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Progress towards a DORIS combination for the next ITRF

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ABSTRACT

The International DORIS Service (IDS), in operation since 2003, submitted three sets of solutions to ITRF2005 from the IGN/JPL, LEGOS/CLS, and INASAN analysis centers, but no DORIS technique combination. Since that time a new analysis center, Geodetic Observatory Pecny (GOP) has become operational using Bernese, a software not originally designed to process DORIS data, and other analysis centers have offered to provide SINEX solutions. A routine DORIS combination as well as a contribution for the next ITRF must resolve significant operational and technical challenges. One of these challenges includes whether or not to consider Jason-1 in the next DORIS combination even with the South Atlantic Anomaly (SAA) correction model (for the ulta-stable oscillator behaviour) of *J.M. Lemoine and Capdeville* (2006). Other challenges including updating the modelling standards, and assuring that all the disparate software packages (Gipsy, GINS, Bernese, GEODYN) can accommodate the new modelling requirements.

In this paper we describe a preliminary combination consisting of SINEX submissions by four analysis centers (IGN/JPL, LEGOS/CLS, GOP and INASAN) using DORIS data from 2005 to 2007, a period when the DORIS on-orbit constellation included four satellites (in addition to Jason-1), and where the submissions use ITRF2005 as *a priori*. The SINEX submissions are processed using the CATREF software, and we describe the results in comparison with the analysis center inputs to ITRF2005, where preliminary results show a dramatic improvement in the scale agreement with the LEGOS/CLS and IGN/JPL analysis centers. We show the results of tests by the analysis centers on the impact of including Jason-1 data with the SAA correction in the SINEX solutions. We also describe the results of detailed intercenter orbit comparisons using DORIS satellite orbits in 2005, which allow us to diagnose potential anomalies in the processing and implement improvements in the future DORIS/IDS ITRF submission. We include orbit comparisons from ESOC (European Space Operations Center) for ENVISAT, anticipating their potential contribution to the DORIS combination for ITRF2008, as an associate analysis center.

COMBINATION DATASET

(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. Loosely constrained with var-cov and EOPs.
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.

CATREF software

IGN CATREF combination software uses the similarity transformation and associated equation:

$$\begin{cases} X_s^i = X_c^i + (t_s^i - t_0)\dot{X}_c^i + T_k + D_k X_c^i + R_k X_c^i \\ \qquad + (t_s^i - t_k)\left[\dot{T}_k + \dot{D}_k X_c^i + \dot{R}_k X_c^i\right] \\ \dot{X}_s^i = \dot{X}_c^i + \dot{T}_k + \dot{D}_k X_c^i + \dot{R}_k X_c^i \end{cases}$$

where for each individual frame k, D_k is the scale factor, T_k the translation vector and R_k rotation matrix. The dotted parameters designate their derivatives with respect to time (*Altamimi and Boucher, 2003*).

Weekly Combination Strategy

Validation step (per AC Individual cumulative combination)

Main objectives are a) the estimation of internal consistency and the detection of discrepancies of the solutions, b) SINEX cleaning.

The validation includes projection using inner-constraints, cumulative combination with inner-constraints on translation, scale and rotation (no datum used). At each iteration, stations with high residuals are rejected.

Weekly combination step

A 7 parameter transformation is then calculated every week using an IDS ITRF2005 datum - sub-network with best σ on position (< 1 cm) and velocity (< 2 mm/yr) with common stations to the week to process -. The solutions are weighted with variance factor of each combination.

DORIS Inter-Center ORBIT comparisons

Purpose

1. Level of **agreement/disagreement** between orbits of IDS centers
2. Quality control: **systematic effects** and spurious arcs (alerts to AC's)
3. Work with analysis to identify issues and improvements
4. Ultimate objective: develop the **best possible IDS product for ITRF2008**

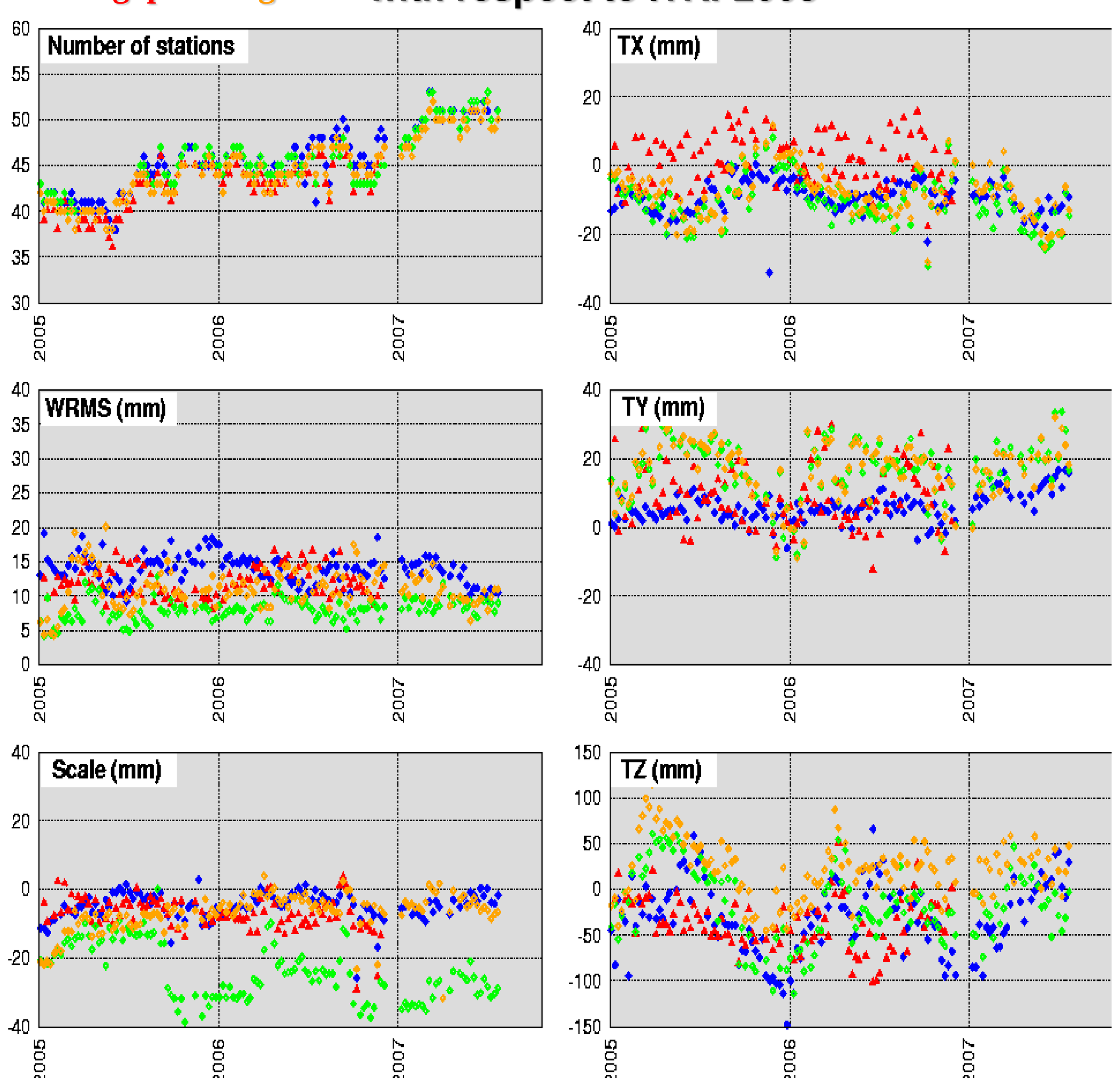
DORIS-orbits sets

AC Series & Satellites	Orbit Strategy & Software
IGN *ENV, SP2, SP4, SP5, 2005*	**30-hr arc, Gipsy.**
INA *ENV, SP2, SP4, SP5, JA1, 2005*.	**30-hr arc, Gipsy.**
GOP *ENV, SP2, SP4, SP5, JA1, Jan. 2005*	**Bernese.**
LCA *ENV, SP2, SP4, SP5, JA1, 2005-7*	**3.5-day arcs, GINS.**
LCA2 *ENV (updated ENV models, GINS vers.)*	**3.5-day arcs, GINS.**
GSFC *ENV, SP2, SP4, SP5, JA1, 2005-6*	**7-day arcs, GEODYN0712.**
AUS *ENV, SP2, SP5, JA1*	***7-day* arcs, GEODYN0511.**
ESOC *ENV, 2005-2007*	***7-day arcs (SLR+DORIS)***

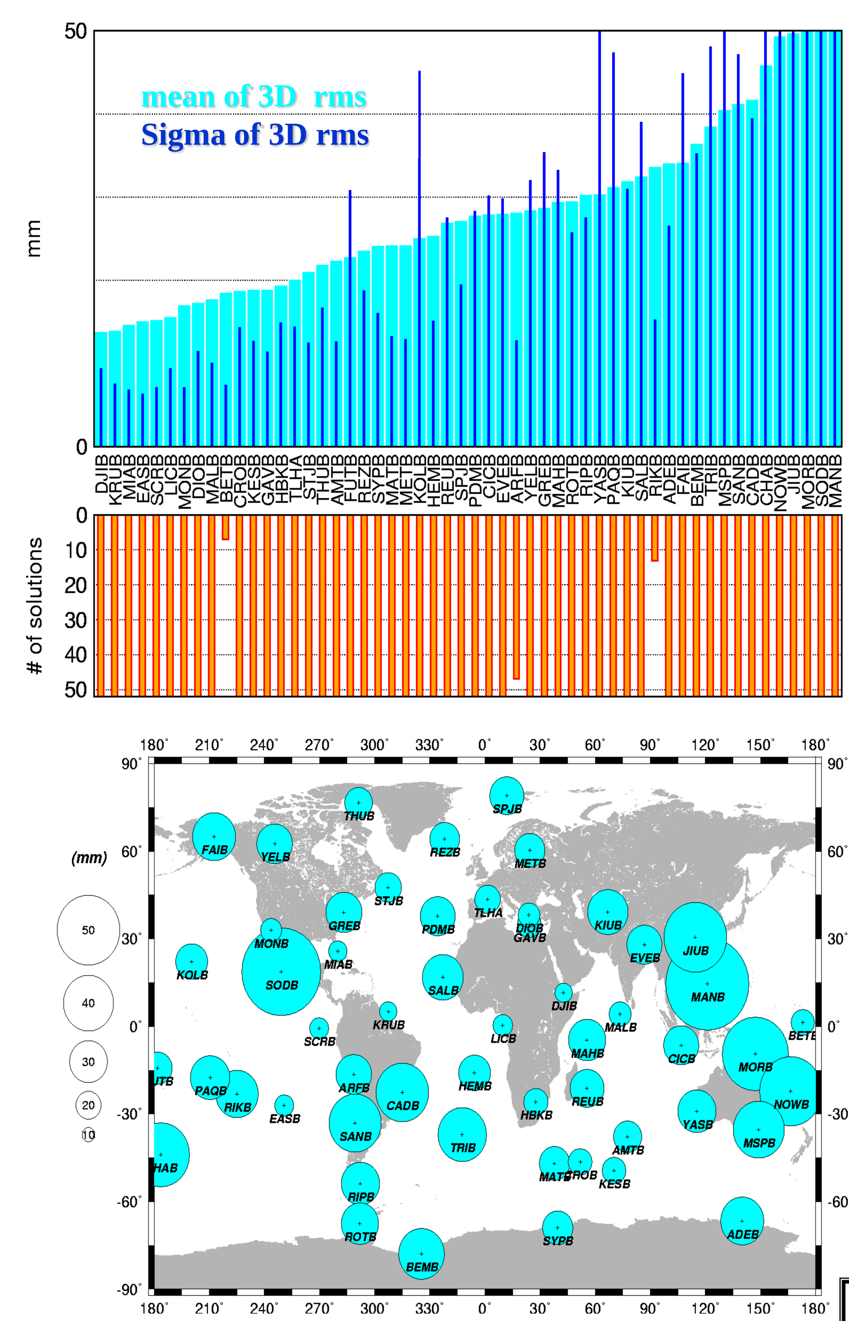
Notes:
1. Actual arc lengths in any week depend on orbit maneuvers.
2. Bernese used to process DORIS data at GOP is derived from version 5.
3. ESOC uses the NAPOES software.
4. IGN, INA, LCA, GSFC, AUS, generally used CNES-supplied macromodels, although other models (cf. University College London) are available for ENV and JA1. ANGARA model used at ESOC for ENV to apply nonconservative forces.
5. All centers are generally compliant with IERS standards, and used ITRF2005 as a priori for the DORIS processing.

WEEKLY COMBINATIONS (multi-satellites solutions)

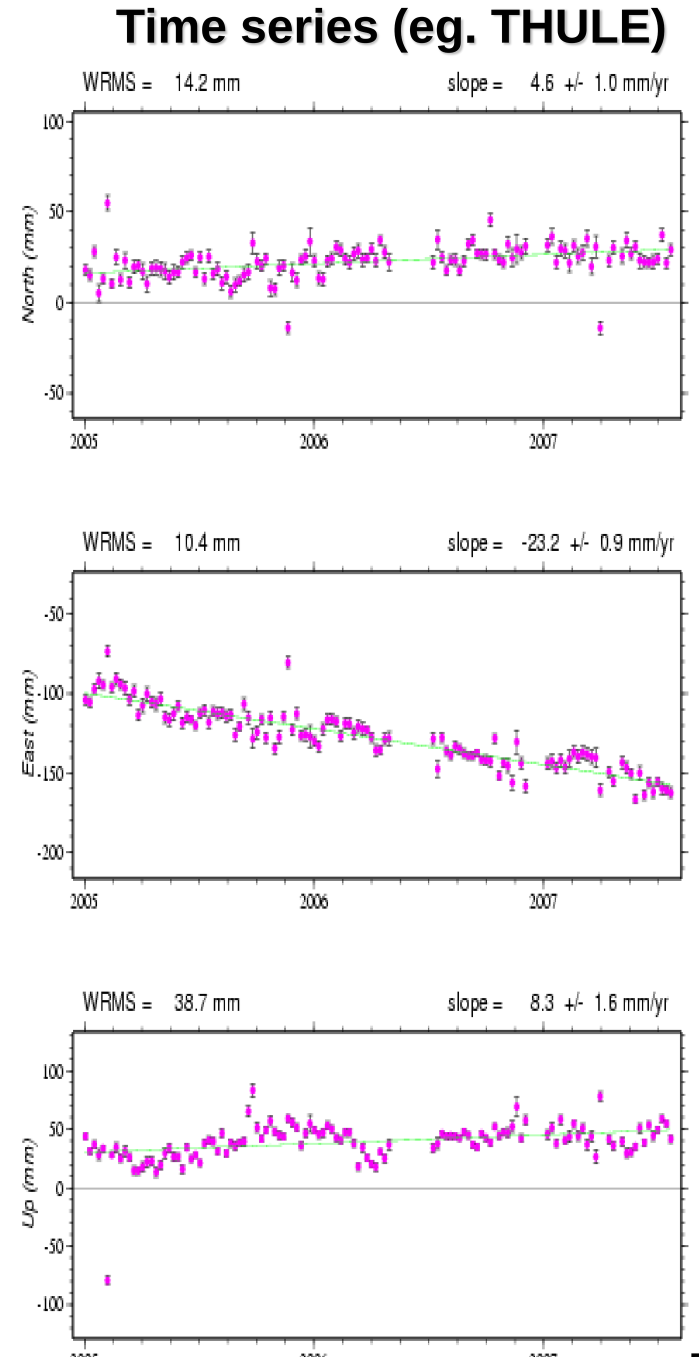
TRF parameters (Geocenter & Scale) with respect to ITRF2005



Per station Residuals (2006))



Time series (eg. THULE)



For comparison, the collocated THU2 (GPS) station (using data from 3.5 years or 2004 through mid 2007) yields velocities of 4.59 ± 0.11 mm/yr (north), -22.37 ± 0.11 mm/yr (east) and 9.40 ± 0.40 mm/yr (up)¶. So the geodetic velocities at Thule from DORIS and GPS are in agreement and both show an uplift of about 8-9 mm/yr.

¶ GPS comparison solution from http://sideshow.jpl.nasa.gov/mbh/series.html , NASA/JPL, courtesy of M. Heflin, 2007.9.

Encouraging

Four AC's provide very consistent solutions based on three independent software packages, two of them are operational with routine production
Weighted RMS of the combinations are between 10 to 15 mm with the for AC solutions. More info at ftp://ftp.cls.fr/pub/ids/combinations

To be investigated and understood

Systematic effects remain in the TRF parameters such as large TZ yearly signal or 1-3 cm TY bias,
Some behaviour is puzzling (INA scale jump at end of 2005). Solutions from AUS are at a lower level than other AC's (not plotted here). AUS is now reprocessing Jason-1, analyzing SPOT-4 data and performing intercomparisons with the other GEODYN analysis center (GSFC).

ORBIT COMPARISONS (2005-2007)

ENVISAT: RMS

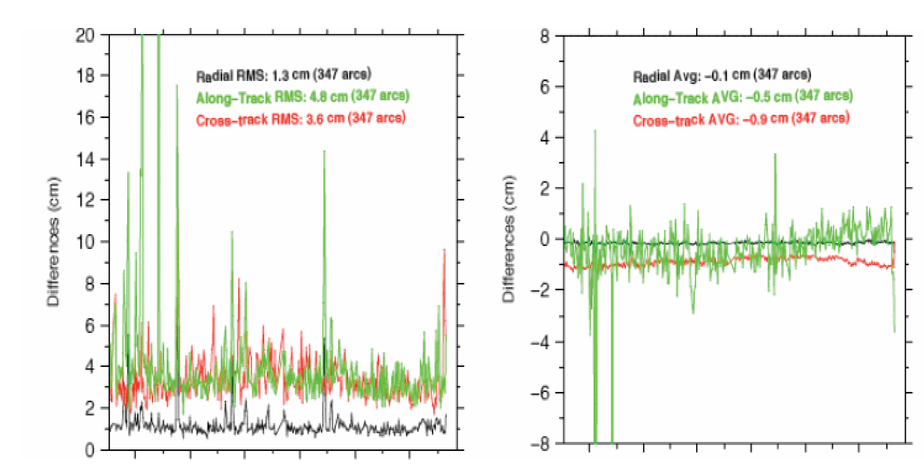
ENVISAT				
Orbit Set	Npts	RMS Orbit Differences (cm)		
		Radial	Cross-tr.	Along-tr.
ESOC vs IGN	299	1.5	3.2	5.4
IGN vs GSFC	295	1.7	4.2	6.3
IGN vs INA	294	1.3	4.8	11.6
INA vs GSFC	292	2.0	6.0	13.0
ESOC vs INA	292	1.6	4.5	12.6
ESOC vs GSFC	347	1.3	3.6	4.8
AUS vs GSFC	42	1.0	9.2	8.3
ESOC vs GOP	29	1.8	4.7	9.8
GOP vs GSFC	28	2.4	5.0	11.7
GOP vs IGN	30	2.1	4.7	11.8
IGN vs LCA	284	5.4	7.2	14.6
IGN vs LCA2	273	2.1	6.0	6.2
GSFC vs LCA	227	5.6	7.3	15.4
GSFC vs LCA2	103	2.3	7.4	6.1
INA vs LCA	274	5.8	7.1	14.7
ESOC vs LCA	732	5.5	6.5	15.3
ESOC vs LCA2	320	1.9	5.9	4.6

ENVISAT: Mean

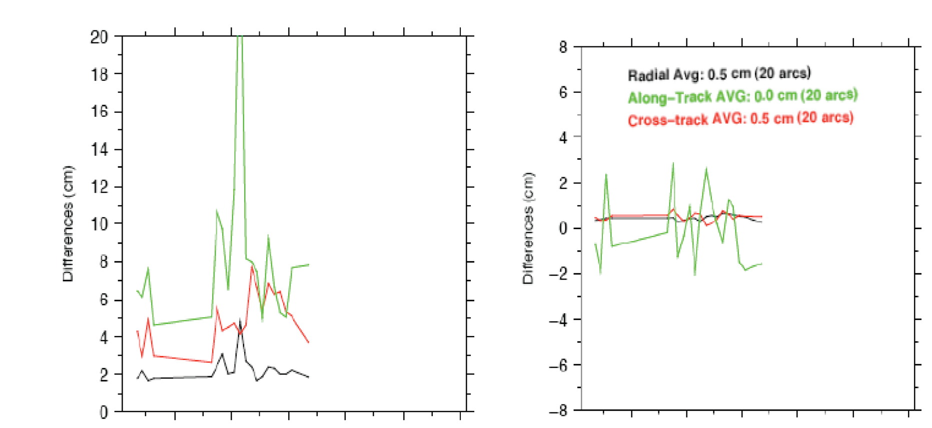
ENVISAT				
Orbit Set	Npts	Average Orbit Differences (cm)		
		Radial	Cross-tr.	Along-tr.
ESOC vs IGN	299	0.1	-0.1	-0.6
IGN vs GSFC	295	-0.2	-0.8	-0.2
IGN vs INA	294	-0.5	-0.3	9.5
IGN vs LCA	284	-0.2	-1.0	8.1
IGN vs LCA2	273	-0.5	-2.3	-2.0
LCA vs GSFC	227	-0.4	-1.9	9.5
LCA2 vs GSFC	103	-0.7	-3.2	-1.5
INA vs LCA	274	0.3	-0.6	-2.2
ESOC vs LCA	732	-0.2	-0.9	9.6
ESOC vs LCA2	320	-0.5	-2.3	-1.2
INA vs GSFC	292	-0.7	-1.2	9.7
ESOC vs INA	292	0.6	0.2	-10.1
ESOC vs GSFC	347	-0.1	-0.9	-0.5
AUS vs GSFC	42	0	0	2.5
ESOC vs GOP	29	0.5	0.1	0.4
GOP vs GSFC	28	-0.7	-1.2	-1.1
GOP vs IGN	30	0.4	0.3	0.8

notable differences:
IGN-INA & AUS/GSFC while same software is used (under investigation)
also with LCA (ENVISAT reprocessing planned)

ESOC vs. GSFC v2 (2005 ENVISAT)



GOP vs. IGN (Jan. 2005, SPOT2)



Per satellite RMS orbit differences average

Satellite	Radial	Cross-tr.	Along-tr.
ENVISAT (w. LCA2)	1.8	4.6	8.6
SPOT2	1.6	5.0	8.5
SPOT4	1.6	4.9	7.8
SPOT5	1.3	4.7	7.5

Overall inter-center orbit consistency is good: < 2 cm (radially) even with issues by some AC
Systematic orbit differences revealed by AC or by satellite in some cases.

WORK PLAN FOR IDS CONTRIBUTION TO ITRF2008

Several problems have to be solved in order to prepare the IDS contribution to ITRF2008 (planned at end of year). The causes of orbits differences have to be elucidated. Some differences should be easy to resolve (eg., IGN vs INA, new LCA ENVISAT orbits), others are more subtle (1 cm mean along-track difference in some GSFC orbits). Simultaneously, origin of incoherencies in some SINEX series have to be found (INA, AUS...). Present processing strategy and models have been examined and a plan is under discussion to the application of standards. Further analysis of the combinations per satellite and per station (worst stations and core network) are also needed. After corrections and alignment of the software to the IDS ITRF2008 recommendations, stations coordinates and EOP parameters will be re-calculated by the AC's. A combined IDS solution will then be generated with CATREF.

Strong collaboration between analysts is stimulated by an **Analysis Working Group. Next meeting is planned next June.** Contact : F. Lemoine (IDS analysis coordinator)

References

Altamimi Z, Boucher C (2003) Multi-technique combination of time series of station positions and Earth orientation parameters. In: Richter B, Schwegmann W, Dick W(eds) Proceedings of the IERS workshop on combination research and global geophysical fluids. IERS Technical Note No. 30. Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt am Main, pp 102–106.
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