The Next-Generation Australian Geodetic Datum

Benefits and Challenges

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Acknowledgments

Geoscience Australia – Geodesy and Seismic Monitoring Group
(Gary Johnston, John Dawson, Guorong Hu, Minghai Jia, Anna Riddell,
Craig Harrison, Ryan Ruddick, Bob Twilley)

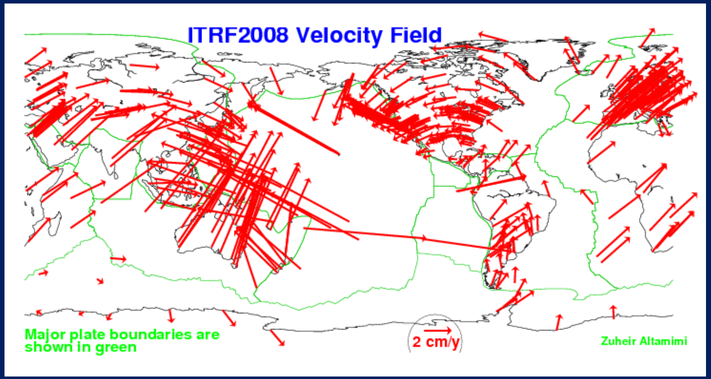
Geodetic Survey – Office of the Surveyor-General Victoria (OSGV) - DTPLI
(Roger Fraser, Alex Woods)

GPSnet VICMAP Position – DEPI
(Hayden Asmussen, Peter Oates)

CRC SI Positioning Program - Next Generation Datum 1.02
(Chris Rizos, Craig Harrison, Joel Haasdyk, Nic Donnelly, Richard Stanaway)
UNSW - Craig Roberts **LINZ** – Chris Crook

The motivation for datum modernisation – Drivers for change and benefits

Maintaining alignment of Australia's geodetic datum with International Reference Frames (e.g. ITRF, Global Geodetic Reference Frame (GGRF), WGS84) – intrinsically used by GNSS



Improved precision for a wider spectrum of users who will use GNSS precise positioning and SBAS

Mitigating unmodelled errors arising from deformation events (e.g. earthquakes, subsidence) and plate rotation effects

Meckering, WA 1968

The future of positioning circa 2030

multi-GNSS
+ augmentation (e.g. SBAS)
+ indoor positioning (e.g. Locata)
+ miniature inertial sensors

real-time
precise broadcast
orbits

4D GIS in the cloud

real-time positions

mm
accurate

active transformation model

real-time information currency

centralised data
+ clone

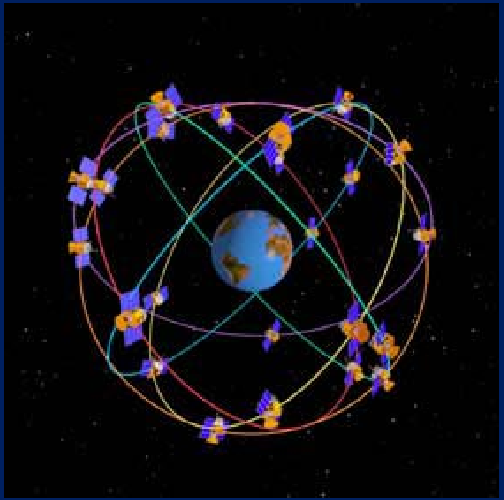
authoritative

ubiquitous

5G/6G wireless
and satellite comms.
(e.g. Beidou, Galileo)

mm/cm accurate real-time personal positioning and navigation – everywhere - No need for “coordinates” *per se*!

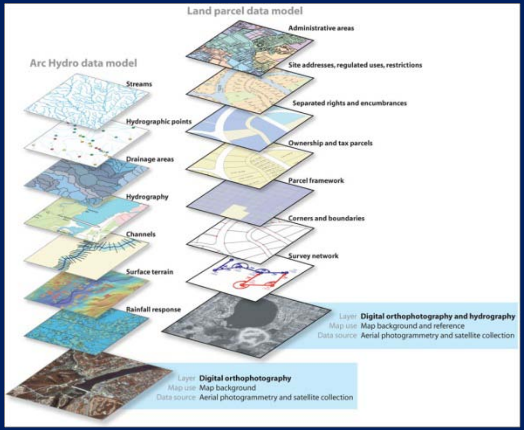
Spatial Data and Positioning in the future



GNSS Positioning within ITRF / GGRF

Complex time dependent deformation modelling

Software matches epoch of positioning with epoch of data in order to maintain context

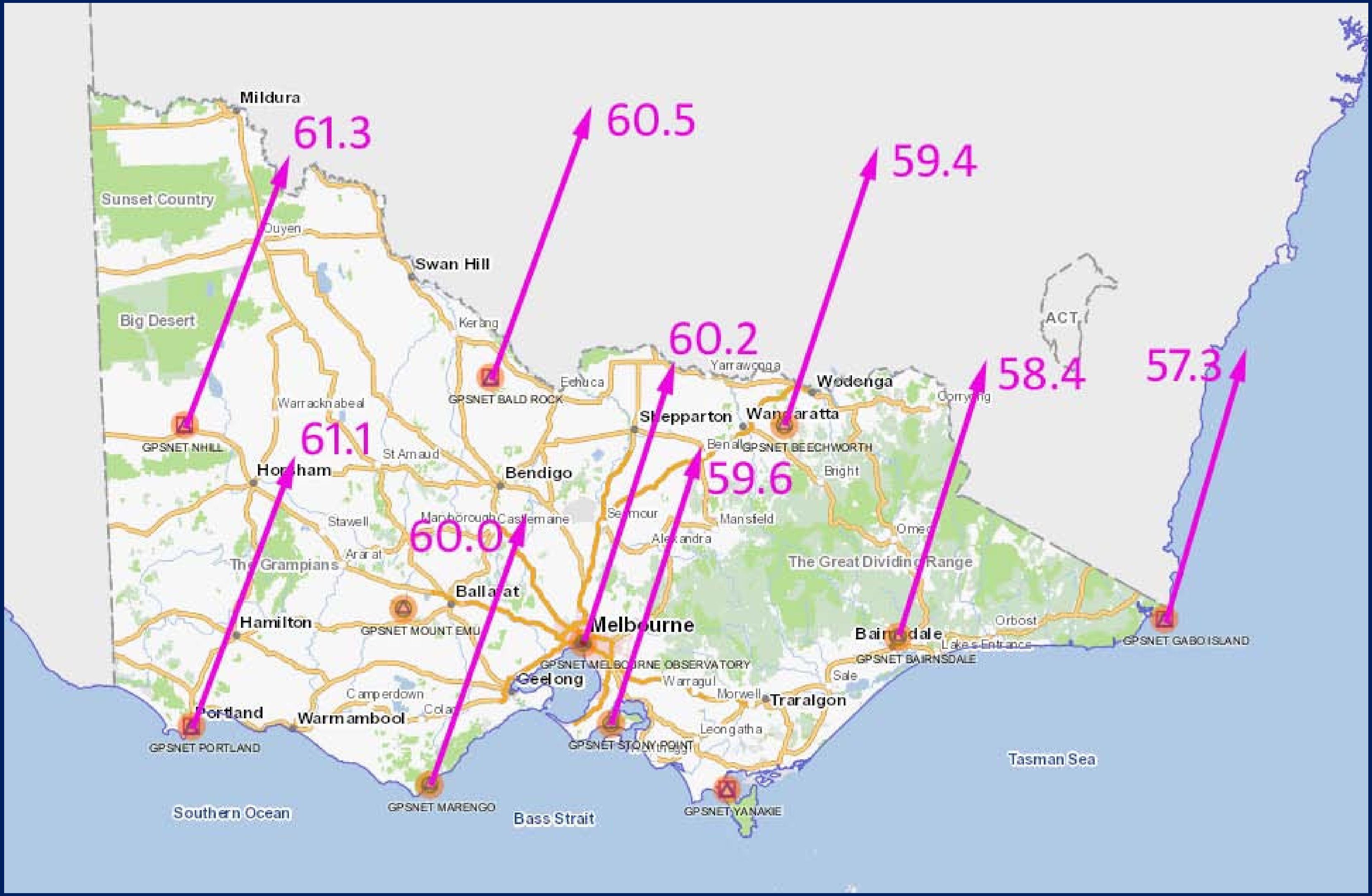


ESRI

Kinematic Spatial Data

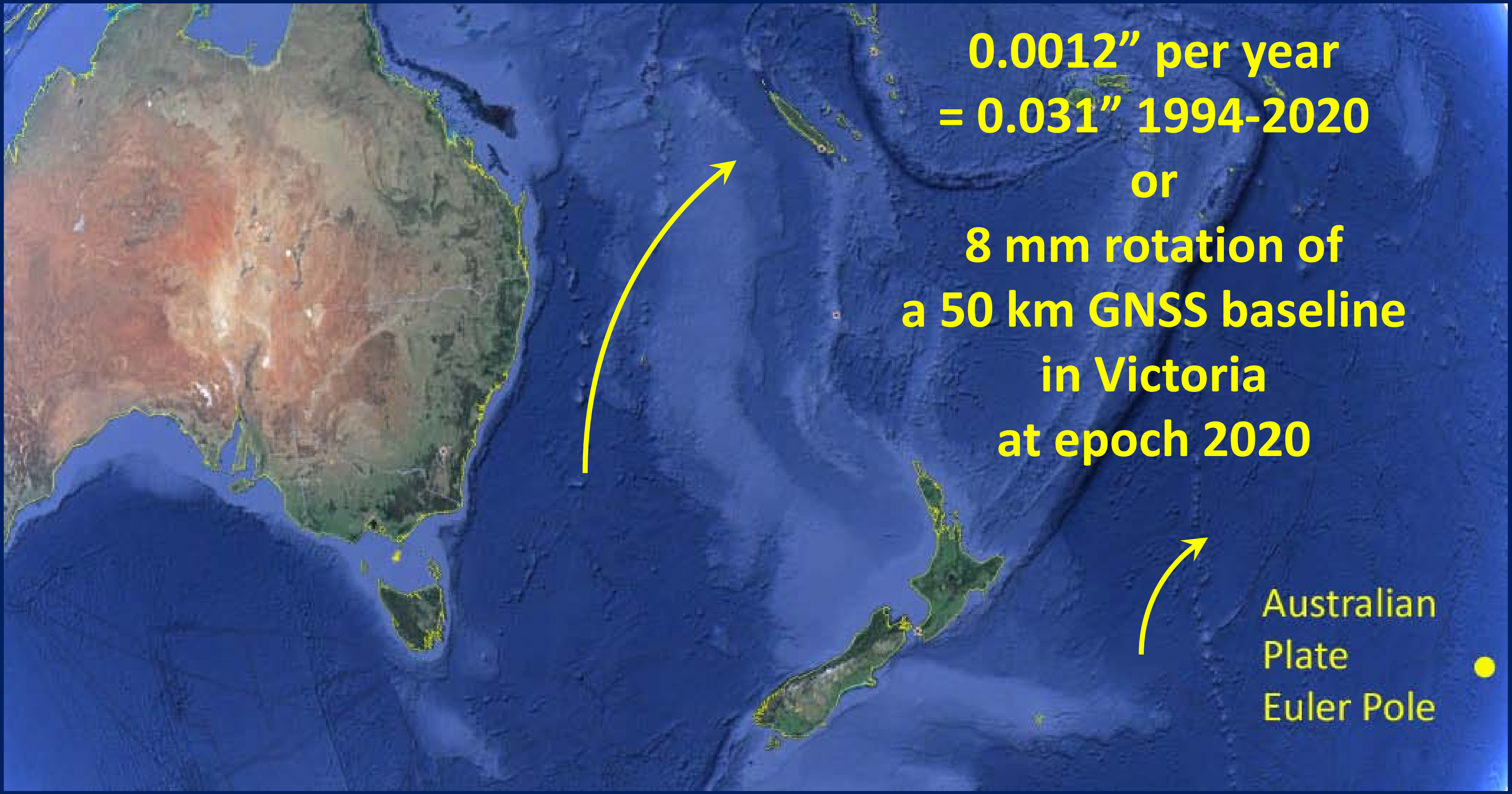
Data "tagged" with datum and epoch metadata

Station velocities (ITRF) – Victorian AuScope – mm/yr



Computed from GA APREF 2014.0 solution (John Dawson and Guorong Hu)

Rotation of Victorian network – Australian Plate motion

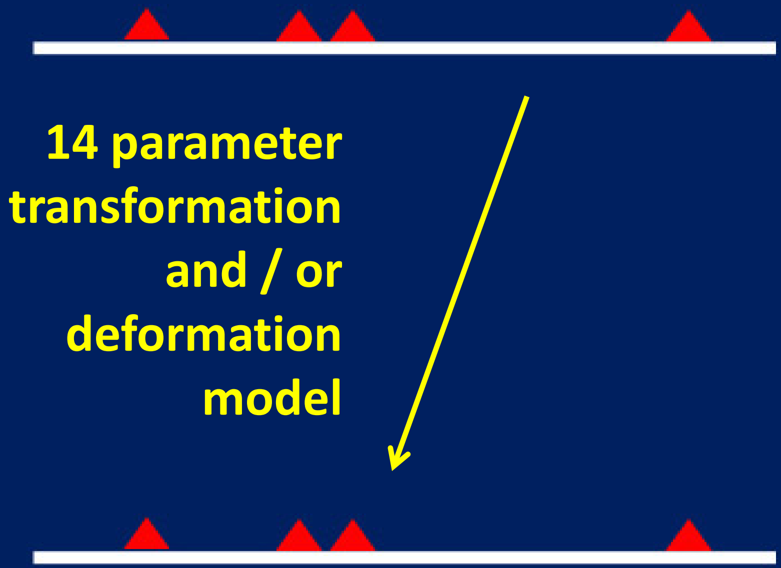


GNSS baseline vector computation is in ITRF at epoch of measurement NOT GDA94!

Positioning precision and plate tectonics

Coordinates of ground features move due to plate tectonics (approx. 60 mm/yr in Victoria)

GNSS Reference Frames (e.g. ITRF2008 and WGS84)



Static Geodetic Datum (e.g. GDA94)

How do we position ourselves now?

Real-time Single Point-positioning (SPP) accuracy 2-10 metres

ITRF

NRTK or RTK
Auspos
(using CORS)
accuracy
5-20 mm

CORS at
Bald Rock
AuScope

GNSS reference frame intrinsically ITRF and transformed to a static frame using 14 parameter model or Euler Pole

ITRF

GDA94

Precise Point-positioning (PPP) accuracy cm-dm (using IGS or Commercial Orbits)

ITRF

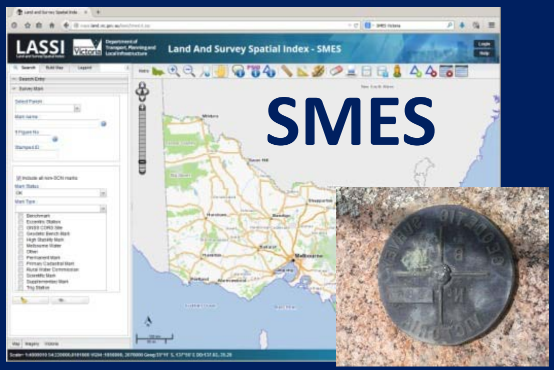
DGNSS and Wide-area RTK (e.g. OmniSTAR and StarFire)
10 cm – 1 m depending on level of service

GDA94

Passive geodetic control
(e.g. PMs, PSMs)

Current compatibility between GNSS usage and GDA94

✓ Good



If used as GNSS reference stn.
Most passive control has PU better than 50 mm, but can be more than 1 m (mostly ROs)

✓ Very good

NRTK and RTK
data processed in GDA94
Long baseline
plate rotation effect
1 mm per 10 km baseline length

✓ Excellent

data processed in ITRF and transformed to GDA94 using 14 parameter model – recommended approach

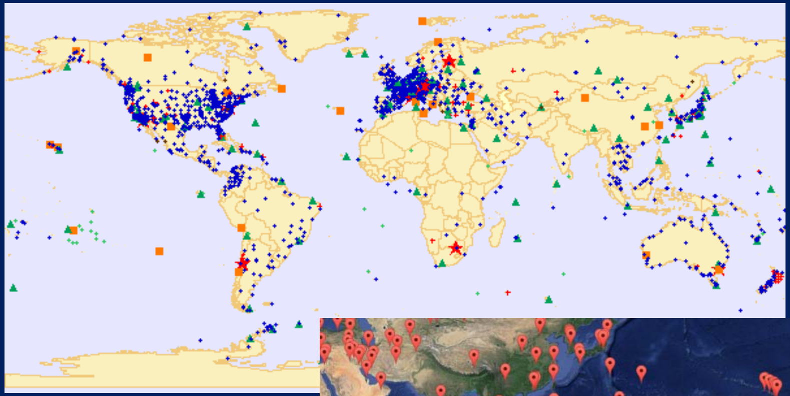
Partial Compatibility (ITRF only)

OmniSTAR.

ITRF2008 – requires 14 parameter transformation otherwise ~ 1.2 m difference

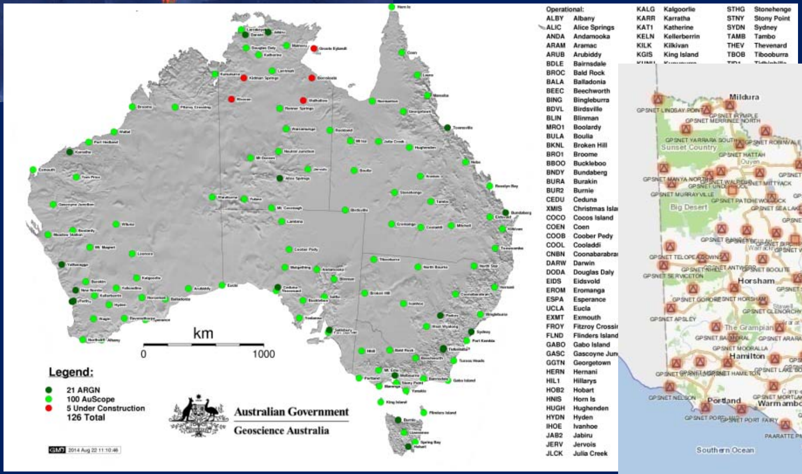
Single Point-positioning – WGS 84 (mass market and handheld)
2-10 m precision, so difference marginally noticeable at present

Hierarchy of Reference Frames in Victoria



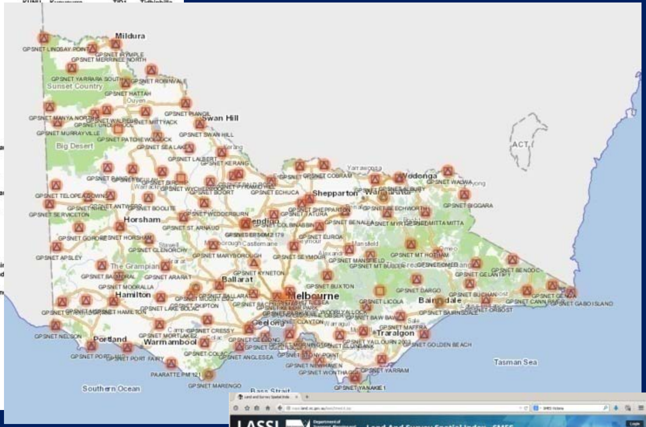
International Terrestrial Reference Frame (ITRF)

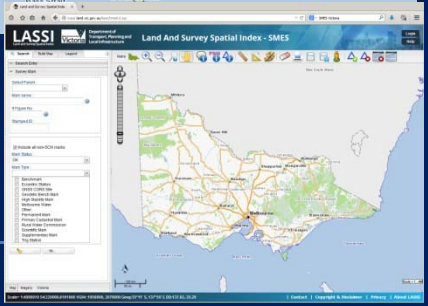
Asia-Pacific Reference Frame (APREF)



Australian Regional GNSS Network (ARGN) & AuScope

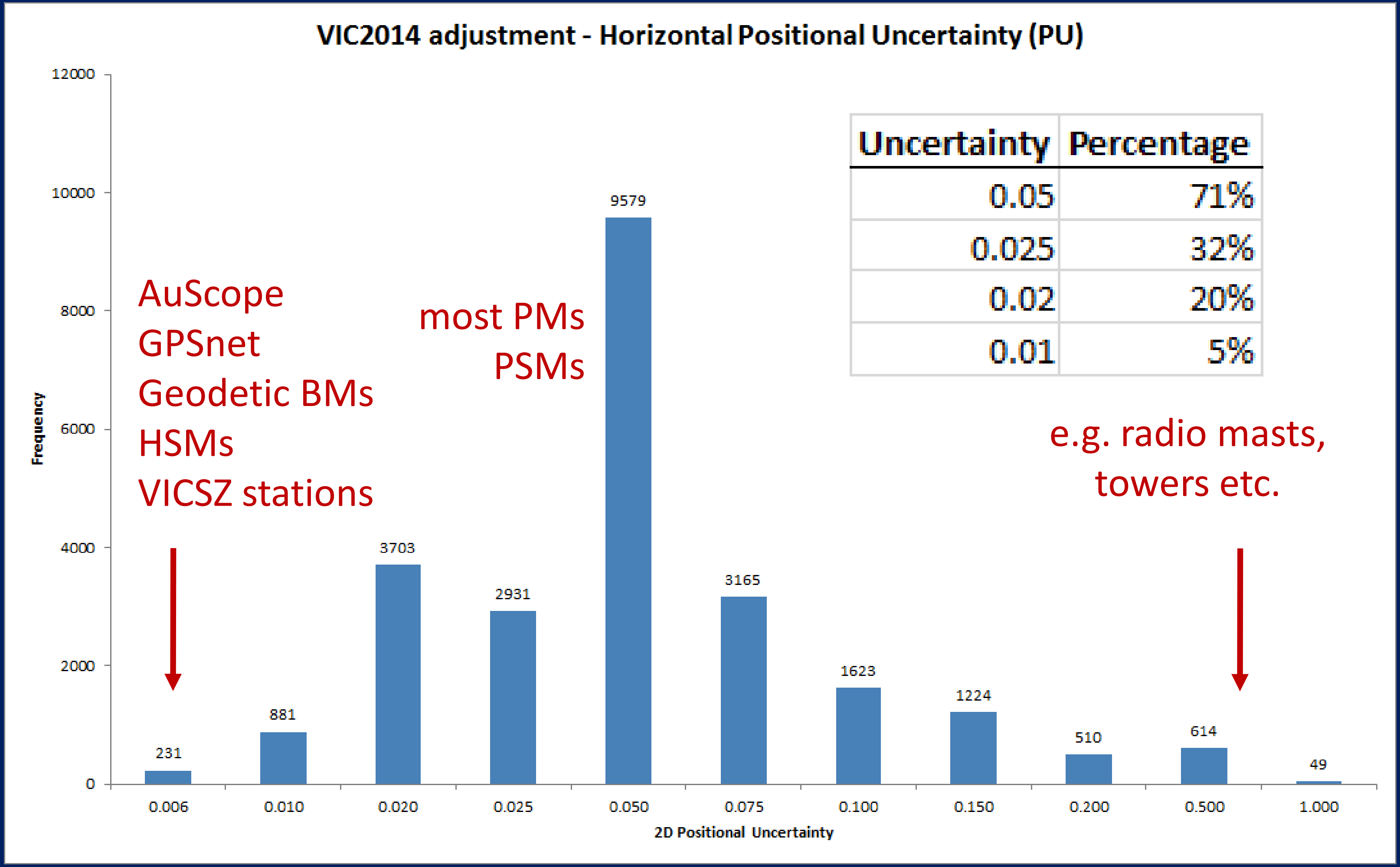
VICMAP Position - GPSnet





Passive geodetic marks – accessed by SMES

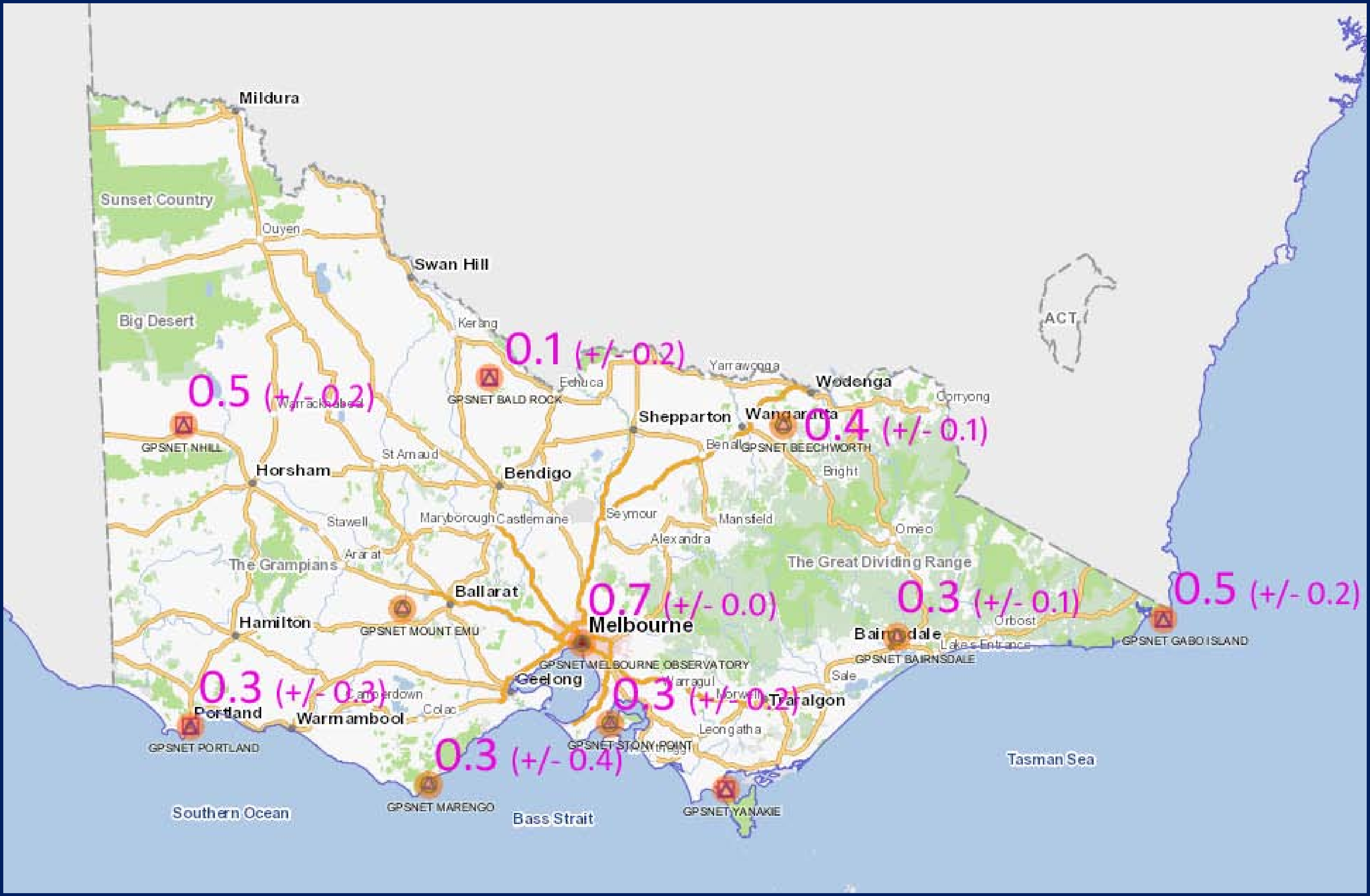
Current status of GDA94 in Victoria



Uncertainty	Percentage
0.05	71%
0.025	32%
0.02	20%
0.01	5%

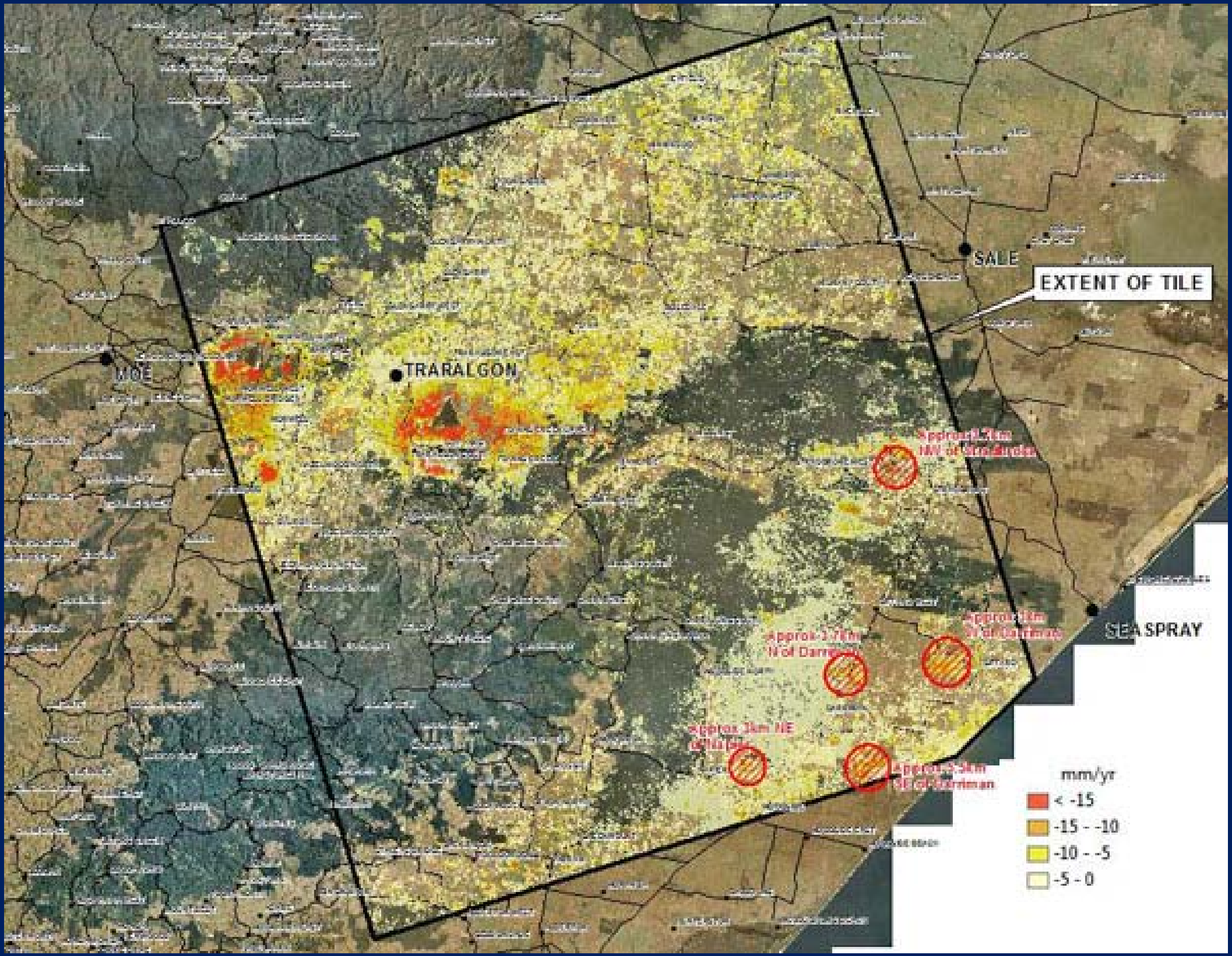
Roger Fraser, Manager Geodetic Survey, OSGV - DTPLI

Stability of Victorian AuScope network mm/yr



Computed from GA APREF 2014.0 solution (John Dawson and Guorong Hu) and ITRF2008 Plate Model (Altamimi et al.)

Localised instability (mining subsidence, clay soil etc.)



From DEPI report -*Trial of satellite radar interferometry (InSAR) to monitor subsidence along the Gippsland Coast*– prepared by Linlin Ge and Xiaojing Li, University of New South Wales

Current proposal for datum modernisation (ICSM PCG)

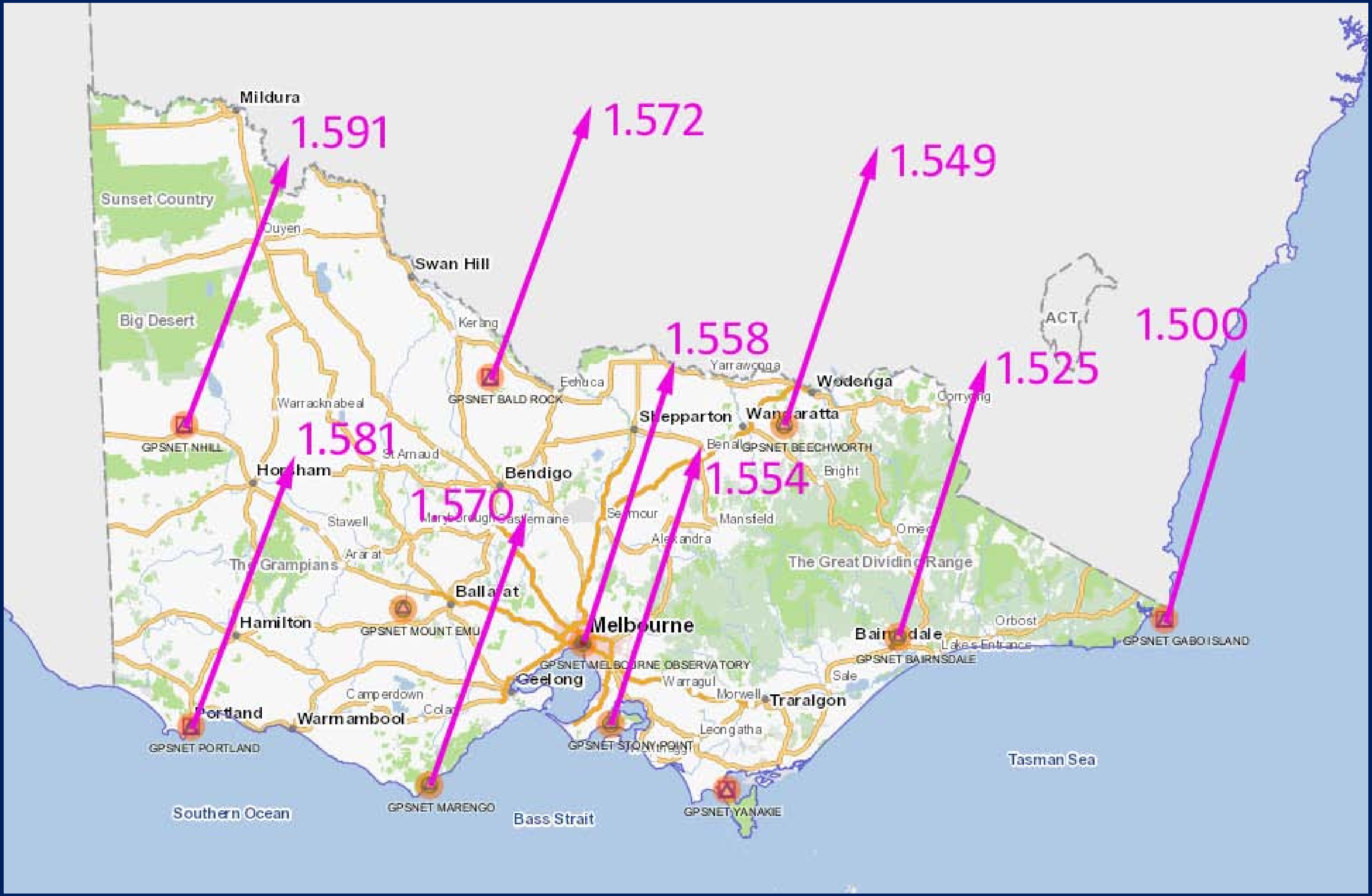
Update GDA from current reference epoch (1994.0 for GDA94) to epoch 2020.0 (static datum readjustment and update with annual readjustments up until 2020)

From 2020 onwards, Australian datum (or Australian Terrestrial Reference Frame) is proposed to be fully kinematic and continuously aligned with ITRF or GGRF

Positional Uncertainties will improve from ~8 mm (GDA94) to ~ 2 mm (2020 datum) at epoch of measurement

Ellipsoid Height changes of ~ 80 mm in Victoria
(will require definition of Ausgeoid09 in terms of new datum)

GDA94 to 2020 epoch – coordinate change (m)



Transformation options from GDA94 to epoch 2020.0

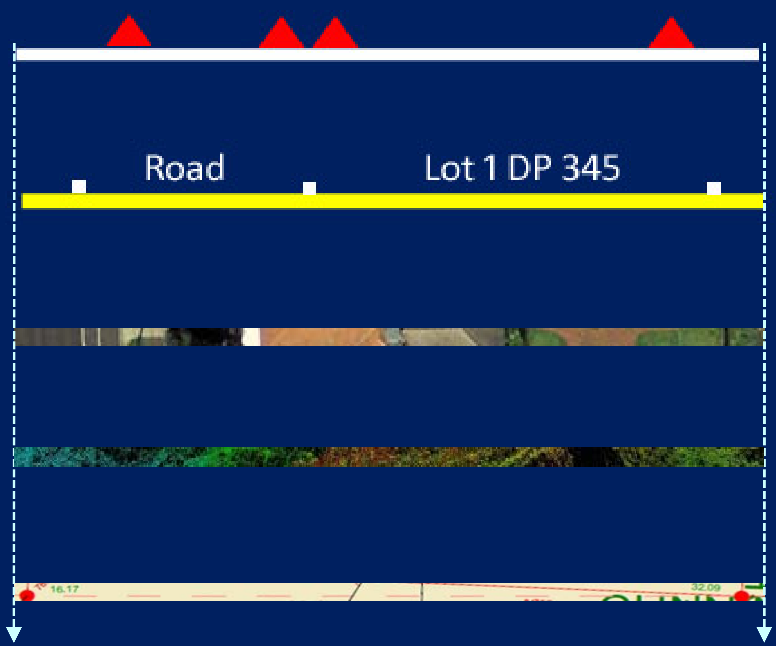
7-parameter transformation
Euler pole transformation (3 parameter)
Absolute deformation model (coordinate shift e.g. NTv2)
7-parameter + residual deformation model (NTv2)
Euler pole + residual deformation model (NTv2)

Transformation options from GDA94 to kinematic ATRF

14-parameter transformation (7 parameters + rates + epoch)
Euler pole transformation (3 parameter + epoch)
Absolute deformation model (coord. shift + rate + epoch)
14-parameter + residual deformation model + epoch
Euler pole + residual deformation model + epoch

GIS requirement - Alignment of Data in a 2D/3D GIS

Different layers in GIS have to be aligned at a common epoch for meaningful analysis and data context (relative precision of layers wrt. each other and datum)



Geodetic Control layer (Datum e.g. GDA94)

Cadastral Layer (GDA94)

Imagery Layer (GDA94?)

Elevation Layer GDA94 (e.g. LiDar)

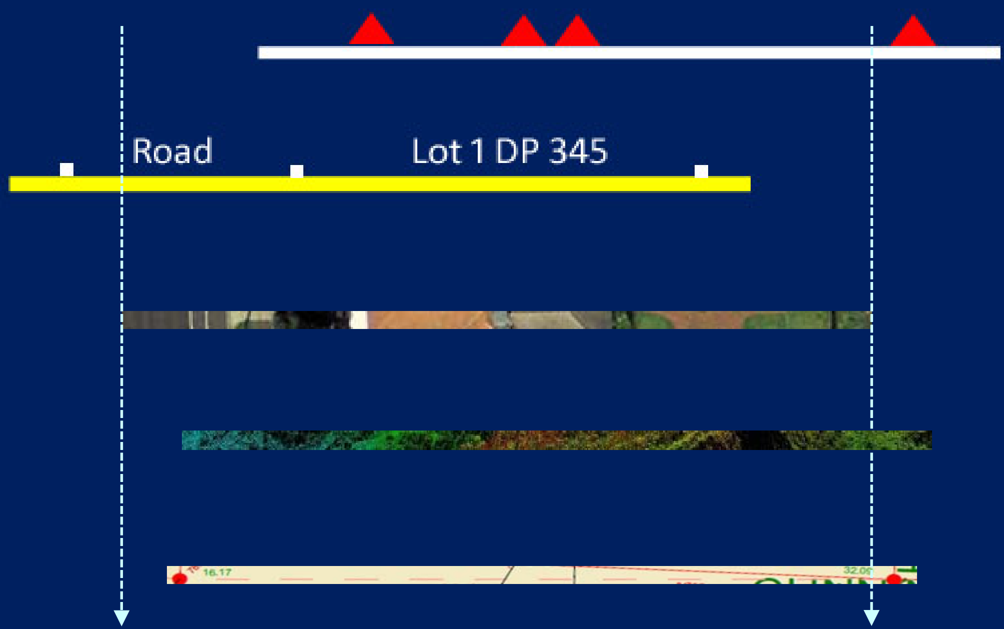
Utilities Layers (GDA94)
(e.g. Water, Electricity, Optical Fibre)

Existing GDA94 GIS data can be transformed to 2020 or vv. using a 7 parameter transformation (not computed yet)

Future challenges –
Alignment of Data with arbitrary epochs in a 4D GIS

Different layers in GIS <u>still</u> have to be aligned at a common epoch for meaningful analysis and context.

Potential for metre + errors if epoch metadata is ignored



Geodetic Control layer (Kinematic Datum)
e.g. epoch 2026.45

Cadastral Layer (e.g. epoch 1994.0)

Imagery Layer (e.g. epoch 2010.095)
(Raster layer adopted as common epoch for computational efficiency)

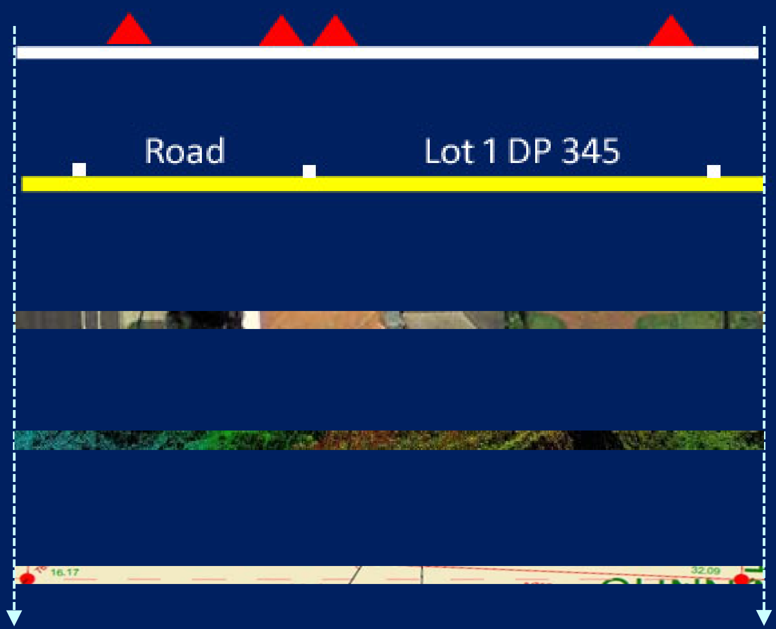
Elevation Layer (e.g. LiDar) (e.g. 2014.98)

Water utility Layer (e.g. 2014.0)

Requires universal acceptance and consistent application of kinematic transformation models in all GIS – requires GIS user skill and care!

Alignment of Data in a 4D GIS

14-parameter transformation or deformation model used to align different epoch layers and data at a common epoch



Geodetic Control layer (Datum)
– e.g. 2026.45 transformed to 2010.095

Cadastral Layer (e.g. 1994.0 transformed to 2010.095)

Imagery Layer (e.g. 2010.095)
(epoch 2010.095 used as common epoch)

Elevation Layer (e.g. LiDar)
(e.g. 2014.98 transformed to 2010.095)

Water utility Layer
(e.g. 2014.0 transformed to 2010.095)

Challenges – User perspectives and software

A 1.6 m "mistake" is small for many users

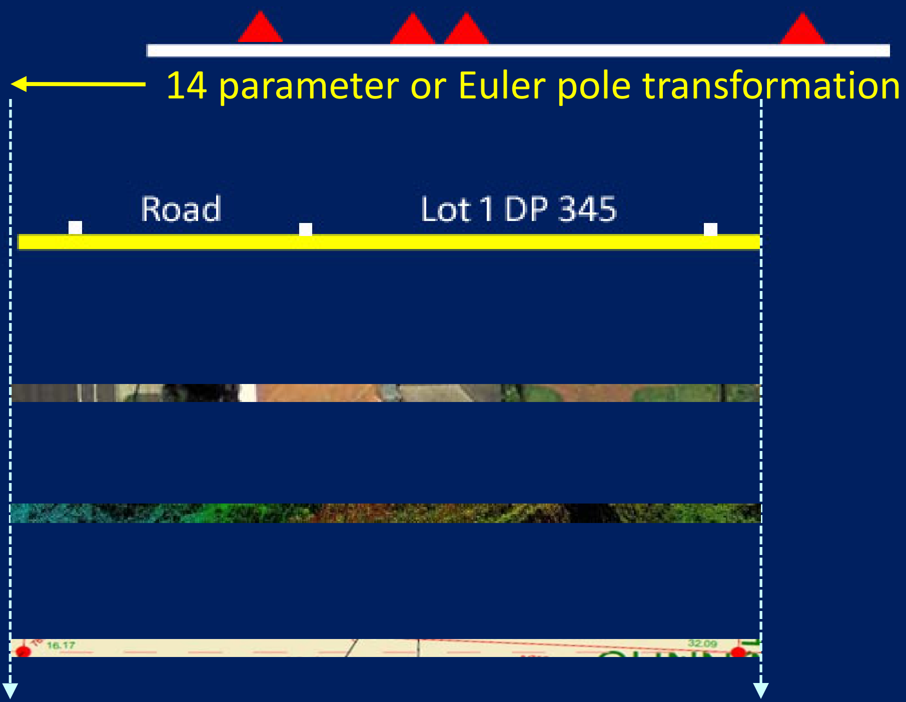
but can be significant for others!

Terrestrial surveys (e.g. total station, TLS) data epoch is dependent upon epoch of passive control coordinates (are they updated monthly or not?)

Will surveying and CAD software (e.g. Liscad, 12DModel, Terramodel) be able to manage survey data within a kinematic datum?

Other options for datum modernisation– (e.g. dual-frame)

Positioning in ITRF but consistently transforming positions to an Australian plate fixed frame so that data can maintain local context (approach adopted in Europe (EUREF), North and South America)



Requires <u>consistent</u> application of 14-parameter and deformation models in positioning equipment – and surveyor skill!

Option for a Reference Frame fixed to the Australian Plate (a GDA94 like reference frame)

Defined by Euler pole of the Australian Plate
(Frame moves with stable portion of the Australian Plate)

Station velocities minimised (typically less than 0.2 mm/yr)

Reference epoch has minimal impact on coordinate changes

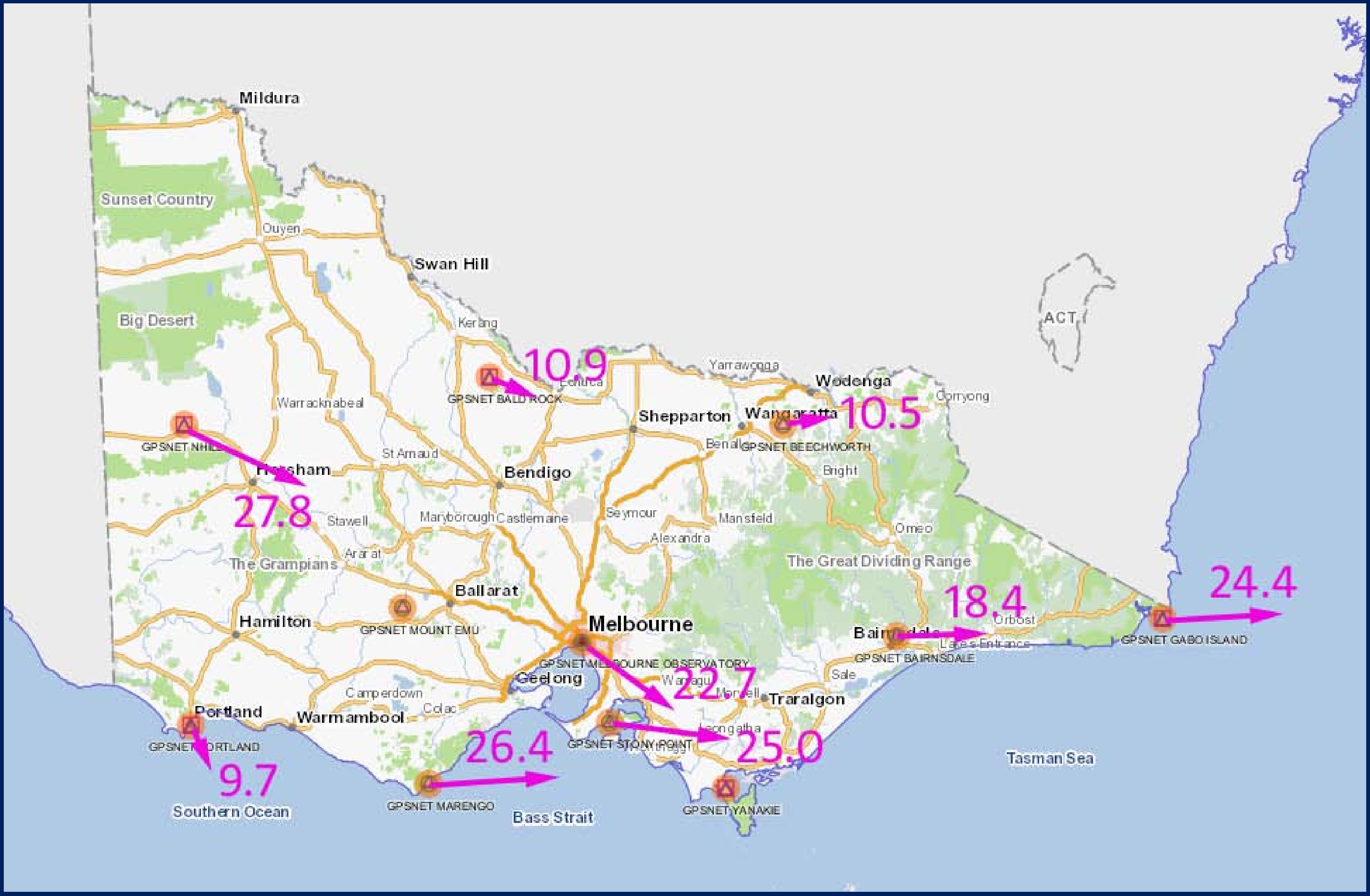
Distortion free

Linkable directly to ITRF by 3 parameter transformation
(without loss of precision)

Localised deformation can be better visualised and analysed

Supports stability of GIS data management until 4D GIS is fully developed, tested and implemented

Correction to Victorian datum if epoch 1994 is maintained (ITRF2008 @ 1994.0) (mm)



Datum Modernisation & epoch change - Conclusions

✓ Benefits

Maintains alignment with ITRF
Supports native GNSS precise positioning
Mitigates effects of deformation and plate rotation

Challenges

~1.6 metre change in fundamental coordinate system
Requires robust GIS transformation strategy and metadata
Risks if epoch or datum metadata are not managed or communicated in a robust manner

Two-frame option (ITRF and Australian plate fixed frame)

To maximise benefits of either type of reference frame
(until 4D GIS and transformation tools are developed)