



GALILEO in GEOPHYSICS

GNSS data is extensively exploited by INGV scientists to monitor a variety of geophysical parameters to learn, for instance, about geodesy and physics of the lower and upper atmosphere. The advent of **Galileo** provides additional capability in terms of spatial coverage and spectrum extension. In this framework, the former GPS networks are now being upgraded with GNSS (multi-constellation) receivers, capable to track Galileo satellites.

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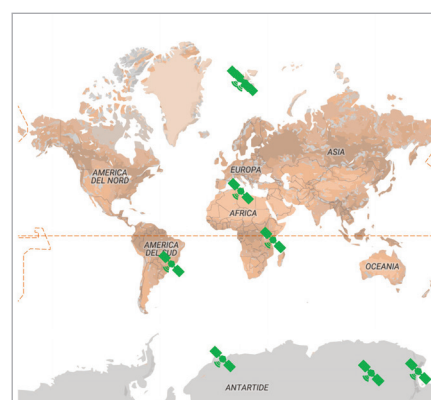
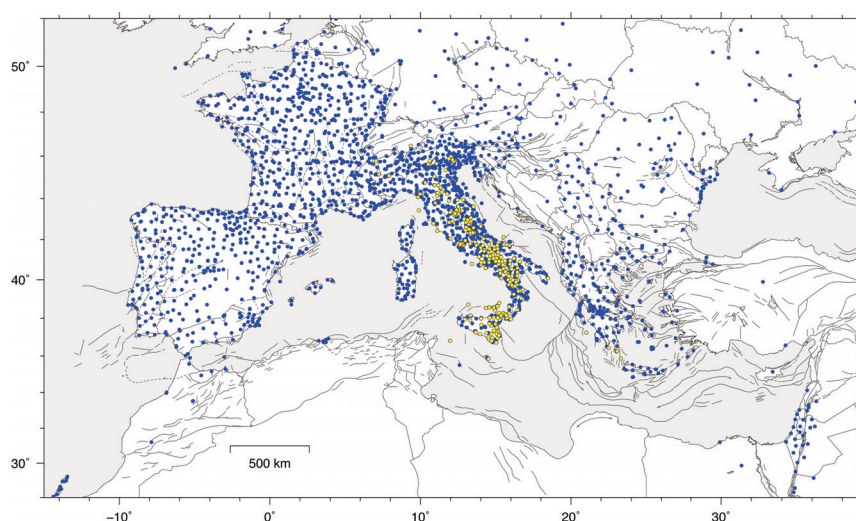


The INGV networks

The INGV network of GNSS stations, called **RING** (Rete Integrata Nazionale GNSS), is a nation-wide network of over **200 permanent stations**, established since **2004**. Raw data at 30-sec and 1-sec sampling rates are available to the public. In the next two years we plan a basic receiver

upgrade to acquire full constellation data, including **GALILEO**. We also collect and archive all GNSS data for stations all over Europe and Africa. The raw GNSS data are archived on a dedicated database, and processed routinely by three INGV Analysis Centers using different

approaches and scientific software. Position time series of all European stations are also available to the public. INGV manages directly **14 permanent stations** established since **2003**, located **all over the world** and configured to monitor the **upper atmosphere** conditions.



RING network highlighted in yellow, European stations in blue (left panel) and upper atmosphere network (right panel).

INGV skills

INGV personnel matured **ICT skills** to design and realize **data archives** and **data bases** collecting INGV data and gathering **GNSS data** acquired by other networks or single stations. INGV scientists have a long expertise on **GNSS data handling and analysis** addressed to **scientific uses** and to the development of **products and services** supporting a broad spectrum of **GNSS-based operations**. INGV collaborates with a number of **institutions, academies and private**

bodies to provide **consultancy, services and products** based on GNSS data. INGV makes use of GNSS data for **validation and calibration** of other **satellite-based products**. INGV deploys and manages **low cost receivers** to monitor **landslides, slope deformations and strategic infrastructures**. INGV makes use of GNSS data to monitor, **forecast and mitigate space weather events**. INGV collaborates with GNSS

receivers **manufacturers** to assess the receivers' **performance under space weather events** and under **extreme environmental conditions**. INGV collaborates with **Software-Defined Radio GNSS receivers' developers** to assess the actual capability to monitor the upper atmosphere. INGV is deeply involved as data provider and it is appointed as **GNSS analysis center** of EPOS (European Plate Observing System), the **European Research Infrastructure** on solid earth.



INGV products

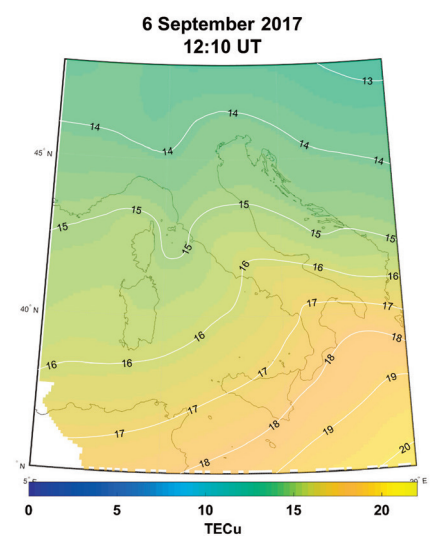
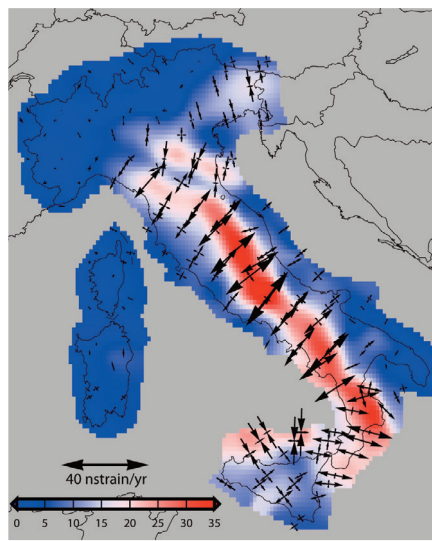
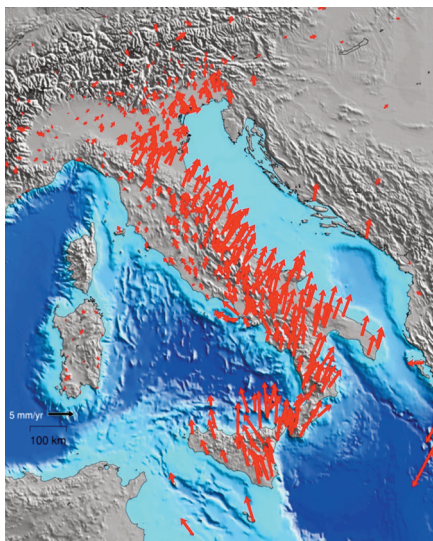
INGV provides a number of products based on GNSS data.

Here follows an overview not exhaustive but **representative of the broad spectrum of applications**.

Precise daily positions are computed routinely for all the archived stations. These time series allow the estimation of the **crustal deformation** and the establishment and maintenance of a **reliable reference system** for the whole area.

Velocity field and strain-rate maps are computed periodically for the Italian and European area. These products are input for **tectonic studies, volcano deformation monitoring** and regional **seismic hazard evaluations**. RING data and other GNSS data

contribute in the estimation of the **coseismic deformation** pattern observed after major earthquakes. Full 3D position estimates are used for **calibrating** other geodetic techniques, e.g. InSAR and terrestrial surveys.



Map of velocities (left panel), crustal deformation (mid panel) and Total Electron Content (right panel) from **GNSS data**.

INGV provides assistance to monitor, forecast and mitigate the **space weather impact on GNSS precision positioning**. Space weather events induce perturbations in the ionized part of the atmosphere, the ionosphere, that increases the degradation, already caused by the ionosphere under quiet conditions, of GNSS signals. The result is an increase of the positioning error provided by GNSS.

INGV is partner of the **Pan-European Consortium for Aviation Space weather User Services**. The **PECASUS** initiative aims for a global space weather information service center as specified by the International Civil **Aviation Organization (ICAO)**. On the 7th of November 2019 PECASUS started its **24/7** operations to provide civil aviation with information on space weather that has the

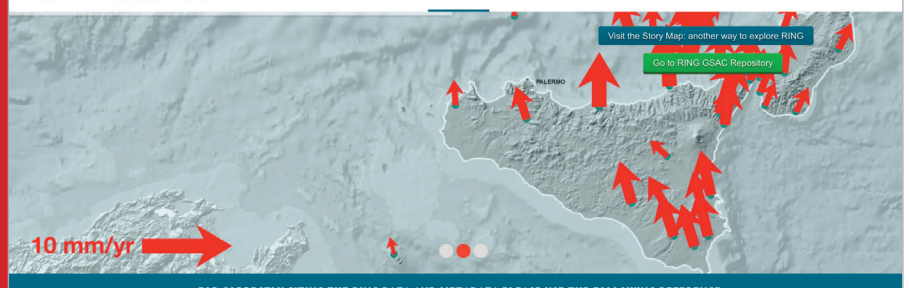
potential to affect communications, navigation and the health of passengers and crew. INGV took part of the consortium that designed and realized the European Commission-funded **Galileo Ionosphere Prediction Service (IPS)**. IPS monitors the ionospheric activity and informs GNSS users in good time of an upcoming event that could **disrupt GNSS signals and applications**.

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