Introduction to

SAR Polarimetry

ESA-MOST Dragon 4 Cooperation

ADVANCED LAND REMOTE SENSING INTERNATIONAL TRAINING COURSE

“龙计划4”高级陆地遥感国际培训班

Eric POTTIER

University of Rennes 1 - France

20-25 November 2017 | Yunnan Normal University
Kunming, Yunnan Province, P.R. China

2017年11月20日——11月25日
云南师范大学，中国，昆明

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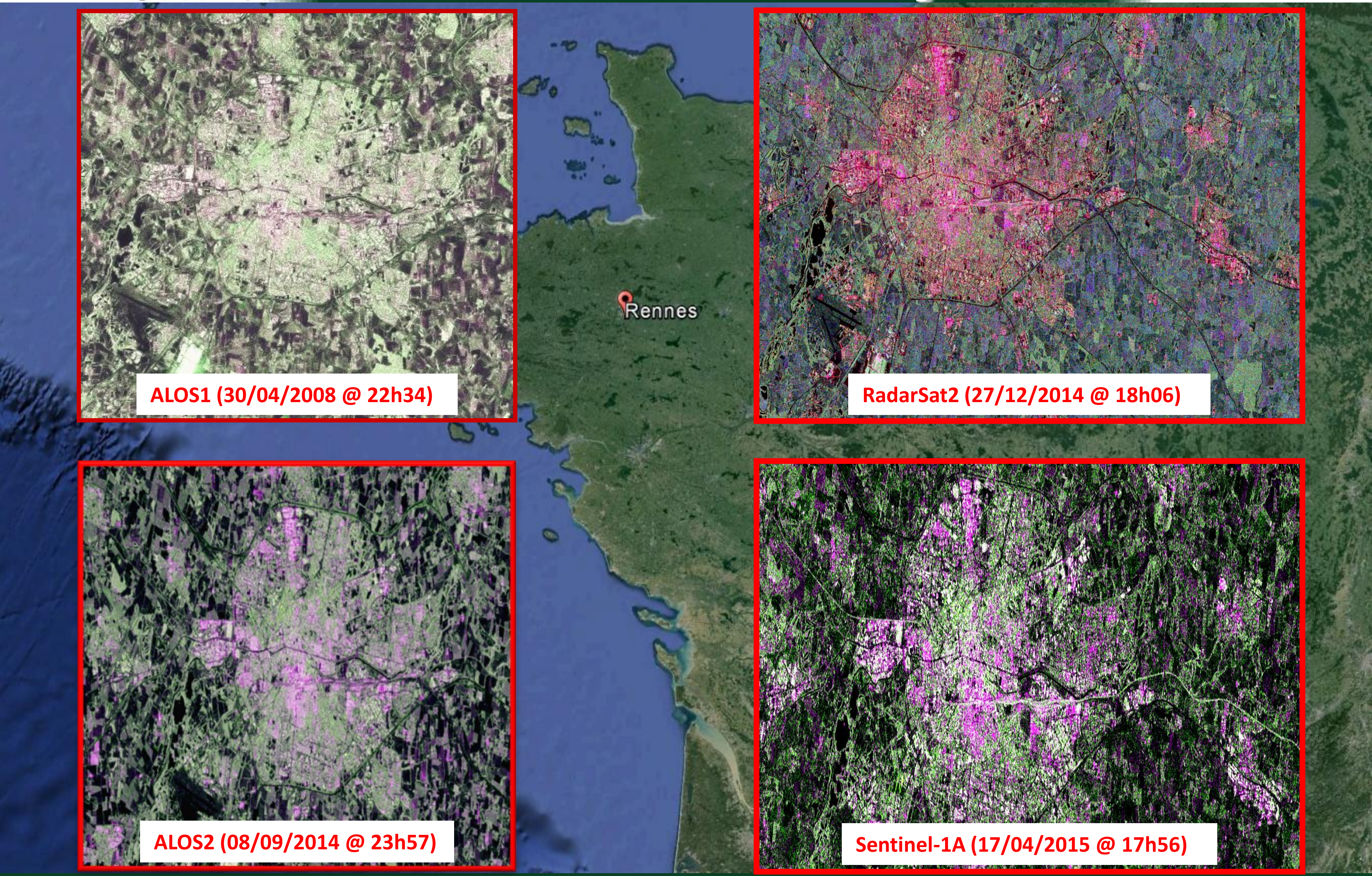
SHINE

SAR & Hyperspectral multi-modal Imaging and sigNal processing, Electromagnetic modeling

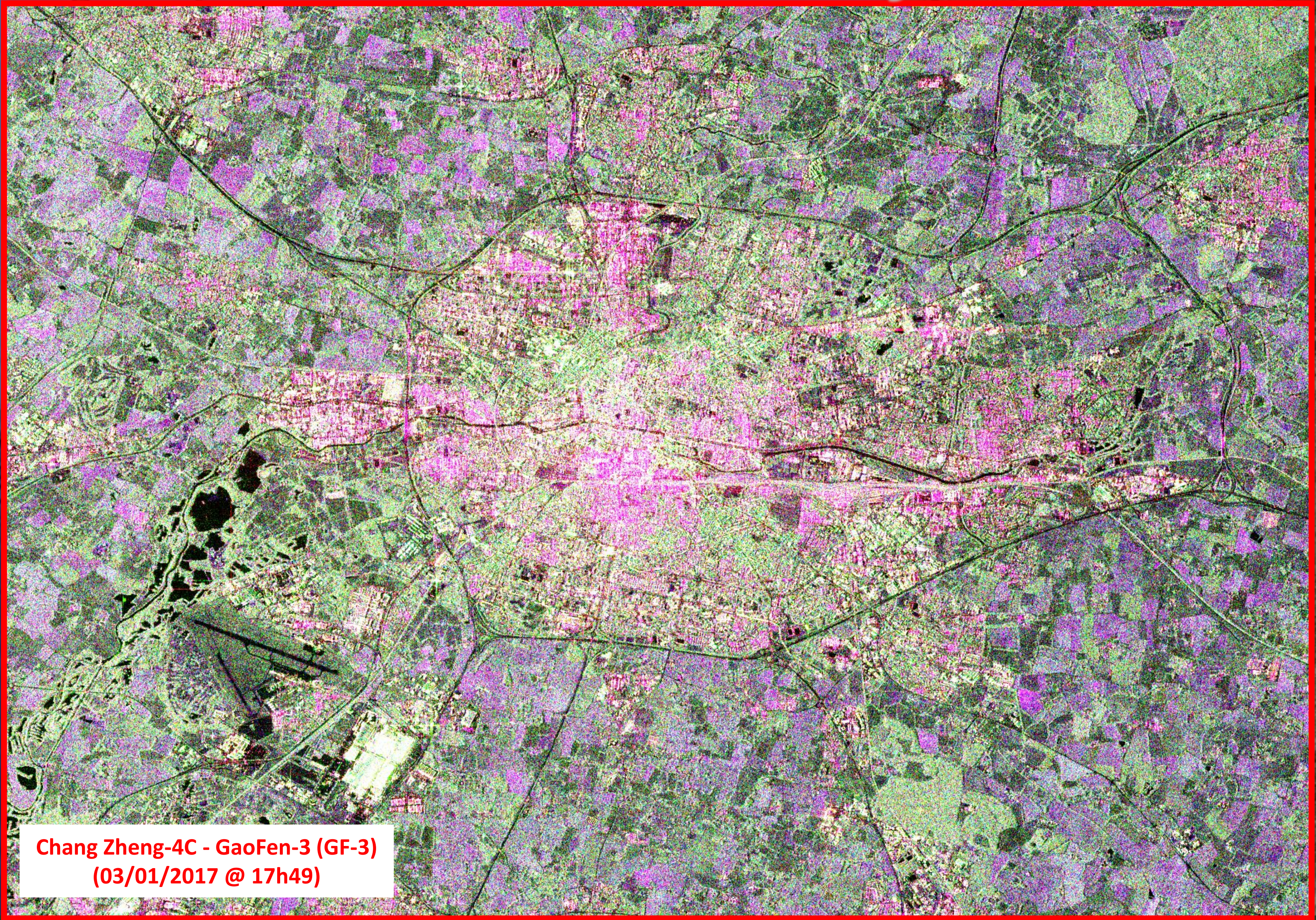
UNIVERSITÉ DE RENNES 1

Rennes - Britanny

Rennes - Britanny



Rennes - Britanny



Objective

To provide

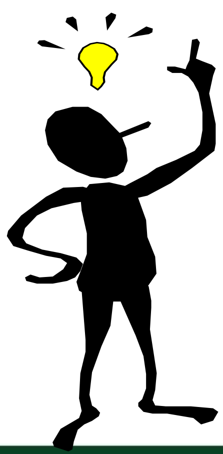
the minimum, but necessary,

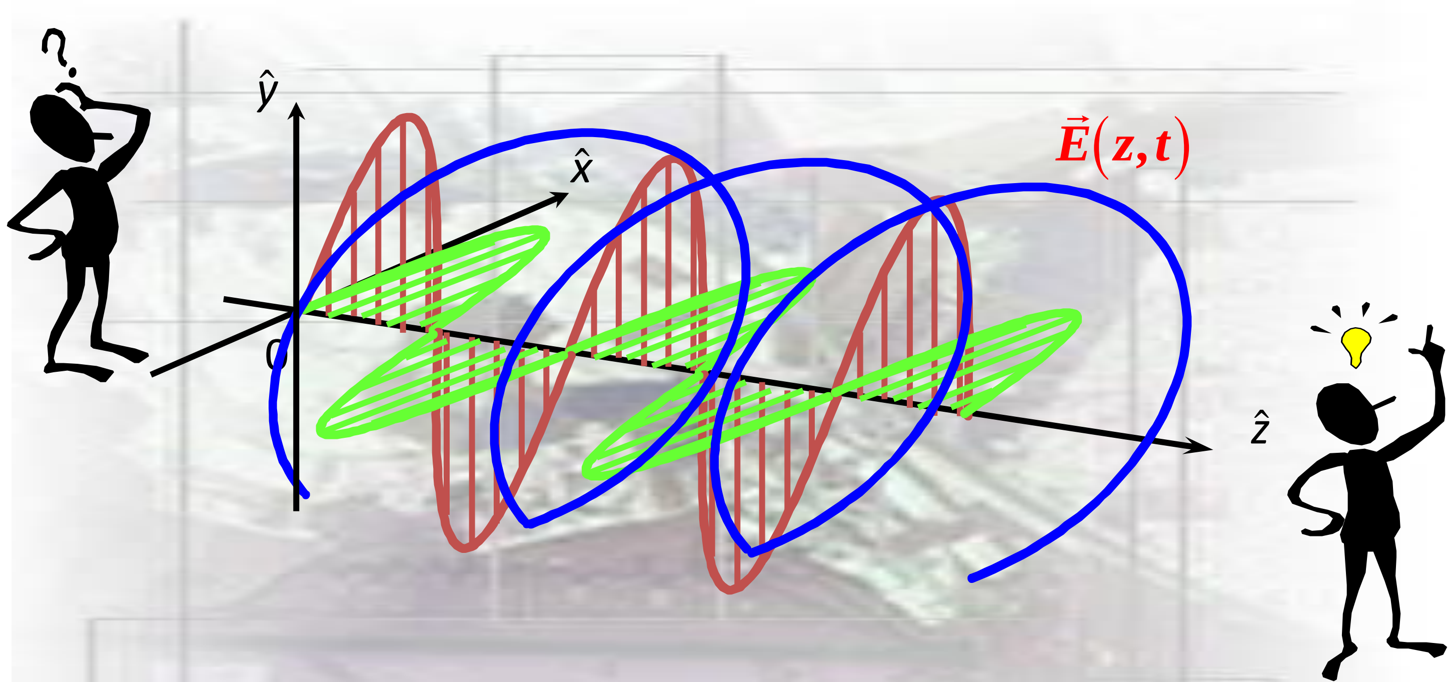
amount of knowledge required

to understand

scientific works on

SAR Polarimetry (PolSAR)



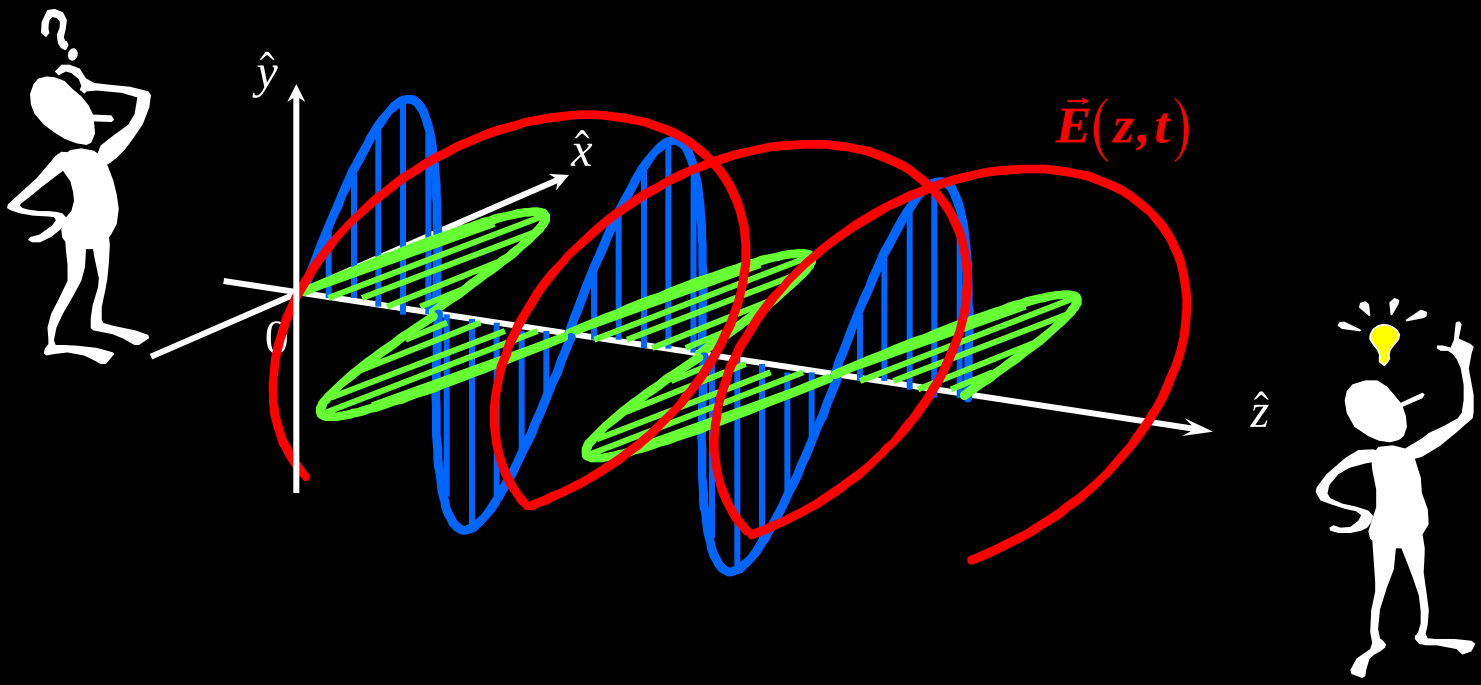


GENERAL INTRODUCTION

RADAR POLARIMETRY

- **A bit of History**
- **Airborne and Space-borne Polarimetric SAR Sensors**
- **Software / Toolbox**
- **Learning / Training / Results**

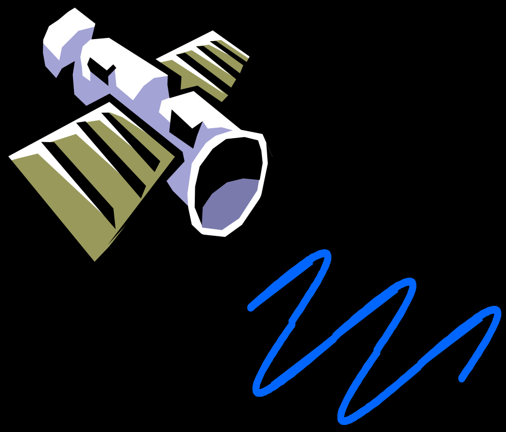
Radar Polarimetry



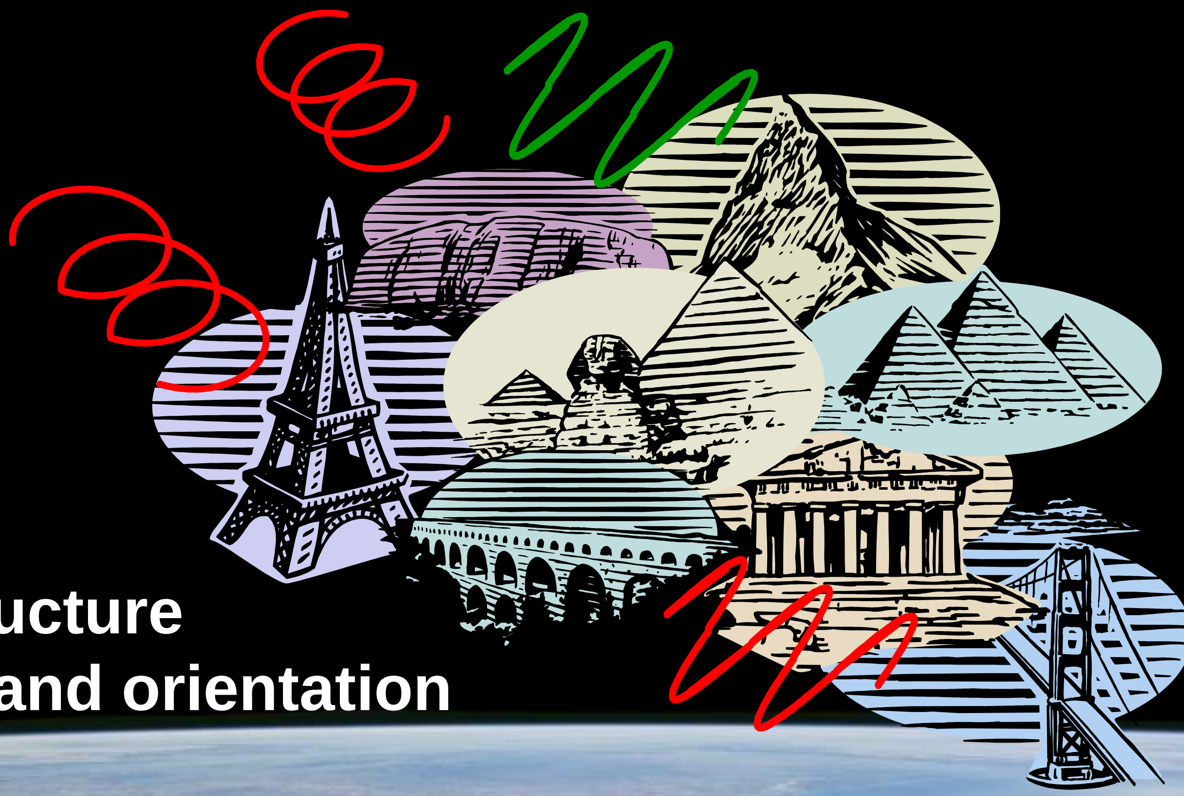
Radar Polarimetry (Polar : polarisation Metry: measure) is the science of acquiring, processing and analysing the polarization state of an electromagnetic field

Radar Polarimetry deals with the full vector nature of polarized electromagnetic waves

Radar Polarimetry



The POLARISATION information
Contained in the waves backscattered
from a given medium is highly related to:



its geometrical structure
reflectivity, shape and orientation

its geophysical properties such as humidity, roughness, …

SAR Polarimetry Applications

Forest Vegetation

- Forest Height
- Forest Biomass
- Forest Structure
- Canopy Extinction
- Underlying Topography

- Forest Ecology
- Forest Management
- Ecosystem Change
- Carbon Cycle

Agriculture

- Soil Moisture Content
- Soil roughness
- Height of Vegetation Layer
- Extinction of Vegetation Layer
- Moisture of Vegetation Layer

- Farming Management
- Water Cycle
- Desretification

Snow and Ice

- Topography
- Penetration Depth / Density
- Snow Ice Layer
- Snow Ice Extinction
- Water Equivalent

- Ecosystem Change
- Water Cycle
- Water Management

Urban Areas

- Geometric Properties
- Dielectric Properties

- Urban Monitoring

DLR Courtesy of Dr. I. Hajnsek

A Bit Of History

Radar Polarimetry

Discovery of the Phenomena of Polarized Electromagnetic Energy

AD 1000
Use of the polarized skylight to locate a hidden sun

Crystal of calcite
Iceland Spar
Sunstone

1669
First known Quantitative work on light observation

Bartholinus

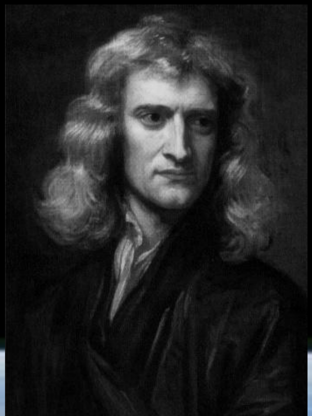
Discovery of the double refraction in calcite

1677
Wave nature of light discovery
Explanation of the double refraction

Huygens

Corpuscular model or « longitudinal » waves

1704
Corpuscular Model of light



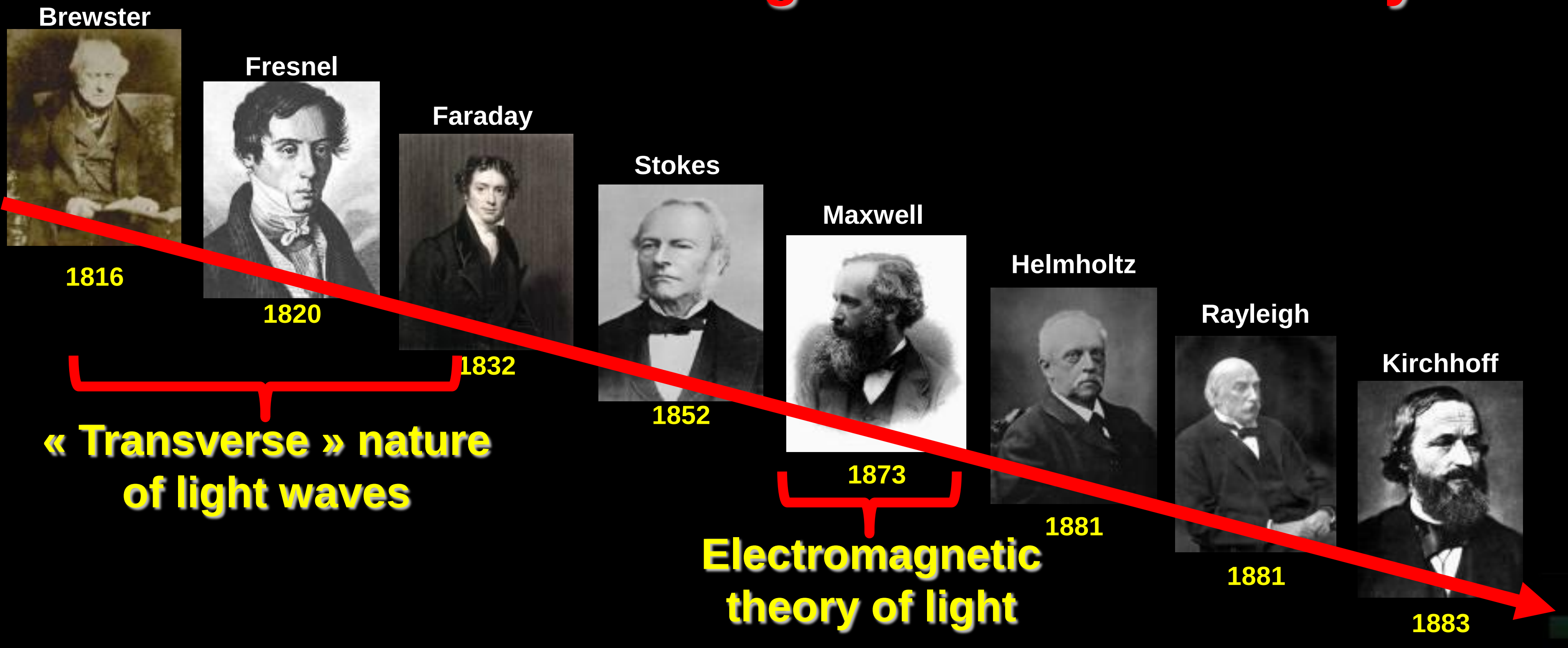
Newton

1808
Discovery of the polarization of light (intrinsic property of light and not of crystals)

Malus
X-1795

#E. Pottier (06/2017)

Non Exhaustive Chronological List of the Main Pionners who contributed to the discovery of Polarization leading to Radar Polarimetry



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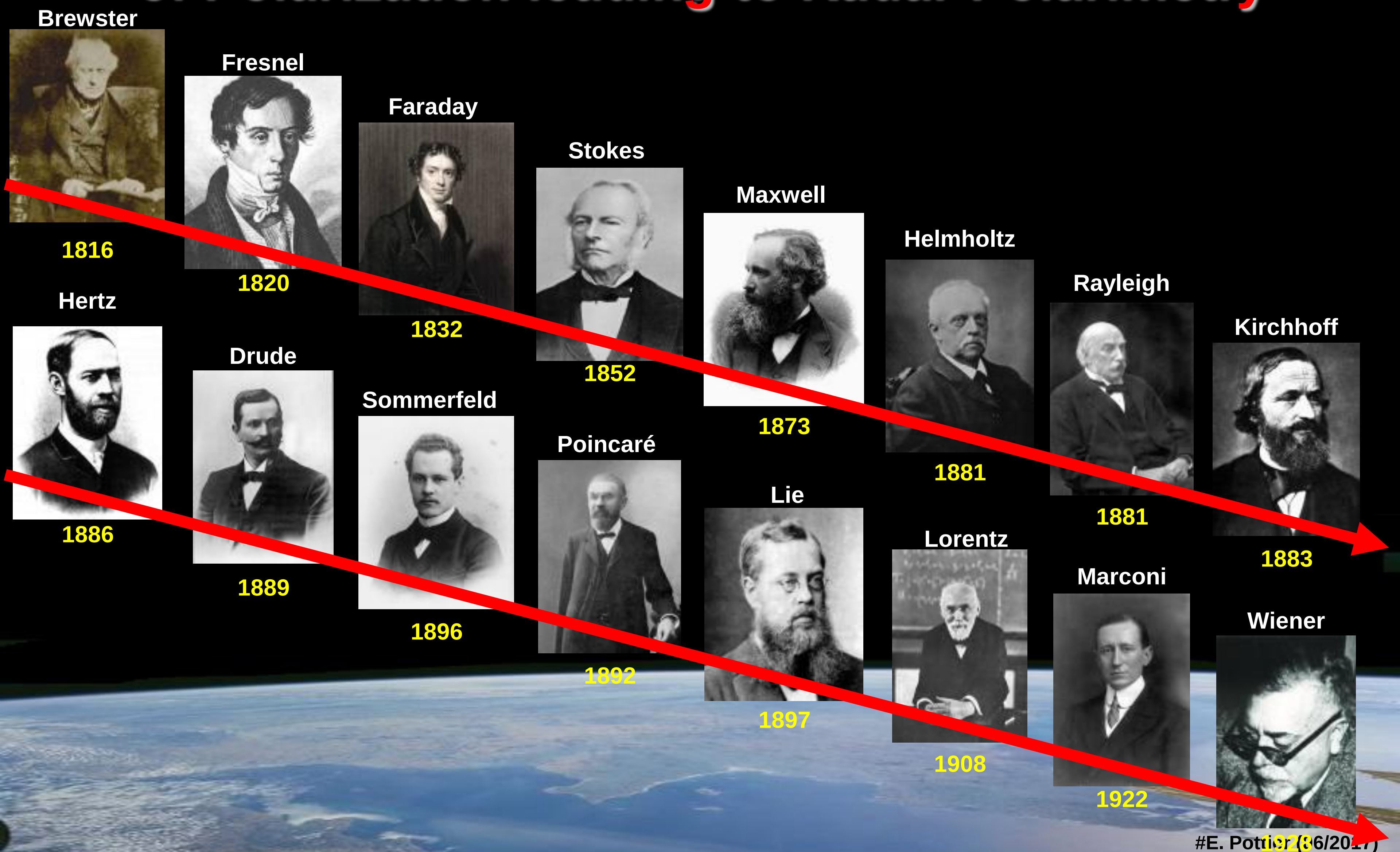
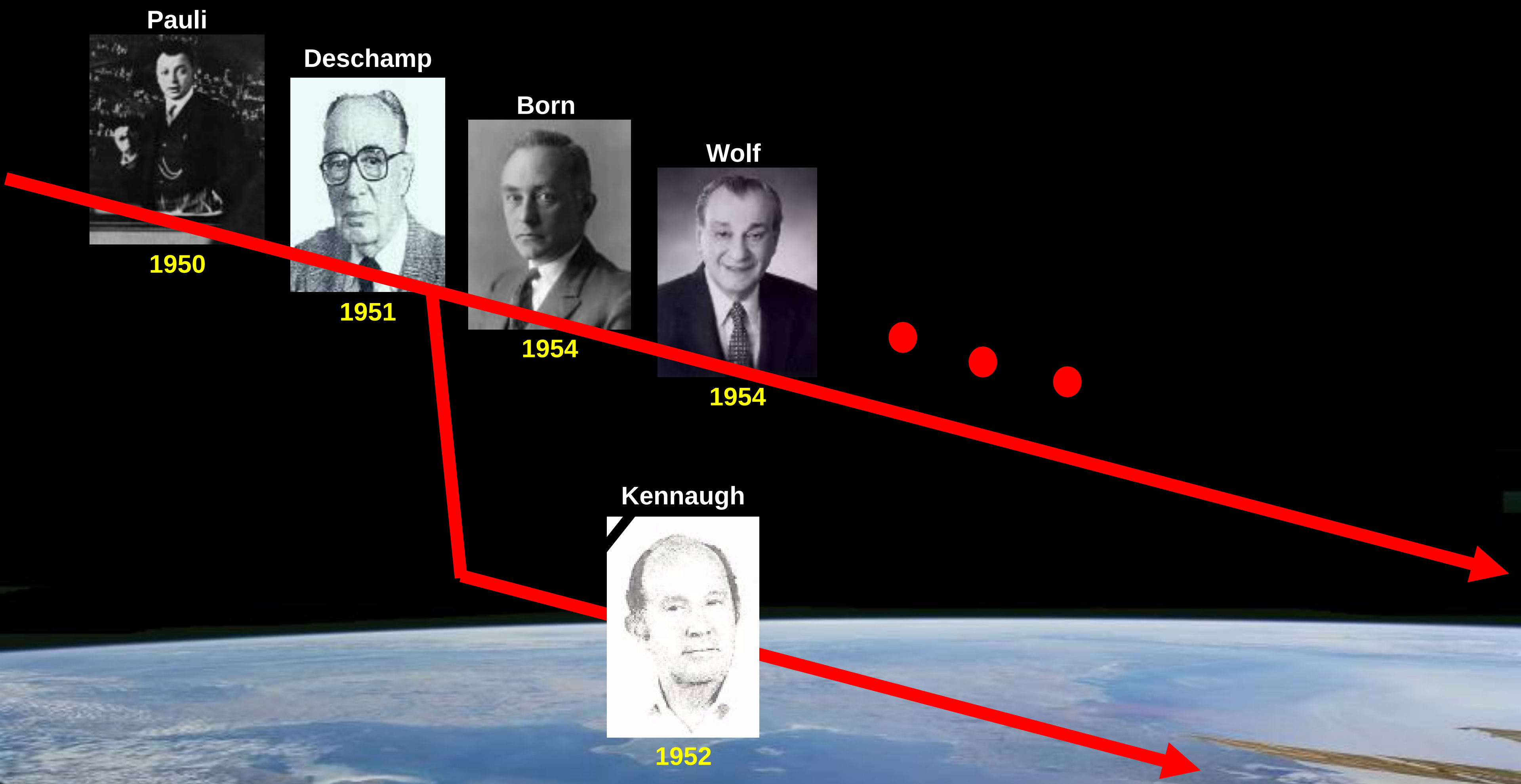


Non Exhaustive Chronological List of the Main Pionners who contributed to the discovery of Polarization leading to Radar Polarimetry



Non Exhaustive Chronological List of the Main Pionners who contributed to the discovery of Polarization leading to Radar Polarimetry

Kennaugh

1952

Huynen

1970

W. M. Boerner

1980

The Radar Polarimetric Triptych

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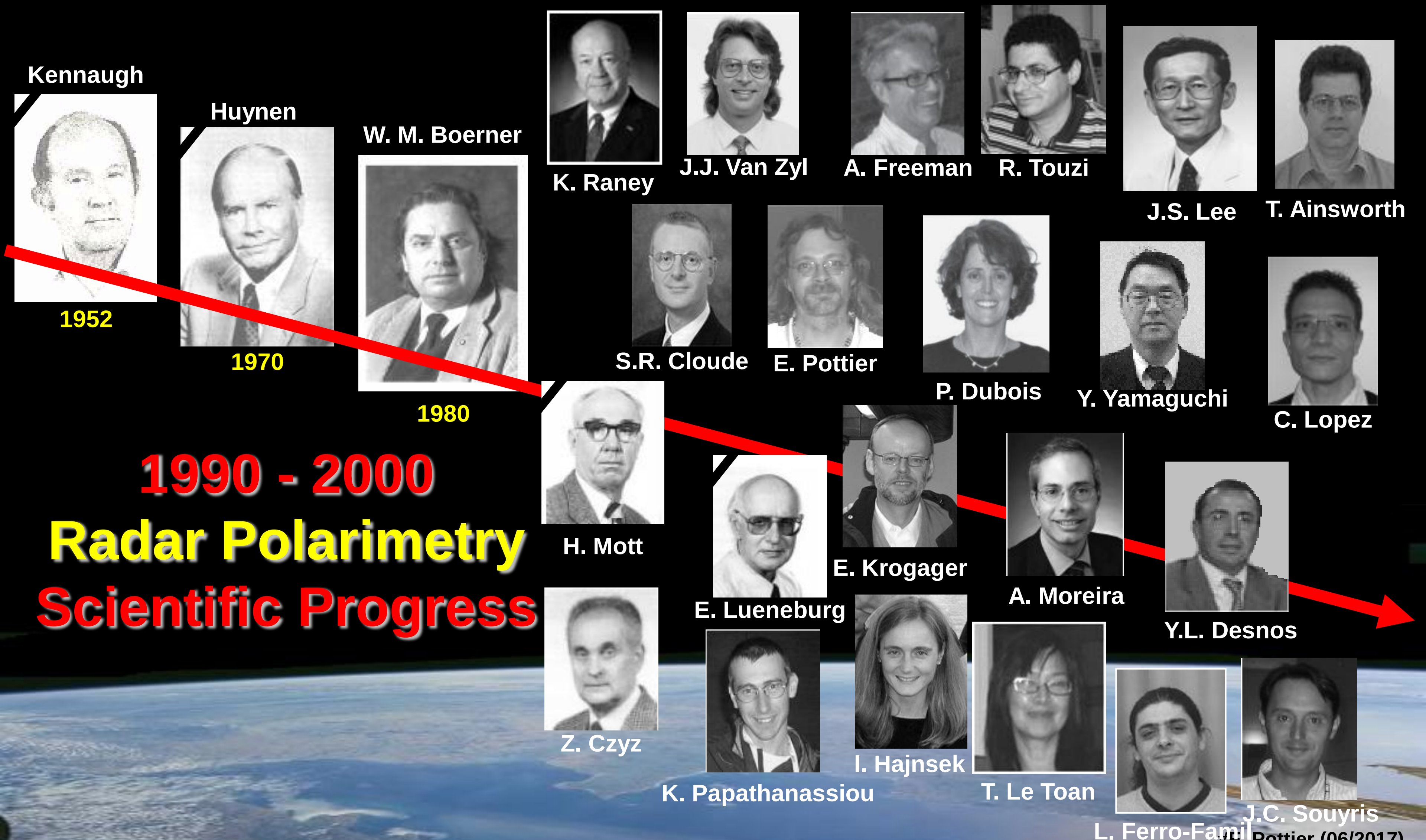
Non Exhaustive Chronological List of the Main Pionners who contributed to the discovery of Polarization leading to Radar Polarimetry



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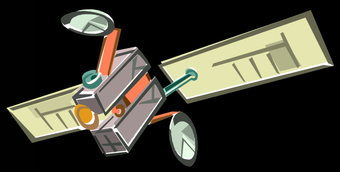
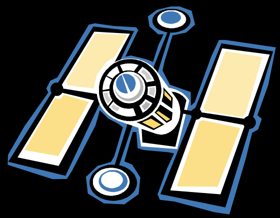
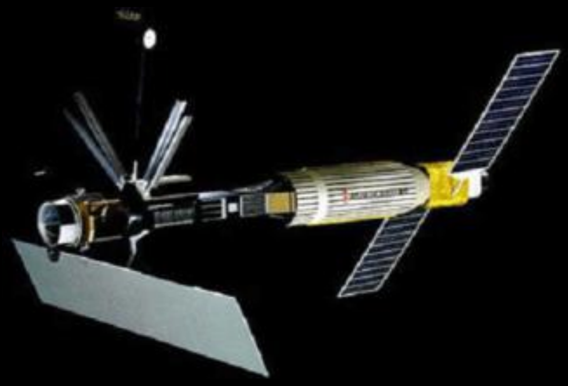
Polarimetric Radar (SAR)



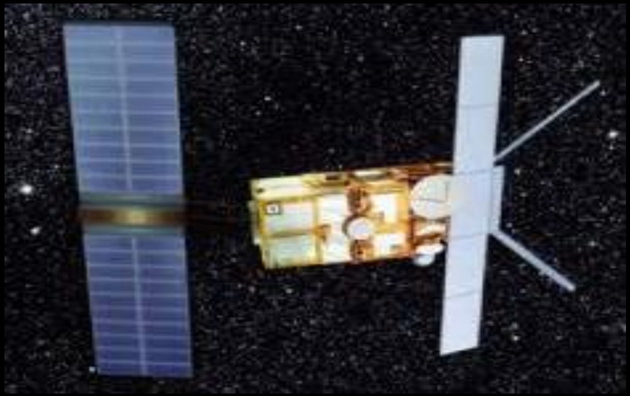


Spaceborne Sensors

Space-borne Sensors



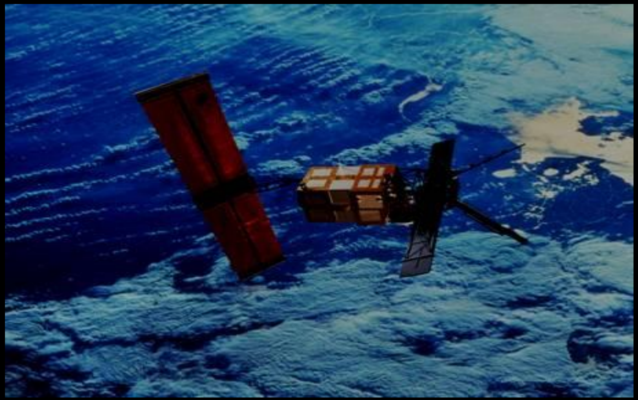
SEASAT
NASA/JPL (USA)
L-Band, 1978



ERS-1
European Space Agency (ESA)
C-Band, 1991-2000

J-ERS-1
Japanese Space Agency (NASDA)
L-Band, 1992-1998

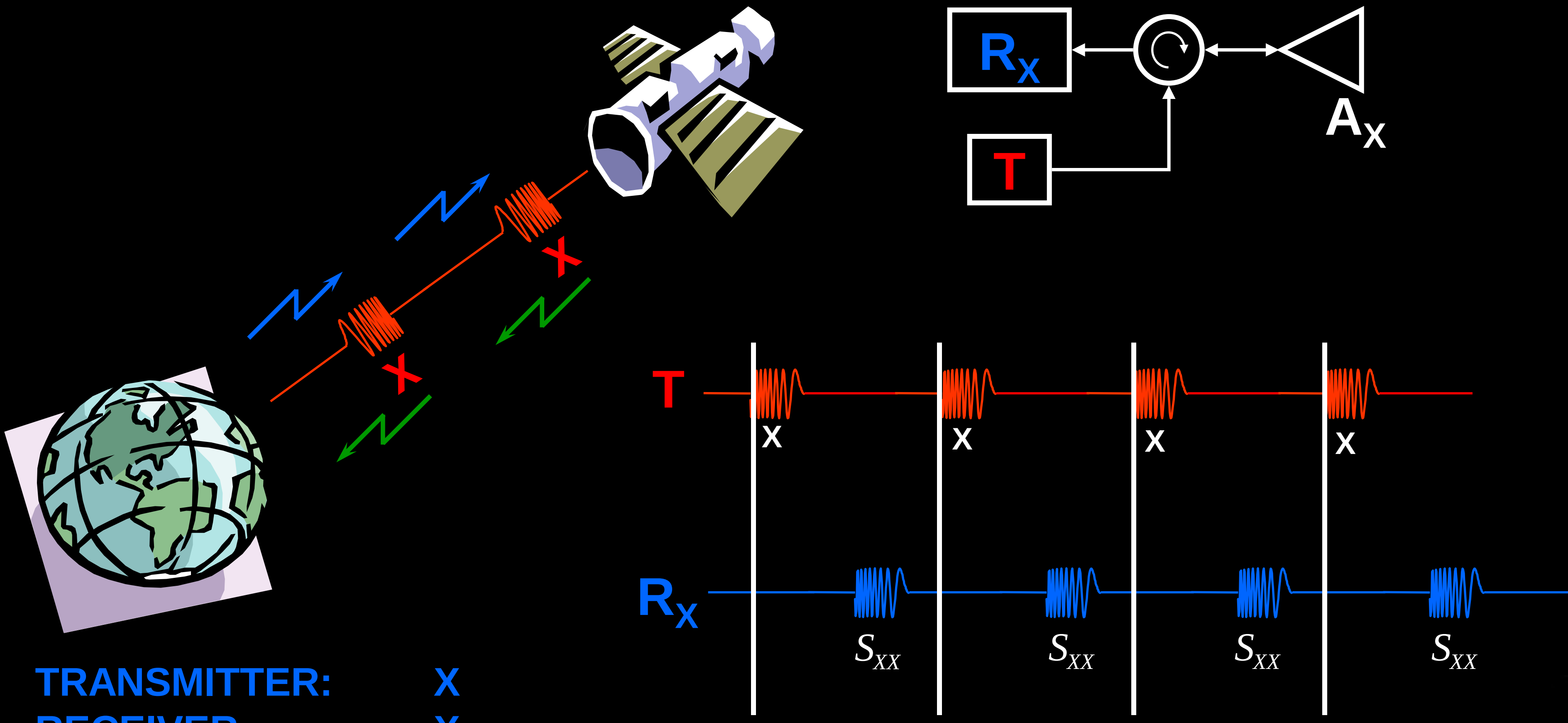
RadarSAT-1
Canadian Space Agency (CSA)
C-Band, 1995



ERS-2
European Space Agency (ESA)
C-Band, 1995

Shuttle Radar Topography Mission
NASA/JPL (C-Band), DLR (X-Band)
February 2000

Scattering Coefficient

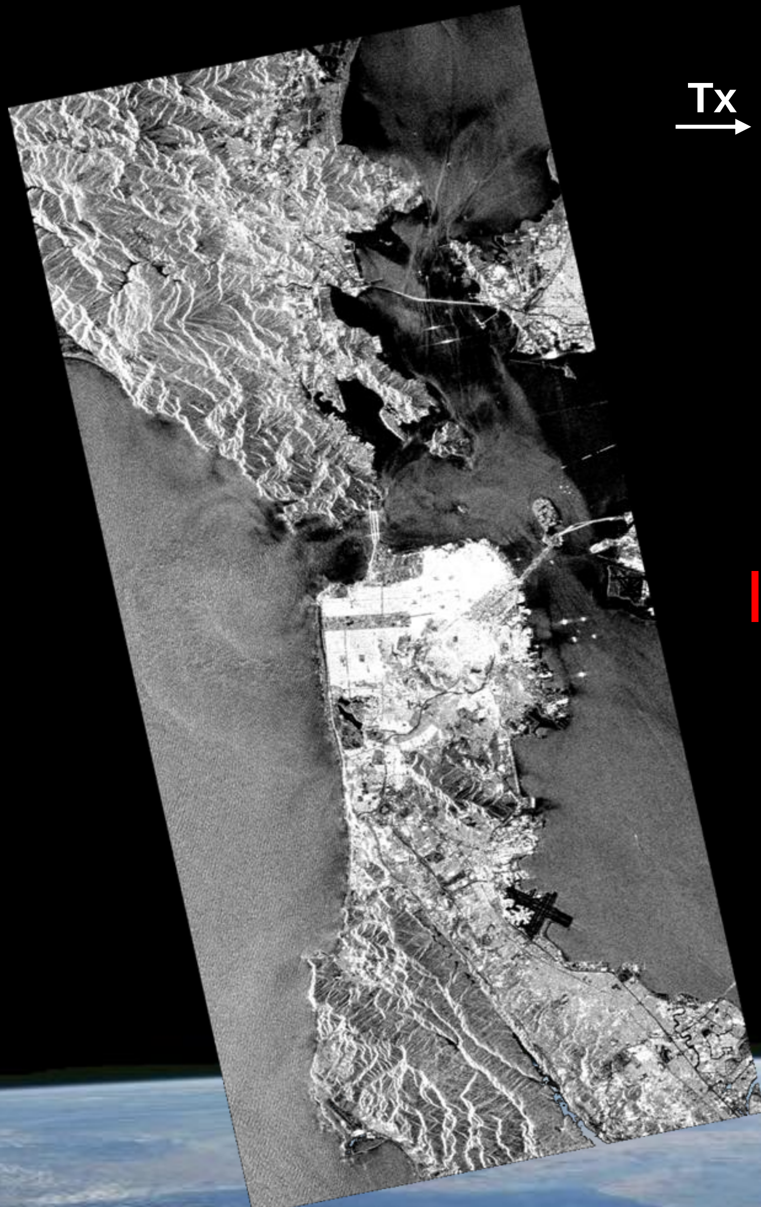


TRANSMITTER: X
RECEIVER: X

BACKSCATTERING COEFFICIENT $\{ S_{XX} \}$

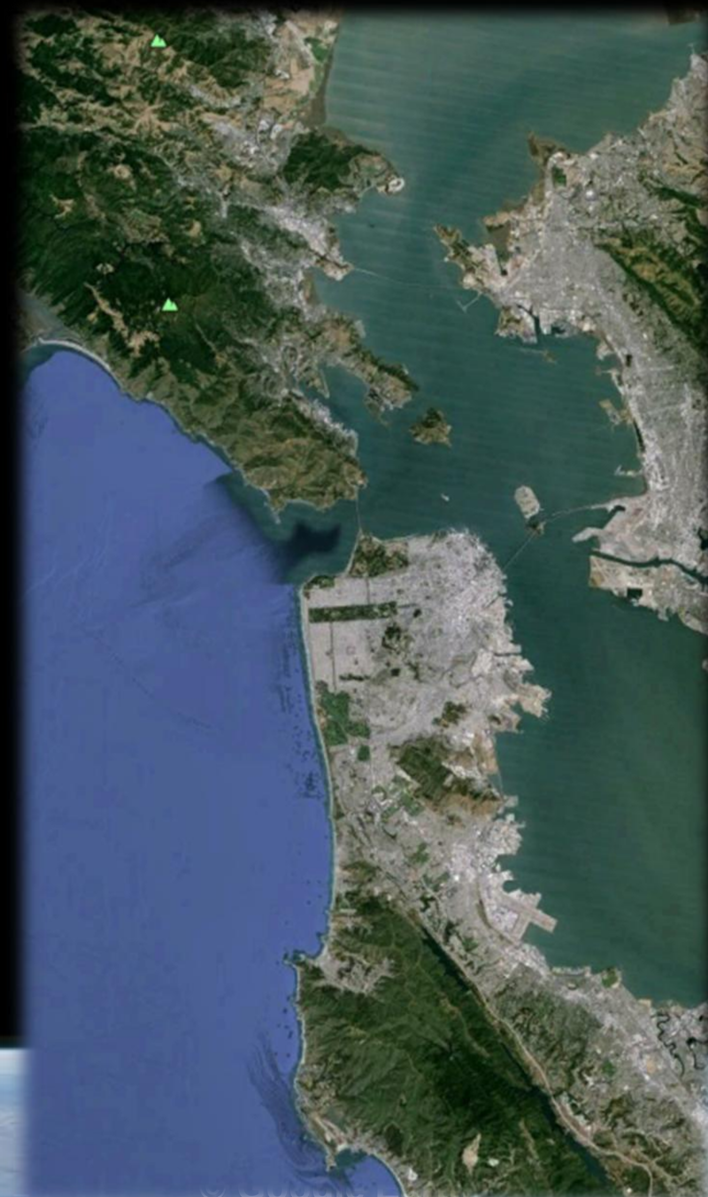
NO POLARIMETRY

Space-borne Sensors



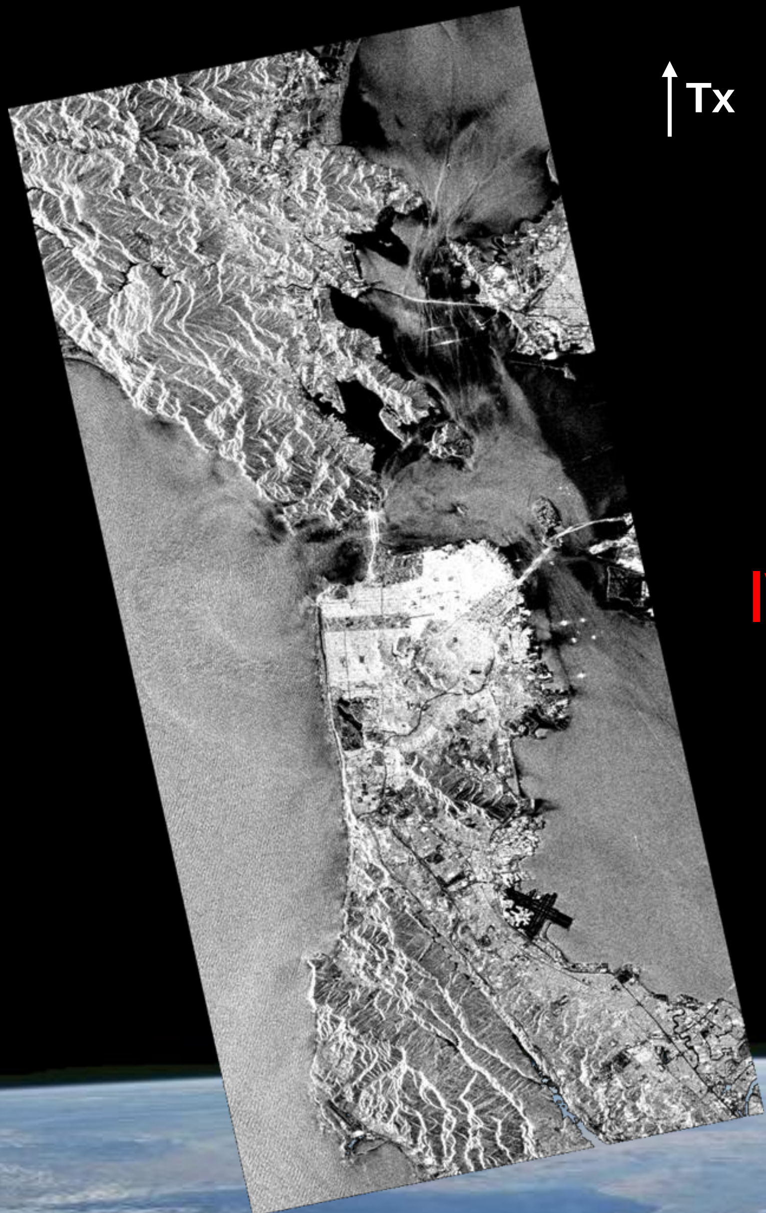
Tx → Rx →

$|HH|_{dB}$



San Francisco Bay – (L-Band)

Space-borne Sensors

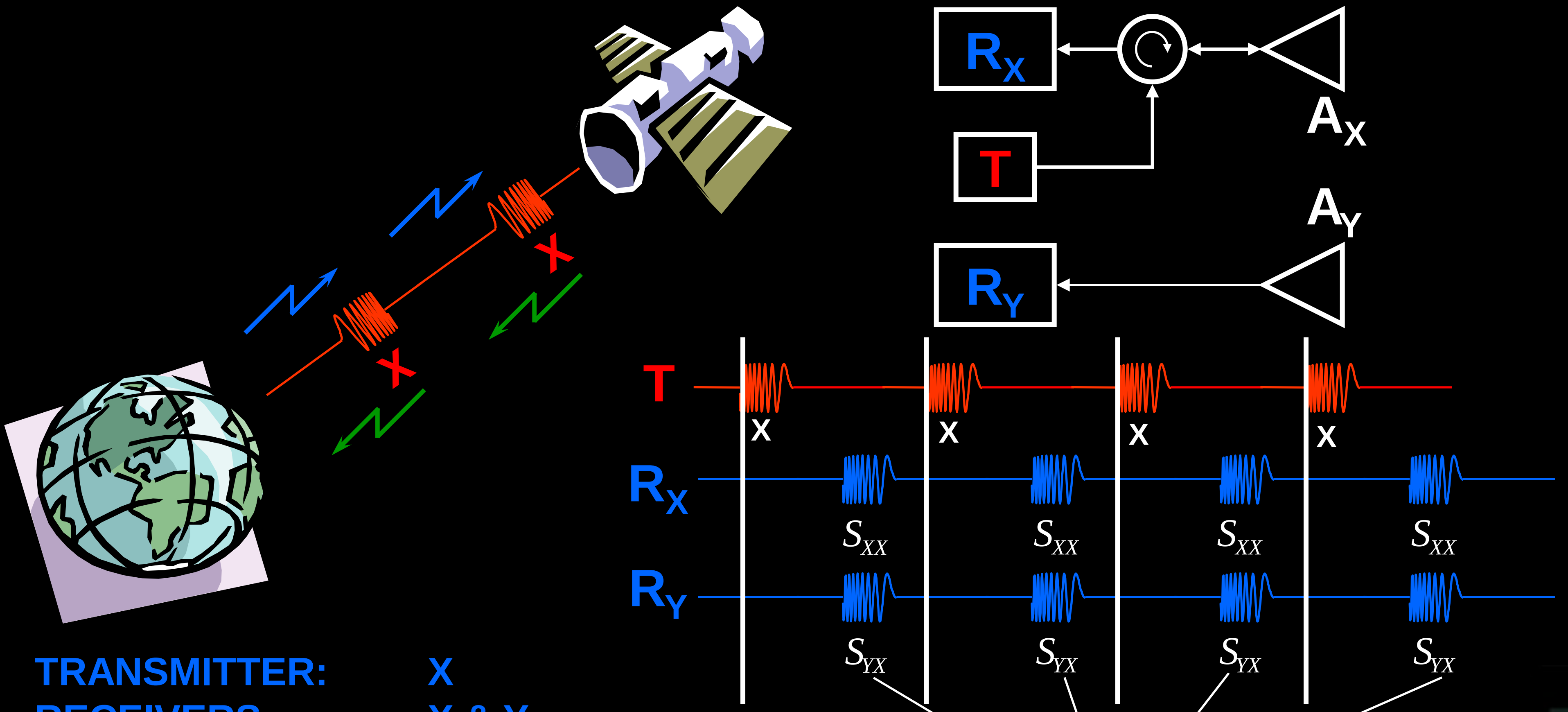


↑ Tx ↑ Rx

$|VV|_{dB}$

San Francisco Bay – (L-Band)

Wave Polarimetry



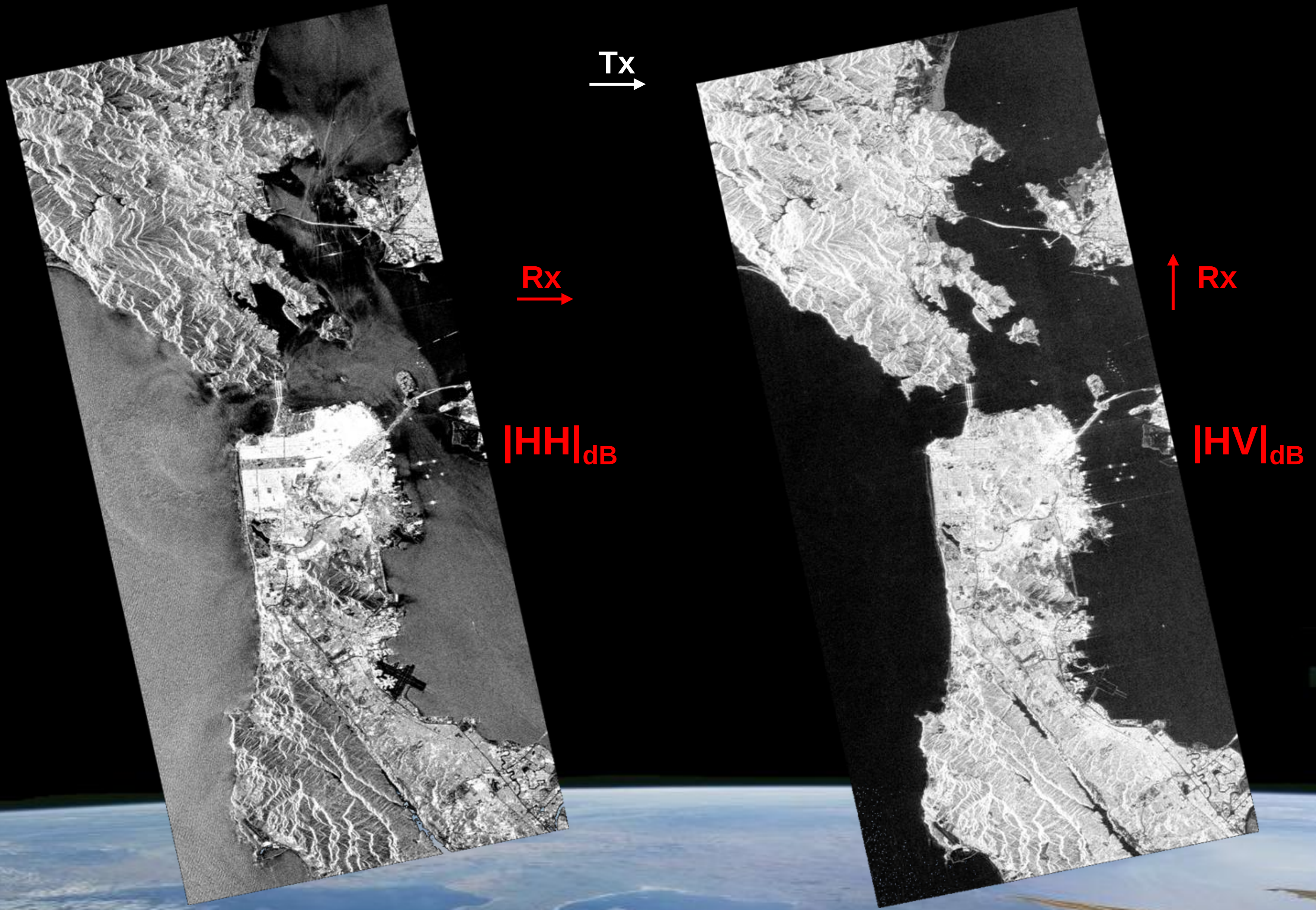
TRANSMITTER: X

RECEIVERS: X & Y

JONES VECTORS $\left\{ \underline{E}_S = \begin{bmatrix} S_{XX} \\ S_{YX} \end{bmatrix} \right\}$

WAVE POLARIMETRY

Space-borne Sensors



San Francisco Bay – (L-Band)

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Space-borne PolSAR Sensors

ENVISAT - ASAR

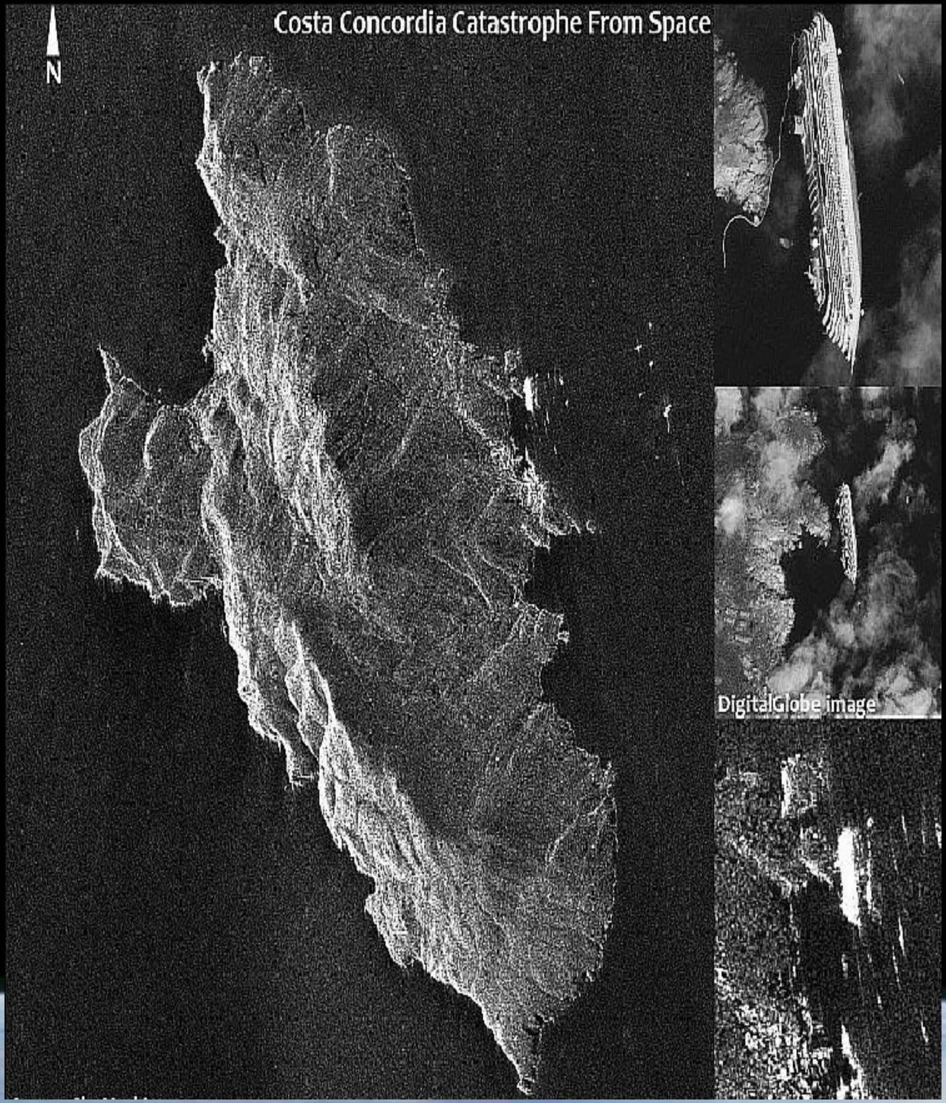
October 2001

C-Band (Sngl / Dual Inc)

Space-borne PolSAR Sensors

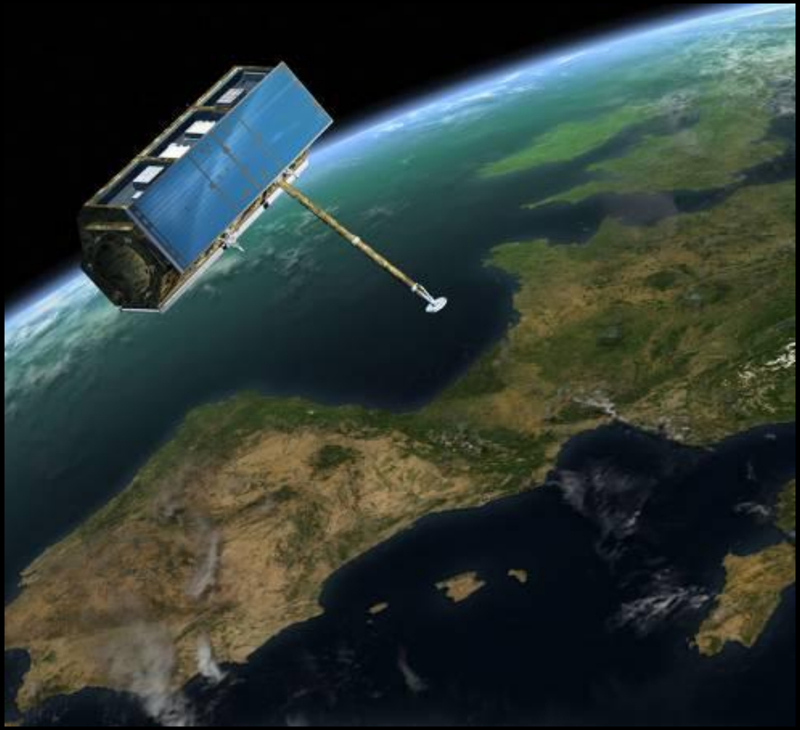
COSMO - SkyMed

June 2007, Dec. 2007
Oct. 2008, Nov. 2010
X-Band (Sngl / Dual)
Revisit : 1 day



Space-borne PolSAR Sensors

TerraSAR - X



June 2007

X-Band (Sngl / Twin HH-VV / Quad Exp.)

Space-borne PolSAR Sensors

RISAT-1A

26 April 2012

C-Band (Sngl, Dual, Hybrid)

Operational since 2015

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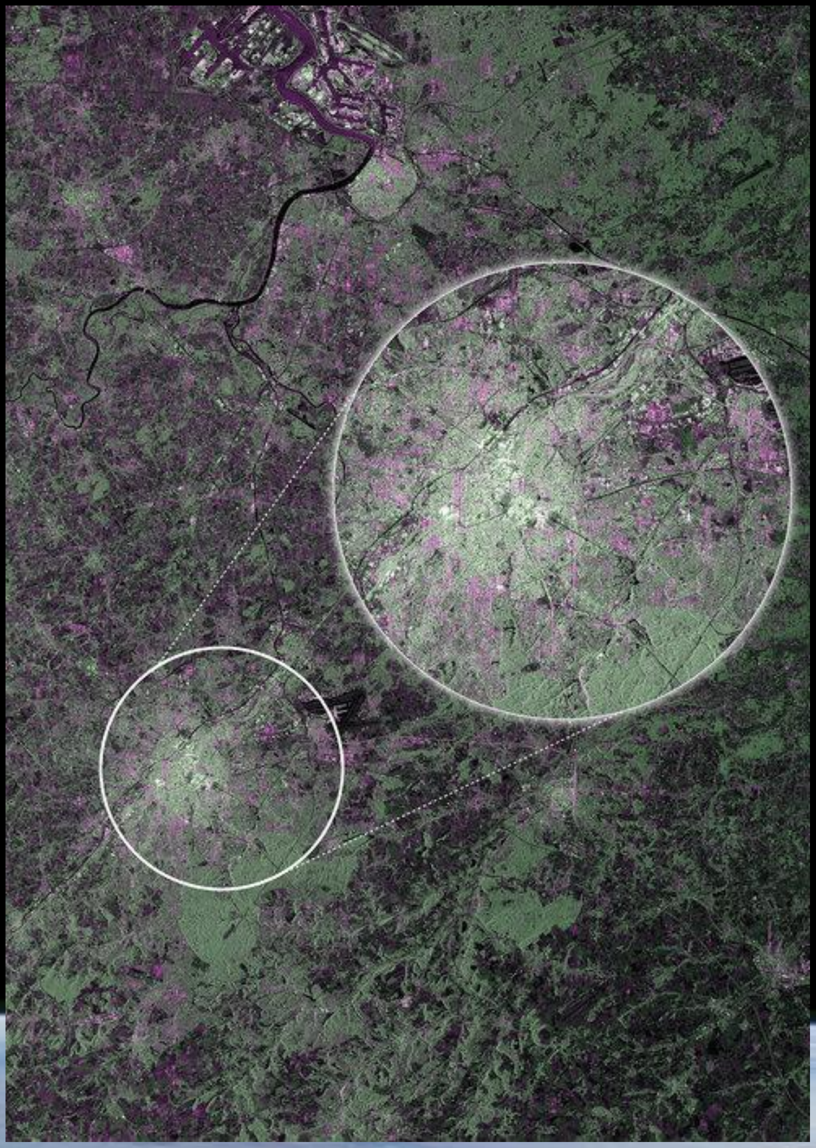
Space-borne PolSAR Sensors

SENTINEL – 1A

S1A : April 2014 S1B : April 2016

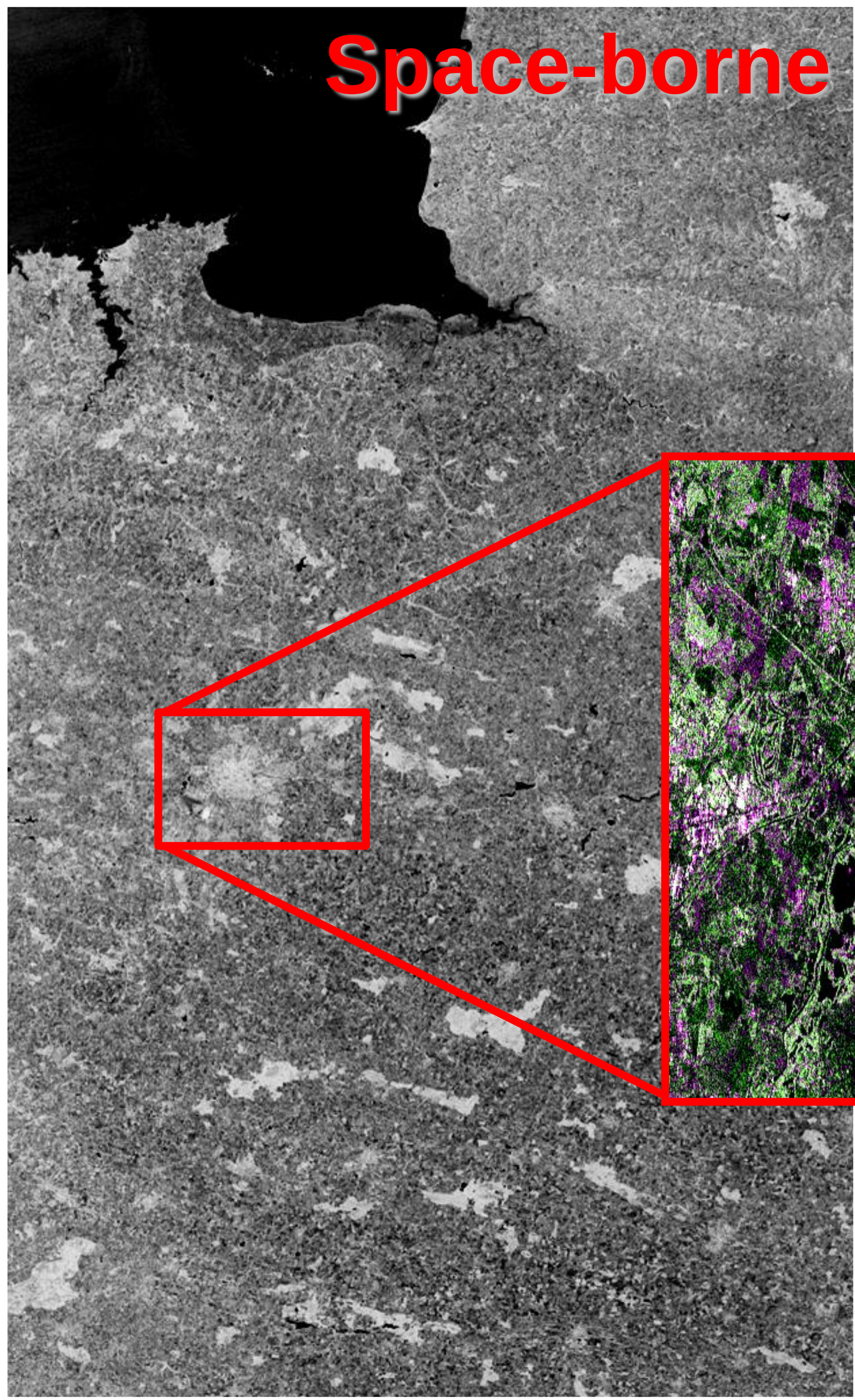
C-Band (Sngl, Dual)

Revisit : 6 days



Brussels – 12 April 2014

Space-borne PolSAR Sensors

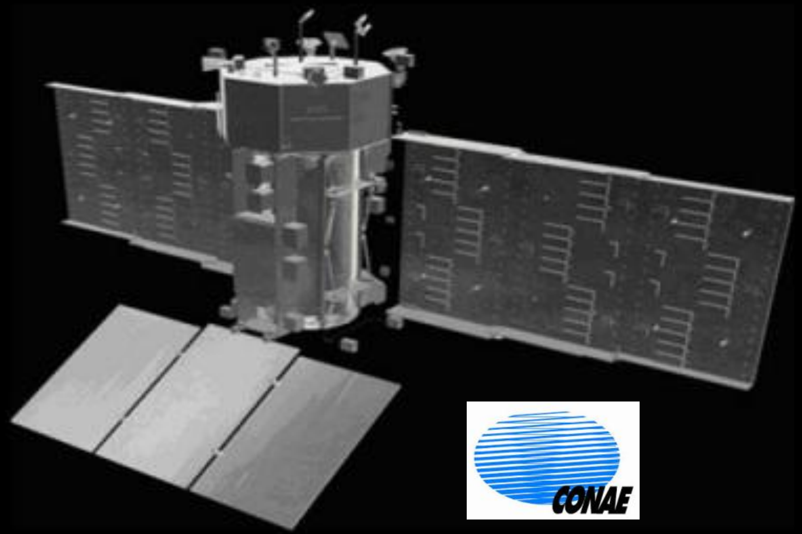


Rennes
Britanny
France

17/08/2016 @ 17h56

Space-borne PolSAR Sensors

SAOCOM – SAR-L

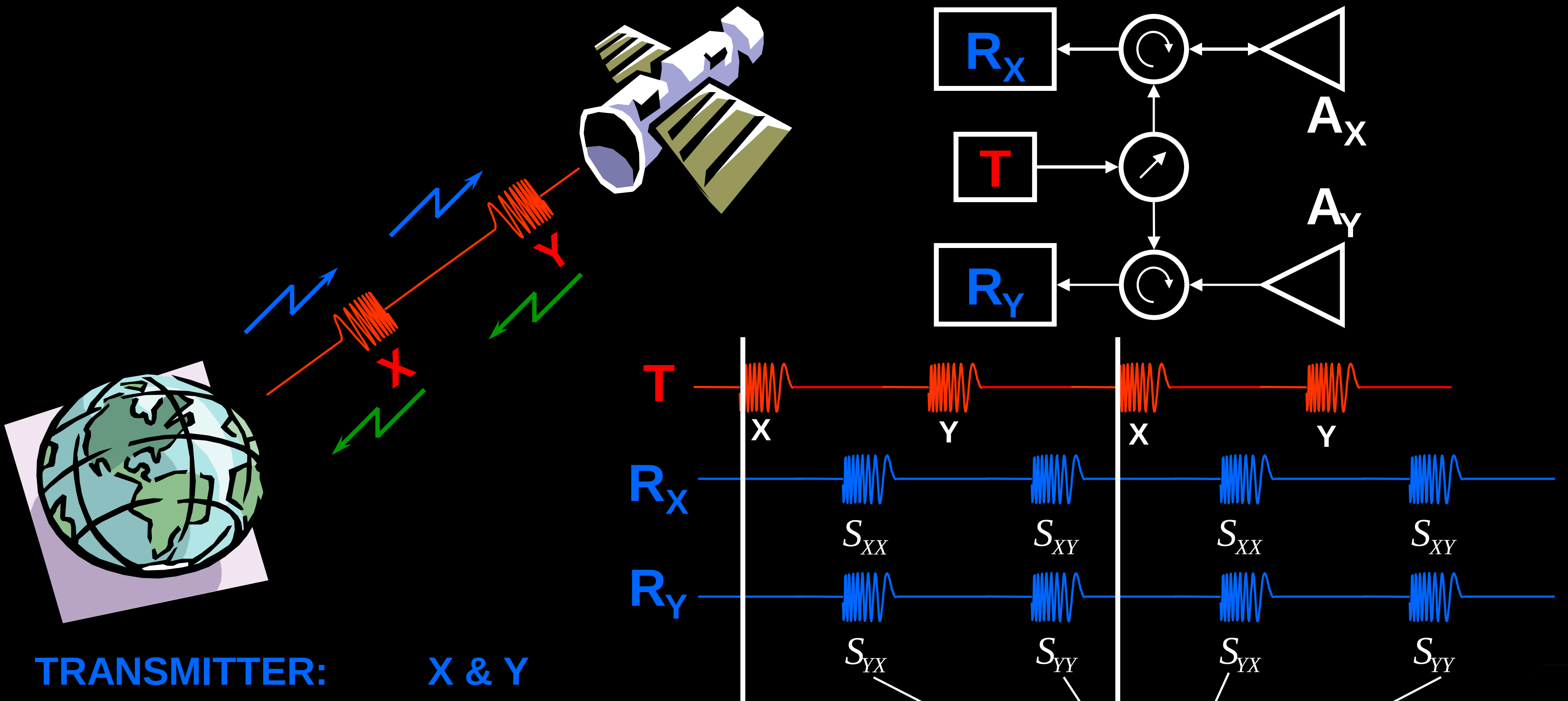


1A : 2017   1B : 2018
2A : 2019   2B : 2020
L-Band (Sngl, Dual, Twin HH-VV)
Revisit : 4 days

RADARSAT Constellation Mission (RCM)

1A : 2017   1B / 1C : 2018
C-Band (Sngl, Dual, Hybrid)
Revisit : 4 days

Scattering Polarimetry



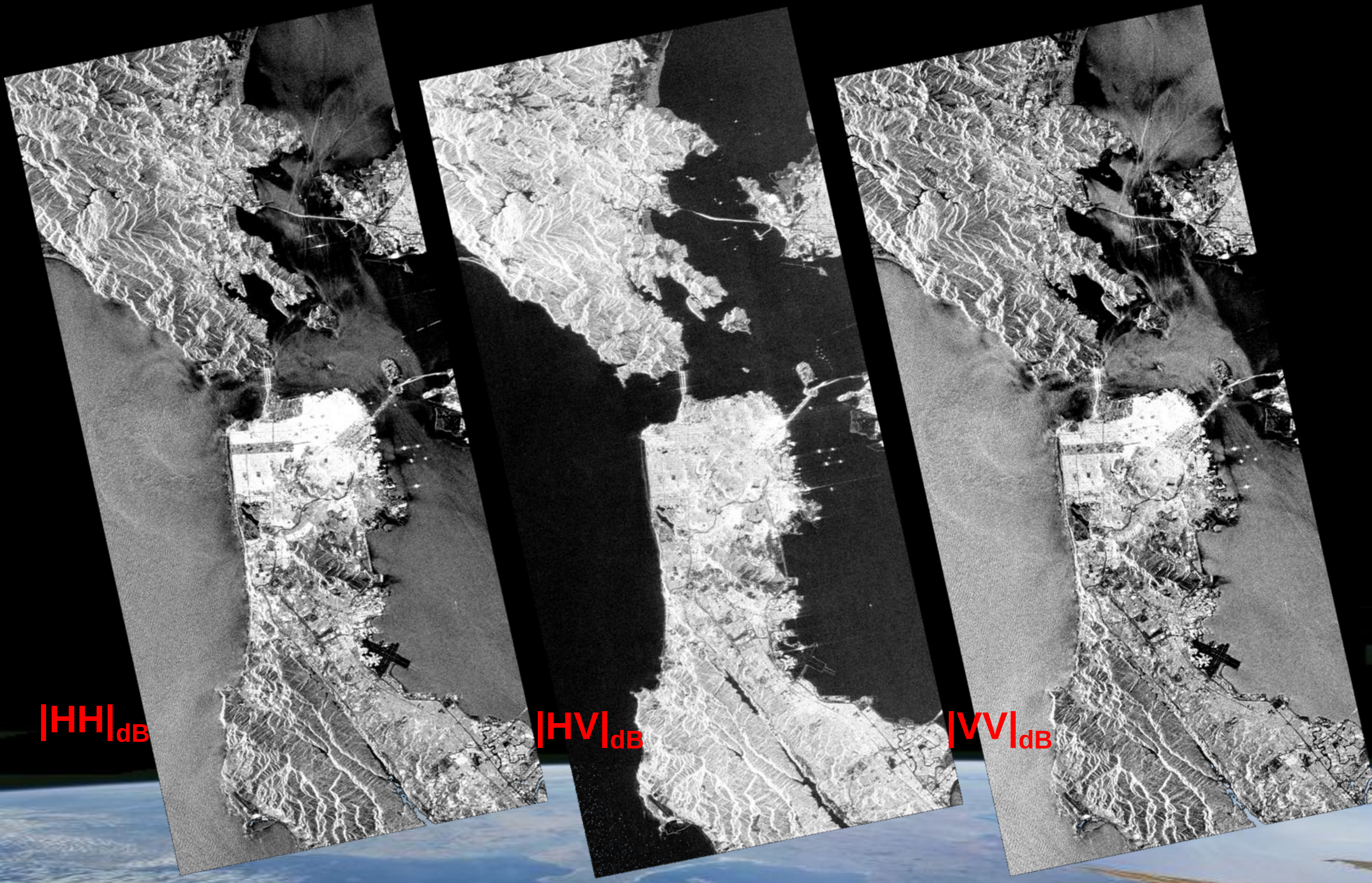
TRANSMITTER: X & Y
RECEIVERS: X & Y

SINCLAIR MATRICES

$$\left\{ [S] = \begin{bmatrix} S_{XX} & S_{XY} \\ S_{YX} & S_{YY} \end{bmatrix} \right\}$$

SCATTERING POLARIMETRY

Space-borne Sensors



San Francisco Bay – (L-Band)

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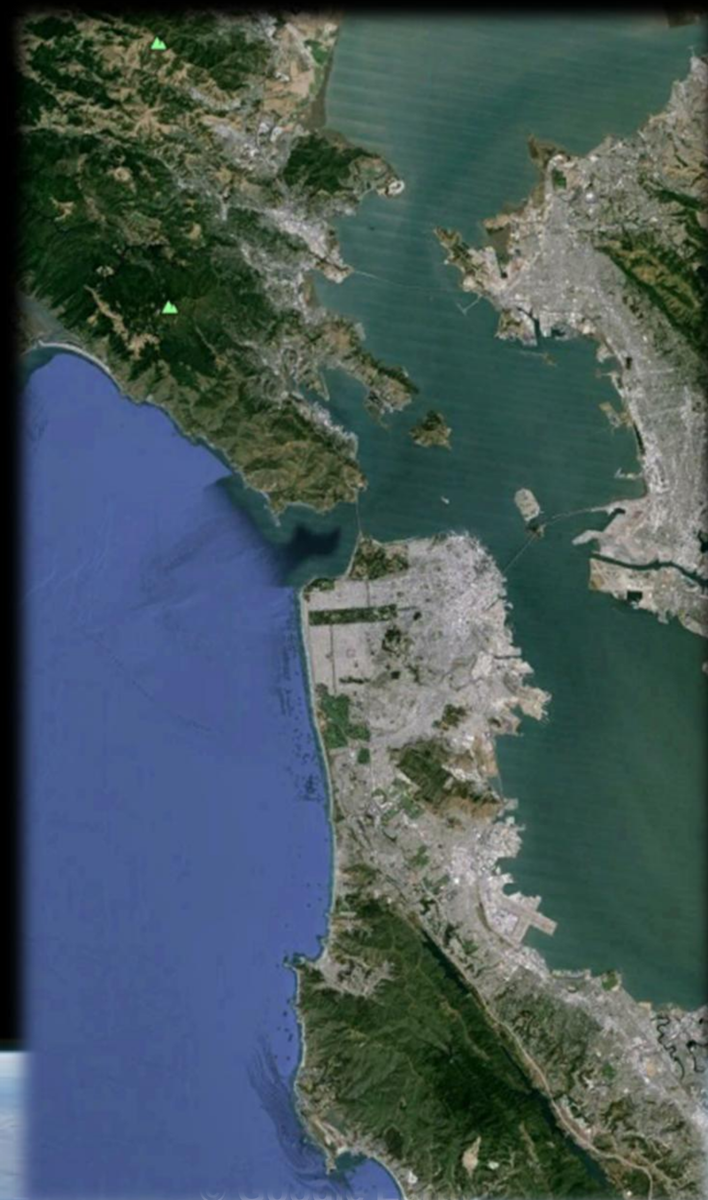
Space-borne Sensors

$|HH|_{dB}$

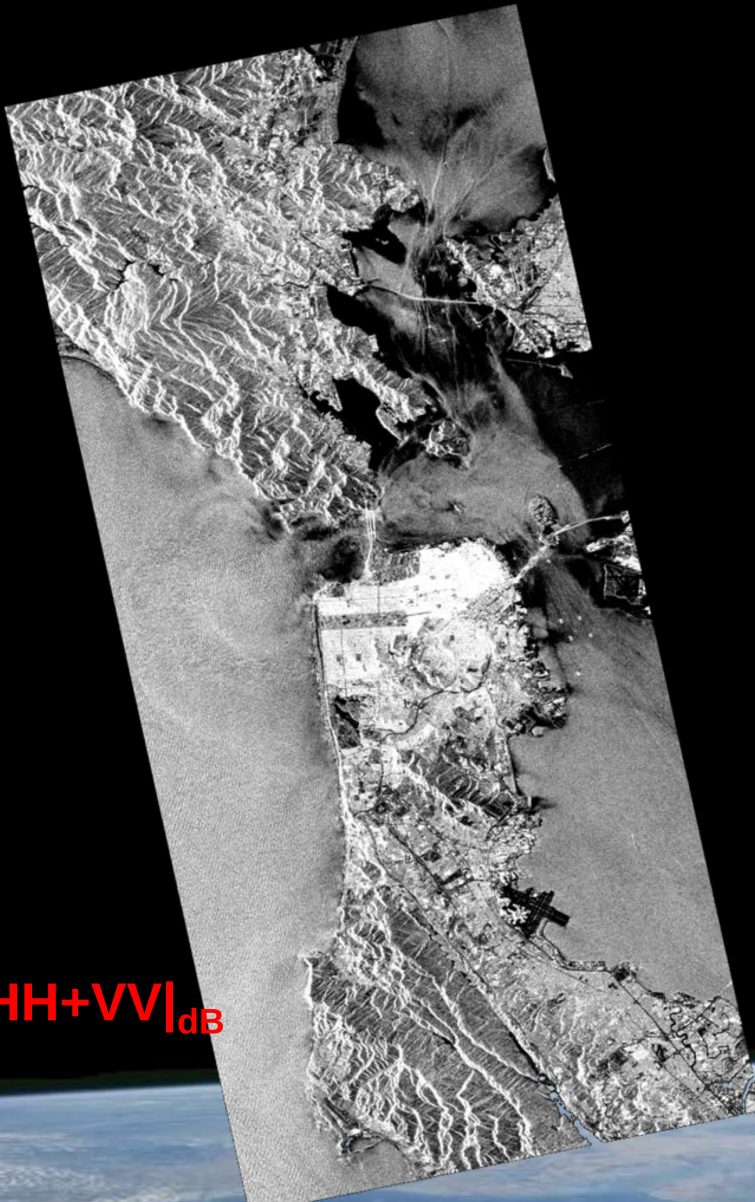
$|HV|_{dB}$

$|VV|_{dB}$

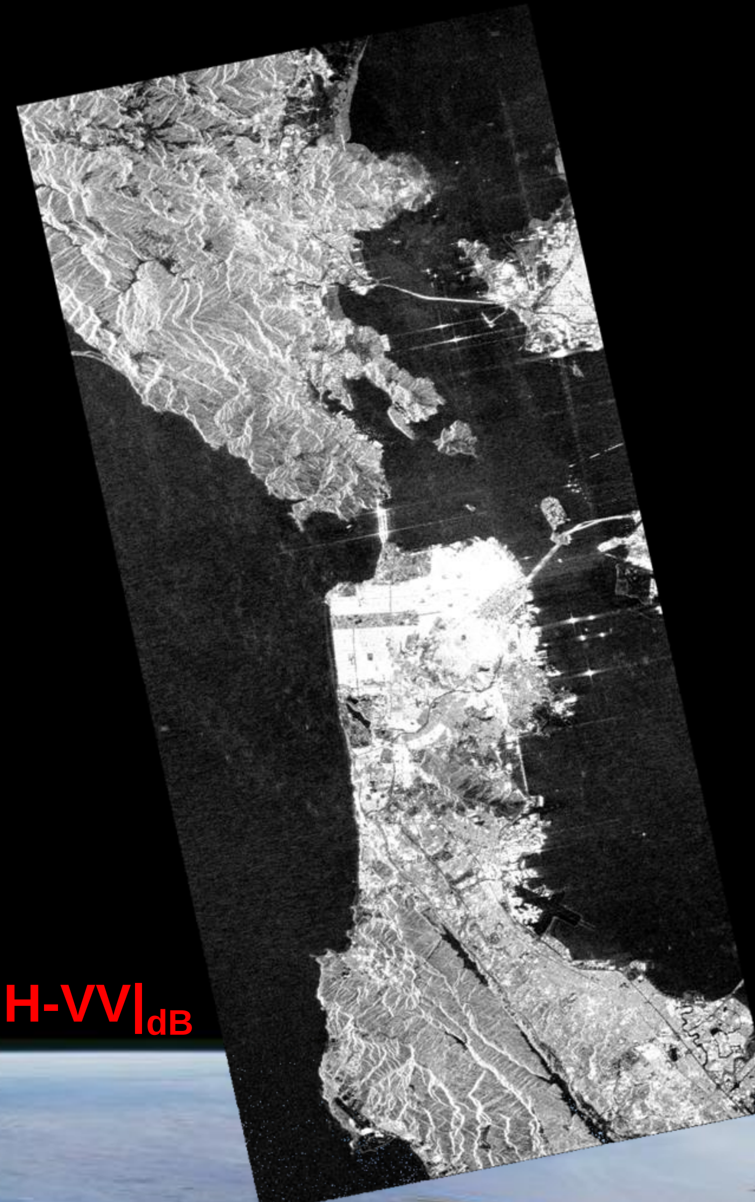


San Francisco Bay – (L-Band)

Space-borne Sensors



$|HH+VV|_{dB}$



$|HH-VV|_{dB}$

San Francisco Bay – (L-Band)

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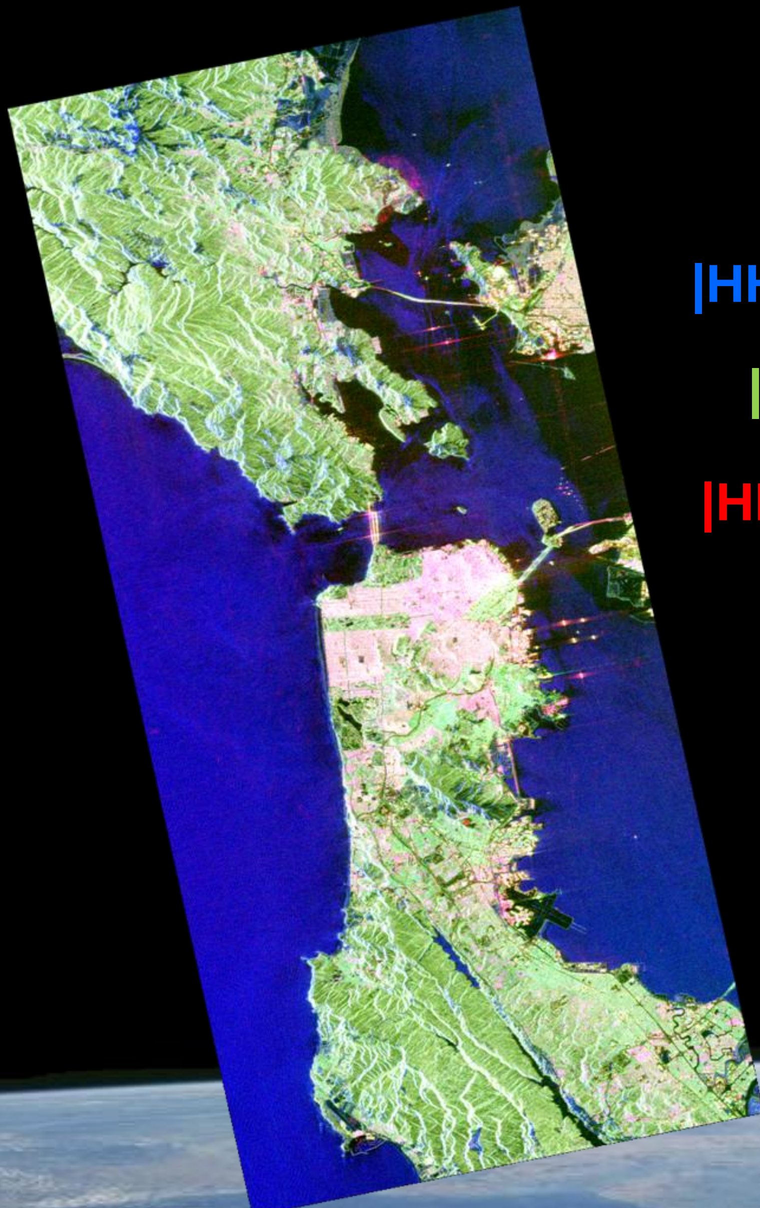
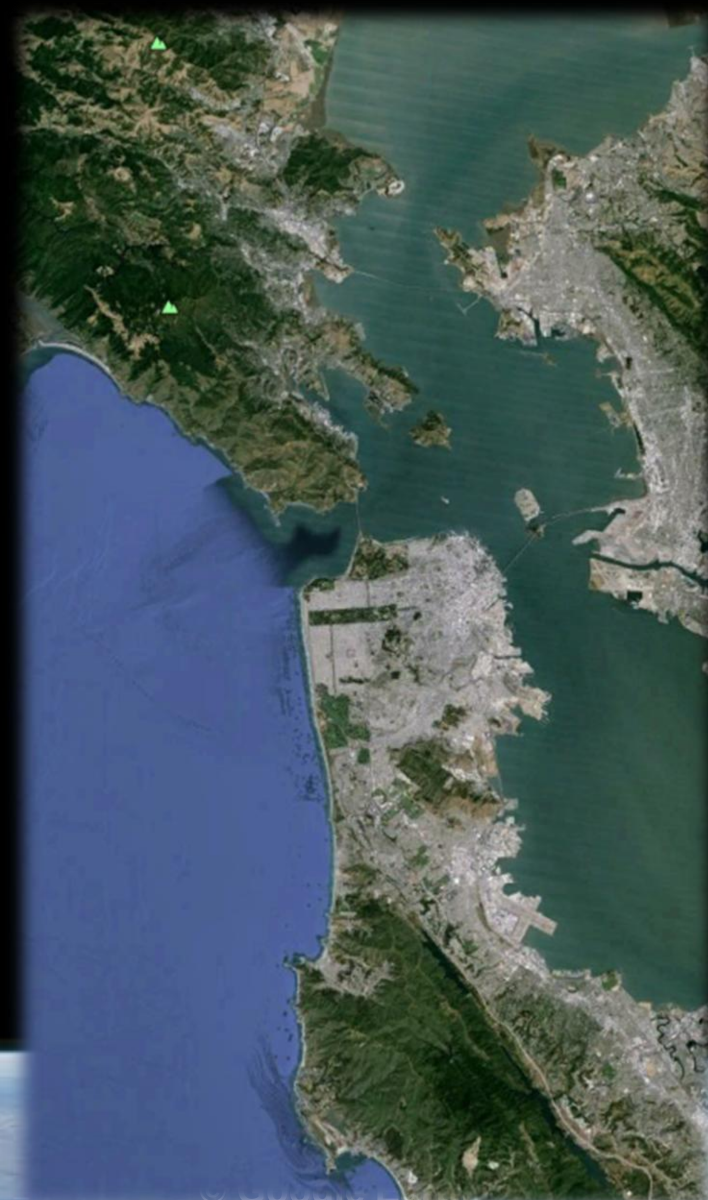
Space-borne Sensors



$|HH+VV|_{dB}$

$|HV|_{dB}$

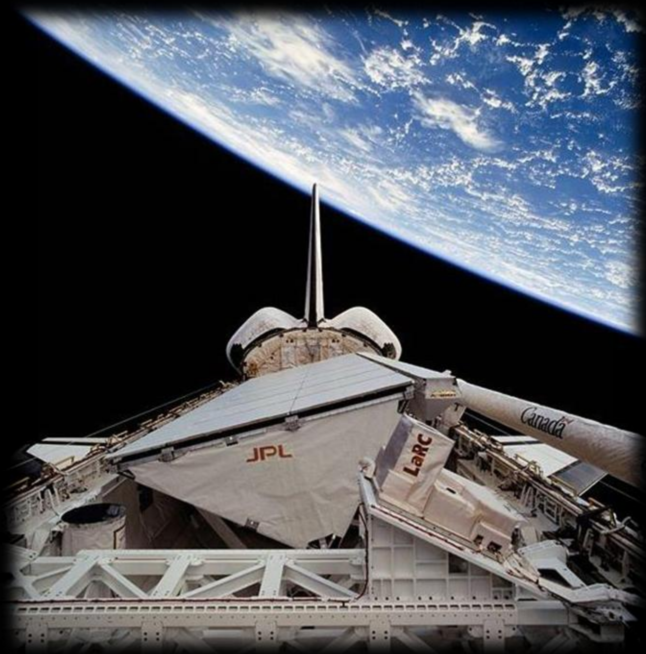
$|HH-VV|_{dB}$

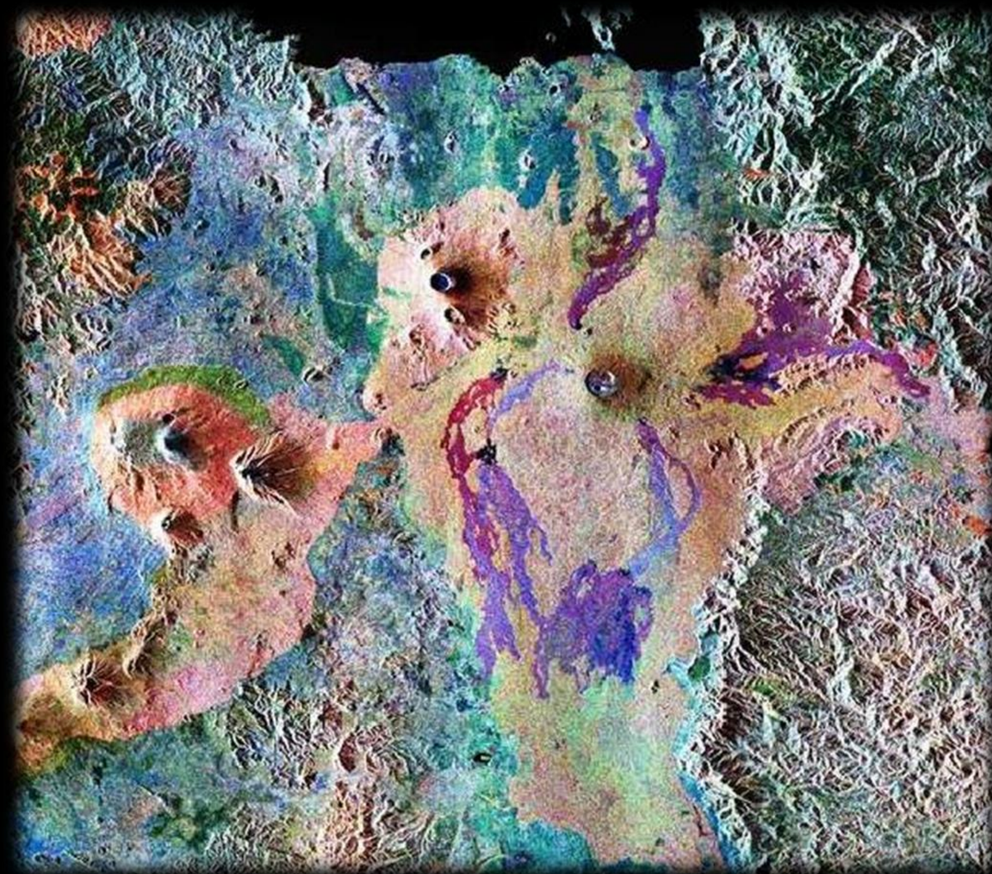


San Francisco Bay – (L-Band)

Space-borne PolSAR Sensors

SIR-C / X-SAR





April 1994

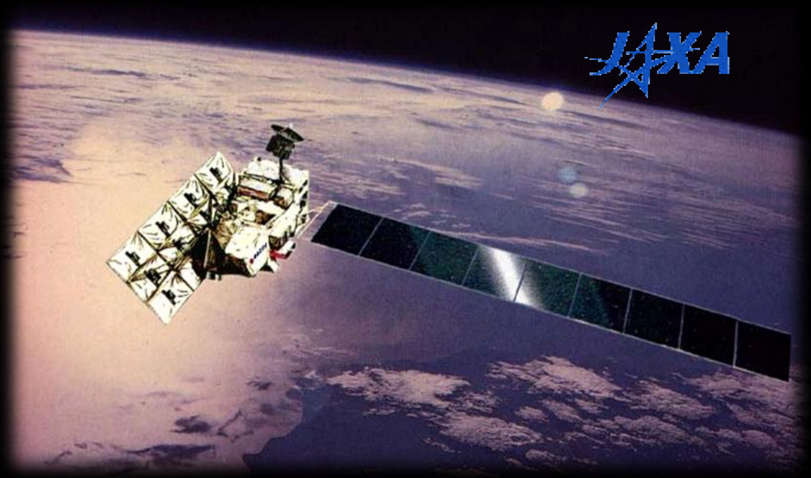
L- and C-Band (Quad)

X-Band (Sngl)

Rwanda, Zaire, Uganda

Space-borne PolSAR Sensors

ALOS - PALSAR



January 2006

L-Band (Sngl / Twin / Quad)

ALOS : Advanced Land Observing Satellite

PALSAR : Phase Array L-Band SAR

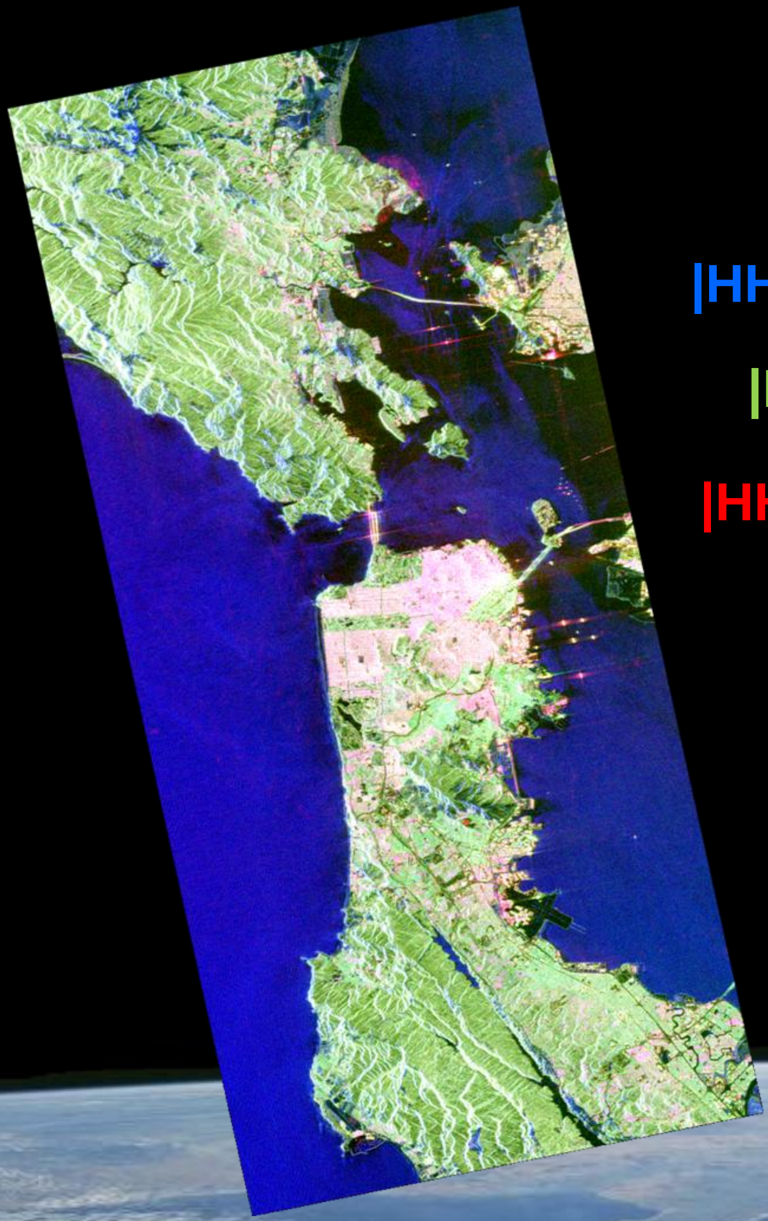
Space-borne PolSAR Sensors

RADARSAT - 2

December 2007

C-Band (Quad)

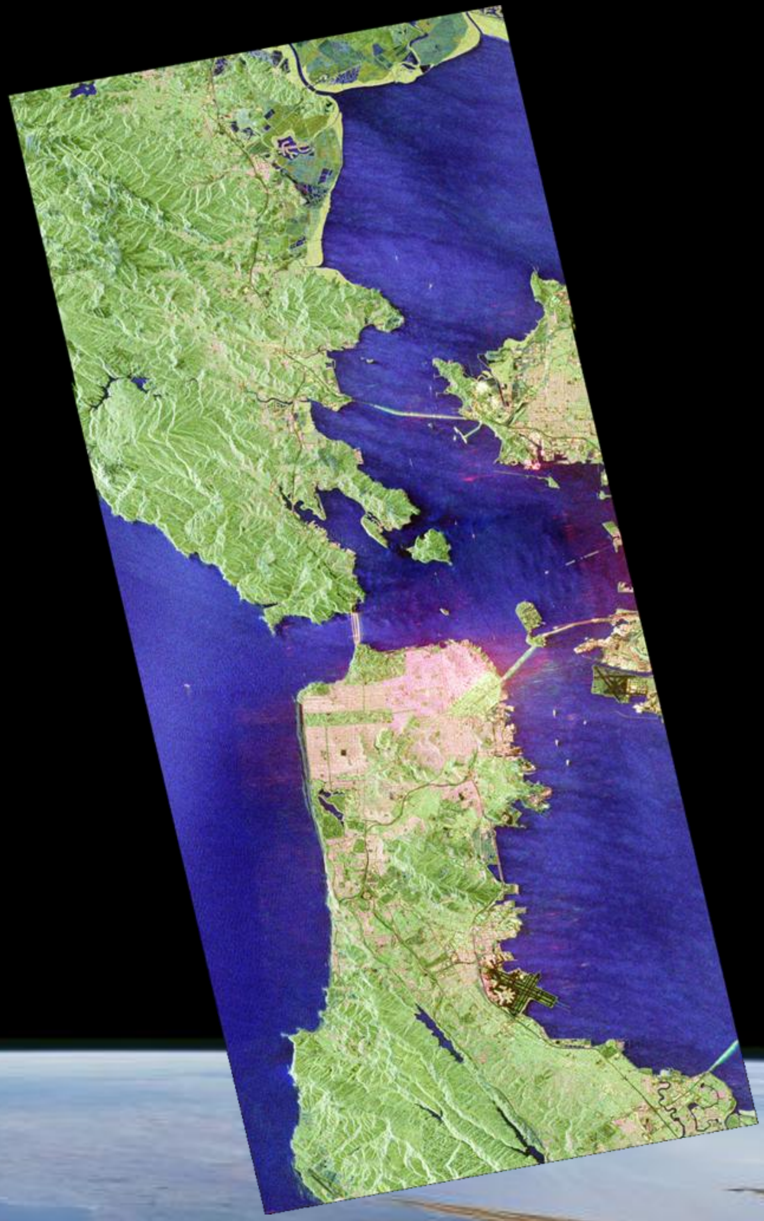
Space-borne Sensors



$|HH+VV|_{dB}$

$|HV|_{dB}$

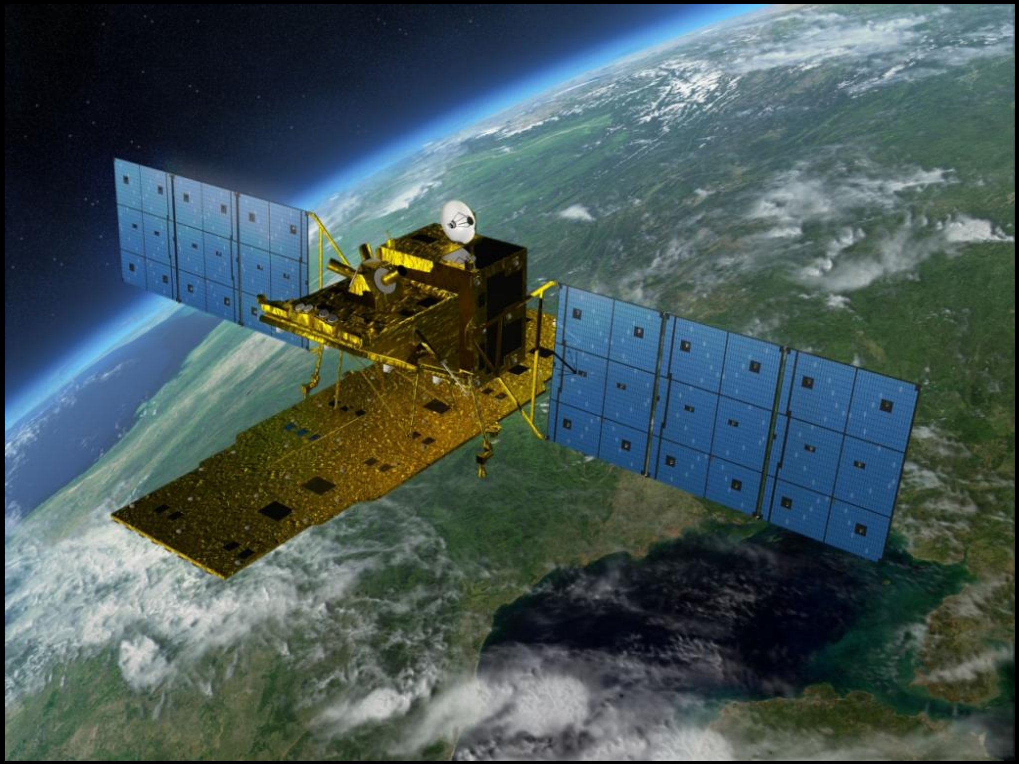
$|HH-VV|_{dB}$



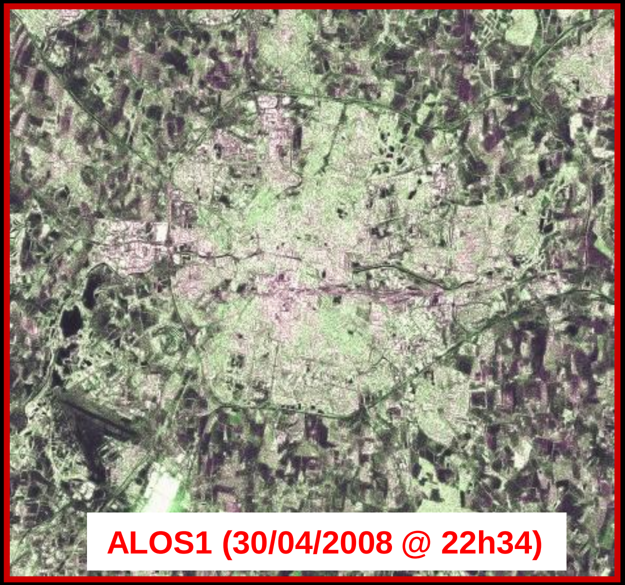
San Francisco Bay – (L-Band and C-Band)

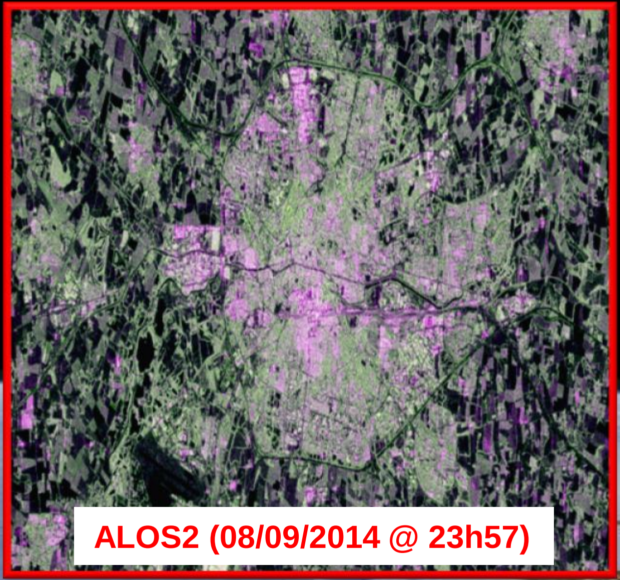
Space-borne PolSAR Sensors

ALOS - 2



May 2014
L-Band (Quad)





Space-borne PolSAR Sensors

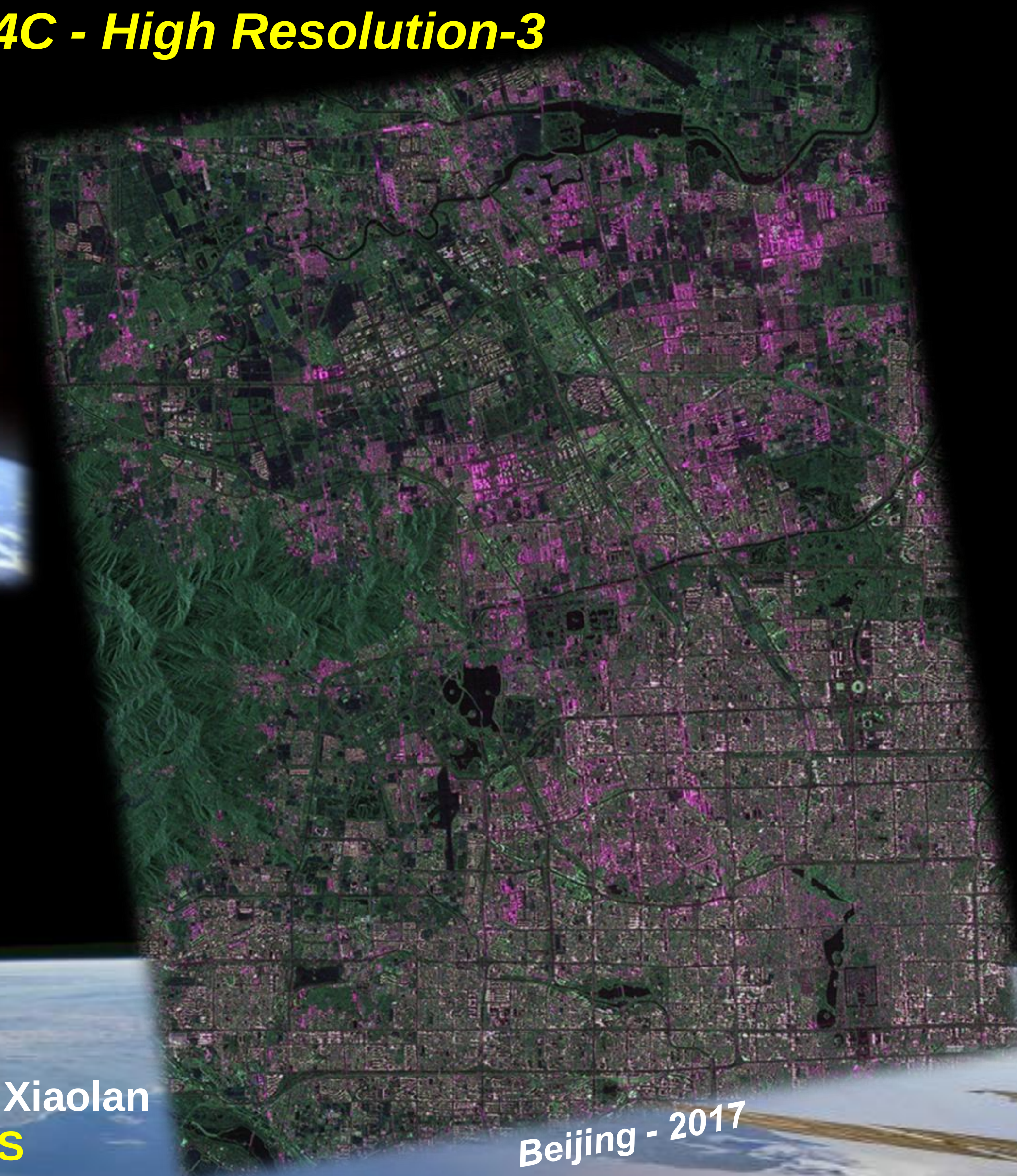
Chang Zheng-4C - GaoFen-3 (GF-3)

Long March-4C - High Resolution-3

August 2016

C-Band (Quad)

中国空间技术研究院
China Academy of Space Technology

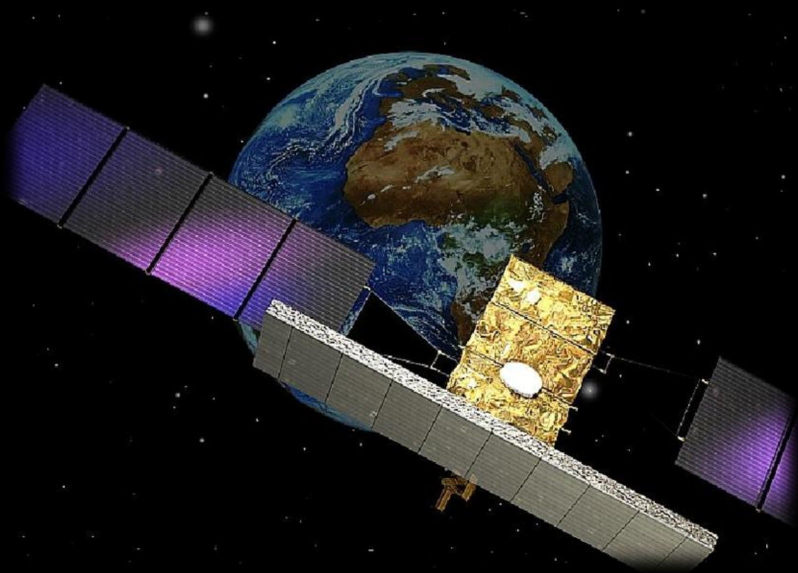


IECAS **Courtesy of Dr. Qiu Xiaolan**

IECAS / GIPAS

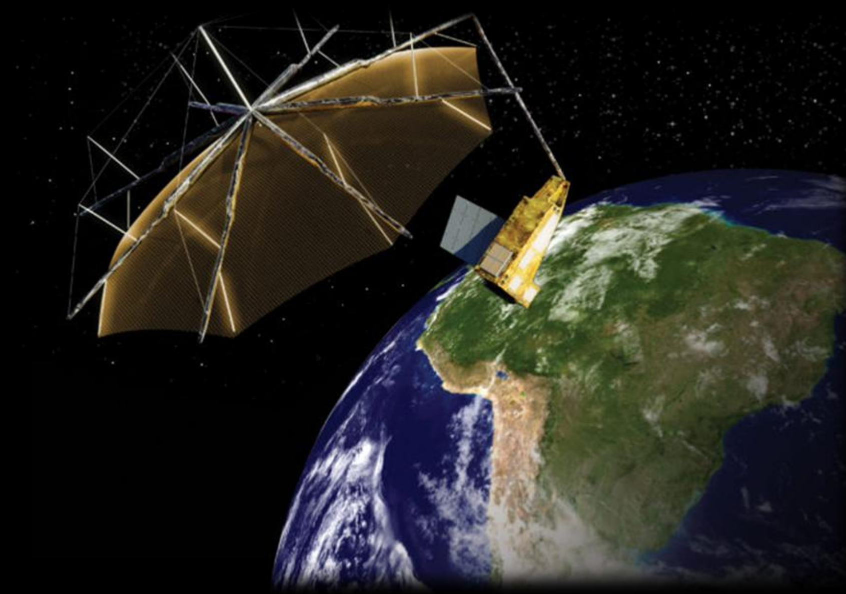
Space-borne PolSAR Sensors

COSMO - SkyMed - CSG



2A : 2018 2B : 2019
X-Band (Sngl / Dual / Quad Exp.)

Earth Explorer - BIOMASS



2021
P-Band (Quad)

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Space-borne PolSAR Sensors

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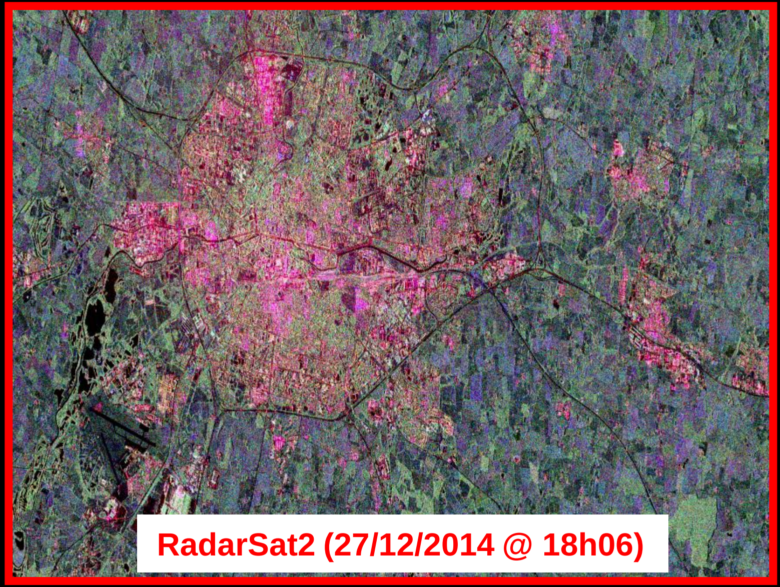
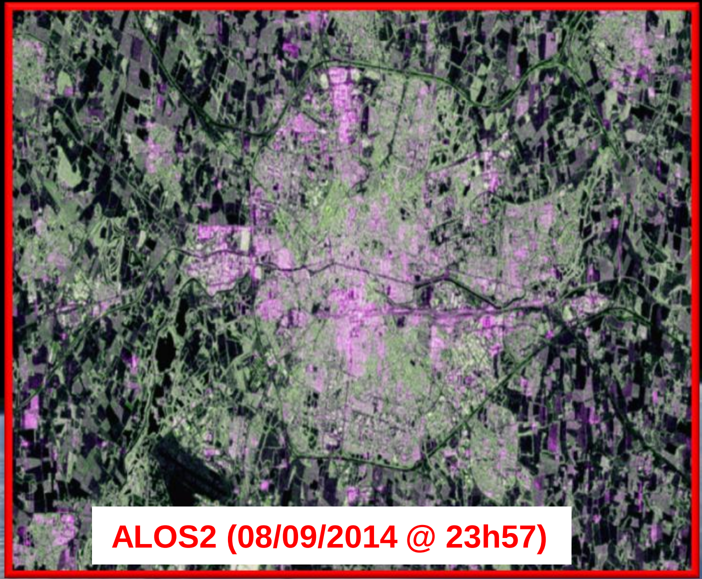
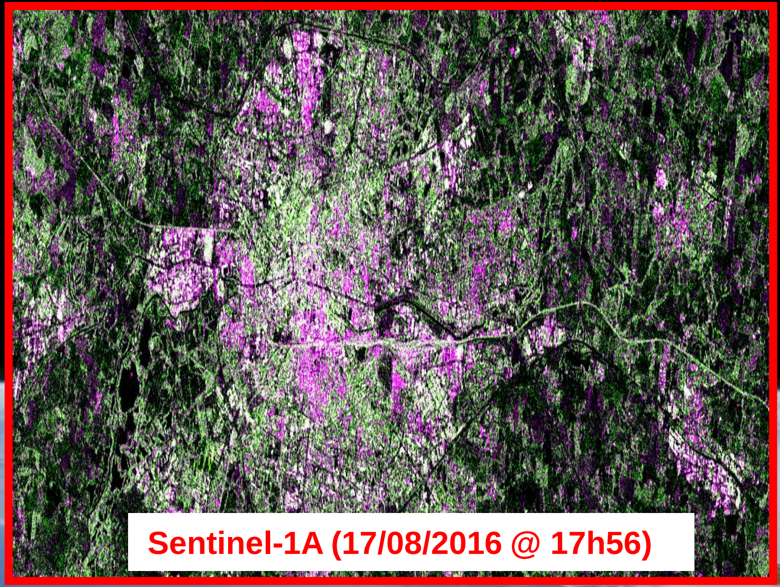
Space-borne PolSAR Sensors







Space-borne PolSAR Sensors

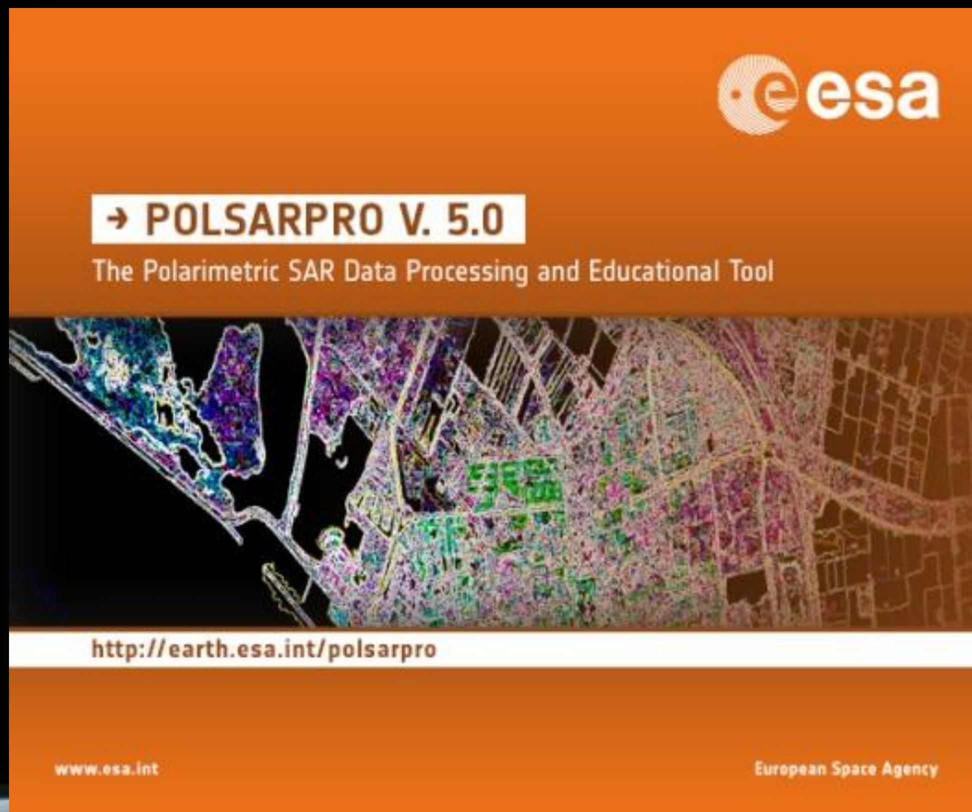
#E. Pottier (06/2017)

What About

Software / Toolbox ?

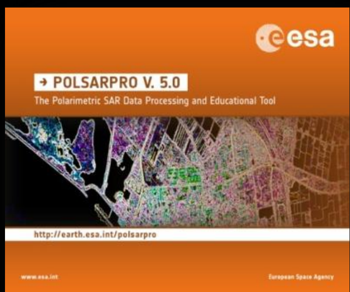
ESA PolSARpro Toolbox

The Polarimetric SAR Data Processing and Educational Toolbox



ESA PolSARpro Toolbox

Polarimetric SAR data processing and educational toolbox



ESA funded project since 2003

+ 3000 registered users / + 70 foreign countries

Toolbox specifically designed to handle : Pol-SAR, Pol-InSAR and Pol-TimeSAR data

Educational Software offering a tool for self-education in the field of Polarimetric SAR data processing and analysis

International collaborative project : space agencies (4), research centres (14) and universities (19).

Airborne sensors : AIRSAR, CONVAIR, ESAR, EMISAR, FSAR, PISAR, SATHI, UAVSAR.

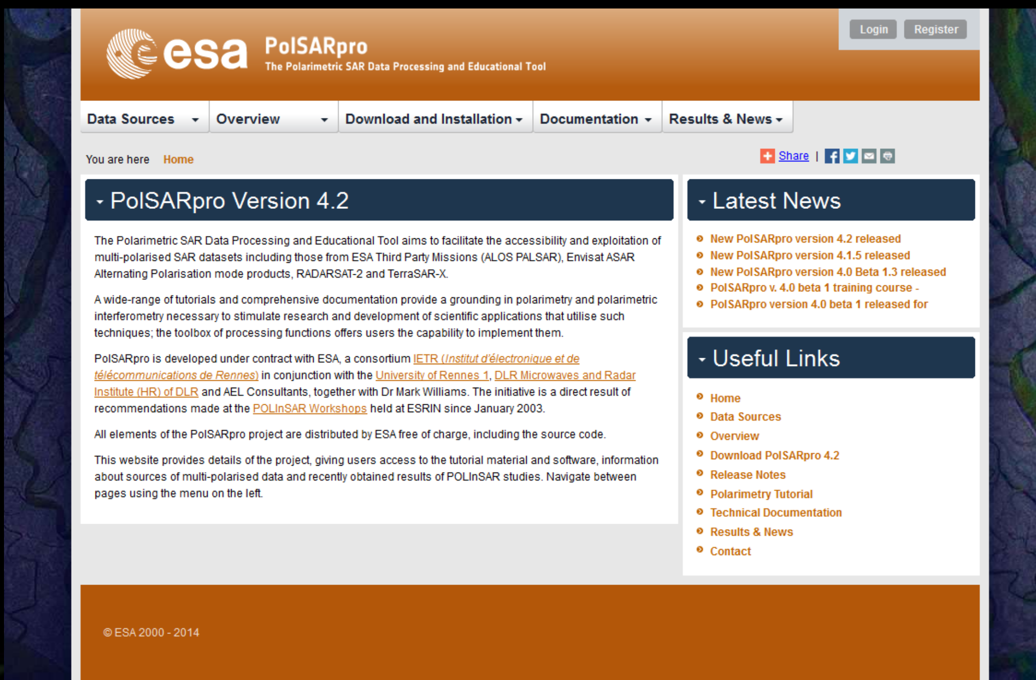
Spaceborne sensors : ALOS1, ALOS2, COSMO-Skymed, RADARSAT-2, RISAT, Sentinel 1A/B, TerraSAR-X, Tandem-X,

More than 550 different Pol-SAR, Pol-InSAR, Pol-TomSAR, Pol-TimeSAR functionalities.

ESA PolSARpro Toolbox

http://earth.esa.int/web/polsarpro

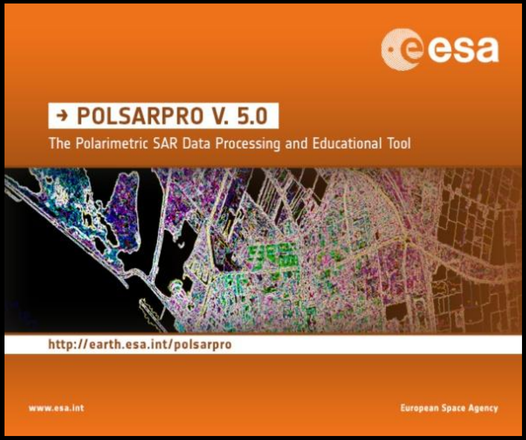
The Web Site provides

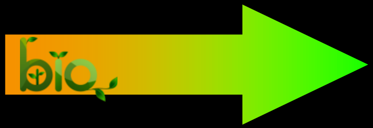


- **Details of the project**
- **Access to the tutorial and software**
- **Information about status of the development**
- **Demonstration Sample Datasets**

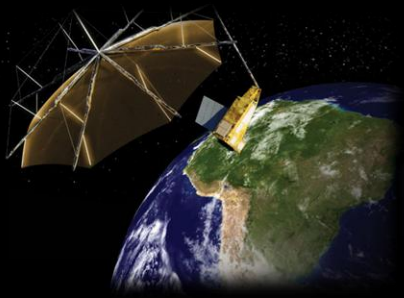
ESA PolSARpro Toolbox

ESA & third party fully polarimetric SAR missions (PolSARpro-Bio)



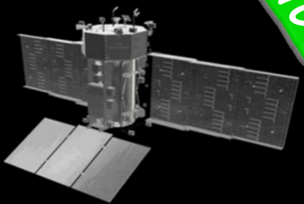


Future spaceborne sensors



BIOMASS

R.C.M

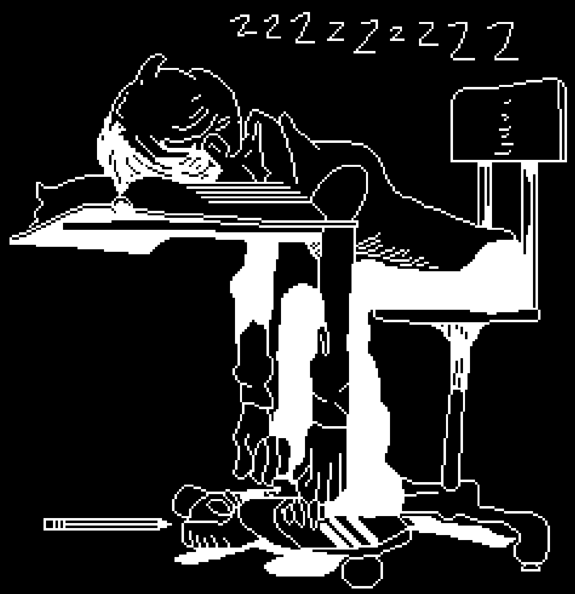


SAOCOM-CS

New functionalities : Pol-SAR, Pol-TomSAR and Pol-TimeSAR / Cloud-based infrastructure …

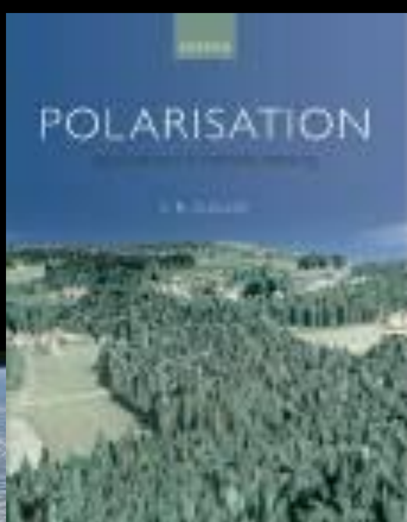
Learning / Training

Next P.I Generations



Books On Polarimetric Radar
SAR, Polarimetric Interferometry

Polarimetric Radar Imaging: From basics to applications
Jong-Sen LEE – Eric POTTIER
CRC Press; 1st ed., February 2009, pp 422
ISBN: 978-1420054972



Polarisation: Applications in Remote Sensing
Shane R. CLOUDE
Oxford University Press, October 2009, pp 352
ISBN: 978-0199569731

Books On Polarimetric Radar
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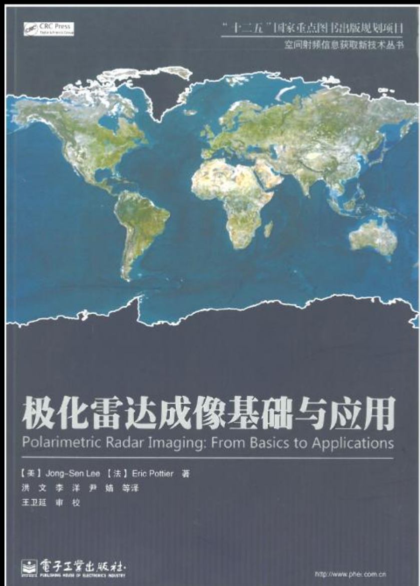

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Prof. Wen HONG, Dr. Qiang YIN et al.

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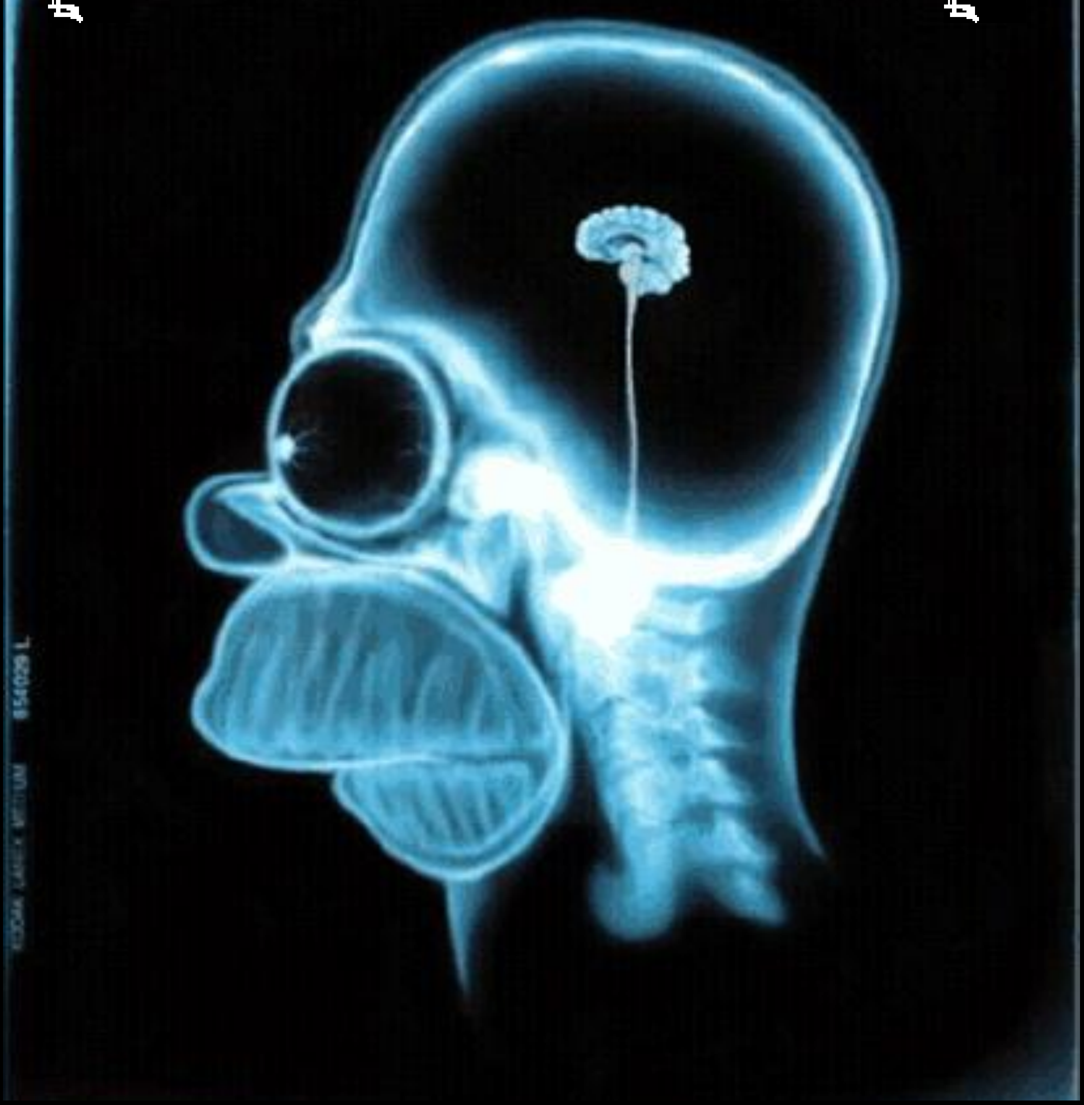
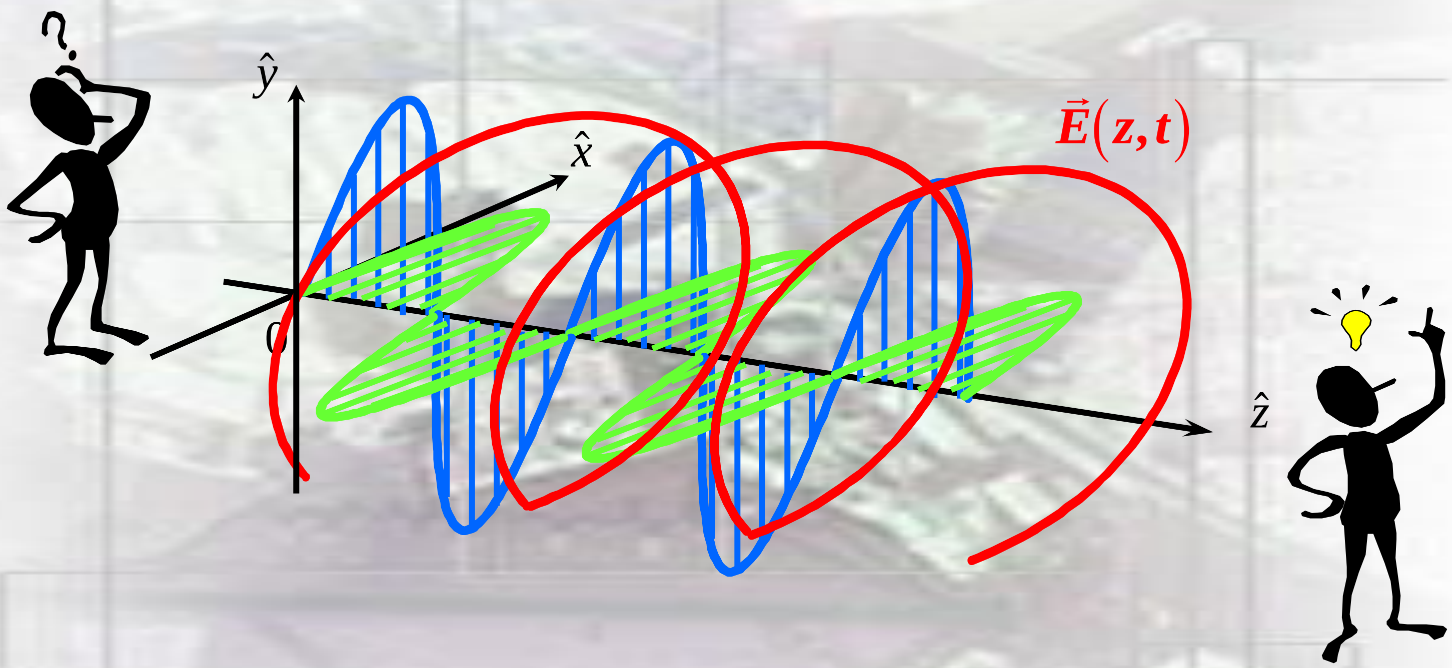
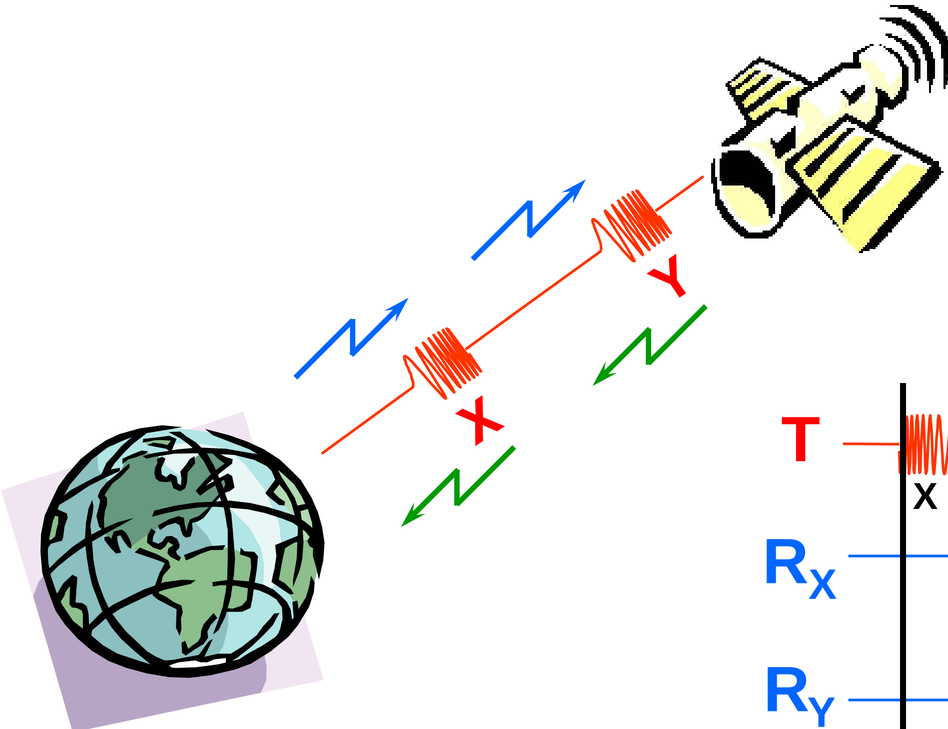
Questions ?

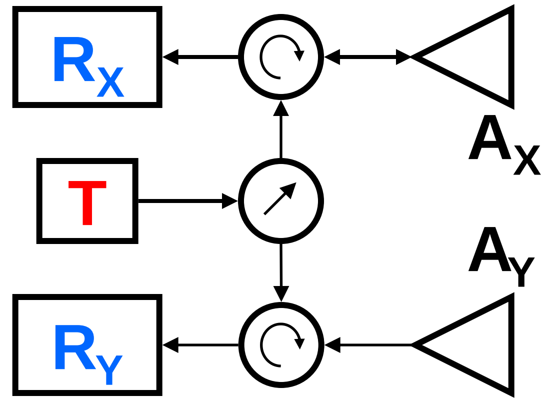


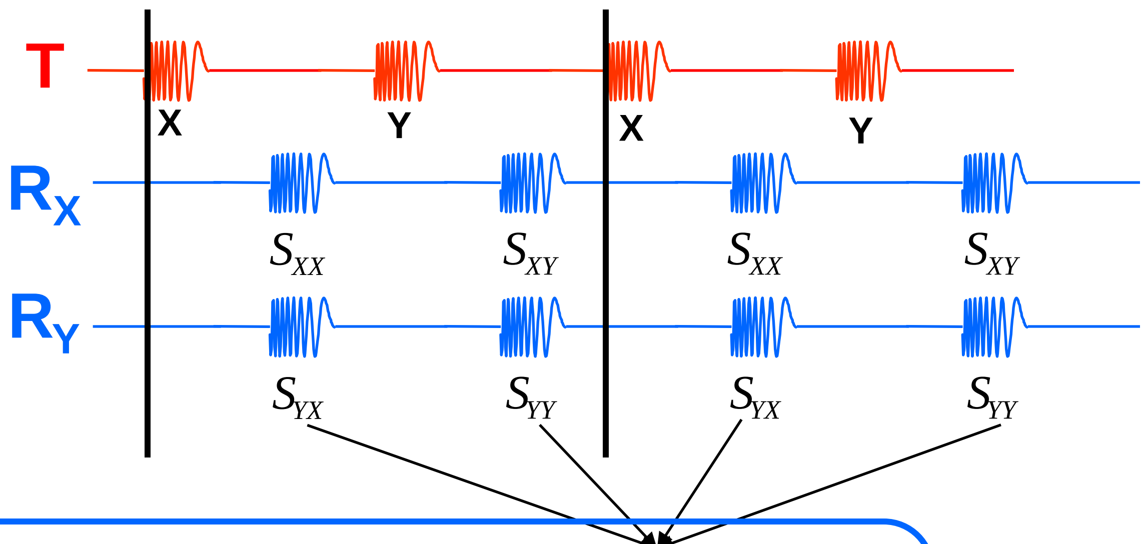


BASIC CONCEPTS

SCATTERING POLARIMETRY







TRANSMITTER: X & Y

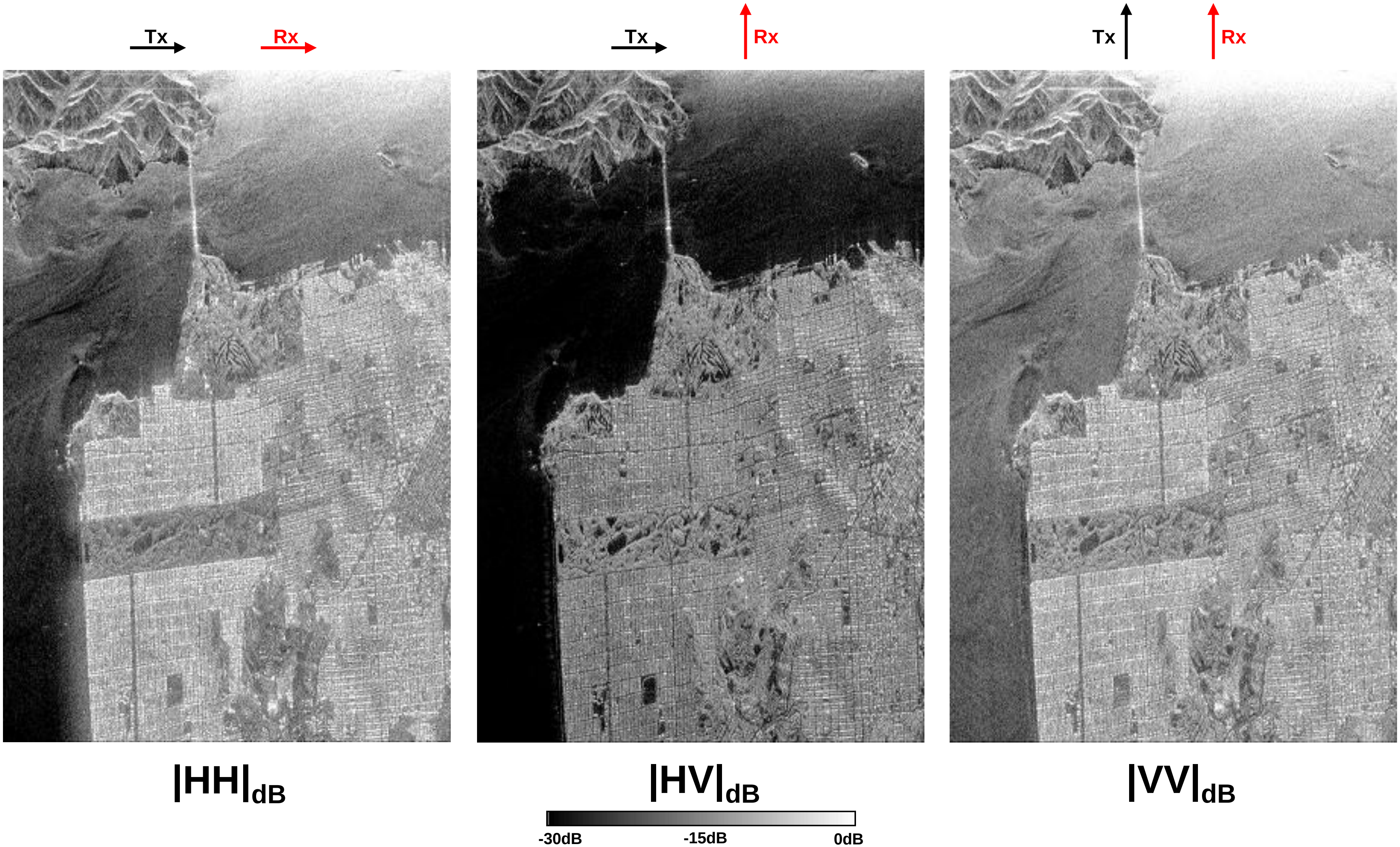
RECEIVERS: X & Y

SINCLAIR MATRICES

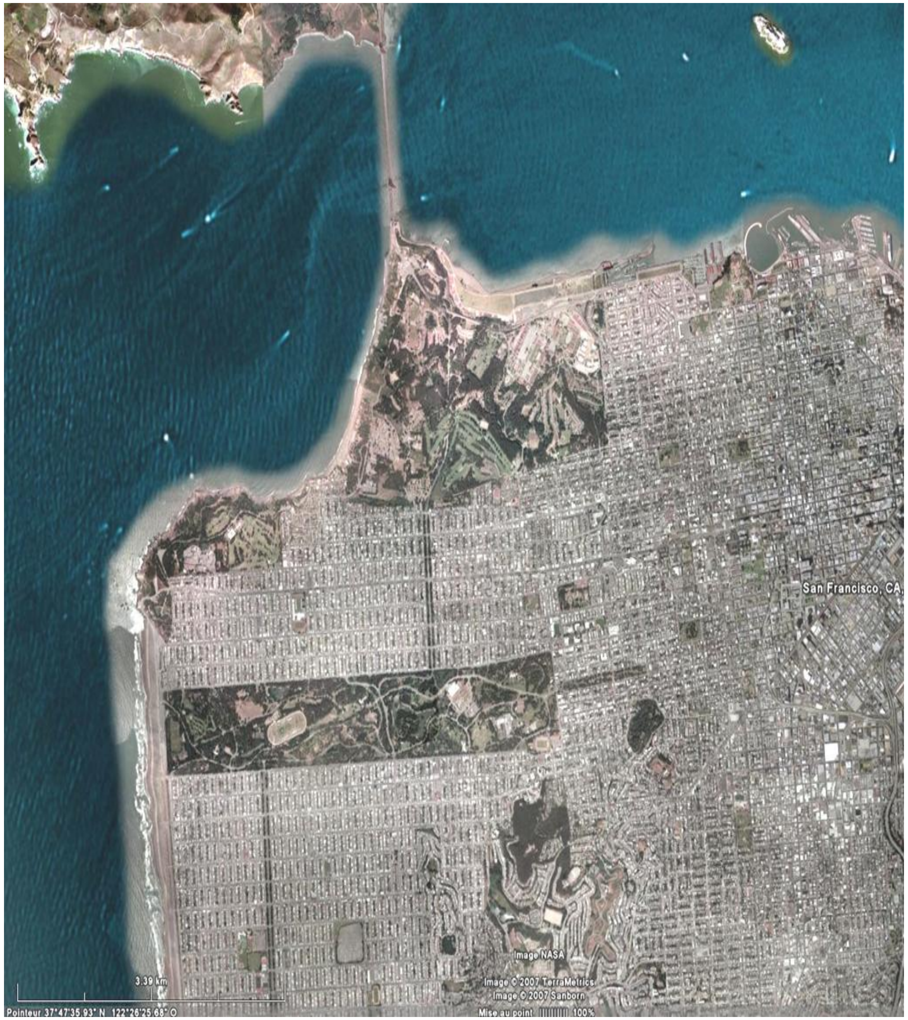
$$\left\{[S]=\begin{bmatrix} S_{XX} & S_{XY} \\ S_{YX} & S_{YY} \end{bmatrix}\right\}$$

SCATTERING POLARIMETRY

SCATTERING POLARIMETRY



SCATTERING POLARIMETRY

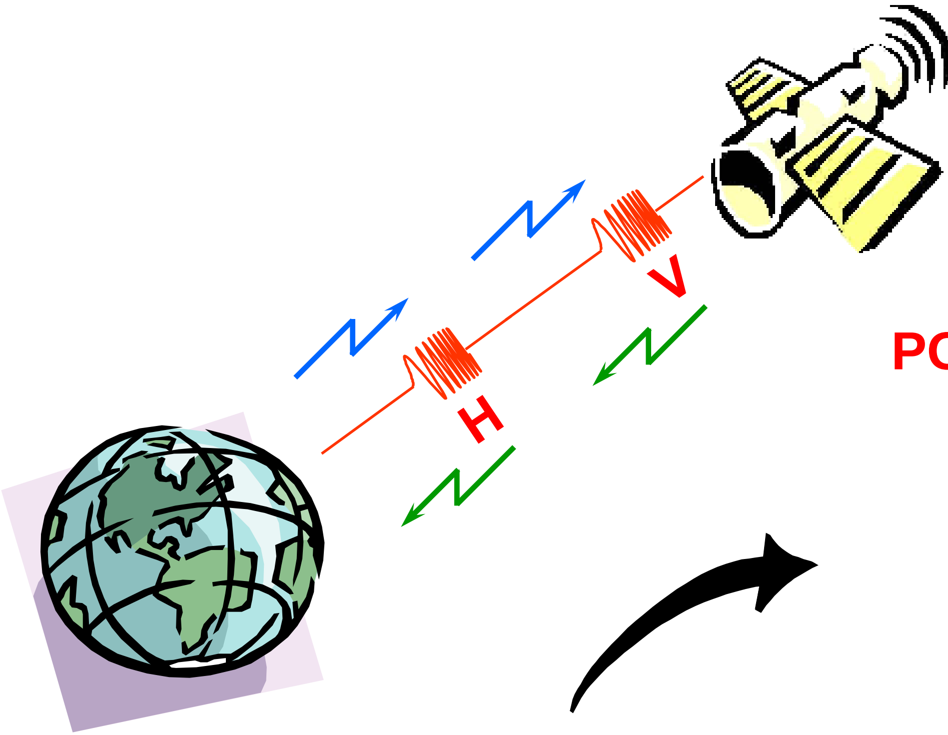


© Google Earth

Sinclair Color Coding

|HH| |HV| |VV|

SINCLAIR MATRIX



TRANSMITTER: H & V
RECEIVERS: H & V

POLARIMETRIC DESCRIPTORS

[S] SINCLAIR Matrix

$$[S] = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix}$$

$\underline{k}$ Target Vector

[T] 3x3 COHERENCY Matrix

COHERENCY MATRIX

TARGET VECTOR *k*

$$\underline{k} = \frac{1}{\sqrt{2}}\left[S_{HH}+S_{VV} \quad S_{HH}-S_{VV} \quad 2S_{HV}\right]^{T}$$

↓

COHERENCY MATRIX [*T*]

$$\left[T\right] = \underline{k}\cdot\underline{k}^{*T} = \begin{bmatrix} 2A_0 & C-jD & H+jG \\ C+jD & B_0+B & E+jF \\ H-jG & E-jF & B_0-B \end{bmatrix}$$

HERMITIAN MATRIX - RANK 1

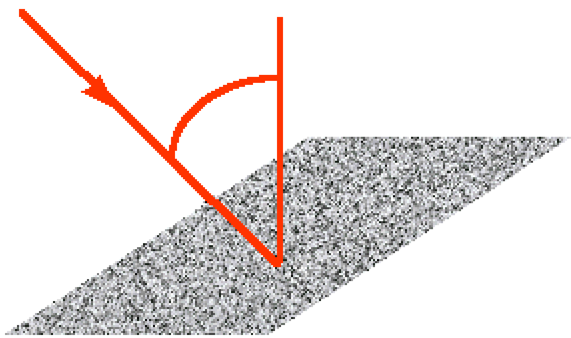
A0, B0+B, B0-B : HUYNEN TARGET GENERATORS

↓

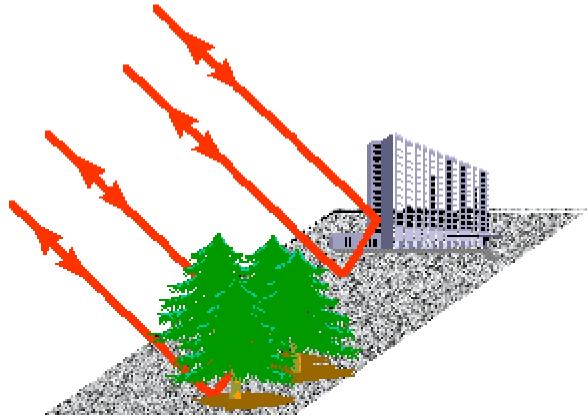
[*T*] is closer related to Physical and Geometrical Properties of the Scattering Process, and thus allows a better and direct physical interpretation

PHYSICAL INTERPRETATION

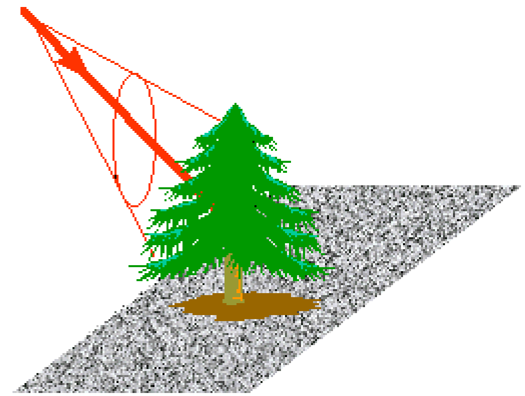
SINGLE BOUNCE SCATTERING
(ROUGH SURFACE)



DOUBLE BOUNCE SCATTERING



VOLUME SCATTERING

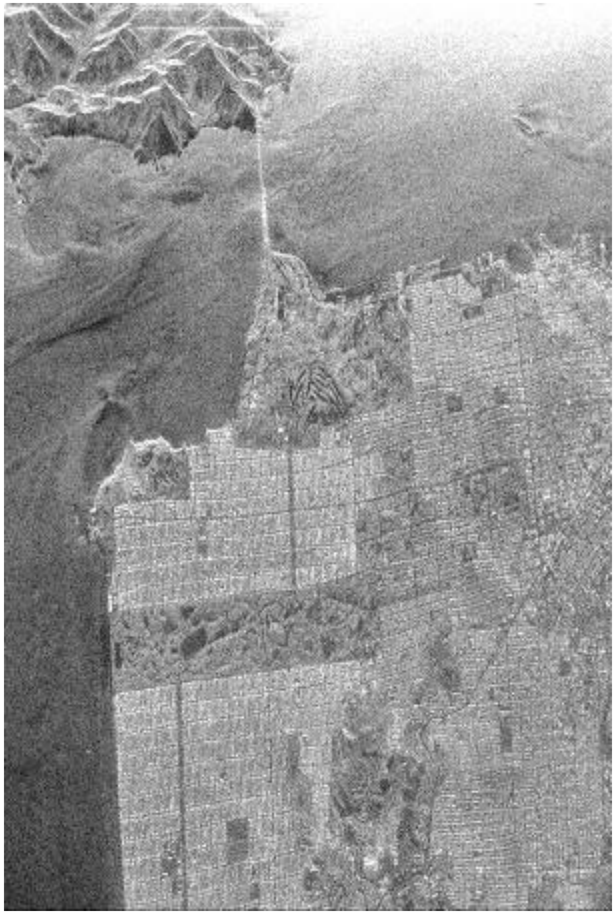


$$T_{11} = 2A_0 = \left|S_{XX} + S_{YY}\right|^2$$

$$T_{33} = B_0 - B = 2\left|S_{XY}\right|^2$$

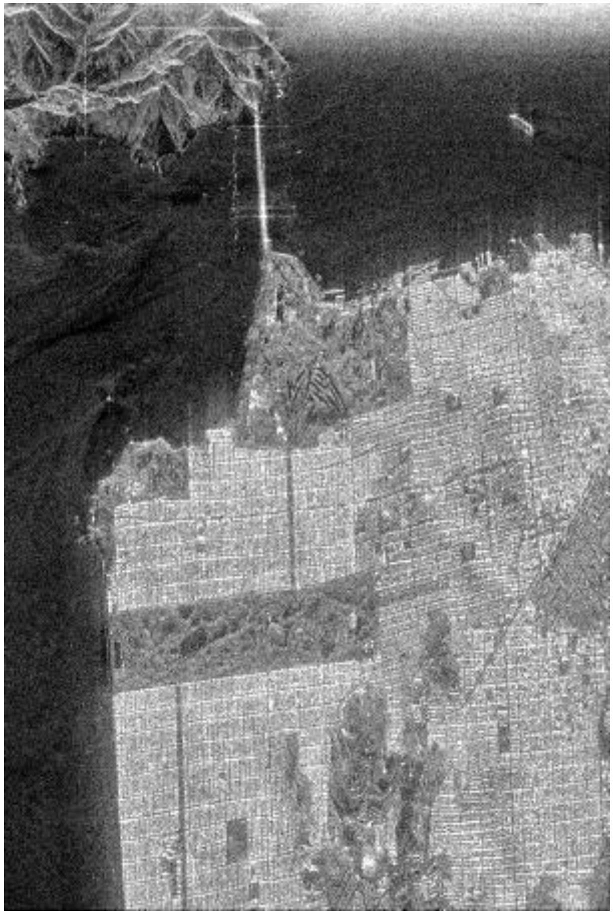
$$T_{22} = B_0 + B = \left|S_{XX} - S_{YY}\right|^2$$

TARGET GENERATORS



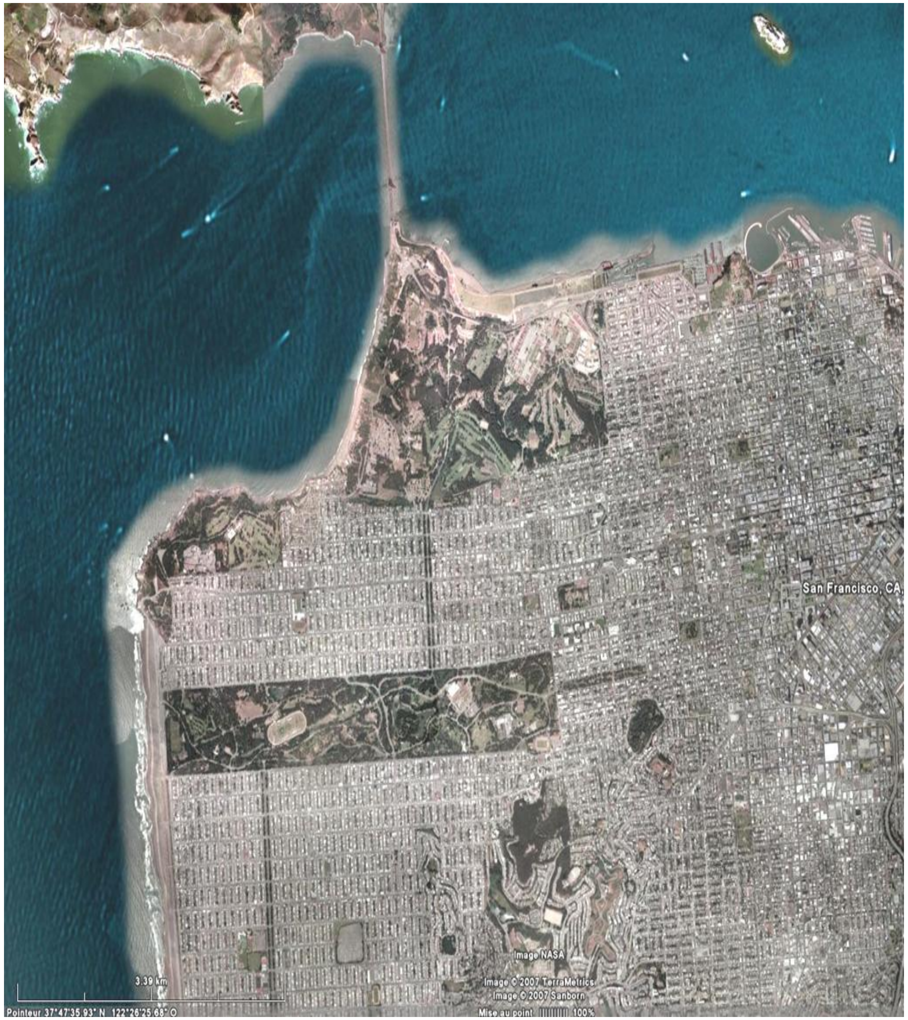
$|HH+VV|_{dB}$

$|HV|_{dB}$



$|HH-VV|_{dB}$

TARGET GENERATORS



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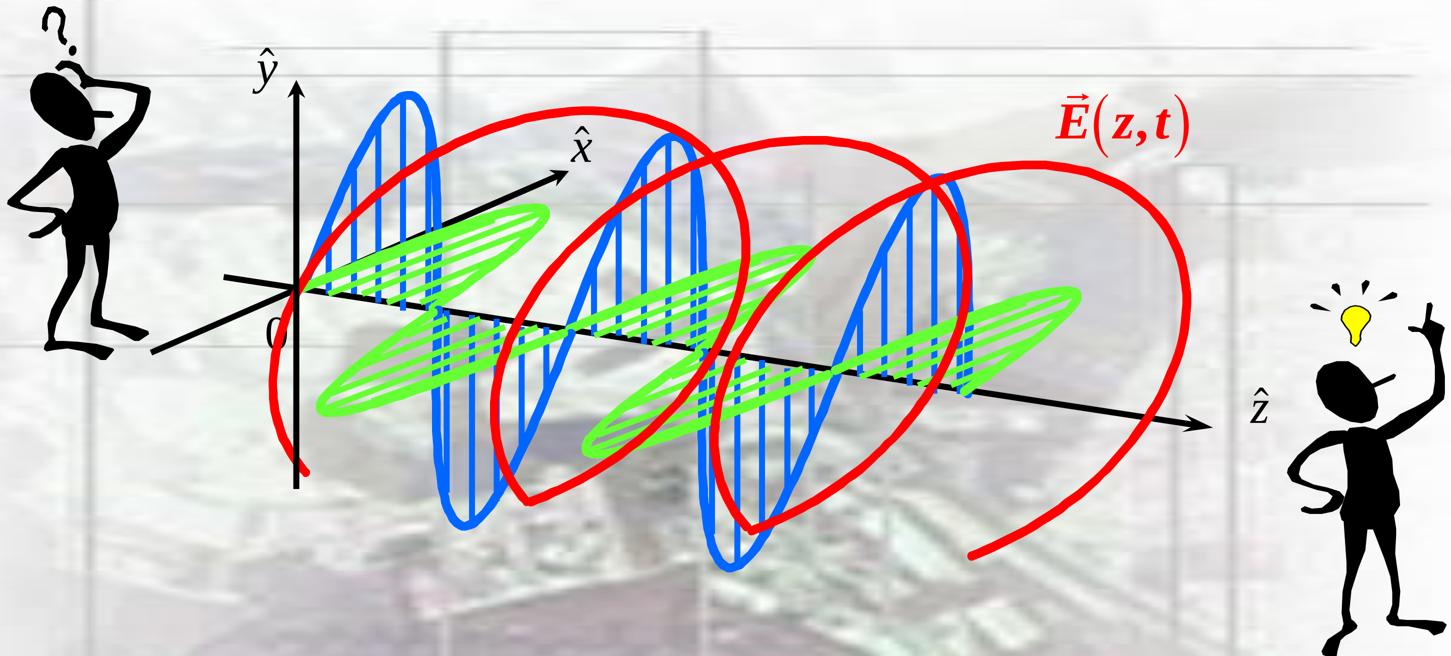
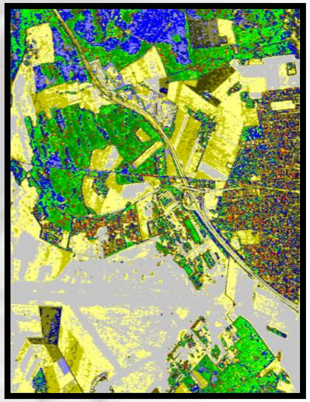
(H,V) POLARISATION BASIS

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



POLARIMETRIC REMOTE SENSING

POL-SAR PROCESSING
PHENOMENOLOGIC
QUALITATIVE ANALYSIS



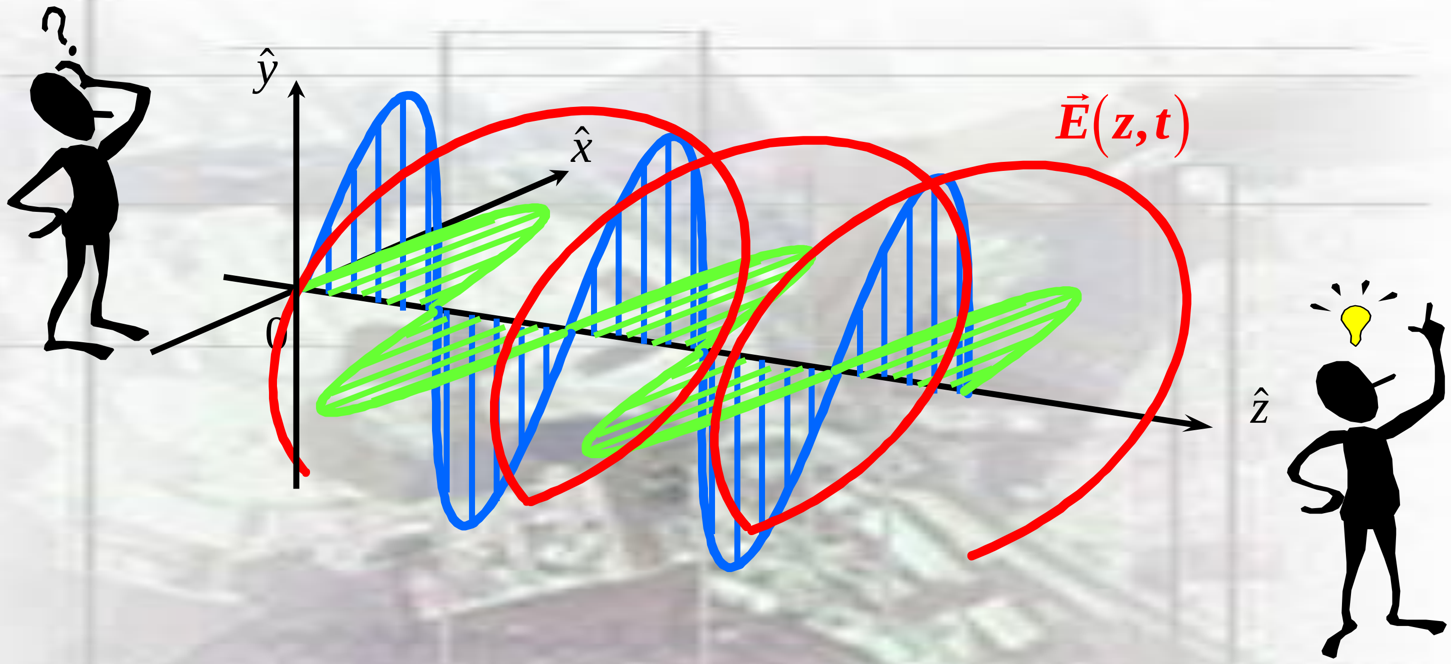
POLARIMETRIC SPECKLE FILTERING

→

POLARIMETRIC TARGET DECOMPOSITION

→

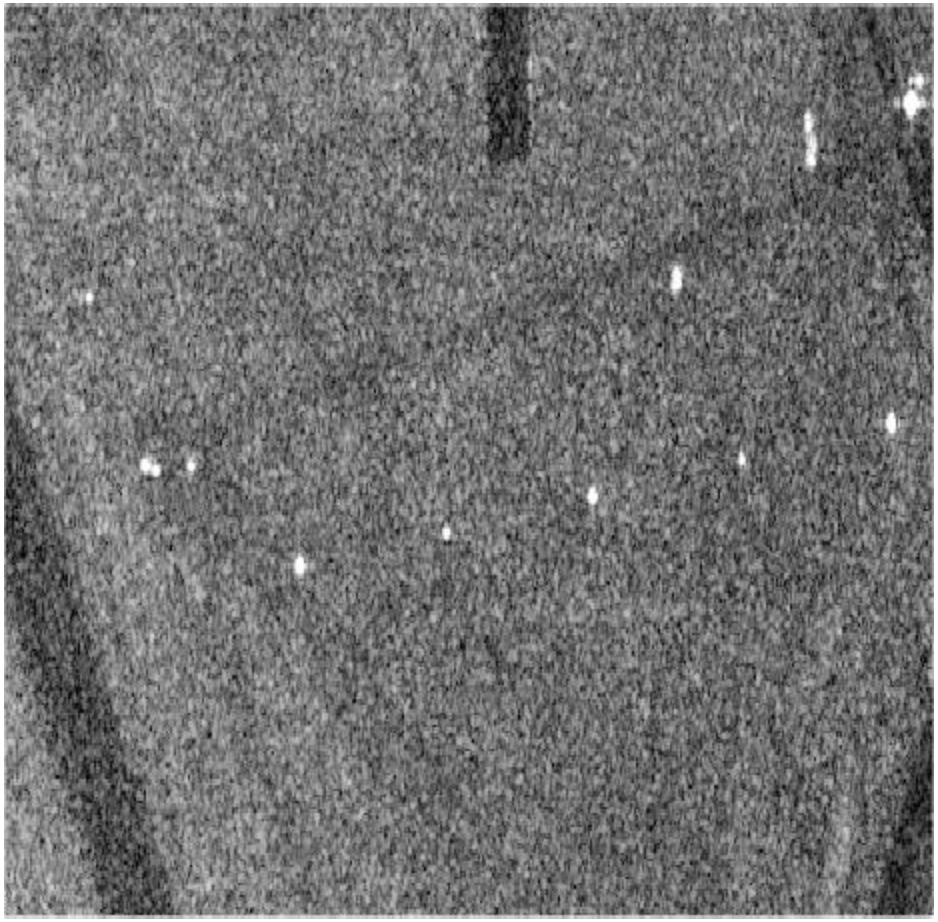
POLARIMETRIC CLASSIFICATION
MONO/DUAL CHANNELS



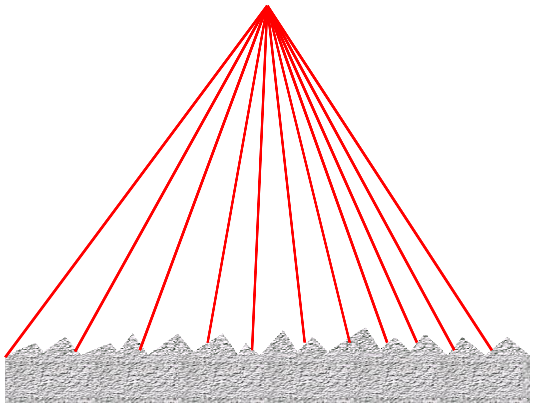
POLARIMETRIC SPECKLE FILTERING

An Introduction

SPECKLE PHENOMENON



OBSERVATION POINT



SURFACE ROUGHNESS
WAVELENGTH

SCATTERING FROM DISTRIBUTED SCATTERERS

↓

COHERENT INTERFERENCES OF WAVES SCATTERED FROM MANY RANDOMLY DISTRIBUTED ELEMENTARY SCATTERERS INSIDE THE RESOLUTION CELL

↓

GRANULAR NOISE

↓

SPECKLE PHENOMENON

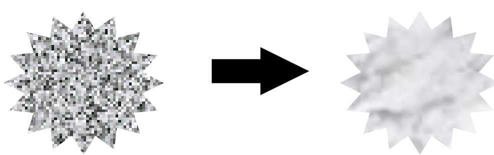
SPECKLE PHENOMENON

↓

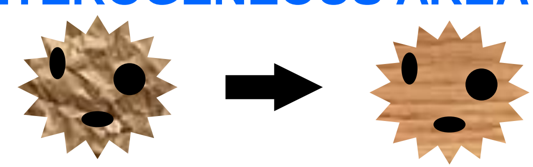
DISTORTION OF THE INTERPRETATION

SPECKLE FILTERING

HOMOGENEOUS AREA

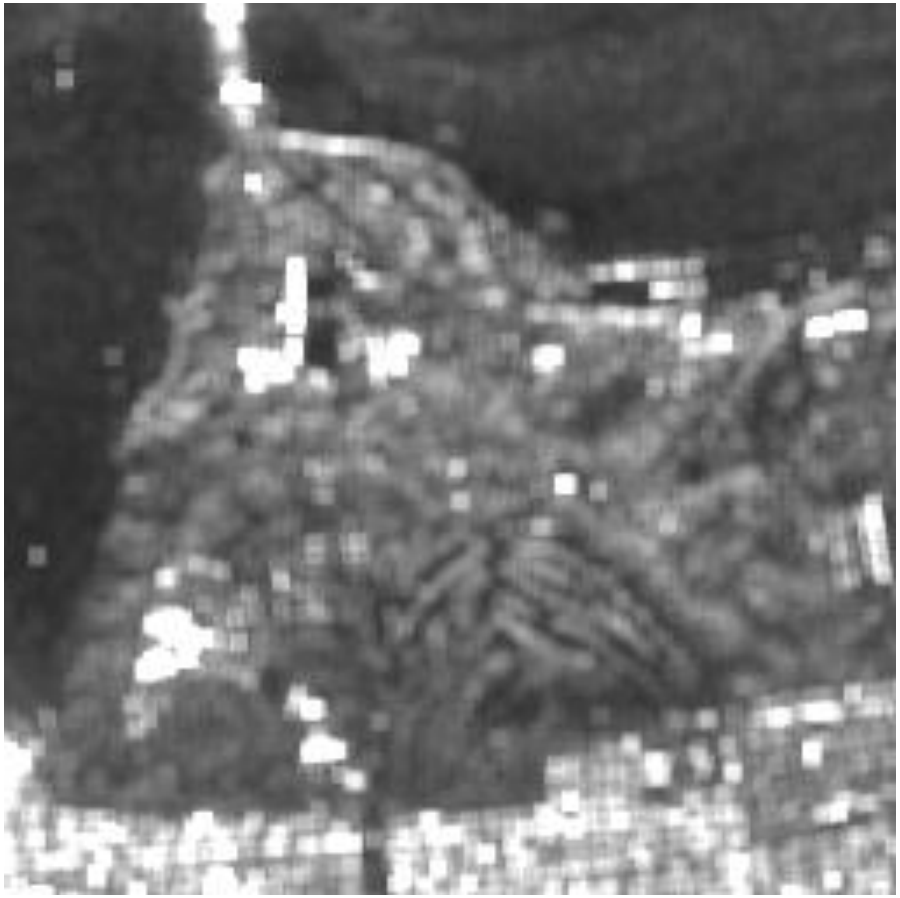


HETEROGENEOUS AREA



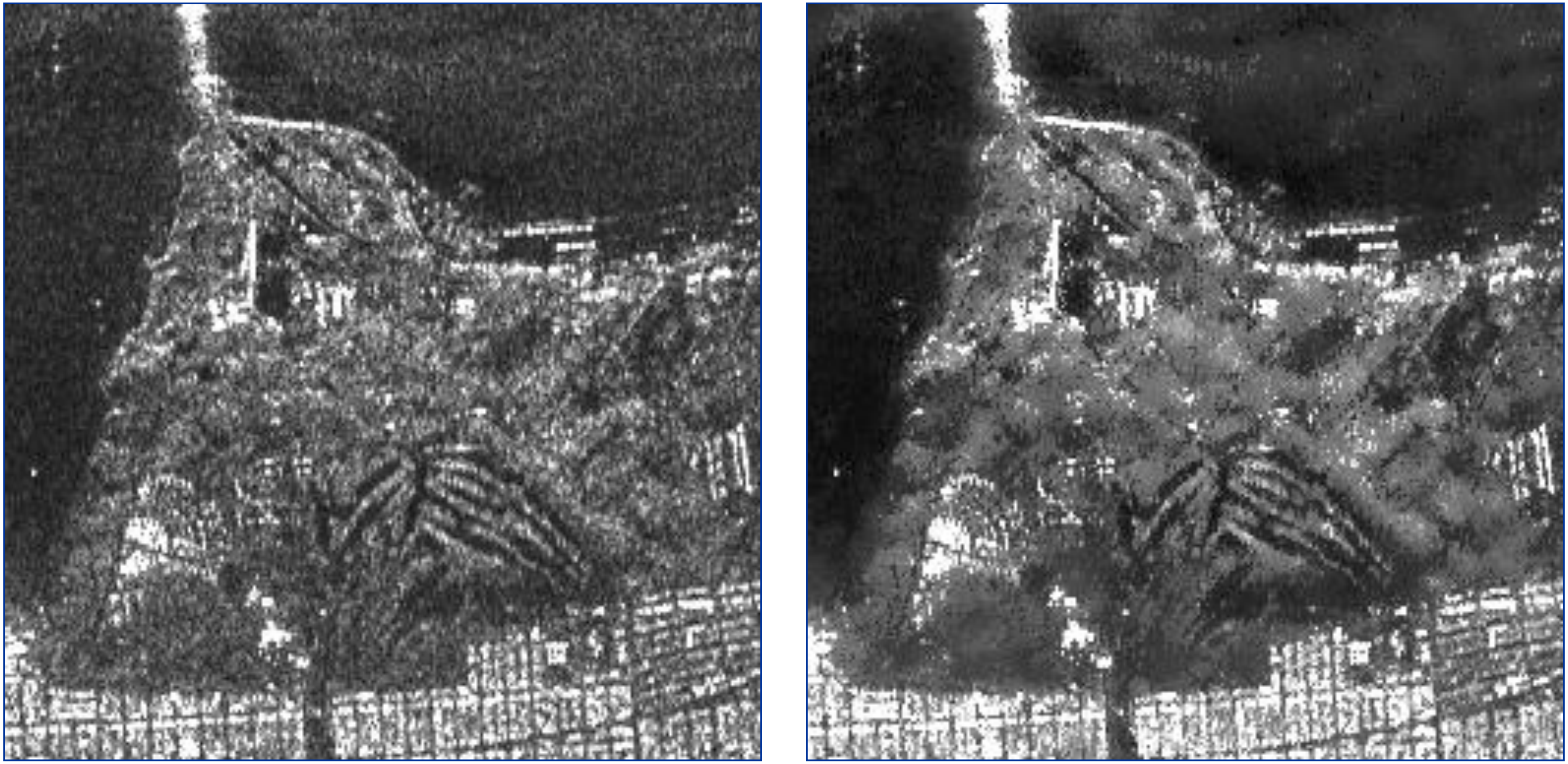
SPECKLE REDUCTION
(RADIOMETRIC RESOLUTION)

DETAILS PRESERVATION
(SPATIAL RESOLUTION)



SAN FRANCISCO BAY JPL - AIRSAR L-band 1988

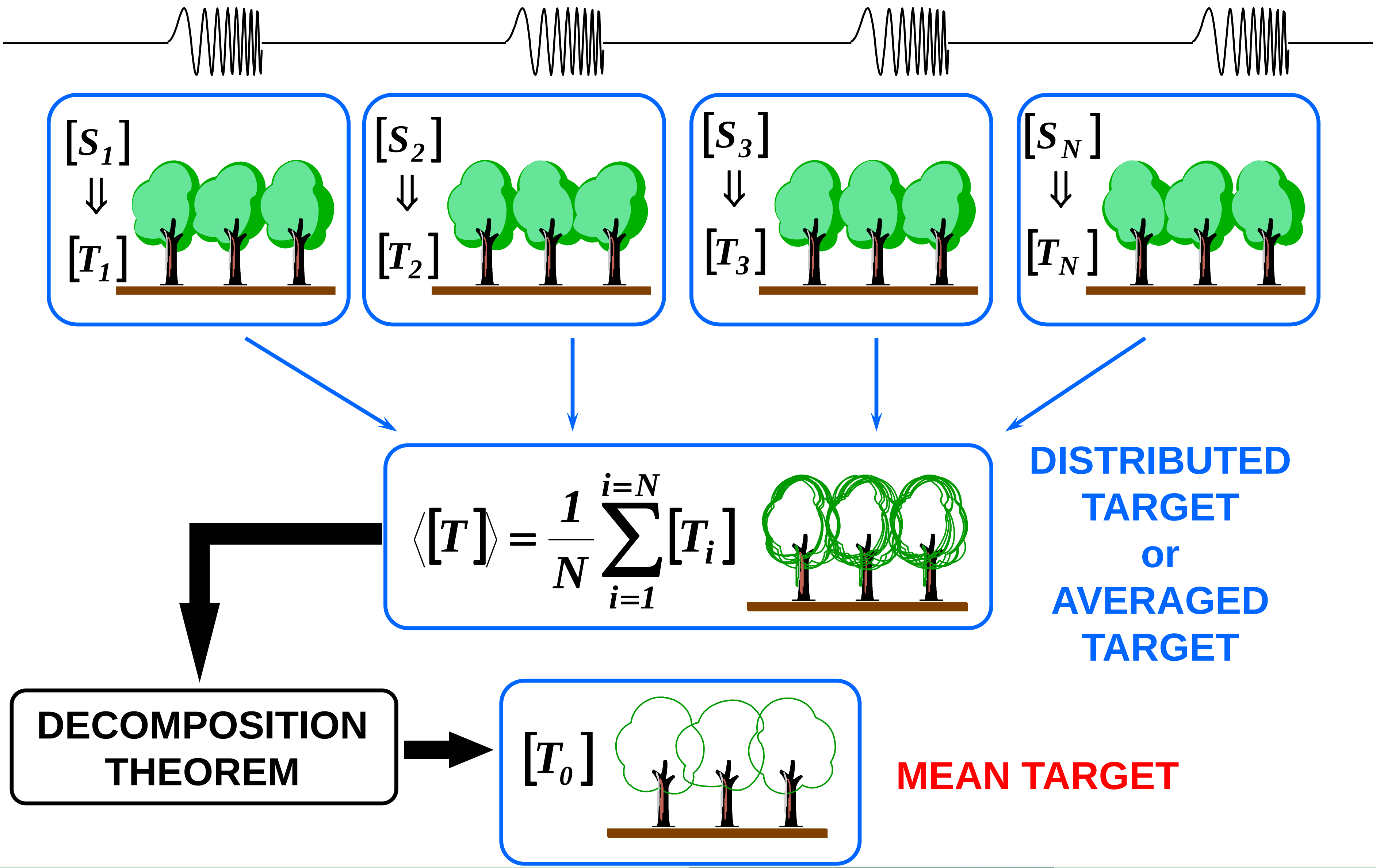
BoxCar Filter



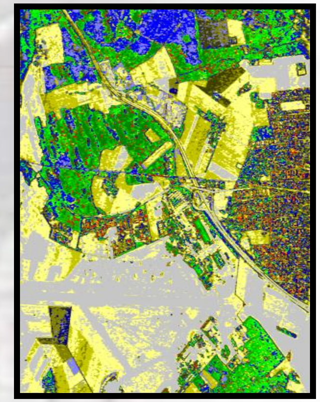
SAN FRANCISCO BAY JPL - AIRSAR L-band 1988

J.S. Lee, D.L. Schuler, T.L. Ainsworth, M.R. Grunes, E Pottier, L. Ferro-Famil, "*Scattering Model Based Speckle Filetring of Polarimetric SAR Data*" IEEE – TGRS, vol 1, January 2006

TARGET DECOMPOSITIONS

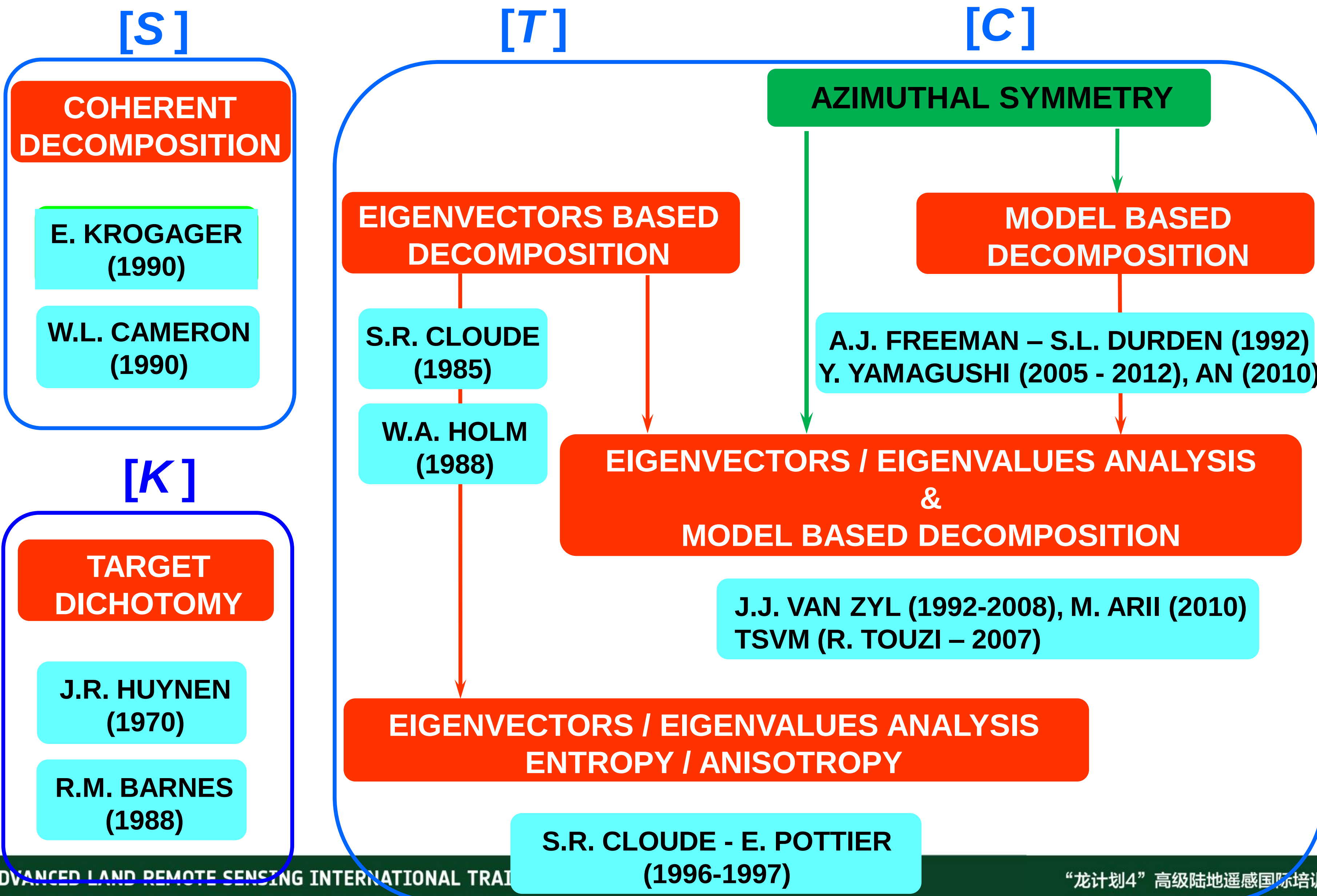


POL-SAR PROCESSING
PHENOMENOLOGIC
QUALITATIVE ANALYSIS

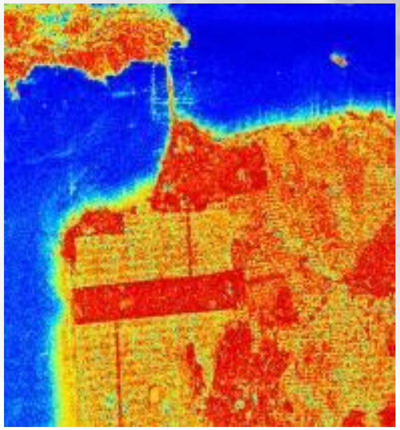


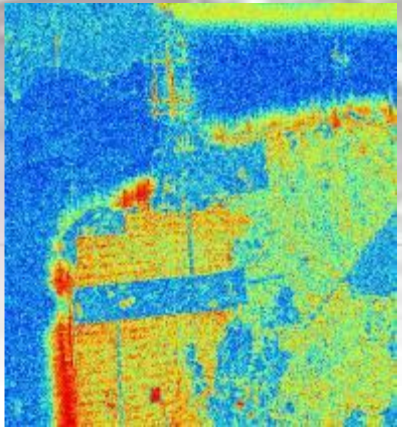
POLARIMETRIC SPECKLE FILTERING → **POLARIMETRIC TARGET DECOMPOSITION** → **POLARIMETRIC CLASSIFICATION**
MONO/DUAL CHANNELS

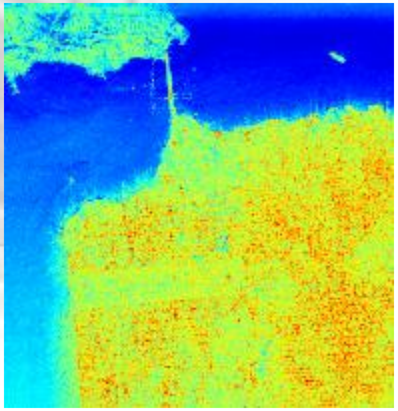
TARGET DECOMPOSITIONS



THE H / A / $\underline{\alpha}$ POLARIMETRIC TARGET DECOMPOSITION THEOREM







S.R. CLOUDE - E. POTTIER (1995 - 1996)

H / A / $\underline{\alpha}$ DECOMPOSITION

TARGET VECTOR

$$\underline{k} = \frac{1}{\sqrt{2}}\left[S_{XX}+S_{YY} \quad S_{XX}-S_{YY} \quad 2S_{XY}\right]^T$$

LOCAL ESTIMATE OF THE COHERENCY MATRIX

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

EIGENVECTORS / EIGENVALUES ANALYSIS

$$\langle[T]\rangle = [U_3][\Sigma][U_3]^{-1} = \begin{bmatrix}\underline{u}_1 & \underline{u}_2 & \underline{u}_3\end{bmatrix}\begin{bmatrix}\lambda_1 & 0 & 0\\ 0 & \lambda_2 & 0\\ 0 & 0 & \lambda_3\end{bmatrix}\begin{bmatrix}\underline{u}_1 & \underline{u}_2 & \underline{u}_3\end{bmatrix}^{*T}$$

ORTHOGONAL EIGENVECTORS

REAL EIGENVALUES $\lambda_1 > \lambda_2 > \lambda_3$

$$P_i = \frac{\lambda_i}{\sum_{k=1}^{3}\lambda_k}$$

H / A / α DECOMPOSITION

EIGENVALUES λ_1 λ_2 λ_3 : ROLL INVARIANT

PROBABILITIES P_1 P_2 P_3 : ROLL INVARIANT

ENTROPY

(DEGREE OF RANDOMNESS
STATISTICAL DISORDER)

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

PURE TARGET

$\lambda_1 = SPAN \quad \lambda_2 = 0 \quad \lambda_3 = 0$

$H = 0$

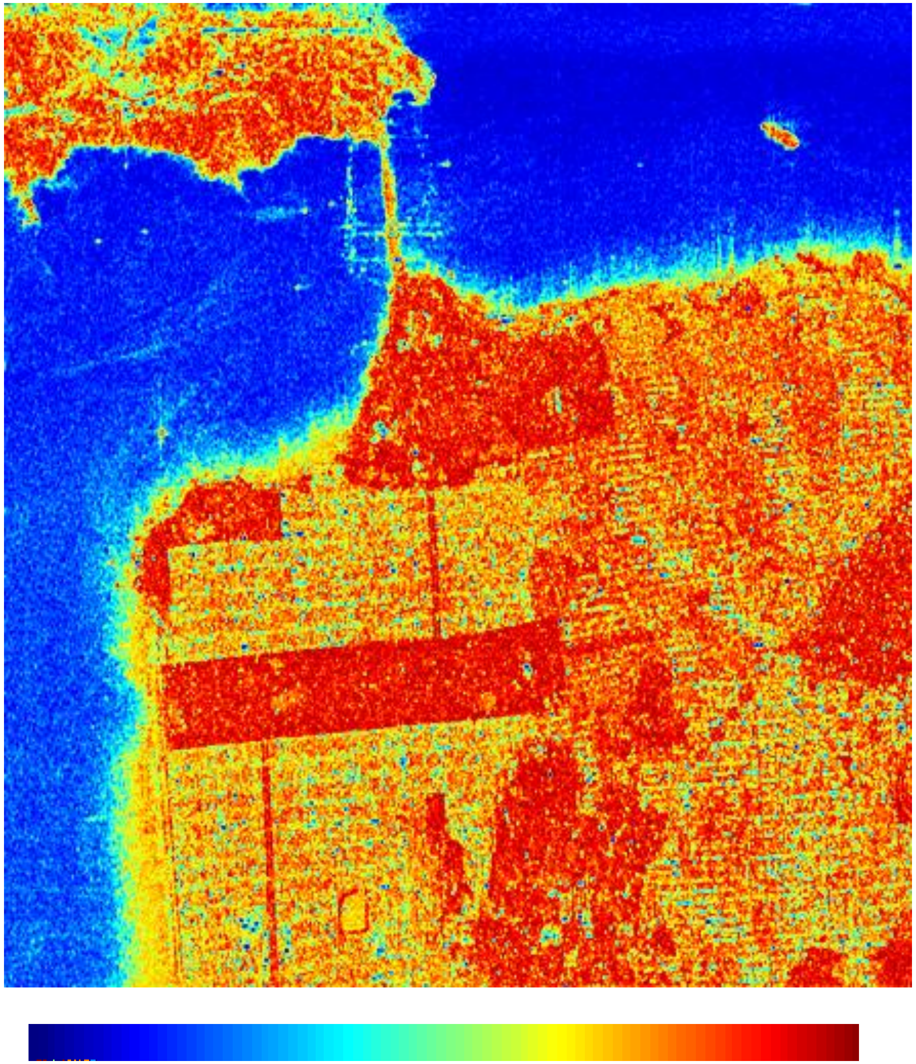
DISTRIBUTED TARGET

$\lambda_1 = \lambda_2 = \lambda_3 = SPAN / 3$

$H = 1$

H / A / α DECOMPOSITION

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



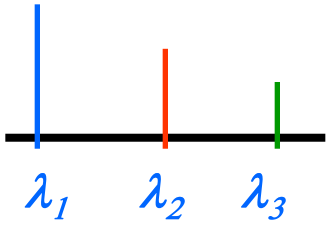
H / A / α DECOMPOSITION

DIFFICULT MECHANISM DISCRIMINATION WHEN : H > 0.7

ANISOTROPY

(EIGENVALUES SPECTRUM)

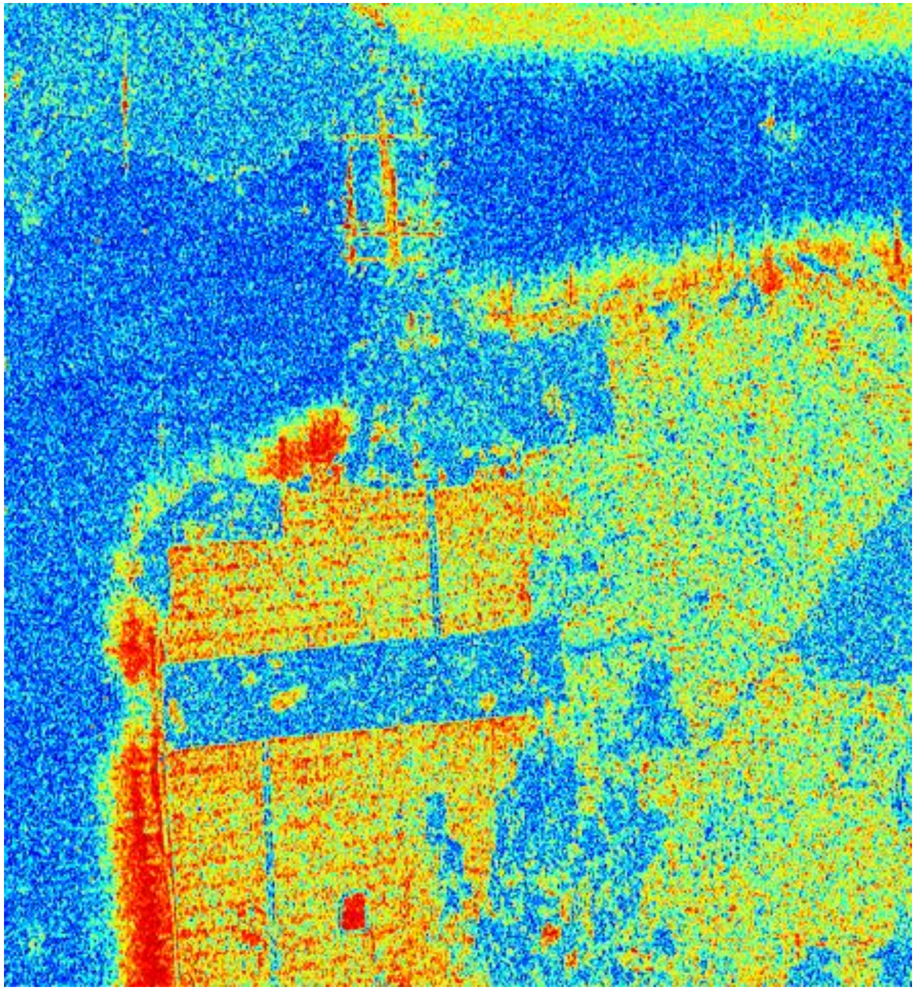
$$A = \frac{\lambda_2 - \lambda_3}{\lambda_2 + \lambda_3}$$



- COMPLEMENTARY TO ENTROPY
- DISCRIMINATION WHEN H > 0.7
- ROLL INVARIANT

H / A / $\underline{\alpha}$ DECOMPOSITION

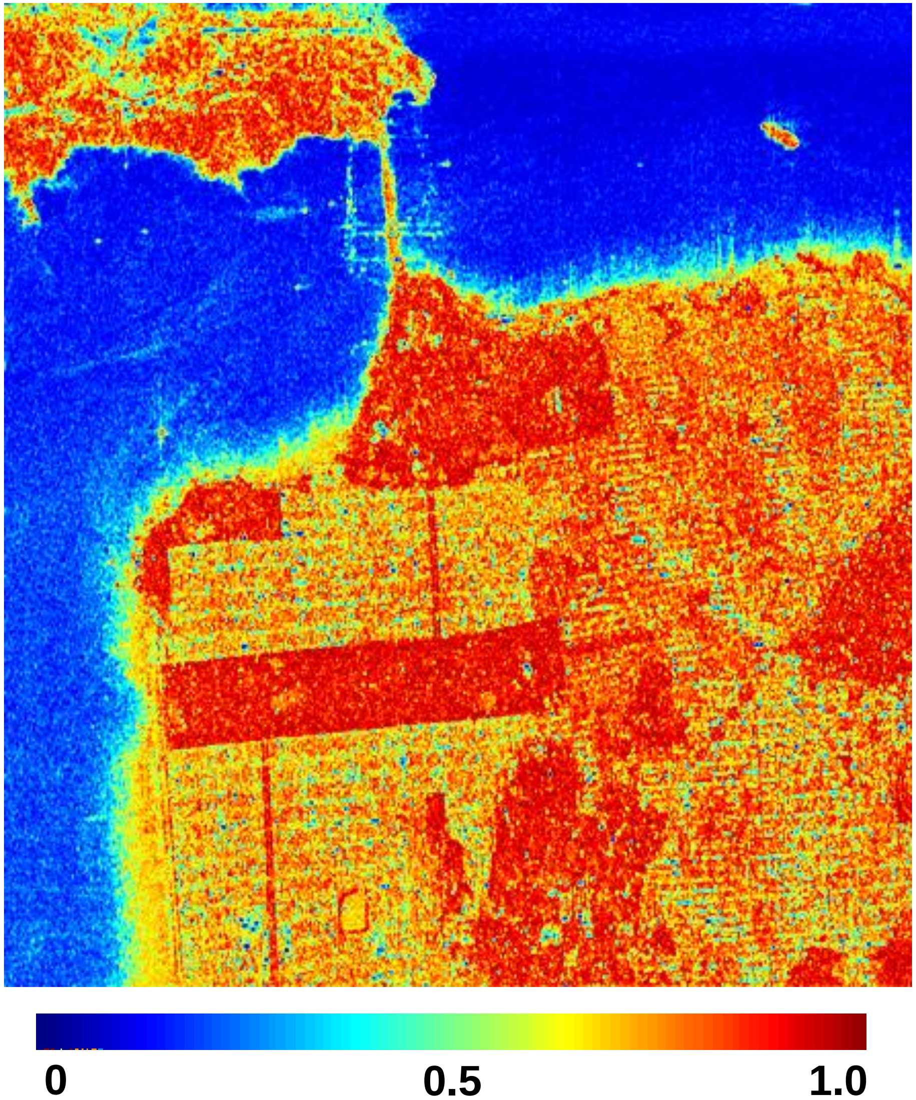
$2A_0$ $B_0 + B$ $B_0 - B$



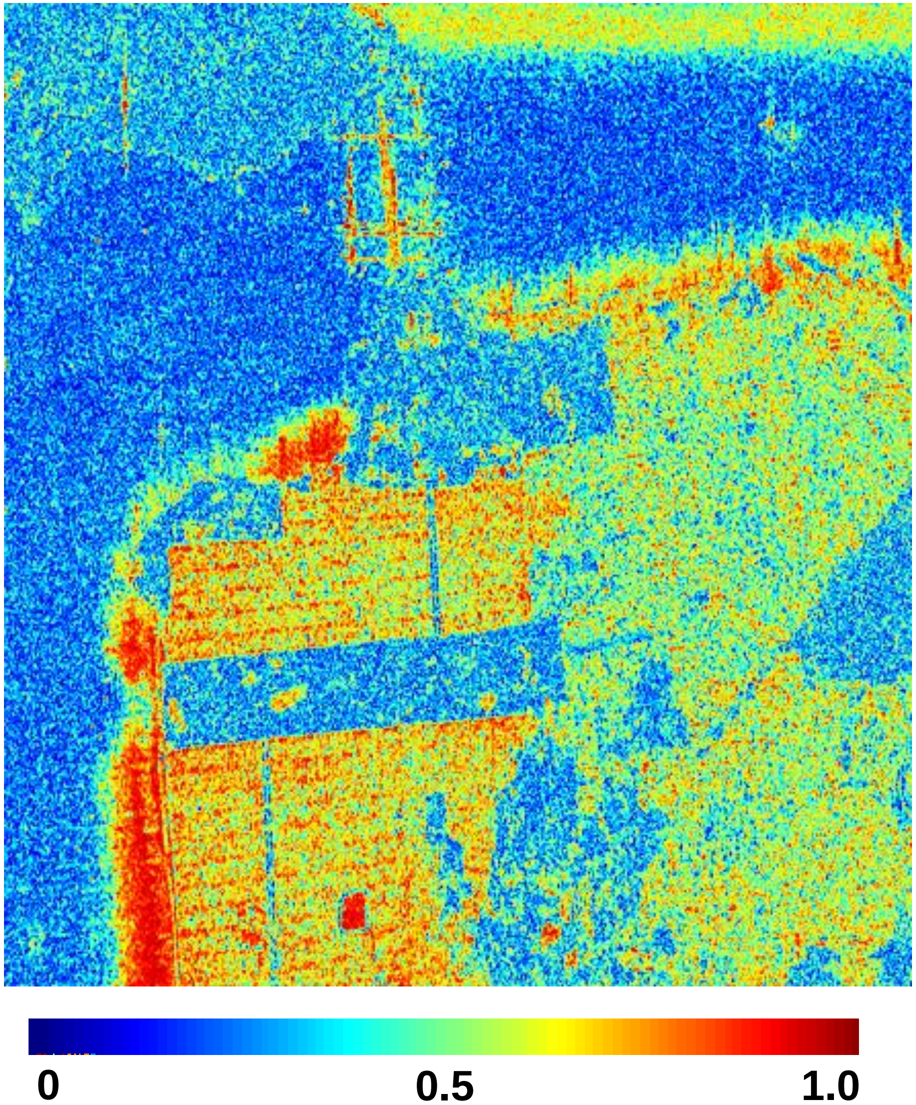
0 0.5 1.0

ANISOTROPY (A)

H / A / α DECOMPOSITION



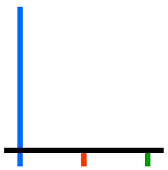
ENTROPY (H)



ANISOTROPY (A)

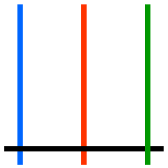
H / A / α DECOMPOSITION

(1-H)(1-A)

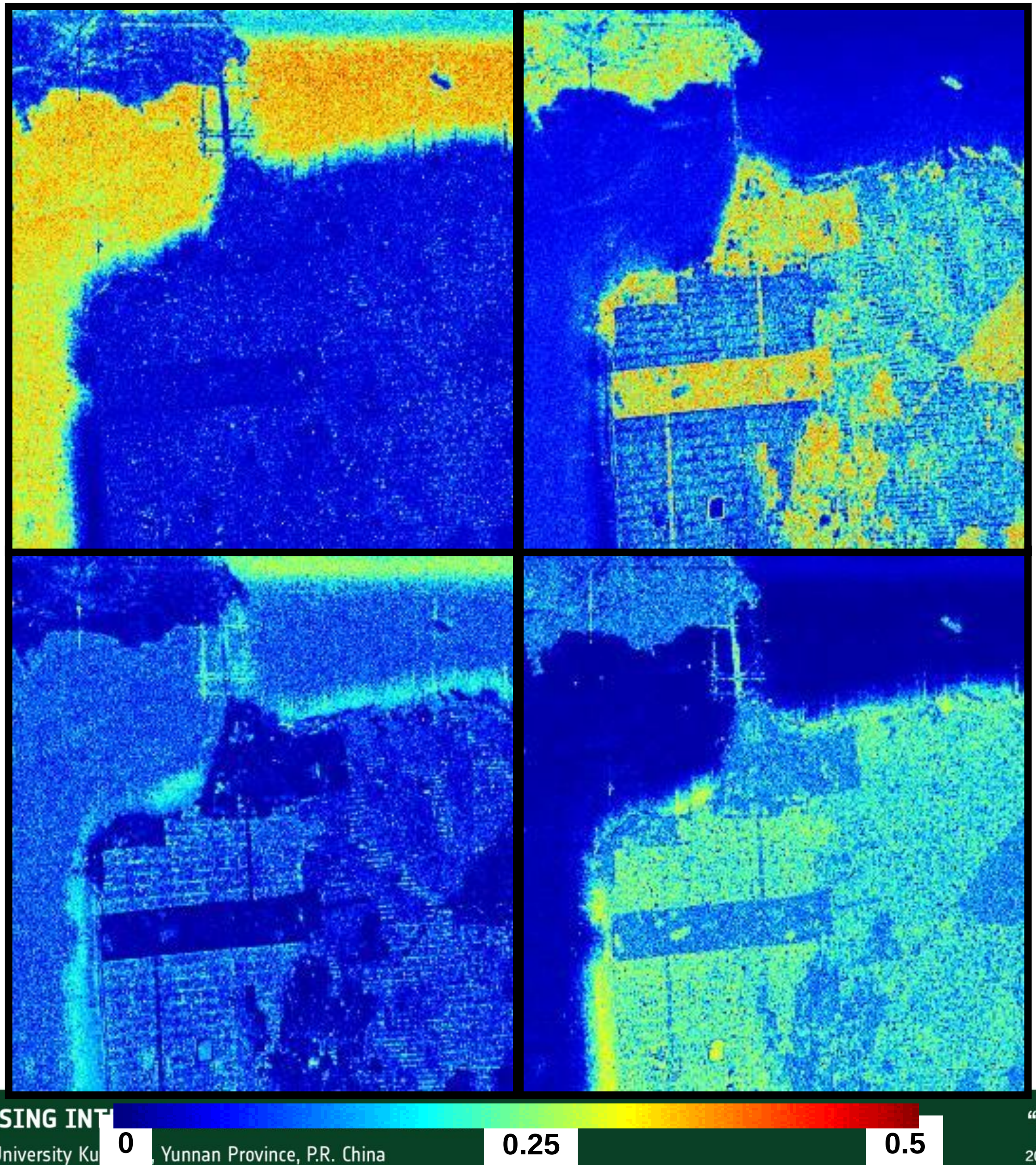


1 MECHANISM

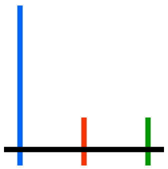
H(1-A)



3 MECHANISMS

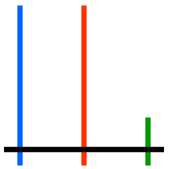


A(1-H)



2 MECHANISMS

HA



2 MECHANISMS

H / A / α DECOMPOSITION

$$\langle [T] \rangle = [U_3][\Sigma][U_3]^{-1} = \begin{bmatrix} \underline{u}_1 & \underline{u}_2 & \underline{u}_3 \end{bmatrix} \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} \begin{bmatrix} \underline{u}_1 & \underline{u}_2 & \underline{u}_3 \end{bmatrix}^{*T}$$

ORTHOGONAL EIGENVECTORS

REAL EIGENVALUES $\lambda_1 > \lambda_2 > \lambda_3$

PARAMETERISATION OF THE SU(3) UNITARY MATRIX

$$[U_3] = \begin{bmatrix} \cos\alpha_1 e^{j\phi_1} & \cos\alpha_2 e^{j\phi_2} & \cos\alpha_3 e^{j\phi_3} \\ \sin\alpha_1 \cos\beta_1 e^{j\phi_1} e^{j\delta_1} & \sin\alpha_2 \cos\beta_2 e^{j\phi_2} e^{j\delta_2} & \sin\alpha_3 \cos\beta_3 e^{j\phi_3} e^{j\delta_3} \\ \sin\alpha_1 \sin\beta_1 e^{j\phi_1} e^{j\gamma_1} & \sin\alpha_2 \sin\beta_2 e^{j\phi_2} e^{j\gamma_2} & \sin\alpha_3 \sin\beta_3 e^{j\phi_3} e^{j\gamma_3} \end{bmatrix}$$

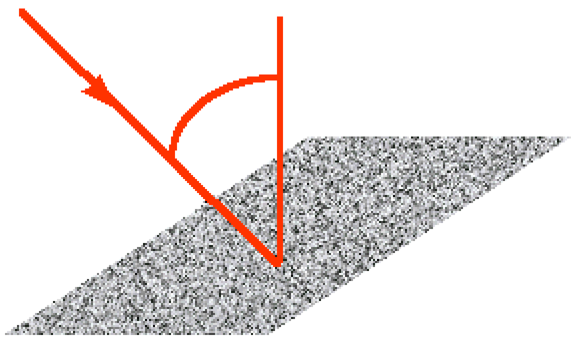
TARGET 1 TARGET 2 TARGET 3

H / A / $\underline{\alpha}$ DECOMPOSITION

$$\underline{\alpha} = P_1\alpha_1 + P_2\alpha_2 + P_3\alpha_3$$

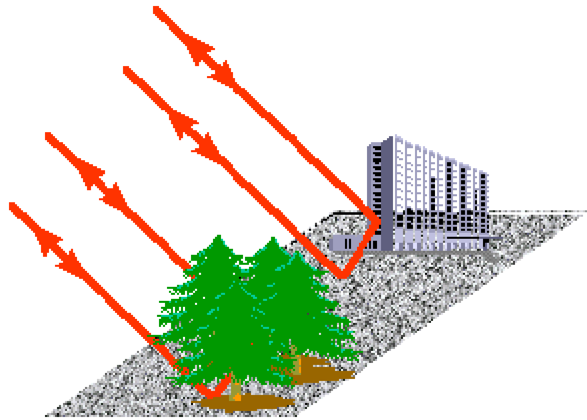
PHYSICAL INTERPRETATION

SINGLE BOUNCE SCATTERING (ROUGH SURFACE)



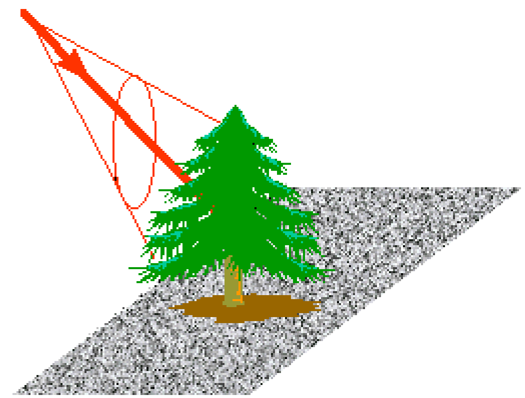
$$a \mapsto b \Rightarrow \nu \mapsto 0$$
$$\Downarrow$$
$$\underline{\alpha} \mapsto 0$$

DOUBLE BOUNCE SCATTERING



$$a \mapsto -b \Rightarrow \varepsilon \mapsto 0$$
$$\Downarrow$$
$$\underline{\alpha} \mapsto \frac{\pi}{2}$$

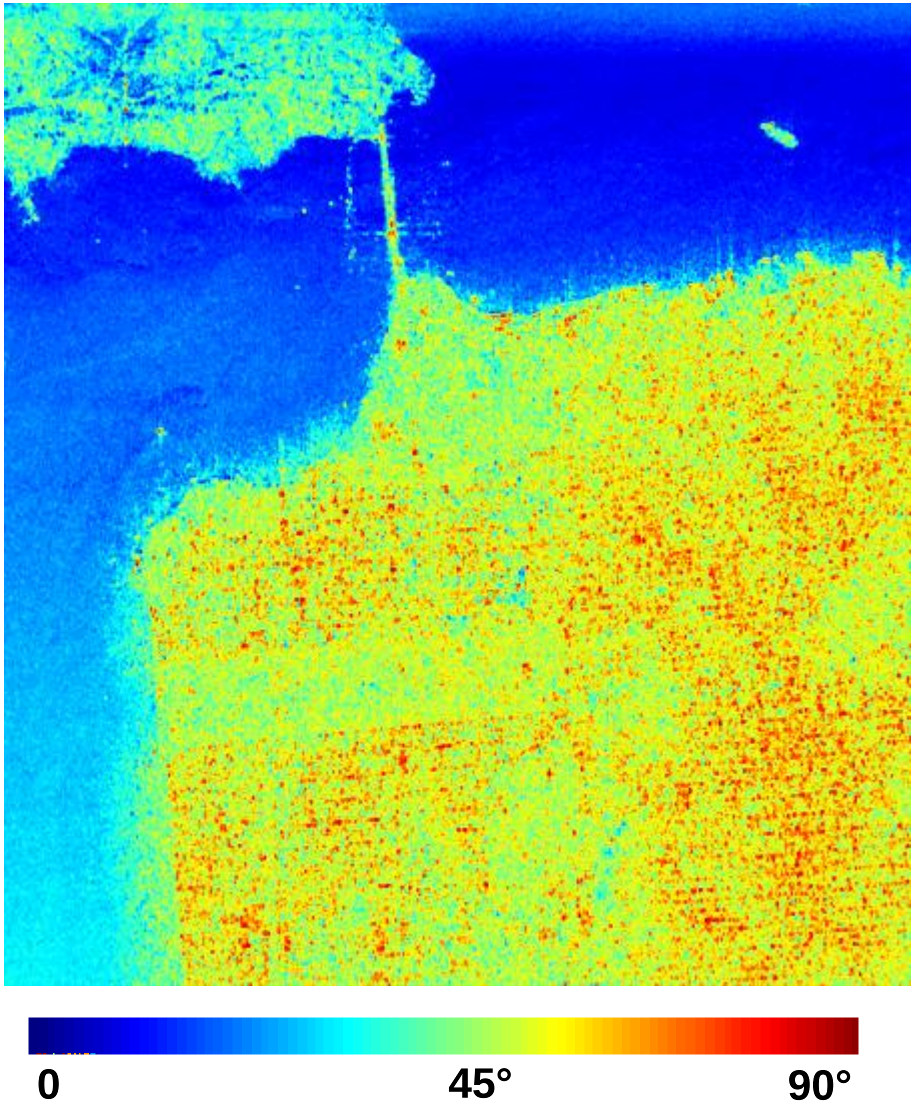
VOLUME SCATTERING



$$a >> b \Rightarrow \varepsilon \approx \nu$$
$$\Downarrow$$
$$\underline{\alpha} \mapsto \frac{\pi}{4}$$

H / A / α DECOMPOSITION

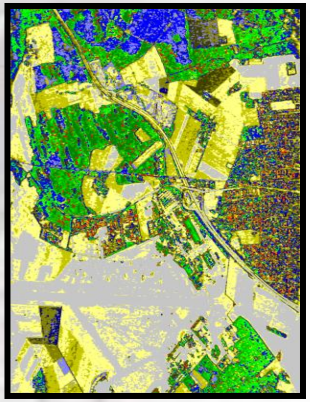
$2A_0$ $B_0 + B$ $B_0 - B$



α PARAMETER

POL-SAR PROCESSING

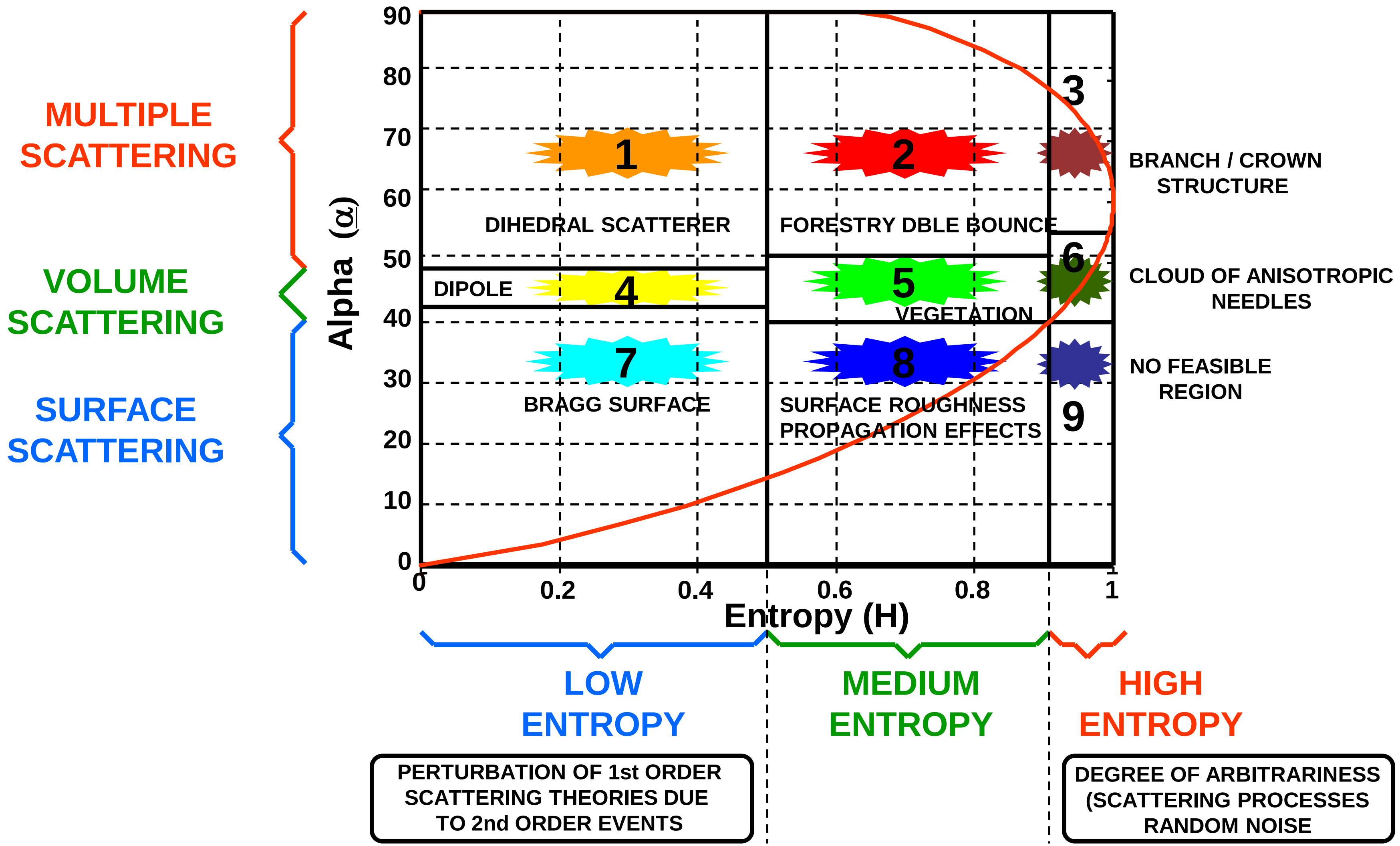
PHENOMENOLOGIC QUALITATIVE ANALYSIS



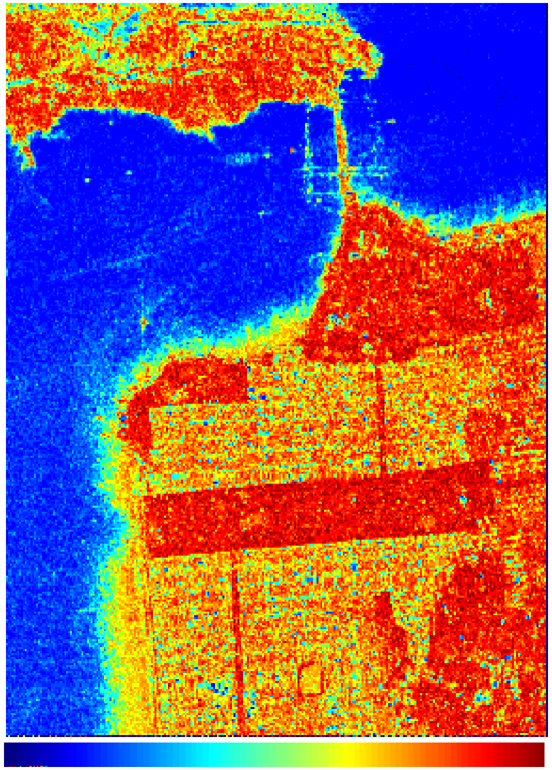
POLARIMETRIC SPECKLE FILTERING → **POLARIMETRIC TARGET DECOMPOSITION** → **POLARIMETRIC CLASSIFICATION**
MONO/DUAL CHANNELS

H / α CLASSIFICATION

SEGMENTATION OF THE H / α SPACE



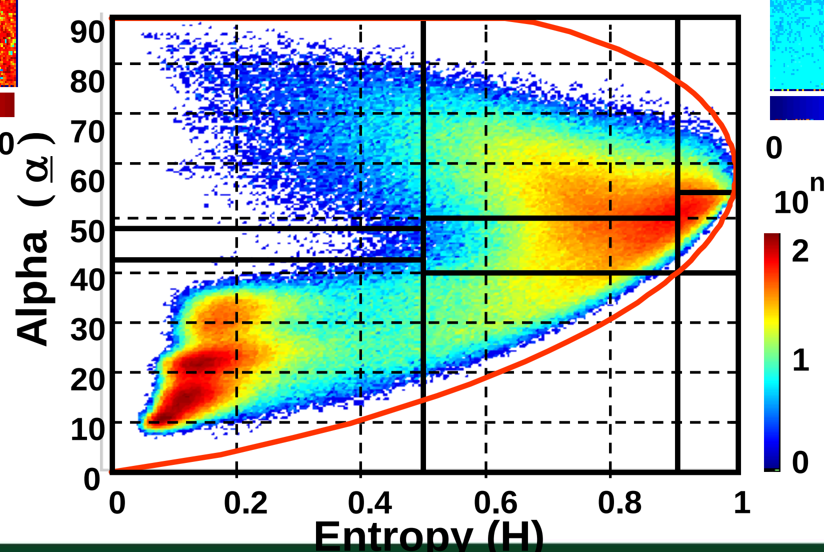
H / $\underline{\alpha}$ CLASSIFICATION

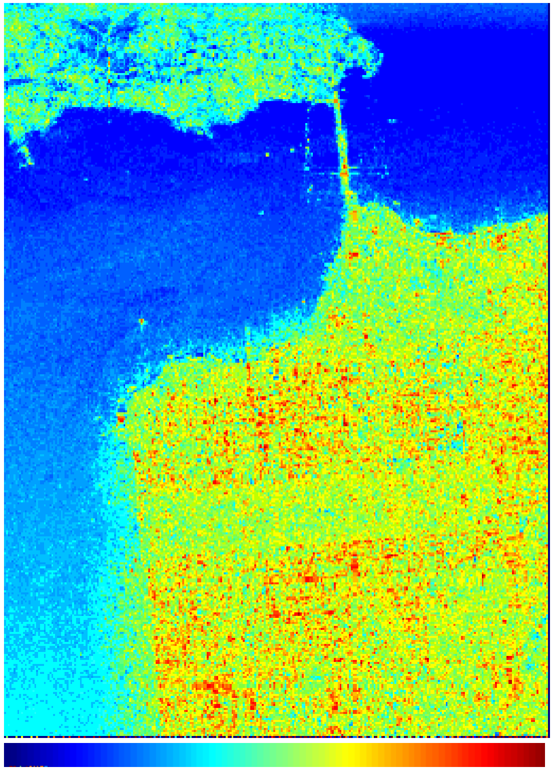


0 0.5 1.0

H

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





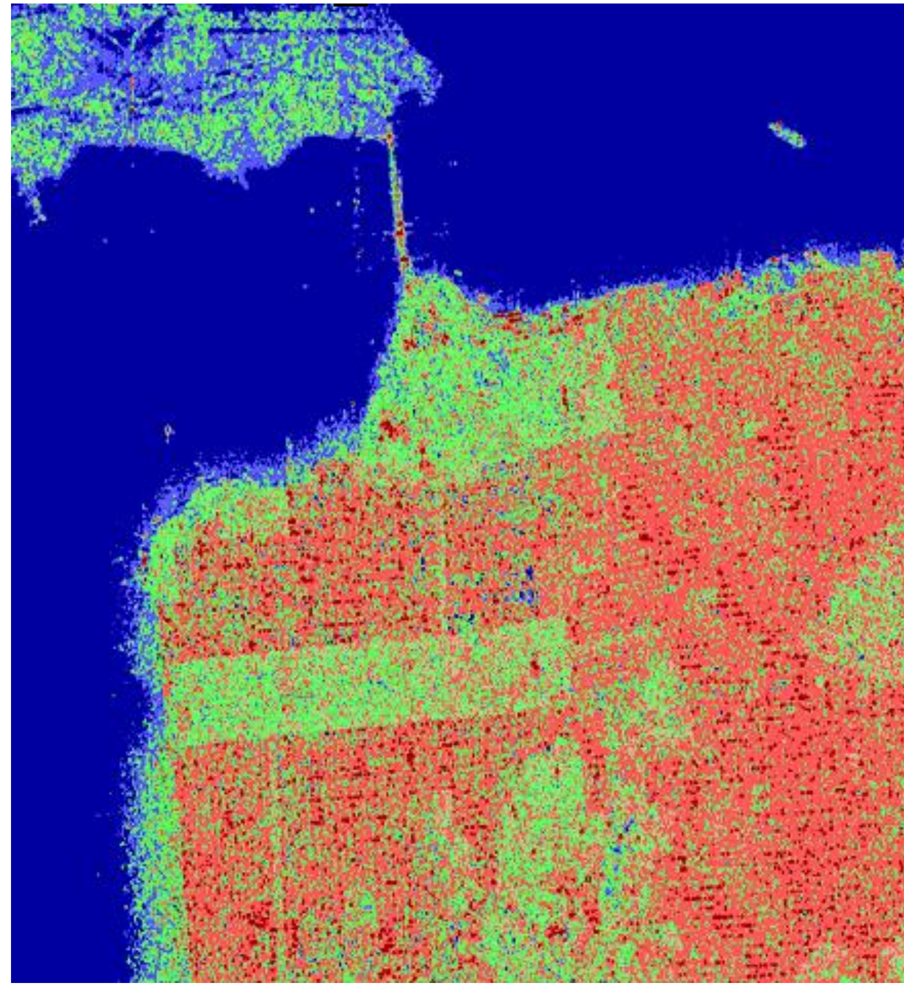
0 45° 90°

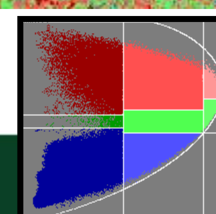
$\underline{\alpha}$

H / $\underline{\alpha}$ CLASSIFICATION

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

H - $\underline{\alpha}$ classification



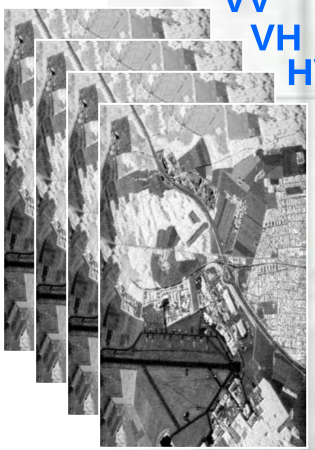


POLARIMETRIC REMOTE SENSING

WISHART PDF

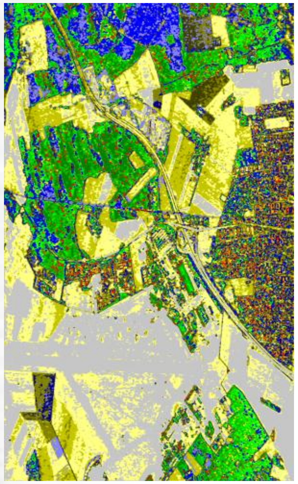
$$P\left(\langle[T]\rangle/[T_m]\right)=\frac{L^{Lp}\left|\langle[T]\rangle\right|^{L-p}e^{-LTr\left([T_m]^{-1}\langle[T]\rangle\right)}}{\pi^{\frac{p(p-1)}{2}}\Gamma(L)\ldots\Gamma(L-p+1)\left|[T_m]\right|^{L}}$$

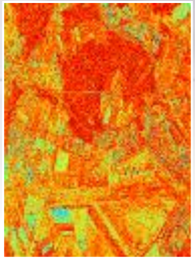
VV
VH
HV
HH



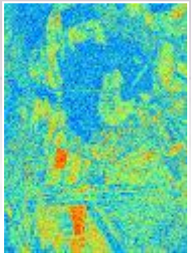
UNSUPERVISED POLSAR CLASSIFICATION

E.POTTIER, J.S LEE (2000)

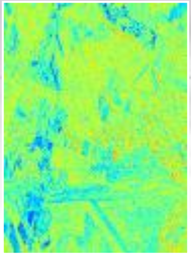




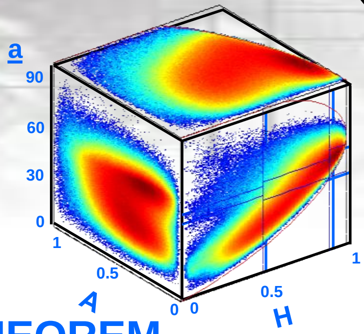
H



A



α



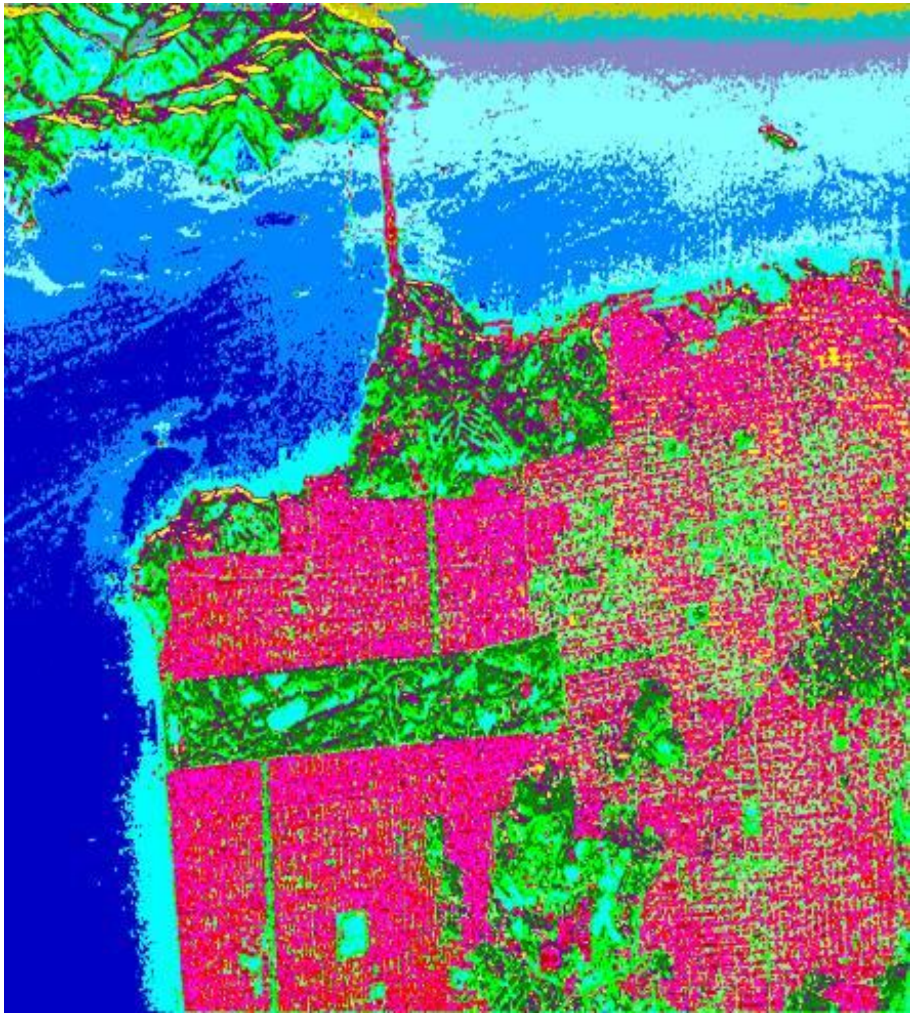
H / A / α DECOMPOSITION THEOREM

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

SAN FRANCISCO BAY JPL - AIRSAR L-band 1988

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

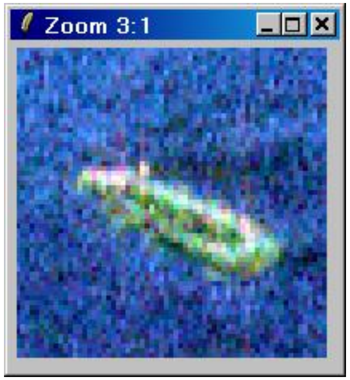
4th ITERATION

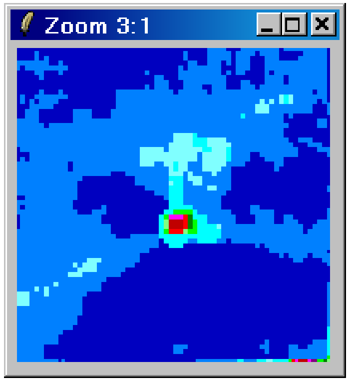


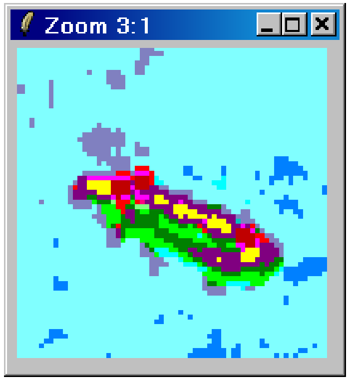
C1	C2	C3	C4	C5	C6	C7	C8
C9	C10	C11	C12	C13	C14	C15	C16

H / A / α - WISHART CLASSIFIER

SAN FRANCISCO BAY JPL - AIRSAR L-band 1988



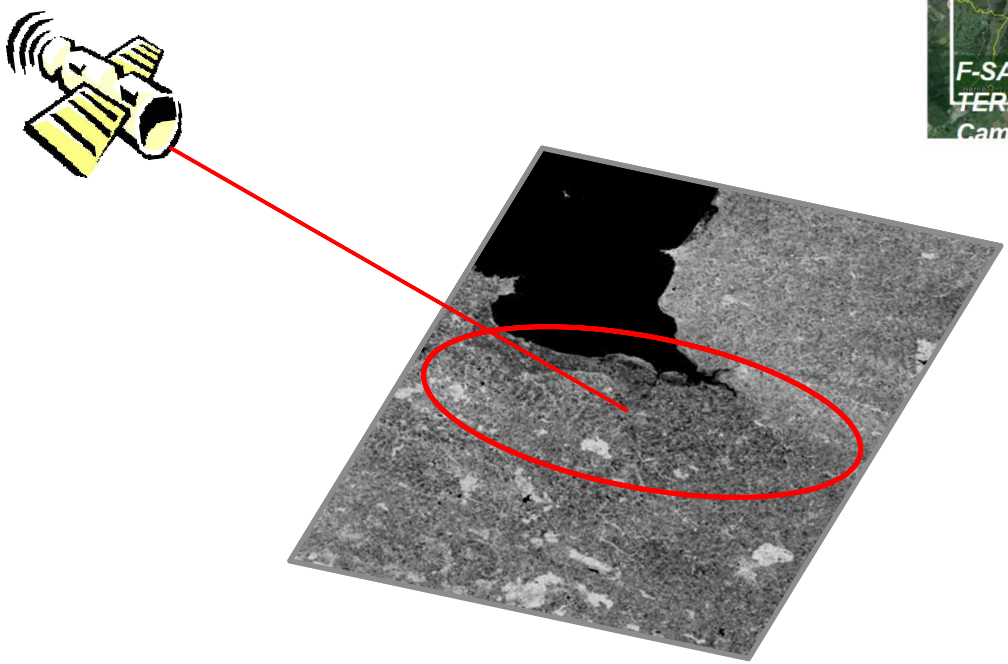


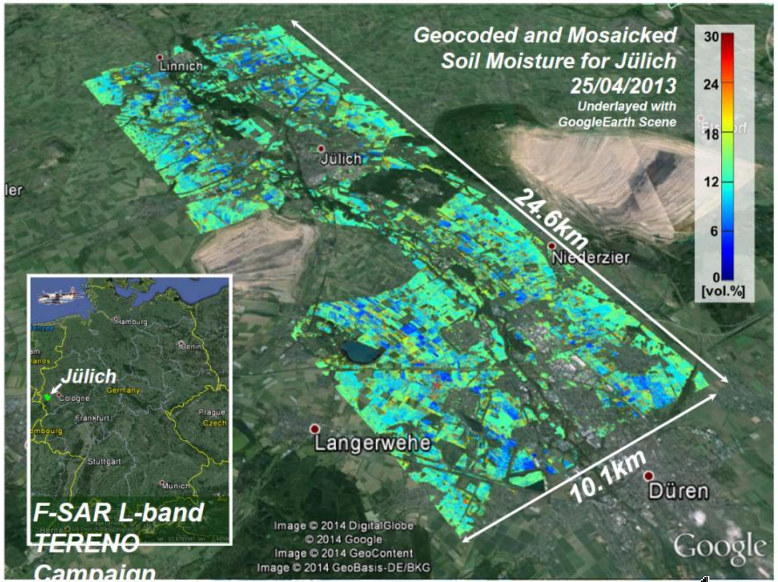


$2A_0$ $\quad B_0 + B$ $\quad B_0 - B$

POLARIMETRY

PolSAR



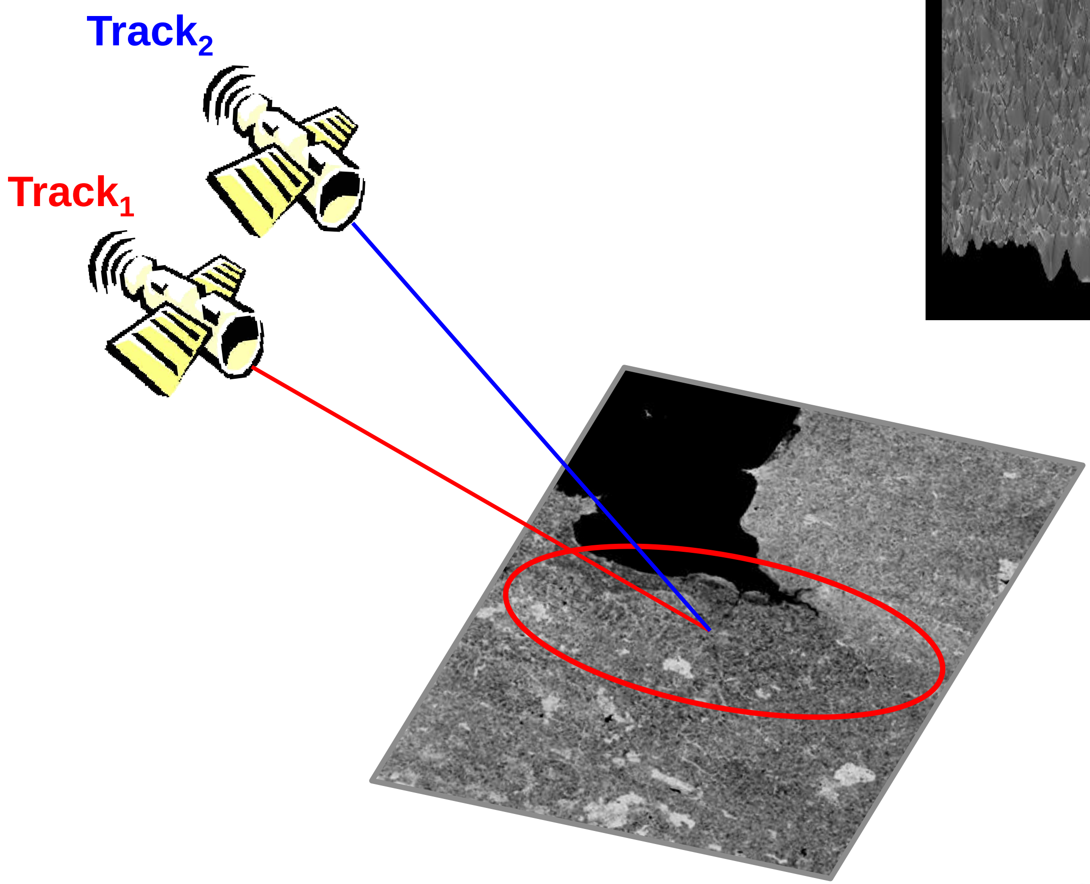


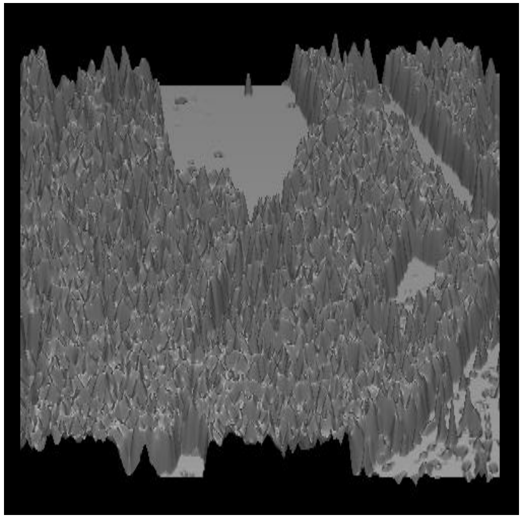
Soil moisture

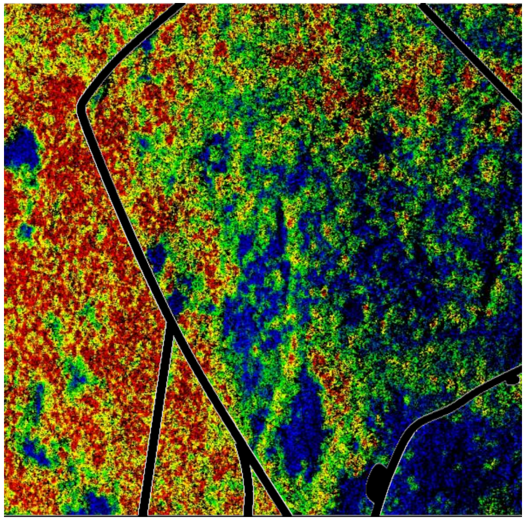
DLR

Urban monitoring

Pol-InSAR



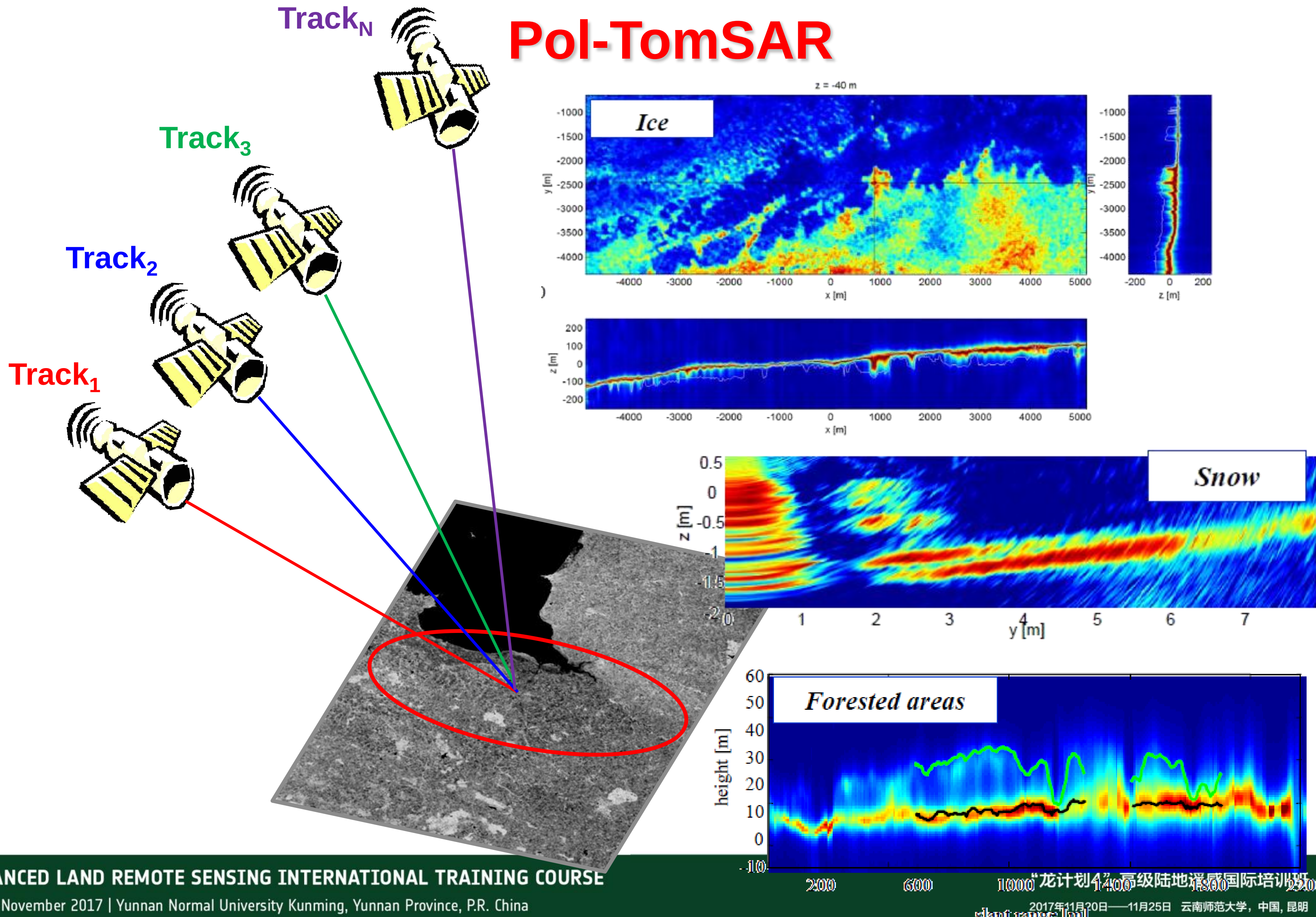




Courtesy of Dr. K. Papathanassiou

POLARIMETRY + TOMOGRAPHY

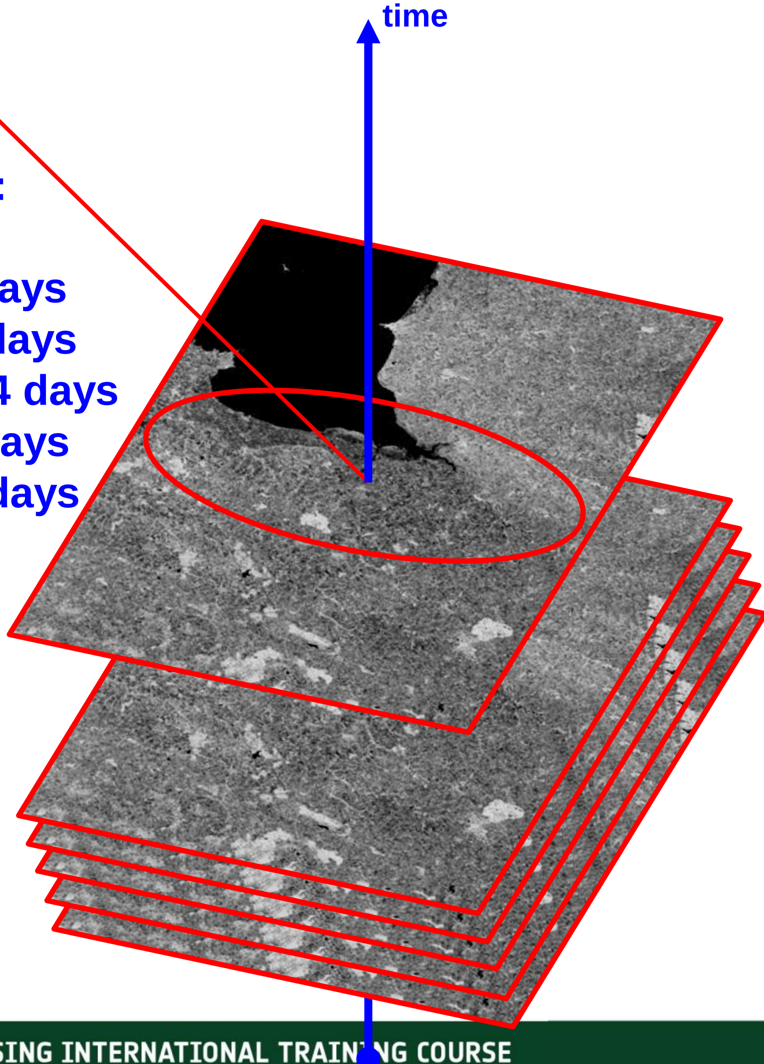
Pol-TomSAR



TIME-SERIES

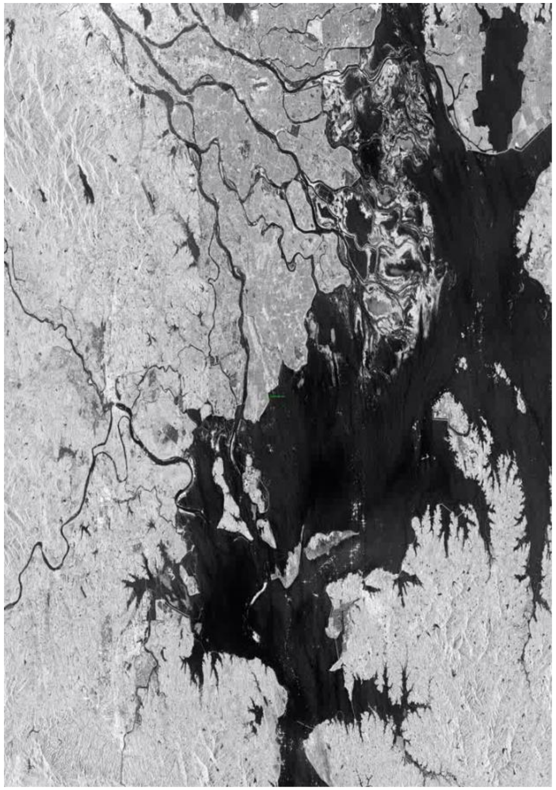
Track$_{1..N}$

Pol-TimeSAR



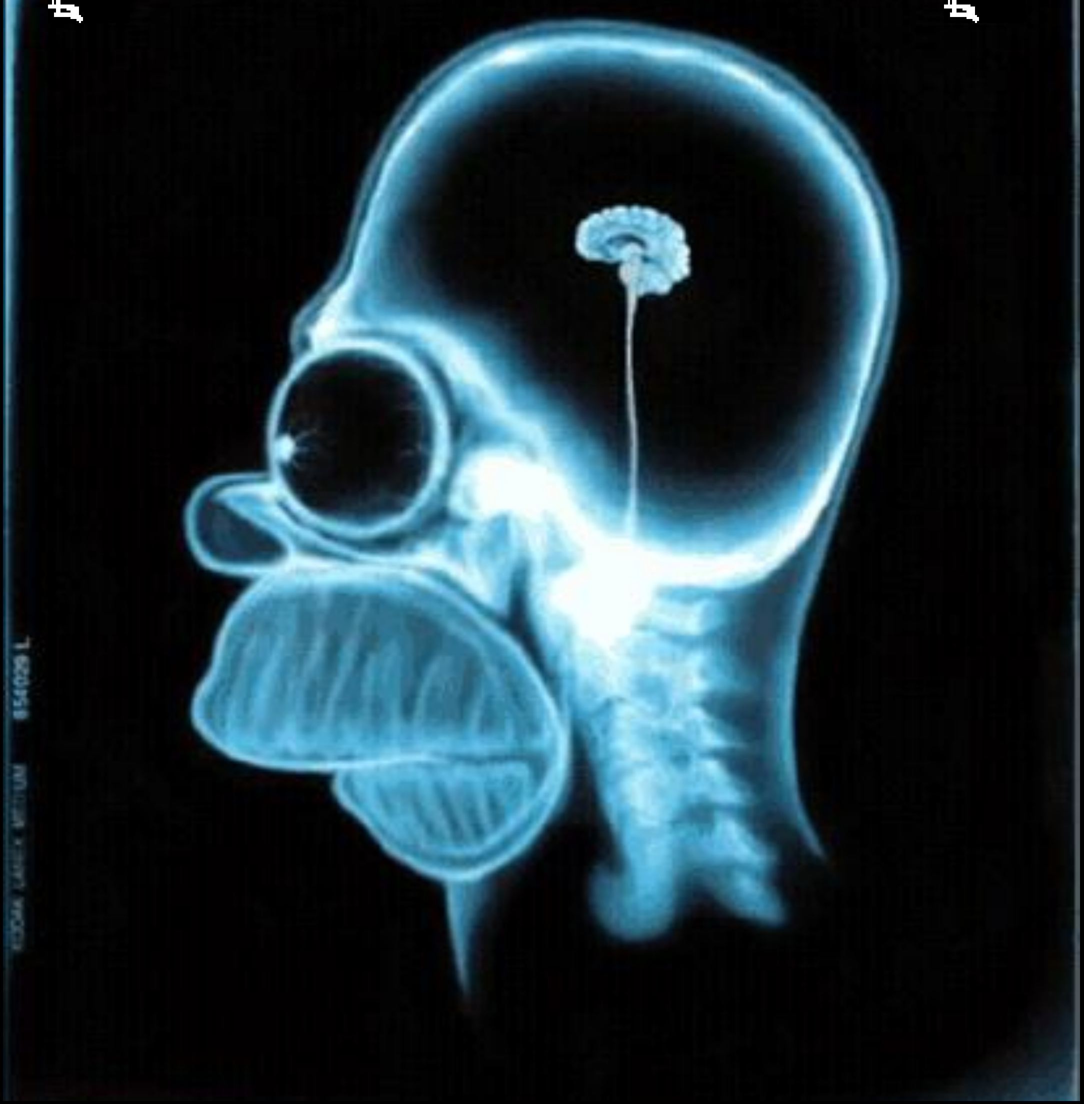
Revisit time :

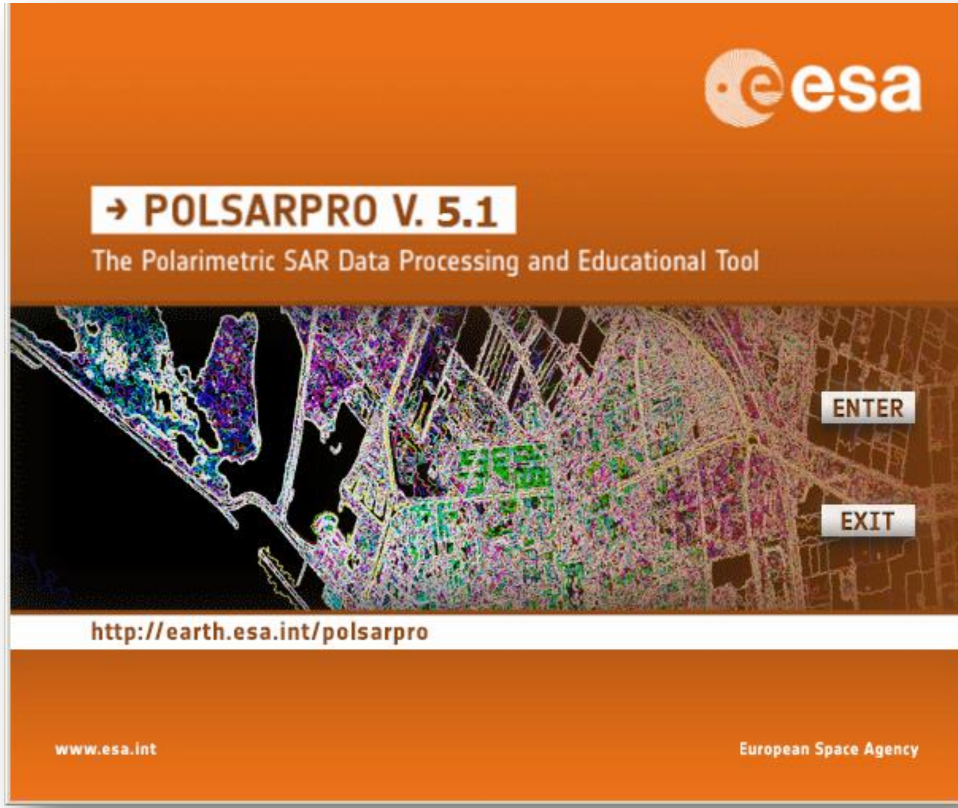
- ALOS-2 = 14 days
- BIOMASS = 4 days
- RADARSAT2 = 24 days
- RISAT-1 = 25 days
- Sentinel-1 = 6 days



Polarimetric feature temporal evolution

Questions ?



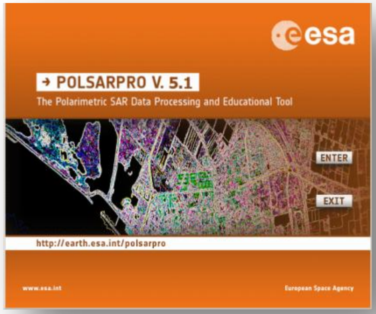


PolSARpro v5.1 Software Training Course

SAN FRANCISCO BAY

ALOS2 - PALSAR

L-Band (Quad - 2015)



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SAN FRANCISCO BAY