

INGV contribution to ESA Space Weather Service Network Development and Pre-Operation (SWESNET)

Carlo Scotto and the SWESNET team



• SCIENTIFIC RATIONALE

Background

Under the ESA Space Situational Awareness (SSA) Programme (2009 – 2019) work began to develop a system to monitor, predict and disseminate Space Weather information and alerts.

The SSA programme successfully demonstrated the feasibility of providing reliable space weather information via a distributed network of federated service providers. On conclusion of the SSA programme the SSA Space Weather Service Network is able to provide ~1500 users with access to 29 prototype services, built upon more than 200 individual Space Weather data products.

New Program

Development in S2P Period 1 will increase the ESA Member States ability to protect critical infrastructure and mitigate the impacts of Space Weather on affected systems, with an emphasis on improved forecasting capabilities and increasing the robustness of the underlying service provision system.

• SCIENTIFIC RATIONALE

CURRENT SPACE WEATHER

SPACE WEATHER AT ESA

SERVICE DOMAINS

Spacecraft Design

Spacecraft Operation

Human Spaceflight

Launch Operation

Transionospheric Radio Link

Space Surveillance and Tracking

Power Systems Operation

Aviation

Resource Exploitation System Operation

Pipeline Operation

Auroral Tourism

General Data Service

EXPERT SERVICE CENTRES

OTHER RESOURCES

CONTACT

REQUEST FOR REGISTRATION

Login Required /

Login Required

The ESA SWE Network has created a series of domain specific dashboards designed to enhance the users' experience and allow easy access to the latest data. These dashboards, as with the products provided, are restricted to registered users. Please **sign in** or **register** in order to view the page you are attempting to display.

If you would like more information about the services and products available before you register, please see the information provided in the links below:

Spacecraft Design Services

The purpose of the Spacecraft Design dashboard is to present an overview of the various tools and products that are available for the data archive service, in-orbit verification and post-event analysis, including long-term solar cycle forecasts for future missions.

Further products, data and archives can be found in the specific services of this domain, which are listed below.

Environment Specification: Data Archive

Environment Specification: In-Orbit Verification

Post-Event Analysis

Space Weather in the Solar System

Read more

Transionospheric Radio Link Services

The purpose of the Transionospheric Radio Link dashboard is to present an overview of the current and forecasted ionospheric conditions with the different types of available data (measurement, nowcast, and forecast) at a global or local level.

Further products, data and archives can be found in the specific services of this domain, which are listed below.

Near Real-Time TEC Maps

Forecast TEC Maps

Quality Assessment of Ionospheric Correction

Near Real-Time Ionospheric Scintillation Maps

Monitoring and Forecast of Ionospheric Disturbances

Read more

Space Surveillance and Tracking Services

The purpose of the Space Surveillance and Tracking dashboard is to present an overview of the current atmospheric, geomagnetic and solar conditions for drag calculation. Currently the dashboard presents indices. Estimates of the atmospheric density are available on the service page (click on the corresponding service box below). The dashboard will be updated with tiles showing the ATMDEN plots in the next portal deployment.

Further products, data and archives can be found in the specific services of this domain, which are listed

Resource Exploitation System Operation Services

The purpose of the Resource Exploitation System Operation dashboard is to provide nowcast and forecast information about geomagnetic and ionospheric activity. Geomagnetic disturbances primarily affect directional drilling and aeromagnetic surveys and ionospheric disturbances primarily affect positioning and GNSS-based activities.

Further products, data and archives can be found in the specific service listed below.

Service to Resource Exploitation System Operators

Pipeline Operation Services

The purpose of the Pipeline Operation dashboard is to provide an overview of Space Weather conditions relevant to Pipeline Operators such as local and global forecast of geomagnetic activity and solar wind data.

Further products including additional GIC and PSV products, data and archives can be found in the specific service listed below.

Service to Pipeline Operators

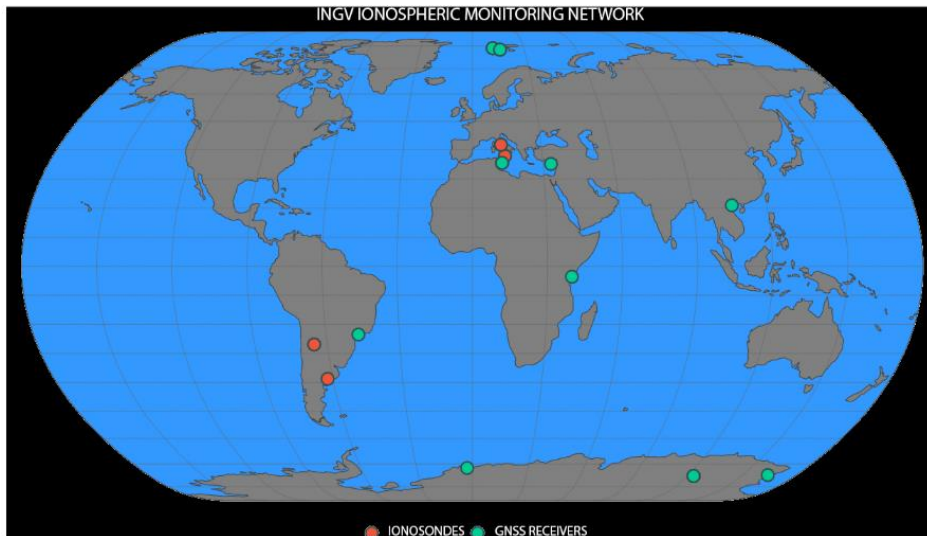
General Data Services

The purpose of the General Data Service dashboard is to provide an overview of the current space weather conditions through presenting a combination of the latest data, nowcasts, forecasts and alerts.

• OBSERVATIONAL INFRASTRUCTURE

Data sources from external infrastructure are integrated

INGV Ionosonde and GNSS network



Ionosondes

38.0°N	23.6°E	Athens
54.6°N	13.4°E	Juliusruh
54.8°N	20.6°E	Kaliningrad
49.8°N	73.0°E	Karagand
55.5°N	37.3°E	Moscow
60.0°N	30.7°E	Peterburg
50.0°N	14.6°E	Pruhonic
41.9°N	12.5°E	Rome
47.2°N	39.7°E	Rostov
51.5°N	359.4°E	Slough
56.5°N	61.1°E	Sverdlovsk
40.8°N	0.5°E	Tortosa
37.9°N	14.0°E	Gibilmanna
52.2°N	21.1°E	Varsaw
35.1°N	33.2°E	Nicosia
50.1°N	4.6°E	Dourbes

GNSS receivers:

- 1) The Italian RING network**
(<http://ring.gm.ingv.it>)
- 2) The EUREF permanent GNSS network**
(<http://www.epncb.oma.be>)
- 3) The IGS network**
(<http://www.igs.org>)

• INFRASTRUCTURE FOR DATA MANAGEMENT

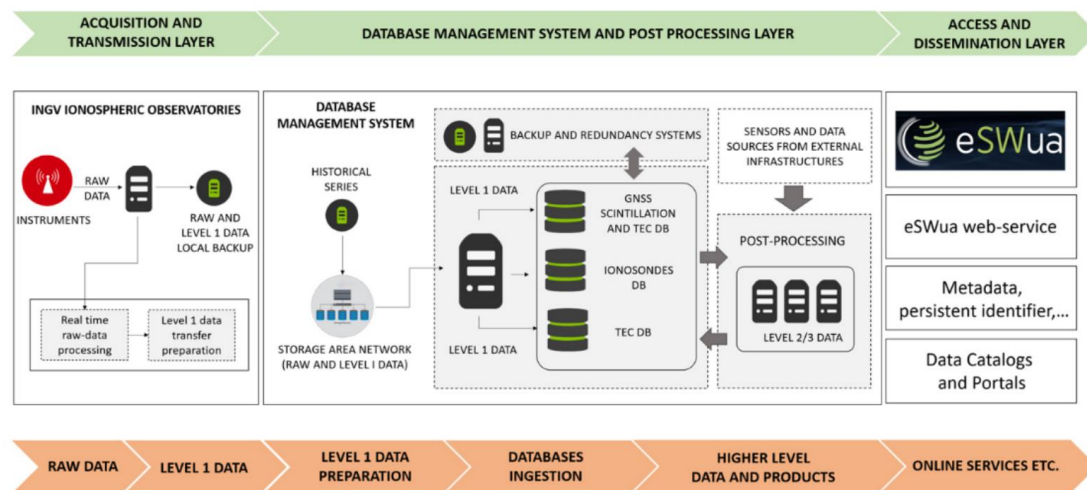
The Space Weather Information Technology system (SWIT) manage the data produced by the INGV ionospheric network, from the acquisition of the instruments to the dissemination layer.

In the **acquisition layer**: the raw observations are real-time processed at the remote facilities to produce Level 1 ionospheric data in different encoding formats, depending on the particular acquisition instrument.

In the **database management system (DBMS) layer**, the Level-1 data coming from the remote stations are collected at the INGV storage area network where automatic procedures harvest and elaborate the files.

In the **post-processing layer**, the data collected by the DBMS are exploited to build and validate scientific models and are further processed to produce higher-level data and ionospheric space weather targeted products.

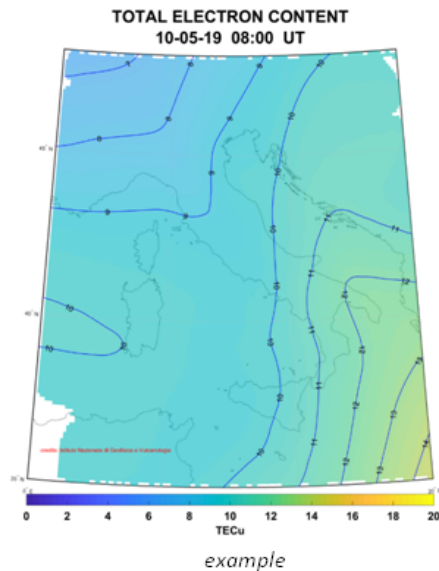
This system also integrates data sources from external infrastructure such as the Italian RING network (<http://ring.gm.ingv.it>), the EUREF permanent GNSS network (<http://www.epncb.oma.be>) and the IGS network (<http://www.igs.org>).



• AVAILABLE PRODUCTS

GNSS Products

Nowcasting of TEC over Mediterrean Area



Thresholds

Quiet	Criteria
Quiet	sTEC < 125 TECu
Moderate	sTEC >= 125 TECu
Severe	sTEC >=175 TECu

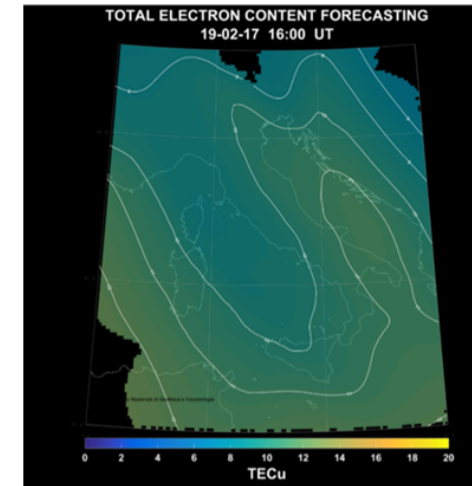
Spatial aspects

Coverage	Resolution
Mediterranean: 5E-20E ; 35N-48N	0.1 degree x 0.1 degree

Time aspects

Property	Value
Update Rate	10m
Latency	1m
Integration Time	1m
Predicted Time	n/a

Forecasting of TEC over Mediterrean Area



example

Thresholds

Quiet	Criteria
Quiet	sTEC < 125 TECu
Moderate	sTEC >= 125 TECu
Severe	sTEC >=175 TECu

Spatial aspects

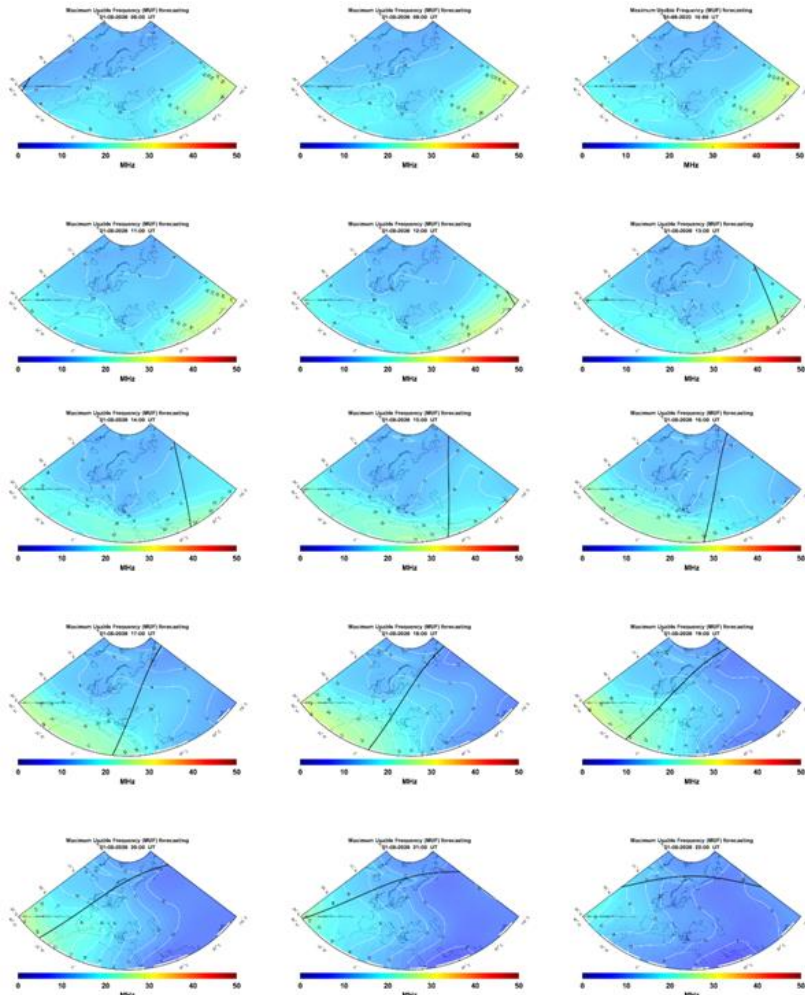
Coverage	Resolution
Mediterranean: 5E-20E ; 35N-48N	0.1 degree x 0.1 degree

Time aspects

Property	Value
Update Rate	10m
Latency	<2m
Integration Time	1h
Predicted Time	30m

• AVAILABLE PRODUCTS

Long Term Forecasting of MUF(3000)F2 over Europe



Result from EUROMAP, a model to forecast Maximum Usable Frequency (MUF) at a distance of 3000 km over Europe.

The input driving parameter are:

- 3h ap indices,
- T index,
- real-time foF2 observations.

The method includes local (for each station) regression storm models to describe strong negative disturbances under $ap(\tau) > 30$ and training over previous 28-day models to describe foF2 variations under $ap(\tau) \leq 30$. Index T is used to specify the background level.

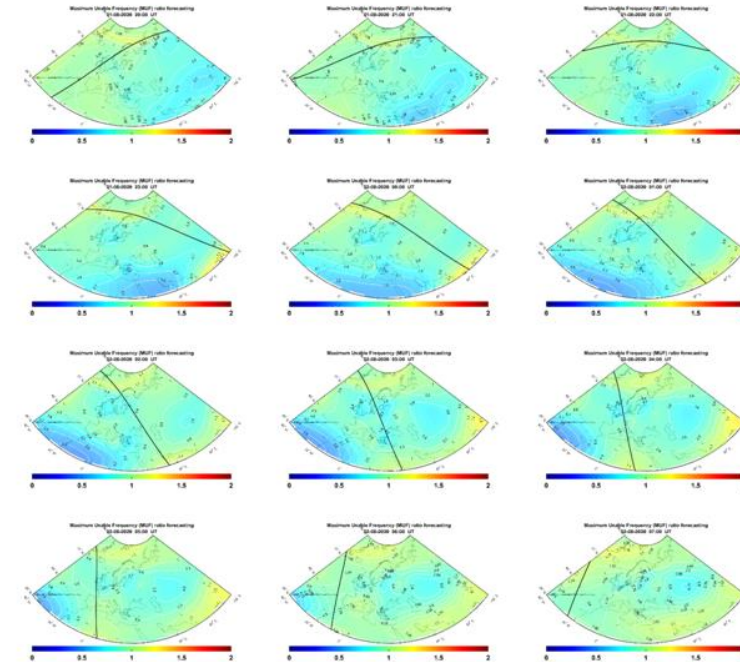
• AVAILABLE PRODUCTS

Long Term Forecasting of MUF(3000)F2 ratio over Europe

This product is the ratio between the forecasted MUF(3000) derived from EUROMAP model and the background.

The background is the MUF monthly median derived from the International Reference Ionosphere Model (IRI).

The input driving parameter for IRI is the R12 index.



example: MUF(3000) - 1 August 2020 07 UT. 24 maps forecasted from +1 hour (01 August 08UT) to 24 hours(01/08 07UT). The black line is the solar terminator.

Thresholds

Quiet	Criteria
Quiet	<30%
Moderate	30%
Severe	>50%

Spatial aspects

Coverage	Resolution
Europe: 40W - 100E ; 10N - 80N	2.5 degrees x 5 degrees

Time aspects

- Update rate: 60 min
- Latency: 15 min

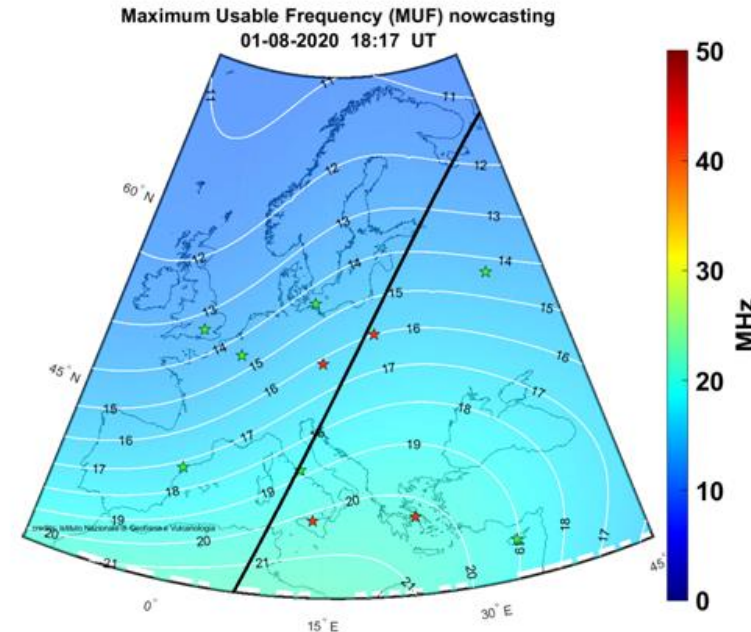
• AVAILABLE PRODUCTS

Nowcasting of MUF(3000)F2 over Europe

The near real-time maps of MUF(3000) are estimated every 15 minutes.

Input data are real-time ionosonde data recorded at several stations over Europe. Such measurements are integrated into the International Reference Ionosphere (IRI) background model, which is upgraded starting from the relative deviations at the stations. Kriging techniques are then applied for spatial interpolation.

The input driving parameter for IRI is the R12 index.



example

Thresholds

Quiet	Criteria
Quiet	no depression or depression < 30% from the modelled median value
Moderate	30% < depression < 50% from the modelled median value
Severe	depression > 50% from the modelled median value

Spatial aspects

Coverage	Resolution
Europe: 12.0W-45.5E ; 32.0N-72.5N	0.5 degree x 0.5 degree

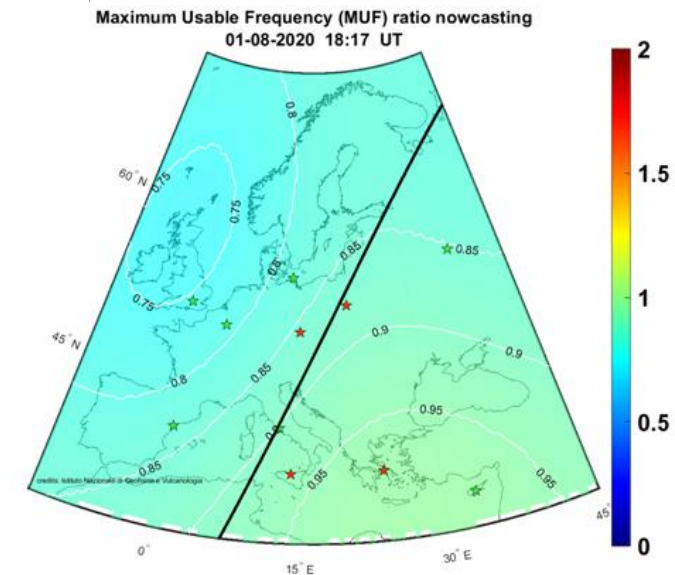
• AVAILABLE PRODUCTS

Nowcasting of MUF(3000)F2 ratio over Europe

This product is the ratio between the nowcasted MUF(3000) derived from real-time ionosonde data and the background.

The background is the MUF monthly median derived from the International Reference Ionosphere Model (IRI).

The input driving parameter for IRI is the R12 index.



example

Thresholds

Quiet	Criteria
Quiet	ratio > 0.7 (no MUF depression or MUF depression < 30% from the modelled median value)
Moderate	0.5 < ratio < 0.7 (30% < MUF depression < 50% from the modelled median value)
Severe	ratio < 0.5 (MUF depression > 50% from the modelled median value)

Europe: 12.0W-45.5E ; 32.0N-72.5N	0.5 degree x 0.5 degree
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Time aspects

- Update rate: 15 min
- Latency: 2 min
- Integration time: n/a
- Predicted time: n/a hours

• CURRENT DISTRIBUTION OF PRODUCTS

Product Group Code	Product Group Name	Number of product files ^[1]	List of used format types (MIME)	Current maturity level ^[2]	Expected maturity level at T0+21m	Current integration maturity index	Expected PIMI at T0+21m	(Expected) date of acceptance review
I.D22	MUF(3000)F2 nowcast maps	96/day	png, json	4	7	1	4	TBD
I.D24	MUF(3000)F2/MUF (3000) _[background] nowcast maps	96/day	png, json	4	7	1	4	TBD
I.D21	MUF(3000)F2 forecast maps	96/day	png, json	4	7	1	4	TBD
I.D24	MUF(3000)F2/MUF (3000) _[background] forecast maps	96/day	png, json	4	7	1	4	TBD
I.D27	TEC nowcast maps	144 /day	png, json	4	7	1	4	TBD
I.D26	TEC forecast maps	144 /day	png, json	4	7	1	4	TBD
I.106	Scintillation data to DLR for integration into the product I.106 (Local Scintillation Data)	96/day	png, txt	4	7	1	4	TBD

TEAM AND PARTERSHIP

INGV TEAM

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SWESNET Consortium

Deutsches Zentrum für Luft- und Raumfahrt

Norwegian Mapping Authority, Geodetic Insititute

Universitat Politècnica de Catalunya

Institute of Space Science, Romania

Observatory of Athens

Institute of Atmospheric Physics, 14131 Prague, Czech Republic

GFZ German Research Centre For Geosciences, Potsdam, Germany

Finnish Meteorological Institute

Collecte Localisation Satellites, France

Graz University of Technology - Elsevier

THERmospheric parameters from IONospheric observations

THERION

L. Perrone, C. Scotto, D. Sabbagh, A. Mikhailov



ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA 

THERMOSPHERE MONITORING

1

Thermospheric storms



2

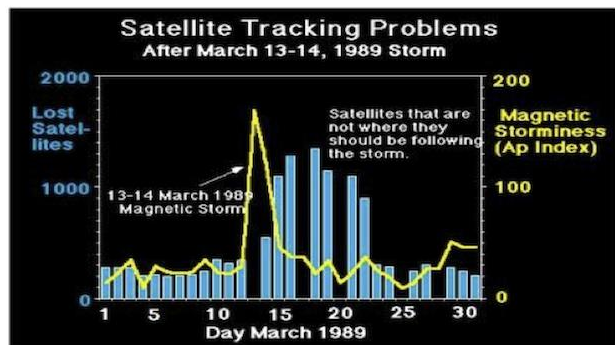
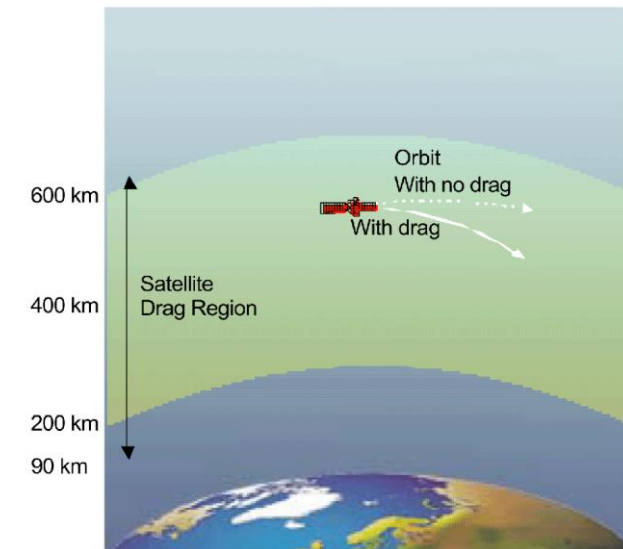
Atmospheric Drag on Satellite



3

Thermosphere monitoring is an actual problem (COS)

The increase of neutral density occurring during thermospheric storms determines an increase in air drag that leads to a stronger drag of low orbiting satellites, necessitating a recalculation of their orbits



**Atmospheric Drag =
Space Object Positioning Error**



THERION

Direct observations of the thermosphere are technically very complicated and expensive. The idea is to retrieve the main thermospheric parameters from ionosonde observations.

A new approach to monitor the thermosphere based on routine ionosonde observations has been recently proposed. This may open a way to monitor the state of the thermosphere using the world-wide ionosonde network observations

(L. Perrone and A. Mikhailov, JGR, 2018)



INPUT:

- f_o (10-14 LT) at 180km,
- f_oF2 (12 LT)
- Solar and Geomagnetic indices.

Physical Model of F region

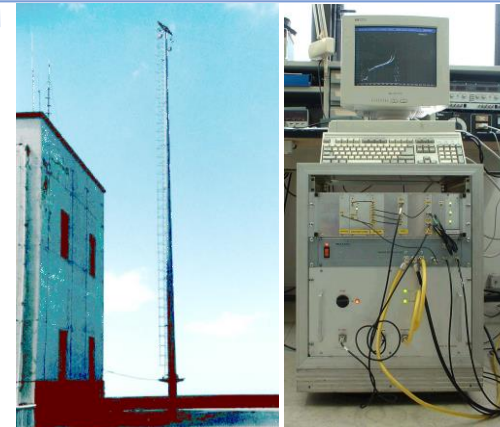
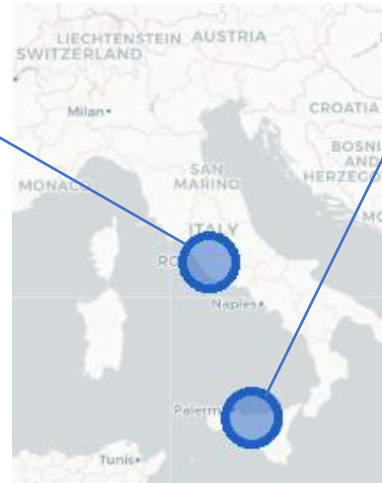
OUTPUT
[O], [N₂],
[O₂], T_{ex} ,
EUV, W

• OBSERVATIONAL INFRASTRUCTURE

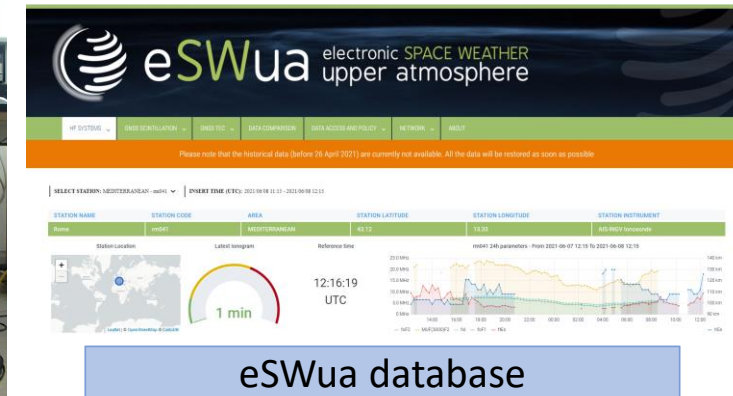
Rome observatory (Italy)



Gibilmanna observatory (Italy)



www.eswua.ingv.it



eSWua database

Antennas (Tx and Rx) AIS-INGV ionosonde



AIS-INGV ionogram with scaled parameters and profile

Autoscala software for the automatic interpretation of the ionograms can be applied to any ionogram (i.e. acquired by any kind of ionosonde)

• PRODUCTS AVAILABLE & CURRENT DISTRIBUTION OF THE PRODUCTS (under development)

THERMOSPHERE

The products are under development:

- Nowcasting neutral composition: [O], [N₂], [O₂]
 - Nowcasting exospheric temperature: T_{ex}
- Nowcasting Vertical plasma drift: W which may be recalculated into the effective meridional thermospheric neutral wind
 - Also the total Solar EUV flux with $\lambda \leq 1050 \text{ \AA}$



The retrieved parameters will be available at the beginning in the Italian INGV ionosonde sites. All retrieved parameters are available once per day (after 14 LT)

- PROGRAMS/PROJECTS OF REFERENCE

SERENA (Pianeta Dinamico 2021 – Theme 3 – MIUR)

ATRIO (PNRA 2018) – waiting for approval

- TEAM AND AFFILIATIONS

L. Perrone, C. Scotto. D. Sabbagh, A. Mikhailov

Affiliation: Roma 2, INGV