Forest & Agriculture Mapping using SAR

Prof. Dr. Christiana Schmullius
Dr. Oliver Cartus *(Woodshole Research Center),*
Tanja Riedel *(University Jena)*
Dr. Maurizio Santoro (*Gamma Remote Sensing****),***
Dr. Christian Thiel *(Earth Observation, Radar Group, Uni Jena)*
And many more …

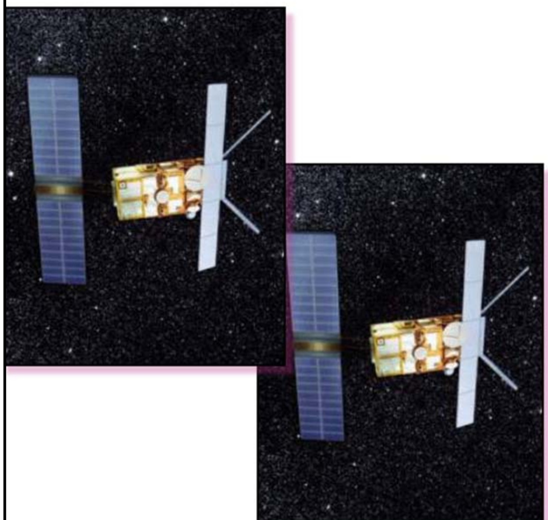
(Kontakt: c.schmullius@uni-jena.de)

Friedrich-Schiller-Universität Jena, Institut für Geographie
Lehrstuhl für Fernerkundungung, Löbdergraben 32, D-07743 Jena
Tel.+49(0).3641.9488-80/-81 Fax-82
Webseite: www.eo.uni-jena.de

Contract Acknowldegments

Boreal Ecosystems:
Results from 18 years of cooperation in 9 EU-Russian projects: SIBERIA-I and –II, GMES-Russia, SibFORD, Irkutsk Environm. Information System, Baikal Monitoring, Marie-Curie-FORCE, ZAPÁS, EuRuCAS
and 8 ESA-projects FEMINE, GMES Forest Monitoring I/II, BIOMASAR-I/-II, DRAGON-1/-2 and the ESA Land Cover Project Office.
Tropical Ecosystems:
FRA-SAR-2010 (DLR/BMBF, cooperation partner GAF), GEO FCT Mexico, Savannah Vegetation Structure in KNP
Mid-latitudes:
ENVILAND-I/-II (DLR), Coop with the Thuringian Forest Agency.

The „Twin Mission“



- Height: 785 km
- Incidence angle: 23°
- C-band, VV-Polarisation
- Swath width: 100 km
- ERS-1 operated 1991-2000
- ERS-2 operated1995-2011
- Repeat pass cycle: 35 days
- ERS-1/2 ”Tandem mission”
- 1 day interval between passes

→ Repeat pass interferometry

Fully polarimetric L-band meets high resolution fully polarimetric X-band

ALOS Advanced Land Observing Satellite

PALSAR
L-band

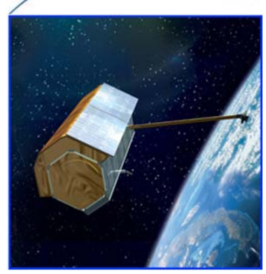
Fine Resolution Mode
8.0-60.0 deg.
HH or VV / HH+HV or VV+VH
7.0-44.3m / 14.0-88.6m
40-70km / 40-70km

ScanSAR Mode
18.0-43.0 deg.
HH or VV / 100m / 250-350km

Polarimetric Mode
8.0-30.0 deg.
HH + HV + VH + VV
24.1-88.6m / 20-60km

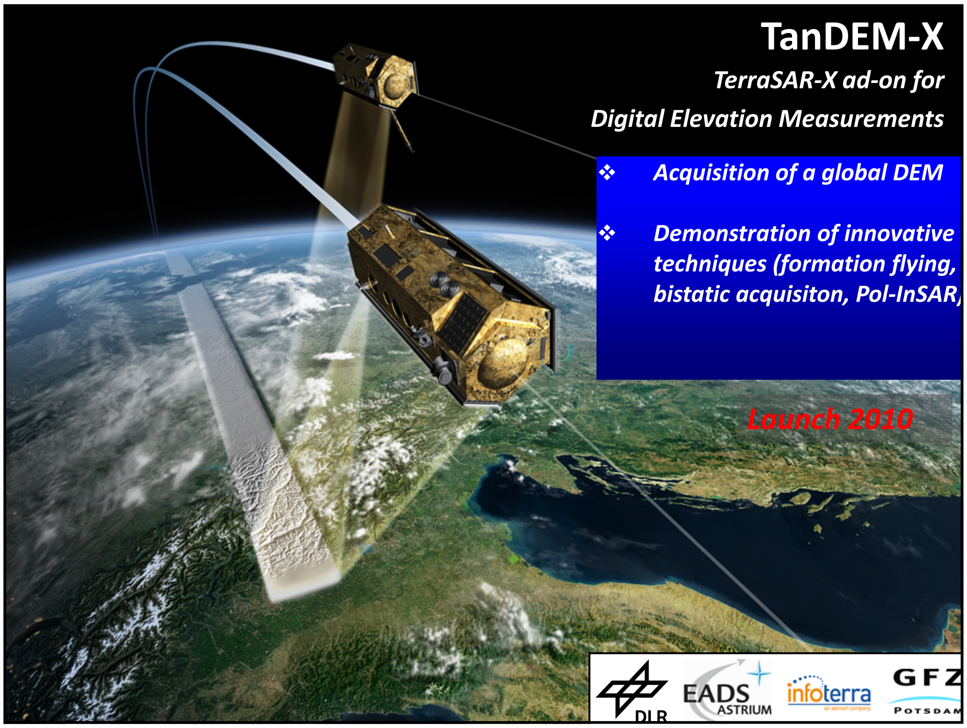
+

TerraSAR X



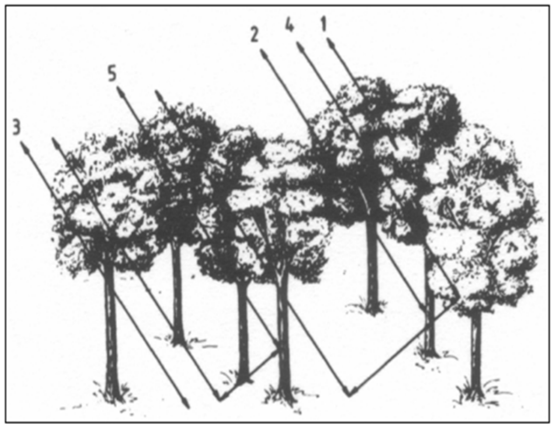
Standard Imaging Mode

	Spotlight	StripMap	ScanSAR
Geometric Resolution	1 m	3 m	16 m
Image Swath Width	10 km	30 km	100 km
Maximum Length per Image	5 km	3000 km	3000 km


TanDEM-X
TerraSAR-X ad-on for
Digital Elevation Measurements
❖ Acquisition of a global DEM
❖ Demonstration of innovative techniques (formation flying, bistatic acquisiton, Pol-InSAR,
Launch 2010
DLR
EADS ASTRIUM
infoterra
GFZ POTSDAM


The ENVISAT Mission:

1. Backscatter Mechanisms in Forests



Frequen-cy band	X	C	L	P	VHF
Main scatterers	Leaves, Twigs	Leaves Small branches	Branches	Branches & Trunk	Trunk

LE TOAN et al. 2001: 4

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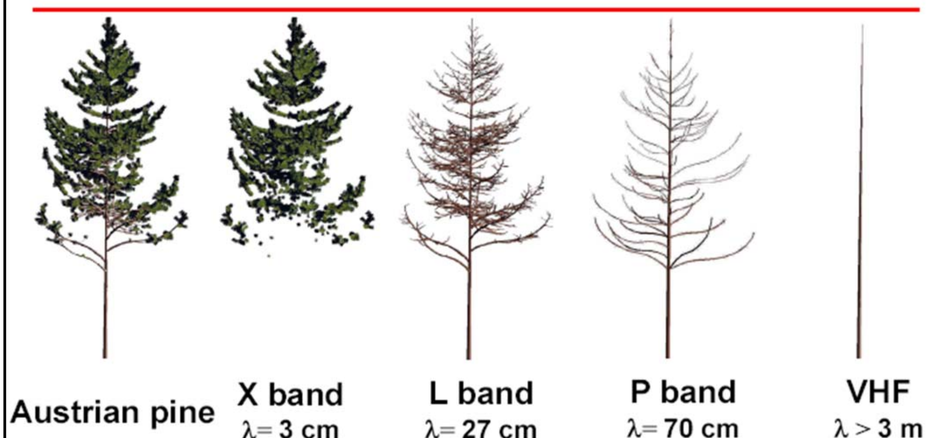
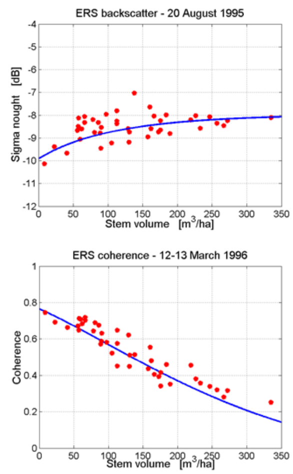
What are the scatterers in the volume scattering?



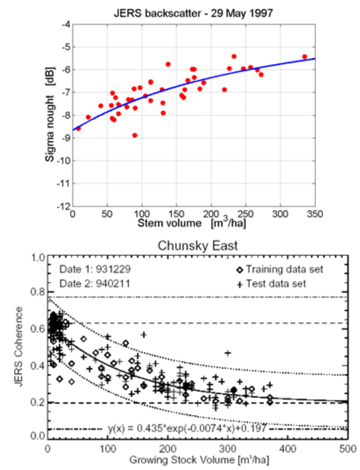
The main scatterers in a canopy are the elements having dimension of the order of the wavelength

Stem volume vs. SAR and InSAR measurements

ERS



JERS



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SIBERIA: SAR Imaging for Boreal Ecology and Radar Interferometry Applications

Methodological Objectives

The analysis methods needed to be

<u>automatic</u> : because of the large amount of data

<u>adaptive</u> : because of changes in image properties

<u>consistent</u> : no scene dependent assignment

<u>validated</u> : confidence of the results

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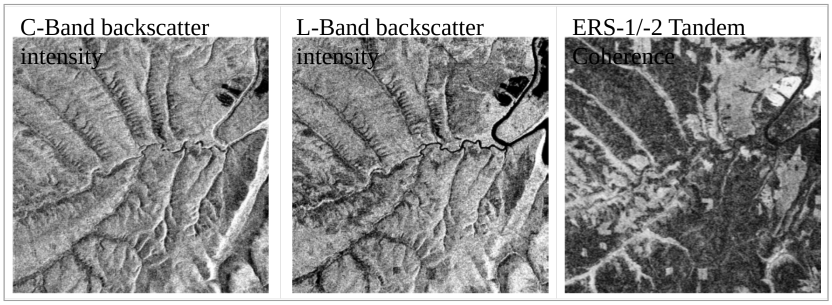
Classification Source Data

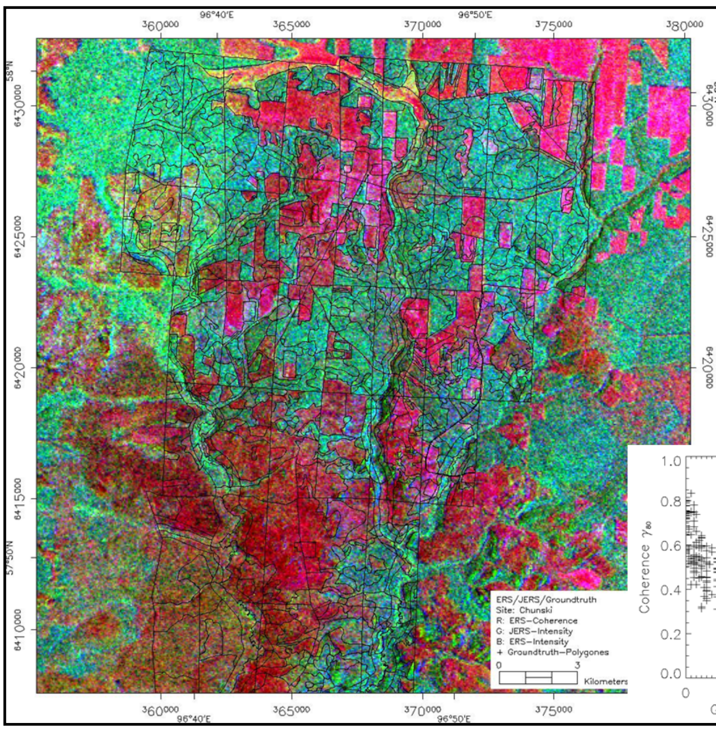


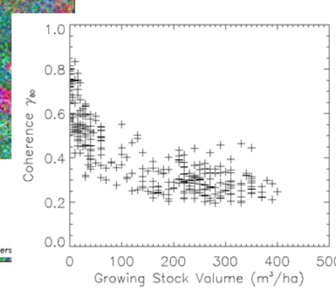
- Small dynamic range
- Variable response to water
- Variable response to open areas
- Can be used as indicator of environmental effects effecting the coherence

- Medium dynamic range
- Stable response to water
- Possible to identify agricultural fields
- Higher frame to frame variations

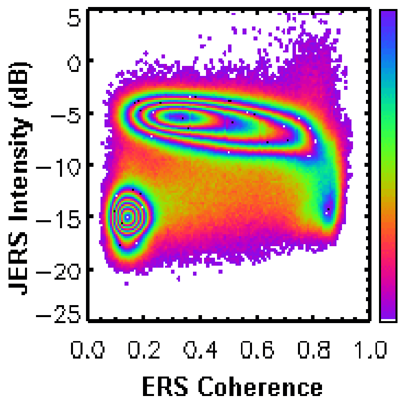
- Higher contrast between forest/non forest
- Higher sensitivity to forest volume
- Confusion between water and dense forest
- Frame to frame variations

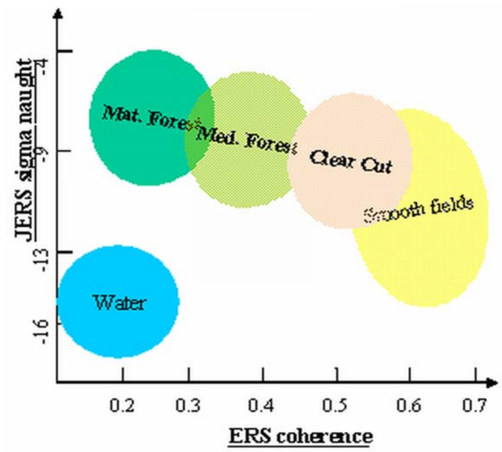
Co-registered Forest-GIS Polygons



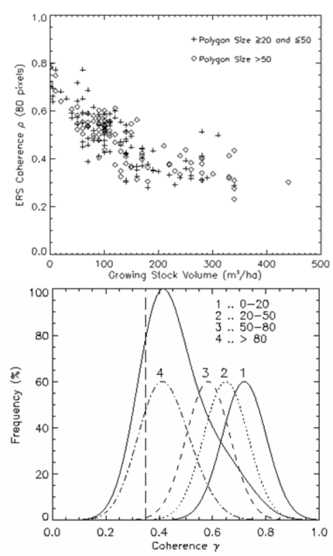


Separability of classes





Model definition for coherence



$$\gamma(v) = \gamma_\infty + (\gamma_0 - \gamma_\infty) \cdot e^{-\frac{v}{V_\gamma}}$$

$$\gamma_\infty \approx \gamma_{75}$$

$$\gamma_0 = a_\gamma + b_\gamma \cdot \gamma_{75}$$

$$\gamma(v) = \gamma_{75} + \left(a_\gamma + (b_\gamma - 1)\gamma_{75}\right) \cdot e^{-\frac{v}{V_\gamma}}$$

$$\gamma(v) = \gamma_{75} + (0.330 + 0.581 \cdot \gamma_{75}) \cdot e^{-\frac{v}{122.1}}$$

v = growing stock volume

γ_0 = coherence at v = 0 m^3/ha (non-forest)

γ_∞ = coherence for asymptotic values of v (corresponding to dense forest)

γ_{75} = value where the coherence distribution reach 75% of the maximum value (see fig.)

V_γ = characteristic v value where the exponential function has decreased by e^{-1}

Wagner et al., RSE, 2003 14

Classification chain

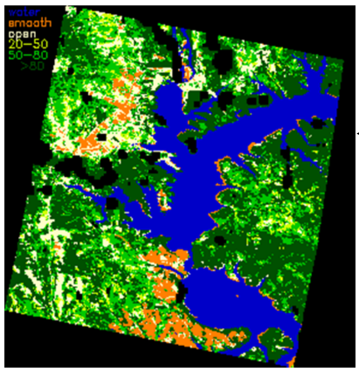
ERS coherence image → Use model to calculate class means

JERS intensity image → Use model to calculate class means

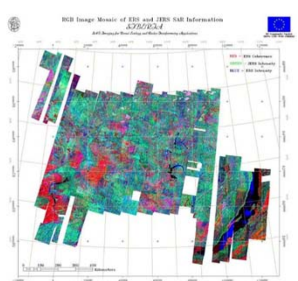
Use model to calculate class means → Maximum Likelihood Classifier

Maximum Likelihood Classifier → Iterated Contextual Probability Classifier (ICP)

Iterated Contextual Probability Classifier (ICP) →

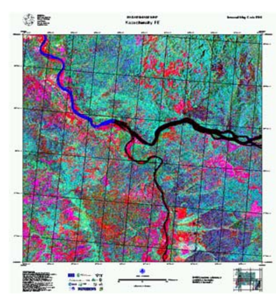


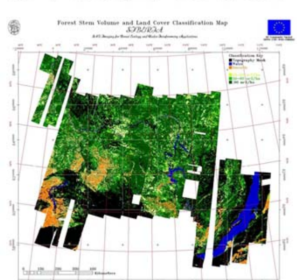
Products



Radar Image Mosaic

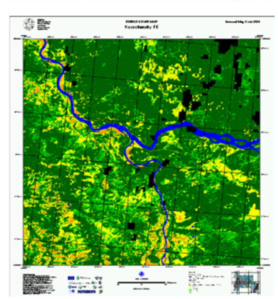
111 Radar Image Maps





Forest Cover Mosaic

96 Forest Cover Maps

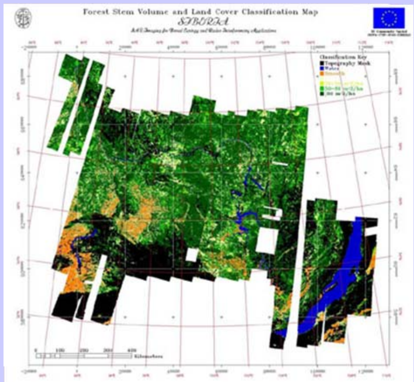


esa

GLOBAL IGBP CHANGE

Vegetation Data Resources

Above Ground Biomass



Nothing as yet global and accessible as Above Ground Biomass

Regional - SIBERIA (1mio km^2 at 50m, 1998) based on SAR Interferometry

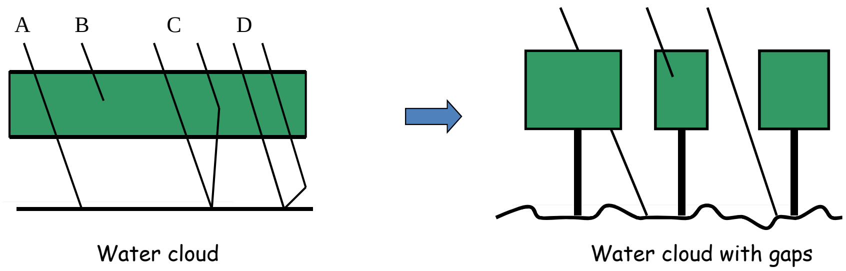
Future - SIBERIA-II (from 2002-5)
Other SAR methods
ESSP VCL?

http://pipeline.swan.ac.uk/siberia/

Independent Russian Field Data

	Ground validation					
Earth Obs. Results	<20 m3/ha	20-50 m3/ha	50-80 m3/ha	>80 m3/ha	Total	User accuracy
<20 m3/ha	908	36	5	9	977	93 %
20-50 m3/ha	76	576	39	15	707	81 %
50-80 m3/ha	12	33	881	58	984	90 %
>80 m3/ha	0	9	120	2182	2311	94 %
Total	1016	655	1045	2264	5232	95 %
Producer accuracy	89 %	88 %	84 %	96 %	95 %	91%

Pooled confusion matrix for the 7 Russian test areas. κ_w = 0.94.



➢ A water cloud with gaps is closer to reality and easy to handle

$$\sigma^o_{for} = \sigma^o_{gr} e^{-\beta V} + \sigma^o_{veg}\left(1 - e^{-\beta V}\right)$$

Ground backscatter

Forest transmissivity

Vegetation backscatter

➢ Forest transmissivity is related to canopy closure and tree attenuation

Interferometric Water Cloud Model (IWCM)

$$\gamma_{for} = \gamma_{gr} \frac{\sigma^o_{gr}}{\sigma^o_{for}} e^{-\beta V} + \gamma_{veg} \frac{\sigma^o_{veg}}{\sigma^o_{for}} \left(\frac{1 - e^{-\beta V}}{1 - e^{-\alpha h}}\right)\left(\frac{\alpha}{\alpha - j\omega}\right)\left(e^{-j\omega h} - e^{-\alpha h}\right)$$

The total forest coherence is a sum of 2 contributions:

Ground coherence, Γ_{gr}

Vegetation coherence, Γ_{veg}

Model considers tree attenuation (α), gaps (β), InSAR geometry (ω)

Empirical relationship

$$\gamma_{for} = \gamma_{gr} e^{-\beta V} + \gamma_{veg}\left(1 - e^{-\beta V}\right)$$

No dependence upon InSAR geometry, forest backscatter and canopy structure

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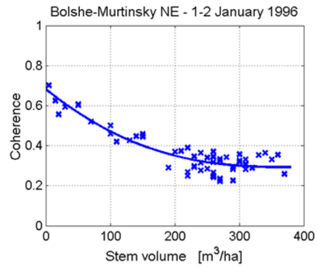
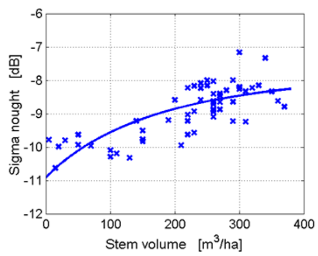
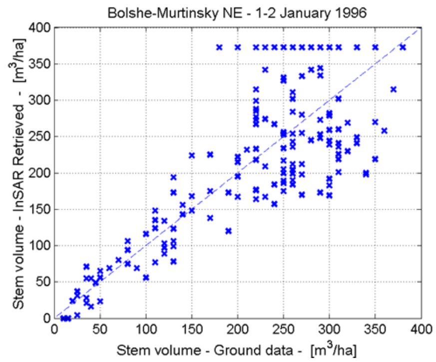
Stem volume retrieval procedure

1. Model training





2. Inversion using a test set



Retrieval statistics

RMSE = 65.6 m^3/ha

Relative RMSE = 29 %

R^2=0.59

Physical backscatter Models like MIMICS describe better what happens but they need a lot of input data → model inversion not possible

DRAGON Project Objectives

The scope of the “FOREST DRAGON“ project is to generate on a regional basis forest structure maps using

> ERS-1/-2 tandem for ~1995

and

> an updated map versions with ENVISAT ASAR data for ~2005.

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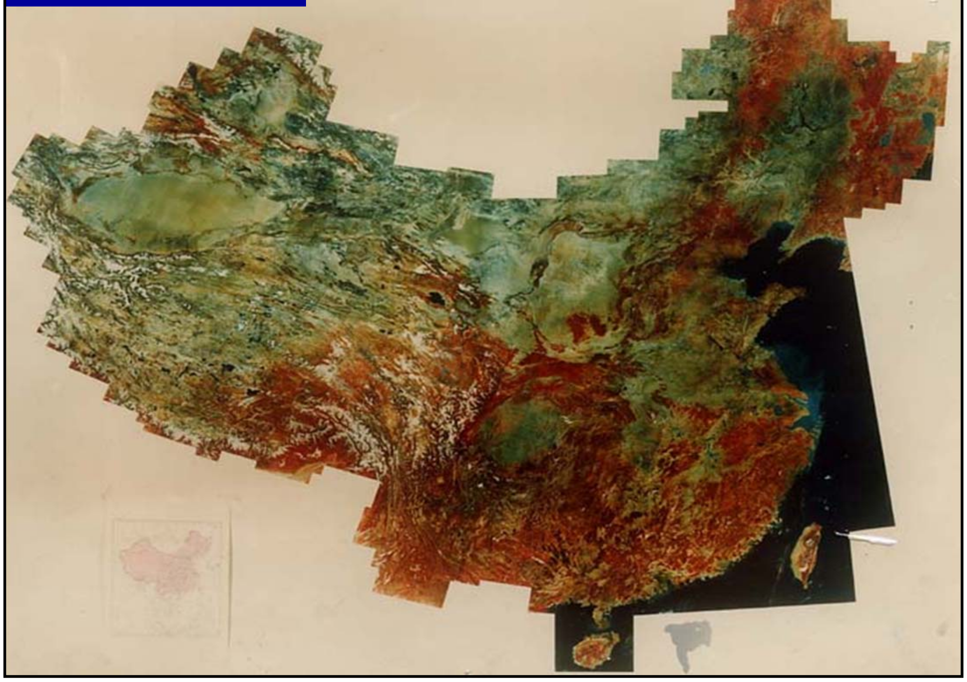
Landsat Mosaic



Interferometric Water Cloud Model

Forest coherence is the sum of
- ground coherence → temporal decorrelation
- canopy coherence → temporal and volume decorrelation

$$\gamma_{for}(V) = \gamma_{gr}\frac{\sigma^0_{gr}}{\sigma^0_{for}}e^{-\beta V} + \gamma_{veg}\frac{\sigma^0_{veg}}{\sigma^0_{for}}\left(1-e^{-\beta V}\right) * \gamma_{vol}(h, B_n, \alpha)$$

Ground contribution Vegetation contribution

$$\sigma^o_{for} = \sigma^o_{gr}e^{-\beta V} + \sigma^o_{veg}\left(1-e^{-\beta V}\right)$$

- γ_{gr} and σ^0_{gr} represent ground temporal coherence and backscatter
- γ_{veg} and σ^0_{veg} represent vegetation temporal coherence and backscatter
- β is related to the forest transmissivity (~0.003 - 0.007 for ERS)
- Volume decorrelation related to
  - h, Height → allometric equation to express it as a function of stem volume
  - B_n, perpendicular baseline
  - α, two-way tree attenuation → 1 – 2 dB/m depending on season

(Askne et al. 1997)

Question:

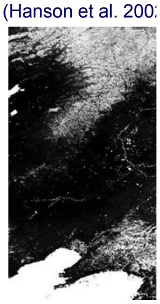
How to calculate the unknowns of the model for each frame without ground-truth data?

Model training based on VCF

What is VCF?

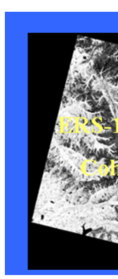
The Modis Vegetation Continuous Field product (VCF) provides global sub-pixel estimates of landscape components (tree cover, herbaceous

(Hanson et al. 200

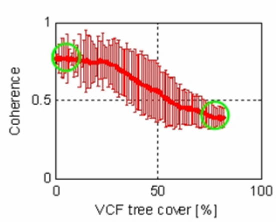


Why is VCF important in this context?

Because coherence and VCF contain similar information

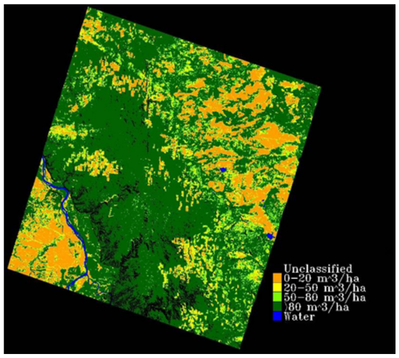


Relationship between VCF and ERS coherence



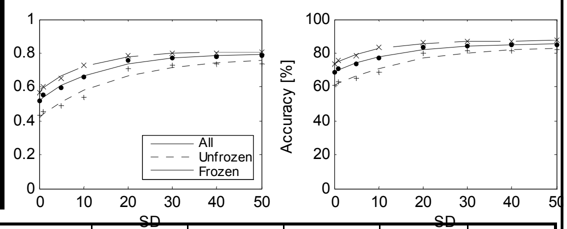
- Areas with VCF tree cover <= 10% → estimate γ_{gr} and σ^0_{gr}
- Areas with VCF max tree cover → estimate γ_{veg} and σ^0_{veg}

Classification accuracy



Classes according to the SIBERIA map:

0-20,20-50,50-80,>80 m^3/ha



Green: VCF-based training

Red: Regression-based training

Test site & image	0-20	20-50	50-80	>80 [m³/ha]	Overall Acc. [%]	kappa
Chunsky N 29-30 Dec.95	78.6 80.4	38.8 26.4	12.4 8.0	93.9 97.2	81.1 82.1	0.69 0.68
Chunsky E 14-15 Jan.96	65.6 73.3	39.8 26.9	29.2 31.4	87.4 84.9	70.5 72.5	0.54 0.54
Bolshe NE 22-23 Sep.97	8.1 72.3	14.1 28.7	51.1 30.0	92.8 84.6	37.0 69.0	0.22 0.52
Bolshe NW 25-26 Sep.97	81.0 82.0	67.8 67.8	34.1 30.9	78.1 76.8	75.6 75.0	0.62 0.62

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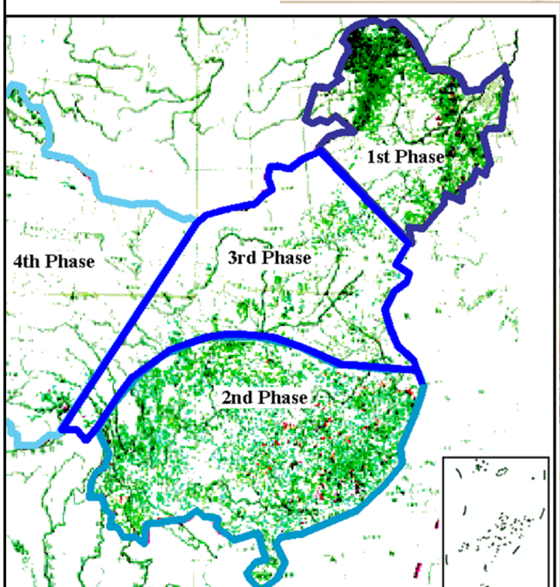
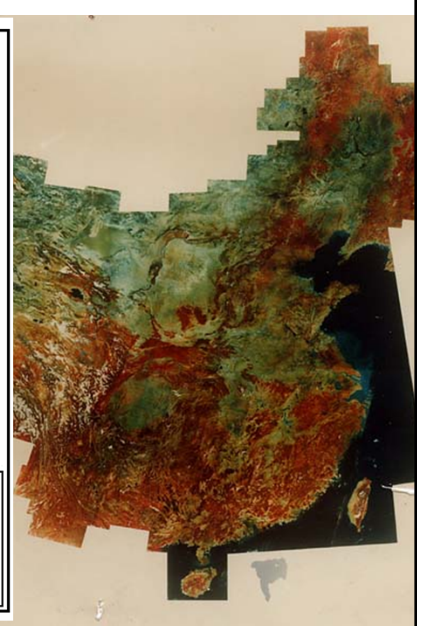
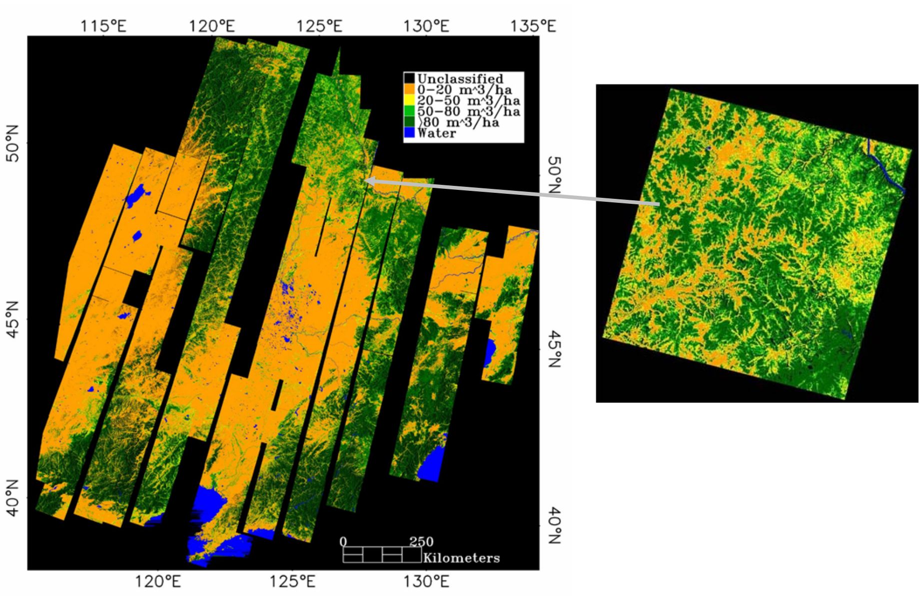
Phased Project Areas and Landsat Mosaic





Forest Structure Map of Northeast China



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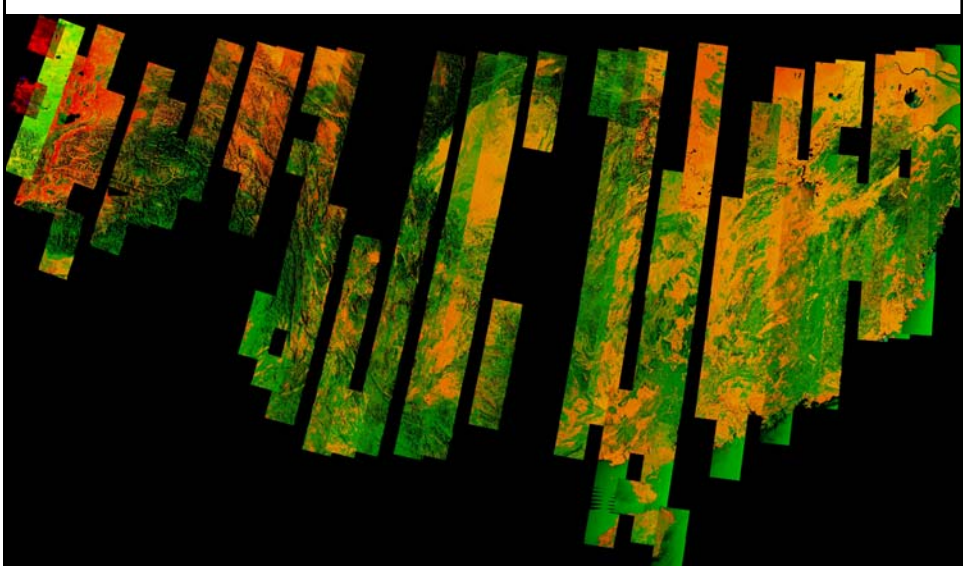
Coherence Map of Southern China



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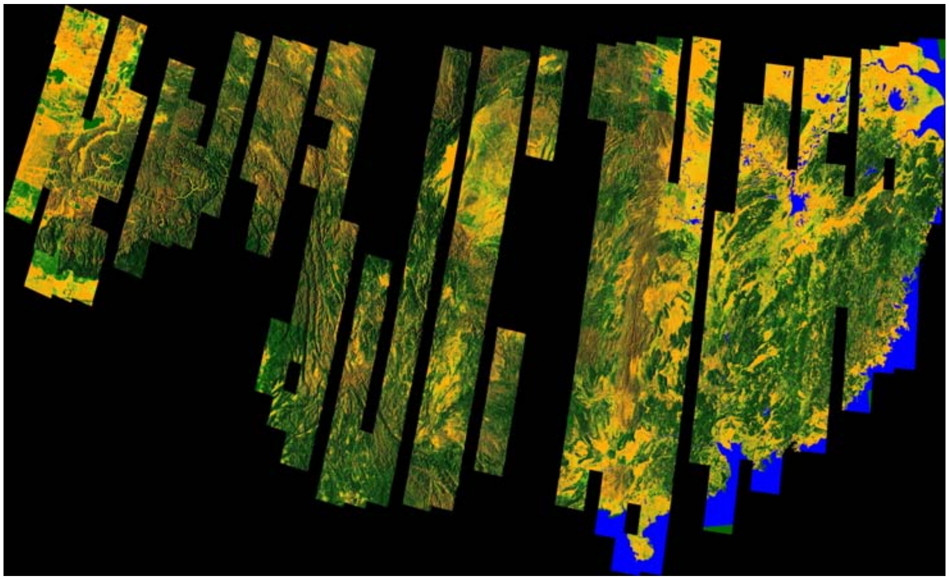
Forest Structure Map of Southern China



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Major DRAGON Conclusions

The new VCF-based classification approach is a fast and easy method to map forest stem volume.

Algorithm was successfully applied to boreal, temperate <u>and</u> subtropical environments.

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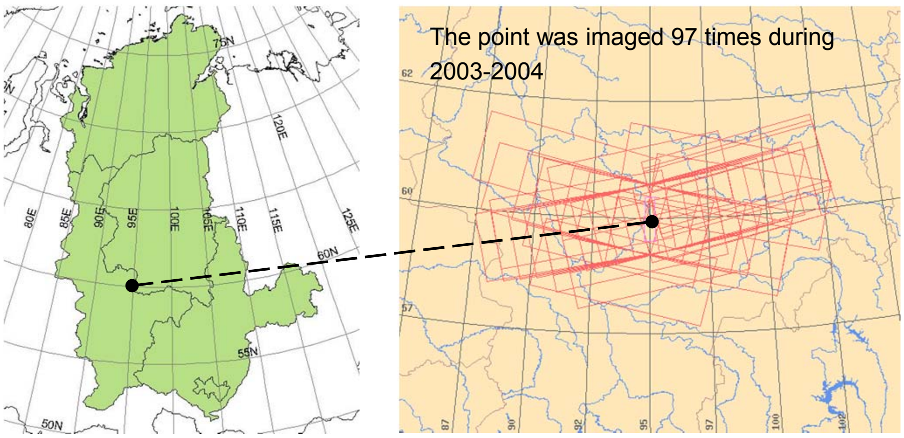
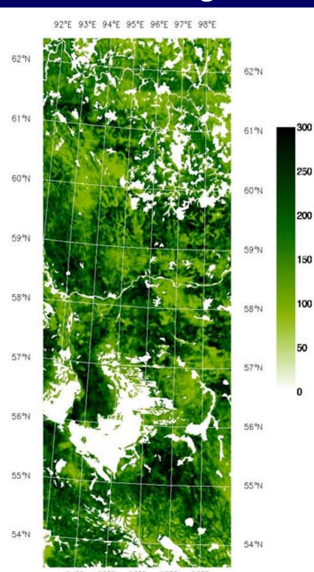
ENVISAT ASAR Wide Swath dataset

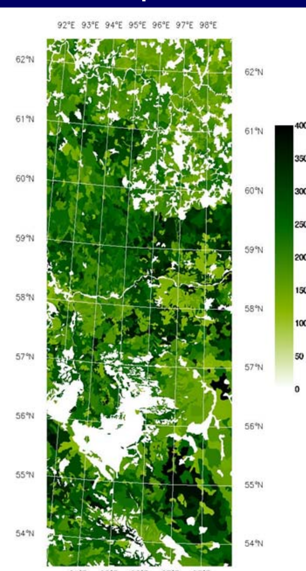
During 2003 and 2004 ENVISAT ASAR data in Wide Swath mode has been acquired over the study area of the SIBERIA-II Project
Several hundred ASAR scenes have been acquired, with a high degree of overlap between neighboring tracks



Growing stock volume maps

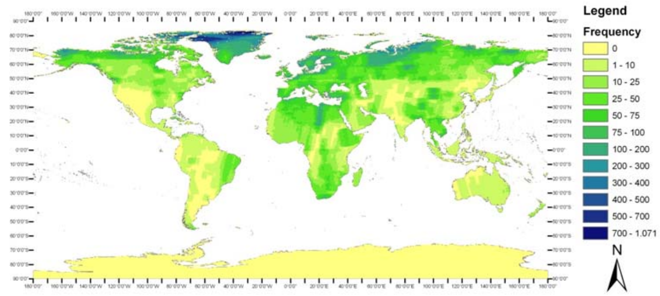


WS-based



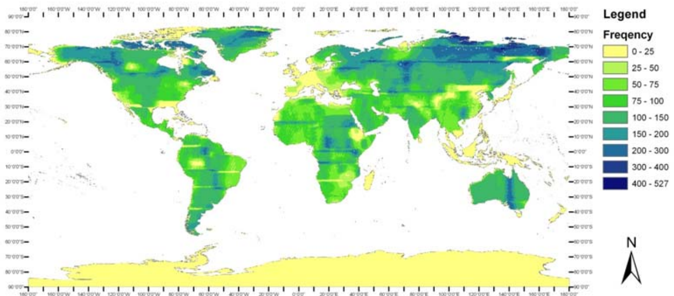
Forest inventory

Envisat ASAR Scansar data distribution



Wide Swath Mode

2007



Global Monitoring Mode

2007

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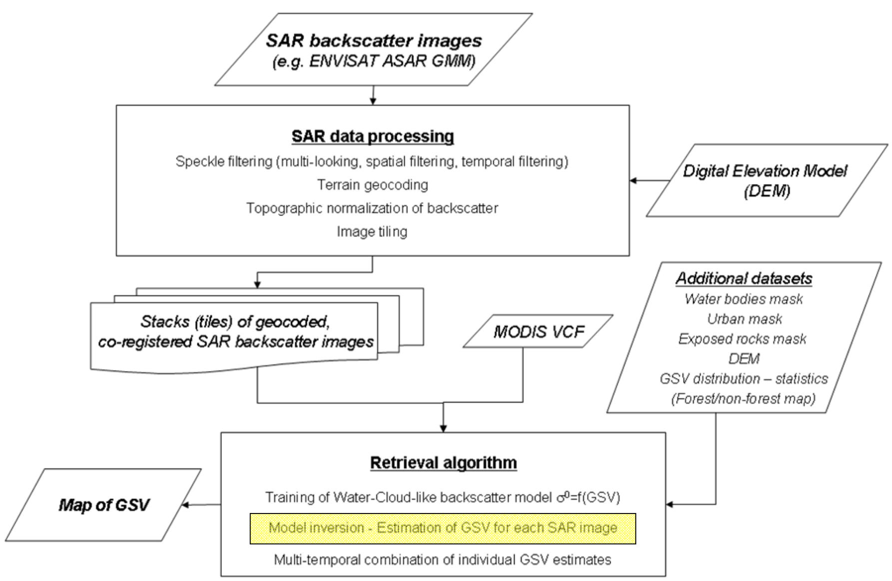
Estimation of model parameters



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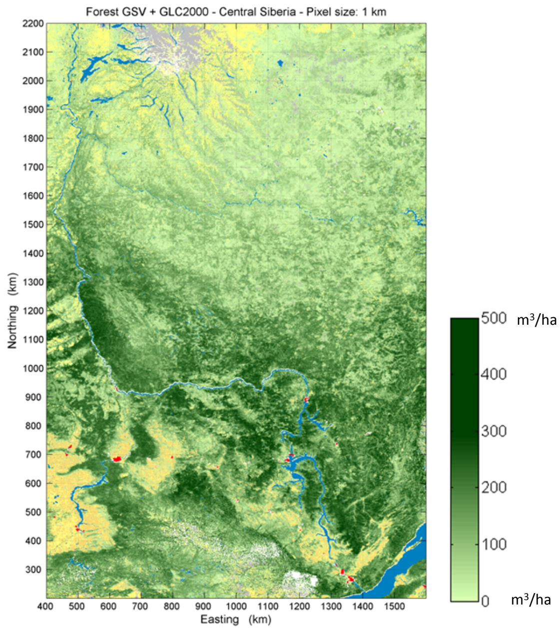
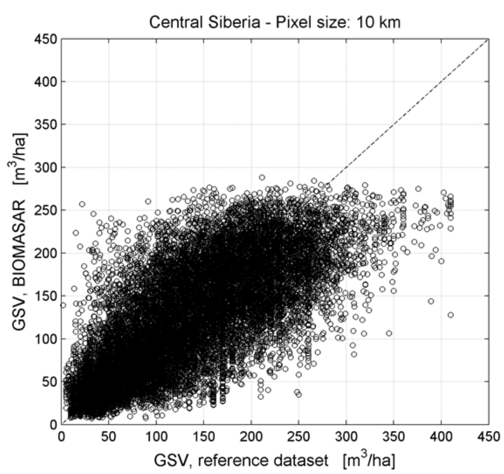
BIOMASAR GSV map of Central Siberia

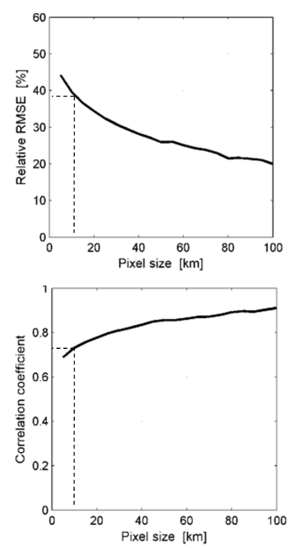


1-km forest GSV map of Central Siberia

- 2,400,000 km²
- ENVISAT ASAR
  Global Monitoring mode
  (Jan. 2005 – Feb. 2006)
- GLC 2000 land cover used as background

Accuracy of retrieved GSV for 10 km pixel size





Relative RMSE: 39.6%

Bias: 10.2 m³/ha

r = 0.73

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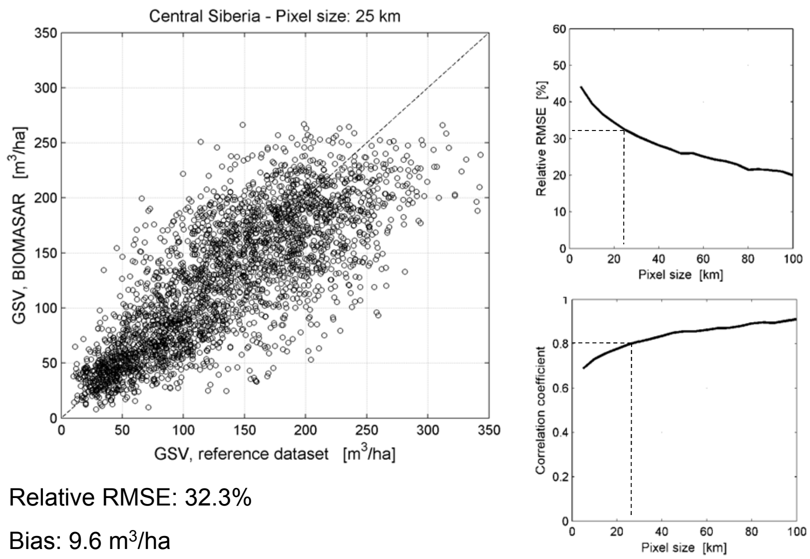
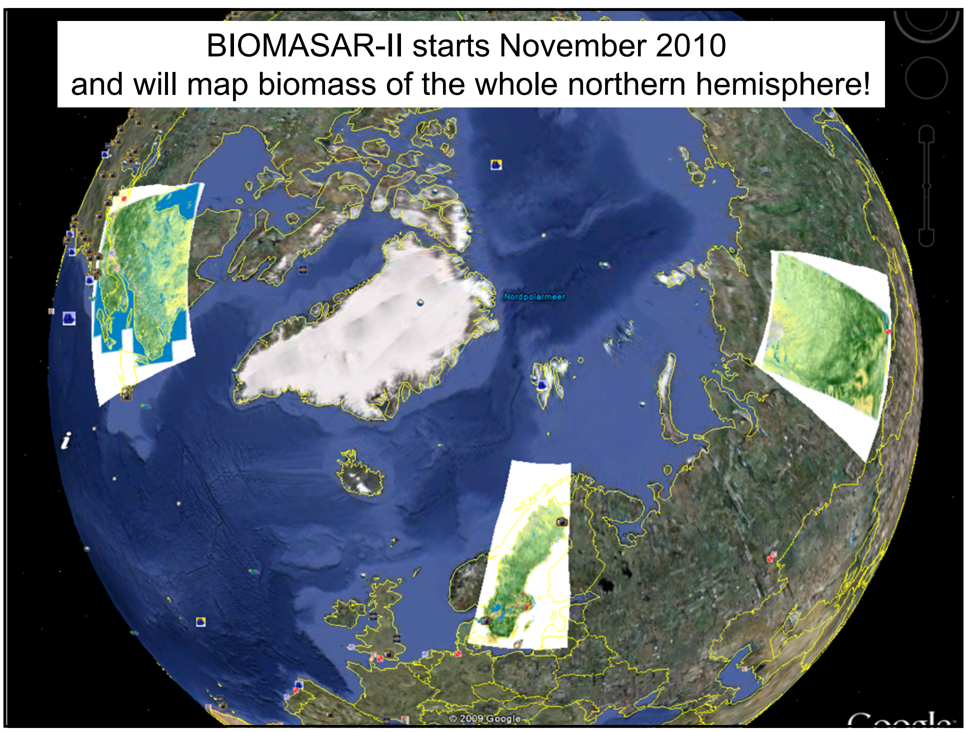
Accuracy of retrieved GSV for 25 km pixel size



Relative RMSE: 32.3%

Bias: 9.6 m^3/ha

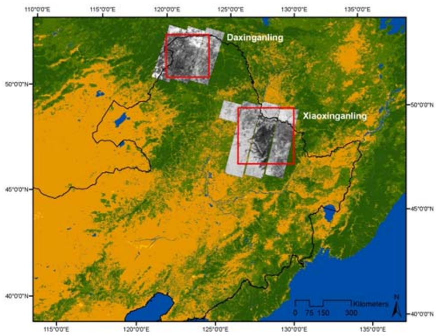
r = 0.80



Forest Cover Change Pilot Study

OVERVIEW

- Forest cover/ structure change from mid 1990 into current decade
- Xiaoxinganling (~300 x 300 km) & Daxinganling (~200 x 200 km) in NE China
- 1 km spatial resolution



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Forest Cover Change Pilot Study

OVERVIEW

- Forest cover/ structure change from mid 1990 into current decade
- Xiaoxinganling (~300 x 300 km) & Daxinganling (~200 x 200 km) in NE China
- 1 km spatial resolution

1. 1995-1997 • ERS-1/2 tandem coherence data
   - GSV retrieval via DRAGON algorithm; Cartus et al. 2008
2. 2007/2008 • hyper-temporal Envisat ASAR GMM data
   - GSV retrieval via BIOMASAR algorithm; Santoro & Cartus 2010
3. Forest Cover (Structure) Change – First Results

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Forest Cover Change Pilot Study

1. ERS-1/2 Tandem Coherence Forest GSV

• multi-seasonal ERS-1/2 dataset (1995-1997) (baselines between 60 – 352 m)

• 1st step: Interferometric processing to generate interferometric SAR coherence

  • frame basis

  • adaptive coherence estimation

2nd step: Model training and model inversion to retrieve forest GSV

  • implementation of DRAGON algorithm at 1 km spatial resolution

  • consideration of scaling effects on GSV

Forest Cover Change Pilot Study

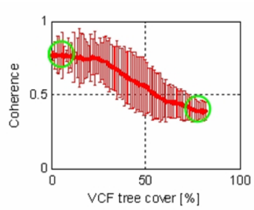
DRAGON algorithm (Cartus et al 2008):

GSV retrieval based on Interferometric Water Cloud Model (IWCM)

Forest coherence is the sum of ground coherence / canopy coherence

• 5 unknowns: γ_{gr}, σ^0_{gr}, γ_{veg}, σ^0_{veg}, β

• MODIS Vegetation Continious Field (VCF) product included in model training phase:



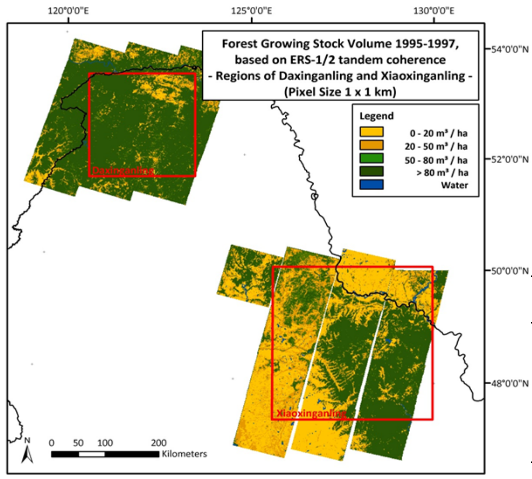
→ clear relationship between coherence and VCF

→ estimation of 4/5 model unknowns (γ_{gr}, σ^0_{gr}, γ_{veg}, σ^0_{veg})

→ model Training independent from inventory data

Forest Cover Change Pilot Study

1. ERS-1/2 Tandem Coherence Forest GSV



	OA Daxinganling ERS-1/2 GSV 50m	OA Xiaoxinganling ERS-1/2 GSV 1 km
NLCD	0.73	0.80
GlobCover	0.78	0.85
VCF (15% CC)	0.91	0.89
GLC2000	0.89	0.83
AVHRR LCC	0.79	0.67

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Forest Cover Change Pilot Study

2. Envisat ASAR GMM Forest GSV (2007/08)

- global availability of hyper-temporal stacks of Envisat ASAR GMM (up to 300 observations)
- multi-temporal combination of estimates of GSV can lead to an improved estimate

- BIOMASAR algorithm (Santoro & Cartus 2010) …

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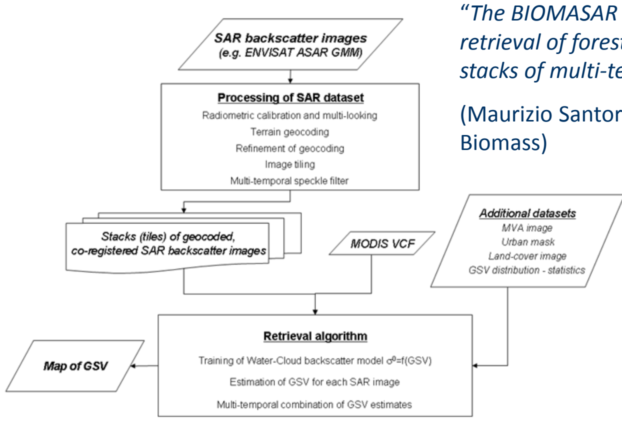
Forest Cover Change Pilot Study

2. Envisat ASAR GMM Forest GSV (2007/08)

BIOMASAR algorithm (Santoro & Cartus 2010):



"The BIOMASAR algorithm: an approach for retrieval of forest growing stock volume using stacks of multi-temporal SAR data"

(Maurizio Santoro, Session 2.1.2 Forestry & Biomass)

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Forest Cover Change Pilot Study

2. Envisat ASAR GMM Forest GSV (2007/08)

- global availability of hyper-temporal stacks of Envisat ASAR GMM (up to 300 observations)
- multi-temporal combination of estimates of GSV can lead to an improved estimate

- BIOMASAR algorithm (Santoro & Cartus 2010) …

  … capable to retrieve continuous GSV using ASAR GMM data in the boreal zone up to 300 m^3/ha, without apparent signs of saturation

  … was used to process 1-year stack (Jan 2007 – Feb 2008) of ASAR GMM data at 1-km pixel size for Xiaxinganling and Daxinganling

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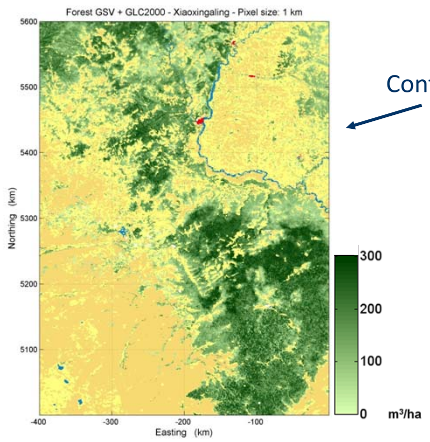
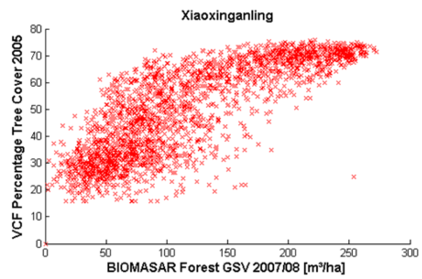
Forest Cover Change Pilot Study

2. Envisat ASAR GMM Forest GSV (2007/08)

BIOMASAR results:



Continuous forest GSV for Xiaoxinganling



Forest Cover Change Pilot Study

2. Envisat ASAR GMM Forest GSV (2007/08)

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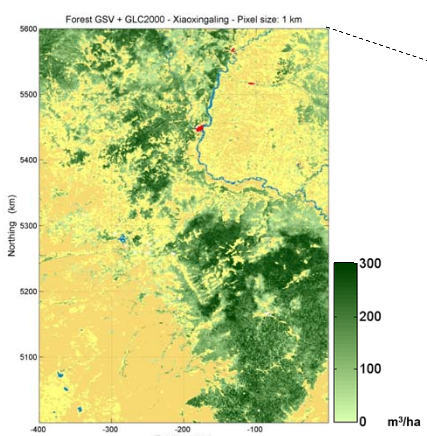
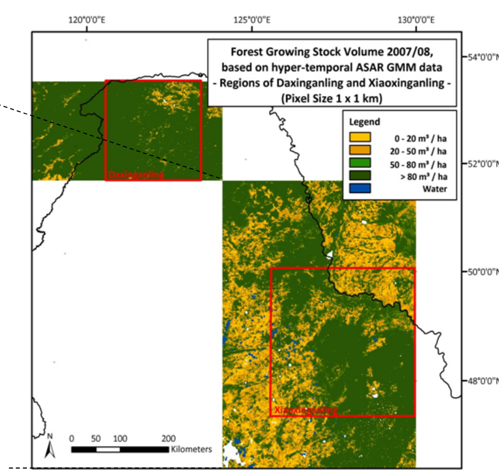
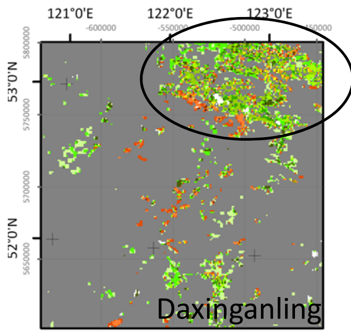




Forest Cover Change Pilot Study

3. Forest Cover (Structure) Change – First Results

- 1995-1998 (ERS-1/2 Tandem) - 2007/08 (ASAR GMM) -



regrowing forest & afforestation after forest fire in 1987

(Yu et al. 2004, Wang et al. 2007)

ASAR / ERS	0-20 m³/ha	20-50 m³/ha	50-80 m³/ha	> 80 m³/ha
0-20 m³/ha				
20-50 m³/ha				
50-80 m³/ha				
> 80 m³/ha				

Projection: Albers Conical Equal Area   0 25 50 100 150 Kilometers

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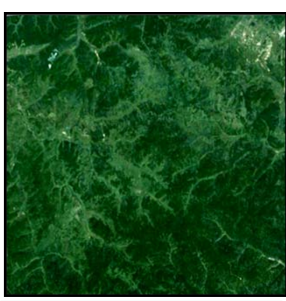
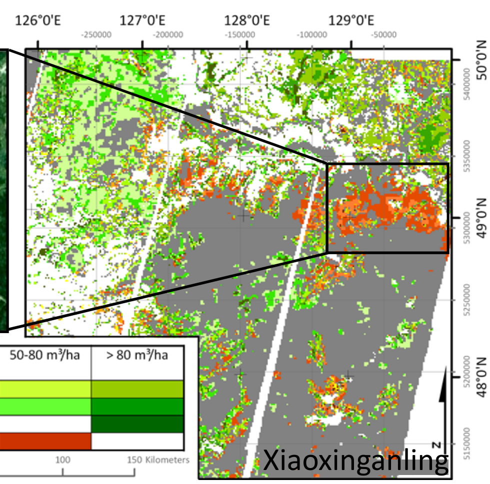
Forest Cover Change Pilot Study

3. Forest Cover (Structure) Change – First Results

- 1995-1998 (ERS-1/2 Tandem) - 2007/08 (ASAR GMM) -





ASAR / ERS	0-20 m³/ha	20-50 m³/ha	50-80 m³/ha	> 80 m³/ha
0-20 m³/ha				
20-50 m³/ha				
50-80 m³/ha				
> 80 m³/ha				

Projection: Albers Conical Equal Area   0 25 50 100 150 Kilometers

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HAROKOPIO UNIVERSITY

- Forest Cover Change Pilot study at Xiaoxinganling & Daxinganling at 1 km

- ERS-1/2 Tandem Coherence (1995-1997) and Envisat ASAR GMM (2007/08)
- First results show reasonable GSV structure changes

- Data and information collection of land cover dynamics during last decades

  -> detailed assessment of the detected changes *(publications ESA Bergen-Conference 2010 by Reik Leiterer and Johannes Reiche)*

→ 4th ADVANCED TRAINING COURSE IN LAND REMOTE SENSING
1–5 July 2013 | Harokopio University | Athens, Greece

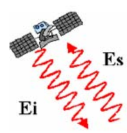
→ ESA ADVANCED TRAINING COURSE IN LAND REMOTE SENSING

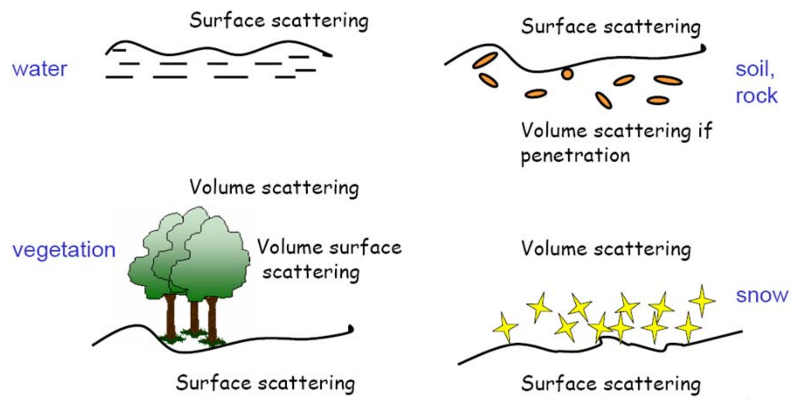
SAR for Agriculture

Chris Schmullius
Department for Earth Observation
University Jena, Germany

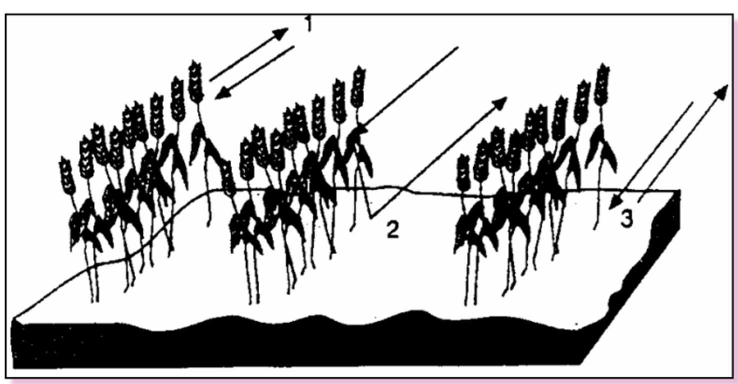
12-16 September 2011 | Kraków, Poland

Scattering mechanisms





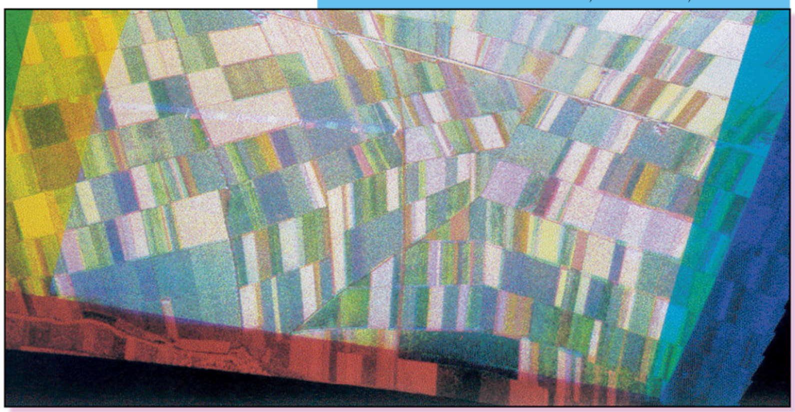
Einleitung



1 Direct Canopy (including multiple scattering)
2 Soil / Canopy Interaction
3 Direct Soil (including multiple scattering)

Einleitun

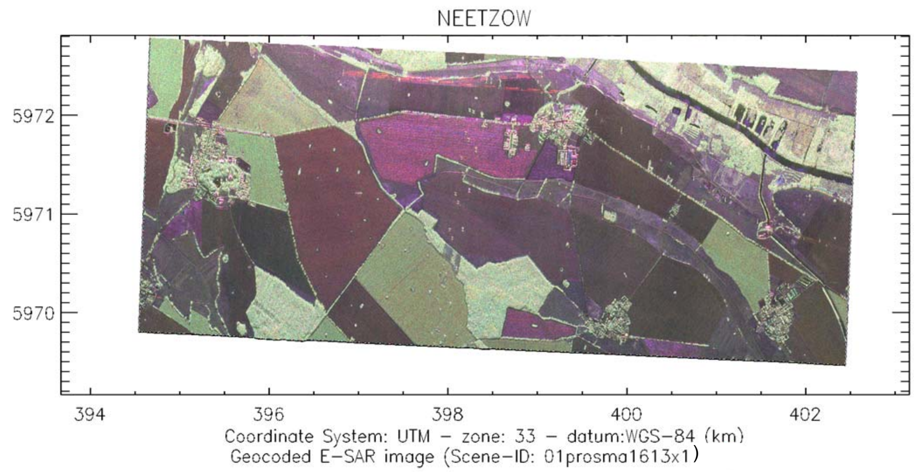
Multifrequente Komposite, Juli, Lechfeld (1995),
R: X-Band, G: C-Band, B: L-Band



Multipolarimetrische Colour-Komposite in C-Band
rot: HV grün: HH blau: VV

Uppsala, Schweden, Juni 1994

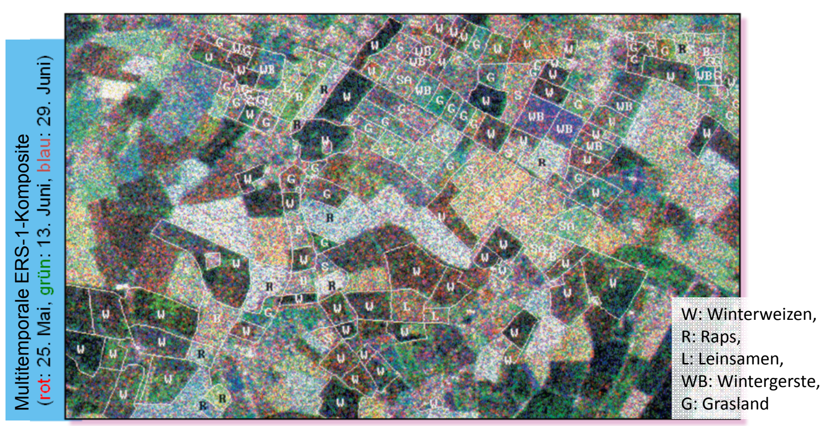
Einleitung



DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
Institut für Hochfrequenztechnik und Radarsysteme

L-band colour composite (HH - red, HV - green, VV - blue).

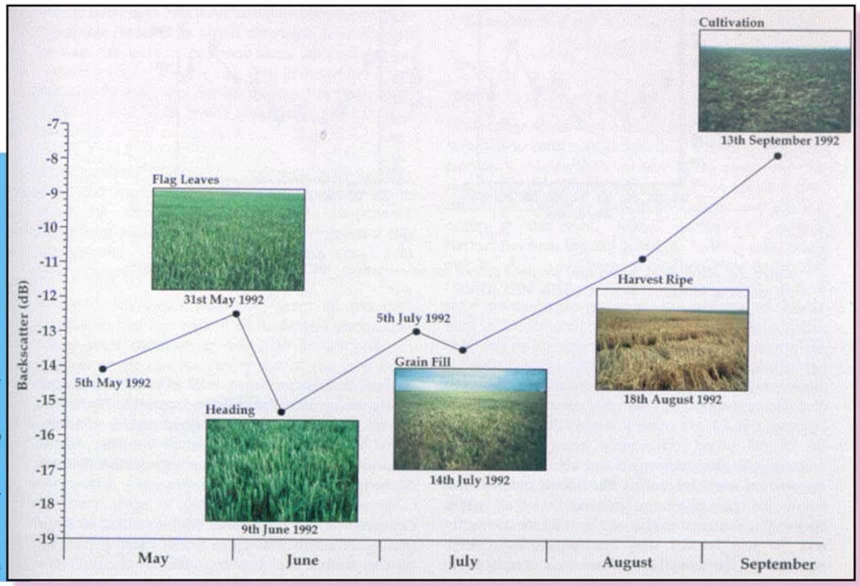
Einleitung



Temporal Crop Signatures

Einleitung

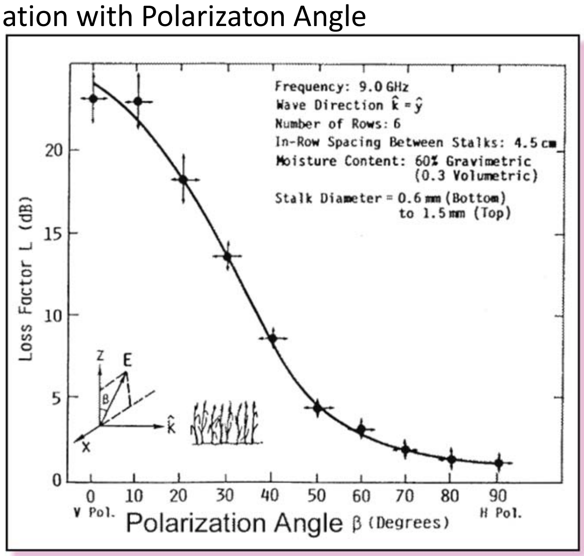
Zeitlicher Verlauf der ERS-1 Radarrückstreuung (multitemporal signature) eines Weizenbestandes



Spezielle Effekte

Propagation Properties

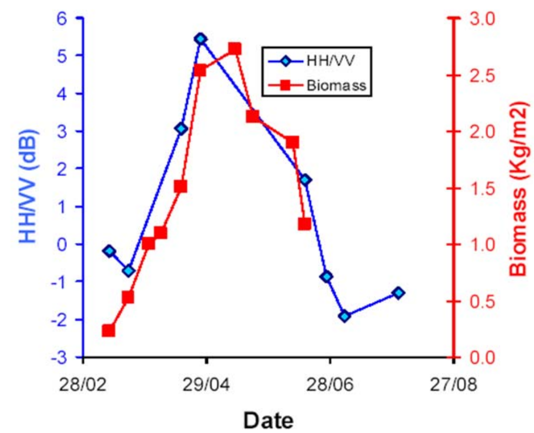
- Variation with Polarizaton Angle



[Lopes, 1983]

Example from ESA Report: „ASAR for Crop Monitoring, 2005

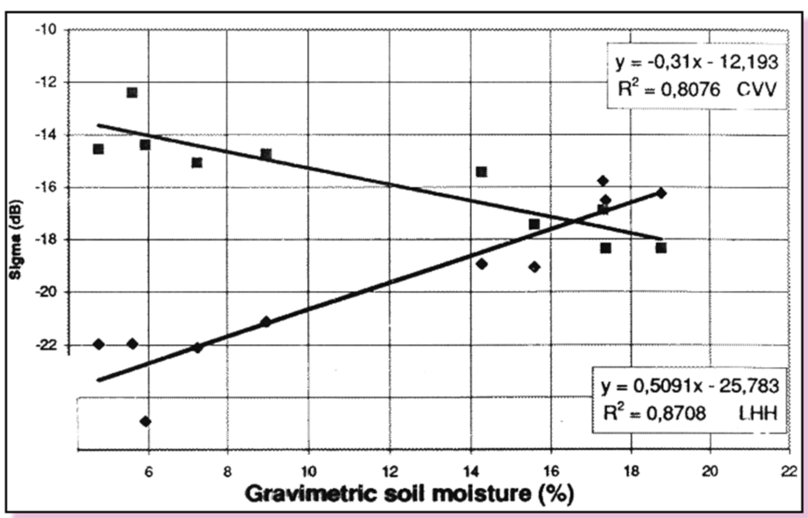
HH/VV of wheat field



ESA-MOST Dragon Programme Advanced training course in Land Remote Sensing, Beijing, October 2005
SAR Day 1- Lecture 1
Thuy LE TOAN, CESBIO, France

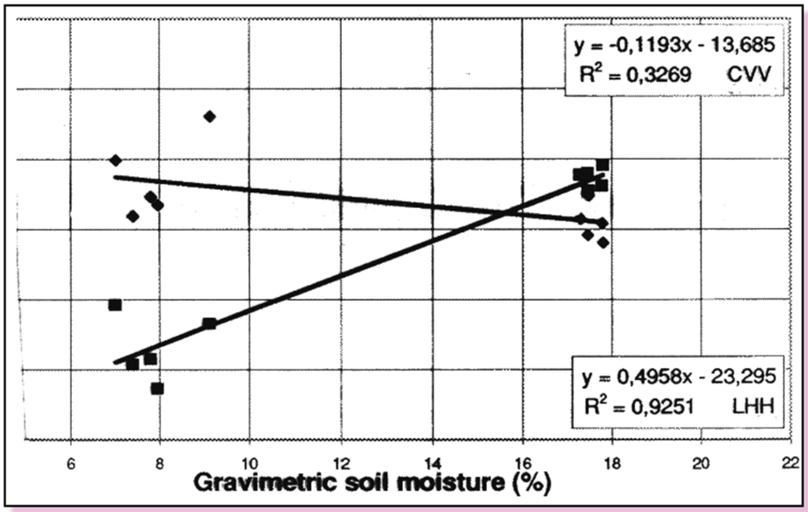
Spezielle Effekte

Summer Barley



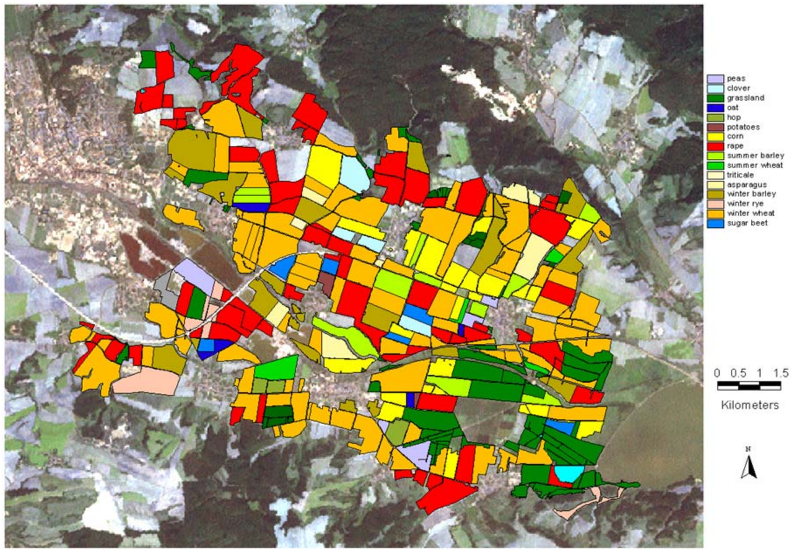
Spezielle Effekte

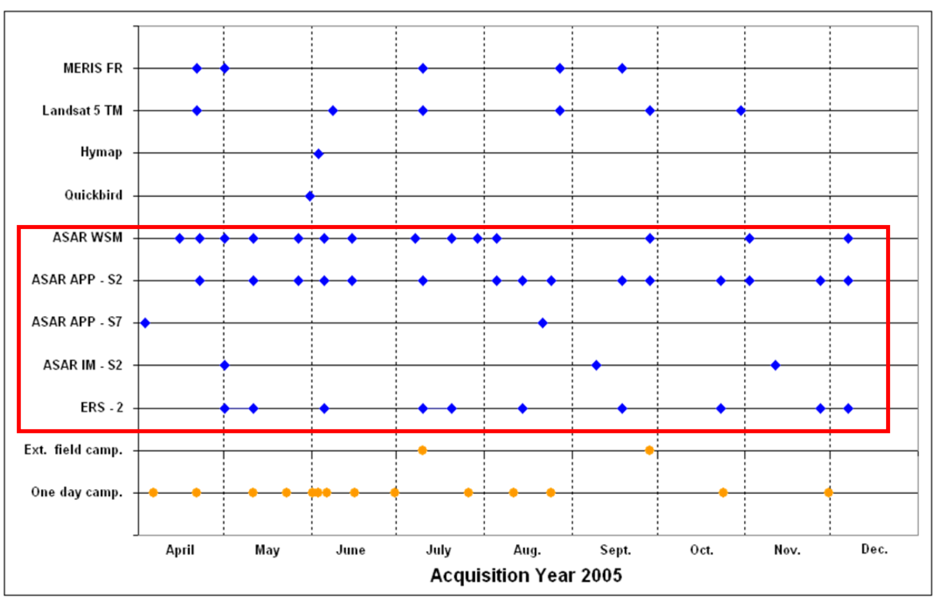
Winter Wheat



- Nordhausen, Thuringia
- Intensive Agriculture
- RAMSAR Wetland Site

Landuse 2005





Multi-temporal metrics

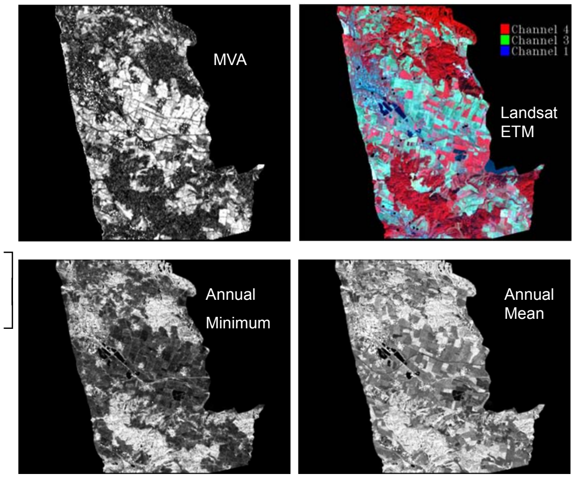
Mean annual variability

$I_{i,j}$= intensity for date i and j

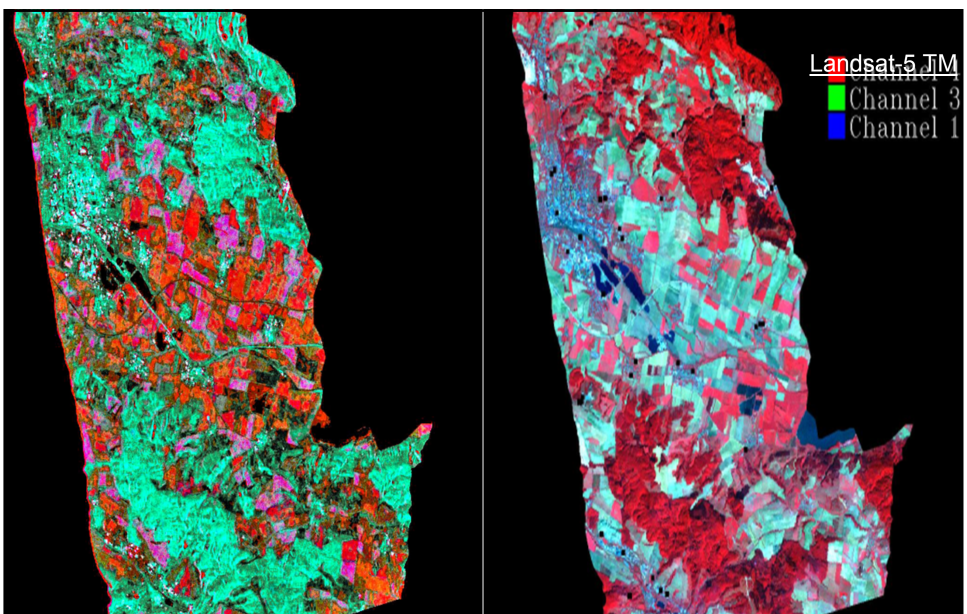
(Quegan et al., 2000):

$$mva = 10 \cdot \log\left[\frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j>i} R_{ji}\right]$$

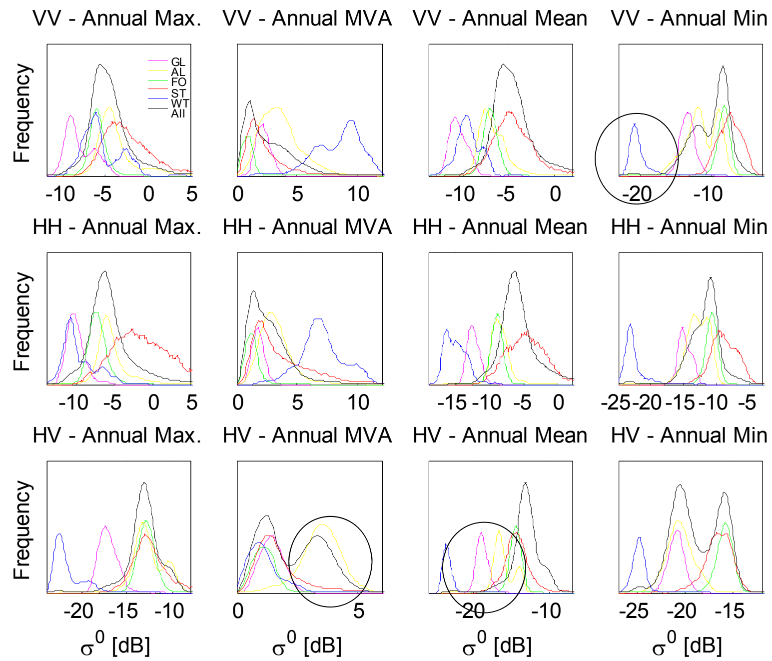
$$R_{ij} = \max\left(I_i / I_j , I_j / I_i \right)$$



14 HV images (ENL=70-100)



Multitempemporal Metrics ASAR Composite: Red - MVA HV
Green - Annual Min. HV
Blue - Annual Mean HV backscatter



Supervised Classification

Maximum Likelihood

Bayes Theorem:

$$p\{c\,|\,\mathbf{x}\} = \frac{p\{c\}\,p\{\mathbf{x}\,|\,c\}}{p\{\mathbf{x}\}}$$

Multidimensional Gaussian Model for Conditional probability:

$$p\{\mathbf{x}\,|\,c\} = \frac{1}{(2\pi)^{K/2}\left|\mathbf{C}_c\right|^{1/2}} \exp\left(-\frac{1}{2}(\mathbf{x}-\boldsymbol{\mu}_c)^t \mathbf{C}_c^{-1}(\mathbf{x}-\boldsymbol{\mu}_c)\right)$$

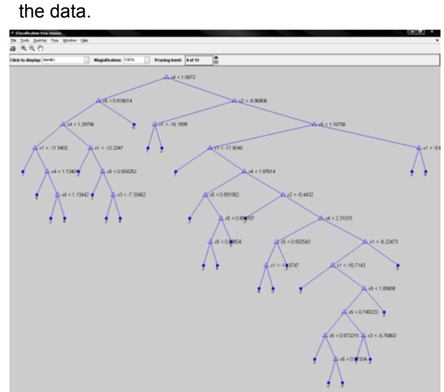
Iterated Contextual Probability (Balzter et al., 2002):

$$p_n(c) = \left(\frac{\sum_\delta p_\delta(c|\mathbf{x})}{n_\delta}\right)^\beta$$

Decision Tree

DTCs are a set of hierarchical rules which divide the data into more homogenous subsets with respect to the required ground-truth information.

Each node is selected according to its ability to minimize the impurity of the resulting subsets of the data.



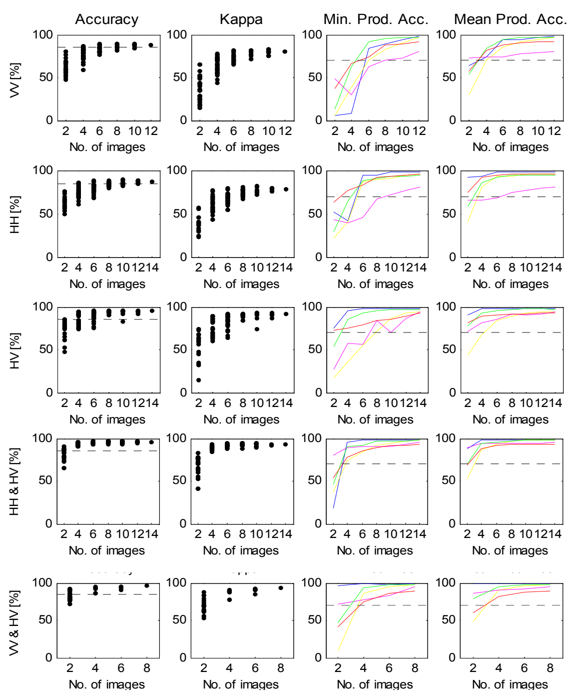
RadarCover Thinning Procedure

In order to test the stability of both classification approaches and to specify the minimum number of acquisitions needed, thinning of the input dataset has been carried out:

1) Using less intensity images for the calculation of the multi-temporal metrics and varying the combination of acquisition dates used. For each number of selected acquisition dates C out of all available dates N, there are N' combinations possible:

$$N' = \binom{N}{C} \longrightarrow \sqrt{N'}$$

2) Classification and accuracy assessment was performed for each combination



Maximum Likelihood Classification

Red – Settlement

Green – Forest

Blue – Water

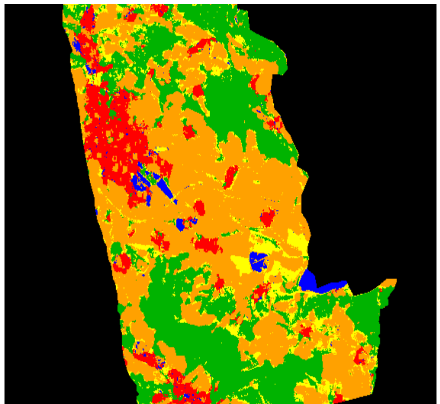
Yellow – Grassland

Magenta – Cropland

(dashed lines show minimum accuracy requirements:

85% overall accuracy,

70% Class Accuracies)



Maximum Likelihood Classifi

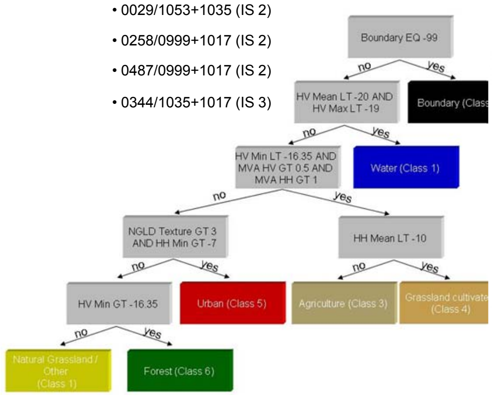
Polarization	Accuracy	Kappa
VV	95.4	0.918
HH	93.8	0.89
HV	96.9	0.945
HH & HV	97.4	0.955
VV & HV	97.4	0.954

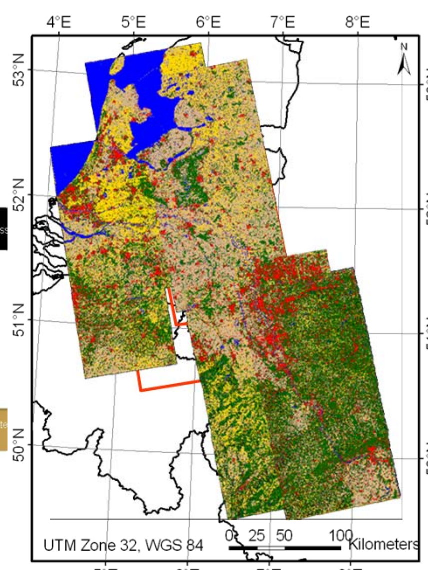
Maximum Likelihood VV & HV / 8 acq. dates	Water	Grassland	Cropland	Forest	Settlement	User accuracy
Water	97.88	1.217	0.27	0.22	0.85	89.35
Grassland	0.53	97.28	2.27	0.10	0.08	75.37
Cropland	1.24	1.503	95.99	0.64	16.82	97.73
Forest	0	0	1.15	98.92	0.085	
Settlement	0.35	0	0.32	0.12	82.16	
Prod. Accuracy	97.88	97.28	95.99	98.92	82.16	97.34

orchards and alfalfa

RadarCover/AMOC Production of Land Cover Map

- AMOC II decision tree based on track 0487, frame 0999
  - 75.000 km² - 10 frames (IS 1 – IS 3)
    - 0487/1053+1035 (IS 1)
    - 0029/1053+1035 (IS 2)
    - 0258/0999+1017 (IS 2)
    - 0487/0999+1017 (IS 2)
    - 0344/1035+1017 (IS 3)





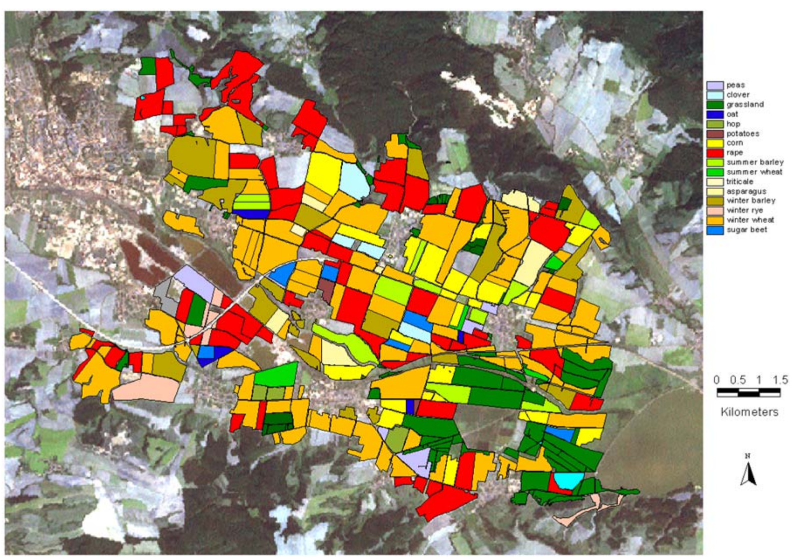
RadarCover Summary

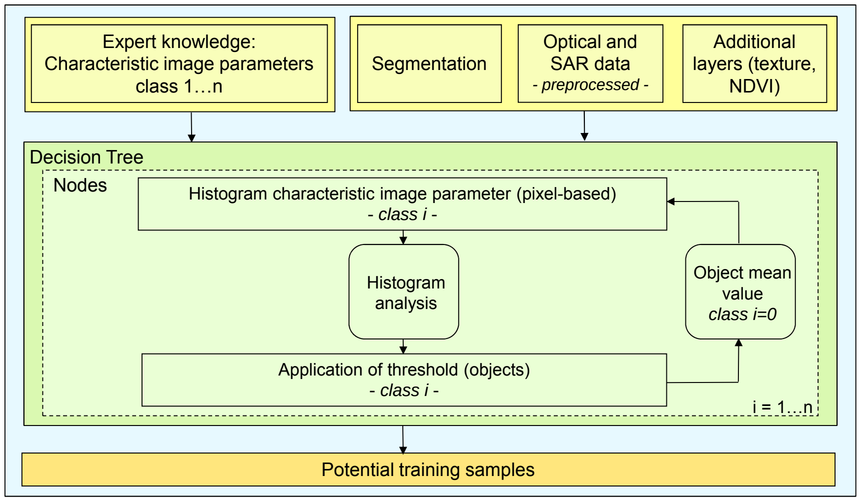
• Classification of basic land cover classes is possible with very high accuracies when using at least four SAR acquisitions and two polarizations.

• Consistent multi-temporal coverage of ENVISAT ASAR APP not available for large areas in Central Europe

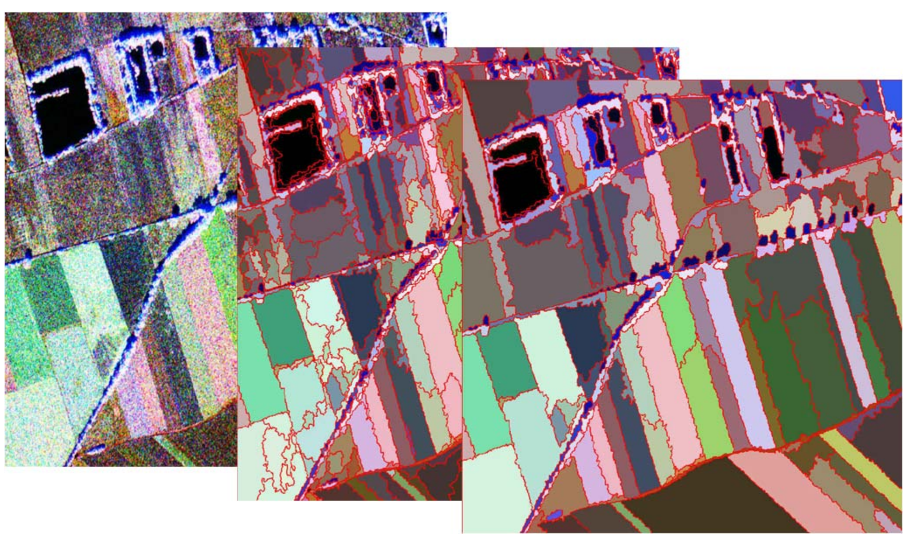
→ SENTINEL-1 will provide consistent coverage in Interferometric Wide Swath Mode

Landuse 2005





Segmentation



Two Types of Scatterers

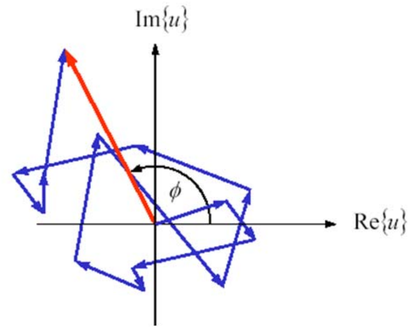
point scatterer: only a single (dominant) scatterer in a resolution cell (e.g. corner reflector, building)

⇒ single wave response

distributed scatterers:
many sub-scatterers in a resolution cell
(e.g. stones, leaves, branches)

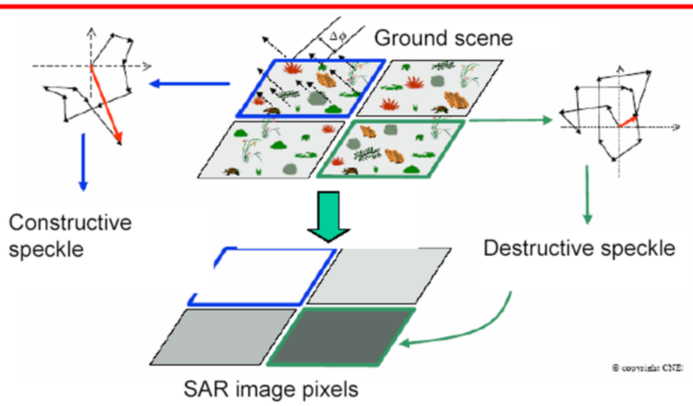
⇒ many wave responses mix to a single phasor

⇒ circular Gaussian statistics



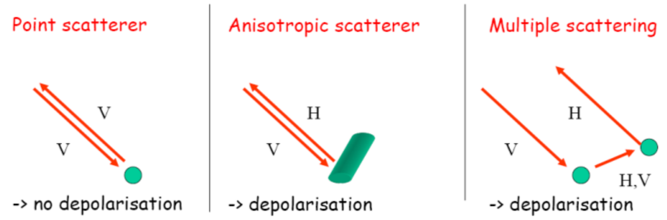
MFFU Sommerschule 2000

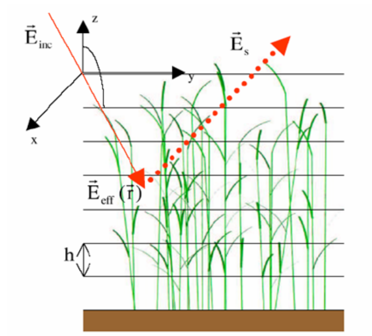
The physical origin of speckle

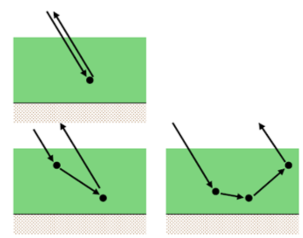


Resolution cells are made up of many scatterers with different phases, leading to interference and the noise-like effect known as **speckle**.

Volume scattering





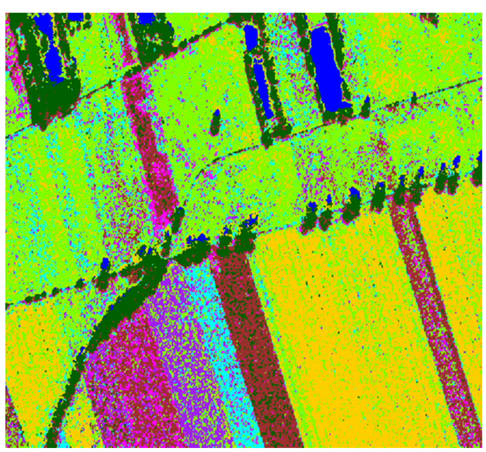


Single and multiple scattering

Objektorientierte Bildanalyse mit eCognition - Einleitung

→„Salt-and-Pepper“ Effect of conventional classifiers

- not usable in a GIS

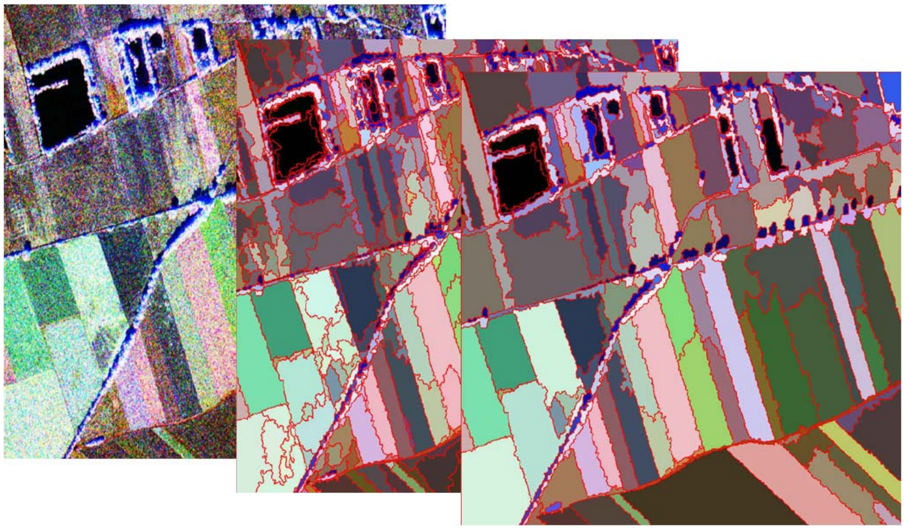


Result of a pixel-based maximum-likelihood classifier

Wasser	
Bäume	
Grünland	
Kartoffel	
Sommergerste	
Mais	
Hafer	
Zuckererbsen	

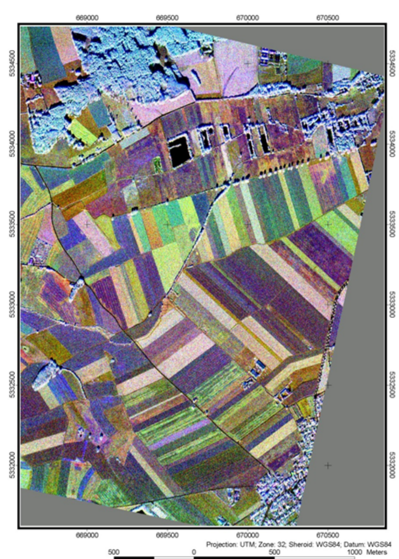
Objektorientierte Bildanalyse mit eCognition – Grundlagen

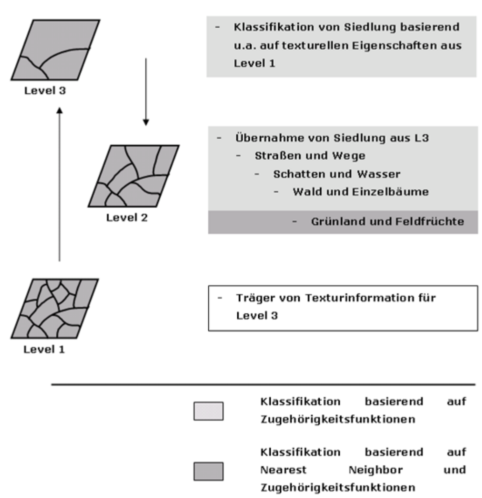
Segmentation



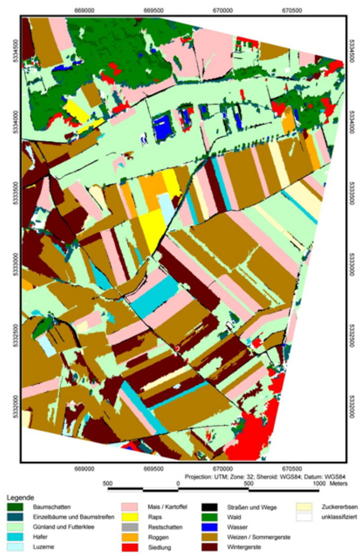
Objektorientierte Bildanalyse mit eCognition – Klassifikation von E-SAR und HyMap™ Daten

E-SAR - RGB =X-HH, C-VV, L-VV

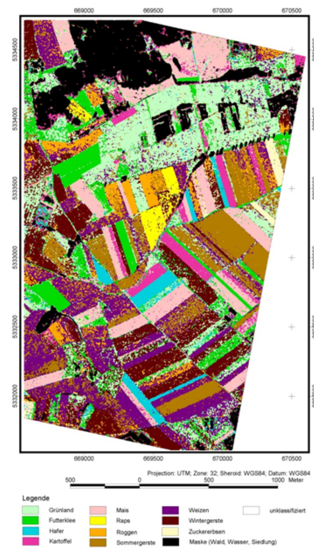


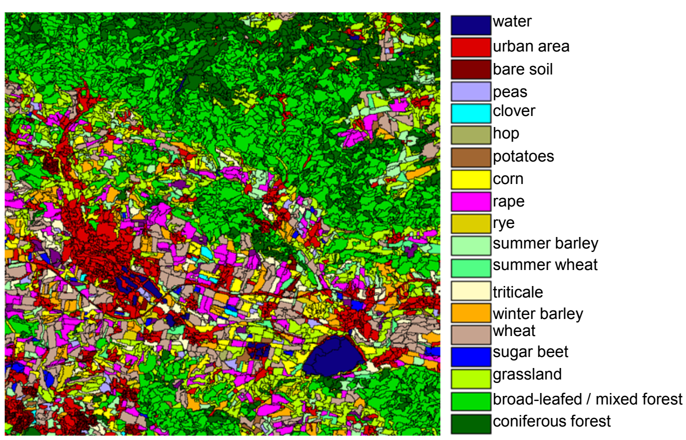


objektorientiertes Klassifikationsergebnis (E-SAR)



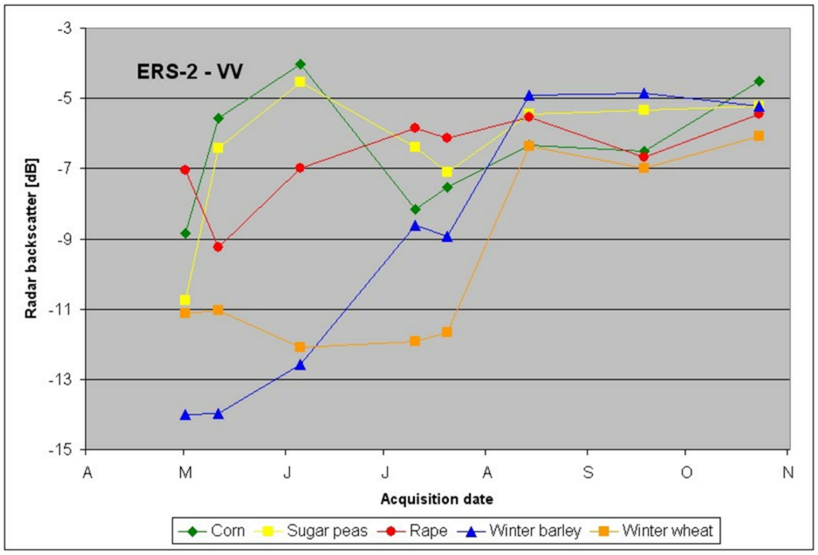
pixelbasiertes Klassifikationsergebnis (E-SAR)

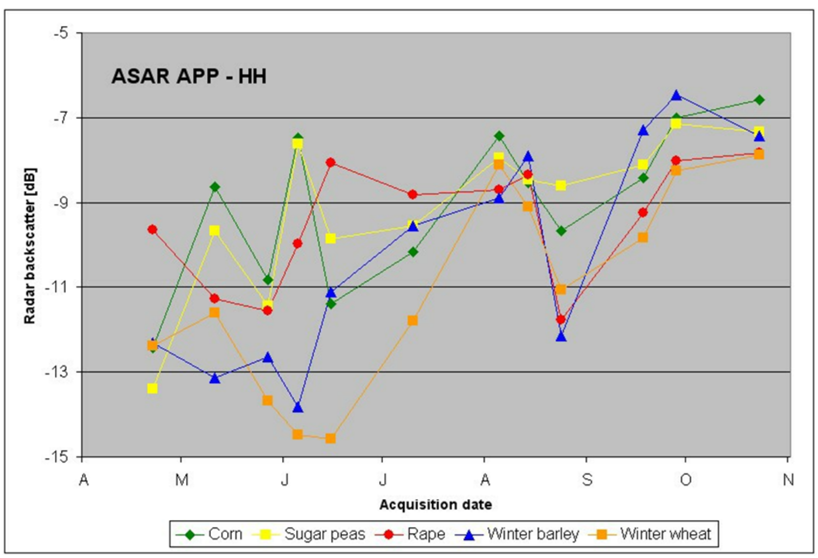


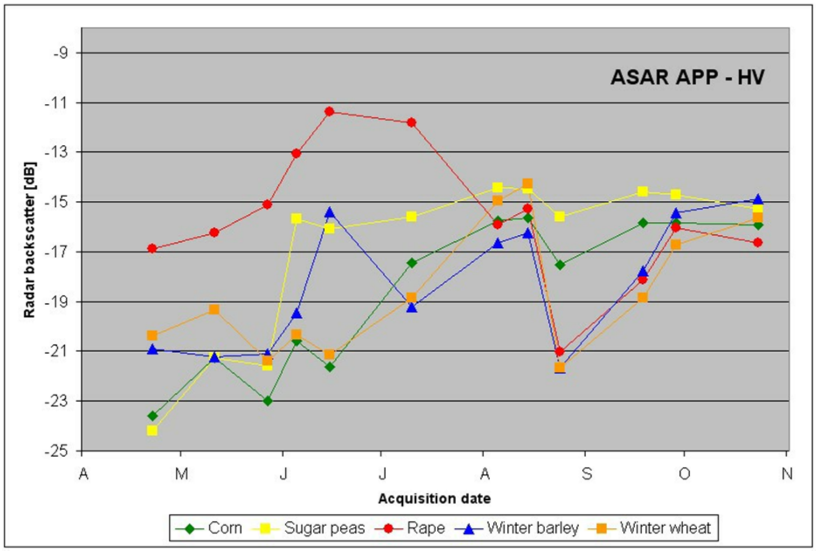


	LS-5 TM	combination
overall accuracy	**77,9**	**84,0**
kappa	**0,78**	**0,80**

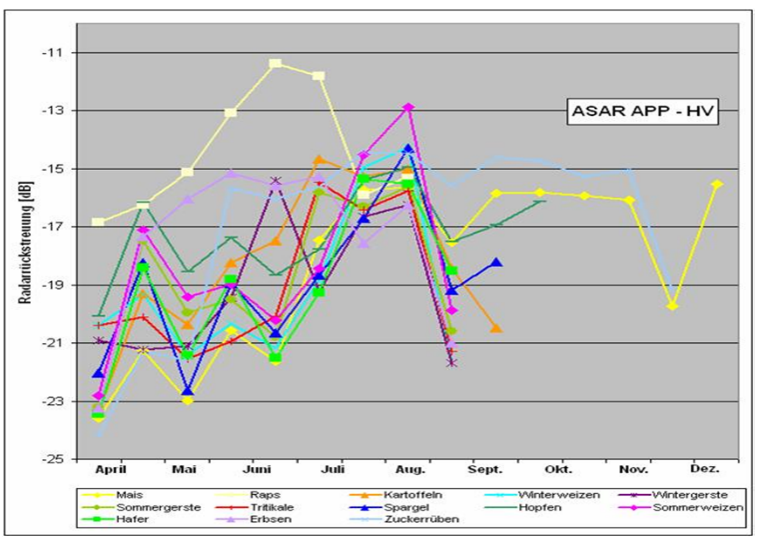
Improvements for: *urban areas, winter wheat, winter+summer barley, grassland, corn, peas*


ERS-2 - VV
Radar backscatter [dB]
-3
-5
-7
-9
-11
-13
-15
A M J J A S O N
Acquisition date
Corn
Sugar peas
Rape
Winter barley
Winter wheat

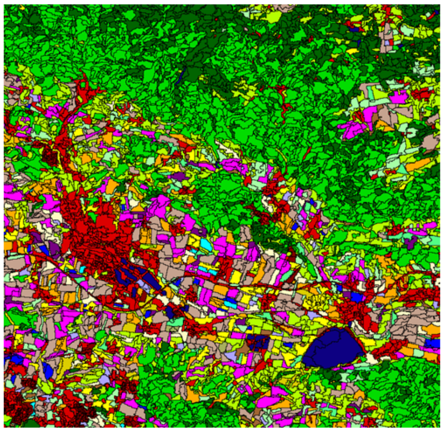

ASAR APP - HH
Radar backscatter [dB]
-5
-7
-9
-11
-13
-15
A M J J A S O N
Acquisition date
Corn
Sugar peas
Rape
Winter barley
Winter wheat



ASAR APP - HV
Radar backscatter [dB]
-9
-11
-13
-15
-17
-19
-21
-23
-25
A
M
J
J
A
S
O
N
Acquisition date
Corn
Sugar peas
Rape
Winter barley
Winter wheat



ASAR APP - HV
Radarrückstreuung [dB]
-11
-13
-15
-17
-19
-21
-23
-25
April
Mai
Juni
Juli
Aug.
Sept.
Okt.
Nov.
Dez.
Mais
Raps
Kartoffeln
Winterweizen
Wintergerste
Sommergerste
Tritikale
Spargel
Hopfen
Sommerweizen
Hafer
Erbsen
Zuckerrüben



	LS-5 TM	combination
overall accuracy	**77,9**	**84,0**
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Improvements for: *urban areas, winter wheat, winter+summer barley, grassland, corn, peas*

Results – potential for land use mapping

Multitemporal optical & SAR data – information gain

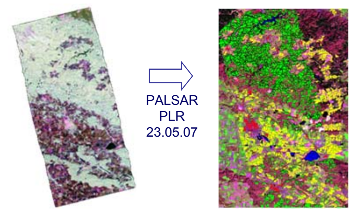
Classification results combined approach – overall accuracy for 20 classes – 50 reference pixel per class

	Exclu-ding SAR	**SAR – HV, VV, texture, HV-min**	**SAR – HV, VV**	**SAR – HV, texture, HV-min**	**SAR – HV**	**SAR – VV, texture**	**SAR – VV**
SAR		**80.2**	**77.9**	**73.3**	**71.9**	**64.3**	**65.2**
LS 21.04.05	**52.8**	**82.8**	**81.8**	**80.4**	**80.4**	**75.8**	**76.8**
LS 10.07.05	**68.3**	**82.4**	**82.7**	**83.6**	**82.2**	**80.1**	**80.6**
LS 21.04. & 10.07.	**77.9**	**83.7**	**83.7**	**84.0**	**83.8**	**82.9**	**82.5**

optical
SAR
optical & SAR

Training sample selection – Expected results / Outlook

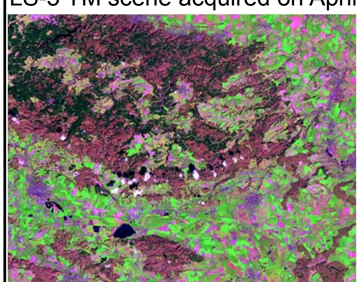
- ALOS PALSAR
  - » HV-Polarisation: forest and urban area mask
  - » HH-texture: differentiation forest and urban areas
  - » Mapping of broad-leaf crops
- TerraSAR-X
  - » Meaningful texture measure
  - » Mapping of narrow-leaf crops
  - » Grassland mapping
- RapidEye
  - » RedEdge channel, high temporal resolution → improved separability of vegetation classes
  - » High resolution → meaningful and stable texture measure in space and time



		oat	wheat / s.rye	s. barley	w. rye	w. barley
X	user	89,9	84,9	92,8	26,4	53,4
	producer	80,3	90,0	83,2	83,6	46,3
C	user	24,9	72,6	70,5	61,9	70,6
	producer	57,8	79,9	49,3	92,7	79,3
L	user	30,1	75,6	82,3	46,2	63,3
	producer	56,9	65,2	67,7	90,4	71,4

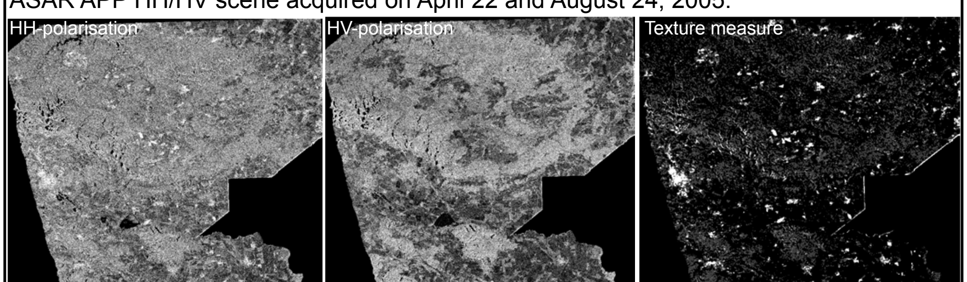
Input data:

LS-5 TM scene acquired on April 21, 2005:

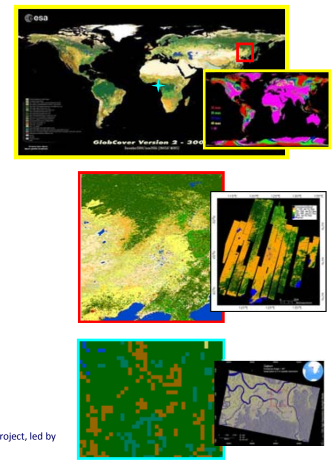


ENVILAND - Potential for land cover classification:
optical vs. SAR vs. optical & SAR

ASAR APP HH/HV scene acquired on April 22 and August 24, 2005:



Integration of SAR Data - Multiscale Approach



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- → Lack / insufficient number of optical data
- → Automation (urban areas)
- → Improvement of specific land cover boundaries
- → Change detection
- → Validation
- → Small-scale landscapes

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Summary for Sentinel-1 Land Applications

- New multi-scale texture measures improve urban mapping.
- Consistent multi-temporal coverage is crucial for high (> 85%) crop classification accuracies for Level-1 Land Cover Classes.
- Multi-temporal co- and cross-polarised C-band data acquisitions are crucial for improved Level-2 Land Cover Class mapping (20 classes with > 75% accuracies).
- Multi-temporal repeat-pass C-band coherence analysis allows forest structure mapping. Saturation not known yet!

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- Multitemporal, multipolarized C-Band SAR-Data proves very high potential for crop mapping.
- Optimal polarisations: HV und VV, HH less information content.
- Temporal & spectral resolution is more important for crop mapping than geometric resolution,

BUT

- segmentation (i.e. detection) results are dependent on field size

AND

- improved urban area mapping using multiscale SAR data.

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THANK YOU
FOR YOUR ATTENTION
&
GOOD LUCK
TO YOUR FUTURE!

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