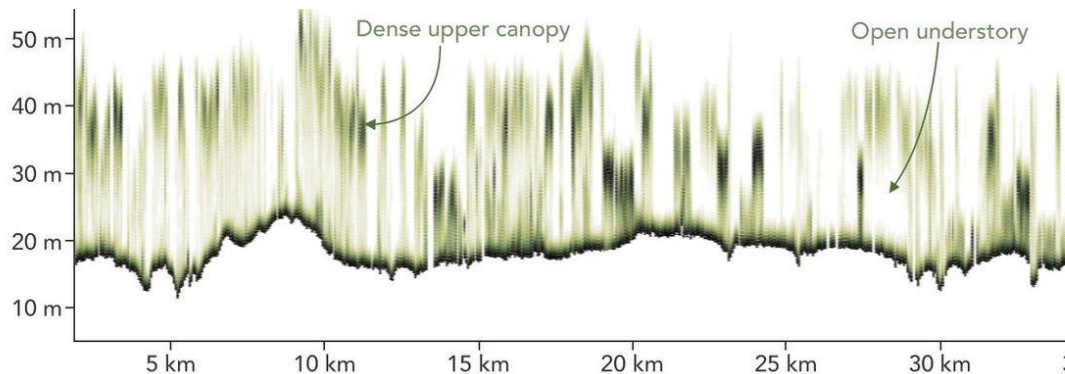
Planet RapidEye 5m



Planet SkySat 0.8m

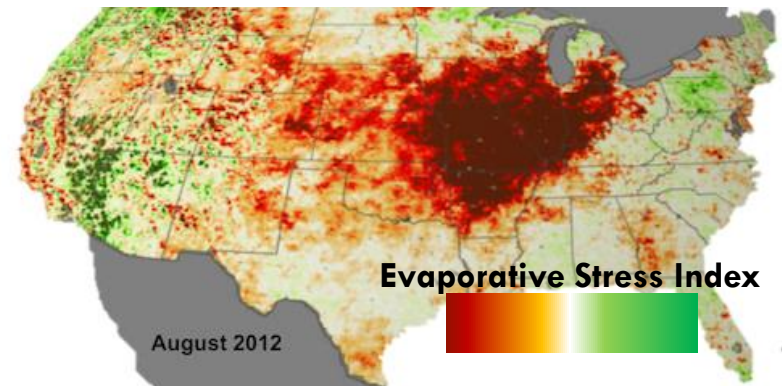
## New Sensors:

**Global Ecosystem Dynamics Investigation (GEDI):** High resolution laser ranging of Earth's forests and topography



## New Sensors:

**ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)**



# Mapping for Impact

Many of the challenges we face today around food, water, equity, energy, invasive species, fire, climate change, conservation – are **complex**, require a ***spatial approach*** and impact ***diverse public groups***.



Addressing these challenges requires innovative ***data collection, data synthesis, novel analytical tools, and increased communication and cooperation*** between scientists and public.

**data**

**people**

**tools**

***Drones are part of our 21<sup>st</sup> century scientific toolkit***

# Thank You

Maggi Kelly

Professor and CE Specialist, UC Berkeley

Faculty Director, Geospatial Innovation Facility (GIF)

Director ANR Statewide Program in Informatics and GIS (IGIS)

Email: [maggi@berkeley.edu](mailto:maggi@berkeley.edu)

Twitter: [@nmaggikelly](https://twitter.com/nmaggikelly)

<http://kellylab.berkeley.edu>

<http://gif.berkeley.edu>

<http://igis.ucanr.edu/>