GDA94, ITRF & WGS84
What's the difference?

Working with Dynamic Datums

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QUICKCLOSE

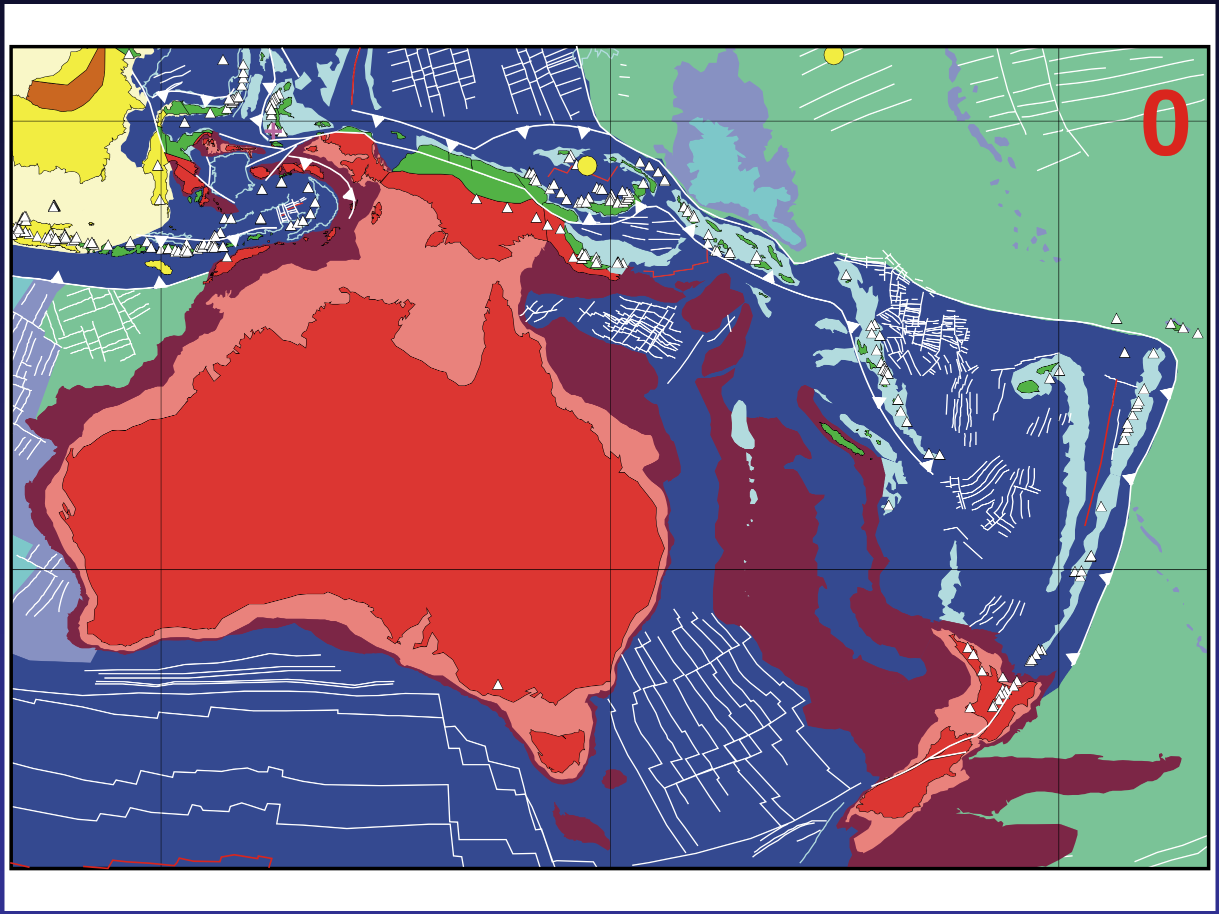
Spatial Sciences Institute
Biennial International Conference
SSC2007

14–18 May 2007
Hotel Grand Chancellor
Hobart, Tasmania, Australia

The assumption

"GDA94 and WGS84 coordinates are identical (for all practical purposes)"

Movement of the Australian Plate



← Millions of Years b.p.

← ITRF / WGS84

Hall, R. 2002. Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: computer-based reconstructions and animations. Journal of Asian Earth Sciences, 20 (4), 353–434.

In Close Up


2100
MGA E 527140
E 527140
MGA N 5252360
N 5252360
WGS84/ITRF
UTM Zone 55

The assumption

"GDA94 and WGS84 coordinates are identical (for all practical purposes)"

WRONG!!

Well, they were back in 1994

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International Terrestrial Reference Frame (ITRF)

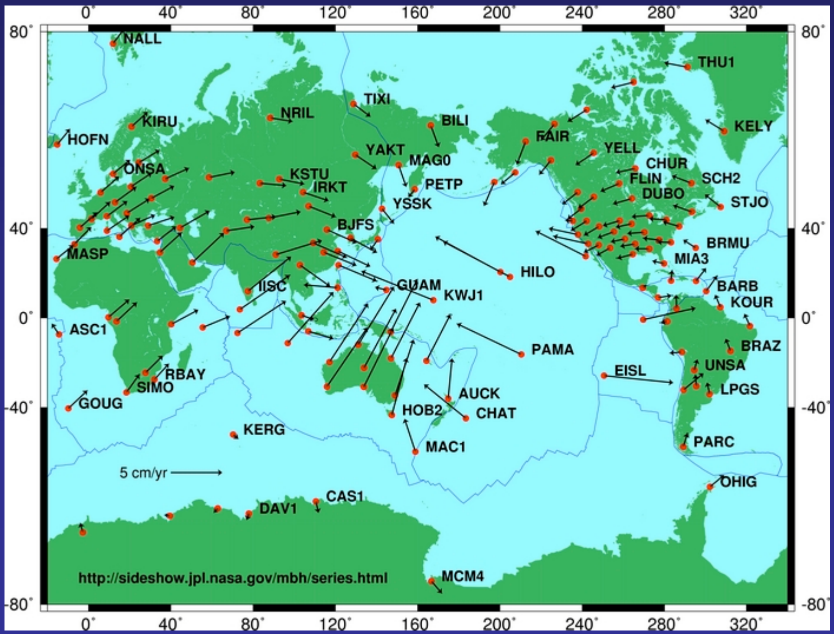
ITRF is the fundamental reference datum used in geodesy

Defined by large networks of GPS, SLR, VLBI, DORIS

Coordinates defined at Reference Epoch + site velocities

Velocities up to 80 mm/yr due to tectonic motion

Latest realisation: ITRF2005



World Geodetic System 1984 (WGS84)

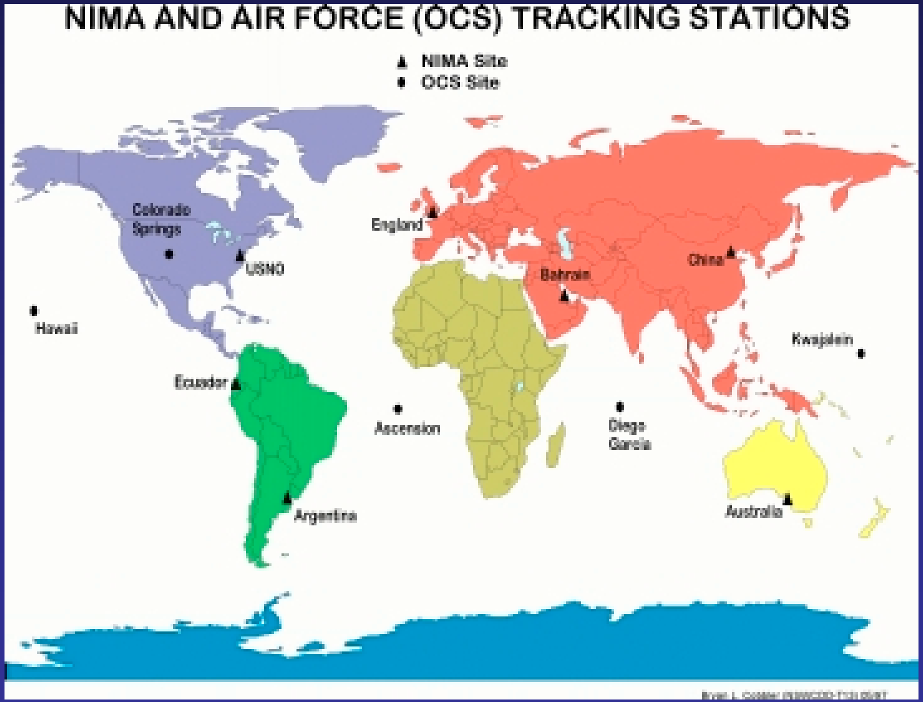
WGS84 is the datum used by the GPS System

Defined by coordinates of tracking & control stations

Regularly Aligned with ITRF (at < 0.1m)

Latest realisation:
WGS84 (G1150)

1150 = GPS week



Geocentric Datum of Australia (GDA94)

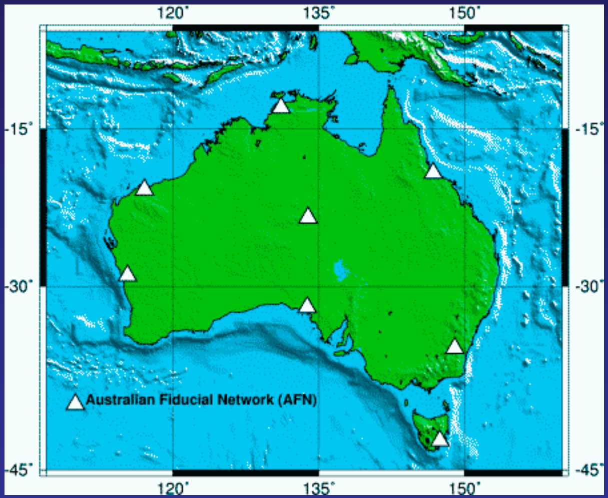
Geocentric datum used in Australia

Defined by ITRF92 coordinates of the AFN

Coordinates fixed at 1st January 1994 values

Now offset from ITRF and WGS84 by almost 1 metre

Offset increasing at up to 70mm/yr

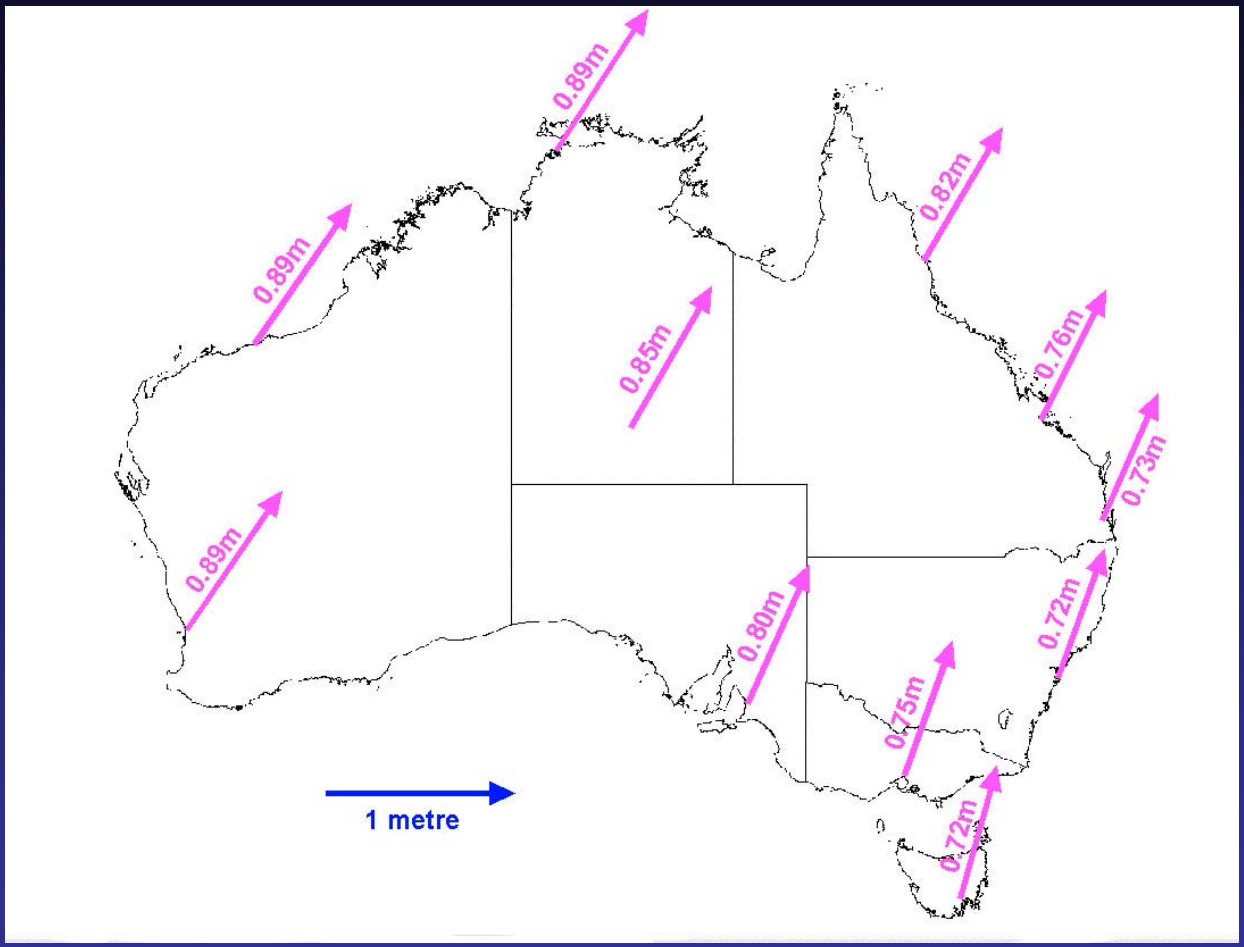


GDA94 =
ITRF92 (Epoch 1994.0)

Name_3	Lat_De	Lat_Mi	Lat_Sec	Long_D	Long_I	Long_S	Zone	Easting	Northing	Hz_Cl	Hz_C	Orthometric_Heig
DON 95 RM4	-29	-2	-47.617	115	20	49.1	50	339055.537	6785728.465	AAA	0	266.528
TIDBINBILLA AF	-35	-23	-57.156	148	58	47.984	55	679807.853	6080884.469			646.322
MT STUART	-19	-20	-50.428	146	46	30.791	55	476391.361	7860723.942	AAA	0	528.673
DARWIN AFN	-12	-50	-37.358	131	7	57.848	52	731469.125	8579189.658	AAA	0	73.933
HOBART AFN	-42	-48	-16.985	147	26	19.435	55	535873.396	5260777.230	AAA	0	44.756
KARRATHA AFI	-20	-58	-53.17	117	5	49.873	50	510101.763	7679903.807	AAA	0	115.902
ALICE SPRINGS	-23	-40	-12.446	133	53	7.8476	53	386352.390	7381850.772	AAA	0	587.643
5634/ 1173	-31	-52	-0.0166	133	48	35.375	53	387415.765	6473725.240	AAA	0	153.284

AFN Coordinates (Geoscience Australia)

Offset of WGS84/ITRF and GDA94 in 2007



Arrows indicate motion of the Australian Plate between 1994 and 2007

Advantages of GDA94 over ITRF/WGS84

Coordinates do not constantly change

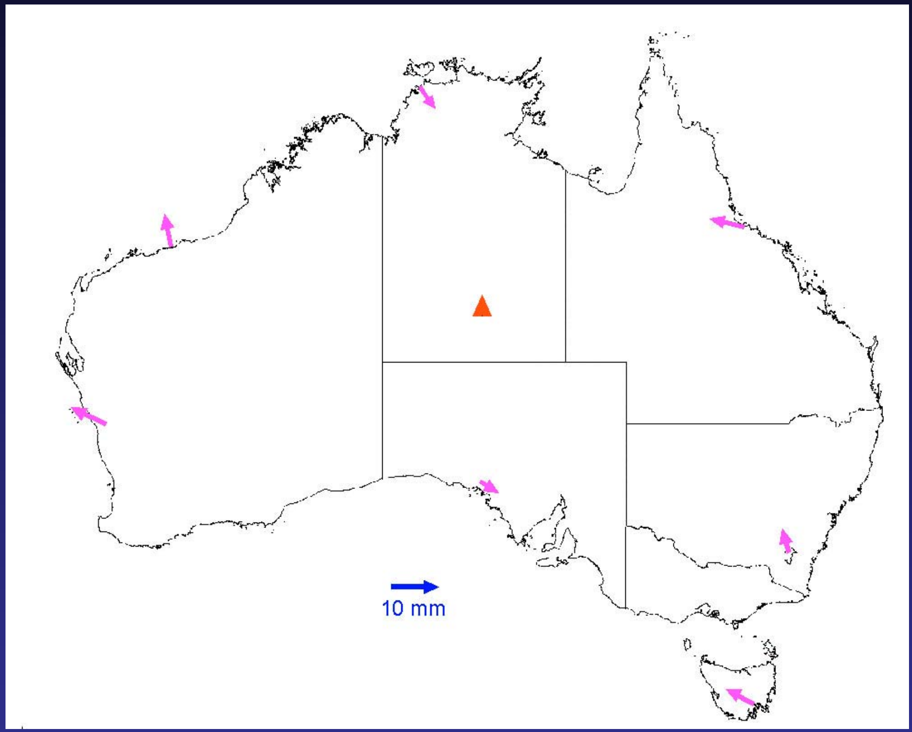
No requirement for epoch of coordinate acquisition

No requirement for a velocity model

Tendency towards homogeneity of spatial data

Positional uncertainties will decrease over time as technology & geodetic infrastructure improves

Internal stability of the Australian Plate



Australian Datum internally homogeneous at <10mm over 15 year period

(excluding localised deformation events)

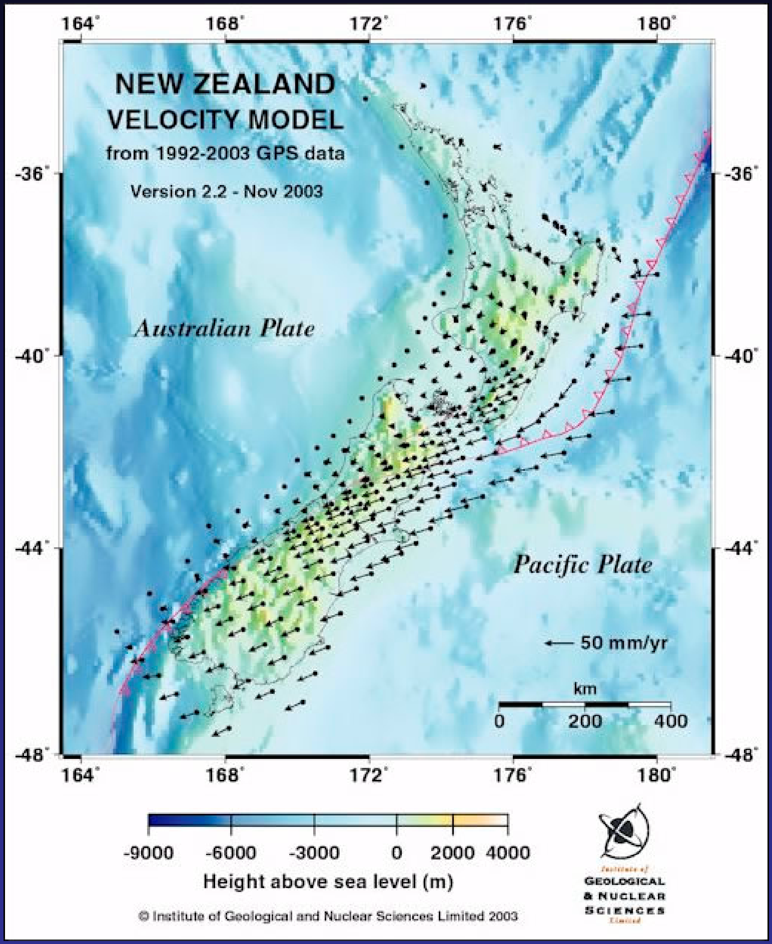
Intraplate deformation of the Australian continent between 1994 and 2007

(from baseline analysis of ITRF2005 solution)

An example of Plate Boundary deformation

Mw 8.0 New Ireland Earthquake
Papua New Guinea
16th November 2000

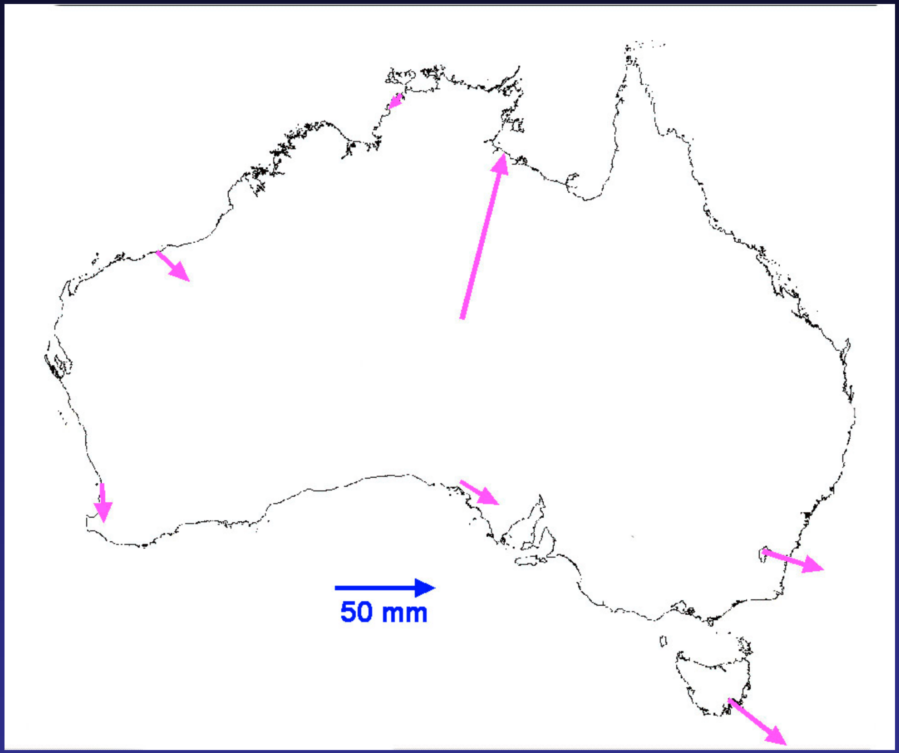
Deformation at the edge of the Australian Plate



(Geological and Nuclear Sciences, New Zealand)

Deformation near Plate boundaries up to 80 mm/yr

Requires a dynamic or semi-dynamic datum for coordinate stability (as implemented in New Zealand)



Difference between GDA94 and ITRF2005 at Epoch 1994.0

GDA94 could be "updated" to fit ITRF2005 at Epoch 1994

Coordinate difference (GDA94 to update) typically < 30mm in major cities

NGRS benefits

Aligning GDA94 update with ITRF at current epoch (2007+) <u>not</u> recommended

One metre offset would result in confusion for many users

Potential for misinterpretation of coordinates in absence of datum metadata

Spatial datasets would have to be updated (unnecessary cost and effort)

ITRF/WGS to GDA94 transformation strategies

Accuracy	Strategy
Higher Accuracy (<15mm) (Australia only)	**Geoscience Australia 14 parameter model** (http://www.ga.gov.au/image_cache/GA3795.pdf)
Medium Accuracy (<30mm) (Any Rigid Plate e.g. Australian Plate)	**Use Global Plate Motion model (e.g. APKIM)**
Lower Accuracy (<50mm) (Location specific within rigid plate only)	**Use Plate Motion Calculator (e.g. UNAVCO)**

High Accuracy transformation - GA 14 parameter transformation

High Accuracy
(<15mm)

Accounts for Reference Frame transformation
(from ITRF92 to ITRF2000)

7 parameters (at Epoch 2000.0)
+ 7 parameter rates (per year)

t (years)	d_x (metres)	d_y (metres)	d_z (metres)	r_x (as)	r_y (as)	r_z (as)	s_c (ppm)
2000.00	-0.0761	-0.0101	0.0444	0.008765	0.009361	0.009325	0.007935
/year	0.0110	-0.0045	-0.0174	0.001034	0.000671	0.001039	-0.000538

Parameters (epoch) = Parameters (2000) + Rate * (epoch - 2000)

Computes 7 parameter transformation for any given epoch

Example of GA 14 parameter transformation

ITRF2000 coordinates for a station in Hobart at Epoch 2007.0 (1st January 2007)	X -3950071.762 Y 2522415.276 Z -4311637.953	Equivalent UTM coordinates Zone 55 E 535873.613 N 5260777.939 Ellipsoid Ht 41.072

Compute parameters for epoch 2007.0

d_x(2007) = -0.0761 + (2007.0-2000)*0.0110 = 0.009m
d_y(2007) = -0.0101 + (2007.0-2000)*-0.0045 = -0.0416m
d_z(2007) = 0.0444 + (2007.0-2000)*-0.0174 = -0.0774m
r_x(2007) = 0.008765 + (2007.0-2000)*0.001034 = 0.016003"
r_y(2007) = 0.009361 + (2007.0-2000)*0.000671 = 0.014058"
r_z(2007) = 0.009325 + (2007.0-2000)*0.001039 = 0.016598"
s_c(2007) = 0.007935 + (2007.0-2000)*-0.000538 = 0.004169ppm

Example GA 14 parameter continued....

X -3950071.762
Y 2522415.276
Z -4311637.953
(ITRF2000
Epoch 2007.0)

Transforms to ➔

X -3950071.281
Y 2522415.228
Z -4311638.513
(GDA94)

Equivalent
UTM coordinates
Zone 55
E 535873.613
N 5260777.939
Ellipsoid Ht 41.072

Equivalent
MGA coordinates
Zone 55
E 535873.391
N 5260777.236
Ellipsoid Ht 41.136

Difference from tabulated
MGA coordinates
E -0.005
N +0.006

Medium Accuracy transformation - Using global plate model

Medium Accuracy (<30 mm)

Rot. Vector (cart.)

OMEGA(X) [deg/Ma]	OMEGA(Y) [deg/Ma]	OMEGA(Z) [deg/Ma]	Plate Name
0.0193	-0.1618	0.2137	Africa
-0.0680	-0.0856	0.2168	Antarctica
0.2849	-0.0467	0.3675	Arabia
0.4078	0.3067	0.3498	Australia
-0.0413	-0.1252	0.1378	Caribbea
-0.0170	-0.1364	0.2192	Eurasia
-0.0577	-0.4537	0.4537	Nazca
0.0370	-0.1940	-0.0083	N. America
-0.0812	0.2640	-0.5977	Pacific
-0.0545	-0.0665	-0.0342	S. America
-0.1158	-0.0672	0.3431	East Asia
-0.0089	-0.1955	0.2162	Somalia

(Actual Plate Kinematic Model, Drewes, H. et al, 2002)

Rigid plate rotation rate (e.g. from APKIM)

Assumes plate is rigid

Not to be used in deforming zones (e.g. plate boundaries)

Rotation (epoch) = Rate(°/Ma) * 0.0036* (epoch - 1994)

Example using Global plate model (e.g. APKIM)

X -3950071.762
Y 2522415.276
Z -4311637.953
(ITRF2000
Epoch 2007.0)

X -3950071.262
Y 2522415.191
Z -4311638.461
(GDA94)

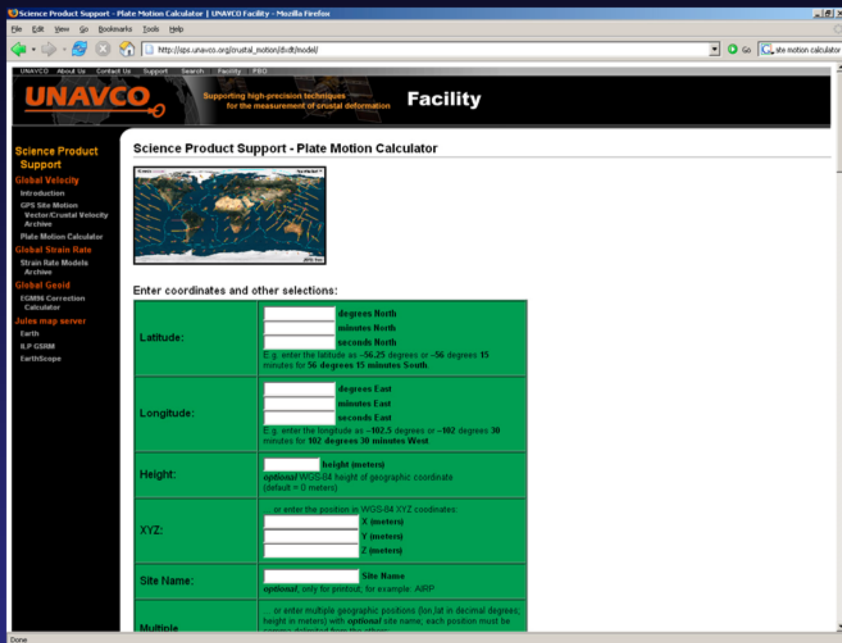
Transforms to ➔

Equivalent
UTM coordinates
Zone 55
E 535873.613
N 5260777.939
Ellipsoid Ht 41.072

Equivalent
MGA coordinates
Zone 55
E 535873.412
N 5260777.250
Ellipsoid Ht 41.074

Difference from tabulated
MGA coordinates
E +0.016
N +0.020

Lower Accuracy transformation - Using Plate Motion Calculator



(http://sps.unavco.org/crustal_motion/dxdt/model/)

Computes Horizontal velocity for given location (dynamic block shift)

Assumes plate is rigid

Not to be used in deforming zones (e.g. plate boundaries)

Easting (MGA) = Easting (ITRF @ epoch) + Velocity* (1994-epoch)
Northing (MGA) = Northing (ITRF @ epoch) + Velocity* (1994-epoch)

Example using Plate Motion calculator

-42°48'17"
147°26'19"

Velocity from
Plate Motion
Calculator
(ITRF2000
Australian Plate)

E = +14.79mm/yr
N = +54.84mm/yr
(Dynamic block shift)

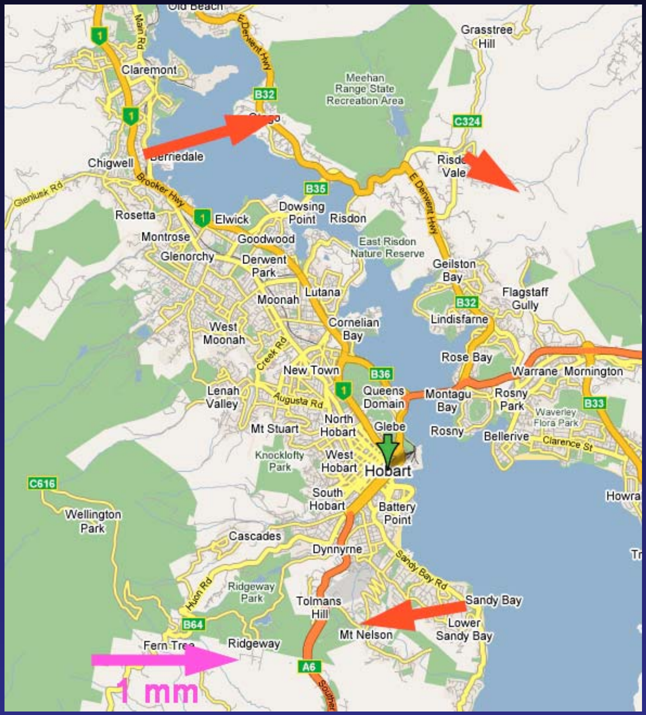
Equivalent
UTM coordinates
Zone 55
E 535873.613
N 5260777.939
(ITRF2000 epoch 2007.)

+(0.01479*(1994-2007))
+(0.05484*(1994-2007))

Equivalent
MGA coordinates
Zone 55
E 535873.421
N 5260777.2226

Difference from tabulated MGA coordinates
E +0.025
N -0.004

Block shift in Hobart



Coordinate difference typically < 30mm in major cities

Error escalates beyond 20 km
(requires new velocity calculation)

Error arising from using standard Hobart velocity in outer suburbs (between 1994 and 2007)

Take Home Points

ITRF & WGS84 coordinates for locations are changing constantly in Australia (up to 80mm/yr!)

GDA94 & MGA coordinates are fixed to the internally stable Australian continent ($\therefore$ change <1mm/yr)

ITRF & WGS84 coordinates must be transformed using some dynamic model in order to obtain equiv. GDA94 & MGA coordinates

ITRF & WGS84 coordinate accuracy is <u>meaningless</u> unless epoch metadata are provided