DORIS Analysis Strategies

(draft presented at the IDS Workshop, Venice, Italy, March 13-15, 2006; to be finalized after conclusion of the workshop with agreed upon recommendations)

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Abstract

Since the official start of the International DORIS Service in 2003, several key steps were taken. New groups have upgraded their software packages to process the DORIS data for geodesy and some have submitted significant amount of results for test purposes. Several groups, including the IDS Central Bureau, have successfully combined such results to obtain combined products for station coordinates, geocenter motion or polar motion. However, DORIS data processing strategies are still different for each Analysis Centers, potentially creating inconsistencies and discontinuities in combined time series. Furthermore, only one individual solution (IGN/JPL) is currently available soon after the data are delivered and no combined products are generated on an operational basis. The goal of this paper is to present key problems that are facing Analysis Centers and Combination Centers when generating their products. Some recommendations will be made concerning the DORIS data analysis strategy. We will also show problems that need to be resolved in the future in order to produce accurate, reliable and timely IDS products, resulting from a combination of individual solutions.

Introduction

The International DORIS Service (IDS) was constituted as a service of the International Association of Geodesy (IAG) in July 2003. The service was organized to manage data collection, to perform intra-technique combination of geodetic products, to promote the advancement of DORIS as a space geodetic technique, and to serve as a forum to study the myriad technical issues that impact the quality of the geodetic products produced by the IDS. The structure of the IDS is organized in parallel to the services of the other geodetic techniques (SLR, VLBI, GPS). Consisting of a central bureau, distinct analysis centers, and other users of DORIS data, the service delivers products outlined in Table 1. These include weekly and monthly time series of station positions, cumulative solutions (position and velocities), solutions for geocenter, Earth orientation parameters (EOP), and ionosphere products. The main analysis centers that routinely analyze DORIS data include IGN/JPL, LCA, SSALTO, and INASAN. Other groups participate in analysis campaigns or other aspects of DORIS data analysis (GRGS/CNES, Geoscience Australia, NASA GSFC, UT/CSR). The Pecny Observatory is developing the analysis of DORIS data through the use of the Bernese software. Other institutions are involved in DORIS data analysis, although not formal analysis centers, the use of DORIS data is central to the fulfillment of their mission responsibilities. These include the CNES, NASA, and UT/CSR orbit teams who produce medium orbit precision ephemeredes (MOE's) and precise orbit ephemeredes (POE's) for altimeter satellite missions (Topex, Jason-1, and Envisat). Other groups (TU/Delft, Univ. Newcastle, NASA GSFC) have analyzed DORIS data in the context of different research projects. For example NASA GSFC and the GRGS have included DORIS data in the time-variable gravity solutions from satellite tracking data (pre-GRACE). It is important for the IDS to recognize that the DORIS community embraces more than just the current main analysis centers, and we must think how we can broaden participation in the IDS, especially since we seem to be a smaller community than SLR or GPS.

Availability of DORIS Data and Products

It is useful to review the availability for the current set of IDS products (Table 1). Weekly SINEX files are available from six centers (Table 2), however only three groups (IGN/JPL, INASAN, and LCA) have made available a time series spanning the full 12+ years over which DORIS data are available. These three long time series formed the basis for the IDS contribution to the ITRF2005. These SINEX files include station coordinates, EOP, (and pole rates for IGN/JPL and INASAN). Monthly SINEX file solutions have been supplied by some groups, with the latest monthly solution from LEGOS/CLS dated May 2005 (and Oct 2002 for IGN/JPL). Two groups supply derived geocenter time series: INASAN and IGN/JPL (Figure 1). Only one group supplies an EOP time series: IGN/JPL (Table 2).

DORIS ionospheric corrections are calculated routinely by the CNES during the POE process for each observation.   The SOD now routinely delivers a supplementary data file that contains the two frequency information as well as supplementary information such as elevation angle and local time. These files are available for Topex/Poseidon from January 2001- November 2004; for Jason-1 from Aug. 2002; for Spot2/4 from January 2001, and for Spot5 from May 2004. A comparison is shown in Figure 2 between the Total Electron Content (TEC) for JASON in 2004 and the DORIS derived ionosphere correction. We see that the IGS derived solutions are all coherent with each other, and that all the GPS derived TEC values differ from the DORIS derived value by 0.2 to 0.5 TECU. At the Jason altimeter frequency of 13.6 Ghz, 1 cm of range corresponds to 4.6 TECU. Thus the DORIS ionosphere product agrees with GPS to within 2 mm during the passage through the ionospheric equatorial anomaly for this particular comparison.

A station coordinate differences (STCD) file is available by station from LEGOS/CLS,(monthly) IGN/JPL (weekly), and SSALTO. These files, derived from the SINEX, show the week-by-week (or month-by-month) change in the station coordinate systems from an *a priori* value (*Soudarin and Noll*, 2006). Two of the analysis centers provide plots which users may access (URL: http://ids.cls.fr/html/doris/ids-station-series.php3), and for collocated sites, comparisons are possible with velocities obtained by other techniques. We illustrate the station coordinate differences from the IGN/JPL weekly series, and the LEGOS/CLS monthly series in Figure 3 for station PAQB (Tahiti). With these sorts of plots, we may make direct comparisons of the coordinate time histories at a site and see how they differ for different time series. In this example we see the difference in detail observable between the weekly and monthly solutions, but also the difference in station coordinate RMS wrt the linear fits. The citations for these series are *Cretaux et al.* (2002), and *Willis et al.* (2004). If new references are available (e.g., from J. Geodesy DORIS special issue), these should be placed on this web page. Currently, no attempt has been made to insure that the a priori coordinates are the same between ACS, nor that the a priori coordinates of successive stations in the same DORIS sites are the compatible with the DORIS-DORIS geodetic local ties as provided by SIMB (and regularly updated).

The DORIS data centers do not archive any orbit products for any DORIS satellite. The only orbits available are for very few Jason orbits from LCA in sp1 format. The true precise orbits for the altimetric satellites (Jason-1, Topex/Poseidon, Envisat) are based on multitechnique solutions (SLR+DORIS, or GPS+SLR, or GPS+SLR+DORIS) or GPS reduced-dynamic analyses and are available elsewhere (e.g. for those who are members of the Ocean Surface Topography Mission (OSTM) or Envisat POD teams). No orbits are available at the IDS data centers for the Spot satellites. No comparison of SPOT orbits was ever conducted between Analysis Centers.

It is instructive to review the availability of raw DORIS data at the CDDIS. Obviously the DORIS data cannot be analyzed by the analysis centers until the data are delivered to the data centers by the CNES. This information is summarized in Figure 4. At the time of the last DORIS workshop (May 2004) typical delays were 30 days for Jason-1, Spot2, Spot4 and Spot5, and 50 days for Envisat. Presently, the DORIS data are delivered typically in under 30 days, with the delivery of raw data for Envisat showing a notable improvement since mid-2004, following the recommendations in the previous IDS Workshop.

The product delivery schedule for the period 2002.5 to 2006 is shown in Figure 5. We can see that with the exception of IGN/JPL, INASAN and LEGOS/CLS deliver their time series (all 12 years) all at once, rather than with regular deliveries. The mode of operation, partially at least is to recompute the series for special deliveries (analysis campaigns, ITRF2005). An issue we must face as the IDS is how we transition to a more operational service (continuous and regular delivery of products on a routine basis), and how many centers can participate on this activity (Do the centers have the manpower and scripts available for this regular effort? How long would it take them to achieve this goal?). A related issue is what standards we wish to define for this more regular processing by the analysis centers.

In Figure 6, we illustrate the DORIS data and product downloads by IP network source. The bulk of the product downloads come three countries: France, Germany and the Russian Federation. After the DORIS workshop we may ask the CDDIS to specify the quantity and source of product downloads by product type (2002campaign, 2003campaign, eop, geoc, iono, orbits, sinex_global, sinex_series).

The DORIS system has undergone notable evolution and improvement since 1992. We can see this in the reprocessed RMS of fit for both Topex/Poseidon and Spot-2. In Figure 7 we illustrate the DORIS RMS of fit using two processing standards at NASA GSFC:

(1) the standard processing using JGM-3, and CSR95L02, and ITRF2000 station coordinates for the orbits on the Geophysical Data Records (GDR's), and the new reprocessed orbits (GGM02C; station coordinates from ITRF2000 for SLR, and *Willis and Ries* (2005) for DORIS; application of GRACE-derived time-variable gravity, application of atmospheric gravity @6hrs from NCEP to 50x50). The first part of the processing shows RMS of fit typically around 0.55 cm/s, and after a dip shows a progressive increase through about MJD 51168 (1998-12-21). This corresponds to the degradation in the DORIS channel A on Topex, After the switch to DORIS channel B, we notice a steady improvement where by 2004, the data routinely fit at 0.45 cm/s. The steady improvement in the DORIS performance on Topex is a manifestation of the effects from the rejuvenation of the ground network, and the improvements in the ground pre-processing for DORIS data (cf. See the presentations by Flavien Mercier at this workshop). The improvement in DORIS system performance is also evident in the RMS of fit for Spot-2 data arcs from 1992 through 2004 (Figure 8). We see the same overall trend from 0.55 cm/s to 0.45 cm/s, with a notable scatter in the RMS of fit (and presumably the orbit quality) during late 2001 and early 2002. It is possible but not clear that this scatter might be due to the effects of the solar maximum.

Another way to view DORIS system performance is to examine the weighted RMS of the individual weekly time series combinations (*Tavernier et al.,* submitted). In Figure 9, we show the how this statistic evolves with time. The early dip from 30 mm (1993) to 25 mm (1996) may correspond to the approach of solar minimum and the contribution of Spot-3 to the station time series solutions. This early is followed by an increase to 30 mm (1998), corresponding to the degradation in performance of the Topex DORIS channel A. Afterwards we see a steady improvement to the level of about 15 mm by 2004 to 2005. This improvement results from the rejuvenation of the network and the increase in the number of satellites that have DORIS receivers. Although perhaps we should be cautious about overinterpreting these statistics, there is another increase in RMS to between 25 to 30 mm around 2002. One hypothesis, is that at or near solar maximum, that by virtue of their relative low altitude (~800 km), the Spot and Envisat satellites are much more sensitive to the effects of atmospheric drag mismodelling. Since the Spot satellites are such an important part of the DORIS system, perhaps we must address in terms of methodology of processing or modeling how best to improve the satellite orbits in periods near solar maximum.

The long term stability of the scale of Terrestrial Reference Frames is linked with station height determination and is an important issue in different scientific applications. *Willis et al*. (2006, in press) examined the DORIS weekly time series of station coordinates in 2004 to attempt to understand differences in the DORIS TRF scale between analysis centers. This was analyzed in aggregate and on a satellite by satellite basis. *Willis et al*. (2006, in press) uncovered significant differences on a satellite-by-satellite basis. For example in Figure 10, we show the multisatellite combination, the Topex-only solution, and the Spot5-only solution. The scale differences are largest for Envisat and Spot5 with differences between analysis centers of 9-10 ppb. It is possible that there are satellite-by-satellite differences in modeling between the analysis centers that might account for these differences. We also note that *Tavernier et al*. (submitted) shows the derived scale factor of the individual weekly time series combinations from 1993 to 2005. IGN/JPL consistently has scale factors of –15 to 25 mm, whereas LEGOS/CLS has scale factors from 25 to 45 mm (Figure 11). One of the critical issues that the IDS will need to address in the coming year is to understand the nature of the differences by performing a systematic inventory of the measurement and force modeling for all analysis centers, and to perform satellite-by-satellite comparisons over a specific time frame.

Another issue which may touch on this issue of scale discrepancies are the recovery of the DORIS estimates for geocenter. Geocenter comparisons are discussed in *Feissel-Vernier et al.* (submitted). (See example series in Figure 1). In the equatorial directions there is a reasonable agreement between the DORIS results and the expected geophysical signals. In the axial or north-south direction, the signal recovered by DORIS is large by a factor of ten over the expected geophysical signals with amplitudes of up to 10 cm. The DORIS Z geocenter recoveries are much larger than what is obtained with SLR.

Action items from 2004 Position Paper: Review

At the 2004 IDS workshop, May 3-4, 2004, Willis and Cretaux (2004) presented a position paper on DORIS data analysis strategies. It is useful to review the action items and recommendations from this meeting, and discuss if they are still relevant, and how we may close them. We summarize below the recommendations from the workshop that remain open in Table 3, and list the full text of the recommendations below. In the course of this 2006 workshop, we must decide which of these 2004 recommendations are still relevant and should be carried forward.

Recommendation 2.2: A procedure must be explicitly stated to formally accept a DORIS product as such, including a technical feasibility study, and a validation component. We should presently start assuming that no such IDS product exists presently and to generate them by a standard procedure.

A procedure could easily be defined to do routine weekly combinations easily from IGN/JPL, INASAN, LEGOS/CLS, if all AC's agreed to submit Sinex files within a specified time frame. Could we ask INASAN to change some part of their analysis strategy so as to differentiate the results from the two AC's that use Gipsy?

Recommendation 2.4: It is important that more Analysis Centers participate in the generation of IDS products. Groups wanting to participate must receive some help from an existing AC. It is also important to understand why some groups stop delivering results and to encourage them to resubmit new results.

Recommendation 3.3: CNES in liaison of the IGN/SIMB and the chair of the station selection group, should maintain a list of stations that participate in the IDS, through the DORIS permanent network or through DORIS campaigns as organized by the Station Selections Group.

Recommendation 3.4: Tests should be conducted between CLS and 1 or more AC to finalize delivery of DORIS data for stations outside the permanent network.

We must ensure that the procedure for manufacture of the campaign data is the same as for the stations in the DORIS permanent network, in so far as this is possible.

Recommendation 3.5: CNES should define a new DORIS format for a lower preprocessed level and should make available some test data sets for all satellites during a short period of time to let the IDS AC investigate about the potential advantages of these new types of DORIS data.

Recommendation 3.6: IDS request CNES to officially ask for the release of the DORIS/Pleaides data for scientific uses within the IDS and also to investigate the possibility to add future DORIS receivers on-board future other Space Agency missions, especially constellation of satellites such as NPOESS to ensure the current number of DORIS receivers in flight or even to increase it.

This issue is critical to the future of DORIS, even though we have two confirmed future missions: Cryosat-2 and Altika. We should renew this letter to the CNES, and contact directly ESA and NASA with this request, emphasizing the benefits of DORIS for the specific mission and general scientific applications. We may wish to ask the IERS GB to send a similar letter.

Recommendation 4.1: The Analysis Coordinator, after discussion with the AC's and with the product users (starting with the IERS) should define a clear strategy of how to improve current products without losing the homogeneity and the continuity of the time series. A trade-off compromise should be found.

Recommendation 4.2: AC's should compare their current DORIS models and analysis strategies, starting with tropospheric correctons for which several groups have really different approaches.

Some work has been done. The analysis center descriptions available at ftp://cddis.gsfc.nasa.gov/pub/doris/cb_mirror/centers date from January 7, 2003, and need to be updated by the Analysis Centers. For example the IGN/JPL description says arcs are 1 day for Spot and 3-days for Topex and Jason, when in actuality 30 hr arcs from 21:00 to 03:00 are used (except around maneuvers). The LEGOS/CLS description also says arcs used are 1 day for Spot and 3 days for Topex/Jason, when in fact non-overlapping 3.5 day arcs are used. SSALTO does not have a description file, but for the POE's they use arclengths of 10 days + 6 hr overlaps for the Spot satellites; arclengths of 1 cycle (9.91..days) + 8 hr overlaps for Jason-1, and arclengths of 7 days + 12h54' overlaps for Envisat. For the MOE's which form the basis of the Sinex and STCD deliveries for SSALTO, the arclengths are 30 hrs for all satellites from 20:00 to 02:00.

Recommendation 4.3: The IDS in collaboration with the ITRF Product Center should investigate if the scale bias between DORIS solutions and the ITRF is inherent to the DORIS system or if its inherent to a specific DORIS software. It should investigate technical ways to compensate for such effects (by using a posteriori satellite or ground antenna offset).

Recommendation 5.1: The Analysis Coordinator should propose validation procedures before accepting any IDS individual solutions and IDS product, either internal through combination, or external using any type of information. These validation procedures should be an important part of the IDS product definition.

Central issues, recommendations, and action items

Recommendation 2006.1.0:
We have seen that it is the number of satellites that critically affects the quality of the DORIS results. The DORIS satellites currently on orbit are rapidly aging, and we must face the possibility that a portion of the satellites currently on orbit may cease operations in the near future (see Figure 12). We note that we have been extremely lucky with Spot-2, that has been operational since 1990 (for 16 years!). We should renew our request to the CNES for the Pleiades data, and look for other flights of opportunity. At an appropriate stage, we should consider the intercession of the IERS GB.

Recommendation 2006.2.0: **Conduct measurement and force model inventory.** We need to conduct a detailed inventory of the measurement and force modeling implemented at the analysis centers. A part of this effort will be to ascertain whether the AC's follow the IERS2003 recommendations (eg., Earth tides, precession, nutation). The inventory should also include whether the DORIS antenna corrections are applied from the data or calculated by the analysis package (GEODYN, ZOOM, GYPSY, GINS). This should also include the macromodel values used for the different satellites, and what type of opr's are adjusted.

Recommendation 2006.2.1: **Analysis centers should update their analysis description forms on file at the CDDIS and IDS central servers.** The analysis center forms should be updated reflect what the centers submitted in 2005 either for the IAG or for the ITRF2005. We must be able to document exactly the models used for the ITRF2005 submissions.

Recommendation 2006.3.0: New POD Standards for the IDS. A subcommittee should examine the POD standards used presently for GRACE, Topex, Jason, and Envisat and recommend what models the IDS should use. The key would be to update to improved standards, but allow sufficient flexibility. For example one recommendation might be to use a GRACE era gravity model, without specifying which one (GGM01C, GGM02C or the GFZ/GRGS models). The Analysis Coordinator will compare these recommendations with current processing at the centers and through contact with the AC's assess the feasibility of their implementation, and determine a schedule and mode of implementation taking into account Recommendation 4.1 above.

Recommendation 2006.4.0: **Decide orbit format for analysis campaigns (Recommendation 2006.4.1)** Decide standard for exchange of orbits between AC's and Combination center: Sp1, Sp3, POE? The issue is for simple orbit differences, we may rely on ECF formats (sp1, sp3). However if we wish to pass through external data (SLR, altimeter crossovers), we need to rotate the orbits to inertial coordinates in order to pass them through an orbit determination analysis package and obtain independent SLR and crossover fits (Topex, Jason, Envisat).

Recommendation 2006.4.1: Conduct analysis campaign for TRF scale and geocenter comparisons. Conduct a focused analysis campaign (2003-2004? the period with the most satellites) available. We should set standards for the analysis campaign (which models to use) in order to minimize the free variables in the analysis. We will ask the analysis centers to submit orbits for all satellites, weekly sinex series, as well as summaries of orbit determination results (RMS of fit, internal overlaps if available, Nobs etc). We will have a better idea of the permutations to try after Recommendations 2006.2.0 and 2006.3.0 are completed, but at a minimum, the centers should try solutions with the data supplied corrections and calculating their own measurement offset corrections (if possible). If possible, perform external comparisons for Topex, Jason, and Envisat with SLR and with altimeter crossovers. Single-satellite solutions or solutions using multi-techniques should also be part of the whole test.

Recommendation 2006.5.0: Conduct analysis campaign for Jason-1 SAA model validation. In order to validate the SAA model (Lemoine and Capdeville, this workshop) for Jason-1, we must conduct a campaign to assess its impact on geodetic products (stations, EOP, scale). What is the minimum period necessary for this analysis? How will we implement this model?

Recommendation 2006.6.0: Evolve IDS towards an operational service. Since data are available within 30 days, ask analysis centers to deliver products to combination center within another 30 days. Ask combination center to create combined product within a reasonable delay. Is this delivery schedule sensible given people's resources? How does it compare to ILRS and IGS? Should we wait to initiate this until after the POD standards for the centers have been updated?

Recommendation 2006.7.0: Request submission of ionosphere files for years prior to 2000-2001. Is this feasible? How much work is involved? What delays should be expected?

Recommendation 2006.7.1: Publicize availability of ionosphere data.

Recommendation 2006.8.0: Ask analysis centers to define arcs so that overlaps are available. Conduct orbit overlaps on a routine basis, and make overlap results available to IDS on routine basis in plot and tabular form.

Recommendation 2006.9.0: Harmonize *a priori* positions in all STCD files: Investigate how to harmonize *a priori* positions in all STCD files and possible consistency with geodetic local ties provided by SIMB

Recommendation 2006.9.1: Ensure that all AC's can create STCD files and associated plots. Provide scripts to all groups to create GIF files (plots) from STCD files and update the Web to include all available results (plots from all solutions and from all ACs).

Recommendation 2006.9. Publicize availability of STCD files and plots among the geophysics community (e.g., IGSMAIL, SLRMAIL, other means).

Other issues:

1. **EOP and EOP-rates (proposal from P Willis).**
2. **Analysis Campaign for time-variable gravity estimation from satellites with DORIS data.**
3. **International Polar Year.**

Summary and conclusions

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 (such as modeling differences with analysis centers) and operational issues in order continue to improve the contributions that DORIS might make to satellite geodesy.

References

Feissel et al. submitted.
Lemoine, J.M. and Capdeville, this workshop.
Soudarin, L., and C. Noll, STCD (Station Coordinates Difference) format (version 1.0), February 16, 2006.
Tavernier et al. submitted
Willis and Cretaux, previous Position Paper, May 2004.
Willis and Ries, J. Geodesy (2005)
Willis et al. IAG, Cairns (in press, 2006)
Willis J Geod TZ/SPOT4

Product	Present AC	Previous AC (no recent solution)	Proposed AC	Combined Product
Cumulative solutions (positions/velocities)	IGN/JPL LEGOS/CLS*		INASAN Geoscience Australia IAA	No
Weekly series	IGN/JPL INASAN LEGOS/CLS SSALTO ¶	SOD GSFC (1 yr)	Geoscience Australia IAA Pecny/CODE	No
Monthly series		IGN/JPL INASAN LEGOS/CLS SSALTO	Geoscience Australia IAA	No
STCD (station coordinate differences)	IGN/JPL SSALTO	LEGOS/CLS		
Geocenter	IGN/JPL INASAN			No
EOP	IGN/JPL	LEGOS/CLS	INASAN	No
Orbits		LEGOS/CLS		No
Ionosphere	SSALTO			No

Not available at NASA/CDDIS. ¶ Covariance information not in SINEX file since positions are derived from orbits that are held fixed.

Table 1: Current IDS Products (March 2006). The term "Present AC" includes those analysis centers that regularly submit products; The term "Previous AC" includes those centers who have submitted products, but not recently; The term "Proposed AC" refers to those centers who have expressed a willingness to participate in the IDS, but have not yet submitted solutions.

Group	Software	Solution	Start	End	Files	Geocenter	EOP
GSC	GEODYN	WD02	JAN-2004	DEC-2004	104		
IGN	GIPSY/OASIS	WD05	JAN-1993	OCT-2005	668	X	X
		MD03	JAN-1993	OCT-2005	118		
INA	GIPSY/OASIS	WD05	JAN-2003	DEC-2005	1355		
LCA	GINS/DYNAMO	WD13	JAN-1993	SEP-2005	664		
		MD02	JAN-2003	DEC-2002	120		
SOD	ZOOM	WD01	JUN-2001	JUN-2001	3		
SSA	ZOOM	WD01	JAN-2000	JAN-2005	209		
		MD01	FEB-2001	APR-2002	16		

Table 2. SINEX time series available at the IDS Data Center. February 2006.

Action	Status	Comment
2.1. Survey of current uses of IDS products	Open	Rejected during meeting.
2.2 Define procedure to accept an IDS product	Open	
2.3 Split DORISMail and create DORISReports	Closed	
2.4 Understand why some AC's have stopped	Open	
3.1 Request data delivery < 6 weeks	Closed.	
3.2 Change to backup DORIS receiver on Jason	Closed	Done, but SAA problem remains.
3.3 List of IDS Stations (network + campaigns)	Open	
3.4 Test data delivery for campaign stations	Open	
3.5 Define new format (rawer data)	Open	
3.6 Request data from Pleiades (+NPOESS)	Open	Done, but unsuccessful.
4.1 Improve products but keep continuity.	Open	
4,2 Compare AC's analysis strategies.	Open	Some documentation online.
4.3 Investigate TRF scale bias	Open	Some tests done. *Willis et al.* (2006, in press) Cairns/IAG
4.4 Investigate TZ 1998 (Spot4 data)	Closed	*Willis et al.* J. Geod. (2006)
5.1 Define validation procedures	Open	

Table 3: Summary of Action items from May 2004 DORIS workshop: Status as of March 10, 2006.

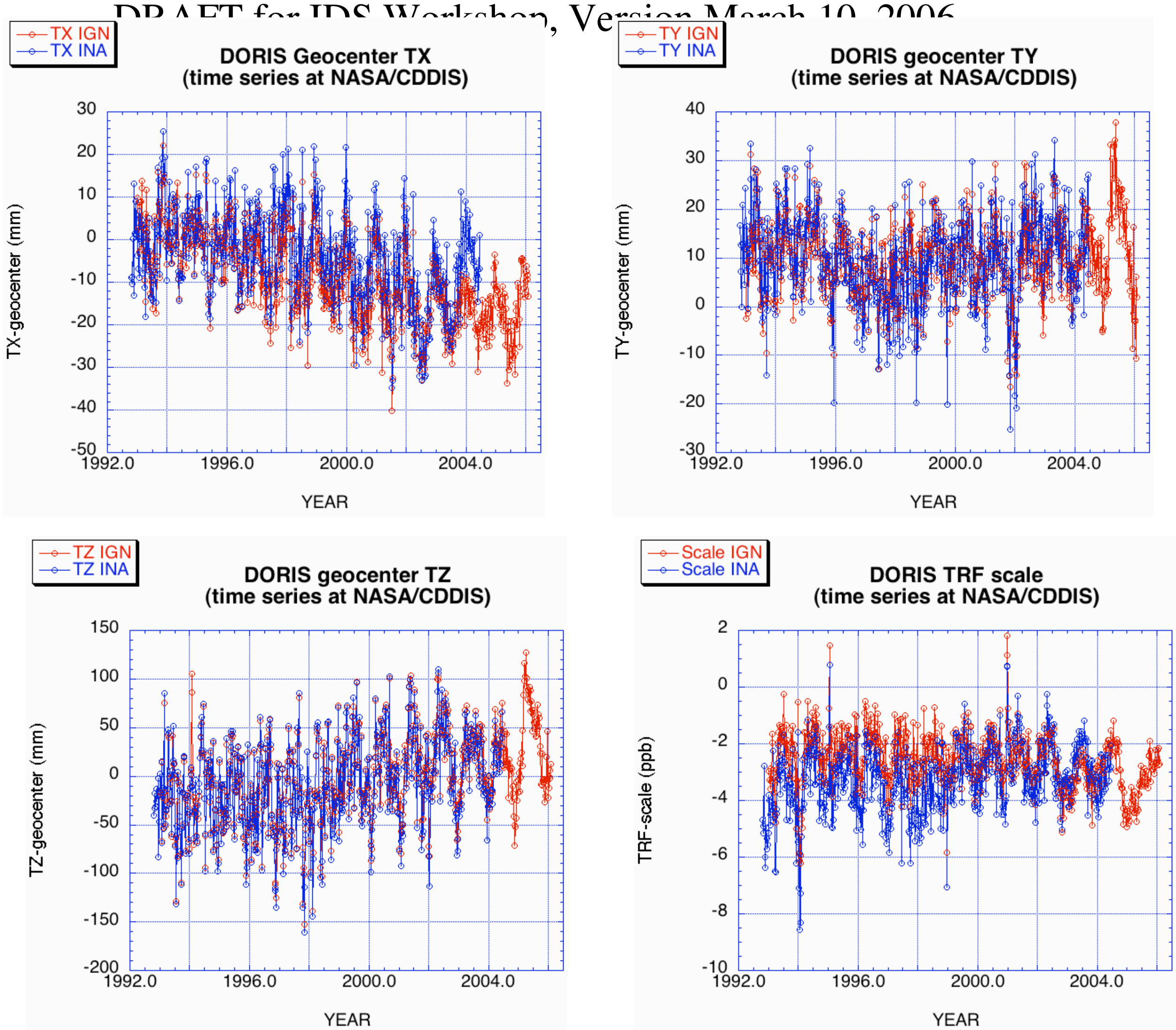


Figure 1: DORIS geocenter and scale from time series of IGN/JPL and INASAN available at NASA/CDDIS.

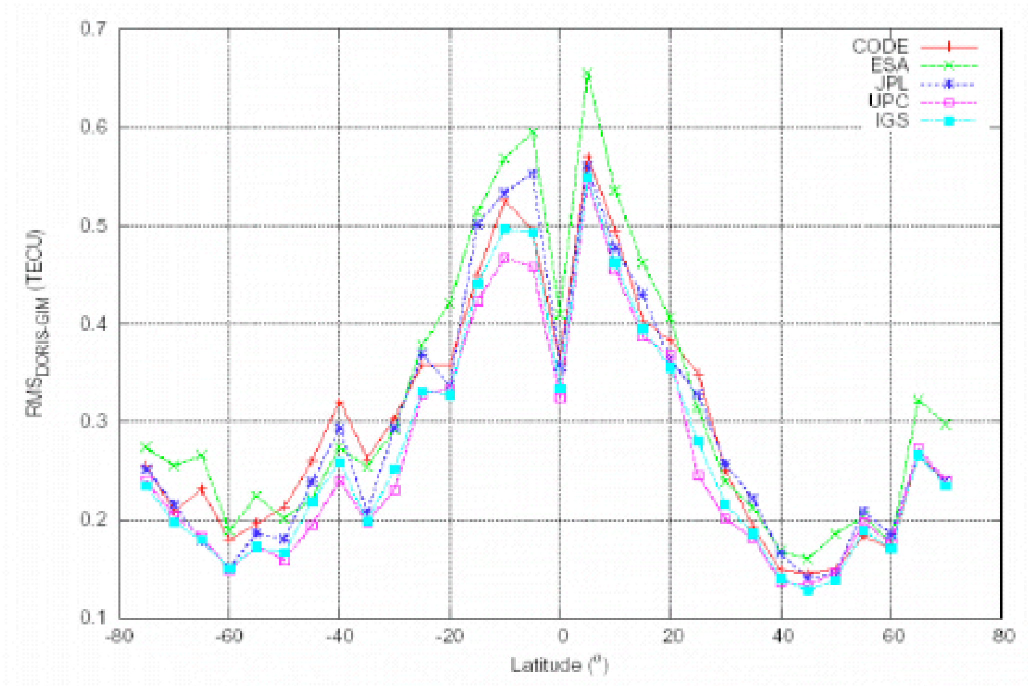


Figure 2: Comparison of DORIS derived vertical total electron content (VTEC) for JASON in 2004 with VTEC results from different IGS analysis centers. The display indicates the RMS difference between each IGS center and DORIS for 2004. The units are TEC units (TECU). At the Jason altimeter frequency of 13.6 Ghz, 1 cm of range corresponds to 4.6 TECU. (from M. Pajares, April 2004-2005, IGS working group report)

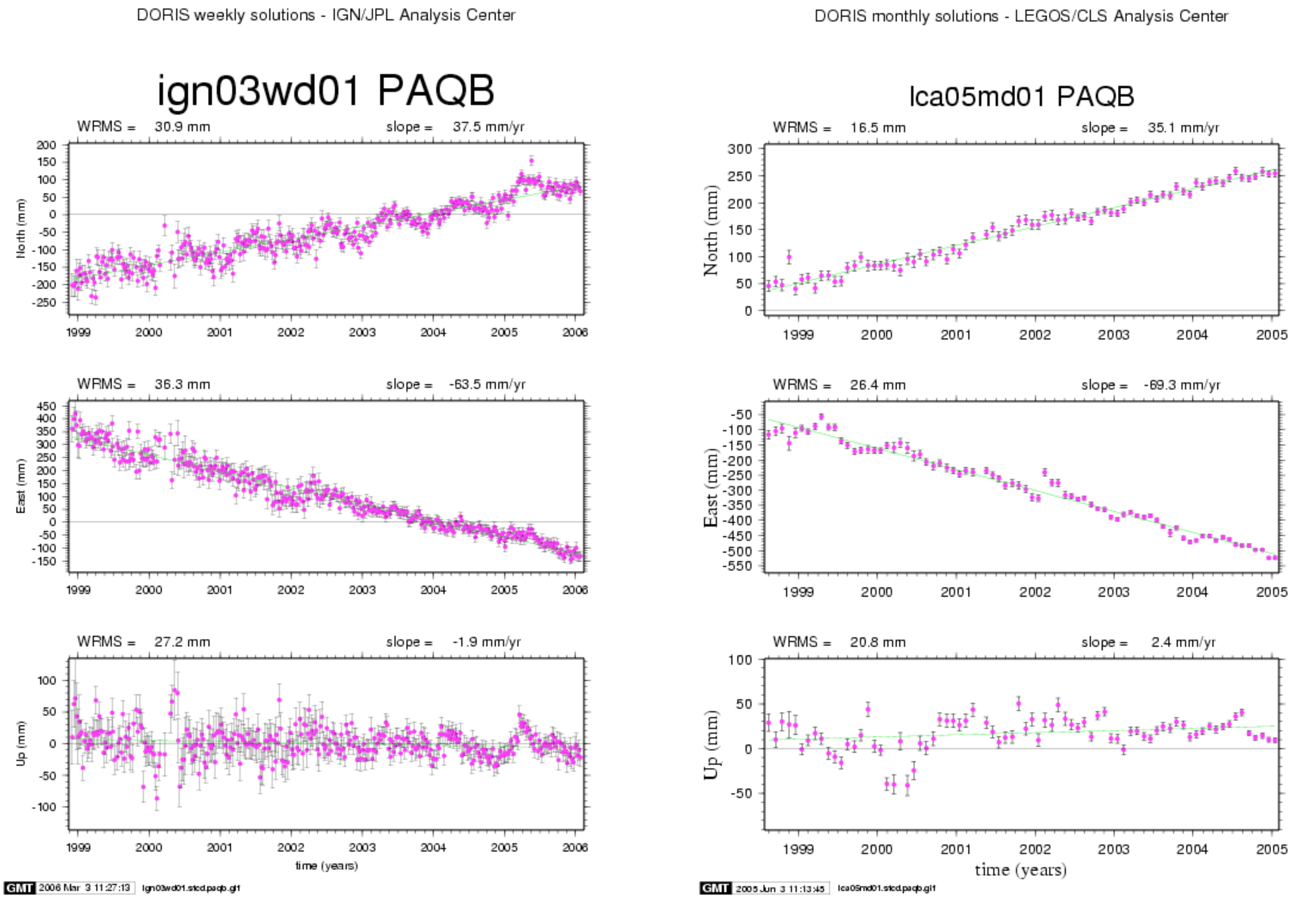


Figure 3: Station coordinate differences (STCD) for the PAQB station from the weekly IGN/JPL solution (available at ftp://cddis.gsfc.nasa.gov/pub/doris/products/STCD/ign03wd01/ign03wd01.STCD.paqb.gif) and the monthly solution from LEGOS/CLS (available at ftp://cddis.gsfc.nasa.gov/pub/doris/products/STCD/lca05md01/lca05md01.STCD.paqb.gif).

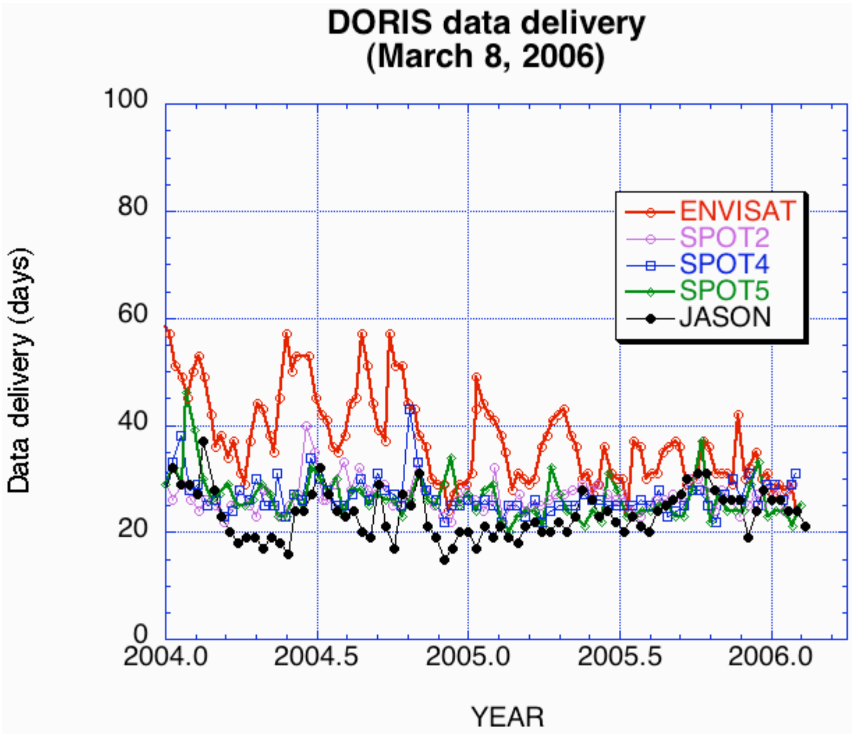


Figure 4: DORIS data delivery to the CDDIS.

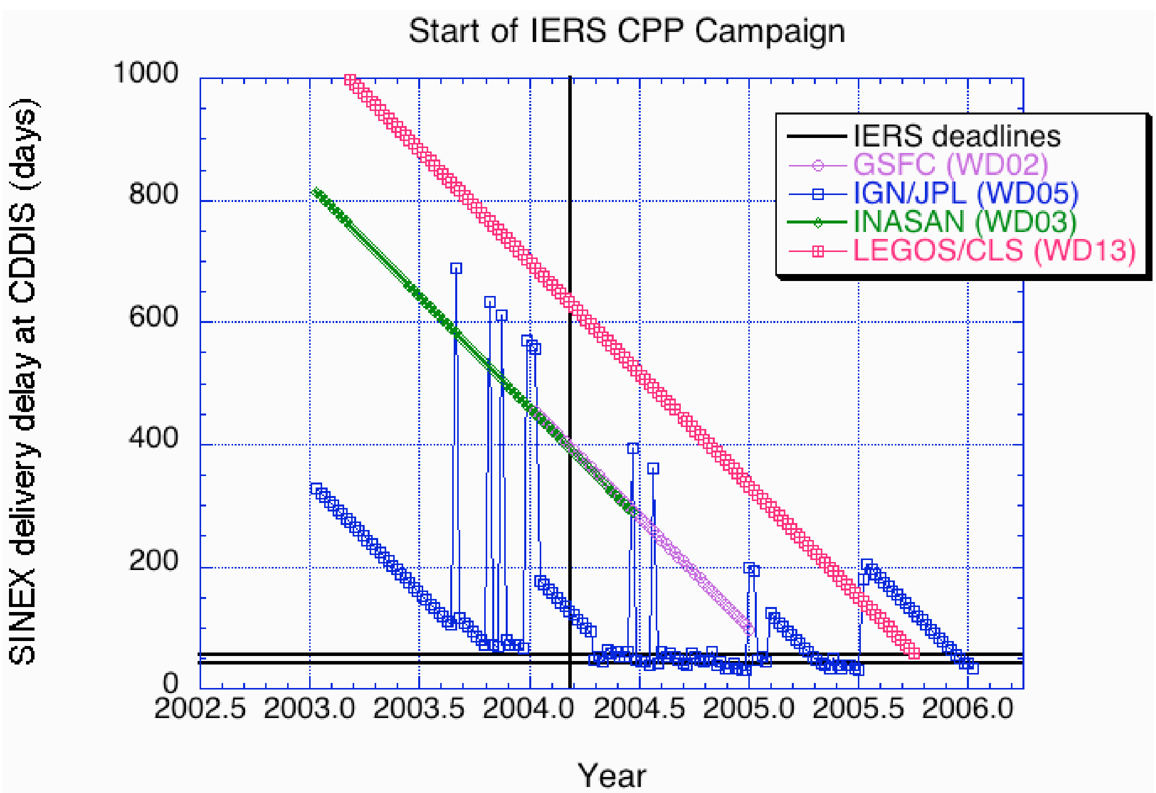
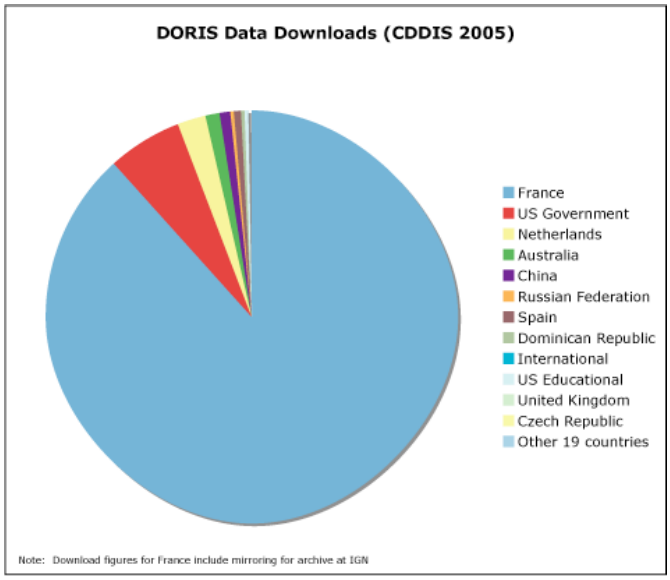


Figure 5: SINEX file delivery delay at the CDDIS.



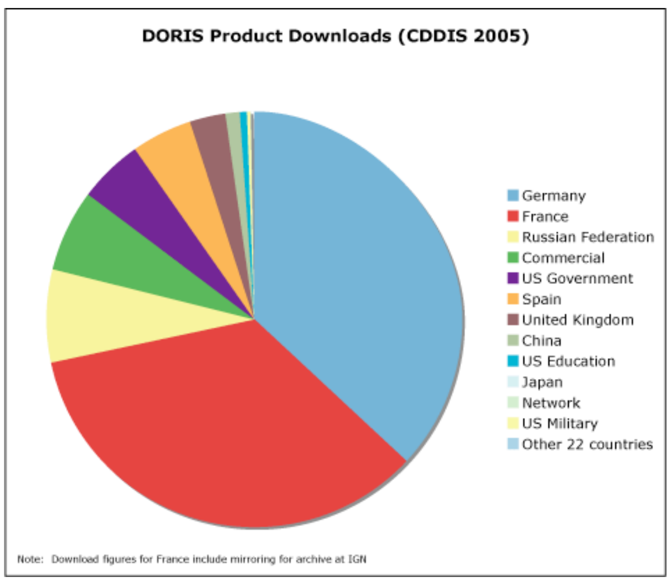


Figure 6: DORIS Data and Product Downloads at the CDDIS in 2005 by source.

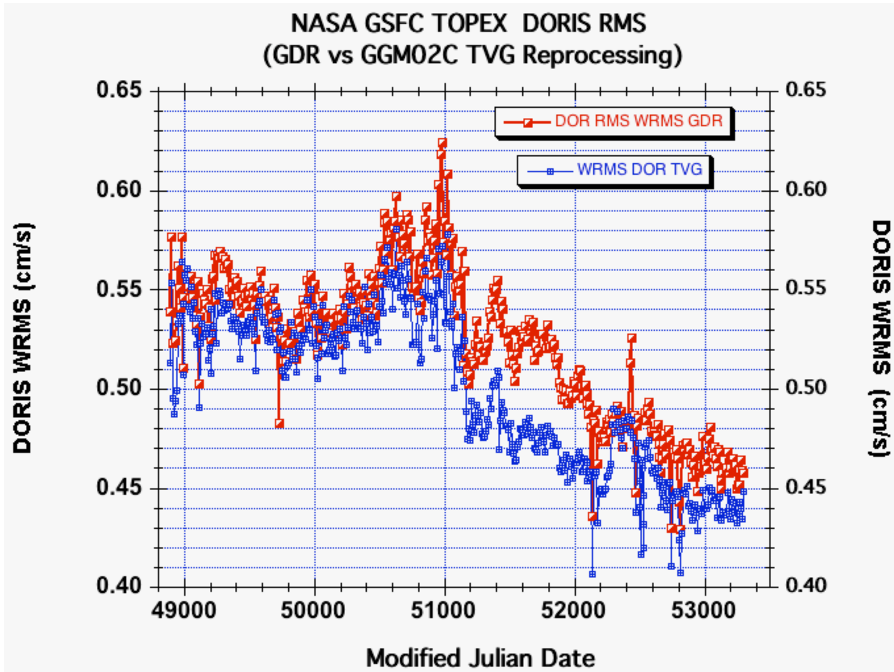


Figure 7: Topex DORIS RMS of fit for cycles from 1992 through 1994 from processing at NASA GSFC. The first generation processing (JGM3, CSR95L02, ITRF2000) is shown in red; the new second generation processing (GGM02C, ITRF2000 + DORIS core, + time-variable gravity from GRACE) is shown in blue.

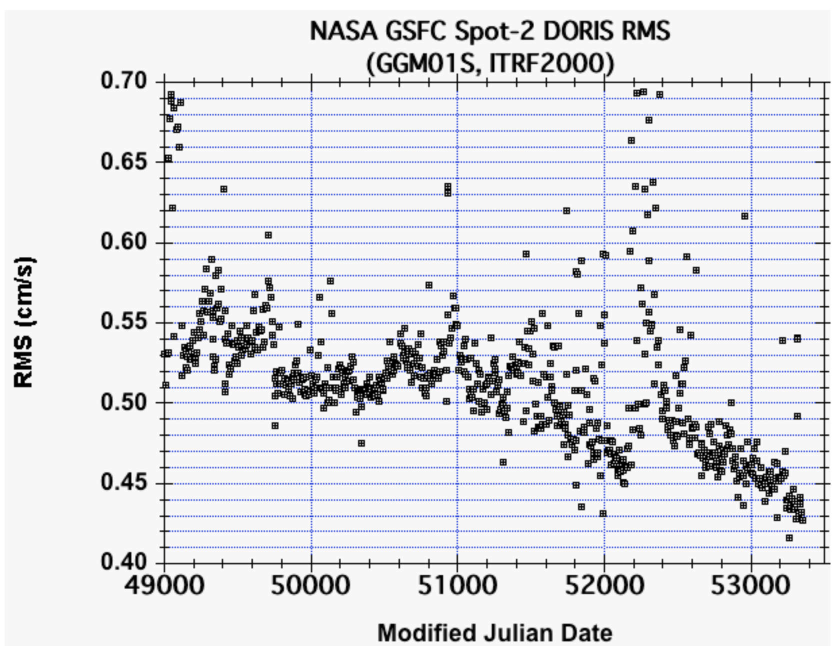


Figure 8: DORIS RMS of fit for Spot-2 from NASA GSFC processing using GGM01S and ITRF2000.

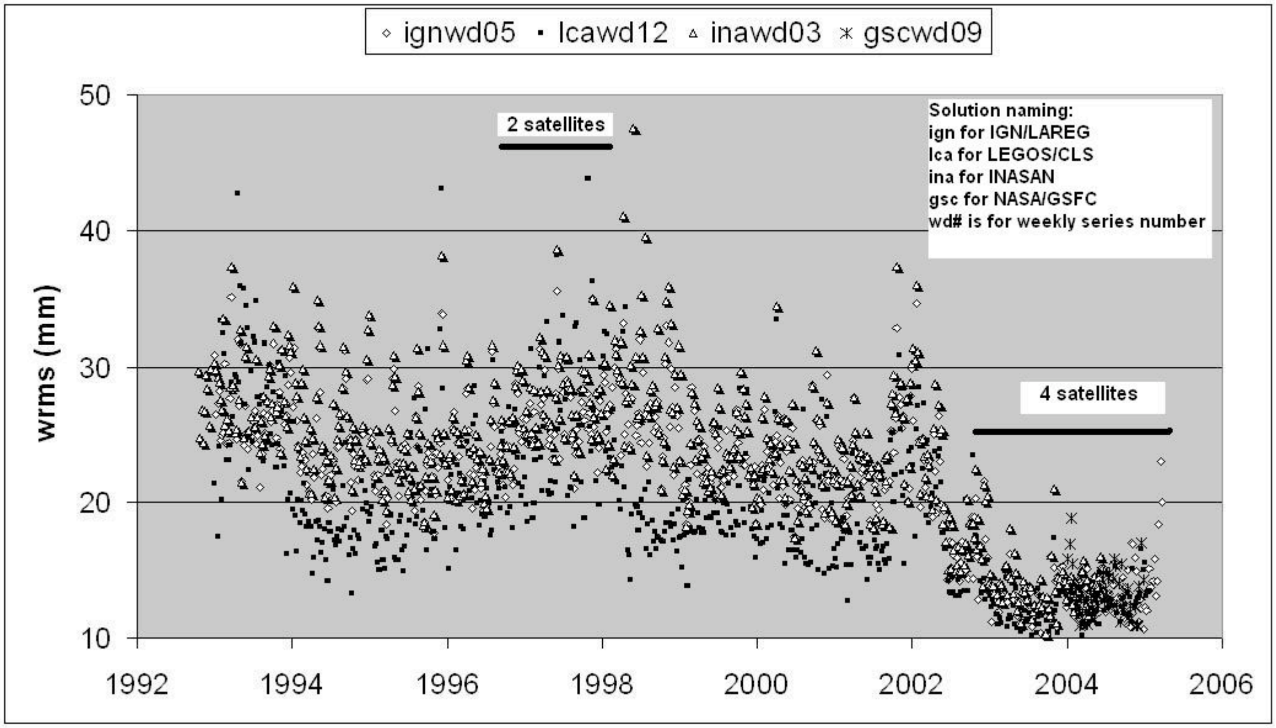


Figure 9**.** Weighted RMS of the individual weekly time series combinations (*Tavernier et al.*, 2006).

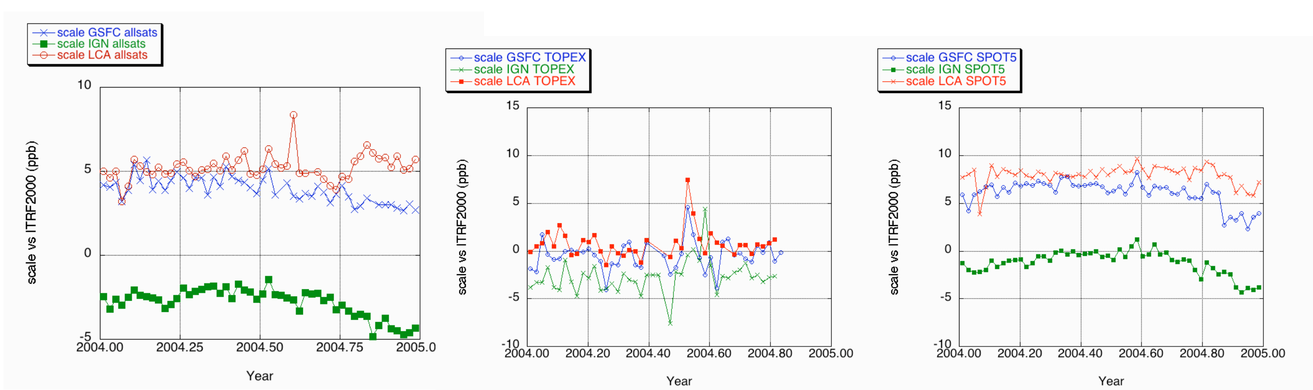


Figure 10: Weekly scale factor determination towards ITRF2000 using multi-satellite SINEX solutions. GSFC (white circle), IGN/JPL (black squares), LEGOS/CLS (crosses). January – December 2004: Left (all satellites); Center (Topex); Right (Spot5) (*Willis et al.,* 2006, in press).

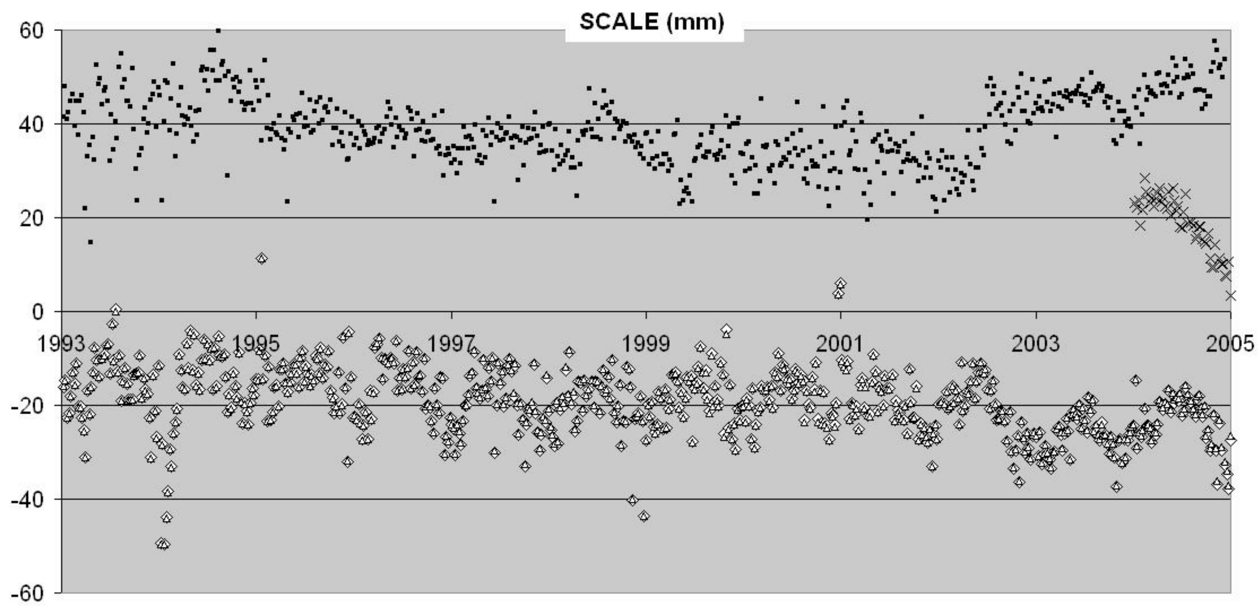


Figure 11: Scale factor of the individual weekly time series combinations from *Tavernier et al*. (2006). IGN/JPL (diamonds); LEGOS/CLS (black dots); GSFC (crosses).

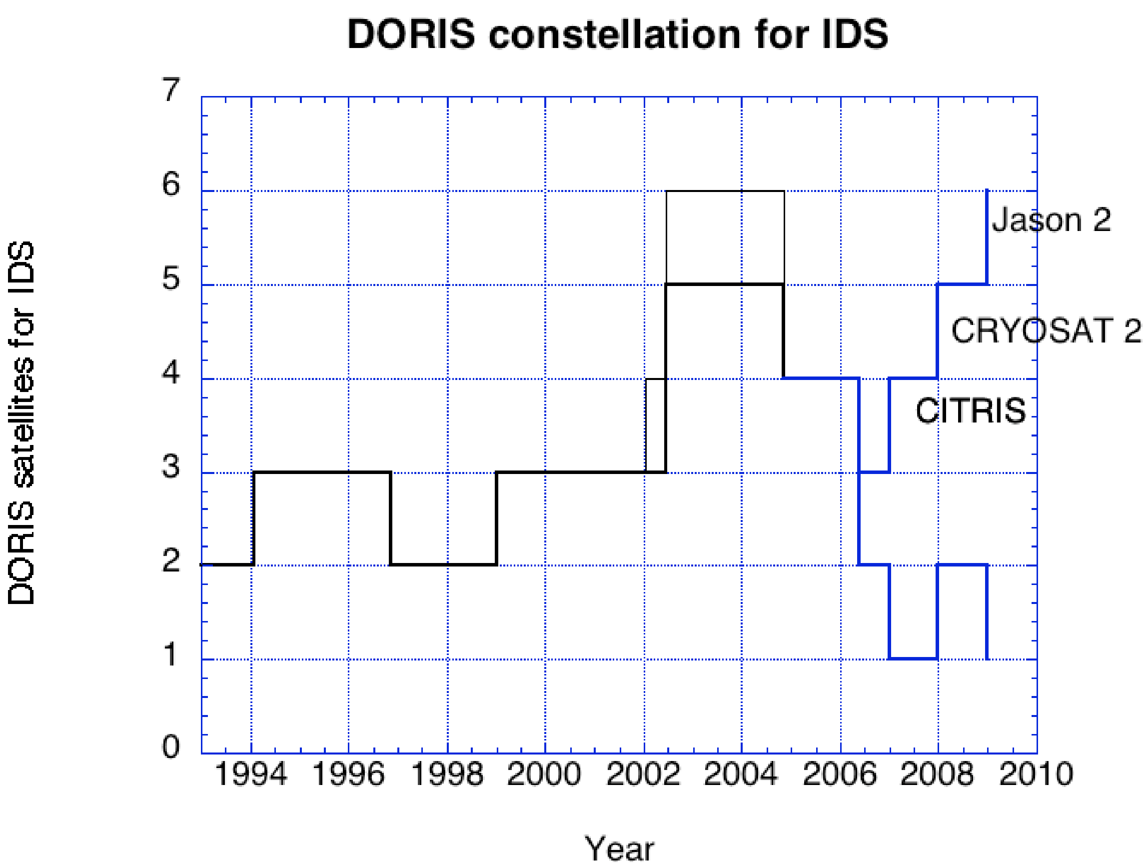


Figure 12: Evolution of the DORIS satellite constellation with predictions for 2006 or later based on optimistic and pessimistic satellite survival scenarios.