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Challenges for geodetic VLBI in the southern hemisphere

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Abstract

Inhomogeneous networks and reference frames are an important issue for Very Long Baseline Interferometry (VLBI). In this work we examine the performance of southern stations and baselines in routine VLBI experiments. A positive impact on baseline length repeatabilities of the increased observing effort by the Australian AuScope VLBI antennas is found by analysing three years of global rapid-turnaround VLBI sessions: while worse results are found for southern baselines compared to northern baselines for the first half of the investigated sessions, the northern and southern baseline length repeatabilities are about the same in the second half of the period. In simulations, the actual observing plan with a significantly lower number of observations for southern stations is identified as a major reason for the worse length WRMS for southern baselines, though other factors seem to influence the results as well. Simulating radio source position uncertainties, effects of up to 10 mm are found on baseline length WRMS for long southern baselines. Improving all source position uncertainties through more frequent observations to better than 50 μas could reduce this effect by up to 30%.

Keywords: VLBI; Southern hemisphere reference frames; Source uncertainties; IVS; AuScope

1. Introduction

Very Long Baseline Interferometry (VLBI) is a space geodetic technique measuring the emission from extra-galactic radio sources with globally distributed radio antennas. Global observations are coordinated by the International VLBI Service for Geodesy and Astrometry (IVS; Schuh and Behrend, 2012) and made freely available to the public (e.g. at http://ivscc.gsfc.nasa.gov). Positions of the observed radio sources make up the International Celestial Reference Frame (ICRF2; Ma et al., 2009), the most precise quasi-inertial reference frame. Besides that, VLBI is uniquely capable of fully determining the Earth's orientation in space in terms of the Earth orientation parameters (EOPs). Together with the Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR), and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), VLBI is used to establish the geodetic coordinate system on Earth, the International Terrestrial Reference Frame (ITRF2008; Altamimi et al., 2011).

The ideal network of VLBI antennas would be homogeneously distributed around the globe and observe continuously, 24 h a day, 7 days a week (24/7). In practice, the northern hemisphere dominates in both landmass and countries capable of contributing to radio astronomy research by funding dedicated observatories. As a consequence, there is a highly unequal distribution of VLBI radio telescopes contributing to the IVS. The lack of radio telescopes also causes an uneven distribution of radio sources in the ICRF, in both the number of sources as well as their nominal uncertainties (Ma et al., 2009). In short, the ICRF2 is more sparse and less accurate in the south.

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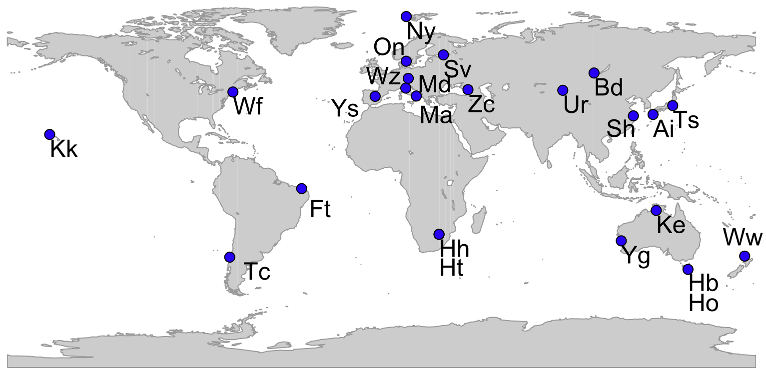

Fig. 1. Map of stations participating in the 2012–2014 R1 and R4 sessions.

Irregular antenna availability, e.g. due to shared facilities with astronomical observing or operational and budget constraints, does not allow for full 24/7 observing and causes the observing network to change from session to session.

The Australian AuScope VLBI array (Lovell et al., 2013) was built in order to tackle these issues, i.e. to (a) increase the number of stations and observations in the southern hemisphere and (b) strengthen the celestial reference frame in the south. An improvement in positions of southern stations through an increase of observations is expected (station position uncertainties scale with the inverse square root of the number of observations). On the other hand, it is not clear in what way southern stations and baselines will profit from a better southern hemisphere CRF. Previous studies confirmed that erroneous source positions can affect other geodetic results like estimated EOPs (MacMillan and Ma, 2007; Nilsson et al., 2012). In an analysis of VLBI data until 2006, Titov (2007) showed that the selection of reference radio sources can have a significant effect on VLBI station positions. This effect is increased for isolated stations (e.g. in the southern hemisphere) and stations with a very low number of observations (e.g. due to low antenna slew speeds).

In this work we investigate the performance of southern hemisphere VLBI stations due to a lower number of observations as well as due to observing sources with less accurate astrometry than their northern counterparts. In Section 2 the motivation of this study is provided by analysis of three years of standard geodetic VLBI observational data. We use simulations to investigate the influence of the observation schedule on geodetic parameters in Section 3, in particular focusing on the difference between northern and southern hemispheres. Our findings are summarised in Section 4.

2. VLBI analysis

IVS rapid-turnaround sessions (R1, R4) are undertaken twice a week. Using a fairly stable network of about 7–11 antennas, the data are shipped, correlated and analysed usually within two weeks of the experiment. The timeliness of the data, but also the high cadence and hence large amount of observations, make the IVS R-sessions a strong contributor to the standard VLBI products, such as the EOPs, TRF, and CRF.

2.1. The data

In our investigation, we analysed three years of rapid sessions from 2012 to 2014.[1] Excluding stations that only observed in 1–2 sessions, we find a total of 24 stations observing 463 sources in 302 rapid sessions. As can be seen in Fig. 1, 9 stations are in the southern hemisphere whereas the other 15 in the northern hemisphere. Despite this clear imbalance, for each session the participating stations are distributed as uniformly as possible. On average, 5 northern stations and 4 southern stations contributed to each R-session. In Table 1 the stations are listed in order of increasing latitude (from south to north), showing the number of sessions in which each station took part as well as the median number of scans and observations per session. While a scan is defined as several antennas observing the same source, when more than two antennas observe the identical source at the same time, in one scan one antenna can have several observations with other antennas. When observing in global networks, at each observation epoch the antennas are usually divided in sub-nets, each of them observing one common source. For a antennas observing the same source, the number of observations (or baselines b) in this scan usually is $b = a(a-1)/2$. The process of how these sub-nets are chosen, as well as the selection of target sources and observation epochs is commonly referred to as *scheduling*. Scheduling is a complex procedure including a number of optimisation processes, e.g. described in Petrov et al. (2009) or Sun et al. (2014). Besides basic geometrical issues, the number of scans per station is mainly influenced by the antenna capabilities in terms of sensitivity and slewing speed. One can generally say that larger antennas are much more sensitive than small antennas, however they usually need more time for slewing

[1] At the time of writing, not all data for 2014 were available.