The use of GNSS for Space Weather: the Italian case

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Outline

GNSS signal from Space to Earth
  Delay and Scattering
  Why such effects?
  (solar wind / magnetosphere, ionosphere, perturbations, Scintillation)

How to monitor TEC and scintillation by GNSS?
  Monitoring technique
  Scintillation effect example during the halloween storm at high latitude
  Italian contribution to the international network

Remarks and technologic and scientific challenges

International project results
  ESA-Alcantara
  CIGALA-CALIBRA
  TRANSMIT
  ESPAS
GNSS signal from Space to Earth: effects induced by the Ionosphere

- Total Electron Content (TEC)
  - Delay
- Turbulence
  - Scintillation (Scattering)
Why such effect?

- **Solar Wind-Magnetosphere coupling causes turbulences of the ionosphere**
  - Irregularities with scales in a large range (space and time)
  - Variation (+/-) of the $\rho_{\text{elec}}$
  - Random fluctuations of the refractive index
  - Distortion of the original wave front

- **Diffraction effects on the transionospheric signals**
  - Ranging errors – losses of lock
How to monitor TEC and scintillation by GNSS?
GNSS receivers for scintillation

High frequency sampling (50Hz)
Multiple frequency
Multi constellation (GPS, GALILEO, GLONASS)
TEC gradients

High level of (phase) scintillations

$\sigma^2_{\phi} = \langle \phi^2 \rangle - \langle \phi \rangle^2$

Loss of lock on L2

CONNECTION WITH THE SATELLITE IS LOST!
Loss of lock is not the only threat...

Scintillation

Positioning error
Italian network of Receivers

First receiver installed at Ny-Alesund (Svalbard) since 2003

Polar ionosphere
- Svalbard islands (3)
- Antarctica (4)

Mid latitude ionosphere
- Chania (Crete)
- Huelva (Spain) – stopped
- Huelva station moved to Lampedusa

Equatorial Ionosphere
- Tucuman (Argentina)

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

**eSWua**

[www.eSWua.ingv.it](http://www.eSWua.ingv.it)
International network partners

Institute of Electronics and Telecommunications of Rennes (IETR) - University of Rennes

Vietnam Academy of Science and Technology (VAST), Institute of Geophysics

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Remarks and technologic and scientific challenges
REMARKS

• Space Weather can affect significantly the Navigational and Positioning satellite systems
• This problem has limited the expansion of the GNSS market in mission-critical high-precision applications, such as air, rail and marine transport and even autonomous machinery in areas as agriculture.
• Ionospheric GNSS receivers are reliable, low cost and robust systems able to monitor the Space Weather effects in the ionosphere
• There is a need for a new generation of researchers, trained with ionospheric and Space Weather expertise directly connected to their GNSS knowledge.
TECHNOLOGIC AND SCIENTIFIC CHALLENGES

• **Advance the physical modelling** of the underlying processes associated with the ionospheric plasma environment and the knowledge of its influences on human activities
• **Develop new techniques** to detect and monitor space weather threats, with the introduction of new prediction and forecasting models, mitigation tools and improved system design
• **Establish a real time system to monitor the ionosphere**, capable of providing useful assistance to users, which exploits all available resources and adds value for worldwide services and products
• **Incorporate solutions to this system** that respond to all end user needs and that are applicable in all geographical regions of interest (polar, high and mid-latitudes, equatorial region).
International efforts to tackle the problem
GINESTRA – MIMOSA - MEDSTEC

COMPETENCE SURVEYS WITHIN THE ESA

ALCANTARA INITIATIVES

MImOSA
Monitoring Ionosphere Over South America

GINESTRA
Ground-based Ionosphere monitoring NEtworks in SouthesTeRn Asia: a survey

MEDSTEC
Towards Mapping of Electron Density, Scintillation and Total Electron Content

WHO

WITH

[Logos of various institutions]
CALIBRA: Countering GNSS high accuracy applications limitation due to ionospheric disturbance in BRAzil
FP7–GALILEO–2011–GSA–1a

- CALIBRA builds on the outcomes of CIGALA
- Mitigate impact of ionospheric disturbances
  - Scintillation
  - TEC variations
- Focus on high accuracy GNSS positioning techniques
  - Better than 10cm
- Address applications in Brazil
- Devise commercially applicable solutions
- Implementation at receiver level
- Provide reassurance for users of GNSS at low latitudes
An FP7 Marie Curie Initial Training Network. The project addresses in particular ionospheric threats to Global Navigation Satellite Systems (GNSS) and related applications, in areas such as civil aviation, marine navigation and land transportation. TRANSMIT is a 4-year project and involves the recruitment of 16 young researchers across its partners.
Near-Earth space data infrastructure for e-science

A platform to integrate heterogeneous data from earth’s thermosphere, ionosphere, plasmasphere & magnetosphere

- Supports the systematic exploration of multipoint measurements from the near-Earth space through homogenised access to multi-instrument data
- Provides access to 40+ datasets from: Cluster, EISCAT, GIRO, DIAS, SWACI, CHAMP, SuperDARN, FPI, magnetometers INGV, SGO, DTU, IMAGE, TGO, IMAGE/RPI, ACE, SOHO, PROBA2, NOAA/POES, etc.
- Supports data visualization, search, statistics, modelling

ESPAS User Interface is accessible through
http://www.espas-fp7.eu

Final ESPAS release: in April 2015
GRAZIE!

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