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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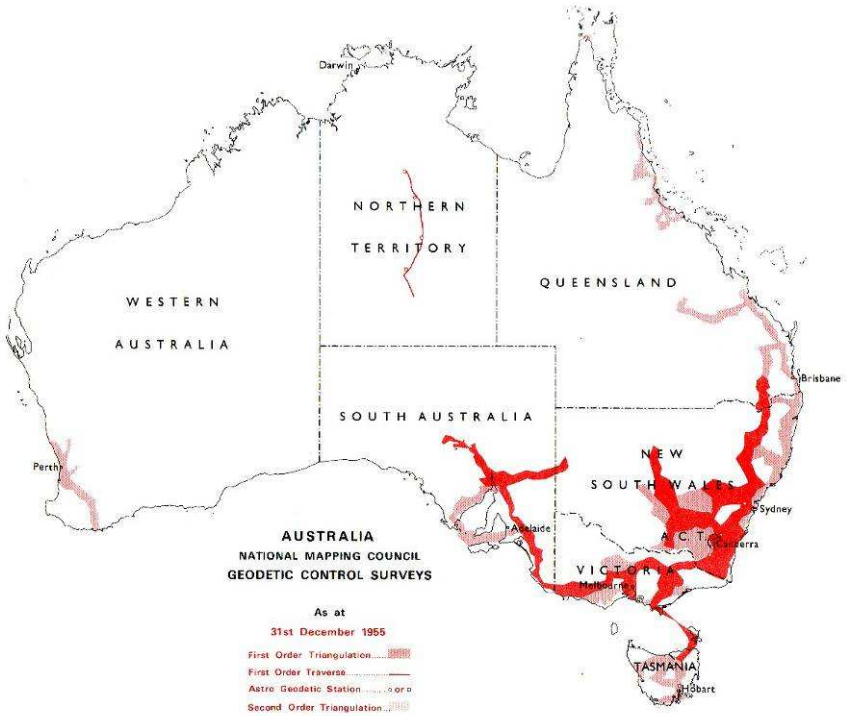
Presentation Overview

- 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

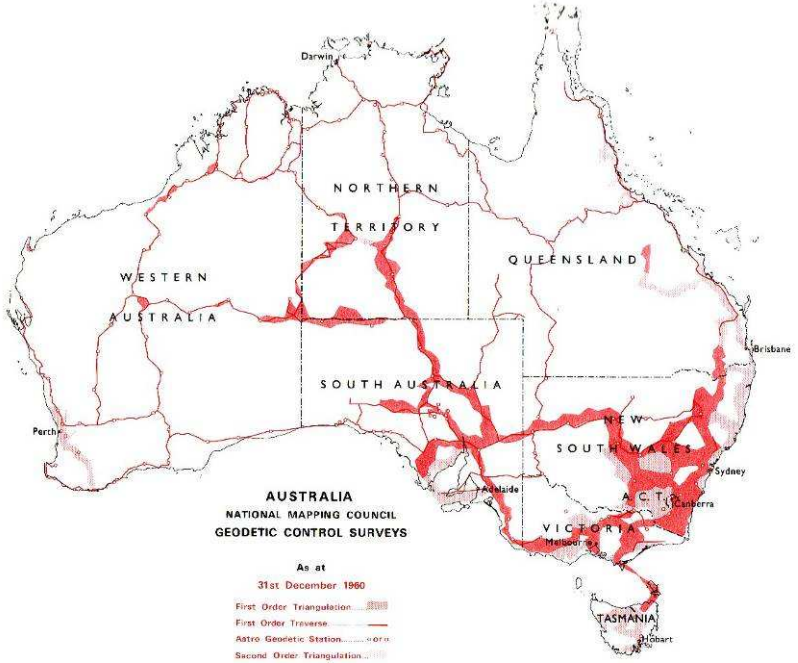


Australia's Reference Frame: Triangulation - labour Intensive

Australia's Reference Frame: Triangulation - challenges

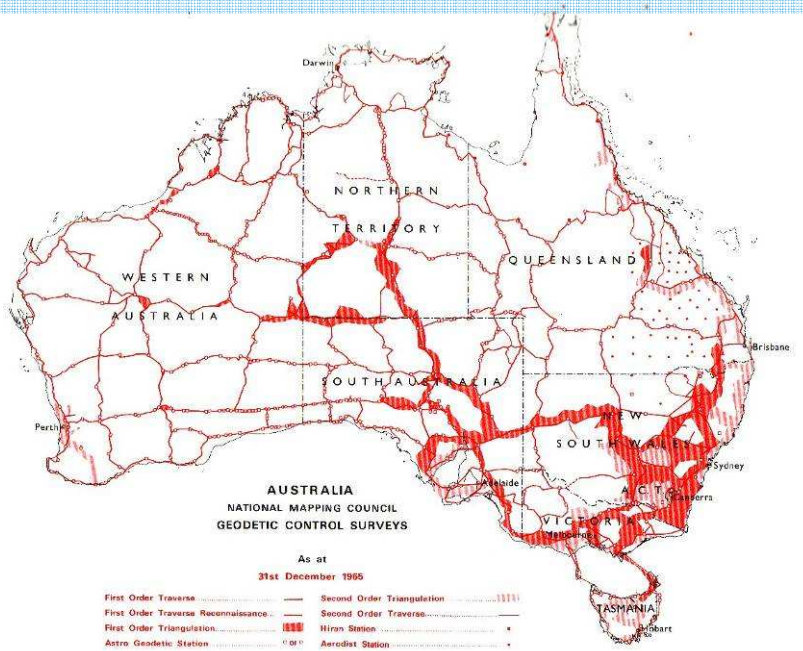
Geodimeter

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



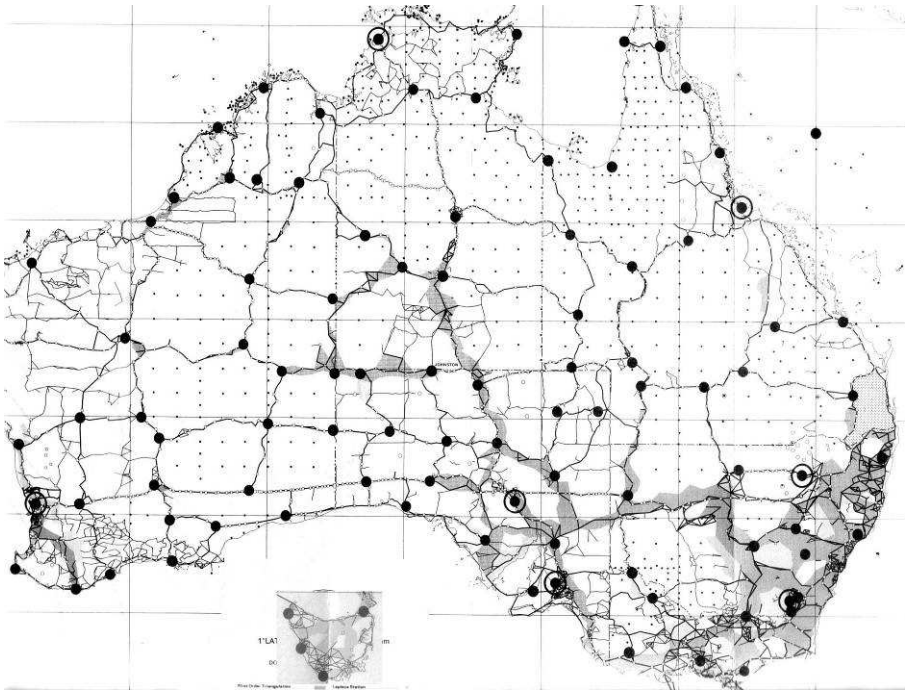
Tellurometer

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



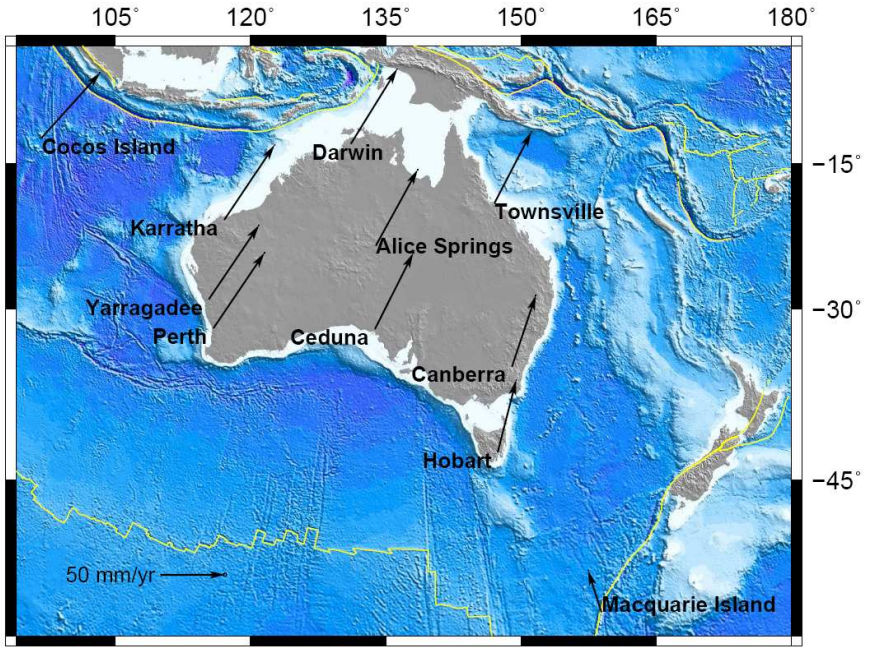
Australian DOPPLER Survey, 1975 to 1977

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



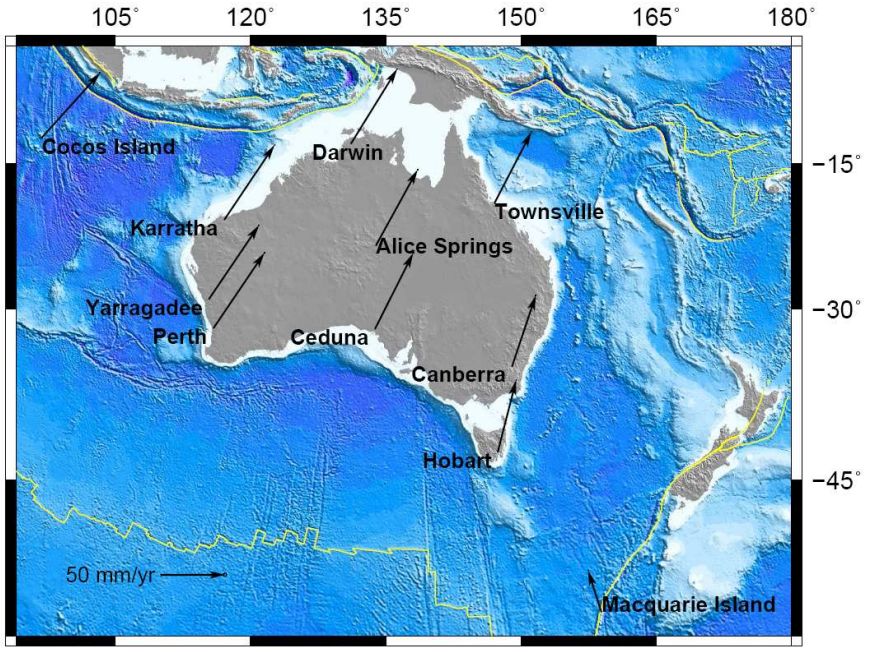
Australian Regional GPS Network (ARGN)

- 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

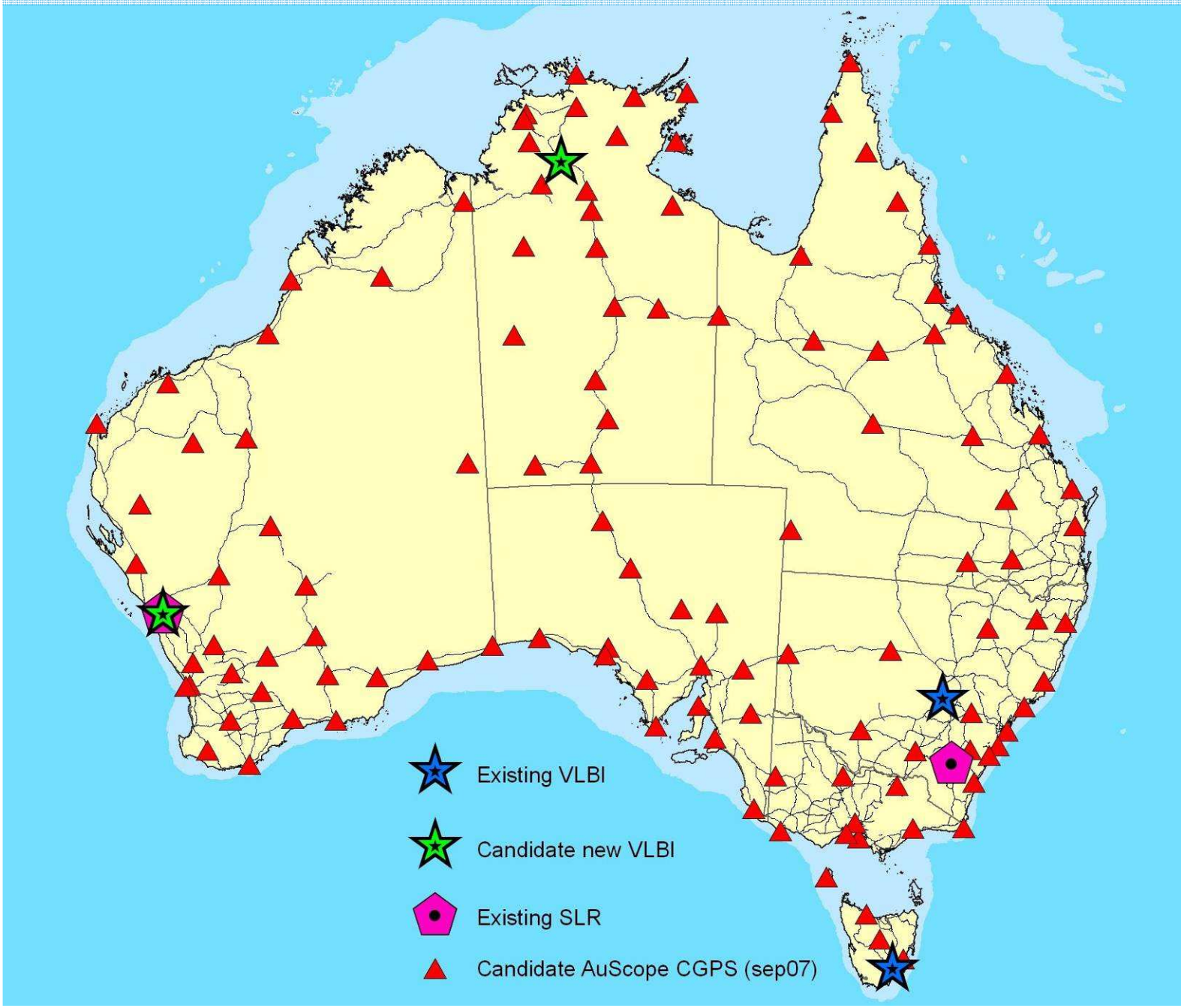


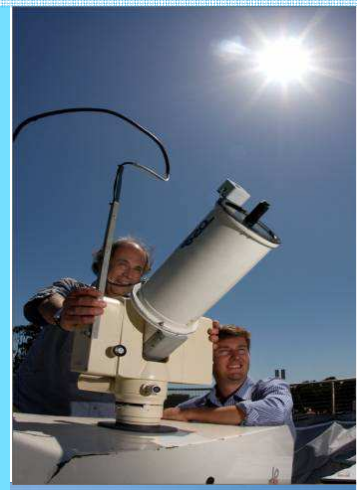
Geocentric Datum of Australia 1994 (GDA94)

- 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.)



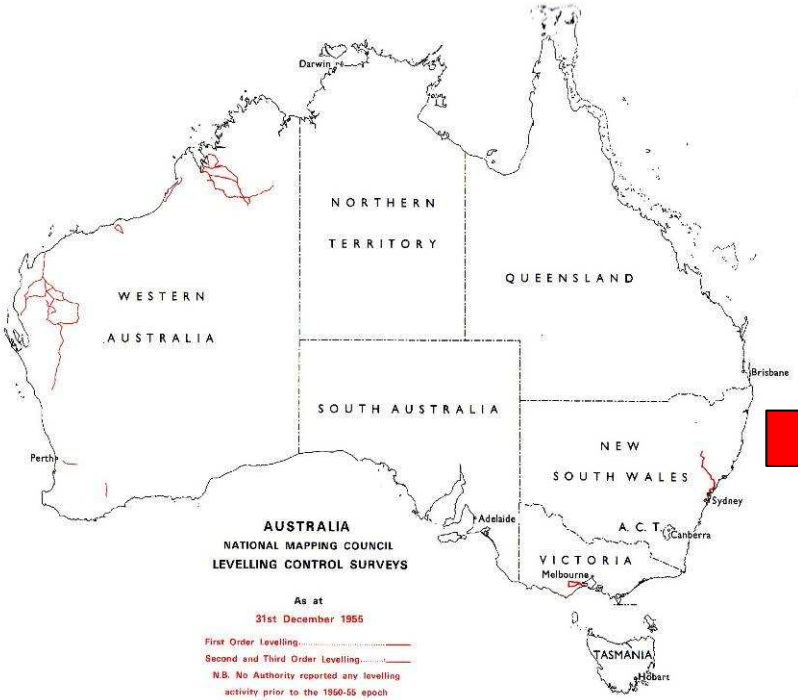
Australia's National Geodetic Infrastructure

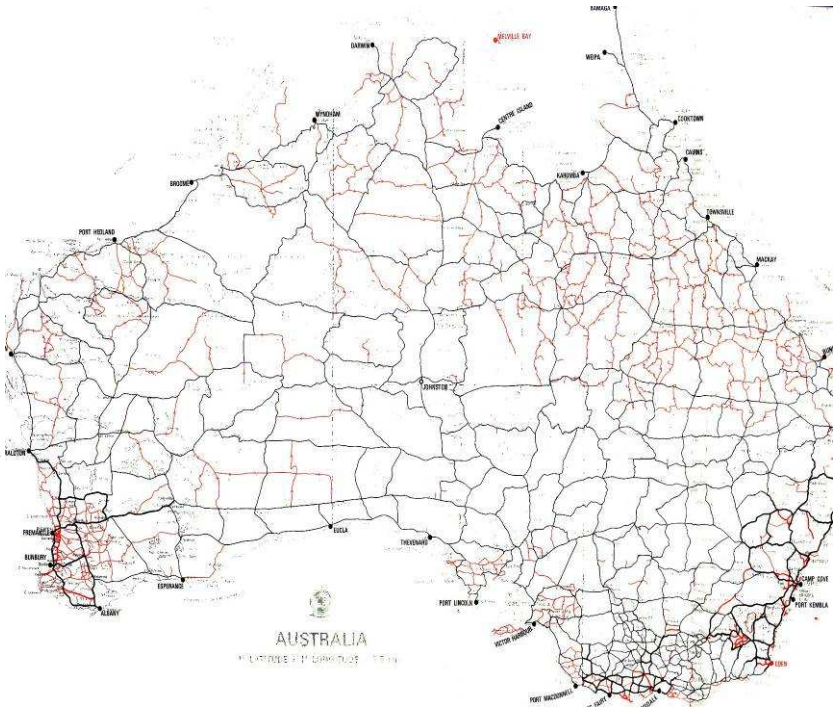




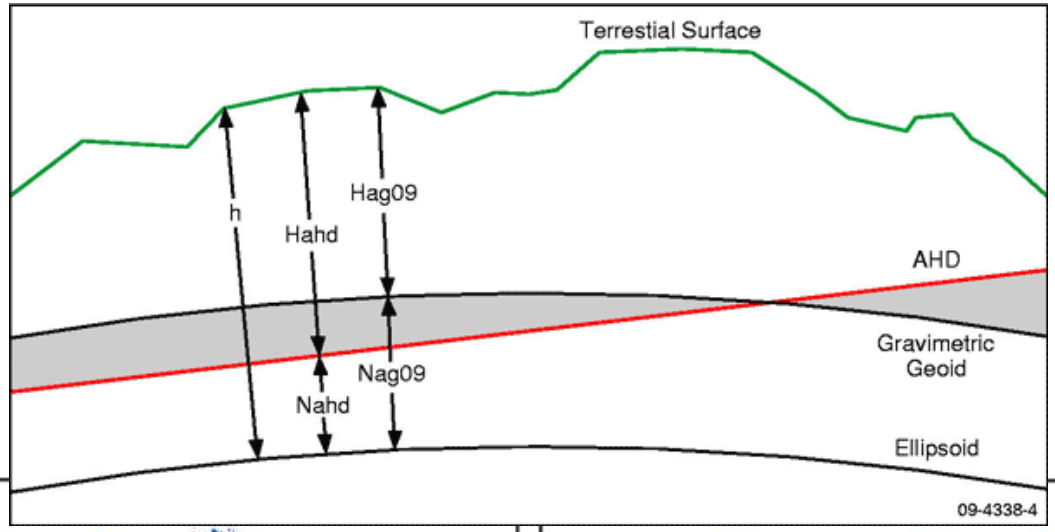
Australian Height Datum, 1971

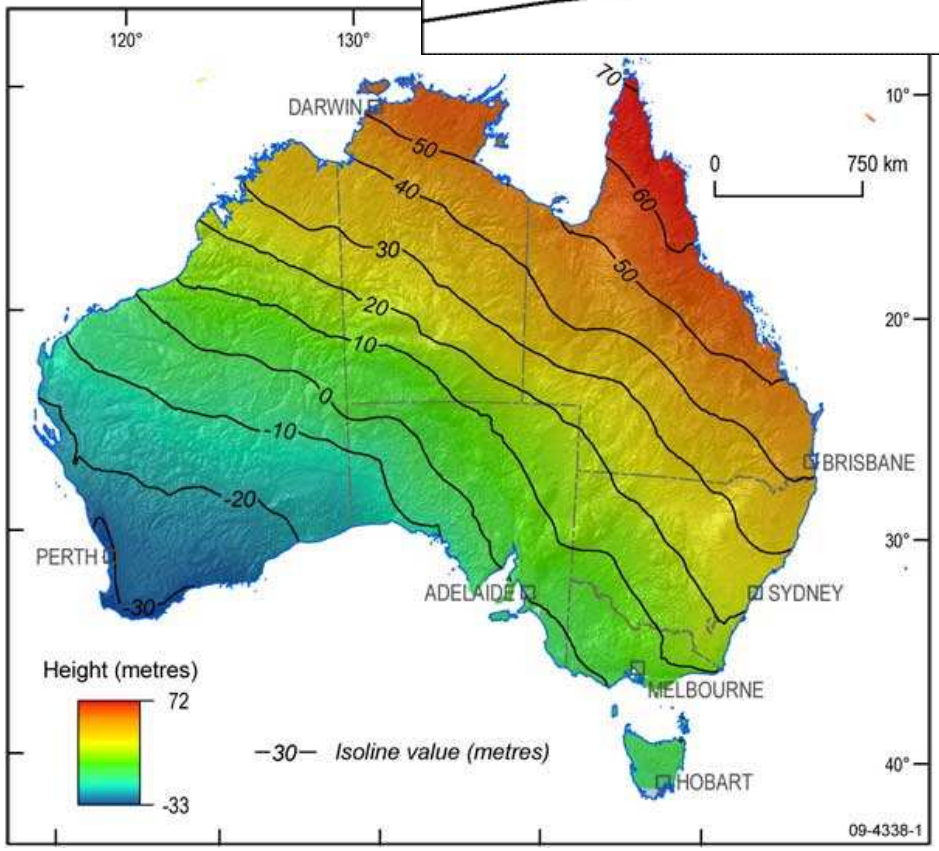
- At 1970:
  - 160,000 km of level lines
  - ~ 100,000 Bench Marks
  - 32 tide gauges (MSL 1966-68)
  - Mostly 3rd order

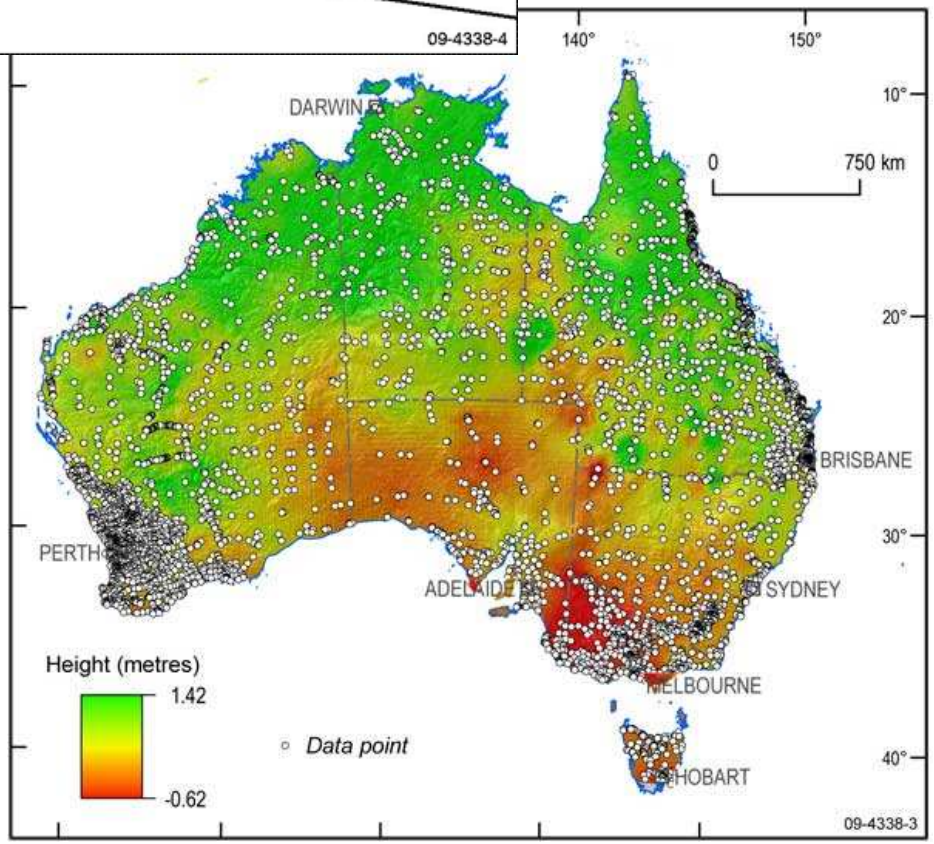




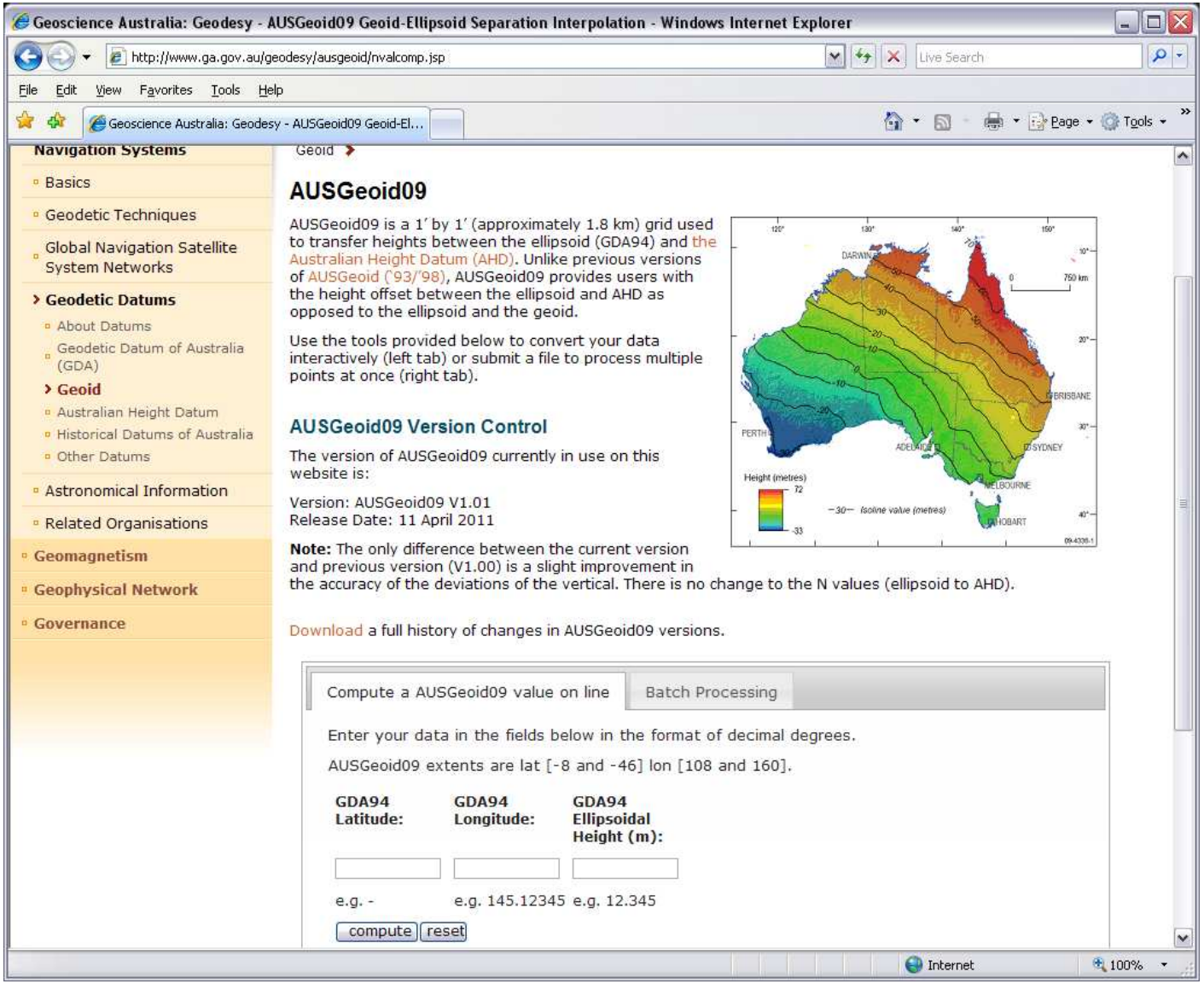
The Australian National Geoid Model (AUSGeoid)



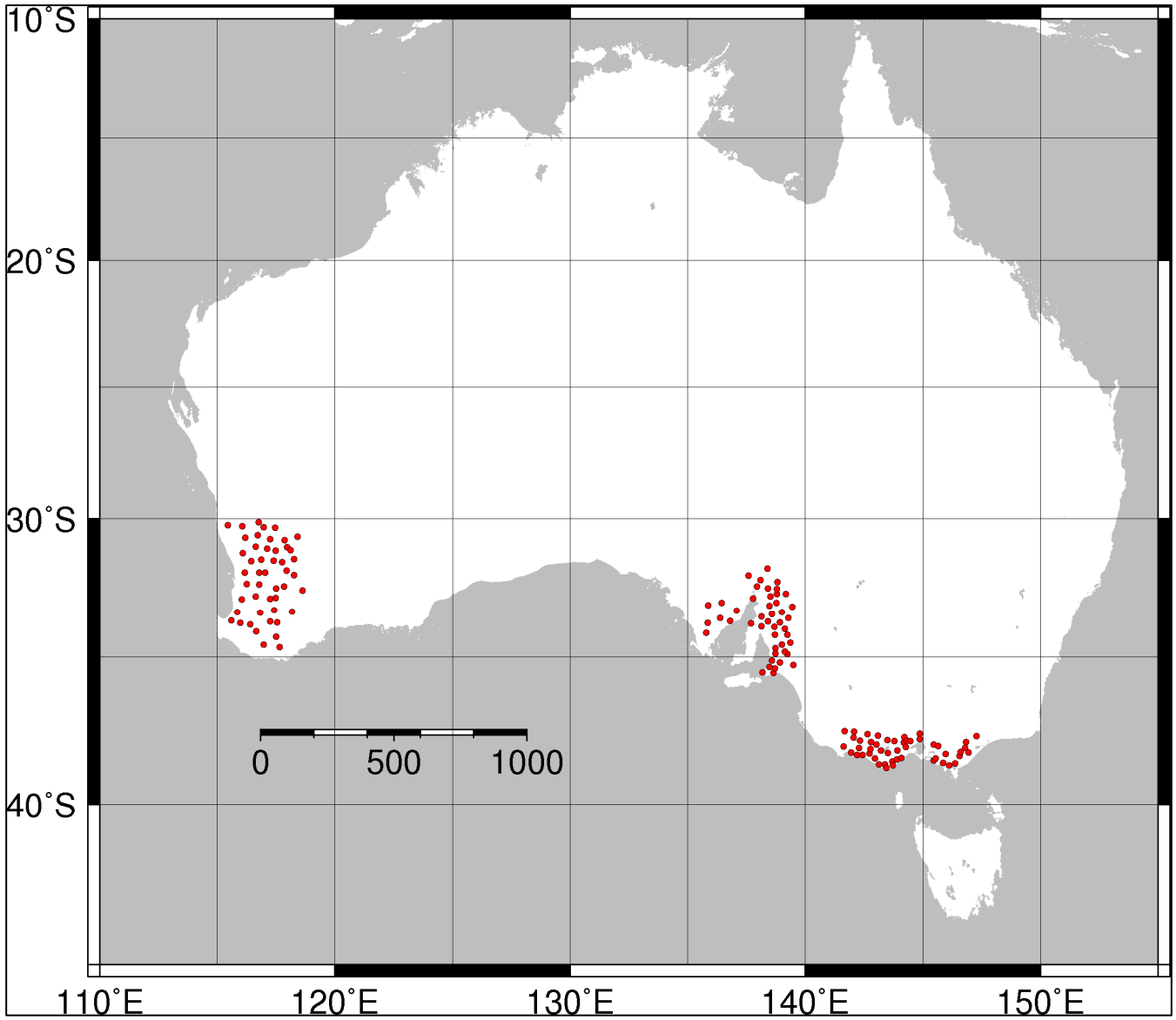




Australian Geodesy

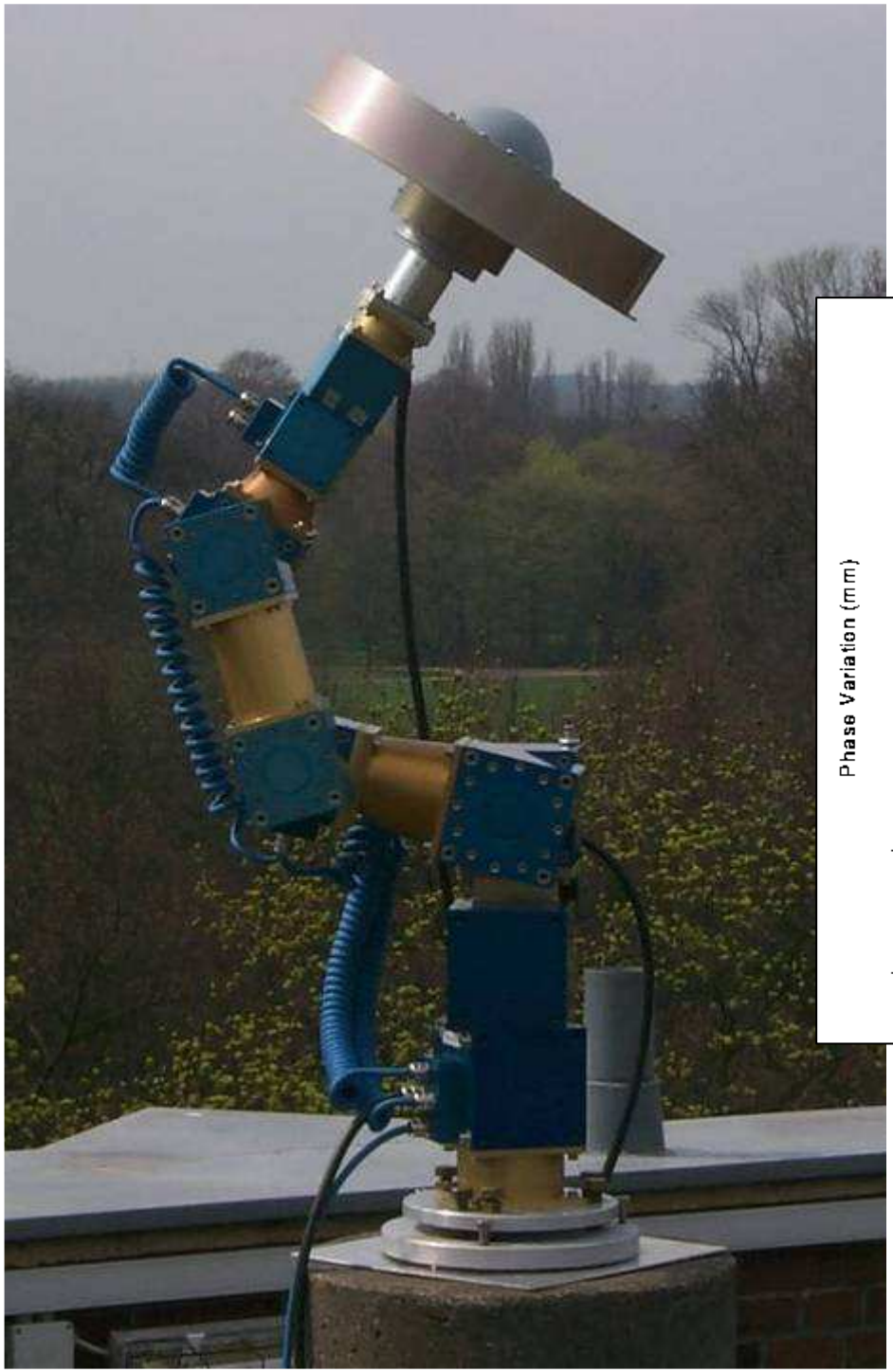


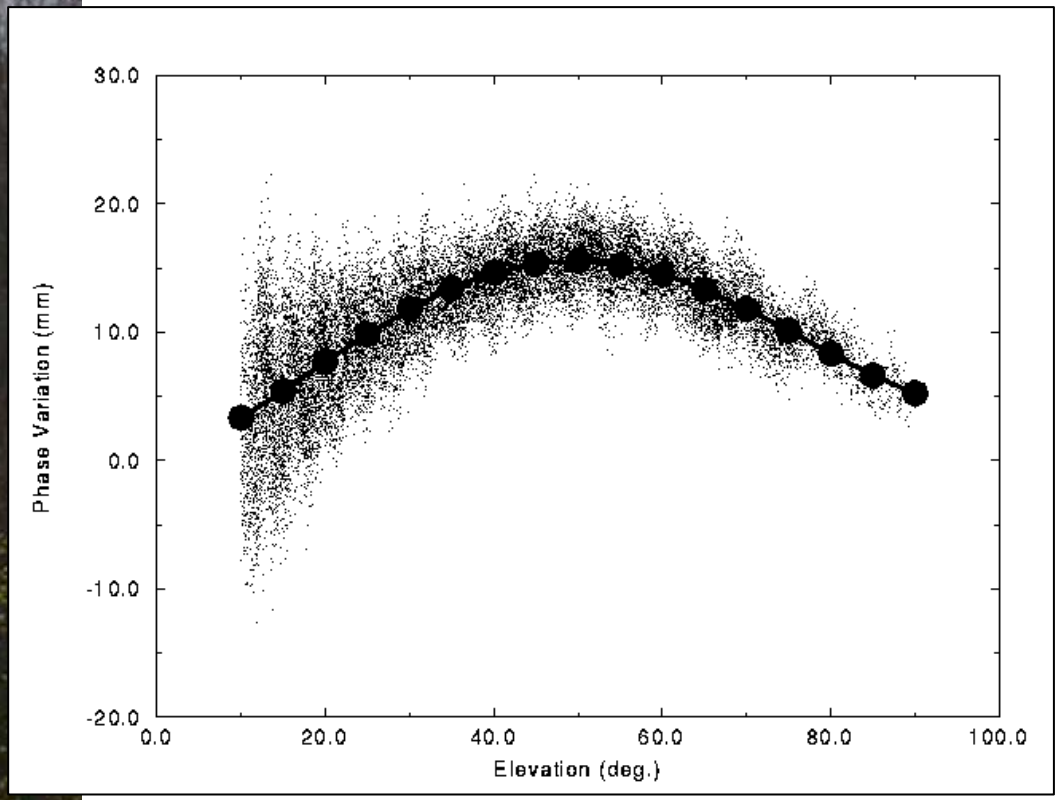
Additional episodic GNSS networks



A deployable GNSS instrumentation pool

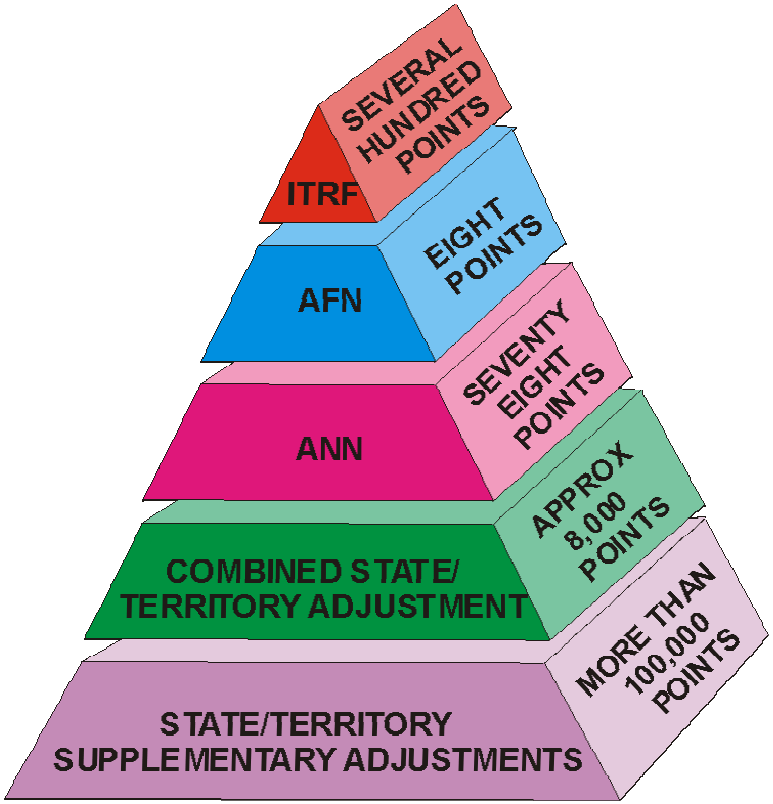
A Robotic antenna-calibration system





Promulgating reference frame in Australia

Traditional Approach
(via survey marks)



Increasingly Common Approach
(via CORS services, AUSPOS)

Accessing the Frame: AUSPOS

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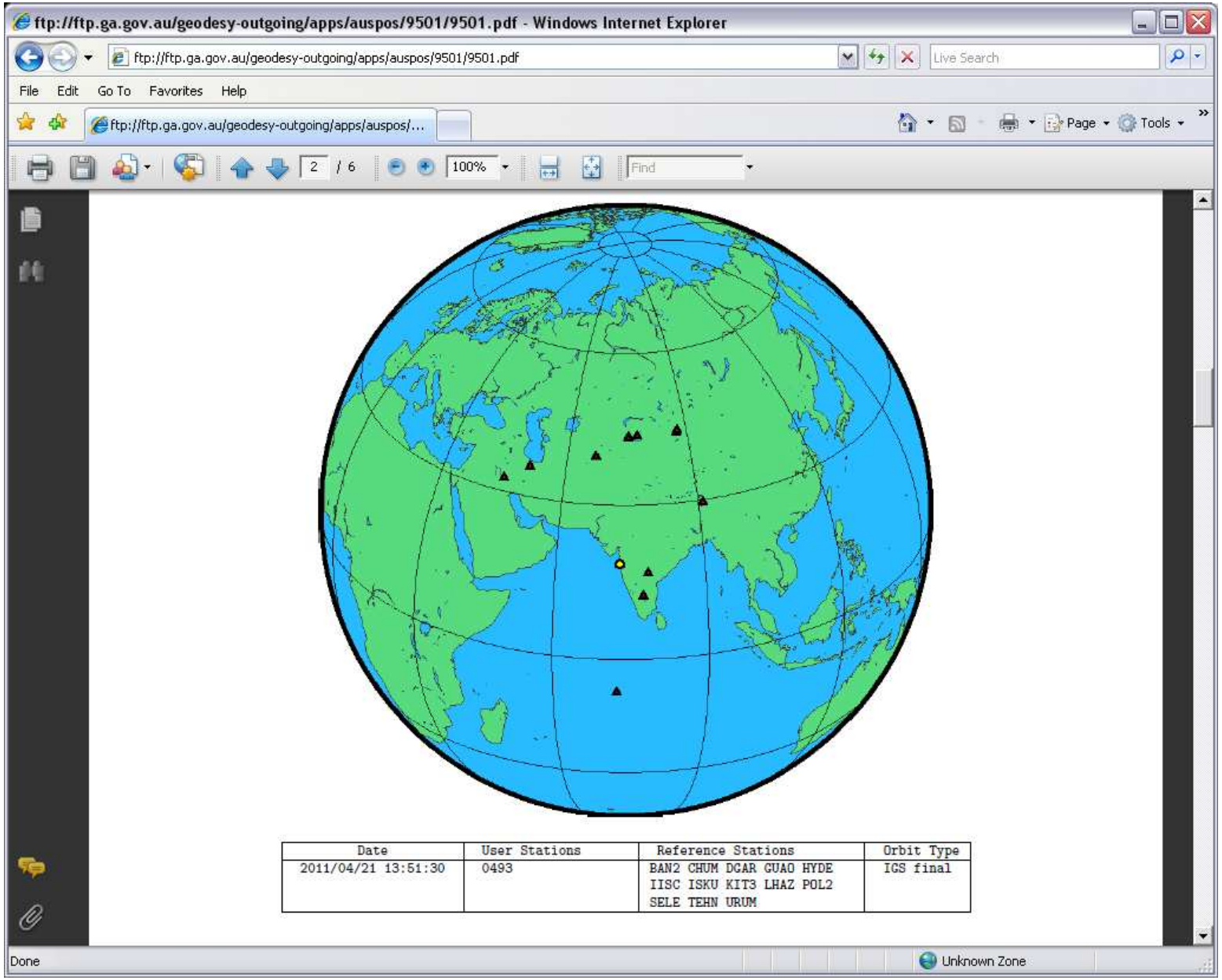
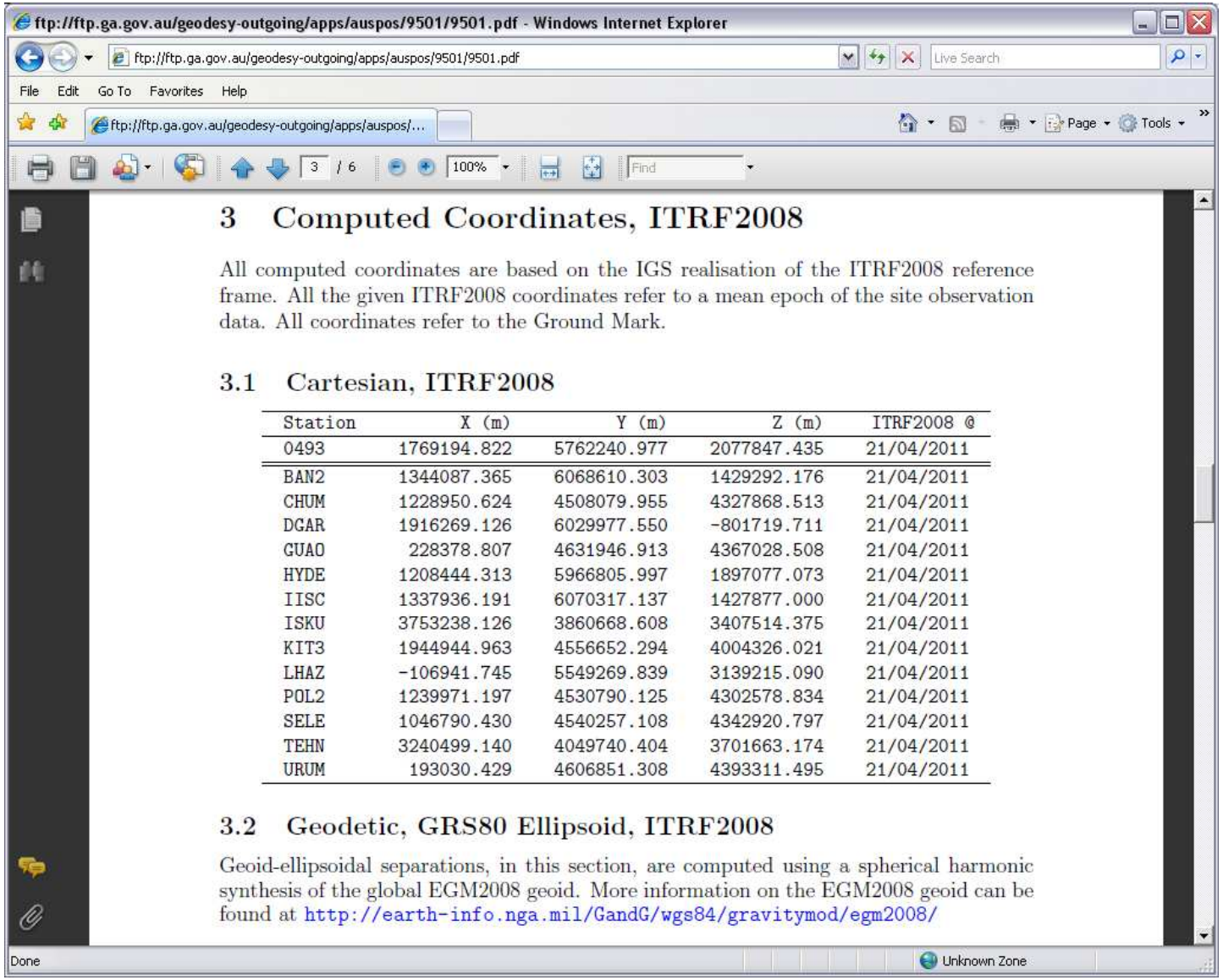


Accessing the Frame: AUSPOS



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
GUAO	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/

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

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

$$\begin{pmatrix} 1 & r_z + \dot{r}_z(t-t_0) & -r_y - \dot{r}_y(t-t_0) \\ -r_z - \dot{r}_z(t-t_0) & 1 & r_x + \dot{r}_x(t-t_0) \\ r_y + \dot{r}_y(t-t_0) & -r_x - \dot{r}_x(t-t_0) & 1 \end{pmatrix} \begin{pmatrix} X_{ITRF} \\ Y_{ITRF} \\ Z_{ITRF} \end{pmatrix}$$

- 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

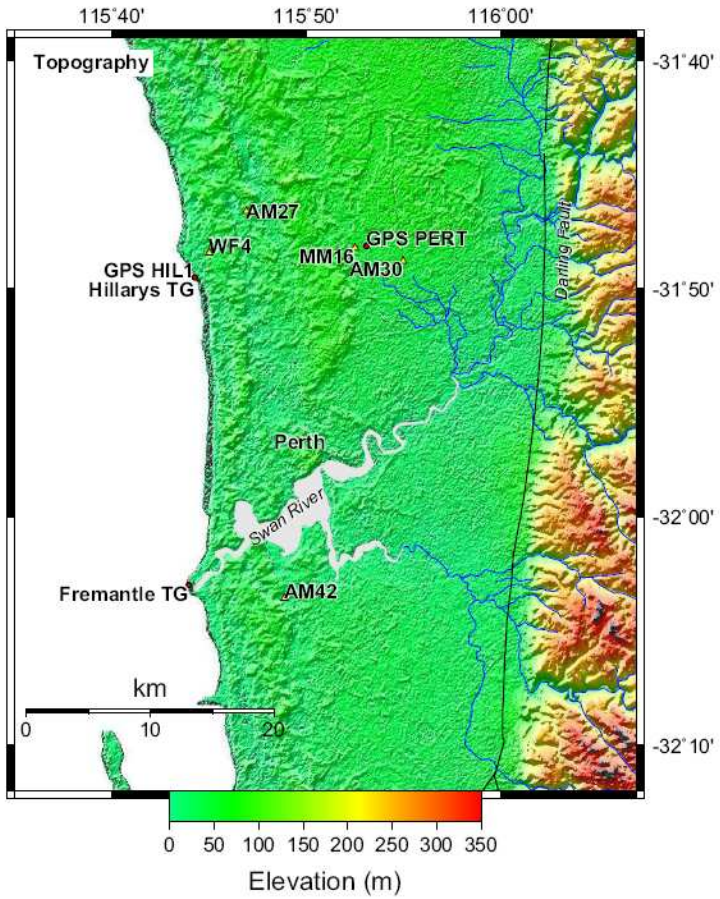
Table 4: The RMS of the weekly station coordinates (126 × 7-day solutions), with respect to the combined solution, after transformation to GDA94 and the mean residual with respect to their gazetted positions.

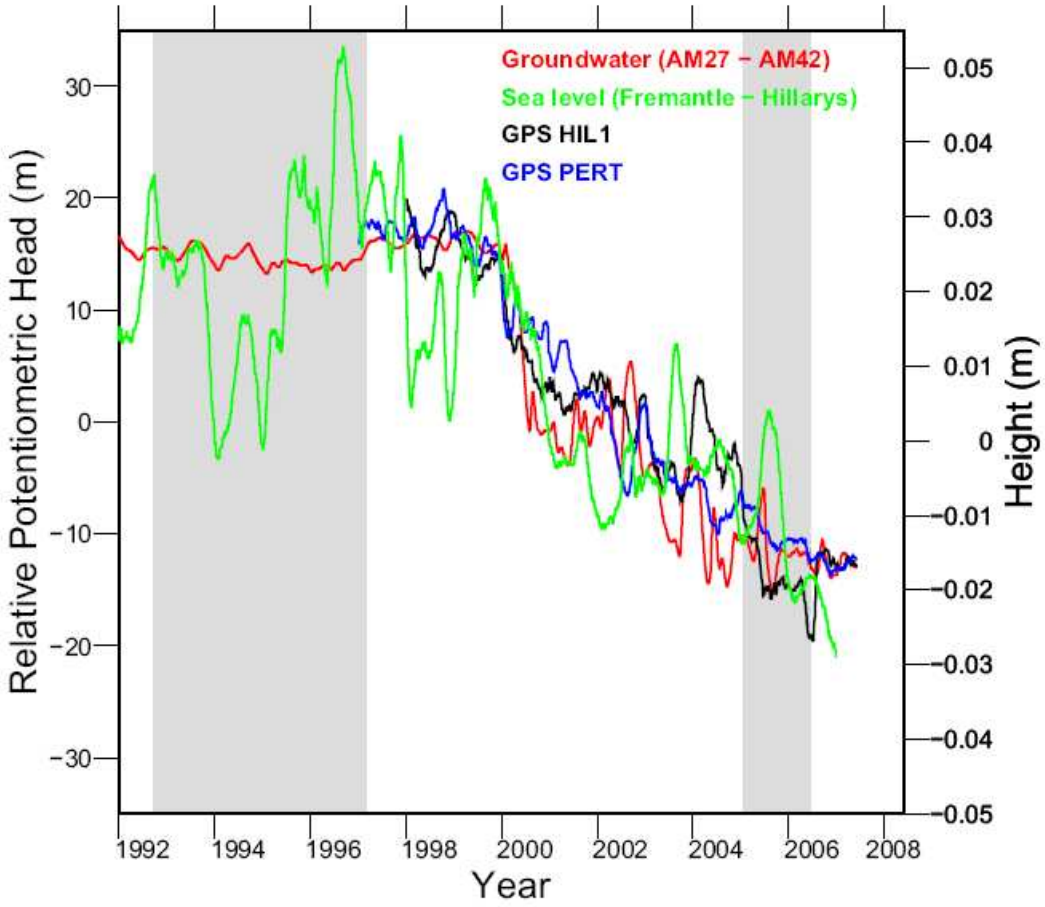
	ITRF-to-GDA94 Transformed Coordinate RMS			Mean Residual Transformed - Gazetted		
Station	North (mm)	East (mm)	Up (mm)	North (mm)	East (mm)	Up (mm)
Alice Springs	1.5	1.0	4.3	0.0	8.9	-13.1
Ceduna	1.5	1.3	3.3	-0.5	10.8	18.2
Darwin	1.8	1.6	6.6	1.5	-14.7	4.8
Hobart	1.9	1.4	3.5	-16.5	8.1	11.4
Karratha	1.9	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
					RMS	
All sites	1.8	1.8	4.7	8.4	17.5	36.4

Complications – vertical deformation

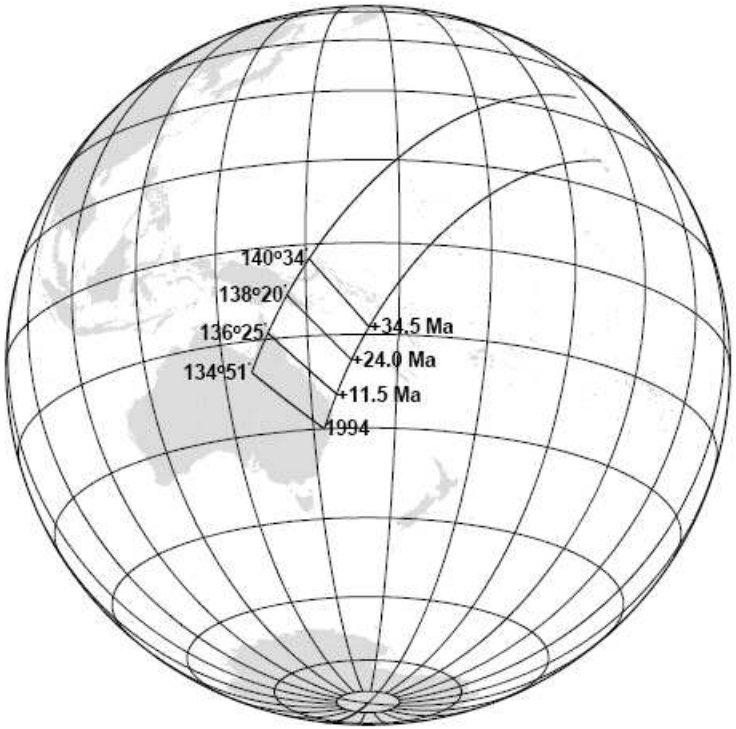
Station	Vertical Velocity (mm yr^{-1})	Deformation 1994 to 2010 (mm)
Alice Springs	-0.4 ± 0.3	-6 ± 4.8
Ceduna	-2.0 ± 0.3	-32 ± 4.8
Darwin	-1.0 ± 0.4	-16 ± 6.4
Hobart	0.6 ± 0.2	10 ± 3.2
Karratha	0.8 ± 0.3	13 ± 4.8
Perth	-6.0 ± 0.3	-96 ± 4.8
Tidbinbilla	-0.2 ± 0.2	-3 ± 3.2
Townsville	1.2 ± 0.3	19 ± 4.8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

Example: Perth Groundwater – GPS – Sea Level





Impact of using ITRF orbits and GDA94 coordinates @ 2010

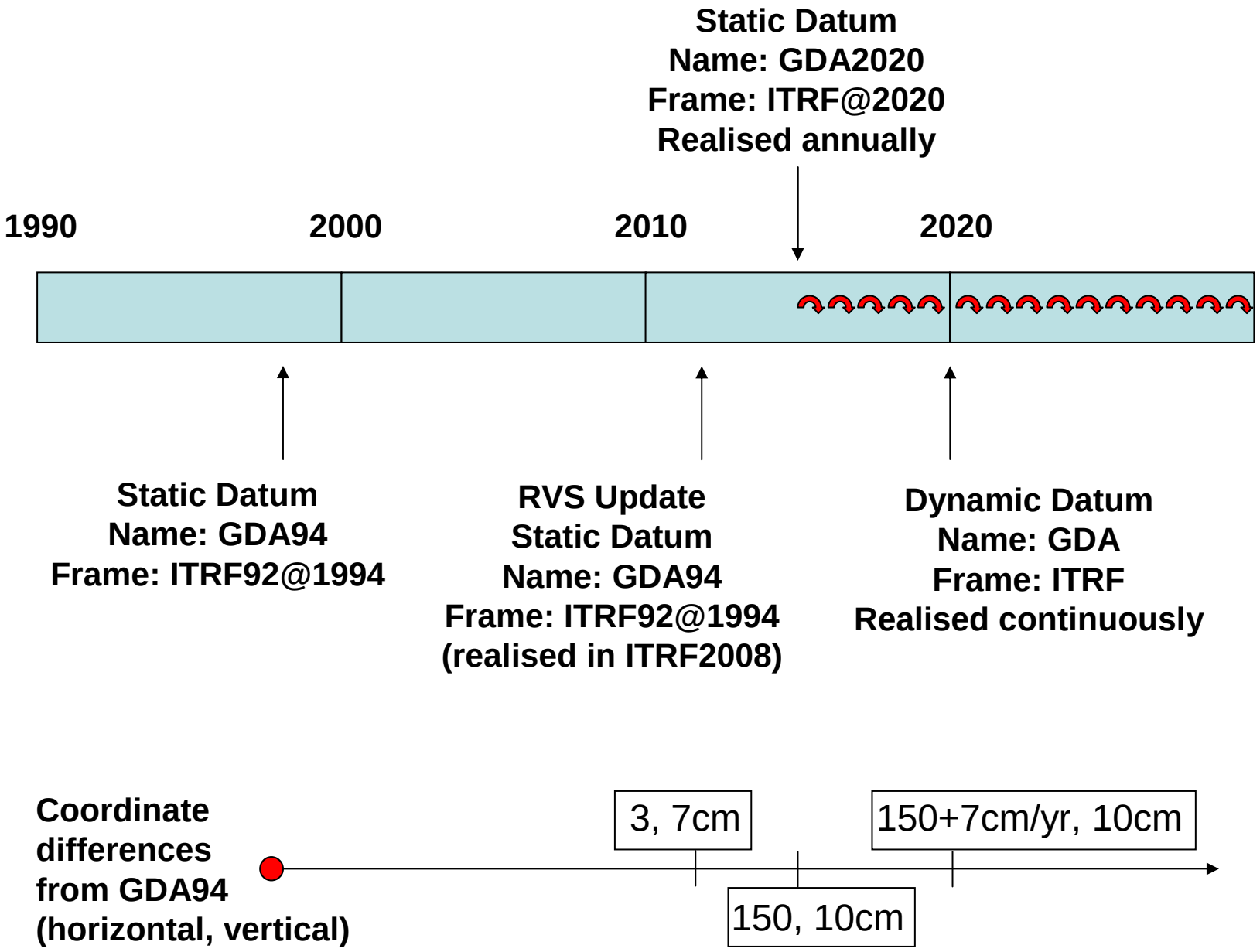


Baseline Length (km)	Maximum Horizontal Difference (mm)	Maximum Vertical Difference (mm)
20	2	4
70	6	12
150	14	26
300	28	53
500	75	88
1000	100	175

Reference Frame Directions in Australia

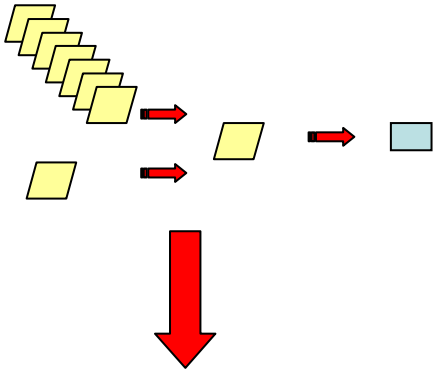
- We have updated the recognised-value standard for position using ITRF2008
  - Including 21 ARGN and AuScope stations
- Address limitations of ‘official’ positional uncertainty
- Broad-scale deformation modelling
  - Start in the capital cities and exploit CORS, GNSS observations and time-series radar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

National Geodetic Datum - Roadmap

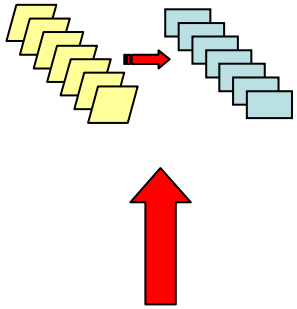


National Geodetic Datum - Framework

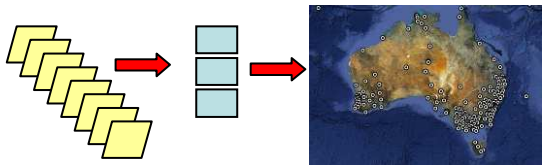
National GNSS Campaign Solution



Jurisdictional Adjustments



National GNSS CORS Solution



Geodetic Model of Australia

- Thank you!
- Questions?

- Further Information: John.Dawson@ga.gov.au