Remote sensing and in-situ measurement of habitat diversity and function

Phil Townsend

John Gamon, Clayton Kingdon, Aditya Singh, Shawn Serbin, John Couture, Eric Kruger

Contributions: Gil Bohrer, Francisco Chavez, Steve Garrity, Thomas Hilker, Fred Huemmrich, Alasdair MacArthur, John Olson, Eric Ross, Joe Sexton, Rob Sohlberg, Lee Vierling, Ben Zuckerberg

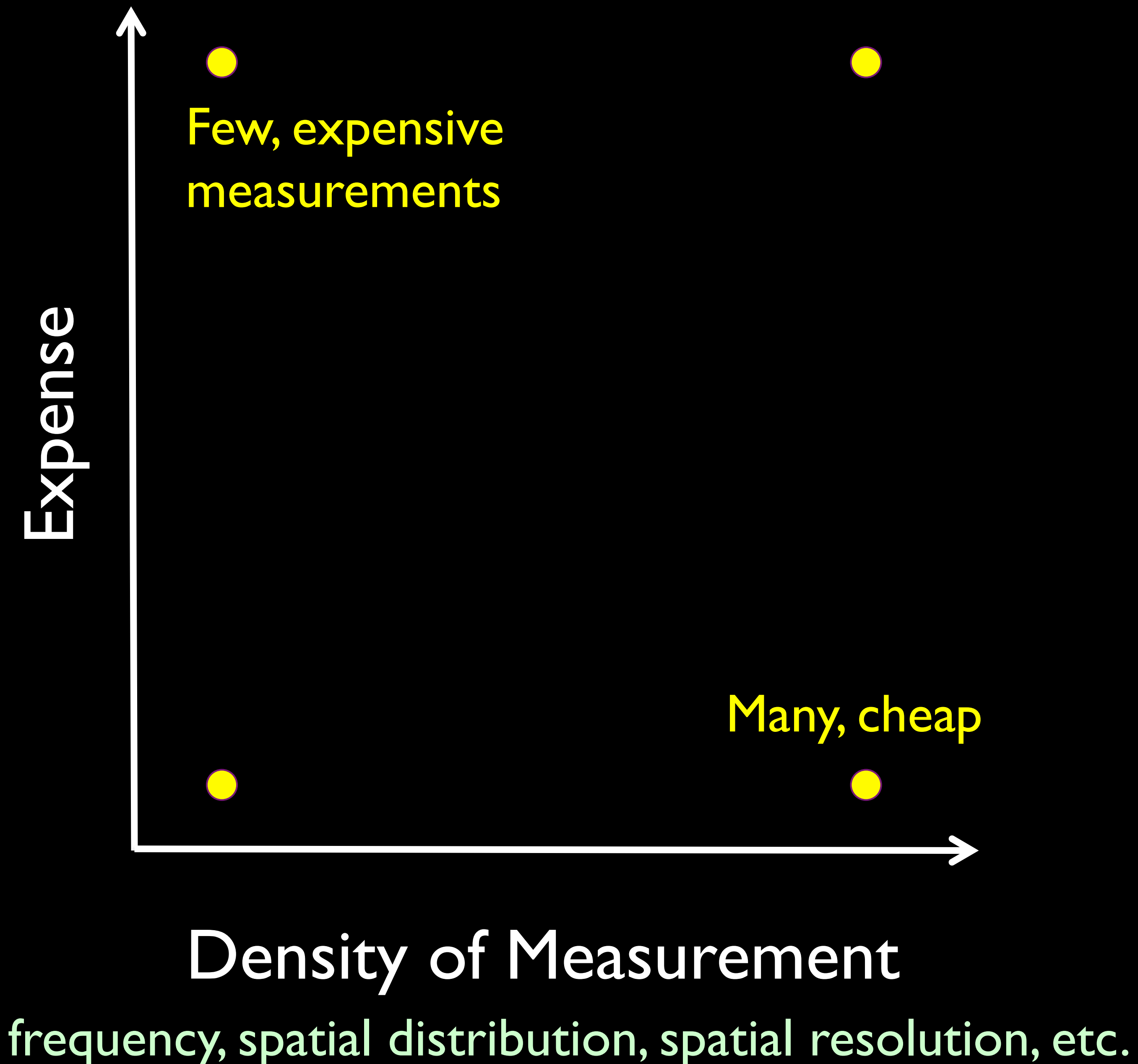
What do we want from our NASA satellites for CC&E?

- More frequent Landsat
- High spatial resolution
- More bands, narrower bands, or…
- Hyperspectral!
- Lidar, SAR, fluorescence….

When do we want it? Now!

In-situ measurements

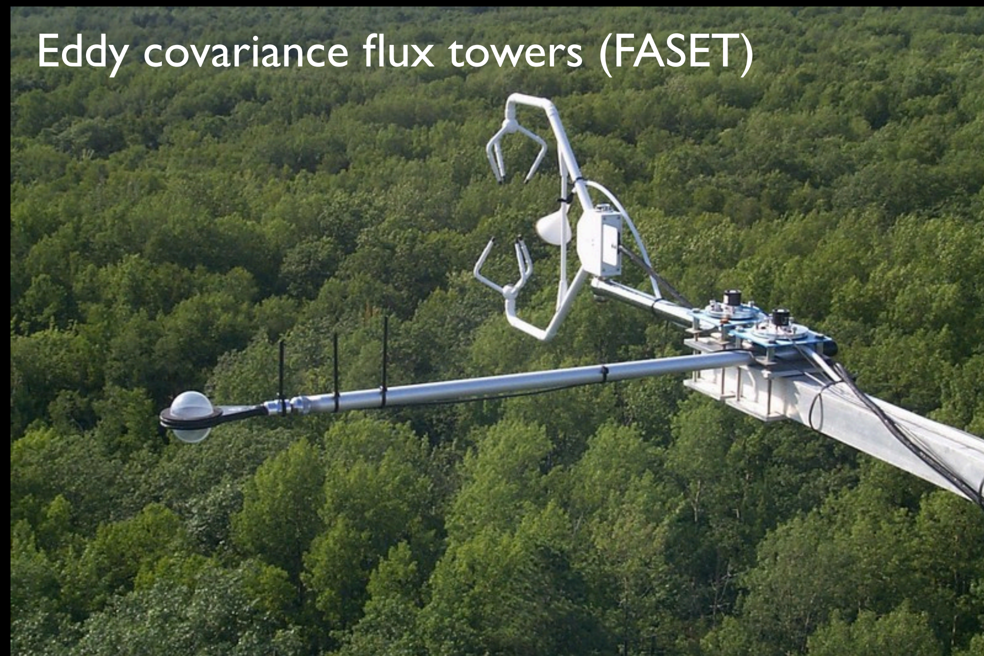
- Validation/calibration;
- Measurements that cannot be currently made from remote sensing;
- Measurements of features we want to predict from remote sensing; and
- Fill in gaps in the remote sensing record.



idea from J. Gamon

Expense

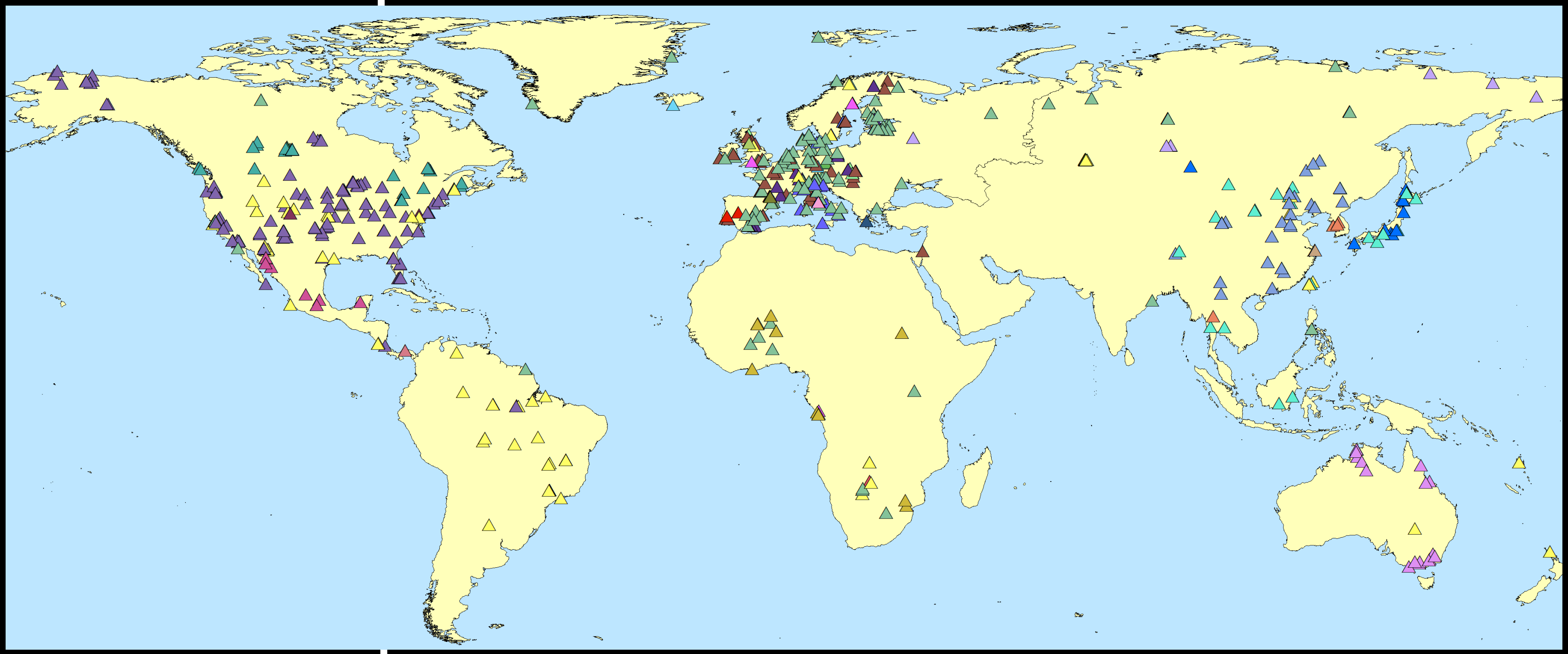
Few, expensive measurements



Density of Measurement

Spatial distribution is low, but…

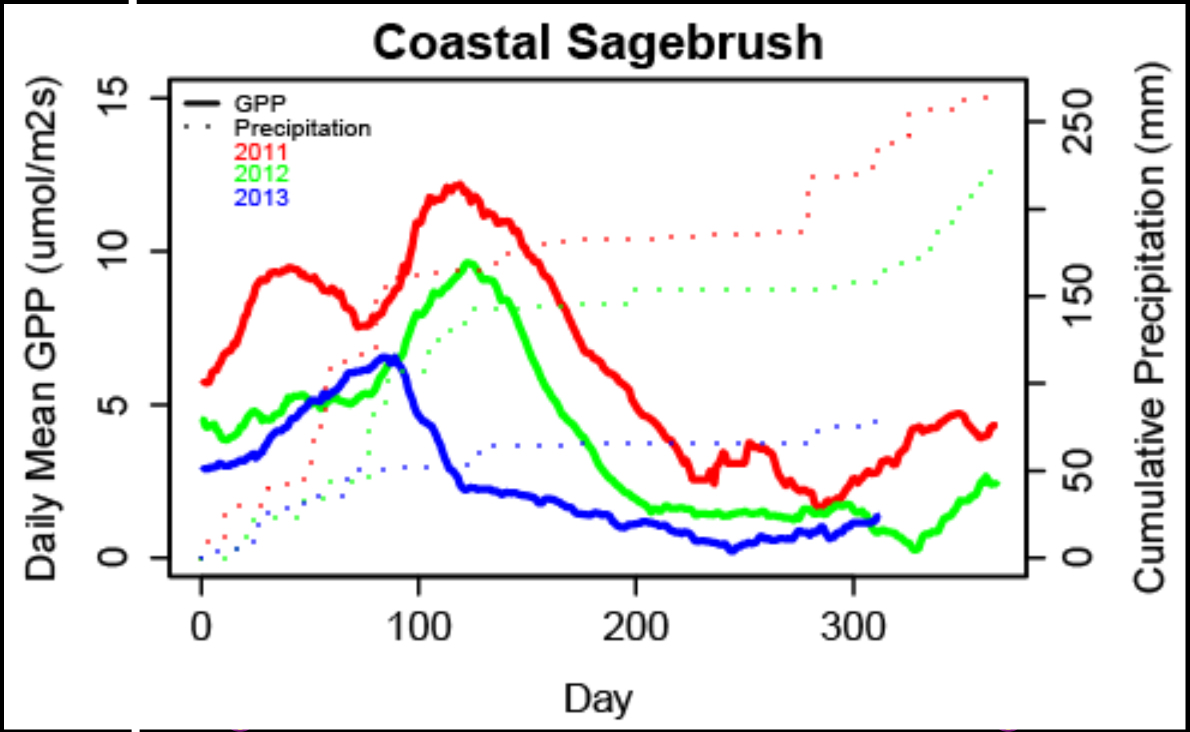
- Few, expensive measurements



Density of Measurement

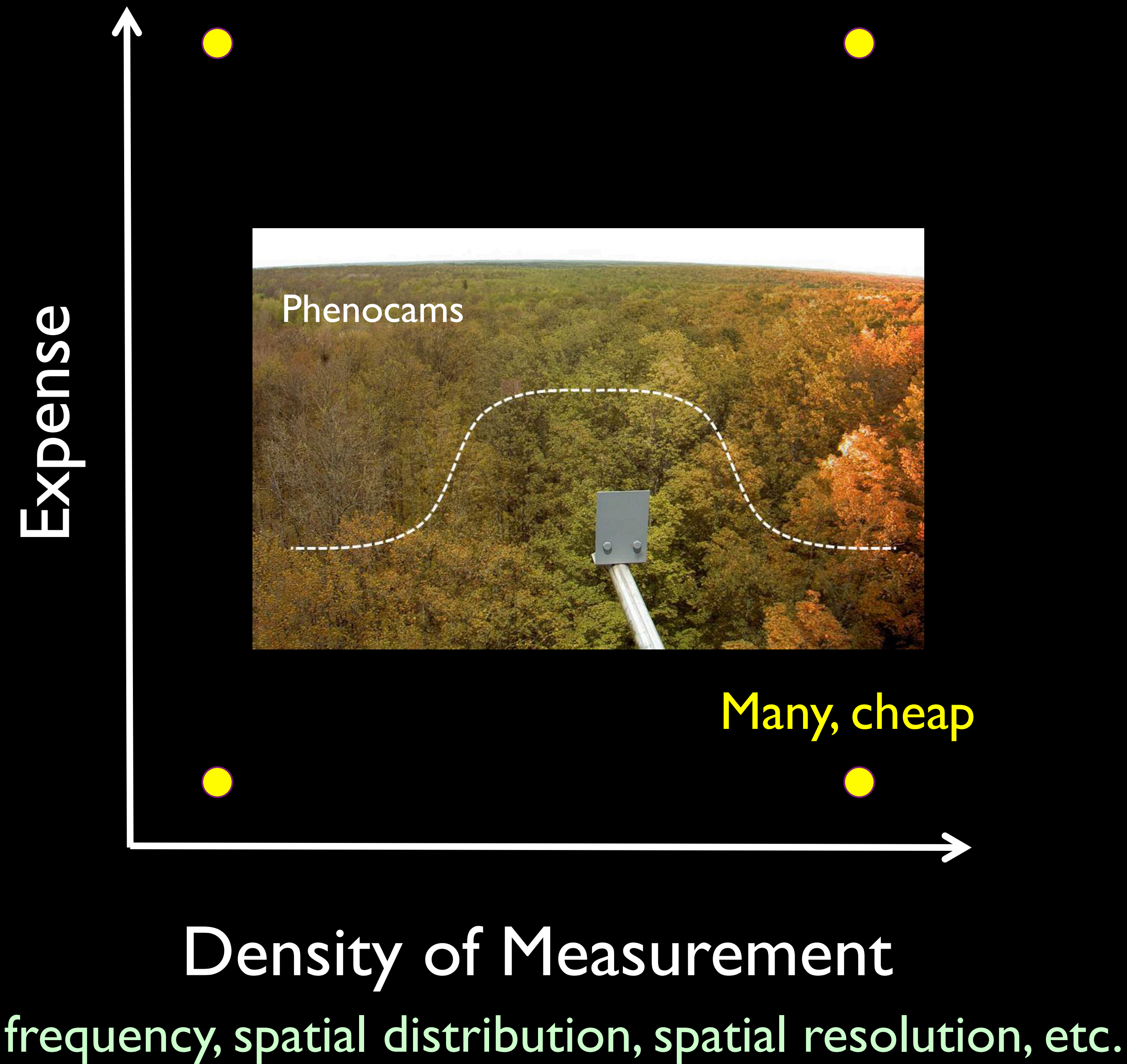
Spatial distribution is low, but…

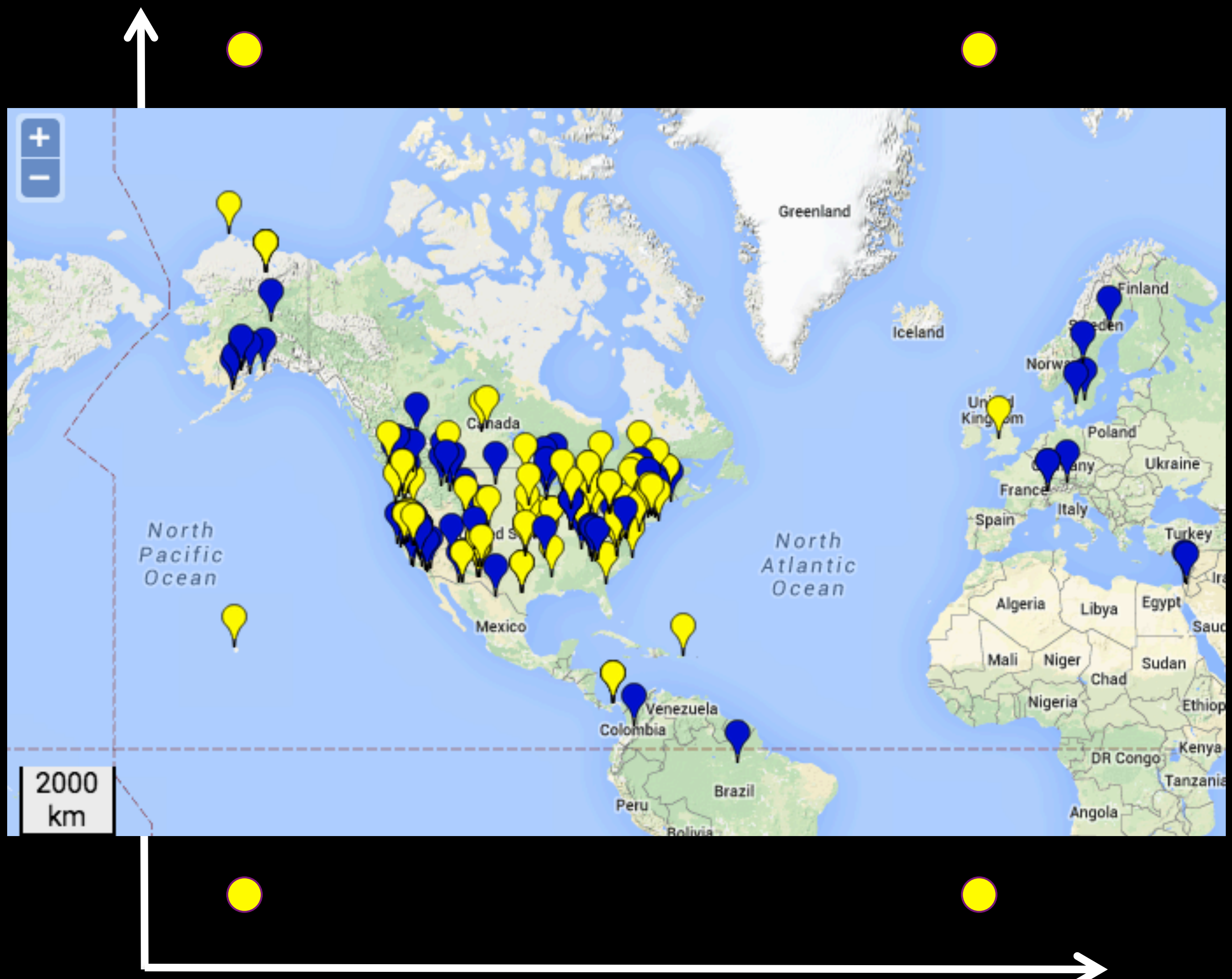
Many, expensive measurements



Density of Measurement

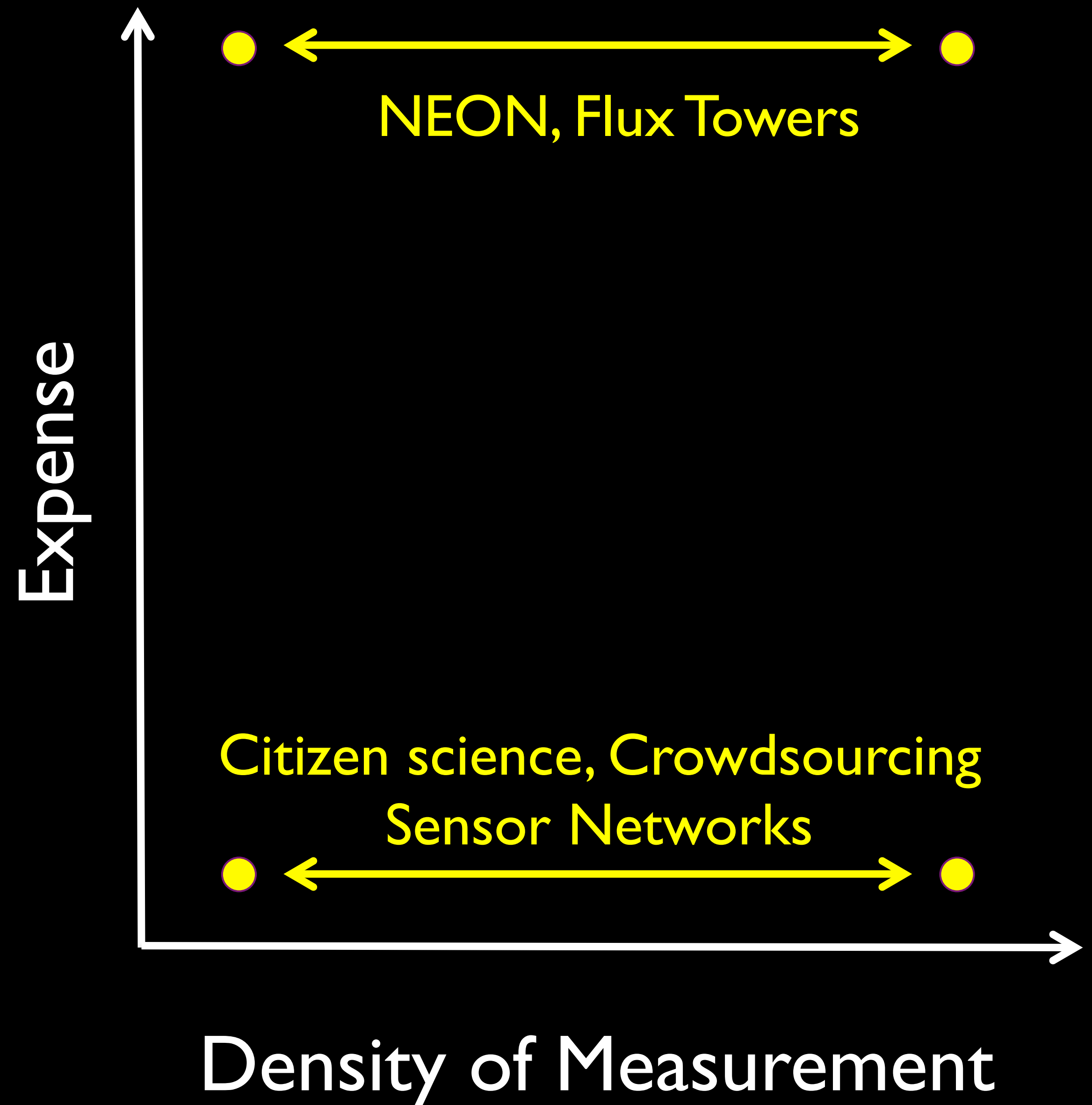
….temporal resolution is high.


Expense
Phenocams
Many, cheap
Density of Measurement
frequency, spatial distribution, spatial resolution, etc.

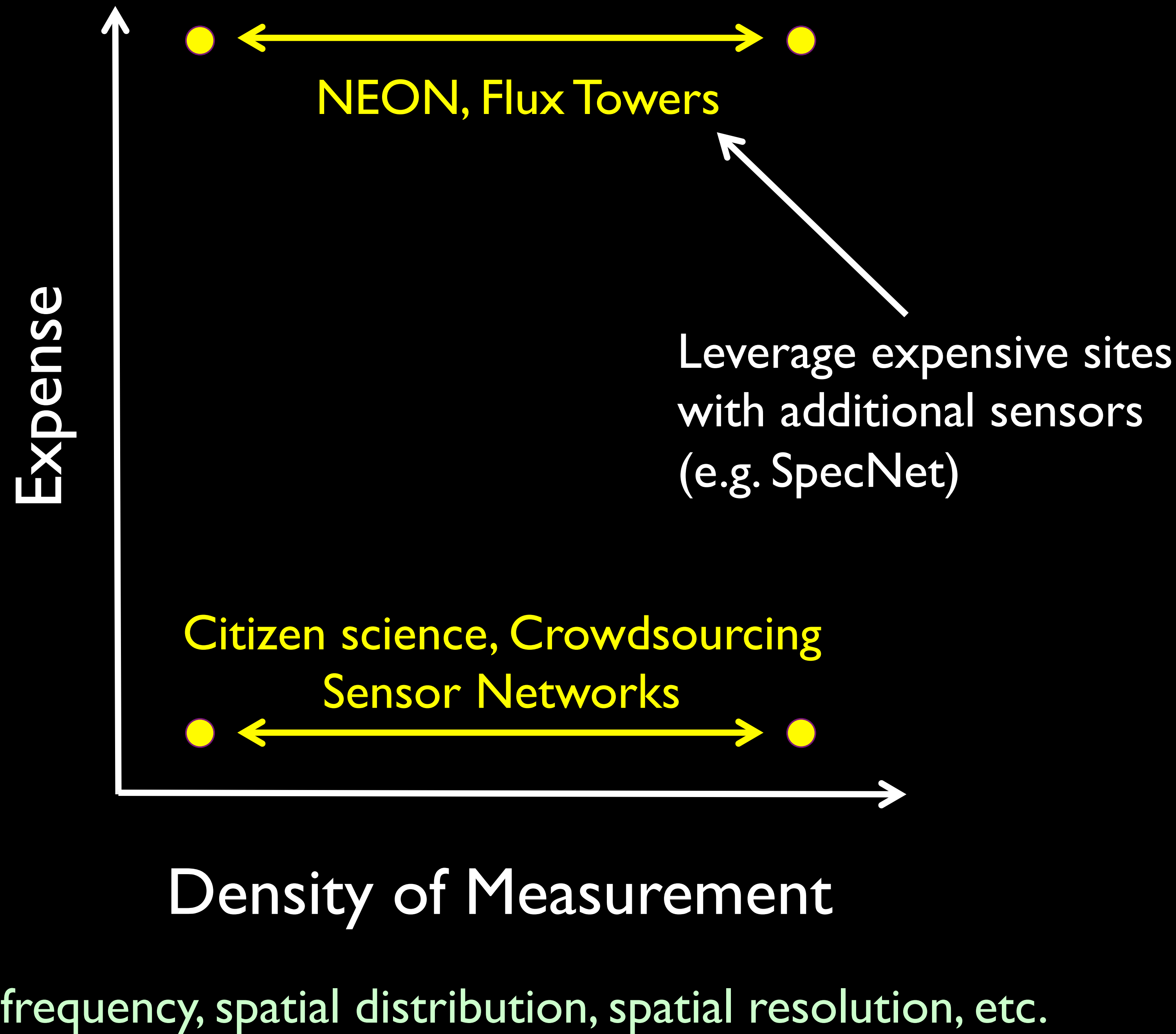


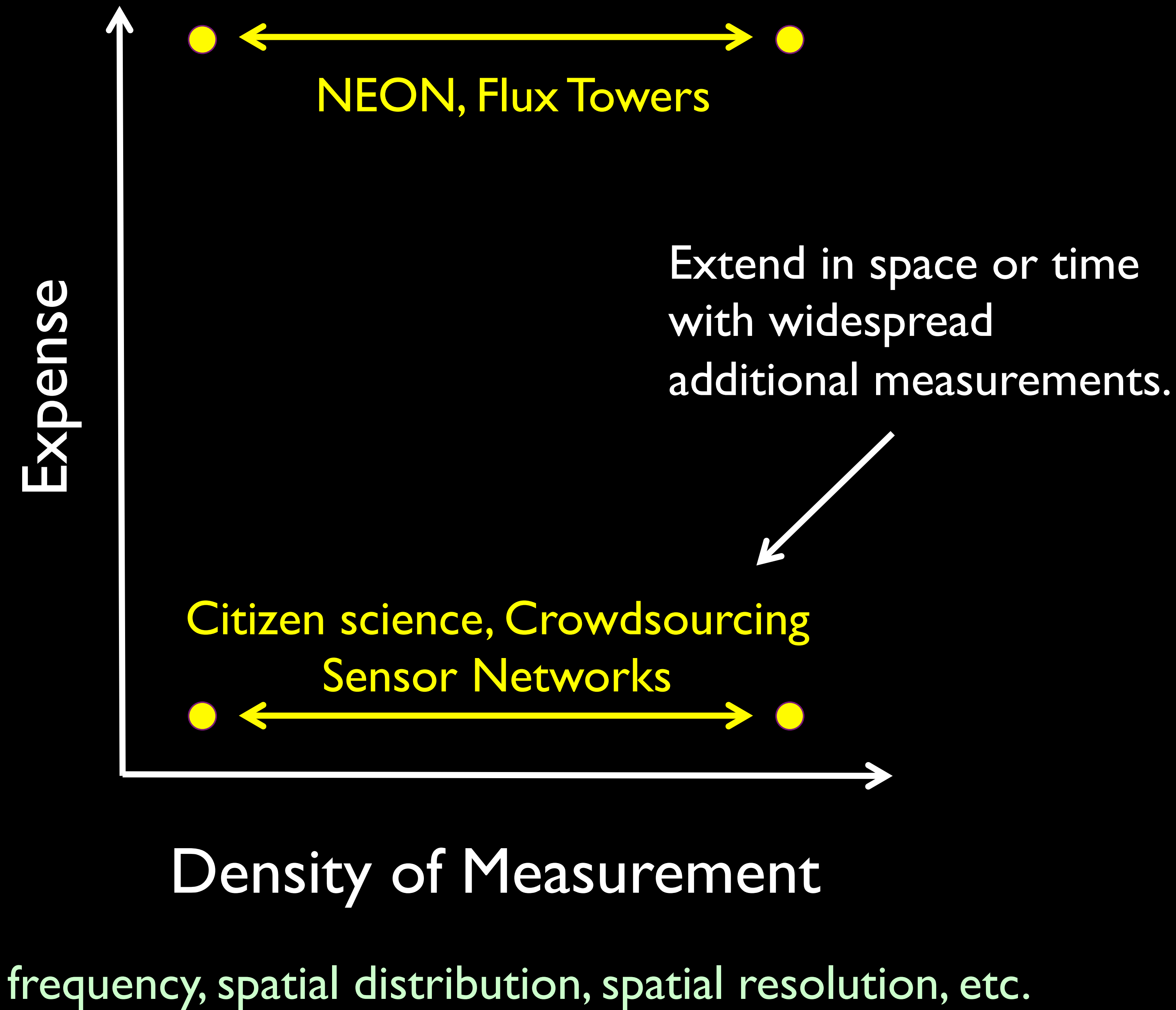
Density of Measurement

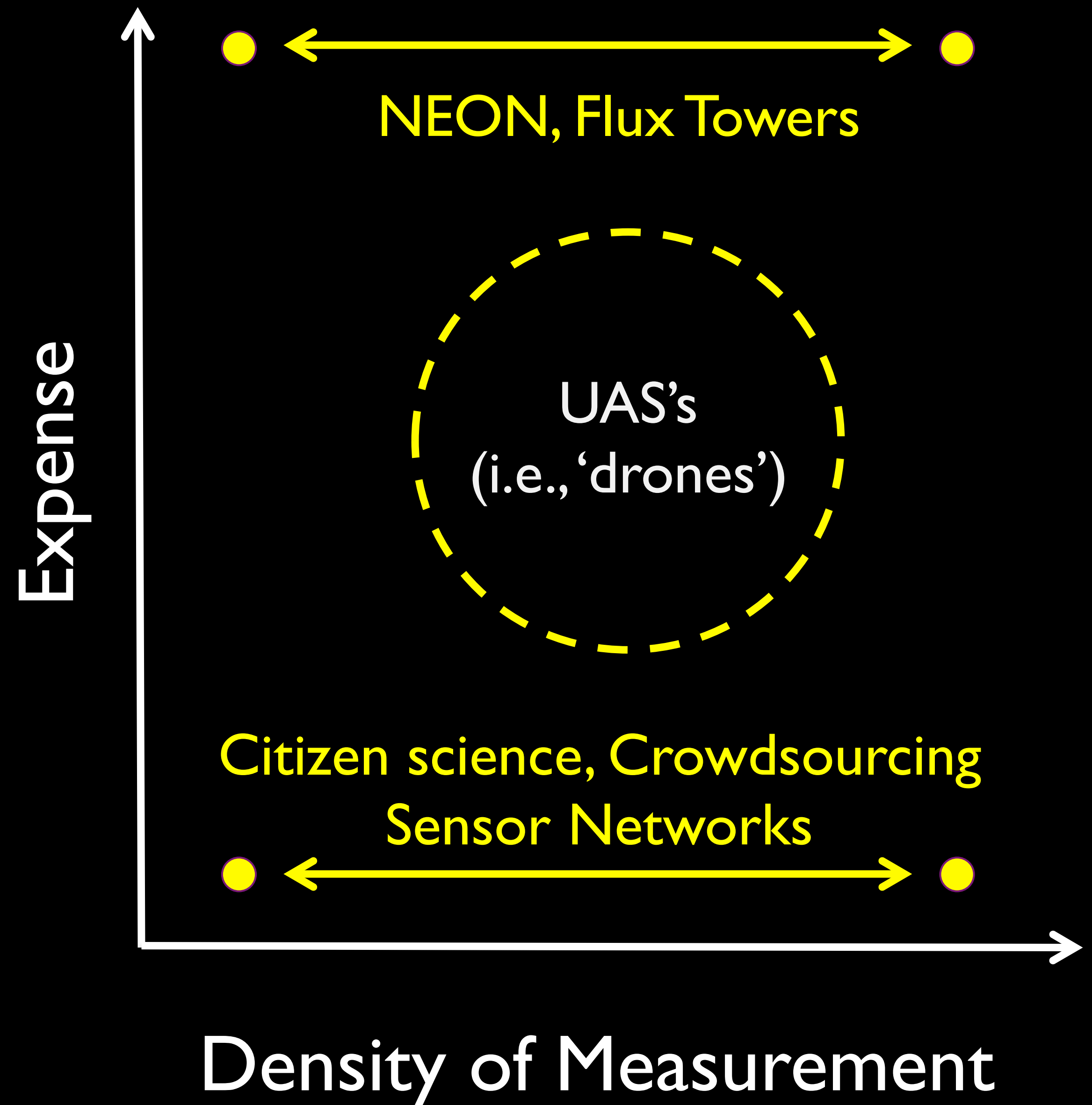
frequency, spatial distribution, spatial resolution, etc.



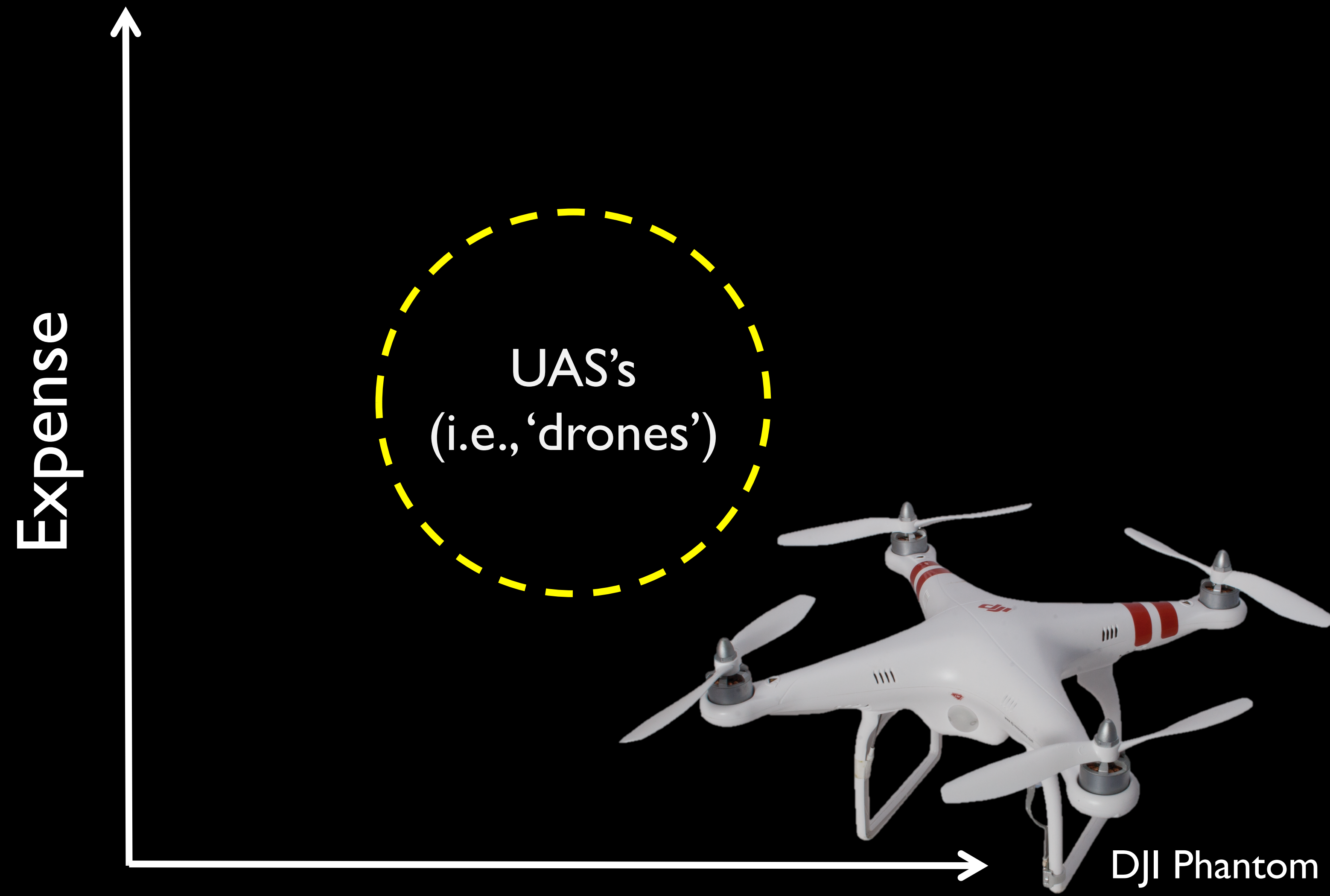
frequency, spatial distribution, spatial resolution, etc.


NEON, Flux Towers
Leverage expensive sites
with additional sensors
(e.g. SpecNet)
Expense
Citizen science, Crowdsourcing
Sensor Networks
Density of Measurement
frequency, spatial distribution, spatial resolution, etc.


NEON, Flux Towers
Extend in space or time with widespread additional measurements.
Expense
Citizen science, Crowdsourcing
Sensor Networks
Density of Measurement
frequency, spatial distribution, spatial resolution, etc.

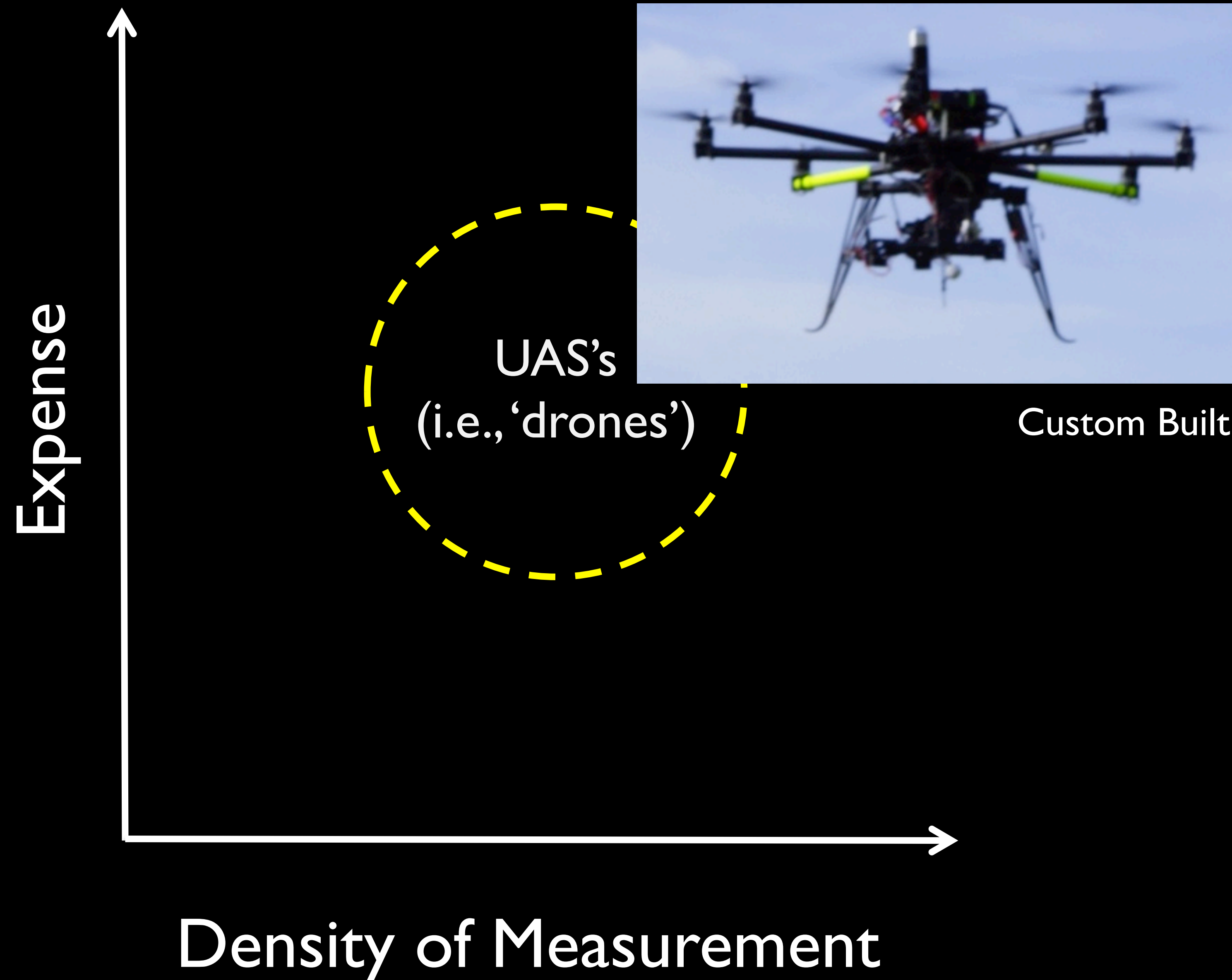


frequency, spatial distribution, spatial resolution, etc.



Density of Measurement

frequency, spatial distribution, spatial resolution, etc.



frequency, spatial distribution, spatial resolution, etc.

Custom Built

In-situ measurements – take-home messages:

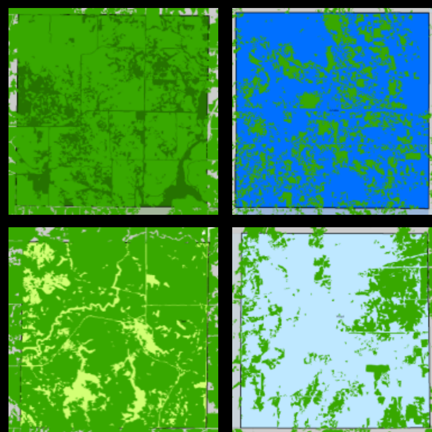
- The new methods aren't new.
- Creative deployment and leveraging:
  - Take advantage of new computing power
  - Crowdsourcing and citizen science
  - Big drops in the cost of instrumentation or analysis (think eDNA or sequencing in general).
- The maker mentality.

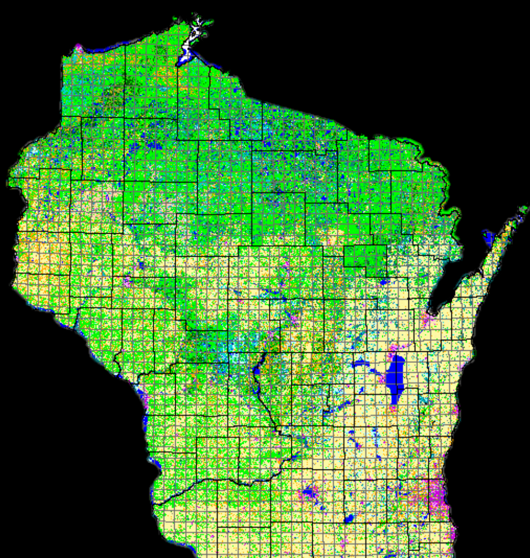
Many, cheap

Citizen science

Trailcams

Townsend *et al.* w/ Wi DNR



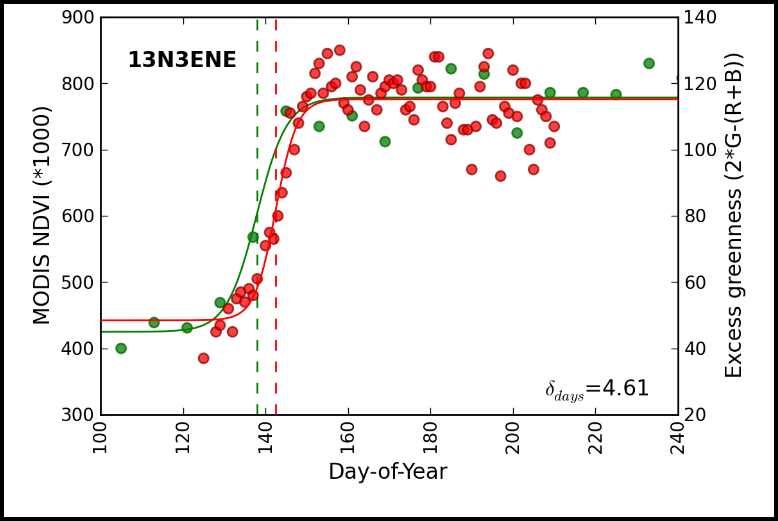


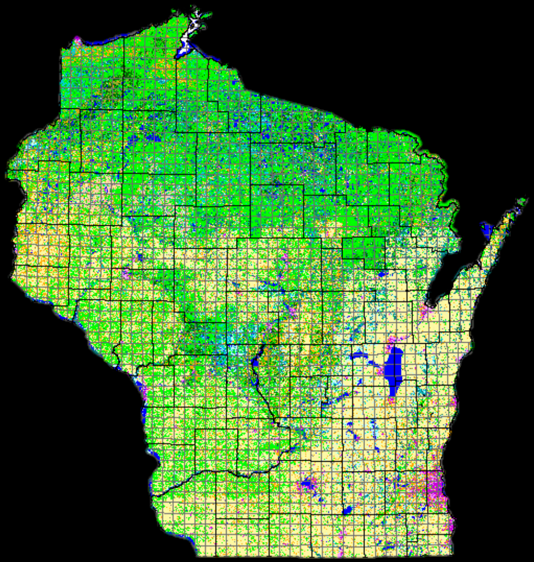
Many, cheap

Link to NASA imagery

Trailcams

Townsend *et al.* w/ Wi DNR

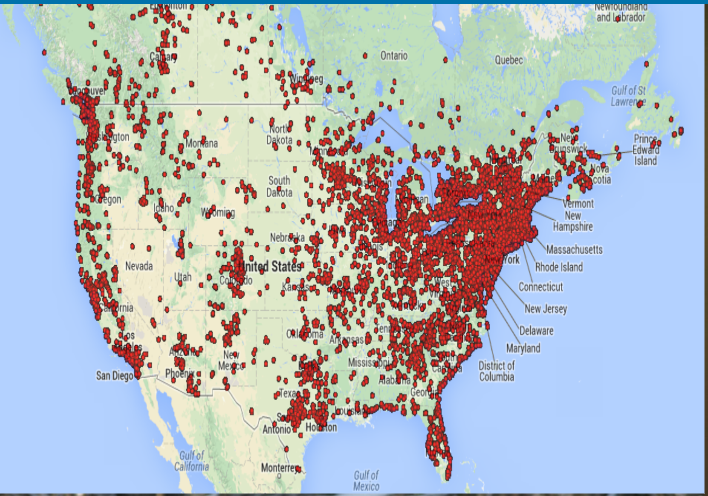




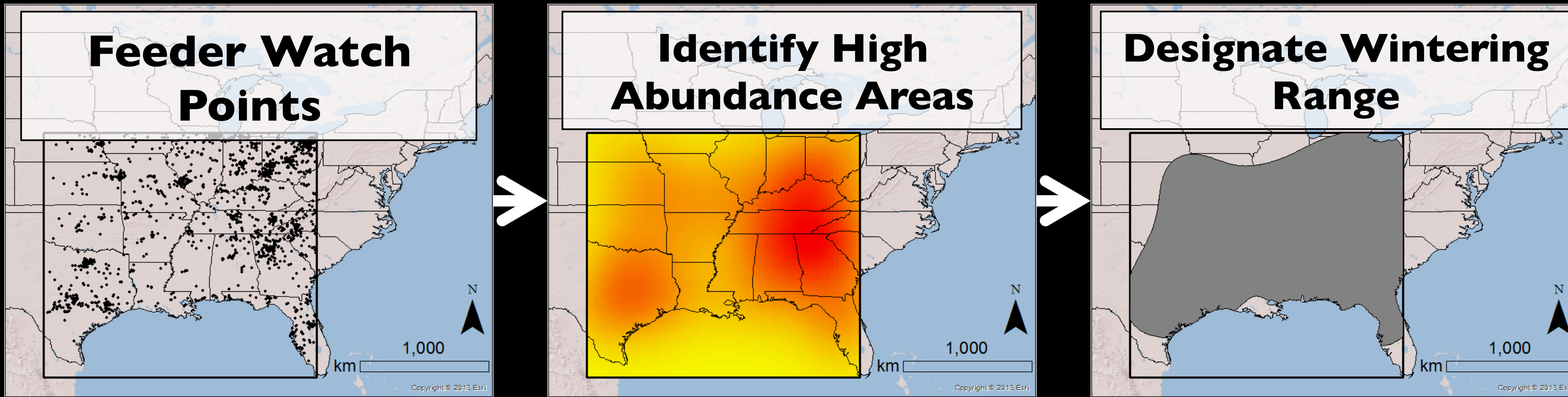
TheCornellLab · BIRD STUDIES CANADA / ÉTUDES D'OISEAUX CANADA

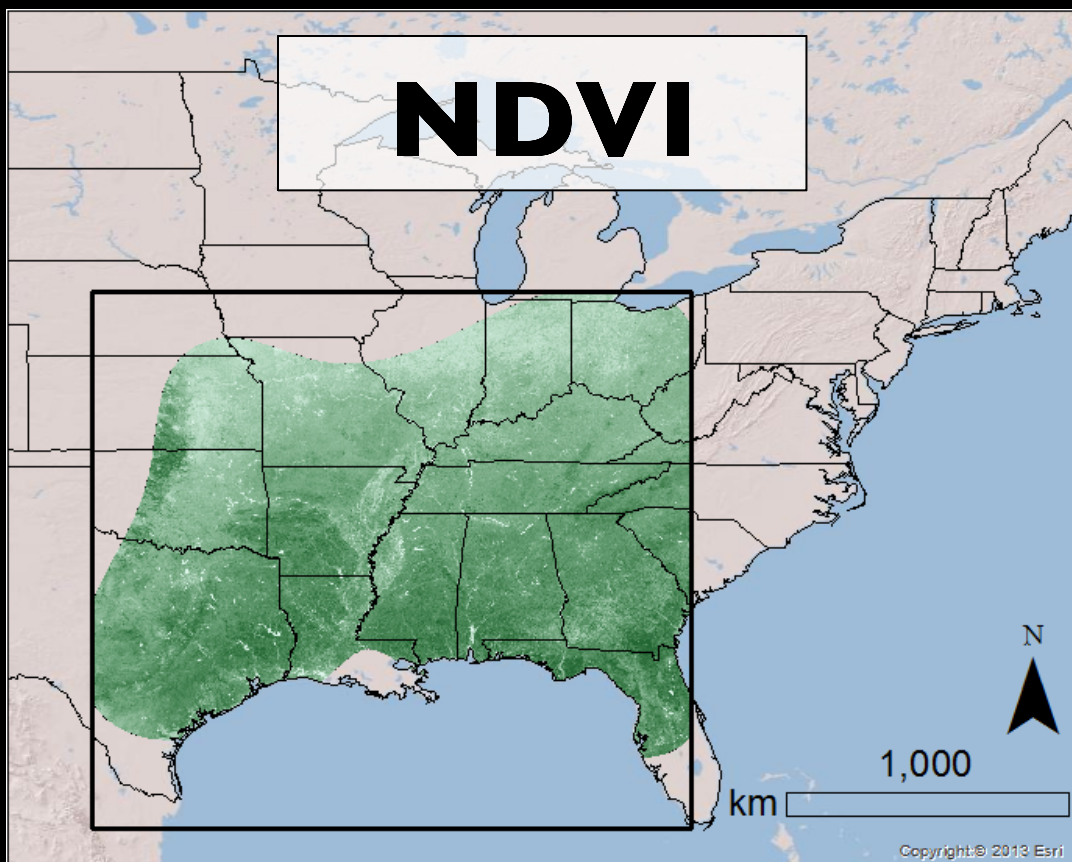
Project FeederWatch

Many, cheap
Citizen science
Bird feeders
Ben Zuckerberg



> 12,000 participants
> 20 years of data





Many, cheap

Citizen science

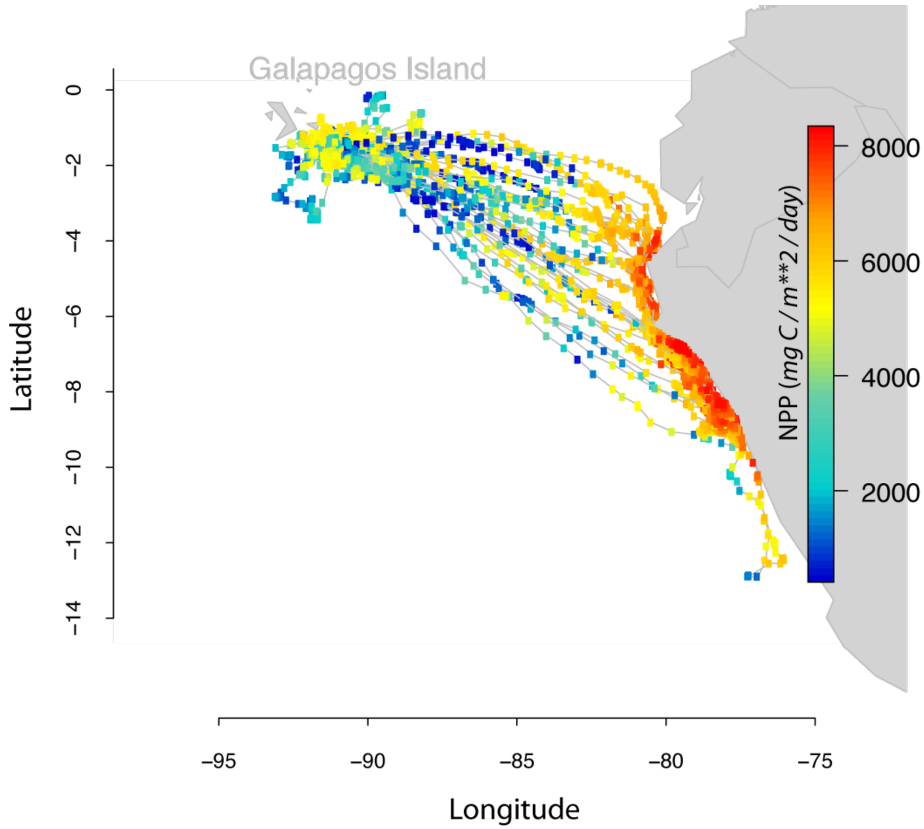
Link to NASA imagery

Eric Ross & Ben Zuckerberg.

Env-DATA– Environmental Data Automated Track Annotation system in MoveBank

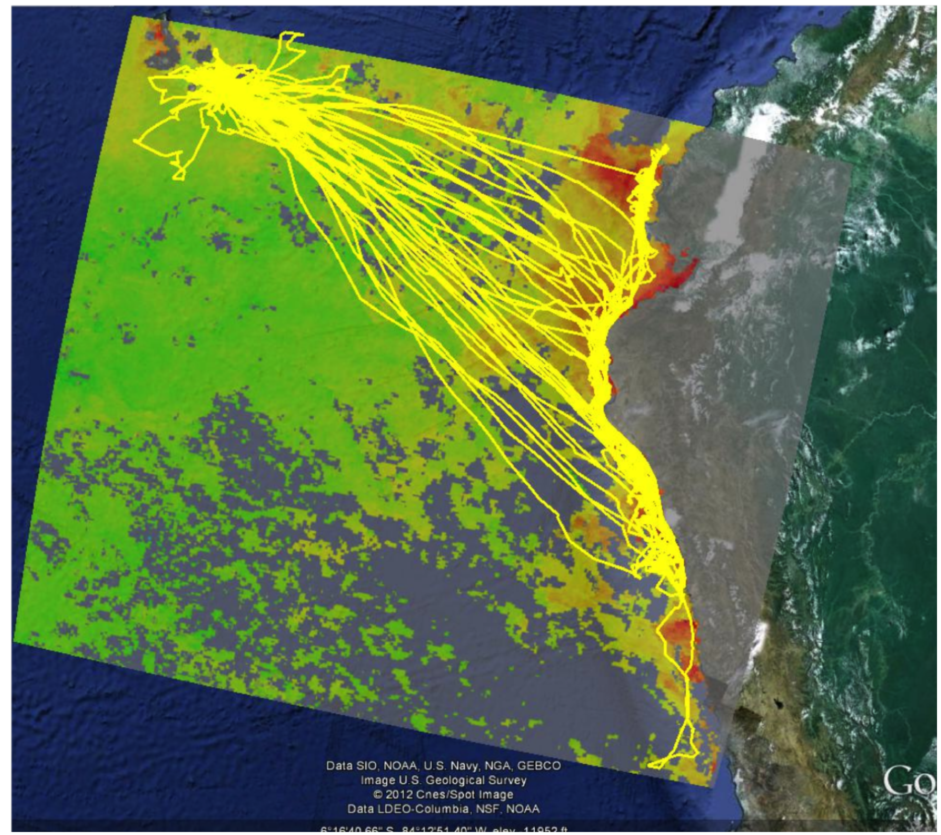
Track annotation:

a) Albatross tracks annotated by Ocean NPP



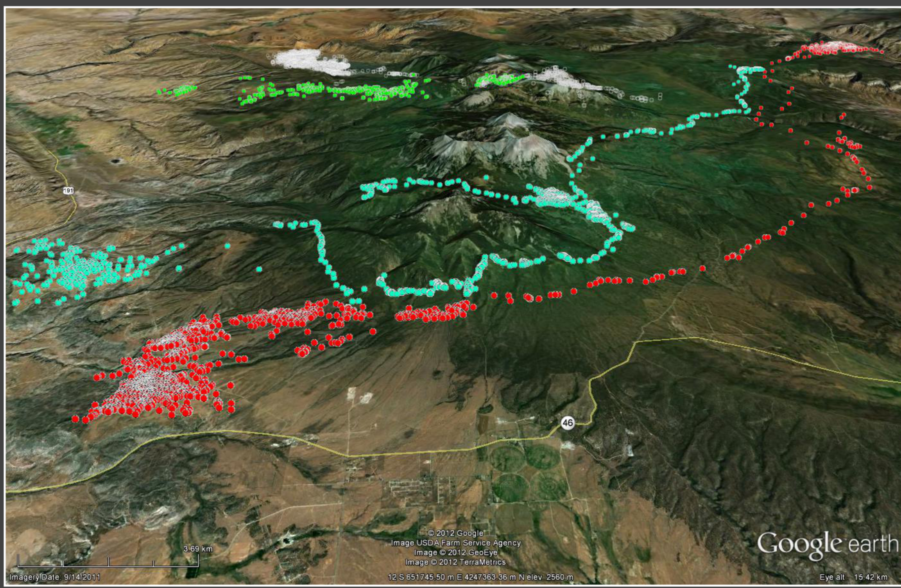
Areal (home-range) annotation:

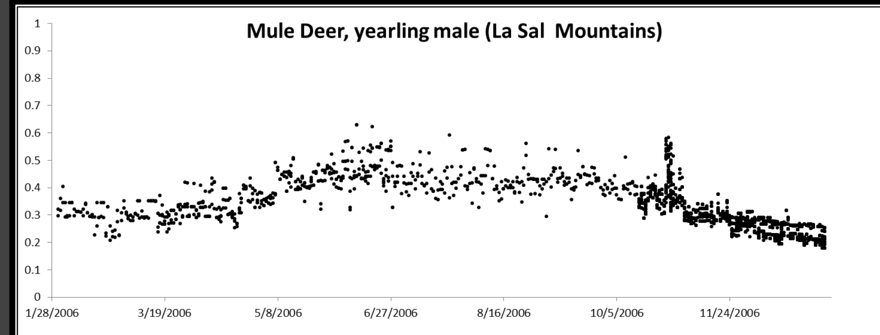
b) Albatross data overlaid on chlorophyll-a

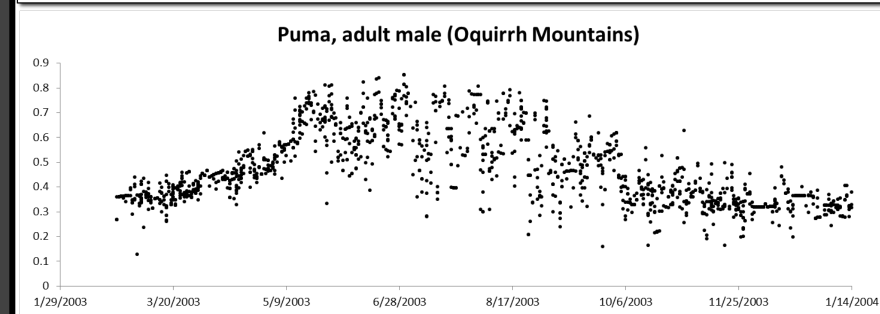


Dodge et al 2013, *Movement Ecology*, 1:3

Wildlife Tracking





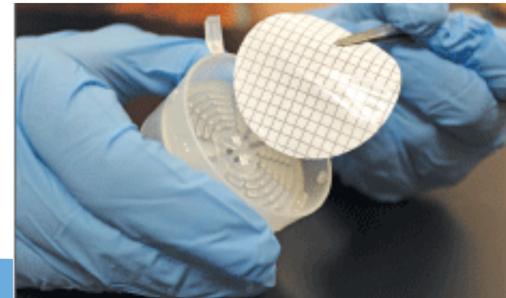


- Habitat Modeling
- Livestock Management
- Game Management
- Endangered Species Protection
- Human-Wildlife Conflict Prevention

Mattson, Sexton et al. 2010-2015. NASA Biodiversity & Ecological Forecasting Program.

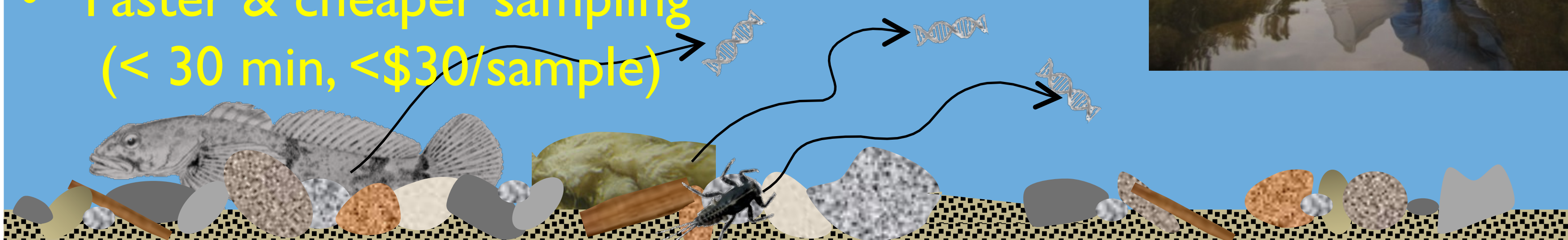
Freshwater fish, invertebrates & algae are often difficult to detect:

- Small, cryptic, rare
- Low detection rates
- Time and resource intensive

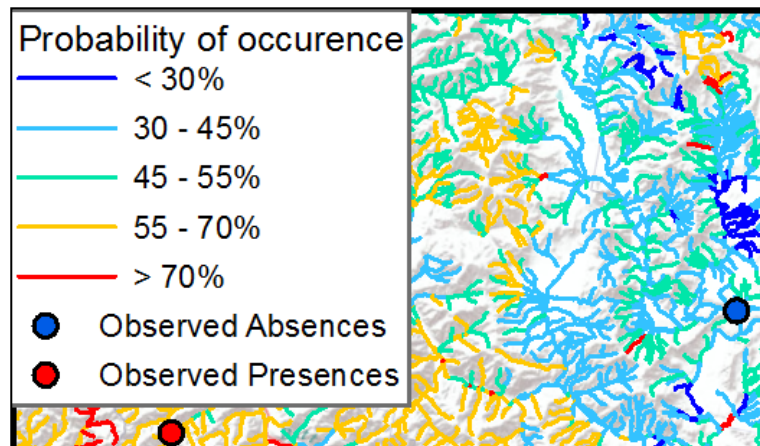


Environmental DNA (qPCR)

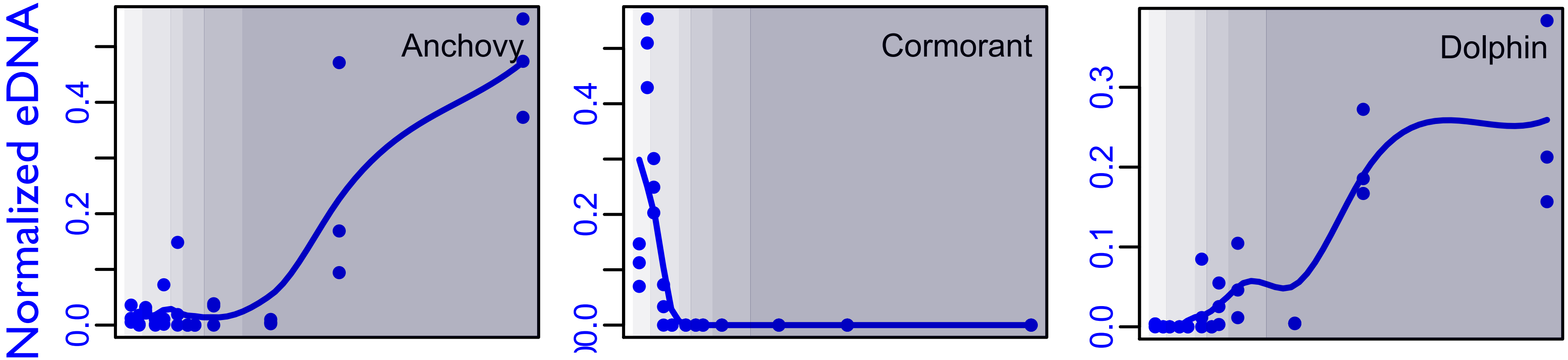
- Detection rates 80-96%
- Faster & cheaper sampling (< 30 min, <$30/sample)



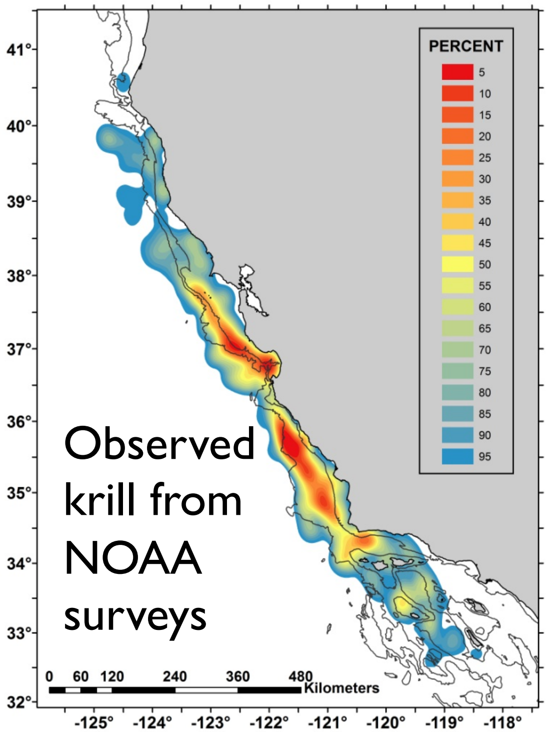
More and better occurrence data
→ Robust relationships to NASA data
→ Resulting in reliable predictions



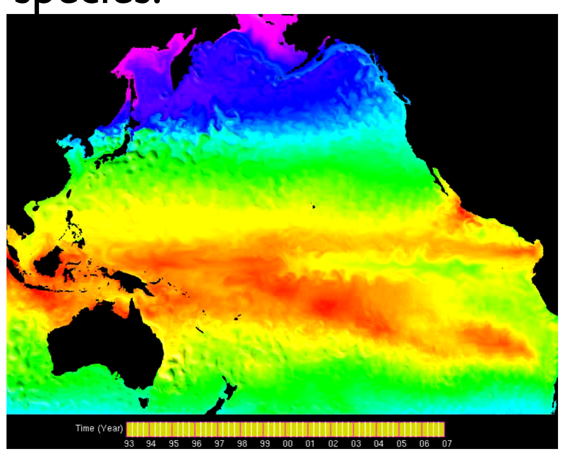
MaxEnt diatom model correctly classified 93-100% of validation sites using eDNA and traditional data

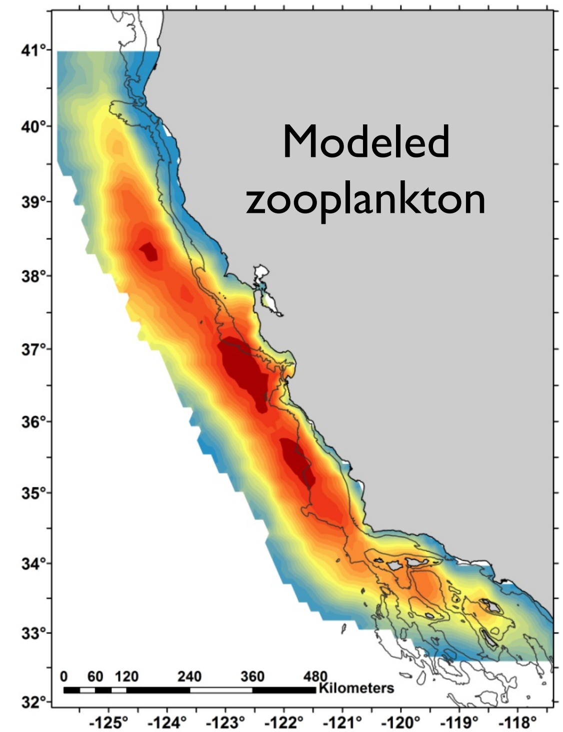


eDNA can detect organisms that divers do not



The models can now simulate zooplankton that are important food for salmon and other commercially important species.



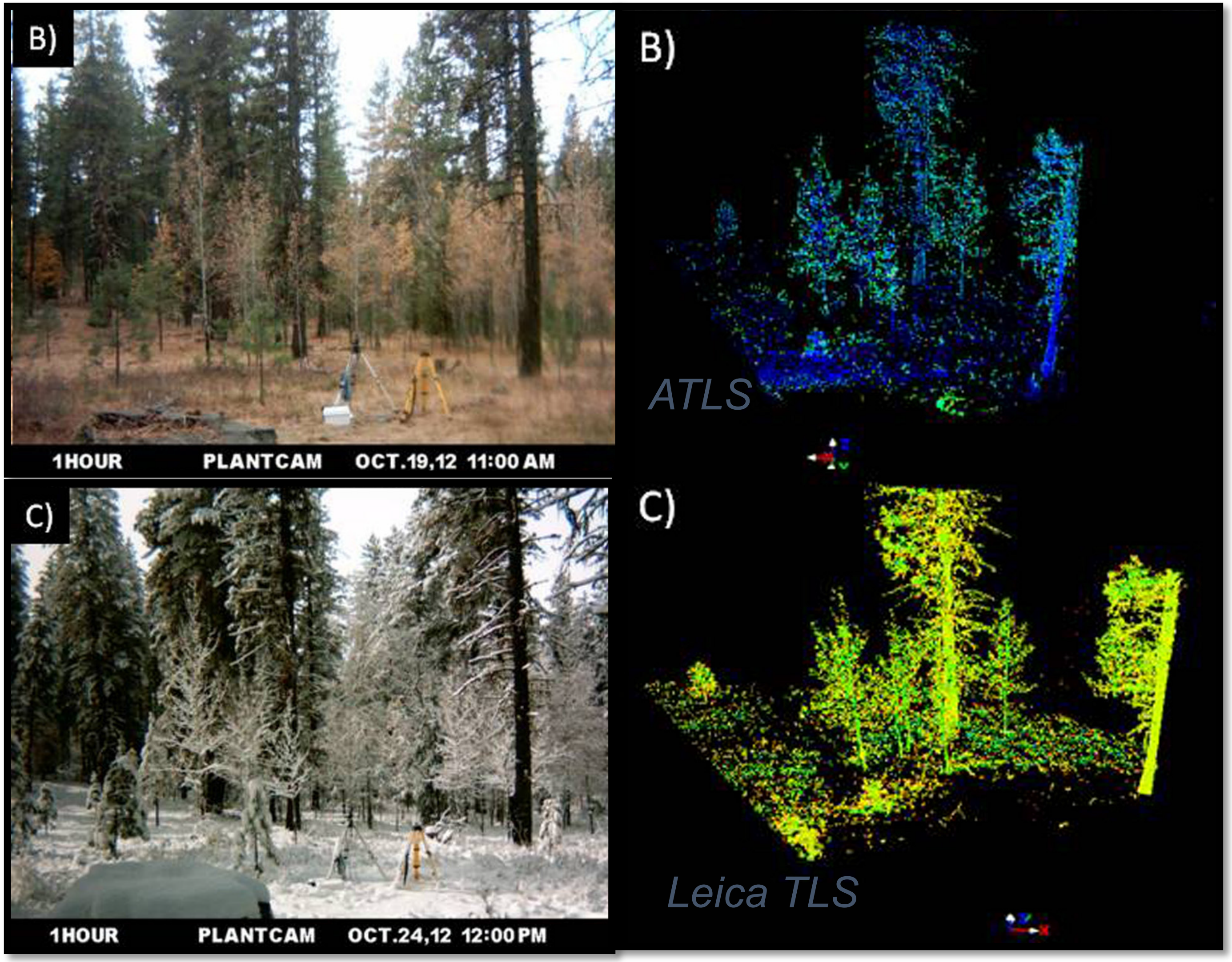


Many, cheap | Broadscale sampling (eDNA) | Francisco Chavez

Increasing temporal sampling

Autonomous Terrestrial Laser Scanner (ATLS)

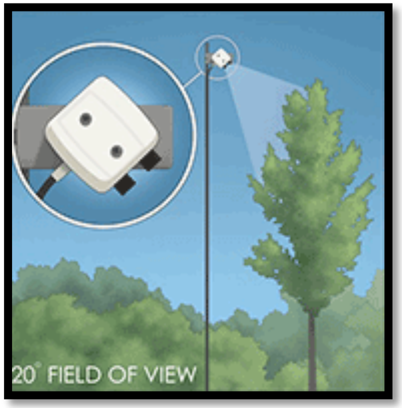
Eitel, Vierling, Magney (AFM, 2013)



Small, inexpensive, calibrated spectral radiometers

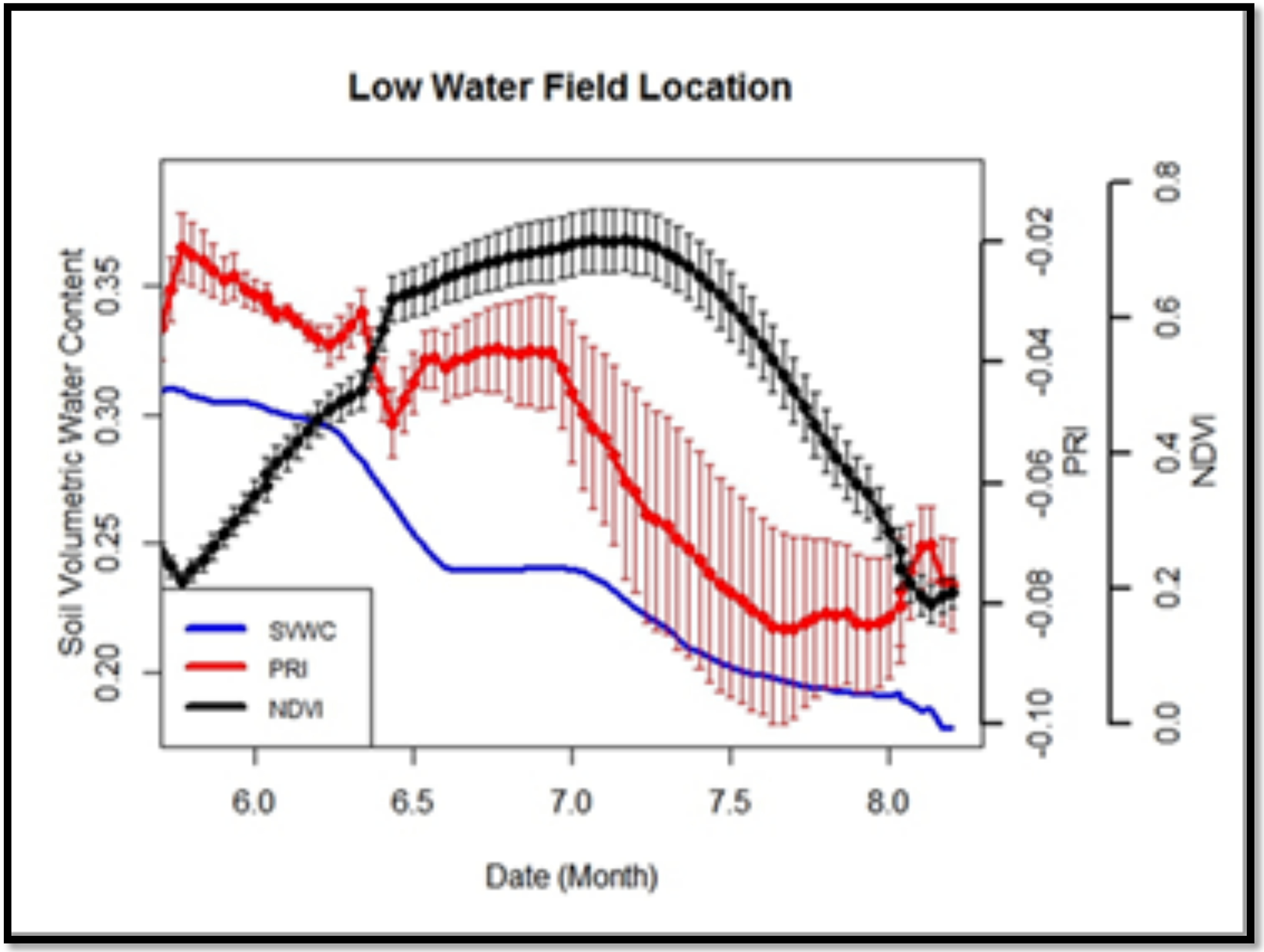
Original design

(Garrity, Vierling, et al., AFM, 2010)



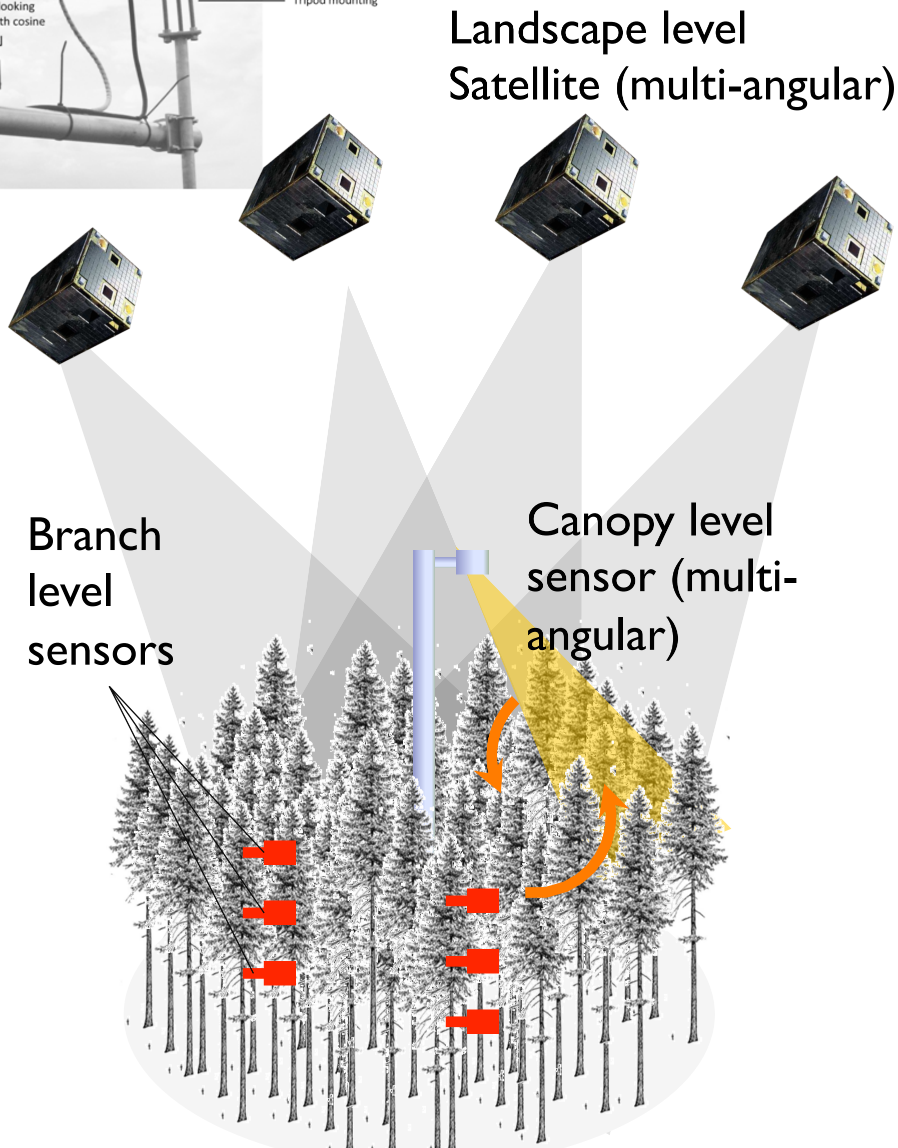
Decagon design

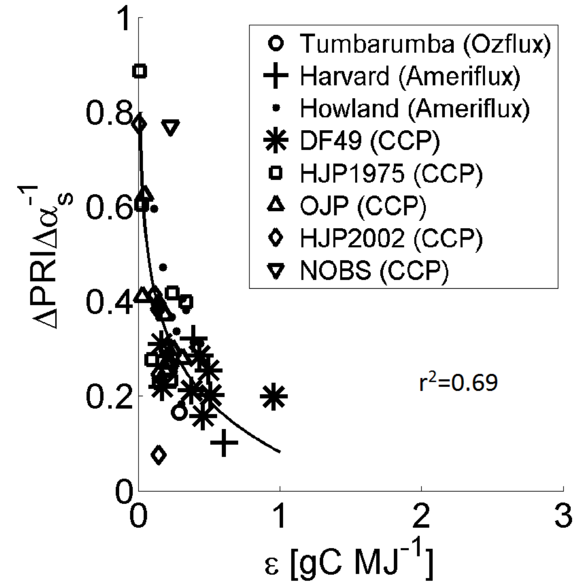
(Campbell, Garrity, et al.)

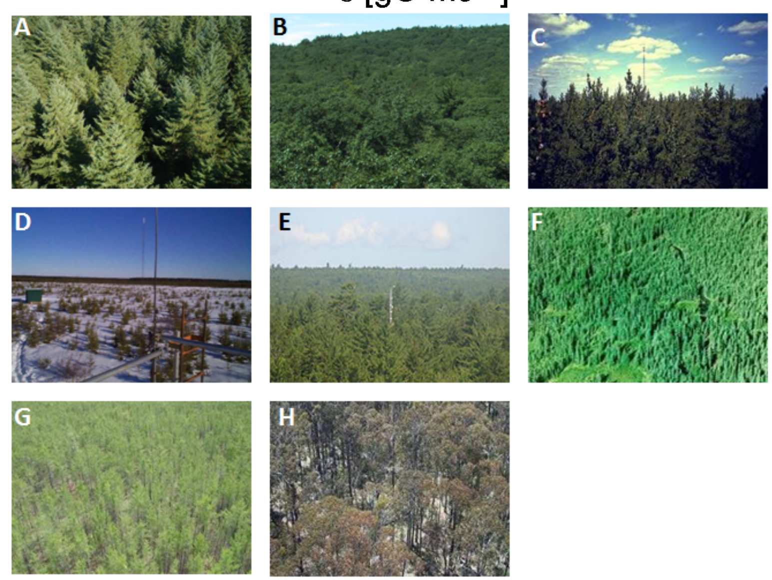


Seasonal PRI and NDVI trends (Magney et al., in review)

Multi-angle PRI to estimate LUE





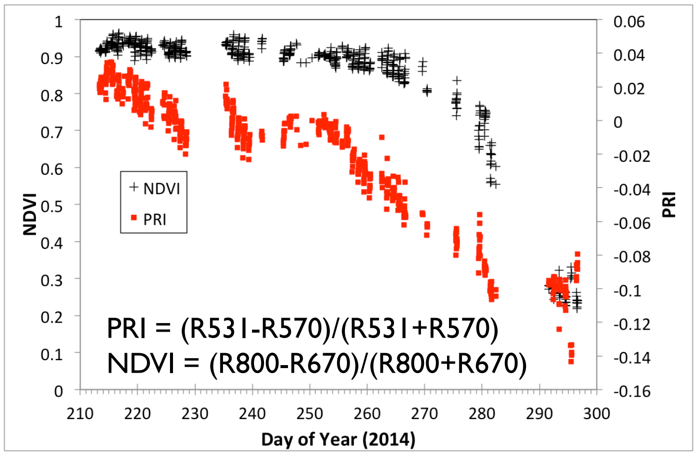


More expensive | Piggybacking Spectrometer/Tower | Thomas Hilker

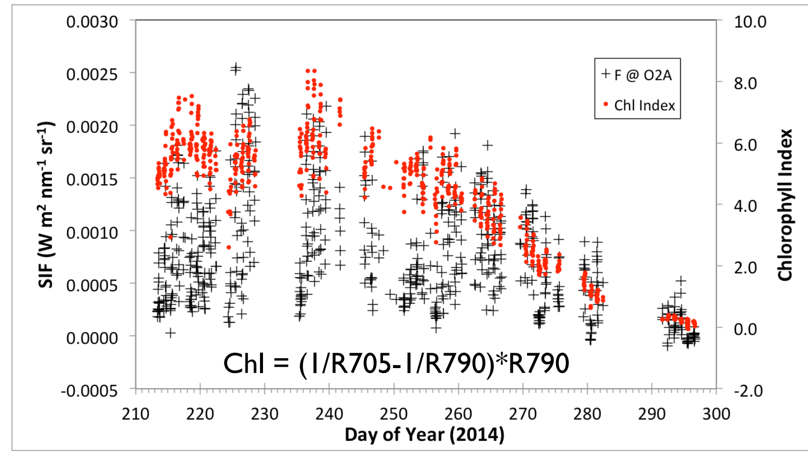
Seasonal/Diurnal Spectral Vegetation Indices from FUSION

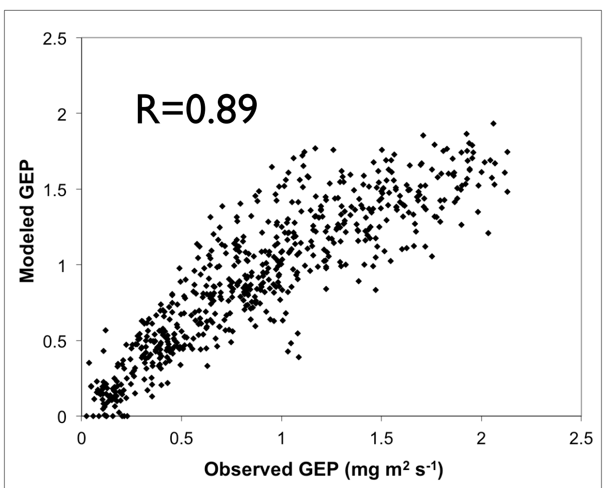
Automated tower collects hyperspectral bidirectional measurements
Data from cornfield in Beltsville, MD
All observations with 25° VZA and 330° from N VAA

NDVI and PRI



Far-red Fluorescence and Chlorophyll Index





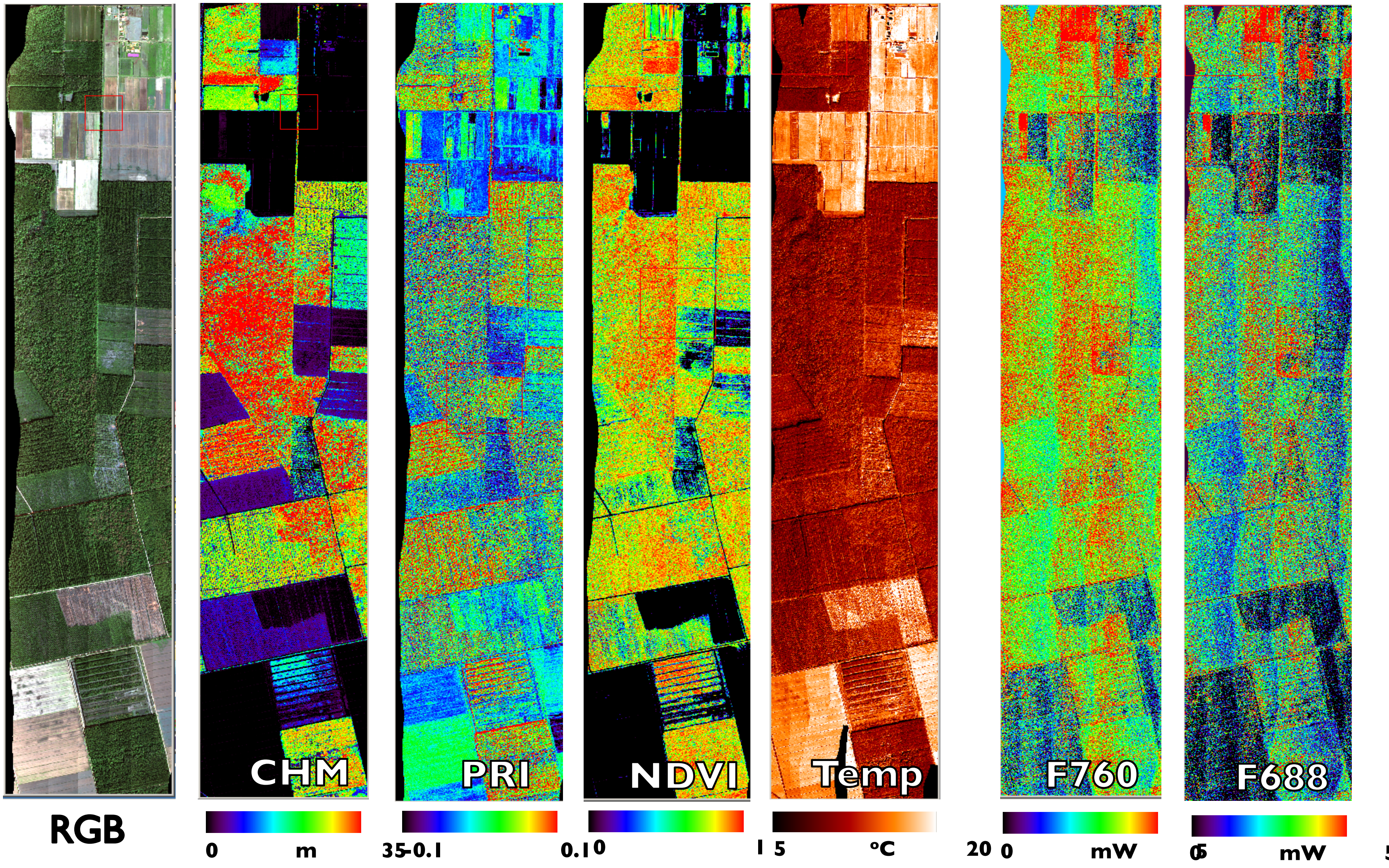
Model of GEP using NDVI, PRI and SIF for half-hourly values through the growing season

More expensive
Tower Instrumentation
Fluorescence
Betsy Middleton *et al.*

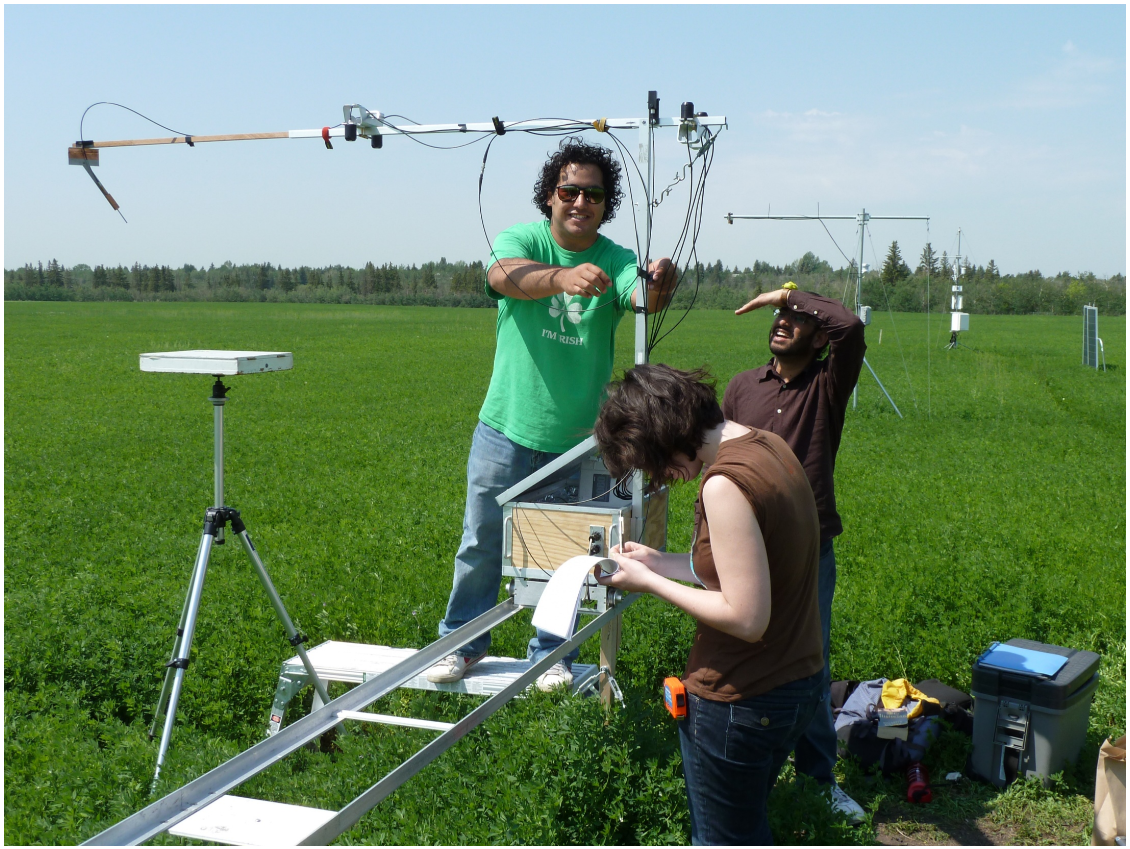
FLEX-US 2013 Parker Tract NC

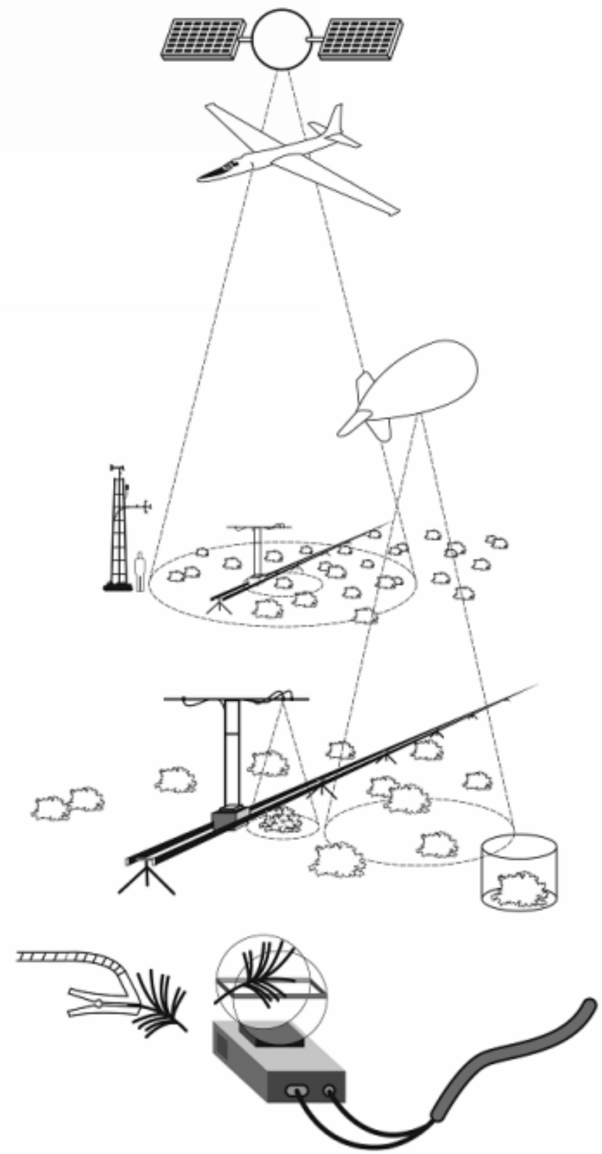
NASA Goddard's LiDAR Hyperspectral Thermal Imager (G-LiHT)

Plant Fluorescence

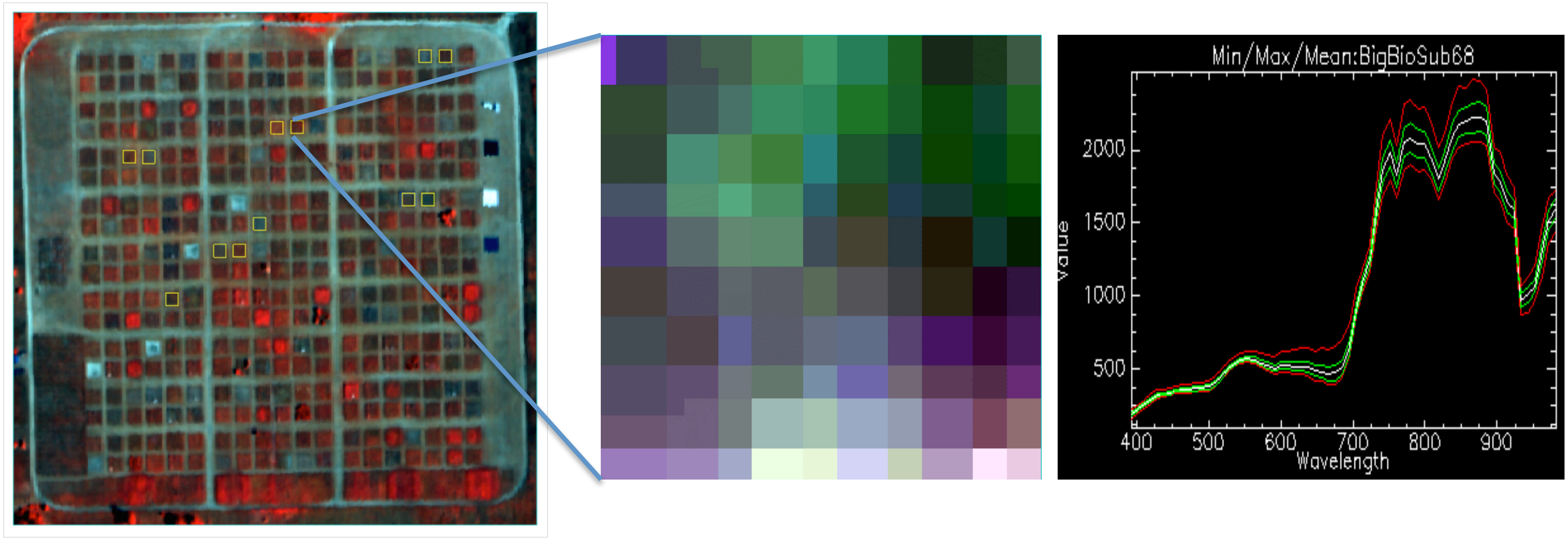


Remote sensing of carbon fluxes: what can bottom-up approaches provide?

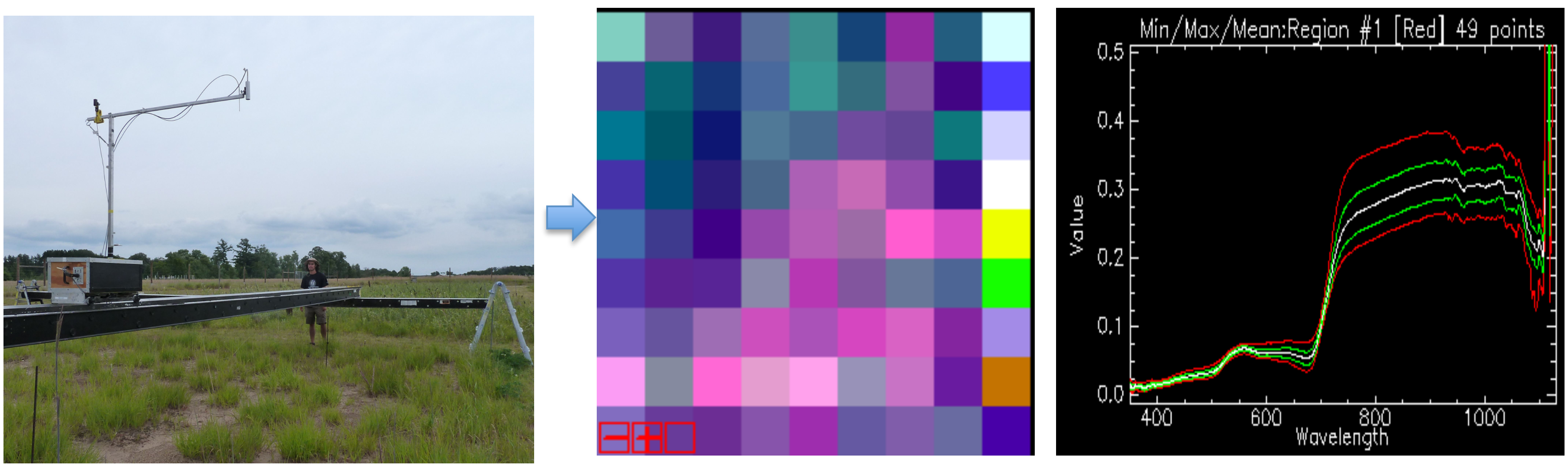




Slide from John Gamon

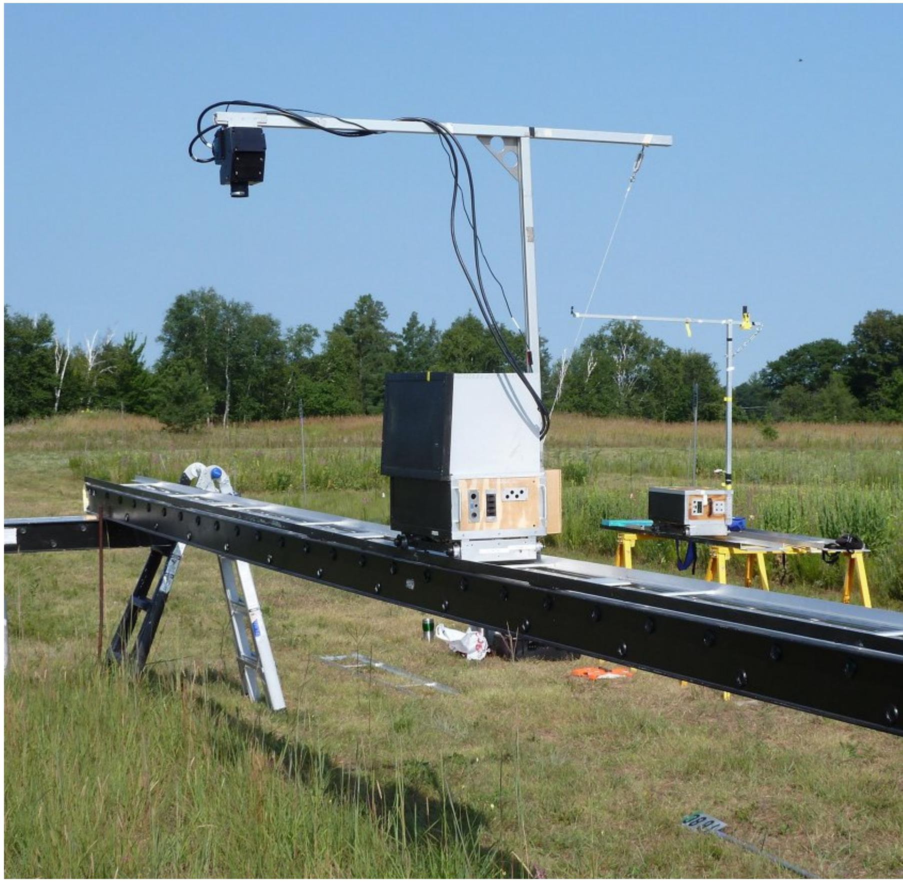


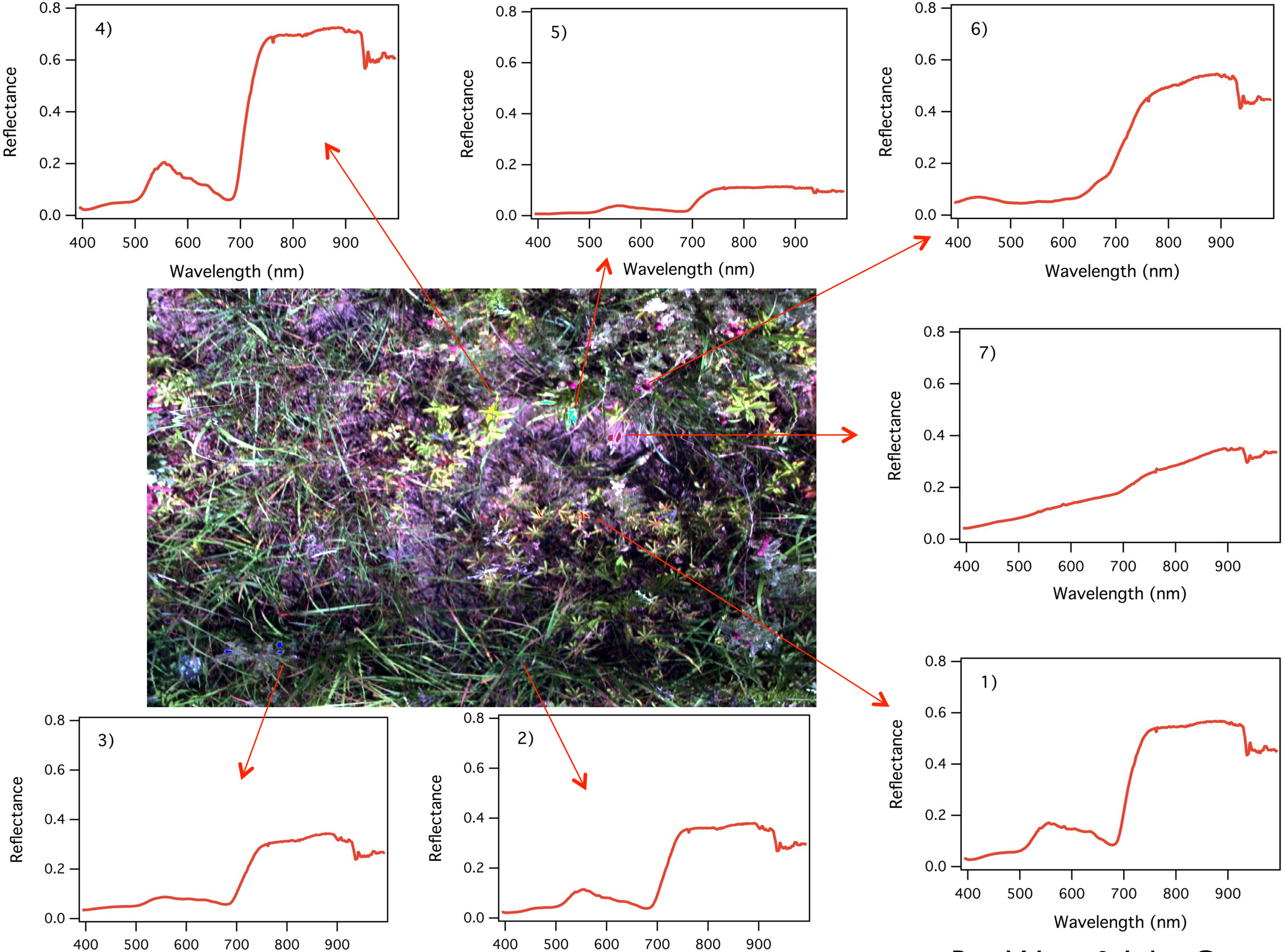
Plot 68 (SR = 16)



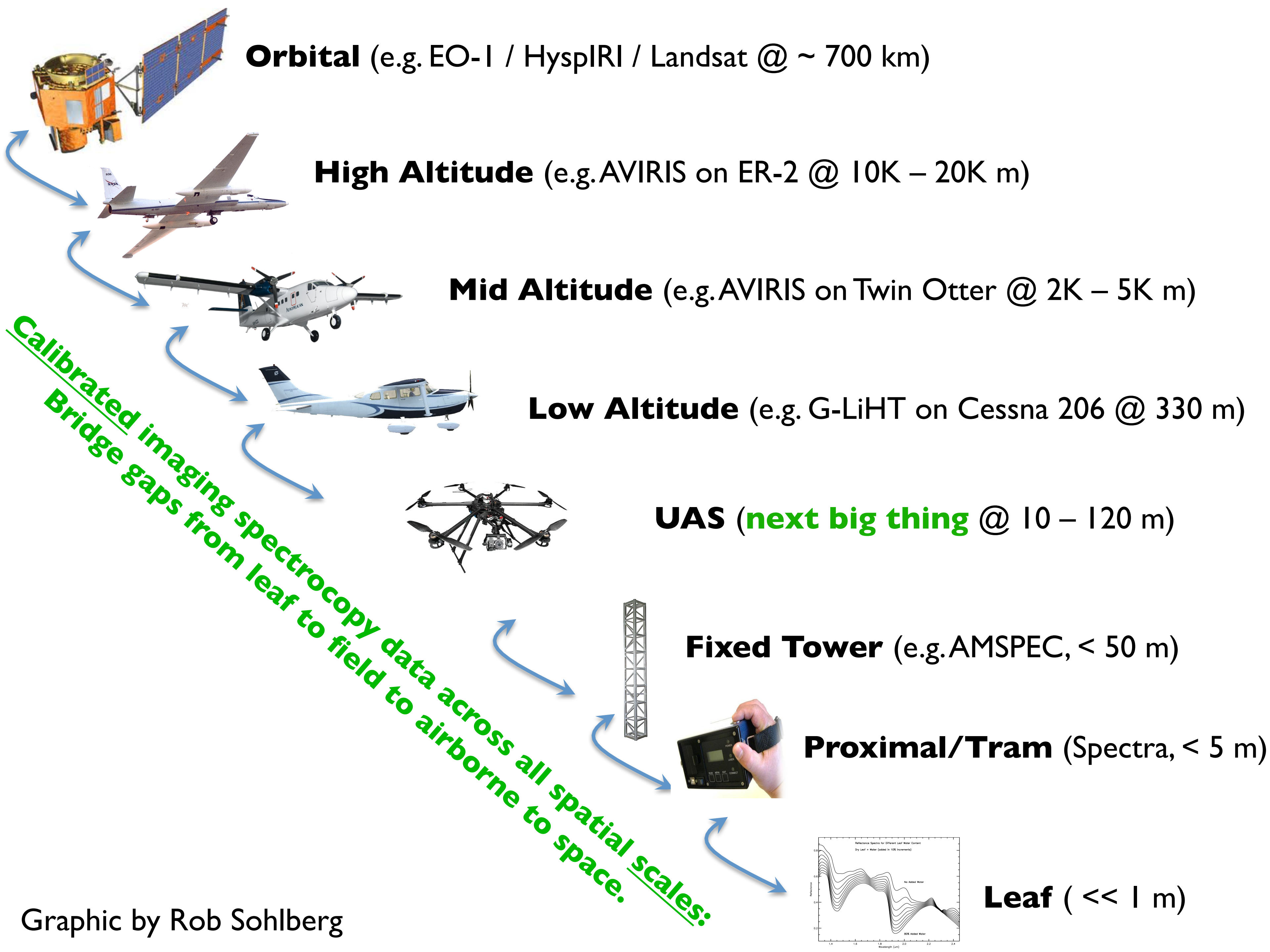
Intermediate | Spectrometer on a tram | John Gamon

Imaging Spectrometer on Tram



Ran Wang & John Gamon

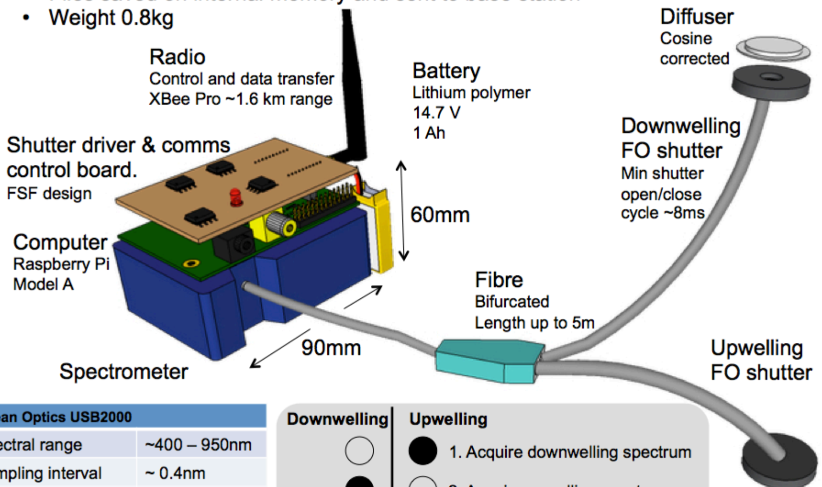

Orbital (e.g. EO-1 / HyspIRI / Landsat @ ~ 700 km)
High Altitude (e.g. AVIRIS on ER-2 @ 10K – 20K m)
Mid Altitude (e.g. AVIRIS on Twin Otter @ 2K – 5K m)
Low Altitude (e.g. G-LiHT on Cessna 206 @ 330 m)
UAS (next big thing @ 10 – 120 m)
Fixed Tower (e.g. AMSPEC, < 50 m)
Proximal/Tram (Spectra, < 5 m)
Leaf (<< 1 m)
Calibrated imaging spectroscopy data across all spatial scales:
Bridge gaps from leaf to field to airborne to space.
Graphic by Rob Sohlberg

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Field Spectroscopy Facility
National Centre for Earth Observation

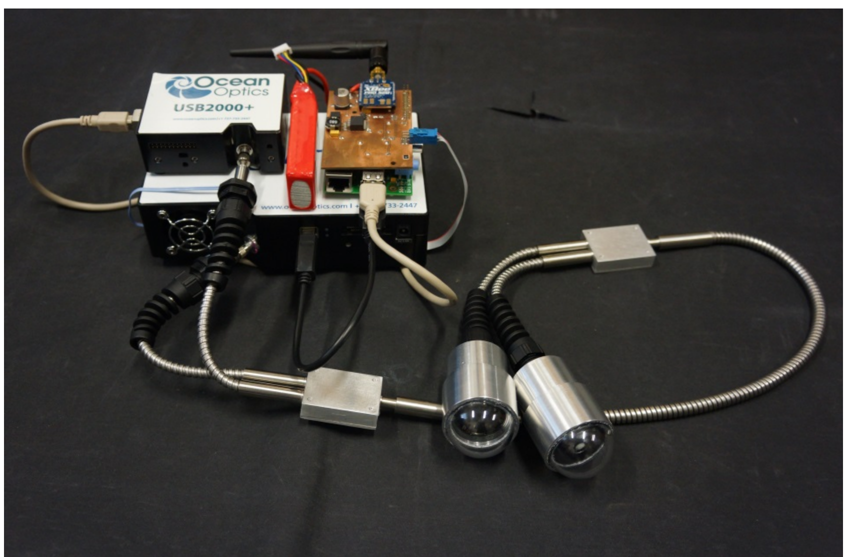
FSF Piccolo wireless DFOV single spectrometer system

- measurements on demand or time series
- Files saved on internal memory and sent to base station
- Weight 0.8kg



Ocean Optics USB2000	
Spectral range	~400 – 950nm
Sampling interval	~ 0.4nm
FWHM	1.3nm
Digitisation	16-bit

Downwelling	Upwelling	
○	●	1. Acquire downwelling spectrum
●	○	2. Acquire upwelling spectrum
●	●	3. Acquire dark spectrum



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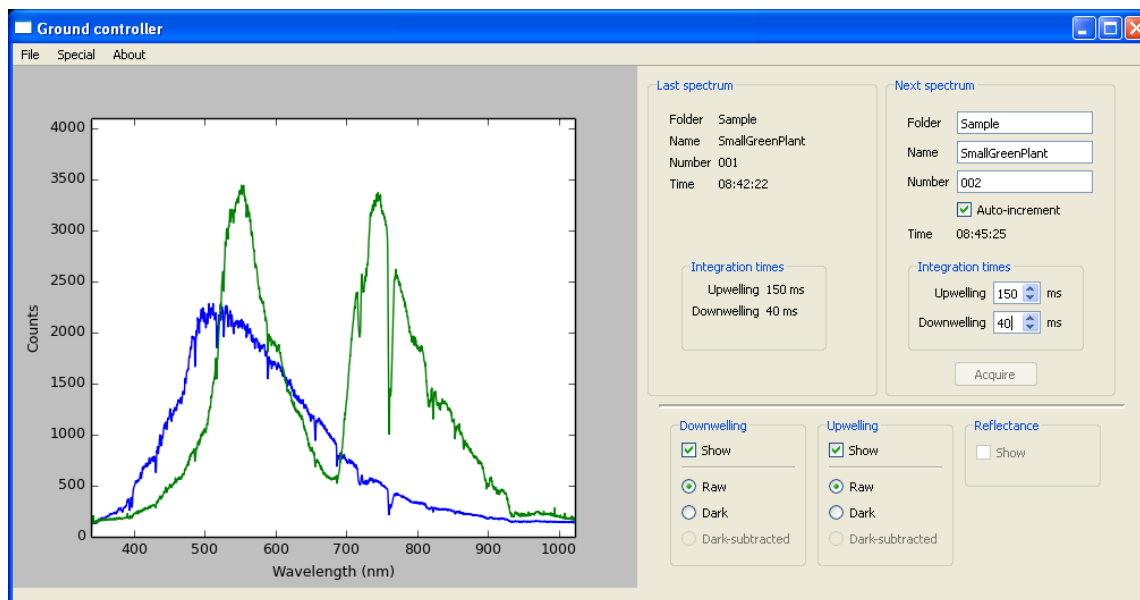
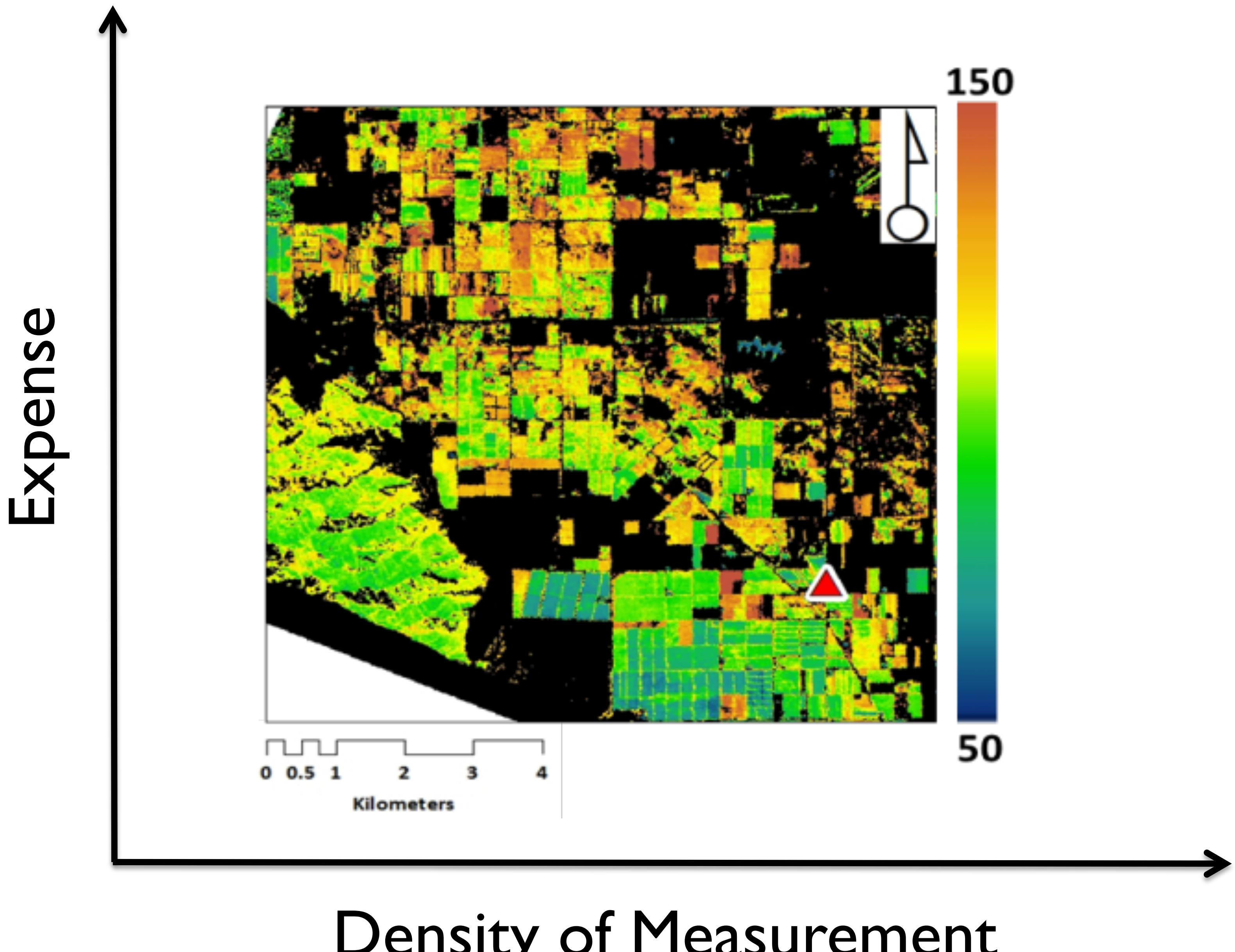
Field Spectroscopy Facility

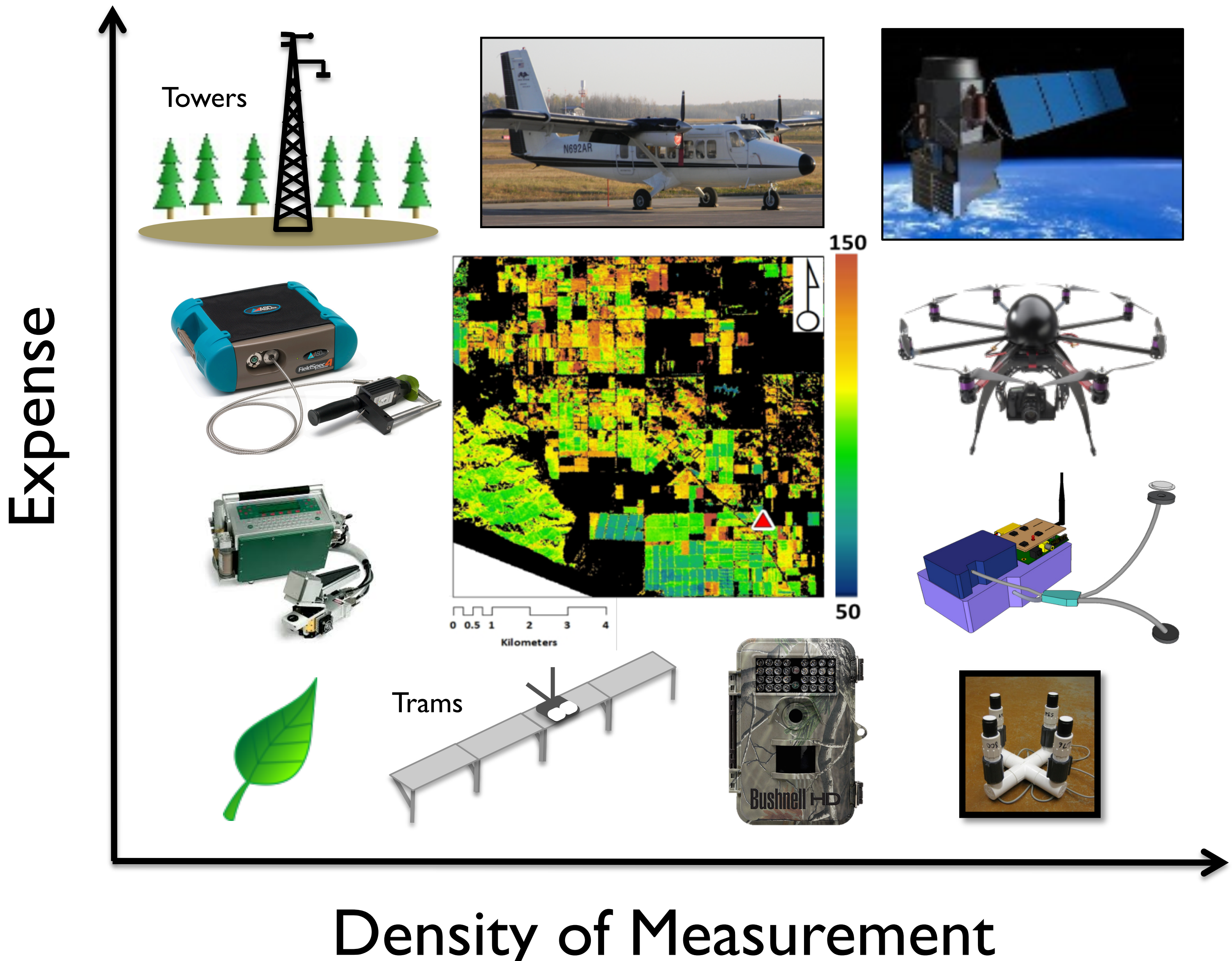
National Centre for Earth Observation



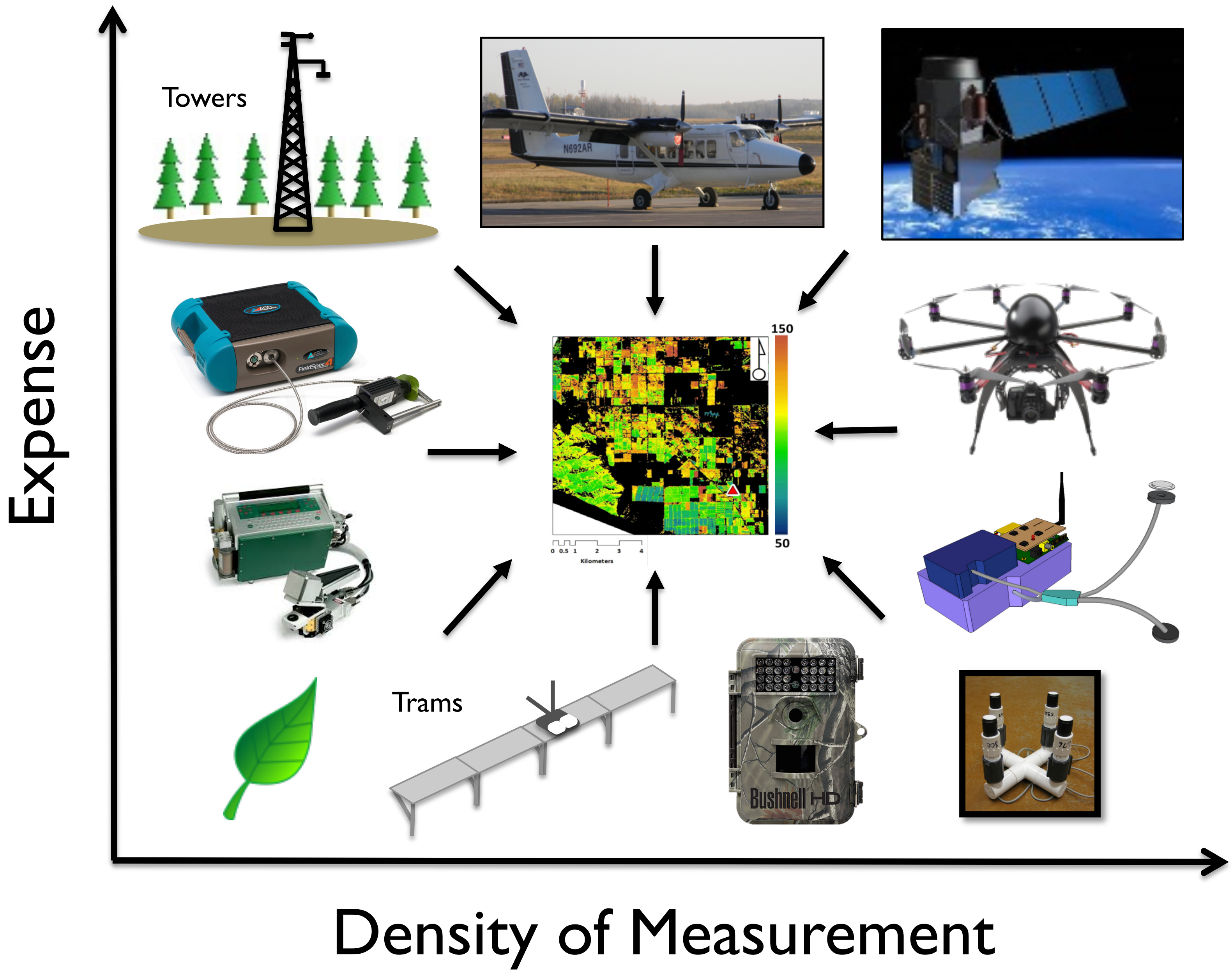
Scaling Complexity to Enable Science

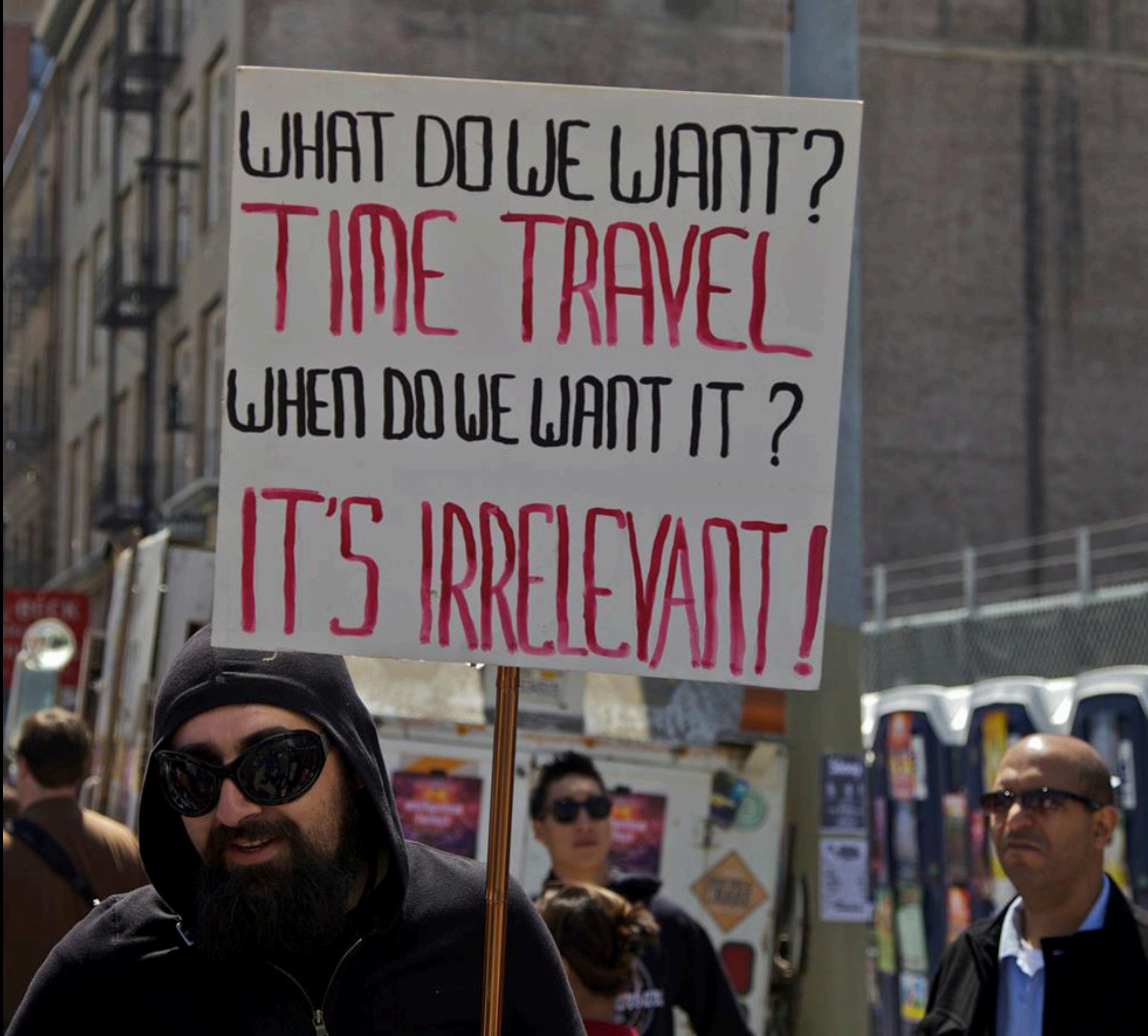


Scaling Complexity to Enable Science



Scaling Complexity to Enable Science




WHAT DO WE WANT?
TIME TRAVEL
WHEN DO WE WANT IT?
IT'S IRRELEVANT!