The Contribution of DORIS to Space Geodesy

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Outline

- **I. Introduction**
  - DORIS as a geodetic technique.
  - Description of Ground Segment.
  - Description of Space Segment.
  - System Advantages.
- **II. International DORIS Service**
  - Organization.
  - Analysis Centers.
  - Data Centers & Data Flow.
  - Products.
- **III. Science Results**
- **IV. Current Activities.**

What is DORIS?

I. DORIS = Doppler & Radiopositioning Integrated by Satellite.

II. Dual-Frequency Doppler Beacons (2.036 Ghz & 401.25 Mhz), Distributed Around the World.

III. Developed by the CNES (Centre National d'Etudes Spatiales) & IGN (Institut Géographique National).

IV. The network was developed to support Precision Orbit Determination (POD) for LEO satellites, such as the SPOT Remote Sensing Satellites & Altimeter Satellites such as TOPEX/Poseidon.

V. The oldest sites in the network have been occupied since the late 1980's (DORIS data are routinely available since 1992, or the launch of TOPEX/Poseidon).

DORIS System Schematic

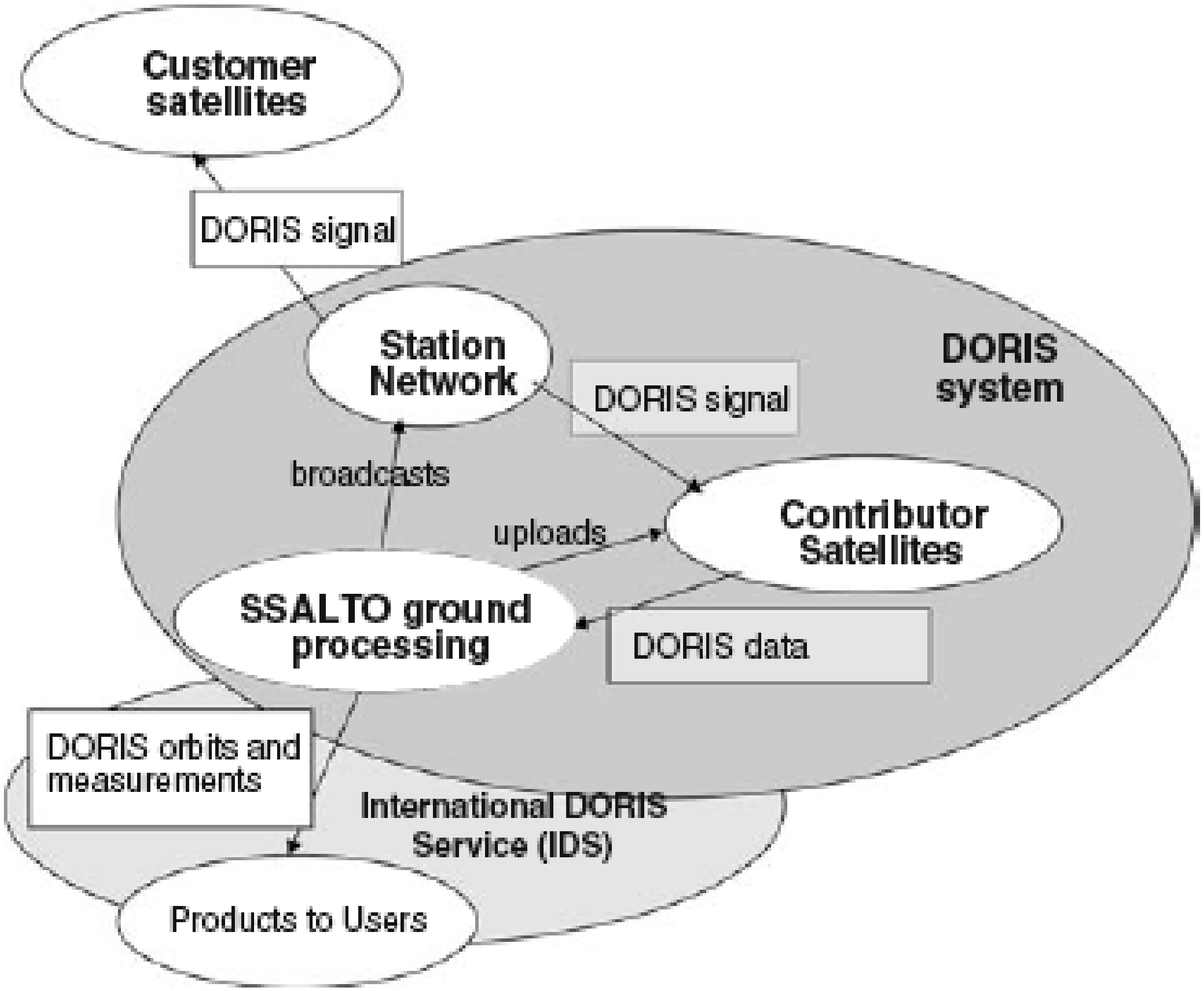
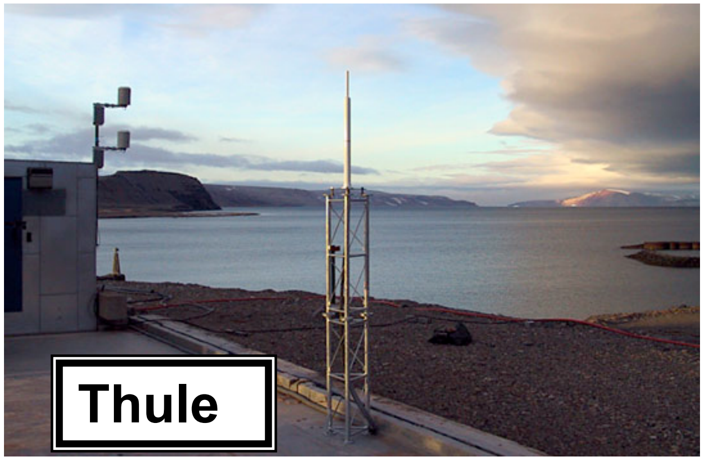


Fig. 1 The DORIS system: external and internal connections

(Figure from Jayles et al. 2006)

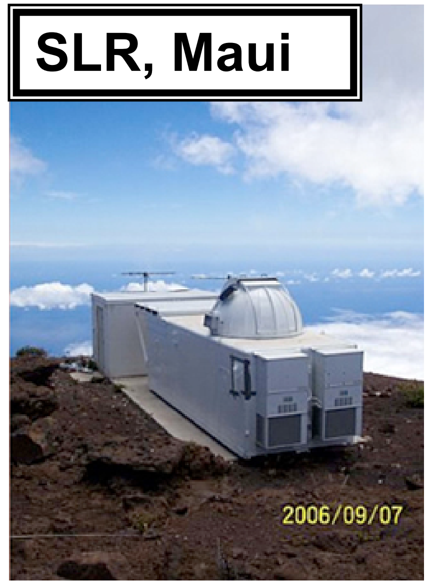
Geodetic Networks are the cornerstone of the Global International Terrestrial Reference Frame

DORIS

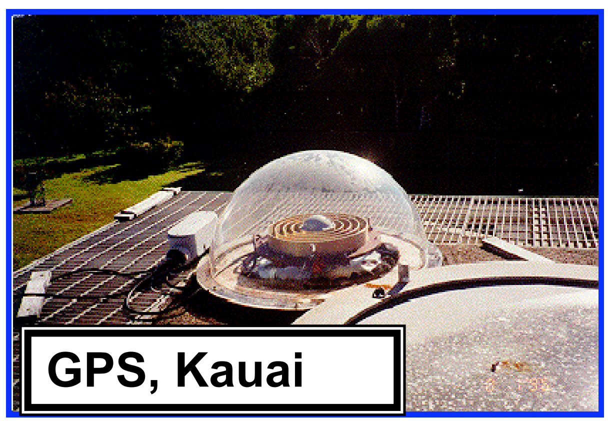


Rothera

Satellite Laser Ranging (SLR)



GPS



VLBI

VLBI, Hartebeesthoek

DORIS Ground Network *(as of June 2008)*

DORIS Satellite Receivers

DORIS antenna

2 kg
h 420 x ϕ160
(mm)

(Table from Jayles et al. 2006)

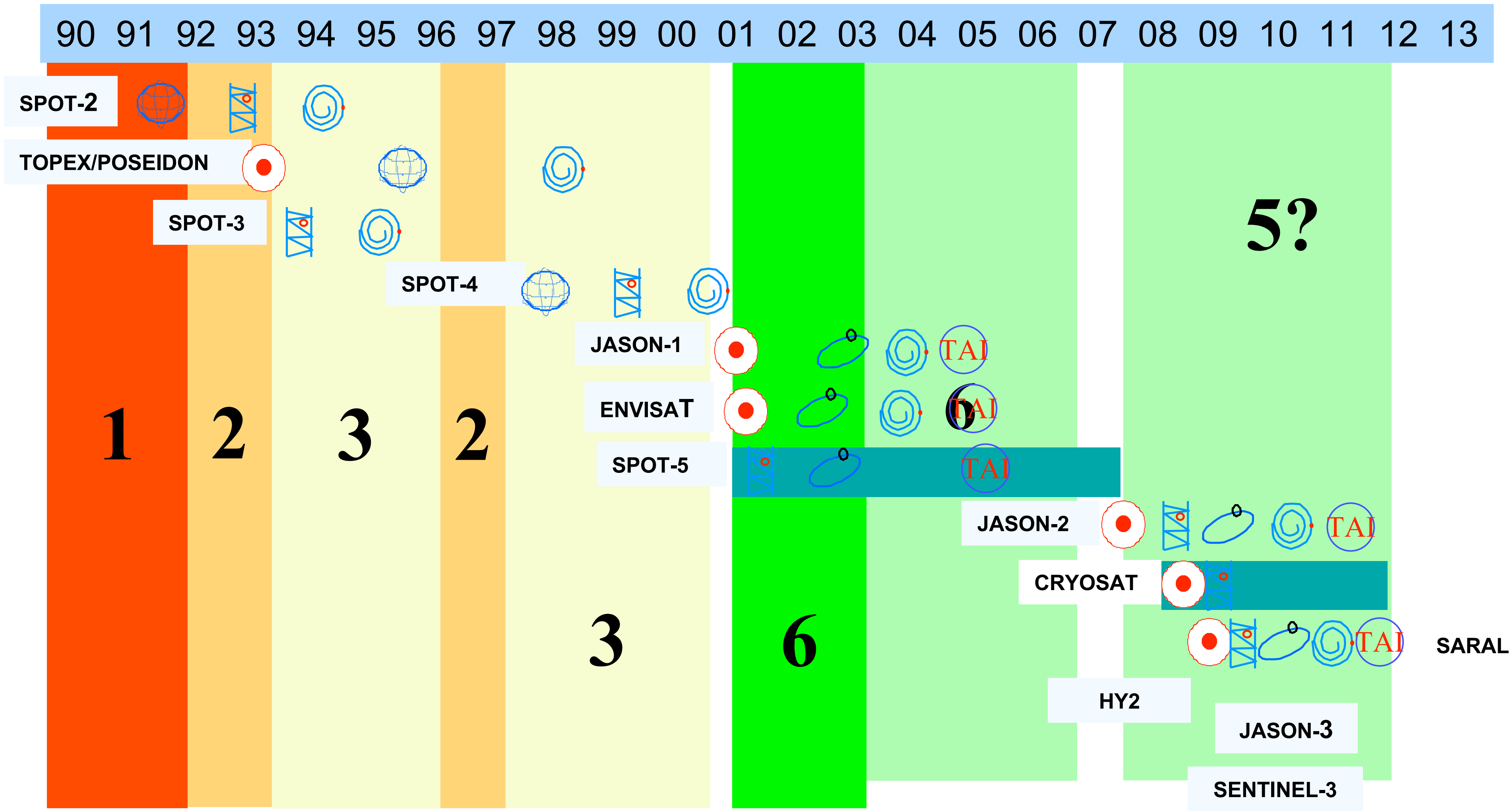
1st generation (WBUT = 18 kg)	2nd generation (WBUT = 5.5 kg)	2nd generation miniaturised (WBUT = 3 kg)
SPOT2, SPOT3, TOPEX-Poseidon (*), SPOT4	ENVISAT (*)	Jason-1 (*), SPOT5
1 channel	2 channels	2 channels

Intermediate DGXX (WBUT = 3 kg)	Full DGXX generation (WBUT = 1.15 kg)
CryoSat (*)	Jason-2, Pléiades, AltiKa
2 channels	2 x 7 channels
	twinned (redundant) in one box including USOs and automated antenna switching

1st. Generation receivers can track one beacon at a time; 2nd generation can track two beacons; Jason-2 & later can track up to seven beacons.
(*Therefore much more tracking data is available from ENVISAT & SPOT5 & Jason-1 than on SPOT2 & TOPEX/Poseidon*).

DORIS Satellite Constellation

(number of satellites & Year of Launch)



Co-locations

DORIS Network

- **57 stations (49 Third generation beacons): Homogenous global coverage.**
- **Improved long term stability of the antenna reference point.**
- **Co-location with other IERS techniques.**
    - **GPS, 37; SLR, 9; VLBI, 7.**
- **Co-location with tide gauges (sea level monitoring)**
    - **23 stations**

Satellite co-location

- *Past*: **TOPEX/Poseidon (SLR, Demonstration GPS)**
- *Current*: **Jason-1 (SLR, GPS), ENVISAT(SLR)**
- *Future*: **Jason-2 (SLR, GPS), CryoSat-2 (SLR), SARAL (SLR)**
- *Possible*: **Jason-3 (SLR, GPS), HY-2A (SLR , GPS), Sentinel-3 (SLR)**

IDS Activities

- IDS accepted as service of the IAG (July 2003).
- Station renovation has substantially improved the DORIS network since its inception in the 1990's. New requirements implemented for station quality and monument stability.
- Groups that contribute products on a regular basis:
  IGN, INASAN, LEGOS/CLS, SSALTO.
- **<u>New Analysis Centers</u>: GOP (Geodetic Observatory Pecný, Czech Republic), 2007; ESOC (European Space Operations Center, Darmstadt, Germany), 2008.**

- Other associate or candidate AC's: IAA, Geoscience Australia.
- Contribution to ITRF2005 (*JoG: Altamimi et al., 2006*).
- Special Issue: Journal of Geodesy, Volume 80(8-11): Published November 2006. ***The other technique services (IVS, IGS, ILRS) have since "copied" IDS and arranged for their own technique special issues in the JoG!***

CURRENT IDS PRODUCTS

Product	Present AC	Previous AC (no recent solution)	Combined product
Cumulative solutions (pos./velocities)	IGN; LEGOS/CLS		No
Weekly series	IGN; INASAN; LEGOS/CLS; SSALTO; GOP*	SOD GSFC (1 yr)	-Operational (No). -Testing in progress (Valette et al., 2008, EGU, 2008)
Monthly series		IGNL INASAN LEGOS/CLS SSALTO	No
STCD	IGN; LEGOS/CLS; INASAN; SSALTO		
Geocenter	IGN; LEGOS/CLS; INASAN		No
EOP	IGN; INASAN		No
Orbits	LEGOS/CLS		No
Ionosphere	SSALTO		No

DORIS Data at the IDS Data Centers from Existing or Past DORIS Satellites

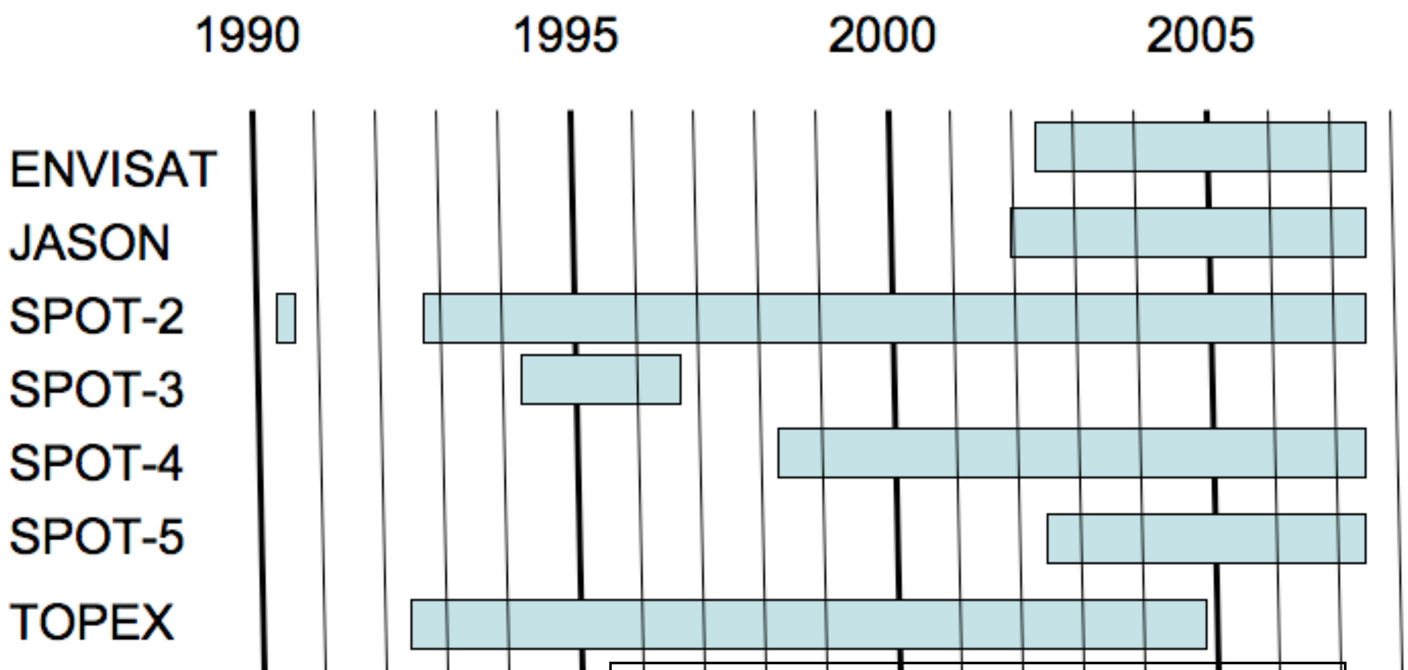
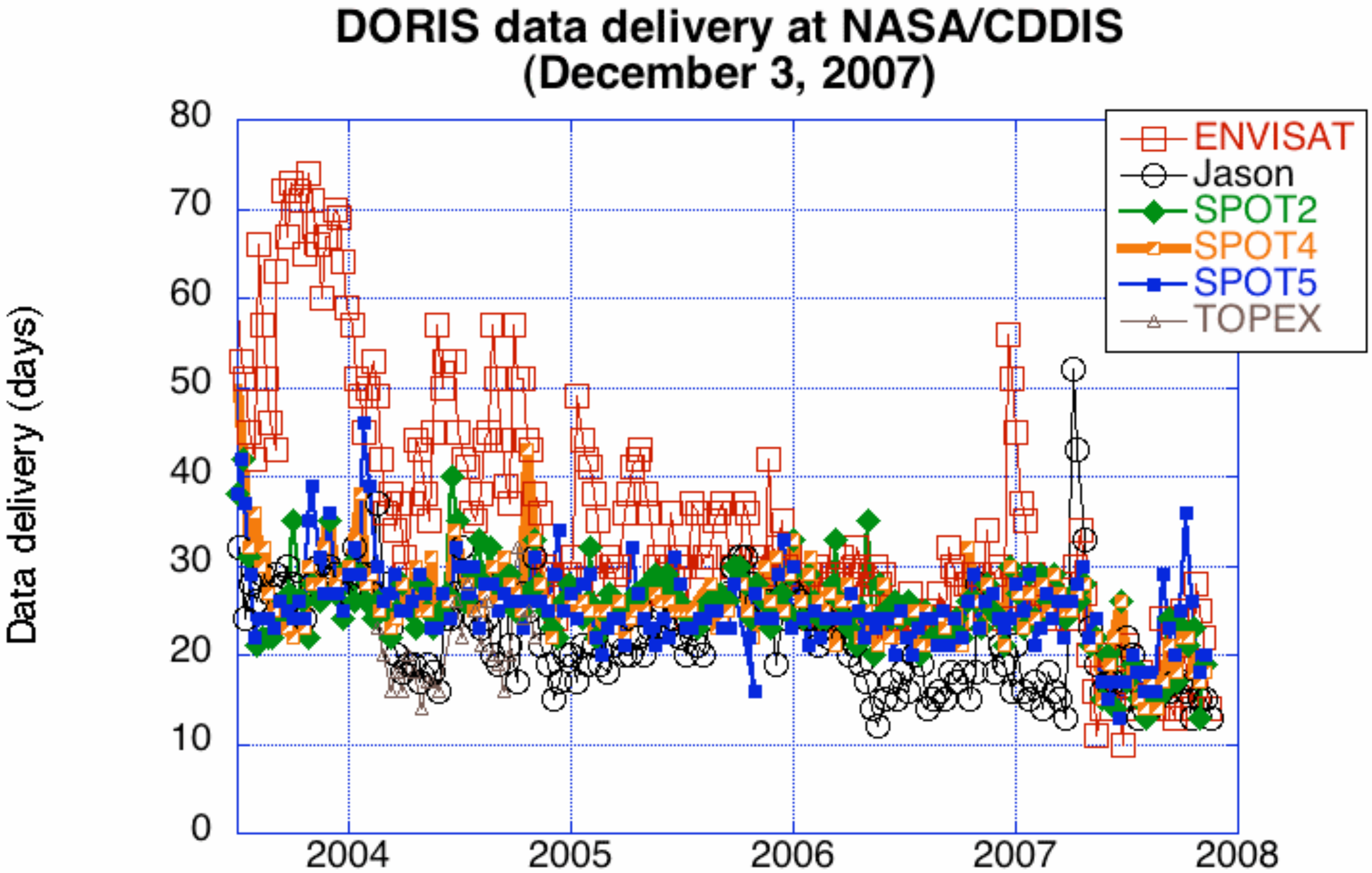


Figure From CR Geoscience, Willis et al. 2007

IDS Data Centers:

- CDDIS (*NASA GSFC, Greenbelt, Maryland, USA*.
- IGN (*Institut Géographique National, FRANCE*)

INTERNATIONAL DORIS SERVICE



• Latency of data delivery due to current processing streams for DORIS data.
• New software & data format (RINEX-style) will ensure more rapid data delivery after June 2008 for Jason-2 & future satellites.

Weekly DORIS SINEX Solutions Available at the IDS Data Centers

(as of August 2007).

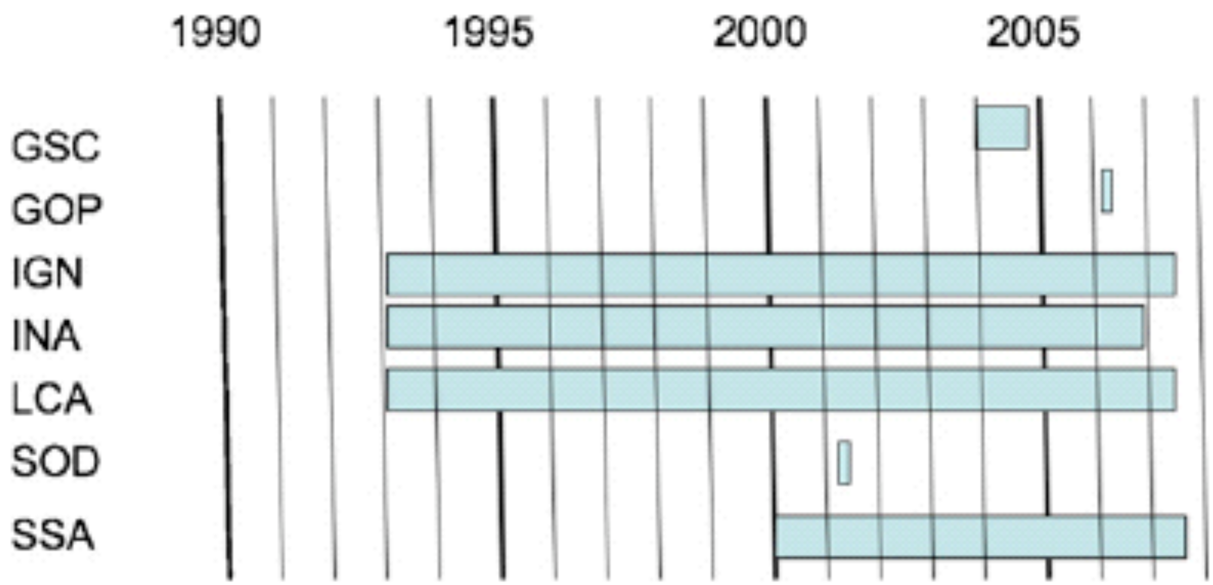
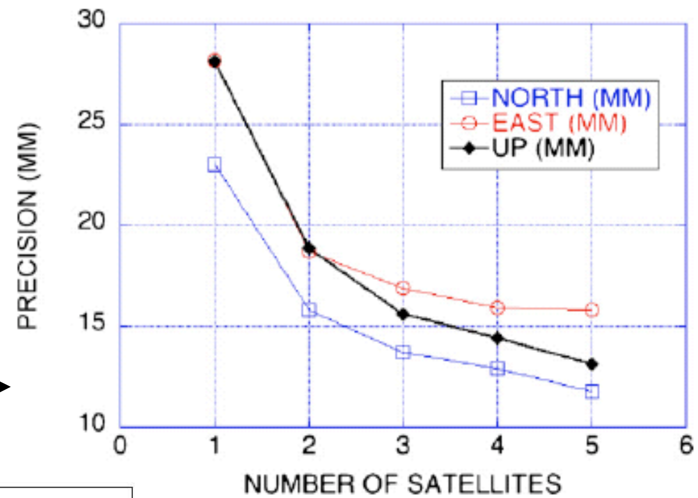


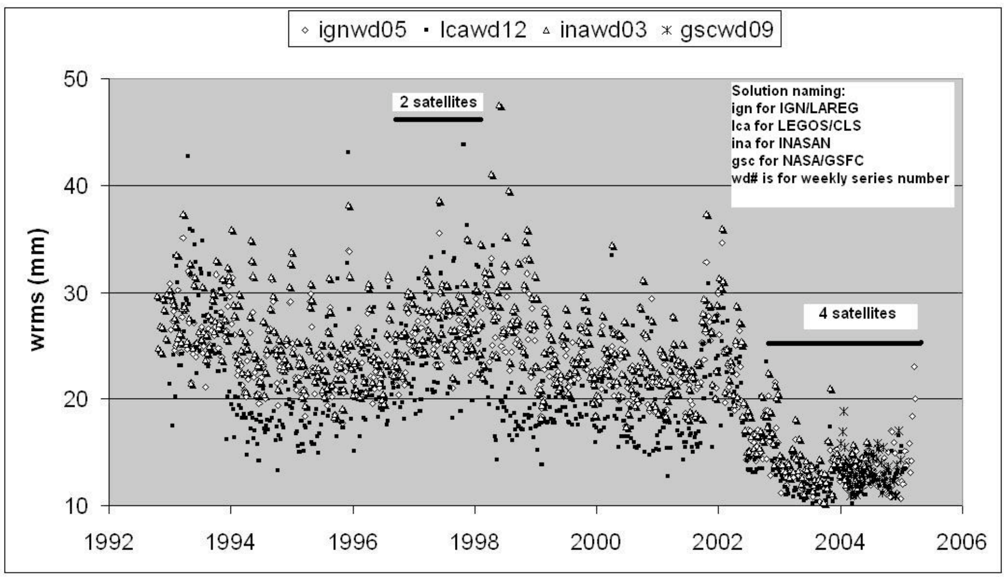
Figure From CR Geoscience, Willis et al. 2007

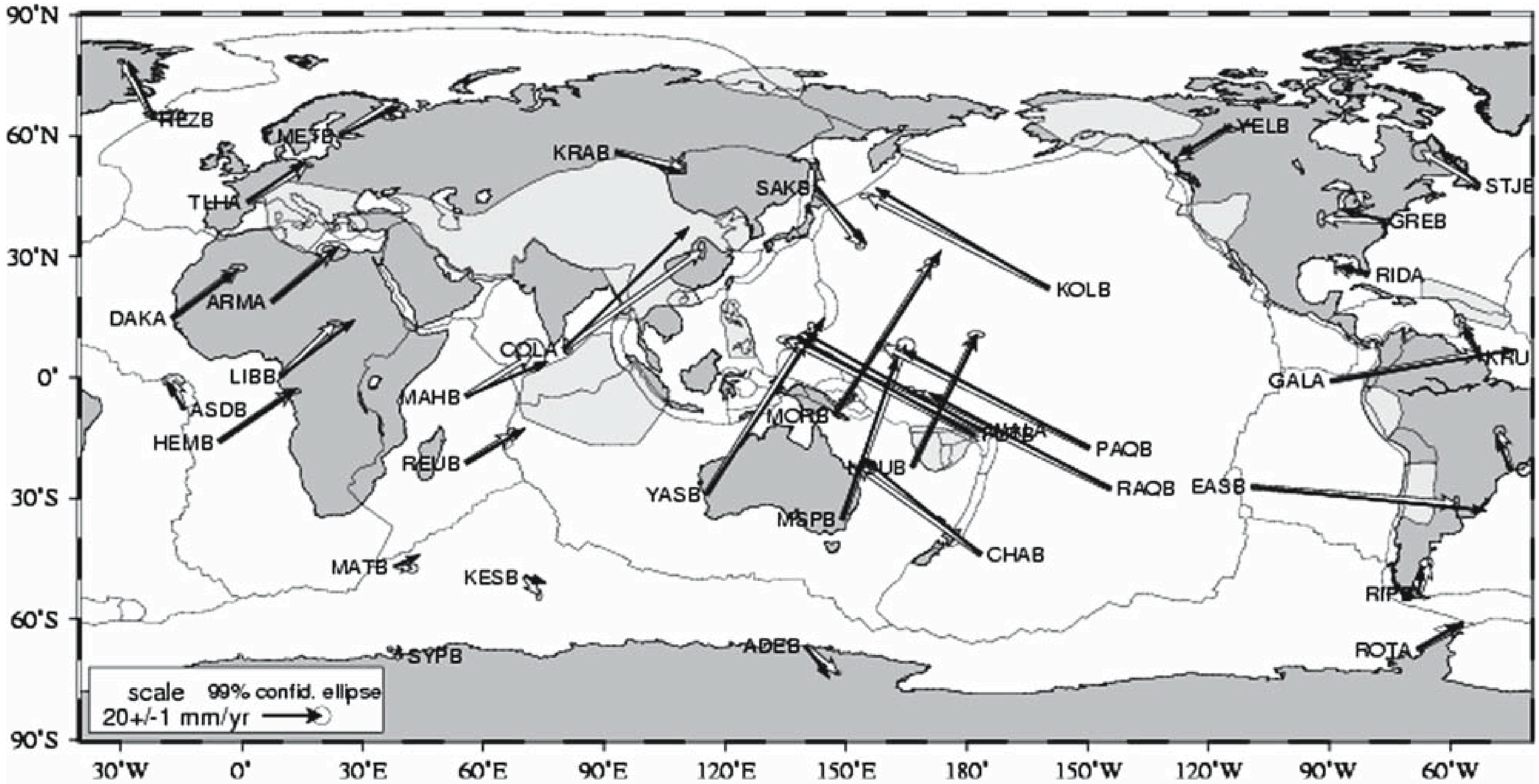
Number of DORIS Satellites in SINEX Solutions Affects Geodetic Positioning Quality

DORIS positioning precision w.r.t the number of satellites used - for one week in February 2004.
(CR Geoscience Willis et al. 2007)



Weighted RMS of the individual weekly series combinations.
(J. Geodesy, Tavernier et al., 2006)

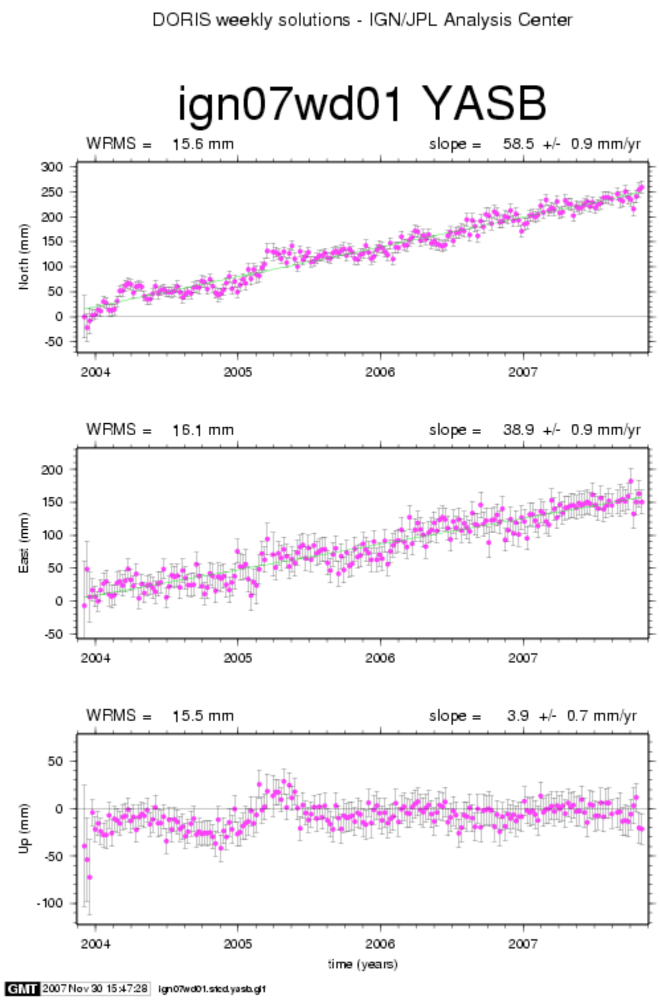




Horizontal velocity of 37 DORIS sites located in stable plate interiors - Velocities expressed in ITRF2000.

Figure from Soudarin & Cretaux, JoG, 2006)

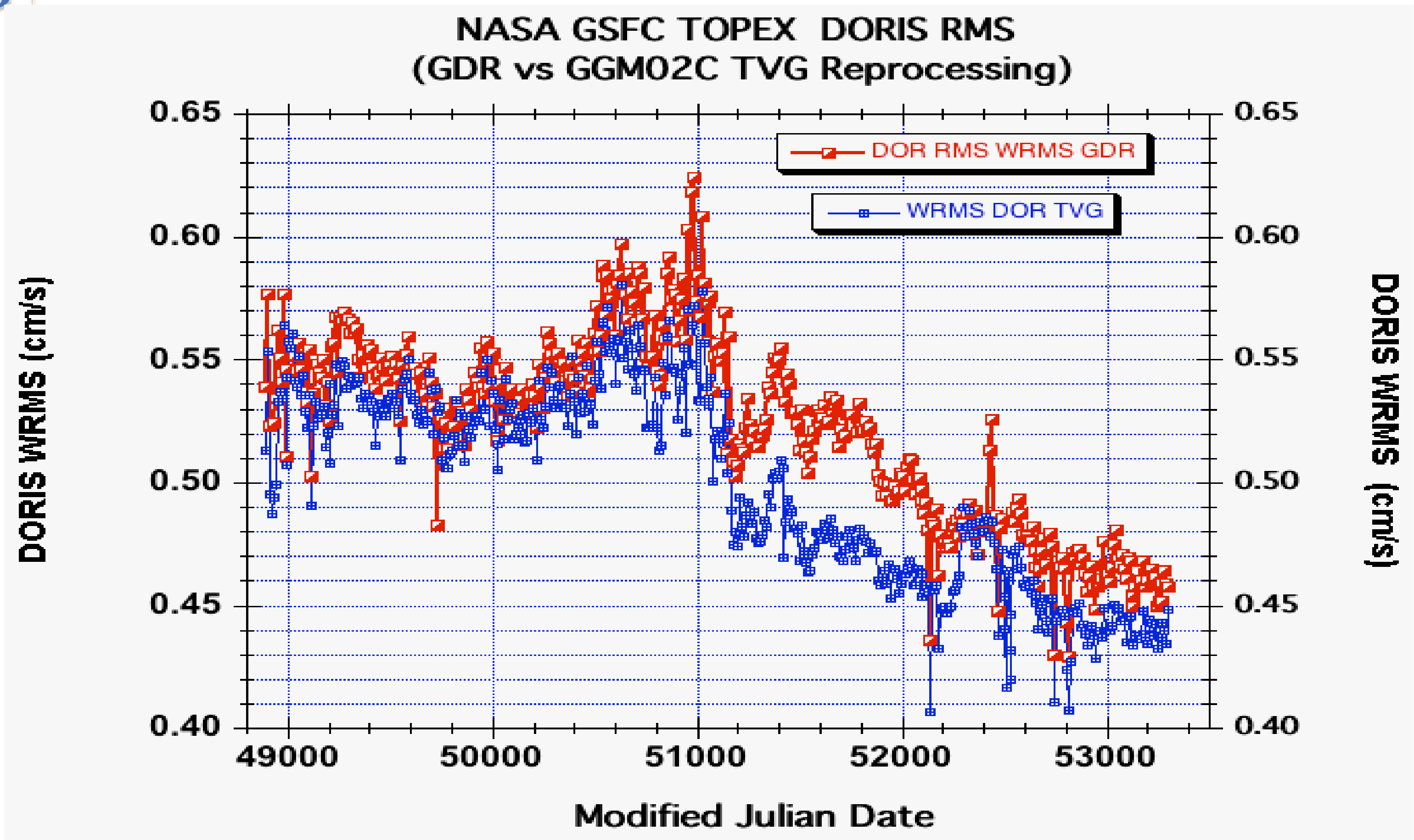
Station Position Coordinate Differences (STCD) (http://ids.cls.fr/html/doris/ids-station-series.php3)



Station Coordinate Differences (STCD) (YASB, DORIS vs. YAR2 GPS)

Series	Latitude	Longitude	Height
IGN ign07wd01	58.5 ± 0.9 mm/yr	38.9 ± 0.9 mm/yr	3.9 ± 0.7 mm/yr
LCA lca05md01	50.4 mm/yr	37.1 mm/yr	5.6 mm/yr
INA ina07wd01	45.6 ± 1.5 mm/yr	28.4 ± 3.1 mm/yr	4.9 ± 1.7 mm/yr
GPS Heflin et al. 2007.6	58.14 ± 0.03 mm/yr	38.61 ± 0.05 mm/yr	1.91 ± 0.11 mm/yr

DORIS Evolution from TOPEX analysis



The network upgrade (new antennae, more stable & robust monumentation & other improvements) is evident in the TOPEX *(& SPOT-2, not shown)* **DORIS data quality improvement with time.**

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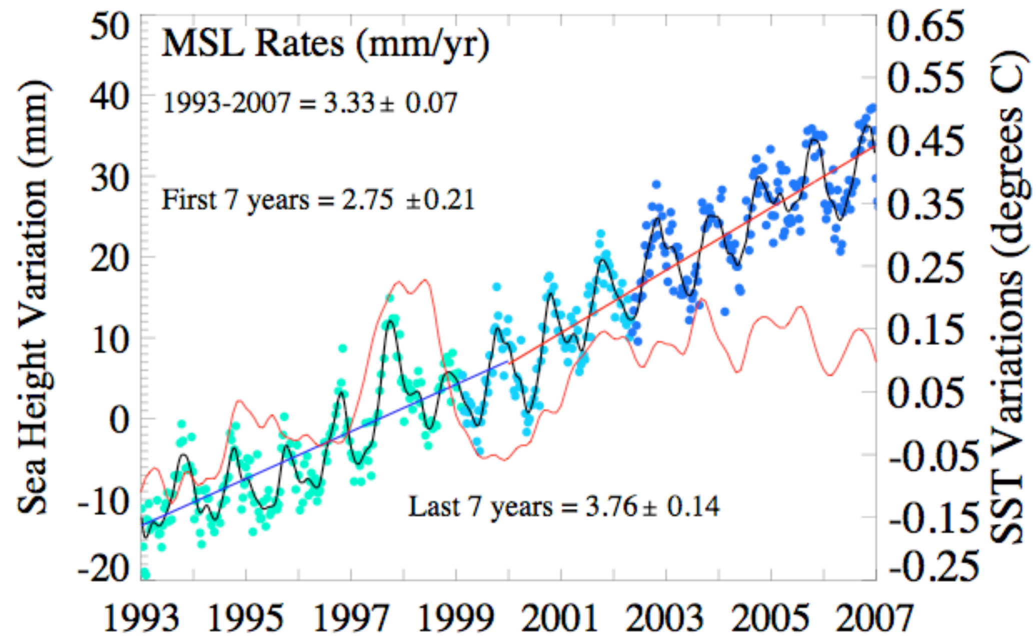
Global Mean Sea Level Trends from TOPEX and Jason-1 Altimetry (an example) - Computed Using Orbits that Result from Joint Analysis of SLR & DORIS Tracking Data

Global Computation of MSL change from satellite altimetry requires precise orbits (eg from SLR, DORIS & GPS) and a robust and stable terrestrial reference frame (using the geodetic network data to compute a reference frame realization)



B. D. Beckley, F. G. Lemoine, S. B. Luthcke, R. D. Ray, and N. P. Zelensky , A reassessment of global and regional mean sea level trends from TOPEX and Jason-1 altimetry based on revised reference frame and orbits, ***Geophys. Res. Lett.***, **34, 2007**.

DORIS

WITHOUT SLR & DORIS TRACKING - MSL Rates from Satellite Altimetry using T/P & Jason-1 could not be computed.

TEST AC SINEX Submissions in Preparation for ITRF2008

(since ITRF2005)

AC	solution	software
IGN	ign (wd05)	GIPSY/OASIS
LEGOS/CLS	lca (wd18)	GINS/DYNAMO
INASAN	ina (wd03)	GIPSY/OASIS
PECNY	gop (wd03)	BERNESE
Geosc. Aus	aus (wd02)	GEODYN

1. SINEX Submissions Also anticipated from ESOC.
2. IGN, LCA & GOP processed the ENVISAT and SPOT(2,4,5) satellite data.
3. INA also processed the Jason-1 satellite data.
4. Geosc. Aus. processed SPOT(2,5), Jason-1 & ENVISAT.

DORIS AWG Meetings in Paris, March 13-14 & June 5-6, 2008 to Prepare for ITRF2008

IDS AC Orbit Intercomparison Results

(Part of Preparation of ITRF2008, for orbits compared in 2005)

Satellite	RMS, Radial, rm	RMS, Cross-tr., cm	RMS, Along-tr., cm
ENVISAT (w. INA2 & LCA3)	1.5	3.3	5.5
SPOT2 (w. INA2)	1.6	4.2	7.5
SPOT4 (w. INA2)	1.5	4.5	6.6
SPOT5 (w. INA2)	1.3	4.5	6.9

Overall inter-center orbit consistency is good: < 2 cm (radially).
Systematic orbit differences revealed by AC or by satellite in some cases led to identification of anomalies and processing improvements.

Conclusion

DORIS as a geodetic observing system is at a crossroads. It has achieved a level of maturity in the quality of the products that it produces. We must focus on the technical issues (e.g. modelling differences between centers) and operational issues in order to continue to refine and improve the contribution DORIS makes to satellite geodesy.

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More Information

IDS Website: http://ids.cls.fr

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DORISMAIL (Regular mails on DORIS) issues.

ANALYSIS FORUM: Email: ids.analysis.forum@cls.fr

Data Centers: ftp:// cddis.gsfc.nasa.gov/pub/doris

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NASA

INSTITUTE OF ASTRONOMY RUSSIAN ACADEMY OF SCIENCES

GO PECNY VÚGTK

IPGP INSTITUT DE PHYSIQUE DU GLOBE DE PARIS

IGN INSTITUT GEOGRAPHIQUE NATIONAL

CLS COLLECTE LOCALISATION SATELLITES