
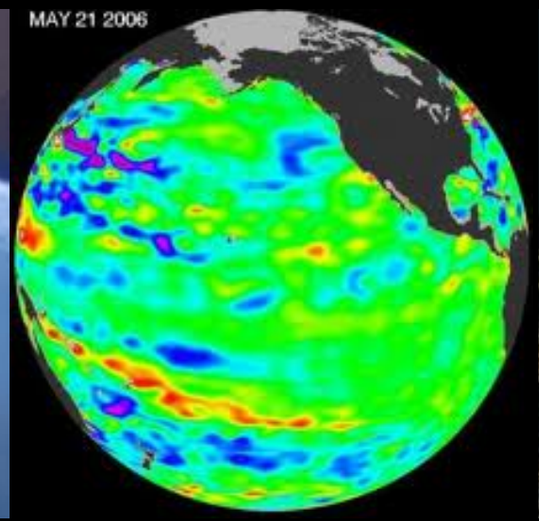


Ground and Airborne Remote Sensing

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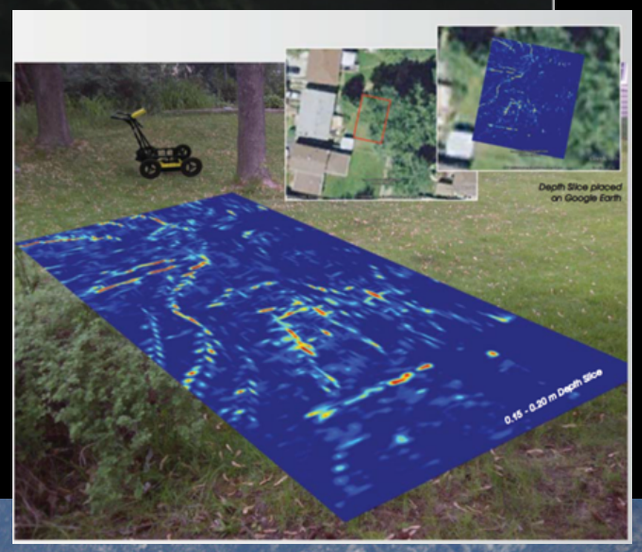
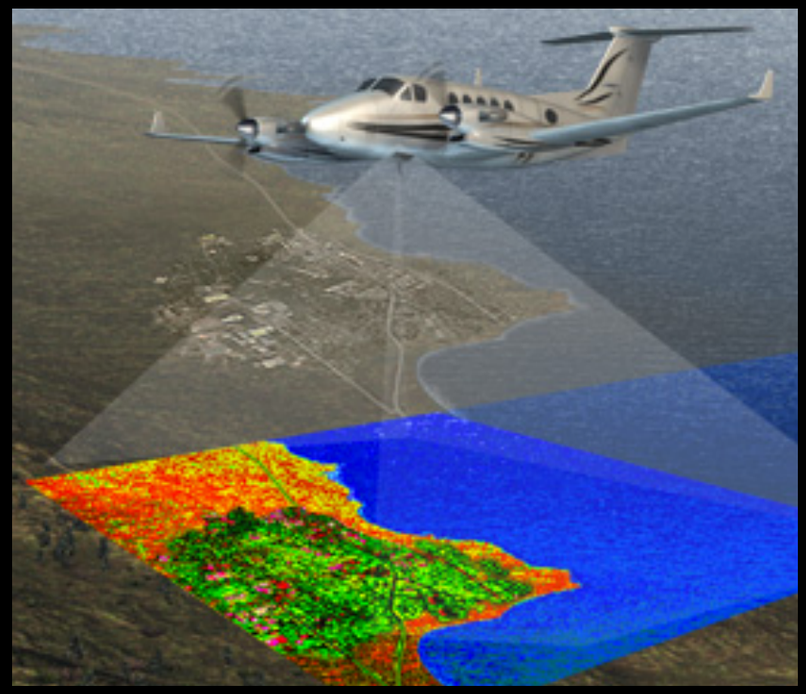
EVSC 4010/7010 Week 12

Why ground/airborne remote sensing?

- Proof-of-concept
- Validation
- Provides more details
- Cheaper?

Examples of ground/airborne remote sensing





Examples of ground/airborne remote sensing

- Measurements of solar radiation
- Vegetation
  - Leaf area index
  - Reflectance
  - Thermal
- Underground Remote Sensing
- Trace-gas measurements on the ground
- Drone-based Remote Sensing

Examples of ground/airborne remote sensing

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Solar radiation

Pyranometer
(irradiance)

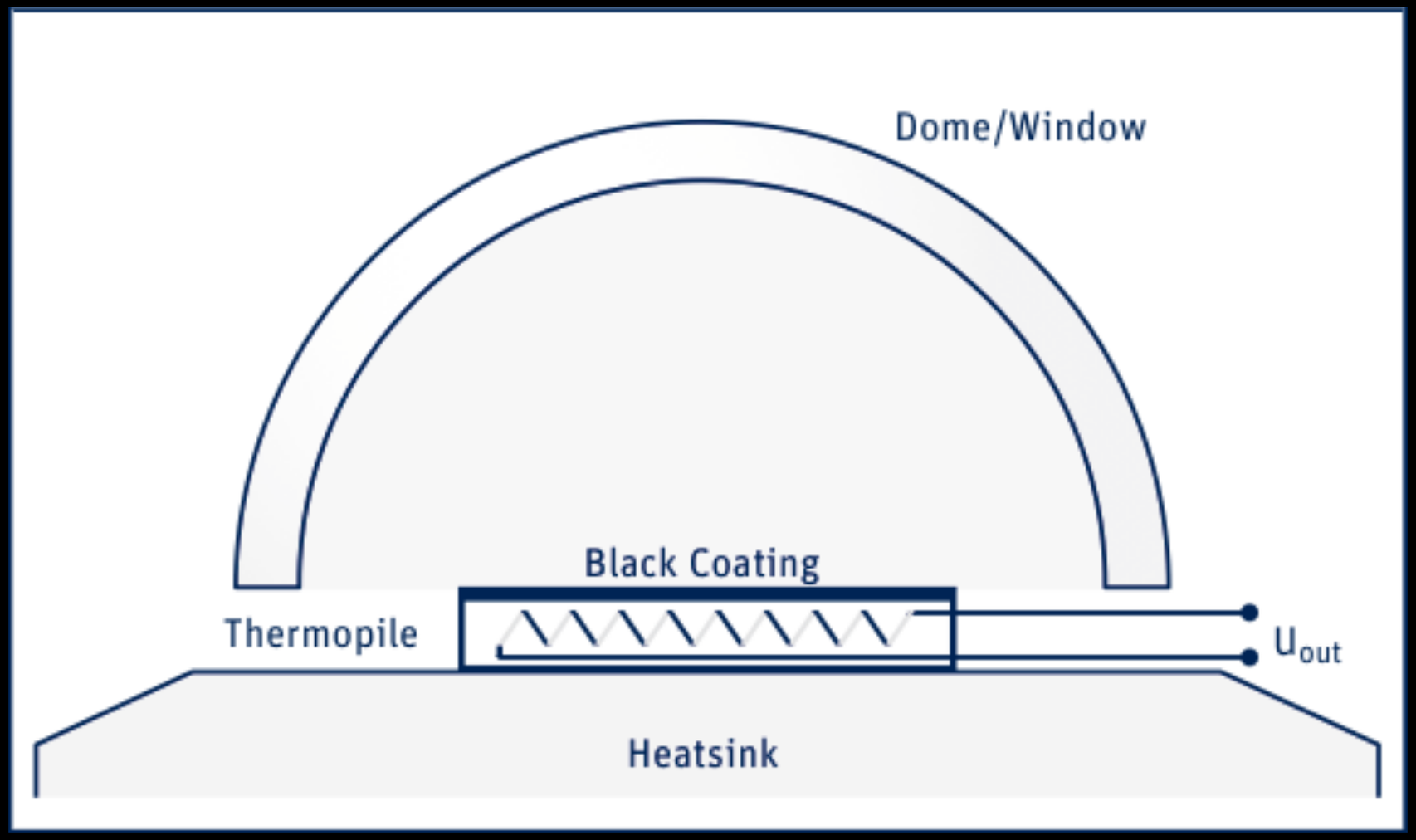
Pyrgeometer
(IR radiation)

Albedometer
(Albedo)

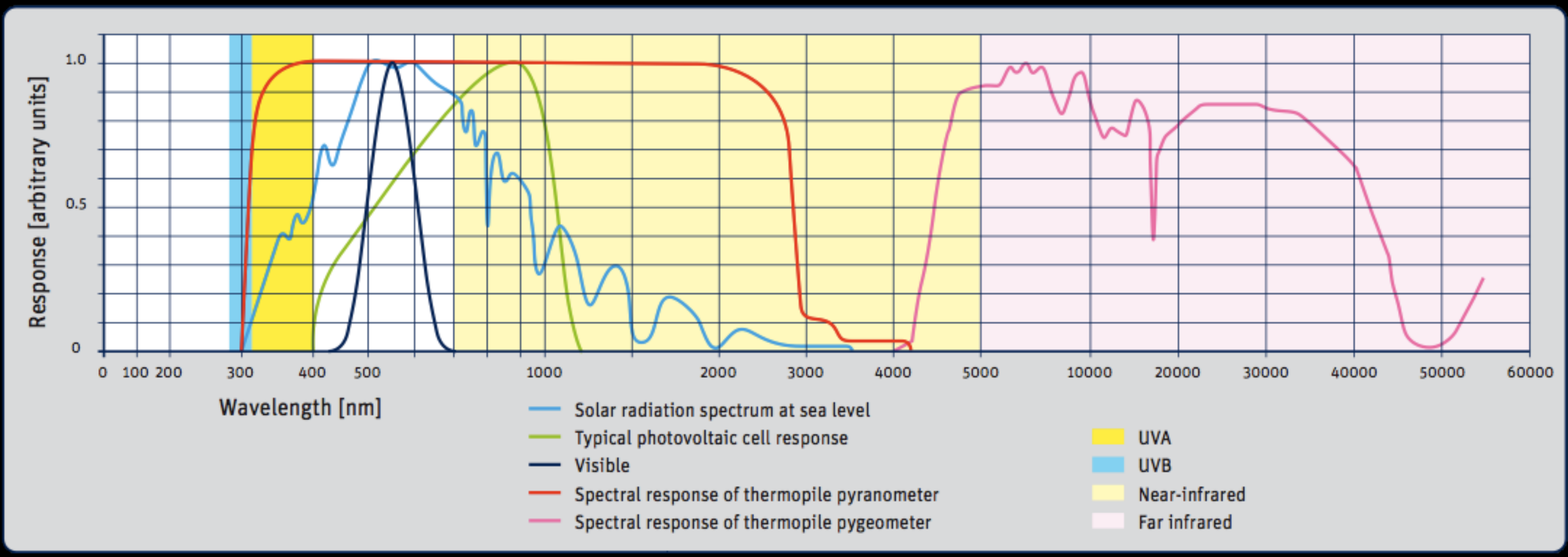
Sun tracker
(all radiation)

PAR sensor
(PAR)

How does a pyranometer work?



Irradiance and Spectral response



Integrated Irradiance = response(λ) * irradiance (λ)

Examples of ground/airborne remote sensing

- Measurements of solar radiation
- Vegetation
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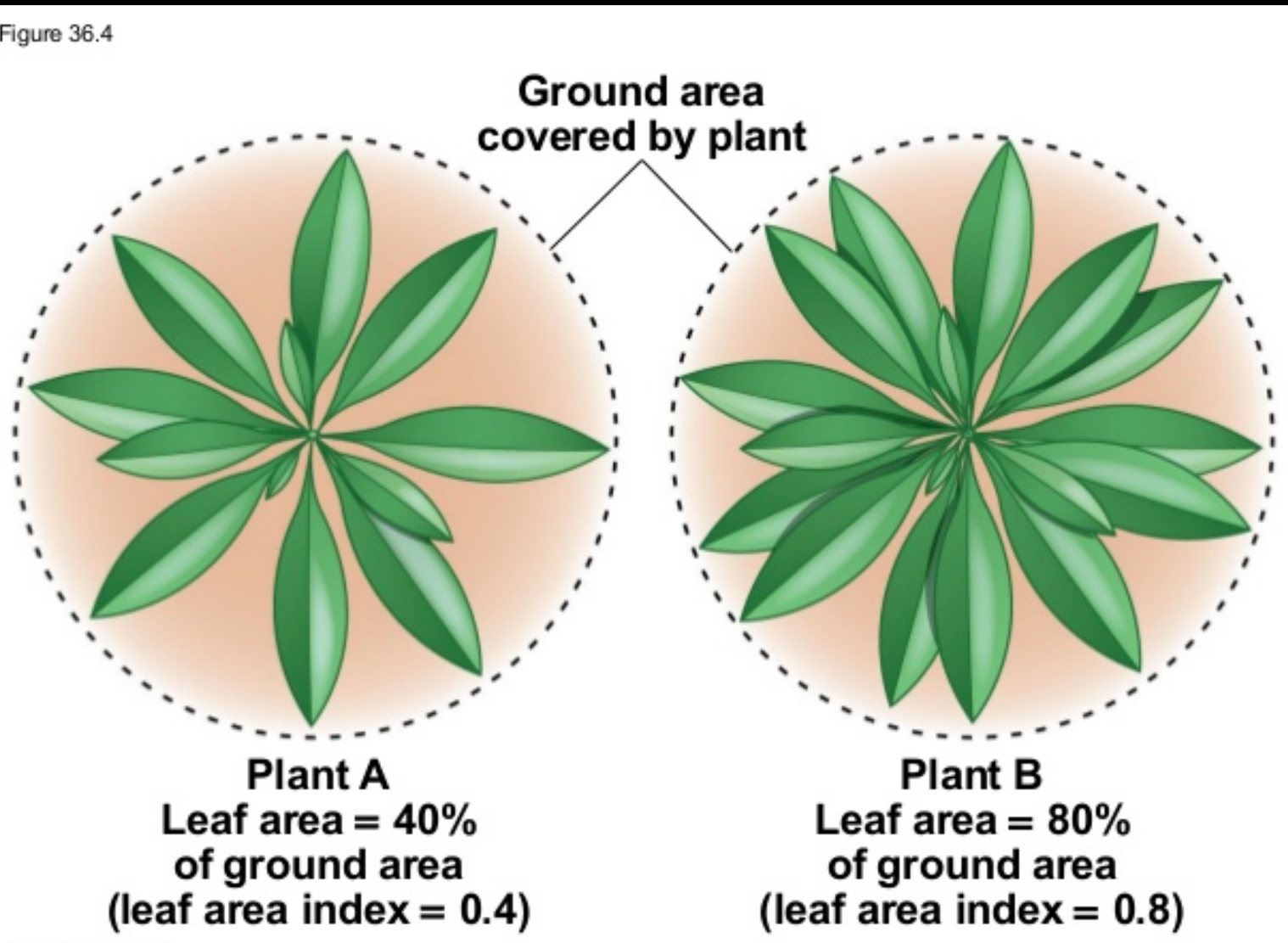
Leaf area index

Figure 36.4



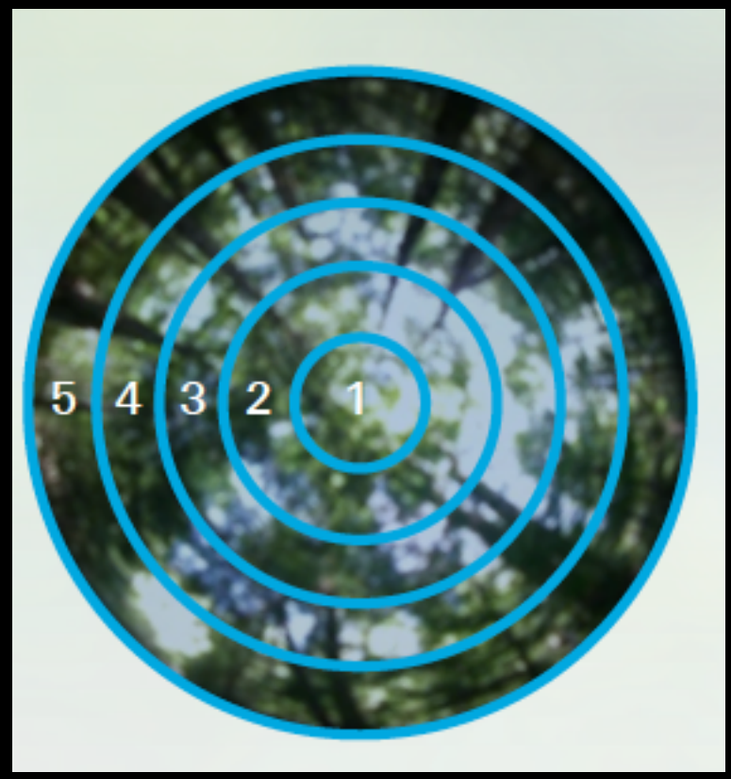
Beer's law

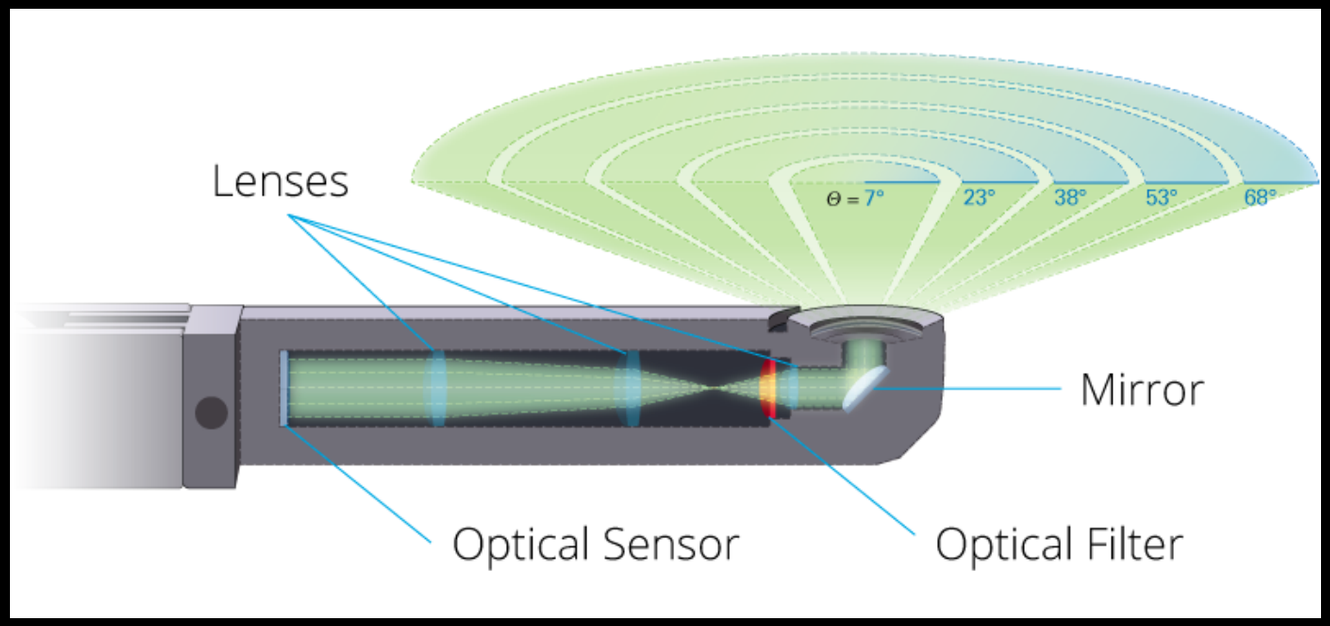
$$I_z = I_0 \times e^{-\tau}$$

$e^{-\tau}$: transmissivity

τ: optical depth

How to measure LAI using Beer's law?





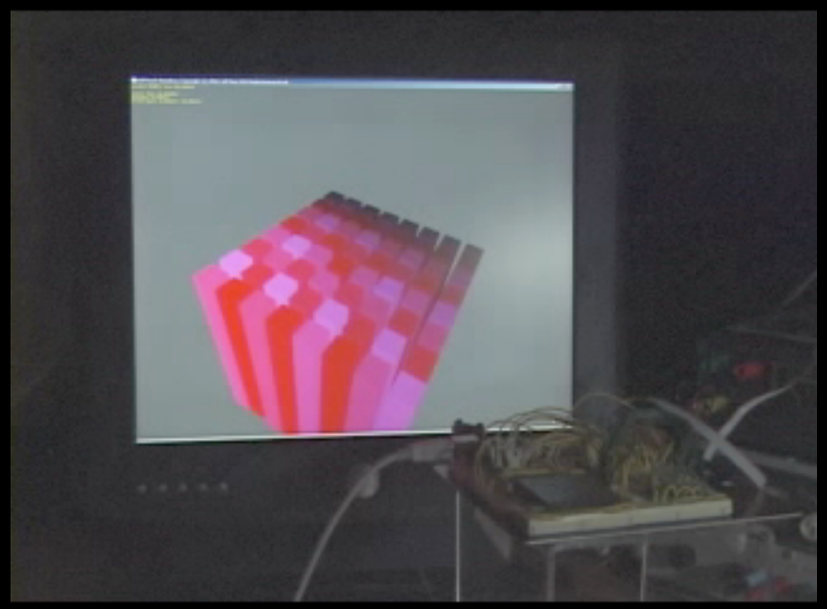
$$I_z = I_0 \times e^{-\tau}$$

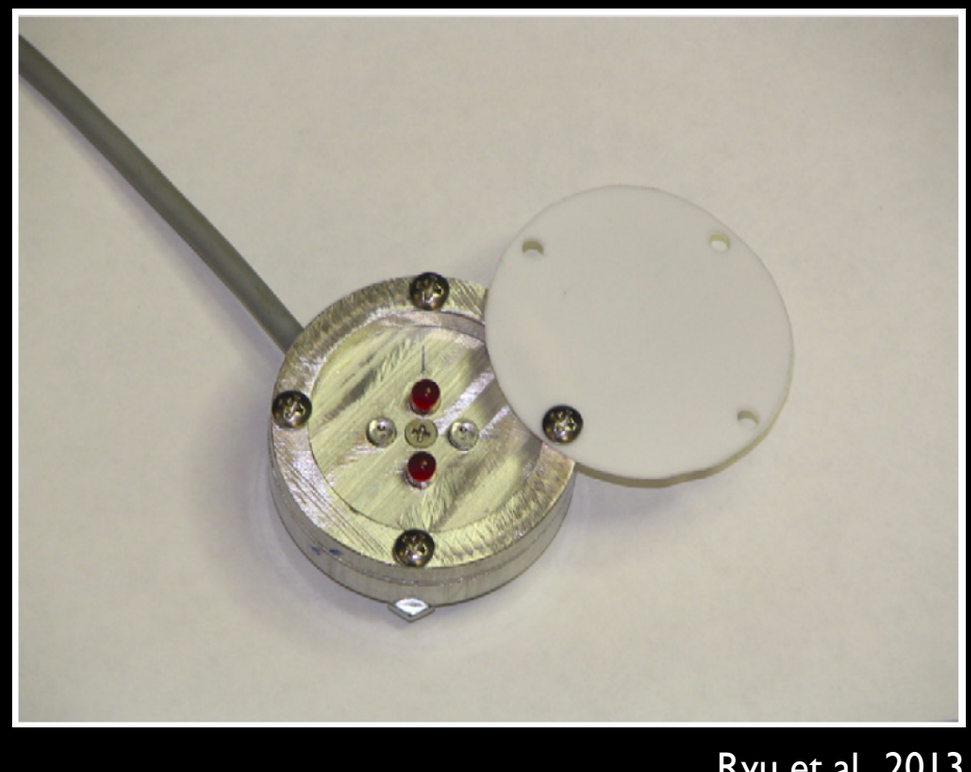
$$\tau = f(LAI)$$

Phenocam

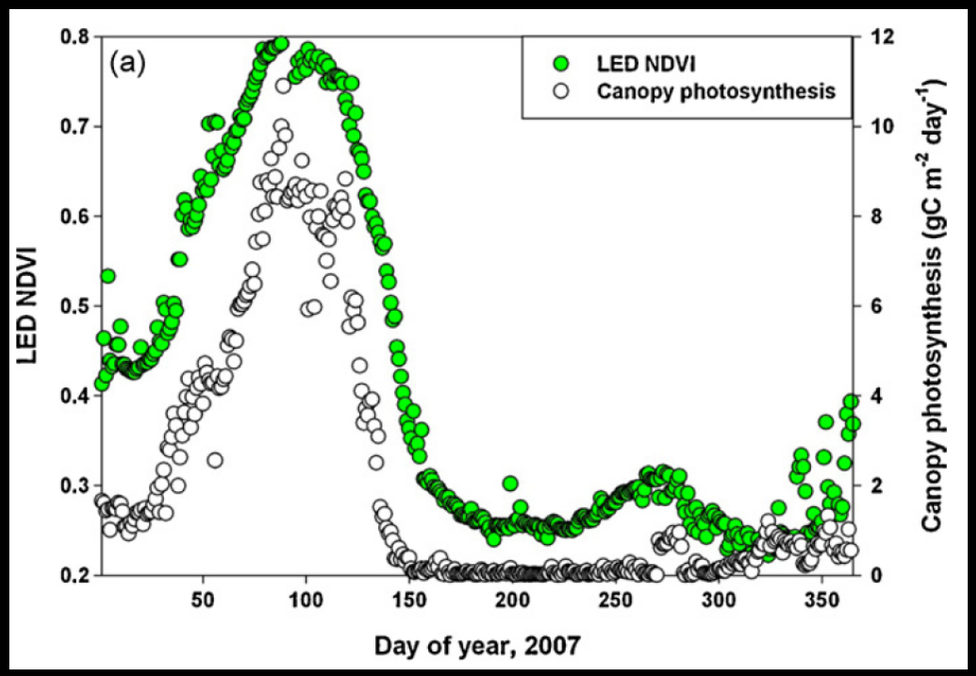
https://phenocam.sr.unh.edu/webcam/sites/pace/

LED sensors





Ryu et al., 2013



Tonzi, California

Multispectral and Hyperspectral cameras

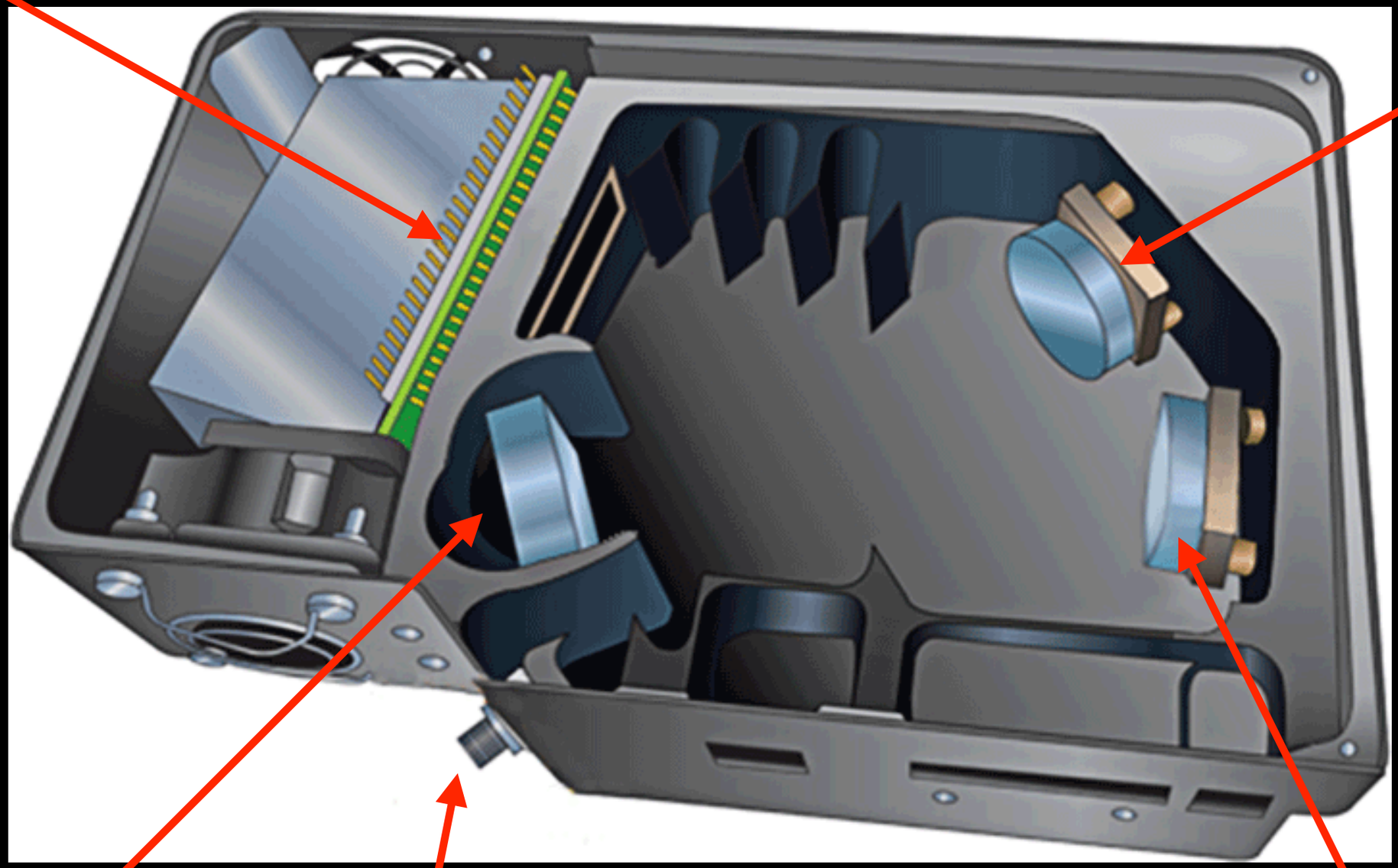
ADC

TetraCam

SPECIM hyperspectral camera

How does a spectrometer work?

Detector



Collimating mirror

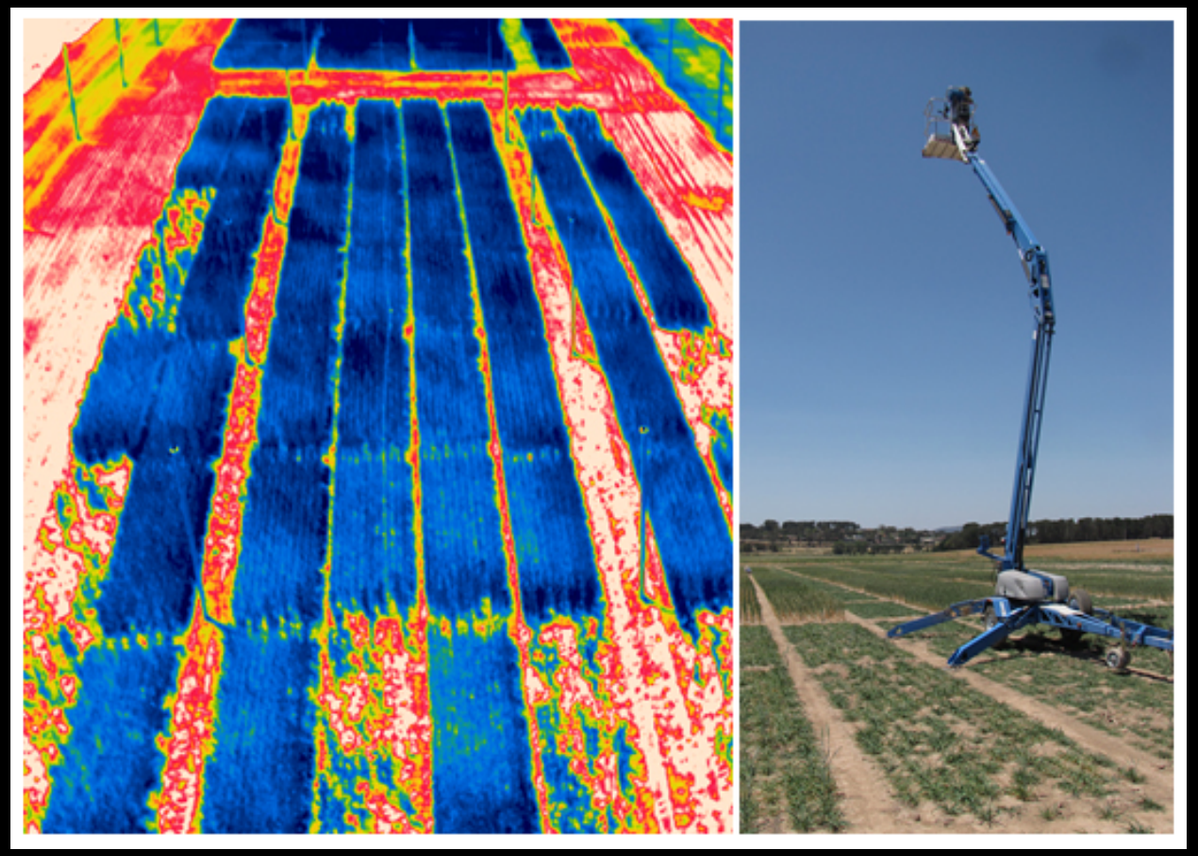
Grating (disperse the light)

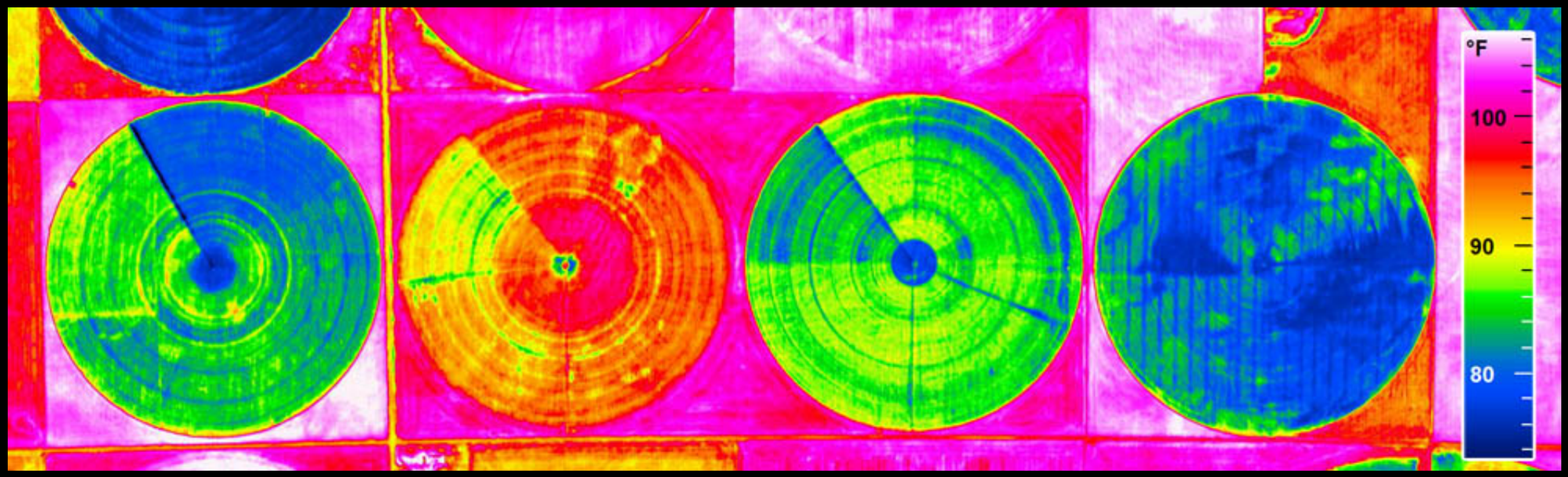
Entrance

Focusing mirror

Ocean Optics

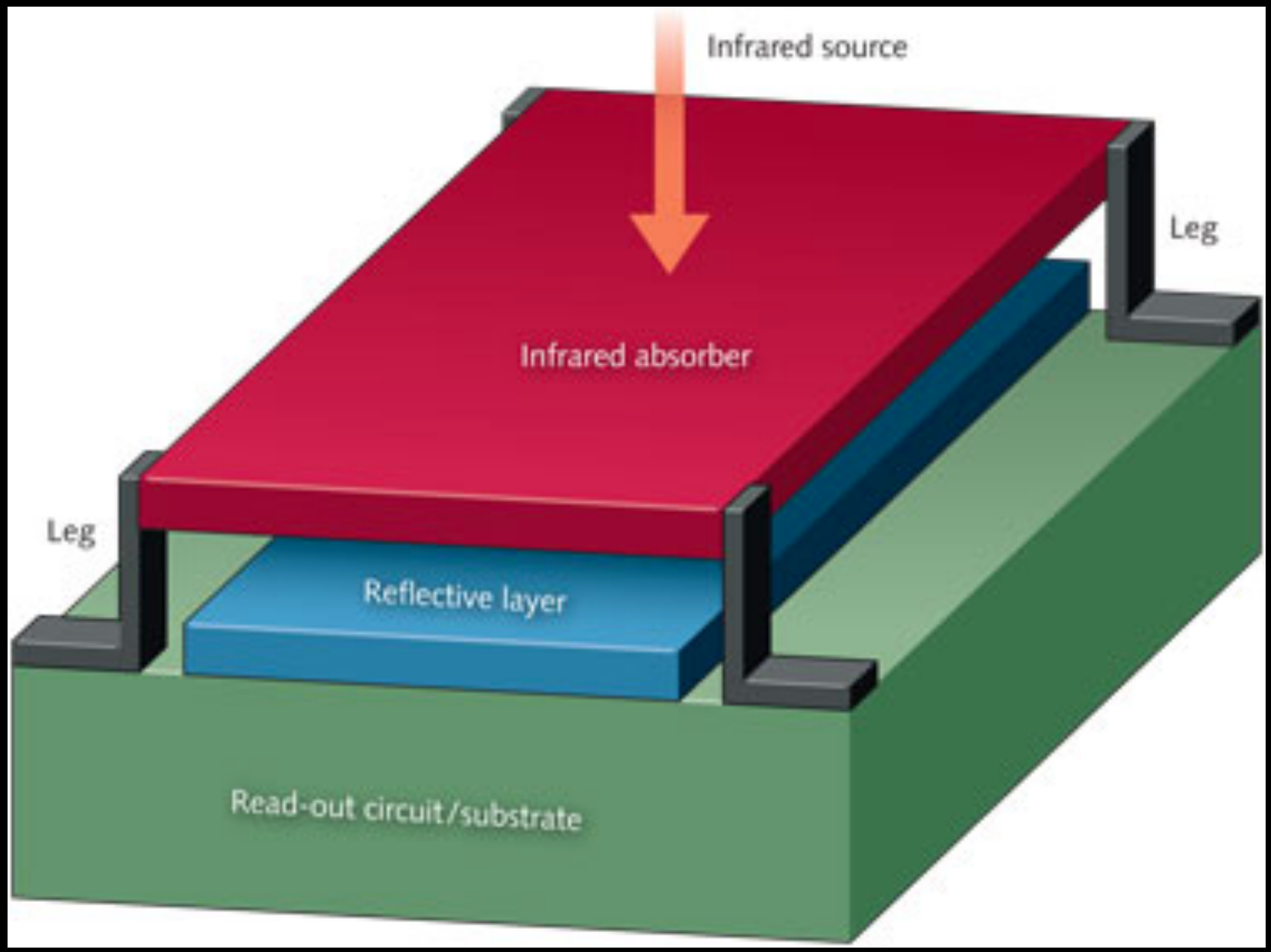
Thermal infrared cameras





How does a thermal camera work?

Microbolometer



LaserFocusWorld

Examples of ground/airborne remote sensing

- Measurements of solar radiation
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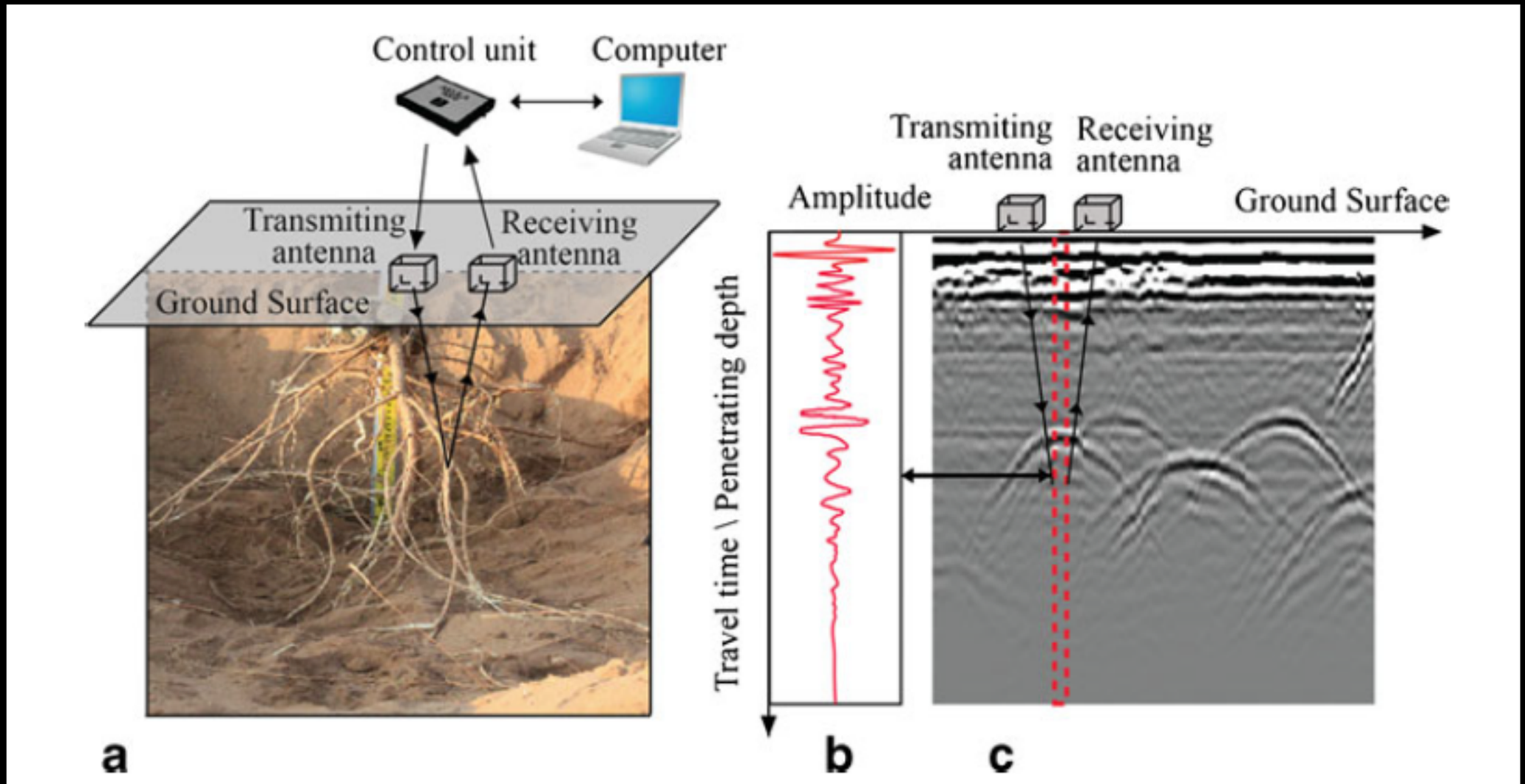
Ground-Penetrating Radar (GPR)

- The related remote sensing theory: the relationship between wavelength and penetration.
- Longer wavelength, lower frequency, higher penetration.

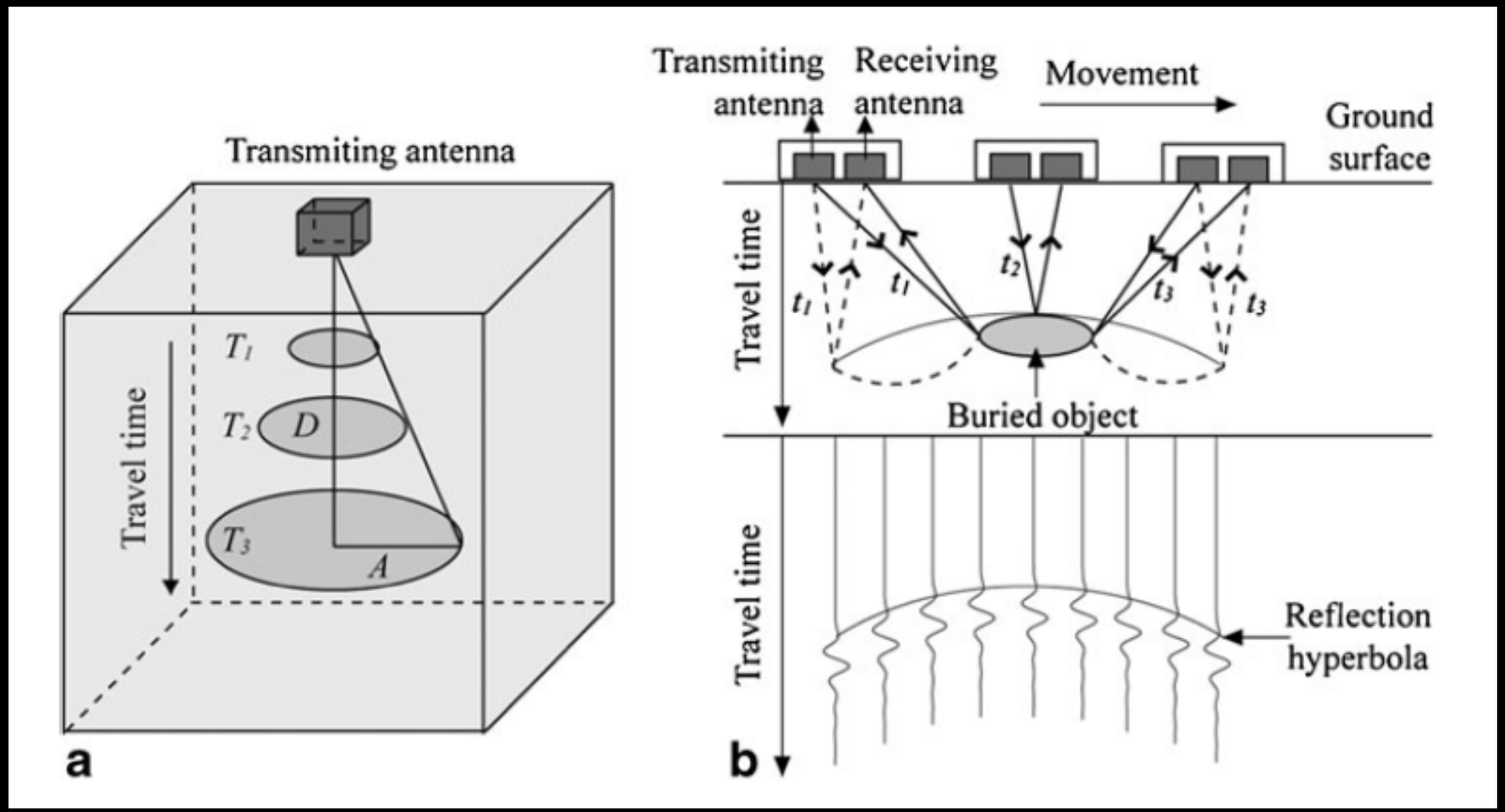
How does a GPR work?



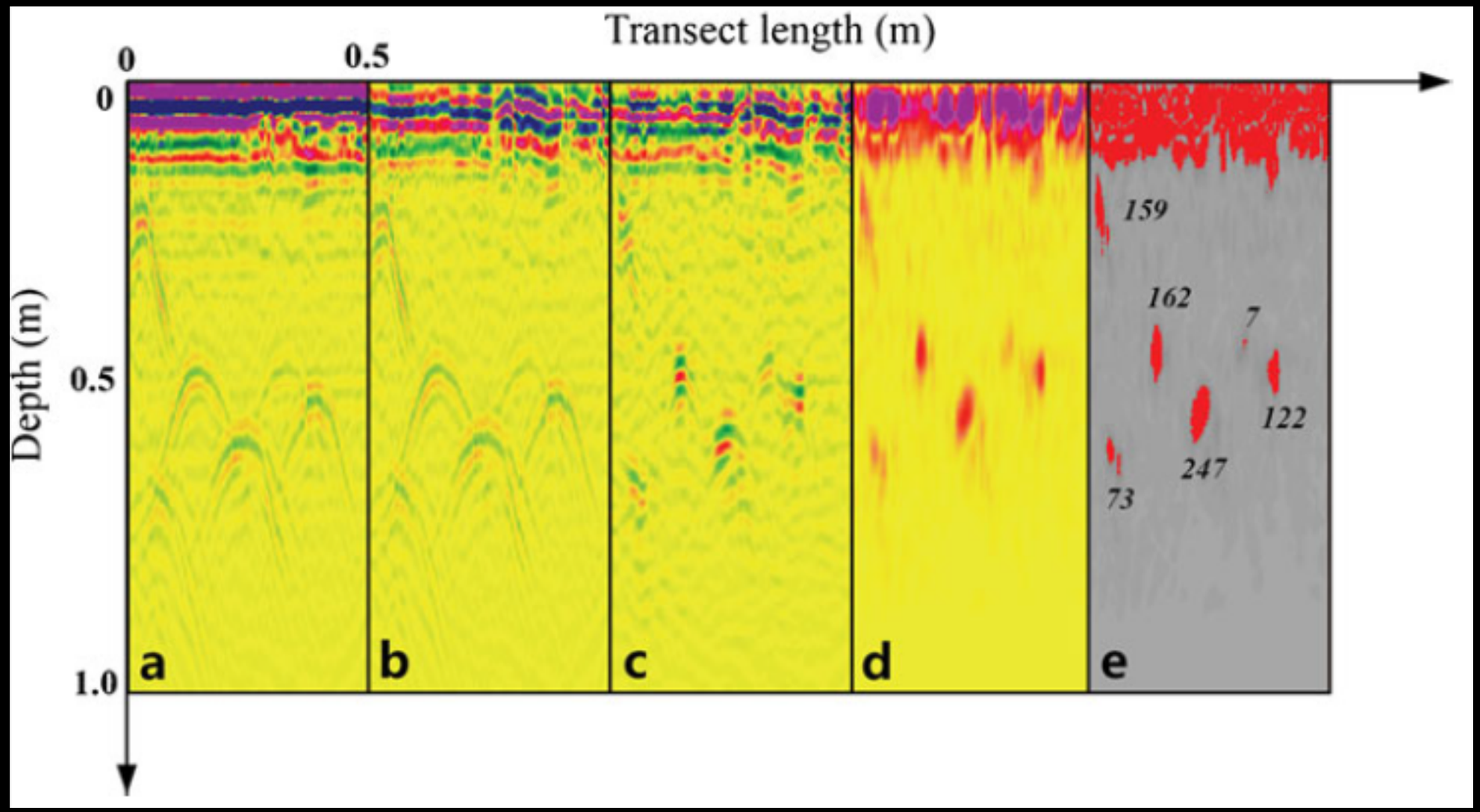
$$R = \frac{\sqrt{\varepsilon_A} - \sqrt{\varepsilon_B}}{\sqrt{\varepsilon_A} + \sqrt{\varepsilon_B}}$$

epsilon is the permittivity of objects A and B
The contrast between two different objects can cause a change in R, reflection coefficient
Permittivity = dielectric constant

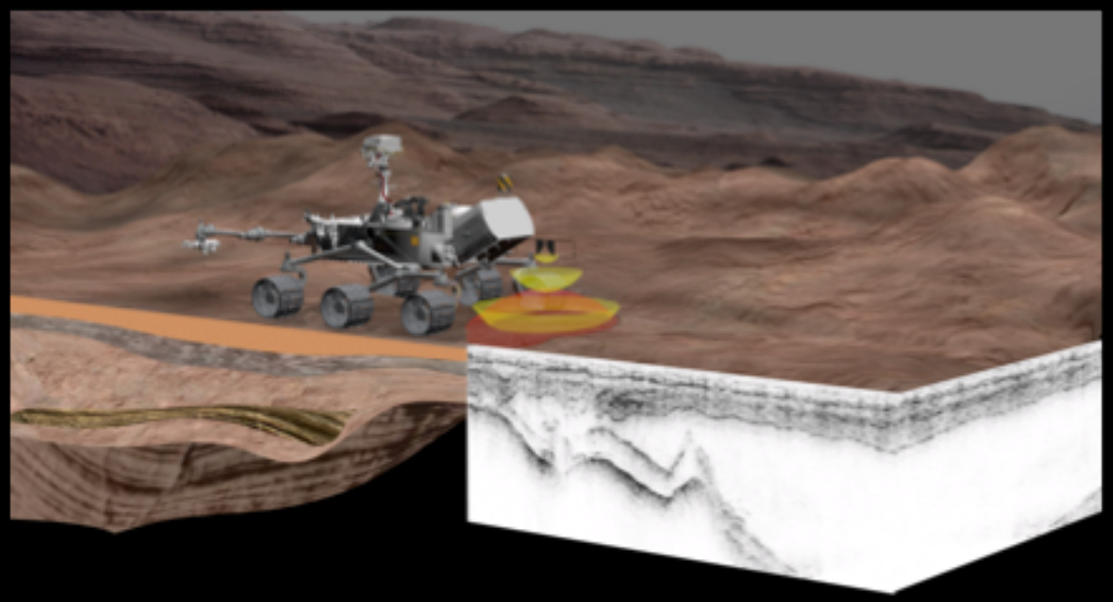
How does a GPR work?



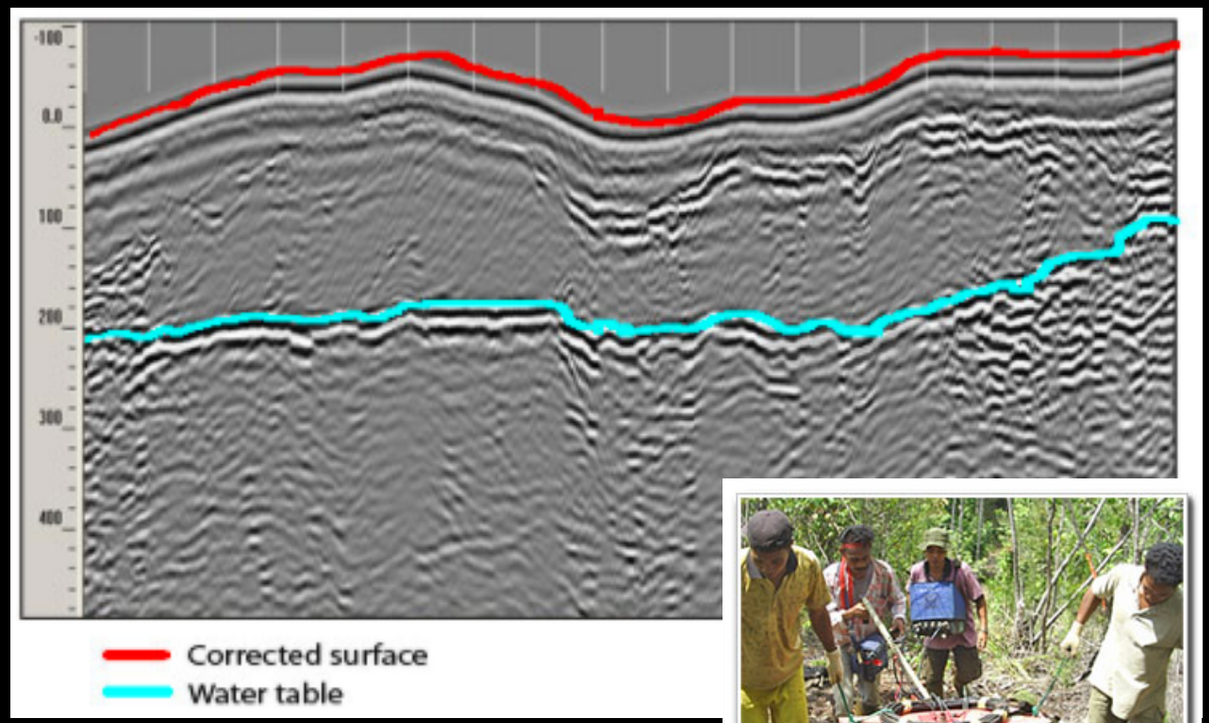
How does a GPR work?



The applications of GPR



Mars 2020



Water table

Other applications: military; mining; building inspection.

Examples of ground/airborne remote sensing

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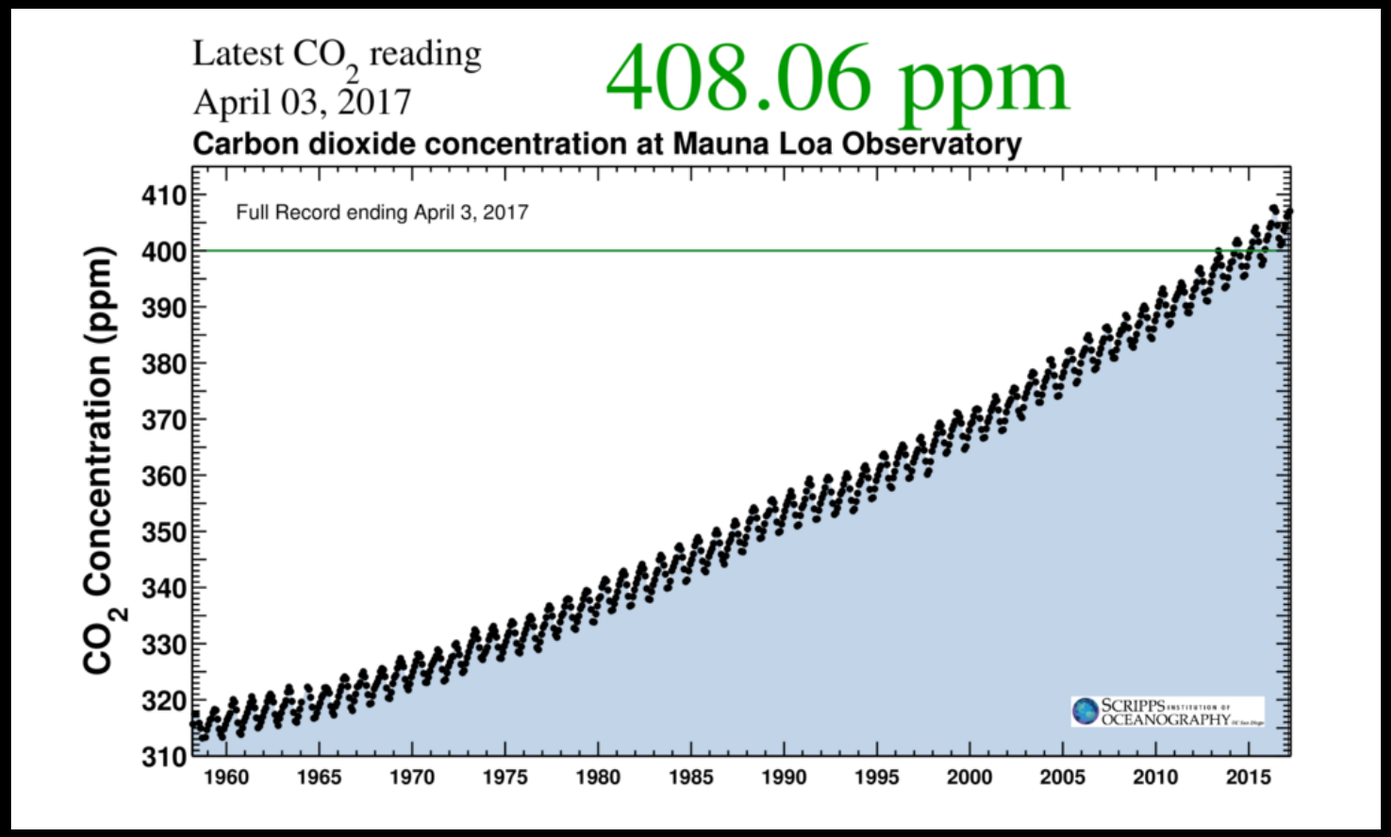
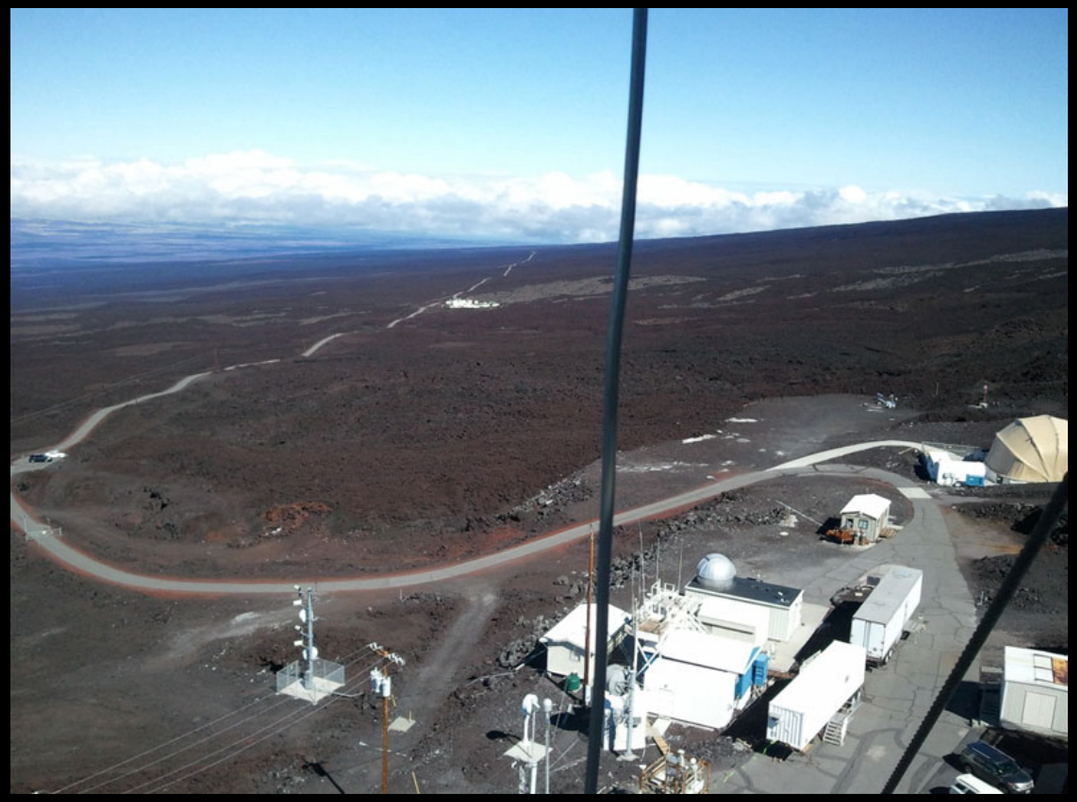
The Keeling curve

Measurements based on optical spectroscopy

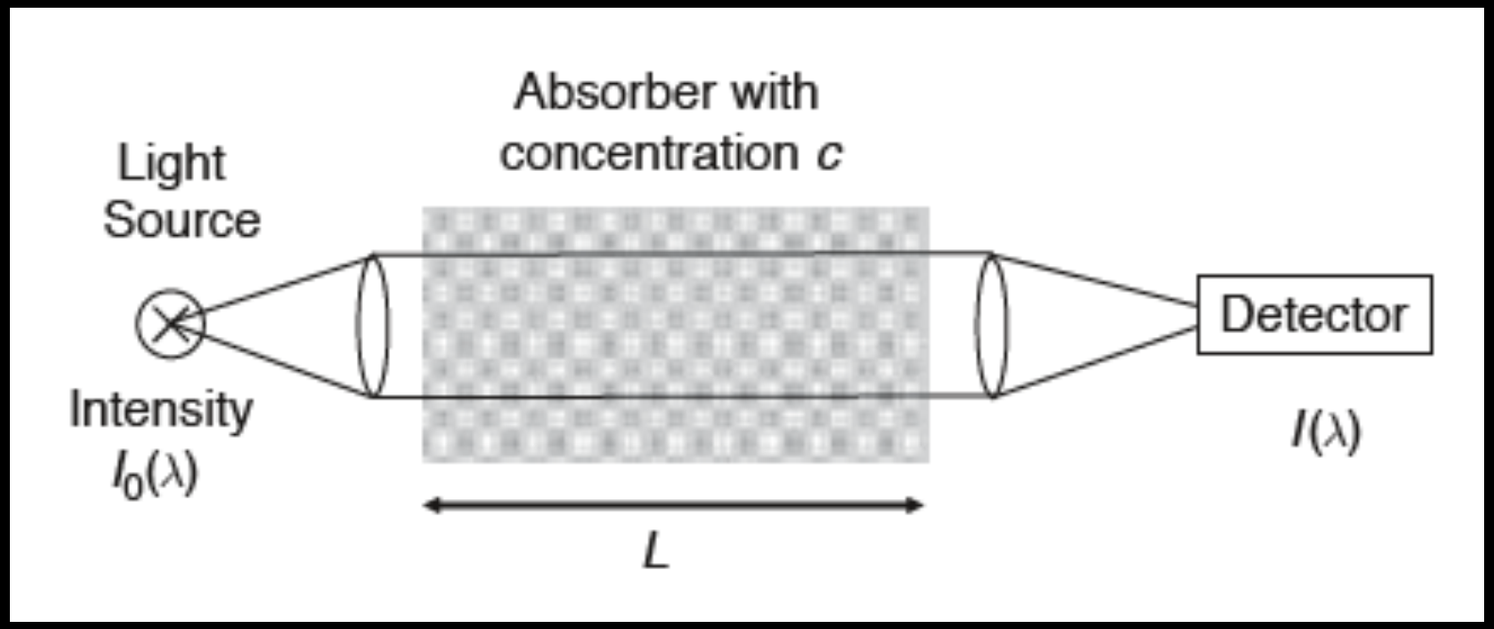




- Measurements of CO_2 concentration in Mauna Loa
- Estimation of the CO_2 concentration by the absorption features in the infrared

Differential Optical Absorption Spectroscopy

The basis of DOAS is Beer-Lambert law



$$\mathrm{I}(\lambda) = \mathrm{I}_0(\lambda) \cdot \exp\left(-\sigma(\lambda) \cdot \mathrm{c} \cdot \mathrm{L}\right)$$

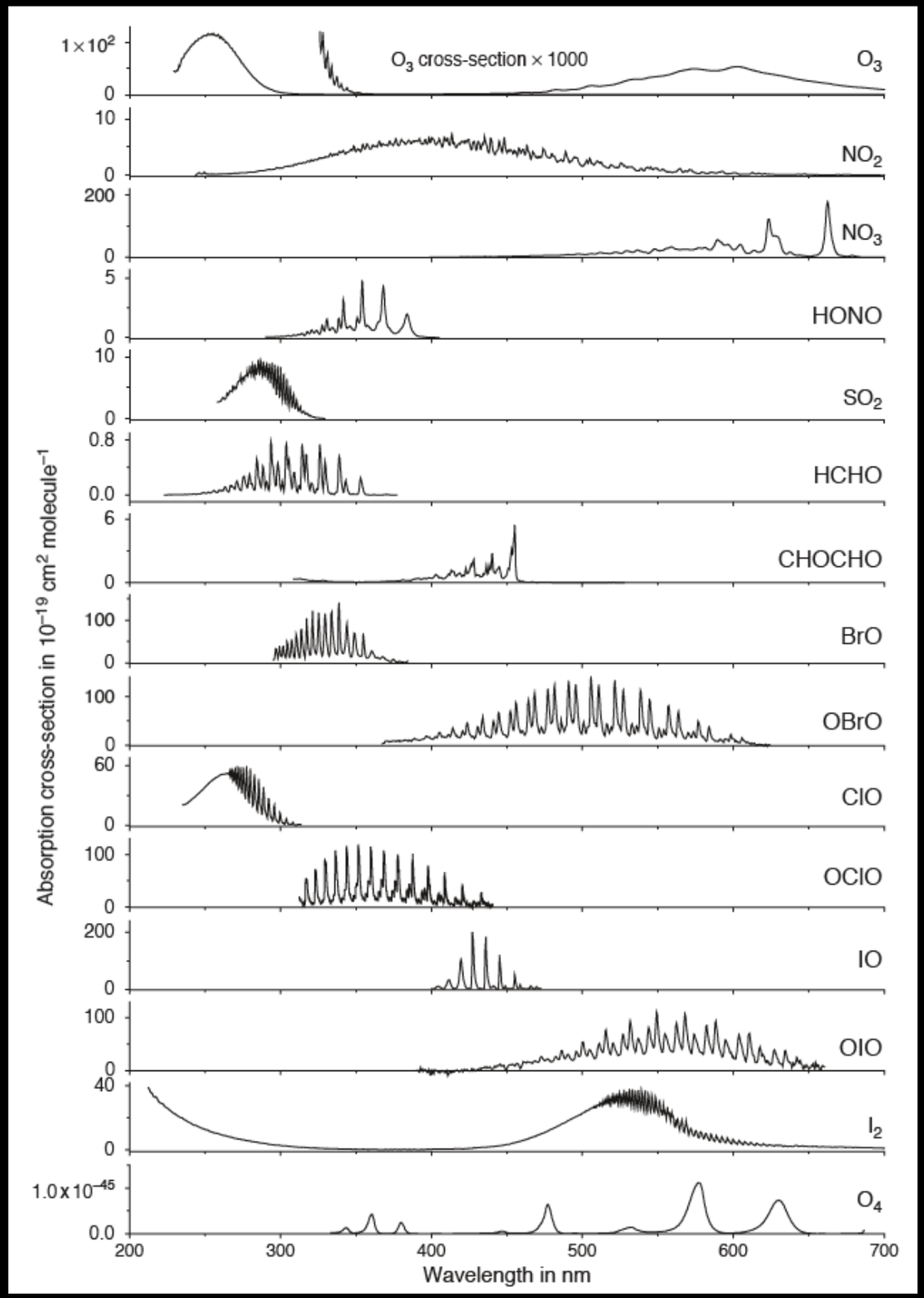
- σ(λ) is the absorption cross-section
- c is the concentration of the gas
- L is the thickness of the gas layer

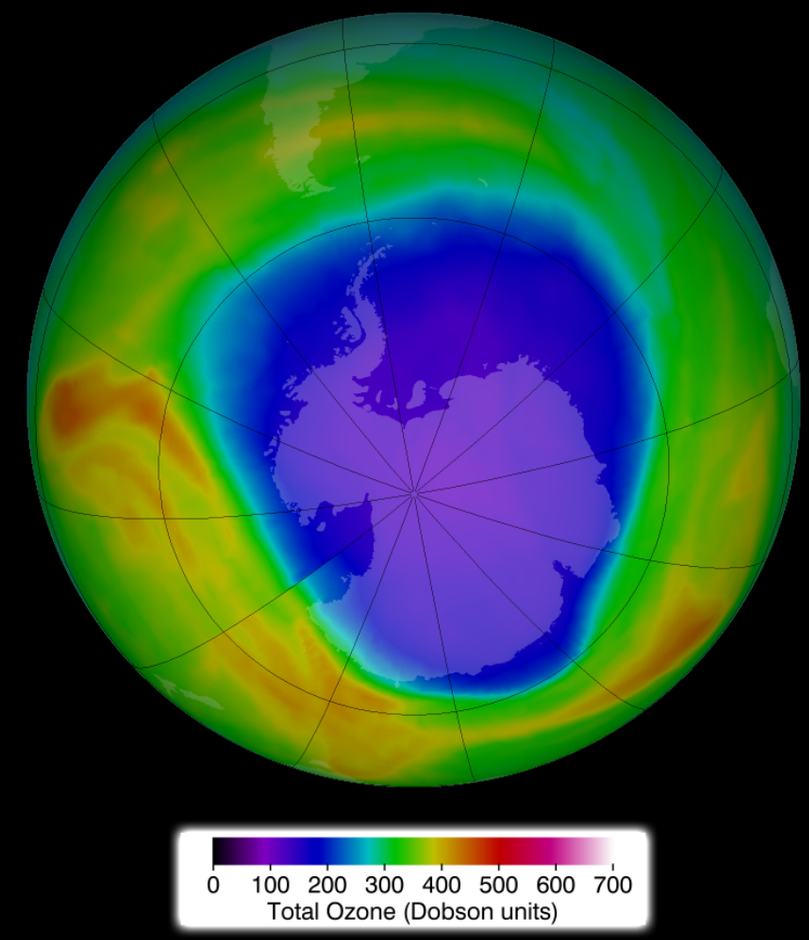
$$\mathrm{c} = \frac{\ln\left(\frac{\mathrm{I}_0(\lambda)}{\mathrm{I}(\lambda)}\right)}{\sigma(\lambda) \cdot \mathrm{L}} = \frac{D}{\sigma(\lambda) \cdot \mathrm{L}} \cdot$$

$$\mathrm{D} = \ln\left(\frac{\mathrm{I}_0(\lambda)}{\mathrm{I}(\lambda)}\right)$$

Platt and Stuz 2008

Fingerprints of the trace gases

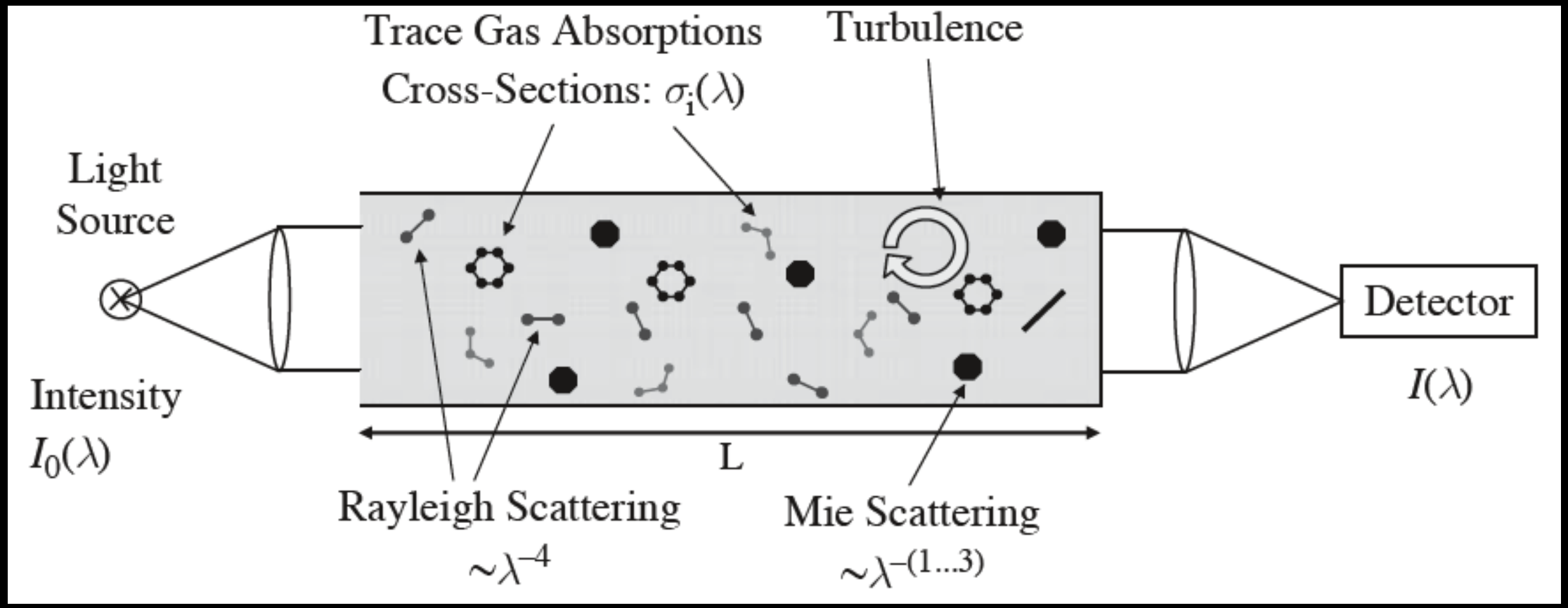




Ozone hole

Absorption cross section

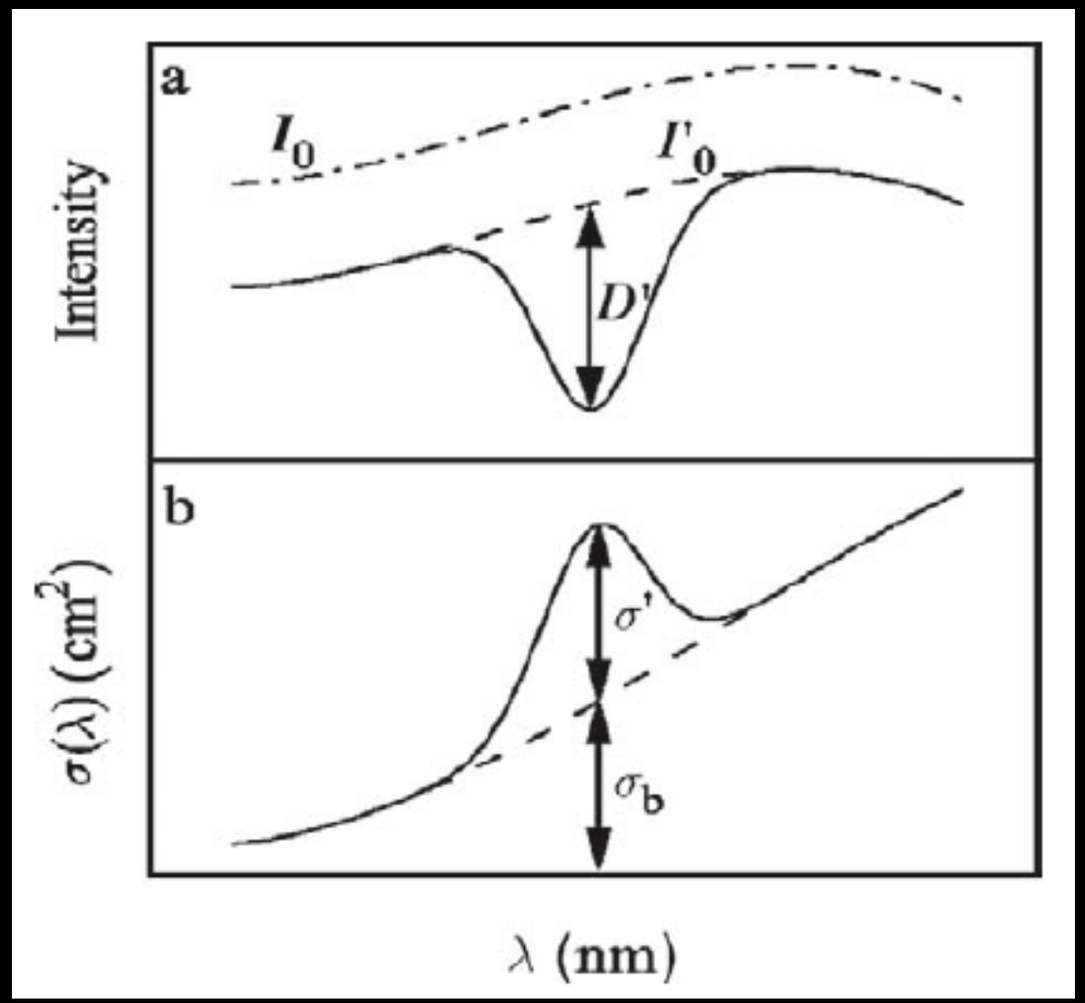
DOAS is useful for a real atmosphere



- Rayleigh scattering
- Mie Scattering
- Multiple trace gases absorption
- Turbulence

- Only trace gases show narrowband absorption structures

Principle of DOAS

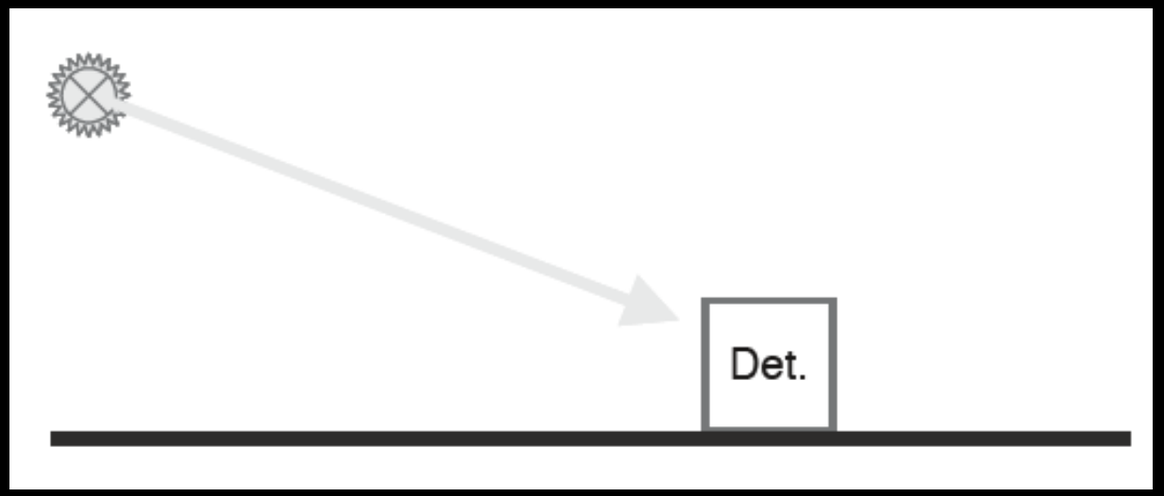


- Top-of-Atmosphere intensity cannot be measured.
- Io' is estimated instead.
- Once Io' is estimated, we can use Beer's law.

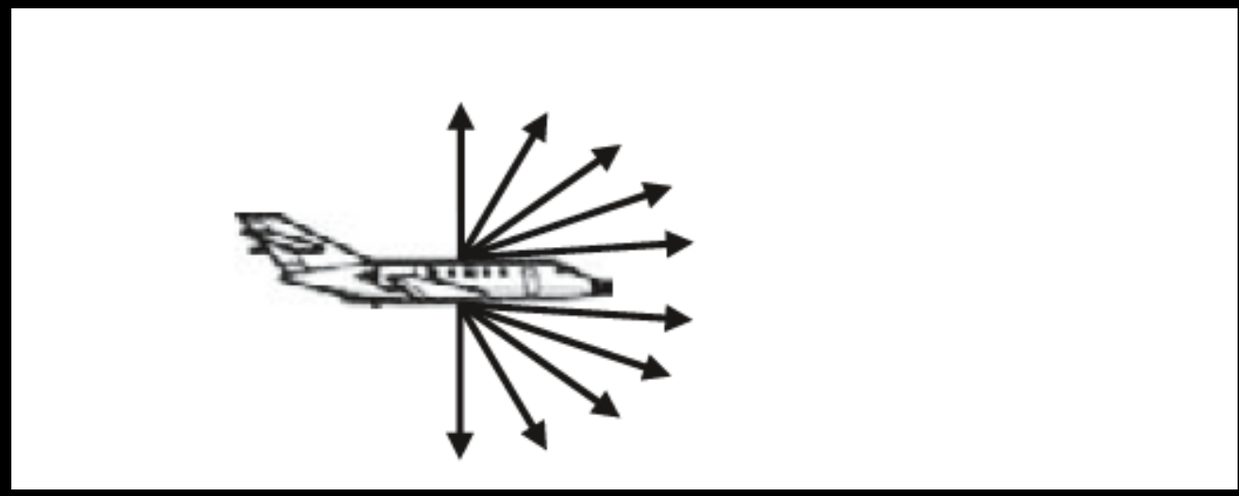
$$\sigma_j(\lambda) = \sigma_{j0}(\lambda) + \sigma'_j(\lambda)$$

- Exploiting the "fast" and "slow" variations in light intensity

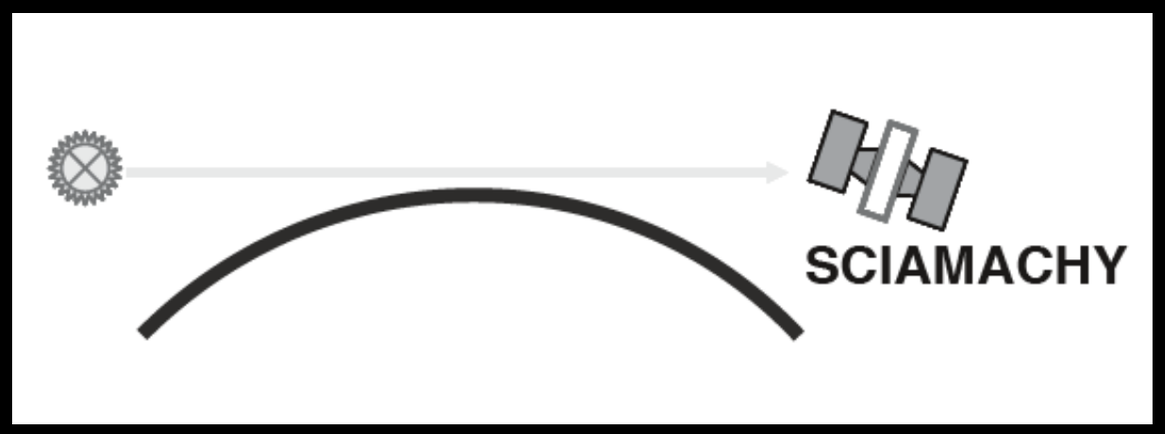
Types of DOAS



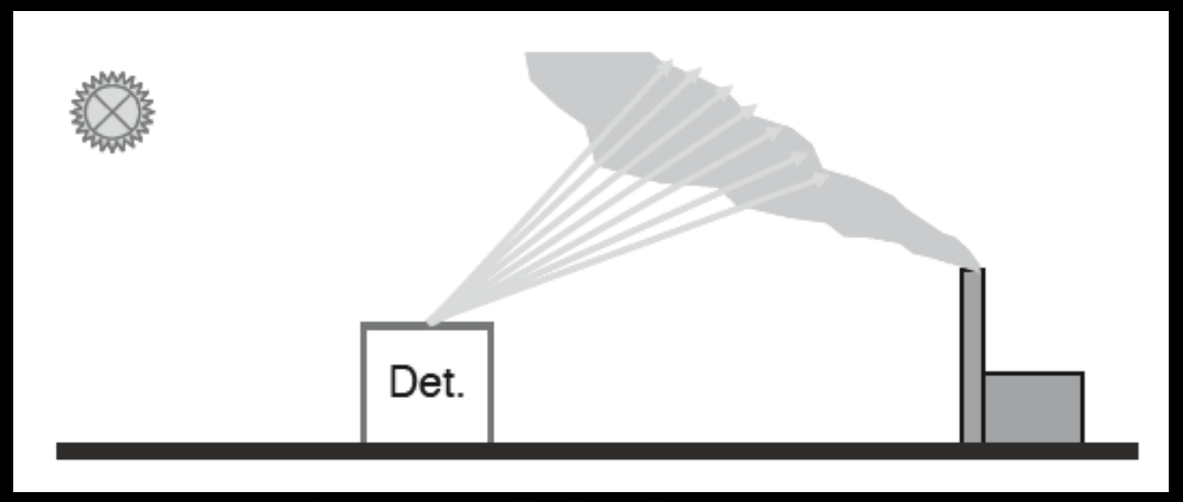
Direct Sunlight DOAS



Airborne Multi-Axis DOAS



Spaceborne DOAS



Imaging DOAS

Recap

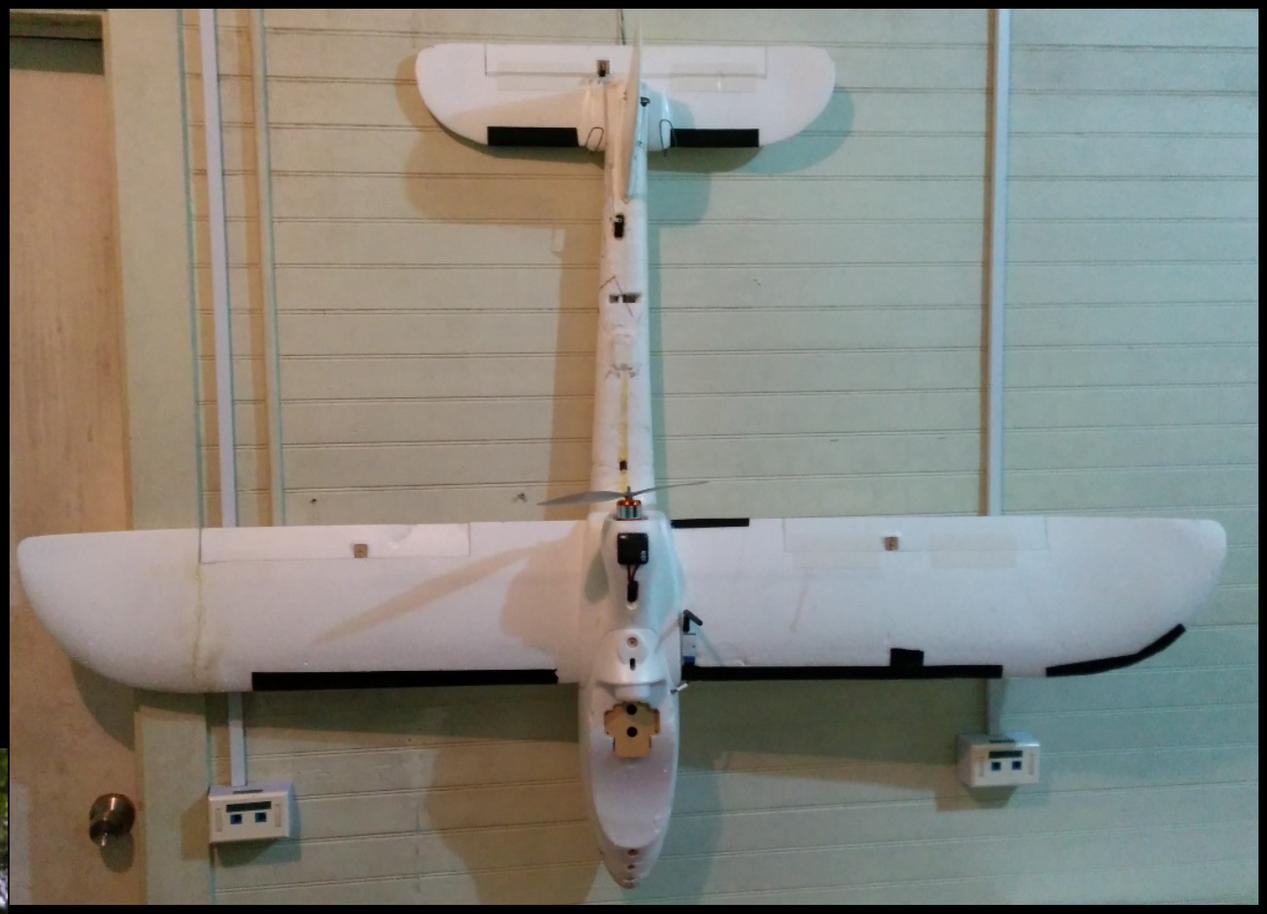
- The mechanism of trace-gas detection: the absorption features are narrow features compared with broadband features such as Rayleigh and Mie.
- Beer-lambert law: the concentration of the gases is related to the “depth” of the absorption feature.

Examples of ground/airborne remote sensing

- Measurements of solar radiation
- Vegetation
  - Leaf area index
  - Coloring
  - Thermal
- Underground Remote Sensing
- Trace-gas measurements on the ground
- Drone-based Remote Sensing*

Many slides from Jonathan Dandois

Drones



- Fixed-wing
- Gas-propelled

The advantage/disadvantage of drone RS

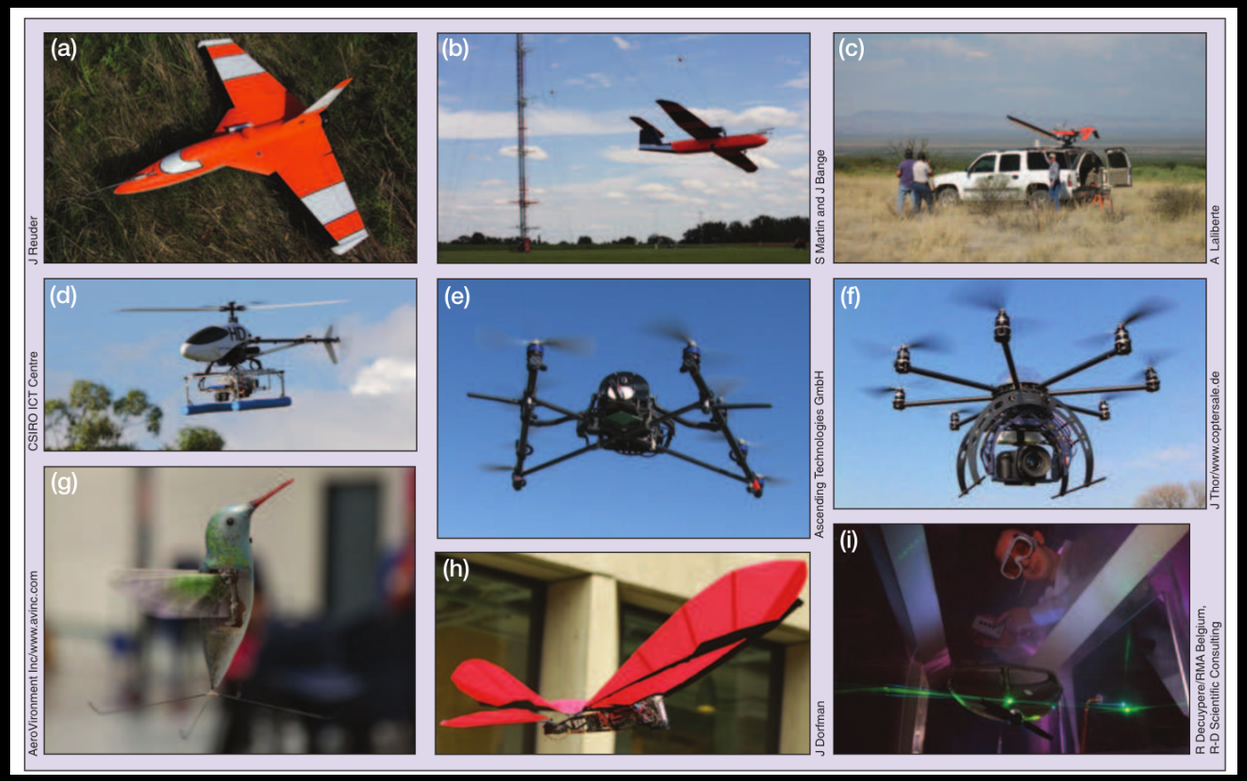
- Octocopter

- Hexacopter

- Quadcopter

Commercial and research grade drones

- $1000-$5000
- Flying weight: 1 - 10 kg
- Payload: 0.5 - 5 kg
- Flight time: 10-45 min



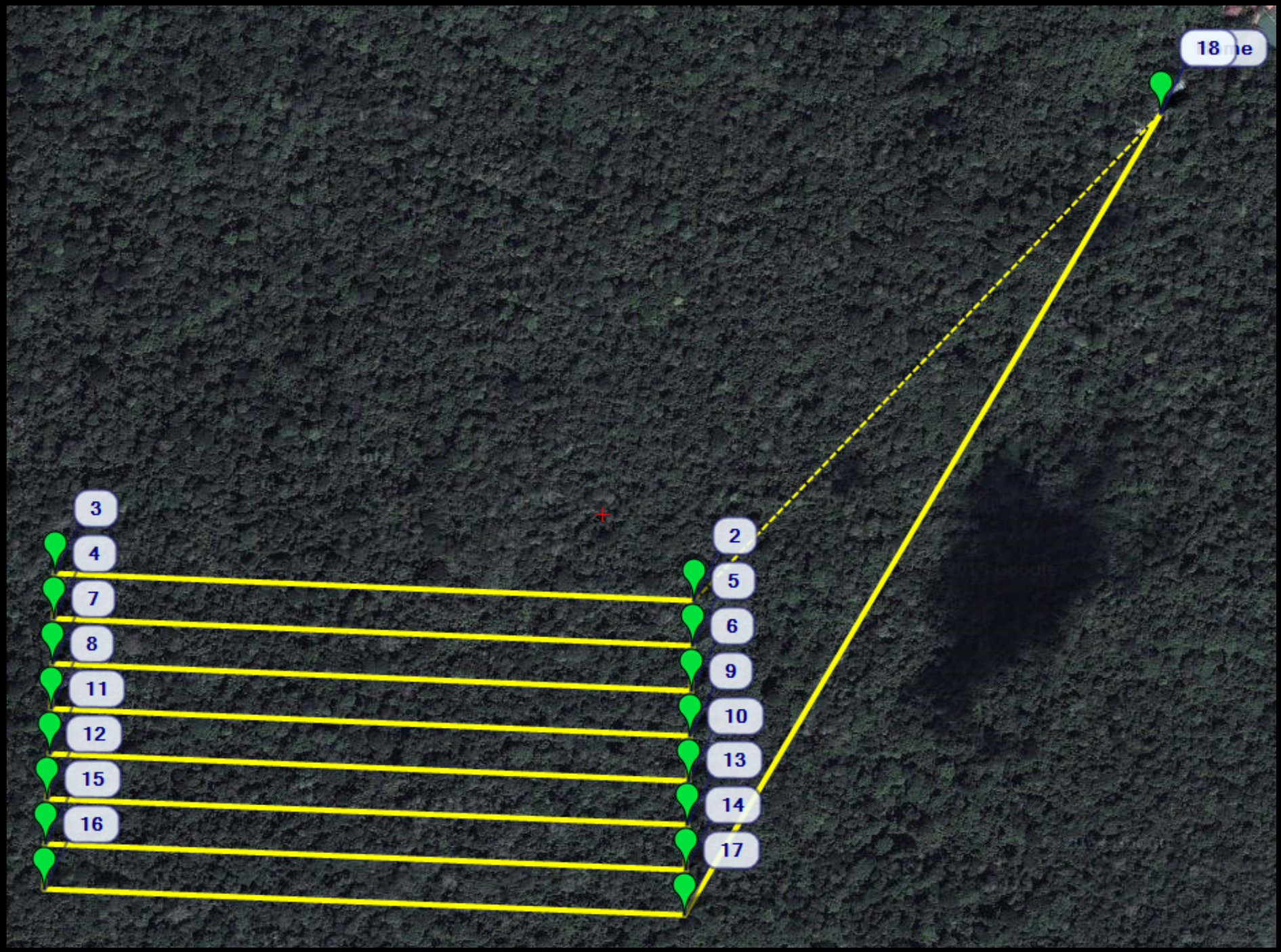
- Fixed-wing
- Helicopter
- Mini-drones
- Ornithopter

Anderson and Gaston, 2013

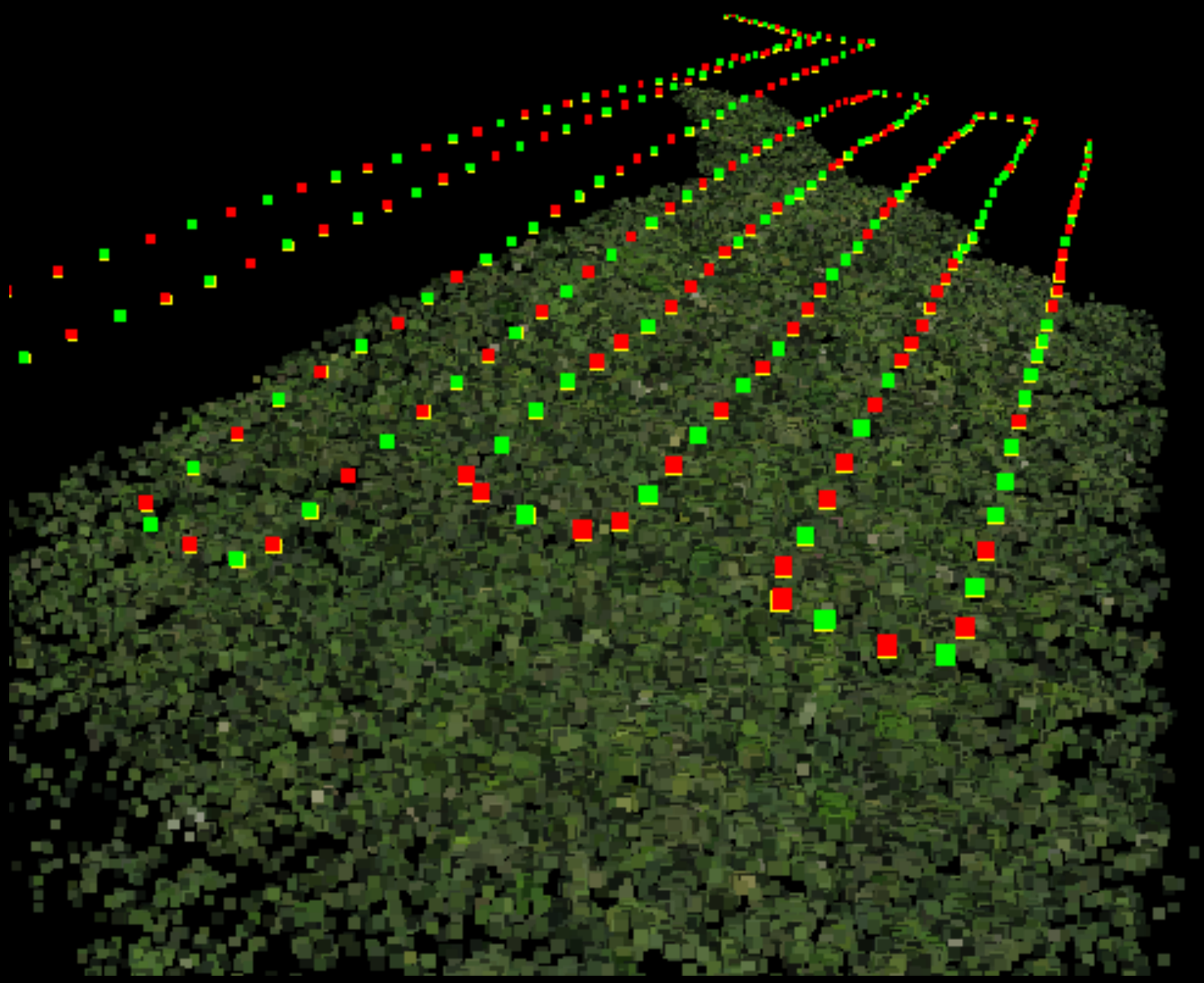
A personal remote sensing system

+

Automated waypoints

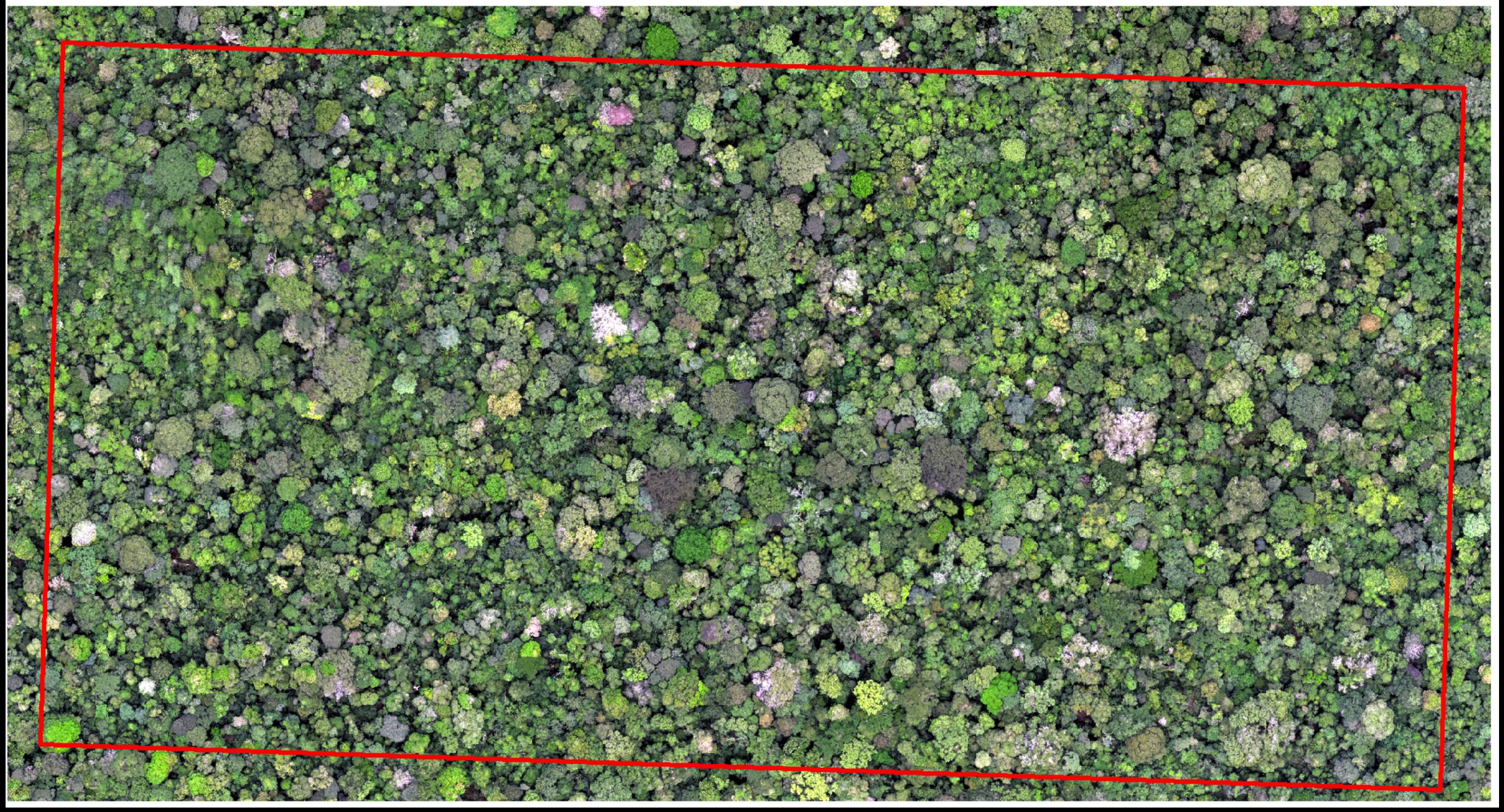


Structure from Motion (SfM)



- The challenge: trees move!

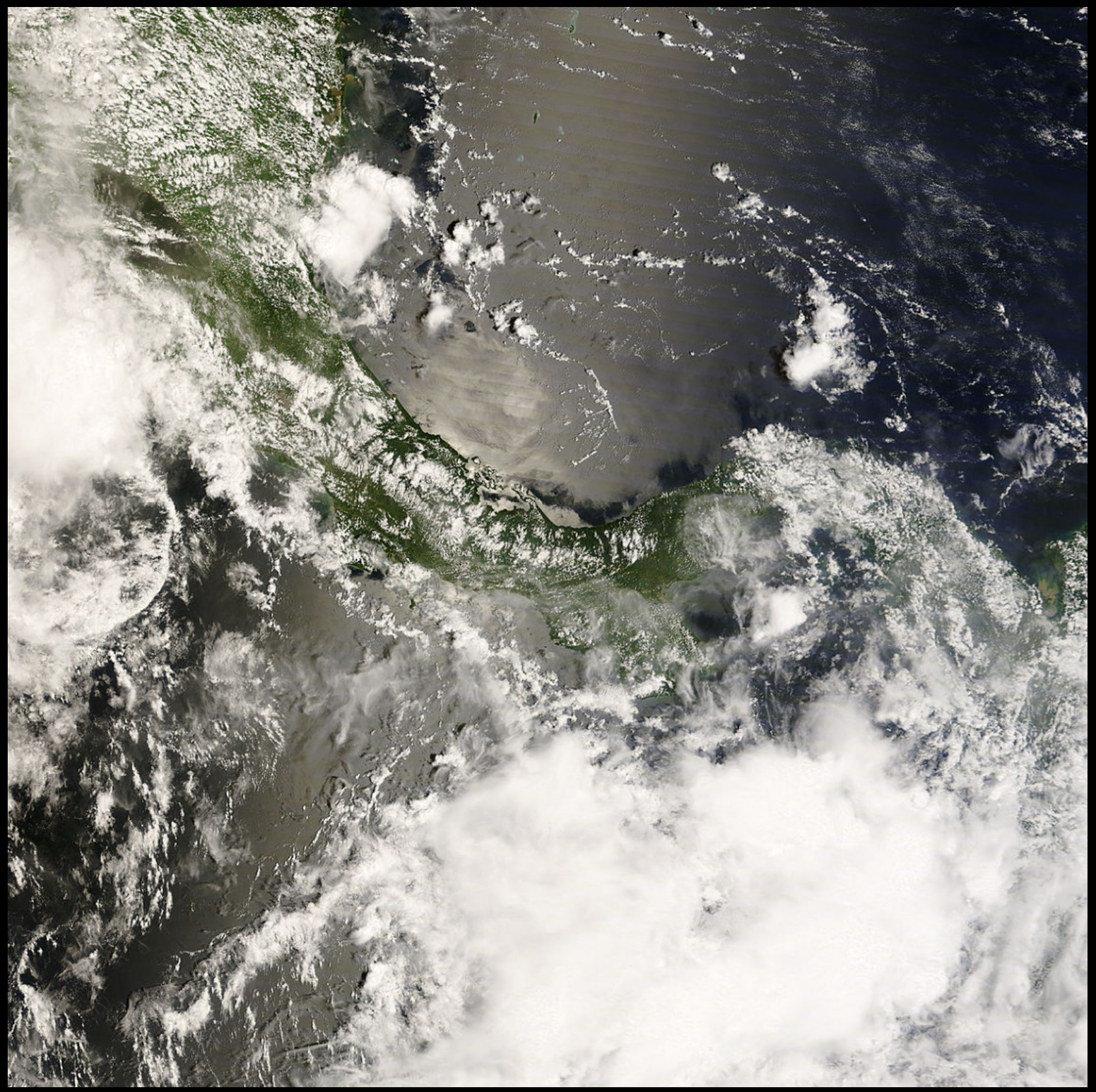
Orthorectified image of a 50-ha plot



- Panama

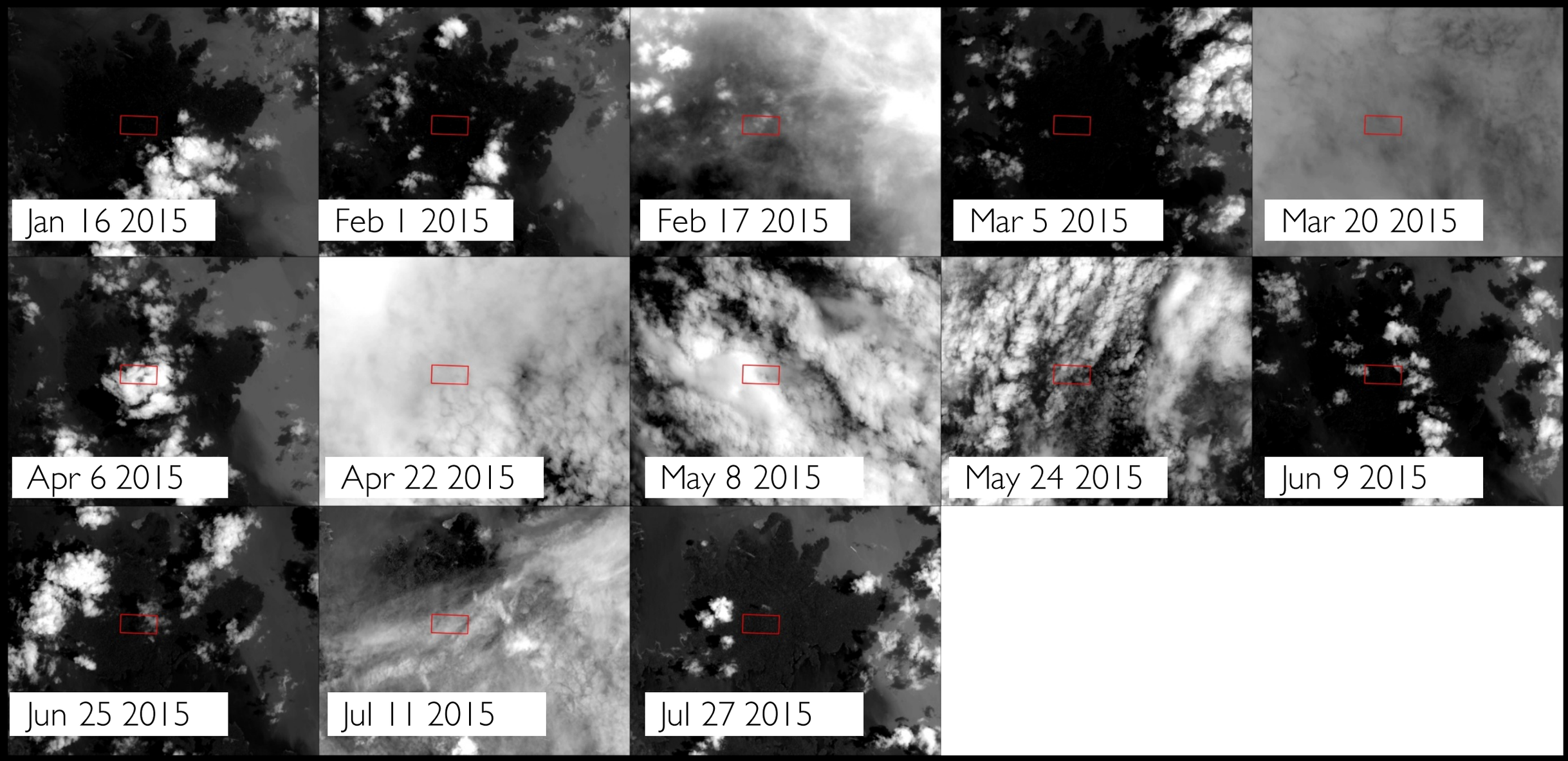
Dipteryx panamensis flowers in July, Panama

Advantage of drone-based remote sensing



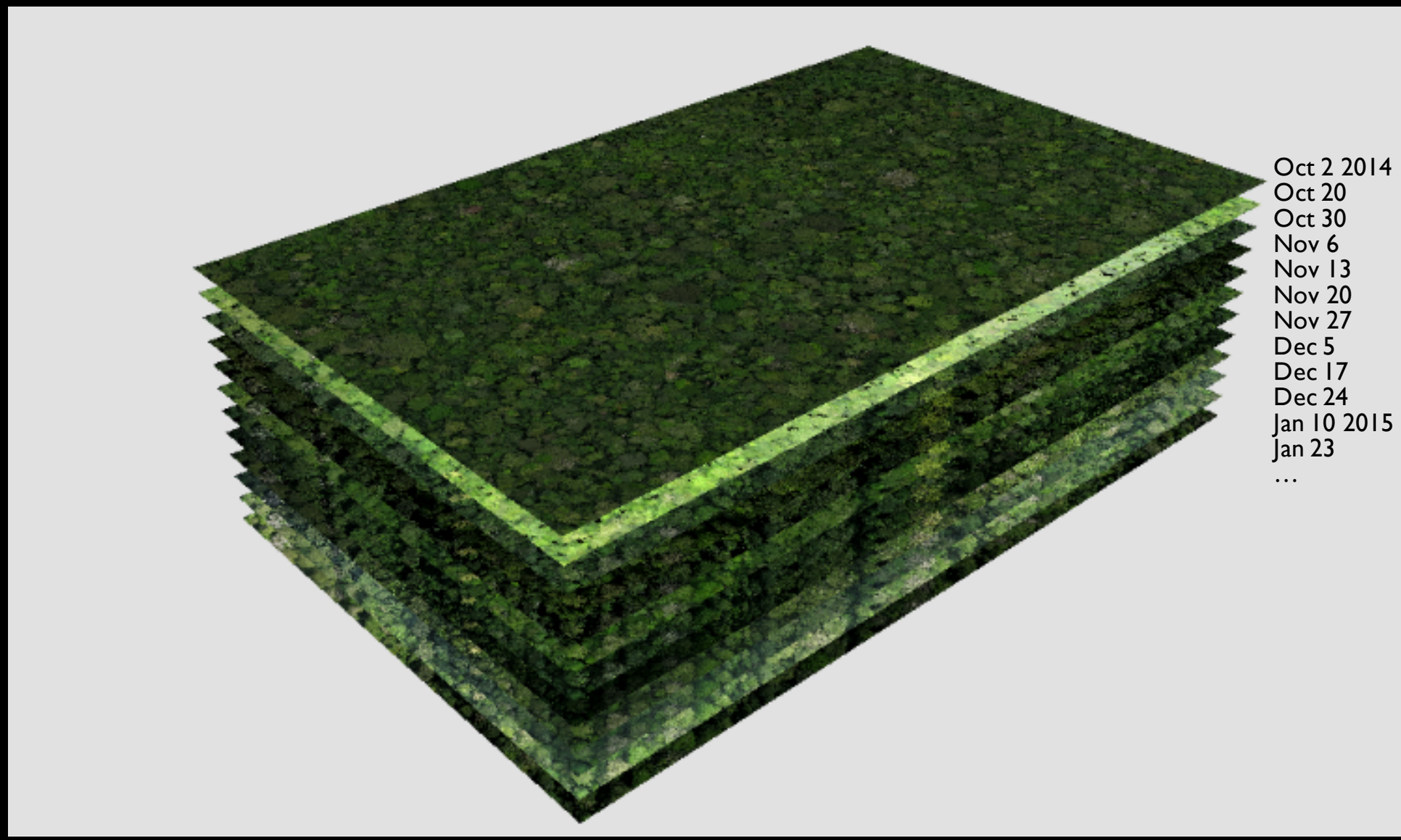
True color satellite image from NASA MODIS sensor centered on Panama (2008-09-22).

Landsat 8 OLI band 8 panchromatic

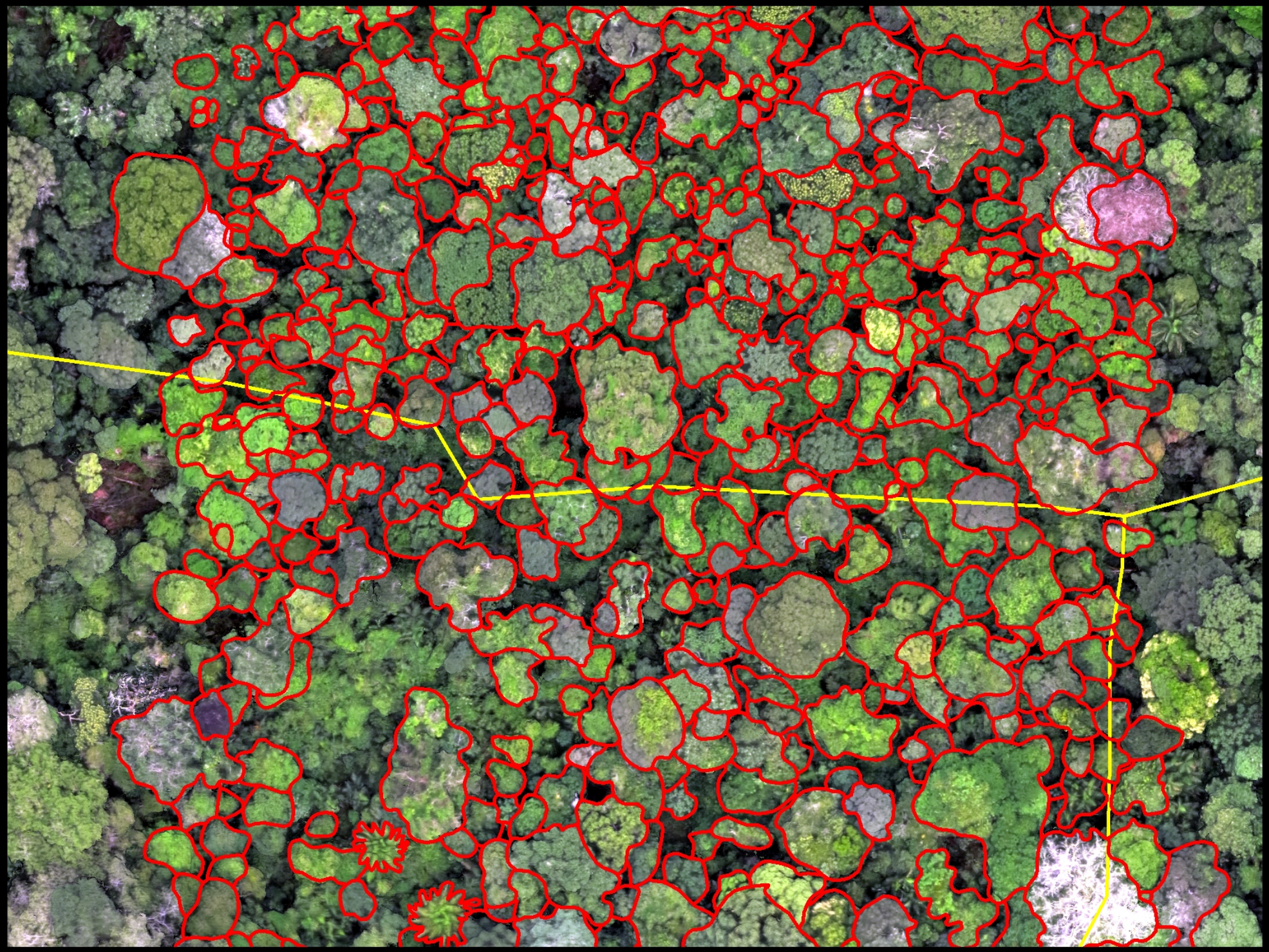


PhenoCam only covers a limited area

Weekly flights create time-series data

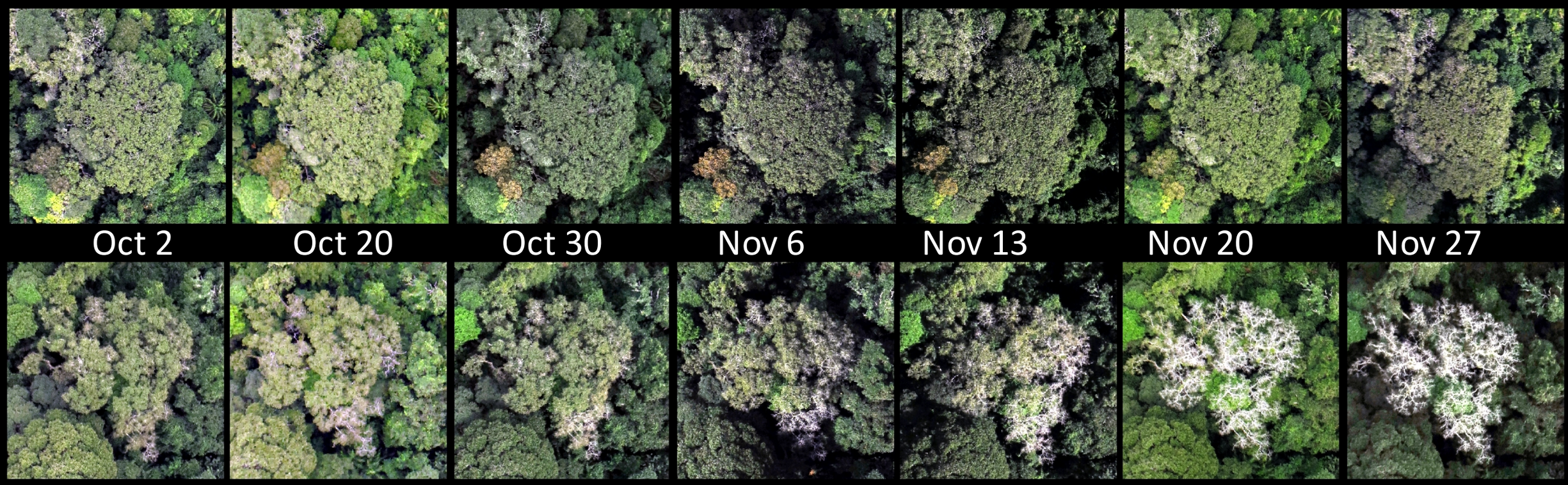


A computer vision problem: how to do the segmentation?



Trees in evergreen forests are not always green

Crowns stay constantly green

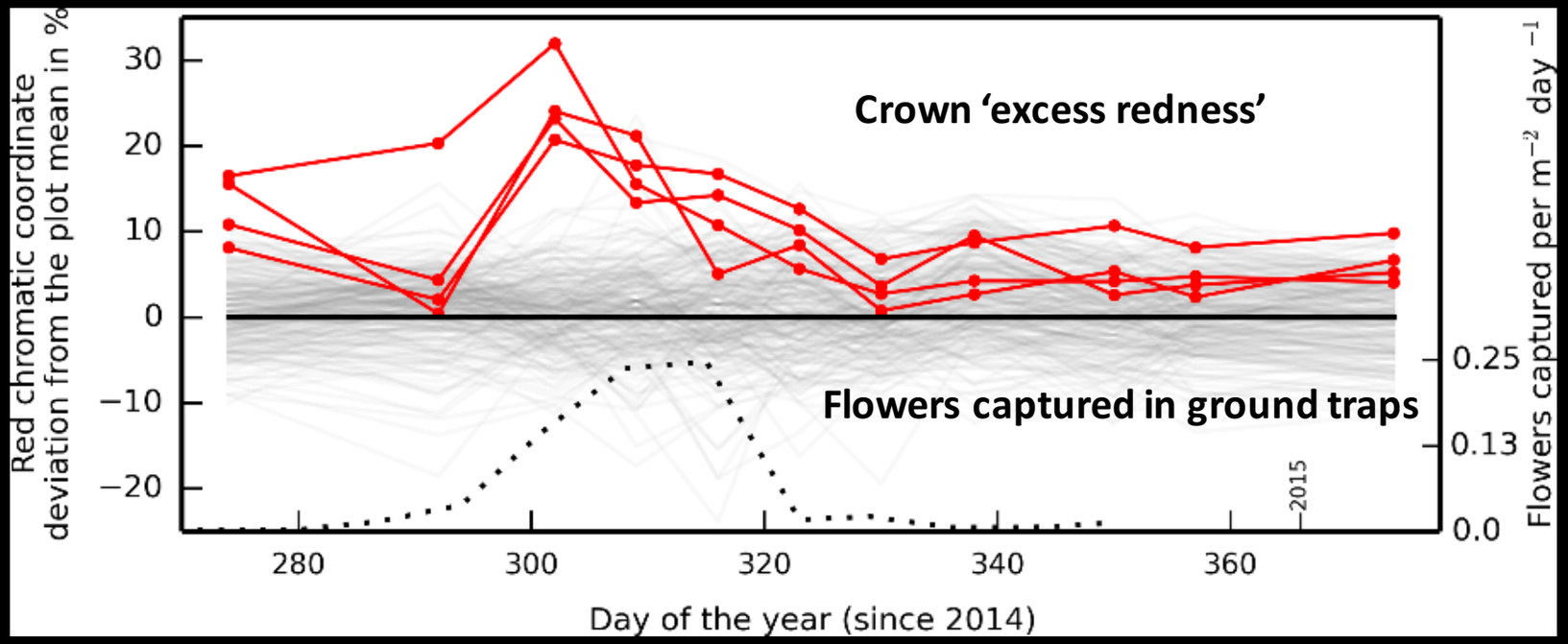


Trees that drop leaves

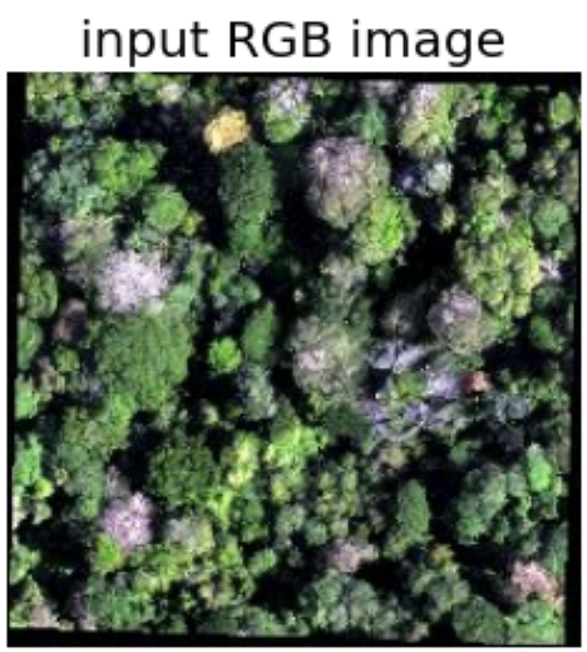
Seasonality!

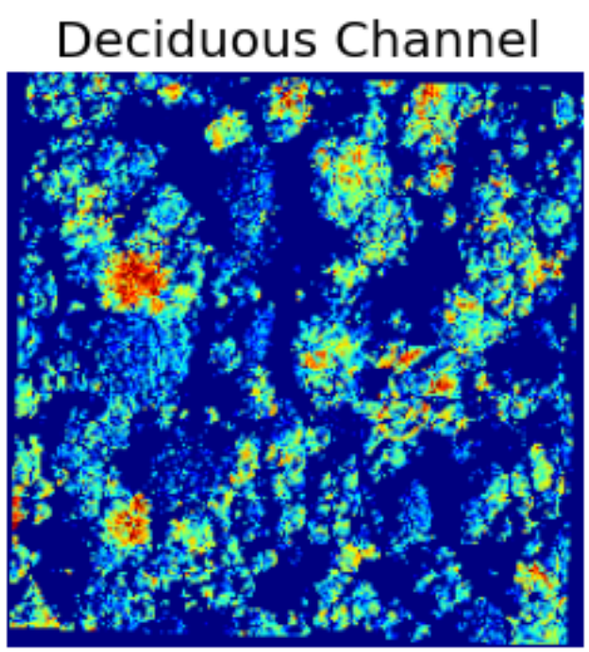
Oct 2 | Oct 20 | Oct 30 | Nov 6 | Nov 13 | Nov 20 | Nov 27

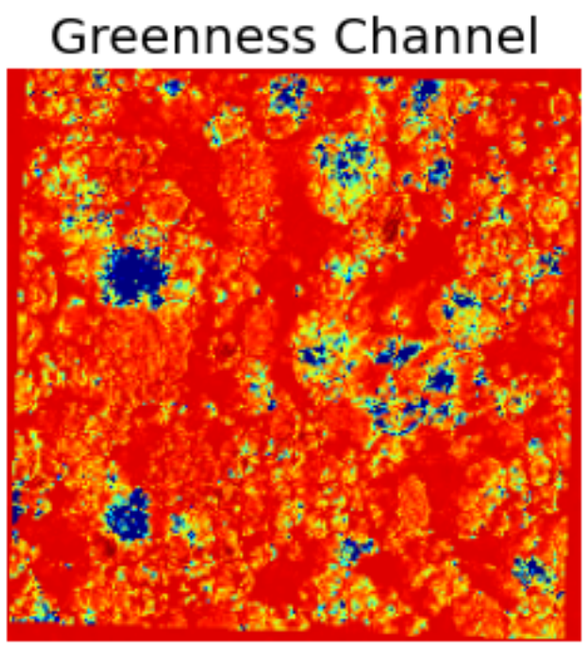
Virola surinamesis

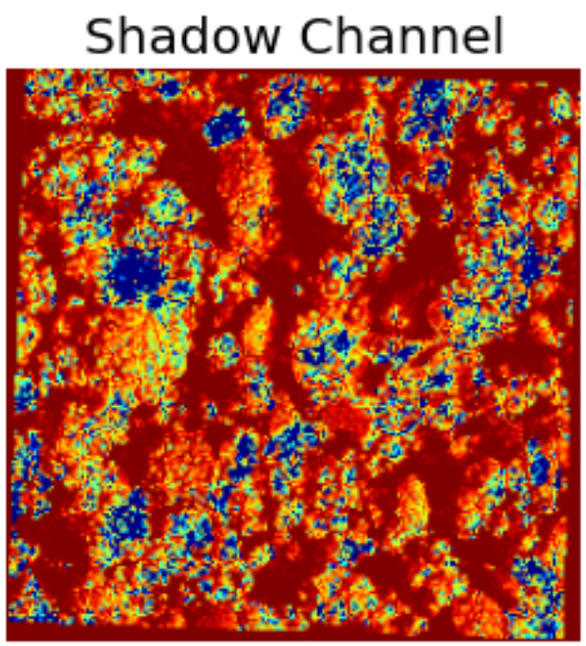


Spectral Mixture Analysis









How many endmembers?

What are the end members?

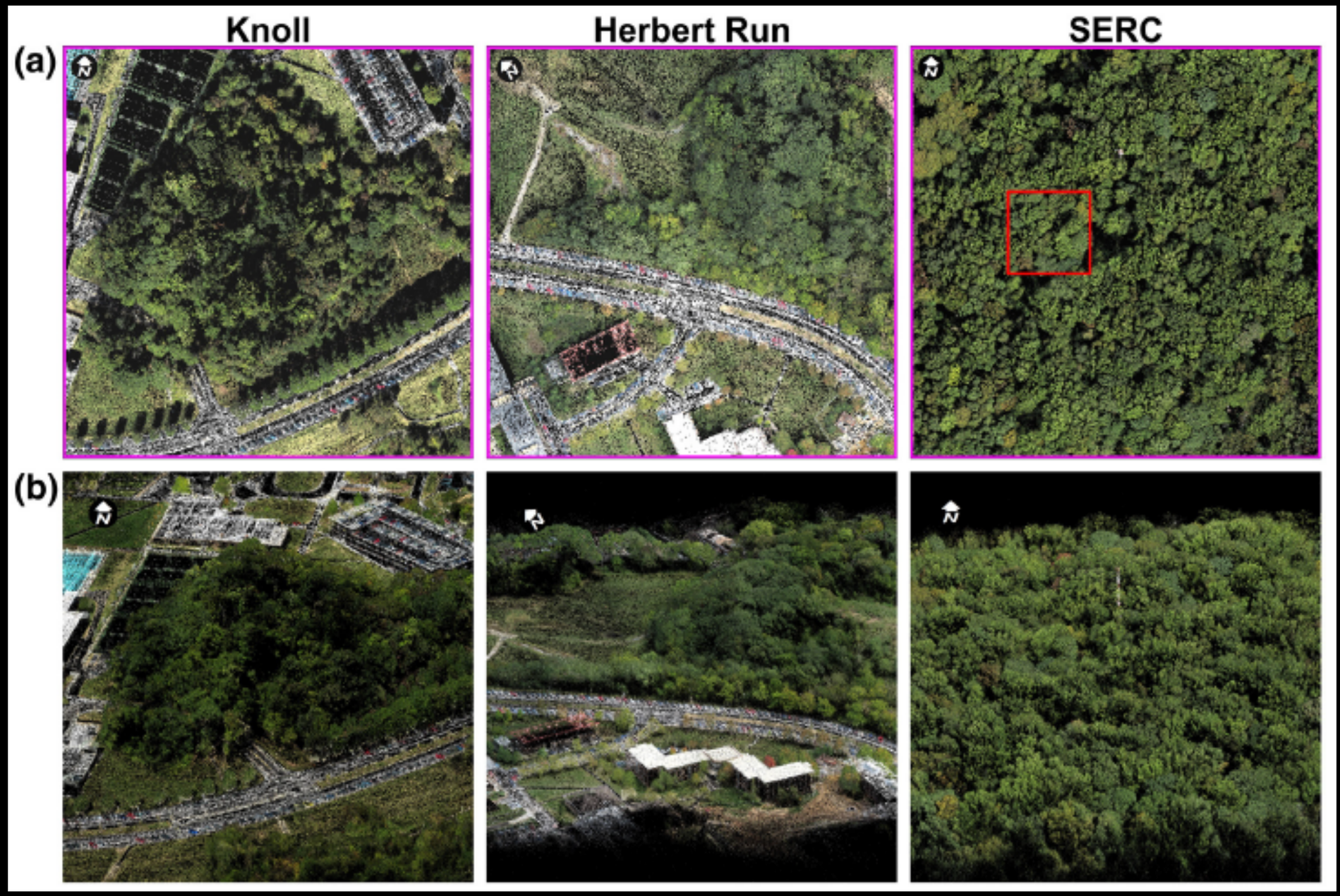
Change detection

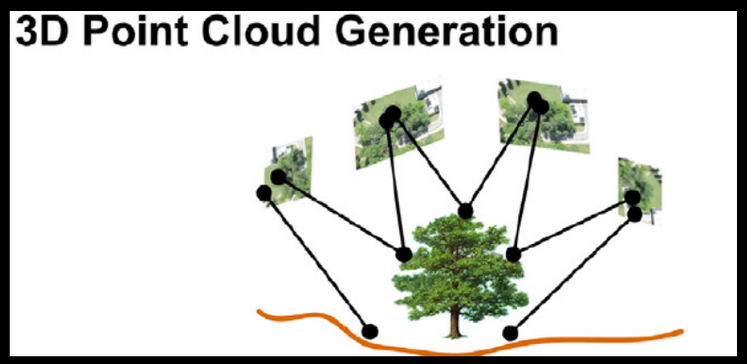
The changes in tree crowns (not the colors)

10-12-2014

12-05-2014

3D structure

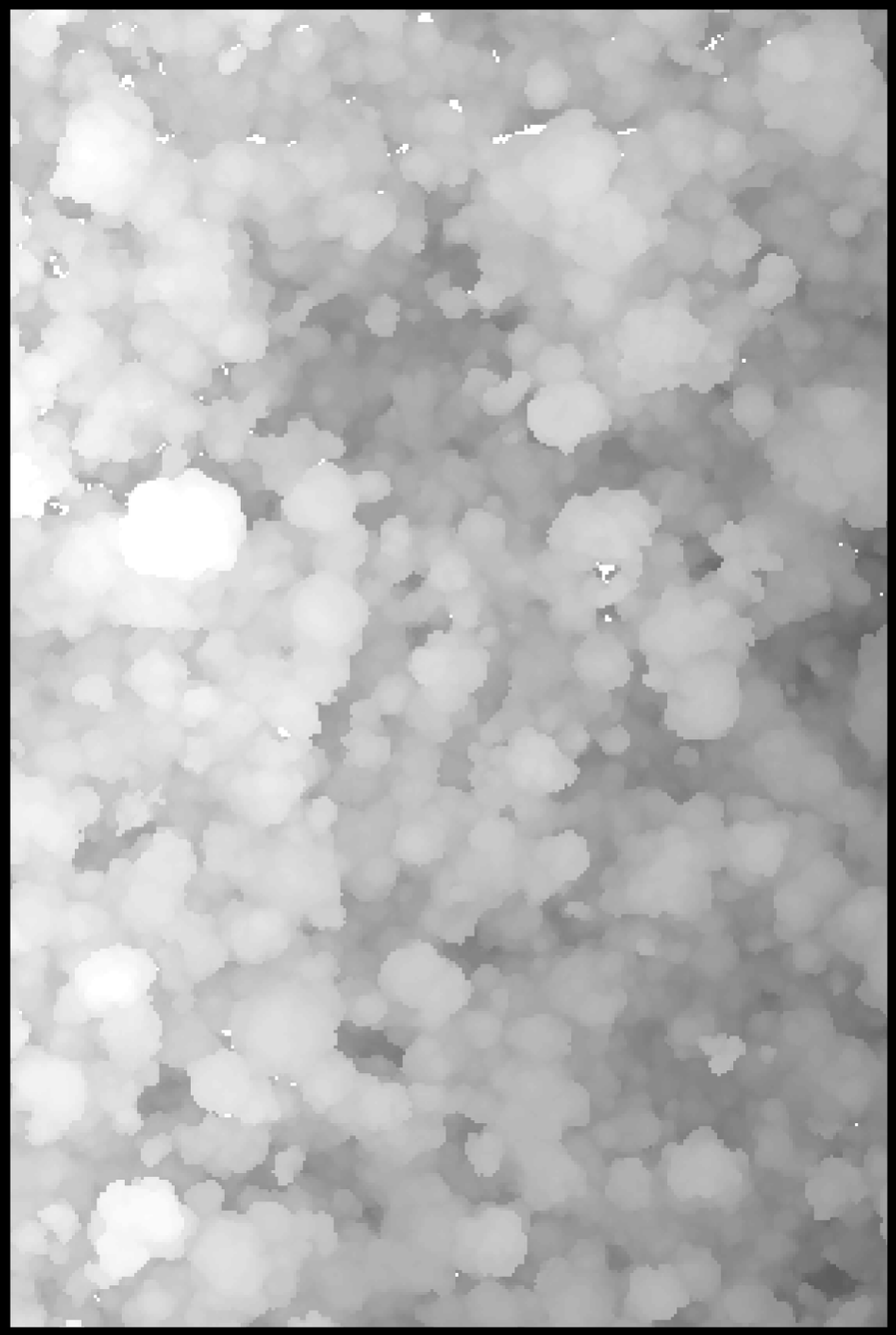




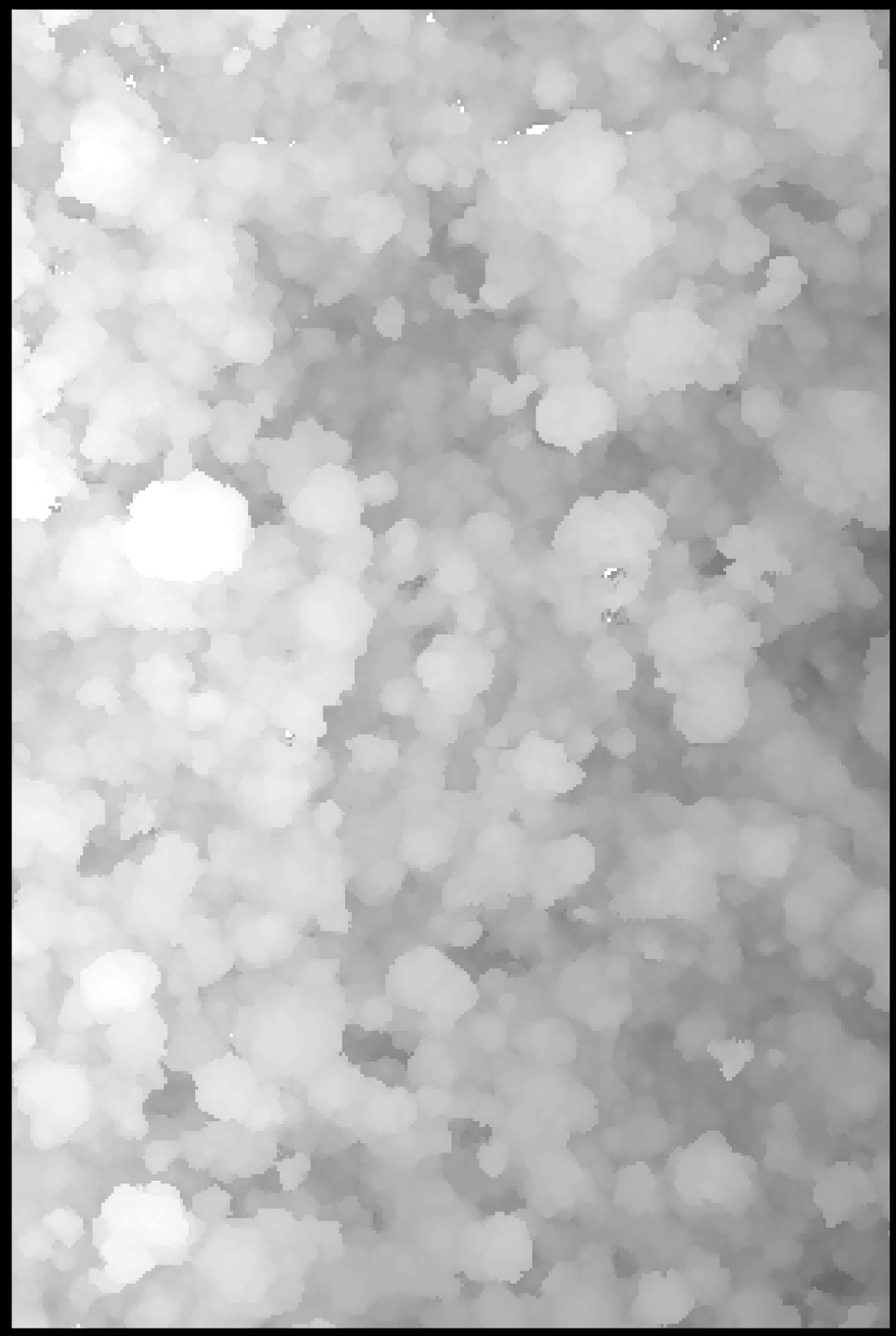
Dandois and Ellis, 2014

Change detection

Digital Surface Model



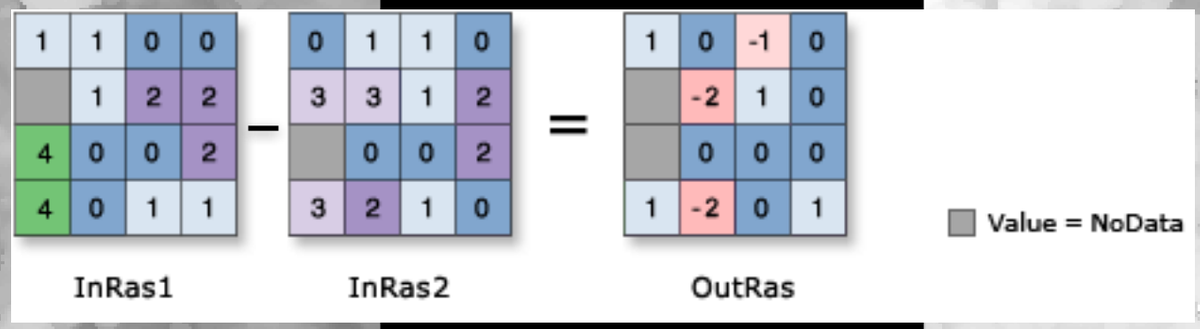
10-12-2014



12-05-2014

Change detection

Digital Surface Model

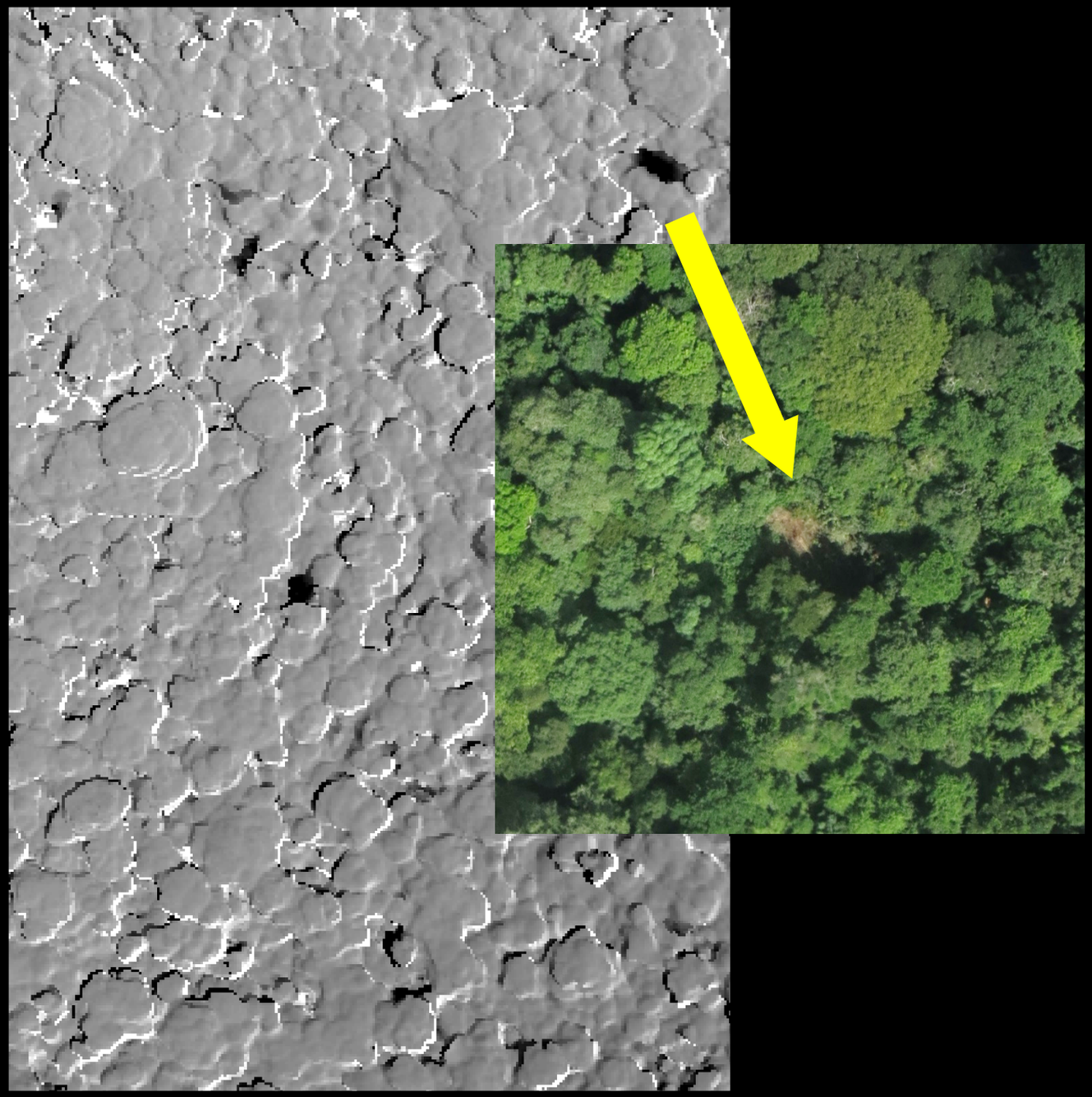


10-12-2014

12-05-2014

Change detection

Digital Surface Model - Difference Map



Recap

- Drones provide a cheap way to obtain data with high spatial resolution, high temporal resolution, and even 3D information.
- Drone-based remote sensing is more than just taking pretty pictures.
- Imaging what you can do with drones!