H2020-TWINN-2015.	Grant Agreement no 691936
Project full title:	Remote Sensing Science Center for Cultural Heritage
Project acronym:	ATHENA
Work Package	WP6
Deliverable	D6.7 Webinars

	H2020-TWINN-2015 **Grant Agreement no 691936** This project is funded under the **EUROPEAN COMMISSION** in the Framework Programme for Research and Innovation (2014-2020).	
Call:	Work programme **H2020** under **"Spreading Excellence and Widening Participation", call: H2020-TWINN-2015: Twinning** (Coordination and Support Action).	
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Work Package (WP):	**WP6**	
Deliverable (D):	**D6.7 - Webinars**	
Due date of deliverable:	**December 2018**	**Version: 1**
Author(s):	**Diofantos G. Hadjimitsis, Evagoras Evagorou, Christodoulos Mettas, Athos Agapiou, Vasiliki Lysandrou, Andreas Christofe, Marios Tzouvaras, Christiana Papoutsa, Argyro Nisantzi, Kyriacos Themistocleous**	
Contributor(s):	**Rosa Lasaponara, Nicola Masini, Thomas Krauss, Gunter Schreier**	
Start date of project:	**1/12/2015**	Duration: **36 months**

Dissemination Level		
PU	Public	√
CO	Confidential, only for members of the consortium (including the Agency Services)	□

Document Sign-off				
Nature	**Name**	**Role**	**Partner**	**Date**
DRAFT	Diofantos G. Hadjimitsis, Evagoras Evagorou, Christodoulos Mettas, Athos Agapiou, Vasiliki Lysandrou, Andreas Christofe, Marios Tzouvaras, Christiana Papoutsa, Argyro Nisantzi, Kyriacos Themistocleous	Coordinator	CUT	02/11/2018
REVIEWED	Rosa Lasaponara, Nicola Masini, Thomas Krauss, Gunter Schreier	Partner 2 & 3	DLR and CNR	20/11/2018
APPROVED	Diofantos G. Hadjimitsis	Coordinator	CUT	28/11/2018

Work Package: 6 –Dissemination and exploitation Deliverable: D6.7 – Webinars				
Sections to be protected	**Description**	**Owner**	**Access Rights** **Period**	**Type***
none				

Table of Contents

1 INTRODUCTION

The purpose of this Report is to describe the webinars that took place during the project, related to TASK 6. Particularly, through the webinars, all the methods and techniques used during the project are described. This deliverable includes the agenda, the participants and the presentations of ATHENA's webinars.

This deliverable is closely related to deliverable 4.8, which is the material of the virtual trainings. Basically, the material of the webinars is mainly from the virtual trainings organized by the ATHENA's team.

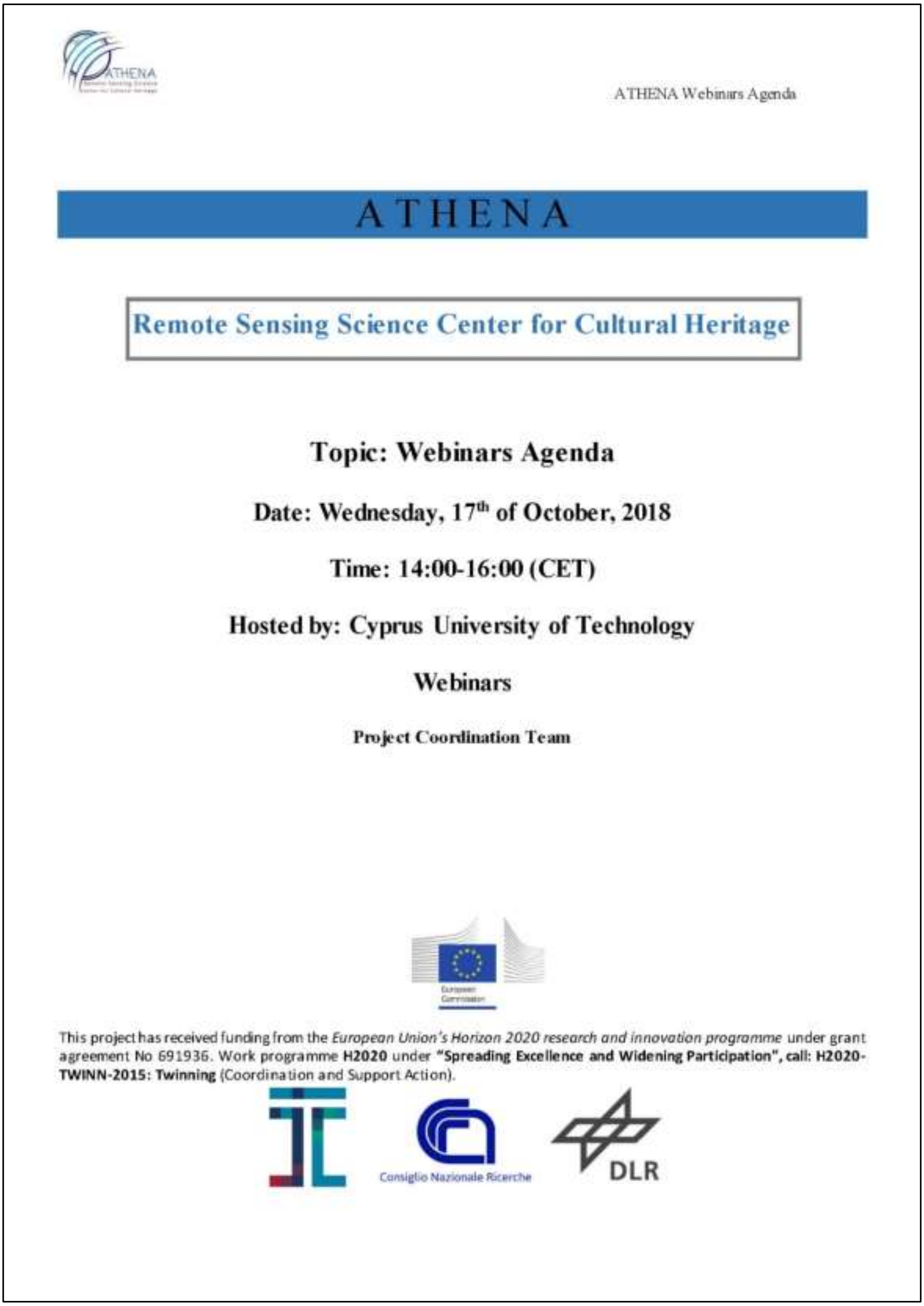
1.1 Description

ATHENA Web-based Webinars were held on the 17th of October 2018, between 14:00-16:00 CET (Central European Time) (Fig. 1). During this session, seven presentations were carried out through WebEx with thirty-one participants. The webinars' session was divided into four parts. The first part of the session was opened, through a welcoming speech made by Mr. Andreas Christofe from CUT. Followed, an introduction presentation of the ATHENA project was performed by the project coordinator, Professor Diofantos Hadjimitsis. During the second part, the first webinar took place in which DLR indicated their contribution in ATHENA through three presentations. The third part, was comprised by the second webinar, where CNR had three presentations showing their methods and techniques used in the ATHENA project. Lastly, an open discussion took place during the final part where all questions that have been raised, were answered by members of the consortium team.

Figure 1: Dissemination of the ATHENA Web-based seminar through the ATHENA's webpage

1.2 Agenda

This chapter includes the agenda (Figs 2 and 3) of the webinars that was sent out with the registration.



ATHENA Webinars Agenda

ATHENA

Remote Sensing Science Center for Cultural Heritage

Topic: Webinars Agenda

Date: Wednesday, 17th of October, 2018

Time: 14:00-16:00 (CET)

Hosted by: Cyprus University of Technology

Webinars

Project Coordination Team

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 691936. Work programme **H2020** under **"Spreading Excellence and Widening Participation", call: H2020-TWINN-2015: Twinning** (Coordination and Support Action).

Figure 2: First page of the Webinar's Agenda

ATHENA Webinars Agenda

Webinars

2 hours web-event

(Targeted audience graduate and post graduate students, researchers, private sector)

14:00 -14:15(CET)	**Introduction to the ATHENA project (D.Hadjimitsis- CUT)**
14:15–15:00(CET)	**Webinar 1 , DLR contribution to ATHENA** Geo Information Systems (GIS)(V.Jaspersen –DLR) Analysis of hyperspectral images (D.Cerra- DLR) Multi-Temporal Remote Sensing Analyses (U.Gessner –DLR)
15:00-15:45(CET)	**Webinar 2, CNR contribution to ATHENA** Archaeological looting (N.Massini & R.Lasaponara-CNR) Integration of RS data for Cultural Heritage management (R.Lasaponara-CNR) Geophysics (F.Soldovieri and I.Catapano)
15:45-16:00(CET)	**Discussion -Questions**
End of Webinars	

Page | 2

Figure 3: Second page of the Webinar's Agenda

1.3 Registration

The ATHENA webinars were disseminated through the ATHENA's website and through the accounts of ATHENA in social media, targeting the attraction of more people to watch this session. In order for someone to be able to attend these webinars, an access request was essential which could take place through the three ATHENA's social spaces (Webpage, Facebook, Twitter) (Figs 4-7). Invitations through email were sent by the team's members.

Figure 4: Disseminate the event through website

Figure 5: Disseminate the event through Facebook

Figure 6: Disseminate the event through Twitter

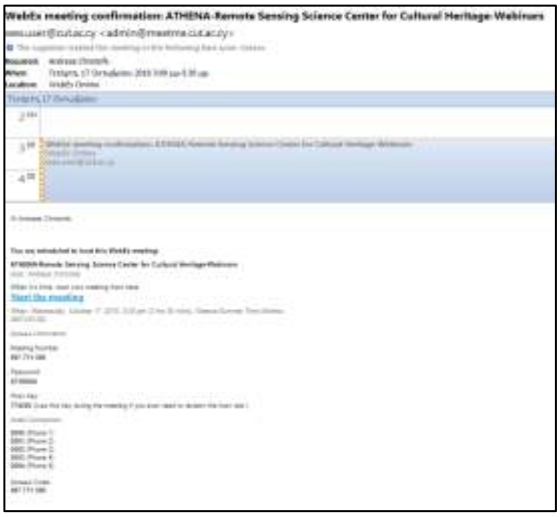


Figure 7: Email confirmation

1.4 Participants – Registrants

ATHENA's webinars were watched by thirty-one people. The list of participants of the ATHENA's webinar can been seen on Table 1.

Table 1: List of participants

A/A	Name	Surname	Organization	Email
1	Anastasia	Yfantidou	CUT	ai.yfantidou@edu.cut.ac.cy
2	Andreas	Christofe	CUT	andreas.christofe@cut.ac.cy
3	Argyro	Nisantzi	CUT	argyro.nisantzi@cut.ac.cy
4	Athos	Agapiou	CUT	athos.agapiou@cut.ac.cy
5	Christiana	Papoutsa	CUT	christiana.papoutsa@cut.ac.cy
6	Christodoulos	Mettas	CUT	christodoulos.mettas@cut.ac.cy
7	Christos	Theocharidis	CUT	cd.theocharidis@edu.cut.ac.cy
8	Daniele	Cerra	DLR	Daniele.Cerra@dlr.de
9	Dimitris	Kouhartsiouk	GEOFEM	info@geofem.com
10	Diofantos	Hadjimitsis	CUT	d.hadjimitsis@cut.ac.cy
11	Eleni	Loulli	CUT	eleni.loulli@cut.ac.cy
12	Evagoras	Evagorou	CUT	evagoras.evagorou@cut.ac.cy
13	Francesco	Solvovieri	CNR	soldovieri.f@irea.cnr.it
14	George	Ioannou	CUT	gem.ioannou@edu.cut.ac.cy
15	Georgios	Leventis	CUT	georgios.leventis@cut.ac.cy
16	Ilaria	Catapano	CNR	catapano.i@irea.cnr.it
17	Kyriacos	Themistocleous	CUT	k.themistocleous@cut.ac.cy
18	Kyriakos	Neocleous	CUT	kyriacos.neocleous@cut.ac.cy
19	Maria	Prodromou	CUT	ml.prodromou@edu.cut.ac.cy
20	Marios	Tzouvaras	CUT	marios.tzouvaras@cut.ac.cy
21	Marios	Makrides	CMP	marios.makrides@cmp-cyprus.org
22	Milto	Miltiadou	CUT	milto.miltiadou@cut.ac.cy
23	Monica	Proto	CNR	Monica.Proto@imaa.cnr.it
24	Nikoletta	Papageorgiou	CUT	nt.papageorgiou@edu.cut.ac.cy
25	Rosa	Lasponara	CNR	rosa.lasaponara@imaa.cnr.it
26	Sarah	Asam	DLR	Sarah.Asam@dlr.de
27	Thomaida	Polydorou	CUT	thomaida.polydorou@cut.ac.cy
28	Thomas	Krauss	DLR	Thomas.Krauss@dlr.de
29	Vasiliki	Lysandrou	CUT	vasiliki.lysandrou@cut.ac.cy
30	Verena	Jaspersen	DLR	Verena.Jaspersen@dlr.de
31	Zoe	Aristotelous	CUT	aristotelouszoe@gmail.com

1.5 Introduction to the ATHENA project

The first presentation of the ATHENA's webinars was carried out by Professor Diofantos Hadjimitsis summarizing the project (Fig. 8). The activities and the knowledge transferred during this project were also mentioned. It has been specified that the challenge of the ATHENA project, was to address networking gaps and deficiencies among the research institutions of the low performing Member States. Finally, examples from common research activities and conclusions of the ATHENA project have been referred. In ANNEX 2.1, the presentation of the introduction to the ATHENA project, performed by Prof. D. Hadjimitsis, can be found.

Figure 8: Prof. Diofantos Hadjimitsis presents at the ATHENA's webinar

1.6 Webinar 1 - DLR contribution to ATHENA

The session continued with presentations performed by Dr. Sarah Asam, Dr. Daniele Cerra and Ms. Verena Jaspersen. DLR contribution was presented in this webinar as well as the methods, techniques and knowledge transferred during the project. The second presentation of the webinars which was carried out by Ms. V. Jaspersen was referring to Geo Information Systems (GIS). The presentation can be found in ANNEX 2.2. During this presentation, Ms. V. Jaspersen referred to the meaning of the Geospatial Information Systems and Geospatial Data Models, mentioned GIS applications and GIS softwares and described the definition of the standards for geospatial content and services, GIS data processing and data sharing.

Following, Dr. Danielle Cerra proceeded with the third presentation. The subject of the presentation was the "Analysis of hyperspectral images". The features of a hyperspectral image were described during this presentation as well as the differences between Hyperspectral, Multispectral and Panchromatic imaging of the spectral and spatial resolution and were compared through examples in vegetation analysis. This presentation can be found on the ANNEX 2.3. The final presentation of the second part was carried out by Dr. Sarah Asam with the name subject of ''Multi-temporal Analyses in Earth Observation''. For this presentation the usage of Time series in earth observation, the time series processing, background, methods and examples for Earth observation application based on time series were described. Dr. S. Asam's presentation can be found on ANNEX 2.4.

1.7 Webinar 2 - CNR contribution to ATHENA

During the third part of the webinar, two presentations were performed by Dr. Rosa Lasaponara and one presentation by Ms. Ilaria Catabano. The fifth was carried out by Dr. Lasaponara while the subject was based on the "Archaeological looting" (ANNEX 2.5). This presentation started by referring to the extraction of archaeological looting patterns through satellite images using automatic procedures. Methods and techniques were described, and case studies were mentioned. Dr. Lasaponara also carried out the next presentation titled "Integration of RS data for Cultural Heritage management" (ANNEX 2.6). Needs and challenges from the extraction of big data were described related to the monitoring and preservation of Natural and Cultural Heritage. The name of the final presentation of the webinar, which was carried out by Ms. Ilaria Catabano, was "Geophysics". This presentation referred to Ground Penetrated Radar (GPR) surveys performed during the project, onsite. More particularly, the site that the GPR was tested was the columns of Tomb 4 and Tomb 3 at the UNESCO site known as "Tombs of the Kings", an ancient necropolis in Paphos, Cyprus (ANNEX 2.7).

1.8 Discussion, questions

During the final part of the webinars, some questions were raised to specific participants. Prof. Hadjimitsis asked about the difficulties that an archaeologist might experience by using satellite remote sensing techniques.

Dr. Lasaponara informed the attendees that in general, the application of Remote Sensing technics in archaeology is a very easy and quick-learning technology (can only take 10-20 hours until fully understandable). Some difficulties, with the data processing may only be faced, but these can be overcome through trainings and studying.

In addition, Prof. Hadjimitsis questioned Dr. Lasaponara for the level of the progress made related to the of use of Copernicus data and services for the studying cultural heritage.

Dr. Lasaponara replied that this is something that still in progress. There is a significant level of progress made but it needs more work to be performed, while several suggestions were received about this matter. A specific call will be scheduled for the definition of particular services for culturalities during next year. Also, the European Community will hold a meeting in December, in New Delhi, India, to discuss about different components of cultural heritage and check the level of interest in other potential services.

Mr. Andreas Christofi referred to Mr. Marios Makrides (Committee of Missing Persons in Cyprus – CMP, http://www.cmp-cyprus.org/), who is currently working on a governmental project related to missing people since the war of 1974 in Cyprus and questioned whether the technology with archeological looting can contribute in helping in the search of missing people. Dr. R. Lasaponara replied that this is a big issue and remote sensing technologies may help in finding missing people. This should be discussed with Dr. Nicola Masini, in order to plan some common activities related to the subject, take advantage of some opportunities and check for the best practices.

Dr. Kyriakos Themistocleous ended the webinar with a small video provided by DLR partners about remote sensing for Cultural Heritage, in situ measurements and data processing. Prof. Hadjimitsis thanked all the members of the team, CNR and all the attendees of the two webinars.

2 ANNEX

2.1 First presentation - Introduction to the ATHENA project

Outline

- Introduction
- About the project
- Training activities and knowledge transfer
- Examples from common research activities
- Conclusion

Introduction

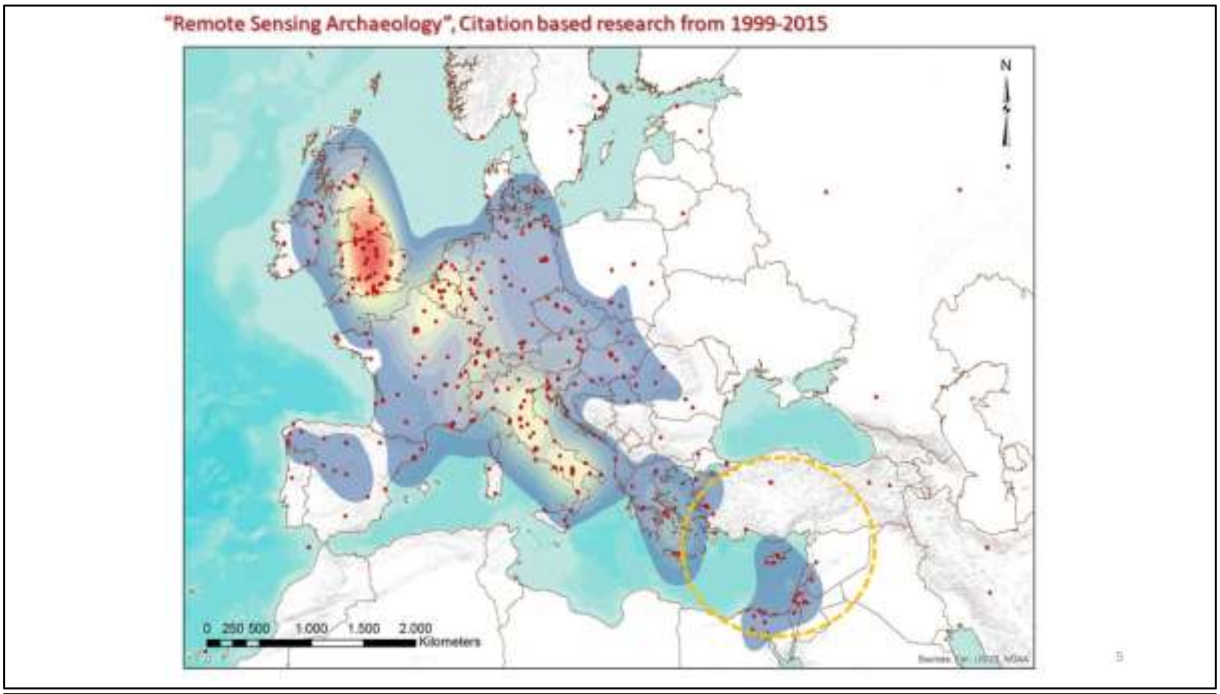
Twinning call

Specific challenge: The specific challenge is to address networking gaps and deficiencies between the research institutions of the low performing Member States and regions and internationally-leading counterparts at EU level.

Twinning

Twinning will:

1. Enhance the capacity of the linked institutions;
2. Help raise staff's research profile as well as the one of the institutions involved.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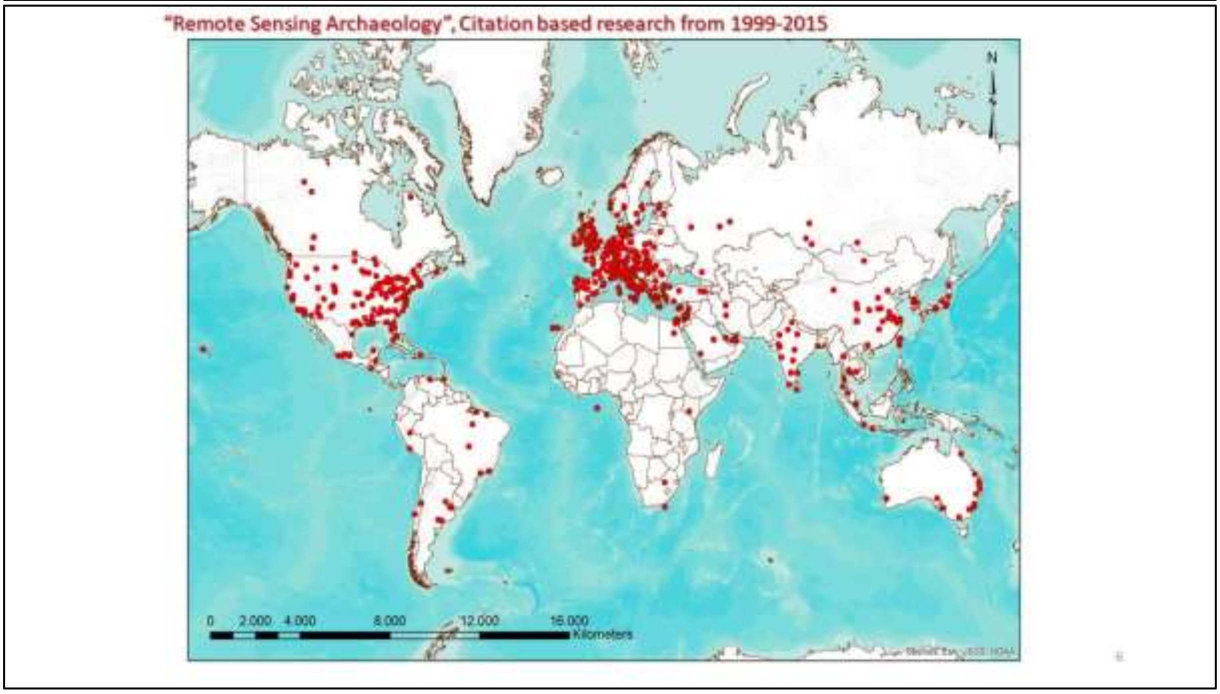
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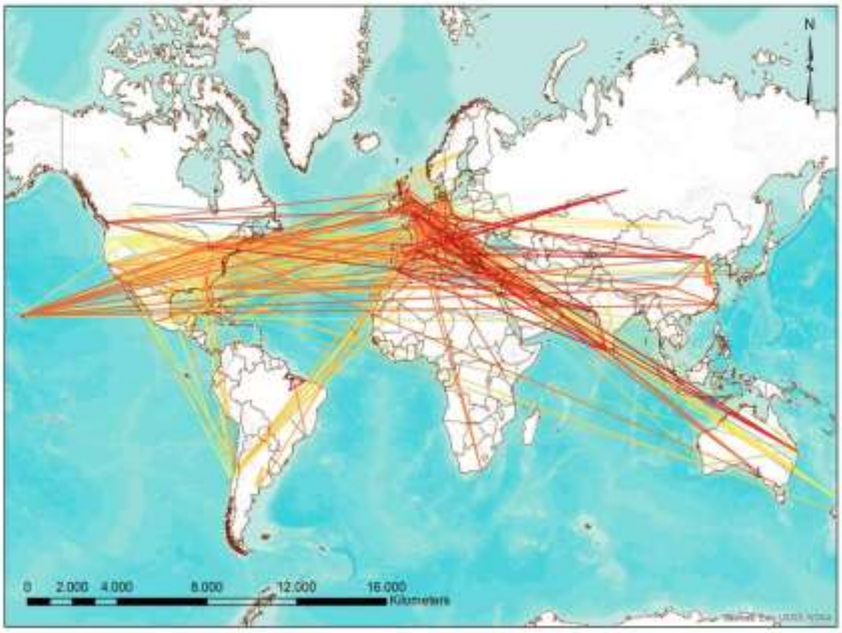
"Remote Sensing Archaeology", Citation based research from 1999-2015



Introduction

Remote Sensing and Geo- Environment Lab

- Significant experience in various topics of Earth Observation
- Some experience in CH projects
- Some experience in optical RS for CH

> ➤ *Motivation and scientific curiosity:*
> Exploit Remote Sensing techniques and technologies in the field of Archaeology and Cultural Heritage

Outline

- Introduction
- About the project
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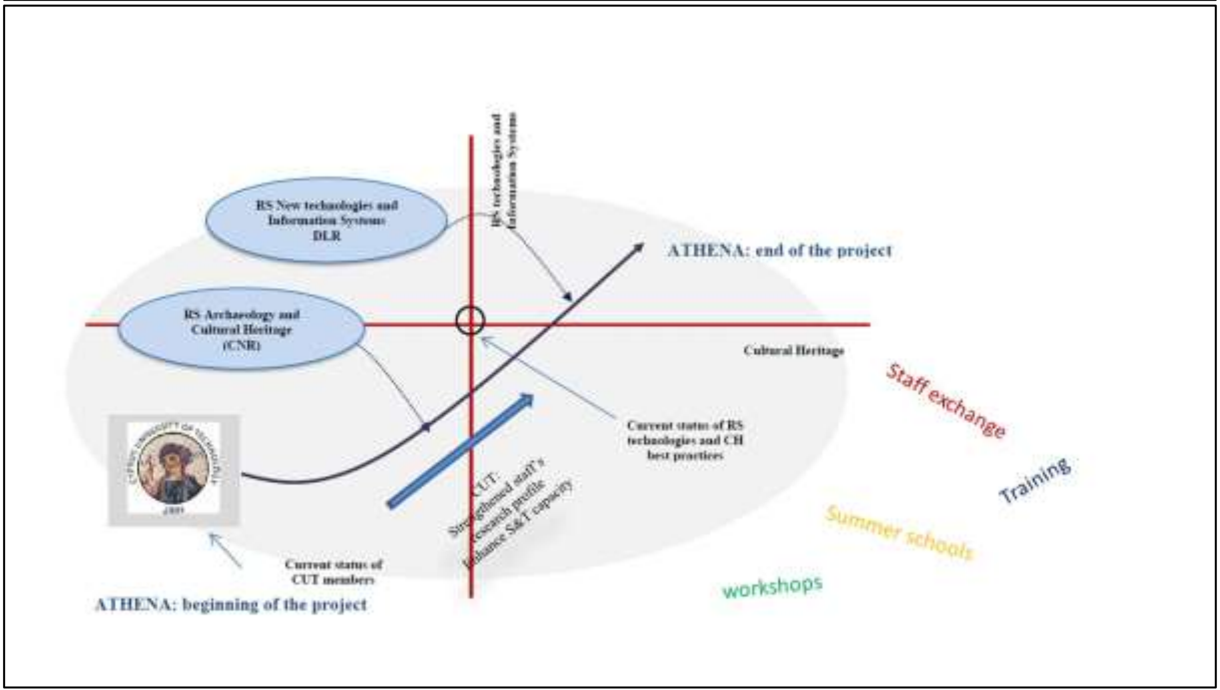
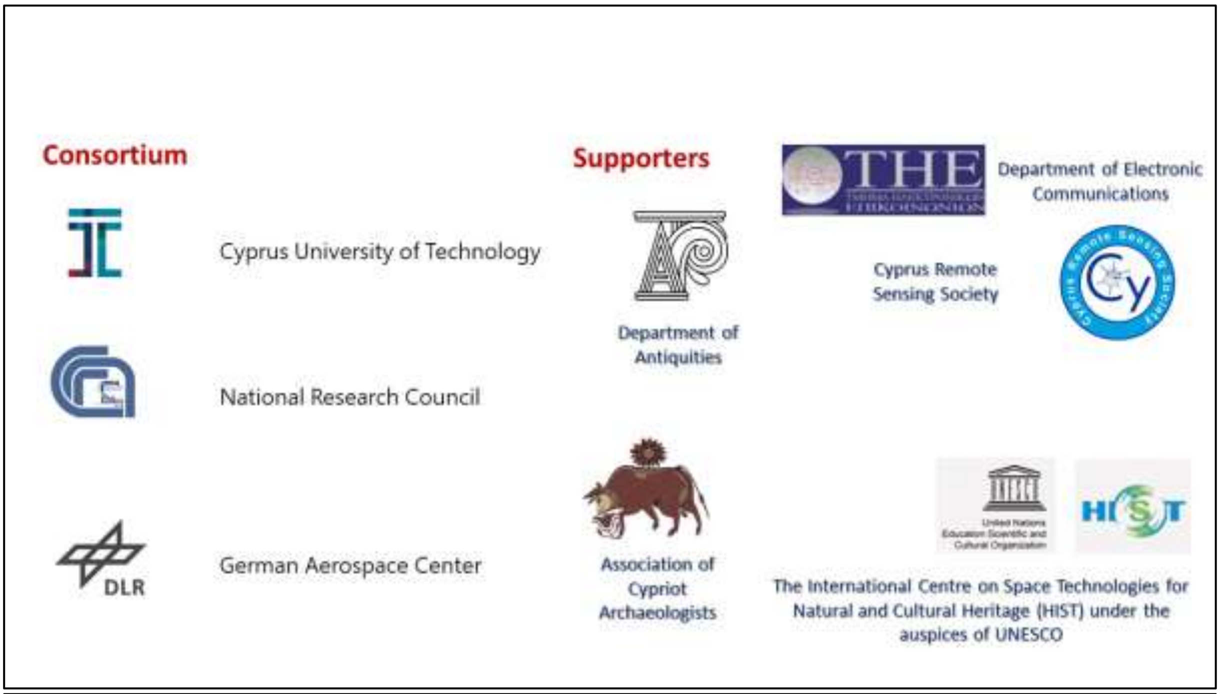



Consortium
Cyprus University of Technology
National Research Council
DLR
German Aerospace Center
Supporters
Department of Antiquities
Association of Cypriot Archaeologists
THE
Department of Electronic Communications
Cyprus Remote Sensing Society
HIST
The International Centre on Space Technologies for Natural and Cultural Heritage (HIST) under the auspices of UNESCO


About the project
• Introduction
• About the project
• Training activities and knowledge transfer
• Examples from common research activities
• Conclusion

Training activities and knowledge transfer

3rd Virtual Training

Topic: Archaeological looting: Ancient problems and New approaches based on Remote Sensing

Trainer: CNR

1st September 2017

Cyprus University of Technology, Limassol - Cyprus

2nd Workshop

Topic: Remote sensing for Cultural Heritage beyond Europe

Trainer: CNR/DLR

20th April 2017

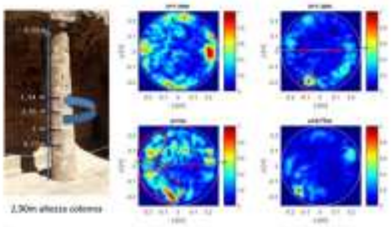
RSCy2017, Paphos - Cyprus

Training activities and knowledge transfer

2nd Short term visit on site (OS2)

The second short term visit on site within the ATHENA project activities for testing, evaluation and discussion in Cultural Heritage sites has been carried out during March 2017.

CNR & CUT staff researchers visited the UNESCO archaeological site "Tombs of the Kings" in Paphos. Portable GPR's have been used to map the preservation status of specific elements of tomb no. 4.



Training activities and knowledge transfer

ATHENA @ the Departments of Civil Engineering and Geomatics summer school June 2017

ATHENA presented at Sheffield University.

Training activities and knowledge transfer

ATHENA supported RSCy 2017

remote sensing

The ATHENA team participated in the Special Issue

"Advances in Remote Sensing for Archaeological Heritage"

ATHENA supported EGU Special Session

Training activities and knowledge transfer

ATHENA...
back to school!

Researcher's Night 2016

About the project

- Introduction
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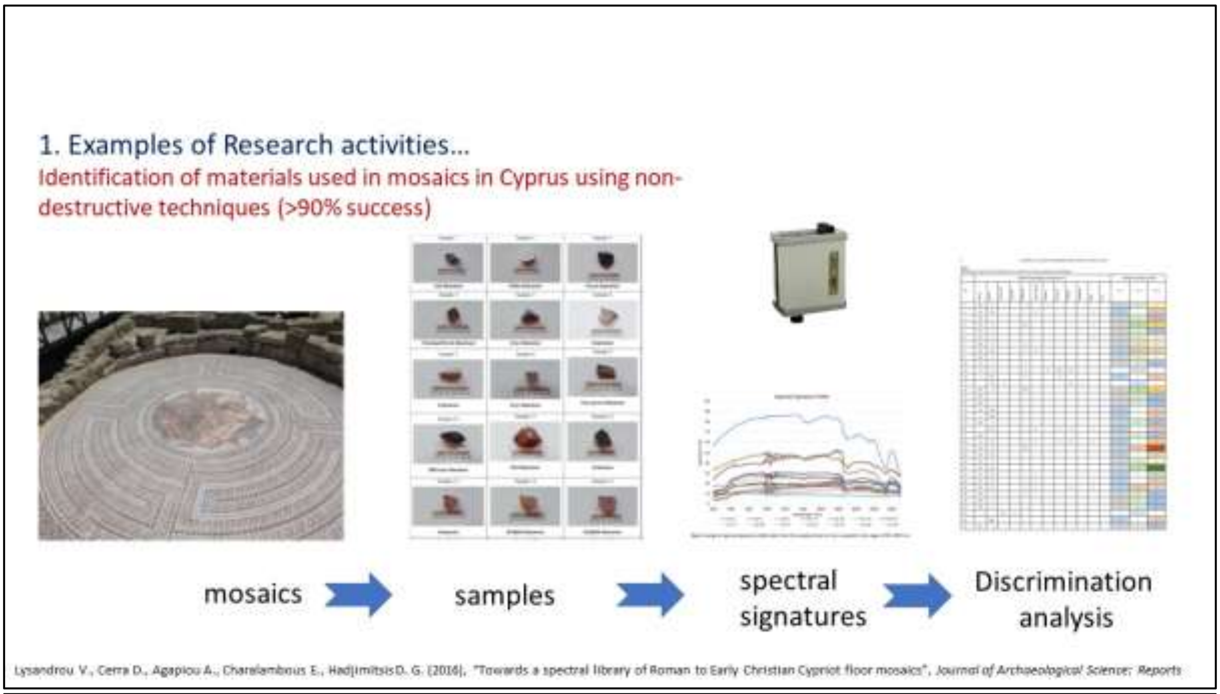
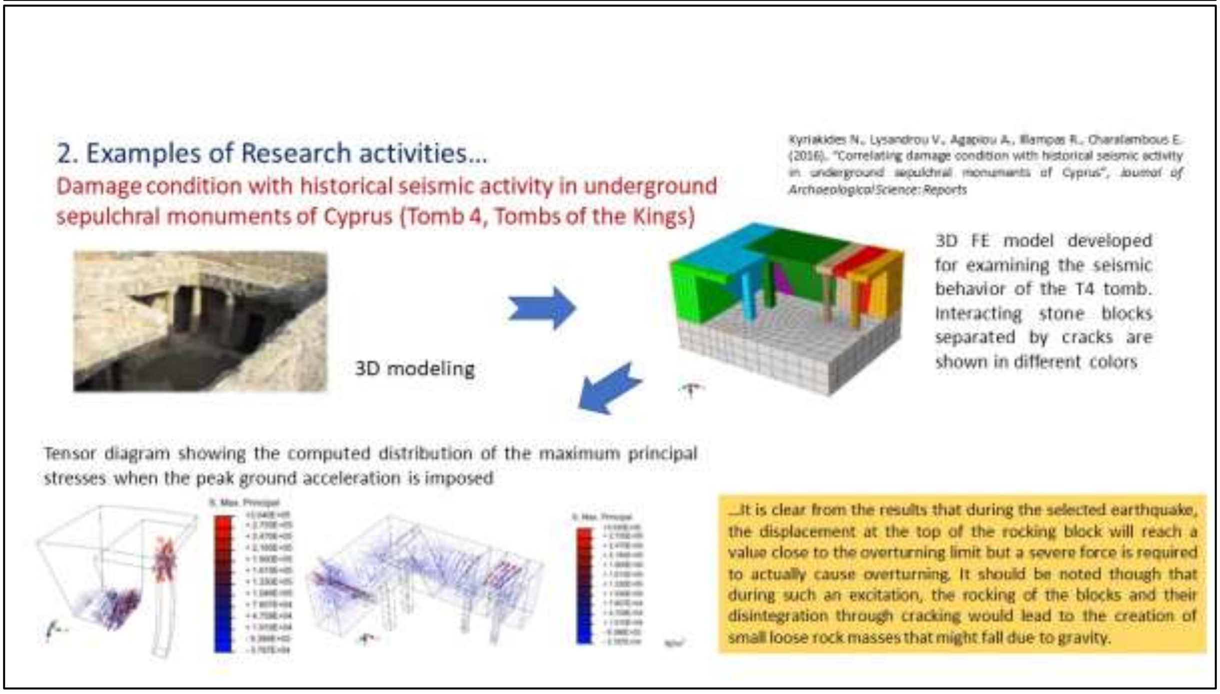

1. Examples of Research activities…
Identification of materials used in mosaics in Cyprus using non-destructive techniques (>90% success)
mosaics
samples
spectral signatures
Discrimination analysis
Lysandrou V., Cerra D., Agapiou A., Charalambous E., Hadjimitsis D. G. (2016), "Towards a spectral library of Roman to Early Christian Cypriot floor mosaics", Journal of Archaeological Science: Reports


2. Examples of Research activities…
Damage condition with historical seismic activity in underground sepulchral monuments of Cyprus (Tomb 4, Tombs of the Kings)
Kyriakides N., Lysandrou V., Agapiou A., Illampas R., Charalambous E. (2016). "Correlating damage condition with historical seismic activity in underground sepulchral monuments of Cyprus", Journal of Archaeological Science: Reports
3D modeling
3D FE model developed for examining the seismic behavior of the T4 tomb. Interacting stone blocks separated by cracks are shown in different colors
Tensor diagram showing the computed distribution of the maximum principal stresses when the peak ground acceleration is imposed
…It is clear from the results that during the selected earthquake, the displacement at the top of the rocking block will reach a value close to the overturning limit but a severe force is required to actually cause overturning. It should be noted though that during such an excitation, the rocking of the blocks and their disintegration through cracking would lead to the creation of small loose rock masses that might fall due to gravity.

3. Examples of Research activities…
Mapping and monitoring looted areas

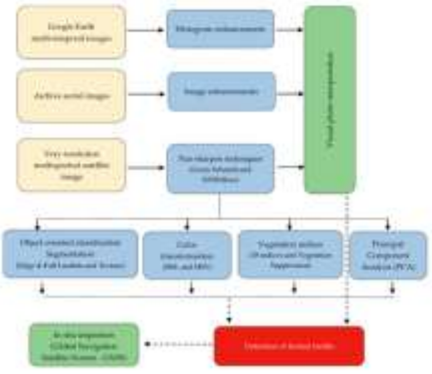
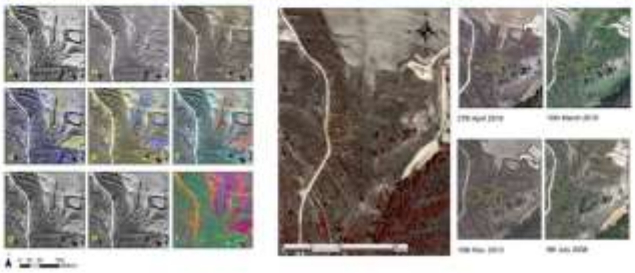


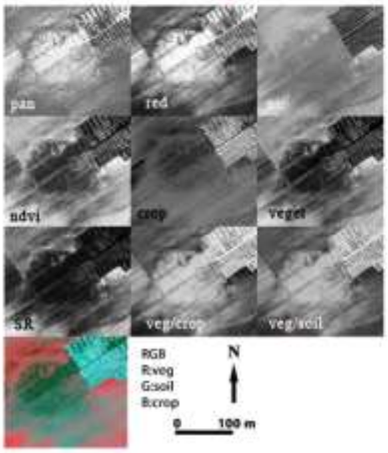
Figure 1. Overall methodology and resources used for the current study.

……existing literature is mainly focused on the exploitation of remote sensing technologies for extended looted areas, where hundreds of looted signs are visible from space and air. On the contrary, this paper aims to present small-scale looting attempts which seem to have been made in recent years in Cyprus. In addition, no scheduled flight or satellite overpass was performed to monitor the site under investigation. Therefore, the use of existing datasets captured by various sources and sensors was the only means of mapping the looting imprints.

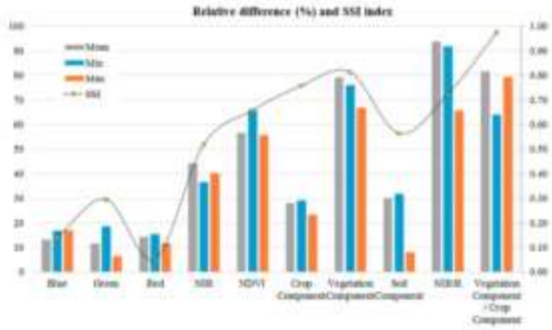


Agapiou, A.; Lysandrou, V.; Hadjimitsis, D.G. Optical Remote Sensing Potentials for Looting Detection. Geosciences 2017, 7, 98.

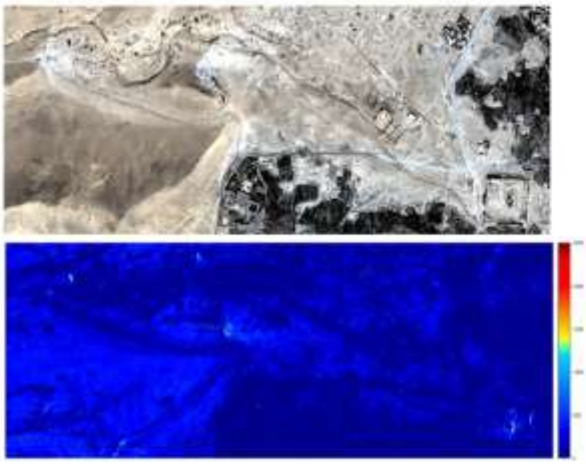
4. Examples of Research activities…
Detection of underground buried remains



Agapiou A., Lysandrou V., Lasaponara R., Masini N., Hadjimitsis D. G., 2016, Study of the variations of archaeological marks at Neolithic site of Lucera, Italy using multispectral high resolution datasets, Remote Sensing, 8(9), 723; doi:10.3390/rs8090723.



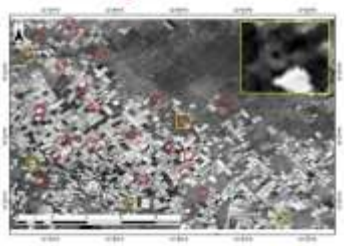
5. Examples of Research activities…
Monitoring CH sites in in-accessible areas



The intentional damage to local Cultural Heritage sites carried out in recent months by the Islamic State have received wide coverage from the media worldwide. Earth Observation data provide important information to assess this damage in such non-accessible areas, and automated image processing techniques will be needed to speed up the analysis if a fast response is desired. This paper shows the first results of applying fast and robust change detection techniques to sensitive areas, based on the extraction of textural information and robust differences of brightness values related to pre- and post-disaster satellite images. A map highlighting potentially damaged buildings is derived, which could help experts at timely assessing the damages to the Cultural Heritage sites of interest. Encouraging results are obtained for two archaeological sites in Syria and Iraq.

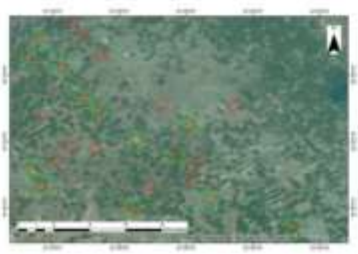
Cerra, D., Plank, S., Lysandrou, V., Tian, J., 2016, Cultural Heritage Sites in Danger—Towards Automatic Damage Detection from Space. Preprints 2016, 2016090055 (doi: 10.20944/preprints201609.0055.v1).

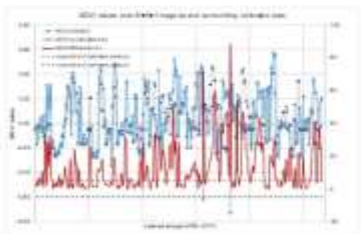
6. Examples of Research activities…
Use of big data..



This study aims to demonstrate results and considerations regarding the use of remote sensing big data for archaeological and Cultural Heritage management large scale applications. For this purpose, the Earth Engine© developed by Google© was exploited. Earth Engine© provides a robust and expandable cloud platform where several freely distributed remote sensing big data, such as Landsat, can be accessed, analysed and visualized.

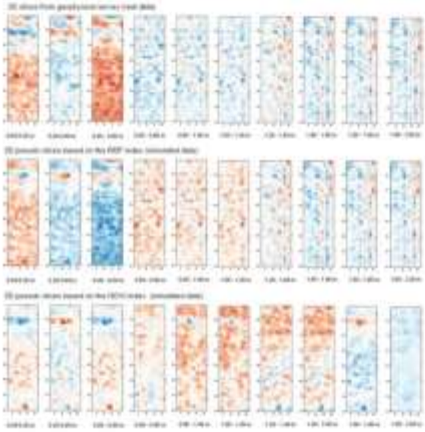
Agapiou A., 2016, Remote Sensing Heritage in a petabyte-scale: Satellite Data and Heritage Earth Engine© applications, International Journal of Digital Earth, 10.1080/17538947.2016.1250829.

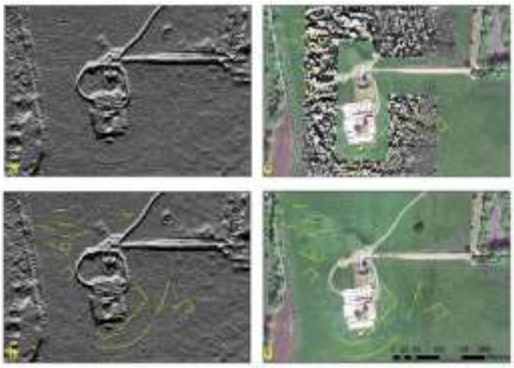




7. Examples of Research activities…

Research on fusion of RS data..





Agapiou A., Sarris A., Papadopoulos N., Hadjimitsis D. G., Pseudo penetration of optical remote sensing images: Application for the detection buried archaeological remains in the area of Vészto-Mágor Tell, Hungary, Remote Sensing, (under review).

About the project

- Introduction
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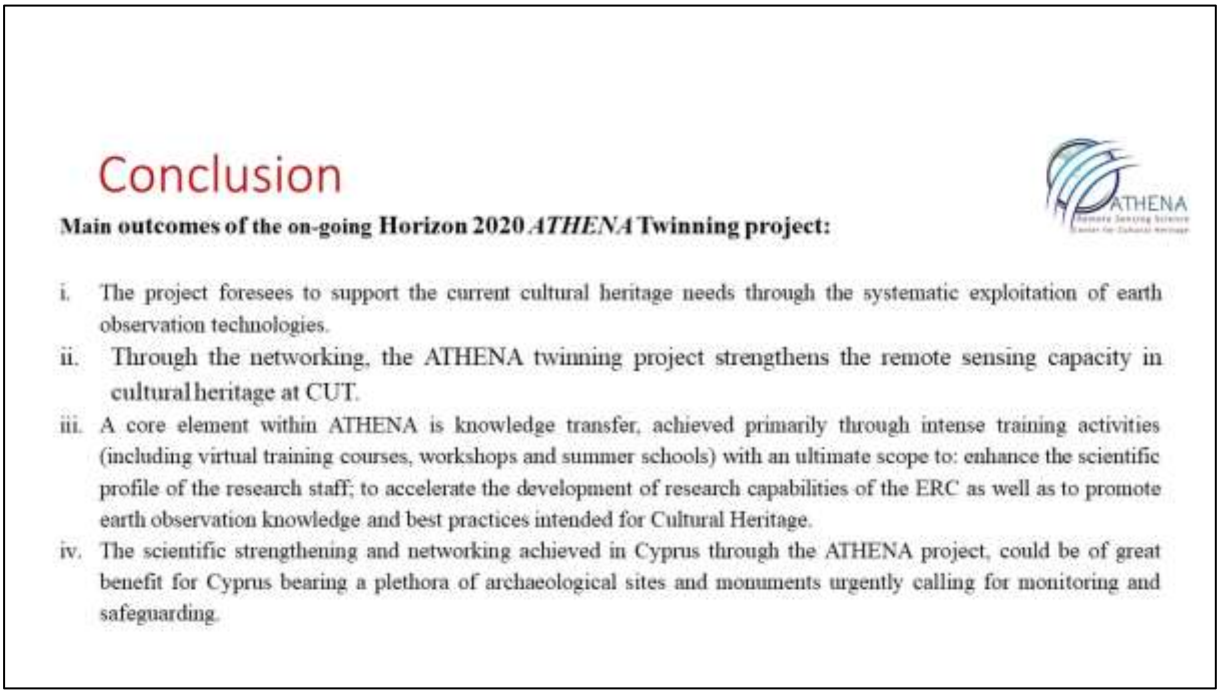
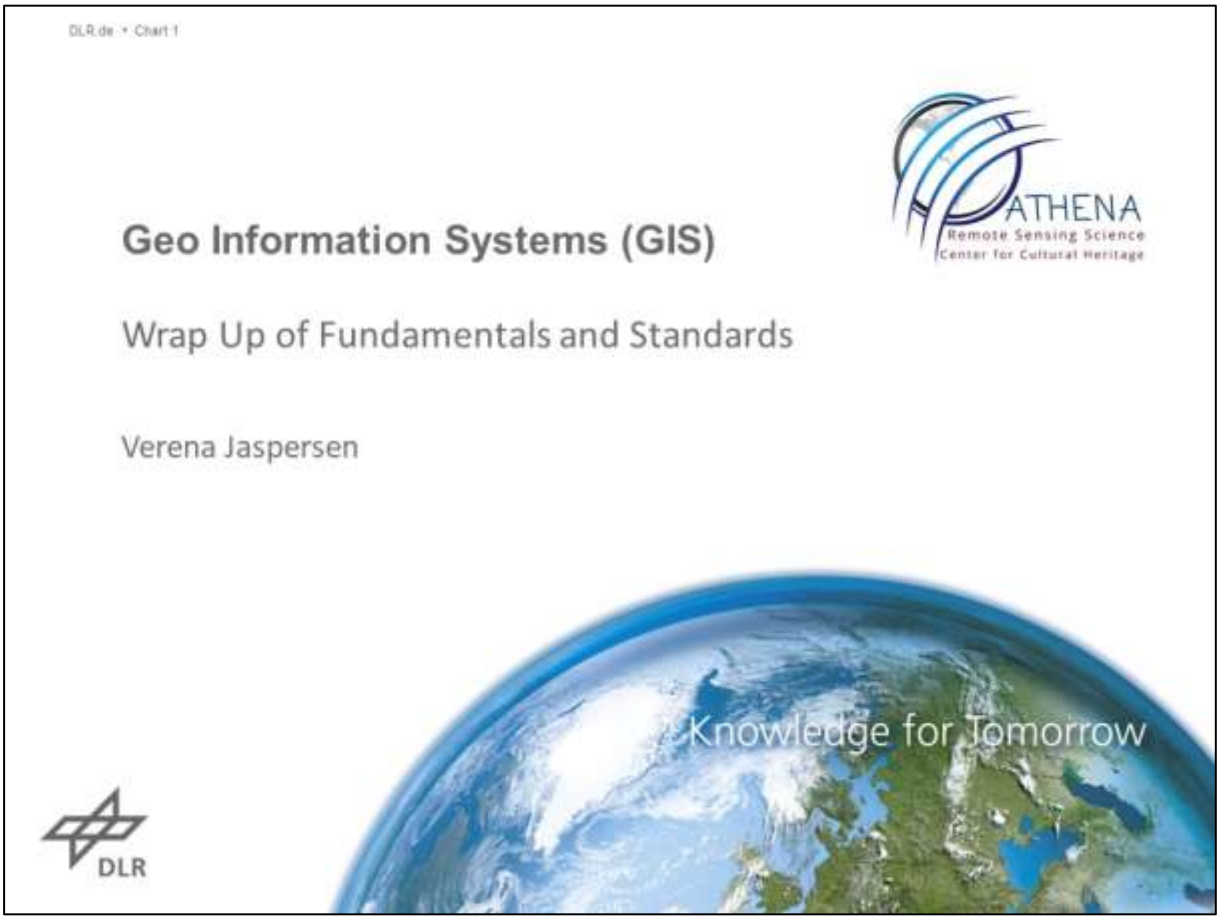
- Examples from common research activities
- Conclusion



2.2 Second presentation - Geo Information Systems (GIS)



DLR.de • Chart 2 > GIS > Verena Jaspersen > Webinar 17/10/2018

Agenda

- What is GIS
- Understanding Geospatial Data Models
- GIS Applications and GIS Software
- GIS and the Need for Standards
- Open Geospatial Consortium and OGC Standards
- INSPIRE

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DLR.de • Chart 3 > GIS > Verena Jaspersen > Webinar 17/10/2018

What is GIS

GIS is a computer based system to aid in the

- Collection
- Maintenance
- Storage
- Analysis
- Output
- Distribution

of spatial and non spatial data

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https://learn.canvas.net/courses/464/files/238860/preview?verifier=4Yg61PzISQCTViw simGQrRk4y4QdwPIN57fquJjk

Understanding Geospatial Data Models

- spatial data (where):

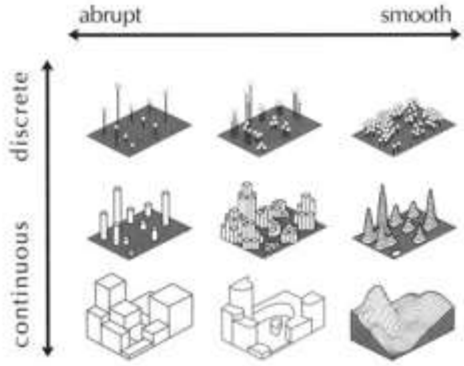
  specific location

- attribute data (what):

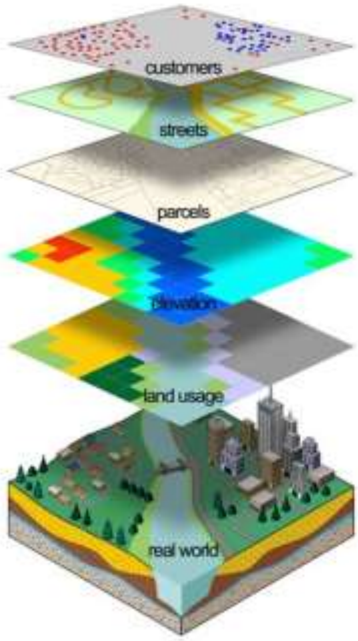
  specifies what is at that location
  stored in a database table

DLR.de • Chart 6 > GIS > Verena Jaspersen > Webinar 17/10/2018

Types of spatial phenomena



https://www.e-education.psu.edu/geog486/sites/www.e-education.psu.edu.geog486/files/image/L05_fig01.jpg



http://www.williamsnd.com/usrfiles/dept/136/img/gis_layers.png

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Attributes

Attributes of Recent Earthquakes

Object ID	Earthquake Date	Depth	Earthquake ID	Latitude	Longitude	Magnitude
52263583	12/15/2011	9.4	60291161	19.3043	-155.2217	2.8
52263587	12/15/2011	2.9	60291156	19.3808	-155.282	2.5
52263599	12/15/2011	60.9	c0007727	13.0353	-88.6686	4.9

Record: 0 Records (0 out of 29 Selected) Options Commit

http://doc.arcgis.com/de/maps-for-sharepoint/arcgis-map-web-part/GUID-AF491B84-B33B-4CFD-8929-88D4E53D2F45-web.png

Options Zoom to Clear Selection Refresh

Cities | Continent | World

OBJECTID	POP_RANK	CITY_NAME	POP
144	1	Sao Paulo	10021295
451	1	Bogota	7102602
1104	1	Cairo	7734614
85	1	Lima	7737002

https://doc.arcgis.com/de/web-appbuilder/create-apps/GUID-62B44A73-C4E0-41F7-9C03-A65B7BCD4667-web.png

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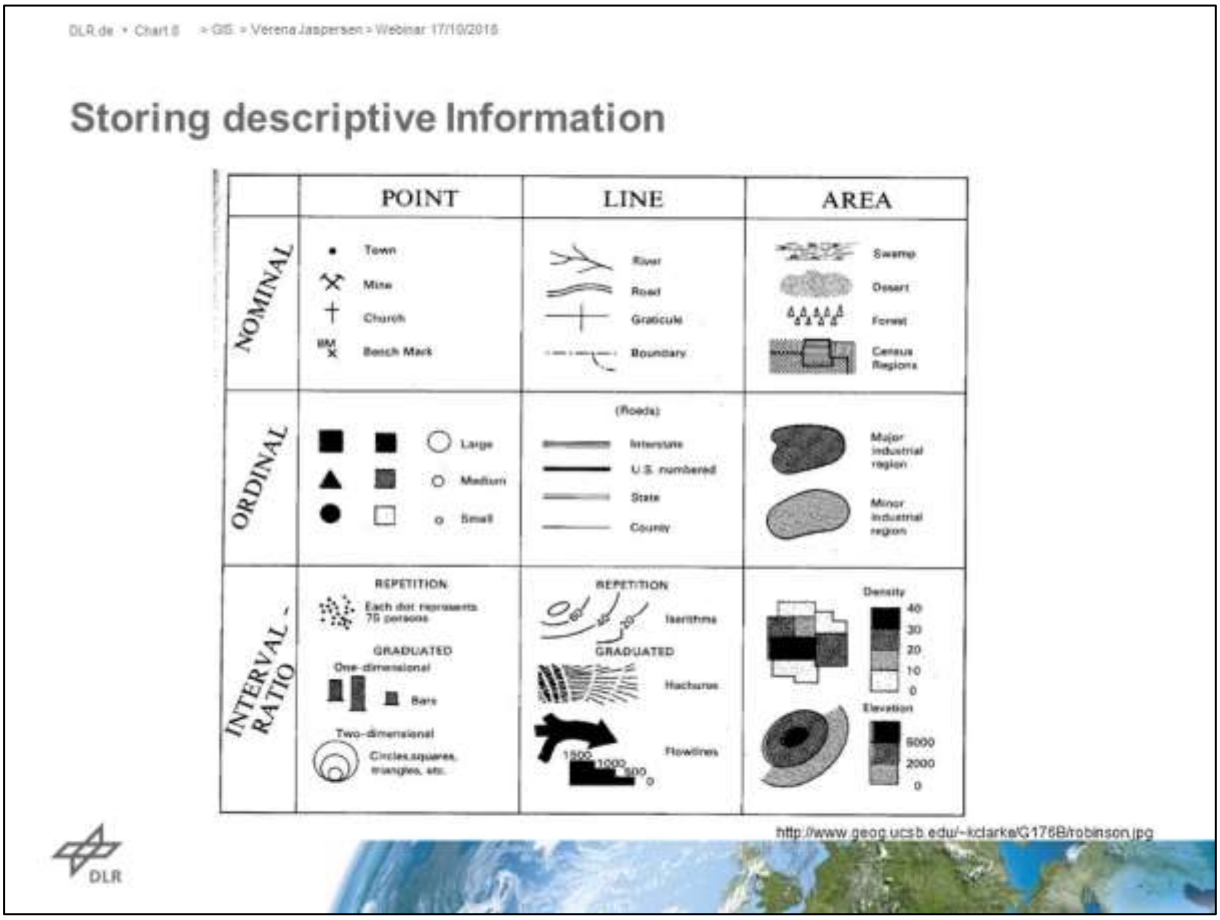
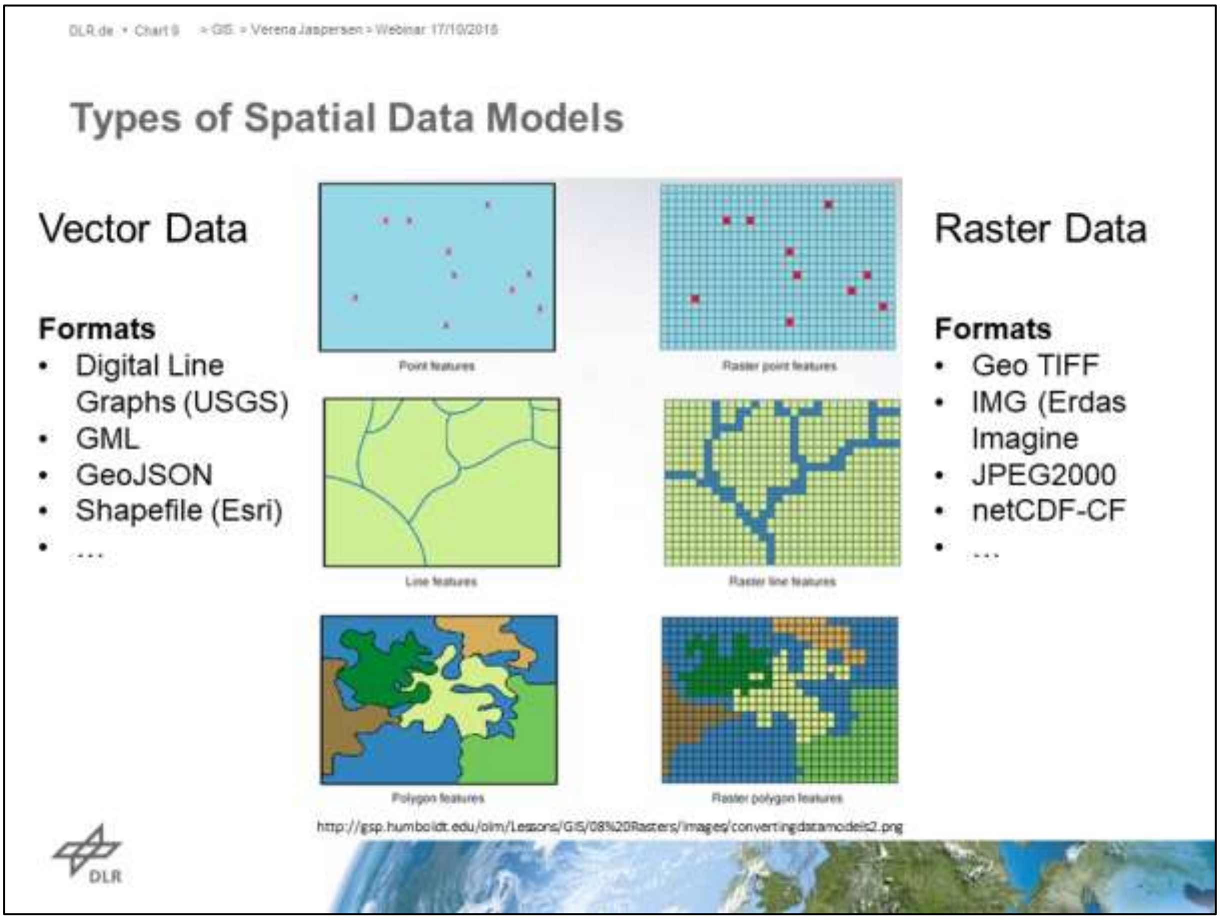
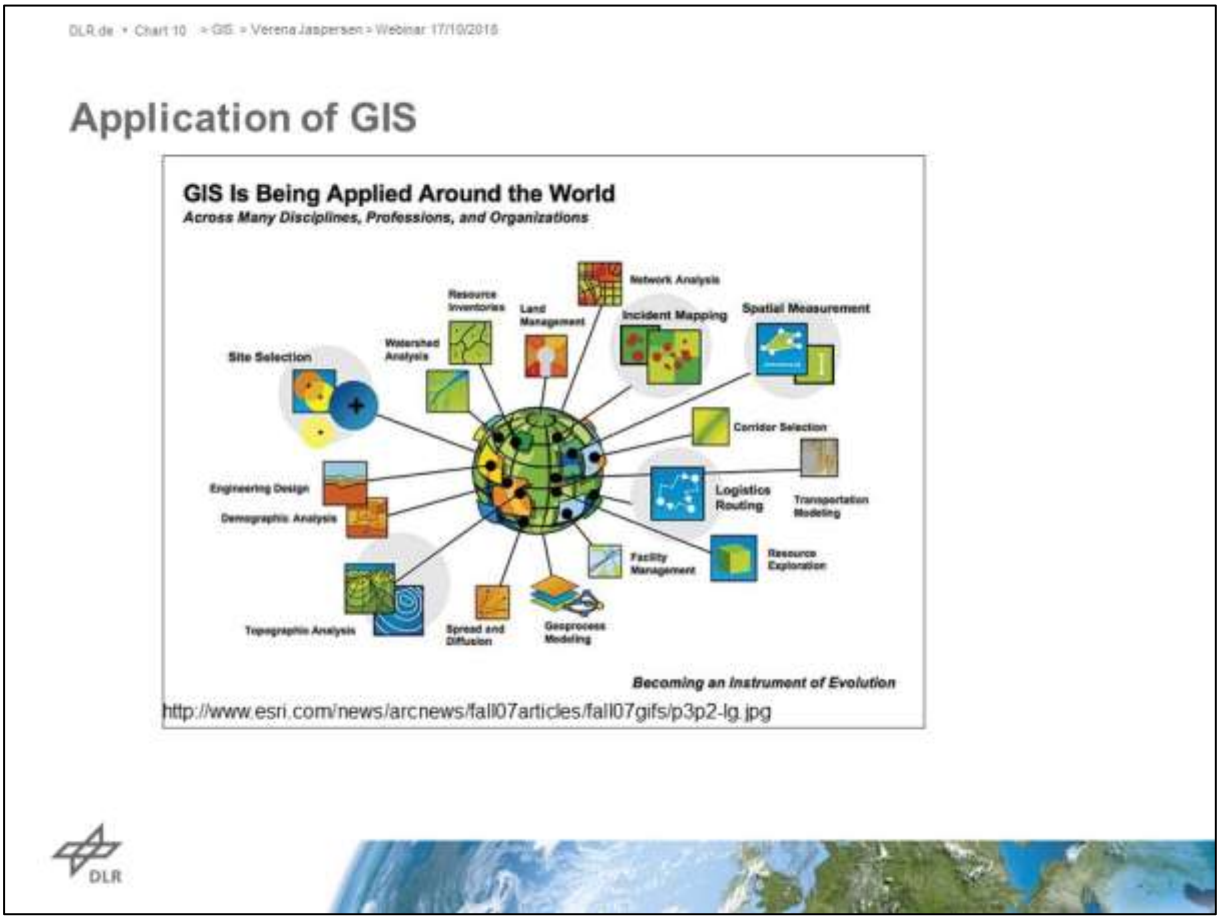
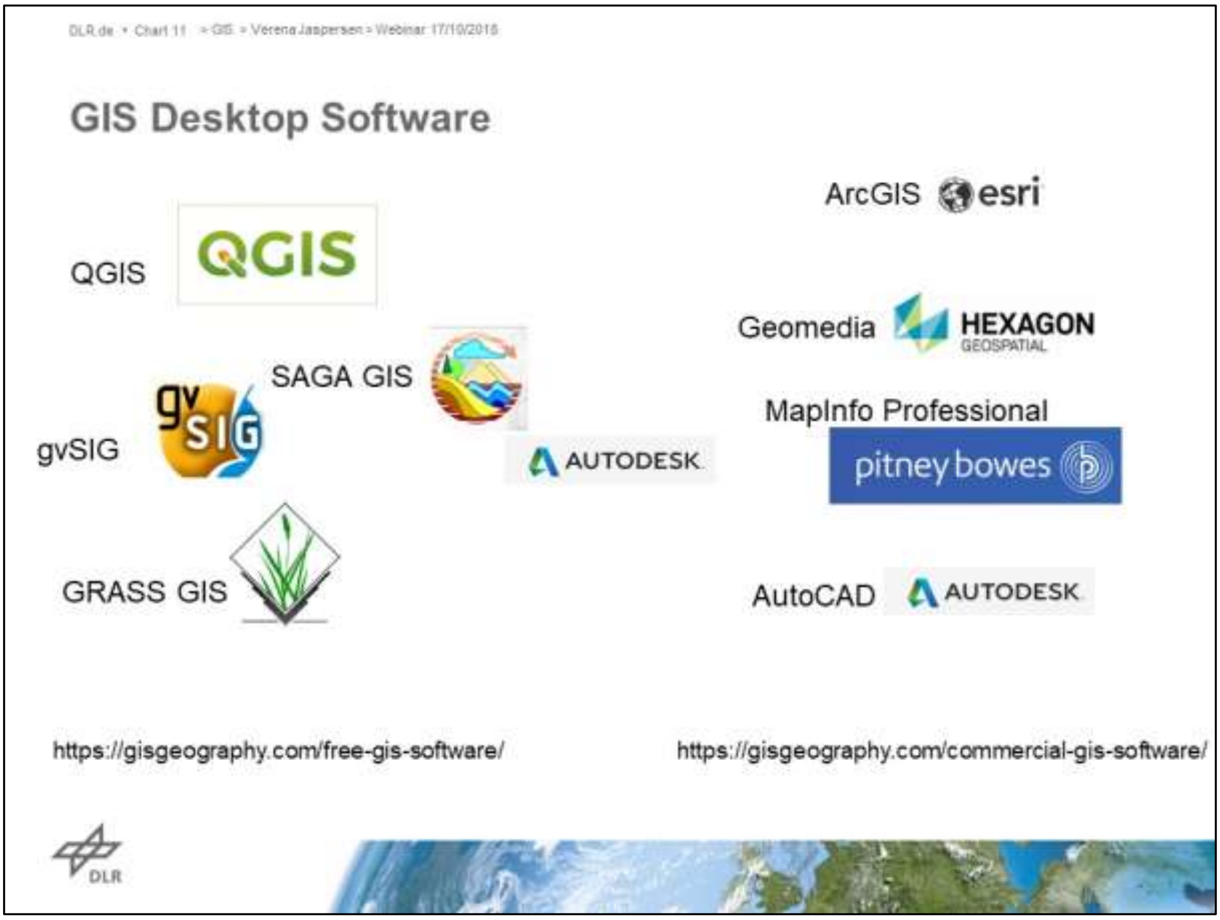
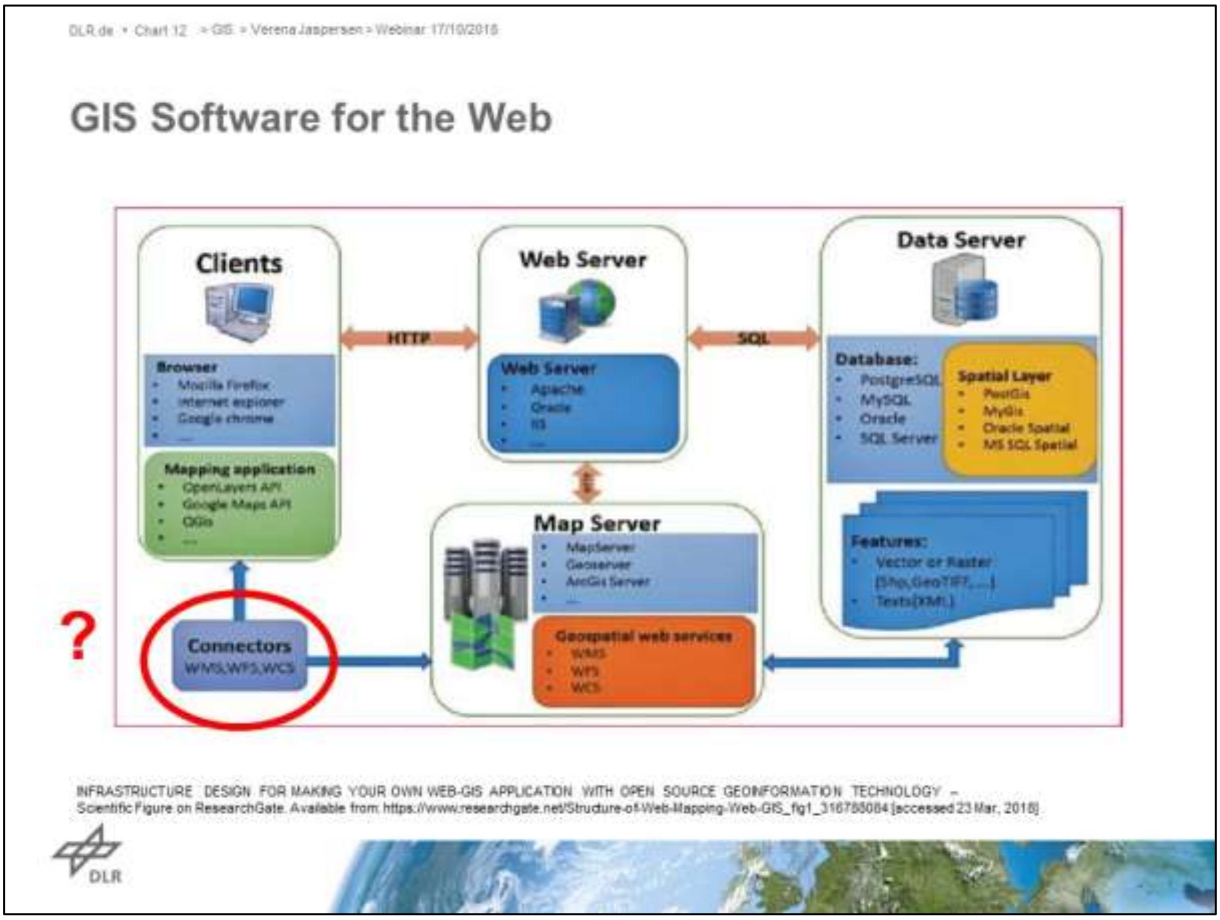
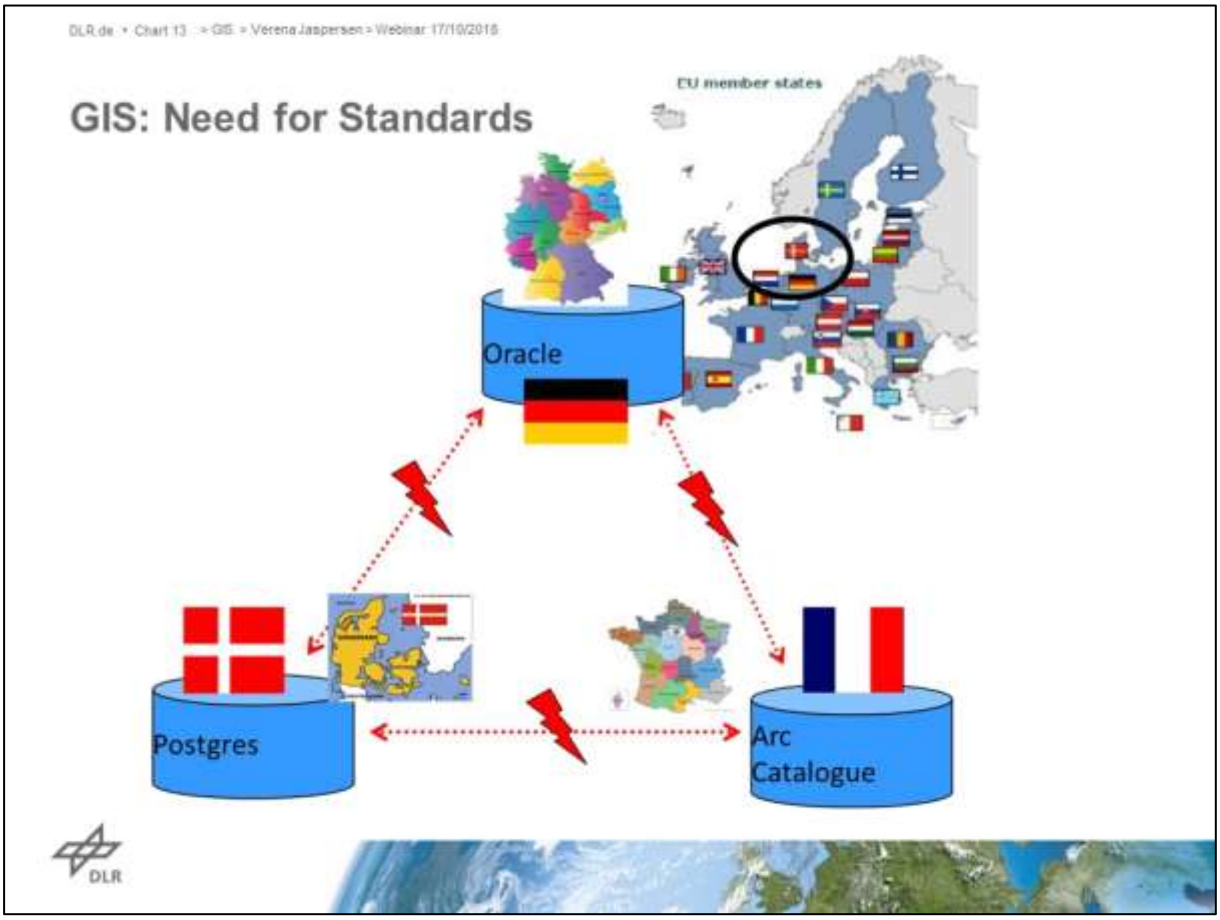

DLR.de • Chart 8 > GIS > Verena Jaspersen > Webinar 17/10/2018
Storing descriptive Information
POINT
LINE
AREA
NOMINAL
ORDINAL
INTERVAL - RATIO
Town
Mine
Church
Bench Mark
River
Road
Graticule
Boundary
Swamp
Desert
Forest
Census Regions
(Roads)
Large
Medium
Small
Interstate
U.S. numbered
State
County
Major industrial region
Minor industrial region
REPETITION
Each dot represents 75 persons
GRADUATED
One-dimensional
Bars
Two-dimensional
Circles, squares, triangles, etc.
Isarithms
Hachures
Flowlines
Density
40
30
20
10
0
Elevation
5000
2000
0
http://www.geog.ucsb.edu/~kclarke/G176B/robinson.jpg
DLR

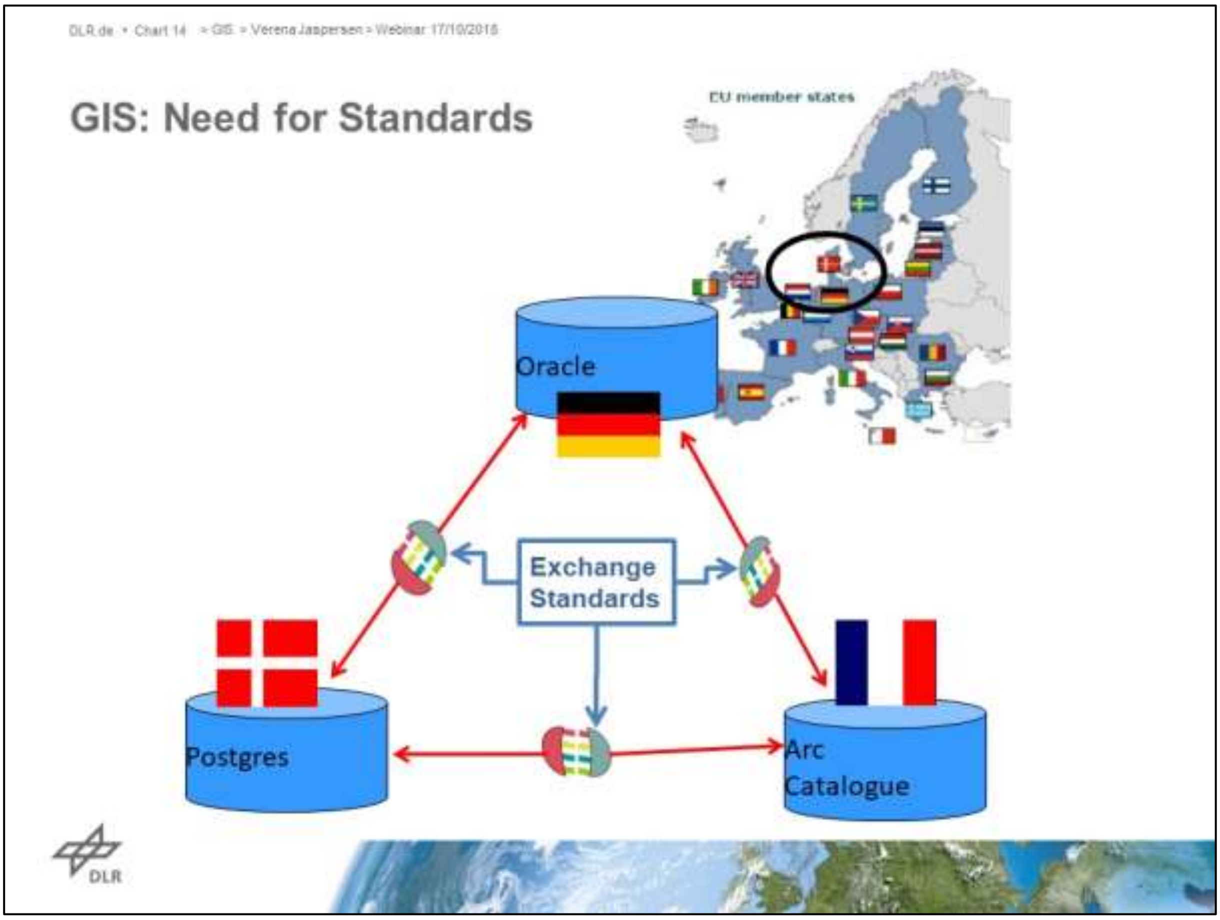

DLR.de • Chart 9 > GIS > Verena Jaspersen > Webinar 17/10/2018
Types of Spatial Data Models
Vector Data
Formats
• Digital Line Graphs (USGS)
• GML
• GeoJSON
• Shapefile (Esri)
• ...
Point features
Raster point features
Line features
Raster line features
Polygon features
Raster polygon features
Raster Data
Formats
• Geo TIFF
• IMG (Erdas Imagine
• JPEG2000
• netCDF-CF
• ...
http://gsp.humboldt.edu/olm/Lessons/GIS/08%20Rasters/Images/convertingdatamodels2.png
DLR

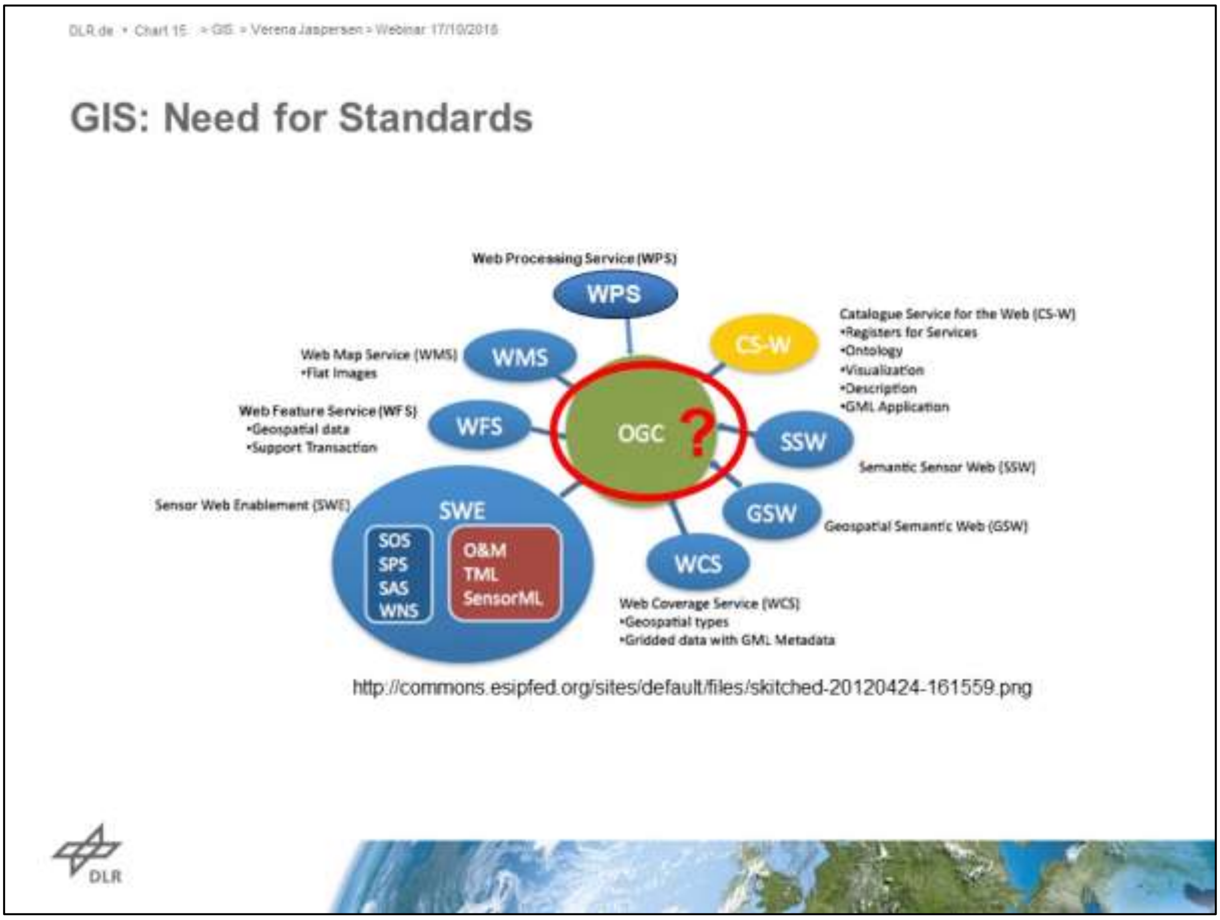

DLR.de • Chart 10 > GIS > Verena Jaspersen > Webinar 17/10/2018
Application of GIS
GIS Is Being Applied Around the World
Across Many Disciplines, Professions, and Organizations
Network Analysis
Resource Inventories
Land Management
Incident Mapping
Spatial Measurement
Watershed Analysis
Site Selection
Corridor Selection
Engineering Design
Demographic Analysis
Logistics Routing
Transportation Modeling
Facility Management
Resource Exploration
Topographic Analysis
Spread and Diffusion
Geoprocess Modeling
Becoming an Instrument of Evolution
http://www.esri.com/news/arcnews/fall07articles/fall07gifs/p3p2-lg.jpg
DLR


DLR.de • Chart 11 > GIS > Verena Jaspersen > Webinar 17/10/2018
GIS Desktop Software
QGIS
QGIS
SAGA GIS
gvSIG
gvSIG
GRASS GIS
AUTODESK
ArcGIS
esri
Geomedia
HEXAGON
GEOSPATIAL
MapInfo Professional
pitney bowes
AutoCAD
AUTODESK
https://gisgeography.com/free-gis-software/
https://gisgeography.com/commercial-gis-software/
DLR


DLR.de • Chart 12 > GIS > Verena Jaspersen > Webinar 17/10/2018
GIS Software for the Web
Clients
Browser
Mozilla Firefox
Internet explorer
Google chrome
Mapping application
OpenLayers API
Google Maps API
QGis
HTTP
Web Server
Web Server
Apache
Oracle
IIS
SQL
Data Server
Database:
PostgreSQL
MySQL
Oracle
SQL Server
Spatial Layer
PostGis
MyGis
Oracle Spatial
MS SQL Spatial
Map Server
MapServer
Geoserver
ArcGis Server
Features:
Vector or Raster (Shp,GeoTIFF,...)
Texts(XML)
Geospatial web services
WMS
WFS
WCS
?
Connectors
WMS,WFS,WCS
INFRASTRUCTURE DESIGN FOR MAKING YOUR OWN WEB-GIS APPLICATION WITH OPEN SOURCE GEOINFORMATION TECHNOLOGY – Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/Structure-of-Web-Mapping-Web-GIS_fig1_316788084 [accessed 23 Mar. 2018]
DLR


DLR.de • Chart 13 > GIS > Verena Jaspersen > Webinar 17/10/2018
GIS: Need for Standards
EU member states
Oracle
Postgres
Arc
Catalogue
DLR


DLR.de • Chart 14 > GIS > Verena Jaspersen > Webinar 17/10/2018
GIS: Need for Standards
EU member states
Oracle
Exchange
Standards
Postgres
Arc
Catalogue
DLR


DLR.de • Chart 15 > GIS > Verena Jaspersen > Webinar 17/10/2018
GIS: Need for Standards
Web Processing Service (WPS)
WPS
Web Map Service (WMS)
•Flat Images
WMS
Web Feature Service (WFS)
•Geospatial data
•Support Transaction
WFS
Sensor Web Enablement (SWE)
SWE
SOS
SPS
SAS
WNS
O&M
TML
SensorML
OGC ?
CS-W
Catalogue Service for the Web (CS-W)
•Registers for Services
•Ontology
•Visualization
•Description
•GML Application
SSW
Semantic Sensor Web (SSW)
GSW
Geospatial Semantic Web (GSW)
WCS
Web Coverage Service (WCS)
•Geospatial types
•Gridded data with GML Metadata
http://commons.esipfed.org/sites/default/files/skitched-20120424-161559.png
DLR

DLR.de • Chart 16 > GIS > Verena Jaspersen > Webinar 17/10/2018

Open Geospatial Consortium

http://www.opengeospatial.org/

- OGC is an international standardization organization
- Definition of standards for geospatial content and services,

  GIS data processing and data sharing

➔ Interoperable Services

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OGC Web Services (OWS)

http://www.eclipse.org/community/eclipse_newsletter/2014/march/images/article1.1.png

Services

CSW – Catalogue Service for the Web
WMS – Web Map Service
WFS – Web Feature Service
WCS – Web Coverage Service
WPS – Web Processing Service

Formats

SLD – Styled Layer Descriptor
GML – Geographic Markup Language
Simple Features for SQL
...

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DLR.de • Chart 18 > GIS > Verena Jaspersen > March 2018

INSPIRE
Infrastructure for Spatial Information in the European community

- aims to create a **European Union spatial data infrastructure** for the purposes of EU environmental policies and policies or activities which may have an impact on the environment.
- Focused on sharing of environmental spatial information among public sector organisations ➔ semantic interoperable services
- Based on the infrastructures established and operated by the Member States of the European Union
- The Directive came into force on 15 May 2007 and will be implemented in various stages, with full implementation required by 2021.

https://inspire.ec.europa.eu/

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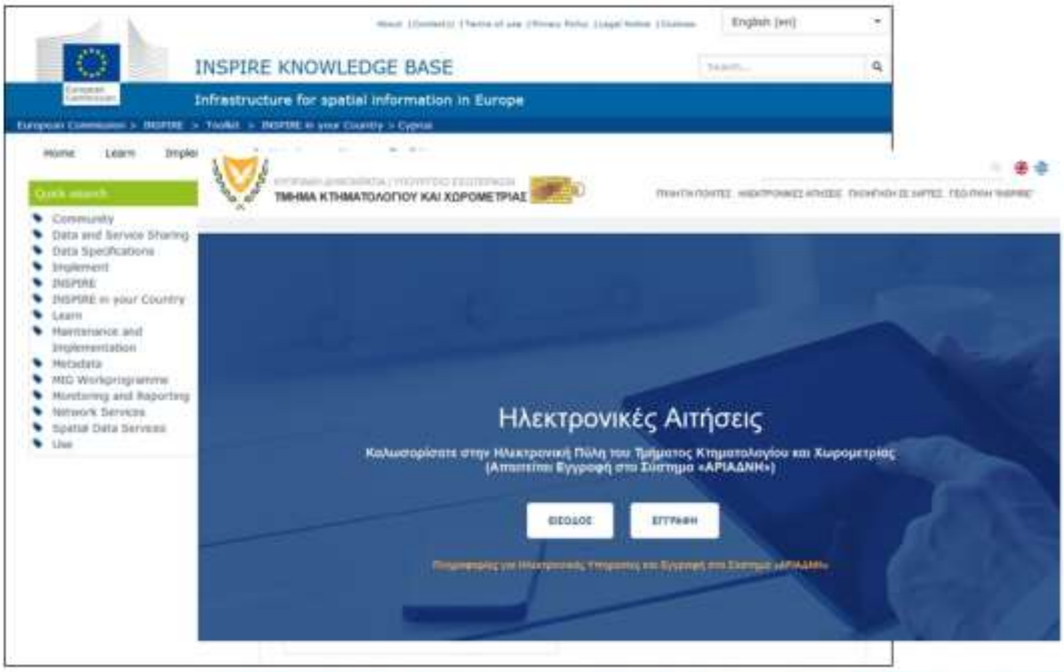
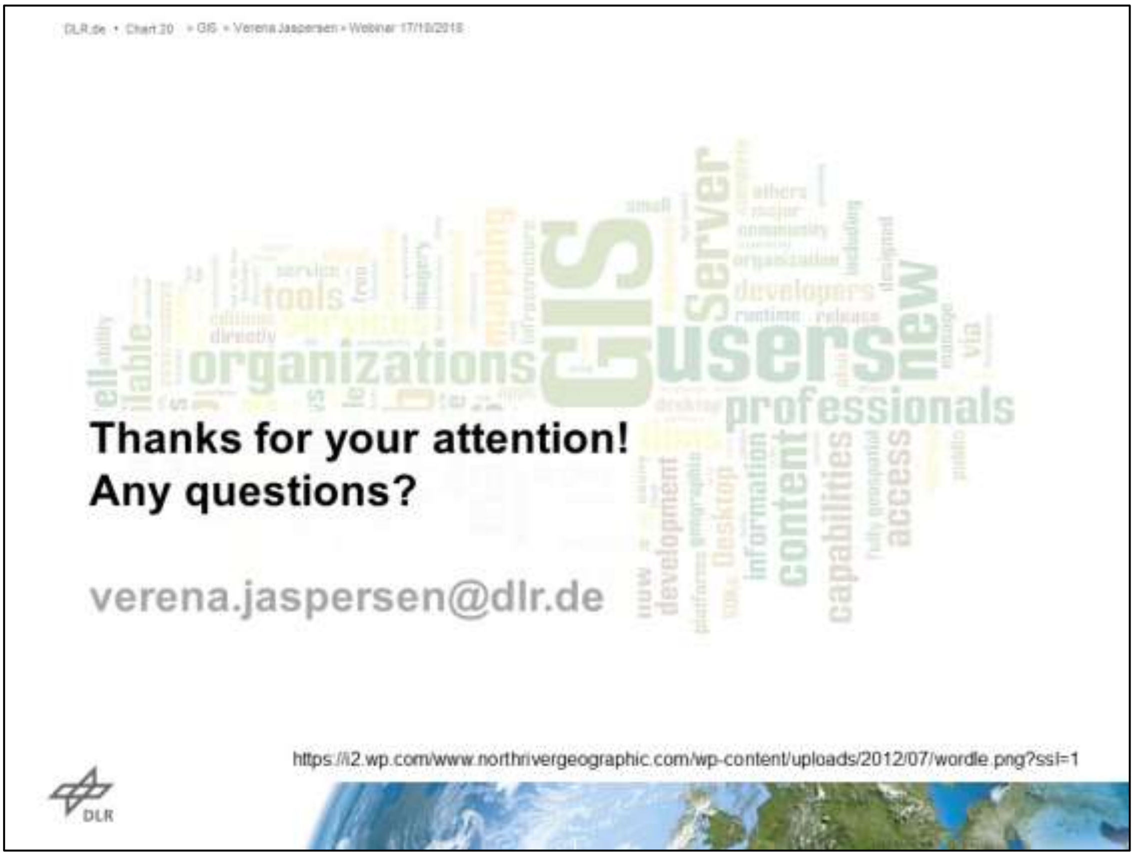
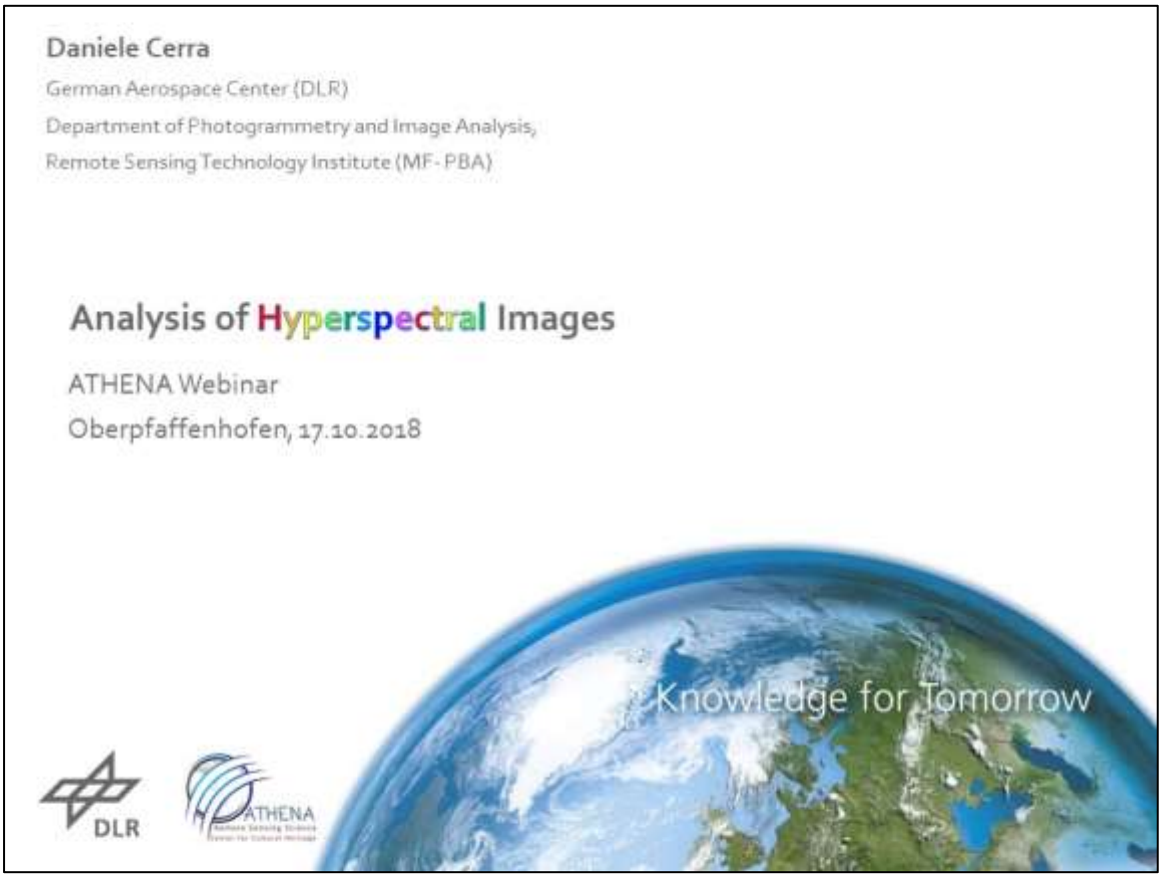
INSPIRE in your Country https://inspire.ec.europa.eu/INSPIRE-in-your-Country

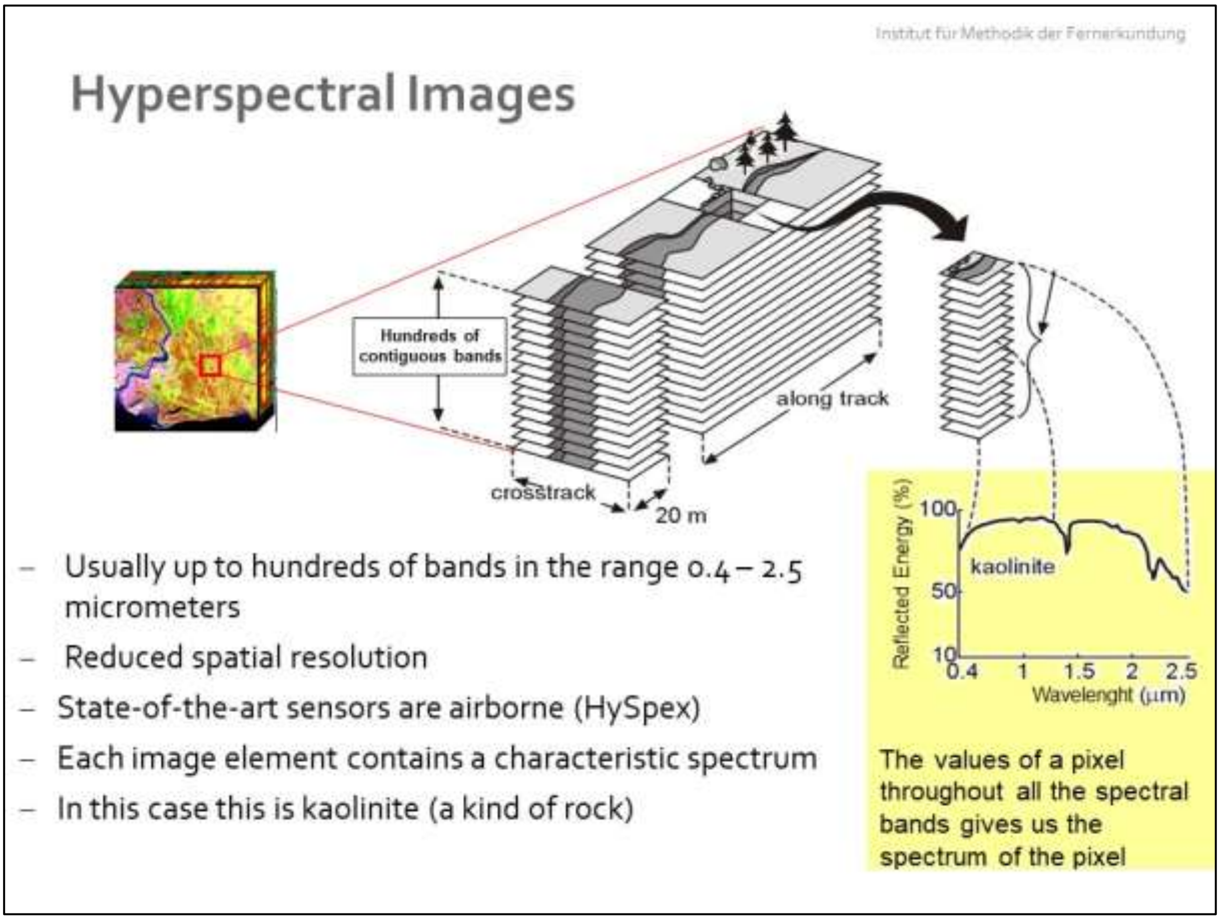


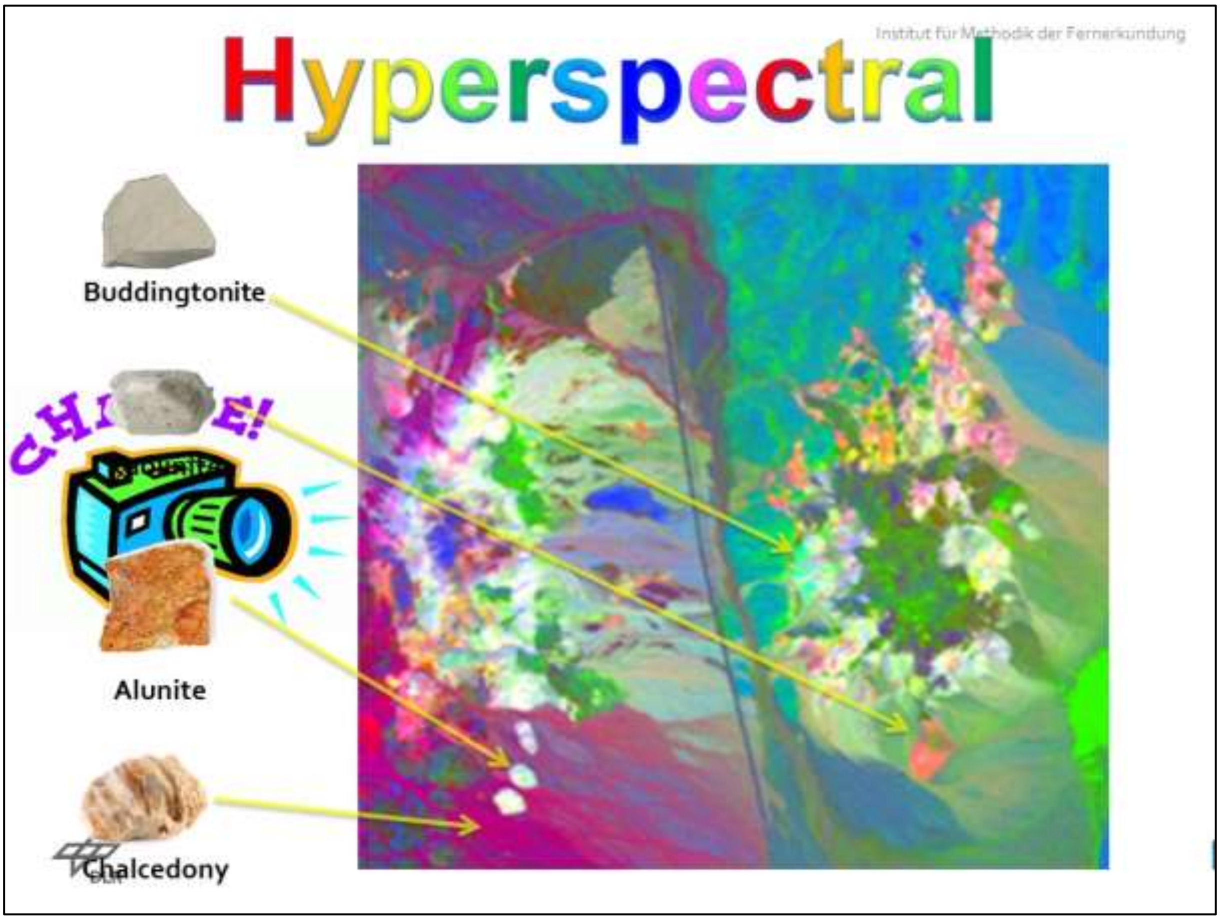
DLR

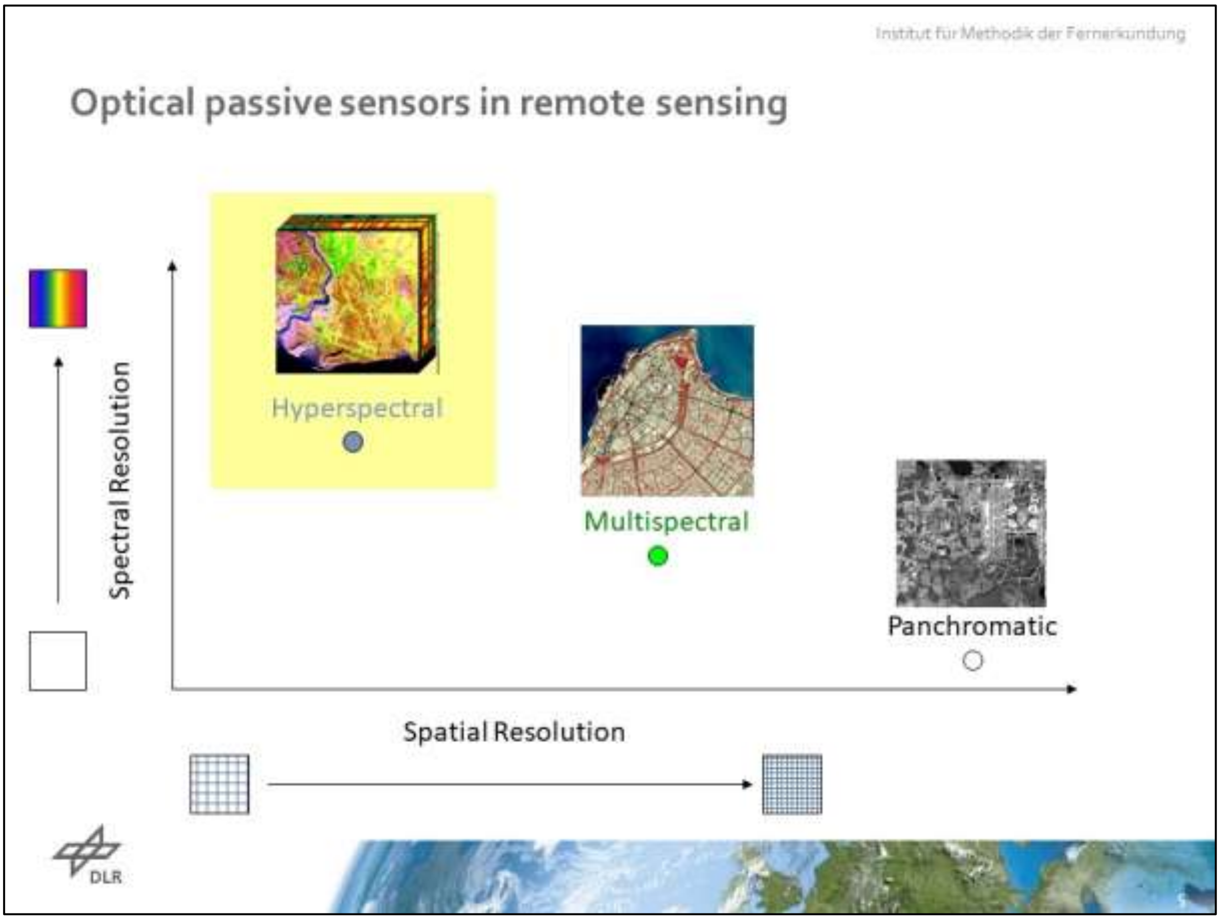


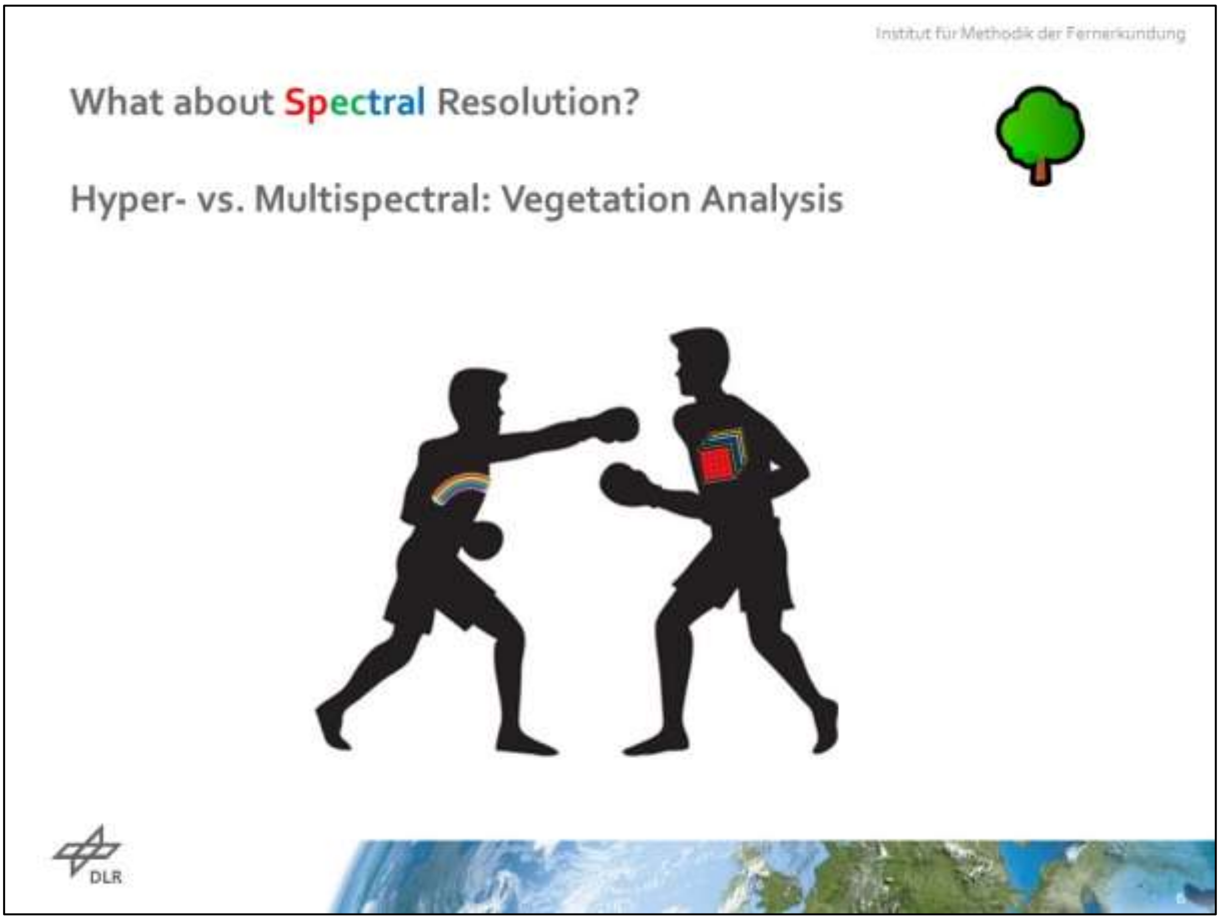
2.3 Third Presentation - Analysis of hyperspectral images

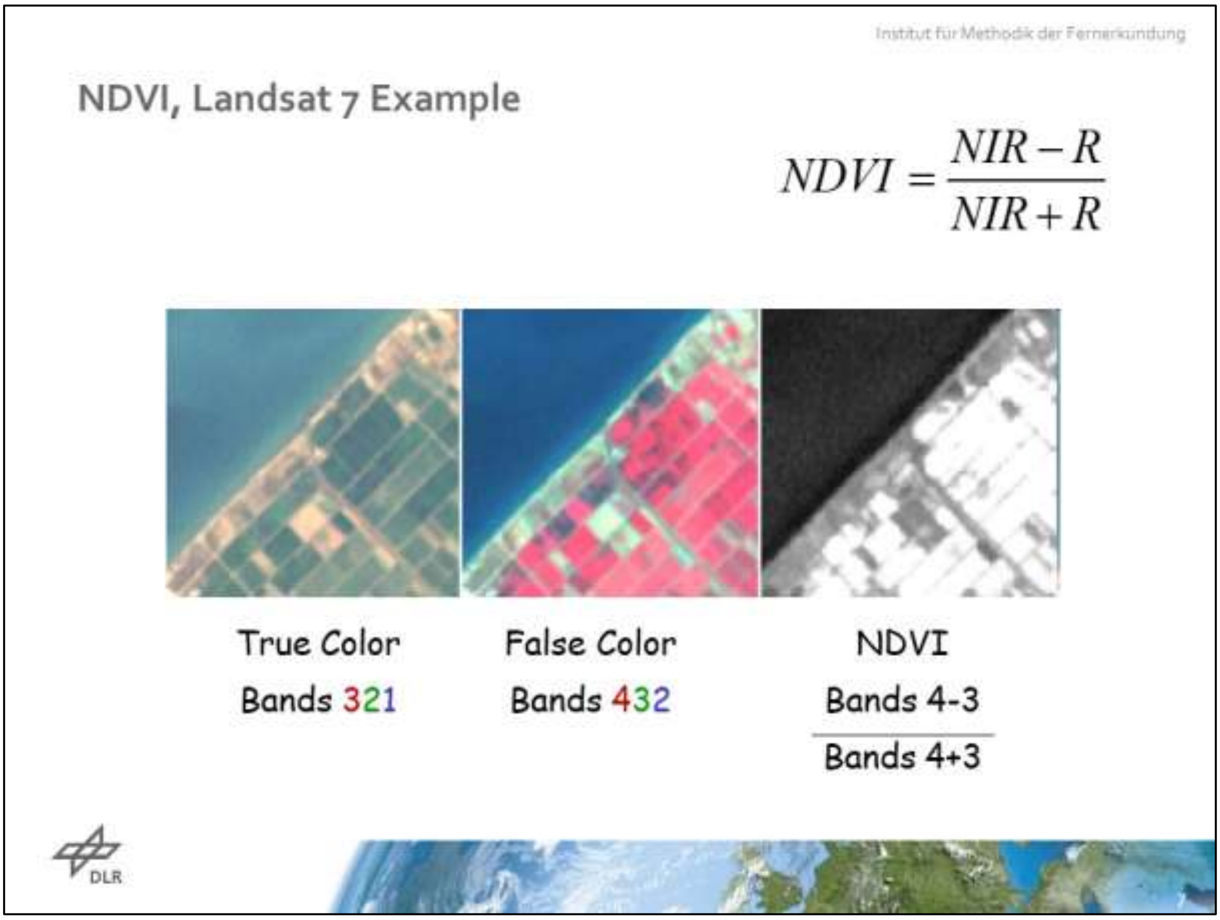


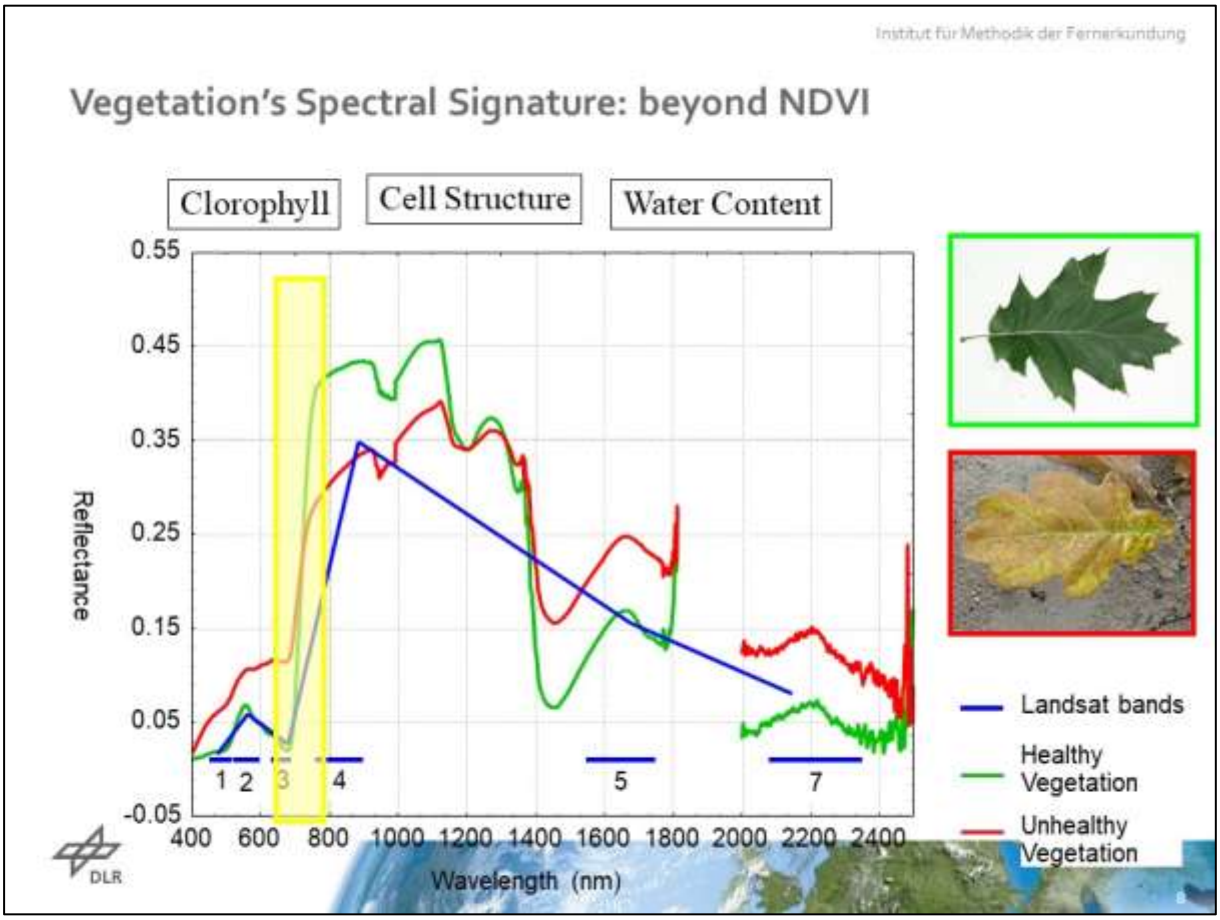

Institut für Methodik der Fernerkundung
Hyperspectral Images
Hundreds of contiguous bands
along track
crosstrack
20 m
Reflected Energy (%)
100
50
10
kaolinite
0.4 1 1.5 2 2.5
Wavelenght (µm)
– Usually up to hundreds of bands in the range 0.4 – 2.5 micrometers
– Reduced spatial resolution
– State-of-the-art sensors are airborne (HySpex)
– Each image element contains a characteristic spectrum
– In this case this is kaolinite (a kind of rock)
The values of a pixel throughout all the spectral bands gives us the spectrum of the pixel

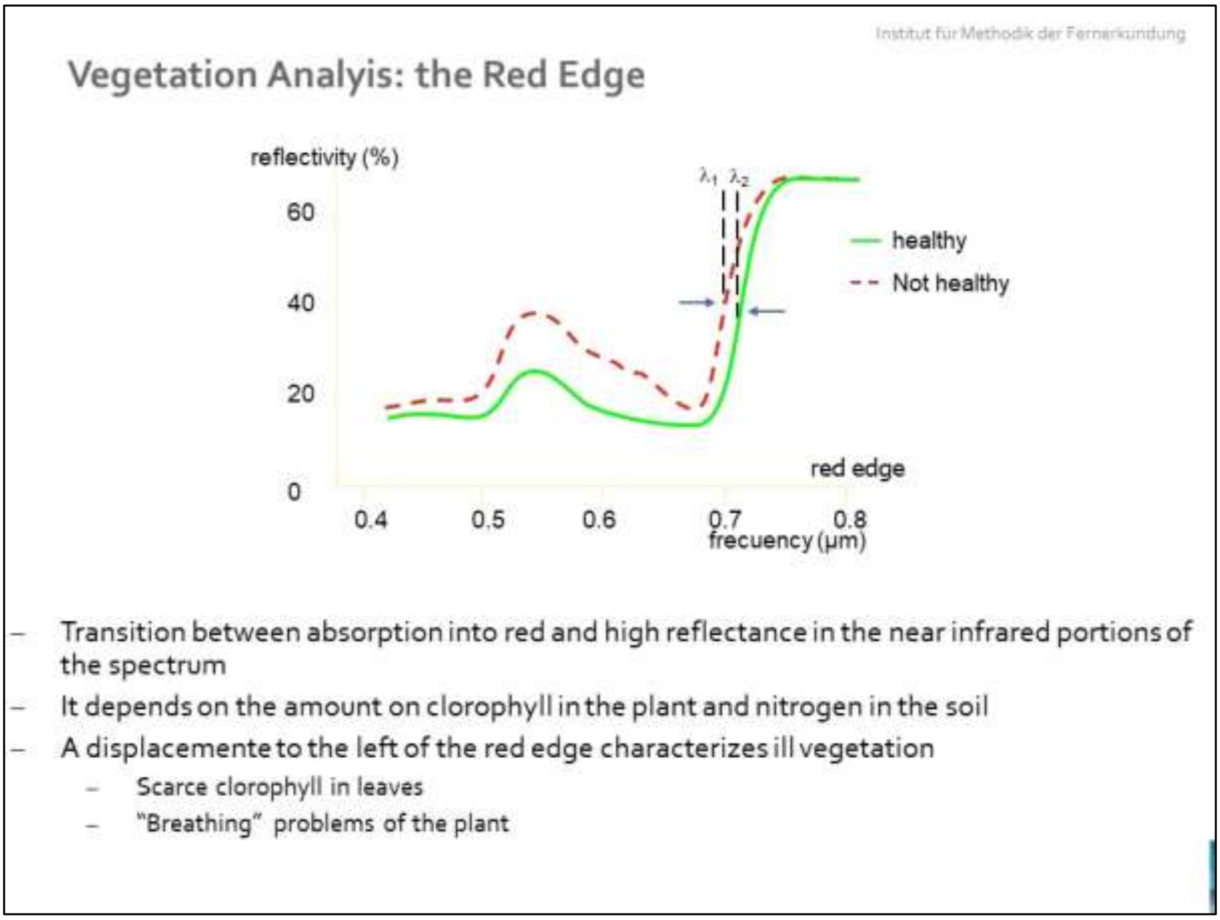

Institut für Methodik der Fernerkundung
Hyperspectral
Buddingtonite
Alunite
Chalcedony

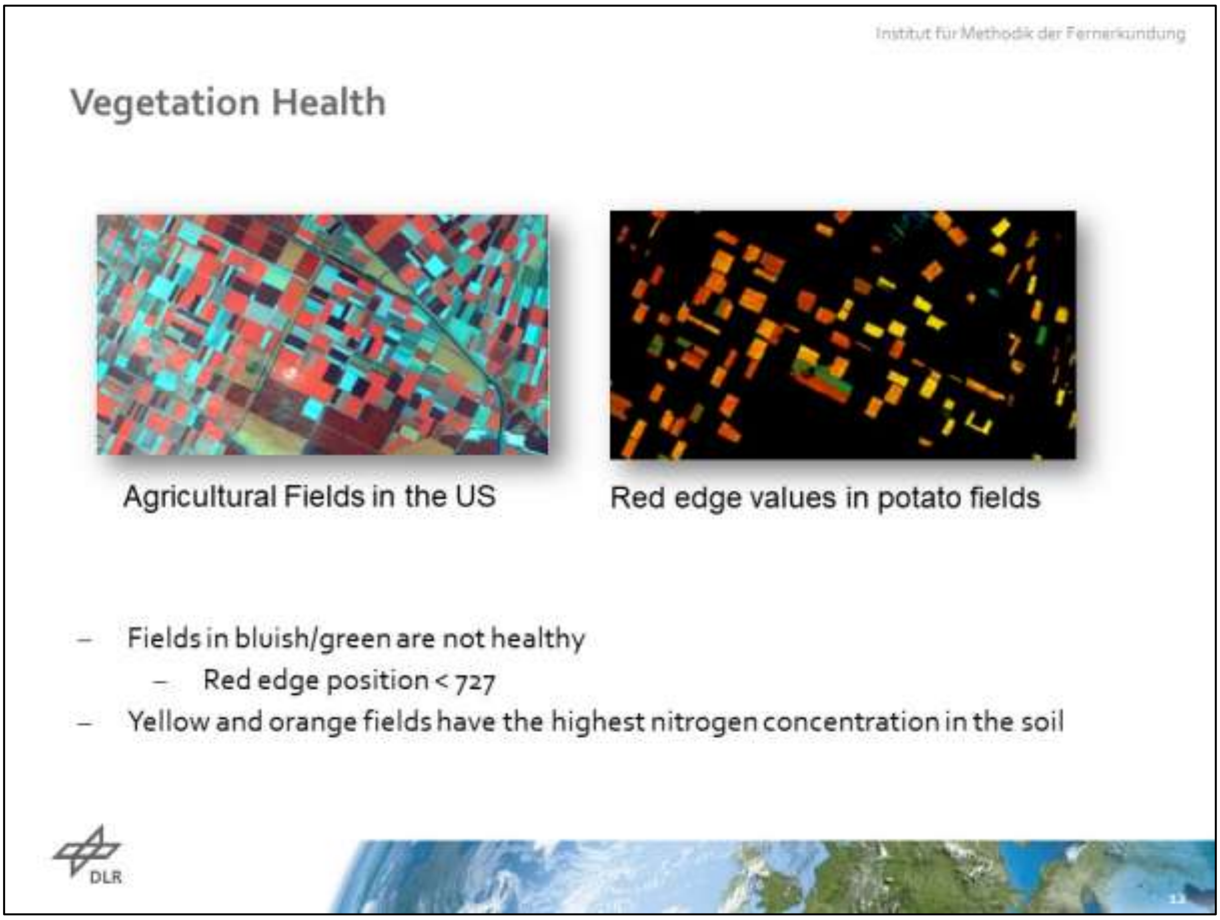

Institut für Methodik der Fernerkundung
Optical passive sensors in remote sensing
Hyperspectral
Multispectral
Panchromatic
Spectral Resolution
Spatial Resolution
DLR


Institut für Methodik der Fernerkundung
What about Spectral Resolution?
Hyper- vs. Multispectral: Vegetation Analysis
DLR


Institut für Methodik der Fernerkundung
NDVI, Landsat 7 Example
$NDVI = \frac{NIR - R}{NIR + R}$
True Color
Bands 321
False Color
Bands 432
NDVI
Bands 4-3
Bands 4+3
DLR


Institut für Methodik der Fernerkundung
Vegetation's Spectral Signature: beyond NDVI
Clorophyll
Cell Structure
Water Content
Reflectance
0.55
0.45
0.35
0.25
0.15
0.05
-0.05
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400
Wavelength (nm)
1 2 3 4 5 7
Landsat bands
Healthy Vegetation
Unhealthy Vegetation
DLR

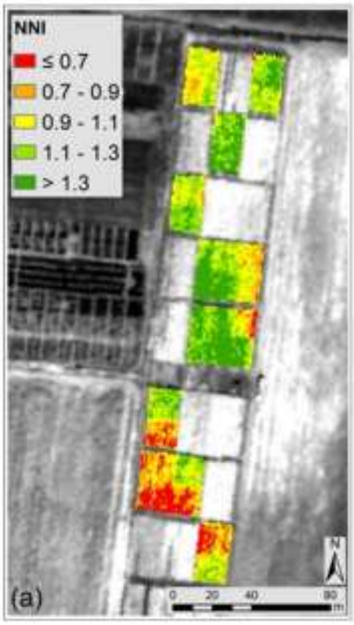

Institut für Methodik der Fernerkundung
Vegetation Analyis: the Red Edge
reflectivity (%)
60
40
20
0
0.4
0.5
0.6
0.7
0.8
frecuency (µm)
λ1 λ2
healthy
Not healthy
red edge
– Transition between absorption into red and high reflectance in the near infrared portions of the spectrum
– It depends on the amount on clorophyll in the plant and nitrogen in the soil
– A displacemente to the left of the red edge characterizes ill vegetation
– Scarce clorophyll in leaves
– "Breathing" problems of the plant


Institut für Methodik der Fernerkundung
Vegetation Health
Agricultural Fields in the US
Red edge values in potato fields
– Fields in bluish/green are not healthy
– Red edge position < 727
– Yellow and orange fields have the highest nitrogen concentration in the soil
DLR

Institut für Methodik der Fernerkundung

Vegetation health status: Normalized Nitrogen Index (NNI)

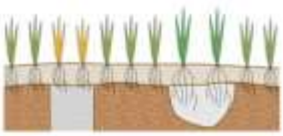
Corn fields in the USA



Chiara Cili et al.

DLR

About Vegetation Health: Crop Marks



Local vegetation health altered by buried objects (negatively) or dug sites (positively)

Evident crop marks in Grezac, France
RGB True Color Composite
(source: wikipedia)

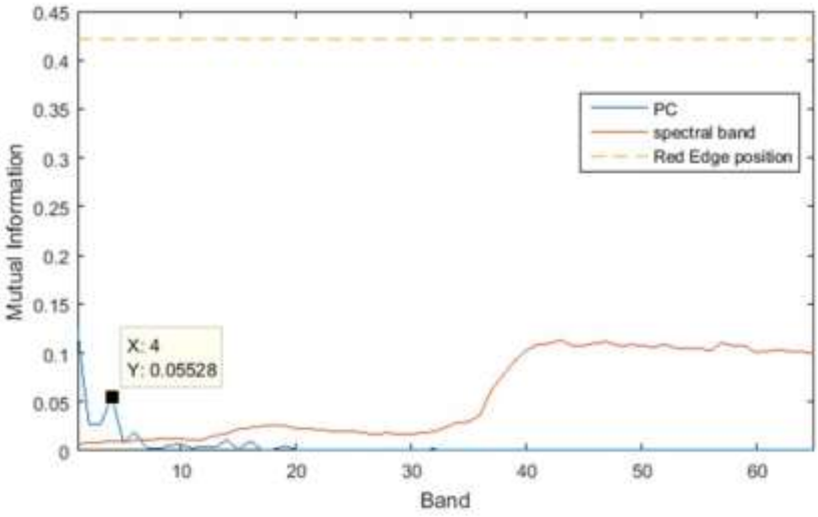
DLR


Not always that easy…
The Roman city of Carnuntum (1 century AD) once stood in these agricultural fields (now in Austria)
DLR

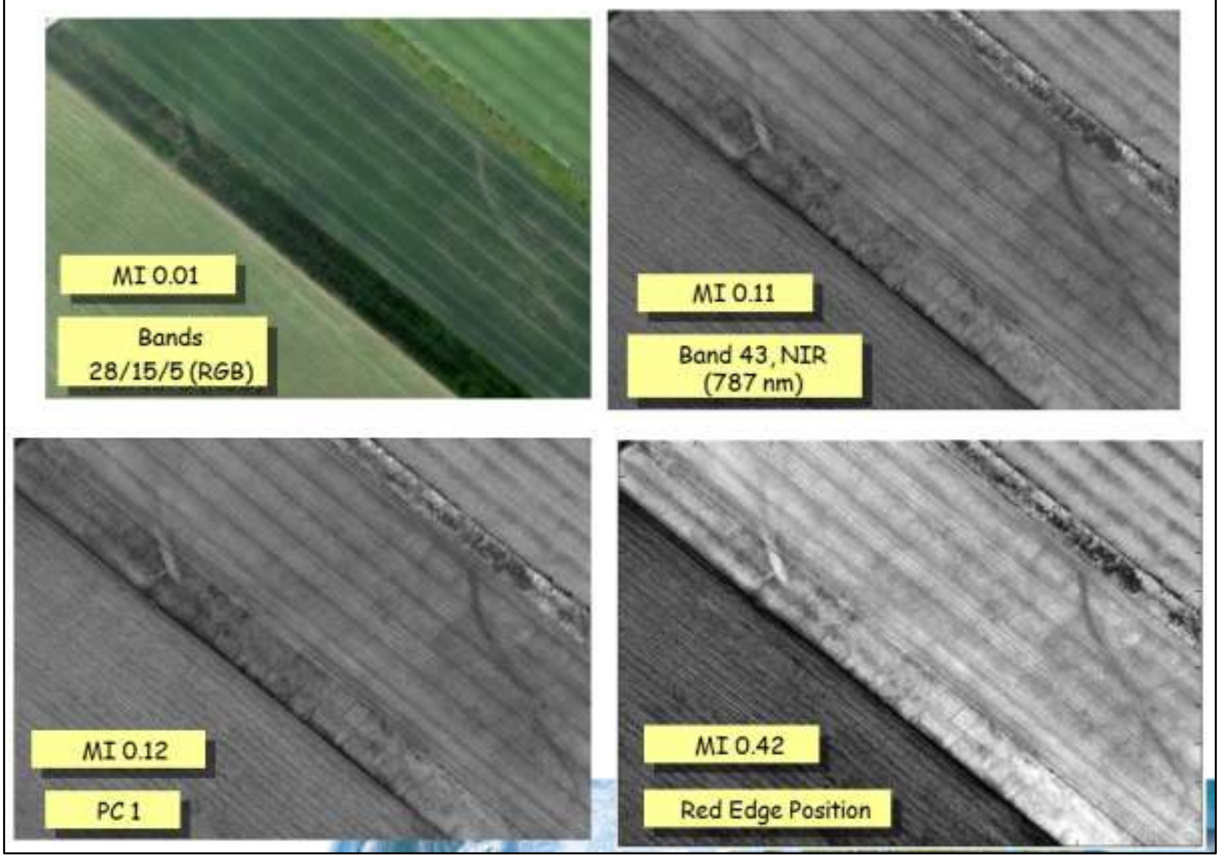

Not always that easy…
B
Hyperspectral image: RGB True Color Composite
DLR

Statistical correspondence

Spectral feature → map of buried archaeological structures



DLR



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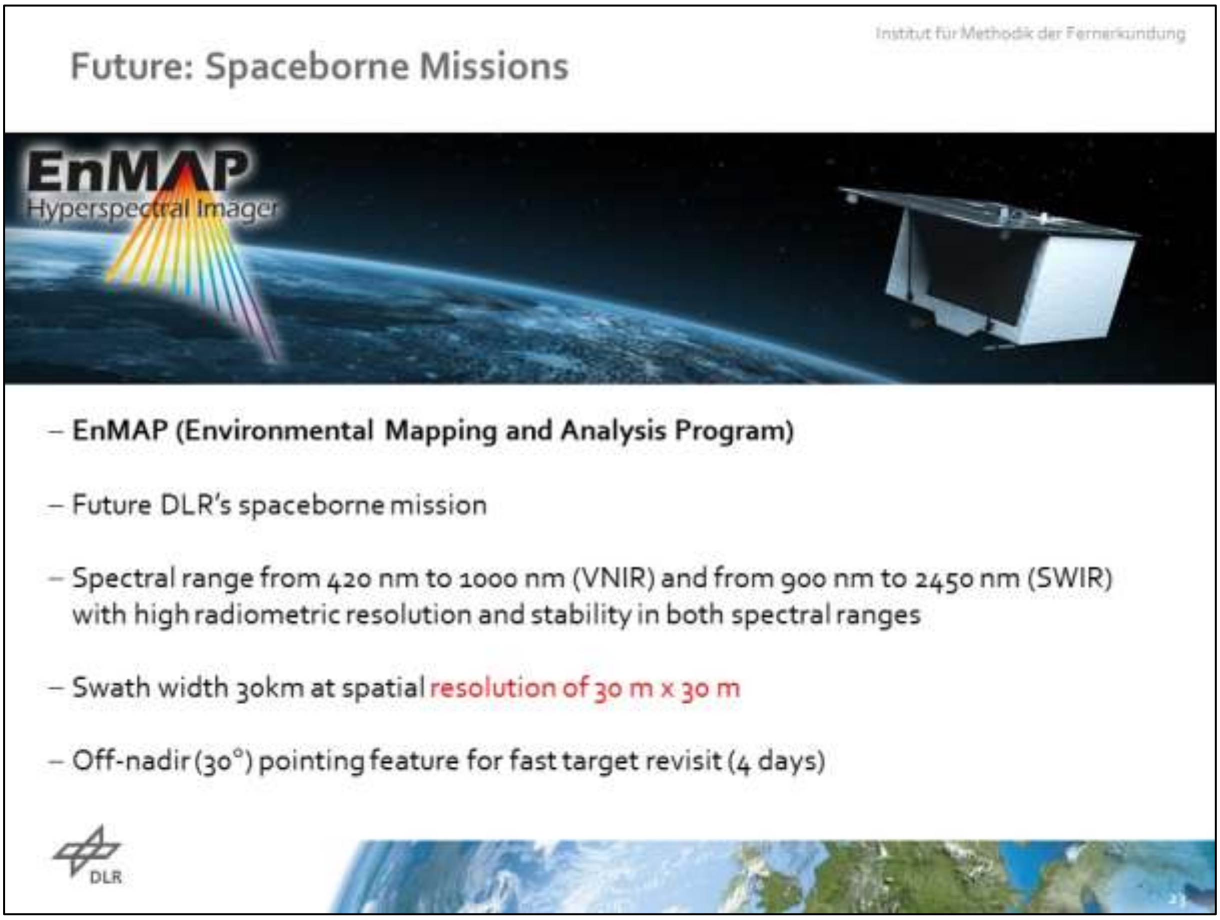
Future: Spaceborne Missions

- **EnMAP (Environmental Mapping and Analysis Program)**
- Future DLR's spaceborne mission
- Spectral range from 420 nm to 1000 nm (VNIR) and from 900 nm to 2450 nm (SWIR) with high radiometric resolution and stability in both spectral ranges
- Swath width 30km at spatial resolution of 30 m x 30 m
- Off-nadir (30°) pointing feature for fast target revisit (4 days)

DLR


Institut für Methodik der Fernerkundung
Future: Spaceborne Missions
EnMAP
Hyperspectral Imager
– EnMAP (Environmental Mapping and Analysis Program)
– Future DLR's spaceborne mission
– Spectral range from 420 nm to 1000 nm (VNIR) and from 900 nm to 2450 nm (SWIR) with high radiometric resolution and stability in both spectral ranges
– Swath width 30km at spatial resolution of 30 m x 30 m
– Off-nadir (30°) pointing feature for fast target revisit (4 days)
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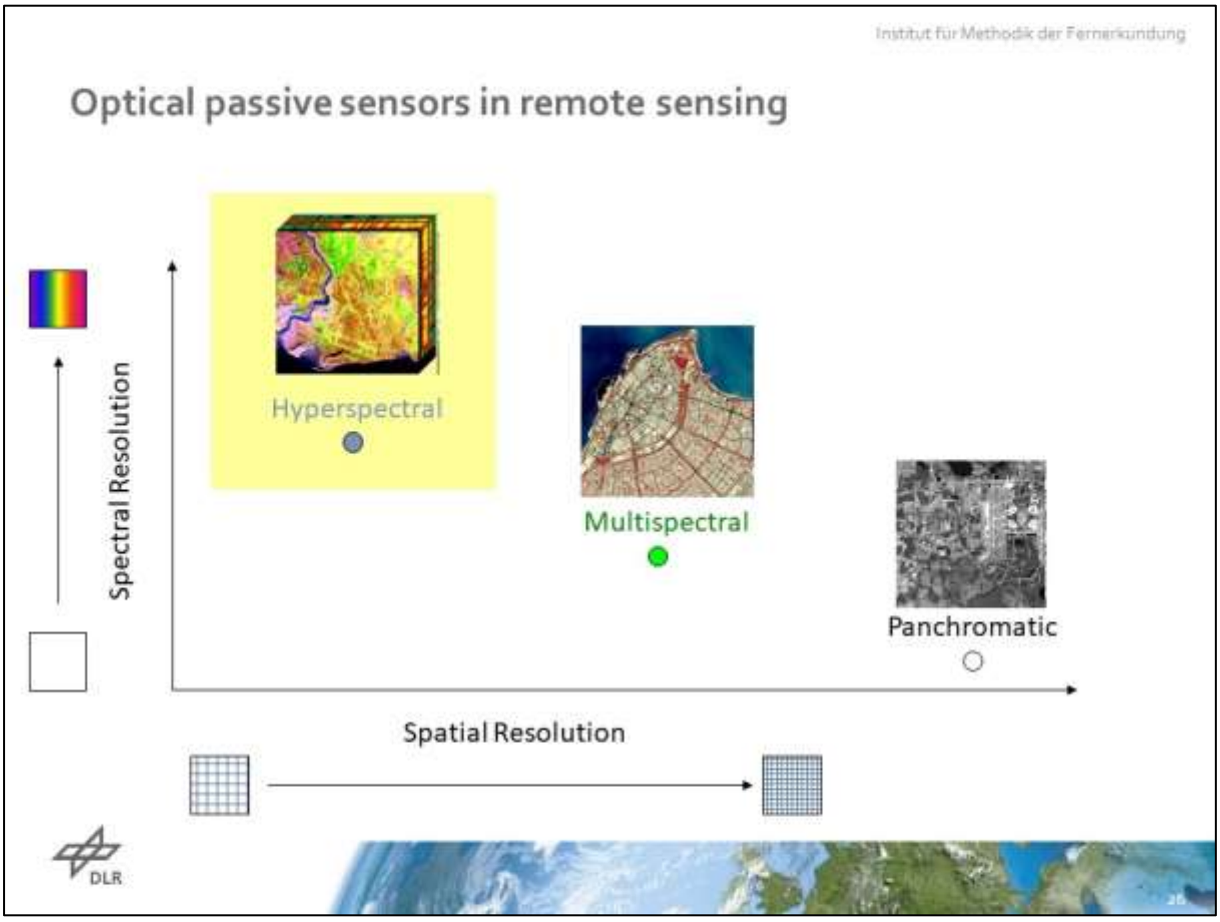
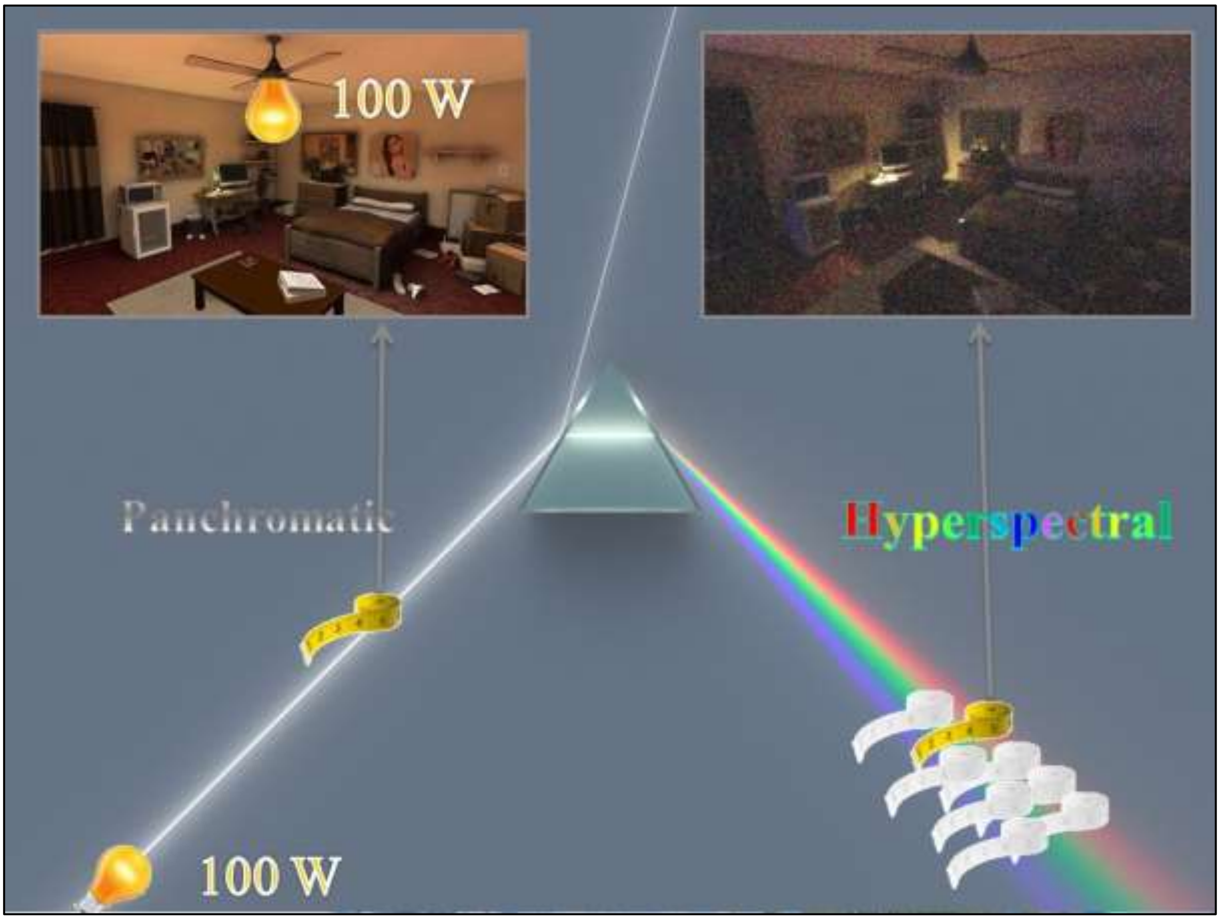
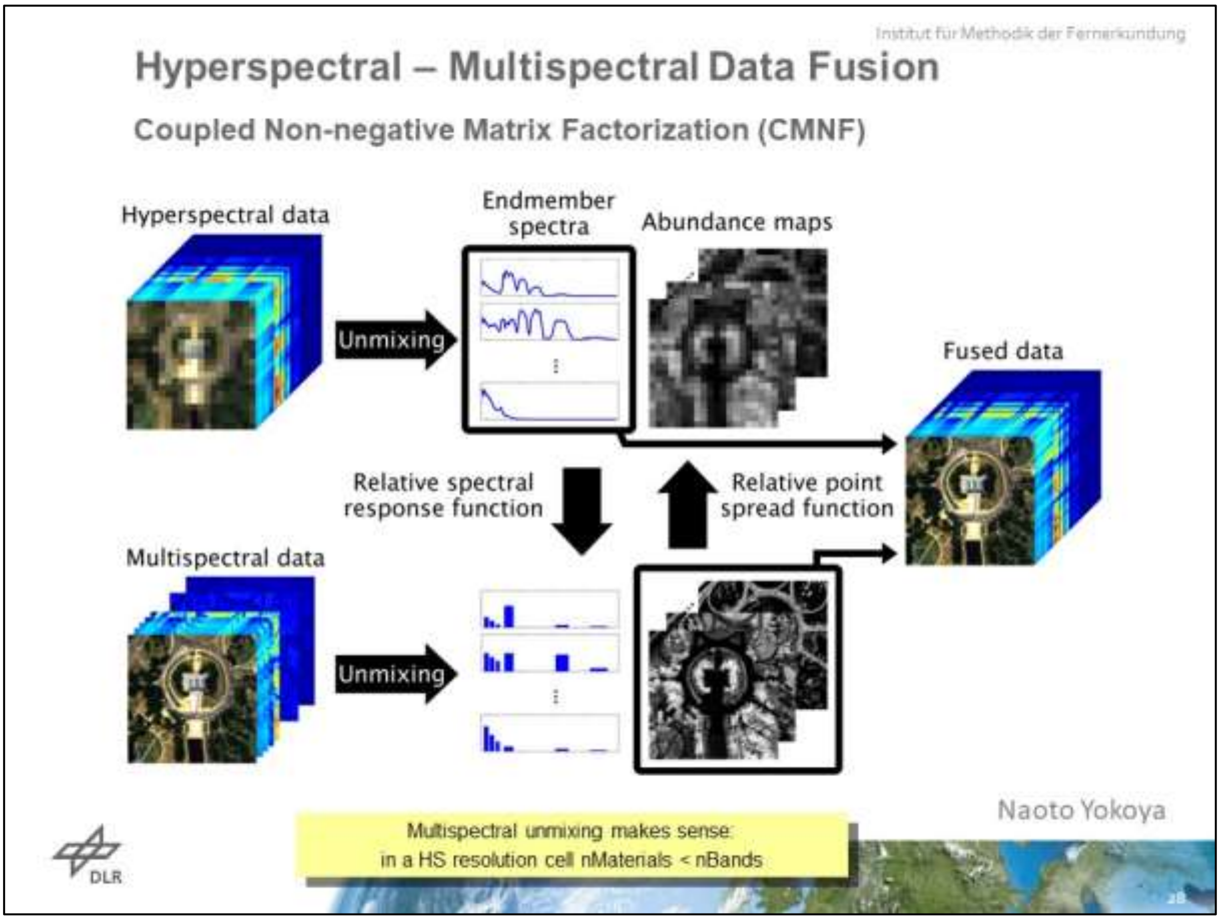
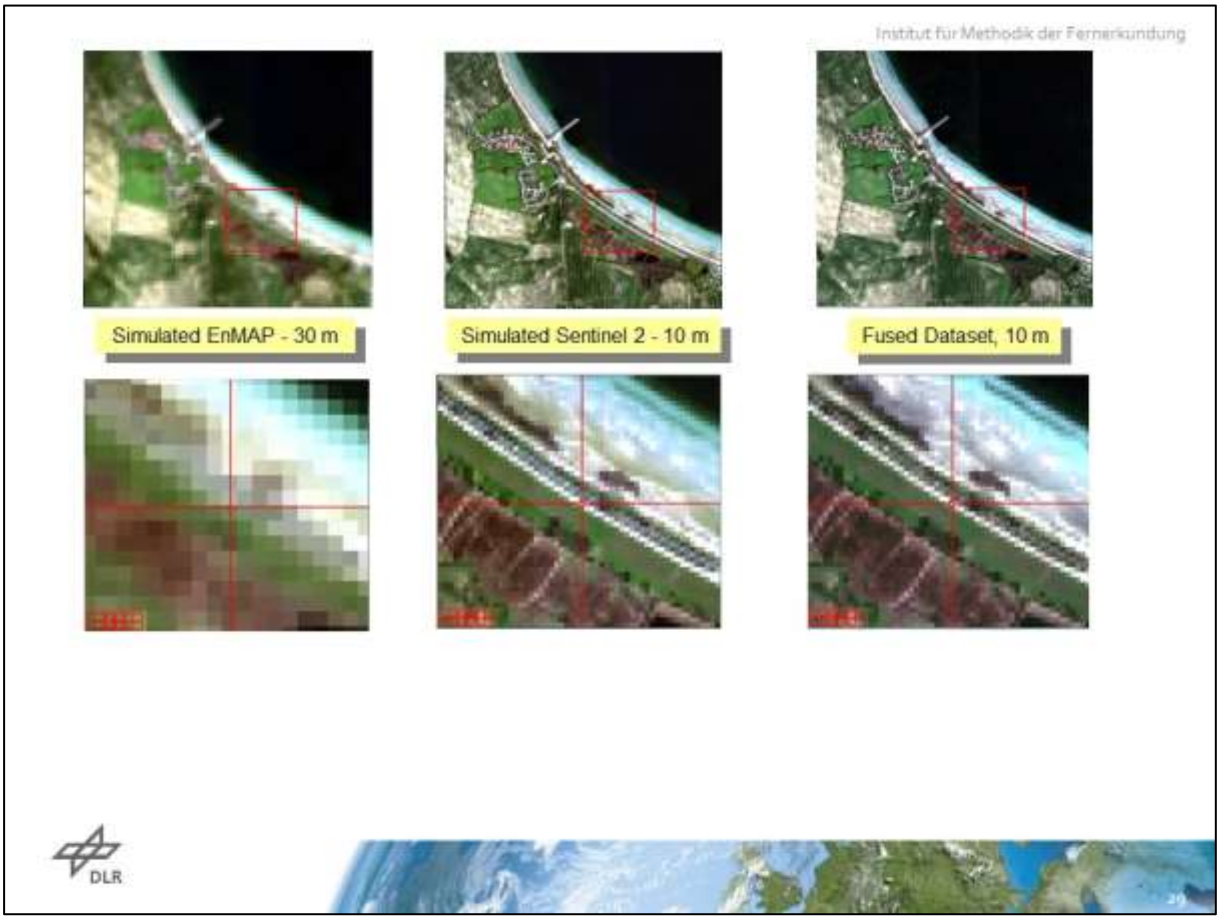
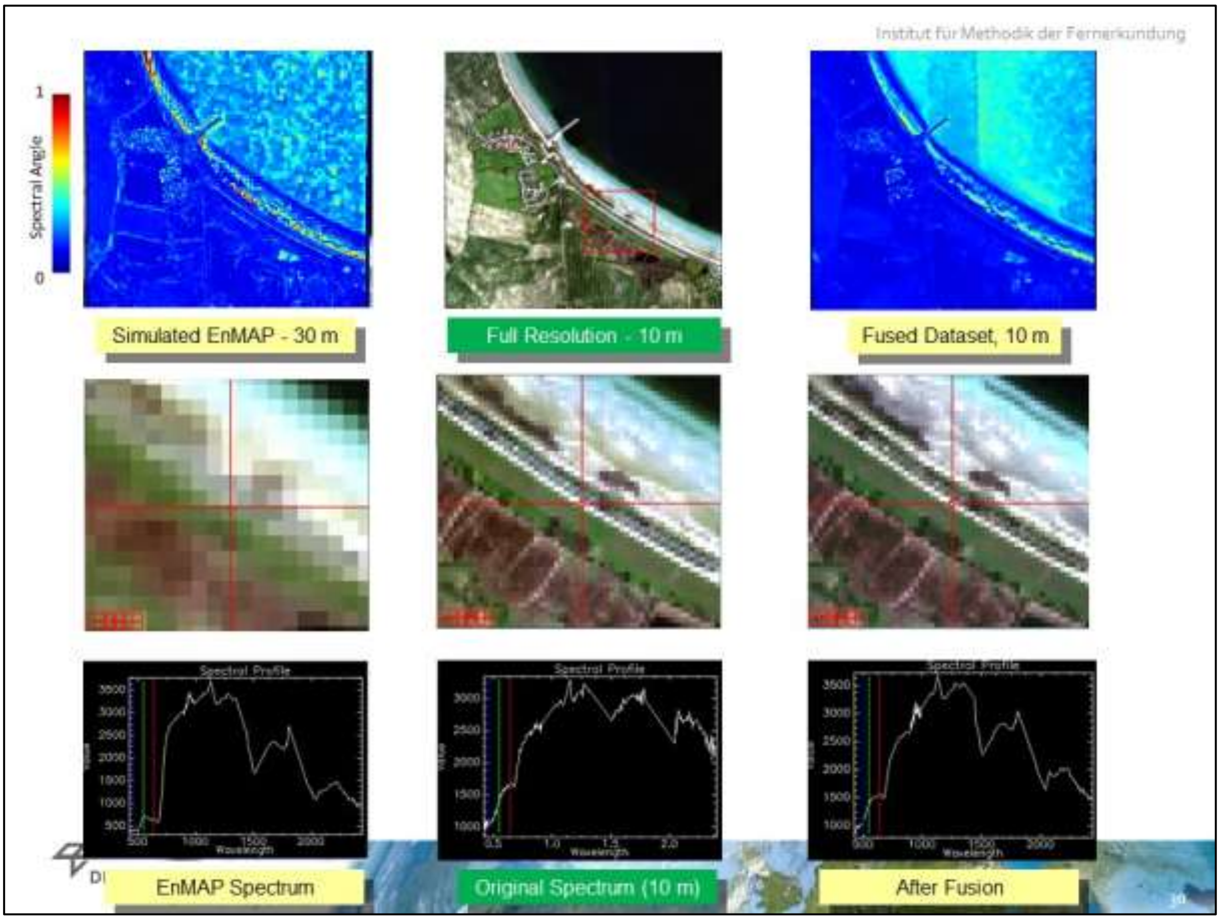
MUSES
Hyperspectral Sensor DESIS on ISS
DLR
Teledyne
NASA
mounted on the ISS
nths!)
se
• 450 to 915 nanometres
• Spatial resolution around 30m

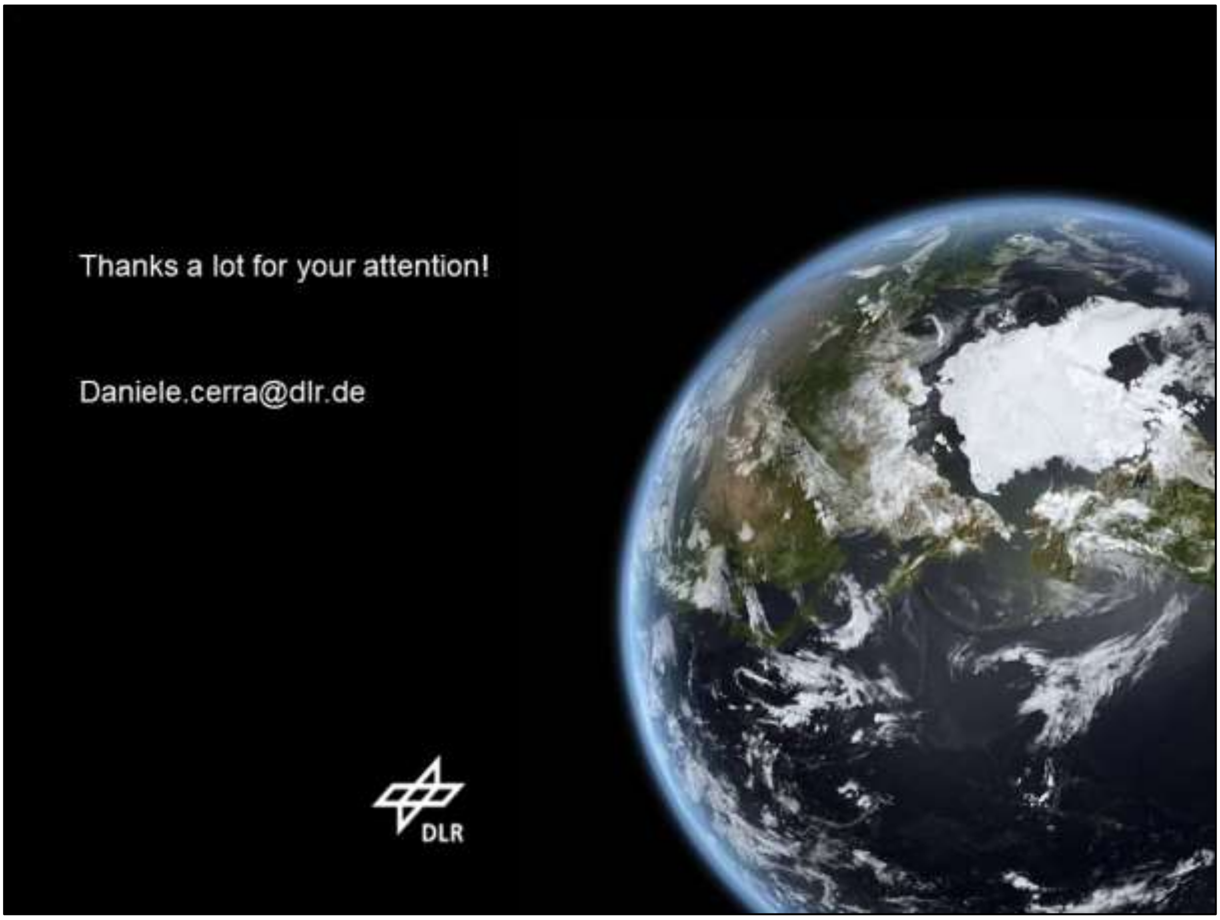

Institut für Methodik der Fernerkundung
Optical passive sensors in remote sensing
Hyperspectral
Multispectral
Panchromatic
Spectral Resolution
Spatial Resolution
DLR


100 W
Panchromatic
Hyperspectral
100 W

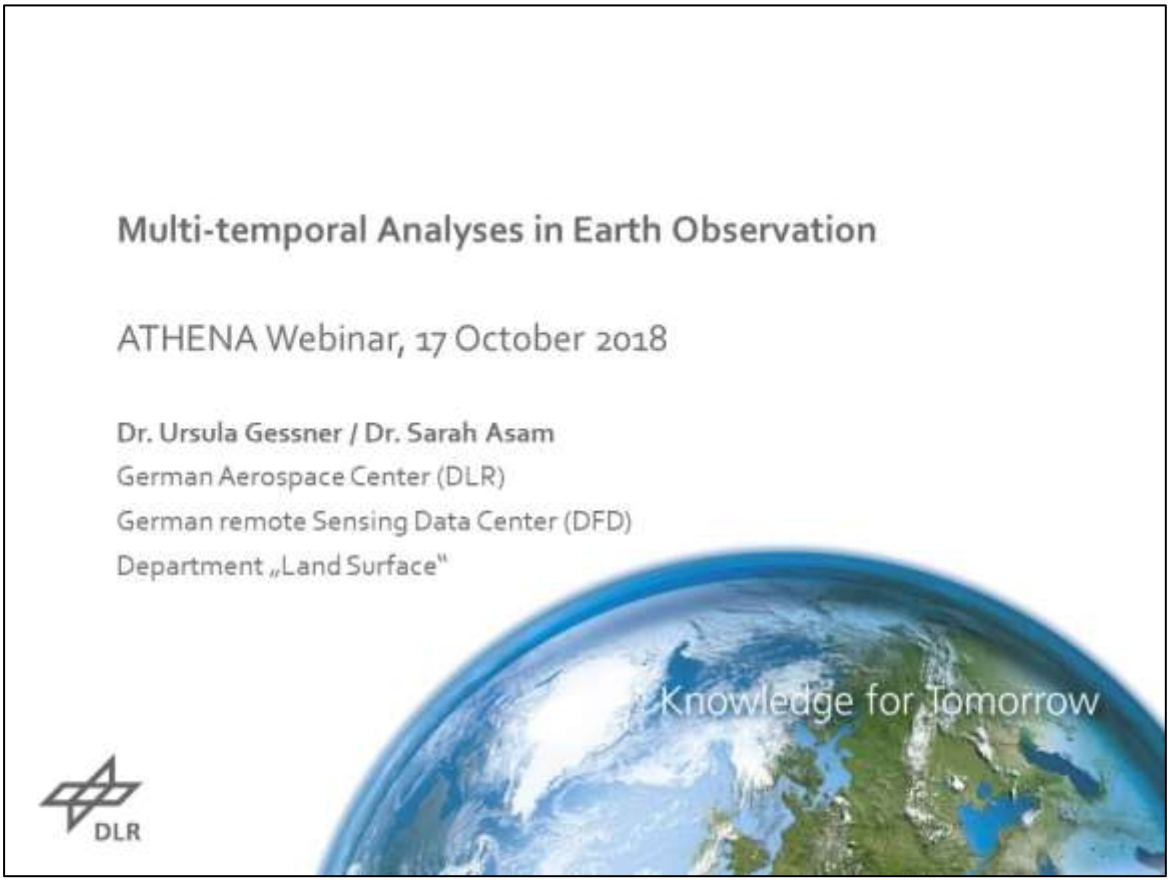

Institut für Methodik der Fernerkundung
Hyperspectral – Multispectral Data Fusion
Coupled Non-negative Matrix Factorization (CMNF)
Hyperspectral data
Endmember spectra
Abundance maps
Unmixing
Fused data
Relative spectral response function
Relative point spread function
Multispectral data
Unmixing
Naoto Yokoya
Multispectral unmixing makes sense:
in a HS resolution cell nMaterials < nBands
DLR


Institut für Methodik der Fernerkundung
Simulated EnMAP - 30 m
Simulated Sentinel 2 - 10 m
Fused Dataset, 10 m
DLR


Institut für Methodik der Fernerkundung
1
Spectral Angle
0
Simulated EnMAP - 30 m
Full Resolution - 10 m
Fused Dataset, 10 m
Spectral Profile
EnMAP Spectrum
Original Spectrum (10 m)
After Fusion



2.4 Forth Presentation - Multi-Temporal Analyses in Earth Observation



Earth Observation Center

Contents

- **Time series in earth observation**
  - Suitable sensors and missions
  - Types of EO time series & variables
- **Time series processing – background and methods**
  - Time series components and characteristics
  - Handling of outliers & noise; smoothing & filtering methods
  - Analysis of multi-year developments
  - Analysis of seasonality
- **Examples for EO applications based on time series**
  - Land Use & Agriculture
  - Droughts
  - Net Primary Productivity
  - Surface water resources for agriculture
  - Snow Cover

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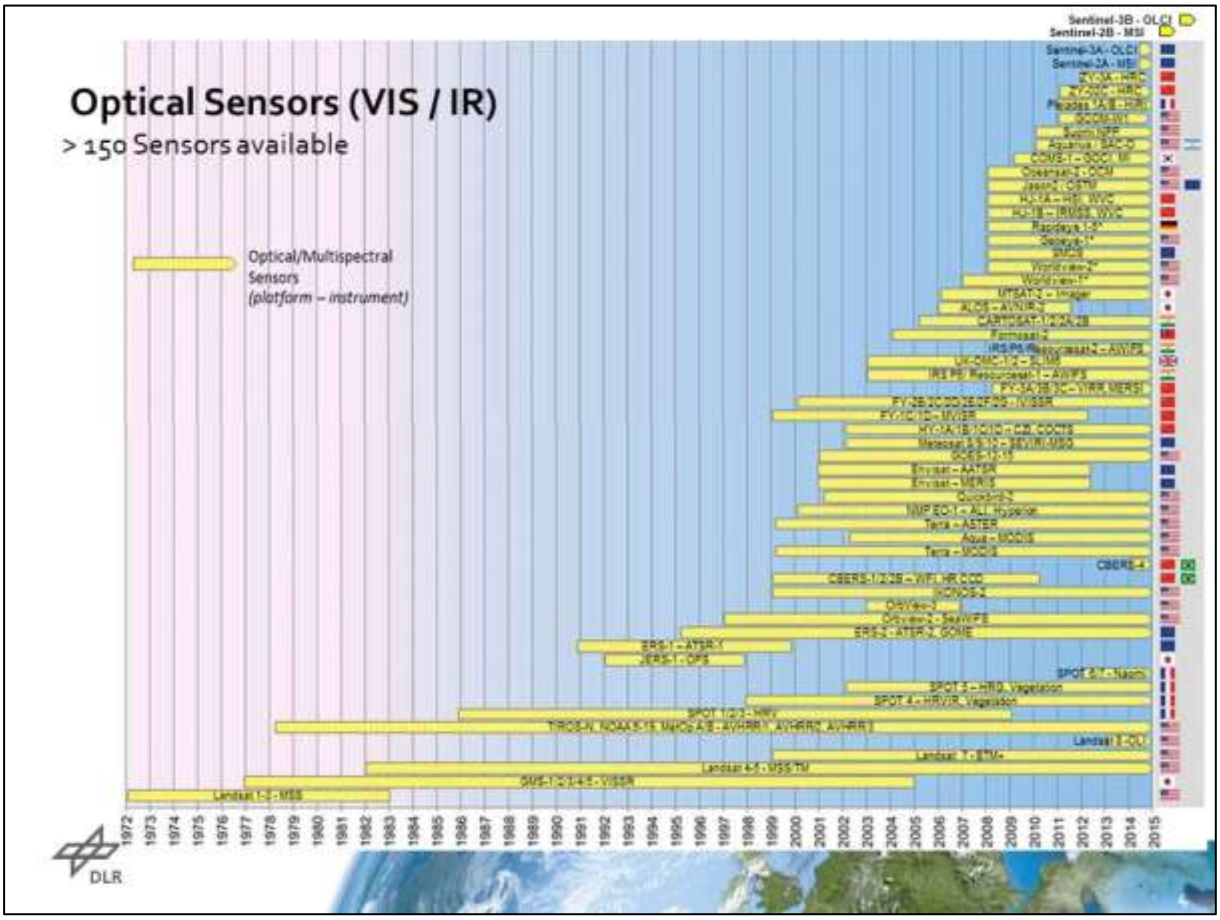
Earth Observation Center

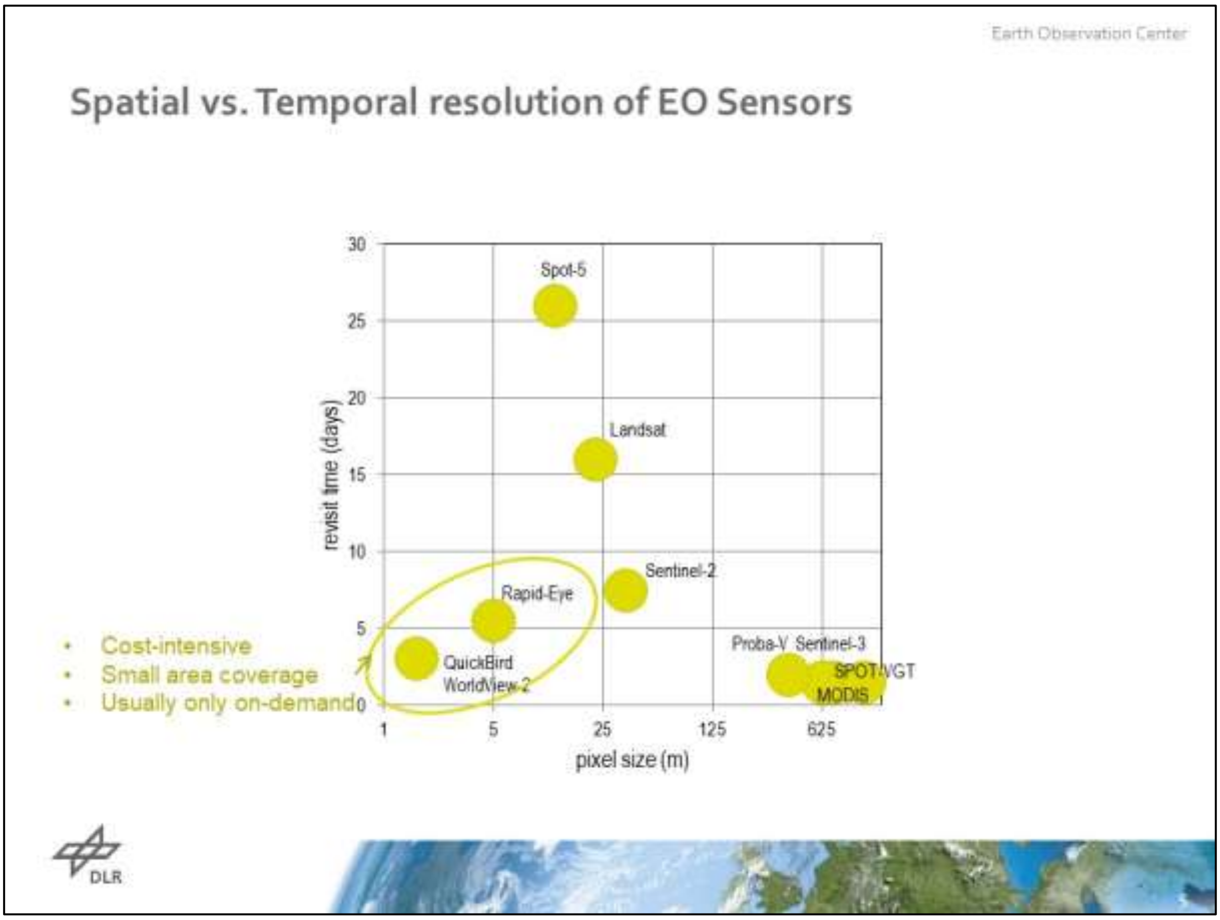
Earth Observation Time Series

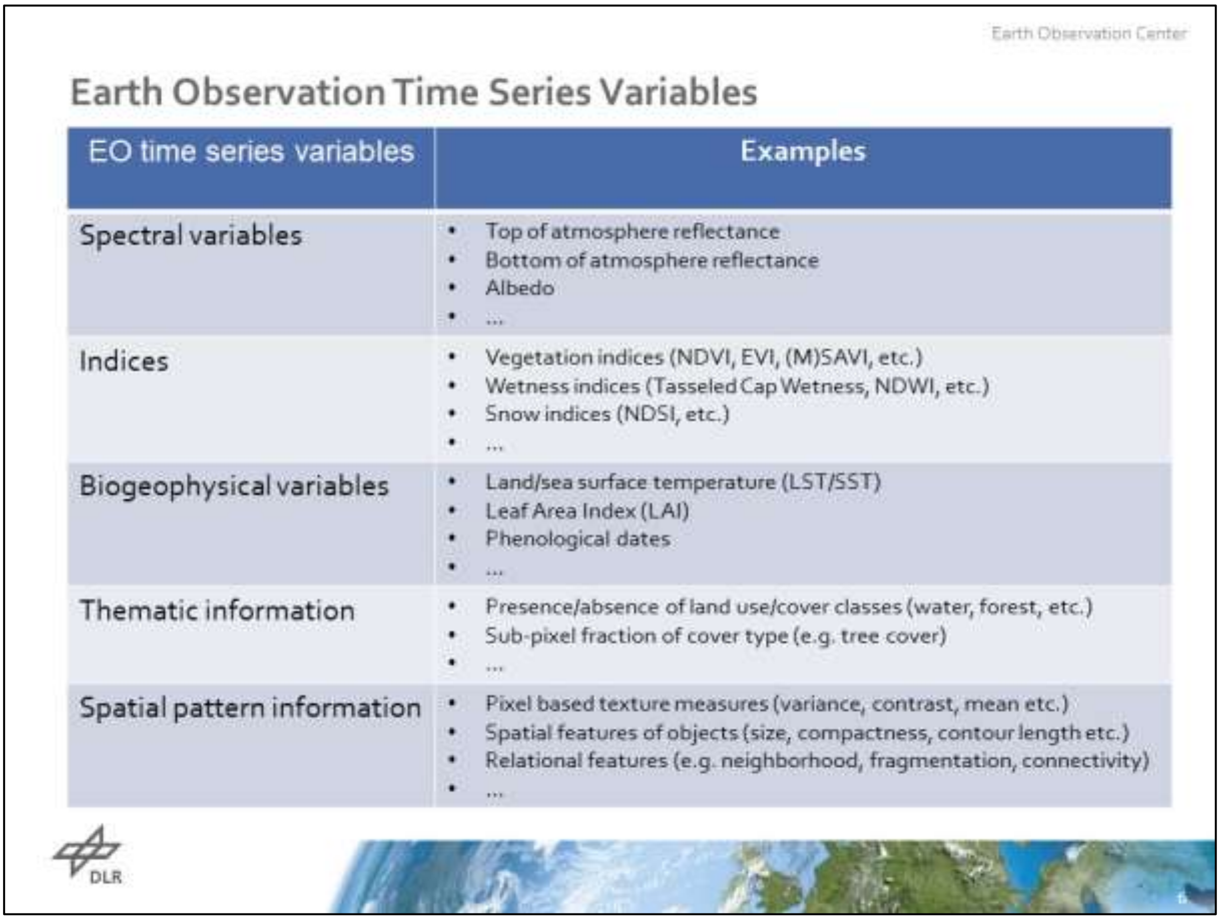
A time series...

- ...is *"a sequence of values collected over time on a particular variable"* (Haan, 1977).
- ...can consist of the values of a variable observed at:
  - **discrete times** (e.g. spectral information recorded at overpass of EO-sensor)
  - averaged over a given **time interval** (e.g. vegetation index value averaged over the period of 8-days)
  - recorded **continuously** with time (not common for EO, e.g. hygrographs in museums)

DLR


Optical Sensors (VIS / IR)
> 150 Sensors available
Optical/Multispectral Sensors (platform – instrument)
DLR


Earth Observation Center
Spatial vs. Temporal resolution of EO Sensors
revisit time (days)
pixel size (m)
Spot-5
Landsat
Sentinel-2
Rapid-Eye
QuickBird
WorldView-2
Proba-V
Sentinel-3
SPOT VGT
MODIS
• Cost-intensive
• Small area coverage
• Usually only on-demand
DLR

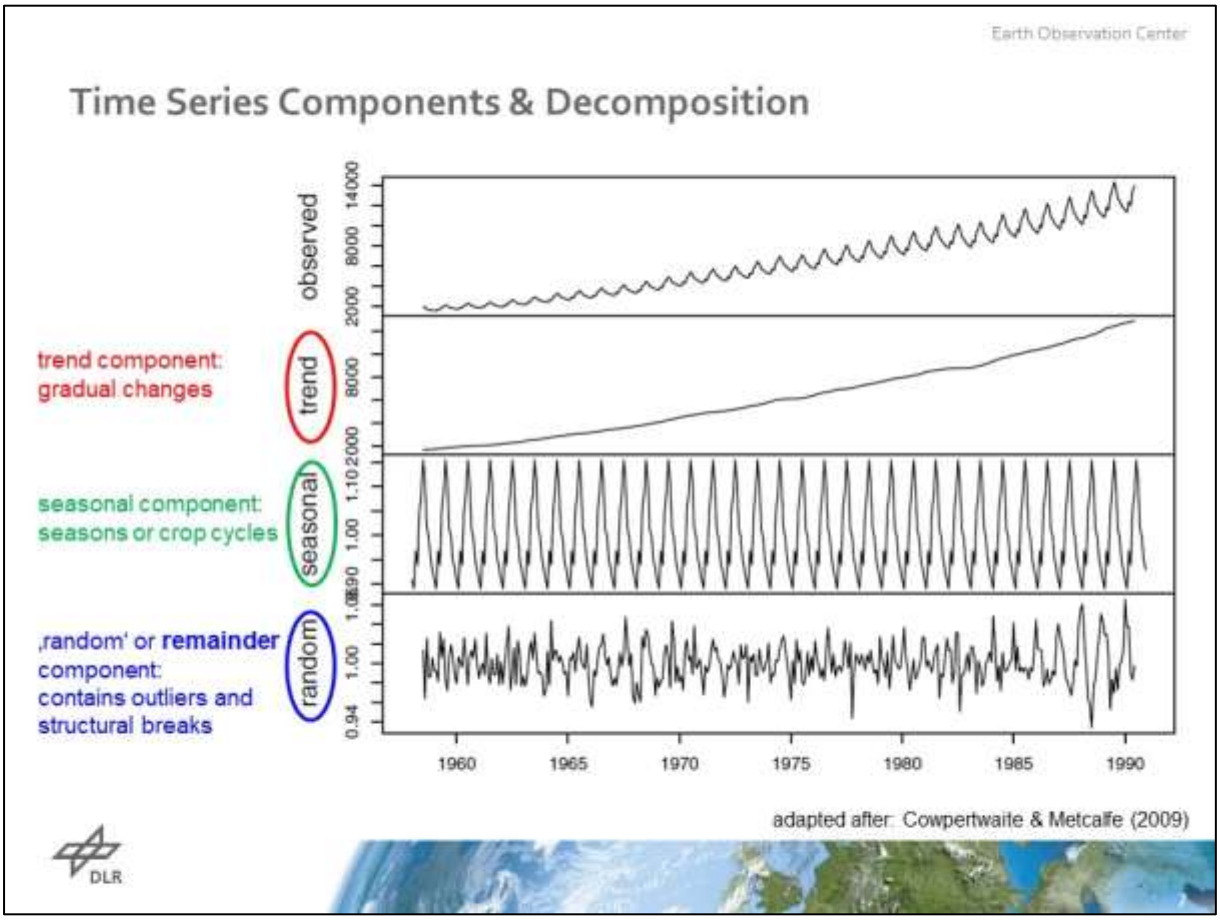


Earth Observation Center

Earth Observation Time Series Variables

EO time series variables	Examples
Spectral variables	• Top of atmosphere reflectance • Bottom of atmosphere reflectance • Albedo • …
Indices	• Vegetation indices (NDVI, EVI, (M)SAVI, etc.) • Wetness indices (Tasseled Cap Wetness, NDWI, etc.) • Snow indices (NDSI, etc.) • …
Biogeophysical variables	• Land/sea surface temperature (LST/SST) • Leaf Area Index (LAI) • Phenological dates • …
Thematic information	• Presence/absence of land use/cover classes (water, forest, etc.) • Sub-pixel fraction of cover type (e.g. tree cover) • …
Spatial pattern information	• Pixel based texture measures (variance, contrast, mean etc.) • Spatial features of objects (size, compactness, contour length etc.) • Relational features (e.g. neighborhood, fragmentation, connectivity) • …

DLR



Earth Observation Center

EO time series – handling of outliers & ‚noise'

Reasons for outliers / noise in optical EO time series

- Atmospheric effects
- Clouds / haze
- Sun-sensor-geometry
- Sensor failures
- (pre-)processing errors

Not related to land surface characteristics

-> shall be removed by noise removal procedures

- Floods
- Bushfires
- (short) snow cover

Related to actual land surface characteristics. No noise!

-> can nevertheless be removed by noise removal procedures!

DLR

Earth Observation Center

EO time series – handling of outliers & ‚noise'

Outlier identification

- based on quality information layers
  -> available for some time series products, e.g. for most MODIS products

Bit No.	Parameter Name	Bit Comb.	Sur_refl_qc_500m
31	adjacency correction performed	1	yes
		0	no
30	atmospheric correction performed	1	yes
		0	no
26–29	band 7 data quality four bit range	0000	highest quality
		1000	dead detector; data interpolated in L1B
		1001	solar zenith >= 86 degrees
		1010	solar zenith >= 85 and < 86 degrees
		1011	missing input
		1100	internal constant used in place of climatological data for at least one atmospheric constant
		1101	correction out of bounds pixel constrained to extreme allowable value
		1110	L1B data faulty
		1111	not processed due to deep ocean or clouds
22–25	band 6 data quality four bit range		SAME AS BAND ABOVE

DLR

Earth Observation Center

EO time series – handling of outliers & ‚noise‘

Outlier identification

- based on quality information layers
  -> available for some time series products, e.g. for most MODIS products

- Based on statistics / rulesets, e.g.:
  - a value is classified as an outlier if
    - it deviates more than a deviation threshold from the median in a moving window and/or
    - it is lower (higher) than the mean value of its immediate neighbors minus (plus) a threshold value
    - or similar…

DLR

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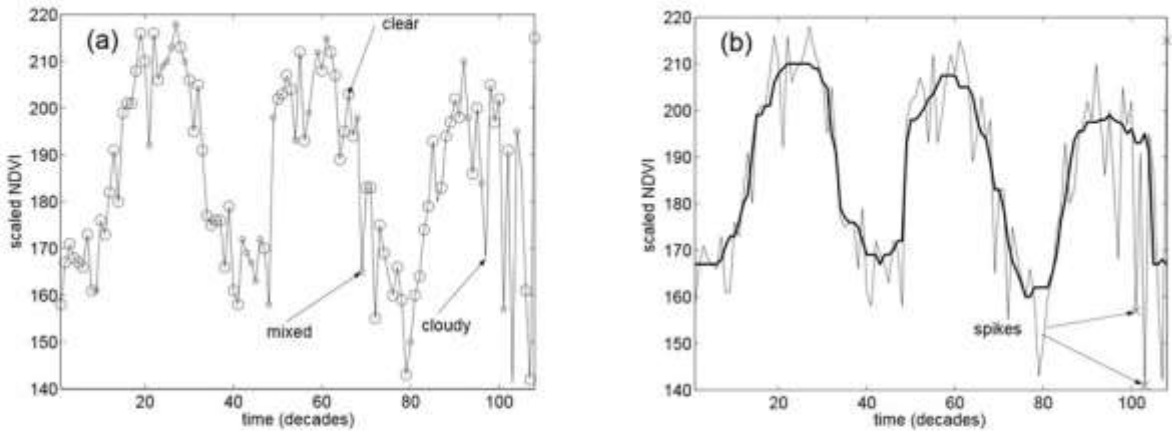
Earth Observation Center

EO time series – handling of outliers & ‚noise‘

Weighting of time series values

Weights are assigned based on an STL decomposition (Cleveland et al. 1990).

[Seasonal Trend Decomposition based on Loess smoother]



Eklundh & Jönsson (2015)

DLR

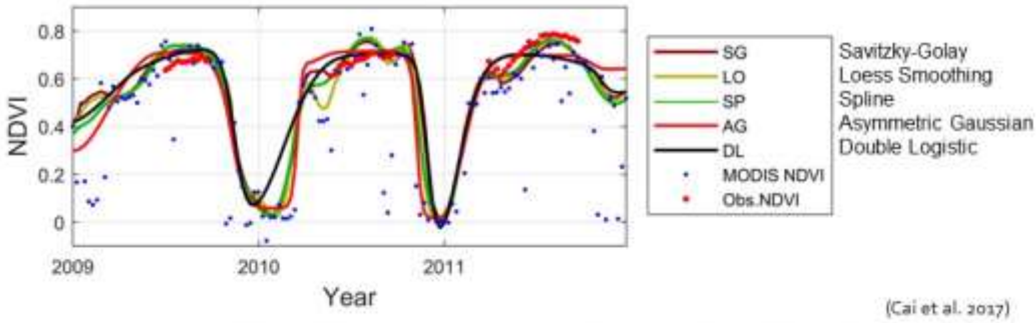
11

Earth Observation Center

EO time series – handling of outliers & ‚noise'

1. Temporal filtering /smooting (with outliers removed or weighted

- **Moving average**:
  replace each data value by a linear combination /mean of nearby values in a window
- **Savitzky-Golay filter**:
  Least squares fit to a quadratic polynomial of the form: $f(t) = c_1 + c_2 t + c_3 t^2$
  Polynomial is fit to values in moving window and cental value is replaced by fitted value
- Fit to **asymmetric Gaussian** and **double logistic** functions



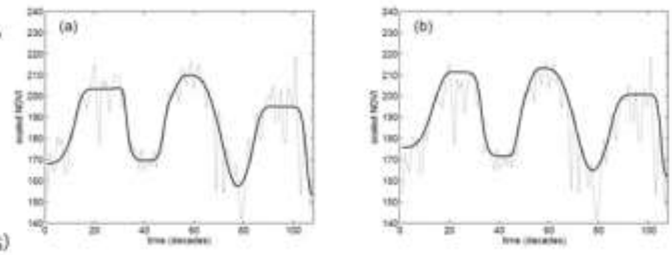
(Cai et al. 2017)

DLR

Earth Observation Center

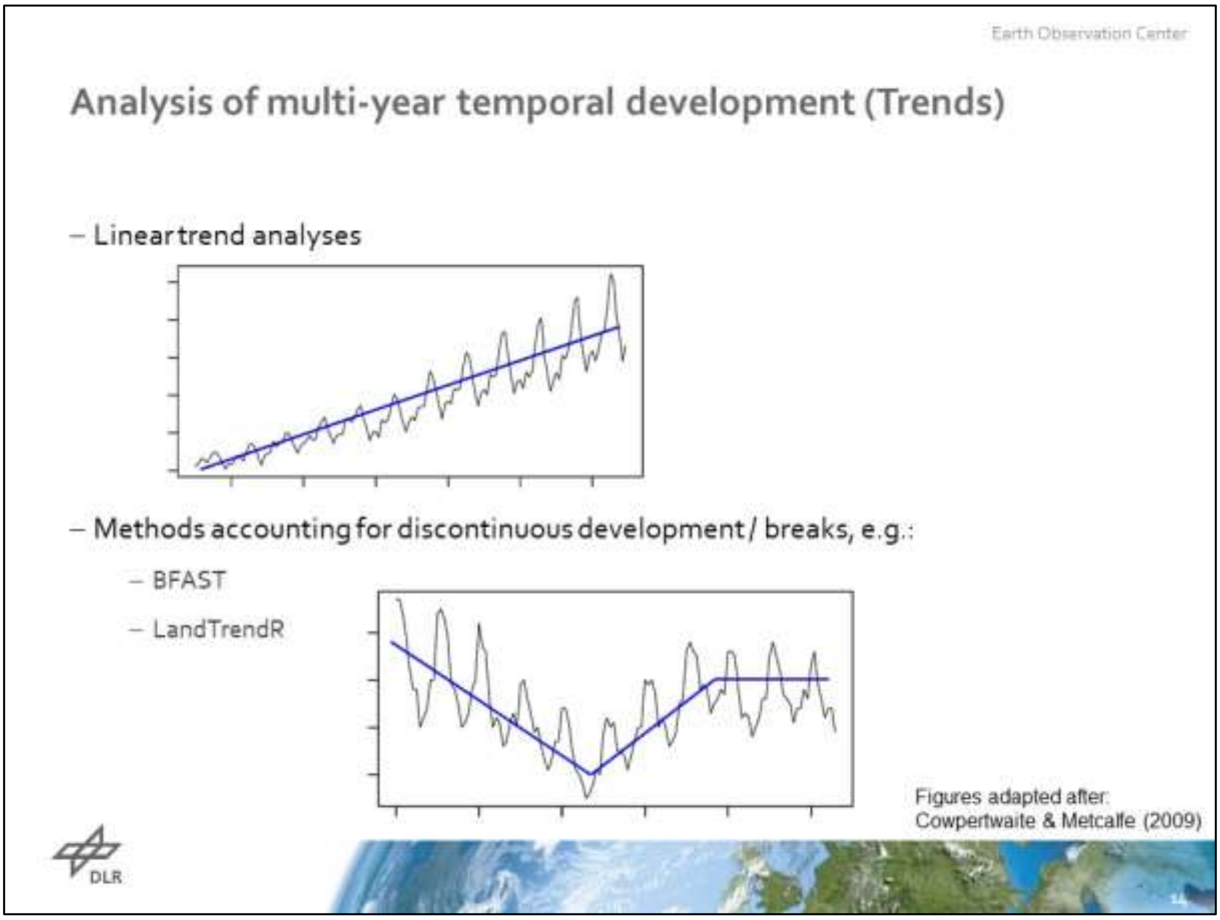
EO time series – handling of outliers & ‚noise'

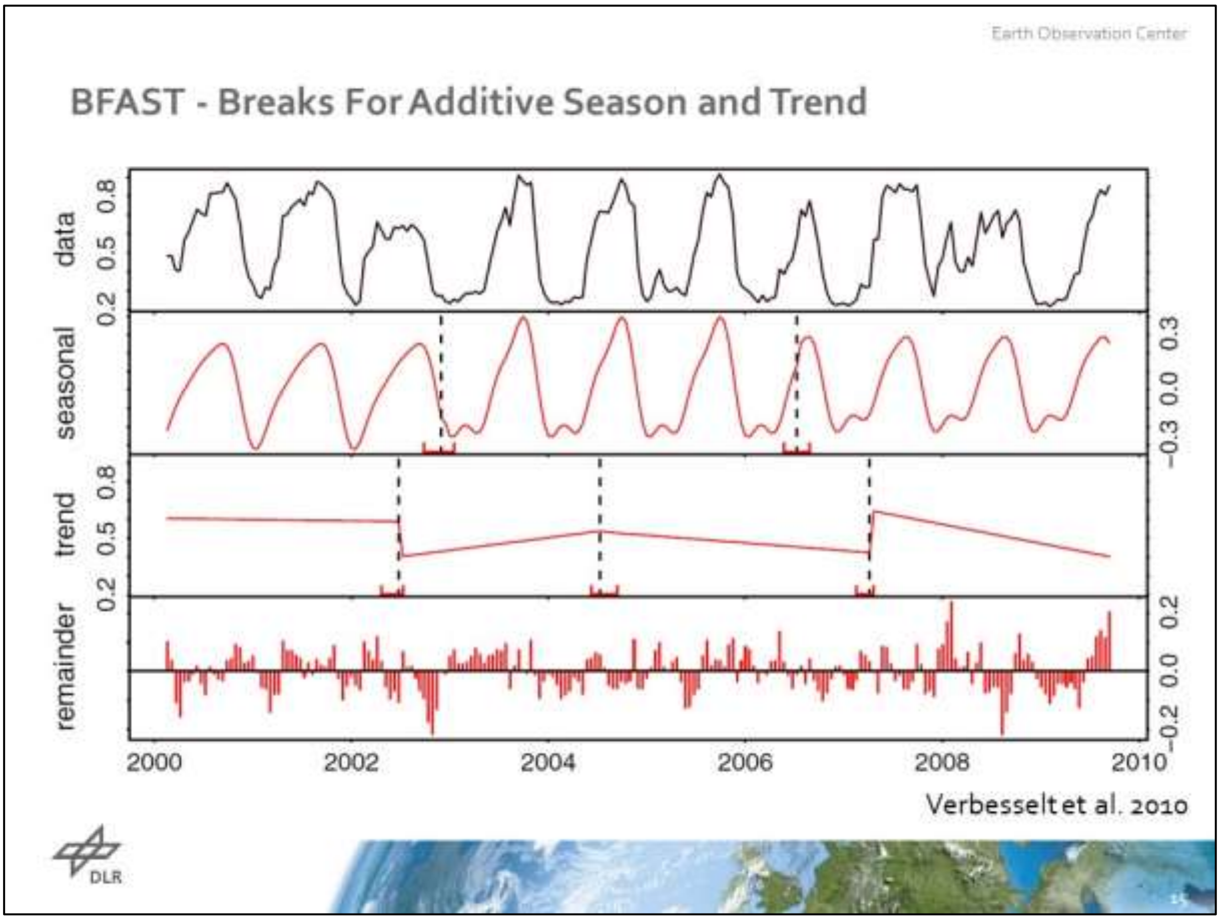
- General option when fitting smoothing functions to EO data:
  Fitting to the upper envelope
- Background:
  - Noise in VI time series is usually associated with a decrease (e.g. cloud effects)
  - An adaption of the smoothed / filtered time series to the higher rather than the lower values of a time series is favoured.
- Method:
  1) A function (e.g. Gaussian, quadratic polynomial) is fitted to a time series
  2) Data values of the original time series below the fitted function are given a lower weight
  3) Function is fitted a second time, with values weighted according to step 2)
  4) 2-3 can be repeated



Eklundh & Jönsson (2015)

DLR


Earth Observation Center
Analysis of multi-year temporal development (Trends)
– Linear trend analyses
– Methods accounting for discontinuous development / breaks, e.g.:
– BFAST
– LandTrendR
Figures adapted after:
Cowpertwaite & Metcalfe (2009)
DLR


Earth Observation Center
BFAST - Breaks For Additive Season and Trend
data
seasonal
trend
remainder
0.2 0.5 0.8
-0.3 0.0 0.3
0.2 0.5 0.8
-0.2 0.0 0.2
2000 2002 2004 2006 2008 2010
Verbesselt et al. 2010
DLR

Earth Observation Center

Trend Analysis of EO data

- When analysing EO time series for trends, several particularities of these datasets have to be considered:
  - Usually short time series
  - Sometimes high level of noise
  - Overlay of multiple noise effects and actual land surface dynamics / characteristics
  - Autocorrelation
  - Etc.
- Good overview on statistical particularities for EO time series analyses in:

De Beurs, K. M., & Henebry, G. M. (2005). A statistical framework for the analysis of long image time series. *International Journal of Remote Sensing*, *26*, 1551–1573.

DLR

Earth Observation Center

Analyses of Seasonality in EO time series

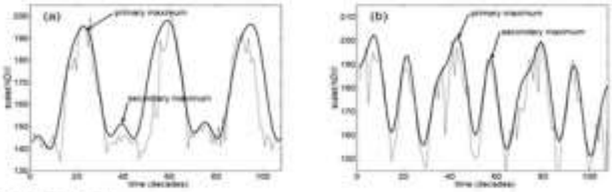
- Calculation of suitable seasonal/annual statistics (mean, median, variance, amplitude, integrals etc.) of the values of a variable in a time series
  - basis for trend analyses
  - usage as feature e.g. for land use/cover classification
- Determination of number of seasons per year

DLR

Earth Observation Center

Analyses of Seasonality in EO time series

Determination of number of seasons



Different approaches possible, e.g.:

- In Timesat Software (Eklundh & Jönsson, 2015):
  - de-trended data values (ti; yi), i = 1, 2,..,N for all years in the time-series are fit to a model function
  - fitting delivers a primary maximum, and possibly a secondary maximum.
  - amplitude ratio between the 2nd maximum and the 1st maximum > user defined threshold: -> 2 annual seasons, otherwise: 1 annual season
- Harmonic analysis
  - predefine one, two harmonics
  - Determine best fit

DLR

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Earth Observation Center

Analyses of Seasonality in EO time series

- Calculation of suitable seasonal/annual statistics (mean, median, variance, amplitude, integrals etc.) of the values of a variable in a time series
  - basis for trend analyses
  - usage as feature e.g. for land use/cover classification
- Determination of number of seasons per year
- Analysis of Land Surface Phenology

DLR

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Earth Observation Center

Phenology

Phenology analyzes life cycle events of <u>plants</u> and <u>animals</u>.

examples:

– when do cherry trees blossom?

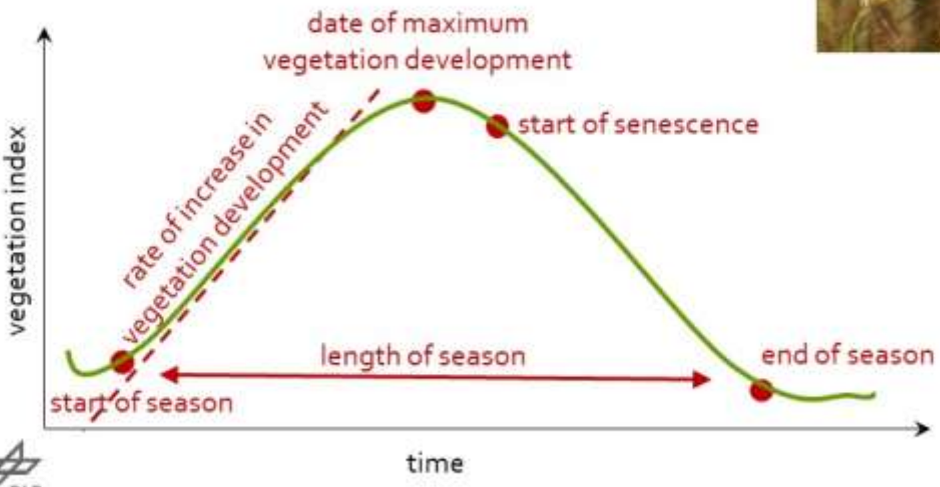
– when is barley in grainfilling stage?

Phenology is usually studied at plant / animal level.

DLR

Land Surface Phenology

SEASONALITY PARAMETERS



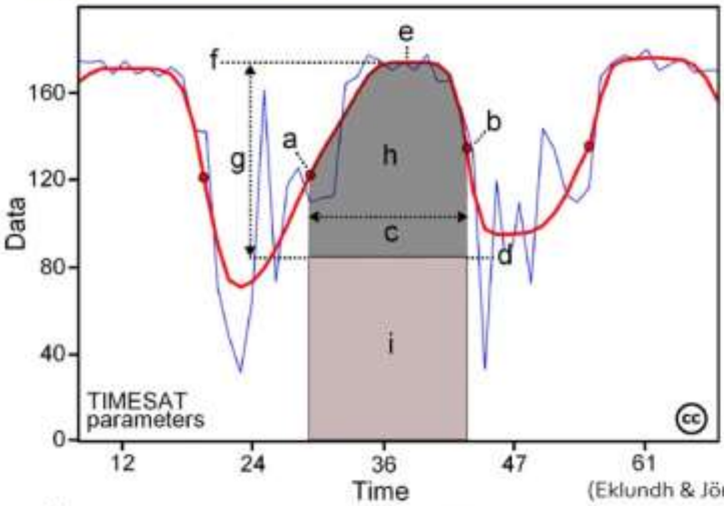
DLR

Earth Observation Center

Delineation of seasonality parameters from EO data

Seasonality parameters can be extracted from EO time series data for example using e.g. the TIMESAT software (Eklundh & Jönsson, 2015)

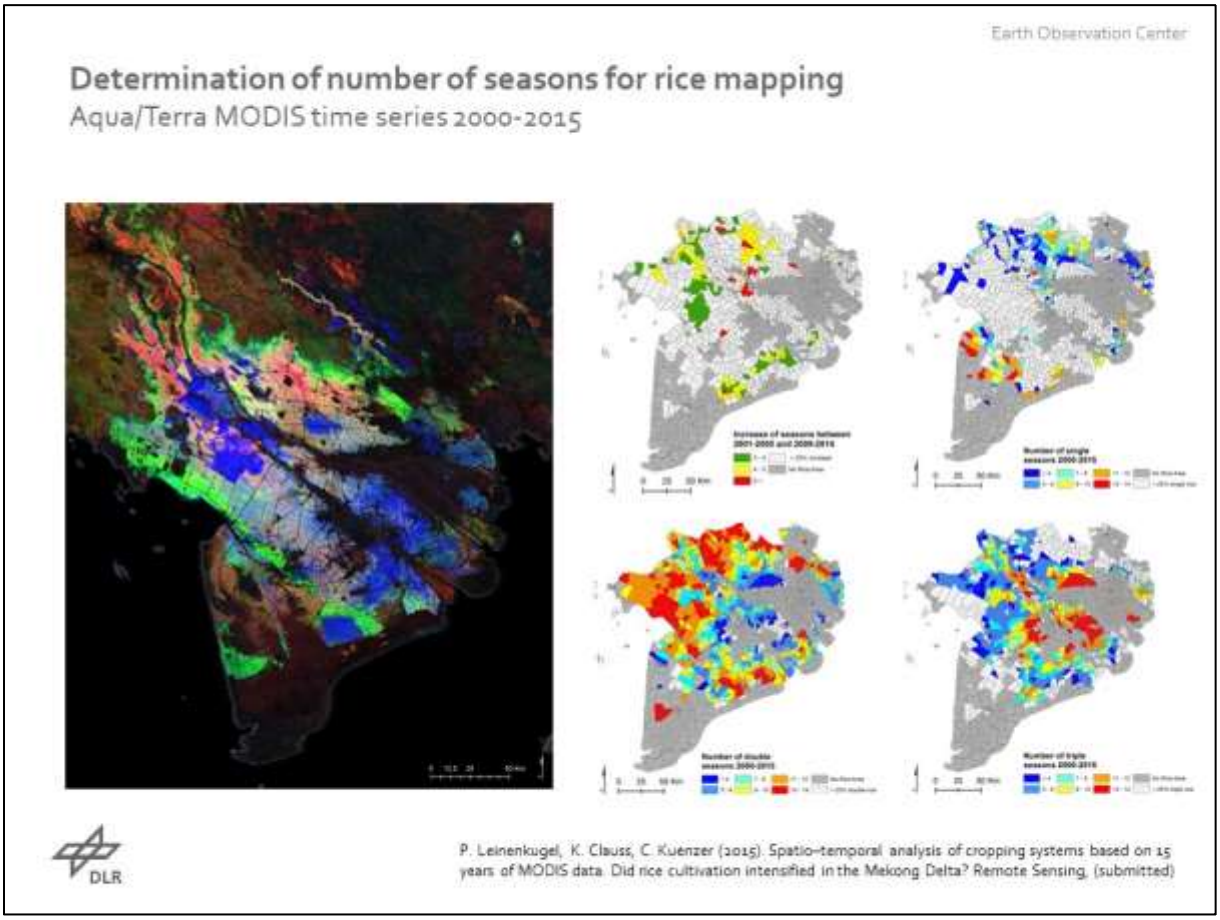
http://web.nateko.lu.se/timesat/timesat.asp

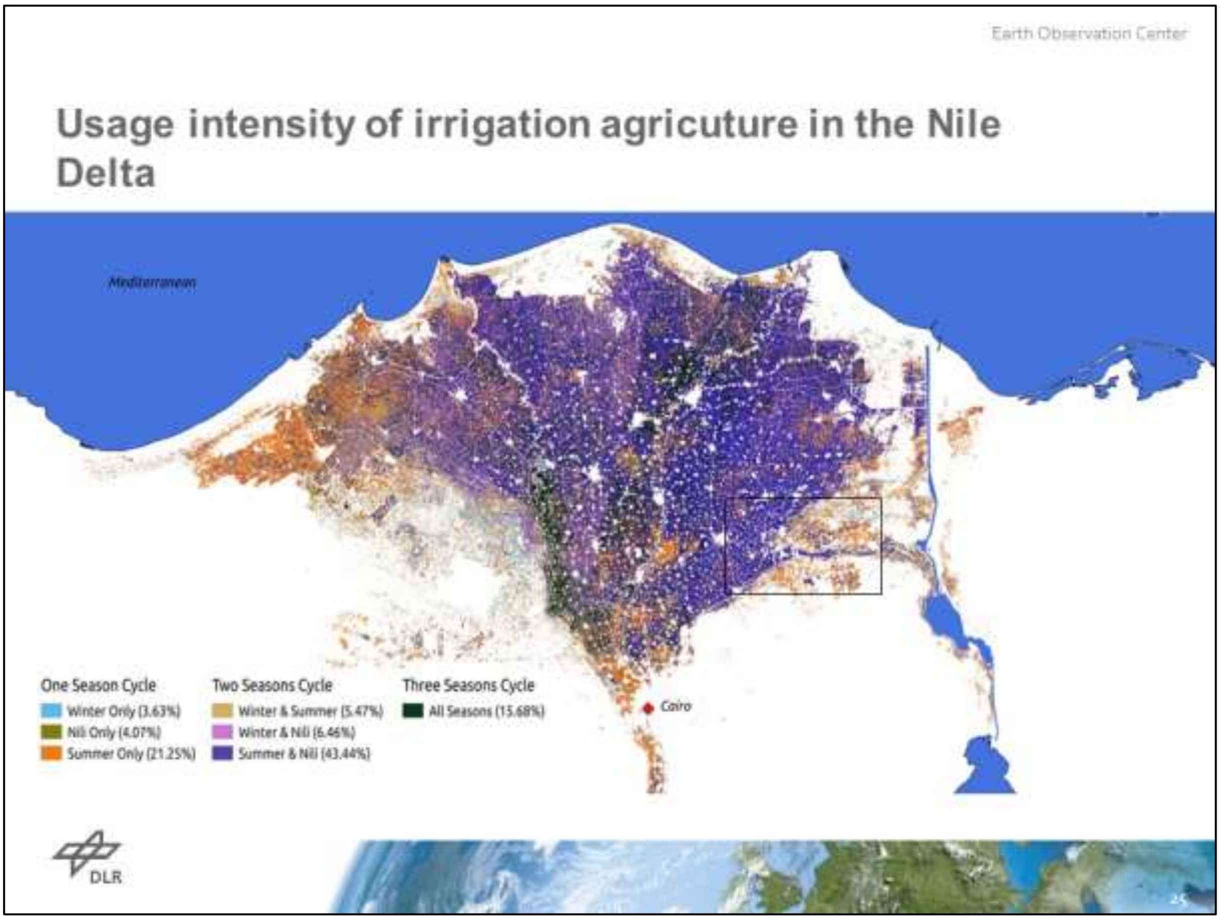


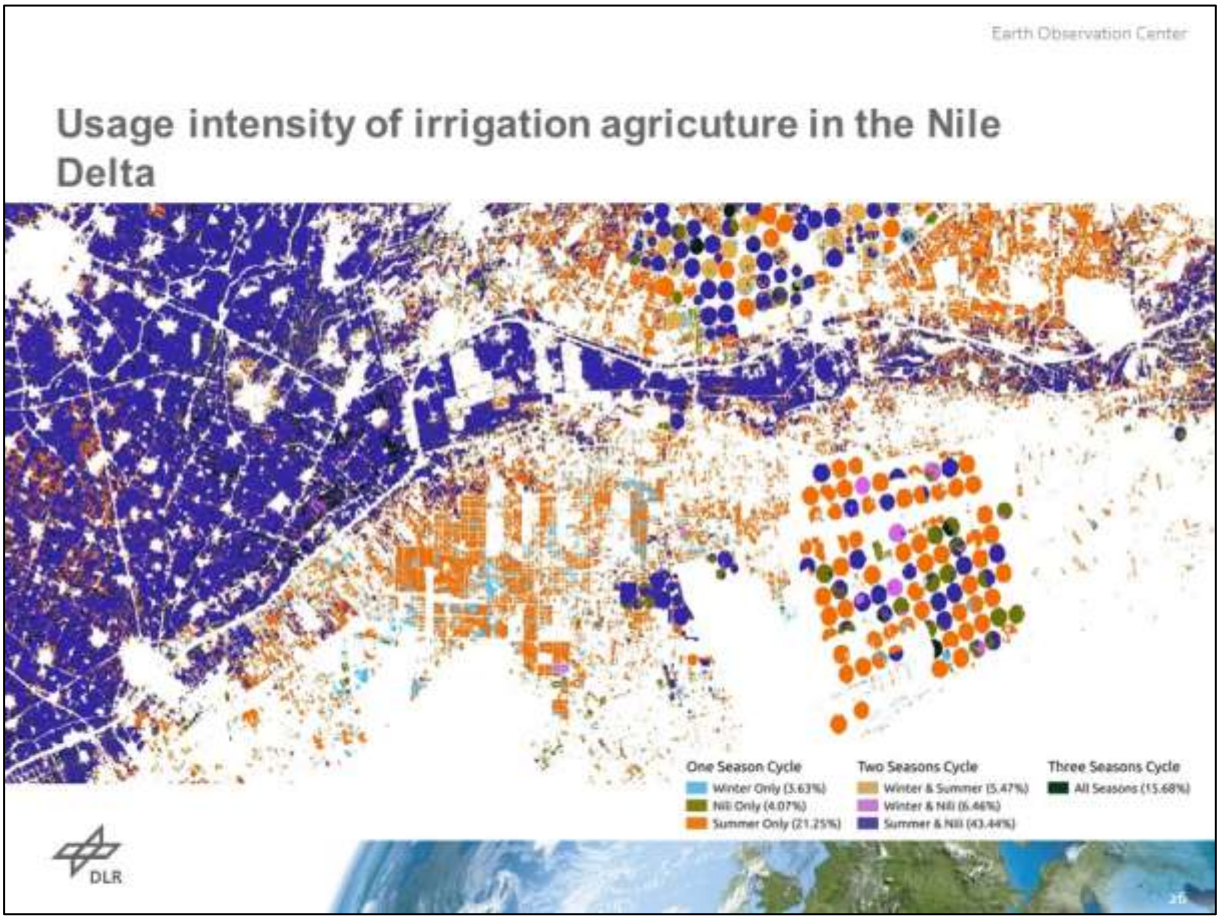
1. Time for the start of the season (a)
2. Time for the end of the season (b)
3. Length of the season (c)
4. Base level (d)
5. Time for the mid of the season (e)
6. Largest data value for the fitted function (f)
7. Seasonal amplitude (g)
8. Rate of increase at the beginning of the season
9. Rate of decrease at the end of the season
10. Large seasonal integral (h)
11. Small seasonal integral (h+i)

(Eklundh & Jönsson, 2015)

DLR


Earth Observation Center
Determination of number of seasons for rice mapping
Aqua/Terra MODIS time series 2000-2015
DLR
P. Leinenkugel, K. Clauss, C. Kuenzer (2015). Spatio-temporal analysis of cropping systems based on 15 years of MODIS data. Did rice cultivation intensified in the Mekong Delta? Remote Sensing, (submitted)


Earth Observation Center
Usage intensity of irrigation agricuture in the Nile Delta
Mediterranean
Cairo
One Season Cycle
Winter Only (3.63%)
Nili Only (4.07%)
Summer Only (21.25%)
Two Seasons Cycle
Winter & Summer (5.47%)
Winter & Nili (6.46%)
Summer & Nili (43.44%)
Three Seasons Cycle
All Seasons (15.68%)
DLR


Earth Observation Center
Usage intensity of irrigation agricuture in the Nile Delta
One Season Cycle
Winter Only (3.63%)
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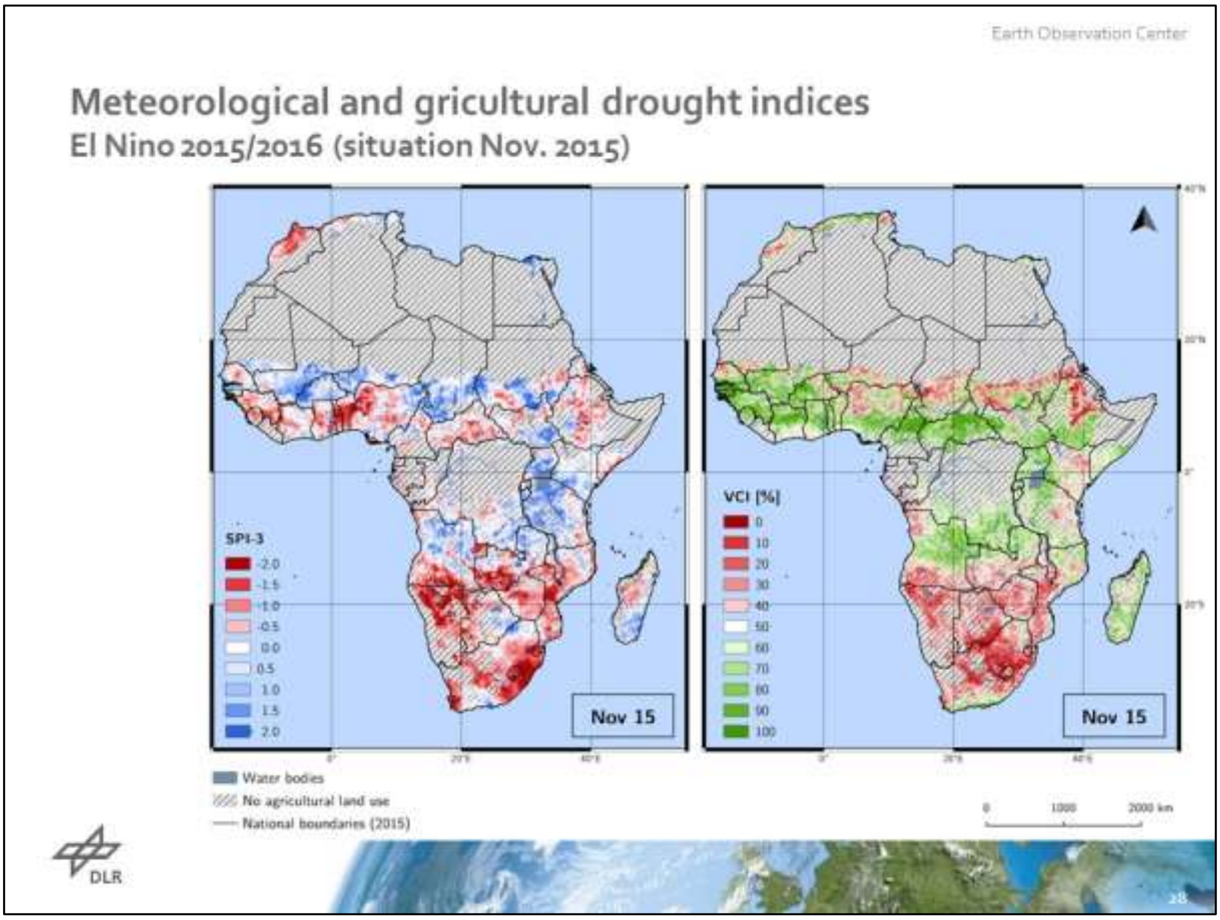
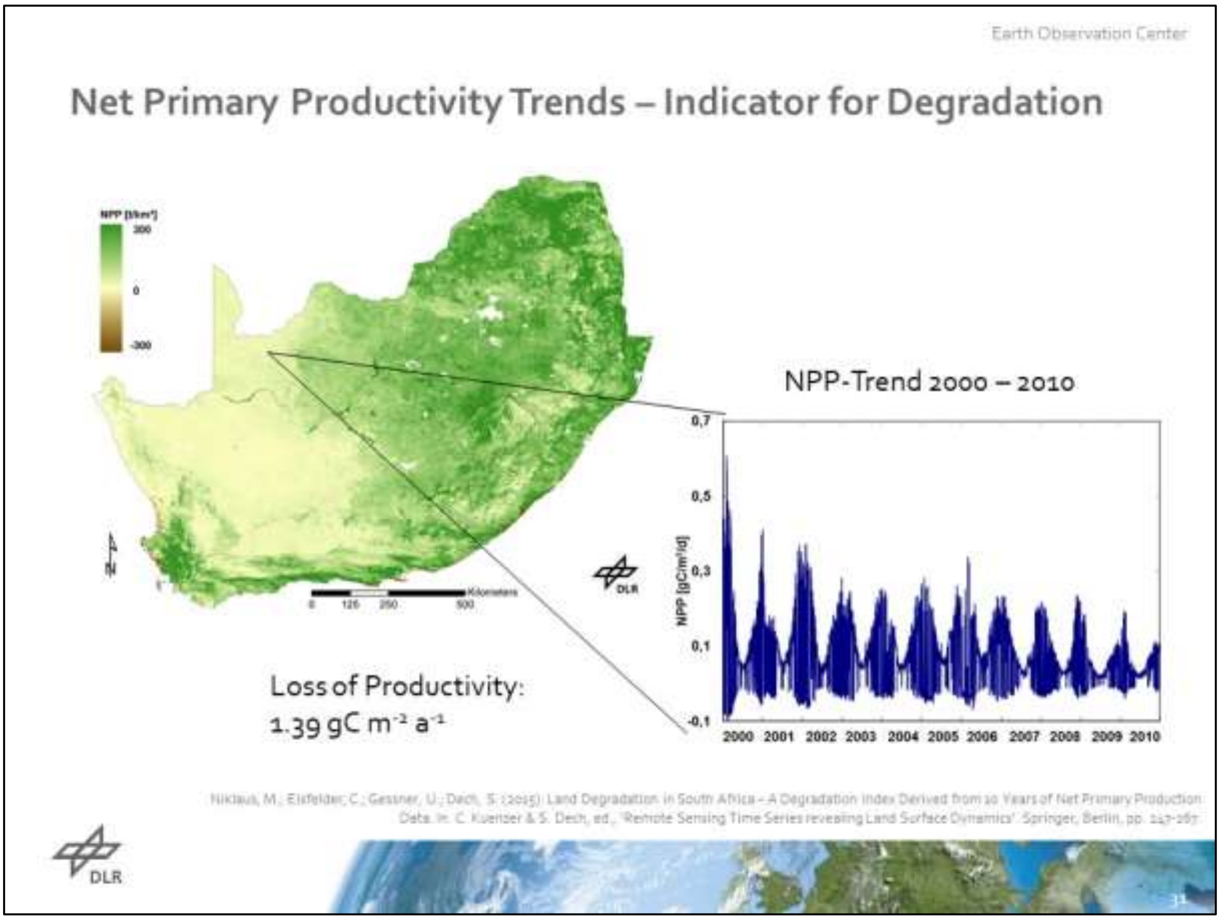
Two Seasons Cycle
Winter & Summer (5.47%)
Winter & Nili (6.46%)
Summer & Nili (43.44%)
Three Seasons Cycle
All Seasons (15.68%)
DLR


Drought Analyses

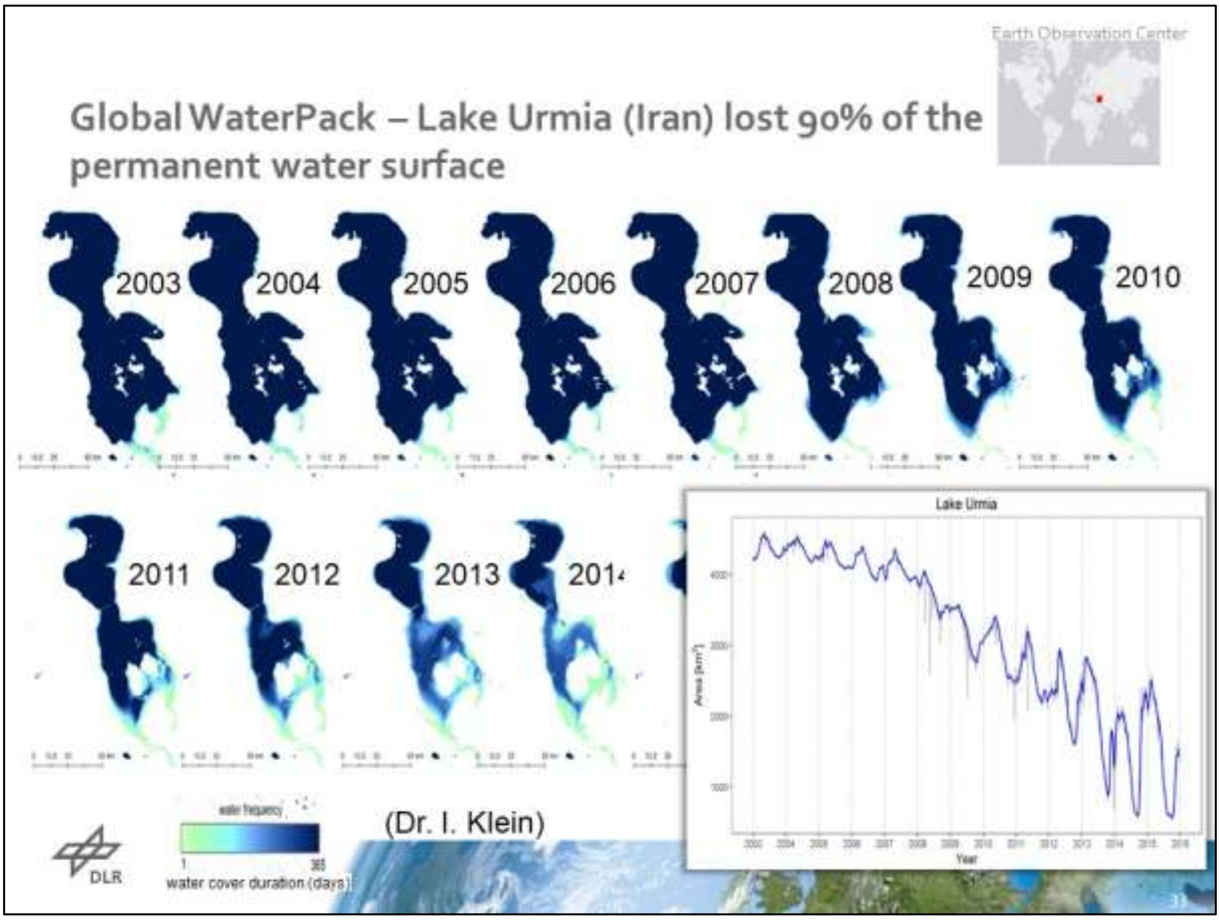

Earth Observation Center
Meteorological and gricultural drought indices
El Nino 2015/2016 (situation Nov. 2015)
SPI-3
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Nov 15
VCI [%]
0
10
20
30
40
50
60
70
80
90
100
Nov 15
Water bodies
No agricultural land use
National boundaries (2015)
0 1000 2000 km
DLR


Net Primary Productivity
DLR

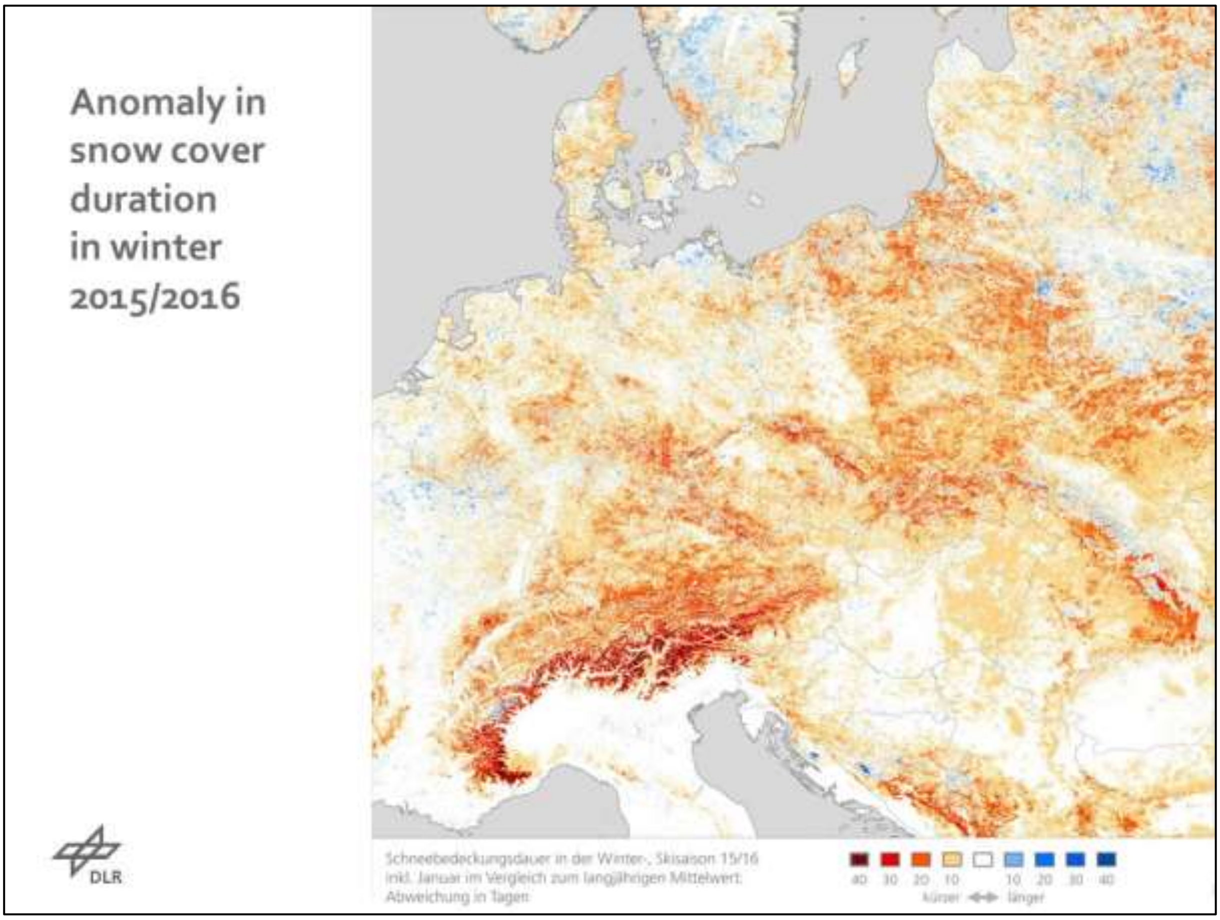

Earth Observation Center
Rangeland Productivity and Degradation
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
DLR
Niklaus, M., Eisfelder, C., Gessner, U., Dech, S. (2015): Land Degradation in South Africa – A Degradation Index Derived from 10 Years of Net Primary Production Data. In: C. Kuenzer & S. Dech, ed., 'Remote Sensing Time Series revealing Land Surface Dynamics'. Springer, Berlin, pp. 247-267


Earth Observation Center
Net Primary Productivity Trends – Indicator for Degradation
NPP-Trend 2000 – 2010
0,7
0,5
0,3
0,1
-0,1
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Loss of Productivity:
1.39 gC m⁻² a⁻¹
DLR
Niklaus, M., Eisfelder, C., Gessner, U., Dech, S. (2015): Land Degradation in South Africa – A Degradation Index Derived from 10 Years of Net Primary Production Data. In: C. Kuenzer & S. Dech, ed., 'Remote Sensing Time Series revealing Land Surface Dynamics'. Springer, Berlin, pp. 247-267

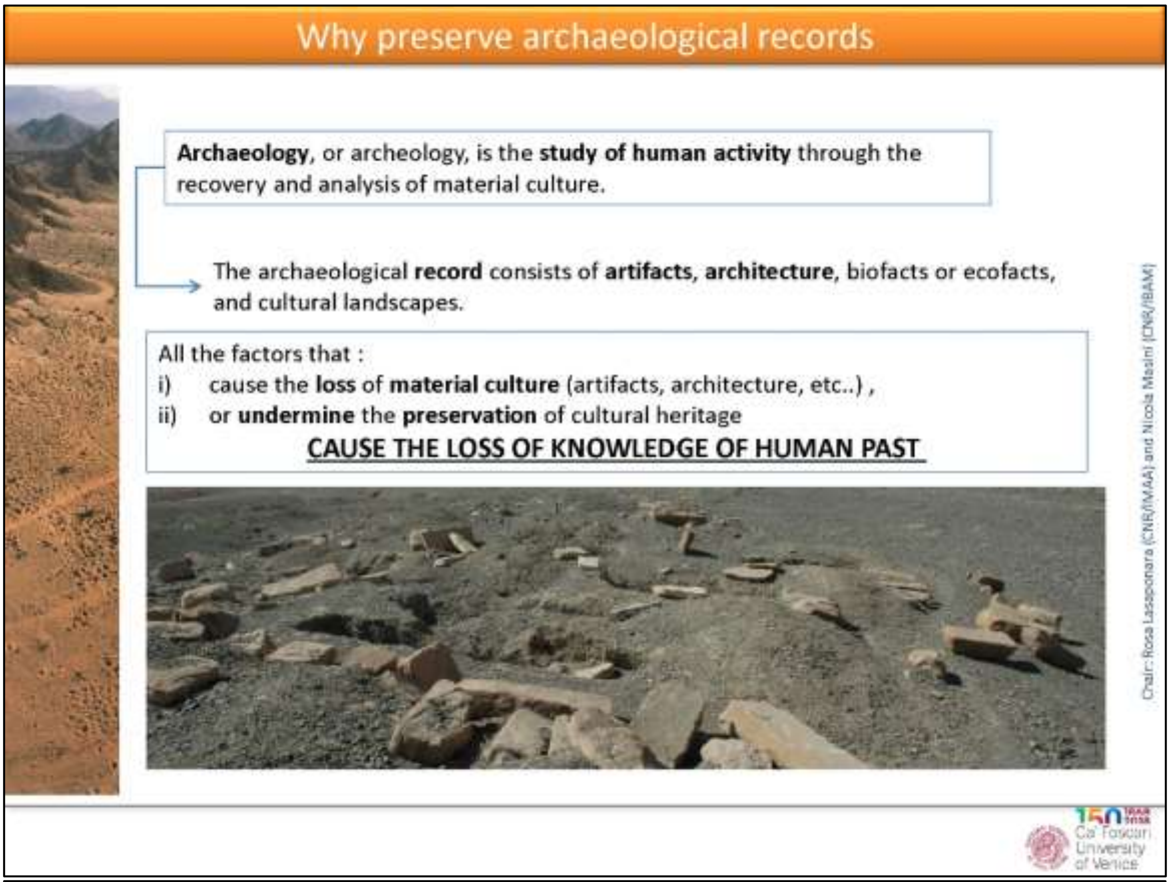

Surface water resources for agriculture


Earth Observation Center
Global WaterPack – Lake Urmia (Iran) lost 90% of the permanent water surface
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
201
Lake Urmia
Area [km²]
Year
water frequency
1
365
water cover duration (days)
(Dr. I. Klein)
DLR

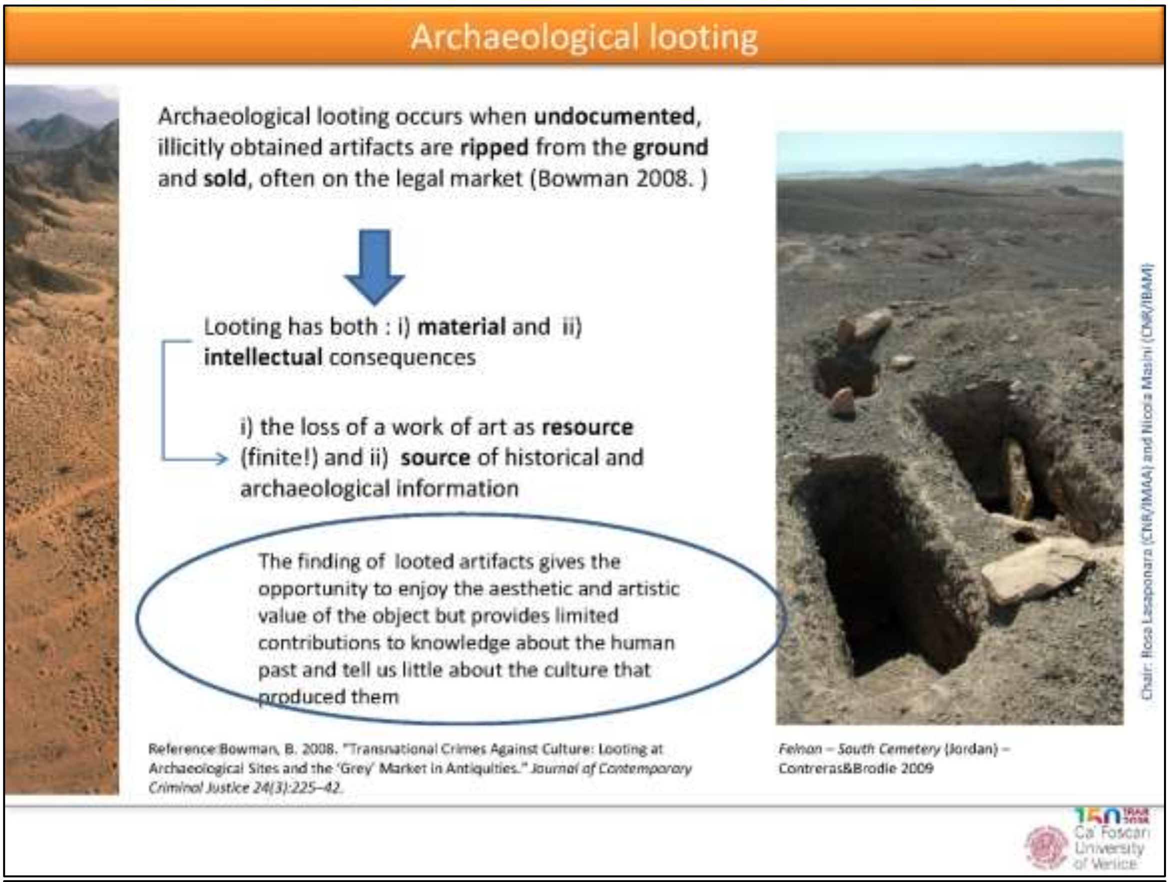

Snow Cover

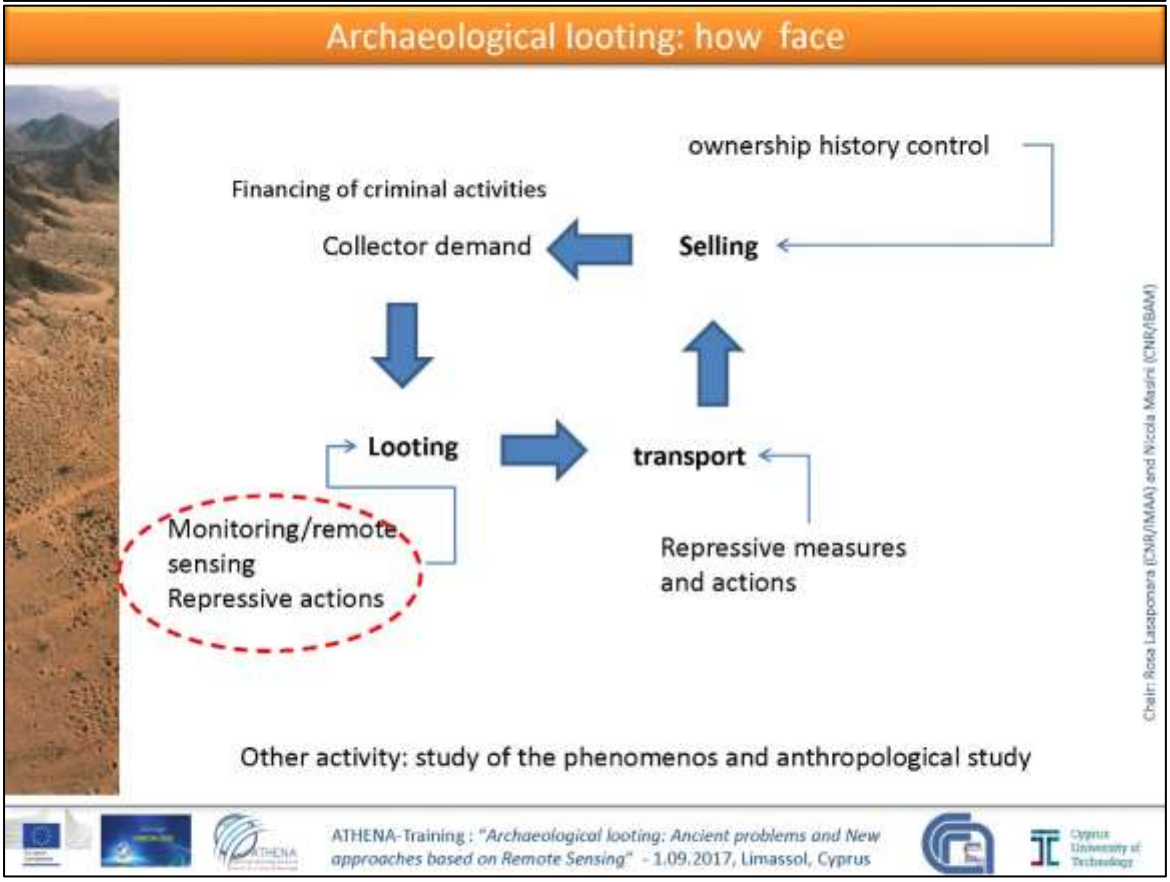

Anomaly in
snow cover
duration
in winter
2015/2016
DLR
Schneebedeckungsdauer in der Winter-, Skisaison 15/16
inkl. Januar im Vergleich zum langjährigen Mittelwert:
Abweichung in Tagen
40 30 20 10 10 20 30 40
kürzer länger

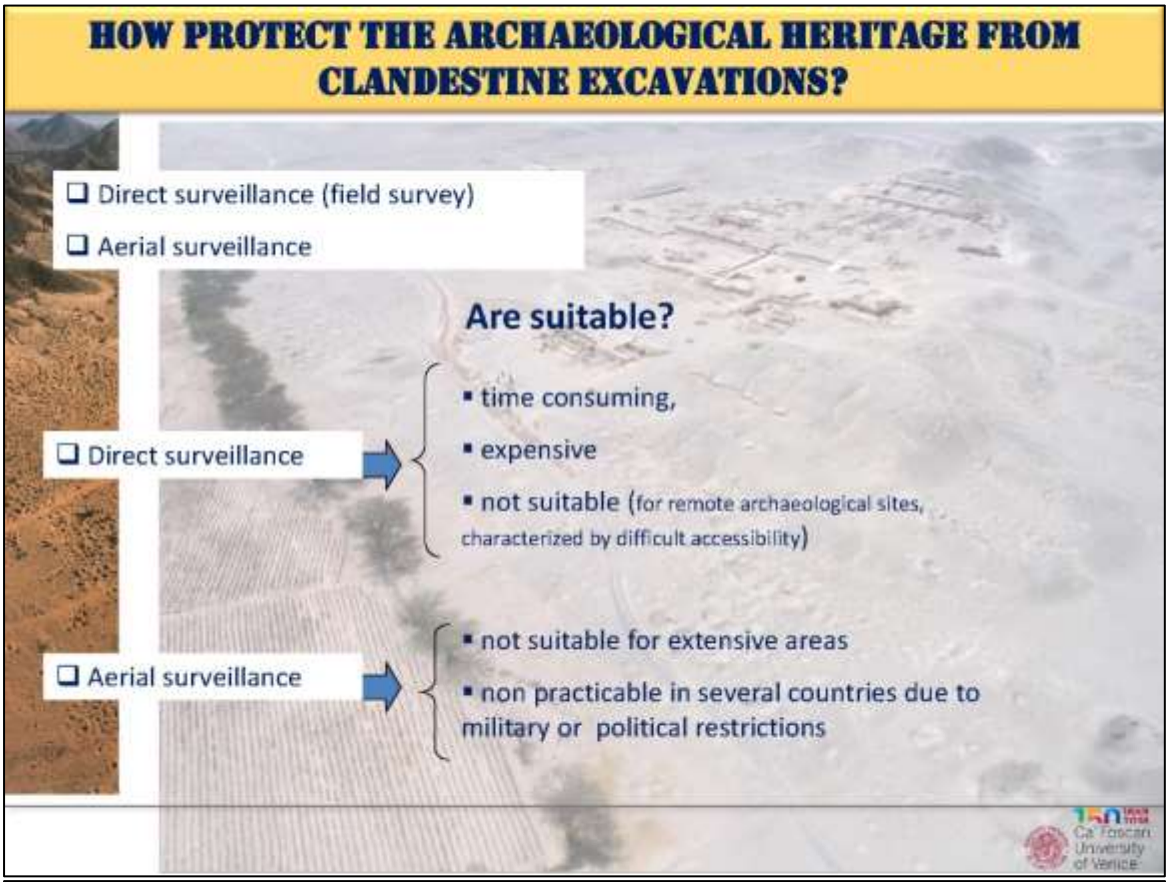
2.5 Fifth presentation - Archaeological looting

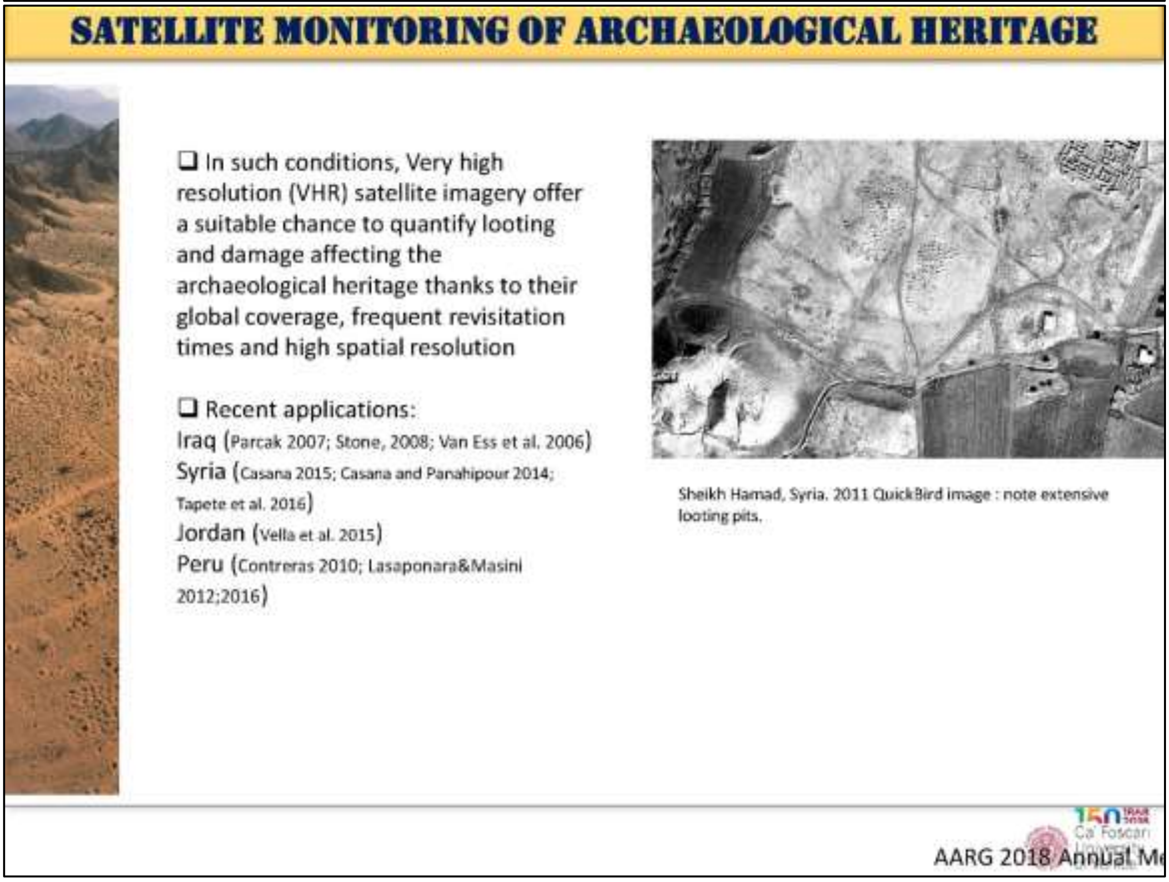

Why preserve archaeological records
Archaeology, or archeology, is the **study of human activity** through the recovery and analysis of material culture.
The archaeological **record** consists of **artifacts**, **architecture**, biofacts or ecofacts, and cultural landscapes.
All the factors that :
i) cause the **loss** of **material culture** (artifacts, architecture, etc..) ,
ii) or **undermine** the **preservation** of cultural heritage
CAUSE THE LOSS OF KNOWLEDGE OF HUMAN PAST
Chair: Rosa Lasaponara (CNR/IMAA) and Nicola Masini (CNR/IBAM)
Ca' Foscari University of Venice

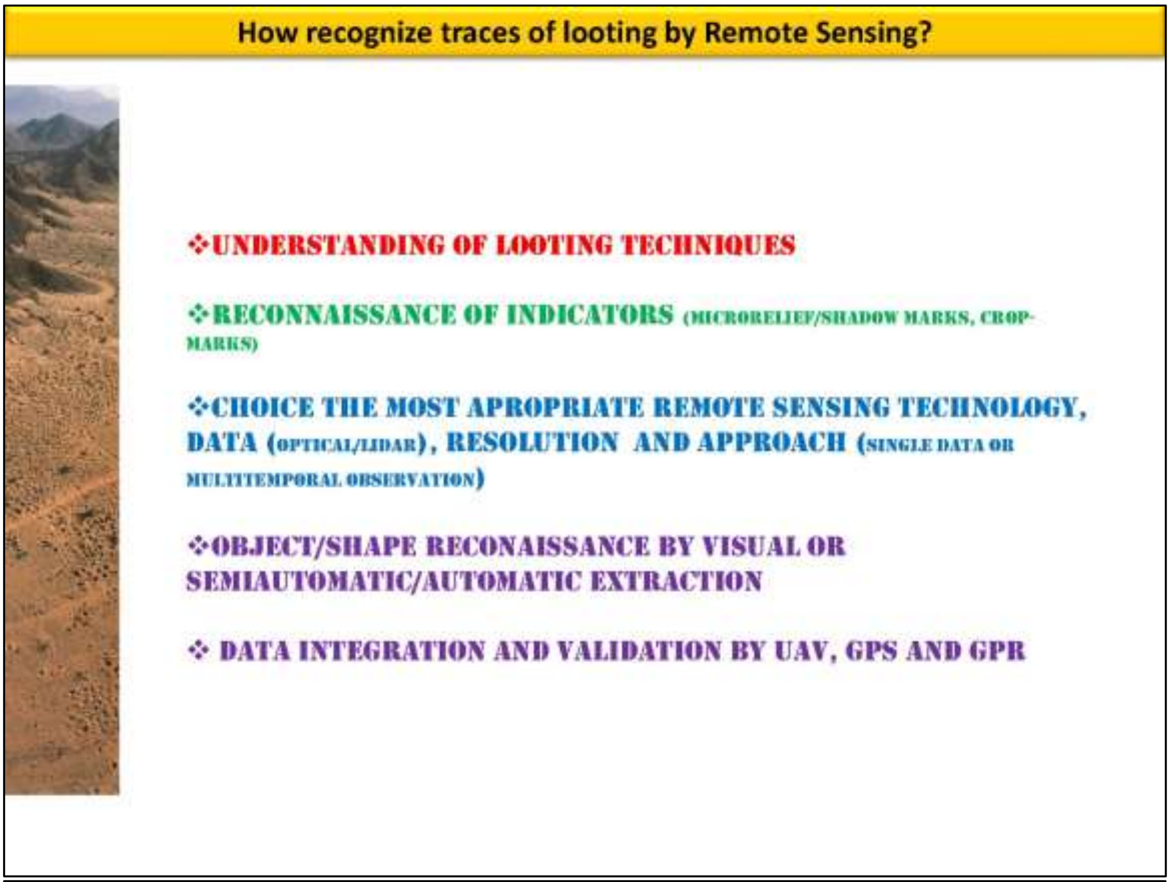

Archaeological disturbance
Vandalism
Anthropic pressure
Palmira (Syria)
Giza Piramid (Egypt)
Looting
Ventarron (Peru)
Ca' Foscari University of Venice

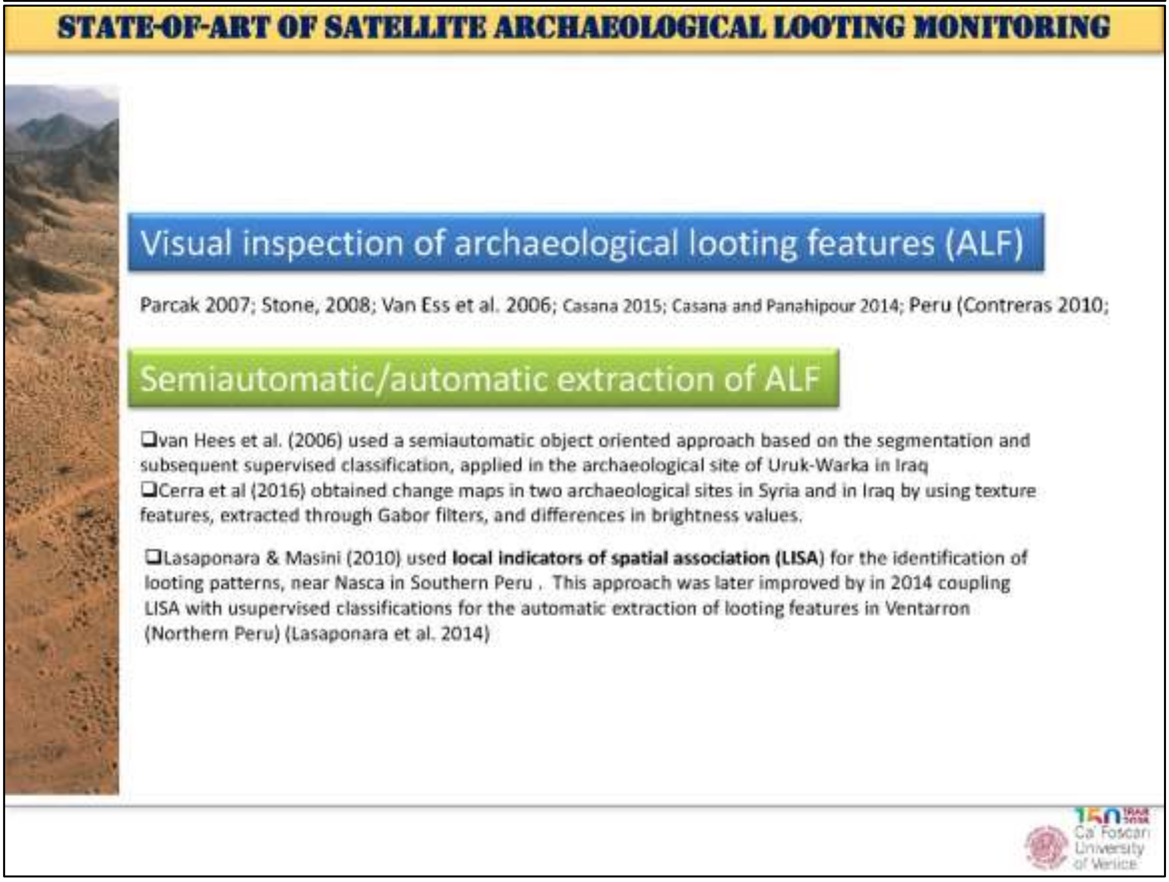

Archaeological looting
Archaeological looting occurs when **undocumented**, illicitly obtained artifacts are **ripped** from the **ground** and **sold**, often on the legal market (Bowman 2008.)
Looting has both : i) **material** and ii) **intellectual** consequences
i) the loss of a work of art as **resource** (finite!) and ii) **source** of historical and archaeological information
The finding of looted artifacts gives the opportunity to enjoy the aesthetic and artistic value of the object but provides limited contributions to knowledge about the human past and tell us little about the culture that produced them
Reference:Bowman, B. 2008. "Transnational Crimes Against Culture: Looting at Archaeological Sites and the 'Grey' Market in Antiquities." *Journal of Contemporary Criminal Justice 24(3):225–42.*
Feinan – South Cemetery (Jordan) – Contreras&Brodie 2009
Chair: Rosa Lasaponara (CNR/IMAA) and Nicola Masini (CNR/IBAM)
Ca' Foscari University of Venice

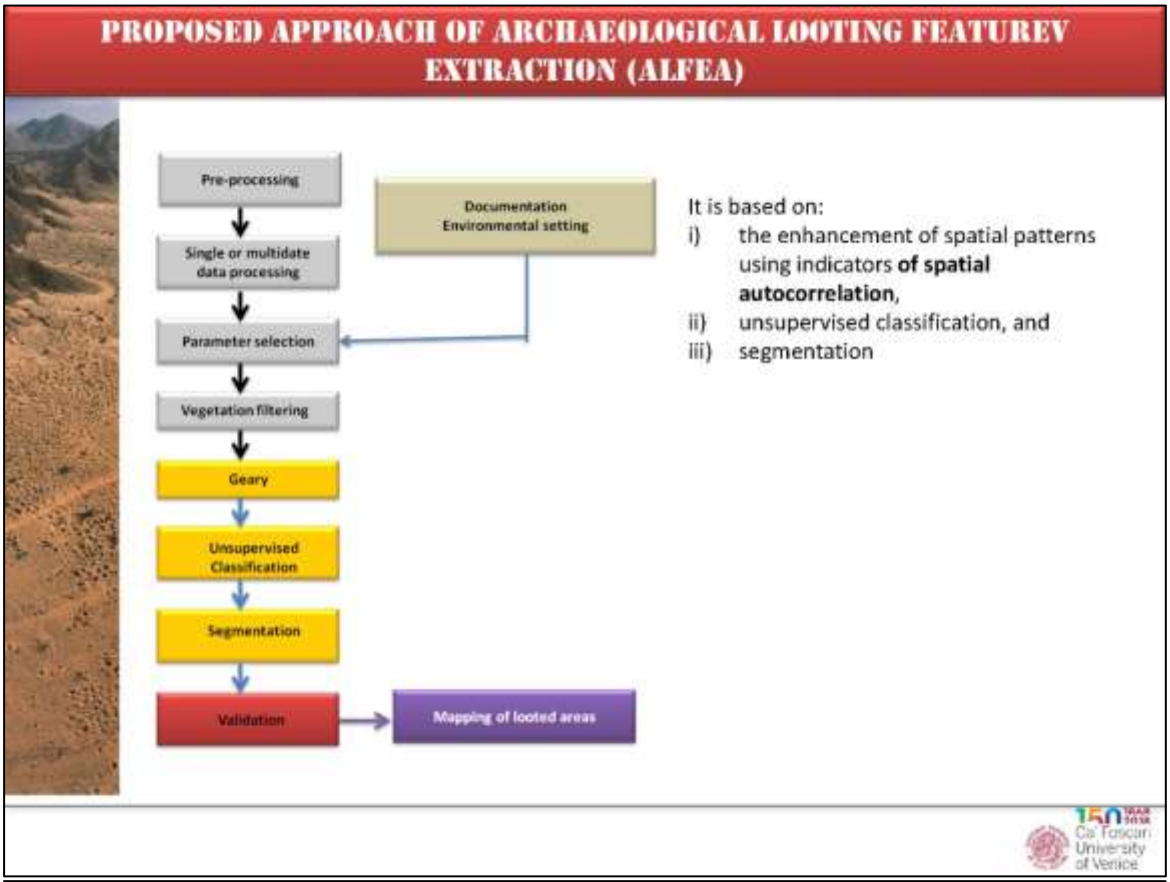

Archaeological looting: how face
ownership history control
Financing of criminal activities
Collector demand
Selling
Looting
transport
Monitoring/remote sensing
Repressive actions
Repressive measures and actions
Other activity: study of the phenomenos and anthropological study
Chair: Rosa Lasaponara (CNR/IMAA) and Nicola Masini (CNR/IBAM)
ATHENA-Training : *"Archaeological looting: Ancient problems and New approaches based on Remote Sensing"* - 1.09.2017, Limassol, Cyprus
Cyprus University of Technology

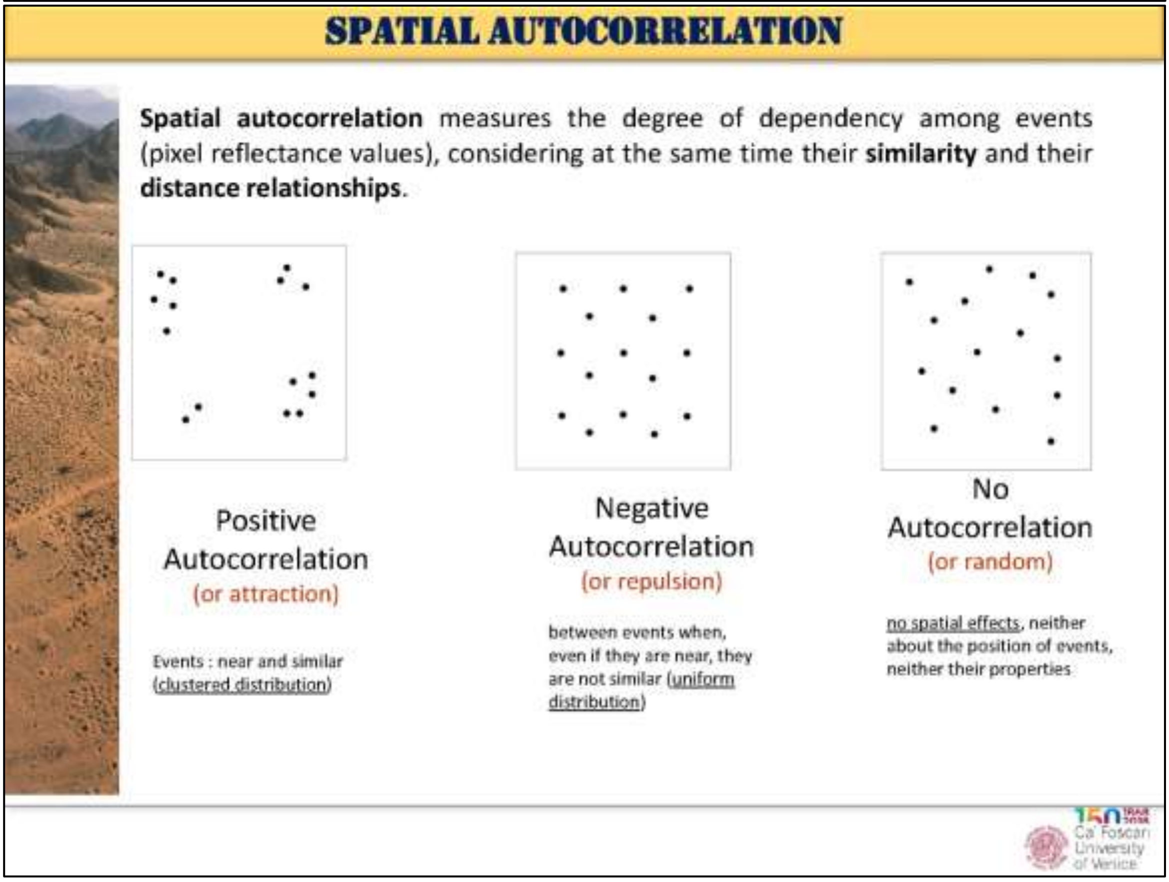

HOW PROTECT THE ARCHAEOLOGICAL HERITAGE FROM CLANDESTINE EXCAVATIONS?
❑ Direct surveillance (field survey)
❑ Aerial surveillance
Are suitable?
❑ Direct surveillance
▪ time consuming,
▪ expensive
▪ not suitable (for remote archaeological sites, characterized by difficult accessibility)
❑ Aerial surveillance
▪ not suitable for extensive areas
▪ non practicable in several countries due to military or political restrictions
Ca' Foscari University of Venice


SATELLITE MONITORING OF ARCHAEOLOGICAL HERITAGE
❑ In such conditions, Very high resolution (VHR) satellite imagery offer a suitable chance to quantify looting and damage affecting the archaeological heritage thanks to their global coverage, frequent revisitation times and high spatial resolution
❑ Recent applications:
Iraq (Parcak 2007; Stone, 2008; Van Ess et al. 2006)
Syria (Casana 2015; Casana and Panahipour 2014; Tapete et al. 2016)
Jordan (Vella et al. 2015)
Peru (Contreras 2010; Lasaponara&Masini 2012;2016)
Sheikh Hamad, Syria. 2011 QuickBird image : note extensive looting pits.
Ca' Foscari
AARG 2018 Annual M


How recognize traces of looting by Remote Sensing?
❖UNDERSTANDING OF LOOTING TECHNIQUES
❖RECONNAISSANCE OF INDICATORS (MICRORELIEF/SHADOW MARKS, CROP-MARKS)
❖CHOICE THE MOST APROPRIATE REMOTE SENSING TECHNOLOGY, DATA (OPTICAL/LIDAR), RESOLUTION AND APPROACH (SINGLE DATA OR MULTITEMPORAL OBSERVATION)
❖OBJECT/SHAPE RECONAISSANCE BY VISUAL OR SEMIAUTOMATIC/AUTOMATIC EXTRACTION
❖ DATA INTEGRATION AND VALIDATION BY UAV, GPS AND GPR


STATE-OF-ART OF SATELLITE ARCHAEOLOGICAL LOOTING MONITORING
Visual inspection of archaeological looting features (ALF)
Parcak 2007; Stone, 2008; Van Ess et al. 2006; Casana 2015; Casana and Panahipour 2014; Peru (Contreras 2010;
Semiautomatic/automatic extraction of ALF
❑van Hees et al. (2006) used a semiautomatic object oriented approach based on the segmentation and subsequent supervised classification, applied in the archaeological site of Uruk-Warka in Iraq
❑Cerra et al (2016) obtained change maps in two archaeological sites in Syria and in Iraq by using texture features, extracted through Gabor filters, and differences in brightness values.
❑Lasaponara & Masini (2010) used local indicators of spatial association (LISA) for the identification of looting patterns, near Nasca in Southern Peru . This approach was later improved by in 2014 coupling LISA with usupervised classifications for the automatic extraction of looting features in Ventarron (Northern Peru) (Lasaponara et al. 2014)
Ca' Foscari University of Venice


PROPOSED APPROACH OF ARCHAEOLOGICAL LOOTING FEATUREV EXTRACTION (ALFEA)
Pre-processing
Single or multidate data processing
Parameter selection
Vegetation filtering
Geary
Unsupervised Classification
Segmentation
Validation
Documentation Environmental setting
Mapping of looted areas
It is based on:
i) the enhancement of spatial patterns using indicators of spatial autocorrelation,
ii) unsupervised classification, and
iii) segmentation
Ca' Foscari University of Venice


SPATIAL AUTOCORRELATION
Spatial autocorrelation measures the degree of dependency among events (pixel reflectance values), considering at the same time their similarity and their distance relationships.
Positive Autocorrelation
(or attraction)
Events : near and similar (clustered distribution)
Negative Autocorrelation
(or repulsion)
between events when, even if they are near, they are not similar (uniform distribution)
No Autocorrelation
(or random)
no spatial effects, neither about the position of events, neither their properties
Ca' Foscari University of Venice

LOCAL INDICATORS OF SPATIAL AUTOCORRELATION (LISA)

LISA allow us to understand **where clustered pixels are**, by measuring **how much are homogeneous** features inside the fixed neighbourhood

Local Moran's index

(Anselin, 1995),

$$I_i = \frac{(X_i - \overline{X})}{S_X^{\ 2}} \sum_{j=1}^{N} (w_{ij}(X_j - \overline{X}))$$

Clustering: Positive values indicate a cluster of similar values, while negative values imply no clustering (that is, high variability between neighboring pixels)

Local Geary's C index

(Cliff & Ord, 1981)

$$c = \frac{n-1}{\sum_{i=1}^{n}(X_i - \overline{X})^2} \cdot \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(X_i - X_j)^2}{2\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}}$$

Detection of areas of **dissimilarity** in reflectance value, thus enabling to detect **edge areas** between clusters and other areas with dissimilar values neighboring values

Getis and Ord's Gi index

$$G_i(d) = \frac{\sum_{i=1}^{n} w_i(d)\, x_i - \bar{x}_i \sum_{i=1}^{n} w_i(d)}{S(i)\sqrt{\left[(N-1)\sum_{i=1}^{n} w_i(d) - \left(\sum_{i=1}^{n} w_i(d)\right)^2\right] \Big/ N-2}}$$

(Getis and Ord, 1992; Illian et al., 2008)

Hot spot: determination of concentrations of low values and high values

- N is the events number
- X_i ed X_j are the intensity values in the point i and j (with i≠j)
- $\overline{X}$ is the intensity mean
- w_{ij} is an element of the weights matrix

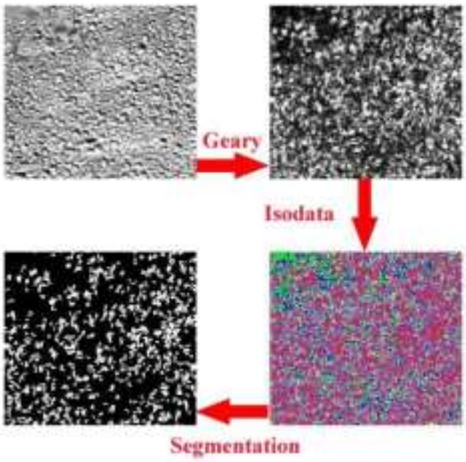
For the purpose of our investigations, it is expected that the use of **Local Geary's C index** should enhance traces and features linked to illegal excavation

CLASSIFICATION AND SEGMENTATION

After the Local Geary's C, unsupervised classification and segmentation were applied.

Unsupervised classification (**UC**) enables: i) to obtain an automatic clusterization process, ; ii) and to overcome the need of a priori pre-defining known classes.
ISODATA method has been used considered more flexible than other **Ucs** (such as K-Means)

Segmentation allows us to refine the outputs from classification, selecting meaningful feature classes thus improving the interpretation



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CASE STUDY 1: DURA EUROPOS

- Dura Europos, located at east of Syria close to the border with Iraq
- It was founded by the Seleucids in the 3rd century BC. Over the centuries was a crossroad between different cultures.
- It is characterized by religious temples related to diverse cults such as the Greek Zeus temple, the shrine of Sumerian goddess Nanaia, the shrine of Syrian goddess Atargatis, the temple of the Palmyran god Bel, and thee Jewish synagogue
- The citadel is around 60 hectares today completely covered by looters' pits mainly excavated from 2012 to 2015

CASE STUDY 1: DURA EUROPOS

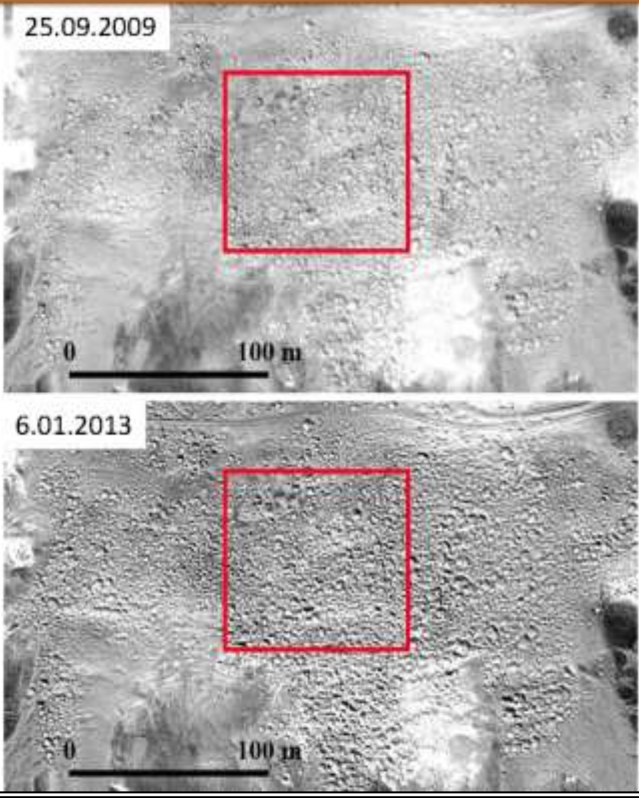
CASE STUDY 1: DURA EUROPOS – LOOTING TECHNIQUES

Rectangular well digging with manual toc
compact soil
The **walls** of the well are **vertical**

CASE STUDY 2: CAHUACHI

- Cahuachi is located in the South of Peru and it is the most important Ceremonial Centre of Nasca Culture, dating back from 400 BC to 400 AD. The geomorphology characterized by several mounds has been exploited by the Nasca to create pyramids built in adobe where rituals and ceremonies took place.
- Cahuachi is an emblematic case of massively looted sites since the Colonial Period
- The damage caused by grave robbers is easily recognizable by means of circular holes

CASE STUDY 2: CAHUACHI

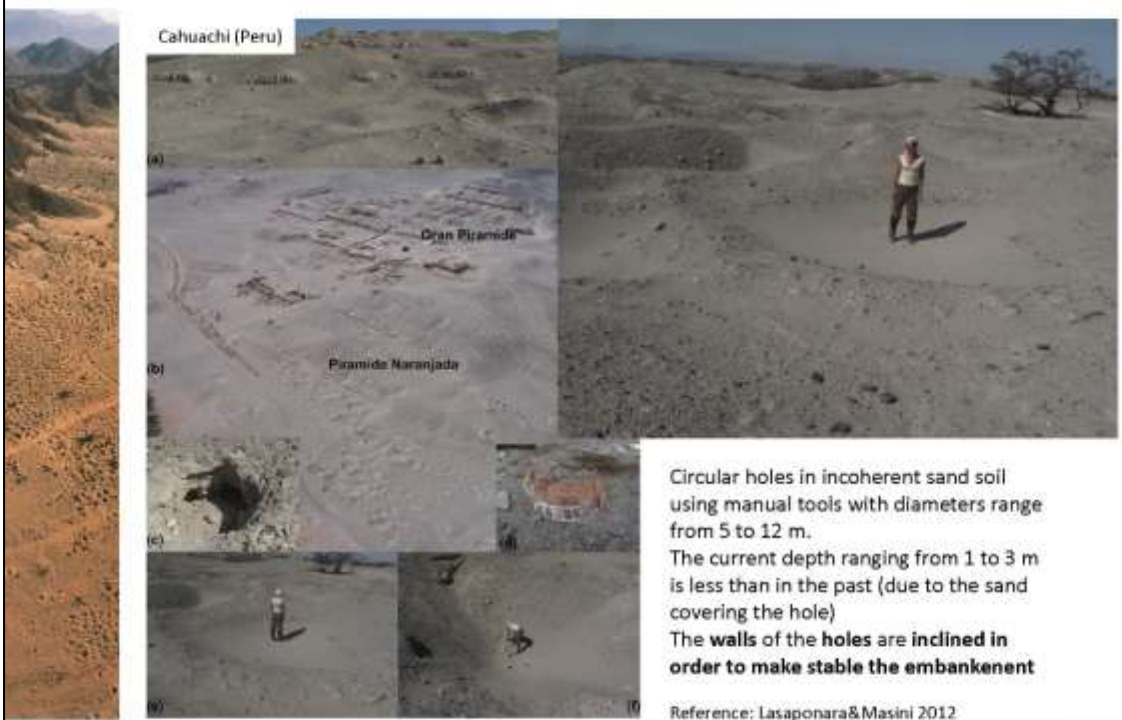


Between the two images acquired in 2009 and 2014, there is no difference in terms of looting but simply in visibility of the looting holes that are more clear in 2013 than in 2009:

i) for the better resolution of 2013 image

ii) the 2009 image has been acquired in a period characterized by the Paracas Winds with associated transport of dust and sand that make the edges of circular holes less visible.

CASE STUDY 2: CAHUACHI– LOOTING TECHNIQUES



Circular holes in incoherent sand soil using manual tools with diameters range from 5 to 12 m.
The current depth ranging from 1 to 3 m is less than in the past (due to the sand covering the hole)
The walls of the holes are inclined in order to make stable the embankenent

Reference: Lasaponara&Masini 2012

Chair: Rosa Lasaponara (CNR/IMAA) and Nicola Masini (CNR/IBAM)

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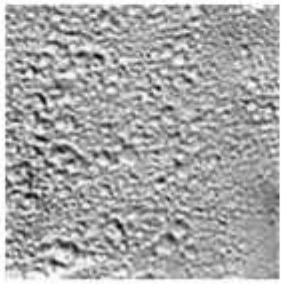
COMPARISON BETWEEN LOOTING HOLES IN TWO CASE STUDIES

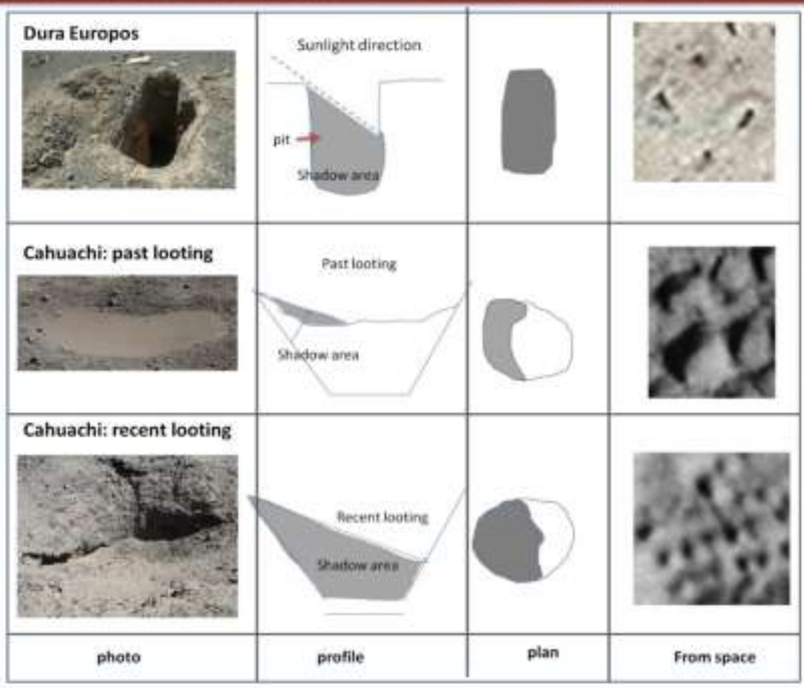
Dura Europos: the looting fetures are pits with diameters 2 – 4 m and 1.5 to 3 meters deep

Cahuachi: the looting fetures are circular holes with diameters ranging from 3 to 10 m and depth from 0.5 to 1.5 m



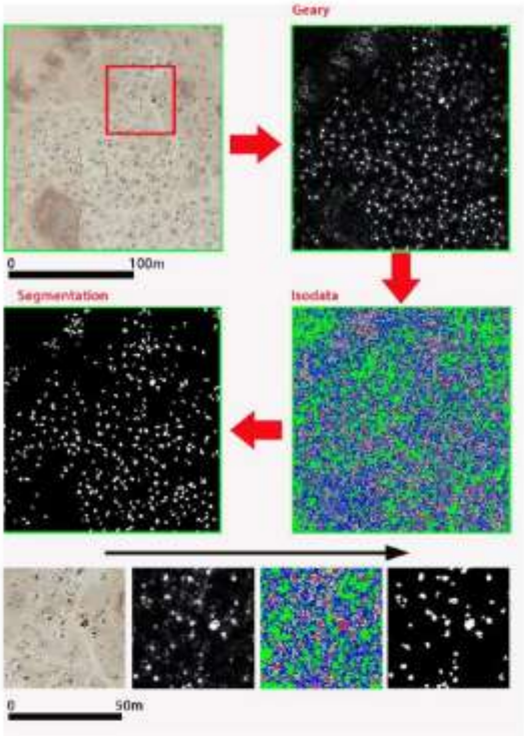
The identification and mapping of pits in Dura Europos is easier respect to the circular holes in Cahuachi: In Dura Europos the looting is much more recent than in Cahuachi where the sand covered partially the holes of grave robbers.

COMPARISON OF THE LOOTING CHARACTERISTICS FOR THE TWO TEST CASES



In situ analysis of the diverse looting characteristics in the two selected case studies Dura Europos and Cahuachi. These diverse characteristics create diverse looting features and provide an example of the complexity to face in order to set up a change detection approach suitable to automatically recognize the diverse looting patterns (and signatures) from space

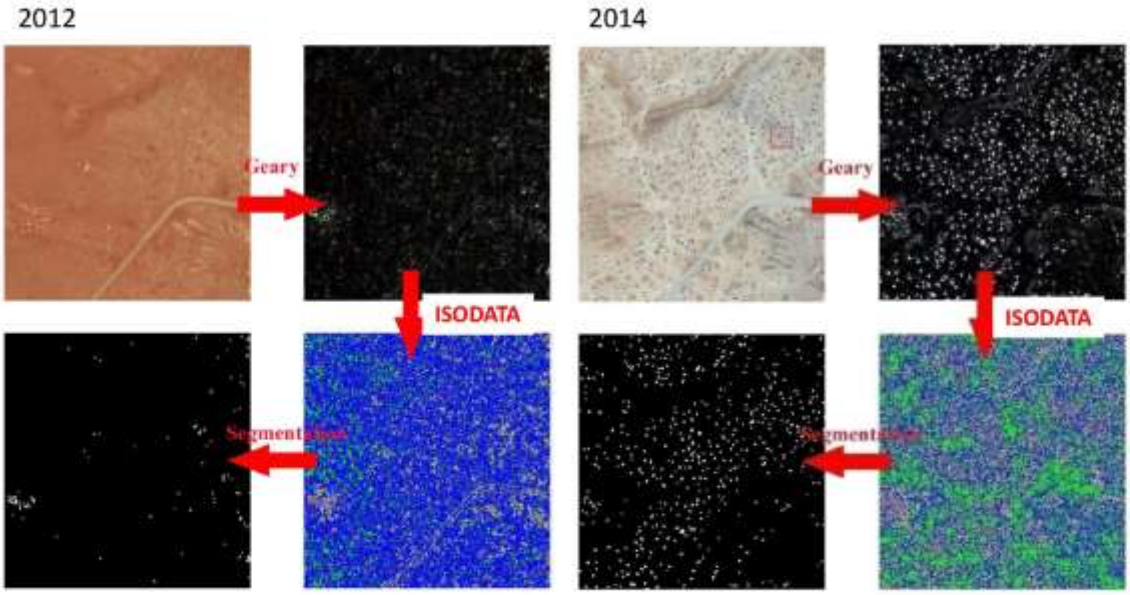
PARAMETERS SETTING OF THE ALGORYTHM



- **Local Geary's C**: as Neighborhood Rule, the Queen's Case which uses all eight neighboring pixels has been assumed
- The variability map obtained has been classified with **ISODATA** assuming the following parameters: numbers of classes ranging from 5 to 10, change threshold = 5%, minimum class distance = 5. The result is a map with 7 classes, among which classes 6 and 7 (coloured magenta and purple, respectively) are related to archaeological looting features .
- The final step has been the **segmentation** which enable to partition the classified map and improving the discriminations of looting features:
  - i) choicing adequately the classes to be segmented,
  - ii) setting some parameters in order to optimize the ratio between target (looting features) and false alarms, in particular, the **minimum population** (i. e. the minimum number of pixels that must be contained in a segment) and the **number of neighbors**.
  - The best results have been obtained selecting classes 6 and 7 and imposing values of minimum population and number of neighbors equal to 10 and 4, respectively.

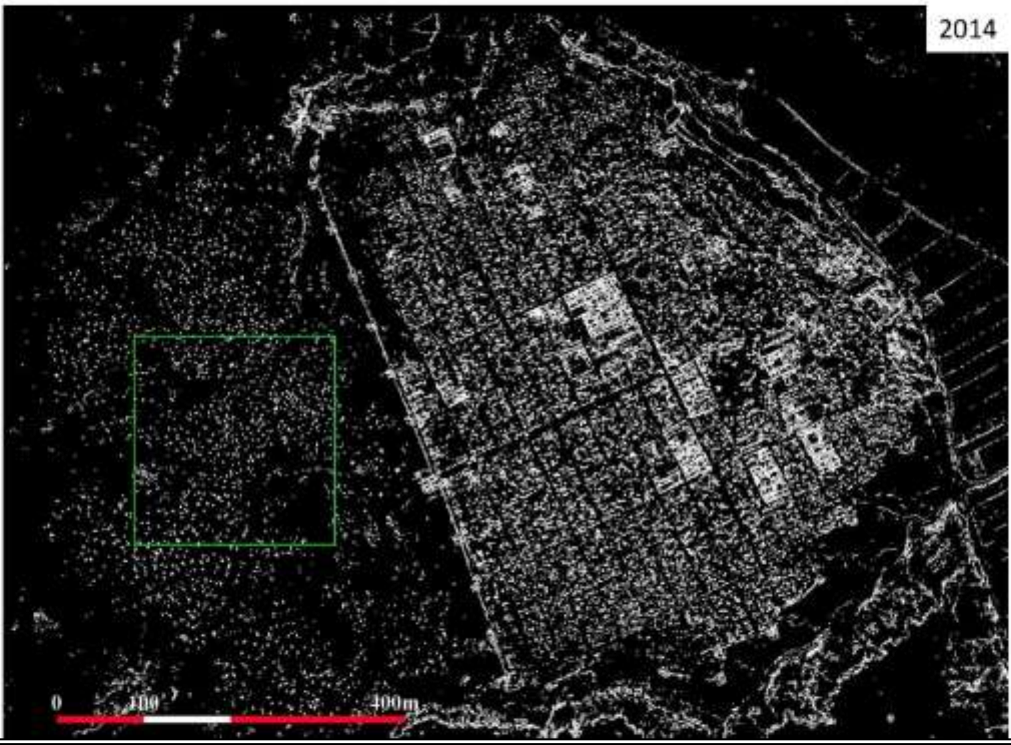
DURA EUROPOS

RESULTS FROM ARCHAEOLOGICAL FEATURE EXTRACTION



DURA EUROPOS

RESULTS FROM ARCHAEOLOGICAL FEATURE EXTRACTION



DURA EUROPOS

RATE OF SUCCESS ASSESSMENT

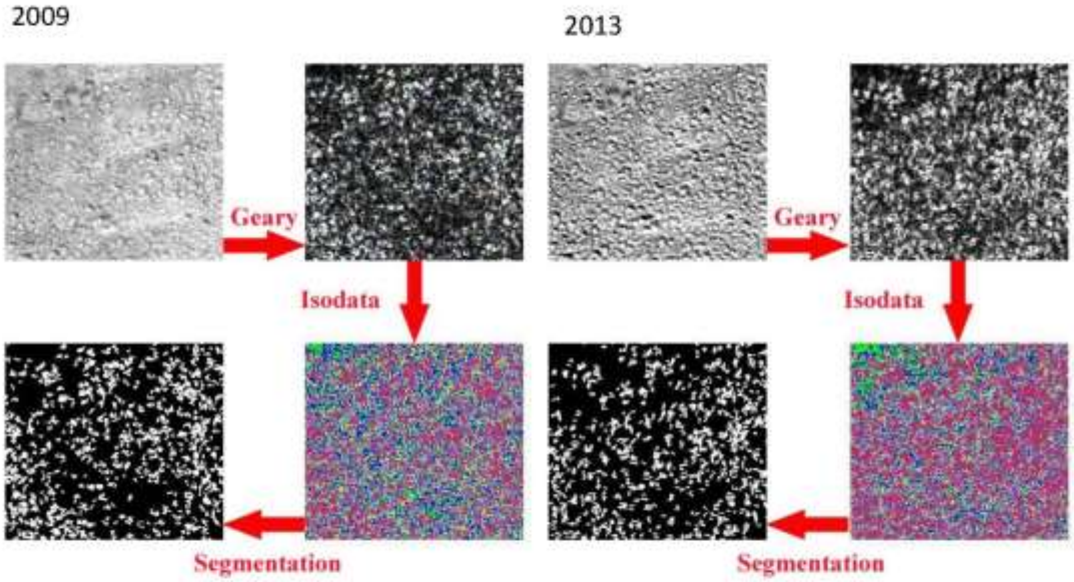
image 2012				
NH	TD	TnD	FA	N_{FA}= FA/(FA+TD)
34	30	4	2	
	88%	12%		6,25%
image 2014				
NH	TD	TnD	FA	N_{FA}= FA/(FA+TD)
506	469	37	35	
100,00%	92,69%	7,31%		6,94%

NH: number of holes
TD: targets detected
FA: false alarms
NFA: normalized false alarm index (FA/(FA+TD))

Assessment method: visual inspection of satellite imagery and ancillary data from independent analyses (UNITAR 2014)

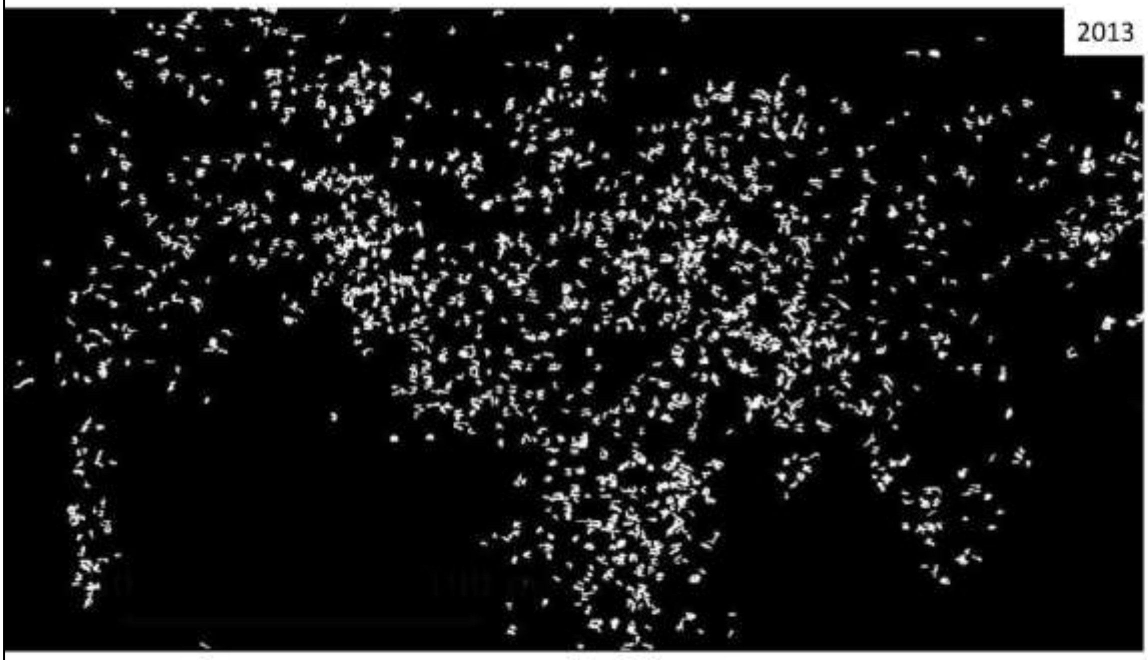
CAHUACHI

RESULTS FROM ARCHAEOLOGICAL FEATURE EXTRACTION



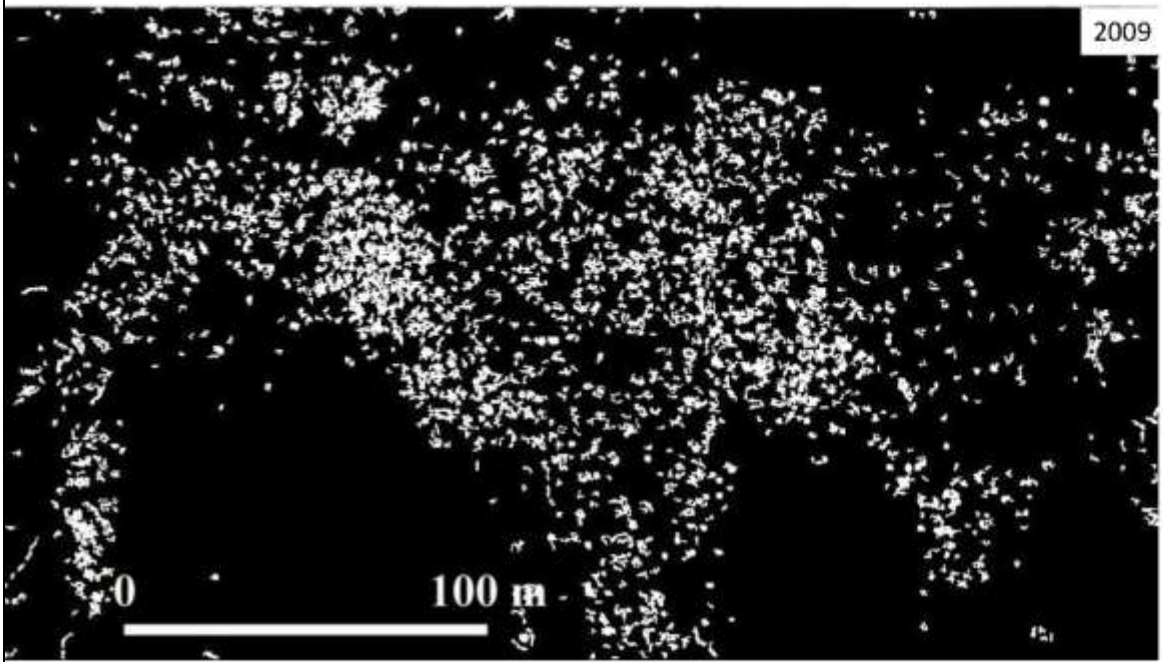
CAHUACHI

RESULTS FROM ARCHAEOLOGICAL FEATURE EXTRACTION



CAHUACHI

RESULTS FROM ARCHAEOLOGICAL FEATURE EXTRACTION



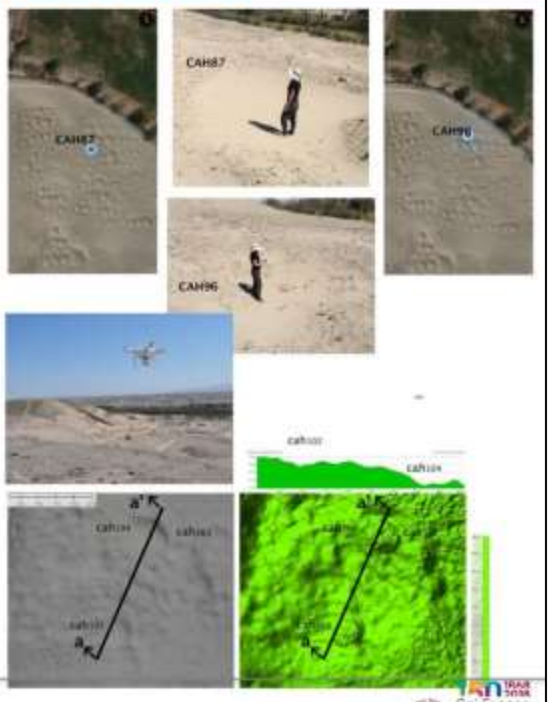
CAHUACHI

RATE OF SUCCESS ASSESSMENT

Image 2009				
NH	TD	TnD	FA	N_{FA}= FA/(FA+TD)
178	161	17	26	
	90,04%	9,96%		13,90%
Image 2013				
NH	TD	TnD	FA	N_{FA}=FA/(FA+TD)
178	173	6	5	
100,00%	97,19%	3,37%		2,81%

NH: Number of Holes
TD: targets detected
FA: False Alarms
NFA: normalized false alarm index (FA/(FA+TD))

Assessment method: visual inspection of satellite imagery, aerial survey by drone and field survey



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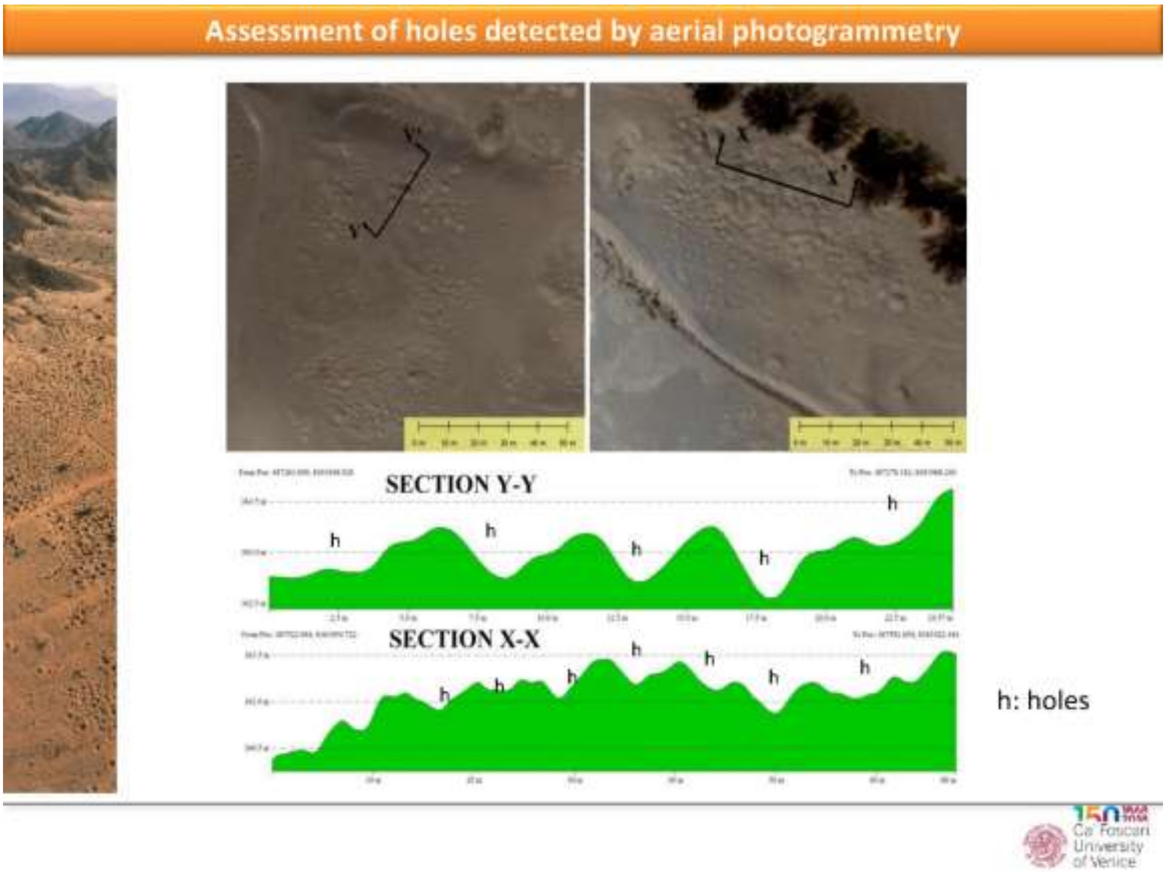
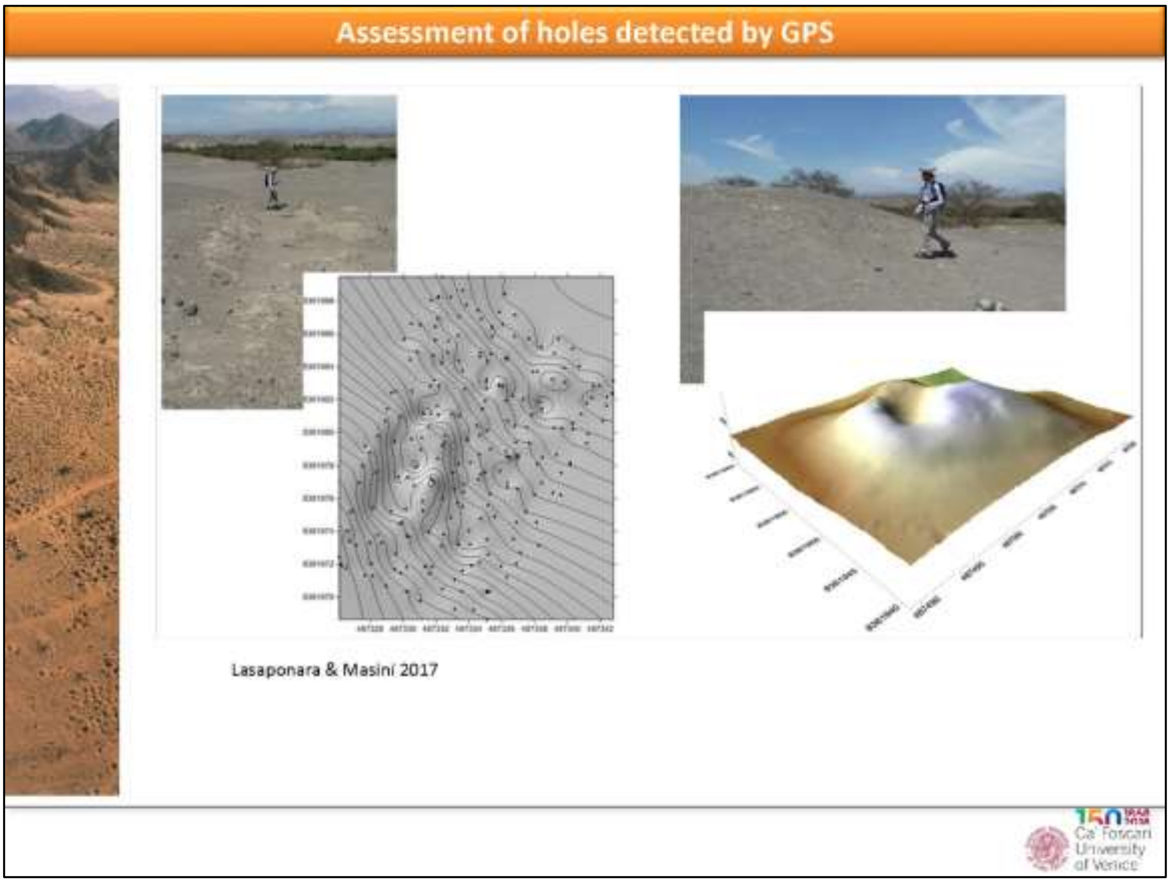
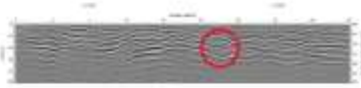

Assessment of holes detected by aerial photogrammetry
SECTION Y-Y
SECTION X-X
h: holes
Ca' Foscari University of Venice


Assessment of holes detected by GPS
Lasaponara & Masini 2017
Ca' Foscari University of Venice

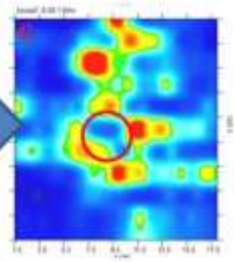
Future perspectives: GPR prospecting of looting areas

The typical outputs of GPR prospecting are: i) the radargrams, ii) the time slices and III) 3D visualization of iso-amplitudes.

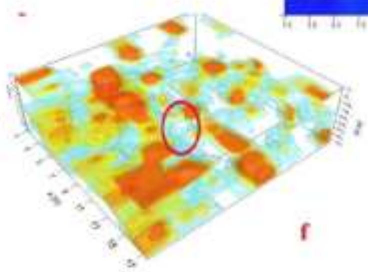
i) The **radargram** is a measure of the reflection amplitudes and the travel time that the reflections take.



ii) Multiple radargrams collected over an area may be used to build 3d tomographic images, depictable as 3d blocks or as **horizontal slices** (also known also as depth or **time slices**) that are maps obtained for specific depths which enable to spatially visualize reflectors or discontinuities in the subsoil linked to the presence of archaeological remains



iii) The 3D representation of iso amplitudes make the interpretation of GPR results easies



CONCLUSIONS

❑Looting represents one of the main risk factors which affect the archaeological heritage throughout the world.

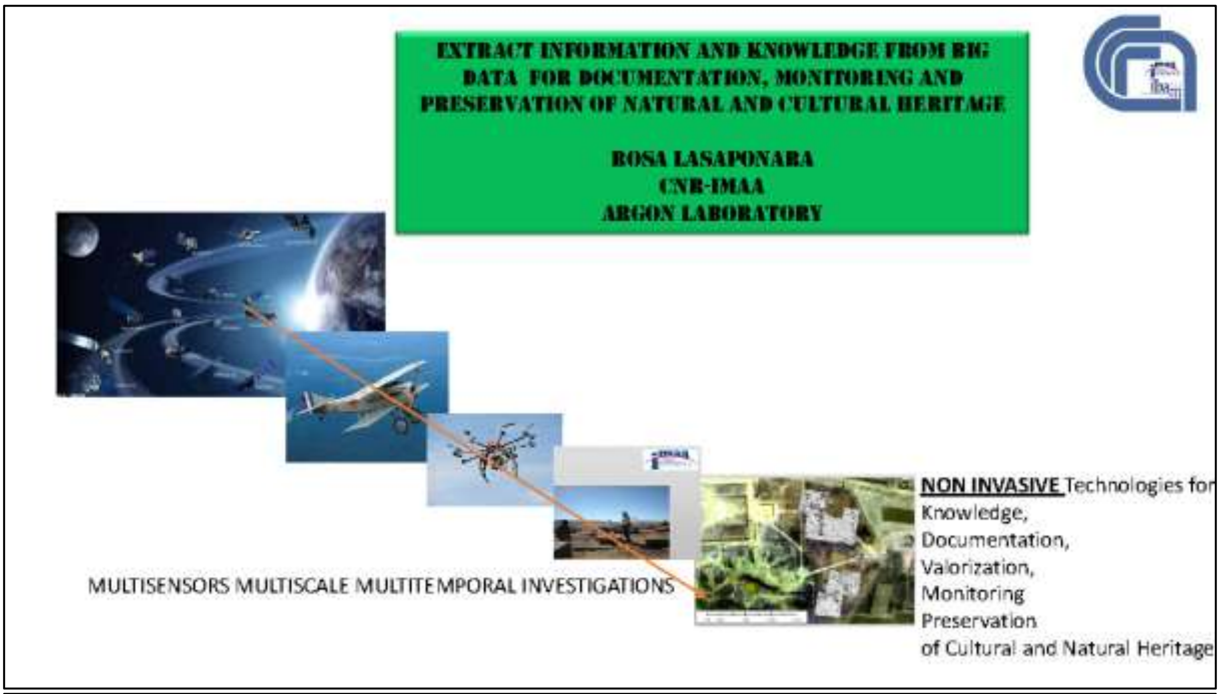
❑ Actions oriented to quantify and monitor looting can be supported by satellite observations systems.

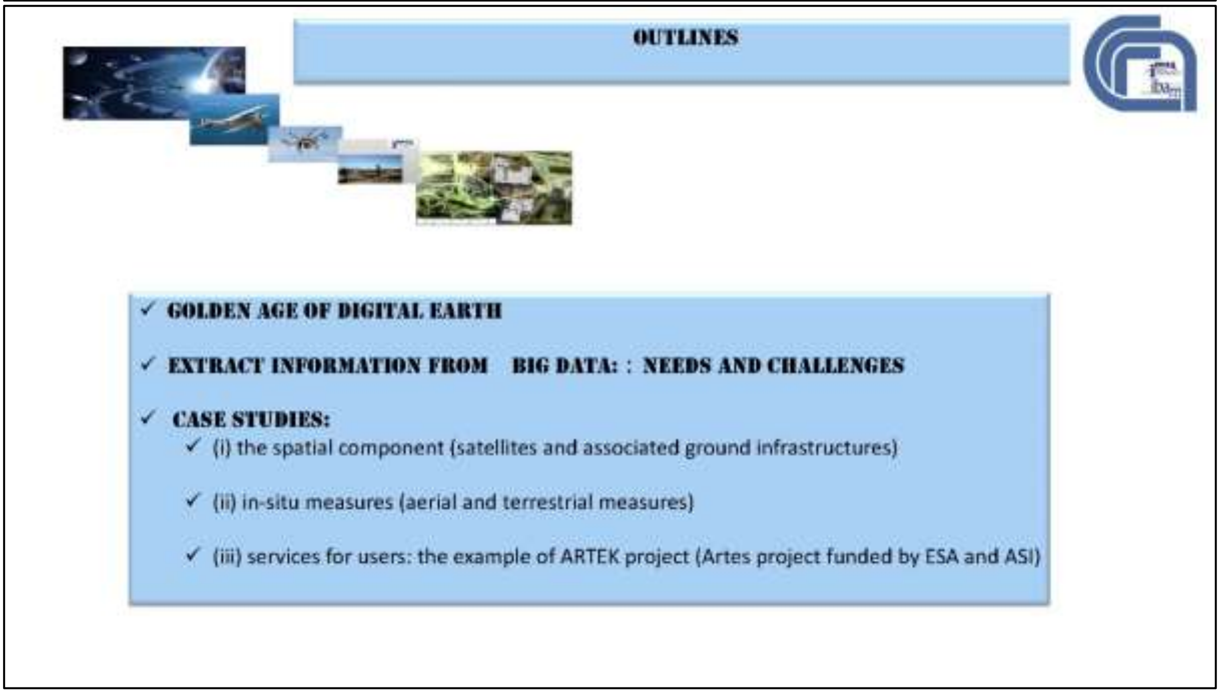
❑ In order to extractions looting features a an obiect oriented approach based on local indicators of spatial autorrelation, unsupervised classification and segmentation has been adopted

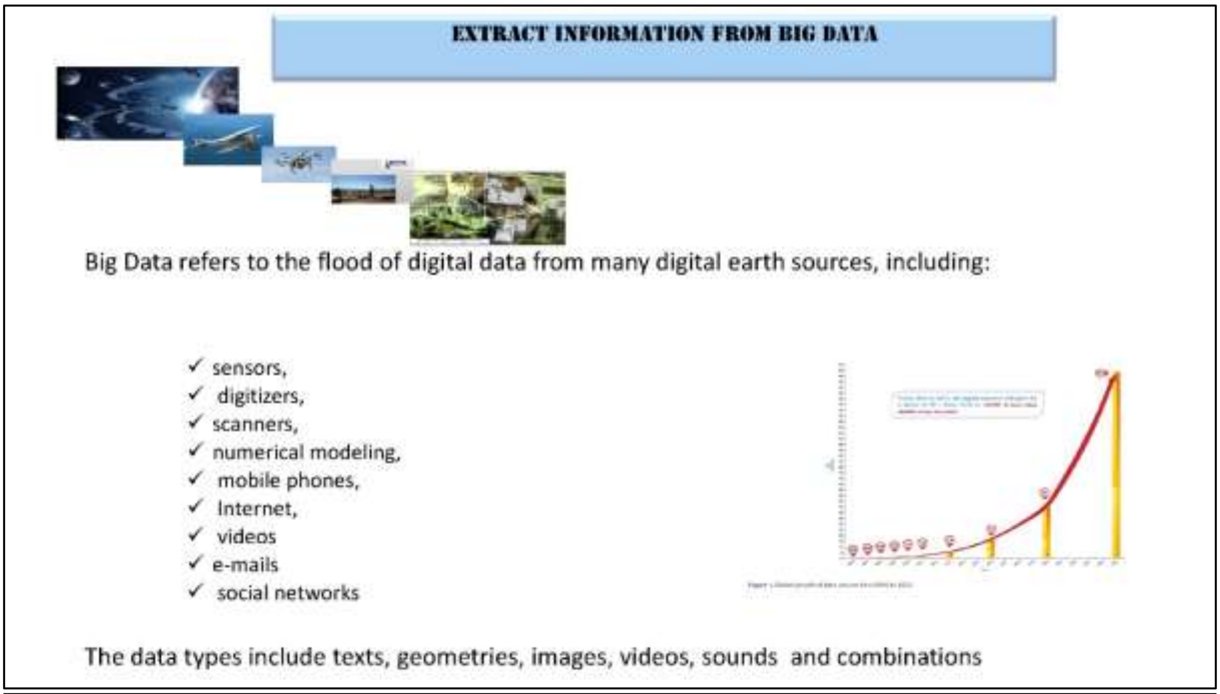
❑ The method provided satisfactory results for two different test sites located in two different geographical areas (Peru and Syria), selected because characterized by different looting morphological characteristics and looting dynamics: frequent in the past for Cahuachi and still ongoing in Dura Europos, where the looting fetures are deeper and better visible than in Cahuachi

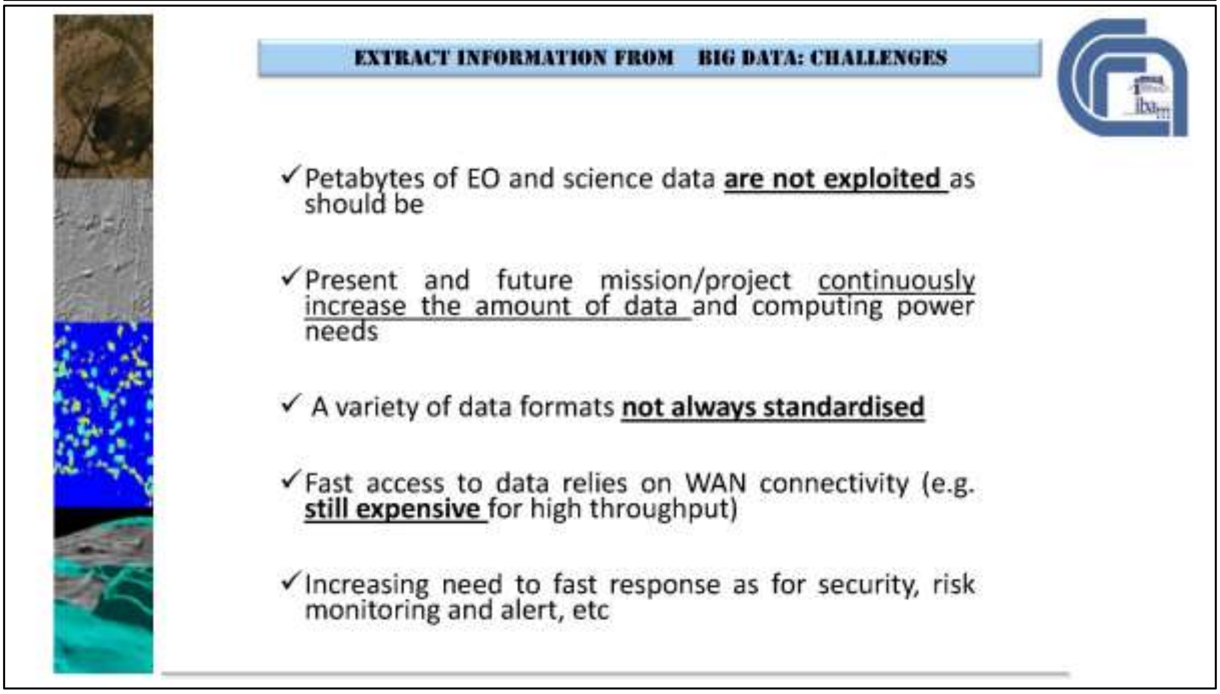
❑ The method provided a high rate of success with **low rate of false alarm** even in noisy image and in area where over the years the desert sand tend to cover looting features (radiometrically obscuring the looting features)

2.6 Sixth Presentation - Integration of RS data for Cultural Heritage management






EXTRACT INFORMATION FROM BIG DATA
Big Data refers to the flood of digital data from many digital earth sources, including:
✓ sensors,
✓ digitizers,
✓ scanners,
✓ numerical modeling,
✓ mobile phones,
✓ Internet,
✓ videos
✓ e-mails
✓ social networks
The data types include texts, geometries, images, videos, sounds and combinations


EXTRACT INFORMATION FROM BIG DATA: CHALLENGES
✓Petabytes of EO and science data are not exploited as should be
✓Present and future mission/project continuously increase the amount of data and computing power needs
✓ A variety of data formats not always standardised
✓Fast access to data relies on WAN connectivity (e.g. still expensive for high throughput)
✓Increasing need to fast response as for security, risk monitoring and alert, etc

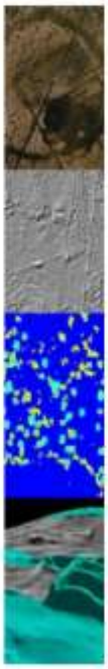
EXTRACT INFORMATION FROM BIG DATA: NEEDS

The capability to **extract information** from data is linked with the capability to **integrate data and info** available ***from diverse sources***

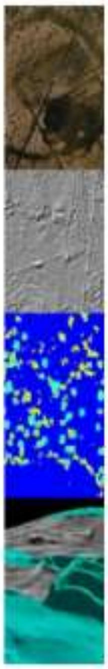
Transformation: from data to (useful) knowledge

EXTRACT INFORMATION AND KNOWLEDGE FROM BIG DATA FOR DISCOVERY, DOCUMENTATION, MONITORING AND PRESERVATION OF NATURAL AND CULTURAL HERITAGE

BIG DATA INTEGRATION NEEDS AND CHALLENGES

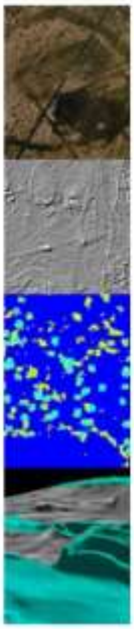


- ✓ No magic: **Careful planning and setting goals, vision** and narrative important. Once narrative is in place, integration "only" become a technical issue
- ✓ Experimental **design, data quality, outlier** identification is an important **part of the integration** –
- ✓ Data integration **important, but often challenging** - especially for ad-hoc data
- ✓ **From single-discipline to multidisciplinary and interdisciplinary approaches**



COPERNICUS DATA

- The constellation Copernicus has changed the paradigm with which the citizen is related to the spatial datum, because it is open access, available to all.
- Therefore, space is a huge opportunity for a society, today, that evolves very quickly and offers challenges and opportunities.
- In **the light of recent sensor developments and data availability, innovative models and methodologies are needed for data analy**sis and the integration of different information, as well as new strategies for the exploitation.



COPERNICUS DATA

There are four pillars, on which Copernicus is founded:

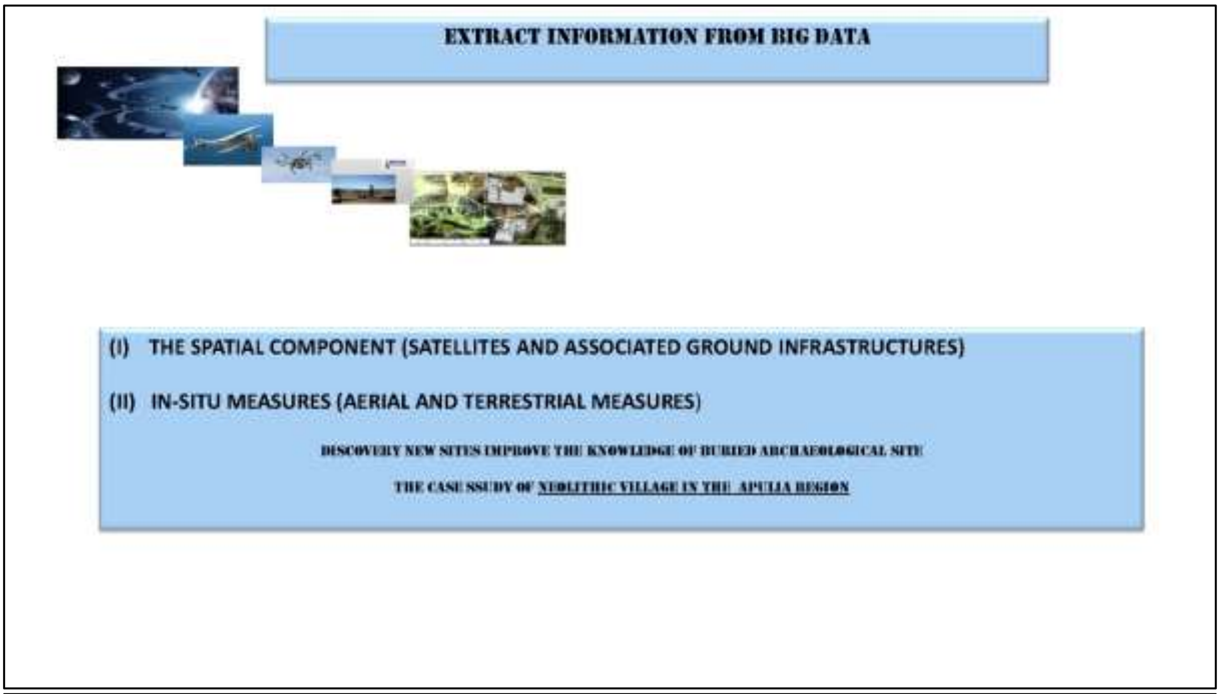
(i) the spatial component (satellites and associated ground infrastructures),

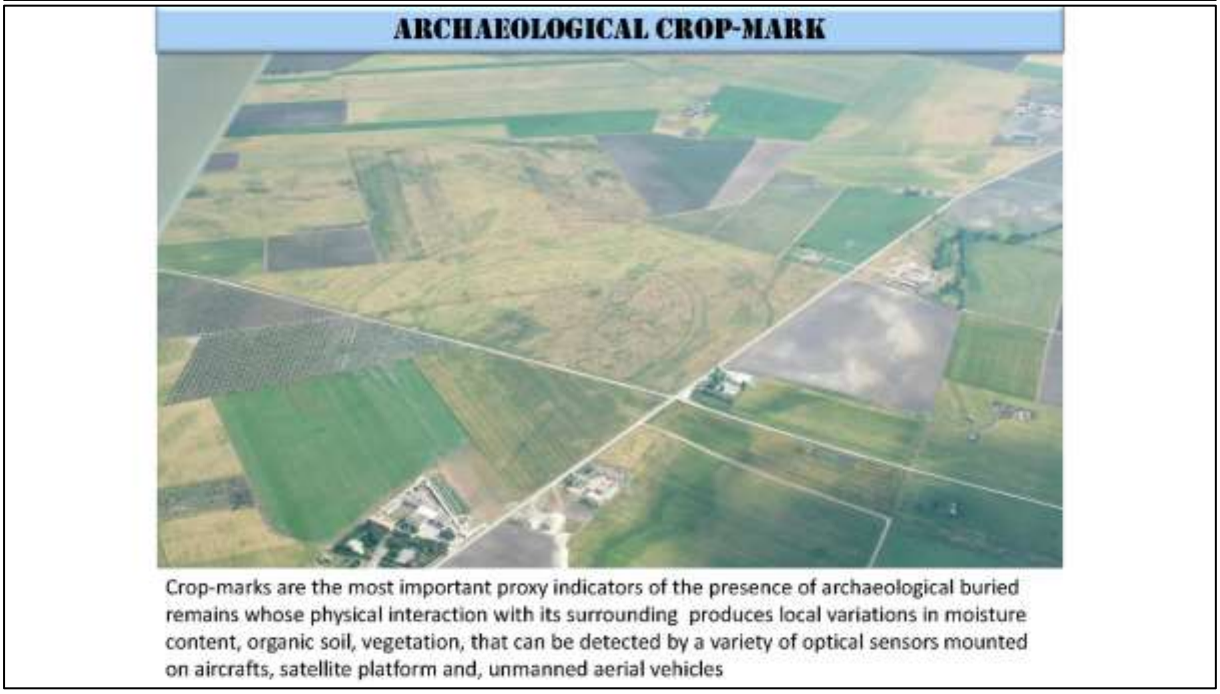
(ii) in-situ measures (aerial and terrestrial Measures),

(iii) harmonisation/standardization of data and

(iv) services for users.

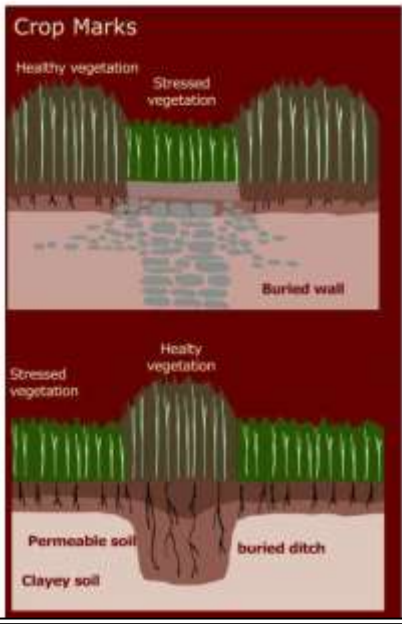
The Copernicus services are based on information from a constellation of dedicated satellites, called "Sentinels", and dozens of other satellites, the so-called "participating missions". This information is supplemented with data obtained from in situ (i.e. local) sensors. In particular, the spatial component related to the constellation of dedicated satellites, consists of various Sentinel missions with the following objectives.


EXTRACT INFORMATION FROM BIG DATA
(I) THE SPATIAL COMPONENT (SATELLITES AND ASSOCIATED GROUND INFRASTRUCTURES)
(II) IN-SITU MEASURES (AERIAL AND TERRESTRIAL MEASURES)
DISCOVERY NEW SITES IMPROVE THE KNOWLEDGE OF BURIED ARCHAEOLOGICAL SITE
THE CASE SSUDY OF NEOLITHIC VILLAGE IN THE APULIA REGION


ARCHAEOLOGICAL CROP-MARK
Crop-marks are the most important proxy indicators of the presence of archaeological buried remains whose physical interaction with its surrounding produces local variations in moisture content, organic soil, vegetation, that can be detected by a variety of optical sensors mounted on aircrafts, satellite platform and, unmanned aerial vehicles

ARCHAEOLOGICAL CROP-MARK

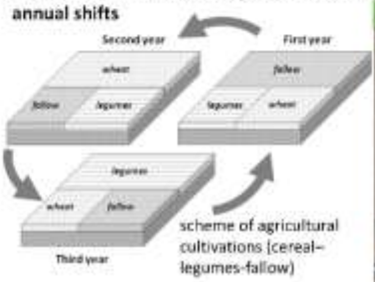
Results from Remote sensing based detection of cropmarks depends on
1_State of conservation of archaeological features
2_ Geophysical contrast target (feature)-matrix
3_Boundary conditions : land use, meteorological parameters, soil and vegetation types



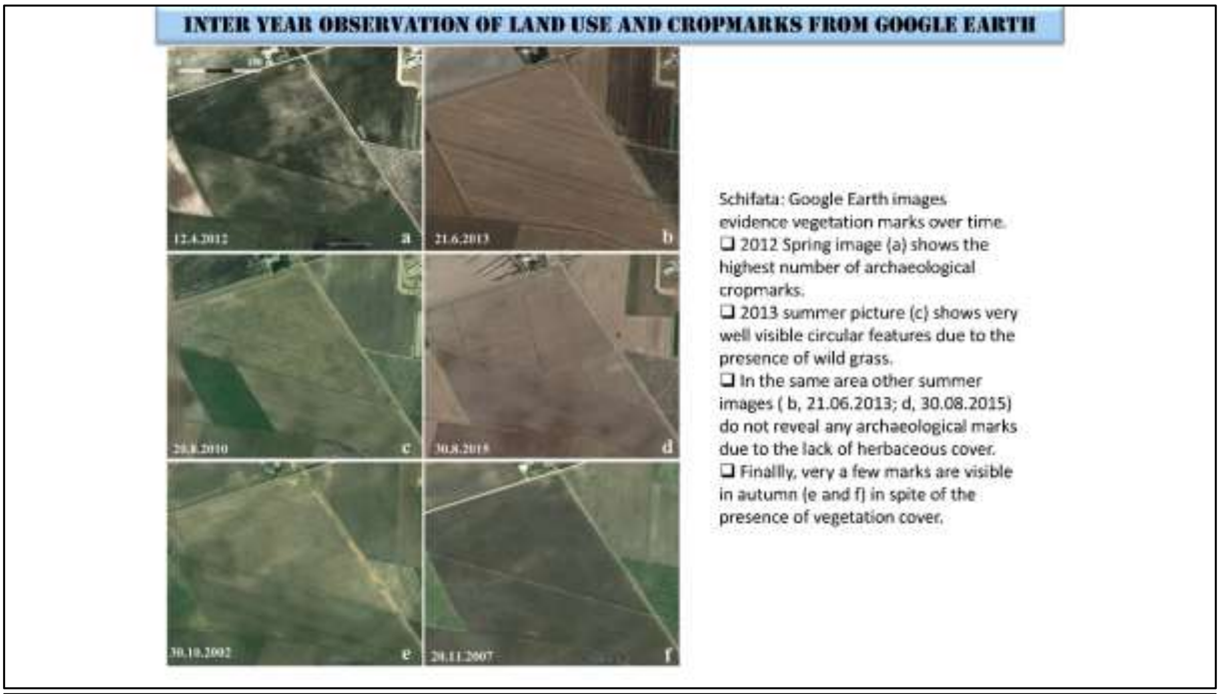
MULTITEMPORAL ANALYSIS OF ARCHAEOLOGICAL CROP-MARKS

Neolithic settlement in Apulia: seasonal behaviour form multi-dates Google Earth images

The **different seasonal behaviour** of archaeological proxy indicators can be depicted **using multi-date**s Google Earth images which, unfortunately, **rarely allow a systematic intra-year analysis**, than can only be indirectly deduced by images taken in different years whose results strongly depend on land use and **crop rotation with annual shifts**

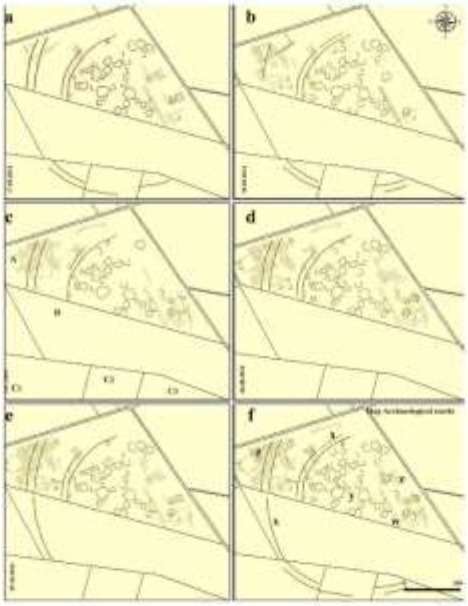


scheme of agricultural cultivations (cereal–legumes-fallow)


INTER YEAR OBSERVATION OF LAND USE AND CROPMARKS FROM GOOGLE EARTH
12.4.2012 a
21.6.2013 b
20.8.2010 c
30.8.2015 d
30.10.2002 e
20.11.2007 f
Schifata: Google Earth images evidence vegetation marks over time.
❑ 2012 Spring image (a) shows the highest number of archaeological cropmarks.
❑ 2013 summer picture (c) shows very well visible circular features due to the presence of wild grass.
❑ In the same area other summer images (b, 21.06.2013; d, 30.08.2015) do not reveal any archaeological marks due to the lack of herbaceous cover.
❑ Finallly, very a few marks are visible in autumn (e and f) in spite of the presence of vegetation cover.


INTRA-YEAR OBSERVATION OF LAND USE AND CROPMARKS FROM GOOGLE EARTH
Remarks
▪ Most of marks are in A, in spring (a-b, e-f), due to the presence of crop, as well as in summer and in autumn, in presence of wild herbaceous plants
▪ In B the marks are only visible in Autumn (d) because of the presence of sparsely wild herbaceous which evidenced a double trench. No marks are evident in spring, when the soil is bare due to plowing, and in summer, when the terrain is cultivated with legumes and tomatoes
▪ In plots C1, C2 and C3 two double trenches are evident only in Spring when the area was cultivated with wheat
Fig. 4. Orthophotos related to: March 17 (a), May 10 (b), August 26 (c), October 29 (d). Tone, type of marks and vegetation changes over season (e, f, g, h). The images g and h show a detail of plot A related to a double trench and circular compounds which are visible thank to wheat-marks with light and dark tones in March (a) and in May (b). In Summer (c), the archaeological features manifested as vegetation marks linked to spontaneous wild grass. The image in October (d) shows both grass and soil moisture marks. Field survey: the persons in the photo (26 August 2014) are located following one of the circular crop-marks (I).

COMPARATIVE ANALYSIS, MAP AND INTERPRETATION OF CROP-MARKS



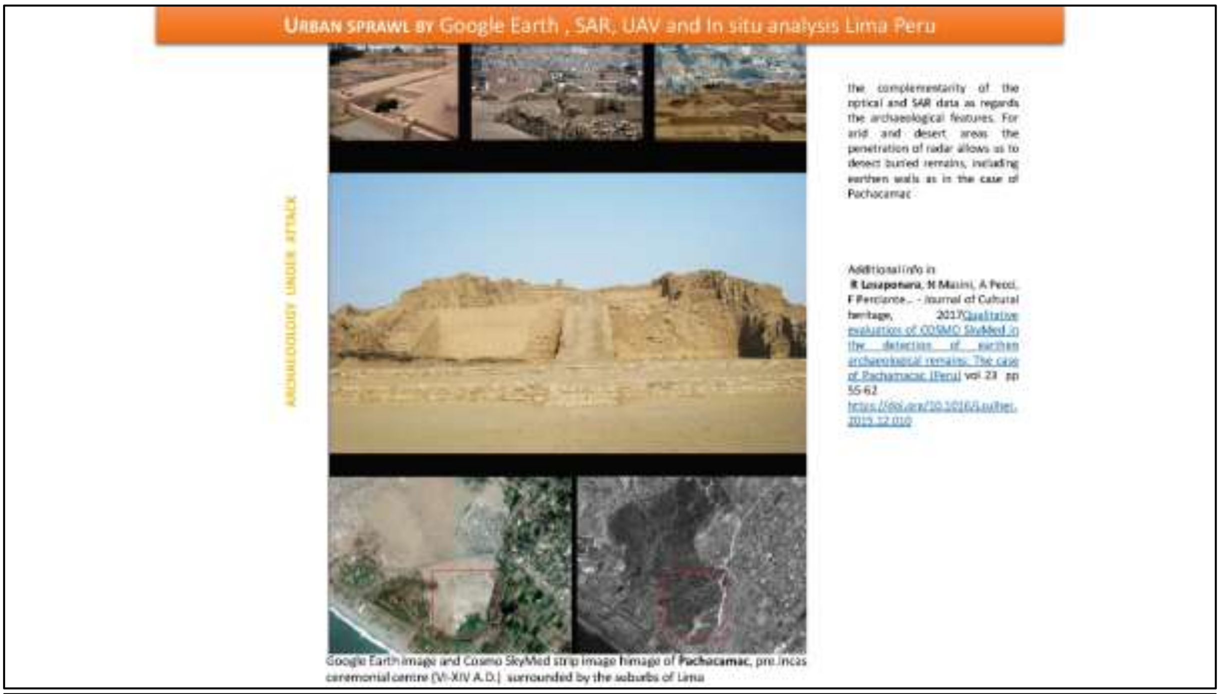
- The comparative observation of the six aerial images evidences some differences in the growth of cropmarks
- Map **f** shows all the features recognized from each image.
- There are **two curvilinear double trenches** surrounding the Neolithic settlement. One is evident in sectors A, B and C, especially in Spring and in Autumn (radius of 198 and 218m, respectively; covering an area of 12,3Ha)
- About **fifty** smaller **circular and C-shape** features (diameters ranging from 12 to 42m) referable to ditches surrounding **compounds of huts** (from 3 to 10)
- The **second double trench** has radius from 320 to 347m, respectively, covering approximately an area of 32Ha, exhibits scarce evidences of compounds likely due to the not favorable characteristics of the soil and vegetation cover.
- The maps show also linear features referable to ancient roads and old land use such as potential orchards (see Fig.5f, denoted with 'w' and 'z', respectively), particularly visible in summer and in autumn.

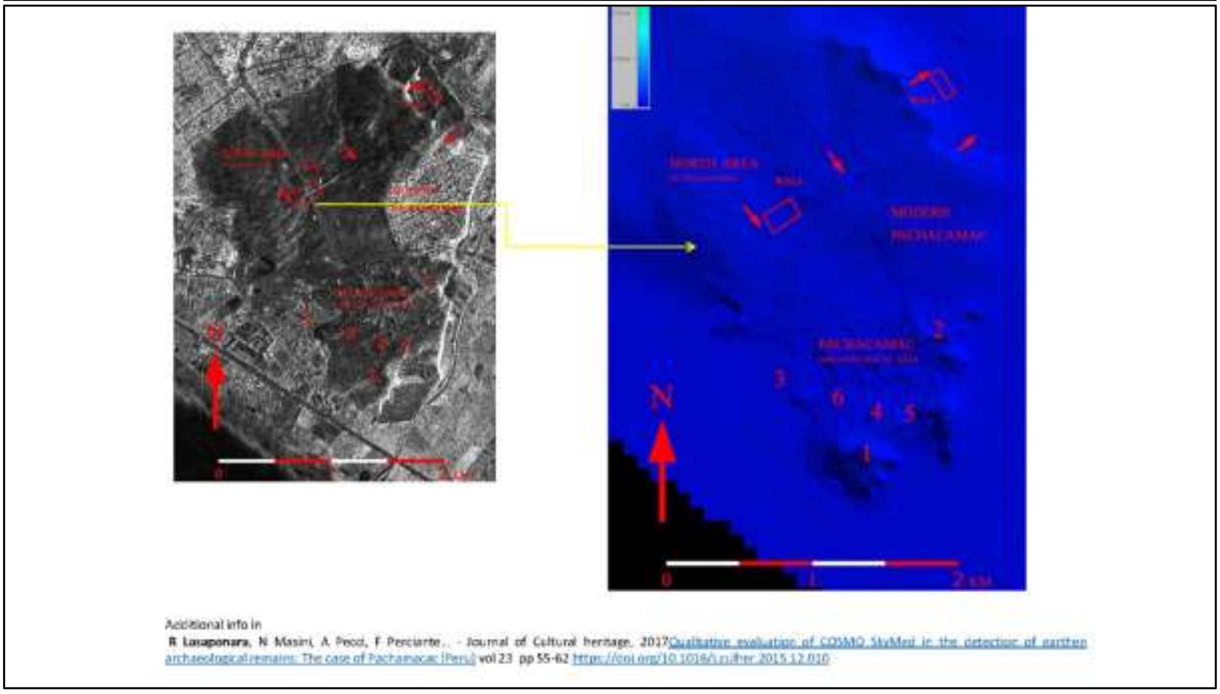
EXTRACT INFORMATION FROM BIG DATA

(I) THE SPATIAL COMPONENT (SATELLITES AND ASSOCIATED GROUND INFRASTRUCTURES)

(II) IN-SITU MEASURES (AERIAL AND TERRESTRIAL MEASURES)

PACHACAMAC MULTIPURPOSE INVESTIGATIONS BASED ON ACTIVE AND PASSIVE SATELLITE DATA INTEGRATED WITH DRONE SURVEY AND GEOPHYSICAL PROSPECIONS


URBAN SPRAWL BY Google Earth , SAR, UAV and In situ analysis Lima Peru
ARCHAEOLOGY UNDER ATTACK
the complementarity of the optical and SAR data as regards the archaeological features. For arid and desert areas the penetration of radar allows us to detect buried remains, including earthen walls as in the case of Pachacamac
Additional info in
R Lasaponara, N Masini, A Pecci, F Perciante... - Journal of Cultural heritage, 2017 Qualitative evaluation of COSMO SkyMed in the detection of earthen archaeological remains: The case of Pachamacac (Peru) vol 23 pp 55-62 https://doi.org/10.1016/j.culher.2015.12.010
Google Earth image and Cosmo SkyMed strip image himage of Pachacamac, pre incas ceremonial centre (VI-XIV A.D.) surrounded by the suburbs of Lima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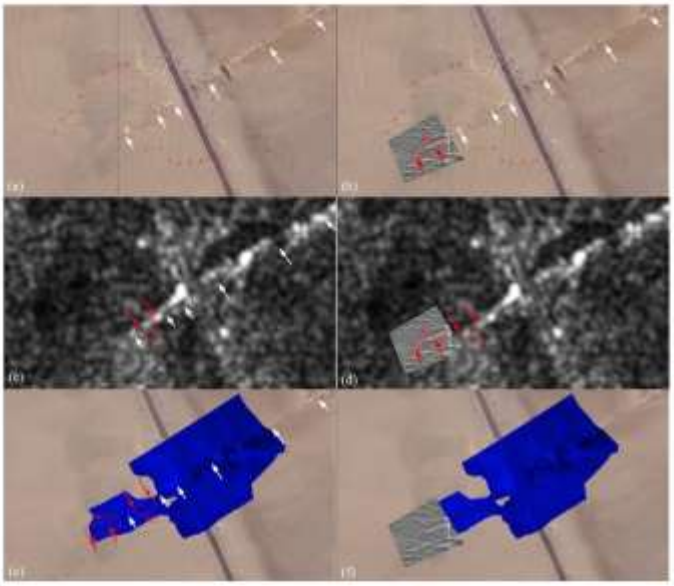
6
Additional info in
R Lasaponara, N Masini, A Pecci, F Perciante... - Journal of Cultural heritage, 2017 Qualitative evaluation of COSMO SkyMed in the detection of earthen archaeological remains: The case of Pachamacac (Peru) vol 23 pp 55-62 https://doi.org/10.1016/j.culher.2015.12.010



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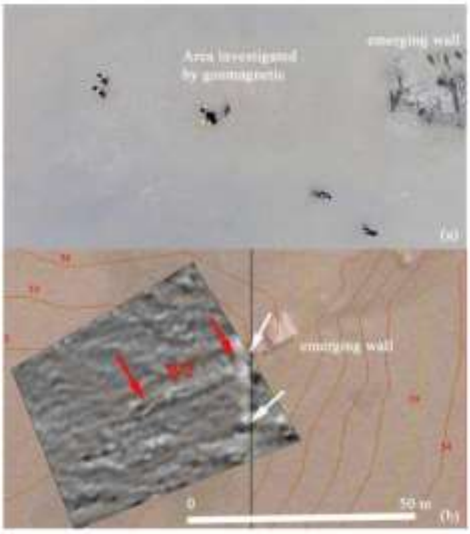


Additional details in :

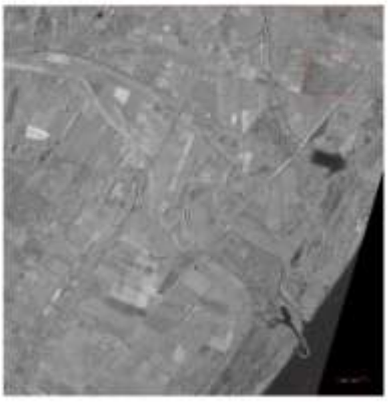
Lasaponara R, Nicola Masini, Antonio Pecci, Felice Perciante, Denise Pozzi Escott, Enzo Rizzo, Manuela Scavone, Maria Sileo (in press). Qualitative evaluation of COSMO SkyMed in the detection of earthen archaeological remains: the case of Pachamacac (Peru).. **JOURNAL OF CULTURAL HERITAGE**, CULHER-D-15-00358R1, ISSN: 1296-2074

EXTRACT INFORMATION FROM BIG DATA

(I) THE SPATIAL COMPONENT (SATELLITES AND ASSOCIATED GROUND INFRASTRUCTURES)

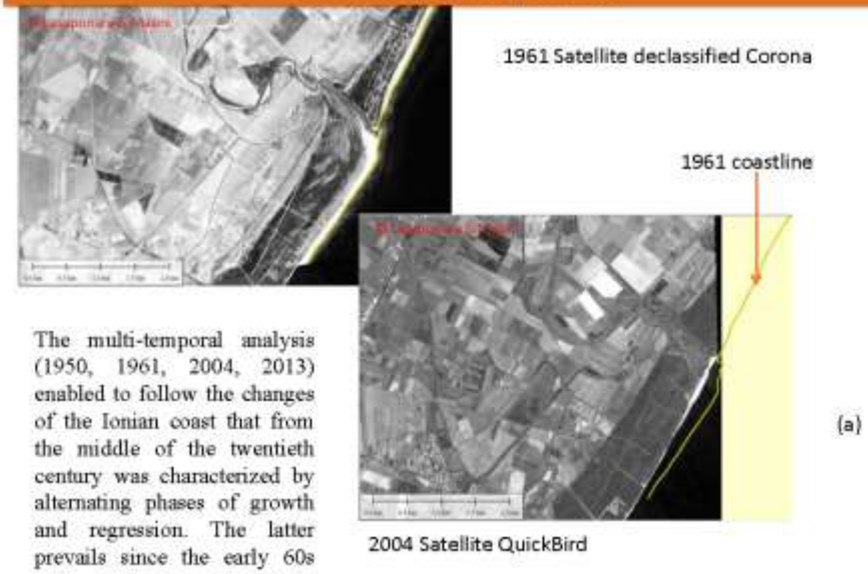
(II) IN-SITU MEASURES (AERIAL AND TERRESTRIAL MEASURES)

METAPONTO : MULTIPURPOSE INVESTIGATIONS BASED ON ACTIVE AND PASSIVE SATELLITE DATA INTEGRATED WITH ANCILLARY INFORMATION AND DOCUMENTARY SOURCE

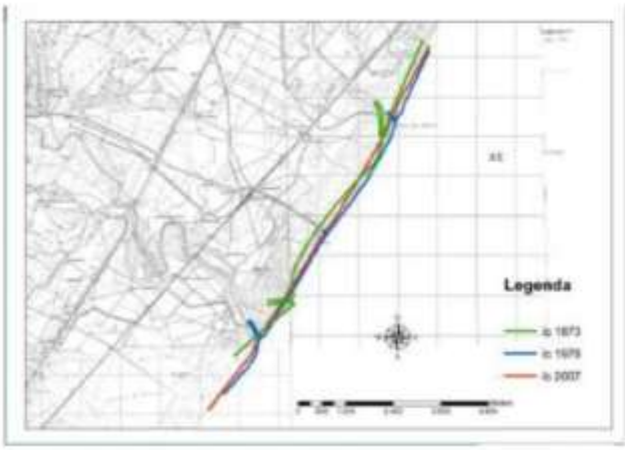


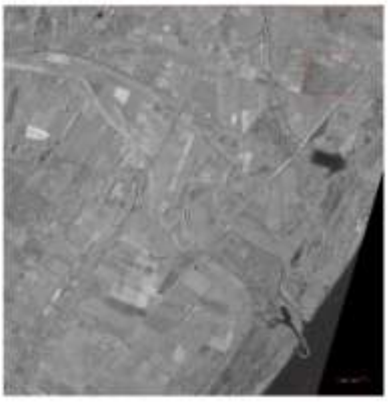
Some historical data on the movements of the coastline come from archeology. In particular, the inner dune belt, near the ancient Metaponto could be dated between the 7th and 3rd centuries BC. Just in this last century the dune was cut artificially, probably to facilitate the drainage of inland wetlands to the sea. This hypothesis supported by the presence of archaeological remains, possibly belonging to the old port, would lead us to suggest the presence of a nearby coast. Two other bands of dune ridges, which are located further inland, would be formed between the Roman period and the Middle Ages. As for the medieval coastline, some indications of its position may be derived from the remains in the mouth of Basento rivers, near a medieval village, named Torre Mare, that, around the twelfth or thirteenth century, had served as a port.

Case study : Metapontum



The multi-temporal analysis (1950, 1961, 2004, 2013) enabled to follow the changes of the Ionian coast that from the middle of the twentieth century was characterized by alternating phases of growth and regression. The latter prevails since the early 60s and continues today with varying rates of erosion





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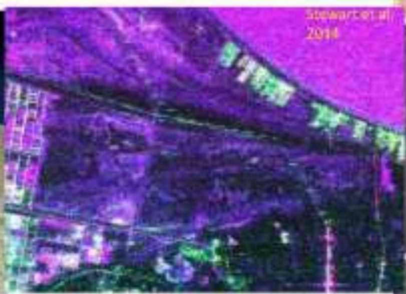
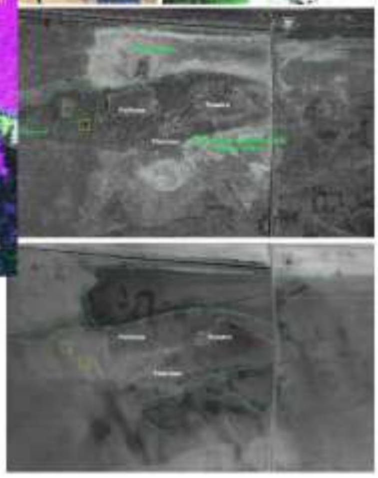
Shoreline variations : the Case study of Pelusium

Optical image acquired on 7 February 2007. Courtesy Google Earth. Image copyright 2013 Cnes/Spot image. Copyright 2013 ORION-ME.



Colour combination of C3 matrix elements in linear 0°/90° polarisation basis: **C11** (red), **C22** (green) and **C33** (blue).



Additional details in

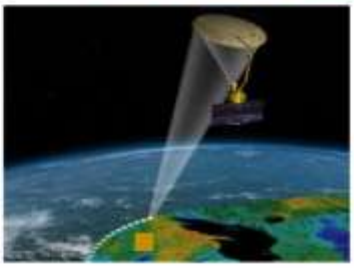
C Stewart, **R Lasaponara, G Schiavon 2013 ALOS PALSAR analysis of the archaeological site of Pelusium Archaeological Prospection 20 (2), 109-116**

DATA INTEGRATION

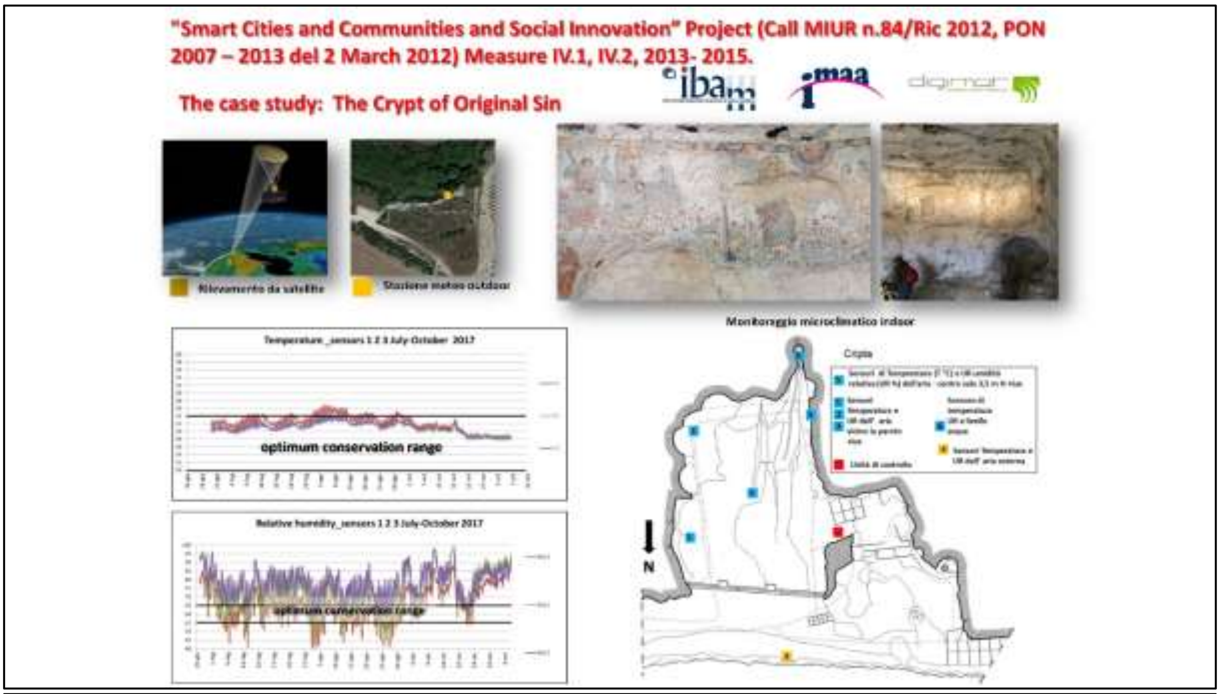
✓ (iii) **DATA INTEGRATION SATELLITE AND IN SITU MEASUREMENTS**
CRITA DEL PECCATO

"Smart Cities and Communities and Social Innovation" Project (Call MIUR n.84/Ric 2012, PON 2007 – 2013 del 2 March 2012) Measure IV.1, IV.2, 2013- 2015.

The Crypt of Original Sin – monitoring system indoor – outdoor - satellite



- Satellite surveying - environmental parameters / pollution
- Outdoor weather station (T / UR air, wind rainfall)
- Indoor microclimatic monitoring


"Smart Cities and Communities and Social Innovation" Project (Call MIUR n.84/Ric 2012, PON 2007 – 2013 del 2 March 2012) Measure IV.1, IV.2, 2013- 2015.
The case study: The Crypt of Original Sin
ibam
imaa
Rilevamento da satellite
Stazione meteo outdoor
Monitoraggio microclimatico indoor
optimum conservation range
optimum conservation range
Cripta
N


rosa.lasaponara@imaa.cnr.it
Thank you

2.7 Seventh Presentation – Geophysics

ATHENA Webinar 2 - Geophyisics

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691936. Work programme H2020 under "Spreading Excellence and Widening Participation", call: H2020-TWINN-2015: Twinning (Coordination and Support Action)

ATHENA Remote Sensing Science Center for Cultural Heritage

GPR surveys at 'Tombs of the Kings' necropolis in Cyprus

Francesco Soldovieri and Ilaria Catapano

Institute for Electromagnetic Sensing of the Environment National Research Council of Italy

istituto per il rilevamento elettromagnetico dell'ambiente

National Research Council of Italy

Topic

The present webinar deals with GPR surveys referred to the columns of Tomb 4 and Tomb 3 at the UNESCO site known as "Tombs of the Kings", an ancient necropolis.

Tomb 3

Tomb 4

Aim of the survey

A correct management of architectural and archaeological monuments requires a detailed analysis of the state of conservation, building techniques and materials for a correct planning of the restoration interventions.

In particular, it is crucial to detect and map decay patterns, cracks and anomalies to assess stability of load bearing structures whose brittleness makes mandatory the use of non invasive investigations, in agreement with the Theories of Restoration [1]. The improvement of geophysical techniques in terms of sensor performance and resolution, the increasing availability of software for data analysis, processing and interpretation have led to an increasing interest in the use of in situ non-invasive technologies such as Ground-penetrating radar (GPR).

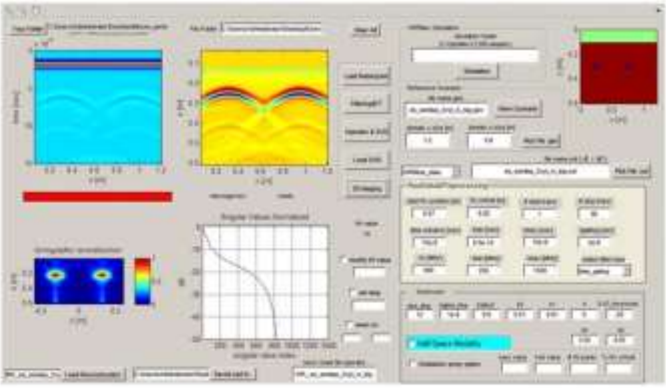
GPR exploits microwave ability of penetrating non-metallic objects and registers into radargrams electromagnetic variations occurring in different media, such as subsoil or building materials. These variations are visible as hyperbolas and advanced data processing, among which microwave tomographic approaches [2], are useful to improve imaging capabilities and obtain easily interpretable images.

[1] Brandi (1963)
[2] Soldovieri, F.; Crocco, L (2011) Electromagnetic Tomography; Vertiy Subsurface Sensing; Ahmet, S., Turk Koksal, A., Hocaoglu Alexey, A., Eds.; Wiley: Hoboken, NJ, USA.

GPR device & data processing

GPR survey was performed with a Ris Hi-Mod GPR system, IDS System, 2 GHz frequency

GPR data processing was performed by using Microwave Tomography and by exploiting a flexible interface able to manage 2D and 3D imaging in several reference scenarios under different measurement configurations



Survey at Tomb 3 - Hellenistic necropolis of the 'Tombs of the Kings'

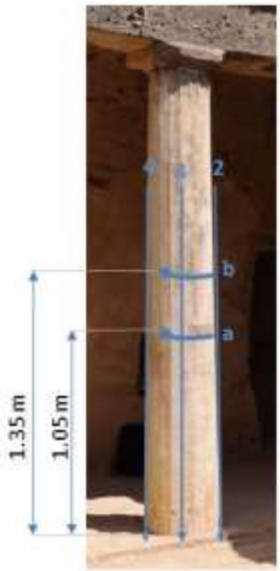


The columns of Tomb 3 were restored and do not show significant crack patterns

GPR survey aimed at retrieving information on the restoration process

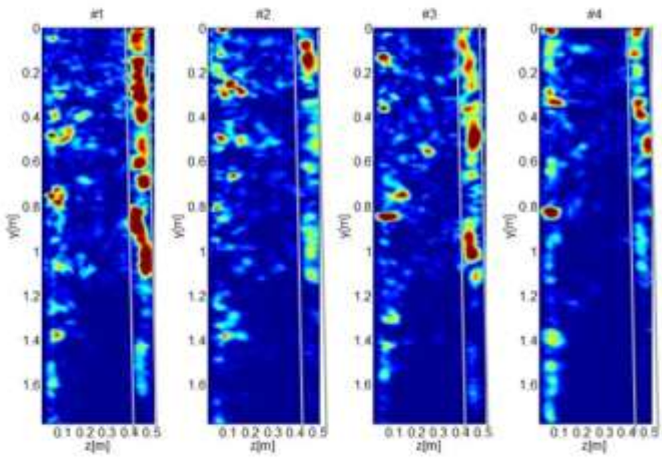
- imaging the column structures
- detecting non visible fractures and fractures filled with mortar
- discovering iron elements

Survey at Tomb 3 - Hellenistic necropolis of the 'Tombs of the Kings'



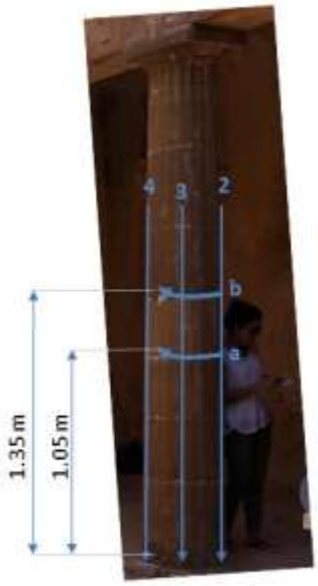
Column #3

4 vertical scans spaced of 90°
2 horizontal scans (along the circumference)



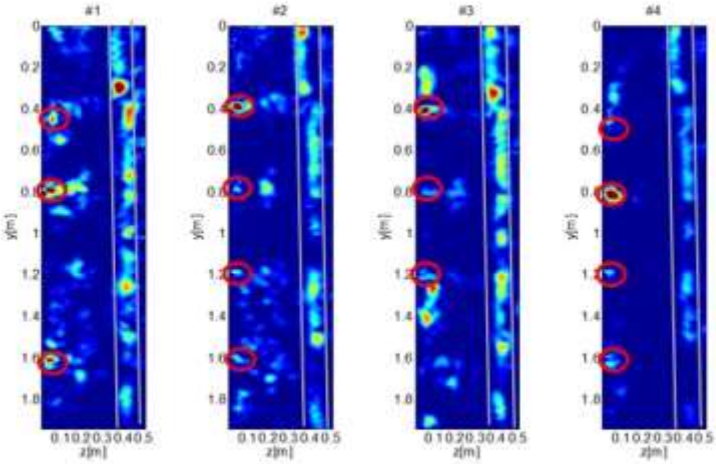
The tomographic images show that, although the column appears homogeneous, its interior is characterized by many anomalies mainly localized into the upper part
Moreover the back side of the column is visible

Survey at Tomb 3 - Hellenistic necropolis of the 'Tombs of the Kings'



Column #5

4 vertical scans spaced of 90°
2 horizontal scans (along the circumference)



The tomographic images show the evenly spaced mortar junctions between the circular stone blocks (red circles) Moreover, the column interior is quite homogeneous even is several localized anomalies appear

Survey at Tomb 3 - Hellenistic necropolis of the 'Tombs of the Kings'

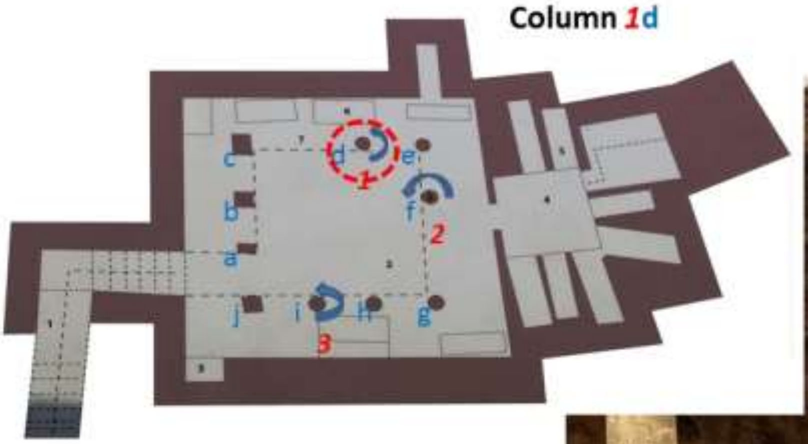
A number of columns at the tomb's atrium exhibit fracturing at their base or incorporate cracks which extend throughout their height.

GPR survey aimed at characterizing the deterioration status of pillars

- **instability of the columns due to the presence of fractures**
- **sedimentation in the direction of loads,**
- **fractures filled with mortar**

GPR Survey

Column 1d



The 1d column is composed of cylindrical calcareous stones and probably a lime mortar. The column is circular and its circumference is 1.62 m and its height is 2.90 m

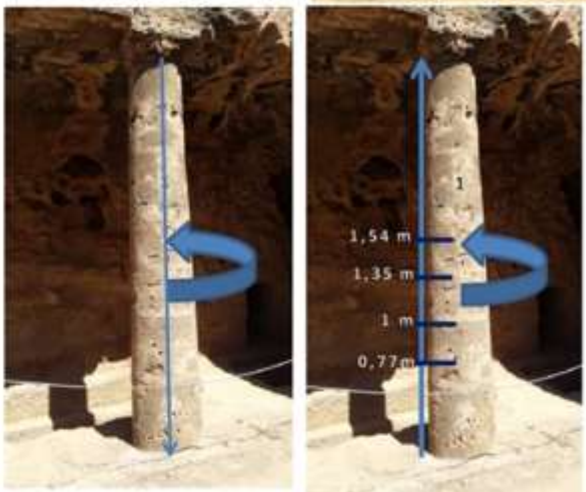
Presence of iron inner core ?

Decay of cylindrical stones

GPR Survey - Column 1d

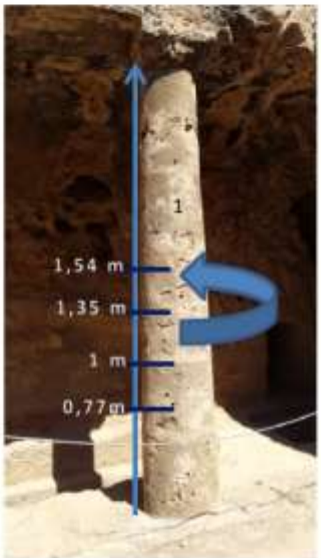
Two longitudinal sections were performed from top to bottom, of which the first section was made on the inner wall of the column, which faces the atrium of the tomb and then the cross-section at 90 degrees, see figures.

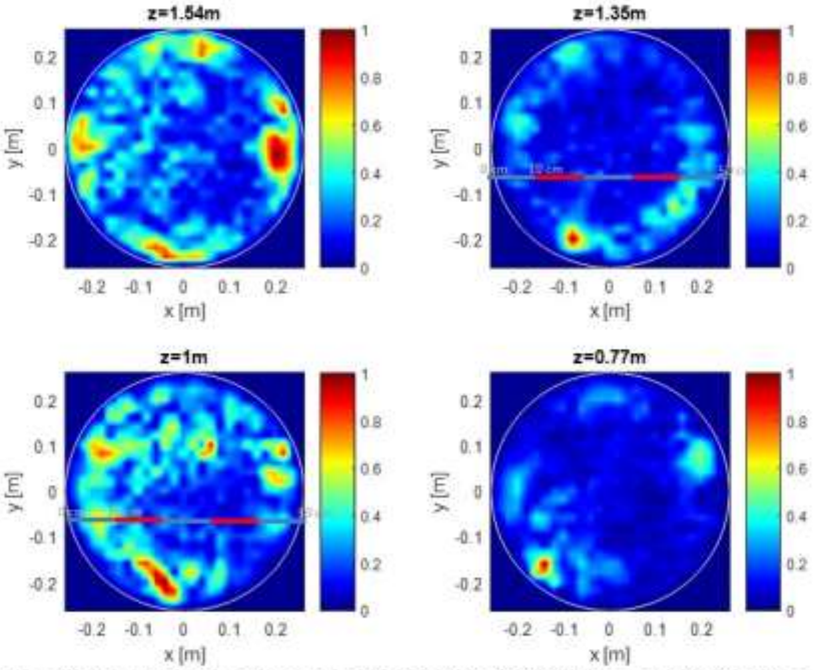
Further radargrams have been acquired in circular section with 4 heights from the ground, two circular sections on the stone rocks made in the central part at 1.54m 0.77 m high from the ground, two sections on mortar joints at heights of 1 and 1.35 m from the ground . The circular sections start from the inside as in the picture and extend according to a circular anti-clock motion.



Column d 1 longitudinal section and circular sections

GPR Survey - Column 1d



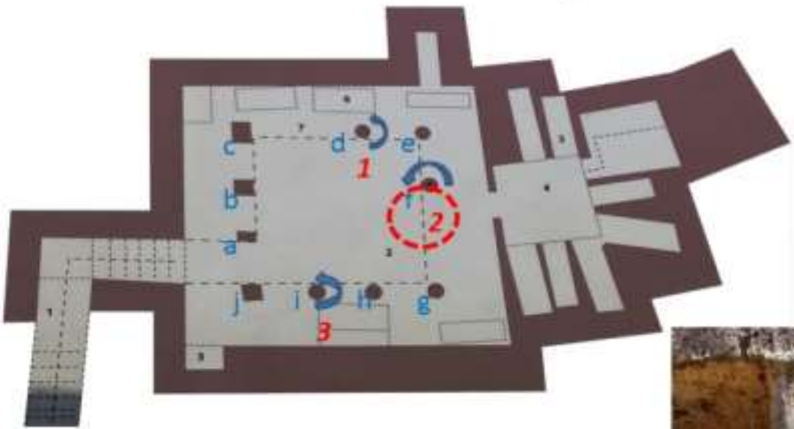


The images at z = 1.35 m and z = 0.77 m show abnormalities in the first 10 cm, probably due gaps into the porous structure of the rock - the interior is quite homogeneous

The images at z = 1.54 m and z = 1 m show abnormalities spreading into the all section

There is no structural pivot in the center of the rocks

GPR Survey - Column 2f



The 2f column is a circular section of calcarenic monolith rock with longitudinal fracture closed with concrete and mortar

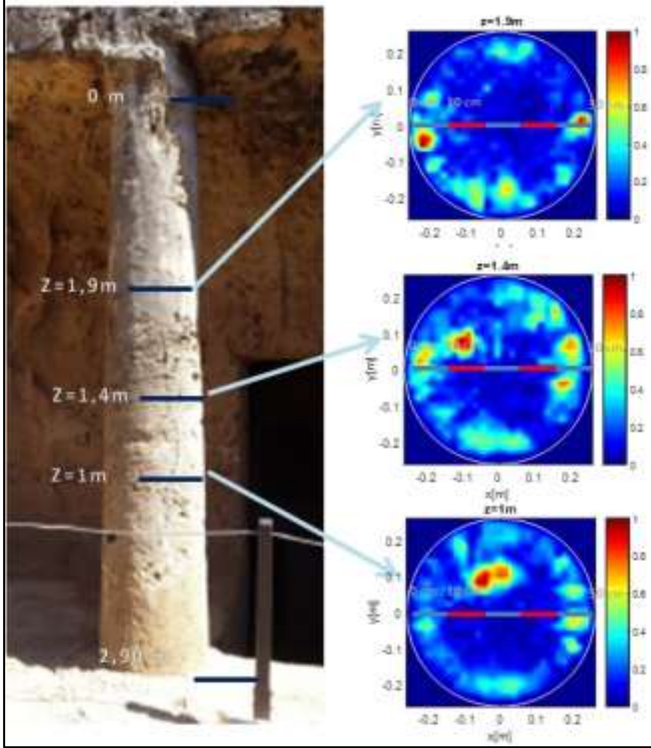
The circumference is 1.77 m and the height is 2.90 m

Frontal view from atrium and fron the back of the column

GPR Survey - Column 2f

Radargrams have been acquired in circular section at 3 heights from the ground, at 1.00m, 1.40m and 1.90m

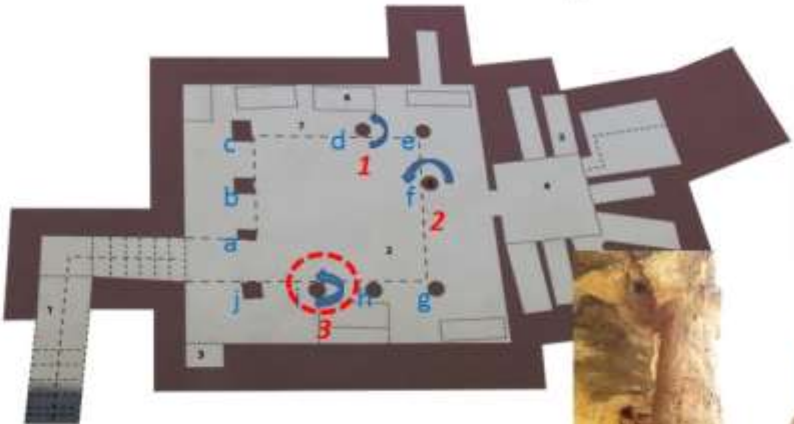
The circular sections start from the inside and extend according to a circular anti-clock motion



The circular tomographic images show that the fracture surface appears not completely closed but that up to 1.4 meters this discontinuity generates strong anomalies.

GPR Survey - Column 3i

Column 3 is a circular sectional calcare
multiple longitudinal fractures and has a c
and a height of 2.80 m.
The GPR survey provided the execution of t
from top to bottom, of which the first se
inner wall of the column, which faces the at
the other at 120 degrees from the first.
Further radargrams have been acquired i
heights from the ground to 0.45 m, 1.00 m
the ground, Circular sections start from the
picture and extend according to a circular an



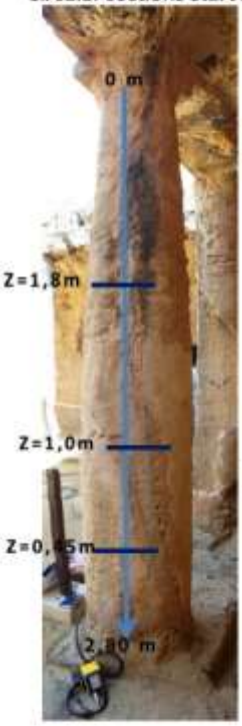
Frontal view from atrium and fron the back of the column

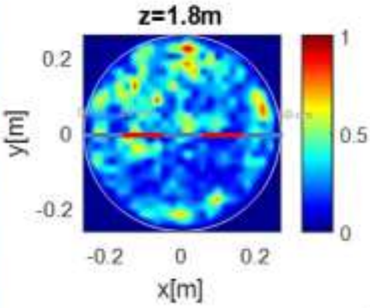
The 3i column is a circular section of calcareous monolith rock with multiple longitudinal fractures

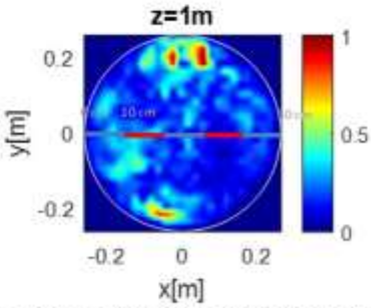
The circumference is 1.80 m and the height is 2.00 m

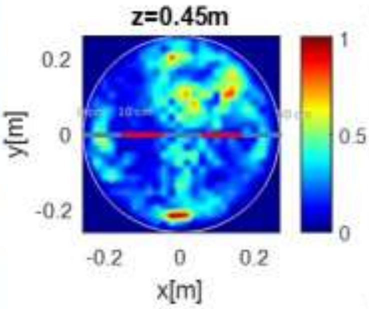
GPR Survey - Column 3i

Radargrams have been acquired in circular section at 3 heights from the ground, i.e. at 0.45 m, 1.00 m and 1.80 m
Circular sections start from the inside as shown in the picture and extend according to a circular anti-clock motion









The circular tomographic images show that the complex system of fractures pervades the entire section of the column.

Specifically, at 0.45 m and 1.8 m in height, several abnormal structures affect about half of the column section. This indicates that the degree of fracturing is very intense and pervades the entire column.

At 1.0m the anomalies appear less evident probably due to the presence of trapping shallow structures (f.i. surface discontinuities)

Conclusions

- **On site GPR surveys were performed to examine the condition and analyze the pathology of the columns of Tomb 3 and Tomb 4 of the ancient necropolis, known as 'Tombs of the Kings' , Paphos, Cyprus.**
- **The raw GPR data were processed by means of a processing chain based on the use of microwave tomography approach, which faces the imaging as a linear inverse scattering problem and provides focused images referred as tomographic images**
- **The obtained tomographic images provide indications concerning the development/propagation of cracks and the existence of discontinuities within the rock material.**
- **On going activities regards the processing of the data gathered by means of the GPR MALA system (400 MHz) and referred to the floor of the tombs**