DORIS

The space surveyor

IGN
INSTITUT GEOGRAPHIQUE NATIONAL

cnes
De l'Espace pour la Terre

Measuring to the closest centimetre from outer space

Space is an excellent observatory for studying the oceans, which is a constantly changing environment. To be put to use by scientists, the precious information collected by the instruments of an altimeter satellite must be accompanied by information on its precise position. Since the middle of the 1990s, the DORIS system allows full exploitation of the data generated by these tools by providing an orbit of centimetre-like precision. DORIS is also a high-precision positioning system. It is a fundamental player in the study of geodesy and geophysics. Its data, which contributes to the definition of the terrestrial reference frame ITRF, are essential for studying the form and most minute movements of the Earth.

Thus, DORIS plays a major role in the remarkable results of the French-American ocean study missions TOPEX/POSEIDON, Jason-1 and OSTM/Jason-2. As real space surveyor, DORIS will meet new challenges in the years to come and will contribute to the success of future missions for observing and studying our planet.

A customized and proven system

The DORIS[1] (Determination of Orbit and Integrated Radiopositioning by Satellite) system was designed and developed by the CNES jointly with the Space Geodesy Research Group[2] (GRGS) and the National Geographic Institute[3] (IGN) to finely determine the position of the satellites and their orbits and to precisely locate terrestrial stations.

[1] Détermination d'Orbite et Radiopositionnement Intégré par Satellite
[2] Groupe de Recherches de Géodésie Spatiale
[3] Institut Géographique National

DORIS

An exemplary network of stations

As early as 1986, the CNES and the IGN installed autonomous stations worldwide which are used as reference points on the ground, to continuously cover the trajectory of the satellites. Thanks to an exemplary joint project, the DORIS system represents a network of some 60 stations uniformly spread across the globe.

System monitoring and maintenance

At system level, the upgrades and improvements to DORIS are diverse and profound: in particular, the activity of the integrity monitoring team is now seasoned and effective, ensuring the immediate detection of a faulty beacon or its first signs of aging well before its performances are affected.

In synergy with the work of this team, the network of beacons has been maintained and improved with renovated stations and a stability check of its antennas. Its homogeneity, maintenance and ongoing monitoring make the network of DORIS stations a major asset of the system and a guarantee of a stable performance.

An expanding processing centre, a growing constellation of satellites

The data acquired and stored on board the satellites is transmitted regularly to SSALTO, the multi-mission altimetry, orbit determination and location ground segment, located in Toulouse. It monitors the operation of the stations, processes all measurements, calculates the orbit of the carrier satellites and archives and distributes the data.

Since 1990, some ten satellites, including at least four simultaneously since 2002, have made their contribution of measurements processed by the international scientific community. Today, six contributing satellites are in flight and the future missions under preparation guarantee such a constellation beyond 2020.

On board the satellite:
An antenna pointed toward the ground receives the radioelectric waves sent by the stations flown over. An electronic receiver makes Doppler frequency shift measurements. An ultra stable oscillator, the instrument clock and key of the system, ensures measurement precision and time tagging.

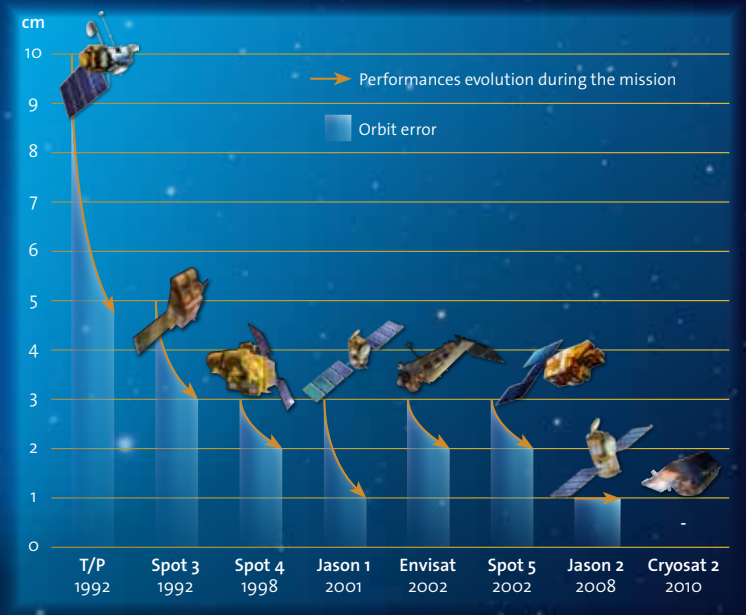
On the ground:
All over the world, about 60 stations emit a radioelectric signal received by the carrier satellites.

An increasingly precise trajectory

Spectacular results

Since its first demonstrator mission on the SPOT 2 satellite, the DORIS system has overcome every challenge. The objective set for the TOPEX/POSEIDON mission was to know the altitude of the satellite with a precision of 13 cm. A very ambitious gamble because the best systems existing at that time only provided measurements to the closest meter, which is insufficient for space oceanography.

The precision of the orbits calculated with the DORIS measurements quickly reached 10 cm, then 2.5 cm, a major feet for this new concept that enabled the success of the TOPEX/POSEIDON mission. Over the years, the performance required of the DORIS system has grown steadily. Hence, the global precision of the Jason-1 altimeter system, of which DORIS is the orbitographic core, assumes that the "space surveyor" achieves the centimetre level.



The Earth in movement

The constant progress of DORIS makes it a leading system for precision orbitography, which is a crucial aspect of altimetry applications, ranging from operational oceanography, modelling to climatic studies.

Monitoring ocean levels

More a hot topic than ever, climatic studies require indicators to measure and in some cases better forecast the consequences of global warming whose devastating effects affect a large part of the world population. The rising sea level is a global warming indicator that must be precisely and continuously monitored using several techniques. In this respect, DORIS data combined with those from orbiting altimeters and tide gauges enable the rise in the level of the oceans to be monitored over several decades.

On a shorter time scale, the study of the sea level by altimeters combined with other observations allows the detection of phenomena such as cyclones or climatic disruptions (El Niño for example).

From geodesy to geophysics

DORIS has put its unique network of stations and its precise positioning capability at the service of geodesy and geophysics.

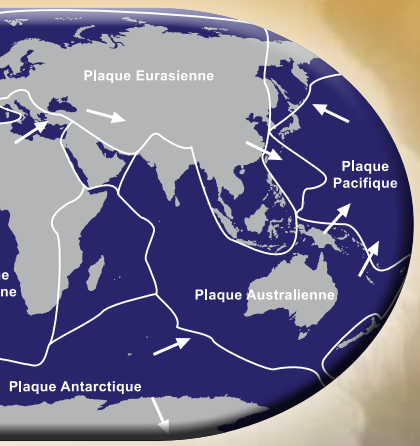
Determining the movement of the tectonic plates

The Earth's surface is made of tectonic plates that move very slowly relative to each other. The precision obtained by accumulating DORIS measurements over several years allows increasingly minute horizontal movements to be monitored.

It even allows deformations at the border zones of these plates to be monitored, where most earthquakes occur.

Participating in the international reference frame

The reliability of the network, combined with its dense and homogeneous coverage, and the increase in the number of satellites in the DORIS constellation (>4 since 2002), has allowed the DORIS system to characterize the positions of the stations and their speed with high



geodesic precision. In this manner, in 1994 DORIS became one of the positioning techniques for defining the International Terrestrial Reference Frame (ITRF).

The ITRF is a geodesic reference frame on a planetary scale that collects and publishes the coordinates and average speeds of some 500 space geodesy instruments - GPS antennas, DORIS beacons, LASER telescopes and VLBI (Very-Long-Base Interferometry) antennas.

This system is used by all applications requiring precise positioning: determination of precise orbits, astronomy, geophysics, climatology and all the sciences that study the deformations and movements of our planet.

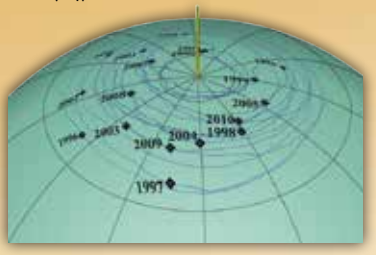
The IDS service (International DORIS Service, http://www.ids-doris.org) was created in the early 2000s. It distributes data and DORIS positioning products to a scientific community of geodesists and geophysicists. Beginning in 2007, the performance levels of the DORIS system gave a real boost to the IDS: seven international analysis centres contributed to a combined DORIS solution for the ITRF2008.

Understanding the movement of the Earth's centre of masses

The Earth's centre of gravity is not set. It moves within a cube of 1 cm^3 according to certain redistributions of mass on the surface of the globe. These redistributions are due to oceanic shifts, the soil moisture, the weight of the snow cover, the volume of the water table, etc. Over the seasons, DORIS measures these millimetre variations that affect the calculation of the orbit.

Measuring variations in the Earth's axis of rotation

The Earth rotational speed varies and the planet continuously "oscillates" very slightly around its axis. These "movements of the pole", set within a square with a side of approximately 20 m, are measured day after day thanks to DORIS with a precision that increases with the number of satellites (>4).



Observing the movements of a volcano

The measurements made by the Mexican station of Soccoro were used to identify a specific shift and connect it to the activity of the volcano Mt Evermann located nearby.

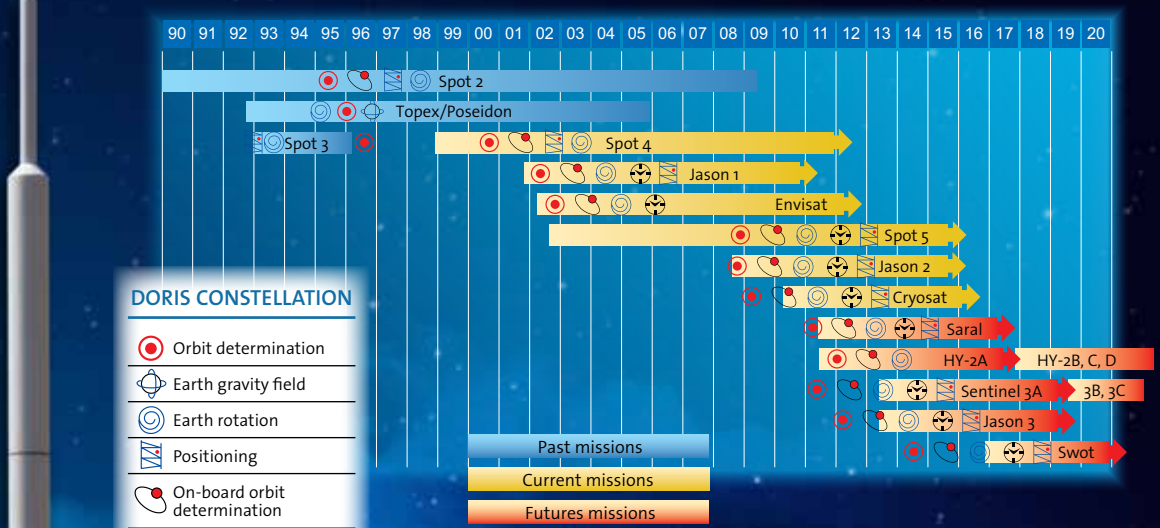
Other applications:

monitoring the melting of a glacier, detecting the seasonal movements of stations, characterising the electron content in the atmosphere, etc.

DORIS: 20 years of success

The DORIS system is a technical, operational and scientific success. Installed on various satellites and studied for new missions, DORIS ensures that its users will enjoy the quality and continued existence of an orbitography and precise positioning operational service. Over the next decade, the system will bring on new partners as part of the International DORIS Service (IDS) and will provide the international scientific community with yet more measurements and by-products.

With even more carrier satellites, the DORIS system will increase its precision.
This performance increase will serve numerous fields in geosciences.



Tomorrow, new products and new applications

More autonomy on-board satellites, more precision in orbit restitution, more reliable and less cumbersome equipment, and additional functions: the DORIS system is being constantly upgraded. A new decade is opening up, geared toward the development of applications dedicated to greater knowledge of our planet.

Ever more performance

From the end of 2001, the third-generation DORIS stations were implemented. They are more reliable and have several upgrades, including the capacity to shift their emission frequencies to eliminate the risk of jamming between neighbouring stations. The existing network was expanded in order to equip new sites, in particular near tide gauges, in order to play on the complementarity of the sea level observations.

On board the satellites, the sizing of the receivers has decreased. Simultaneously, the receiving capacity has increased. Initially with just one channel, the last generation receivers DGXX have seven and can therefore receive signals from up to seven stations simultaneously.

DIODE, a major step towards satellite autonomy

The use of the DIODE[4] (immediate on-board orbit determination by DORIS) navigator on SPOT 4 and then on Jason 1, SPOT 5, Envisat and recently on OSTM/Jason 2 and CryoSat 2, has represented a milestone in the development of satellites towards real navigation autonomy.

The measurements made by the DORIS receiver are continuously processed onboard by the DIODE software, which calculates the satellite trajectory in real time.

Today, by cumulating years of life in orbit, DIODE has been shown to be quite operational with an availability of more than 99.5%. It provided SPOT 4 with a precision of a few meters, today improved to 4 centimetres for the radial component of OSTM/Jason 2. The DORIS carrier satellites can use this information on board (pointing), on the ground in their control centres for trajectory monitoring, or for ground processing of their data (images, altimeter measurements): DORIS/DIODE is paving the way towards complete satellite autonomy.

[1] Détermination Immédiate d'Orbite par Doris Embarqué

More information:
Service International DORIS : http://ids-doris.org
CNES : http://cnes.fr