cnes
Space for Earth

DORIS

IDS

DORIS

A PERMANENT EVOLVING SPACE TECHNIQUE FOR EARTH SCIENCES RESEARCH

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GRGS

esa

IGN
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

CLS

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Introduction

DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite) was proposed by CNES, GRGS (Groupe de Recherches de Géodésie Spatiale) and IGN in 1982 as a dedicated fully optimised system in support of POSEIDON oceanographic altimetric experiment. To get an in-flight validation of DORIS before TOPEX/POSEIDON, DORIS was flown on board the SPOT2 satellite as a passenger experiment. Recognising the ability of the system to provide both precise positioning of ground beacons and orbit of centimeter-like precision, DORIS was approved for flying on board SPOT3, SPOT4, JASON-1, ENVISAT-1, SPOT5, JASON-2, CRYOSAT-2 and on HY-2A.

This document introduces the DORIS technique as well as its components, then details scientific activities supported by DORIS, and finally presents major evolutions and perspectives.

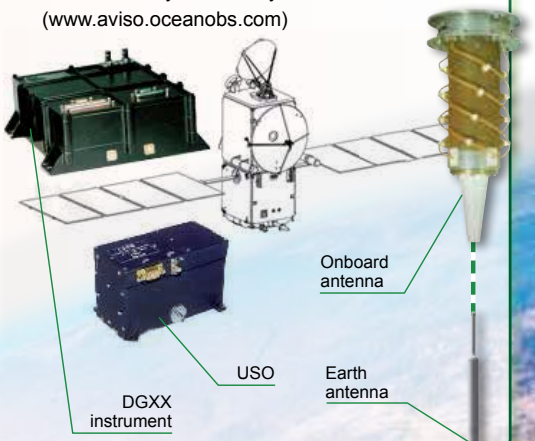
DORIS Technique and System Components

Principle

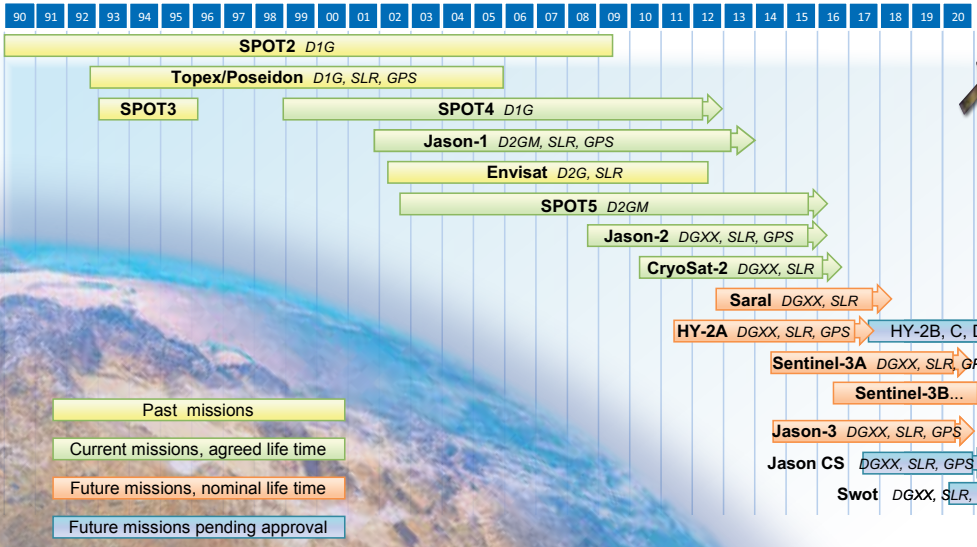
- Doppler shifts measurements of RF signal (2,036.25 MHz and 401.25 MHz)
- One way signal transmitted by a world wide beacons network
- Very high ultra-stable oscillator (USO) stability (beacons and on board)
- On board receiver computes relative velocity to Earth
- Ionospheric Propagation error eliminated thanks to the 400 MHz signal

Components

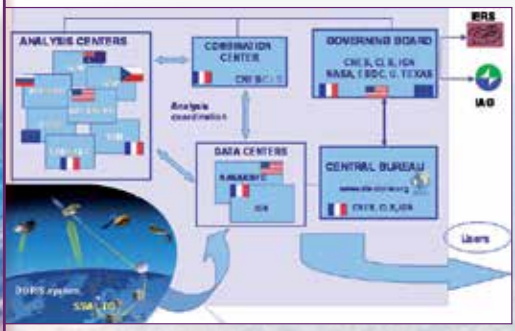
- Onboard instruments
  - Doris receiver + USO + omni-directional antenna
  - on board LEO satellites
- A network of 60 stations uniformly spread across the globe: beacon + USO + omni-directional antenna
- A ground segment SSALTO (in Toulouse, France):
  - precise Orbit Determination,
  - multi-missions altimetry processing,
  - archive/distribution of data and products
- ➔ to the International DORIS Service (www.ids-doris.org)
- ➔ to the Altimetry community AVISO (www.aviso.oceanobs.com)



DORIS Satellites Constellation



International DORIS Service



The International DORIS Service (IDS) is a service of the International Association of Geodesy (IAG) and operates in close cooperation with the International Earth rotation and Reference frames Service (IERS).

Its primary objective: to provide a service to support, through DORIS data and data products, geodetic and geophysical research activities. IDS also participates in the Global Geodetic Observing System (GGOS).

The IDS collects, archives and distributes DORIS observation data sets as well as the following derived products:

- Coordinates and velocities of the IDS tracking stations
- Geocenter and scale of the Terrestrial Reference Frame
- Ionospheric information
- High accuracy ephemerides of DORIS satellites
- Earth rotation parameters

IDS facilities are:

- IDS Website **http://ids-doris.org**
- IDS ftp site **ftp://ftp.ids-doris.org/pub/ids**
- e-mail service : DORISmail, DORISreport, IDS analysis forum…
- Data centers web sites at CDDIS and IGN

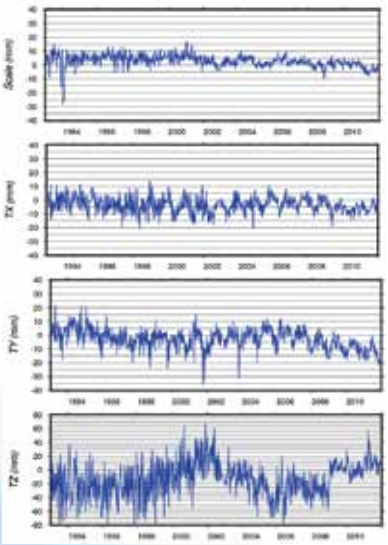
In line with the successful DORIS contribution to ITRF2008, IDS decided to extend the combination process to an operational service. Thus, in early 2010,

	SPOT-2 1990-2009	TOPEX 1992-2004	SPOT-3 1993-1996	SPOT-4 1998	JASON-1 2001	ENVISAT 2002-2012	SPOT-5 May 2002	JASON-2 2008	CRYOSAT-2 2010	HY-2A 2011
Onboard Instruments	1st generation (1 channel)				2nd generation (2 channels)			DGXX (7 channels)		
Inclination (deg)	98.7	66.5	98.6	98.8	66.0	98.6	98.8	66.0	92.0	99.4
Altitude (km)	830	1300	830	800	1330	780	820	1330	720	960

- 10 Satellites on different LEO orbits have contributed to the international scientific community
- As of 2012, 6 DORIS satellites are in flight
- Several future missions under preparation

➔ **DORIS constellation is guaranteed beyond 2028.**

the IDS Combination Center (IDS CC) has been opened and is now fully operational. The IDS CC aims to i) evaluate all the ACs weekly solutions, ii) perform the IDS multi ACs weekly combined solution, iii) support the ACs in the continued improvements of the DORIS products and iv) compute and deliver the DORIS contribution to the next ITRF. Routine analysis by the IDS CC of the ACs weekly solutions has revealed that when Jason-2 is included (early 2009) the Tz geocenter component is better centered. To understand this result, IDS conducted several single satellite studies which have shown that the Tz phenomenon is the consequence of the new DGXX 7-channel DORIS receiver on board of Jason-2.

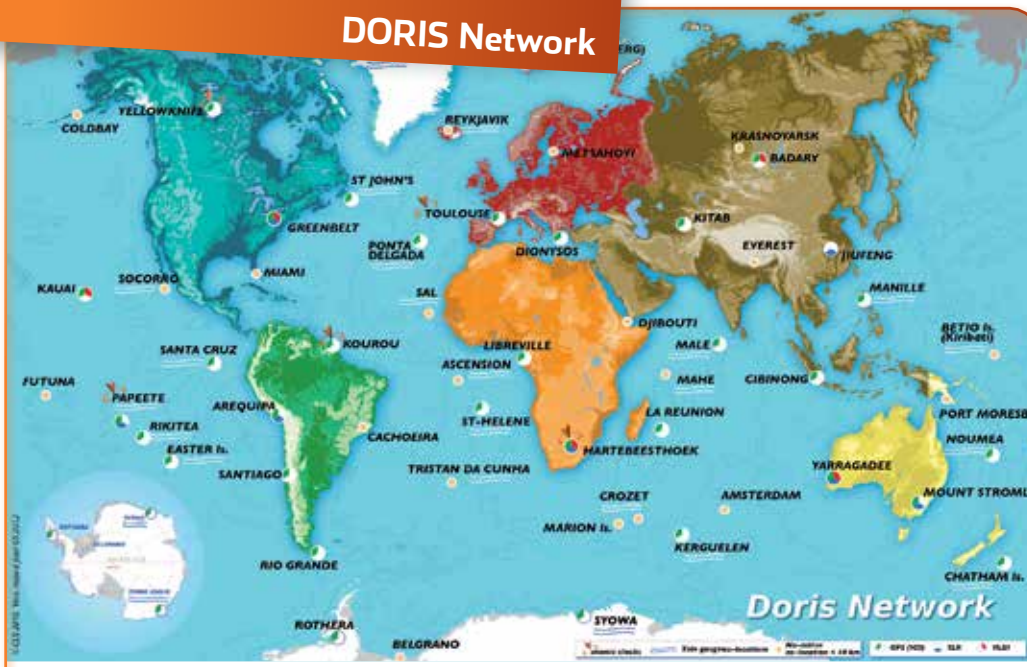


Time evolutions of the scale and Origin of the Earth reference system observed with DORIS

Some milestones

1990: first DORIS data on SPOT-2
1994: first contribution of DORIS to activities for the realization and maintenance of the ITRF
1999: IAG and IERS initiate a DORIS Pilot Experiment
2003: official start of IDS as an IAG Service
2005: 3 analysis centers respond to the call of participation to ITRF2005
2009: 7 analysis centers participate to the IDS contribution to ITRF2008,
2010: initialization of the routine combination by the Combination Center

DORIS Network



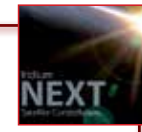
- Network of third generations stations uniformly spread across the globe
- Most of the stations have been installed early 1986 and are operated through partnerships with local national agencies
- Co-locations with GNSS, Laser, VLBI stations and tide gauges is one of the key points in DORIS site selections
- DORIS integrity monitoring team has been created to ensure the immediate detection of a faulty beacon or its first signs of aging well before its performances are affected
- Maintenance and renovations of the beacons is a join CNES-IGN permanent work

➔ **Homogeneity, maintenance and ongoing monitoring make the network of DORIS stations a major asset of the system and a guarantee of a stable performance.**

DORIS beacon electronics evolution

Examples of DORIS beacon antennas

DORIS: a system constantly evolving and open to new applications



Ever more performance

- Since 1990, 3 generations of stations were implemented improving reliability, robustness and performance, including the capacity to eliminate the risk of jamming between stations.
- A centralized maintenance of the network is effective through a permanent monitoring of the system integrity and remote control.
- Since 2008, with Jason-2, a 3rd generation of instrument is currently onboard: miniaturization, increased capacity of receiving (up to 7 stations simultaneously) and providing phase measurements.
- DIODE (Immediate on-board orbit determination by DORIS), a major step towards autonomy: radial accuracy < 4 cm.

A constellation of satellites open to different missions

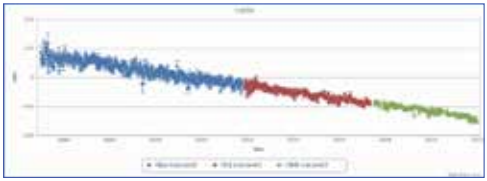
- The free DORIS signal allows DORIS receiver to fly on different type of satellites and orbits with no limitation of number, and can be used by different scientific concepts, such as:
  - CITRIS instrument on STPSat1 was used for ionospheric studies,
  - GRASP (Geodetic Reference Antenna in Space) proposes to colocate onboard GPS, SLR, VLBI and DORIS sensors to enhance all the space geodetic techniques,
  - IRIDIUM NEXT plans to carry a DORIS receiver on board 60 satellites of its constellation for ionospheric data and POD.

DORIS contributes to a larger scientific comunity, meets the needs of GGOS

- The existing network was expanded to equip new sites, in particular near tide gauges in order to play on the complementarity of the sea level observations.
- The future installations of DORIS station will take into account the GGOS recommendations and encourage multi-techniques colocation with accurate local ties determination.
- Many groups joinned IDS and were qualified as analysis centers for ITRF2008, other new groups are welcome.

DORIS Scientific Applications

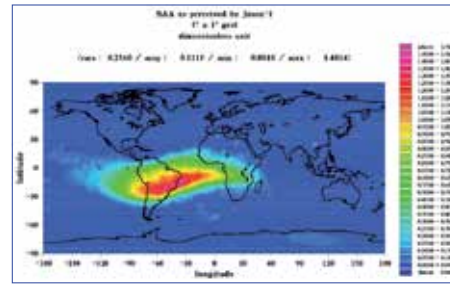
The DORIS system was primarily designed for the precise orbit determination required for observing the oceans using altimetry but it has also proven greatly valuable for applications in the solid earth and atmospheric sciences.



Time evolution of the latitude component of the DORIS station in Yellowknife, Canada

Some applications

- **Orbitography and navigation**
  - Precise Orbit Determination
  - Real-time orbit determination with the DIODE navigator
- **Geodesy and geophysics**
  - Measurement of the continental drift (contribution to tectonic models: ITRFVEL, GEODVEL),
  - Monitoring the geophysical deformations (eg. Volcanic deformation in Socorro, Mexico),
  - Measurement of ice movement (Sorsdal glacier's drift in Antarctica),
  - Contributing to the international terrestrial reference frame (eg. ITRF2008),
  - Determination of the rotation and the gravity parameters of the Earth
- **Altimetry and oceanography**
  - Monitoring stations heights for altimetry/tide gauges
- **Atmospheric sciences**
  - Tropospheric sounding: estimation of Zenithal Total Delays
  - Map of the South Atlantic Anomaly at the altitude of Jason
  - Ionospheric sounding: estimation of the Total Electronic Content,
  - Scintillations studies (e.g. CITRIS =scintillation and tomography receiver in space)
- **Time transfer**
  - Contribution of the DORIS/Jason-2 ultra-stable oscillator to the T2L2 experiment (Time Transfer by Laser Link)



Map of the relative SAA dose exposure perceived by Jason-1 (Lemoine and Capdeville, 2006)

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