Space It Up!

SIU! Days

FLORENCE

JANUARY, 26-28
2026

SPOKE 5

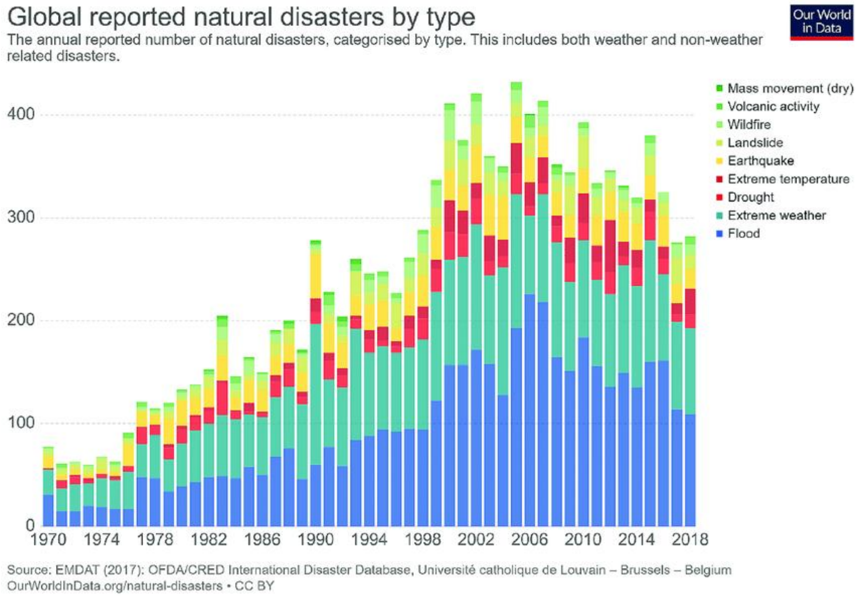
AGENZIA SPAZIALE ITALIANA

Ministero dell'Università e della Ricerca

The Space It Up! project is funded by the Italian Space Agency (ASI) and the Ministry of University and Research (MUR), under contract no. 2024-5-E.0 – CUP I53D24000060005.

Spoke 5
Planetary Protection and Geohazards Mitigation

<u>Mission statement</u> The prosperity and development of contemporary, strongly interconnected societies depend significantly on the ability of mitigating the effects of natural and anthropogenic disasters. Objective of **Spoke 5** is to explore and improve the TRL on **innovative methods of space observation for the protection from natural disasters** using **nanosatellite constellation architectures** aimed to the **mitigation of the effects of natural and anthropogenic disasters on the Earth's surface**.



Explore monitoring of rapid hazard phenomena and identify <u>current gaps to be filled</u>.

<u>Mission concepts and tools</u> for mitigating natural hazards induced damages

Design of <u>infrastructures</u> for implementation and operations of sustainable mitigation strategies

Development of innovative <u>technologies</u> for improved <u>mitigation strategies</u>

Spoke 5 Partners

UNITN Spoke Leader R. Battiston
INGV Spoke CoLeader F. Buongiorno

18 Partners

	Partner	Activities
WP L	UNITN	General and Quality Management, miniaturisaton and qualification of sensors for nanosatellite remote sensing, advanced EO data processing,
WP CL	INGV	Risk management, instruments for geo-hazard mitigations and monitoring, remote sensing,
WP CL	CNR	On board data driven software specification, Advanced DInSAR and GNSS techniques
	UNIROMA1	New instrumentation and technologies for remote sensing, miniaturisation, on board processing, AI tools
	UNIFI	Miniaturisation and future quantum sensors, AI tools, Advanced DInSAR and GNSS techniques
	UNIPI	Particle detectors and non imaging remote sensing , COTS electronic, AI tools
	UNICAL	Lithospheric – magnetospheric coupling model development, simulation and testing
	POLITO	Remote sensing database, signals of opportunity systems
	INAF	Miniaturization of electric, search coil and plasma instruments
	INFN	Solid state sensors and related electronics, detectors and front-end/DAQ electronics

Partner	Activities
FBK	Miniaturized electronics, sensors development and integration
CMCC	M onitoring and modelling of climate change and atmospheric weather related phenomena, AI tools , multiparametric integration
CIRA	Aerostatic platforms remote sensing, qualification facilities
ARGOTEC	Mission analysis issues and technlogy roadmap, small satellite platform
E-GEOS	Advanced DInSAR and GNSS techniques, remote sensing techniques, AI tools. Geodetic measurements algorithms
LEONARDO/ TAS-I	Nanosatellite qualification, digital twins, modelling and multiparametric integration
LINKS	Satellite data usage for remote sensing activities, AI techniques, EO based operating services
MAPSAT	Remote sensing services, satellite data management, environmental monitoring

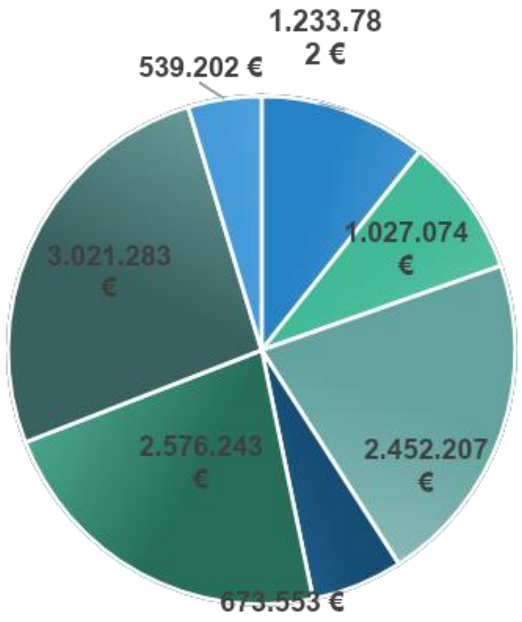
Tot. Budget Spoke 5

11.523.345 € *

* Excluding co-funding

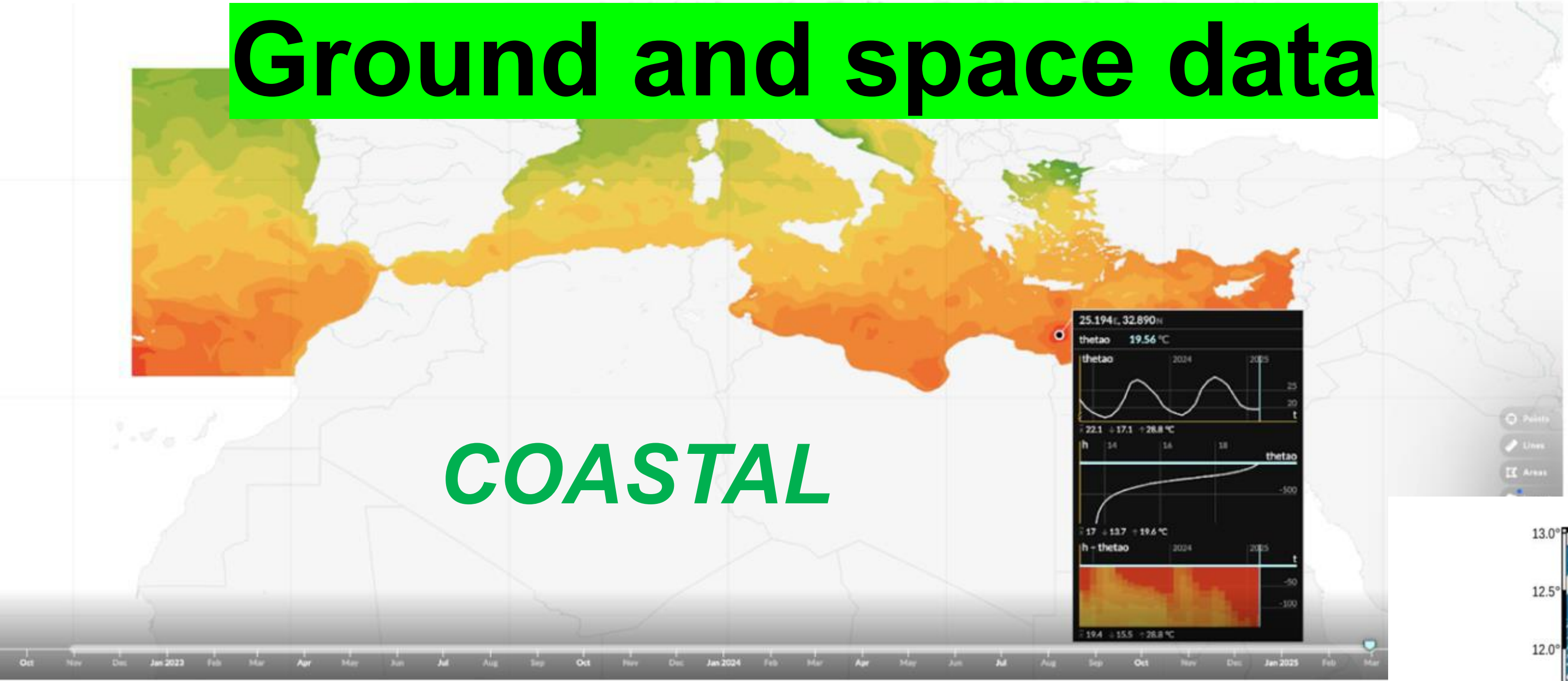
Spoke Administration, management, travel and dissemination

Experimental research for innovation in EO methods

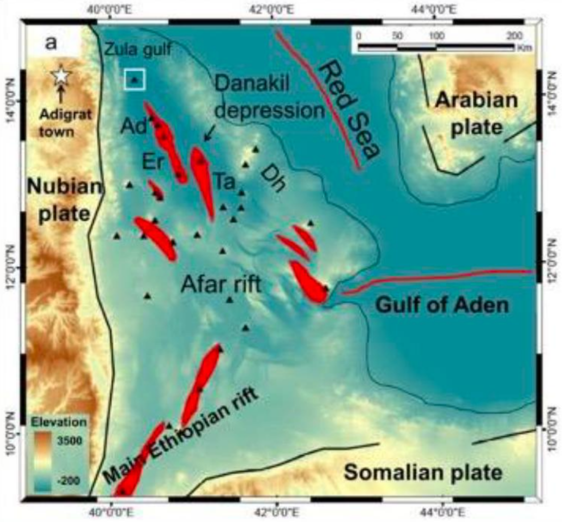


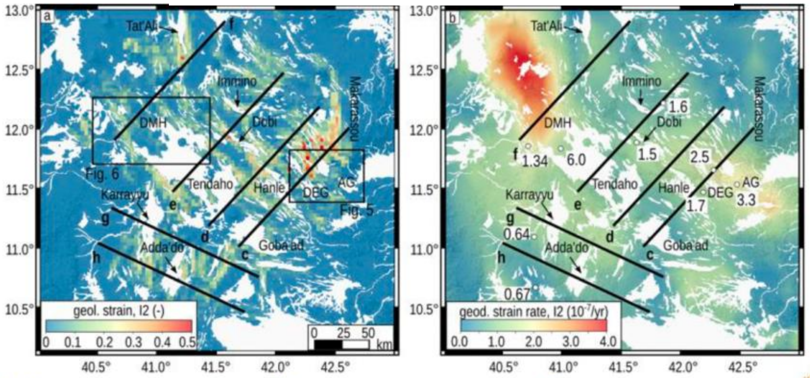
NATURAL HAZARDS MITIGATION

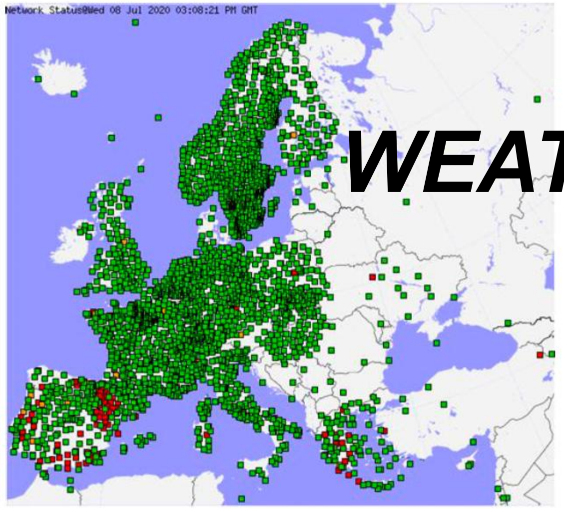
Ground and space data

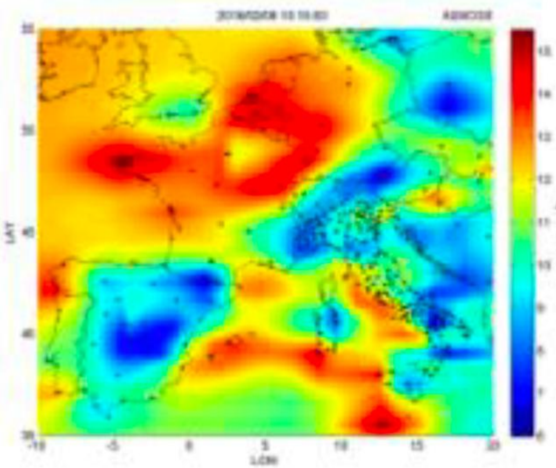


COASTAL

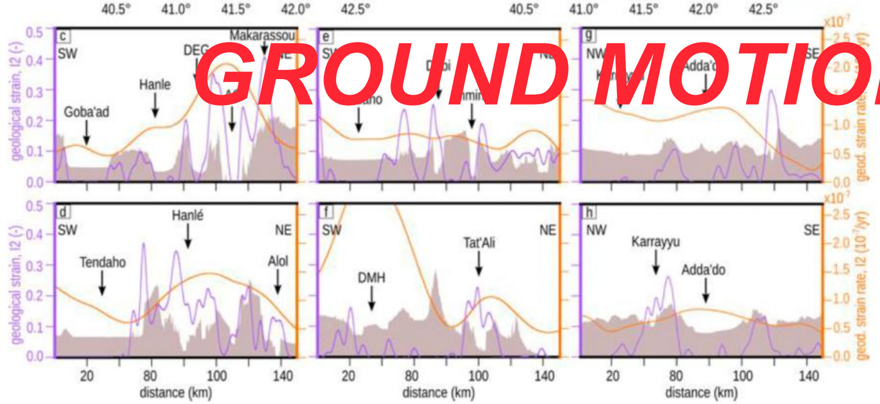








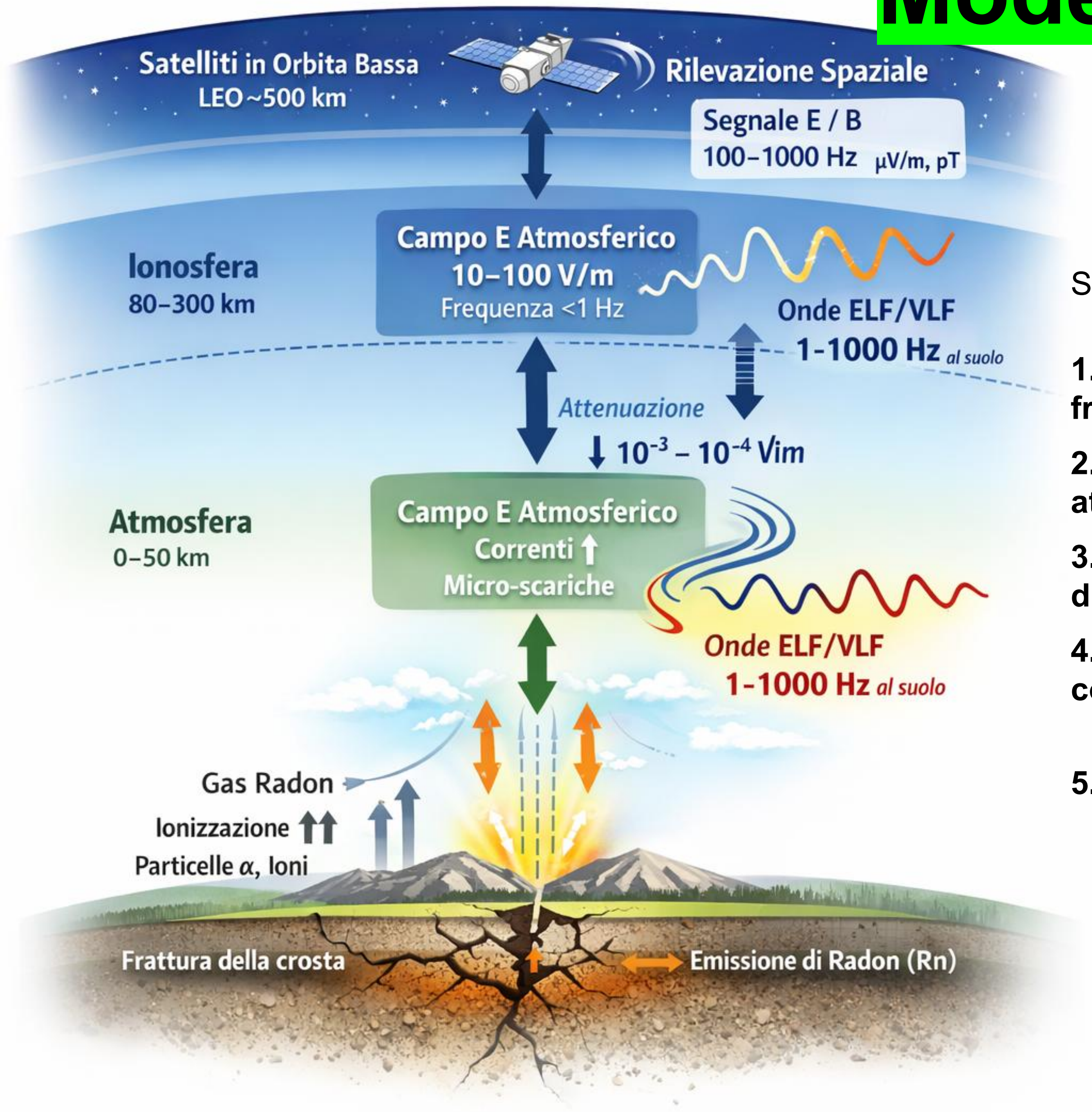
WEATHER



GROUND MOTION

Figure 11. Within the E-GVAP – EIG EUMETNET Project, ~3000 GPS sites are currently analysed, focusing on GPS-only hourly processing, delivering only ZTD in 90mins, followed by operational assimilation at European National Met Services.

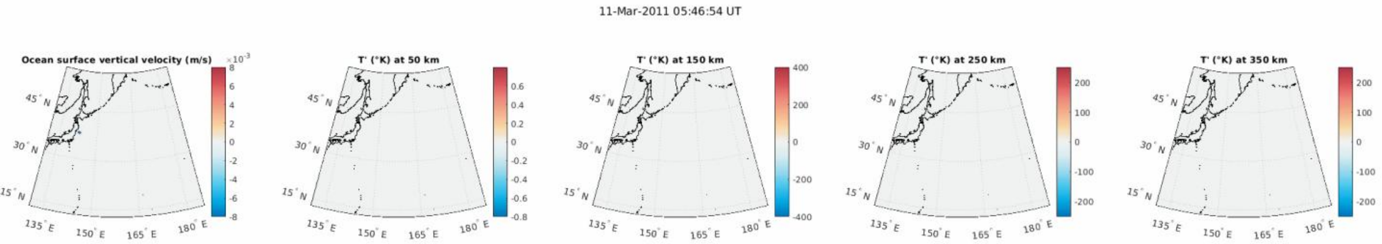
Modeling of layer coupling

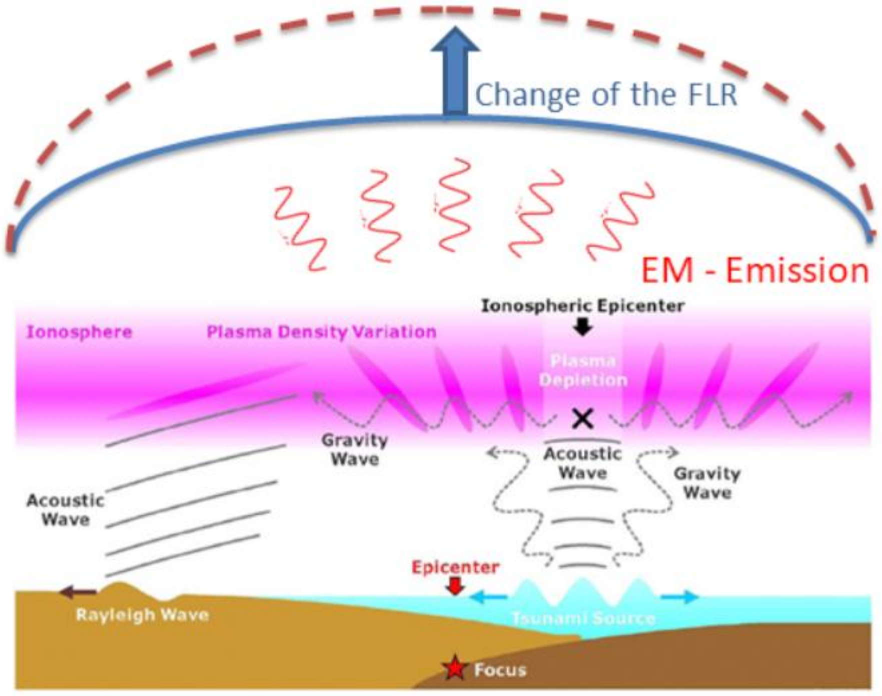


Possible E.Q. coupling mechanisms

Stage	Process	Characteristic scale / frequency	Observable
1. Crustal fracture*	radon release (Rn-222)	—	gas flux, α-emission
2. Lower atmosphere	air ionization, σ↑	< 1 Hz	E-field perturbation
3. Micro-discharges	pulsed currents	1 Hz – 10 kHz	ELF/VLF radiation
4. Ionospheric coupling	guided propagation	1–1000 Hz	modulated E/B fields
5. LEO detection	EFD/SCM anomalies	100–1000 Hz	μV/m – pT level signals

MODELING LITOSPHERE- IONOSPHERE INTERACTION
MILC MODEL





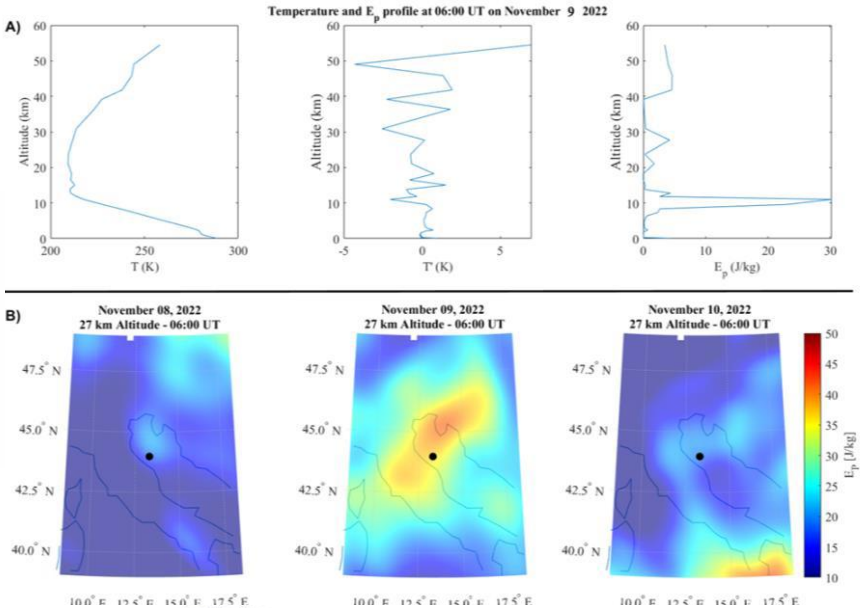
Visione schematica del modello. Crediti: V. Carbone

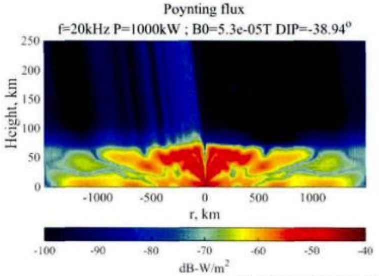
Step 1: VLF waves propagate in the ionosphere

Step 2: whistler mode ray propagation in magnetosphere

Step 3: Interaction with radiation belt electron and pitch angle scattering

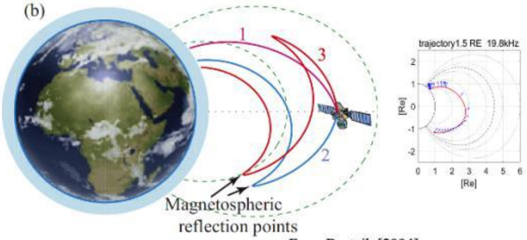
Step 4: Electron precipitation and influence the ionosphere electron density and emit x-ray





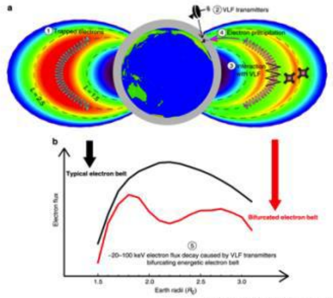
From Zhao Shufan [2015]

Figure 1. VLF propagation Full Wave Model



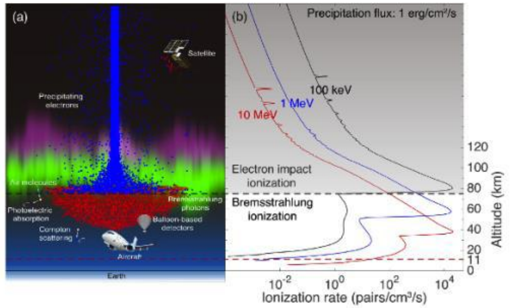
From Bortnik [2004]

Figure 2. VLF propagation Ray tracing Model



From Man Hua at all [2020]

Figure 3. Schematic illustration of bifurcating energetic electron belt caused by VLF transmitters



From Xu wei at all [2021]

Figure 4. Modification of High-energy precipitation by Monte Carlo model

Upstream&Downstream

Spoke 5: Technical WP's
WP 5.3 & WP 5.5 - Technologies for multipoint remote sensing and data analysis

WP 5.3

- On board processing advanced architectures
- Miniaturization of instrumentation and measuring devices.
- Environmental sensing based on signals of opportunity

L: UNITN, CL: INGV, TL: UNIROMA1, INAF, UNIPI, INFN
. Others : CNR, FBK, LINKS, UNIFI, TAS-I, PoliTo

Technology developments for nanosatellite remote sensing

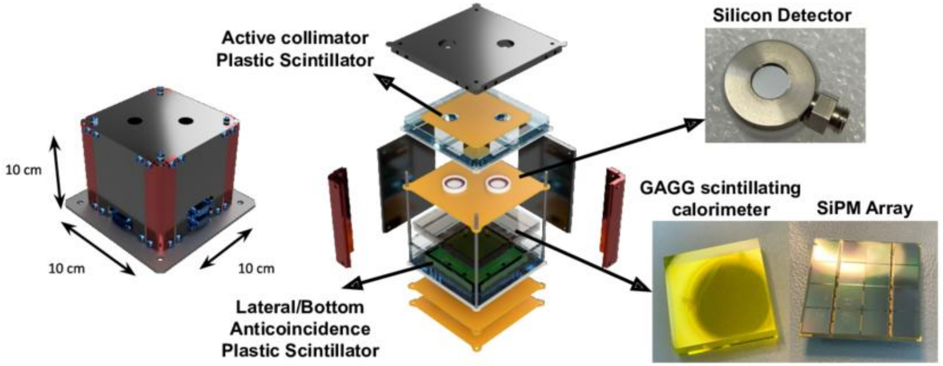
WP 5.5

- integrating physical modelling, data assimilation and AI for multimodal systems
- AI techniques for multitemporal data
- Advanced DInSAR and GNSS techniques

L: UNITN, CL: INGV, TL: UNIROMA1, CNR, UNIPI, PoliTo, UNICAL
Others: EGEOS, INAF, UNIFI, LEONARDO, LINKS, CMCC,MAPSAT

Technology developments for remote sensing data analysis

Payload miniaturization



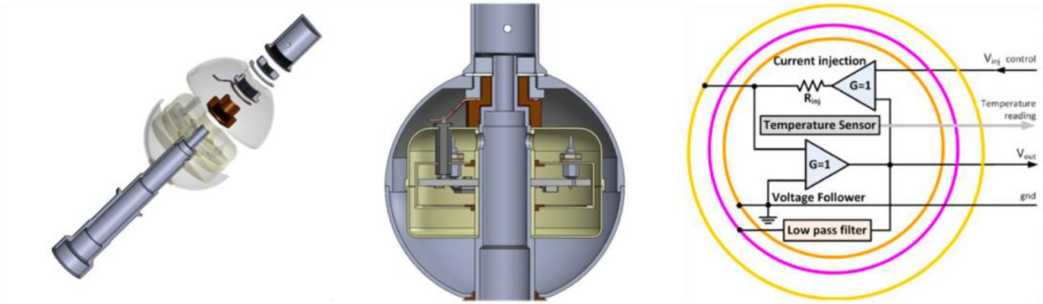
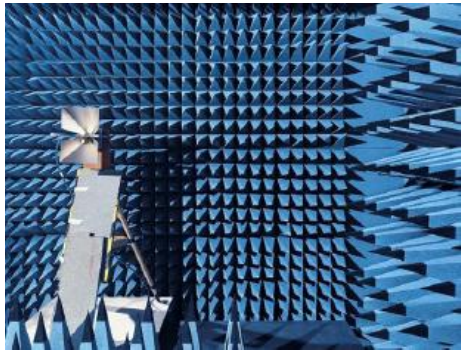


Figure 3 : EFIP sensor sketches ; from the left, the overall design of the sensor, in the center the section, and on the right the electronic diagram of the Front End

Development of Digital Twin qualification facilities



Spoke 5: Technical WP’s
WP 5.2 & 5.4 – Downstream and upstream advanced strategies and tools

Strategies for bridging gaps in current EO systems

WP 5.2

- Available ground and satellite data on Earth natural hazard
- Understand gaps in planned EO constellation
- Identify requirements for nano-satellites constellation

L: UNITN, CL: INGV, TL: UNITN, INGV
Others: CNR, UNIROMA, UNIFI, UNIPI, POLITO, CMCC, INFN, LINKS, CIRA, LEONARDO, ARGOTEC,MAPSAT

New services based on advanced data and IT technologies

WP 5.4

- Physical and AI tools for EO big data analysis
- Cross database and data fusion tools and products
- Role of inflatable for EO
- Advanced EO data processing

L: UNITN, CL: CNR, TL: UNITN, CNR
Others: INGV, UNIROMA, UNIFI, UNIPI, POLITO, CMCC, INFN, LINKS, EGEOS

Figure 2. the e-GEOS operational AI-based frame for Geoinformation

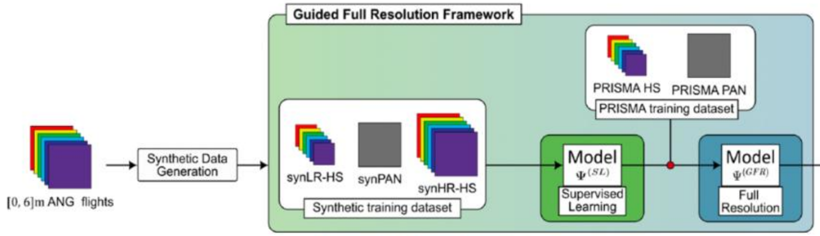
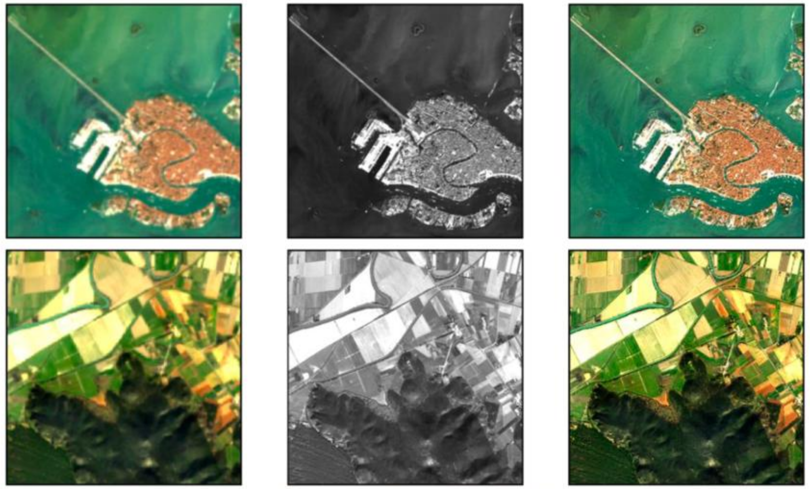


Figure 8. Hypersharpening frame



Pansharpening results of λ-MSRN on PRISMA over Venice and the surroundings of Grosseto. Bands at 655-567-489 nm have been selected as red, green column displays the PRISMA hyperspectral image (30m), the second shows the PRISMA panchromatic image (5m), and the third image (5m). Data generated under a license from ASI Original PRISMA Product - © Italian Space Agency (ASI) - (2021, 2022,

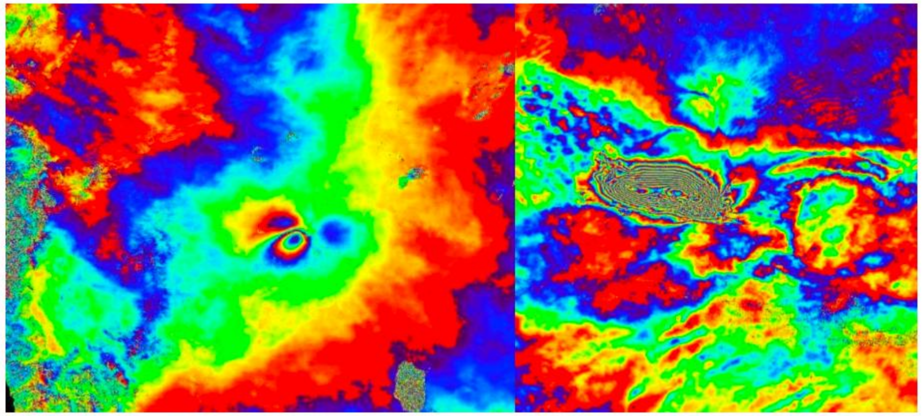
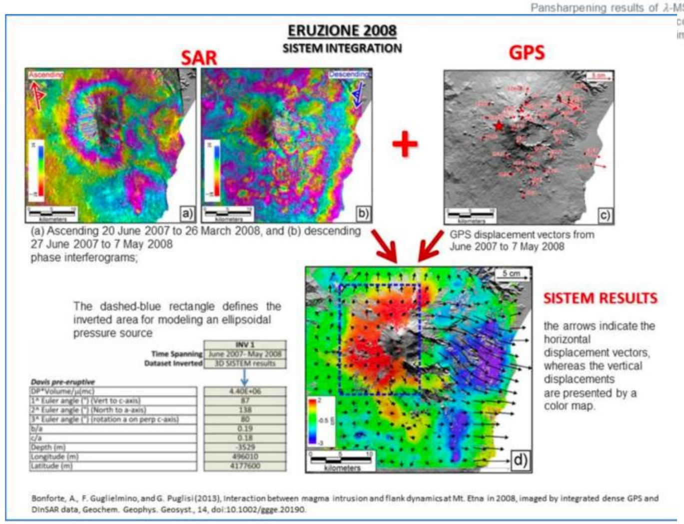


Fig. 3. Example of two distinct coseismic patterns after InSAR processing: fringes describe the surface deformation corresponding to two distinct earthquakes, of magnitude 5.9 (left) and 6.3 (right).



UPSTREAM

Appendix A — Preliminary Upstream Requirements by Application (M15 draft)

Note: Values are indicative and will be tightened at M20. Units: GSD in meters (m), revisit/latency in hours (h). "NRT" indicates near-real-time products delivered as compact layers (masks/indices/quick-looks).

Application	**Primary Observables**	**Target GSD / Bands**	**Revisit Target**	**Latency Target**	**All-weather?**	**NRT Products**	**Candidate WP5.3 levers**	**Cal/Val dependencies**
Earthquakes & tsunamis	Co-seismic deformation & damage; EM/plasma/particles; GNSS/SoOp ocean/atmo proxies	SAR (X/C/L) — deformation; LAIM (E-field, B-field, low-E particles); GNSS-R/TEC	≤ 12 h (risk corridors)	≤ 3 h from pass	Partial (SAR yes)	InSAR quick-looks; damage proxy maps; EM/ionosphere/particle context	5.3.2 (EFIP/MIB), 5.3.3 (LEM), 5.3.5 (SoOp), SAR partnerships	GNSS, strong-motion, magnetometers, ionosondes
Volcanoes	Thermal hotspots, LST; plume load/phase; gases proxies	TIR (≤60–100 m), MWIR; SWIR/VNIR; GEO-link attenuation	6–12 h (active arcs)	< 3 h	No (optical/TIR); mitigated via SoOp/SAR/HAPS	Hotspot/LST maps; ash/lapilli proxy; ash/smoke masks	5.3.4 (mini-TIR/HSI), 5.3.5 (GEO atten., GNSS vapor), HAPS	DOAS/LiDAR, thermal cams, met
Wildfires	Ignition & spread; smoke; perimeter	MWIR/TIR (≤100 m); GEO fusion; SAR for perimeter	3–6 h (high-risk belts)	< 1–3 h	Partial (SAR yes)	Fire detections (with confidence), spread vectors, perimeter masks	5.3.4 (TIR/MWIR), 5.3.1 (edge-AI), SAR partnerships	Fire networks, met, crowdsourcing
Floods & storm surges	Inundation extent; rainfall; soil moisture	C-band SAR; SoOp microwave; GNSS-R	6–12 h (during events)	< 3 h	Yes (SAR/SoOp)	Flood extent masks; rainfall/attenuation maps; SM anomalies	5.3.5 (SoOp; GNSS-R), SAR partnerships	Gauges/booms, hydrology
Marine heatwaves & coastal	SST anomalies; humidity/water-vapor; coastal levels	LEO/GEO SST; SoOp microwave; GNSS-RO/R	Daily to sub-daily	< 6 h	Yes (microwave/RO)	Heatwave indices; humidity fields; coastal risk	5.3.5 (SoOp), altimetry/SST fusion	Buoys, Argo, gliders

Appendix B — State of the Art (indicative) and Gaps

Application	Typical SoA assets	Typical GSD	Typical revisit	Typical latency	Key weaknesses
Earthquakes & tsunamis	Global SAR missions; sparse marine seismo	3–30 m (SAR)	6 h–3 d	6–48 h	Sparse oceanic seismo; limited LAIM context; slow NRT in some regions
Volcanoes	LEO optical/TIR + GEO thermal	30–375 m	6 h–2 d	3–24 h	Cloud/ash blockage; ash vs hydrometeor discrimination; sparse in-situ
Wildfires	GEO/LEO thermal + cameras	30–375 m	15 min–1 d	0.5–24 h	High camera false positives; uneven coverage; night/overcast gaps
Floods & surges	C-band SAR + limited gauges	3–30 m	6 h–3 d	6–48 h	Sparse tide/wave sensors; model coupling not systematic
Marine heatwaves/coastal	LEO/GEO SST; Argo/gliders	1–10 km	hourly–daily	1–24 h	Uneven coastal sampling; humidity fields sparse over sea

Appendix C — SpaceItUp (WP5.3) Contributions by Application

WP5.3 Task	Core contribution	EQ/Tsu	Volcano	Wildfire	Floods/Surges	Marine
5.3.1 Edge-AI	On-board masking/detection; compression	◉	◉	◉	◉	◉
5.3.2 EFIP/MIB	E-field/plasma; hybrid magnetometer	◉	◉	○	○	○
5.3.3 LEM	Low-E particles (0.1–10 MeV)	◉	◉	○	○	○
5.3.4 Mini-TIR/HSI	Nanosat thermal/multispectral	○	◉	◉	○	○
5.3.5 SoOp	GEO attenuation; GNSS-R/RO	◉	◉	◉	◉	◉

Legend: ◉ primary relevance; ○ secondary/supporting relevance.

DOWNSTREAM

Appendix A — Preliminary downstream requirements tables

A1. Cross-cutting analytics requirements

Capability	Minimum	Target (M20)	Notes
NRT product latency	≤3 h (EO pass-to-API)	≤1–2 h (where GEO/edge)	Per hazard SLA; event feeds
SITS classifier generalization	Cross-sensor	Domain adaptation	Domain adaptation + self-training
Explainability	Saliency/attention	XAI dashboards + uncertainty	Required for alerts
Fusion	Feature-level	Pixel + feature + decision	Uncertainty propagation

A2. Per hazard — product & performance targets (indicative)

Hazard	Core product	KPI (accuracy/IoU)	Latency
Earthquake	Co/deformation map; damage proxy	IoU ≥0.6 damage; mm-cm trend precision	≤3 h / daily trends
Volcano	Hotspot/LST; plume proxy; deformation trend	TPR ≥0.85 hotspot; MAE LST ≤2 K	≤3 h / daily
Wildfire	Ignition/perimeter; FDI 1 km	F1 ≥0.8 detection; perimeter ±100 m	≤1 h (GEO fusion)
Flood/Surge	Flood extent; risk index	IoU ≥0.7; AUC ≥0.85	≤3 h / 6-hourly risk
Landslide/Subsidence	PS-InSAR trend; alerts	mm-cm precision; FAR ≤5%	Daily–weekly

SPACE IT UP!

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