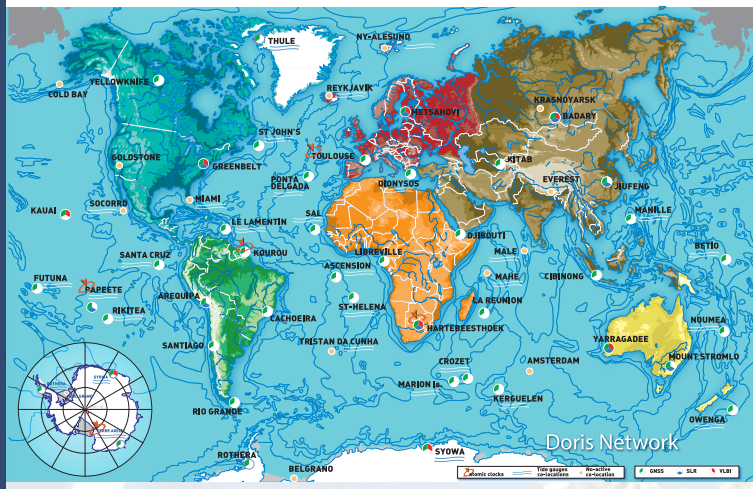
IGN
INSTITUT NATIONAL
DE L'INFORMATION
GÉOGRAPHIQUE
ET FORESTIÈRE

cnes
CENTRE NATIONAL
D'ÉTUDES SPATIALES

MESURING FROM SPACE TO

Space is an excellent observatory for studying the Earth and its oceans, lakes and rivers. To be able to exploit the valuable data collected by a satellite's altimetry instruments, scientists also need information about its exact position. Since the beginning of the 1990s, the DORIS system has enabled scientists to exploit all of the data derived from these tools, by providing orbital elements that are accurate to the nearest centimetre. DORIS is also a highly accurate positioning system, of vital importance for geodesy and geophysics. The data it provides, which are used to determine the International Terrestrial Reference Frame (ITRF), are essential for studying the shape and even the tiniest distortions of the Earth.

DORIS thus plays a major role in the remarkable results of observation missions, whether for oceanography, glaciology, hydrology with the joint French-American series of TOPEX/Poseidon and Jason satellites, or the ESA satellites Envisat and Cryosat, the French-Indian SARAL-AltiKa satellite, the Chinese HY-2A mission, or accurate imaging with the Pleiades satellites. As a genuine surveyor of the Earth from space, DORIS will continue to take on new challenges during the years to come, thus contributing to the success of future missions for observing and studying our planet.



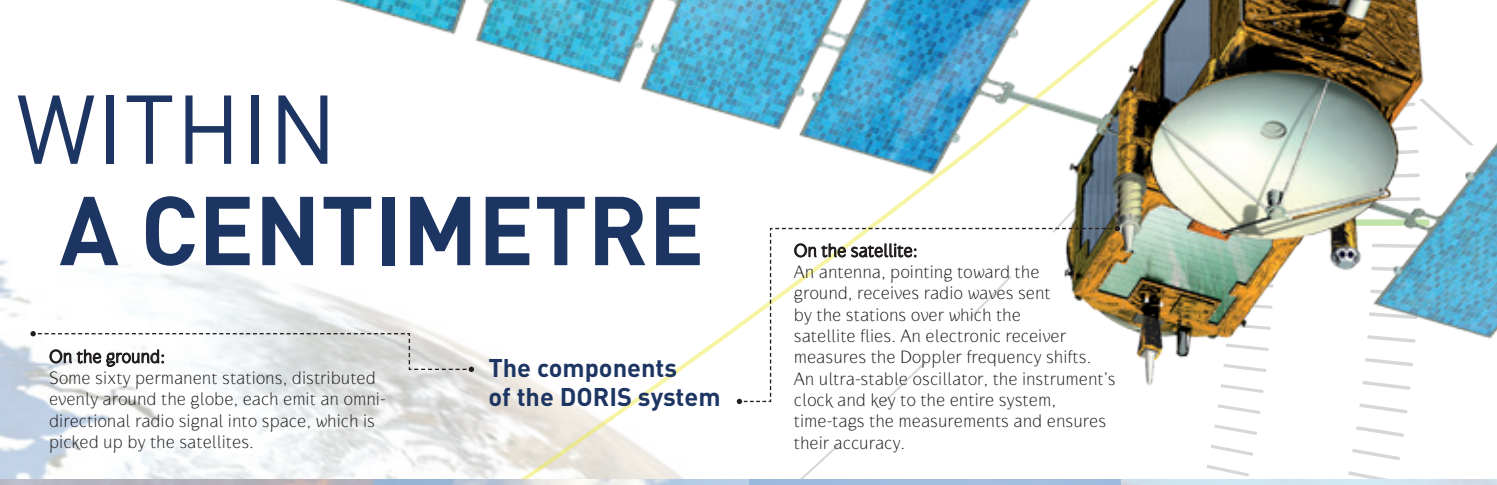
A TAILOR-MADE SYSTEM THAT HAS PROVED ITS WORTH

The DORIS system (Doppler Orbit determination and Radio-positioning Integrated on Satellite) was designed and developed by CNES jointly with the French National Geographic Institute (IGN) and the Research Group for Space Geodesy (GRGS) to determine the exact position of satellites on their orbits and precisely locate terrestrial stations.

AN EXEMPLARY NETWORK OF STATIONS

A network of independent stations was deployed throughout the world in 1986. They are used as ground control points, to provide continuous coverage of satellite trajectories. Thanks to exemplary international cooperation, the DORIS system has a network of about sixty stations spread evenly around the world.

WITHIN A CENTIMETRE



On the ground:
Some sixty permanent stations, distributed evenly around the globe, each emit an omni-directional radio signal into space, which is picked up by the satellites.

The components of the DORIS system

On the satellite:
An antenna, pointing toward the ground, receives radio waves sent by the stations over which the satellite flies. An electronic receiver measures the Doppler frequency shifts. An ultra-stable oscillator, the instrument's clock and key to the entire system, time-tags the measurements and ensures their accuracy.

MONITORING AND MAINTAINING THE SYSTEM

At the system level, DORIS has undergone various far-reaching developments and improvements: in particular, the integrity-monitoring team can immediately ensure a remote detection of a faulty station, or its first sign of aging, well before its performance starts to decline.

Working in synergy with this team, the IGN carries out maintenance work on the network to improve the performance of the stations and ensure they remain compliant with the current requirements of the system. The homogeneity, reliability, maintenance, and constant upgrades of the network of DORIS stations are among the system's most notable features, guaranteeing stable performance over the long term.

AN EXPANDING PROCESSING CENTRE, PLUS A GROWING CONSTELLATION OF SATELLITES

The data acquired and stored on satellites are periodically transmitted to SSALTO, the multi-mission orbitography and altimetry centre located in Toulouse. It monitors stations to ensure that they are operating correctly, processes all the measurement data, determines the orbit of the instrument-carrying satellites, then, archives and distributes the data.

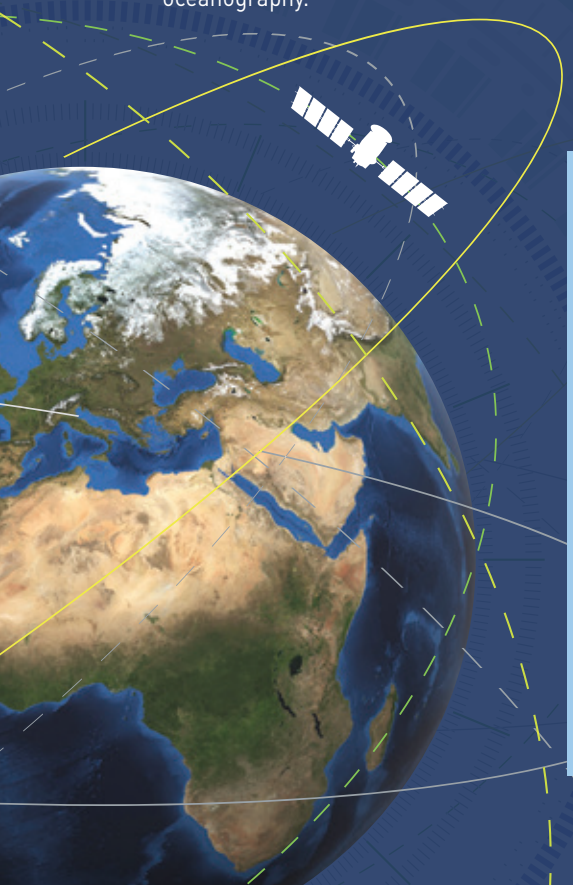
Since 1990, a dozen satellites, with four always in orbit simultaneously since 2002, have provided measurements that are then exploited by the international scientific community. There are currently five contributing satellites in orbit, and the future missions being prepared will ensure that a DORIS constellation continues to fly beyond 2030.

Ever-more-accurate trajectories

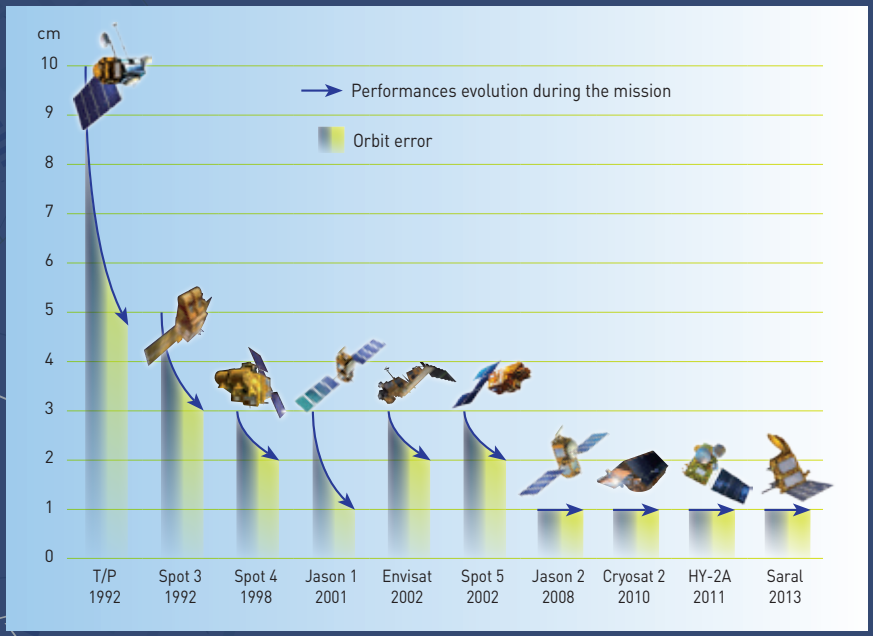
SPECTACULAR RESULTS

Since its first test mission on the SPOT 2 satellite, the DORIS system has successfully met every challenge. The goal set for the TOPEX/Poseidon mission was to determine the altitude of the satellite to within 13 cm. This was a very ambitious challenge, because even the best systems at the time could only measure to within a metre, which is insufficient for satellite-based oceanography.

The orbits calculated with the DORIS measurements quickly achieved an accuracy of 10 cm, then 2.5 cm, a fine achievement for the system, which contributed to the success of the TOPEX/Poseidon mission. Over the years, the DORIS system has been called on to provide ever-better performance. For instance, on the Jason-2 altimetry system DORIS plays a central role in orbit determination, providing measurements to within a centimetre or even better.



Orbits determined with centimeter accuracy



TRACKING THE EARTH'S MOVEME

The constant improvement of DORIS has made it a benchmark for precision orbitography, which is a crucial aspect of altimetry applications, ranging from operational oceanography, modelling to climatic studies.

MONITORING THE LEVEL OF THE OCEANS

Climate issues are more in the news than ever, the rise in sea level, is a crucial indicator to measure and better predict the consequences of global warming. DORIS data, combined with information from orbiting altimeters and in-situ tide gauges, enable scientists to follow the rise of the mean ocean level over several decades.

Over shorter time scales, altimetric investigation of sea level coupled with other observations can enable advance warning of phenomena such as cyclones or unusual climate events such as El Niño.

DETERMINING THE MOVEMENT OF TECTONIC PLATES

The Earth's surface is made up of tectonic plates that move very slowly in relation to each other (a few centimetres per year). The accuracy and the progressive accumulation of DORIS measurements over more than two decades make it possible to detect the most infinitesimal horizontal movements (less than one mm/year). Distortions at boundary areas between plates, where most earthquakes occur, can now be monitored. DORIS thus provides information to complement ground-based geological observations.

PARTICIPATING IN THE INTERNATIONAL TERRESTRIAL REFERENCE FRAME (ITRF)

All applications that require accurate positioning, such as orbit determination for altimetry satellites, astronomy, geophysics, climatology and all sciences that study the distortions and movements of our planet, must be characterized in an accurate and stable terrestrial reference system.

The ITRF (International Terrestrial Reference Frame) was recently chosen by the United Nations as the basis for the future Global Geodetic Reference Frame for Sustainable Development. It gathers and publishes the coordinates and velocities of some 500 space-geodesy instruments.

The DORIS network is an integral part of the ITRF in the same way as the networks of other space geodesy systems such as GNSS (GPS, GLONASS, Galileo), SLR (Satellite Laser Ranging) telescopes and VLBI (Very Long Base Interferometry). The reliability of the network, associated with its dense and homogeneous coverage and the constantly improving performance of DORIS instruments in orbit, means that the position and velocity of DORIS stations can be pinpointed with great geodetic accuracy and thus makes a significant contribution to the ITRF.

NTS

From geodesy to geophysics

DORIS has made good use of its unique network of stations and its highly accurate positioning capability, to address the needs of geodesy and geophysics.

This is why the IDS (International DORIS Service, (http://www.ids-doris.org) was created at the beginning of the century. This service is now fully operational. It disseminates DORIS data and products to the geodesy and geophysic scientific community, and contributes to the realization of the ITRF, with constantly improved accuracy (sub-centimetre 3D for the ITRF 2014) thanks to the regular upgrades of the DORIS system and improved processing of its measurements by the IDS analysis and combination centres.

MEASURING VARIATIONS IN THE EARTH'S ROTATION AXIS

The speed of the Earth's rotation varies and the planet continuously «oscillates» very slightly around its axis. DORIS accurately measures these «movements of the pole», which occur within a square about 20 m on each side, day after day to within one centimetre.

UNDERSTANDING THE MOVEMENT OF THE EARTH'S CENTRE OF MASSES (THE GEOCENTRE)

The centre of gravity of the whole Earth-Oceans-Atmosphere system is not fixed in relation to the solid Earth. It moves inside a space of just 1 cubic centimetre, according to the way certain masses close to the Earth's surface are redistributed over time. These can be caused by movements of the oceans, soil moisture, the weight of snow cover, the volume of groundwater and so on. DORIS measures these seasonal millimetre-scale variations, which also affect orbit determination.

OBSERVING THE MOVEMENTS OF VOLCANOES

The measurements taken by the DORIS station on Socorro Island (Mexico) have enabled scientists to identify specific movements and relate them to the nearby volcano, Mount Evermann.

AND EVEN MORE APPLICATIONS, SUCH AS:

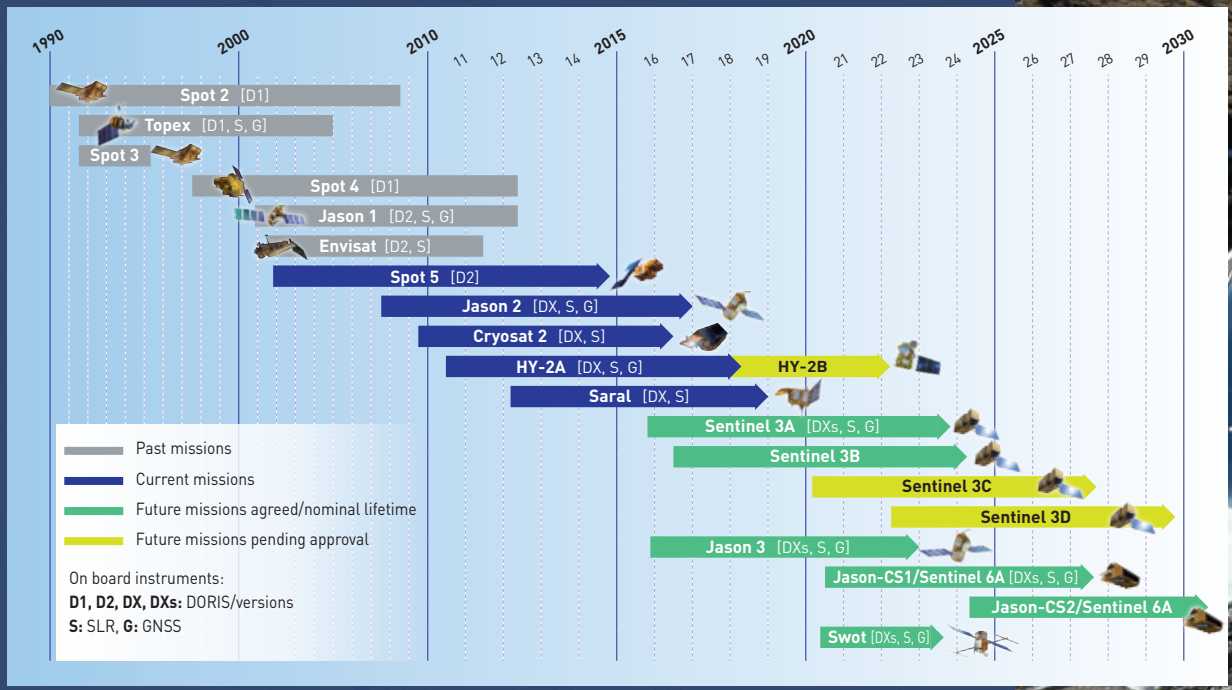
following the flow of a glacier; detecting the seasonal movement of stations; characterising the proportion of free electrons in the atmosphere; determining the vertical movement of the Earth at the locations of tide gauges; determining water-vapour content of the atmosphere for climate applications, etc.

DORIS : 25 YEARS OF ACHIEVEMENT

The DORIS system has now been operated for 25 years, and is unquestionably a technical, operational and scientific success. Installed on several satellites and also under study for new missions, DORIS ensures for its users the quality and sustainability of an accurate operational orbitography and positioning service.

During the next decade, even more partners will join the system in the framework of the International DORIS Service (IDS), a service of the International Association of Geodesy (IAG), and the international scientific community will benefit from even more measurements and derived products.

DORIS missions



AND TOMORROW...

TOMORROW, NEW PRODUCTS AND NEW APPLICATIONS

The DORIS system is perpetually being improved to provide greater onboard autonomy for satellites, increasingly accurate orbit determination, ever-more reliable equipment and additional functions. It is constantly being used to develop applications to further our knowledge of planet Earth. Furthermore, through its accurate navigation function, DIODE (Immediate Determination of orbit by Doris Onboard), DORIS will provide new real-time services for the altimetry missions Jason-3, Jason-CS and SWOT (a joint French-American hydrology and oceanography mission) to help them target areas of interest and enable onboard pre-processing of altimetry echoes. Similarly, determination of the Earth's polar coordinates will be available in near real-time, every 10 seconds.

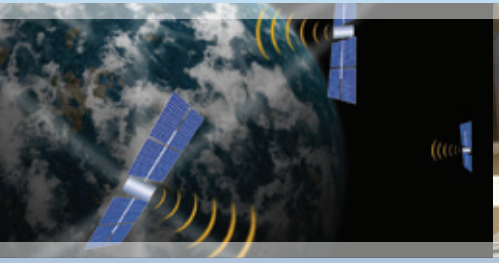
NEW STATIONS

New transmitters, currently being designed, will soon take over from the third-generation beacons now coming to the end of their working lives. These new fourth-generation stations will be able to use antennas at a distance from potential masking obstacles, offering a wider choice of sites for installation.

DIODE, A BIG STEP TOWARD SATELLITE AUTONOMY

The use of the DIODE navigation software on SPOT 4, and then on all the DORIS satellites, was a milestone on the road toward genuine satellite autonomy as regards navigation.

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



Now that DIODE has amassed nearly a century of experience in orbit, it can claim to be totally operational with an availability rate of more than 99.5%. It can determine the radial component of Jason-2 to an accuracy of 2 to 3 centimetres.

The satellites Cryosat2 (ESA mission for the study of ice) and Pleiades (French mission for high-resolution imaging) use DORIS/DIODE onboard in their attitude and orbit control systems. On the ground, the control centres for satellites carrying a DORIS instrument use the DIODE information for trajectory tracking, or for processing their data (images, altimetry measurements): DORIS/DIODE is a major step toward satellite autonomy.

Finally, in close association with the altimetry instruments, DORIS/DIODE enables the autonomous acquisition and tracking of areas of interest as well as onboard preprocessing of altimetry measurements.

DORIS

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

IDS

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