Southern Hemisphere Geodesy and Astrometry with AUSTRAL

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Abstract The AuScope VLBI array is currently participating in geodetic and astrometric programs at the level of 150 days per year. Sixty of these days are dedicated to southern hemisphere focused AUSTRAL sessions. Here we describe the aims of the AUSTRAL program and new simulation and observing techniques under trial. We report on the progress to date, with a particular focus on our first 15-day southern hemisphere 'CONT' campaign carried out in November/December 2013.

Keywords VLBI, reference frame, astrometry

1 Introduction

The AuScope geodetic VLBI array [1] consists of three new 12-m radio telescopes and a correlation facility in Australia. The telescopes, all operated by the University of Tasmania, are at Hobart (Tasmania), Katherine (Northern Territory), and Yarragadee (Western Australia). They are co-located with other space geodetic techniques including GNSS, gravity, and, in the case of Yarragadee, SLR and DORIS facilities. The correlator is located at Curtin University in Western Australia.

Between July 2013 and July 2015 the array is participating in IVS programs at the level of 150 days per year. Sixty of these days are dedicated to AUSTRAL sessions with scheduling in VieVS [3], observations with the three AuScope antennas plus the Hobart 26 m, Warkworth 12 m, and Hartebeesthoek 15 m and 26 m (Figures 1 and 2), and correlation at Curtin University.

Fig. 1 Hobart 12 m schematic. (credit: P. Lovell)

The AUSTRAL observing program is divided into three streams focussed on high priority geodetic and astrometric aims in the southern hemisphere:

1. Astrometric observations to monitor and enhance the southern hemisphere reference frame in preparation for ICRF3;
2. Regular observations to improve the density of the geodetic time series for the southern antennas and to measure and monitor the motion and deformation of the Australian plate;
3. Four 15-day CONT-like campaigns over two years to demonstrate the full capabilities of the array,

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2. Curtin University, Australia
3. Auckland University of Technology, New Zealand
4. Hartebeesthoek Radio Astronomy Observatory, South Africa
5. Vienna University of Technology, Austria
6. Shanghai Astronomical Observatory, China
7. Geoscience Australia, Australia
8. Mount Stuart Primary School, Australia

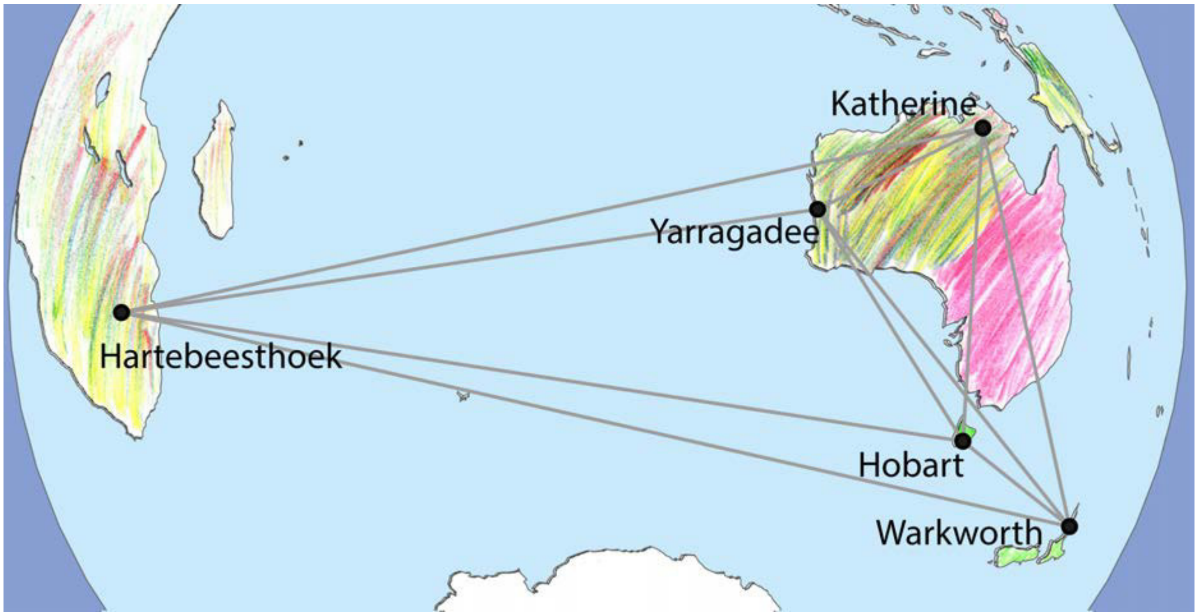

Fig. 2 The AUSTRAL Array, consisting of the three 12-m Australian AuScope antennas, the Hartebeesthoek 15 m, and the Warkworth 12 m. (credit: S. Lovell)

characterize the level of systematic errors caused by the troposphere and source structure, and develop and test error mitigation strategies.

2 Understanding the Systematics

Baseline length repeatability is a fundamental measure of the precision of the VLBI technique. In Figure 3 we show residuals for a typical long baseline between Hobart 12 m (Hb) and Kokee Park, Hawaii (Kk) ($\sim 8,300$ km). The two sets of points represent different observing campaigns, with filled points representing the CONT11 campaign.

The weighted RMS (WRMS) for the Hb-Kk baseline length during the CONT11 campaign is 0.010 m. This suggests that centimeter level accuracy in position measurements is achievable even with present techniques. By comparison, the WRMS of the baseline residuals for all other available observations is 0.021 m (Figure 4).

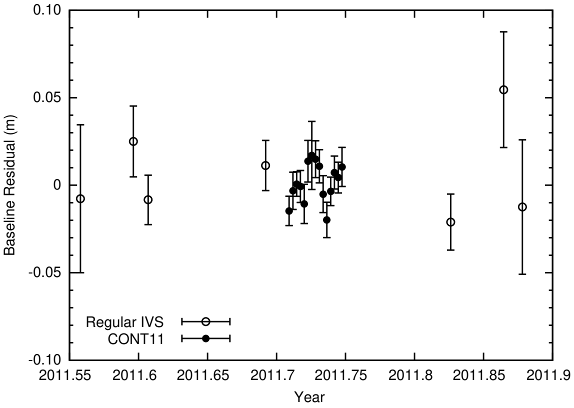

Fig. 3 Time series for residuals for the Hobart-12-m–Kokee (Hb–Kk) baseline. Filled circles represent data from the CONT11 campaign. Open circles are standard IVS sessions. Figure reproduced from [1].

Our results highlight an important point. While formal uncertainties in station positions and baseline lengths can be reduced by increasing the number of observations, this is not particularly useful when attempting to assess the quality of individual position measurements. It is clear that the main factor at present limiting the accuracy of VLBI observations lies in systematic biases inherent to the analysis. For example, ignorance of quasar structure and variability (which can exhibit different temporal behavior at S and X bands; e.g., Shabala et al., these proceedings, and [2]) will map into source and station positions. Furthermore, the magnitude and sign of these effects

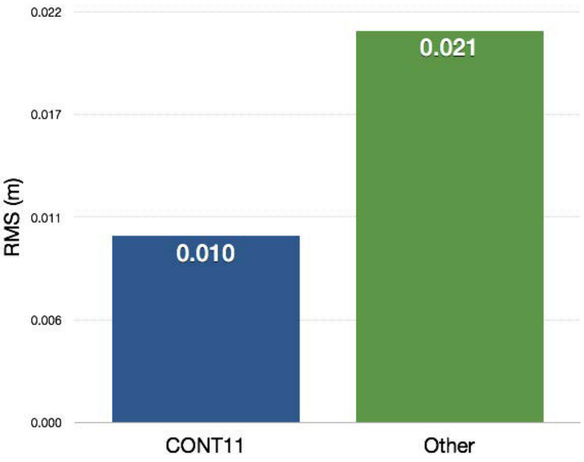

Fig. 4 A comparison of weighted RMS baseline residuals on the Hobart 12 m to Kokee baseline for CONT11 and all other observations. This demonstrates a clear improvement when systematic biases (such as array geometry) are removed.

will in fact depend in a complicated fashion on network geometry and the observing schedule.

One of the main aims of the 15-day continuous AUSTRAL campaigns is to further understand these systematic effects and develop strategies to mitigate against them.

As well as the 15-day campaigns, for four 24-h experiments during 2014, the 26-m antennas at Hartebeesthoek and Hobart will join the AUSTRAL array. With the same atmosphere and clocks at each site, and with baselines to each pair observing the same source structure, we hope to further understand the systematic uncertainties due to troposphere and source structure.

3 The 15-day AUSTRAL Observing Strategy

In the two-year period between July 2013 and July 2015, we plan to observe four 15-day CONT-like campaigns with the AUSTRAL array. The first of these campaigns has already taken place (November/December 2013) with the second one planned for November 2014. For each of the systematic effects we have identified, we are implementing the following strategies:

1. Array geometry can play an important factor in the solutions as the CONT11 results demonstrate. We will use the same array for all of the 15-day AUST campaigns.
2. Source structure. For the November/December 2013 campaign, we selected two source samples based on their Structure Index (SI):

   - The "good" sample containing sources with median SI < 2.5, observed on eight out of the 15 days.
   - The "bad" sample containing sources with median SI > 2.5, observed on seven out of 15 days.

   There are two schedules, one for the good sources and one for the bad. The schedules are repeated in sidereal time so that baseline orientation to source structure is fixed, removing random effects due to structure but preserving systematic effects.
3. Troposphere. For every sidereal day, we alternated between the "good" and "bad" source schedules so that, as much as possible, the weather conditions between consecutive days are comparable.

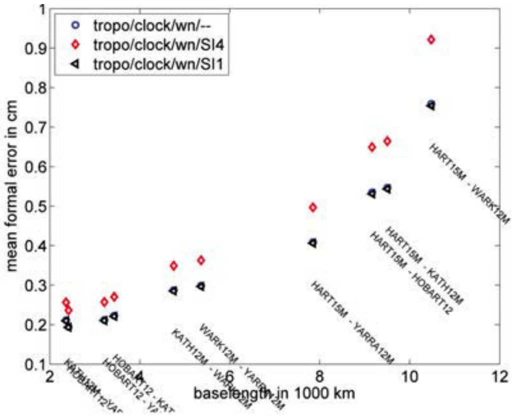

Fig. 5 Formal uncertainties for baseline lengths from simulations of the November 2013 AUSTRAL 15-day campaign. There is a clear indication that the uncertainties will be lower for sources with small Structure index (black triangles) than high Structure Index (red diamonds).

4 Simulations

Simulations of the AUSTRAL 15-day campaigns were conducted in VieVS, making use of the new source

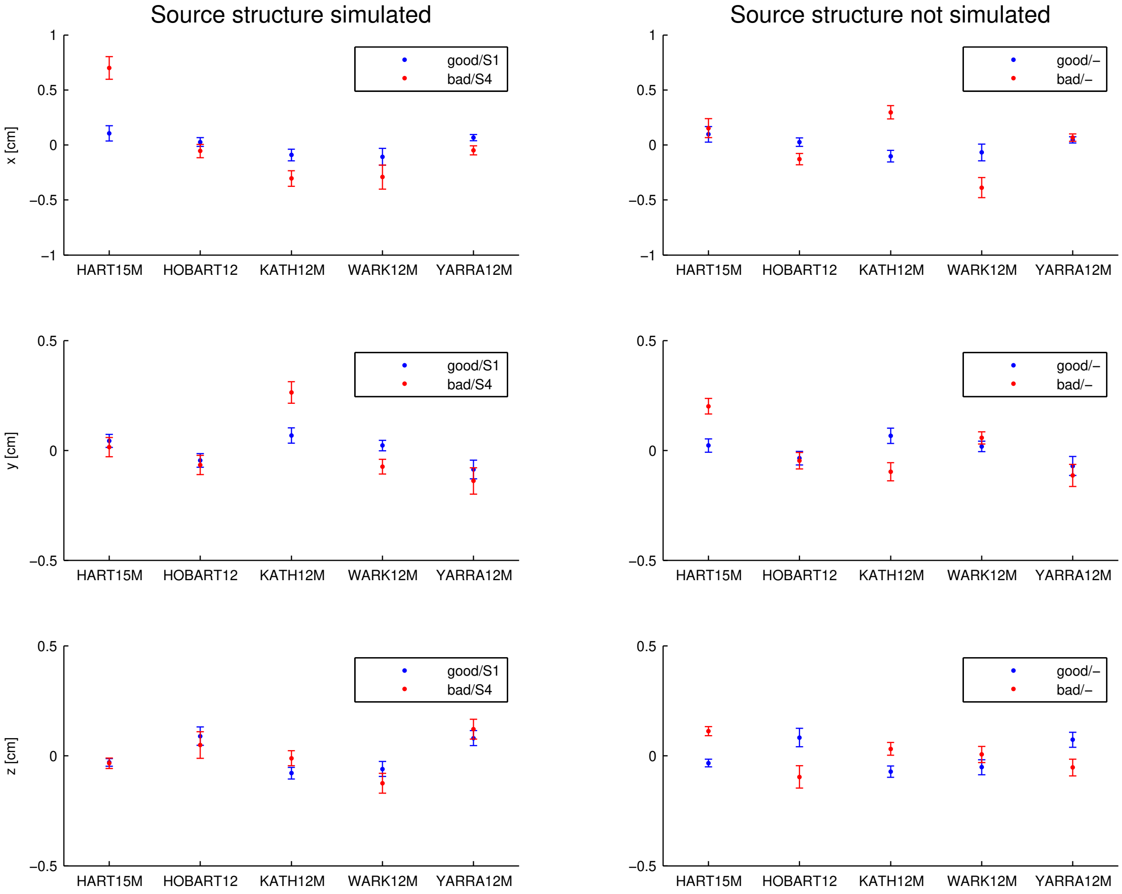

Fig. 6 Station cartesian coordinate residuals from simulations of the November 2013 AUSTRAL 15-day campaign for the "good" (blue) and "bad" (red) source selections. Panels on the left show results when source structure is simulated, and panels on the right are from simulations when structure is not simulated (i.e., point sources are assumed).

structure simulator [3]. The actual schedule files used in the November/December 2013 AUST 15-day campaign were used with 30 realizations each. Moderate values of Cn and H were used to characterize the troposphere, but this was still the dominant error over clock and white noise. The "good" and "bad" sources were simulated with Structure Index values of 1 and 4, respectively. While this is a reasonably crude approximation to real sources (which exhibit a distribution of structure indices), such simulations allow us to make an estimate of the source structure effect.

The simulations clearly show an improvement in the formal uncertainties for the low SI (good) sources over the high SI (bad) sources. In Figure 5 we show the simulated formal uncertainties as a function of baseline length, and in Figure 6 the station cartesian coordinates with formal errors derived from the VieVS global solution.

Lastly, in Figure 7 we show source coordinates as a function of declination. Once again the difference between low and high SI sources is clearly apparent.

5 Conclusions

We will use our analysis of the first 15-day campaign to validate the simulations and provide feedback to further develop our scheduling and observing strategies for the AUSTRAL program. Data from AUSTRAL sessions are released to the VLBI community in the same way as other IVS-coordinated programs.

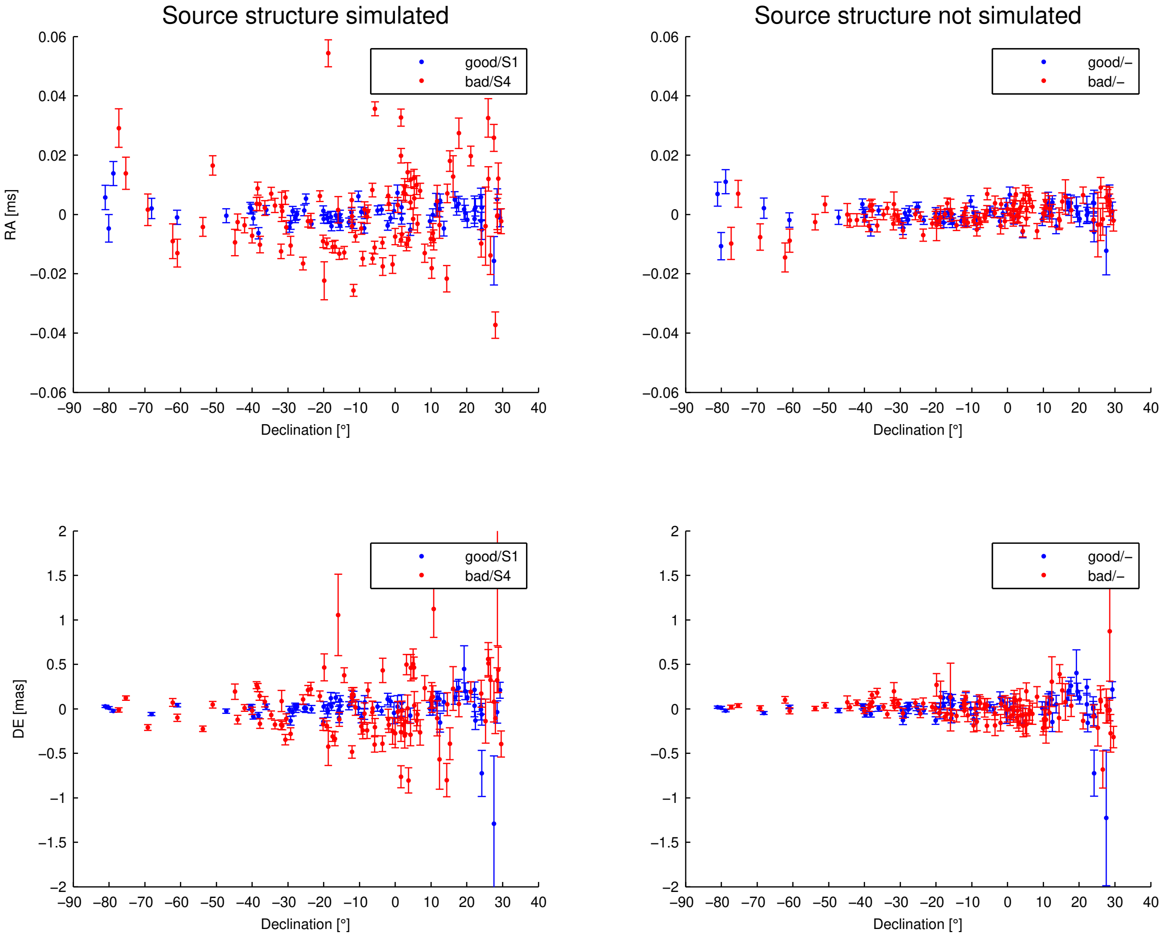

Fig. 7 Source position estimates from simulations of the November 2013 AUSTRAL 15-day campaign for the “good” (blue) and “bad” source selections. Panels on the left show results when source structure is simulated, and panels on the right are from simulations when structure is not simulated (i.e., point sources are assumed).

References

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