EGU General Assembly 2022

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Remote sensing for environmental monitoring

An integrated approach for environmental multi-source remote sensing

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EGU General Assembly – Vienna, 24 May 2022

- satellite remote sensing is the most efficient tools for surveying the Earth at local, regional, and global temporal and spatial scale
- space-based observations support non-destructive methods for monitoring atmosphere, ground surface and marine ecosystems and for safely collecting data in hazardous environments without putting people or equipment at risk
- large-scale continuous satellite observations integrate detailed sparse field observations and provide unique datsets for theoretical modelling and data assimilation

Environmental monitoring- range of remote sensing fields related to land ecosystems and processes

atmosphere
- weather prediction
- monitoring of environmental pollution
- climate change

ocean surfaces
- coastline dynamics
- sea surface temperature and salinity
- ocean ecosystem and carbon biomass
- sea level change
- marine traffic
- fisheries
- mapping of water current
- topography in shallow waters

land
- mineral resources
- floods and droughts
- soil moisture
- vegetation
- deforestation
- forest fires
- urban planning
- dryland ecosystems
- drought monitoring and assessment
- archaeological and cultural heritage
- dumpsites monitoring

agriculture
- vegetation photosynthesis and carbon cycle
- vegetation phenology
- evaporation and water cycle

social science
- survey global crises (COVID-19)
- classify human environments
- socioeconomic datasets

global information
- planetary topography
- atmospheric profiles of the temperature, water vapor, carbon dioxide and other trace gases;
- mineral and chemical compositions of surface and atmospher
- properties of cryosphere such as snow, sea ice, glacier, and melting ponds,
- particle and electromagnetic properties of the thermosphere, ionosphere and magnetosphere.

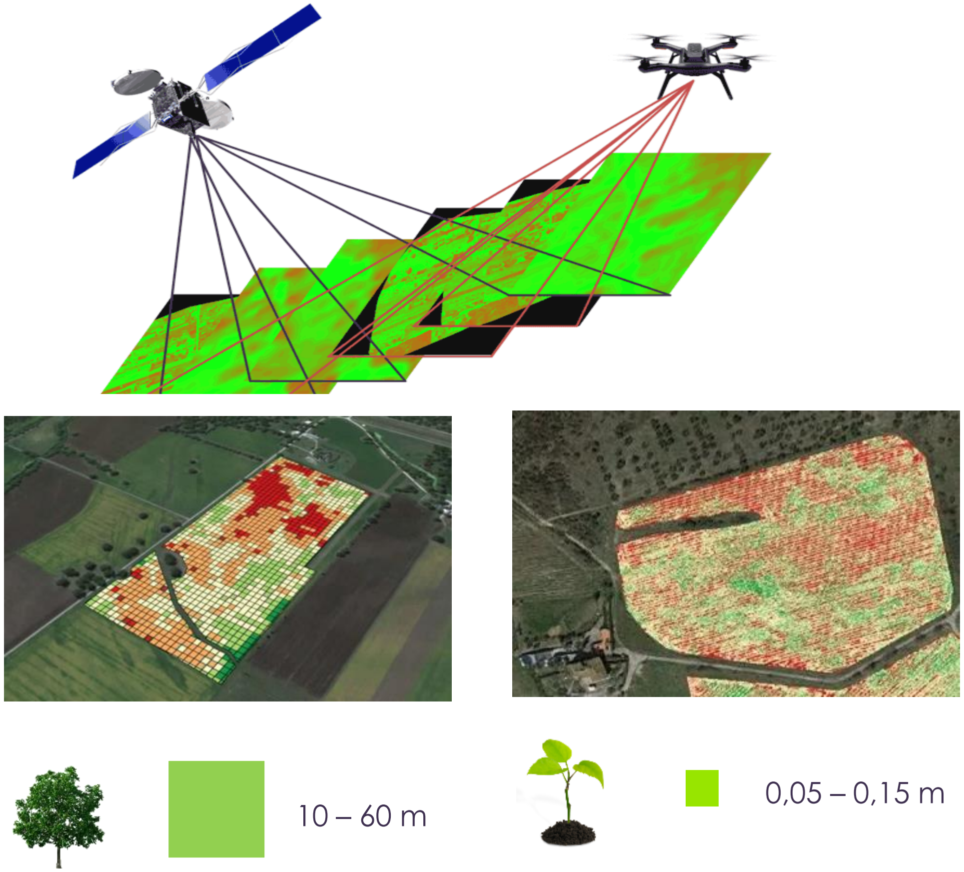
deep space remote sensing
- missions such as Voyager and the Cassini-Huygens space-research mission

State of art

1. coverage and spatial and temporal **resolution** of observations
2. synergies of **complementary observations**, of different sensitivities spectral ranges, and different time or spatial scales and deployment of new sensors with enhanced capabilities and synergistic retrievals
3. Advanced **data processing** approaches that rely on rigorous forward modelling and numerical inversion methodologies, considers extensive sets of state parameters
4. **long- term** data acquisition

1. From global to local scale coverage

- many natural phenomena at higher temporal and spatial variability are not fully captured
- trade-off between spatial coverage and the resolution of satellite images (orbit&sensors)
- synergies of complimentary observations to address specific objects and relevant problems



Platform	Spatial resolution (m)	Frequency (days)	Bands	Data processing
	Sentinel-2: 10 to 60	Sentinel-2: 10 (one satellite) to 5 (two satellites)	13	Vegetation Indexes
	Landsat 8: 15 to 100	Landsat 8: 16	11	Thermal anomalies
	Sentinel-1 IW: 5x20	Sentinel-1: 12 (one satellite) to 6 (two satellites)	1	Displacement analysis Flood detection
	COSMO-SkyMED SM: 3x3	CSK: 16	1	Displacement analysis
	Pleiades HR: 0.5 to 2.8	Pleiades HR: 26	5	Coastal erosion, vegetation indexes
	WorldView-3: 0.31 (PAN) 1.24 (MS) – 3.7 (Short Wave IR)	WorldView-3: <1	28	Vegetation Indexes, nitrogen concentration
	GeoEye-2 (worldView-4): 0.3 (PAN) - 1.2 (MS)	GeoEye-2 (worldView-4): <3	5	Vegetation Indexes, nitrogen concentration
	SPOT 6 & 7: 1.5 (PAN) - 8 (MS)	SPOT 6 & 7: 1	4	Vegetation Indexes
	RapidEye: 5 (MS)	RapidEye: 1	5	Vegetation Indexes, nitrogen concentration
	QuickBird: 0.65 (PAN) - 2.6 (MS)	QuickBird: 1 – 3.5	4	Vegetation Indexes
 DJI MATRICE 300 RTK	Optical: 0.05 – 0.15 m	on demand	3	Optical orthophotos
	Thermal: 0.05 – 0.15 m		1	Thermal orthophotos
	Multispectral: 0.05 – 0.15 m		3	Multispectral orthophotos
	Lidar: 0.05 – 0.15 m		1	Digital Surface Model (DSM)

2. Synergies of **complementary observations** and deployment of new sensors with enhanced capabilities and synergistic retrievals

- **Active remote sensing instruments** (lidars and radars) for vertical variability of the atmosphere (ESA Aladin wind lidar onboard the Aeolus satellite Living Planet Program)
- Synergy of **passive imagery** with active vertical profiling of the atmosphere and **hyperspectral spectrometry**, combining observations of different **sensitivities** obtained in different **spectral ranges**, or at different **time or spatial scales**
- Deployment of coordinated observations by **passive** (polarimeter, spectrometer, microwave radiometer) and **active** (lidar and radar) sensors (A-Train for polarimetric, radiometric, lidar or NASA ACCP-Aerosol and Cloud, Convection and Precipitation)

2. Synergies of **complementary observations** and deployment of new sensors with enhanced capabilities and synergistic retrievals

Active remote sensing instruments (lidars and radars) for vertical variability of the atmosphere (ESA Aladin wind lidar onboard the Aeolus satellite Living Planet Program)

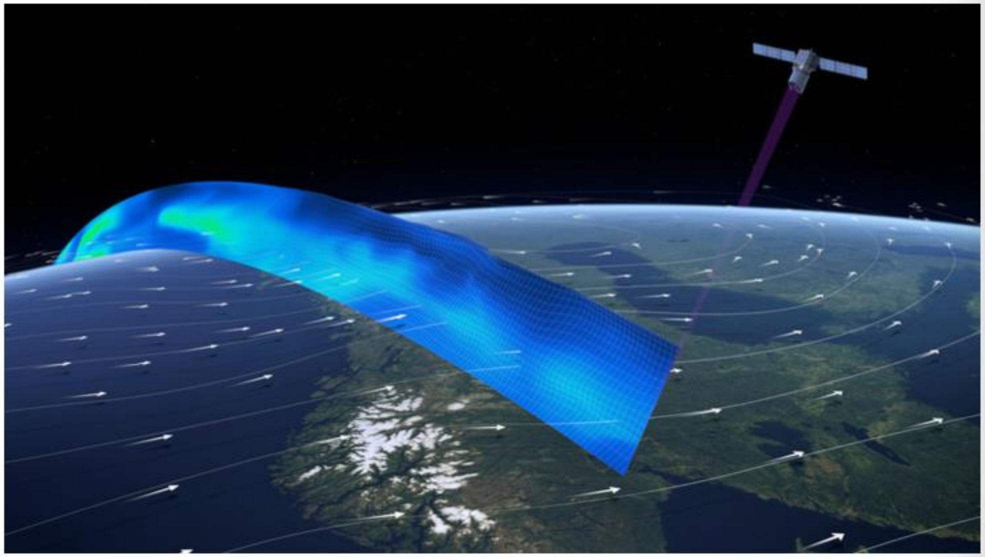


Figure 1: "Profiling the world's winds" ESA

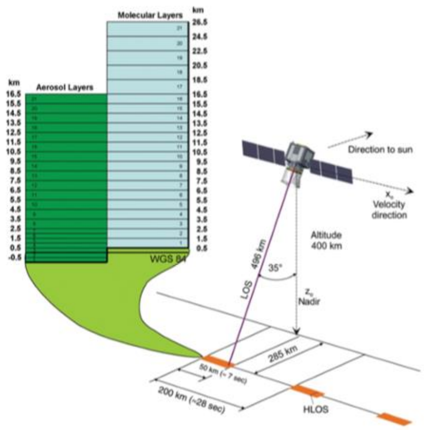


Figure 2: Aeolus measurement geometry and principles (Stoffelen et al., 2005).

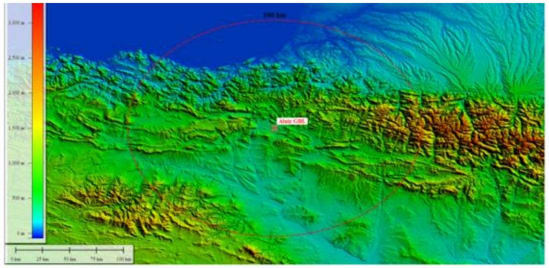


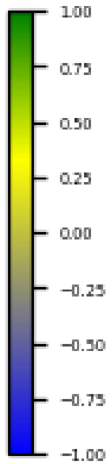
Figure 5: Digital elevation map of the study area.

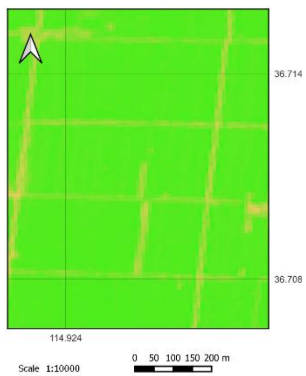
Master Thesis - Lorenzo Lugaresi - DTU Wind Energy-M-0415 -December 2020

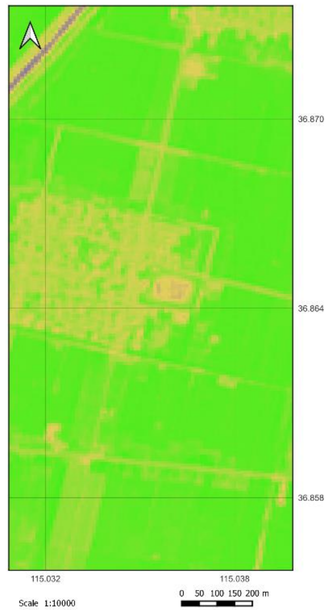
2. Synergies of **complimentary observations** and deployment of new sensors with enhanced capabilities and synergistic retrievals

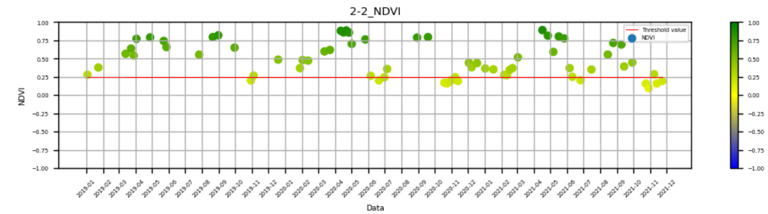
Time series analysis of vegetation indices for each field.

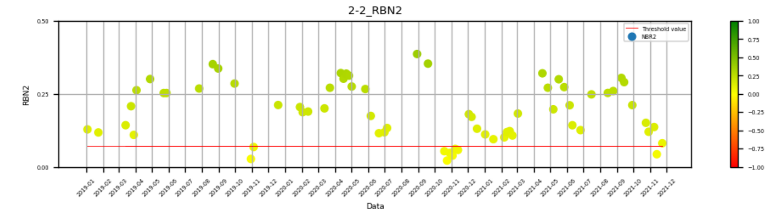
Sentinel 2 NDVI.

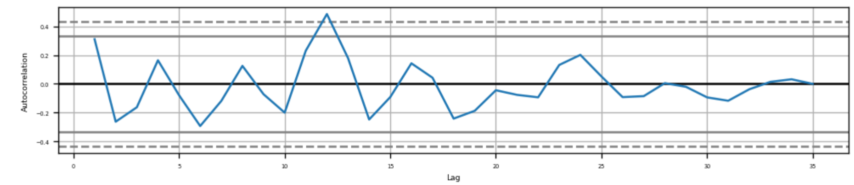








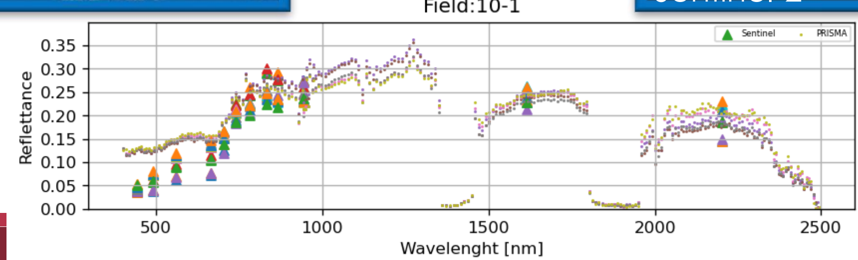




Use Machine Learning and reflectance spectrum to retrieve:

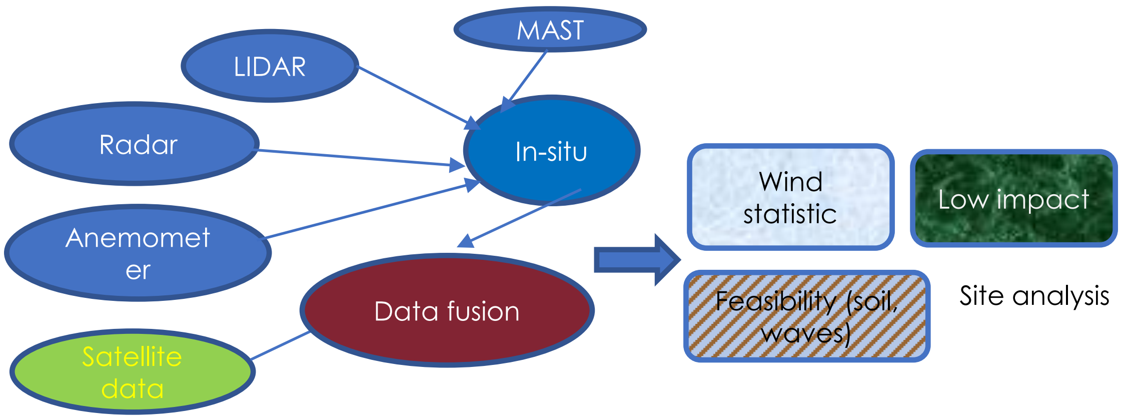
- Soil Organic Matter(SOM)
- pH
- Effective Phosphorus
- Available Potassium
- Total Nitrogen
- Different crop biophysical variables

Use of Hyperspectral data.

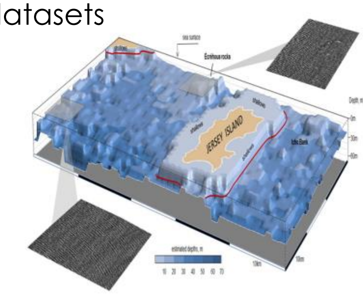


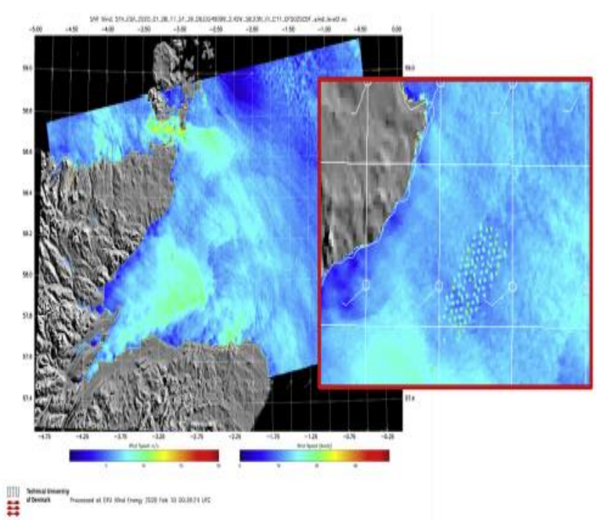
PhD research project: Retrieval of soil and crop properties
Candidate: Francesco Rossi

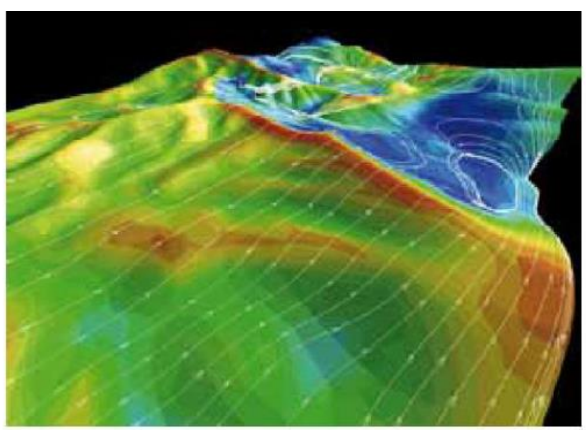
2. Synergies of **complimentary observations** and deployment of new sensors with enhanced capabilities and synergistic retrievals

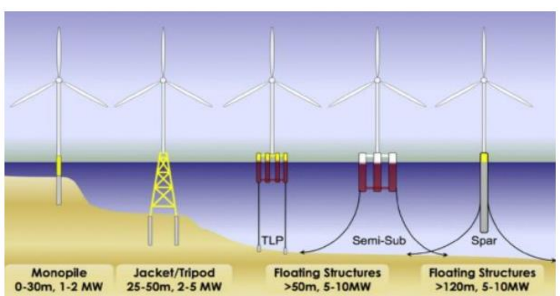


- Medium wind speed from SAR data (SENTINEL_1, ENVISAT)
- Wave Height and Period (meteorology, SAR data (SENTINEL_1, ENVISAT)
- Bathymetry of sea bed/ soil characterization (eco sounders, SAR data)
- Surface roughness (morphology) form STEREO VIS and SAR datasets







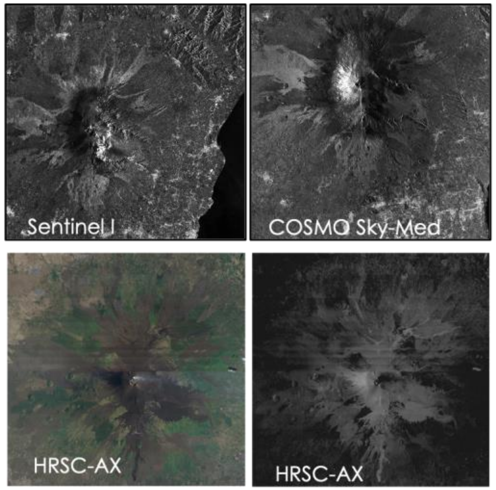


PhD research project – Candidate: Jacopo di Cave

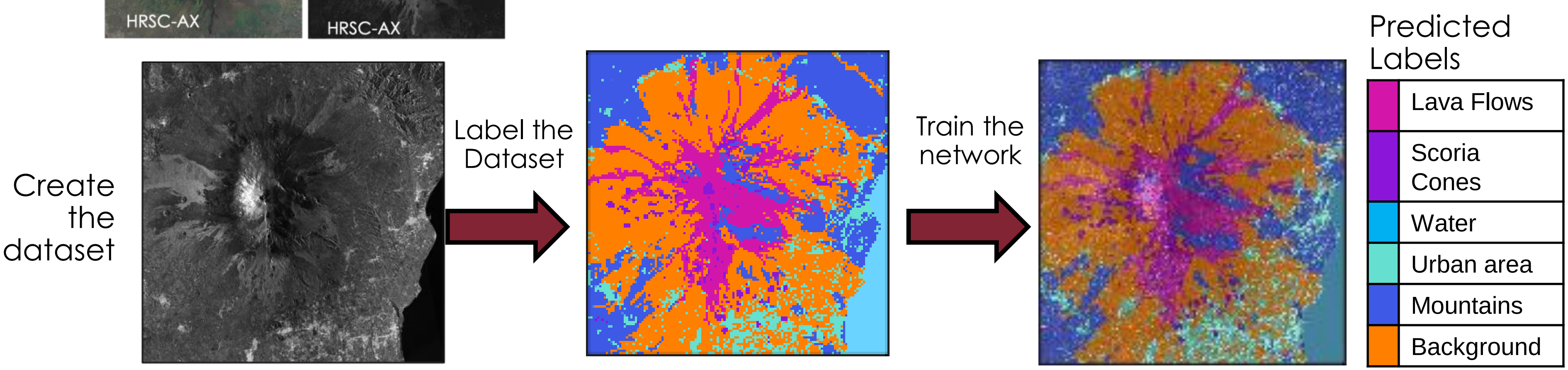
3. Advanced Data Processing Approaches

- Automatic extraction of spatio-temporal relations enforce the capability of forecasting and modelling physical phenomena at multiple timescales
- Quality, reliability and performance of remote-sensing **retrieval algorithms** (assimilate advanced atmospheric modeling and retrieving a large number of parameters)
- Capable of **analyzing multi-instrument** measurements for improving the accuracy of the retrievals
- **Machine learning** to extract patterns and features from the remote sensing and geospatial data
- **Deep learning** and deep neural networks to process and analyse huge amounts of data

3. Advanced Data Processing Approaches



- Analyze optical and Synthetic Aperture Radar (SAR) images representing one of the most tectonically and magmatically active zones in the Mediterranean Sea Area, *i.e.*, Mt. Etna.
- Develop an automatic feature extraction algorithm that identifies the most common structures originating from volcano-tectonic activities.
- Train a Machine Learning (ML) model for the task of Semantic Segmentation, which involves assigning a class label (*e.g.*, scoria cones, lava flows) to every pixel in the image
- Future goal: adaptation of the procedure to planetary missions



An approach for volcano-tectonic features extraction using optical and radar remote sensing data A. M. Gargiulo, M. Marsella, M. Coltelli, A. Genova

3. Advanced Data Processing Approaches

An application to volcanic ash cloud for volcanic risk mitigation

AI System

→ Satellite and in-Situ

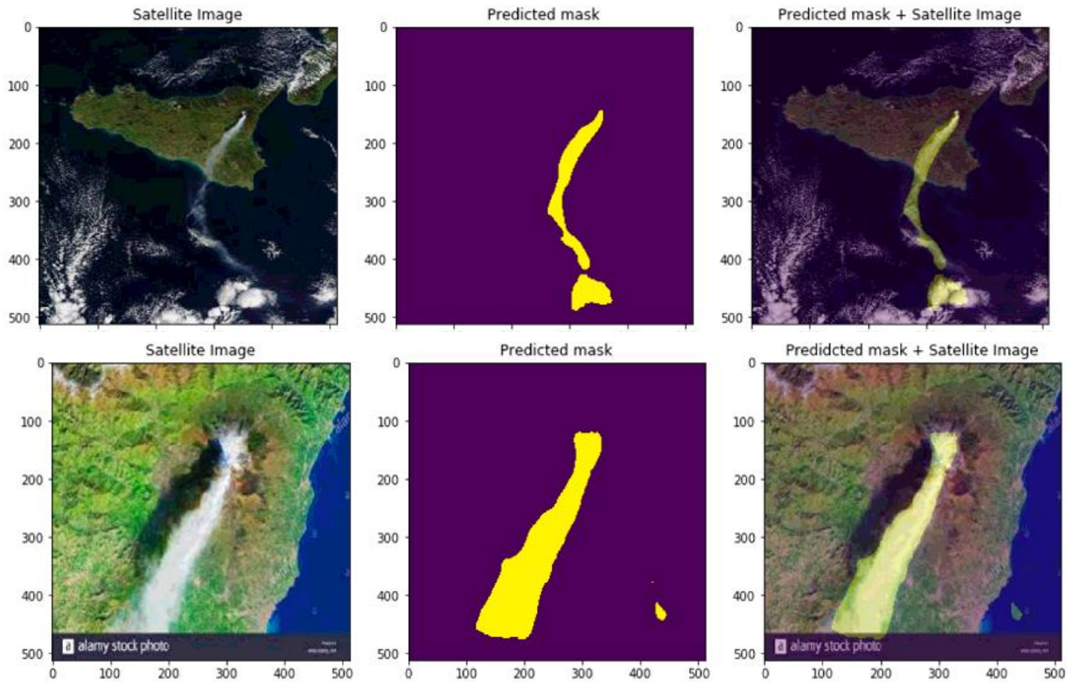
Build CNN models

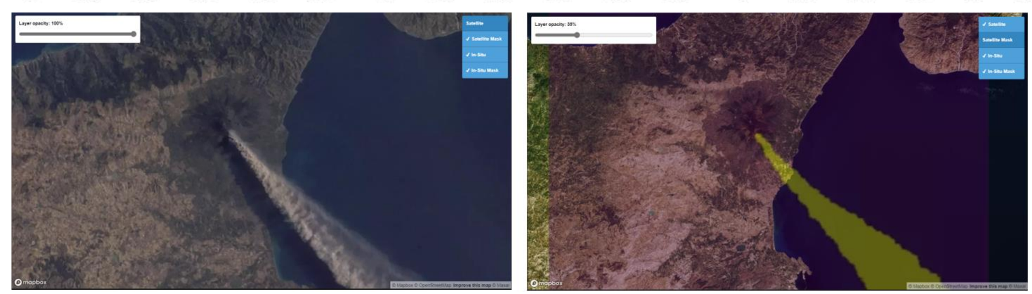
→ Classification model

→ Semantic segmentation

→ 3D Reconstruction

WEBGIS



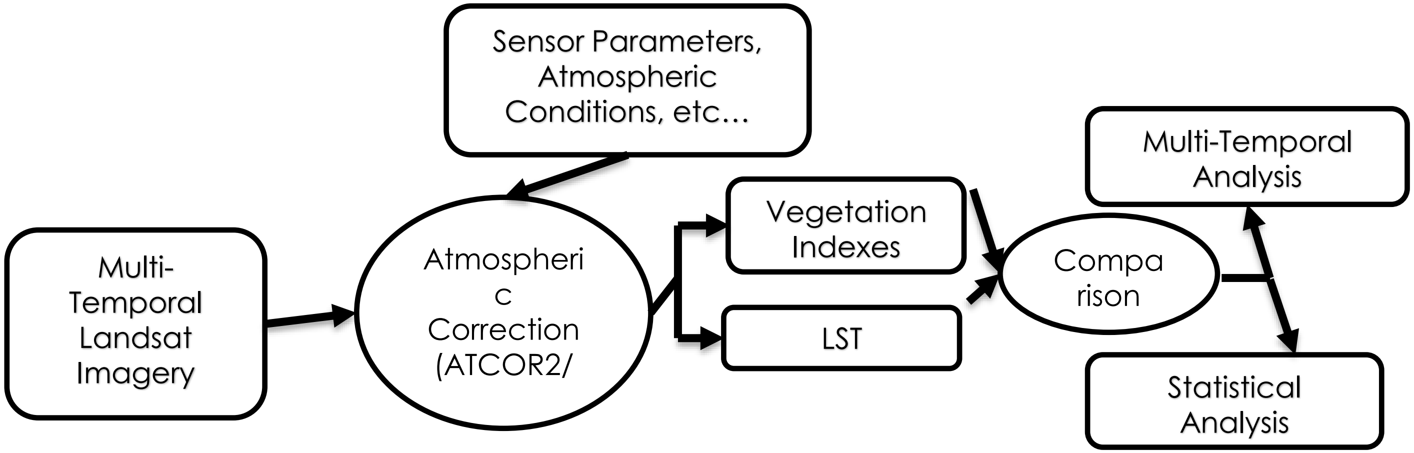


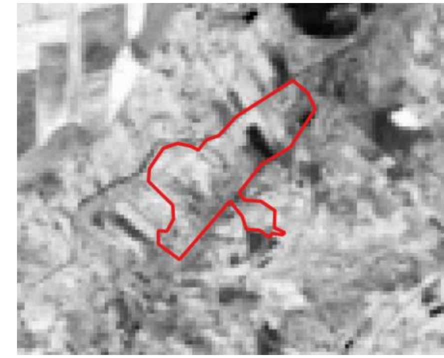
PhD Francisco Guerrero - An innovative approach based on Deep Learning - Convolutional Neural Networks for the integrated analysis of the effects on the Territory and Infrastructures due to Natural Hazards, applied to Mt. Etna (Italy); Case study Galeras volcano (Colombia)

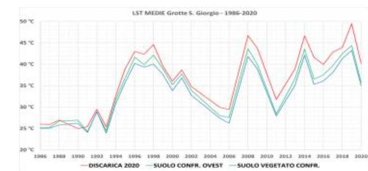
4. Long-Term data acquisition

- A long-term and high-quality record of essential **climate variables** is critical for monitoring and studying the Earth's Climate change
- Continue **observations without interruptions** in a multi-instrument data record
- Absolute **calibration** of each instrument and the intercalibration of multiple sensors (relevant issue of multi-satellite constellations)
- Control the evolution of **long-term natural** hazard processes finds valuable support in **historical archives** (such as ESA and NASA repository)
- Availability of surface soil moisture time series contribute to understanding of the water cycle in support of climate change mitigation actions in agriculture and water resources management

4. Long-Term data acquisition



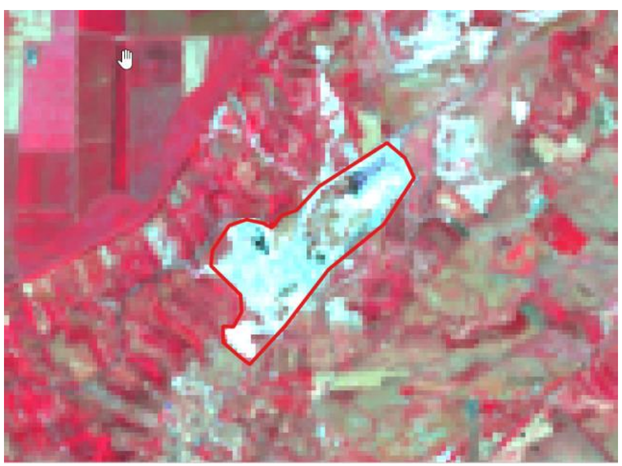


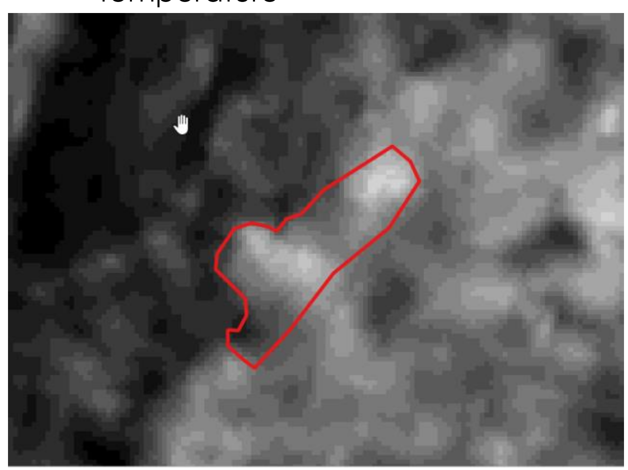


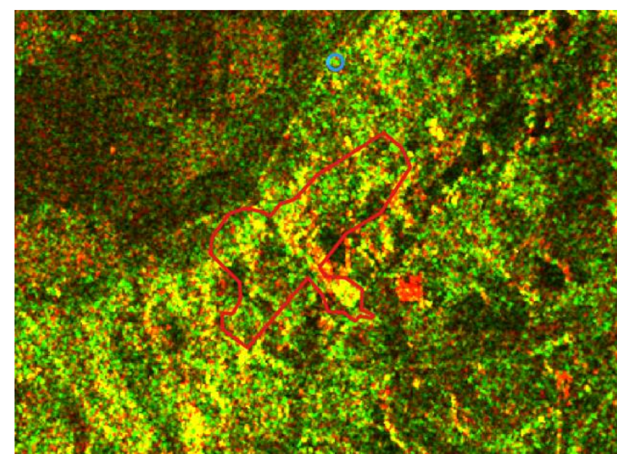
Multi/hyperspectral images
- Visual interpretation
- Study of the spectral signature
- vegetation index

LST Images (Land Surface Temp.)
- obtained from corr. atm. of TIR images
- Landfills have higher surface temperature

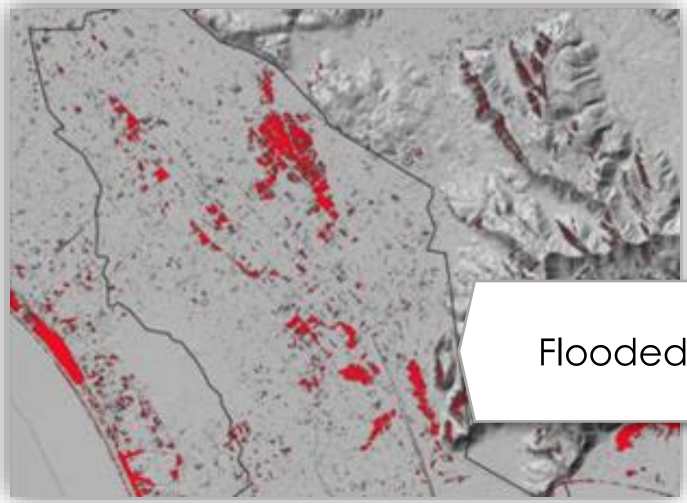
SAR
- Amplitude <-> anisotropic characteristics
- Interferometry <-> areas of decorrelation, topography



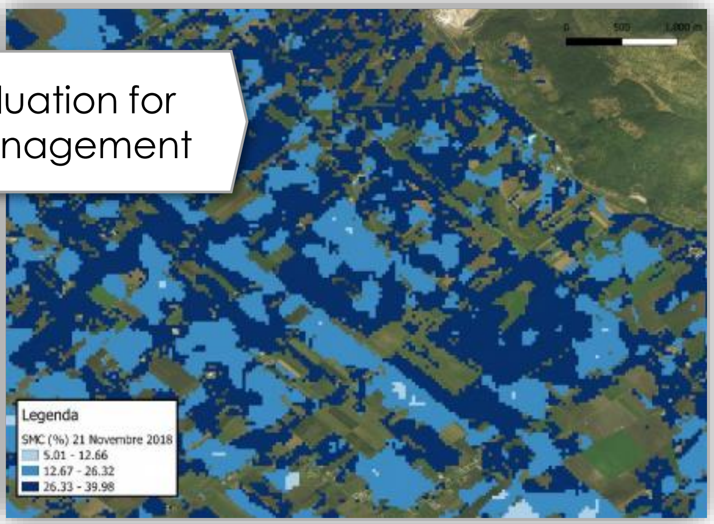




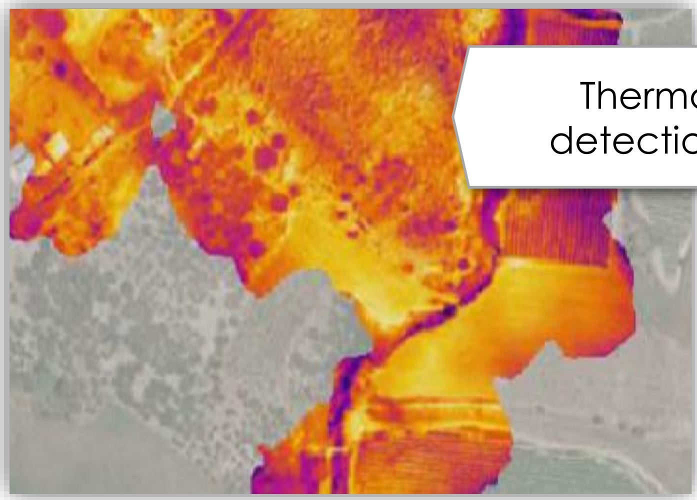
4. Long-Term data acquisition



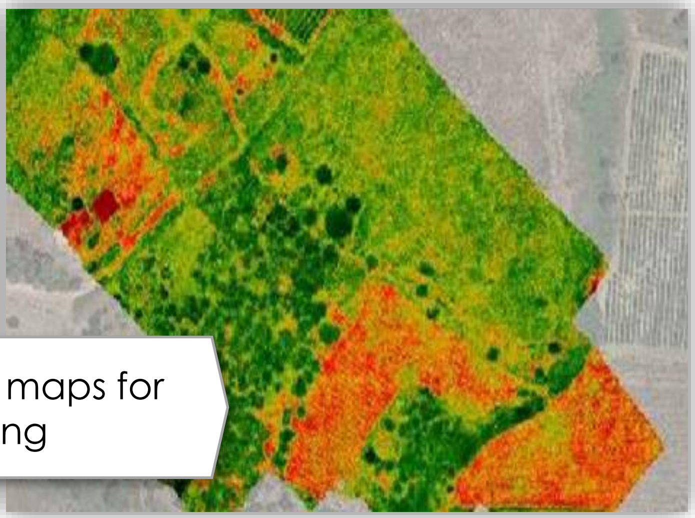
Flooded area detection



Soil Moisture evaluation for crop irrigation management



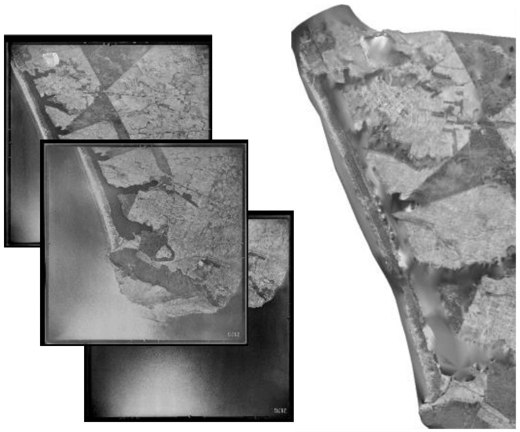
Thermal anomalies detection (crop stress)



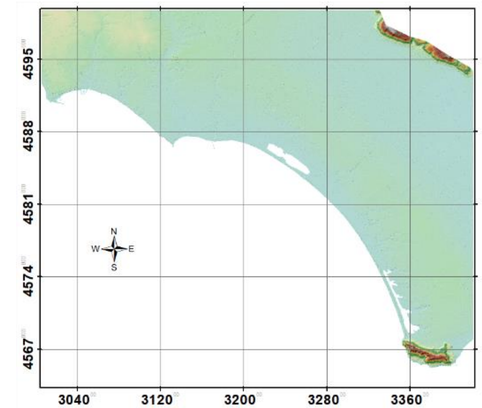
Vegetation indexes maps for crop monitoring

4. Long-Term data acquisition

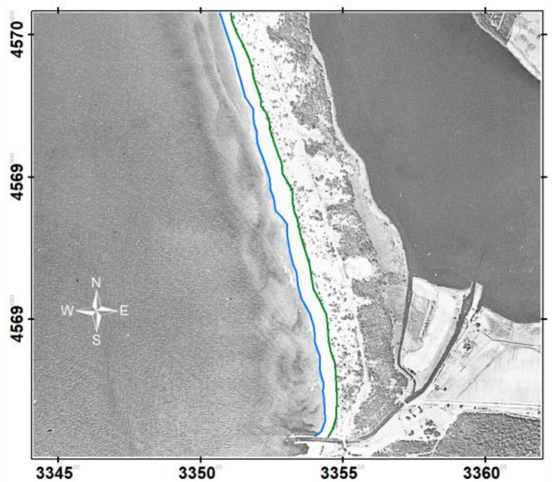
1954 - Aerial photogrammetry



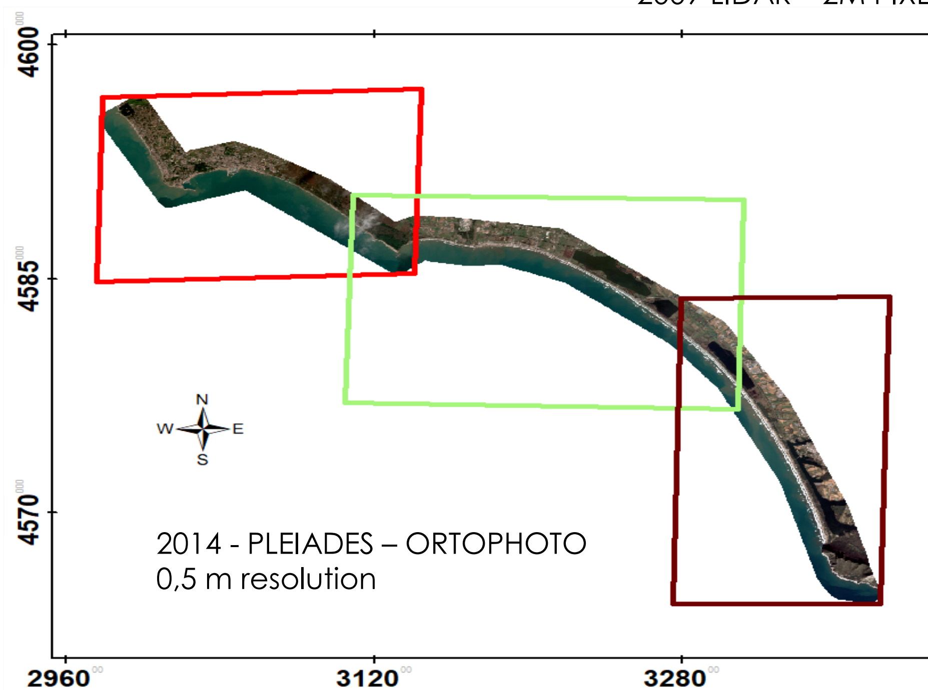
feature extraction from historical photograms, LIDAR data, and PLEIADES multispectral/pancromatic images



2009 LIDAR – 2M PIXEL



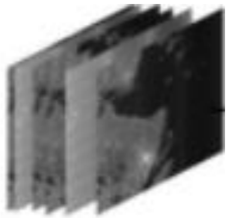
study area of Capo D'Anzio – San Felice Circeo



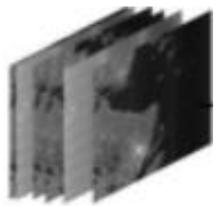
2014 - PLEIADES – ORTOPHOTO
0,5 m resolution

4. Long-Term data acquisition

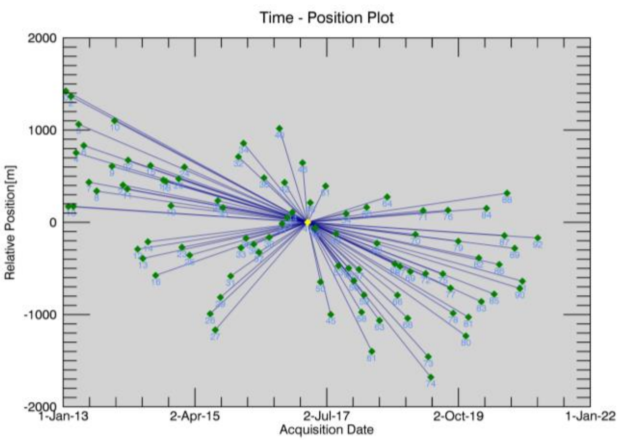
SAR dataset



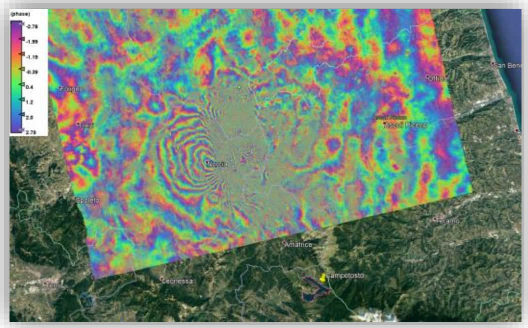
Coregistration



Connection graph

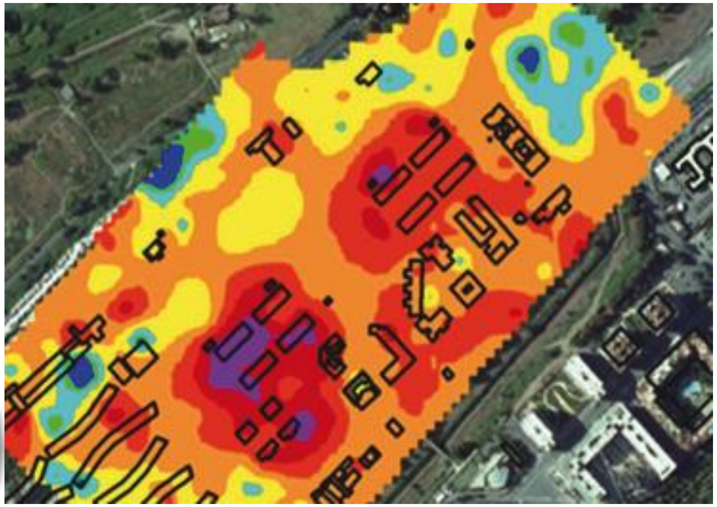


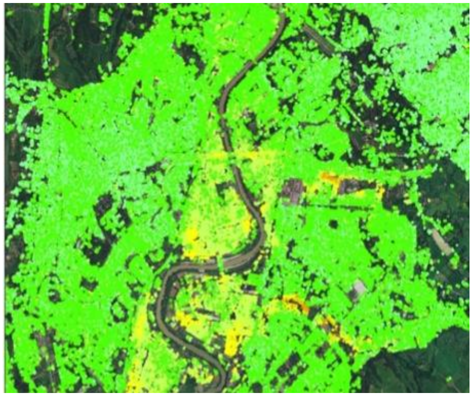
Land mapping scale analysis

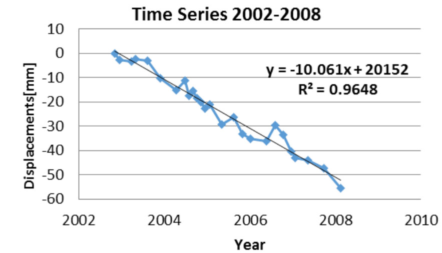


PSInSAR tecnique

Deformation Maps

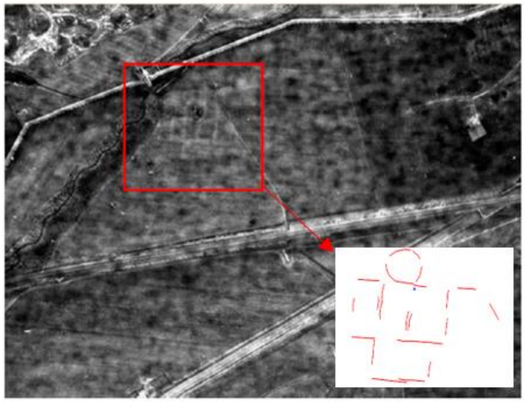






2D archaeological feature extraction

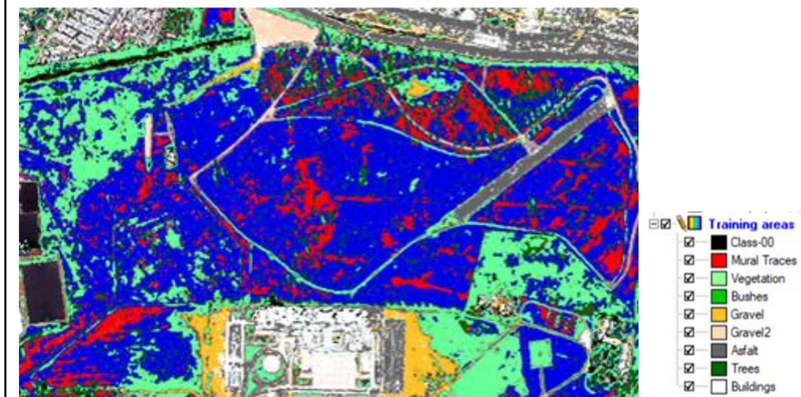
Spatial Convolutions and Lineament Extractions on historical fotograms



High Pass, Low Pass, Edge Enhance, Edge Detect and Thresholding, using matrices 3X3 or 7X7, can be applied to enlight the contrast of geometric features.
Lineament Extraction from the libraries of tools, have been then used to automatically recognize features

Rome (Park of Tor Fiscale): High Pass Filter on a historical photogram (SARA 1932) and lineament extraction of the structure (on the right)

Upervised classification of multispectral HR images

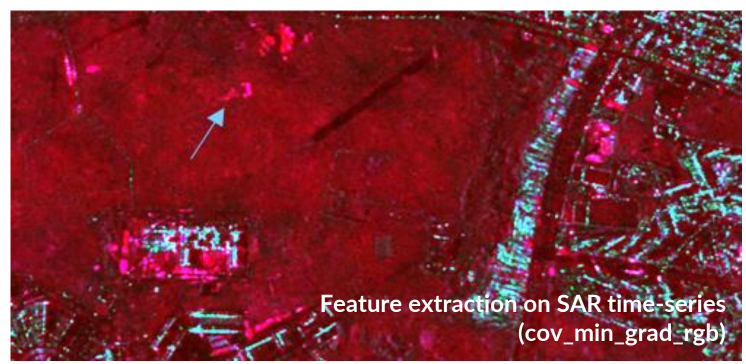


Centocelle archaeological Park: supervised classification of the Pleiades Pansharpened image (01/01/2017)

Automatic Feature identification using SAR data

Master slc of 12/02/2015

Feature extraction on SAR time-series (Feature_cov_ql)



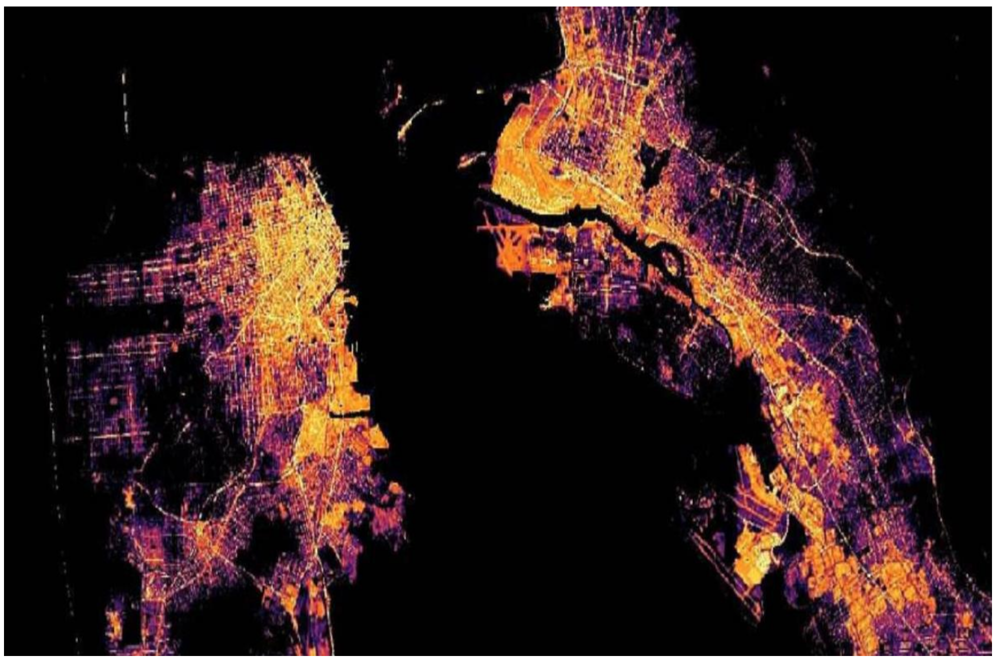
Coefficient of Variation STD/Mean Ratio(red), min index (green), max variation (blue)

Multi-temporal features can be extracted from coregistered dataset (**10 images from april 2014 till february 2015**), showing features that change with **seasons**, due to fluctuations in vegetation - soil moisture.

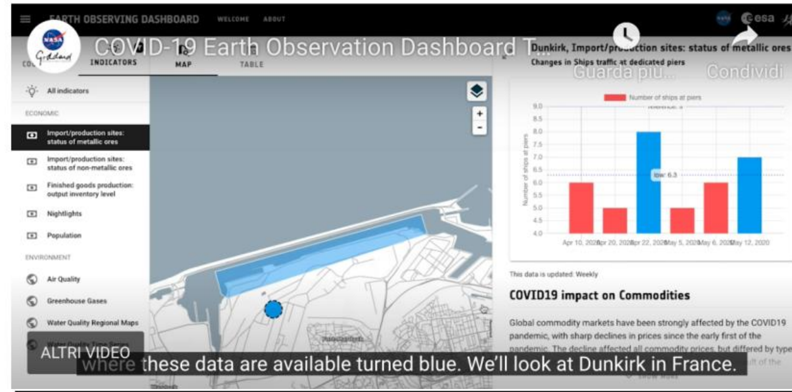
NASA, ESA, JAXA Release Global View of COVID-19 Impacts

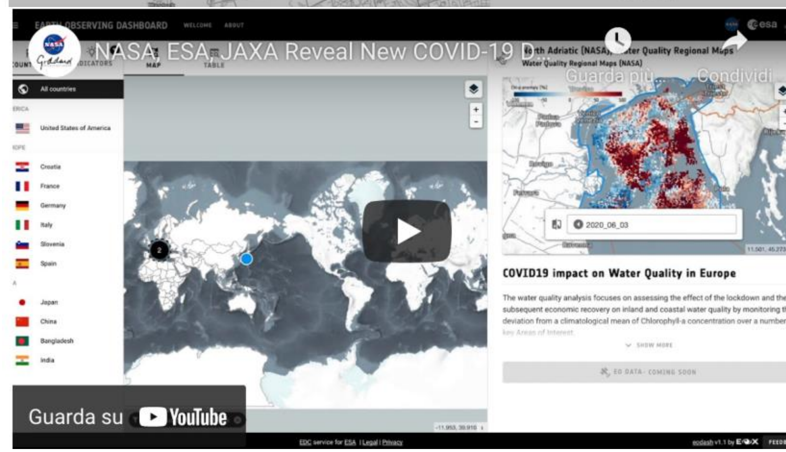
'COVID-19 Earth Observation Dashboard' integrates multiple satellite data records from the three space agencies with analytical tools to allow users to track changes in air and water quality, climate change, economic activity and agriculture.

The tri-agency platform gives the general public and policy-makers a unique platform to explore the short and long term impacts of the coronavirus lockdown.



"nightlights" data from the NASA-NOAA Suomi NPP satellite - San Francisco Bay (image credit: NASA)





COVID-19 led to changes in human activities around the globe. Some bodies of water have run clearer, emissions of pollutants have temporarily declined, and transportation and shipment of goods have decreased. We can see some of these changes from space. NASA, ESA (the European Space Agency) and the Japan Aerospace Exploration Agency (JAXA) are making satellite data available on the new COVID-19 Earth Observation Dashboard (video credit: NASA)

Main challenges

1. Increasing coverage and spatial and temporal **resolution** of observations
2. Increasing **information content** of observations by deploying satellite instruments with enhanced capabilities
3. exploring synergies of **complimentary observations**, of different sensitivities spectral ranges, and different time or spatial scales and deployment of new sensors with enhanced capabilities and synergistic retrievals
4. Development innovative **data processing approaches** to implement rigorous backward and forward modelling based on large multi-sensor datasets extensive sets of state parameters
5. Enduring **long- term data** acquisition

Reference: Dubovik O, Schuster GL, Xu F, Hu Y, Bösch H, Landgraf J and Li Z (2021) Grand Challenges in Satellite Remote Sensing. Front. Remote Sens. 2:619818.