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Comparison and Validation of VLBI Derived Polar Motion Estimates

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Abstract. For a rigorous combination of VLBI and GPS data, they should not be subject to systematic differences. However, at some periods of time such systematic differences of up to 0.2 mas are present when comparing the official polar motion time series of the International VLBI Service for Geodesy & Astrometry and the International GNSS Service.

In a careful analysis of VLBI sessions we try to relate these systematic differences in polar motion to various possible causes. As the GPS terrestrial reference frame is much more stable than the one from VLBI the discrepancies are expected to be caused by VLBI. Therefore, we examine the VLBI solution setup and the data itself regarding network changes, analysis options and observation schedules.

1. Introduction

The International VLBI Service for Geodesy & Astrometry (IVS) provides an official combined VLBI solution. This combined product is calculated from the contributions of several IVS Analysis Centers (ACs). The ACs provide datum-free normal equations in the Solution Independent Exchange (SINEX) format which is used as input for the IVS combination. This combination is computed at the IVS Analysis Coordinator's office (e.g. [1, 5]).

As a rough quality assessment, the derived combined time series of the EOP is compared to those of the International GNSS Service (IGS). The differences of the y-pole component show a systematic behaviour around 2006-2007 (Fig. 1). These systematics are present between the IGS time series and the IVS combined solution as well as between the IGS and the individual solutions of the ACs calculated from the SINEX files. Furthermore, these systematics can also be seen in EOP-series computed by the ACs themselves. Since the IVS and the IGS solutions differ in terms of modelling and parametrization, such differences are not astonishing. But even between completely homogenized so-

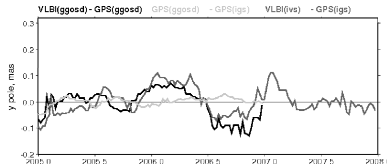

Figure 1. Y-pole differences (smoothed by a 70-day median filter; offsets removed) of IVS and IGS solution (dark gray), homogenized VLBI and GPS solutions (black) as well as the GPS differences (light gray)

lutions, produced in the German research project GGOS-D [3], such effects are present. Therefore, the systematics can not simply be explained by different solution setups.

In this study, a detailed analysis is performed on the basis of the IVS R1 and R4 sessions from the years 2005 to 2007. The VLBI analysis was done with the software package CALC/SOLVE [4]. Here, a state of the art modelling with VMF1, thermal deformation and atmospheric pressure loading was used. However, the change of these options as well as changes in the parametrization setup do not change the studied systematics significantly. In order to estimate the EOP, the station positions are fixed to their a priori values (ITRF2005[1]). As these a priori values are not totally consistent to our data, this might possibly lead to systematic effects. Nevertheless, this approach has been chosen since the use of a consistent TRF did not revise the situation.

The aim of this investigations is to validate whether the VLBI observables are responsible for the systematics. Changes in network geometry, the sensitivity of the solution on presence or absence of stations and analysis options are considered. Furthermore, the sensitivity of each individual session in view of the estimation of the y-pole component will be addressed.

2. Network Differences

In the time span considered, the R1 and R4 networks are subject to some changes. These are, on the one hand, the stop of operation at Fairbanks (end of 2005) and Algonquin Park (middle of 2006). On the other hand new stations started observing. The global distribution of stations is mainly changed by the absence of Fairbanks due to it's unique location in Alaska. But the overall volume of the observing network has not varied a lot.

The situation turns out to be slightly different if R1 and R4 networks are examined independently. This is shown in Fig. 2. The station distribution of the R1 network is fairly global. The station participation differs from session to session. Thus, the volume of the observing polyhedron varies but is comparably big on average. In contrast, the R4 network is concentrated on the western part of the world and is dominated by the stations Kokee Park and Wettzell. The volume of the R4 networks does not change a lot but it is significantly smaller than the volume of the R1 network. These differences in the network volume

[1]Except those of Zelenchukskaya and Svetloe which have been estimated from all VLBI observations up to the end of 2007.

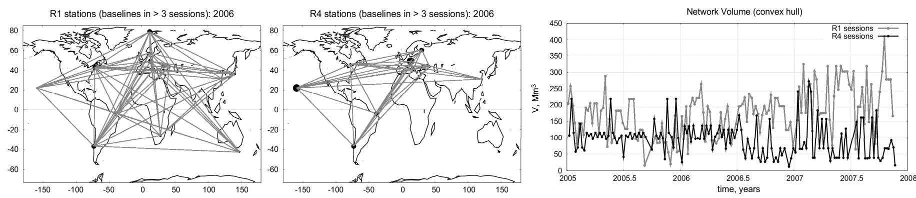

Figure 2. Station distribution of the R1 (left) and R4 (right) networks in 2006 as well as the volume of the session-wise observing polyhedron in 2005-2007 (right: R1 (gray) and R4 (black))

correspond to the quality deviations of the y-pole time series that are derived from the two individual sub-nets separately (Fig. 3). It can be seen that the systematics shown in Fig. 1 are mainly produced by the observations of the R4 network. The y-pole estimated from R1 sessions only shows systematics at the end of 2005 where the network volume is small, too.

Obviously, there is a relation between the y-pole systematics and the volume of the observing network. That corresponds to the fact that the network volume is somehow proportional to the formal errors [2]. The connection of the formal errors and the systematics under investigation will be discussed in more detail in section 4.

3. Impact of Single Stations

To verify the impact of single stations on the y-pole estimation two tests have been carried out. In the first test, the datum definition has been modified with respect to the standard solution to see whether one single station is responsible for the systematics. Step by step, one single station has been excluded from the datum definition. This means that all but one of the station's positions are fixed to their a priori values to estimate the EOP. As shown exemplarily for Fairbanks in Fig. 4, the estimates are affected systematically during specific time spans depending on the stations that are used to define the datum. Thus, for each independent session it should be decided which stations must not be fixed to their a priori values to take part in the datum definition. However, there are only a few observing stations and the fewer stations are used to define the datum, the weaker the EOP estimation is due to the correlation of EOP and the estimated station positions. Furthermore, it is not possible to choose the defining sub-nets doubtlessly until now: no connection between the variations in polar motion and the non-fixed stations can be seen. Neither is there a connection with the values of the estimated station positions nor do the correlation coefficients of the y-pole and the estimated coordinates exhibit any relations.

In the second test, a network change was simulated by removing all observations of a single station. Thereby, the scatter of the polar motion estimates is increased. And depending on the excluded station almost arbitrary new systematic variations can be created. These results have to be judged very carefully and critically since the original schedule of the session is disturbed and the remaining observations are not chosen to be optimal for the remaining network. Nevertheless, they document the delicateness of the equation system and the sensitivity on single station variations.

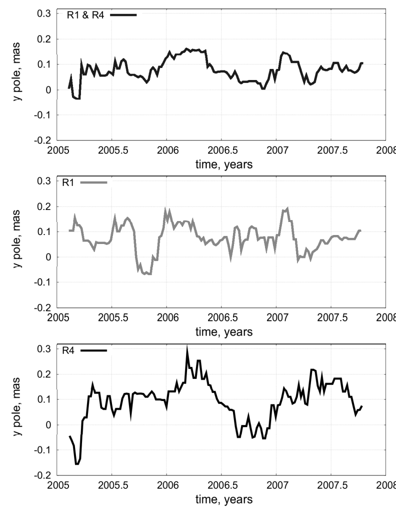

Figure 3. Y-pole differences to IGS (smoothed by a 70-day median filter) for estimates from R1 and R4 sessions (top), R1 sessions (middle) and R4 sessions (bottom) only

4. Sensitivity Due to Y-Pole Estimation

This section gives a deeper insight into the observation equation system itself and therefore into the effective observing geometry. This leads to a better understanding of how good the y-pole is defined by the observations in different sessions.

In general, the stochastic properties (formal error and correlations with other parameters) of a parameter describe how stable this parameter can be estimated from the given observations equations. In Fig. 5, the formal errors are displayed. The most obvious fact is that the formal errors are high during time spans where the systematic differences are high as well (Fig. 3).

Another possibility to judge the quality of the parameter estimation are the correlation coefficients. However, they are small and no significant difference between R1 and R4 sessions could be detected.

5. Conclusions

The IVS R1 and R4 sessions from 2005 onwards were analyzed regarding the estimation of the y-pole. Several aspects have been considered to explain systematic differences of VLBI and GPS derived estimates.

No coherence between the systematic differences and station position variations has been found. However, the systematics can be assigned to a weak network geometry. It was revealed that the R1 and R4 networks result in different y-pole estimates. Above all, the time series from R1 sessions is more stable and does not show such distinct systematics in comparison to GPS as the one derived from R4 sessions does.

To improve the stability of polar motion estimates, large networks, i.e. more stations with even distribution, should be scheduled. This would lead to a bet-

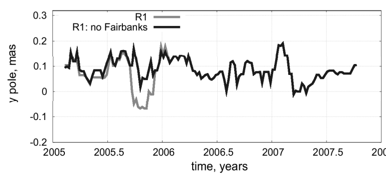

Figure 4. R1 y-pole differences to IGS from the standard approach (gray) and without Fairbanks in the datum definition (dark gray)

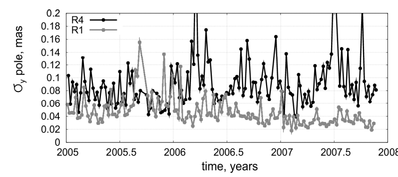

Figure 5. Formal errors of y-pole estimates in R1 (gray) and R4 (black) sessions

ter definition of the hemisphere over each telescope, particularly for those on the southern hemisphere and, thereby, to a better separation of estimated parameters. Furthermore, it should be noted that the participation of stations may differ from session to session as long as the volume of the observing polyhedron remains big. There are less systematics in the R1 y-pole estimates and the scatter of the individual estimates is less than the one from R4 sessions where the station participation is more unique.

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