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Reference Frame in Practice

Manila, Philippines 21-22 June 2013

Going Geocentric: The Australian Experience

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Sponsors :

Objectives

To learn about:

→ The development of geodetic datums in Australia including Australia's approach (technical and institutional) to changing to a geocentric datum

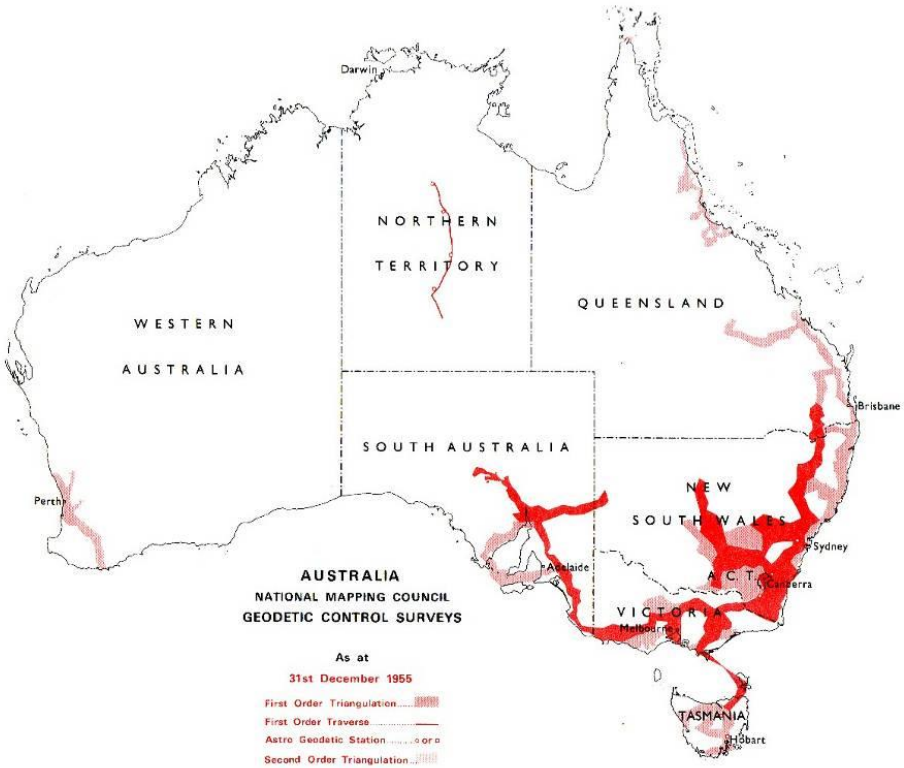
→ How the Geocentric Datum of Australia (GDA) is currently maintained

→ Australia's future plans for GDA

Early Geodetic Datums in Australia

- → Prior to 1966: there were some twenty different datums using four different spheroids
- → The spheroid in general use until 1961 was the Clarke 1858 spheroid
- → Most triangulations were computed from bases measured in British feet and there were a number of distinct astronomically determined origins
- → National integration of state surveys was commenced in the late 1950s

Largely triangulation before 1956



Triangulation - labour Intensive

Triangulation - challenges

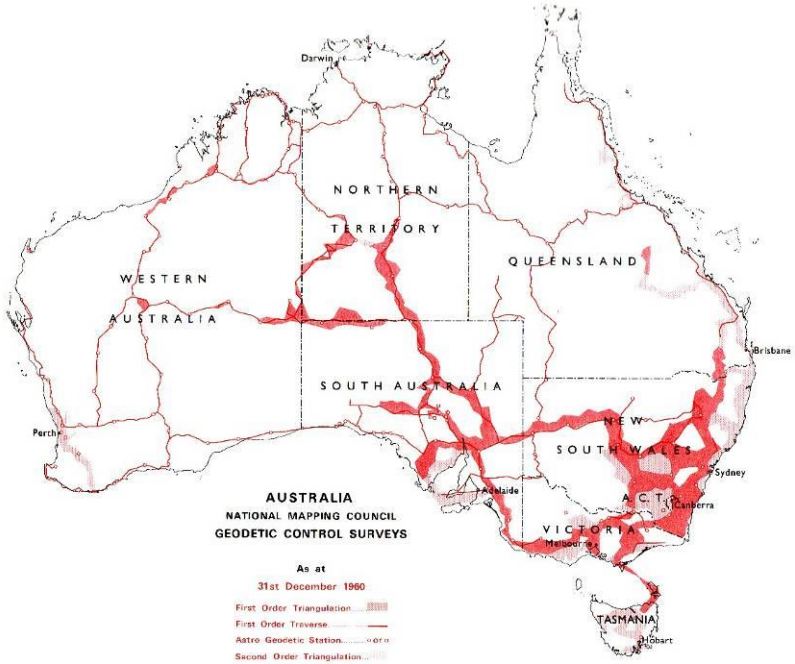
Geodimeter

Model 1 (1954 to 1956)

Model 8 (1968)

→ More portable

→ Increased accuracy, ~1 ppm



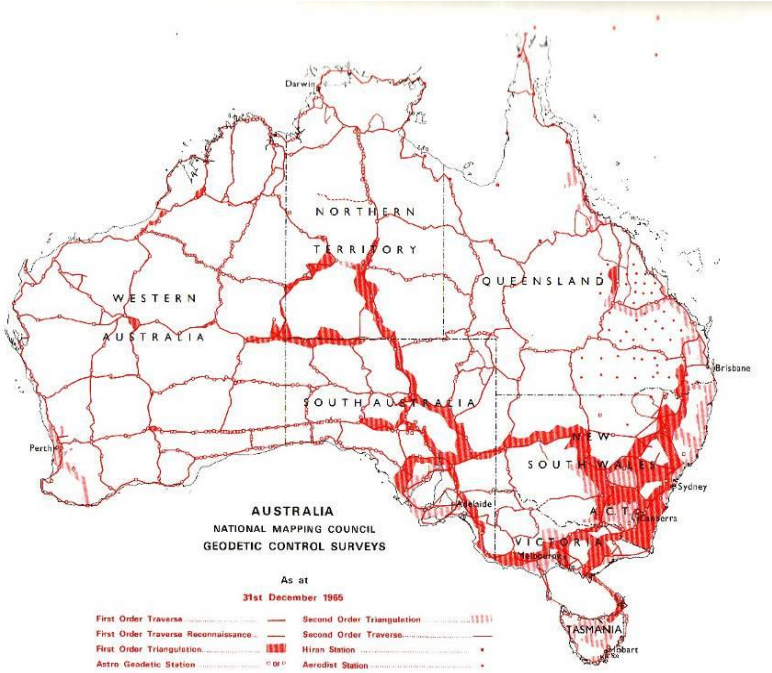
Tellurometer

Introduced in 1956

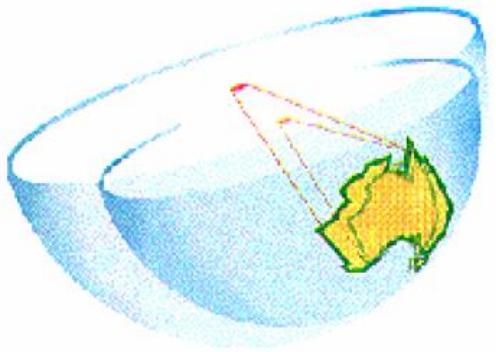
→ Long traverses & loops possible

→ More coverage

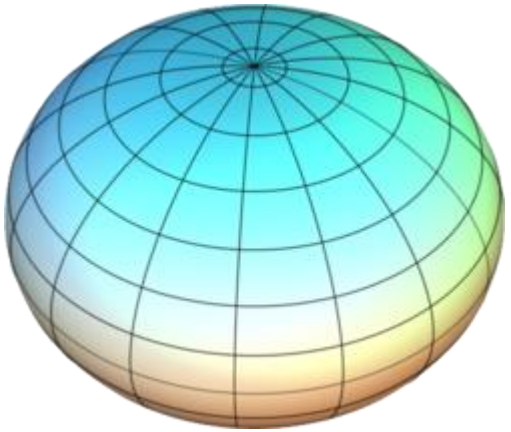
→ Accuracy ~ 5 ppm



Spheroids Used in Australia



- → 1962: geodetic computations were performed on the so-called "NASA" spheroid and then on a preliminary local spheroid (the "165" spheroid)
- → 1965: a better fitting local ellipsoid -- the Australian National Spheroid (ANS)
- → Although the ANS was used to best fit to the local geoid surface in Australia, its centre did not coincide with the centre of mass of the earth – i.e. it was non-geocentric



Australian Geodetic Datum 1966

- → From May 1965 to March 1966 a complete least squares adjustment of the Australian geodetic network was carried out
- → Australian Geodetic Datum (AGD66) adopted April 1966
- → Grid coordinates derived from a Universal Transverse Mercator projection of the AGD66 coordinates were termed the Australian Map Grid coordinates (AMG66)

Australian DOPPLER Survey, 1975 to 1977

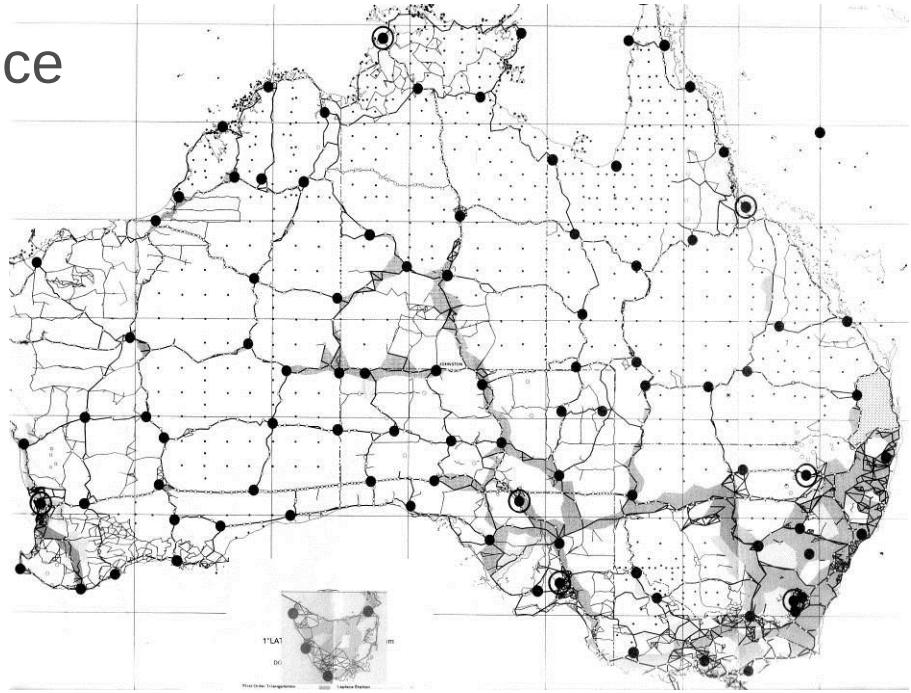
Satellite positioning

→ 106 stations

→ 7-day observations (~40 passes) !

→ Post processing by US Defence

→ ~1 metre accuracy



Australian Geodetic Datum 1984

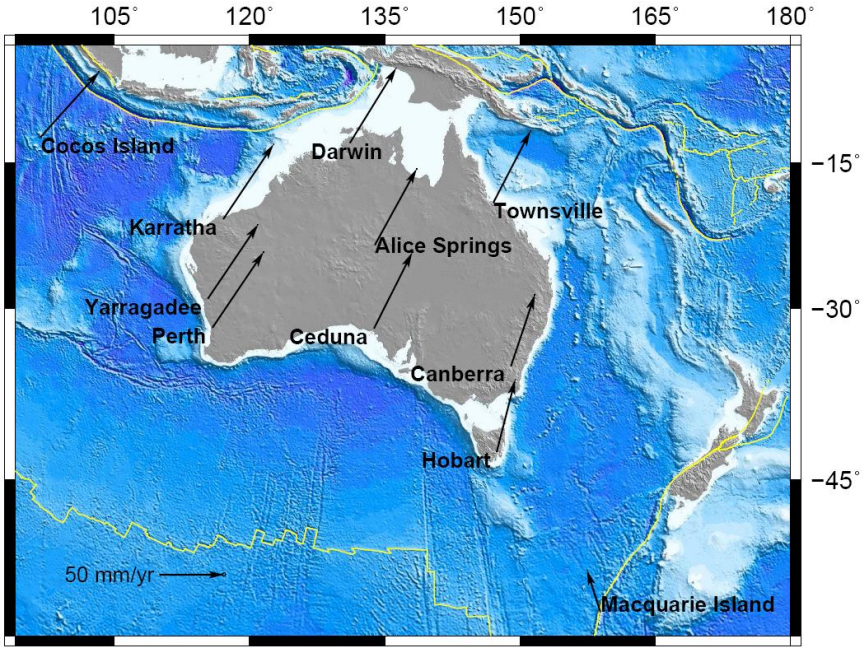
- → 1982: a new national adjustment was performed using the ANS and incorporating all previous data as well as additional terrestrial and space-based Transit Doppler observations.
- → It also included geoid-ellipsoid separations, which were assumed to be zero in the 1966 adjustment.
- → Known as the Australian Geodetic Datum 1984 (AGD84)
- → Grid coordinates derived from a Universal Transverse Mercator projection of the AGD84 coordinates were termed the Australian Map Grid coordinates (AMG84)

Moving to a Geocentric Datum: Motivation

- → Compatibility with satellite navigation systems, such as the Global Positioning System (GPS) in use by ICAO and IHO
- → Compatibility with all national mapping programs being carried out on a geocentric datum, such as Defence agencies
- → Encourage a single standard for the collection, storage and dissemination of spatial information at global, national and local levels
- → Compatibility with GPS service providers
- → Compatibility with resolutions of the International Association of Geodesy and the resolutions of the United Nations

Geocentric Datum of Australia 1994 (GDA94)

→ 1992: as part of the world-wide International GPS Service (IGS) campaign, continuous GPS observations were undertaken on eight geologically stable marks at sites across Australia, which formed the Australian Fiducial Network (AFN)



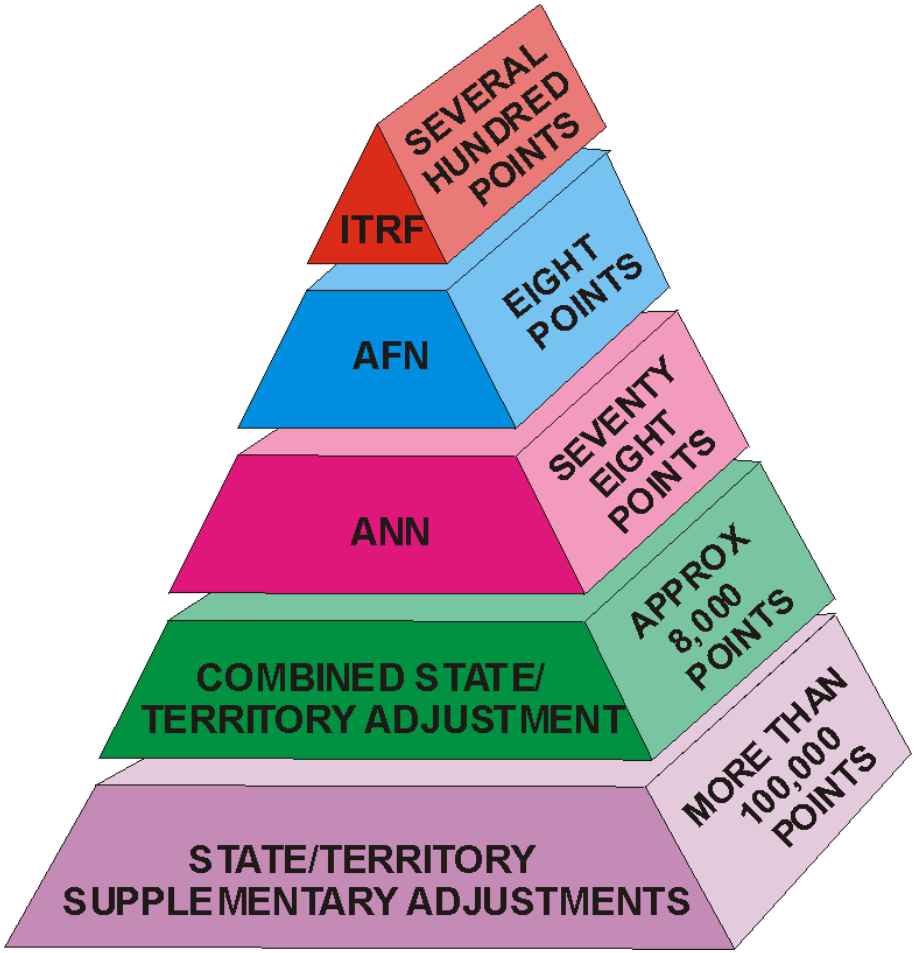
Geocentric Datum of Australia 1994 (GDA94)

- → 1992: GPS observations were also carried out at a number of existing geodetic survey stations across Australia
- → 1993-1994: supplemented by further observations producing a network of about 70 well determined GPS sites, with a nominal 500 km spacing across Australia. These sites are collectively known as the Australian National Network (ANN)
- → The GPS observations at both the AFN and ANN sites were combined in a single regional GPS solution in terms of the International Terrestrial Reference Frame 1992 (ITRF92) and the resulting coordinates were mapped to a common epoch of 1994.

Geocentric Datum of Australia 1994 (GDA94)

- → 1994: Inter-governmental Committee on Surveying and Mapping (ICSM) adopted GDA94
- → 1994: ICSM recommends progressive implementation Australia-wide by 1 January 2000
- → GDA94 has an origin that coincides with the centre of mass of the earth (i.e. geocentric)
- → The International association of Geodesy (IAG) the Geodetic Reference System 1980 ellipsoid (GRS80) was used to express the positions as latitude and longitude and when converted to a Universal Transverse Mercator projection they are known as Map Grid of Australia 1994 coordinates (MGA94)

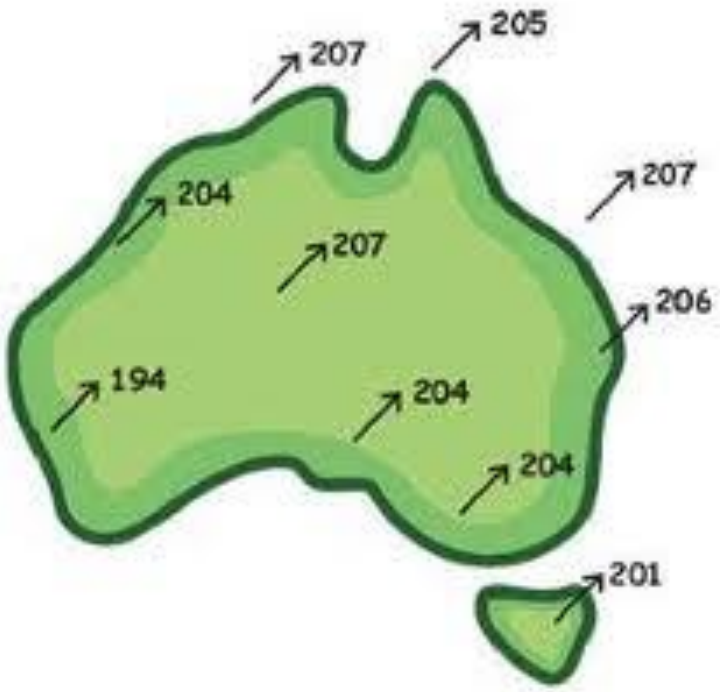
Geocentric Datum of Australia 1994 (GDA94)



Moving to a Geocentric Datum: the tools

Coordinate Transformations

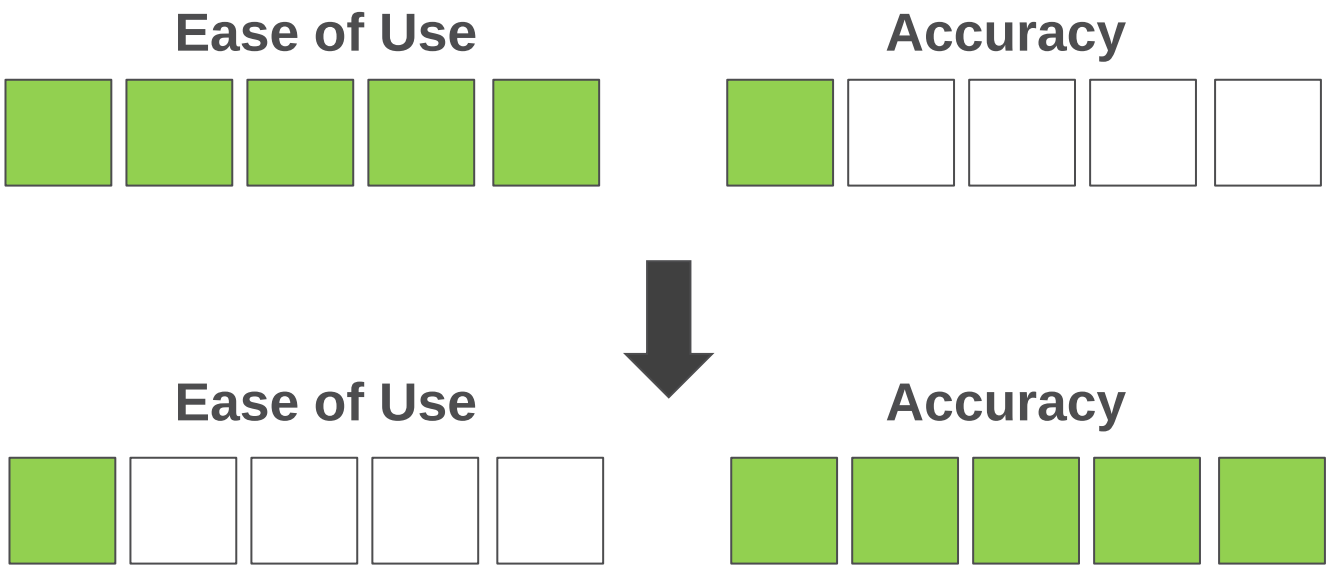
→ Geodetic (AGD) to Geocentric (GDA) was ~ 200 metre shift



Moving to a Geocentric Datum: the tools

Multiple transformations methods were provided for users

→ Approach taken depends on fitness-for-purpose



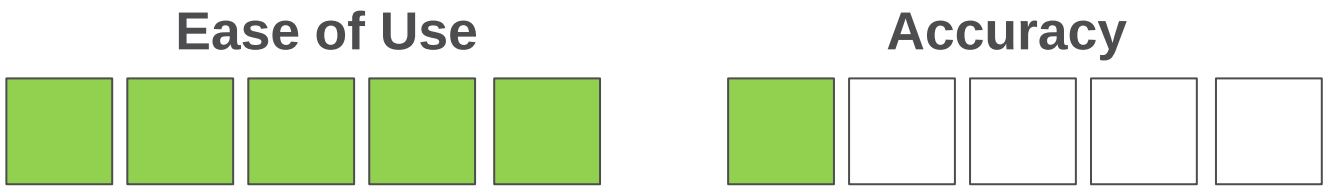
Moving to a Geocentric Datum: Transformations

→ Simple latitude and longitude shift

→ 10 metre accuracy

→ Used for transforming 1:250,000 topographic maps

→ Made available to users as a spread sheet (for each map tile)



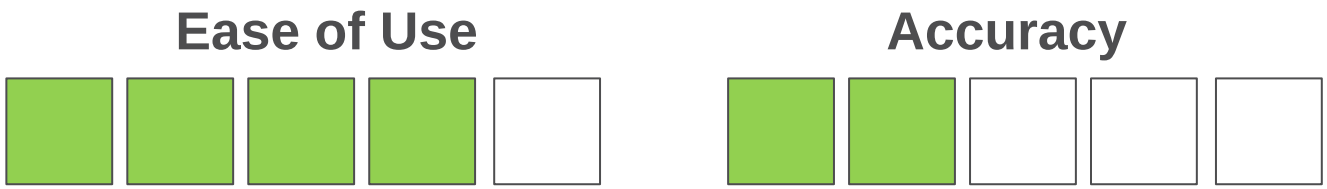
Moving to a Geocentric Datum: Transformations

→ Molodensky Transformation

→ 5 metre accuracy

→ Relatively simple

→ Convert to GDA94 directly from latitude and longitude



Moving to a Geocentric Datum: Transformations

→ Similarity Transformation

→ 3 shifts, 2 rotations and scale

→ 1 metre accuracy

→ More complex requiring earth-centred Cartesian coordinates

Ease of Use

Accuracy

Moving to a Geocentric Datum: Transformations

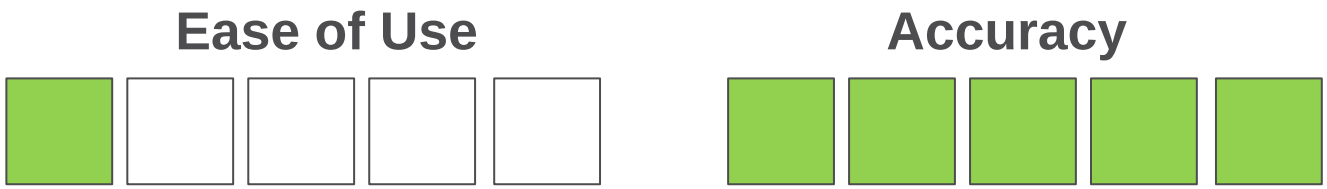
→ Distortion modelling based on grids in the Canadian format known as National Transformation version 2 (NTv2)

→ 0.1 metre accuracy

→ Significantly more complex

→ Requires lots of common points

→ Software and support required



Moving to a Geocentric Datum: Promotion

Strategy for the promotion of GDA94:

→ A full time promotions officer was employed

→ Regular industry briefings were held

→ Published extensively in industry literature

→ Worked closely with software vendors providing technical support and encouragement

→ Established a dedicated web site

→ Developed a comprehensive technical manual

Moving to a Geocentric Datum: Documentation

Geocentric Datum of Australian Technical Manual

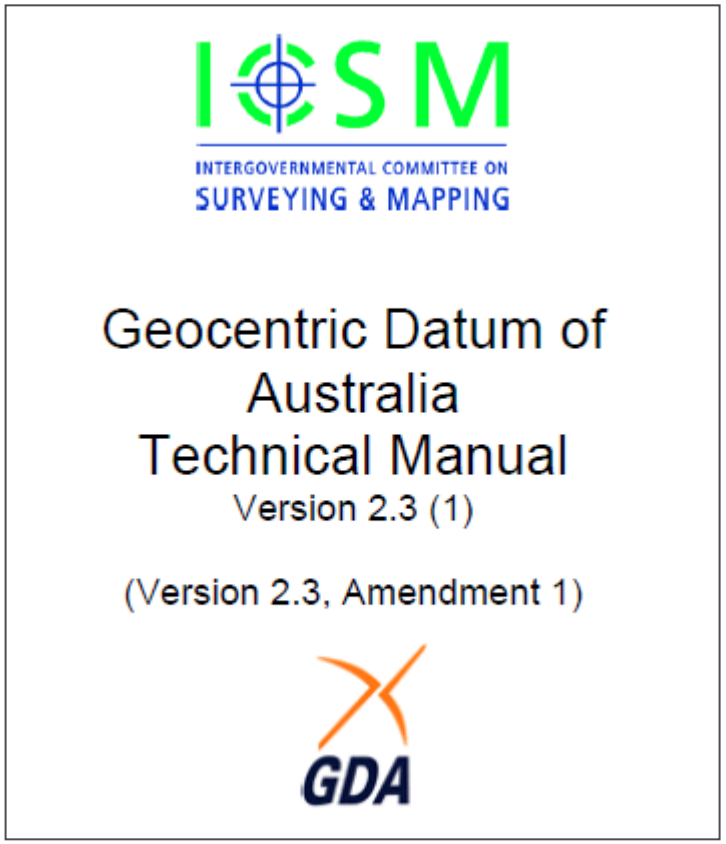
→ Background and explanation

→ Sample ellipsoidal calculations

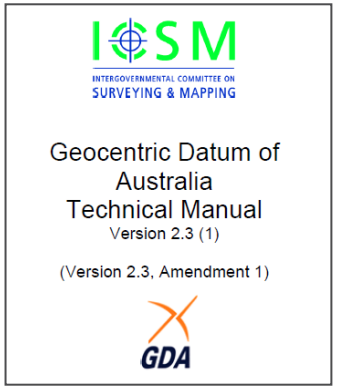
→ Sample map grid calculations

→ Transformation methods

→ Test data



Moving to a Geocentric Datum: Documentation



Chapter 4
Computations on the Ellipsoid

Excel Spreadsheet – Vincenty's Formulae (Direct and Inverse)

There are a number of formulae available to calculate accurate geodetic positions, azimuths and distances on the ellipsoid (Bomford, 1980). Vincenty's formulae (Vincenty, 1975) may be used for lines ranging from a few cm to nearly 20,000 km, with millimetre accuracy. The formulae have been extensively tested for the Australian region, by comparison with results from other formulae (Rainsford, 1955 & Sodano, 1965).

Vincenty's Inverse formulae

Given: latitude and longitude of two points (ϕ_1, λ_1 and ϕ_2, λ_2),

Calculate: the ellipsoidal distance (s) and forward and reverse azimuths between the points ($\alpha_{1\text{-}2}$, $\alpha_{2\text{-}1}$).

$\mathrm{Tan}U_1 = (1\text{-}f)\,\mathrm{Tan}\phi_1$

$\mathrm{Tan}U_2 = (1\text{-}f)\,\mathrm{Tan}\phi_2$

Starting with the approximation,

$$\lambda = \omega = \lambda_2 - \lambda_1$$

Iterate the following equations, until there is no significant change in σ:

$$\mathrm{Sin}^2\sigma = (\mathrm{Cos}U_2\,\mathrm{Sin}\lambda)^2 + (\mathrm{Cos}U_1\,\mathrm{Sin}U_2 - \mathrm{Sin}U_1\,\mathrm{Cos}U_2\,\mathrm{Cos}\lambda)^2$$

$$\mathrm{Cos}\sigma = \mathrm{Sin}U_1\,\mathrm{Sin}U_2 + \mathrm{Cos}U_1\,\mathrm{Cos}U_2\,\mathrm{Cos}\lambda$$

$$\mathrm{Tan}\sigma = \mathrm{Sin}\sigma / \mathrm{Cos}\sigma$$

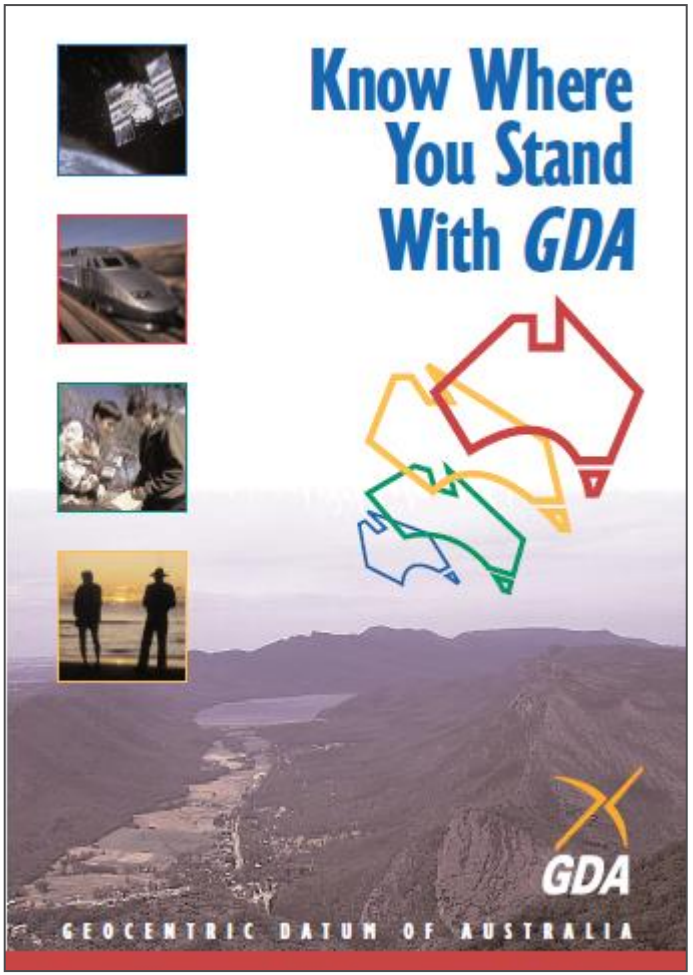
$$\mathrm{Sin}\alpha = \mathrm{Cos}U_1\,\mathrm{Cos}U_2\,\mathrm{Sin}\lambda / \mathrm{Sin}\sigma$$

Moving to a Geocentric Datum: Promotion

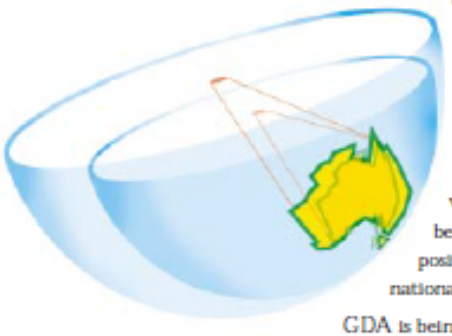
Published Brochures

→ "*Know Where You Stand with GDA*"

→ "*Get In Step With the Geocentric Datum - Discussing the Business Issues*"



Moving to a Geocentric Datum: Promotion



The AGD and GDA are two different mathematical models of the shape of the Earth. Each has a different origin and subsequently a point on the Earth's surface will have different coordinates based on each datum.

advantages of the GDA over Australia's current datum are that GDA is totally compatible with satellite-based navigation systems such as the Global Positioning System (GPS) and with major international geographic systems. In fact, the GDA will provide very significant and substantial benefits to those using satellite positioning and/or operating nationally or internationally.

GDA is being progressively introduced, with all government mapping agencies and authorities scheduled to have it adopted by 2000. Prior to 2000, most other private and public organisations which produce or use geographic information in any form, will need to assess and prepare for the change, and where appropriate, implement their own changes.

To assess both the impact and benefits of GDA, organisations will need to understand both their current and future operational requirements as well as the broader financial, administrative and managerial issues. In particular, they will need to consider:

- existing and future spatial data requirements and use – for example many organisations are linking spatial and other business systems, some of which may be accessed and maintained by other organisations;
- spatial data collection, storage and management practices – migration from paper to electronic documents, access and as some boundaries and leases, etc.

The following sections outline the GDA in more detail including how you can obtain more information.

What Do I Need to Do ?

Organisations need to plan for transition to GDA. The key issues are:

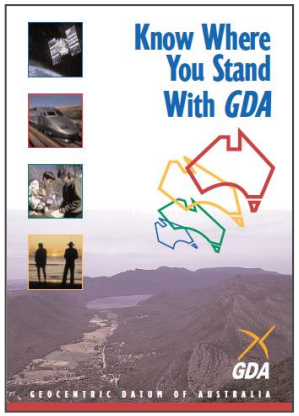
- raising the awareness of GDA internally and promoting discussion about GDA with clients, providers and industry bodies;
- making an assessment of the urgency to change to GDA, based on the implications on operations, clients and providers;
- determining the appropriate strategies and timetable for any changes; and
- make the strategies and timetables publicly accessible to aid others developing strategies.

Common Questions About GDA

What is the GDA ?

A "datum" is a mathematical surface on which a mapping and coordinate system is based. A "geocentric datum" is a datum which has its origin at the Earth's centre of mass. The advantage of the geocentric datum is that it is directly compatible with satellite-based navigation systems.

Therefore the GDA is based on a model which is a best fit model for the whole Earth with the GDA's centre being coincident with the Earth's centre of mass.



Moving to a Geocentric Datum: Promotion

Information Factsheets

→ "Maps and the GDA"

→ "Transformation Options"

→ "GDA Grid Transformation Using Distortion Modelling"

→ "What is the difference between WGS84 and GDA94?"

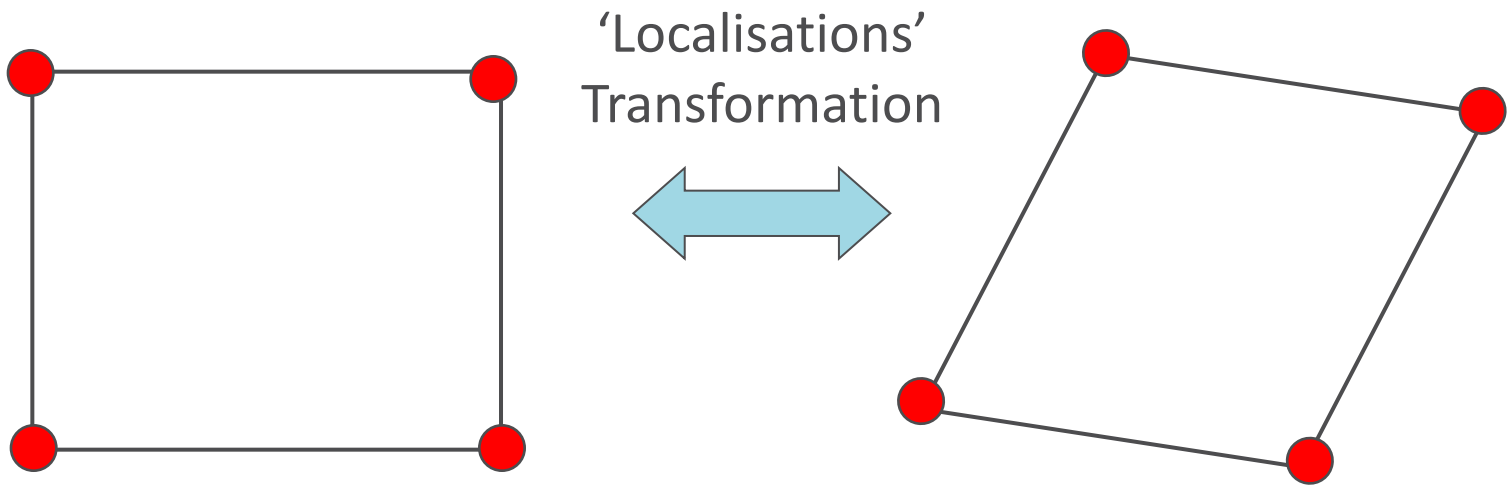
Maintenance of GDA94

- → Ongoing operation of the Australian Regional GNSS Network
- → Provision of ITRFXX to GDA coordinate transformation parameters
- → Delivery of processing services
  - → AUSPOS – GA's online GPS processing service
  - → Legal traceability of GPS in Australia

GDA94: problems, issues, complications

Large local distortions

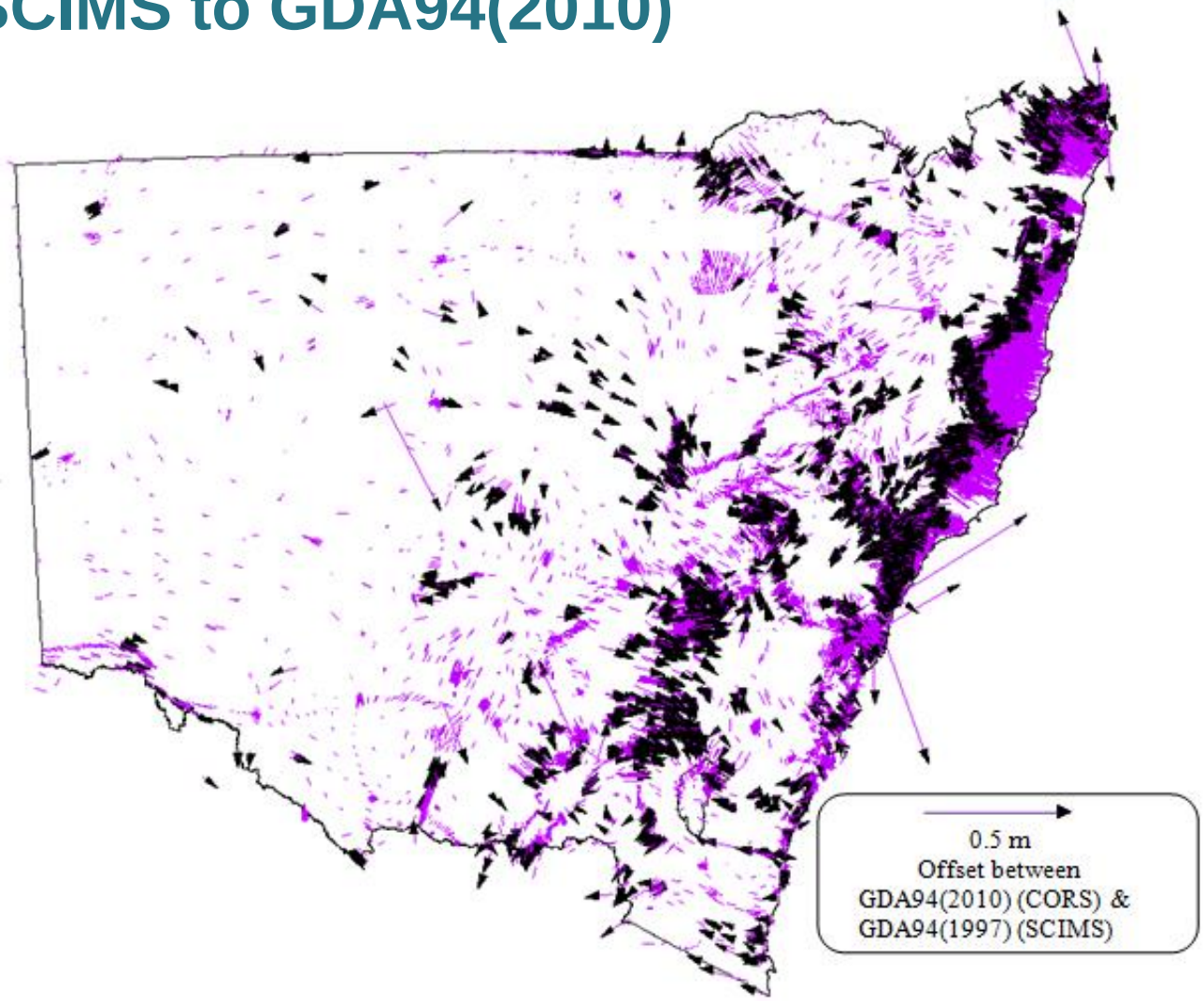
→ 30 cm in horizontal differences in parts



GDA94 via ITRF, AUSPOS, ARGN

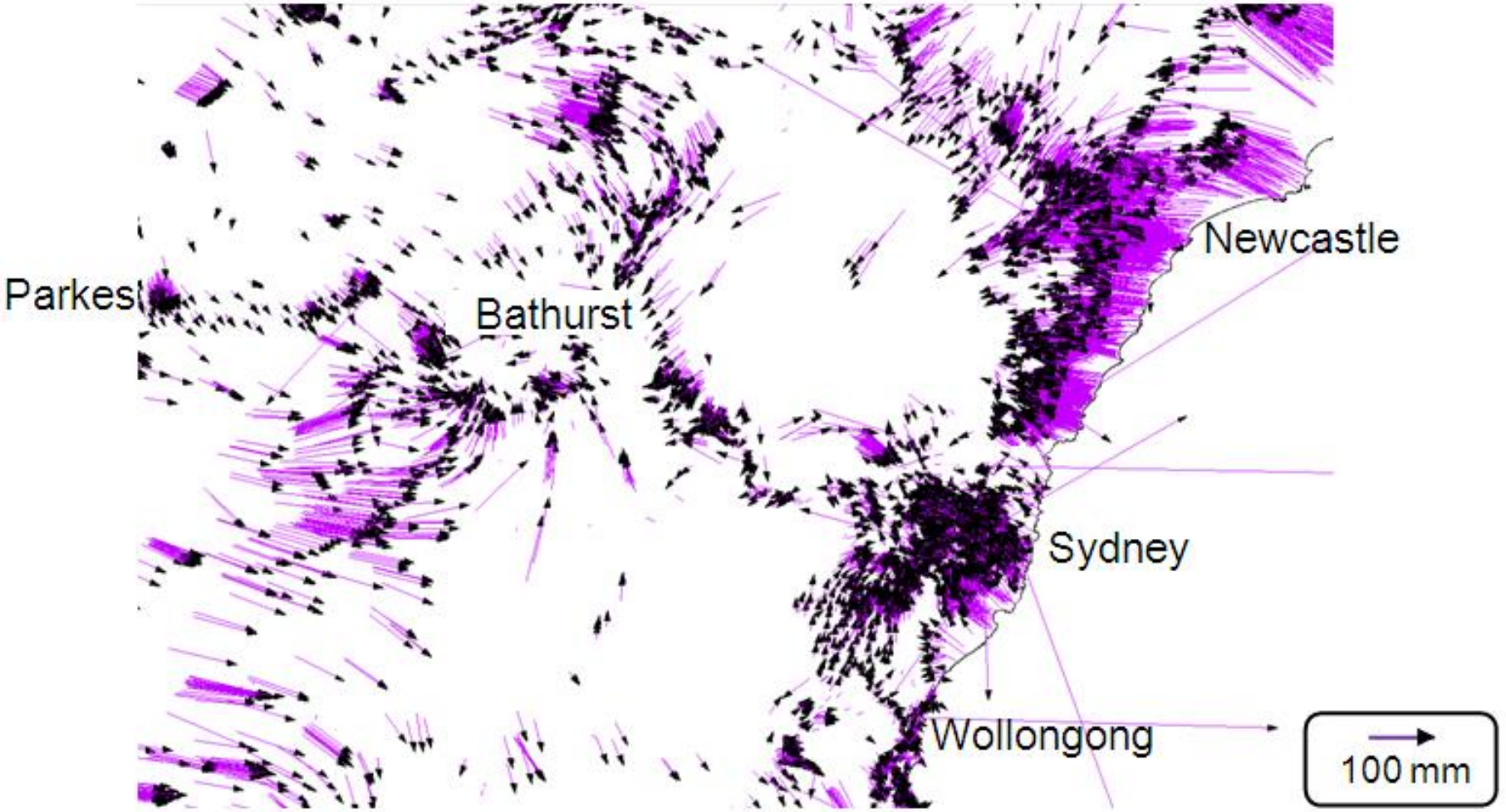
Local

NSW SCIMS to GDA94(2010)



Source: Joel Haasdyk and Tony Watson, LPI NSW, APAS Conference 2013

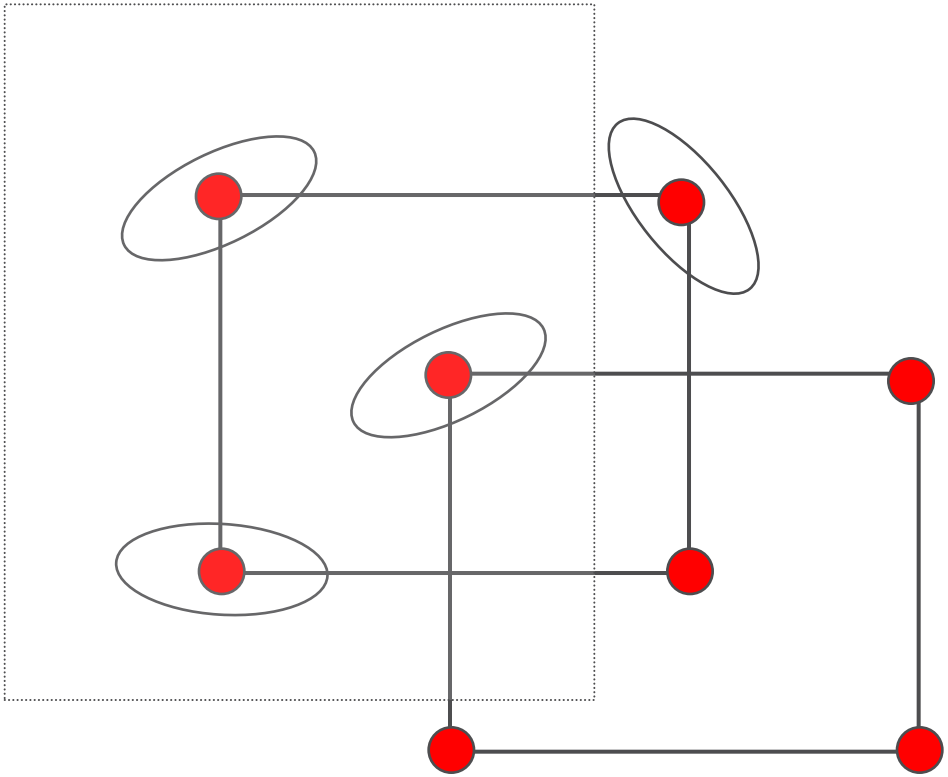
NSW SCIMS to GDA94(2010)

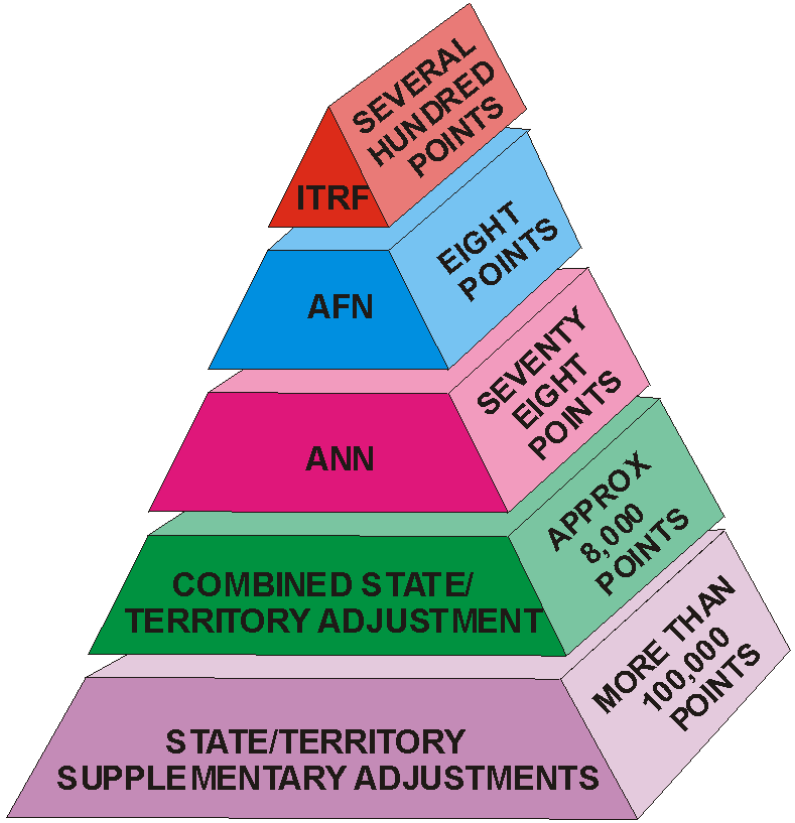


Source: Joel Haasdyk and Tony Watson, LPI NSW, APAS Conference 2013

GDA94: problems, issues, complications

Relative uncertainty not always able to be determined

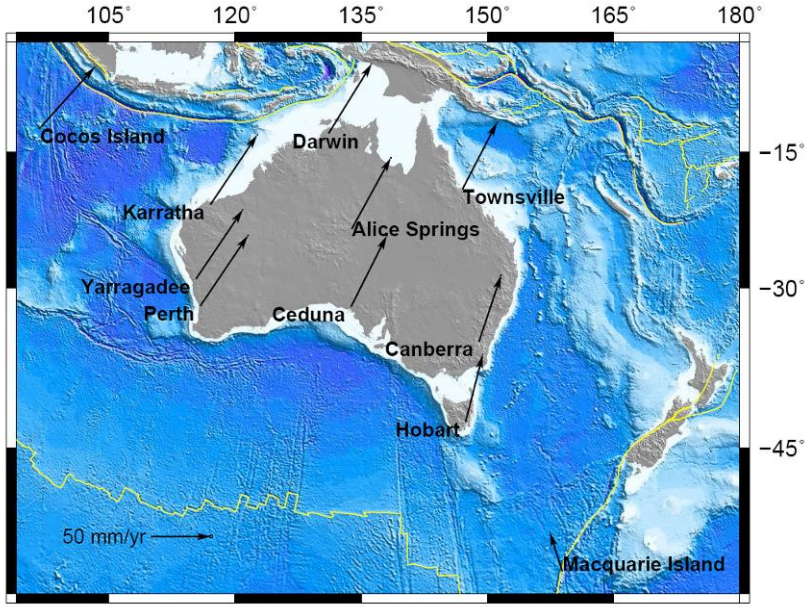




GDA94: problems, issues, complications

Absolute difference between GDA94 and ITRF will exceed 1.8 metres by 2020

→ pseudorange-based positioning services will have a positional uncertainty of 6 cm (PU 95%, open sky)



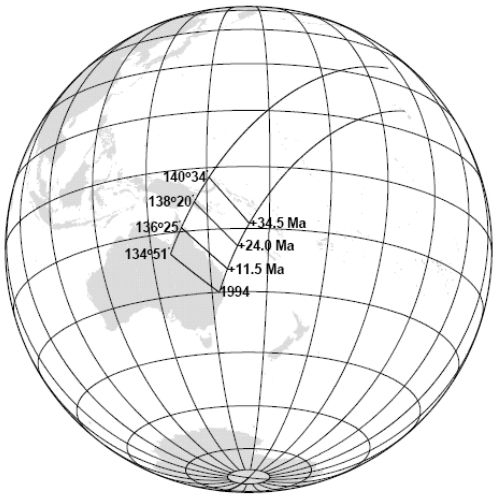
~ 70 mm/year tectonics

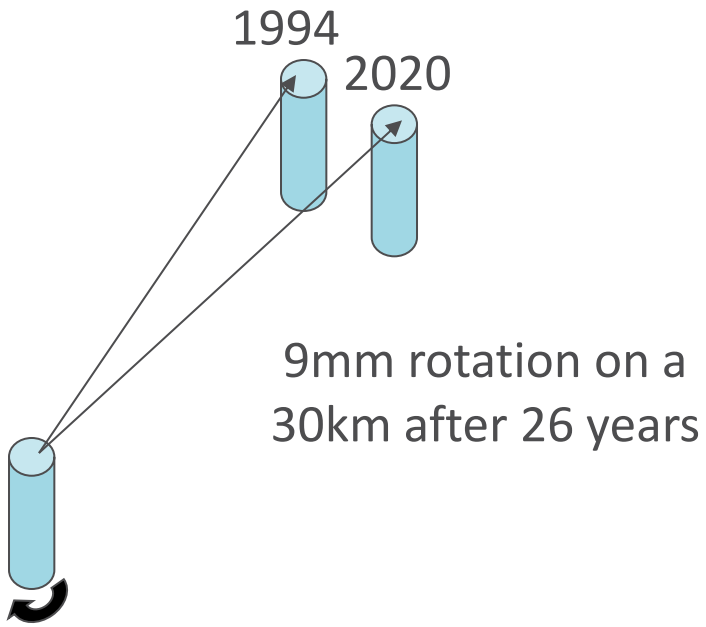
Geocentric Datum of Australia – referenced at 1994

GDA94: problems, issues, complications

Rotation of the Australian Plate

→ has become significant for survey applications



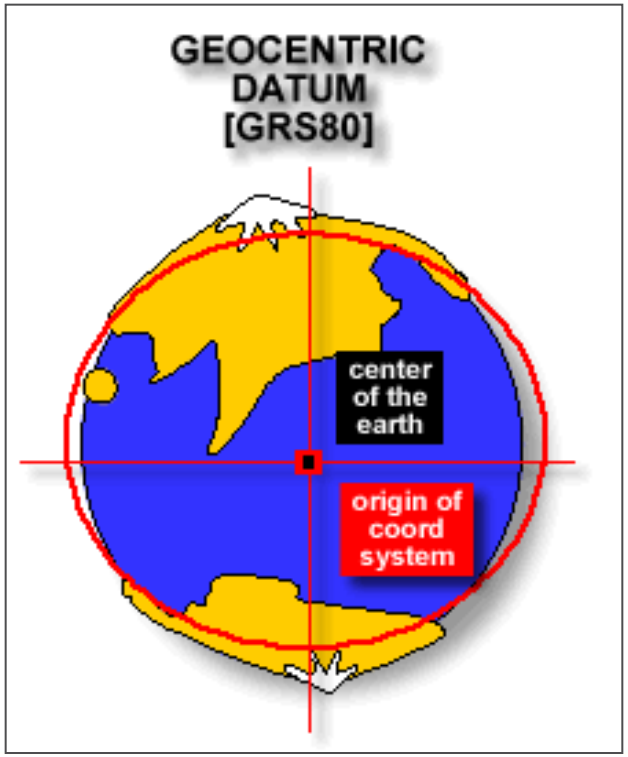


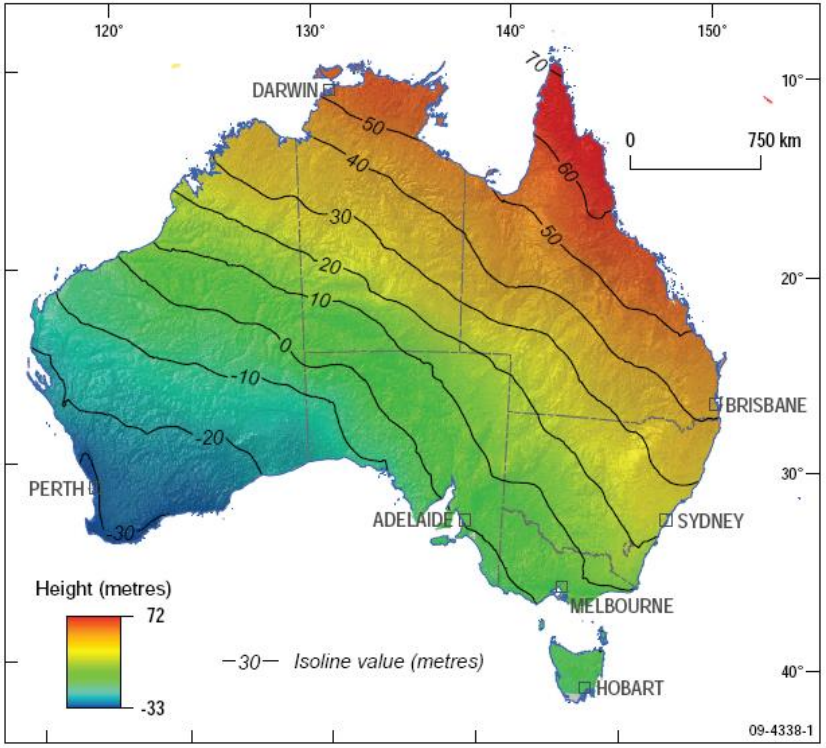
GDA94: problems, issues, complications

Heighting not well supported in GDA94

→ 9cm vertical bias with respect to the recent ITRFs

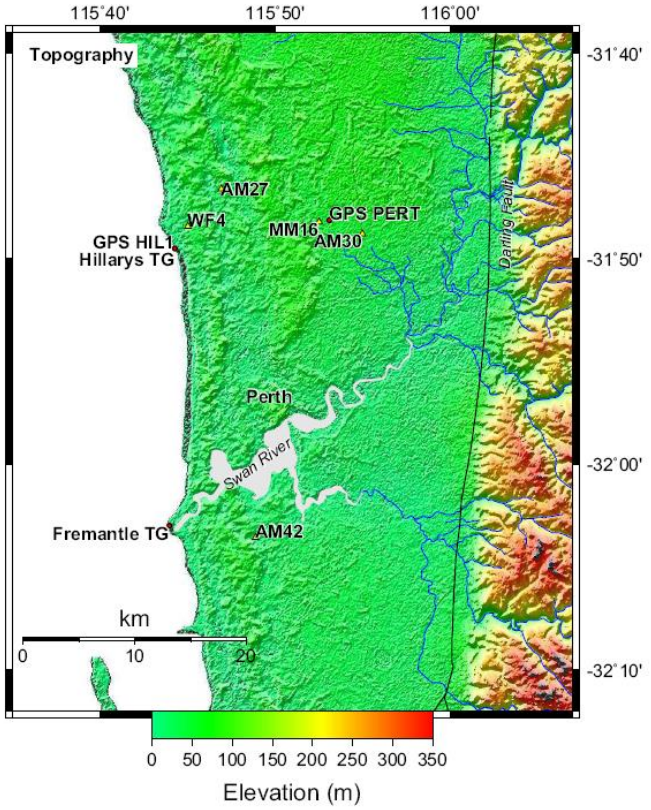
→ uncertainty of vertical coordinates is not rigorously propagated

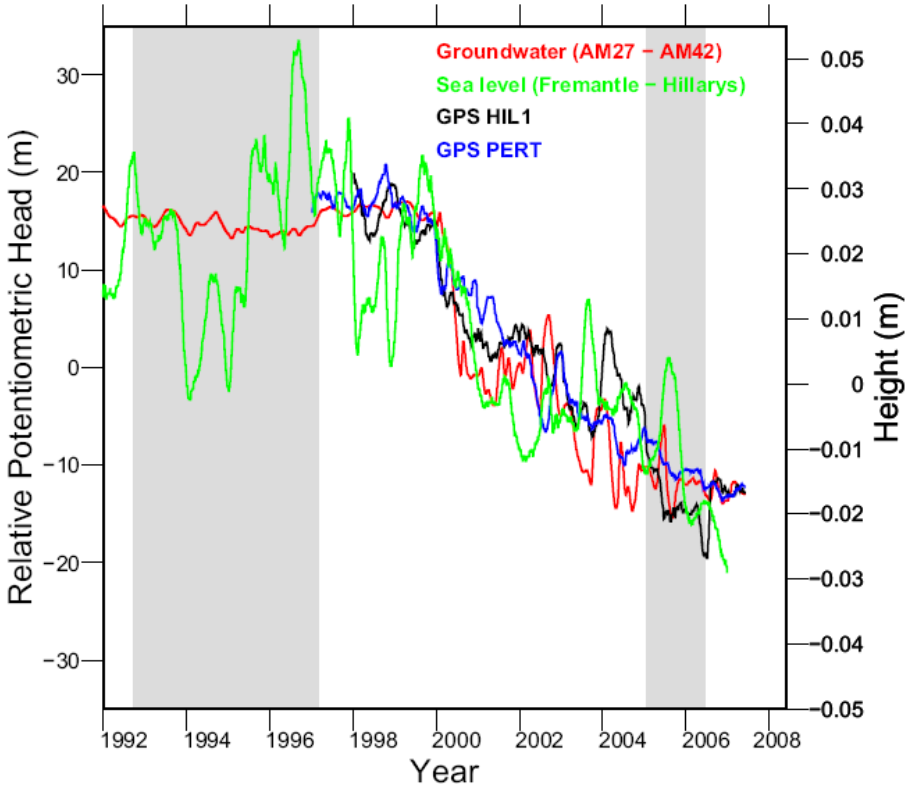




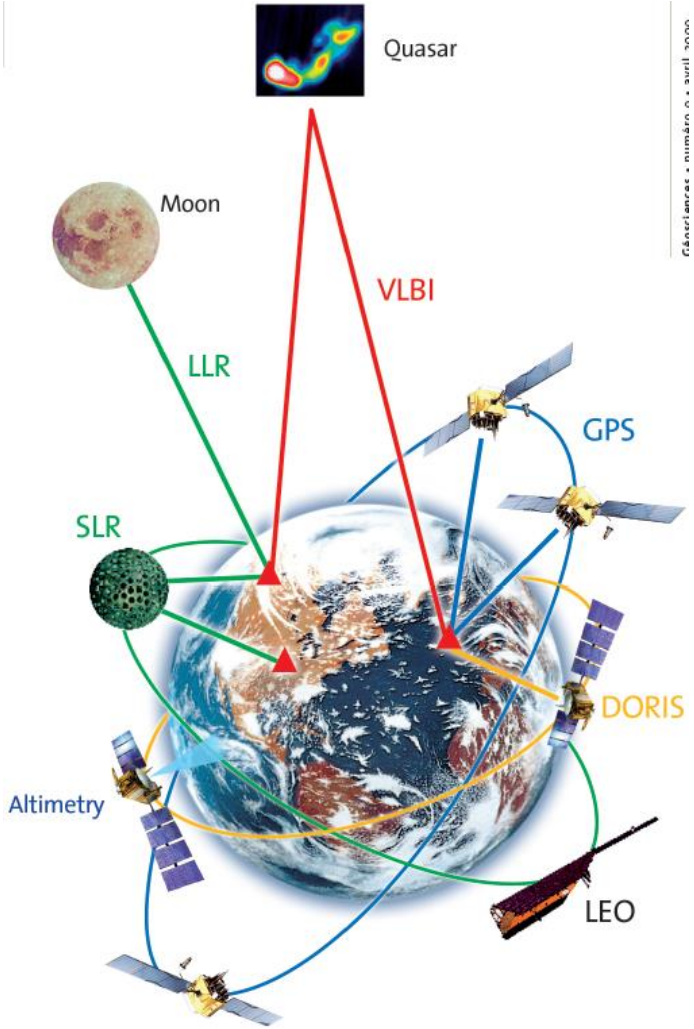
GDA94: problems, issues, complications

Coordinate transformation back to 1994 increasingly difficult

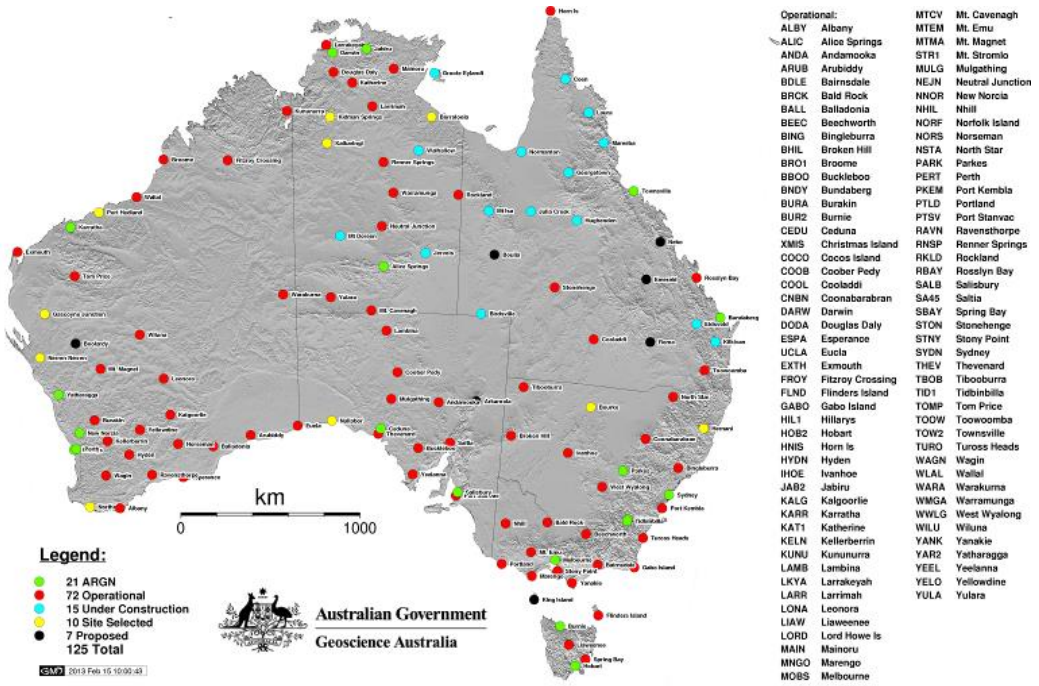




Ground and Space Infrastructure Developments

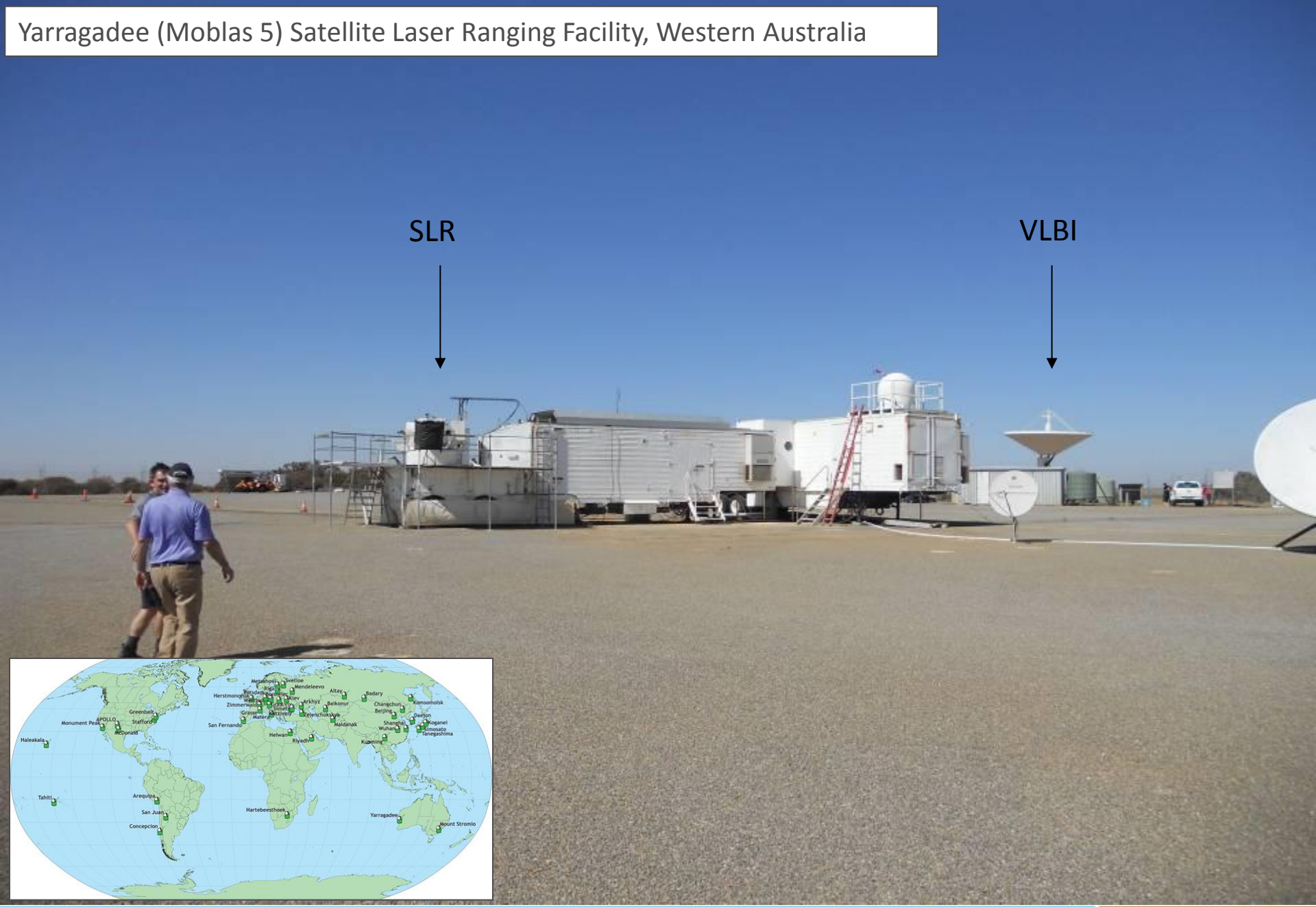


National GNSS Network

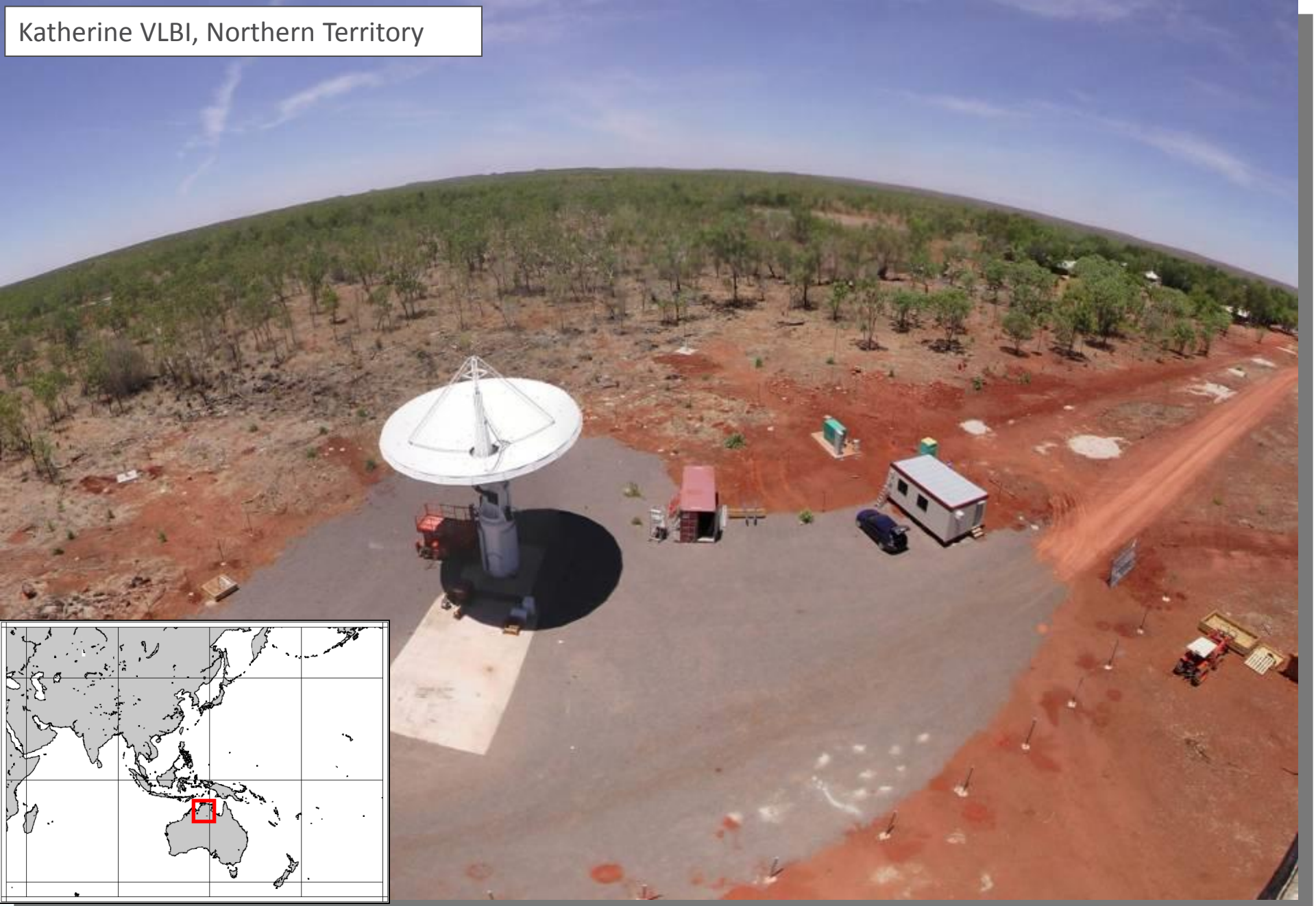


Mount Stromlo Satellite Laser Ranging Facility, Canberra

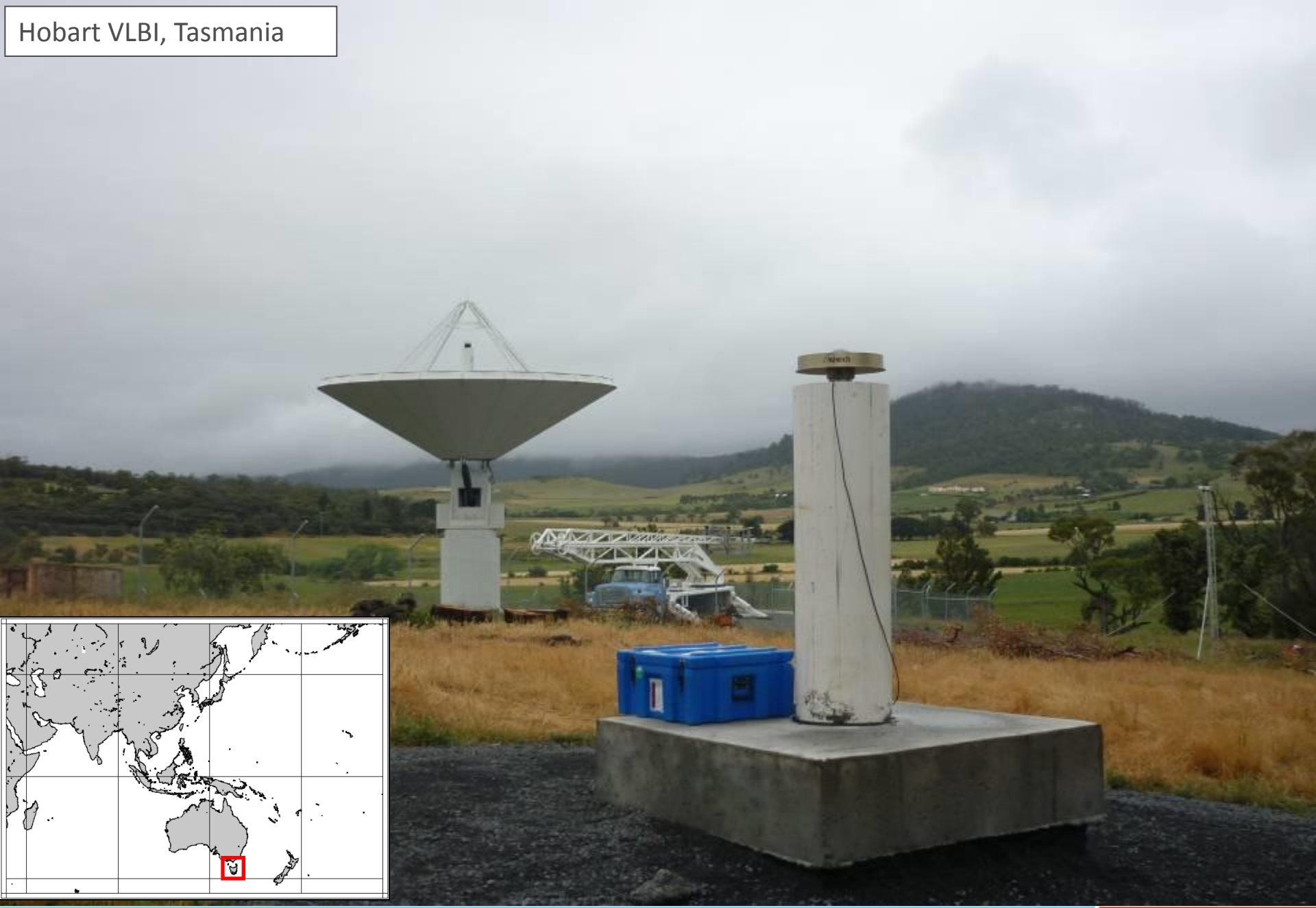
Yarragadee (Moblas 5) Satellite Laser Ranging Facility, Western Australia



Katherine VLBI, Northern Territory

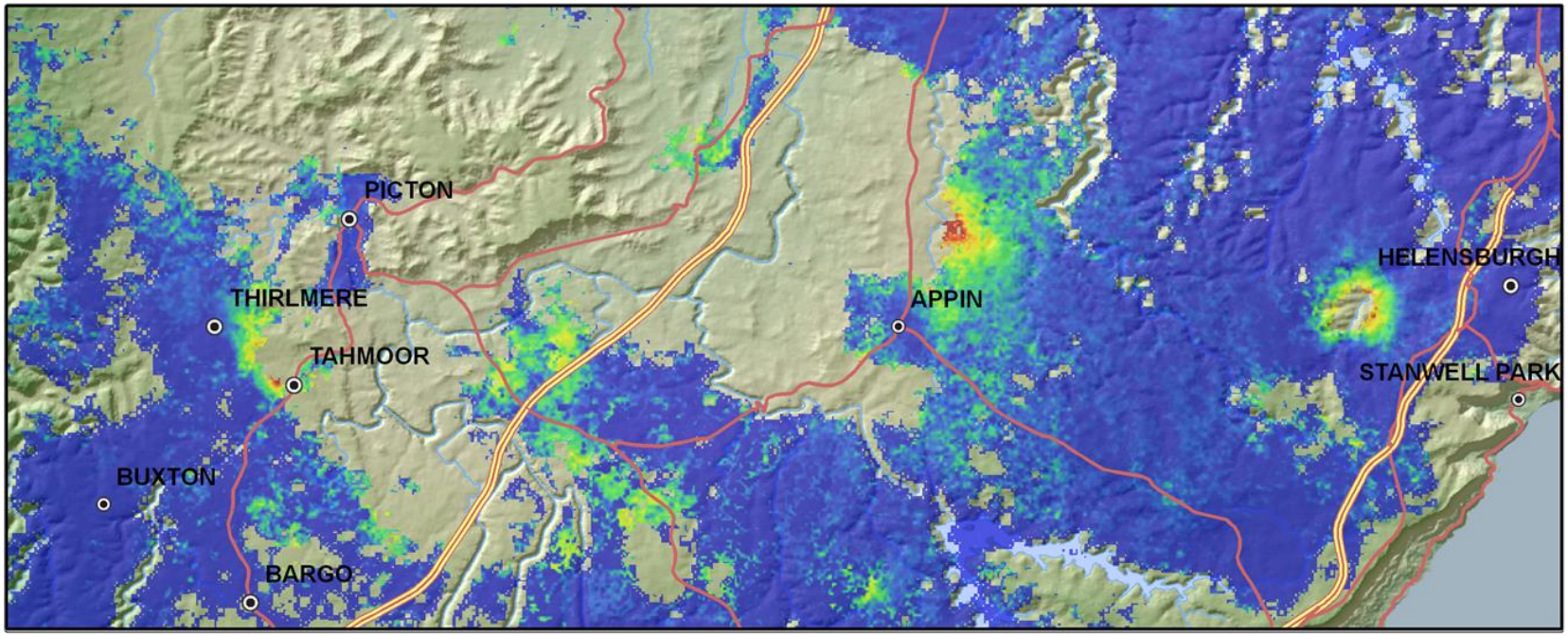


Hobart VLBI, Tasmania



Subsidence mapping using satellite radar

Southern NSW Coalfields



A New Datum For Australia

→Government's objective is to provide leadership and assistance to the geospatial industry to adapt in a rapidly changing environment

→ Australia's datum (GDA94) does not meet users expectations now or into the future i.e. in terms of accuracy, consistency and uncertainty

→ Users (industry, government, public) have an expectation that the positioning infrastructure will deliver +/- 2 cm (PU 95% CL)

→ These user expectations are realistic and achievable within the 2015-2020 timeframe

A New GDA: what should we aim for?

→ Datum should support +/- 2 cm user positioning (PU 95% CL)

→ The relationship to the ITRF is also always known at the +/- 2 cm (PU 95% CL) or better

→ Fully 3-D datum (i.e. ellipsoidal)

→ Relative uncertainty can be computed between any and every survey mark

A New GDA: what should we aim for?

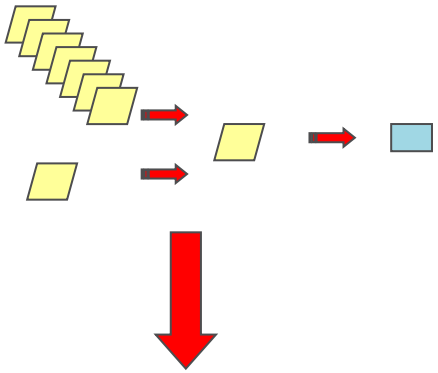
→ Datum updated continuously as new observations are contributed and blunders detected

→ Datum supports the continuous update of the national Geoid model

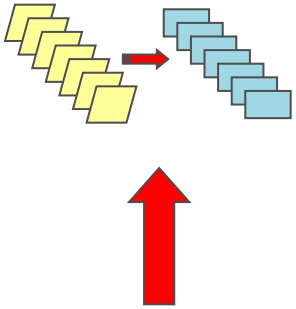
→ Datum supports time-based corrections (i.e. deformation models)

→ Datum has tools and services that facilitate its use by the mass-market (e.g., time based transformations)

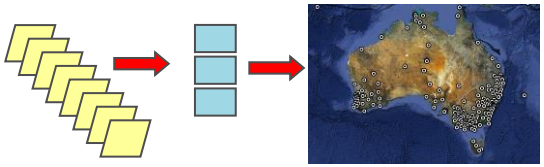
National GNSS Campaign Solution



Jurisdictional Adjustments



National GNSS CORS Solution



Australian Terrestrial Reference Frame (ATRF)

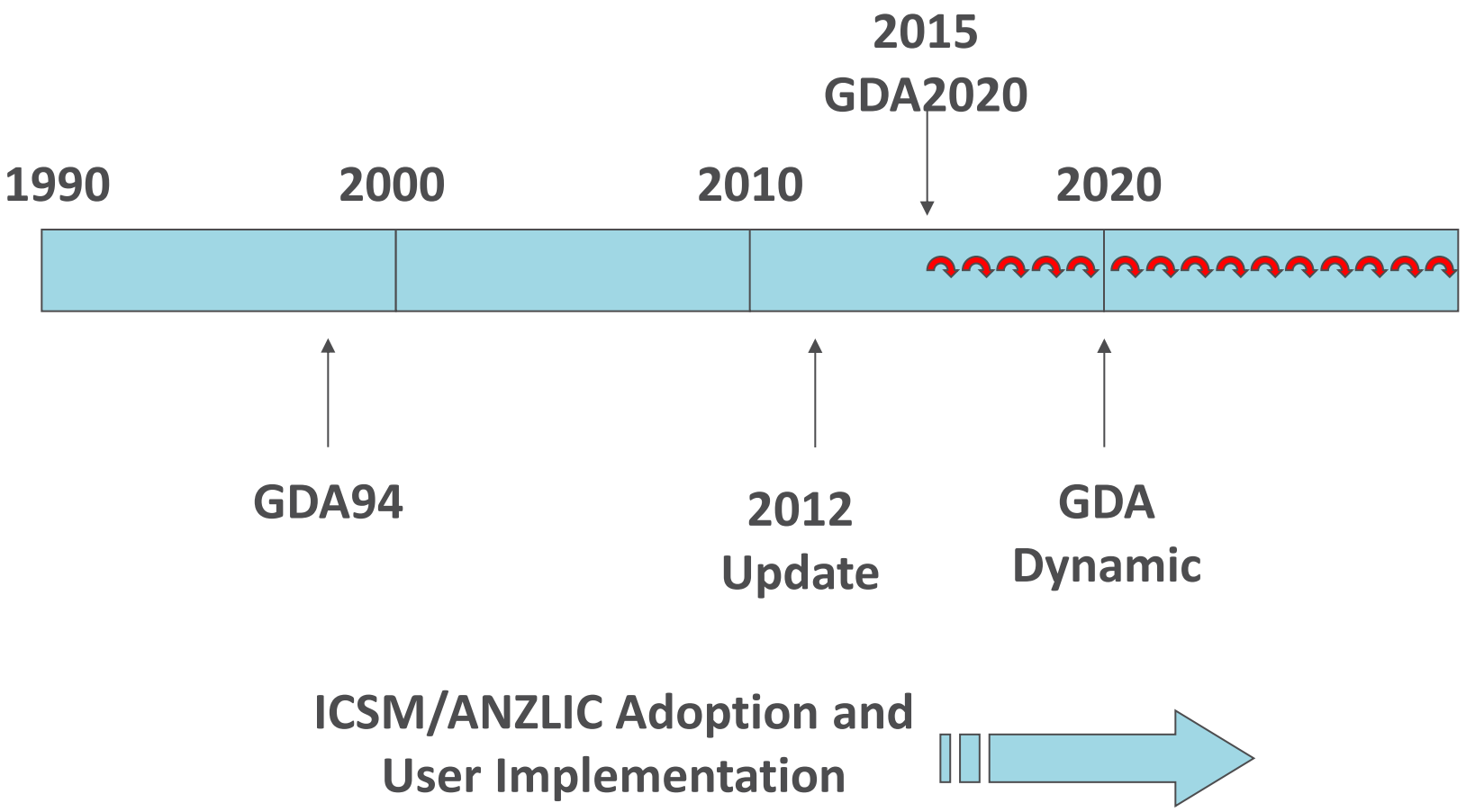
Fully rigorous geometric adjustment

→ aspire for an all stations-and-observations adjustment (down to the street corner)

→ phased-adjustment strategy

→ work-flows managed automatically (using e-Geodesy technology)

Roadmap for a New National Datum



IAG / FIG / UNGGIM / UNICG / PhilGEGS

Reference Frame in Practice

Manila, Philippines 21-22 June 2013

Going Geocentric: The Australian Experience

John Dawson

Leader National Geospatial Reference Systems

Geoscience Australia

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