
Recent Improvements in DORIS Data Processing at IGN in View of ITRF2008, the ignwd08 Solution

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Abstract

In preparation for the computation of ITRF2008, the DORIS IGN analysis center has undertaken the task of a complete reprocessing of all DORIS data from 1993.0 to 2009.0, using all available DORIS data as well as the most recent models and estimation strategies. We provide here a detailed description of the major improvements recently made in the DORIS data processing, mainly in terms of solar radiation pressure, atmospheric drag, gravity field, and tropospheric correction. We address here the impact of the new IGN time series (ignwd08) on geodetic products using comparison to the previous IGN solutions (ignwd04). In particular, previous artifacts, such as 118-day or 1-year periodic errors in the TZ-geocenter solution or in the vertical component of high latitude DORIS tracking stations, have now disappeared, leading to more precise and reliable time series of DORIS station coordinates. Finally, possible future improvements are discussed proposing new investigations for the future.

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6.1 Introduction

DORIS (Doppler Orbitography and Radiopositioning Integrated on Satellite) is one of the four geodetic techniques participating in the realization of the International Terrestrial Reference System (ITRS) (Willis et al. 2006). Figure 6.1 presents the current DORIS permanent network, demonstrating a dense and homogenous geographical distribution of 57 tracking stations (Fagard 2006).

Since 2003, an International DORIS Service (IDS) was created in order to foster international cooperation (Tavernier et al. 2002; Willis et al. 2010a). The Institut Géographique National (IGN) is one of the seven IDS Analysis Service, providing products on a weekly basis (Willis et al. 2010b). In preparation of ITRF2008 (Altamimi and Collilieux 2010), a new DORIS time

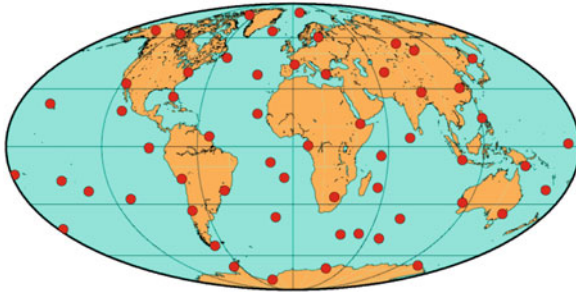


Fig. 6.1 DORIS permanent tracking network (as of September 2009)

series (ignwd08) was reprocessed using data from 1993.0 to 2009.0. Since then, new IGN weekly solutions using the same processing strategy are regularly delivered at the IDS data center, on average once a week.

The goal of this article is to present the major differences in terms of data analysis between this new reprocessed solution (ignwd08) and the previous DORIS solution (ignwd04), and to provide an overview of current available geodetic products from the IGN Analysis Center (AC): weekly time series of station coordinates, velocity field, terrestrial reference frame and polar motion.

6.2 DORIS Data Analysis

Table 6.1 summarizes the main differences between the ignwd04 and the ignwd08 analysis strategies. A more recent GGM gravity was used (Tapley et al. 2005). C21 and S21 rates were corrected to follow the IERS 2003 conventions (McCarthy and Petit 2004). No annual correction was taken into account in the gravity field coefficients.

Using the more recent GMF mapping function (Boehm et al. 2006) allowed us to use DORIS data at a lower elevation without any drawback. Following recent investigations (Gobinddass et al. 2009a, 2009b), solar radiation pressure models were rescaled using a constant empirical parameter per satellite. Atmospheric drag parameters were reset every 1-hour for the SPOT and Envisat satellites (Gobinddass et al. 2010). This new strategy can be used for all days, even during high geomagnetic activity (Willis et al. 2005a). For the previous ignwd04 solution, a specific strategy was earlier required

Table 6.1 Main differences in models and analysis strategies used for the two latest DORIS/IGN weekly solutions

Model/strategy	ignwd04	ignwd08
Gravity field	GGM01C	GGM03S
Tropospheric mapping function	Lanyi	GMF
Elevation cut-off	15°	10°
Solar radiation pressure coefficient	estimated	fixed
Atmospheric drag parameter	Reset/6h	Reset/1 h

(resetting the drag parameter for estimation every minute instead of every 6 h). This involved some non-automated processing for these few days, while the new procedure is fully automated.

6.3 Time Series of ignwd08 Station Coordinates

Unlike other IDS Analysis Centers, DORIS data are processed automatically as soon as they appear at the IDS data centers. Weekly station coordinates in SINEX format are available at these data centers within a few hours, and are provided in free-network (loosely constrained) for the IDS combination but also after projection and transformation in the latest ITRF solution (currently ITRF2005 but soon in ITRF2008 as this transformation is straightforward and does not require any DORIS data processing). These results are freely available to the scientific community at the following URL address for further geophysical investigations: <http://ids.cls.fr/html/doris/ids-station-series.php3>. This technique provides SINEX results for geodesists (including full covariance information in a loosely constrained terrestrial reference frame). It also provides tabulated results in STCD format (Noll and Soudarin 2006) for geophysicists directly expressed in ITRF2005 (Altamimi et al. 2007).

Figure 6.2 provides an example of such results for the Rio Grande station in Argentina. Different colors indicate the different occupations of this station, as related to equipment upgrades. The positions of successive occupation at the same site were tied together using geodetic local tie information. Smaller scatter after 2002.4 indicates an improvement in repeatability when 4 or 5 DORIS satellite are available. No large discontinuity can be noticed, showing a good

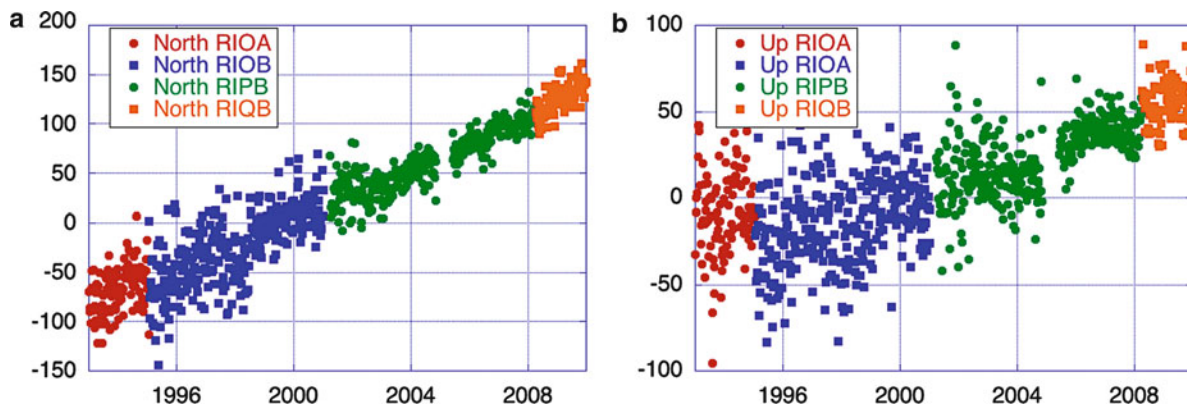


Fig. 6.2 Weekly time series of ignwd08 Rio Grande station coordinates expressed in ITRF2005 (from STCD files). In North (a) and Up (b) (in mm)

agreement between the DORIS results and the geodetic local tie vectors. However a closer inspection may indicate possible problem after first occupation or after data gap (vertical). The East component (not displayed here) is noisier due to the North-South tracks of the sun-synchronous satellites (SPOTs and Envisat), especially for mid-latitude stations.

Other authors already showed that previous artifacts in the DORIS time series at 118 days (TOPEX draconitic period) are no longer visible in the vertical component for the high-latitude station when solar radiation pressure models are empirically rescaled (Amalvict et al. 2009; Kierulf et al. 2009). The previous periodic effects visible in the ignwd04 time series were due to an improper handling of the solar radiation pressure (Gobinddass et al. 2009a, 2009b) and were observed in previous time series (le Bail 2006; Williams and Willis 2006) but were never fully appreciated. These problems were rather serious for altimetry as they affected mostly the Z-component of the stations, which is the major factor for mean sea level determination (Morel and Willis 2002, 2005; Beckley et al. 2007). Table 6.2 provides some information on annual signals present in DORIS/IGN time series in the polar region.

Table 6.2 demonstrates that the previous annual signals around 10 mm in the ignwd04 time series of vertical coordinates of high-latitude station are not present anymore in the new ignwd08 time series. Currently observed annual signals around 3 mm could easily be explained by real geophysical reasons, as geocenter motion is estimated to be at this level.

Table 6.2 Amplitude of annual signals in DORIS vertical time series (in mm)

Station	Lat (deg)	ignwd04	ignwd08
SPJB	78°55'	13.7	2.7
THUB	76°32'	11.6	2.7
ADEA	-66°40'	3.4	1.9
ROTA	-67°34'	6.6	3.0
SYOB	-69°00'	6.5	3.9
BEMB	-77°52'	11.2	5.0

A similar problem was also previously detected at 1 year (draconitic periods of SPOT and Envisat, being sun-synchronous satellites) and also disappeared in this new ignwd08 solution (Willis et al. 2010b).

6.4 ign09d02 Derived Velocity Field

At regular intervals (every 6 months to 1 year), we also stack all the available DORIS weekly solutions and provide a cumulative position and velocity solution, making full use of geodetic local ties between successive DORIS occupations, using proper a priori variance, as provided by IGN.

The latest IGN velocity field (ign09d02) available at both IDS data centers (CDDIS in USA and IGN in France). In most cases, these results can be explained by plate tectonics (Soudarin and Crétaux 2006; Argus et al. 2010). However, in other cases, such as the Socorro Island (Mexico), the station displacement is not linear and can be attributed to local volcanic deformations (Briole et al. 2009). While GPS is the

key player for geodynamics due to its easy densification, DORIS may still have a role to play in a few cases such as Africa where the geodetic infrastructure is still sparse (Nocquet et al. 2006; Argus et al. 2010).

We do not estimate the DORIS-derived velocity more often than every 6 months, as a large number of DORIS observations is already available (16 years) For most stations, formal errors of 0.15–0.30 mm/yr are typical.

6.5 Terrestrial Reference Frame

As our DORIS weekly solutions are provided in free-network form, we can compute for each week the 7-parameters for the TRF (origin, orientation and scale), looking at the best transformation fit into the ign09d02 position/velocity solution already aligned on ITRF2005, but including all DORIS stations.

Figure 6.3 displays results for the ignwd08 weekly scales with respect to ITRF2005. No antenna map correction was used for DORIS (Willis et al. 2005b) to map these results toward any ITRF. While the weekly scatter is small, a significant drift can be seen toward ITRF2005 realization. This is currently visible in all results from all DORIS Analysis Centers, sometimes with lower values (Valette et al. 2010) and no convincing explanation has yet been proposed.

No significant discontinuity can be seen in these results. In our opinion, the discontinuities detected at the end of 2004 by Altamimi and Collilieux (2010) and Valette et al. (2010) may be related to results from other DORIS ACs that could map into the IDS-3 combination, which is the DORIS combination submitted for ITRF2008. Such problems could be related to the end of the TOPEX/DORIS data or to a software modification in the Envisat satellite (Willis et al. 2005b, 2007). The IGN weekly solutions also contain more DORIS stations than the IDS-3 solution, as a pre-selection was done for IDS-3, based on recommendation from DPOD2005 (Willis et al. 2009). Finally, when transforming into ITRF2005, we do not use the original ITRF2005 coordinates and velocities but our internal ign09d02 long-term solution. We also disregard some DORIS stations (six in total) on a week-by-week basis, taking into account possible temporary problems with these data, as done recently in a more sophisticated way using genetically modified networks (Coulot et al. 2009). It is certainly too early to have a definite conclusion on this difficult problem and more tests are required to understand the exact nature of such possible discontinuities.

In Fig. 6.3, a different behavior may be observed for the very early data. This is still under investigation but it could be linked to data availability (only two DORIS satellites : TOPEX/Poseidon and SPOT-2) or

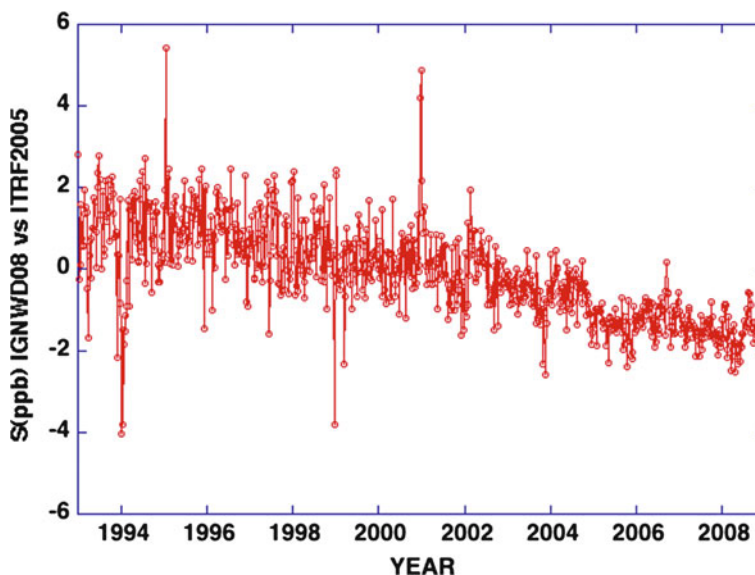


Fig. 6.3 Weekly determination of the TRF scale between the ignwd08 solution and ITRF2005 (through ign09d02)

to a preprocessing problem as detected earlier in the case of SPOT4 for most of the 1998 data and some early 1999 data (Willis et al. 2006).

6.6 Polar Motion

We also update every week polar motion estimation derived using the DORIS data. Tables 6.3 and 6.4 display direct comparisons of these daily DORIS results with the JPL/GPS time series.

When considering the full data set (from 1993.0) in Table 6.3, a clear improvement can be seen for the most recent ignwd08 solution.

When considering only the best DORIS results, when four or five satellites are available after 2002.4, the improvement is even more pronounced and RMS of 0.5 mas are now achievable (Table 6.4), even if a small bias of 0.3 mas in X still needs to be explained. This is a significant improvement when compared to earlier determination (Gambis 2006): RMS of 1.74 mas for XPole and 0.99 mas for YPole, with a -0.24 offset for recent data (2000.0–2004.0).

Part of these improvements is due to the fact that no daily polar rates are estimated in the recent ignwd08 solution. Another improvement is related to systematic errors at the 5.2 day period (SPOT sub-cycle), linked again to the solar radiation pressure estimation as demonstrated in Willis et al. (2010).

Table 6.3 DORIS polar motion external precision compared to IGN/JPL time series (mean removed)

	XPole RMS (mas)	YPole RMS (mas)	XPole mean (mas)	YPole mean (mas)
ignwd04	1.864	1.440	-0.287	-0.164
ignwd08	1.228	1.290	-0.126	-0.373

Period 1993.0–2002.4

Table 6.4 DORIS polar motion external precision compared to IGN/JPL time series (mean removed)

	XPole RMS (mas)	YPole RMS (mas)	XPole mean (mas)	YPole mean (mas)
ignwd04	1.387	0.740	0.003	-0.287
ignwd08	0.584	0.525	0.289	0.012

2002.4–2008.7

6.7 Discussion on Future Improvements

While the ignwd08 solution is still very new and regularly updated, future possible improvements are already considered:

- Early analysis of Jason-2 data showed that it could improve the realization of the terrestrial reference frame (Zelensky et al. 2010) and that no effect related to the South Atlantic Anomaly (Willis et al. 2004) is observed in these data.
- New DORIS satellites will be launched soon (Cryosat-2 from ESA and Altika from India and France). Direct use of the new DORIS phase and pseudorange (Mercier et al. 2010) should be investigated.
- While only minor improvement is expected at the altitude of the DORIS satellite from a GOCE-derived gravity field (Visser et al. 2009), time-varying effects, new tide models and AOD (Atmospheric and Ocean De-aliasing) corrections could improve the DORIS orbits.
- For the tropospheric correction, VMF (Boehm 2004) could be used instead of GMF. Early tests showed that horizontal tropospheric gradients could be considered for DORIS data processing as well (Flouzat et al. 2009).
- Previous studies using Laser data also demonstrated possible time tagging problems in the DORIS data files (Zelensky et al. 2010).
- Finally, the recent inter-comparisons between the 7 IDS Analysis Centers (Valette et al. 2010) should certainly lead to new investigations, for example for problems related to the South Anomaly (Bock et al. 2010, Stepanek et al. 2010).

6.8 Conclusions

In conclusion, the new ignwd08 solution is a clear improvement over the previous ignwd04 solution. In particular, due to a better analysis strategy concerning the solar radiation pressure, previous artifacts at 118 days and 1 year have now disappeared in the Z-geocenter as well in the vertical component of high-latitude station time series. Significant improvements were also obtained for polar motion for which 0.5 mas

comparison with GPS results can be observed, when 4 or more DORIS satellites are available. Finally, with the use of more recent satellites (Jason-2, Cryosat-2, and Altika) equipped with new digital DGXX equipments, more improvements are already foreseen and currently under investigation.

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