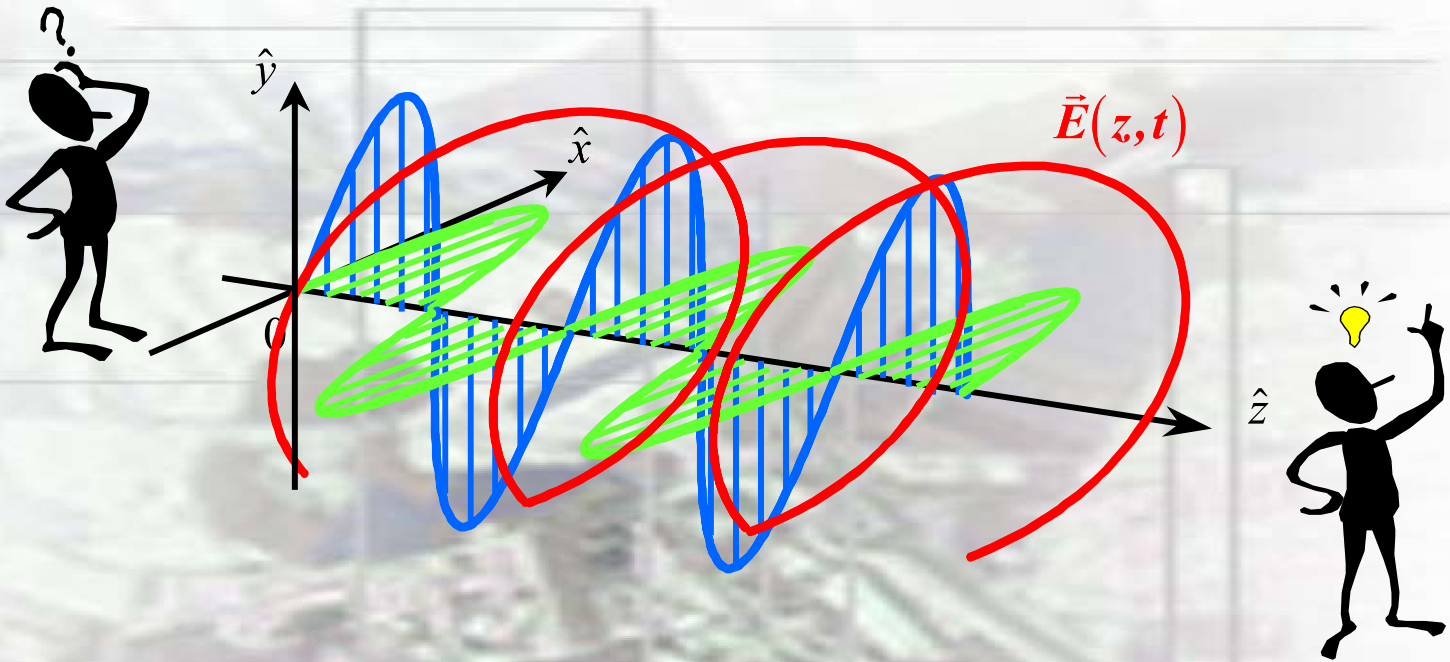
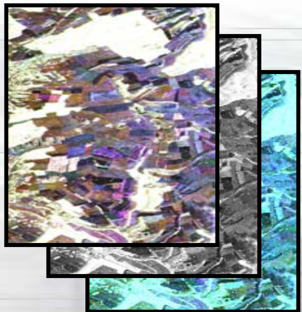


POL-SAR CLASSIFICATION

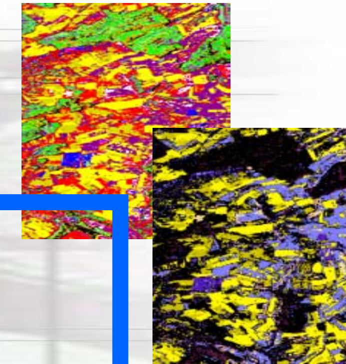
DATA INVERSION - APPROACH

SAPHIR



POLARIMETRIC
SAR DATA SET(S)

POLSAR - POLINSAR
DATA
PROCESSING



QUALITATIVE ANALYSIS

POLARIMETRIC
DESCRIPTORS
EXTRACTION

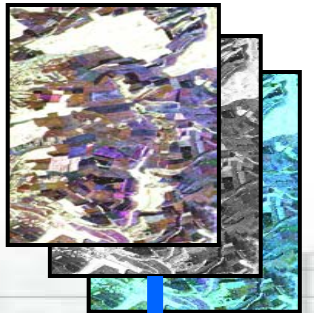
TWO-STEP INVERSION PROCEDURE

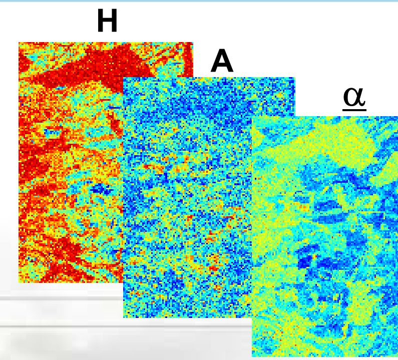
MODEL-BASED
PHYSICAL PARAMETER
INVERSION

BIO and GEO PHYSICAL
PARAMETERS

QUANTITATIVE ANALYSIS

QUALITATIVE ANALYSIS

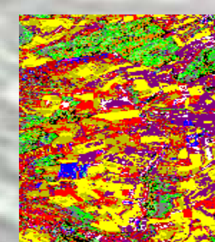




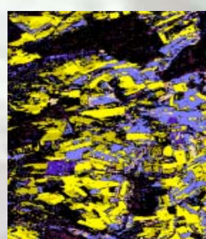
SPECKLE FILTERING

POLARIMETRIC TARGET DECOMPOSITION

WISHART POLARIMETRIC SEGMENTATION
MONO/DUAL FREQUENCY INTERFEROMETRY



CLUSTER POLARIMETRIC IDENTIFICATION



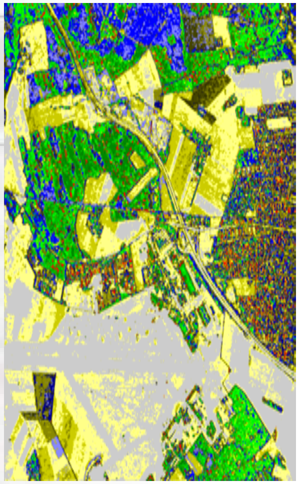
POLARIMETRIC DESCRIPTORS EXTRACTION

WISHART PDF

$$P(\langle[T]\rangle/[T_m]) = \frac{L^{Lp}\left|\langle[T]\rangle\right|^{L-p} e^{-L\,Tr\left([T_m]^{-1}\langle[T]\rangle\right)}}{\pi^{\frac{p(p-1)}{2}}\Gamma(L)\ldots\Gamma(L-p+1)\left|[T_m]\right|^{L}}$$

SUPERVISED POLSAR CLASSIFICATION

J.S LEE, M.R GRUNES, E.POTTIER (2002)



WISHART CLASSIFIER

Target Vector

$$\underline{X} = \left[S_{HH} \quad \sqrt{2}S_{HV} \quad S_{VV}\right]^T \qquad P(\underline{X}) = \frac{1}{\pi^3 \left|[C]\right|} e^{-\underline{X}^{*T}[C]^{-1}\underline{X}}$$

$$\underline{k} = \frac{1}{\sqrt{2}}\left[S_{HH}+S_{VV} \quad S_{HH}-S_{VV} \quad 2S_{HV}\right]^T \qquad P(\underline{k}) = \frac{1}{\pi^3 \left|[T]\right|} e^{-\underline{k}^{*T}[T]^{-1}\underline{k}}$$

Coherency Matrix

$$\langle [T] \rangle = \frac{1}{N}\sum_{i=1}^{N} \underline{k}_i \cdot \underline{k}_i^{*T} = \frac{1}{N}\sum_{i=1}^{N}[T_i]$$

$$P\left(\langle [T] \rangle / [T_m]\right) = \frac{L^{Lp} \left|\langle [T] \rangle\right|^{L-p} e^{-LTr\left([T_m]^{-1}\langle [T] \rangle\right)}}{\pi^{\frac{p(p-1)}{2}} \Gamma(L)\ldots\Gamma(L-p+1)\left|[T_m]\right|^L}$$

COMPLEX WISHART DISTRIBUTION

L: Number of Look p: Polarimetric Dimension

WISHART CLASSIFIER

$$P\left(\langle[T]\rangle/[T_m]\right)=\frac{L^{Lp}\left|\langle[T]\rangle\right|^{L-p}e^{-LTr\left([T_m]^{-1}\langle[T]\rangle\right)}}{\pi^{\frac{p(p-1)}{2}}\Gamma(L)\ldots\Gamma(L-p+1)\left|[T_m]\right|^{L}}$$

⬇

SUPERVISED WISHART CLASSIFIER (Lee 1994)

BAYES MAXIMUM LIKELIHOOD CLASSIFICATION PROCEDURE

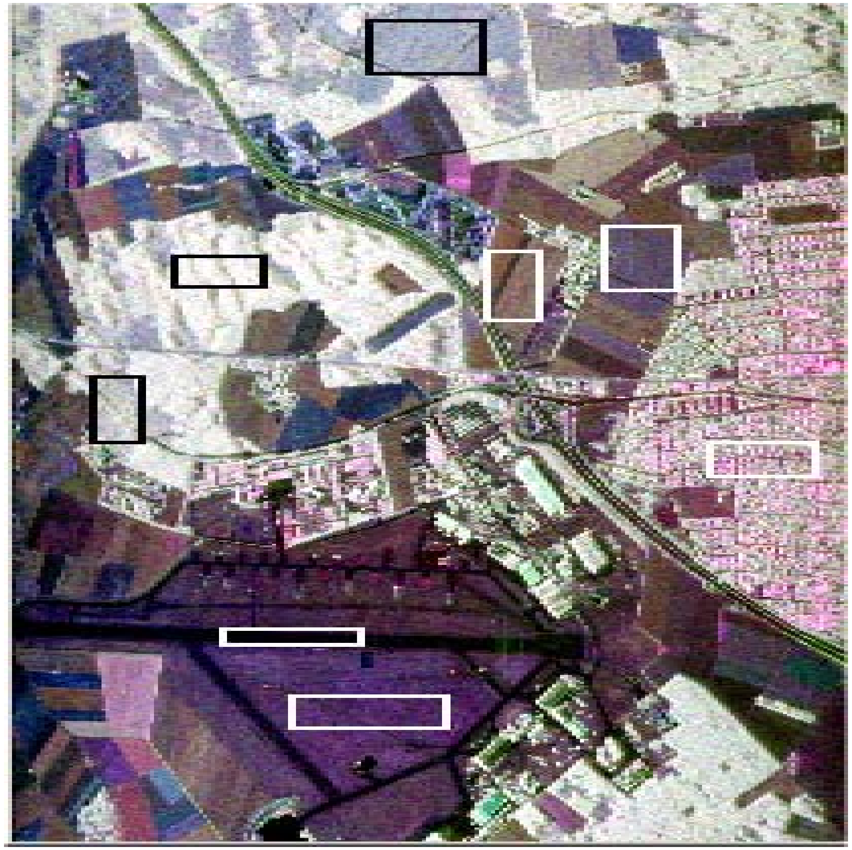
$$\langle[T]\rangle\in[T_m]\quad if\quad d_m\left(\langle[T]\rangle\right)<d_j\left(\langle[T]\rangle\right)\quad\forall\ j\neq m$$

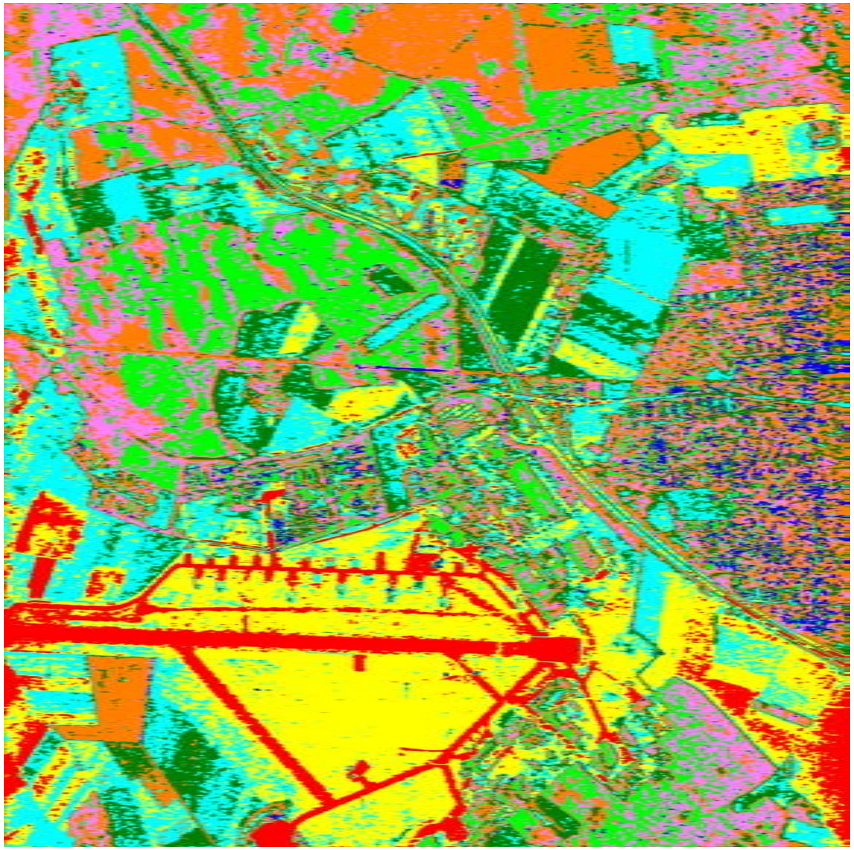
with

$$d_m\left(\langle[T]\rangle\right)=LTr\left([T_m]^{-1}\langle[T]\rangle\right)+L\ln\left(\left|[T_m]\right|\right)-\ln\left(P\left([T_m]\right)\right)+K$$

$[T_m]$: Cluster Center of the class *m*

WISHART CLASSIFIER

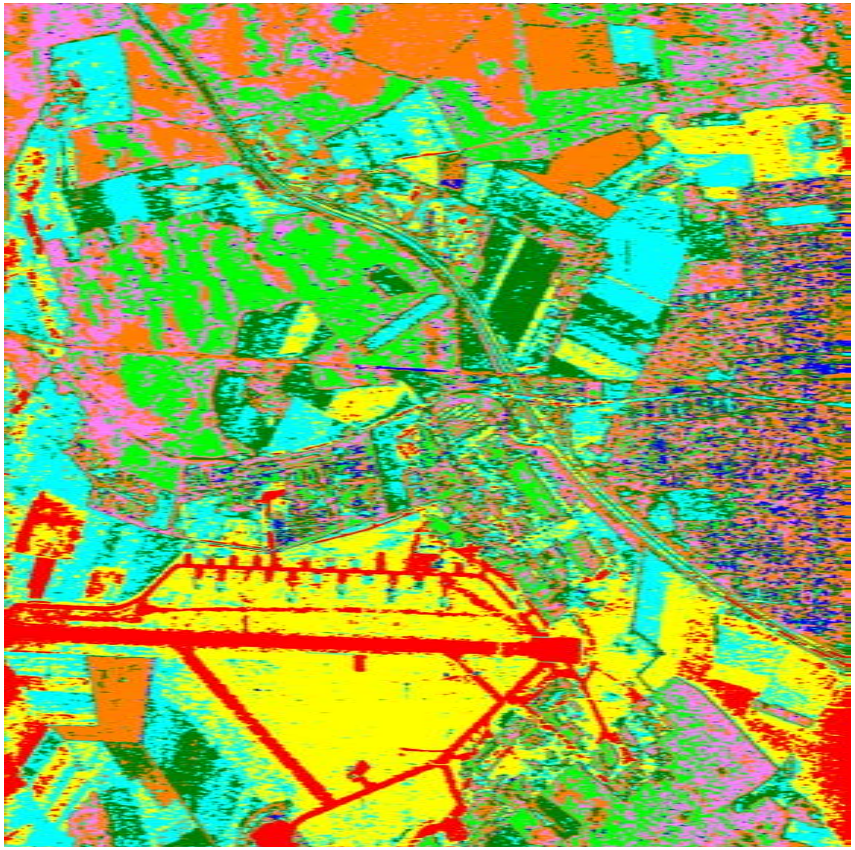




$2A_0$ $\quad B_0 + B$ $\quad B_0 - B$

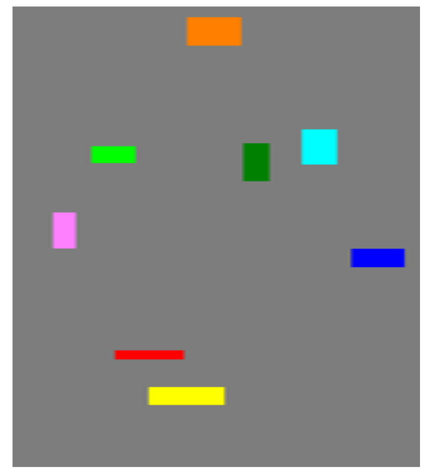
WISHART CLASSIFIER

FULLY POLARIMETRIC DATA CLASSIFICATION



Fully polarimetric coherent data segmentation

Training areas definition quality



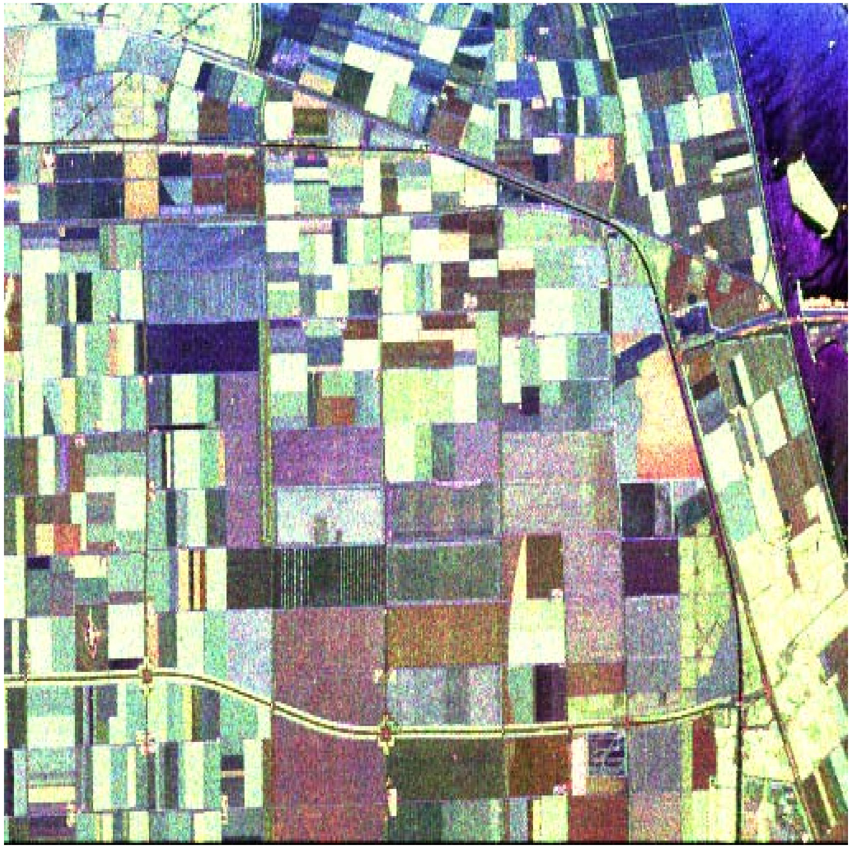
User defined training areas

Classified training areas

CONFUSION MATRIX

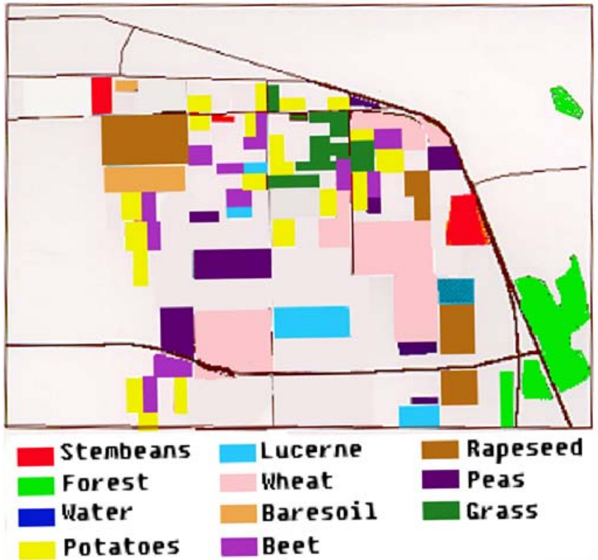
WISHART CLASSIFIER

Courtesy of Dr J.S Lee

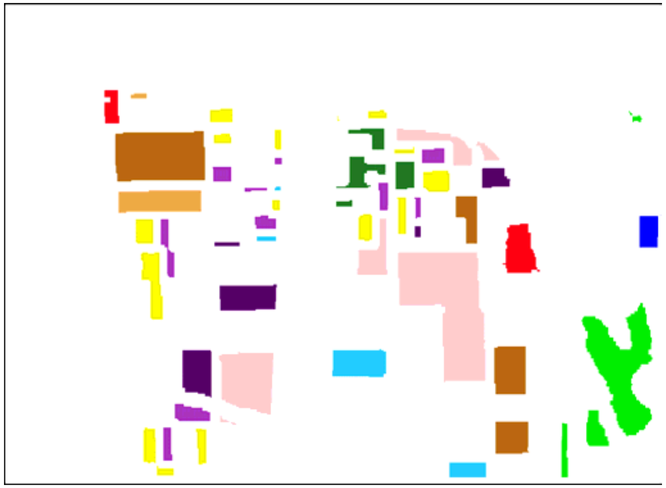


$2A_0$ $B_0 + B$ $B_0 - B$

JPL AIRSAR
P-L-C Band Flevoland Data



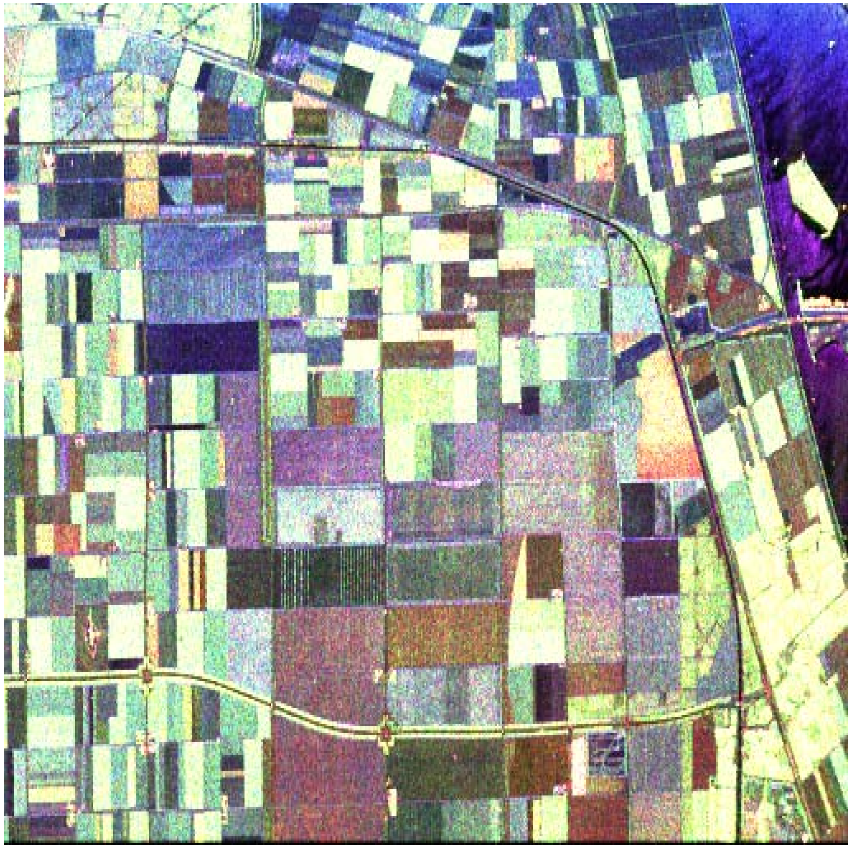
Original Ground- Truth



Training Sets / Reference map

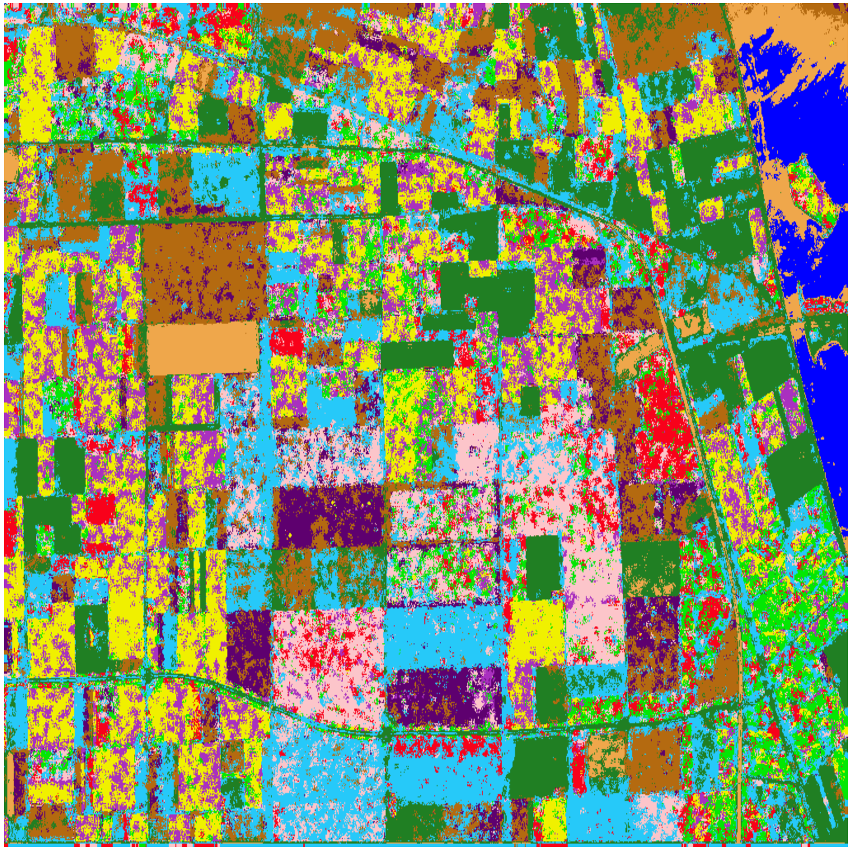
WISHART CLASSIFIER

Courtesy of Dr J.S Lee



$2A_0$ $B_0 + B$ $B_0 - B$

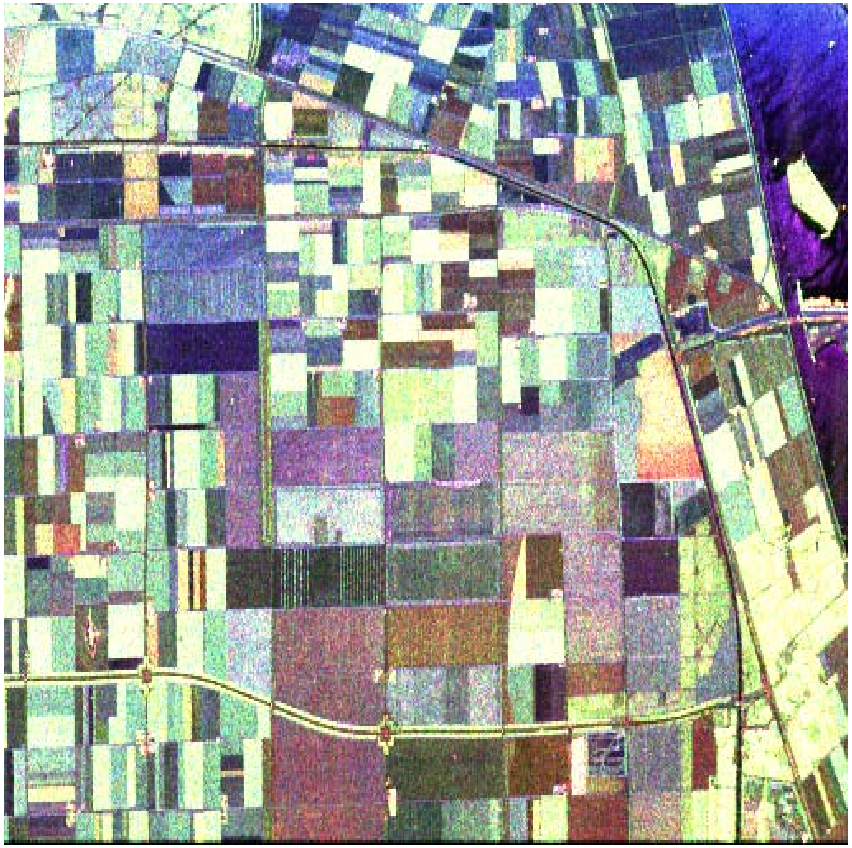
JPL AIRSAR
L-Band Flevoland Data



C-band (66.53%)

WISHART CLASSIFIER

Courtesy of Dr J.S Lee



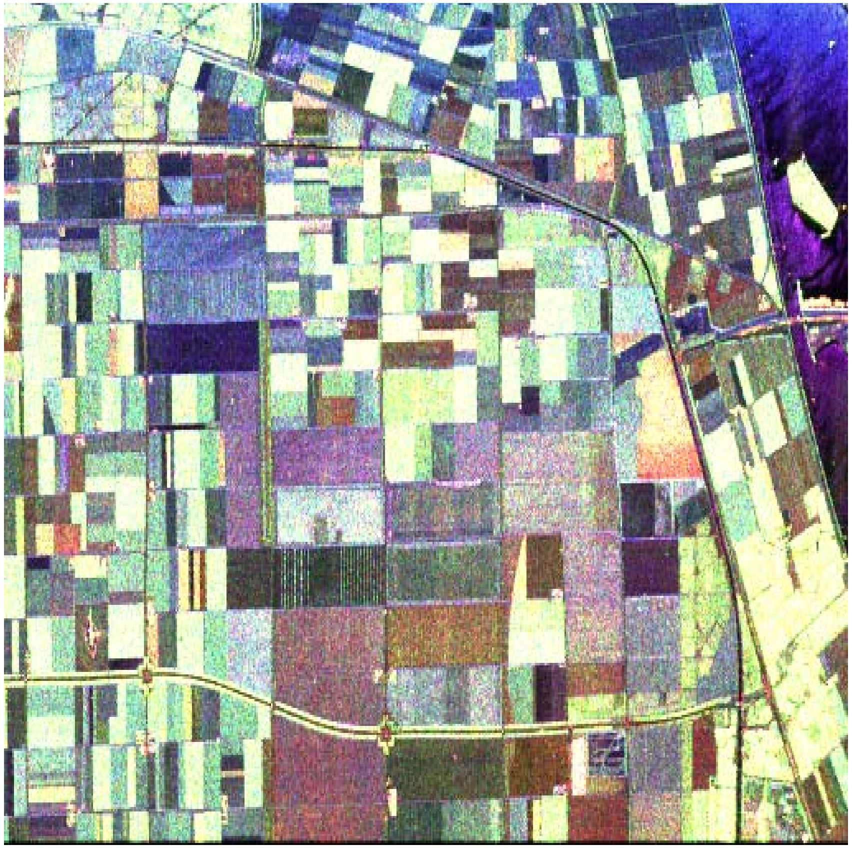
$2A_0$ $B_0 + B$ $B_0 - B$

JPL AIRSAR
L-Band Flevoland Data

L-band (81.63%)

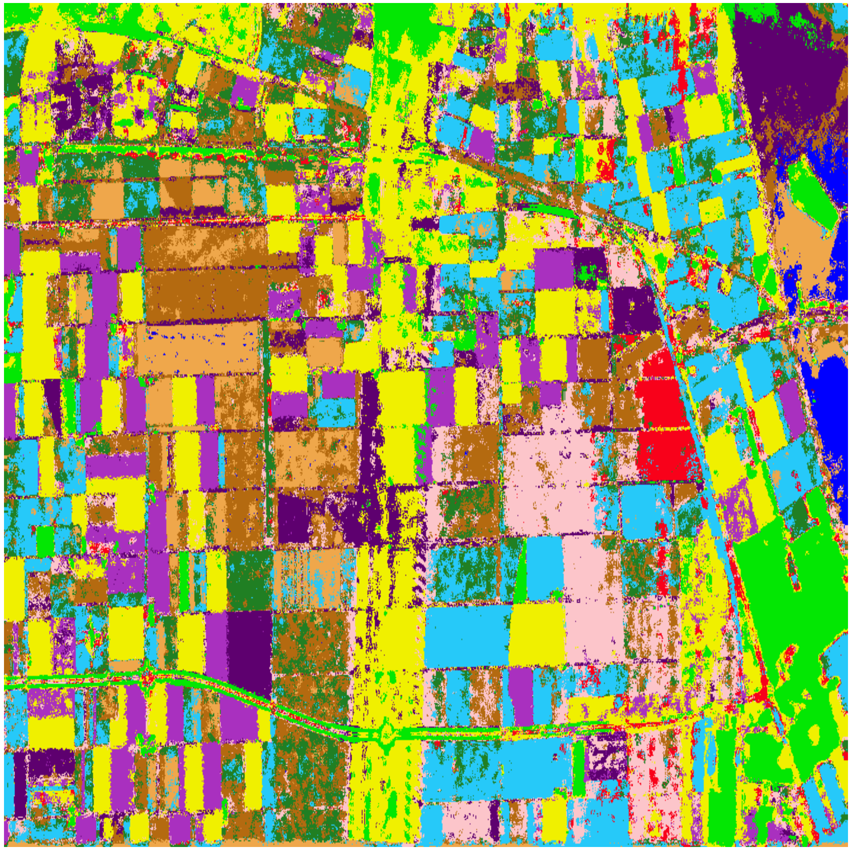
WISHART CLASSIFIER

Courtesy of Dr J.S Lee



$2A_0$ $B_0 + B$ $B_0 - B$

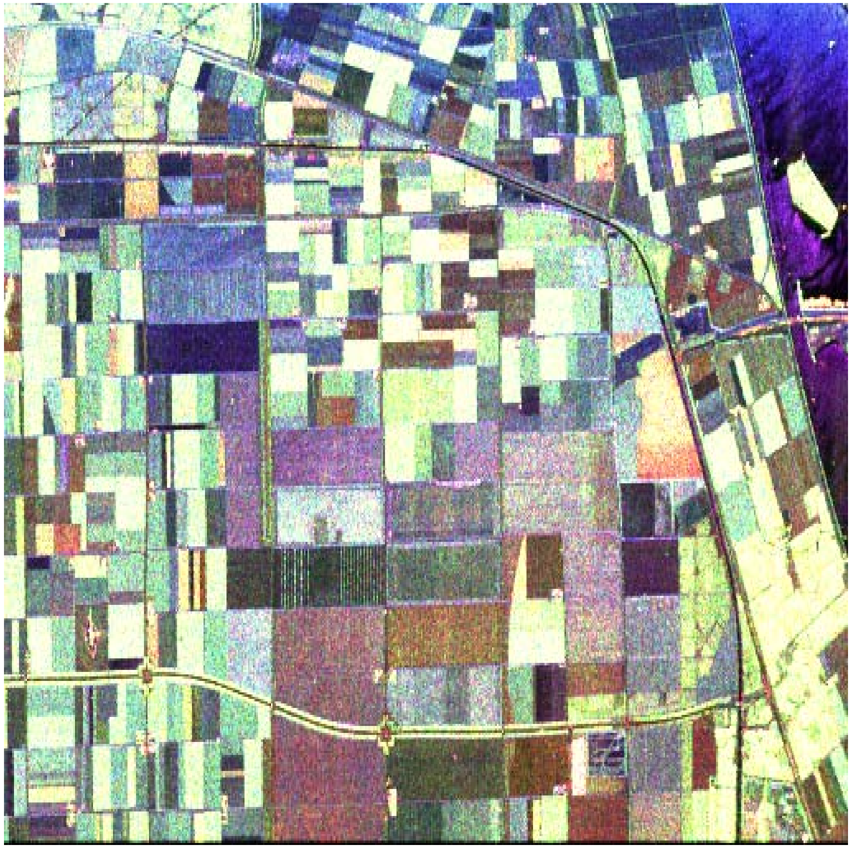
JPL AIRSAR
L-Band Flevoland Data



P-band (71.37%)

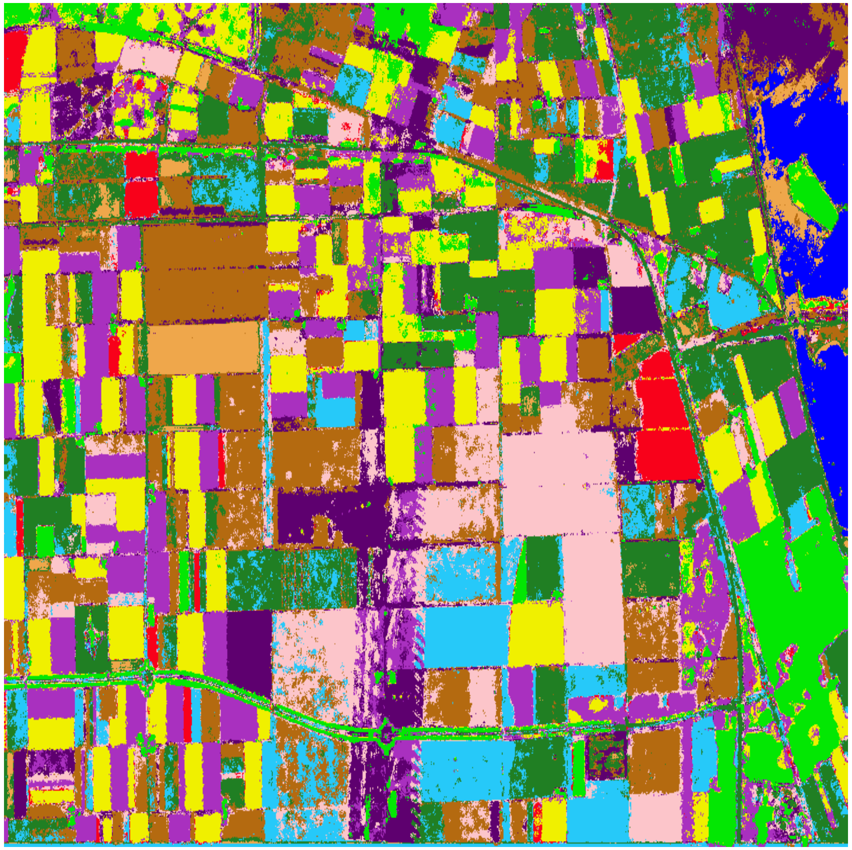
WISHART CLASSIFIER

Courtesy of Dr J.S Lee



$2A_0$ $B_0 + B$ $B_0 - B$

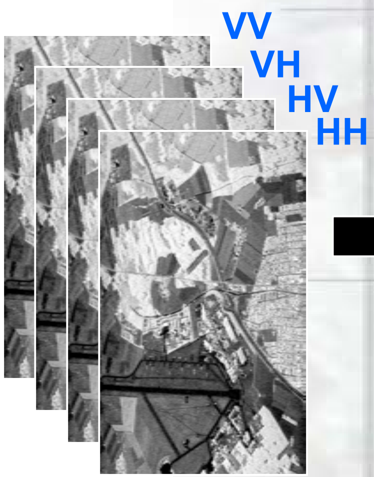
JPL AIRSAR
L-Band Flevoland Data



P-L-C band (91.21%)

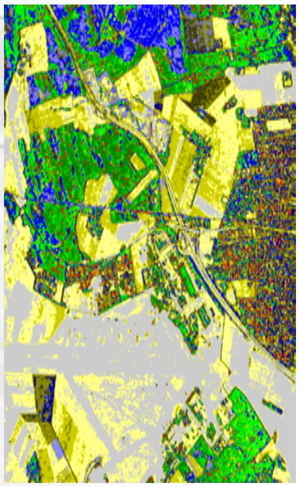
WISHART PDF

$$P(\langle[T]\rangle / [T_m]) = \frac{L^{Lp} |\langle[T]\rangle|^{L-p} e^{-LTr([T_m]^{-1}\langle[T]\rangle)}}{\pi^{\frac{p(p-1)}{2}} \Gamma(L) \ldots \Gamma(L-p+1) |[T_m]|^{L}}$$



SUPERVISED POLSAR CLASSIFICATION

J.S LEE, M.R GRUNES, E.POTTIER (2002)



Quantitative Comparison
Fully Polarimetric versus Dual Polarizations

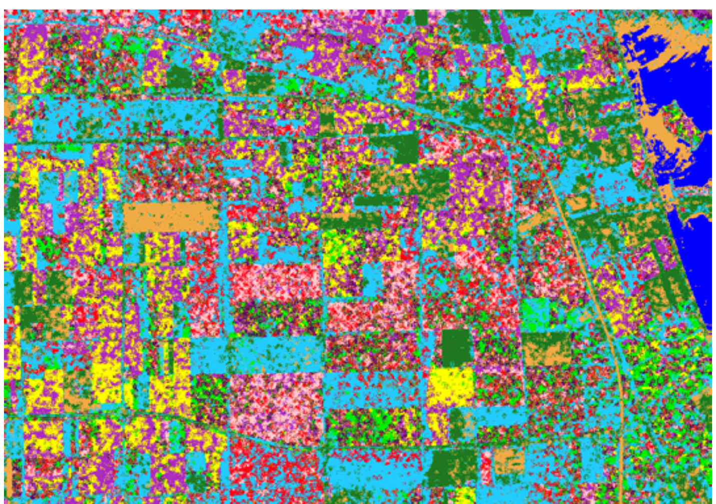
J.S. Lee, M. R. Grunes and E. Pottier, "Quantitative Comparison of Classification Capability: Fully polarimetric versus Dual- and Single polarization SAR," IEEE TGRS, November 2002

SUPERVISED CLASSIFIER

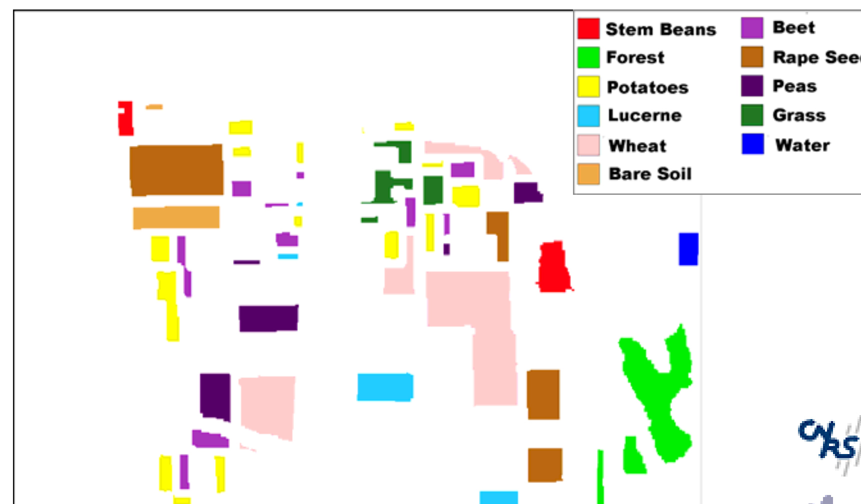
Courtesy of Dr J.S Lee

C-band Fully Pol. (66.55%)

C-band complex HH and VV (55.00%)



C-band HH and VV Intensities (37.22%)



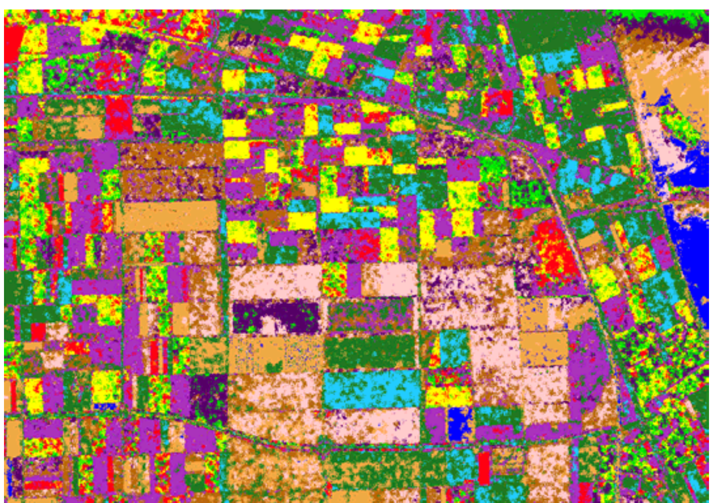
Reference map for comparison

SUPERVISED CLASSIFIER

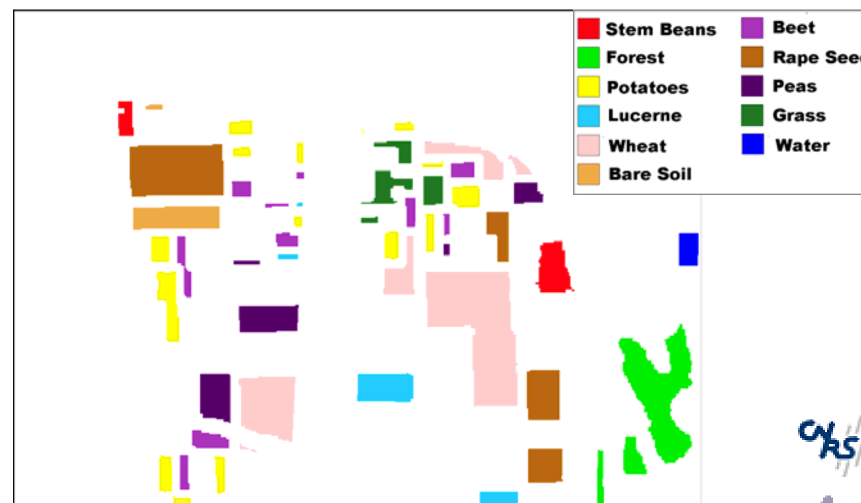
Courtesy of Dr J.S Lee

L-band Fully Pol. (81.63%)

L-band complex HH and VV (80.91%)



L-band HH and VV Intensities (56.35%)



Reference map for comparison

SUPERVISED CLASSIFIER

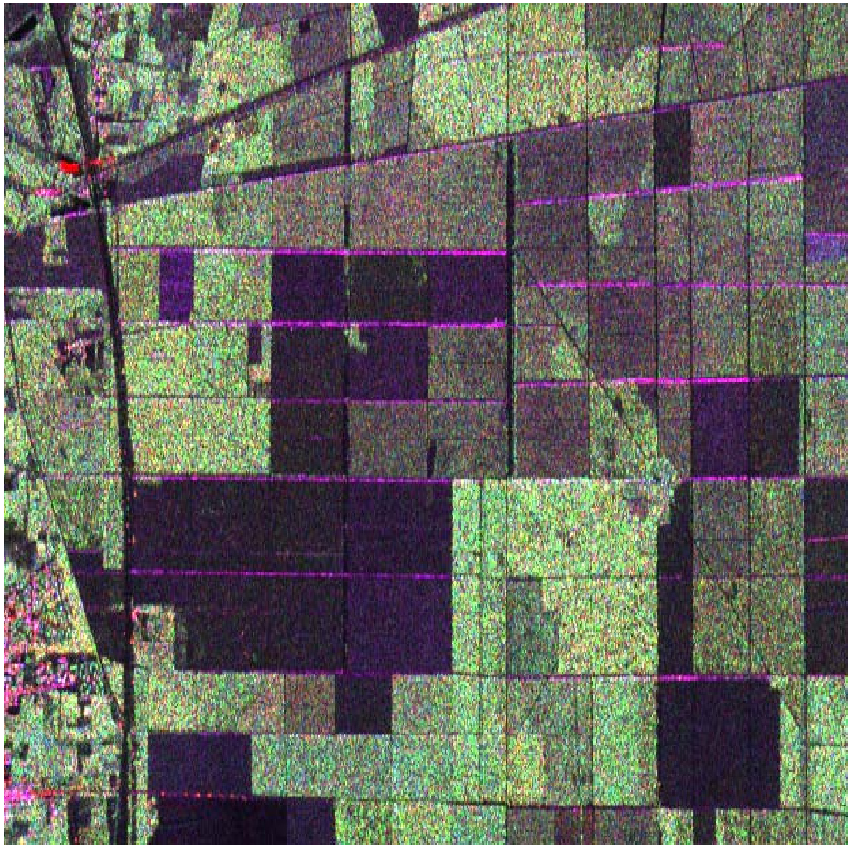
Courtesy of Dr J.S Lee

	Fully Polarimetric	Complex HH, HV	Intensity HH, HV	Complex HH, VV	Intensity HH, VV	Complex VV, HV	Intensity VV, HV
Stem Bean	**95.32**	**51.16**	**63.27**	**90.64**	**61.73**	**35.97**	**31.29**
Forest	**81.07**	**66.73**	**68.39**	**75.75**	**33.83**	**60.05**	**60.91**
Potatoes	**82.89**	**67.53**	**66.36**	**81.52**	**49.35**	**54.40**	**59.15**
Lucerne	**97.91**	**39.29**	**38.23**	**99.26**	**65.15**	**67.49**	**65.30**
Wheat	**64.80**	**49.77**	**44.27**	**68.02**	**53.72**	**49.43**	**41.65**
Bare Soil	**99.36**	**90.04**	**82.86**	**98.42**	**93.15**	**90.93**	**63.74**
Beet	**89.26**	**68.80**	**66.36**	**86.22**	**81.98**	**75.94**	**74.77**
Rape Seed	**89.05**	**55.01**	**53.23**	**87.18**	**49.85**	**82.31**	**77.12**
Peas	**86.47**	**50.77**	**39.25**	**84.59**	**65.21**	**81.82**	**79.59**
Grass	**91.05**	**66.44**	**65.06**	**90.13**	**71.08**	**75.36**	**75.19**
Water	**100**	**90.39**	**87.33**	**100**	**99.86**	**96.30**	**70.53**
TOTAL	**81.63**	**59.16**	**55.38**	**80.91**	**56.35**	**64.72**	**60.12**

L-Band Crop Classification Results

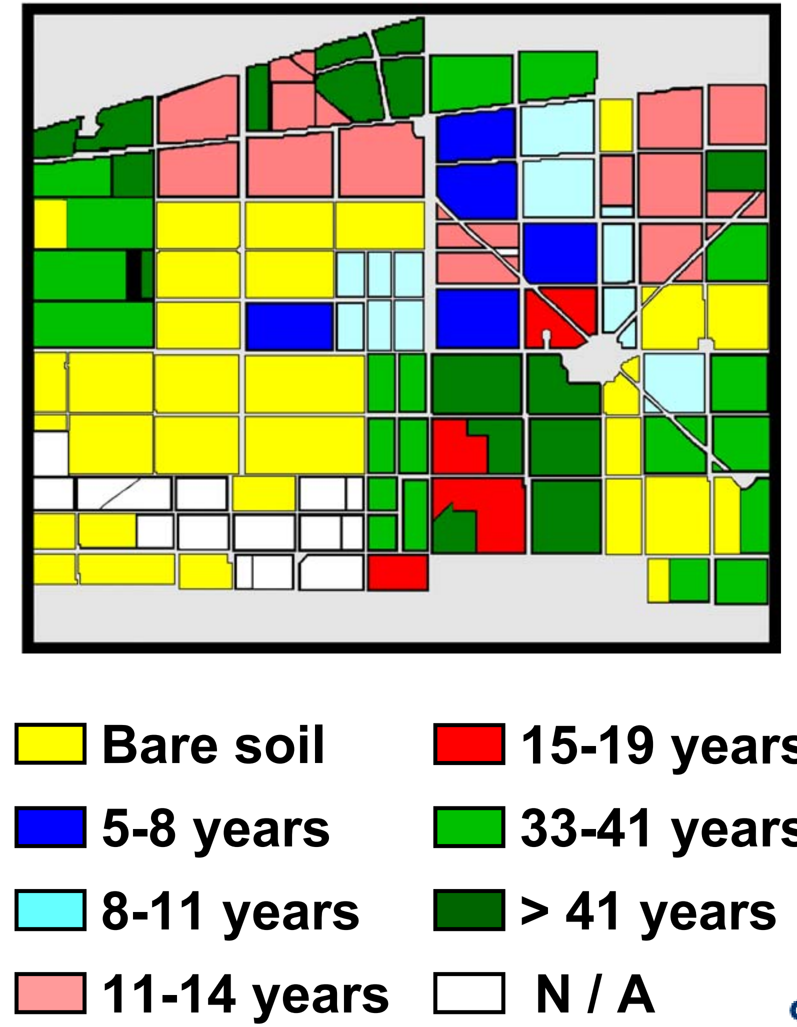
WISHART CLASSIFIER

Courtesy of Dr J.S Lee



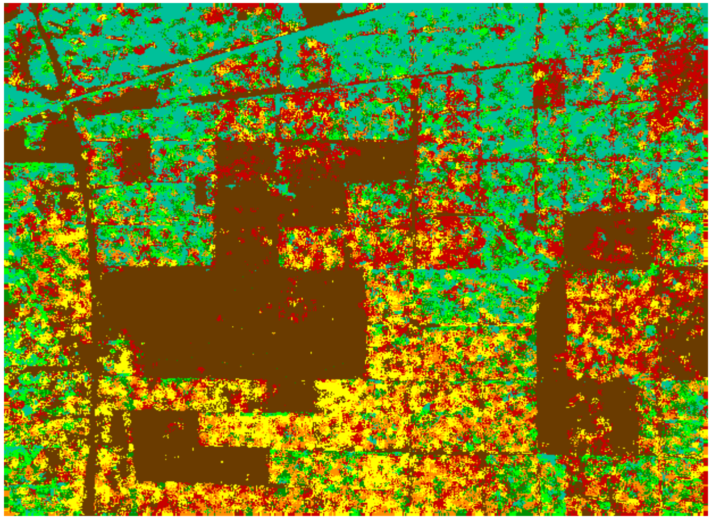
$2A_0$ $B_0 + B$ $B_0 - B$

JPL AIRSAR
P-L-C Band Nezer Forest Data

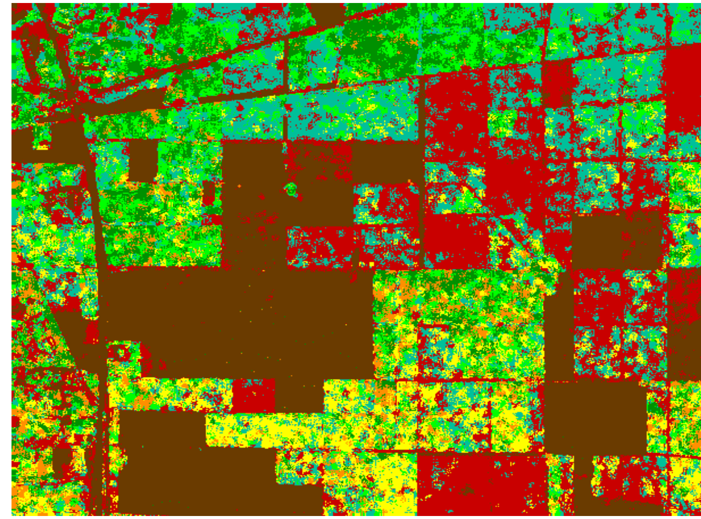


SUPERVISED CLASSIFIER

Courtesy of Dr J.S Lee

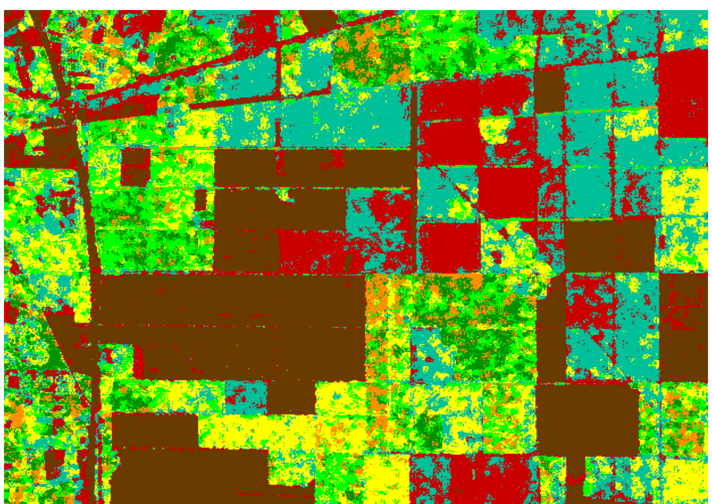


C-band Fully Polarimetric (42.96%)

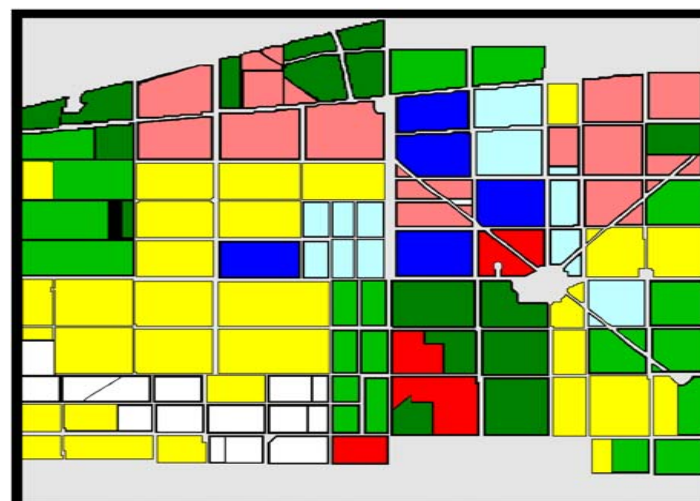


L-band Fully Polarimetric (64.68%)

Bare Soil
5-8 Years
8-11 Years
11-14 Years
15-19 Years
33-44 Years
>41 Years



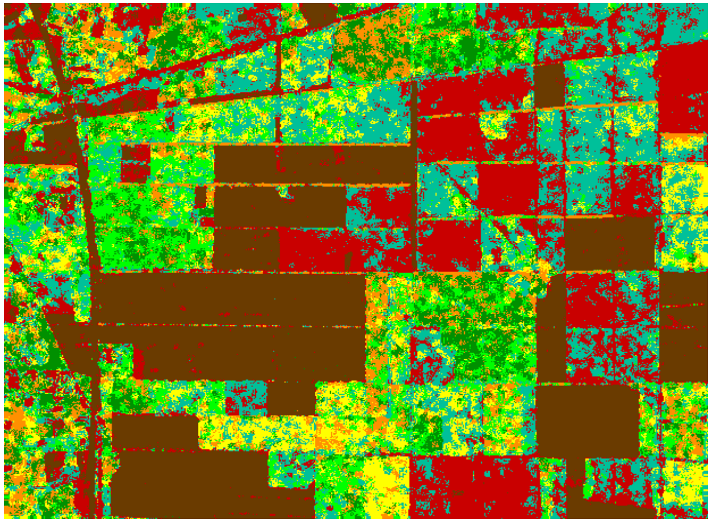
P-band Fully Polarimetric (79.16%)



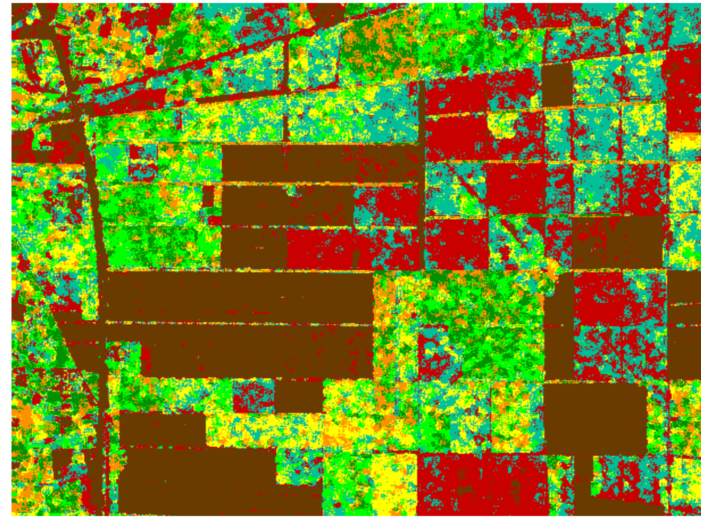
Reference Map

SUPERVISED CLASSIFIER

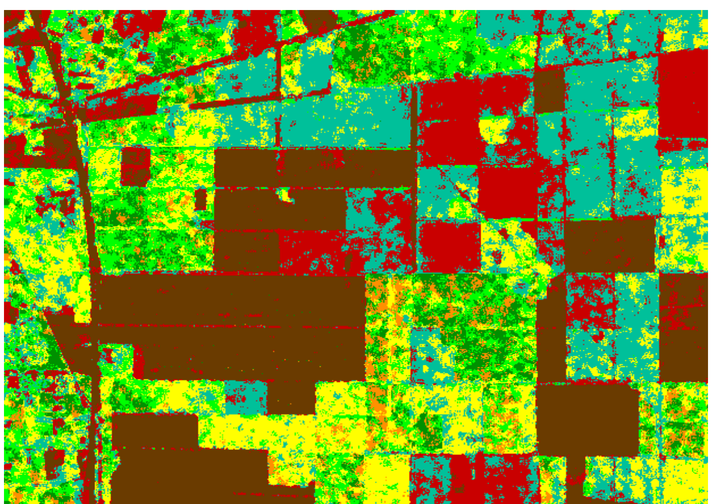
Courtesy of Dr J.S Lee



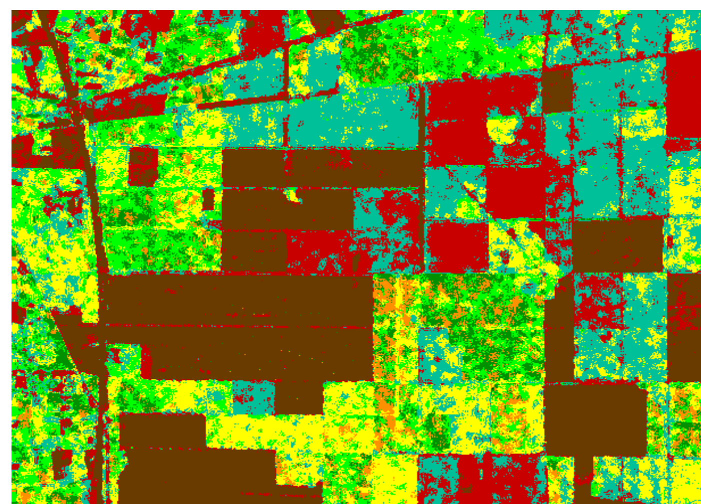
P-band Complex HH and VV (68.56%)



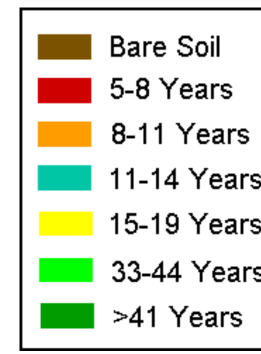
P-band Intensity HH and VV (65.30%)



P-band Complex HH and HV (75.95%)



P-band Intensity HH and HV (75.44%)

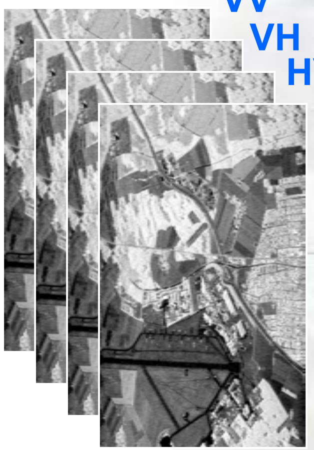


SUPERVISED CLASSIFIER

- For crop classification
  - L-band is better than P-Band and C-band
  - Dual-pol HH and VV with coherence (Including phase differences) is almost as good as fully polarimetric
- For forest classification
  - P-band is better than L and C
  - HV is the most important polarization
  - Coherence is not important for classification

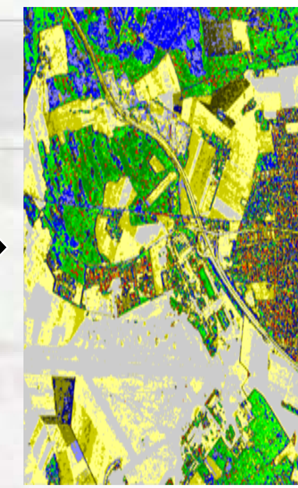
WISHART PDF

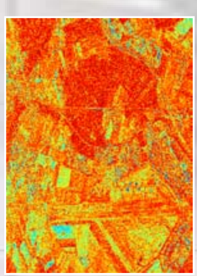
$$P(\langle[T]\rangle/[T_m]) = \frac{L^{Lp}\,|\langle[T]\rangle|^{L-p}\, e^{-L\,Tr([T_m]^{-1}\langle[T]\rangle)}}{\pi^{\frac{p(p-1)}{2}}\,\Gamma(L)\ldots\Gamma(L-p+1)\,|[T_m]|^{L}}$$



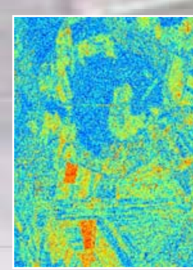
UNSUPERVISED POLSAR CLASSIFICATION

E.POTTIER, J.S LEE (2000)

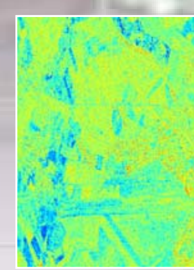




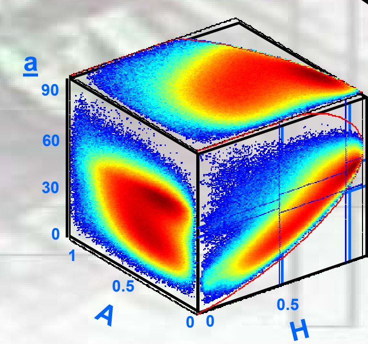
H



A



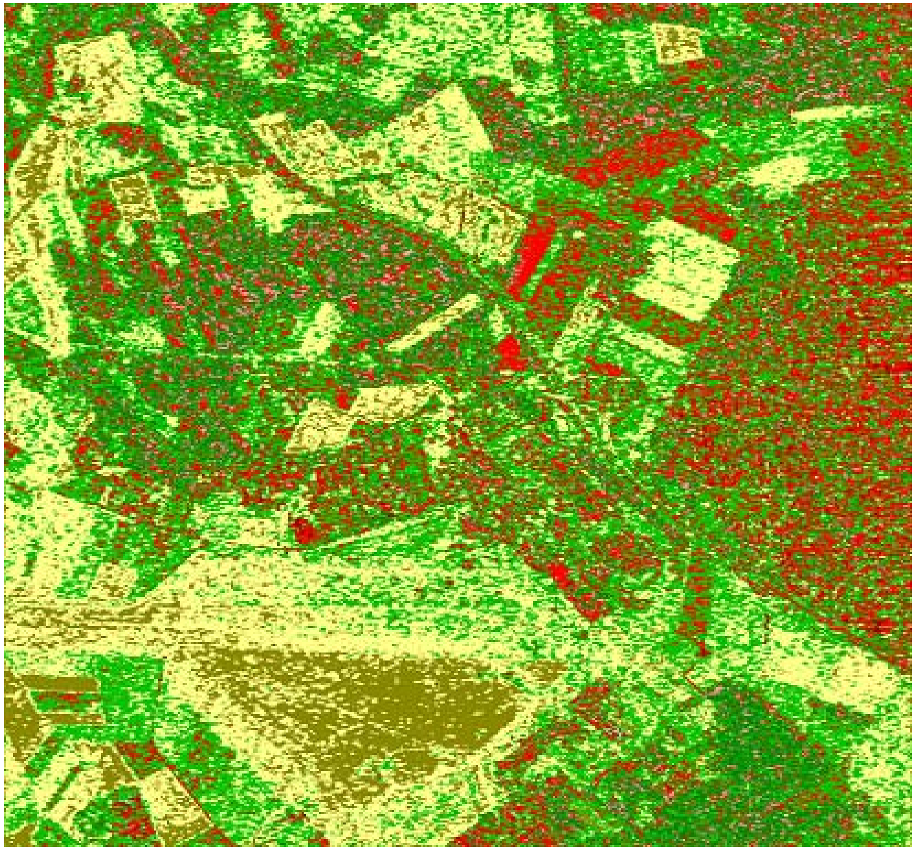
α

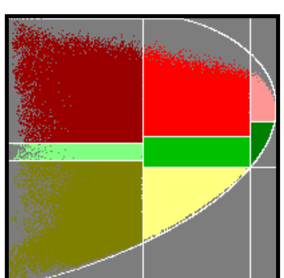


H / A / a DECOMPOSITION THEOREM

H / α CLASSIFICATION

H-α classification





H / α Classification Space Sub-divised into 9 basic zones

↓

Location of the boundaries is arbitrary and generically

Degree of arbitrariness on the setting of these boundaries

↓

Segmentation is offered merely to illustrate the unsupervised classification strategy and to emphasize the geometrical segmentation of physical scattering processes

H / $\underline{\alpha}$ - WISHART CLASSIFIER

Dr J.S. LEE
N.R. L US -NAVY

1994 *LEE et al.* PROPOSED A SUPERVISED ALGORITHM BASED ON THE COMPLEX WISHART DISTRIBUTION FOR THE COMPLEX COVARIANCE / COHERENCY MATRIX.

1998 *LEE et al.* DEVELOPED A COMBINED UNSUPERVISED CLASSIFICATION METHOD THAT USES THE H / $\underline{a}$ PLANE WHICH INITIALLY CLASSIFIES THE POLSAR IMAGE. THIS SEGMENTED IMAGE IS THEN USED AS TRAINING SETS FOR THE INITIALIZATION OF THE SUPERVISED WISHART CLASSIFIER.

1999 INTRODUCTION OF THE ANISOTROPY (*E. POTTIER - J.S.LEE*)

IMPROVEMENT OF THE CAPABILITY TO DISTINGUISH BETWEEN DIFFERENT CLASSES WHOS CENTERS END IN THE SAME ENTROPY (H) AND ALPHA ($\underline{\alpha}$) ZONE.

H / α - WISHART CLASSIFIER

k - mean CLASSIFICATION PROCEDURE

PROVIDE INITIAL $[T_m]^{(0)}$ FOR EACH CLASS

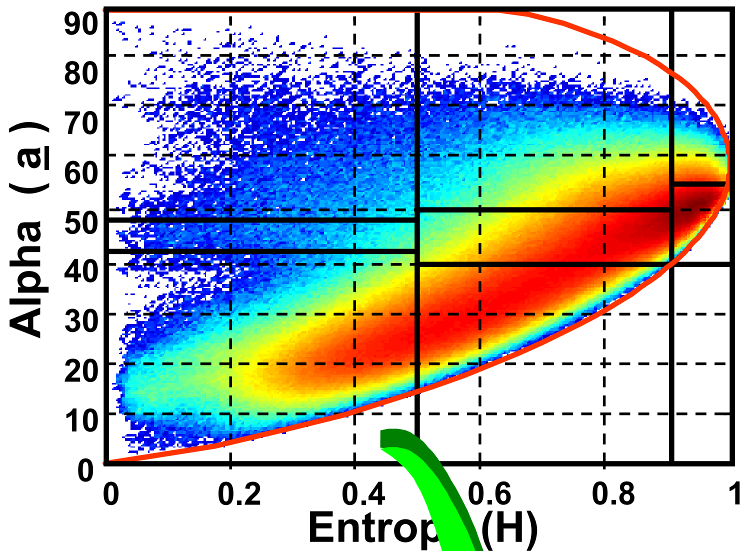
CLASSIFY THE WHOLE IMAGE WITH THE DISTANCE PROCEDURE

$$\langle[T]\rangle \in [T_m] \quad if \quad d_m(\langle[T]\rangle) < d_j(\langle[T]\rangle) \quad \forall\, j \neq m$$

COMPUTE $[T_m]^{(k+1)}$ FOR EACH CLASS USING THE CLASSIFIED PIXELS OF STEP 2

$$[T_m]^{(k+1)} = \frac{1}{N_m}\sum_{j=1}^{j=N_m}\langle[T]\rangle_j$$

TERMINAISON CRITERION ?



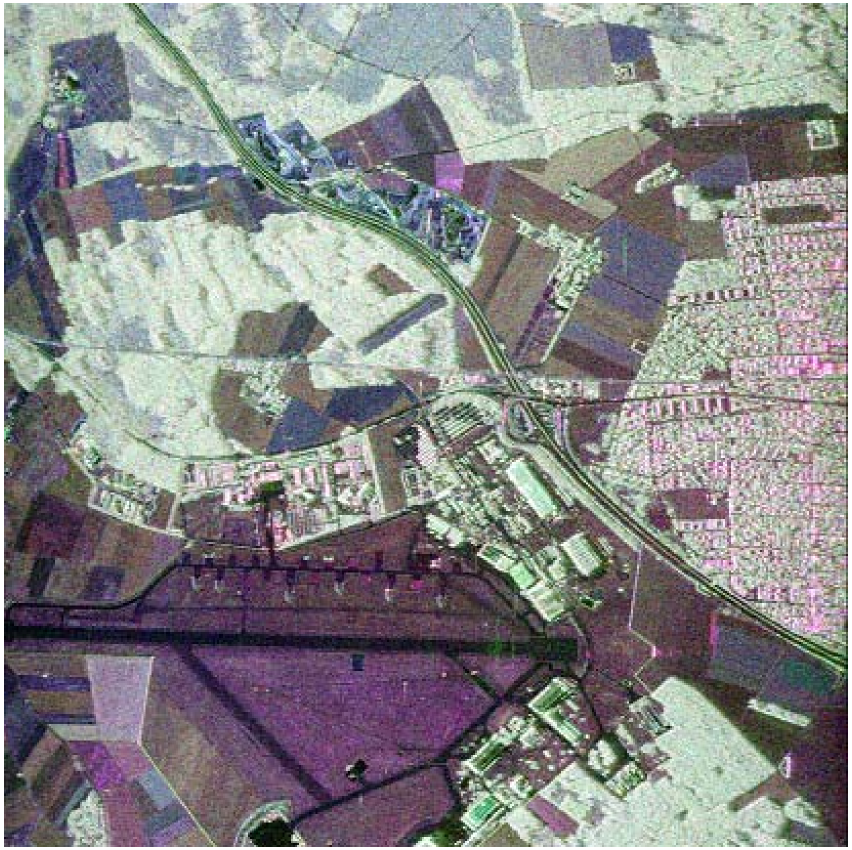
$$[T_m]^{(0)} = \frac{1}{N_m}\sum_{k=1}^{k=N_m}\langle[T]\rangle_k$$

Cluster Center of the class *m*

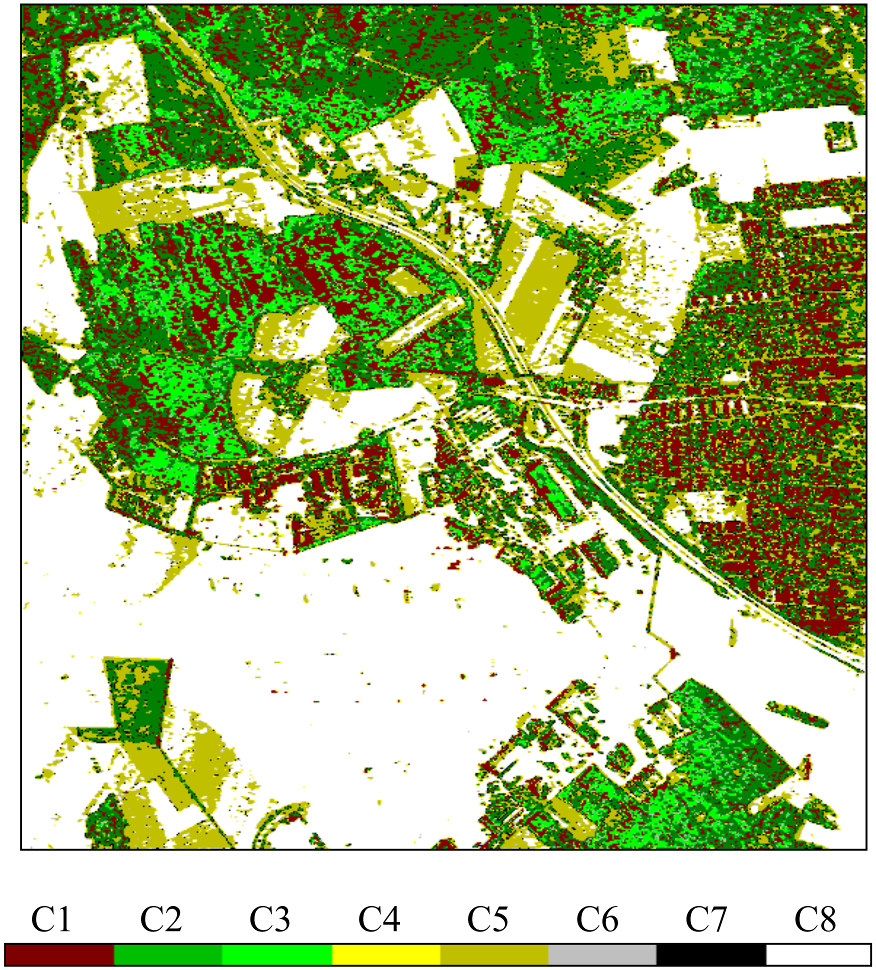
(Lee 1998)

H / α - WISHART CLASSIFIER

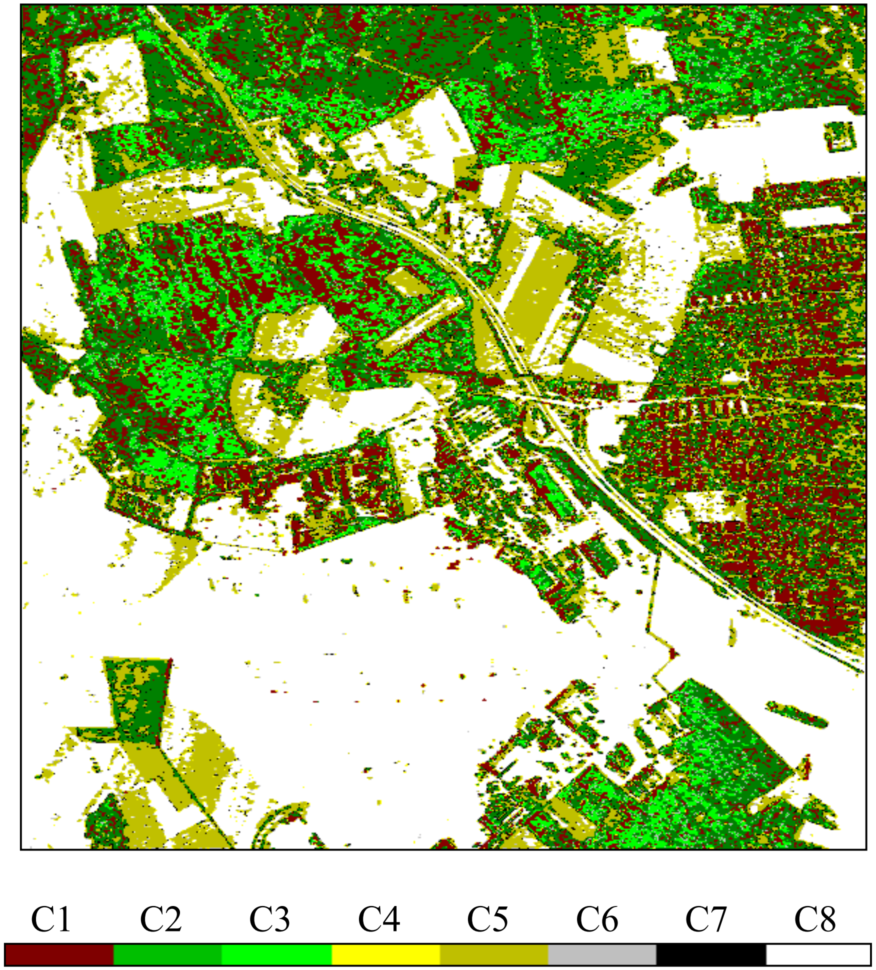
4th ITERATION



$2A_0$ $B_0 + B$ $B_0 - B$



H / α - WISHART CLASSIFIER



During the classification,the cluster centers can move out their zones or several clusters may end in the same zone

↓

Identification of the terrain type may cause some confusion due to the color scheme

↓

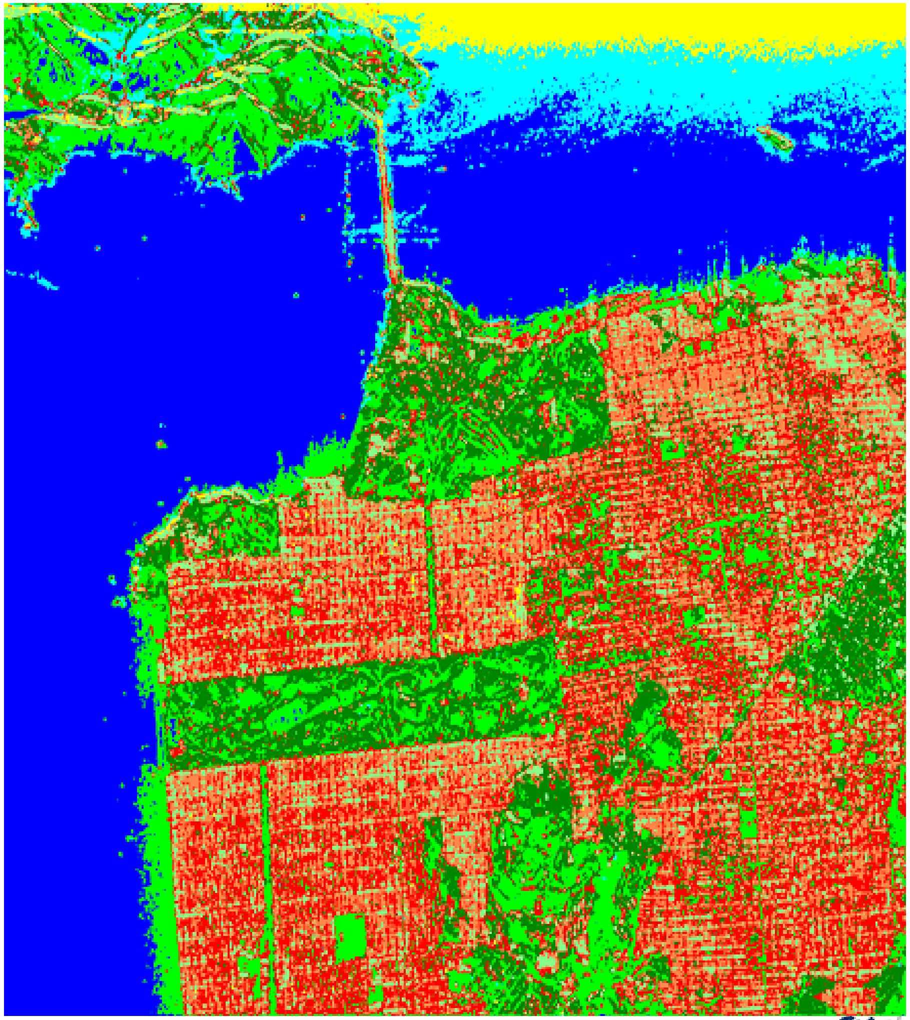
The combined Wishart classifier is extended and complemented with the introduction of the Anisotropy (A)

H / α - WISHART CLASSIFIER

SAN FRANCISCO BAY JPL - AIRSAR L-band 1988

$2A_0$ $B_0 + B$ $B_0 - B$

H / α and WISHART CLASSIFIER

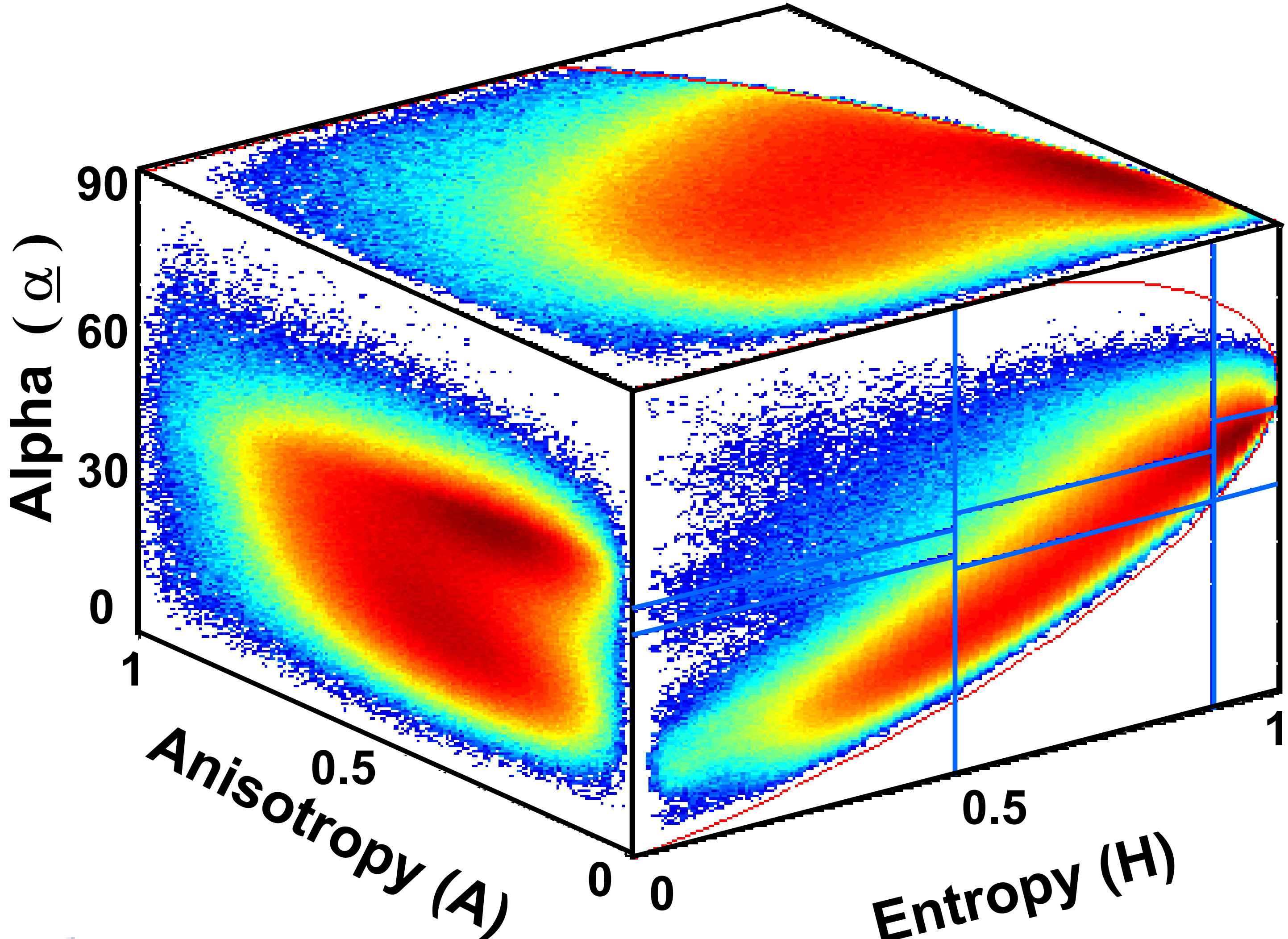


C1	C2	C3	C4	C5	C6	C7	C8

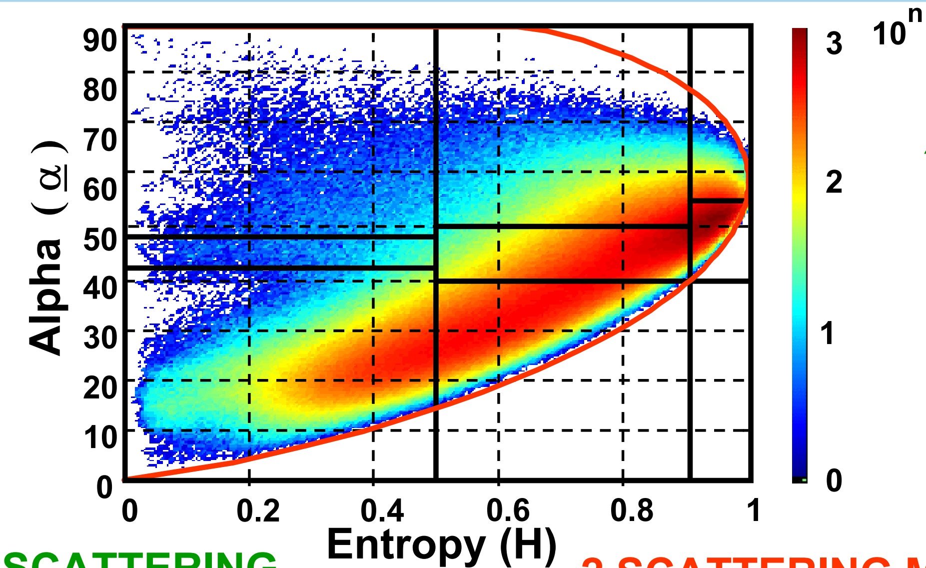
H / A / $\underline{\alpha}$ - WISHART CLASSIFIER

SAPHIR

POLSAR DATA DISTRIBUTION IN THE H / A / $\underline{\alpha}$ SPACE



H / A / α - WISHART CLASSIFIER



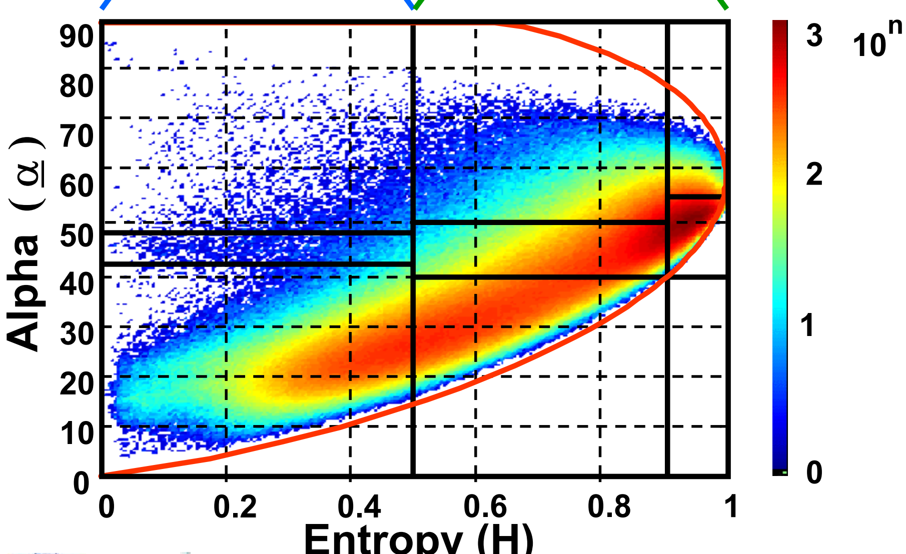
A < 0.5

$\lambda_2 == \lambda_3$

A > 0.5

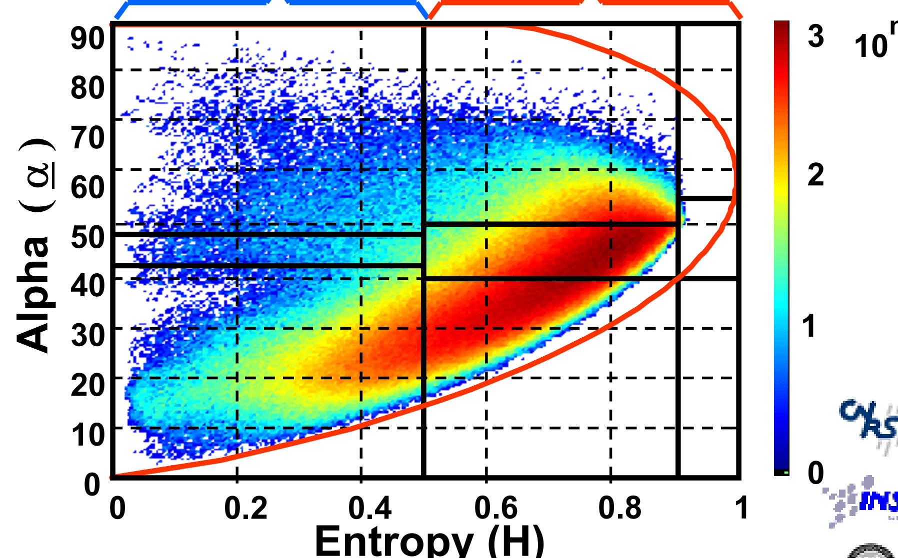
$\lambda_2 >> \lambda_3$

1 SCATTERING MECHANISM | **3 SCATTERING MECHANISMS**



2 SCATTERING MECHANISMS

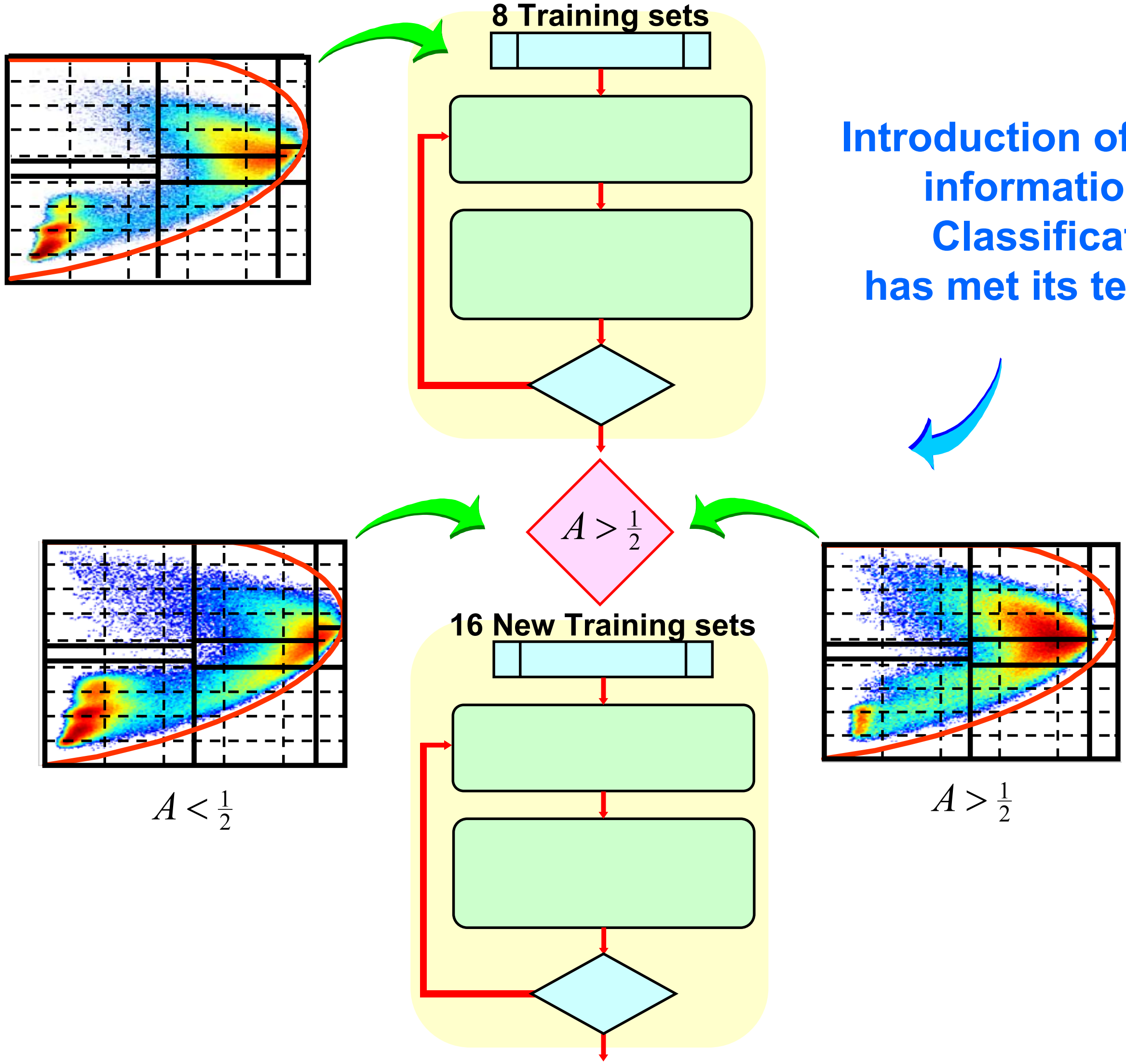
$(1+\varepsilon)$ | $(\varepsilon+\varepsilon)$



H / A / $\underline{\alpha}$ - WISHART CLASSIFIER

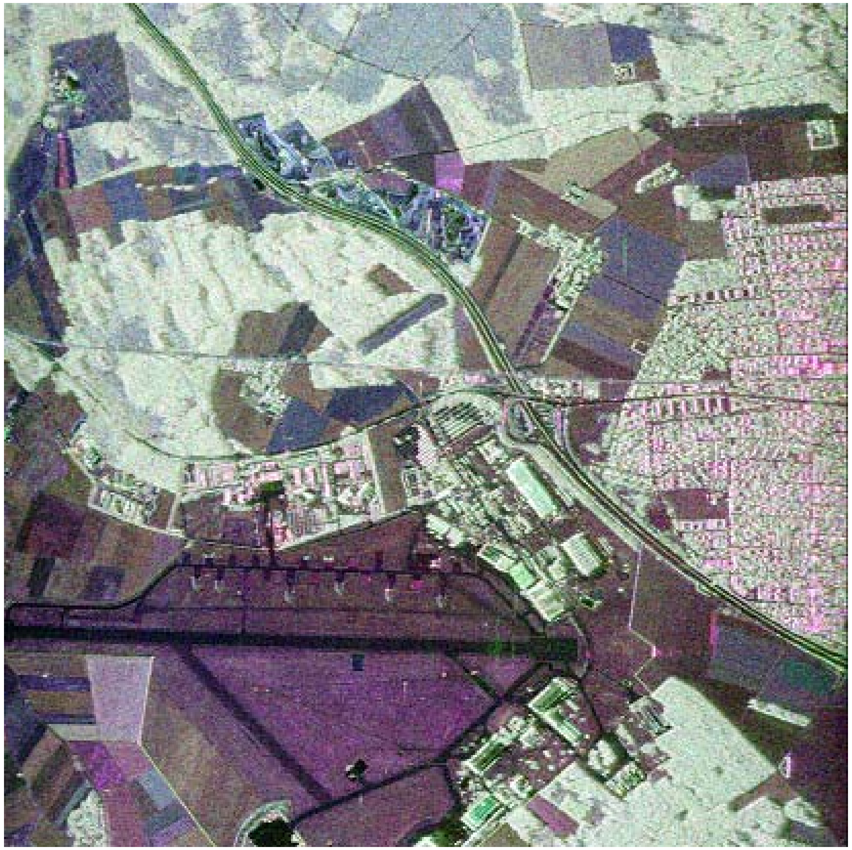
SAPHIR

2 Successive k - mean Classification procedures



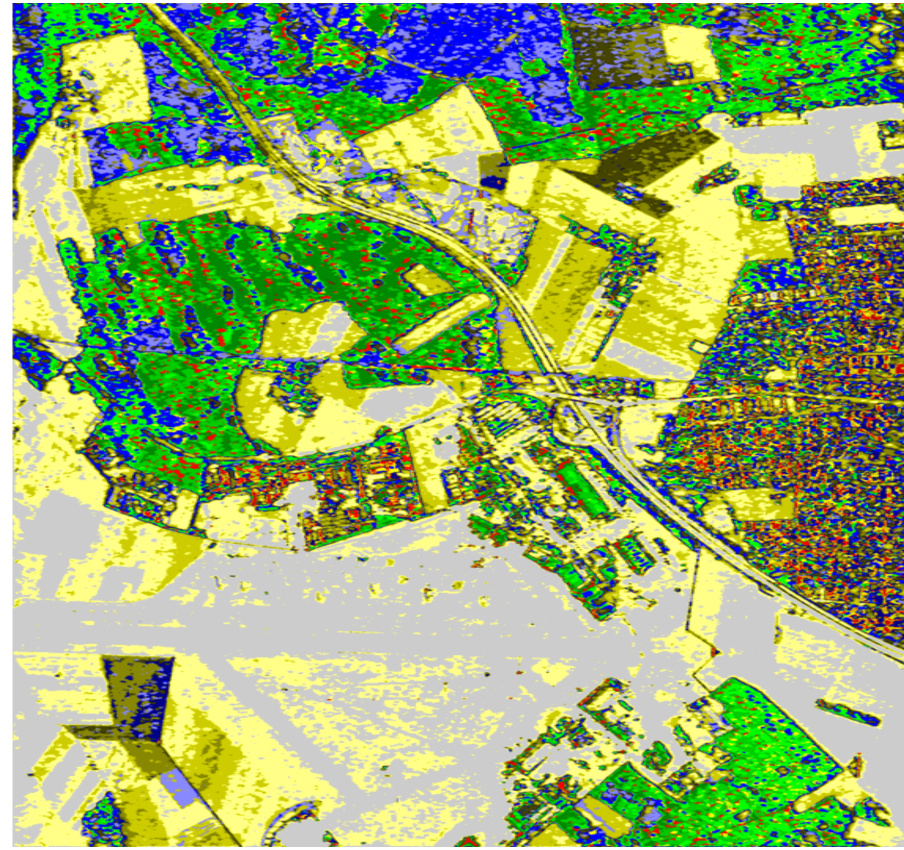
Introduction of the Anisotropy (A) information once the first Classification procedure has met its termination criterion

H / A / $\underline{\alpha}$ - WISHART CLASSIFIER



$2\,A_0$ $\quad B_0 + B$ $\quad B_0 - B$

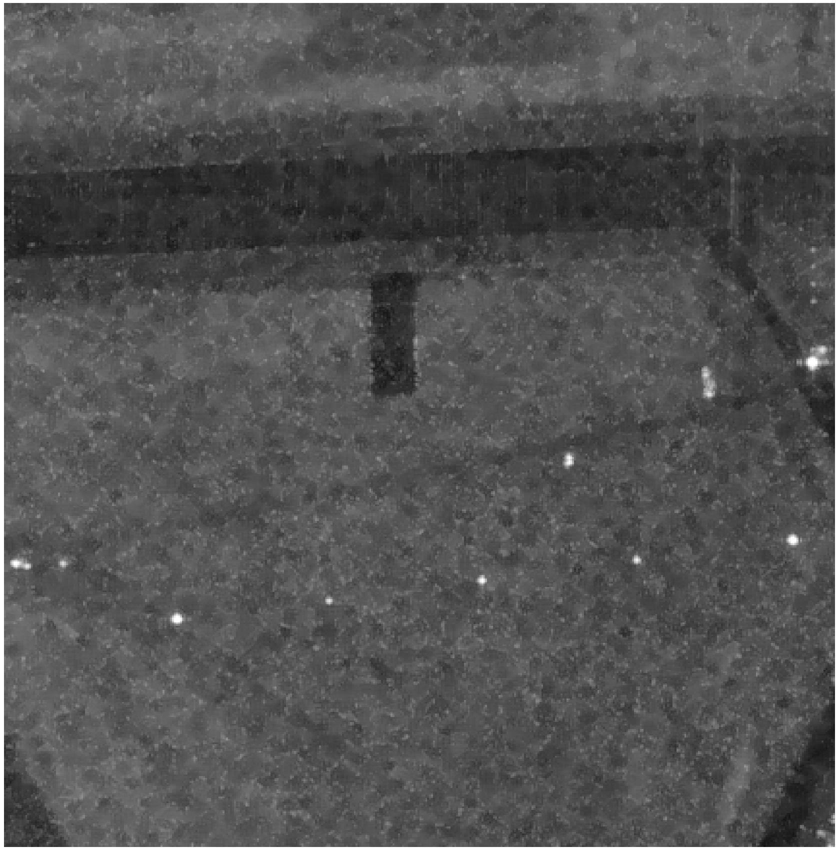
Wishart H-A-$\underline{\alpha}$ segmentation

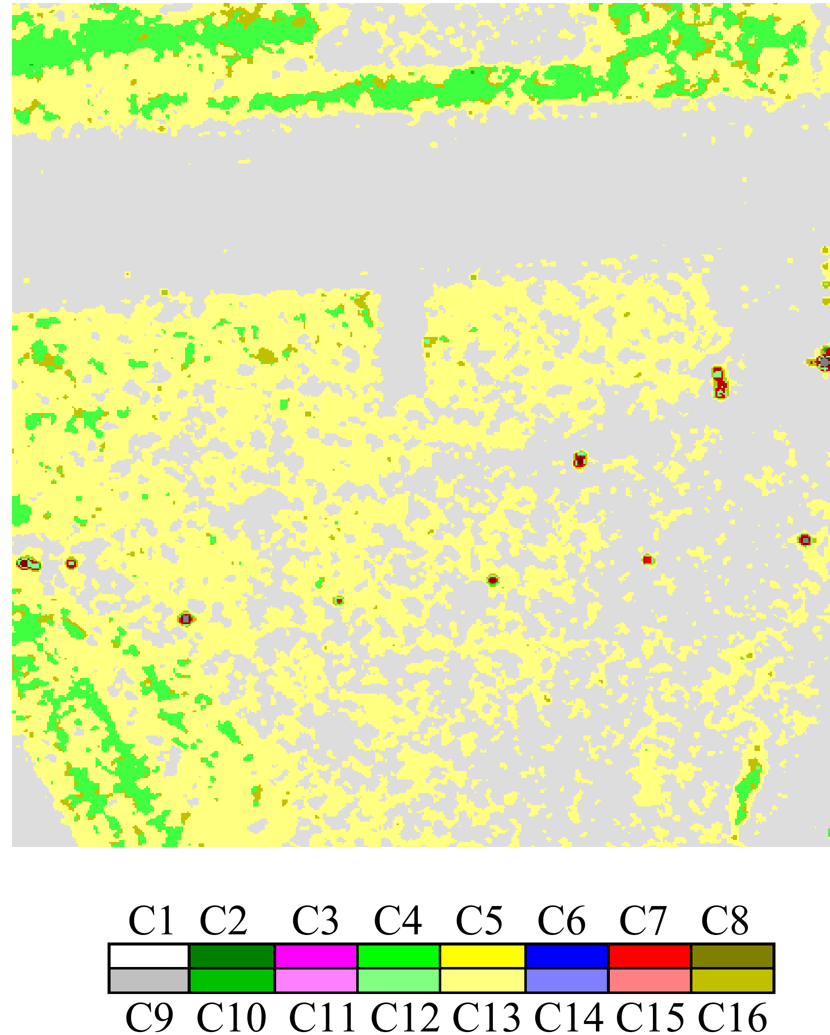


C1 C2 C3 C4 C5 C6 C7 C8

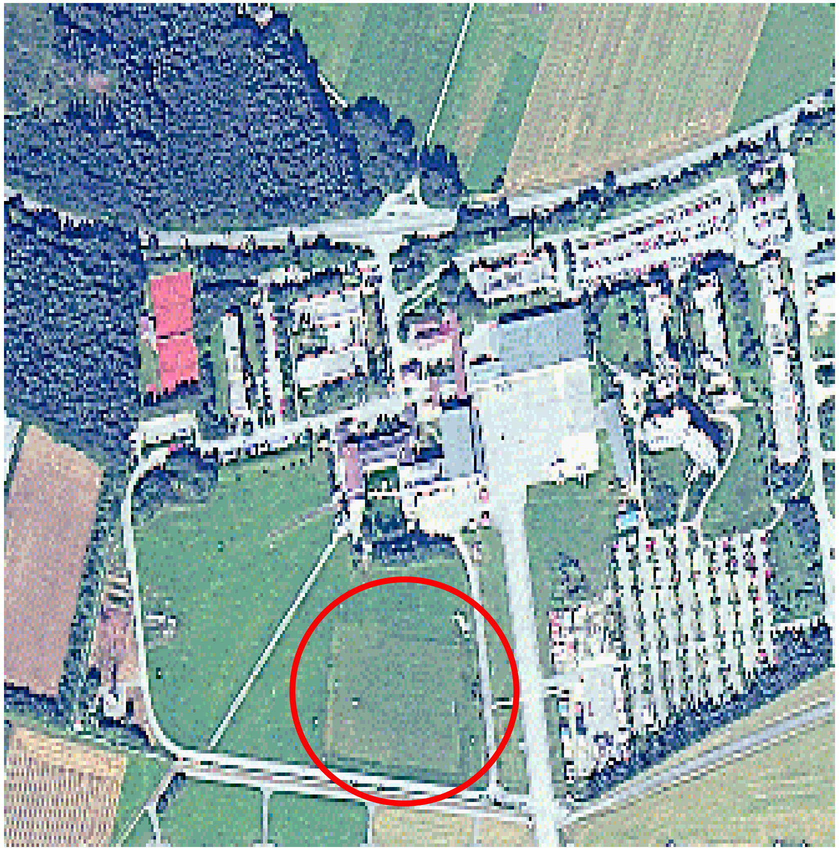
C9 C10 C11 C12 C13 C14 C15 C16

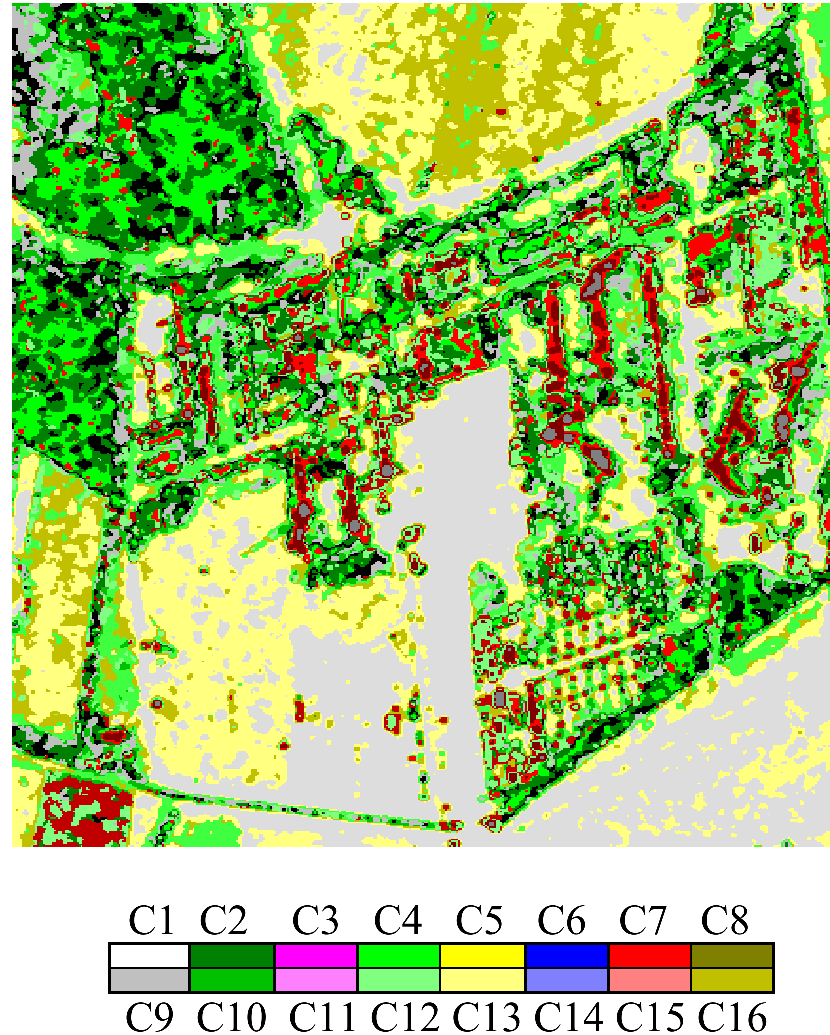
H / A / α - WISHART CLASSIFIER





H / A / α - WISHART CLASSIFIER



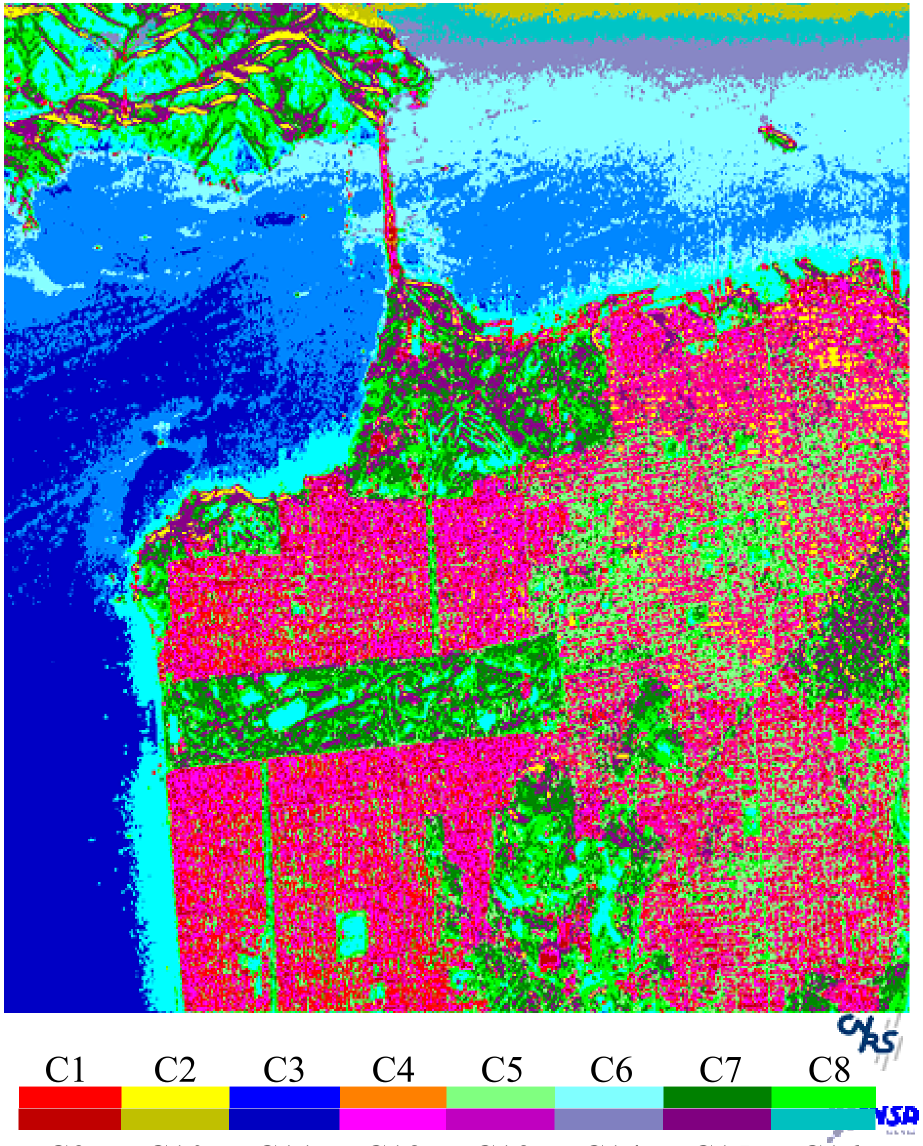


H / A / $\underline{\alpha}$ - WISHART CLASSIFIER

SAN FRANCISCO BAY JPL - AIRSAR L-band 1988

$2A_0$ $B_0 + B$ $B_0 - B$

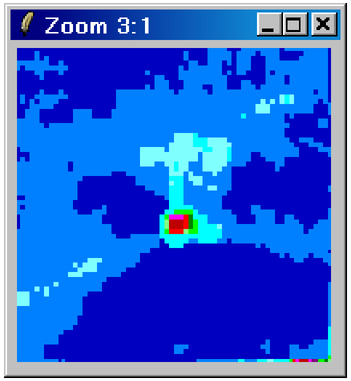
4th ITERATION

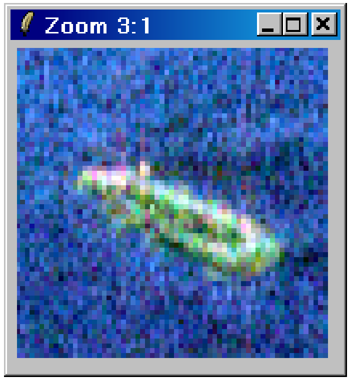


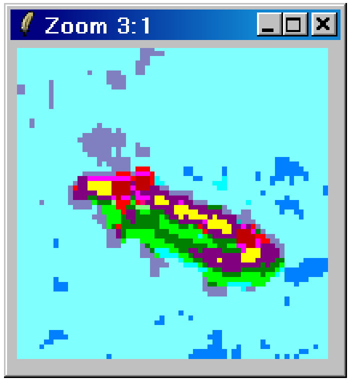
 E. Pottier, L. Ferro-Famil (01/2004)

H / A / α - WISHART CLASSIFIER

SAN FRANCISCO BAY JPL - AIRSAR L-band 1988



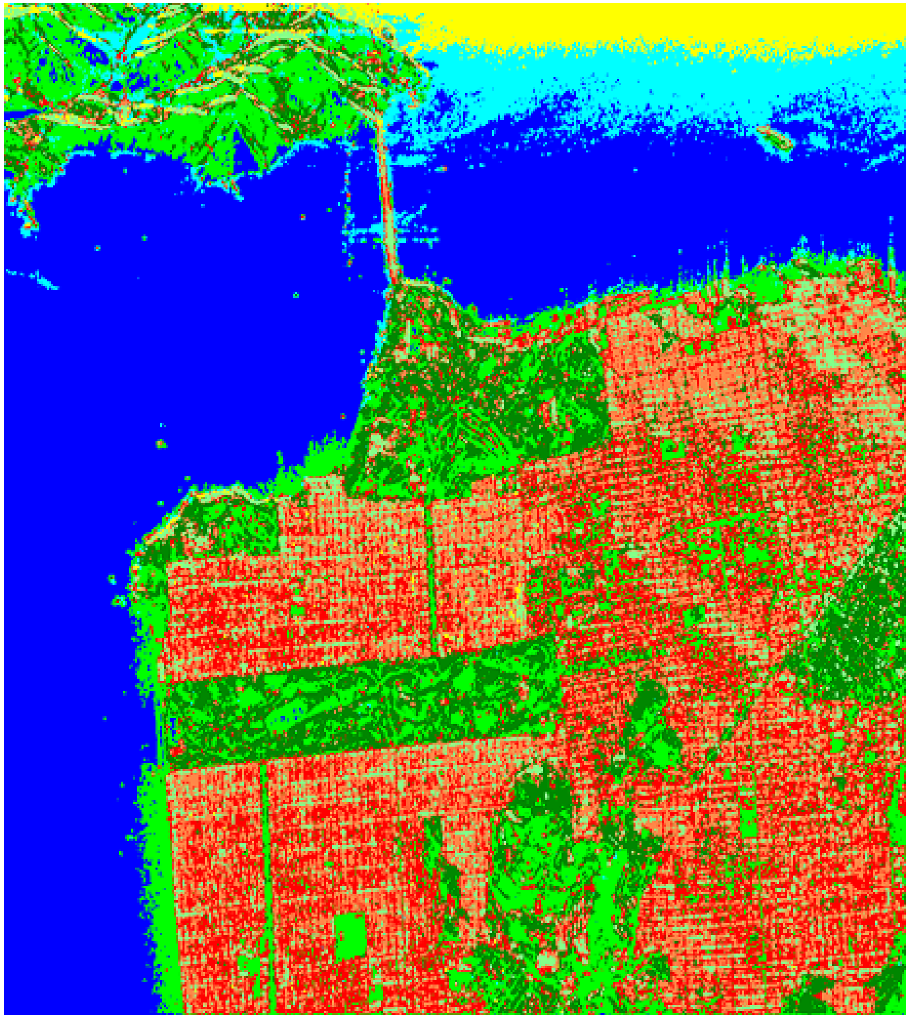




$2A_0$ $\quad$ $B_0 + B$ $\quad$ $B_0 - B$

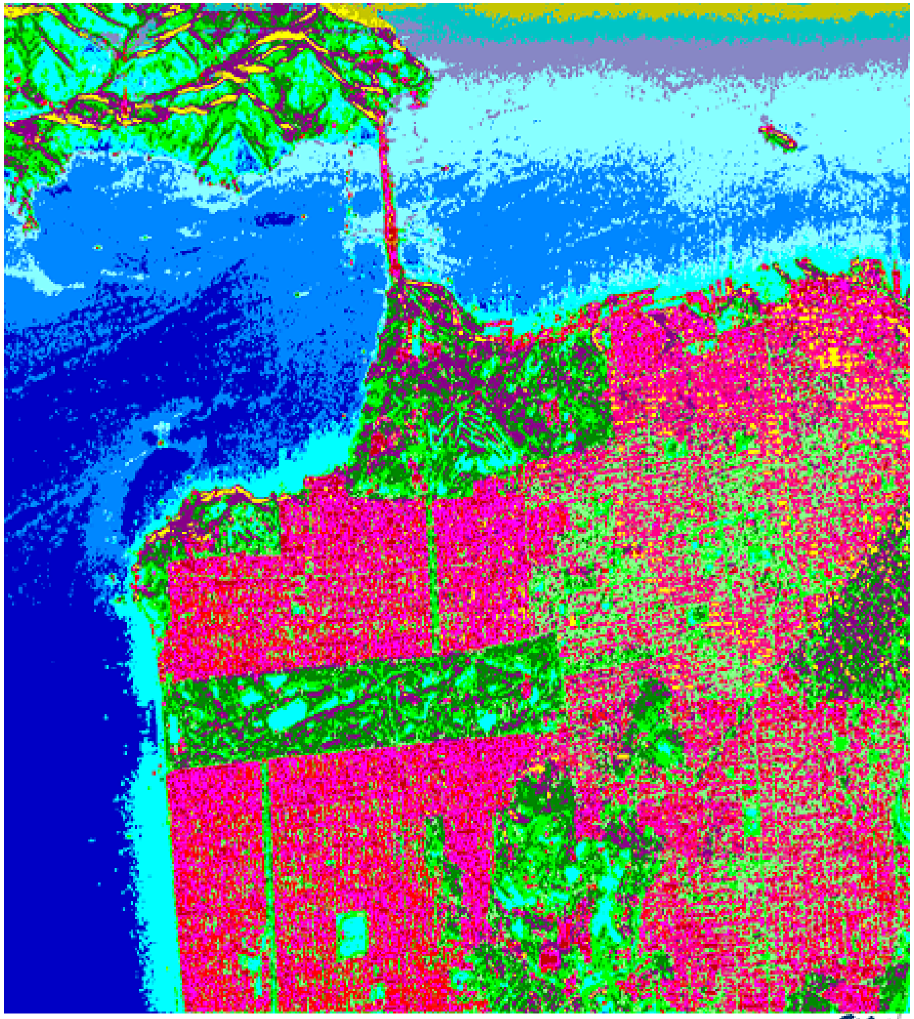
H / A / α - WISHART CLASSIFIER

H / α and WISHART CLASSIFIER



C1 C2 C3 C4 C5 C6 C7 C8

H / A / α and WISHART CLASSIFIER



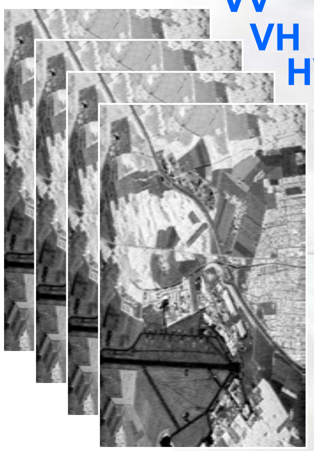
C1 C2 C3 C4 C5 C6 C7 C8

C9 C10 C11 C12 C13 C14 C15 C16

SAPHIR

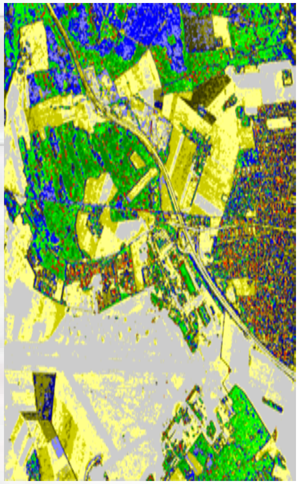
WISHART PDF

$$P\left(\langle[T]\rangle/[T_m]\right)=\frac{L^{Lp}\left|\langle[T]\rangle\right|^{L-p}e^{-LTr\left([T_m]^{-1}\langle[T]\rangle\right)}}{\pi^{\frac{p(p-1)}{2}}\Gamma(L)\ldots\Gamma(L-p+1)\left|[T_m]\right|^{L}}$$



UNSUPERVISED POLSAR CLASSIFICATION

E.POTTIER, J.S LEE (2000)



Unsupervised Classification Preserving Scattering Mechanisms

J.S. Lee, M.R. Grunes, E. Pottier and L. Ferro-Famil,"Segmentation of polarimetric SAR images that preserves scattering mechanisms" Proceedings of EUSAR2002

INTRODUCTION

– Polarimetric SAR (POLSAR) classification
  - Complex Wishart distribution (Lee et al., 1994)
  - Wishart + Entropy/Alpha (Lee et al., 1999)
  - Wishart + Entropy/Alpha/Anisotropy (Pottier and Lee, 2000)
  - Deficiency: Wishart classifier is a statistic operator. Pixels in a class can be mixed in scattering mechanisms

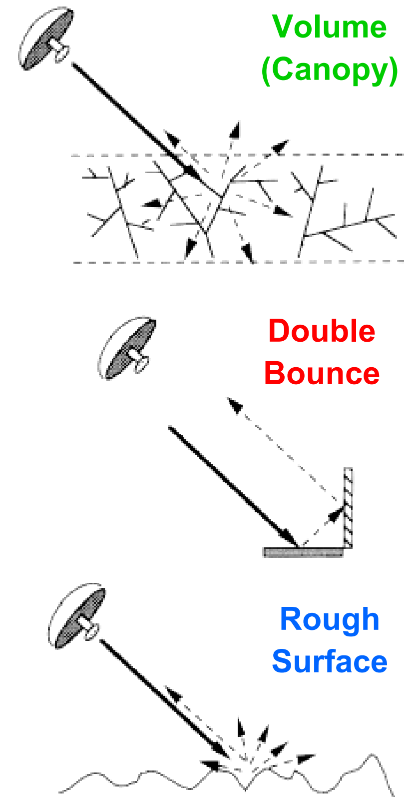
– A new approach
  - Preserving scattering property of each pixel based on Freeman and Durden decomposition:
    – Double bounce
    – Surface
    – Volume (Canopy)
  - Better stability in convergence
  - Automated color rendering

FREEMAN DECOMPOSITION

Courtesy of Dr J.S Lee

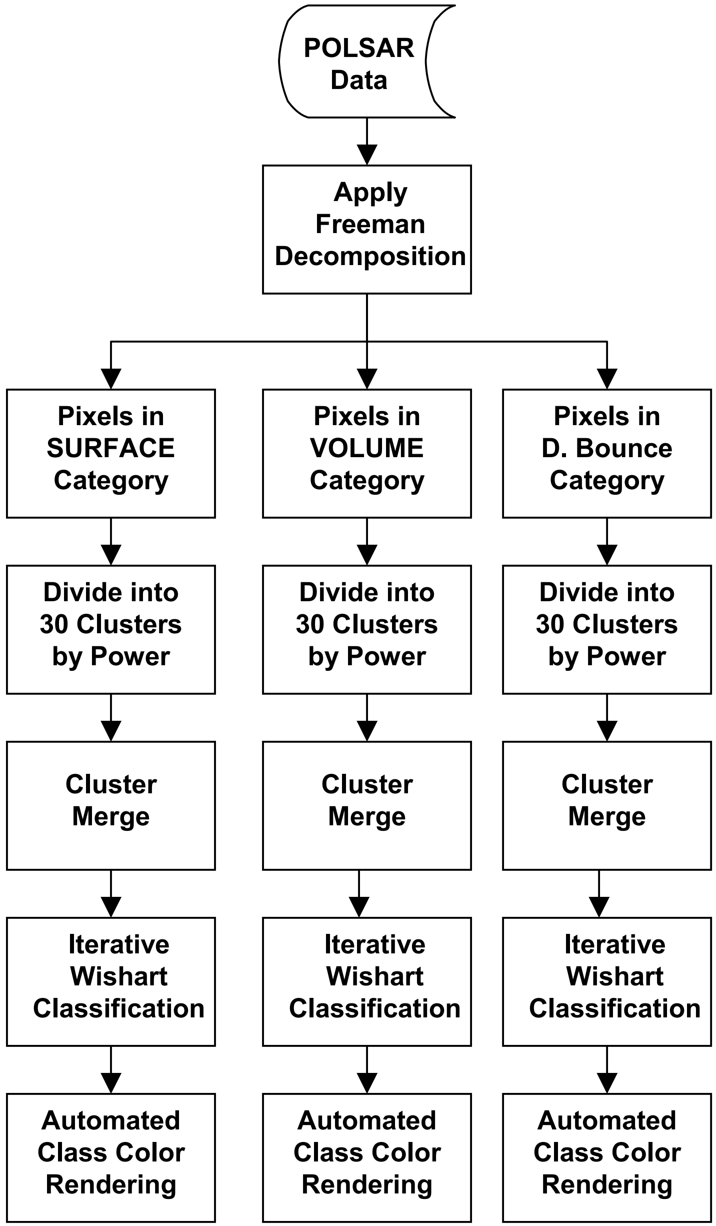
|HH-VV|, |HV|, |HH+VV|

Freeman and Durden



A. Freeman and S.L. Durden, "A Three-Component Scattering Model for Polarimetric SAR Data" IEEE TGRS, vol. 36, no. 3, May 1998

FLOW CHART


POLSAR Data
Apply Freeman Decomposition
Pixels in SURFACE Category
Pixels in VOLUME Category
Pixels in D. Bounce Category
Divide into 30 Clusters by Power
Divide into 30 Clusters by Power
Divide into 30 Clusters by Power
Cluster Merge
Cluster Merge
Cluster Merge
Iterative Wishart Classification
Iterative Wishart Classification
Iterative Wishart Classification
Automated Class Color Rendering
Automated Class Color Rendering
Automated Class Color Rendering

Wishart Iteration – After Class Merge

Classification Maps

First Iteration

Second Iteration

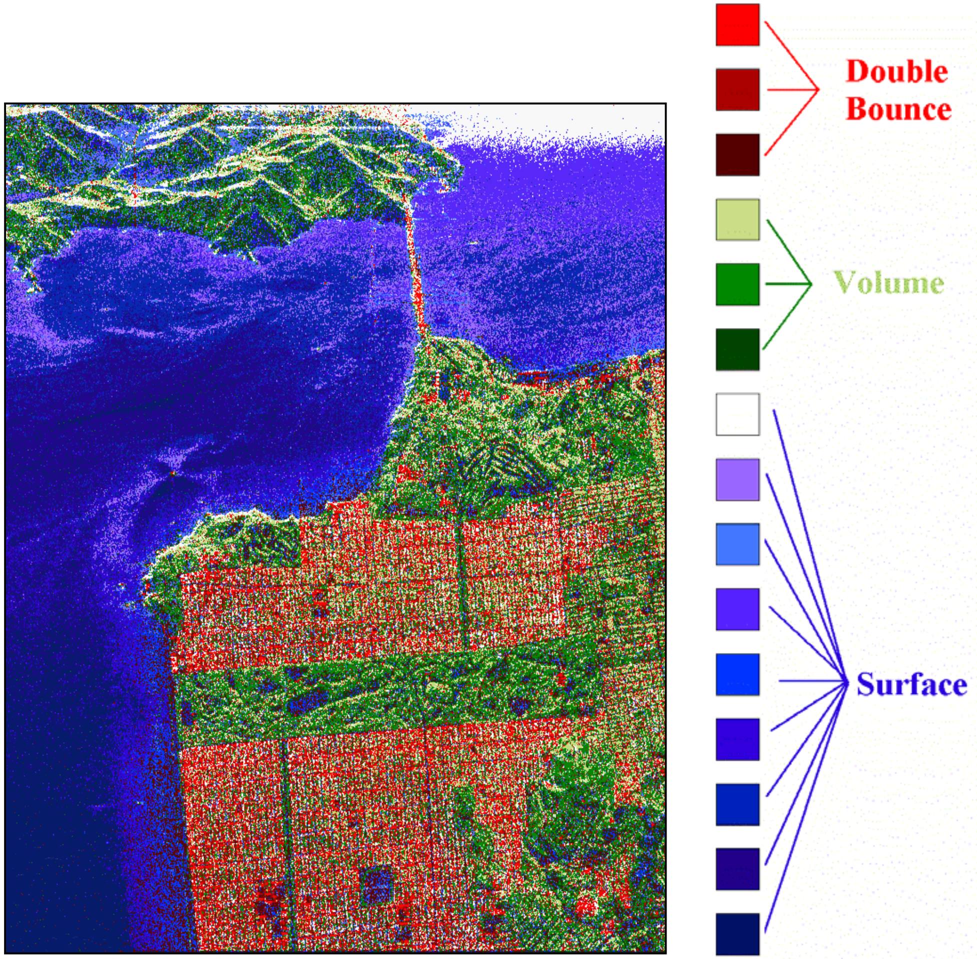
Third Iteration

Note: Stability insures good convergence

FREEMAN - WISHART CLASSIFIER

Courtesy of Dr J.S Lee

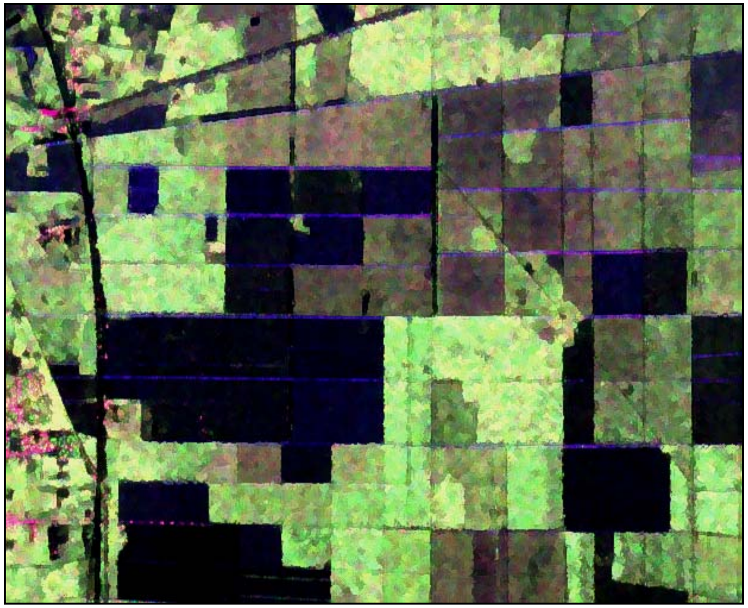
|HH-VV|, |HV|, |HH+VV|



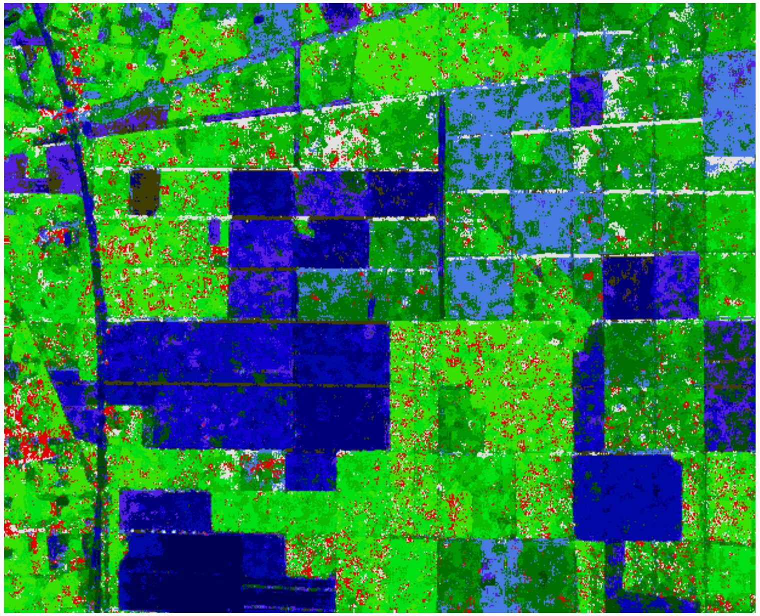
4th Iteration (15 classes)

FREEMAN - WISHART CLASSIFIER

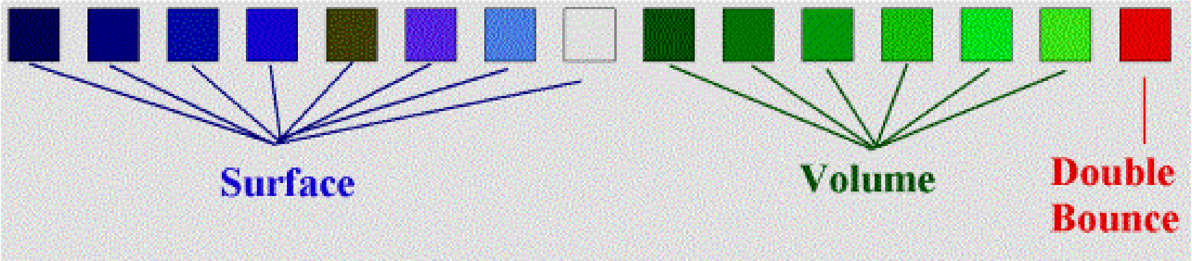
Courtesy of Dr J.S Lee



|HH-VV|, |HV|, |HH+VV|

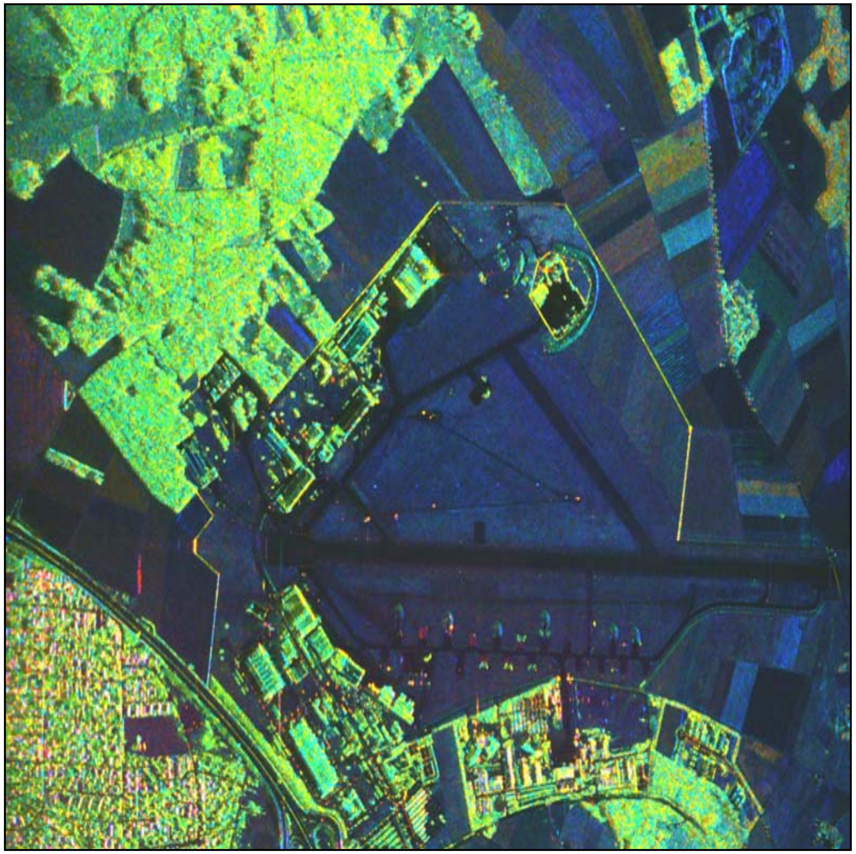


4th Iteration (15 classes)

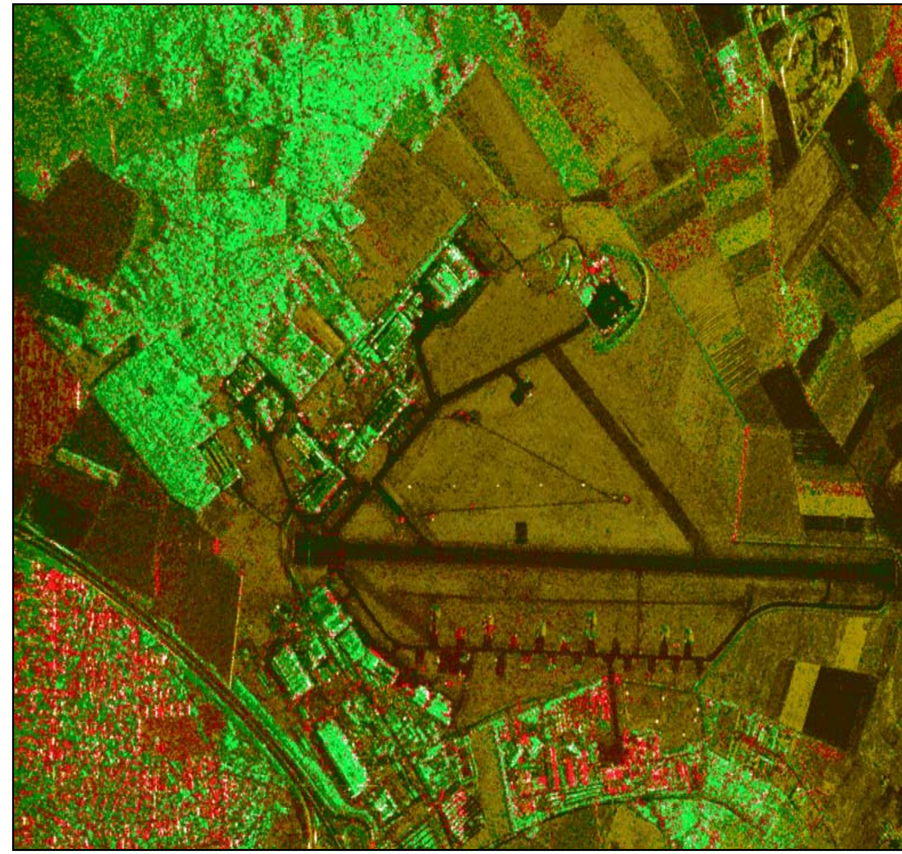


FREEMAN - WISHART CLASSIFIER

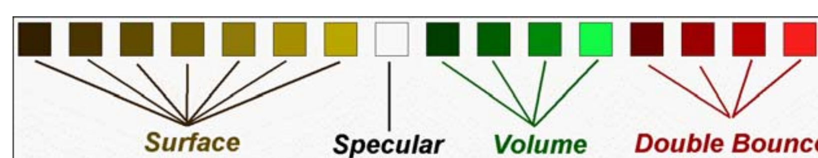
Courtesy of Dr J.S Lee



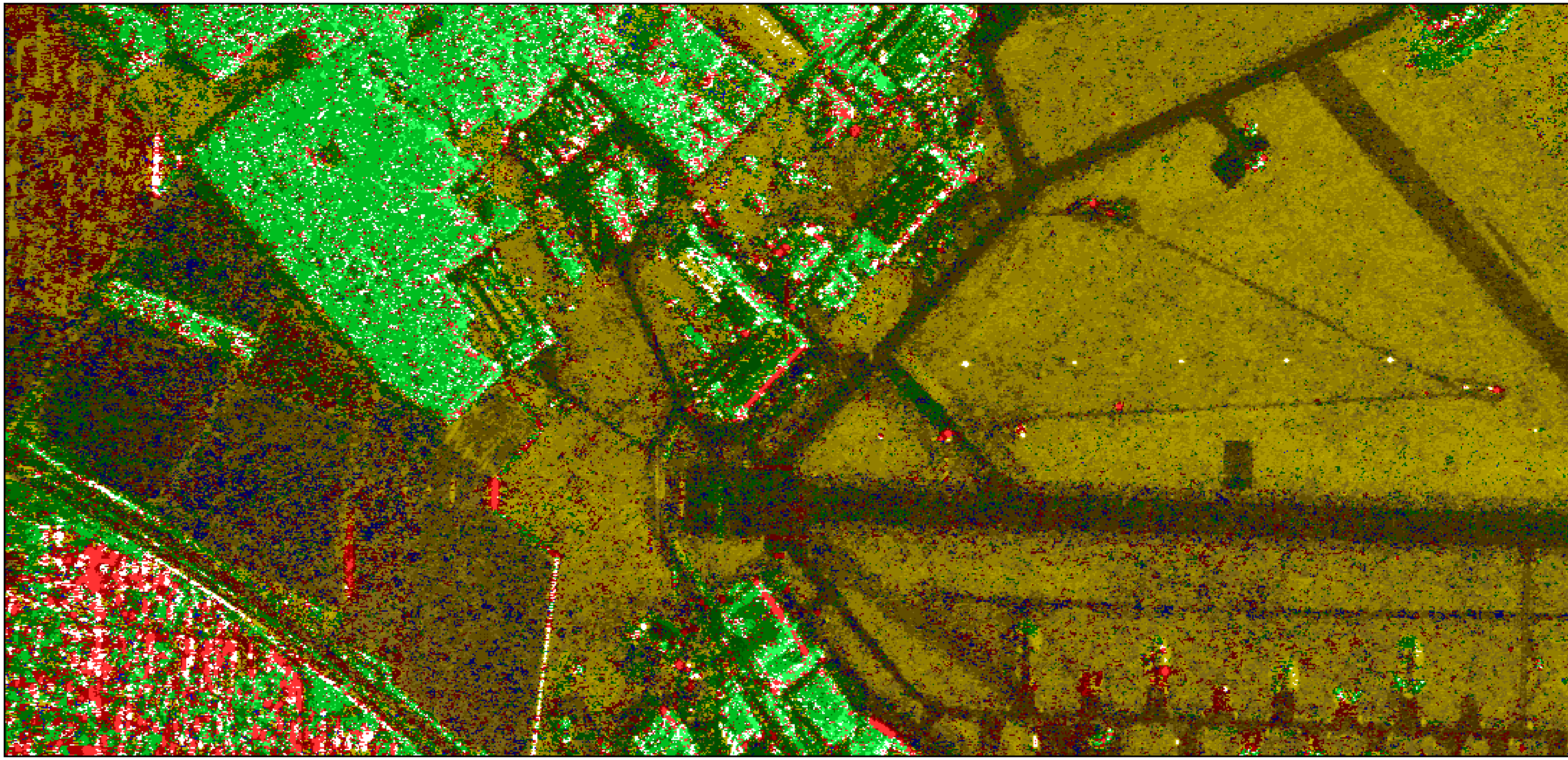
$2A_0$ $B_0 + B$ $B_0 - B$

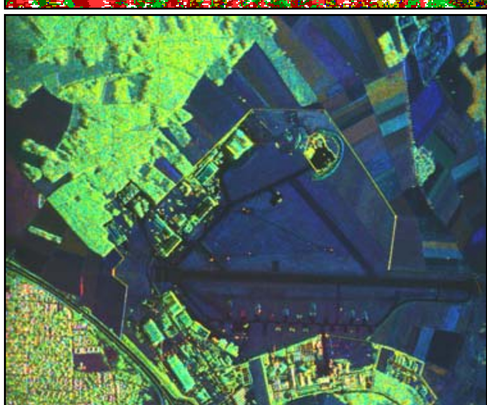


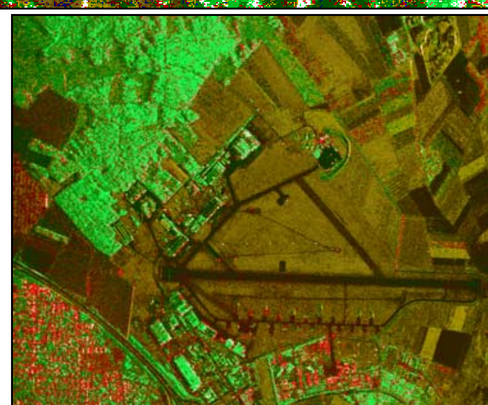
4th Iteration (15 classes)

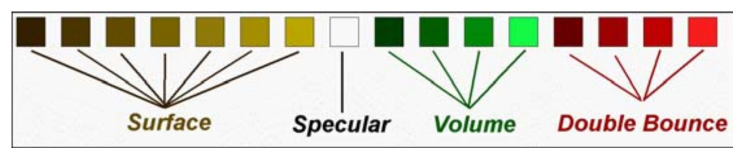


FREEMAN - WISHART CLASSIFIER









INSTITUT D'ÉLECTRONIQUE ET DE TÉLÉCOMMUNICATIONS DE RENNES