Tackling Space Weather at INGV: science, tools and services

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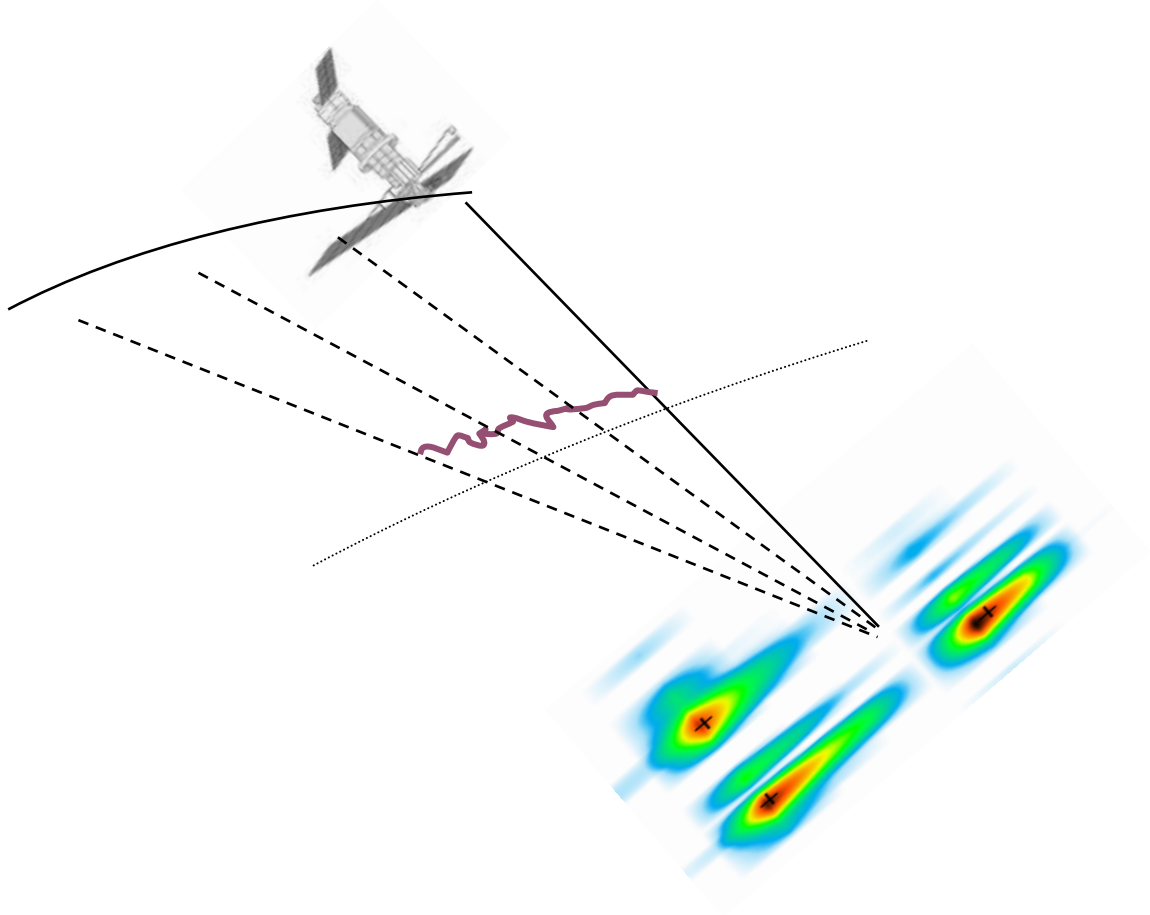
ISTITUTO NAZIONALE
DI GEOFISICA E VULCANOLOGIA

“Space Weather as a global challenge” Embassy of Italy, Washington D.C. , May 18, 2017

Outline

- INGV in the international initiatives
- Monitoring
- Recent scientific results
- Tools
- Services
- On going projects
- Final remarks

INGV contribution to international initiatives



INGV at United Nations – Office for Outer Space Affairs

Ministero degli Affari Esteri
e della Cooperazione Internazionale
FARNESINA

agenzia spaziale italiana

United Nations
Office for Outer Space Affairs

UNITED NATIONS
Committee on the Peaceful Uses of Outer Space

INGV is the Italian representative at the Space Weather Expert Group of COPUOS (Committee on the Peaceful Uses of Outer Space)

ISWI

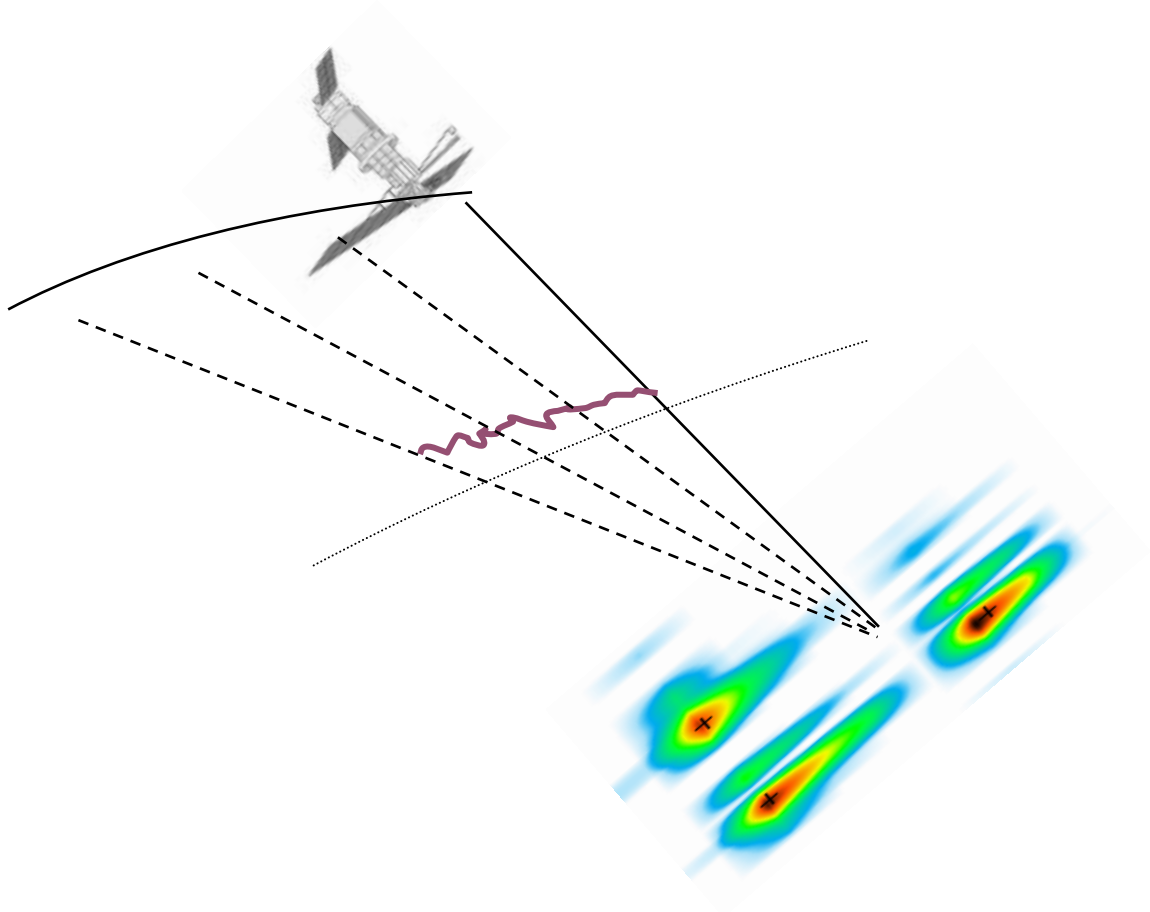
INGV is the Italian co-coordinator in ISWI (International Space Weather Initiative). ISWI is supported by NASA

INGV at SCAR – Scientific Committe for Antarctic Research

SCAR

INGV leads the SCAR expert group called GRAPE (GNSS Research and Application for Polar Environment). Eleven countries are involved. US participants:
U.S. Geological Survey, USGS - MIT Haystack Observatory, Westford, MA, - Johns Hopkins Applied Physics Laboratory, JHAPL - Virginia Polytechnic Institute and State University, (VT)

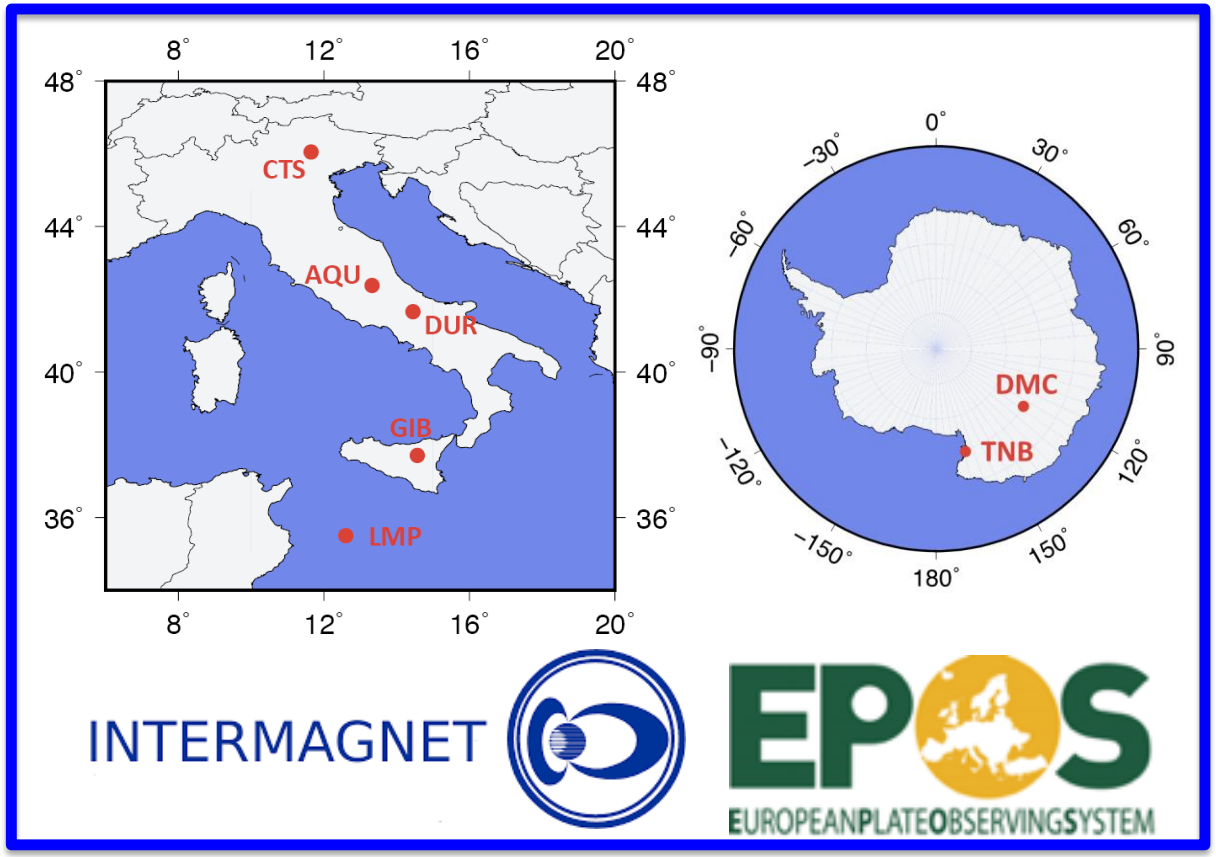
Monitoring



Geomagnetic Observatories

Magnetic observatory data, and scalar magnetic indices derived from the data, are widely used for:

- tracking the geographic evolution of magnetic disturbances during storms;
- measuring the absolute size of magnetic storms;
- providing statistics on past storm occurrences;
- assessing physics-based models of the magnetosphere and ionosphere;
- estimating the induction of ground electric currents that represent hazards for the operation of electric power grids.



Real-time observatory data can be used for low cost monitoring or "nowcasting" of space weather.

Ionospheric Observatories

Gibilmanna (Italy)

Rhombic Antennas (TX and RX)

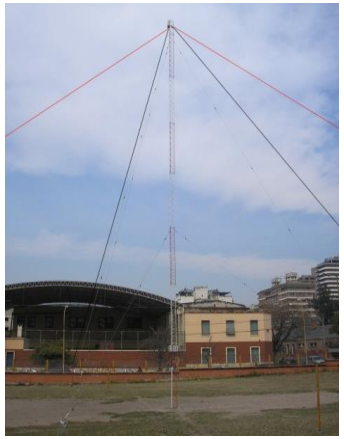
AIS - INGV

Rome (Italy)

AIS - INGV

Antennas (TX and RX)

S. Miguel de Tucumán and Bahia Blanca (Argentina)

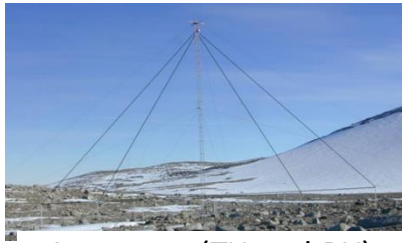


Delta Antennas (TX and RX)

AIS – INGV with AUTOSCALING

Mario Zucchelli Station (Antarctica)

AIS - INGV

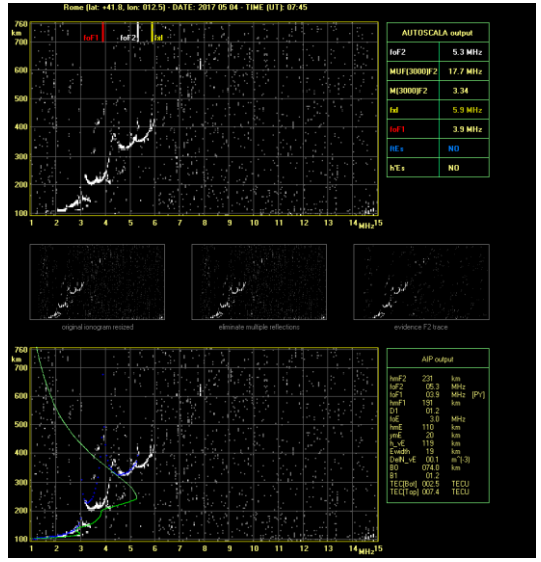


Antennas (TX and RX)

Space Weather forecast

Achievement of forecasting and nowcasting three dimensional (3-D) electron density mapping of the ionosphere.

Real-Time Alert of Ionospheric Storm based on HF methods



Real-time autoscaling

GNSS receivers network for ionospheric scintillation and TEC (including Galileo)

- First receiver installed at Ny-Alesund (Svalba
- Polar ionosphere
  - Svalbard islands (4)
  - Antarctica (5)
- Mid latitude ionosphere
  - Chania (Crete)
  - Huelva (Spain) – stopped
  - Huelva station moved to Lampedusa (Sicily, Italy)
- Equatorial Ionosphere
  - Tucuman (Argentina)

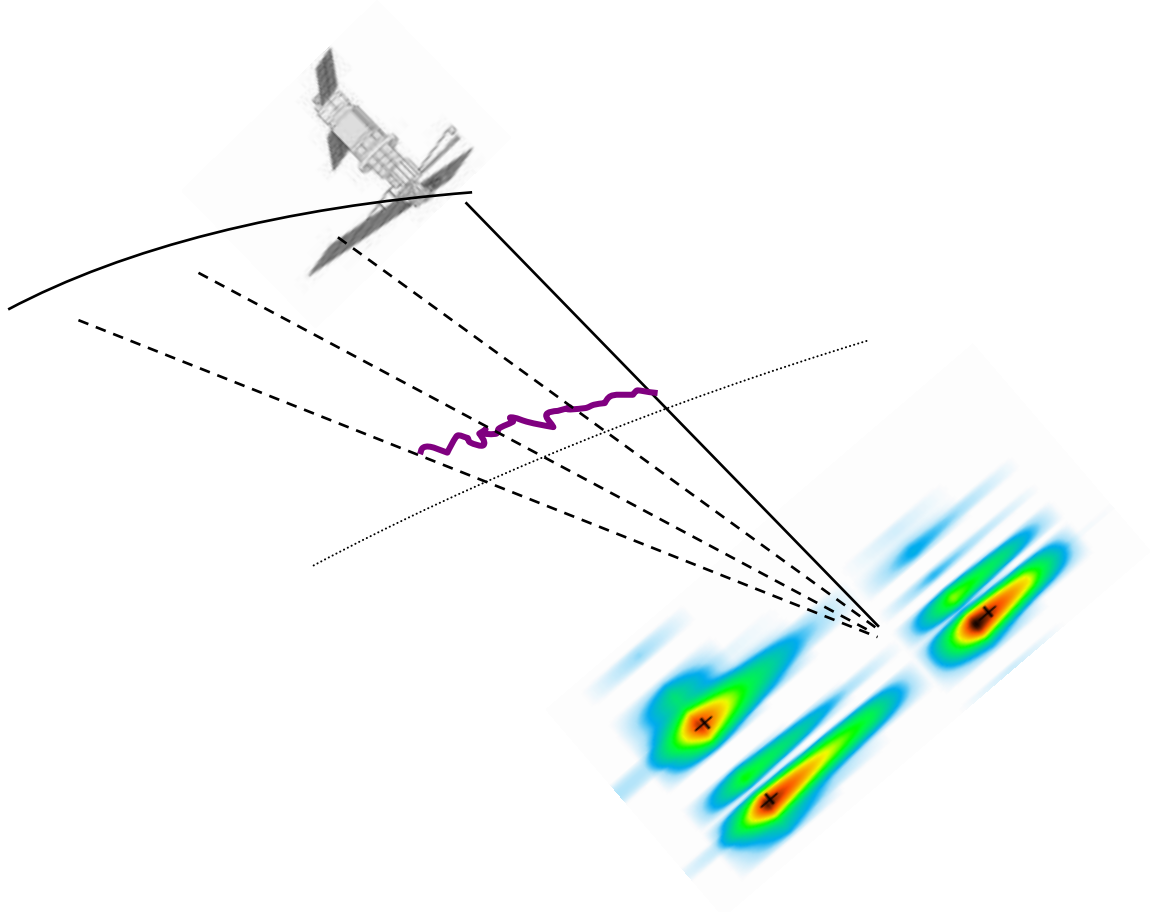
Data are accessible at the *electronic Space Weather upper atmosphere* website

eSWua

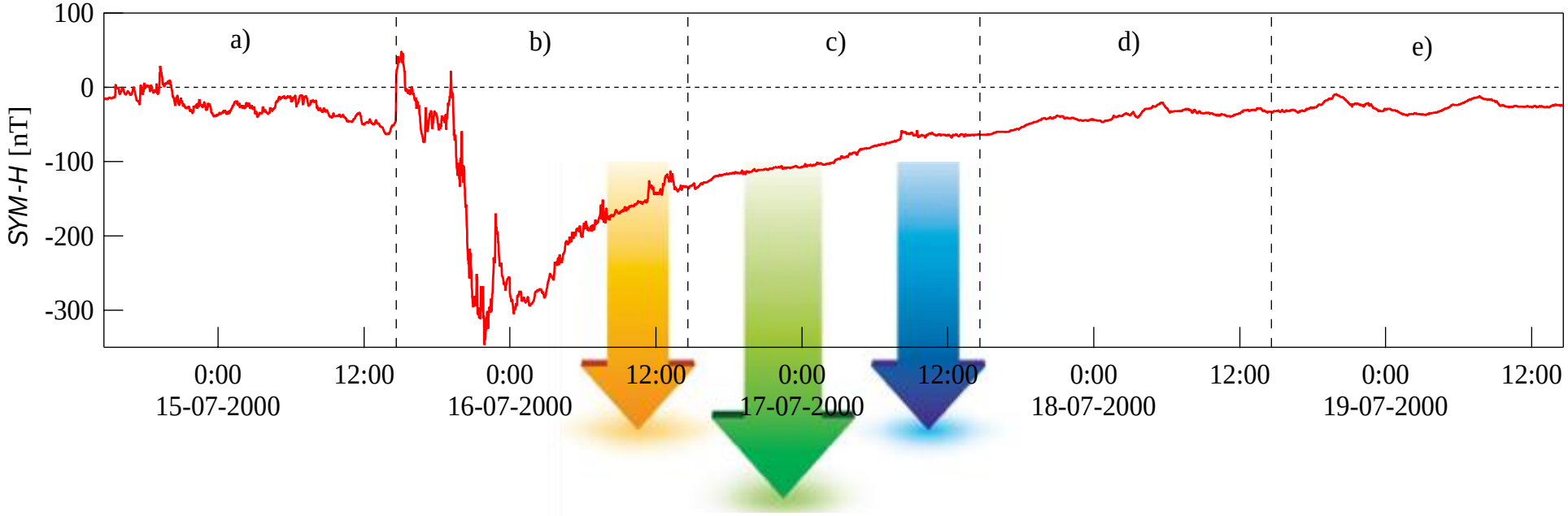
www.eSWua.ingv.it

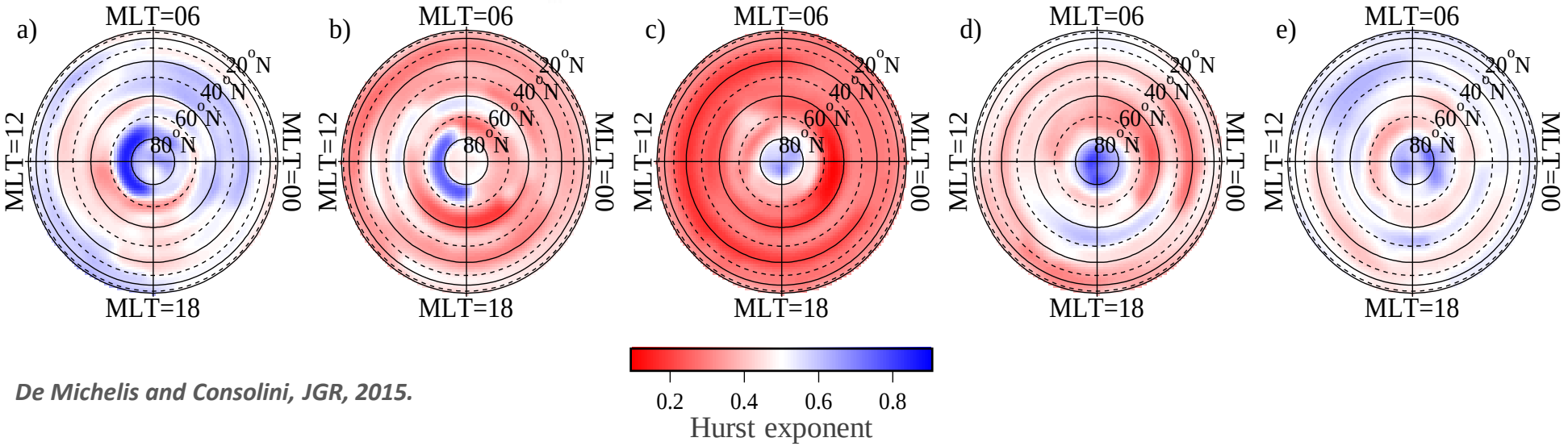
www.spaceweather.it

Recent scientific results



Space Weather with Ground Magnetic Data





De Michelis and Consolini, JGR, 2015.

Identifying proxies of magnetospheric and ionospheric response to space weather events opens the way to the forecast of magnetosphere and ionosphere dynamical status.

<u>An example</u> of a possible proxy using ground magnetic data (changing of the persistence character of geomagnetic field fluctuations).

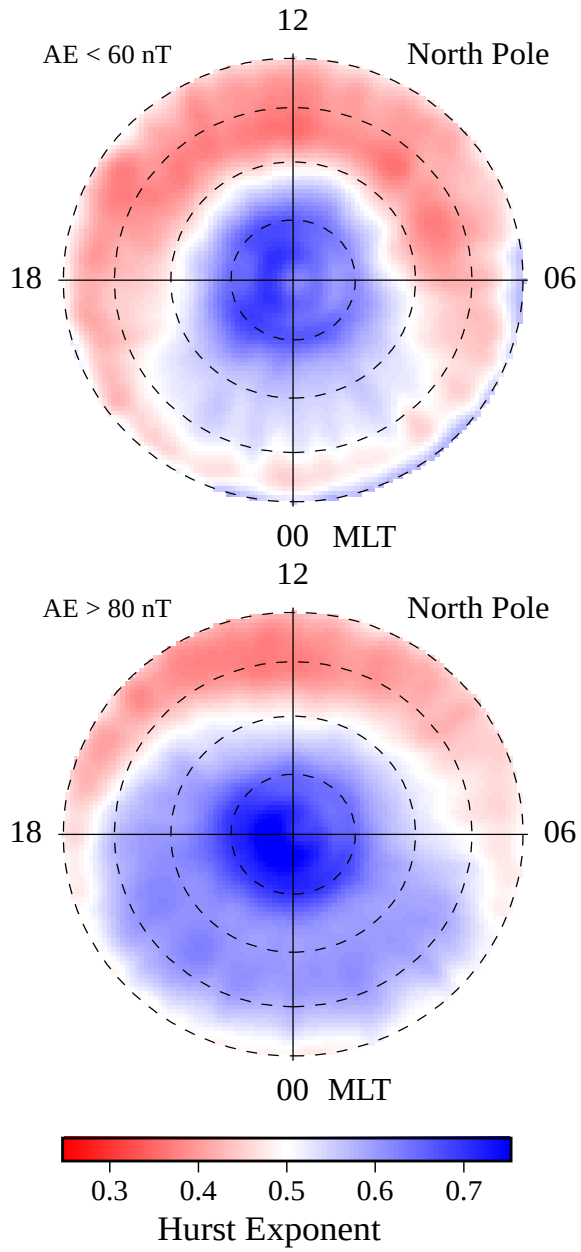
Space Weather with Satellite Magnetic Data

Ionospheric turbulence has an important impact on the operability of all those communication systems affected by the ionospheric medium (e.g. GNSS positioning accuracy, HF radio propagation).

An example of ionospheric turbulence investigation is the evaluation of the spatial distribution of the different turbulence regimes according to two geomagnetic activity levels:

- *quiet (AE index <60 nT);*
- *disturbed (AE index >80 nT).*

Results obtained using 1-year time series from ESA Swarm satellite (470 km altitude).



De Michelis et al., GRL, 2015.

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Mitigation on high accuracy GNSS positioning

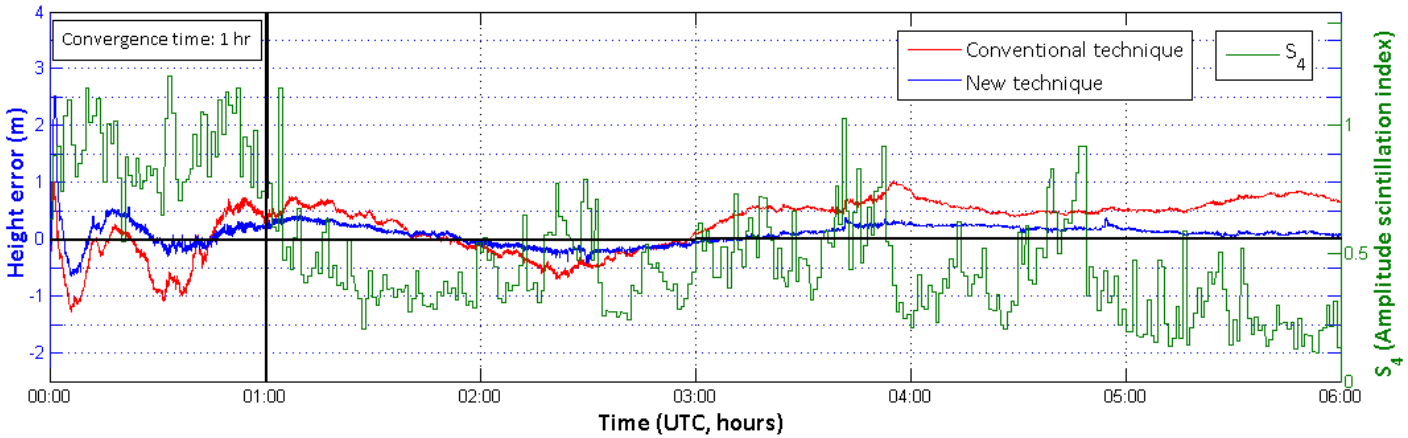
In collaboration with University of Nottingham and Space Research Centre Polish Academy of Science

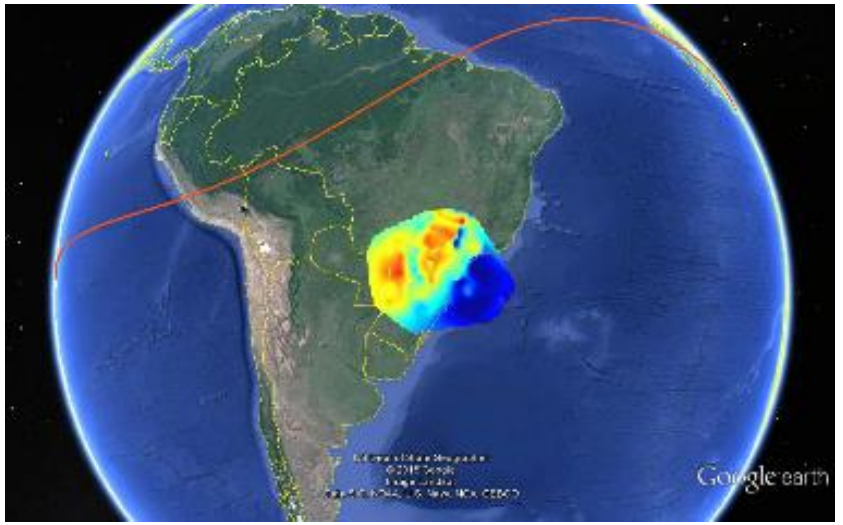
The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

CBK PAN

INGV spin-off SPACEARTH TECHNOLOGY

Short-term forecasting model for TEC and scintillation parameters (S4, σϕ, p, T)





Forecasted Total Electron Content (5 min.)

Precise Point Positioning results

Future application to high precision services

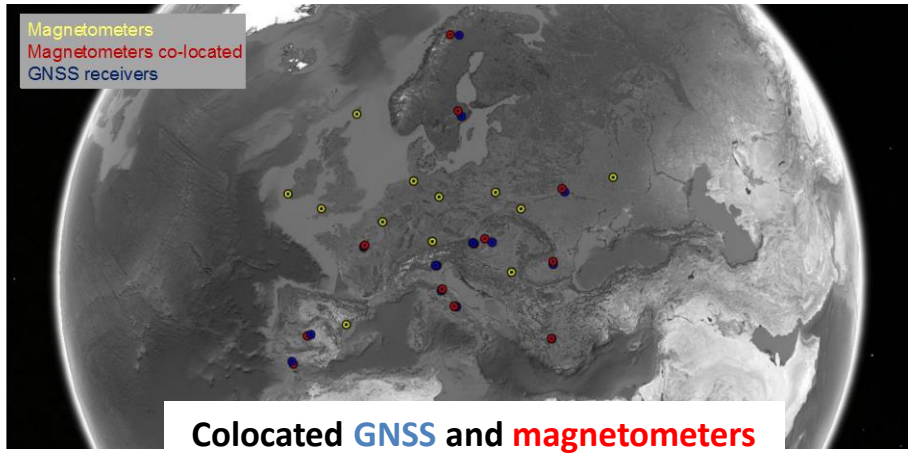
OWNERSHIP OF AN INTERNATIONAL PATENT

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)
(19) World Intellectual Property Organization
International Bureau
(43) International Publication Date
24 November 2016 (24.11.2016)
WIPO | PCT
(10) International Publication Number
WO 2016/185500 A1

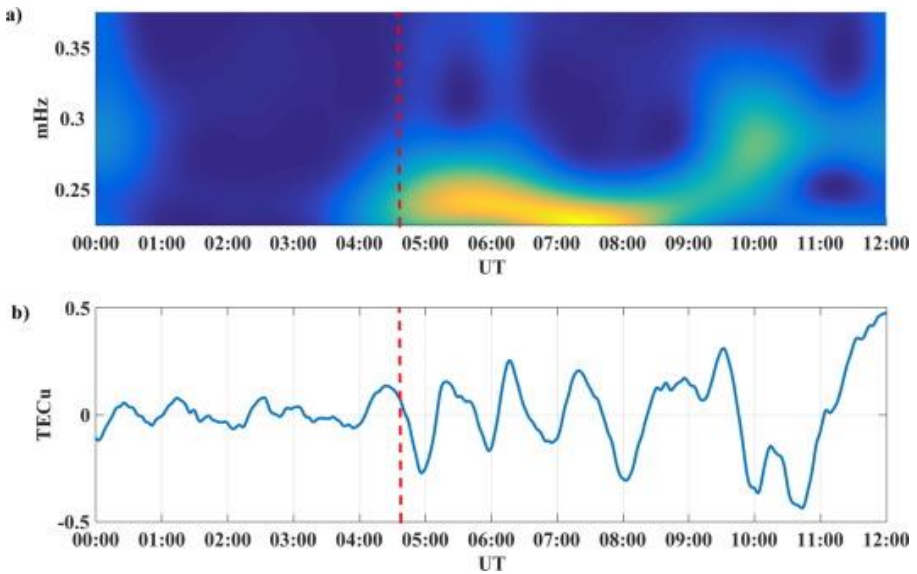
Grzesiak et al. 2017, submitted to Radio Science

	RMS of height error (m)		
	NEW	CONVENTIONAL	**IMPROVEMENTS**
DURING convergence	**0.21**	0.51	**60%**
AFTER convergence	**0.16**	0.54	**69%**

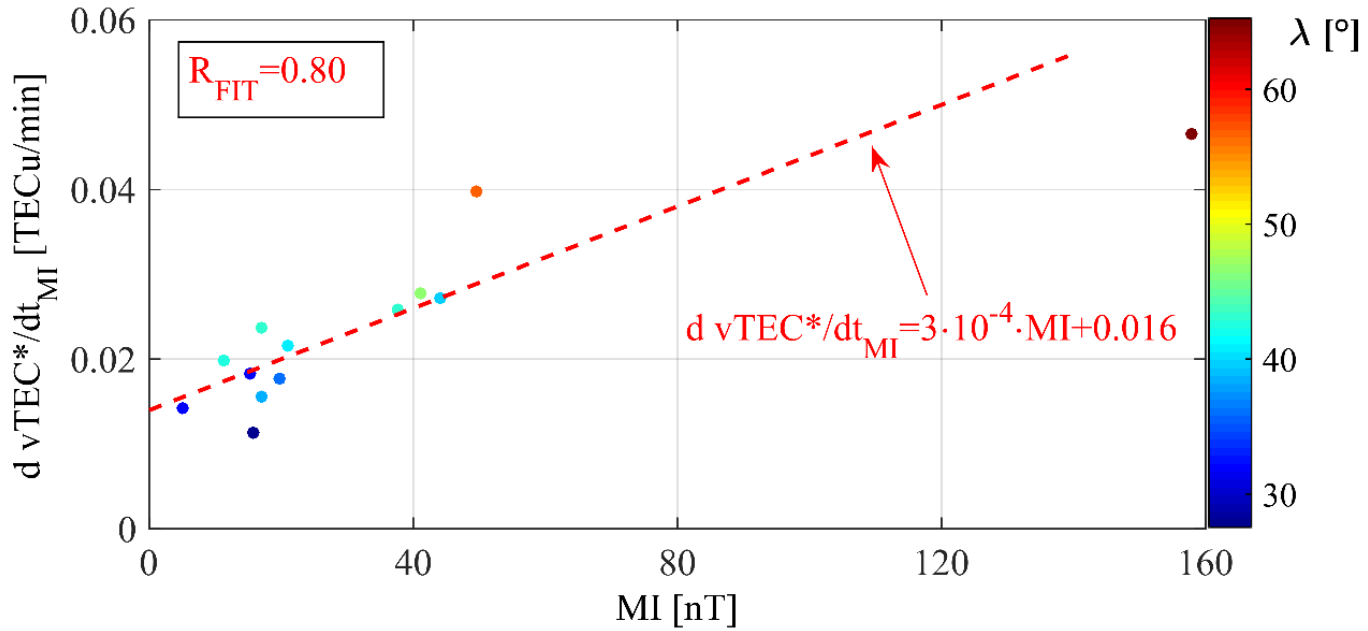
From GNSS Total Electron Content to Ground Induced Currents: a step toward forecasting



Colocated GNSS and magnetometers



A **peculiar TEC mode has been identified to switch-on at the onset** of the largest geomagnetic storm of the current solar cycle (2015-03-17 Saint Patrick's Day Storm).



Linear relationship between the **ionospheric currents** at the main impulse (MI) and the temporal variation of such **peculiar vTEC component.**

When statistically assessed, this would allow to robustly correlate storm-induced TEC perturbation and ionospheric currents.

Current investigations focus on TEC forecasting to provide a **GIC forecasting**.

Piersanti M. et al. ***Does TEC react to a sudden impulse as a whole? The 2015 Saint Patrick's day storm event****, ASR, 2017.*

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BOSTON UNIVERSITY

The first use of coordinated ionospheric radio and optical observations over Italy

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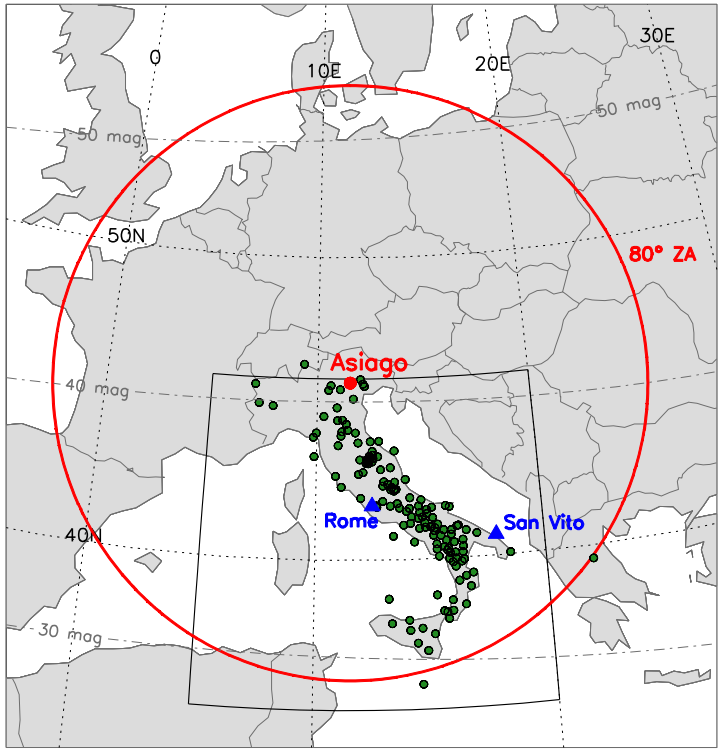
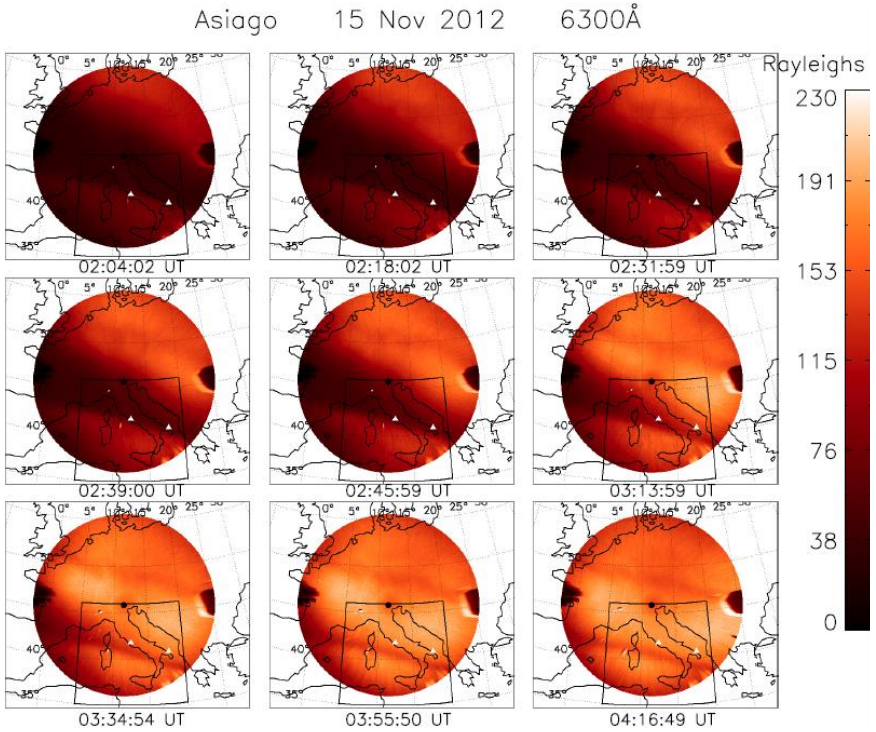
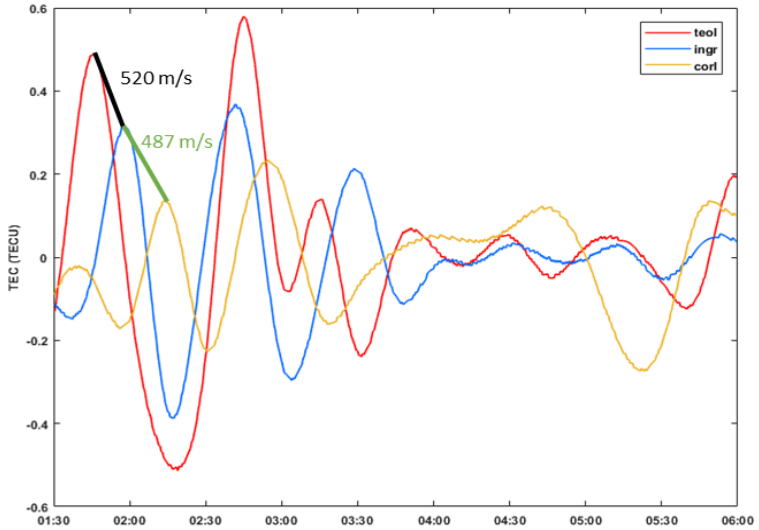


All-Sky Imager, GNSS receivers network and Ionosondes in Italy



Optical images (630 nm emission) revealing wave-like perturbations during the night of 15 November 2012



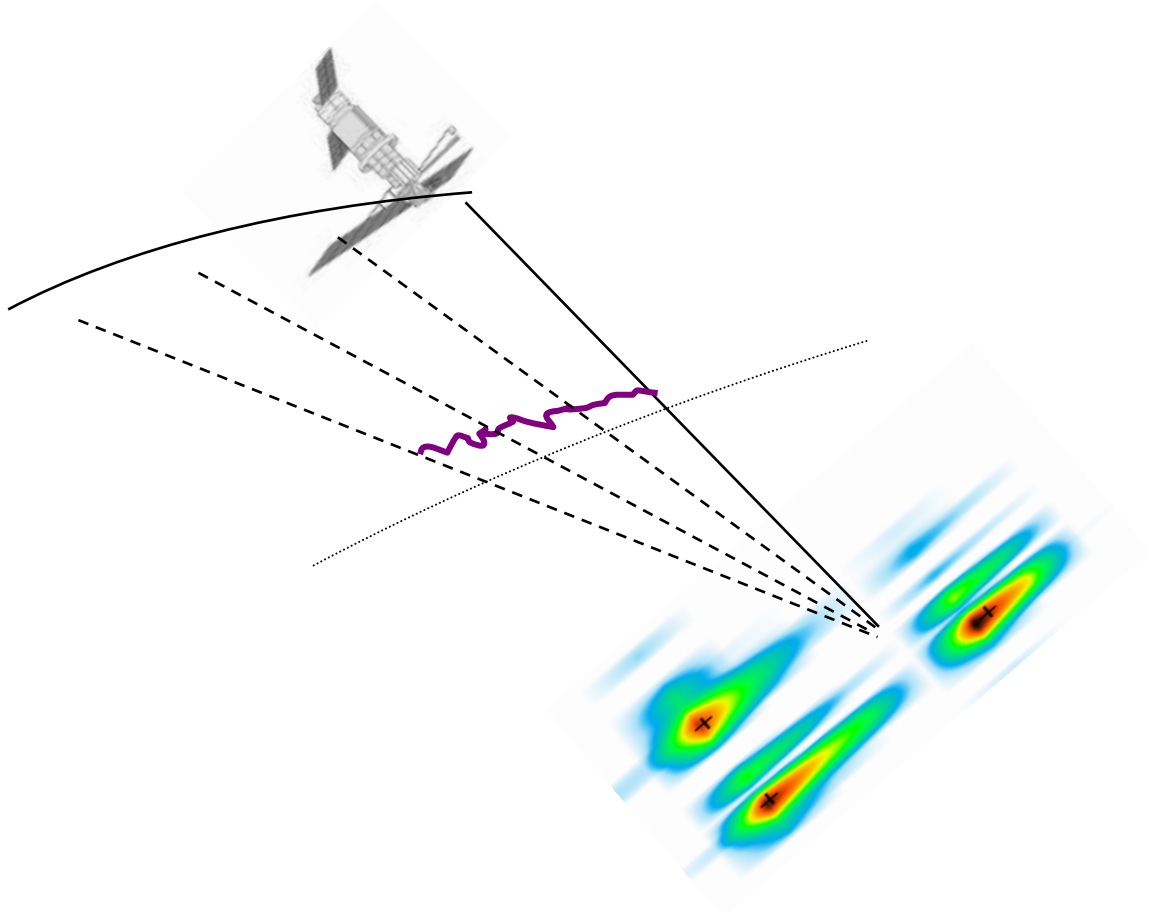
The Ensemble Empirical Mode Decomposition, applied to the TEC values revealing the presence of **travelling ionospheric disturbances (TIDs)** propagating southward.

TIDs were characterized by very faint TEC oscillations (about ±0.4 TEC unit), a period of about 45 minutes and a velocity of about 500 m/s typical of Large Scale TIDs (LSTIDs).

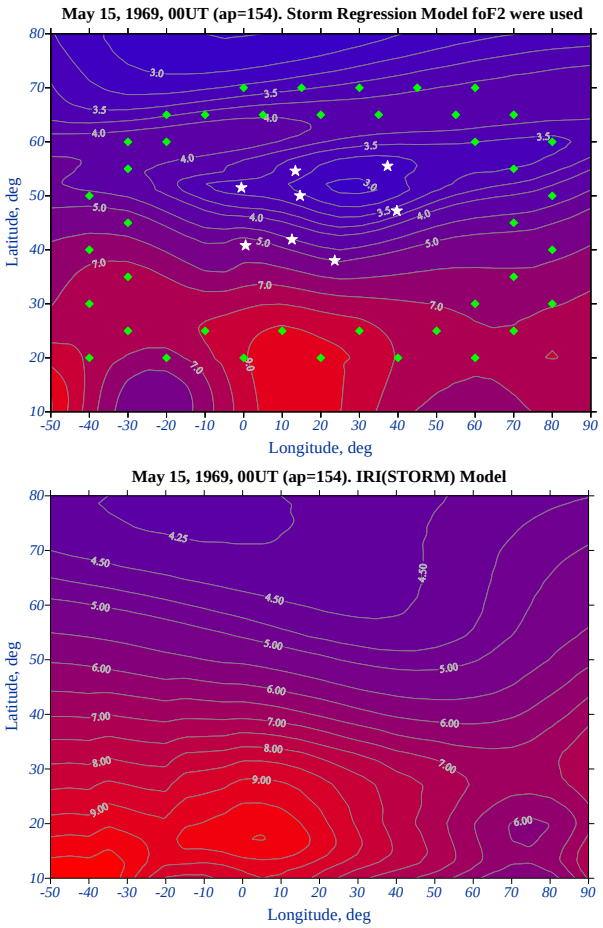
Optical images showed an enhanced airglow entering the field of view of the ASI from the N-NE at 02:00UT and propagating to the S-SW, reaching the region covered by the GPS stations after 03:00UT, when TEC fluctuations are very small.

Cesaroni C., et al. ***The first use of coordinated ionospheric radio and optical observations over Italy: Convergence of high and low latitude storm-induced effects****, submitted to JGR*

Space Weather tools

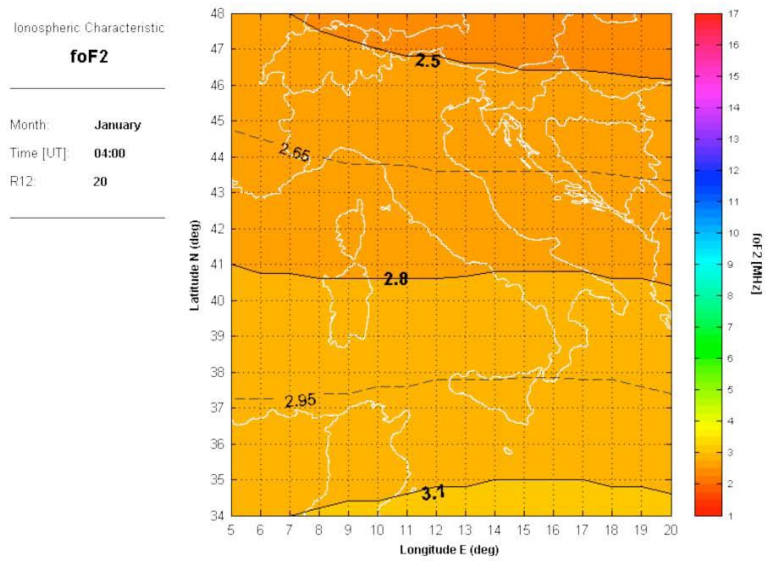


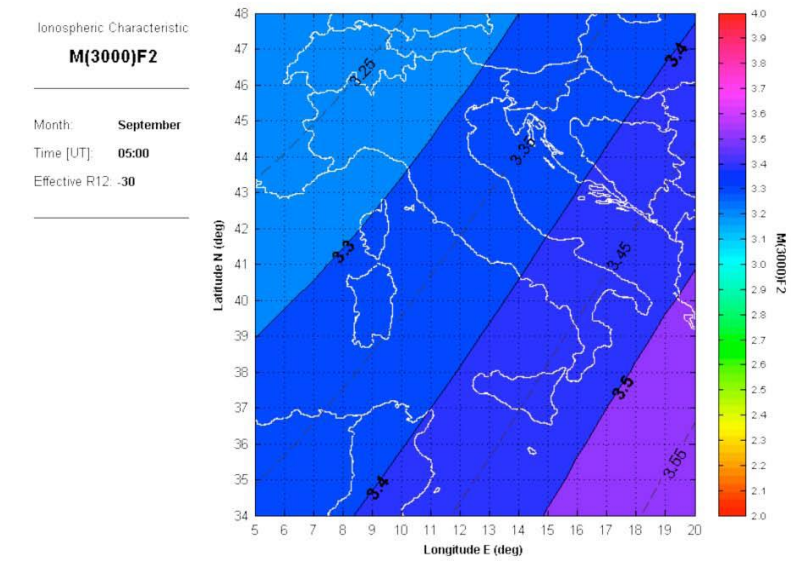
Mapping foF2 over the European region for a severe geomagnetic storm
A comparison with the IRI(STORM) model is given



Mikhailov and Perrone (Radio Sci., 49, 253–270, doi:10.1002/2014RS005373.)

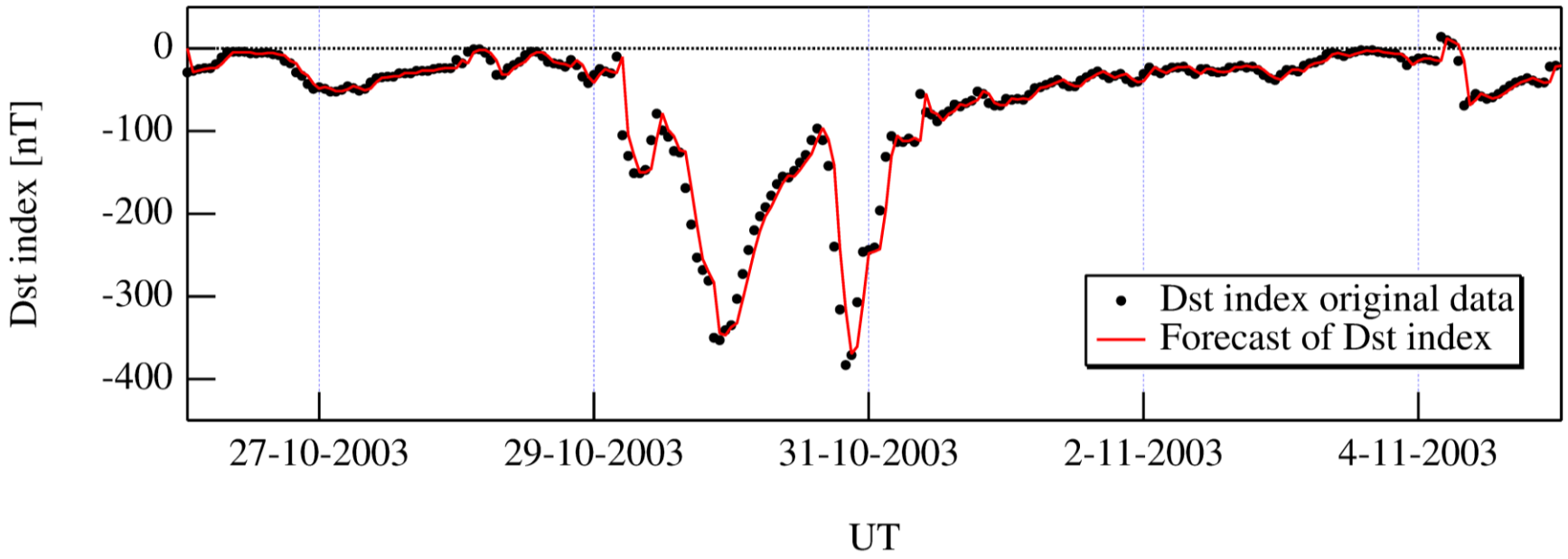
foF2 and M(3000)F2 nowcasting for middle Mediterranean area (ESA- GFINT)





Magnetic Field Forecasting

Present stage of the tool: forecast 1 hour in advance of Dst index starting from interplanetary and magnetospheric data using neural networks.



Future goal: forecast 1 hour in advance of Earth's rapid magnetic field variations due to space weather events using advanced mathematical methods. The need to forecast these variation relates to the fact that they induce an electric field in the surface of the Earth that, on turn, induces geomagnetically induced electric currents (GICs).

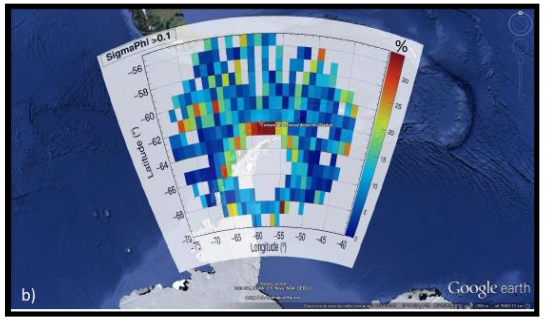
DEMOGRAPE TOOL

Demonstrator for GNSS Research and Application for Polar Environment

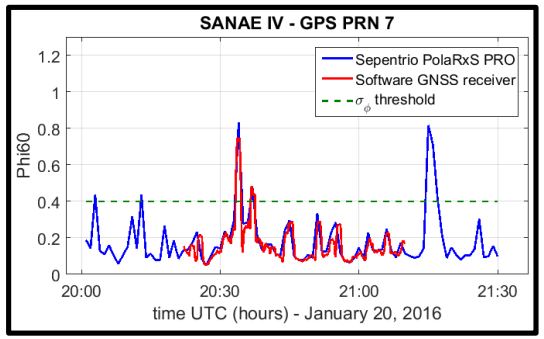
A pilot project for **Space Weather e-science in Antarctica**

This project has received funding from the PNRA, under contract 2013/C3.01.

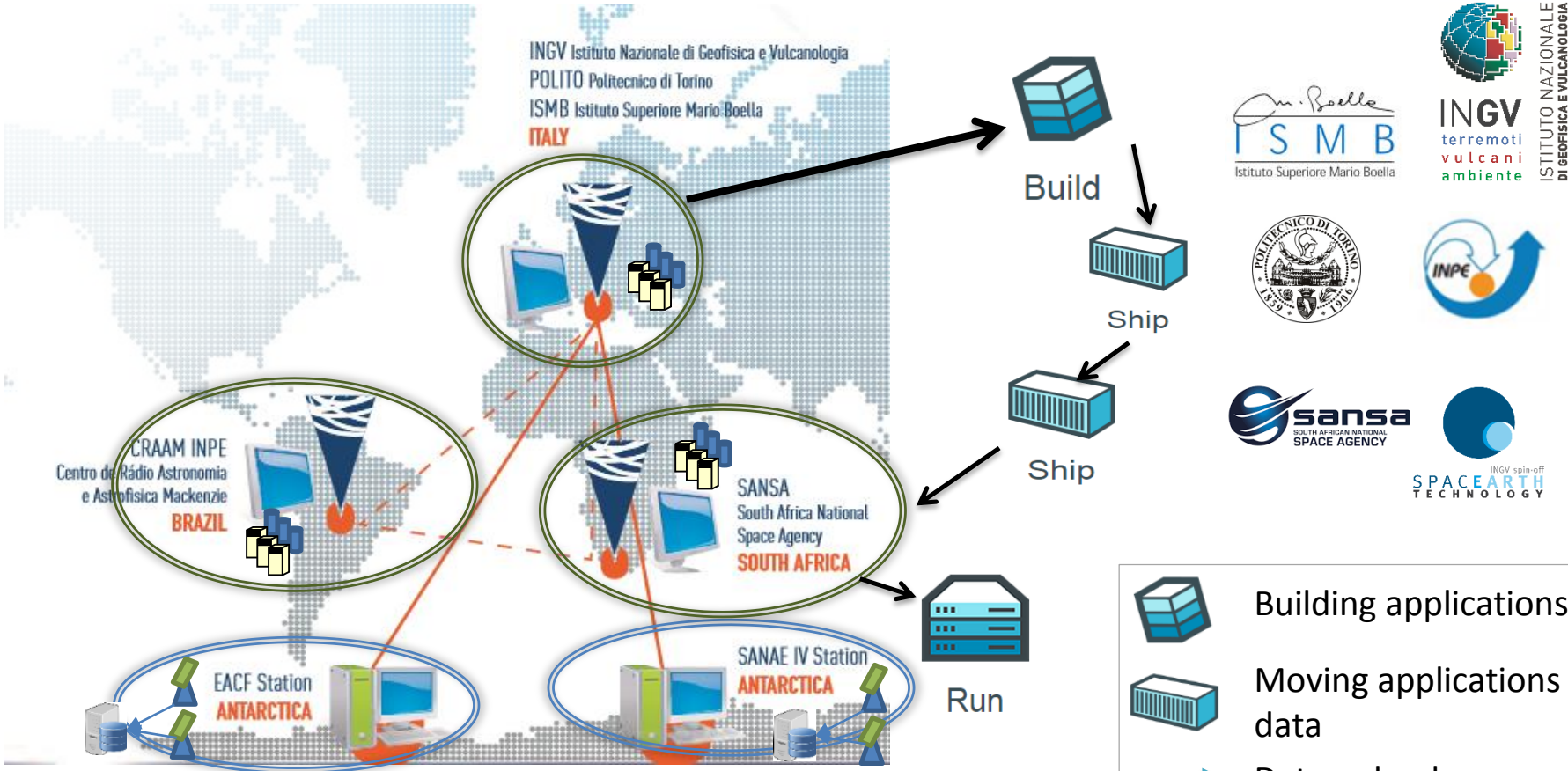
The DemoGRAPE software handled by the Federated Cloud



Comandante Ferraz occurrence of $\sigma_\Phi > 0.1$ - 10-13 November 2015



σ_Φ monitoring from SDR and Professional receiver SANAE IV 20 January 2016



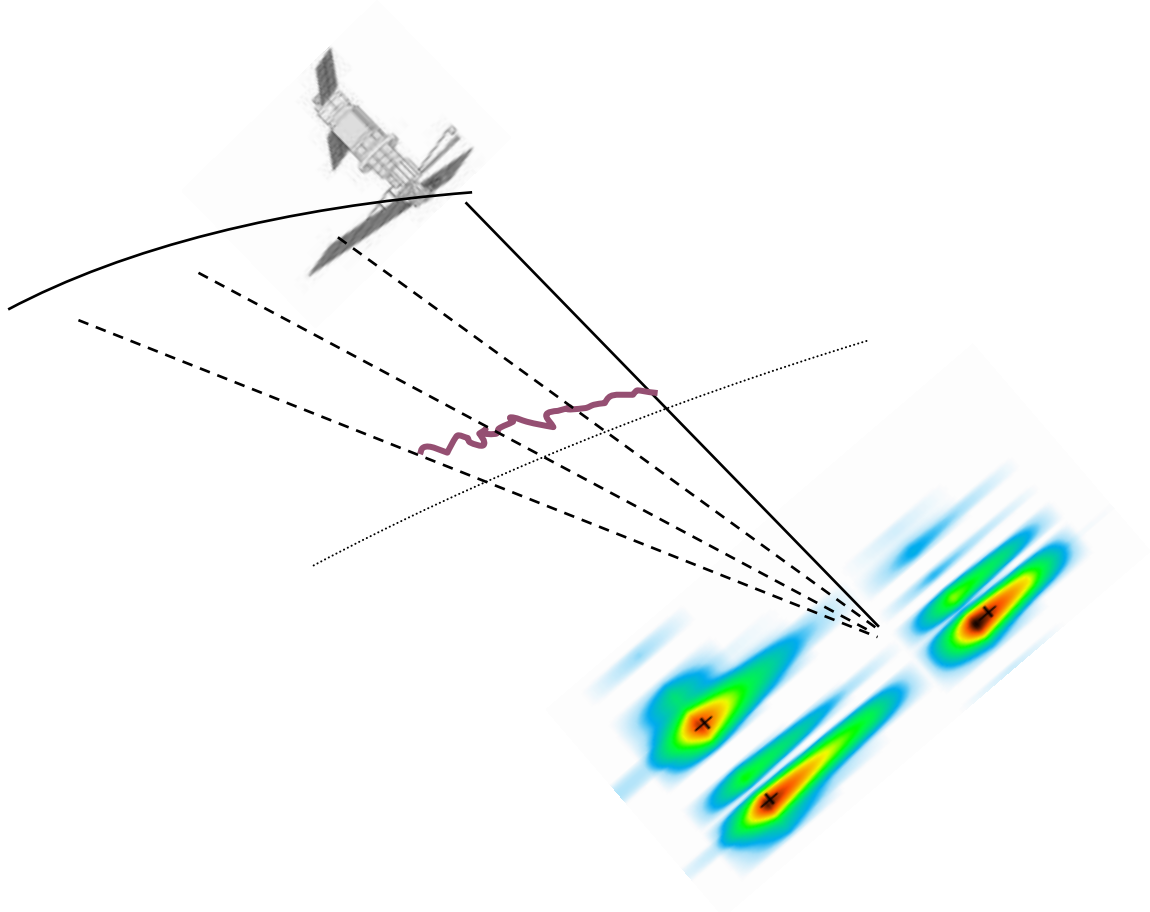
DemoGRAPE Data Management
From Polar Regions to Scientist Community

Sensors, equipments for scientifics measurements

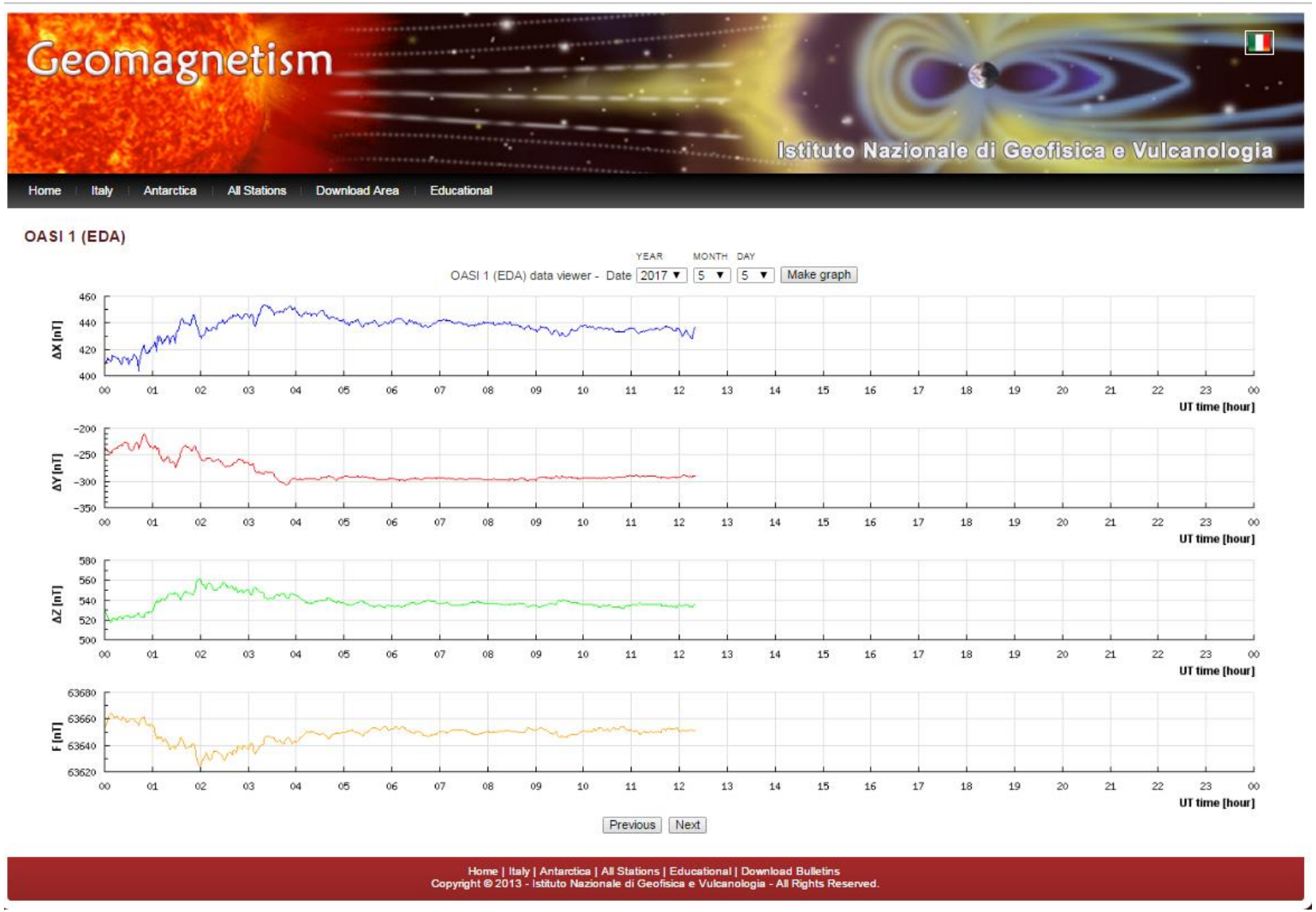
- Building applications
- Moving applications to data
- Data upload
- Sensors
- Dataset
- Resources

Alfonsi L. et al., First Observations of GNSS Ionospheric Scintillations from DemoGRAPE Project. Space Weather, 2016.

Space Weather services



Magnetic Data and Indices



At the following URL address http://geomag.rm.ingv.it the user can find:

- Real-time observatory data (available for plot and download);
- Monthly Bulletins;
- Magnetic K index;
- SSC and SI;
- Annual mean observatory data.

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Ionospheric Prediction Service EU Project

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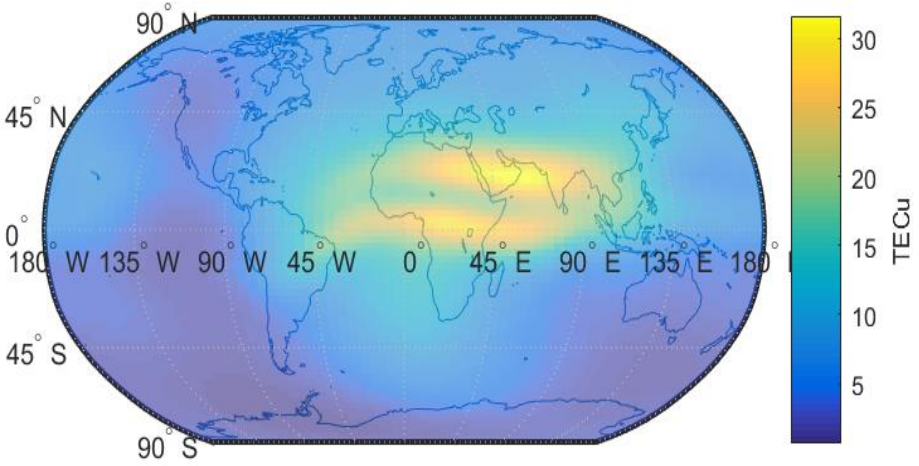
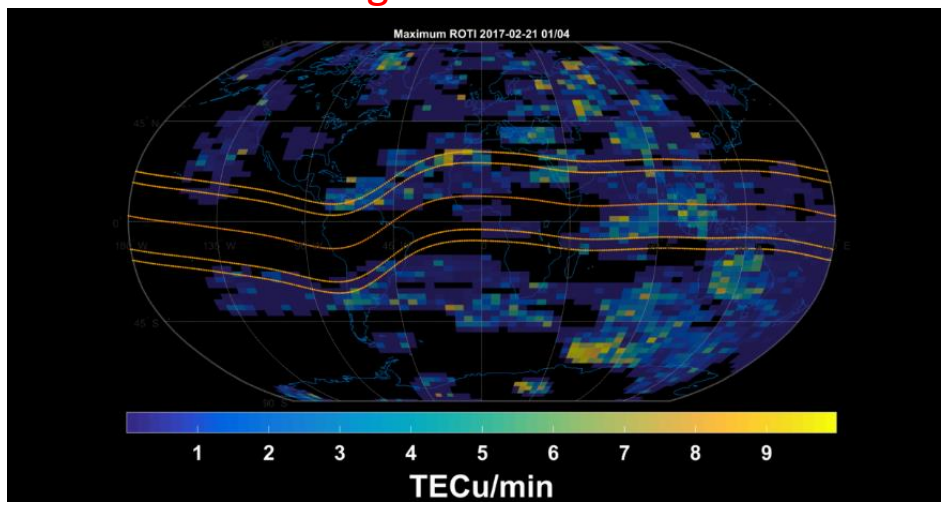
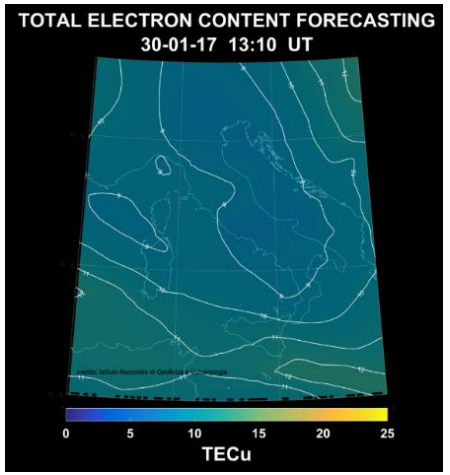
Long term forecasting TEC at global level



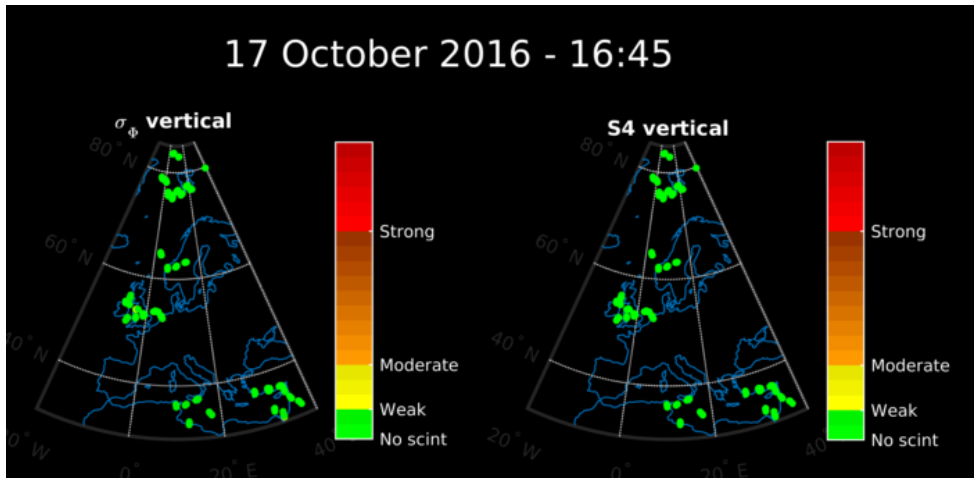
Long term forecasting Proxy Scintillation Index at global level



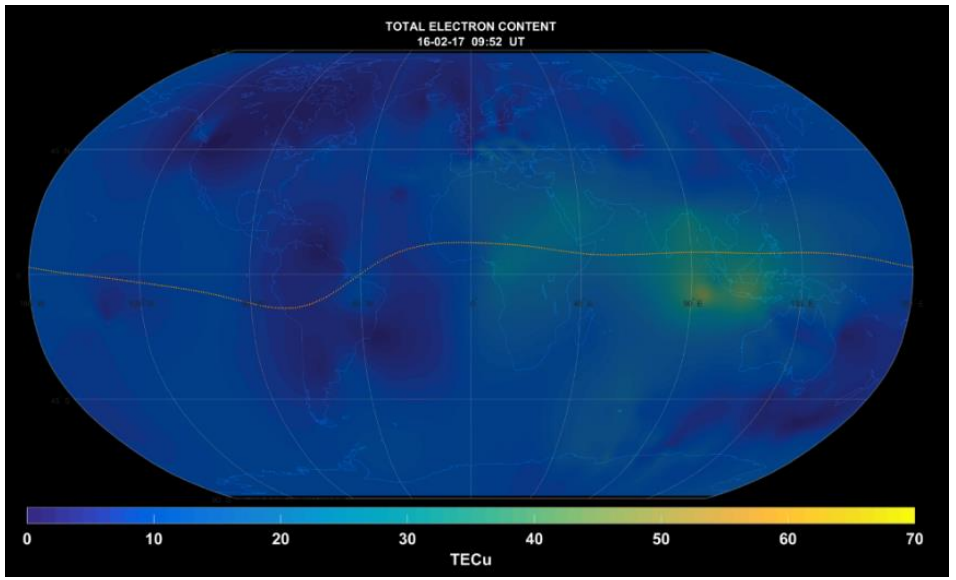
Short term forecasting TEC over Italy



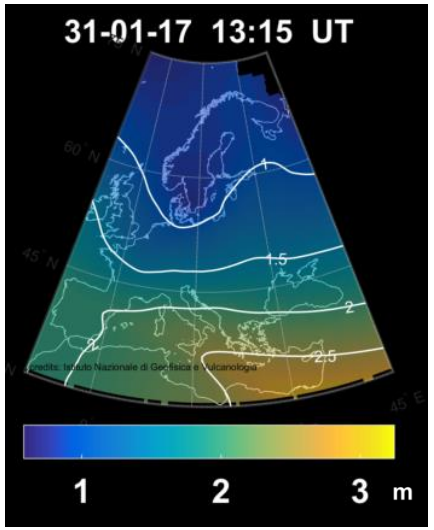
Nowcasting scintillation indices over Europe



Nowcasting TEC at global level



Nowcasting Ionospheric Range Error over Europe



TELESPAZIO a LEONARDO and THALES company

INGV

The University of Nottingham UNITED KINGDOM · CHINA · MALAYSIA

NSL

Università di Roma Tor Vergata

Istituto Nazionale di Geofisica e Vulcanologia

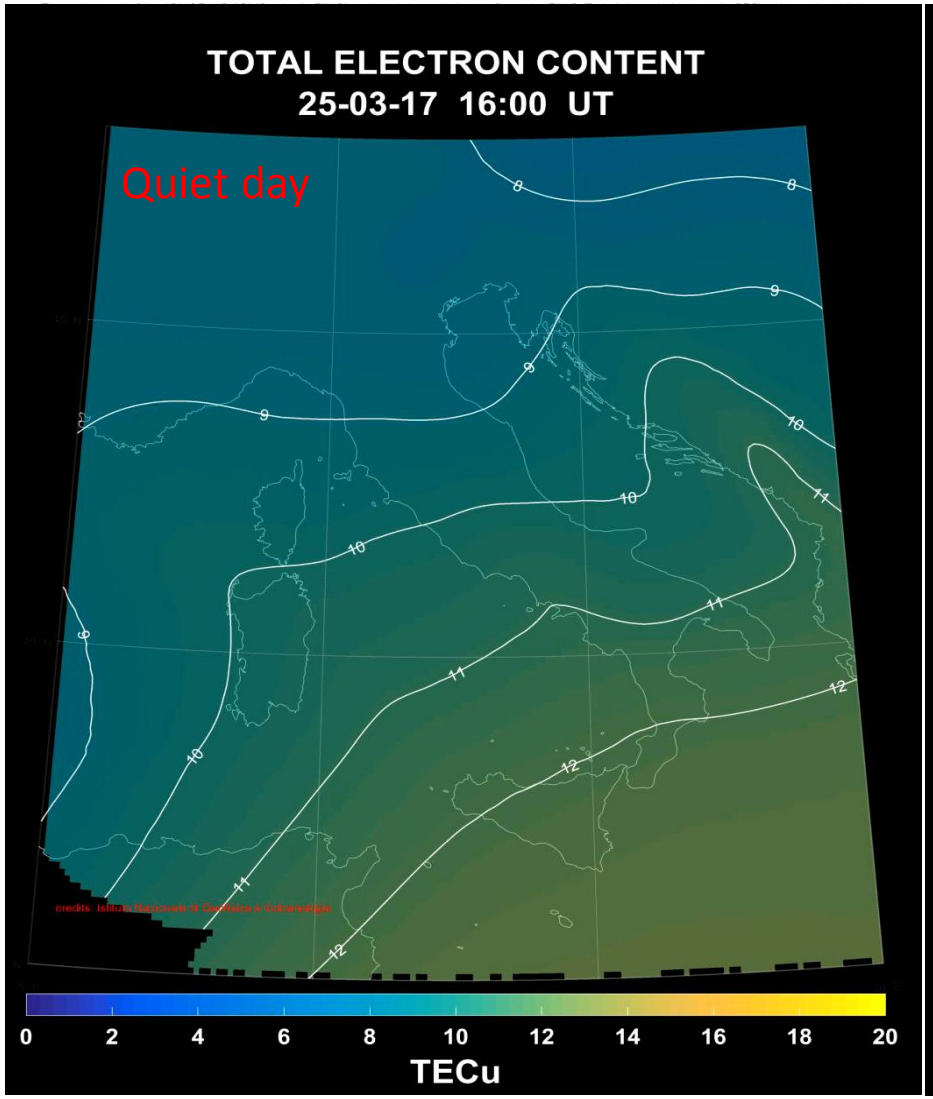
INGV

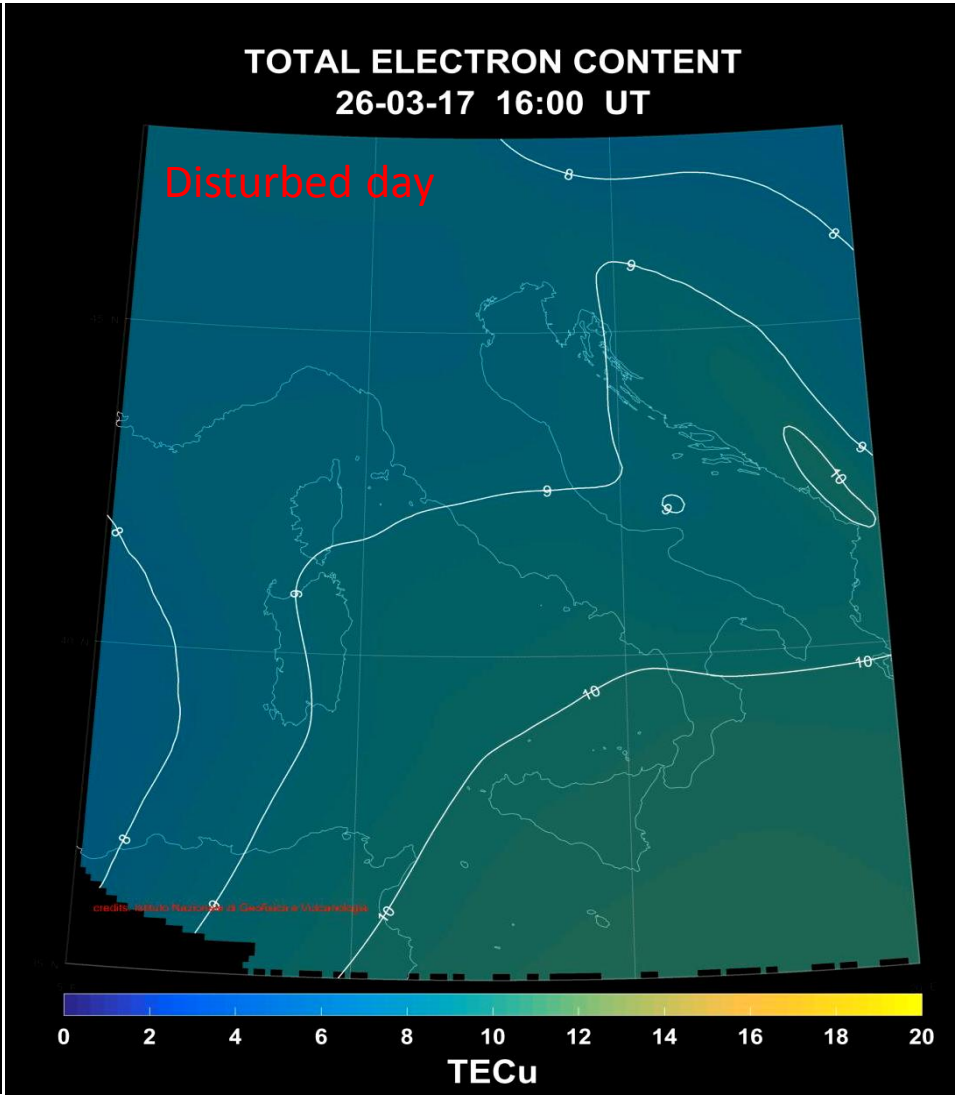
IONORING - Real-time Total Electron Content over Italy

by Upper Atmosphere Physics research group

http://ionos.ingv.it/Ionoring/ionoring.htm

IONORING
real-timetotalelectroncontentoveritaly





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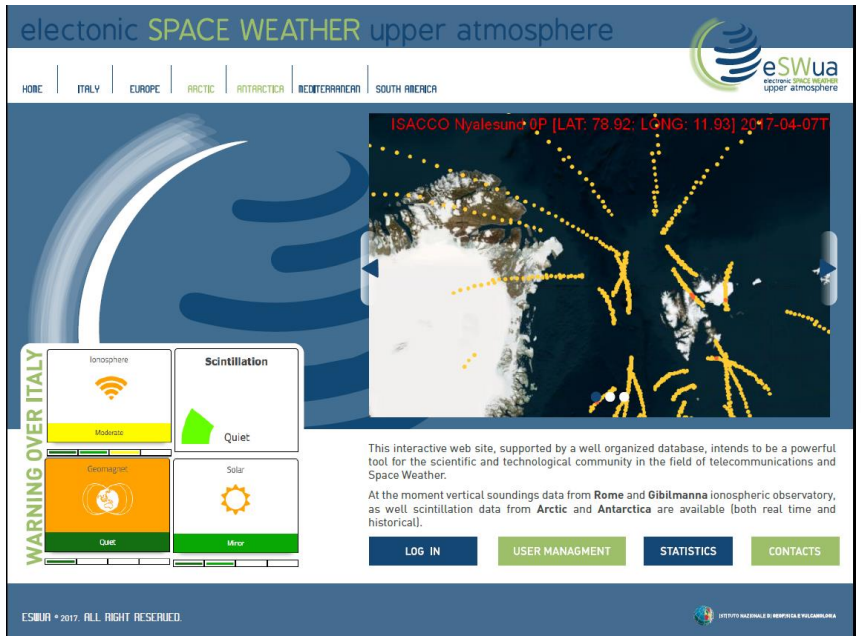
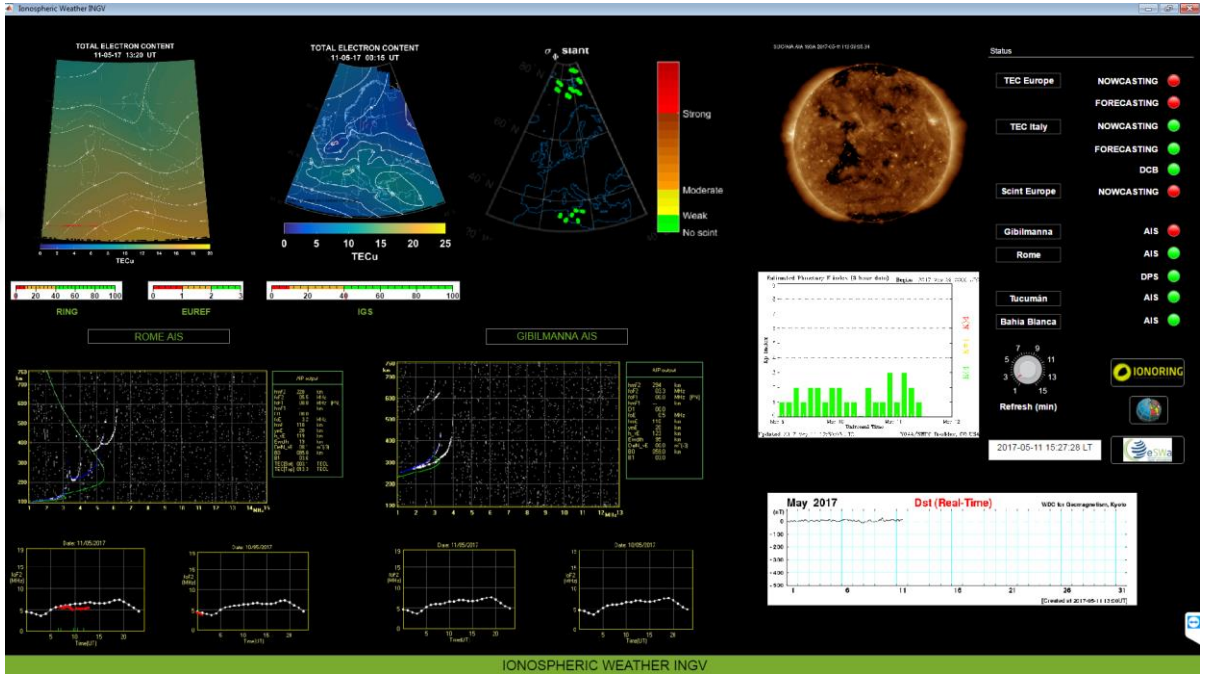
IONOSPHERIC WEATHER SERVICE

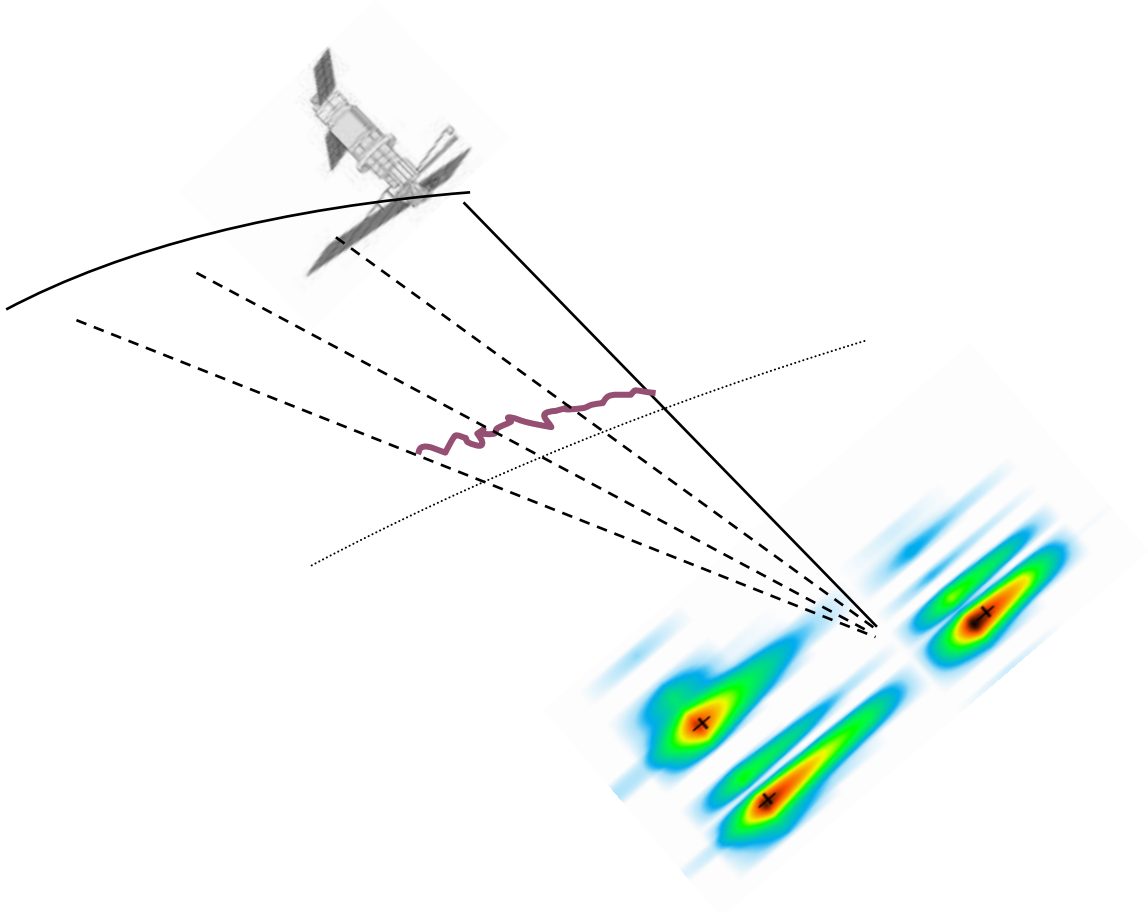




www.eswua.ingv.it
www.spaceweather.it

The ionospheric weather service at ionolab at INGV

On going projects



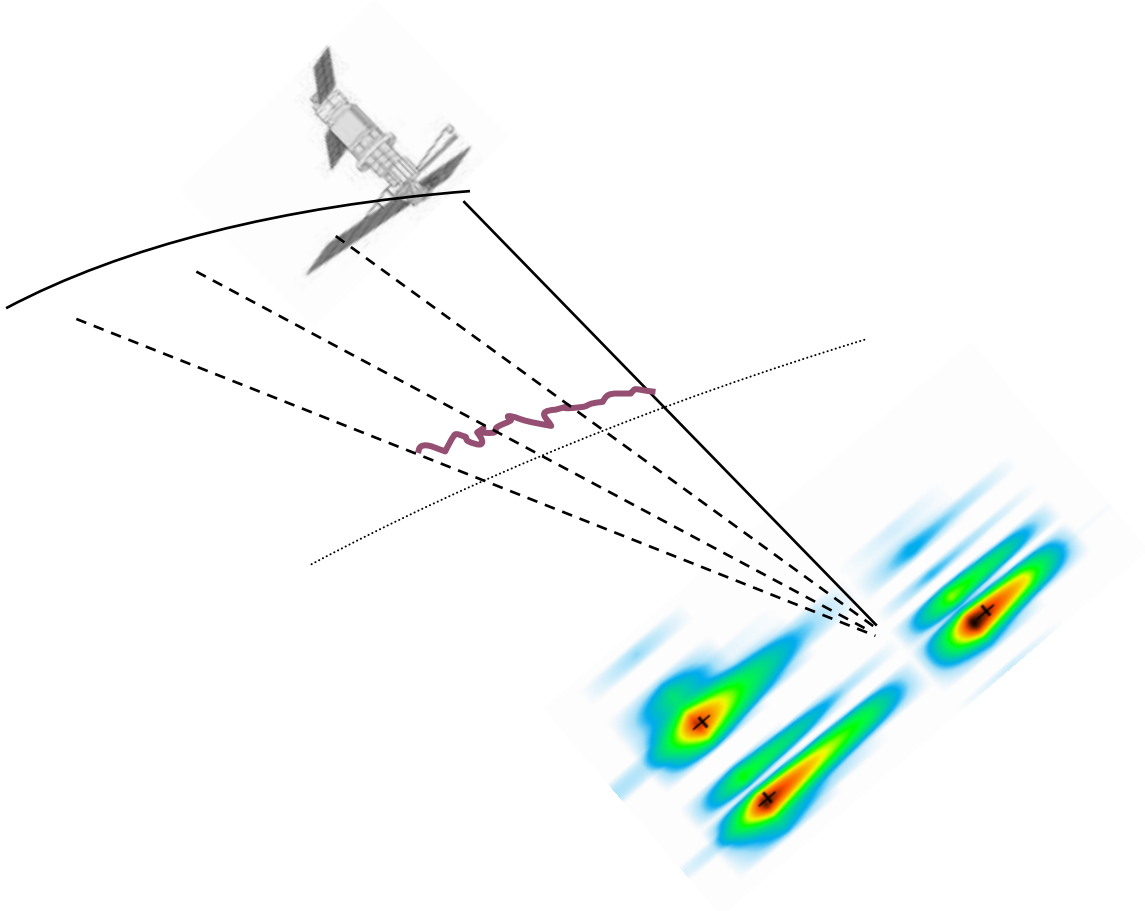
Most relevant on-going projects/initiatives

- **DemoGRAPE**: Demonstrator of GNSS Research and Application for Polar Environment, PNRA
- **GRAPE**: GNSS Research and Application for Polar Environment, SCAR
- **TREASURE:** Training, REsearch and Applications network to Support the Ultimate Real time high accuracy EGNSS solution, H2020-ITN Marie Curie
- **IRIS:** Ionospheric Research for Biomass in South America, ESA
- **IBISCO:** Ionospheric environment characterization for Biomass Calibration over South East Asia, ESA
- **IPS**: Ionospheric Prediction Service, EC
- **Arctic Table at the Italian Ministry of Foreign Affairs**. Task Force on Telecommunication Infrastructures in the Arctic (TFTIA) within the Arctic Council
- **PNRA** "Geomagnetic Observatory at Mario Zucchelli station".
- **PNRA** "Geomagnetic Observatory at Concordia station - Dome C, Antarctica".
- **PNRA** "Italian magnetometer network for longitudinal and latitudinal monitoring in Antarctica".
- **PNRA** “Upper atmosphere observations and Space Weather”
- **PNRA** “Bipolar Ionospheric Scintillation and TEC”
- **COPUOS** - Committee on the Peaceful Uses of Outer Space – SW expert group
- **ISWI** – International Space Weather Initiative

Final Remarks

- INGV has a large community involved in investigation of Space Weather
- INGV and Italy have a consolidated international role in several Space Weather projects and initiatives
- Several scientific results became innovative tools and services to operation
- INGV is ready to support a National Space Weather Centre

Thank you!



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