gAGE research group of Astronomy and GEomatics

Algunes experiències del grup de recerca gAGE sobre transferència tecnològica a l'àmbit de la navegació per satèl•lit

(or Research group of Astronomy and Geomatics: Research, Innovation and Technology Transfer in Global Navigation Satellite Systems)

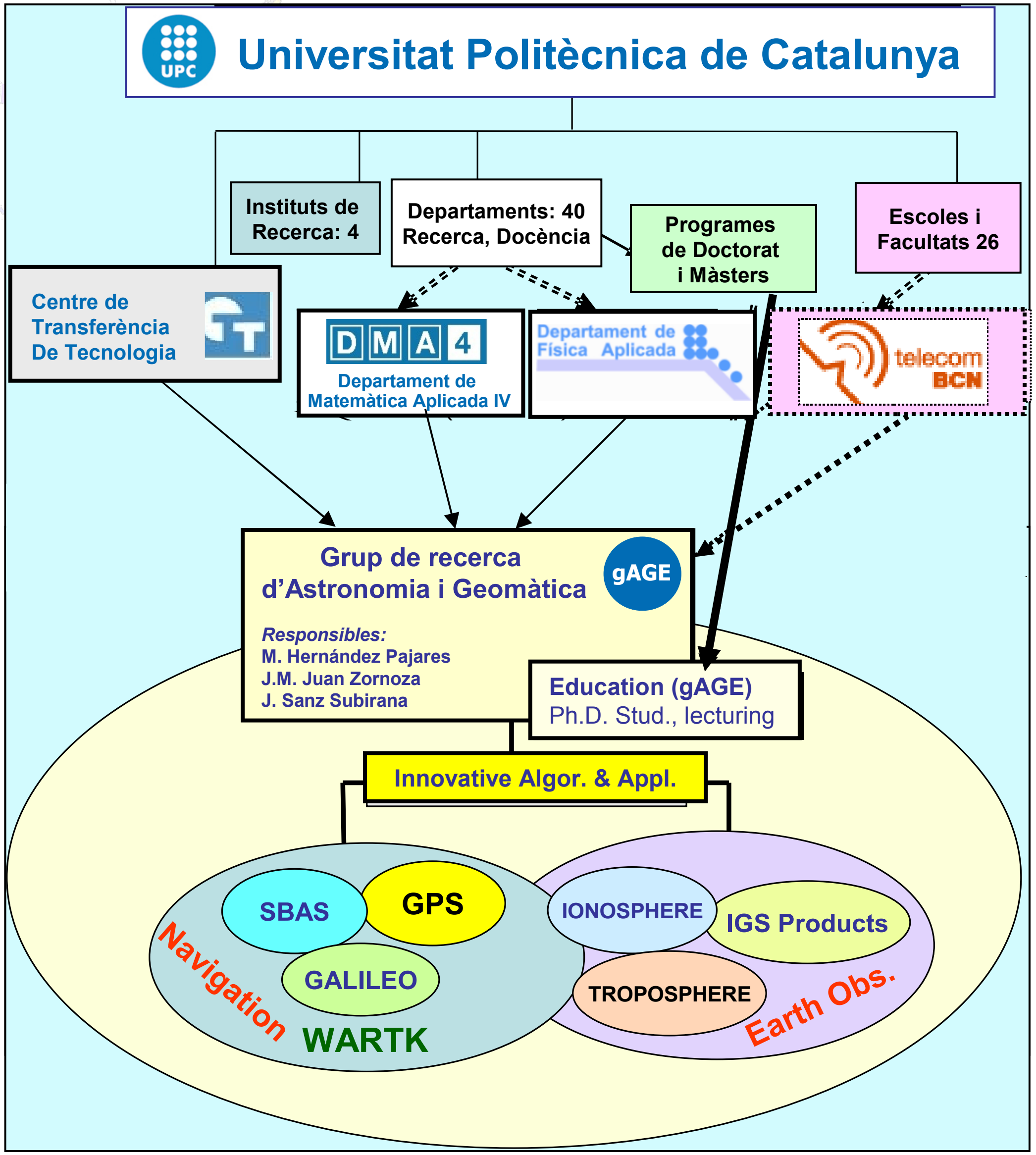
M.Hernández-Pajares, J.M.Juan, J.Sanz

http://www.gage.es

Layout

- gAGE in few slides
- Three selected Scientific topics with Technological transfer
- gAGE funding agencies & partners
- How to deal with increasing opportunities in research and technological transfer in the satellite navigation arena?
- Conclusions

gAGE in few slides (1/3)



The research group of Astronomy and Geomatics focus most part of its activities on innovative algorithms and applications of satellite navigation systems and Earth observation.

Personnel:

Staff (Associate Professors)

- 2 Applied Mathematics IV
- 1 Applied Physics.

Ph.D. Students

- 1 Mathematician + Physisicist (contractor as Researcher and project management support)
- 1 Telecomm.Eng.+Physisicist
- 1 Telecomm.Eng.+ Economist.
- 1 Telecomm.Eng.
- 1 Aeron.Eng. (also visiting professor).

Master Ph.D. Students

gAGE in few slides (2 of 3)

- **Research group of Astronomy and Geomatics (gAGE) is composed by:** Three permanent staff (M.Hernández-Pajares, J.Sanz, J.M.Juan), one lecturer, one research assistant, involving 5 Ph.D. students, at Campus Nord UPC, Barcelona, Spain.

- **Targeted research, development and innovation topics:** New techniques in satellite navigation systems (GNSS, such as GPS, Galileo, GLONASS): Very precise navigation, Space Weather, multipath mitigation on satellites, navigation integrity in GNSS civil aviation (EGNOS, WAAS), weather forecasting, international lecturing on GNSS, among others.

- **Technical transfer and collaboration with Enterprises:** Responsible of more than 30 national and international projects in the field, including the coordination of 6 ESA projects and 1 EC VI-FP/GJU project. Many of these projects have been performed in collaboration with relevant organizations and enterprises in the field: ESTEC/ESA, ESOC/ESA, GSFC/NASA, JPL/NASA, GJU, IfEN, GMV, INDRA, CTAE, FGI, Imperial College, Univ. Torino,...

gAGE in few slides (3 of 3)

- **Research:** More than 40 papers corresponding to journals with JCR impact index (67% in the first two factor impact quartiles, from them 42% in the first quartile). Four “Best Paper awards” by USA Institute of Navigation (in 1999, 2004 and 2006). Invitation to participate in several main international commissions of experts and invitation to chair the more relevant international meetings in the field, associate editor in IEEE TGARS. Chairmanship of the Service of Ionospheric Corrections for GNSS, within the International GNSS Service (IGS, coordinating to ESA, JPL and Univ. Bern).
- **Patents:** New precise navigation concept (WARTK) which is being supported by the Galileo Joint Undertaking and the European Space Agency: in terms of one VI-FP/GJU European granted project and several ESA funded activities, ITT, and international patent (among three additional patents of different aspects of satellite based navigation).
- **Lecturing activity:** Creation of, probably, the first lectures in GPS and GNSS at UPC, in both Ph.D. and degree levels (performed since 1994 and 1996 respectively). Invitation to participate in International GPS and Galileo courses in USA, Asia and Europe.

Three selected Scientific topics with Technological transfer

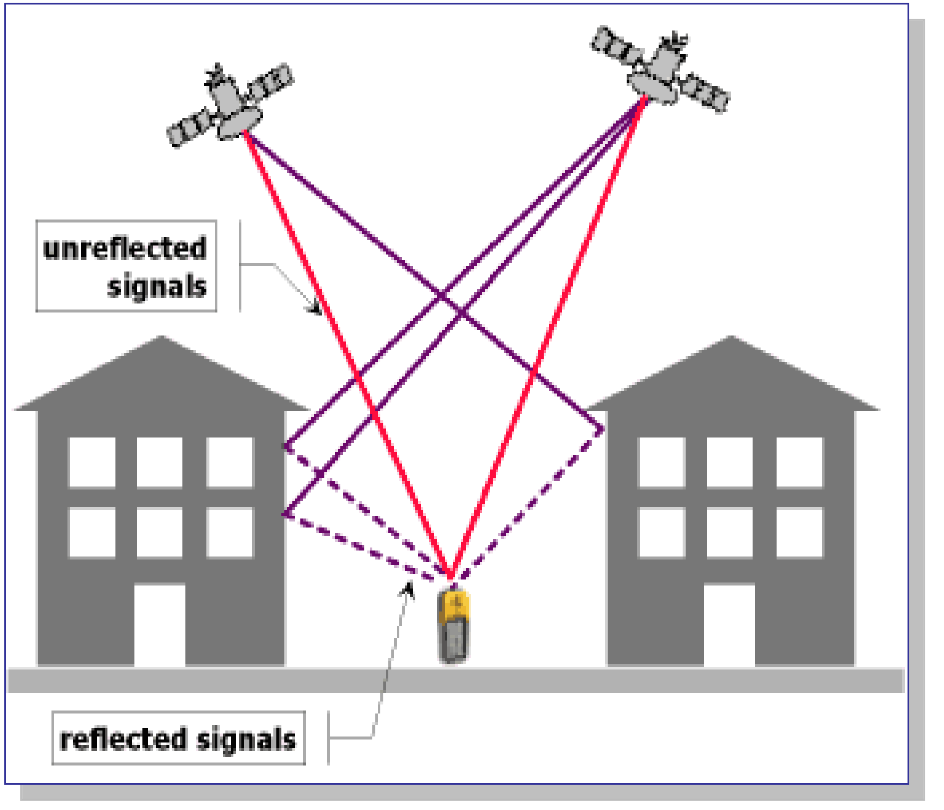
1) GPS multipath computation for LEO GPS satellite environment.
2) New algorithms and tools for GNSS integrity monitoring in civil aviation.
3) New technique allowing decimeter-error-level GNSS navigation at continental scales (WARTK).

1) GPS multipath computation for LEO GPS satellite environment.

gAGE research group of Astronomy and GEomatics

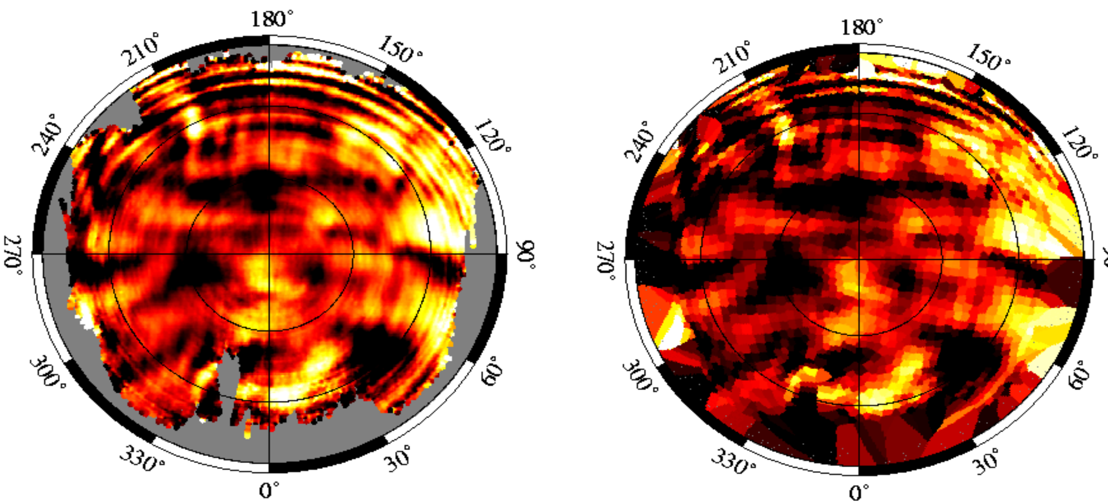
Multipath

- The multipath is a GNSS source error associated to the indirect reflected signal. Then they are highly dependent on the receiver environment.
- It can reach typically to several meters for typical pseudorange receivers.

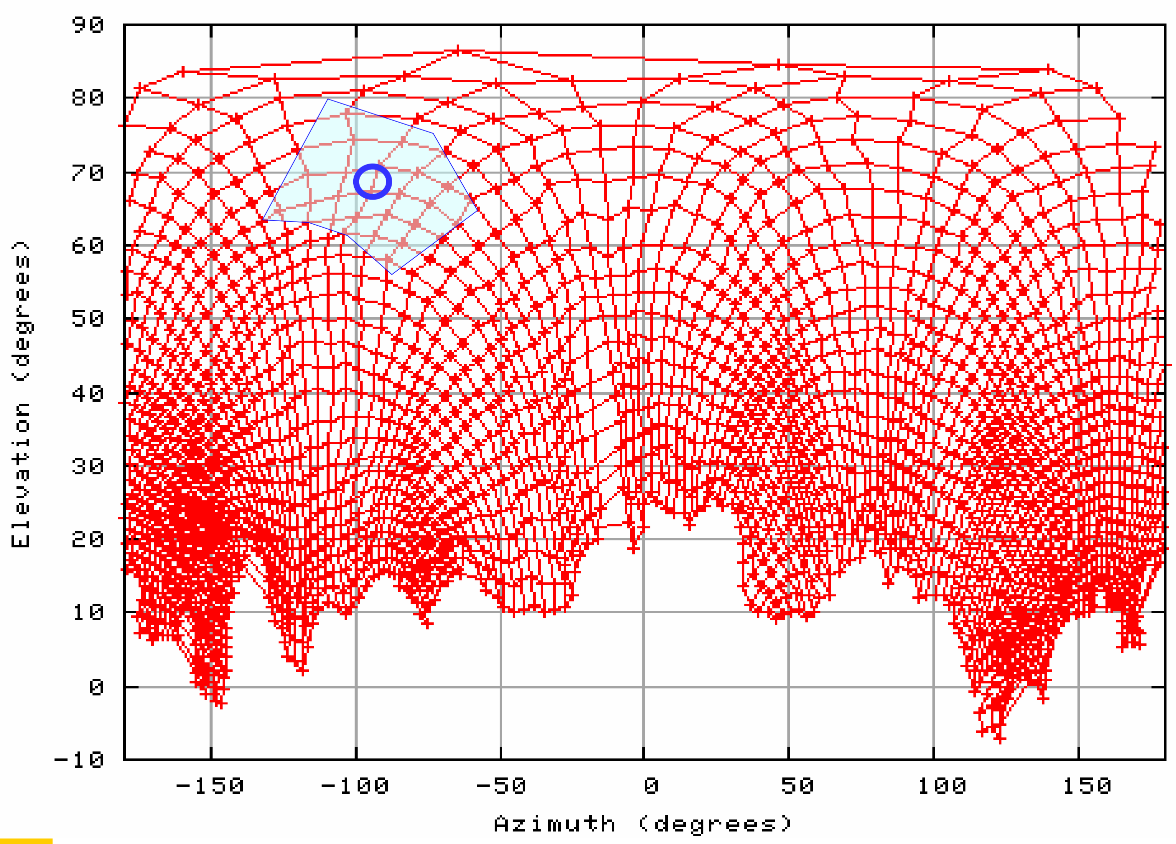


GPS Multipath Mitigation in LEO scenarios (ESA, 1998-1999,2005-06)

We contributed to these two ESA funded projects providing neural network algorithms specially designed to mitigate the Low Earth Orbiter GPS receiver multipath, at the observable level, demanding an small LEO satellite CPU computational load.

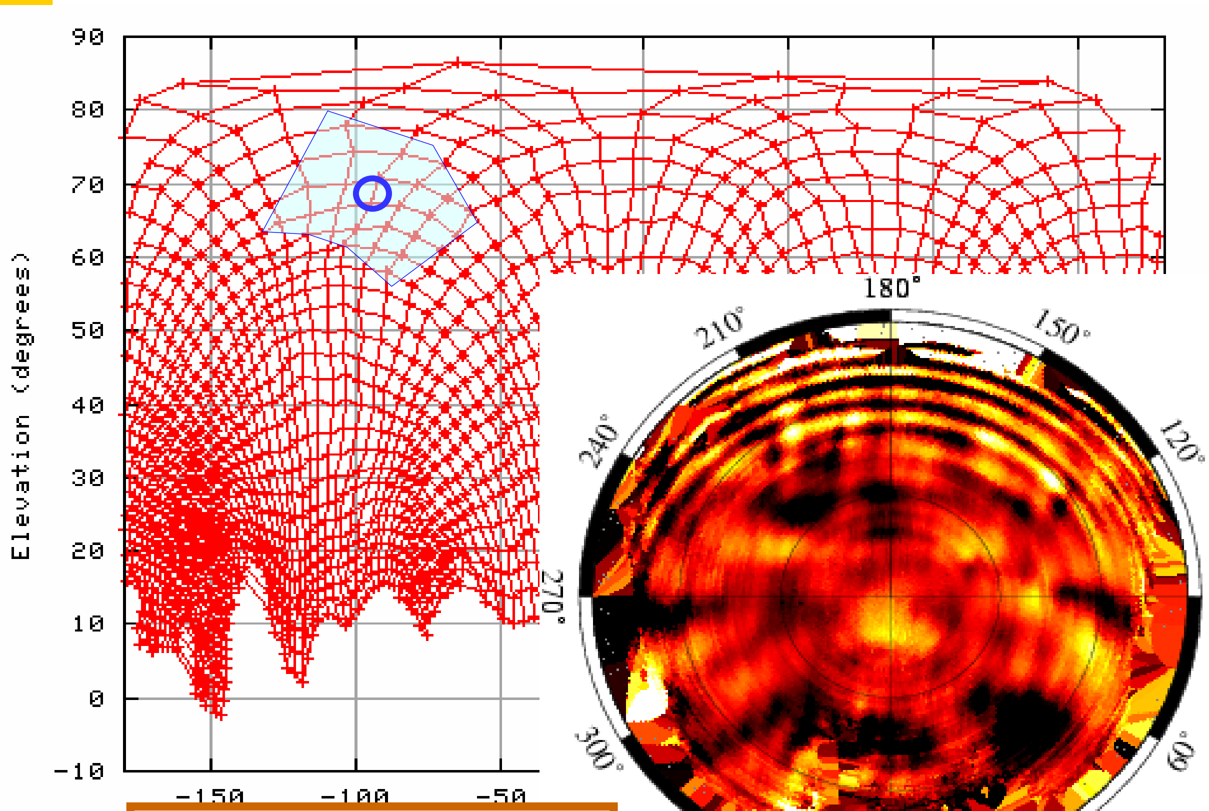


Multipath mitigation– A Self-Organizing Kohonen Neural Network (SOM) is trained taking into account the detected multipath gradients from the LEO satellite.



- The neighbourhood topological relationship is maintained at the same time the clustering is done with more resolution where more multipath gradient has been detected.
- In the figure the neighbourhood relationship is shown, being this point very important to ensure a fast usage of this maps onboard the LEO satellite.

Multipath mitigation– A Self-Organizing Kohonen Neural Network (SOM) is trained taking into account the detected multipath gradients from the LEO satellite.



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topol
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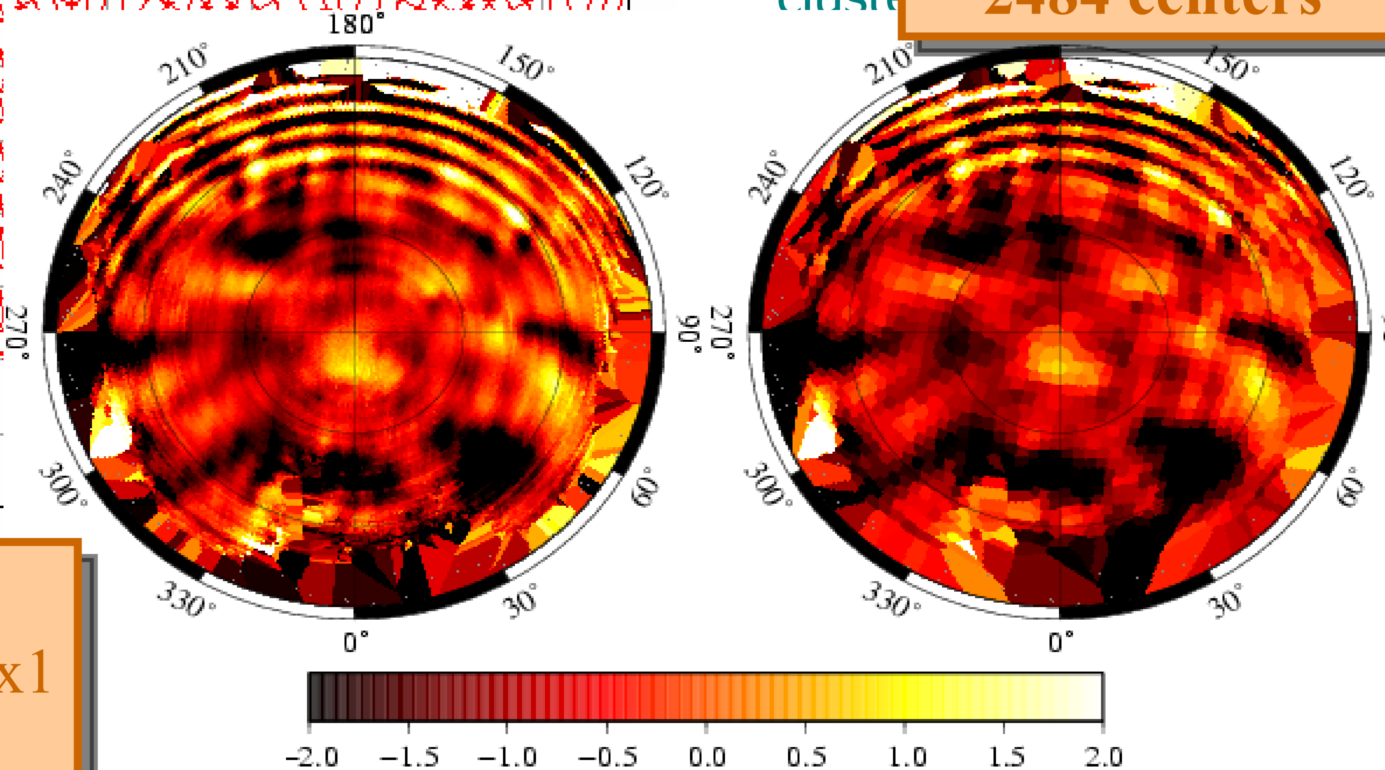
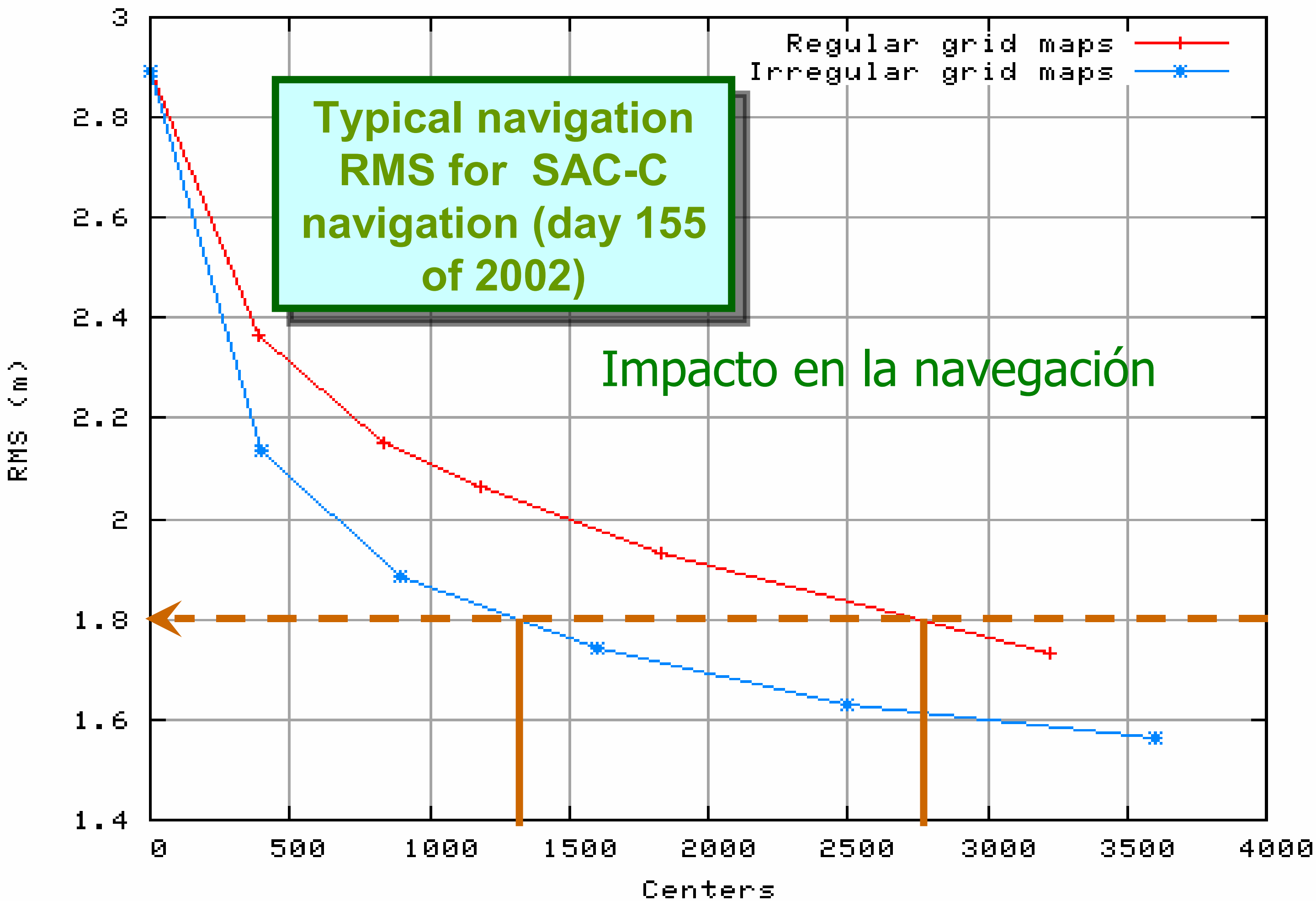
SOM multipath sky map: **2484 centers**



Multipath regular map (1x1 deg): **26347 centers**

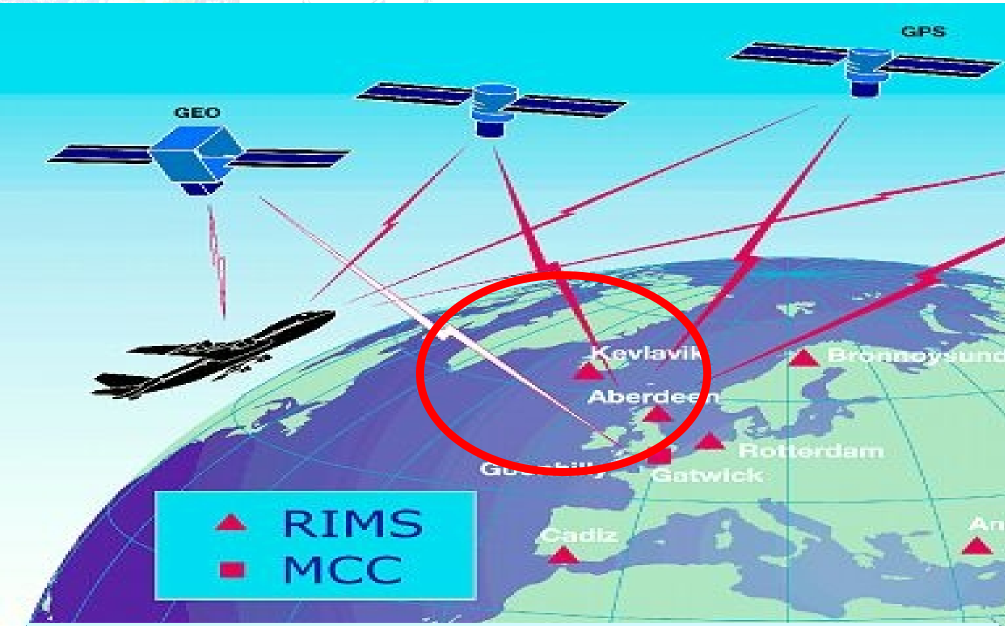
Multipath mitigation: improvement in navigation in terms of accuracy and/or LEO satellite CPU resources

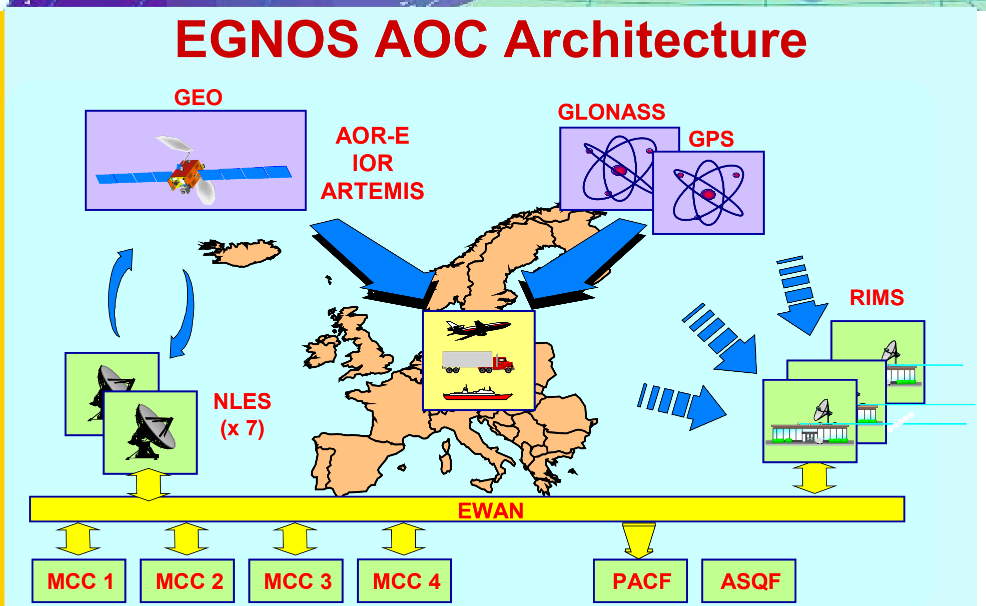


- The same GPS navigation performance is used with the usage of a SOM multipath map requiring the half part of the centers than a regular multipath map.
- A reduction of 30-50% of LEO satellite positioning error is achieved thanks to the multipath correction in real-time mode.

2) New algorithms and tools for GNSS integrity monitoring in civil aviation.

EGNOS: GNSS for Civil Aviation





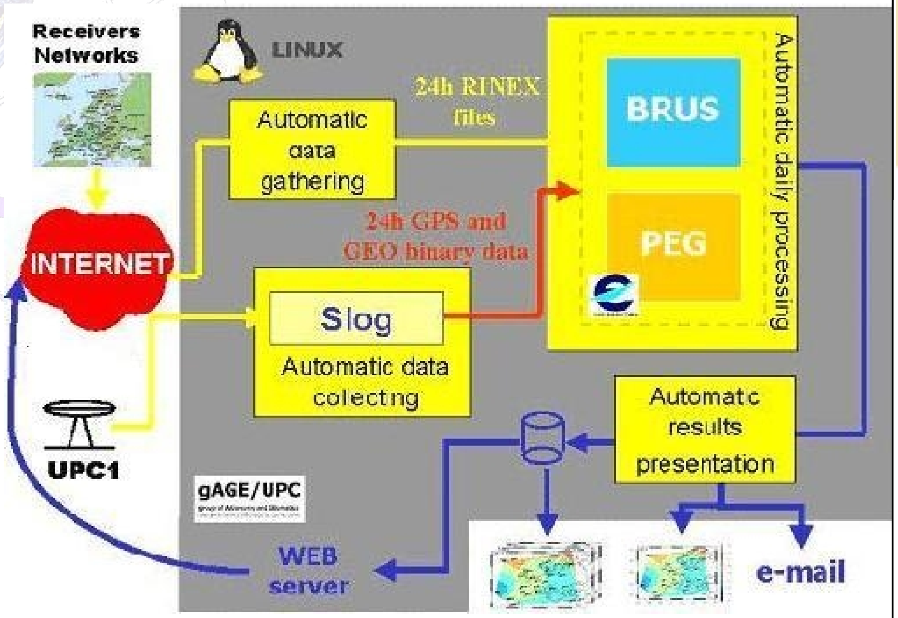
✓GPS is being used for the optimization of airplane routes, becoming a central navigation instrument.

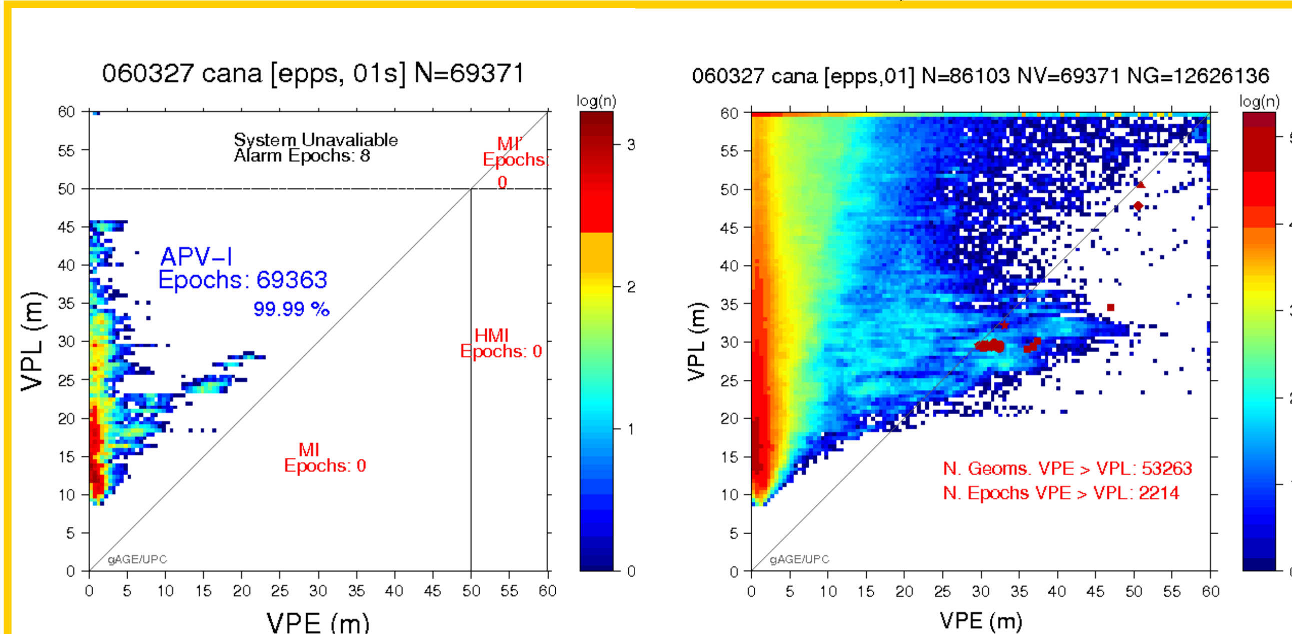
✓To do that is very important not just the *accuracy*, but also the *availability*, *continuity* and specially the *integrity* of the system (this means that the error estimate should not be “never” optimistic –i.e. with a probability less than 10^{-7} in vertical and 10^{-9} in horizontal coordinates for a given approach maneuver-)

✓To allow that, a network of monitoring stations must be used with very robust algorithms to provide corrections to the users: EGNOS system in Europe.

GMS: EGNOS/WAAS monitoring tool developed by gAGE for EUROCONTROL

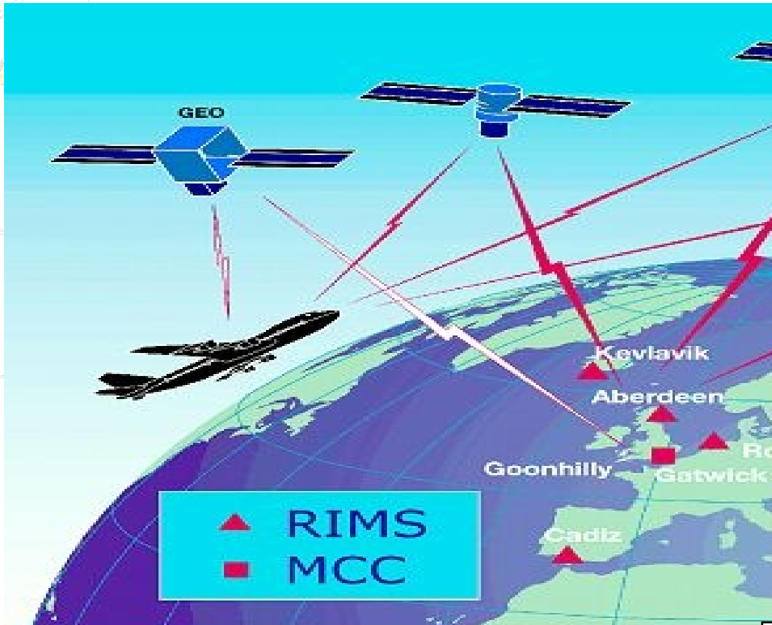
gAGE research group of Astronomy and GEomatics



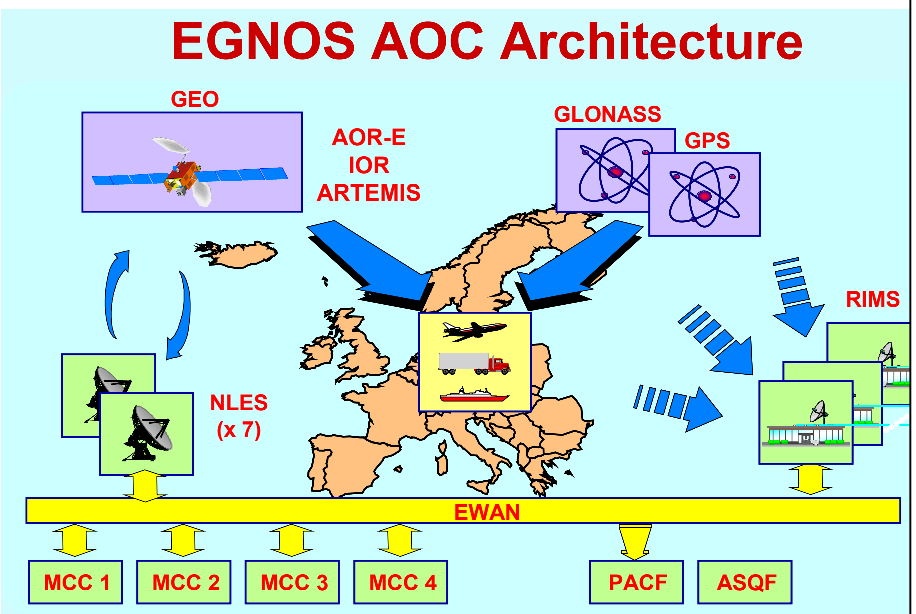


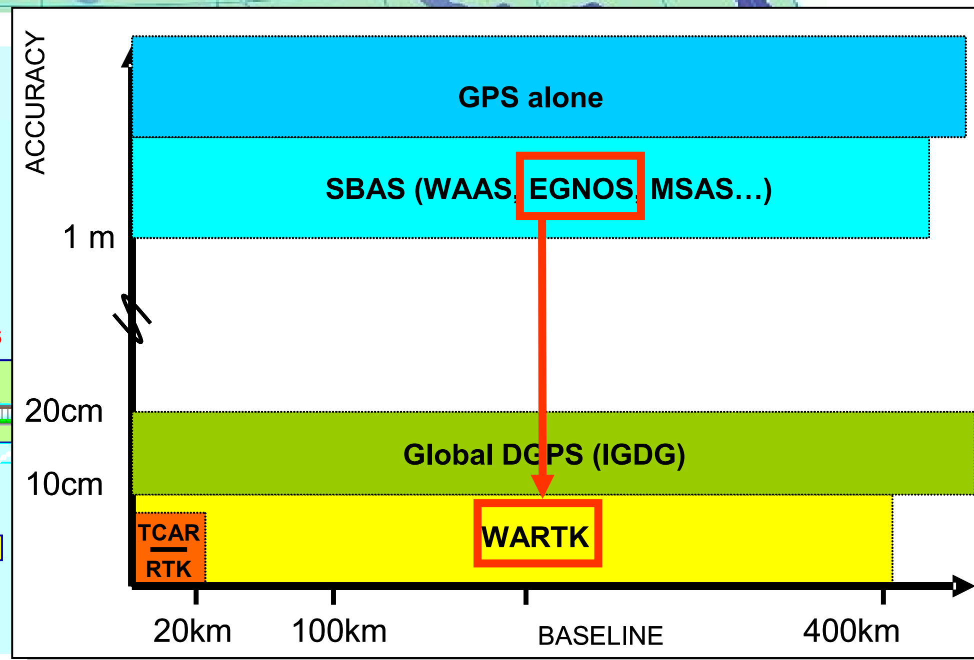
The Stanford-ESA integrity plot has been recently adopted by the GNSS Supervisory Authority (GSA) as a main tool to validate EGNOS (European augmentation system for civil aviation)

From EGNOS to WARTK



- ✓Reusing the existing EGNOS infrastructure, and thanks to a new and accurate ionospheric-geodetic GNSS modeling (WARTK technique), allows a centimeter-error-level-navigation over Europe (100 times more precise than EGNOS).
- ✓This means a double use of investments already done by the European Union.

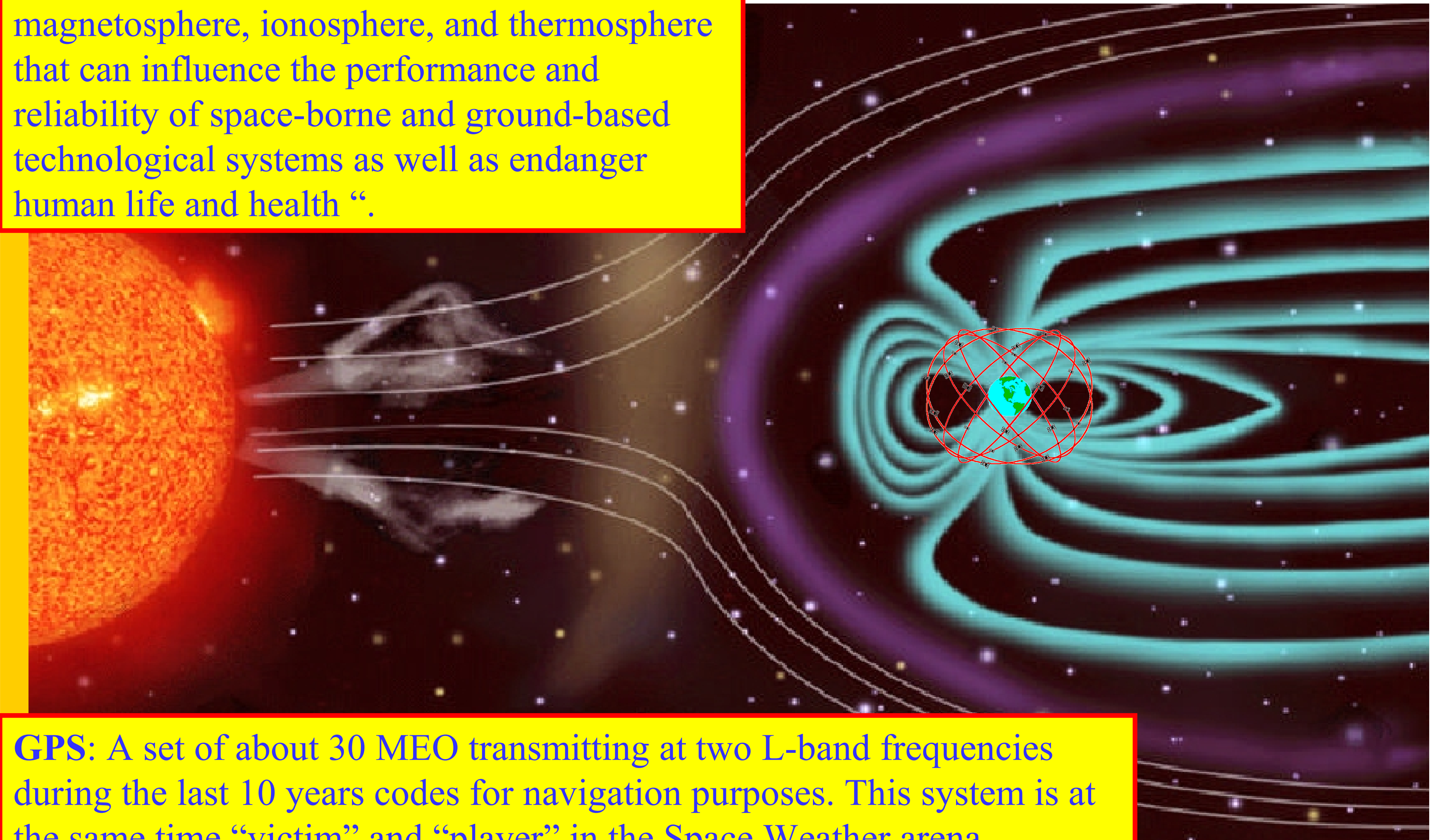




3) New technique allowing decimeter-error-level GNSS navigation at continental scales (WARTK).

Introduction

The Space Weather can be defined as "Conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems as well as endanger human life and health ".



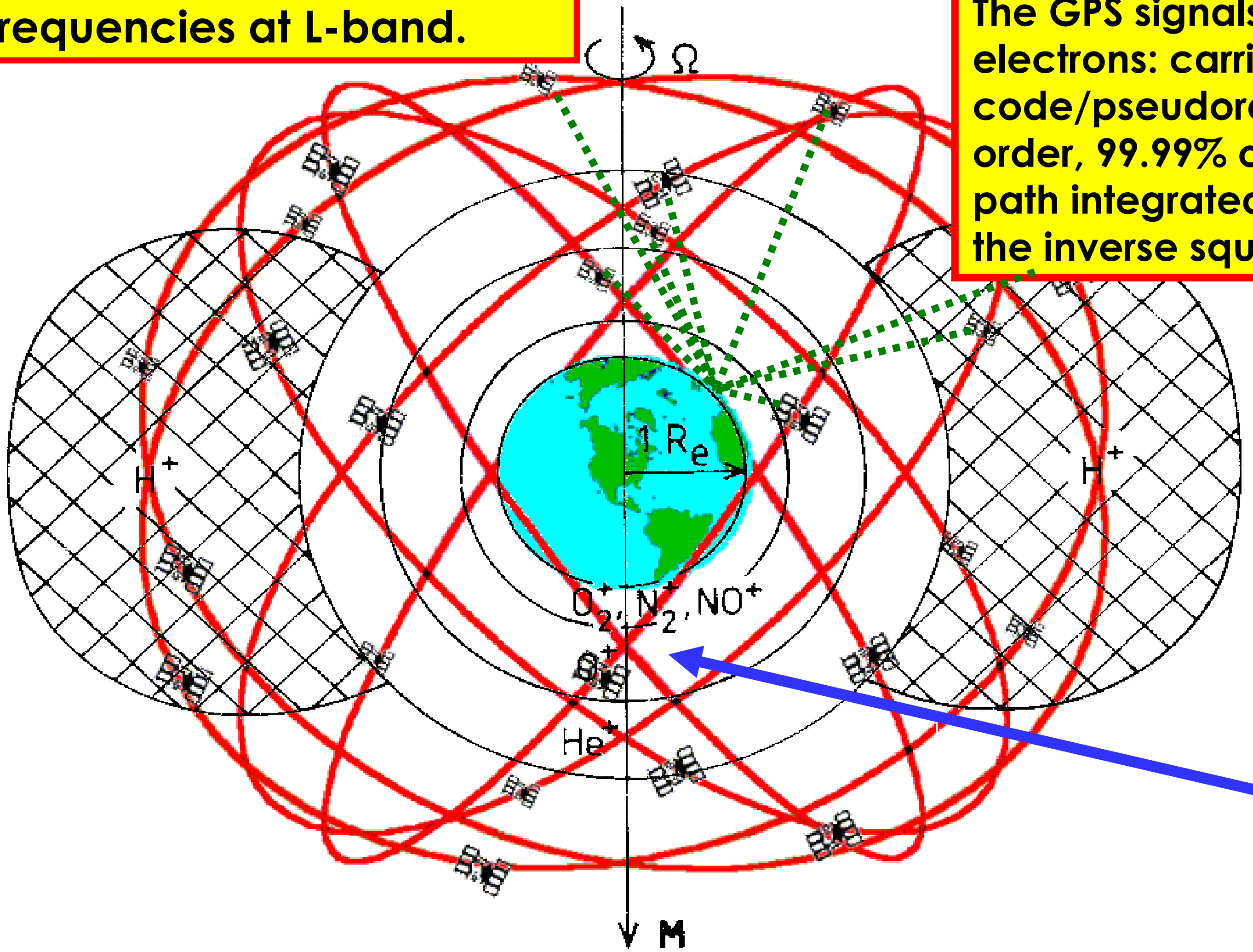
GPS: A set of about 30 MEO transmitting at two L-band frequencies during the last 10 years codes for navigation purposes. This system is at the same time "victim" and "player" in the Space Weather arena, specially affected by the ionospheric conditions.

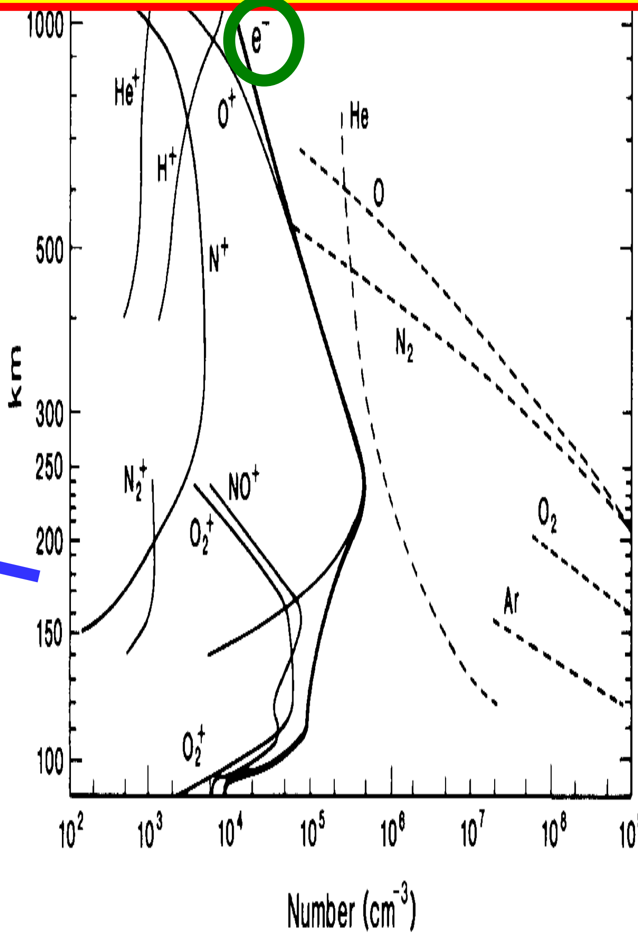
Sanz

GPS and the Ionosphere

Global Positioning System (GPS): near 30 MEOs transmitting in two frequencies at L-band.

The GPS signals are affected by the free electrons: carrier phase advance and code/pseudorange delays, proportional (1st order, 99.99% of the total delay) to the ray-path integrated electron density (STEC) and to the inverse squared freq.

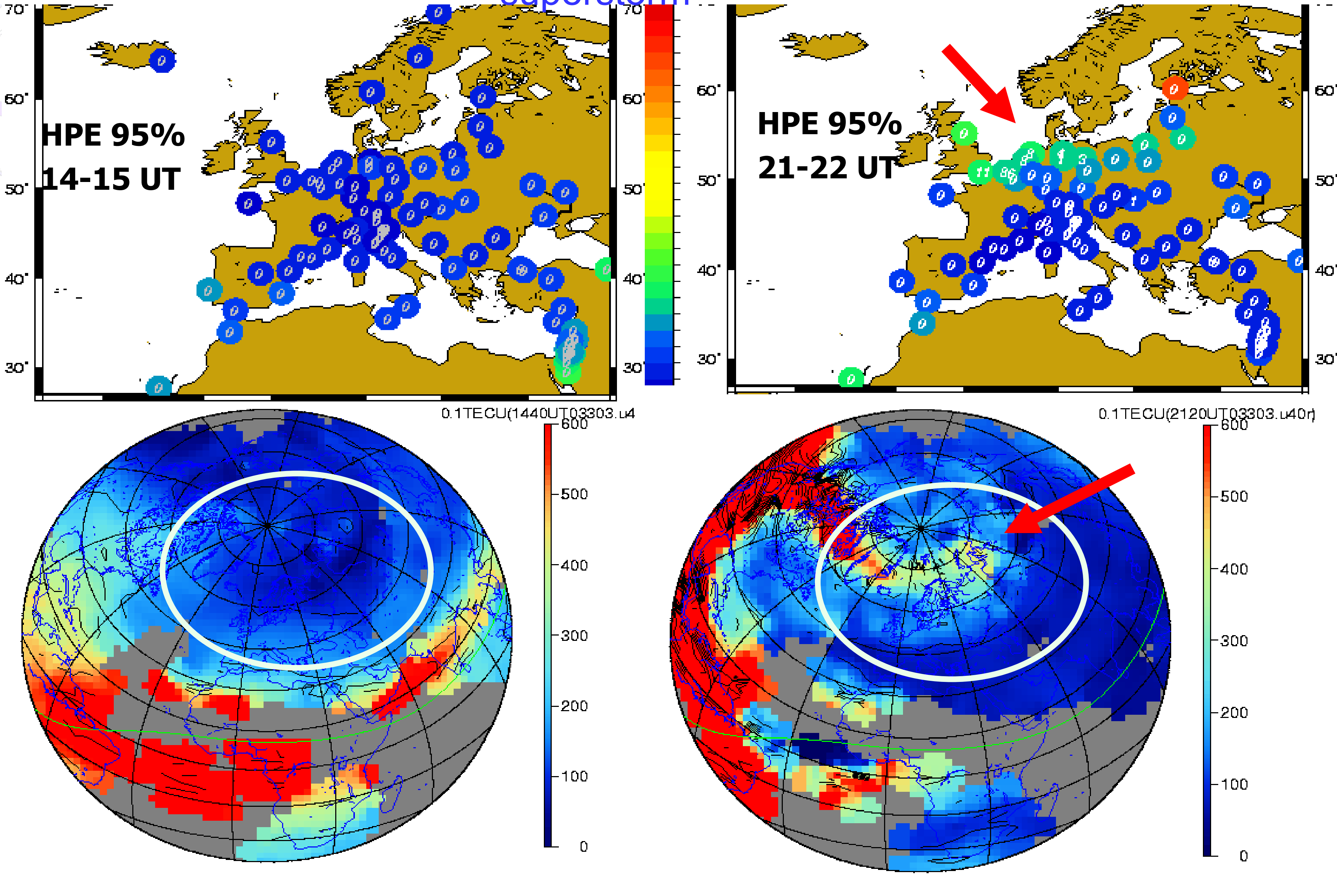




The UV (and X) Solar radiation ionizes the region above 50-100 km: Ionosphere (to 1000 km) and Protonosphere/Plasmasphere (above 1000 km).

Example of Space Weather effect on GPS: single-frequency navigation based on broadcasted iono corrections (EGNOS Test Bed) during the October 30 2003 superstorm

October 30th

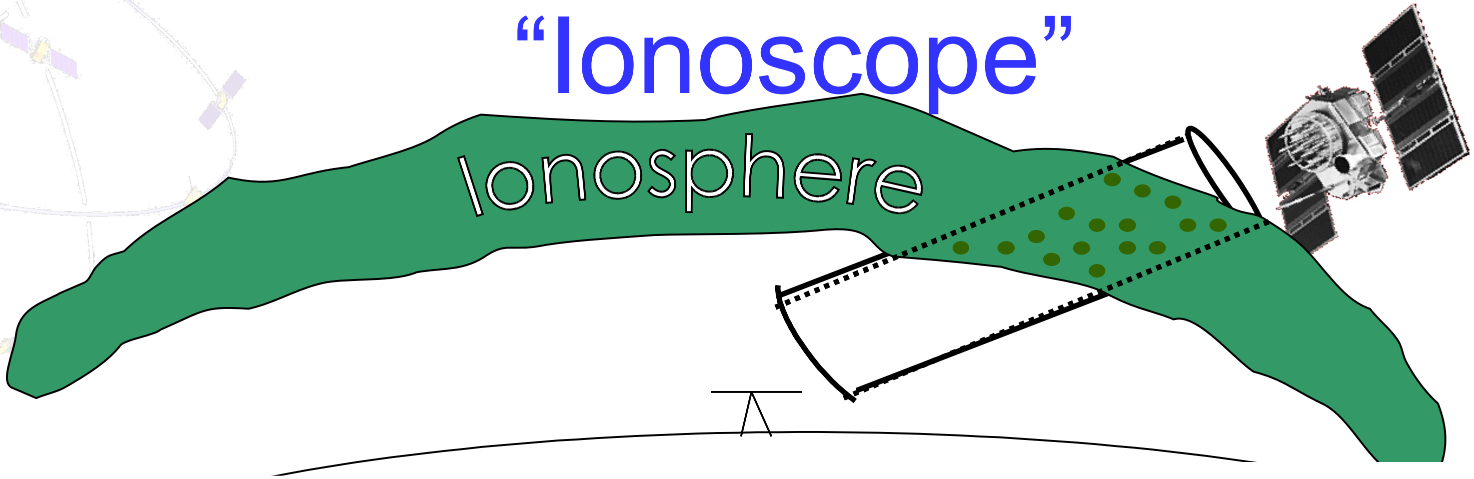


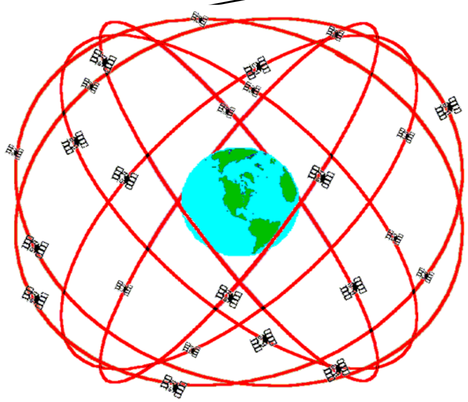
gAGE research

GPS+ IGS: Global Iono. scanner "Ionoscope"

gAGE UPC

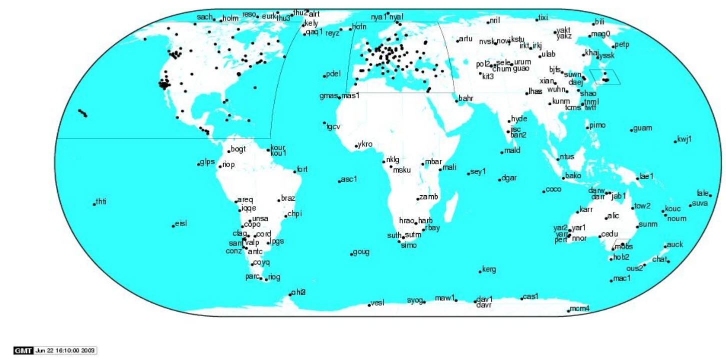
group of **A**stronomy and **GE**omatics





GPS+ IGS

Sat. **Rec.**

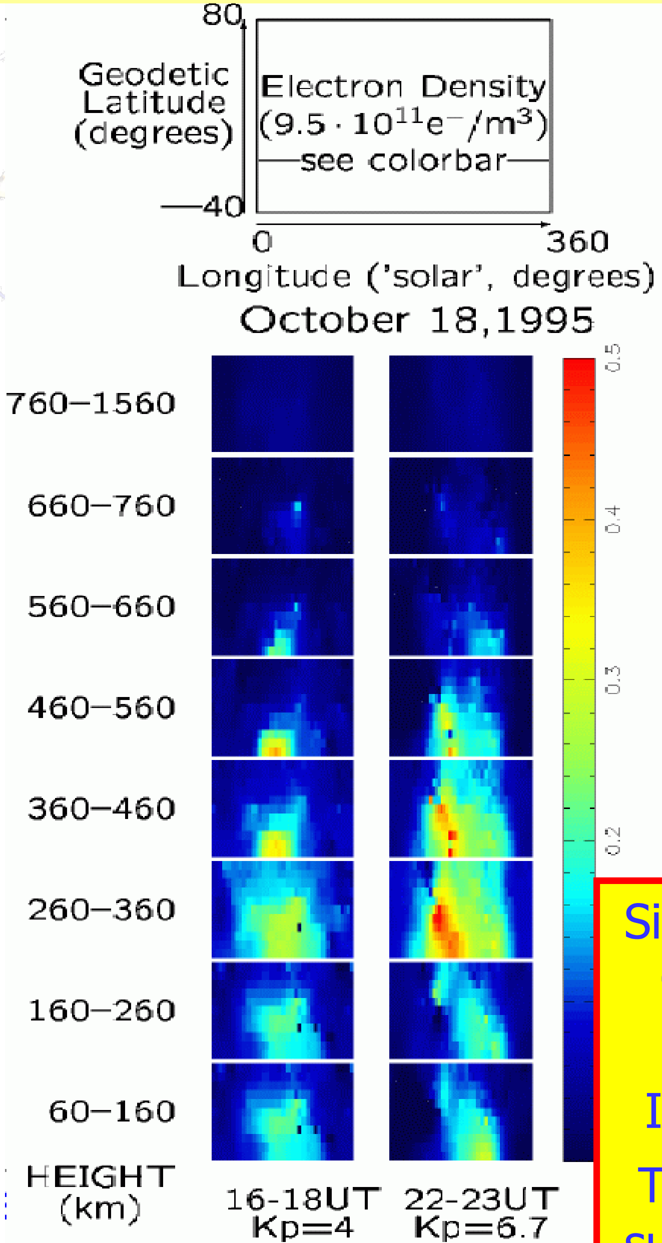


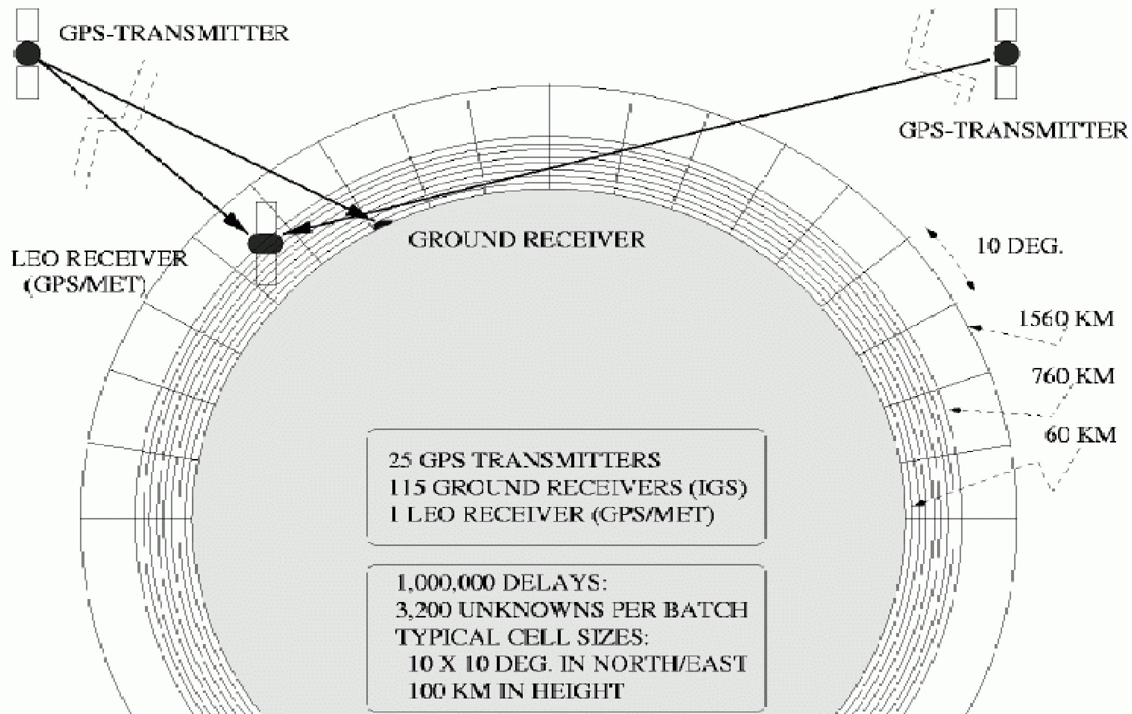
Worldwide *scanner* of the Ionosphere that can be used to monitor the Space Weather signatures on VTEC, such as Storm Enhanced Densities (SED), X-Flares, Scintillation, Large Scale TIDs.

Low orbiting GPS receivers (CHAMP, SAC-C…) are also available adding 3D estimation capability (electron density) with great vertical resolution.

GPS Tomography of the Ionosphere: New glasses for Science & Technique

gAGE developed at the mid of the 90s specific tomographic algorithms for ionospheric sounding capable of being used in real-time with unprecedented accuracy (gAGE/UPC patent 1999)





Since 1998 UPC is providing global Ionospheric maps for GNSS users in the International GNSS Service (IGS).

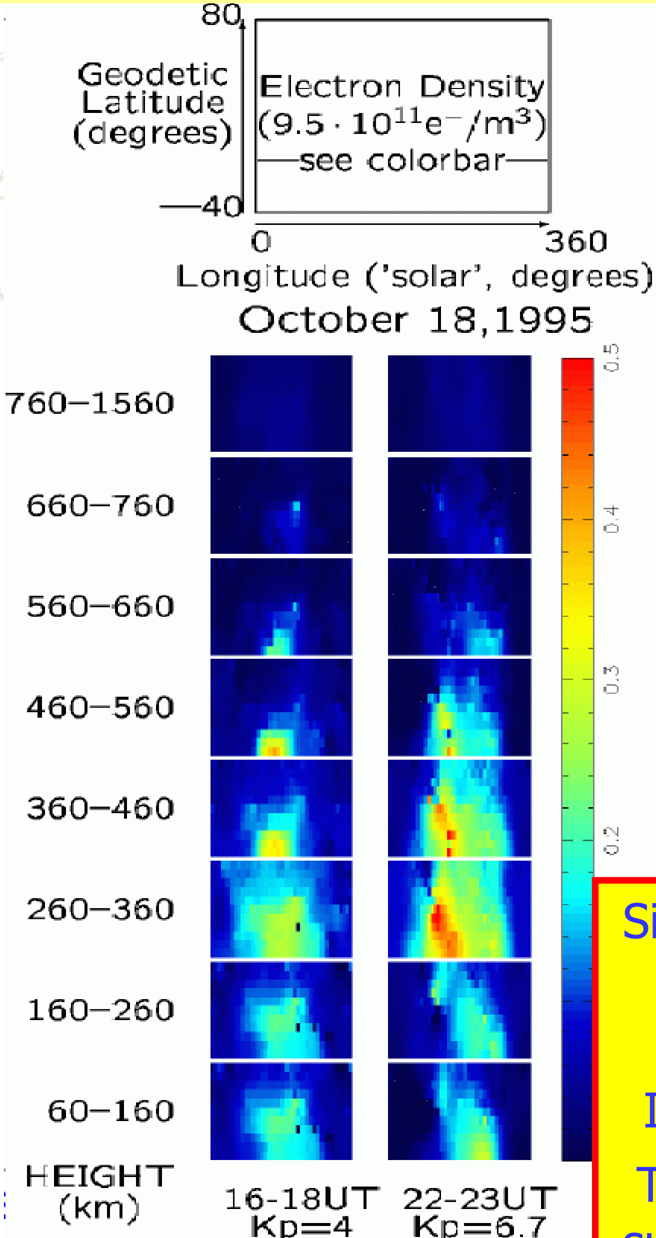
Since 2002 to 2007 UPC has coordinated IGS Ionospheric activities from JPL, ESA and Univ. of Bern.

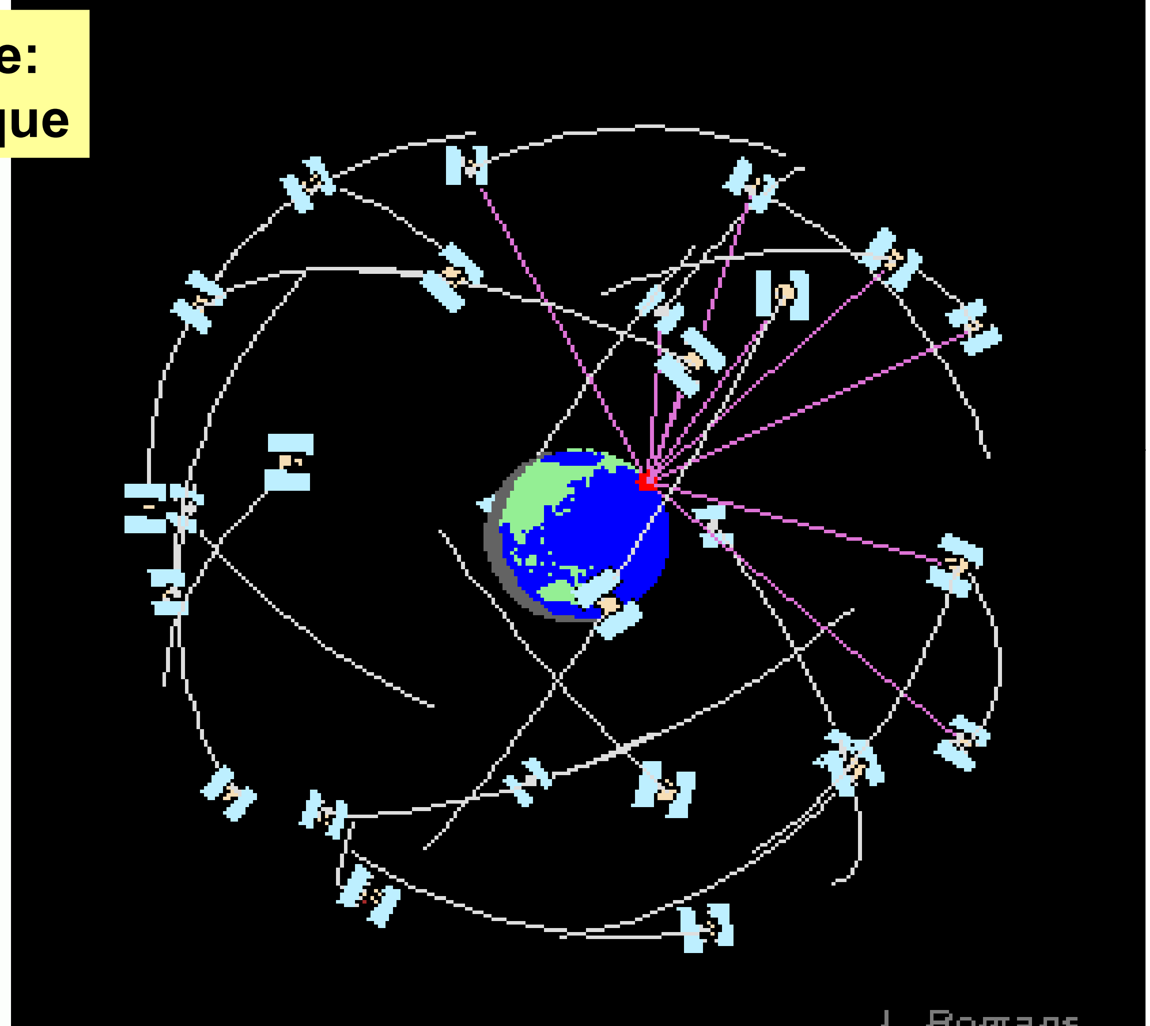
This technique is one cornerstone of WARTK, providing subdecimeter-error-level navigation at continental scales

gAGE

gAGE research group of Astronomy and GEomatics

GPS Tomography of the Ionosphere: New glasses for Science & Technique





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This iono. *scanner* is a WARTK's cornerstone, providing subdecimeter-error-level navigation at continental scales

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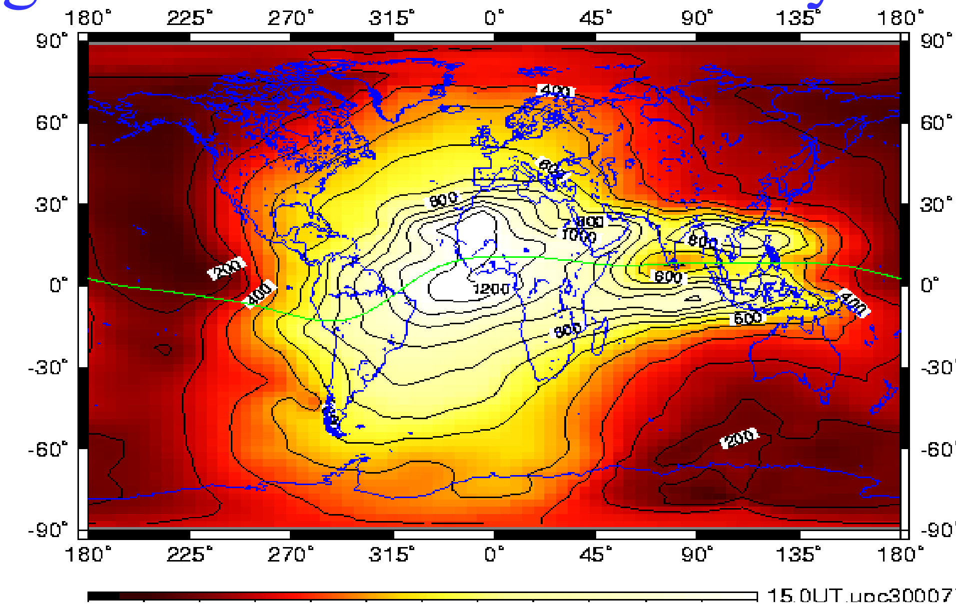
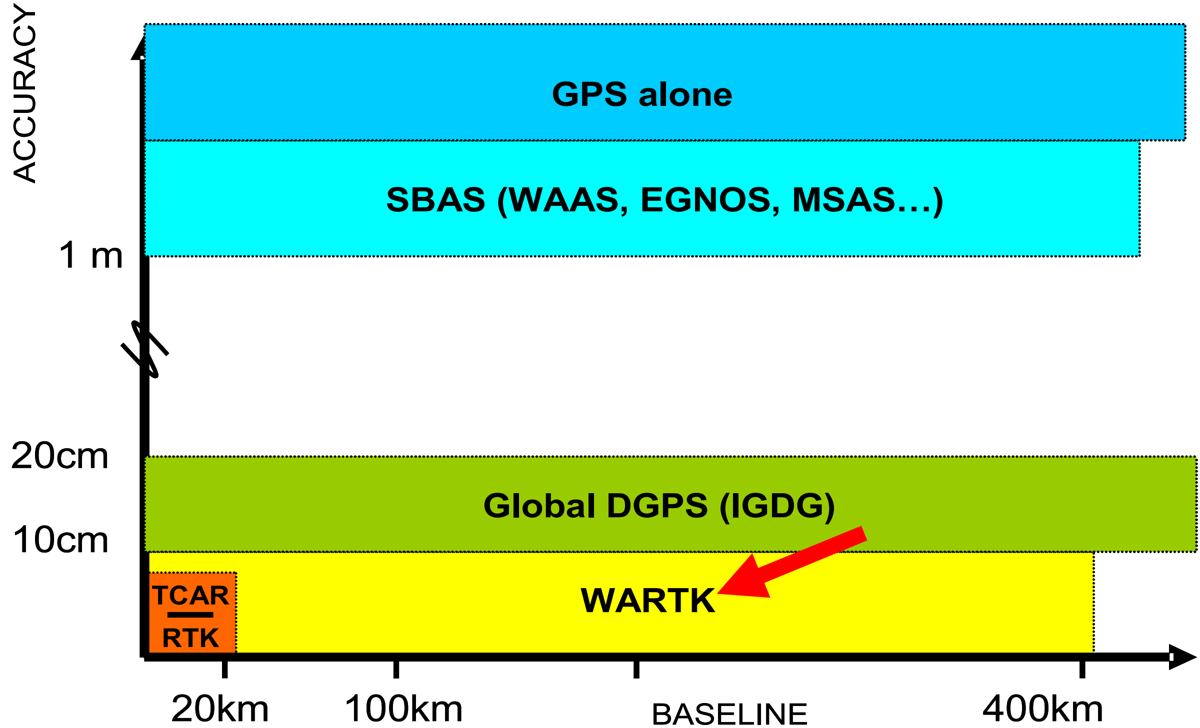
WARTK: subdecimeter-error navigation at hundreds km away

- The differential ionospheric refraction typically limits the real-time ambiguity fixing (and the corresponding navigation with sub-decimeter errors) to baselines of few tens of km in different approaches in both two and three-frequency systems (RTK, LAMBDA, TCAR, CIR, ITCAR, FMCAR).
- Wide Area RTK (WARTK) overcomes this problem incorporating an accurate real-time ionospheric model: (1) in two-frequency systems (GPS: WARTK), and (2) in three-frequency systems (Galileo and Modernized GPS: WARTK-3, which allows the extension of Local High Precision services to continental scales, adding *instantaneity*).
- Both approaches (WARTK and WARTK-3) were presented in previous papers and demonstrated in many experiments but is in WARTK-EGAL project when an specific feasibility study based on EGNOS RIMS is being performed.

UPC Global Ionospheric Map: 077 2000, 15UT

Units: tenths of TECU



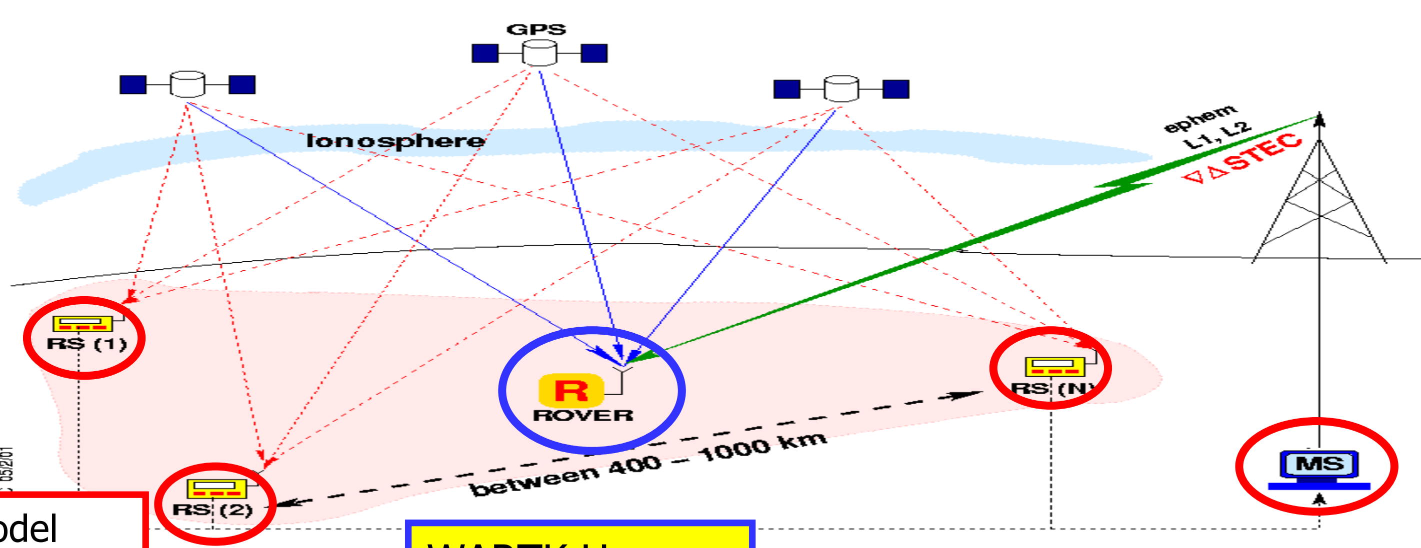


WARTK layout

Feasibility study of a Wide Area High-precision Navigation Service for EGNOS and Galileo (FES-WARTK)

gAGE UPC

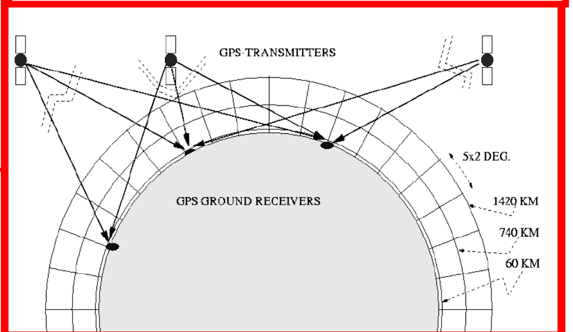
Long–Baseline (hundreds Km) OTF Ambiguity Resolution



WARTK Central Processing Facility

WARTK User

Real-time **Iono.** model

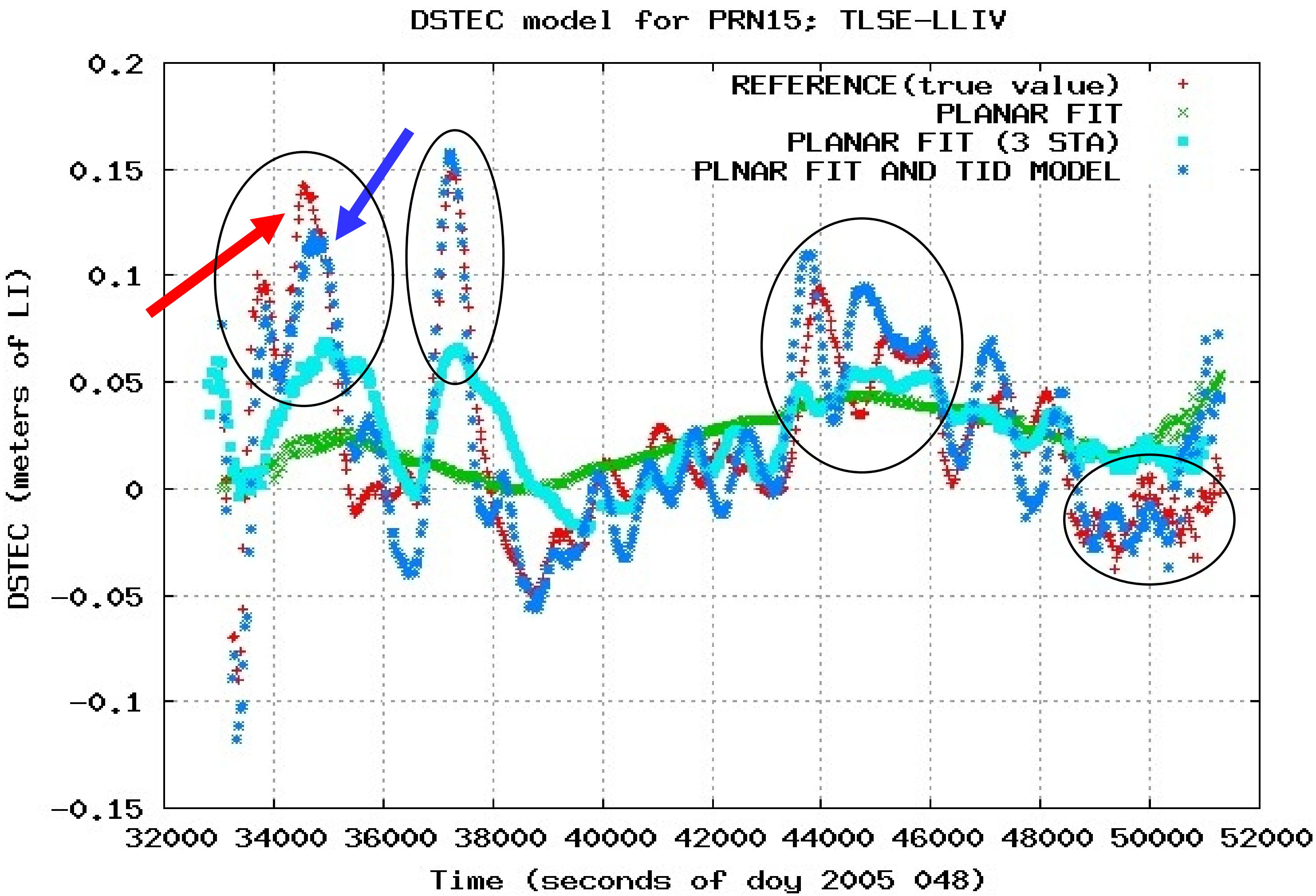


$$L_I = STEC + B_I = \int_{REC}^{SAT} N_e dl + B_I = \sum_i \sum_j \sum_k (N_e)_{i,j,k} \Delta s_{i,j,k} + B_I$$

Real-time **geodetic** model

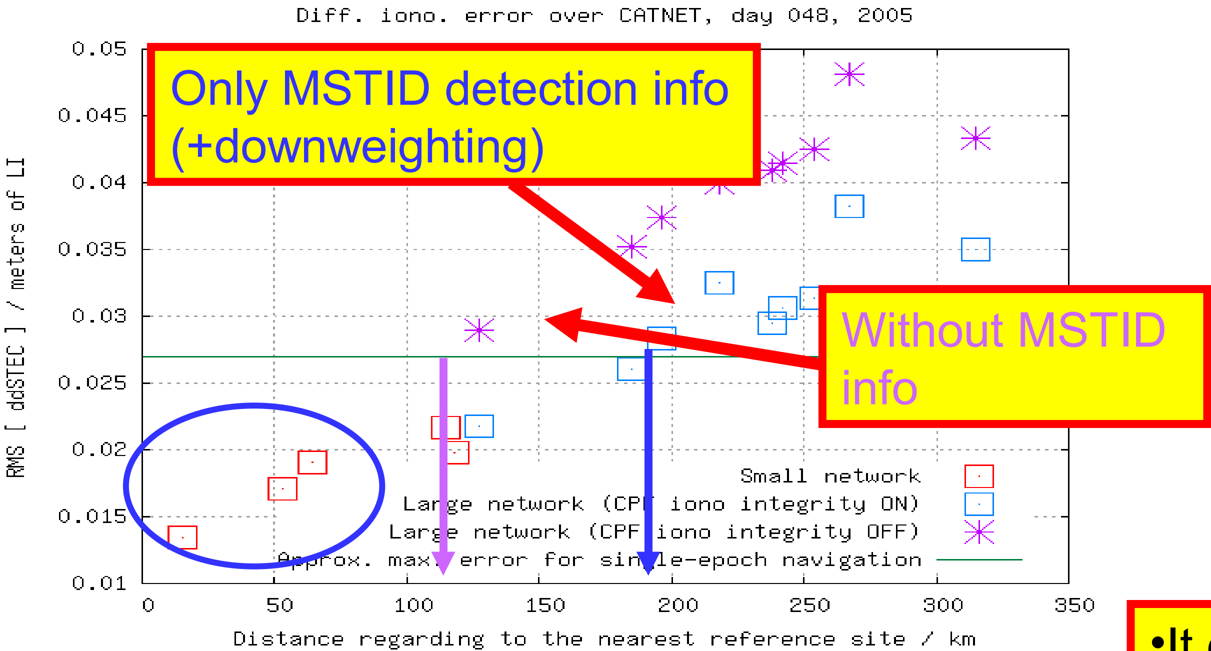
- In WARTK the usual dependence of differential ionospheric refraction can be predicted with errors of few tenths of TECU, also in difficult scenarios (low latitude, Solar cycle maximum and distances of many hundreds of kilometres) thanks to the real-time tomographic modelling.
- But “shorter scale” ionospheric perturbations (MSTIDs) –from tenths to few TECUs- can affect to GNSS precise positioning: they have been studied and modelled as well by gAGE/UPC.

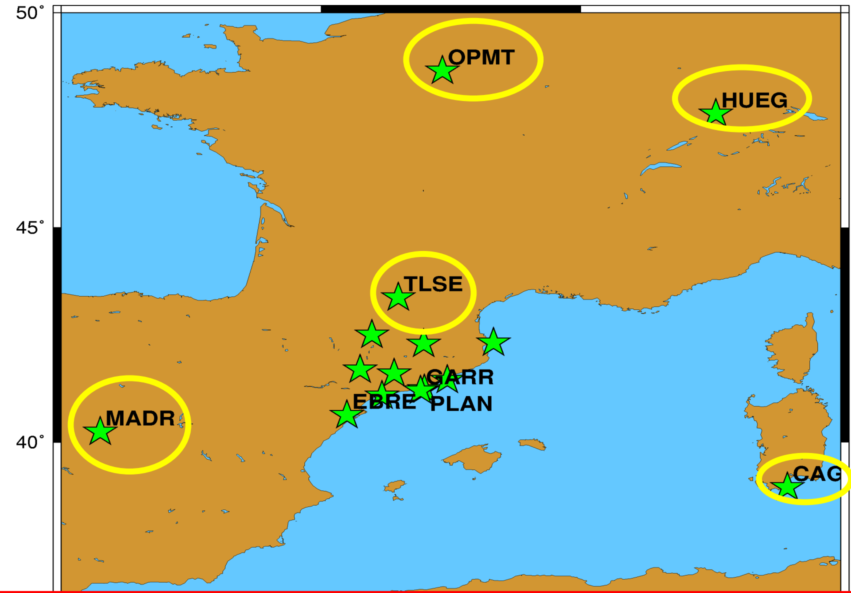
Example of DMTID performance

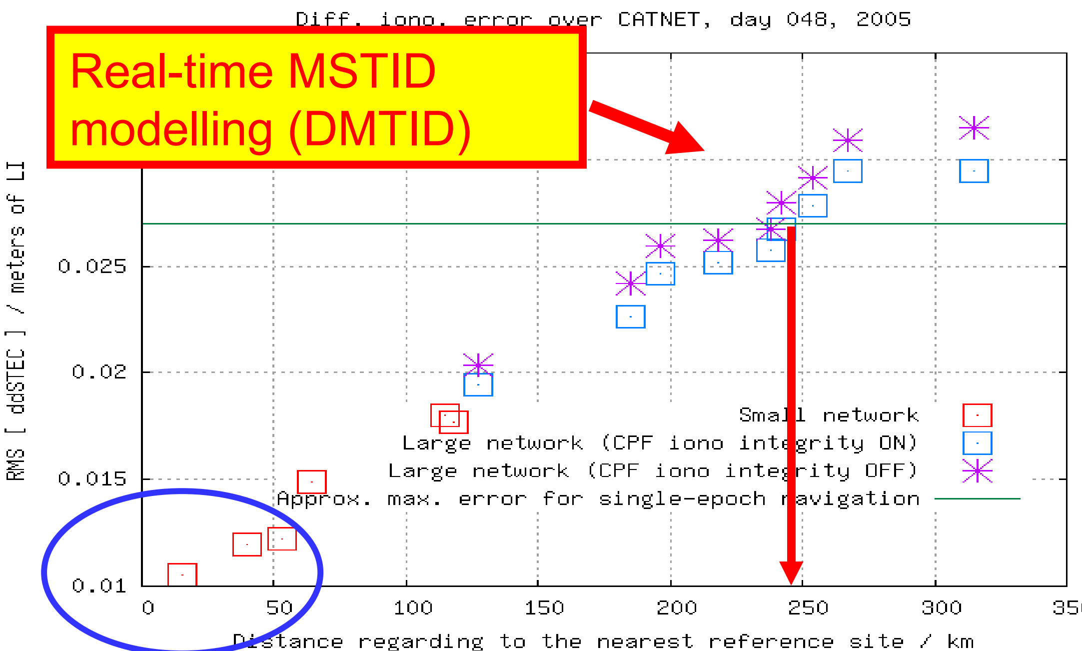


The comparison of linear interpolated single-difference STEC, taking into account the **DMTID predicted delay on the user pierce points –dark blue points-, are more similar to the actual ones –red points-**, than using only linear interpolation procedures without the DMTID delay -in light blue and green- (rover: LLIV, ref.site: TLSE, satellites: PRN 22, 15, 18 &19 respectively, during day 48, 2005 –winter conditions-).

Precise navigation Service area improvement







- It can be seen the daily performance vs. the baseline length by using:
  (1) Without any MSTID info ("classical" approach, ~115 km max.),
  (2) Only the MSTID detection info (downweighting, ~185 km max.)
  (3) the DMTID real-time MSTID model (~250 km max.).
- The DMTID **service area is doubled**
- **Also improvement at RTK scales.**

Hernández-Pajares, Juan and Sanz

Several future applications of WARTK

2 BEST PAPER awards ION, USA

Vision for the Future

[Patents: WARTK gAGE-UPC 1999, 2004, 2006, WARTK3 gAGE-ESA, 2002]

Applications: Centimeter error-level navigation over Europe and other regions: Extending the present RTK commercial applications to continental scales (**civil engineering**, **precise farming, transportation systems**…), and open new applications, such as **Instantaneous GPS Meteorology**, **contribution to Tsunami detection**, **real-time mapping**, **Cadastre**, **single GNSS antenna orientation**, among others.

gAGE funding agencies & partners

gAGE funding agencies/ partners in last years

gAGE research group of Astronomy and GEomatics

gAGE
Industry (ESA, Eurocontrol,…)

Other enterprises in Consortia
leaded by gAGE

gAGE

European GNSS Supervisory Authority

Contact : GSA-info@ec.europa

About this site

About the GSA

- Background
- Mission
- Vision
- Tasks
- Strategic Objectives
- Organisation
- Governance
- GSA Graphic Identity

Galileo

EGNOS

R & D

- FP6 2nd Call
- FP6 3rd Call

Press

- Press releases
- Contact

Careers

Call for tenders

- Financial Form
- Legal entity Form

R & D Projects

http://ec.europa.eu/transport/gsa/rd/rdwarktegal.html

WARTK EGAL

Prime: Uni Catalunya

Partners :

FGI, Pildo Labs, IFen, ICC

The most part of contracts offered by the European Space Agency, EUROCONTROL..., are strongly competitive, between the main European enterprises and universities in the field. It is difficult to get inside.

OBJECTIVE/DESCRIPTION OF ACTIVITIES

The main goal of the WARTK-EGAL project is to show the capability of using the EGNOS reference station network for supporting wide-area sub-decimeter error level navigation over the EGNOS service area, with GPS/Galileo signals. The main techniques supporting this new approach are related with an accurate real-time computation of ionospheric corrections, combined with an optimal processing of GNSS observables (carrier phases in particular) in both 2 and 3-frequency systems. This is the so called Wide Area Real Time Kinematics technique, WARTK, previously developed by gAGE/UPC and protected by two patents.

To successfully perform this project several partners with complementary experience have been joined in the WARTK-EGAL Consortium: gAGE/UPC responsible of the new technique development, Pildo helping on the management and EGNOS message usage, FGI working on the broadcasting problem using Internet in general and SiSNET in particular; ICC responsible of a testbed suitable to form the WARTK-EGAL testbed core; and finally IfEN whose experience in tropospheric modelling can provide significant synergies with WARTK.

esa General Studies Programme
European Space Agency

ESA GSP

Article contents
- Relevance to GSP and ESA future programmes:
- Background:
- Brief Description:
- References:

More information
- Introduction
- 2006 Review Workshop

Planned
- Inspirational
- Utilitarian
- Basic

Completed
- Inspirational
- Utilitarian
- Basic

Services
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  - ESA Home
  - GO
- Advanced Search

...and we have been lucky: ESA decided to offer an Open Competition Tender (ITT), dedicated to the technique we invented (WARTK).

http://www.esa.int/SPECIALS/GSP/SEMQSE6DIAE_0.html

Basic
05B10

Planned

Year of Execution: 2005/6
Duration: 12 months

Feasibility study of a wide area high-precison navigation service for EGNOS and Galileo

Objective:

This feasibility study will address the introduction of a Wide Area High-Precision Navigation Service for EGNOS and Galileo, using real-measurements and demonstrations.

Relevance to GSP and ESA future programmes:

A number of Navigation User-groups have strict requirements on accuracy, which cannot be fulfilled today by GPS or EGNOS. Geodesy, hydrography, and GIS users are examples of such user groups. It is expected that other User Groups will develop more demanding requirements on accuracy in order to accommodate new applications, e.g. "lane keeping" for Road Users. These user-groups require sub-metre or sub-decimetre level real-time positioning.

Background:

EGNOS is not expected to deliver sub-metre or sub-decimetre level real-time positioning. Galileo might be unable as well to comply with these requirements. The services proposed for Galileo will not deliver high accuracy in a large area without using additional infrastructure:

- For the Open-Service, the horizontal position accuracy of Galileo is specified to be 4 meter (GSRD-348, [Ref 1]
- The Local High-Precision Navigation Services ([Ref 1]) can be used in a limited area only, and it requires additional infrastructure

It is expected that a Wide Area High-Precision Navigation Service for EGNOS and Galileo will be of commercial interest.

Brief Description:

Wide Area Real Time Kinematics (RTK) has been implemented and tested using laboratory data and simulations (Galileo and modernized GPS) [Ref 2]. This technique is an ESA patent [Ref 3]. However, the next step to be taken is to show the feasibility of such a system with European coverage and real measurements. It is expected that the

The WARTK concept invented by gAGE/UPC is being considered in the Galileo evolution plans in ESA, with the corresponding competitite projects:
→gAGE/UPC has leaded four Consortia, involving 8 additional European Universities and Enterprises, winning the corresponding Calls: WARTK-EGAL (2005-2006), FES-WARTK (2006-2007), EPPP (2008-2009) and PRTODTS (2008-2009).

References:

[Ref 1] - Galileo Global Component System Requirements Document (GSRD), ESA-APPNS-REQ-00011, 27 July 2004
[Ref 2] - WARTK: High Precision Navigation with Galileo and GPS signals, Hernandez-Pajares et al., Navitec 2004, ESTEC, The Netherlands
[Ref 3] - ESA/PAT/482:"WARTK-3"

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How to deal with increasing opportunities in research and technological transfer in the satellite navigation arena?

Active Funded Projects (Dec. 2008)

- ✓**PRTODTS** (European Space Agency): 2008-2009 gAGE/UPC, Development of new improved algorithms for GPS and Galileo satellite orbits and clocks.
- ✓**EPPP** (European Space Agency): 2008-2009 gAGE/UPC (coordinator), Imperial College London, CTAE, Development of new improved Precise Point Positioning high accuracy navigation algorithms.
- ✓**FES-WARTK** (European Space Agency): 2006-2009 gAGE/UPC (coordinator), TUD, GMV, Feasibility study of WARTK.
- ✓**MRS** (European Space Agency): 2007-2009 Indra Espacio, gAGE/UPC, Astrium, Deimos, modernization of EGNOS and WARTK.
- ✓**EDUNAV** (European Space Agency): 2008-2009 gAGE/UPC, development of innovative educational tools for Satellite based navigation.
- ✓**EGNOS Performance Analysis** (EUROCONTROL): 2008-2009 Pildo, ENAC, gAGE/UPC, TU-Delft
- ✓ **SEAGAL** (GNSS Supervisory Authority): 2008-2011, ISMB, POLITO, gAGE/UPC, UPF, HUT and AIT, Implementation plan for an European GNSS Collaboration Center in South-East Asia.
- ✓**GBAS receiver prototype** (Indra Espacio): 2008-2009, gAGE/UPC, Development of a first GBAS receiver prototype.
- ✓**Computation of precise coordinates in Catalonia** (Institut Geològic de Catalunya): 2008-2009, gAGE/UPC, computation of cm-error level coordinates.

One way of managing this:

UNIVERSITY (gAGE/UPC)

Ground GPS
LEO/occultation GPS
High frequency measurements (50-100 Hz)
Galileo & Modernized GPS

DATA

Solar X-Flares
Storm Enhanced Densities (SEDs)
Large Scale Travelling Ionospheric Disturbances (LSTIDs)
Scintillation…

PHYSICAL PHENOMENA

TECHNIQUES

Tomographic mapping
IGS Ionosphere
Improved Abel transform
High precision dSTEC estimation
Combination of geodetic and Ionospheric processing…

APPLICATIONS

Satellite Based Augmentation Systems (EGNOS, WAAS, MSAS…)
Wide Area Sub-decimeter error-level navigation (WARTK)
…

SPIN-OFF (gAGE-NAV, 1er premi 7e concurs d'idees de negoci d'universitats catalanes, Març 2008)

There is *life* after the Ph.D. ...
...maybe in an spin-off (gAGE-NAV)

DLR

One gAGE cornerstone is the excellent group of Ph.D.students.

Our main purpose is to help on forming them as good professionals in the GNSS arena, with high skills in such a way that they can easily join any international or local enterprise or research group in the field.

Up to now, all of them (three), usually after Ph.D. Completion in DocTA program, have been selected and contracted by international agencies in the field of Space Engineering and Research (European Space Agency –ESA-, German Space Agency –DLR-, Univ. Of Kyoto at Japan).

The spin-off gAGE-NAV can be a good place to recover several of them, with the idea of bringing the new company in an autonomous way, at mid/long term.

京都大学

esa

Conclusions

gAGE is an small research group, within the Technical University of Catalonia, working at GNSS since 1989.

In spite of its size, and the associated difficulties on growing in the UPC framework, gAGE is maintaining a high activity in GNSS research, invention and technology transfer.

This activity is supported by international projects in the Space Research and Engineering domain.

Moreover gAGE is also maintaining, since 1994, a continuous teaching activity in GNSS, in terms of Books, Master, Ph.D. and Post-doctorate lecturing, within national and international universities, research labs & companies.

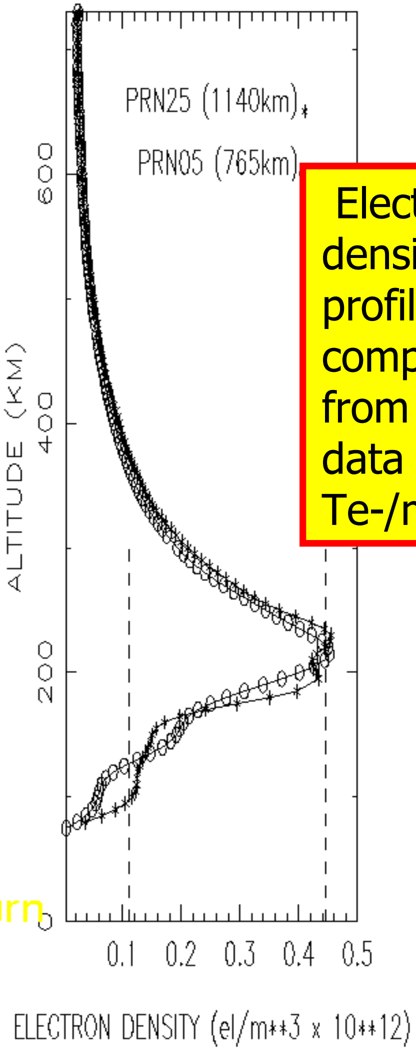
Finally an spin-off (gAGE-NAV) is in the process of constitution, participated by UPC, in the framework of the new legislation.

More information at: http://www.gage.es

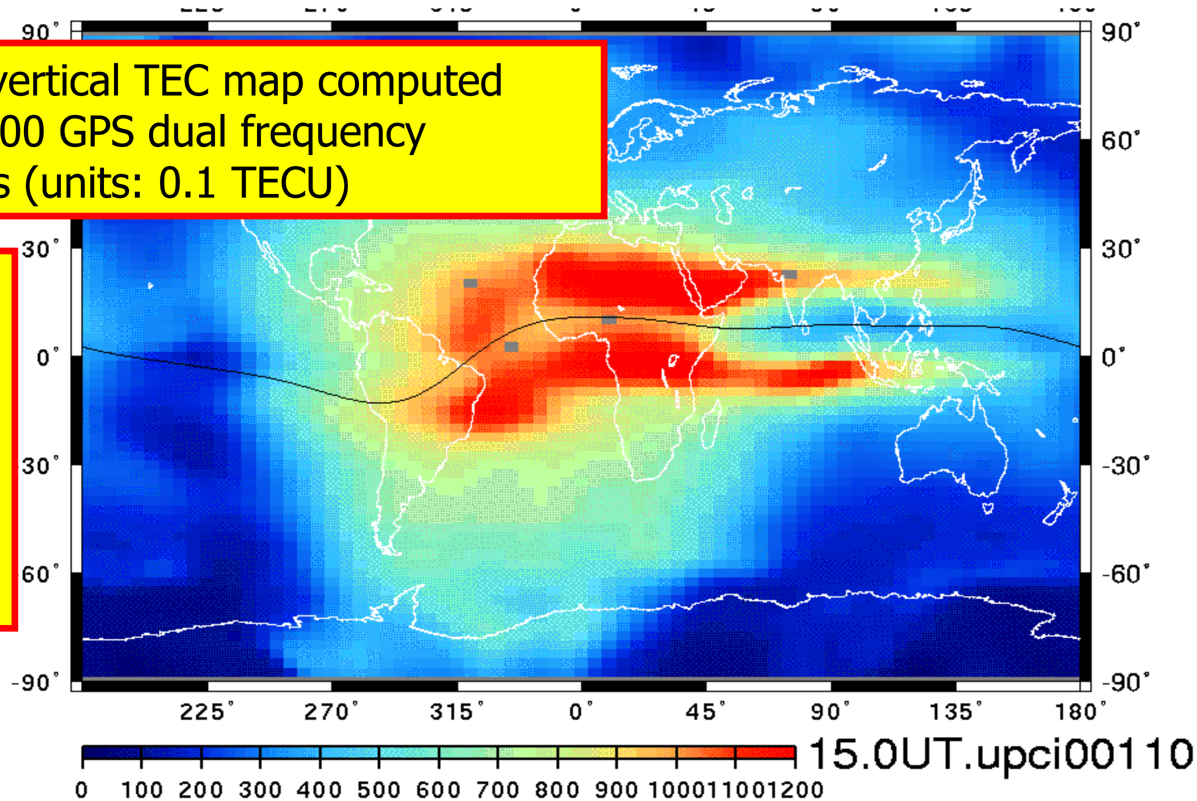
THANK YOU!

Backup slides

Typical Vertical and Horizontal electron content distribution (estimated from LEO and ground based GPS data)



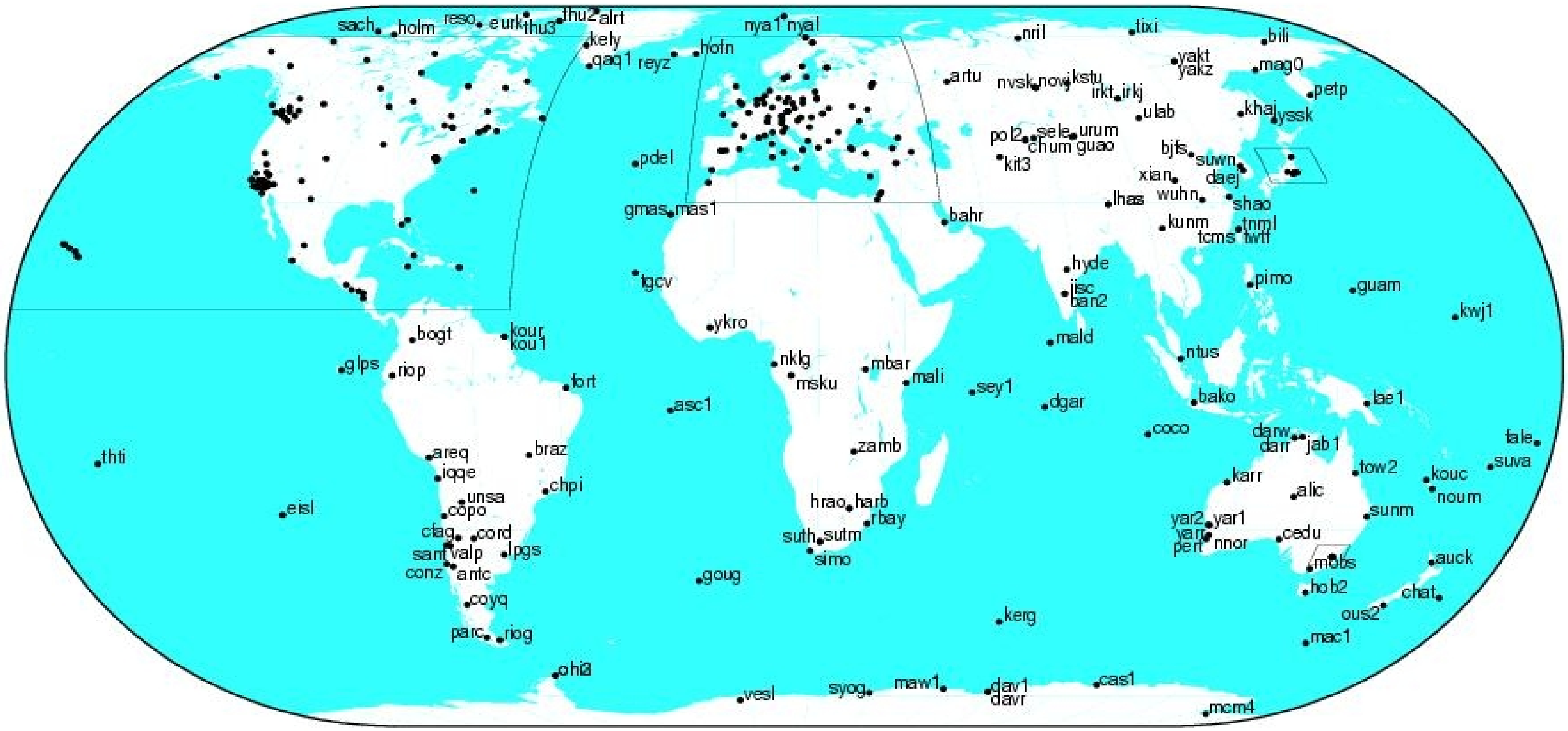
Electron density (Ne) profile computed from LEO GPS data (units: Te-/m**3)



Global vertical TEC map computed from ~100 GPS dual frequency receivers (units: 0.1 TECU)

- Typical horizontal distribution: Maximum values at both sides of the geomagnetic equator (equatorial anomalies), correlated with the Sun position as well.
- Typical vertical distribution: Maximum density height at 200-400 km (or higher during the night) with maximum electron densities of 10^{11}- 10^{12} e-/m^3 (lower in the night).

International GPS Service, IGS



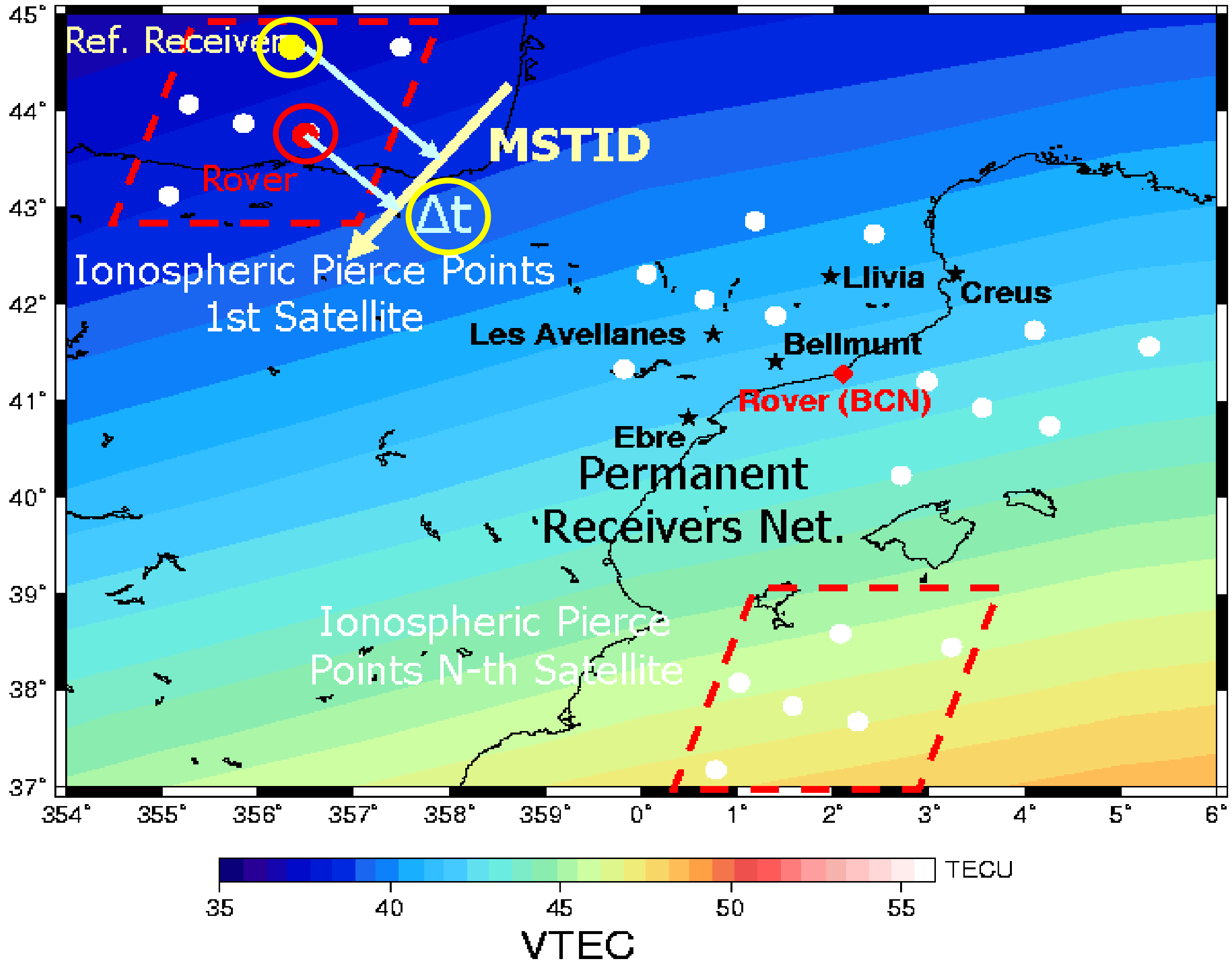
IGS directly manages more than about 350 permanent GPS stations, observing some 4-10 satellites at 30 sec rate: more than 250,000 STEC worldwide observations/hour, but there is lack of stations at the South and over the Seas.

A total number of more than 1000 permanent GPS receivers are available taken into account other networks.

gAGE UPC

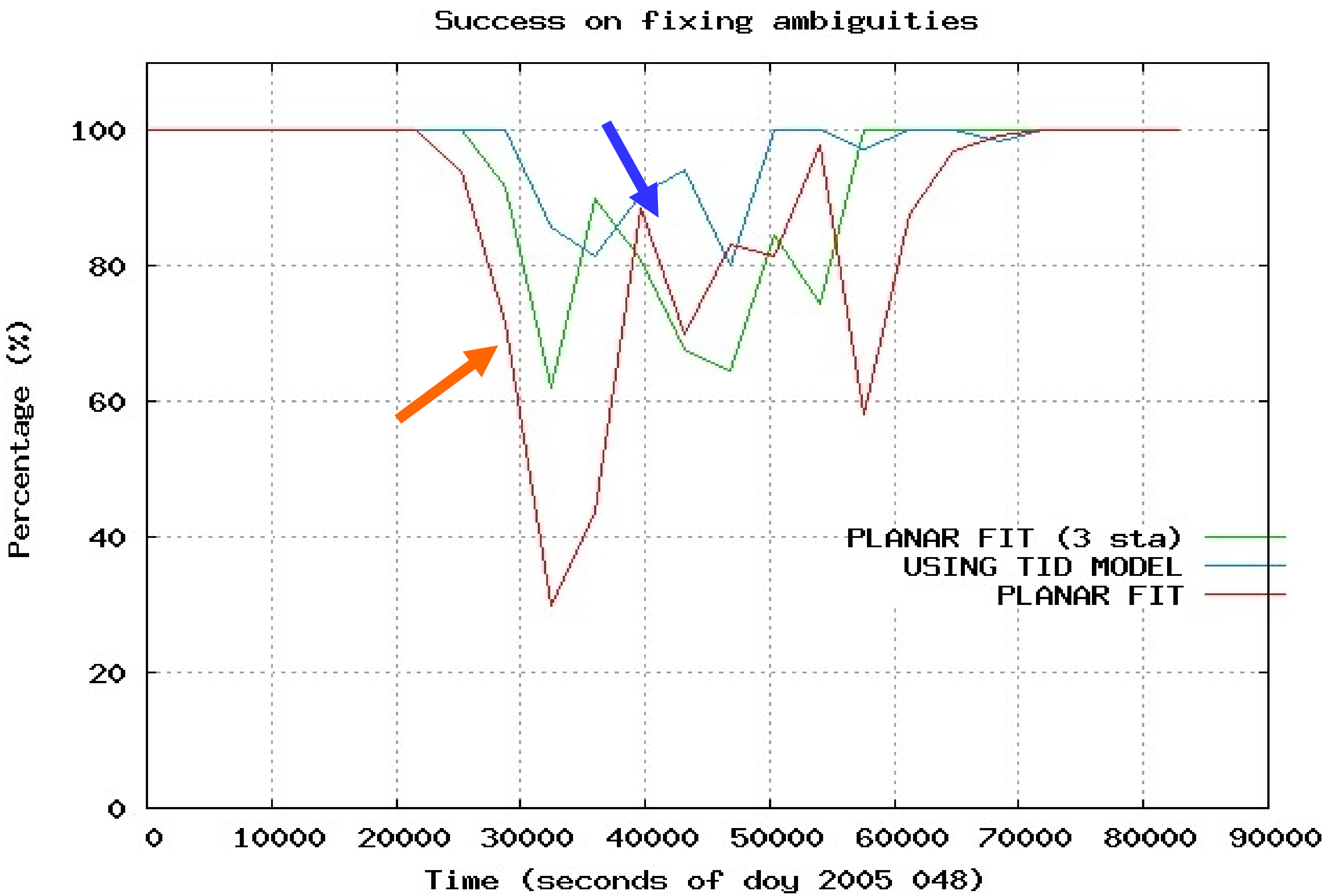
gAGE research group of **A**stronomy and **GE**omatics

The real-time differential delay model for mitigating MSTIDs (DMTID)



In few words: DMTID consists on correcting the MSTID user state (red pierce point) by the values experienced before by a reference site (yellow pierce point), considering a delay Δt given by a planar wave model, feed with the propagation parameters summarized above.

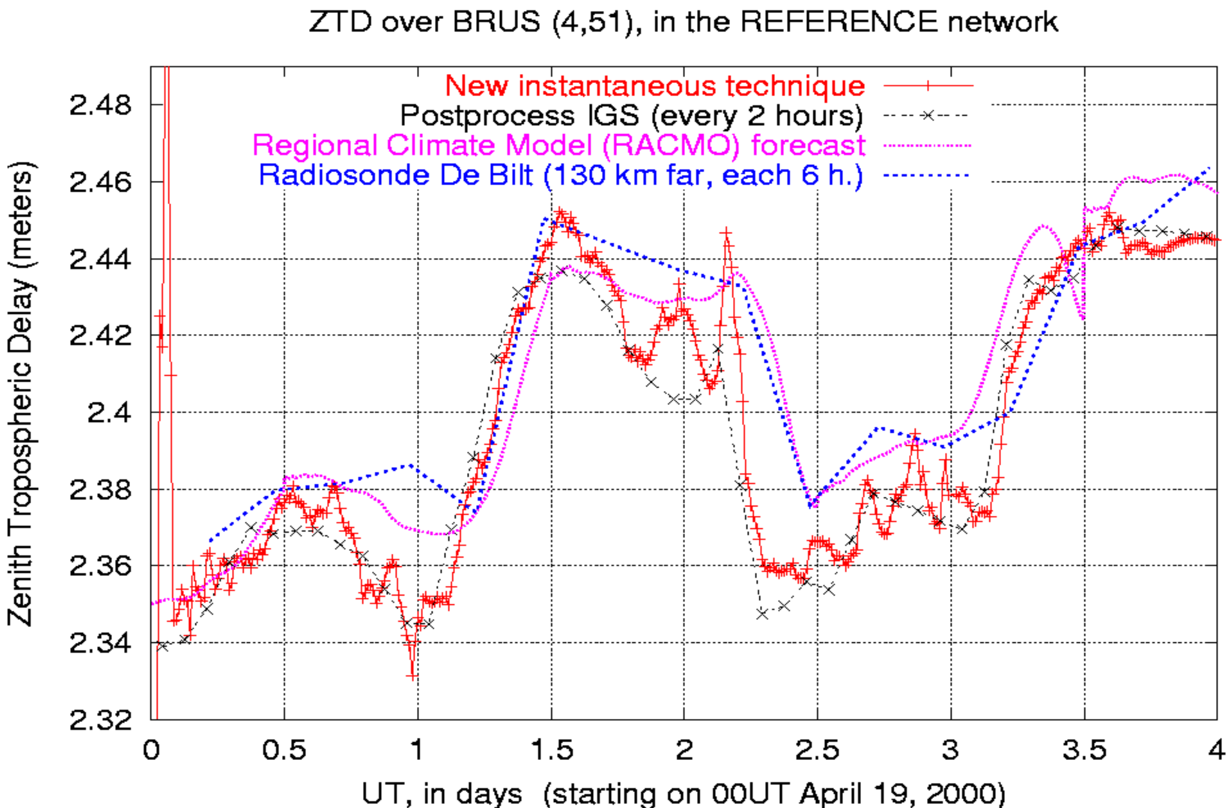
Ambiguity fixing improvement using DMTID



The DMTID positive impact on ambiguity fixing rate is also clear (blue line), which is translated in the corresponding sub-decimeter error-level user navigation, compared to simply applying a more or less local ionospheric interpolation, in green and red lines: The L1 ambiguity success rate is maintained equal or greater than 80%. (receiver LLIV treated as rover in a 127 km baseline, day 048, 2005)

WARTK is able to support instantaneous GPS meteorology

REAL-TIME Water Vapor Determination



The WARTK reference stations can act as accurate meteorological sensors, providing the water vapour content instantaneously, thanks to the continuous ambiguity fixing.

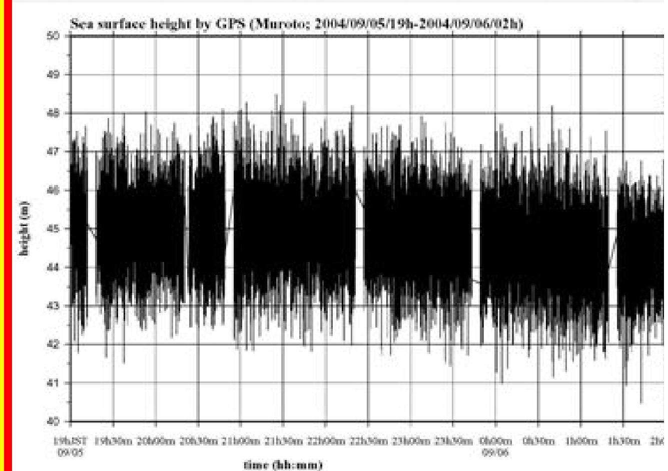
This capability of ingesting such measurements in the weather forecast models can reduce its uncertainties.

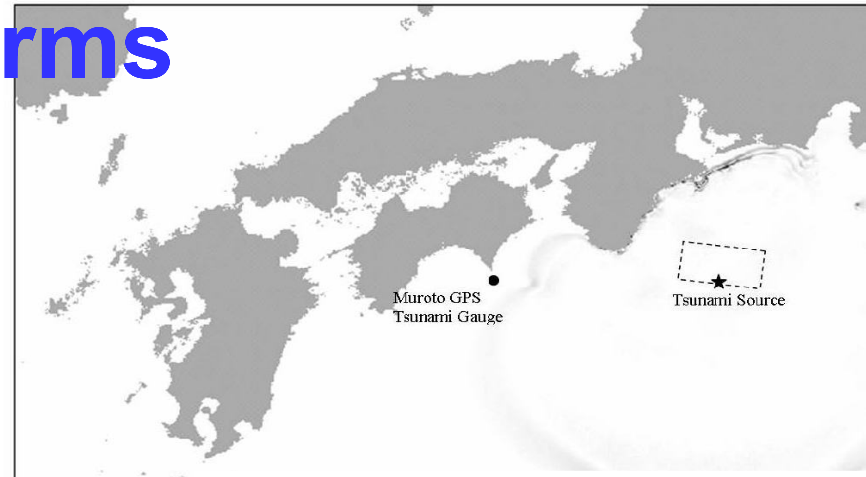
We have shown as well that a dual use of a GPS receiver inside the WARTK Service Area is feasible: both Navigation at cm-level and Meteorological sensor.

WARTK could help on providing useful Tsunami alarms

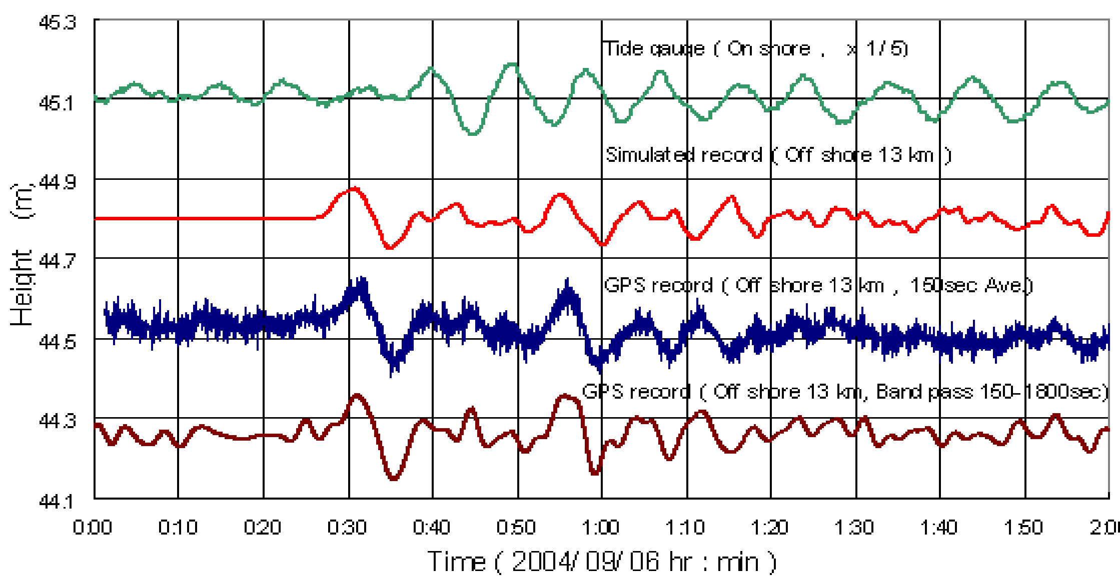
During 6 Sept. 2004 in Japan, it was possible to detect with a GPS buoy, and 10 minutes in advance, the 20 cm tsunamis' amplitude, 15 km north from the coastline.

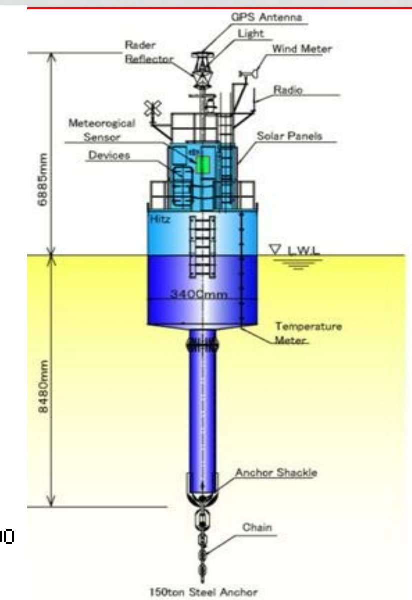
WARTK can help on fixing carrier ambiguities at more than 100 km from the coastline, making more feasible alarms in advance for the population.





(Courtesy of Dr. Oscar Colombo, from NASA GSFC)

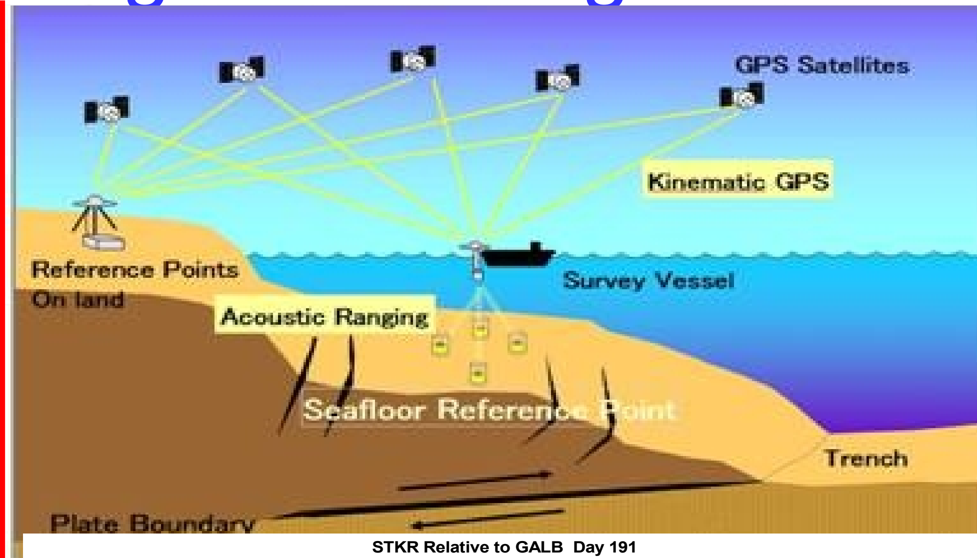


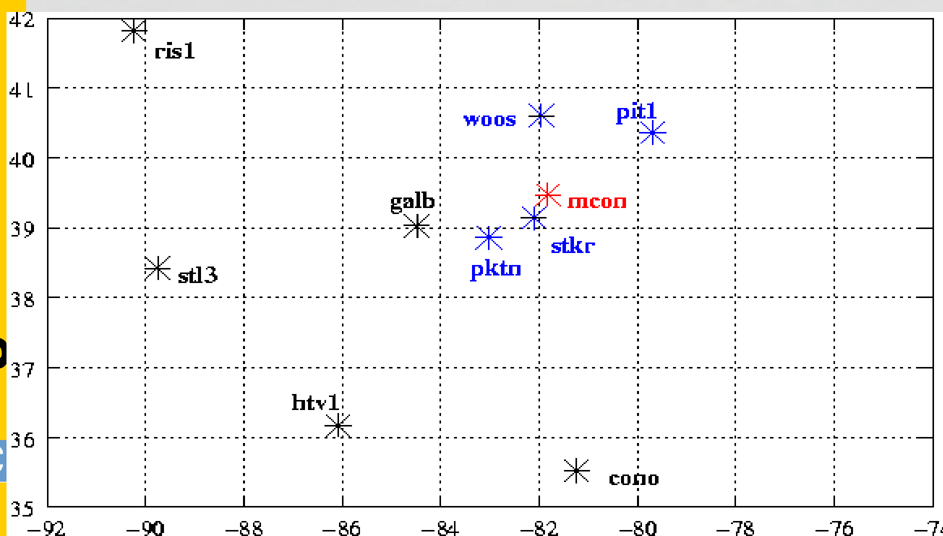


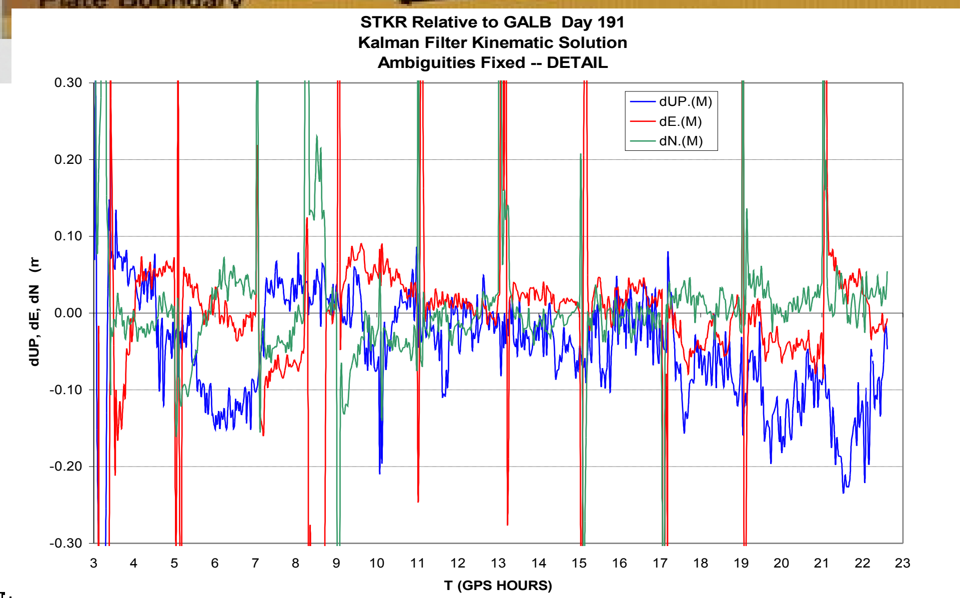
WARTK buoys could help on deep waters precise navigation & pilotage & mooring

The extension of the network of reference receivers with dual-frequency GNSS buoys would allow accurate WARTK navigation (typical errors< 10 cm) on deep waters.

See snapshot of study presented at the ION-GNSS 2005 by Colombo, Hernandez, Juan and Sanz. 2005, in which such accurate buoy-supported navigation can be achieved within a few minutes after each restart.



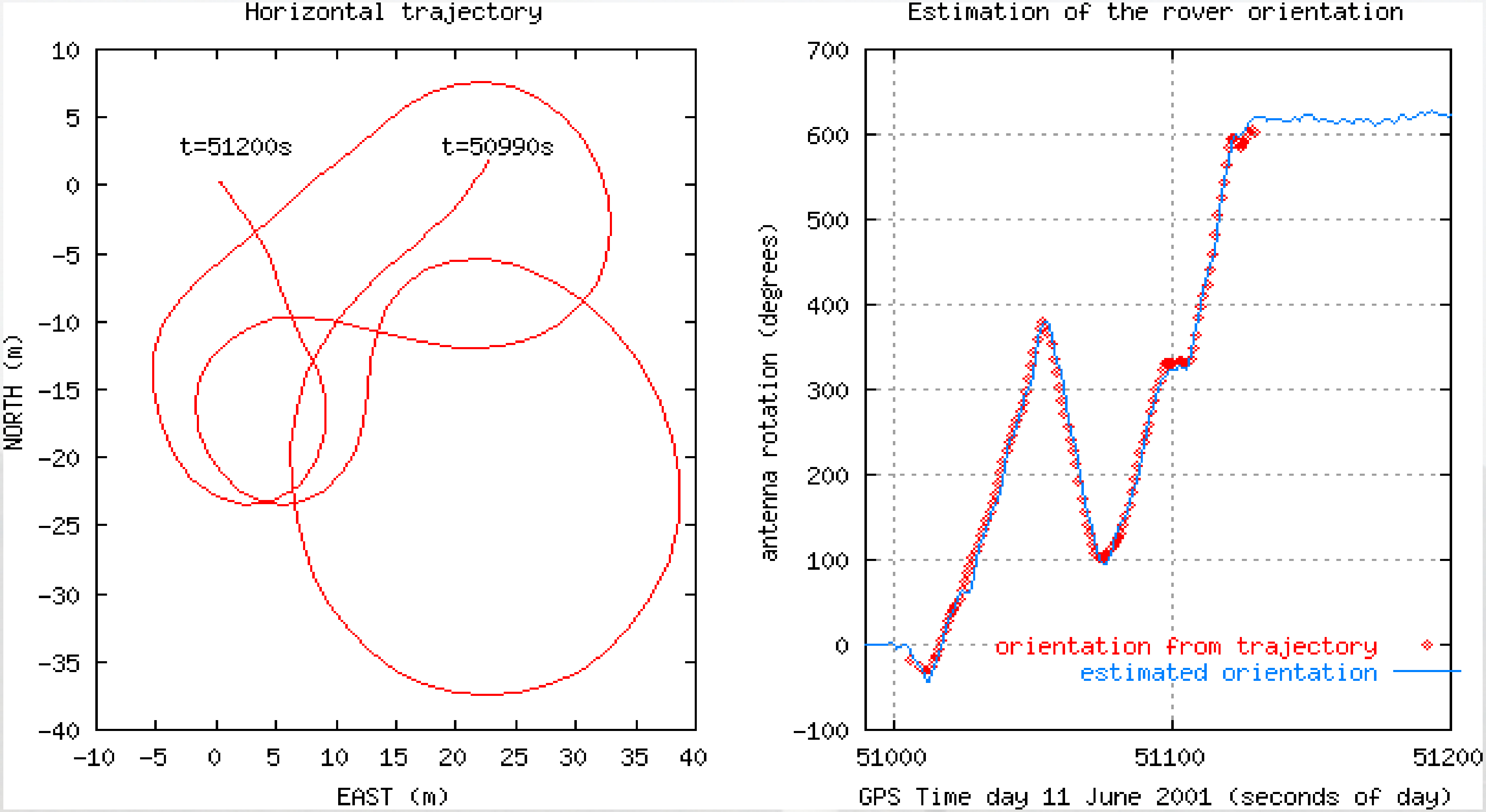




gAGE Research

UPC

Real-time single antenna orientation estimation



The single antenna rotation estimated with the updated WARTK is compatible at the level of few degrees with the antenna rotation deduced from both the car trajectory (right hand plot), and the second antenna on the car roof.

MRS Assumptions

- MRS To be developed with current baseline of Galileo and EGNOS v2.3 baseline (including GPS L1/L5, Galileo RIMS NG available and regenerative payload)
- First priority is to provide GPS and Galileo Regional Integrity using L1/L5 and E1/E5
- Integrity service to be given to dual frequency SOL users (CAT-I), keeping single frequency iono information as a fall back solution (APV-II)
- GPS/Galileo/Glonass(TBC) integrity shall be provided through GEO in SBAS format (FC/SC/UDRE).
- ERIS channel will be used for liability critical application users with a format TBD considering limited BW of ERIS channel (8b/s/region)
- WARTK is foreseen as one of the most promising Commercial Services for EGNOS
- Other means of broadcasting integrity in real-time will be considered reusing EDAS – SISNET concept for instance
- It is assumed that Galileo provides Global Integrity for Galileo through the MEOs
- MRS evolutions shall be tackled in other activities looking at the GNSS panorame in the timefrane of 2015-2025.

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THANK YOU!