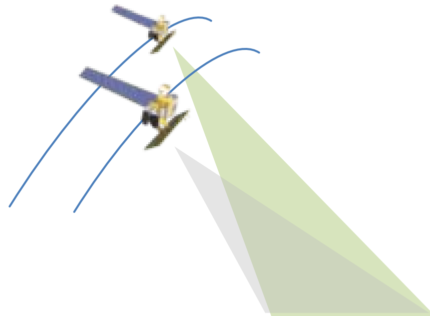

PolInSAR Forest Parameters Retrieval

Results using the ESA ALOS-PALSAR Prototype Processor

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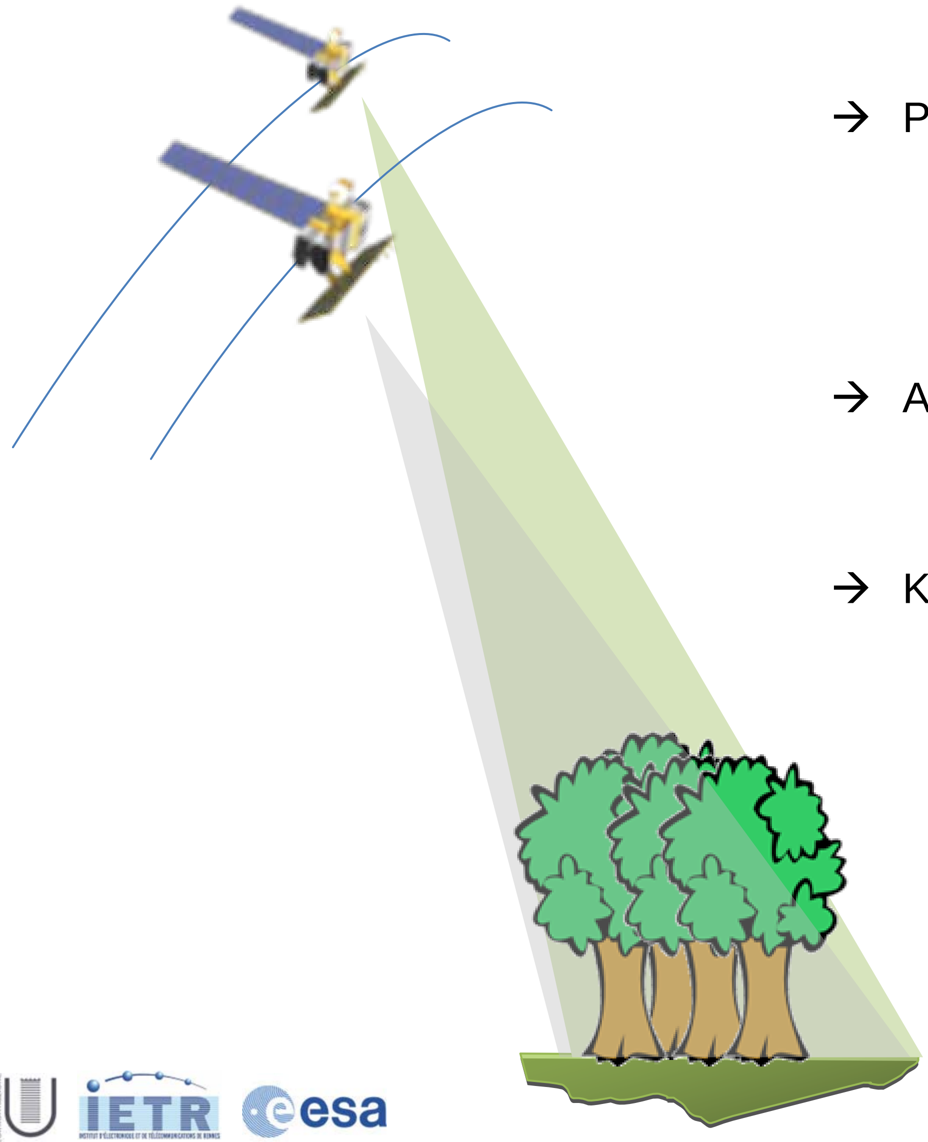
PolInSAR Workshop 26-31 Jan 2008

Outline

- Introduction
  - PolInSAR basic idea and inversion approach
- Forest parameters estimation
  - Optimum PolInSAR coherence
  - Coherent model analysis
  - Processing and observations of ALOS-PALSAR data
- Results of preliminary forest height inversion
- Conclusions

Introduction

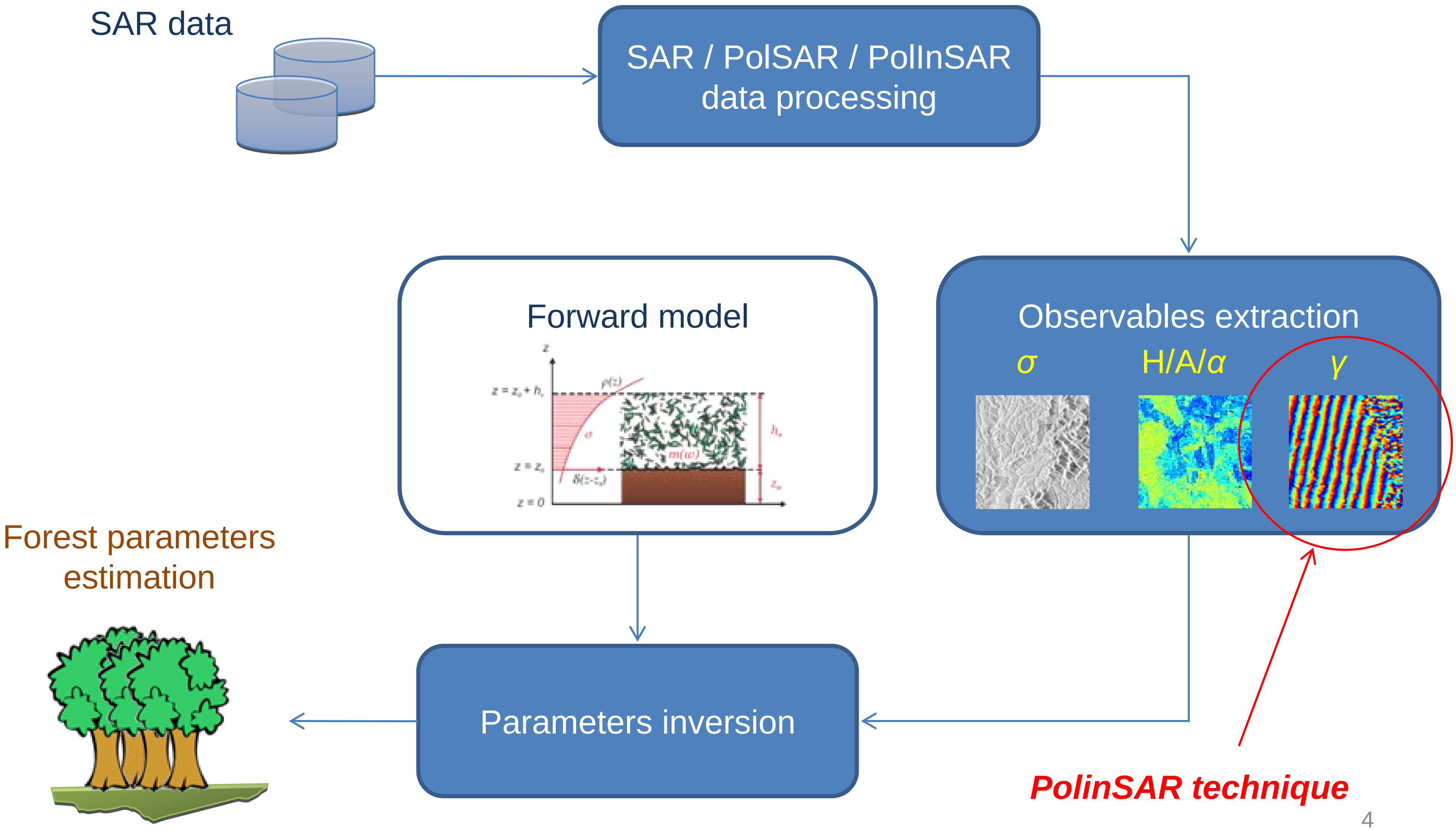
Polarimetric SAR Interferometry



- → PolInSAR basic idea (Cloude, Papathanassiou 1997)
  - → InSAR coherence has different sensitivity according to polarization
  - → To discriminate among different components of the vertical structure of vegetation
- → ALOS PALSAR
  - → L-band
  - → 46 days revisit time
- → Key observable
  - → Complex degree of coherence $\tilde{\gamma}$

Introduction

Forest parameters inversion from SAR data: general scheme



Introduction

Random Volume over Ground (RVoG) Model

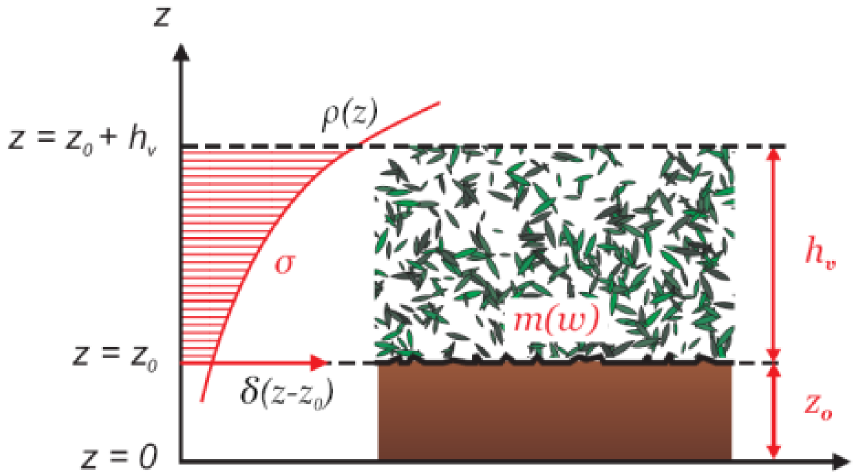
Forward model

Vegetation height: h_v

Vertical reflectivity function: $\rho(z)$

Gound/Volume Ratio: $\mu(\vec{w})$

$\Rightarrow \tilde{\gamma}$



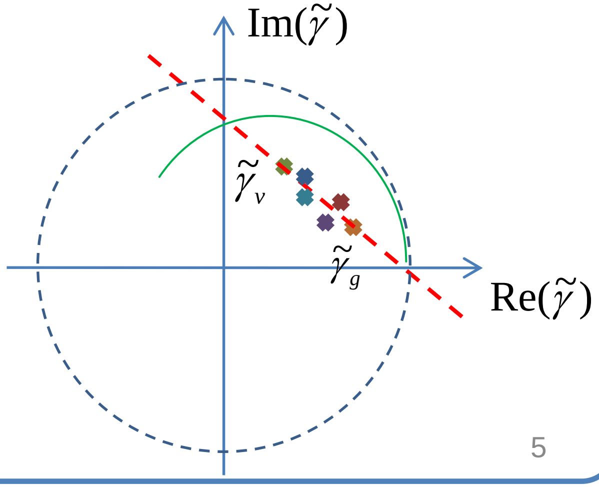
Inversion procedure

1) Line fitting in the complex plane

$$\tilde{\gamma}_{RVoG} = e^{jk_z z_0}\left[\tilde{\gamma}_v + \frac{\mu(\vec{w})}{1+\mu(\vec{w})}\left(1-\tilde{\gamma}_v\right)\right]$$

2) Vegetation bias removal

3) Height and extinction estimation

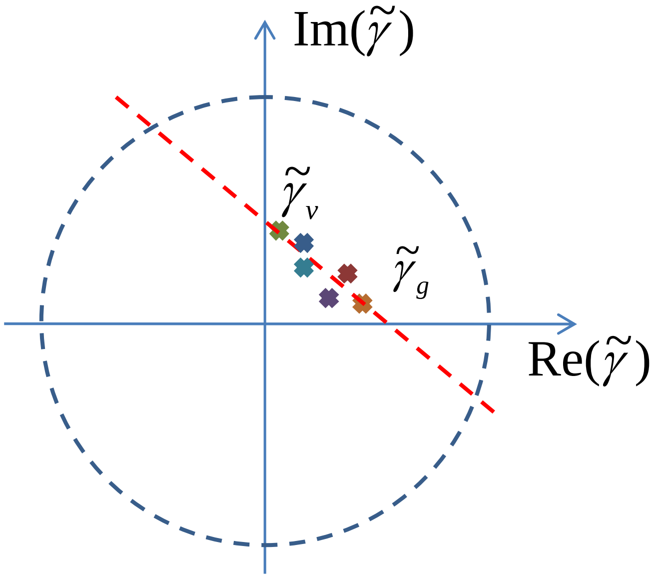


RVoG inversion with PALSAR data

Main issue

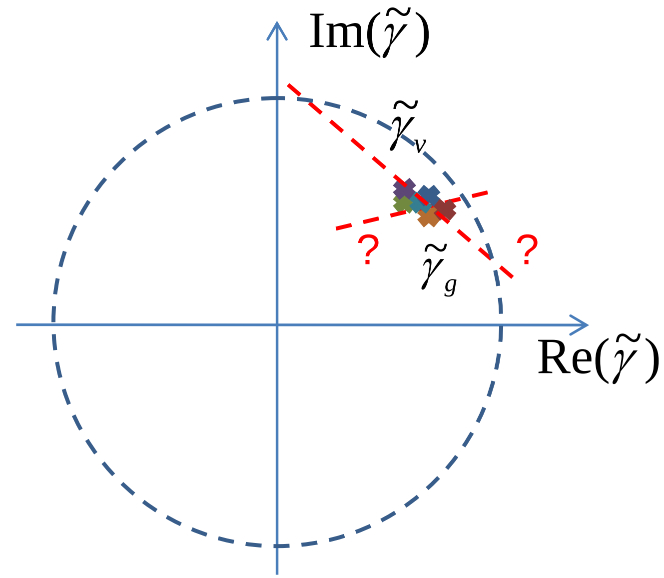
LARGE BASELINE
(>800m)

High decorrelation



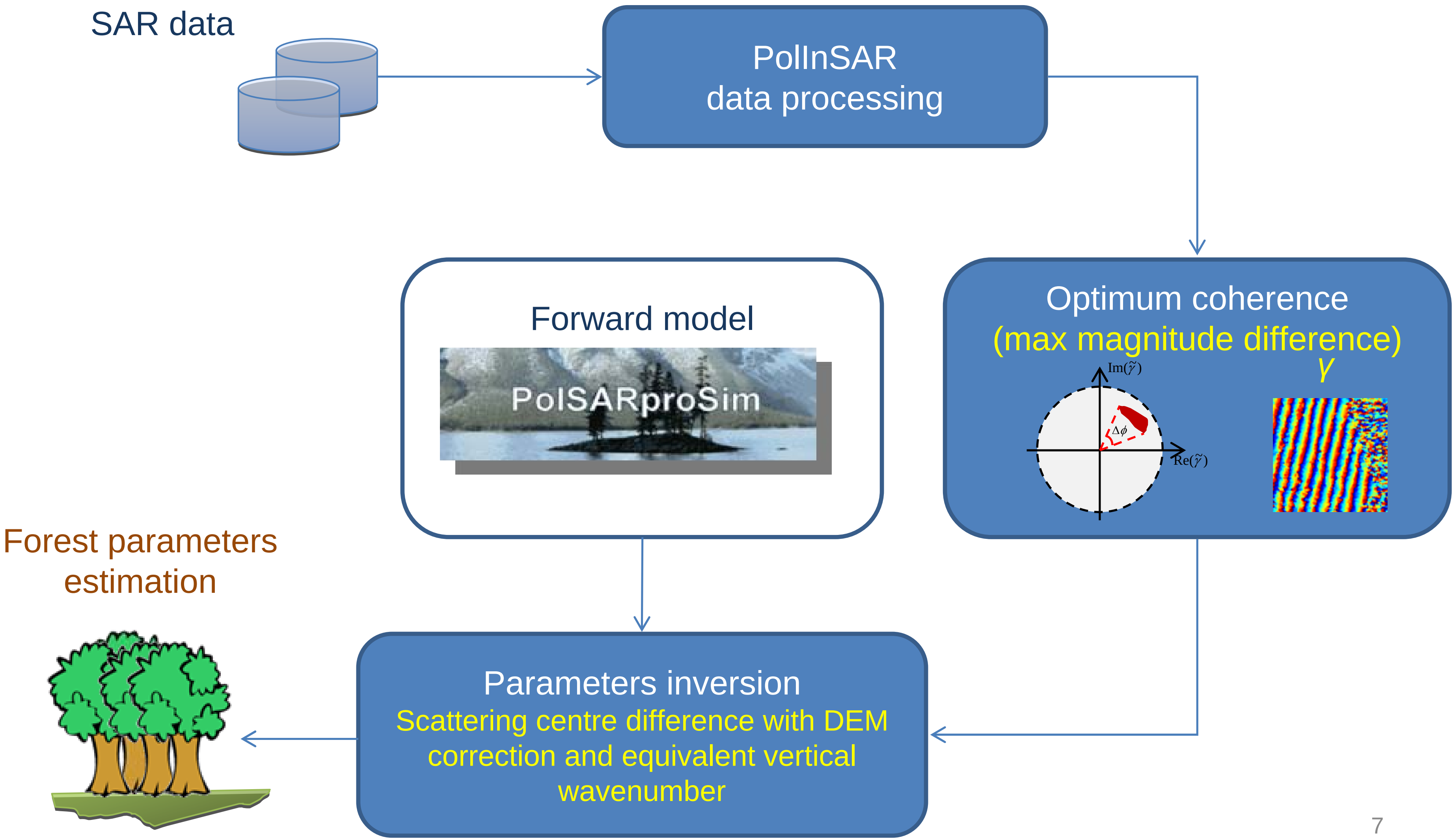
SMALL BASELINE
(<200m)

Line fitting fails



Proposed approach

Forest parameters inversion from SAR data: general scheme



Proposed approach

Coherent PolInSAR Scattering Model

→PolSARProSIM

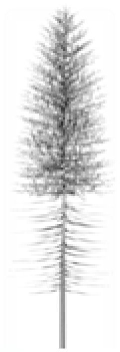
- Maxwell-based scattering model (Williams, 2006)
- Fully coherent PolInSAR simulator
- Only target decorrelation

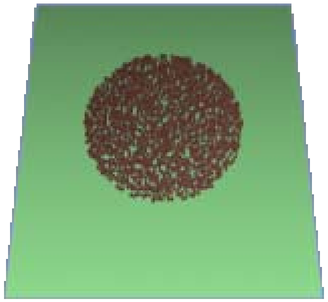
→ Input Parameters

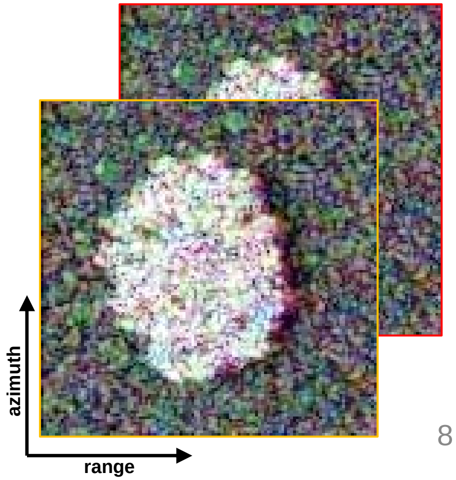
- Acquisition geometry (satellite altitude, baseline, inc. angle)
- Forest (height, density, tree type)
- Soil (roughness, moisture content, terrain slope)

→ Simulated scenario:

- ALOS/PALSAR
- pine forest







Proposed approach

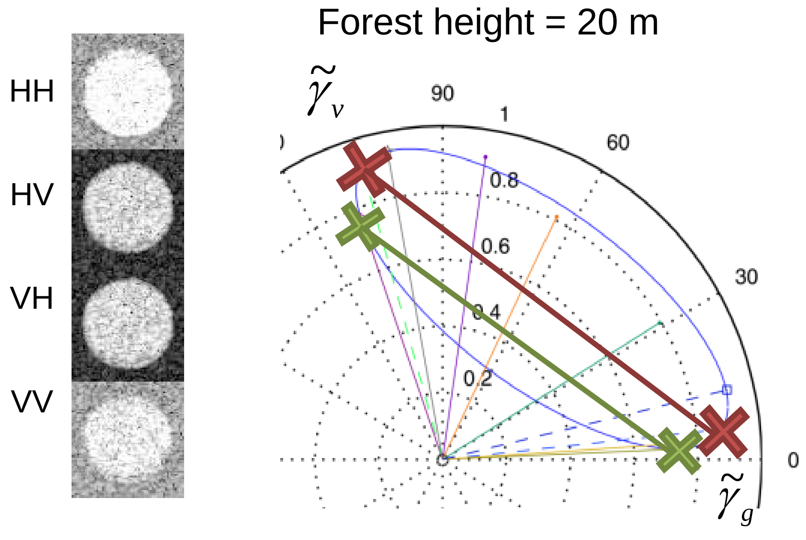
PolInSAR optimum coherence

→ Coherence region in the complex plane calculated through the *field of values F* of the normalized coherency matrix $T_{11}^{-1/2}\Omega_{12}T_{22}^{-1/2}$

→ Different Optimisation algorithms (SVD, numerical radius, phase diversity, etc.)
→ Iteration for the maximization of magnitude difference

$$\max_{\gamma_i,\gamma_j\in F}\left|\tilde{\gamma}_i-\tilde{\gamma}_j\right| \longrightarrow \phi_{opt_1}=\tilde{\gamma}_{i^*}\ ,\quad \phi_{opt_2}=\tilde{\gamma}_{j^*}$$

→ Example of coherence boundary

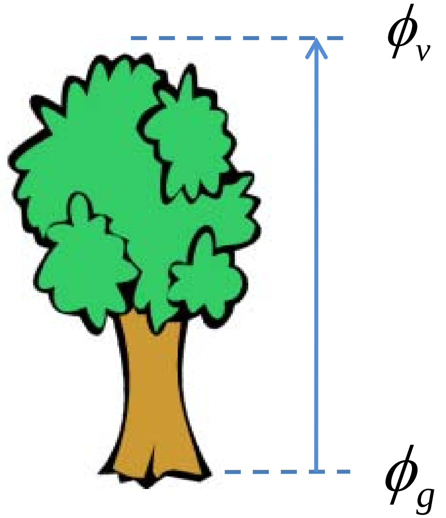


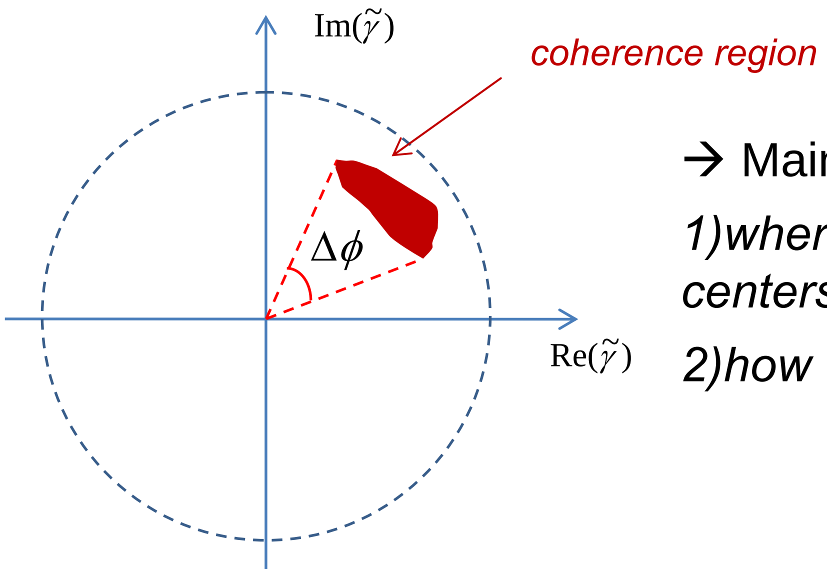
Proposed approach

Forest height estimation

→Simple scattering phase center difference
- physically related to the problem

→ Scattering phase center positions
- Depends on many factors (acquisition geometry, forest parameters, soil properties)





→ Main challenges

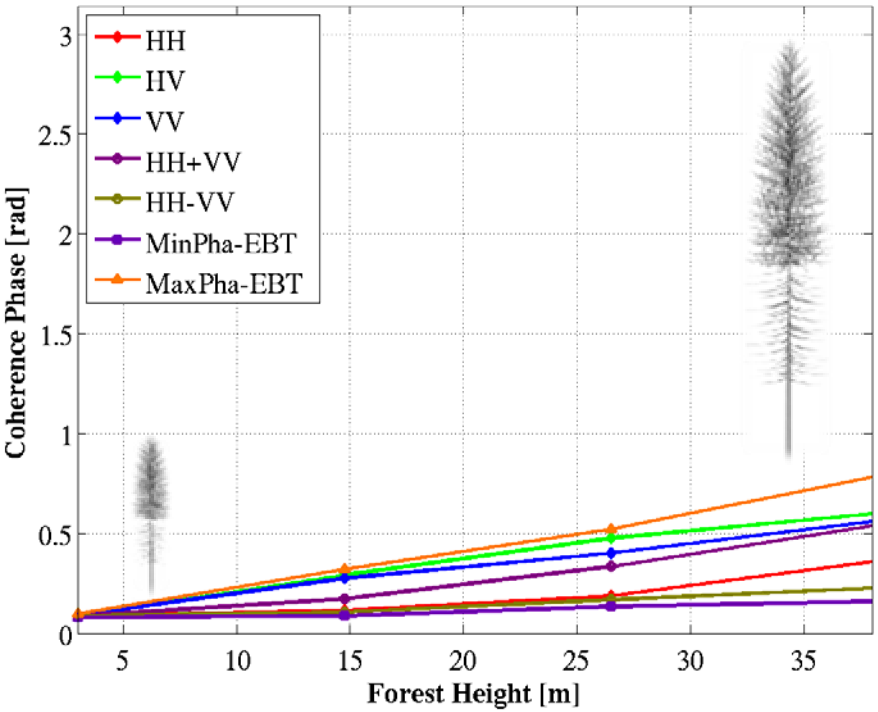
1)where are located exactly the scattering phase centers while varying the polarization?

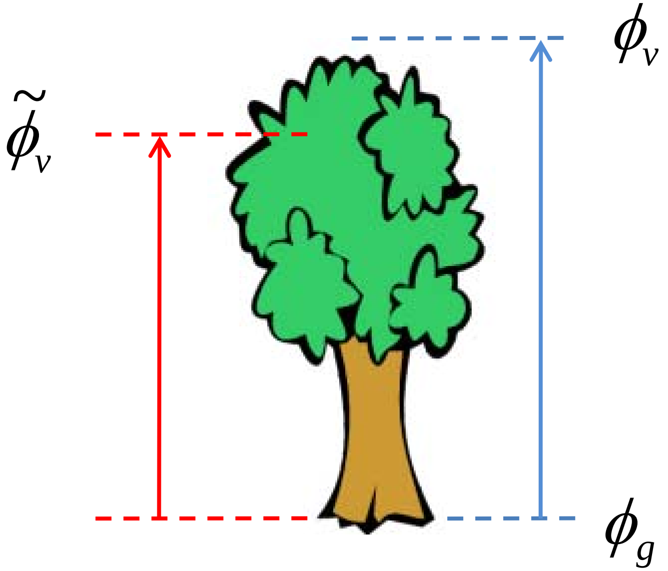
2)how to cope with temporal decorrelation?

Model Analysis

Coherence vs Vegetation Height

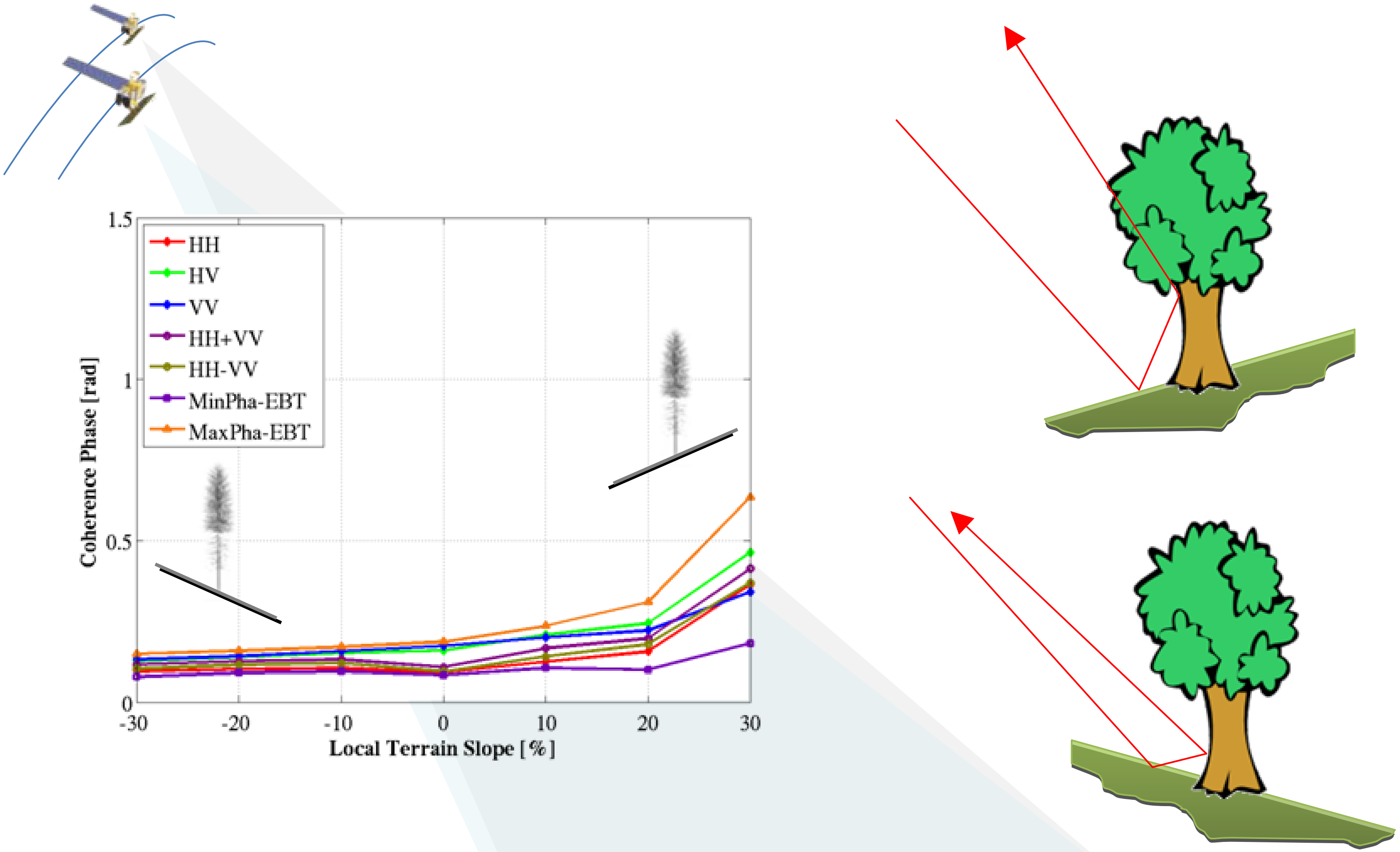
→ Simulated scenario
- ALOS/PALSAR
- Baseline 100 m





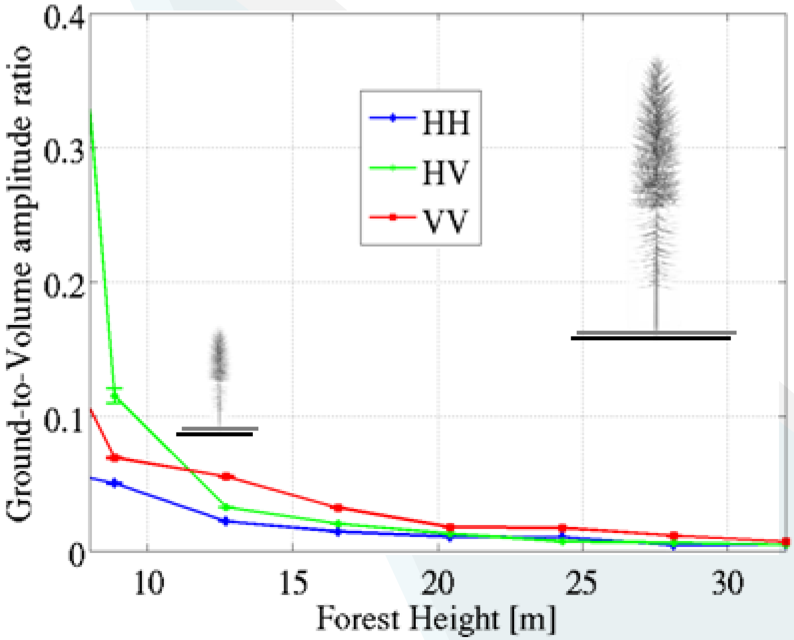
Model Analysis

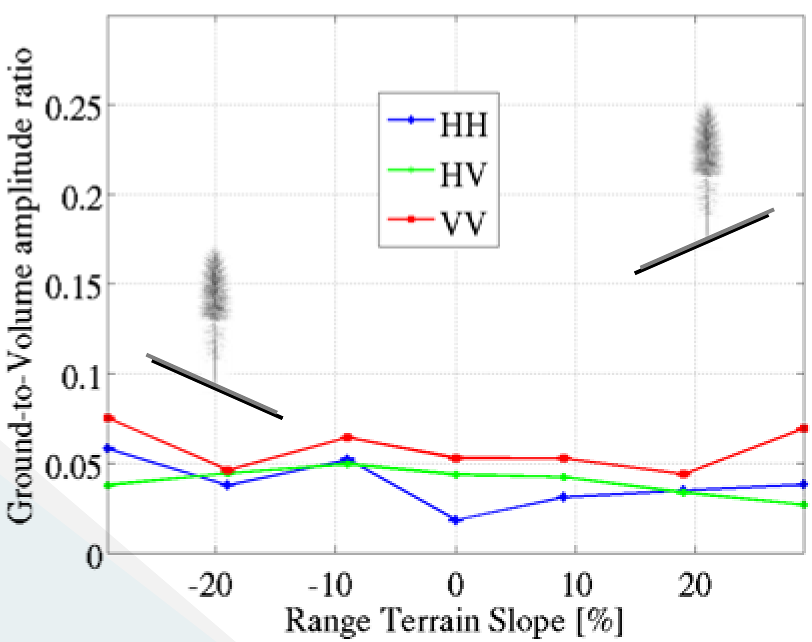
Coherence vs Local Terrain Slope



Model Analysis

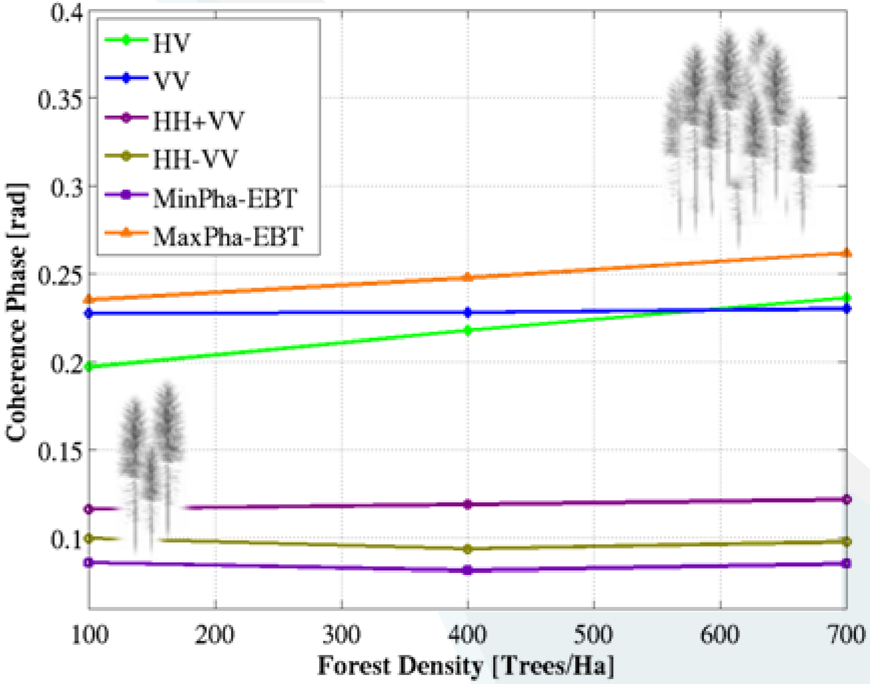
Ground-to-Volume ratio

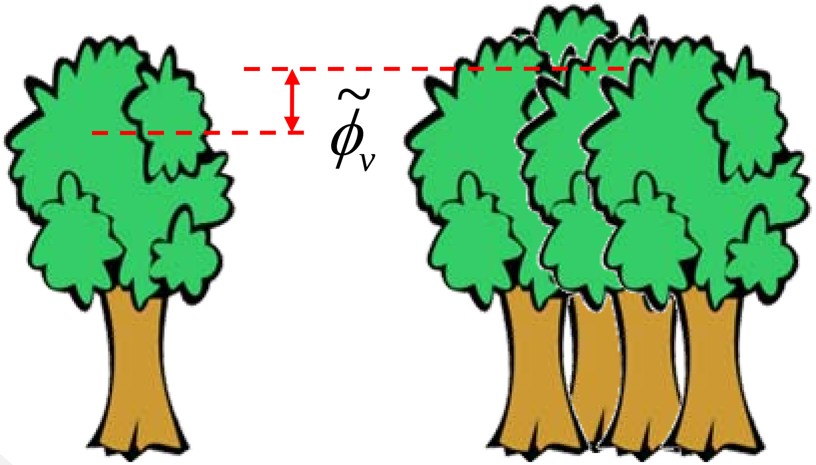




Model Analysis

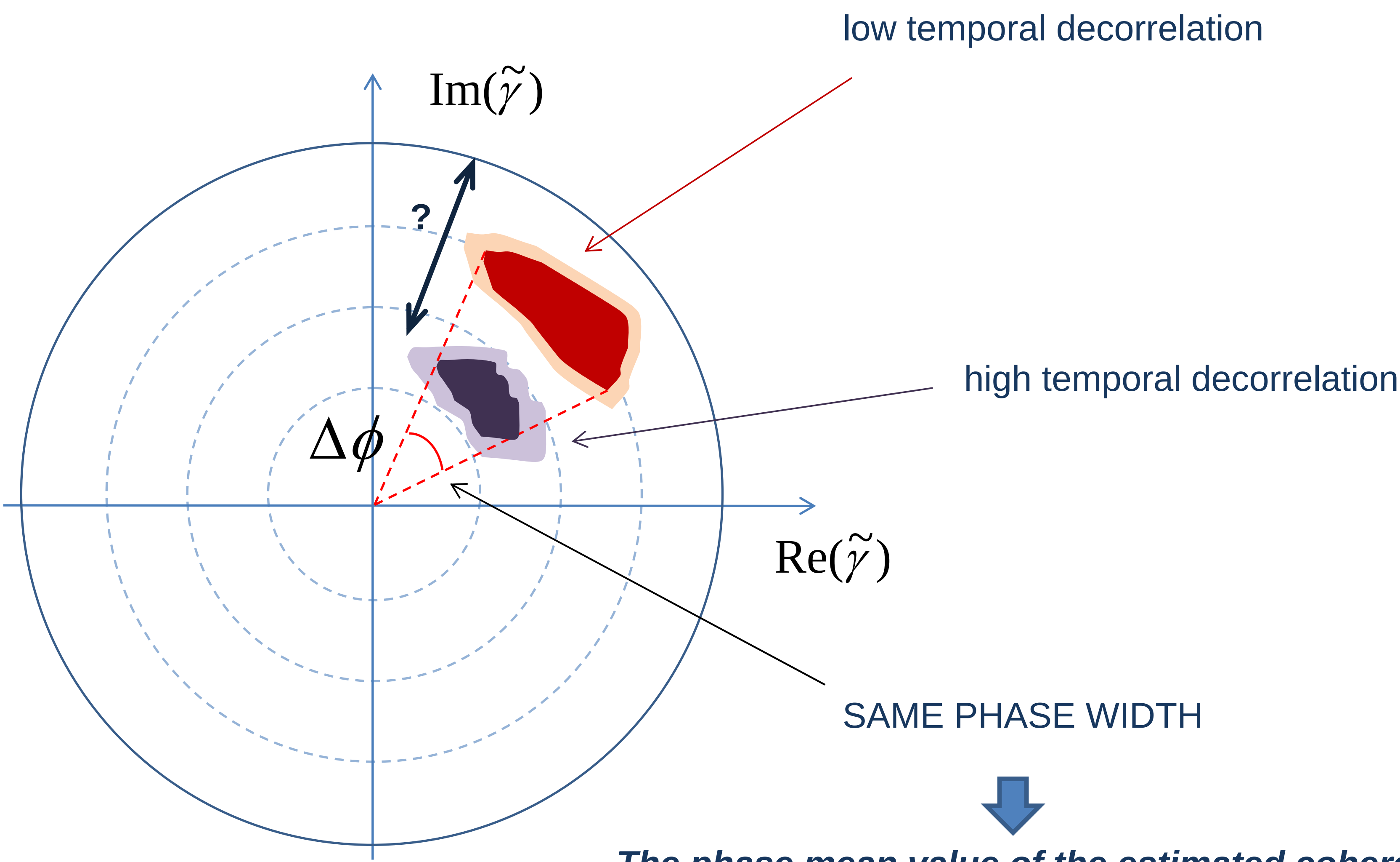
Coherence vs Forest Density





Effect of the temporal decorrelation

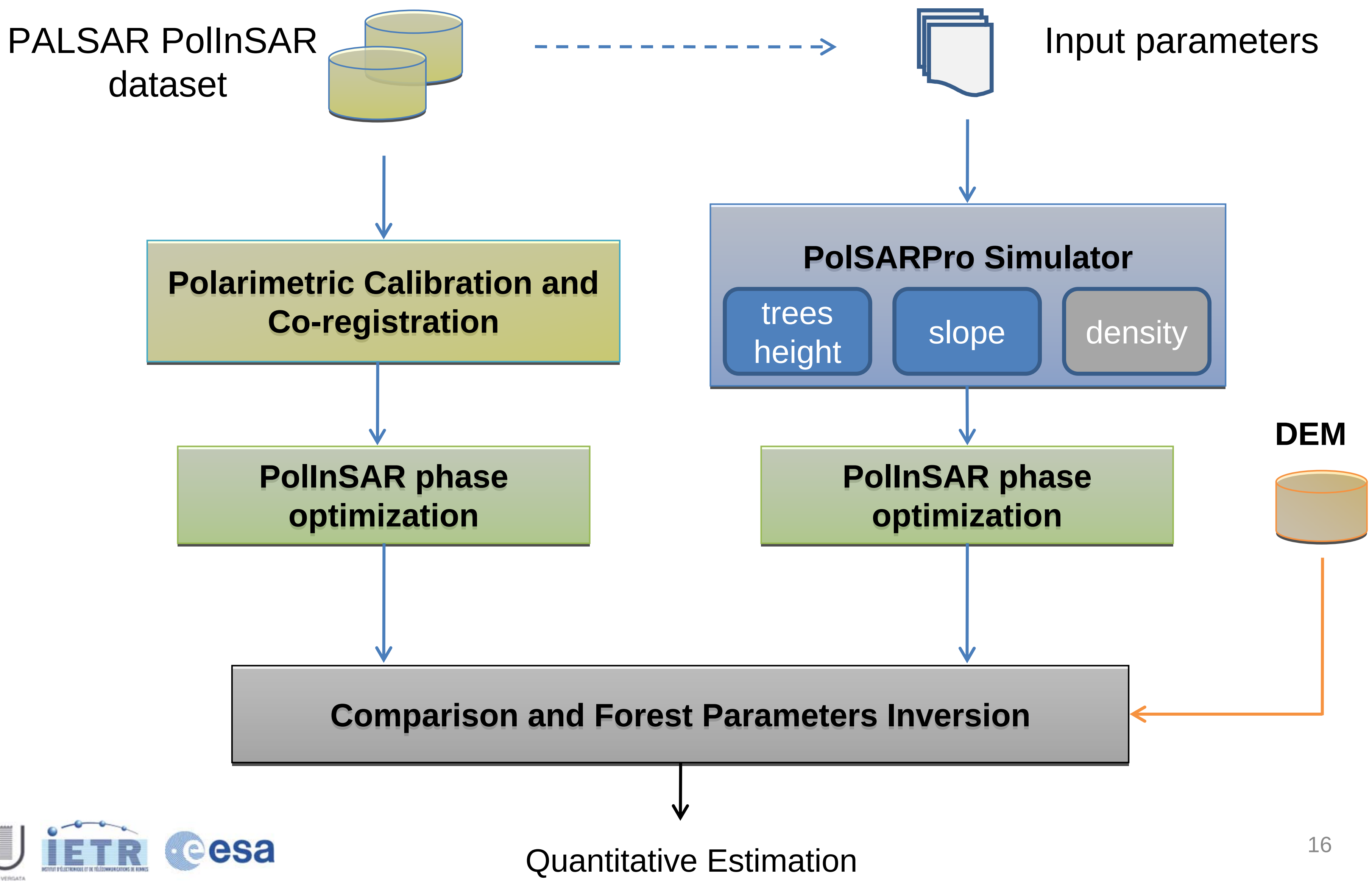
Coherence region



The phase mean value of the estimated coherence can be used for the inversion

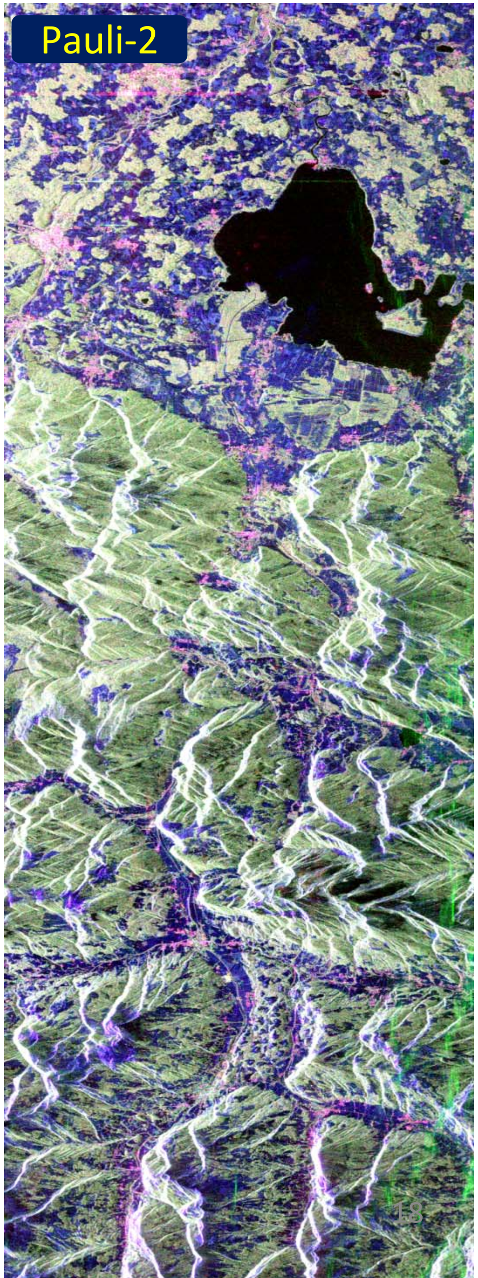
Processing chain

General Scheme



Results using ALOS-PALSAR data

Results – ALOS PALSAR

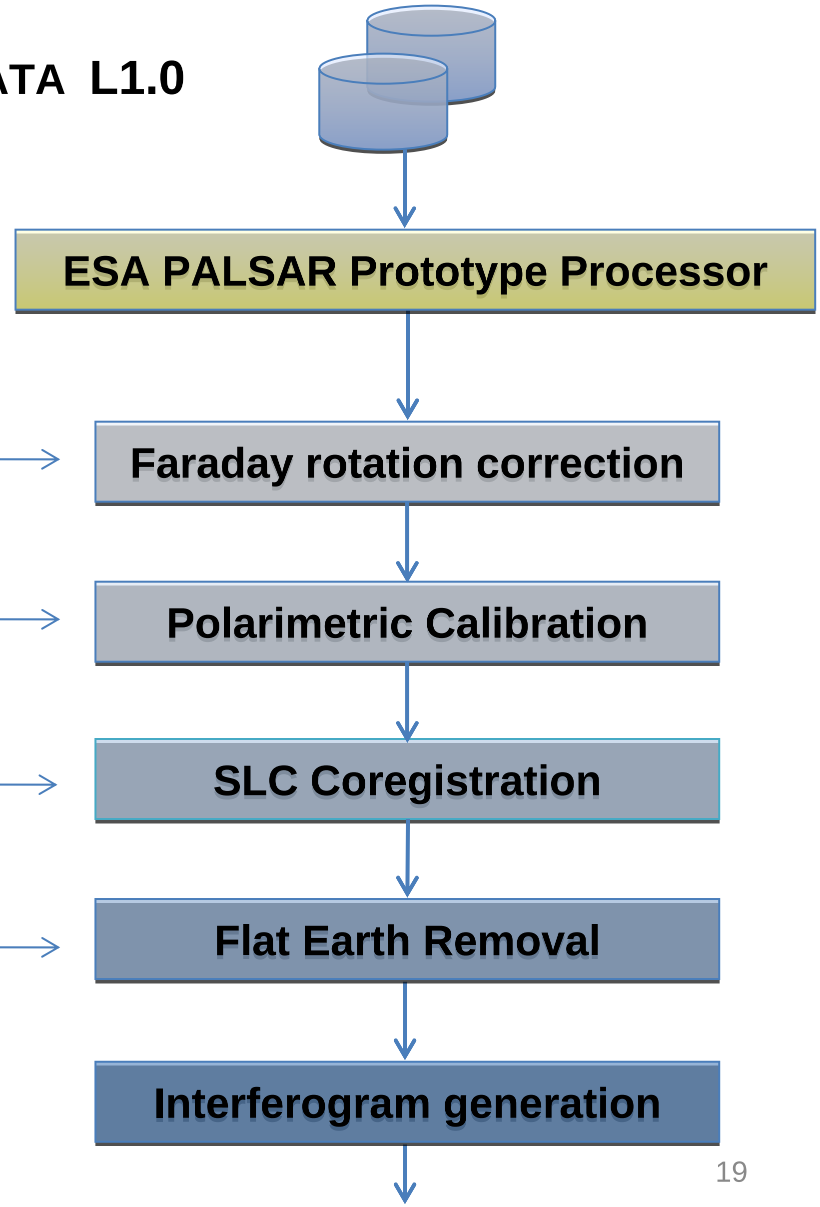


→ 2 PALSAR PolInSAR acquisitions

- Germany / Traunstein area
- Descending pass
- Baseline 210 m

ALOS PALSAR processing

PALSAR RAW DATA L1.0



Faraday rotation estimated using the method of Bickel and Bates

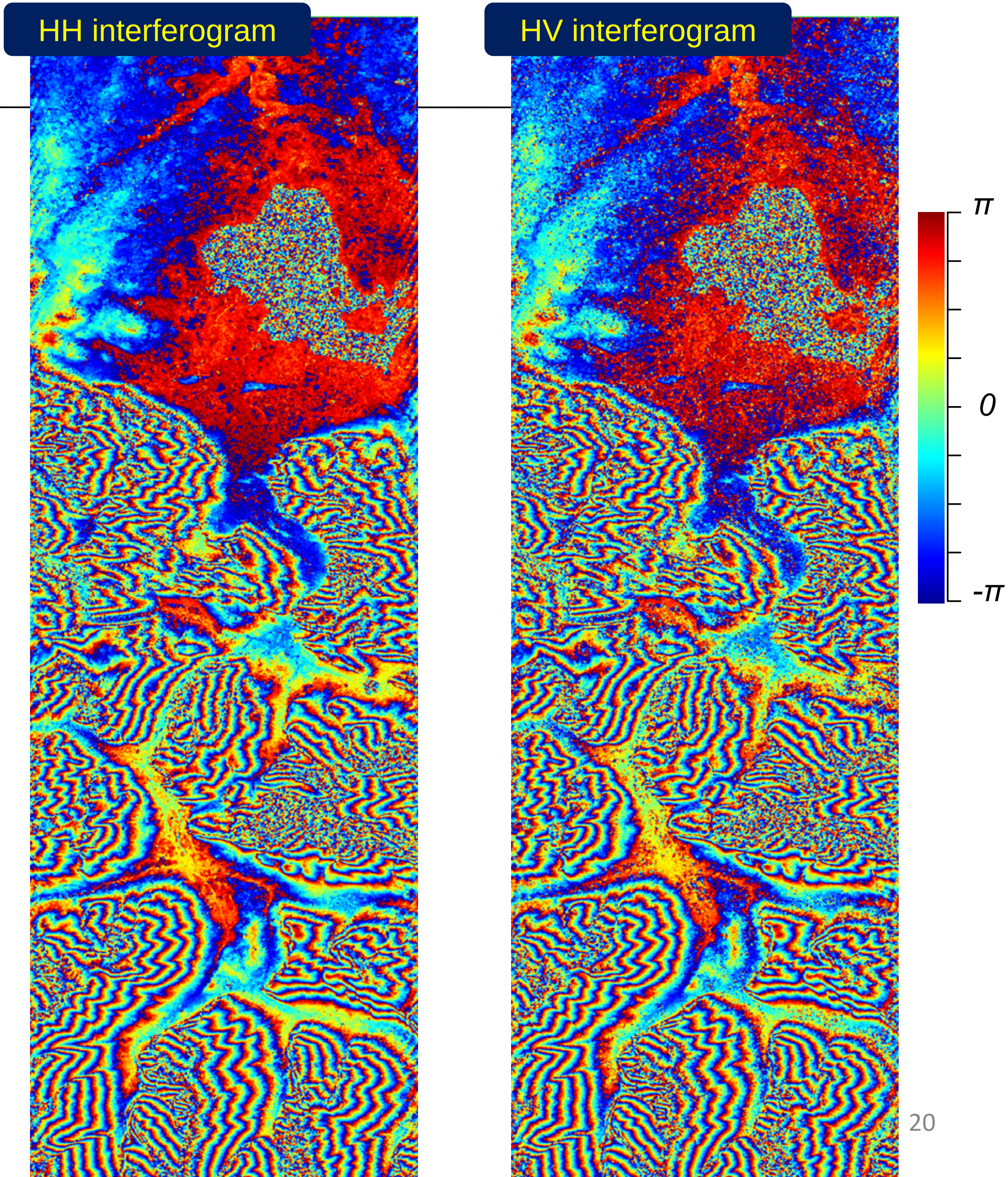
Old distortion matrix removed and new calibration matrices applied (*Shimada, IGARSS'07*)

Coarse and fine coregistration (including spectral shift and filtering)

Ellipsoid WGS-84
<u>No</u> digital elevation model

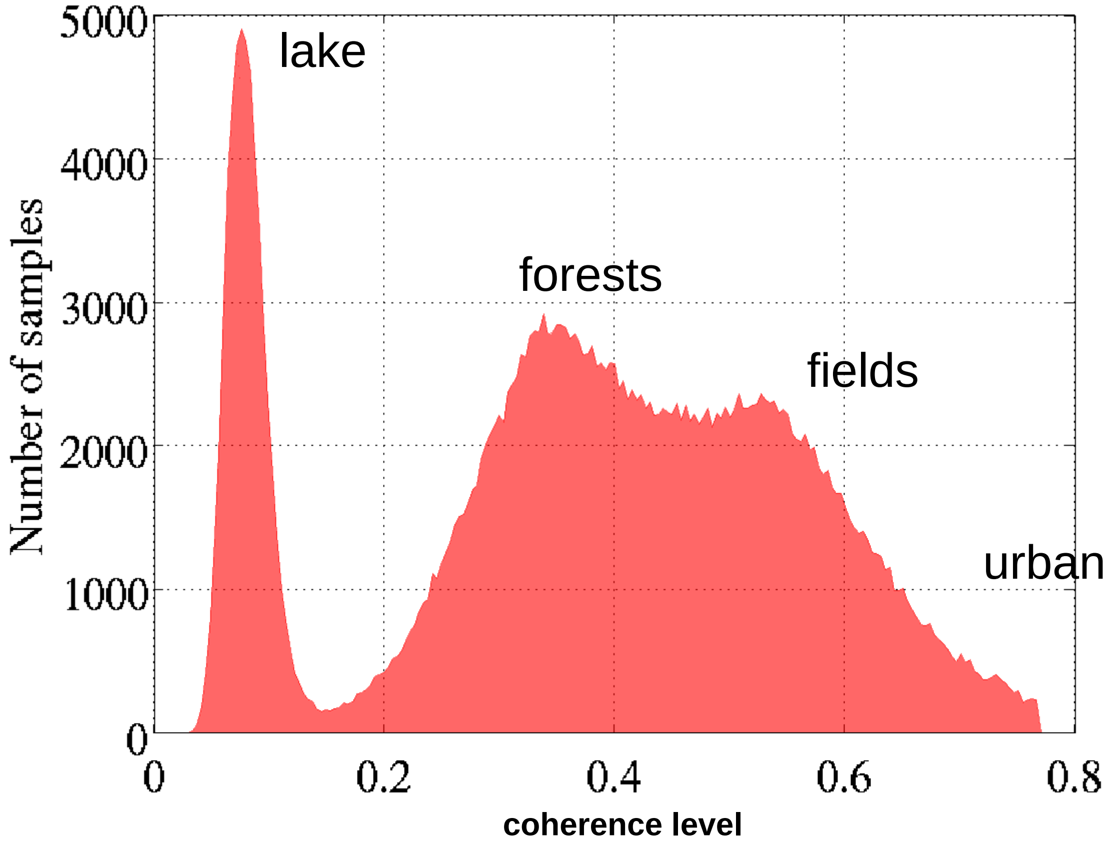
Results

Flattened interferogram



Results – ALOS PALSAR

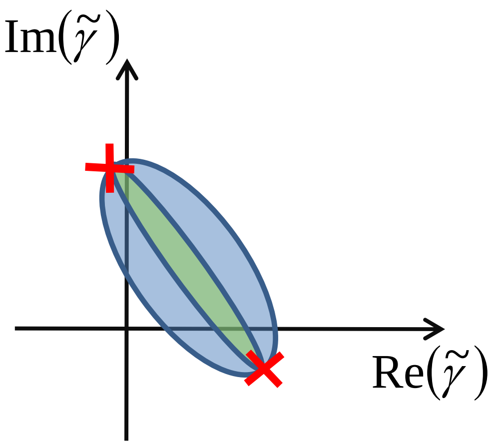
Max coherence level

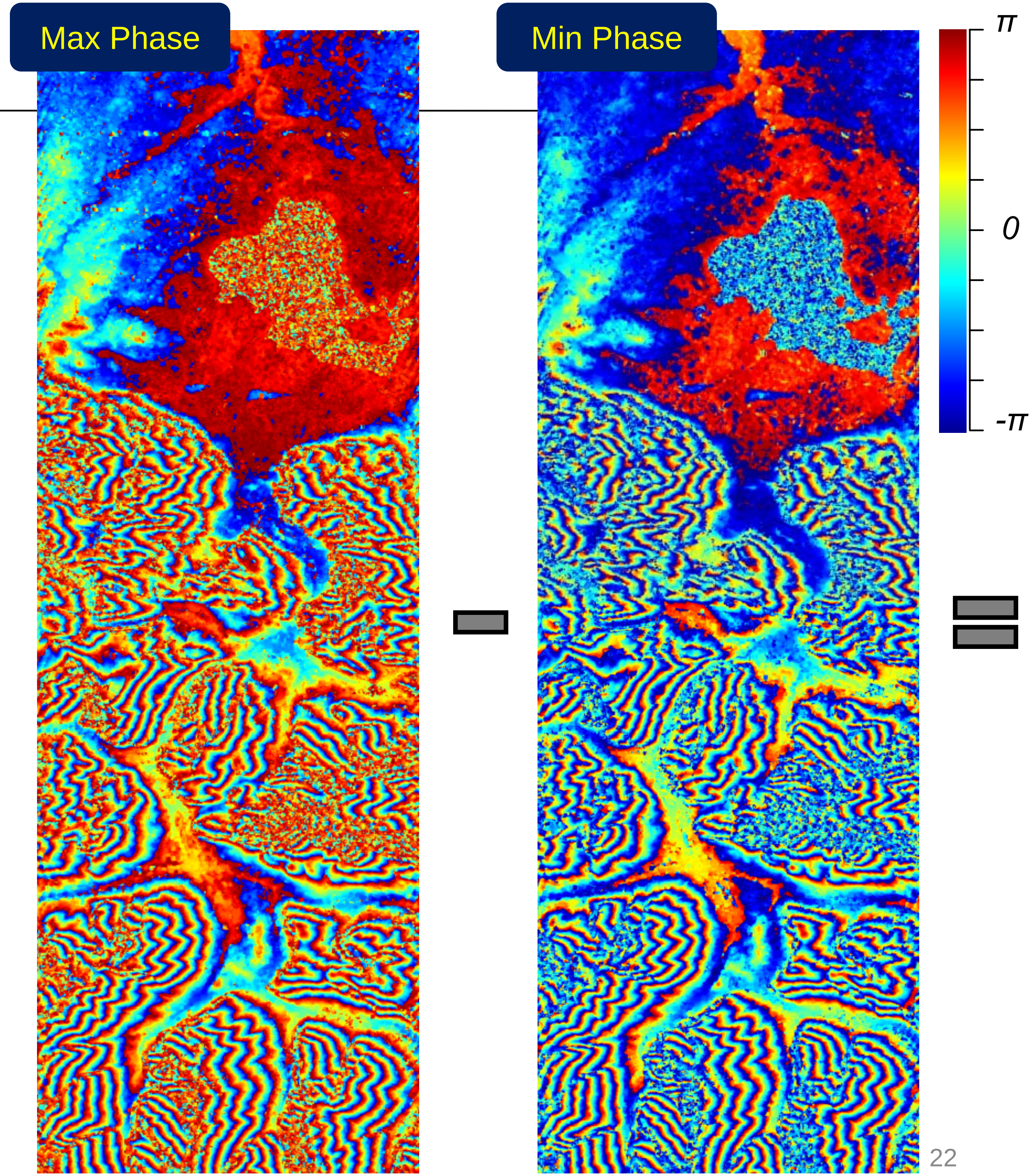


Results

Optimum interferogram

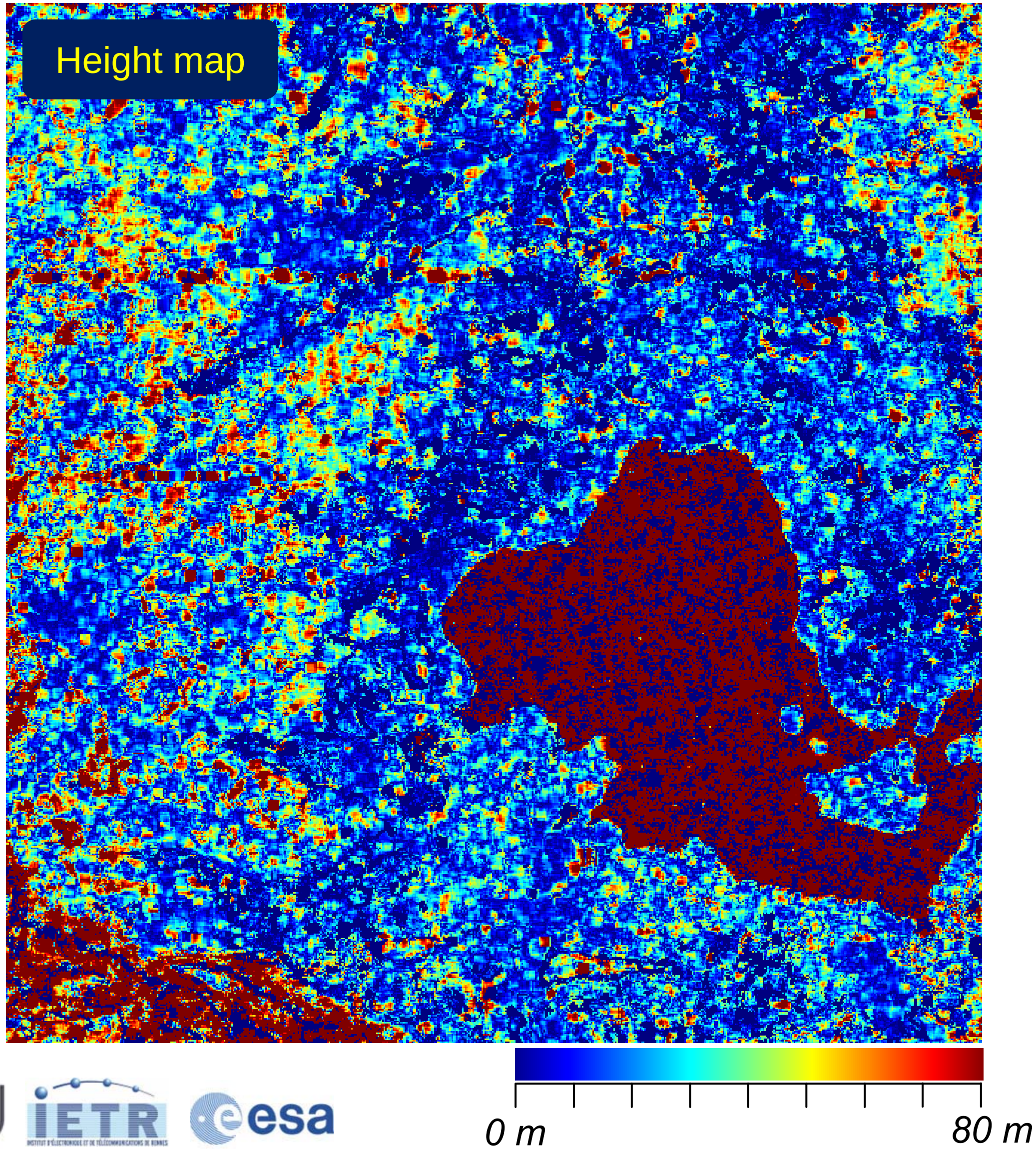
→ Maximization of the magnitude difference





Results – ALOS PALSAR

Estimation of phase centers height

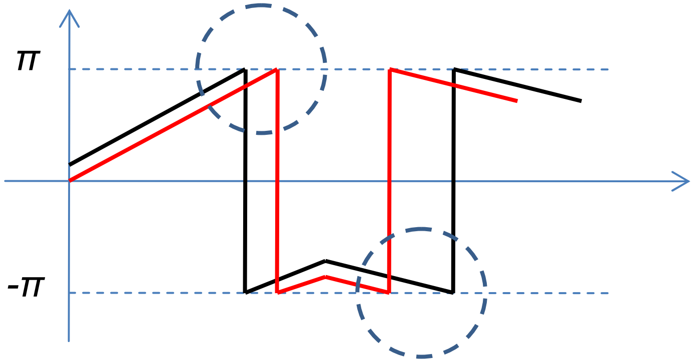


→ Simple difference between optimized phase centers:

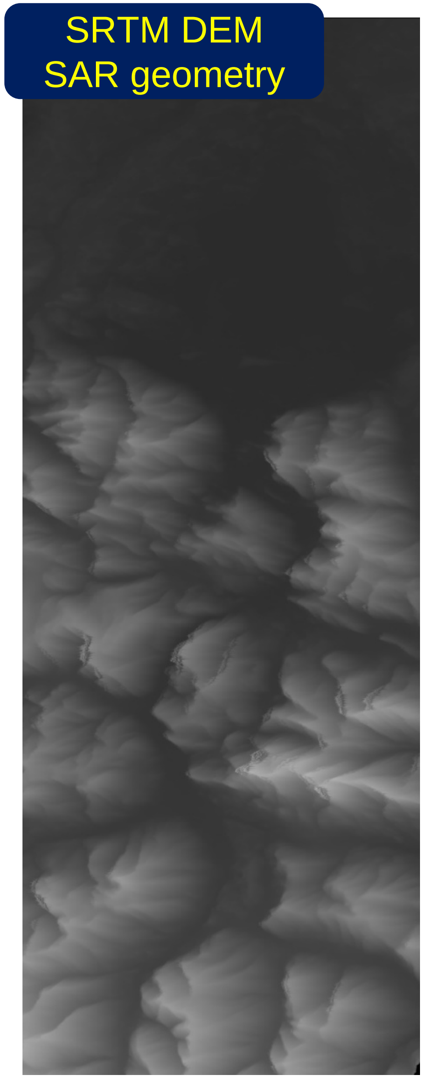
$$h_v = \frac{\phi_v - \phi_g}{k_z}$$

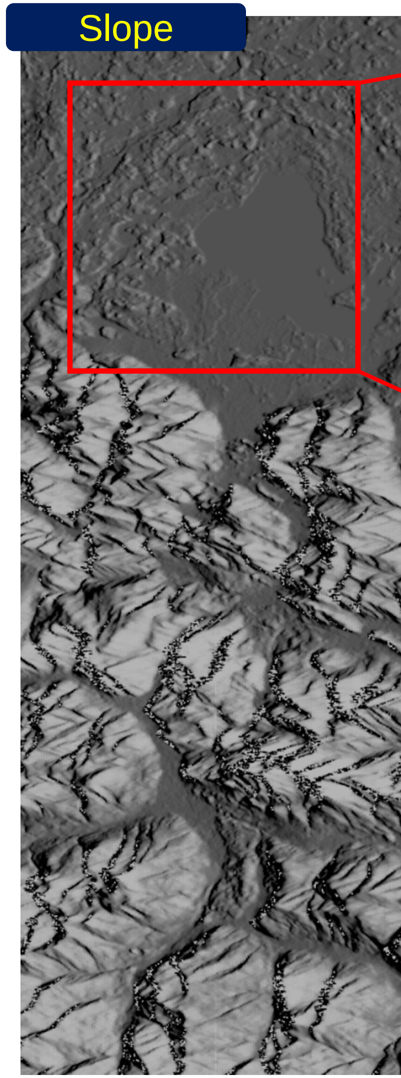
→ No residual topography

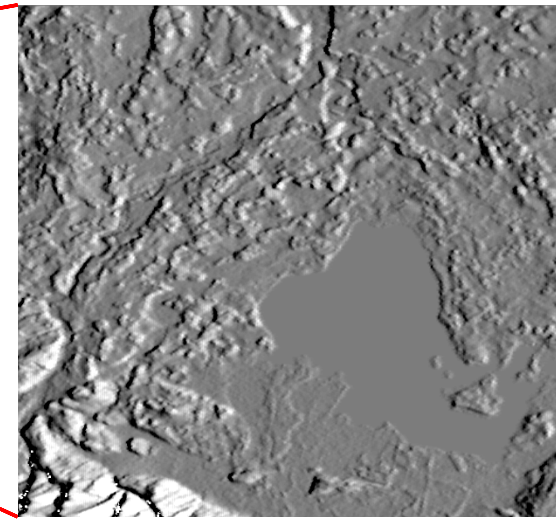
→ Low coherence values not masked



DEM in slant range geometry



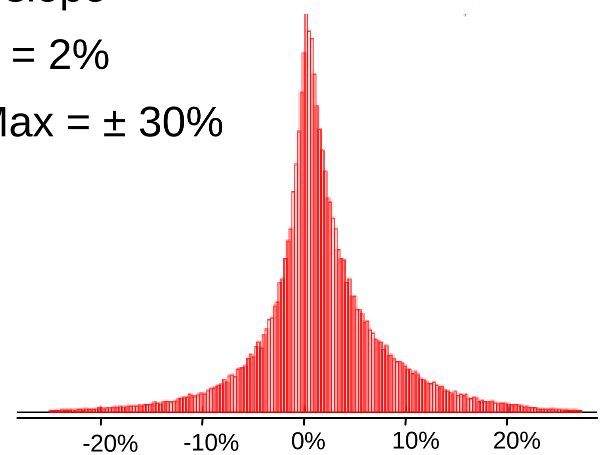




→ Terrain slope

Mean = 2%

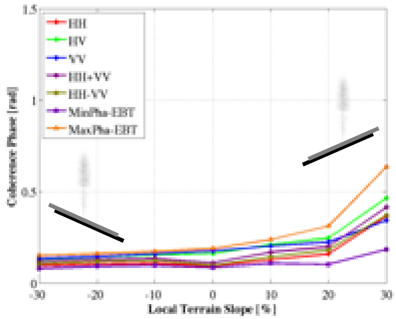
Min/Max = ± 30%



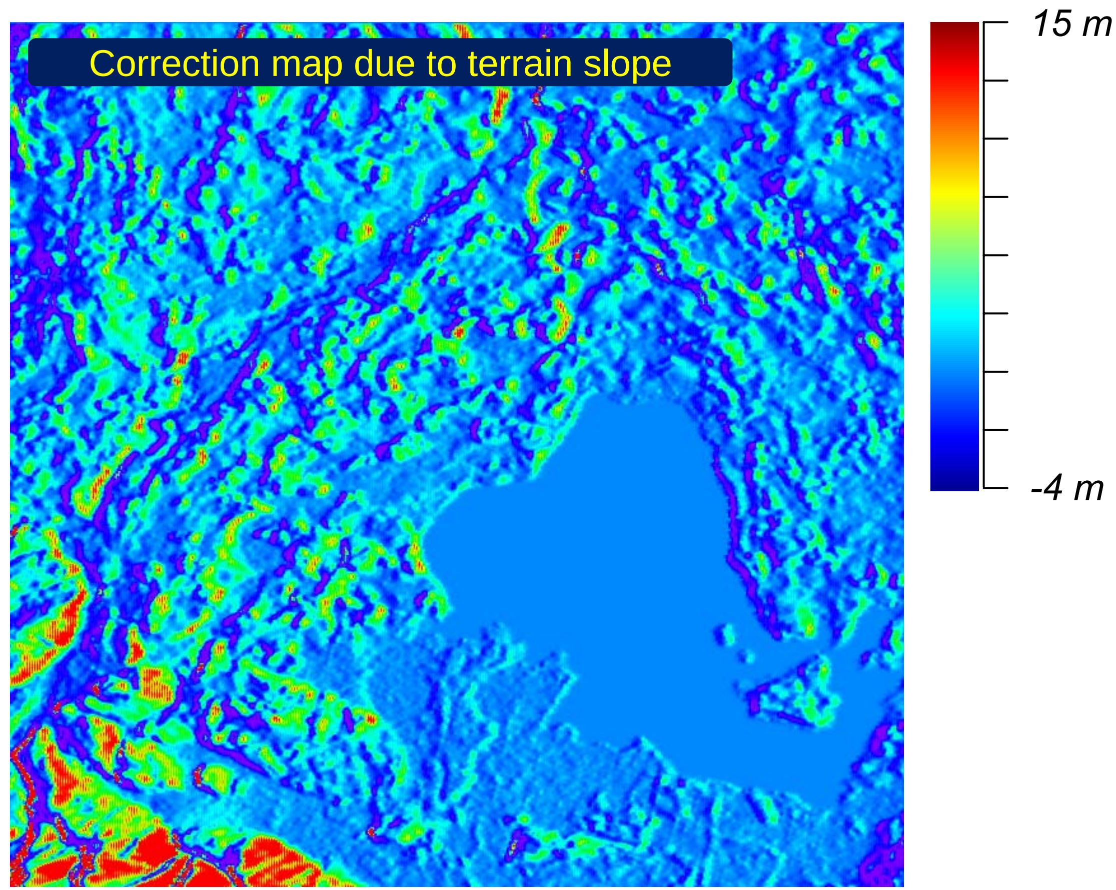
Height correction

Effect of the terrain slope

→ Not linear dependence of optimized coherence on terrain slope (from EM model analysis)



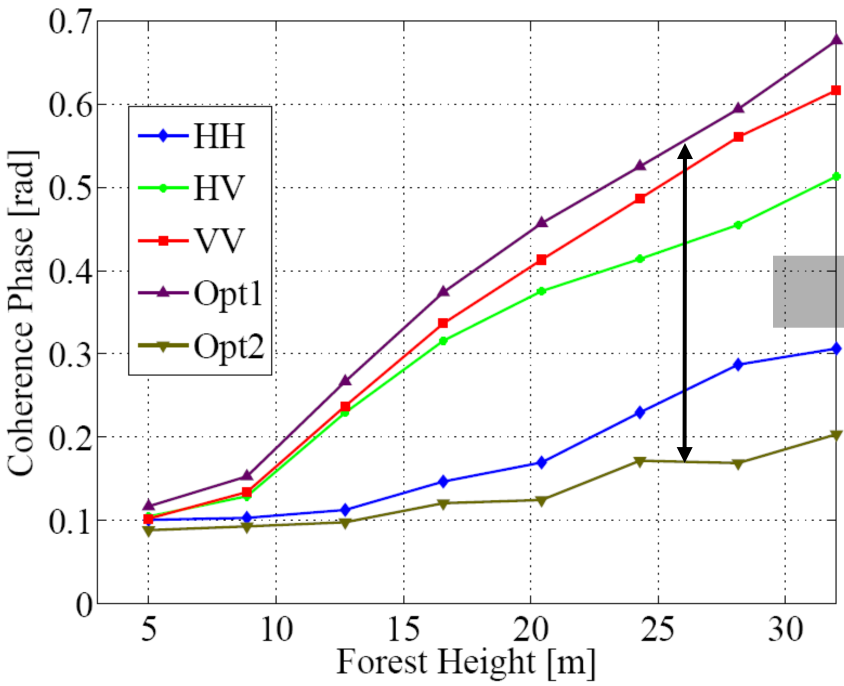
$$h_v = \frac{(\phi_v - \phi_{slope}) - \phi_g}{k_z}$$

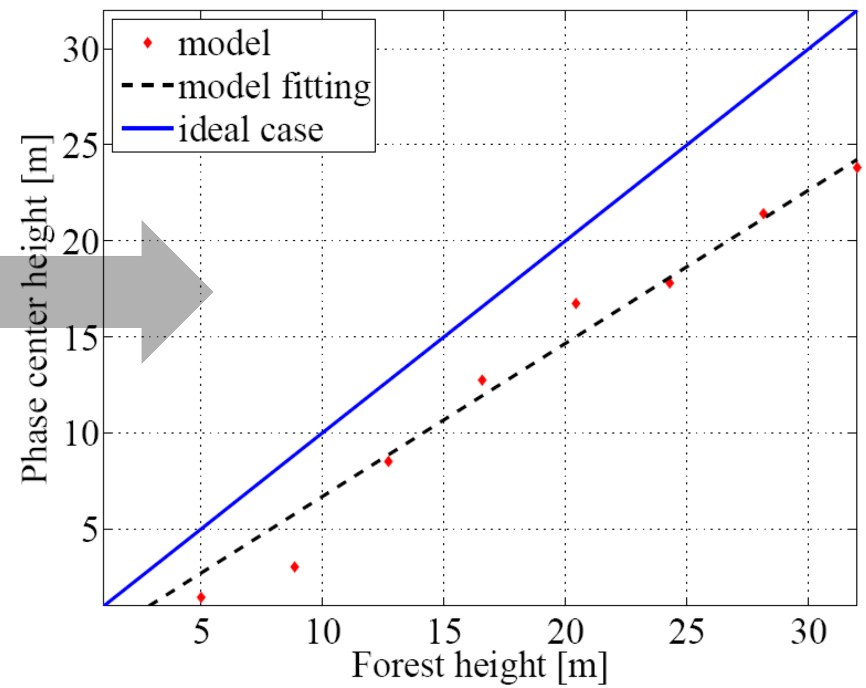


Height correction

Effect of the volume penetration

→ Dependence of optimized coherence on vegetation height

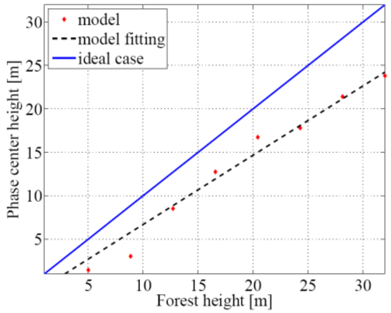




Phase center height map

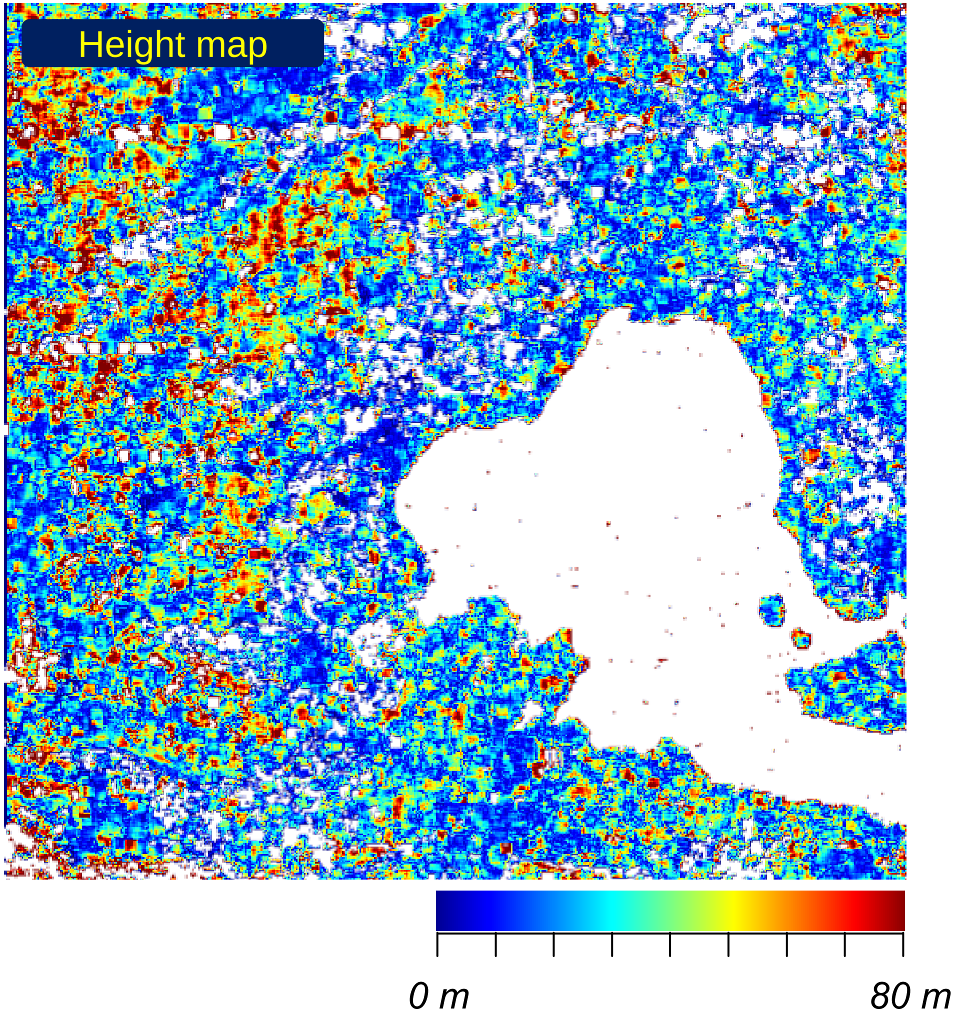
Estimation of forest height

→ Dependence of coherence on terrain slope (from EM model)



$$\phi_{penetr} \qquad \alpha = \frac{k_z}{k_z^{eq}}$$

$$h_v = \frac{(\phi_v - \phi_{slope} - \phi_{penetr}) - \phi_g}{k_z} \alpha$$



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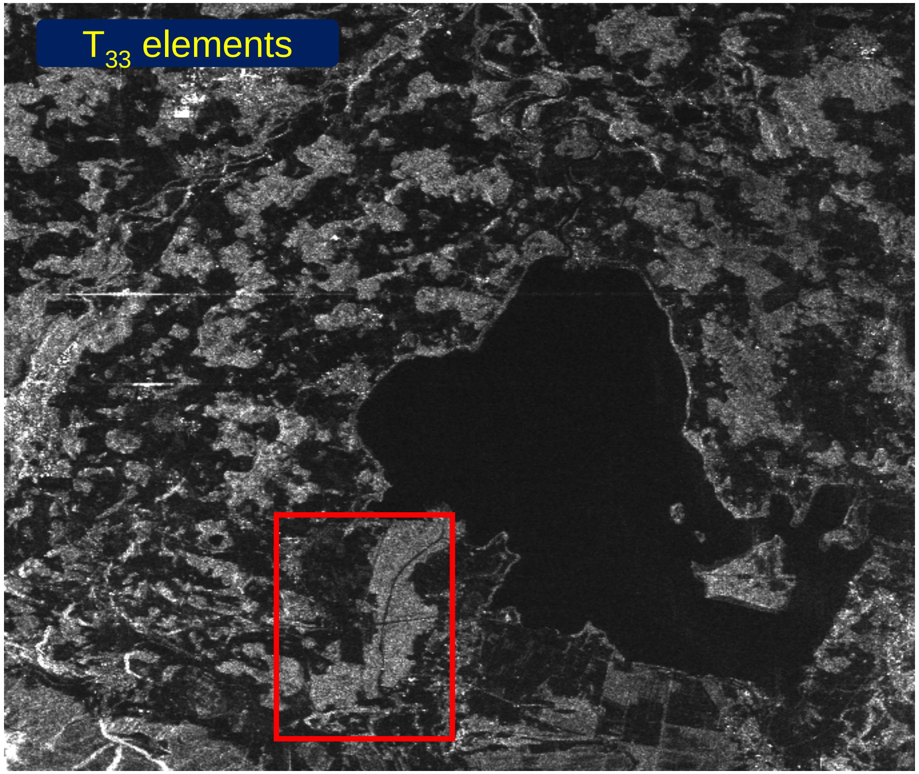
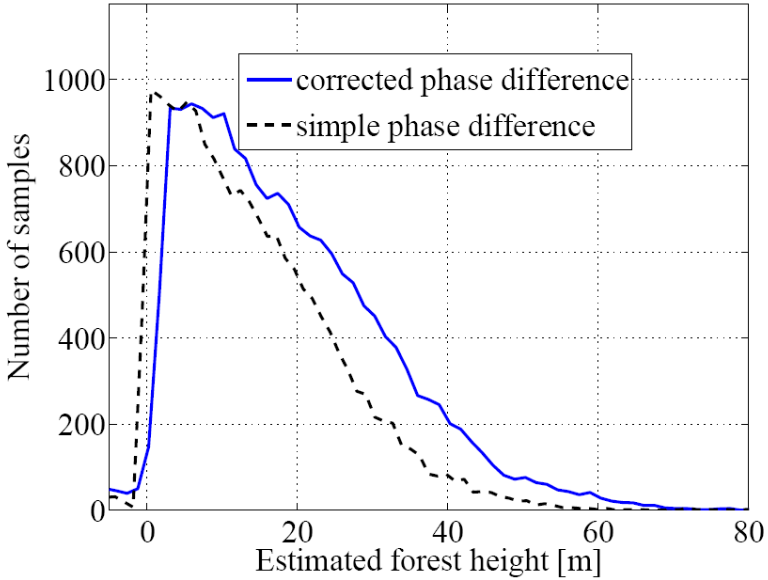


→ Amount of height correction depends on the local terrain slope and forest height



Proposed approach VS RVoG

Preliminary forest parameters inversion

Pro
Con

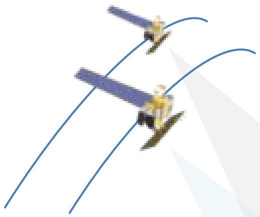
PolSARProSIM approach

- Slow in computing the model output (Con)
- The inversion must be accurately defined (polarization or frequency diversity) (Con)
- Model inputs includes many scene parameters (Pro)
- Inversion uses the slope information from external DEM (Pro)
- Require the generation of LUT that depends on the acquisition geometry (Con)

RVoG inversion

- Fast implementation and computational time (Pro)
- Inversion procedure is well defined (Pro)
- Model inputs are trees height, ground-to-volume ratio, canopy extinction (Con)
- Fitting of the line can fail for small baseline dataset (Con)
- Fully automatic (Pro)

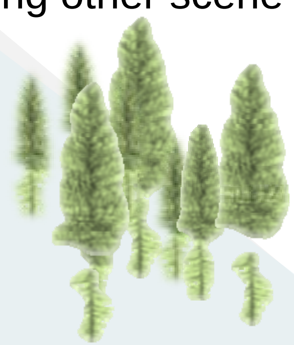
Conclusions & Future works



→Forest parameters retrieval approach
- Uses a PolInSAR coherent EM model (PolSARProSIM)
- Optimum interferograms are based on the maximization of the magnitude difference among coherence values
- Preliminary inversion based on compensation of terrain slope effects and volume wave penetration

→Application to PALSAR data
- Temporal decorrelation is the main limitation of PolInSAR technique
- Preliminary inversion has promising results

→ Future challenges
- Development of a full inversion procedure including other scene parameters
- Integration of SAR/PolSAR information



Proposed approach

PolInSAR optimum coherence

→Coherence region in the complex plane calculated through the *field of values* F of the normalized coherency matrix $T_{11}^{-1/2}\Omega_{12}T_{22}^{-1/2}$

→Different Optimisation algorithms (SVD, numerical radius, phase diversity, etc.)

→ Iteration for the maximization of magnitude difference

$$\max_{\gamma_i,\gamma_j \in F} \left|\tilde{\gamma}_i - \tilde{\gamma}_j\right| \longrightarrow \quad \phi_{opt_1} = \tilde{\gamma}_{i^*}\ , \quad \phi_{opt_2} = \tilde{\gamma}_{j^*}$$

→Example of coherence boundary