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# GNSS Space weather monitoring and study at INGV: an overview

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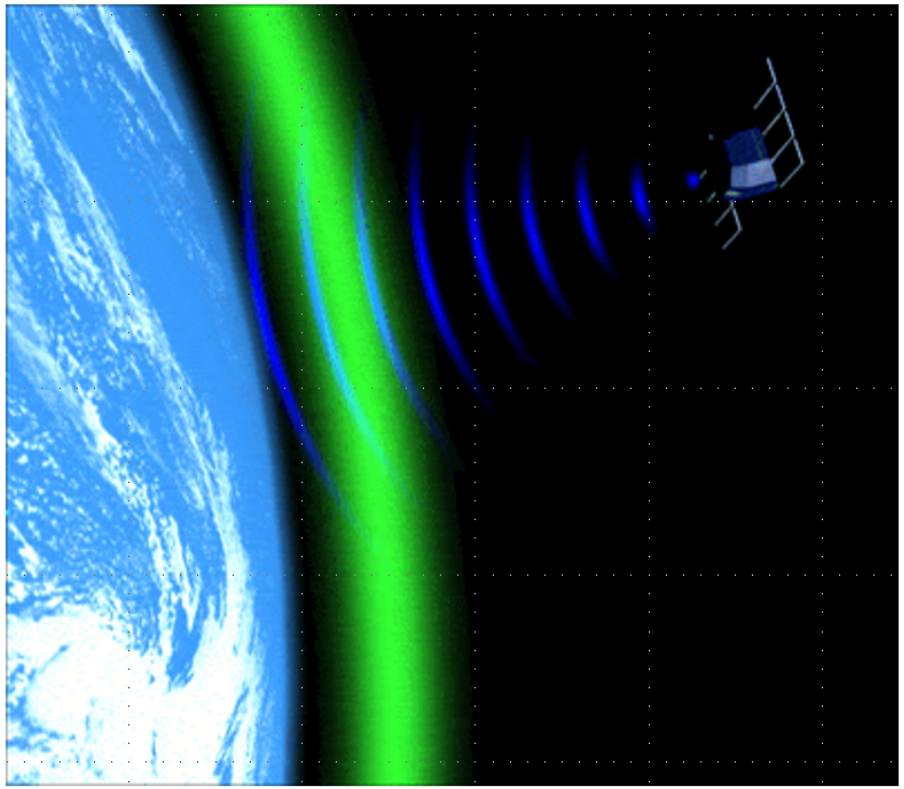
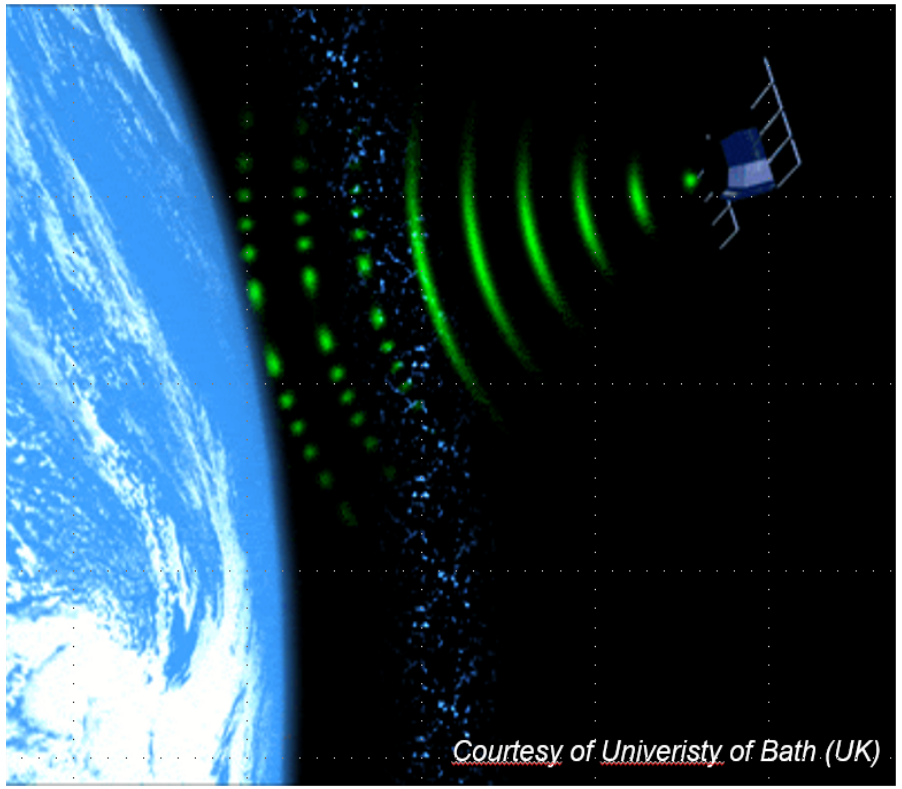
# GNSS signal from Space to Earth: effects induced by the Ionosphere



**Total Electron Content (TEC)**

**DELAY**

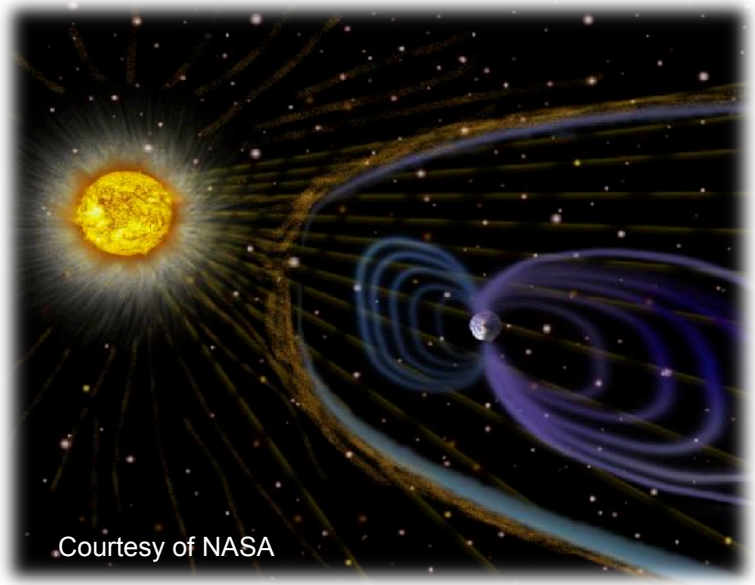


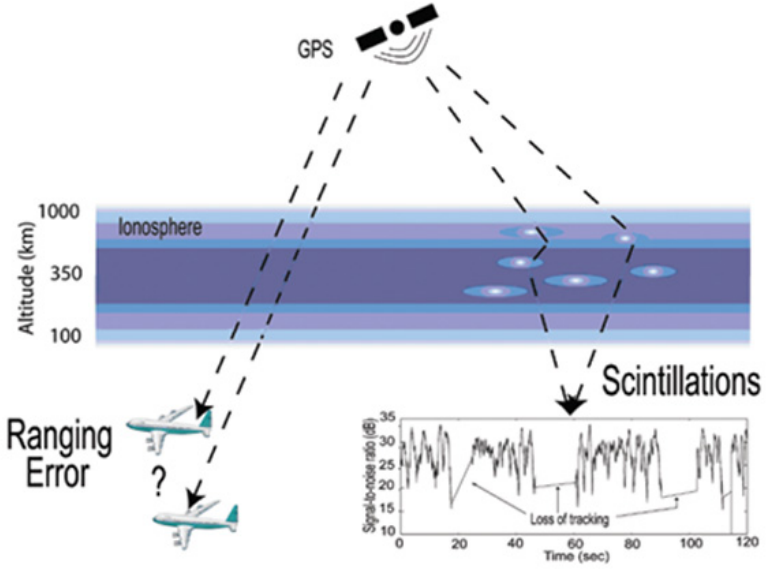

**Turbulence**

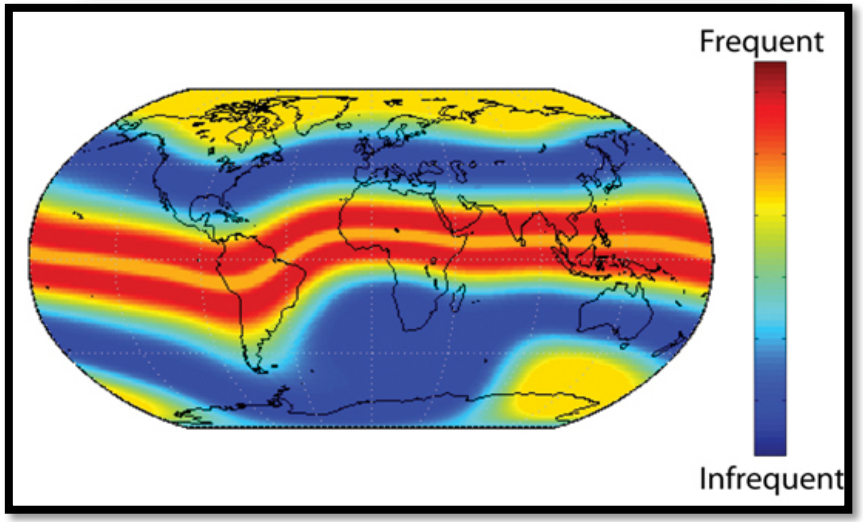
**SCINTILLATION (SCATTERING)**

# Why such effect?

- Solar Wind-Magnetosphere coupling causes turbulences of the ionosphere
  - Irregularities with scales in a large range (space and time)
  - Random fluctuations of the refractive index
  - Distortion of the original wave front
- Diffraction effects on the transionospheric signals
  - Ranging errors – losses of lock



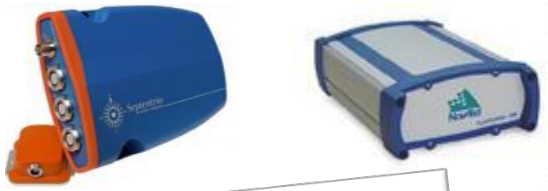



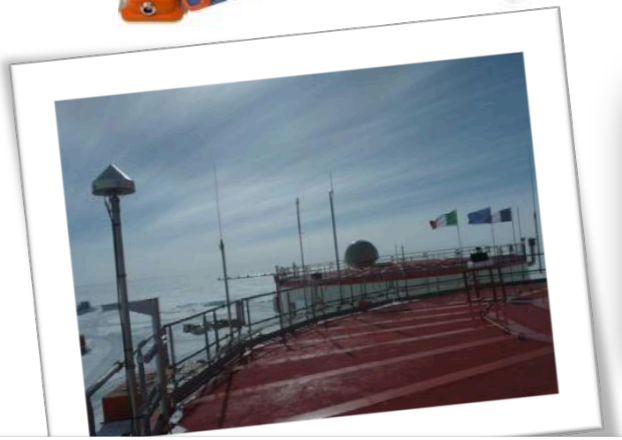

Global occurrence characteristics of scintillation (Courtesy of P. Kintner)

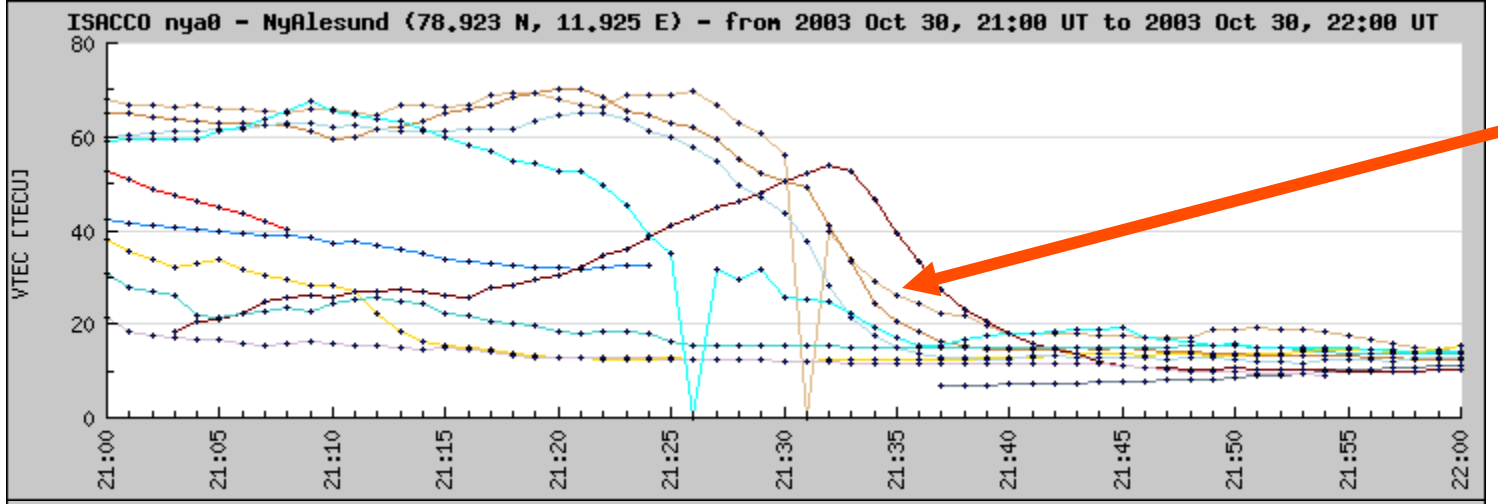
# How to monitor TEC and scintillation by GNSS?

## GNSS receivers for scintillation

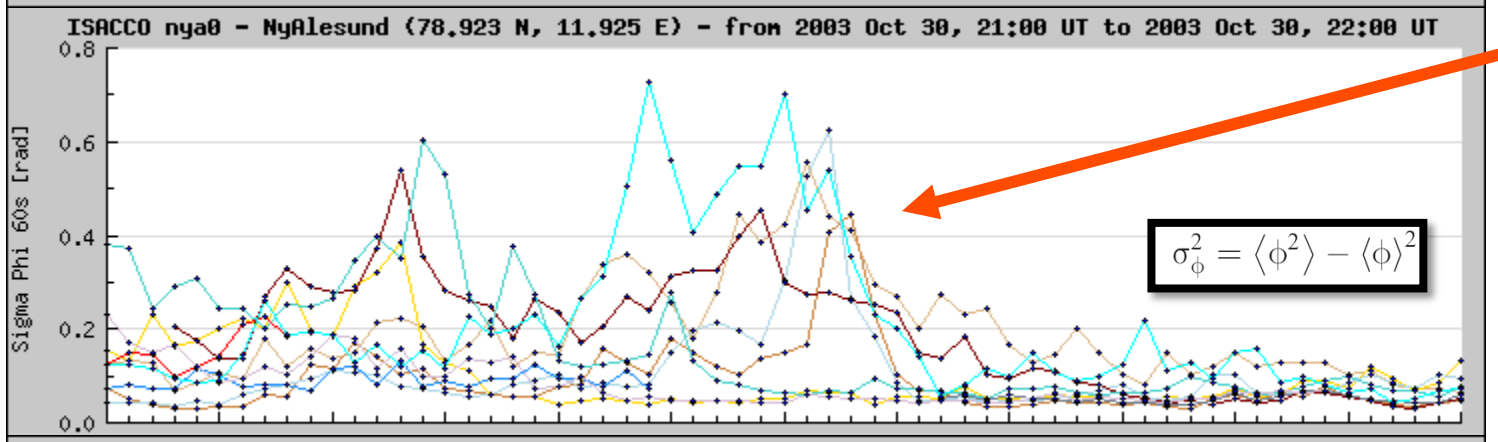
- High frequency sampling (50Hz)
- Multiple frequency
- Multi constellation (GPS, GALILEO, GLONASS)

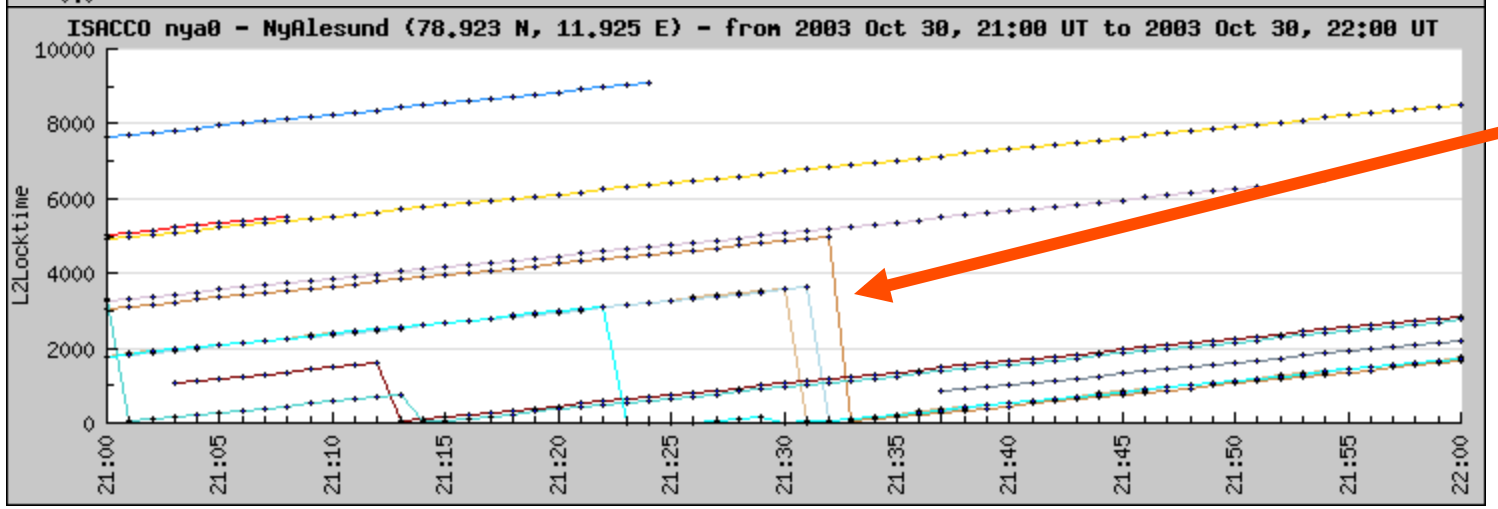





TEC gradients




High level of (phase) scintillations




Loss of lock on L2

CONNECTION WITH THE SATELLITE IS LOST!

# INGV receivers network

- First receiver installed at Ny-Alesund (Svalbard) on 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

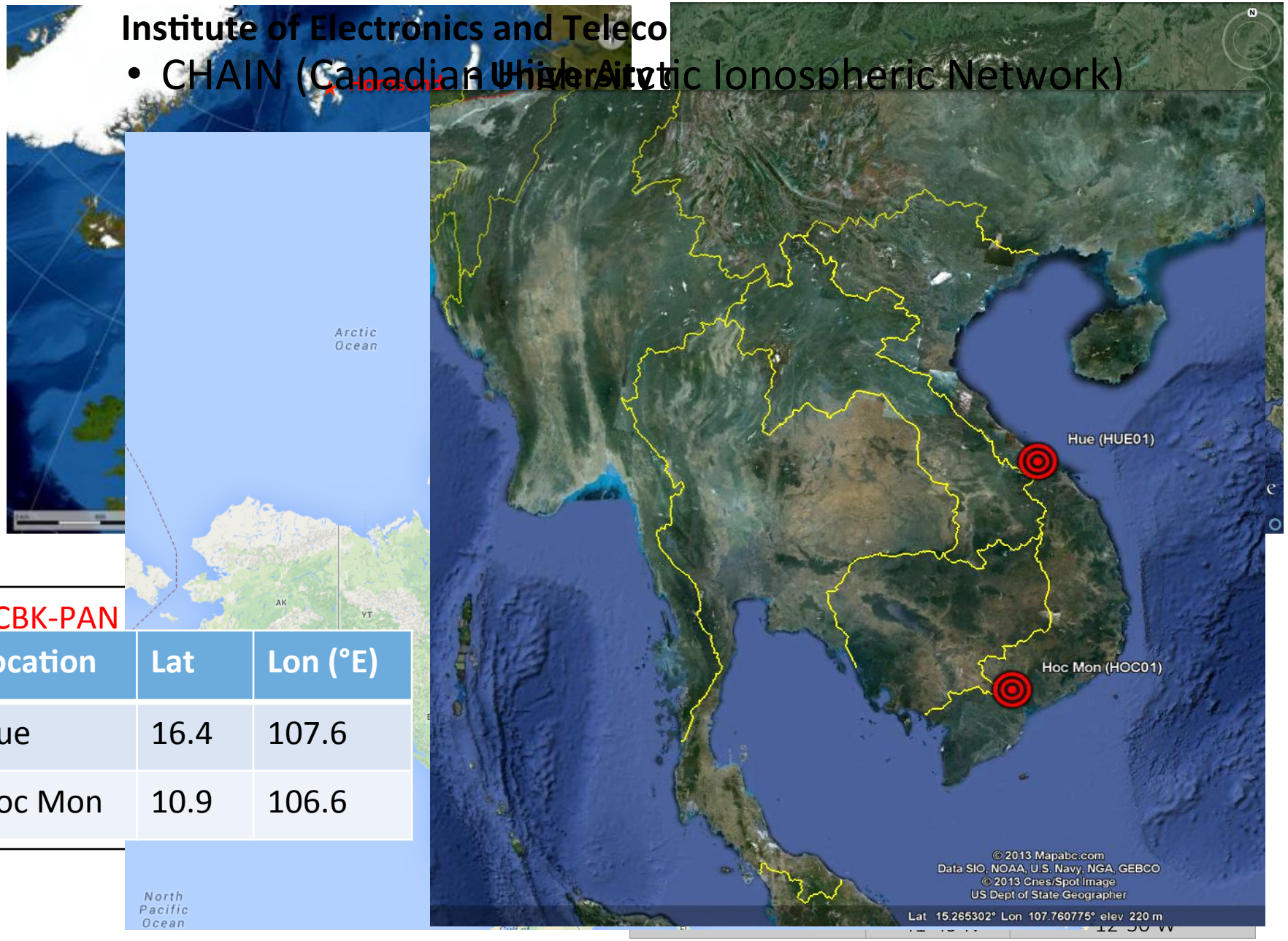
**eSWua**

www.eSWua.ingv.it

# INGV network partners

**Institute of Electronics and Teleco**

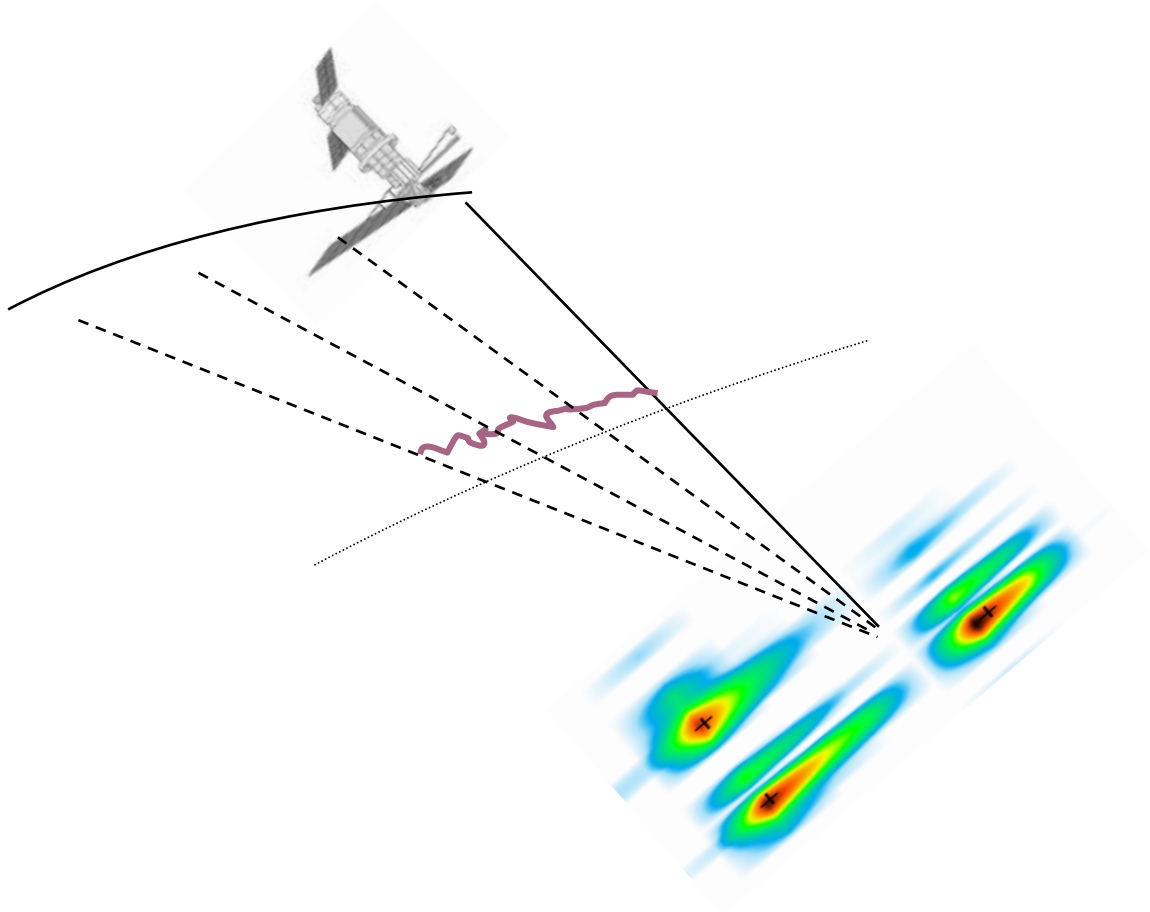
- CHAIN (Canadian High Arctic Ionospheric Network)




CBK-PAN

| Location | Lat | Lon (°E) |
|---|---|---|
| Hue | 16.4 | 107.6 |
| Hoc Mon | 10.9 | 106.6 |

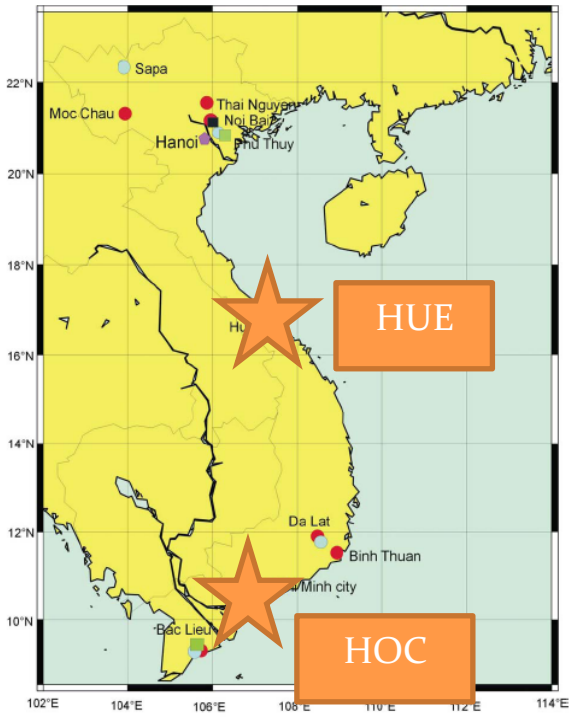
# Examples of relevant results



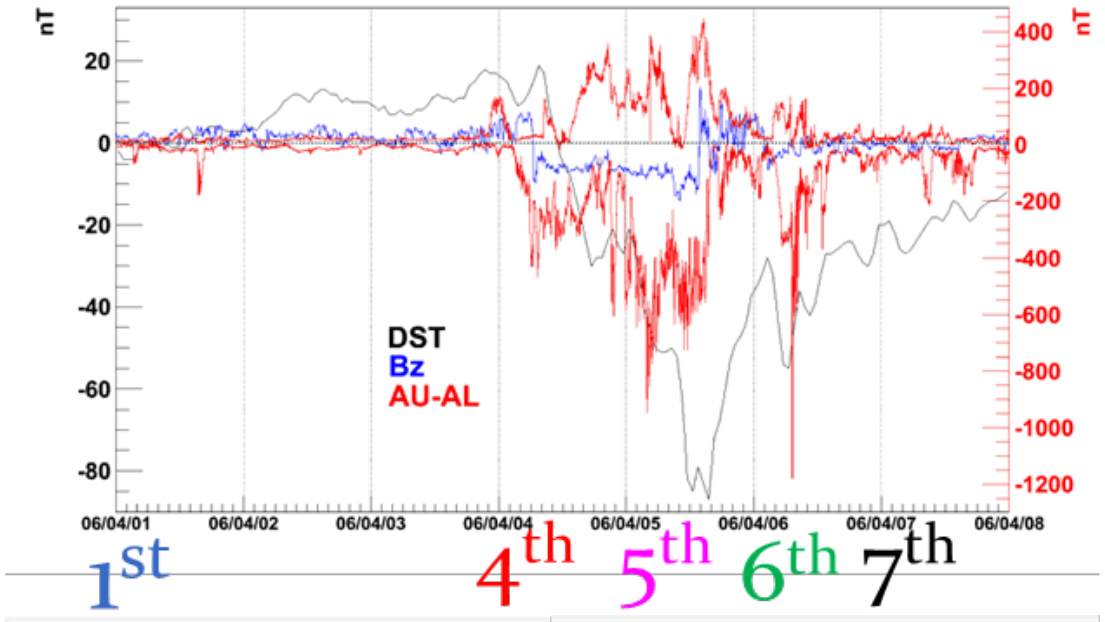
# Scintillation inhibition over Vietnam

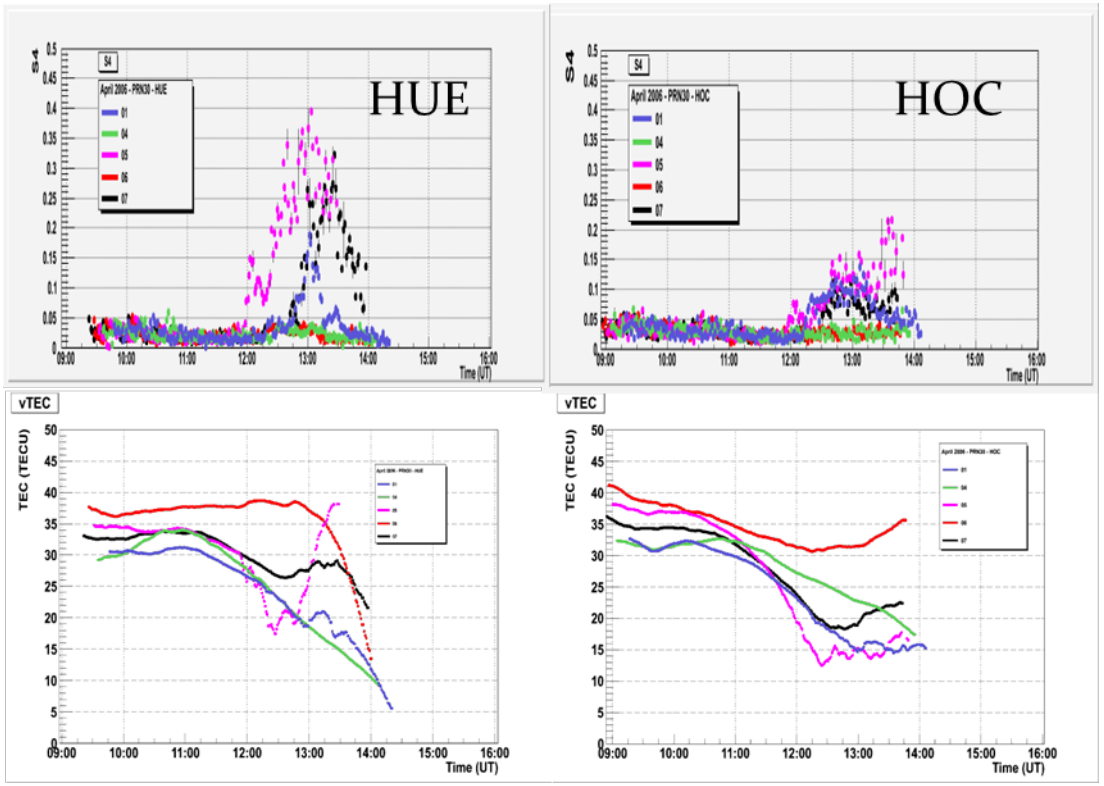
*(INGV-Un. of Bath, Un. Of Rennes, Vietnam Academy of Science and Tecnology)*

**1 April 2006** was a quiet day, with typical levels of scintillation at low latitudes. **5 April 2006** was during an ionospheric storm, with elevated TEC values, but similar levels of scintillation. On **6 April 2006**, the ionospheric storm was still in progress, but scintillation was suppressed.



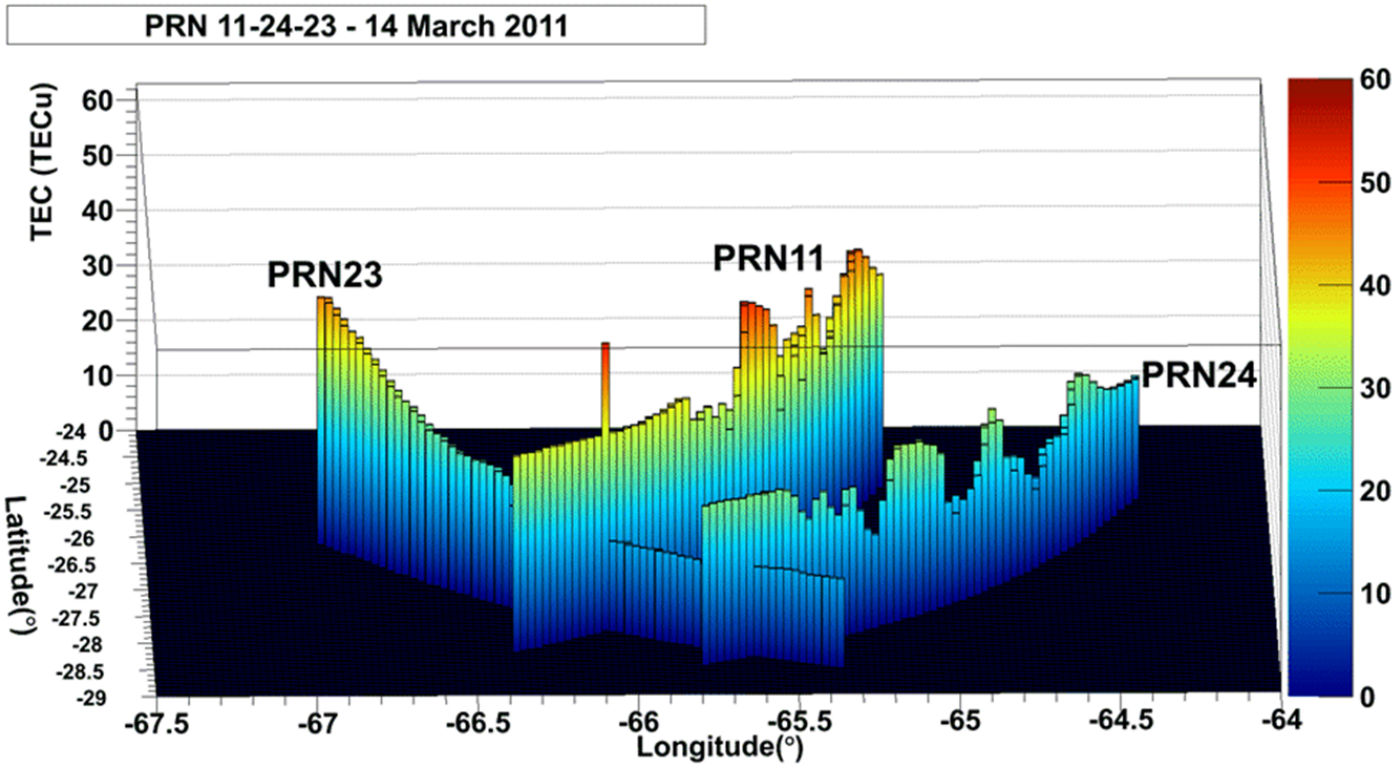

*Alfonsi et al., ASR, 2011*



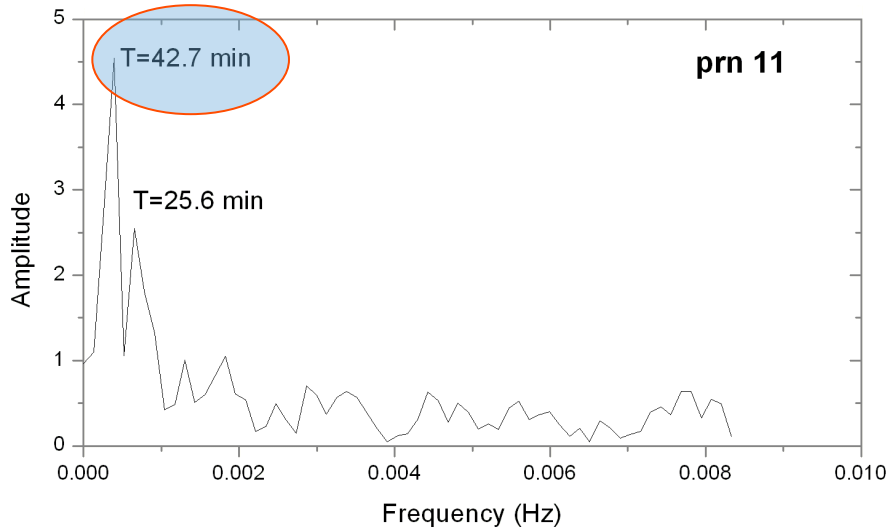



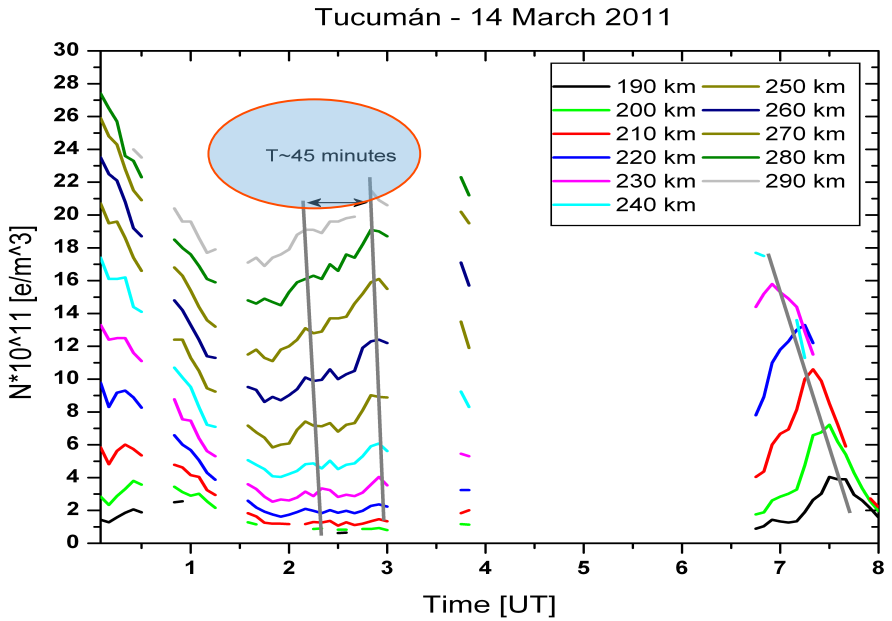
# Concurrent observations of Travelling Ionospheric Disturbance from Ionosonde and GNSS receiver at Tucuman (Argentina)

*(INGV, Universidad Nacional de Tucumán, Universidad Tecnológica Nacional, Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina)*



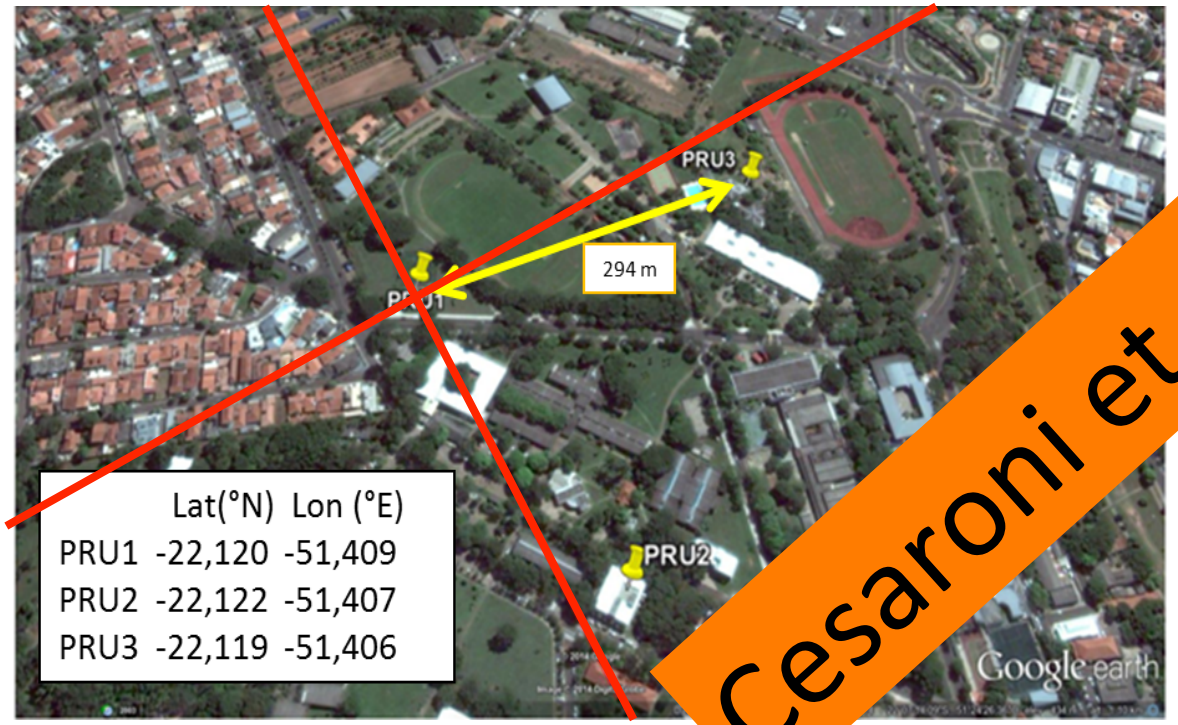

*Alfonsi et al., JGR, 2013*



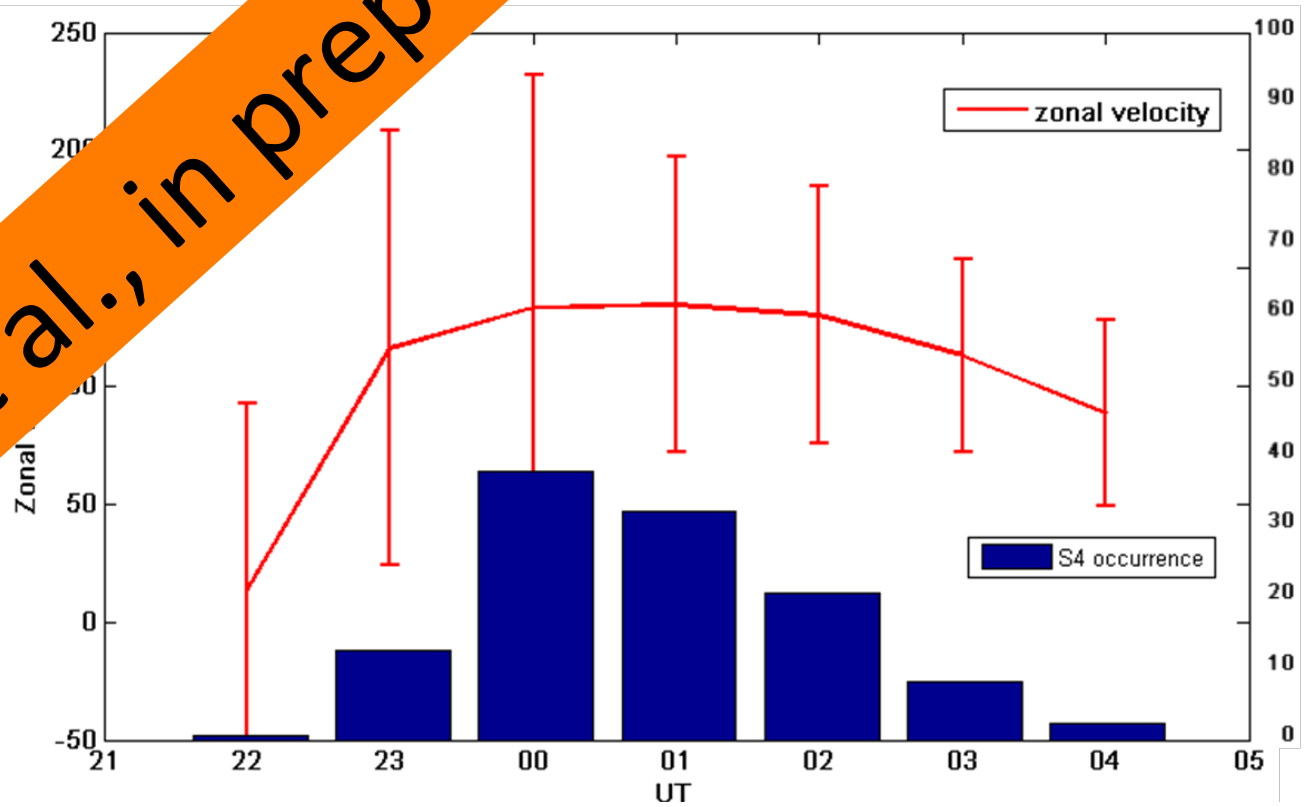



# Zonal velocity of the Equatorial ionospheric irregularities over São Paolo

*(INGV-Un. of Nottingham- UNESP)*




PRU1 and PRU3 receivers are displaced almost along E-W magnetic direction PRU1 and PRU3 distance is about 300 meters (≈First Fresnel zone for L-band frequencies)

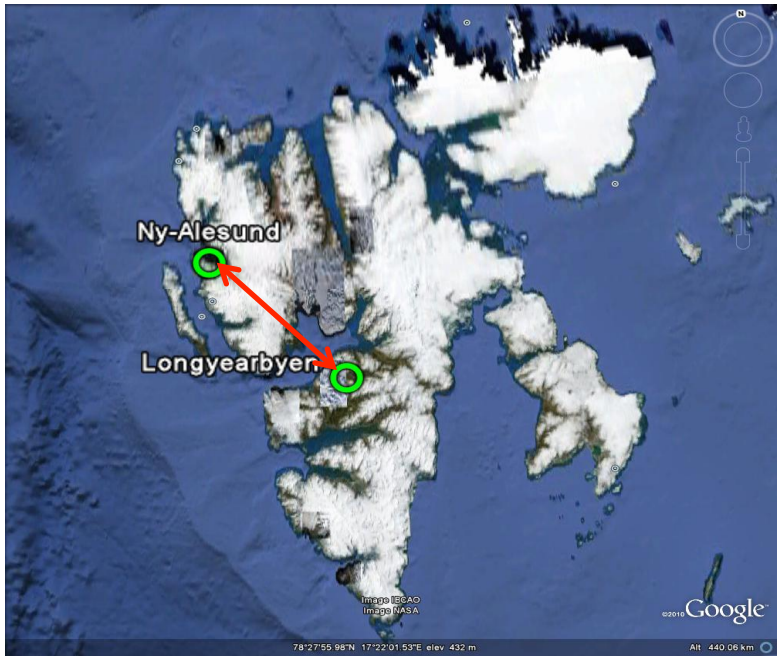



Mean value of the zonal velocity of ionospheric irregularities and occurrence of S4 above 0.25 as a function of the Universal Time (LT=UT-3).

Cesaroni et al., in preparation

# Mitigation of the positioning errors due to ionospheric scintillations

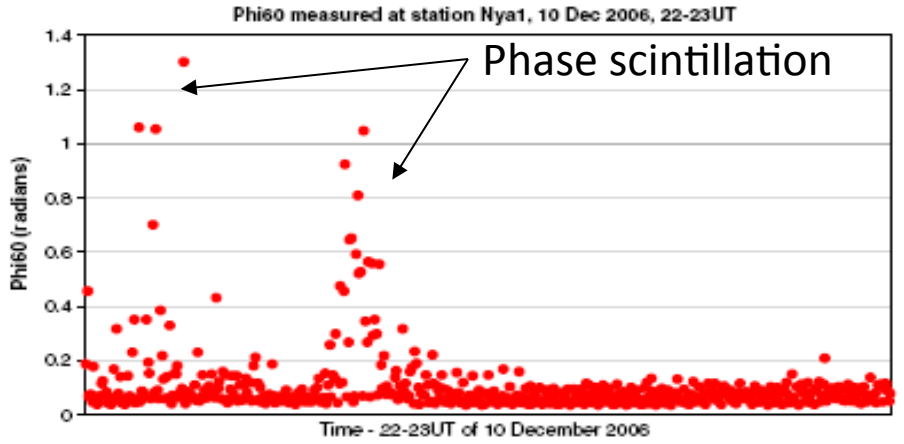
*(INGV-Un. of Nottingham)*

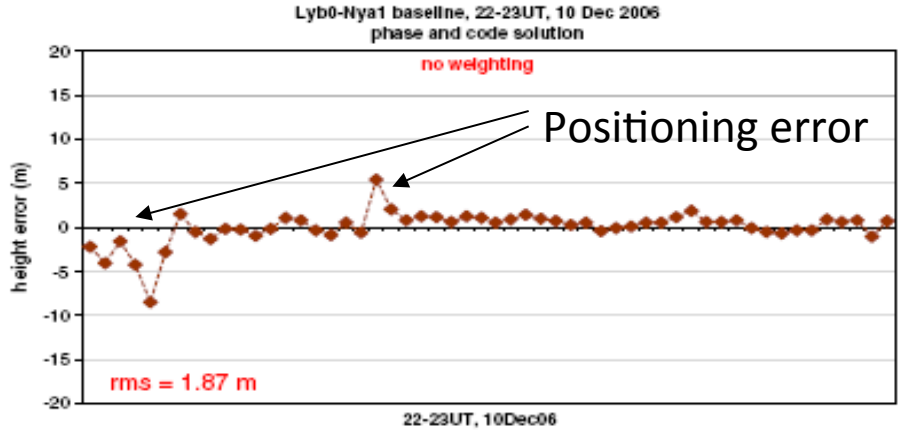


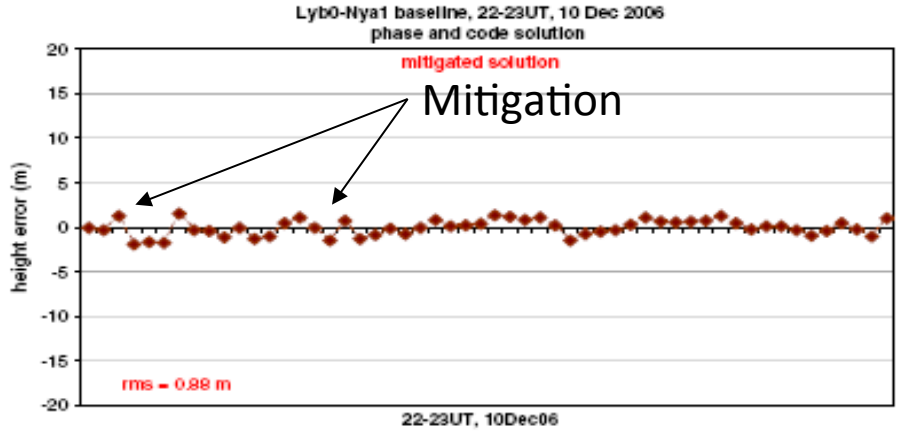

The Ny Alesund-Longyearbyen (Svalbard Islands) baseline (125 km) has been used to test an original approach able to **mitigate the positioning errors due to scintillations**

Such advancement effectively **supports several applications demanding high precision positioning** , such as: civil aviation, precision agriculture, oil drilling, buildings monitoring, etc.

*Aquino et al., J. Geod, 2009*

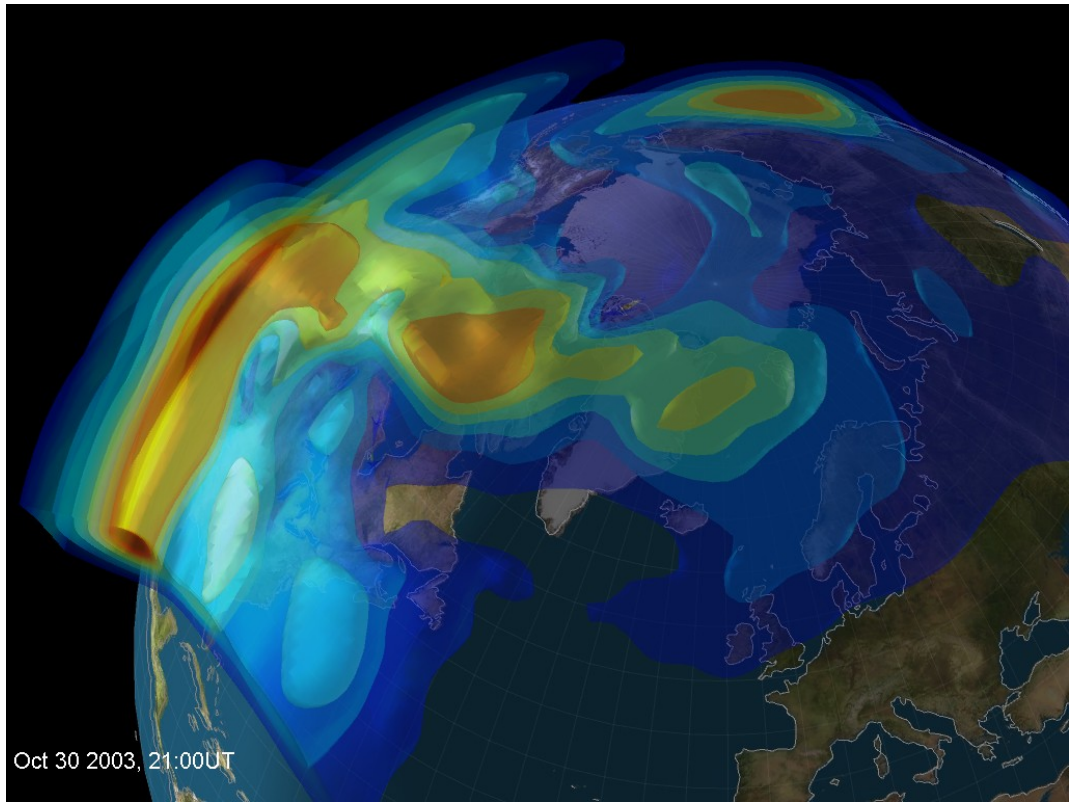


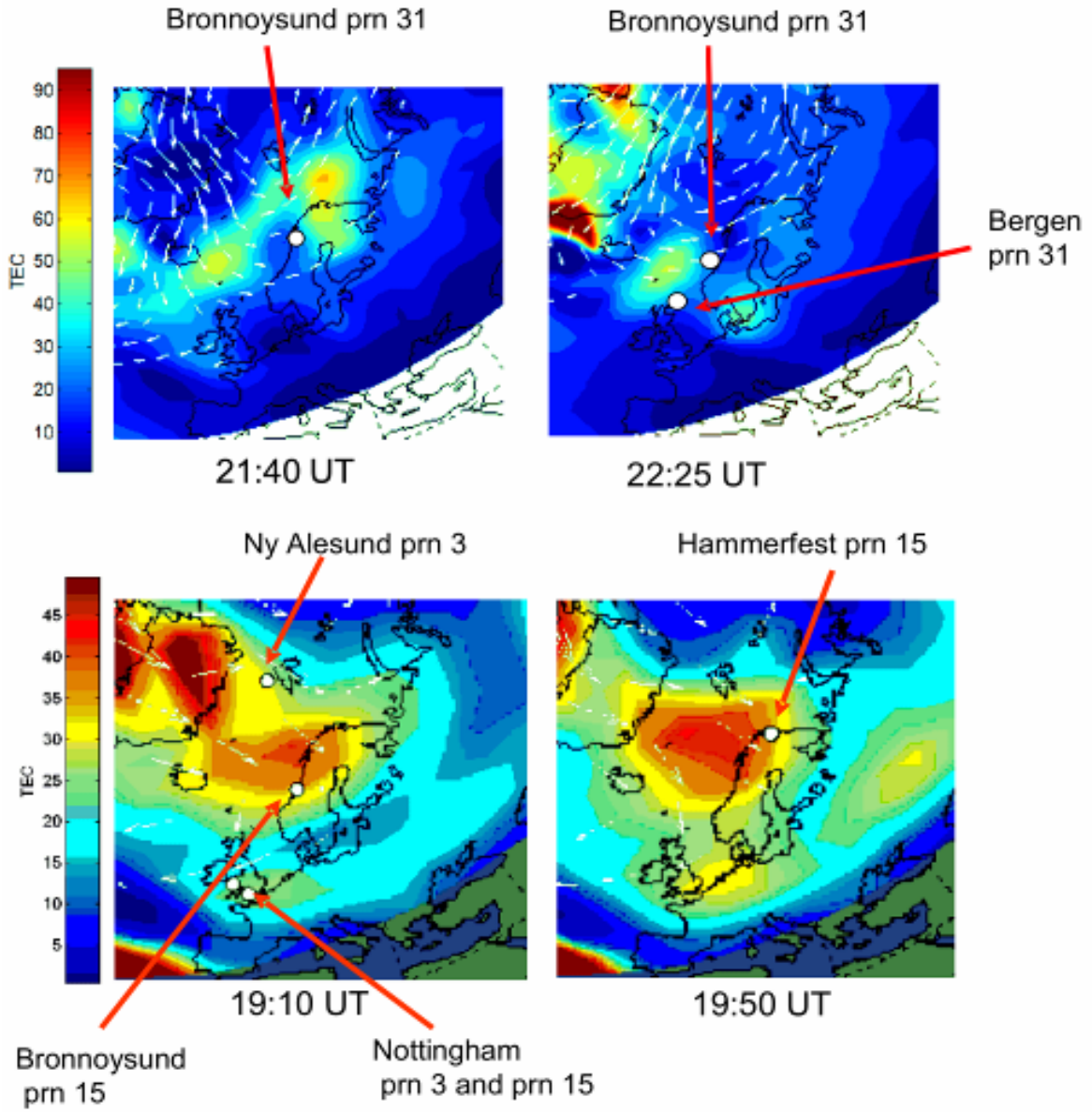



# TEC and scintillations enhancement over Arctic

*(INGV, Un. Of Bath, Un. Of Nottingham, Polish Academy of Sciences-Space Research Center)*




Synergyc adoption of tomographic technique and scintillations measurements




*De Franceschi et al., JASTP, 2008*

# Most relevant on-going projects

**CALIBRA**: Countering GNSS high Accuracy applications LImitation due to ionospheric disturbance in BRAzil, FP7–GALILEO–2011–GSA–1

**TRANSMIT**: Training Research and Applications Network to Support the Mitigation of Ionospheric Threats, FP7-ITN Marie Curie

**ESPAS**: Near-Earth space data infrastructure for e-science, FP7-Research Infrastructure

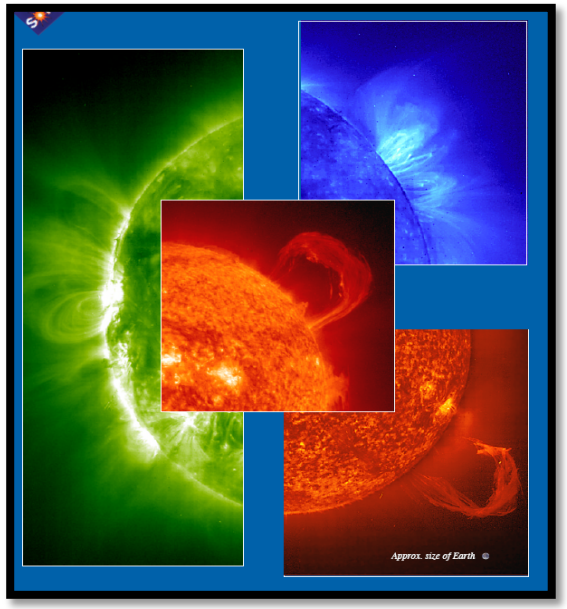
**MISW**: Mitigation of space weather threats to GNSS services, FP7-Space

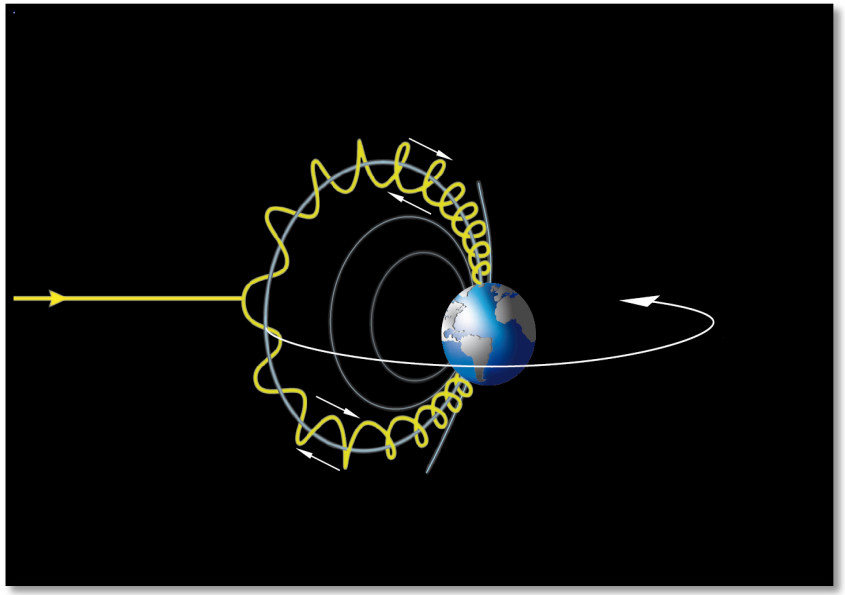
**ERICA**: EquatoRial Ionospheric Characterization in Asia, ESA-ALCANTARA

**DemoGRAPE**: Demonstrator of GNSS Research and Application for Polar Environment, PNRA

**GRAPE**: GNSS Research and Application for Polar Environment, SCAR

# 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.

# THANK YOU!

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