Tandem-L: Mapping Forests in 4 Dimensions !

K. Papathanassiou

1st German/Japanese Science & Application Workshop for next Generation SAR

Sola City, Tokyo, June 27, 2013

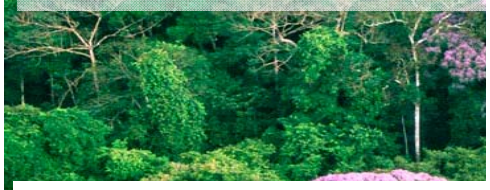
Microwaves and Radar Institute

Biosphere

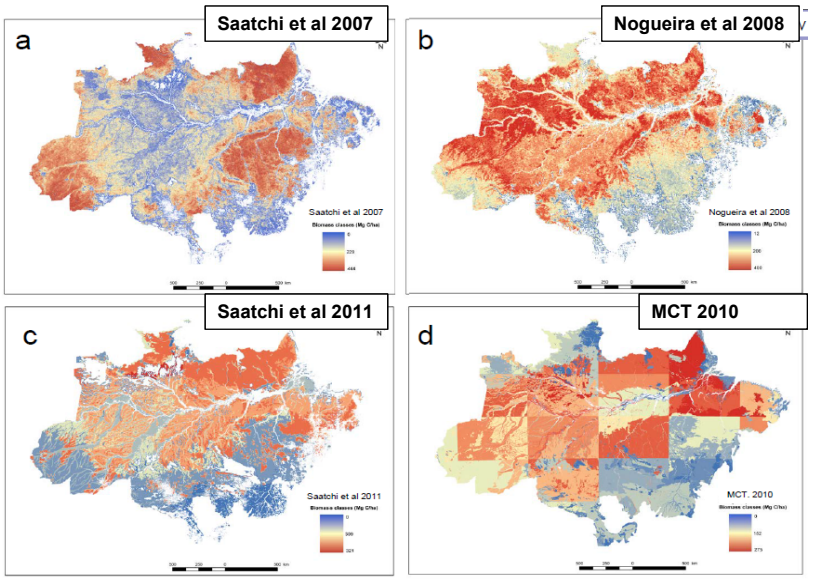
Carbon Cycle and (Forest-)Biomass

Biomass characterises the spatial distribution of Carbon. ~50% of the biomass is C;

Biomass **inventory, distribution & -dynamics** are today - in a large scales - unknown !



Amazonas basin



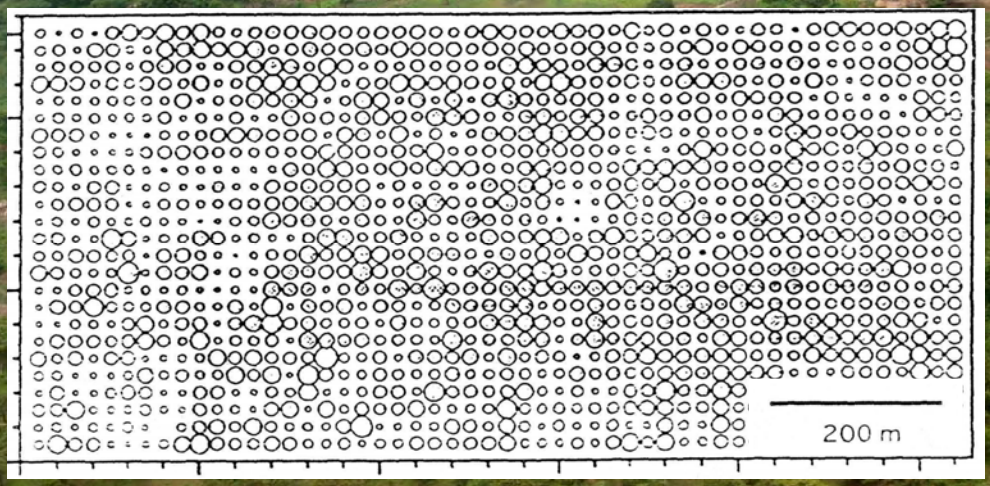
Brazilian Ministry Science and Technology (MCT)
Ometto et all, 2012

Biosphere

Challenge:

High spatial variability of local biomass (due to natural disturbance regimes and human activities) and structure (vertical & horizontal):

Example: Lowland tropical forest in Lambir, Malaysia (Tsuyoshi Yoneda et al. 1996, 50ha, 200K trees)



Size of circles indicate local biomass (20x20 m, 1300 plots)

Biosphere

Carbon Cycle and (Forest-)Biomass

Changing climate conditions can convert vegetation:

In dry conditions forest has been reported to become a Carbon source!

- Europe 2003 with +0.5 Gt C (from -0.4Gt C)
- Amazon 2005 with +1.6 Gt C (from -1.3Gt C)

Cias et al. 2005 Nature, Phillipps et al. 2009 Science

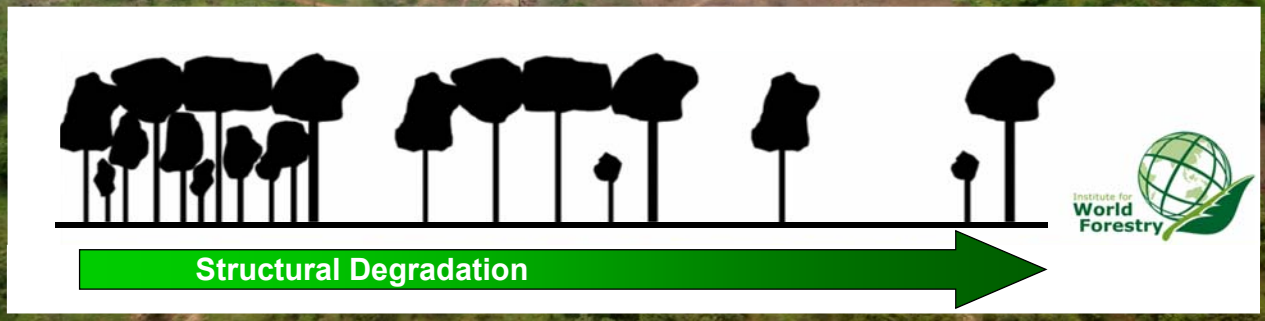
In comparison: Total C emission in the Atmosphere is ~ 3 Gt C / Year

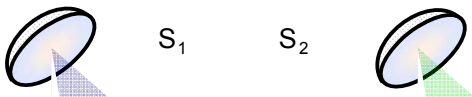
Biosphere

Biodiversity & Forest

- 80% of the terrestrial Biodiversity lives in - primarily tropical - Forest-Ecosystems.
- Besides the reduction of forested areas (deforestation), forest fragmentation and degradation impacts biodiversity seriously.

Structural degradation of forest (caused by legal / illegal logging, fire and other human activities) is not possible to be detected with conventional remote sensing techniques.





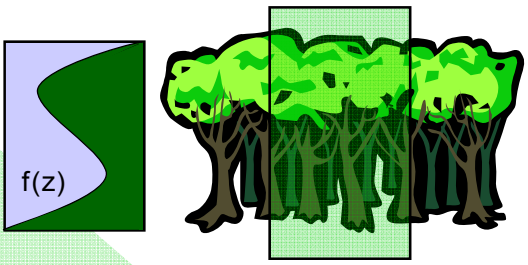
Interferometric Coherence

$$\tilde{\gamma}(S_1\ S_2) = \frac{< S_1\ S_2^* >}{\sqrt{< S_1\ S_1^* >\ < S_2\ S_2^* >}}$$

SAR Interferometry for Volume Structure

Volume Coherence

$$\tilde{\gamma}_{Vol}(f(z)) = e^{ik_z z_o} \frac{\int_o^{h_v} f(z)\, e^{ik_z z} dz}{\int_o^{h_v} f(z)\, dz}$$

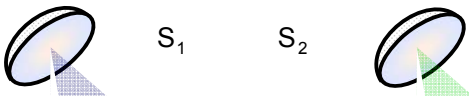


f(z) … vertical reflectivity function

Vertical Wavenumber: $\kappa_z = \frac{\kappa \Delta\theta}{\sin(\theta_0)}$

$$\tilde{\gamma} = \tilde{\gamma}_{Temporal}\ \gamma_{SNR}\ \tilde{\gamma}_{Volume}$$

- $\tilde{\gamma}_{Temporal}$ … temporal decorrelation
- γ_{SNR} … additive noise decorrelation
- $\tilde{\gamma}_{Volume}$ … geometric decorrelation



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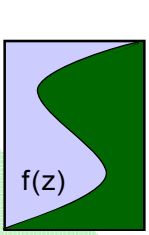
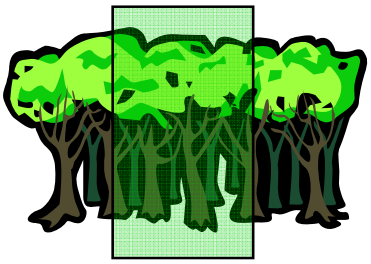
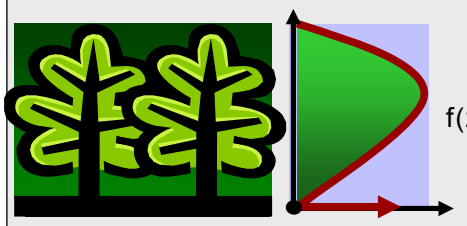




2 Layer Inversion Model



$$f(z) = f_0 e^{\left(\frac{2\,\sigma(z)\,z}{\cos\theta_0}\right)} + m'_G \delta(z - z_0)$$

$$\tilde{\gamma}_{Vol}(\vec{w}) = \exp(i\varphi_0)\frac{\tilde{\gamma}_V + m(\vec{w})}{1 + m(\vec{w})}$$

Volume Coherence

$$\tilde{\gamma}_V = \frac{I}{I_0}$$

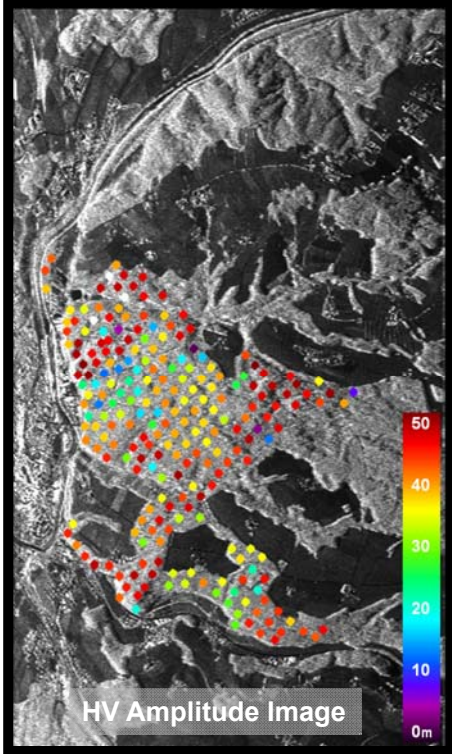
$$I = \int_0^{h_V} \exp(i\kappa_z z') \exp\left(\frac{2\,\sigma(z)\,z'}{\cos\theta_0}\right) dz' \qquad I_0 = \int_0^{h_V} \exp\left(\frac{2\,\sigma(z)\,z'}{\cos\theta_0}\right) dz'$$

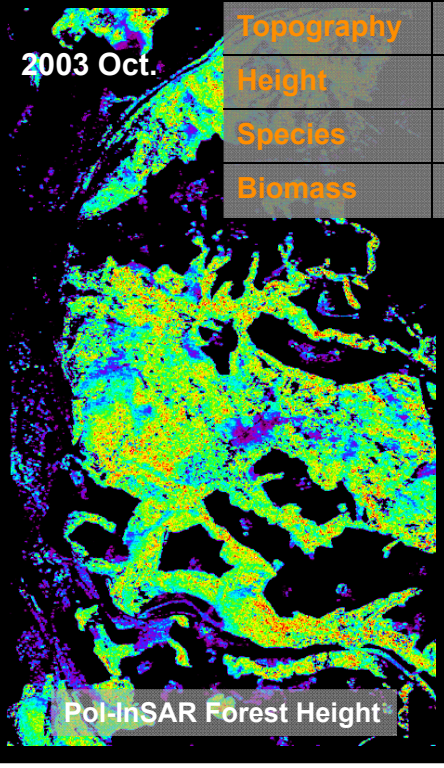
$$m(\vec{w}) = \frac{m_G(\vec{w})}{m_V(\vec{w}) I_0} \qquad \kappa_z = \frac{\kappa \Delta\theta}{\sin(\theta_0)}$$

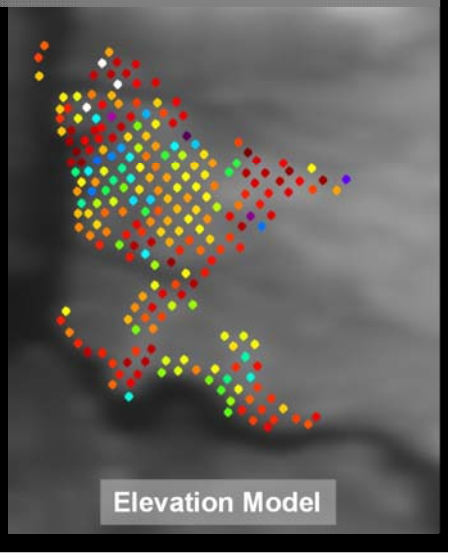
- $\sigma(z)$ has to be parameterised
- Volume Height h_V
- Topography φ_0
- G/V Ratio $m(\vec{w})$

Traunstein Test Site

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







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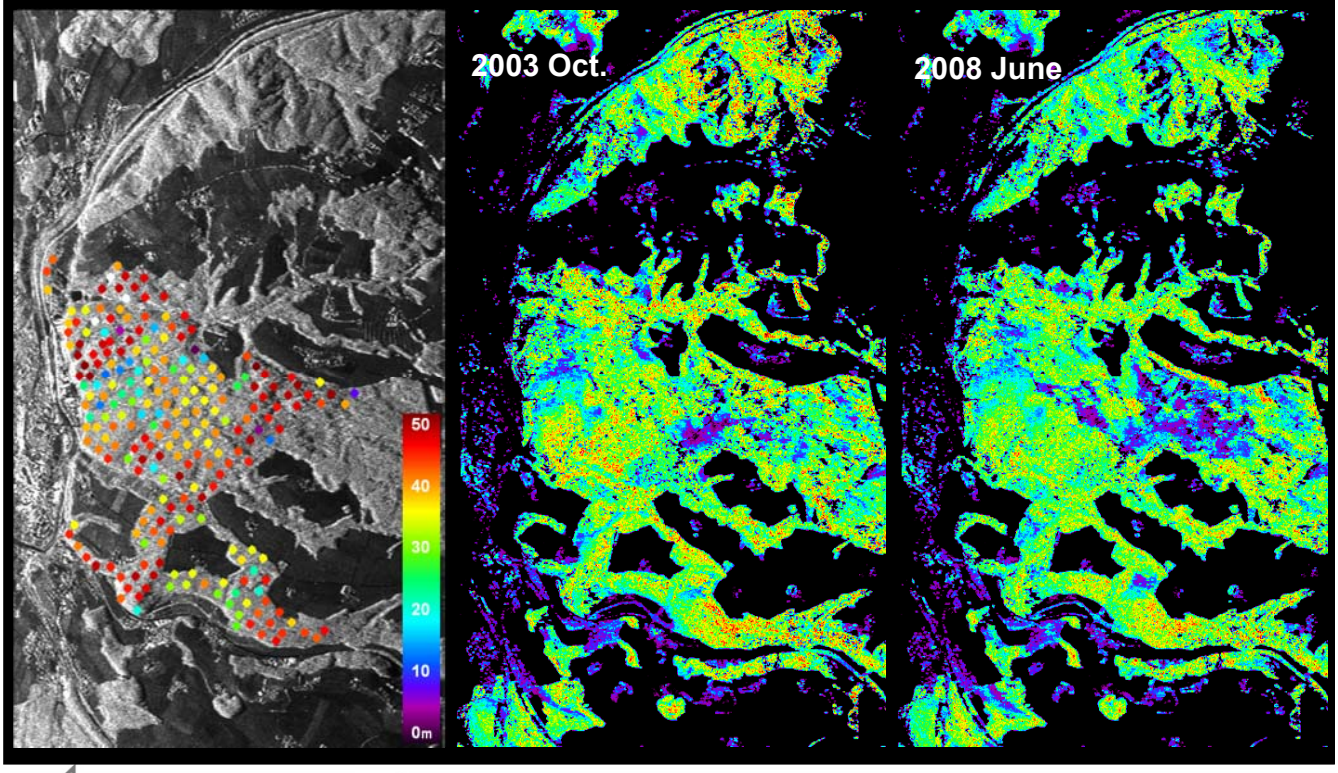

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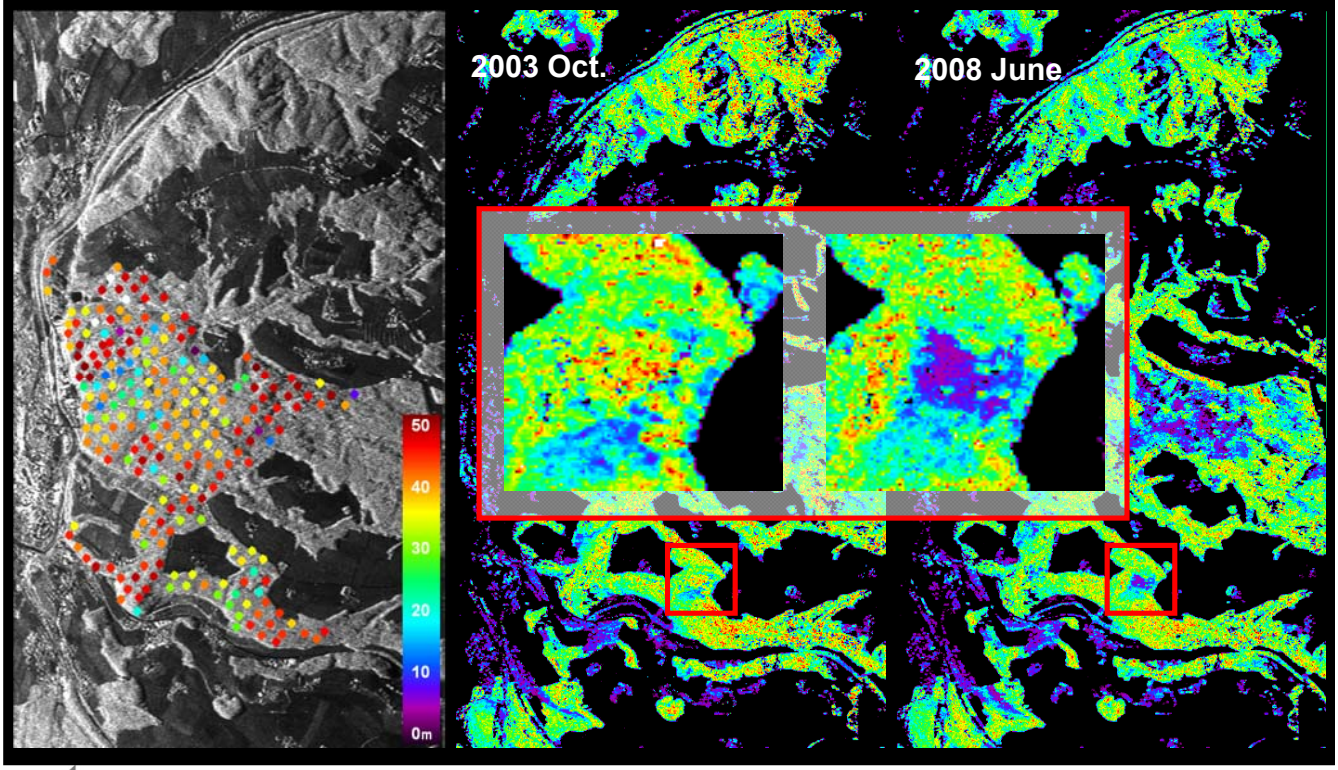

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SAR Interferometry for Volume Structure

Volume Coherence

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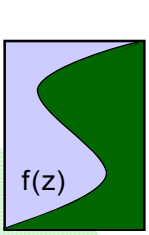
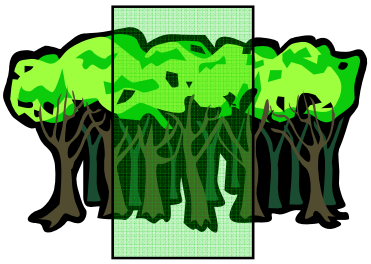
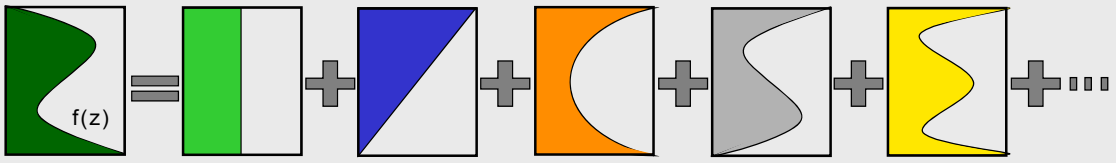


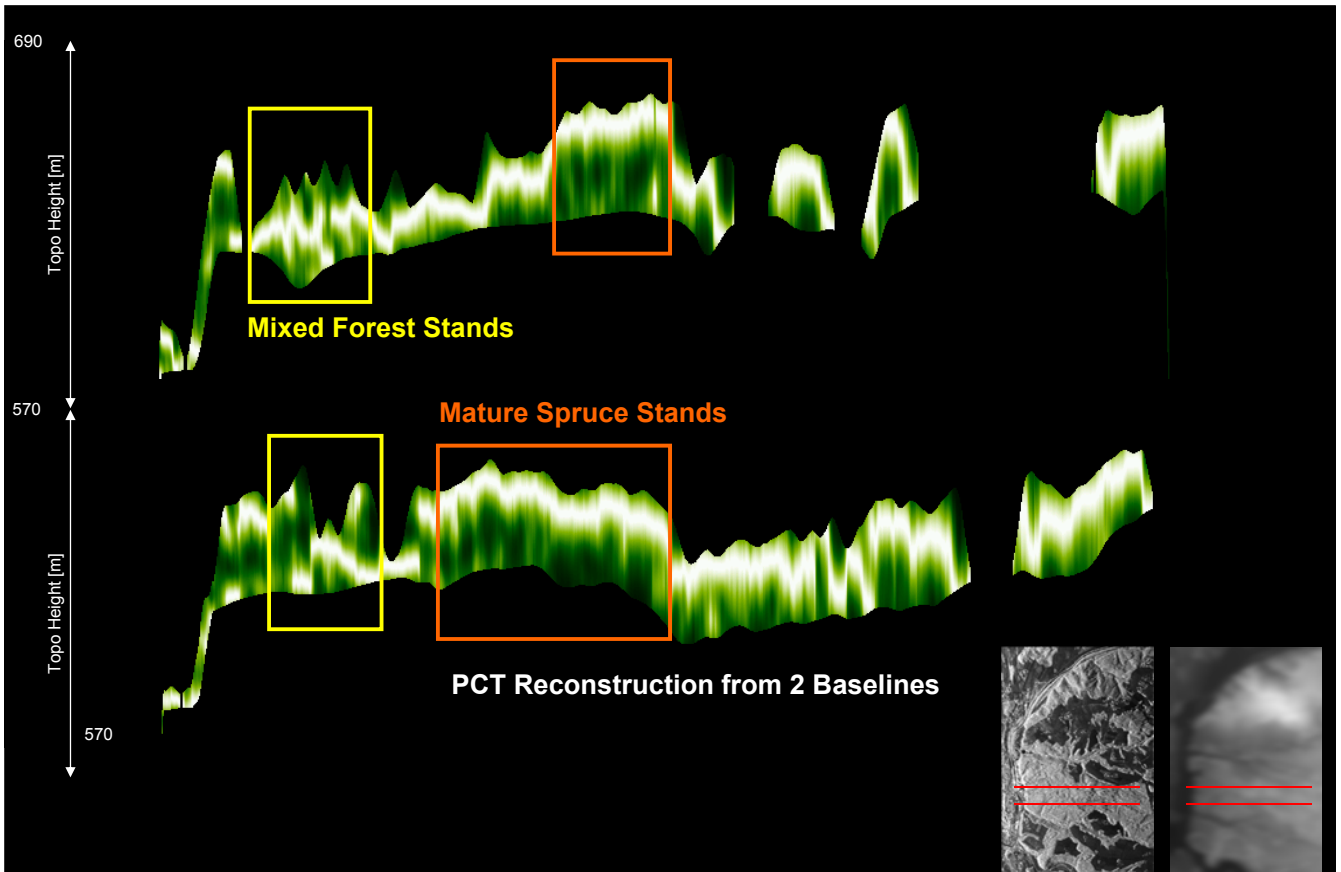




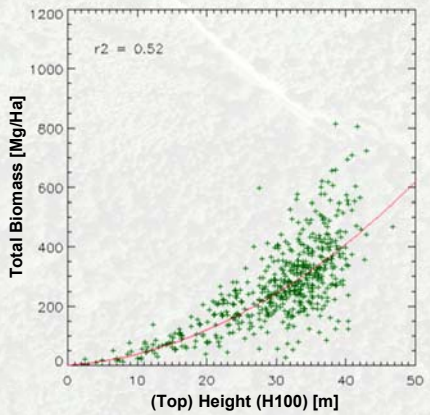
$$\tilde{\gamma}_{Vol}(f(z)) = e^{ik_z z_o} \frac{\int_o^{h_v} f(z)\, e^{ik_z z} dz}{\int_o^{h_v} f(z)\, dz} \rightarrow \int_0^{h_v} f(z)\, e^{ik_z z} dz = \frac{h_v}{2} e^{i\frac{k_z h_v}{2}} \int_{-1}^{1} (1 + f(z'))\, e^{i\frac{k_z h_v}{2} z'} dz'$$

$$\rightarrow \int_0^{h_v} f(z)\, dz = \frac{h_v}{2} \int_{-1}^{1} (1 + f(z'))\, dz'$$

Fourier Legendre Series: $f(z') = \sum_n a_n P_n(z')$ **where** $a_n = \frac{2n+1}{2} \int_{-1}^{1} f(z') P_n(z') dz'$

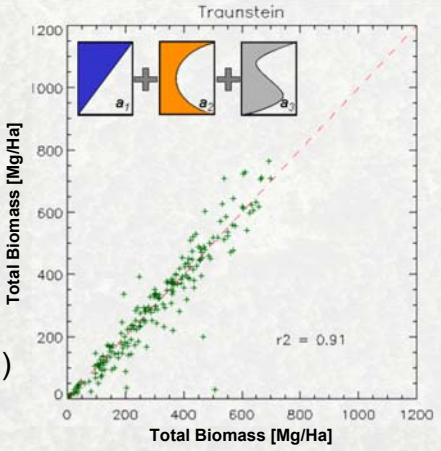


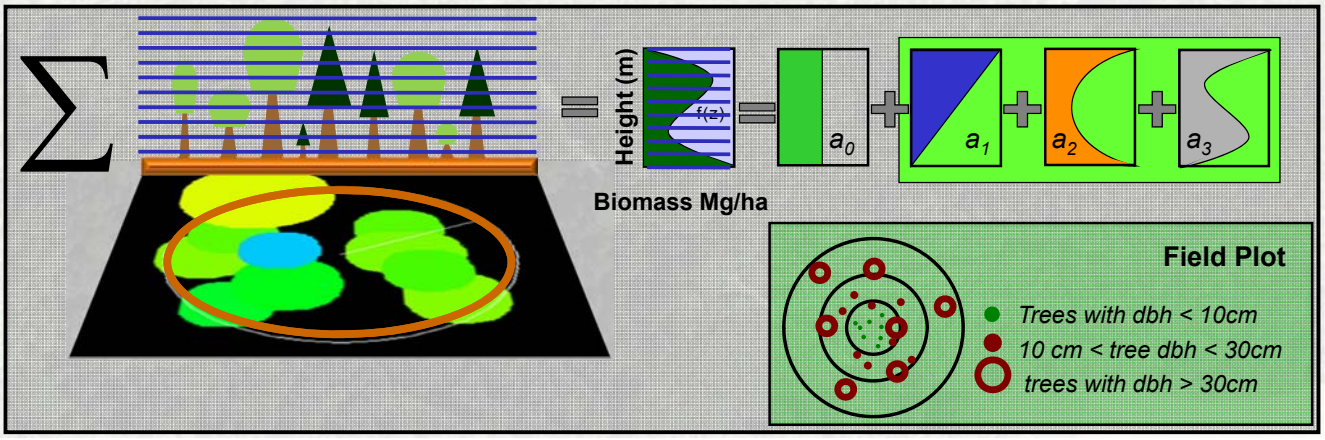
Structure-to-Biomass Allometry



$$B = la * 1.66\, H^{1.50}$$

$$B = 3.11 * \sum_{i=0}^{H} \sum_{j=1}^{3} a_j * P_j(z_i)$$





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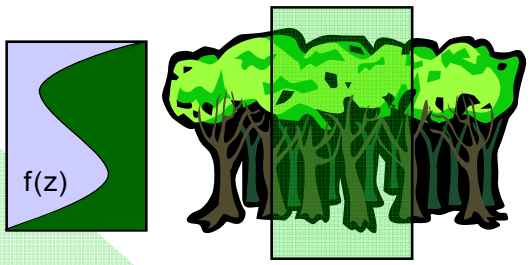

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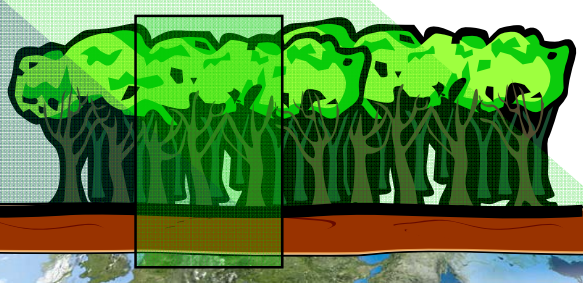

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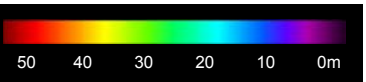
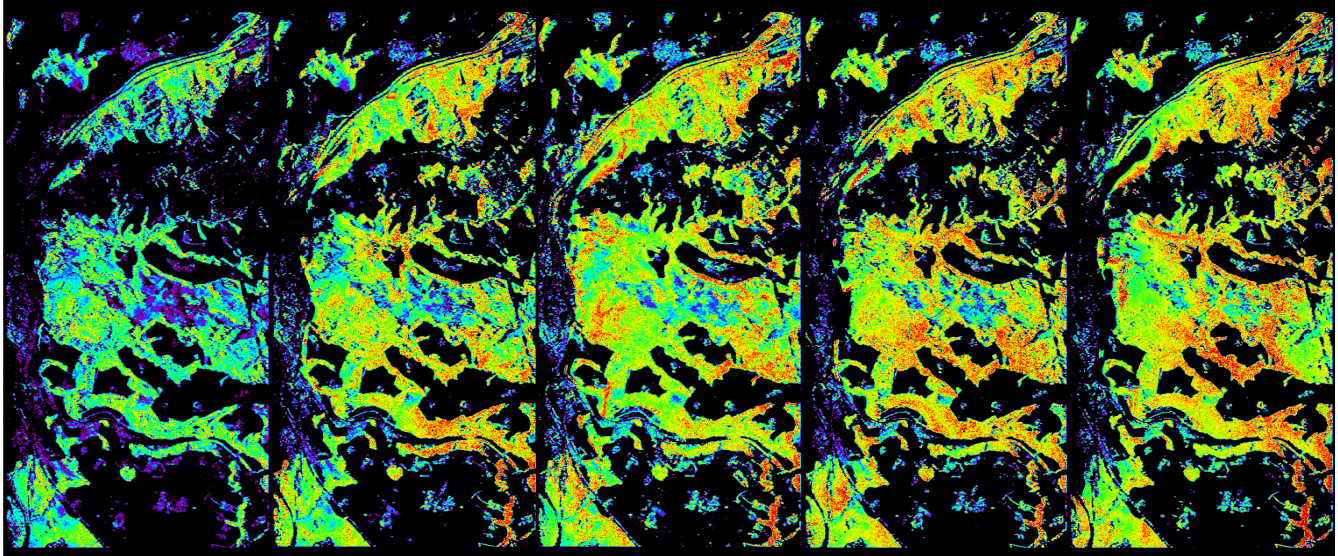


Forest Height Maps from different Temporal Baselines: 10min-13days



ΔT=10min ΔT=1day ΔT=5days ΔT=7days ΔT=13days

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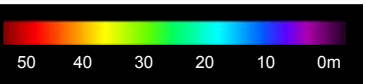
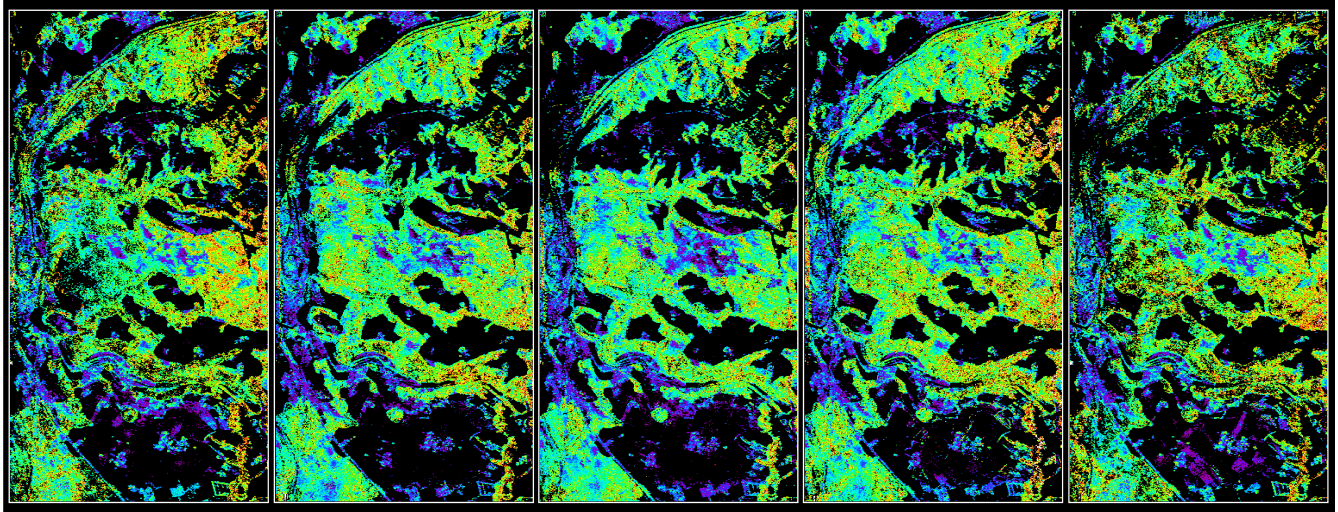
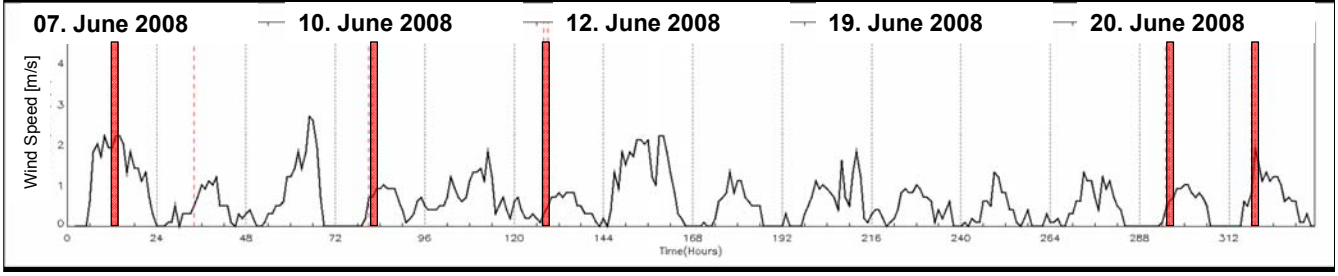


Forest Height Maps 10min Temporal Baseline

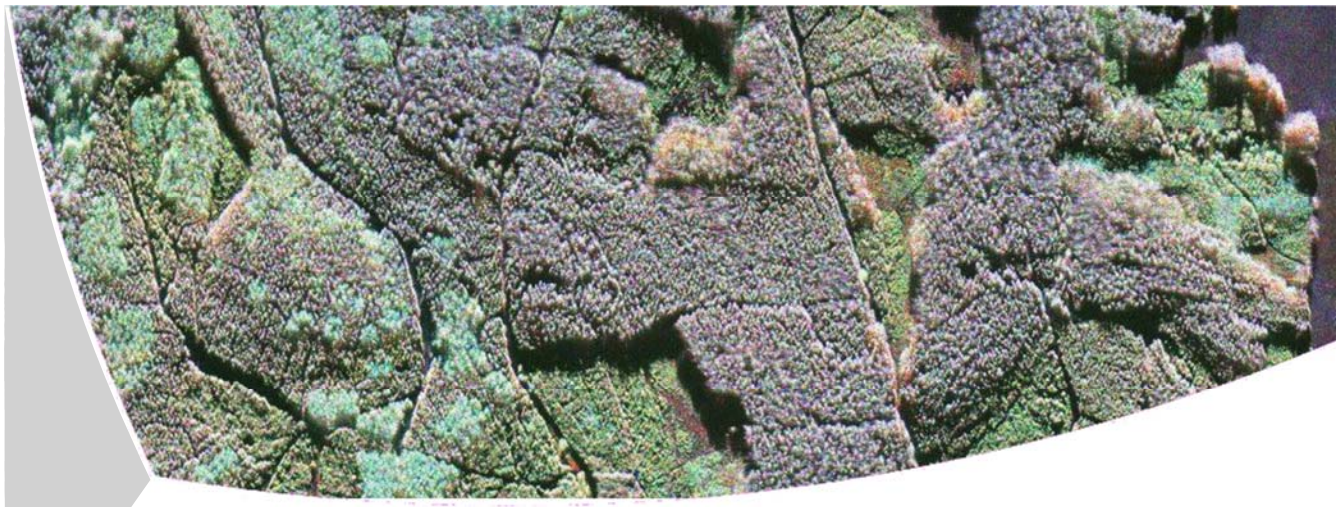




Tandem-L

	Tandem-L Science Products	Resolution	Revisit
Biosphere	Forest height	20 - 50 m	16 days - seasonal
	Above ground biomass		
	Vertical forest structure		
Geo-/ Lithosphere	Plate tectonics	5 - 100 m	weekly
	Volcanoes		
	Landslides		
	Deformation		
Cryo- & Hydrosphere	Glacier flow	50 - 500 m	weekly
	Soil moisture		weekly
	Water level change		on demand
	Snow water equivalent		seasonal
	Ice structure Change		seasonal
	Ocean Currents		weekly
Global	Digital Terrain and surface model	20 - 50 m	yearly

DLR JAXA



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