Case Study Australia

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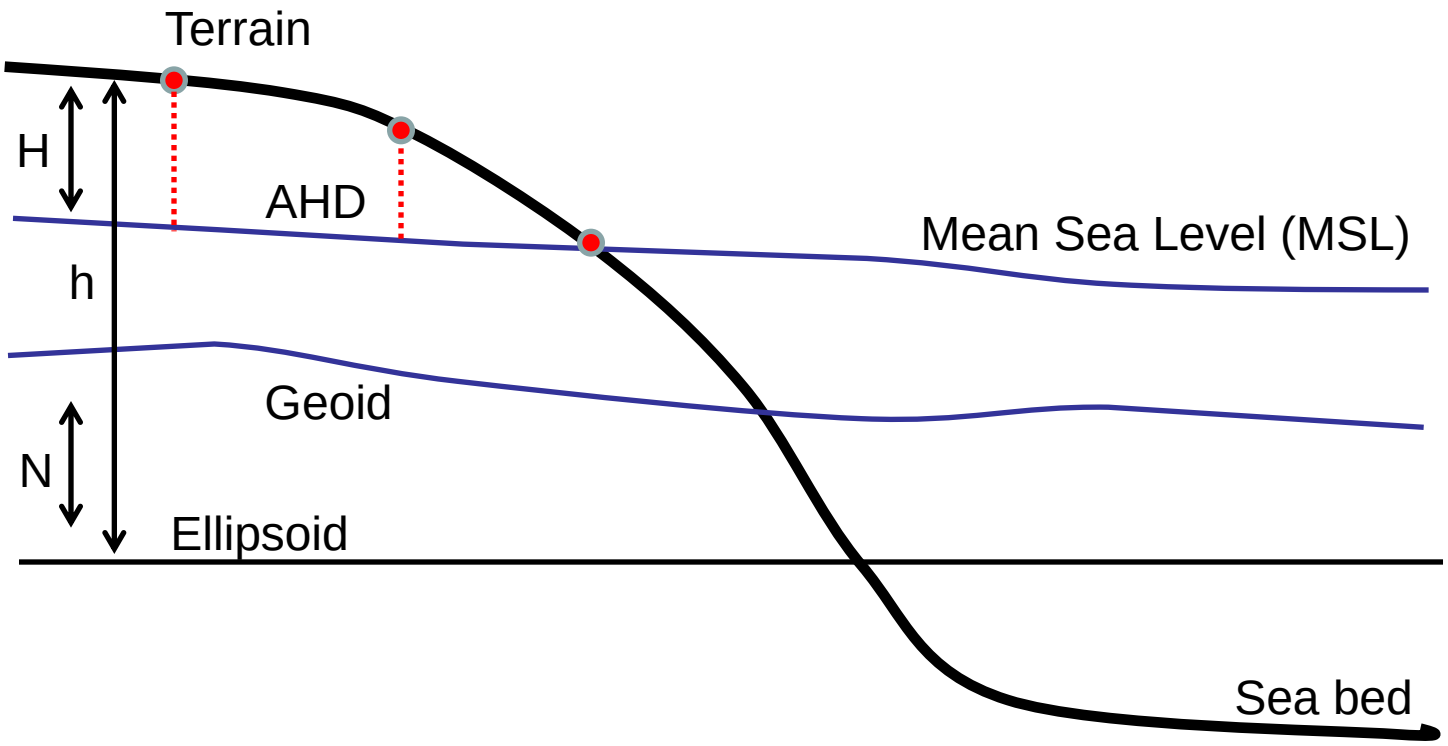
Chair UN-GGIM-AP WG1
Chair APREF

Overview

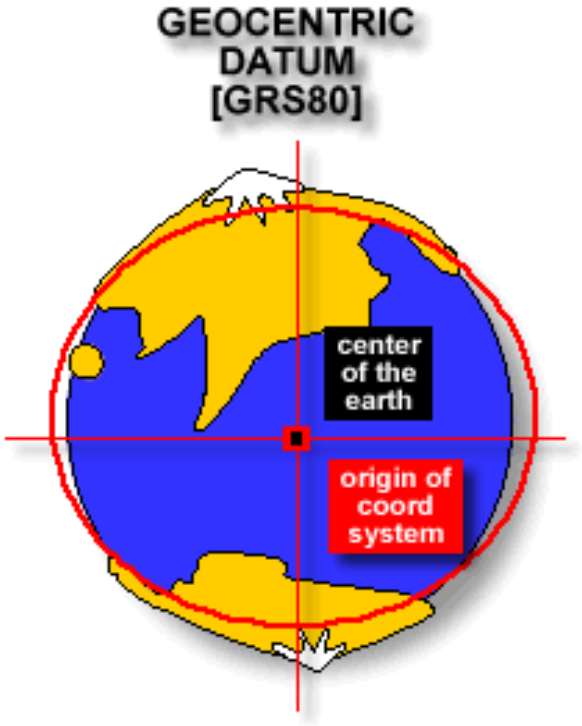
1. Australian height system
   - Australian Height Datum (AHD)
   - Ellipsoidal heights
   - National Geoid model
2. Satellite InSAR contributions
   - InSAR basics and examples
3. A future Australian height datum
   - Problems with AHD
   - Future options

Part 1 – Australian height system

Concepts: AHD (H), Geoid (N), Ellipsoid (h)

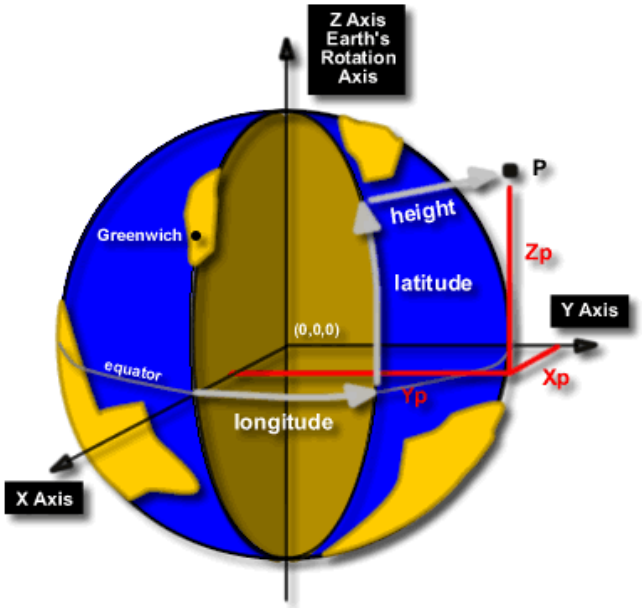


Concepts: Ellipsoid (h)



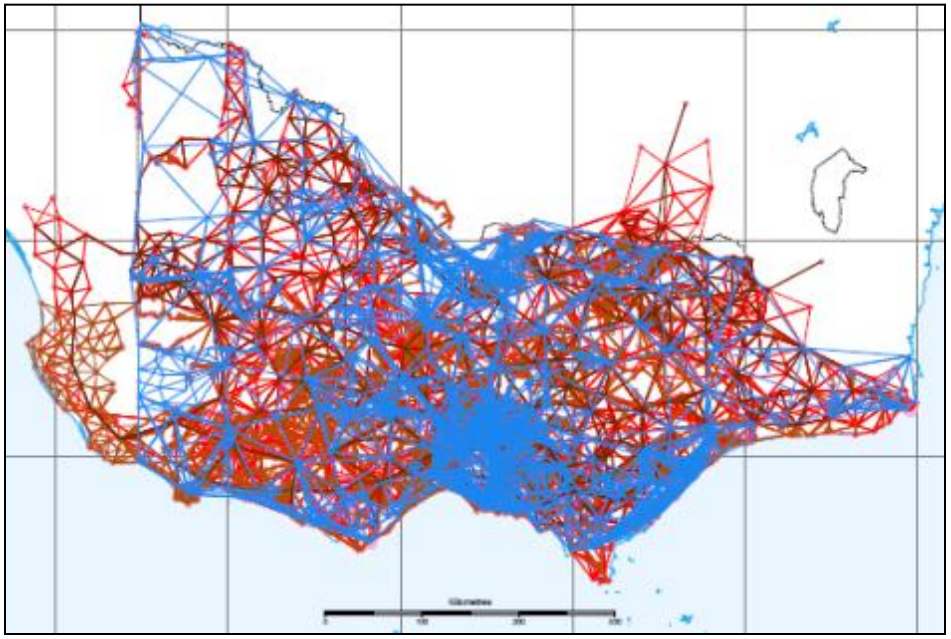
- Australia: GRS80 ellipsoid realised Geocentric Datum of Australia 1994 (GDA94 - ITRF1992@1994)
- Offset from ITRF2005 by 9cm in vertical component
- Relationship between ITRF and GDA94 realised through a 14 parameter transformation
- *ITRF to GDA94 coordinate transformations*, John Dawson and Alex Woods, Journal of Applied Geodesy 4 (2010), 189–199 (available on www.ga.gov.au)

Concepts: Ellipsoid (h)

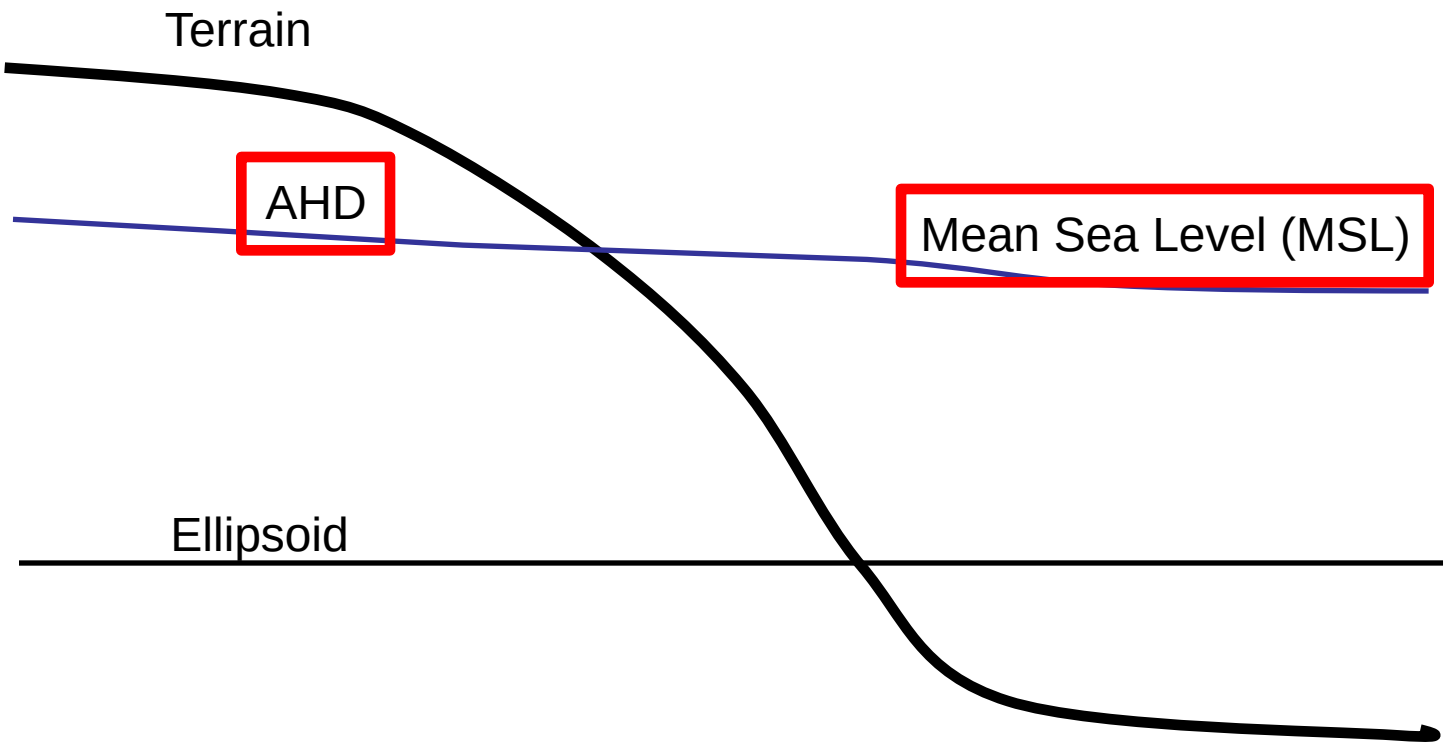


- Hierarchical geodetic adjustment connected to Australian Fiducial Network (AFN)
- AFN includes highest quality Australian International GNSS Service (IGS) and Asia Pacific Reference Frame (APREF) GNSS stations
- For more information on APREF go to www.ga.gov.au

Concepts: Ellipsoid (h)



Concepts: AHD (H)



The Australia Height Datum (AHD)

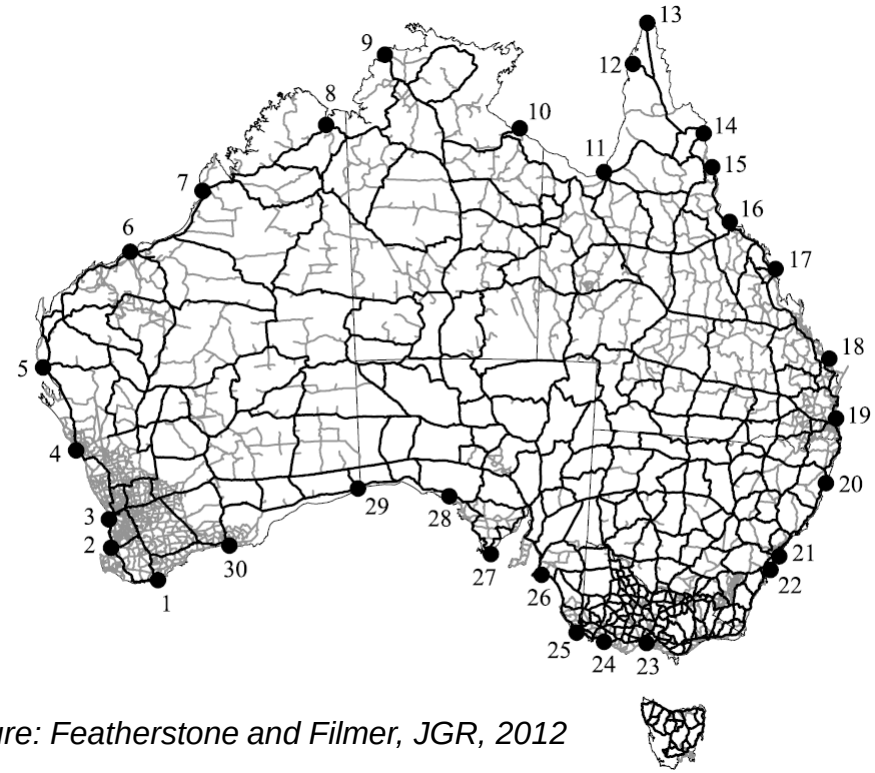


Figure: Featherstone and Filmer, JGR, 2012

- Unique internationally in that it is a single levelling network traversing an entire continent
- Local mean sea level given zero heights determined between 1966 and 1968
- 30 tide gauges around mainland Australia

The Australia Height Datum (AHD)

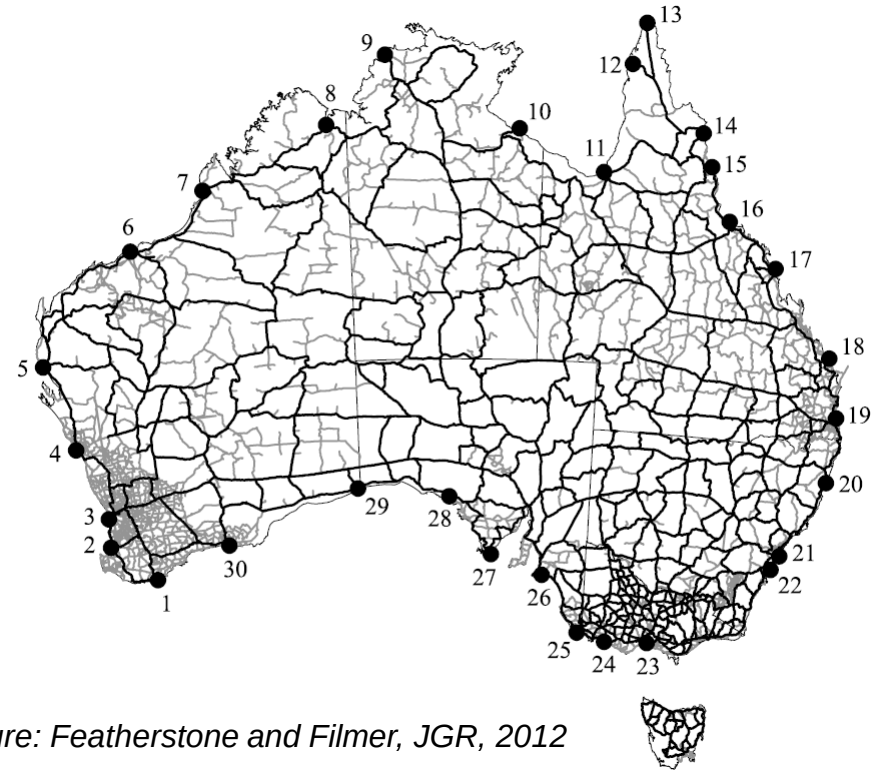


Figure: Featherstone and Filmer, JGR, 2012

- Multiple tide gauges used to avoid negative heights on dry land
- Gravity data was not available along the levelling traverses

The Australia Height Datum (AHD)

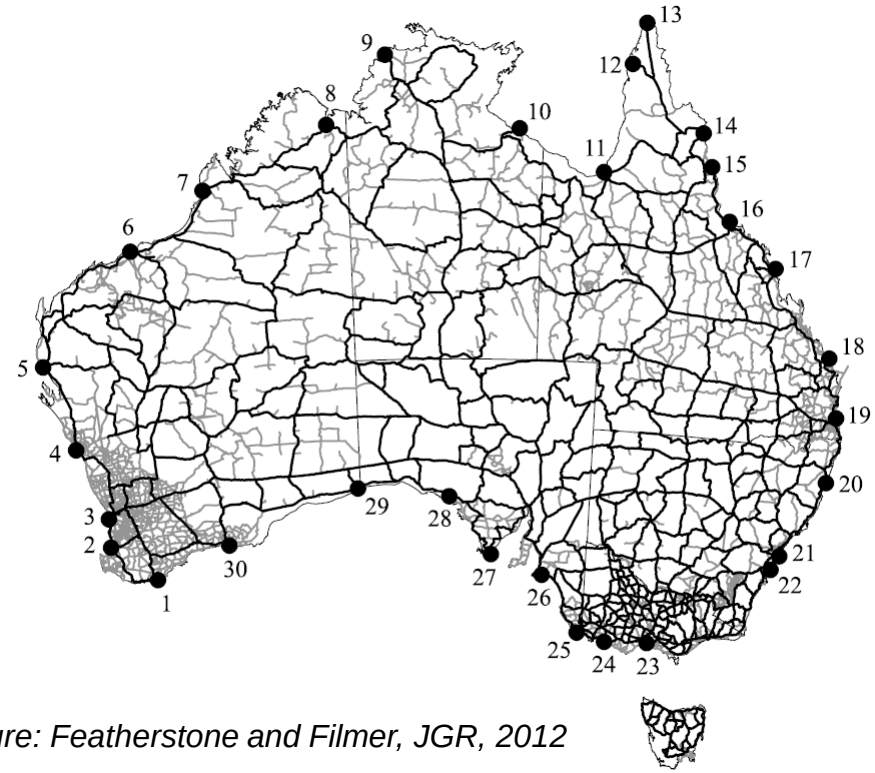


Figure: Featherstone and Filmer, JGR, 2012

- Differential levellling data had a normal-orthometric (latitude dependent) correction applied to partially account for non-parallelism of equipotential surfaces
- Normal-orthometric correction has a magnitude of 15mm/degree or ~0.4m in total

The Australia Height Datum (AHD)

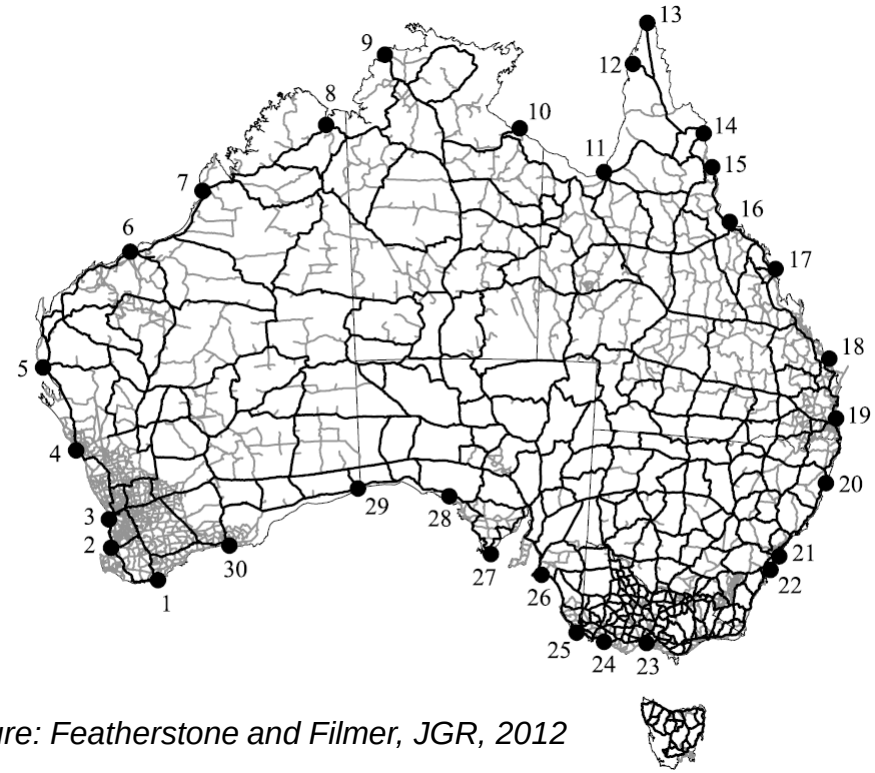


Figure: Featherstone and Filmer, JGR, 2012

- 97,230 kilometres of two-way basic levelling (black lines)
- Least squares adjustment
- Additional supplementary adjustment (grey lines)
- Tasmania: mean sea level for 1972 at the tide gauges at Hobart and Burnie (32 tide gauges in total)

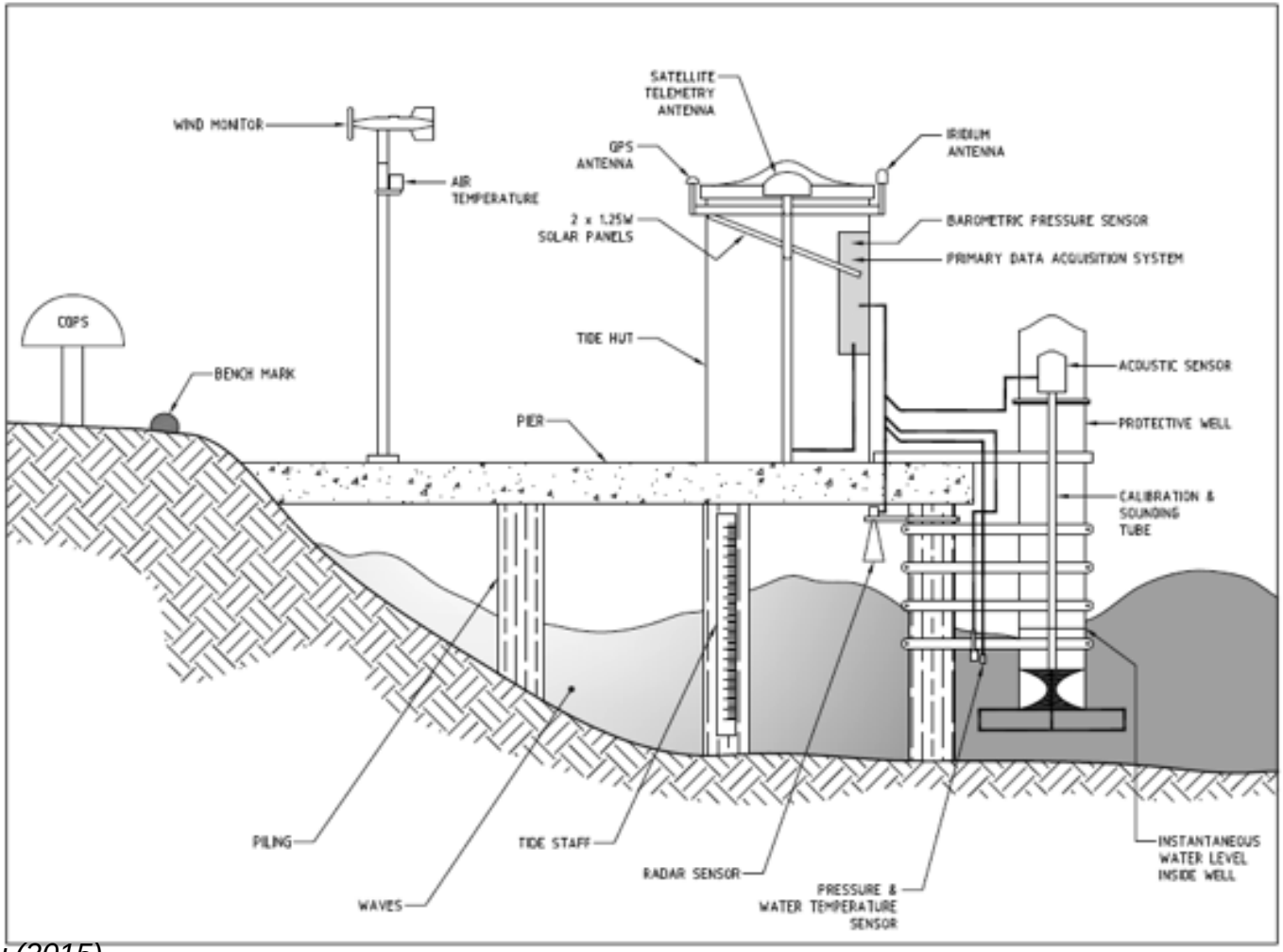
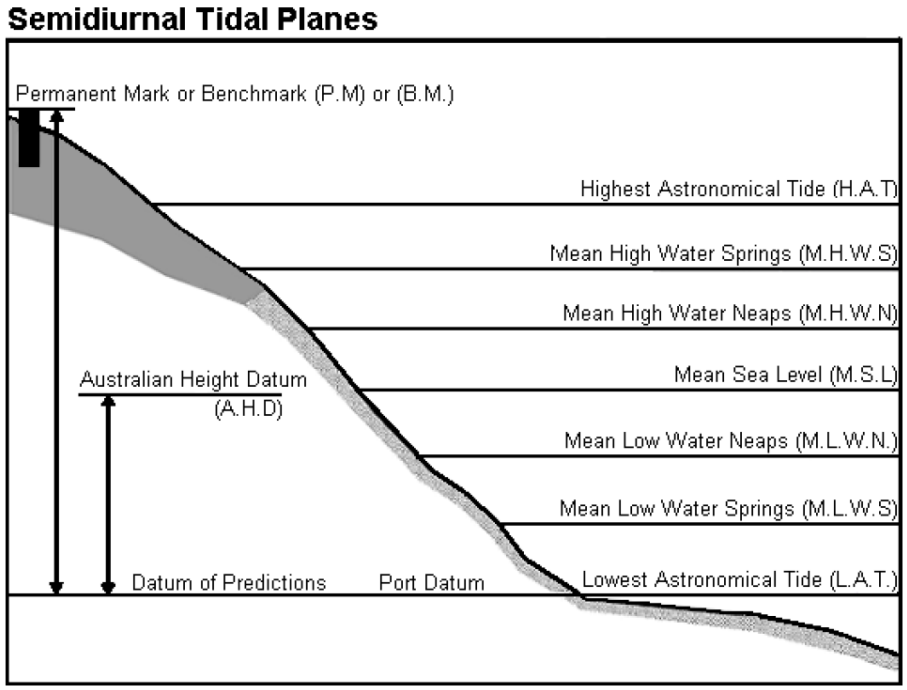
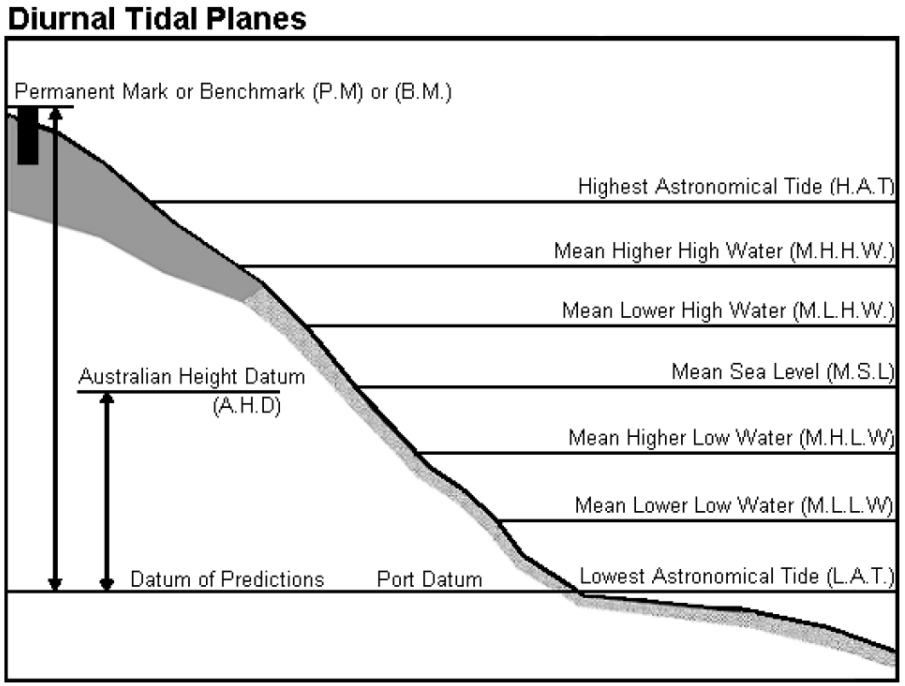


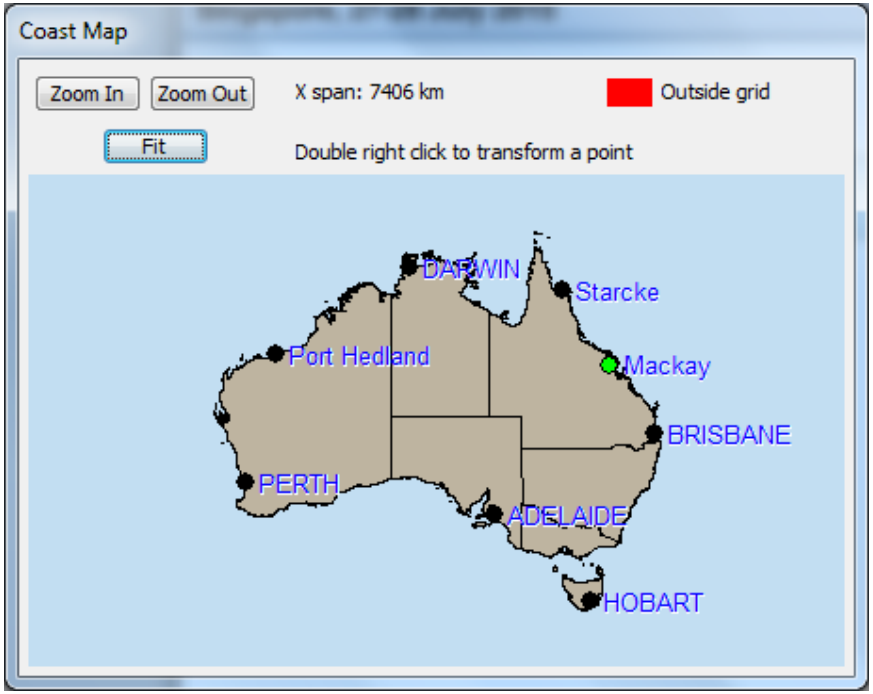
Figure: bom.gov.au (2015)

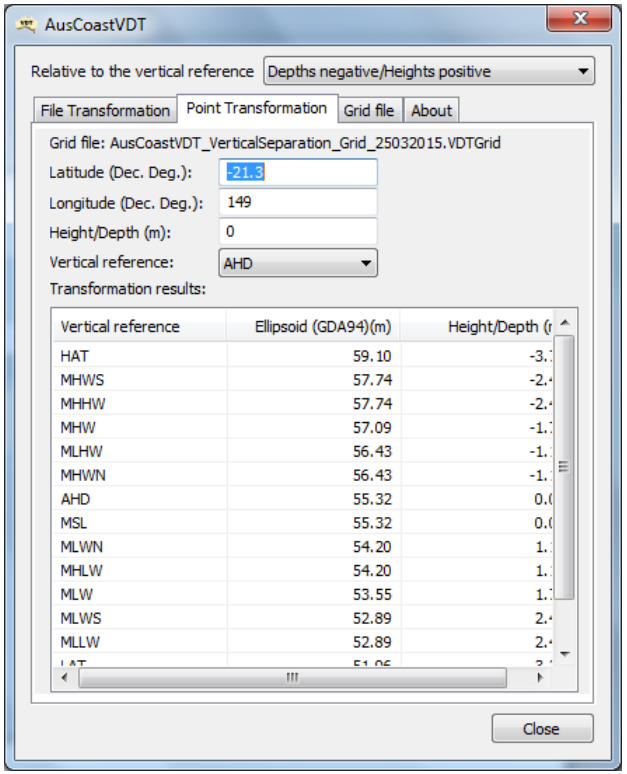
Bathymetric surfaces used in Australia



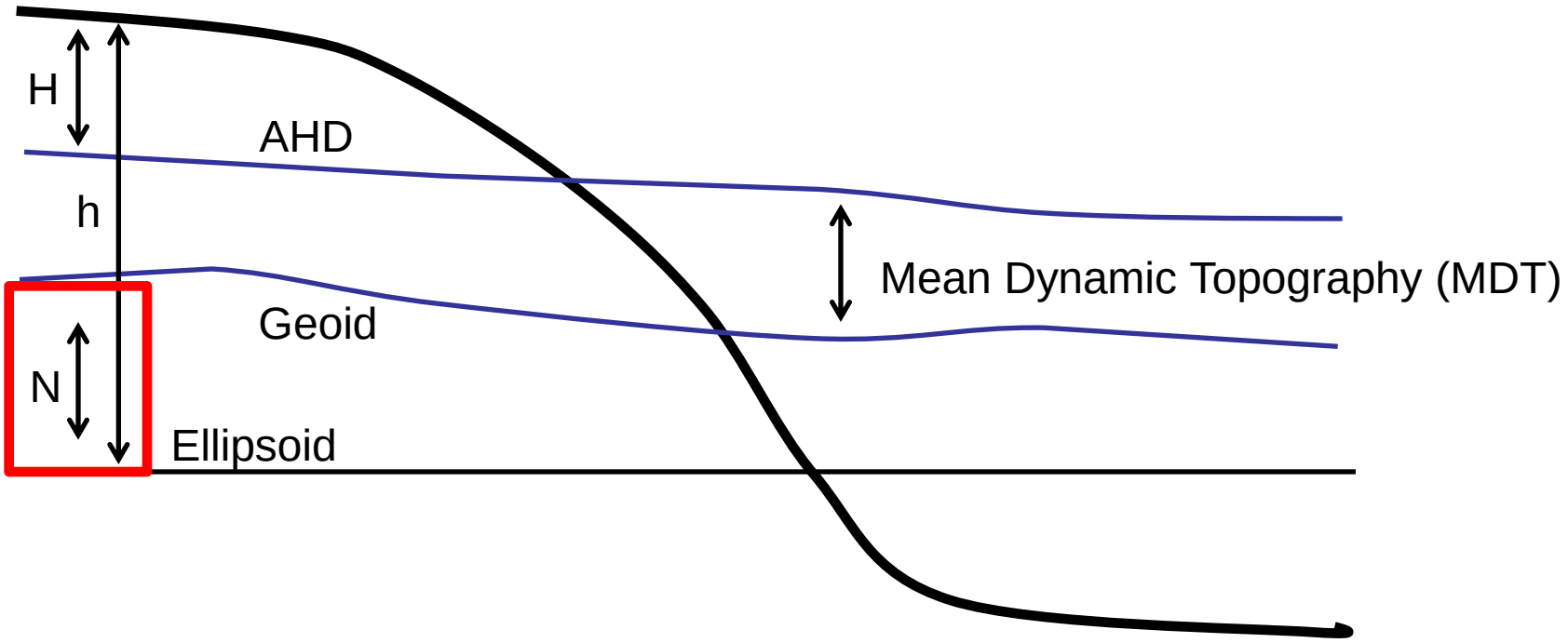


Bathymetric surfaces used in Australia: AusCoastVDT

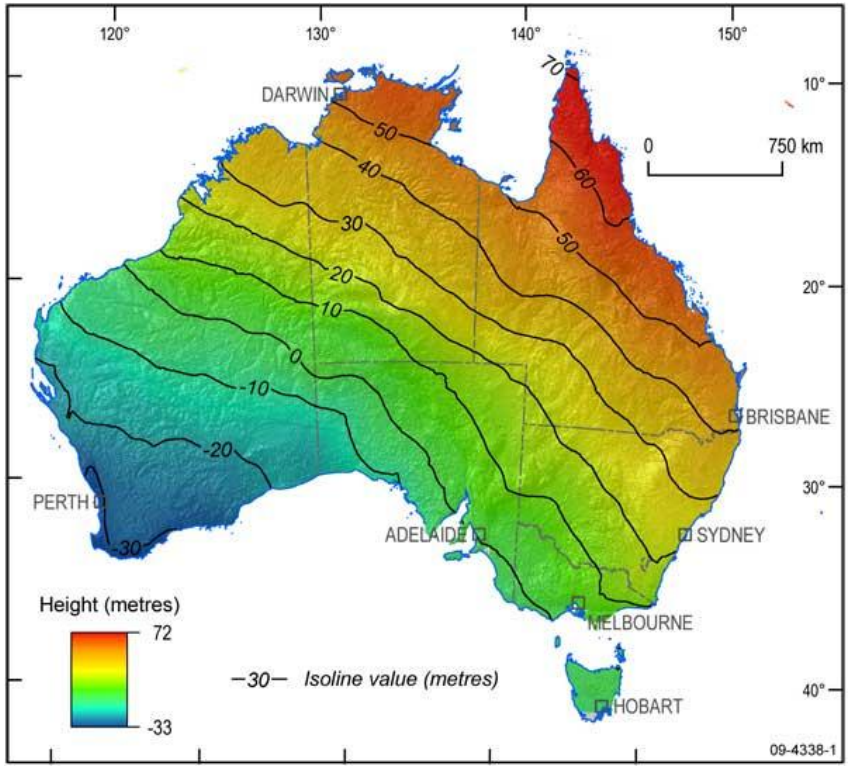




Concepts: Geoid (N)

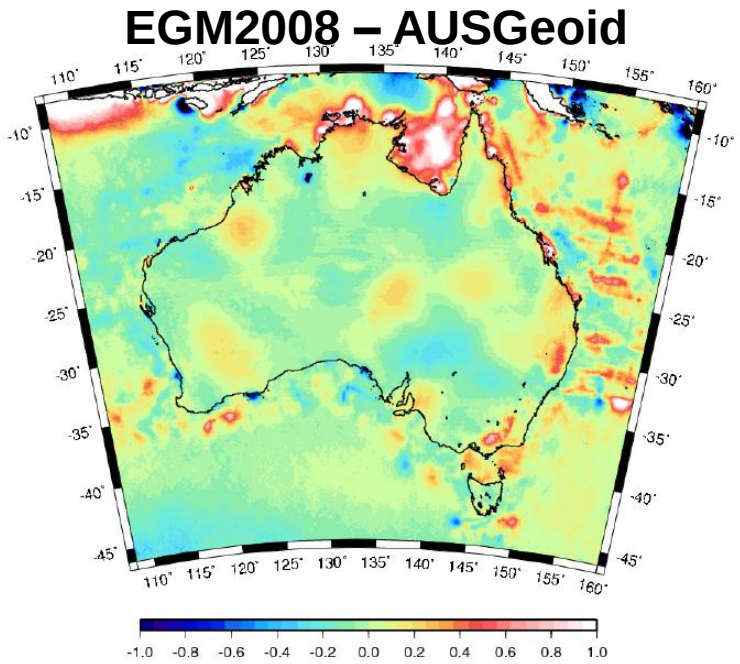


National Geoid (N)



- Quasigeoid model was computed using a hybrid of the remove-compute-restore technique with a degree-40 deterministically modified kernel over a one-degree spherical cap
- Spherical harmonic synthesis of Earth Geopotential Model 2008 (EGM2008) and 1.4 million points from Geoscience Australia's land gravity database
- Australian digital elevation model (9"x9" GEODATA-DEM9S)

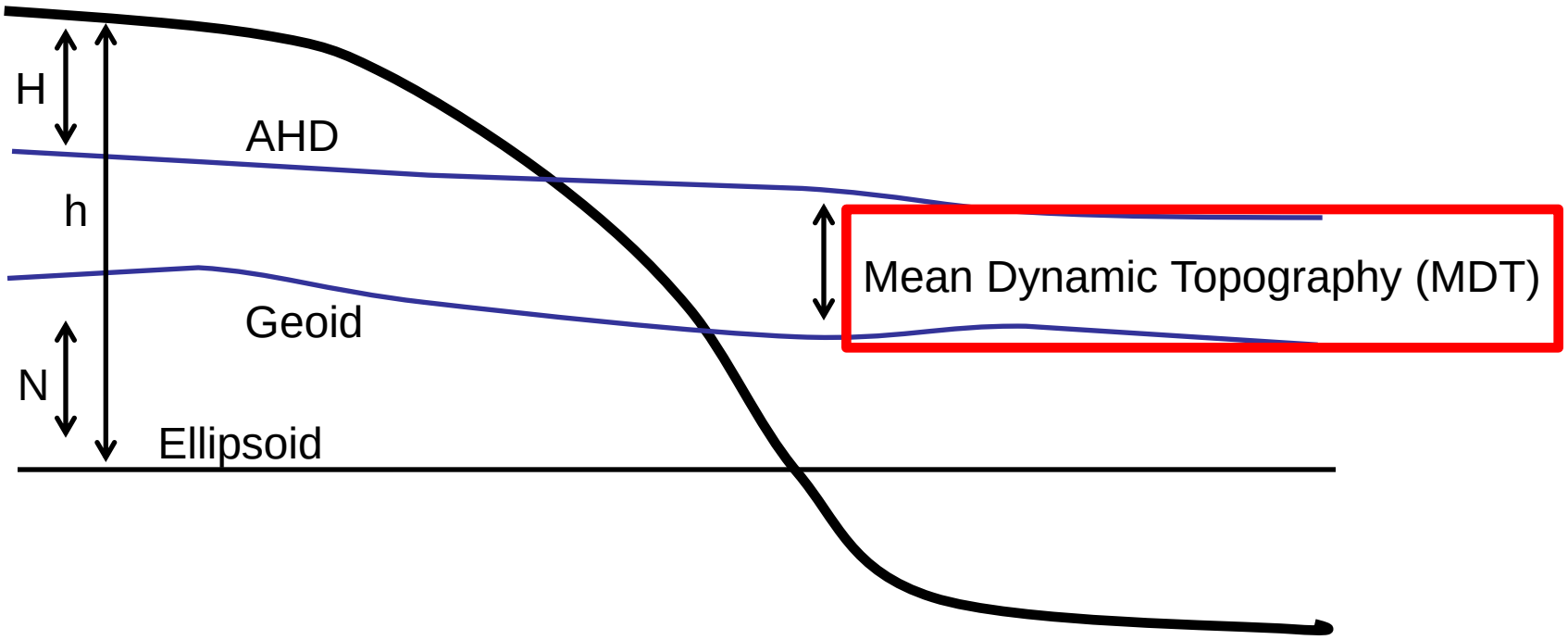
Australia's National Geoid Model



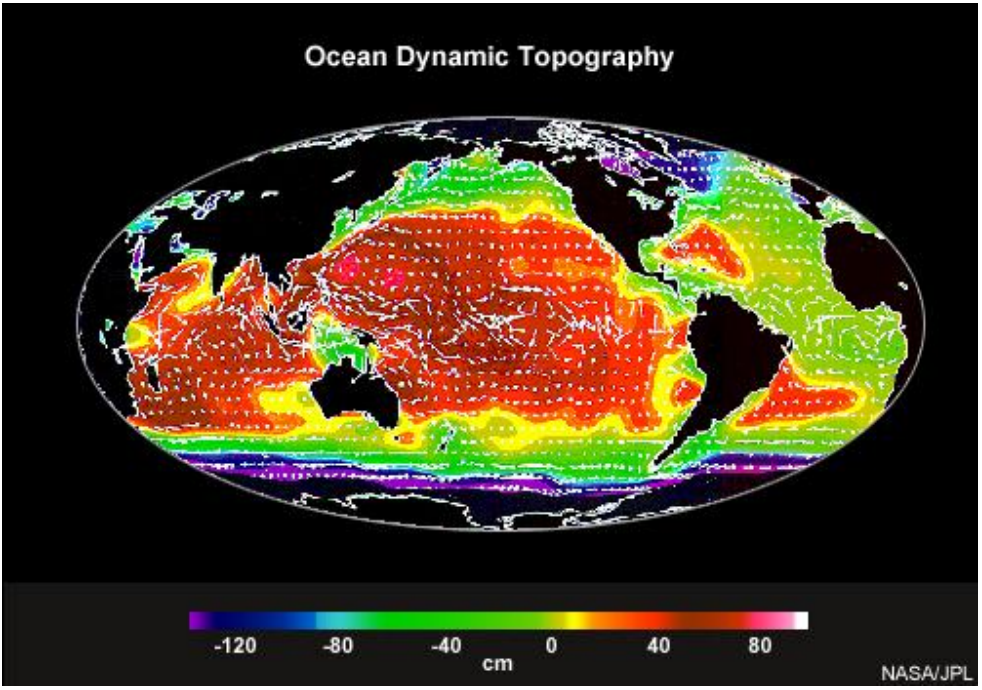
Source: Claessens et al., 2009

- Altimeter-derived gravity anomalies offshore (1'x1' DNSC2008GRA)
- Up to 50cm differences between EGM2009 and the quasigeoid

Concepts: AHD, Geoid, Ellipsoid

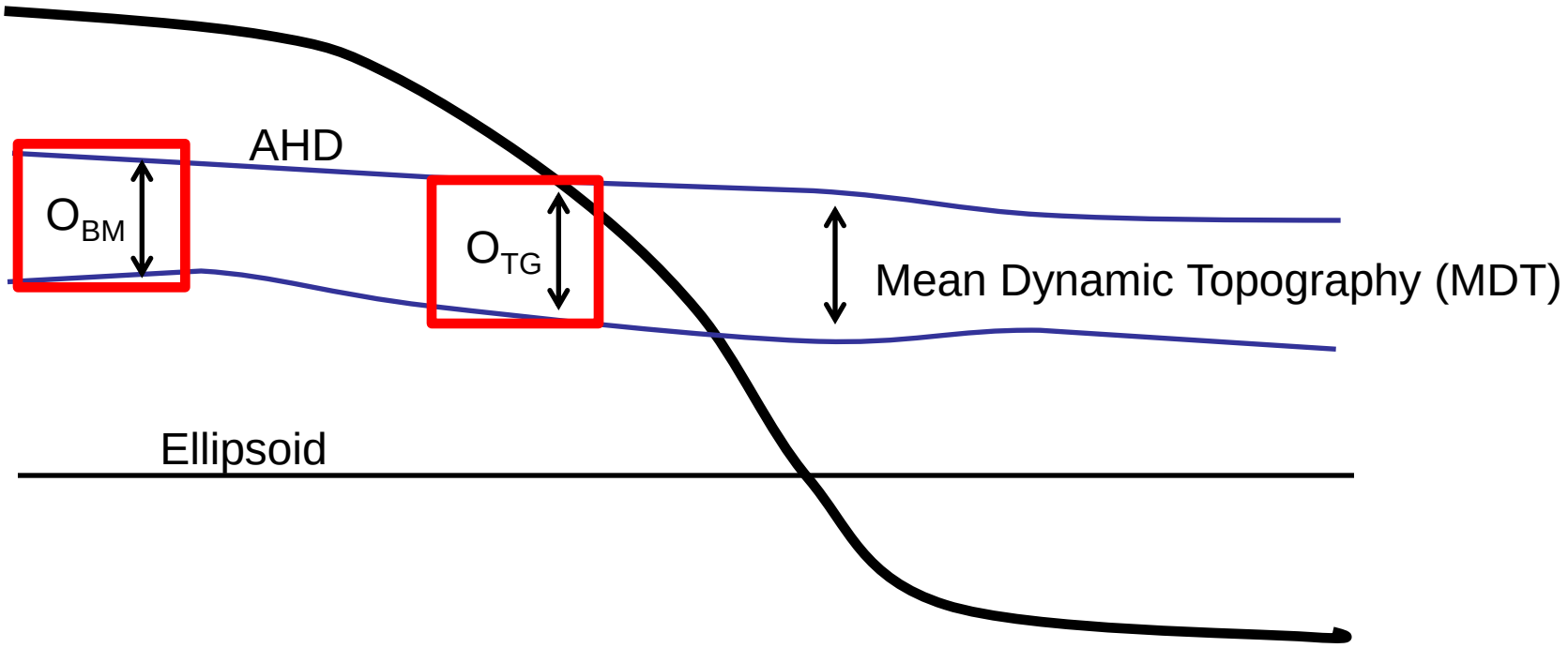


Ocean Mean Dynamic Topography

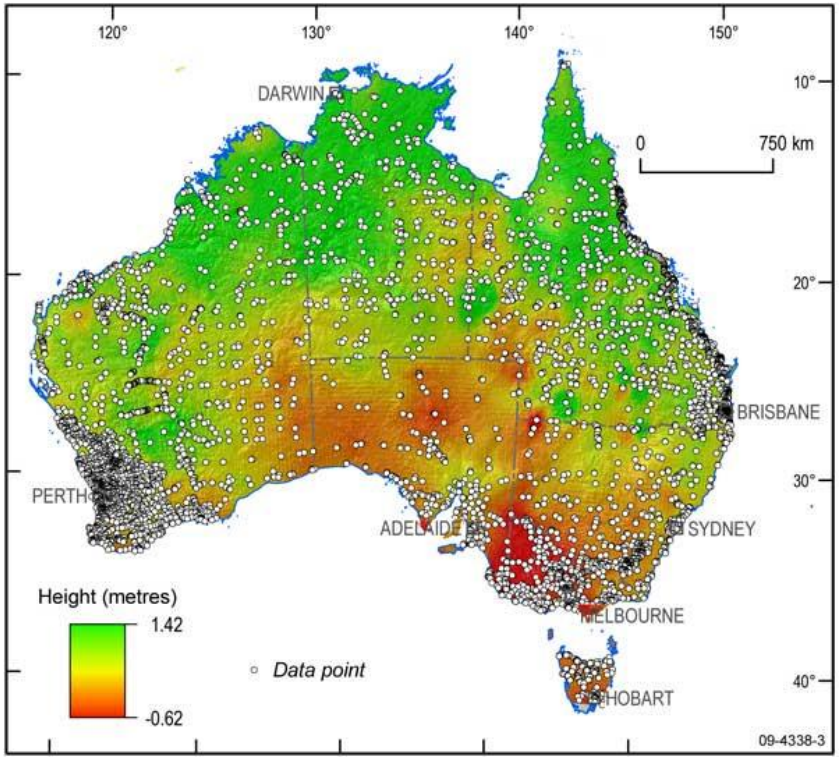


- AHD has a ~1m north-south tilt and ~0.5m regional distortions with respect to the quasigeoid
- Tilt is related to changes in water density
- Oceanographic model: Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atlas of Regional Seas 2009 (CARS2009)

Concepts: AHD, Geoid, Ellipsoid

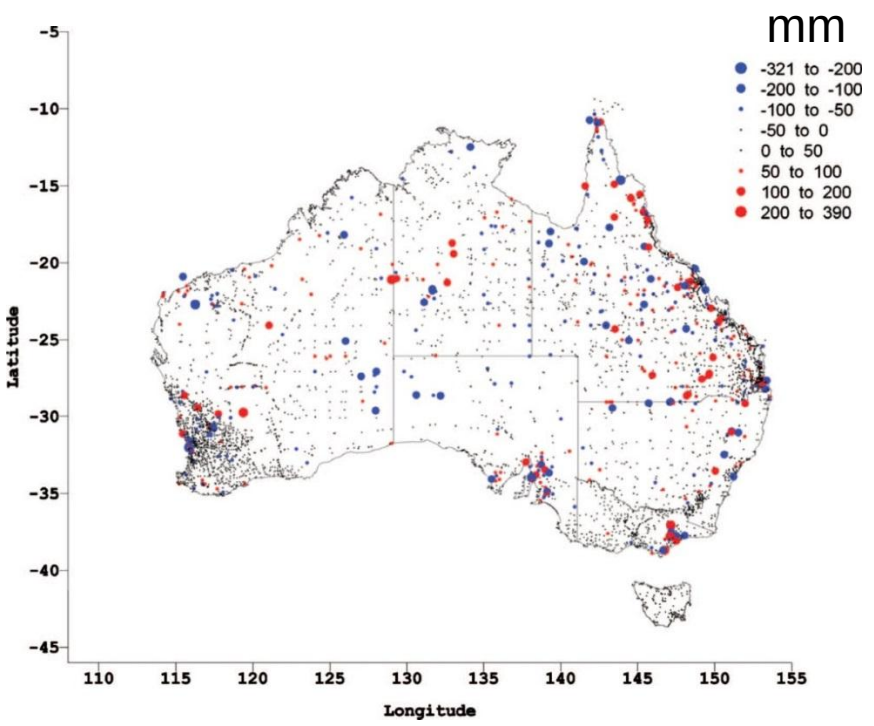


Offset (O_{TG} and O_{BM})



- Offset was computed at 6871 locations
- Distortions related to errors in the levelling
- Least Squares Collocation used to compute an AHD to gravimetric geoid offset value at every node on a 1' x 1' grid
- Geometric component was added to gravimetric component to form AUSGeoid09

Residual Offsets and Uncertainty of AUSGeoid09



- AUSGeoid09 has an estimated absolute uncertainty of ±60mm (95% CI)
- AUSGeoid09 provides relative uncertainties comparable to 12 mm * √k in km (95% CI)
- See: *The AUSGeoid09 model of the Australian Height Datum, Featherstone et al Journal of Geodesy (2011) 85:133–150*

Geoscience Australia: Geodes

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

Australian Government
Geoscience Australia

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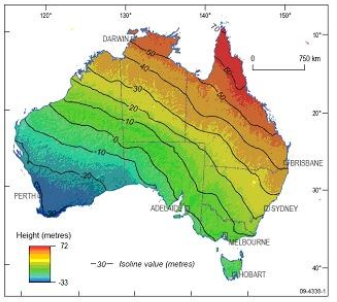
AUSGeoid09

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):
e.g. -35.12345	e.g. 145.12345	e.g. 12.345

compute reset

Download AUSGeoid09 grid files

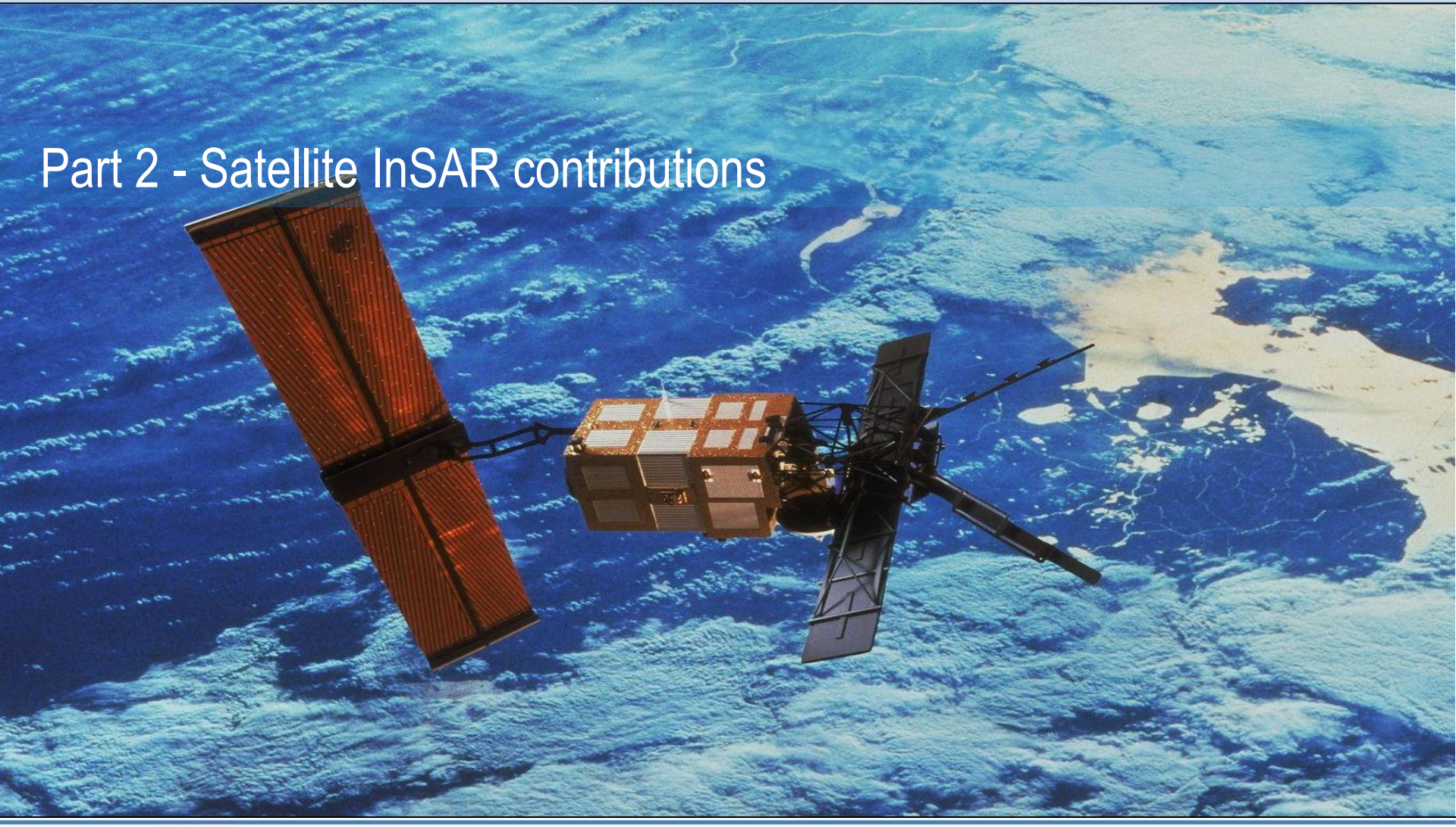
The national AUSGeoid09 grid file or components of it can be downloaded and used to compute AHD heights in real time when used in Real Time Kinematic GNSS receivers. Alternatively, a batch processing system is available above to interpolate an AHD value from the GNSS data in the office.

AUSGeoid09 data files contain data covering the Australian region. The data is available for each State and in 1:250K map sheets in unix and text format which you can use to interpolate geoid-ellipsoid separations for the positions required. You can use your own interpolation software, or you can use the interpolation software developed by Roger Fraser (Geoid_Interpolator). This can be downloaded from the ICSM website.

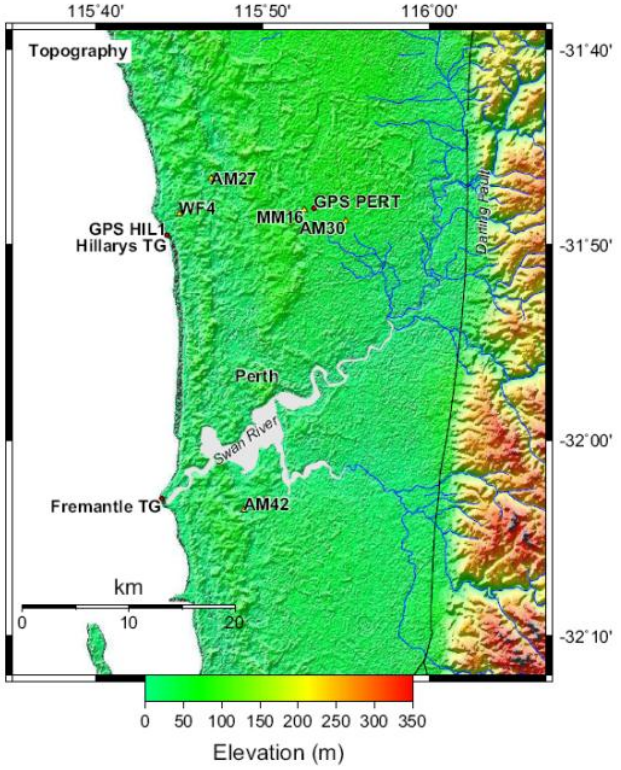
Feedback | Disclaimer | © Commonwealth of Australia, 2011

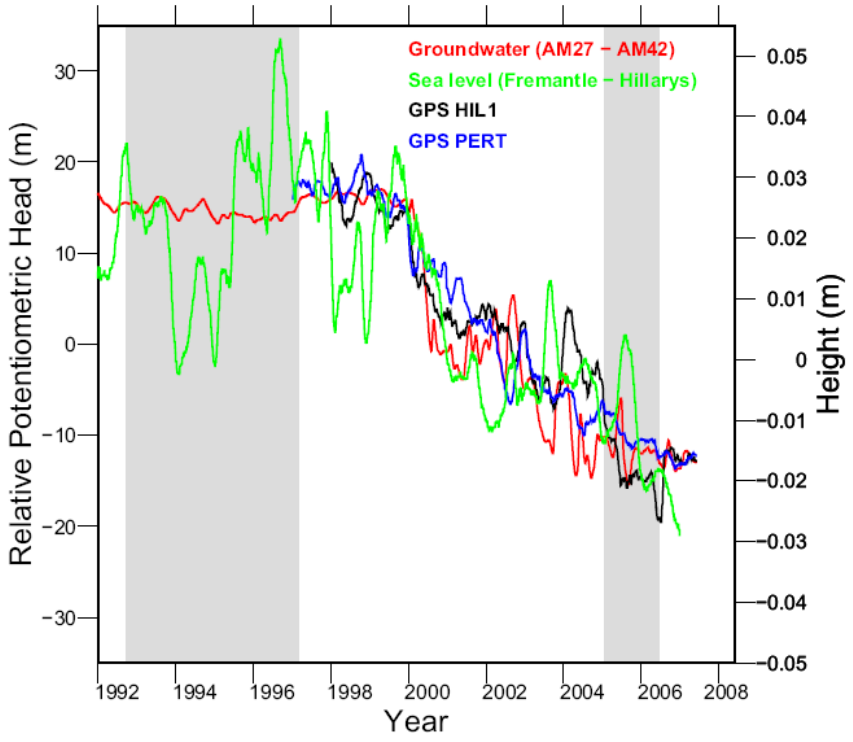
Department of Resources, Energy and Tourism

Part 2 - Satellite InSAR contributions



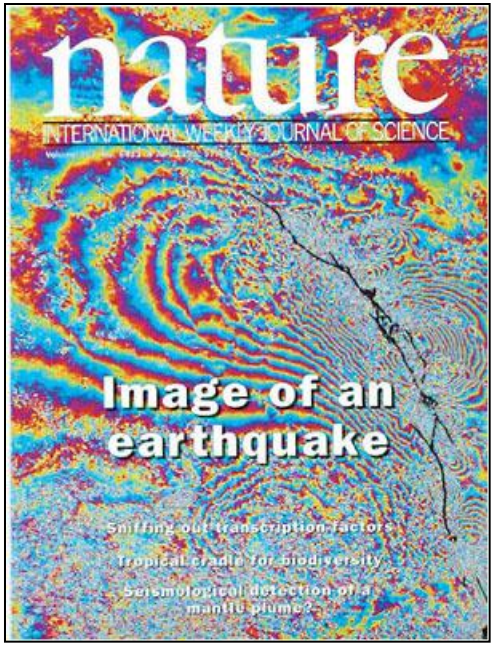
But height is not constant in time: Perth example





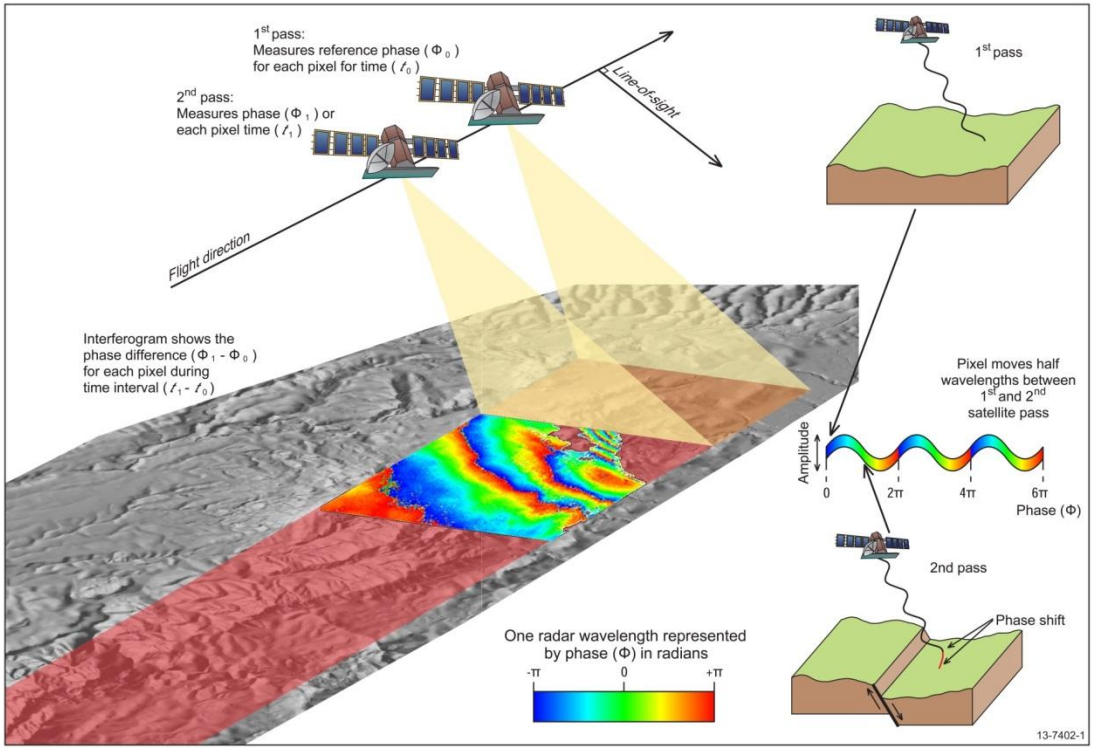
Interferometric Synthetic Aperture Radar (InSAR)

- Repeat-pass remote sensing technique that compliments traditional geodetic techniques
- Uses the phase component of two SAR images to identify surface movements through time
- Interferograms map changes in the distance between the ground and satellite – **in the satellite line of sight**



Landers Earthquake
(Massonnet et. al. *Nature*, 1994)

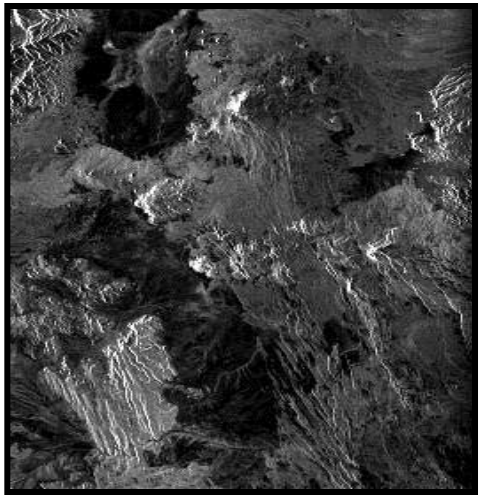
How InSAR Works

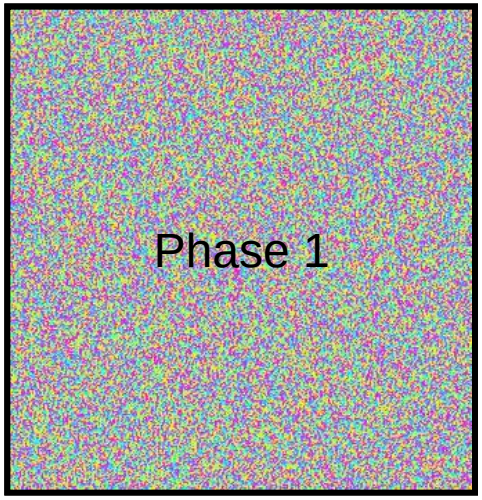


Magnitude

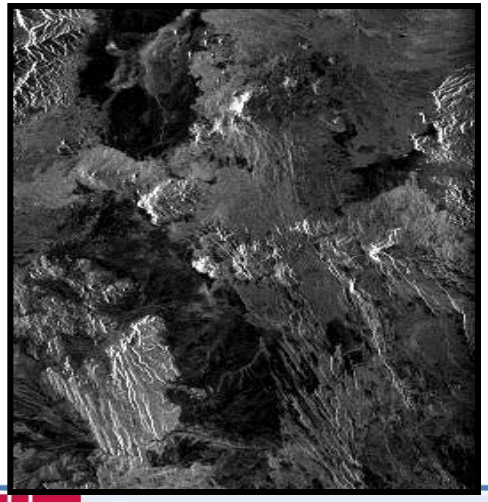
Phase

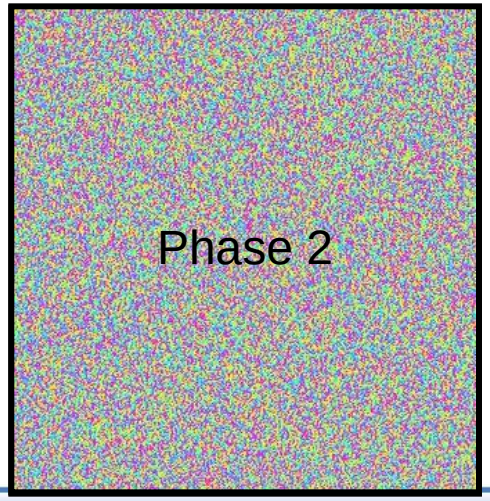
1st Pass



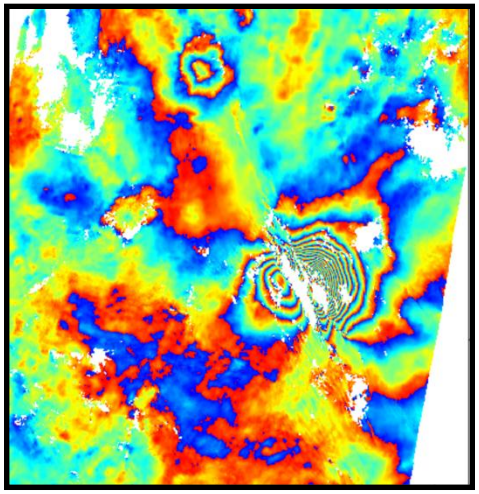


2nd Pass





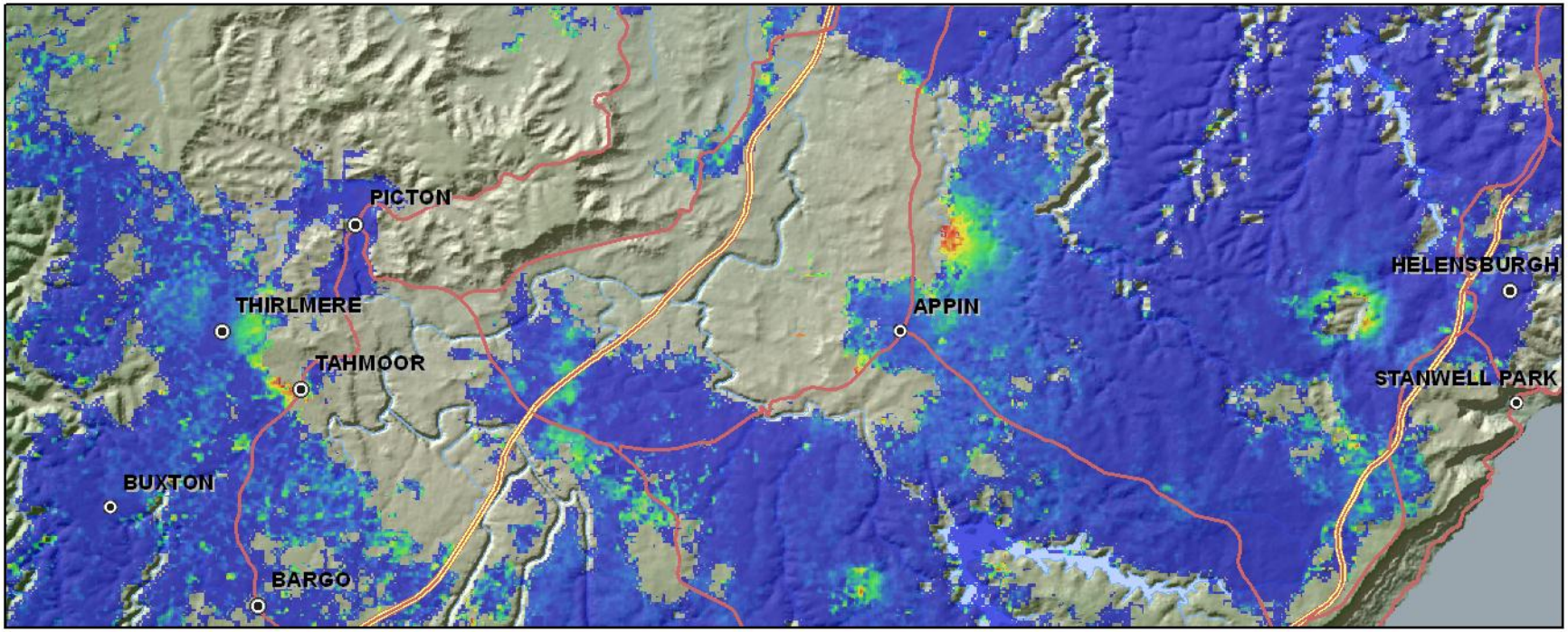
Phase 1 – Phase 2
= Interferogram



Ground movement time series

South Sydney basin, NSW

19-04-2010

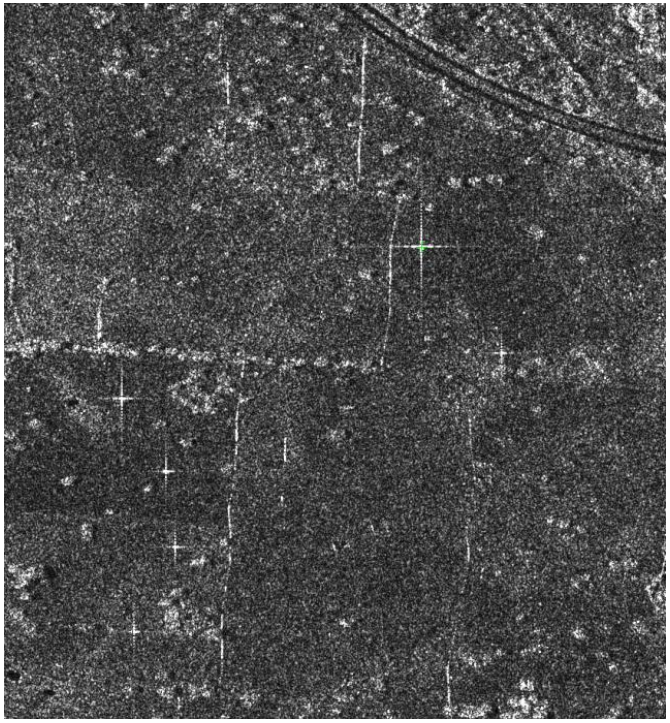


Line of Sight Displacement (mm)

0 20 40 60 80 100 120

InSAR Data: Ground Control

TSX image of Gunning test site

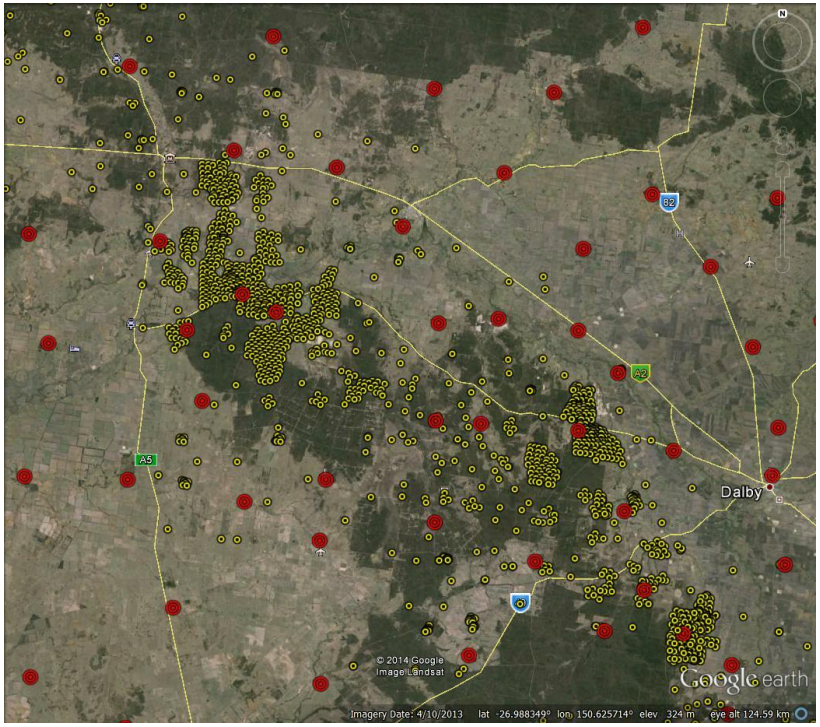


1.5m trihedral

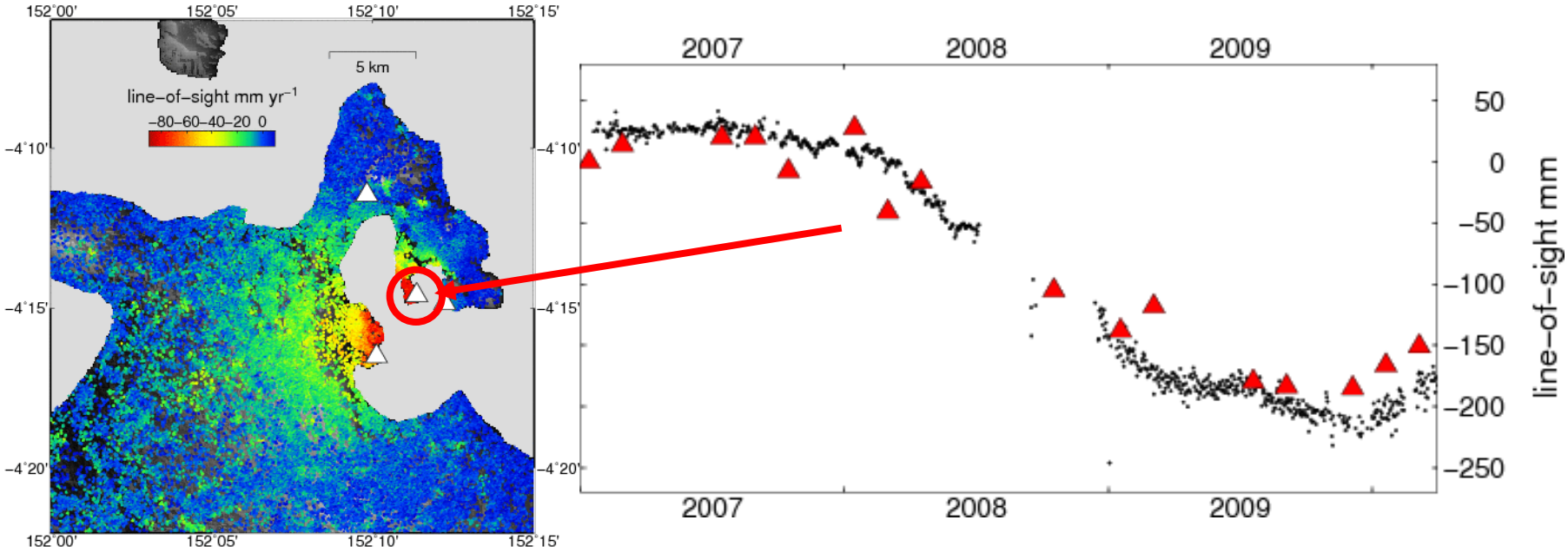
2.5m trihedral

Surat Basin subsidence monitoring infrastructure

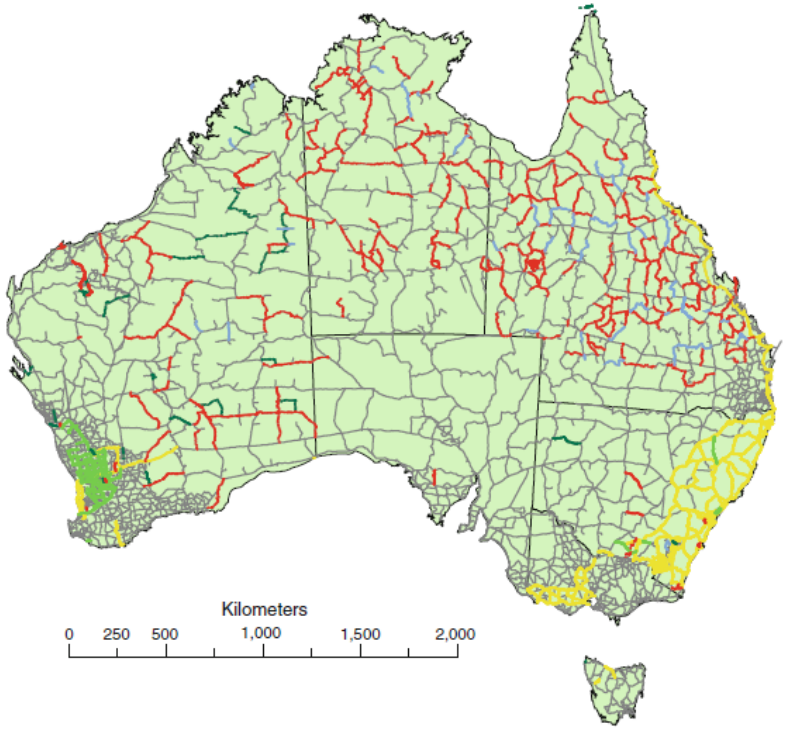
- 40 sites with co-located corner reflectors and geodetic survey marks in the Dalby/Miles/Chinchilla region
- Extraction of groundwater in this region is inducing localised subsidence
- Test area for methods of combining InSAR and GNSS techniques



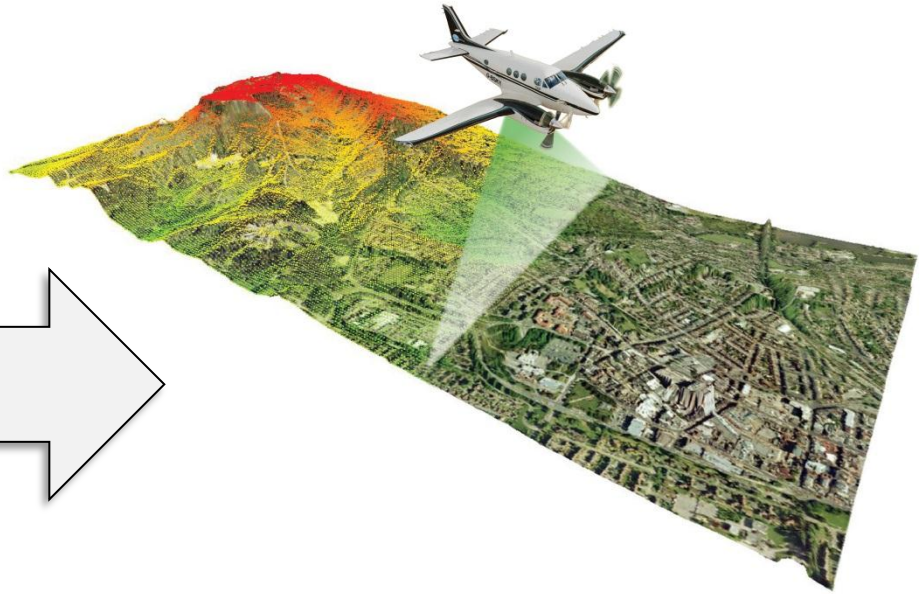
Comparing GNSS to InSAR: Volcano deformation



Part 3 - Options for a future Australian height datum



ANLN (Filmer et al., 2010)

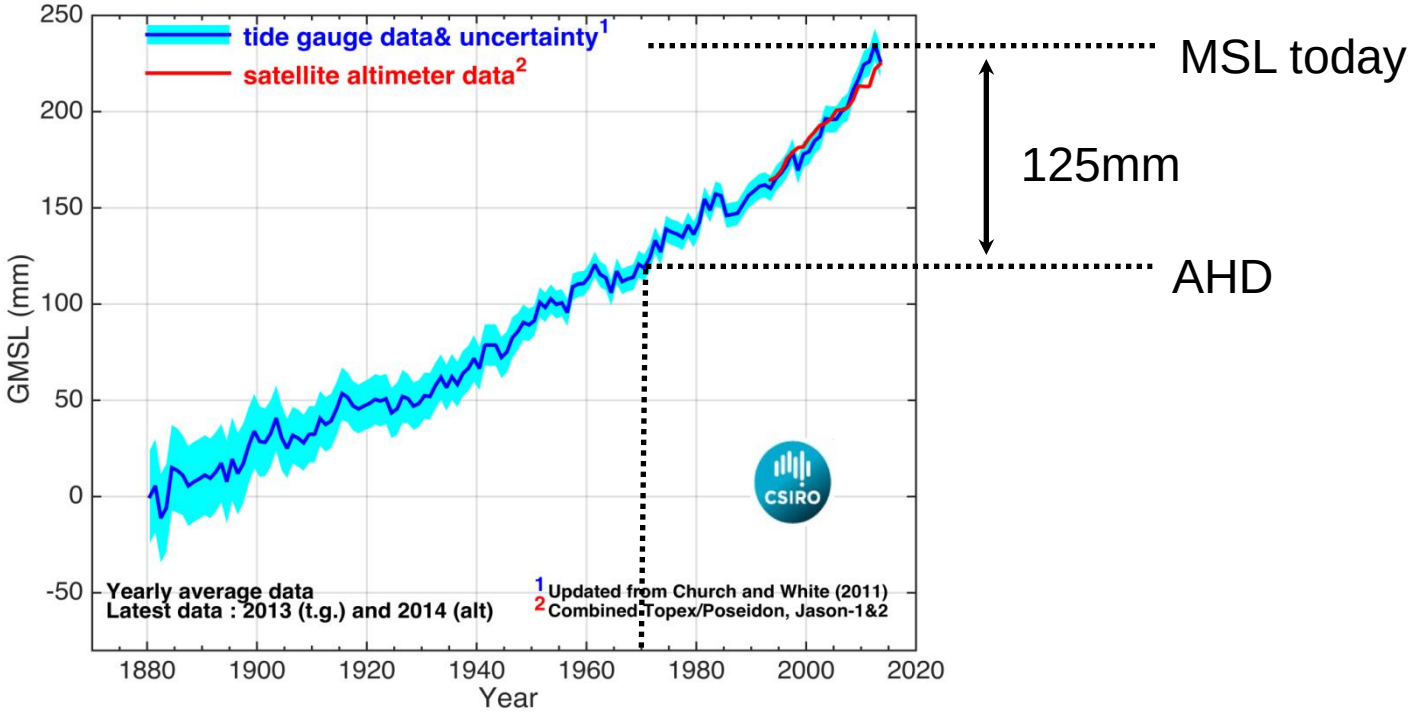


Source: bluesky-world.com

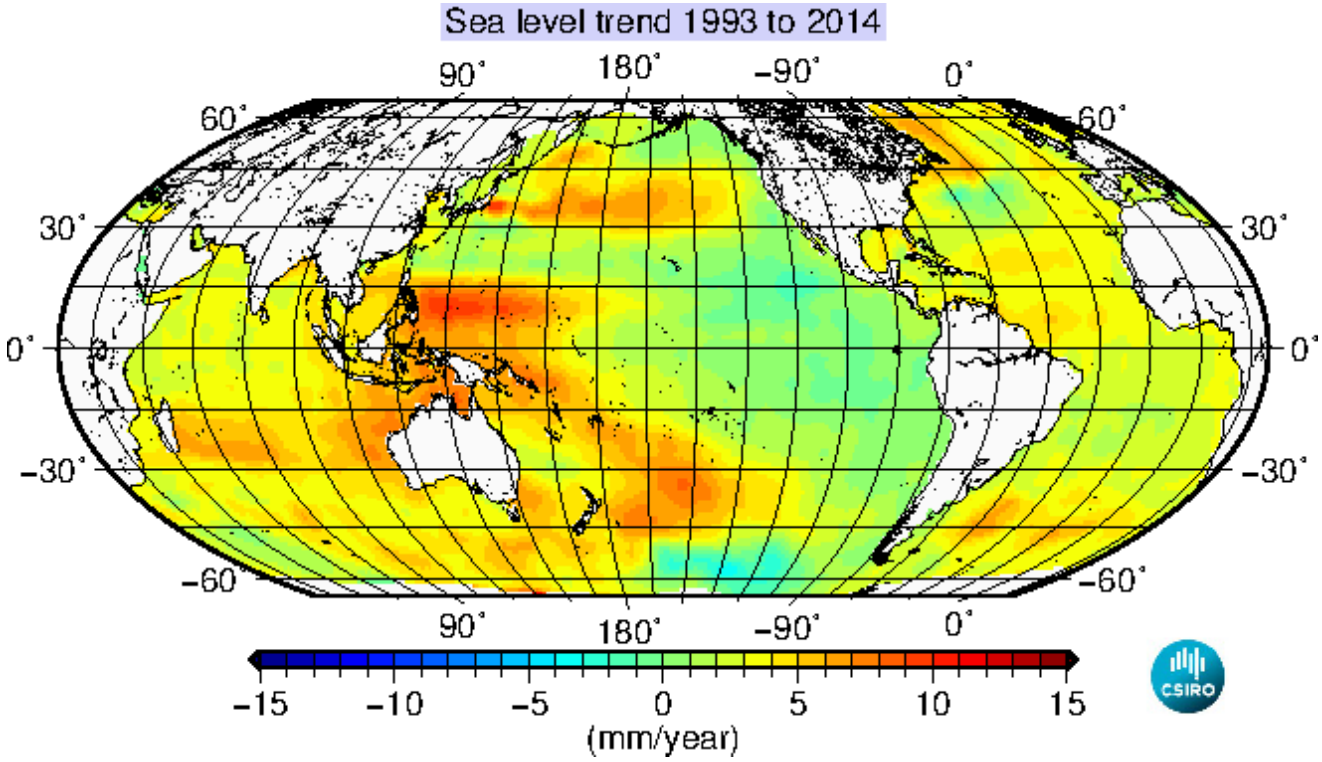
Issues with AHD that warrant attention

- Loss of ground mark infrastructure and the associate costs of maintenance
- Errors in existing levelling network
- Local and regional ground deformation (subsidence)
- Sea level change since 1968
- Offset between the Geoid and AHD including north-south tilt makes AHD incompatible with global heights

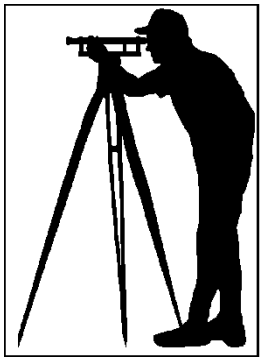
Problems with AHD: Sea Level Change

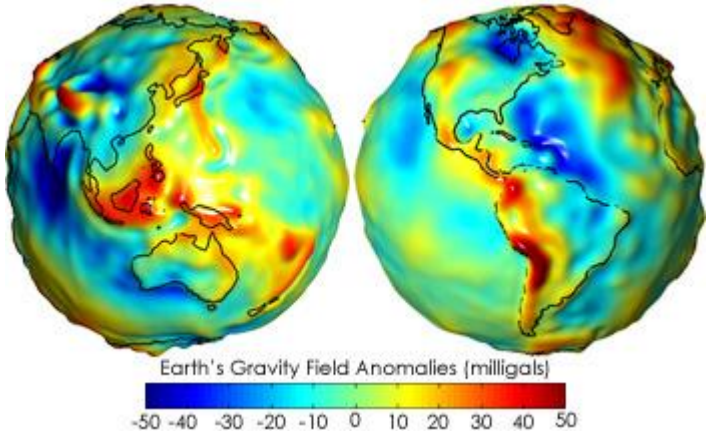


Problems with AHD: Sea Level Change



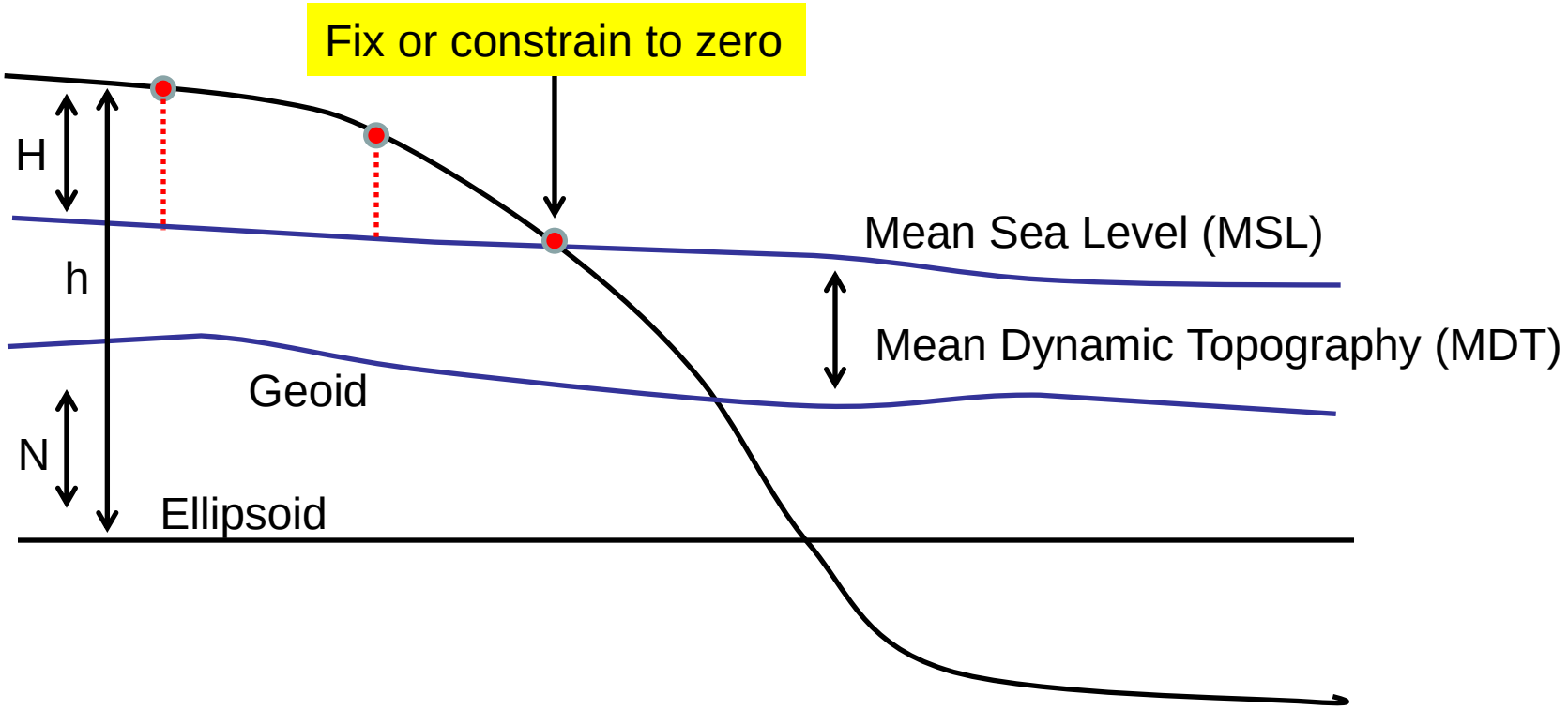
Options for a future Australian Height Datum



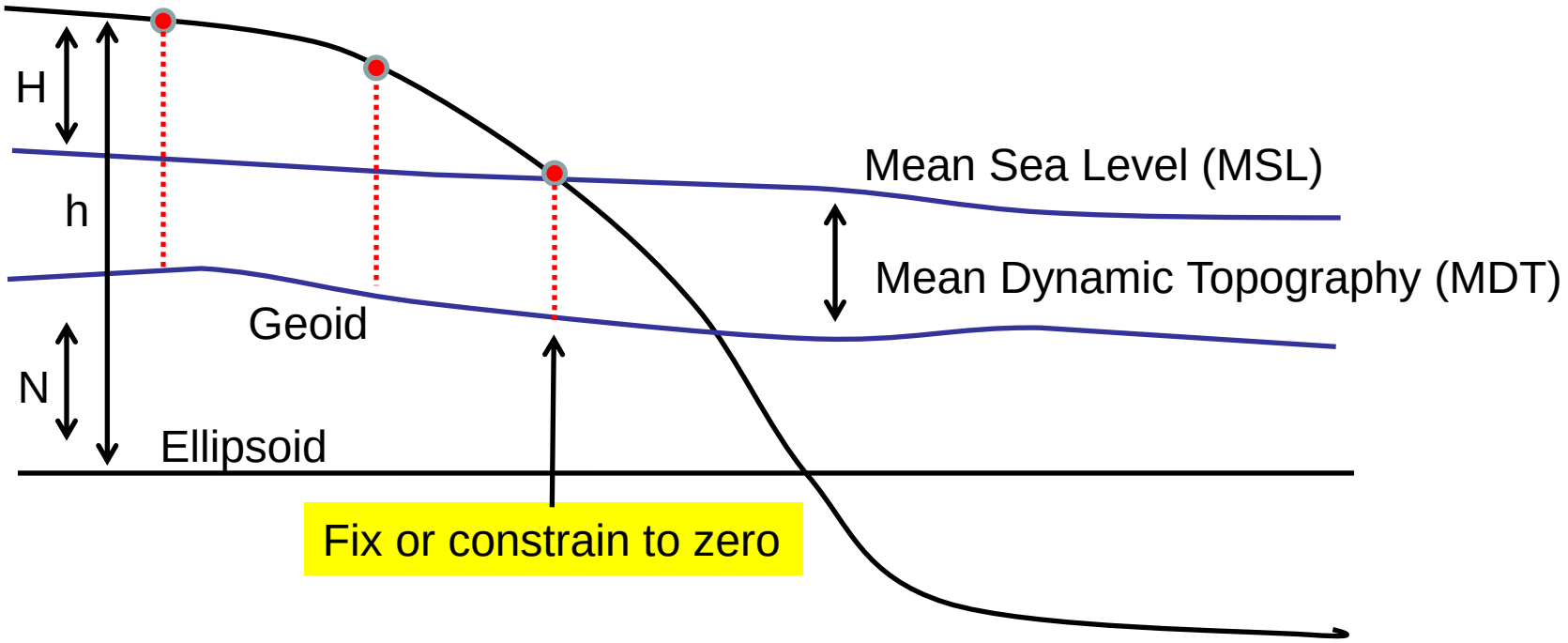


Levelling only → Combined → Geoid only

Levelling Only Approach A



Levelling Only Approach B



Levelling Only Approaches

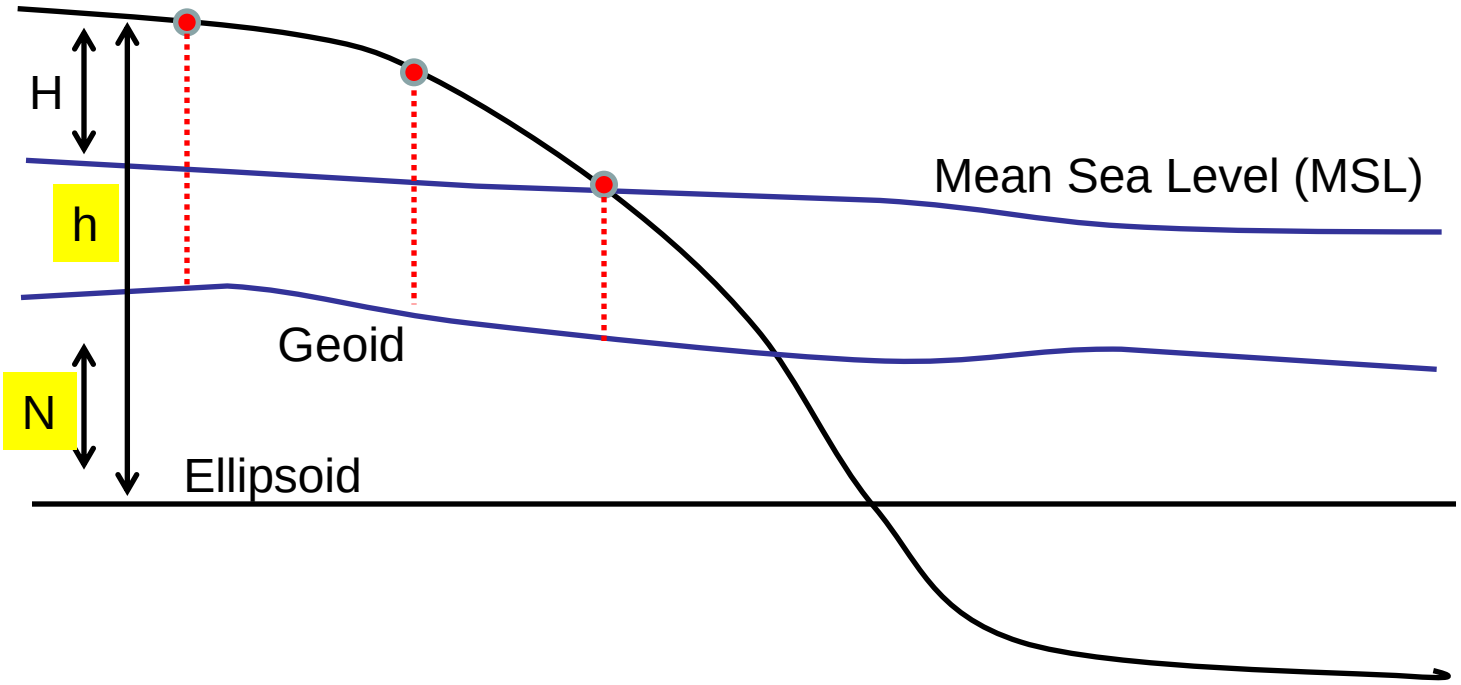
Advantages

- Datum is independent of $h-N$
- No need for GNSS to realise heights
- A levelling based datum is very precise over short distances

Disadvantages

- Ground infrastructure is expensive to maintain
- Long-wavelength systematic and gross levelling errors generally present
- Subsidence or uplift has a significant impact on the datum
- Difficulties in connecting Islands

Geoid Only Approach



Geoid Only Approach

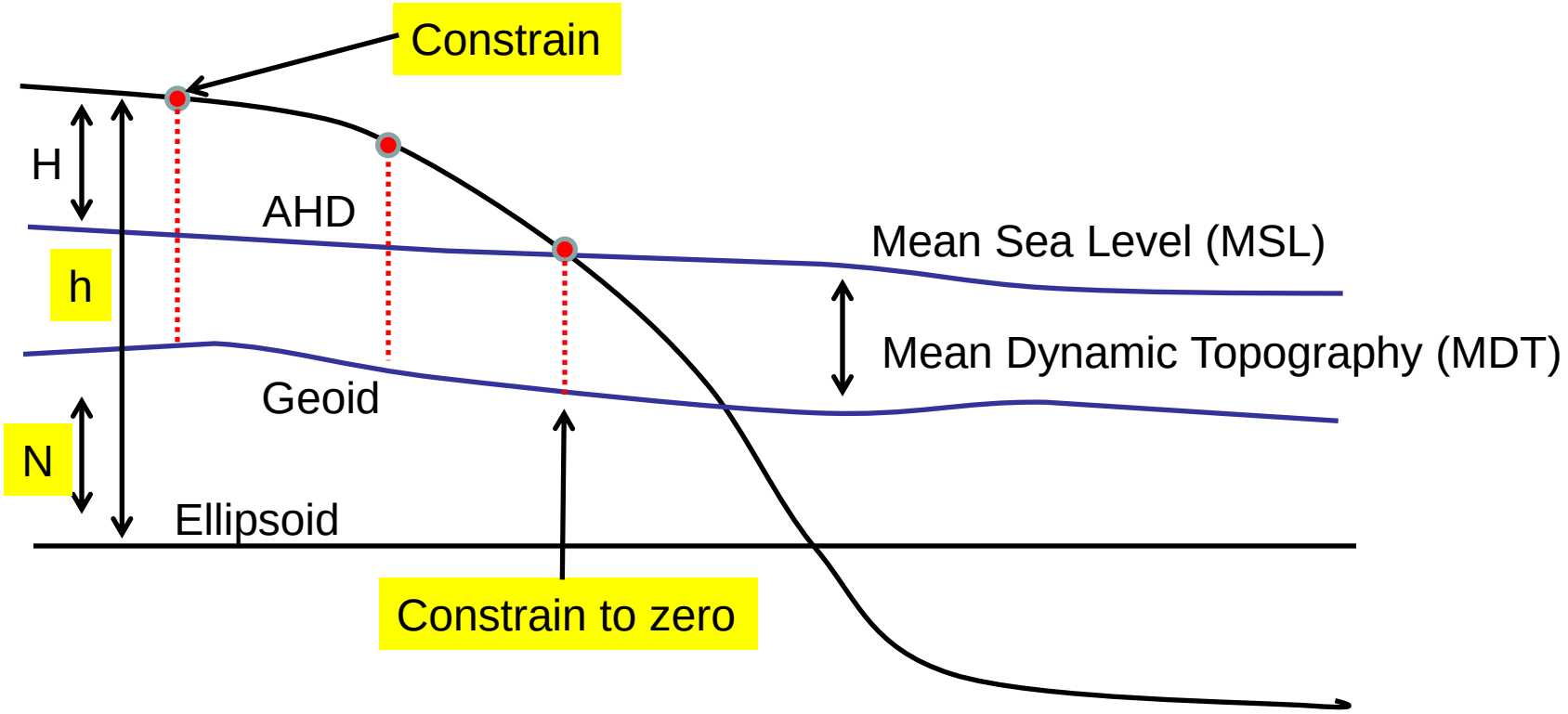
Advantages

- Does not necessarily require ground infrastructure (i.e. Benchmarks)
- Works well with GNSS
- Compatible with global and regional gravimetric quasi/geoid models
- Suitable for validating global and regional heights

Disadvantages

- Needs GNSS to realise heights
- Need to ensure terrestrial gravity and airborne gravimetry databases are fit-for-purpose
- Local precision may be poorer, particularly in mountainous and coastal regions

Combined Approach



Combined Approach

Advantages

- Can access height without ground marks
- Allows the use of levelling in areas where high precision is a requirement
- Exploits GNSS in remote areas

Disadvantages

- Still requires national levelling network

Final Comments

1. Australian height system
2. Satellite InSAR contributions to the Australian Height System
3. Options for a future Australian height datum

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