SAR IMAGE PROCESSING FOR CROP MONITORING

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Agriculture and Vegetation at a Local Scale

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CONTENTS

I. CONTEXT

$$pixel = \underbrace{\underbrace{A}_{amplitude}}_{SAR} \exp(j \underbrace{\underbrace{\underbrace{\phi}_{phase}}_{InSAR}) \underbrace{\underbrace{\vec{p}}_{polarisation\ state}}_{PolSAR}}_{PolInSAR}$$

II. InSAR

Projects :

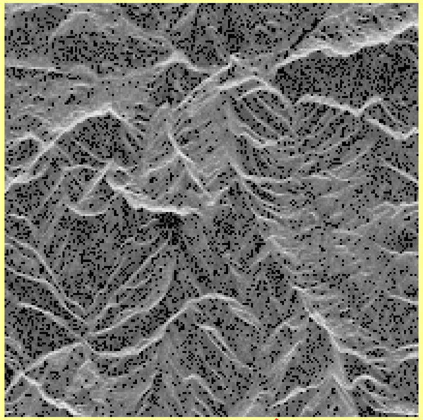
TELSAT Project T3/12/012 « Demonstration and Evaluation of SAR Interferometry » (1993-1995)
CSL

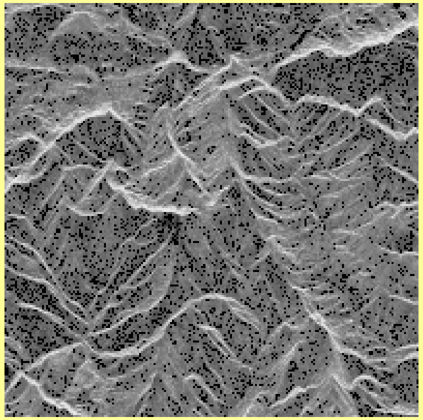
ERS Tandem Project B302 « An Assessment of SAR Phasimetry by Case Studies in Tectonics and Agronomy » (1997-1998)
CSL, FUSAGx, CRA, UCL-MILA, ULg-LGT

STEREO Project SR/00/01 « Modelling Crop Growth Based on Hydrology and Assimilation of Remotely Sensed Data » (2001-2006)
UCL, UGent, CSL

II.1 InSAR : Basic Principles

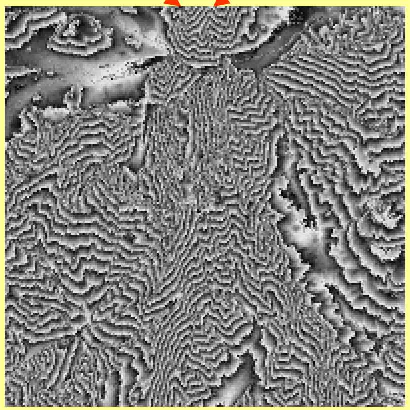
Pass 1
(μ_1)





Pass 2
(μ_2)

($\mu_1 \mu_2^*$)



Interference pattern
==> Topography, terrain and atmospheric changes

II.2 InSAR : Sample Results

InSAR Coherence for Crop Parameters Monitoring

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**Proc. FRINGE'99 Symp., Liège 10-12 Nov. 1999,
ESA SP-478**

Basic Product : the Coherence Map

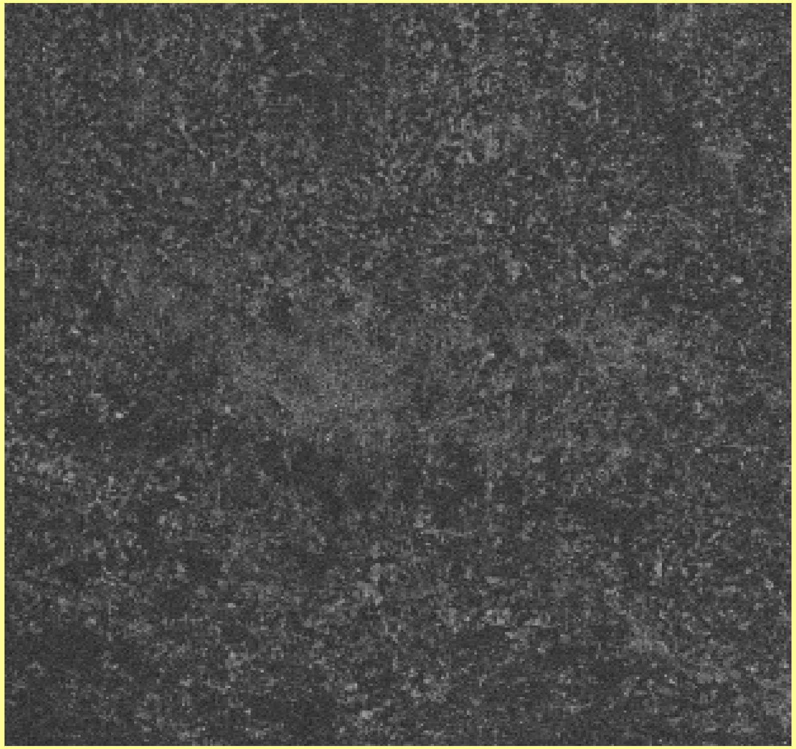
$$\gamma = \frac{\left|\langle \mu_1 | \mu_2^* \rangle\right|}{\sqrt{\langle \mu_1 | \mu_1^* \rangle \langle \mu_2 | \mu_2^* \rangle}}$$

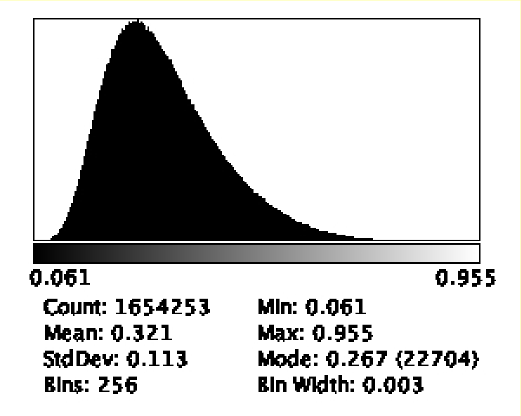
$$= \gamma_{SNR}\, \gamma_{Baseline}\, \gamma_{Tempor}$$

(ERS acquisition over Belgium:

region of Charleroi - 03 & 04/1996

Interfererometric baseline = 330 meters)





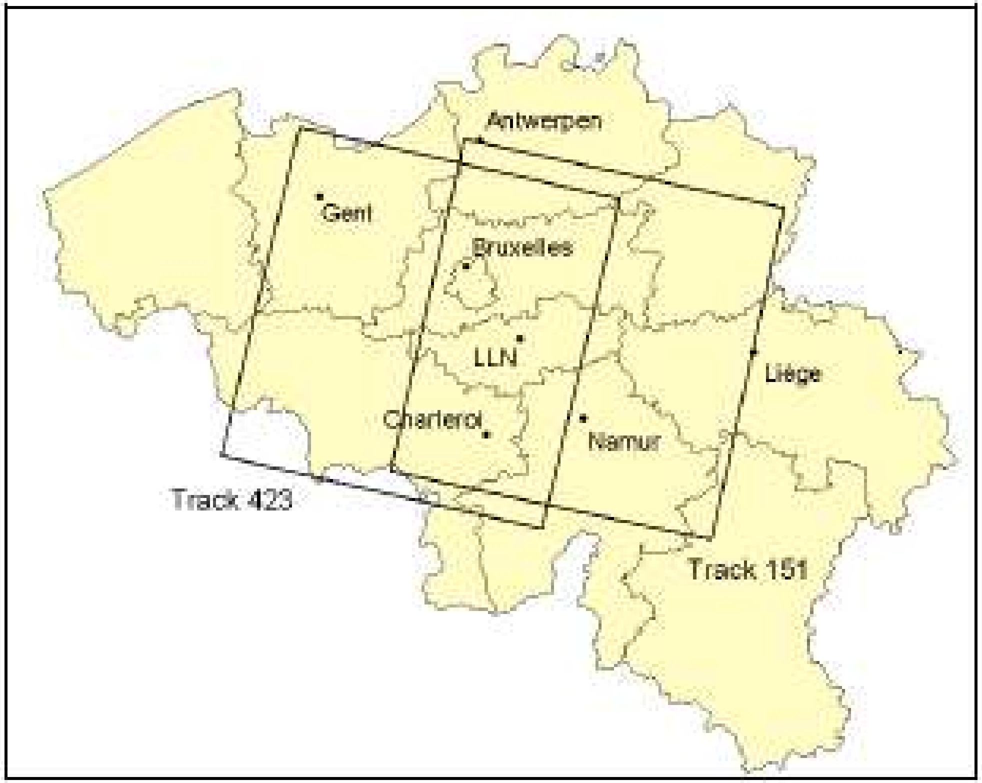


Figure 1: Localisation of the two set of images over the study area.

Strong relationships between the plant height and the coherence are observed for the 4 crops. A prediction model of the wheat height has been computed and the mean absolute error of about 7 cm seems compatible with the information requirements for a crop monitoring systems. The shape of these relationships varies according to the crop structure and their respective development type.

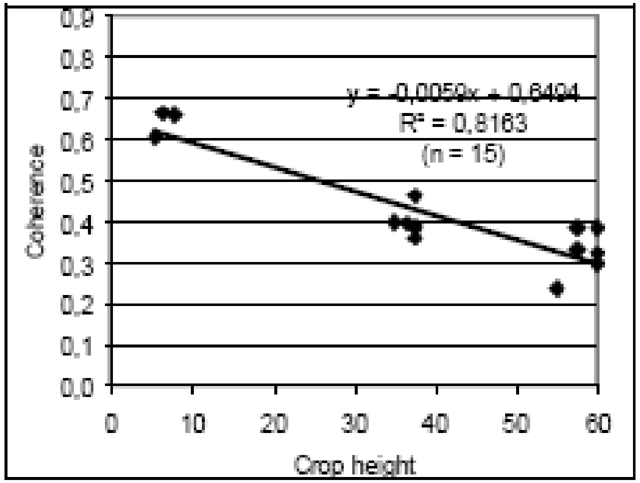


Figure 7: Linear regression between the tandem coherence and the potato height.

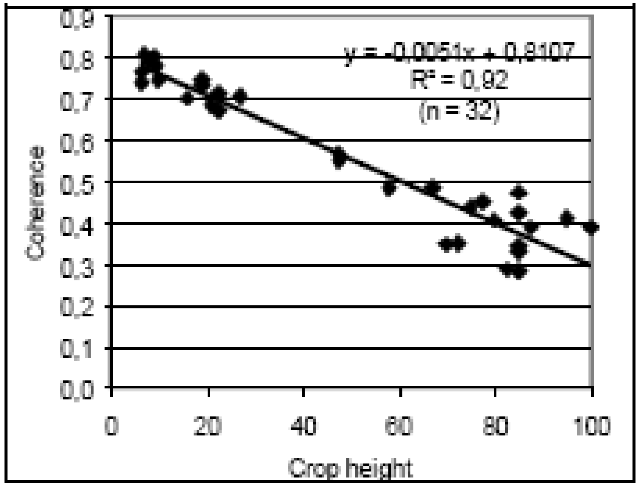


Figure 5: relationship between the tandem coherence and the winter wheat height.

III. PolSAR

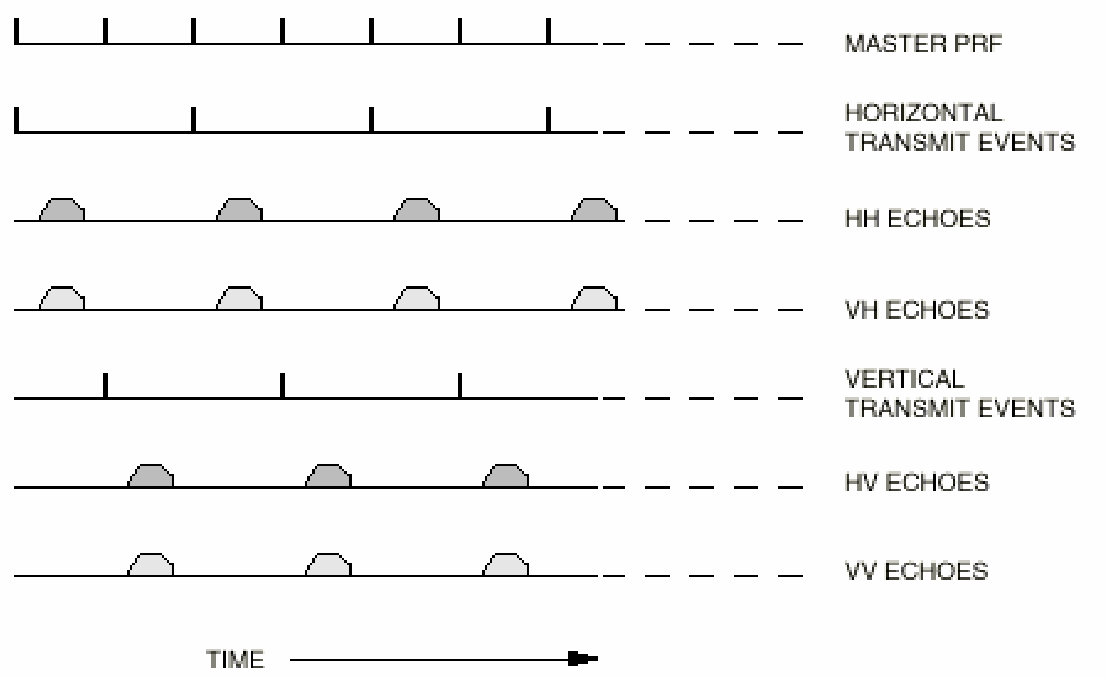
Projects :

Project SA/12/001 « Development of a SAOCOM SAR Processor» (2000 - 2008)
CSL, SPACEBEL

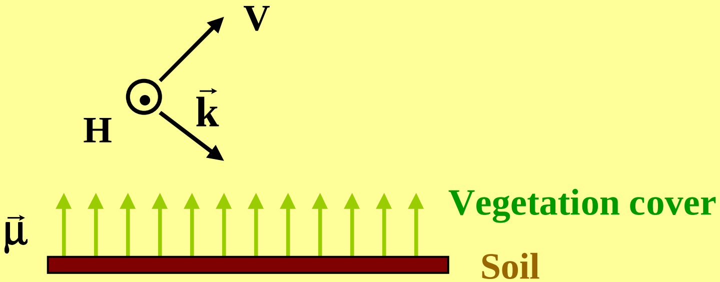
STEREO Project SR/00/01 « Modelling Crop Growth Based on Hydrology and Assimilation of Remotely Sensed Data » (2001-2006)
UCL, UGent, CSL

III.1 PolSAR : Basic Principles

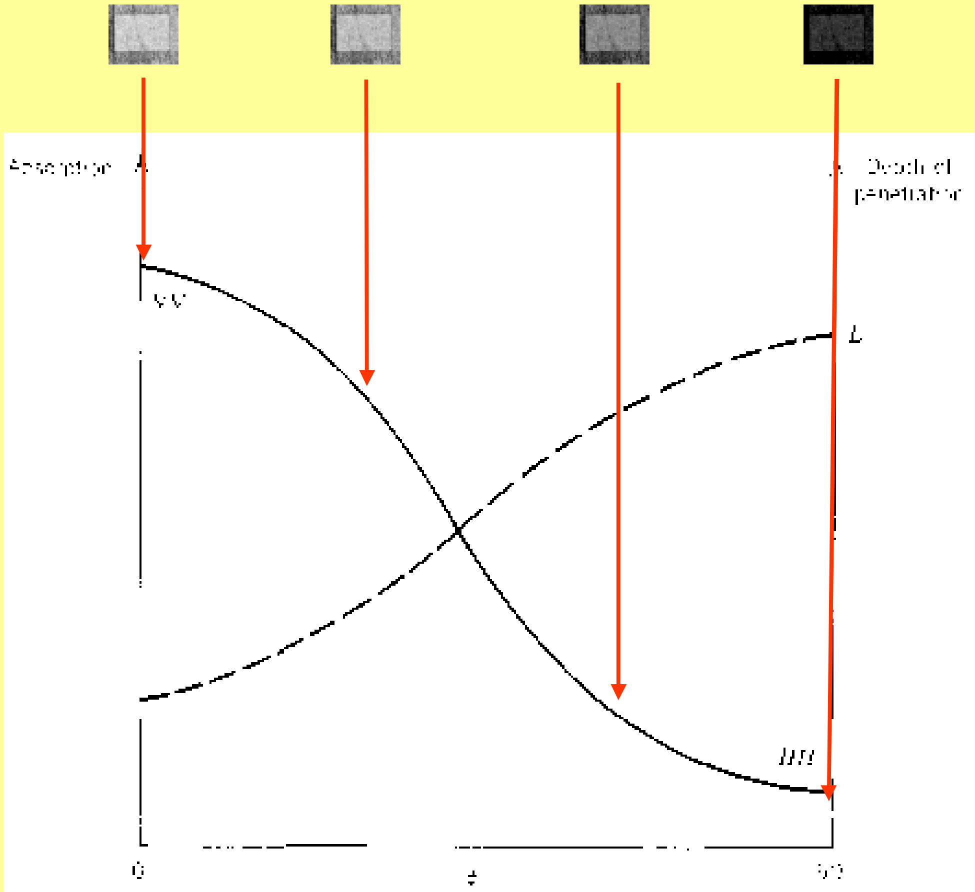
- **Single-polarization mode**
  - transmit in 1 single linear polarization: H or V
  - receive in the same polarization
  - *1 acquisition:* ***HH*** *or* ***VV***
- **Dual-polarization mode**
  - transmit in H or V
  - receive in H and V
  - *2 acquisitions:* ***HH/HV*** *or* ***VV/HV*** *or* ***HH/VV***
- **Quad-polarization mode**
  - transmit alternatively H and V
  - receive in H and V
  - *4 acquisitions:* ***HH HV VH VV***



PolSAR provides scattering mechanisms information.



$$U_{int} = -\vec{\mu}.\vec{E}$$



III.2 PolSAR : Sample Results

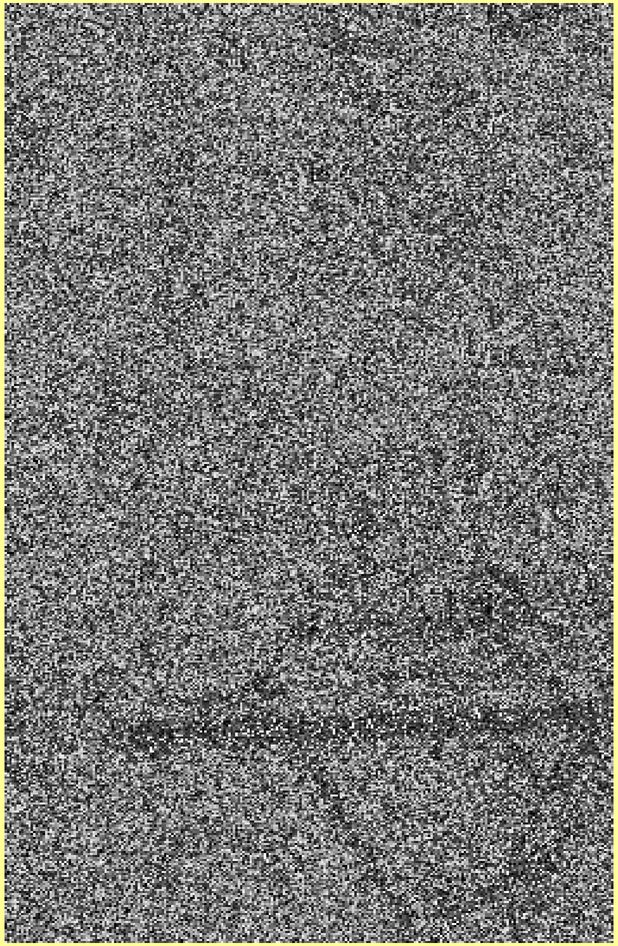
Polarimetric Processor

→ Input: images produced by the SAR processor

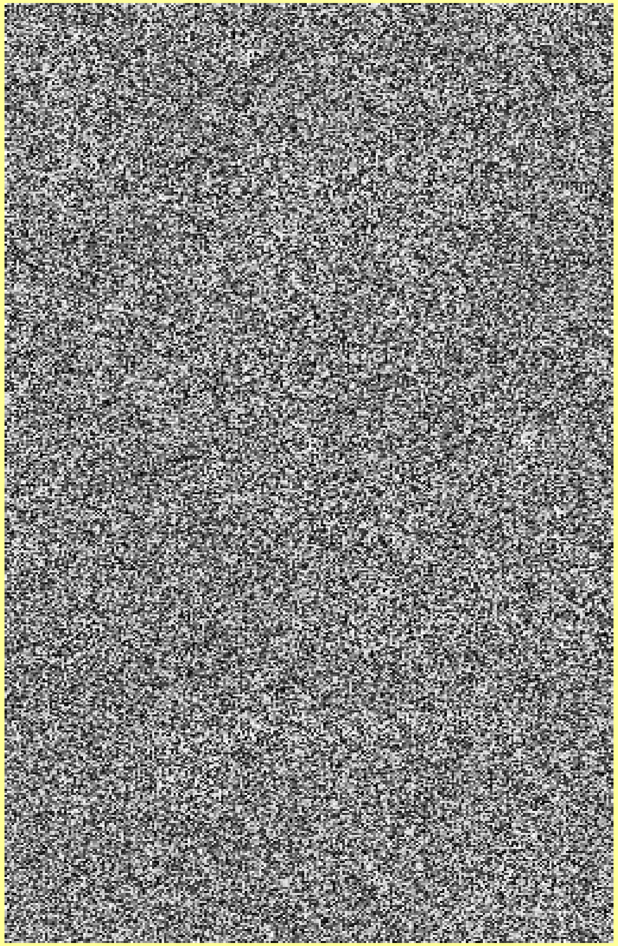
- **Backscattering coefficient images σ°**
- **Quad-polarimetric processor**
- **Dual-polarimetric processor**

1.Backscattering Coefficient Images

$\sigma°_{VV}$



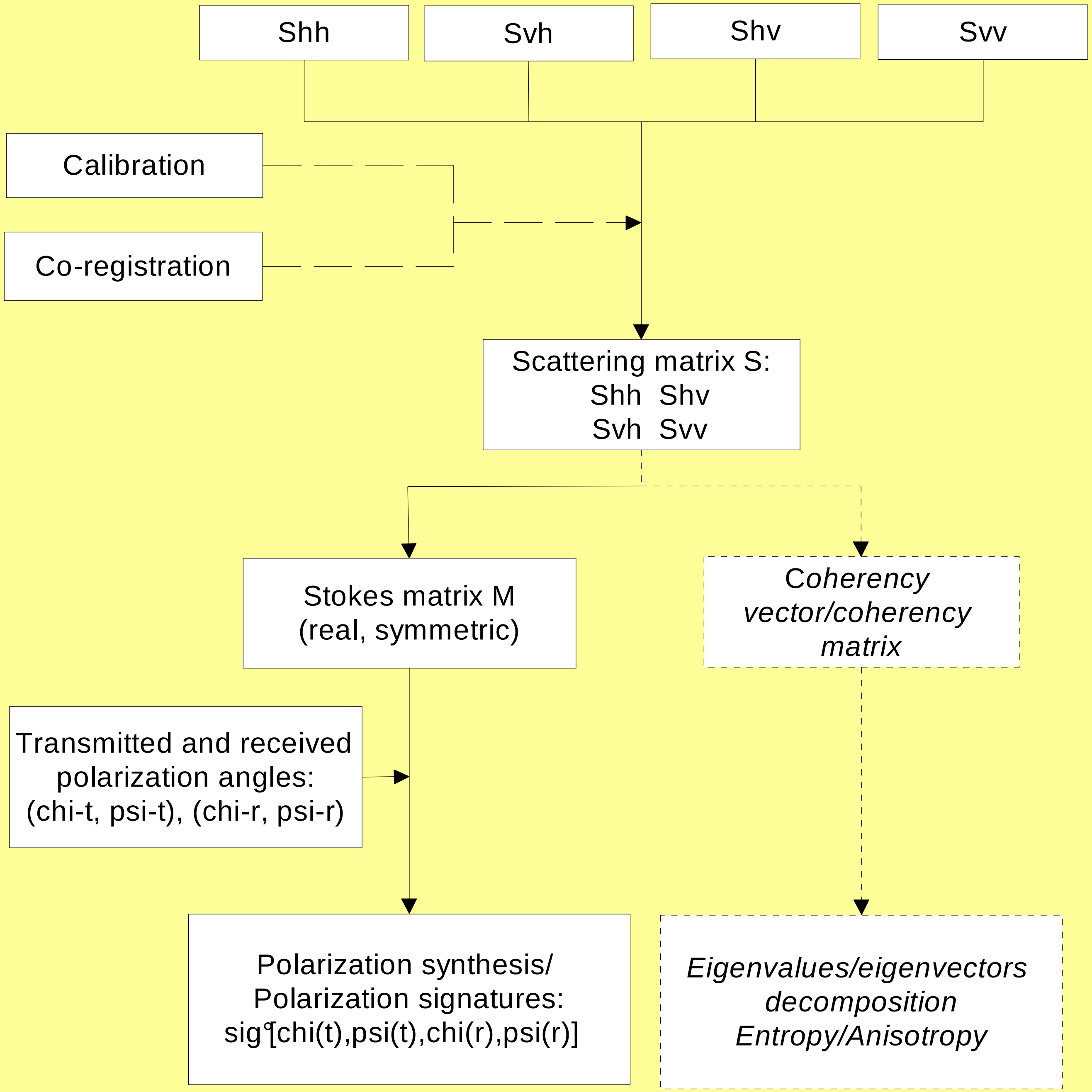
$\sigma°_{HH}$



$\sigma°_{HV}$

All the images presented here have been produced at CSL, using polarimetric data provided by the DLR

2. Quad-Polarimetric Processor



Decomposition H/A/α

H

α

A

$$H = -\sum_{i=1}^{3} P_i \log_3(P_i)$$

$$P_i = \frac{\lambda_i}{\sum \lambda_i}$$

α target scattering type [0°,90°]

$$A = \frac{\lambda_2 - \lambda_3}{\lambda_2 + \lambda_3}$$

Classification methods based on **scattering mechanisms**:

urban areas, forests, vegetated/non-vegetated, clear-cut, water/ice surfaces…

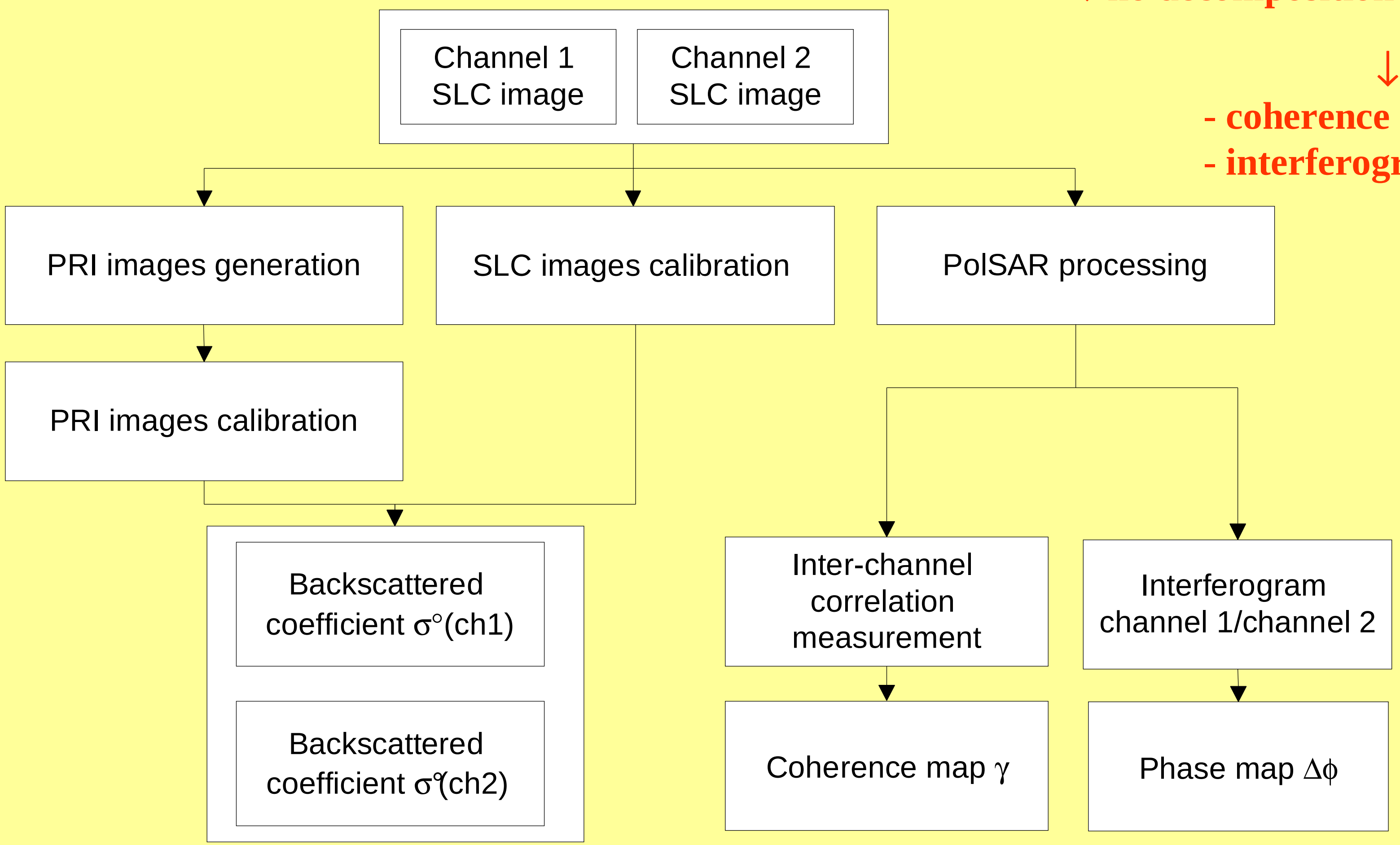
3. Dual-Polarimetric Processing

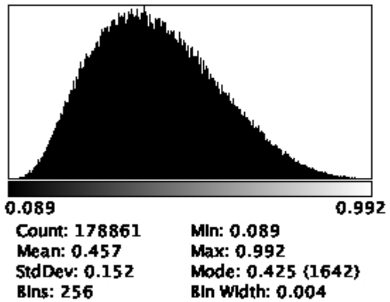
2 measurements: HH/HV or VV/HV

→ no polarization synthesis
→ no decomposition algorithm

↓

- coherence analysis
- interferogram





Coherence HH/VV

Interferogram HH/VV

IV. PolInSAR

Project :

STEREO Project SR/00/53 «Polarimetric SAR Interferometry » (2001-2006)
CSL, UCL, RMA

IV.1 PolInSAR : Basic Principles

PolInSAR = vector InSAR

InSAR → height information
PolSAR → scatteing mechanisms information

PolInSAR → height distribution of scattering mechanisms

IV.2 PolInSAR : A Picture Book Example

S.R. Cloude and K.P. Papathanasiou,
"Polarimetric SAR Interferometry",
IEEE Trans. Geosci. Remote Sensing 36(5), 1551-1656 (Sept. 1998)

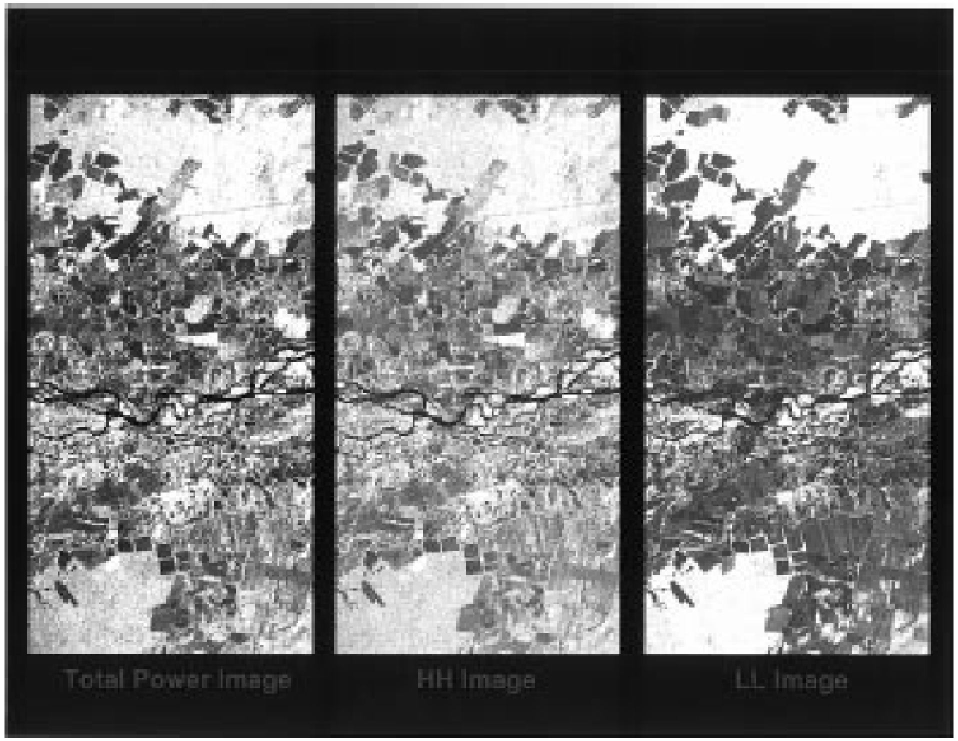


Fig. 1. SAR images of the test area across the Selenga delta at SE Lake Baikal. (Tien Shan test site, latitude N 52.16°, longitude E 106.67°). (a) Total power image, (b) HH image, and (c) LL image.

The Coherence Maps

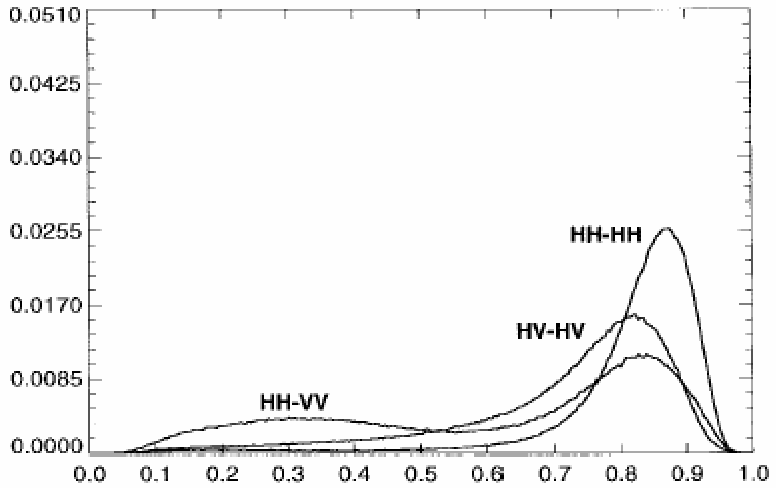


Fig. 3. Coherence histograms in the (H, V)-polarization basis.

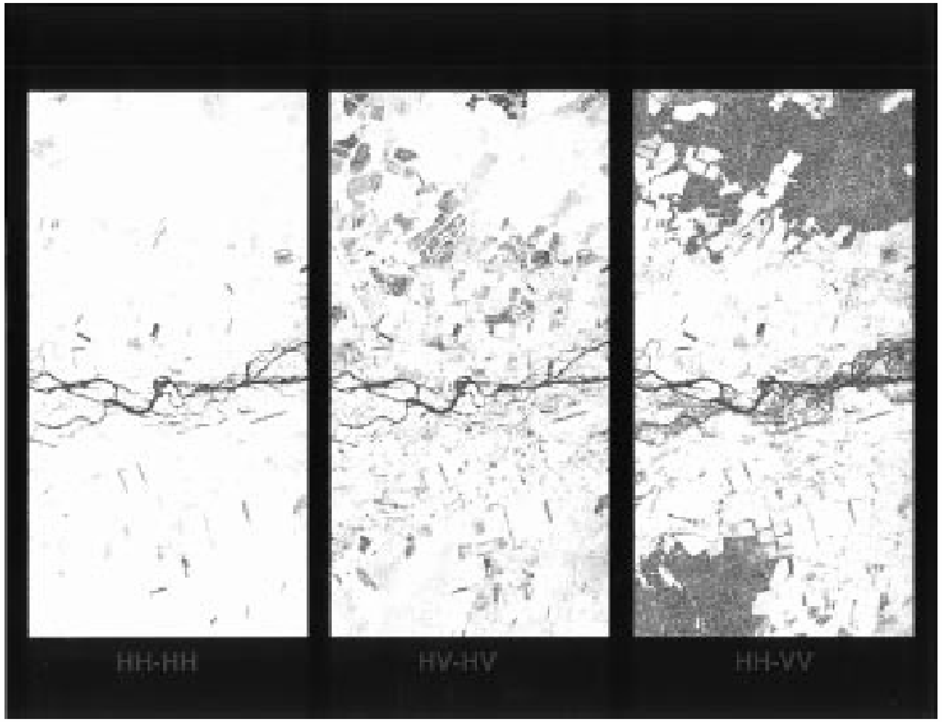


Fig. 2. Coherence maps of interferograms in the (H, V)-polarization basis (Left: HH–HH. Middle: HV–HV. Right: HH–VV).

Decomposition Into Coherence-Optimized States

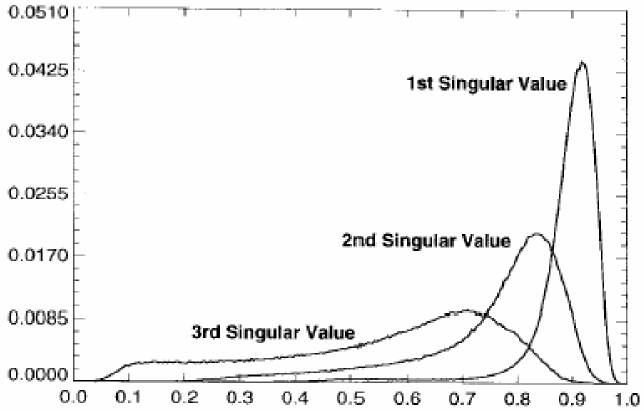


Fig. 6. Coherence histograms of the optimized interferograms.

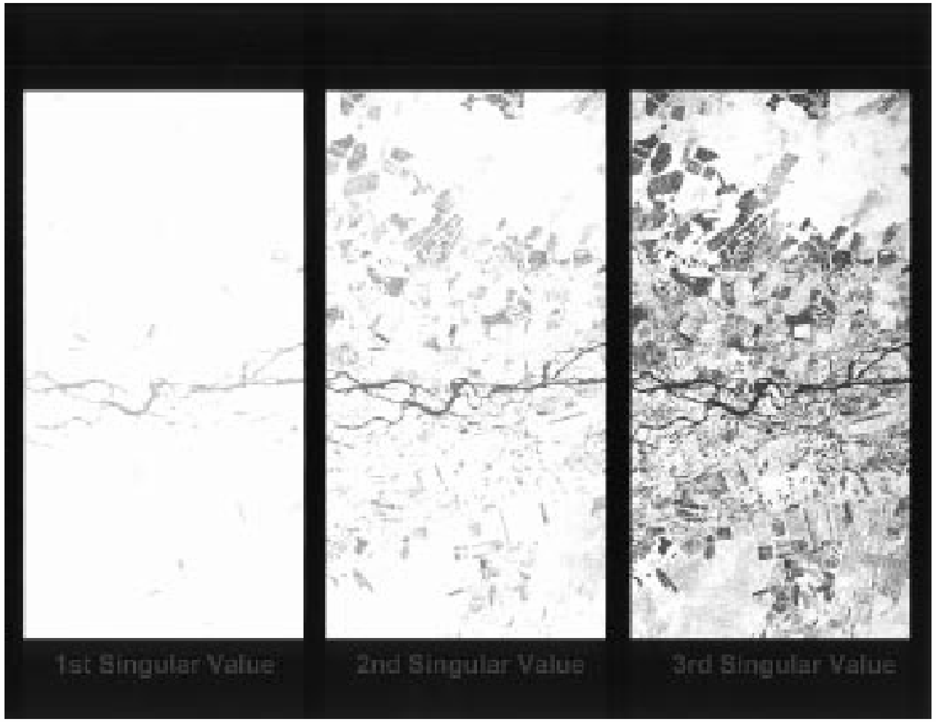


Fig. 7. Coherence maps of interferograms generated by using the optimum scattering mechanisms related to the first (left), second (middle), and third singular value (right).

Interpretation through a MODEL

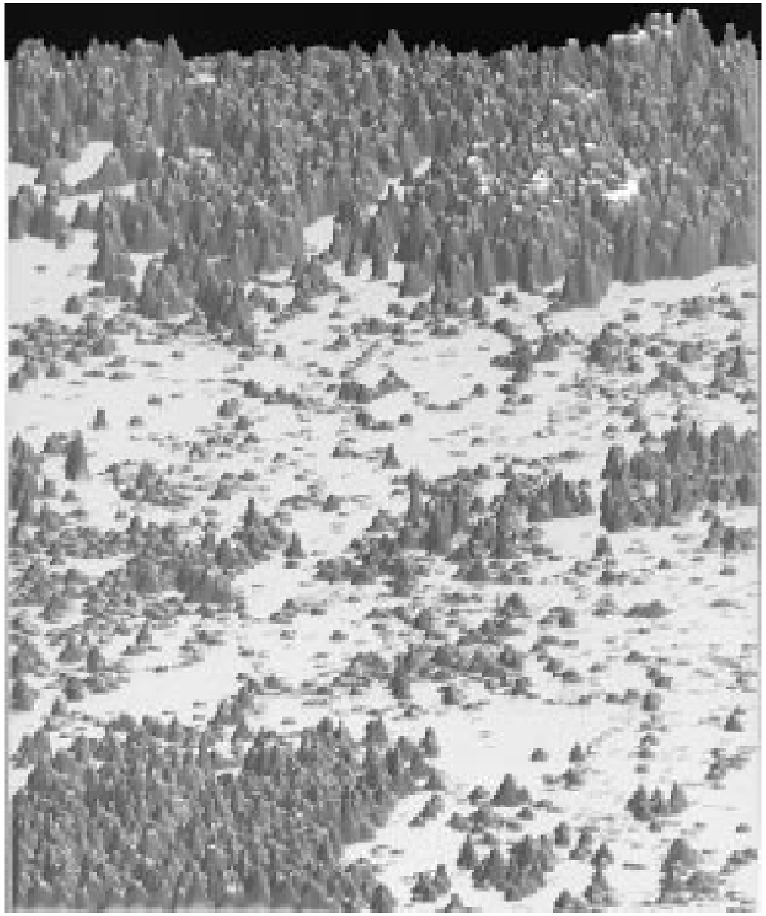


Fig. 9. Three-dimensional representation of the height difference between effective phase scattering centers of the forested areas.

V. CONCLUSIONS AND PERSPECTIVES

1) **ALL processing tools are now developed and available at CSL**

2) **Need of DATA**

- **Reliable acquisition plans**

- **Future sensors (RADARSAT-2, TerraSAR X, ALOS, SAOCOM,…)**