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IVS Combination Center at BKG - Recent Activities

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Abstract

In addition to the routine rapid combination, the IVS Combination Center at BKG is working on various other projects based on VLBI combination. The generation of a quarterly solution (long term combination of VLBI sessions) is one of the main projects. This solution includes the computation of a VTRF and the analysis of station coordinates and velocities. Mainly the changes in station position and station motion caused by recent significant earthquakes are being investigated. Results of all projects are published on the Combination Center's Web site, including features to perform Web-based data analysis.

1. Introduction

Various products based on long term combined VLBI solutions are generated at the IVS Combination Center at BKG for the IVS. These products include long term EOP series as well as station coordinates and velocities which are used to calculate a terrestrial reference frame of VLBI stations (VTRF). The challenge is to include new stations and stations which undergo significant displacements into the existing frame. The results of the products out of the investigation of long term data series are presented at the Combination Center's Web site: `http://ida.bkg.bund.de/IVS`.

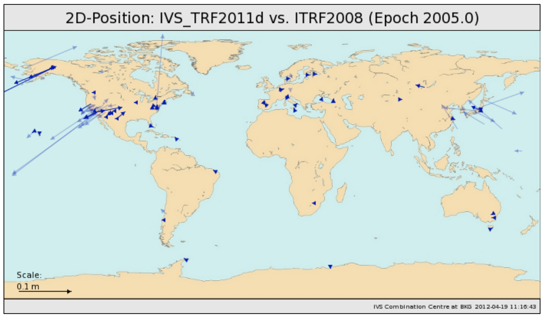
2. Quarterly EOP Solution

Within the quarterly solution, long term data series of earth orientation parameters (EOP) and station coordinates are generated. The data sets include all daily VLBI sessions that can be found in the IVS Data Center (see `ftp://ivs.bkg.bund.de/pub/vlbi/ivsproducts/daily_sinex/`). This series includes all sessions of the last 30 years, i.e., back to the 1980s. The combined quarterly EOP series and individual series generated within the combination process (i.e., equal parameterization for every AC) can be found at the Combination Center's Web site.

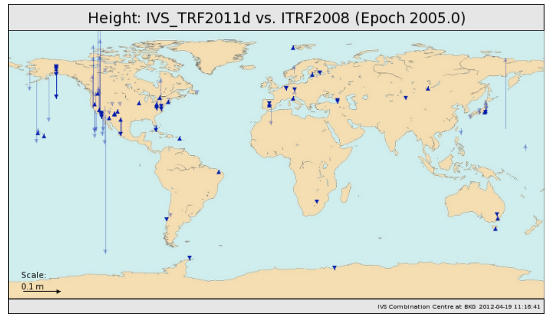
3. IVS TRF

Based on station coordinates a VTRF is computed. The latest VTRF (IVS_TRF2011d with reference epoch 2005.0) includes station coordinates and velocities for the most frequently used VLBI stations. The VTRF is compared to the current International Terrestrial Reference Frame (ITRF2008).

A 14 parameter transformation is implemented according to Equation 1 [1]. The parameters are shown in Table 1. Stations with very few or unstable observations are not used to calculate the transformation parameters.



2D-Position IVS_TRF2011d vs. ITRF2008.



Height IVS_TRF2011d vs. ITRF2008.

Figure 1. IVS_TRF2011d in comparison to ITRF2008.

$$
\begin{aligned}
\mathbf{X}_2 &= \mathbf{X}_1 + \mathbf{T} + D\mathbf{X}_1 + \mathbf{R}\mathbf{X}1 \\
\dot{\mathbf{X}}_2 &= \dot{\mathbf{X}}_1 + \dot{\mathbf{T}} + \dot{D}\mathbf{X}_1 + D\dot{\mathbf{X}}_1 + \dot{\mathbf{R}}\mathbf{X}_1 + \mathbf{R}\dot{\mathbf{X}}_1
\end{aligned} \tag{1}
$$

where $\mathbf{X}_1$ is the coordinate vector in the VTRF, $\mathbf{T} = [t_x, t_y, t_z]^T$ the translation vector, $\mathbf{R}(r_x, r_y, r_z)$ the rotation matrix, D the scale factor and $\mathbf{X}_2$ the transformed coordinate vector in the ITRF. $\dot{\mathbf{X}}_1$, $\dot{\mathbf{X}}_2$, $\dot{\mathbf{T}}$, $\dot{D}$, $\dot{\mathbf{R}}$ are the first derivatives of the afore mentioned parameters.

Table 1. Transformation parameters between IVS_TRF2011d and ITRF2008.

Name	$t_x[mm]$	$t_y[mm]$	$t_z[mm]$	D	$r_x[\mu as]$	$r_y[\mu as]$	$r_z[\mu as]$
Position	0.57	-0.11	1.1	-4.436e-10	8.15	20.86	1.97
$\sigma_{Position}$	0.9	0.88	0.91	1.393e-10	33.82	34.82	30.91
	$t_x[mm/y]$	$t_y[mm/y]$	$t_z[mm/y]$	D	$r_x[\mu as/y]$	$r_y[\mu as/y]$	$r_z[\mu as/y]$
Velocity	0.15	0.09	-0.08	-5.590e-12	0.08	2.9	-2.7
$\sigma_{Velocity}$	0.07	0.07	0.11	1.547e-11	4.7	4.61	3.16

Via a Web application (`http://ida.bkg.bund.de/IVS/trf`), the user has the possibility to calculate the transformation parameters on the fly for all available VTRFs, to interactively select the VLBI stations which are used for the calculation of the transformation parameters, and to plot the result of the comparison of the transformed VTRF and the ITRF.

4. Station Coordinates and Velocities for the VTRF

A good global distribution of VLBI telescopes leads to a well defined TRF. Fortunately, new stations are being built around the world to densify the VLBI network and to optimize the net geometry. These stations need to be integrated into the IVS TRF generation. Some new telescopes have been built in proximity to existing telescopes, e.g. Hobart12 and Hobart26. Other telescopes are built on new sites (e.g., in Australia and New Zealand) where no information is currently available about site motion.

4.1. New Telescopes

4.1.1. Telescopes on Existing Sites

If a new telescope is built close to an older telescope which has been established in VLBI experiments for a sufficient time, the assumption can be made that the new telescope is built on the same tectonic environment and thus undergoes the same velocities as the older telescope. This facilitates the integration of the new telescope into the IVS TRF, due to the fact that the existing velocity vector for this site can be used for the new telescope as well. The assumption (equal velocities for both telescopes) can be verified by a congruence test with the known formula [2] for a three component test value with, for example, a probability of 99.9%:

$$T = \frac{\mathbf{d}^T \mathbf{Q}_{dd}^{-1} \mathbf{d}}{3} \sim F_{3,\infty,1-0.001} \quad | \quad H_0 \tag{2}$$

with

$$\mathbf{d} = \mathbf{v}_2 - \mathbf{v}_1 \text{ and } \mathbf{Q}_{dd} = \mathbf{Q}_{v_1 v_1} + \mathbf{Q}_{v_2 v_2} \tag{3}$$

Applying the congruence test to the values resulting from the combination process for the velocities for stations Hobart12 and Hobart26 (see Table 2), the test value is

$$T = 17.4 > F_{3,\infty,1-0.001} = 5.4 \quad \rightarrow H_0 \text{ rejected} \tag{4}$$

Therefore, the assumption that both telescopes undergo the same velocity (in this case the H_0 hypothesis) has to be corrected (H_0 rejected). The station coordinate series of the new station is still too short to determine reliable velocity parameters. At Hobart, this lack of data can be bridged by constraining the velocities of Hobart12 by the velocities of Hobart26.

Table 2. Velocities of Hobart12 and Hobart26.

	v_X	v_Y	v_Z
Hobart12	-0.0397	0.0110	0.0561
Hobert26	-0.0390	0.0082	0.0411

4.1.2. Telescopes on New Sites

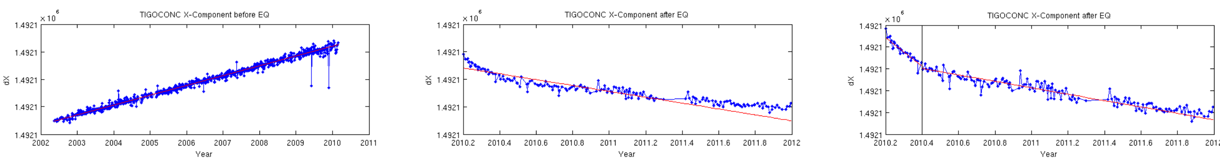
New stations need to be integrated into VLBI experiments as soon as possible in order to be able to rapidly determine reliable station coordinates and velocity parameters. Some new stations have been built in Australia (Yarragadee and Katherine) and New Zealand (Warkworth) which significantly help to densify the VLBI network in the Southern Hemisphere (see also `http://ivscc.gsfc.nasa.gov/stations/ns-map.html`).

To estimate reliable velocities for these stations, an adequate number of observations are needed. In March 2012, these stations participated in too few 24h VLBI experiments to estimate reliable station coordinates and velocity parameters: Yarragadee: 11 sessions, Warkworth: 3 sessions, and Katherine: 12 sessions (see `http://lupus.gsfc.nasa.gov/sess/`). Additionally, not all IVS ACs analyze new stations yet, which is what decreases the number of observations of these stations within the combination.

4.2. Telescopes Affected by Earthquakes or Man-made Displacements

Some of the IVS telescopes are particularly affected by earthquakes (EQ), e.g., TIGO in Chile. Large earthquakes may shift the telescope some centimeters to a few meters, which implies a change in the station coordinate and, in some cases, a change in the station velocity components. Man-made displacements may also introduce a change in the station coordinates, such as changes in the antennas' bearing or counter weights. The coordinates and velocities of these stations are modeled epoch-wise as a piece-wise linear function in order to take these changes into account. The TIGO station gives an example on how these changes in the position and velocity can be modeled within the VTRF.

A large earthquake occurred in Chile in February 2010 which caused major changes in the coordinates (espacially in the X component) and velocity of the station TIGO. Figure 2 shows the station coordinates before the EQ (left), after the EQ modeled with one epoch (middle), and with two epochs (right) of the X component.



Before EQ. One-epoch modeling. Two-epoch modeling.

Figure 2. Station velocity X for TIGO after EQ.

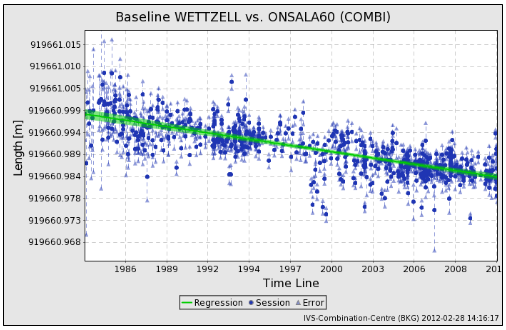
The gradient for the X-component before the EQ was 0.0351 m/year. With a one-epoch modeling the gradient is -0.0821 m/year, and a two-epoch modeling gives -0.3672 m/year and -0.0652 m/year showing the higher characteristic change in the velocity shortly after the EQ. The changes in the velocity components have been modeled within the VTRF generation for two epochs:

1. 2010.1597 (date of the EQ: February 27, 2010),
2. 2010.4 ($\approx$ 90 days after the EQ, black vertical line in figure 2 on the right).

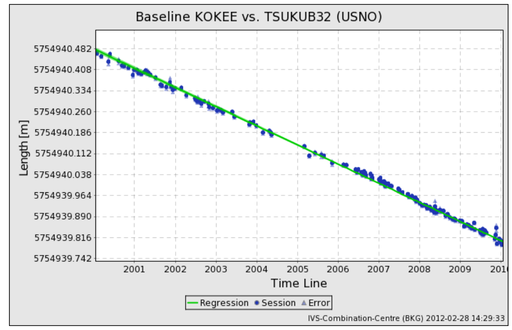
The second epoch has been estimated by numerical comparison of the drift at different epochs along the station coordinates of the station component which has been the highest affected by the EQ. Figure 2 shows the station modeling with different epochs. Similar to TIGO, also other telescopes are affected by displacements caused by earthquakes. As soon as these stations participate in sufficient VLBI sessions, new coordinates and velocities can be estimated. A minimum time span of a half year or one year has to be calculated.

5. Baselines

In the beginning of 2012 BKG took over the baseline project from the Analysis Coordinator Axel Nothnagel at Uni Bonn. A Web-based analysis allows the user to choose two stations, the time span, and the individual or combined solution and returns statistic results for the chosen baseline (slope, y-axes intercept, WRMS, number of sessions, and number of excluded sessions) and a plot of the baseline length. The baselines are integrated in the Combination Center's Web site and can be found at `http://ida.bkg.bund.de/IVS/baseline`. The data for the baselines are generated within a quarterly solution and updated regularly in a MySQL database. Figure 3 shows two examples for baseline lengths.



Baseline Wettzell-Onsalla from combined data.



Baseline Kokee-Tsukuba from USNO data.

Figure 3. Baselines.

6. Outlier Test and Weighting Strategies

One of the main activities of the Combination Center was the implementation of a robust outlier detection and the improvement of the weighting strategy within the combination process. These activities are presented in the proceedings of the 7th IVS General Meeting [3] as well.

7. Summary and Outlook

A consistent VTRF requires a careful modeling of station coordinates, especially for stations on new sites and sites which undergo significant displacements. Reliable outlier tests and weighting strategies provide the basis to estimate reliable EOPs and station coordinates. Results are published on the Combination Center's Web site, which also offers various Web-based analyses in order to allow detailed analysis of the combined products.

References

[1] Altamimi, Z., Sillard, P., Boucher, C.: ITRF2000: A new release of the International Terrestrial Reference Frame for earth science applications. Journal of Geophysical Research, Vol., 107, doi:10.1029/2001JB000561, 2002.

[2] Niemeier, W.: Ausgleichungsrechnung. Walter de Gruyter, Berlin, ISBN:3-11-014080-2, 2002.

[3] Bachmann, S., Lösler, M.: IVS combination center at BKG - Robust outlier detection and weighting strategies. IVS 2012 General Meeting Proceedings, Madrid, March 05-08, 2012, edited by Behrend, D. and Baver, K. D., this volume.