3.3 Analysis Coordinator

Introduction

In this report, we outline the activities of the Analysis Coordinator during 2016. The main activities were an investigation into the scale differences between the ITRF2014 and DTRF2014 systems for the VLBI and SLR stations, and preparations for the Unified Analysis Workshop (UAW) to be held in 2017. The organization of the 2017 UAW is being led by GGOS.

VLBI/SLR scale differences between ITRF2014 and DTRF2014

Preparations for the transition from ITRF2008 to ITRF2014 are well underway and the IGS will transition on January 29, 2017 (GPS week 1934 day 0). For the IGS, there are two major changes associated with this switch: (1) A new set of coordinates, velocities and, for some stations, post-seismic deformation models are being adopted for the core set of IGS sites that define the IGS realization of the ITRF2014 system; and (2) the antenna phase center models are being changed for the GPS satellites and for some GPS ground antennas. The changes to the IGS antenna calibration models were mostly due to the introduction of Earth albedo and antenna thrust models that effectively increased the altitudes of all the GPS satellites resulting in a small terrestrial scale change of ~0.3 ppb. The GPS terrestrial scale was aligned to the ITRF2014 scale by systematic changes of the radial coordinate of the GPS satellite antenna phase center relative to center of mass. The small -0.02 ppb scale difference between ITRF2014 and ITRF2008, at epoch 2010.0, was also included in the change to the satellite antenna phase center positions. There is however a scale rate difference between ITRF2014 and ITRF2008 of 0.03$\pm$0.02 ppb/yr and this rate difference can clearly be seen in the IGS comparisons between ITRF2014 and ITRF2008 with ITRF2008 showing little difference in scale rate. The only way this rate difference can be accommodated in the GPS analyses is to introduce rates of the satellite antenna phase center locations. The scale rate will result in the IGS scale differing by 0.21 ppb when ITRF2014 is adopted at the beginning of 2017. This difference is similar to the total scale change introduced by incorporating Earth albedo and antenna thrust models suggesting that to absorb this scale rate through changes in force models would require an accumulated effect over a decade of the same magnitude of the total force. It seems unlikely that a force with such a high rate of change (i.e., for Earth albedo the force would, depending on the sign of the time interval, either need to double or go to zero over a decade) could have been neglected in IGS orbital modeling by all analysis groups.

The ACC has also been looking at the scale difference between ITRF2014 and DTRF2014 reference frames by a direct comparison of the position estimates of collocated VLBI and SLR stations in the

SINEX files available for ITRF2014 and DTRF2014. We can compare the SLR and VLBI coordinates from the DTRF and ITRF solutions for the collocated sites that are separated by <10 km and whose baseline length between the VLBI and SLR sites have an uncertainty (at the reference epoch of the SINEX files, 2005.0) of less than 10 mm. Figure 1 shows the velocity estimates at the collocation sites from the two ITRF solutions. Table 1 gives the site codes and DOMES numbers of the sites within 10 km of each other. Not all these sites are used in the comparisons. There are large differences in the velocities at many sites especially at those sites with large post-seismic signals. These differences arise from the different parameterizations used by the two ITRFs. These differences in velocities complicate the comparison of the average differences in site positions because the difference becomes dependent on the epoch of the comparison. For the comparison here, we compare at the reference epoch of the ITRF (2005). In addition to these differences in velocities, there are some sites that have very large differences in position and standard deviations between the two ITRFs. We have excluded sites with large standard deviations and large differences between the ITRFs. Some of these differences arise because the discontinuity lists are not the same between the two solutions. Our analysis requires quite a lot of editing of the position estimates due to large differences despite the two ITRFs sharing the same input SINEX files.

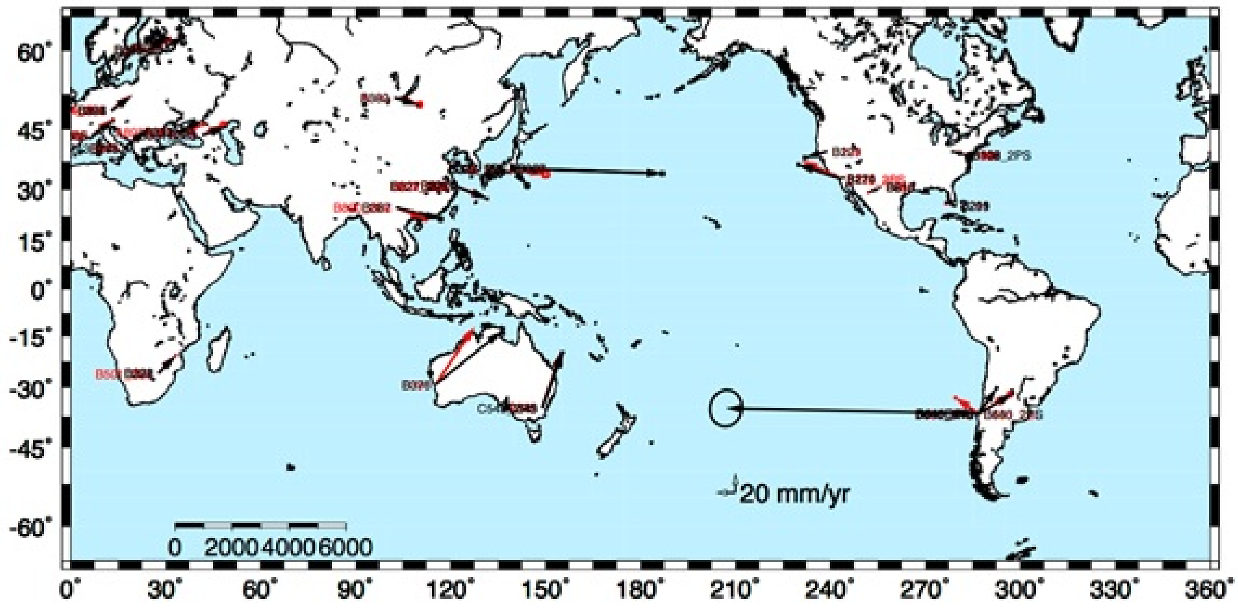

Fig. 1: *Comparison of the velocity estimates for ITRF2014 (red vectors) and DTRF2014 (black vectors). DRTF2014 uses piecewise linear functions to represent postseismic motions and as a result some sites affected by large earthquakes have very large short term velocities. Sites shown here have separations < 10 km and length uncertainty between VLBI and SLR sites less that 10 mm. Velocity differences between ITRF2014 and DTRF2014 make comparison of scale difference difficult.*

Table 2 gives the results of the average scale differences between the SLR sites (35) and VLBI sites (23 sites) as given the ITRF2014 and DTRF2014 SINEX files. These differences in scale estimates are consistent with the expectation that DTRF2014 sees little difference in scale between VLBI and SLR while ITRF2014 shows a difference of ~1.4 ppb. As an additional comparison for the VLBI sites we include a comparison with a combined VLBI solution available from the BKG/IVS ftp site. No combined SLR SINEX file is available from the ILRS. The BKG solution, compared at just 9-10 VLBI sites, falls between the two ITRFs. Since the scale difference arises from the application of local survey ties the difference in the TRFs must arise from the weight given to the survey ties and the number of such ties used. If the survey ties are given very low weight, the VLBI and SLR parts of the combined solutions would each adopt the scale inherent in the technique and there should be a ~9 mm (1.4 ppb) mean difference between the observed tie and those inferred from the difference between the SLR and VLBI site positions. When looking at individual stations, the weighted RMS scatters of the height differences (after the mean is removed) are 2.1 mm (35 sites) and 5.4 mm (23 sites) for SLR and VLBI, respectively. We also compared the scale rates between ITRF2014 and DTRF2014 and found scale rate differences of 0.018 ± 0.007 ppb/yr for SLR and 0.00 ± 0.01 ppb/yr for VLBI. The SLR scale rate difference is two-thirds of the ITRF2014/ITRF2008 scale rate difference.

There are number of steps that can be taken to improve this type of comparison. Fully combined solutions for the VLBI and SLR solutions, generated by the respective services, would make comparisons of this type easier e.g., the IGS already generates such as solution and it is updated weekly by the IGS combination center. For the comparison here, we used such a VLBI solution generated by BKG. There are large differences in the standard deviations of the position between the two TRFs and the relationship is not a simple scaling. Some of these differences arise from the difference in post-seismic motion modeling but some of the differences also arise from different discontinuity lists used in the two TRF solutions. (The BKG solution has a different set of discontinuities to both ITRF2014 and DTRF2014). In future, a consistent, common discontinuity list should be adopted by all combination centers. The scale differences between VLBI and SLR and between ITRF2014 and DTRF2014 are still not understood. There needs to be continued analysis of these scale differences. This topic will be addressed at 2017 UAW as it was at 2015 UAW.

Table 1: *Collocated sites between VLBI and SLR that are within 10 km of each other. For a site to be used in our comparisons, the standard deviation of the baseline length between the SLR and VLBI site must be less than 10 mm so not all sites in this table are used in the comparisons shown in Table 2.*

4-char CODE	VLBI DOMES #	VLBI Name (from IVS combined SINEX file)	SLR DOMES #
7108	40451M125	GGAO7108 ORION MV3 at Greenbelt, MD, USA	40451M105 40451M114 40451M117 40451M120 40451M116
7216	40442S003	HRAS 085 HRAS at Fort Davis, TX, USA	40442M001 40442M006 40442M008
7221	40433M004	QUINCY, USA	21605S001 21605S010
7227	21605S009	SESHAN25 Shanghai, China	21605S001 21605S010
7274	40497M003	MON PEAK mobile Monument Peak	40497M001 40497M002
7327	21704S004	KOGANEI 11-m Keystone at Koganei, Japan	21704S002 21704M001
7332	12337S008	CRIMEA Simeiz, Ukraine	12337M001 12337S003 12337S006
7380	12350S001	SVETLOE Svetloe, Russia	12350S002
7613	40442S017	FD-VLBA VLBA at Fort Davis, TX, USA	40442M001 40442M006 40442M008
7640	41719S001	TIGOCONC TIGO at Concepcion, Chile	41719M001
7102	40451M102	GORF7102 ORION MV3 at Greenbelt, MD, USA	40451M105 40451M114 40451M117 40451M120 40451M116
7201	40499S019	MIAMI20 Miami, FL, USA	40499M002
7219	40499S001	RICHMOND Richmond, FL, USA	40499M002
7224	14201S004	WETTZELL Wettzell, Germany	14201S002 14201M004 14201S018 14201M005
7232	30302S001	HARTRAO Hartebeesthoek, South Africa	30302M003
7243	12734S005	MATERA Matera, Italy	12734S001 12734M005 12734M004 12734S008
7367	21609S003	KUNMING 40-m antenna at Kunming, Yunnan, China	21609S002

7376	50107S012	YARRA12M 12-m at Yarragadee, Australia	50107M001 50107S009
7378	30302S009	HART15M 15-m antenna at HartRAO, South Africa	30302M003
7381	12351S001	ZELENCHK Zelenchukskaya, Russia	12351S002
7382	12338S003	BADARY Badary, Russia	12338S004
7385	10503S002	METSAHOV Metsahovi, Finland	10503S001 10503S014
7593	14201S100	TIGOWTZL TIGO at Wettzell, Germany	14201S002 14201M004 14201S018 14201M005
7601	10503M002	METSHOVI mobile Metsahovi, Finland	10503S001 10503S014
7605	10002M003	GRASSE mobile Grasse, France	10002S001 10002S002

Table 2: *Comparison of the scale differences for the SLR and VLBI sites which are collocated and that appear in ITRF2014 and DTRF2014. The list of sites has been reduced to remove sites with large differences and large standard deviations at the 2005.0 epoch of the solutions. The BKG solution is a VLBI only combination.*

Technique	**Scale difference (ppb)**	**± (ppb)**
SLR (35 sites) DTRF to ITRF	0.63	0.04
VLBI (23 sites) DTRF to ITRF	-0.83	0.19
BKG to DTRF (9 sites)	0.11	0.07
BKG to ITRF (10 sites)	-0.48	0.18

Preparations for the 2017 Unified Analysis Workshop

Unified Analysis Workshops are co-organized by the International Association of Geodesy's (IAG's) Global Geodetic Observing System (GGOS) and International Earth Rotation and Reference Systems Service (IERS). The UAW in 2017 will be the 5th in a series of workshops that are held every two to three years for the purpose of discussing issues that are common to all the space-geodetic measurement techniques.

The 2017 Unified Analysis Workshop will be held in Paris, France during July 10–12, 2017 following the IGS Workshop and like the IGS Workshop. Both workshops will be hosted by the Institut National de l'Information Géographique et Forestière (IGN). Both the IGS workshop and UAW will held at the University of Paris-Diderot (15 rue Hélène Brion 75013 Paris). The previous UAW was held in Pasadena, California, USA in 2015 and was largely organized by the IERS in collaboration with the IGS. The organization of 2017 UAW will be led by GGOS through its science panel chair Richard Gross.

The attendance at the UAW will be by invitation only with each of the IAG Services, as well as GGOS, selecting 5 to 6 experts to participate in the workshop. The Analysis Coordinators for each of the services are expected to be one of the delegates from each Service. The Service Chairs and Central Bureau Directors are also welcome and will not count towards the limit of 5-6 experts from each Service.

The sessions at the UAW Workshop will focus on:

- Systematic errors and biases in GNSS observations
- Systematic errors and biases in VLBI observations
- Systematic errors and biases in SLR observations
- Systematic errors and biases in DORIS observations
- Site survey and co-location
- Reference systems and frames
- Conventional mean pole
- Standards, conventions, and formats
- Interoperability of portals and metadata

As in previous UAWs, the geometric services of the IAG will be well represented and there will be little representation or discussion of unifying the analysis methods and models of gravity field services with the geometric services.

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