Above Ground Biomass Estimation Using L-band SAR Measurements at different polarizations for DESDynI Mission

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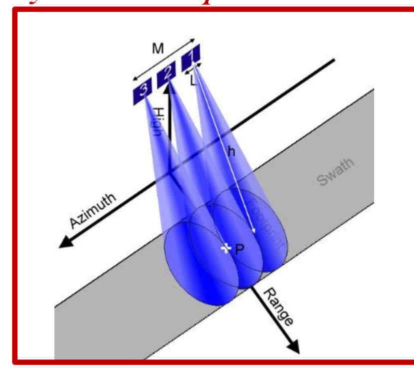
Overview of DESDynI Mission

DESDynI (Deformation, Ecosystem Structure, and Dynamics of Ice) mission is an Earth satellite mission with the aim to study land surface and climate changes.

Synthetic Aperture Radar



Instruments

- L-band Synthetic Aperture Radar (SAR) with multiple polarizations able to operate as an interferometric SAR
- Multi-beam Light Detection and Ranging (Lidar)

Objectives

1. Determine the likelihood of earthquakes, volcanic eruptions, and landslides
2. Predict the response of ice masses to climate change and impact on sea level
3. Ecosystem objectives
   - Characterize global distribution of aboveground vegetation biomass
   - Quantify changes in terrestrial sources and sinks of carbon
   - Characterize habitat structure for biodiversity assessments

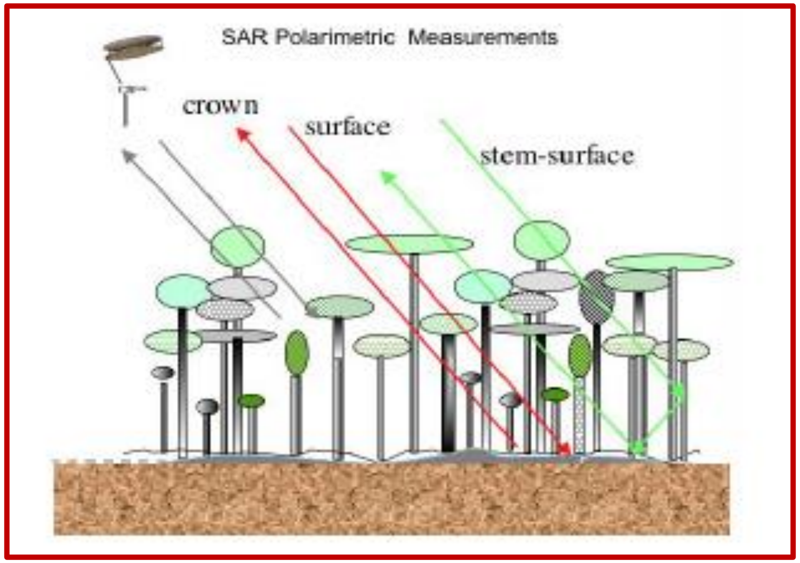
To achieve these goals, biomass and vegetation structure estimates will be used

[Donnellan, A.; Rosen, P.; Ranson, J.; Zebker, H., "Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI)," *Geoscience and Remote Sensing Symposium, 2008. IGARSS 2008. IEEE International*, vol.3, no., pp.III - 5, III - 8, 7-11 July 2008]

Objective and Methods

Implementation of a code able to estimate the **Above Ground Biomass (AGB)** from the backscattering coefficients (σ°) obtained by biomass scattering mechanism of the transmitted radiation. Such radiation is related to an L-band SAR at different polarizations, HH, HV and VV (H-Horizontal; V-Vertical) in order to respect the DESDynI mission requirements.

Scattering from Biomass



The work has been carried out as follow:

1) Implementation of the forward model and study of the results

1.1) Test for the surface scattering model: Oh Model [Oh et all, 1992] (results not shown in this presentation)

2) Inversion of the forward model using the Levenberg-Marquardt algorithm

Forward Model (FM)

The complex behavior of the scattering from biomass is semplified considering three different components:

- Volume scattering
- Double-bounce scattering;
- Surface scattering

Such components determine the radar backscattering coefficients for the three polarizations HH, HV and VV:

$$\sigma_{HH}^{0} = A_{HH} W^{\alpha_{HH}} \cos\theta \left(1 - e^{-B_{HH} W^{\beta_{HH}}/\cos\theta}\right) + C_{HH}\Gamma_{HH} W^{\delta_{HH}} \sin\theta\, e^{-B_{HH} W^{\beta_{HH}}/\cos\theta} + S_{HH} e^{-B_{HH} W^{\beta_{HH}}/\cos\theta}$$

$$\sigma_{HV}^{0} = A_{HV} W^{\alpha_{HV}} \cos\theta \left(1 - e^{-B_{HV} W^{\beta_{HV}}/\cos\theta}\right) + C_{HV}\Gamma_{HV} W^{\delta_{HV}} \sin\theta\, e^{-B_{HV} W^{\beta_{HV}}/\cos\theta} + S_{HV} e^{-B_{HV} W^{\beta_{HV}}/\cos\theta}$$

$$\sigma_{VV}^{0} = A_{VV} W^{\alpha_{VV}} \cos\theta \left(1 - e^{-B_{VV} W^{\beta_{VV}}/\cos\theta}\right) + C_{VV}\Gamma_{VV} W^{\delta_{VV}} \sin\theta\, e^{-B_{VV} W^{\beta_{VV}}/\cos\theta} + S_{VV} e^{-B_{VV} W^{\beta_{VV}}/\cos\theta}$$

Where:

$A_{pq}\, B_{pq}\, C_{pq}$ are calibration factors

$a_{pq}\, b_{pq}\, d_{pq}$ are structural parameters

$$\Gamma_{pq} = r_g \,|R_p R_q^*|\exp(-4k^2 s^2 \cos^2\theta)$$

s is the rms of height-takes into account the roughness

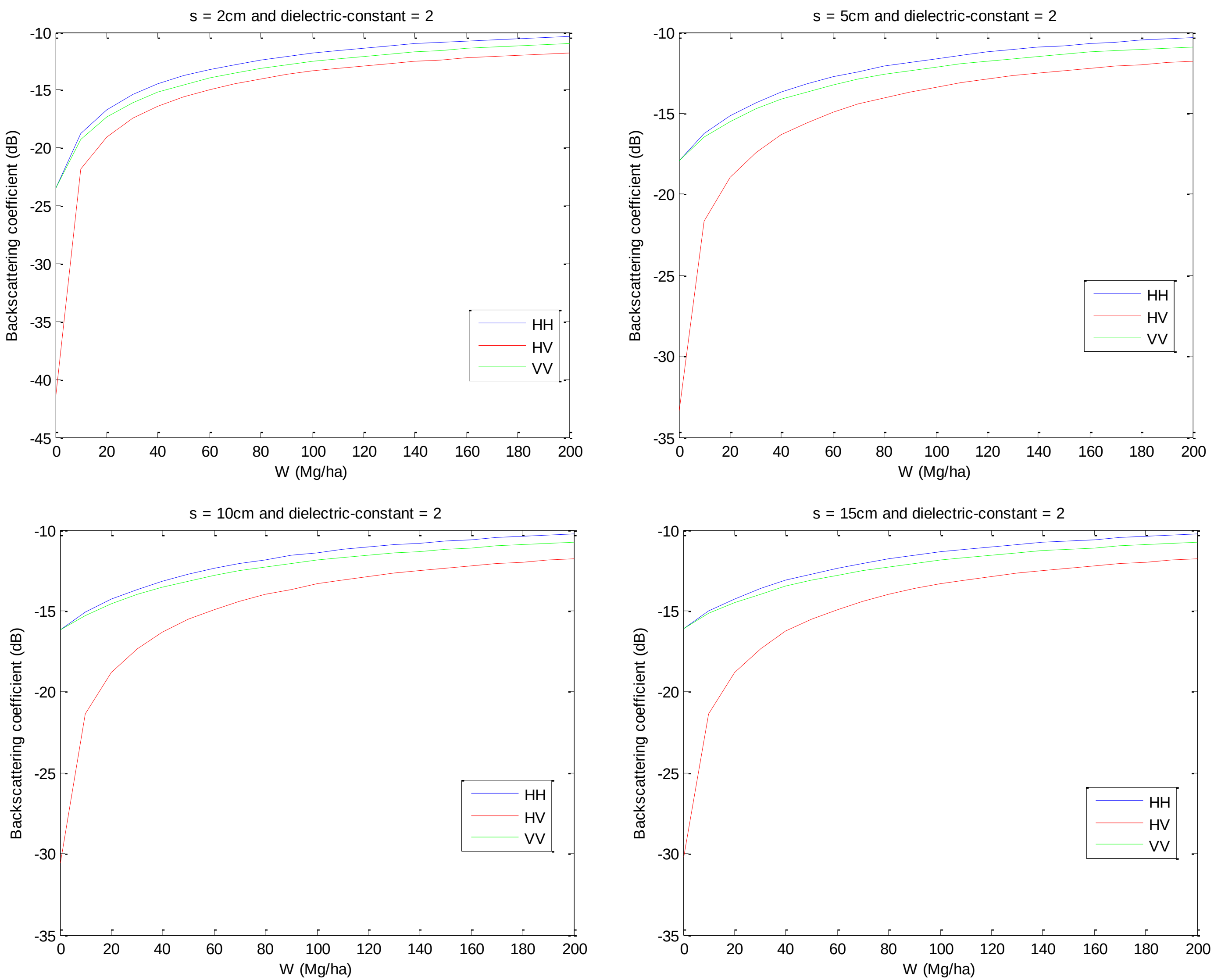
R are the Fresnel reflection coefficients of the ground

$S_{HH}\, S_{VV}\, S_{HV}$ are the backscattering coefficients of bare soil surface

Parameters: frequency = 1.25GHz
incidence angle θ = 35°

Results for the Forward Model (1/2)

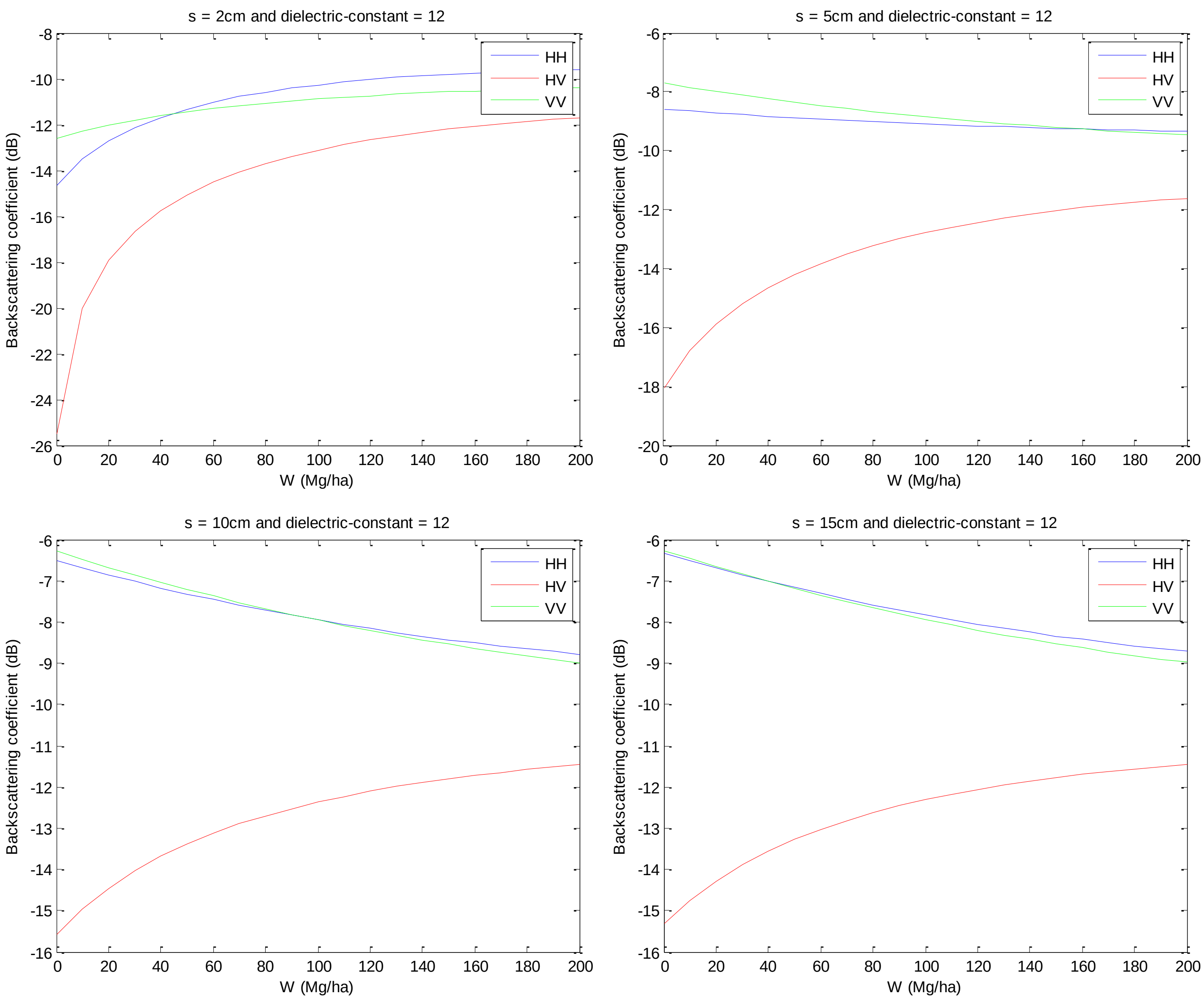
Behavior of the backscattering coefficient over the biomass (W) for dry soil and different values of roughness



Sigma naught increases when the biomass increases. For the HV polarization it has always lower values

Results for the Forward Model (2/2)

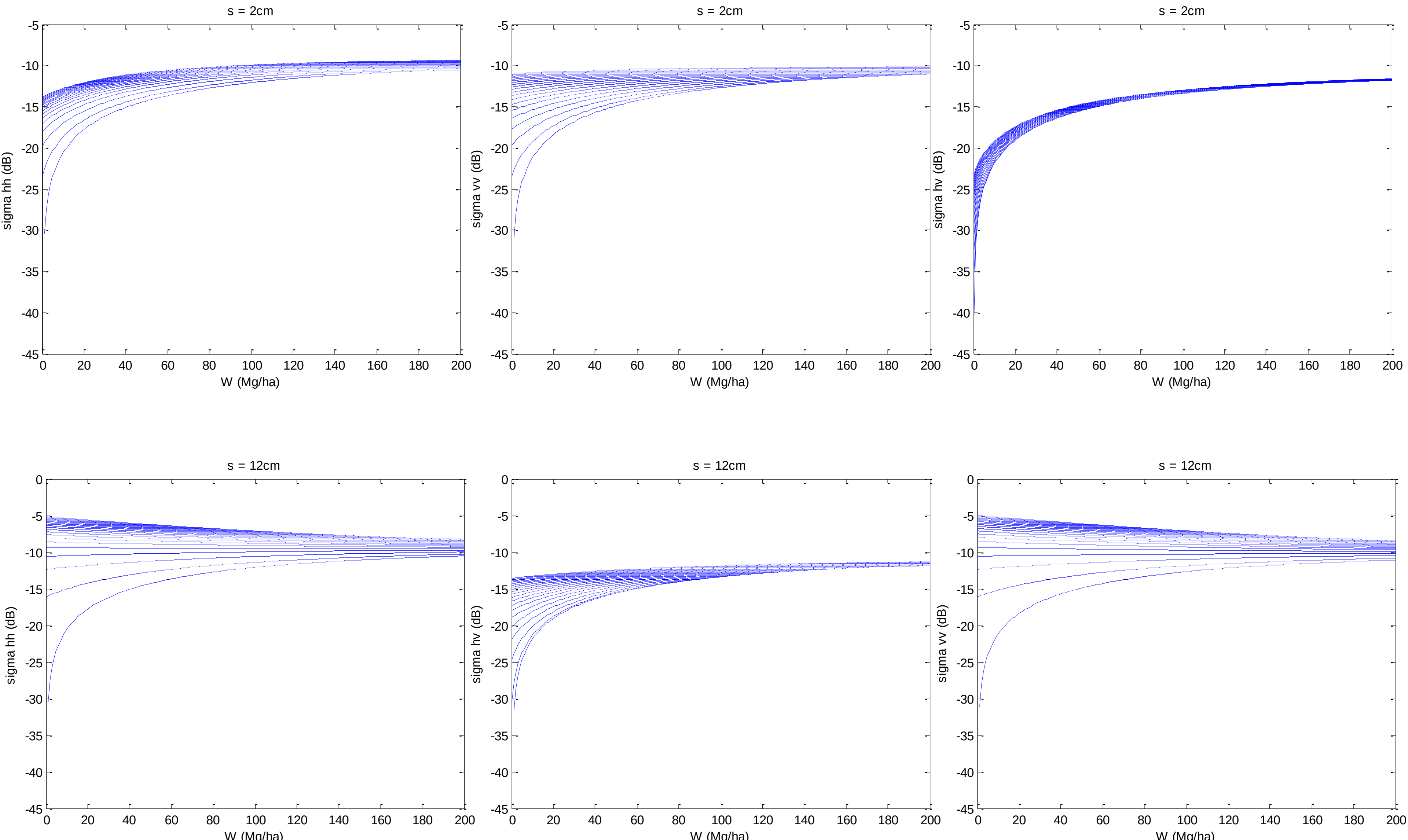
Behavior of the backscattering coefficient over the biomass for wet soil and different values of roughness



For high values of dielectric constant, the effect of the surface scattering increases, thus the sigma naught increases for low values of biomass especially for rough surface.

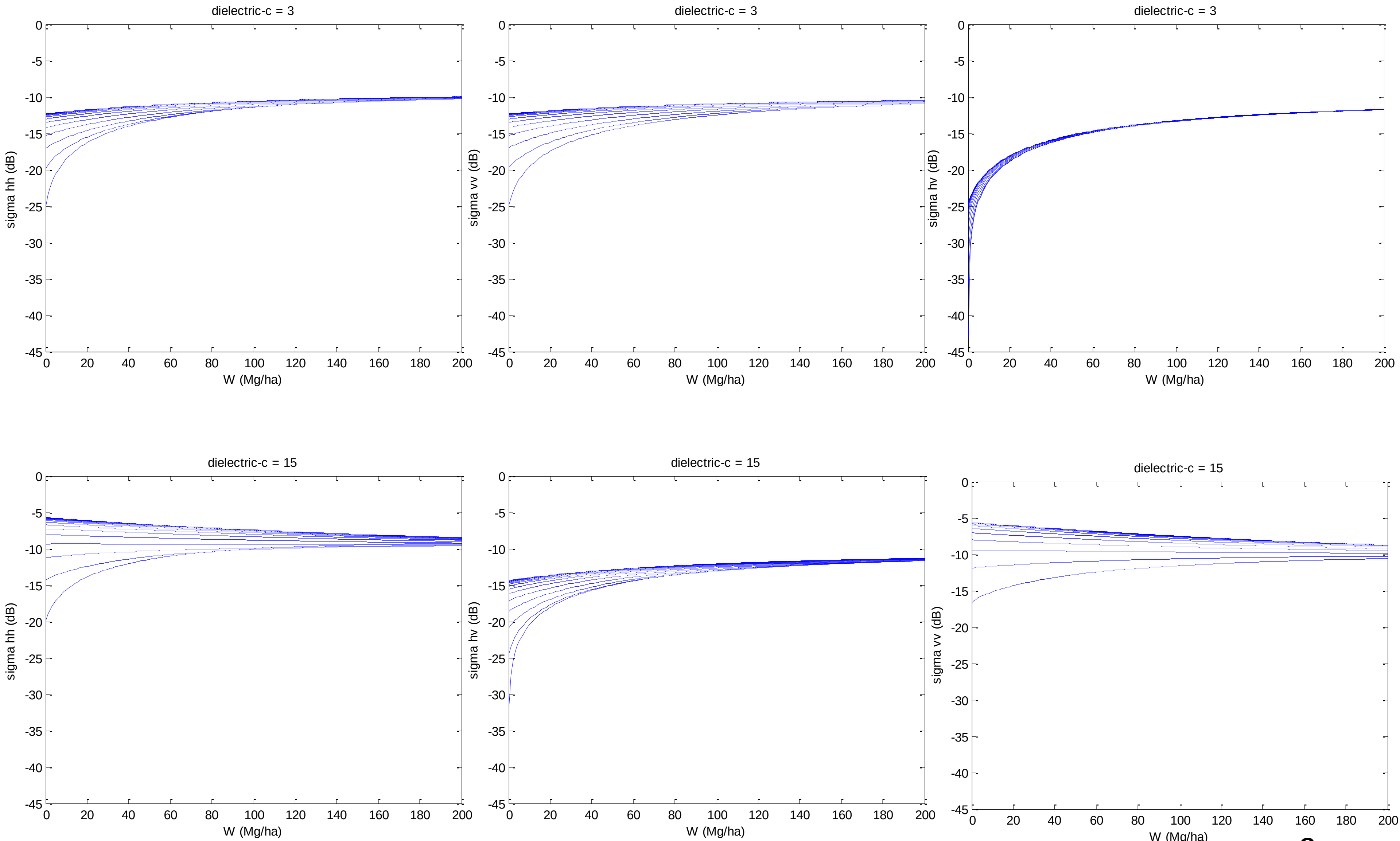
Sigma0 sensitivity to dielectric constant

Fixed roughness - Dielectric constant values from 1 up to 20



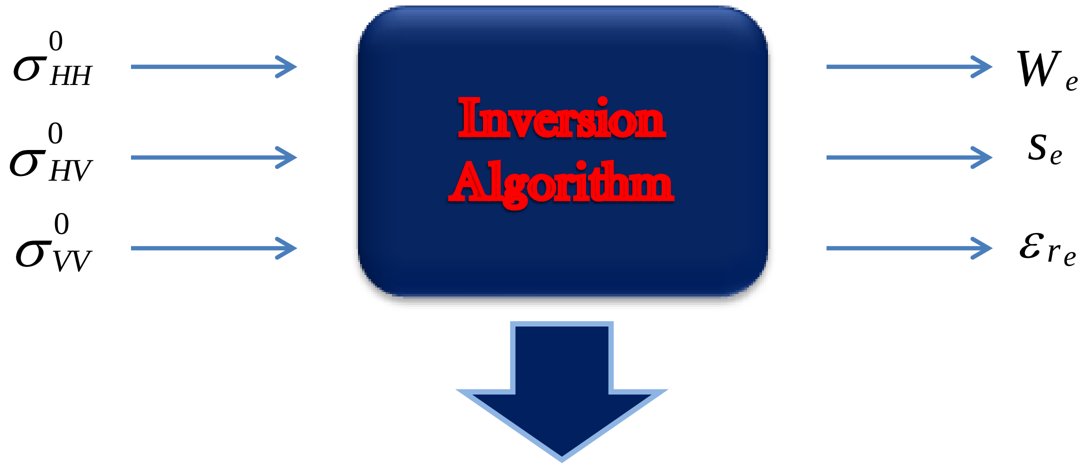
Sigma0 sensitivity to roughness

Fixed dielectric constant - s values from 1cm up to 20cm



Biomass Estimation: FM Inversion (1/2)

In order to obtain the biomass estimation W_e (as well as roughness estimation s_e and dielectric constant estimation ε_{r_e}) from remote sensing data, the inversion of the forward model has to be carried out



Levenberg-Marquardt Algorithm

$$\sum_i \left[\sigma^0{}_{meas_i} - \sigma^0{}_{FM_i}(W^*, s^*, \varepsilon_r{}^*) \right]^2 \Rightarrow \min$$

Necessity of Initial Conditions

Biomass Estimation: FM Inversion (2/2)

First step:

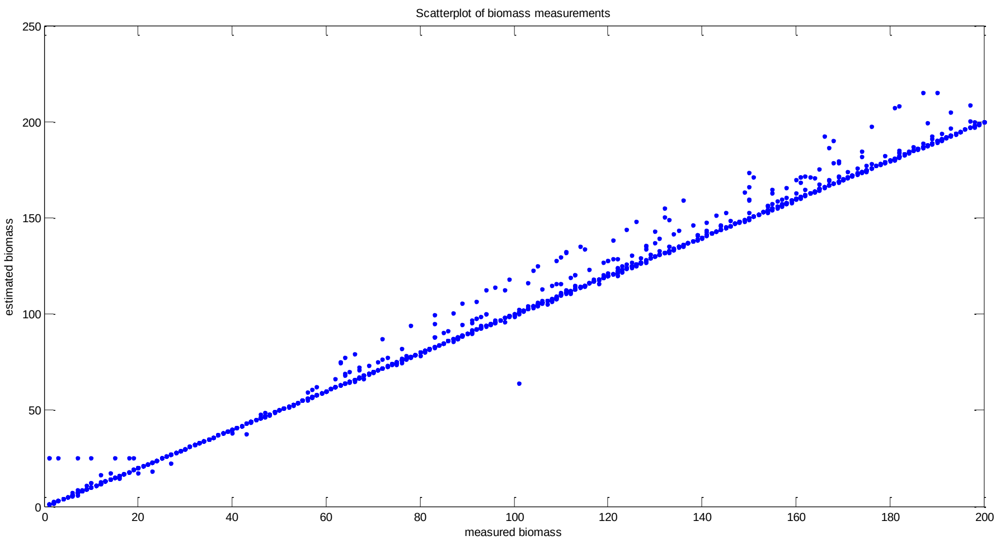
Implementation of the Inversion Algorithm using a dataset previously created

Results: The results show that the selection of the right initial conditions is necessary to find the correct estimates of the geophysical quantities

Second step:

The Algorithm has been corrected in order to run the inversion with the right initial conditions

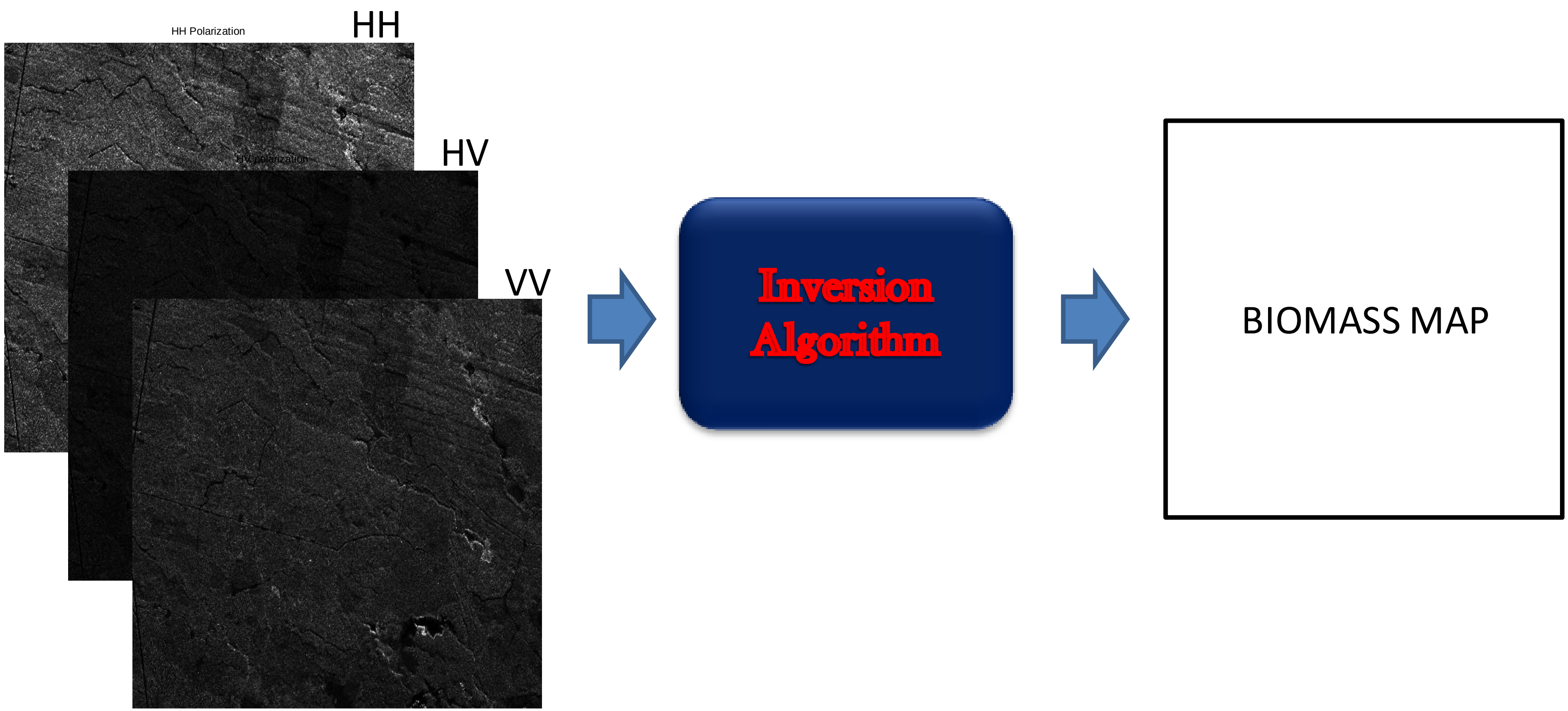
Results:



The scatterplot of the biomass shows that there is a good agreement between the measured and estimated values

Third step: *Make the algorithm not dependent on the accuracy of the initial conditions*

Final Goal



The code has to be able to take an image as an input and give the biomass map of that area as output taking into account the effects of the noise over each image pixel

Conclusions

1) In order to estimate the above ground biomass using L-band polarimetric SAR data, the Forward Model of the biomass scattering mechanism has been implemented;

2) The Forward Model has been used in order to develop the inversion algorithm, based on Levenberg-Marquardt method, necessary to do the estimation. After its correction, the algorithm shows a good agreement between estimated and measured biomass values;

3) Now we are working on make the algorithm not dependent on initial conditions;

4) The final step will be to adjust the algorithm in order to make it able to estimate biomass from SAR images considering also the effects of noise.

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