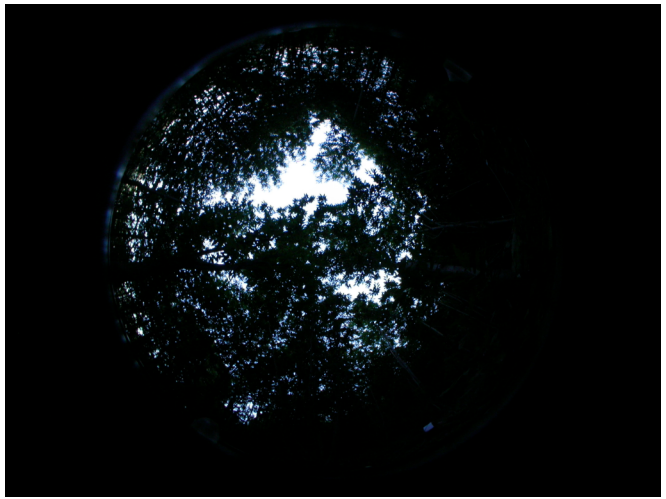
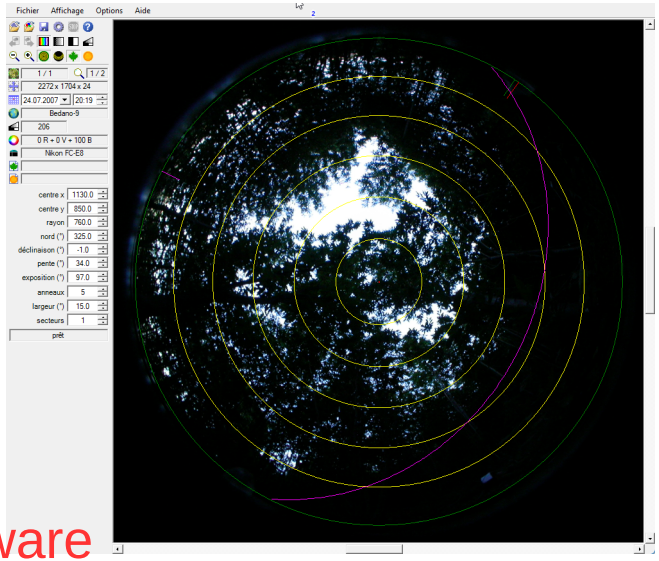
# Estimation of leaf area index (LAI) of forests by hemispherical photography: challenges and solutions

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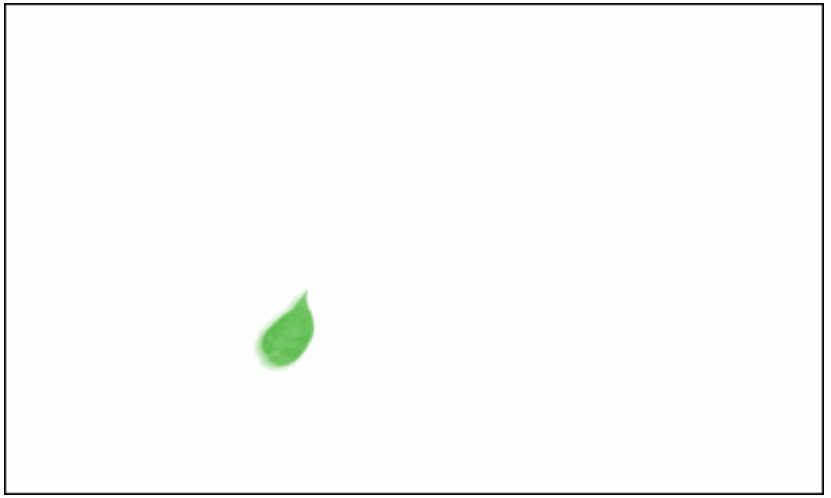

LAI 4.55

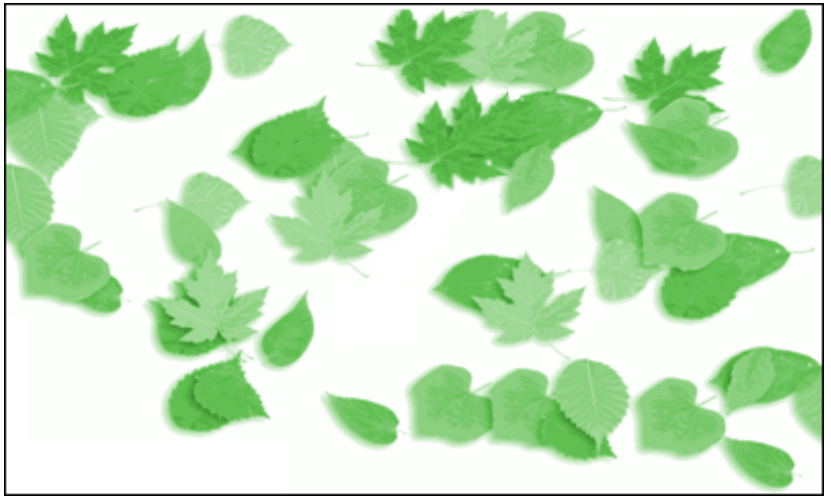
picture

software

result

# Challenge 0: optical overlap





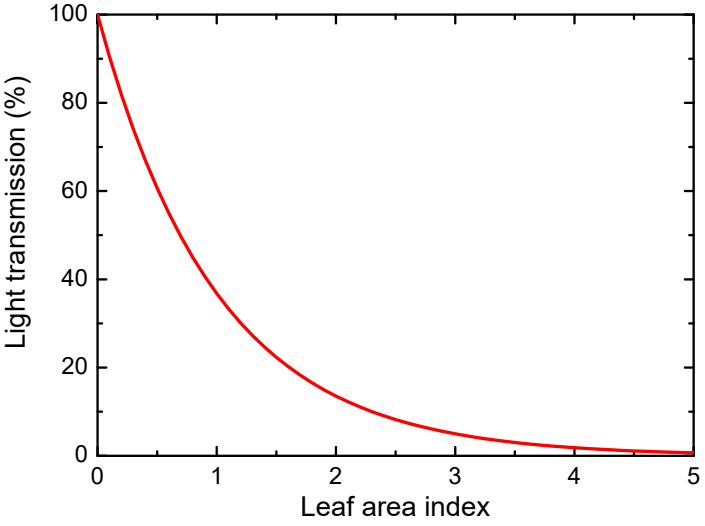
Solution: Beer-Lambert-Bouger

Formulate it as a differential equation and solve it:

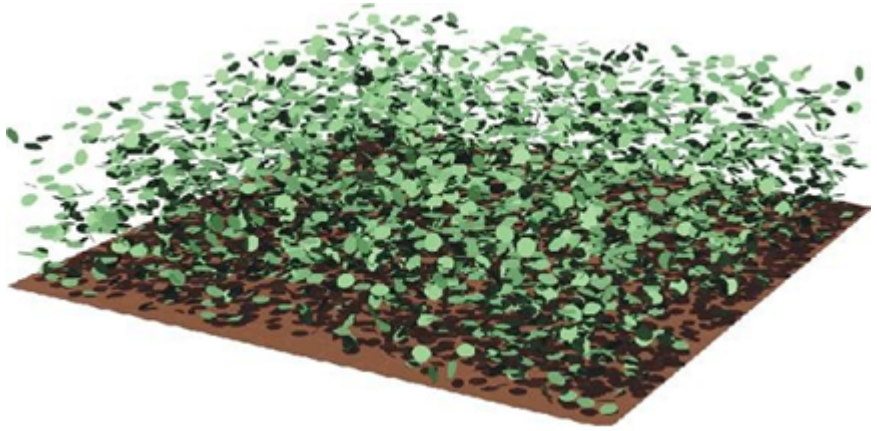
$dI / I = L$

$I = I_0 e^{-L}$

$L = -\ln (1 - I) = -\ln (T)$



# Challenge 1: 3rd dimension



Solution: projection trigonometry

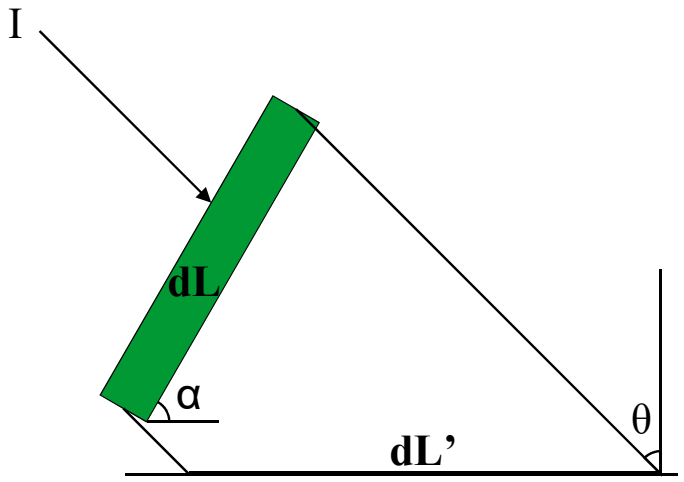
Ideal 3-dimensional canopy:

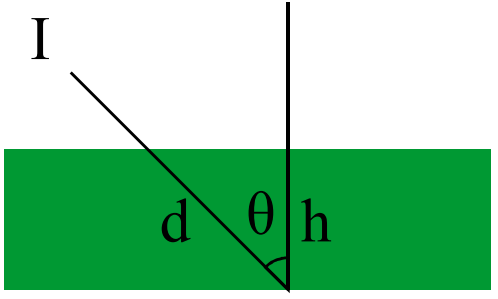
$I(\theta) = I_0(\theta)\, e^{-G(\theta,\alpha)L / \cos\theta}$

θ: zenith angle of light

α: leaf inclination angle

$d = h / \cos\theta$

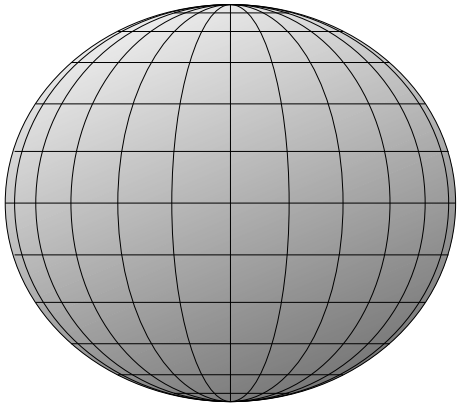


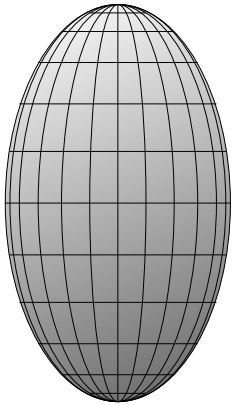
# Challenge 2: leaf angle

Solution: statistical model

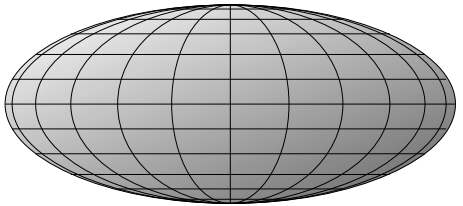
Ellipsoidal model for leaf angle distribution



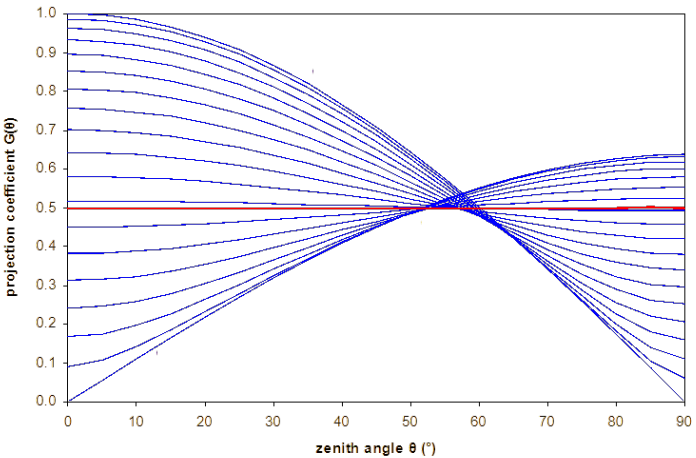
all probabilities equal
spherical distribution
x = 1
average α = 57.3°



erectophile foliage
x = 0.5
average α = 71°



planophile foliage
x = 2
average α = 38°



# Challenge 3: canopy clumping

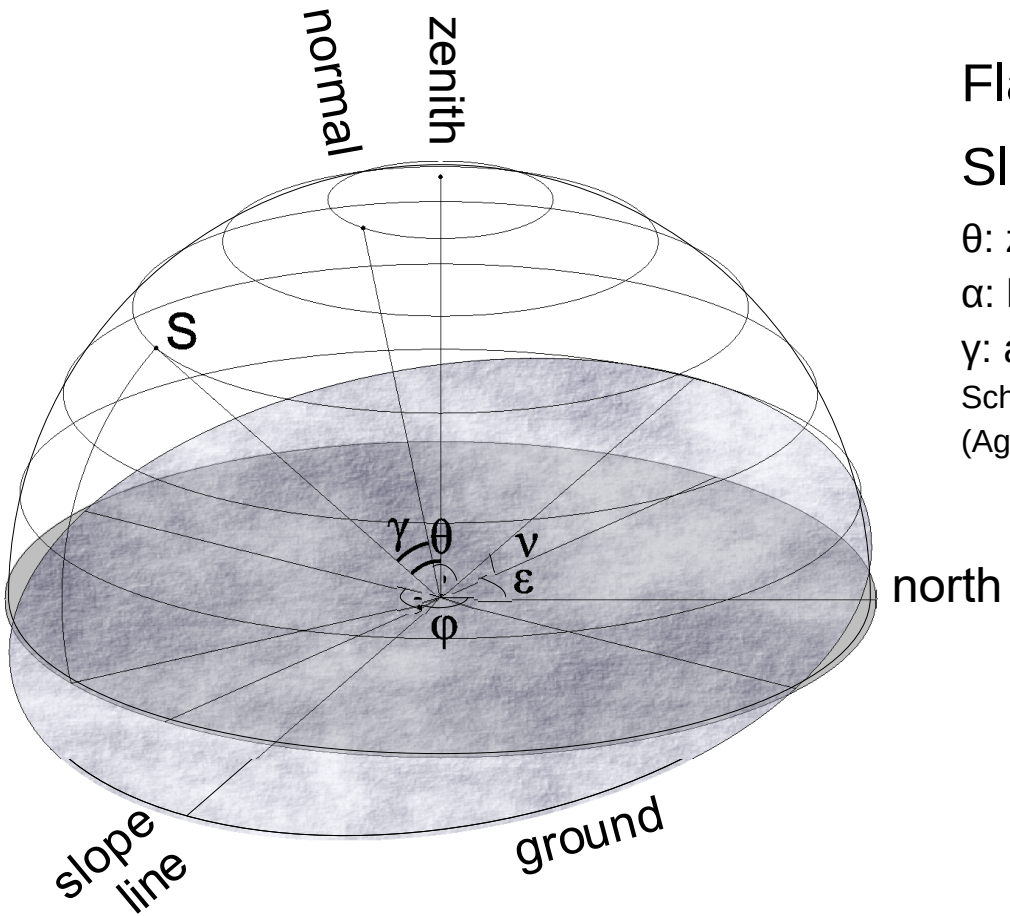


Solution: statistical model

Large gaps statistically incompatible with a random distribution of the foliage are separated. LAI calculation restricted to areas with foliage.

apparent LAI: 1.34
agregation factor: $\Omega = 0.75$
corrected LAI: 1.80

# Challenge 4: ground slope




Solution: more trigonometry

Flat ground: $I(\theta) = I_0(\theta)\, e^{-G(\theta)L / \cos\theta}$

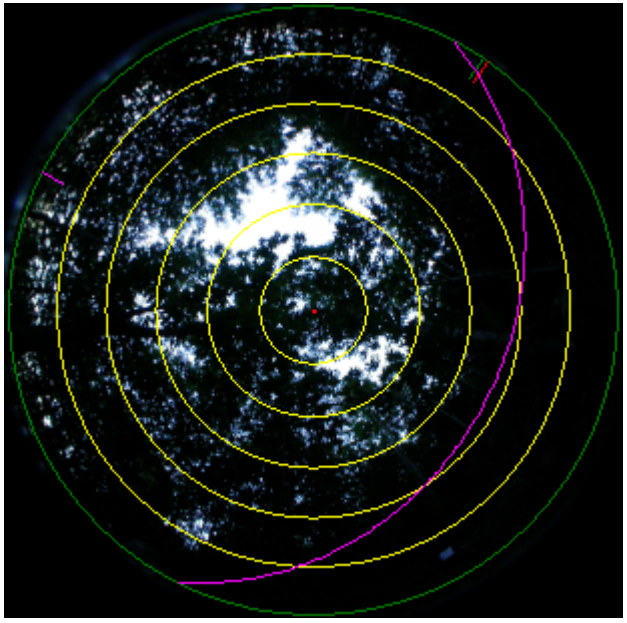
Slope: $I(\theta,\gamma) = I_0(\theta,\gamma)\, e^{-G(\theta)L / \cos\gamma}$

θ: zenith angle of light

α: leaf inclination angle

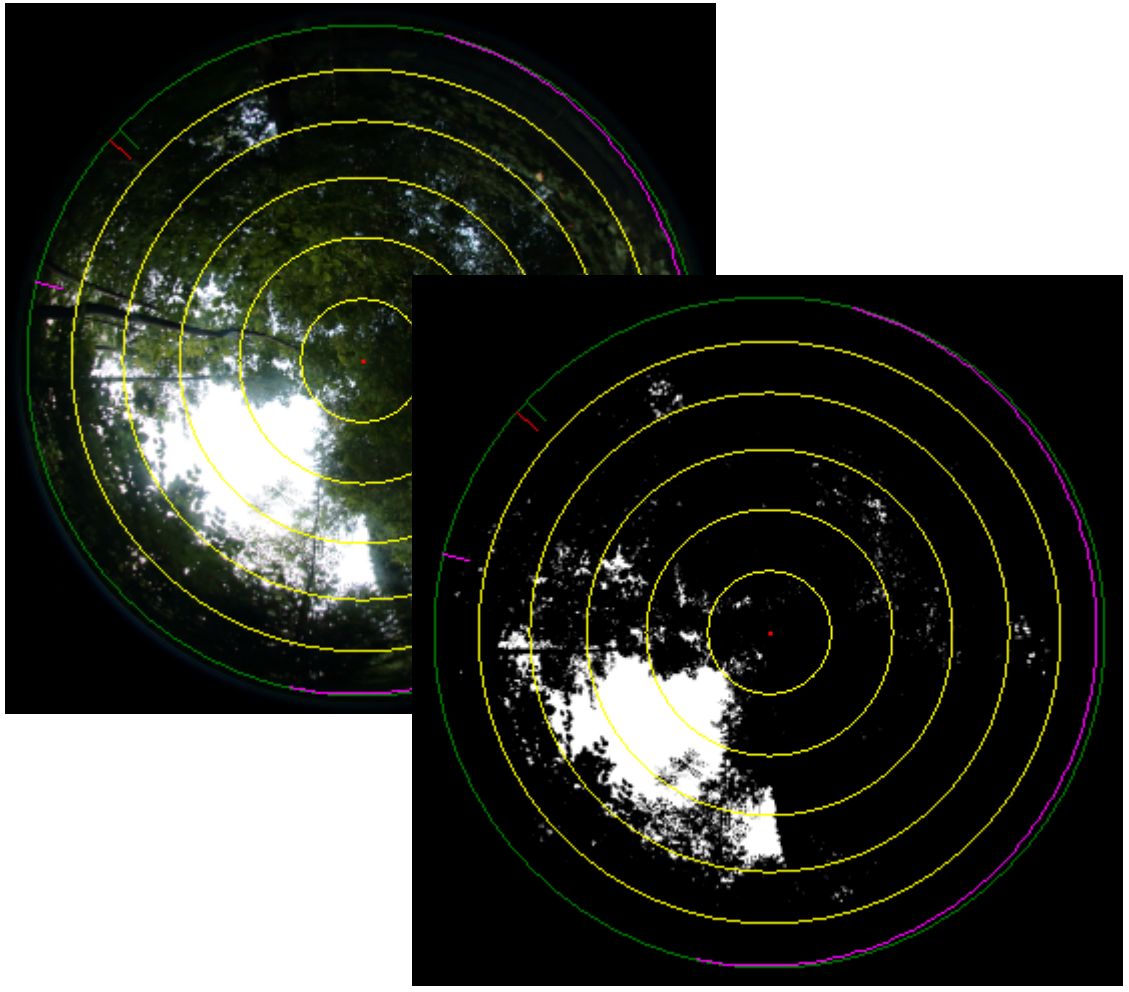
γ: angle of incidence

Schleppi *et al.*, 2007
(Agric. Forest Meteorol.)



$\cos\gamma = \sin\beta \cos\nu + \cos\beta \cos(\varepsilon - \varphi) \sin\nu$

# Challenge 5: thresholding

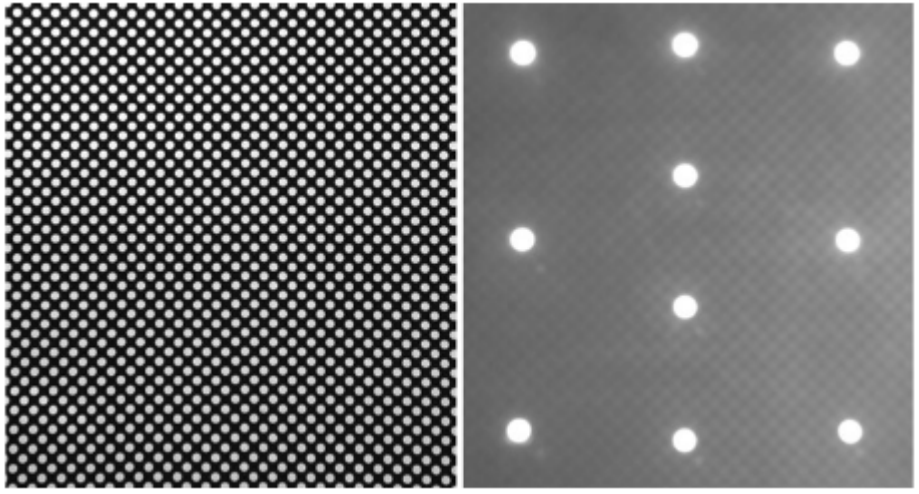


Solution: existing algorithms

Remaining challenges:

- enough contrast necessary
- remains dependent on exposure

# Challenge 6: exposure



Blooming effect in auto-exposure: holes on both sides have the same size, but appear 10 times larger on the picture where auto-exposure is longer (because or few light)

Solution: exposure bracketing

1) measure the light of the sky
2) take + 1 EV as central setting
3) take 5 or 7 pictures around



Tool: web-app
https://www.schleppi.ch/hemisfer/hexpo/

# Challenge 7: exposure choice

Solution: avoid blooming



blooming → →

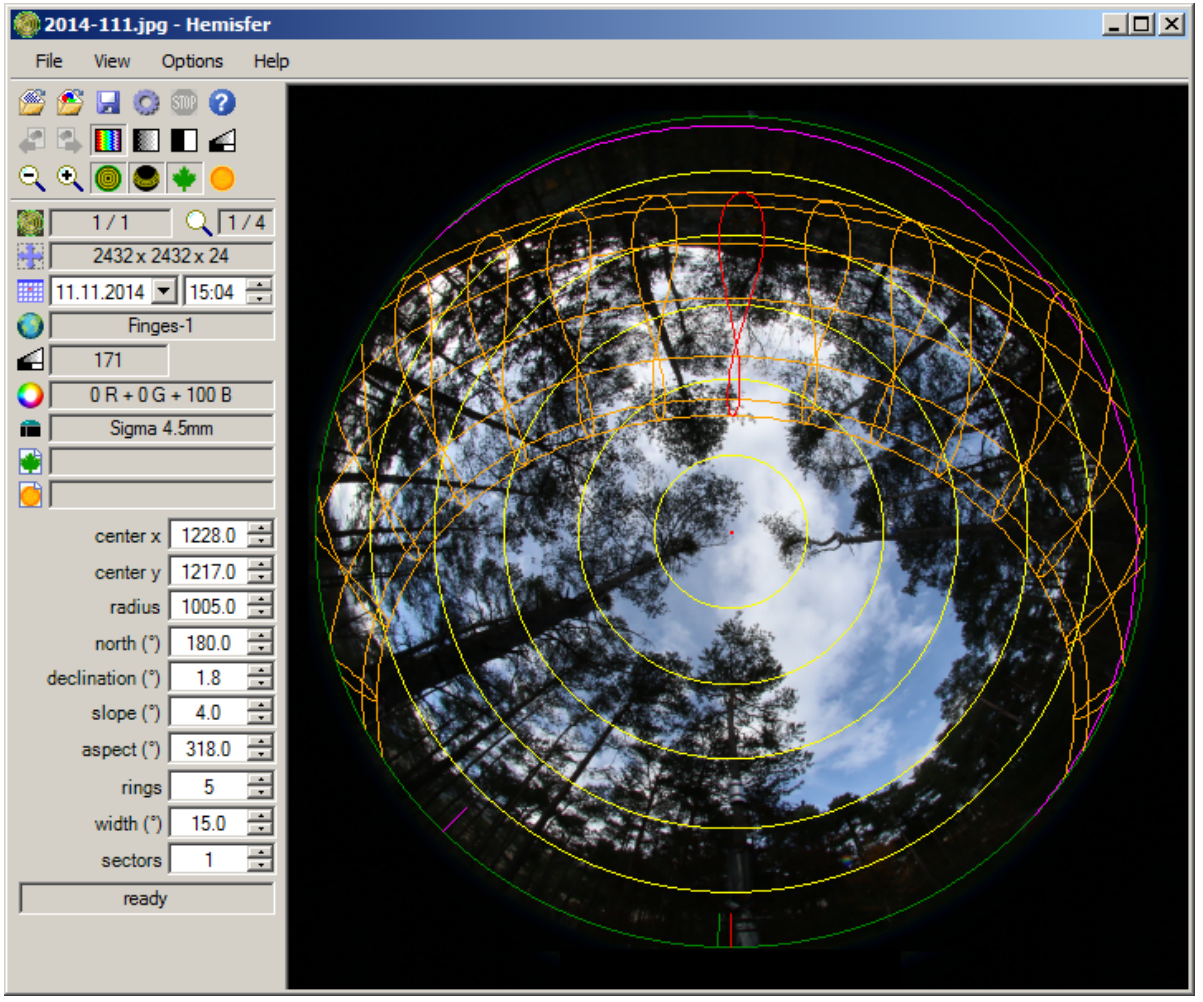
Remaining challenges:

- remains subjective
- machine learning:

  - what is the truth for training?

  - does not adapt well to other canopies
- still searching for an algorithm...

# Challenge 8: software




Solution: ... I'm too biased ;-)

1) How to chose the software
2) How to chose all the settings

https://www.schleppi.ch/hemisfer/