COMPUTE talk

Dept. of Physical Geography and ecosystem Science, 20 Aug 2012

LUND UNIVERSITY

What are you looking at with a light sensor?

A view from statistics and sensors

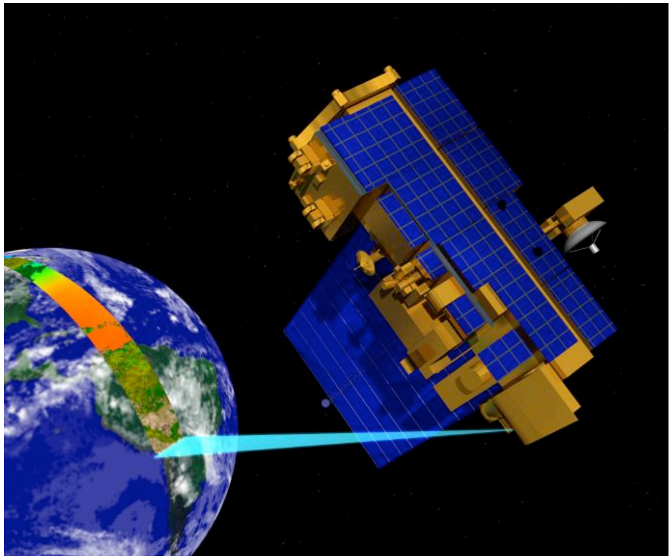
Hongxiao Jin

Supervised by **Lars Eklundh**, **Anna-Maria Jönsson**

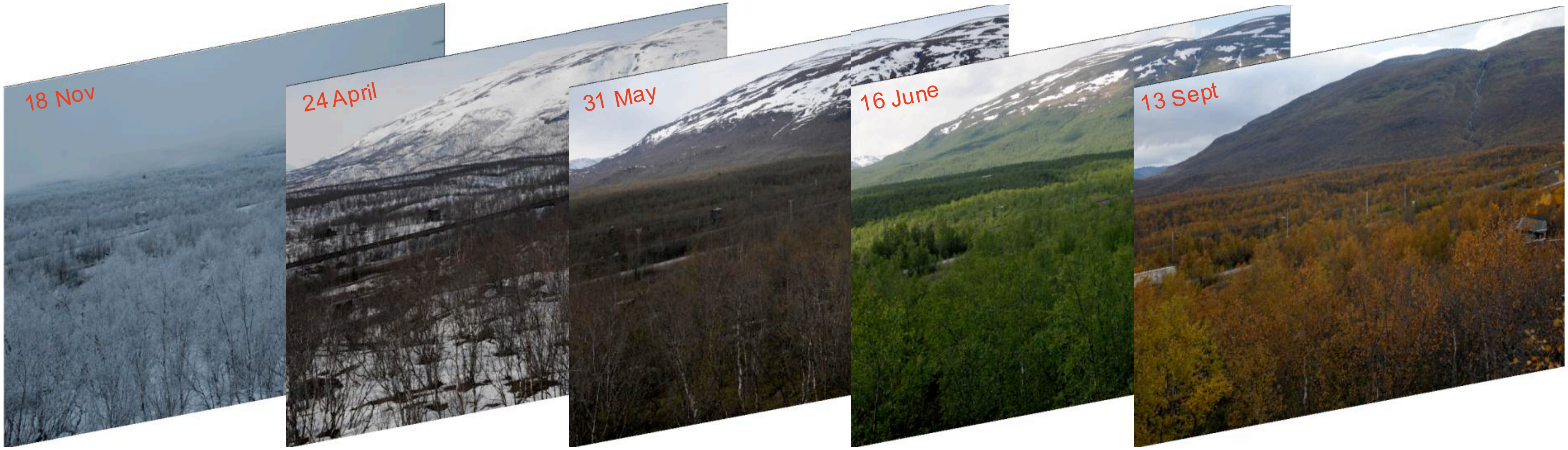
Per Jönsson, **Johan Lindström**

My PhD project

Mapping the forest phenology (seasonal cycle) in Fennoscandia region in the past 30 years by using satellite remote sensing data



The first work package of the programme
"Climate change impacts on forest phenology, and implications for Swedish forest management", Funding, Formas (PI: Prof. Eklundh).



With the validation of ground observations

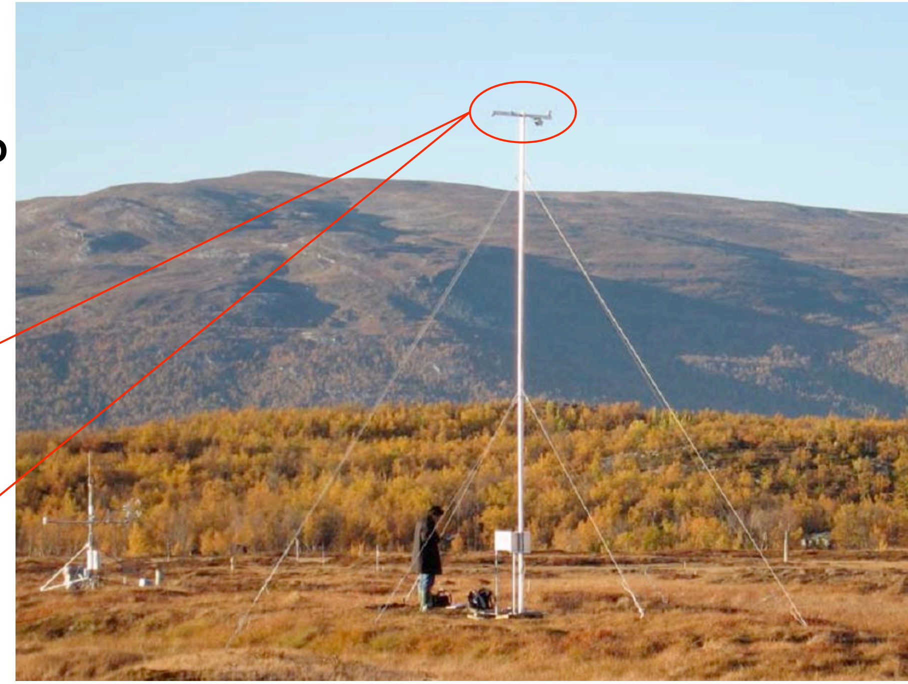
→ Ground remote sensing

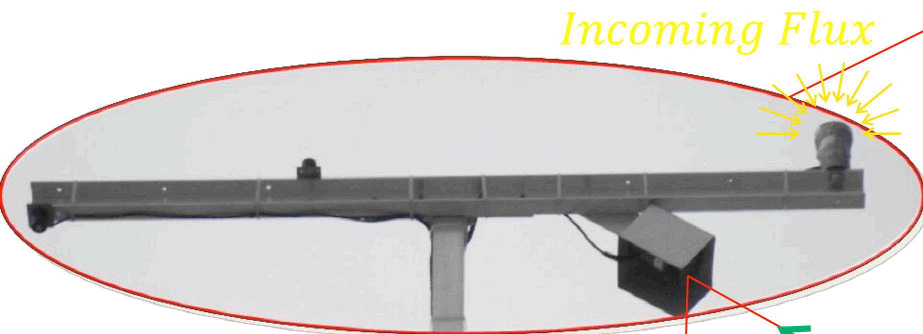
↓ Phenology cameras

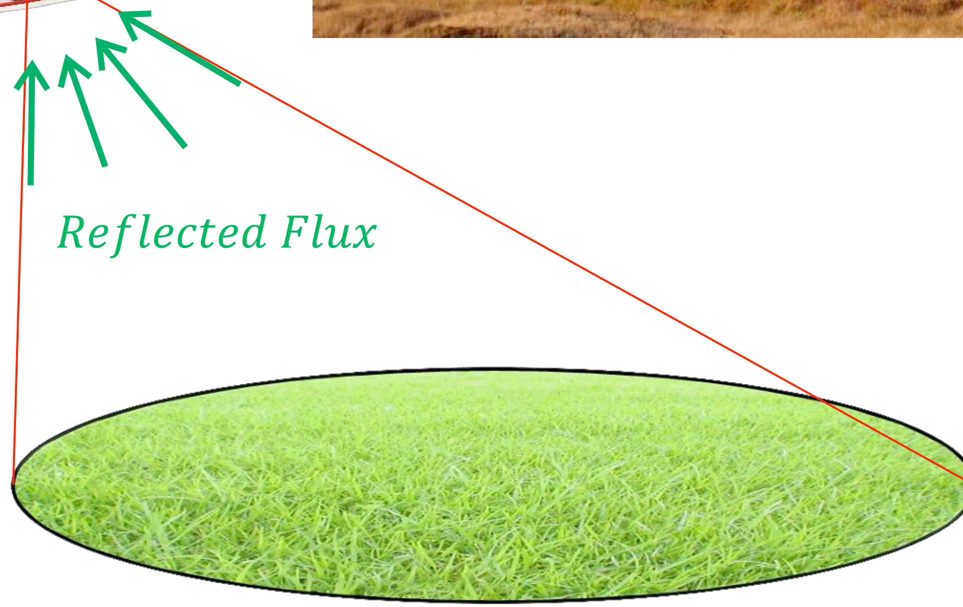
↓ And manual observation by naked eyes

My main talk today

What's the light sensor looking at?



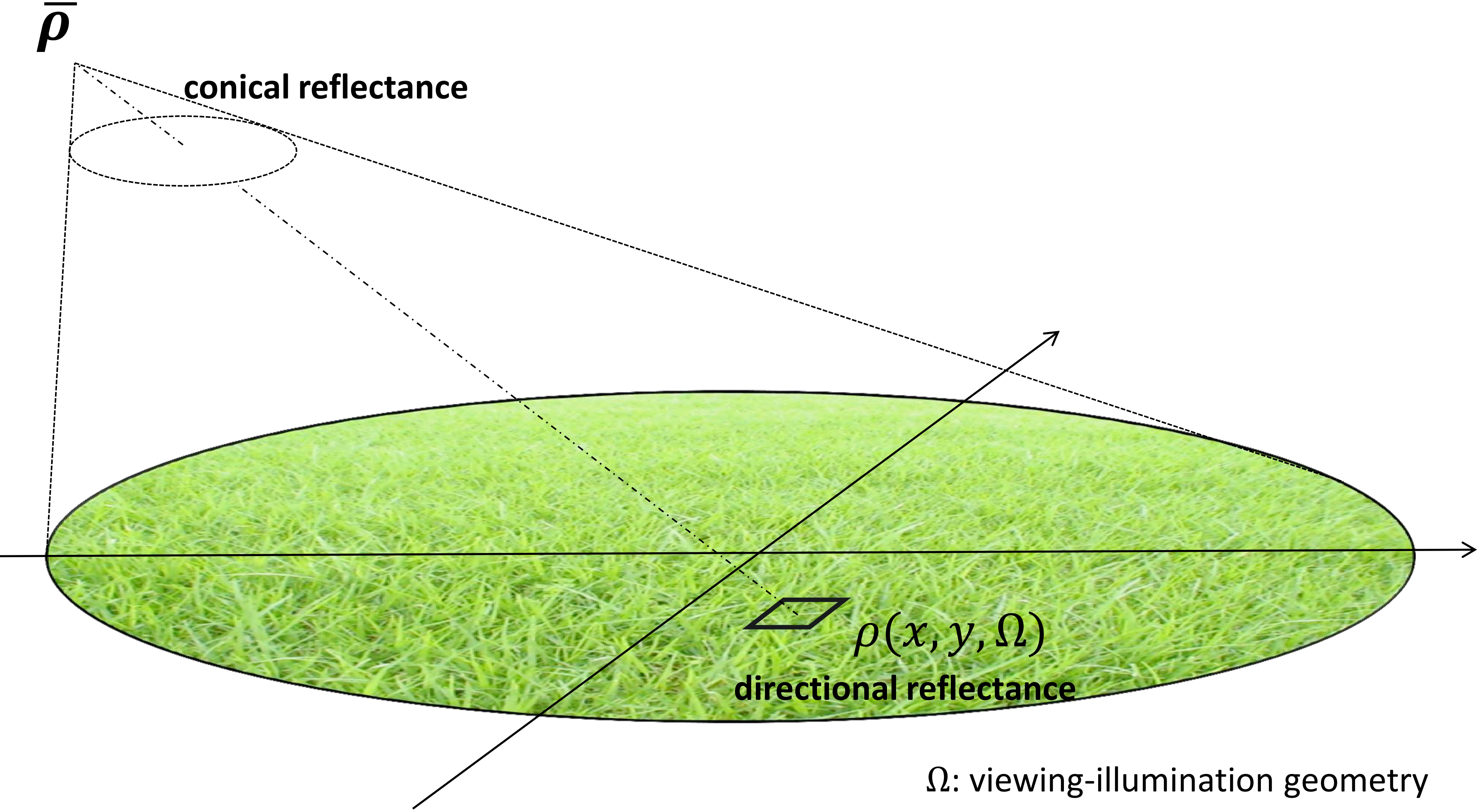




Reflectance

$$\rho = \frac{Reflected\ Flux}{Incoming\ Flux}$$

From directional reflectance to conical reflectance

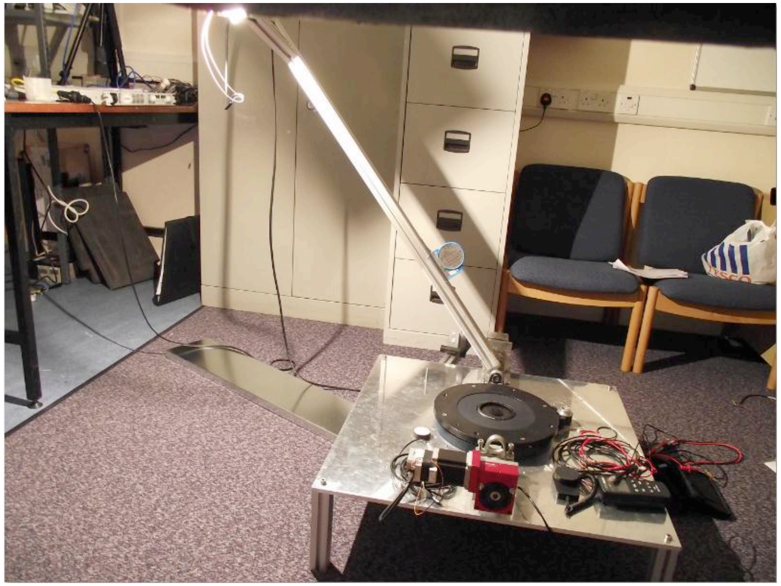


Ω: viewing-illumination geometry

Directional

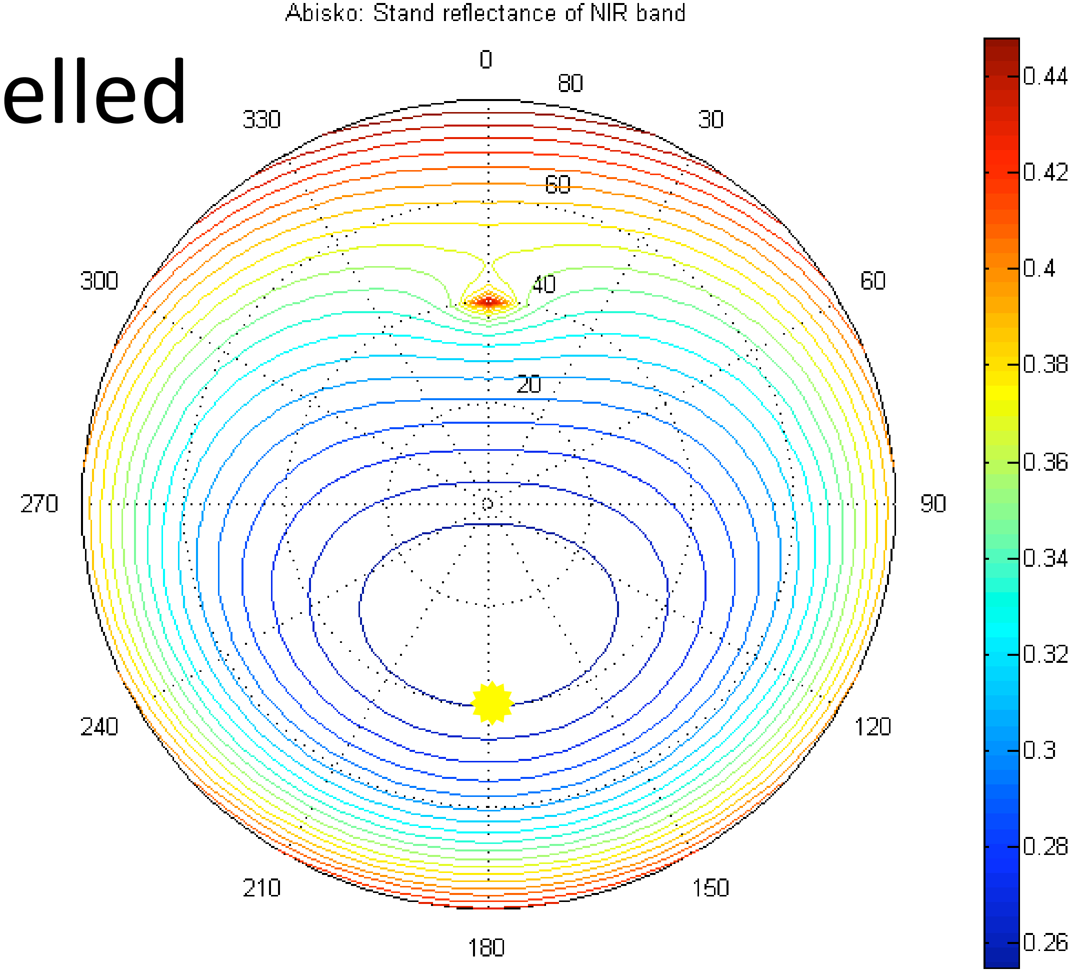
Bidirectional **r**eflectance **d**istribution **f**unction (BRDF)
Hemispherical **d**irectional **r**eflectance **f**actor (HDRF)

- Measured

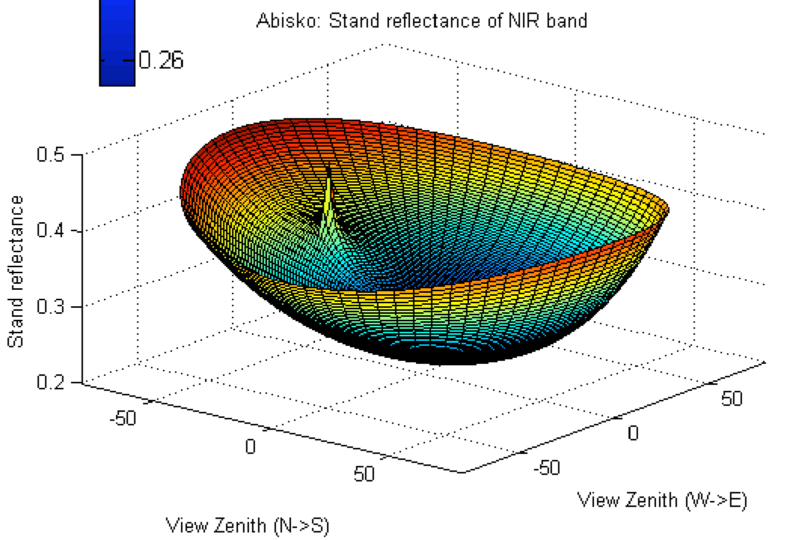


Goniometer

Modelled



Abisko: Stand reflectance of NIR band
0
30
60
90
120
150
180
210
240
270
300
330
20
40
60
80
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26



Abisko: Stand reflectance of NIR band
Stand reflectance
0.5
0.4
0.3
0.2
-50
0
50
View Zenith (N->S)
View Zenith (W->E)

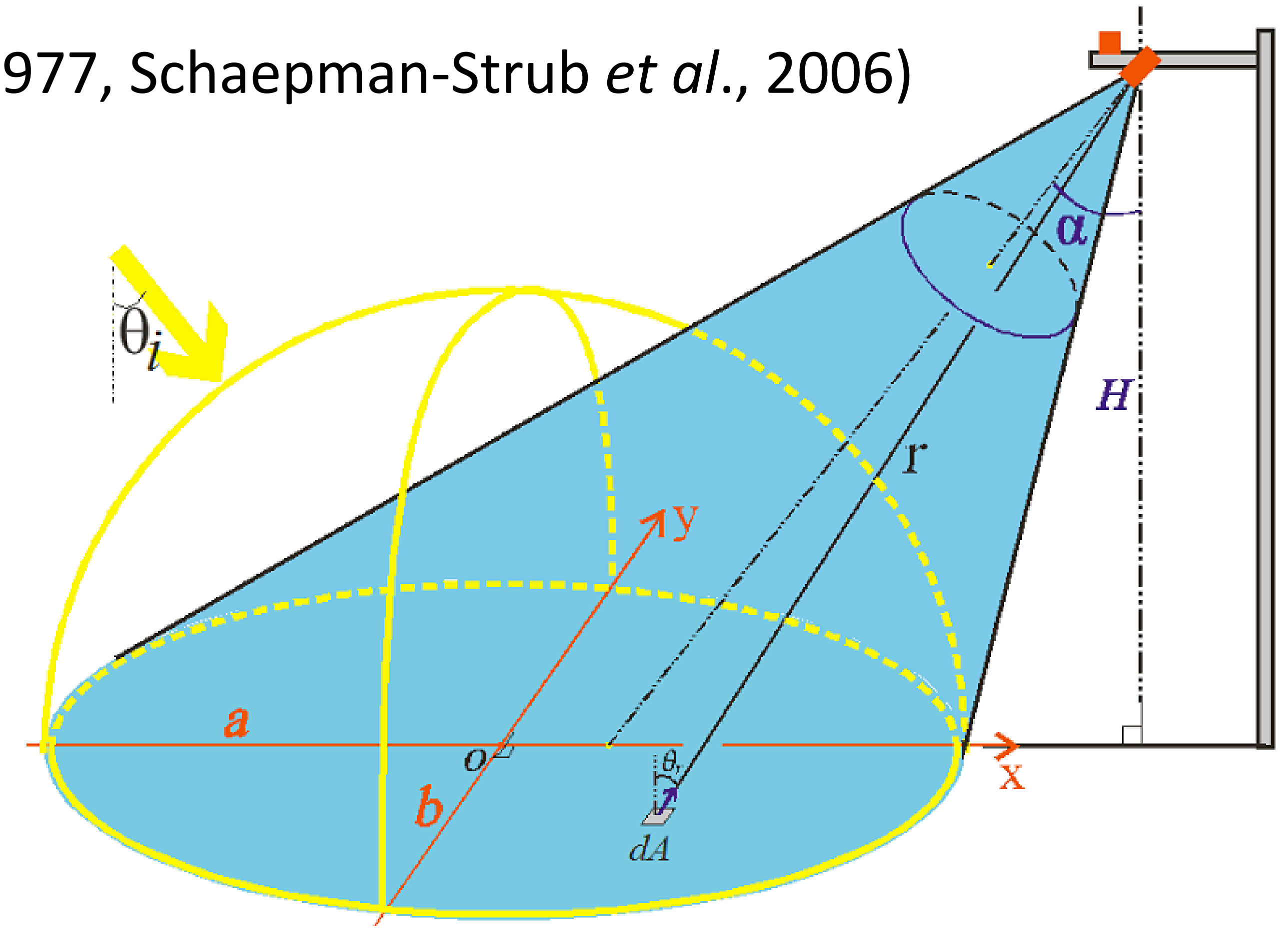
Conical

Hemispherical **conical r**eflectance **f**actor (HCRF)

- All the field measured reflectance are HCRF
- No one has modelled HCRF.
- Modelling HCRF will help us to understand the difference between directional reflectance and conical reflectance
- Help us to use light sensors with optimal field-of-view for specific research target
- Help us understanding the measurements on heterogeneous target.

$$HCRF = \frac{\int_{\omega_r}\int_{2\pi} f_r(\theta_i, \phi_i; \theta_r, \phi_r) \cdot L_i(\theta_i, \phi_i) \cdot d\Omega_i \cdot d\Omega_r}{\Omega_r/\pi \cdot \int_{2\pi} L_i(\theta_i, \phi_i) \cdot d\Omega_i}$$

(Nicodemus *et al.*, 1977, Schaepman-Strub *et al.*, 2006)



It ends up with an elliptic integral, which has no analytic solution.

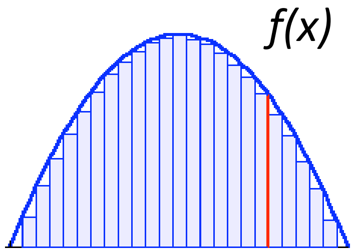
Re-write the formula in Cartesian coordinate system and try numerical method for the elliptic integral (Eklundh *et al*., 2011):

$$HCRF = \frac{\int_{\boldsymbol{A}} HDRF(\theta_r, \phi_r) \cdot \frac{\cos(\theta_r)}{r^2} dxdy}{\int_{\boldsymbol{A}} \frac{\cos(\theta_r)}{r^2} dxdy}$$

Numerical methods

Univariate

$$\int_a^b f(x)dx \approx \sum_{i=1}^{n} f(x_i) \cdot \Delta x$$



Multi-variate

Monte-carlo integration

$E(x) = \int x f(x) dx$, *X* is a random variable with pdf *f(X)*

And $E(x) \approx \frac{1}{n}\sum_{i=1}^{n} x_i$.

$$\int_A \frac{\cos(\theta_r)}{r^2} dxdy = \int_A \frac{\cos(\theta_r)}{r^2 \cdot f(x,y)} f(x,y) dxdy$$

$$\approx \frac{1}{n}\sum_{i=1}^{n} \frac{\cos(\theta_r)}{r^2 \cdot f(x_i,y_i)},$$

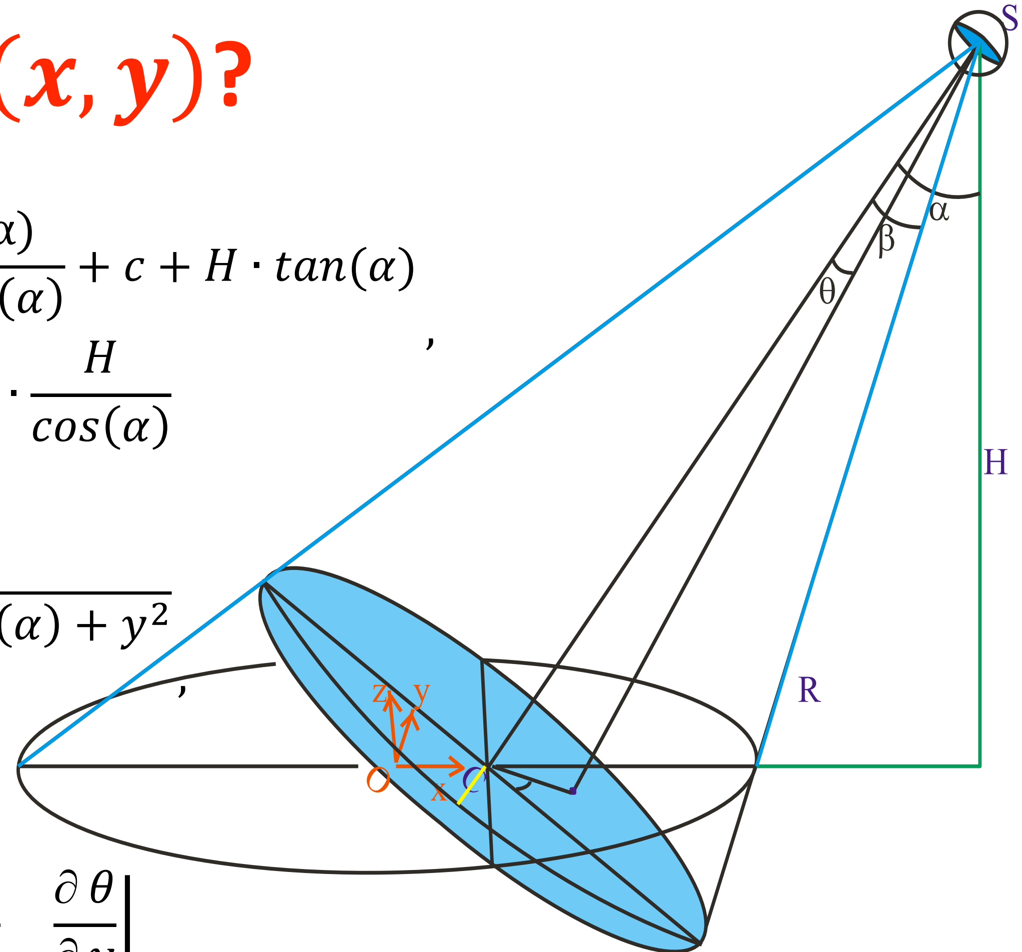
r and θ_r are functions of x_i, y_i

$f(x, y)$?

$$\begin{cases} x = H \cdot \dfrac{tan(\theta) \cdot \cos(\varphi) - tan(\alpha)}{1 + tan(\theta) \cdot cos(\varphi) \cdot \tan(\alpha)} + c + H \cdot tan(\alpha) \\ y = \dfrac{tan(\theta) \cdot sin(\varphi)}{1 + tan(\theta) \cdot cos(\varphi) \cdot \tan(\alpha)} \cdot \dfrac{H}{cos(\alpha)} \end{cases},$$

$$\begin{cases} tan(\theta) = \dfrac{\cos(\alpha)}{H} \sqrt{(x-c)^2 \cos^2(\alpha) + y^2} \\ \tan(\varphi) = \dfrac{y}{(x-c) \cdot cos(\alpha)} \end{cases},$$

$$f(x, y) = f(\theta(x, y), \varphi(x, y)) \left| \begin{vmatrix} \dfrac{\partial \theta}{\partial x} & \dfrac{\partial \theta}{\partial y} \\ \dfrac{\partial \varphi}{\partial x} & \dfrac{\partial \varphi}{\partial y} \end{vmatrix} \right|.$$



$$f(\theta, \varphi) = f(\theta) \cdot f(\varphi).$$

$$f(\theta) = f(h(\theta))|h'(\theta)| = \frac{\sin(\theta)}{1 - \cos(\beta)}.$$

$$f(\varphi) = \frac{1}{2\pi},$$

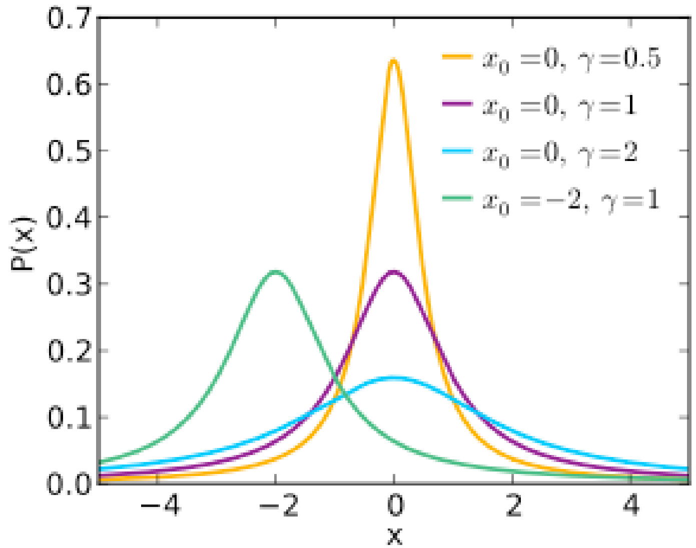
Distribution

$$f(x, y) = \frac{H}{2\pi[1-\cos(\beta)]} \cdot \frac{1}{[(x-c)^2\cos^2(\alpha) + y^2 + (H/\cos(\alpha))^2]^{3/2}}.$$

Cauchy distribution

$$f(x, y) = \frac{1}{\pi} \cdot \frac{\gamma}{[(x-x_0)^2 + (y-y_0)^2 + \gamma^2]^{3/2}}$$

$$f(x) = \frac{1}{\pi} \cdot \frac{\gamma}{(x-x_0)^2 + \gamma^2}$$

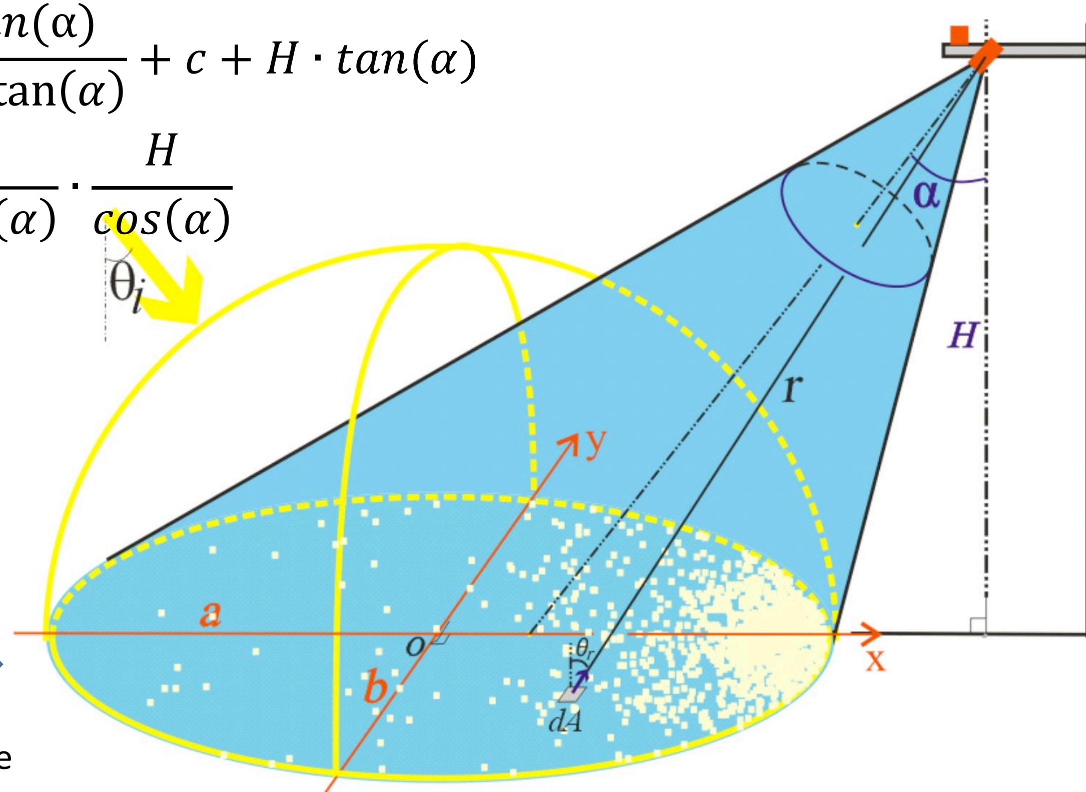


Sample method

$$\begin{cases} h \in U\left(\frac{H}{\cos(\alpha)}, \frac{H}{\cos(\alpha)\cdot\cos(\beta)}\right) \\ \varphi \in U(0,2\pi) \end{cases}$$

$$cos(\theta) = \frac{h \cdot \cos(\alpha) \cdot \cos(\beta)}{H}$$

$$\begin{cases} x = H \cdot \frac{tan(\theta)\cdot\cos(\varphi) - tan(\alpha)}{1 + tan(\theta)\cdot cos(\varphi)\cdot\tan(\alpha)} + c + H\cdot tan(\alpha) \\ y = \frac{tan(\theta)\cdot sin(\varphi)}{1 + tan(\theta)\cdot cos(\varphi)\cdot\tan(\alpha)} \cdot \frac{H}{cos(\alpha)} \end{cases}$$



Matlab GUI show

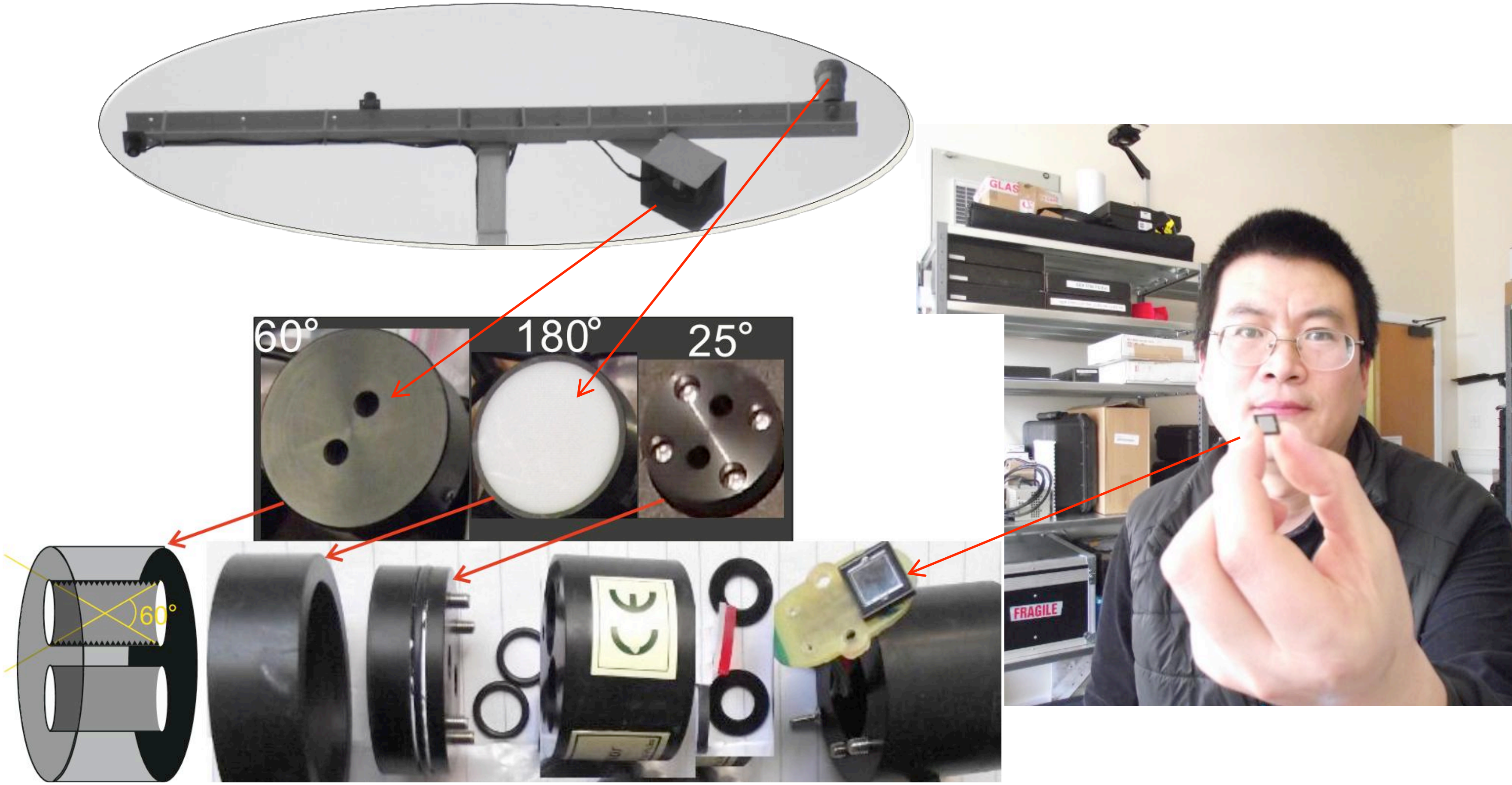
D:_PhD\PresenstationForLars\code

HCRF Model results:

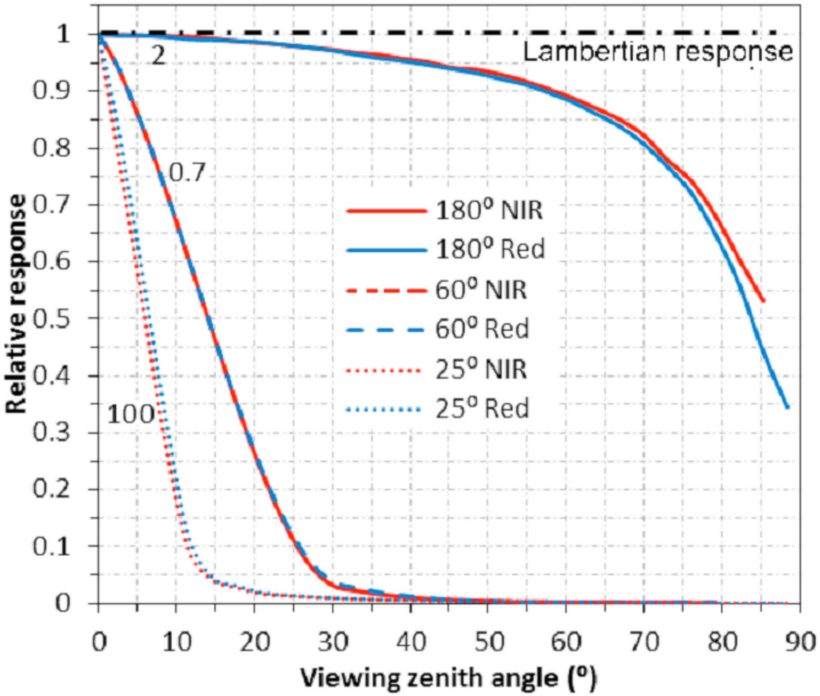
1. Within the light sensor footprint, each point does not equally contribute to the reflectance (radiance) measurement. Near points contribute more.
2. Conical measurements are close to directional ones
3. Hemispherical sensors, like PAR sensor, only look at limited area, not hemipherically unlimited area.
4. Points within 10h (h PAR sensor height) radius of PAR sensor make 95% of total contribution. Those within 2h contributes 50%.

More problems

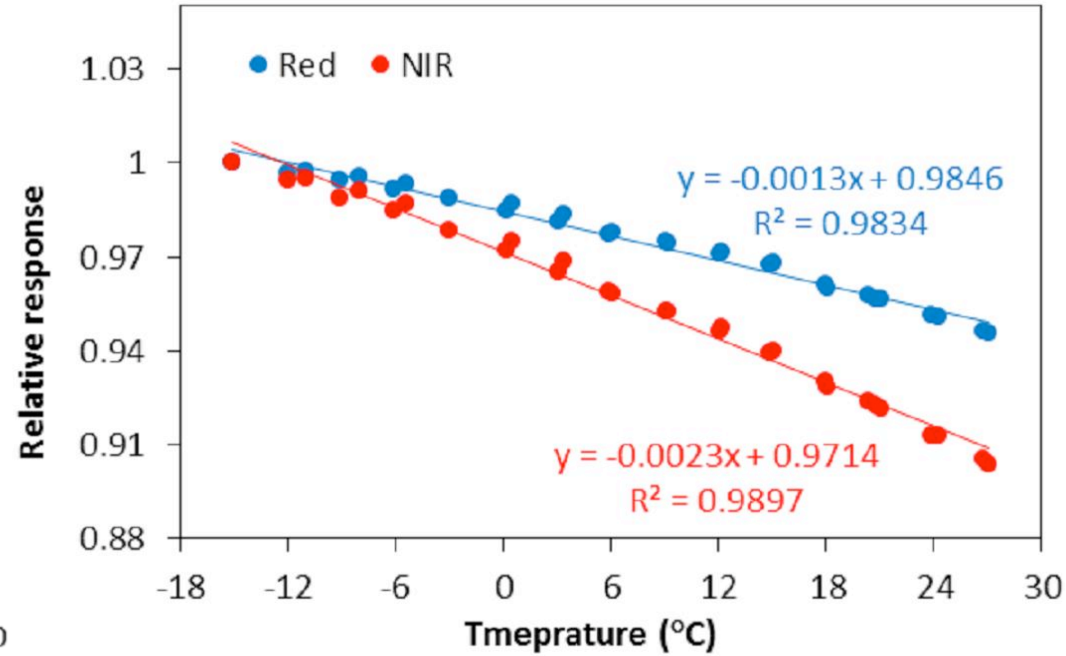
We assumed the light sensor has isotropic response in previous HCRF modelling



↓ Directional response

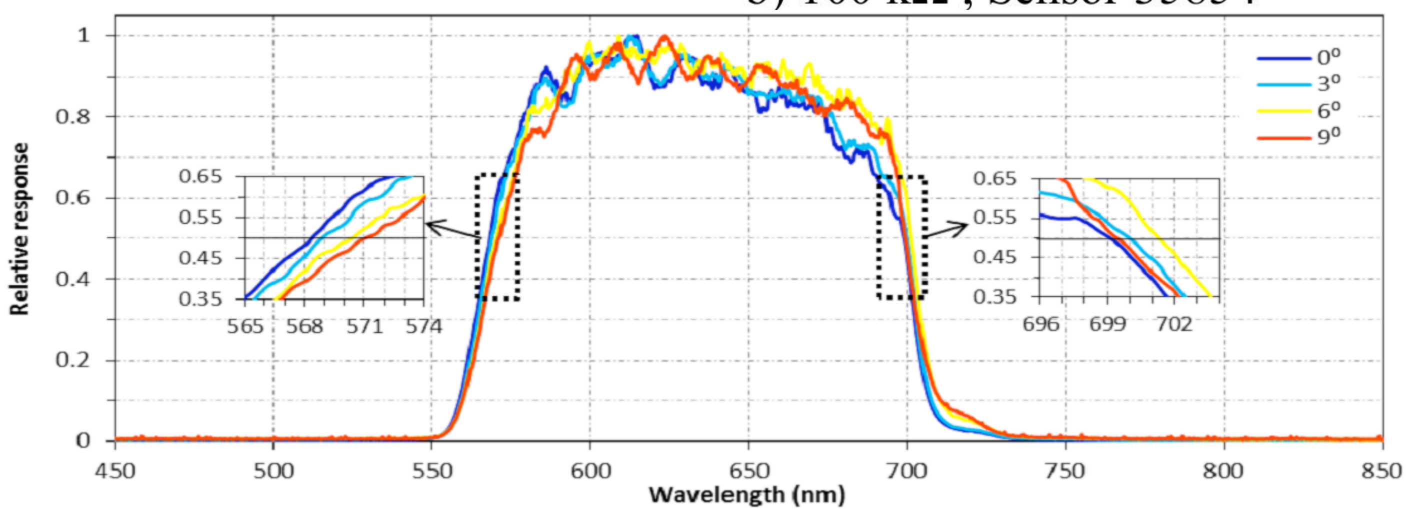


↓ Temperature drift



b) 100 kΩ , Sensor 35854

→ Spectral shift



a) Red filter, no cosine diffuser

Conclusion

Be fully aware of what you are looking at with light sensor, and be aware of non-vegetation induced anormalies.

with respect to

inhomogeneous vegetation, anistropic sensor response, and temperature-dependent response


Thanks!