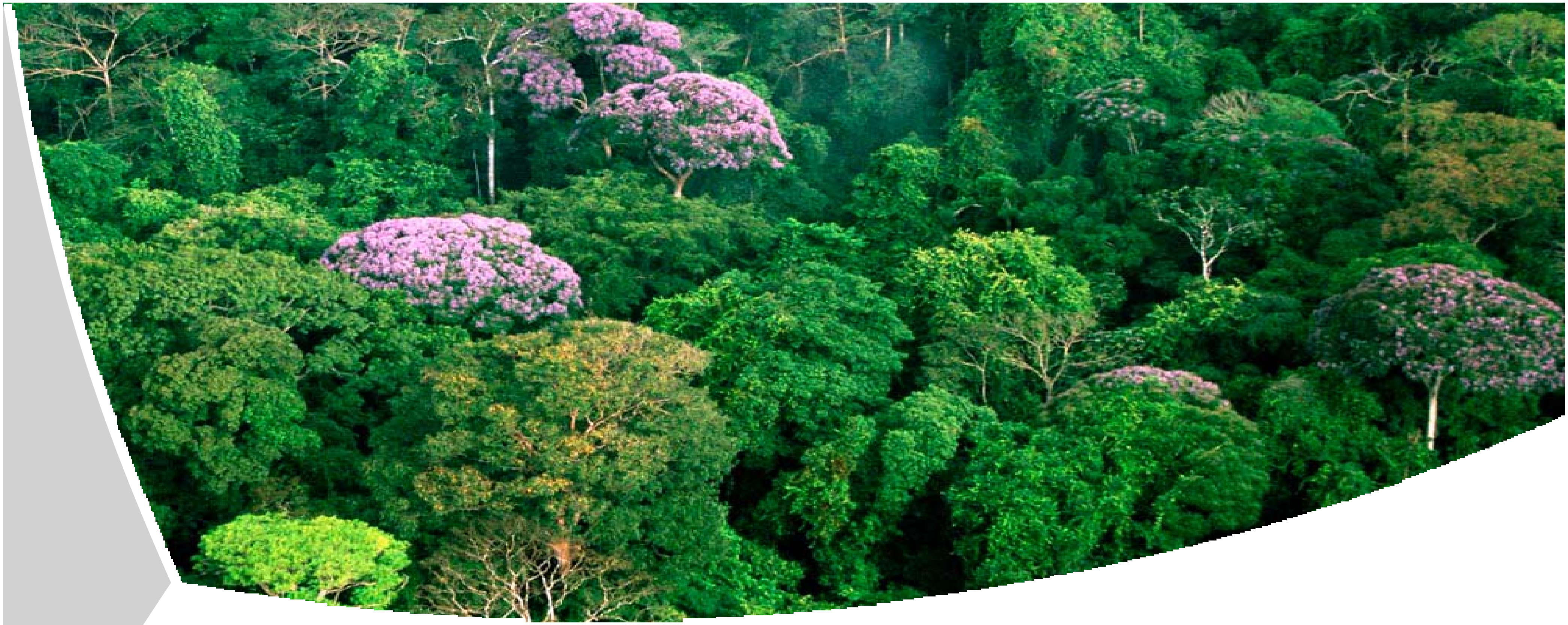

Forest biomass estimations derived from 3D forest structure for application in remote sensing (LiDAR, Radar)

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German Aerospace Center (DLR)

Microwaves and Radar Institute

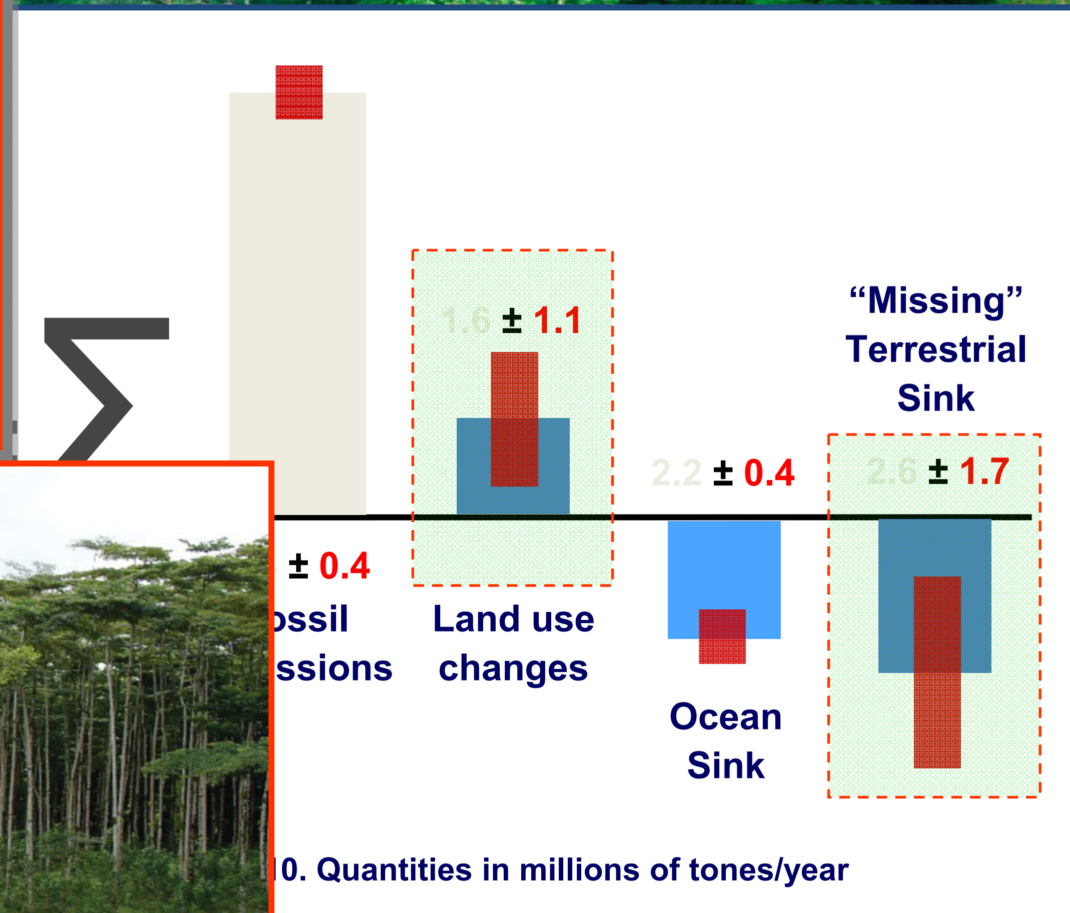
Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

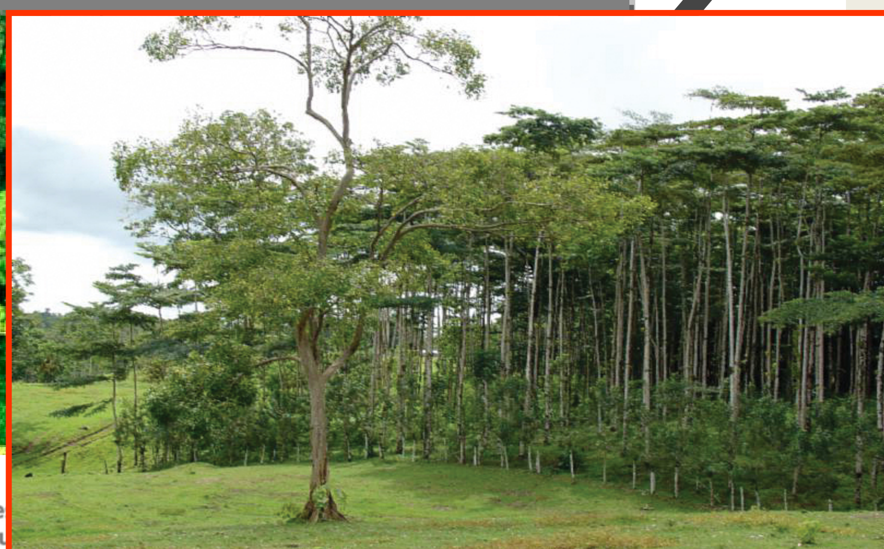
Technische Universität München

Waldwachstum Systemanalyse

Carbon balance and (Forest) Biomass

The terrestrial (Vegetation) component is the largest unknown parameter in the Gobal Carbon Balance

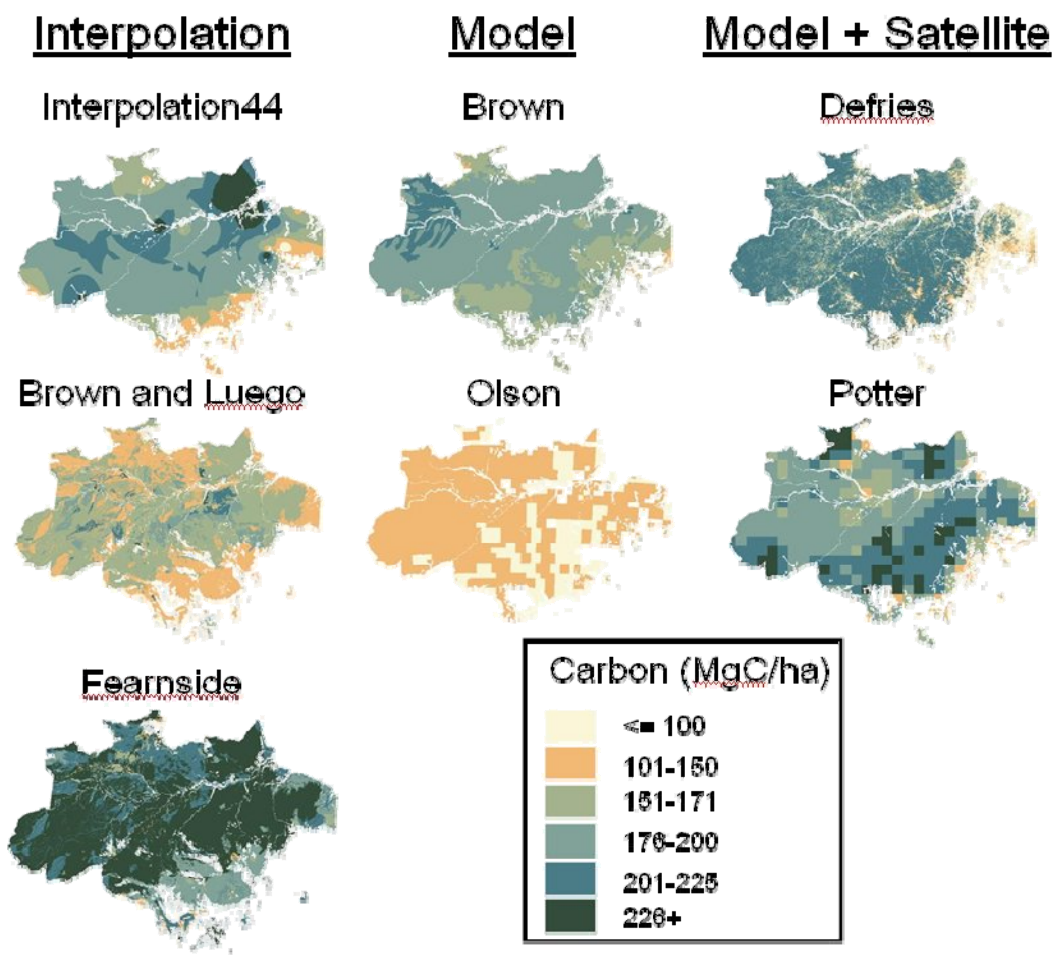




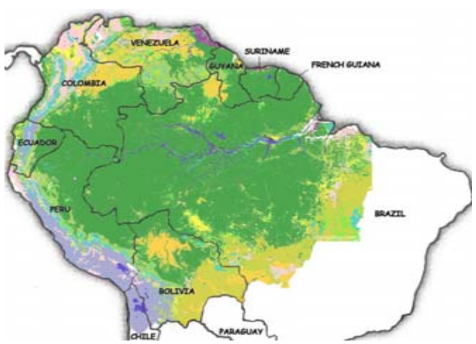
Carbon balance and (Forest) Biomass

Biomass characterizes the spatial distribution of Carbon (50% of Biomass is C);

Biomass Inventory & Dynamics are globally unknown!



Amazonas basin



… estimation varies from 39 to 93 GtC

Introduction. Motivation and Context

- Forest biomass is a second order parameter:

$$B = \frac{\pi \cdot DBH^2}{4} \cdot H \cdot f_{species} \cdot \rho_{wood}$$

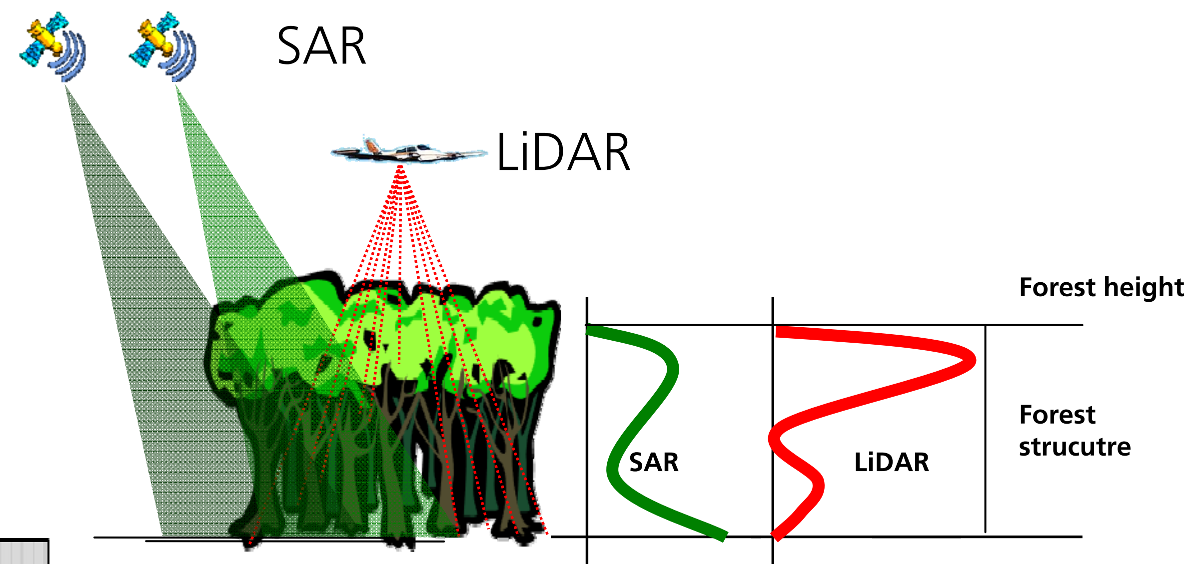
- Reduce of number of parameters (allometry) - empirical relations.

  Allometry: Science that studies the relations between the size dimensions of living forms (trees).

- Reduce effort of measurements using Remote Sensing

- Mette with Pol-InSAR (Radar). Height - Biomass allometry.

$$B = l_a \cdot 1.66 H^{1.50}$$

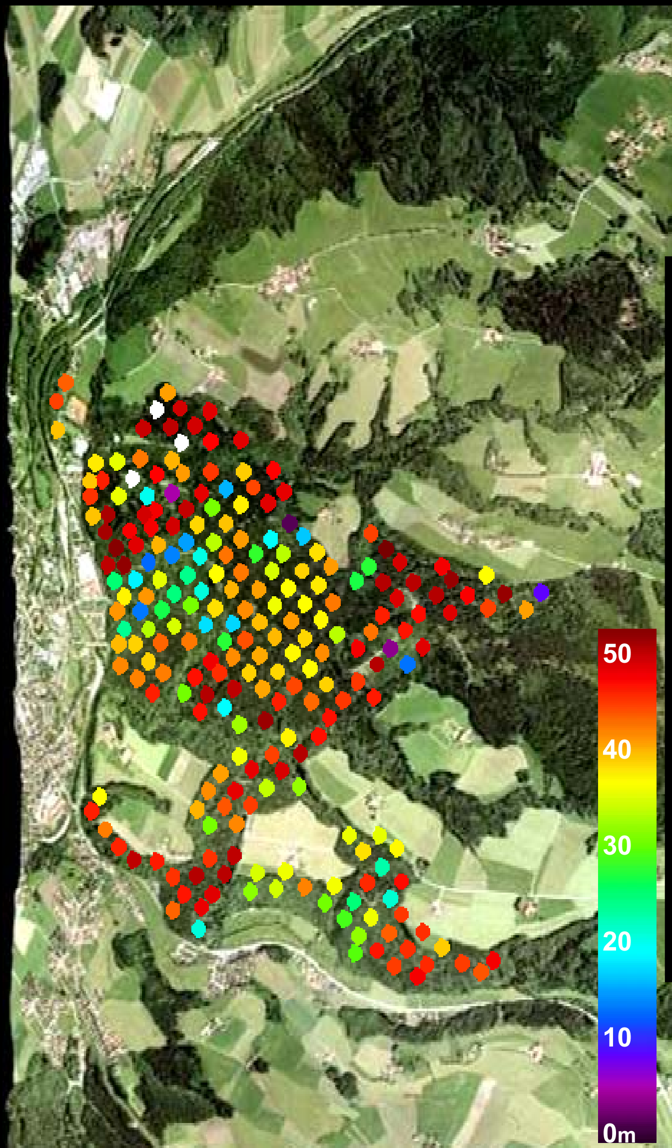


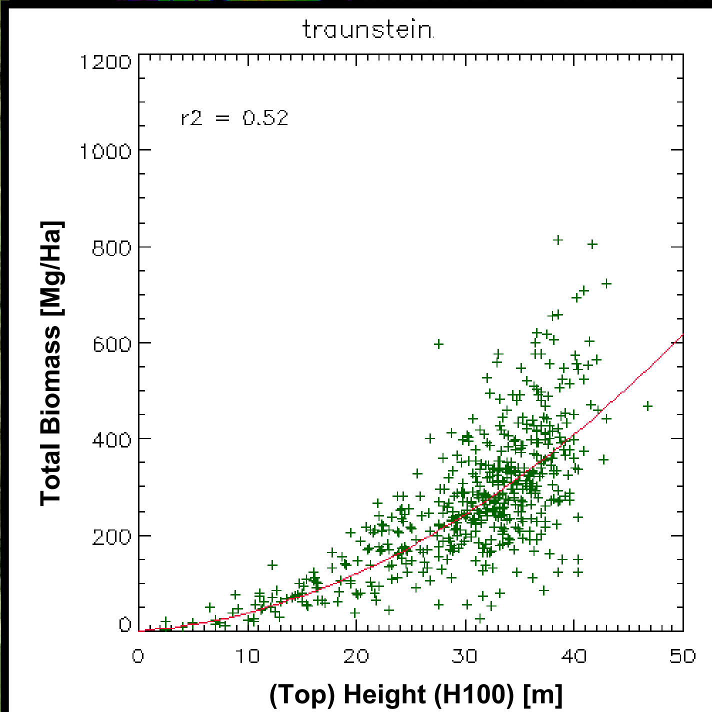
Lidar/Radar resolve structural forest parameters
HEIGHT
Vertical backscattering STRUCTURE

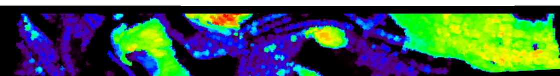
DBH= breast height diameter
H= height
f= form factor
ρ= density
la= allometric level

Traunstein Test Site

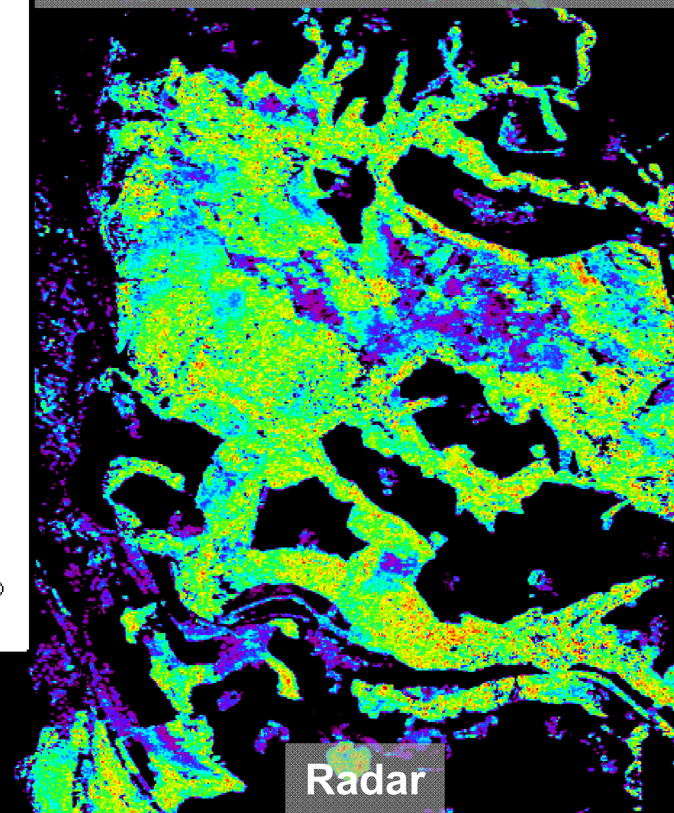
Forest type	Temperate
Topography	Moderate slopes
Height	25 ~ 35m
Species	N. Spruce, E. Beech, White Fir
	40 ~ 450 t/ha







LiDAR

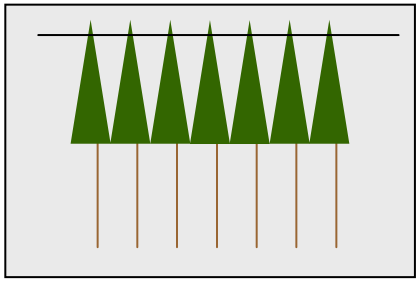


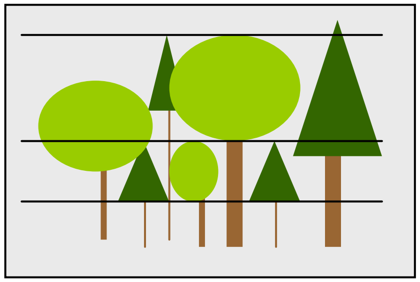
Radar

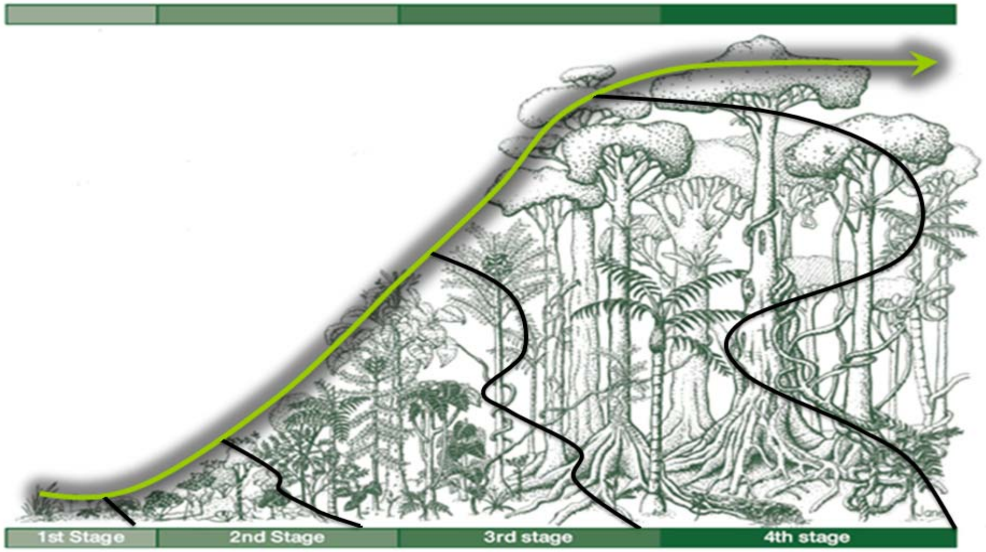
Influence of structure in the biomass

- **Height Biomass relation:** works best for traditional forest structure. High density, single species, even aged.

- **Complex forest structure:** Internal structure affects the biomass stock.
  - Height – Biomass relation looses accuracy.
  - Second parameter is needed: e.g. Density or STRUCTURE.

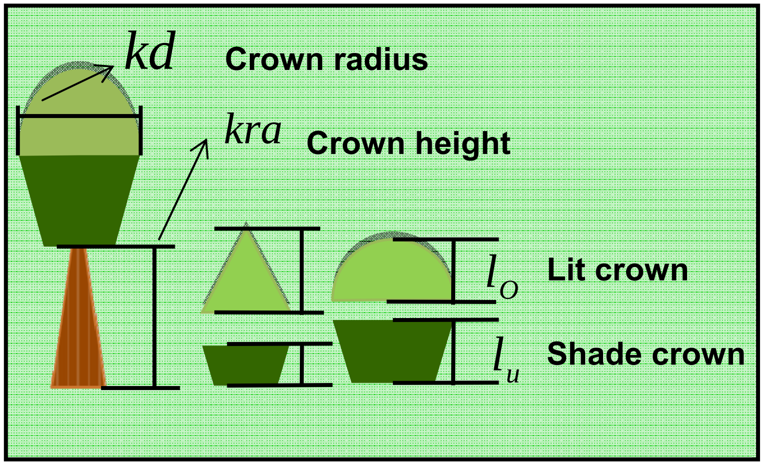


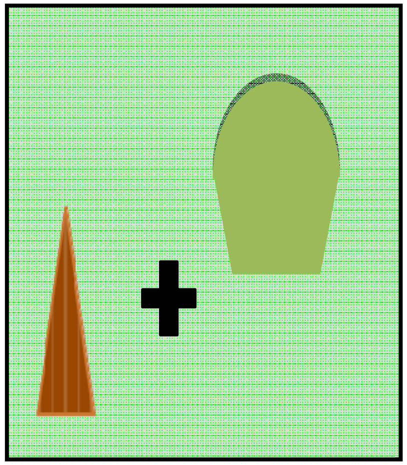


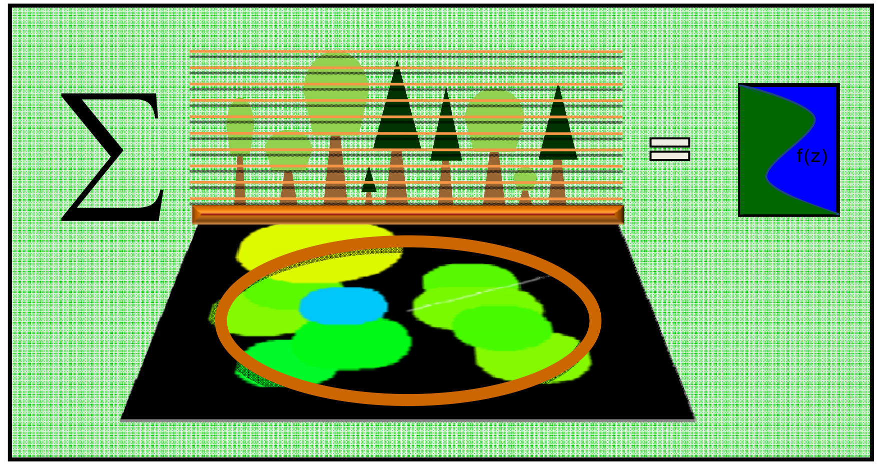


Forest vertical structure changes with time and forest height, i.e. with forest evolution

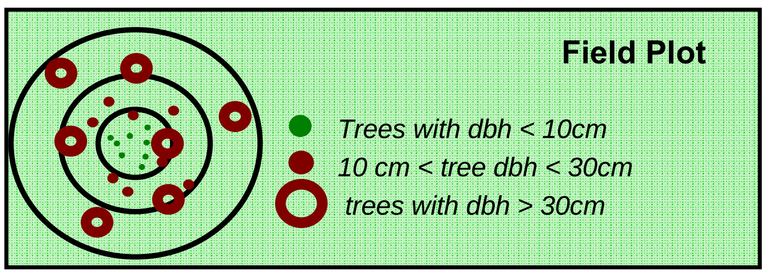
Vertical structure characterization: Vertical Biomass profiles

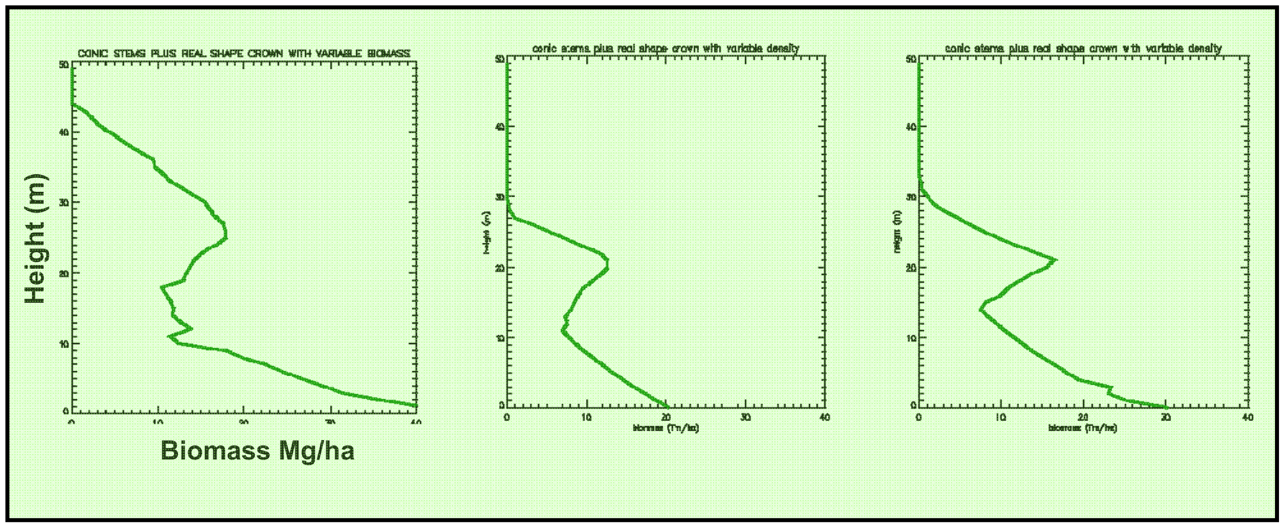




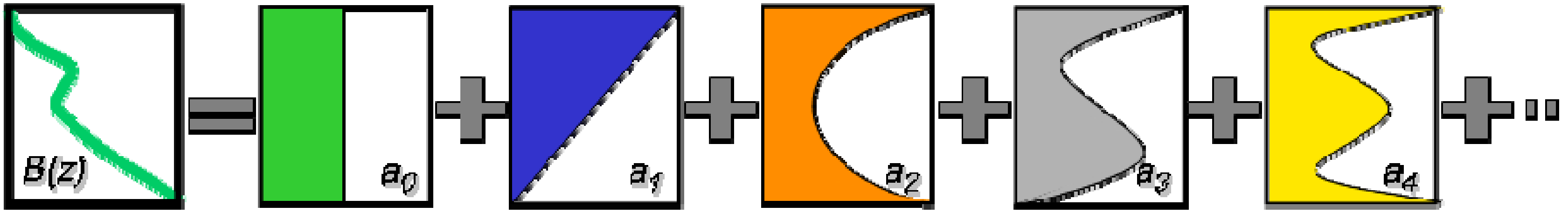


kd= crown diameter
kra= crown height
rl= light crown radius
rs= shadow crown radius
a,b,c,d= species specific parameters
h= tree height
bhd= breast height diameter
lo= length of light crown
lu= length of shadow crown
E= Distance to the top



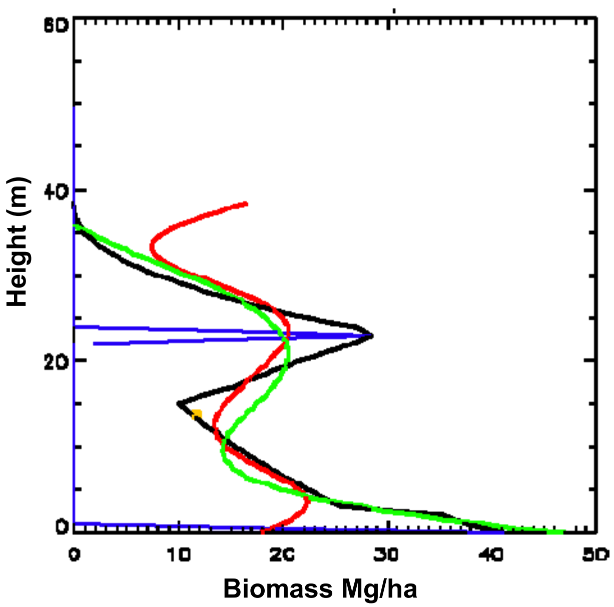


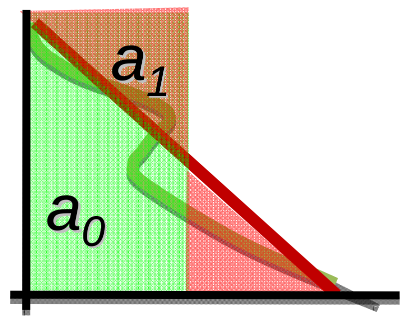
Vertical structure characterization: Legendre Decomposition.



Legendre Coefficients:

– Each Coefficient represents the degree of adjustment of the polynomial with the original curve (biomass profile) .





$$P_0(z) = 1$$

$$P_1(z) = z$$

$$P_2(z) = \frac{1}{2}\left(3z^2 - 1\right)$$

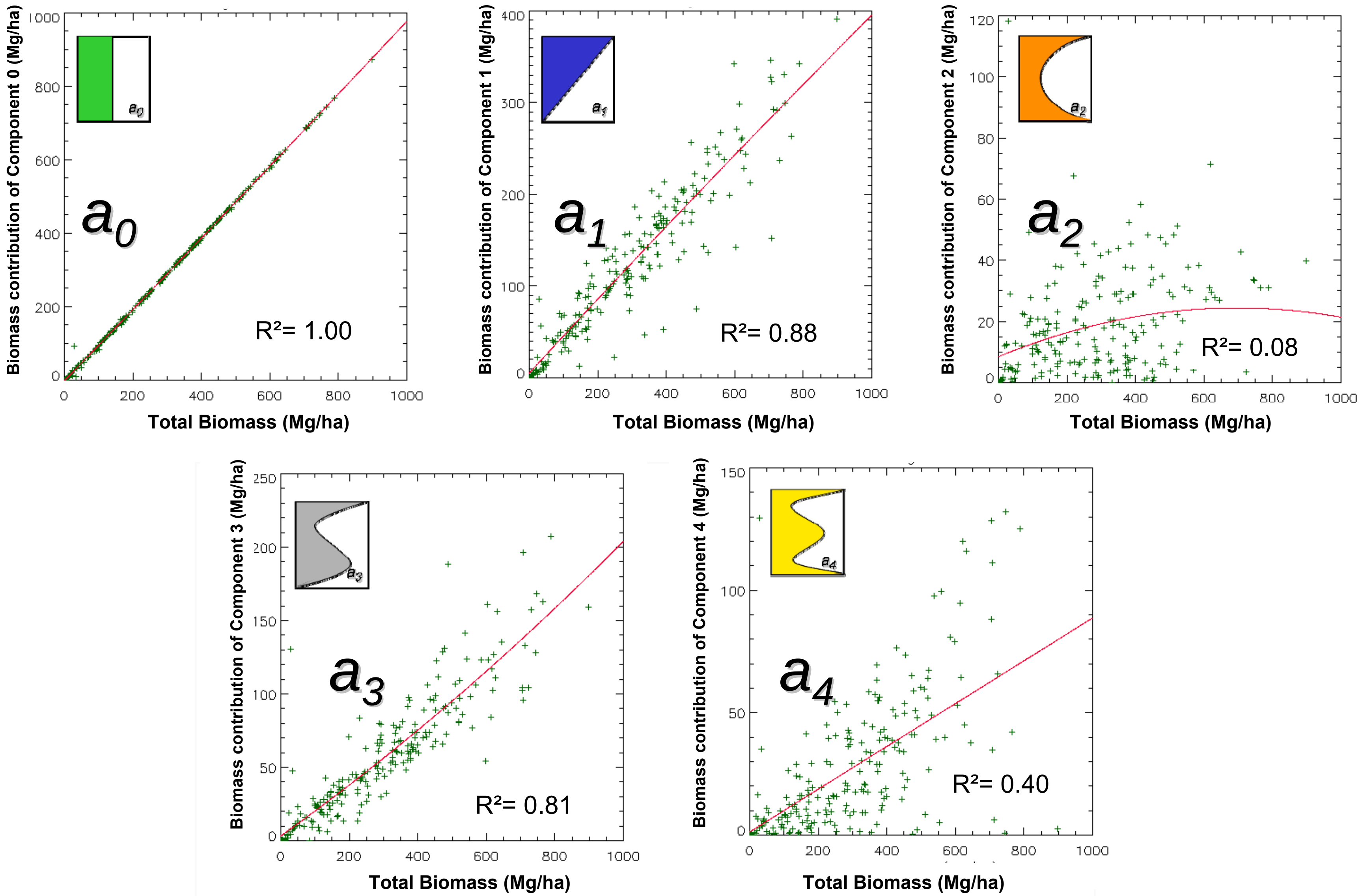
$$P_3(z) = \frac{1}{2}\left(5z^2 - 3z\right)$$

$$P_4(z) = \frac{1}{8}\left(35z^2 - 30z + 3\right)$$

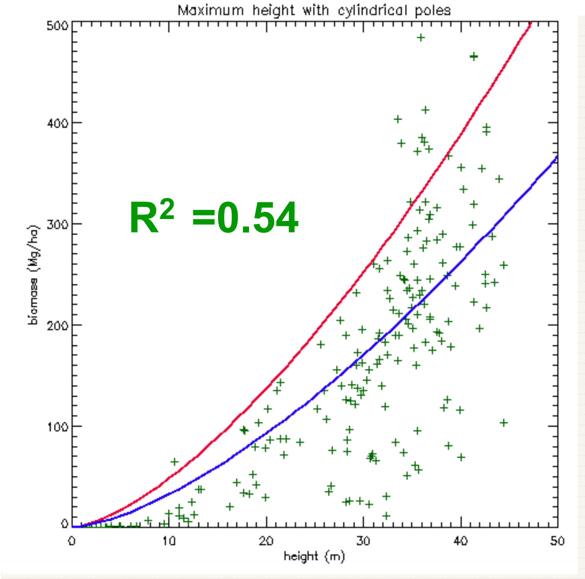
$$B = \sum_{i=0}^{H} \sum_{j=0}^{n} a_j \cdot P(z)$$

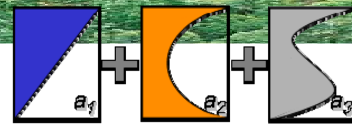
B = Total Biomass (Mg/ha)
H = Total Height (m)
a = LeGendre coefficient
P = LeGendre characteristic Polynomial

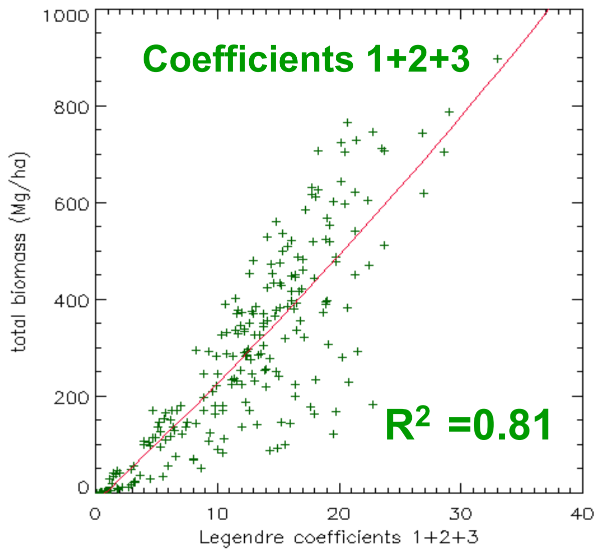
Legendre Decomposition: individual coefficients

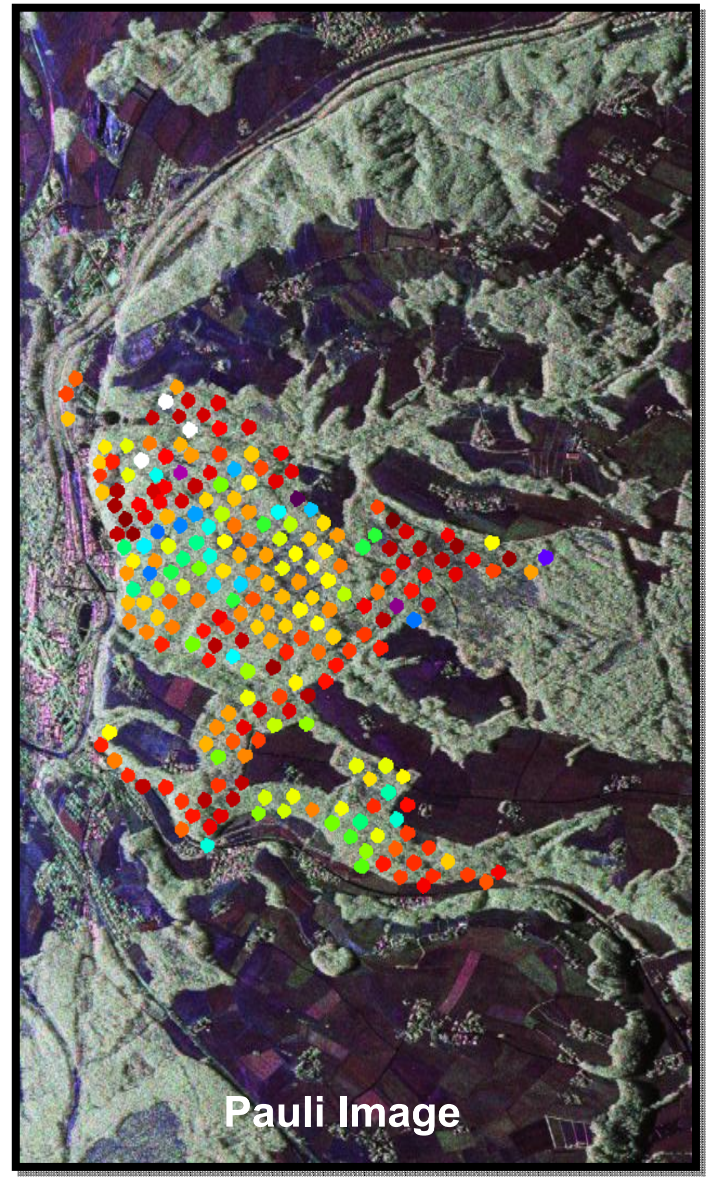


$$B = l_a \cdot 1.66 H^{1.58}$$





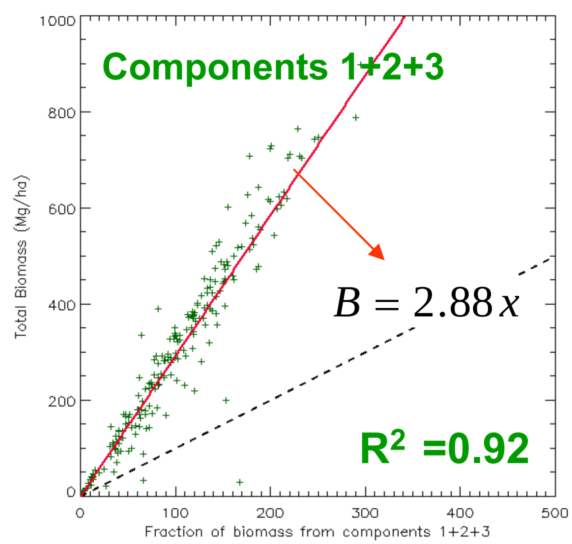




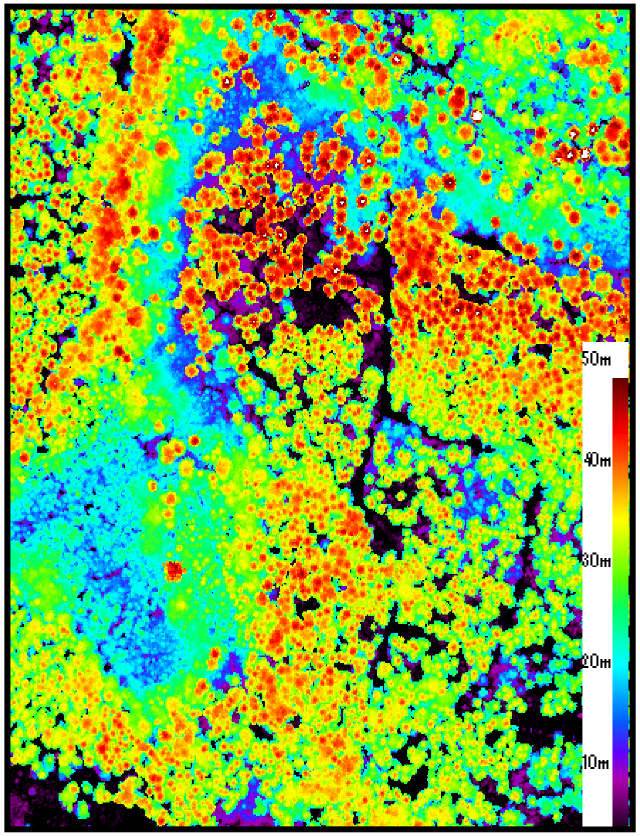
la= 0.925

la= 0.625

$$B = la * \sum_{i=0}^{H} \sum_{j=1}^{3} a_j \cdot P(z)$$

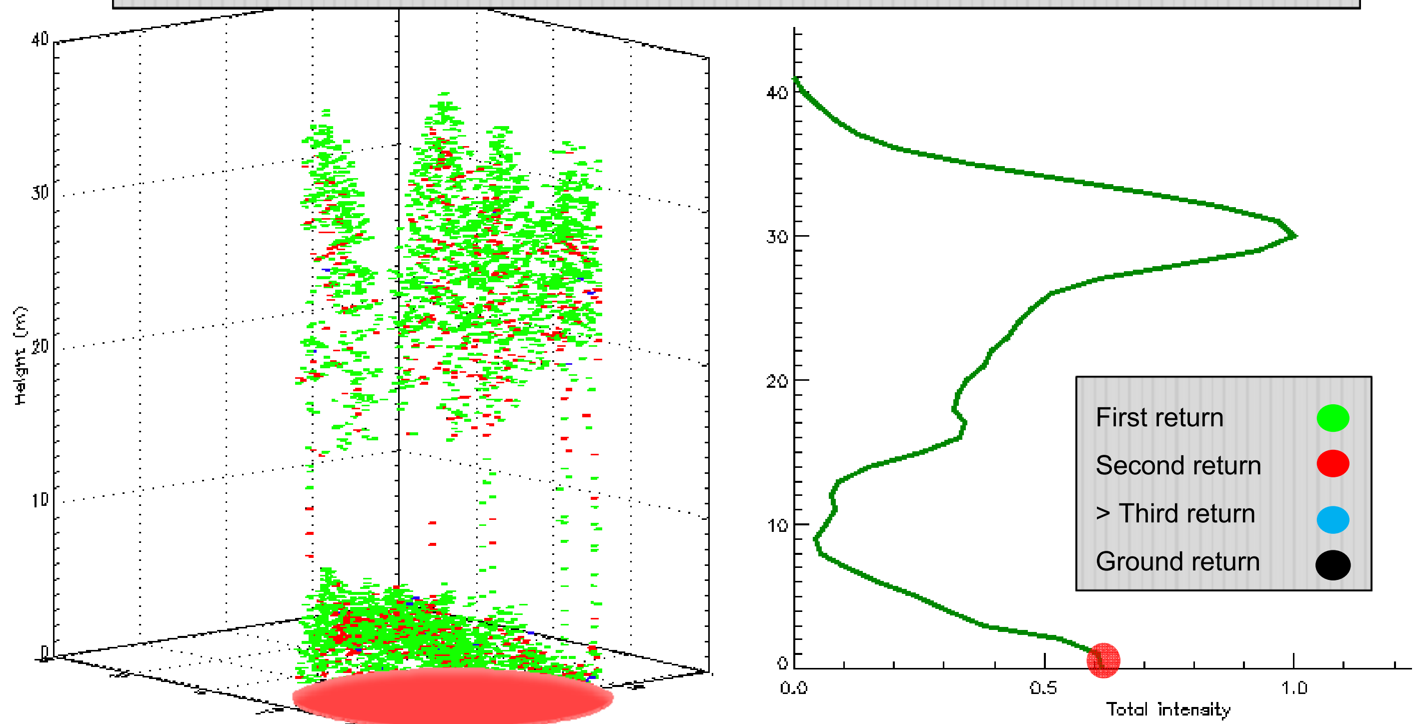


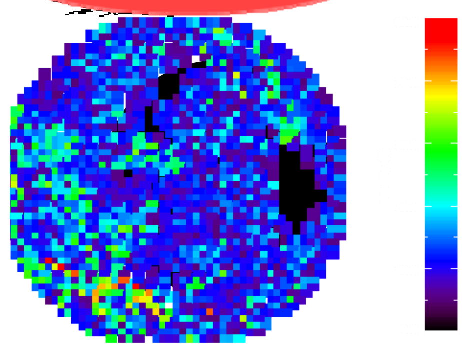
LiDAR heights and Profile Generation



Tree Heights Traunstein

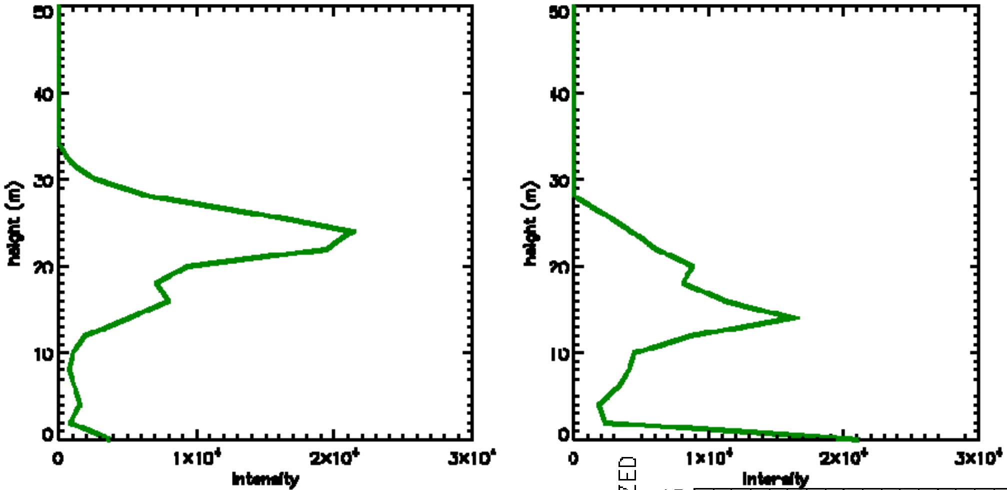
Sum the total intensity of the elements that fall within 1 m height bins.





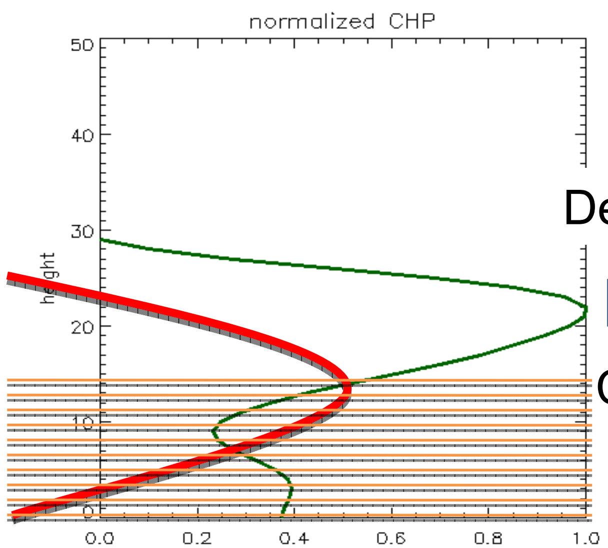
Intensity (amplitude) horizontal projection

LiDAR Intensity profiles



$$x = [-1, 1]$$

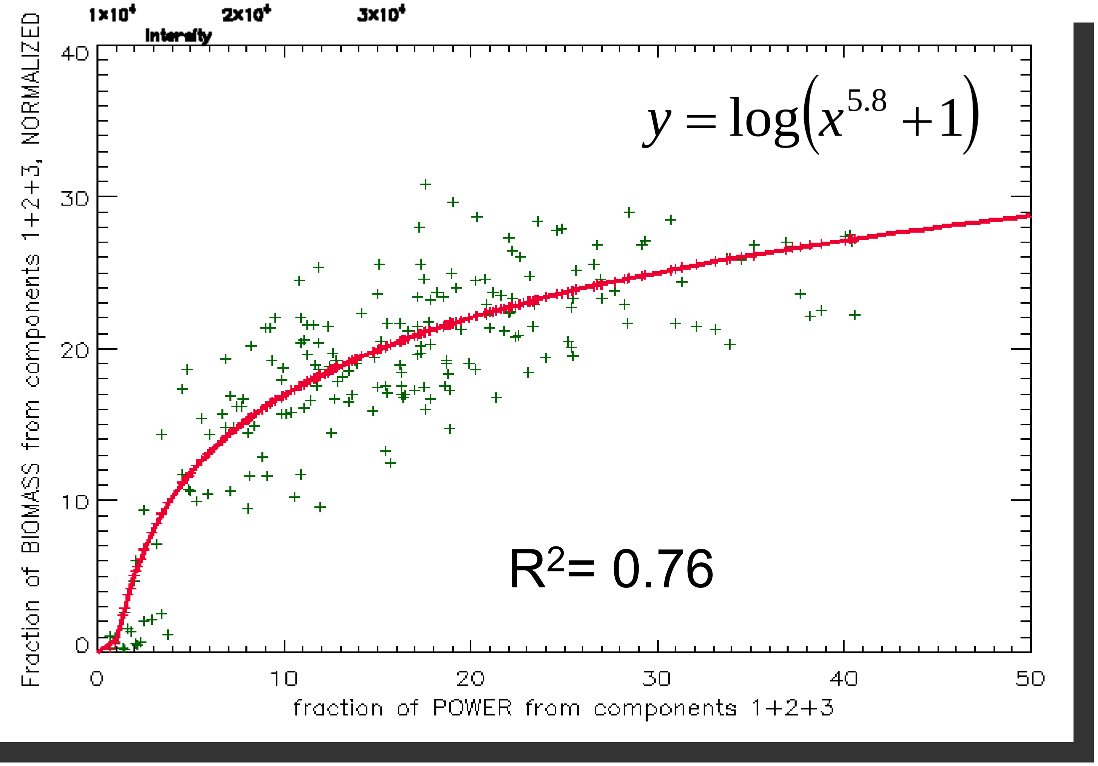
$$y = -\frac{9}{40} + \frac{1}{12}x - \frac{1}{360}x^2$$



Normalized Profile

Decomposition

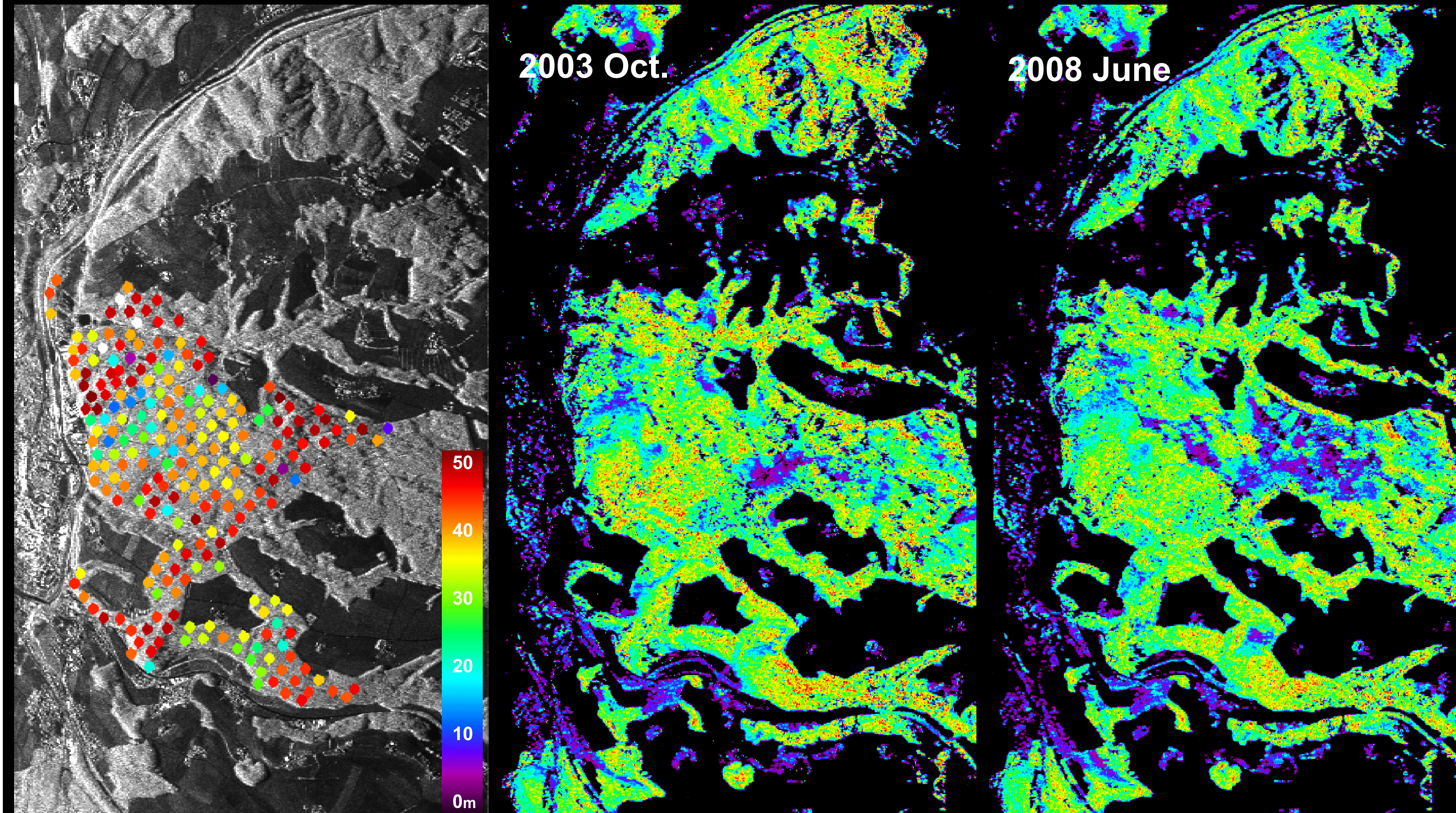
Correlation

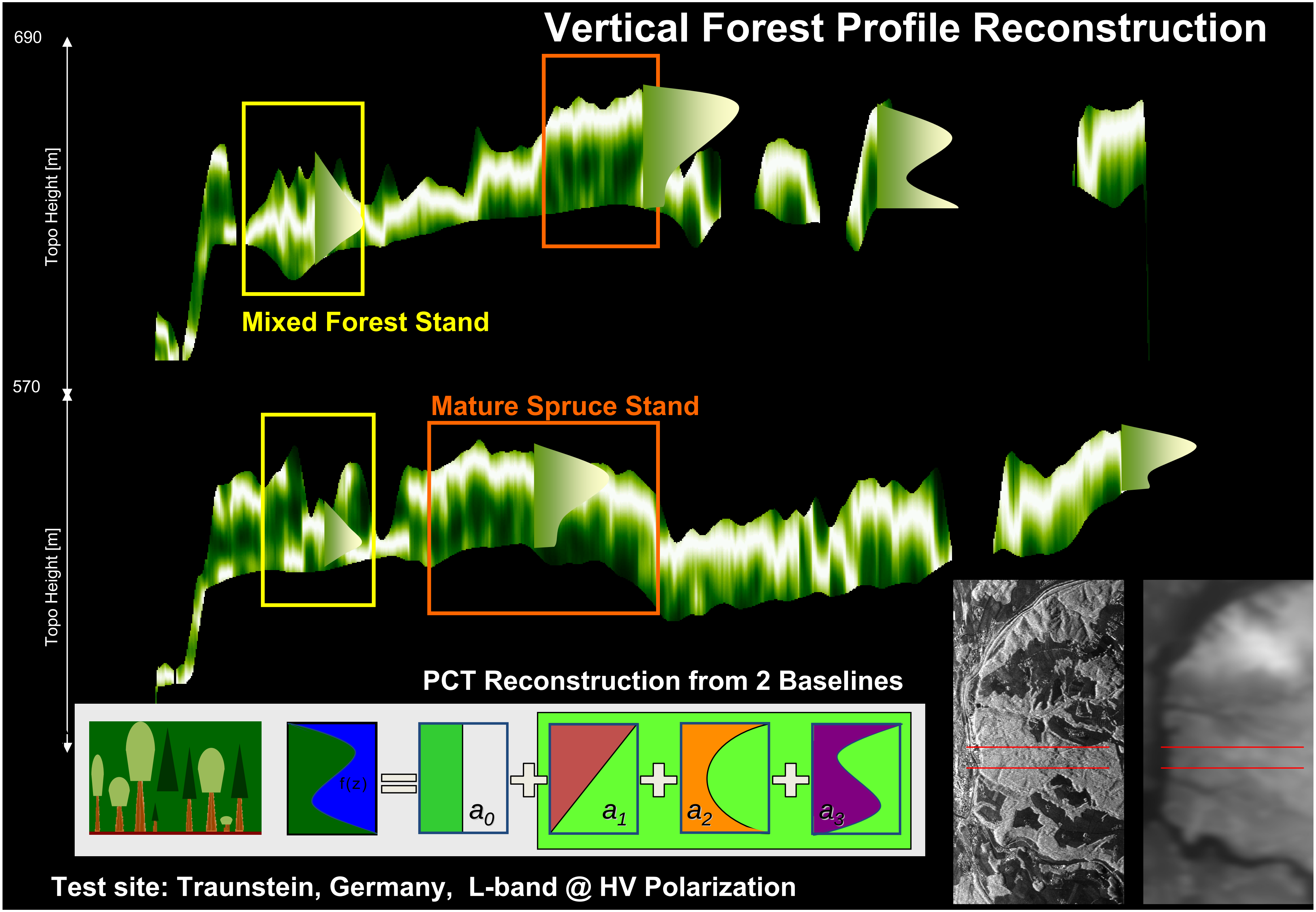


$$y = \log\left(x^{5.8} + 1\right)$$

$R^2 = 0.76$

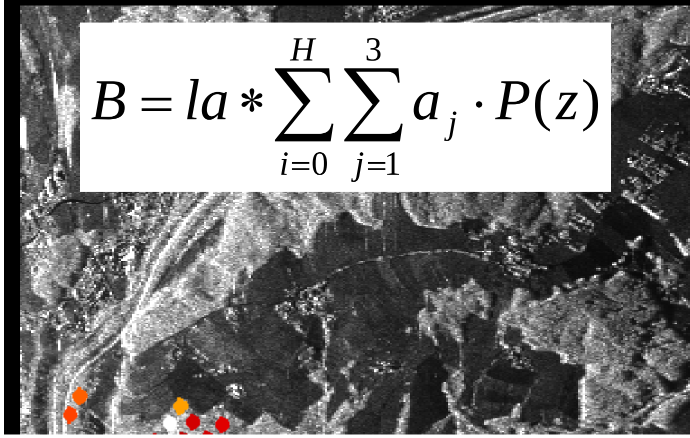
Traunstein Test Site: PolInSAR height



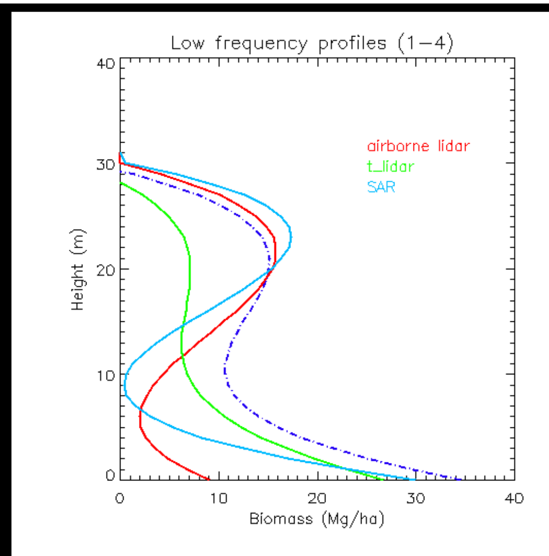


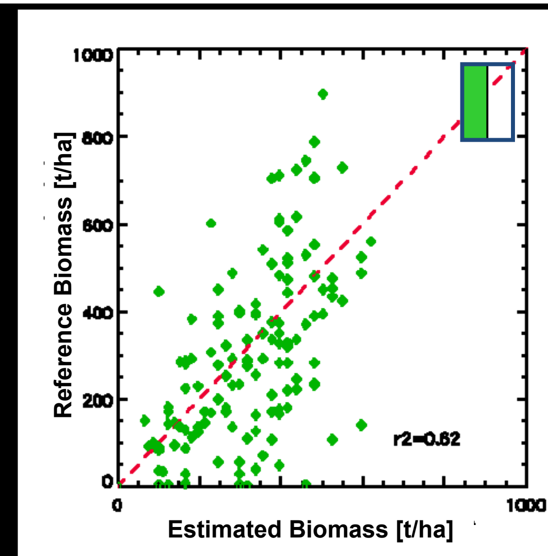
Vertical Forest Profile Reconstruction
690
570
Topo Height [m]
Topo Height [m]
Mixed Forest Stand
Mature Spruce Stand
PCT Reconstruction from 2 Baselines
f(z)
a_0
a_1
a_2
a_3
Test site: Traunstein, Germany, L-band @ HV Polarization

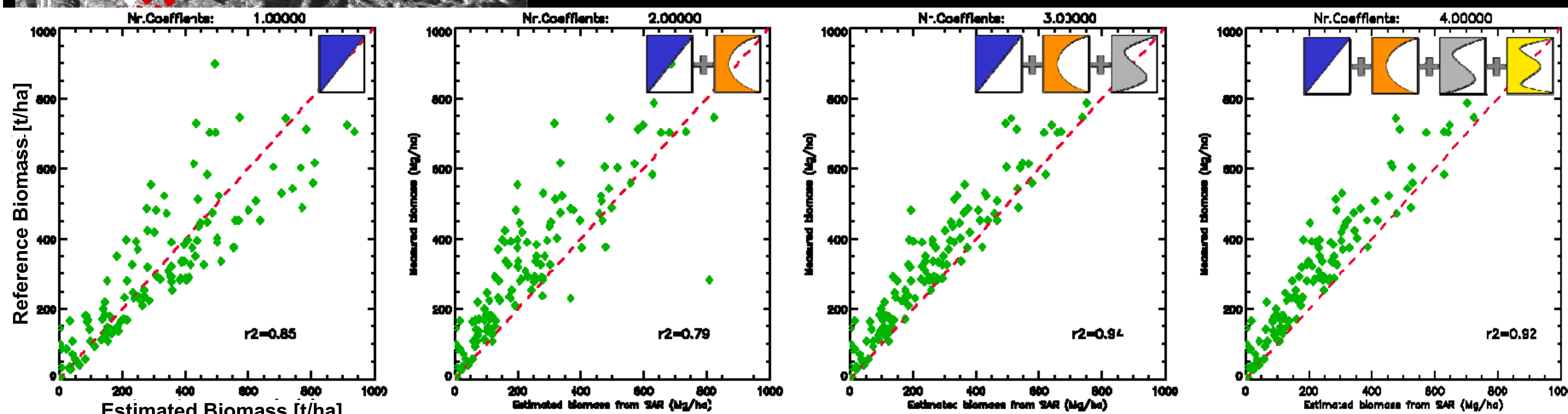
Traunstein Test Site

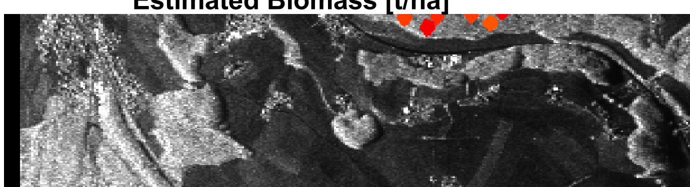


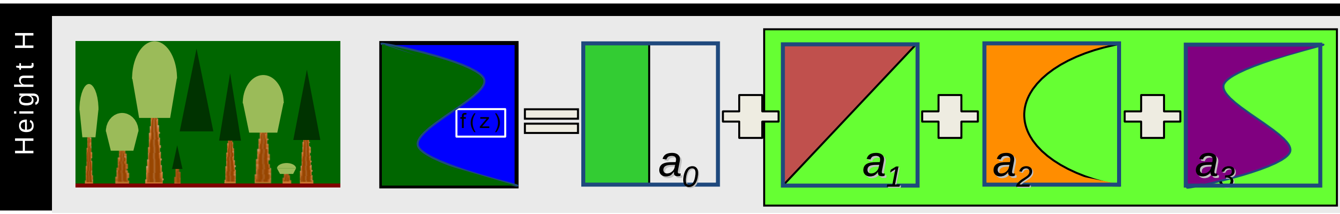
$$B = la * \sum_{i=0}^{H} \sum_{j=1}^{3} a_j \cdot P(z)$$









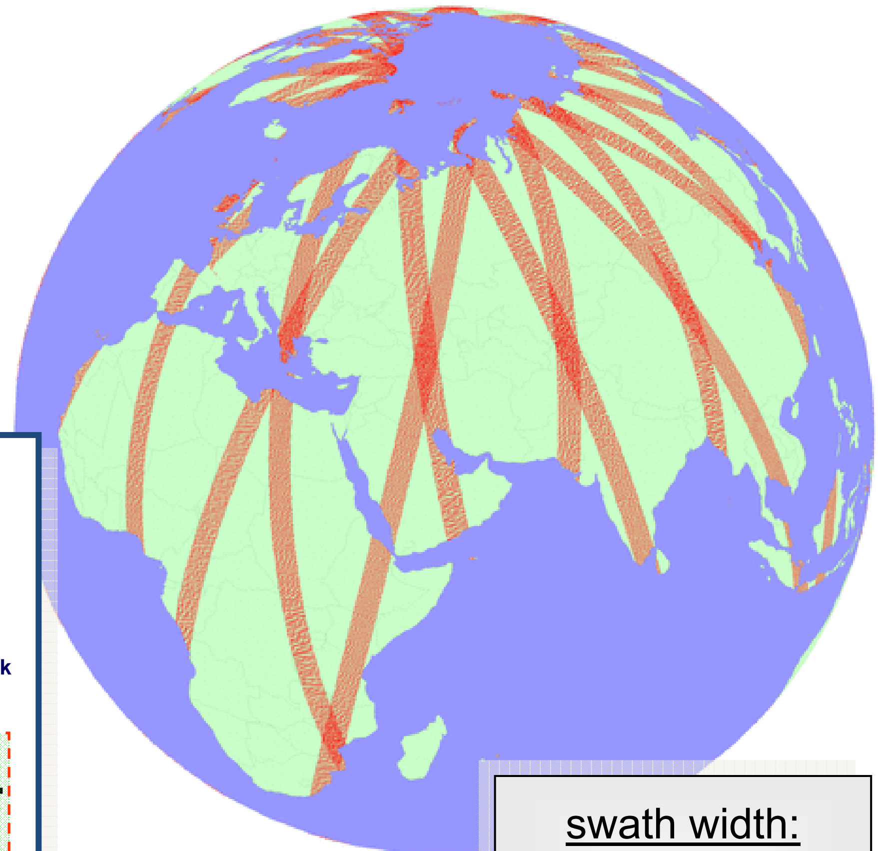


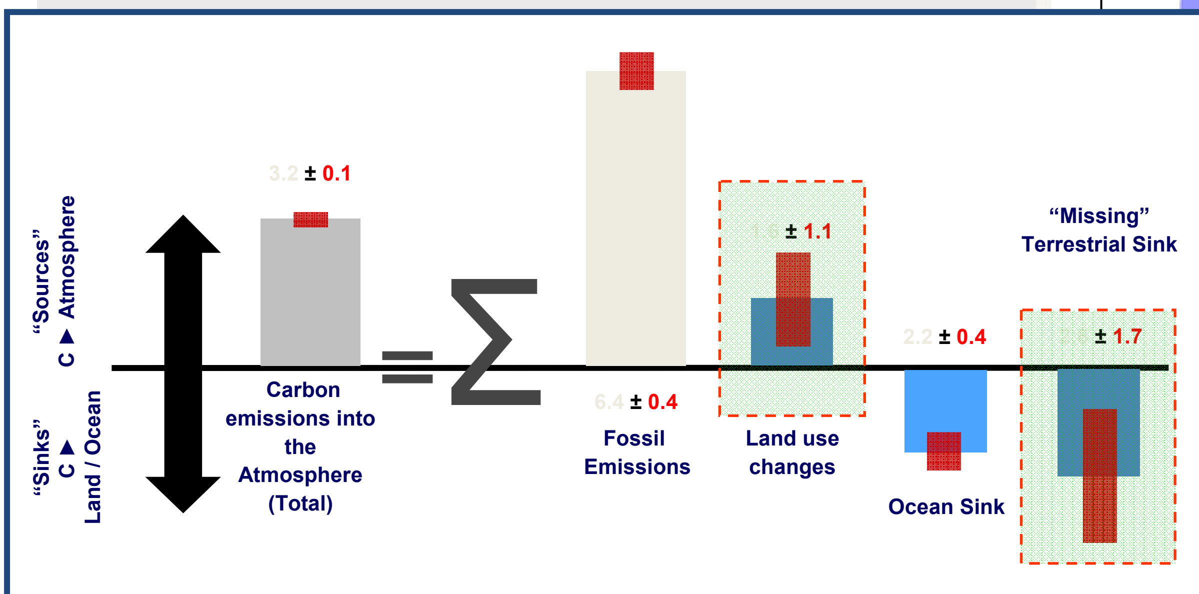
Future missions: Tandem-L

Joint future mission between Germany-DLR and The USA-Nasa(JPL)

State of the art implementation is able to provide at a spatial resolution on the order of 7x2m

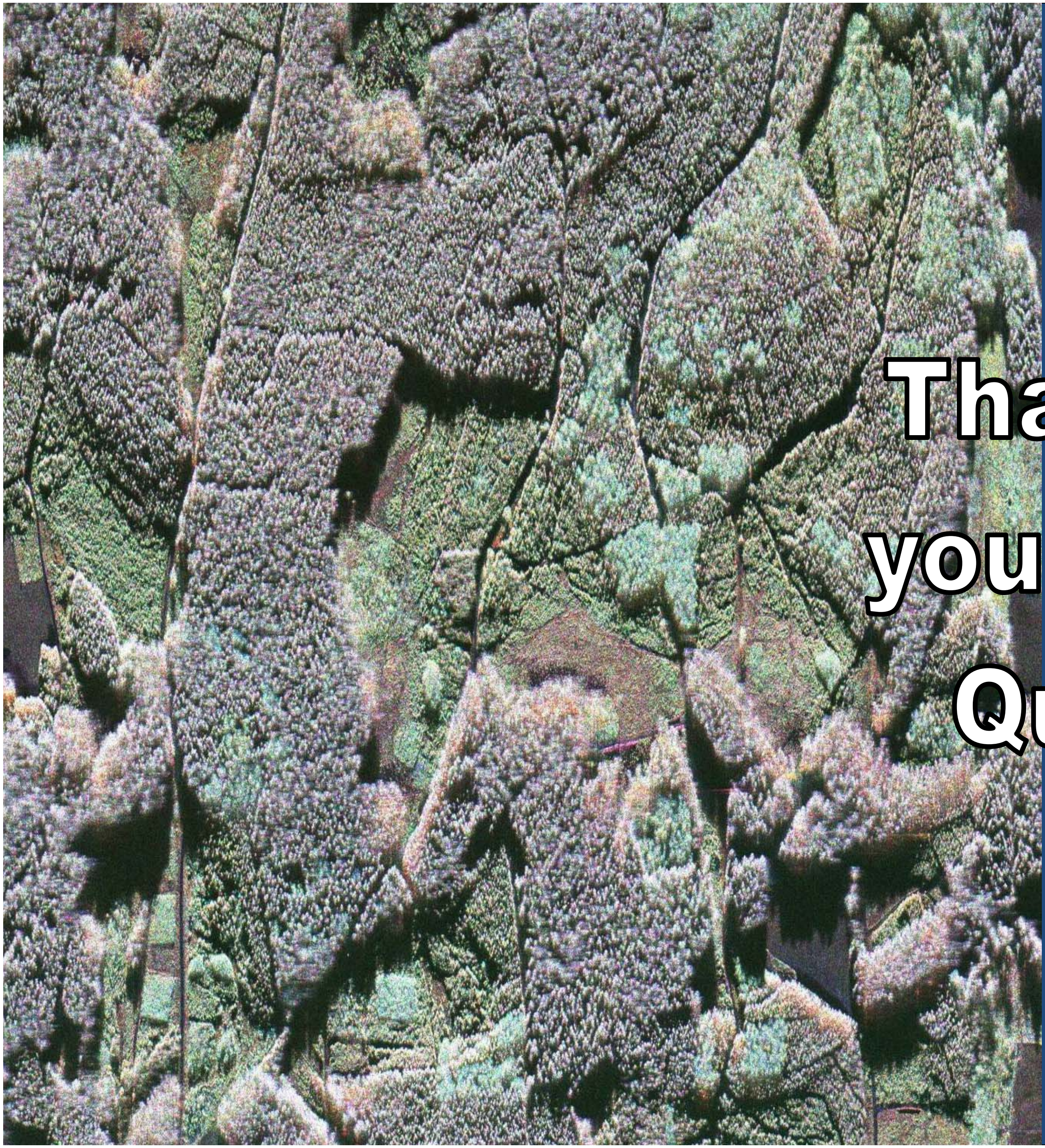
- ▶ Every week: forest / non-forest mapping at 10x10m
- ▶ Every 2 weeks: forest height change detection at 30x30m
- Every 2 months: global structure map
- ▶ forest height map at 30x30m
- ▶ forest structure map 50x50m





IPCC 2010. Angaben in Milliarden Tonen Kohlenstoff / Jahr

swath width:
350 km
duty cycle:
30 min / Orbit



Thank you for your attention, Questions?

POlarimetric SAR image