Agenzia Spaziale Italiana

Italian national agency for new technologies, energy and sustainable economic development

13° workshop Tematico AIT-ENEA
Oratorio San Filippo Neri - Bologna
22-23 settembre 2022

Sessione 5: COPERNICUS e Piattaforme Servizi EOT
23 settembre 2022

Il programma ASI “SAR multi-missione e multi-frequenza” per lo sviluppo di algoritmi innovativi e l’integrazione di dati satellitari SAR a supporto di applicazioni di downstream scientifico

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Agenzia Spaziale Italiana (ASI)

National context & downstream

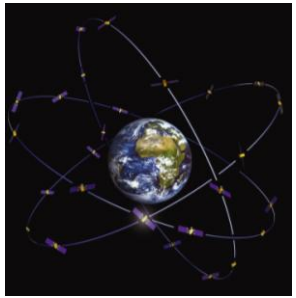
"Telecommunications, Earth Observation and Navigation" (TLC/EO/NAV) sector is the 1st by priority order within the Italian Government's guidelines on space and aerospace matters to achieve the strategic objectives of the national space policy [1].

TLC/EO/NAV satellite services and applications (the so-called "*downstream*") will be exploited by citizens and valorized by Institutions under an integrated application perspective.

[1] https://presidenza.governo.it/AmministrazioneTrasparente/Organizzazione/ArticolazioneUffici/UfficiDirettaPresidente/UfficiDiretta_CONTE/COMINT/DEL_20190325_aerospazio.pdf

ASI's Earth Observation missions and EC Copernicus Programme

Athena-Fidus



Galileo constellation

Scientific downstream

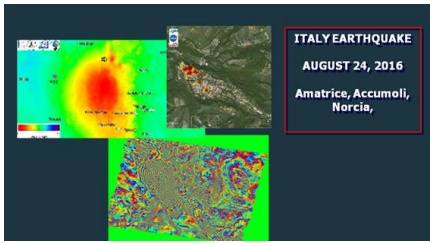
What is **"scientific downstream"**? Which role does satellite data-based geosciences play?

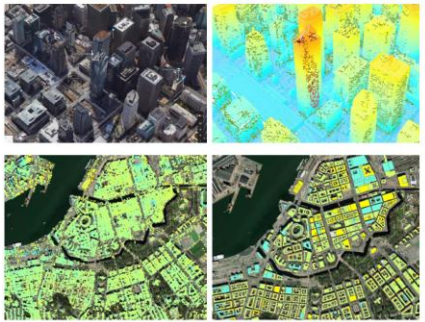
- *applications enabled by the exploitation of mature and validated algorithms that have been originally developed to answer scientific questions and/or retrieve geophysical parameters, and have been brought to the stage that they can generate products addressing specific user needs beyond scientific and academic purposes only*

- from Earth observations and data to information and products – SUCCESSFUL STORIES WITH SAR & InSAR!

Early 1990s - Science

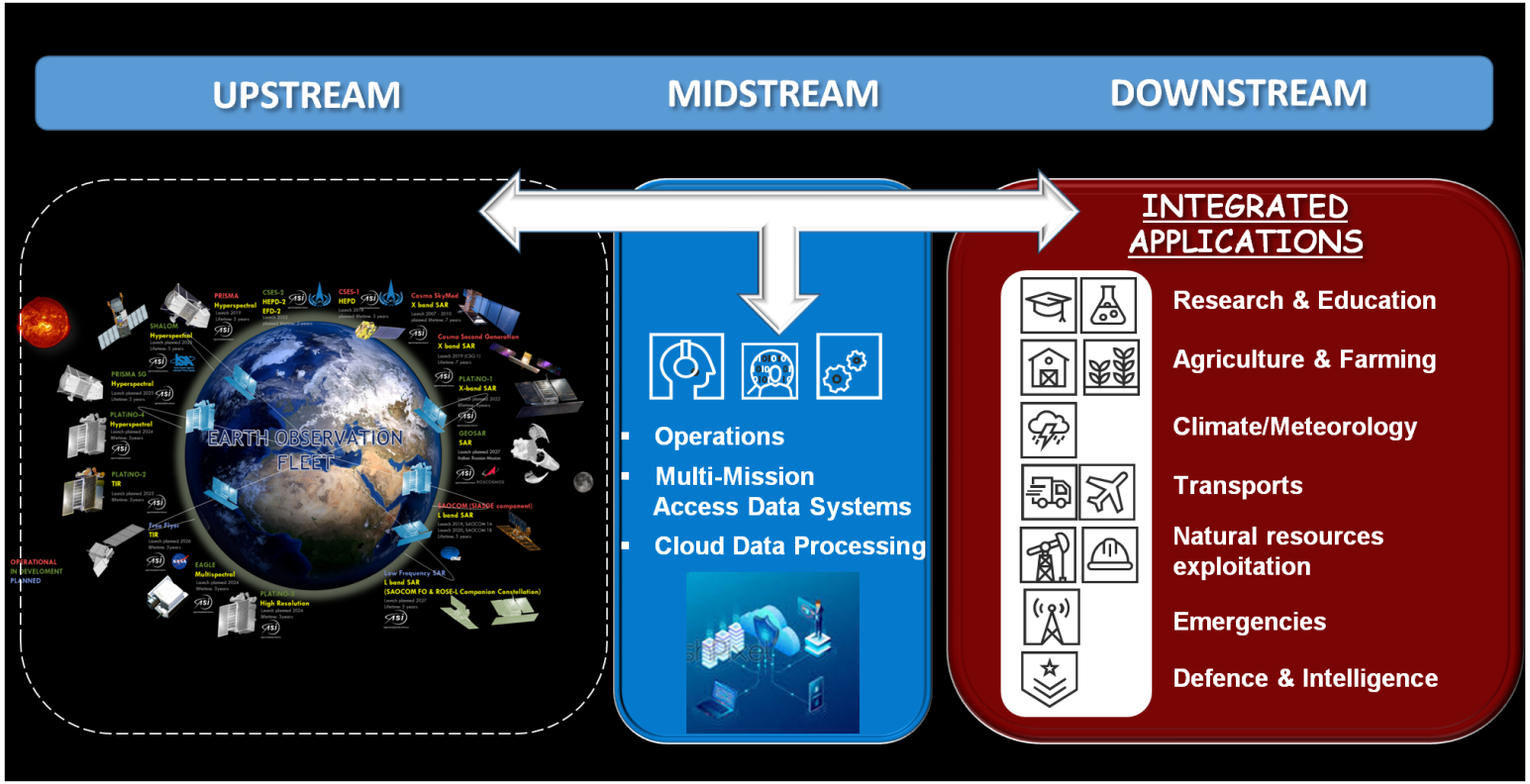
Today – operational products for civil protection & emergency response



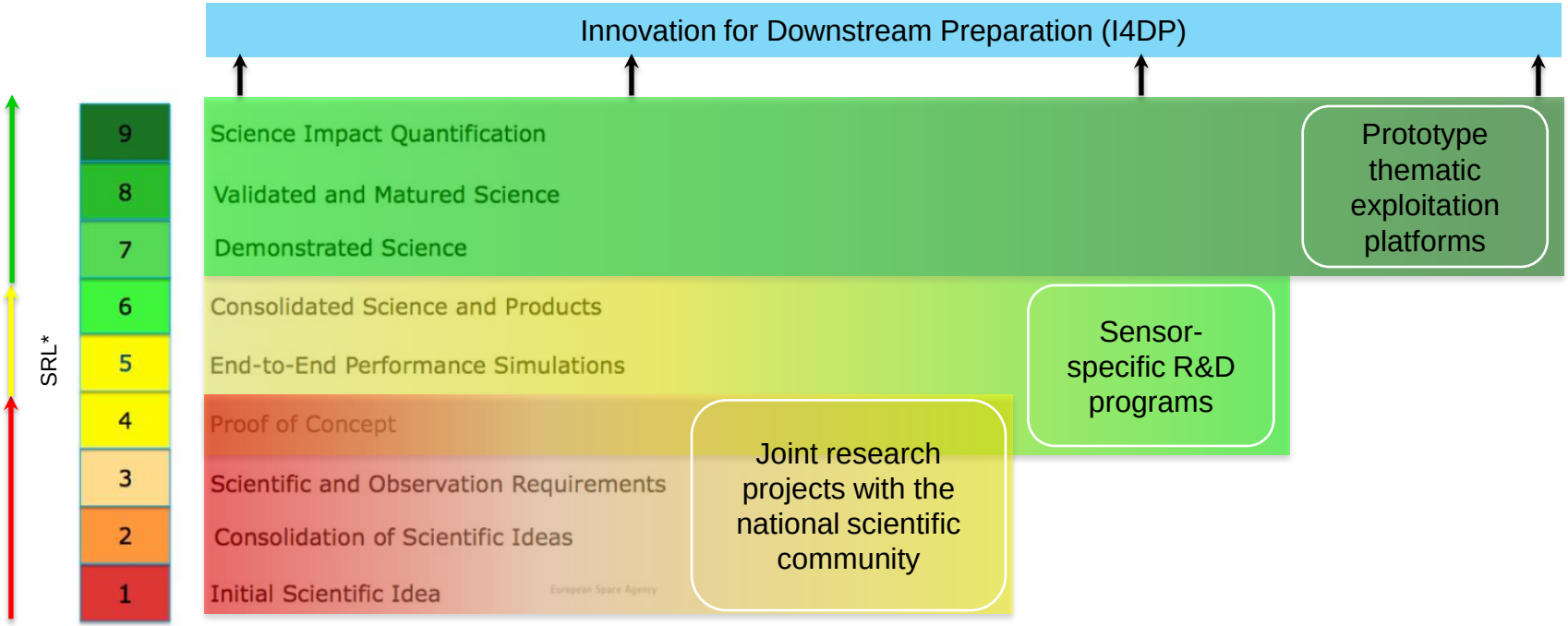


Today – value-added products & operational guidelines for users

From space assets to applications & services



ASI's initiatives & scientific downstream portfolio

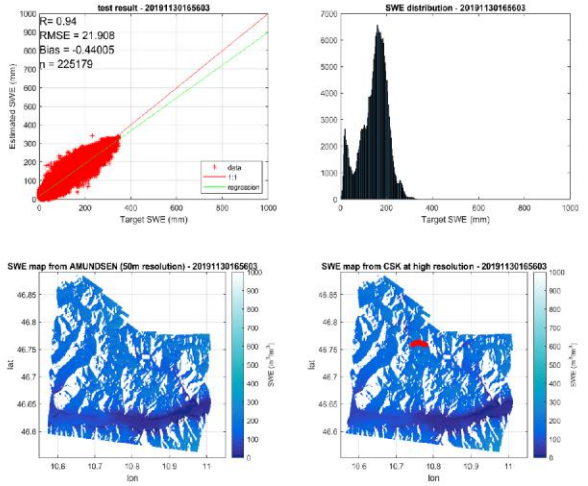


* SRL – *Scientific Readiness Level* as per the definition in the European Space Agency (ESA) SRL Handbook EOP-SM/2776

Joint research projects with the national scientific community

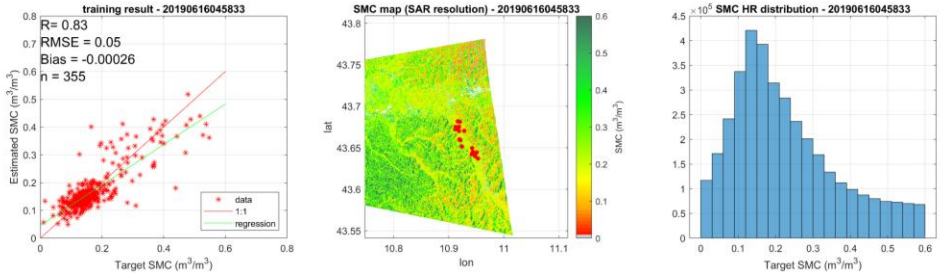
*"Development of algorithms for estimation and monitoring of **hydrological parameters** from satellite and drone"* (2019-2022) funded by ASI under grant agreement n. 2018-37-HH.0 (***"ALGORITHMS" project***)

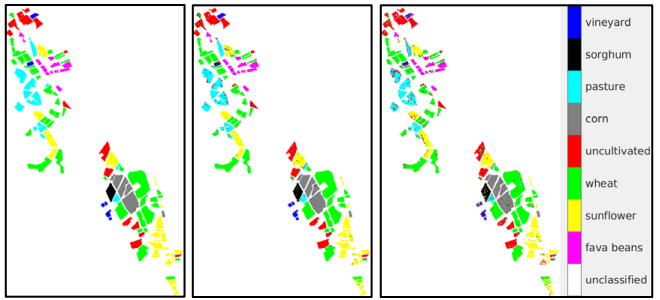
Snow Water Equivalent (SWE) map generation using COSMO-SkyMed StripMap and PingPong time series



Scan the QR code to request a copy of the paper

Soil moisture mapping at high resolution by merging SMAP, Sentinel-1 and COSMO-SkyMed data with the support of machine learning





Crop classification & early-season crop mapping using Sentinel-1 and COSMO-SkyMed data and convolutional neural networks

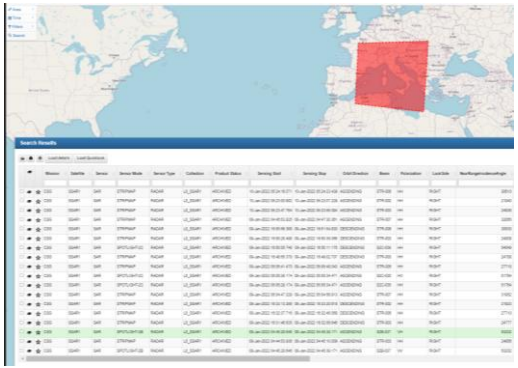
Sensor-specific R&D programs: Multi-mission & multi-frequency SAR

- **10 R&D projects** (from April 2021 to July 2023) about methods, techniques & algorithms for *exploitation* of multi-mission & multi-frequency SAR data, also integrated with other types of EO and/or non-EO data
- **Focus on L-band SAR (e.g. SAOCOM)**, also in relation to ASI-CONAE SIASGE cooperation
- **Pre-operational projects**, based on innovative ideas & algorithms, with credible perspectives of engineering and pre-operational development
- Update the background and needs of the SAR user community to support and define **medium-to-long term strategies** of new EO applications
- In turn, enable user-driven applications → **scientific downstream**
- Support the SAR-based research activities carried out by public and private national community – **also in cooperation with international partners** –, contributing to maintain a leading position within the international context

Facilitated accessibility to satellite SAR data

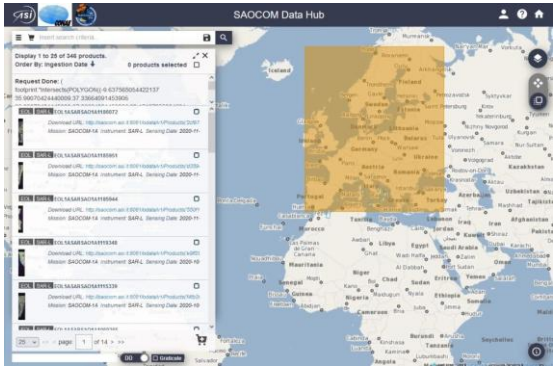
COSMO-SkyMed First & Second Generation (CSK & CSG)

- New portal for institutional users (https://portal.cosmo-skymed.it/CDMFE/home)
- Opportunity to task CSG to concatenate temporally and spatially with existing archive CSK images, and thus achieve observation continuity
- Over Italy, through MapItaly Project



SAOCOM

- New dedicated ASI portal (http://saocom.asi.it:8081)
- Data dissemination over the “Zone of Exclusivity” (ZoE; 10W-50E longitude range and 30-80N latitude range), currently via:
  - Archive imagery provision service
  - Beta-testing for ordering new acquisitions & products



R&D areas of specific interest & ASI projects

Agriculture

- SARAGRI
- CLEXIDRA

Urban areas

- MultiBigSARData

Natural hazards

- MUSAR
- MEFISTO
- DInSAR-3M

Cryosphere

- CRIOSAR
- SMIVIA

Sea & coast

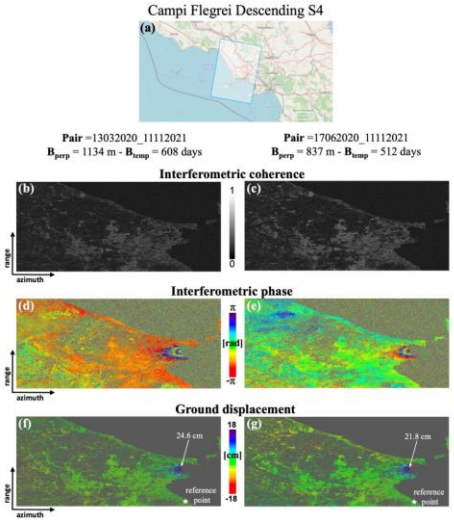
- APPLICAVEMARS
- COAST

Validation of products generated from multi-frequency SAR data by using ground-truth data

Natural Hazards - 1

- **Projects:**
  - **DInSAR-3M** (CNR-IREA & IRPI, Firenze Univ., “Parthenope” Napoli Univ., UniCuyo)
  - **MEFISTO** (CNR-IREA & IRPI, “Parthenope” Napoli Univ., Salerno Univ., UniCuyo)
  - **MUSAR** (NHAZCA S.r.l., CERI - “Sapienza” Univ. Roma)

- **Objectives:**
  - Novel InSAR routines to **process L-band SAOCOM data** and integrate with X-/C-band consolidated InSAR products;
  - Improved InSAR and TomoSAR methods, for applications also in rural and vegetated areas;
  - 3D surface deformation maps, by means of integration / data fusion approaches, **also applied to airborne data**;
  - Automated classification of deformation processes via machine learning methods



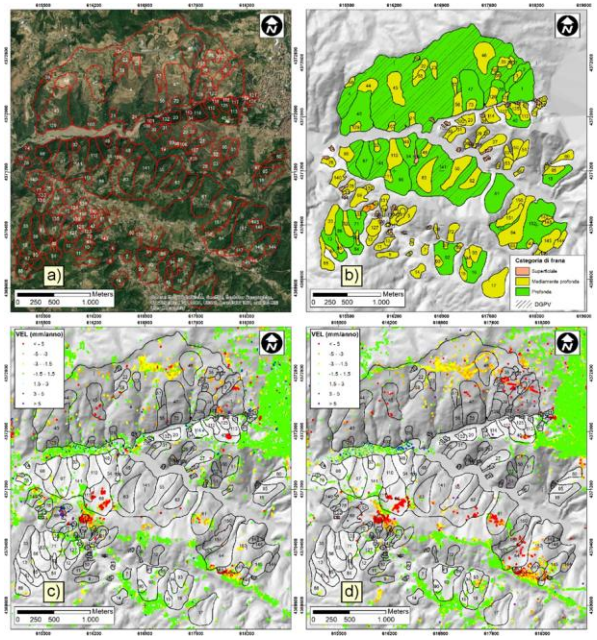
Preliminary tests on the quality of the interferometric products following the phase unwrapping procedure applied to SAOCOM-L1A interferograms, over the Campi Flegrei Caldera test site (**image courtesy CNR-IREA, DInSAR-3M project**). Product produced from Original SAOCOM Product - ©CONAE – COMISION NACIONAL DE ACTIVIDADES ESPACIALES (2020-2021)

L-band Tx/Rx antenna layer of the new Italian airborne Multiband Interferometric and Polarimetric SAR (MIPS) system

Natural Hazards - 2

- **Projects:**
  - DInSAR-3M (CNR-IREA & IRPI, Firenze Univ., “Parthenope” Napoli Univ., UniCuyo)
  - **MEFISTO** (CNR-IREA & IRPI, “Parthenope” Napoli Univ., Salerno Univ., UniCuyo)
  - **MUSAR** (NHAZCA S.r.l., CERI - “Sapienza” Univ. Roma)

- **Objectives:**
  - Novel InSAR routines to process L-band SAOCOM data and integrate with X-/C-band consolidated InSAR products;
  - **Improved InSAR and TomoSAR methods, for applications also in rural and vegetated areas**;
  - 3D surface deformation maps, by means of integration / data fusion approaches, also applied to airborne data;
  - Automated classification of deformation processes via machine learning methods

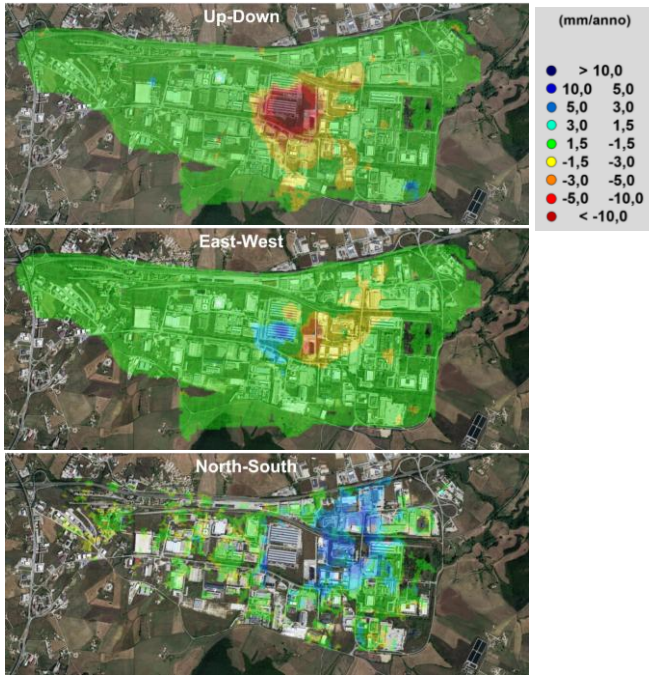


(Upper left) Landslide inventory map of the Acri area; (Upper right) preliminary typified landslides through geological and geomorphological features; (Lower left) map of the mean deformation velocity generated with the Sentinel-1 data; (Lower right) map of the mean deformation velocity generated with the COSMO-SkyMed data. **Image courtesy CNR-IREA, MEFISTO project**.

Natural Hazards - 3

- **Projects:**
  - DInSAR-3M (CNR-IREA & IRPI, Firenze Univ., “Parthenope” Napoli Univ., UniCuyo)
  - **MEFISTO** (CNR-IREA & IRPI, “Parthenope” Napoli Univ., Salerno Univ., UniCuyo)
  - **MUSAR** (NHAZCA S.r.l., CERI - “Sapienza” Univ. Roma)

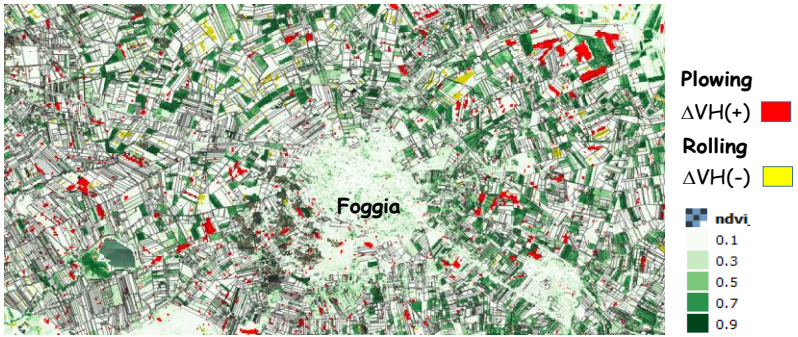
- **Objectives:**
  - Novel InSAR routines to process L-band SAOCOM data and integrate with X-/C-band consolidated InSAR products;
  - Improved InSAR and TomoSAR methods, for applications also in rural and vegetated areas;
  - 3D surface deformation maps, by means of integration / **data fusion approaches**, also applied to airborne data;
  - Automated classification of deformation processes via machine learning methods



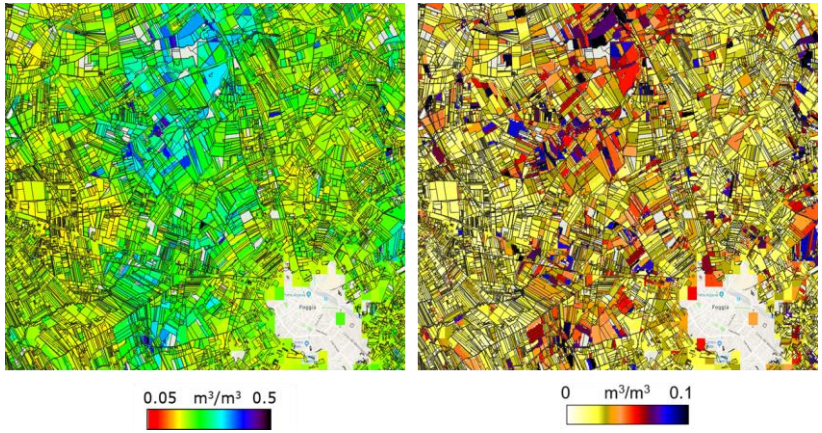
Preliminary tests on the estimation of 3D displacement components achieved through data fusion of COSMO-SkyMed and Sentinel-1 Persistent Scatterers in a built-up area affected by subsidence (**image courtesy NHAZCA S.r.l., MUSAR project**).

Agriculture

- **Project:** **SARAGRI** (CNR-IREA, CREA, ITACyL)
- **Objectives:** Consolidate and validate algorithms for the retrieval and monitoring of:
  - surface soil moisture (SSM)
  - vegetation water content (VWC)
  - irrigation extent
  - tillage practices



Map of temporal changes (22-28/07, 2021) of VH S-1 data onto a NDVI S-2 image, highlighting rolled and ploughed fields in the Apulian Tavoliere (Italy).

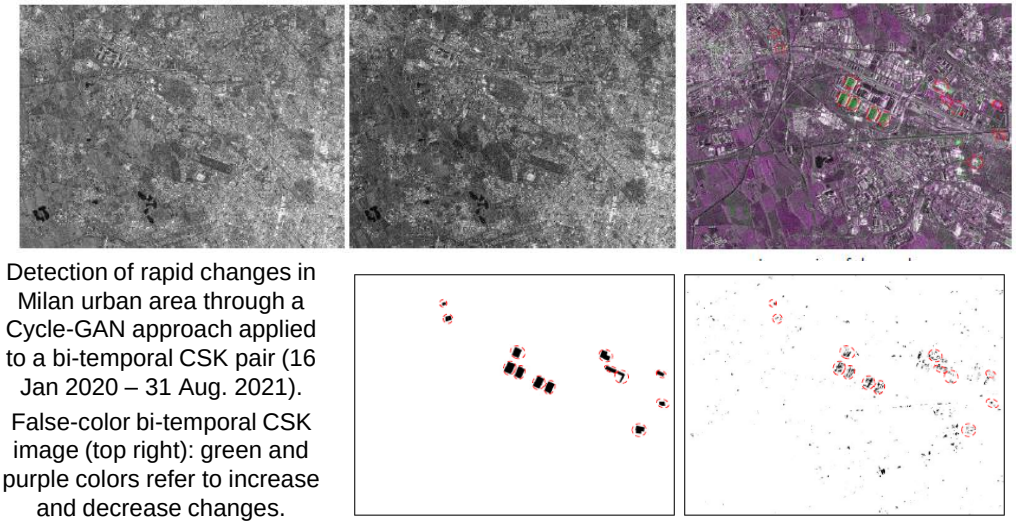


SSM maps at “field scale” (~0.1 km resolution) derived from S-1 & S-2 data acquired over the Apulian Tavoliere (Italy) on 25/08/2018. (a) Mean SSM; and (b) SSM standard deviation.

Images courtesy CNR-IREA, SARAGRI project

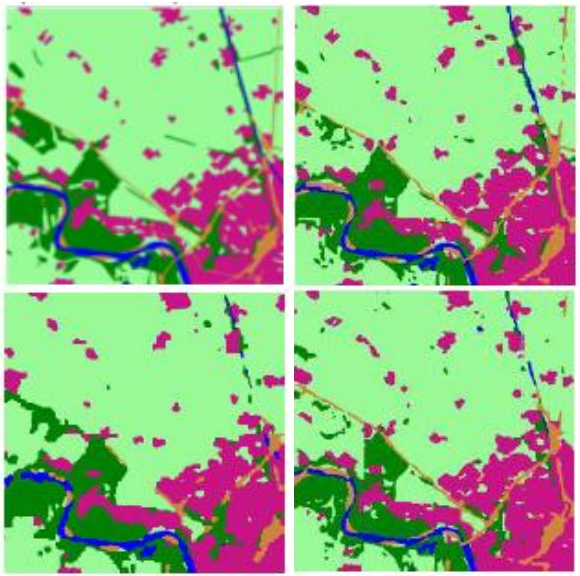
Urban Areas

- **Project:** **MultiBigSARData** (Pavia Univ., Genova Univ., FBK, Exprivia S.p.A.)
- **Objectives:** a) develop ad hoc pre-operative software prototypes to combine SAR data, techniques and products based on Artificial Intelligence approaches; b) retrieve indexes and proxy parameters for risk analysis.



Detection of rapid changes in Milan urban area through a Cycle-GAN approach applied to a bi-temporal CSK pair (16 Jan 2020 – 31 Aug. 2021).

False-color bi-temporal CSK image (top right): green and purple colors refer to increase and decrease changes. Reference map (bottom left) and change map (bottom right)



Classification results gathered over Parasacco rural area: (top left) ground truth, neural network results trained with COSMO-SkyMed (top-right), SAOCOM (bottom left) and combined COSMO-SkyMed/SAOCOM images (bottom right). Class legend: Building, low vegetation, high-vegetation water bodies soil. The classification approach is based on MRF, ensemble learning and DL methods. **Image courtesy UNIPV, MultiBigSARData project**. Product produced from Original SAOCOM Product - ©CONAE – COMISION NACIONAL DE ACTIVIDADES ESPACIALES (2020-2022)

Cryosphere

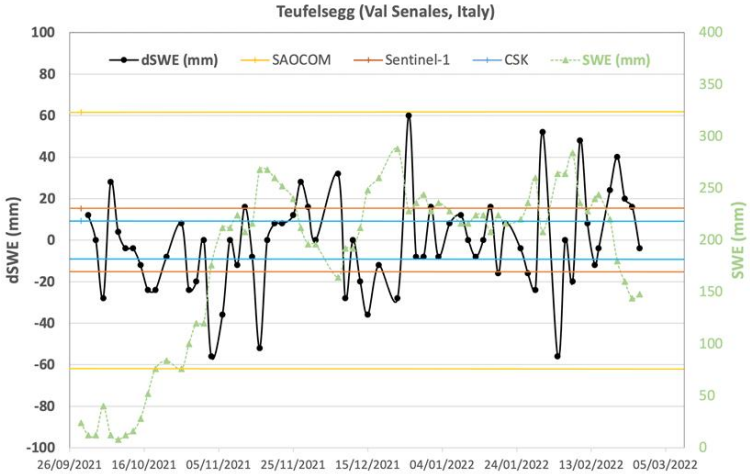
Projects:

- **CRIOSAR** (CNR-IFAC & IREA, EURAC, Pavia Univ., Milano-Bicocca Univ.)
- **SMIVIA** ("Sapienza" Roma Univ., L'Aquila Univ., HIMET s.r.l., Roma Tre Univ., Perugia Univ.)

Objectives:

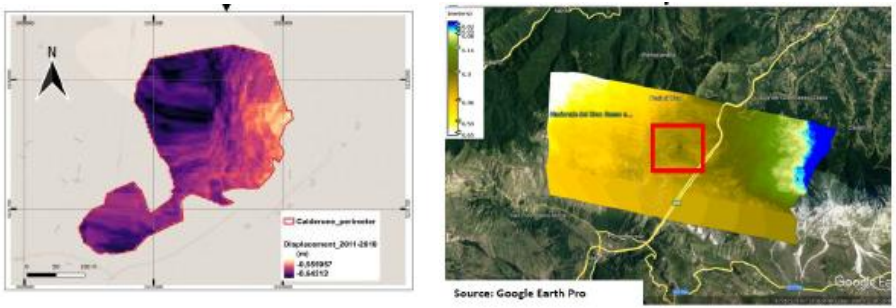
a) Improve the retrieval of snow and permafrost properties.

b) Develop and assess SAR-based *Data fusion* techniques, models and in situ measurements for the monitoring of snow / glaciers as well as the forecast analyses of both snow melting processes and avalanches risk scenarios.



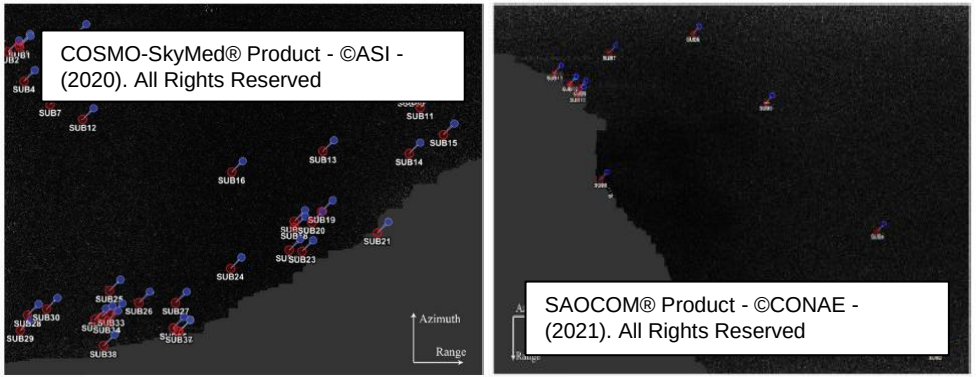
Upper Figure. Δ SWE (black) and SWE (green) values measured at Teufelsegg site between Sept 2021 and Feb 2022. The horizontal yellow, orange and light blue lines correspond to the max ΔSWE values measurable through DInSAR SAOCOM, Sentinel-1, and CSK SAR datasets. **Image courtesy CNR-IFAC, CRIOSAR project**.

Bottom Left Figure. X-band SAR data from CSK (Stripmap) processed to obtain some preliminary mass balance results for Calderone glacier area. **Image courtesy "Sapienza" Roma Univ. SMIVIA project**.

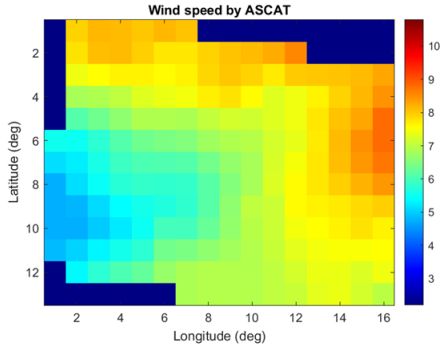


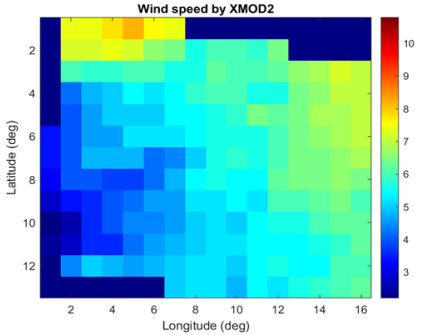
Sea & Coast

- **Projects:**
  - **APPLICAVEMARS** (“Parthenope” Napoli Univ., CNR-ISP, ICM-CSIC)
  - **COAST** (“Federico II” Napoli Univ., Euro.Soft srl)
- **Objectives:**
  - Improve, assess, generate and validate SAR wind field retrievals at different spectral bands and with multi-frequency multi-mission SAR data.
  - Improve multi-frequency and multi-polarimetric ship detection algorithms based on target related properties.



Bottom Left Figure. Results from the ship detection approach (land masking, calibration, CFAR, SLA) applied to CSK (left) and SAOCOM (right) images. **Image courtesy UNINA, COAST project**.





Upper Left Figure. Wind speed map obtained by ASCAT **(top)** and estimated with CSK data by XMOD_2 **(bottom)** using the ASCAT wind direction. **Image courtesy Parthenope, APPLICAVEMARS project**.

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Grazie per l'attenzione!

Per ulteriori informazioni:

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