Evaluation of Vegetation Effect on the Retrieval of Snow Parameters from Backscattering Measurements

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Outline

- Vegetation at global scale in COREH2O perspective
- Forest backscattering signature
- Forest/snow model
- Model Sensitivity
- Conclusions and Perspectives

Mapping Vegetation at global scale

What type of vegetation must be considered for the analysis ?

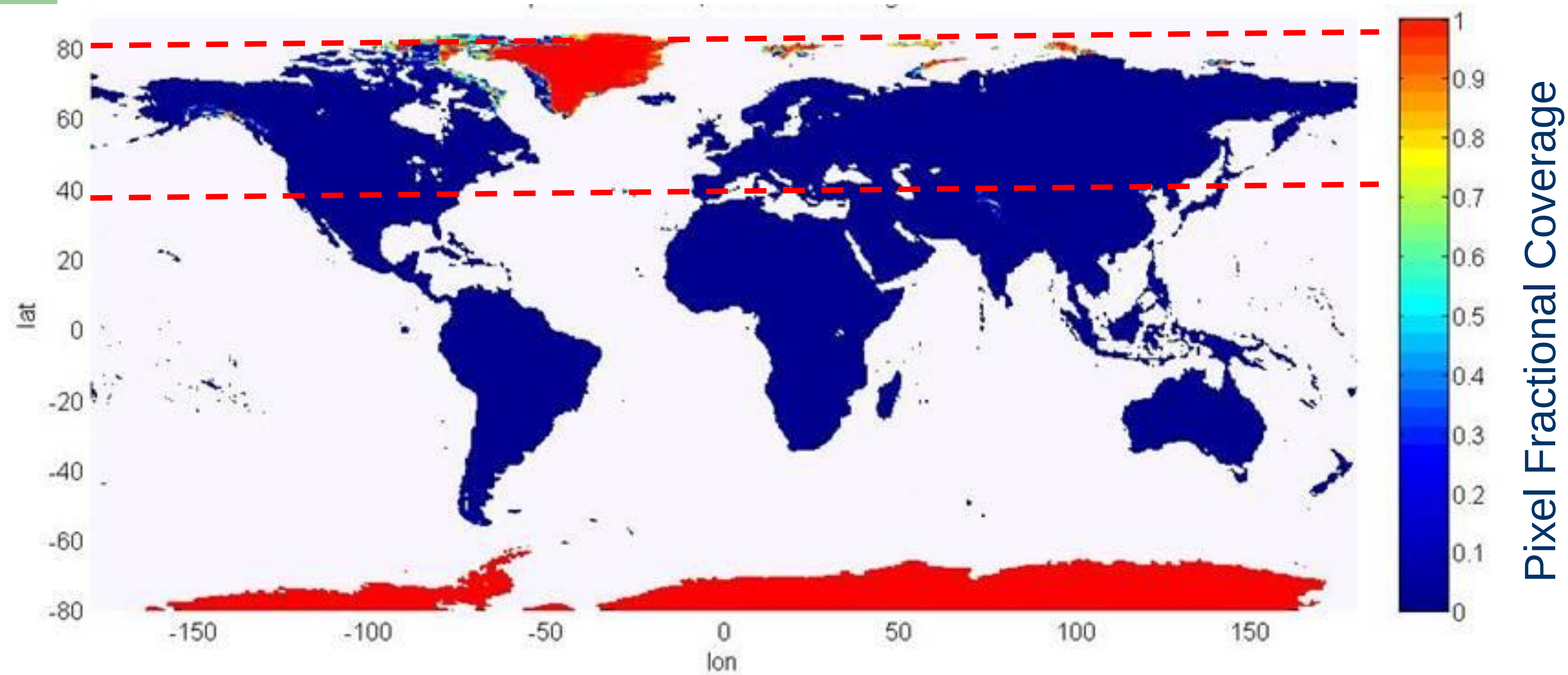
- COREH2O – Parameters and Objectives (Resolution, Frequency 9.6,17.2 GHz, Latitude, etc.)
- Vegetation Global scale data base : ECOCLIMAP, GLOBCOVER,Other
- Regional scale data base : available in some parts of the world
- Vegetation parameters : resolution, vegetation type, fractional cover, height, stem volume,etc.

Example of global scale classification

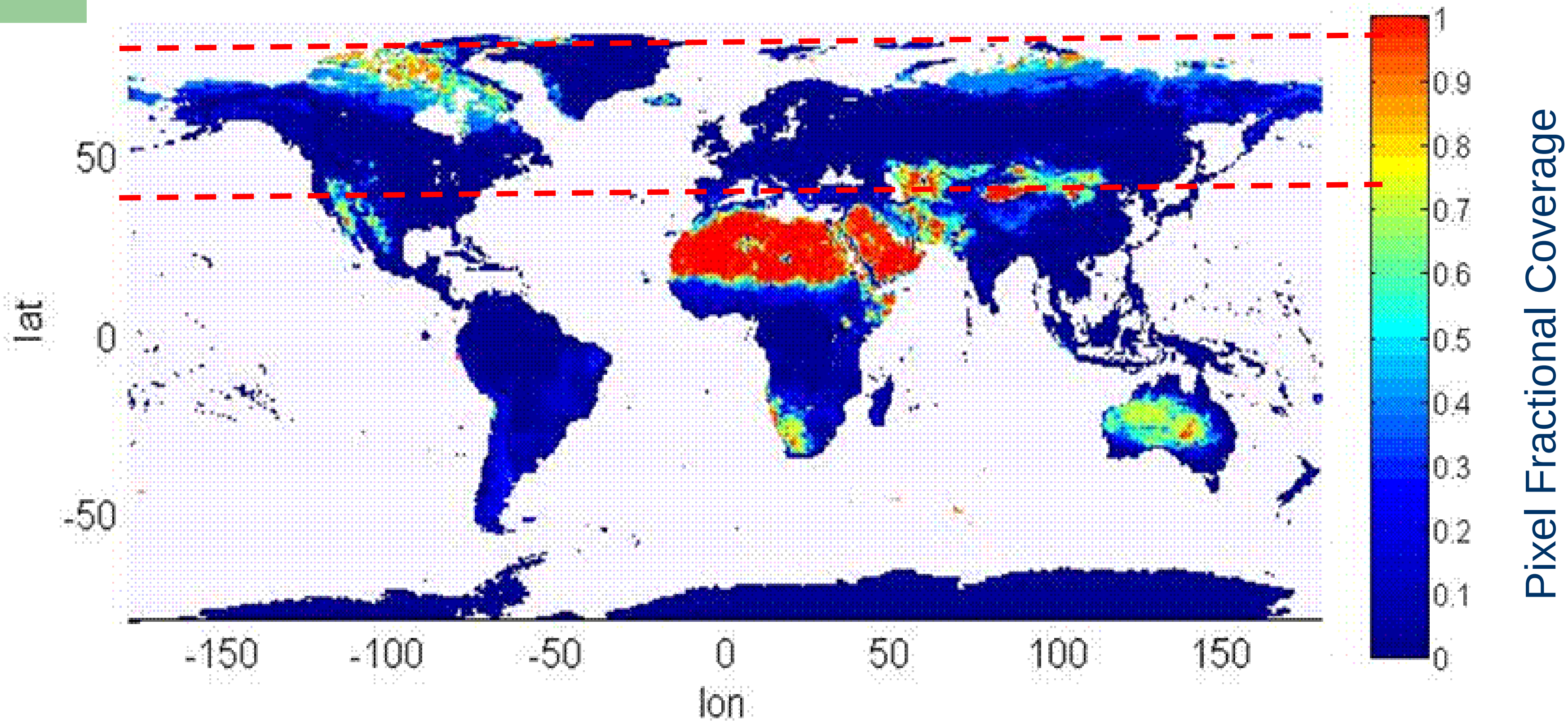
ECOCLIMAP:

- 215 ecosystems representing areas of homogeneous vegetation are derived by combining existing land-cover maps and climate maps, in addition to using the AVHRR satellite data.
- 11 land cover types: bare soil, rocks, permanent snow and ice, C3 crops, C4 crops, irrigated crops, natural herbaceous, wetland herbaceous or irrigated grass, needle leaf trees, evergreen broadleaf trees, deciduous broadleaf trees.
- the data sets provide the percentage of each class at pixel level.
- Resolution 1 Km

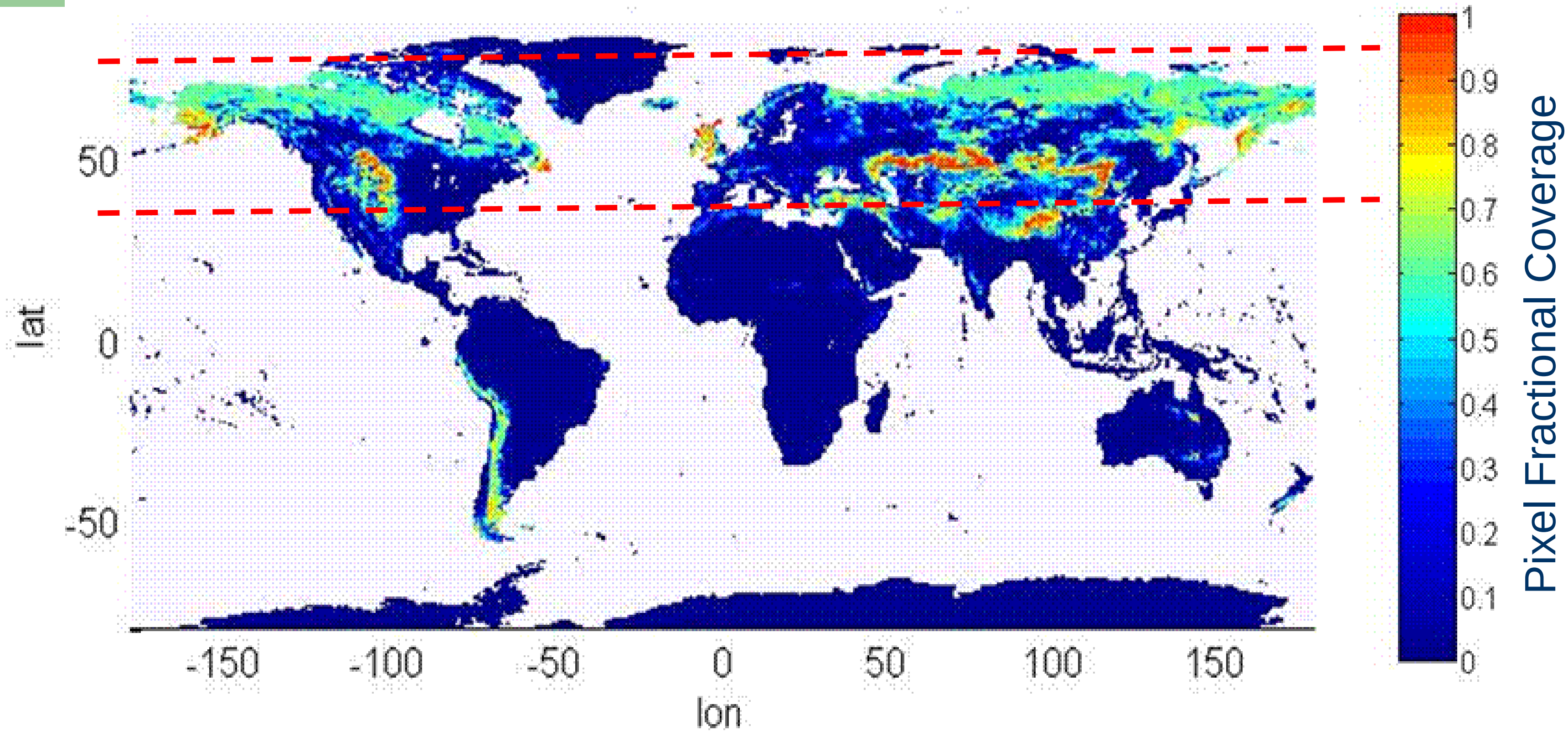
No vegetated: Permanent Snow



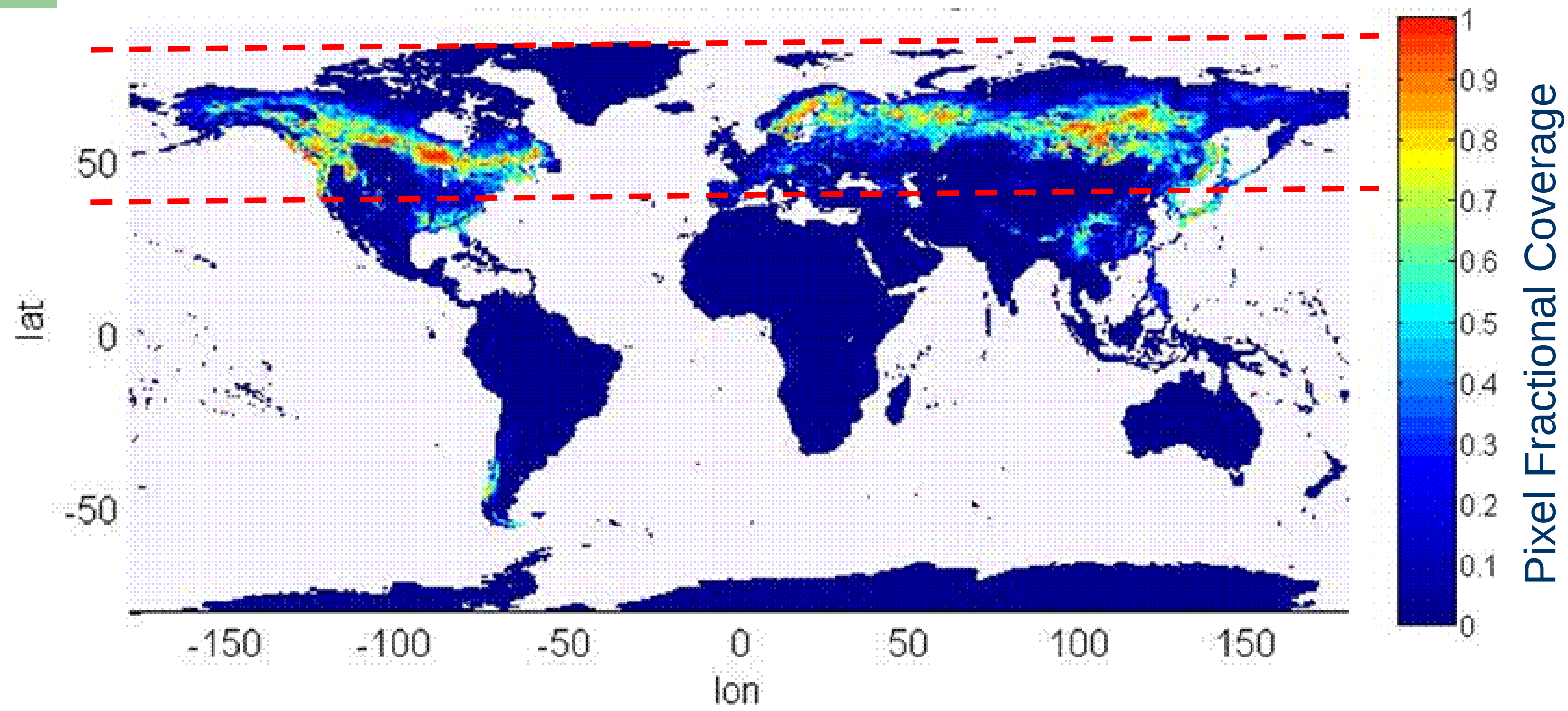
No vegetated: Bare Soil



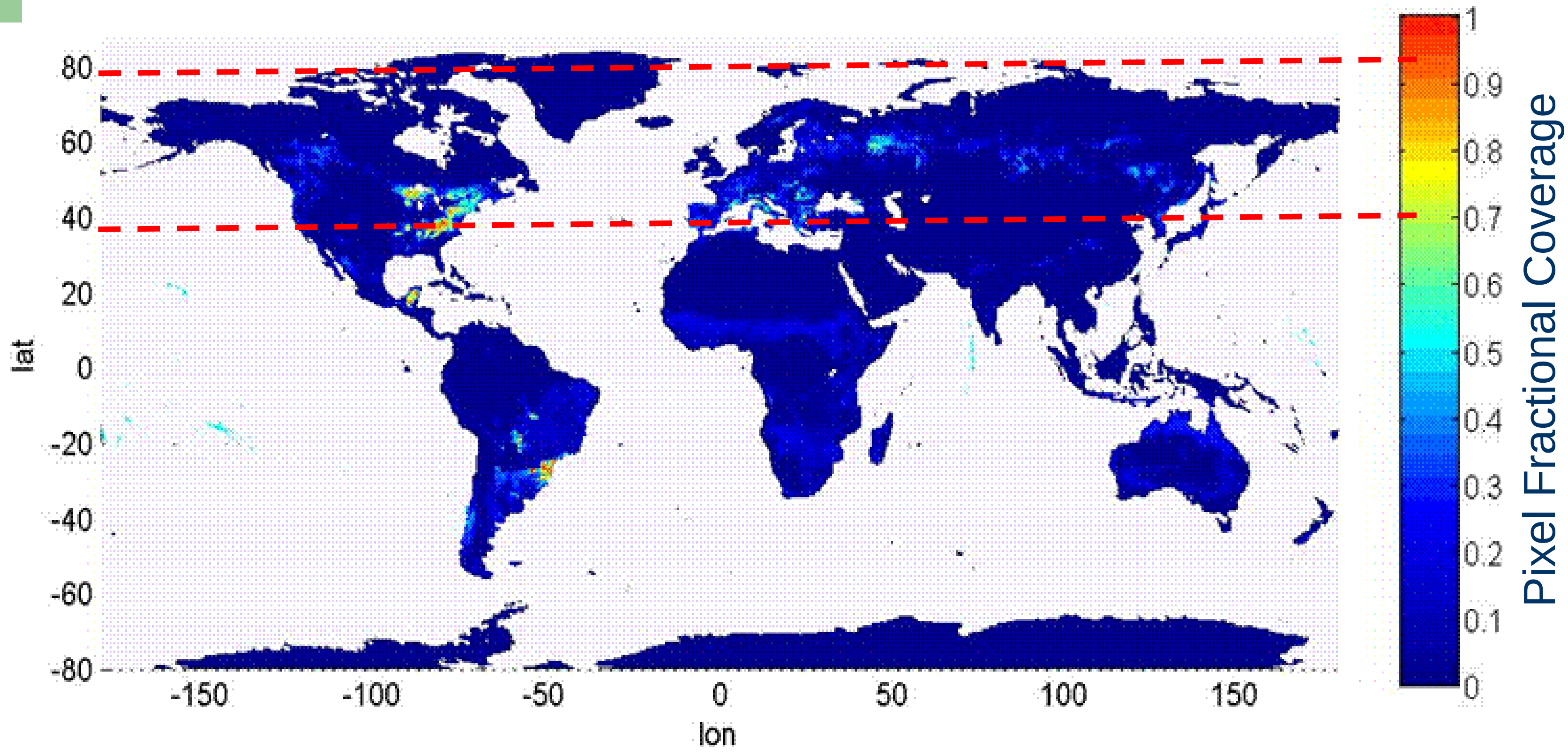
Vegetated: Herbaceous Crops



Vegetated: Coniferous Forests



Vegetated: Deciduous Forests



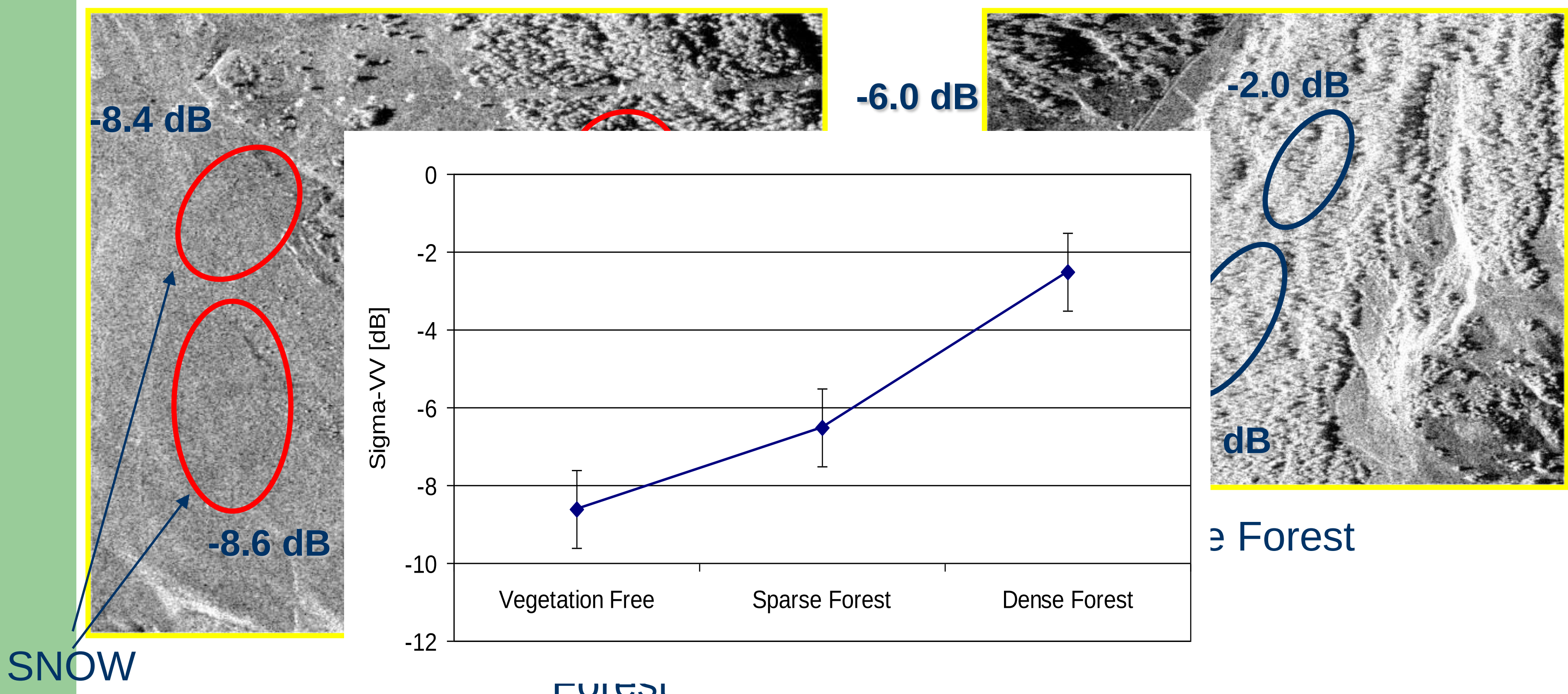
Summary between 40 and 88 ° of latitude

Surface Type	Percentage of Coverage
Herbaceous Vegetation	33.7
Coniferous Trees	22.3
Bare Soil and Rock	16.5
Permanent Snow	11
Agricultural Crops	10.5
Deciduous Trees	4.2
Others	1.8

No Problem for 40 % of the area

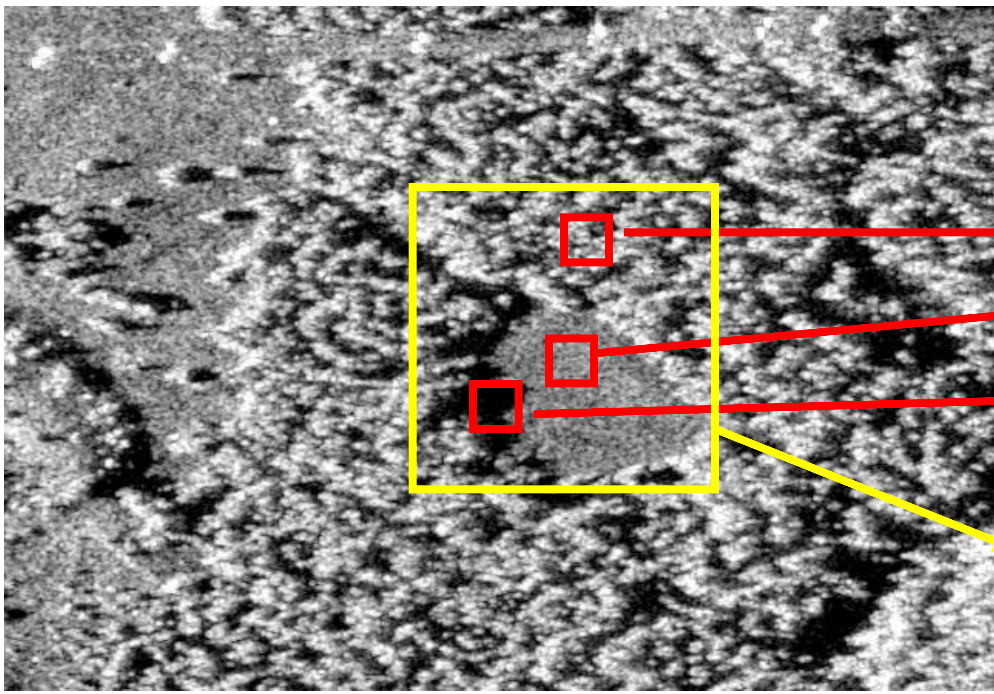
Open question for > 50%

Forest Effect on Snow Backscattering Signal



X band – SAR - Data - VV polarization – High resolution

Consideration on ground resolution



Very High Resolution : Homogenous area

$\sigma_v^o = vegetation$

$\sigma_{ground}^o = ground$

$\sigma_{ground\_s}^o = shadow area$

Mid Resolution (COREH2O): Sum of different contribution weighted by the Cover Fraction

$$\sigma_{tot}^o = \sigma_v^o CF + (1 - CF)(\sigma_{\text{int}}^o + CS\sigma_{ground}^o + (1 - CS)\sigma_{ground\_s}^o)$$

Simulation of Sigma0 of vegetated snow terrain

Motivation :

Only few backscattering data of vegetated snow covered area are available at X and Ku band (Improvements are expected from last winter experiments both in US and Europe)

The variability of vegetation at global scale could be very high → how many experiments we need to represents the globe?

Benefits of model analysis:

A model analysis could separate the different mechanisms that determine the signature of a complex media (e.g. effect of ground, volume scattering,etc.) and in interpreting SAR data

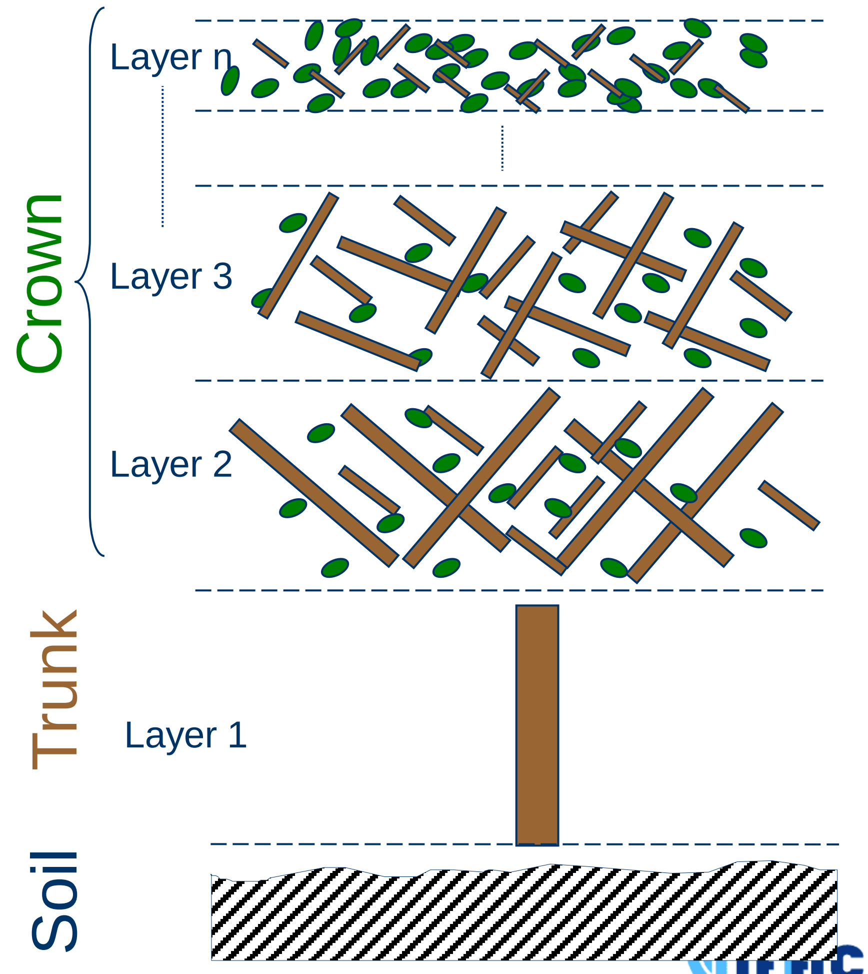
A model could link the complexity of a real vegetation structure to the inputs of the model

The model could help in individuating a strategy for the mitigation of vegetation on SWE retrieval

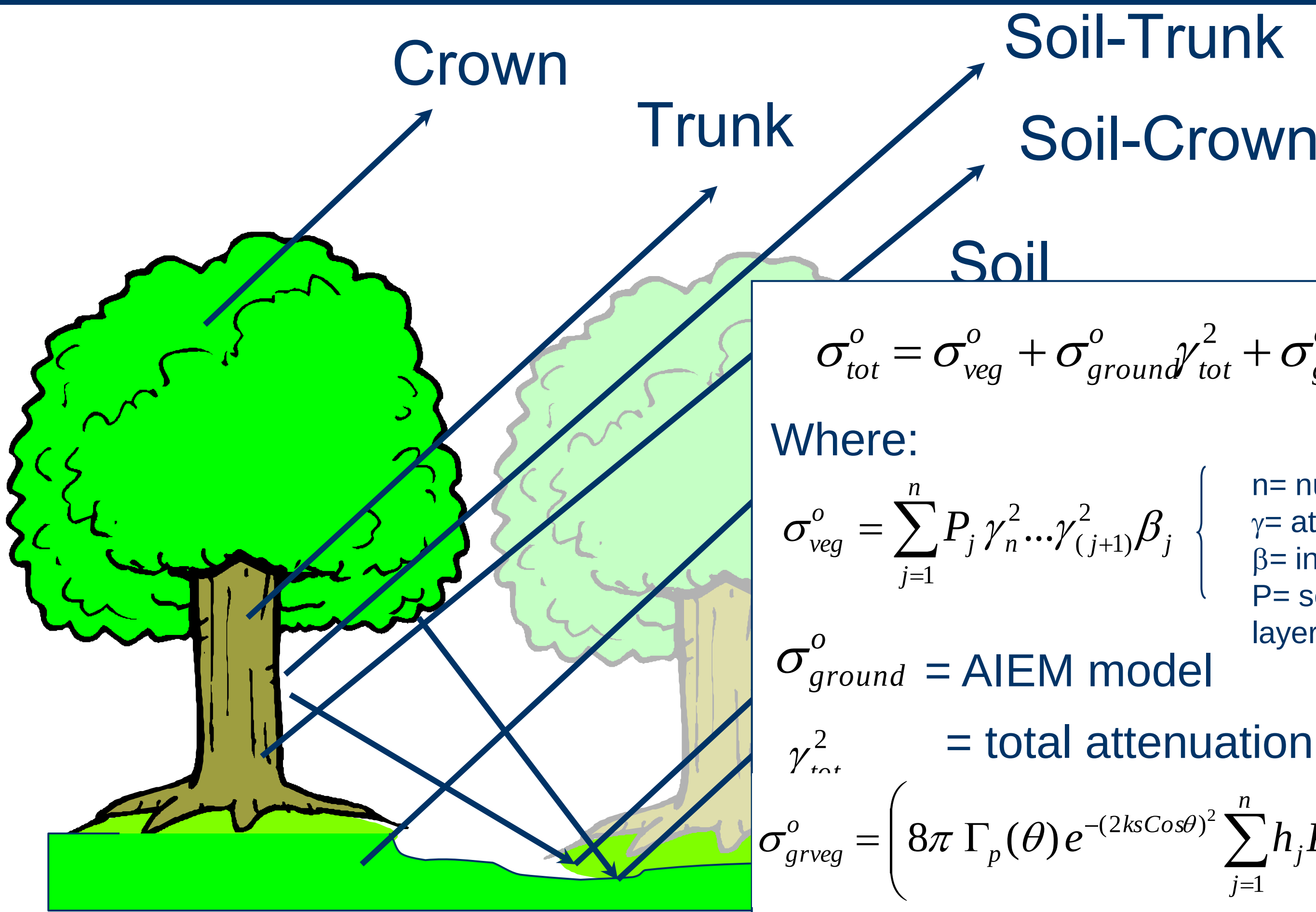
Simulation of Sigma0: Discrete model

- Forest is represented as a multi-layered medium over a rough interface (soil) + snow.

- According to forest characteristics, each layer is constituted by an ensemble of cylinders (trunk or branches) and disks or needless (leaves).



Combination of scattering components



$$\sigma^o_{tot} = \sigma^o_{veg} + \sigma^o_{ground}\gamma^2_{tot} + \sigma^o_{grveg}$$

Where:

$$\sigma^o_{veg} = \sum_{j=1}^{n} P_j \gamma^2_n \ldots \gamma^2_{(j+1)} \beta_j$$

n= number of layers
γ= attenuation of j layer
β= inetraction of j layer
P= scattering matrix of j layer

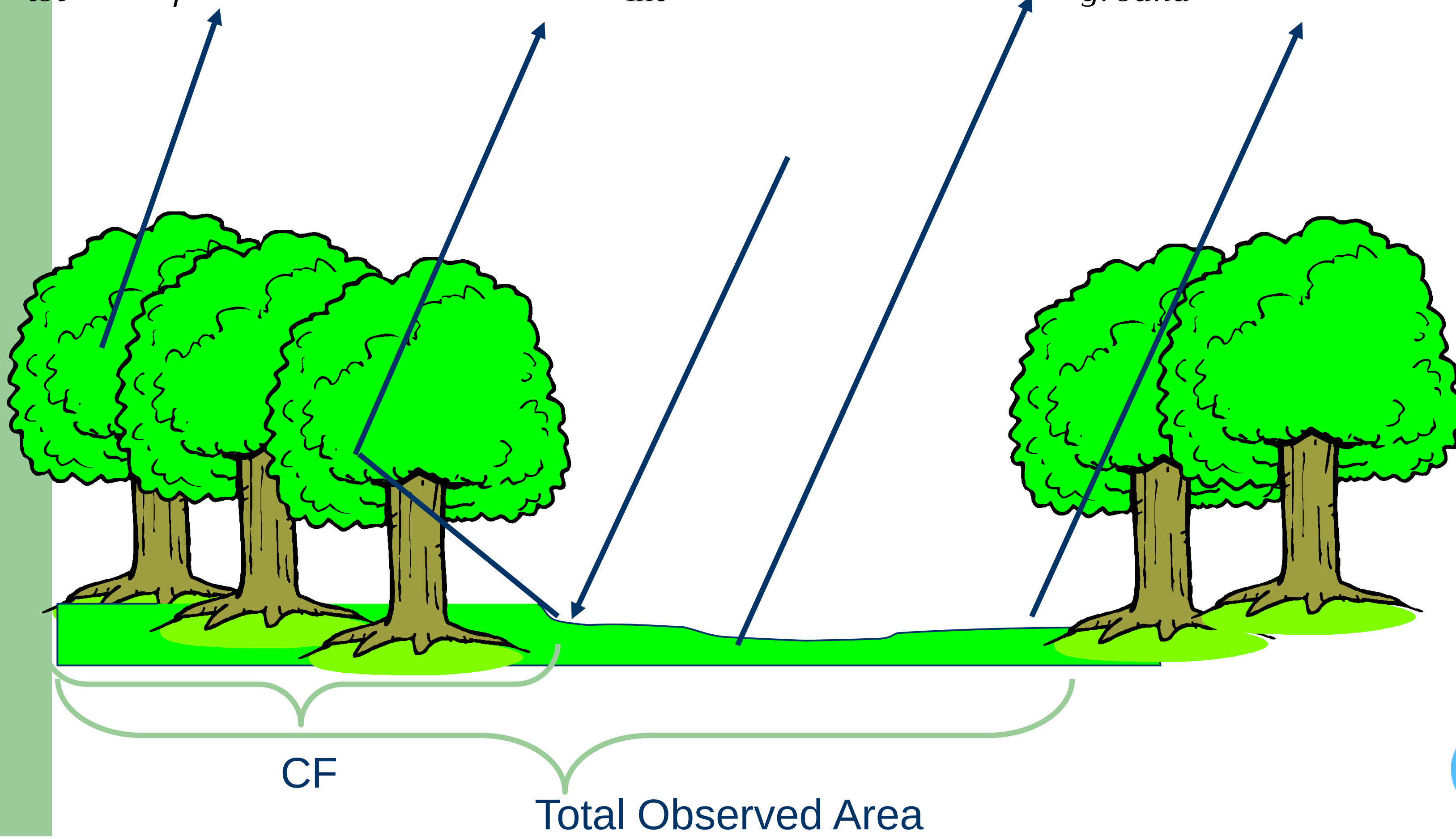
σ^o_{ground} = AIEM model

γ^2_{tot} = total attenuation

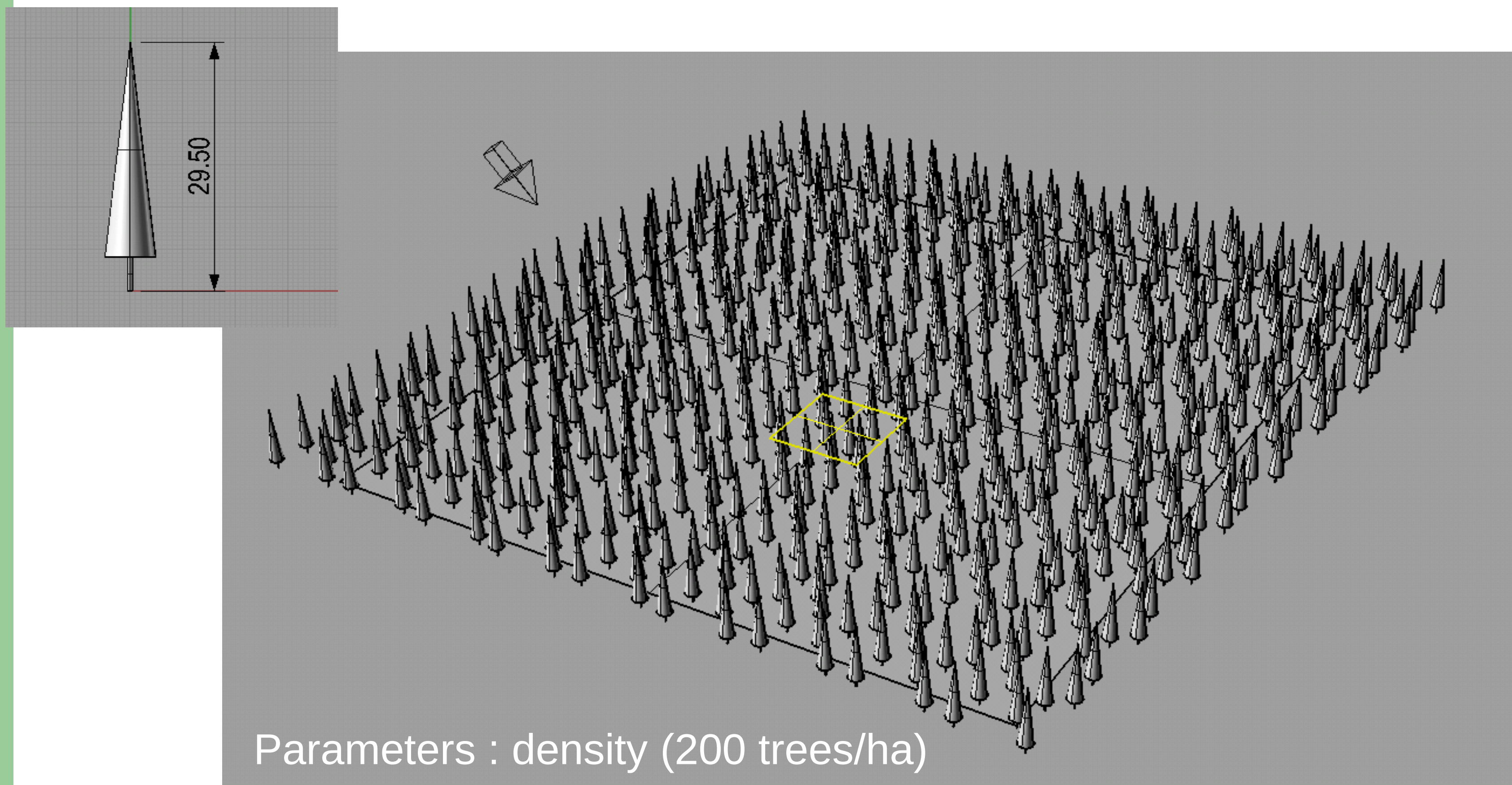
$$\sigma^o_{grveg} = \left(8\pi\, \Gamma_p(\theta)\, e^{-(2ksCos\theta)^2} \sum_{j=1}^{n} h_j P_j \right) \gamma^2_{tot}$$

Cover Fraction and Shadow effect

$$\sigma^o_{tot} = \sigma^o_f\, CF + (1-CF)\sigma^o_{\text{int}} + (1-CF)(Cs\,\sigma^o_{ground} + (1-Cs)\sigma^o_{ground\_s})$$

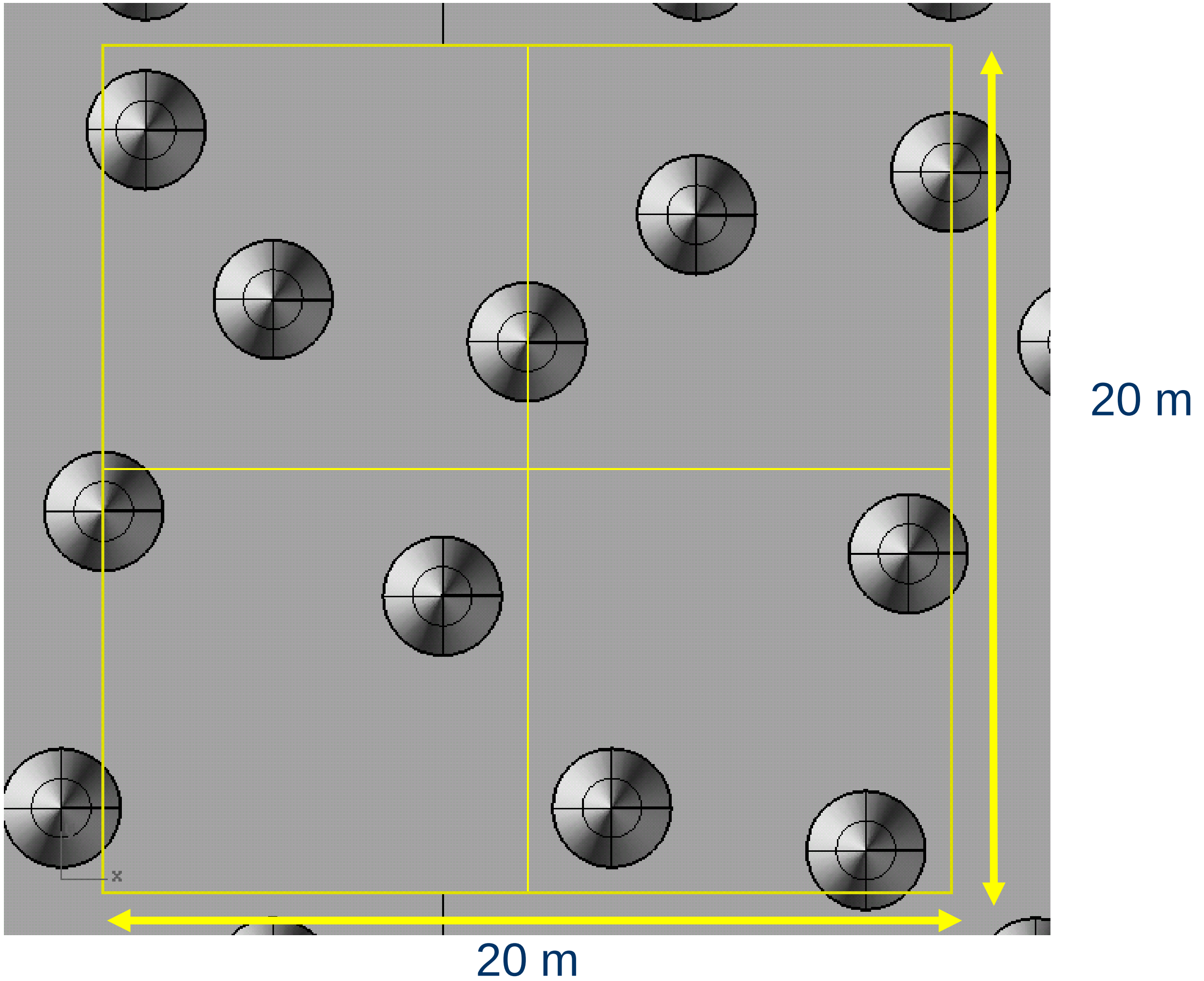


Computation of Cover Fraction and Shadow Area

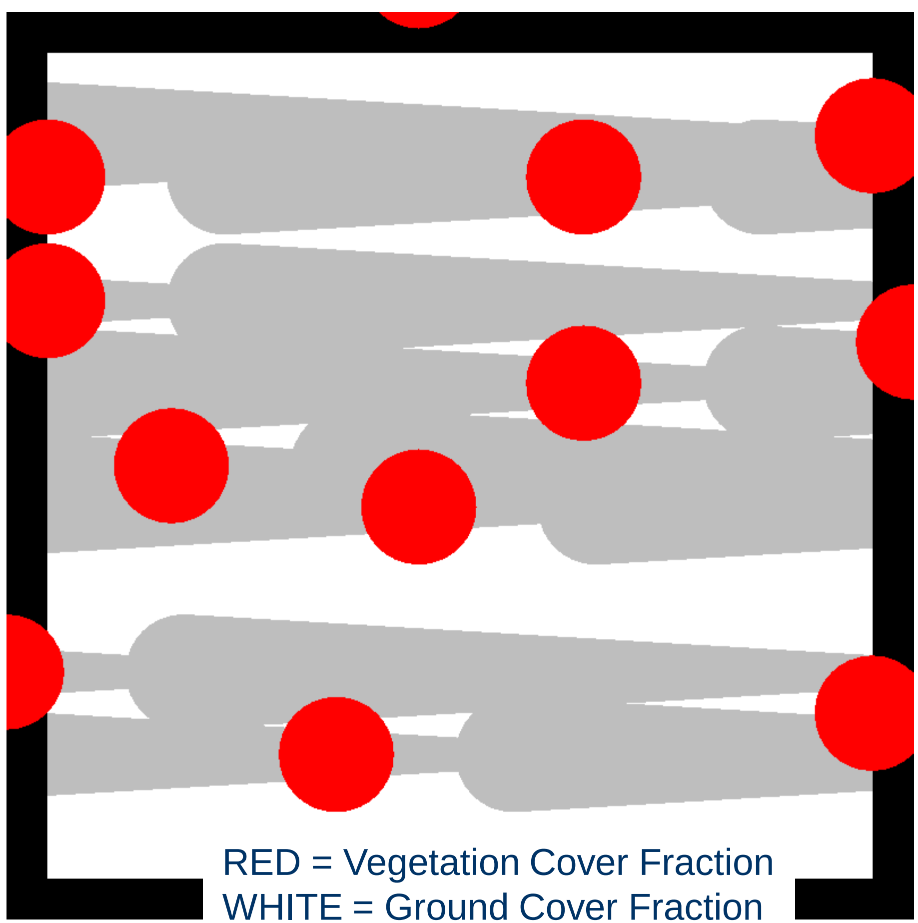


Generation of the 3D - forest

Random selection of n - samples



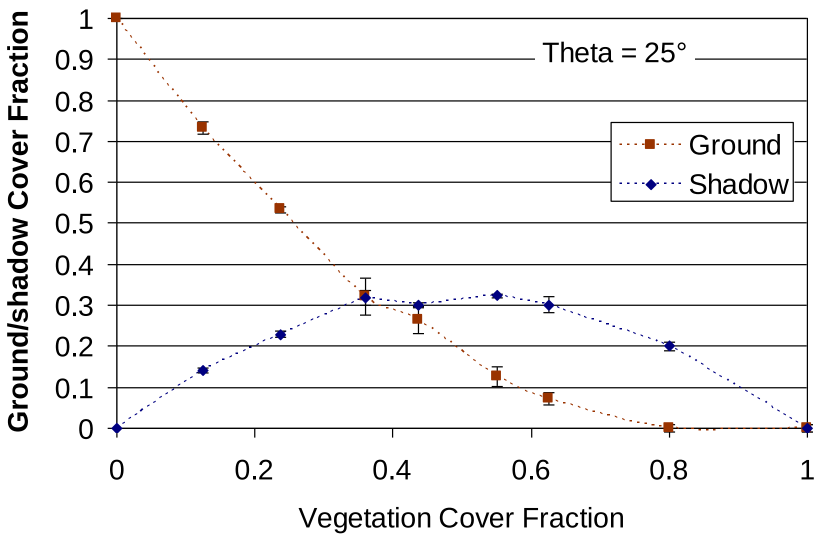
Shadow computation

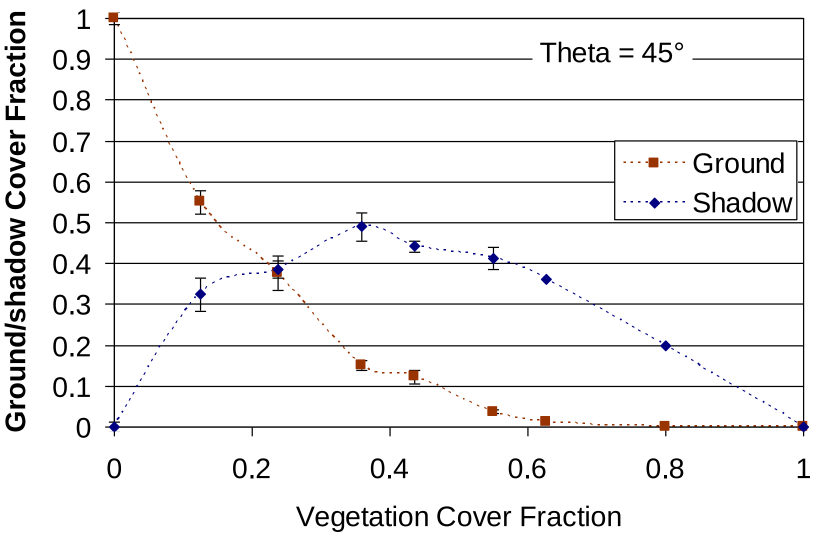


Theta = 65°

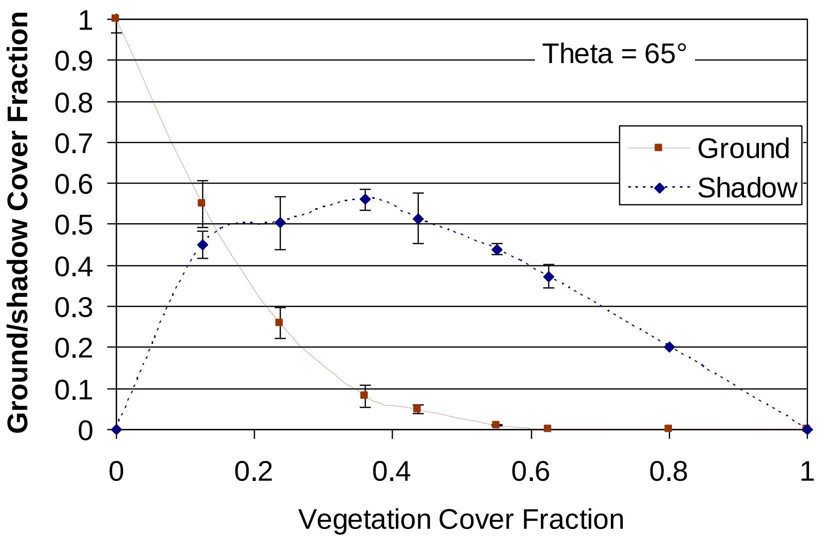
RED = Vegetation Cover Fraction
WHITE = Ground Cover Fraction
GRAY = Shadow Cover Fraction

Shadow / Ground vs cover fraction





Small tree



Model Sensitivity: Sparse Vegetation

- Sparse vegetation was represented as a homogenous layer of almost vertical small cylinders (*Ledum groenlandicum)*

- The vegetation was considered as in the winter dormant and frozen state; dielectric constant was derived from litterature

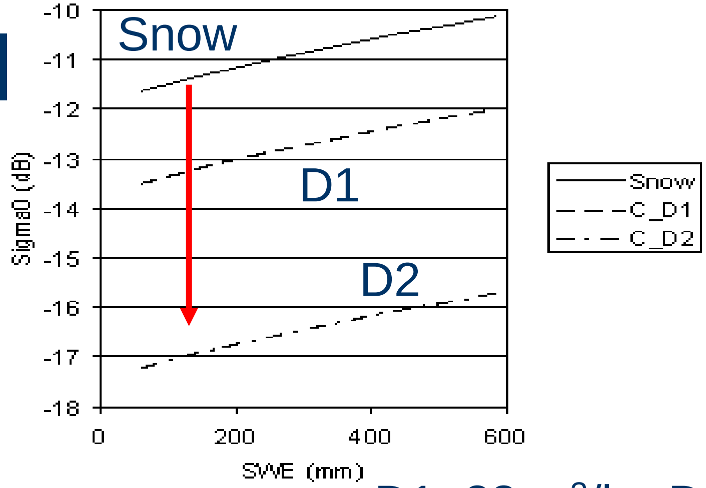
Cylinder radius (m)	0.0015
Cylinder semi- lenght (m)	0.2
Dielectric constant	(4.6,-1.4)
Cylinder density (n/m3)	1000 - 3000
betamin (degrees)	0
betamax (degrees)	60
betamean (degrees)	30
beta0 (degrees)	0
Power	1

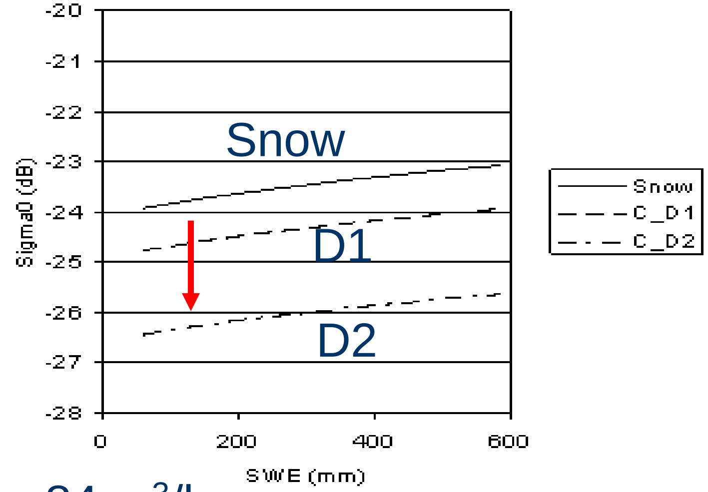
Sensitivity to vegetation density

VV

HV

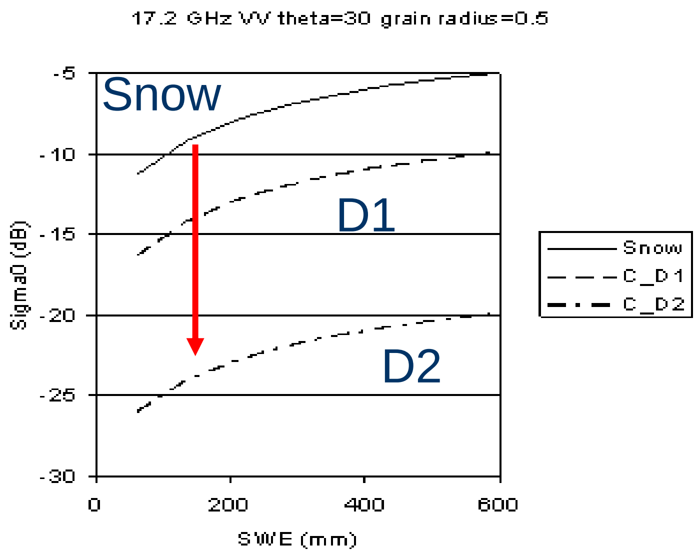
9.6 GHz

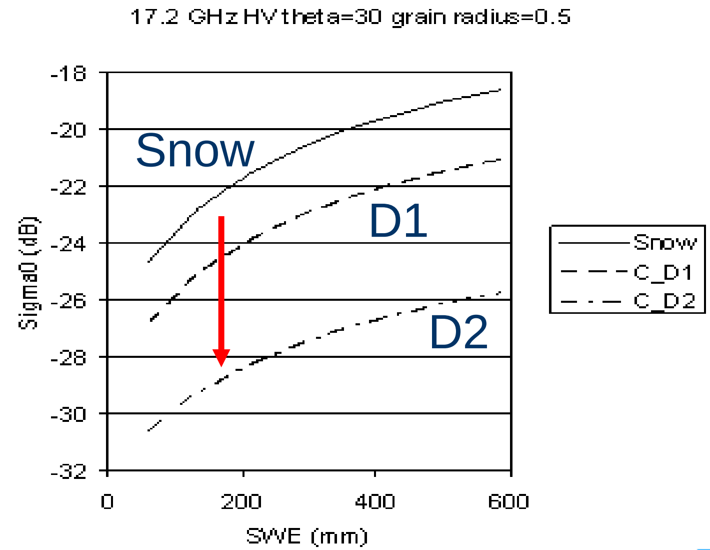




D1=28 m^3/ha D2 = 84 m^3/ha

17.2 GHz

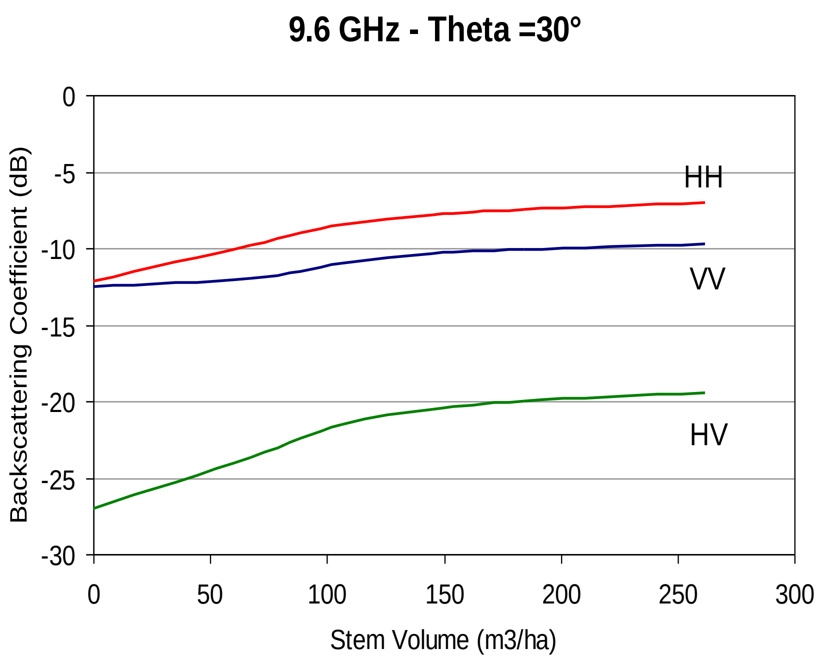


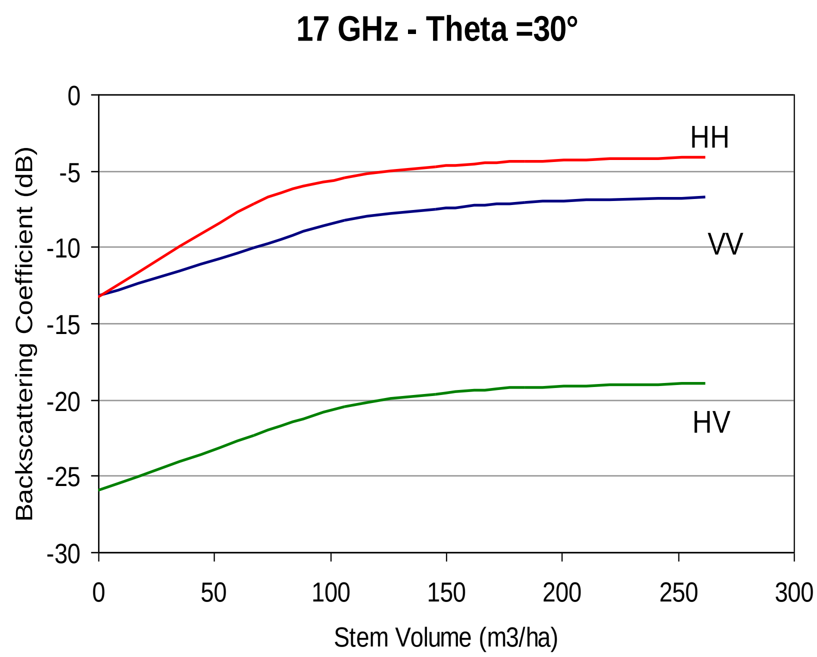


Model Sensitivity: Coniferous Forest

- Black spruce (typical of subarctic areas)
- Vegetation data were obtained from litterature.
- Using allometric equations other examples of forest (of the same specie), in the 50 – 250 m3/ha biomass range, were realized.
- The forest was divided into three homogeneous horizontal layers which differed from the scatterers' size, orientation, and density.
  - Layer 1: needles, stems, small branches, and the top part of the trunk.
  - Layer 2: needles, stems, middle and long branches, and the major part of the trunk.
  - Layer 3: bottom part of the trunk and understory, mainly *Ledum groenlandicum*, above the underlying soil.

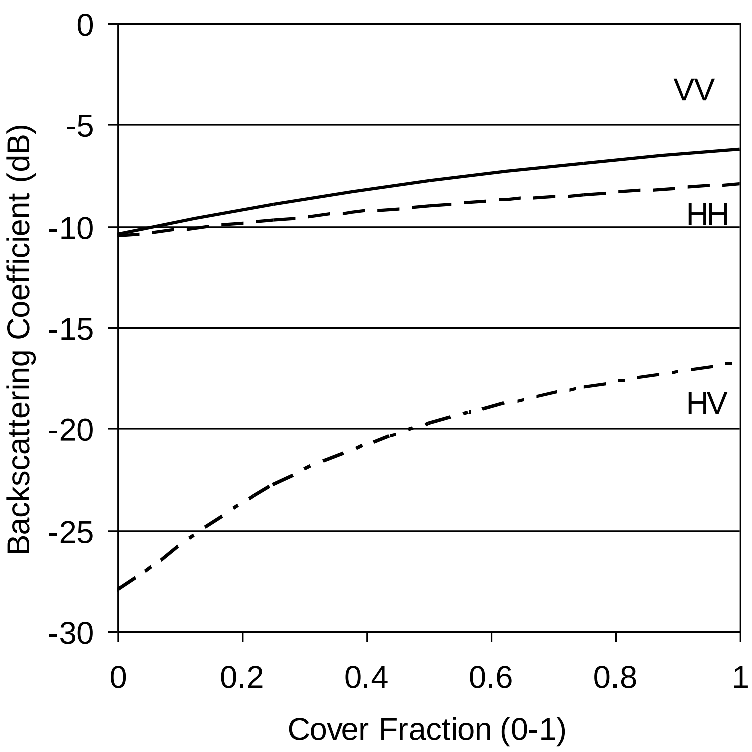
Sensitivity to Stem Volume (snow free)



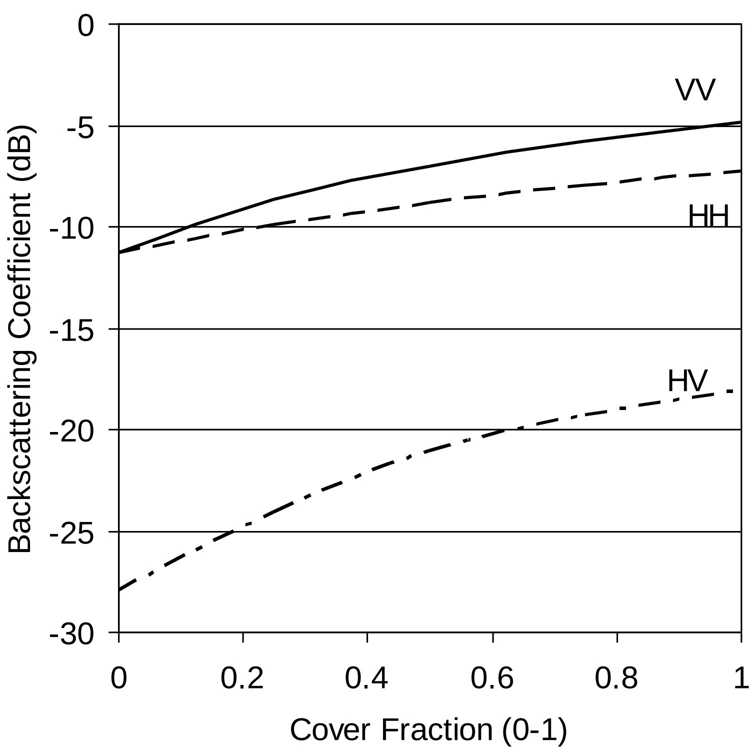


Sensitivity to Cover Fraction (snow free)

9.6 GHz



17 GHz

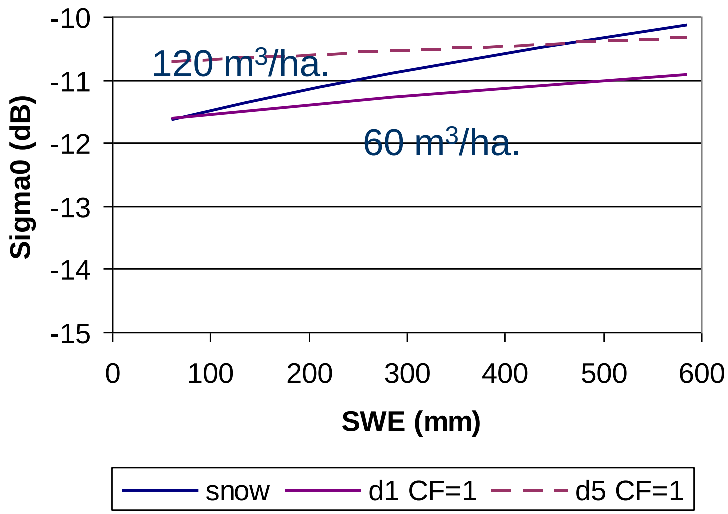


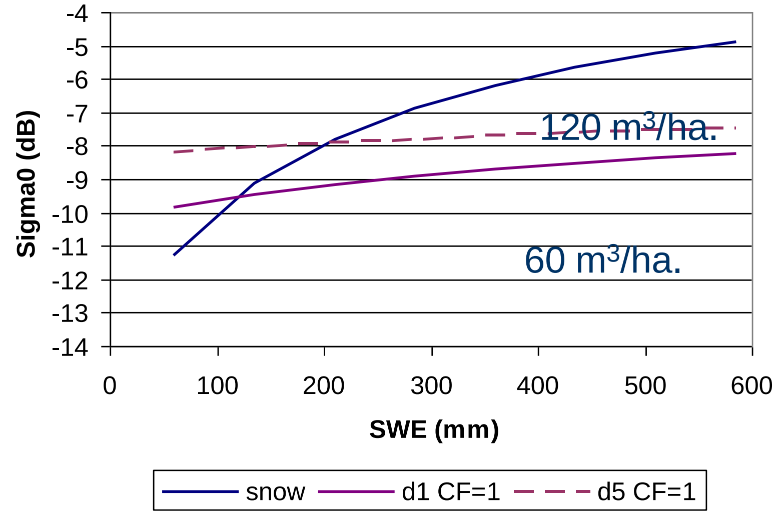
Senstivity to SWE & Woody volume

9.6 GHZ

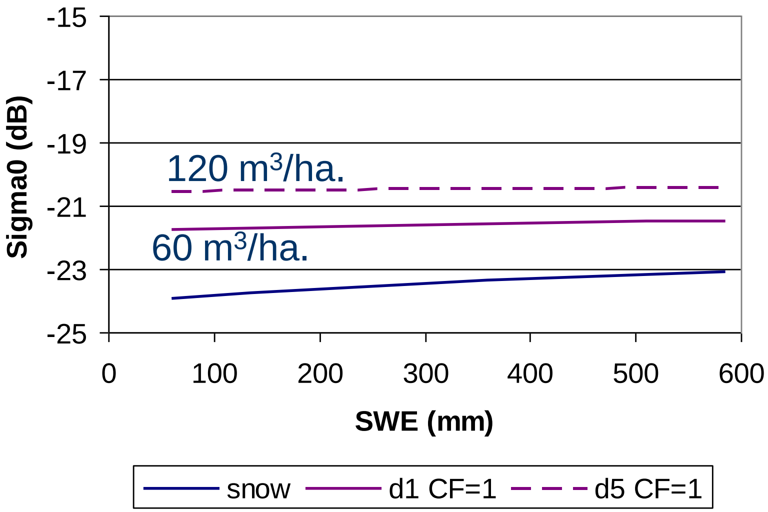
17.2 GHz

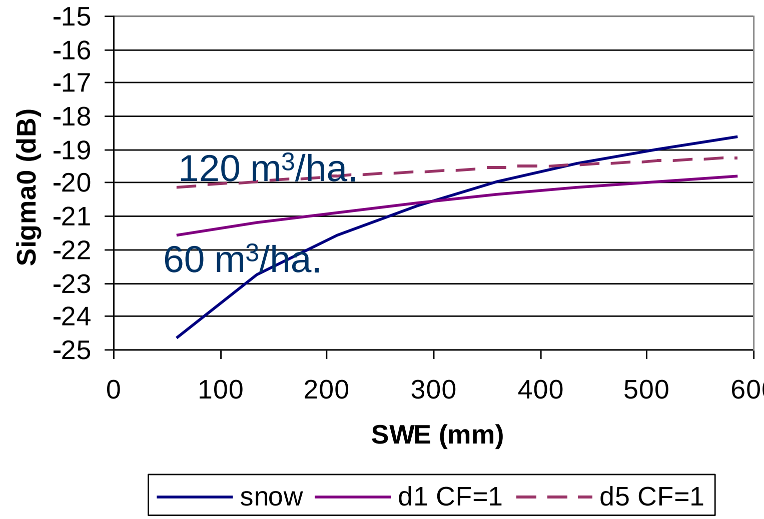
VV





HV

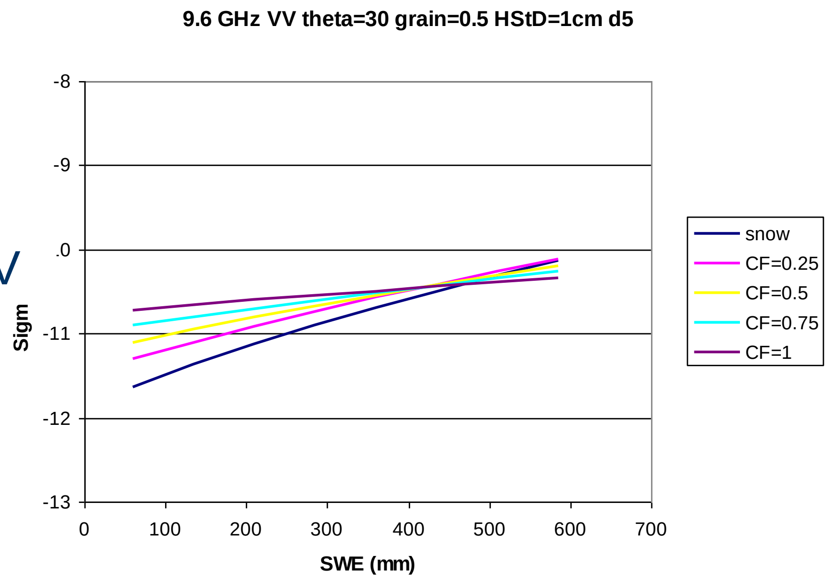


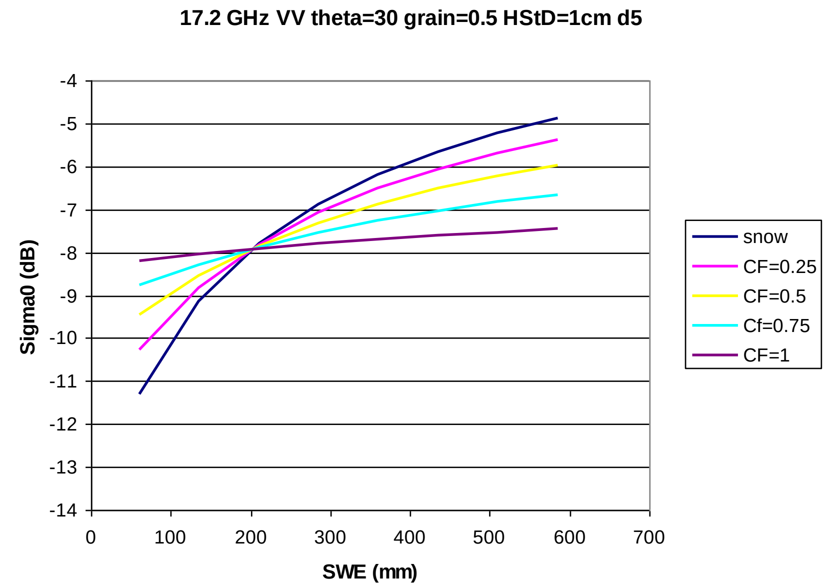


9.6 GHz

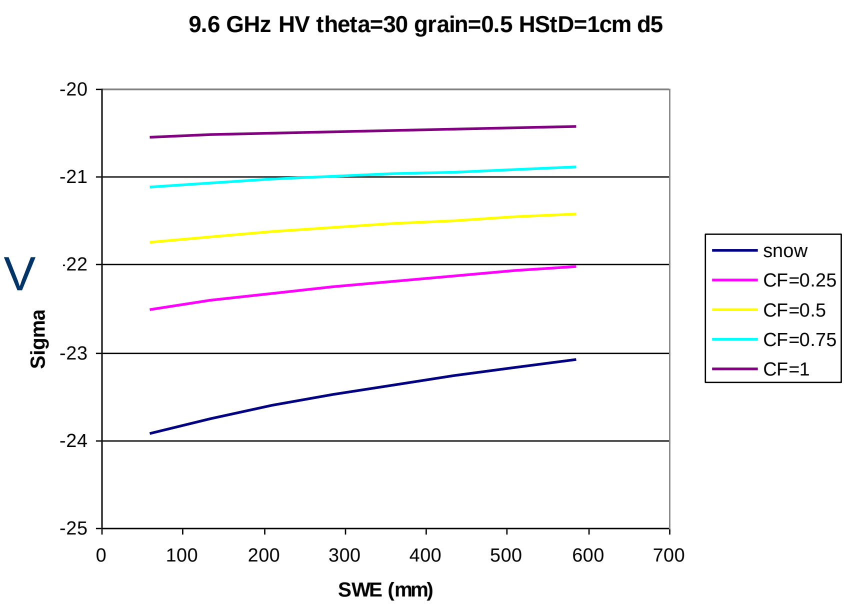
17.2 GHz

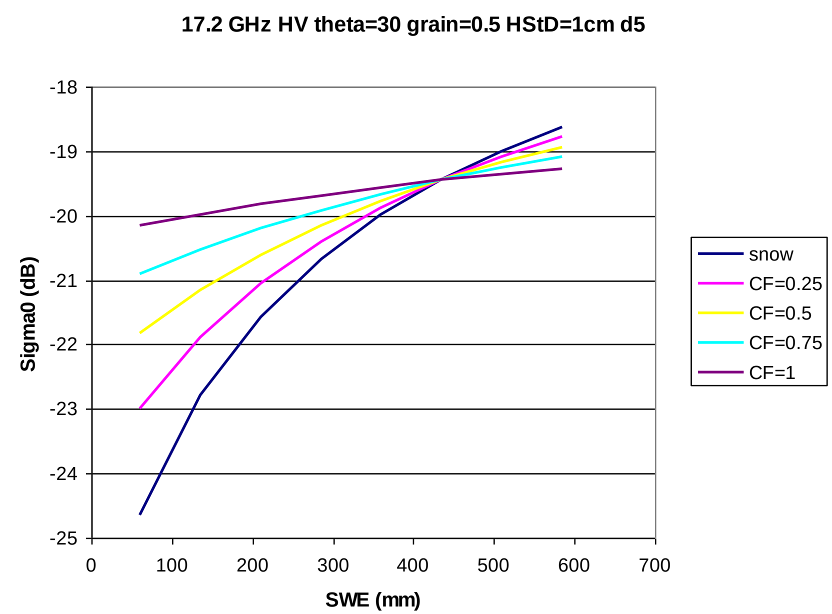
VV





HV





σ^0 sensitivity – Forest example

CF = 0.5

	SNOW		60 m^3/ha.		110 m^3/ha.		220 m^3/ha.	
dB/500 mm	VV	VH	VV	VH	VV	VH	VV	VH
9.6 GHz	1.5	1	1.1	0.4	0.8	0.3	<0.1	<0.1
17.2 GHz	6.4	6	4.2	3.6	3.5	2.8	<0.1	<0.1

CF = 1

	SNOW		60 m^3/ha.		110 m^3/ha.		220 m^3/ha.	
dB/500 mm	VV	VH	VV	VH	VV	VH	VV	VH
9.6 GHz	1.5	1	0.7	0.3	0.4	0.1	<0.1	<0.1
17.2 GHz	6.4	6	1.6	2.8	0.7	0.8	<0.1	<0.1

Theta = 30° Grain size = 0.5 mm – HSTD =1 cm

Summary of Model Sensitivity

- **Sparse vegetation** attenuated σ^0 of snow at both CoReH2O frequencies and polarizations:
  - The attenuation increased with density and frequency, is higher at VV than HV polarization (vertical cylinders)
  - **The sensitivity to SWE was not affected by sparse vegetation.**
- **Forest vegetation** strongly influences σ^0 of snow covered terrain: the effect depend on snow and vegetation properties and/or frequency and polarization:
  - For relative low woody volume value (<= 110 m^3/ha) σ^0 was influenced by the snow and soil properties (grains size, SWE, soil roughness, etc.). Grains size had the strongest impact on σ^0 signature.
  - Cover fraction (CF) influenced the σ^0 signature: at low woody volume value, the sensitivity to SWE was strongly reduced if CF was higher than 0.5.
  - Furthermore, when the when woody volume was higher than 200 m^3/ha, and CF was higher than 0.25, the sensitivity to snow properties disappeared at all frequencies and polarizations.

Strategy for COREH2O objectives

- An a-priori knowledge of vegetation parameters (type, density, CF) is fundamental in order to implement a SWE retrieval algorithm at global scale

- **Short Vegetation:**
  - Multi-temporal observation of vegetated areas, starting from a snow-free condition, can provide an initial σ^0 value that can be used for the retrieval of snow properties.

- **Forest:**
  - High cover fraction/high density → **Flag !!! ..not feasible**
  - Low density/low cover fraction:
  1. pixel degradation (1km), to take into account of vegetation variability
  2. pixel classification (from global data set) and estimation of vegetation effect (from parametrized forward model)
  3. Iterative procedure to refine the first estimation (from the comparison of the nearest no vegetated area if exist) in snow free condition
  4. SWE estimation (multitemporal evolution and comparison with no-vegetated area,)

Thank you for your attention !!!

Need of measurements and also…… destructive sampling!