

Contribution to LAIC studies

Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) as seen from space in occasion of strong earthquakes

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Day 1 – COS workshop – 9 June 2021

• TEAM AND AFFILIATIONS

(1)



(2)



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(3)



(4)



• PROGRAMS/PROJECTS OF REFERENCE

SAGA-4 (Italian & Chinese Foreign Offices)*

LAIC-U (Free Research – Ricerca Libera – INGV)*

SAFE – SwArm For Earthquake study (ESA funds)*

LIMADOU Science+ (ASI funds)

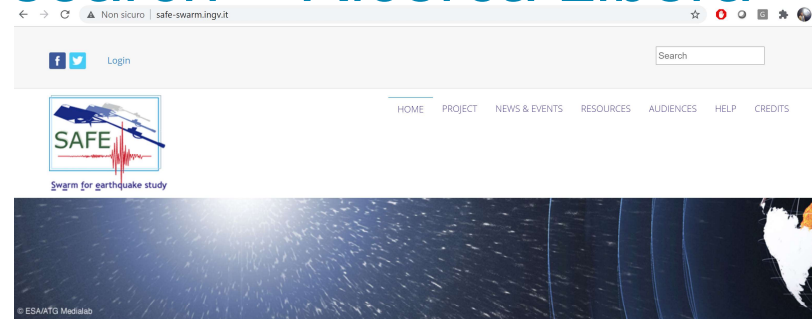
FURTHER (Earthquake Dep. Project – INGV)

SINFONIA (Working Earth – Task A1 – MiUR)

CHOPIN (Working Earth – Theme 5 – MiUR)

LAICA (Free Research – Ricerca Libera – INGV)

* Concluded



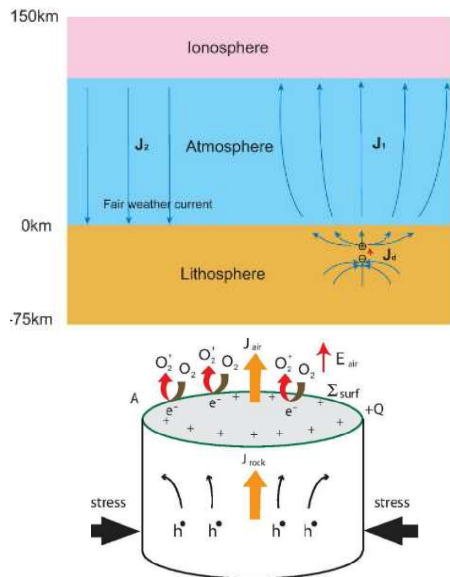
SAFE (Swarm for earthquake study) is a project funded by ESA (Contract No. 4000116832/15/NL/MP) in the frame of STSE (Support To Science Element) Swarm + Innovation Program.

• SCIENTIFIC RATIONALE

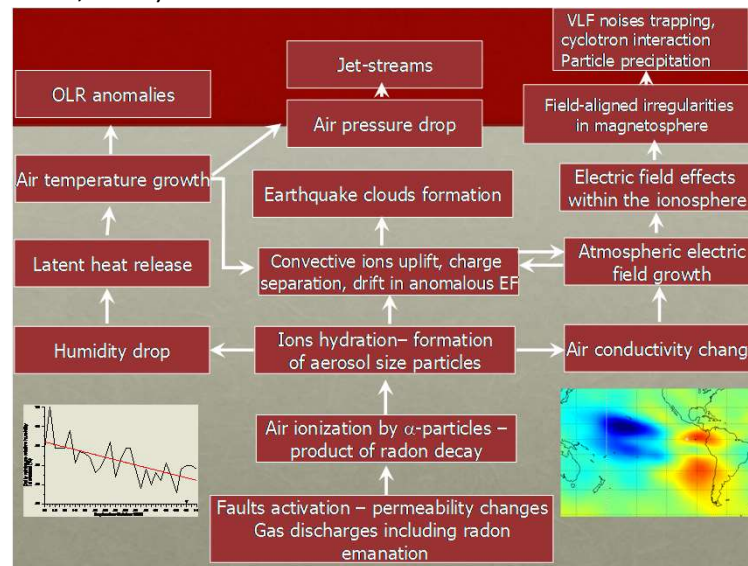
- In Laboratory, rocks under stress show peculiar electric and thermal properties before break
- In Nature, during the preparation of earthquakes some precursors could appear due to a Lithosphere-Atmosphere-Ionosphere Coupling (LAIC)

Three possible Models of LAIC

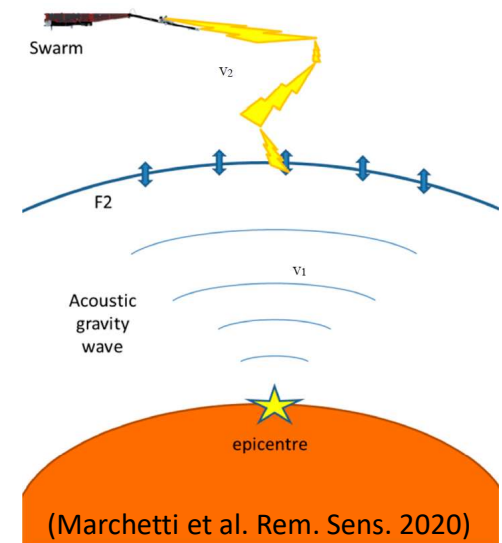
1. Dynamo from stressed rocks (Freund, JAES, 2011; Kuo et al., JGR, 2014)



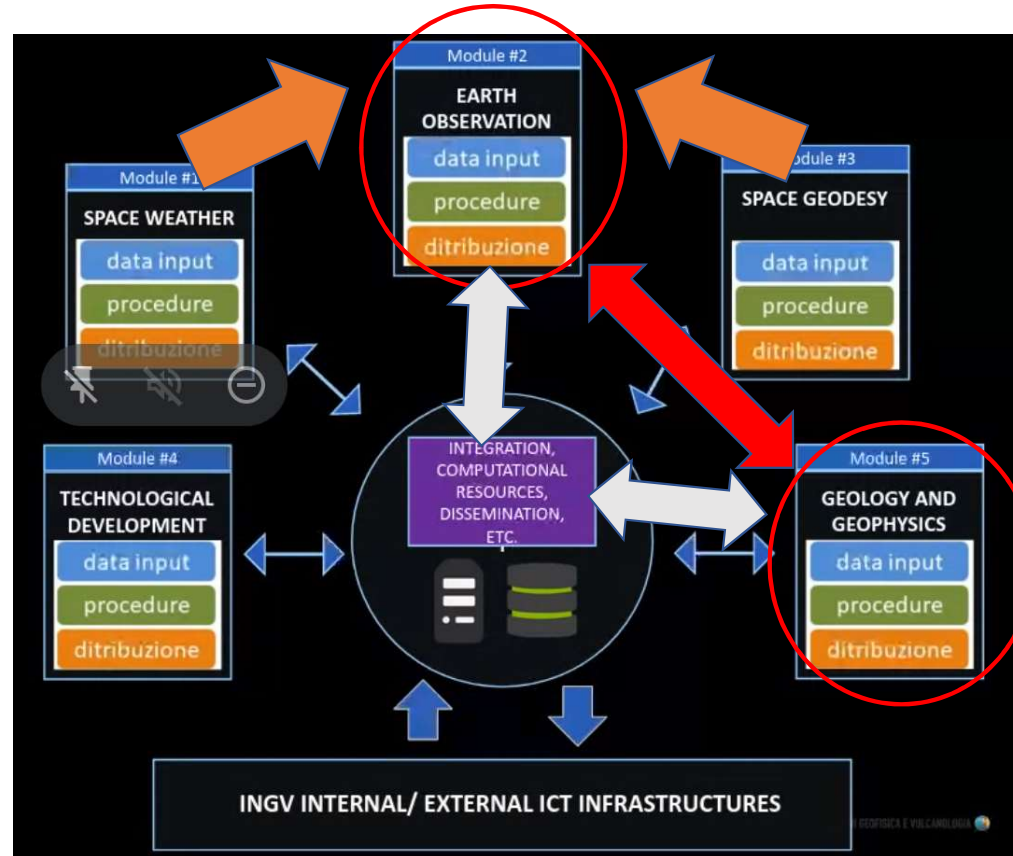
2. Dynamo from injection of radon and/or charged aerosols (Sorokin and Hayakawa, MAS, 2013; Pulnits & Ouzounov, JAES, 2011)



3. Acoustic Gravity Waves (AGW) (Hayakawa et al., JAE, 2011)



- SCIENTIFIC INTERCONNECTION RATIONALE within COS



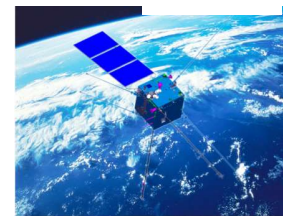
From Marcocci et al. presentation

• OBSERVATIONAL INFRASTRUCTURE

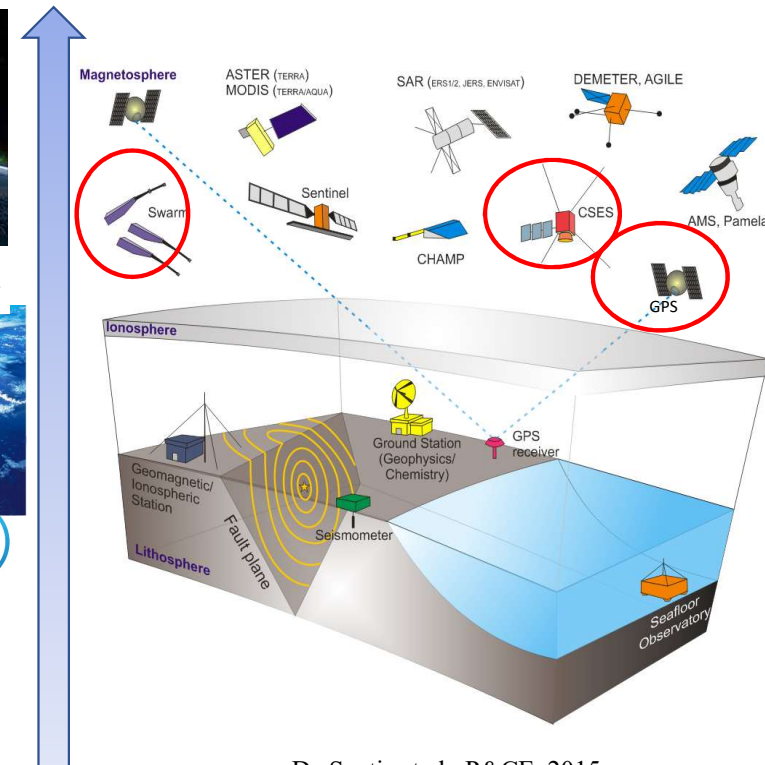
- Swarm three satellites (ESA), launched on 22 November 2013 in quasi-polar orbits at 460 km (two satellites) and 510 km (third satellite)
- The Chinese Seismo-Electromagnetic Satellite (CSES) has been launched on 2 February 2018 in a fixed sun-synchronous polar orbit at around 500 km altitude
- Different Payloads sharing some similar instruments: magnetometers, Langmuir Probes, *High Energy Particle Detector*, *Electric Field Detector*, etc.
- Meteo-Climatological networks (ECMWF and NASA/NOAA)
- Earthquake seismic networks (USGS, EMSC, ...)
- Ionosondes and GPS/GNSS receivers



Swarm



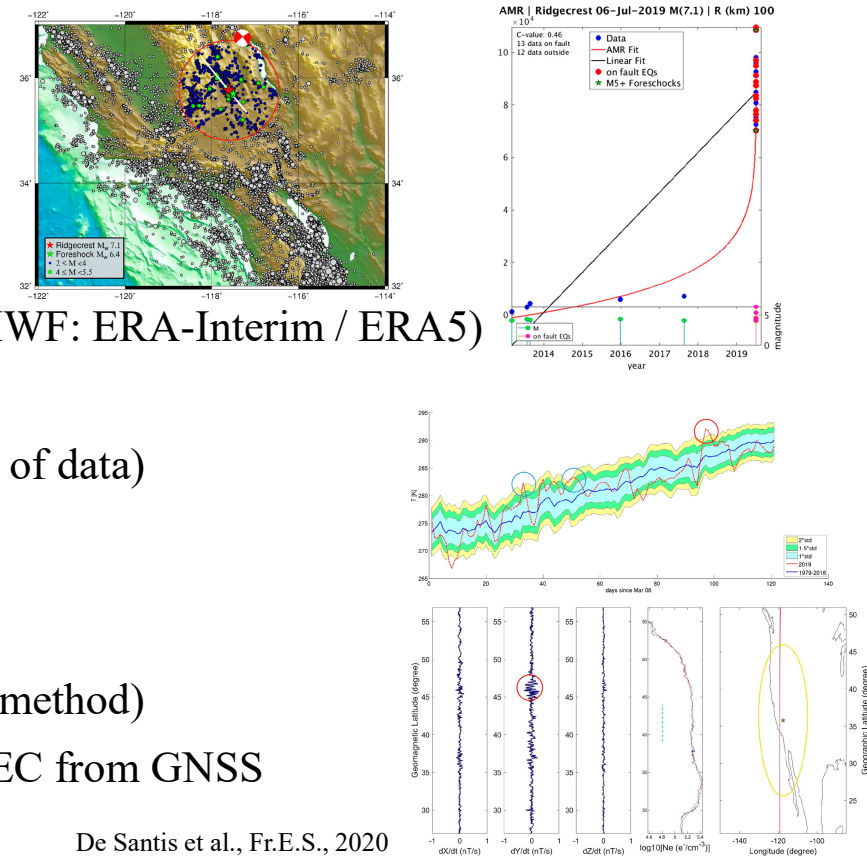
CSES



De Santis et al., P&CE, 2015

• INFRASTRUCTURE FOR DATA MANAGEMENT, PROCESSING & AVAILABLE PRODUCTS (under development; now only for research)

- **Lithosphere:** Earthquake catalogs (USGS, EMSC, ISIDE, etc.)
Earthquake Epicentre location and depth, origin time, magnitude
(Cumulative reduced Benioff strain and R-AMR method)
- **Atmosphere:** Climatological databases (NASA: MERRA2; ECMWF: ERA-Interim / ERA5)
skin temperature, ozone, water vapour, aerosol, CO, CH₄, SO₂
(three-month analysis and historical background based on >10 yrs of data)
- **Ionosphere:**
From Satellites: Magnetic field, electron density and temperature
(track-by-track data analysis for anomaly identification – MASS method)
From ground (Observatories): Magnetic field, Ionosonde data, TEC from GNSS



De Santis et al., Fr.E.S., 2020

• POTENTIAL DISTRIBUTION OF PRODUCTS (on demand)

- **Lithosphere:**

Cumulative reduced Benioff strain and R-AMR method (*Cianchini et al., PAGeoph 2020*)

- **Atmosphere:**

Three-month analysis and historical background based on >10 yrs of data (*Piscini et al. PAGeoph, 2017*)

- **Ionosphere:**

From Satellites:

Track-by-track data analysis for anomaly identification – MASS method (*De Santis et al. Atmosphere, 2019*)

Space-Time Plots and Spectrograms (*De Santis et al., Sci. Rep. 2019*)

From ground (Observatories):

Time Plots, Spectrograms, EFD; TEC plots; Ionograms (*Perrone et al. Ann. Geoph. 2018*)

- **Single case studies**

SAFE Website (<http://safe-swarm.ingv.it/>)

• Publications on LAIC by INGV team (2015-2021)

- Akhoondzadeh M.**, A De Santis, D Marchetti, A Piscini, Jin S., Anomalous seismo-LAI variations potentially associated with the 2017 Mw = 7.3 Sarpol-e Zahab (Iran) earthquake from Swarm satellites, GPS-TEC and climatological data, **Adv. Space Res.**, 64, 143-158, 2019.
- Akhoondzadeh M.**, De Santis A., Marchetti D., Piscini A. and Cianchini G., Multiprecursors analysis associated with the powerful Ecuador (Mw=7.8) earthquake of 16 April 2016 using Swarm satellites data in conjunction with other multi-platform satellite and ground data, **Adv. Space Res.**, 61, 248-263, 2018.
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- De Santis A.** et al., Magnetic Field and Electron Density Data Analysis from Swarm Satellites searching for Ionospheric Effects by Great Earthquakes: 12 Case Studies from 2014 to 2016, **Atmosphere**, 10, 371, 2019.
- De Santis A.**, Balasis G., F.J. Pavón-Carrasco, Cianchini G., Manda M., Potential earthquake precursory pattern from space: The 2015 Nepal event as seen by magnetic Swarm satellites, **Earth Planet. Sc. Lett.**, 461, 119-126, 2017.
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- De Santis A.** et al., Geosystemics View of Earthquakes, **Entropy**, 21(4), 412, 2019.
- De Santis A.**, Cianchini G., Marchetti D., Piscini A., Sabbagh D., Perrone L., Campuzano S.A., Inan D., A multiparametric approach to study the preparation phase of the 2019 M7.1 Ridgecrest (California, USA) Earthquake, **Frontiers in Earth Science** (Solid Earth Geophysics), 2020.
- De Santis A.**, D. Marchetti, L. Perrone, S.A. Campuzano, G. Cianchini, C. Cesaroni, D. Di Mauro, M. Orlando, A. Piscini, D. Sabbagh, M. Soldani, L. Spogli, Z. Zhima, and X. Shen (2021). Statistical correlation analysis of strong earthquakes and ionospheric electron density anomalies as observed by CSES-01, **Nuovo Cimento C**, in press, 2021.
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- Ghamry E.**, Mohamed E.K., Abdalzaher M.S., Elweikel M., Marchetti D., De Santis A., Hegy M., Yoshikawa A., Fathy A. Integrating pre-earthquake signatures from different precursor tools, **IEEE Access**, vol.9, 33268- 33283, 2021, doi: 10.1109/ACCESS.2021.3060348.
- Ippolito A.**, Perrone L., De Santis A., Sabbagh D., Ionosonde data analysis in relation to the 2016 central Italian earthquakes. **Geosciences** 10, 354, 2020.
- Liu Q.**, De Santis A. et al., Multi-Parametric Climatological Analysis Reveals the Involvement of Fluids in the Preparation Phase of the 2008 Ms 8.0 Wenchuan and 2013 Ms 7.0 Lushan Earthquakes, **Remote Sensing**, 12, 1663; doi:10.3390/rs12101663, 2020
- Marchetti D.**, De Santis A., Shen X, Campuzano S.A., Perrone L., Piscini A., Di Giovambattista R., Jin S., Ippolito A., Cianchini G., Cesaroni C., Sabbagh D., Spogli L., Zhima Z., Huang J., Possible Lithosphere-Atmosphere-Ionosphere Coupling effects prior to the 2018 Mw=7.5 Indonesia earthquake from seismic, atmospheric and ionospheric data, **Journal of Asian Earth Sciences**, 188, 104097, 2019.
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