ESA Space Weather Assets

EGNOS

European Geostationary Navigation Overlay System

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OUTLINE

- Introduction
- What is EGNOS
- How does EGNOS work
- Ionospheric Data collected by EGNOS
- Possible links to space weather community
- Outlook

Introduction

ESA is participating in the development of a world-wide Satellite-Based Augmentation System (SBAS) for GPS. The purpose of this system is to provide integrity to the (aeronautical) users and to improve the accuracy of the single-frequency navigation receivers.

For ESA this is the first step in working on Global Navigation Satellite Systems (EGNOS is also called "GNSS1") where already during the development a close co-operation with the user community (civil aviation, "Eurocontrol") is exercised.

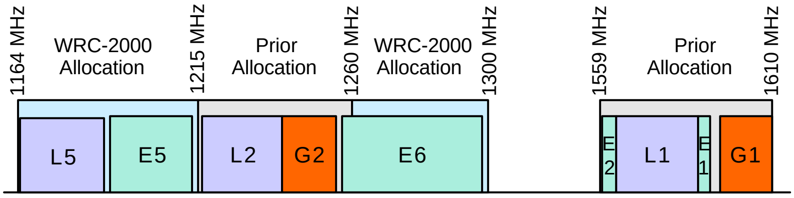
Other SBAS elements currently under development are WAAS (USA, Canada) and MSAS (Japan). The EGNOS system is currently operating in test-bed mode with a limited number of Reference Stations

What is EGNOS

EGNOS stands for **"European Geostationary Navigation Overlay System"**.

- Is an initiative of the European Commission, Eurocontrol and ESA to build a civilian complement to military satellite navigation systems (GPS and GLONASS)
- Is currently in test-bed operation (ESTB), will be operational in 2004.
- The key users community is the civil aviation industry for whom integrity information is of crucial importance. But a number of other users can benefit form EGNOS such as maritime merchant ships, precision farming, and even the leisure user of navigation receivers.
- More information: http://www.esa.int/navigation

Satellite Navigation Frequency bands



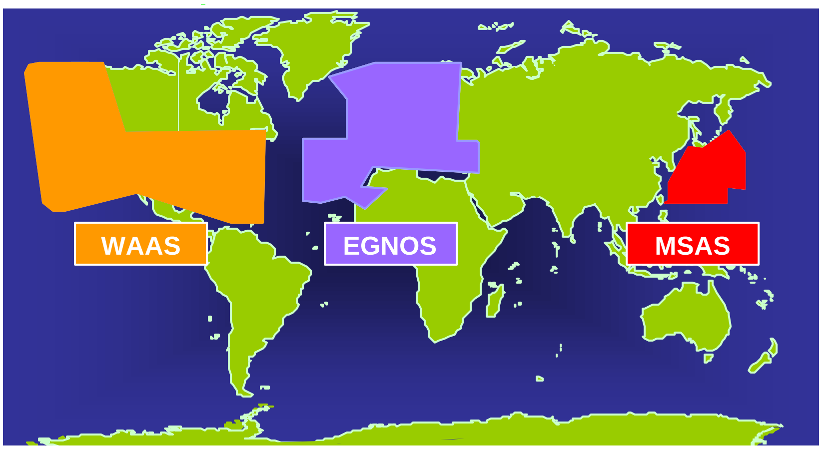
GPS: L1 = 1575.42 MHz (C/A code), L2=1227.6 MHz (P-code), L5

GLONASS: G1, G2

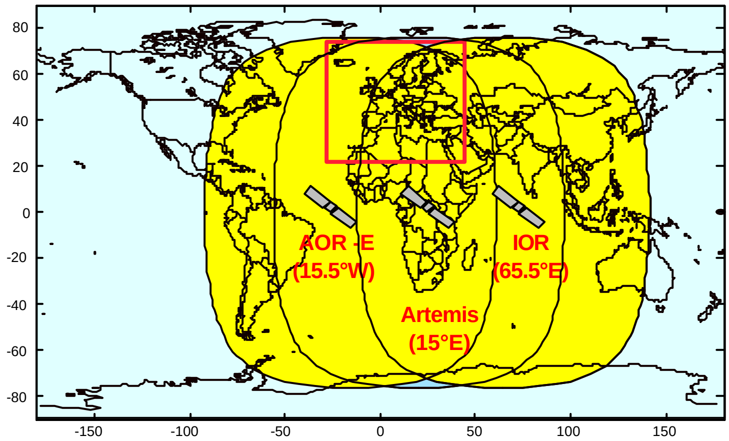
GALILEO: E1, E2, E5, E6. There is also a C-band (5 GHz) allocation but at this time its use is still under discussion.

Note: WRC-2000 refers to allocations granted at the World Radio Conference in Istanbul in Spring 2000

Three SBAS Systems

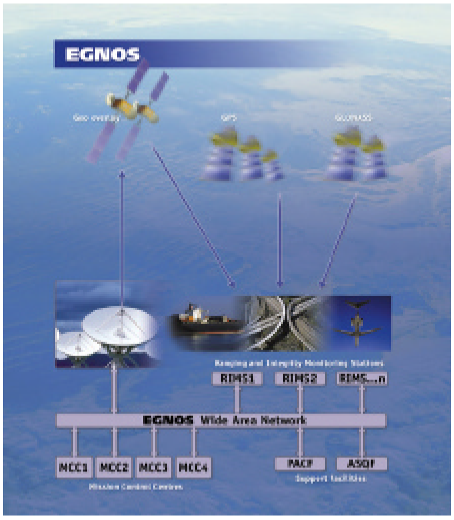


EGNOS Coverage



2 Inmarsat Satellites and ARTEMIS are broadcasting the EGNOS message, the region outlined in red is the ECAC region where EGNOS is active

How does EGNOS work



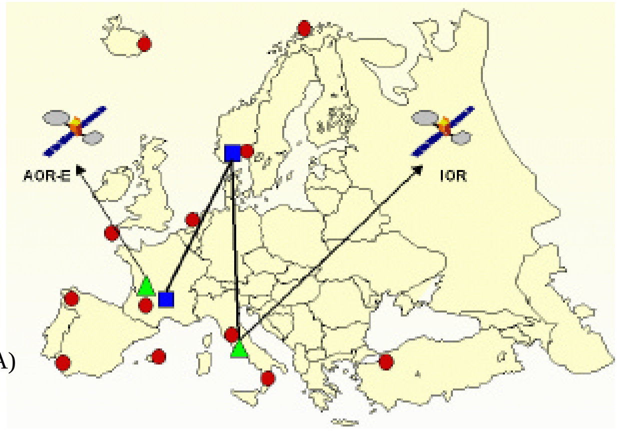
It consists of an autonomous network of monitoring stations (RIMS) located throughout Europe (the "ECAC" region) which observe all visible GPS (and Glonass) space vehicles. These observations are used to generate integrity messages and now-casting of ionospheric conditions at a central processing facility.
The information is then broadcast via 3 Geostationary Satellites the EGNOS users.

EGNOS System Test Bed

ESTB Reference station

ESTB Processing Facility

NLES



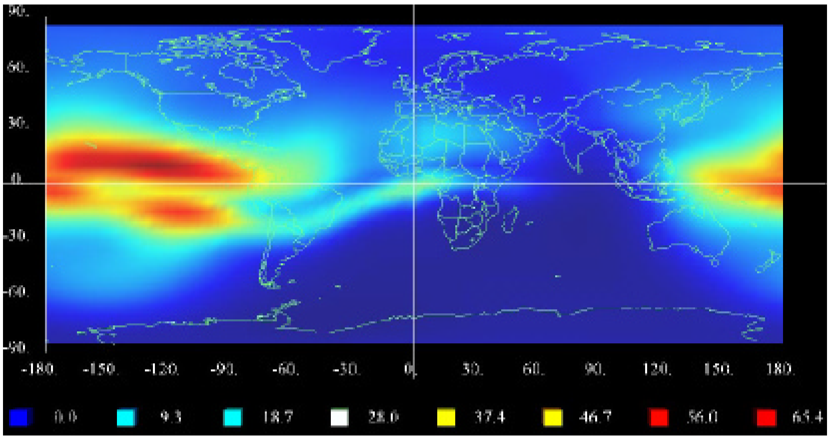
Not on map:
Kourou (FG)
Hartebeshoek (ZA)

Currently, only two INMARSAT satellites are carrying an active EGNOS payload (AOR=Atlantic, IOR=Indian Ocean)

Ionospheric Data processed by EGNOS

- The RIMS (Reference Integrity Monitoring Stations) are collecting slant propagation delay at two different frequencies (L1 = 1575.42 MHz, L2=1227.6 MHz).
- At the Central Processing Facility (CPF), these data are converted to slant total electron content and, using a mapping function, to vertical TEC at the “Pierce Points” (at 350 km)
- Vertical TEC is calculated for regularly spaced “Ionospheric Grid Points” (IGP) and the Grid-point TEC values are broadcast to the users at 5-minute intervals
- The user receiver interpolates the the values for his own pierce points and thereby corrects for the ionospheric delay.

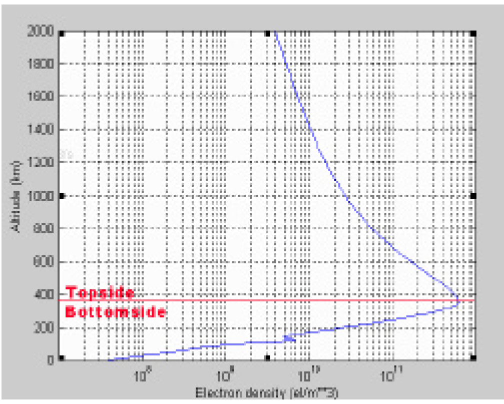
Global Map of Vertical TEC



Vertical TEC plotted in TECU (calculated using NeQuick)
F10.7 = 150, 1999-07-15, 23:00 UTC

Source: Y. Beniguel, "Improved version of GIM"

Profile of Ionospheric Electron Density



The ionosphere

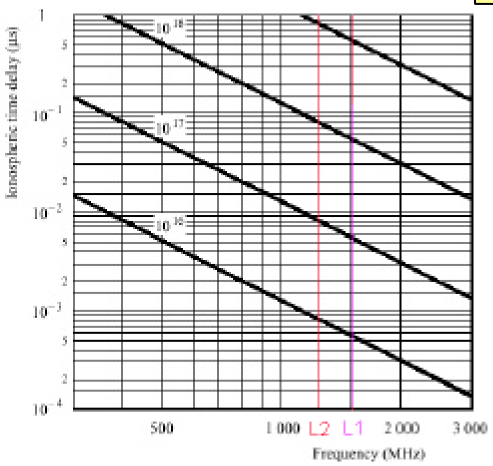
The peak is between 350 and 400 km height.

1 TECU = 10^{16} el / m^2

For calculating ionospheric delay, the Electron Density along the propagation path (GPS-orbit is about 20000 km) has to be integrated (giving Total Electron Content)

Trans-ionospheric delay

Group delay: $\Delta t = \mathbf{1.343}\ N_T / f^2 \times 10^{-7}$ [s]



Source: ITU-R Rec P.531-5

Where:

Δt: delay time [s] with reference to propagation in a vacuum

f: frequency of propagation [Hz]

N_T: total electron content along the slant propagation path.

Ranging error: (s = c.t)

$\Delta s = \mathbf{40.3\ TEC} / f^2$ [m]

TEC in TECU (1 TECU=10^{16} el/m^2)

at L1, 1 TECU means 0.16 m

1 µs delay means 300 m range error

Trans-ionospheric delay correction

Dual frequency receiver: use differential delay ($\Delta t_2 - \Delta t_1$)

$TEC = (\Delta t_2 - \Delta t_1)\ f_1^2\ f_2^2\ 10^{-4} / (f_1^2 - f_2^2)$

$\Delta s_1 = 40.3 \times TEC / f_1^2$

Single frequency receiver: use parameters in navigation message. For GPS, the Klobuchar model is used:

$\Delta t_1 = A_1 + A_2 \cos [2\pi (t - A_3) / A_4]$

where

$A_1 = 5 \times 10^{-9}$ s

$A_2 = \alpha_1 + \alpha_2\ \varphi_{IP} + \alpha_3\ \varphi_{IP}^2 + \alpha_4\ \varphi_{IP}^3$

$A_3 = 14{:}00^{h}$ local time

$A_4 = \beta_1 + \beta_2\ \varphi_{IP} + \beta_3\ \varphi_{IP}^2 + \beta_4\ \varphi_{IP}^3$

all α_i and β_i are transmitted

$t = t_{UT} + \lambda_{IP} / 15$

t_{UT} is UTC, IP is Iono Point

λ_{IP} is longitude of IP

φ_{IP} is the spherical distance of IP from geomagnetic pole

Sources: 1. Hoffmann-Wellenhof et. al.. "GPS Theoryu & Practise, Spinger Verlag
2. http://home-2.worldonline.nl/~samsvl/pseucorr.htm

Other Ionospheric effects

- Ionospheric scintillations

This effect (rapid variations in phase and amplitude) can lead to loss-of-lock and needs to be considered in the design of receivers. Can be strong in the equatorial anomaly region and in auroral regions. Code-less L2 receivers (civilian dual frequency GPS receivers tend to be vulnerable)
The EGNOS Reference station receivers have been carefully designed to remain operational during strong scintillations (S4 > 0.5).

- Faraday rotation

This effect is noticeable at 1.5 GHz but for SatNav systems using circular polarization, it has no significant impact.

Possible Links to Space Weather Community

- Data from Outside Sources
  - EGNOS is required to be completely autonomous - this limits the possibility of acting as “customer” for space weather services
- Data Potentially available to Space Weather Services and the scientific community
  - Vertical Total Electron Content at Grid points at 5 minute intervals (either using an EGNOS receiver or from Internet)
  - Potentially raw data (slant delays)

Outlook

- The EGNOS system can potentially contribute to a European Space Weather Programme
- ESA is working on GALILEO, which could extend this aspect to a global scope (however it will be commercially operated) and which could be interested in using now-casting an forecasting products.