DORIS weekly solutions
Status report and open problems

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Abstract
Since the official start of the International DORIS Service (IDS) in 2003, several Analysis Centers have submitted time series of station coordinates in SINEX format. We discuss here the different DORIS weekly solutions available for ITRF2004 and for the IERS Combination Campaign Project. More specifically, we investigate current problems (either DORIS-specific or common to all IERS techniques) as well as open issues. We show that more technical discussions are currently needed between Analysis Centers generating weekly DORIS solutions as well as with the Combinations Centers, either doing an intra-technique combination (DORIS alone) or an inter-technique combination (DORIS with other IERS techniques).

1. Introduction

In July 2003, the International DORIS Service (IDS) was officially recognized as a new Service of the International Association of Geodesy (Tavernier et al. 2005), in a way following the example set up for GPS by the International GNSS Service (IGS) (Beutler et al. 1999). One of the major goals of these services is to provide geodetic results of sufficient accuracy to properly maintain the Terrestrial Reference Frame (TRF). In the past, the International Terrestrial Reference Frame (ITRF) was based on a combination of station positions and velocities with full covariance information (Altamimi et al. 2002). More recently, it seemed more optimum to directly combine time series of weekly station coordinates solution, instead of combining station coordinates and velocities (Altamimi et al. in press). This led to a new call for participation for the near-to-come ITRF2004 (Altamimi in press).
The goal of this paper is to present the current DORIS time series of weekly station coordinates that are currently available for scientific uses at the NASA/CDDIS data center of the IDS and to discuss some open questions related to generation or use of these time series.

2. Available DORIS weekly solutions at the International DORIS Service

Table 1 presents the list of all available DORIS weekly time series (station coordinates) available through the IDS. These weekly solutions are in fact all quite different in nature. Only the Institut Geographique National / Jet Propulsion Laboratory = IGN/JPL (Willis and Heflin 2004; Willis et al. 2005) and the Laboratoire d'Etude en Geophysique et Oceanographie Spatiales / Collecte Localisation par Satellites = LEGOS/CLS solutions (Soudarin and Cretaux submitted) will be

considered for ITRF2004, as they provide independent long time series in free-network or loosely constrain solutions.

Acronym	Analysis Center	Software	Series	Files	Latest data	Type
GSC	GSFC	GEODYN	WD02	53	Dec 26, 2004	Loose constrains
IGN	IGN-JPL	GIPSY-OASIS	WD04 WD05	658 658	Aug 7, 2005 Aug 7, 2005	Free-network ITRF2000
INA	INASAN	GIPSY-OASIS	WD04 WD05	609 609	Jun 13, 2004	Free-network ITRF2000
LCA	LEGOS-CLS	GINS-DYNAMO	WD12	630	Jan 23, 2005	Loose constrains
SSA	CNES	ZOOM	WD01	209	Jan 23, 2005	ITRF2000

Table 1. DORIS weekly solutions available at the IDS NASA/CDDIS Data Center (September 21, 2005). http://cddis.gsfc.nasa.gov/pub/doris/products/sinex_series

The Goddard Space Flight Center (GSFC) solution consists of one year of data (2004) realized for test purposes and is equivalent in terms of precision to the 2 other time series. It is expected that this series will be expanded in the future to a much larger data set, in cooperation with Geoscience Australia. The INASAN solution is almost directly derived from the IGN/JPL solution (same software package and analysis strategy) and cannot really be considered as independent. The Centre National d'Etudes Spatiales (CNES) solution cannot be used at all for ITRF2004, as it is computed using a Point Positioning Technique (PPP) (Zumberge et al. 1997) and no covariance information is provided between station coordinates. However, this solution can be provided ahead of time of the other as it is computed at CNES in Toulouse sometimes even before the DORIS data distribution to IDS users.

It must also be noted that IGN/JPL and INASAN provide for every week two different solutions: the first one is expressed in free-network and can directly be used for combination (ie. intra-technique or inter-technique such as ITRF2004), the second one has been projected and then transformed using a standard 7-parameter technique into ITRF2000 and can directly be used by geophysicists.

All Analysis Centers (ACs) weekly solutions are provided on a different timetable. Figure 1 shows the delivery delay (time interval between the availability of the weekly solution at NASA/CDDIS and the epoch of the last DORIS data used) for different weekly solution since mid-2003.

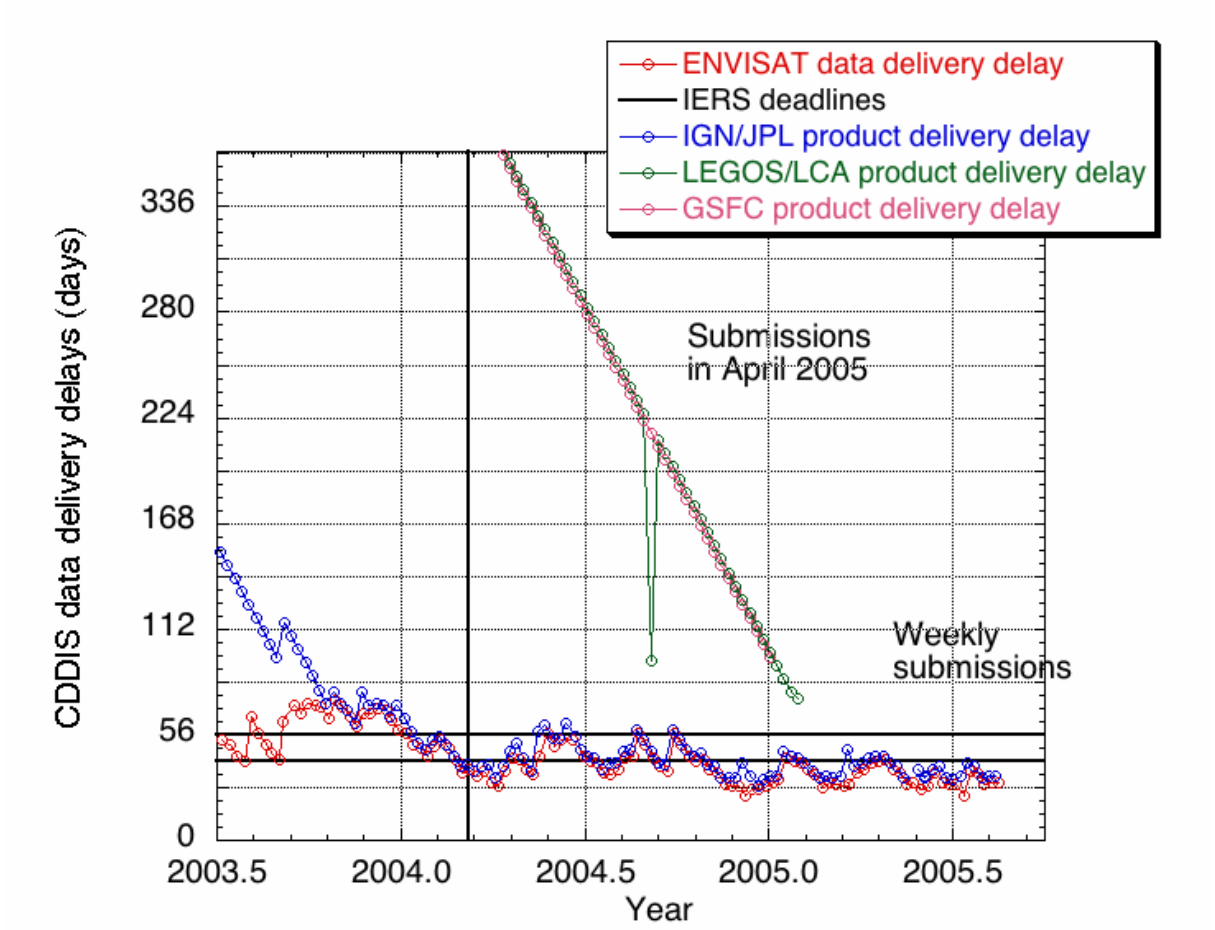

Figure 1. Delivery at the NASA/CDDIS Data Center of recent DORIS weekly station coordinate solutions in SINEX format (September 21, 2005)

It can be seen that the IGN/JPL AC is the only one that presently process the data on a regular weekly basis and fulfills the IERS CPP requirements (maximum of 4 to 6 weeks delay). DORIS data are processed at JPL the same day they are delivered by CNES at the NASA/GSFC data center. Solutions are submitted as soon as DORIS data from the last satellite (most of the time ENVISAT) is available. Other ACs process several months or years of data at once and then submit all relevant weekly solutions on the same day.

3. DORIS station-related problems

Recently several authors have shown that some DORIS station coordinates were affected by discontinuities related to Earthquakes or even some non-linearity effects related to post-seismic or volcanic activity (Willis and Sillard 1998; Cazenave et al. 1999). For a complete study of such problems, please see Willis and Ries, 2005 or Feissel-Vernier, 2005. These discontinuities are very important to take into account because otherwise derived velocity estimations would be significantly biased (Williams 2003).

Figure 2 shows an example of non-linearity in the case of the Amsterdam station (lat -37°48' deg, lon 77° 34' deg). This DORIS site has been occupied successively three times, using 3 different antennas: successive acronyms AMSA, AMSB, AMTB.

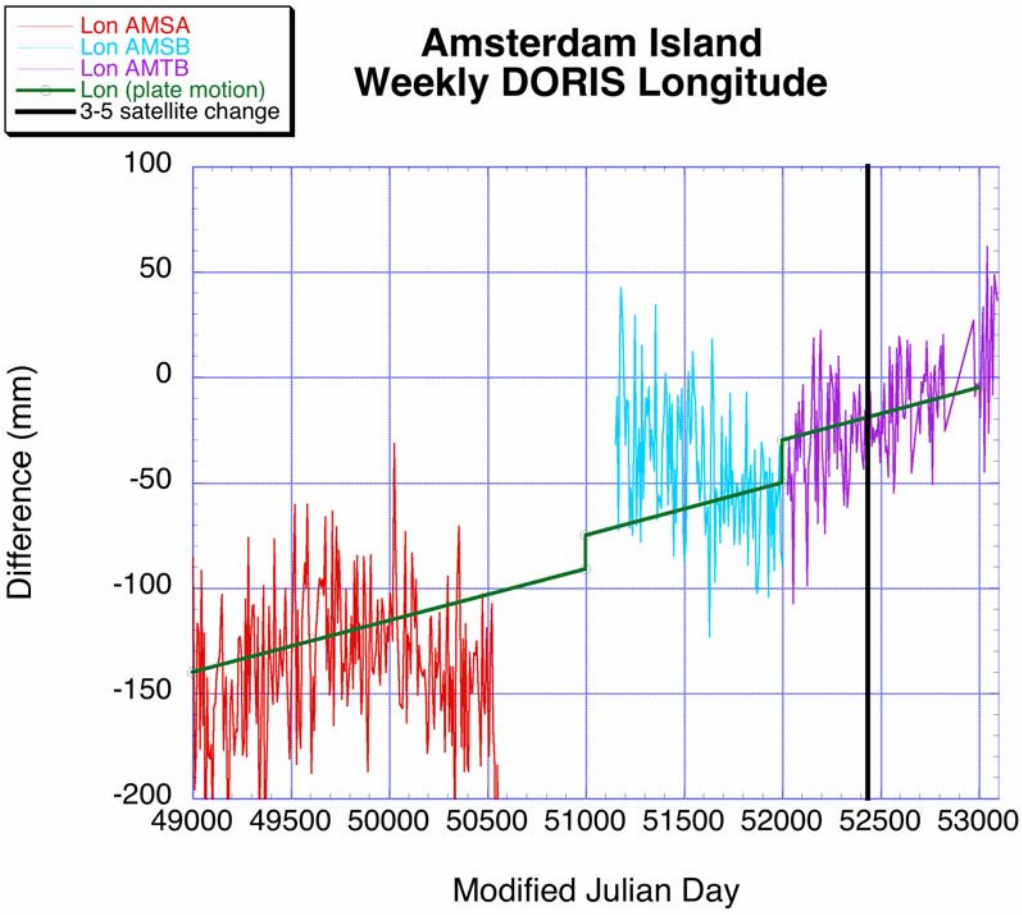

Figure 2. Antenna movement of the DORIS station in Amsterdam Island detected from IGN/JPL weekly time series of station coordinates

The non-linearity of this station is now fully understood. The metal strings were corroded by salt due to the difficult weather conditions on this remote island and the antenna became loose (end of AMSA observations and almost all AMSB observations), showing an additional velocity of 2 cm/yr when compared to the plate tectonic velocity. This is of course an extreme example, as all the other DORIS stations are better installed and regularly verified on site by a geodetic team (Fagard submitted). We would like to point out here that it is critical that all DORIS weekly solutions remove the Amsterdam station during the time of the antenna instability (Jan 1996 to March 2001). Even if one AC does not take this precaution, the whole combination will be affected and all results will be degraded for this station and most probably for surrounding stations.

4. How to find information concerning DORIS stations

Being aware of such possible DORIS station-related problem is critical for intra or inter-technique combinations. Fortunately, a lot has been done recently on that issue within the IDS and several sources of information can be used by the Combination Centers:

- Realization of the DPOD2000 network (Willis and Ries, 2005). This information is available on paper as well as in electronic form in text and SINEX format at NASA/CDDIS (ftp://cddis.gsfc.nasa.gov/pub/doris/general/dpod). Regular upfates are also available when new stations are brought into the DORIS network.
- Synthesis realized by the DORIS Analysis Coordinator (Feissel-Vernier 2005) at http://lareg.ensg.ign.fr/IDS/ITRF2004.html. This includes several documents and plots analsysis the station coordinate stability or discussing possible discontinuities
- Discussions on the IDS Analysis Forum (technical discussion for Analysis Ceneters and Combination Centers) at http://listes.cls.fr/wws/info/ids.analysis.forum. Regular technical discussions on all type of DORIS analysis issues.
- DORIS site logs describing in detail all successive occupations as well as collocation with other techniques at http://ids.cls.fr/html/doris:sitelog.html
- DORISMails (general information related to DORIS) at http://listes.cls.fr/wws/arc/dorismail

We hope that intra and inter-technique Combination Centers (CCs) will take profit of these different sources of information. These problems are not more frequent than for other techniques but they need to be accounted for, otherwise accuracy will be lost.

5. DORIS satellite-related problems

Recently, two problems were found related to DORIS satellites:

- In the case of Jason, an unexpected sensitivity to radiations corrupts the data, as the on-board oscillator is affected by a large acceleration when crossing the South Atlantic Anomaly (SAA) (Willis et al. 2004). If not taken into account estimated DORIS station coordinates in the SAA or closely by are strongly biased, leading to spurious velocities of several tens of centimeters per year. One DORIS AC is now proposing a correction model (Lemoine et al. submitted) that could be used for Precise Orbit Determination (POD) as well as geodesy. Presently, all DORIS weekly solutions presented in Table 1 are rejecting all Jason/DORIS data. If successful, this model could be used the IDS Acs to reprocess the Jason data.
- For SPOT4, a preprocessing error was recently discovered for all the 1998 data and some of the early 1999 data (Willis et al. in press). DORIS ACs that were recomputing phase center corrections (taking into account the vector between the satellite center of mass and the antenna phase center), were not affected (LEGOS/LCA, GSFC). However, ACs using directly the phase center correction provided in the DORIS data files (IGN/JPL, INASAN) were affected. The consequences was a small degradation in station coordinates but a large Z-geocenter bias of 60 cm when using only the DORIS/SPOT4 data and 20 cm when using the 2 other DORIS satellites (TOPEX/Poseidon and SPOT2) that were not affected by this error. In the most recent solutions (Table 1), these ACs were rejected all 1998 SPOT4 data because of this problem. Until now, these groups provide

solutions including data from 2 satellites (SPOT2 and TOPEX/Poseidon) instead of 3 during the while 1998 year, as they exclude SPOT4 data.

6. Open issues

As this problem is not fully understood, we were able to recomputed correctly the 1998 DORIS data. Figure 3 shows a comparison with the IGN04D02 DORIS cumulative solution (station positions and velocities computed over 12 years of data) for 2 different DORIS solutions: the current operational solution available at NASA/CDDIS using only the SPOT2 and the TOPEX/Poseidon DORIS data), the new solution using SPOT-4 data as well but recomputing the phase center corrections using the proper values.

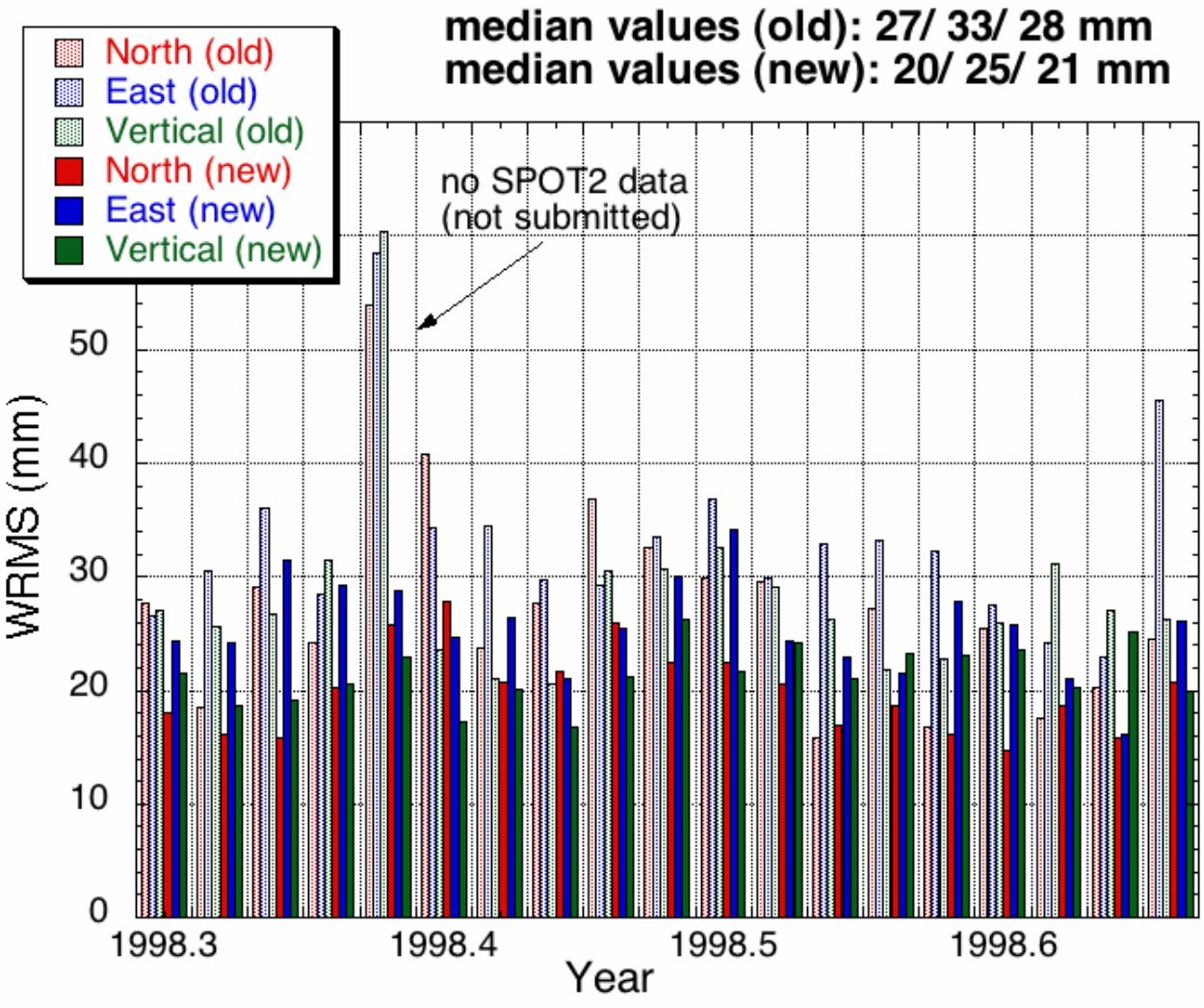

Figure 3. Improvement in the 1998 results of the IGN/JPL weekly time series of station coordinates when using the SPOT-4 DORIS data with proper phase center corrections

Figure 3 shows, as expected, a clear improvement in the station coordinate precision as 3 DORIS satellites were used instead of 2. What is not clear now is whether we should submit this new

solution for 1998 or whether we should wait for a complete recomputation of this time series to submit the 1998 results at the same time.

In general ACs have 2 options:

- constantly improving their time series in a “research-mode” by using a better processing strategy (the case described above for SPOT-4 being an extreme case) or
- using exactly the same processing for years ina “production-mode” but resubmitting a complete time series from time to time.

The first approach is the one usually used by the ACs (IDS and other techniques) as it allows a constant improvement of the results. However, as small improvement is constantly made (and not always documented), discontinuities in time series are more difficult to interpret. Inconsistencies are more likely to happen, reducing the confidence that changes are real. In some cases, specifically for geophysical investigations consistency may be better than chasing the best possible product.

On the other hand, some topics are still really open issues in the DORIS community. For example, recent studies (Willis et al. submitted) showed that the TRF scale factor derived from different ACs was different and showing some large software-related discrepancies (up to 5ppb). Some of these effects could be decreased to a much smaller level (0.5ppb) if some proper calibration towards ITRF would be applied by all ACs. However, the physics behind this parameter (related to the height of all DORIS tracking stations) would then be lost forever. The discussion on this specific aspect is far from being closed within the IDS.

7. Conclusions

Currently, 2 independent long-term DORIS weekly solutions are available through the IDS and therefore, no DORIS intra-technique combination is available (yet). However, some other groups have already delivered some weekly solutions in the past or intent to do so in the near future.
Recently, several authors have analyzed these DORIS time series, a lot of information is available for Combination Centers on that subject and should be used to maintain result accuracy. Some problems are DORIS-specific such as the sensitivity to radiation of the Jason on-board oscillator, or a preprocessing error in the early DORIS/SPOT-4 data. However, most problems are also common with other techniques such as GPS: how to handle station discontinuities, station non linearity, annual signals, satellite phase center issues, general analysis strategy (regular complete reprocessing vs. constant small improvement in the time series). These problems can only be solved by an improved between the technique Analysis Centers and the intra and inter-technique Combinations Centers. It is only under these conditions that an accurate ITRF2004 can be obtained.

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