THE AUSCOPE VLBI PROJECT

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ABSTRACT. The AuScope VLBI array, consisting of three new 12-meter radio telescopes in Australia dedicated to geodesy, has recently commenced operations. The telescopes at Hobart (Tasmania), Katherine (Northern Territory) and Yarragadee (Western Australia) are co-located with other space geodetic techniques including Global Navigation Satellite Systems (GNSS) and gravity infrastructure, and in the case of Yarragadee, Satellite Laser Ranging facilities. This new facility will make significant contributions to improving the densification of the International Celestial Reference Frame in the southern hemisphere, and subsequently, improve the International Terrestrial Reference Frame through the improved ability to detect and mitigate systematic error. Improvements to both the ICRF and ITRF, as well as the simultaneous densification of the GNSS network across Australia will enable the improved measurement of intraplate deformation across the Australian tectonic plate.

1. INTRODUCTION

In 2006 the National Cooperative Research Infrastructure Strategy (NCRIS) initiated program 5.13, "Structure and Evolution of the Australian Continent", which is funded by the Department of Innovation, Industry, Science and Research (DIISR) and managed by AuScope Ltd. (www.auscope.org.au). A major component of this project was the establishment of a national geospatial framework to provide an integrated spatial positioning system spanning the whole continent. Total federal funding for this undertaking is AUD$15.8M, together with AUD$21M from Universities, State Governments and Geoscience Australia. The infrastructure that was funded to achieve this improvement to the geospatial framework included:

- three 12-meter radio telescopes and a software correlator
- about 100 GNSS receivers
- upgrade of existing SLR facilities
- an absolute gravimeter and three tidal gravimeters
- improved computing facilities

As part of this effort, the University of Tasmania (UTAS) has constructed three new radio telescopes, located near Hobart (Tasmania), Yarragadee (Western Australia), and Katherine (Northern Territory). UTAS is responsible for construction and operation of three new VLBI sites (Figure 1). A software correlator has been developed at Curtin University of Technology.

These new telescopes will double the number of IVS stations in the Southern Hemisphere. They will allow the extension of astrometric VLBI solutions to radio sources south of declination -40 deg, an area of the sky that has been severely under-sampled by the existing array because so few telescopes are available in the south. The AuScope telescopes are intended to observe for 180 days per year, increasing

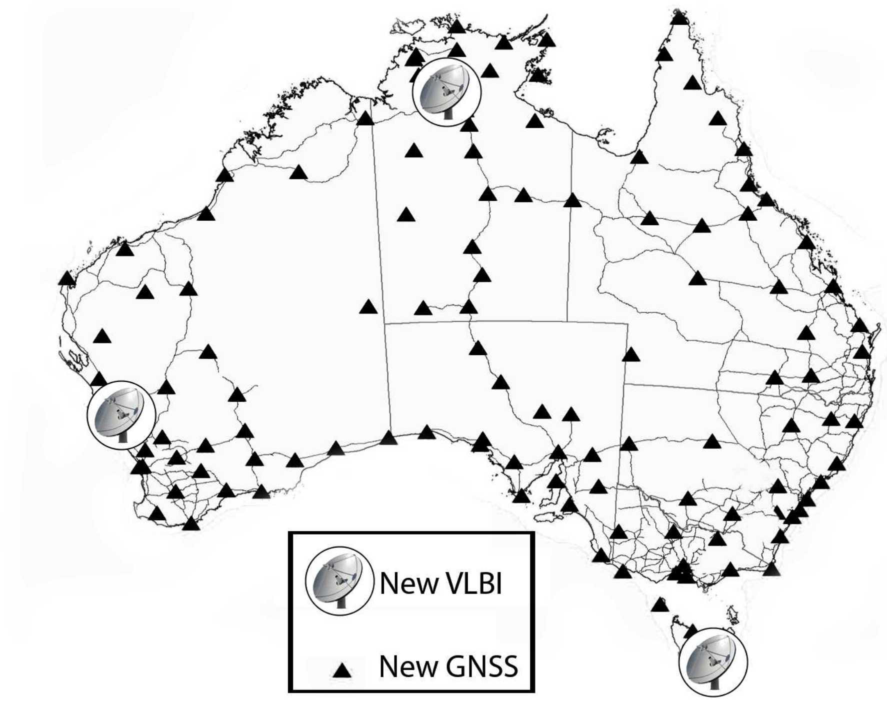

Figure 1: The geographical distribution of VLBI and GNSS infrastructure for AuScope. From West to East, the new VLBI stations are at Yarragadee, Katherine and Hobart. An additional ∼100 GNSS receivers will be distributed across the continent.

the number of geodetic VLBI observations in Australia by a factor of nine. The AuScope telescopes closely follow the International VLBI Service VLBI2010 specification for the next generation of telescopes for geodesy (Petrachenko et al., 2009) or provide an upgrade path to meet the specification where it is not currently possible to do so.

2. INFRASTRUCTURE

Each AuScope VLBI observatory is equipped with a 12.1 m diameter main reflector designed and constructed by COBHAM Satcom, Patriot Products division. The telescope specifications include: 0.3 mm of surface precision (RMS), fast slewing rates (5 deg/s in azimuth and 1.25 deg/s in elevation), and acceleration (1.3 deg/s/s). All three sites are equipped with dual polarization S and X-band feeds from COBHAM with room temperature receivers, developed at UTAS by Prof. Peter McCulloch. The receiver systems cover 2.2 to 2.4 GHz at S-band and 8.1 to 9.1 GHz at X-band. System Equivalent Flux Densities (SEFDs) are 3500 Jy in both bands. Data digitisation and formatting is managed by the Digital Base Band Converter (DBBC) system from HAT-Lab, and data are recorded using the Conduant Mark5B+ system. Each site is equipped with VCH-1005A Hydrogen maser time and frequency standards from Vremya-CH.

Observatory sites were selected to satisfy two main criteria: good geographical coverage over the Australian continent and co-location with existing geodetic techniques. The new Hobart telescope is co-located with the existing 26 m telescope to preserve the more than 20 year VLBI time series at the site. Midway between the 26 m and 12 m telescopes is the HOB2 GNSS installation which has been a core site of the International GNSS Service (IGS) since its conception. A hut capable of housing a mobile gravimeter is also co-located on the site. The Yarragadee telescope provides a far western point on the continent and is co-located with multiple existing geodetic techniques including SLR, GNSS, DORIS and gravity. The Katherine site is new and provides a central longitude, northern site. The telescope at Katherine is co-located with a new GNSS site that forms part of the AuScope GNSS network.

AuScope also includes funding for a software correlator, the Curtin University Parallel Processor for Astronomy (CUPPA), a 20 node beowulf computing cluster. Each node consists of a server class PC with dual quad-core processors, 8 GB of RAM and 1 TB of internal hard disk storage. Additionally, the cluster incorporates external mass storage and a total disk pool of 100 TB is available to the cluster. CUPPA is networked internally with standard 1 GbE (two ports per node) and with a 10 GbE connection to iVEC, the eastern Australian state supercomputing centre. In order to process AuScope data, three Mark5B+ VLBI data recorder/playback units were acquired for CUPPA. For VLBI correlation, CUPPA runs the DiFX software correlator (Deller et al 2007) . DiFX has a global user and developer community and is used for astronomical and geodetic correlation at major facilities in the US, Germany and Australia, as well as minor facilities in Australia, New Zealand, the US and Italy.

3. PROJECT STATUS

Construction of the first AuScope telescope at Hobart was completed in 2009 and officially opened at the IVS General Meeting on February 9 2010. Following a period of commissioning, testing and debugging, the Hobart telescope made its first successful IVS observation in October 2010. Construction and commissioning at the other two sites continued in parallel. Yarragadee made its first successful IVS observation in May 2011 and, following a successful full-network fringe check on June 8 2011, correlated at CUPPA. All three telescopes participated in an IVS observation for the first time on June 16 2011.

All three observatories were designed and constructed to be remotely controlled and monitored to keep operating costs at a minimum. Operation of the AuScope VLBI array is being carried out from a dedicated operations room on the Sandy Bay campus of the University of Tasmania.

At present, the AuScope VLBI facility has sufficient operational funds for ∼70 observing days per year, usually consisting of two AuScope telescopes observing as part of the IVS network. Unfortunately operational funds are not presently sufficient to support correlation at CUPPA.

The three AuScope stations have shown good geodetic results since they started operations. The geodetic position accuracy varies around 5 to 10 mm with a tendency to decrease with time as improvements are made to hardware and operational procedures. In August 2011, the AUSTRAL02 IVS observing session was undertaken, comprising the three AuScope stations and the 64 m radio telescope at Parkes. The AUSTRAL sessions are focussed on improving the celestial and terrestrial reference frame in the southern hemisphere. For all three AuScope stations, the accuracy was 6 to 9 mm for the height components and 2 to 3 mm for the horizontal components. This corresponds to a factor of two improvement compared to standard IVS observations typically involving two Australian stations. The recent AUSTRAL03 session (November 2011), which includes the three AuScope telescopes and Warkworth, was recorded with a higher data rate than AUSTRAL02 (1 Gbps compared to 256 Mbps), therefore permitting more observations and better sky coverage, and will hopefully act as a demonstration of the benefits of the advantages of higher data rates and smaller, faster moving telescopes.

4. GEODETIC RESEARCH AT THE UNIVERSITY OF TASMANIA

Space geodetic tools including Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR) and Very Long Baseline Interferometry (VLBI) are key to the realisation of modern celestial and terrestrial reference frames that underpin the study of both astronomical and Earth based phenomena. "Environmental space geodesy", or the use of space geodetic tools applied to global climate change and sea level studies, crustal strain and seismic deformation, and surface expression of hydrologic loading, is an active theme area of research at UTAS between the School of Maths and Physics and the School of Geography and Environmental Studies. With the completion of the AuScope telescope array, a high priority for research and development within this theme area is geodetic VLBI and its contribution to improving the reference frame. A specific focus of this theme area includes the investigation of systematic errors that currently limit individual space geodetic techniques and therefore their combination in the process of realising the terrestrial reference frame. A specific outcome of the new AuScope telescope array will therefore be the further characterisation and mitigation of systematic error sources within geodetic VLBI and GNSS data analyses.

Areas of activity include automated monitoring of the 26 and 12 m telescopes to better understand thermally induced deformation, source structure and motion studies, network effects, and from a GNSS perspective, investigations into the mitigation of spurious energy at harmonics of the GPS draconitic year in coordinate time series. These are some of a number of sources of systematic error that bias the ITRF and hence limit geophysical interpretation from space geodetic data.

The UTAS Mt. Pleasant Observatory is one of only three radio telescopes in the Southern Hemisphere that contribute regularly to the IVS. The new AuScope telescope array in combination with a new 12 m telescope at Warkworth, New Zealand (Gulyaev & Natusch 2010), will more than double the coverage of the IVS in the Southern Hemisphere. Improved spatial and temporal coverage across the Southern Hemisphere offers significant potential for both improved astrometric and geodetic VLBI. Specifically, improved estimates of intra-plate crustal strain and far field Earthquake deformation will be possible, as well as the further investigation of hydrological loading signals that will dominate the northern telescope site at Katherine. Combined with analyses of GNSS data, the AuScope VLBI and GNSS arrays provide a unique opportunity to address different systematic error contributions to both space geodetic techniques.

By achieving key improvements to systematic error contributions in specific space geodetic analysis techniques, we aim to work towards an improved definition of the terrestrial reference frame (TRF). This will be accomplished through the generation of a TRF based on multiple observational techniques that has an improved handling of effects including non-linear site motion induced by earthquakes, quasi-periodic motion of the crust induced by hydrological loading, and spurious hardware-related offsets in global navigational satellite system (GNSS) measurements. Each of these previously mentioned signals are visible in the time series at the Hobart GNSS site, HOB2, and clear opportunity exists to make significant improvement across these areas.

5. REFERENCES

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