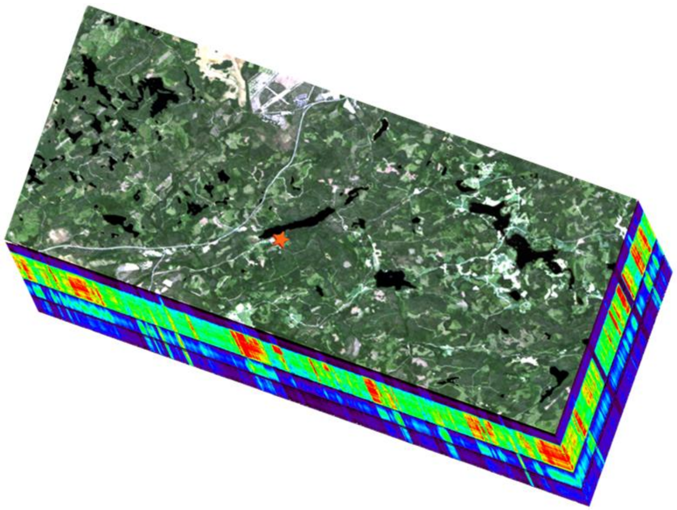
Imaging Spectroscopy for vegetation functioning

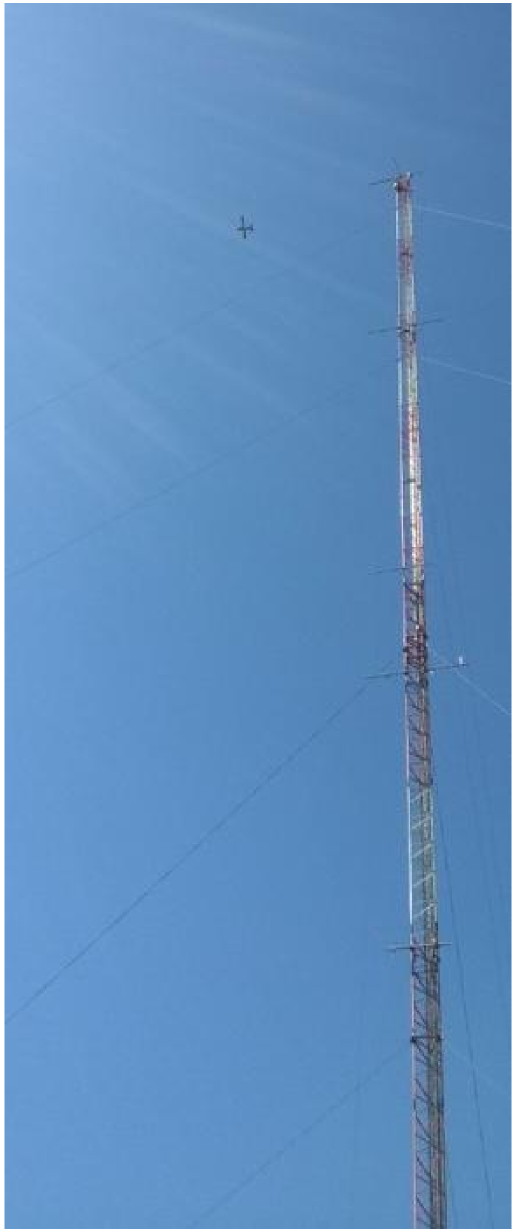


Matti Mõttus

IBC-CARBON workshop Novel Earth Observation techniques for Biodiversity Monitoring and Research, 24.05.2018

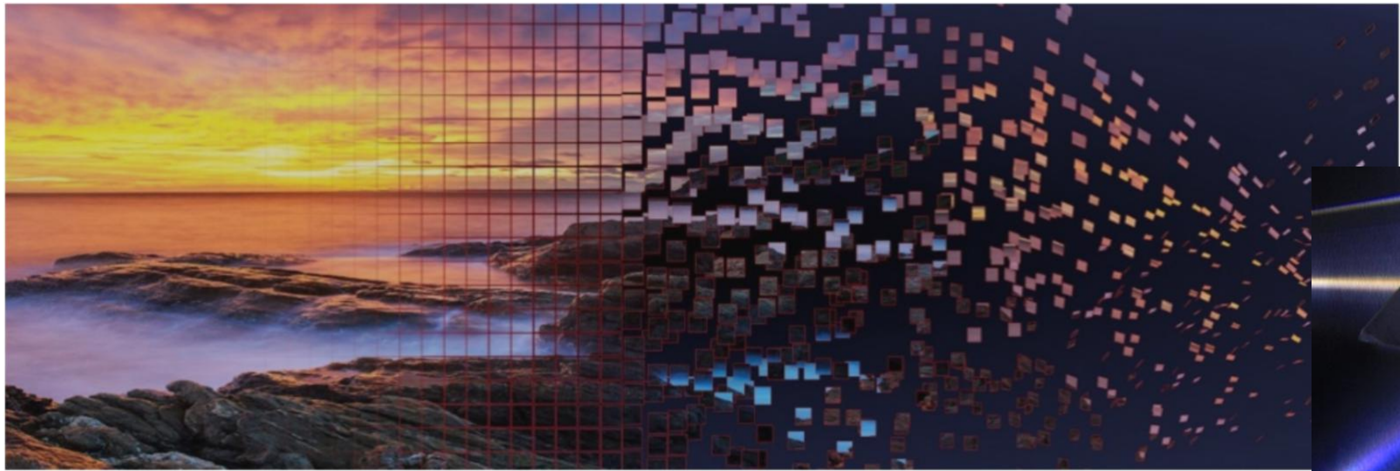
Imaging spectroscopy for plant functioning

- What is imaging spectroscopy
- Why should we do it?
  - Spectral diversity and biodiversity
  - Other things we can learn of vegetation
- Future prospects



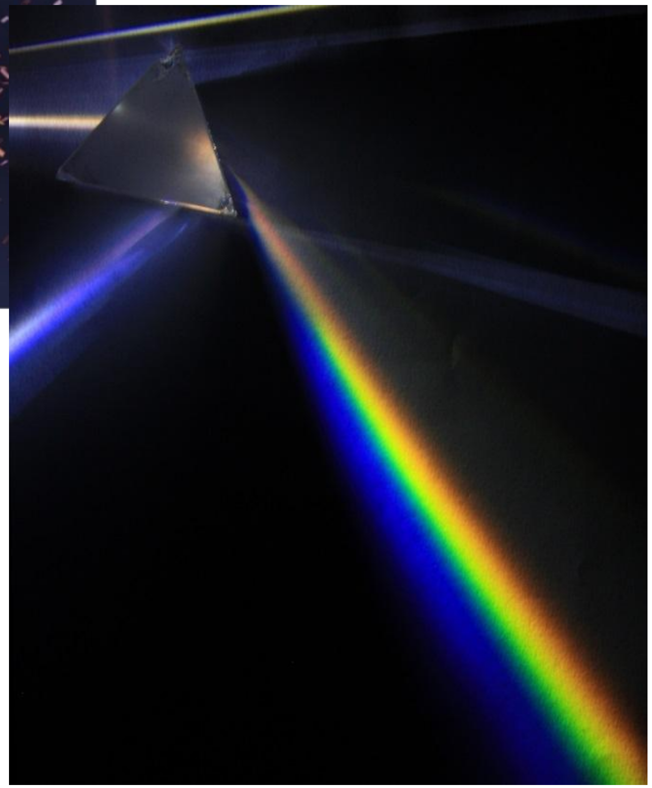
Imaging Spectroscopy

Imaging



technicolor.com

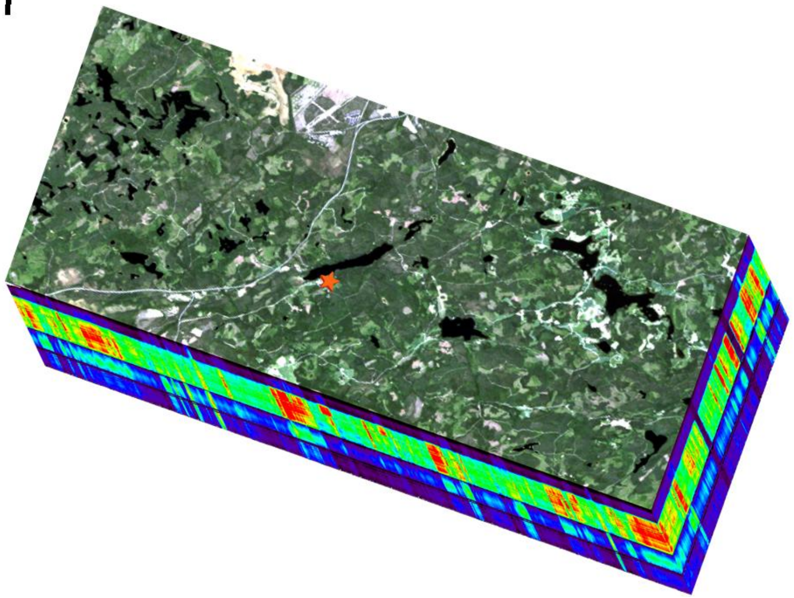
wikipedia



spectroscopy

Imaging Spectroscopy

- Also known as hyperspectral remote sensing
- Continuous spectrum measured in narrow neighboring bands
- Spectral resolution better than 10 nm
- Large number of bands (64-1000)
- Applications in many areas, incl.
  - Geology
  - Material detection
  - Vegetation function
  - Water quality
  - etc.



Why do we do it?

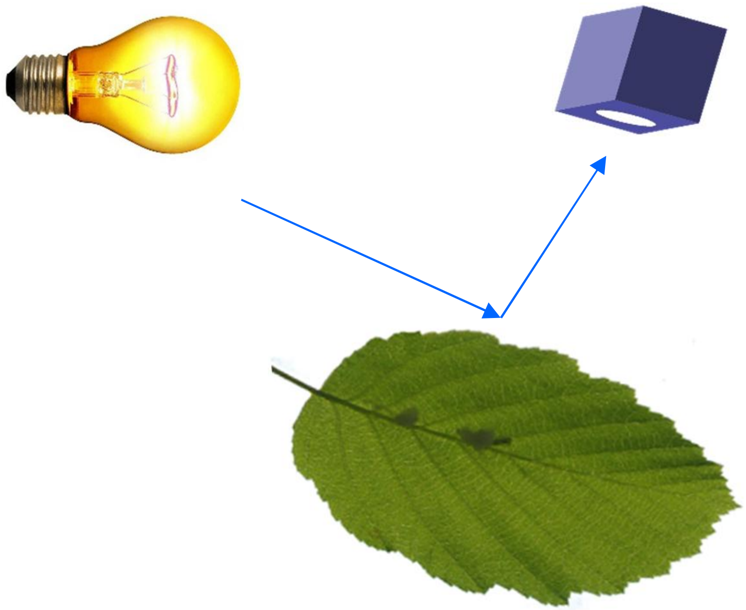
- Spectroscopy allows to determine the chemical compositions of substances based on their *absorption features*.
- Spectroscopic approach assumes the material is a (linear) mixture of *endmembers* (pure substances), and suggests a variety of methods, e.g.,
  - Endmember identification
  - Spectral feature fitting
  - Partial Least Squares Regression
- It is commonly based on libraries of leaf, pigment and other material spectra.

Spectral diversity and biodiversity

- Several researchers suggest that measures of spectral diversity can be used to characterize biological diversity
  - e.g., leaf spectral dissimilarity increases with functional dissimilarity (Schweiger et al., Nature Ecology and Evolution, 2018)
  - The more different spectra we have in a region, the more different [species/genera, plant functional types, …] we have in this region
- Even for the relatively limited boreal zone, species explained up to 69%, 70%, and 62% of reflectance, transmittance, and albedo variability in the broadleaved species group [of 13 species] (Hovi et al. 2017, Silva Fennica)

Vegetation remote sensing

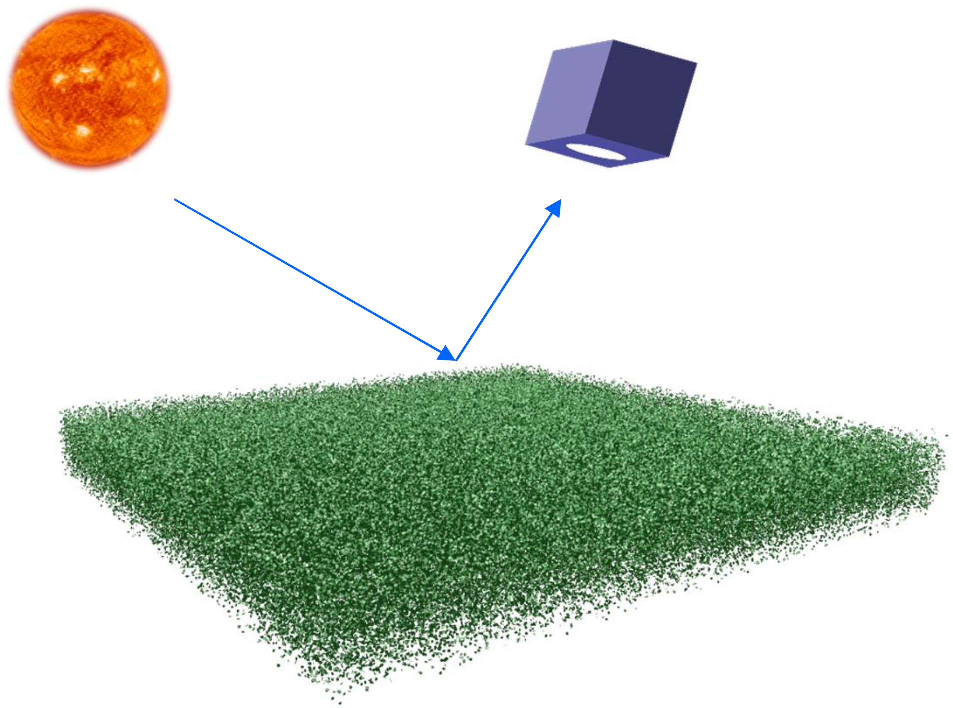
- Leaf spectra have similar features caused by the same biochemical building blocks, but still contain significant variation with species, productivity, photosynthetic status, …



Vegetation remote sensing

- Leaf spectra have similar features caused by the same biochemical building blocks, but still contain significant variation with species, productivity, photosynthetic status, …

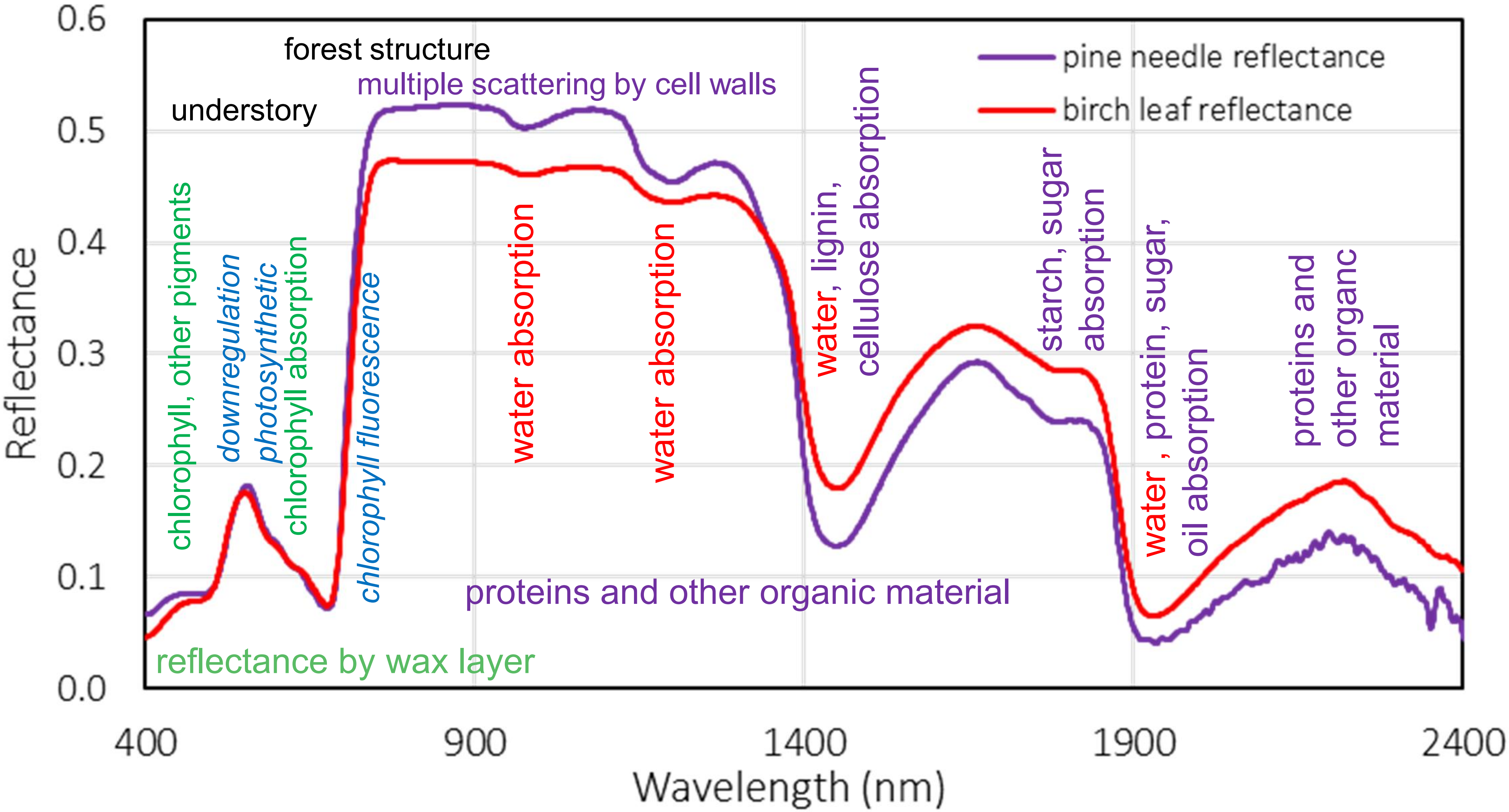
- However, no remote sensing instrument can measure one leaf. What we see is a canopy, a (very) large number of leaves and other material.



Vegetation remote sensing

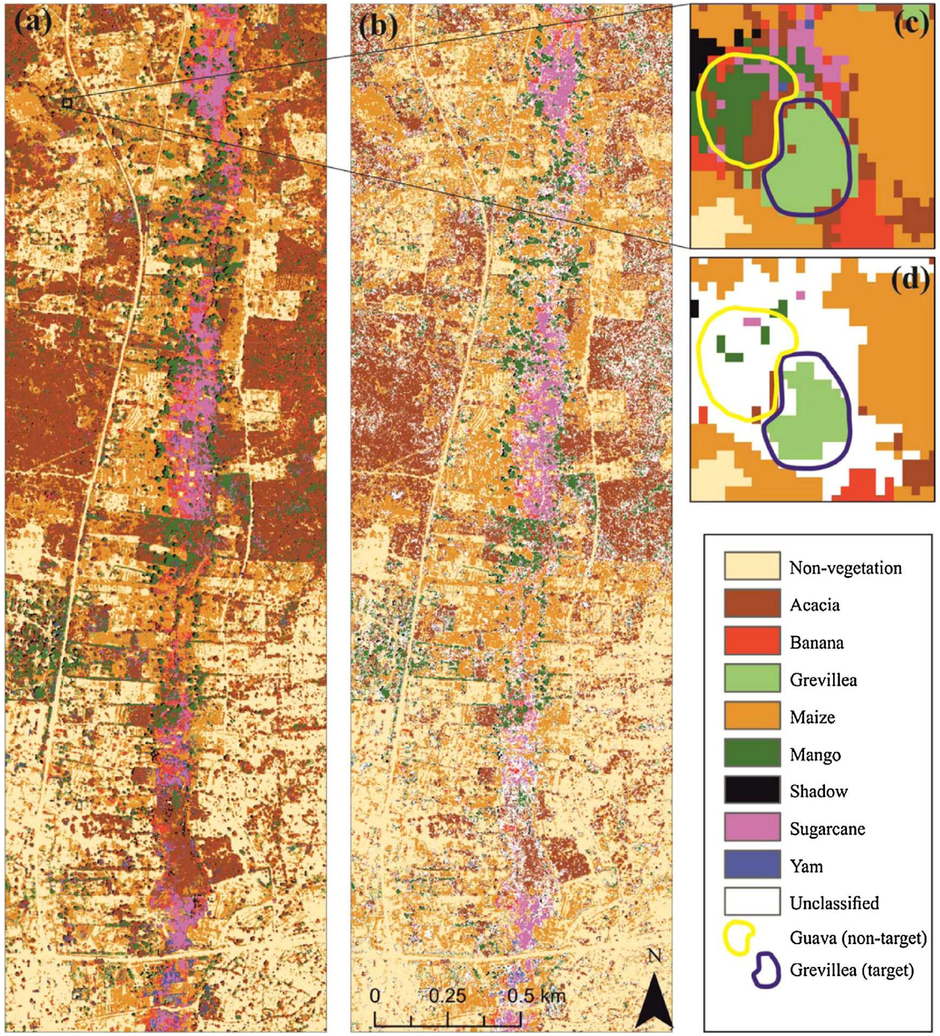
- Incident light field undergoes nonlinear transformation in a canopy
- Photons undergo many interactions in the canopy before being scattered out
- In high spatial resolution data, pixel spectrum can be formed tens of pixels away, and deep in the canopy

What’s in a vegetation spectrum



Information content in hyperspectral data

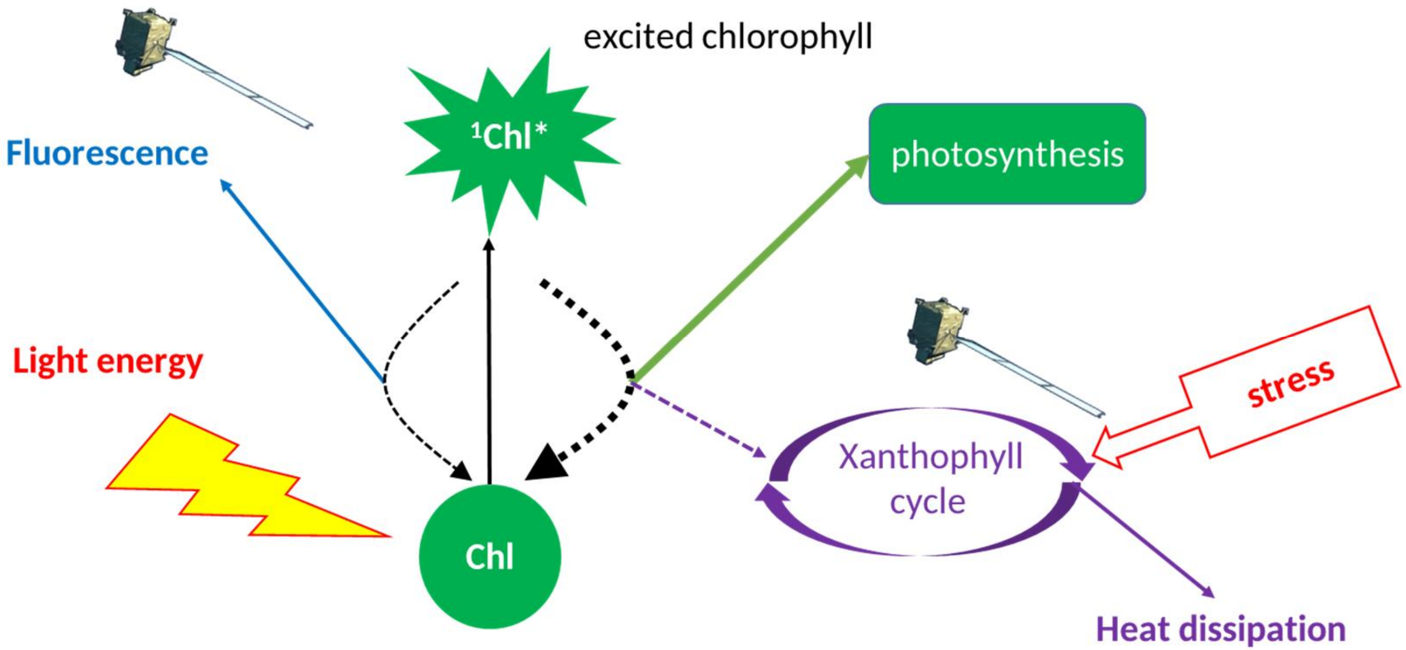
- Canopy-level reflectance still contains information on the diversity in the component spectra.
- A decent empirical classification would allow to distinguish 20+ species in a spectral image – if proper field data is provided.
- The explicit connection – scaling – between leaf and canopy spectra, and their spectral variation, is easily lost.



Piiroinen et al. 2015, Int. J. Appl. Earth Obs Geoinf

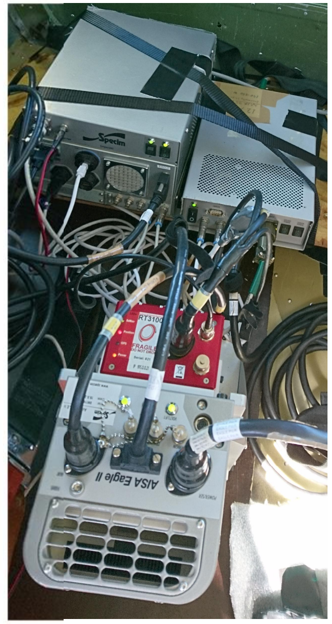
Measuring photosynthesis from space

- Canopy water and pigment content can be estimated from reflectance spectrum
- Leaf photosynthetic status affects its apparent reflectance because of chlorophyll fluorescence and dynamic changes in xanthophylls caused by light stress



Will the future by hyperspectral?

- Finland is 75% forest. Imaging spectroscopy is not required to distinguish the three main forest overstory species.
- Currently, there is no truly hyperspectral civilian sensor in space (at least with decent data availability)
- Airborne imaging spectroscopy requires the availability of instrument, capable aircraft, and processing skills…
  - Instruments are produced in Oulu, but shipped overseas
  - For long time, there was no aircraft with a sufficiently large hole stationed in Finland
  - Mastering measurements takes time
- … and is plagued by weather
- Airborne IS has largely been a low-key research activity in Finland



AISA Eagle II owned by Univ. Helsinki

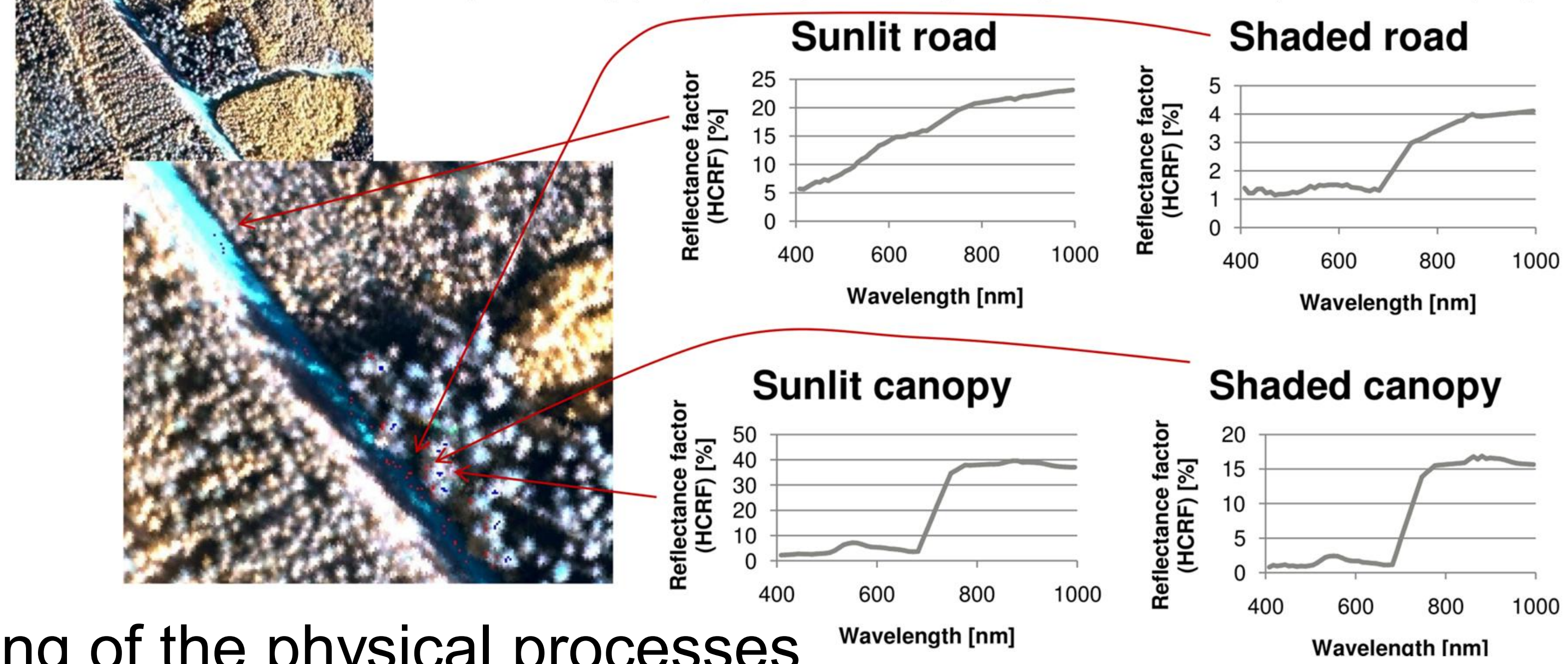
Cessna 185 Skywagon

Will the future be hyperspectral? YES!

- NASA has been working on the HyspIRI mission
  - Routine global coverage with approx 60 m pixel
- Several countries from Europe (Germany, Italy) and elsewhere (Japan) are working on hyperspectral satellite sensors
  - EnMAP and PRISMA close to launch
  - Acquisition on demand, approx. 30 m pixel size
- ESA has started phase A/B studies for the hyperspectral Sentinel Expansion High Priority Candidate Mission, Sentinel-10 (CHIME) with 20 – 30 m pixel size
- Fluorescence Explorer (FLEX, ESA Earth Explorer 8) will provide some spectroscopic capability (very high spectral resolution, reduced spectral range and spatial resulution) for mapping global photosynthesis.

Understanding the signal

Each sample is an average of 4 pixels, 4 classes (scene components) per point-pair, 82 point-pairs at total (tot ~ 1000 pts).



Takala & Mõttus (2016) *Remote Sensing of Environment*

- Full understanding of the physical processes forming the canopy spectrum
  - Not only the mathematical, signal processing approach aiming at a decomposition
- Based on a physical model of signal formation

Key points for hyperspectral remote sensing

- It can be done, also in Finland
  - We have know-how about data acquisition and processing
  - Some of the finest instruments are made in Finland
  - There are more intresting challenges than forest species mapping
  - Drones will come…
- It will be done, globally
  - Satellite missions will become operational within a decade.
  - Despite bad weather, some data will be acquired.
- There are still gaps in knowledge for understanding the signal
  - We need to learn to scale from (within-)leaf to canopy.
  - Physical understanding (modeling) of the process of how reflectance spectrum is formed for full utilization of data.


TECHNOLOGY FOR BUSINESS