First Geodetic Results from the Australasian VLBI Network

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Abstract The Australasian geodetic Very Long Baseline Interferometry (VLBI) array consisting of three new 12-meter radio telescopes in Australia (Hobart, Katherine, and Yarragadee), a 12-meter radio telescope in New Zealand (Warkworth), and a correlation facility in Perth started operations in 2011. The daily positions of the AuScope array are estimated with a precision of a few mm, whereas their daily estimates vary within a range of 20–30 mm on the annual scale. Analysis of geodetic VLBI sessions also reveals small linear trends in the time series of baseline lengths between the Australian and New Zealand stations. A seasonal signal with amplitude of about 10 mm was detected for the baseline Hobart–Katherine. This signal is consistent with seasonal variations of baselines between co-located GNSS stations. We argue this signal should be incorporated in the fitting model to improve the estimates of positions and linear velocities.

Keywords VLBI, AuScope, tectonic velocities

1 Introduction

In the framework of the AuScope project [1] and in a partnership with Geoscience Australia, UTas operates three 12-m radio telescopes located in Hobart (HOBART12), Yarragadee (YARRA12M), and Katherine (KATH12M). Located on the Australian tectonic plate, both AuScope and WARK12M [2] radio telescopes are ideally placed for measurements of intra-plate deformation. Additionally the six baselines of the AuScope+WARK12M array are long enough to contribute to Earth Orientation Parameter (EOP) observations, particularly when coupled together with a Japan–New Zealand baseline.

In this paper, we present a summary of the baseline length variations between AuScope antennas and WARK12M from IVS results for a three-year period, from the beginning of 2011 to the end of 2013. We analyze baseline length variations for the co-located GNSS stations [3, 4, 5].

2 Analysis of VLBI and GNSS Baselines for the Australasian Geodetic Network

AuScope and WARK12M VLBI stations are co-located with GNSS stations HOB2, KAT1, YAR2, and WARK [6, 7]. In this section we compare GNSS vs. VLBI baseline lengths and their linear rates for this Australasian array.

The first AuScope VLBI station, HOBART12, has participated in global IVS sessions regularly since 2010. KATH12M and YARRA12M have regularly taken part in IVS observations since 2011. Regular WARK12M–AuScope observations started in July 2012. In 2012, HOBART12 and KATH12M achieved over 90% sessions analyzed. Unfortunately, this percentage is lower for WARK12M because of a serious problem with the Symmetricom Hydrogen Maser experienced in 2012. Once rectified WARK12M was

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able to resume participation in IVS sessions from January 2013.

Baseline lengths and their rates of change were estimated by using the IVS analysis centers results. Only accurate position measurement data (1-σ < 10 mm) were used. These results are summarized in Table 1 for all types of sessions (e.g., R1, R4, AUST).

We analyzed the VLBI databases applying a uniform strategy across all session types. It is important to do this because the different types of IVS sessions are optimized for different purposes. For example, R1 and R4 sessions are optimized for providing twice weekly EOP results. The purpose of AUST sessions is to determine the station coordinates and their evolution in the AuScope+WARK12M network. We analyzed 134 databases of four types (R1, R4, AUSTRAL, and CRDS) using the Calc/Solve software. In the analysis of R1 and R4 sessions, we excluded TIGOCONC and the Japanese stations (TSUKUM32, KASHIM34, and KASHIM11) in order to avoid the effects of earthquake after-slip. In the analysis of AUST and CRDS sessions, we used only AuScope and WARK12M station data.

Figure 1 shows the VLBI baseline length variations vs. time for six baselines. The linear trends of baselines estimated for different types of sessions are provided in Table 1. For all CRDS sessions, the baseline length standard deviations (sigmas) were all greater than 10 mm. The poor accuracy of the baseline measurements in CRDS sessions can be explained by a specific character of the distribution of scheduled sources—they were all clustered in the celestial south pole direction.

Table 1 Weighted linear rates for six baselines in mm/year.

Baseline	VLBI (OCCAM)	VLBI (CALC/SOLVE)	GNSS
Hb – Ke	7.1 ± 1.8	5.3 ± 0.9	0.3 ± 0.2
Hb – Yg	−0.5 ± 1.6	3.0 ± 1.1	0.8 ± 0.1
Ke – Yg	6.1 ± 1.6	5.6 ± 1.0	−0.8 ± 0.1
Hb – Ww	−0.2 ± 0.5	4.5 ± 2.4	−1.6 ± 0.2
Yg – Ww	20 ± 12	9.9 ± 4.9	−0.6 ± 0.3
Ke – Ww	18 ± 17	11.9 ± 3.7	0.1 ± 0.3

GNSS data from the co-located IGS and PositioNZ stations were analyzed using the GAMIT/GLOBK software. We combined the results with the SOPAC global network file. Figure 2 shows the baseline length residuals and the corresponding rates of change of the six baselines. The rates of change indicated in Table 1 were estimated by formally fitting linear functions to all sets of GNSS baseline data. All GNSS rates of change proved to be very small (about 1 mm/yr or less), which seems realistic as all four stations are located on the Australian Plate. There is a clear annual/seasonal periodic pattern in GNSS baseline data. We argue that this is also evident in the most heavily sampled VLBI baseline data, e.g., for HOBART12–KATH12M baseline. The amplitude of these periodic changes is about 10 mm.

Geodetic VLBI data were also analyzed using the OCCAM software. Estimates obtained by fitting the data with a linear function are presented in Table 1. These numbers indicate, for example, that VLBI antenna KATH12M moves with respect to the two other Australian stations at a rate of 5–7 mm/year. With the Australian continent assumed to be located on a single, quite solid tectonic block, such high rates of linear motion between radio telescopes was not predicted. The New Zealand site belongs to the same tectonic plate. However, the margin between the Australian and Pacific plates is located nearby, therefore the WARK12M site sits on a deformation zone near the tectonic plate margin. As a result, the Trans-Tasman baselines might be expected to show a more substantial linear trend. However, the GNSS results do not support this conclusion. Unfortunately the number of VLBI observations is currently insufficient for robust estimation of these linear trends.

The uncertainties in the linear trend estimates (Table 1) are exaggerated by strong seasonal signals present in both the VLBI and GNSS times series [5]. The seasonal trends, clearly seen in the plotted baseline time series, are likely to be caused by hydrological signals with annual and semiannual periods. However, these signals are not purely harmonical, so temporal changes in periods and amplitudes are expected. Figure 2 shows all six baseline length variations measured with GNSS. The seasonal signals are very indicative with peak amplitudes of 3–6 mm for annual signals and 1–3 mm for semi-annual signals (Table 2).

Figure 3 shows variations of the KATH12M vertical component measured with VLBI and GNSS data, respectively. The GNSS time series shows a steady rate of 6 mm/year with obvious signs of seasonal variation superimposed, whereas the VLBI time series displays a higher annual rate of 14 mm/year and quasi-regular variations. We believe that the quasi-regular variations

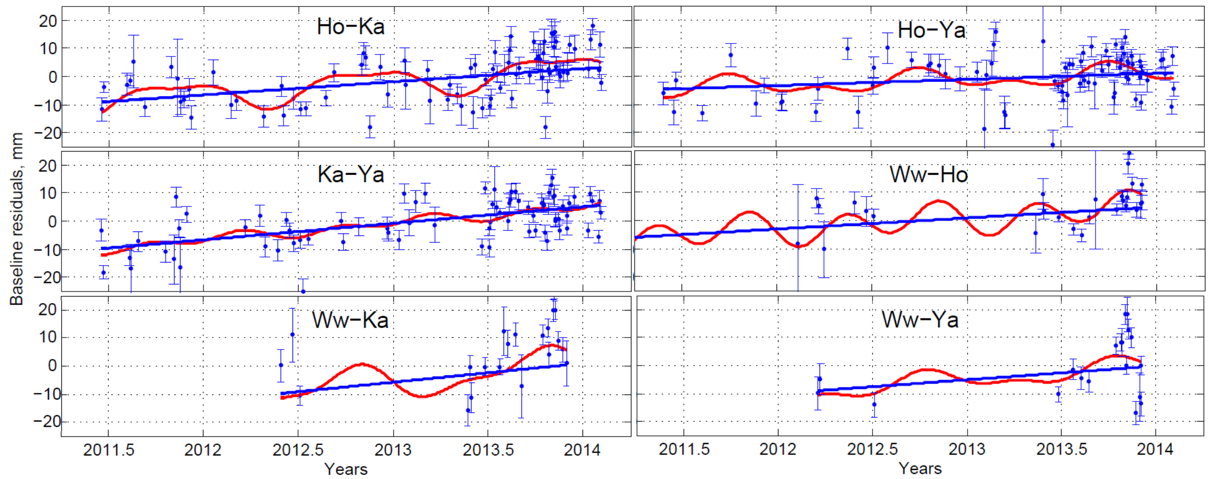

Fig. 1 VLBI derived baselines.

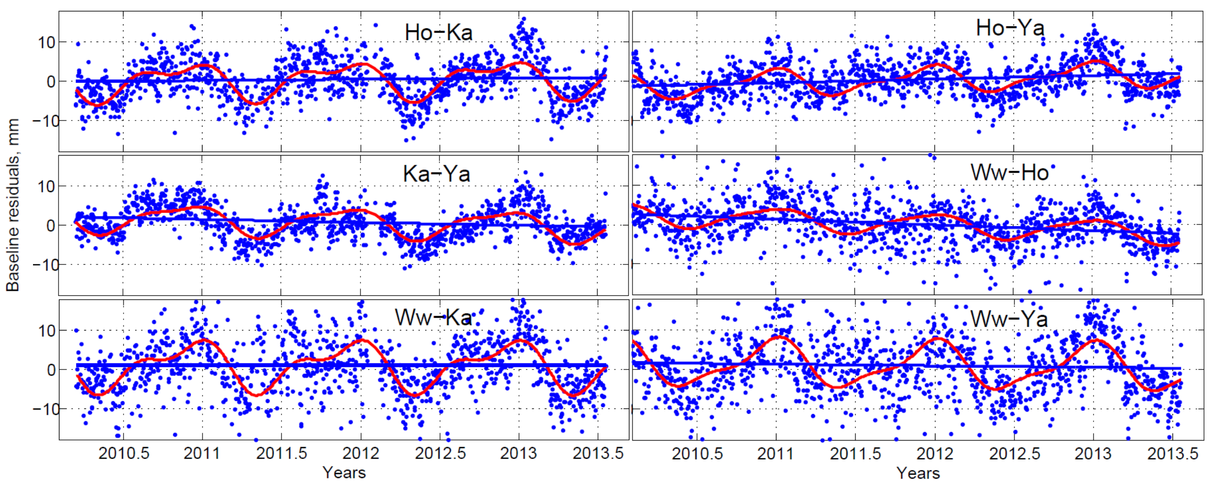

Fig. 2 GNSS derived baseline data.

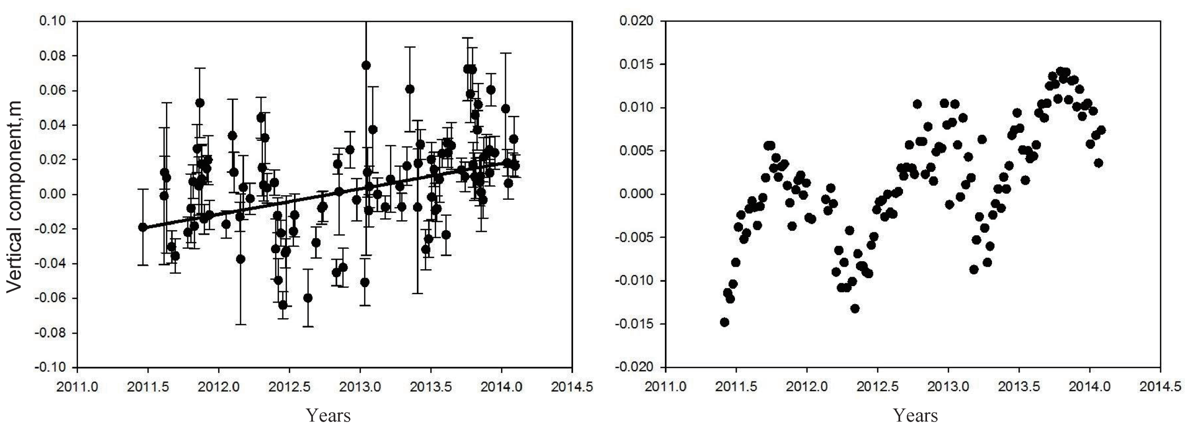

Fig. 3 Vertical components for the Katherine station derived from VLBI (left) and GNSS (right).

Table 2 Peak amplitude of annual and semi-annual signals from GNSS data, units mm.

Baseline	Annual	Semi-annual
Hb – Ke	4.0	2.2
Hb – Yg	2.9	1.4
Ke – Yg	3.5	1.2
Hb – Ww	2.8	0.6
Yg – Ww	5.5	1.9
Ke – Ww	5.5	2.8

of the vertical component may be responsible for the higher rate of the vertical component measured with VLBI. The nature of the uplifting of this area over the three-year period is likely to be caused by hydrological effects. Analysis of a longer times series (since 2010) from the co-located GNSS at KATH12M indicates that the 6 mm/year vertical component rate is a part of long term variations. We suggest therefore that the VLBI-measured rate may have the same explanation. A longer observational time span for VLBI data is necessary to verify this suggestion.

3 Conclusions

The Australasian VLBI network of four 12-meter radio telescopes has been operational since 2011. We have analyzed almost three years of observations and compared the baseline length changes with the corresponding GNSS results. Two Australian baselines including the KATH12M station show a statistically significant linear trend in the VLBI data, but this is not supported by the corresponding GNSS data. At the same time both types of observations reveal quite significant seasonal variations, which may affect the linear rate estimates. The third Australian baseline HOBART12–YARR12M does not show a statistically significant linear trend in accordance with expectations.

The Trans-Tasman baseline changes are difficult to estimate with VLBI due to insufficient observational data. The baseline HOBART12–WARK12M shows no significant tectonic motion, whereas the two longer VLBI baselines KATH12M–WARK12M and YARR12M–WARK12M display somewhat controversial linear rates, arguably due to the sparseness of the time series collected to date. More data must be collected to improve the linear rate estimates.

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