PA 12: Technologies for Aerospace and Earth Observation

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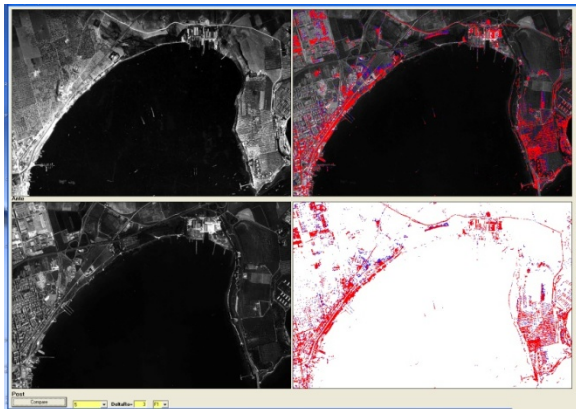
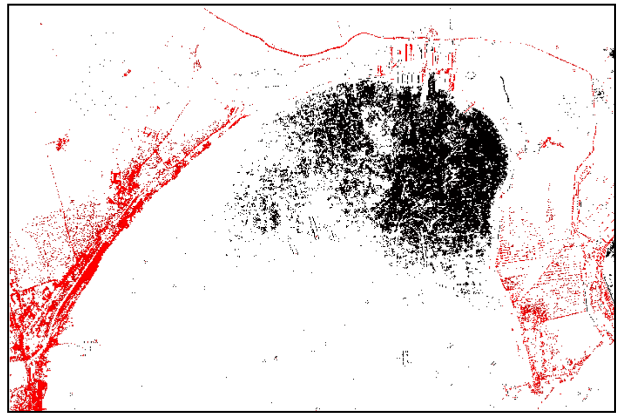
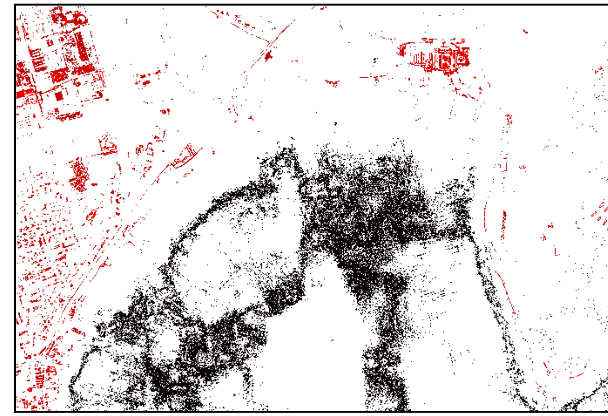
Software development for unsupervised approach to identification of a multi temporal spatial analysis model



The models of spatial statistical analysis are extracted according to image processing, pattern recognition and filter algorithm



The reconstructed image with the I main component – 1940

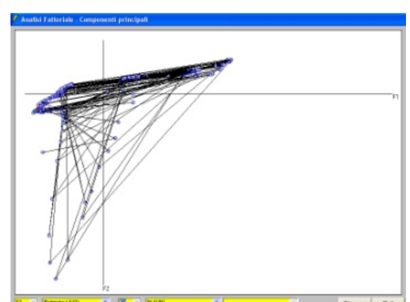


The reconstructed image with the IV main component – 2010

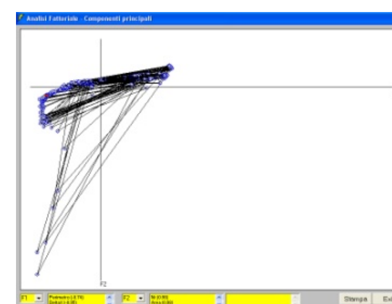
Variable		Description
Nz		Z coordinate - Average depth
Nt		N.ro of pixels of the object
Area		Attributes of the object:-Area
Perimeter		Perimeter of the object (Edge detection – Sobel)
DeltaX		Xmx-Xmn
DeltaY		Ymx-Ymn
IdealArea		Ideal Area=DeltaX * DeltaY
Gx	-	barycentre X
Gy	-	barycentre Y
Jx	-	moment of inertia with respect to the X axis
Jy	-	moment of inertia with respect to the Y axis
Rx	-	radius of inertia X
Ry	-	radius of inertia Y
AreaRect	-	area of the circumscribed rectangle.
RapportAAR	-	relationship between area and area of the circumscribed rectangle.

VARIABLES OF THE MODEL USED

This methodological approach introduces a significant improvement in the evaluation of changes in the territorial scenery, providing a wider interpretation of the problems of the area studied and encouraging a more analytical reading of complex environmental phenomena.



Graphical display between I and II component – 1940



Graphical display between I and II component – 2010

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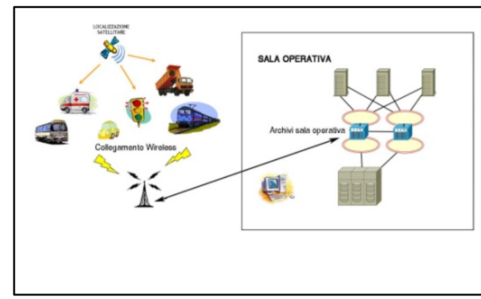
Project DIRS - Device Infomobility Reference Station

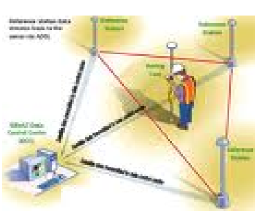
PON RESEARCH AND COMPETITIVENESS 2007-2013 - Law 46/82 art. 14 from the Fund for Technological Innovation (FIT). This project was co-financed by the ERDF - European Regional Development Fund

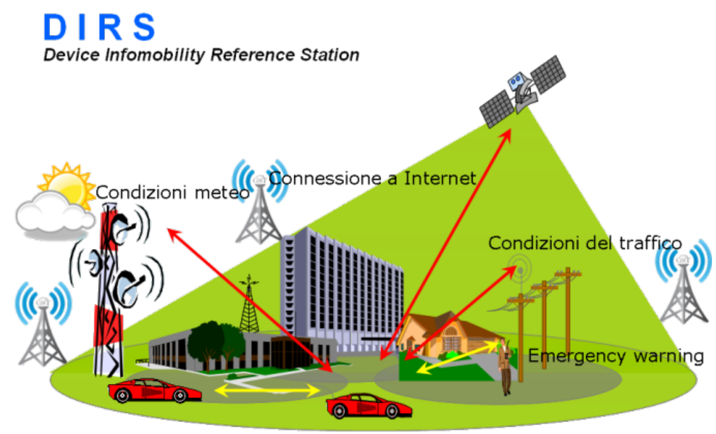
Realization of a Device Infomobility Reference Station by infrastructure network GPS/GNSS. This system can geolocalize mobile devices with high precision and integrate the traffic service for individual security and safety.



TECNOLOGY INTEGRATION

- **Fixed and mobile M2M (machine to machine);**
- **GPS / GNSS technology for high accuracy with VRS (Virtual Reference Station) and the corrections of satellite data;**
- **Telemetry for the collection of environmental information and vehicle;**
- **Control algorithms for the estimation of network saturation (CNR-IASI).**





Project Area 12: Technologies for Aerospace and Earth Observation

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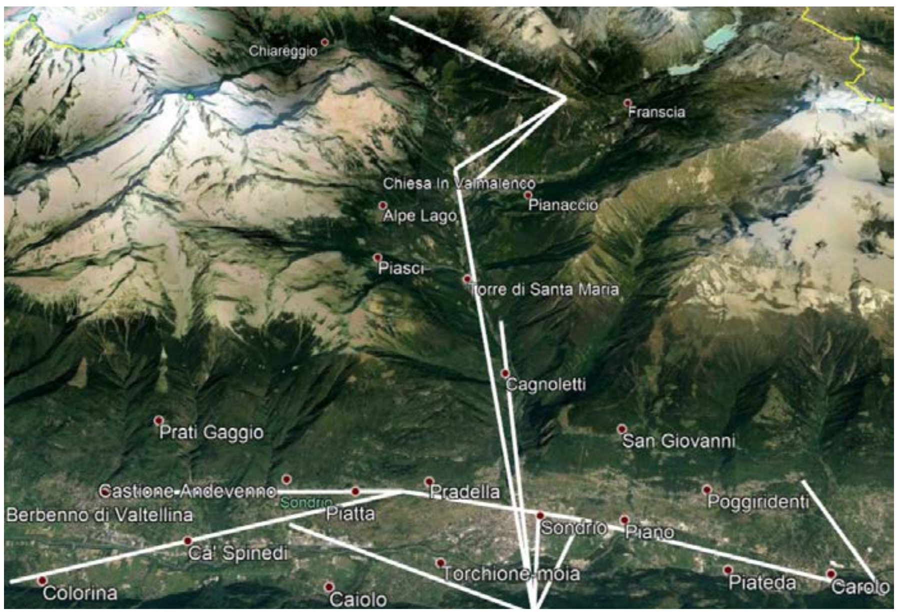
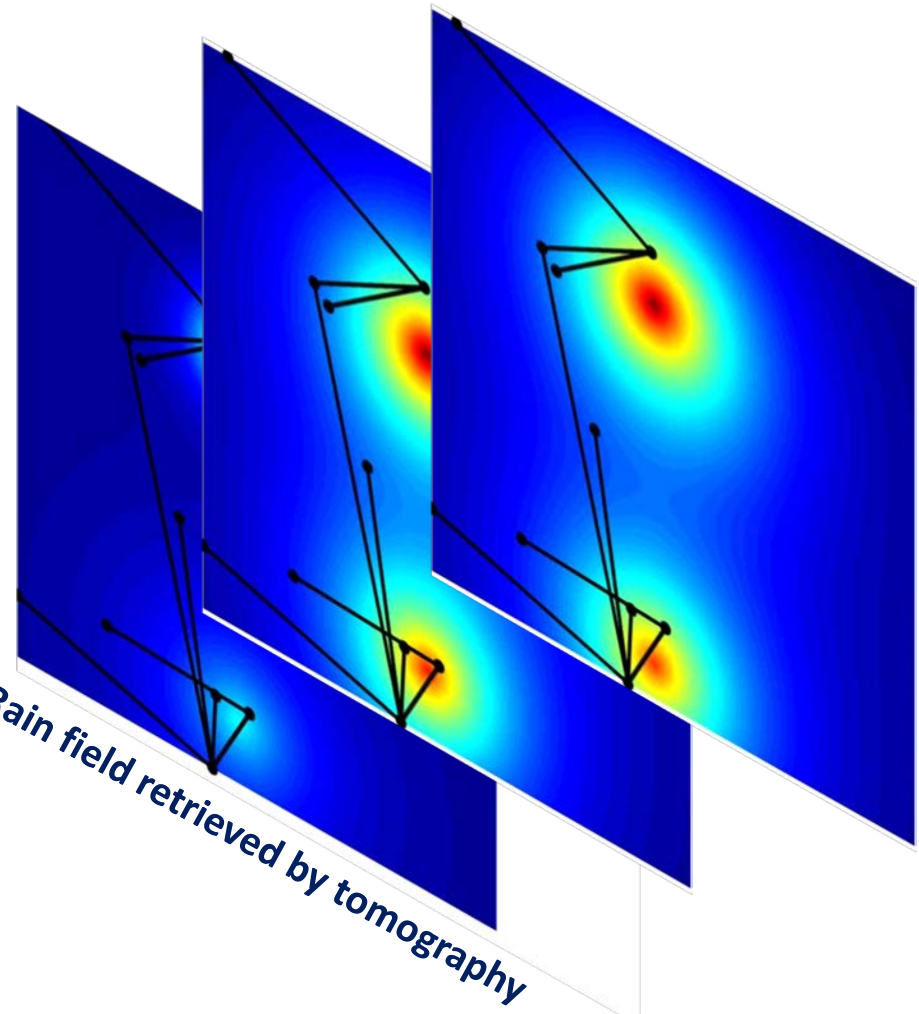
Theme 2: Technologies for Earth Observation

MOnitoring PRecipitation through A network of Microwave radio links (MOPRAM)

http://www.mopram.it/



Microwave links, Valmalenco (Italy)



Rain field retrieved by tomography

Project Area 12: Technologies for Aerospace and Earth Observation

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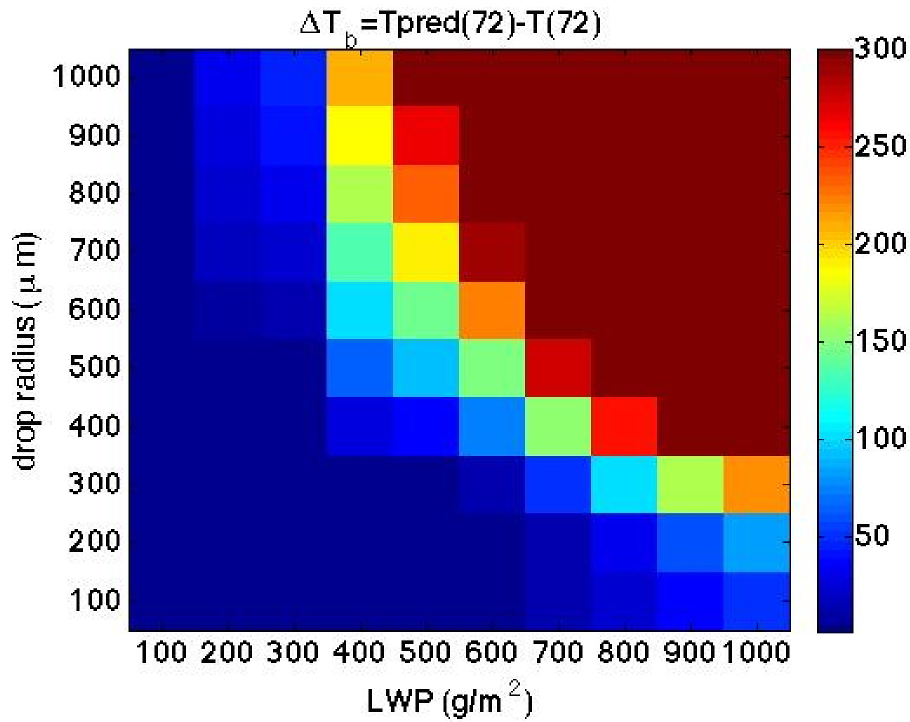
Theme 2: Technologies for Earth Observation

Forward modeling of atmospheric scenarios

The demand of high data rate and mobility applications pushes the future wireless communication systems (5G) higher in frequency spectrum utilization, where the scattering mechanisms are a major impairment to signal transmission and receptions, namely in the presence of hydrometeors. The effects of these mechanisms along the propagation path can be described by observing brightness temperatures with microwave radiometers. A **real time scalar indicator** could detect possible scattering along the propagation path (**SI, Scattering Indicator**).



$$SI = \Delta T_B(72) = \hat{T}_B(72) - T_B(72)$$

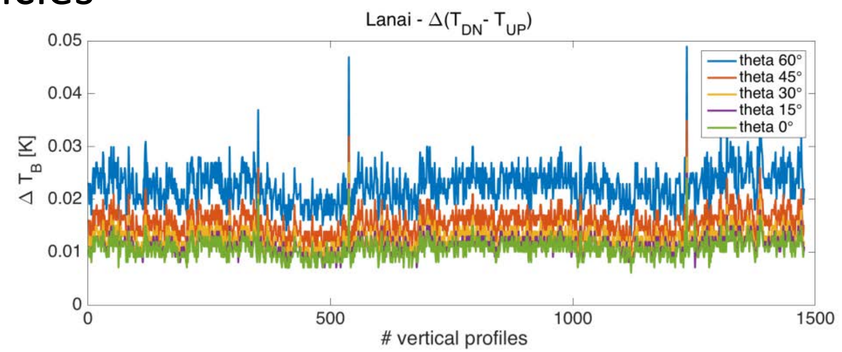
Project Area 12: Technologies for Aerospace and Earth Observation

Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

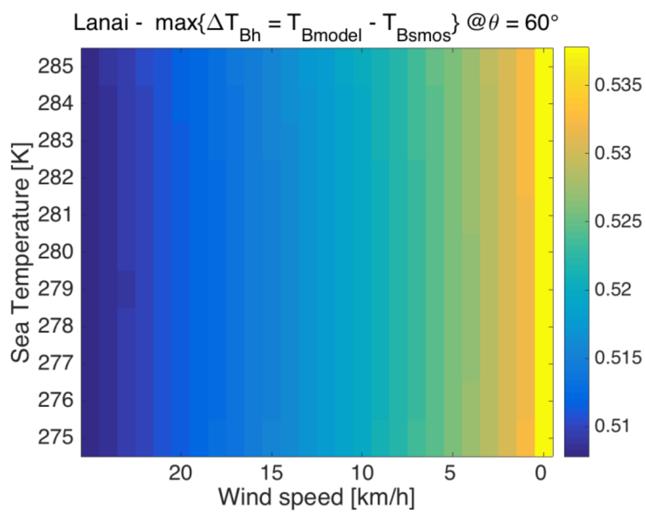
Theme 5: Aerospace and Aeronautics Technologies

Forward modeling of atmospheric scenarios

Analysis of the impact of the atmospheric contribution on the sea surface salinity retrieval at low microwave frequencies



T_B difference between upward and downward self-emission of the atmosphere



Maximum T_B difference when computed using the two approaches

[K]	$\|\Delta T_{BH}\|$	ΔT_{BV}
>0.1	#857	#797
>0.2	#571	#571
>0.3	#857	-

Project Area 12: Technologies for Aerospace and Earth Observation

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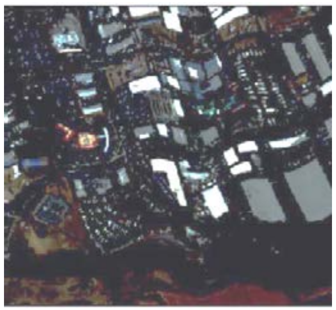
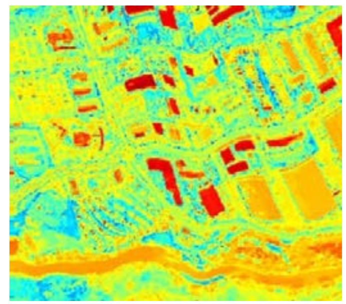
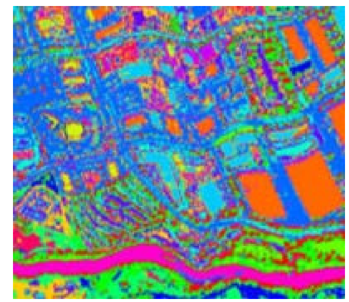
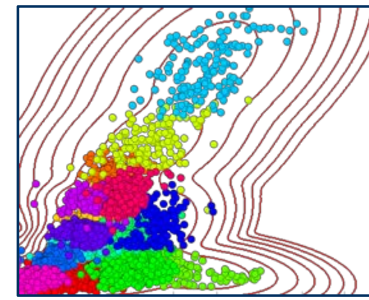
Theme 2: Technologies for Earth Observation

Multi/Hyperspectral image processing

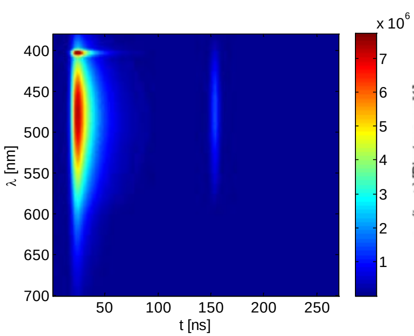


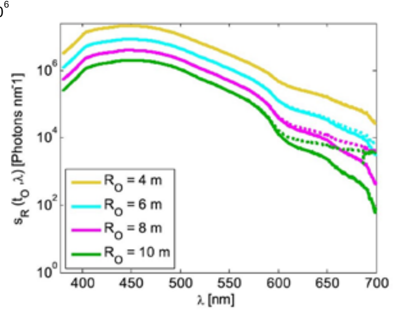


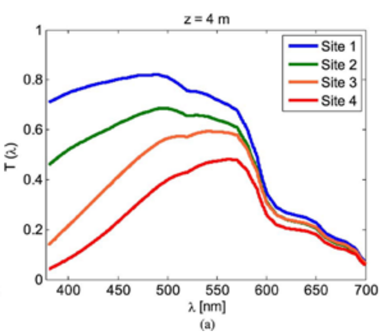


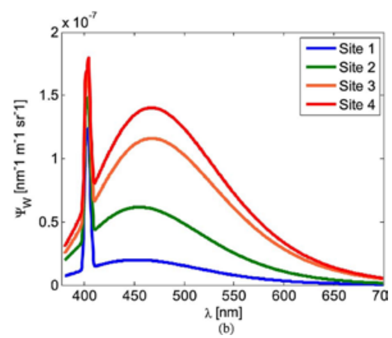


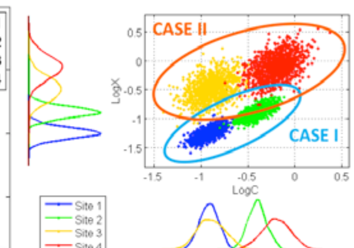
LIDAR underwater remote sensing and propagation modeling











Project Area 12: Technologies for Aerospace and Earth Observation

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Theme 5: Aerospace and Aeronautics Technologies

Micro UAV with corner reflector to calibrate radars in their operative condition

Micro UAV with dipole antenna to operate as a source/probe for Antenna and EM-Field Testing

Project Area 12: Technologies for Aerospace and Earth Observation

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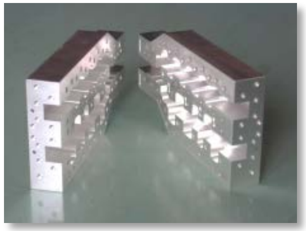
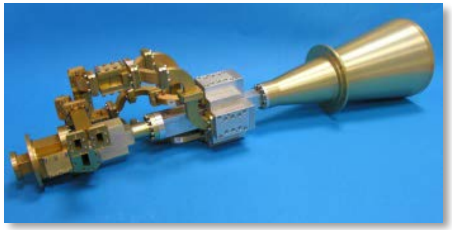
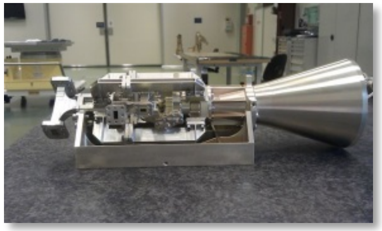
Engineering, ICT and Technologies for Energy and Trasportation Department

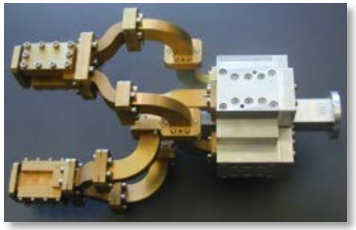
Theme 5: Aerospace and Aeronautics Technologies

Antenna systems for Satellite Communication (courtesy of Thales Alenia Space - Italy)

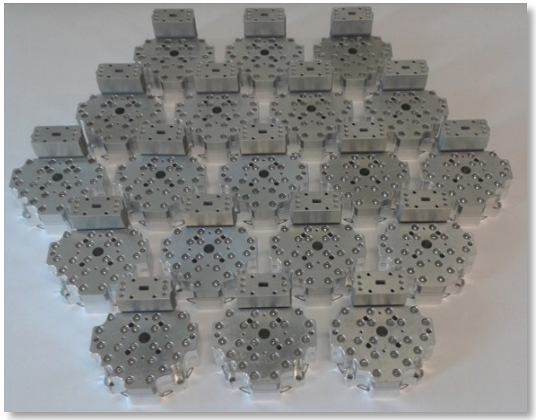








Antenna systems for Radio Astronomy & Astrophysics

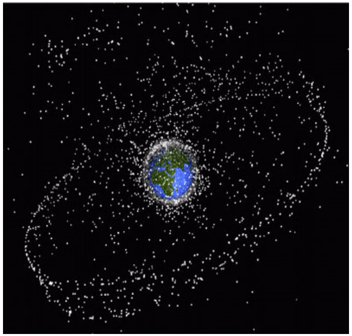


The space debris

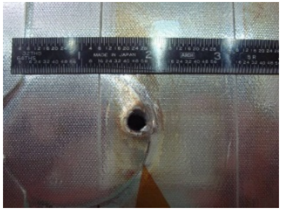
Space debris are all man made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non functional. Since the first artificial satellite, Sputnik 1, launched by the USSR on October 4, 1957, more than 5000 launches have occurred, placing nearly 7000 payloads in orbit. Currently there are about 3500 satellites and probes orbiting the Earth, together with about 1800 upper stages. Of all these spacecraft, only about 900 are operational. All the rest are space debris. Going down to smaller sizes the number of objects larger than approximately 10 cm in Earth orbit exceeds 20000 and the estimates of cm sized particles are of the order of 150 000. All these abandoned objects represent a serious risk for all the space assets and already lead to the disruption of operational satellites.

The IFAC group is working since many years in the field, covering different aspects of the space debris issue: telescope observations, orbit determination, orbital dynamics, collision risk evaluation, modelling of the long term evolution, reentry strategies from different orbital regimes. These activities have the final goal of finding effective mitigation measures to stop the growth of the debris population safeguarding the space for the future generations.

Members of the group are delegates, for the Italian Space Agency, within the the Inter-Agency Space Debris Coordination Committee (IADC) IADC Website, the main international governmental forum for the worldwide coordination of activities related to the issues of man-made and natural debris in space. A. Rossi is the coordinator of the H2020 project ReDSHIFT (http://redshift-h2020.eu/)



Computer generated image of the distribution of the catalogued space debris around the Earth (Courtesy: ESA Space Debris Program Office)



Entry hole created on Space Shuttle Endeavour's radiator panel by the impact of unknown space debris (top). The ESA Space Debris Telescope at Tenerife (bottom).

Collaborations

The space debris research activities are pursued, mostly with European funding, in close collaboration with Italian and international partners including academies, research centers and industries such as: European Space Agency, Italian Space Agency, University of Pisa (Italy), Politecnico di Milano, University of Southampton (UK), IAPS-INAF (Italy), CNRS (France), SpaceDyS (Italy).

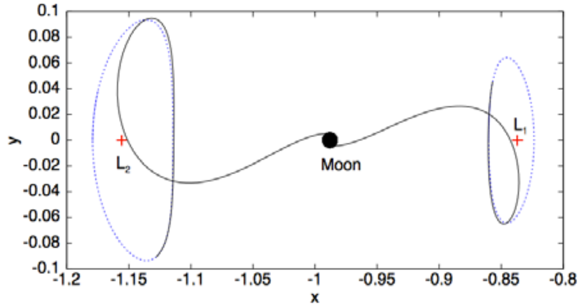
Contacts: Alessandro Rossi, Elisa Maria Alessi, Giulia Schettino, Pierfrancesco Di Cintio, Giovanni B. Valsecchi

Astrodynamics and Planetary Science

The IFAC group is appreciated since many years for the research carried out in the astrodynamics and planetary science fields. Accurate models and algorithms are developed with the aim of describing, understanding and effectively exploiting the dynamics of small bodies orbiting in the Solar System.

Concerning artificial satellites, recent works include the design of trajectories associated with libration points in Sun-Earth and Earth-Moon system, end-of-life disposal options in different orbital regimes, asteroid retrieval trajectories, and interplanetary trajectories.

Moreover, the group is involved in the study of trajectories leading to asteroidal impacts to the Moon and the planets. Orbital and rotational dynamics and physical studies (through spectroscopical observations) of the small bodies of the Solar System are also carried out.



Libration Point Orbits in the Earth-Moon system.

The Chelyabinsk meteor.

An impact crater on the moon.

Collaborations

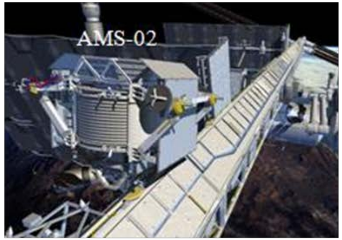
The research activities in this field are pursued, mostly with European funding, in close collaboration with Italian and international partners including academies, research centers and industries such as: European Space Agency, University of Southampton (UK), IAPS-INAF (Italy) IMCCE (France), Universitat Politècnica de Catalunya (Spain), University of Colorado at Boulder (USA), Università di Padova (Italy), INAF-Osservatorio Astronomico di Roma.

Contacts:

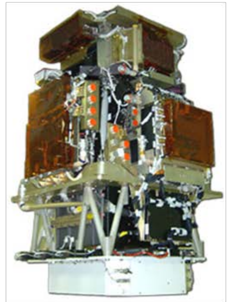
Alessandro Rossi, Elisa Maria Alessi, Giulia Schettino, Pierfrancesco Di Cintio, Giovanni B. Valsecchi

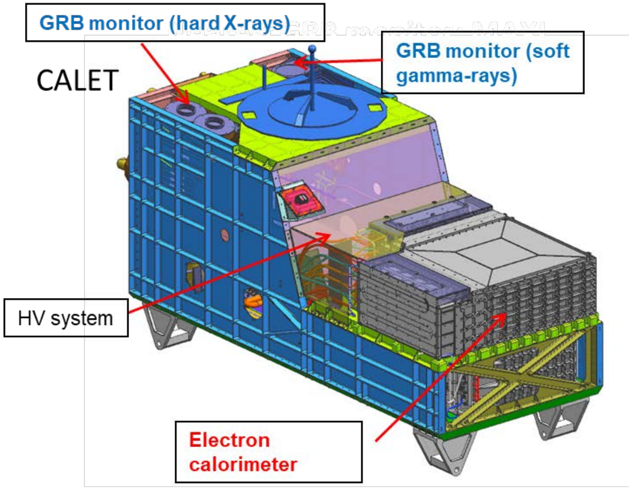
Power, control and processing systems for Space experiments on satellites and ISS

- The Satellites in low-Earth orbit, including the International Space Station (ISS), are fundamental for cosmic-ray and radiation belts observations.
- The design of an optimized electronic apparatus (power consumption, reliability, computing efficiency) is at the base of a successful space mission.
- We designed and implemented several control, power and data processing systems for charged particles and gamma-ray detectors:
  - **PAMELA** on Resurs/DK1 satellite (Russia) and **AMS-01** and -**02** on ISS: spectrometers aimed at antiparticle identification in cosmic-rays.
  - **CALET** on ISS: cosmic-ray electron detector and gamma-ray burst monitor.
  - **CSES** on CAST2000 satellite (China): radiation belt monitor.
- These systems make use of COTS electronic devices to overcome cost and availability of space qualified components, with dedicated fail-safe and redundant design to maintain reliability.
- Power distribution system and high-voltage supplies for PMT and APD photodetectors and silicon microstrip detectors.
- Parallel computing units, based on DSP and semi-custom FPGA, for processing data of custom front-end chips for arrays of photon and charged-particle detectors.



PAMELA





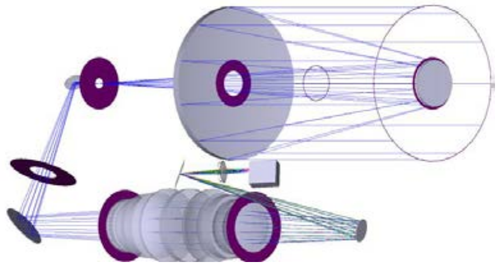
Contacts: *Sergio Ricciarini (s.ricciarini@ifac.cnr.it)*

Compressive sensing technology for aerospace systems

Compressive Sensing (CS) theory, leveraging on the concept of sparsity, affirms that a sparse signal can be efficiently reconstructed by the acquisition of a number of samples far below the minimal one dictated by Nyquist theorem, thus providing a new approach to data acquisition. Besides the inherent compression of data, CS approach enables the development of novel instrumental concepts, like the single-pixel camera that can acquire an image using a single photodetector element instead of an array of detectors. This approach becomes particularly appealing in space applications to work in those spectral regions where the availability of detector matrices is limited. In the whole, several space applications and related instruments could benefit from the CS approach, with a positive impact on system architecture, detector throughput and downlink bandwidth.

At IFAC labs, a CS demonstrator was constructed under ESA contract in order to assess the feasibility of the CS for Earth Observation and to investigate its main critical issues. Further studies were conducted under ESA contract to investigate the potential of CS technologies for optical space instruments for specific space applications, such as stellar spectro-photometry and real-time detection of Near Earth Objects.

Experimental set-up for the CS demonstrator for Earth Observation and the spatial light modulator.



Optical CAD of a CS-based instrument for stellar spectro-photometry.

With regards to enterprises

Several research activities on CS were carried out under ESA contracts (ESA ITB HPSI, ESA ITT OCS-TECH), also with the collaboration of Italian SMEs and LEs such as LEONARDO SpA.

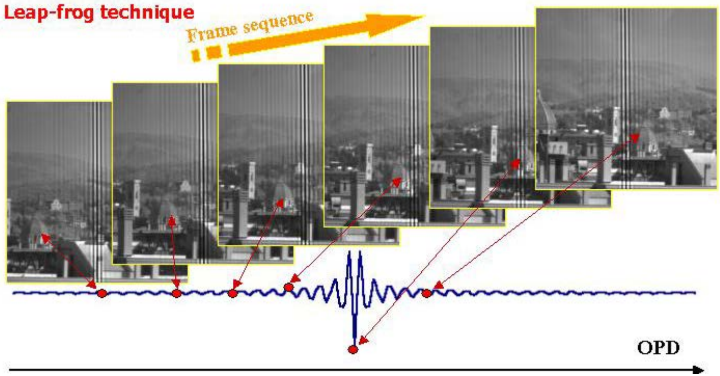
Contact - Valentina Raimondi

Valentina Raimondi (v.raimondi@ifac.cnr.it)

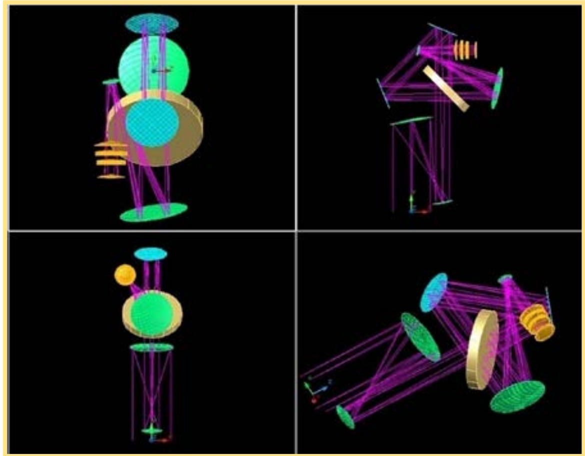
Donatella Guzzi (d.guzzi@ifac.cnr.it)

Image interferometer for aerospace platforms

The stationary image interferometer ALISEO (Aerospace Leap-frog Imaging Stationary Interferometer for Earth Observation) - in-house developed at IFAC - is characterized by its "leap-frog“ configuration, in which the image of the observed scene is modulated by an optical path difference (OPD). In this configuration, each point of the scene is seen with different phase delays and the interferogram of each point is reconstructed through the acquisition of a temporal sequence of images. With respect to a push-broom configuration, this method offers the advantage of providing an image for each acquisition, although it requires more complex data processing procedures for the reconstruction of the interferogram.



Working principle of the ALISEO interferometer.



Optical design of the ALISEO demonstrator.

The applications are typically those related to Earth Observation (environmental monitoring, natural resources, catastrophic events, etc..).

With regards to enterprises...

The demonstrator has been developed within the MIOSAT program of the Italian Space Agency.

Contact:

Valentina Raimondi (v.raimondi@ifac.cnr.it)

Donatella Guzzi (d.guzzi@ifac.cnr.it)

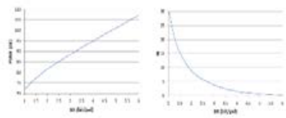
On-Board Compression of Hyperspectral Images

On-board data compression is a key point for an efficient transmission of remote sensing hyperspectral data from the satellite platform to the ground station. For users' applications, a high quality is required, so that DPCM schemes are usually employed for lossless/near-lossless compression, where the maximum absolute error (MAE) can be selected a-priori.

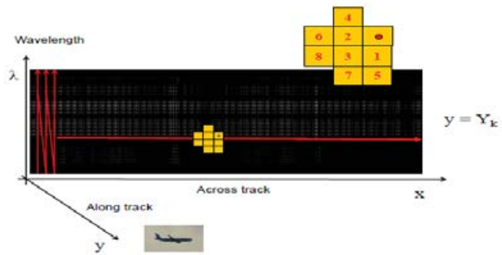
Basically, DPCM consists of a prediction of the data to be sent, which is followed by a coding of the differences, possibly quantized, between the predicted and the original data. Such a prediction can be computed by employing a MMSE linear combination of already transmitted values. For hyperspectral data sets, both spatial and spectral correlations can be exploited to obtain a better prediction.

In case of on-board compression, the space constraints force limitations in the available memory and computational power. Moreover, the algorithms have to work in the data acquisition formats, that is, Band Interleaved by Line (BIL) or Band Interleaved by Pixel (BIP), and not in the usual Band Sequential format (BSQ). To cope with these issues, an algorithm has been implemented by our research group, namely MA-DPCM (MMSE Adaptive DPCM), whose performances are comparable with the CCSDS standard.

Band BSQ of 2006 Aviris data set



Distortion plots of a BIP frame



MA-DPCM scheme for a BIP frame in the along track position Y_k

With regards to enterprises

This work has been supported by the European Space Agency (ESA) and the Italian Space Agency (ASI). Recently, it has been developed in collaboration with Leonardo S.P.A. in the project SAPERE (Space Advanced Project for Excellence in Research and Enterprise – CTNA, National Technological Aerospace Cluster) and in the SMART (Spettrometro Miniaturizzato Avanzato per Ricerca Tecnologica) project, funded by Tuscany Region (POR - FESR 2014-2020).

Contact

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Stefano Baronti (s.baronti@ifac.cnr.it)

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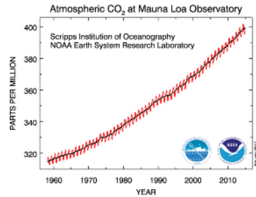
GHG (GreenHouse Gases) study: comparison of carbon dioxide retrieval from IASI on METOP-A and TANSO-FTS on GOSAT

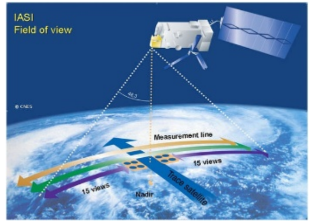
Carbon dioxide is the primary greenhouse gas released into the Earth's atmosphere by human activities. The balance of natural sources and sinks of carbon dioxide lead to stable values of about 280 ppm for atmospheric CO_2 concentration in pre-industrial times. Current levels of CO_2 in the atmosphere exceed the value of 400 ppm.

The study KLIMA-IASI, funded by ESA-ESTEC and coordinated by IFAC, represented an attempt to gain greater insight in the capabilities of passive remote sounding from space in the TIR spectral region to retrieve accurate information on the total amount of atmospheric carbon dioxide.

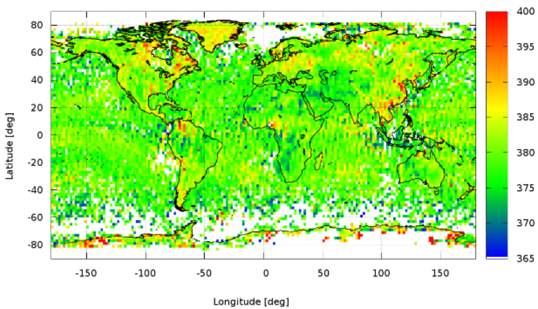
The research effort was conducted by investigating the potential of measurements acquired by the Infrared Atmospheric Sounding Interferometer (IASI), on-board the MetOp-A satellite, to provide CO_2 total column values with precision and accuracy comparable to 1 ppm on monthly averages over 1000×1000 km^2 areas and to compare the retrieved products with CO_2 operational products of the satellite mission GOSAT in the SWIR spectral region.



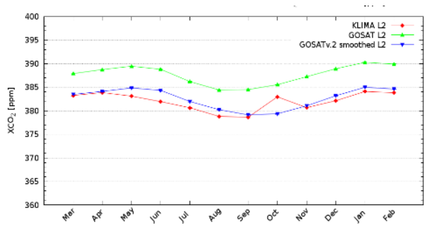
Carbon dioxide monthly mean



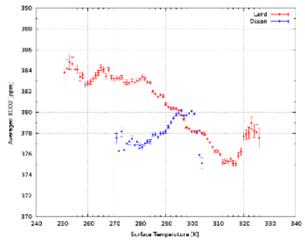
IASI instrument Field Of View



Global map of IASI CO_2



Comparison IASI vs GOSAT CO_2 products



IASI CO_2 vs surface temperature

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Authors: Atmospheric Research Group

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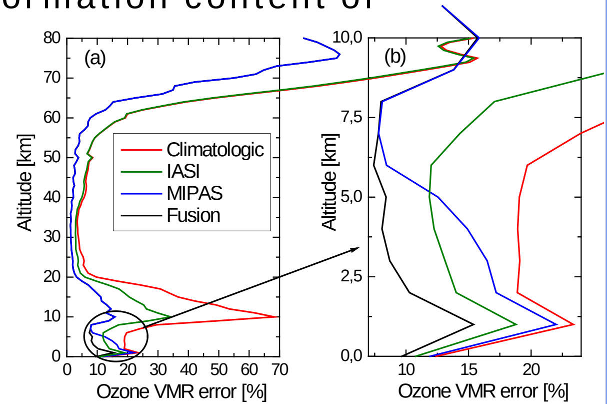
Theoretical analysis to optimize the information content of atmospheric indirect measurements

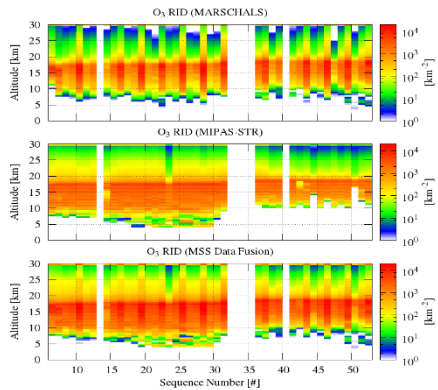
Many observation systems are presently operating on board space-borne and airborne platforms, as well as from ground-based stations, providing complementary and redundant measurements of a variety of atmospheric parameters. The use of potential synergies among these observing systems is a key element for the full exploitation of current and future missions with the purpose to provide target products of t he best quality in t erms of precision and accuracy, as well as spatial and temporal coverage and resolution. The Atmospheric Research Group at IFAC is active in theoretical studies aimed to individuate new approaches for the analysis of atmospheric indirect measurements with the purpose of an optimal exploitation of their information content.

Examples of results obtained in this research field are:

- Development of a retrieval solution (MEASUREMENT SPACE SOLUTION) that keeps separated the information of the observations and of the ret rieval constraint.
- Definition of parameters that evaluate the INFORMATION CONTENT and the QUALITY of atmospheric measurements
- Development of algorithms to perform the DATA FUSION of atmospheric measurements acquired by different instruments in order to exploit the synergy of the measurements.
- Development of an algorithm to perform the AVERAGE OF ATMOSPHERIC VERTICAL PROFILES in order to minimize the effect of the ret rieval const raints.



Quality of the ozone measurements of IASI and MIPAS and of their fusion in terms of the random errors.



Cross-sections of the Relative Information Distribution of MARSCHALS, MIPAS-STR and fused Ozone data

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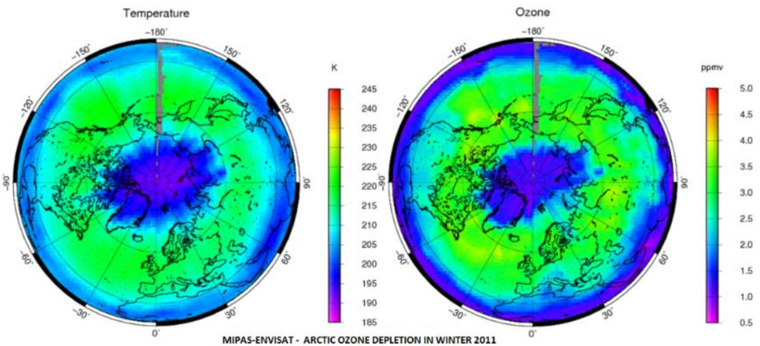
Authors: Atmospheric Research Group

Analysis of remote sensing measurements for the study of the atmosphere

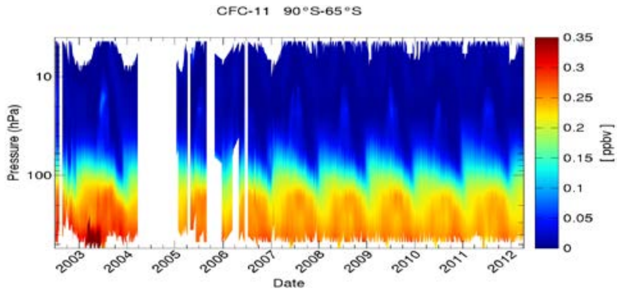
Global challenges like the problems of ozone hole and climate change require the study of the chemistry of stratospheric ozone, the study of the earth radiation budget and the monitoring of Green House Gases. To this purpose, since 80s years passive remote sensing of the terrestrial atmosphere from stratospheric platforms and analysis of measurements from satellite sounding the radiation emitted by the atmosphere have been performed by the Atmospheric Research Group at IFAC. Forward and inverse modelling of the radiative transfer in the atmosphere allow the retrieval of geophysical parameters used for the monitoring and the study of the composition of the stratosphere.

An example of this activity has been the development of the scientific prototype for ESA L2 processor performing the near-real-time analysis of MIPAS measurements on ENVISAT.

ENVIromental SATellite (ENVISAT) hosting Michelson Interferometer for Passive Atmospheric Sounding (MIPAS)



Anomalous very low temperatures and ozone hole in Arctic 2011 winter as measured by MIPAS



Monitoring of ozone depleting substances (CFCs) with MIPAS

Contact: Piera Raspollini

Authors: Atmospheric Research Group

UTLS (Upper Troposphere Lower Stratosphere) study: MARSCHALS data analysis

The UTLS region is a pivotal region of the Earth's atmosphere due to the chemical, radiative and transport processes occurring at these altitudes and having a substantial impact on surface climate. In the UTLS Essential Climate Variables are most sensitive to changes in the distribution of radiatively active gases and clouds.

Remote sensing measurements of this region pose, however, a very challenging problem both from the point of view of modelling the observed radiation and of retrieving the desired quantities from the observations.

MARSCHALS (Millimetre-wave Airborne Receivers for Spectroscopic CHaracterisation in Atmospheric Limb Sounding) is a limb viewing instrument working in the millimeter and sub-millimeter spectral ranges (294-349 GHz). To demonstrate the measurement capabilities of the instrument, IFAC contributed to the development of a suite of codes. in which the most accurate modelling and the most advanced retrieval algorithms have been implemented.

Geophysica stratospheric aircraft

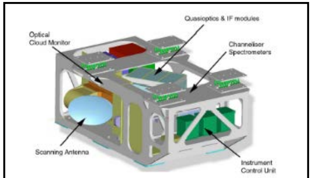
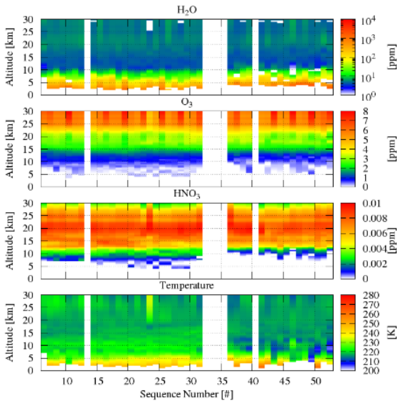


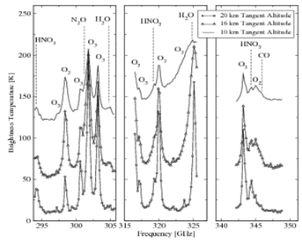
Figure 1 Configuration of MARSCHALS instrument

MARSCHALS configuration



Atmospheric retrieval products

MARSCHALS was deployed on-board the M-55 Geophysica stratospheric aircraft and from 2005 to 2011 many measurement campaigns have been analysed provinding the vertical profiles of Temperature, HNO_3, O_3, H_2O, CO and N_2O. The instrument was flown in 2010 and 2011 as a demonstrator of the millimeter-wave limb sounder, as part of the preparatory studies for the PREMIER mission.



MARSCHALS spectra

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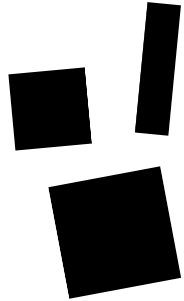
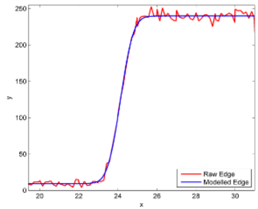
Modulation Transfer Function Estimation

The Modulation Transfer Function (MTF) of an acquisition system is the magnitude of the Fourier Transform of its impulse response. The MTF characteristics directly impact on the quality of the acquired image. Its inadequacy can determine blurring effect or typical noise pattern (aliasing).
Therefore the estimation of the MTF curve contributes to assess the quality of the acquisition system.
In addition, the performance of the restoration process can be improved by considering MTF characteristics. Also pansharpening and hypersharpening take a relevant advantage by considering MTF properties.
Indeed MTF estimation is not an easy task since subpixel resolution is required. It can be obtained acquiring specific targets.
Processing the acquired data, a raw edge profile can be obtained and then analytically modeled. By deriving the edge model and FFT transforming the sampled signal, the MTF can be estimated.

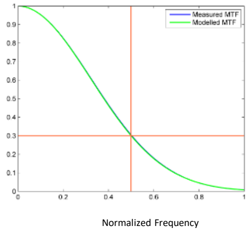
A typical aliasing pattern



Acquisition of specific targets



Modelling of edge



Estimation of the MTF curve

With regards to enterprises

The methodologies have been studied in the framework of PRISMA mission of ASI and are currently developed in the SMART (Spettrometro Miniaturizzato Avanzato per Ricerca Tecnologica) project, funded by Tuscany Region (POR - FESR 2014-2020).
These methodologies are of interest in general for all the companies involved in images acquisition and instrument design.

Contact

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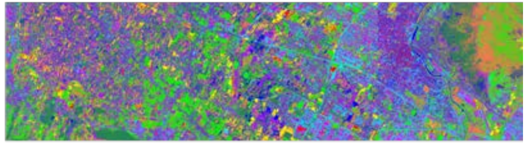
Simulation tools for hyperspectral images

In order to evaluate the performance of a hyperspectral sensor and to test the algorithms which will be used for data processing, a software tool for the simulation of hyperspectral data is recommended. For a realistic simulation of the hyperspectral data/images it is necessary to consider different effects: the interaction of the electromagnetic radiation with the soil and with the atmospheric constituents (gas and aerosols), both illumination and acquisition geometry, spatial and spectral variability of the simulated scenes, instrumental technical characteristics, etc.. Under OPTIMA project funded by the Italian Space Agency (ASI PRISMA mission), IFAC developed a tool for the simulation of hyperspectral images composed by three independent simulation blocks: the scenario builder, the atmospheric propagation calculator and the sensor simulator. The tool was also upgraded by including a block for the simulation of solar-induced fluorescent targets. Further upgrading (adjacency effects, texture, keystone and smiling effects, etc.) is in progress under the SMART project funded by Regione Toscana.

With regards to enterprises

The simulation tool was initially developed under the OPTIMA project and is now being upgraded within the SMART project. In this frame, collaborations were established with several companies, such as: TELESPAZIO SpA, LEONARDO SpA, CGS SpA, SITAEL SpA. The simulation tool was also used for the simulation of sub-nanometric spectral resolution images, including the solar-induced fluorescence contribution, in view of potential applications in the frame of the ESA-funded FLEX mission.

a



b

c

d

(a) Ortho-photo acquired over Firenze; (b) 15-classes thematic map obtained after ortho-photo classification; (c) At-ground reflectance map: 7.5-m spatial resolution, 2-nm spectral resolution; (d) At-sensor radiance image: 30-Km swath, 30-m spatial resolution, 7-12-nm spectral resolution.

Contact - Valentina Raimondi

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New Perspettive in Pansharpening: Hypersharpening

New-generation space-borne imaging sensors operate in a variety of ground scales and spectral ranges.
Pansharpening consists of a spatial resolution enhancement of the lower resolution multispectral/hyperspectral (HS) data using the spatial detail present in a single band (Panchromatic).
Most of pansharpening methods follow a general protocol; At first they extract the high resolution spatial information not present in the HS image from the Panchromatic image . Then they incorporate such spatial details into HS bands by properly modeling the relationships between the HS bands and the Panchromatic image.
Following the technological development of satellite platforms, hypersharpening obtains the high resolution spatial information from another HS data rather than from Panchromatic. This new approach obtains fused images with better quality.

On the left the original HS, on the right HS after pansharpening.

With regards to enterprises

The methodologies have been developing during national and international projects that have involved important Tuscany enterprises. Our usual partners are Leonardo S.p.A. and Flyby.
Pansharpening and hypersharpening are currently used in photo analysis and processing of satellite images but their use can be extended to other fields.

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Microwave radiometers

Microwave radiometers are used on the monitoring of Earth surface and atmosphere since the 70's. These instruments have proven to be very sensitive and accurate for collecting electromagnetic measurements and deriving from them bio-geophysical quantities (e.g. soil moisture, plant water content, snow depth, liquid water vapor).

Since the 80's the IFAC laboratories design and develop microwave radiometers to be used in experimental ground-based and airborne campaigns. Depending on the applications, the instruments are built in different configurations and different frequencies from L-band (1.4 GHz, 21 cm wavelength) up to Ka-band (37 GHz, 8mm wavelength) in the protected part of the electromagnetic spectrum. The instruments are tested and accurately calibrated in the IFAC laboratories and adapted to work autonomously in the most critical environmental conditions.

L-band radiometer installed on the US tower at Concordia Station, Antarctica

X-band radiometer adapted for an ultralight airplane

With regards to enterprises...

Design and construction of the radiometers is performed in conjunction with companies (e.g. Pasquali Microwave Systems) and the European Space Agency (ESA).

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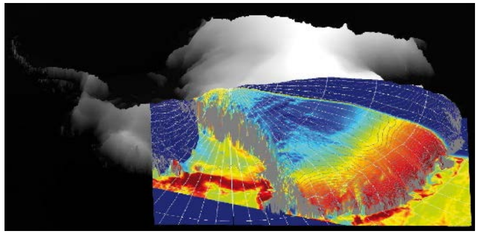
Microwave remote sensing of the cryosphere

Monitoring of the water cycle, and in particular the cryosphere, has been recognized by international organizations as paramount importance for understanding Earth climate. In particular, the cryosphere plays a crucial role in water supply for human and agricultural needs, hydrological risk reductions and energy production. Status of the cryosphere represents one of the most important indicators of the global warming and the monitoring of ice sheets (Antarctica and Greenland) is fundamental to estimate the sea level rising and its consequences on the human coastal settlements.

The research activity is based on active and passive microwave observation of Earth surface carried out by using ground, airborne and spaceborne sensors. Advanced methodology for deriving geophysical quantities are developed starting from microwave data and by using electromagnetic models and retrieval algorithms. Moreover the observation of the ice sheets contribute to the calibration and validation of satellite data.

Domex experiment for the monitoring of ice sheet and cal/vas of ESA SMOS mission at Concordia Station, Antarctica



Microwave brightness temperature of Antarctica

With regards to enterprises

Developing of methodologies, instrumentations and is performed in cooperation with National and international space agencies (ASI, ESA, NASA) and companies.

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Microwave Remote Sensing of natural surfaces:
I – Monitoring of the hydrological cycle on a global scale

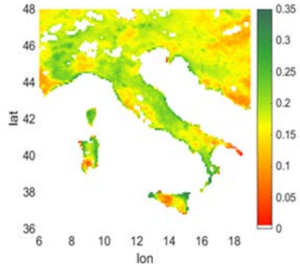
The number of weather-related natural disasters, such as floods, avalanches, cyclones, drought and heat waves, is dramatically increasing. Such disasters are primarily due to environmental global changes and land degradation, which are mostly caused by human impact on the territory. A help in breaking this vicious cycle can be given by a more in-depth knowledge of two fundamental cycles of our planet: the global carbon and hydrological cycles.

Microwave sensors have been proven to be sensitive to water contained in observed bodies and therefore can be used for retrieve information on the main parameters of the hydrological cycle, such as soil moisture, vegetation biomass, snow depth.

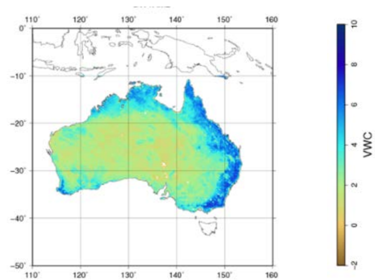
By using satellite microwave radiometers (e.g. AMSR-E/AMSR2, SMOS, SMAP, Aquarius), information on temporal evolution of surface parameter conditions can be assessed although at large spatial scale. A method for improving ground resolution up to 10kmx10km was implemented using SFIM technique.

Innovative inversion algorithms (**HydroAlgo**), based on radiative transfer models and artificial neural networks (ANN), were developed at IFAC for AMSR2 microwave radiometer (JAXA) estimating soil moisture, snow depth and vegetation biomass by using multifrequency, multipolarization data.

The soil moisture retrieval algorithms have also been successfully applied to the heterogeneous Italian landscape.



Soil moisture map of July 2012 from AMSR2 data from HydroAlgo at 10kmx10km spatial resolution



Map of vegetation biomass in Australia from HydroAlgo using AMSR2 data

With regards to enterprises:

Developing of methodologies and instrumentations is performed in cooperation with national and international space agencies (ASI, ESA, NASA, JAXA,) and companies

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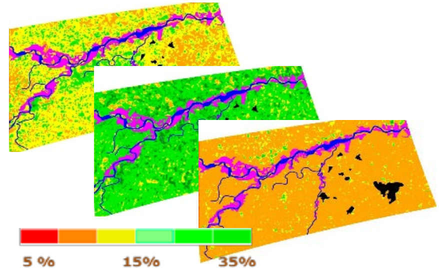
Microwave Remote sensing of natural surfaces:
II – Monitoring of the hydrological cycle on a local scale

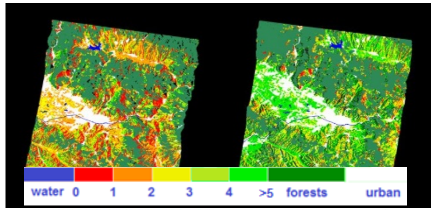
The monitoring of the hydrological cycle from satellite is crucial for many applications, such as agriculture, water management, forecast and management of environmental disasters. The estimate of soil moisture (a key hydrological and climatic variable), snow depth (a parameter significantly related to water resources, avalanches and flood forecast), and finally vegetation biomass (a key factor of the carbon cycle), and the knowledge of their temporal and spatial variations are therefore very important for environmental management activities.

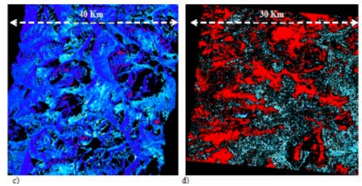
SAR systems, with their high ground resolution (a few meters) and frequent revisit time (2-3 days), demonstrated to be very powerful sensors for parameter retrieval, which is impracticable from ground measurements, due to the high spatial variability of the target variables.

Radar signal (backscattering) was first simulated by using advanced e.m. models implemented. Innovative methodologies based on ANNs were developed at IFAC for deriving high resolution geophysical parameter and for generating maps of soil moisture, vegetation biomass and snow depth by using ALOS/PALSAR (L-band, 1.4 GHz), ENVISAT/ASAR, RADARSAT and Sentinel-1(C-band, 5GHz), TerraSARX and COSMO-SkyMed (X-band, 10 GHz) satellite SAR data.



Soil moisture maps (November, April and June 2003/04) from ENVISAT data in Alessandria area





Wheat biomass (top - over Florence area in March and June 2012) and snow depth (bottom - Cordevole area in winter 2010) maps from Cosmo-SkyMed data

With regards to enterprises

Developing of methodologies and instrumentations is performed in cooperation with national and international space agencies (ASI, ESA, NASA, JAXA,) and companies

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Microwave Remote sensing of natural surfaces:
III – Monitoring of the vegetation biomass using GNSS-R signal

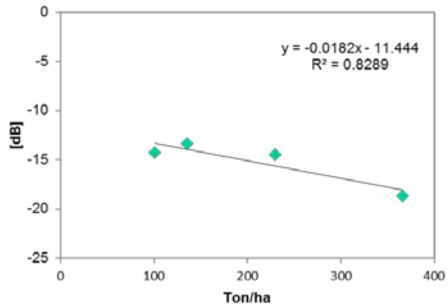
Global Navigation Satellite System (GNSS) Reflectometry could represent a valuable tool for the remote sensing of key bio-geophysical parameters. Previous experiments demonstrated the capability of GNSS bistatic scatterometers to measure variations in land surface reflectivity.

These systems have the advantages to operate at L band, an optimal frequency for monitoring both soil moisture and vegetation biomass, with potentially higher spatial resolution than microwave radiometry, due to the highly stable carrier and code modulations of GNSS signals which enables the use of Delay Doppler mapping.

Ground based and airborne campaigns conducted in Tuscany in the framework of ESA projects (Leimon, GRASS, and GNSSBio) demonstrated the capability of GNSS signal in retrieving forest biomass with an estimated sensitivity of 1.5 dB/(100 t/ha) and with a saturation higher than 150 t/ha. This points out the capabilities of GNSS-R as a remote sensing tool for forest biomass.

Model simulations have been carried out for better interpreting the results

GNSS_R sensor installed on ground and on an ultra-light aircraft (detail of the GNSS antenna)



Sensitivity to of GNSS-R signal to forest biomass

With regards to enterprises

Developing of methodologies and instrumentations is performed in cooperation with the European Space Agency (ESA) and a Spanish company – STARLAB Ltd.

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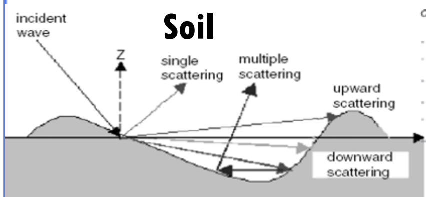
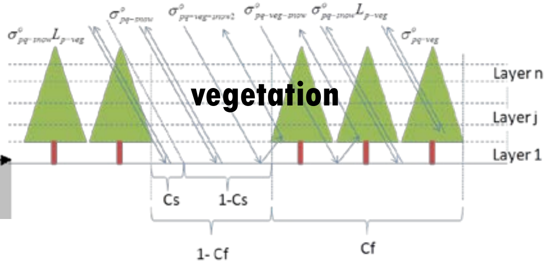
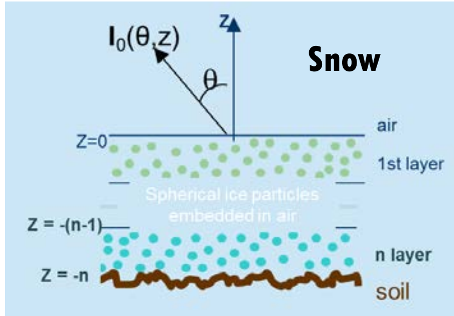
Microwave Remote Sensing of natural surfaces
IV – Experimental and modeling activities

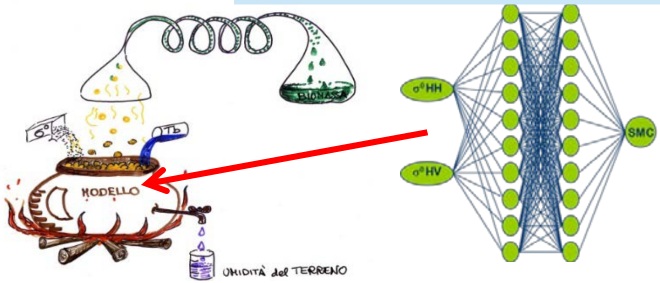
- Experimental activities carried out in the framework of international projects (ASI, ESA, EC) for collecting microwave data over natural surfaces from satellite, airborne and ground-based sensors
- Development of electromagnetic models for simulating microwave emission and backscattering from natural surfaces (bare, vegetated and snow-covered soils, ocean). Most models are based on Radiative Transfer Theory.







- Implementation of methods and algorithms for estimating the main parameters of the hydrological cycle (soil moisture, vegetation biomass, snow water equivalent and snow depth). Most algorithms are based on statistical methodds such as Bayes, Nelder-Mead and ANN.



With regards to enterprises

The set-up of experimental campaigns and the development of methodologies is performed in cooperation with national and international space agencies (ASI, ESA, EC, NASA, JAXA,) and companies

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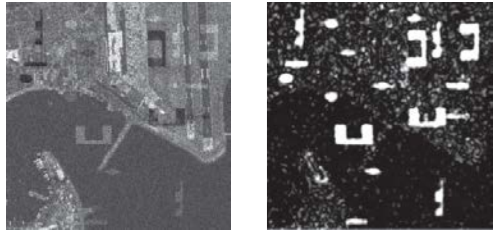
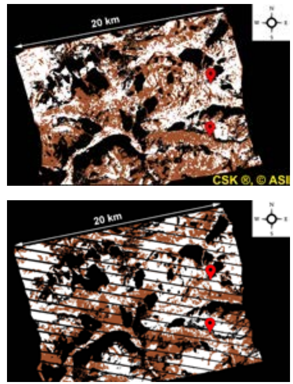
Nonparametric Change Detection for Multitemporal SAR Images

MS-ITCD (Mean Shift Information-Theoretical Change Detection) is a nonparametric algorithm for the automated detection of multitemporal changes in SAR images acquired in different times, for example before and after a meteorological event. In such a context, SAR images can be particularly useful, because of their insensivity to weather conditions, especially in the case of cloud-cover situations. This method is particularly robust to noisy fluctuations due to speckle noise and co-registration inaccuracies. It can provide useful information on urban and suburban environments, but also parameters for water resource management, flood and landslide risk prevention. The algorithm in principle detects small changes, but can be also adjusted for the case of pervasive changes, as in the case of a snow cover map, computed before and during the winter season. The algorithm can work also in a simplified version, where the computational complexity is reduced to manage large size data. In the reported examples, it is applied to urban scenes and alpine areas, in order to retrieve both changes in anthropic environments and a snow cover map, respectively.



1-look SAR image with superimposed changes (left); change retrieval by the MS-ITCD algorithm (right).



Snow cover map of a COSMO-SkyMed® SAR image (top) compared with a reference optical Landsat map (bottom).

With regards to enterprises

Change detection is one of the most important application for monitoring the environmental evolution. The MS-ITCD method has been successfully applied to COSMO-SkyMed® data in the framework of COSMO-SkyMed-AO Project ID-2181 by the Italian Space Agency (ASI).

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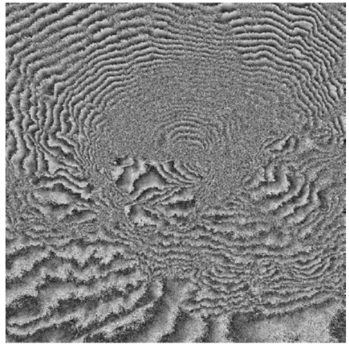
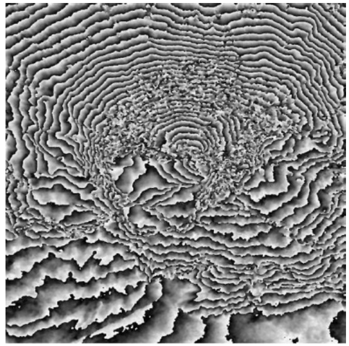
Image Filtering

Digital filtering is usually applied in many applications in order to reduce the noise or enhance such specific features as edges, contours and targets. IFAC has been active in this field already before 1970 with significant results in linear filters, first and in the development of adaptive filters, successively. Original rank filters have been defined and proposed to reduce impulsive noise. Several adaptive filtering schemes have been defined taking into account the advantages of such multiresolution decompositions schemes as Laplacian pyramids and wavelets. Fuzzy logic properties have been exploited to define adaptive filters to be applied when specific signal and noise models cannot be assumed.
In the case a model exists, the estimation of its parameters assumes great importance for filtering. In this perspective modeling of signal dependent noise has been one of the key point of IFAC activity as assessed by several papers on this topic.



Topographic fringes of Mount Etna, Italy, from ERS-1/2 Tandem Mission



Fuzzy logic based filter. Window size is 5x5 with 8 prototype estimators.

With regards to enterprises

Filtering speckle noise present in synthetic aperture radar (SAR) images has been specifically considered in the framework of COSMO-SkyMed mission of the Italian Space Agency (ASI). Algorithms for filtering false alarm from the data produced by Lightning Imager (LI) are being developed within a contract with LEONARDO S.p.A. in the framework of the mission concerning Meteosat Third Generation (MTG) supported by EUMETSAT.

Contact
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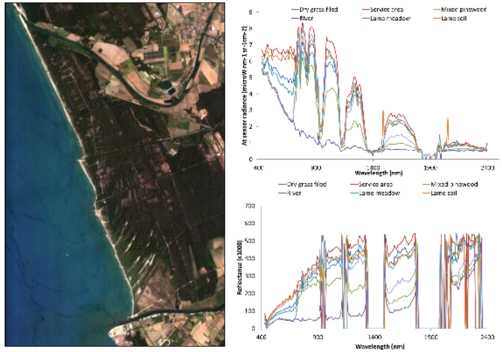
Data correction and calibration for earth observation applications

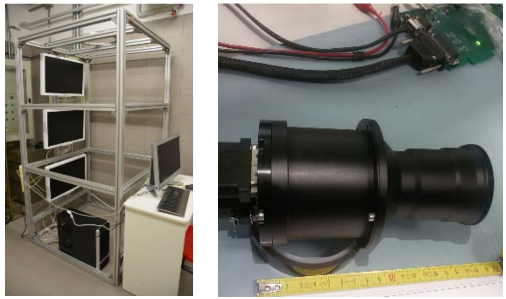
Images acquired by aerospace sensors should be properly processed in order to obtain reliable at-sensor radiance and at-ground reflectance images. On the basis of the characteristics of the sensor, raw data are radiometrically corrected producing at-sensor radiance images. The images can be further processed by removing the effects caused by the atmosphere in order to generate at-ground reflectance images. IFAC has a well-established know-how in algorithms for radiometric corrections - in particular for the removal of spatially-coherent noise (striping) - and in iterative procedures for the correction of the atmospheric effects.
Another branch of activity concerns the development of test systems for star tracker sensors. These test devices are able to simulate real-time dynamic star field scenes that are used to test the performance of star tracker sensors.



At-ground reflectance image of San Rossore area (Pisa, Italy) and at-sensor radiance and reflectance spectra of some representative pixels of the image.

With regards to enterprises

Data correction and calibration procedures were implemented in the frame of several projects, like the OPTIMA funded by Italian Space Agency, during which collaborations were also established with enterprises like Leonardo SpA, Telespazio SpA and CGS SpA. These procedures were also used for processing several data series from remote sensing campaigns performed in collaboration with several enterprises (Leonardo SpA, TELAIR S.T.A., CGR SpA).
Star field simulators were developed in the frame of two projects funded by Regione Toscana: the SAMS project in collaboration with Leonardo SpA and the MINISTAR project with a partnership of several SMEs (SAITEC, Promel, Gestione Silo).



Dynamic star-field simulators: the SAMS laboratory prototype (on the left) and the miniaturized MINISTAR test device on the right.

Contact - Valentina Raimondi

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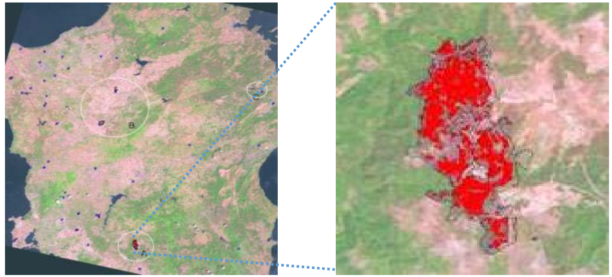
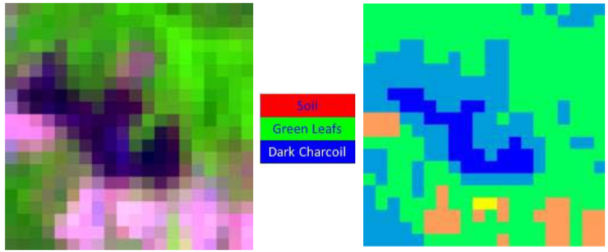
Mapping and classification of burned areas by satellite images

Periodic monitoring of the areas affected by fire, is aimed at producing seasonal mapping of burnt areas with the related fire severity, as an aid to management policies for the restoration of territory. This task can be accomplished by using remote sensing images through suitable processing techniques. The Burnt Area Detection (BAD) method, developed at IFAC-CNR, is a new procedure based on a multicriteria expert approach realized through a decision tree classifier, which identifies with a low level of error those pixels having a high probability to lie within a burned area. The procedure was tested on images acquired on Tuscany and Sardinia regions by SPOT-HRV, Landsat-TM/ETM+ and IRS1C/DLiss3 satellite sensors, and it was found effective also on small dimensions fires. The assessment of the different severity levels of damage to the vegetation for each pixel was obtained by means of an Endmember Spectral Mixture Analysis procedure, developed at IFAC-CNR, that estimates the spectral % contribution of each of the spectral types representative of the environmental context (including charcoal and ash), to the radiance of each pixel.



Mapping of the areas affected by fire (highlighted in red)



Classification of Hyperion image of a fire affected area

With regards to enterprises...

Research activities developed under contracts with Telespazio S,p,A, in the framework of the RISK-EOS project (EC) and PRISMA-OPTIMA funded by Agenzia Spazioale Italiana (ASI)

Contact:
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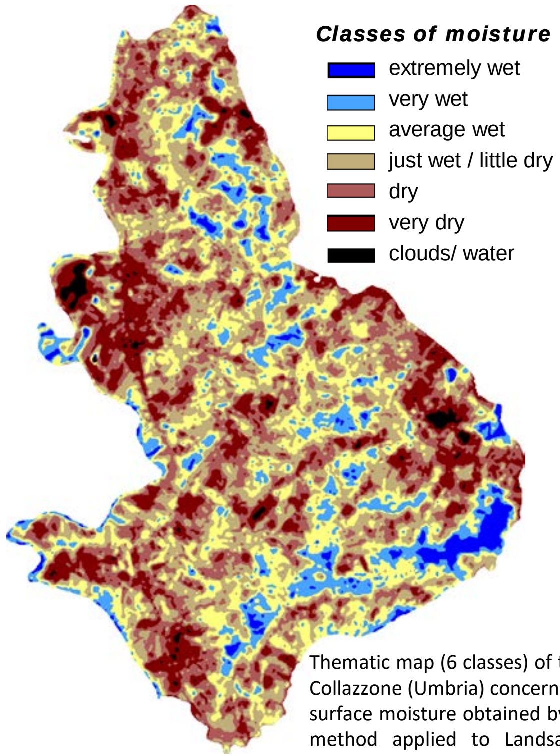
Surface soil moisture evaluation by a multitemporal satellite approach

Soil moisture plays a very important role in many applications related to the management and exploitation of land resources (agriculture, forestry, etc.) and the monitoring and control of the areas affected by natural hazards such as landslides, floods and wildfires. Thus, the monitoring of soil moisture over extended areas is highly desirable. Conventionally, evaluation of soil moisture is based on local measurements. Therefore, the derivation of soil moisture maps by remote sensing assumes great importance to directly access soil characteristics over large areas within a short period. The MTVI method, developed at IFAC-CNR for surface soil moisture monitoring, is a multitemporal approach of the relationship between remotely sensed surface temperature (Ts) and the vegetation coverage (VI). It takes advantage of the self-consistency of the relationship, but at the same time tries to improve its constraint for a better characterization and monitoring of surface soil moisture conditions over large and heterogeneous areas



Thematic map (6 classes) of the area of Collazzone (Umbria) concerning the soil surface moisture obtained by the MTVI method applied to Landsat-TM/ETM images with spatial resolution of 30 m.

With regards to enterprises

The MTVI method has been developed in the framework of the MORFEO project, funded by Agenzia Spaziale Italiana (ASI), and coordinated by the CGS S.p.A. enterprise.

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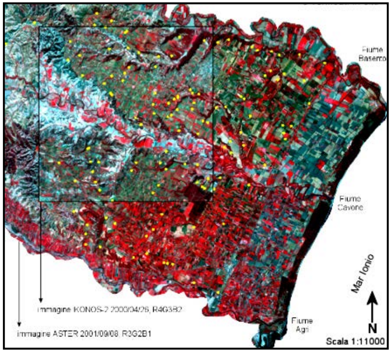
Detection of archaeological sites through remote sensing information

Within the realm of landscape archaeology, it is commonly accepted that the spatial distribution of sites is largely dependent on a wide spectrum of environmental features. Hence, during the past years, predictive models based on environmental parameters have been increasingly applied in investigations attempting to both *explain* the location of sites already known, and *predict* where new sites are most likely to occur.

A deductive predictive method, based on an expert and euristic approach and built on the basis of the past experiences of the authors, was developed at IFAC-CNR. It is based on morphological, pedological and hydrological parameters previously identified as being the most significant ones in describing the basic environmental context. The model was then used to predict the location of unknown archaeological sites in the study area, located in the region of Lucania (southern Italy). As a result 164 locations were identified as being suitable for human occupation. A few extensive field surveys were then carried out within the study area in order to verify the presence of the predicted sites. The surveys positively ascertained the presence of 133 new sites with different typologies and ranging in origin from the Palaeolithic Age to the Roman Age. The prediction also led to 31 failures, with an overall accuracy of approximately 81%



Map of archaeological sites identified and verified

Findings of Lucan Age

Archaeological findings : Greek classic Age (left); Middle Paleolithic Age (right)

With regards to enterprises

The research was undertaken and funded under projects of the National Council of Research of Italy

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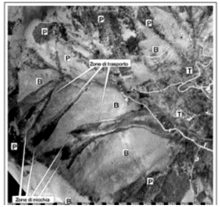
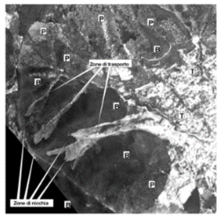
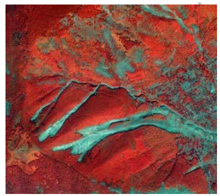
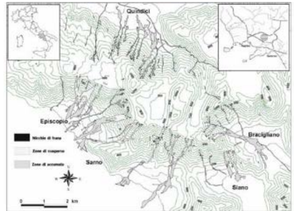
Remote sensing techniques for landslide analysis

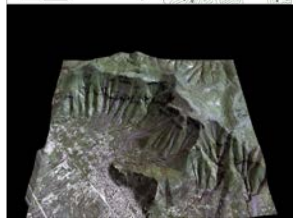
Because of its geological-geomorphological history and climatic characteristics, the Italian territory is subject to natural disasters (earthquakes, floods, landslides, volcanic eruptions, avalanches, etc.) with a very high recurrence. To date, multispectral remote sensing satellite images with very high spatial resolution (VHR), even stereoscopic, are employed for the study and mapping of landslides mainly through traditional techniques of photo-interpretation. Preprocessing techniques, data fusion methods to improve the spatial detail, and stereoscopic tools are also widely used. Despite this, the full exploitation of the potentials of satellite remote sensing for the study and characterization of landslide phenomena, to date, does not seem to have yet reached a level of maturity, at least for the multiplicity of its objectives: identification, control or verification and monitoring. According to the considerations above, at IFAC-CNR is carried out a research activity aimed at identifying and evaluating innovative remote sensing methods for characterization and analysis of the territory as an aid to the analysis of areas with a high susceptibility to landslides. Such methods aim to integrate the traditional techniques (field observations, aerial photographs, ancillary data) and new tools for managing and processing data (GIS), together with the information extracted from imagery acquired by satellite and sensors of last generation, characterized by high radiometric, spectral, spatial and temporal properties.











(Right) – Map of the landslide of May 1998 in the area of Sarno, Bracigliano, Quindici and 3D visualization. (Left) – Night and day thermal images by Daedalus scanner and Ikonos-2 VNIR image, in which bodies of landslide, niche and channels areas are clearly recognizable.

With regards to enterprises

Research developed in the framework of projects funded by Agenzia Spaziale Italiana ASI and under contract with C.G.S. enterprise.

Contact

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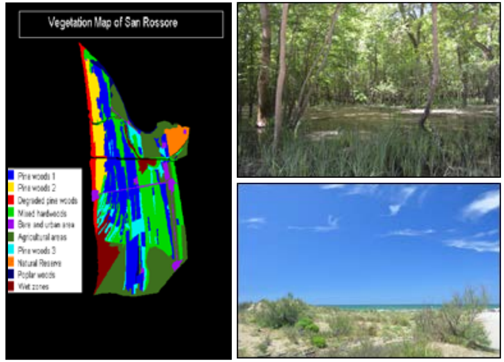
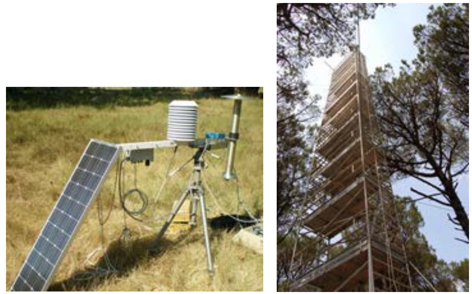
Cal/Val activities and the San Rossore test site

Migliarino-San Rossore-Massaciuccoli Park, located North of Pisa (Italy) along the Tuscany coast, was used over the last 15 years for remote sensing campaigns devoted to coastal zone monitoring. The considerable amount of collected data permitted the characterization of the site and the monitoring of its seasonal changes. In addition, a database of *in situ* spectral reflectance for natural and man-made relevant targets is available for ground truth in remotely sensed data processing. The test site is also equipped with a meteorological station and solar irradiometers, provides time series of atmospheric data (total and diffuse solar irradiance, temperature, relative humidity, and air pressure).
The San Rossore area was also used as Cal/Val test site for several spaceborne and airborne sensors. In particular, it was one of the validation test sites during the European Space Agency (ESA) Sen3Exp campaign and one of the main Cal/Val test sites for the ESA CHRIS-PROBA hyperspectral imaging sensor. Furthermore, MIVIS, CASI, Daedalus, VIRS200 and HyperSIM-GA airborne sensors performed several Cal/Val test campaigns over the park.



Vegetation thematic map of San Rossore park and images of different zones.



Ground measurement instrumentation and eddy covariance flux tower (in collaboration with JRC- Ispra).

With regards to enterprises

IFAC performed validation activities for MIVIS data acquired by Compagnia Generale Ripreseaeree (CGR SpA), for Daedalus data acquired by TELAER SpA. For HyperSIM-GA sensor developed by Leonardo SpA IFAC performed the first calibration and validation campaign of the instrument.

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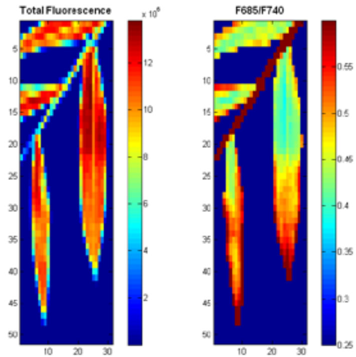
LIF and LIDAR techniques for vegetation monitoring

Fluorescence is widely regarded as a powerful tool to investigate both photosynthetic activity and stress status in vegetation.
IFAC has a well-established know-how for the design and development of fluorescence-based instrumentation and methods to study vegetation, from fiber-coupled Laser Induced Fluorescence (LIF) spectrometers working at leaf level to remote sensing instrumentation (fluorescence LIDAR) that can be used in the field for studies at leaf and canopy level in standoff configuration.
Solar-induced fluorescence of vegetation, and relevant instrumentation and algorithms for its retrieval from the infilling of the O_2-A and O_2-B Fraunhofer lines, were also studied in view of global scale spaceborne monitoring of vegetation photosynthetic activity under the ESA Earth-Explorer-8 FLuorescence EXplorer (FLEX) mission. In this frame IFAC has taken part in several ESA-funded measurement campaigns on vegetation deploying its instrumentation to provide fluorescence data relevant for the assessment of vegetation status.



Movable mirror for the fluorescence LIDAR mapping of corn crops (above) and Laser Induced Fluorescence (LIF) mapping of corn leaves (below).

With regards to enterprises

Fluorescence lidar instrumentation can be useful for agro-forestry applications such as: crop monitoring, precision farming, eco-physiological studies, etc..
Optical-coupled LIF instrumentation can be also used to acquire measurements in the field for diverse applications related to environmental monitoring (e.g. fluorescent pollutants in waters, plants, lichens, etc.).
Possibility to develop dedicated prototypes for similar applications requiring in-field deployment of very compact instrumentation.

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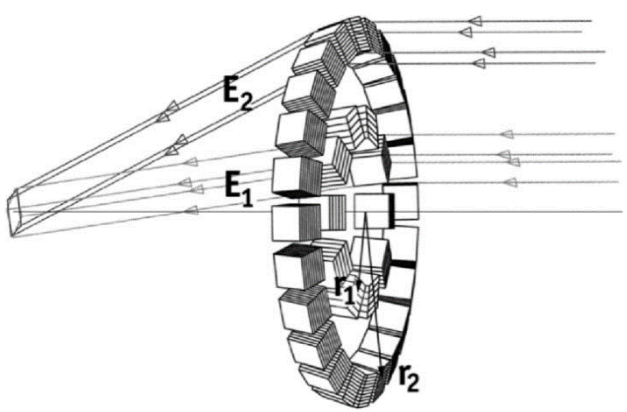
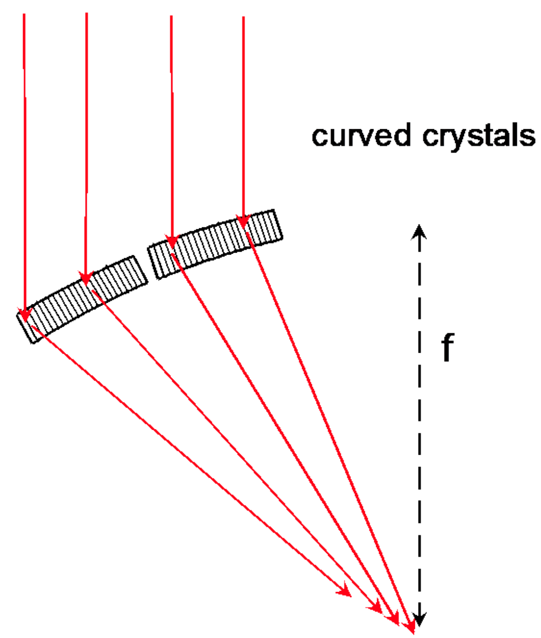
Increase of the Technological Readiness Level for the realization of hard X-/soft Gamma-ray Laue optics)

Objective: a number of key astrophysical questions are still unanswered due to the unsatisfactory sensitivity of the present instrumentation in the hard X-/soft Gamma-ray energy band. The Laue lenses huge potential is strictly connected with two main technological aspects of their realization: the massive production of **properly bent crystals** and the alignment process that must be done with an accuracy better than 10 arcsec. To prove the increase of the Laue lenses TRL from 3-4 to a value of 6, a demonstrator will be presented, made with ~100 perfect bent Ge crystals capable to focus photons in the 90–180 keV energy range.

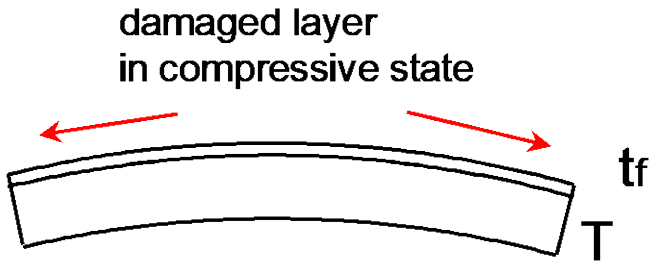


The principle of a Laue lens: a large number of crystal tiles arranged in concentric rings diffract radiation coming from infinity towards a common focus.



Focussing effect by properly bent crystals

Self standing curved crystals: bending technique

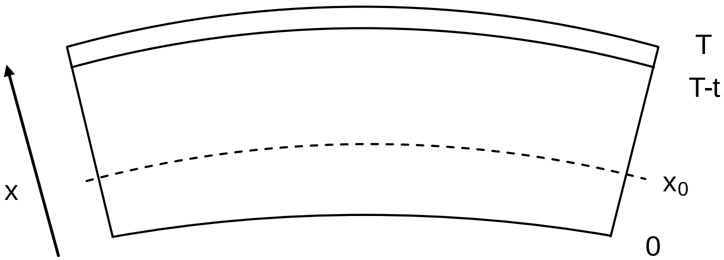


Crystal surface damage with sandpaper

Defects in a layer of a few tens of micrometers

Expansion of the crystal lattice

BENDING with curvature 1/R



Main features of the treated crystals:

- **spherical** curvature in (001) Si and Ge crystals and **elliptical** curvature in (001) GaAs crystals
- the curvature does not depend on the treatment time but only on the grain of the sandpaper

Focusing by curved crystals

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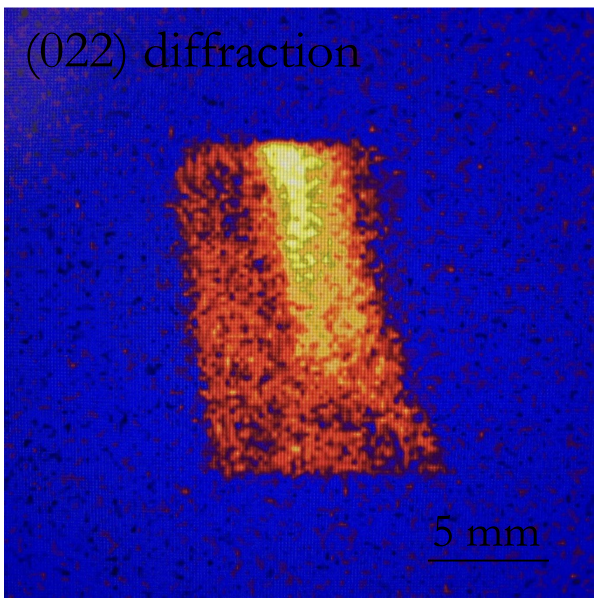
Experiment performed at LARIX facility in Ferrara

Crystal dimensions
$20 \times 10\ mm^2$

D = 26.4 m
R = 40 m

F = 11.4 m

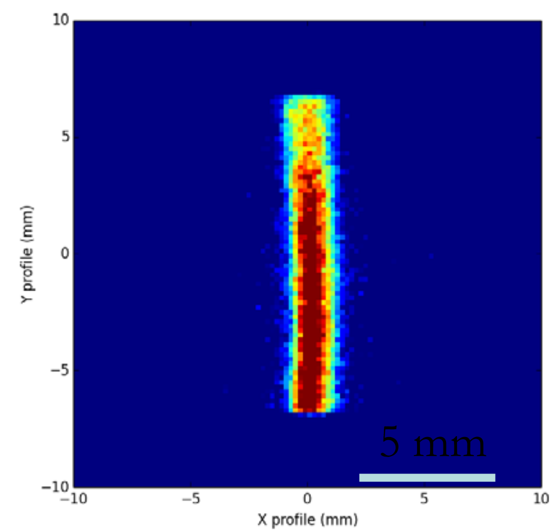
Detector at 11 m



Diffracted spot at 11.4 m

Flat crystal

Curved crystal
R = 40 m



Diffracted spot at 11.4 m

3D-CZT Module for spectroscopic imaging, timing and polarimetry in hard X-/soft γ-rays satellite mission (3DCaTM)

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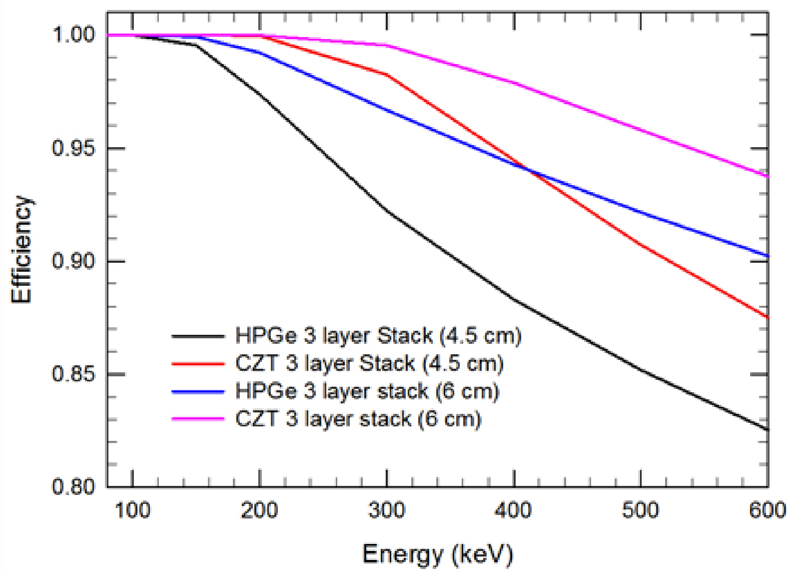
Objective: Hard X-/soft γ-ray astronomy is a crucial window for the study of the most energetic and violent events in the Universe.

New space instruments shall be developed both for deep observations of point sources and for random transient events study and monitoring.

New detectors must achieve

– High detection efficiency, achievable with increased thickness (>80% at 500 keV);
- Fine spectroscopy achievable with small volume charge collection;
- Fine spatial resolution (<0.5 mm) achievable with high segmentation.
- Fine timing resolution (<1 μs) (in particular for transient as GRB's)
- Scattering polarimetry in parallel to spectroscopy, imaging and timing



imem

3D CZT Sensor Unit: the starting point

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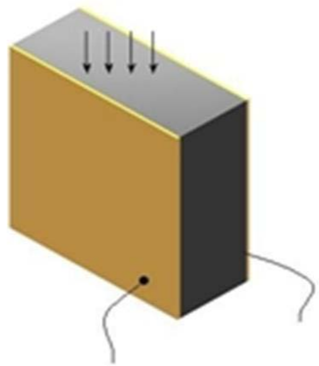
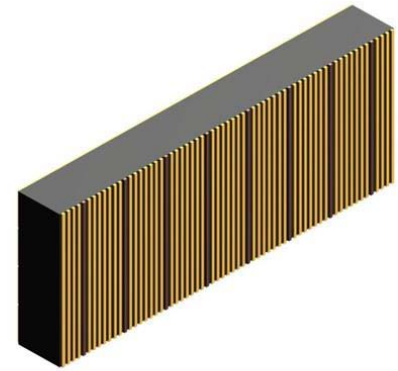
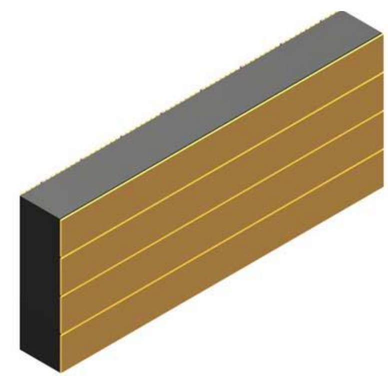
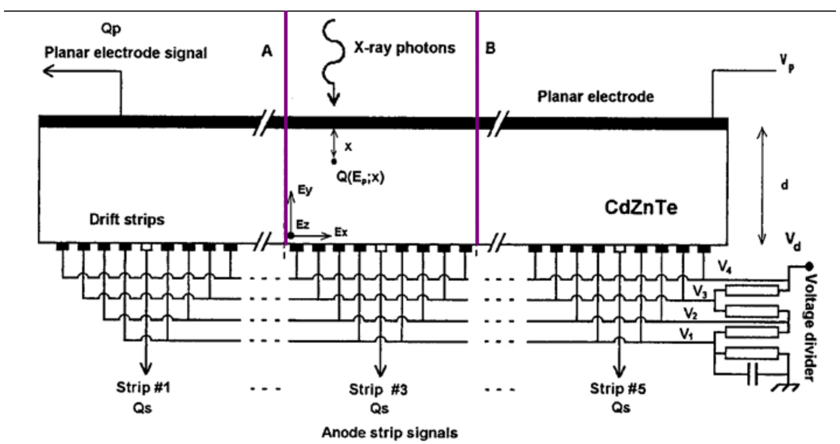


PTF irradiation configuration: Decoupling between photon absorption thickness and charge collection distance

The Anode (top) side implement a drift strip configuration; The cathode segmented orthogonally (bottom)







The anode side electrodes are modified to make the detector more sensitive to electron collection and less sensitive to hole collection.

The Small Gamma-Ray Imager Prototype
A first 3D CZT sensor implementation)

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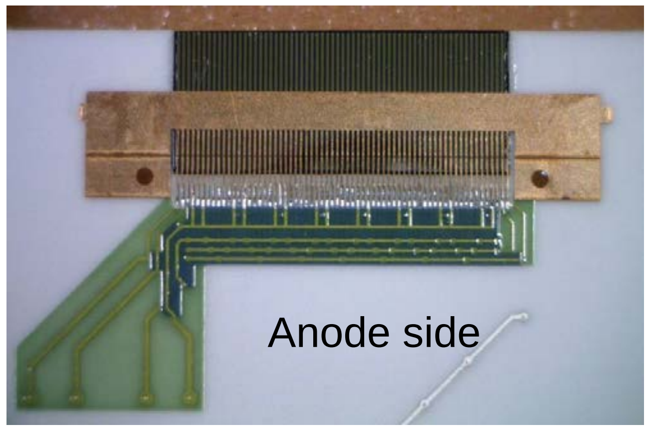
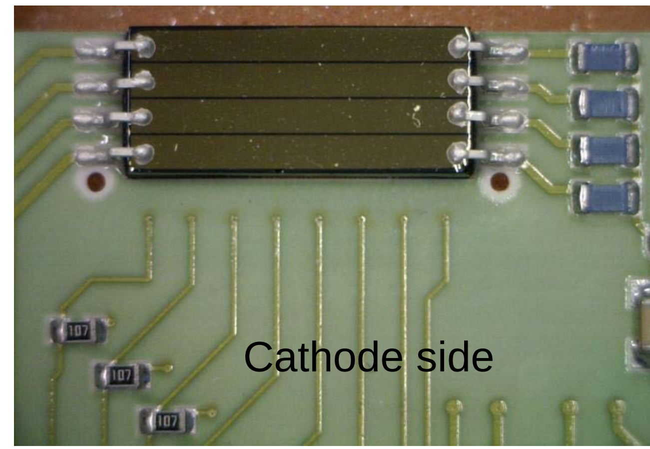
The sensitive unit
CZT by Redlen
Dimension: 19 × 8 × 2.4 mm3
Cathode:
4 strips (2 mm pitch)
Anode:
8 collecting strips;
7 drift strips between each couple of collecting ones;
300 strips pitch (150 μm metallisation and gap).



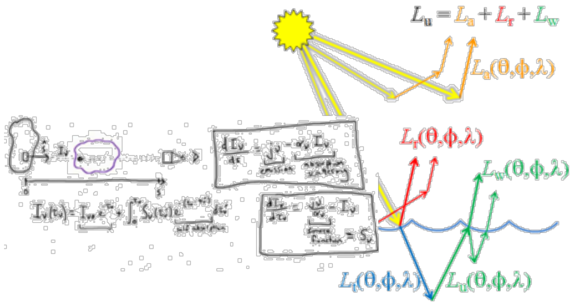


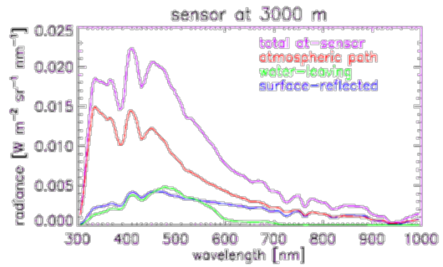
The bonding between the anode strips and the metallic pads on the alumina layer is realized by a thin (50 μm) Cu comb obtained by photo engraving technique. The Cu combs have the same fine μ-strips pattern with the metallic teeth 100 μm wide by AUREL SpA (Modigliana, Italy)

Exploitation Earth observation technology for aquatic ecosystems (1/2)

Methodologies

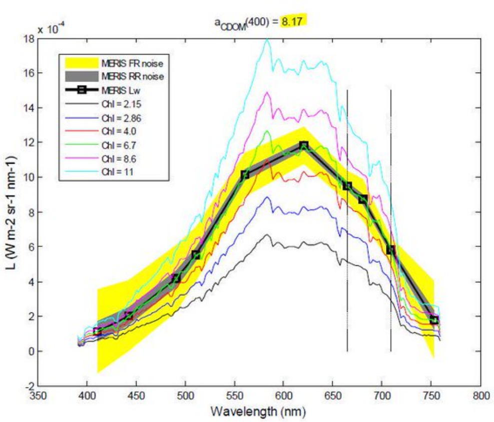
- Establishing a sensor-independent physic based approach for retrieving water quality parameters (e.g. Giardino et al. 2007, 2012)
- Calibrating and validating EO data for quantitative mapping

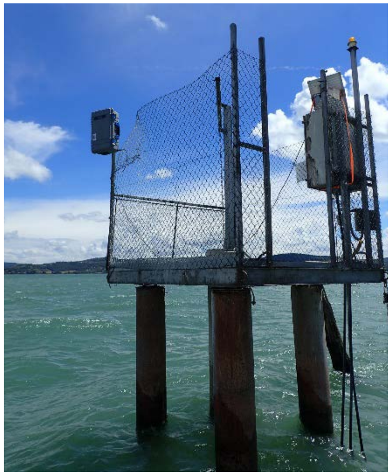




20-years of field campaigns (aquatic optics instrument and lab) (e.g. Brivio et al. 2001; Bresciani et al. 2011, Giardino et al. 2014) and 3 autonomous stations:

- a buoy (lake Maggiore)
- a fixed WISP (lake Trasimeno) and
- an hyperspectral sensor (to be placed in lake Garda)

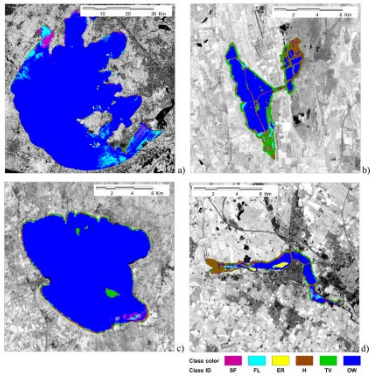




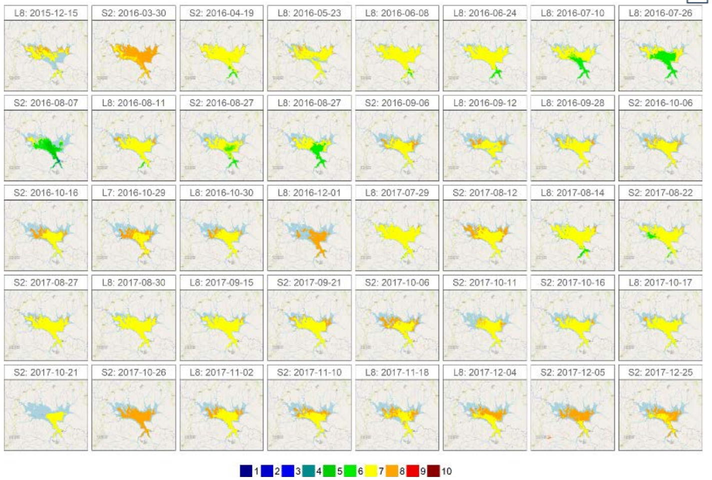
EXPLOITATION EARTH OBSERVATION TECHNOLOGY FOR AQUATIC ECOSYSTEMS (2/2)

Applications

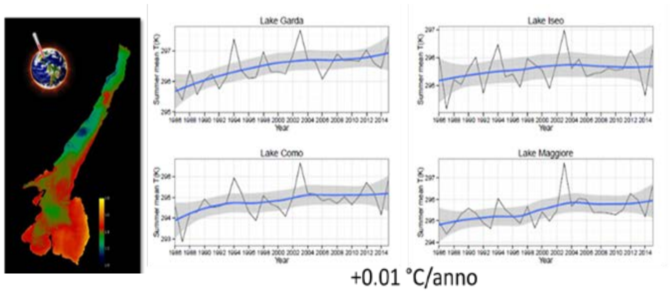
- Using of EO products in water management and lake ecology
- Investigating EO products for climate studies
- Studying sea ice in polar regions



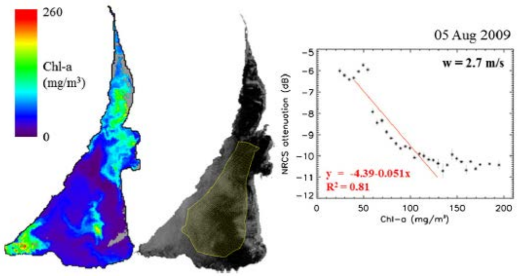
Macrophyte community type map at global scale (Villa et al. 2015)



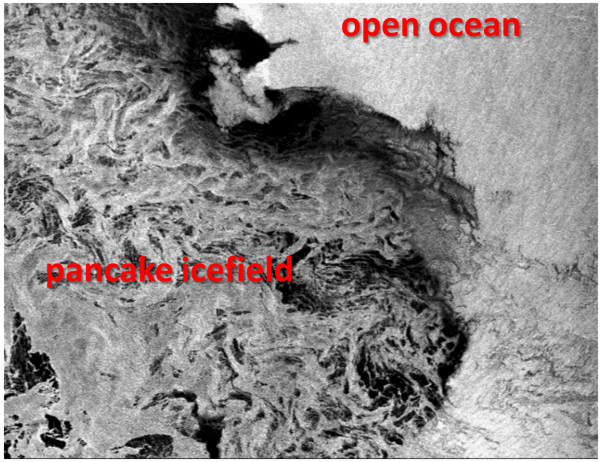
Using EO data to support the implementation of EU directives (Bresciani et al. 2011)



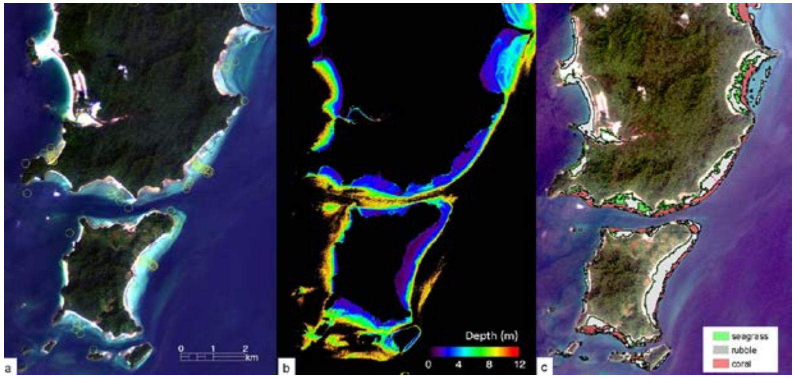
Lakes as sentinels of climate change (Pareeth, Bresciani et al., 2017)



Integration of SAR and Optical data for cyanobacetrial scum (Bresciani et al. 2014)



Assessing ice-pancake thickness from SAR (Doble, De Carolis et al. 2015)



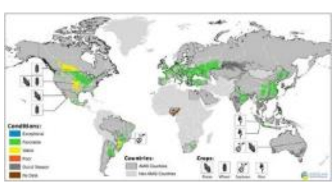
Mapping bottom depth and corals in Mynamar (Giardino et al. 2016)

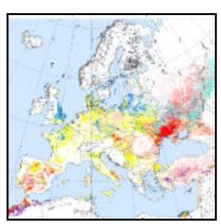
Overview

- **Multidisciplinary team** working on environmental and agricultural monitoring issues
- We study and develop **solutions and methods to generate and provide end-user value-added information** generated by the acquisition, processing and integration of multisource data
- Land monitoring is conducted at Global and Local scale to provide information on environmental issue
  - Land cover and species mapping
  - Land Use Change
  - Ecological indicator
  - Vegetation compound disturbance: Burned area mapping
  - Crop growth monitoring and phenology
- In the frame of Copernicus we are dedicated to the research for the creation of **"Downstream services"** prototypes, especially for the agricultural sector

GEOGLAM Global Agricultural Monitoring

Global scale



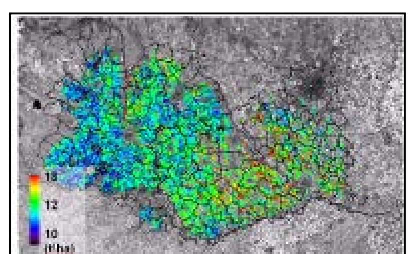


25 anni !

JRC MARS Bullettins

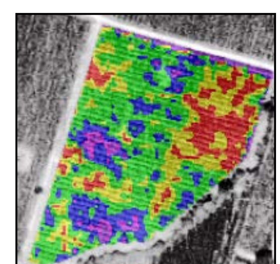
nereus network of european regions using space technologies

Regional scale



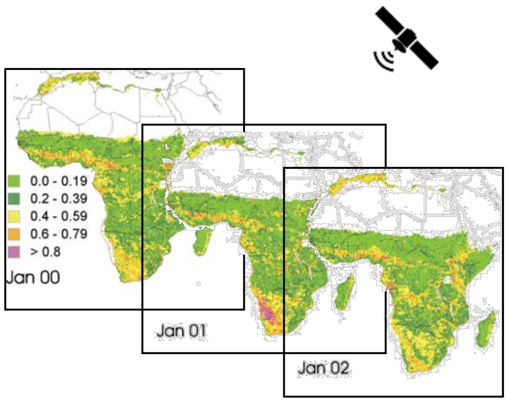
mipaaf

Local scale

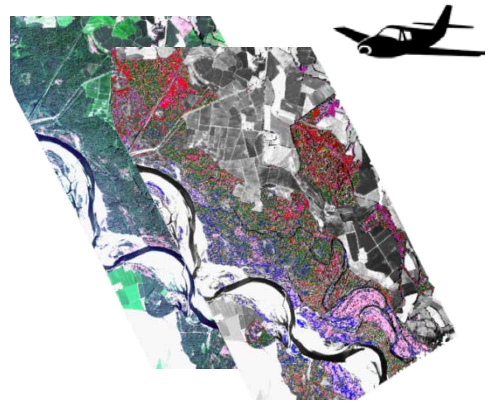


Earth Observation for Natural Resource monitoring (NR Lab) (2/2)

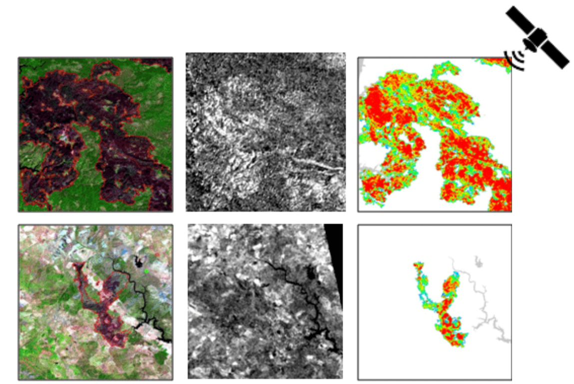
Methodologies



A fuzzy anomaly indicator for environmental monitoring at continental scale Stroppiana et al. (2009), *Ecological Indicators*

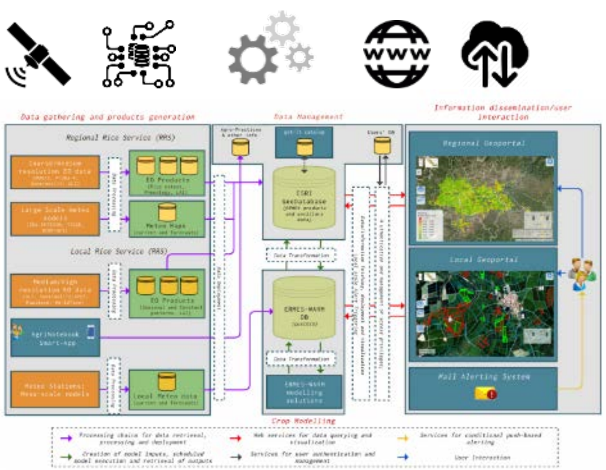


Tree species mapping with Airborne hyper-spectral MIVIS data: the Ticino Park study case - Boschetti et al. (2007), *International Journal of Remote Sensing*

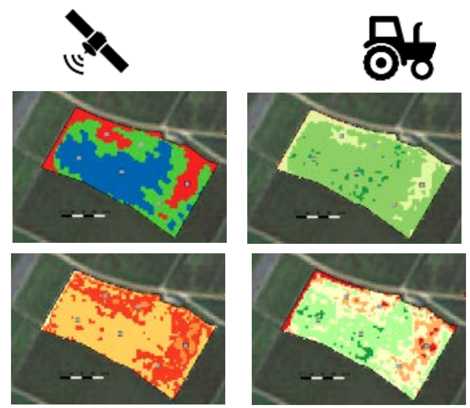


Integration of Optical and SAR Data for Burned Area Mapping in Mediterranean Regions - Stroppiana (2015), *Remote Sensing*

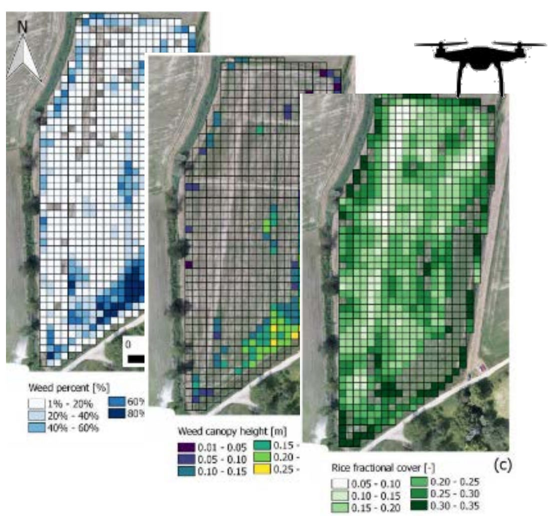
ERMES monitoring systems



Downstream Services for Rice Crop Monitoring in Europe: From Regional to Local Scale - Busetto et al. (2017), *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*



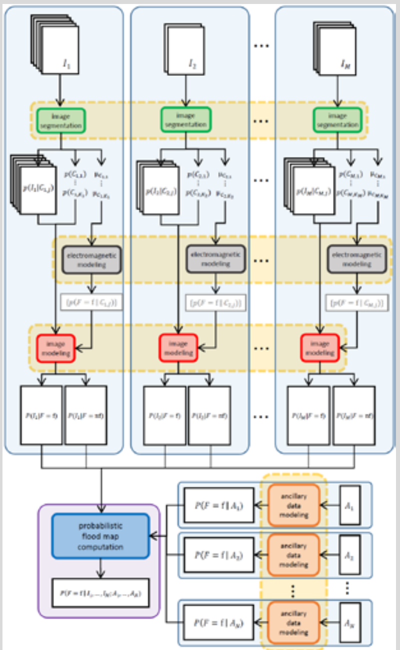
An operational workflow to assess rice nutritional status based on satellite remote sensing and smart apps - Nutini et al. (2018), *Computers and Electronics in Agriculture*



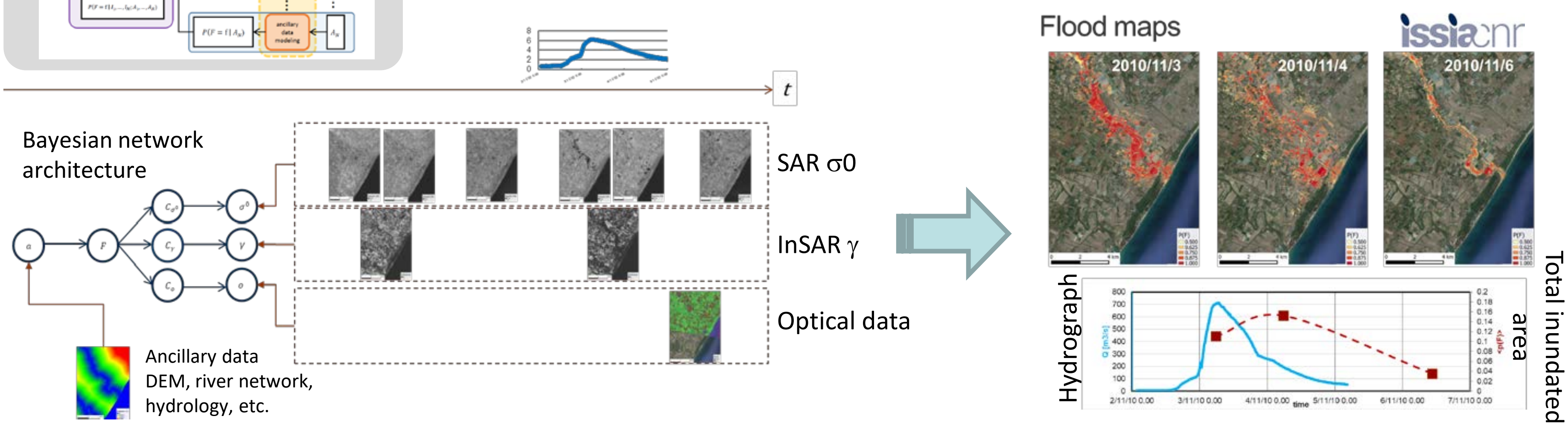
Early season weed mapping in rice crops using multi-spectral UAV data - Stroppiana et al. (2018), *International Journal of Remote Sensing*

Precise identification of flooded areas from integration of radar, optical and ancillary data through Bayesian methods

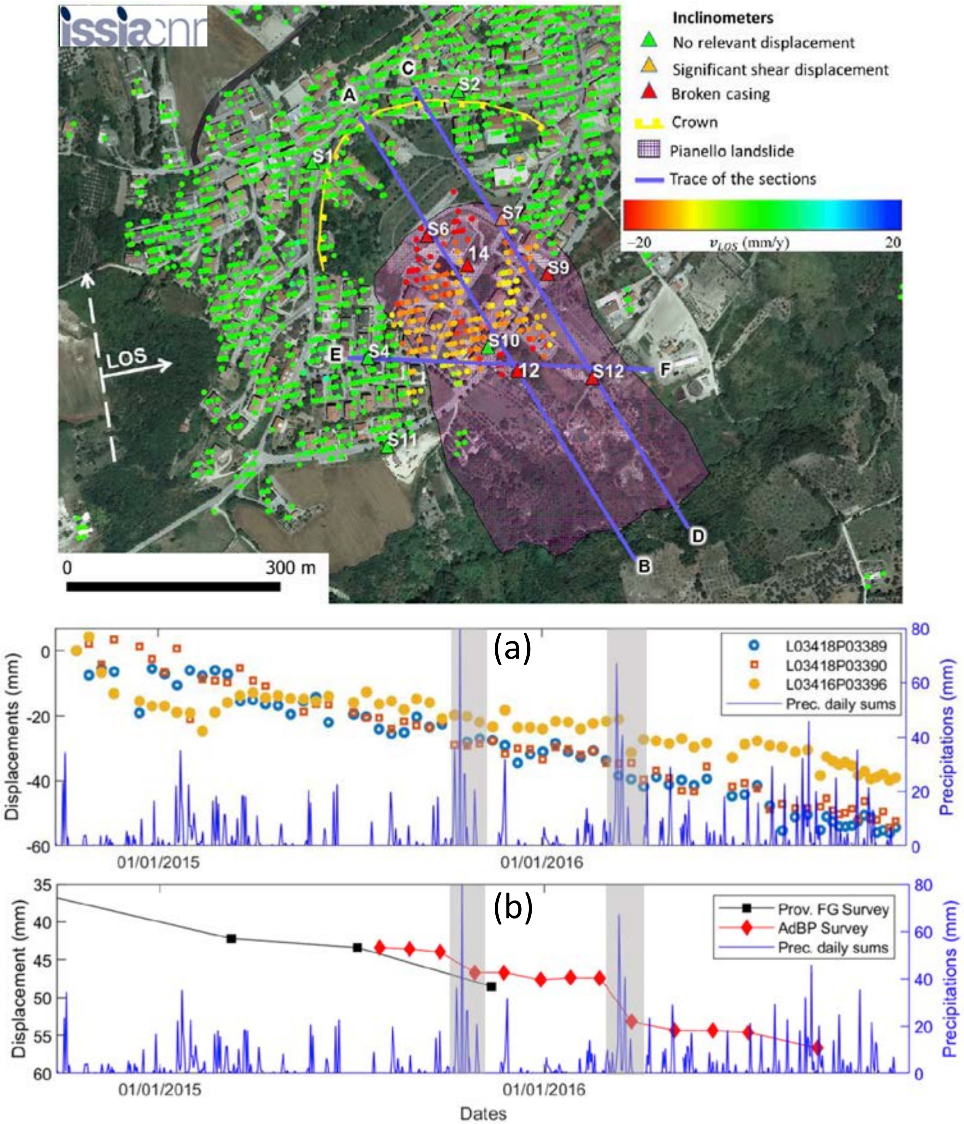
DAFNE Matlab Toolbox



- Integration of SAR intensity, InSAR coherence and optical imagery, as well as ancillary data, can help identifying precisely flooded areas at different dates.
- Bayesian Networks are a powerful tool to perform data integration in the analysis of complex real-world systems, such as, in this case, natural hazard detection.
- Detailed heuristic and process-based modeling information can be included into Bayesian belief networks, thus allowing inference on the behavior of several land cover typologies to the presence of floodwaters (e.g. agricultural fields, urban areas, forests).



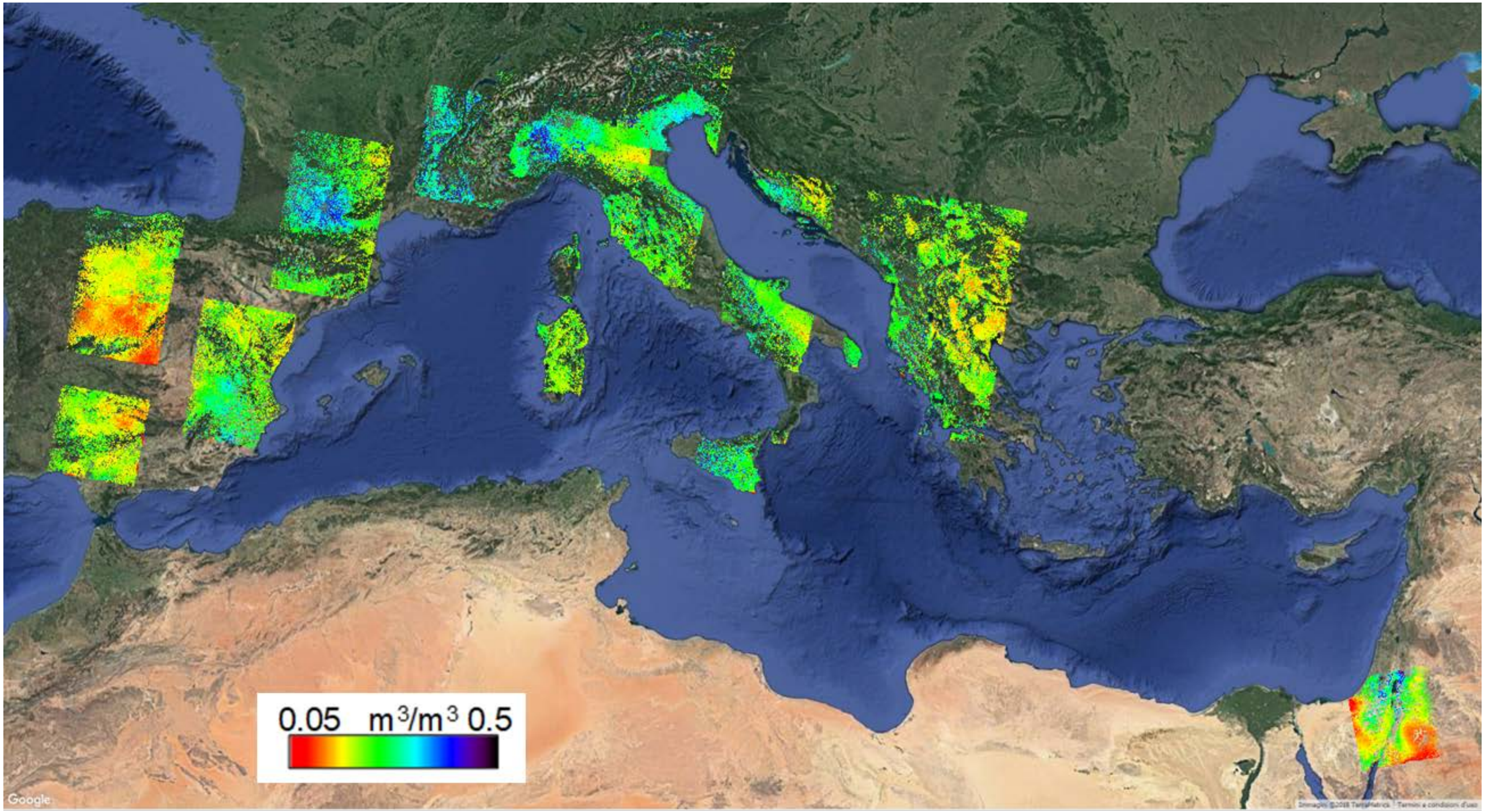
Analysis of displacement time series derived from multi-temporal satellite SAR Interferometry (InSAR) for identifying warning signals



- Example of landslide monitoring (Bovino, Southern Italy): colored points indicate InSAR measurements, with color proportional to velocity according to the colorbar.
- InSAR data are merged with the information coming from the ground sensors and the geotechnical data to get consistent picture of the shape and distribution of the spatial borders as well as the underground shear surface of the landslide.
- Displacement time series from InSAR (a) and inclinometers (b), together with the daily precipitations (blue line): grey rectangles highlight discontinuities recorded in the inclinometer and InSAR connected with precipitation peaks.

Soil Moisture products from Sentinel-1

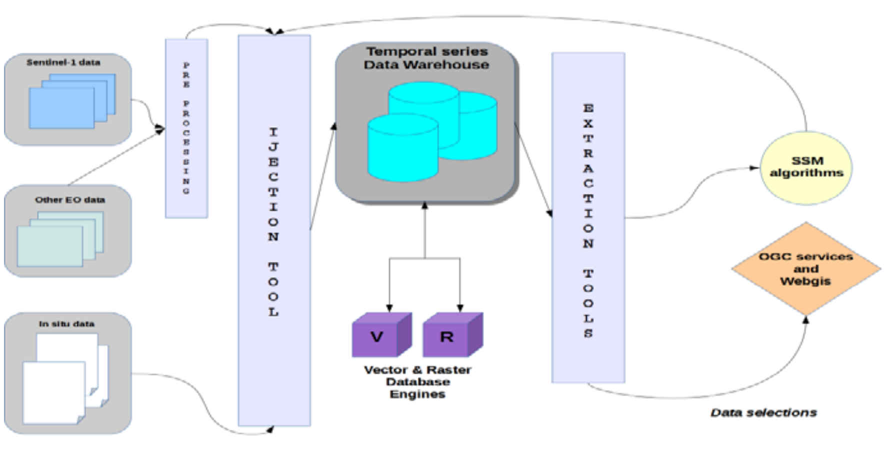
Example of soil moisture (SM) map composite at ~1000m resolution derived from Sentinel-1 IW over Mediterranean areas. The SM map has been obtained by using the SMOSAR code that implements a short term change detection retrieval algorithm [Balenzano *et al., Eur. J of Rem. Sens., v. 46, n. 1, 2013*].

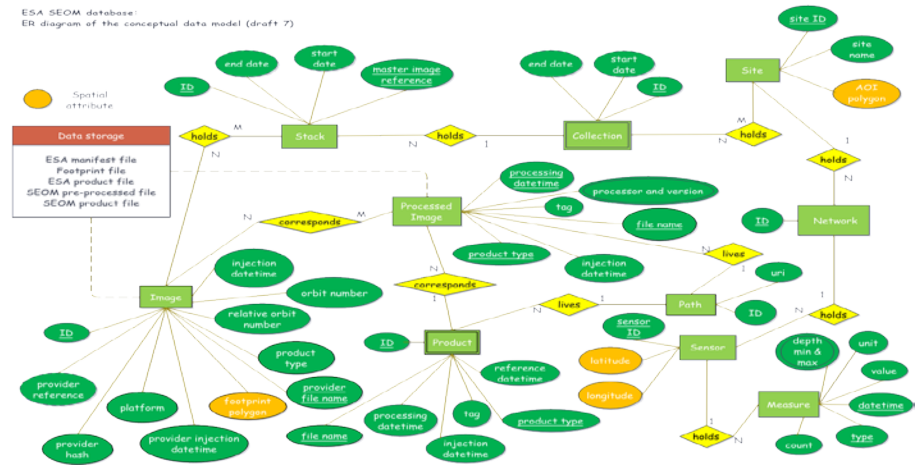


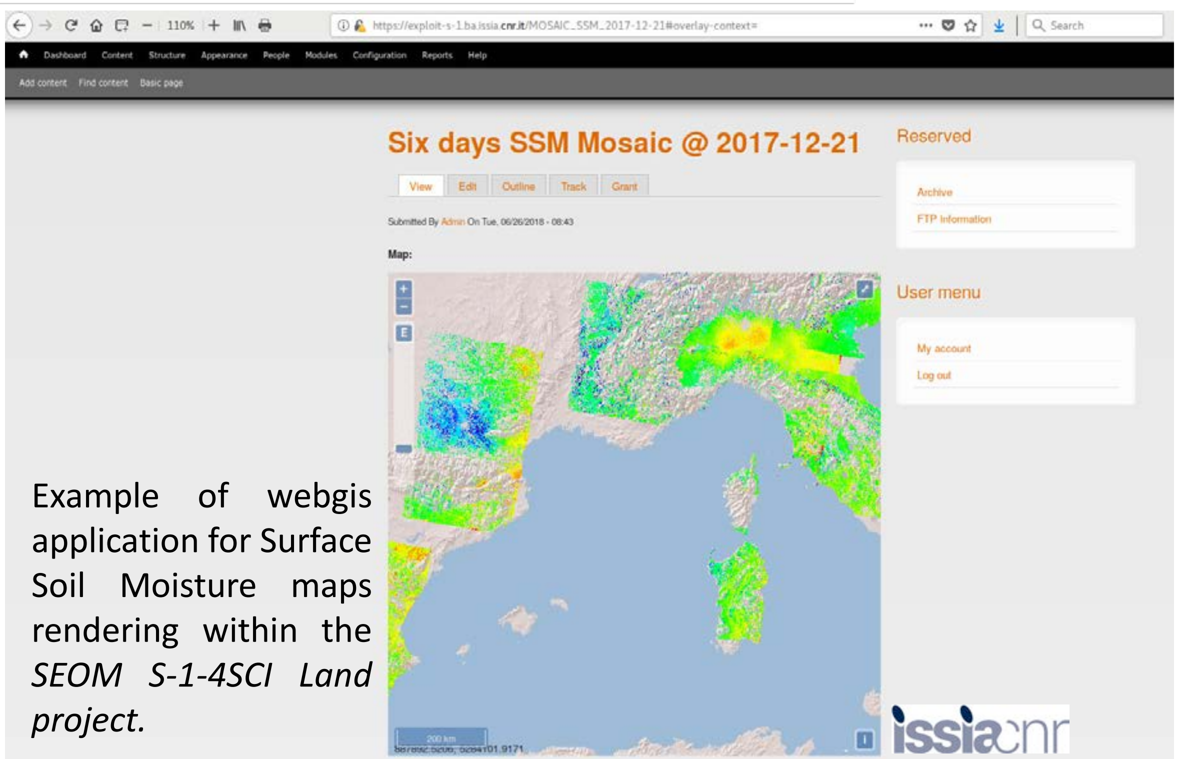
S1-SM Map composite
Range of dates = 2018-01-26 : 2018-01-31

issiacnr

Geospatial technologies for data processing and representation







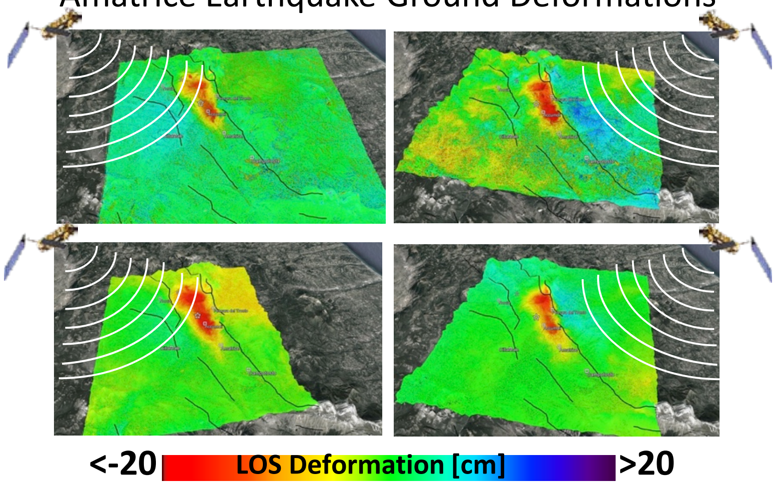
Example of webgis application for Surface Soil Moisture maps rendering within the *SEOM S-1-4SCI Land project.*

- Development of tools for massive/parallel processing of satellite images and other geospatial data.
- Development of software modules for offering multi-layer web services, using OGC protocols.
- Spatial databases implementations and exploitation of multiple ontologies and information schemes .

Development of massive data processing InSAR algorithms to analyze:

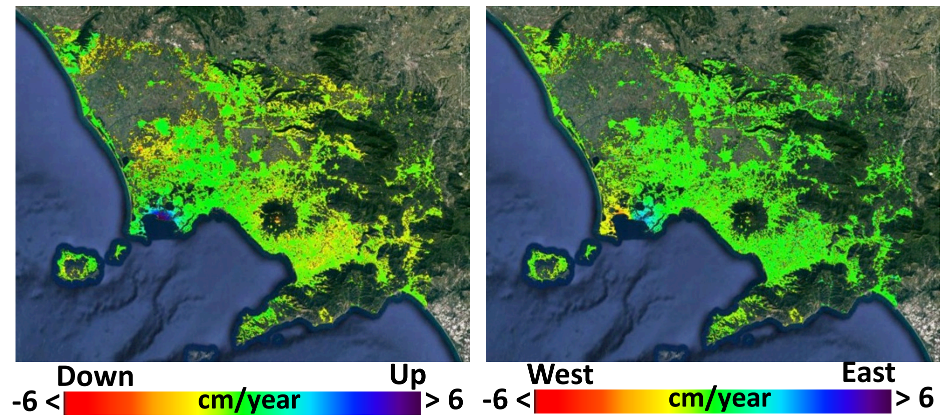
Geo-hazards

Amatrice Earthquake Ground Deformations



Regional scale displacements

Volcanic Complexes of Napoli Bay Area

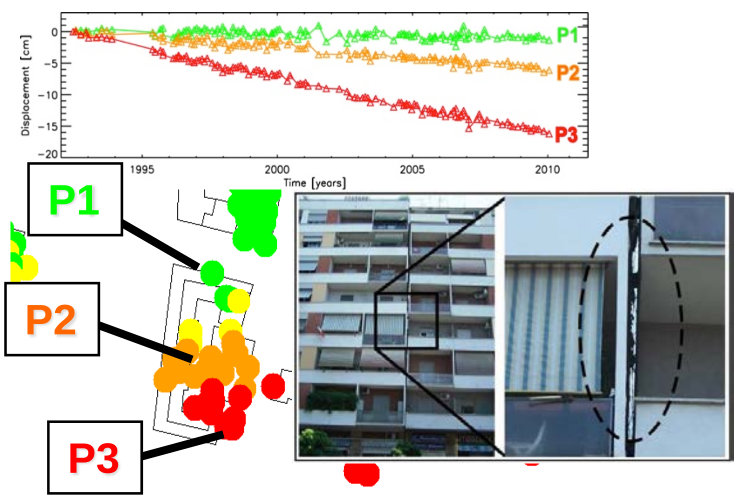


Vertical displacements

East-West displacements

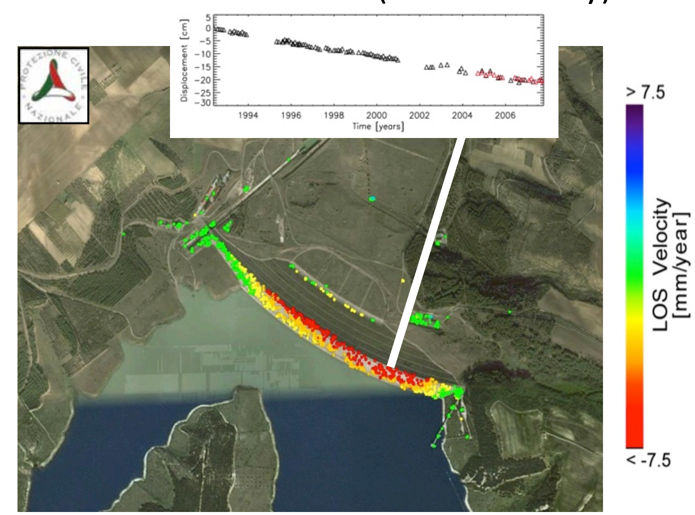
Local scale displacements

Buildings within Urban Area of Roma

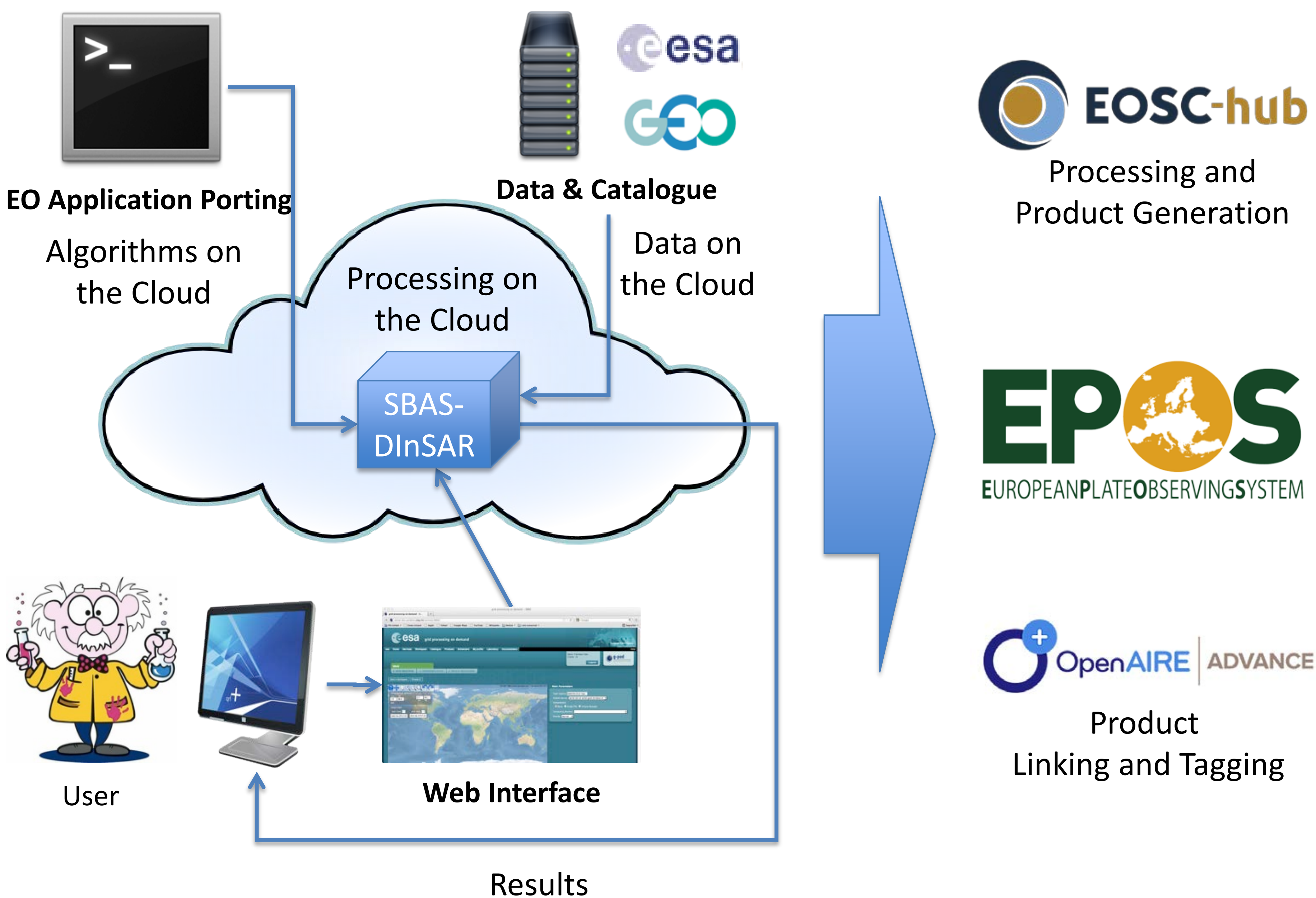


Infrastructure displacements

Lake Locone Dam (Southern Italy)

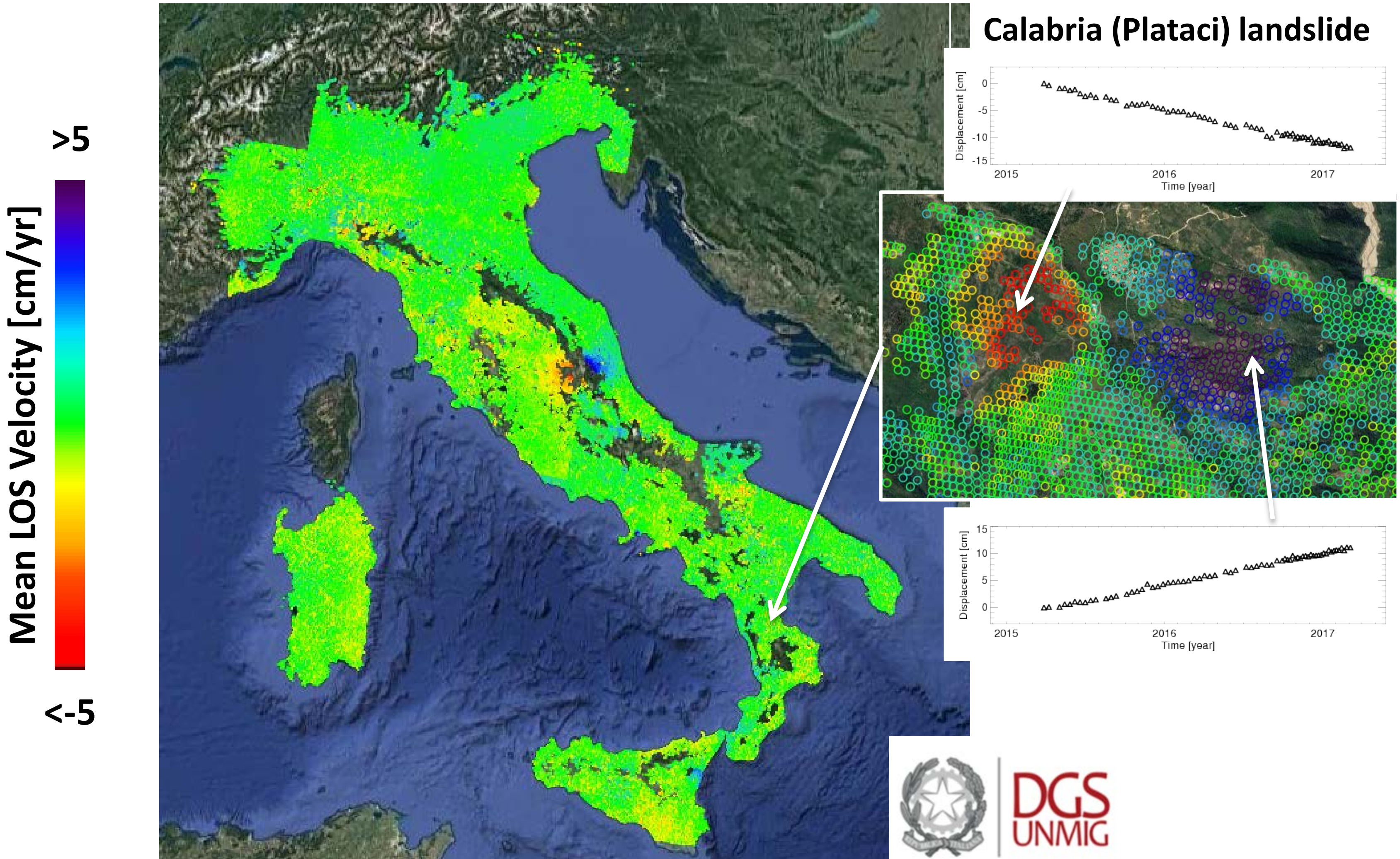


Grid / Cloud computing and geospatial data infrastructures



Surface deformation analysis to support: Ministry of Economic Development (MiSE)

National scale ground deformation mapping

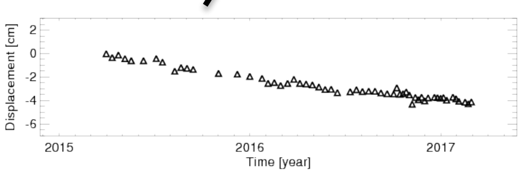


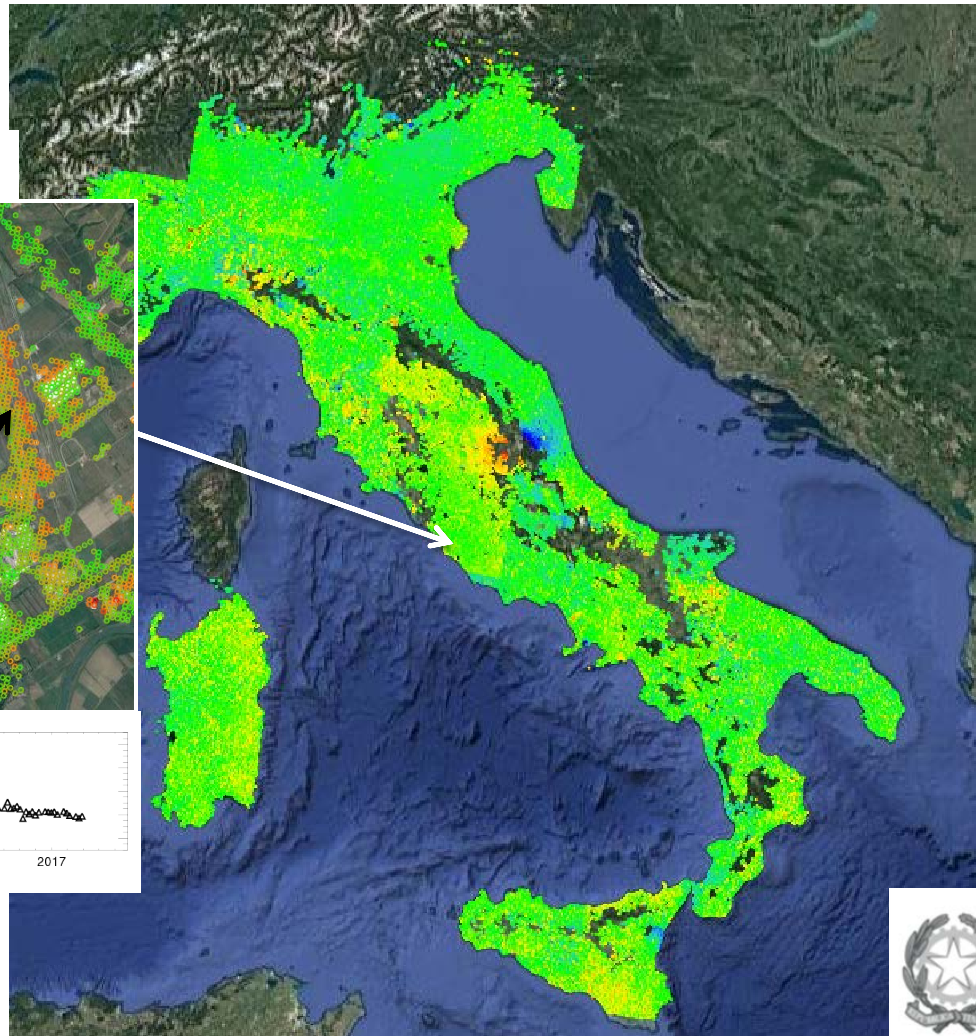
2015-2017 Sentinel-1 SAR data

Surface deformation analysis to support: Ministry of Economic Development (MiSE)

National scale ground deformation mapping

Fiumicino airport





DGS UNMIG

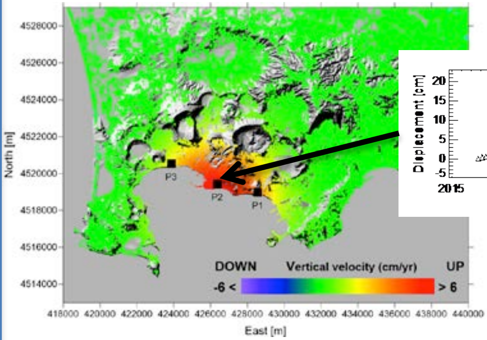
2015-2017 Sentinel-1 SAR data

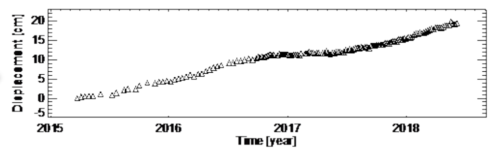
Surface deformation analysis to support: Civil Protection Department (DPC)

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

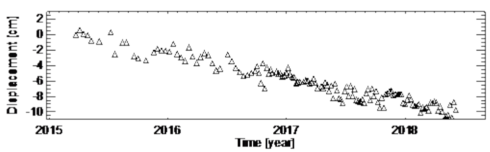
Ground deformation monitoring of the main Italian volcanoes

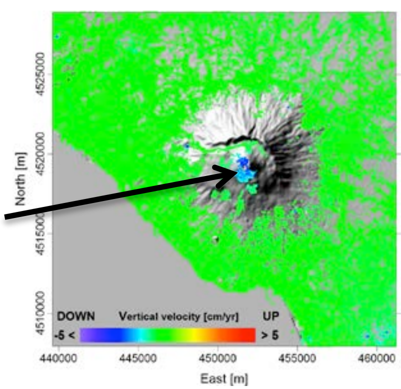
Campi Flegrei Caldera



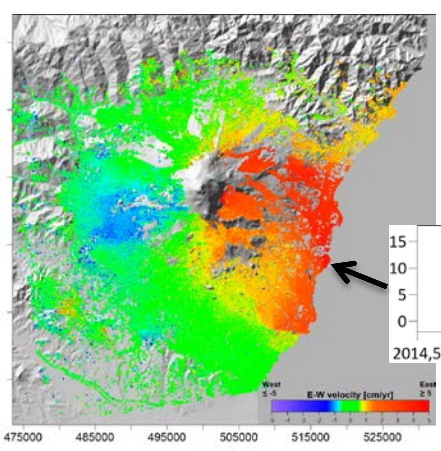


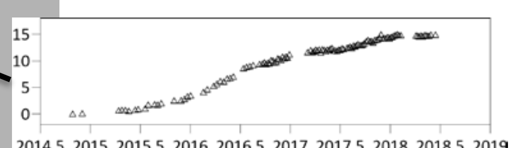
Vesuvio Volcano





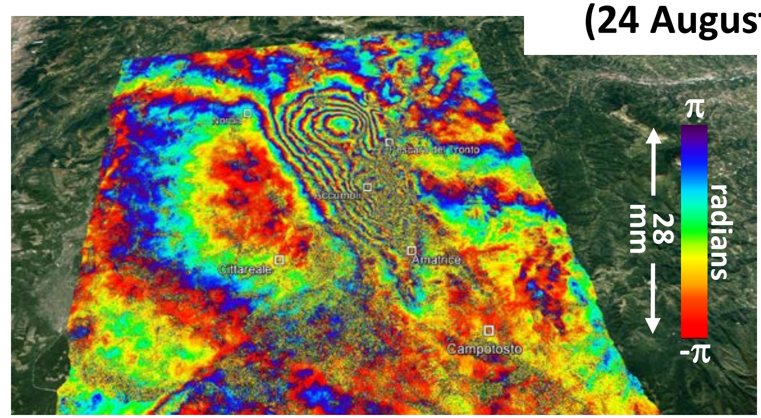
Mt. Etna Volcano



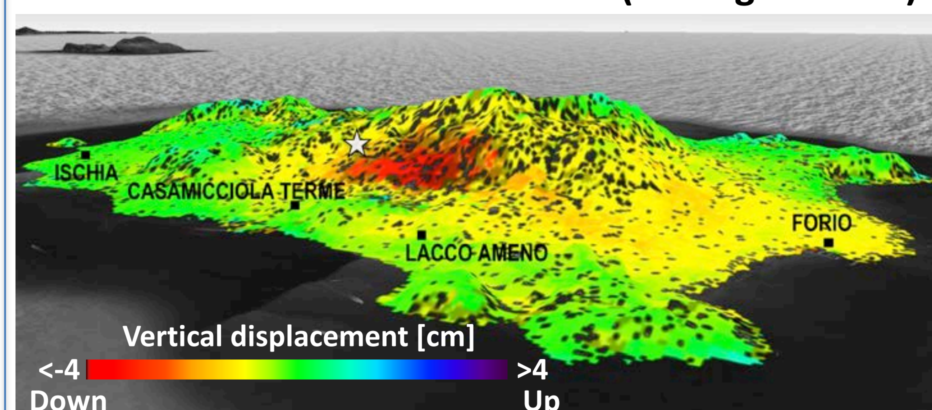


Quick response during seismic emergency phase

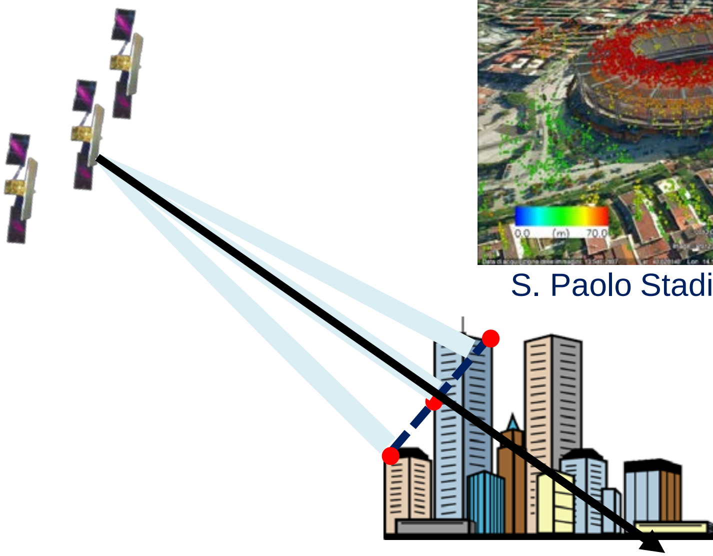
Amatrice earthquake (24 August 2016)

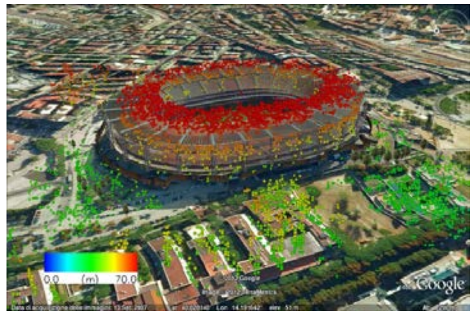


Ischia (Casamicciola) earthquake (21 August 2017)

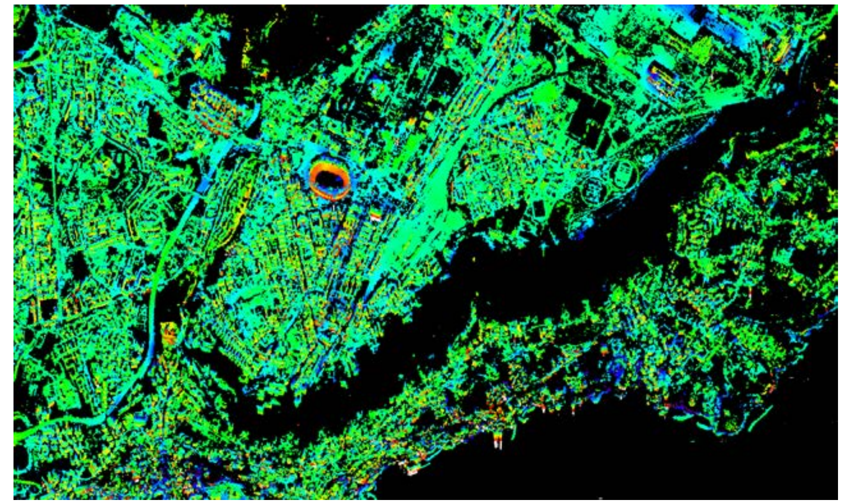


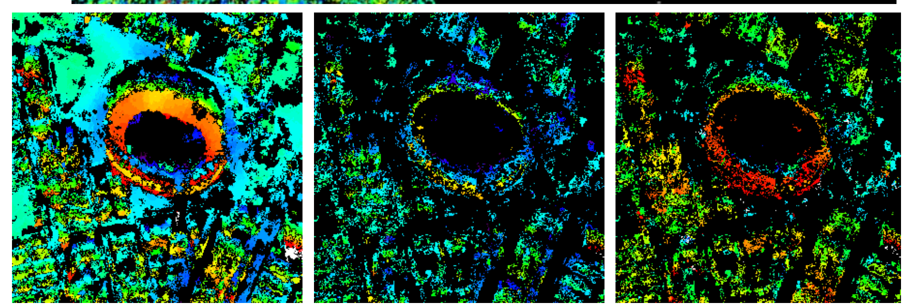
Tomographic approaches with Very High Resolution (VHR) SAR





S. Paolo Stadium





Covariance-based Tomographic Analysis

Musmeci bridge thermal dilations

Synthetic Aperture Radar (SAR) mounted onboard aerial vehicles

InSAeS4 (developed by Orbisat)
X-Band SAR – Single Pass Interferometric

AXIS (developed by Elettra s.r.l.)
X-Band SAR – Single Pass Interferometric

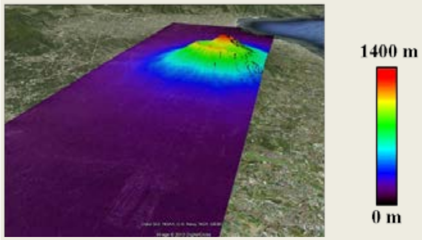
Italian Space Agency (ASI) SAR
(developed by C.O.R.I.S.T.A.)
P-Band SAR – Full Polarimetric

T-Jump SAR (developed by T-Jump)
Multi Frequency SAR - Droneborne

Synthetic Aperture Radar (SAR) mounted onboard aerial vehicles

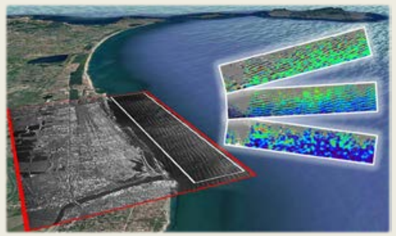
InSAeS4 (developed by Orbisat)
X-Band SAR – Single Pass Interferometric

Digital Elevation Model (DEM)



Napoli area

Sea state parameters



Volturno river area

South Italy, 2013: experimental campaign in the frame of the agreement between IREA-CNR and AGEA

AXIS (developed by Elettra s.r.l.)
X-Band SAR – Single Pass Interferometric

Salerno area, 2018: calibration campaign in the frame of the agreements between IREA-CNR and DPC, and IREA-CNR and Elettra s.r.l.

Italian Space Agency (ASI) SAR (developed by C.O.R.I.S.T.A.)
P-Band SAR – Full Polarimetric

Viterbo area, 2017: calibration campaign in the frame of a project funded by ASI

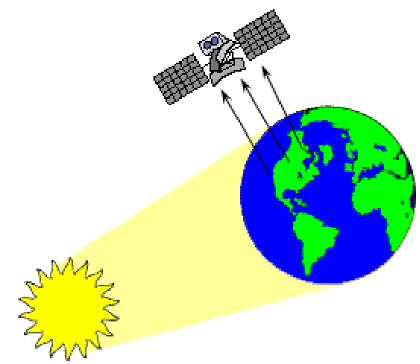
T-Jump SAR (developed by T-Jump)
Multi Frequency SAR - Droneborne

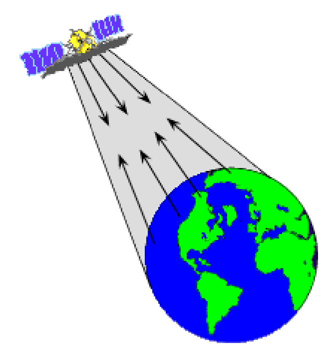
..in progress

Fire Mapping with Sentinels data

- Detection, mapping and monitoring burned areas is relevant for the prevention/mitigation of the fire associated risk
- Satellite data (Sentinel-1 and Sentinel-2) are a valuable source for detecting/mapping/monitoring areas affected by fires

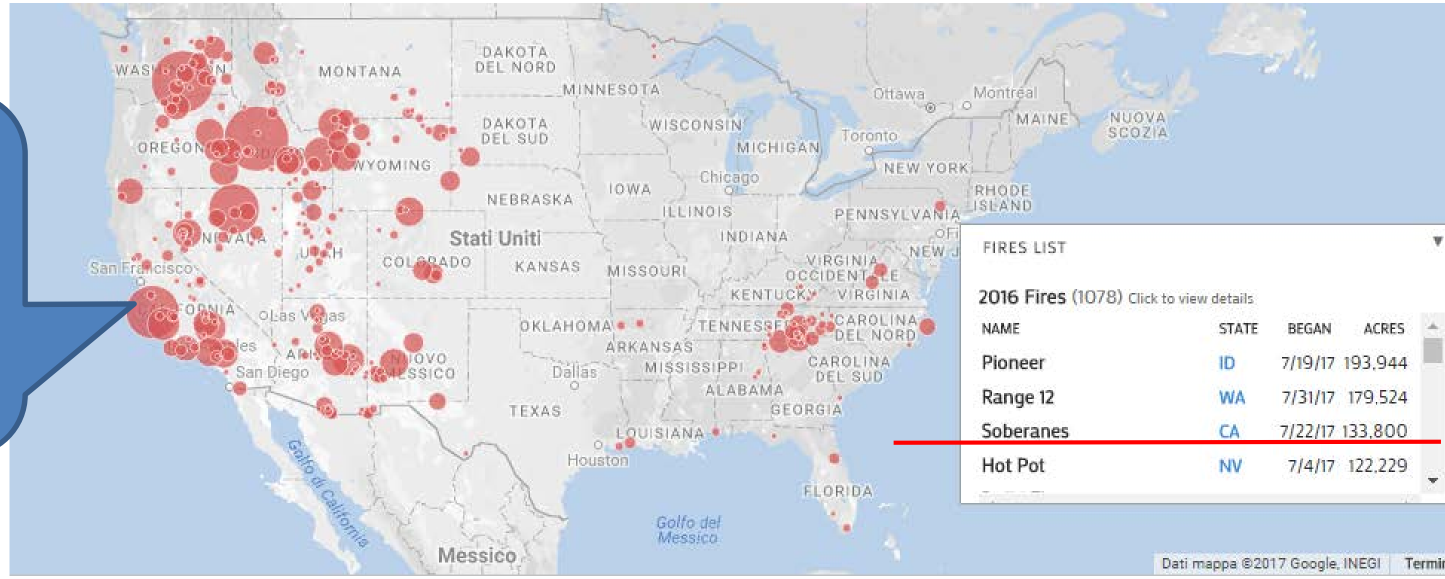
- Toward Integration optical and SAR data





Fire Mapping: Soberanes Study area

Soberanes Fire



First report: *22 July 2016*
Cause: *illegal campfire*
Suppression costs:
~ *$236 million*

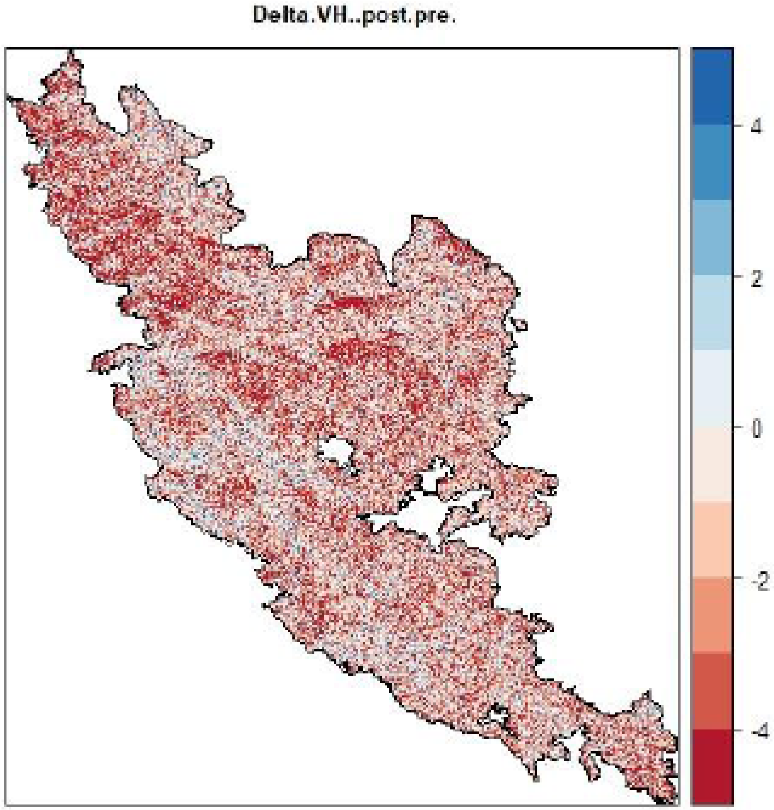
As of 2016, the most expensive wildfire in US history and the 18th of the top 20 largest fires in California!

Smoke from Soberanes wildfire, from U.S. Highway 1, Carmel, California, Saturday, July 23, 2016

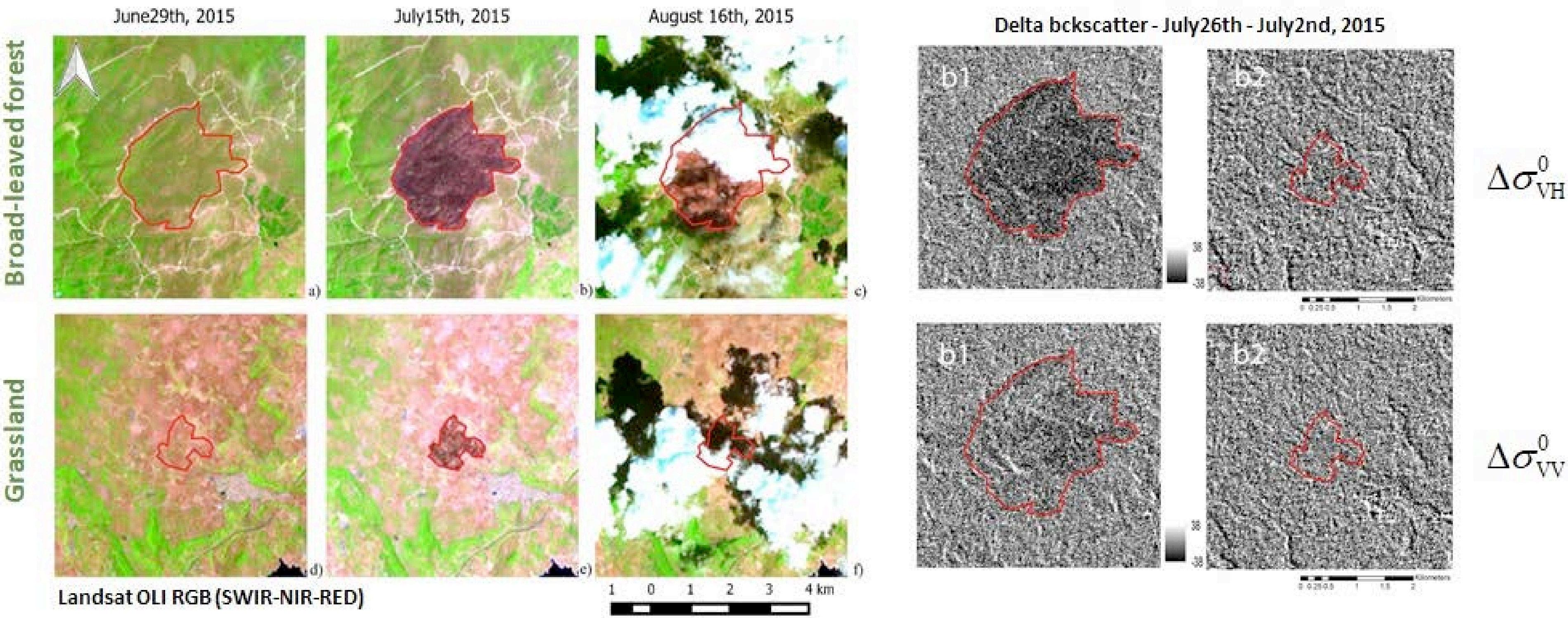
Processing S-1 Amplitude SAR images

- Sentinel-1 (IW mode, SLC, VH pol): pre-fire (17 July 2016) – post-fire (27 October 2016), Soberanes Fire

- ➢ *Co-registration*
- ➢ *Multi-looking*
  (azimuth looks: ; range looks:)
- ➢ *Radiometric calibration and terrain correction*
  (SRTM DEM with 30m x 30m resolutio
- ➢ *Geocoding*
  (from radar to UTM coordinates)
- ➢ Pre- post-fire difference Δσº

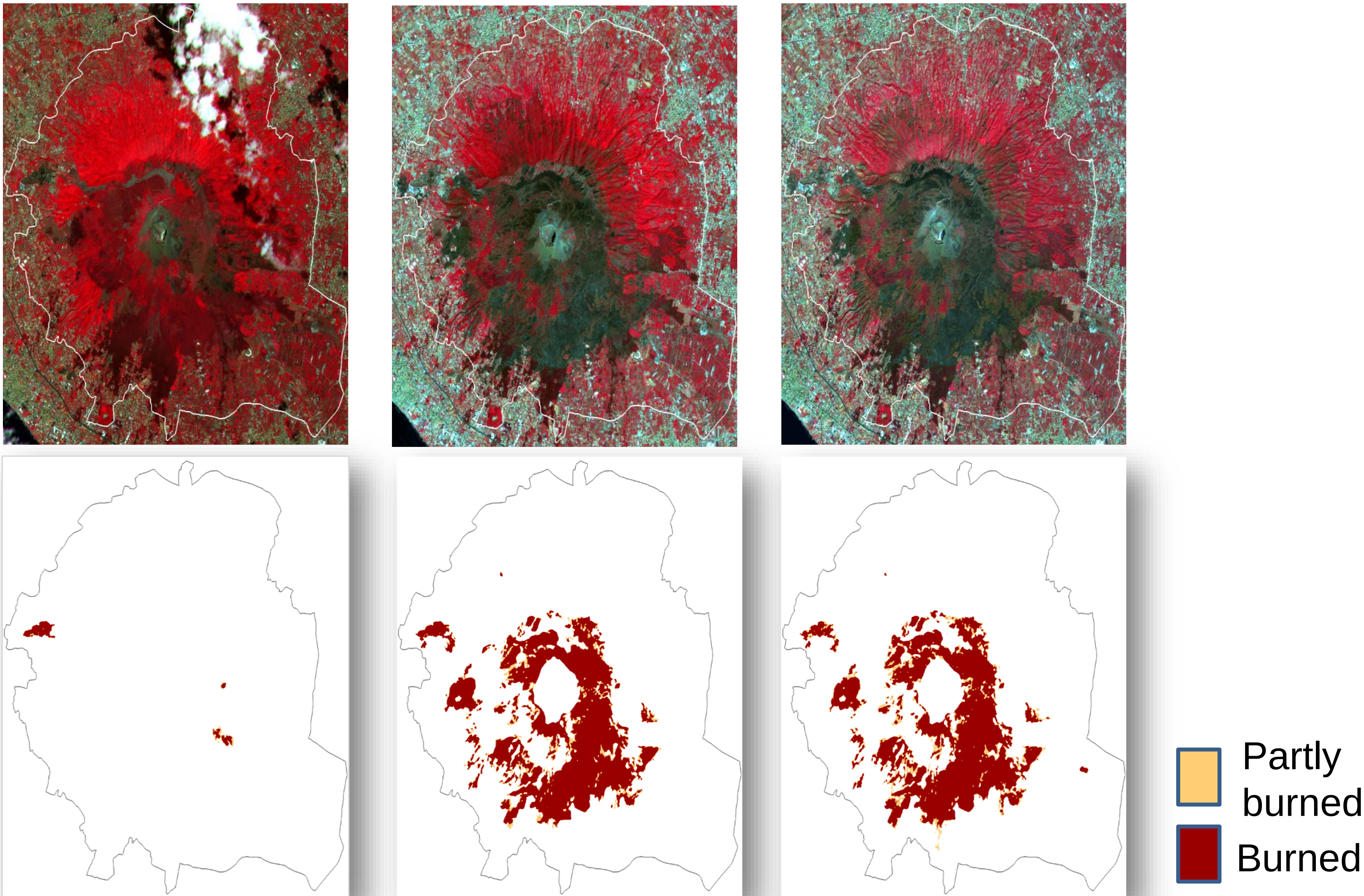


Integration of SAR and Optical Data



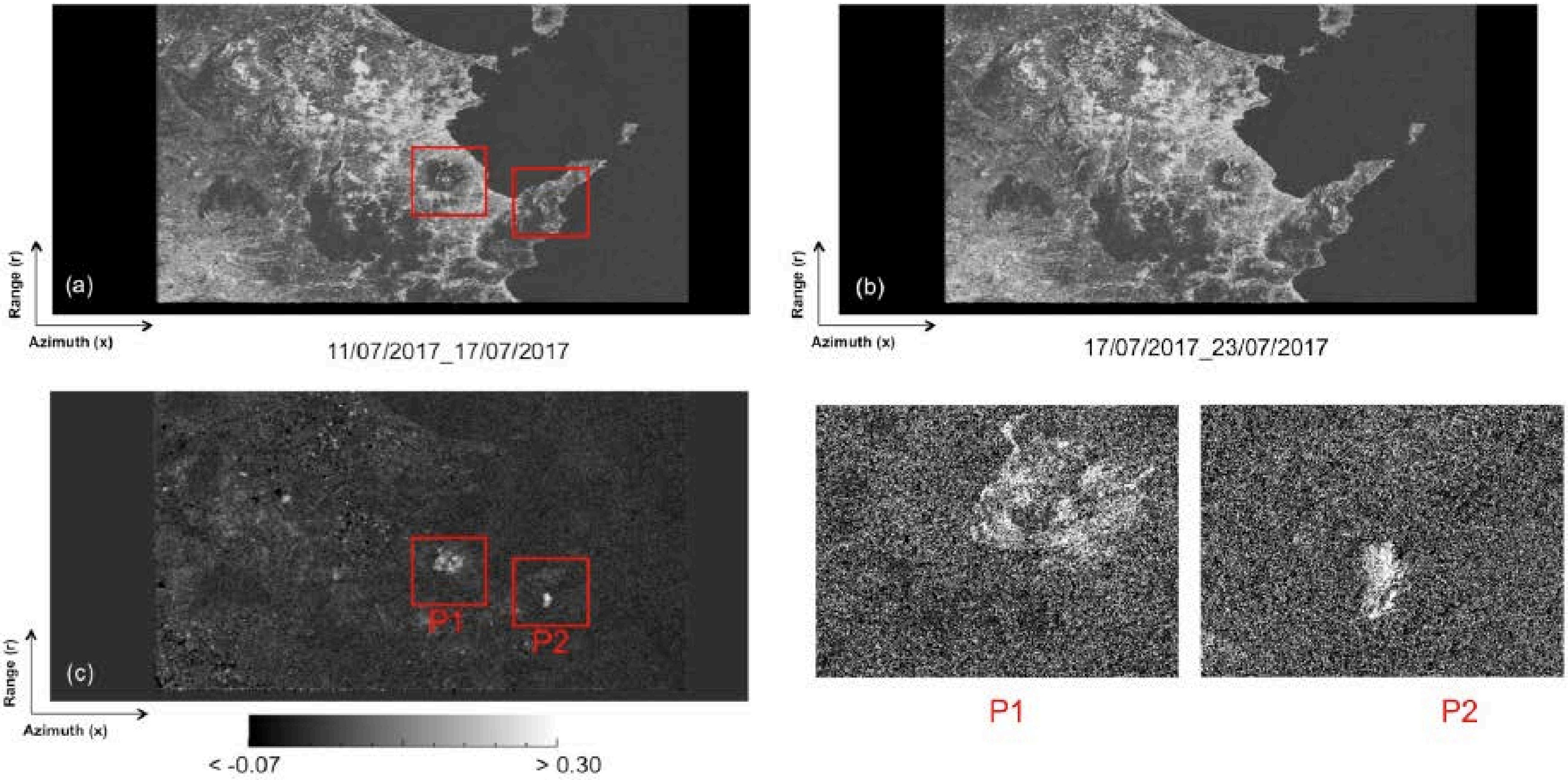
- The largest fire-disturbed area (b1) covers approximately 546 ha of forest vegetation near the town of *Budduso'* (Olbia-Tempio): the fire-event occurred on July 6, 2015.
- S1 Cross-polar (VH) amplitude information has successfully been used for burned area detection.

Map of burned areas (Mt. Vesuvius)



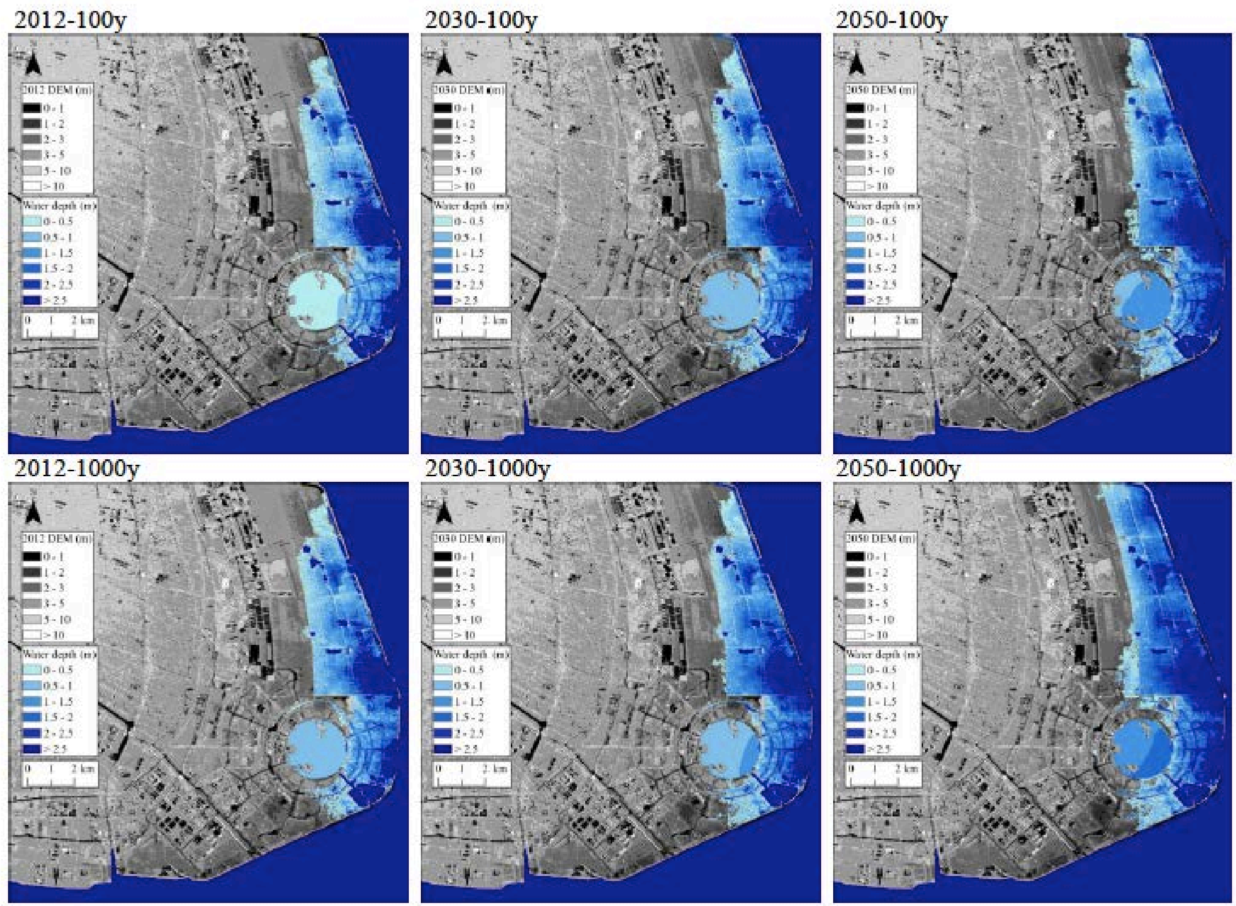
S2A 27/06/2017 S2B 22/07/2017 S2A 26/08/2017

Processing S-1 Amplitude and Phase SAR information: Experiments on Mt. Vesuvius with Sentinel-1



Scars of the burned areas revealed by InSAR coherence maps

Hydrology: Inundation Risk in Coastal areas



Potental Inundated areas retrieved using sequences of Sentinel-1, Cosmo-SkyMed and ENVISAT InSAR time-series.

Open Cooperation with three Chinese Universities for the study of **Sea Level Rise, Climate Change, ocean mechanisms** using InSAR/SAR data.

Possible inundation risk of the Yangtze River Delta due to Sea Level Rise

Land Subsidence Rate

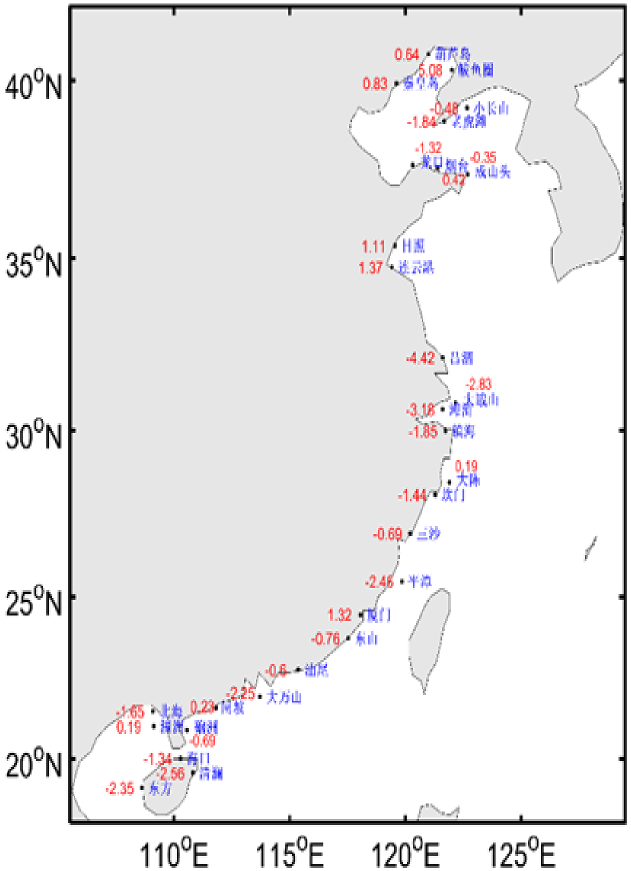
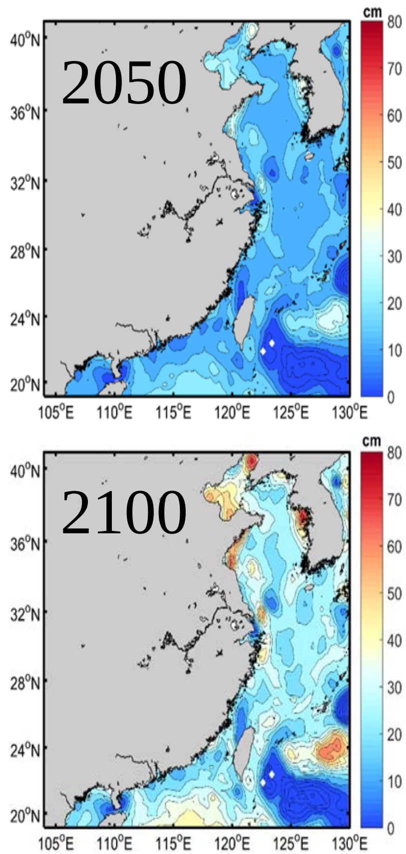
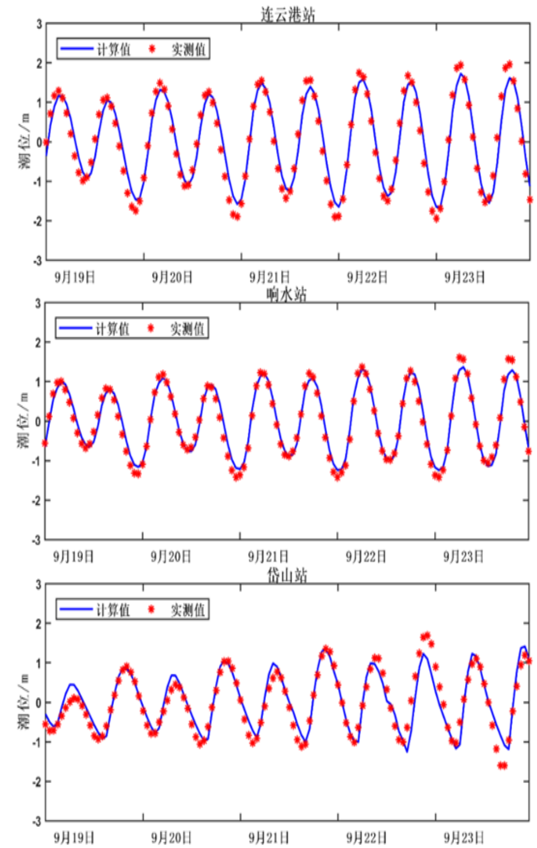


Figure 1



Sea Level Change

Figure 2

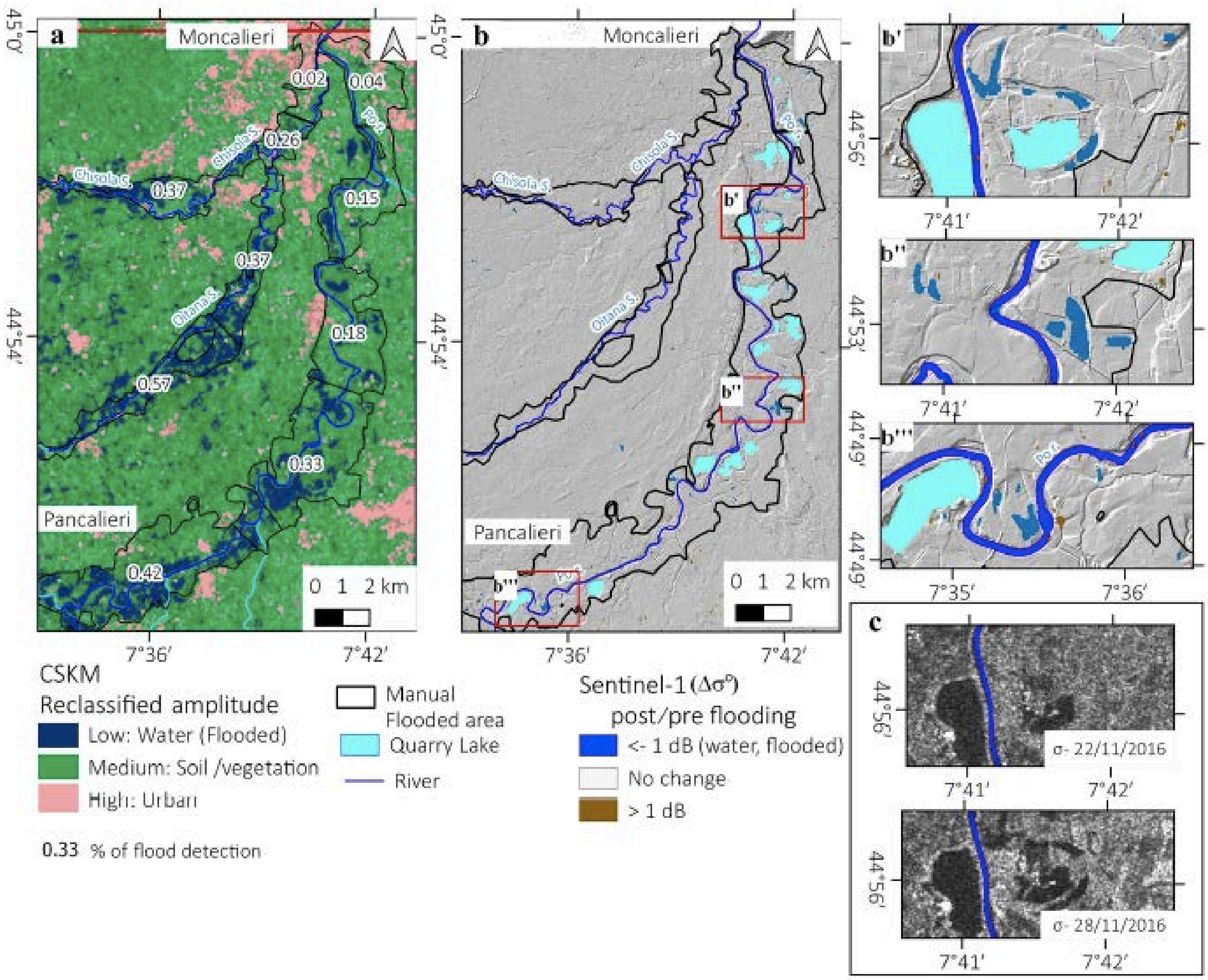


Blue Simulated

Red Measured

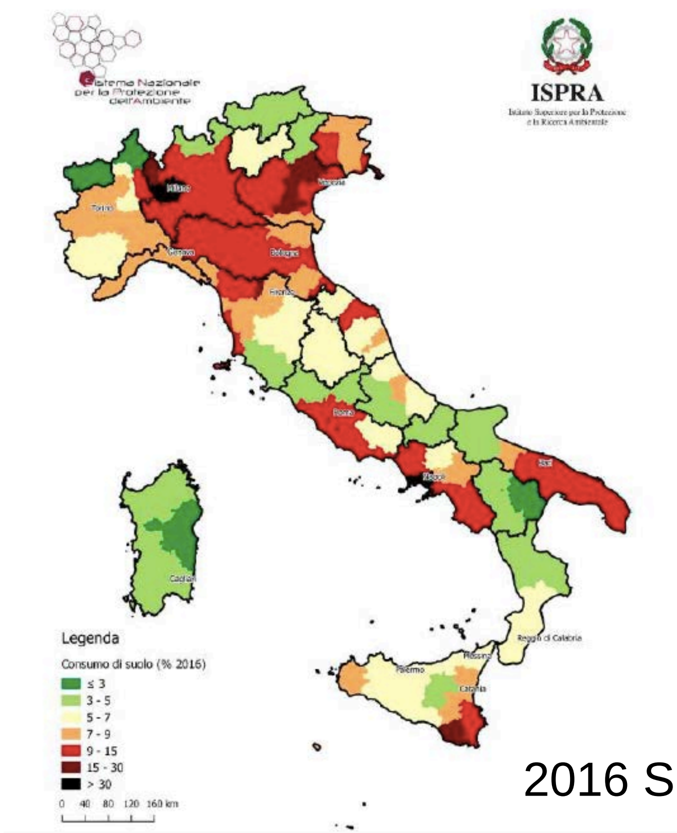
Comparison of Storm Surge Tidal Height typhoon Fung-Wong

Flood Detection



Monitoring Soil Consumption with SAR Data

- Investigate the soil consumption effects through the analysis of the detected SAR reflectivity changes in a sequence of calibrated Sentinel-1 SAR images;
- Algorithm Developments;
- The activity is in cooperation with ISPRA and is currently in progress.



2016 Soil consumption, courtesy of ISPRA

Radiometric Calibration of SAR Images: Development of Novel Theoretical Formulations and Processing Techniques

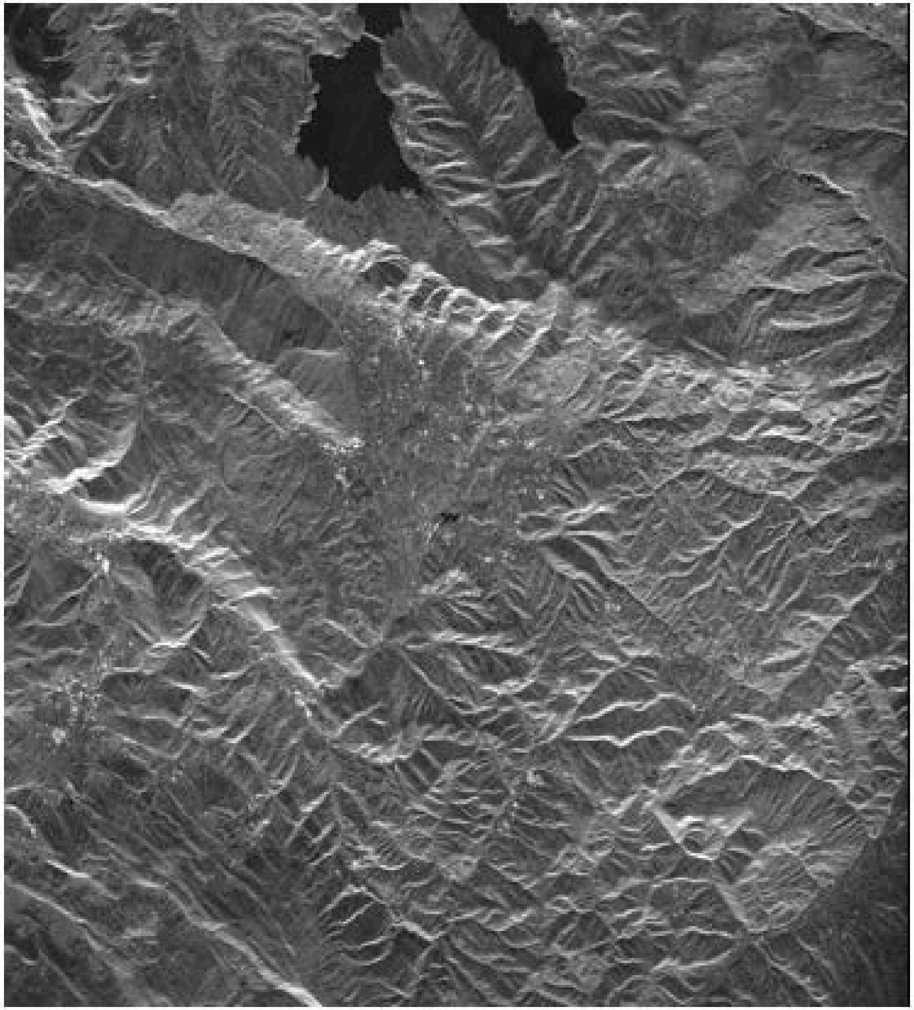


Fig.1. SLC COSMO-Skymed SAR amplitude image.

Fig. 2. Calibrated COSMO-Skymed SAR image obtained by applying the GICAL processing scheme. A layover mask (in green) is also superimposed.

Development of a Sentinel-1 TOPS Focusing Tool

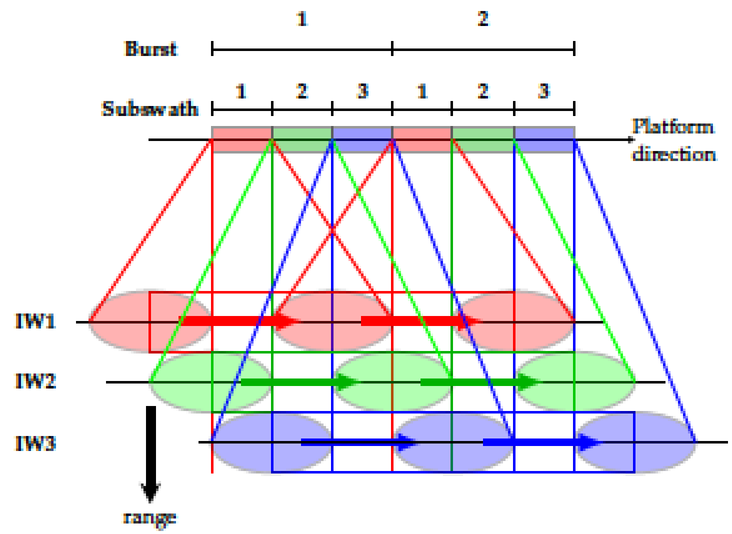


Fig.1: TOPS acquisition mode

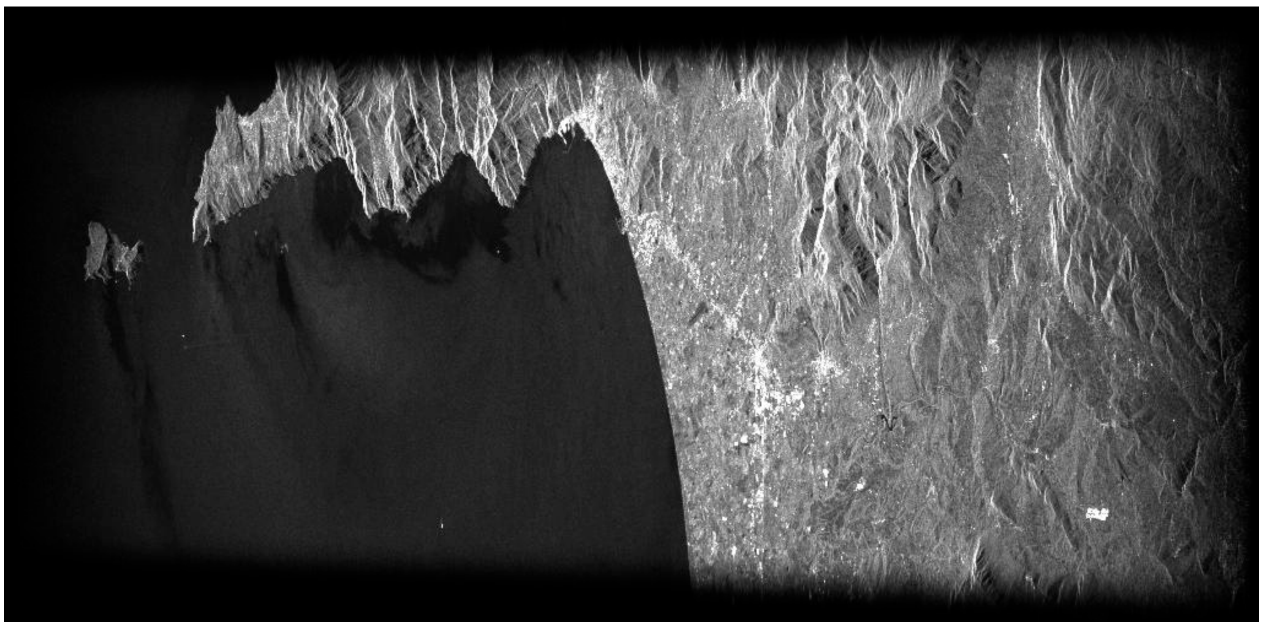


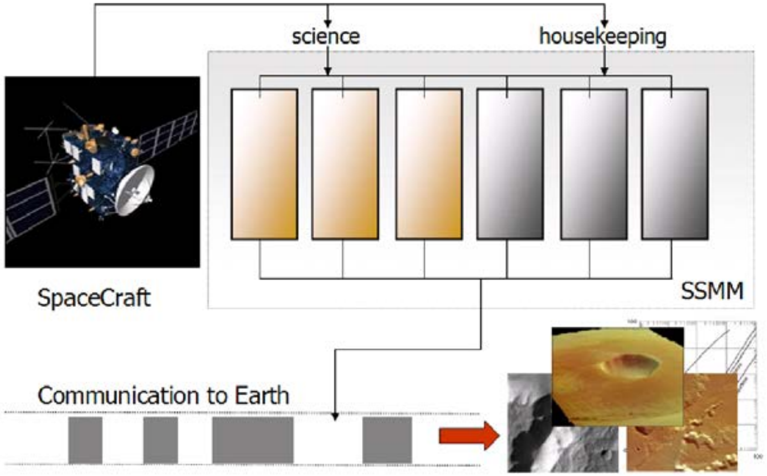
Fig.2 : TOPS Focused SAR Image – Naples bay area

Mars-Express Data Planning Tool (MEXAR2)

Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

MEXAR2 is an advanced AI software tool for continuous support of the mission planning operations of MARS-EXPRESS. It generates the activity plan used to download the satellite data from the on board memory to ground. The problem is solved on a weekly basis at ESOC, the Mission Operations Centre of the European Space Agency (ESA). The tool is still in use and supports the daily work of mission planners within the MARS-EXPRESS mission. Currently, our main tasks are to update the operating model, modify the optimization algorithms, remove malfunctions and improve the software's overall performance. The successful application of MEXAR2 is due to a twofold factor: (i) the use of efficient AI planning & scheduling (P&S), and (ii) a careful design of the human-machine interaction workflow, to augment the capability of the mission planners of exploring the solutions space.

A mission planner working at ESOC, the Mission Operations Centre of the European Space Agency (ESA), using the MEXAR2 software tool.



Overall workflow of the MEXAR2 software tool.

https://www.esa.int/spaceinvideos/Videos/2018/05/Flight_over_Neukum_crater

This **video,** based on images taken by ESA's Mars Express, showcases the 102 km wide Neukum Crater in the southern hemisphere of Mars. Data are produced by the on-board High Resolution Stereo Camera (HRSC) and downloaded to Earth through a dump plan created with the MEXAR2 software tool. The video is publicly available on the above ESA website.

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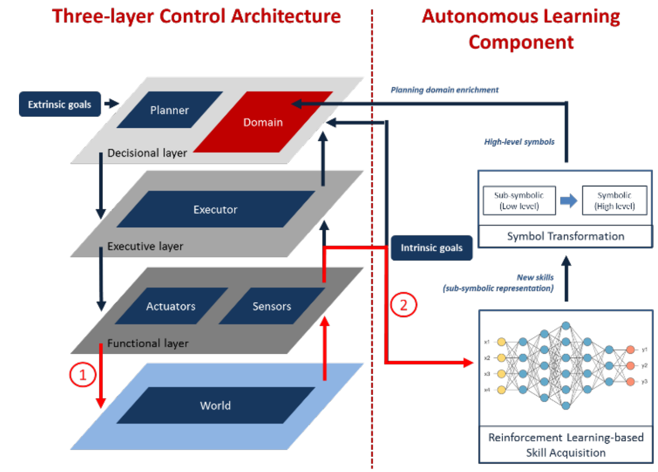
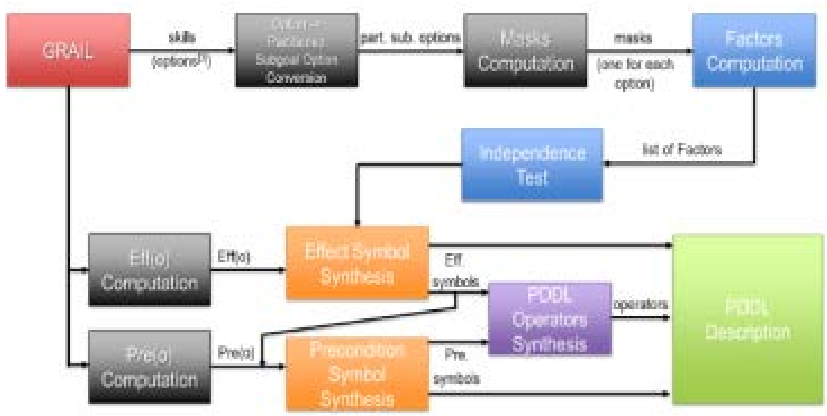
Artificial Intelligence and Autonomous Robotics for Space

Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

This activity aims to study and develop prototypes of software architectures able to control robotic systems as well as complex subsystems operating in space. This problem will be addressed through an interdisciplinary approach integrating techniques of Artificial Intelligence (IA), Autonomous Robotics and Machine Learning. In particular, state-of-the-art AI planning systems and algorithms will be integrated, with reinforcement learning algorithms guided by intrinsic motivations (curiosity, exploration, novelty, surprise). The aim of the research is to: (i) develop a software system that allows a robotic platform to represent the skills autonomously learned through intrinsic motivations during the exploration of the environment, in an appropriate symbolic form; (ii) use the symbolic planning ability to improve the autonomous acquisition of possible additional skills.



A Three-layer Robot Control Architecture extended with an Autonomous Learning Component



From sub-symbolic skill generation to symbolic operators

Research collaboration between the Planning & Scheduling Lab (Angelo Oddi, Riccardo Rasconi) and the Laboratory of Computational Embodied Neuroscience (Gianluca Baldassarre, Vieri Giuliano Santucci, Emilio Cartoni) of the Institute of Cognitive Sciences and Technologies (ISTC-CNR).

Project: **IMPACT - Intrinsically Motivated Planning Architecture for Curiosity-driven roboTs**. Funded by the European Space Agency (ESA), ESA Innovation Triangle Initiative (ITI) 2017, contract N. 4000124068/18/NL/CRS. Contact: Angelo Oddi (angelo.oddi@istc.cnr.it)

Aerospace communications: ongoing research and projects

Alberto Gotta

alberto.gotta@isti.cnr.it

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Fly & Sense Working Group, CNR Pisa

@ CNR Area in Pisa for R&D and ToT linked to UAVs and SAPRs:

- ISTI
- IIT
- IFC

Staff:

- 4 Pisa Research Area
- 1 IFC
- 2 IIT
- 6 ISTI

- payload: 9 kg
- autonomy: 17 min
- 8 engines
- quota: 150m
- Radius for aut. flight: 500m

- payload: 6.6 kg
- autonomy : 15 min
- 6 engines
- quota: 150m
- Radius for aut. flight: 500m

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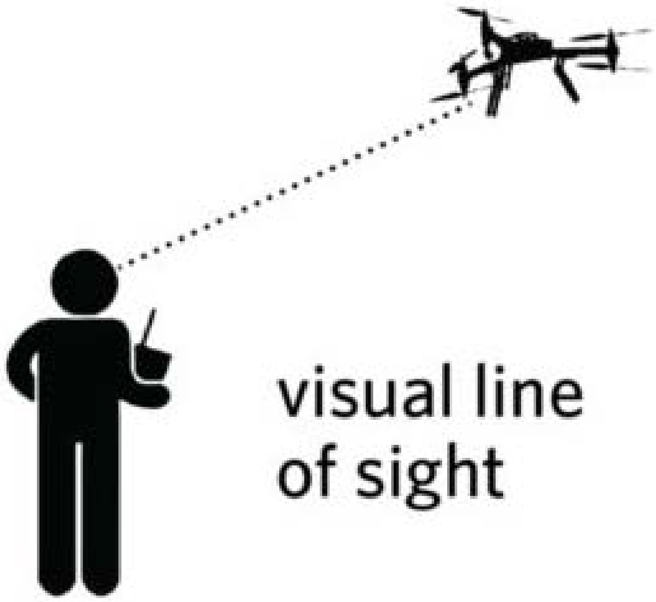
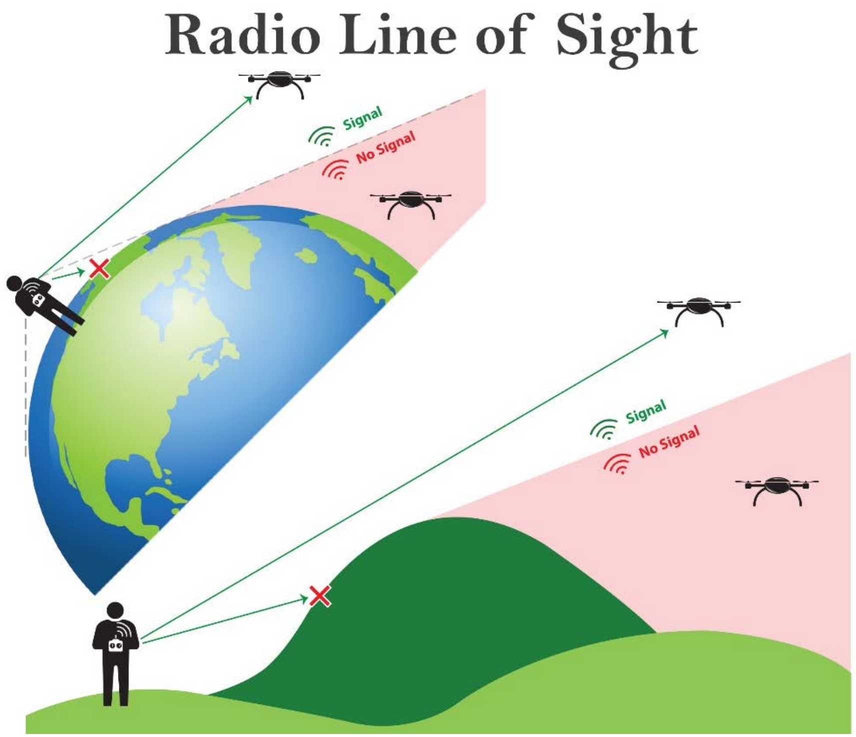
SAPR/UAV today: fundaments

- Line of Sight (LoS)
  - Visual (VLoS)
  - Radio (RLoS)

- Beyond Line of Sight (BLoS)
  - Visual (BVLoS)
  - Radio (BRLoS - NLoS)





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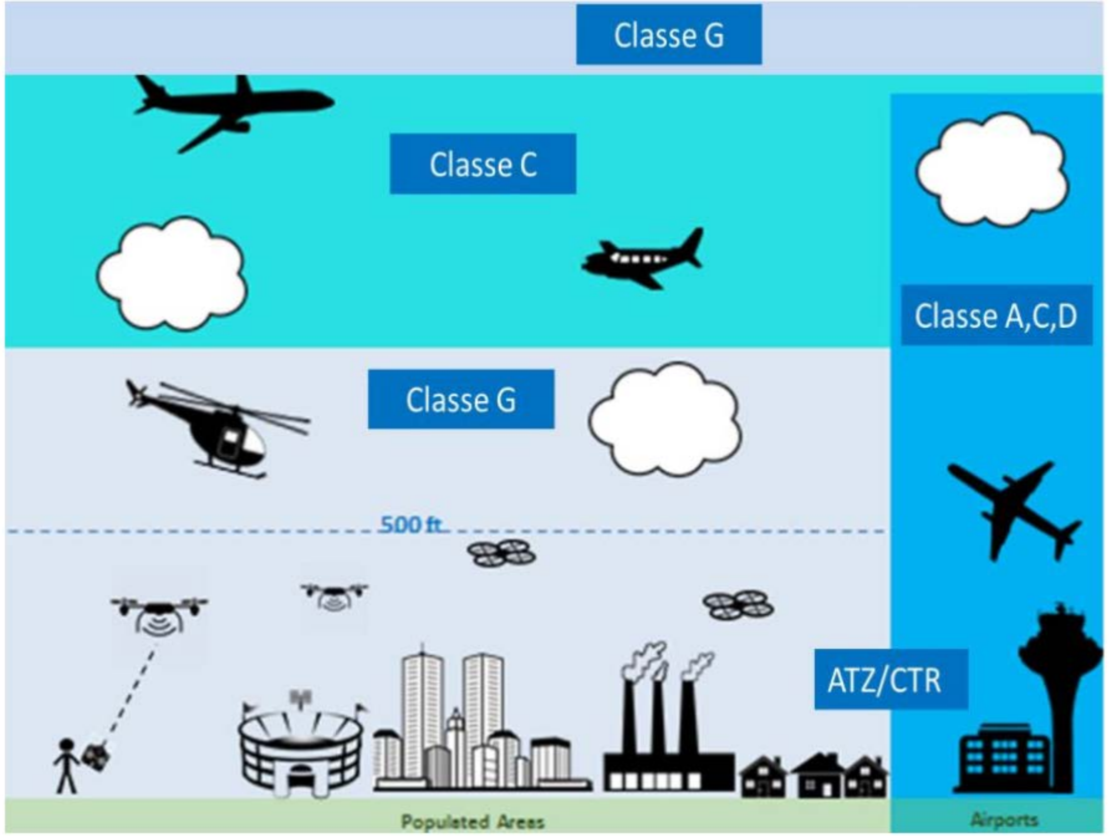
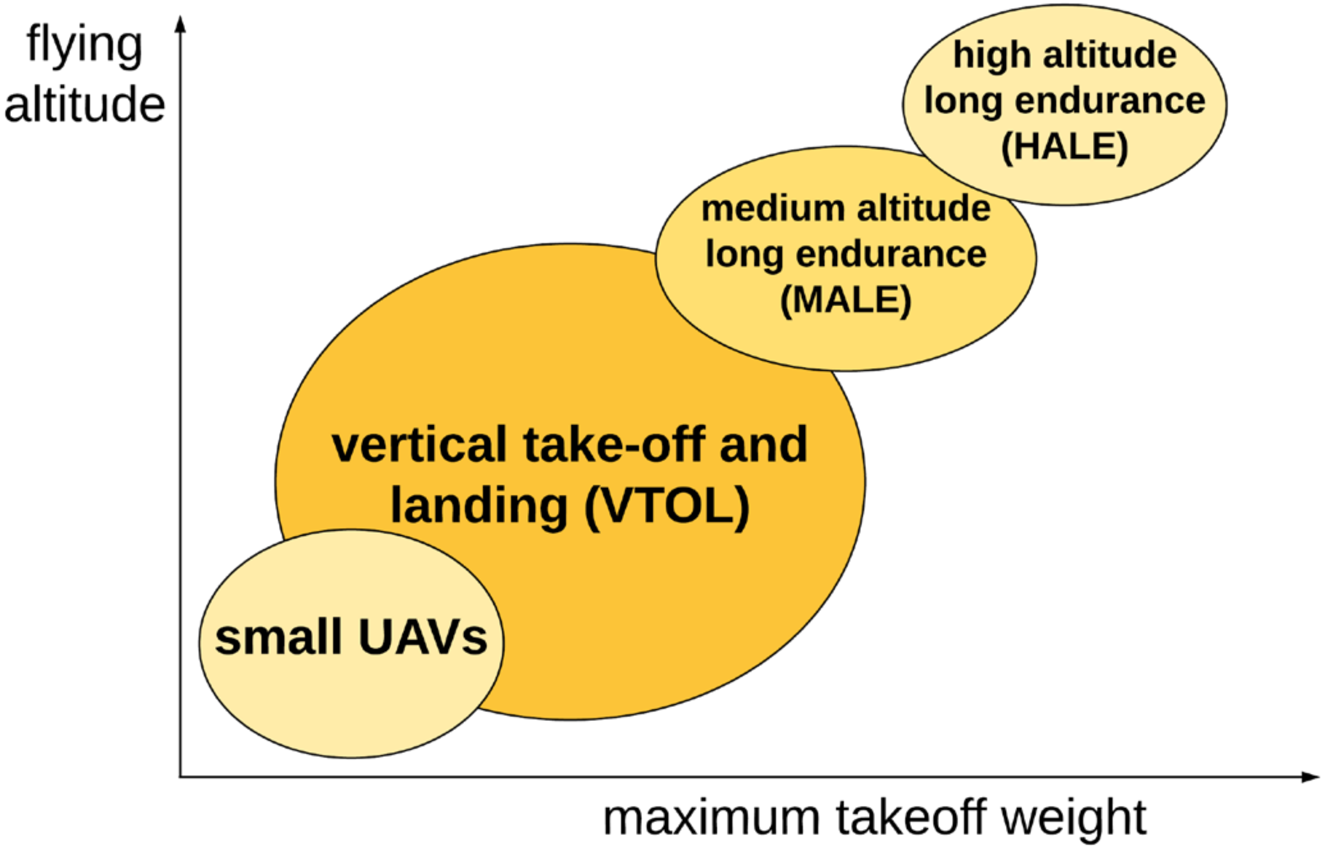
SAPR/UAV today: fundaments

Line of Sight (LoS)	VLoS + RLoS	VLoS + NLoS	BVLoS + RLoS	BVLoS + NLoS
Command Control & Communication (C3)	√ (full control)	X (failsafe)	√ (remote control)	X (???)
ENAC Normative	√	√	X (experimental)	X

SAPR/UAV today: fundaments





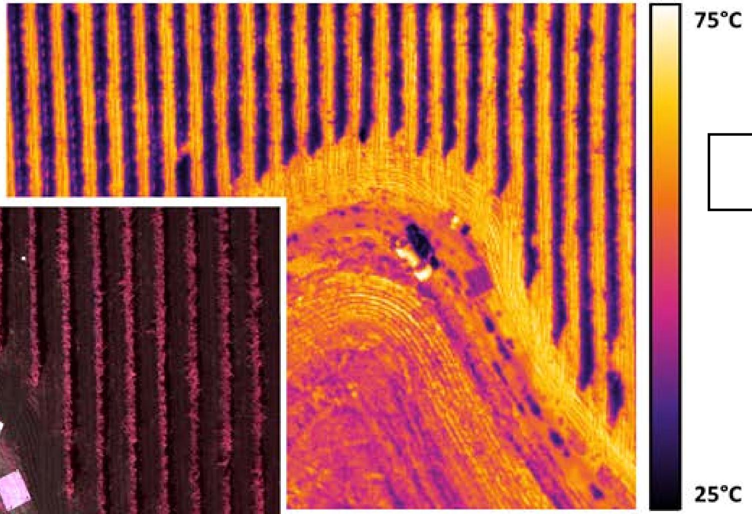
SAPR/UAV Today

Application domains

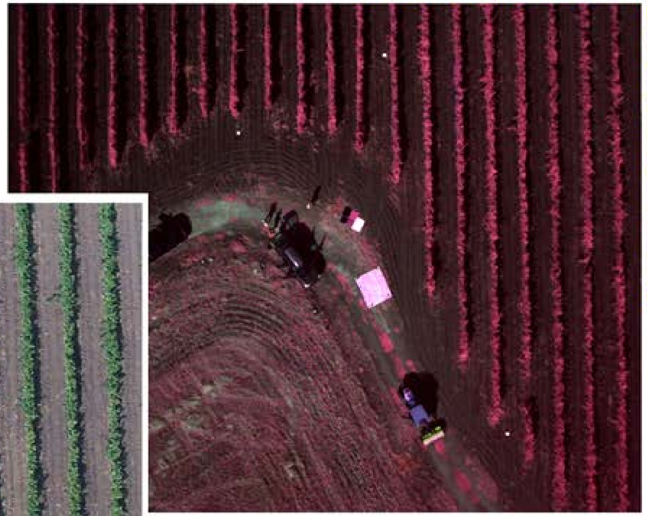
- agriculture
- photogrammetry
- monitoring
    - environment
    - infrastructures
    - events
- search and rescue
- logistic and transport
- media

What CNR does with SAPR/UAV today: - precision agriculture -

Multispectral



Infrared



Visible

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What CNR does with SAPR/UAV today:
- pest control -

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What CNR does with SAPR/UAV today:
- photogrammetry -

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What CNR does with SAPR/UAV today:
- aerial shots -

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Main Ongoing Projects

- **Moscardo** (Tecnologie ICT per il monitoraggio strutturale di costruzioni antiche basato su reti di sensori wireless e droni), *Regione Toscana*
- **Sciadro** (Sciame di droni), *Regione Toscana*
- **Multi-homed network architectures for flying ad-hoc networks and nano-satellite swarms**, *Satellite Network of Experts (SatNEx), ESA*
- **E-navigation** (Realtà aumentata in scenari marittimi con uso di tecniche multipath), Fincantieri
- **Bando MISE 5G,** TIM

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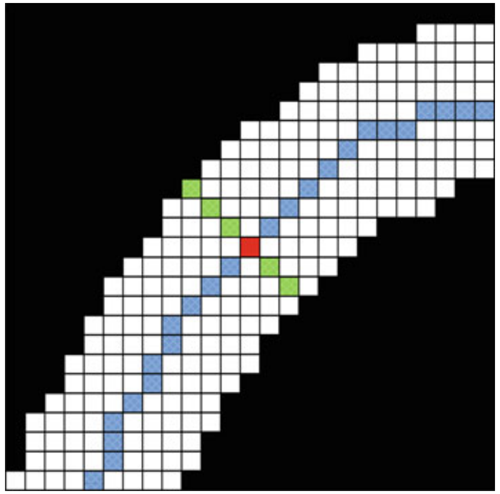
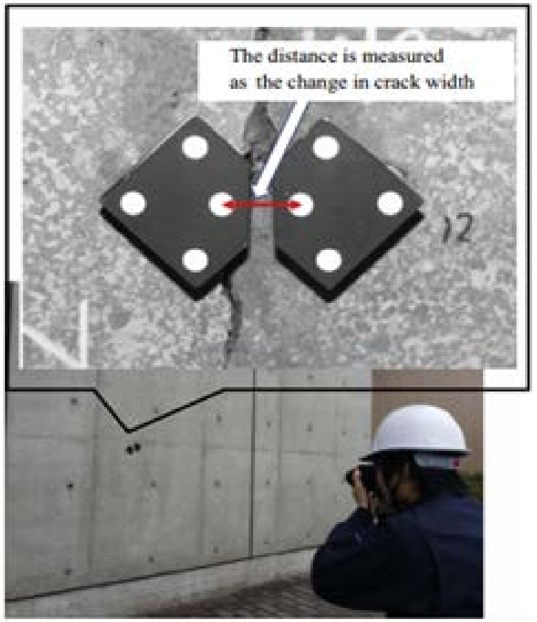
MOSCARDO Computer Vision for Buildings

- Goals:
  - Evaluation of cracks using
    - Image processing
    - Photogrammetry
    - Currently studying suitable marker configurations for achieving sub-millimetric accuracy
- UAV role:
  - Access cracks also in difficult areas
  - Capture cracks from optimal locations





ISTI Consiglio Nazionale delle Ricerche
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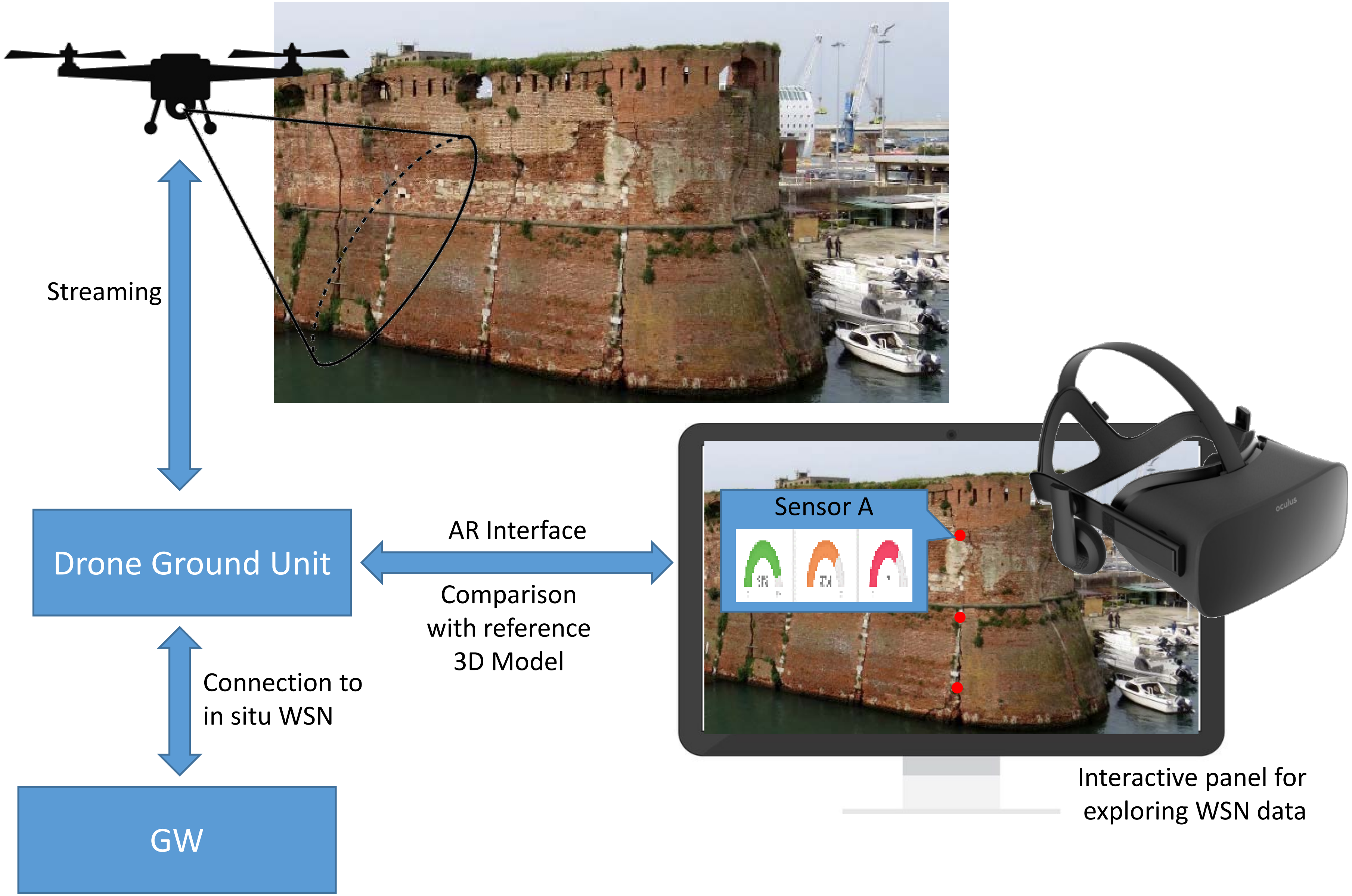
MOSCARDO Augmented Reality



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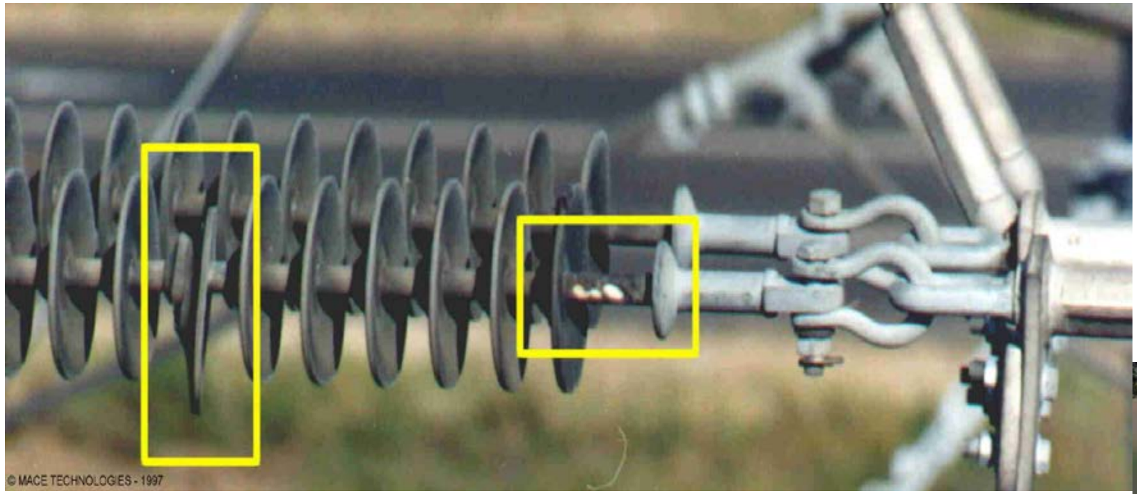
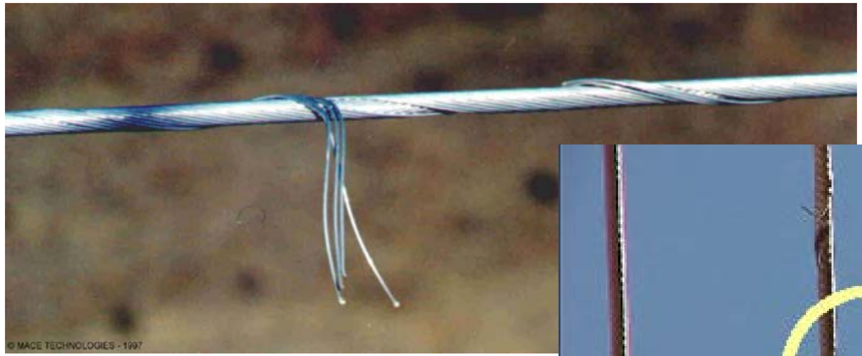
SCIADRO (SCIAme di DROni - UAV Swarm)

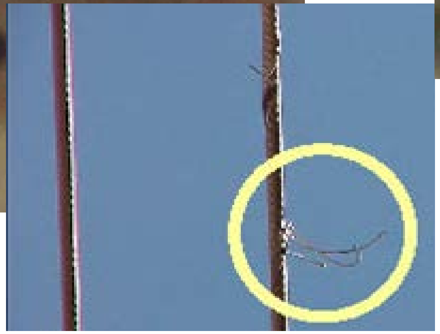
- 2D inspection of aerial power lines

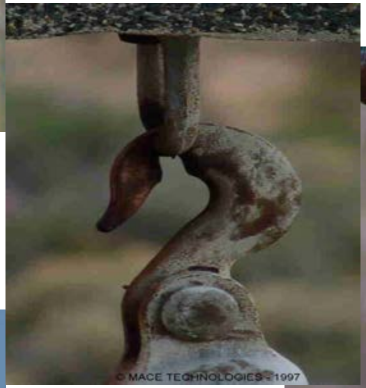


possible defects

- deformed insulators
- broken / damaged wires
- loose /corroded connections







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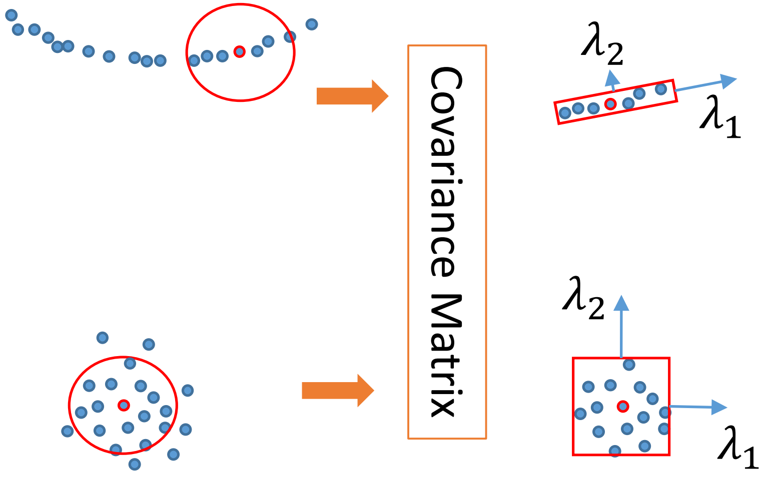
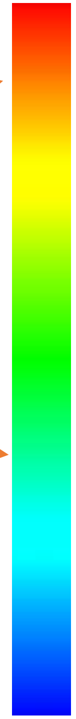
SCIADRO

- 3D inspection of aerial power lines: finding wires

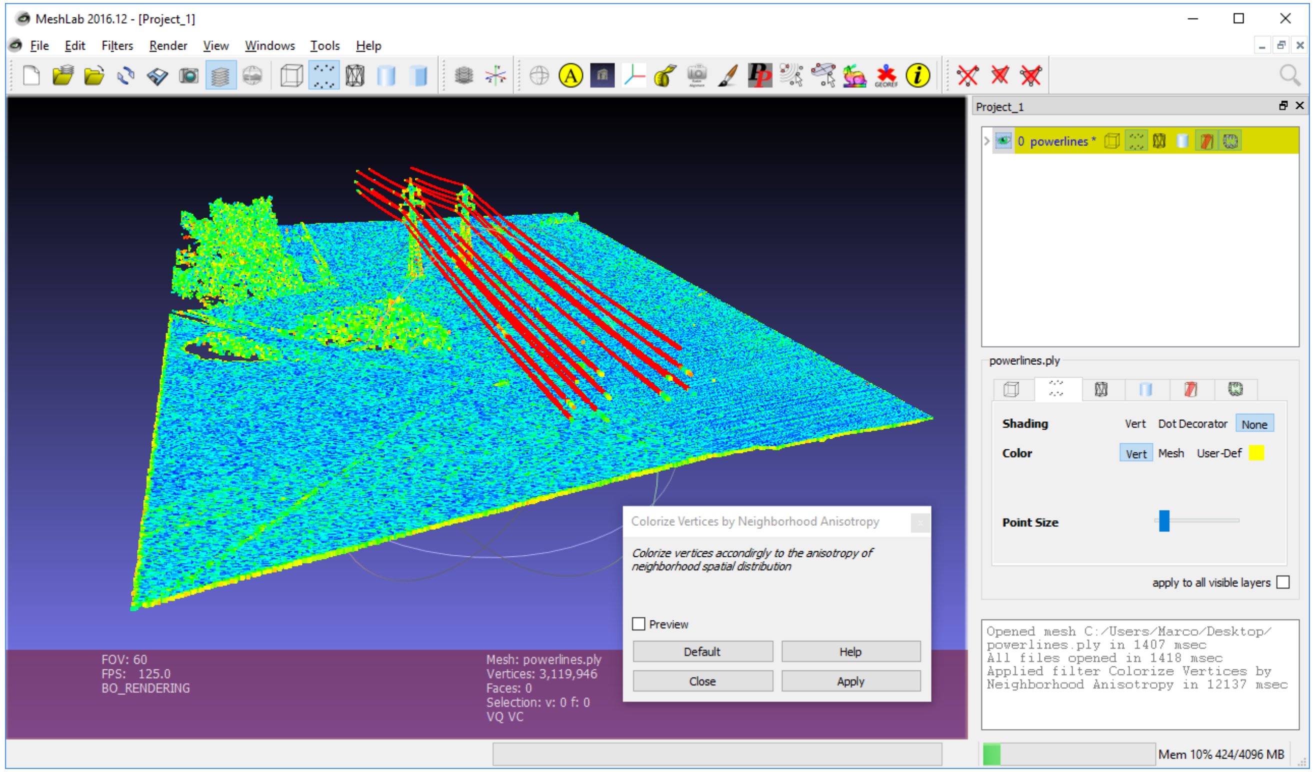
the covariance matrix tell us
how the points are spread



very stringy



points distributed in a sphere



$$\lambda_{imax} = \max\{\lambda_1, \lambda_2, \lambda_3\}$$

$$\text{stringy} = \frac{\lambda_{imax}}{\max\{\{\lambda_1, \lambda_2, \lambda_3\} \backslash \lambda_{imax}\}}$$

If the points are distributed along a line, we will have one eigenvalue much larger than the other two.
If the points are on a plane, we will have two similar egenvalues and a third one very small.

SCIADRO
- *BRLoS, BVLoS: Multipath Communications*

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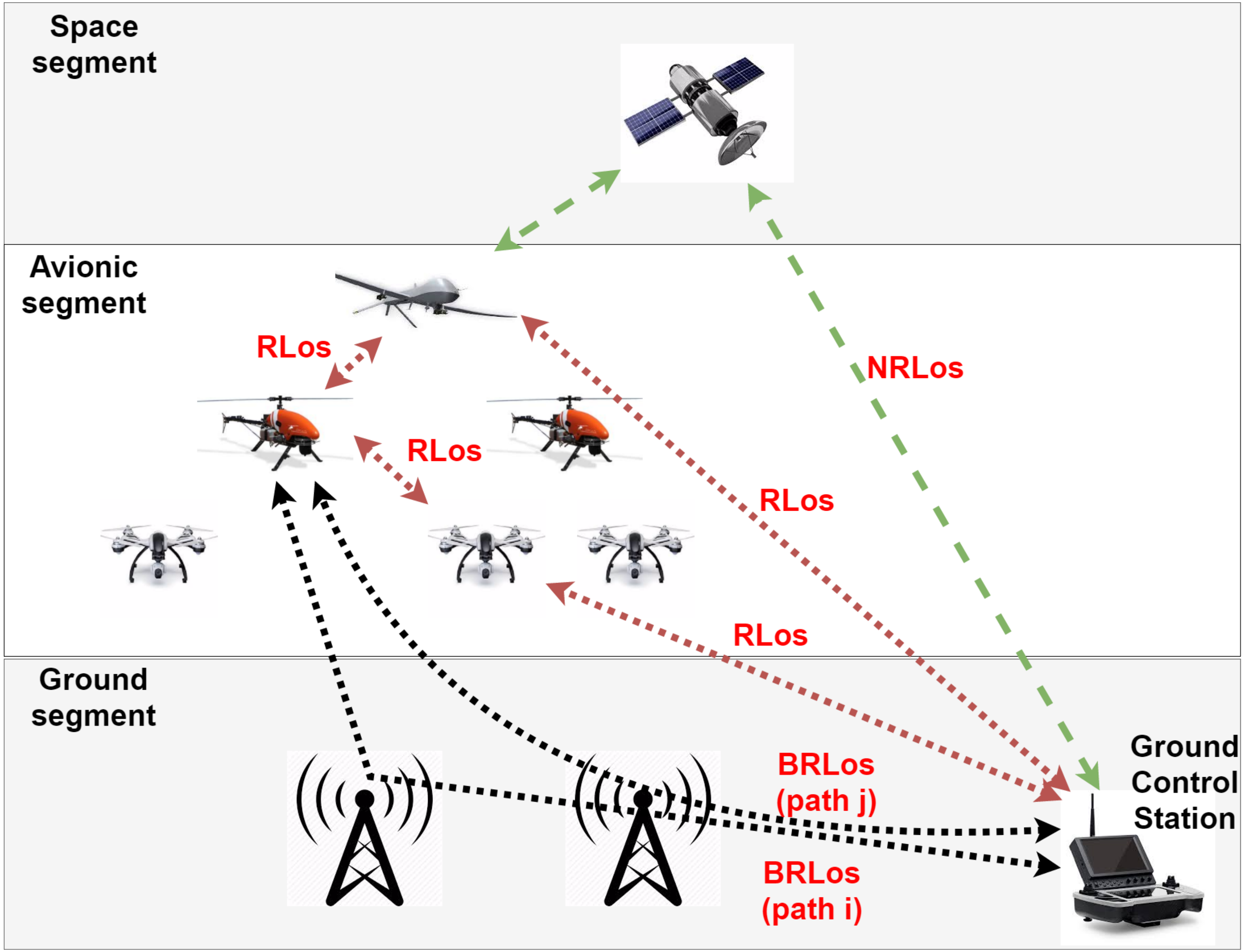
Joint use of multiple communication links in a coordinated manner

- a *logical* link composed of *n physical* links
- necessity of a scheduler to handle *splitting* and *join* operations in a transparent way

1. **High capacity:** multiple low cost and low bandwidth links in use in a coordinated manner
2. **Fault tolerance:** if the active link goes down, backup links can be activated
3. **Low(er) cost:** no need for an expensive and high capacity link with stringent QoS requirements

Multipath communications with UAVs



Los: Line of sight
RLos: Radio Los
NRLos: Non Radio Los
BRLos: Beyond Radio Los

Total bandwidth (without RLoS) = BRLos(i) + BRLos(j) + NRLos

Multipath communications MP-RTP

MP-RTP using a smart scheduler

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Multipath RTP with Network Coding: NC-MPRTP

Future directions (MISE 5G)

- Use of public infrastructure (e.g. 4G/5G cellular networks) to control an UAV (or a swarm) or its payload

- Multipath tecniques in scenarios with joint use of UAVs and nanosatellites to design a low cost architecture able to provide services / applications

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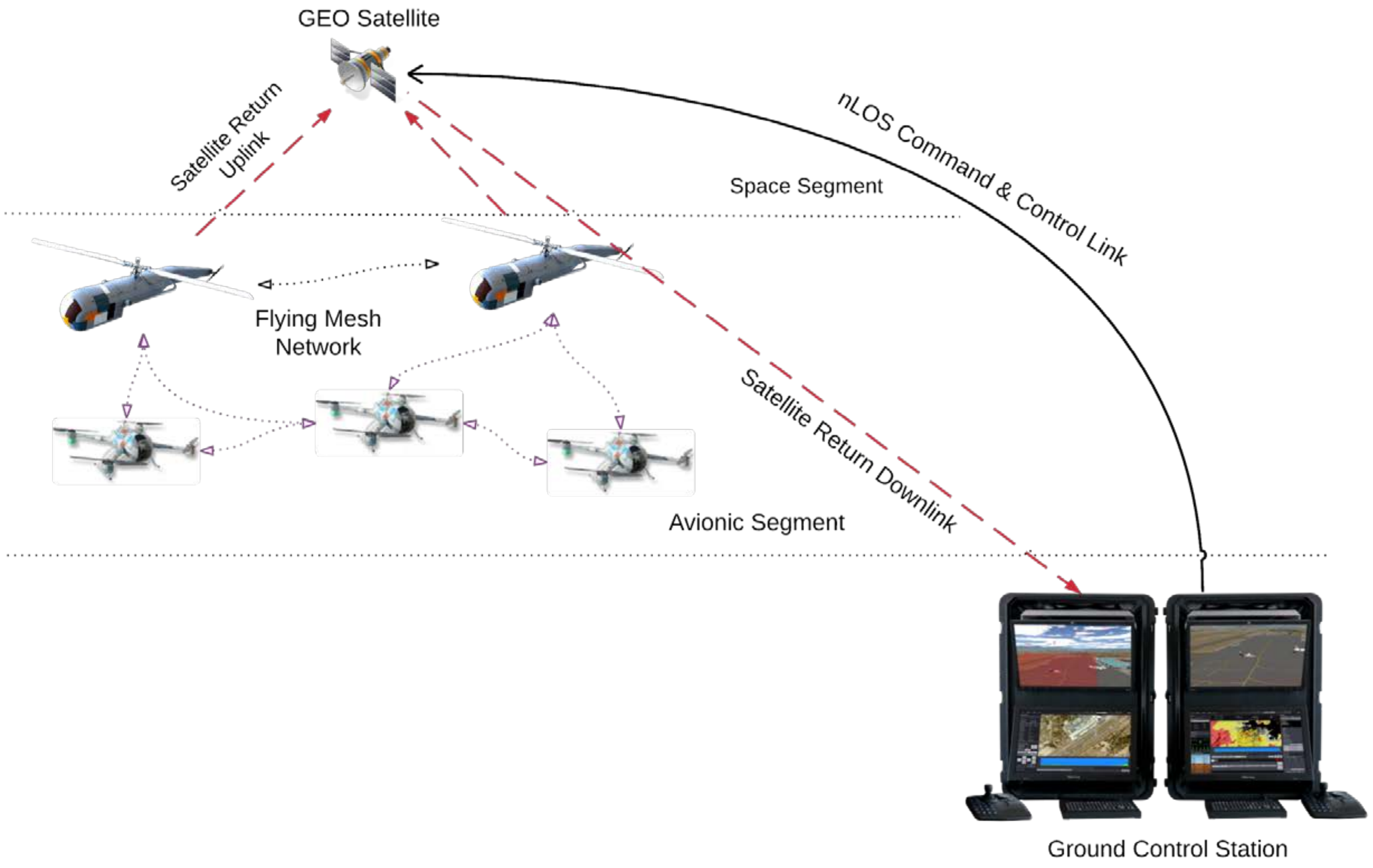
Multi-homed network architectures for flying ad-hoc networks and nano-satellite swarms



Multi-homed network architectures for flying ad-hoc networks and nano-satellite swarms

- Performance Evaluation of a SATCOM system that:
  - uses Geostationary Earth Orbit (GEO) SAT
  - foreseen for small and mid-sized UAVs
  - remote sensing/monitoring on a global scale and from geographically-distant locations
  - effectively manages the multiple access of a small UAV swarm to the satellite infrastructure
- Development and Testing of a vertical solution for M2M message exchange based on the standard ETSI CoAP.
  - UDP-based
  - Confirm delivery/ best effort traffic
  - DVB-RCS2 RA
- Comparison with alternative approaches (information centric) based on the PUB-SUB paradigm of MQTT.
  - TCP-based
  - Focused on the traffic from a publisher (UAV) to a broker (ground station)
  - DVB-RCS2 RA
- Simulation platform: S-NS3
  - development of a CoAP agent on NS3
  - development of a MQTT agent on NS3
- Metrics:
  - message delivery delay/completion time
  - overhead
  - reliability: comparison between application and transport layer recovery mechanisms.

SATNEX IV

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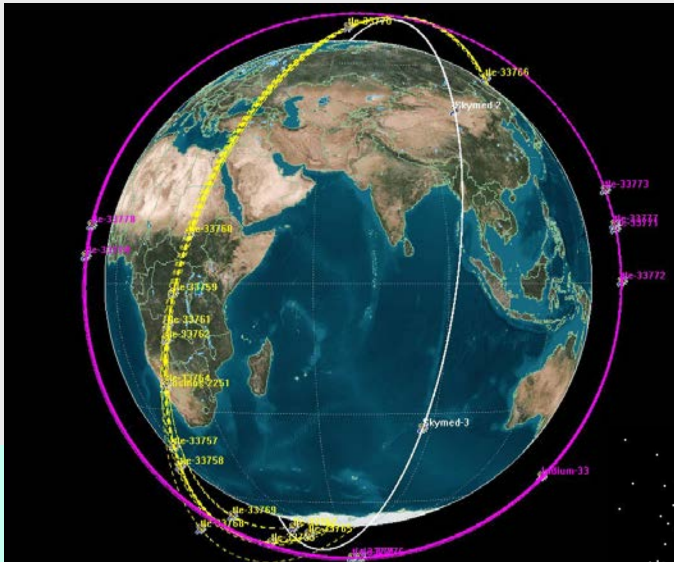
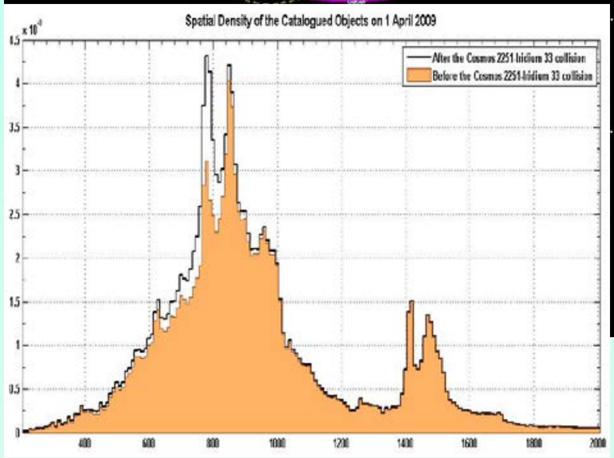
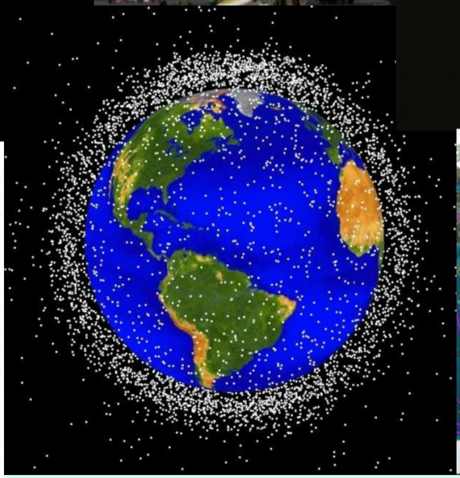
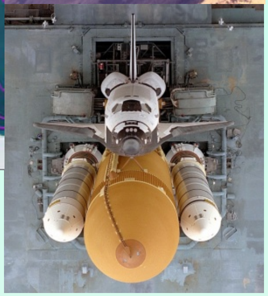
Space Flight Dynamics Laboratory







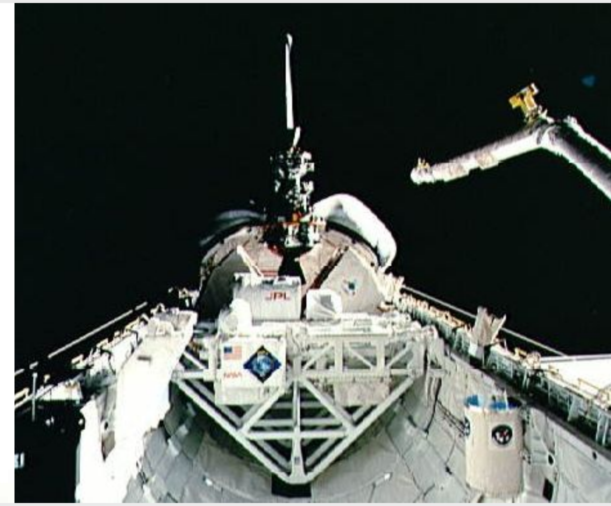


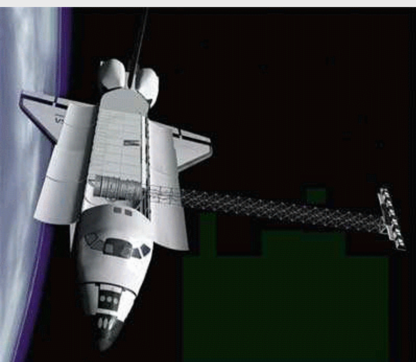


L. Anselmo & C. Pardini
Istituto di Scienza e Tecnologie dell'Informazione (ISTI)

LABORATORY HERITAGE

- Since 1975, support to national and international space projects on:
  - **Orbital dynamics**
  - **Mission analysis**
  - **Flight control and on-orbit operations**
  - **Ground stations planning**

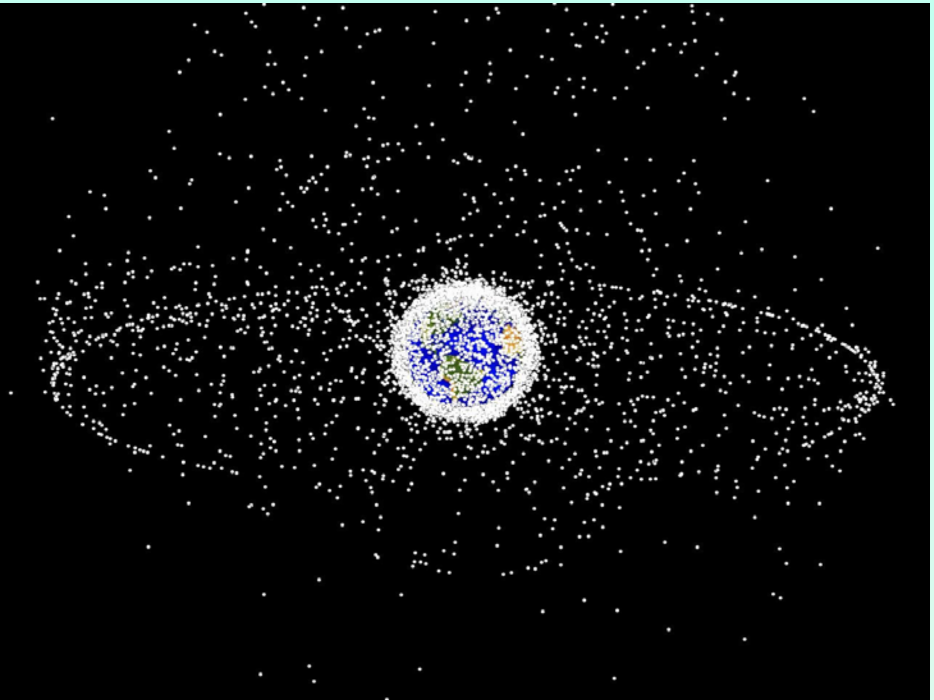




- Orbital management of the first Italian geostationary spacecraft (SIRIO)
- Participation in the phase B2 of Columbus, the European contribution to the International Space Station
- Mission analysis and operational support, at the Mission Control Center in Houston (NASA/JSC), to four Space Shuttle flights (IRIS/LAGEOS-2, two X-SAR/SIR-C, SRTM)
- Support to the ASI ground station in Malindi (Kenya)

CURRENT MAIN ACTIVITIES (I)

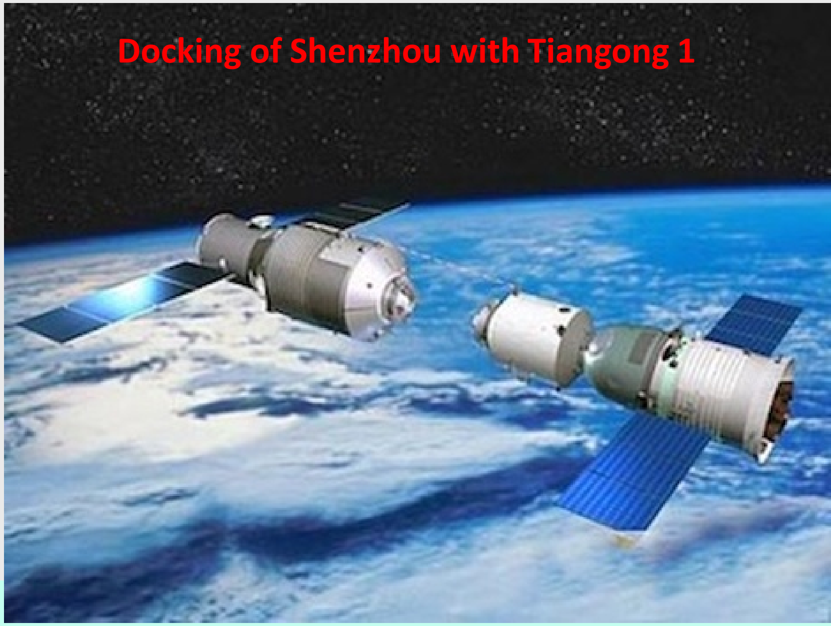
- **Satellite Re-Entry Predictions:** re-entry predictions of potentially risky space objects for ASI and the Italian Civil Protection authorities, performance evaluation of different atmospheric density models, software development, participation in the international re-entry test campaigns promoted by the Inter-Agency Space Debris Coordination Committee (IADC), re-entry predictions and risk assessment for Italian satellites, emergency management

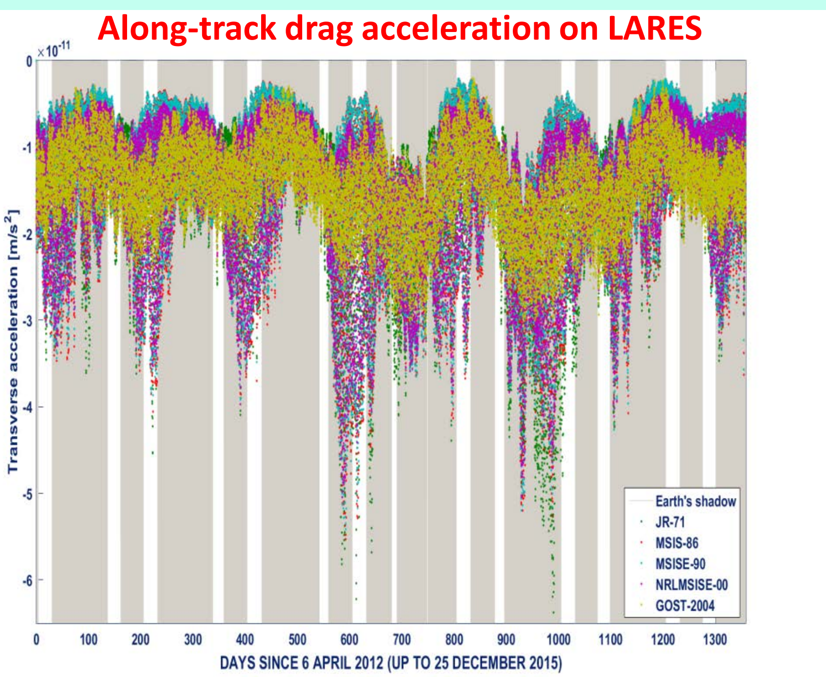


- **Space Debris:** orbital debris environmental models, debris clouds dynamics, modeling of sources and sinks, traffic models, short and long term evolution in low earth and geostationary orbit, satellite constellations, evaluation of impact risk, assessment of mitigation and remediation measures effectiveness, spaceborne tethers survivability, support to space projects and operations, development of software tools, space surveillance, participation in international committees and working groups

CURRENT MAIN ACTIVITIES (II)

- **Space Mission Analysis, Design and Operational Support:** trajectory design, mission planning, ground system requirements, flight dynamics software, orbital perturbations, mission constraints, trajectory determination, flight dynamics operational support, and orbital and coverage analysis for the ASI Malindi ground station (in Kenya) during the Chinese missions of the manned (Shenzhou, Tiangong, Tianzhou) and lunar exploration (e.g. Chang'e 5-T1) programs

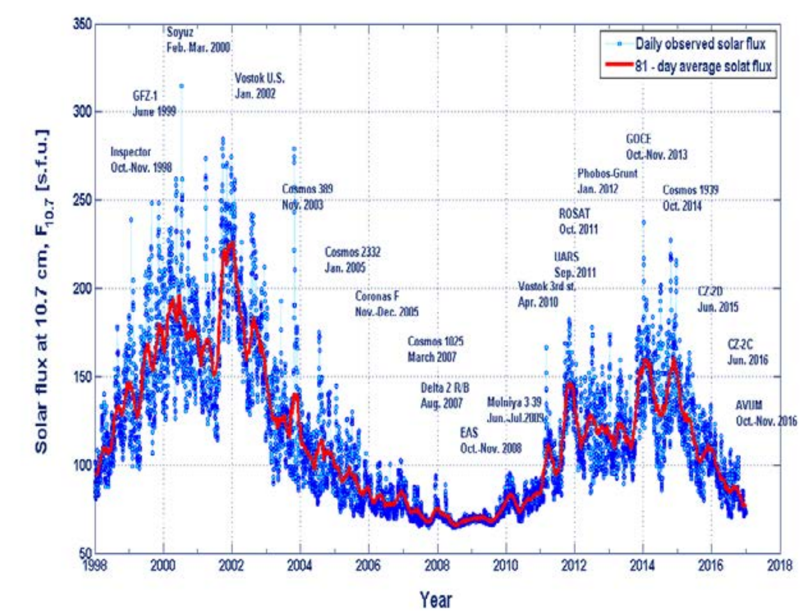




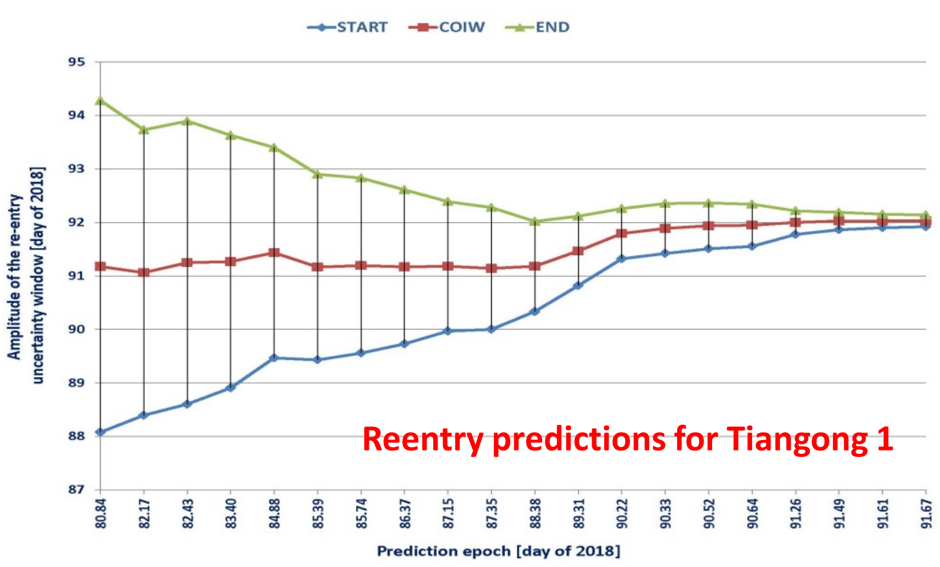
- **Astrodynamics and Space Experiments on Fundamental Physics:** accurate modeling of the orbital motion of satellites for scientific investigations, tests of General Relativity and alternative theories for gravitation, modeling of the effects of non-gravitational perturbations (e.g. atmospheric drag and radiation pressure), accurate and precise orbit determination of laser ranged satellites (e.g. LAGEOS, LAGEOS II and LARES)

REENTRY PREDICTIONS

- Since 1979, the laboratory carried out all the reentry campaigns of potentially hazardous space objects for the Italian civil protection authorities
- 2 nuclear emergencies (Cosmos 1402 and 1900), 4 space stations (Skylab, Salyut 7/Cosmos 1686, Mir, Tiangong 1), 2 Progress cargo ships, 1 very massive satellite (UARS), ~40 campaigns in total
- ISTI (C. Pardini) has been the Italian Technical Contact Point for the 22 reentry campaigns promoted by the Inter-Agency Space Debris Coordination Committee (IADC) since 1998



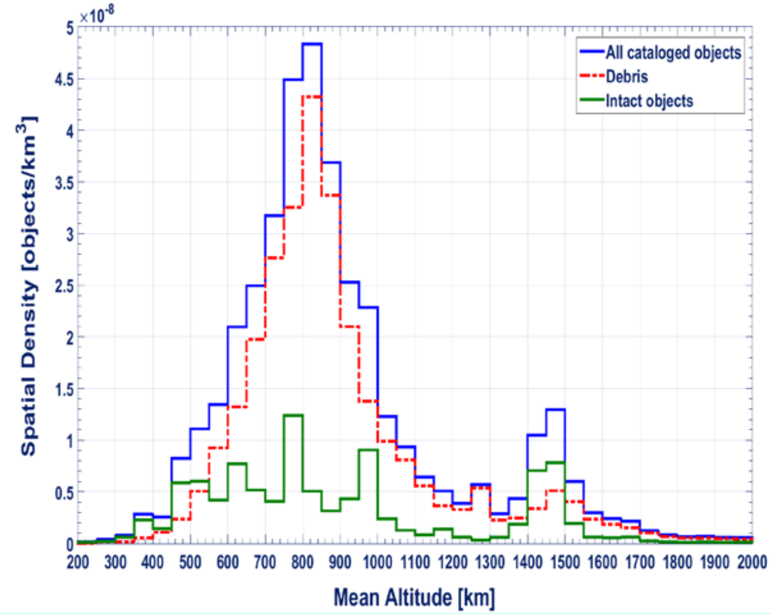
- Over the years, specific procedures and products for civil protection applications were developed and applied
- The error sources and uncertainties affecting the reentry predictions of uncontrolled space objects were extensively evaluated
- The performances of the thermospheric density models were tested in every condition of solar and geomagnetic activity

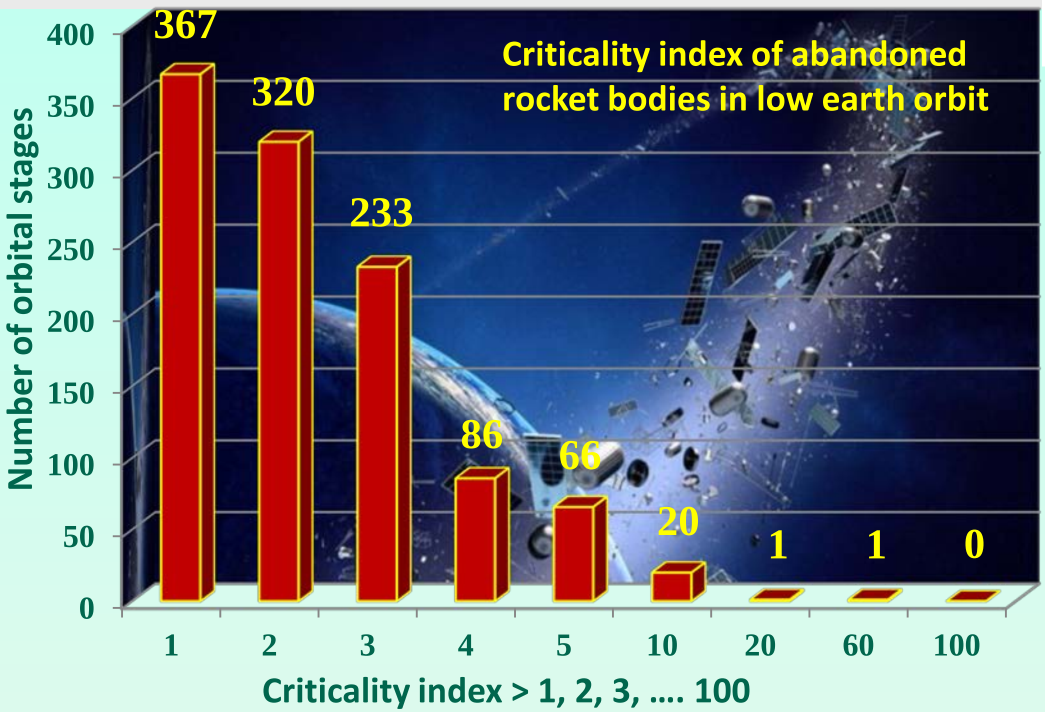


Reentry predictions for Tiangong 1

SPACE DEBRIS

- Since 1999, participation, on behalf of ASI, in the activities of the Inter-Agency Space Debris Coordination Committee (IADC)
- Representatives in WG2 (Modeling and Database), in WG4 (Mitigation) and in the Steering Group
- Short, medium and long term modeling of the debris environment around the earth
- Evaluation of the effectiveness of mitigation measures and remediation activities

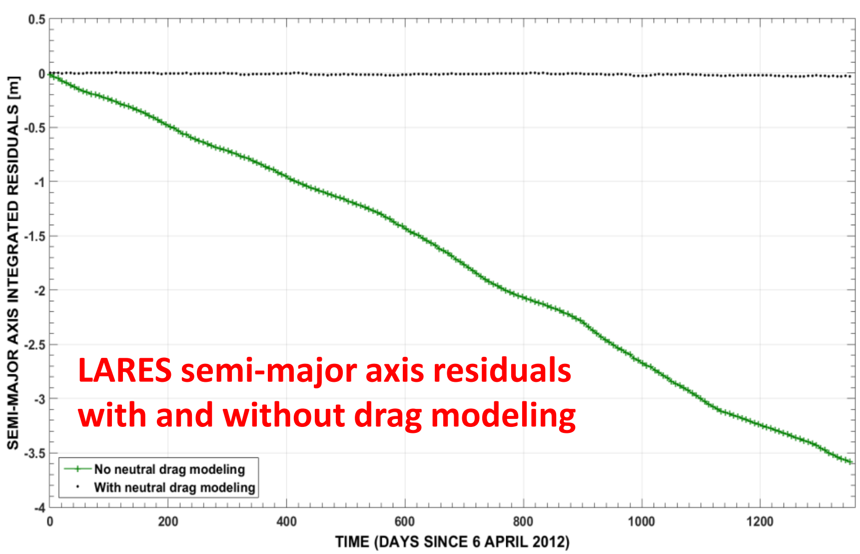




- Studies to support mitigation guidelines and standards
- Development of indexes to evaluate criticality thresholds and the adverse impact of new systems, as large satellite constellations, on the environment
- Statistical collision risk evaluation
- Analysis of end-of-life disposal orbits
- Ranking of potential targets for active debris removal

THE LARASE EXPERIMENT

- The LAser RAnged Satellites Experiment (LARASE) main goal is to provide accurate measurements for the gravitational interaction in the weak-field and slow-motion limit of General Relativity
- This is obtained by means of a very precise laser tracking of geodetic satellites orbiting around the earth (the two LAGEOS and LARES)
- The accurate modeling of non-gravitational perturbations acting on the satellites is of paramount importance, considering the smallness of the effects to be measured, like the Lense-Thirring one



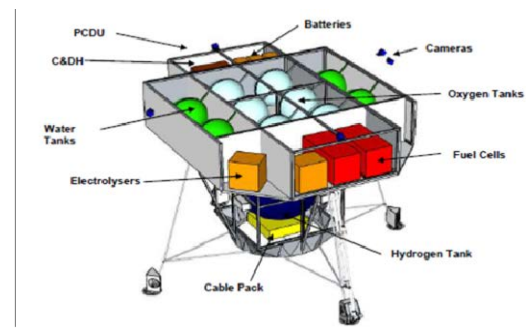
- Among many other things, the neutral drag force acting on LARES was estimated with several thermospheric density models
- It accounts for nearly all (~99%) of the observed semi-major axis decay, approximately 1 meter per year
- The analysis is being extended to longer intervals and to the LAGEOS satellites

Power Technologies: Polymer Electrolyte Fuel Cells (PEFC)

cnr DIITET
Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

<u>Objective:</u> design a **Polymer Electrolyte Fuel Cell** system able to operate in space/low gravity conditions to replace battery. It must power, in smaller scale, a surface vehicle (lunar rover) and a ground station (lunar base) during the 14-days long night on the moon. This target has to be achieved increasing performance and reliability at a cheaper cost and significantly reduce the abandoned objects (battery) at the system end-of-life. Furthermore, the system has to be operated using standard components and in closed-loop mode, where there is no exchange with the external environment other than an input of radiation from the sun and a radiative heat exchange with the outer space.

Artistic view of the Lunar Rover and the Lunar Base



Power Technologies: Polymer Electrolyte Fuel Cells (PEFC)

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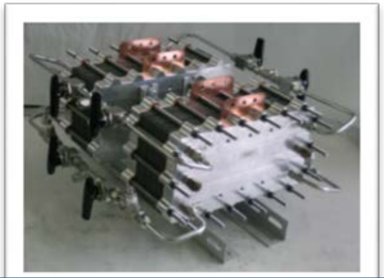
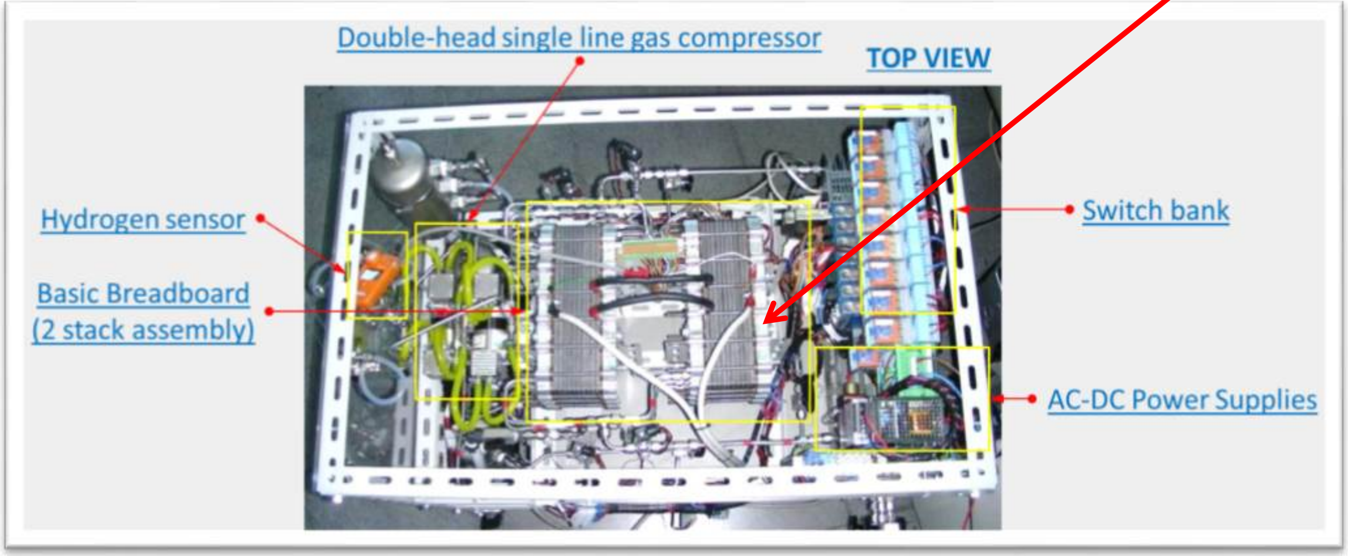
A fully independent closed-loop integrated system has been designed and assembled, including a high efficiency 1 kW PEFC stack, an electrolyser, storage tanks and testing/management software.

Hydrogen and oxygen are produced in the electrolyser out from pure water, powered by the solar energy during the 14-days long lunar day, and stored as compressed gas.

Hydrogen and oxygen are used in the PEFC stack during the 14-days long lunar night, producing the water back to the electrolyser.



1 kW high performance PEFC stack



Power Technologies: Polymer Electrolyte Fuel Cells (PEFC)

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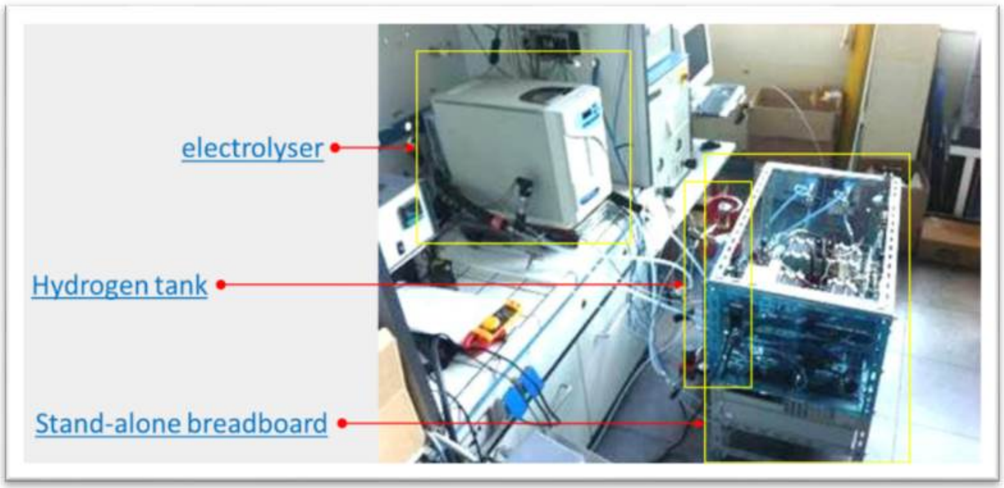
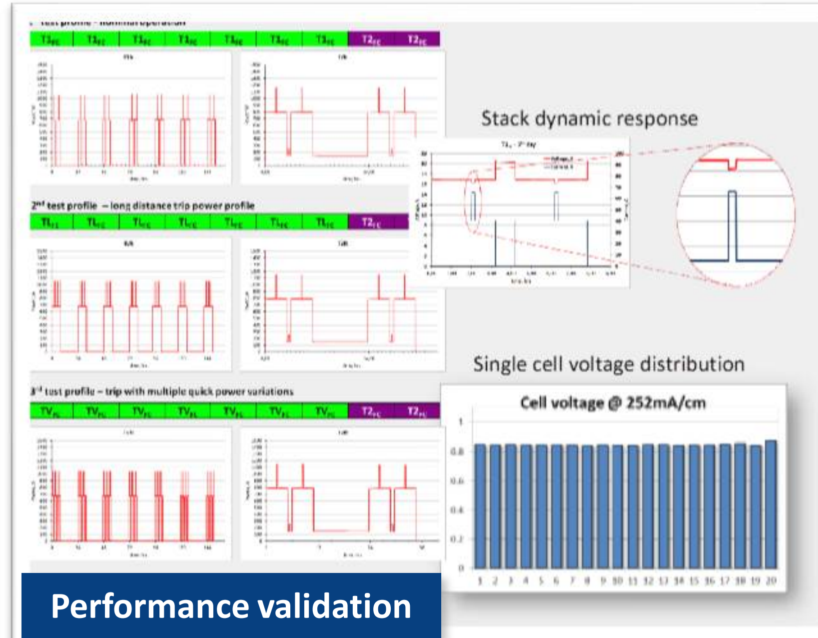
integrated PEFC system





Scientific Impact/Results: The closed-loop system has achieved all the project targets, providing important inputs for design and on critical conditions which might lead to a critical failure. The design has been validated and enhanced, after providing the evidence that some gravity/orientation test led to critical failure and stack flooding. It has demonstrated that it is possible to design and a high performance PEFC system integrated with a PV power source in space conditions, including challenging operations.

These systems can also be used to power any air-independent power system, such as advanced drone

Power Technologies: Solid oxide Fuel Cells and Electrolysers (SOFCs, SOECs)

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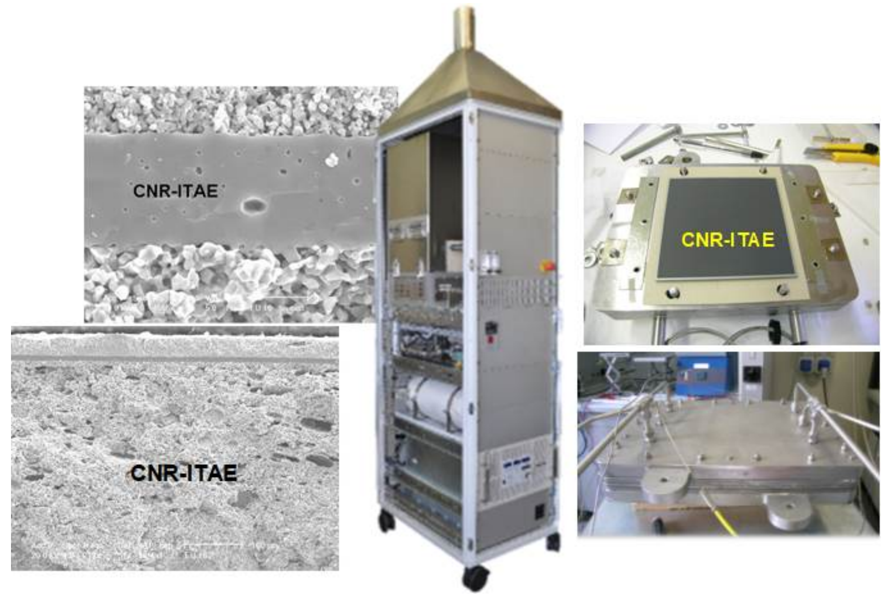
Objectives:

• **Solid Oxide Fuel Cells and Electrolysers** are based on *ceramic materials* and operate at high temperatures (800 ° C) for conversion of fuels, into electrical energy and to produce fuels and oxygen (from H_2O and CO_2) using an energy supply.

• Relevant applications are auxiliary power units, combined heat and power, etc..

The challenges are regarding the reduction of the operation temperature and the enhancement of stability under aerospace applications.

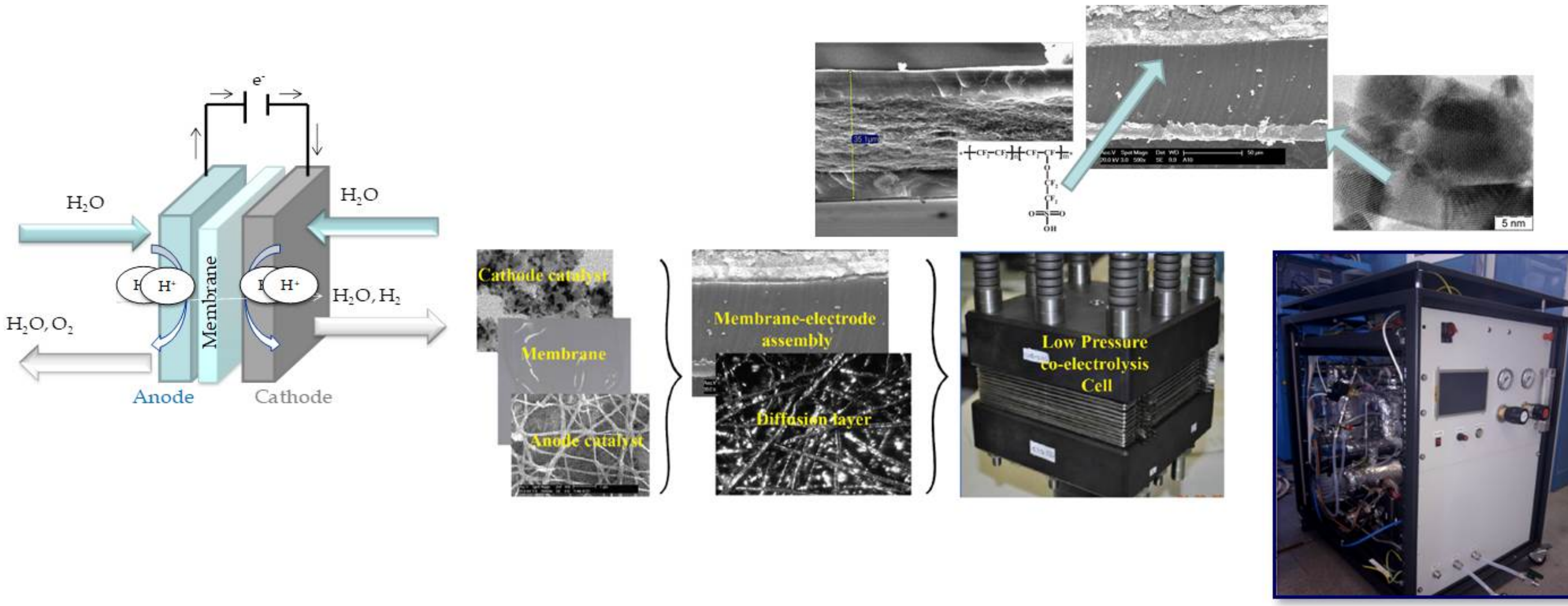


Approach:. The approach is to develop ceramic electrolytes for intermediate temperature operation based on ceria and gallates, use of a multifunctional electrocatalytic layer to favour internal fuel processing and tailor the composition of perovskites for the oxygen process.

Scientific Impact/Results: The new materials and cell architectures have been validated for the direct utilization of organic fuel for APU applications in systems up to 2 kW power and for co-electrolysis applications.

Power Technologies: PEM Electrolysis for H_2 and O_2 generation.

Polymer electrolyte water electrolysers and co-electrolysers can provide enhanced dynamic behaviour (rapid start-up, fast response, wider load and temperature ranges) for aerospace applications.



Enhanced performance and cost-effective materials for PEM water and CO_2 electrolysers are currently developed with the aim to achieve efficient and cost-effective production of hydrogen, sustainable fuels and oxygen.

H2020 EU Projects

LOTERCO2M — https://www.loterco2m.eu/

NEPTUNE — http://www.neptune.eu

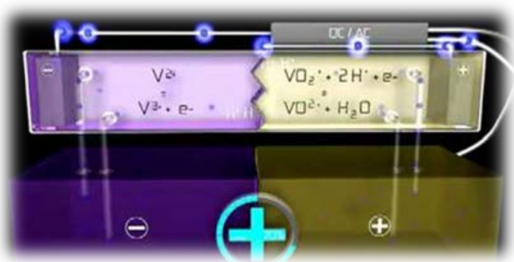
HPEM2GAS — http://www.hpem2gas.eu

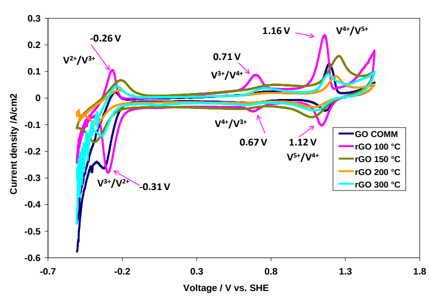
Power Technologies: Batteries and Storage Devices

Consiglio Nazionale delle Ricerche
Engineering, ICT and Technologies for Energy and Trasportation Department

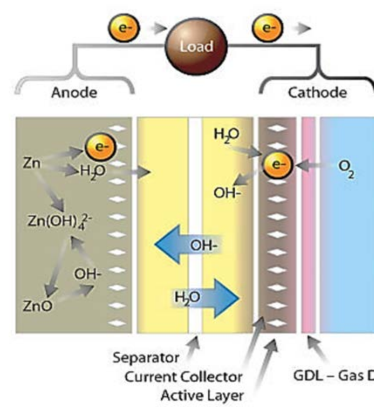
Objectives:

- Innovative and highly performant materials and components for electrochemical storage devices (**Vanadium Redox Flow, Sodium-ions, Iron-Air, Sodium-Nickel Chloride batteries and supercapacitors**) from battery cell level up to kW battery for aerospace applications.
- Improvement of electrochemical performance in terms of current and power density, round-trip efficiency and cycling.





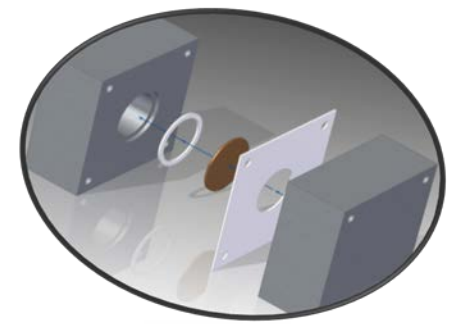
Vanadium Redox Flow Battery



$$O_2 + 2Fe + 2H_2O \underset{charge}{\overset{discharge}{\rightleftarrows}} 2Fe(OH)_2$$

$$3Fe(OH)_2 + \tfrac{1}{2}O_2 \underset{charge}{\overset{discharge}{\rightleftarrows}} Fe_3O_4 + 3H_2O$$

Metal-air Battery process



Na-NiCl2 innovative planar battery

20F - 3V

Supercap proof-of-concept

Power Technologies: Batteries and Storage Devices

Consiglio Nazionale delle Ricerche
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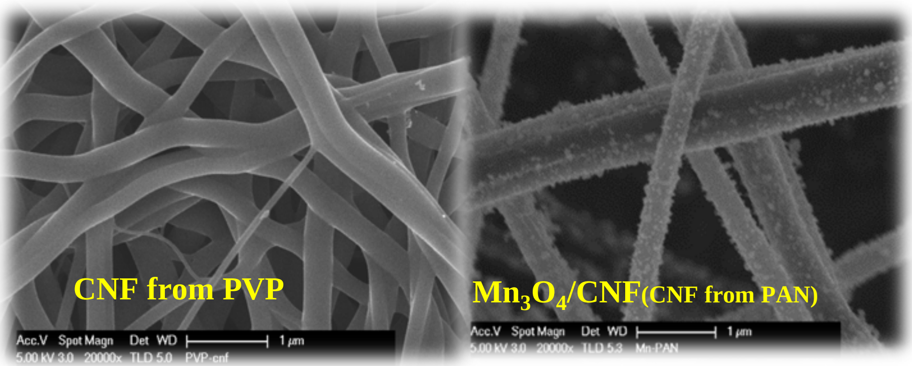
<u>Approach:</u>

- Low cost synthesis methods (**Electrospinning technique, Sol-gel, Hydrothermal)** of materials suitable for scaling-up.
- Low cost materials and components.



<u>Scientific Impact/Results:</u> Optimization of materials, components and design in order to overcome the state of the art of current storage technologies. Proof-of-concept of new electrochemical storage technologies.