Space-weather Impact on Critical Infrastructures

Activities at the EC's Joint Research Centre

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European Commission – Joint Research Centre
Institute for the Protection and Security of the Citizen
Ispra, Italy

Serving society
Stimulating innovation
Supporting legislation

Joint Research Centre

Mission

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies.

7 Institutes in 5 Member States

IRMM - Geel, Belgium
Institute for Reference Materials and Measurements

ITU - Karlsruhe, Germany
Institute for Transuranium Elements

IE - Petten, The Netherlands
Institute for Energy

IPSC - Ispra, Italy
Institute for the Protection and Security of the Citizen

IES - Ispra, Italy
Institute for Environment and Sustainability

IHCP - Ispra, Italy
Institute for Health and Consumer Protection

IPTS - Seville, Spain
Institute for Prospective Technological Studies

~ 2800 staff

European Commission

Directive 2008/114/EC

Council Directive of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection

European Critical Infrastructure (ECI)

…. critical infrastructure located in Member States the destruction or disruption of which would have a significant impact on at least two Member States

ECI must satisfy both:

Cross-cutting criteria: casualties, economic effects, public effects

Sectoral Criteria have been established for transport and energy sectors

The risk of natural-hazard impact on critical infrastructures is increasing due to:

+ More hazards

- Climate change
- Greater industrialisation

+ Higher vulnerability

- Growing urbanisation
- Development of new and vulnerable technologies
- Increasingly complex and interconnected society

→ To increase society's resilience a better understanding of hazards, vulnerabilities, interdependencies and potential consequences is needed.

Space weather

Natural phenomenon (geomagnetic storms, energetic particle events, solar radio bursts) caused by solar activity

→ danger to space-based and ground-based infrastructures and the services they provide

→ potential for the disruption of the smooth functioning of society

+ Communications & Navigation
+ Power grid
+ Transport (communication, navigation)
+ Oil and mineral industries (navigation)
+ Pipelines
+ Finance

JRC's current role in Space Weather

Supporting the Policymakers in:

- Raising Awareness
- Risk assessment for critical infrastructures
- Scientific research towards GNSS resilience

→ AAAS Annual Meetings since 2010 – sessions on Space Weather (with FEMA, NOAA, ESA, …)

→ ESOF-2012 Dublin – Workshop on GNSS black out and space weather

→ **Space Weather Awareness Dialogue (SWAD): 25-26 October, 2011, Brussels**

http://bookshop.europa.eu/en/the-space-weather-awareness-dialogue-pbLBNA25016/


JRC Scientific and Technical Reports

The Space-Weather Awareness Dialogue: Findings and Outlook

An event hosted by the European Commission's Joint Research Centre and co-hosted by the Directorate-General Enterprise and Industry
25-26 October, 2011, Brussels, Belgium

Elisabeth Krausmann

JRC EUROPEAN COMMISSION

ipsc

EUR 25016 EN - 2011

SWAD Objectives

A high-level event of multiple stakeholders to –

• ***raise awareness of the potential impact*** of extreme space weather on technological infrastructures in space and on the ground

• ***identify related scientific, operational and policy challenges*** for disaster prevention, preparedness and response and

• develop proposals to go ***from awareness to action*** at the EU policy level

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SWAD Conclusions 1

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- Space weather is a threat to <u>both space- and ground-based</u> critical infrastructures that needs to be addressed

- The assessment of potential space-weather effects on critical infrastructures requires a <u>multidisciplinary effort</u> from all stakeholders (scientists, engineers, infrastructure operators, policy makers).

- A framework for <u>better structured communication</u> between the stakeholders is required.

- There are <u>uncertainties in models</u> forecasting space-weather events, and there is a <u>lack of impact scenarios and likelihood estimates</u> necessary for increasing preparedness.

- Open space-weather <u>data sharing</u> is required to improve early warning and impact models.

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SWAD Conclusions 2

- Ageing satellites that monitor space weather need to be replaced.
- While there is some preparedness for normal space-weather effects in some infrastructure sectors, no sector seems fully prepared for extreme space weather.
- Space-weather impact assessment would benefit from cross-sector engagement.
- Targeted emergency management exercises could help raise awareness of space-weather effects as well better preparedness.
- International cooperation is required to cope with the space-weather threat as response capabilities may be beyond the capacity of individual countries.

2. Risk Assessment

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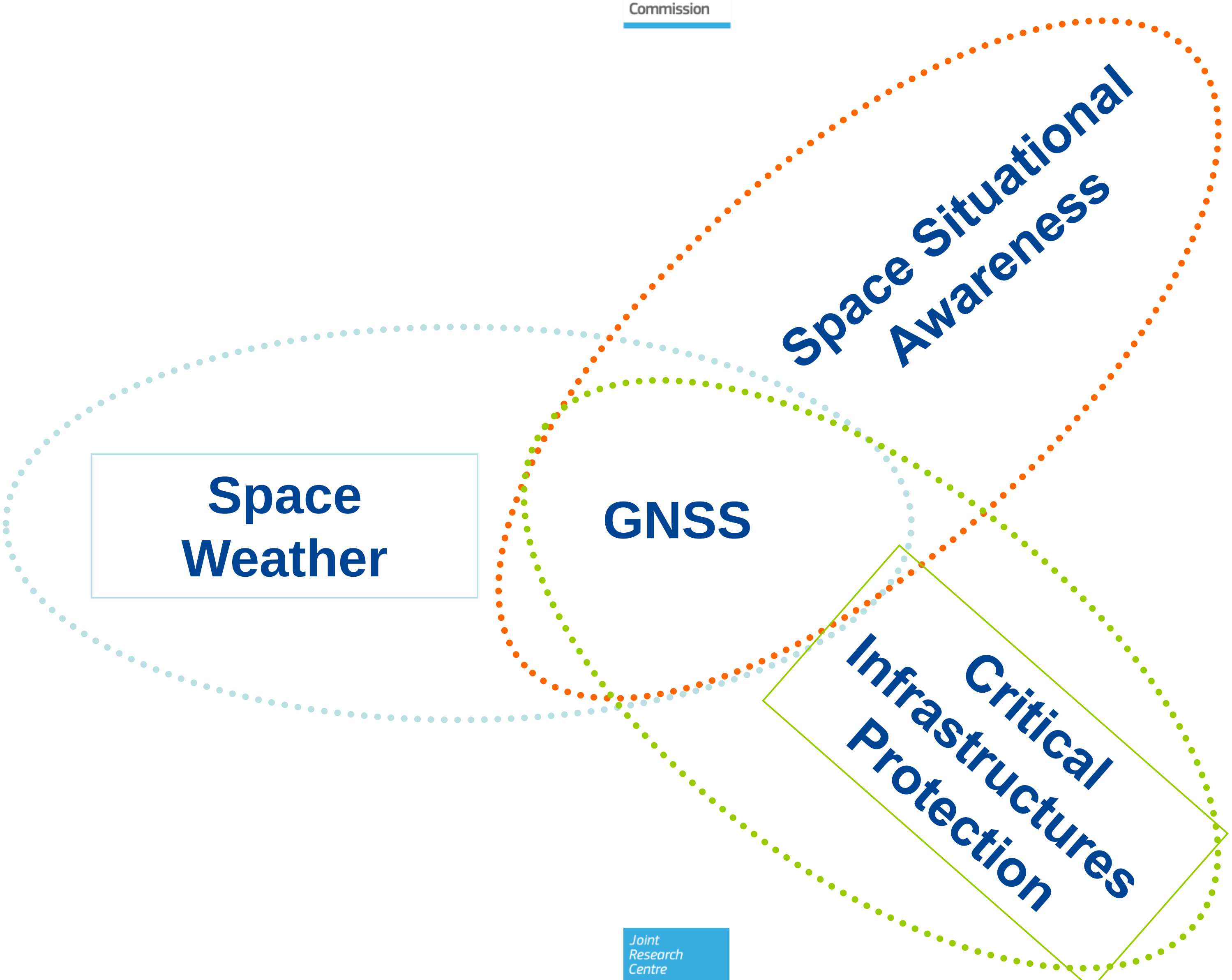
+ **Understand vulnerability of critical infrastructures and services to space weather and possible consequences for society:**

- **risk to infrastructures,**
- **risk to services provided,**
- **risk of cascading effects.**

Analysis of space-weather impact on the European power grid (incident analysis to identify hazard relevance, system weaknesses, consequences)

- **Collaboration with Swedish national grid on the impact of GICs**

+ **Impact assessment of space weather on <u>GNSS receivers</u>**


Space Situational Awareness
Space Weather
GNSS
Critical Infrastructures Protection

Frequency of ionospheric events

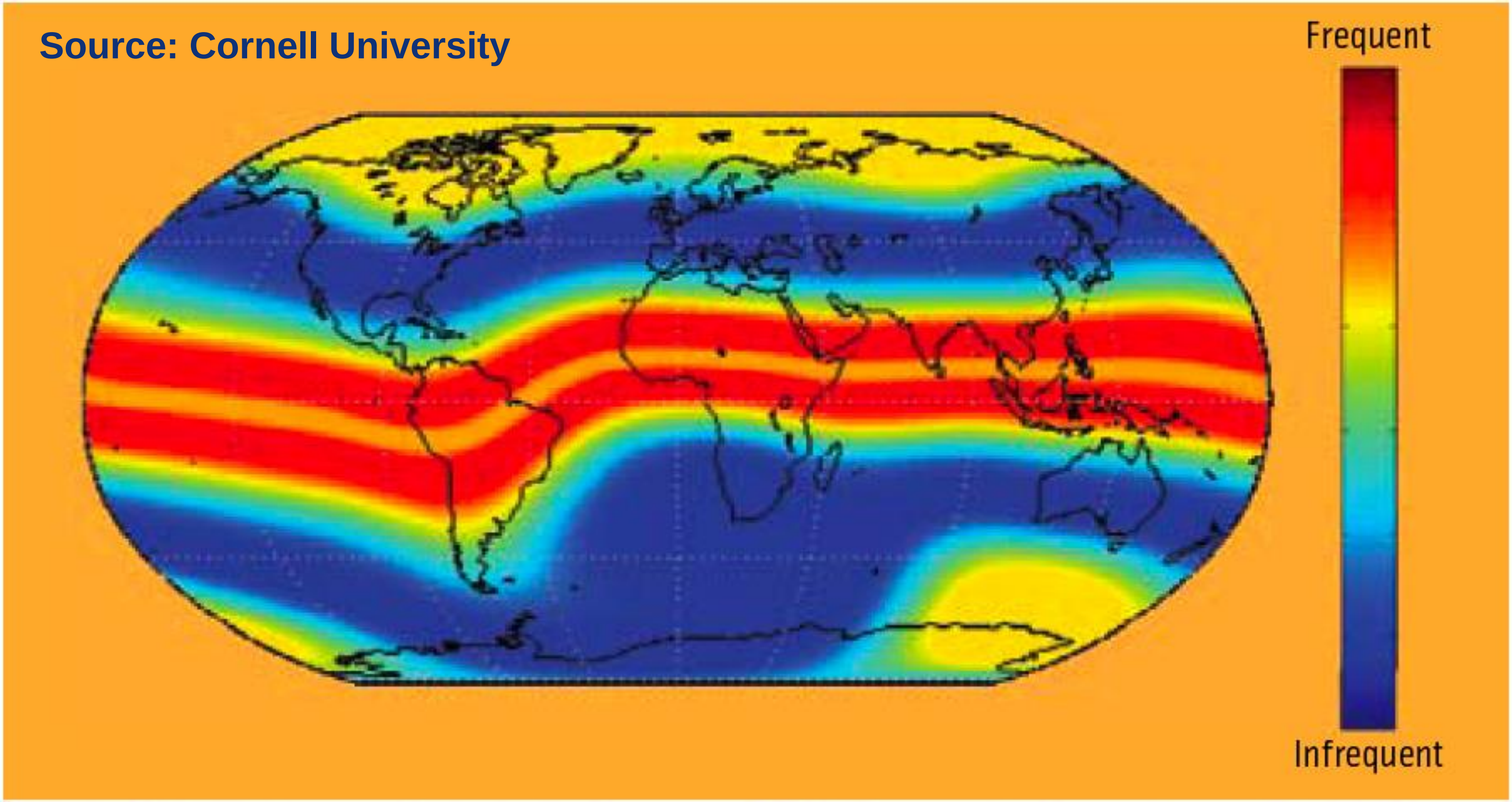


FIGURE 1 Scintillation map showing the frequency of disturbances at solar maximum. Scintillation is most intense and most frequent in two bands surrounding the magnetic equator, up to 100 days per year. At poleward latitudes, it is less frequent and it is least frequent at mid-latitude, a few to ten days per year.

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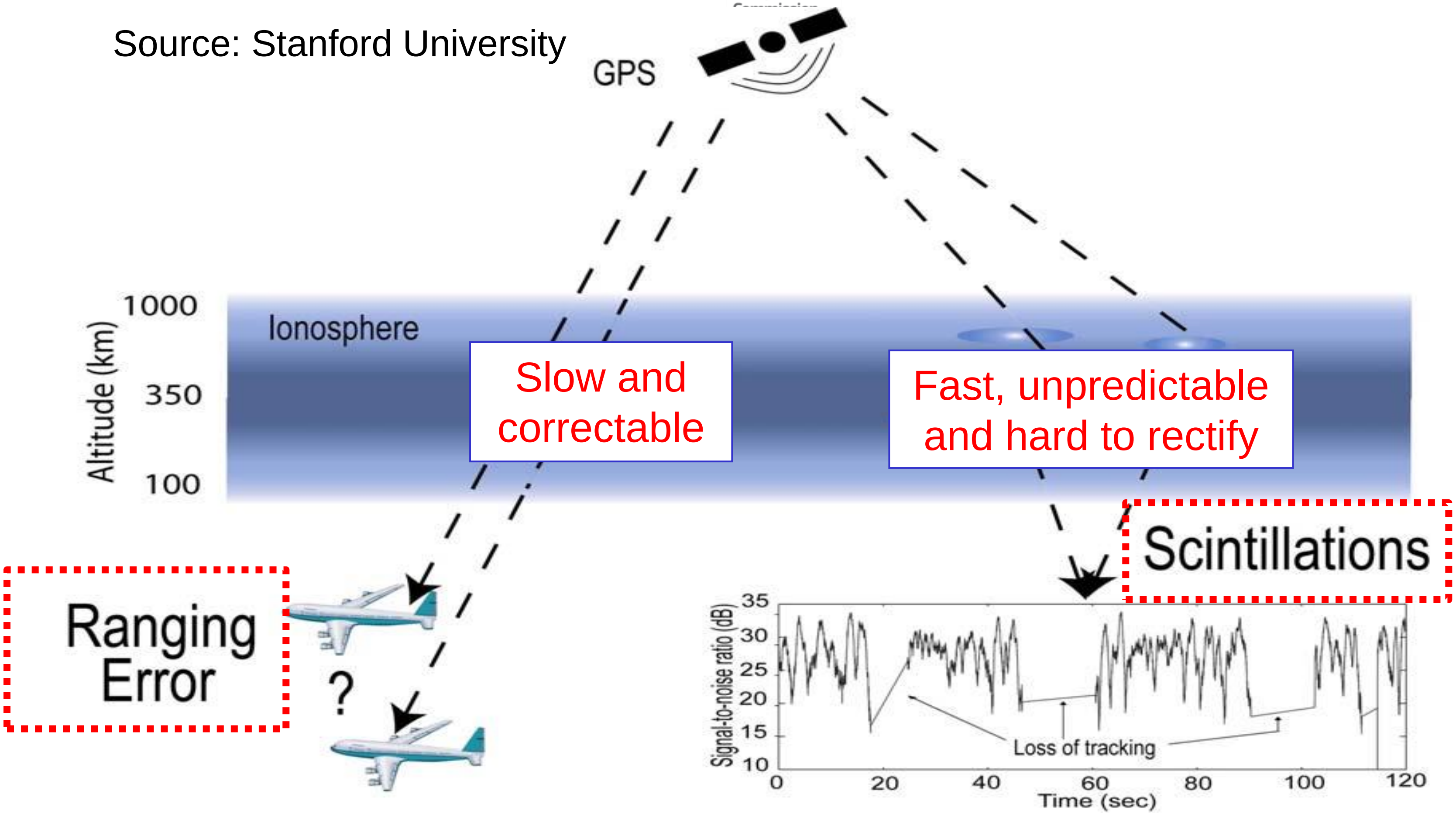
Ionospheric Scintillation

Source: Stanford University



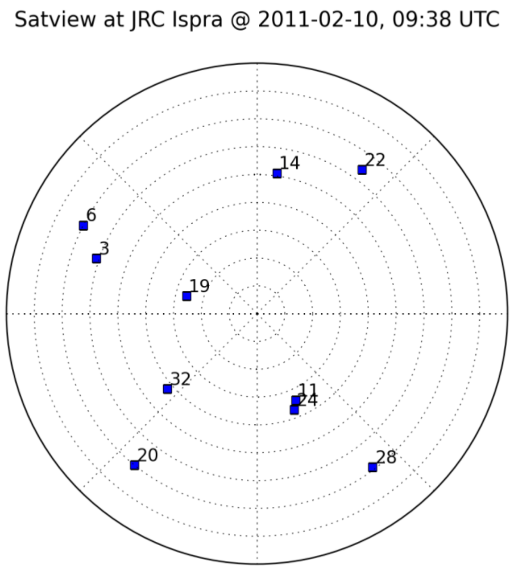
Ionospheric Range Delay result from normal signal propagation through the ionosphere.

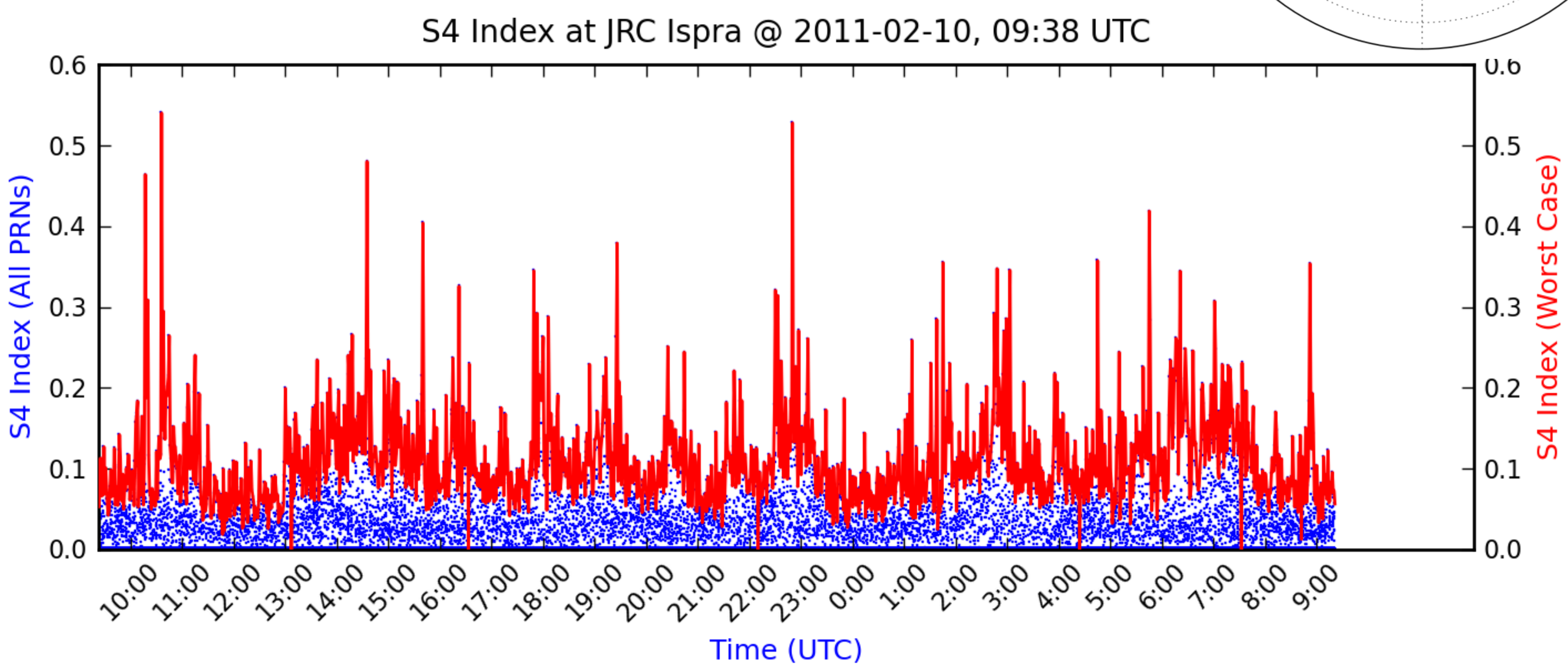
Scintillations result from severe ionospheric signal scattering.

Amplitude Fading or signal to noise degradation are caused by solar radio bursts.

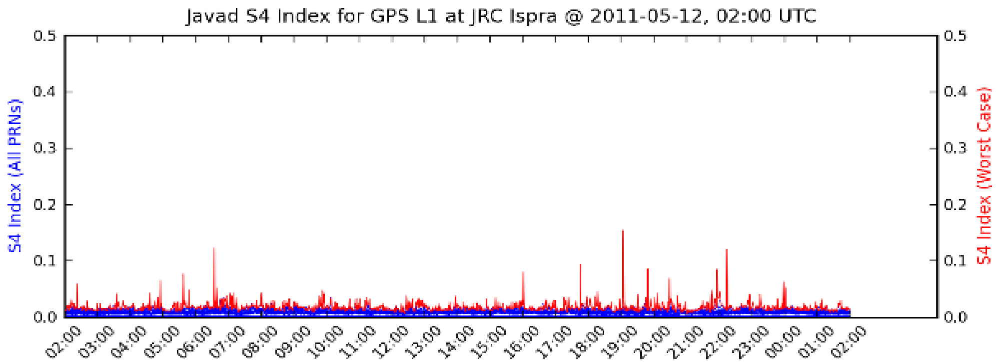
Scintillation Monitoring

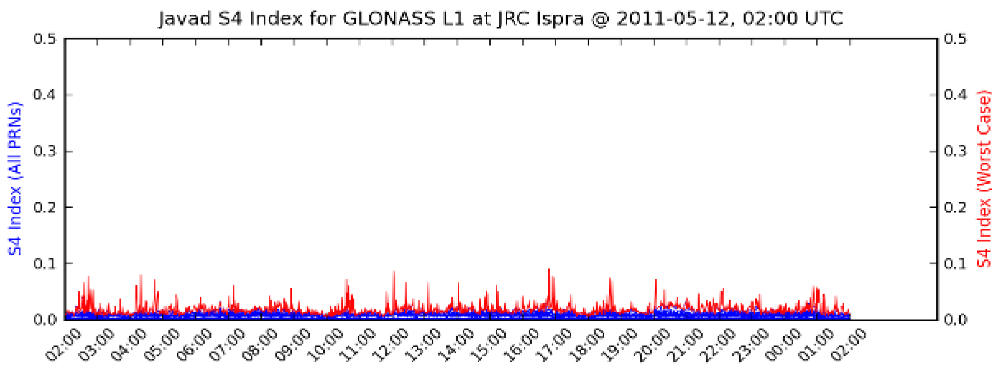
- A commercial GPS L1 receiver (Novatel FlexPak-G2-V1-L1) connected to an ordinary Windows PC
- Custom Python software processing the data and generating the plots, a MySQL database for recording, an Apache web server for displaying
- 24/7 Continuous measurements started on January 2011

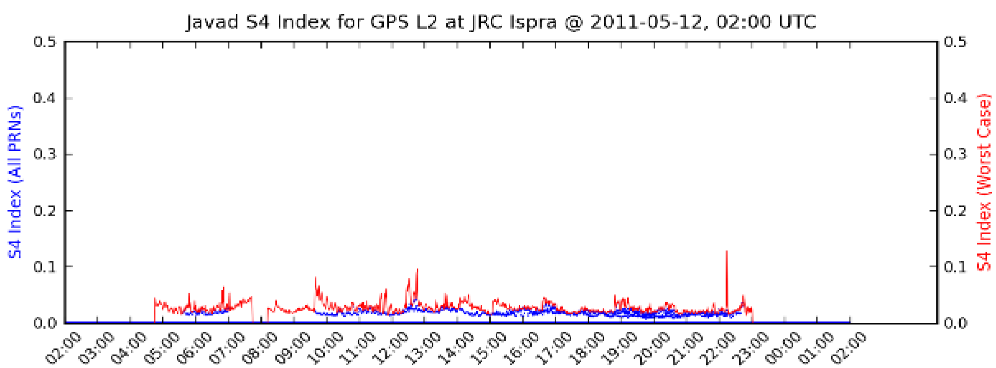


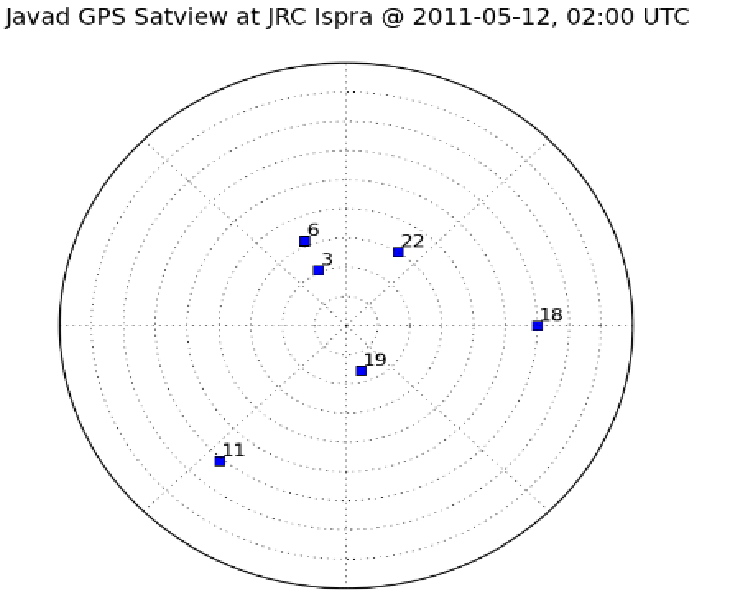


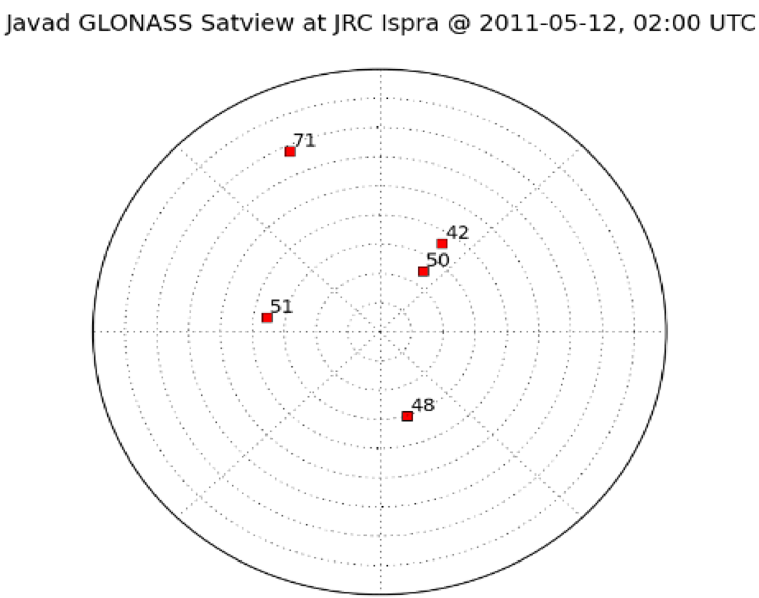
Multi-Band, Multi-Constellation S4 Measurements (using raw I/Q)











Comparison with Other Field Campaigns

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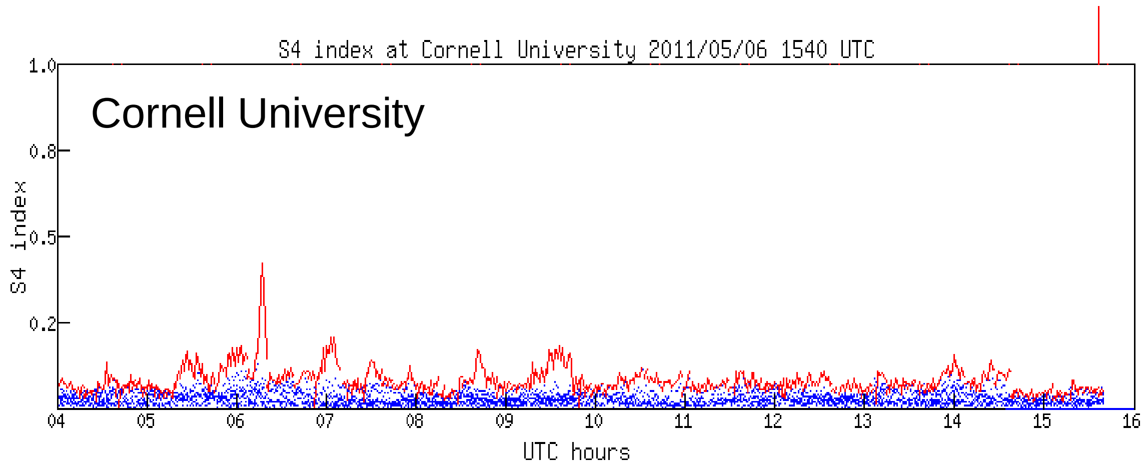
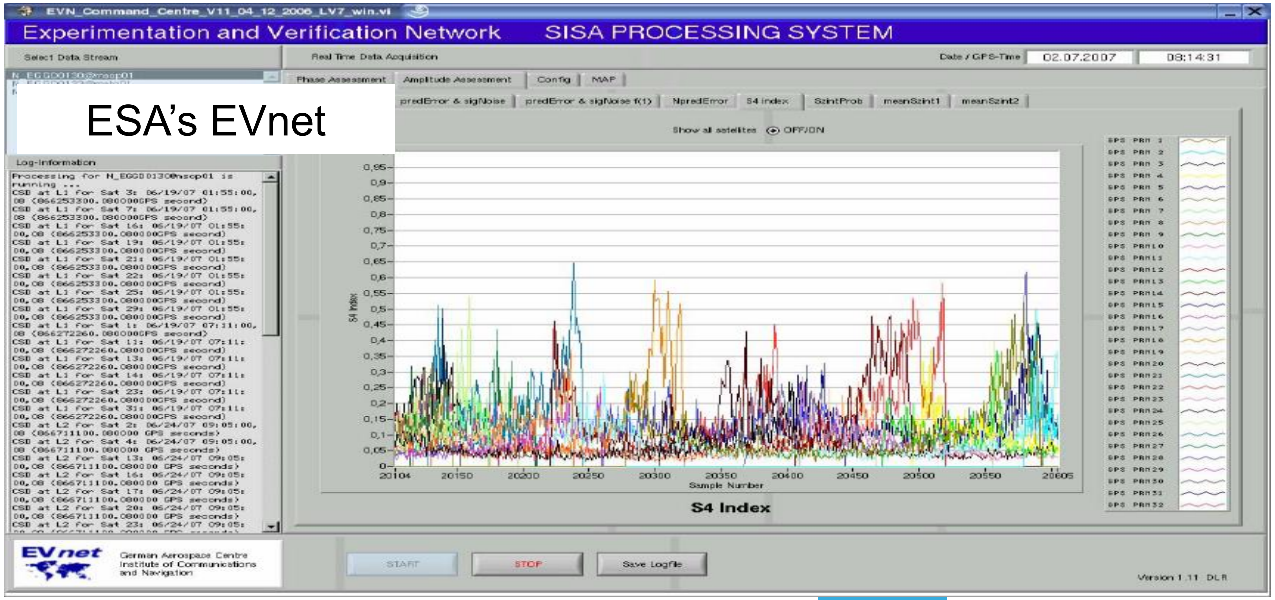




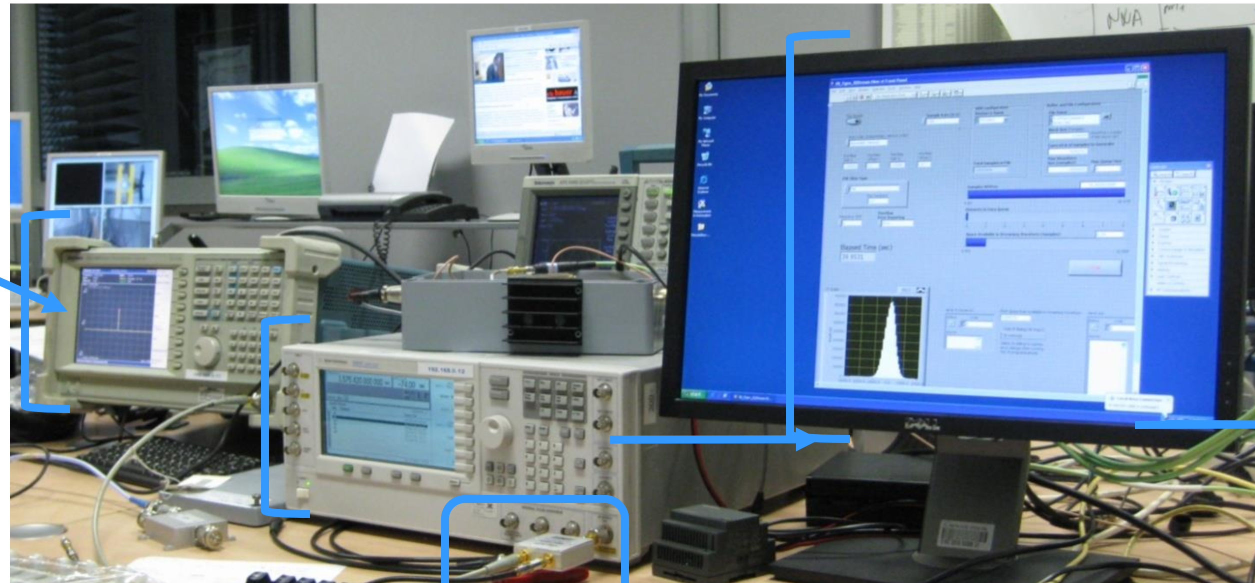
We intend to compare our measurements with those from other groups

Especially those using different algorithms for S4 index estimation

(e.g. Cornell, DLR, ESA)

Record and Playback

Spectrum Analyzer: monitor the spectral characteristics of the transmitted signal



Agilent signal generator: used as RF up-converter

LabView interface for the base-band signal generation

Signal splitter:
- to the commercial receiver
- to the spectrum analyzer

NI system

Large Anechoic Chamber

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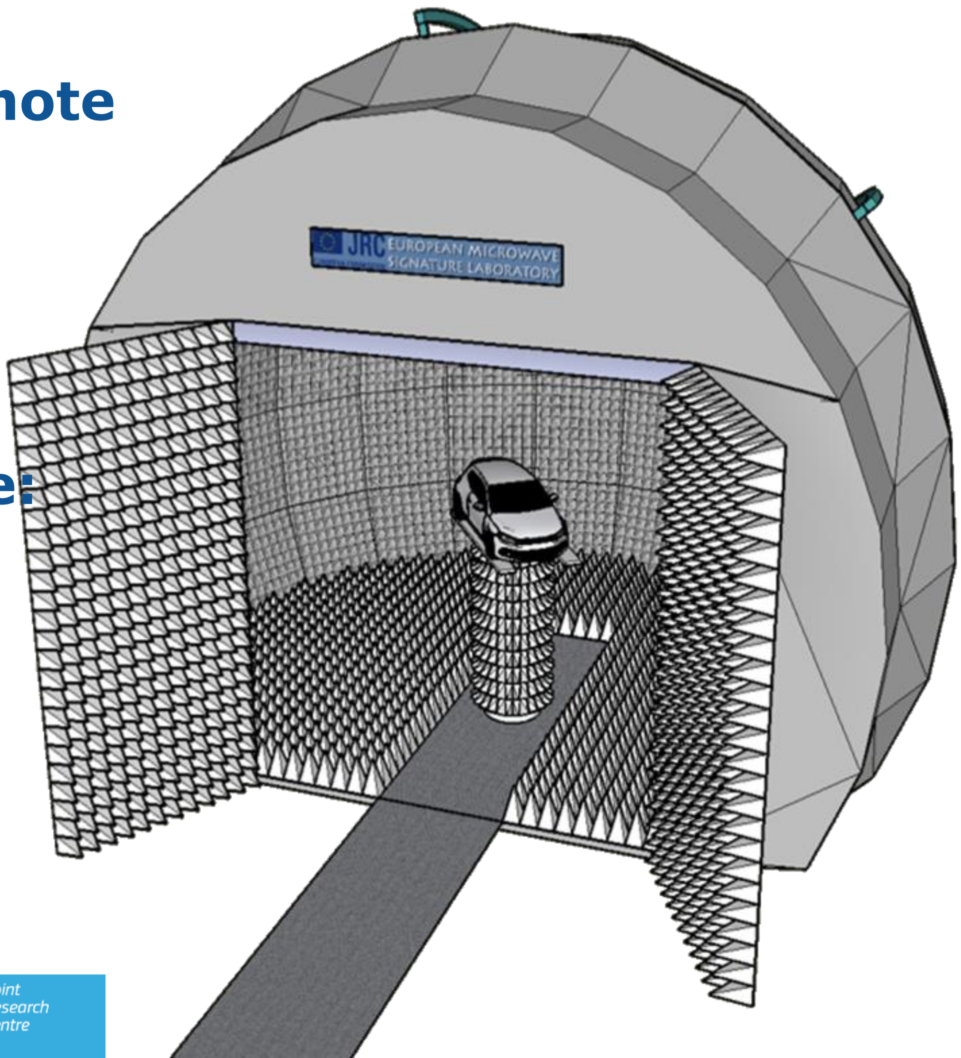
European Microwave Signature Laboratory (EMSL)

- Originally conceived for Remote Sensing applications
- Two “sleds” – positionable antenna mounts
- Ultra-Wide Frequency Range:
  - 0.2 – 26.5 GHz



State of the art instruments

- Vector network analysers
- Wideband digital oscilloscopes
- Real time spectrum analysers
- High speed IF record/playback
- Vector signal generators

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Equatorial region field monitoring

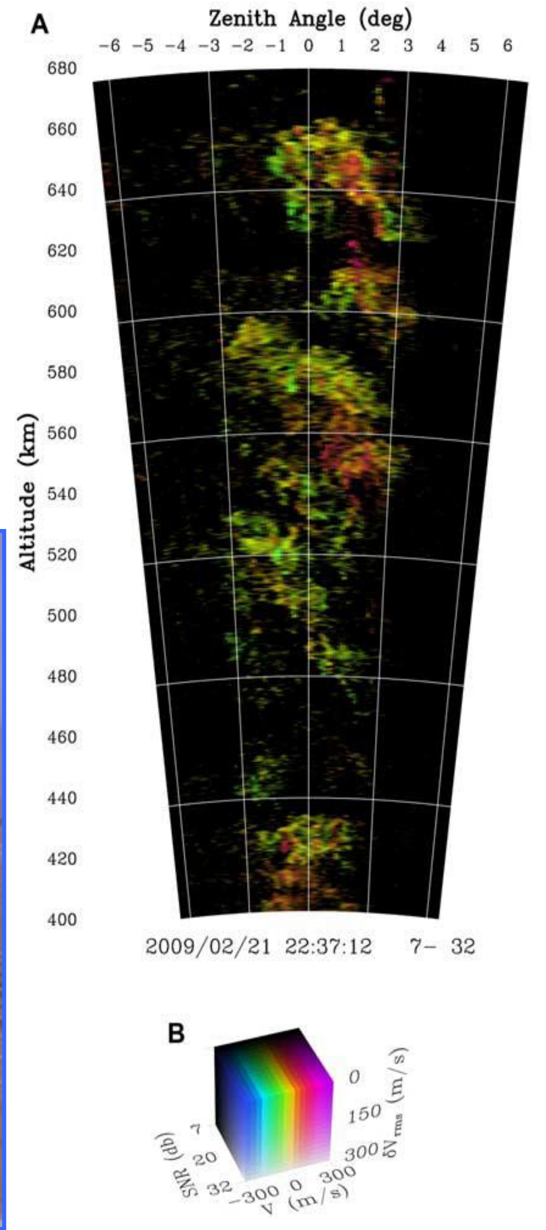
Scintillation monitoring at JRO

European Commission

Our monitoring operations started in April 2012 at Jicamarca Radio Observatory (JRO) in Peru

Why at JRO?

- Largest VHF radar in the equatorial region for ionospheric observations
- Scintillation observed in the GNSS bands can be correlated with observations from the ionospheric radar at JRO
- Fast internet access and remote operation of the monitoring station possible



Our scintillation monitoring station at Jicamarca Radio Observatory

European Commission

JRC Ionospheric Scintillation Station, equipped with a control PC, a professional GNSS receiver and a software radio to record IF datasets

GNSS choke-ring antenna of the JRC Ionospheric Scintillation Station at the Jicamarca Radio Observatory near Lima, Peru

JRC scintillation measurements

+ Monitoring station equipped with a control PC, a professional GPS receiver, and a USRP software radio to record IF datasets during scintillation events

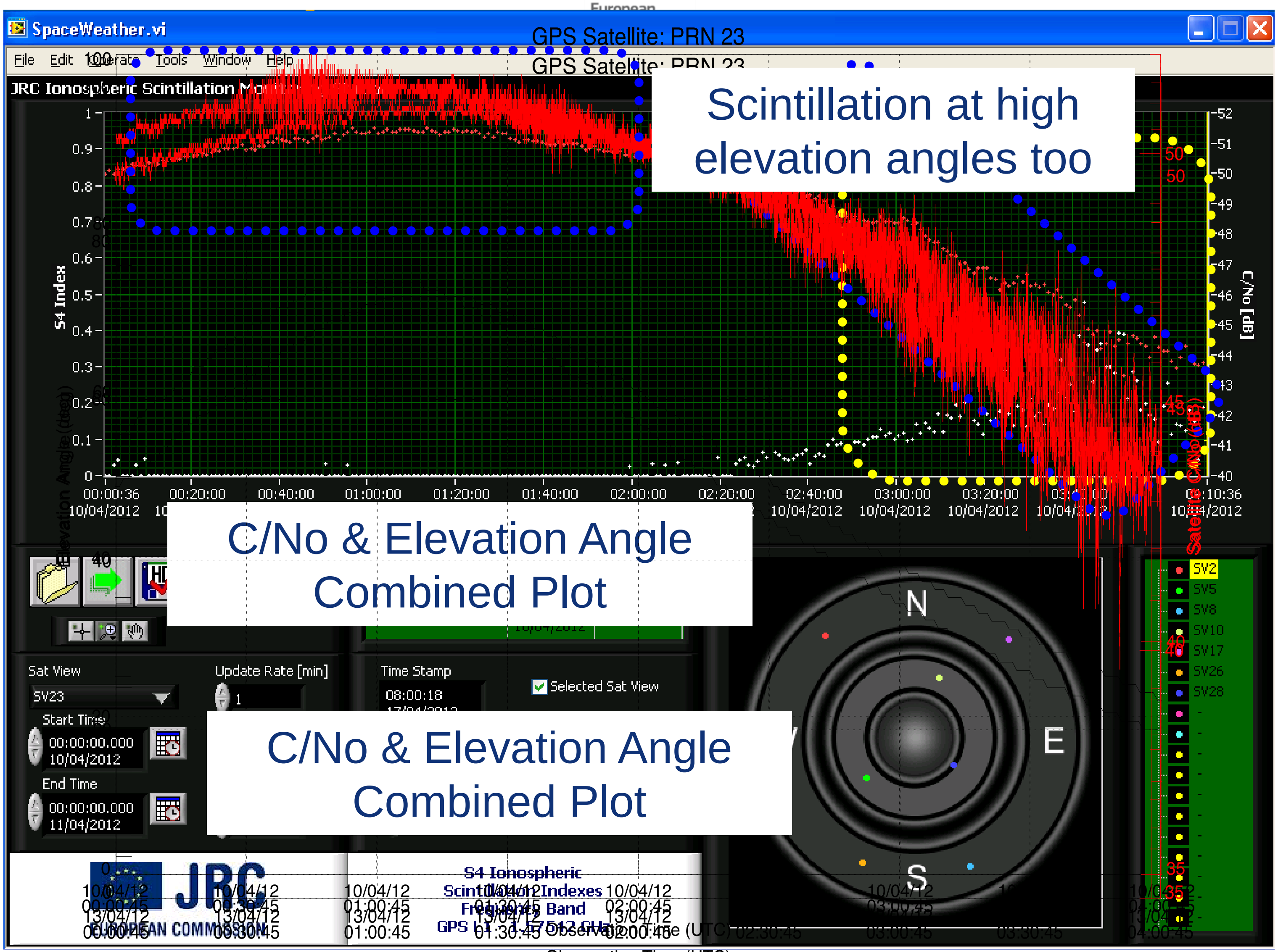
+ S4 indices computed 24/7 in real time from measured C/No at a 20 Hz rate using Van Dierendonck technique (the receiver was calibrated in advance at the JRC)

+ Data compressed and transferred regularly to a JRC server

+ Triggering of USRP acquisitions possible using the real time observations of the S4 scintillation indices

JRC scintillation measurements

April 2012



Observation Time (UTC)

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Future work

European Commission

- Current focus: quantitative assessment of the impact of anthropogenic and natural interference sources on GNSS navigation and timing receivers
- The deployment of the monitoring station at JRO will hopefully lead to the creation of a library of severe scintillation events with raw IF data for subsequent playback and testing of commercial receivers
- Depending on the outcome of this campaign, additional stations could be deployed in equatorial regions (e.g. in Ethiopia) where scintillation is observed all over the year
- The availability of a library of scintillation IF datasets may lead to the establishment of new standards for resilient GNSS receivers used in critical networked infrastructures
- JRC is available to share the results and data collected with our ionospheric scintillation monitoring station(s)

Conclusions

EU policy relevance of Space Weather

- Critical infrastructure protection
- Space situational awareness
- Civic protection

Joint Research Centre supports policy makers on SWx

- Raising awareness
- Risk assessment for critical infrastructures
- Scientific research for GNSS resilience
- International collaboration

in the context of an **all-hazard approach** to risk management

Cross-sector collaboration is needed to better understand

systemic vulnerabilities to natural events

interdependencies between infrastructures

effective approach to preparedness and response

THANK YOU
FOR YOUR ATTENTION!

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