**IDS**

*Meeting minutes*

# IDS AWG - Delft

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**Distribution (*):**

Liste AWG IDS

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## 2. Introduction

The last International DORIS Service Analysis Working Group (IDS-AWG), from May 26 to May 27 2016, was hosted in the Aerospace building of the Technical University of Delft thanks to our guest Ejo Schrama.
The main objectives of this meeting were:

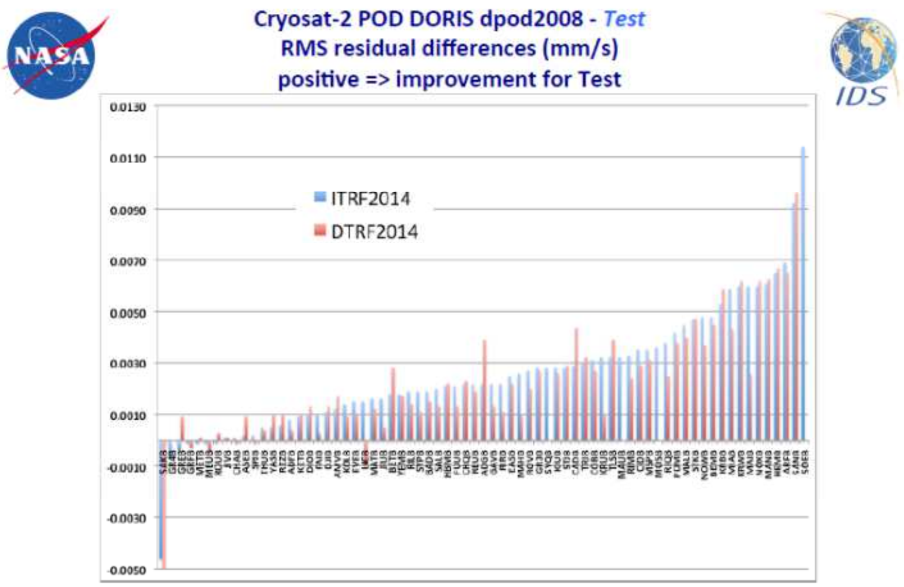
- ACs and CC feedback on the TRF2014 (ITRF, DTRF and JTRF2014) evaluation
- to discuss about the switch to the ITRF2014 for IDS operational products
- to discuss about the open issues following ITRF2014 realization
- ACs status and schedule on the DORIS RINEX data processing
- to focus on the sensitivity to SAA of the DORIS USO of the last satellites
- to show the POD results of the last satellites
- on the IDS studies, as a promising method for geocenter determination using DORIS presented by Alexandre Couhert from CNES

First, we give the highlights of this meeting. In the following part, an abstract with the main conclusions of each oral presentation is given. Finally, we list the actions in progress and the news actions from this AWG.
All the slides displayed during this meeting will be available at:
http://ids-doris.org/report/meeting-presentations.html#ids-awg-05-2016

## 3. Highlights of the AWG

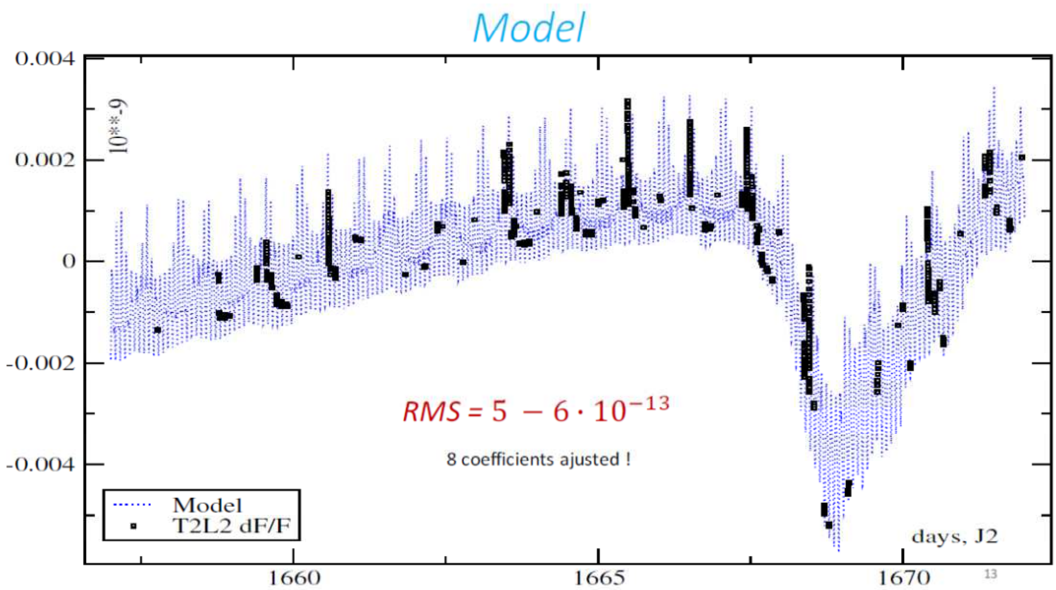
The meeting started with the activity reports of four of the six Analysis Centers (AC): Geodetic Observatory Pecny (GOP, V. Filler), Goddard Space Flight Center (GFC, F. Lemoine), Institut national de l'information Géographique et forestière français (IGN, P. Willis), and Groupe de Recherche de Géodésie Spatiale (GRG, H. Capdeville); and with the report of the IDS Combination Center (IDS CC, G. Moreaux).

A session was then devoted to the assessment of the three realizations of the Terrestrial Reference Frame which are the outcome of the “ITRF2014 effort”: the ITRF2014 (IGN), DTRF2014 (DGFI) and JTRF2014 (JPL). While ITRF2014 and DTRF2014 are formally similar, differing only by the Post Seismic Deformation model (PSD) which have been introduced in the IGN solution, the JPL solution is quite different, being a time series of weekly solutions obtained through a Kalman filter process. Due to editing criteria the JPL solutions contains less stations at a given time than the two others, particularly at the beginning of the processed period, in 1993. The three TRF realizations have been evaluated in terms of DORIS observation residuals, orbit overlaps and transformation parameters of the DORIS network (presentations of G. Moreaux, E. Jalabert and F. Lemoine). All TRF realizations represent a clear improvement over the previous realization, ITRF2008. Based on the different criteria used for evaluation, it has been shown this is the ITRF2014 which presents the best overall performance. It is this model that will serve as a basis for the operational processing of future DORIS data.



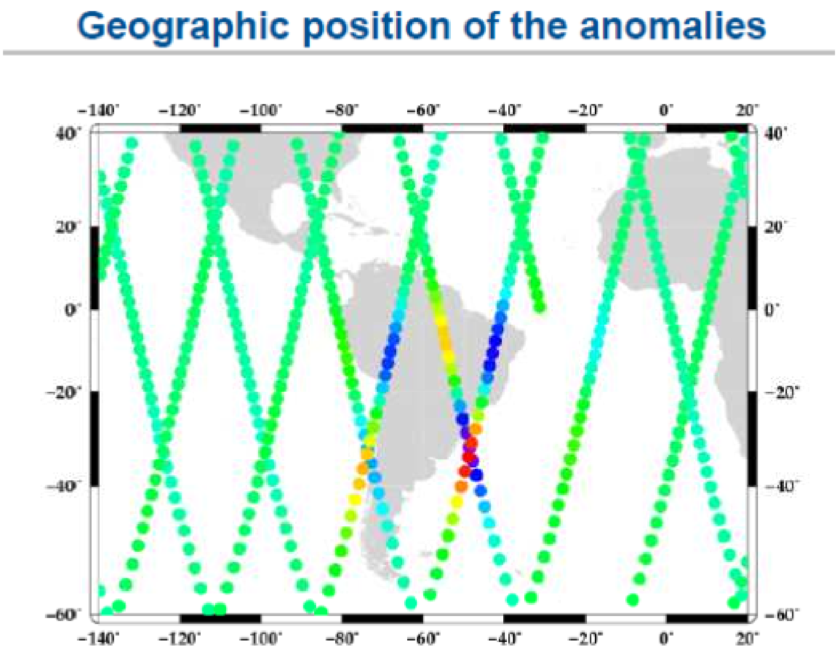
For that purpose the ITRF2014 needs to be supplemented (new DORIS stations not present in the ITRF2014 solutions, if necessary correction of the position and velocity for the stations which had a short observation interval in the ITRF2014). This extension of ITRF2014 for the DORIS network, called DPOD2014, can take two different shapes: one where only the position/velocity of the most recent stations are re-determined (DPOD2008-type), or one where an update the position/velocity of all stations is performed and aligned on the ITRF2014, leading to possible minor adjustment of older stations. The two approaches will be compared by G. Moreaux and a version of the DPOD2014 will be submitted to the evaluation of the users by the end of June 2016. Ejo's conclusion: *Let's switch to ITRF2014.*

The next main session was devoted to the behavior of the various DORIS on-board oscillators in the vicinity of the high radiation area "South Atlantic Anomaly" (SAA). It has been shown by different speakers that all DORIS receivers are frequency-sensitive to the crossing of the SAA, though at very different levels. Thanks to the extremely precise time-tagging of the T2L2 experiment on-board Jason-2, A. Belli and the GEOAZUR team showed that the DORIS on-board Ultra Stable Oscillator (USO) of Jason-2 is approximately 10 times less sensitive to the SAA than the one of Jason-1. Taking into account the temperature of the DORIS USO and the radiations received they managed to draw up a model that accurately represents the variations of Jason-2 USO's frequency (enabling time transfer by laser link between SLR stations that are not in common view). This model is available for test within the IDS at GEOAZUR's ftp site.




P. Willis has shown, thanks to the "DORIS PPP method" on uncorrected Jason-2 DORIS data, that the positioning error due to the SAA can reach up to 10 cm for some stations with this satellite. H. Capdeville and C. Jayles both showed that Jason-3 is also sensitive to the SAA, at a level which is lower than that of Jason-1, but still 4 to 5 times higher than that of Jason-2. The same has been shown by A. Couhert et al. on Sentinel-3A. F. Mercier, using an original method based on the clock determination of the GNSS receiver on-board Sentinel-3A, showed that it is possible with this method to obtain an accurate and continuous observation of the satellite's USO frequency excursions.

One of the conclusions of this session was that, while no noticeable effect of the SAA influence has been shown on POD or reference frame transformation parameters, there is an important impact on the station position estimation for some stations in the vicinity of the SAA area. Building accurate models of frequency variations in response to the temperature and to the SAA radiations for each DORIS USO is therefore a task that is encouraged by the IDS community for the accurate position estimation of all DORIS stations. GRG AC is volunteer to test the model of A. Belli et al. for Jason-2 and analyze its impact on the position estimation of SAA stations.




In the rest of the IDS AWG various topics were discussed: Cryosat-2 POD at TU Delft (E. Schrama makes available the Cryosat-2 quaternions to the IDS community); DORIS-satellites POD at GFZ and the influence of secular gravity signals in POD (S. Rudenko); the importance of taking into account the Jason-2 solar arrays quaternions in the reduction of the 120-day signal in the POD (F. Lemoine); the presence of an annual signal in the LOD determination by GOP (V. Filler); M. Ziebart reported on the improved surface force modeling of Jason-2 at UCL using a refined description of the satellite's shape and optical properties. GA. Hjelle reported on the progress of the new multi-technique POD software "WHERE" at NMA. A. Couhert presented a promising method for geocenter determination using DORIS. In conclusion J. Saunier gave a report on the status of the DORIS network and P. Ferrage on the current and foreseen DORIS missions.

There is an apparent correlation (or not?) of the recent years' increase in the DORIS measurement residuals, which cannot be attributed only to the uncertainty of DPOD2008 in extrapolation mode, with the solar activity (Solar flux at F10.7). On this point, the Analysis Coordinators require the ACs who are willing to participate to provide their time series of satellite measurement residuals. The high scale level of HY-2A has been mentioned and an action has been decided to solve this problem: GSFC, CNES-POD, GRG, INA and IGN have agreed to make a multi-year determination of the HY-2A radial offset. The scale jump in 2012 seems fully explained by a variation in the number of low-elevation measurement included in the processing (H. Capdeville, J. Moyard). First, the IDS CC has to confirm by analyzing all the AC contributions that only AC not using the flagged data in the doris2.2 file (from CNES pre-processing) are impacted. ACs could provide a Jason-2 single satellite solution obtained from processing using homogeneous editing criteria since 2011 (i.e. not relying on the CNES editing flags in the doris2.2 file). Then, if the problem is solved for Jason-2, it has been decided to reprocess all data using these homogeneous editing criteria for the whole period of each satellite having data in 2012.

Analysis coordinators propose to do orbit comparison between all ACs. A chain of comparison is in progress but they need to have orbits in sp3 format (terrestrial frame, TAI scale). Then, on voluntary basis and for test purpose (maybe not on regular basis), ACs and associated may deliver their sp3 orbit to the CDDIS/IGN data centers in the appropriate directory.

Finally, JM. Lemoine delivered some recommendations on the practical implementation of the RINEX measurements in the POD software.

Here the list of actions which have decided during this AWG:

Action 1: concerning the next DPOD 2014, two approaches will be compared by G. Moreaux and a version of the DPOD2014 will be submitted to the evaluation of the users by the end of June 2016.

Action 2: GRG AC is volunteer to test the model of AB for Jason-2 to analyze its impact on the position estimation of SAA stations.

Action 3: Analysis Coordinators require the ACs who are willing to participate to provide their time series of DORIS measurement residuals since 2011.0 for each satellite available

Action 4: GSFC, CNES-POD, GRG, INA and IGN have agreed to make a multi-year determination of the HY-2A radial offset

Action 5: IDS CC has to confirm by analyzing all the AC contributions that only AC not using the flagged data in the doris2.2 file (from CNES pre-processing) are impacted

Action 6: ACs could provide a Jason-2 single satellite solution obtained from processing using homogeneous editing criteria since 2011 (i.e. not relying on the CNES editing flags in the doris2.2 file). Then, if the problem is solved for Jason-2, it has been decided to reprocess all data using these homogeneous editing criteria for the whole period of each satellite having data in 2012

Action 7 for volunteer ACs and ACs associated: on voluntary basis and for test purpose (maybe not on regular basis), ACs and associated may deliver their sp3 orbit to the CDDIS/IGN data centers in the appropriate directory:

ftp://cddis.gsfc.nasa.gov/pub/doris/products/orbits/

# 4. Oral presentations abstracts

## 4.1. Day1 – May 26th

### 4.1.1. ACs and CC Status

**GOP (By P. Stepanek)**

The data until end of 2015 were processed by GOP AC. The software Bernese used by GOP AC was upgraded from 5.0 to 5.2 version (more than 1500 software modules, hundreds of them modified in both versions). Some improvements in processing automation were done. The implementation of DORIS RINEX data processing is still in progress (scheduled late 2016). A LOD estimation campaign began with data 2003.0 – 2016.0. We note the presence of an annual signal in the LOD determination.

**GSC (By F. Lemoine)**

1.We have delivered an updated SINEX series that now includes SARAL (wd27), and in addition we have resubmitted all SINEX files since late 2013, since we reprocessed the data with an updated apriori file, DPOD2008v15.
2. We experimented with modeling the solar array orientation with solar array quaternions. Our conclusion is that the modeling is important, since it appears to reduce systematic signals in the EOP time series.
3. We have begun to look at the Jason-3 DORIS/RINEX data, and have not detected any anomalies in the processing except for a short data gap in March 2016. We still need to tune the macromodel for Jason-3.

**IGN (By P. Willis)**

IGN continues the regular submission of SINEX solutions (every 3 months) using exact same processing strategy of ignwd15 series. IGN AC needs to update satellite models for Saral and HY-2A. After the DORIS/RINEX data processing implementation, the new satellites (Jason-3, Sentinel3A) could be added.
Concerning the DORIS/RINEX data, the development is made in parallel for GIPSY/OASIS and for new G-Core (JPL). IGN is solving current issues/problems as the clock correction. Note that the phase and pseudo-range are processed together (GPS-like data processing).
The future plans of IGN ACs are (assuming DORIS/RINEX data processing is fully operational):

- adding new satellites (Jason-3, Sentinel3A)
- combining DORIS results (multi-satellite solution as before or summing up individual results)?
- phase center correction (using long-term time series of phase residuals)

And the urgent actions are to:

- investigate new CDDIS delivery procedure (in progress)

- finalize DORIS/RINEX data processing for Jason-2 (preprocessing and filtering strategy in progress)

**GRG (By H. Capdeville)**

GRG AC computes DORIS data with 3.5-day arcs and a cut-off angle of 12° using ITRF2014 configuration (from Jan. 2015 to Dec. 2015) for satellites available SPOT5, JASON-2, CRYOSAT2, HY-2A, SARAL. The DORIS and SLR RMS of fit of the orbit determination and the OPR Acceleration Amplitude are similar to those obtained previously. We observed an increase of DORIS RMS of fit of the orbit determination since 2012 for all DORIS satellites. The use of ITRF2014 leads to slightly reduce the RMS but not completely. The DORIS residuals increase could be correlated to solar activity (Solar flux at F10.7).There is also a decrease mid-2015.
A study of the impact of tropospheric model / cutoff angle / low elevation data downweighting on the scale and Geocenter will continue. After the introduction of the last satellites (Jason-3 done and Sentinel-3A in progress) in the GRG processing chain, these data will be added in the multi-satellite solution. When the problem of time-tagging of the RINEX data will be corrected, an evaluation the DORIS/RINEX from PANDOR software will be done.

**IDS CC Status of the routine evaluation/combination (By G. Moreaux)**
That presentation first gives the status of the evaluation of the 6 ACs multi-satellite solutions until 2015 doy 354-361 with respect to the ITRF2014 (including post-seismic deformation corrections). Comparison of EOPs with the preliminary IERS C04 series aligned with ITRF2014 is also depicted. The IDS Combination Center also presented the evaluation of the new combined solution (ids 11) in which all the ACs both contribute to the combined scale and to the combined EOPs. Due to the scale increase of half of the ACs early 2015, the ids 11 scale also exhibits an increase in 2015. Moreover, as all the ACs now contribute to the combined scale, compared to ids 09 (IDS contribution to ITRF2014), ids 11 shows a slightly more important scale increase early 2012.

## 4.1.2. TRF2014 Evaluation

**Evaluation of ITRF2014/DTRF2014/JTRF2014 solutions in Jason precise orbit determination (E.Jalabert)**

In 2015, three new Terrestrial Reference Frames (TRF) have been released: the International TRF (ITRF2014), the JPL TRF (JTRF2014) and the DGFI TRF (DTRF2014).
This presentation compares the four different TRFs solutions in terms of DORIS/SLR/crossover residuals and Jason orbit-induced differences.
The main conclusions are:

- Using a new TRF instead of ITRF2008 gives a low but consistent improvement of the orbits in terms of residuals.
- The orbit differences are small (especially in the radial direction).
- Among the new TRFs, ITRF2014 seems to give better results.

**ITRF2014 Evaluation by GSC (F. Lemoine)**

The ITRF2014, DTRF2014 and JTRF2014 were evaluated by SLR and DORIS data processing for TOPEX, Jason-1 and Jason-2 satellites. There is an improvement when using ITRF or DTRF2014 compared to DPOD2008 in DORIS residuals, less clear for TOPEX. This improvement can also see on the residuals per station except for some stations for which GSC has to understand what happens. For SLR residuals, there is an improvement for Jason-2 but for TOPEX and Jason-1 there is a degradation for most stations.
Note that the JTRF2014 weekly series from 1979 through 2014, consists of a constant number of 972 station positions of which 71 are SLR and 159 DORIS. A given station may be active or inactive over any one weekly period.

**GFZ Evaluation (S. Rudenko)**

ITRF2014 has been tested for precise orbit determination (POD) of TOPEX/Poseidon (September 1992 – October 2005) and Envisat (April 2002 – April 2012). The mean values of the SLR RMS fits improved by 2.5-3.6% for these satellites, when using ITRF2014 instead of ITRF2008+SLRF2008+DPOD2008. The mean values of DORIS RMS fits improved by 0.3-0.8% for these satellites. The most significant reduction of SLR and DORIS RMS fits obtained for years 1992-1998 for TOPEX/Poseidon and 2010-2012 for Envisat. That is, most probably, related to the improved values of station velocities in ITRF2014, as compared to ITRF2008+SLRF2008+DPOD2008. Significant improvement of 2-day orbital arc overlaps obtained for TOPEX/Poseidon orbits, when using ITRF2014 instead of ITRF2008+SLRF2008+DPOD2008: 7.1, 0.9 and 30.8% in radial, cross-track and along-track directions, respectively.

Many outliers disappeared or decreased. The number of used SLR and DORIS observations is 0.7-0.8% and 2.3-4.2% less, when using ITRF2014 instead of ITRF2008+SLRF2008+DPOD2008. That means, there is a need in the generation of SLRF2014 and DPOD2014 by the inclusion of SLR and DORIS stations missing in the ITRF2014.

**IDS evaluation of the DORIS versions of the DTRF2014, ITRF2014 and JTRF2014 solutions (G. Moreaux)**

These slides are the IDS Combination Center EGU2016 presentation. They present the differences in terms of Helmert parameters while using these three solutions as the reference datum in the evaluation of the ids 09 series. The ids 09 series is the DORIS contribution to ITRF2014. As the ITRF2014 presents the more stable series of parameters, gives velocities with geophysical meanings and can be propagated with time, the IDS Combination Center recommends its use as reference for the next evaluations.

## 4.1.3. How and when to switch to the ITRF2014 for operational products

**Proposal for a new DPOD elaboration scheme (G. Moreaux)**
Since summer 2015, the realization of the DPOD belongs to the IDS Combination Center. The IDS CC proposed to build the next DPOD as a cumulative DORIS position and velocity solution from the latest ids multi ACs combined solution. Then, due to the continuity constraints, the adding a recent data can have an impact on both the positions and velocities of old stations. To quantify that impact, the IDS CC compared three cumulative solutions based on the ids 11 series and corresponding to three different time spans: 1993-2008 (ITRF2008), 1993-2014 (ITRF2014) and 1993-2015 (ITRF2014 + one year). The results shows position differences smaller than 2 cm. Comparison of the cumulative solution over the time span 1993-2015 with ITRF2014 shows differences with a RMS smaller than 1.5 cm. After new tests on the determination of the position and velocities of new sites (ex: Owenga), the DPOD users will be contacted to know which DPOD solution they prefer between the old one and the new one (cumulative solution).

## 4.1.4. Temperature, radiation and aging analysis of the DORIS Ultra Stable Oscillator by means of the Time Transfer by Laser Link experiment on Jason-2 (A. Belli)

The Time Transfer by Laser Link (T2L2) was proving to be an extremely good tool to extract time & frequency products (time stability and accuracy). In particular, the relative frequency bias of the DORIS USO (Jason-2) has been determined over a long time period with a precision of a few parts in $10^{-13}$ from ground-to-space time transfer passages. This opened the door to the physical modelling of observed frequency variations of the USO.
Among the physical effects which drive the frequency variations onboard Jason-2 we investigated the temperature (measured onboard), aging and radiations over the South Atlantic Anomaly (SAA) area that the USO was exposed to. A model was established to represent these effects on the short term (every 10 days), and some empirical coefficients (sensitivities of the USO) were adjusted. The analysis allowed us to conclude that: (i) the temperature to frequency dependence is very stable along the mission duration (around 1.2 $10^{-12}$ per °C, (ii) the radiation effects are much lower than those previously detected on the Jason-1 USO with a factor > 10, and (iii) aging is nominal. The swept material used by manufacturers for the Jason-2 quartz oscillator has such properties to avoid non-linear effects >1–2 $10^{-12}$. Now, the model is available at 1 min over several years with a level of consistency of 5 $10^{-13}$, which is the average RMS of the post-fit residuals.
The direct applications of this model can be the POD of Jason-2 and the DORIS station position estimation. The non common view time transfer between distant laser ranging observatories. We expect, by integrating the model over a few hours, to propagate the phase (time) between successive passes of the satellite above several laser stations from a selected one as the reference, to a few nanoseconds (ns). The first results show that nearly all laser stations of the network are not currently synchronized with the UTC (Universal Time Coordinate) time scale at the required limit of 100 ns, as it is recommended by ILRS (International Laser Ranging Service).
The complete model is available (http://www.geoazur.fr/t2l2/en/data/v4/) with a RMS around 5-6 $10^{-13}$ (Belli et al., ASR, in press). Comparison and complementarities between both T2L2 & DIODE techniques were demonstrated at the level of $1.10^{-12}$ [Jayles et al., ASR, in press]. There are complementarities of CARMEN-2 data to DORIS-USO [Capdeville et al., ASR, in press]. DORIS USO JASON-1, -2, and -3 are sensitive to radiations very differently. Our

model opens the door to propose a unified approach. We expected a time transfer in non common view at the level of a few ns for ILRS stations.

### 4.1.5. Is the Jason-2 DORIS Oscillator also affected by the South Atlantic Anomaly Effect (P. Willis)

We analyzed time series of daily DORIS and GPS station coordinate estimates derived from Precise Point Positioning (PPP). The DORIS coordinates were estimated using Jason-2 precise orbits based on GPS data only, implying that the station positions from the two techniques are expressed in the same GPS-based terrestrial reference frame. Comparisons of 3-D vectors of such co-located stations show systematic biases in position around South America when compared to local geodetic ties. We conclude that these results could be explained by a sensitivity of the Jason-2/DORIS oscillator to radiation when the satellite passes over the South Atlantic Anomaly (SAA). The effect for Jason-2 manifests mainly as an offset in station coordinates, though there is also evidence of a drift that diminishes in time. This contrasts with the experience on Jason-1, wherein large, persistent drifts were observed for stations in this same (SAA) region. The spurious drift is much (~90%) smaller for Jason-2, which may be attributable to the steps taken prior to launch to harden the oscillator. Analysis of DORIS Doppler residuals may indicate some small degradation after 2009 for these stations.

### 4.1.6. Behavior of DORIS / Jason-3 USO (C. Jayles)

From first observations of USO frequency behavior performed in the frame of DORIS/Jason3 in-flight commissioning, CNES experts suspect a slight sensitivity to radiations:
- much lower than the one of Jason1 (ten times less),
- but a bit higher than the one of Jason2.

Further investigations are going on to appreciate this sensitivity and its long term trend.
This sensitivity induces :
- no consequence on altimetry,
- almost no impact on orbit computation,
- probably a few centimeters perturbation on Beacon Positioning for beacons in visibility of the South-Atlantic Anomaly.

Jason-3 / DORIS are well within their specifications and even inside their objective goals for NRT altimetry (OGDR), high accuracy Altimetry and POE orbits determination. For station positioning, a model will be necessary.

### 4.1.7. Are the Jason-2 and Jason-3 USO sensitive to the SAA? (H. Capdeville)

Jason-2 is sensitive to SAA but not at the same level as Jason-1 and SPOT-5. It has shown by A. Belli et al. and later on by P. Willis et al. The effect is not strong enough:
- to be observed clearly on the frequency board estimated by CNES MOE processing
- to be observed clearly on Kourou frequency bias/pass adjusted by GRG processing
- to be observed on the DORIS residuals of SAA station

The Jason-2 single satellite solutions show that the Jason-2 USO is affected by SAA. Compared to Cryosat-2 solution, there is a Bias in Up and/or North component for the SAA stations (Cachoeira, Santiago, Arequipa, Kourou, Ascension, Libreville). The multi-satellite solution provided for ITRF2014 contribution can be impacted by the Jason-2 solution for SAA stations.
Jason-3 is more sensitive to SAA than Jason-2. Indeed, the effect is strong enough:
- to be observed clearly on the frequency board estimated by CNES MOE processing (see presentation of C. Jayles)
- to be observed clearly on Kourou frequency bias/pass adjusted by GRG processing
- to be observed on the DORIS residuals of SAA station

The Jason-3 single satellite solutions show that the Jason-3 USO is affected by SAA. Compared to Cryosat-2 solution, there a Bias in Up and/or North component for the SAA stations higher than those obtained with Jason-2 (Cachoeira, Arequipa, Kourou, Ascension, Libreville). So, a data corrective model for Jason-3 is it useful?

### 4.1.8. DORIS USO observation through the Sentinel-3A GPS receiver (F. Mercier)

The Sentinel-3A satellite is the first DORIS satellite to allow a direct observation of the on board DORIS USO frequency using the GPS receiver. The advantage is that the receiver clock is observed continuously at 1s sampling. Unfortunately, a high frequency signal is superimposed on the observed clock in the phase measurements (which should be the USO clock), preventing the correct observation of the USO frequency short term characteristics. However, for intermediate durations (600s, corresponding to a pass duration), it is possible to estimate the remaining signatures due to the USO frequency variations, taking into account the standard DORIS processing (adjusted mean frequency bias over a pass). This estimation shows that there are potentially important model errors (10 cm and more during a pass) when the satellite crosses the South Atlantic Anomaly.

### 4.1.9. Brief POD status on Jason-3 and Sentinel-3A (A. Couhert & F. Mercier)

A POD status for two new Jason-3 and Sentinel-3A DORIS missions was presented, as well as their associated macromodels constructed at CNES and used in the current GDR processing. Jason-3 exhibits higher DORIS residuals than Jason-2, especially over the stations located in the South Atlantic Anomaly. Yet, Jason-3 DORIS-only orbits show similar performances as Jason-2 DORIS-only orbits (~1 cm radial orbit accuracy as validated by independent SLR residuals and comparisons to JPL GPS-based orbits). Sentinel-3A GPS and DORIS orbits are very close to each other (within 1 cm RMS in the radial direction). However, there are still uncertainties in the GPS center of phase cross track location, and this seems also the case for DORIS. This is currently under investigation. The observed DORIS USO shows that there are potentially important SAA effects on Sentinel-3A.

### 4.1.10. CryoSat-2 Precise Orbit Determination (E. Schrama)

The title of the talk was "CryoSat-2 Precise Orbit Determination" and it discussed the status of the POD activities at the Delft University of Technology within the context of a CryoSat-2 product evaluation. Some highlights are that we see that the 10s Doppler rms values are decreasing since 2015, which is around the same time that the solar maximum was reached. The laser residuals which are part of the POD procedure converge at 1.4 cm rms, the CNES SRP model was applied and a more aggressive empirical acceleration modeling scheme was implemented. This results in along track accelerations with a rms of 3.5 nm/s^2 and cross track accelerations around 12 nm/s^2. The external orbit comparisons were implemented with direct crossovers and a 1 on 1 orbit comparison from the CNES trajectories. The crossovers were recently added to our study and we find values comparable to the MOE and the POE orbits crossover residuals. The external orbit comparison directly obtains on average 15 mm radial differences between the orbits computed by the TU Delft and the POE results of the CNES. After the talk it was agreed that SP3 orbits will be submitted by the TU Delft to the IDS for evaluation.

### 4.1.11. Recent DORIS-related activities at GFZ (S. Rudenko)

A study on the impact of the truncation degree of drift terms of the EIGEN-6S4 geopotential model for Envisat POD has been performed. It has been found, that the major contribution of the geopotential drift terms to the Envisat orbit quality is given by low degree terms up to degree 12. However, to reach the best orbit quality in the radial (what is important for altimetry applications) and along-track directions the geopotential drift terms up to degree and order 80 should be used. Slight increase of the cross-track orbit error has been found, when using EIGEN-6S4 geopotential drift terms for degree larger than 20.

### 4.1.12. Progress on the surface force model for Jason-2 (M. Ziebart)

M. Ziebart spoke about progress on the development of a new generation force model for Jason-2. This builds upon the proven successes of the approach trialled on Jason-1. The Jason-2 model offers a number of developments and improvements over the previous generation:

1) Enhanced and more detailed structural model
2) Greater numerical stability and testing procedures in the model computation
3) Details of the material properties and construction of the rear-face of the solar panels (important for Earth radiation forcing)

4) A new model of the solar panel thermal gradient force (the resultant force due to differential heat flow between the front and back of the panels)

Model implementation and testing will be carried out at GSFC with F. Lemoine (GSC) this summer.

### 4.1.13. Where - A new geodetic software being developed at the Norwegian Mapping Authority (GA. Hjelle)

Where is a new analysis software under development at the Norwegian Mapping Authority. The software is planned to be able to analyze data from VLBI, SLR, GNSS and DORIS. At the moment VLBI and SLR are prioritized, and DORIS analysis will be implemented after a first version of the VLBI-part is in place.

## 4.2. Day 2 – May 27th

### 4.2.1. Preprocessing considerations and use of low-elevation DORIS measurements (J. Moyard)

An important gap in adjusted Z position for some DORIS station is identified during orbit determination process. The gap has a direct link with the Geophysical Data Record standard version in regard of the tropospheric model correction. A new preprocessing is implemented using DORIS residuals adjustment on mapping tropospheric model correction. The new preprocessing deals with low elevation measurements (<10°). The use of low elevation measurements during orbit determination needs the integration of a weighting function.

### 4.2.2. Error mitigation in DORIS derived geocenter motion (A. Couhert)

Strategies to mitigate sensitivity to miscentering effects on the orbit coming from the DORIS tracking measurements were examined. In this study, the geocenter motion is estimated simultaneously with the orbit, force and measurement parameters from DORIS data, using only Jason-2. Large benefits are derived through estimating station heights, SRP tuning and the inclusion of the lower elevation data (between 5 and 10 degree elevation cut-off angle). The effect of troposphere errors are also assessed when comparing geocenter estimates based on GPT/GMF and VMF1 models.

### 4.2.3. DORIS Network Status (J. Saunier)

The network availability is maintained over 85% of operating stations since 2012 despite the ageing of the equipment. Most of the recent network events are related to equipment replacement. Managua is a new DORIS site: the station has been installed last April and is co-located with the IGS station "MANA". Sal and Owenga antennas have recently been moved. Station moving at Kitab and new station installation at San Juan (Argentina) are the next network evolution in the coming months. With regard to the stations dedicated to the IDS: DORIS should be part of the fundamental observatory of Wettzell before the end of the year after many compatibility tests with VLBI; Guam in Mariana islands, the second IDS goal, is under negotiation with the University of Guam; finally Sejong, other fundamental site, is still under development with the recent installation of SLR station. Three-quarters of the DORIS stations is co-located with other IERS techniques. Any opportunity to move DORIS (site closure, refurbishment, local event) is seized to have new co-location sites, even where compatibility with VLBI has to be managed.

### 4.2.4. DORIS mission & system news (P. Ferrage)

Today 6 DORIS missions contribute to IDS, including the two last missions Jason3 and Sentinel3. For the future, many other missions are planned, as well as a new generation of DORIS beacons.

### 4.2.5. Status of the articles submitted to ASR (DORIS Special Issue) (E. Schrama & F. Lemoine)

DORIS Special Issue Paper Status (May 27, 2016)

| Paper Status; 20 submitted. | |
|---|---|
| Accepted and online | 11 |
| Minor revision<br>(authors need to make final changes) | 1 |
| Major revision | 1 |
| Under Review (second or later revision) | 2 |
| With Editors | 3 |
| Rejected | 1 |
| Rejected & Resubmitted as two new papers | 1 |

**Papers accepted and online as of May 27, 2016**

| | Authors | Topic | Date online |
|---|---|---|---|
| 1 | **Jayles et al.** | **Compare on Jason-2, DIODE and T2L2 USO DORIS frequency determinations** | **5 Sept. 2015** |
| 2 | **Belli et al.** | **Temperature & Aging of DORIS USO on Jason-2 from T2L2** | **28 Nov. 2015** |
| 3 | **Bloßfeld et al.** | **Assessment of IDS contribution to ITRF2014 by DGFI-TUM** | **18 Dec. 2015** |
| 4 | **Zelensky et al.** | **"Towards the 1-cm SARAL orbit"** | **19 Dec. 2015** |
| 5 | **Moreaux et al.** | **IDS contribution to ITRF2014** | **24 Dec. 2015** |
| 6 | **Lemoine et al.** | **GSFC DORIS Contribution to ITRF2014** | **12 Jan. 2016** |
| 7 | **Capdeville et al.** | **Update of SAA corrective models for Jason-1 and a model for SPOT-5** | **12 Feb. 2016** |
| 8 | **Saunier et al.** | Error budget for Starec DORIS antenna | **24 Feb. 2016** |

| | | | |
|---|---|---|---|
| 9 | Saunier, J. | "Assessment of DORIS network monumentation" | 9 Mar. 2016 |
| 10 | Tourain C | Doris starec ground antenna characterization and impact on positioning | 14 May 2016 |
| 11 | Jayles, C | Doris system and integrity survey | 24 May, 2016 |

### 4.2.6. IDS news (web site news) (By L. Soudarin)

There are some data gaps in RINEX files. The incorrect Jason-2 quaternion files should be replaced soon. The Mass/CoG values are registered in an IDS file available through ftp, and as well available at CDDIS (to be checked). New documents are available on IDS ftp site (macromodels, attitude…). First issue of IDS Newsletter was published in April. The next issue is scheduled in July. A broad delivery is recommended and any suggestion is welcome. Nice videos representing orbit and attitude can be looked at http://ids-doris.org/satellites.html . The next IDS Workshop will be held in October 31-November in La Rochelle. The abstract submissions are expected before July 15, 2016. M. Ziebart makes the offer for holding the 2017 meeting in London.

### 4.2.7. Discussions

- **Open points following ITRF reprocessing**

**DORIS scale jump in 2012**

The increase of the scale factor for Jason-2 and Cryosat-2 is linked to the change of tropospheric model used by CNES in its POD processing (GDR standards): from CNET (GDR-C) to GPT/GMF (GRD-D). It causes a reduction of the amount of data marked as rejected in the doris2.2 file and then, an increase of the data used in GRG analysis considered to be good in CNES pre-processing. The larger number of data, especially at low elevation, could thus be the cause of the change we observe in the scale factor. The date of change is mission dependent. In the case of doris2.2 data, the scale increase of the multi-satellite solutions is due to the jump not at the same time of the Jason-2 and Cryosat-2 solutions but also of the HY-2A high scale. In the case of the RINEX data the jump observed is only due to the contribution of HY-2A. So, IDS ACs need to do their own pre-processing.

To see the impact of the cutoff angle on the scale factor GRG AC has processed a Jason-2 and Cryosat-2 single satellite solution from Jan. 2011 to Jun. 2015 with a cutoff angle of 10° and 20°. When we compared these single satellite solutions to DPOD2008 (computed by CATREF), when an elevation cutoff angle of 20° is applied, the scale jump in 2012 is significantly reduced.

**HY-2A Zoffset and HY-2A Tz**

The high scale level of HY-2A has been mentioned and an action has been decided to solve this problem: GSFC, CNES-POD, GRG, INA and IGN have agreed to make a multi-year determination of the HY-2A radial offset. Some groups have also a high Tz value (~70 mm for GRG). To see which AC is impacted, Analysis Coordinators propose to ACs to provide a HY-2A single satellite solution to IDS CC at least one year (5 years [2011-2015] in the best case).

**SARAL Center of mass**

The initial CoM position in Z for Saral was estimated using DORIS data by CNES POD team: -0.6105 m (initial value was -0.6583). This new value is the one implemented in CNES POE processing since Nov. 6, 2014 and in geometrical correction in the doris2.2 files. The document describing the satellite models implemented in POE processing ftp://ftp.ids-doris.org/pub/ids/satellites/DORISSatelliteModels.pdf has been updated. The Z value of the initial center of gravity in the header of the "mass and center of mass" history file of Saral has also been updated. The re-delivery of the doris2.2 data taking into account the new value of CoM from the beginning of mission to Nov. 6, 2014 by CNES POD team is not urgent, that could be done at the end of Saral mission for example.

**Scale issues on SPOT-5 (sawtooth pattern) / SPOT attitude**

The SPOT-5-only scale clearly showed a sawtooth pattern with breaks. The discontinuities are of the order of -20 mm, so they are significant. This issue is under investigations within the IDS Analysis Working Group.

**Increase of DORIS RMS of fit of the orbit determination**

There is an apparent correlation (or not?) of the recent years' increase in the DORIS measurement residuals, which cannot be attributed only to the uncertainty of DPOD2008 in extrapolation mode, with the solar activity (Solar flux at F10.7). On this point, the Analysis Coordinators require the ACs who are willing to participate to provide their time series of satellite measurement residuals.

**What's Next**

If ACs need help to implement in their POD software the post-seismic models they can contact those that have already done. CC (G. Moreaux) proposes to give to ACs the temporal series of stations impacted by post-seismic model. Note that the next DPOD will not include post-seismic deformation as in the ITRF2014. We are waiting the next DPOD to switch to ITRF2014.

Analysis coordinators propose to do orbit comparison between all ACs. A chain of comparison is in progress but they need to have orbits in sp3 format (terrestrial frame, TAI scale). Then, on voluntary basis and for test purpose (maybe not on regular basis), ACs and associated may deliver their sp3 orbit to the CDDIS/IGN data centers in the appropriate directory.

- **RINEX data processing**

**ACs status:**

- IGN AC: in progress
- GRG AC: awaiting re-delivery of RINEX PANDOR for new tests
- GSC AC: awaiting re-delivery of RINEX PANDOR for new tests
- GOP AC: in progress
- INA AC: depends of IGN
- ESA AC: ?

Finally, JM. Lemoine delivered some recommendations on the practical implementation of the RINEX measurements in the POD software. A bug in time tagging from PANDOR process inferred a high frequency noise in RINEW files. Another problem coming from DIODE was as well removed. The relativistic propagation correction should include not only GM but also the J2 effect. The ionospheric correction has to be computed from RINEX file. ACs should take care that the iono-free phase center is shifted from the 2 GHz phase center by 6 mm on board and 19 mm on ground, so 25 mm at all. Values of CoP-CoM vector and beacon phase center height are newly given for RINEX in an IDS available document. All differences between 2.2 and RINEX data are now explained and the necessary corrections have been applied.

## 5. Actions review

Here, we give the list of the open actions, the news actions are in red:

| Action | Title | Description | who | date | status |
|---|---|---|---|---|---|
| AWG_01 | SPOT5 scale issue | provide the list of suspect attitudes for SPOT satellites (apart from 2011). | F. Lemoine | | open |
| AWG_02 | | plot histogram of residuals for SPOT-4/5, JASON-2 and CRYOSAT-2. See if the center moves according to the elevation | Volunteer ACs | | open |
| AWG_03 | Tropespheric gradient | Ask Michiel whether he does multi-sat or single-satellite gradient estimation | Analysis Coordinators | | open |
| AWG_04 | | Check when GOP AC has problems in the SRP estimation (Saral and Cryostat-2) if it could be related to an event | GOP AC | | open |
| AWG_05 | HY-2A informations | CNES has to contact Chinese agency to have information in particular for the CoP DORIS position. The goal is to obtain information by showing results of HY-2A of scale factor for example. They could also ask if they have GPS-only orbits. | P. Ferrage | | open |
| AWG_06 | ITRF2014 processing | IDS BC invites ACs to check the information given in the Table on the IDS website at http://ids-doris.org/contribution-itrf2013.html. The table was filled in before it was decided to include year 2014 for the ITRF. | All ACs | | open |
| AWG_07 | Next DPOD2014 | concerning the next DPOD 2014, two approaches will be compared by G. Moreaux and a version of the DPOD2014 will be submitted to the evaluation of the users by the end of June 2016 | IDS CC<br>(G. Moreaux) | | open |
| AWG_08 | DORIS data SAA corrective model for Jason-2 | GRG AC is volunteer to test the model of AB for Jason-2 to analyze its impact on the position estimation of SAA stations | GRG AC | | open |
| AWG_09 | Increase of the DORIS residuals | Analysis Coordinators require the ACs who are willing to participate to provide their time series of DORIS measurement residuals since 2011.0 for each satellite available | Volunteer ACs and associated | | open |
| AWG_10 | HY-2A CoM-CoP vector estimation | GSFC, CNES-POD, GRG, INA and IGN have agreed to make a multi-year determination of the HY-2A radial offset | GSFC, GRG, IGN and INA ACs and CNES-POD team | | open |
| AWG_11 | Scale factor increase in 2012 | IDS CC has to confirm by analyzing all the AC contributions that only AC not using the flagged data in the doris2.2 file (from CNES pre-processing) are impacted | IDS CC | | open |
| AWG_12 | Scale factor increase in 2012 | ACs could provide a Jason-2 single satellite solution obtained from processing using homogeneous editing criteria since 2011 (i.e. not relying on the CNES editing flags in the doris2.2 file). Then, if the problem is solved for Jason-2, it has been decided to reprocess all data using these homogeneous editing criteria for the whole period of each satellite having data in 2012 | ACs | | open |
| AWG_13 | Orbit comparison | On voluntary basis and for test purpose (maybe not on regular basis), ACs and associated may deliver their sp3 orbit to the CDDIS/IGN data centers in the appropriate directory: ftp://cddis.gsfc.nasa.gov/pub/doris/products/orbits/ | Volunteer ACs and associated | | open |

# 6. Next Meeting

## 6.1. Next IDS Workshop

IDS WS in October 31-November 01 2016 in La Rochelle (France).

## 6.2. Next AWG

IDS AWG in 2017 in London (England), hosted by UCL (to be confirmed).