Project ID5344

ESA - MOST Dragon 2 Programme

中国科技部-欧洲空间局合作 "龙计划"二期

2011 DRAGON 2 SYMPOSIUM

“龙计划”二期2011年学术研讨会

Forest Structure Information Extraction from PolinSAR/PolSAR Data

Erxue, Chen[1]; Zengyuan, Li[1]; Wen, Hong[2]; Eric, Pottier[3]; Shane, Cloude[4]

[1] *Insitute of Forest Resources Informaiton Technique, CAF.CHINA*
[2] *Intitute of Electronics, CAS, CHINA;*
[3] *I.E.T.R - Univ Rennes 1, FRANCE;*
[4] *AEL Consultants, UNITED KINGDOM*

Project Objectives

DRAGON 2 – Project ID5344

Techniques for Deriving Land Cover and Earth Surface Deformation Information from Polarimetric SAR Interferometry

WP 1
Land Cover Analysis

WP 2
Earth Surface Deformation Monitoring and DEM Extraction

WP 3
Forest Vertical Structure Parameters Extraction

WP 4
PolSARpro Software Continued Development

Outlines

WP 1: Land Cover Analysis

----Forest Fire Scar Mapping Using C- and L-band Polarmetric SAR

WP 2: Earth Surface Deformation Monitoring and DEM Extraction

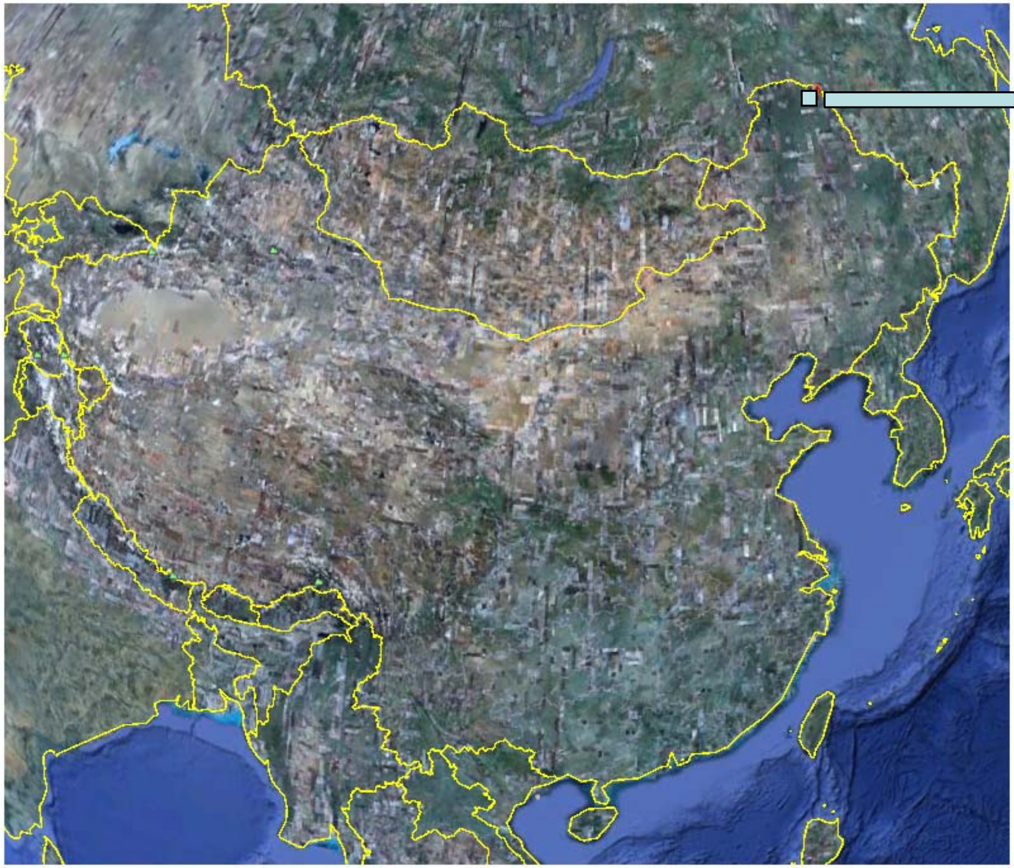
---- Applying coherence optimization methods to DEM extraction from ALOS POLinSAR data

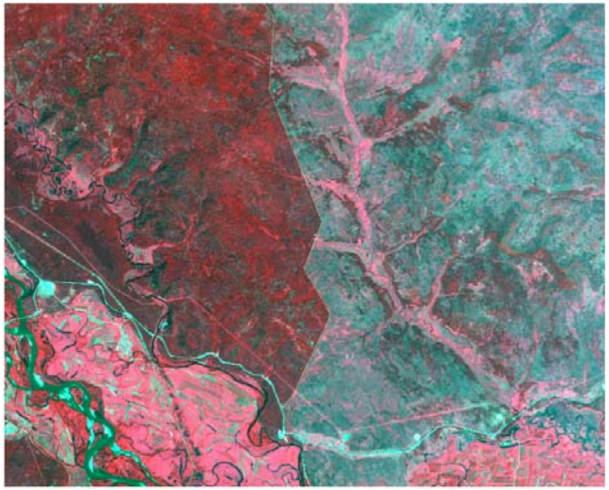
WP 3: Forest Vertical Structure Parameters Extraction

----Forest above Ground Biomass Estimation based on Polarization Coherence Tomography

Forest Fire Scar Mapping Using C- and L-band Polarmetric SAR

TEST SITE & DATA





Test site center: 52°26'N, 125°32'E

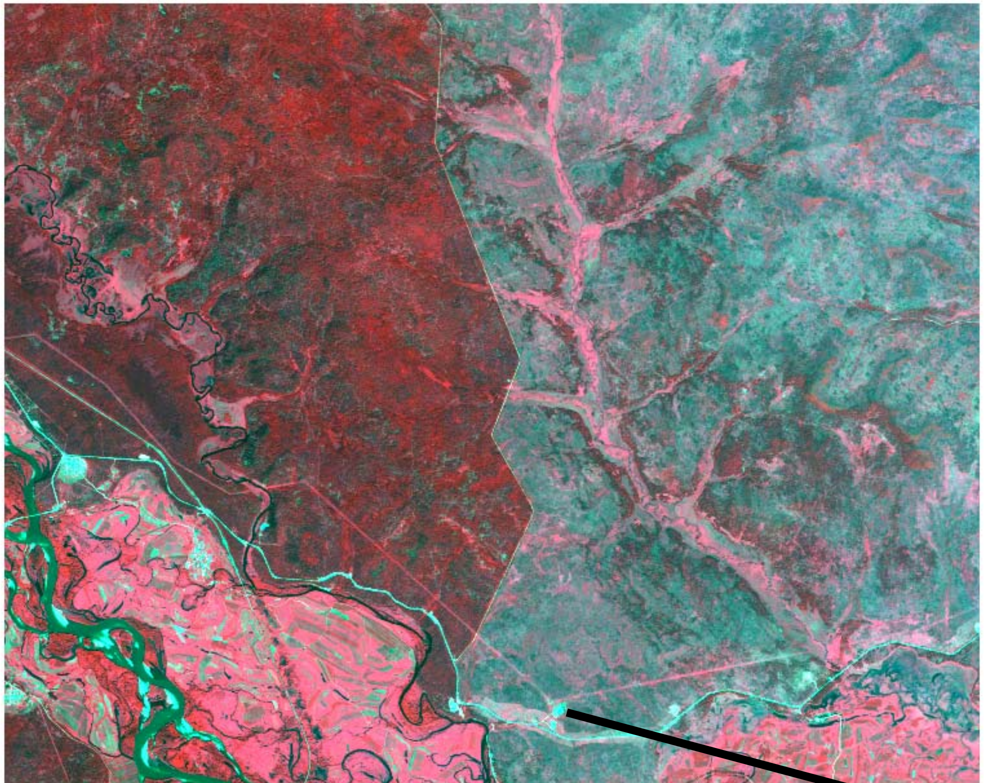
In Tahe County, Heilongjiang Province, China

Climate Zone: Cold temperate zone.

Relatively flat with an average elevation ~330 m, slope less than15°.

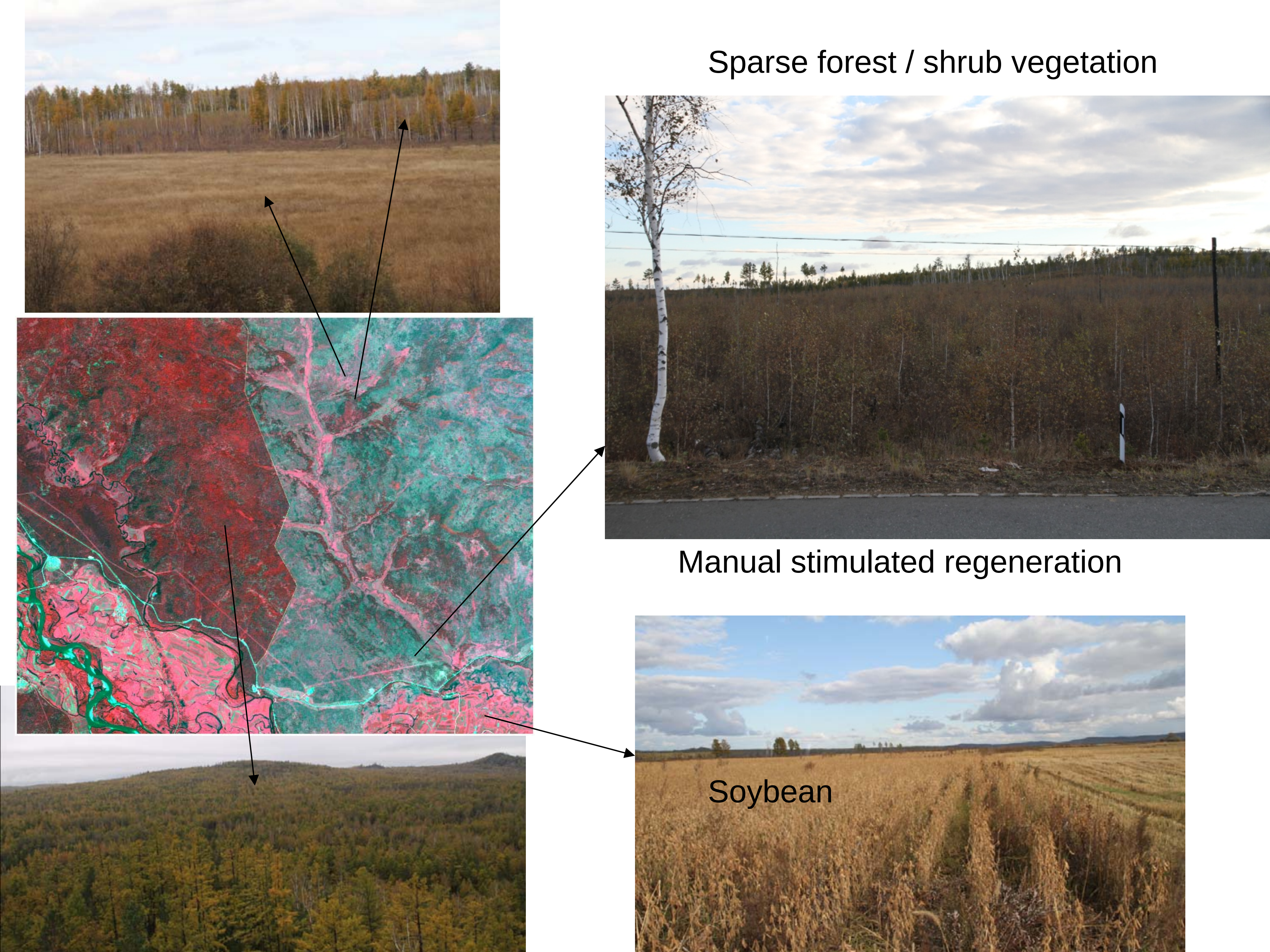
Key dominate tree species: Larch and White Birch.

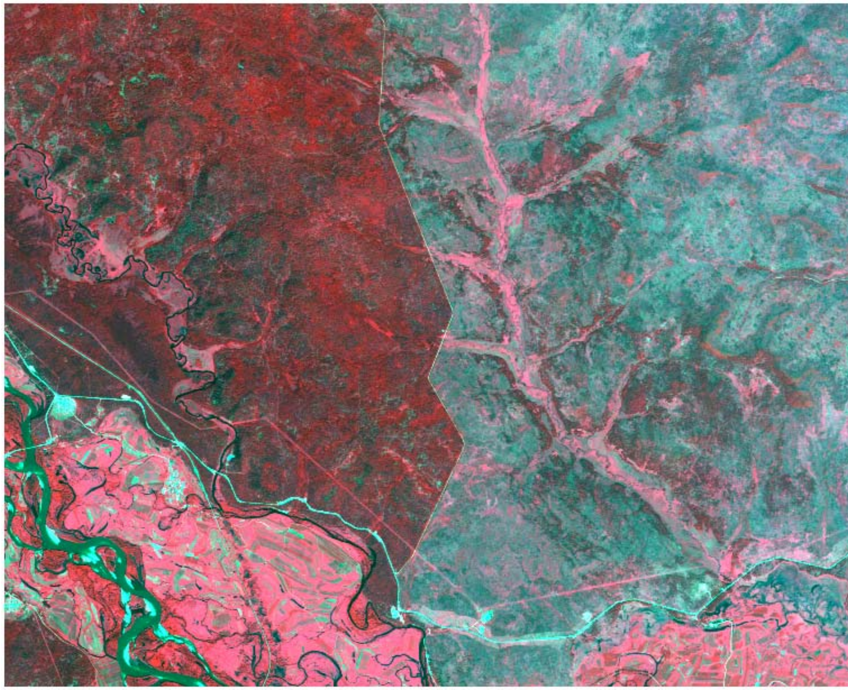
One forest fire occurred in May 17, 2003

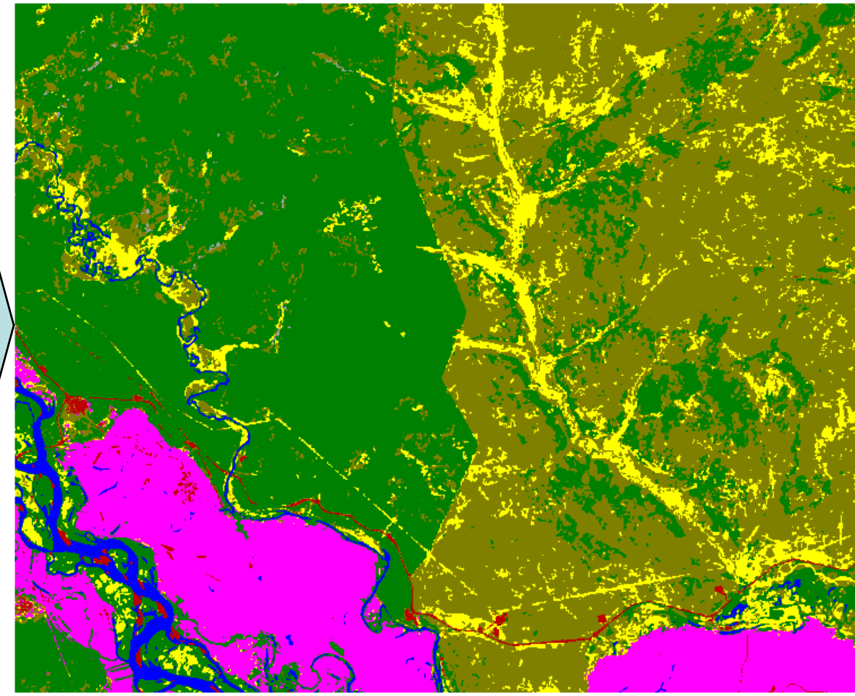


SPOT5 multi-spectral image (R: NIR;G: Red; B:Green)

Imaging date: July 27, 2006


Sparse forest / shrub vegetation
Manual stimulated regeneration
Soybean





SPOT 5 10m multi-spectral (R: NIR; G: R; B:G)

Land cover map from SPOT5 images

Imaging date: July 27, 2006

- Forest
- Grass
- Agriculture field
- Shrub
- River
- Urban, road, bare
- Others

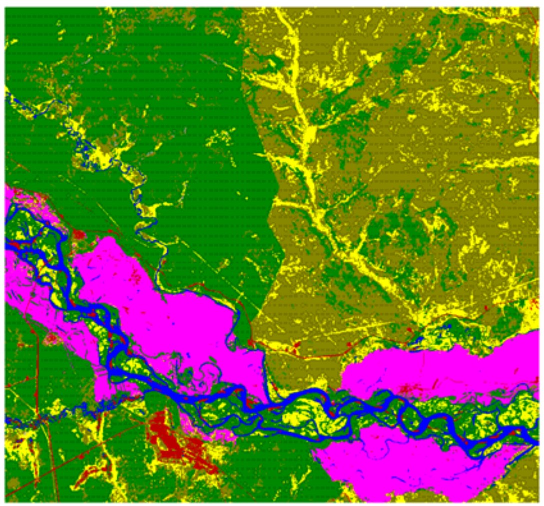
SAR data

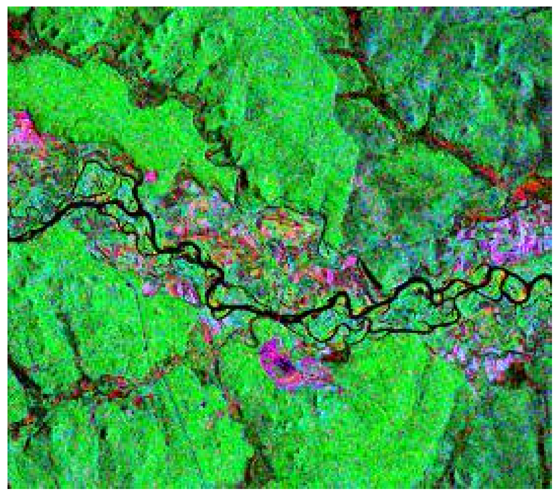
Data Types	Polarization	Imaging Date (y m d)	Incidence Angle (deg)	Orbit direction
PALSAR	HH,HV	20090702	38.7	Ascending
PALSAR	HH,HV	20090817	38.7	Ascending
PALSAR	Quad-pol	20080907	23.9	Descending
Radarsat-2	Quad-pol	20090714	38.4	Descending
Radarsat-2	Quad-pol	20091018	38.4	Descending

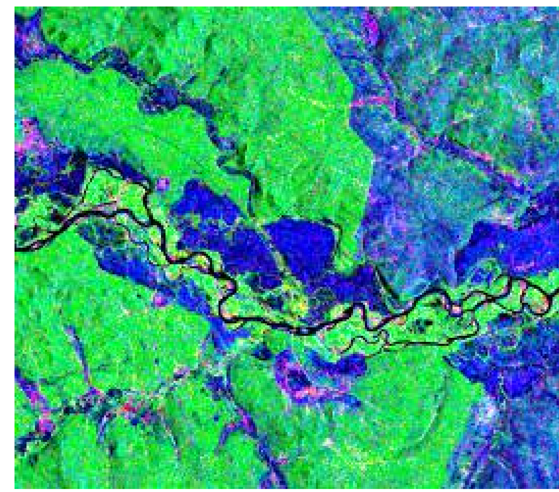
➢The Effect of Imaging Season to Forest Scar Mapping

Land cover map

Radarsat-2 data: Freeman decomposition results







Imaging date: 20060727

Wet, Summer Season

Imaging date: 20090714

Wet, Summer Season

Imaging date: 20091018

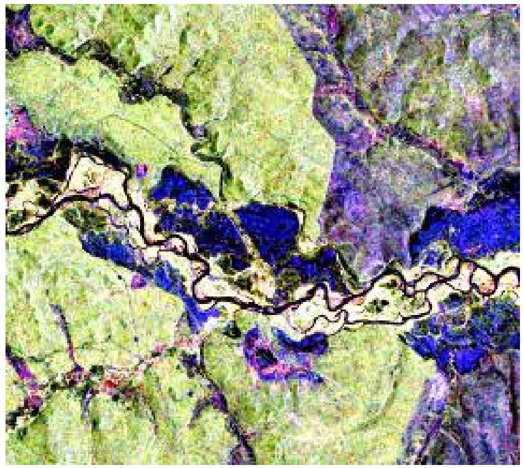
Dry, Fall Season

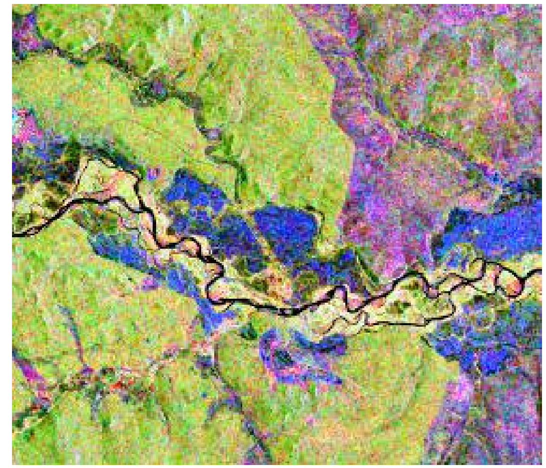
➢ The Effect of Wavelength to Forest Scar Mapping

Pauli-decomposition

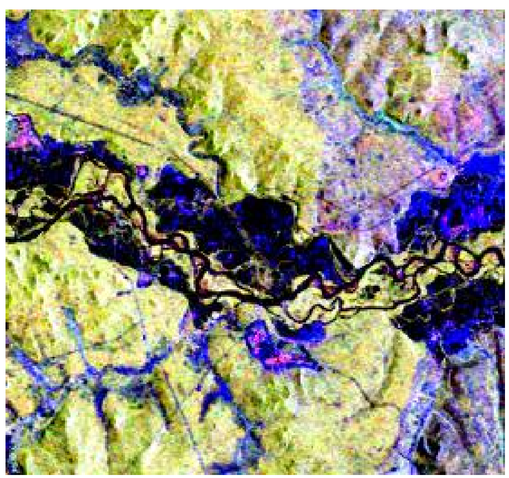
H-Alpha-A decomposition

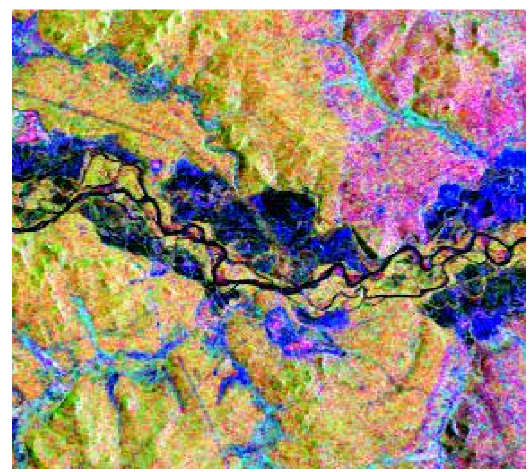
Radarsat-2 imaged in 20091018



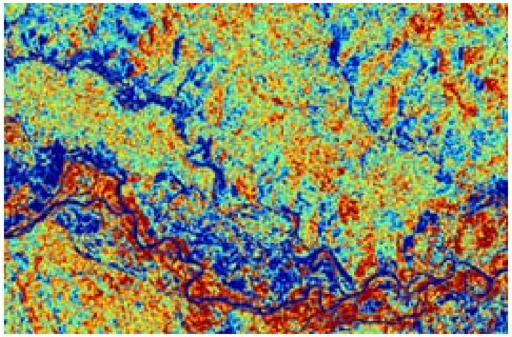


ALOS PALSAR imaged in 20080907

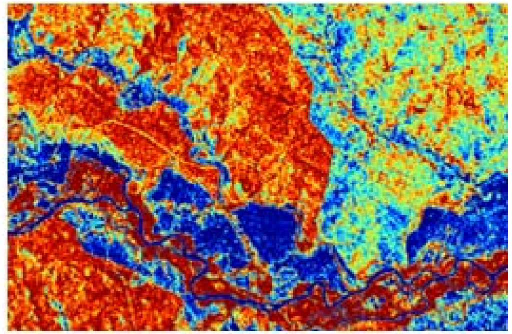




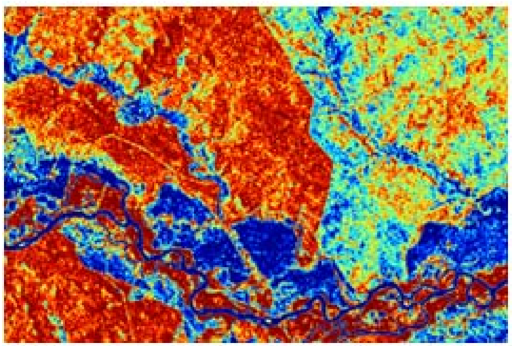
Eigen values and relevant parameters from Radarsat-2 data(20091018)



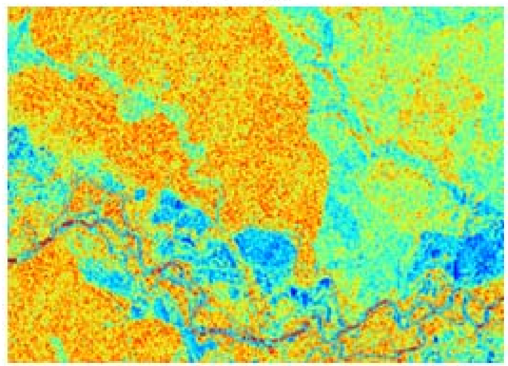
(a) λ_1



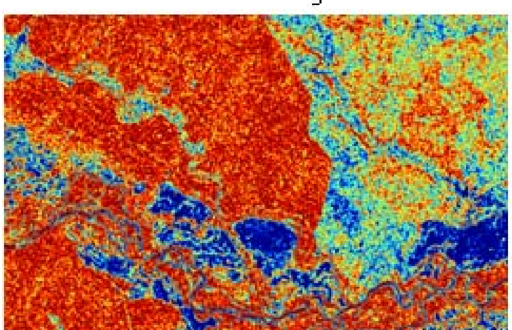
(b) λ_2



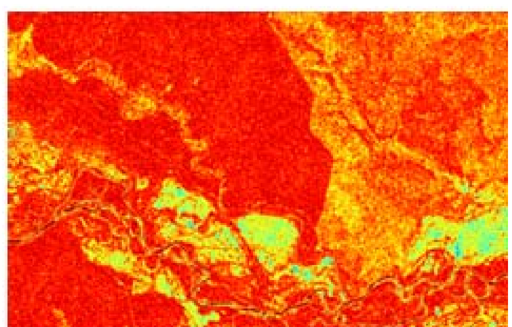
(c) λ_3



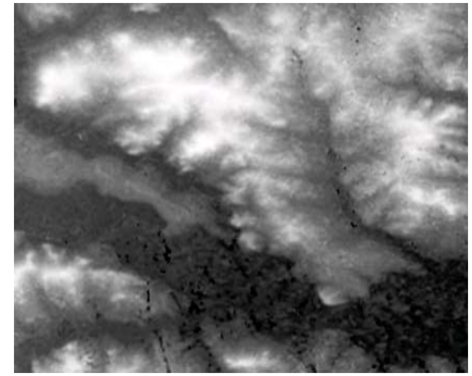
(d) RVI



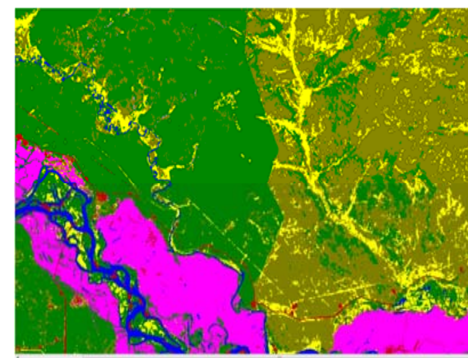
(e) SEP



(f) H

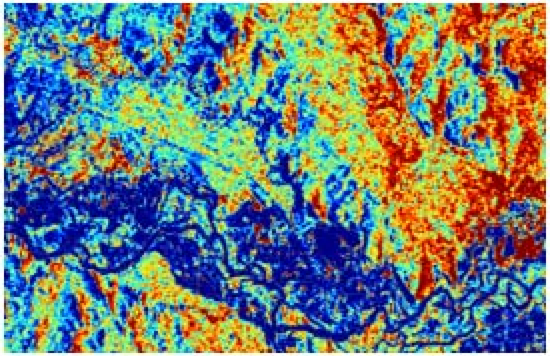


DEM

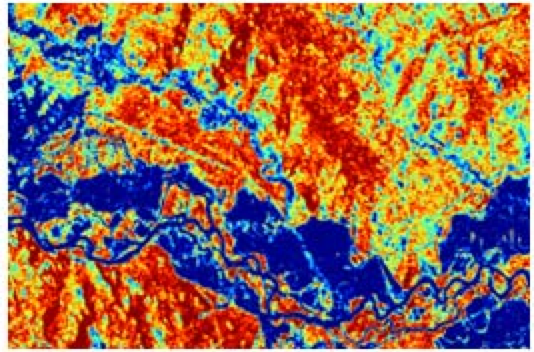


Land cover map

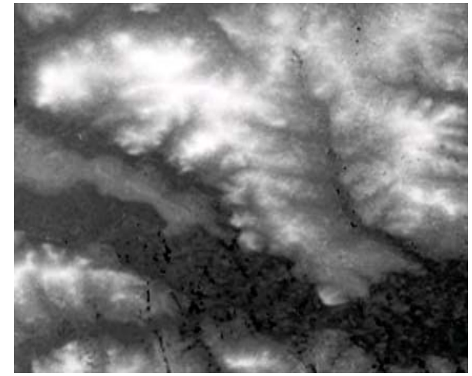
Eigen values and relevant parameters from ALOS PALSAR data (20080907)



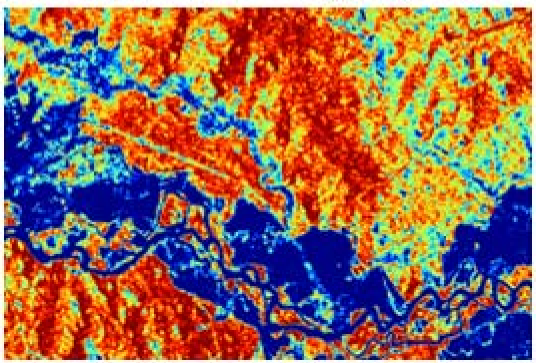
(a) λ_1



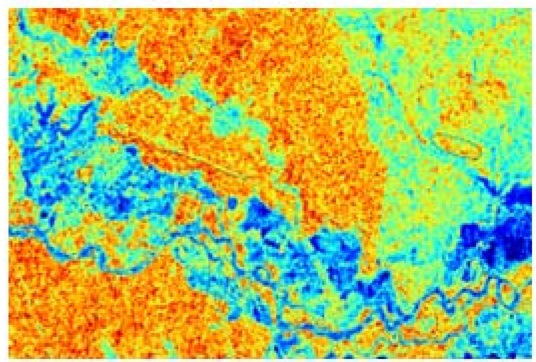
(b) λ_2



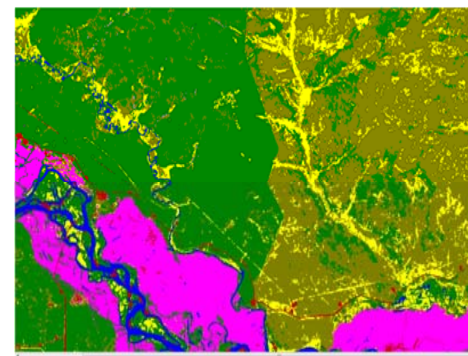
DEM



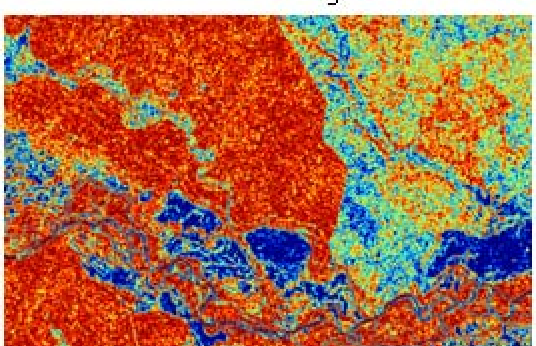
(c) λ_3



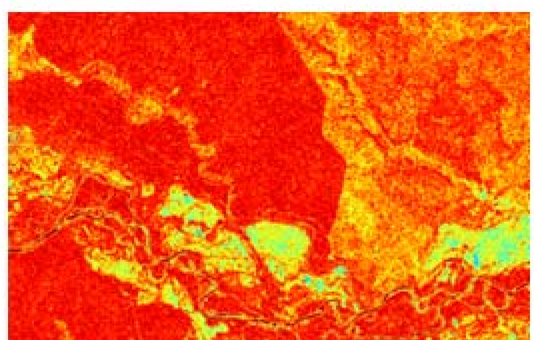
(d) RVI



Land cover map



(e) SEP

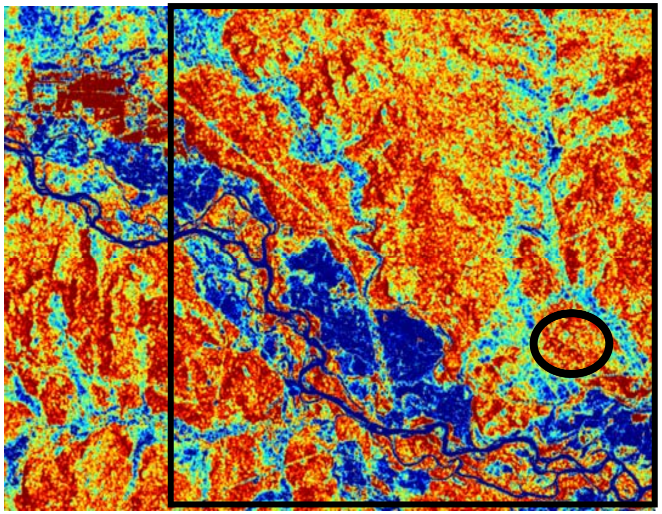


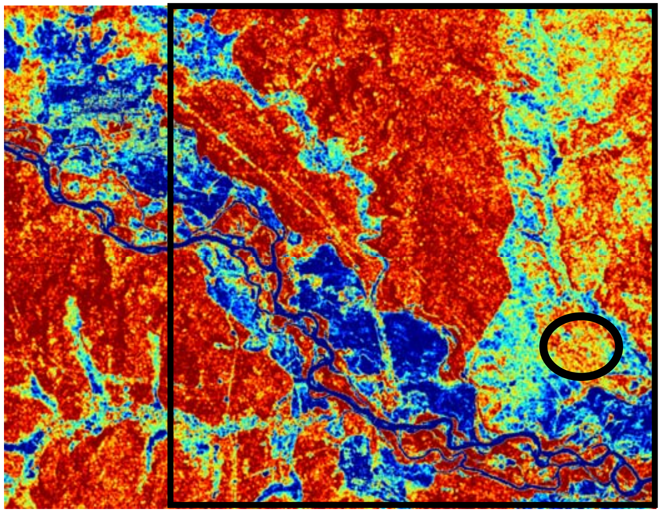
(f) H

➢Forest Scar mapping Using Dual-polarization PALSAR data

PALSAR HH+HV, imaged in 20090817

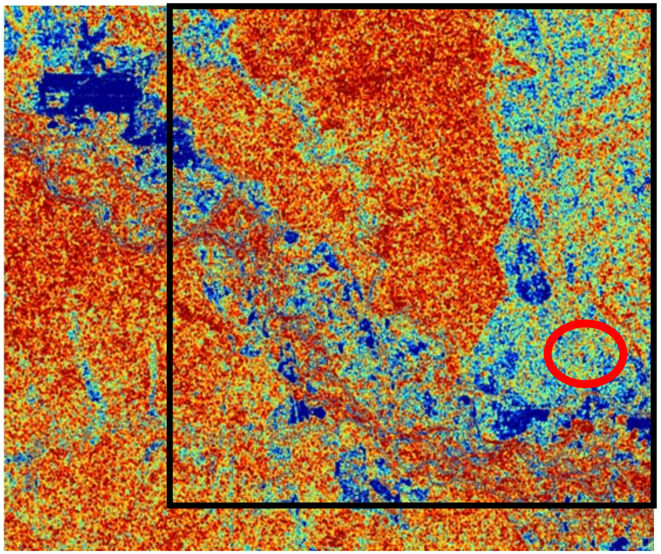
λ_1

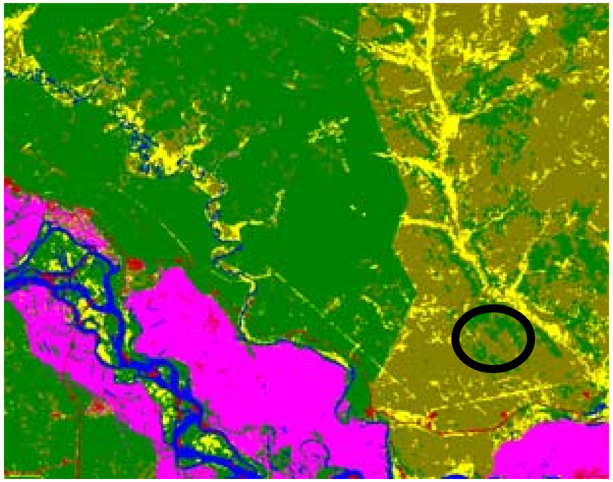




λ_2

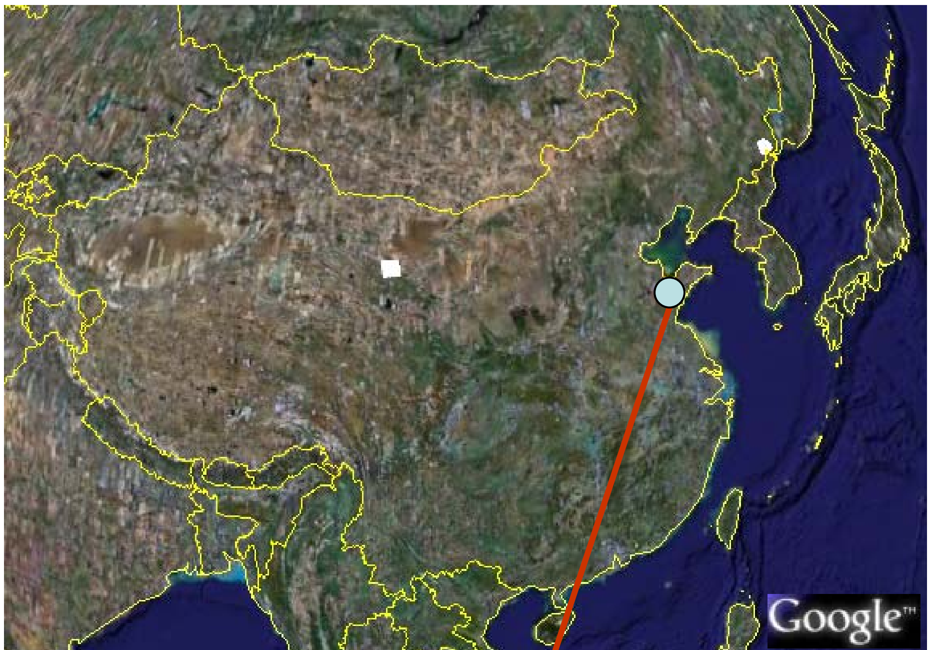
SEP





Applying coherence optimization methods to DEM extraction from ALOS POLinSAR data

Test site and data



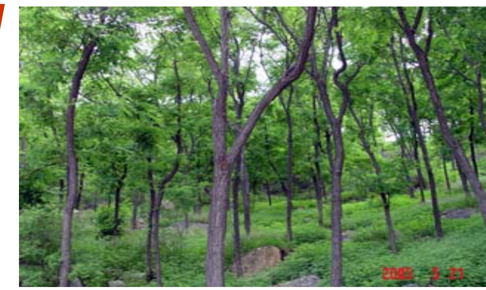
Test site location:

Taishan & Culai, Shandong Province

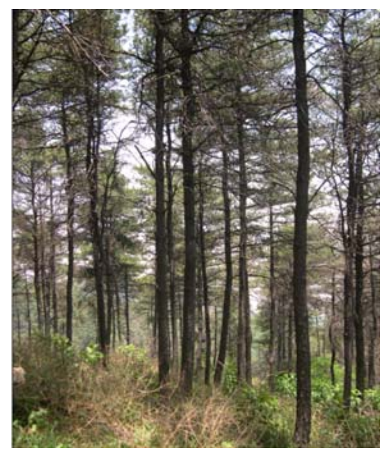
It is one warm temperate forest region;

Two major forest species:

•***Black locust, and***



•***Chinese Pine***



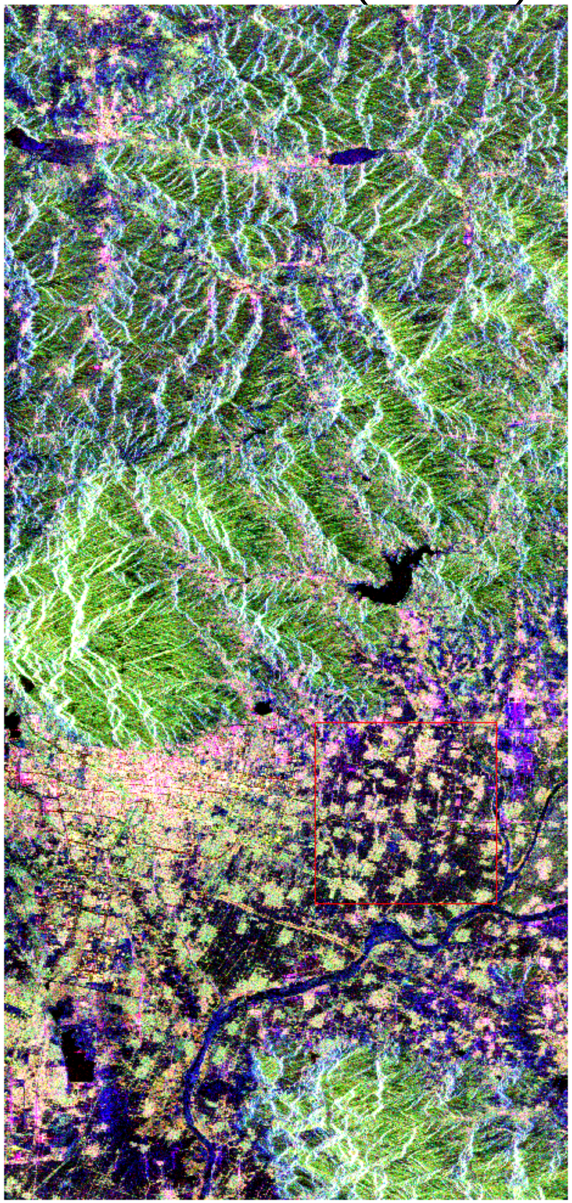
• ALOS PALSAR data for the test site

Imaging Date	Polarization	Azimuth/range pixel size (m)	Incidence angle (degree)
May 19, 2007	Quad	3.55/9.37	23.8
June 21, 2007	HH, HV	3.18/9.37	38.7
July 20, 2007	HH, HV	3.19/9.37	38.7
Sept 21, 2007	HH, HV	3.18/9.37	38.7
Oct. 20, 2007	HH, HV	3.18/9.37	38.7
April 2, 2009	Quad	3.55/9.37	23.8
May 18, 2009	Quad	3.55/9.37	23.8

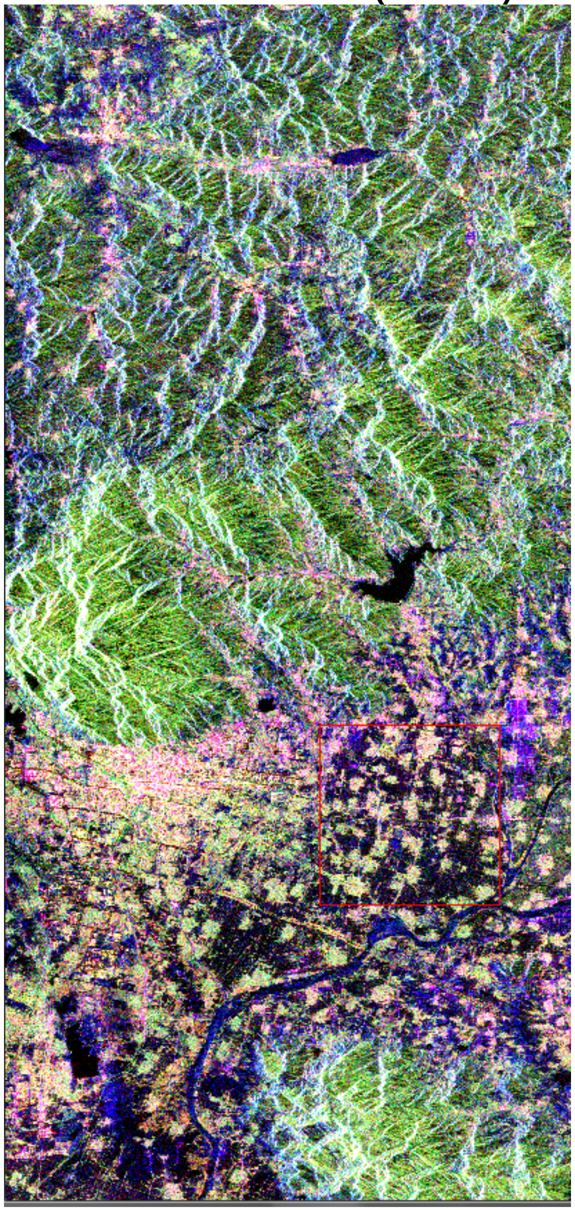
In this report we only focus on the analysis of the two quad-pol images

POLinSAR data after coregistration and baseline parameters

2009.04.02 (master)



2009.05.18 (slave)

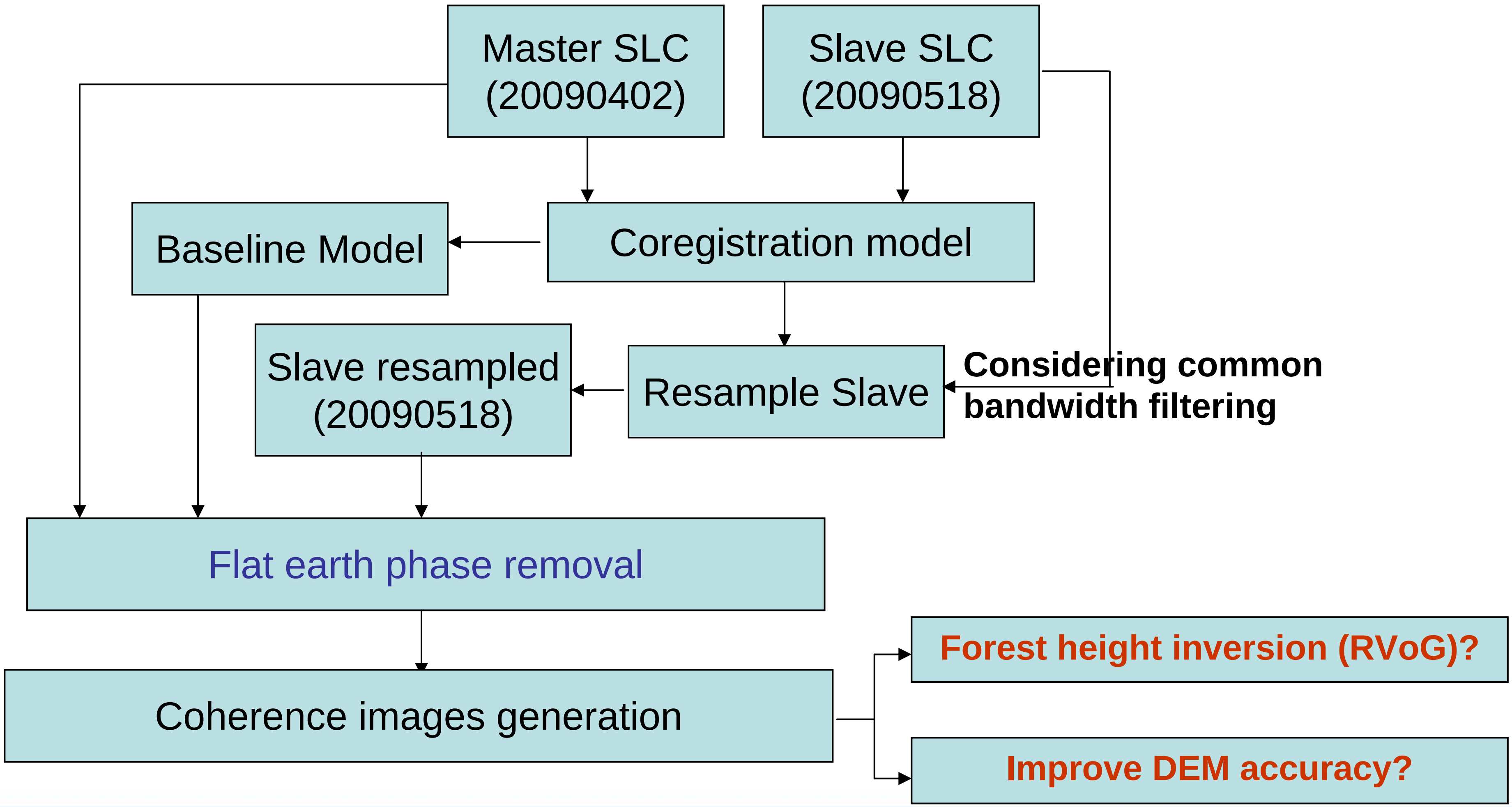


Pauli RBG image:
[s2]→7looksAz*1looksRg

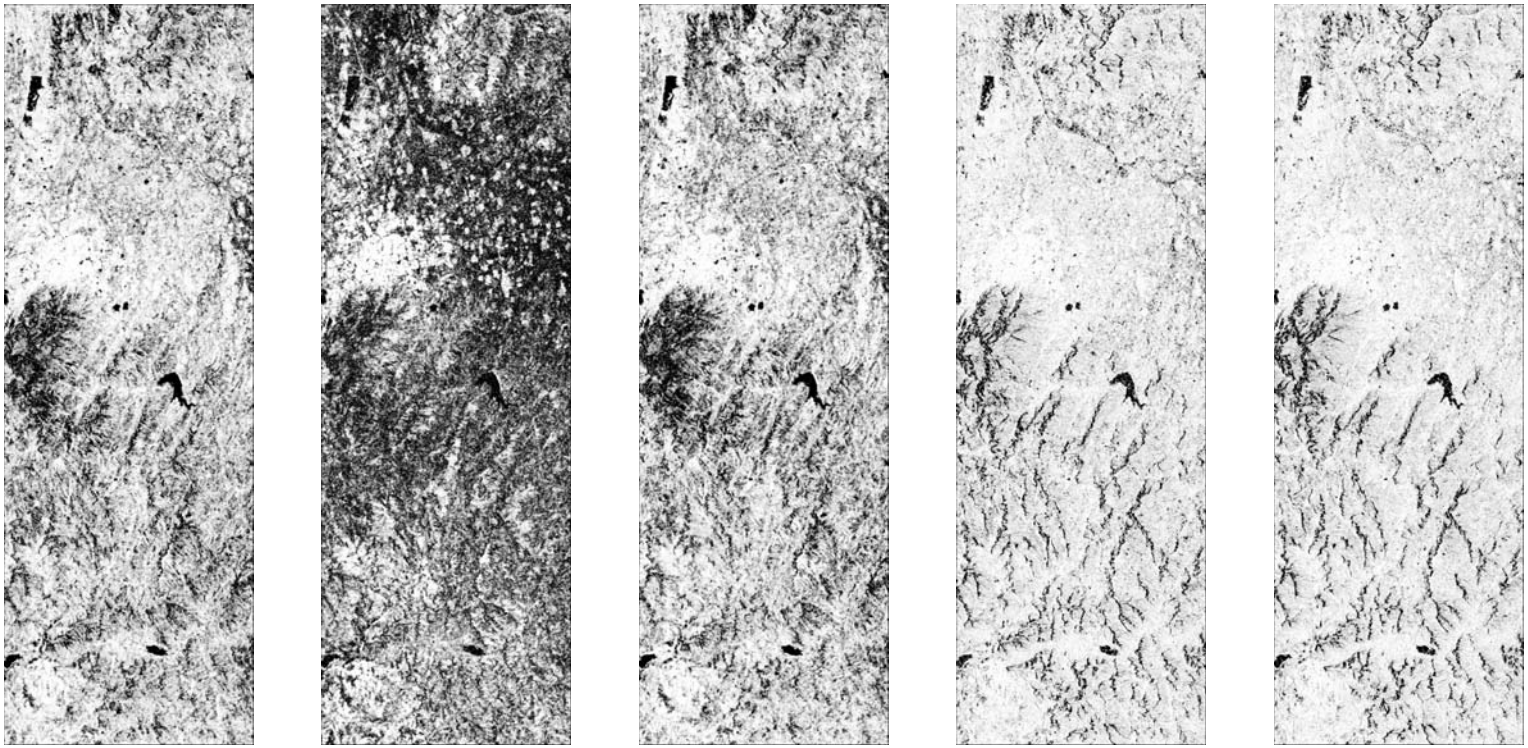
Baseline (226.9m):
•Cross track: 206.1m
•Normal: 94.9m

•Parallel comp.: 163.5m
•Perpendicular: 157.3m

POLinSAR data processing routes

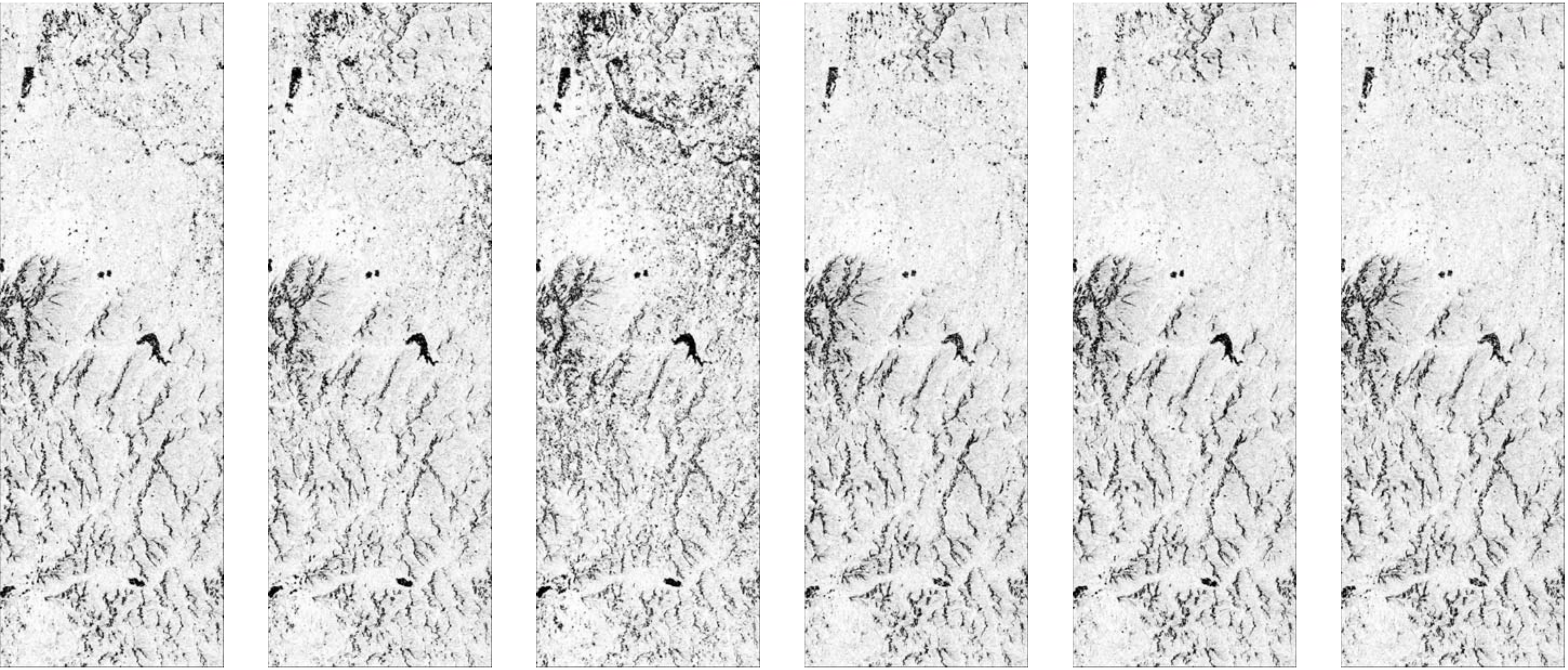


Coherence coefficient of three linear polarizations and three optimization methods



HH-HH HV-HV VV-VV PDHigh PDLow

Phase diversity coherence optimization method
-coherence of high phase center: PDHigh
-coherence of low phase center: PDLow

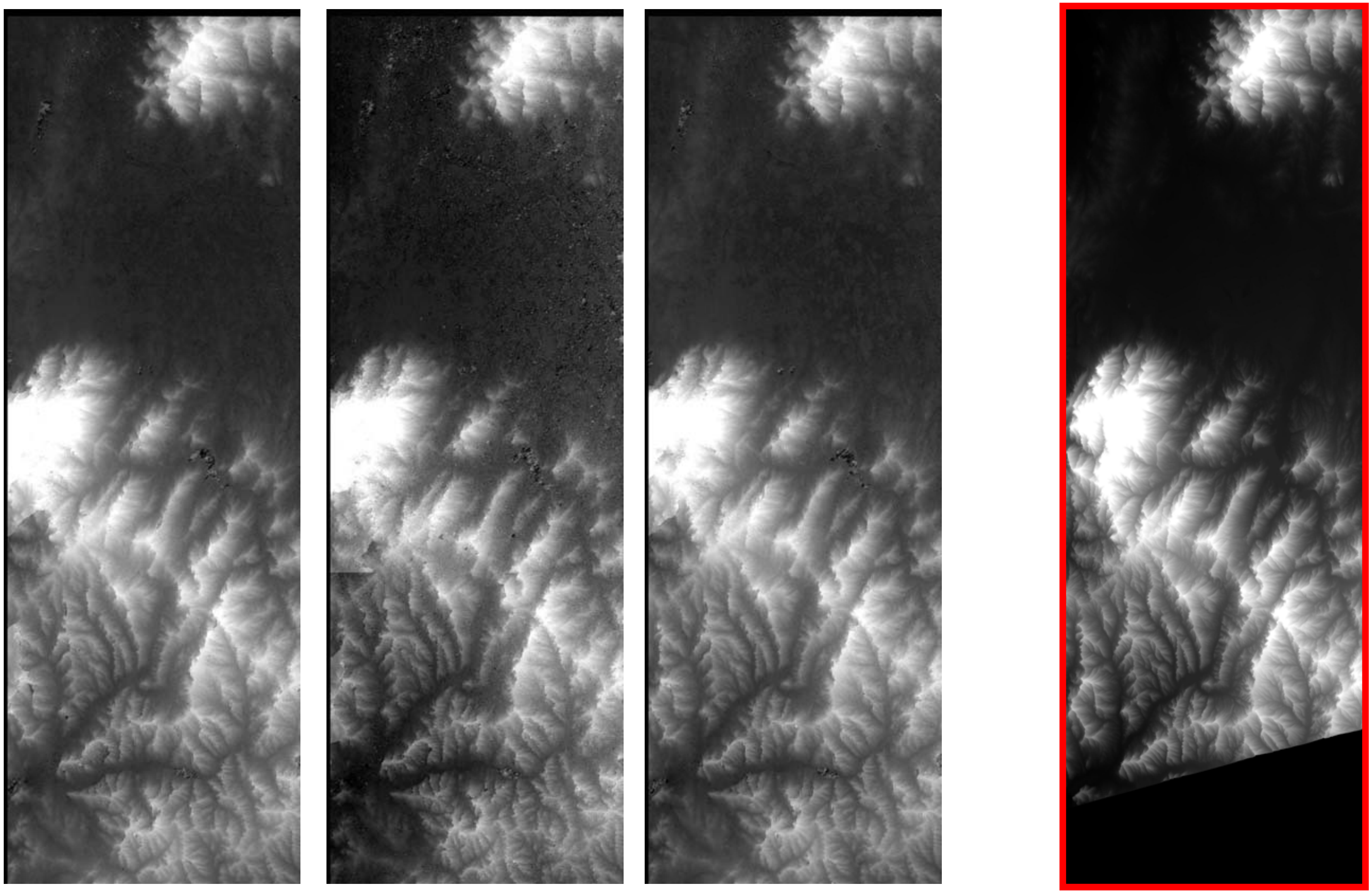


OPT1 OPT2 OPT3 NR1 NR2 NR3

SVD coherence optimization method:
-OPT1: optimal coherence 1
-OPT2: optimal coherence 2
-OPT3: optimal coherence 3

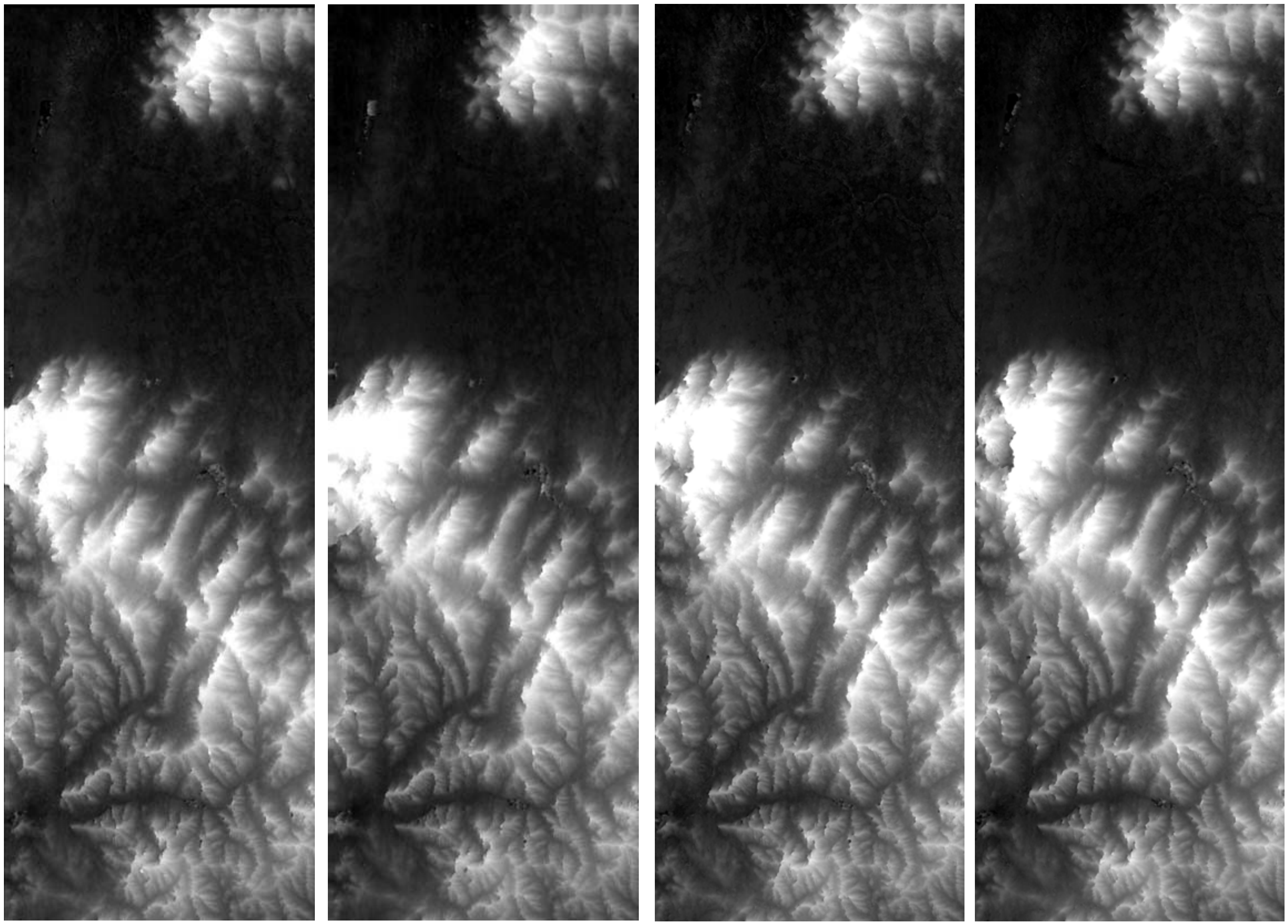
Numerical radius coherence optimization method:
-NR1: Numerical radius coherence 1
-NR2: Numerical radius coherence 2
-NR2: Numerical radius coherence 3

DEM from three linear polarization and the reference DEM in slant range

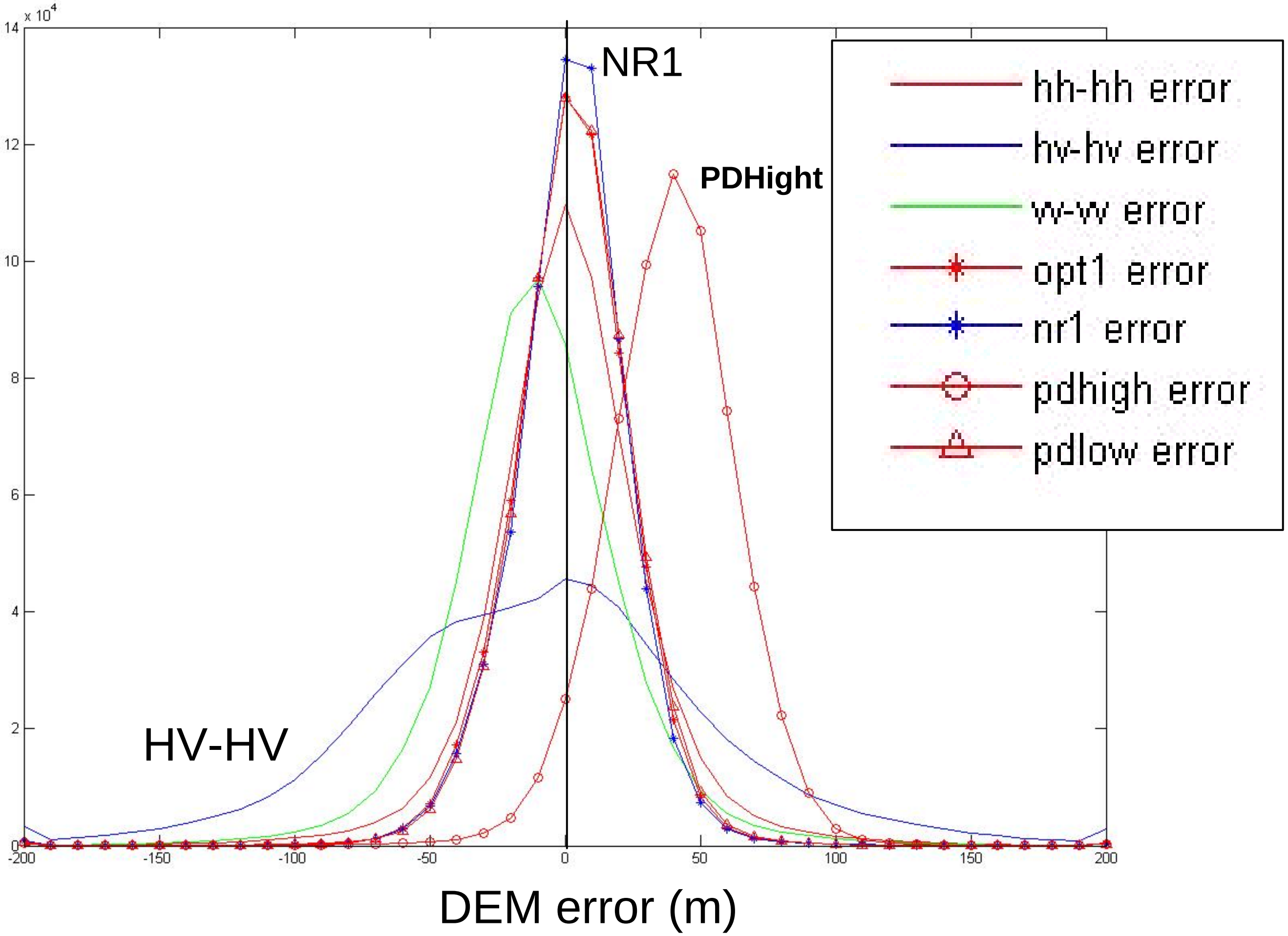


HH-HH DEM　　HV-HV DEM　　VV-VV DEM　　Reference DEM

DEM produced from different coherence optimization methods



Quantitative validation results



RMSE (m):

NR1: 24.4242

PDLow: 24.7515

OPT1: 25.674

HH-HH: 31.985

VV-VV: 35.651

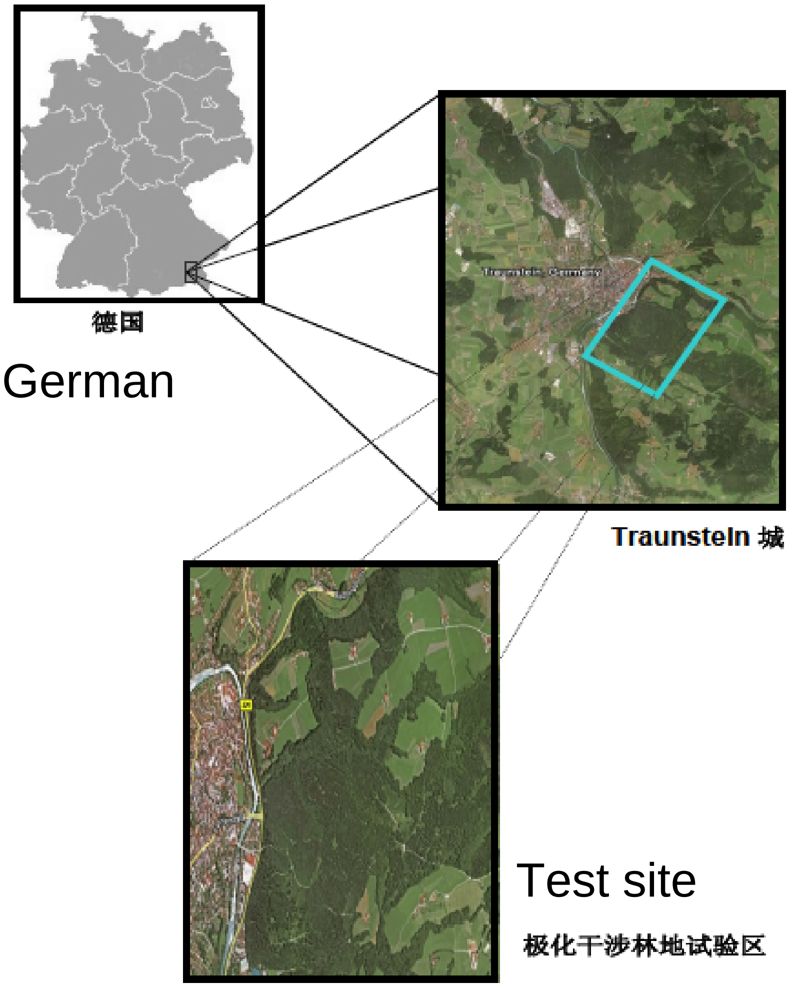
PDHigh: 46.8842

HV-HV: 64.9409

Forest above Ground Biomass Estimation based on Polarization Coherence Tomography

TEST SITE & DATA

- **TREESR Campaign Site: TRAUNSTEIN**
  - **Topography 600~650m;**
  - **Spruce, beech and fir.**
- **E-SAR POLinSAR data:**
  - **L-band repeat pass InSAR;**
  - **3000m above ground;**
  - **Incidence angle: 25~60deg;**
  - **SLC resolution: 1.5m*3m;**
  - **5m nominal spatial baseline;**
  - **20 minutes temporal baseline.**



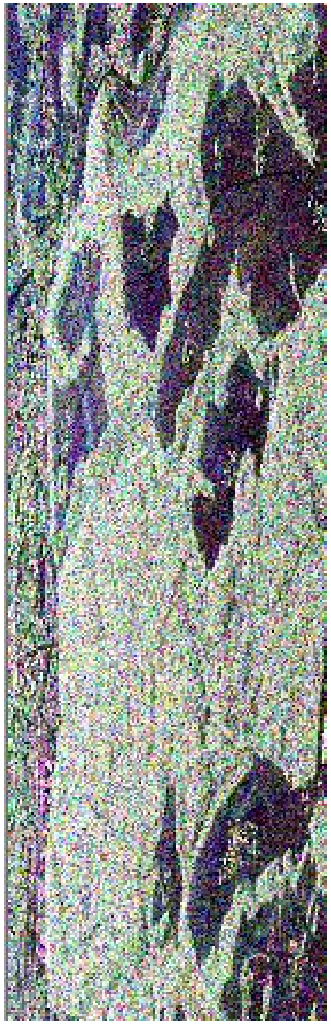
POLinSAR data

- POLinSAR data-SLC

Master

20031011, 9:00

Slave



20031011, 8:40

©DLR

1414width×4642lines

Ground true data

Mean forest height (h100)

36.1m

13.0m

AGB

(ton/ha)

445.2 **ton / ha**

38.7 **ton / ha**

METHODS

Stage 1 : Height and Phase Estimation

$$h_v = \frac{\arg(\tilde{\gamma}_{w_v}) - \hat{\phi}}{k_z} + 0.8\frac{\operatorname{sinc}^{-1}(|\tilde{\gamma}_{w_v}|)}{k_z}$$

where

$$\hat{\phi} = \arg(\tilde{\gamma}_{\underline{w}v} - \tilde{\gamma}_{\underline{w}s}(1 - L_{\underline{w}s})) \quad 0 \le L_{\underline{w}s} \le 1$$

$$AL_{\underline{w}s}^2 + BL_{\underline{w}s} + C = 0 \Rightarrow L_{\underline{w}s} = \frac{-B - \sqrt{B^2 - 4AC}}{2A}$$

$$A = |\tilde{\gamma}_{\underline{w}s}|^2 - 1 \quad B = 2\operatorname{Re}((\tilde{\gamma}_{\underline{w}v} - \tilde{\gamma}_{\underline{w}s}).\tilde{\gamma}_{\underline{w}s}^*) \quad C = |\tilde{\gamma}_{\underline{w}v} - \tilde{\gamma}_{\underline{w}s}|^2$$

POLInSAR preprocessing

Cloude developed a Polinsar height/topography estimation algorithm free of the exponential assumption

Stage 2 : Coherence Normalisation

$$k_v = \frac{k_z h_v}{2}$$

$$\tilde{\gamma}_k(\underline{w}) = \tilde{\gamma}(\underline{w})e^{-ik_v}e^{-i\hat{\phi}}$$

Select arbitrary polarisation channel $\underline{w}$

Baseline information kz

Stage 3 : Legendre Estimate

$$\begin{bmatrix} a_{00} \\ a_{01} \\ a_{02} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & f_{1i} & 0 \\ 0 & 0 & f_2 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ \operatorname{Im}(\tilde{\gamma}_k) \\ \operatorname{Re}(\tilde{\gamma}_k) - f_0 \end{bmatrix}$$

$$f_o = \frac{\sin k_v}{k_v}$$

$$f_{1i} = \left(\frac{\sin k_v}{k_v^2} - \frac{\cos k_v}{k_v}\right)$$

$$f_2 = \frac{1}{k_v^2}\left(3\cos k_v - (3 - k_v^2)\frac{\sin k_v}{k_v}\right)$$

$$\left\|\frac{\delta \underline{a}}{\underline{a}}\right\| \le \frac{k_v^2(\gamma_{w_v}^2 - 1)}{\sqrt{2L}\left(3\cos k_v - (3 - k_v^2)\frac{\sin k_v}{k_v}\right)}$$

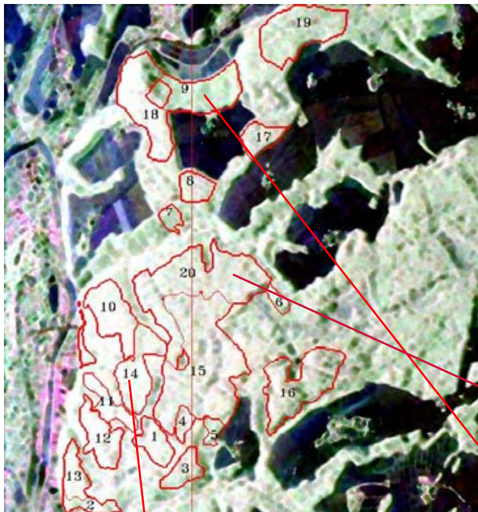
Polarization
Coherence
Tomography

Stage 4 : Profile estimate

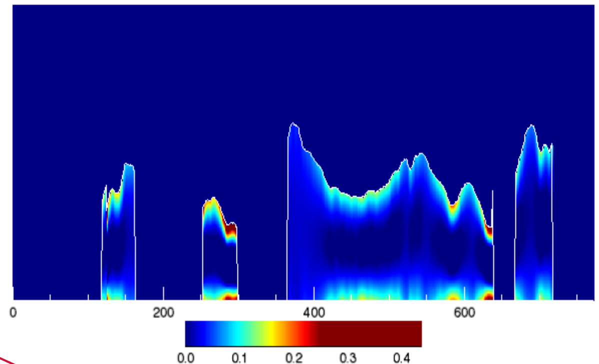
$$0 \le z_h \le h_v \Rightarrow -1 \le z = \frac{2z_h}{h_v} - 1 \le 1$$

$$\hat{f}(z) = a_{00} + a_{01}z + \frac{a_{02}}{2}(3z^2 - 1)$$

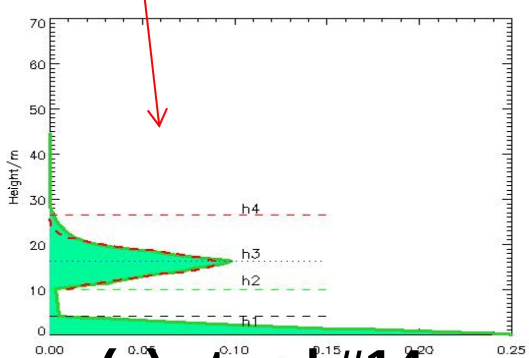
From pixel level reflectivity to stand level



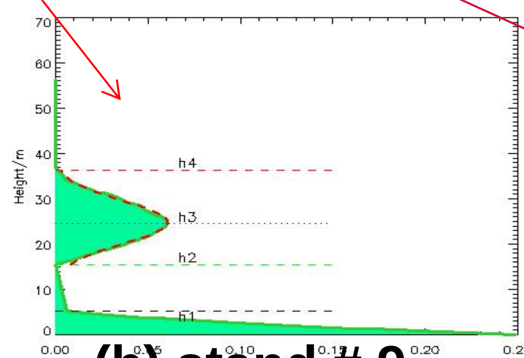
RGB composite image of the polarimetric SAR data of the Traunstein scene in the Pauli basis



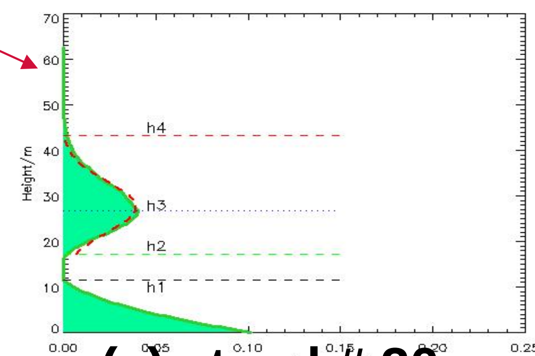
Vertical profile of the relative reflectivity function from PCT in the SAR azimuth direction (along the red line)



(a) stand #14



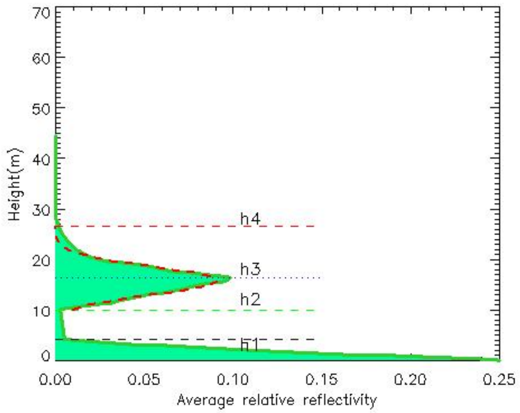
(b) stand # 9

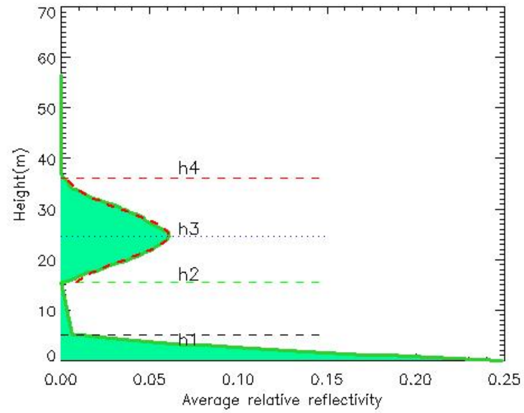


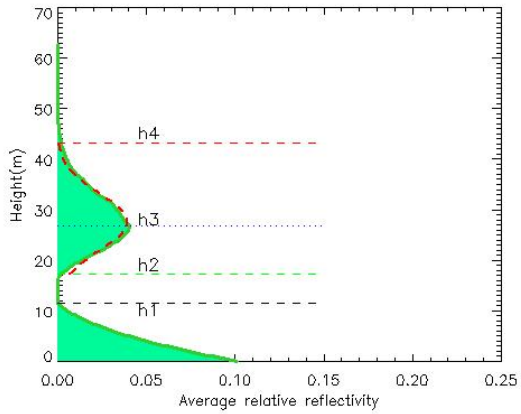
(c) stand # 20

Average relative reflectivity function in optimum polarization channel dominated by volume scattering of 3 typical forest stands in distinct AGB levels (a) No. 14; (b) No. 9; (c) No. 20

- **The mean f(z) of three typical forest stands of different AGB levels**

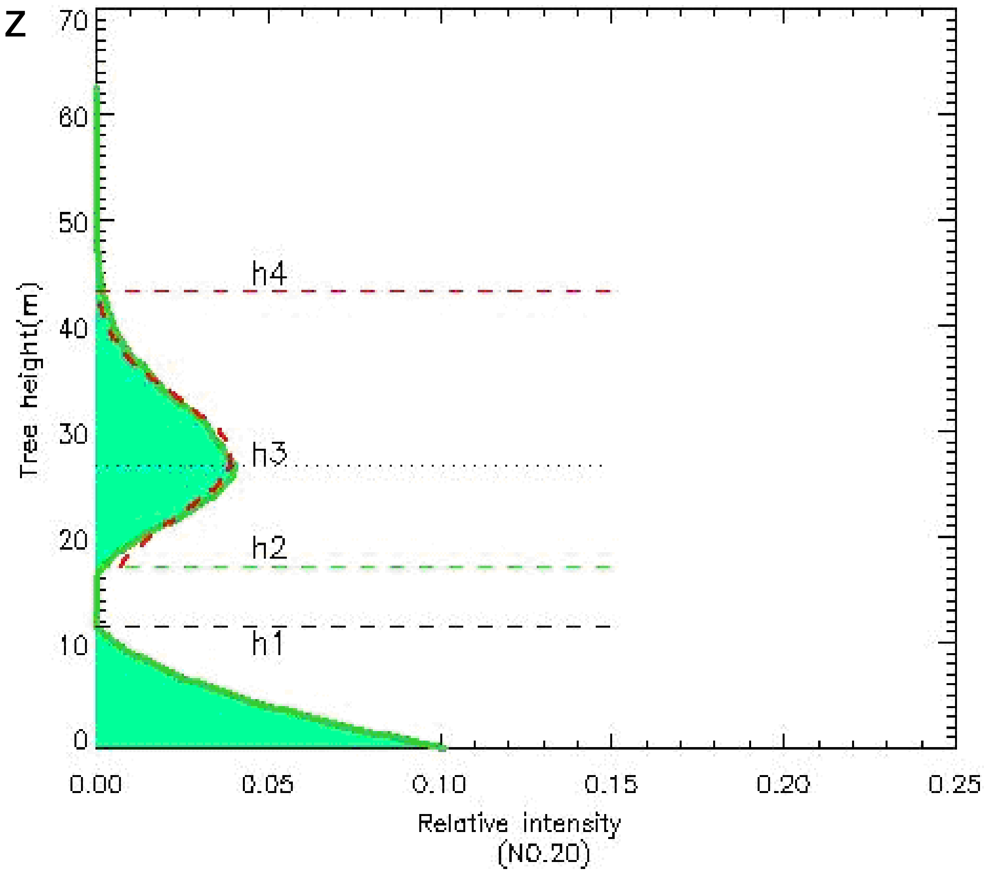






(a)low(135.7 ton/hm^2) **(b)middle(303.3 ton/hm^2)** **(c)high(402.6 ton/hm2)**

•Definition of some feature parameters to describe the f(z)



P1 **: The 1st peak curve length/peak value**

$$P_1 = (h_4 - h_2) / \hat{f}_{I2}(\underline{w}, h_3)$$

P2 **: For the 1st peak, curve value times height, then gets the sum**

$$P_2 = \sum_{z=h_2}^{z=h_4} z \cdot \hat{f}_{I2}(\underline{w}, z)$$

P3、4、5 **: Fit the 1st peak with Gauss function, peak value reciprocal, mean and variance: P3、P4、P5;**

P6 **: Reciprocal of the sum of curve value of the 1st peak**

$$P_6 = 1 / \sum_{z=h_2}^{z=h_4} \hat{f}_{I2}(\underline{w}, z)$$

P7 **: Reciprocal of the sum of curve value of the 2nd peak**

$$P_7 = 1 / \sum_{z=0}^{z=h_1} \hat{f}(\boldsymbol{w}, z)$$

P8 **:** $P_8 = P_6 / P_7$

P9 **: For the 1st peak curve, cutting it into two parts along h_3, sum of curve value down half/top half,**

$$P_9 = \sum_{z=h_2}^{z=h_3} \hat{f}_{I2}(\underline{w}, z) / \sum_{z=h_3}^{z=h_4} \hat{f}_{I2}(\underline{w}, z)$$

- Stepwise regression

$$\ln(B) = \ln(b_0^{'}) + b_1 \ln(P_1) + b_2 \ln(P_2) + \cdots + b_n \ln(P_n)$$

- Model accuracy validation
  - m-fold cross validation method
  - Set m=10, total sample number N=20
  - R^2 and RMSE

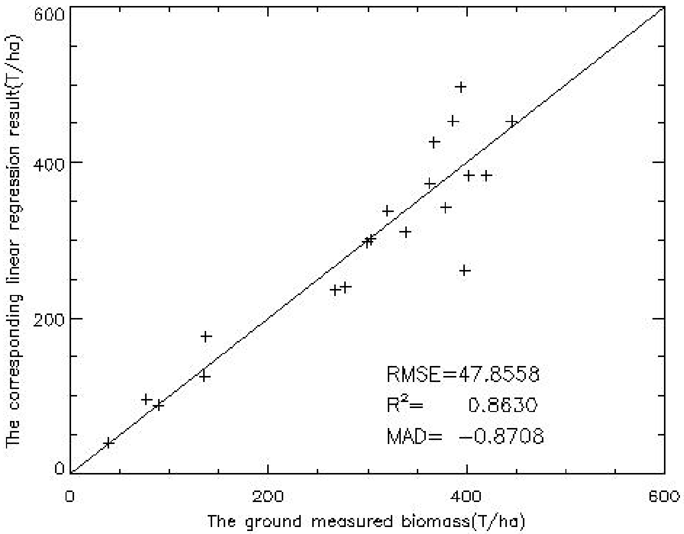
Results & Analysis

- **AGB estimation model fitted**

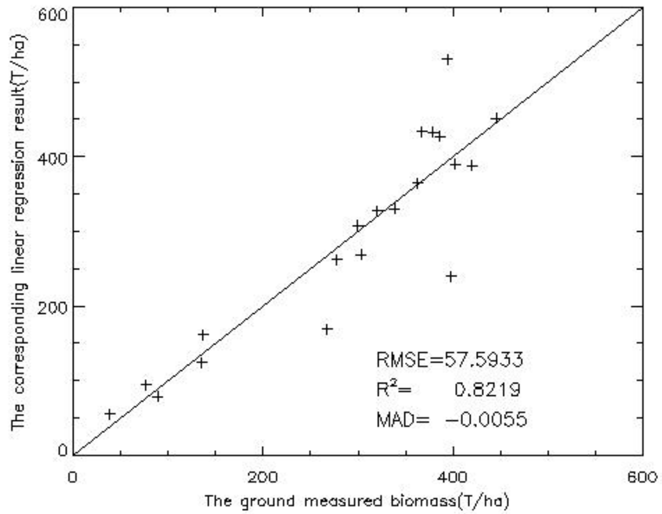
$$\ln B = -2.9966 + 1.7806\ln(P_4) + 0.5765\ln(P_8) - 0.2927\ln(P_9)$$

- **Estimation performance compared with that only using forest height**

$$\ln B = -0.5270 + 1.8457\ln\left(\hat{h}_v\right)$$



(a) Using PCT



(b) Using forest height only

Scatter diagram between estimated and ground measured AGB

•Forest AGB map from PCT and from ground measurement

Ground measurement

Estimated from PCT

Future working plan

➢Forest scar mapping

- Quantitatively investigate the forest scar mapping capability of both L- and C-band polarimetric SAR data and in different seasons;
- Develop object based supervised SVM classification method for forest fire scar mapping using multi-frequence, multi-temporal data.

➢DEM extraction based on coherence optimization

- Physical understanding of the accuracy improvement of DEMs generated from different coherence optimization method;
- Investigate the potential benefit of HH+HV ALOS InSAR data for DEM generation.

➢AGB Estimation based on Polarization Coherence Tomography

- To combine POLInSAR forest structure segmentation method with PCT for forest AGB mapping in stand level;
- Multi-baseline PCT analysis.

Thanks!