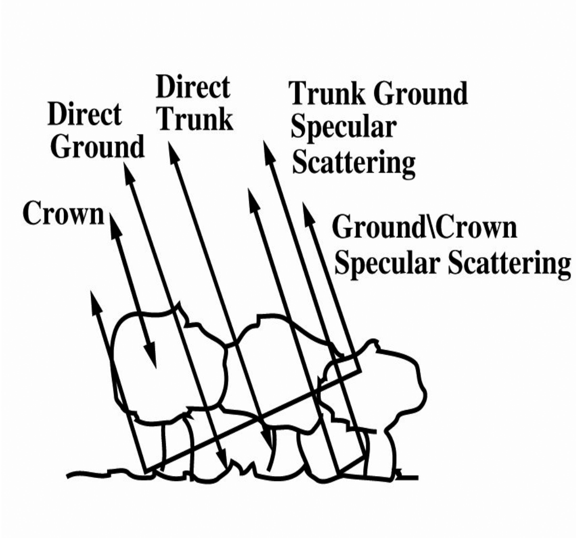
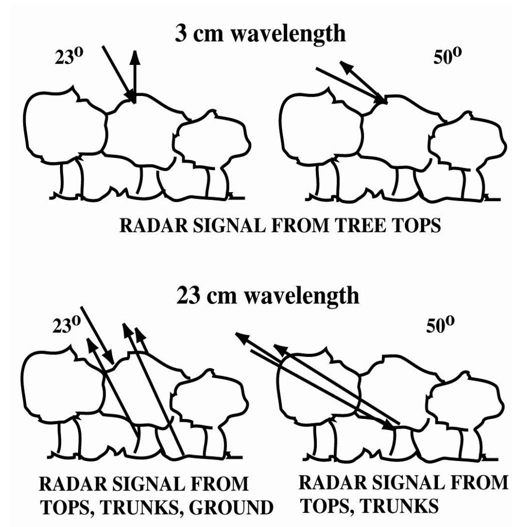
Radar: Sensitivity to Biomass





For a given tree type (jack pine for example):

- σ° is not uniquely related to 'biomass'
- σ° varies linearly with stocking density and diameter
- σ° varies with height squared

If SAR data is used to solve for:

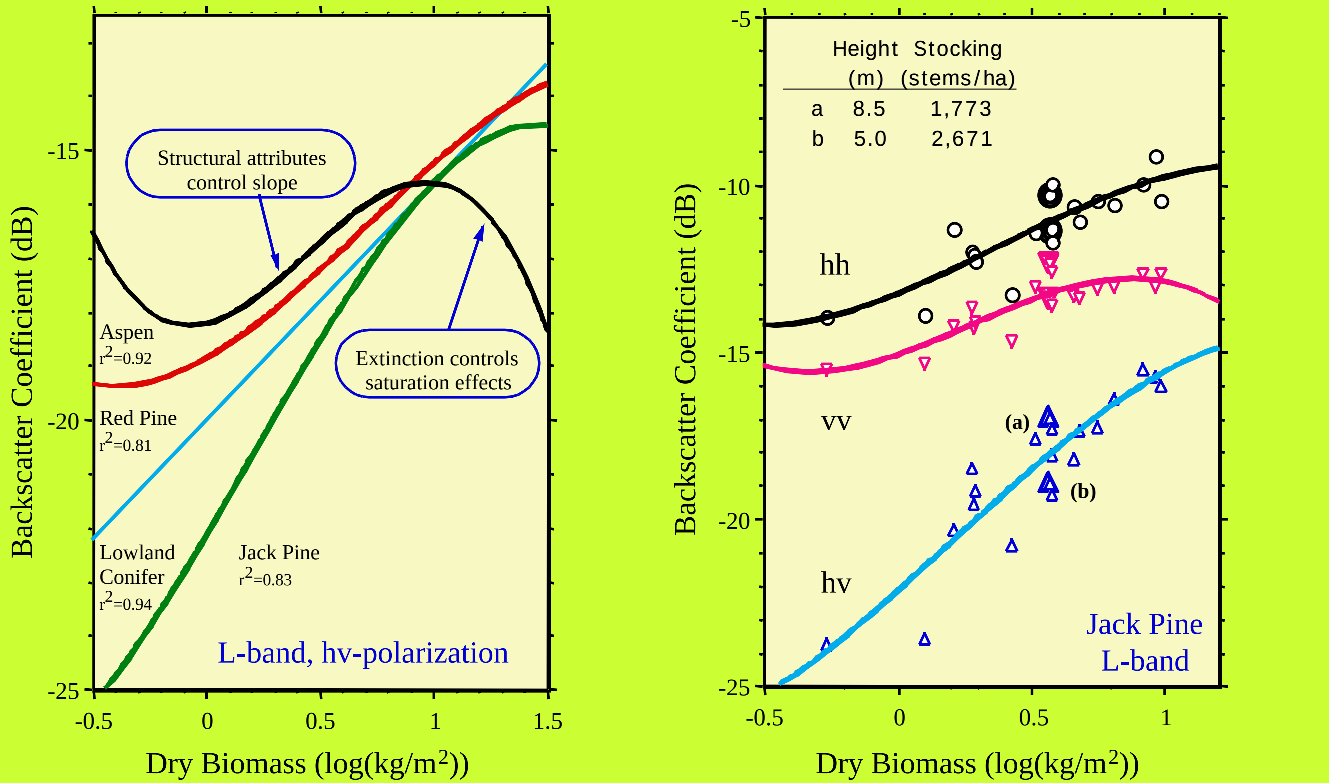
- Basal Area and Height

Biomass can then be uniquely determined

- Assumes knowledge of wood density and taper factor

Effects of Forest Structure on Radar Backscatter

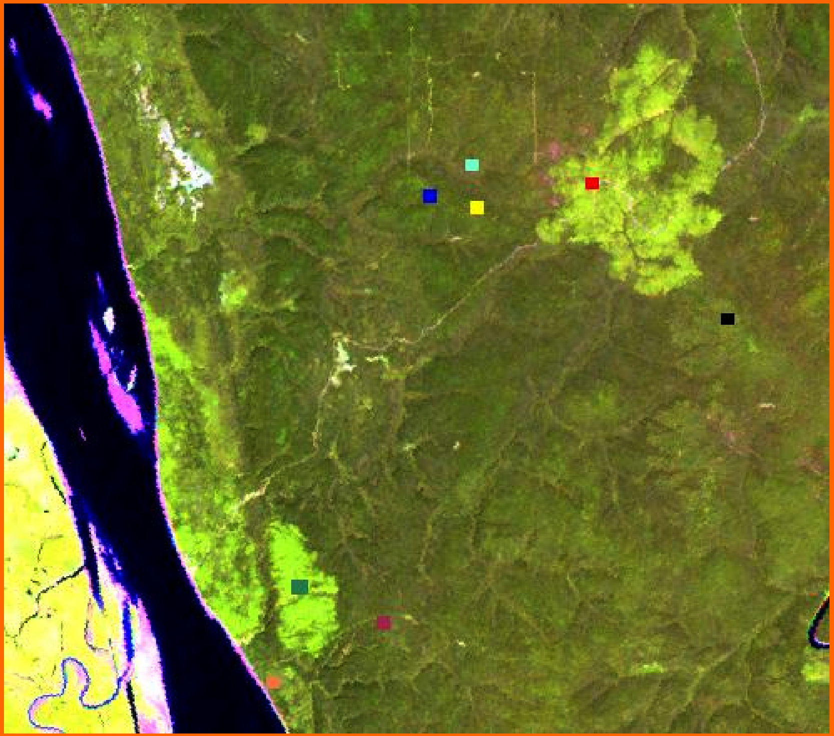
SIR-C observations confirm basic biomass dependence of SAR for many tree species



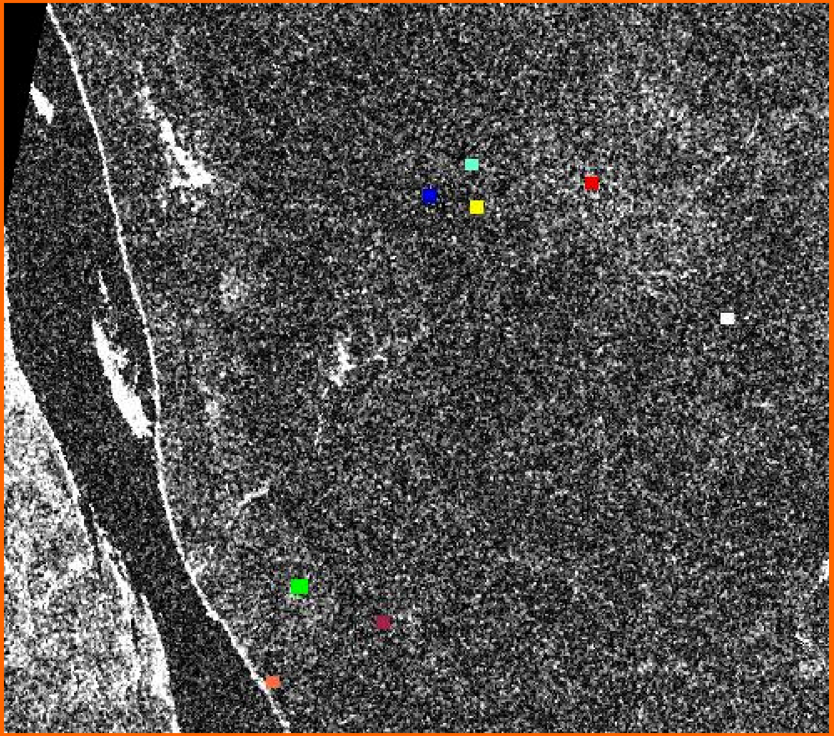
SIR-C Data from the Raco Supersite, SRL-1, DT-102.4 Radiation Laboratory The University of Michigan
Plots courtesy of Craig Dobson and Kathleen Bergen

Interferometric Radar & LandSAT

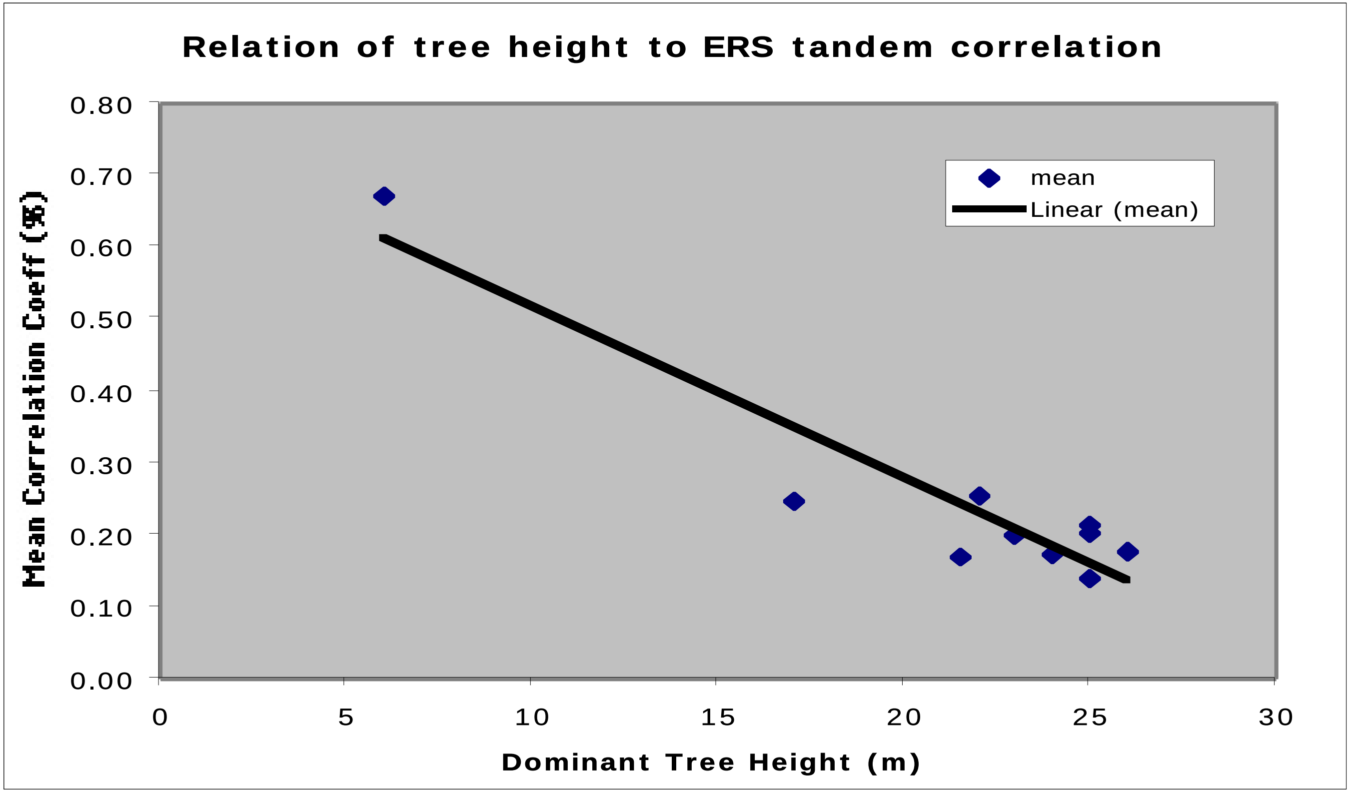
LandSAT bands 3,4,5



ERS-1 and -2 Tandem



Comparison with ground data

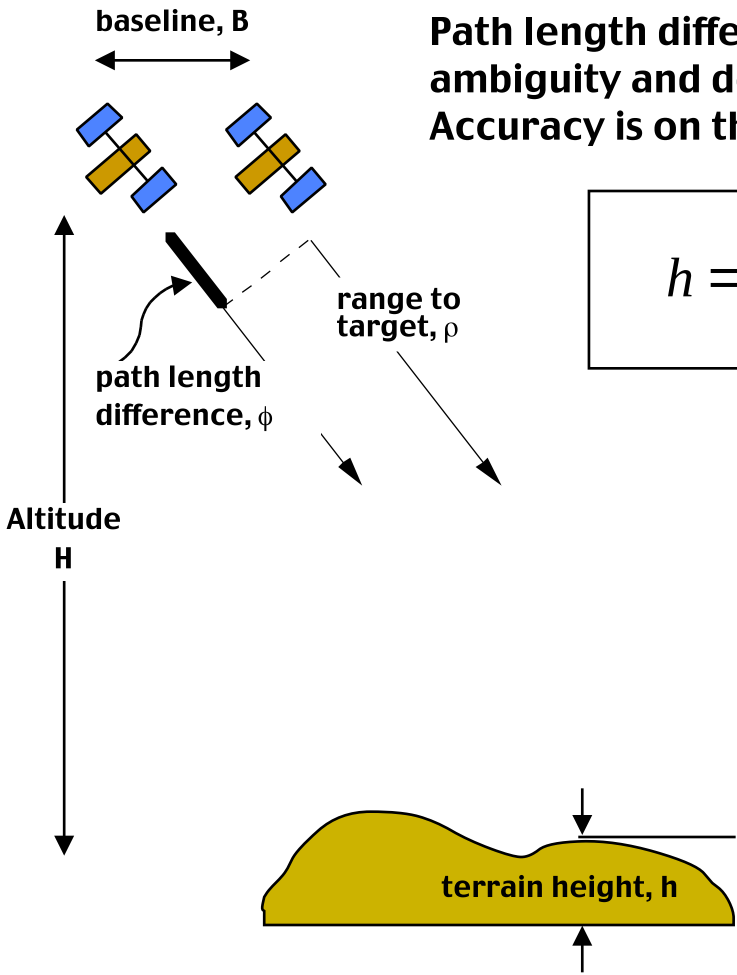


Above trend is applicable to one baseline pair combined with local ground truth and calibration. Used to illustrate trend, but not general rule.

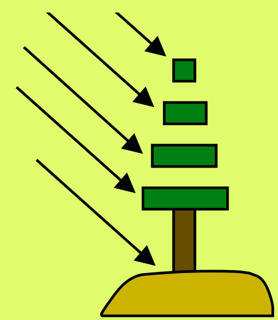
Tree Height Estimation from Radar Interferometry

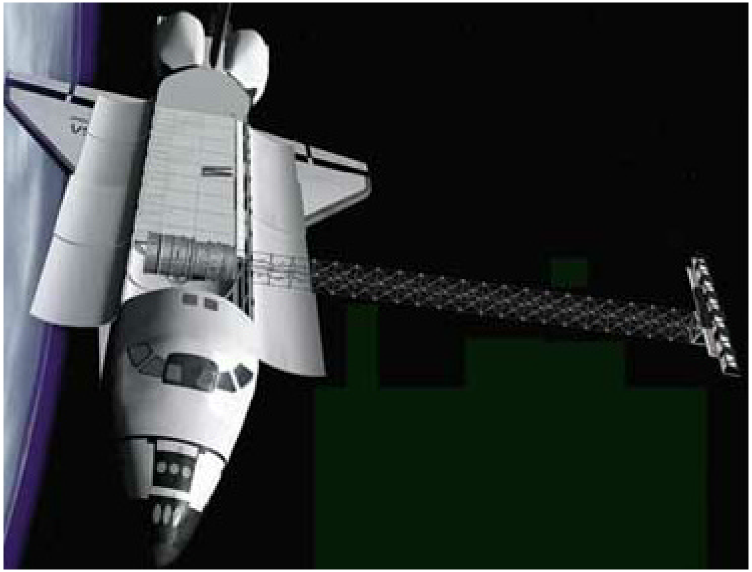
Path length difference can be used to resolve positional ambiguity and determine the height of the terrain. Accuracy is on the order of meters, with a 25m resolution

$$h = H - \rho \cos\left(\sin^{-1}\left(\frac{\lambda\phi}{4\pi B}\right)\right)$$



When the signal return comes from multiple heights, a unique signature is observed by the interferometer

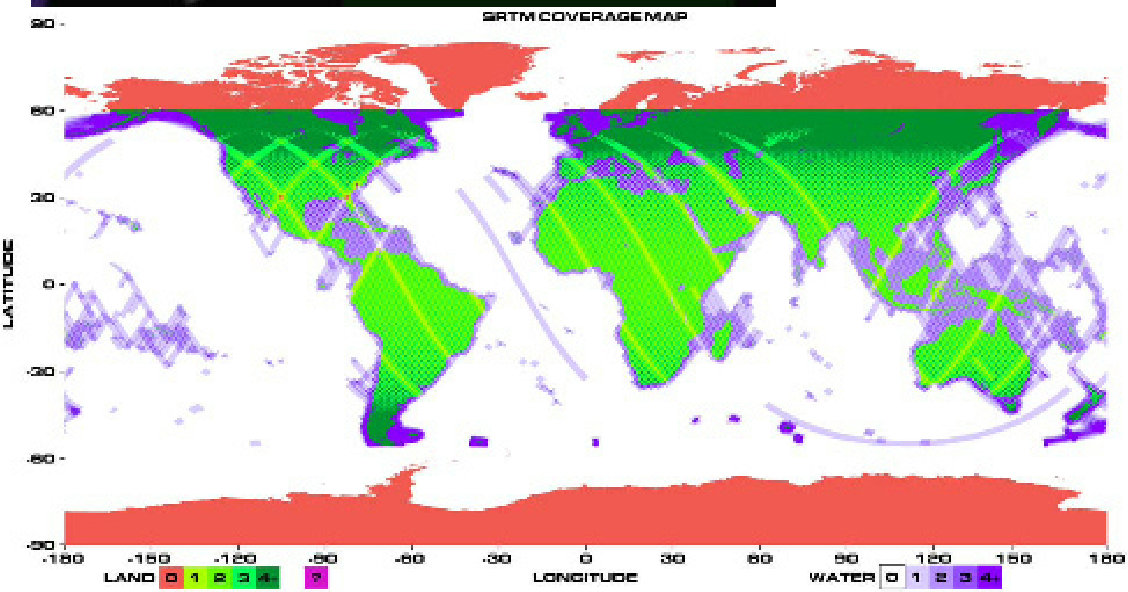




SRTM (Shuttle Radar Topography Mission)

Mapped 80% of the Earth’s landmass using C- and X-band Interferometry.

60 meter antenna baseline created by extending a boom from the Shuttle’s cargo bay.

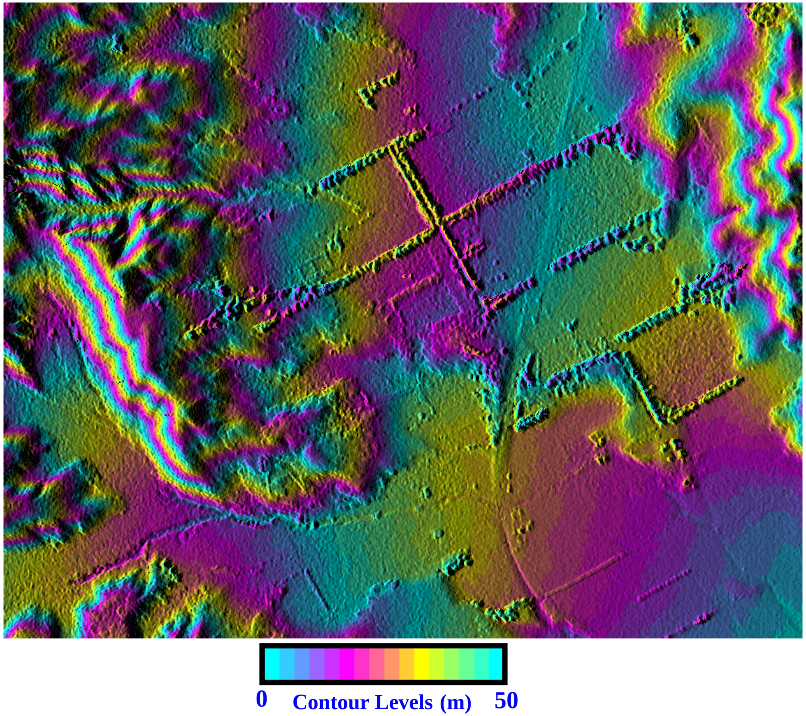


10 day mission executed in February 2000.

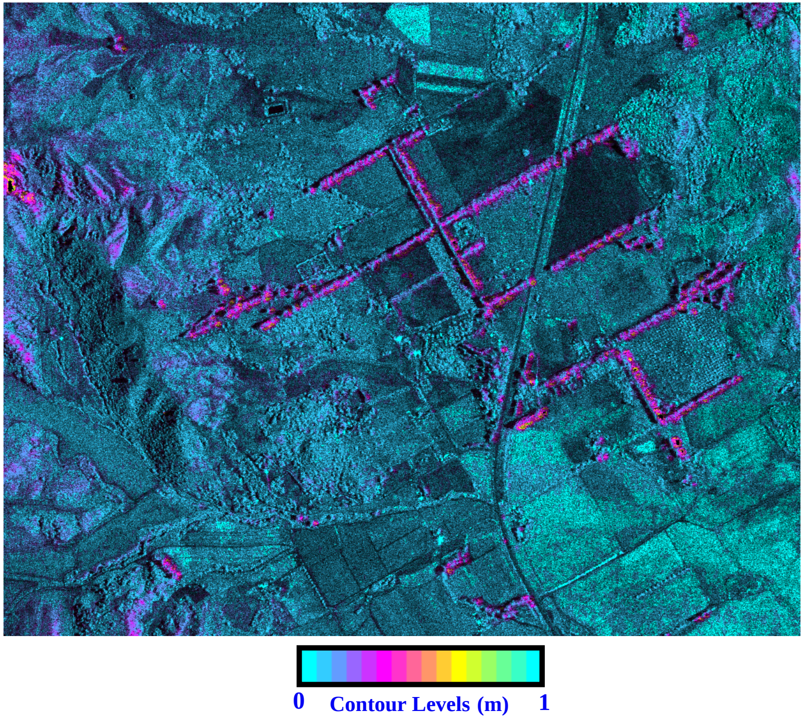
Topographic data products just now becoming available (~30 meter postings)

Interferometric Data Products

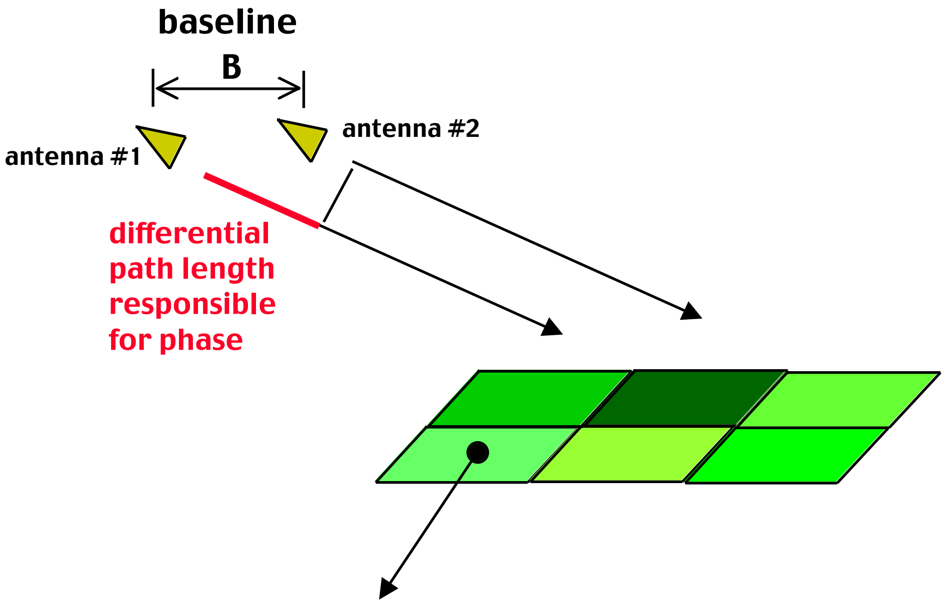
DEM from Interferometry

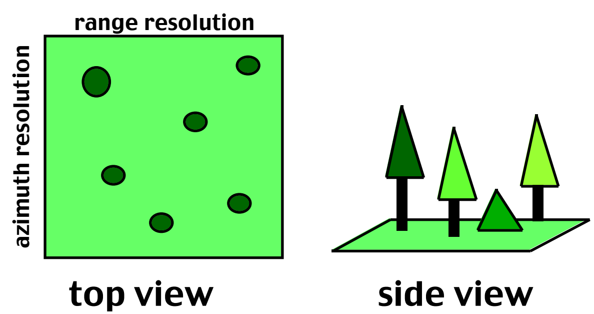


Correlation Map



Interferometry: How it works

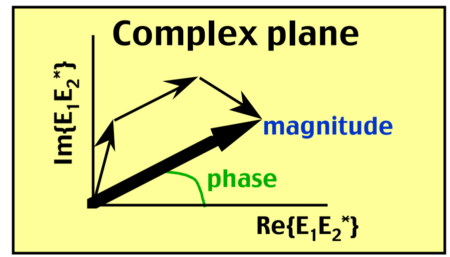




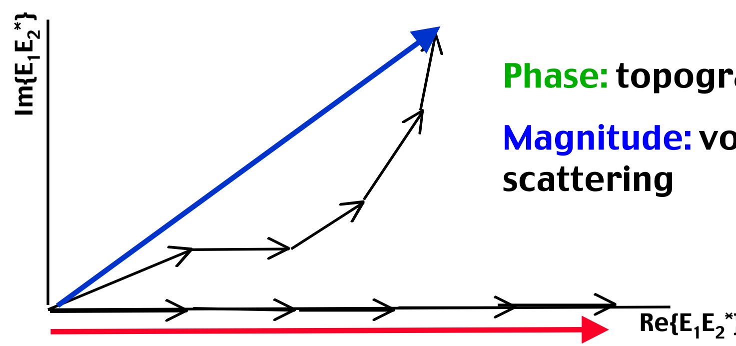
Each resolution cell contains the summed reflection from all scatterers within the cell

antenna 1: $E_1 = \sum_i E_{1i}$

antenna 2: $E_2 = \sum_i E_{2i}$



Sum of resolution elements yields interferometric correlation

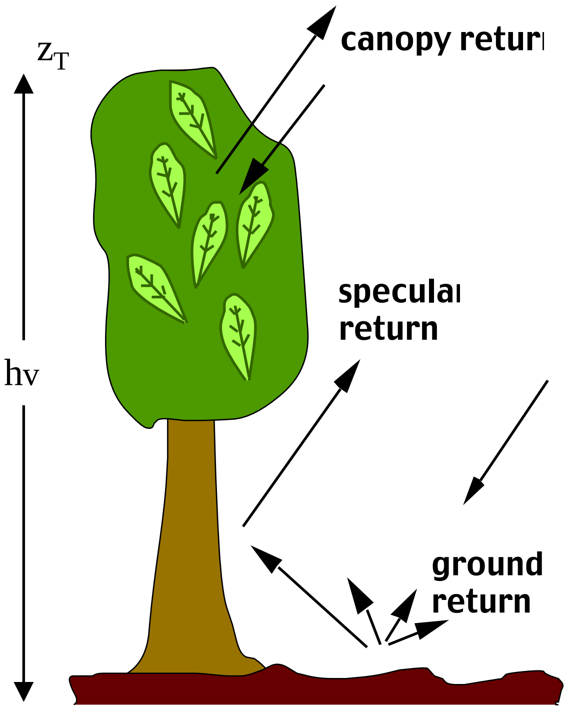


Phase: topography

Magnitude: volume scattering

Forward Modeling

- At X- and P-band, the canopy is composed of many scattering sources. Use a generic bulk medium approach for modeling.



mean direct backscatter

$$\rho_0\langle f_b^2\rangle = \rho_{0,leaves}\langle f_{b,leaves}^2\rangle + \rho_{0,trunk}\langle f_{b,trunk}^2\rangle + \rho_{0,branches}\langle f_{b,branches}^2\rangle \ldots$$

mean specular backscatter

$$\rho_0\langle f_{spec}^2\rangle \Gamma^2 R^2$$

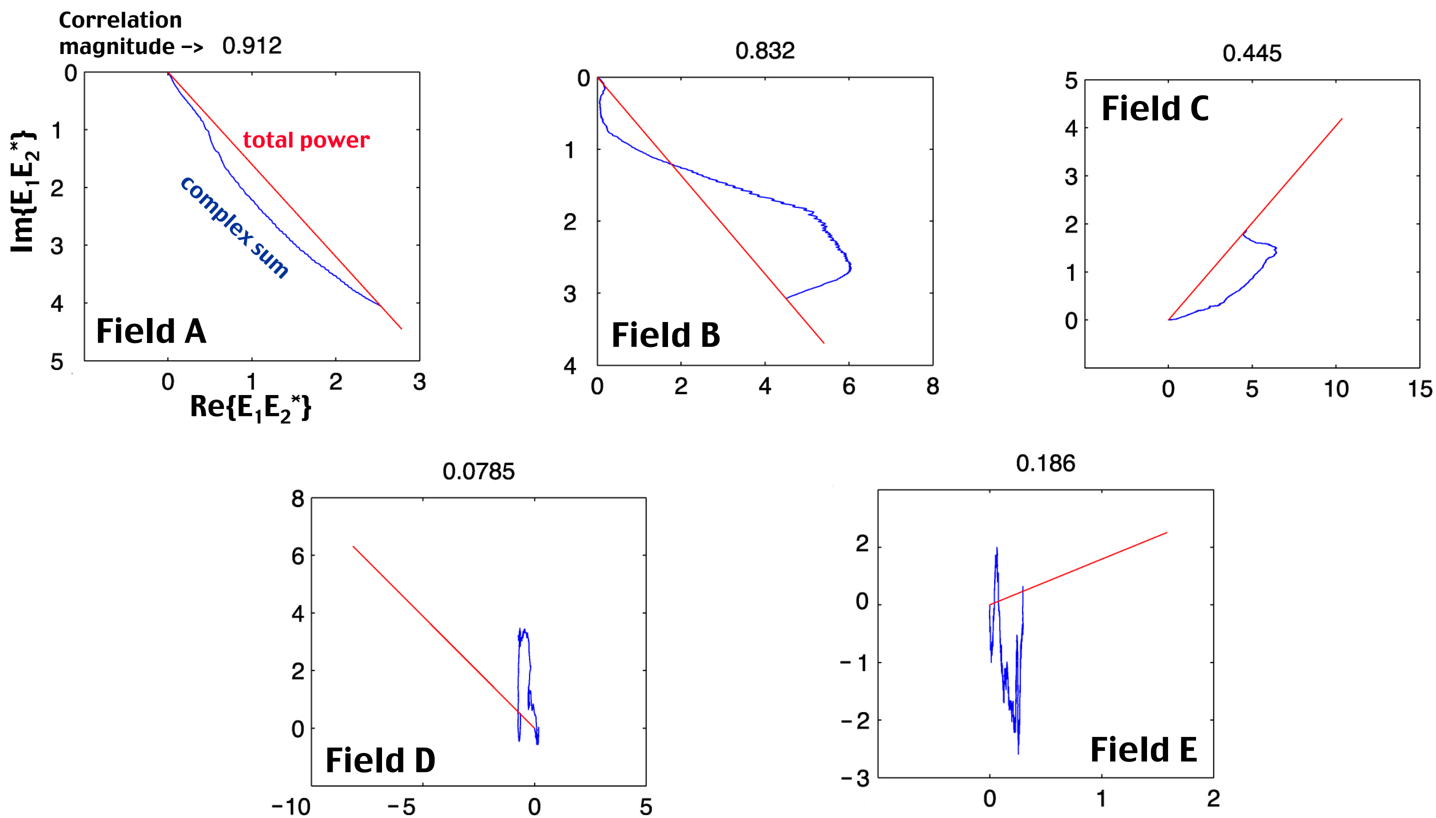
Γ - rough surface loss
R - reflection coefficient

mean direct ground backscatter

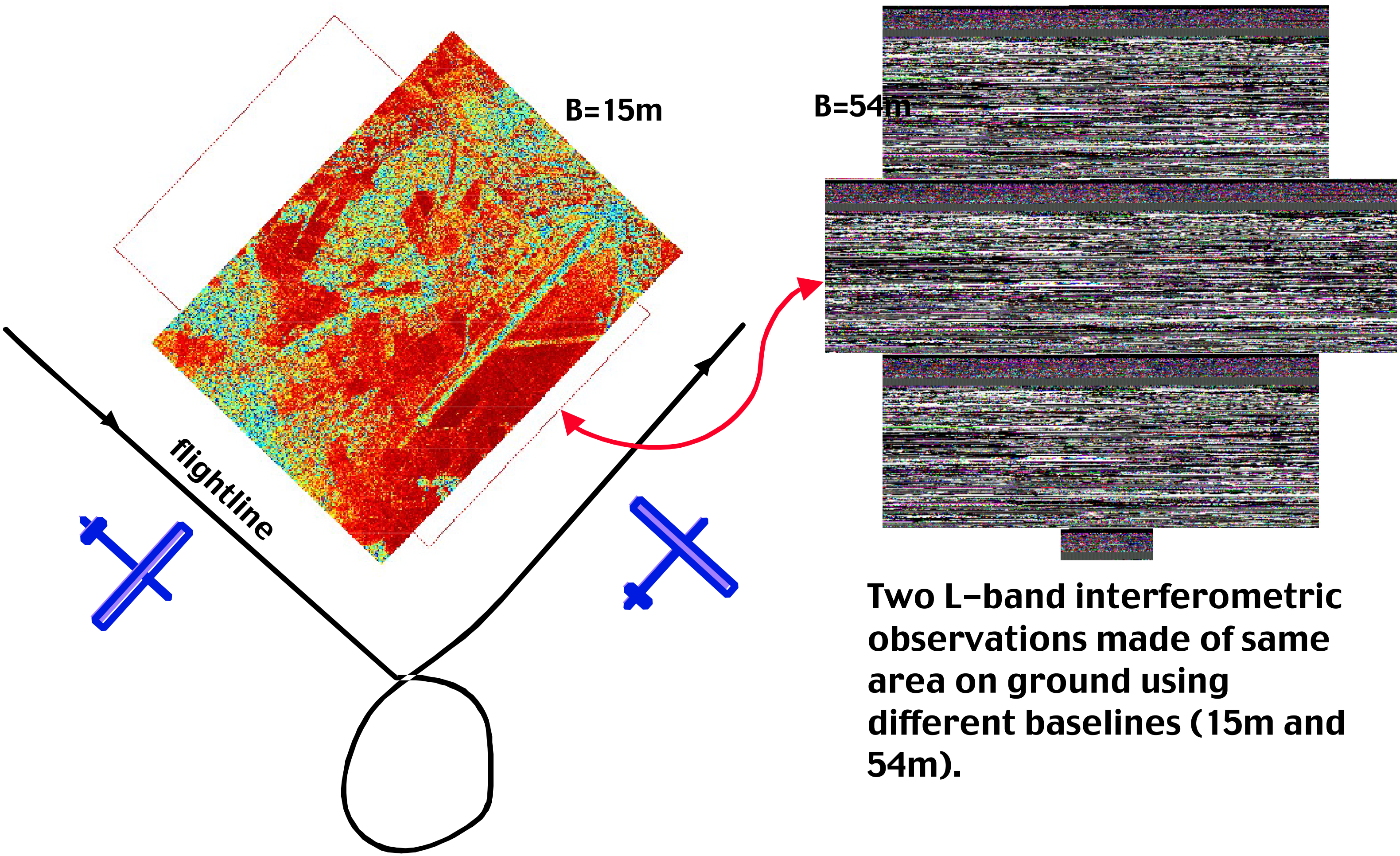
$$k_0^4 \cos^4\theta\, W_P(-2k_0\sin\theta, 0)\langle\alpha^2\rangle$$

α - pol. dependent interaction
W_P - power spectrum of surface roughness

correlation plots in the complex plane



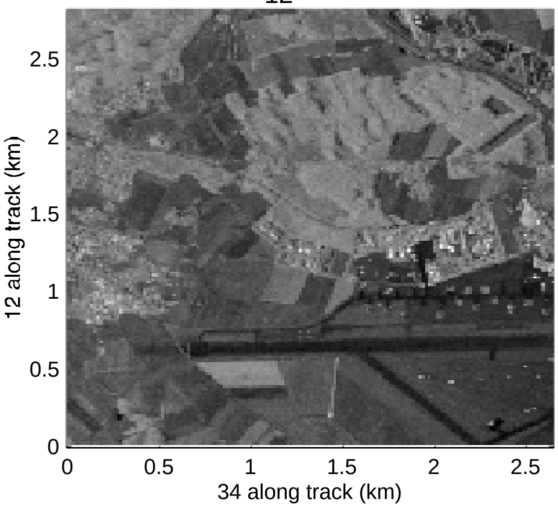
DLR Project



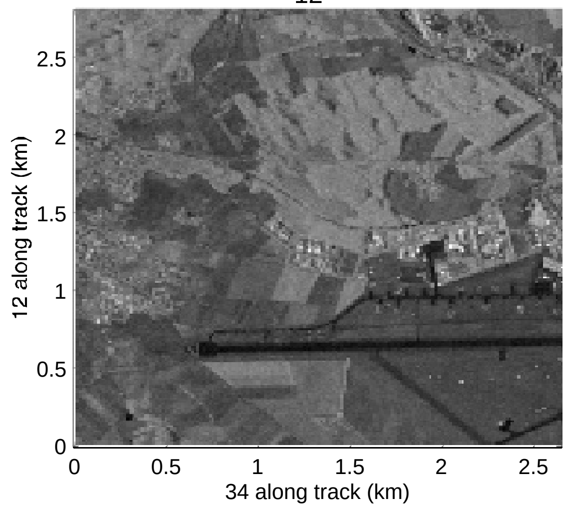
Two L-band interferometric observations made of same area on ground using different baselines (15m and 54m).

Backscattered Power

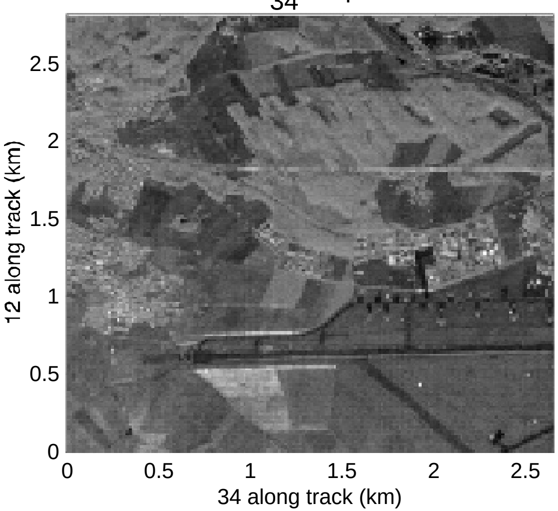
σ^{o}_{12} HHpol



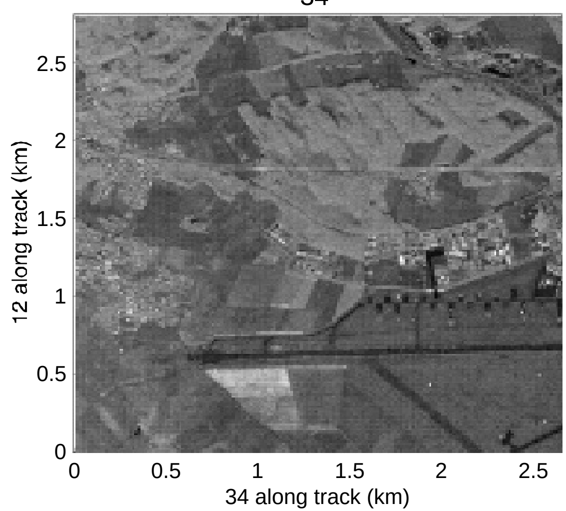
σ^{o}_{12} VVpol



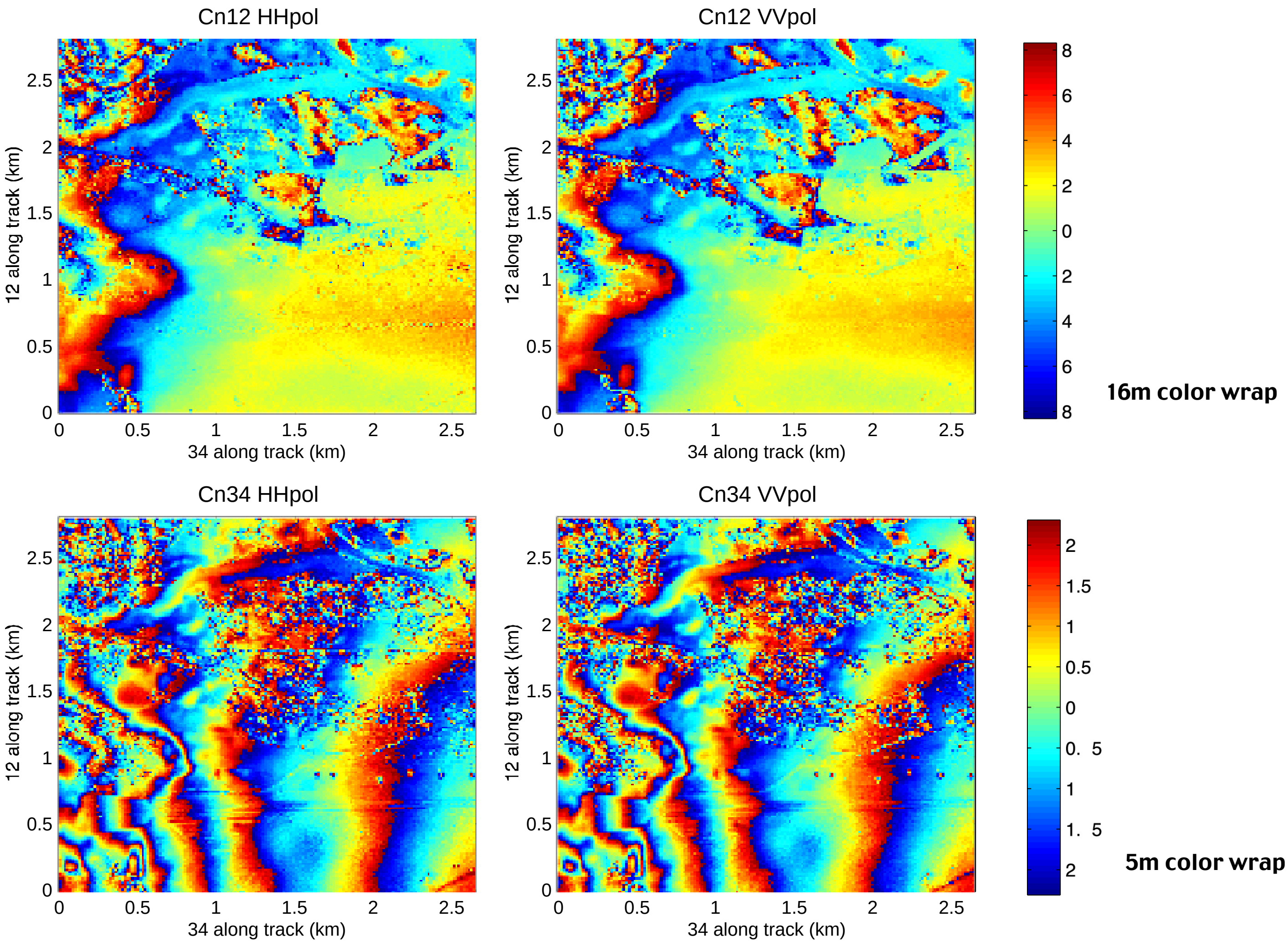
σ^{o}_{34} HHpol



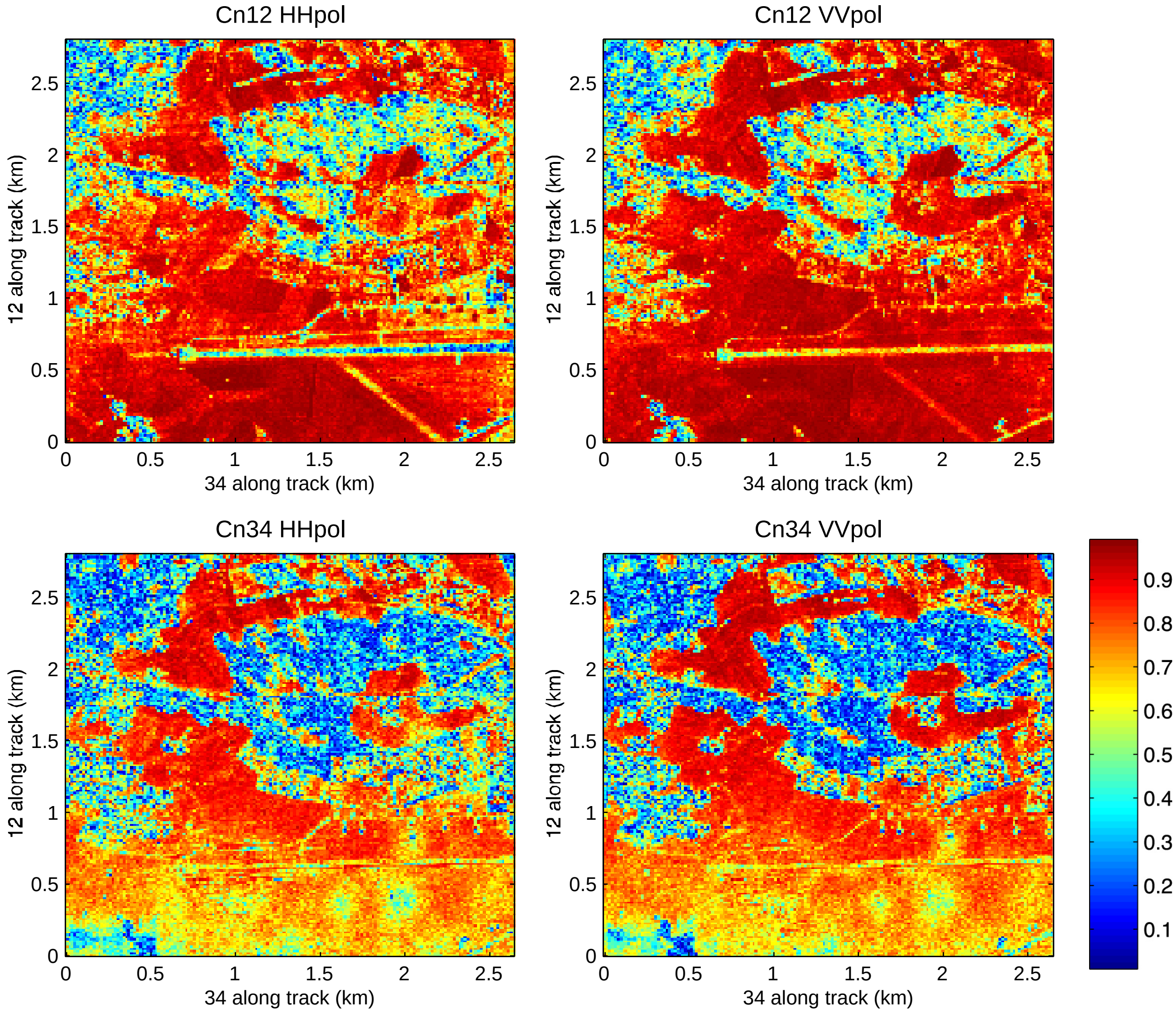
σ^{o}_{34} VVpol



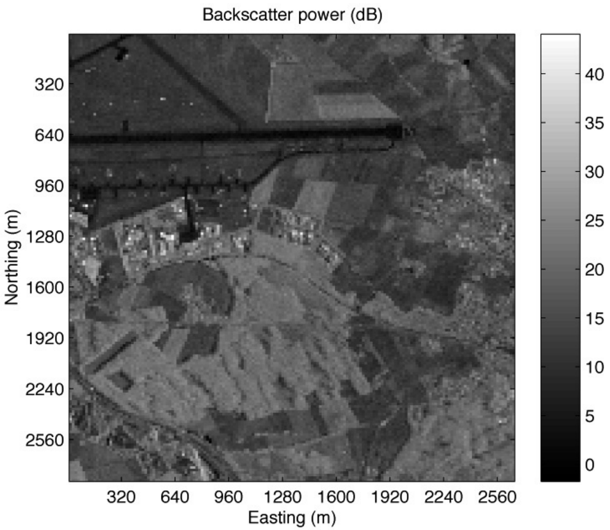
Correlation Phase (topography)



Correlation Magnitude

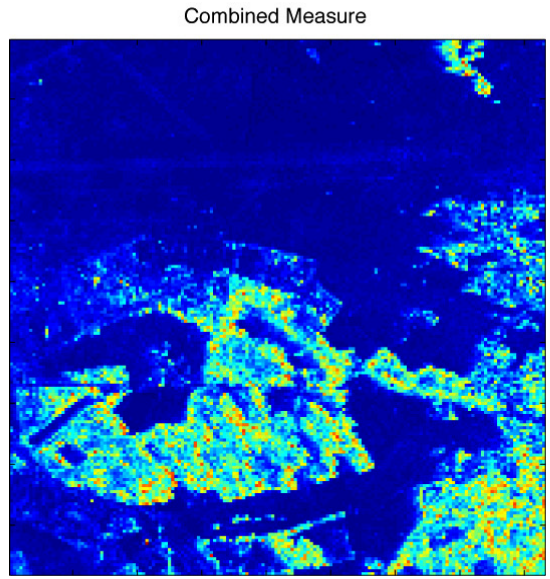


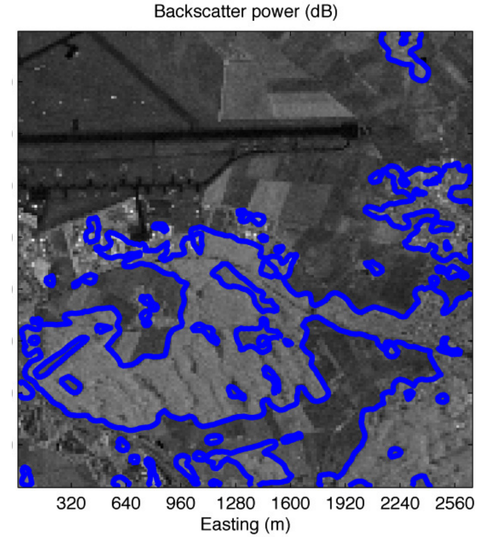
A simple forest detection algorithm

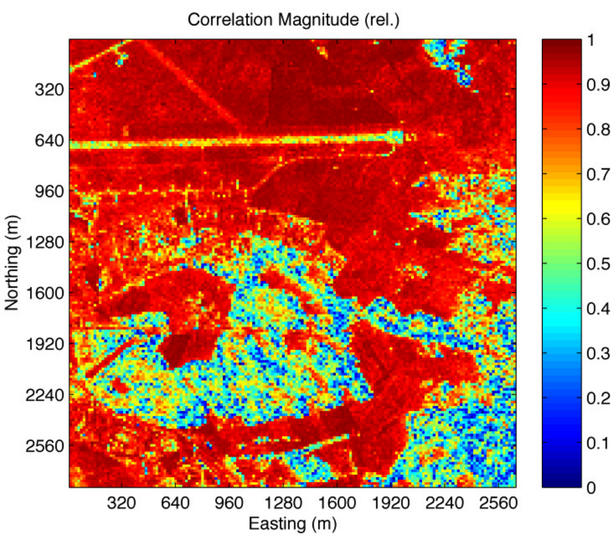


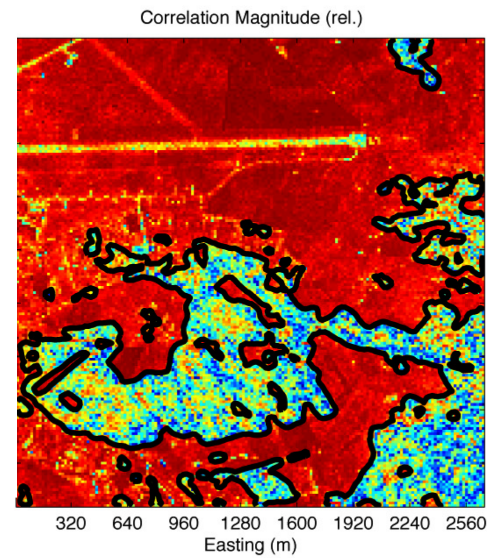
Forest indicated by

- **Bright backscatter**
- **Low correlation**

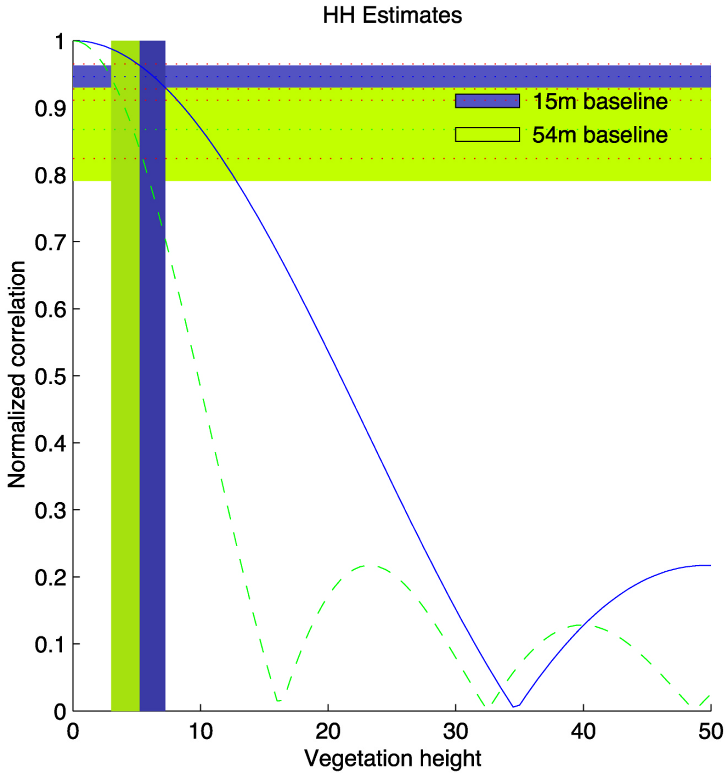


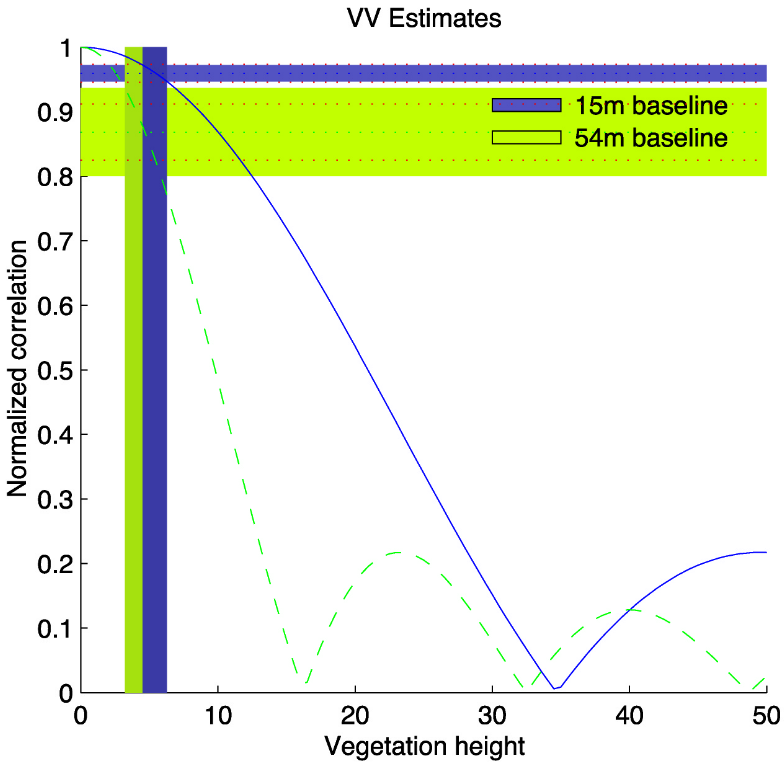




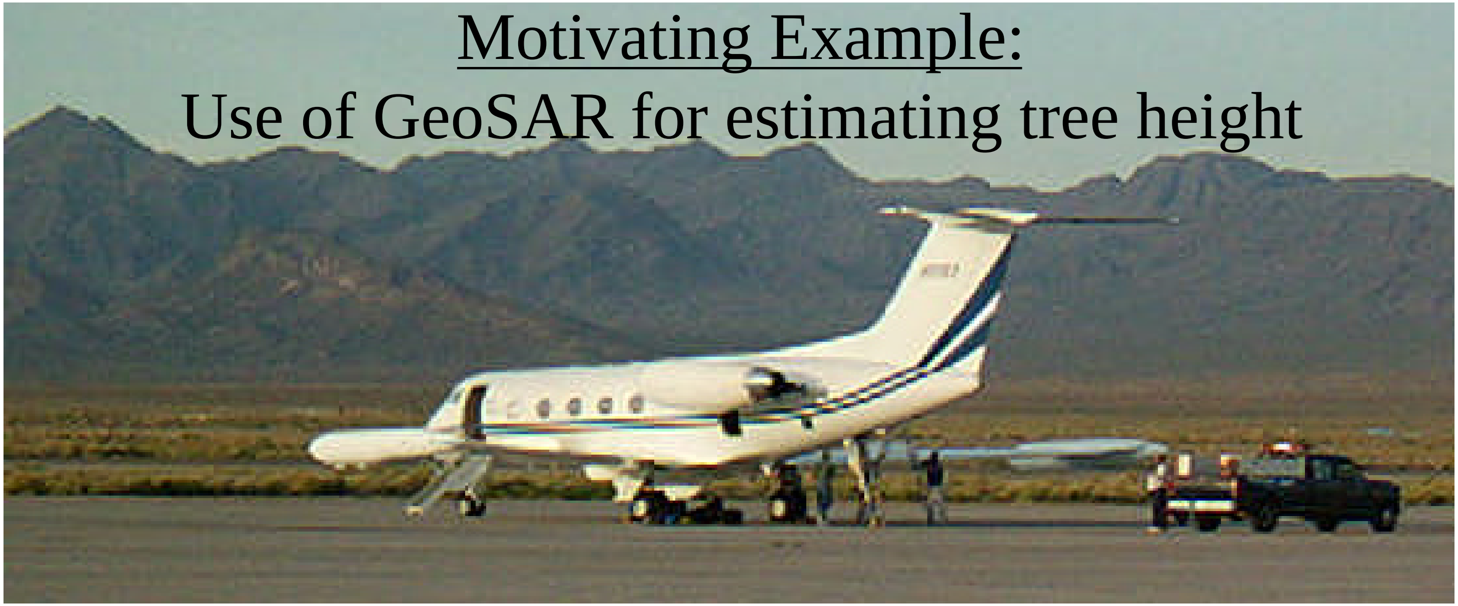


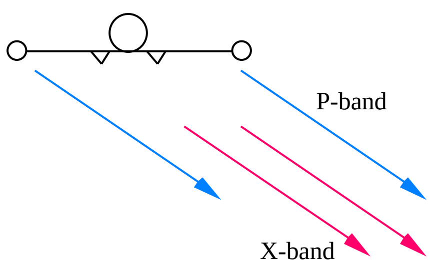
Vegetation height estimates based on correlation magnitude





Motivating Example:
Use of GeoSAR for estimating tree height





- GeoSAR measures interferometric signatures at two frequencies (P- and X-band) and two baselines (single and double baseline at P-band).