

IAG/FIG Commission 5/ICG Technical Seminar

Reference Frame in Practice

Rome, Italy 4–5 May 2012



Session 1.3 Worked examples of Terrestrial Reference Frame Realisations

Australia

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Leader - National Geodesy Program

Geoscience Australia

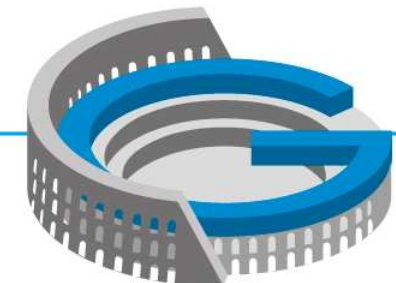
Sponsors:



esri



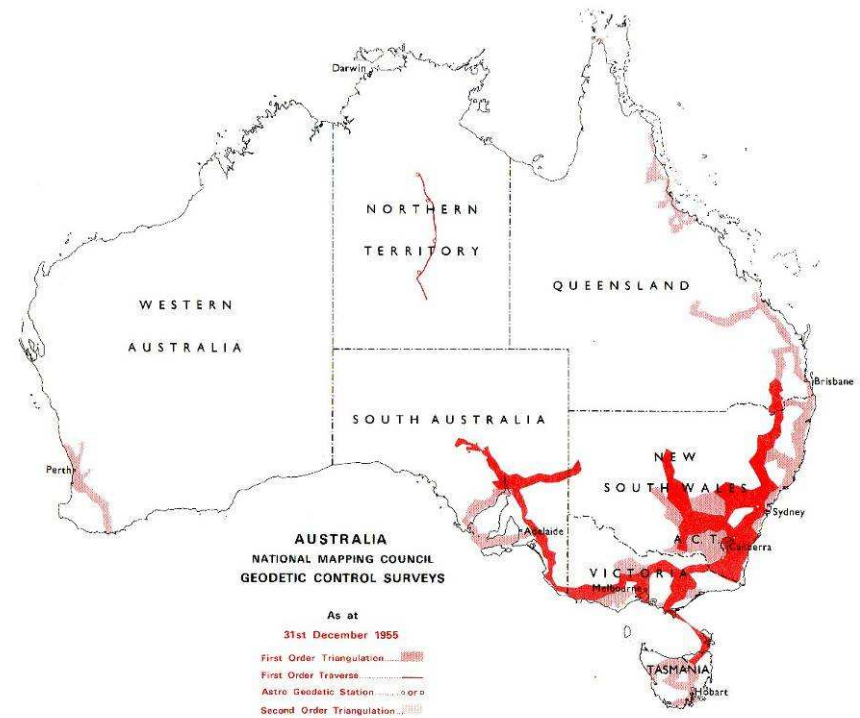
Trimble



Presentation Overview

- Background
 - Australia's early geodetic developments
 - Geocentric Datum of Australia (GDA)
 - Australian Height Datum (AHD)
 - Modelling the relationship between GDA and AHD using the national geoid model (AUSGeoid)
- Practical considerations for accessing and using the reference frame
 - ITRF and its relationship to GDA
 - AUSPOS – the Australian online GPS processing service
- Australian Datum Modernisation
 - Ideas for the future

Australia's Reference Frame: Largely triangulation before 1956



Australia's Reference Frame: Triangulation - labour Intensive

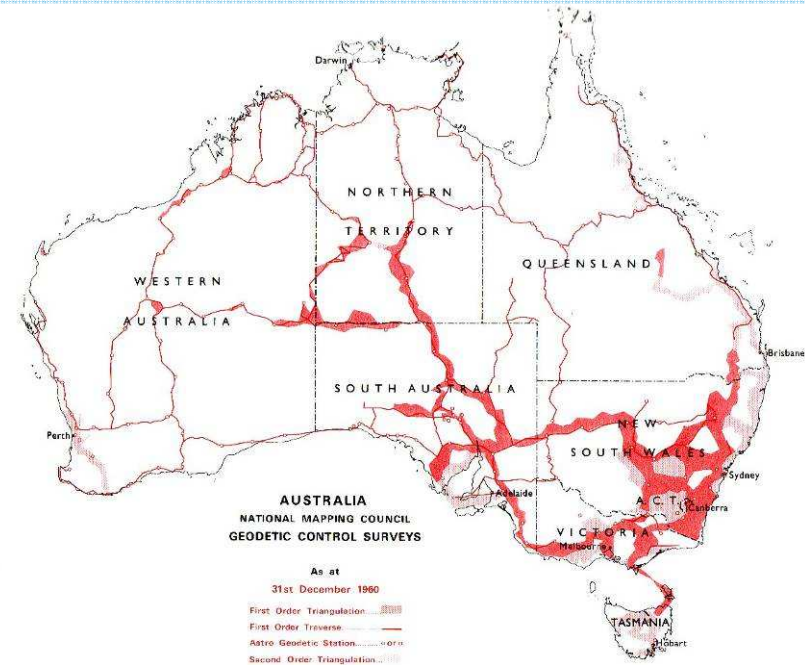


Australia's Reference Frame: Triangulation - challenges



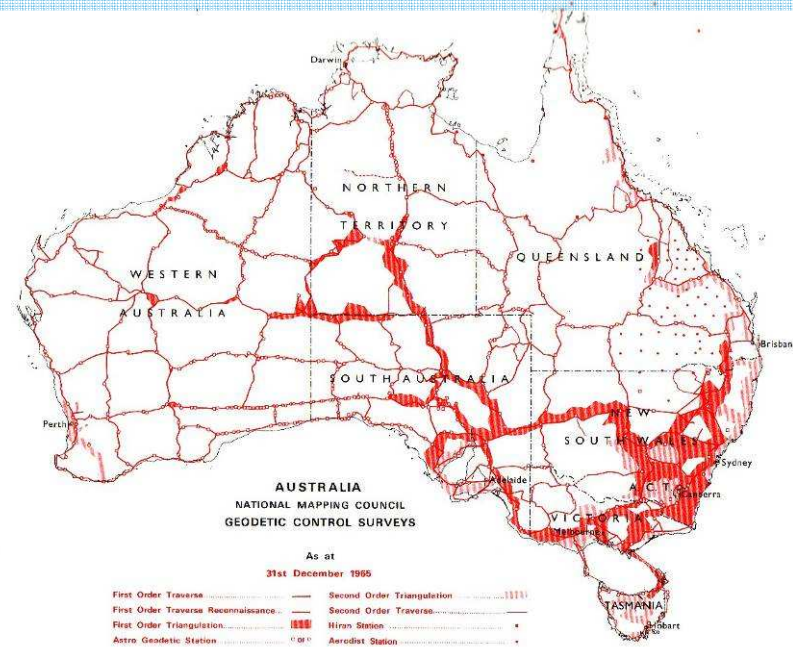
Geodimeter

- Model 1 (1954 to 1956)
- Model 8 (1968)
 - More portable
 - Increased accuracy, ~1 ppm



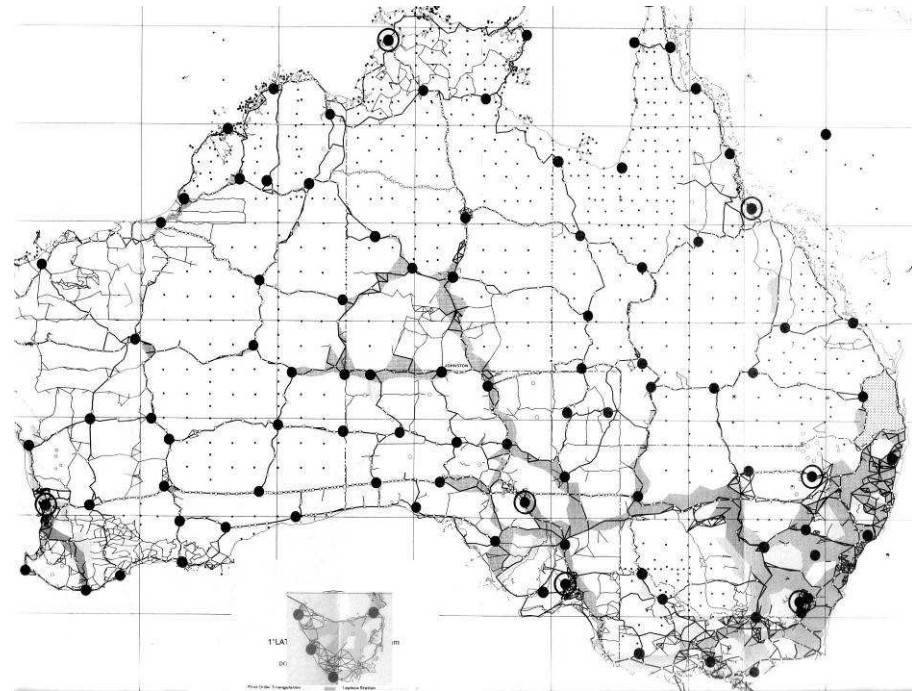
Tellurometer

- Introduced in 1956
 - Long traverses & loops possible
 - More coverage
 - Accuracy ~ 5 ppm



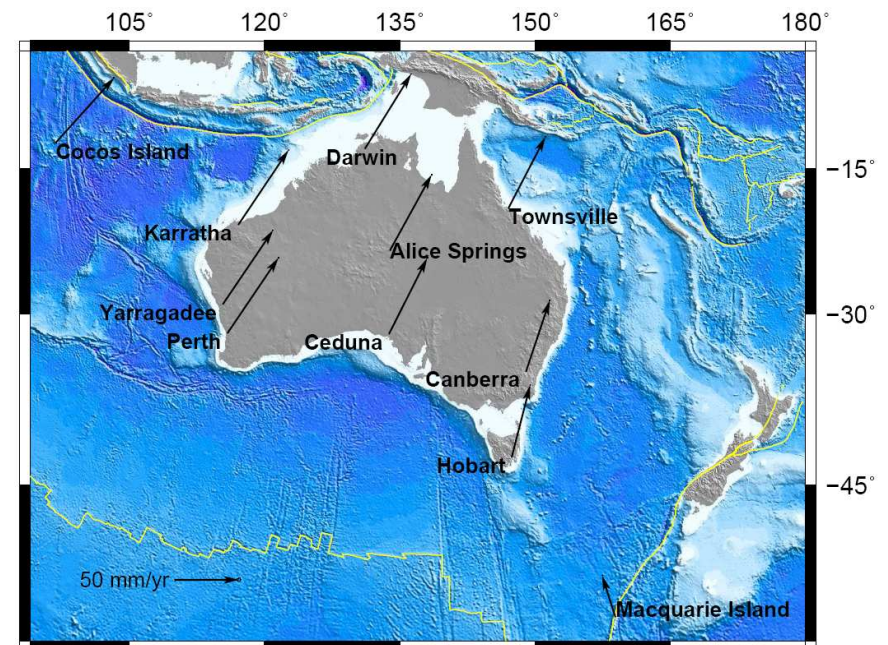
Australian DOPPLER Survey, 1975 to 1977

- Satellite positioning
- 106 stations
- 7-day observations (~40 passes) !
- Post processing by US Defence
- ~1 metre accuracy



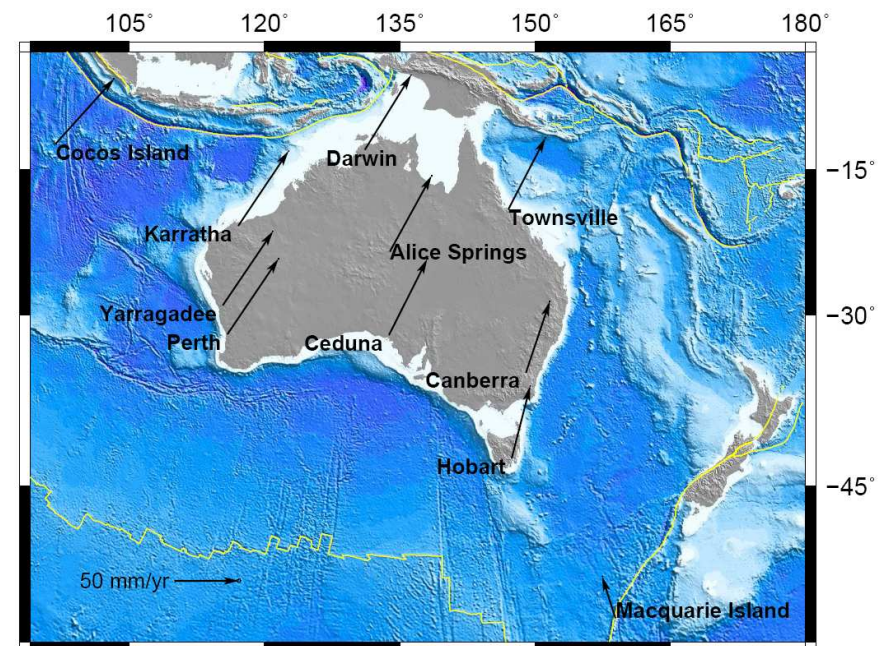
Australian Regional GPS Network (ARGN)

- Established (beginning) 1992
- Includes stations in Antarctica
- Sub-set of the ARGN that define the national datum are referred to as the Australian Fiducial Network (AFN)
- Now renamed to the Australian Regional GNSS Network (ARGN) to reflect the move to multi-GNSS technology

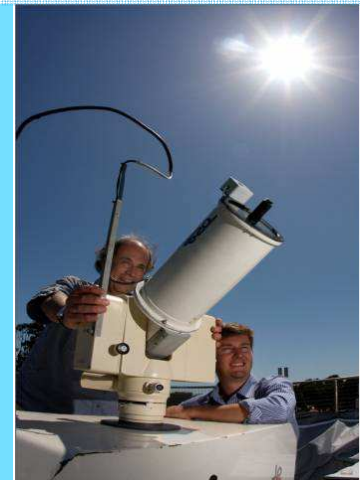
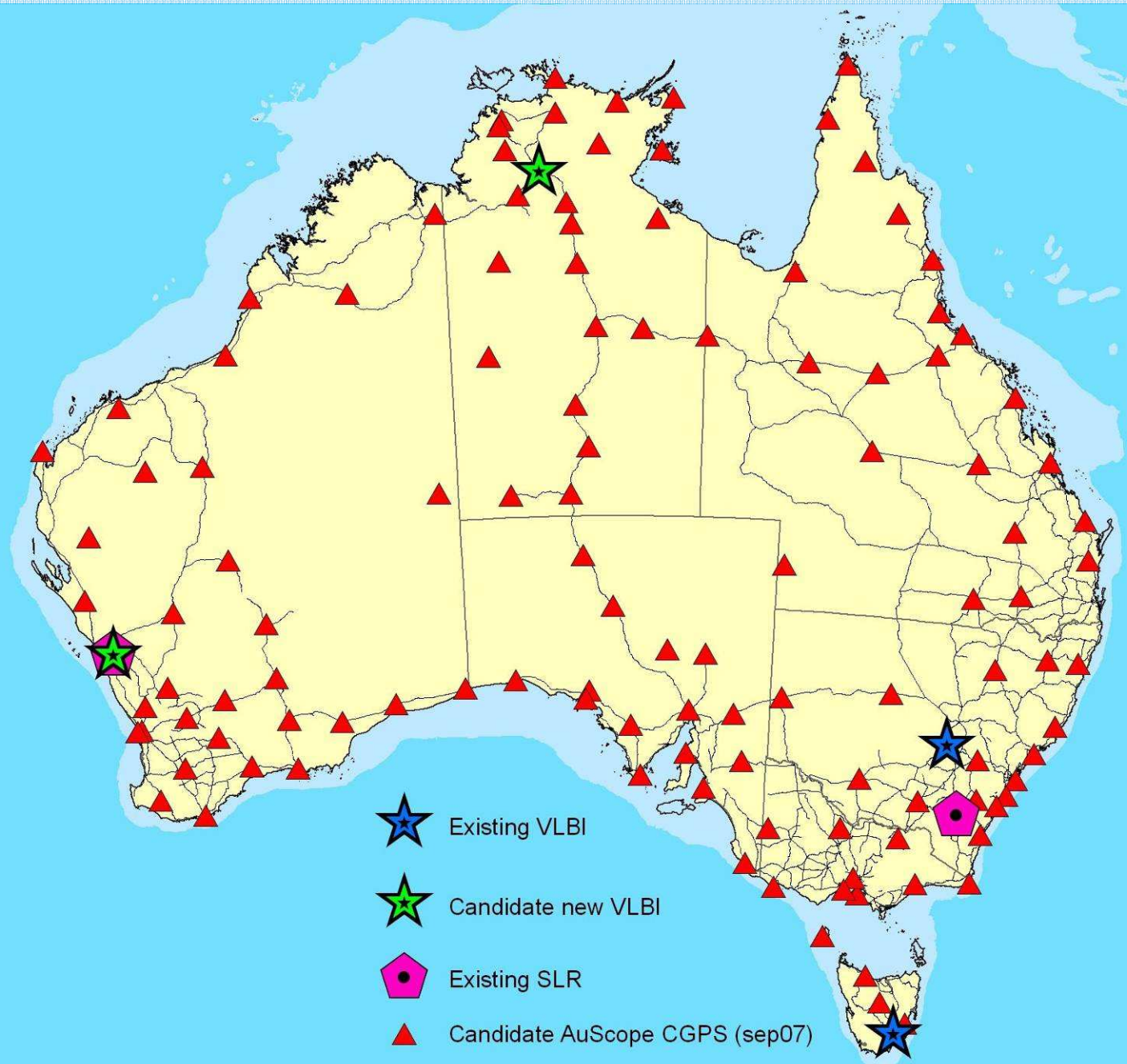


Geocentric Datum of Australia 1994 (GDA94)

- Superseded the Australian Geodetic Datum (AGD) series
 - Geocentric datum
- ITRF1992
 - Holding fixed 13 global stations @ 1994
- Recognised-value standard for position
 - Eight Australian Fiducial Network (AFN) and Perth
- Weakness: no convincing uncertainty analysis
 - 30 and 50 mm (95% C.L.)

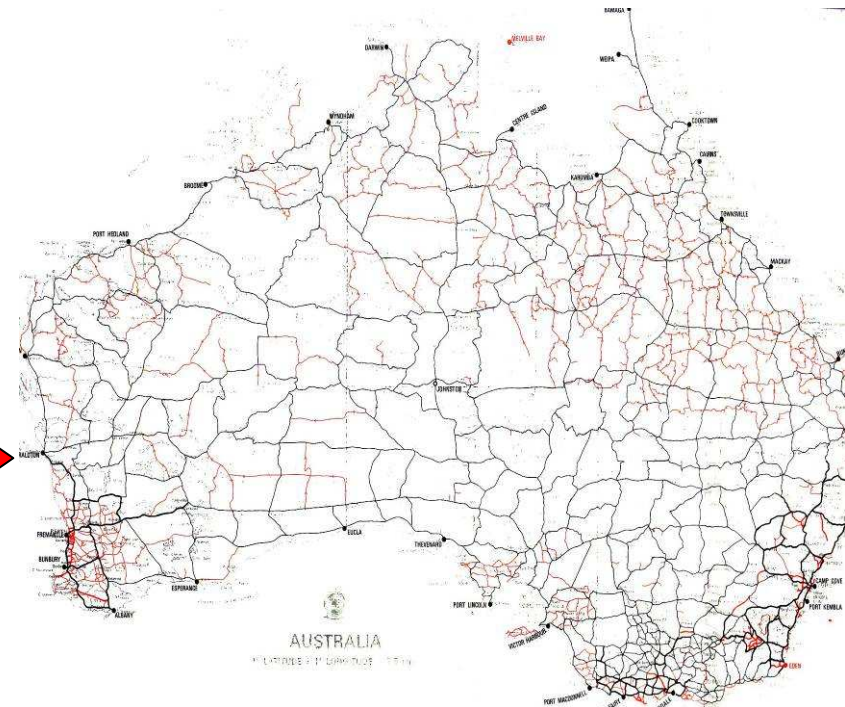
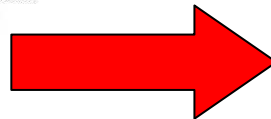
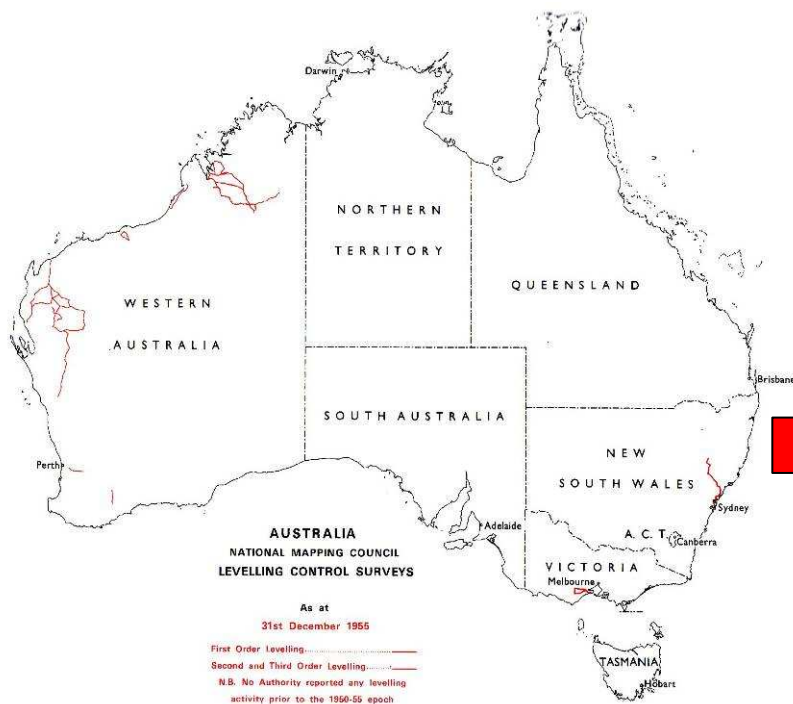


Australia's National Geodetic Infrastructure

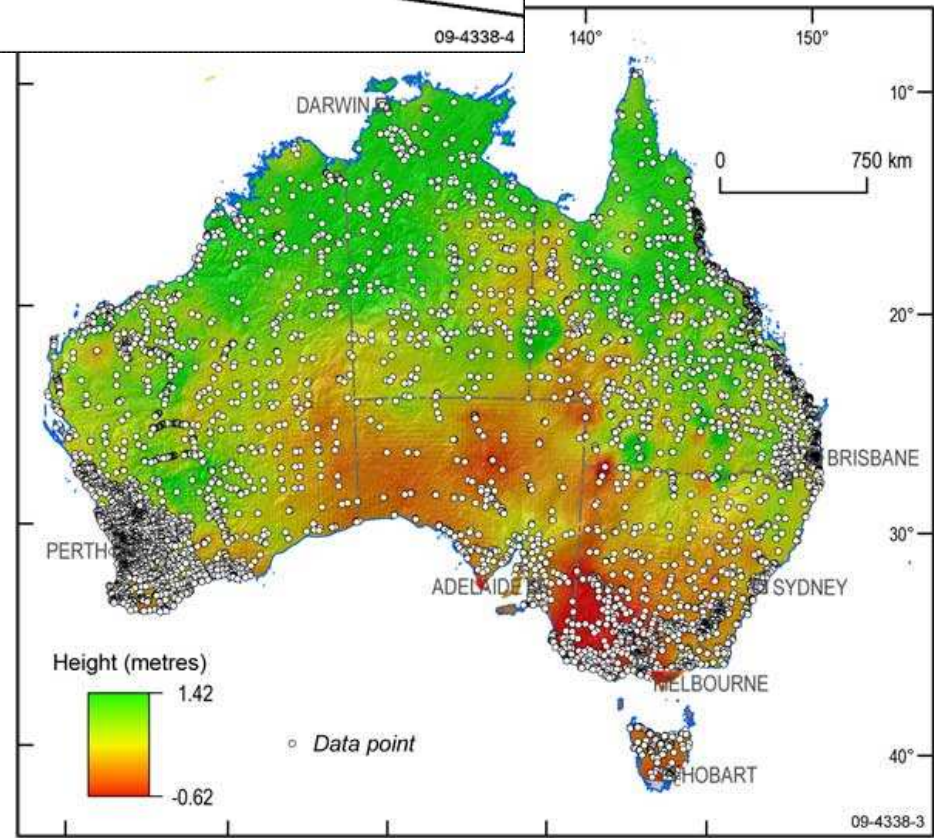
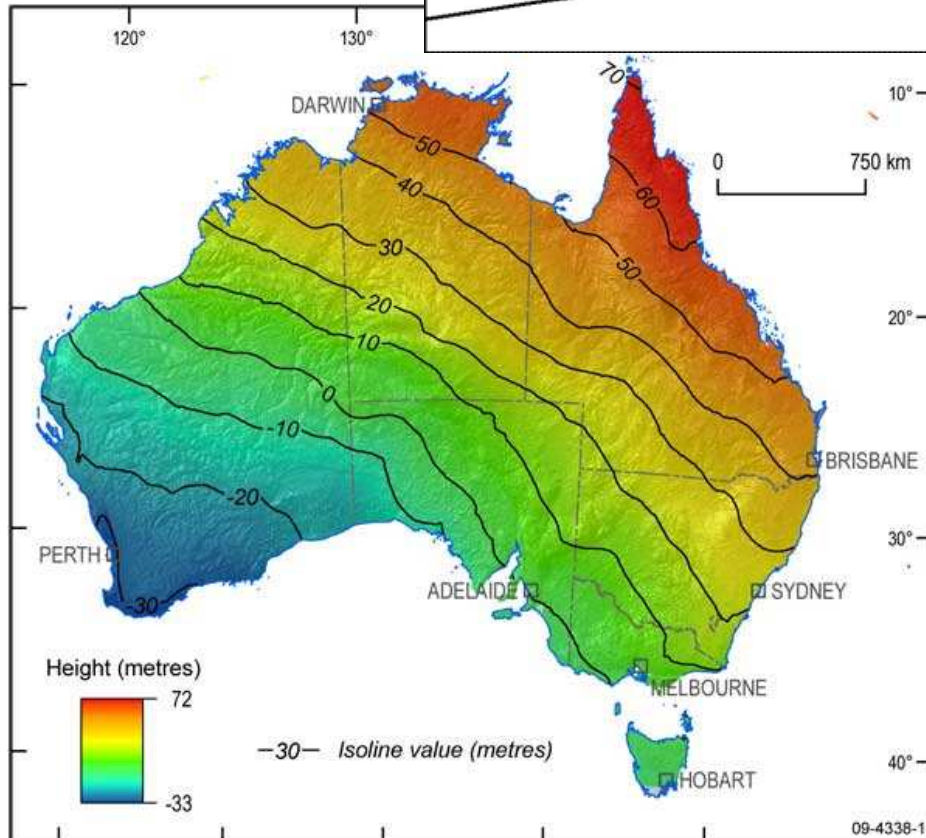
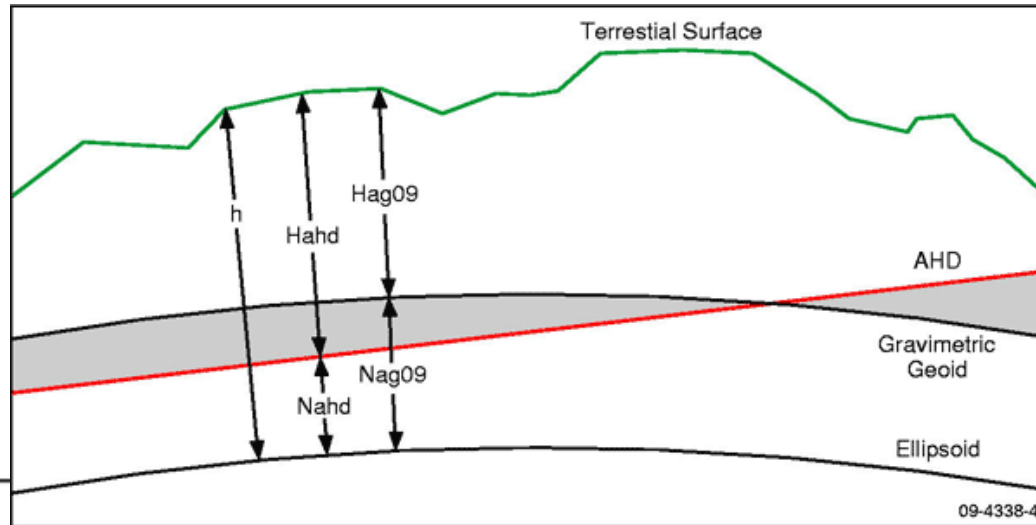


Australian Height Datum, 1971

- At 1970:
 - 160,000 km of level lines
 - ~ 100,000 Bench Marks
 - 32 tide gauges (MSL 1966-68)
 - Mostly 3rd order



The Australian National Geoid Model (AUSGeoid)



Australian Geodesy

Geoscience Australia: Geodesy - AUSGeoid09 Geoid-Ellipsoid Separation Interpolation - Windows Internet Explorer

http://www.ga.gov.au/geodesy/ausgeoid/nvalcomp.jsp

File Edit View Favorites Tools Help

Geoscience Australia: Geodesy - AUSGeoid09 Geoid-El...

Navigation Systems

- Basics
- Geodetic Techniques
- Global Navigation Satellite System Networks
- Geodetic Datums
 - About Datums
 - Geodetic Datum of Australia (GDA)
 - Geoid
 - Australian Height Datum
 - Historical Datums of Australia
 - Other Datums
- Astronomical Information
- Related Organisations
- Geomagnetism
- Geophysical Network
- Governance

Geoid

AUSGeoid09

AUSGeoid09 is a 1' by 1' (approximately 1.8 km) grid used to transfer heights between the ellipsoid (GDA94) and the Australian Height Datum (AHD). Unlike previous versions of AUSGeoid ('93/'98), AUSGeoid09 provides users with the height offset between the ellipsoid and AHD as opposed to the ellipsoid and the geoid.

Use the tools provided below to convert your data interactively (left tab) or submit a file to process multiple points at once (right tab).

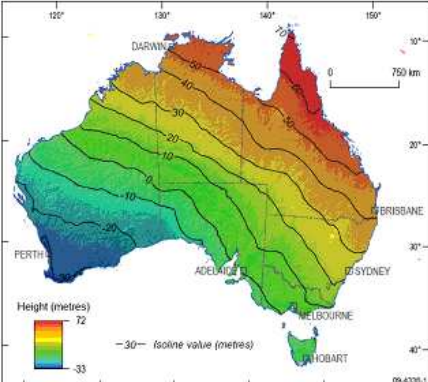
AUSGeoid09 Version Control

The version of AUSGeoid09 currently in use on this website is:

Version: AUSGeoid09 V1.01
Release Date: 11 April 2011

Note: The only difference between the current version and previous version (V1.00) is a slight improvement in the accuracy of the deviations of the vertical. There is no change to the N values (ellipsoid to AHD).

[Download](#) a full history of changes in AUSGeoid09 versions.



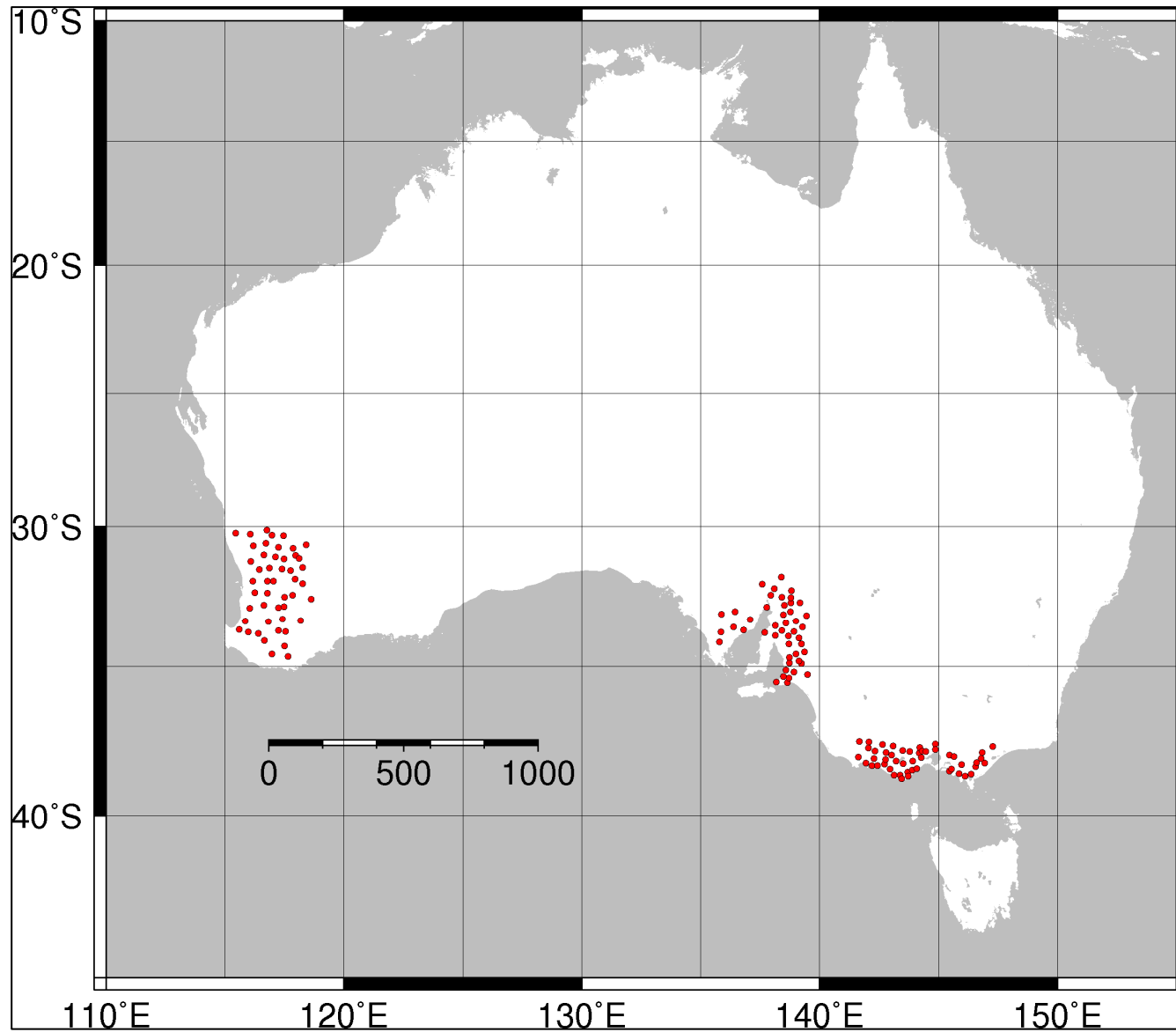
Compute a AUSGeoid09 value on line Batch Processing

Enter your data in the fields below in the format of decimal degrees.
AUSGeoid09 extents are lat [-8 and -46] lon [108 and 160].

GDA94 Latitude:	GDA94 Longitude:	GDA94 Ellipsoidal Height (m):
<input type="text"/>	<input type="text"/>	<input type="text"/>
e.g. -	e.g. 145.12345	e.g. 12.345

Internet 100%

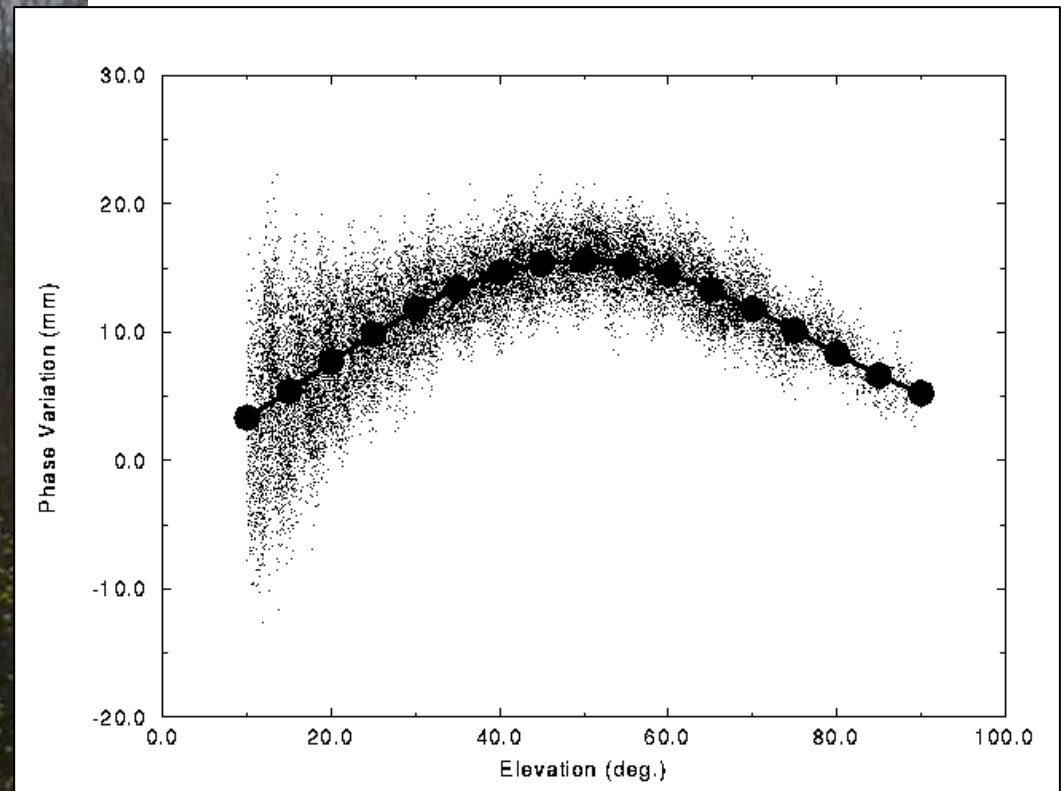
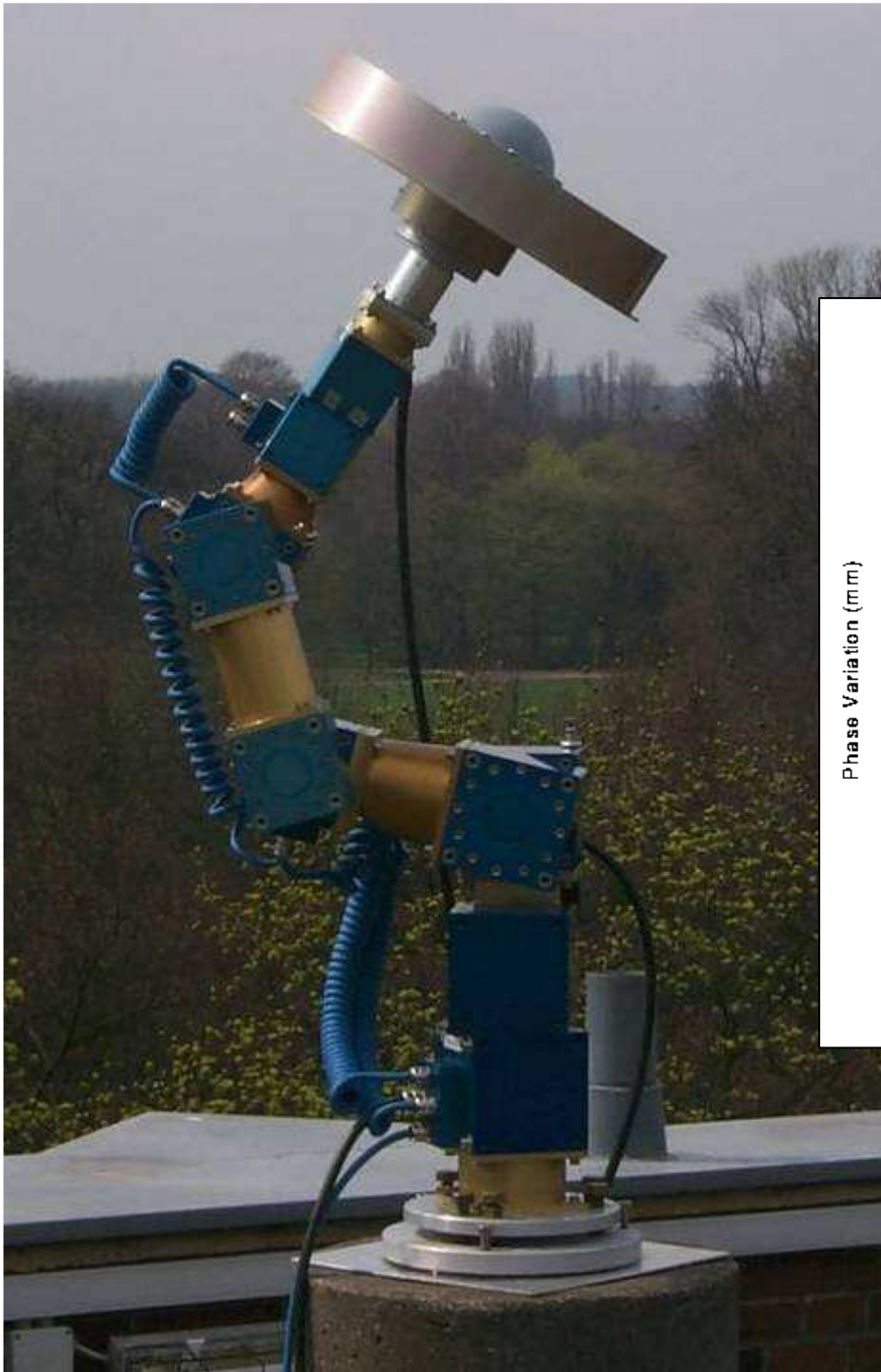
Additional episodic GNSS networks



A deployable GNSS instrumentation pool

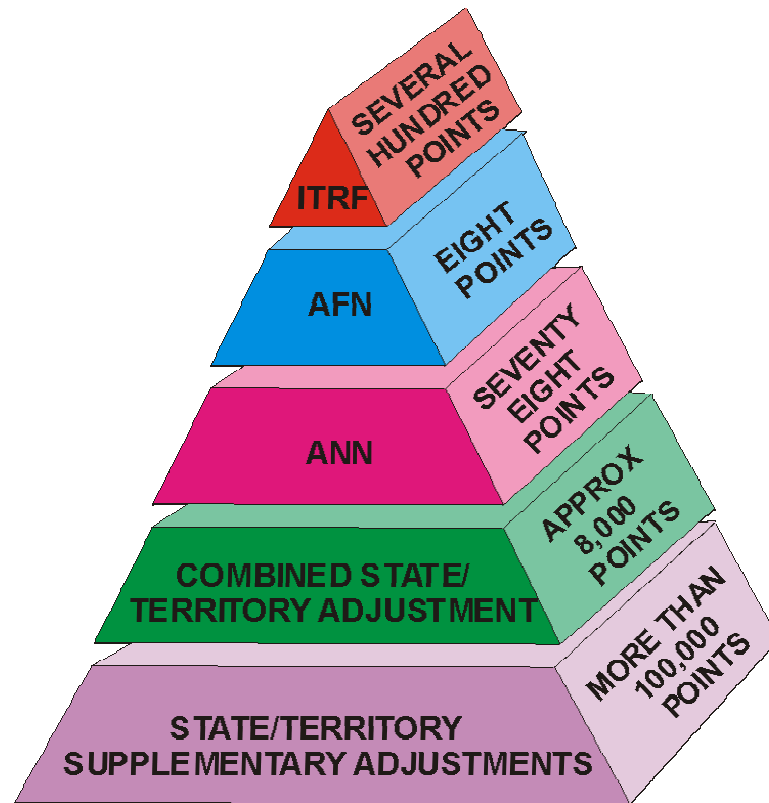


A Robotic antenna-calibration system



Promulgating reference frame in Australia

Traditional Approach
(via survey marks)



Increasingly Common Approach
(via CORS services, AUSPOS)



Accessing the Frame: AUSPOS

The screenshot shows a web browser window titled "Geoscience Australia: Geodesy - AUSPOS Version 2.00 - Windows Internet Explorer". The address bar shows the URL "http://www.ga.gov.au/bin/gps.pl". The page features a navigation menu on the left with categories like "Geodesy and Global Navigation Systems", "Basics", "Geodetic Techniques", etc. The main content area includes a form for submitting RINEX files, with fields for "Number of RINEX files" (set to 1), "File Name", "Height (m)" (0.0000), and "Antenna Type" (DEFAULT(NONE)). There are also radio buttons for "Submit RINEX using" (upload selected, ftp unselected) and a "Your Email Address" field. Below the form are "submit" and "start over" buttons. At the bottom, there is a link to the "Introduction Page" and a Creative Commons Attribution 3.0 Australia Licence logo.

Geoscience Australia: Geodesy - AUSPOS Version 2.00 - Windows Internet Explorer

http://www.ga.gov.au/bin/gps.pl

Australian Government
Geoscience Australia

AUSPOS Version 2.00

Home > Earth Monitoring and Reference Systems > Geodesy and Global Navigation Systems >

Geodesy and Global Navigation Systems

Basics

Geodetic Techniques

Global Navigation Satellite System Networks

Geodetic Datums

Astronomical Information

Related Organisations

Geomagnetism

Geophysical Network

Governance

Number of RINEX files: 1

Submit RINEX using: upload ftp

File Name: [] Browse...

Height (m): 0.0000

Antenna Type: DEFAULT(NONE)

Your Email Address: []

submit start over

Back to the AUSPOS Online GPS Processing Service [Introduction Page](#).

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CC BY

Done Internet 100%

Accessing the Frame: AUSPOS

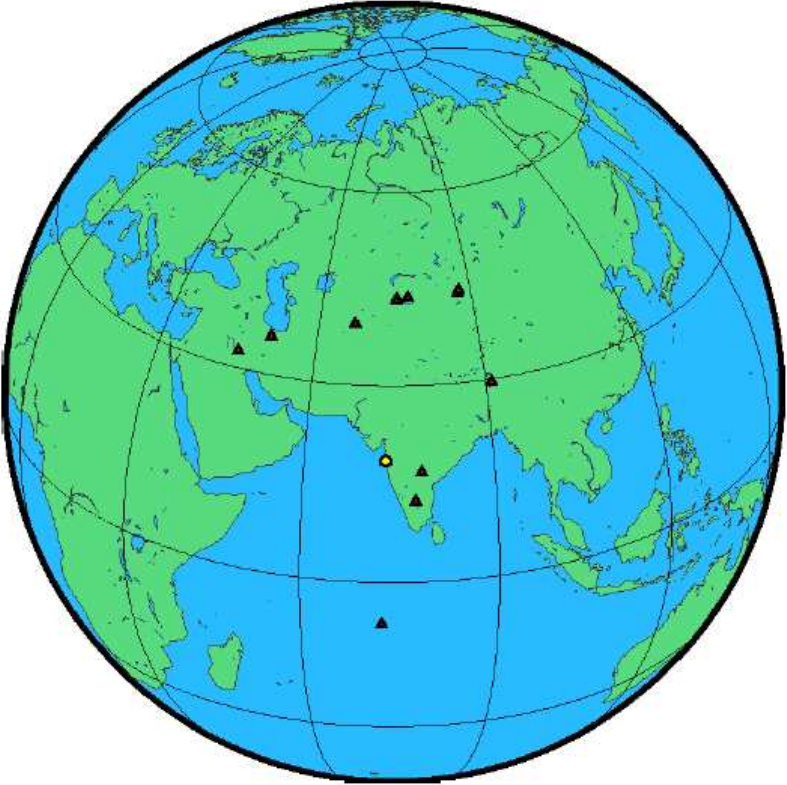
ftp://ftp.ga.gov.au/geodesy-outgoing/apps/auspos/9501/9501.pdf - Windows Internet Explorer

ftp://ftp.ga.gov.au/geodesy-outgoing/apps/auspos/9501/9501.pdf

File Edit Go To Favorites Help

ftp://ftp.ga.gov.au/geodesy-outgoing/apps/auspos/...

100%



Date	User Stations	Reference Stations	Orbit Type
2011/04/21 13:51:30	0493	BAN2 CHUM DGAR GUAO HYDE IISC ISKU KITS LHAZ POL2 SELE TEHN URUM	IGS final

Done

Unknown Zone

Accessing the Frame: AUSPOS

ftp://ftp.ga.gov.au/geodesy-outgoing/apps/auspos/9501/9501.pdf - Windows Internet Explorer

ftp://ftp.ga.gov.au/geodesy-outgoing/apps/auspos/9501/9501.pdf

File Edit Go To Favorites Help

ftp://ftp.ga.gov.au/geodesy-outgoing/apps/auspos/...

3 / 6 100% Find

3 Computed Coordinates, ITRF2008

All computed coordinates are based on the IGS realisation of the ITRF2008 reference frame. All the given ITRF2008 coordinates refer to a mean epoch of the site observation data. All coordinates refer to the Ground Mark.

3.1 Cartesian, ITRF2008

Station	X (m)	Y (m)	Z (m)	ITRF2008 @
0493	1769194.822	5762240.977	2077847.435	21/04/2011
BAN2	1344087.365	6068610.303	1429292.176	21/04/2011
CHUM	1228950.624	4508079.955	4327868.513	21/04/2011
DGAR	1916269.126	6029977.550	-801719.711	21/04/2011
GUA0	228378.807	4631946.913	4367028.508	21/04/2011
HYDE	1208444.313	5966805.997	1897077.073	21/04/2011
IISC	1337936.191	6070317.137	1427877.000	21/04/2011
ISKU	3753238.126	3860668.608	3407514.375	21/04/2011
KIT3	1944944.963	4556652.294	4004326.021	21/04/2011
LHAZ	-106941.745	5549269.839	3139215.090	21/04/2011
POL2	1239971.197	4530790.125	4302578.834	21/04/2011
SELE	1046790.430	4540257.108	4342920.797	21/04/2011
TEHN	3240499.140	4049740.404	3701663.174	21/04/2011
URUM	193030.429	4606851.308	4393311.495	21/04/2011

3.2 Geodetic, GRS80 Ellipsoid, ITRF2008

Geoid-ellipsoidal separations, in this section, are computed using a spherical harmonic synthesis of the global EGM2008 geoid. More information on the EGM2008 geoid can be found at <http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/>

Done Unknown Zone

GDA94 versus ITRF

- Total difference now exceeds 1 metre
 - Tectonic motion (1994 – 2012 @ 70 mm yr⁻¹)
 - ITRF1992 and later ITRFs (16 and 75 mm)
 - Residual intra-plate, regional and local deformation (
 - Horizontal ~1 mm yr⁻¹
 - Vertical ~5 mm yr⁻¹
- Many users work across the two reference frames
 - IGS and WGS84 satellite trajectories

My preferred transformation model

- 14 Parameter Similarity
 - Simple and well understood by users
 - Accurate and effective in Australia i.e. near rigid plate
 - Consistent with ITRF computations

$$\begin{pmatrix} X_{GDA94} \\ Y_{GDA94} \\ Z_{GDA94} \end{pmatrix} = \mathbf{T} \begin{pmatrix} X_{ITRF} \\ Y_{ITRF} \\ Z_{ITRF} \end{pmatrix} = \begin{pmatrix} t_x + \dot{t}_x(t - t_0) \\ t_y + \dot{t}_y(t - t_0) \\ t_z + \dot{t}_z(t - t_0) \end{pmatrix} + (1 + s_c + \dot{s}_c(t - t_0))$$
$$\begin{pmatrix} 1 & r_z + \dot{r}_z(t - t_0) & -r_y - \dot{r}_y(t - t_0) \\ -r_z - \dot{r}_z(t - t_0) & 1 & r_x + \dot{r}_x(t - t_0) \\ r_y + \dot{r}_y(t - t_0) & -r_x - \dot{r}_x(t - t_0) & 1 \end{pmatrix} \begin{pmatrix} X_{ITRF} \\ Y_{ITRF} \\ Z_{ITRF} \end{pmatrix}$$

- Older parameters
 - Dawson and Steed
 - ITRF96, ITRF97, ITRF2000
- Current parameters
 - Dawson and Woods, 2010, Journal of Applied Geodesy
 - ITRF96, ITRF97, ITRF2000, ITRF2005 and ITRF2008

Complications – vertical deformation

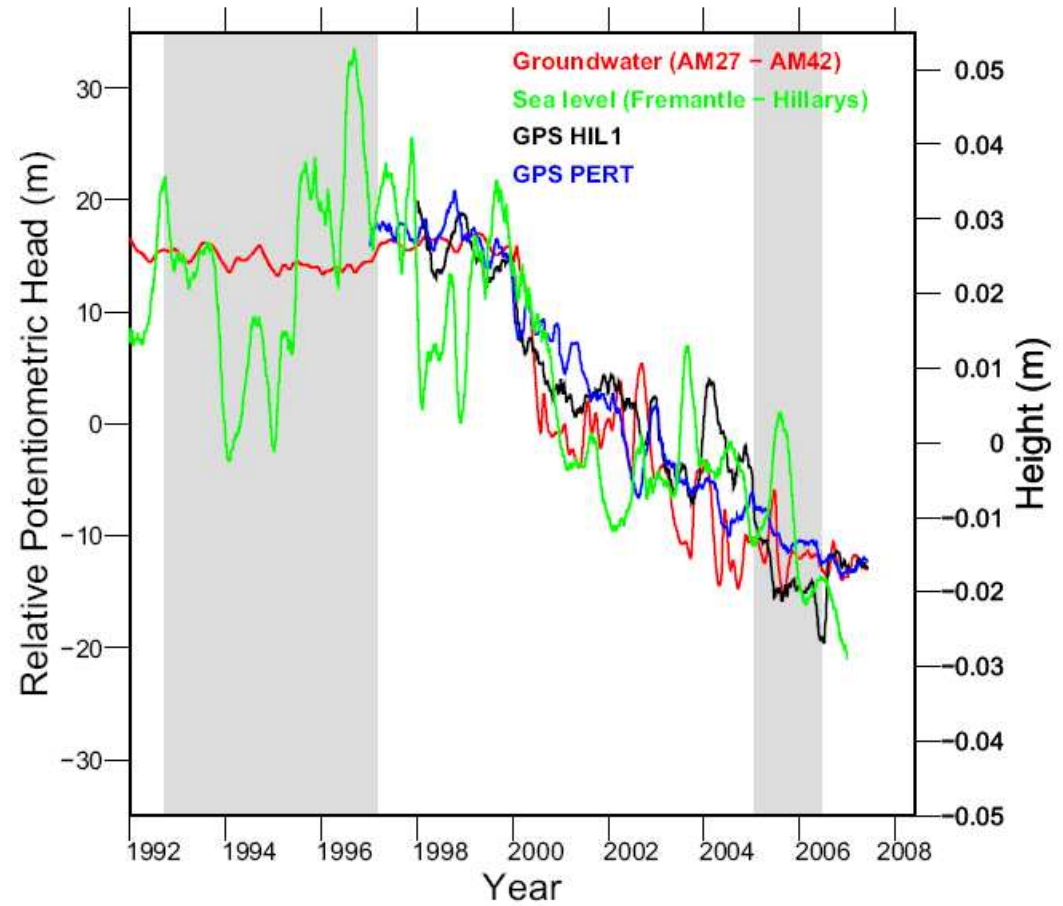
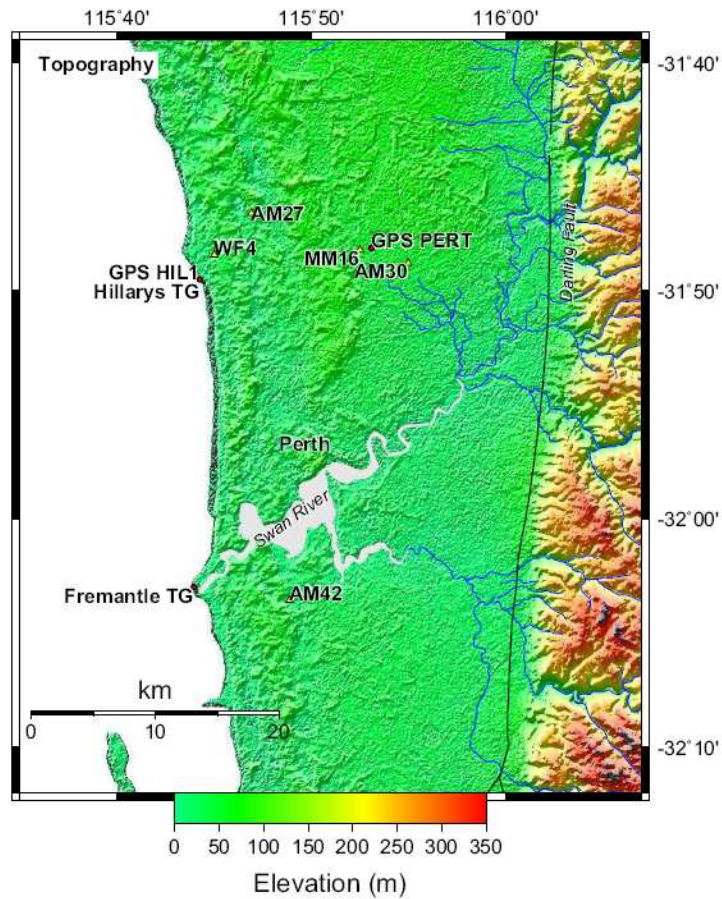
Table 4: The RMS of the weekly station coordinates (126×7 -day solutions), with respect to the combined solution, after transformation to GDA94 and the mean residual with respect to their gazetted positions.

Station	ITRF-to-GDA94 Transformed			Mean Residual		
	Coordinate RMS			Transformed - Gazetted		
	North (mm)	East (mm)	Up (mm)	North (mm)	East (mm)	Up (mm)
Alice Springs	1.5	1.0	4.3	0.0	8.9	-13.1
Ceduna	1.5	1.3	3.3	-0.5	10.8	18.2
Darwin	1.8	1.6	6.6	1.5	-14.7	4.8
Hobart	1.9	1.4	3.5	-16.5	8.1	11.4
Karratha	1.9	1.4	3.6	8.4	8.1	-22.9
Perth	2.5	3.5	6.9	11.9	26.8	-68.4
Tidbinbilla	1.7	1.3	3.3	4.0	5.6	-6.7
Townsville	1.6	1.6	3.9	-8.0	-3.9	-10.2
Yarragadee	1.7	1.5	5.4	-0.9	-33.9	67.9
<i>All sites</i>	1.8	1.8	4.7	8.4	17.5	36.4

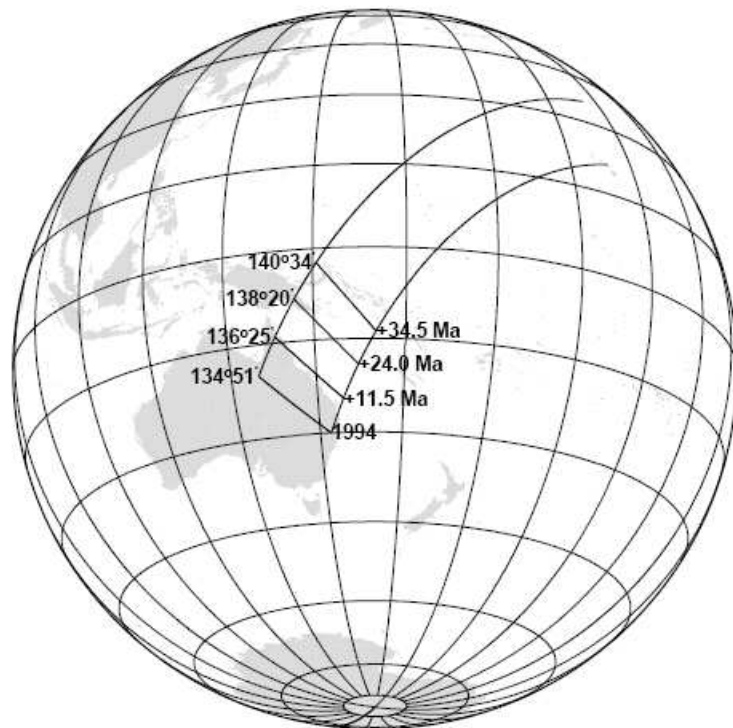
Complications – vertical deformation

Station	Vertical Velocity (mm yr ⁻¹)	Deformation 1994 to 2010 (mm)
Alice Springs	-0.4 ± 0.3	-6 ± 4.8
Ceduna	-2.0 ± 0.3	-32 ± 4.8
Darwin	-1.0 ± 0.4	-16 ± 6.4
Hobart	0.6 ± 0.2	10 ± 3.2
Karratha	0.8 ± 0.3	13 ± 4.8
Perth	-6.0 ± 0.3	-96 ± 4.8
Tidbinbilla	-0.2 ± 0.2	-3 ± 3.2
Townsville	1.2 ± 0.3	19 ± 4.8
Yarragadee	1.0 ± 0.1	16 ± 1.6

Example: Perth Groundwater – GPS – Sea Level



Impact of using ITRF orbits and GDA94 coordinates @ 2010

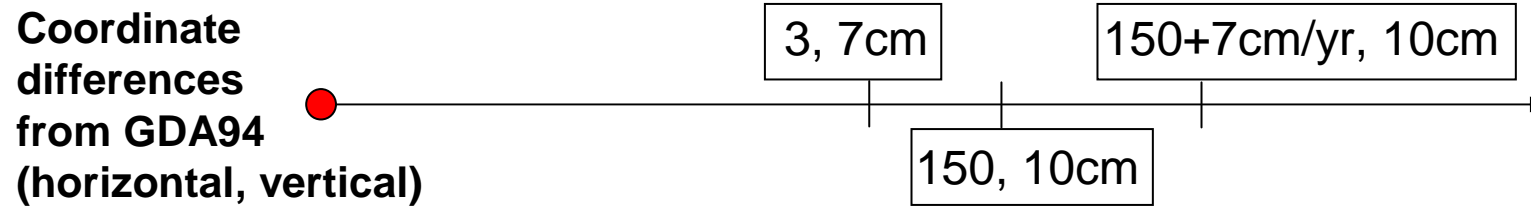
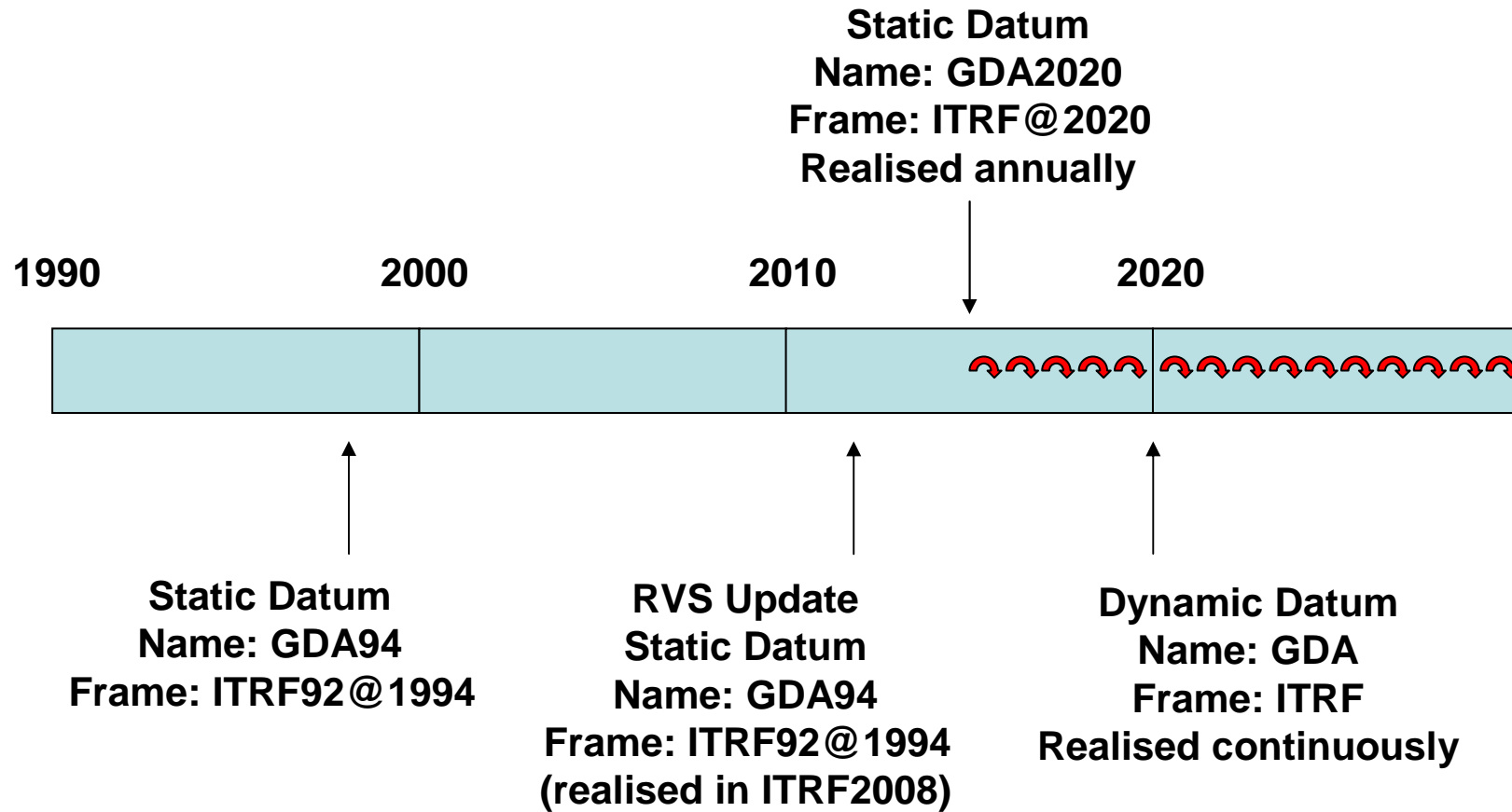


Baseline Length (km)	Maximum Horizontal Difference (mm)	Maximum Vertical Difference (mm)
20	2	4
70	6	12
150	14	26
300	28	53
500	75	88
1000	100	175

Reference Frame Directions in Australia

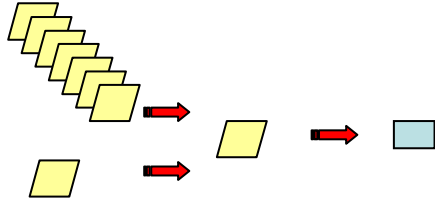
- We have updated the recognised-value standard for position using ITRF2008
 - Including 21 ARGN and AuScope stations
- Address limitations of 'official' positional uncertainty
- Broad-scale deformation modelling
 - Start in the capital cities and exploit CORS, GNSS observations and time-series radar
- Improved GNSS antenna modelling capability
 - Antenna calibration facility located at Geoscience Australia, Canberra

National Geodetic Datum - Roadmap

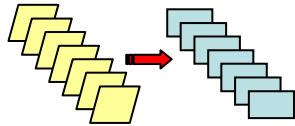


National Geodetic Datum - Framework

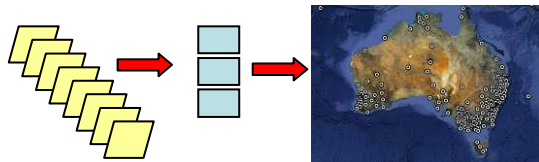
National GNSS Campaign Solution



Jurisdictional Adjustments



National GNSS CORS Solution



Geodetic Model of Australia



IAG/FIG Commission 5/ICG Technical Seminar

Reference Frame in Practice

Rome, Italy 4–5 May 2012



- Thank you!
- Questions?
- Further Information: John.Dawson@ga.gov.au

Sponsors:



esri



Trimble

