MONITOR 2: ionospheric monitoring network in support to SBAS and other GNSS and scientific purposes

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MONITOR2 Project

- Main goal: **Improving our understanding on the influence of the Ionosphere on the GNSS and SBAS Performance.**

- Funded by: **ESA's European GNSS Evolutions Prog. (EGEP).**

- Two steps:
  - ✓MONITOR phase 1 (2010-2014): setting up the main scintillation GNSS network, ionospheric products and ionospheric campaigns.
  - ✓**MONITOR phase 2 (June 2014 – June 2016)**

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Monitor Phase 2 factsheet

Funded by: ESA's European GNSS Evolutions Prog. (EGEP)

Duration:

- Project ~ Summer Solstice 2014 – Spring Equinox 2016
- Data collection ~ spring 2015 – spring 2016

Team: 8 subcontractors + 2 consultants

Interagency agreements: 2 (CNES & ASECNA) – MoUs

New monitoring stations: 6 (+ 5 from CNES SAGAIE)

New products types received routinely: 6

Latency: 1-48 hours

MONITOR Phase 2 - Objectives

- **Expansion of the MONITOR ionospheric scintillation network:**
  - Integration of data from CNES-SAGAIE network
  - New stations at low-latitudes (Africa) and high-latitudes (Scandinavia).
- **Maintenance of MONITOR infrastructure.**
- **Upgrade the current Central Archiving and Processing Facility (CAPF):**
  - Simplified and robust data collection, processing and access.
  - Implementation of flexible data policy
  - Generation of new automatic data, products and reports tailored to EGNOS needs.
  - Routine ionospheric status reporting
- **Tools, datasets and scientific/engineering models:**
  - Identification and analysis of disturbed events
  - Relevant ionospheric scintillation experimental data for system and receiver performance assessment.
  - Integration and archiving of data from other projects, data providers.
  - Production of relevant ionospheric scenarios (TEC and scintillation).
- **Collaboration with external entities:**
  - CNES/ASECNA, SANSA, members of SBAS Ionospheric group, Joint Research Center
  - LISN, SCINDA, CHAIN

MONITOR Products

- **Space weather (***solar and geomagnetic indices obtained from third parties)*
- **Station-based** *(re-computed 1-minute ionospheric scintillation indices, multipath and cycle slips)*
- **Electron content** *(Global Electron Content, Slant TEC, VTEC global maps, EGNOS VTEC maps, EGNOS accuracy and integrity)*
- **Perturbation indices** *(AATR parameter for EGNOS and WAAS reference stations and for SAGAIE network, Rate of TEC, Solar Flares and TIDs)*
- **Reporting** *(automatic and manual reports)*

High-Latitude Stations

Stations:

Kevo and Sodankyla – **Finland**

Kiruna – **Sweden**

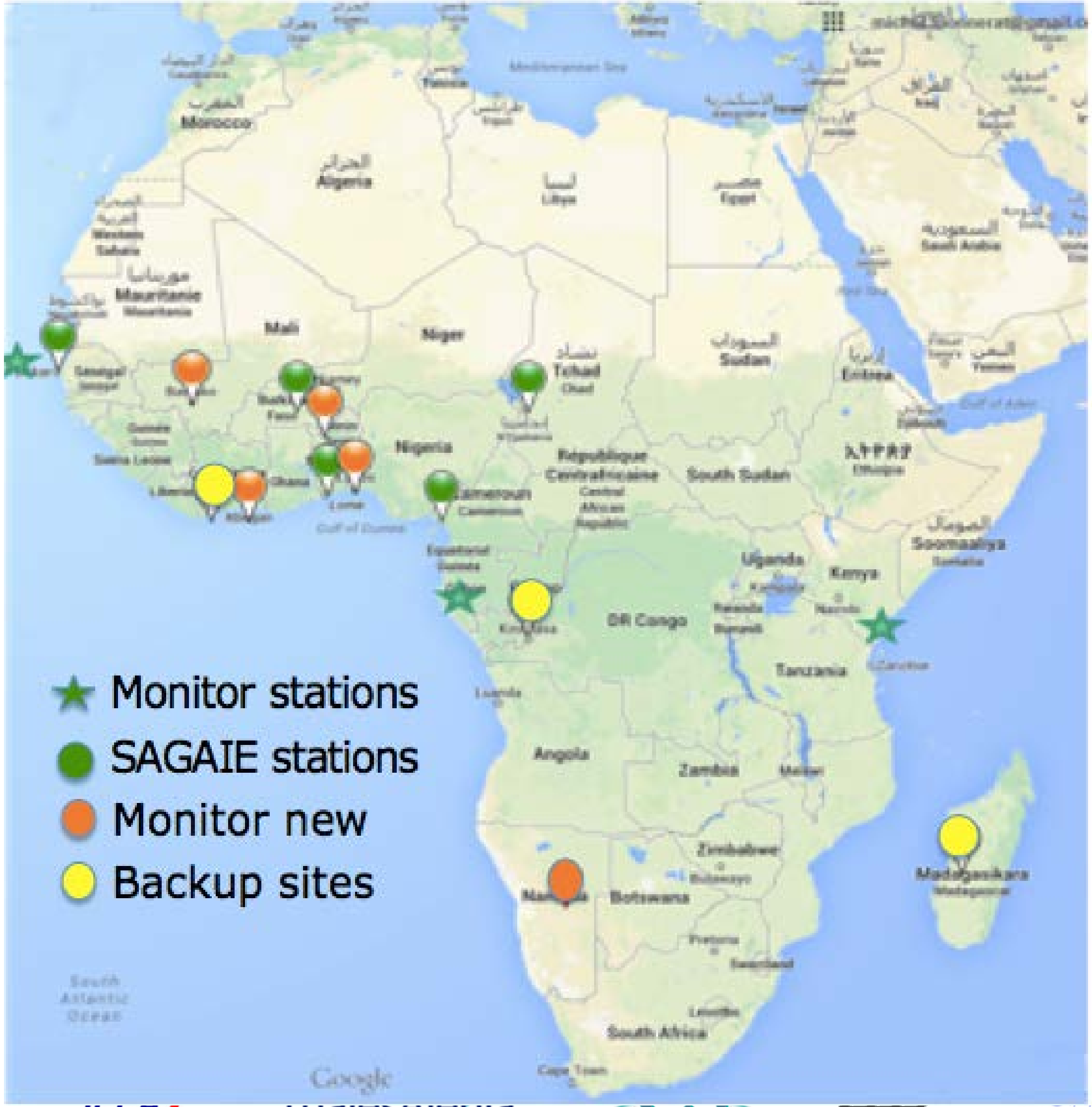
Noordwijk – **The Netherlands**

Other:

Onsala – Sweden, under discussion

Tromsoe – Norway, data exchange?

Selected New Sites Over Africa



Site	Backup Site
Niamtougou (Togo)	-
Cotonou (Benin)	French school of Lomé (for bubbles < 10 km)
Abidjan (Côte d'Ivoire)	Accra (Ghana) within Ghana Space Agency
Bamako (Mali)	Brazzaville (Congo)
Namibia	

ASECNA Sites with

- Internet connection
- Power supply 24/7
- ASECNA staff on site

Namibia in collaboration with SANSA

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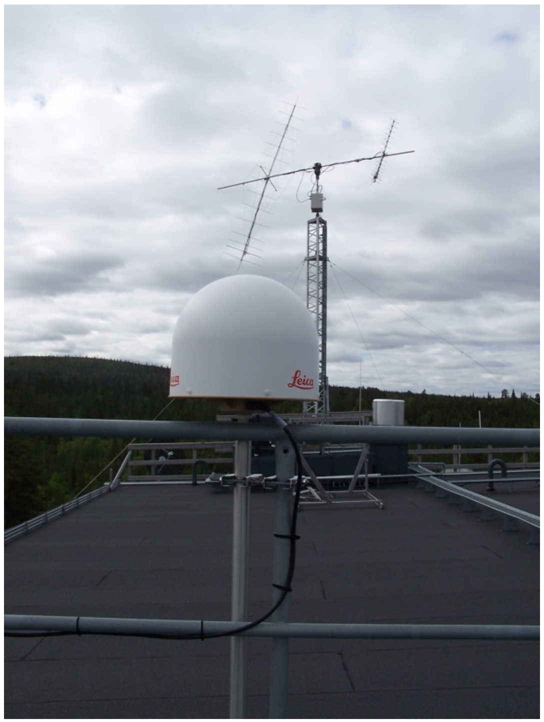
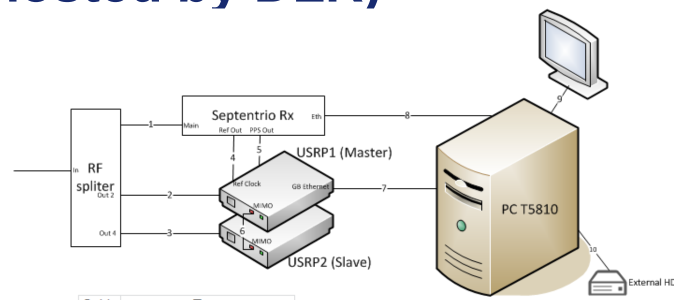
New Station Hardware



Deployment of a Septenrio receiver + bitgrabber at the receiver station (example existing Kiruna station hosted by DLR)



Cable	Type
1	M-TNC to M-TNC
2	M-TNC to M-SMA
3	M-TNC to M-SMA
4	M-BNC to M-SMA
5	M-BNC to M-SMA
6	Mimo cable
7	Gigabit Ethernet cat6E
8	Septentrio Ethernet adaptor
9	DVI cable
10	USB-3 cable

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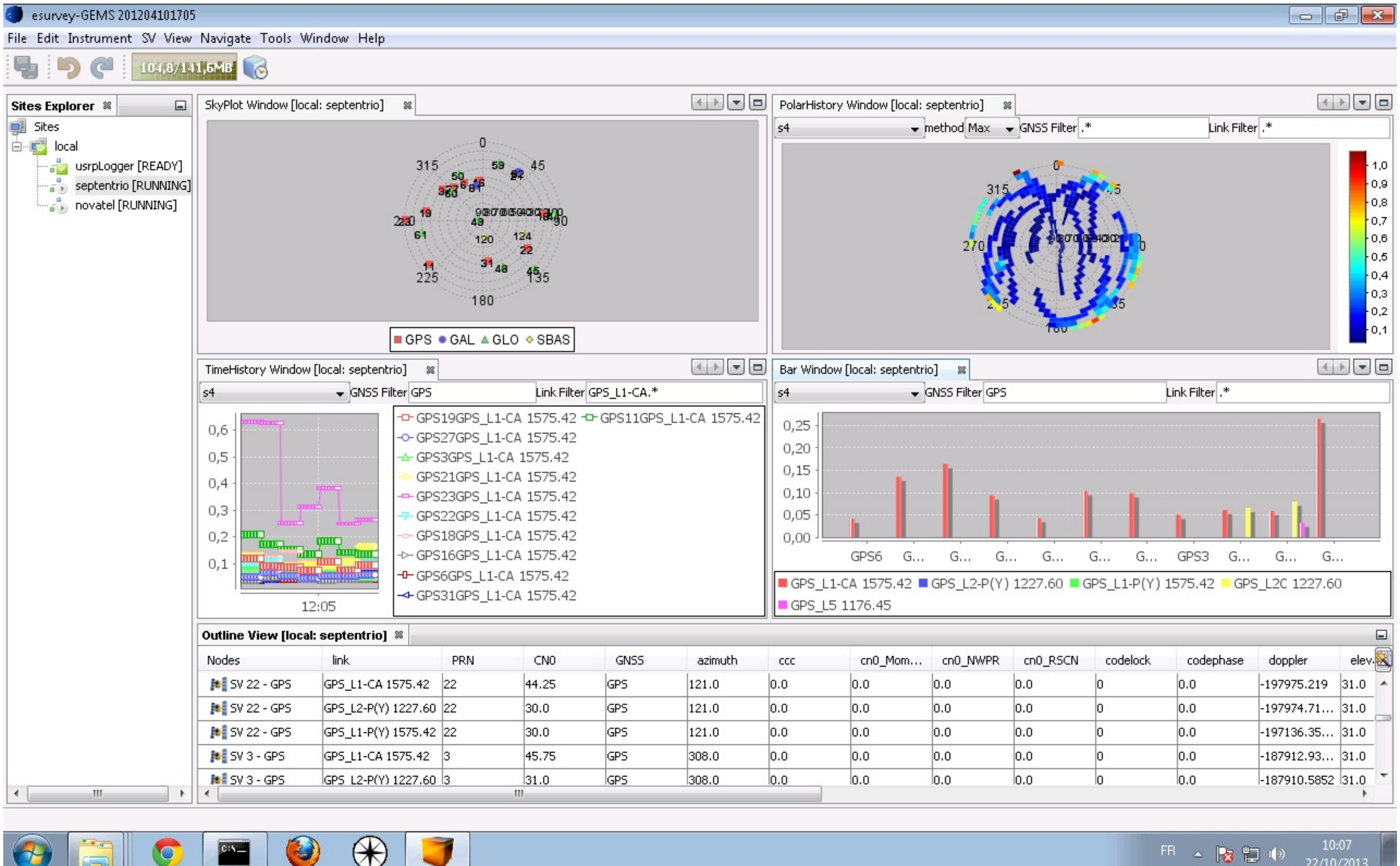
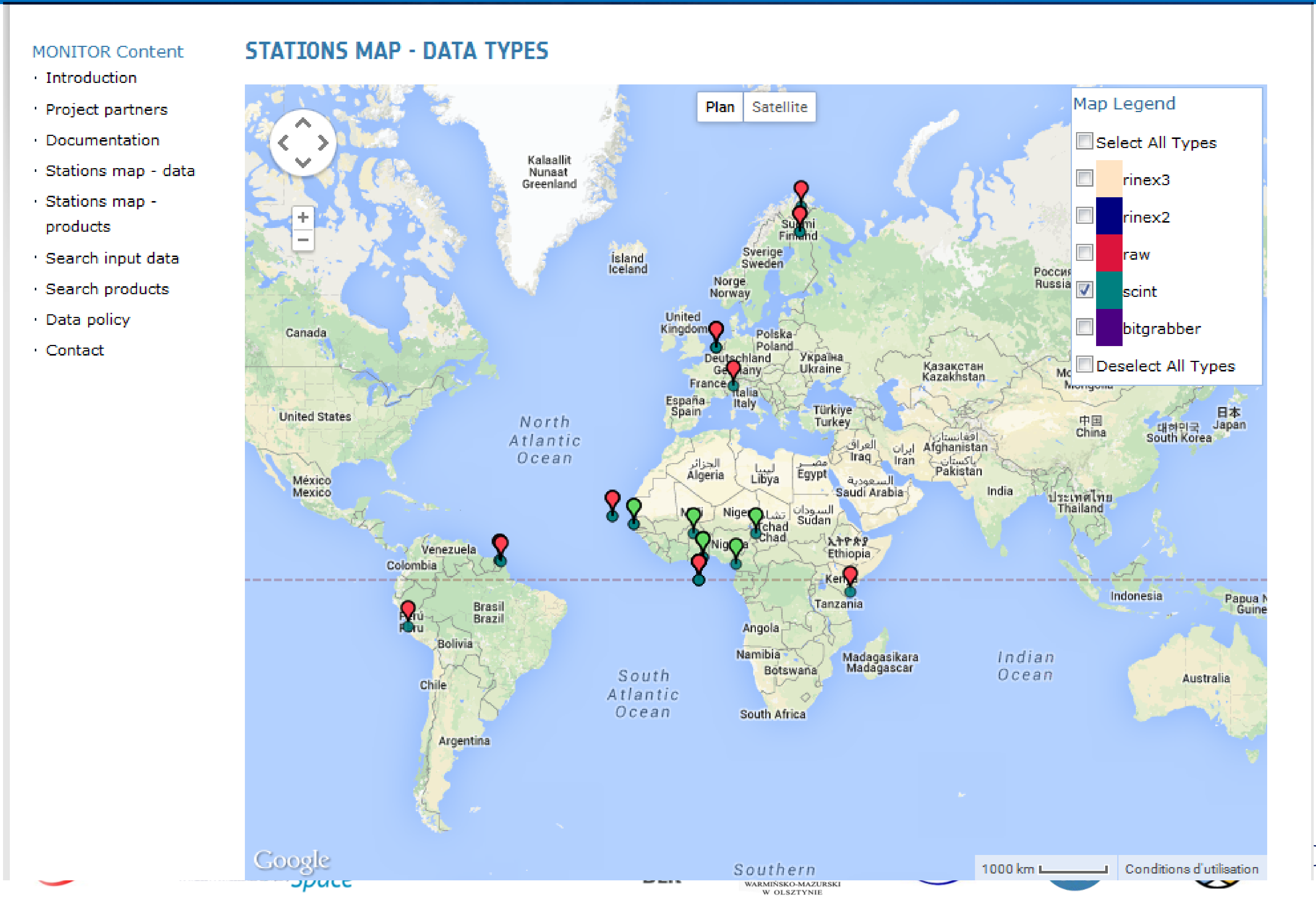
Remote Monitoring / Control with E_survey application



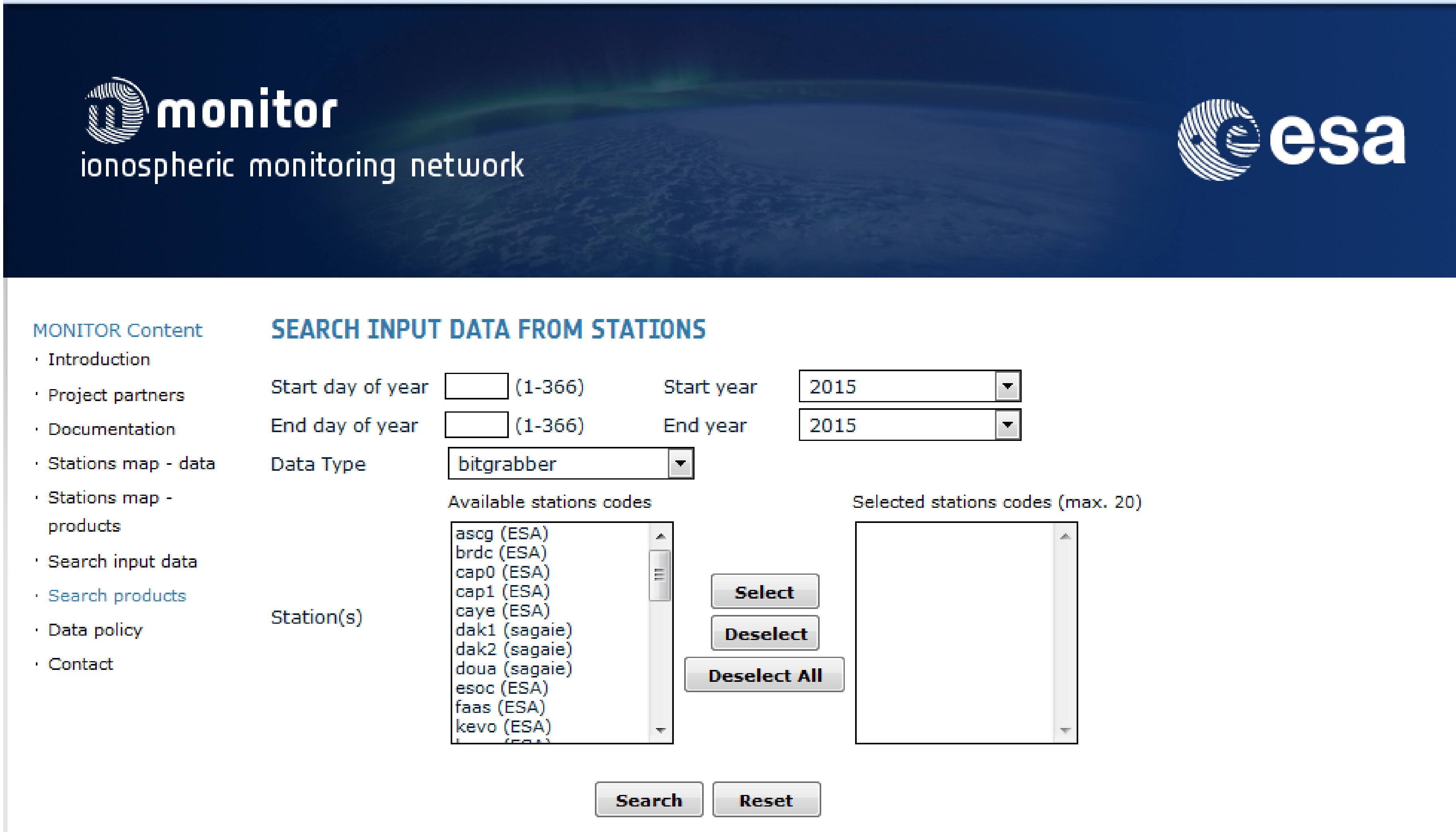
Updated Website

Final Web Site: http://monitor.estec.esa.int (provisional address: http://194.102.135.7)

MONITOR Scintillation receivers



Input Data



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Output Products

monitor

ionospheric monitoring network

esa

MONITOR Content

- Introduction
- Project partners
- Documentation
- Stations map - data
- Stations map - products
- Search input data
- Search products
- Data policy
- Contact

SEARCH OUTPUT PRODUCTS

Day of year [ ] (1-366) Year [2015] Hour [ ] (0-23)

Product Type [aatr] ☑ search plots, too

Select the provider:

◉ Processor [AATR-SAGAIE]

or

○ Station [ab01 (UPC-IonSAT)]

[Search] [Reset]

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Generation and Collection of Relevant Products to Understand the Ionospheric Perturbations

Daily Autoreporting

AutoREPORT

MONITOR AutoREPORT

ESA-ESTEC/UPC-IonSAT

January 28, 2015

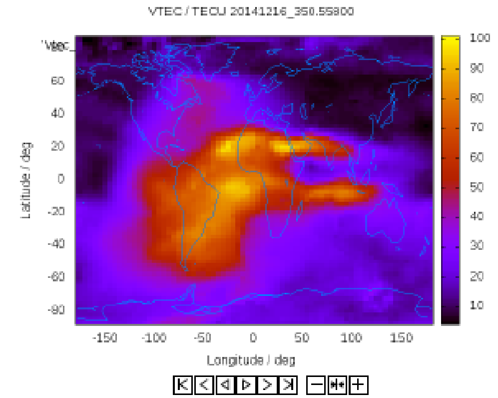
FINNISH METEOROLOGICAL INSTITUTE

AutoREPORT

2 PRODUCTS

2.1 IONEX

2.1.1 TEC-TOMION

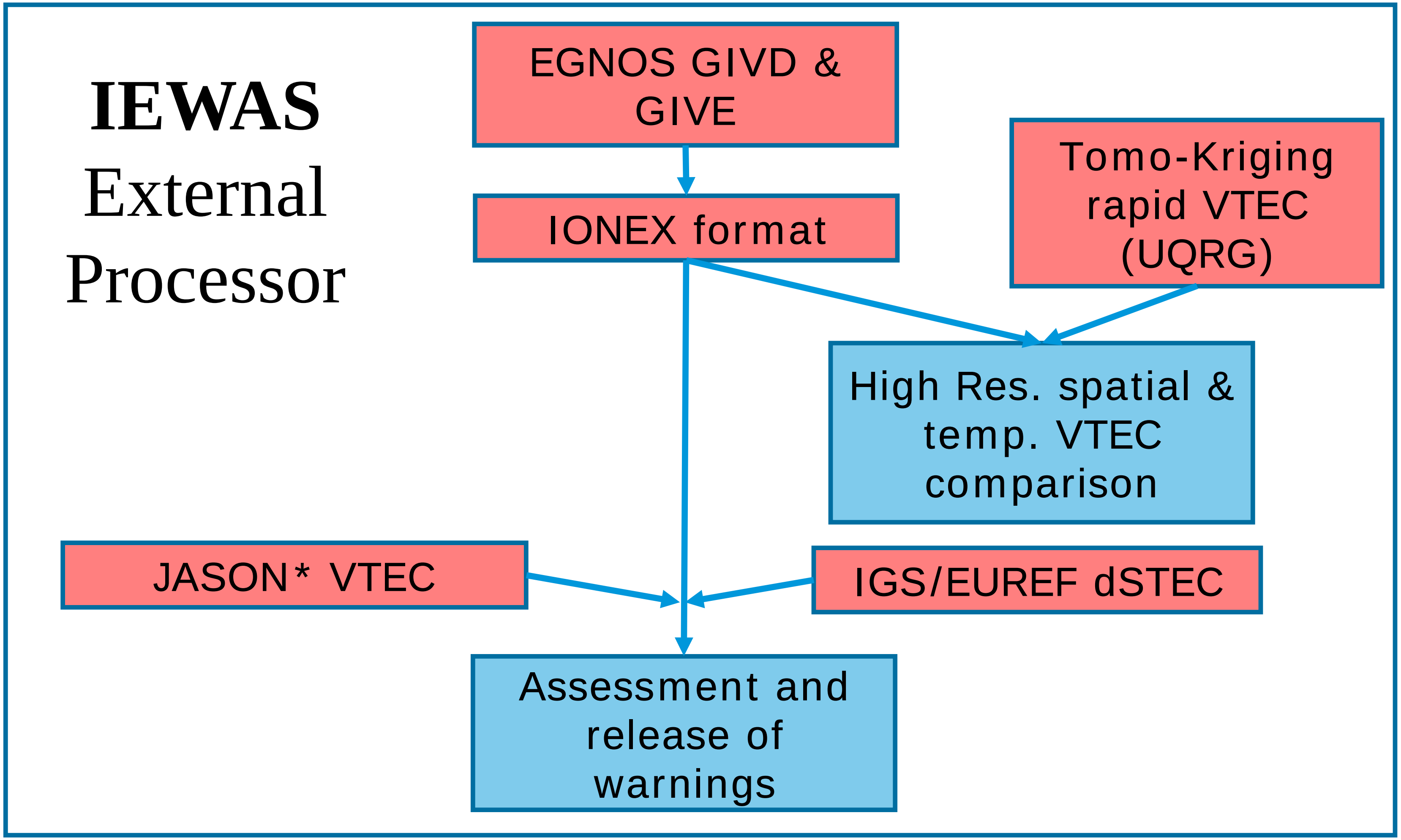


ROMÂNIA

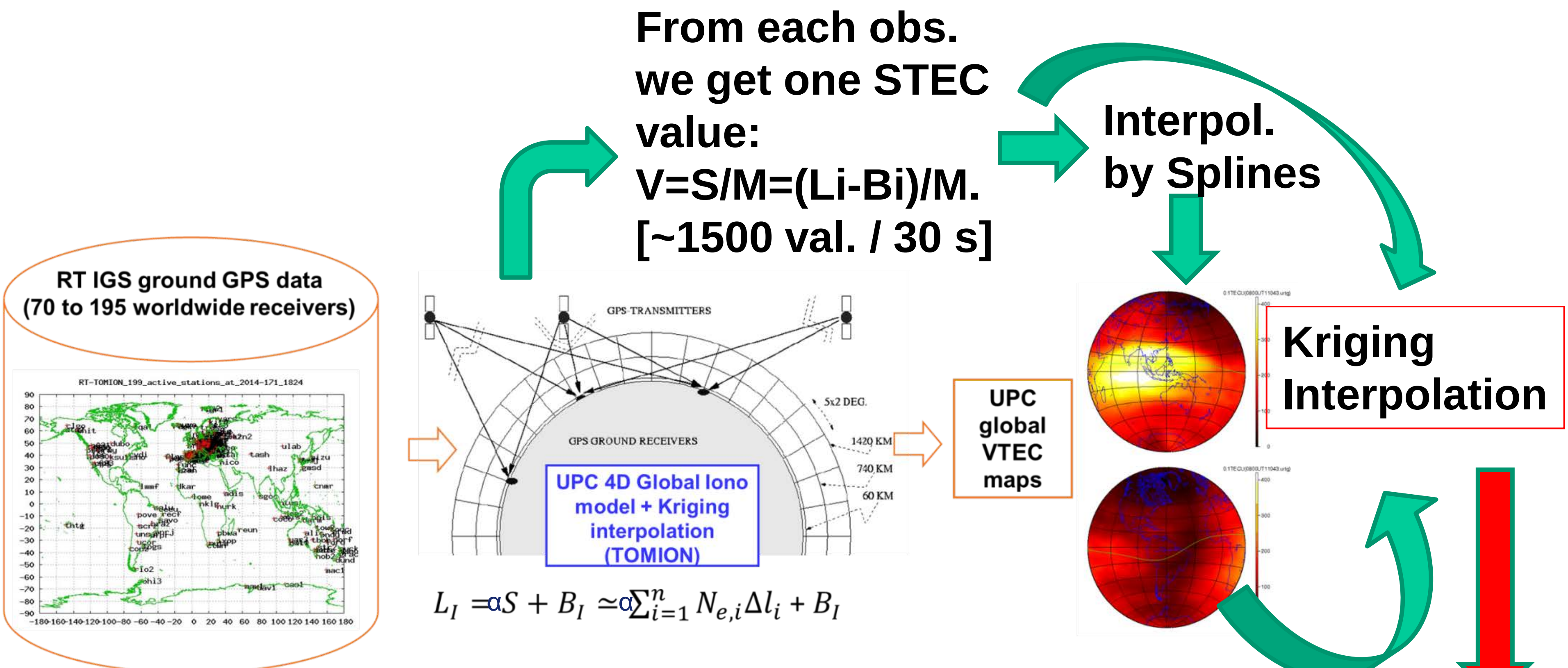
UNIWERSYTET WARMIŃSKO-MAZURSKI W OLSZTYNIE

FMI

Ionospheric EGNOS Warning System (IEWAS)



Rapid & RT Global VTEC Maps @ 15 min Computed with Tomographic-Kriging



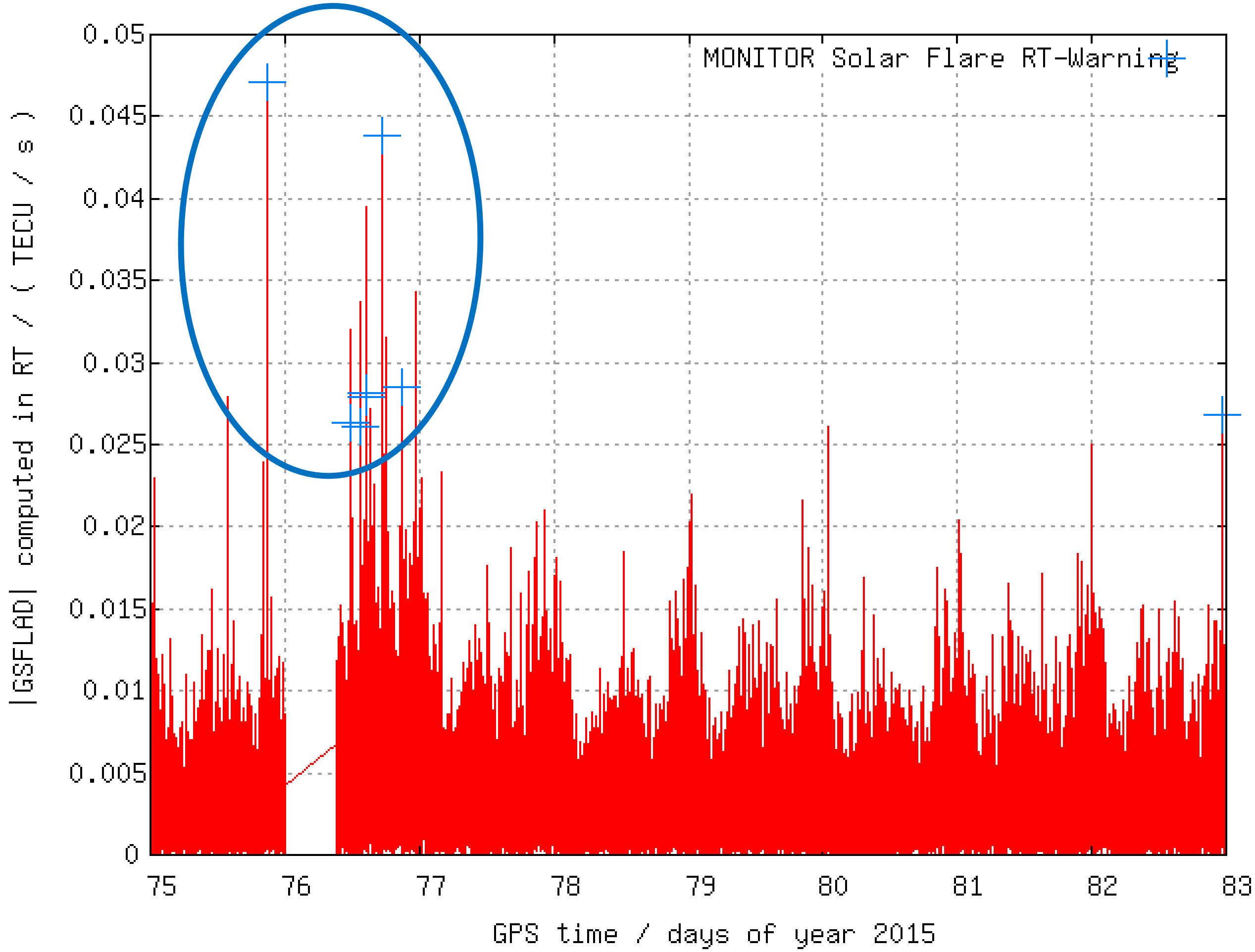
Layout summarizing the global VTEC computation from ground GPS data by means of the UPC TOMION software, including the main tomographic model equation[*]

[*](data: ionospheric combination of carrier phases LI, and length intersection within each voxel, ∆li; unknowns: its ambiguity BI, the STEC, S, which includes the mean electron density within each given voxel, Ne,i).

UPC FMI

Recent Space Weather Events in March 2015 and EGNOS Ionospheric Model Performance

Severe Space Weather MONITOR RT Warnings from GNSS Solar Flare Index (GSFLAI, Days 70-76, 2015)



- Several geoeffective **solar flares that occured during days 75 and 76, 2015.**
- They were detected and **notified in RT by the MONITOR system** by means of GNSS Solar Flare Indicator, GSFLAI[*]

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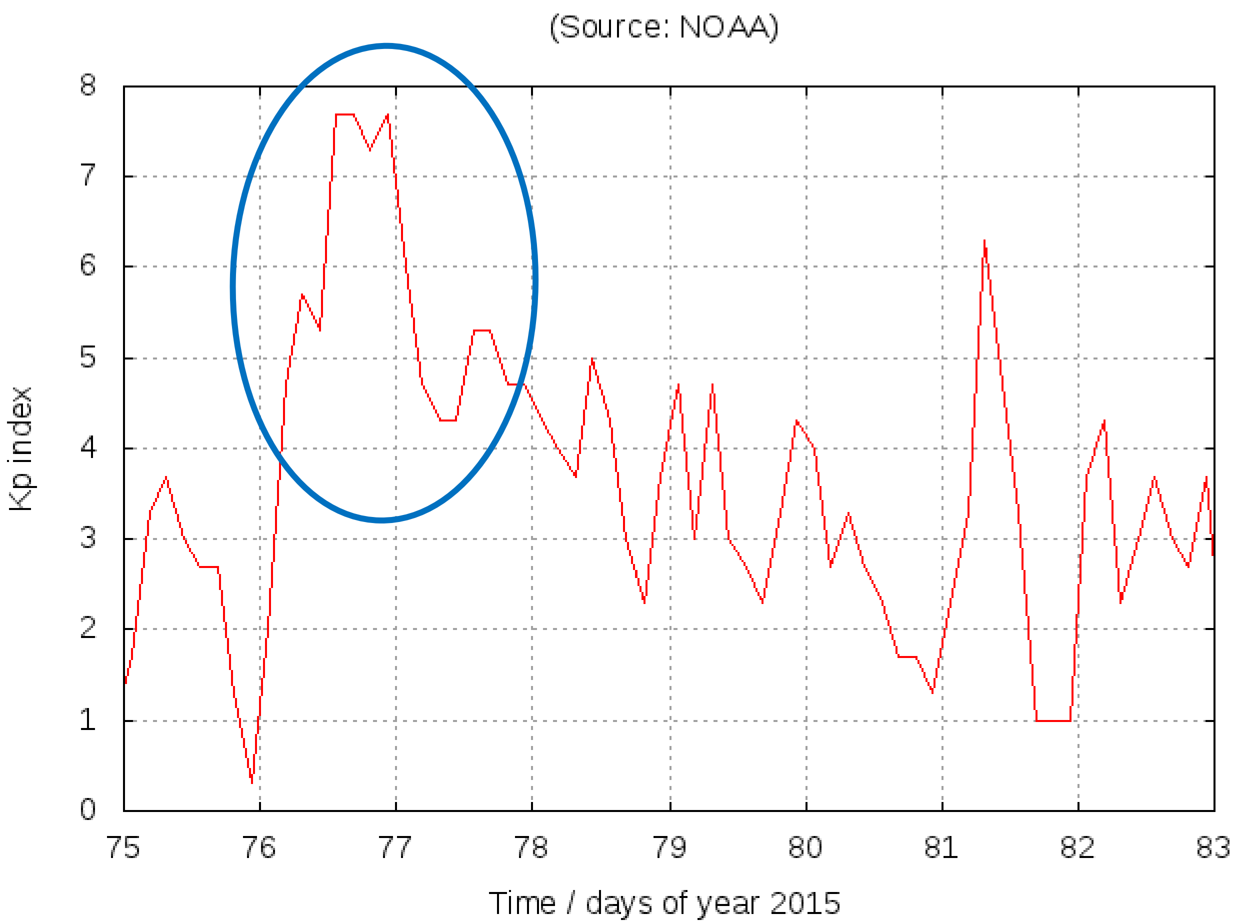

- **Major geomagnetic storm occured on days 76-77, 2015: St. Patrick's storm**

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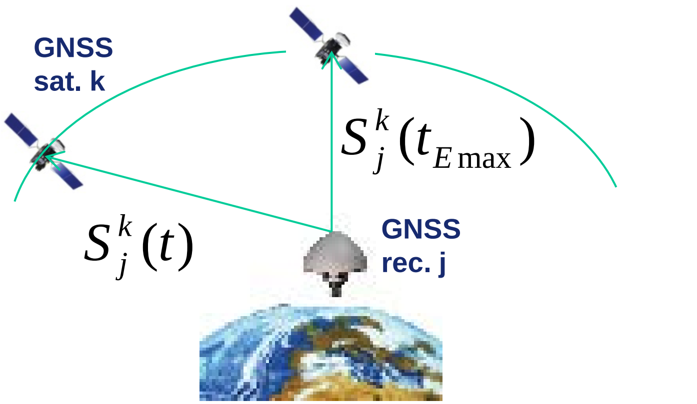
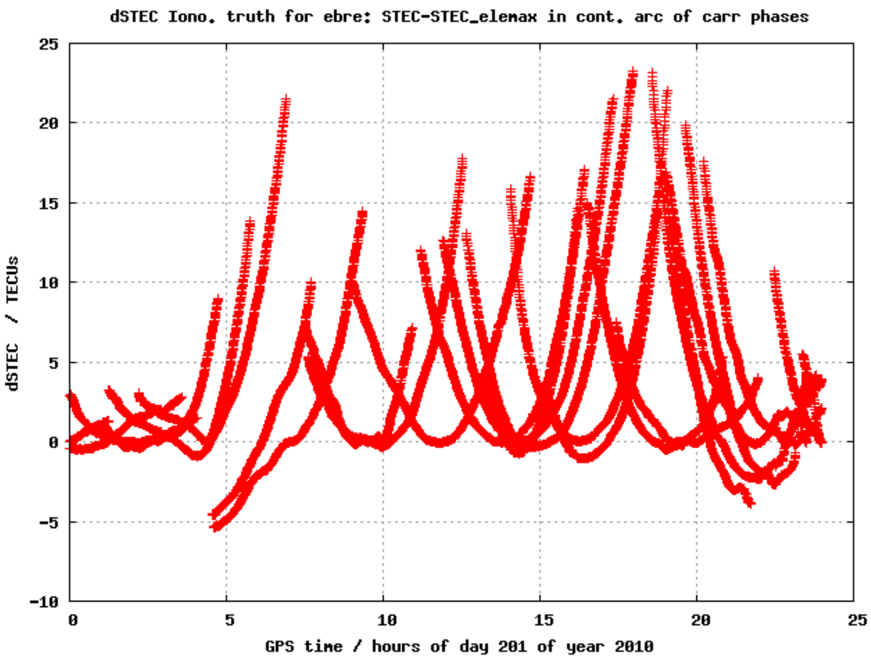
Ionospheric Truth based on STEC Variation, dSTEC (ITSVAR)



$$\Delta S_O \equiv S_j^k(t) - S_j^k(t_{E\max}) =$$
$$= [(L_I)_j^k(t) - (L_I)_j^k(t_{E\max})]/\alpha \equiv \Delta L_I / \alpha$$

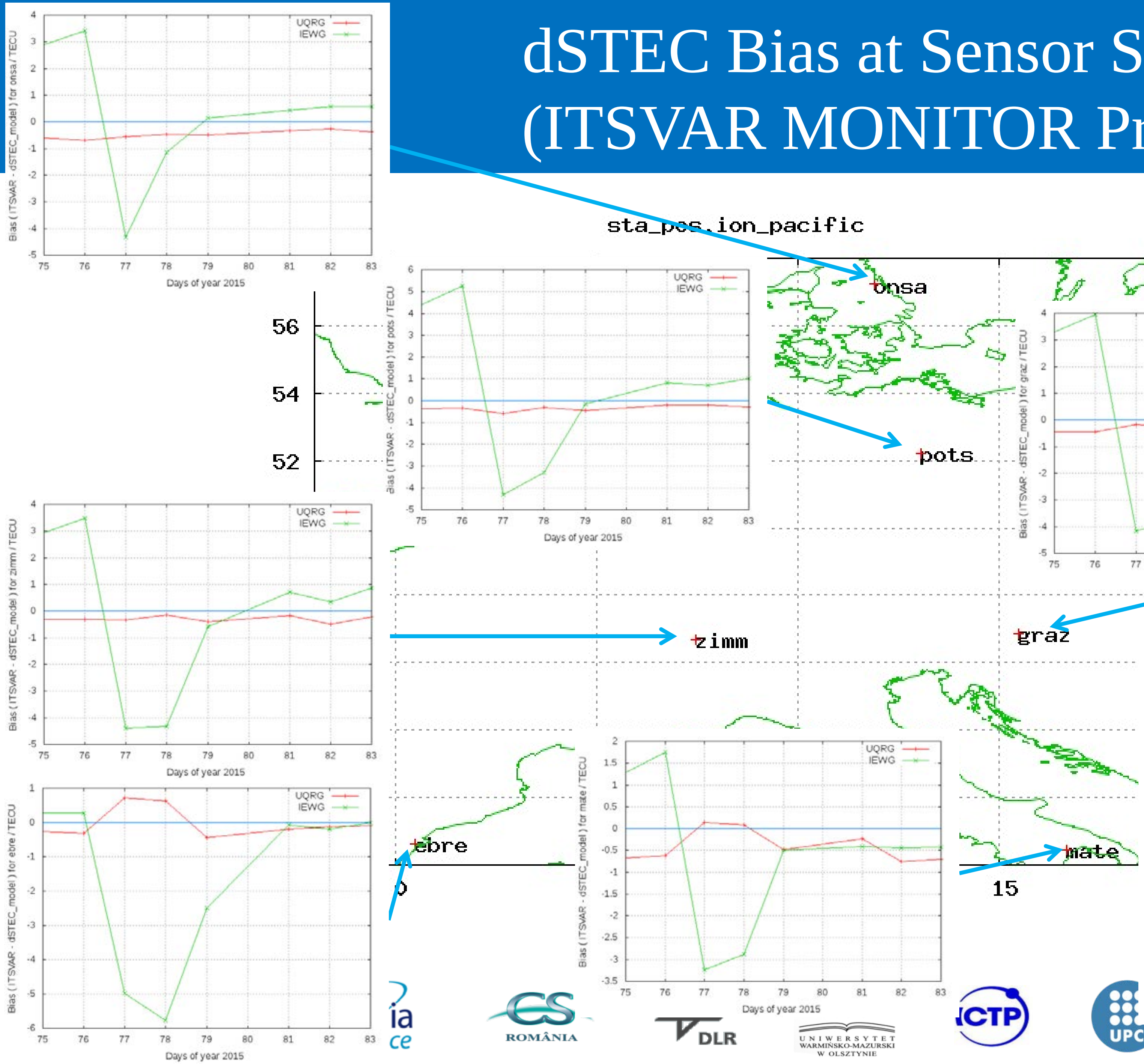


✓The GPS ionospheric carrier phase difference, ΔLI for a given pair rec.(j)-sat.(k), (regarding to the value corresponding to the higher elevation –Emax- ray in the phase-continuous arc of data), provides a **very precise ionospheric truth (ITSVAR) of the STEC variation, ΔSo**, in space and time (typically more accurate than 0.1 TECU).

✓*ITSVAR* (see Figure) **can be used to compare the performance of ionospheric models, i.e. ΔSm –ΔSo,** which can be interpreted (under quiet and similar conditions) as an assessment of the VTEC (V) and mapping function (M) provided by the model:

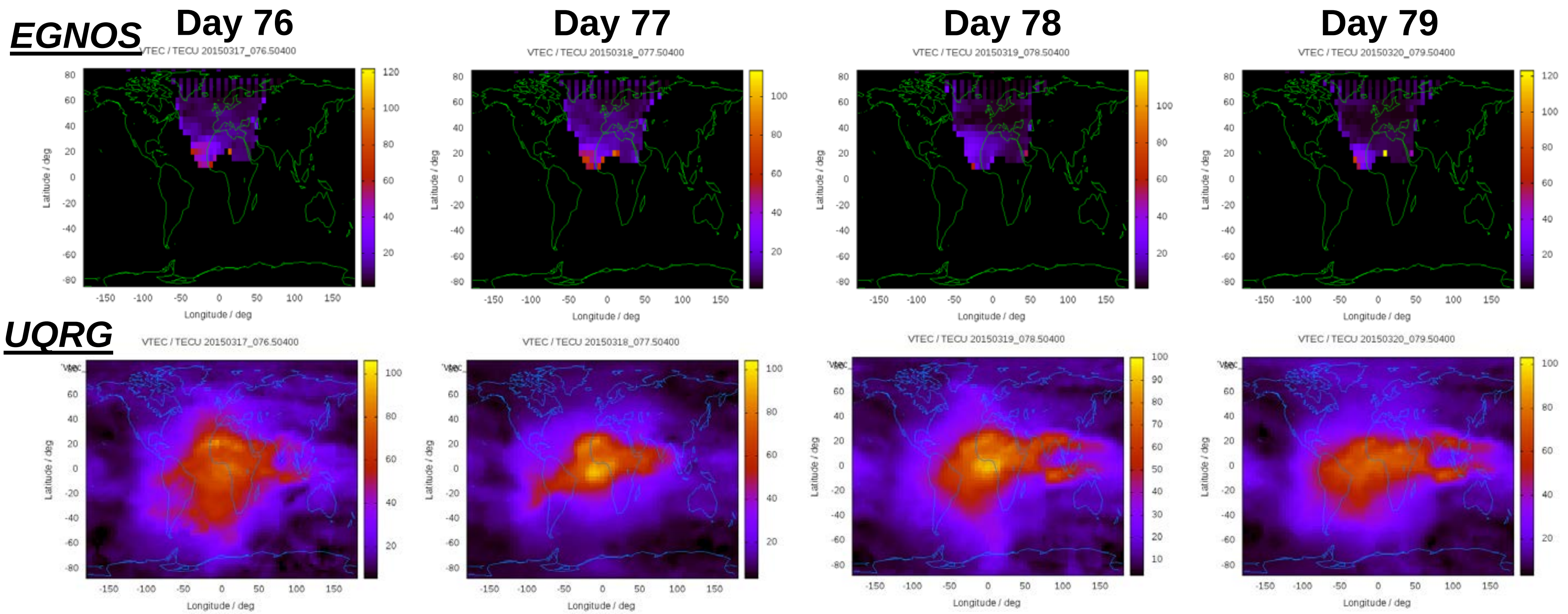
$$\Delta S_O \approx M \cdot V(t) - M_{E\max} \cdot V(t_{E\max}) \sim (M-1) \cdot V$$

dSTEC Bias at Sensor Stations (ITSVAR MONITOR Product)



EGNOS model underestimates TEC significantly on days 75, 76 & overestimates on days 77 & 78.

(RT) EGNOS vs. (Rapid) UQRG VTEC Evolution (Days 076-079, 2015 @ 13:45 GPS Time)



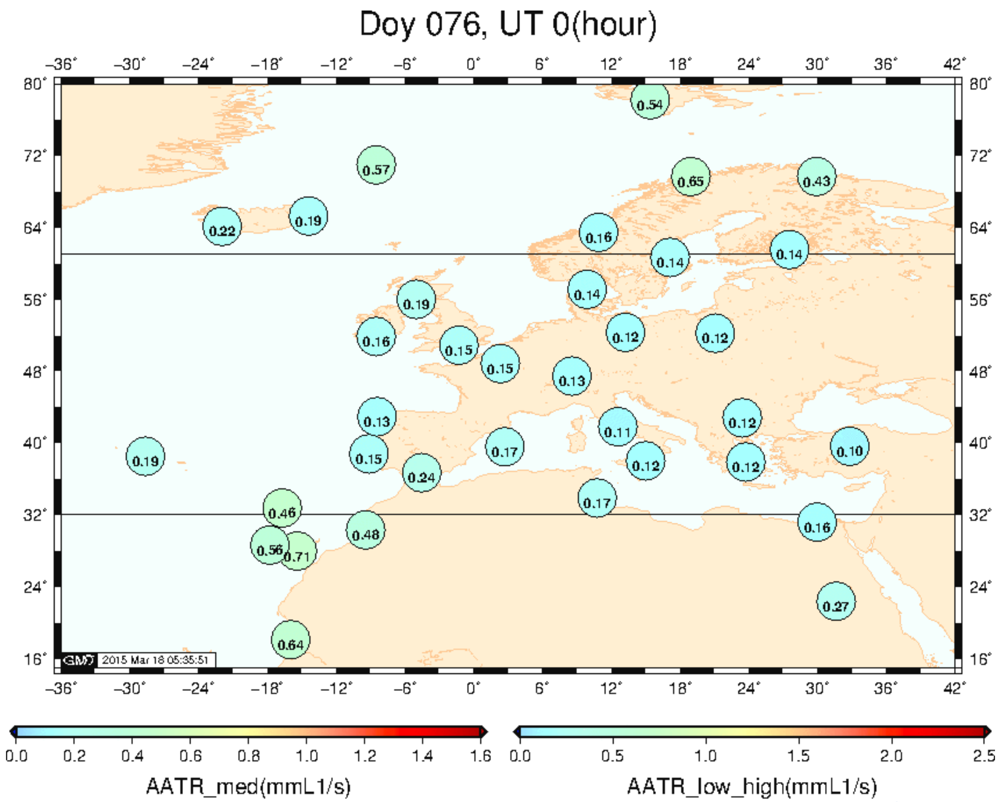
The **positive phase peak at European latitudes can be clearly seen on Day 76, 2015,** on global rapid UPC VTEC maps (UQRG), and the **strong decrease of electron content over Europe** (coinciding with the almost disapearance of the equatorial anomaly) can be also seen during **next day, 77, 2015**.

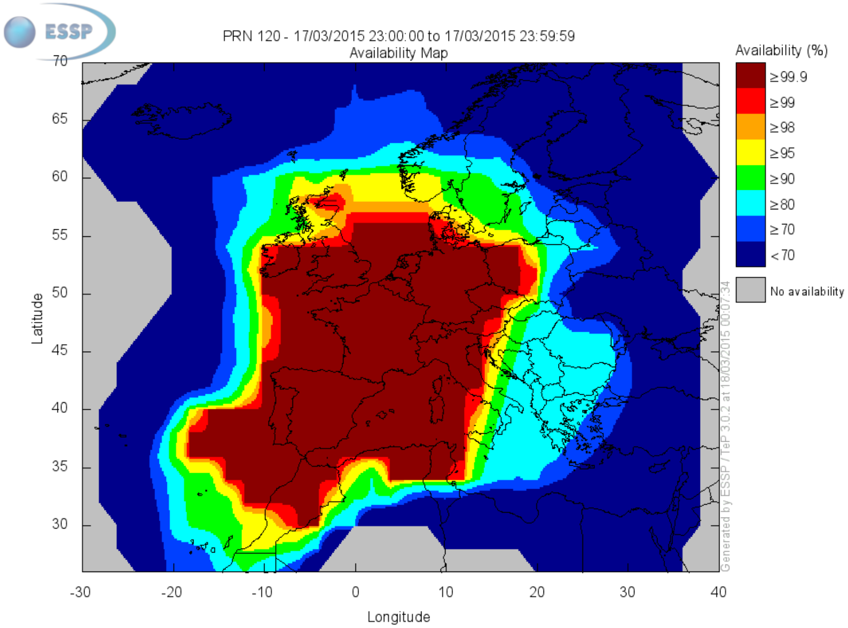
New processor AATR – EGNOS, WAAS and SAGAIE Application to Recent event: St Patrick's storm (17/03/2015)

Along-Arc TEC Rate (AATR) indicator **as the hourly Root Mean Square (RMS) of "weighted" Along-Arc Vertical TEC Rate.**

$$AATR = \frac{\Delta STEC}{\left(M(\varepsilon)\right)^2 \Delta t}$$

where Δt can be 30 or 60 seconds





EGNOS APV-I Performance Service Area

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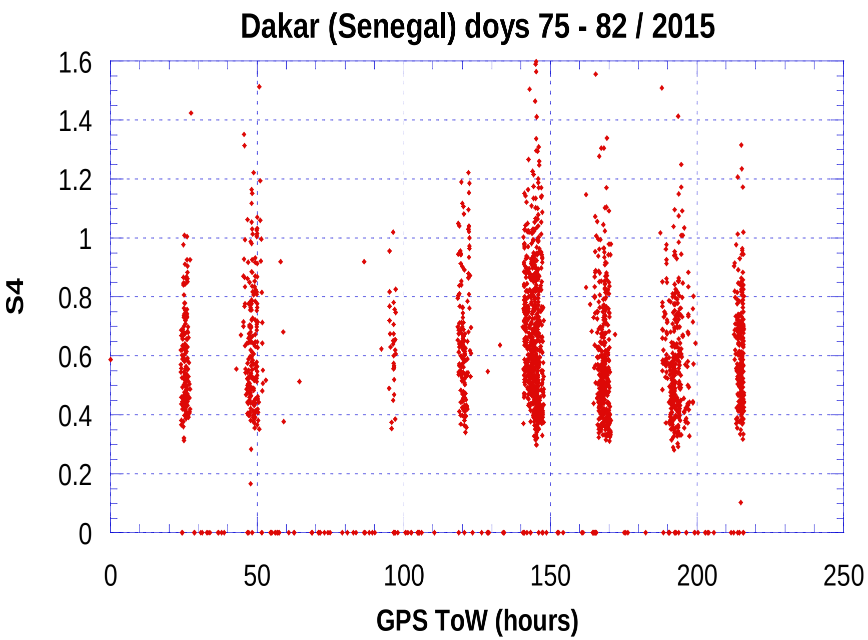
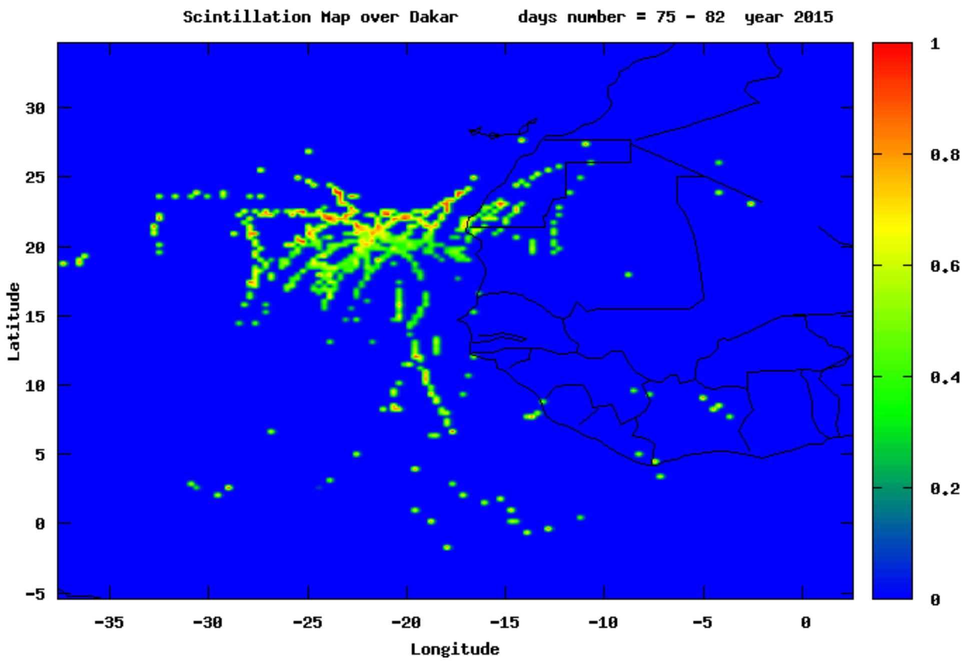
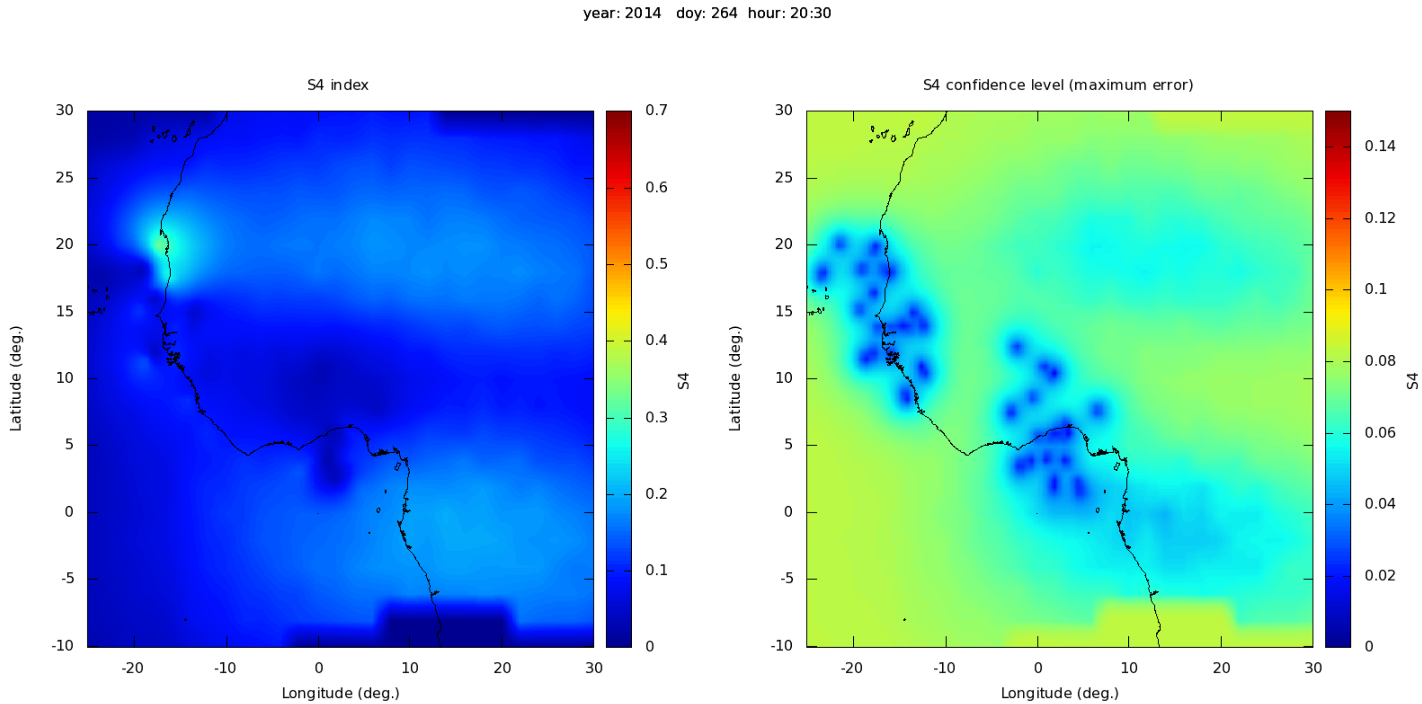
Scintillation Observations for Days 75-82 2015





Scintillation Mapping



Maps updated every 15 mn

Preliminary result with Dakar & Lomé receivers

Kriging technique : GISM scintillation model used as a background

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Summary

- Ionospheric monitoring system: network and processing facility, operating in near-real-time
- Ionospheric Scintillation Network covering low and high latitude stations, many in equatorial Africa, including CNES SAGAIE
- Stations include high-end scintillation receiver, antenna and a bitgrabber that allows to record IF & perform offline analysis
- High added values routine products
- Automatic daily reporting of ionospheric state
- Service to support to SBAS (EGNOS, ASECNA)
- Robust and flexible data policy that allows to serve different data providers / consumers with different requirements

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