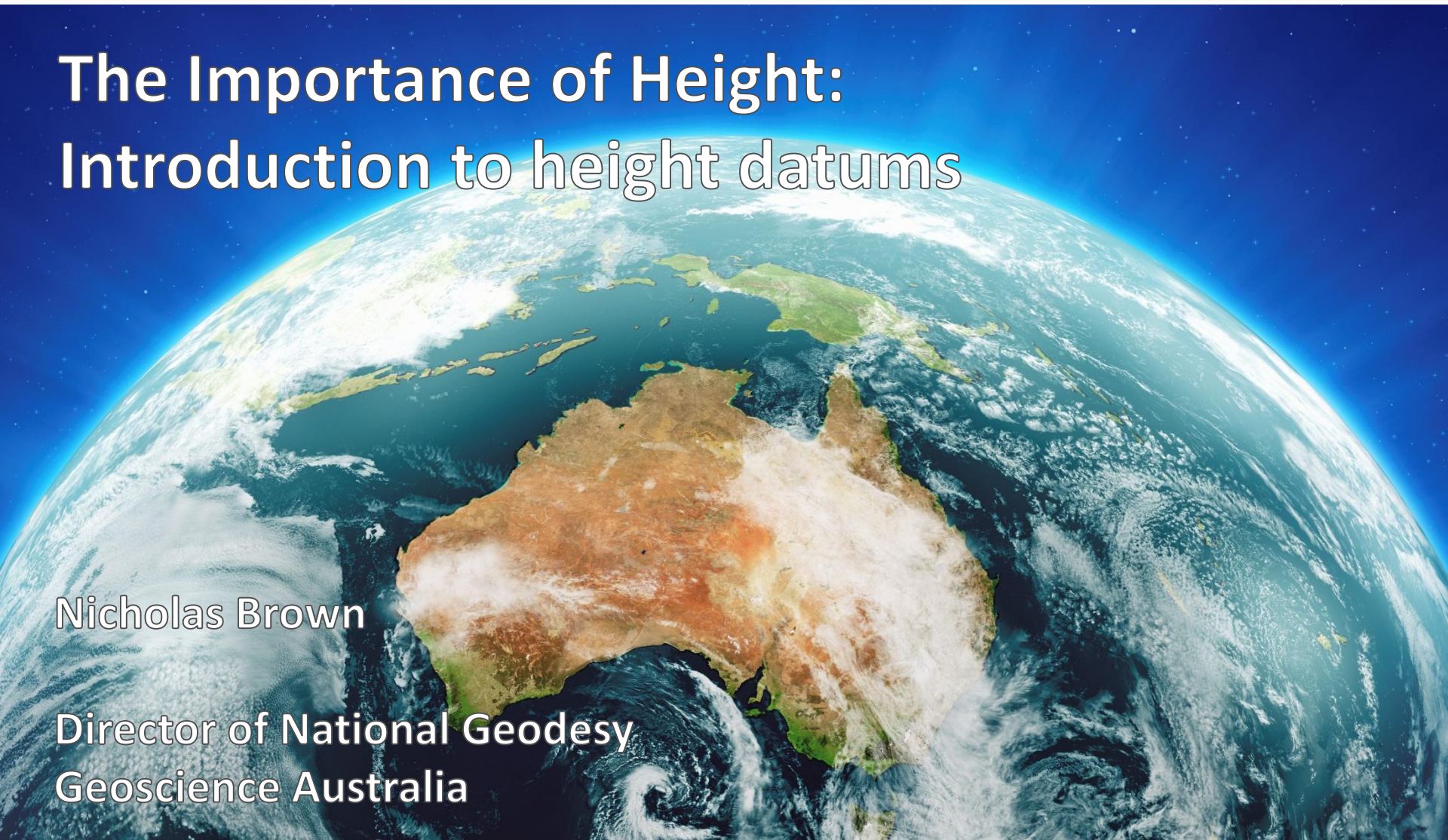
Australian Government
Geoscience Australia

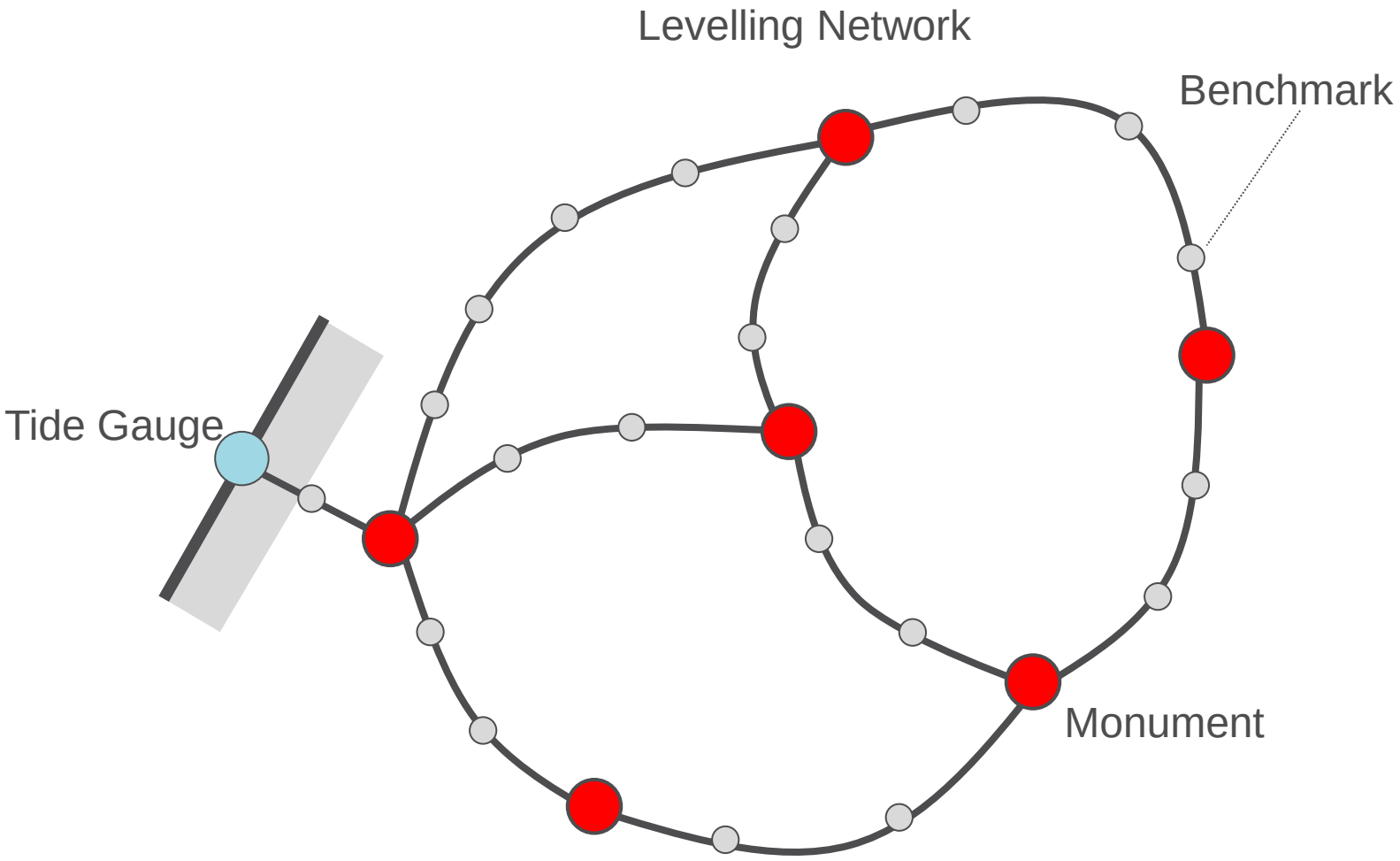
The Importance of Height: Introduction to height datums



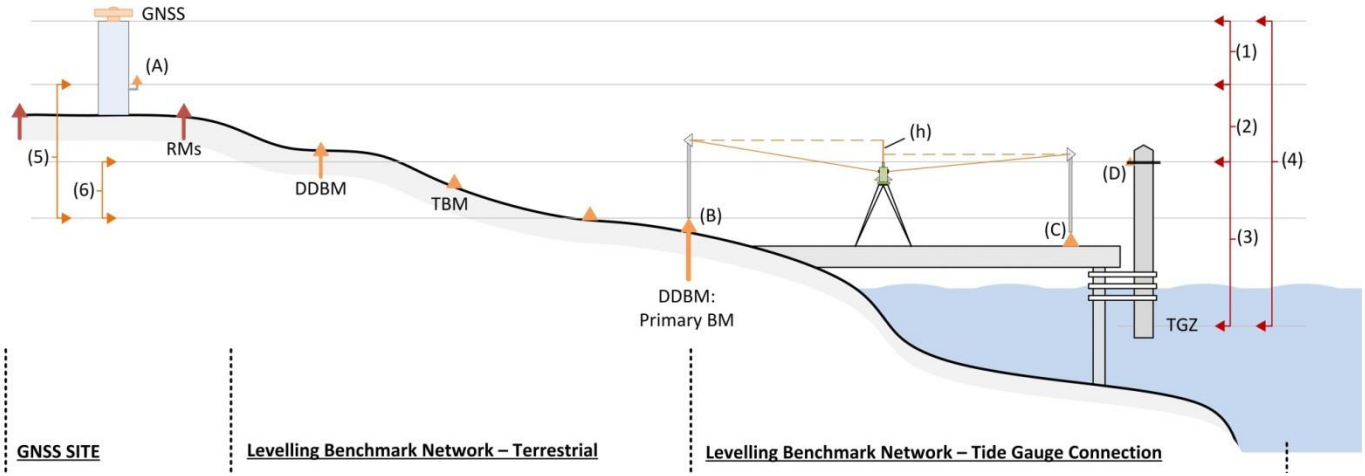
Nicholas Brown

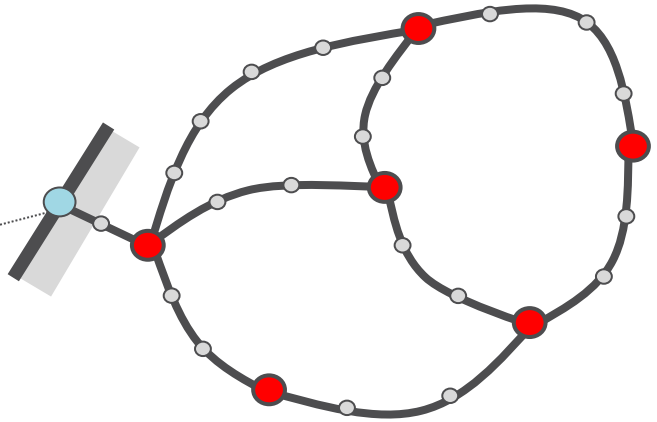
Director of National Geodesy
Geoscience Australia

Height

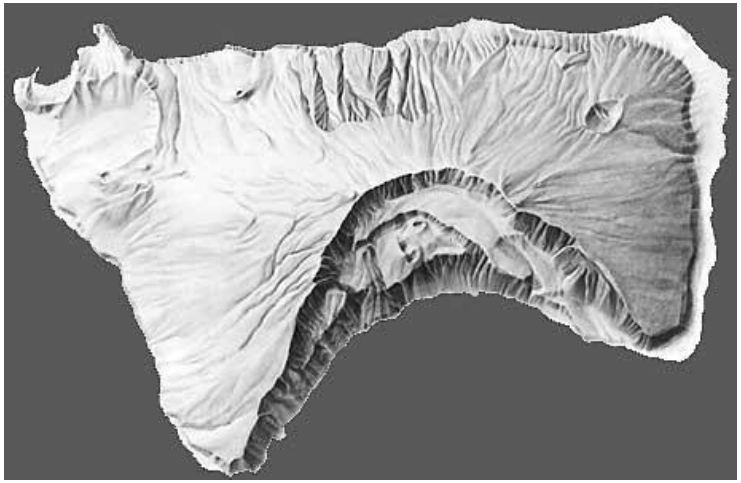


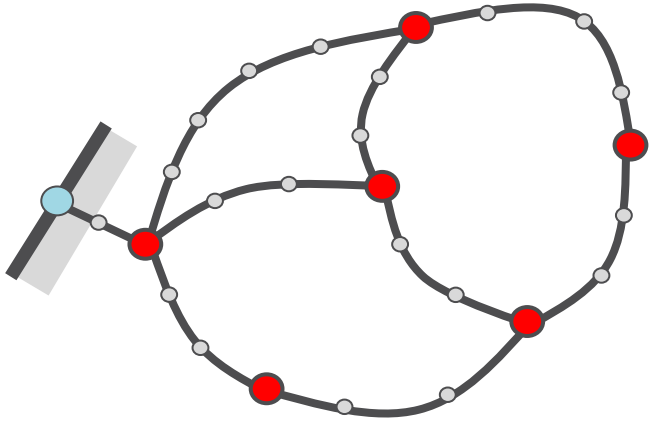
Height

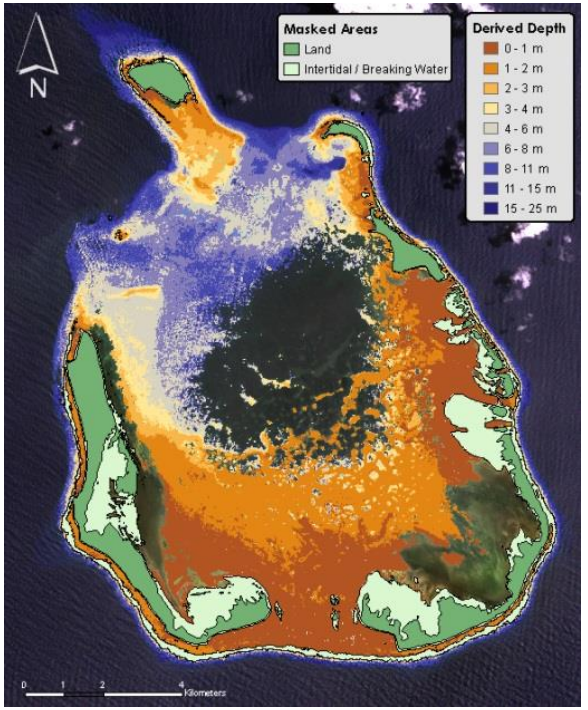




Height

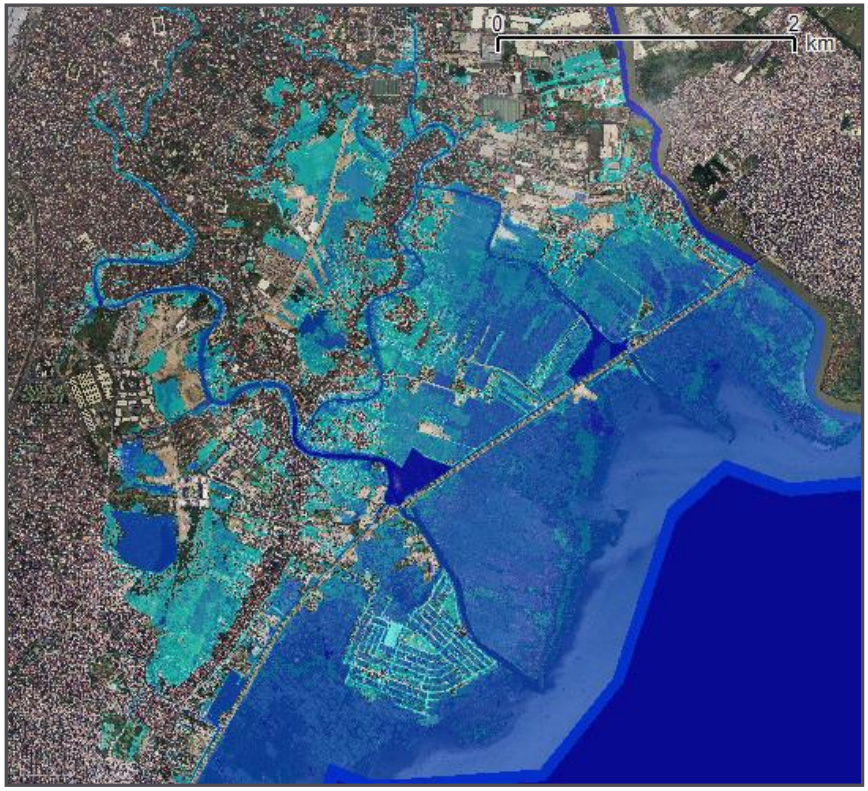






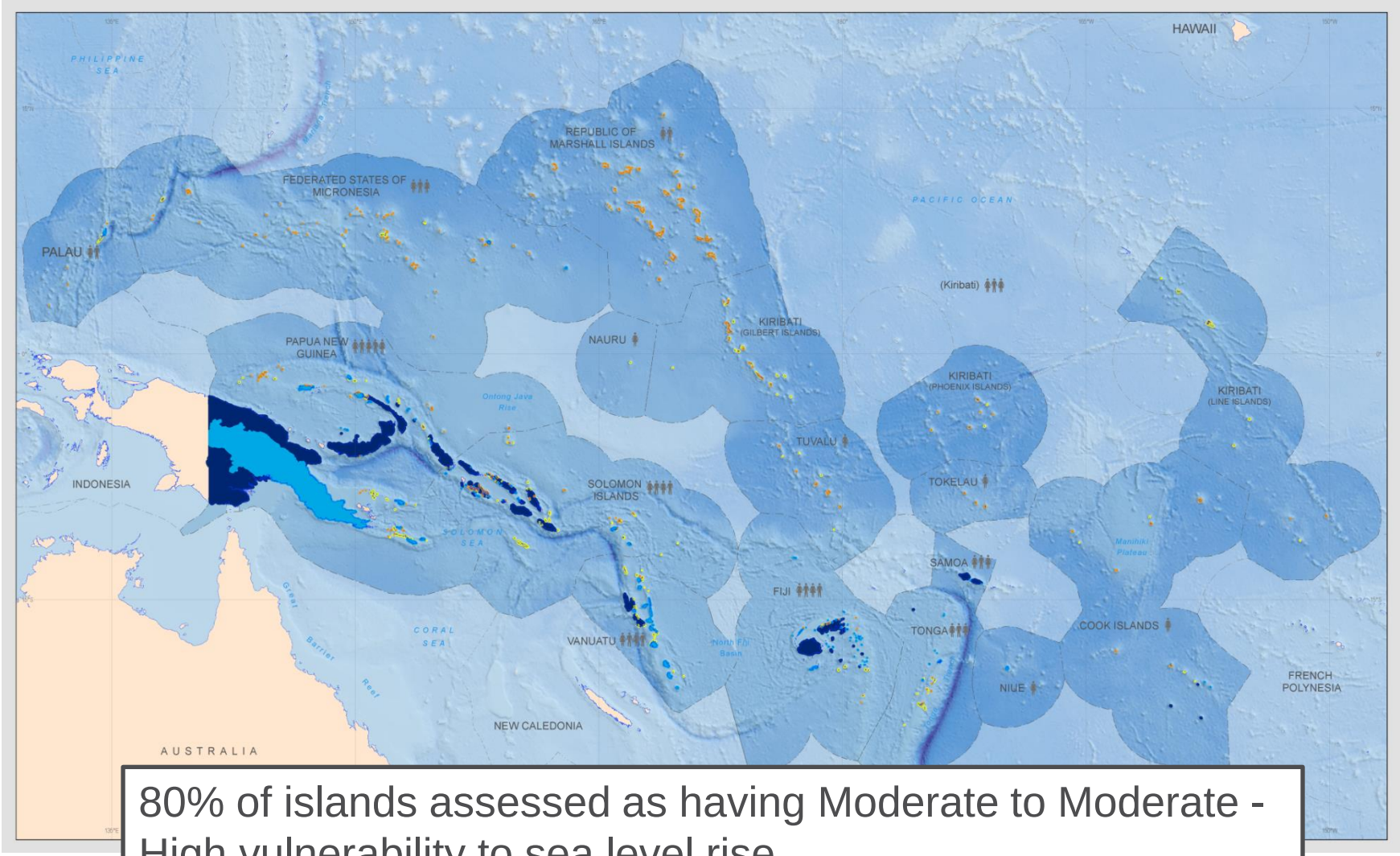
Height

Where should I build my house?



Developing countries need to invest $15 billion / year on climate change adaptation measures – The World Bank

Height - Vulnerability to future sea-level rise 2050



80% of islands assessed as having Moderate to Moderate - High vulnerability to sea level rise

Height

How vulnerable am I to storm surges?

175-year record of cyclones from the Cook Islands indicates 16% for storm surges (annually) and 5% for major storm surge impacts at Rarotonga.

Height

Where should I go to be safe in a natural disaster?

2009 Samoa earthquake and tsunami lead to 189 deaths throughout Western Samoa, American Samoa and Tonga.

Height

Will water flow?

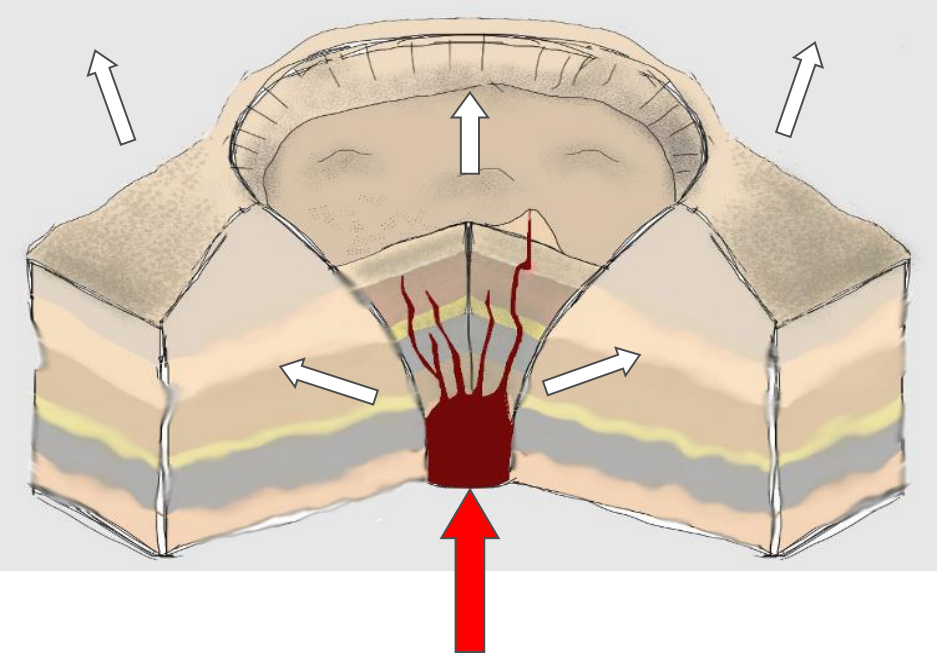
For developing countries alone, an estimated $103 billion per year is needed to finance water, sanitation, and wastewater treatment - WorldBank

Height

Where should I build this infrastructure

Height (changing with time)

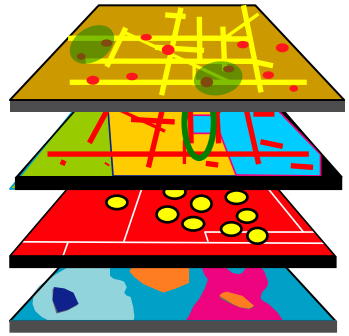
Surface deformation → volcanic plumbing



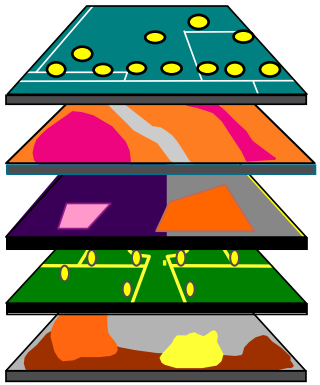
Magma Chamber Inflation/Deflation

Height – UN SDG

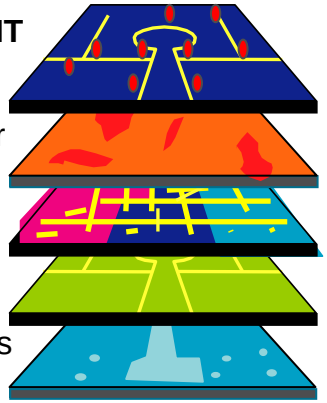
ECONOMIC
Well-being
Cities
Water
Energy
Infrastructure
Industry
Sanitation
Economy



SOCIAL
Society
Poverty
Education
Health
Population
Employment
Water
Sanitation
Equality
Gender
Governance



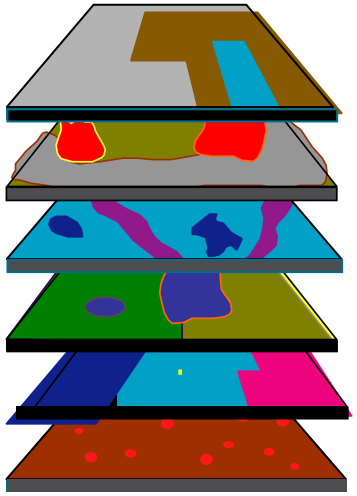
ENVIRONMENT
Water
Seas/oceans
Land use/cover
Ecosystems
Forests
Agriculture
Climate
Biodiversity
Natural hazards
Pollution



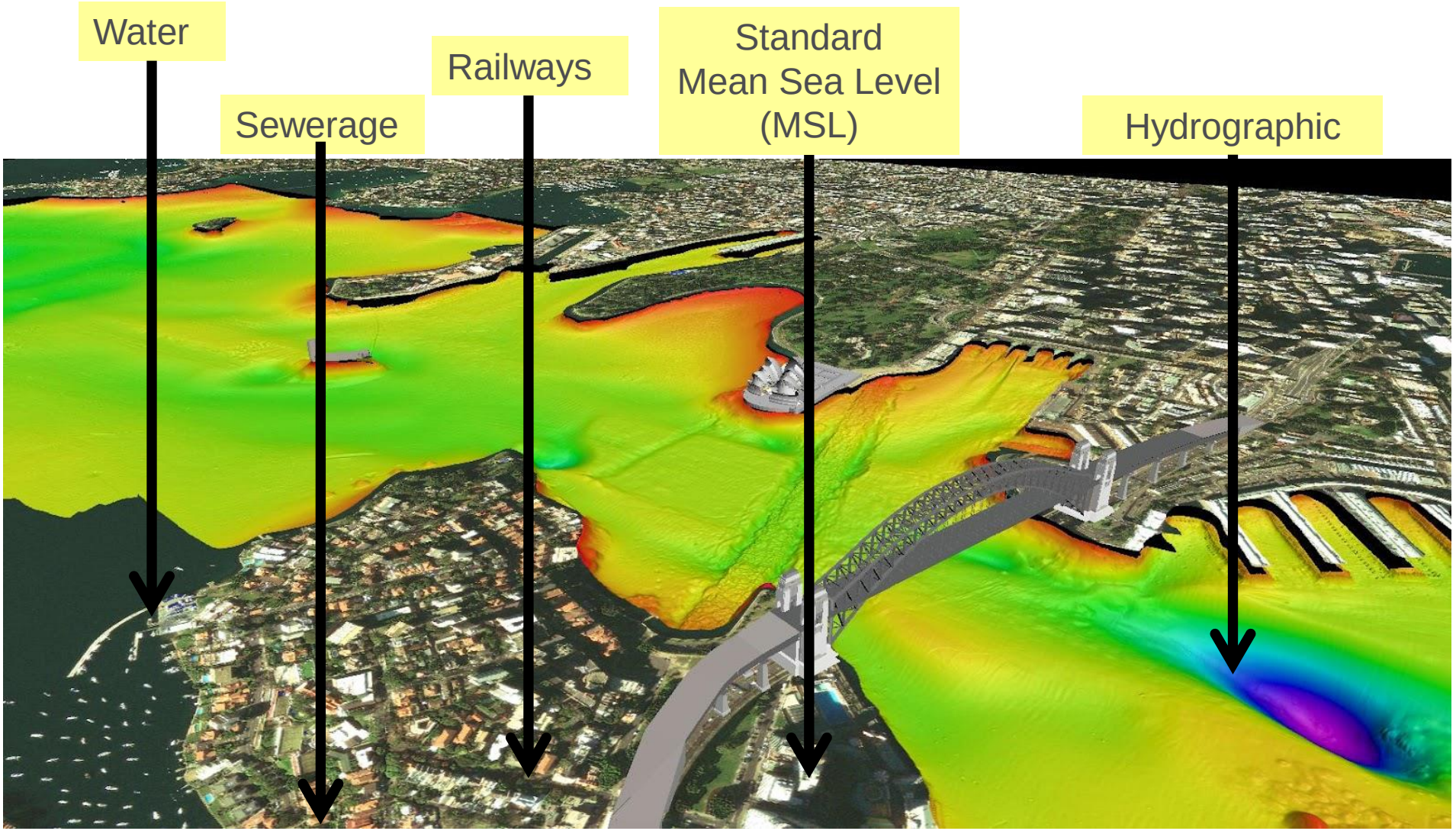
Height – UN SDG

High quality, timely and reliable data

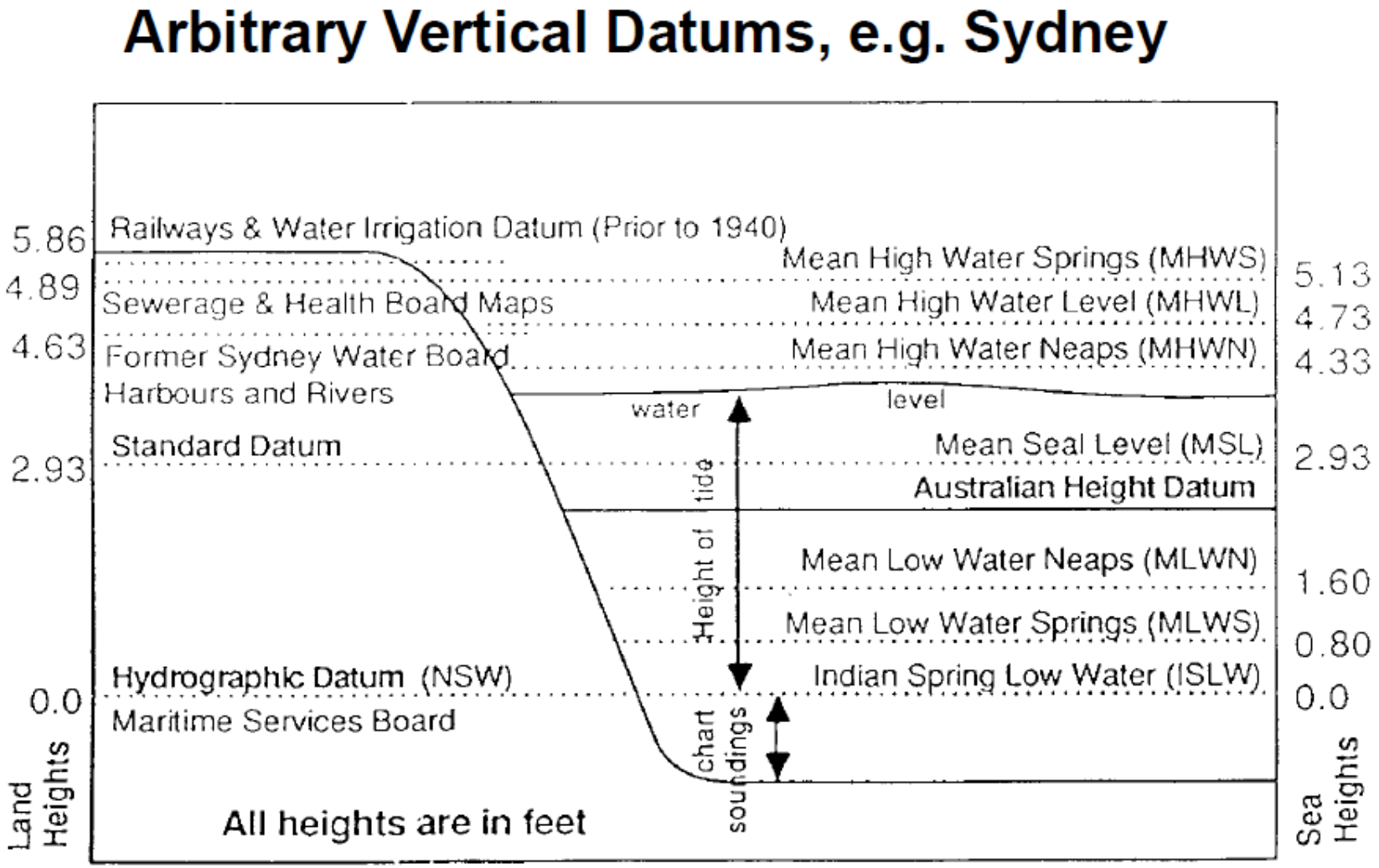
Geodetic
Elevation
Water/Ocean
Land use/cover
Transport
Cadastre
Population
Infrastructure
Settlements
Admin. Bdys.
Imagery
Geology/soils
Observations
etc.



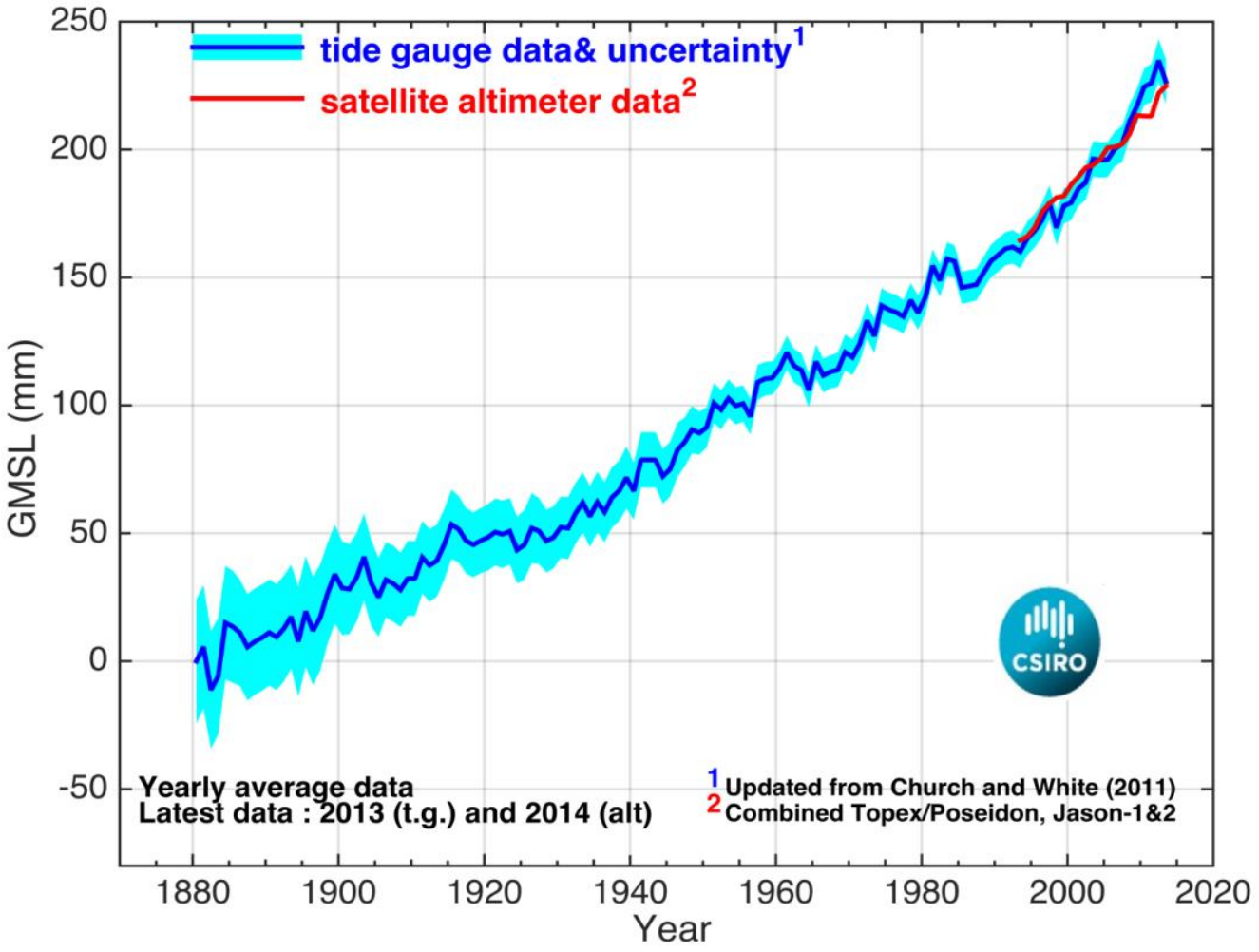
Height – Complications – Sydney example



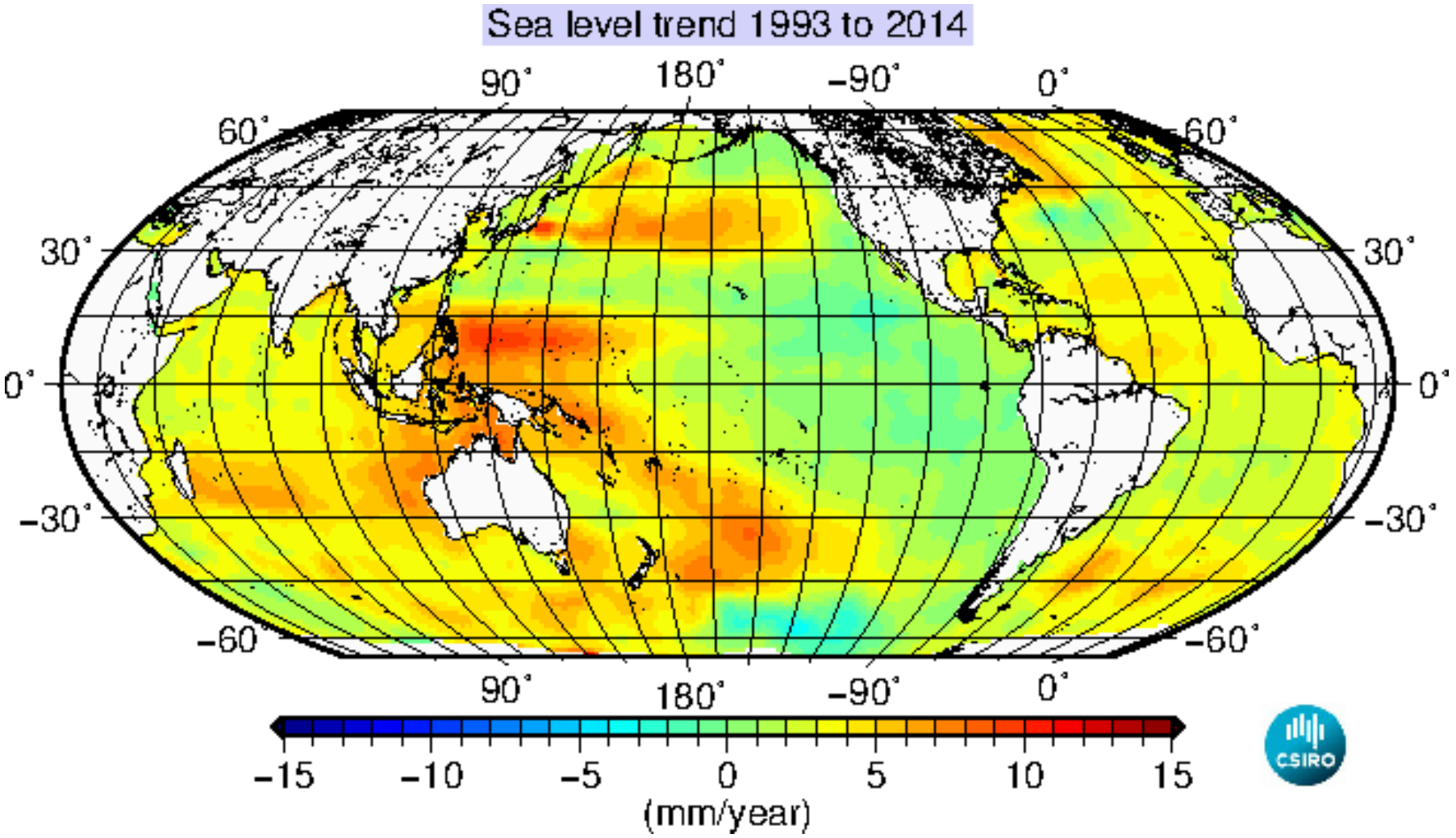
Height – Complications – Sydney example



Sea Level Trend



Sea Level Trend



Introduction to Height

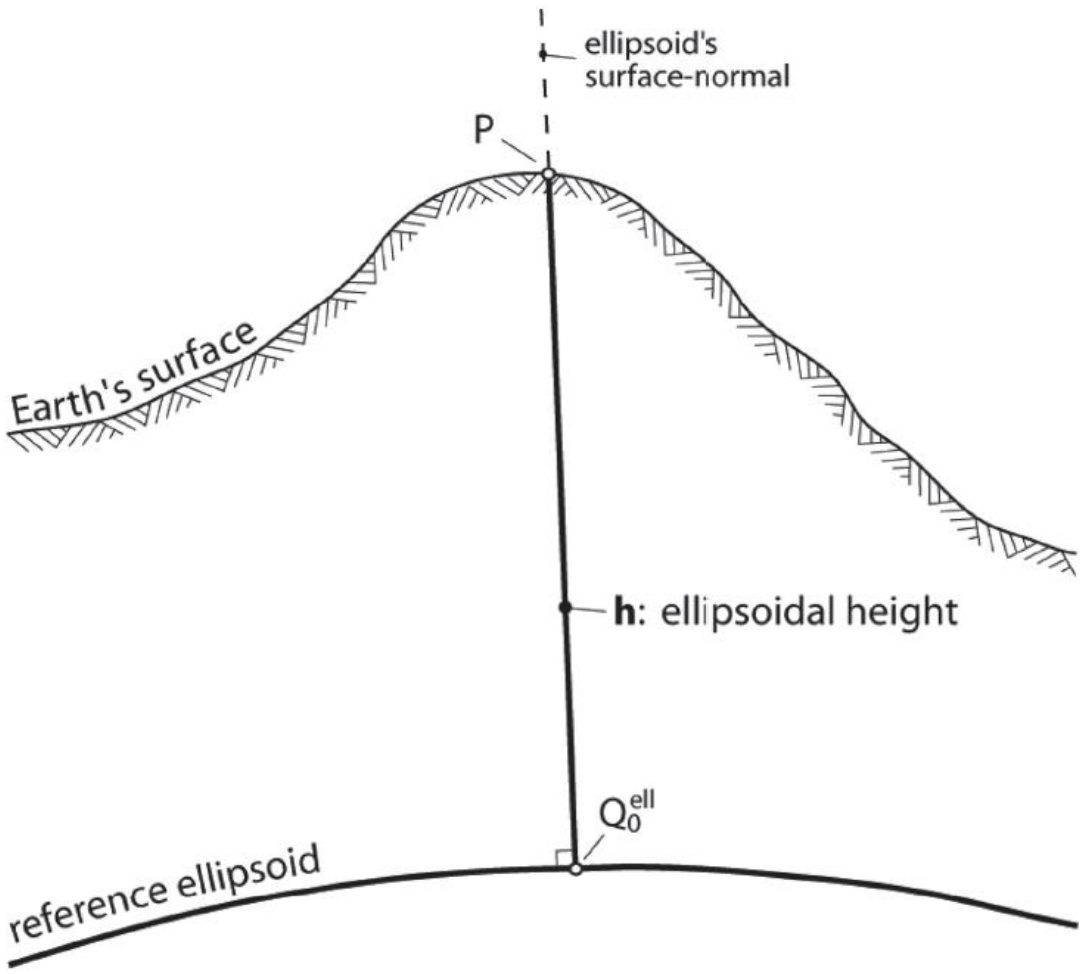
Introduction to height datums

- Traditionally people prefer to know their height relative to sea level:
  - Water flow for drainage systems
  - Height of buildings above a flooding river
- Satellite positioning systems (GNSS and remote sensing) determine heights relative to the ellipsoid
- It is important to understand how these systems are different and how data from these systems can be used together
- This section introduces the various heights systems and how heights can be transformed between these systems

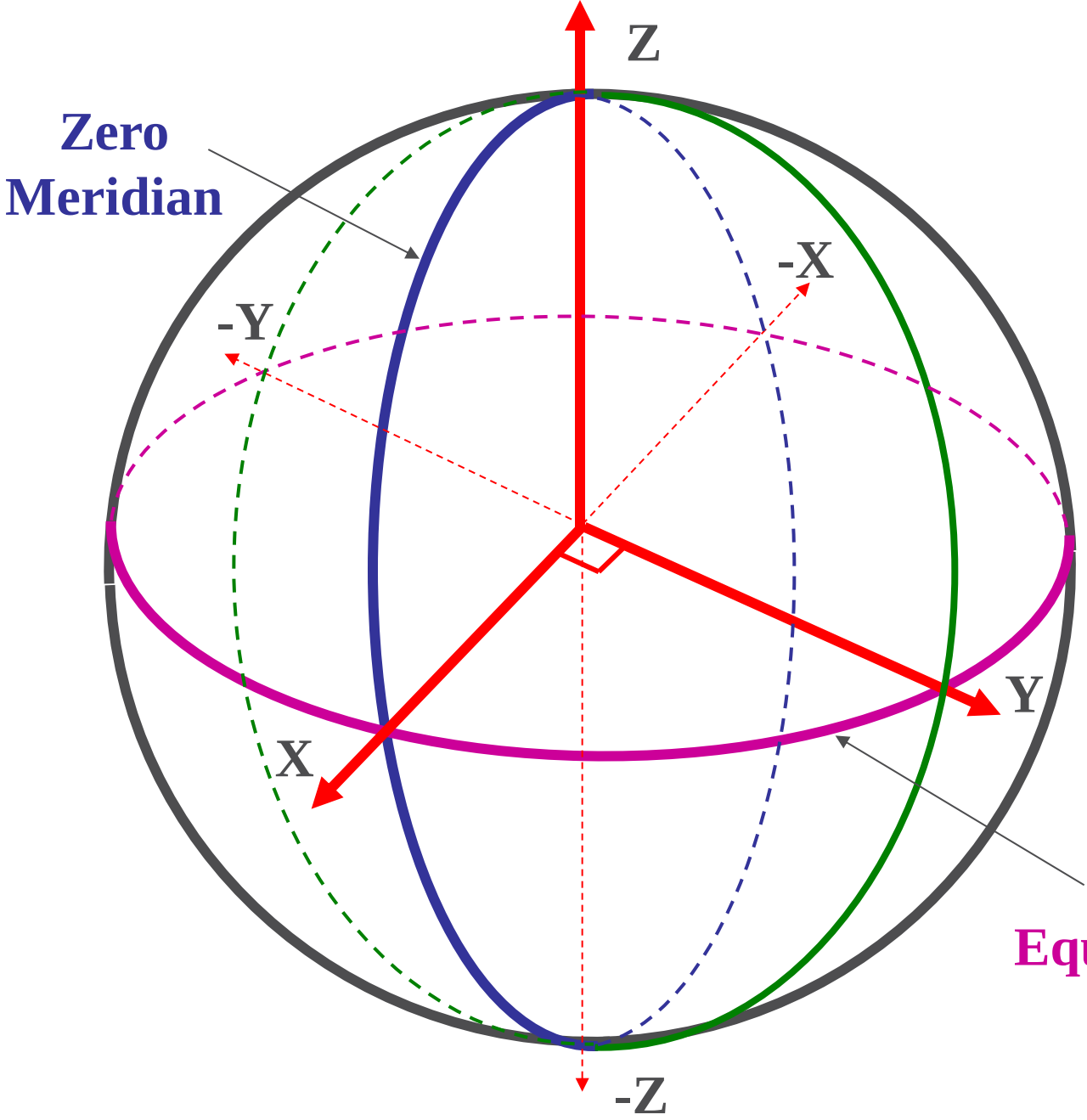
Height Systems

- One dimensional coordinate system used to define the distance of a point from a reference surface along a well defined path
- Complex description because there are a number of **reference surfaces** and a number of **well defined paths**
- Two types of height systems:
  1. Geometric – ignore Earth's gravity field and use straight line paths (e.g. GNSS)
  2. Physical – linked to Earth's gravity field and measured along the curved plumbline (e.g. orthometric heights)
- Explain the different **reference surfaces** and different **paths**

Geometric Height System

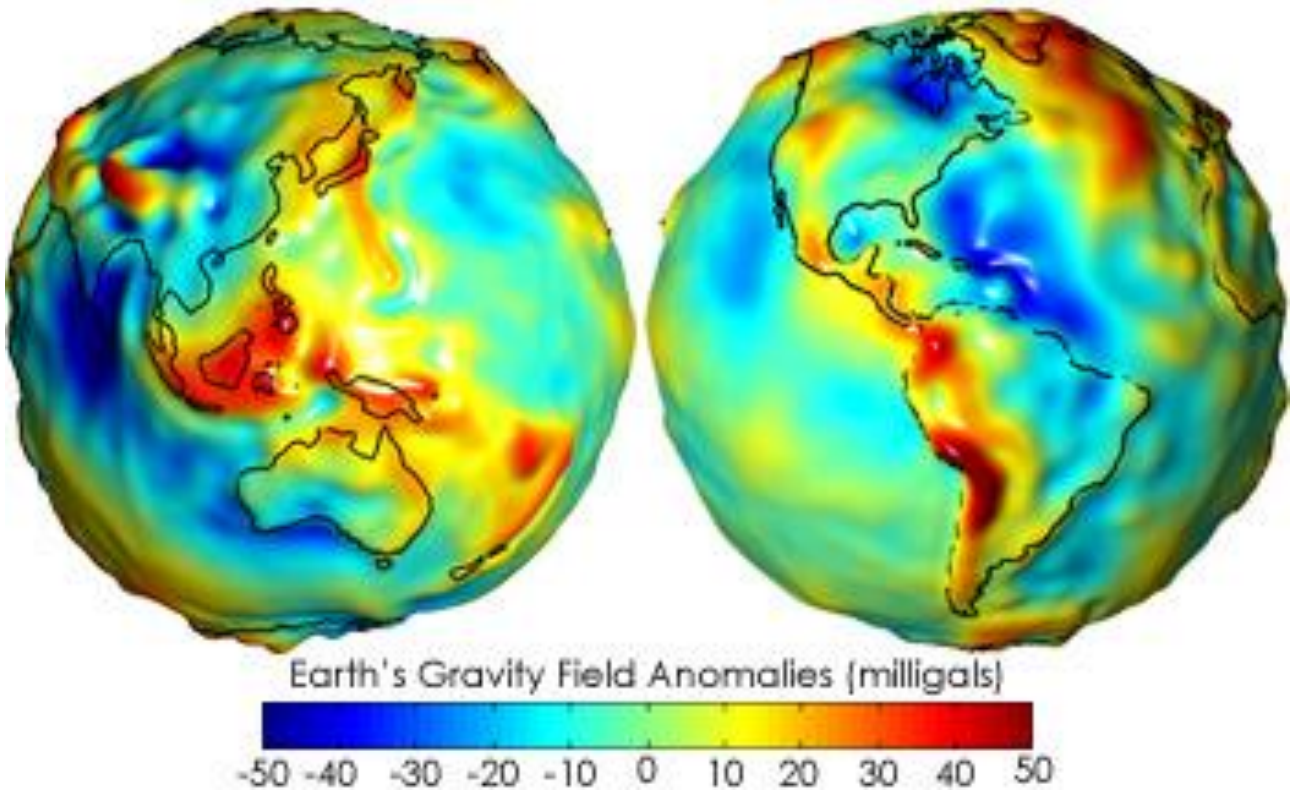


- Ellipsoid – simplified mathematical representation of the Earth
- Coordinates are defined relative to the centre of the ellipsoid (X, Y, Z) (ϕ, λ, h)
- Heights are straight lines above (or below) the ellipsoid

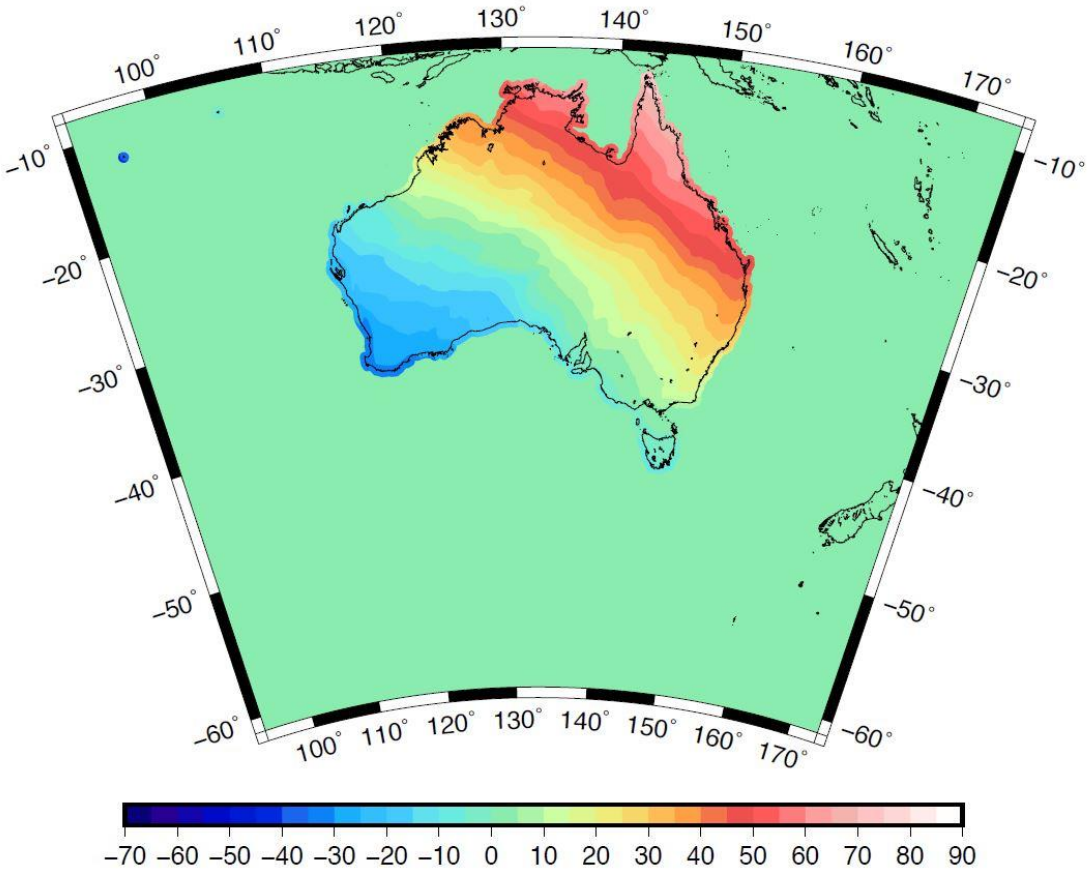


Dan Roman, 2007

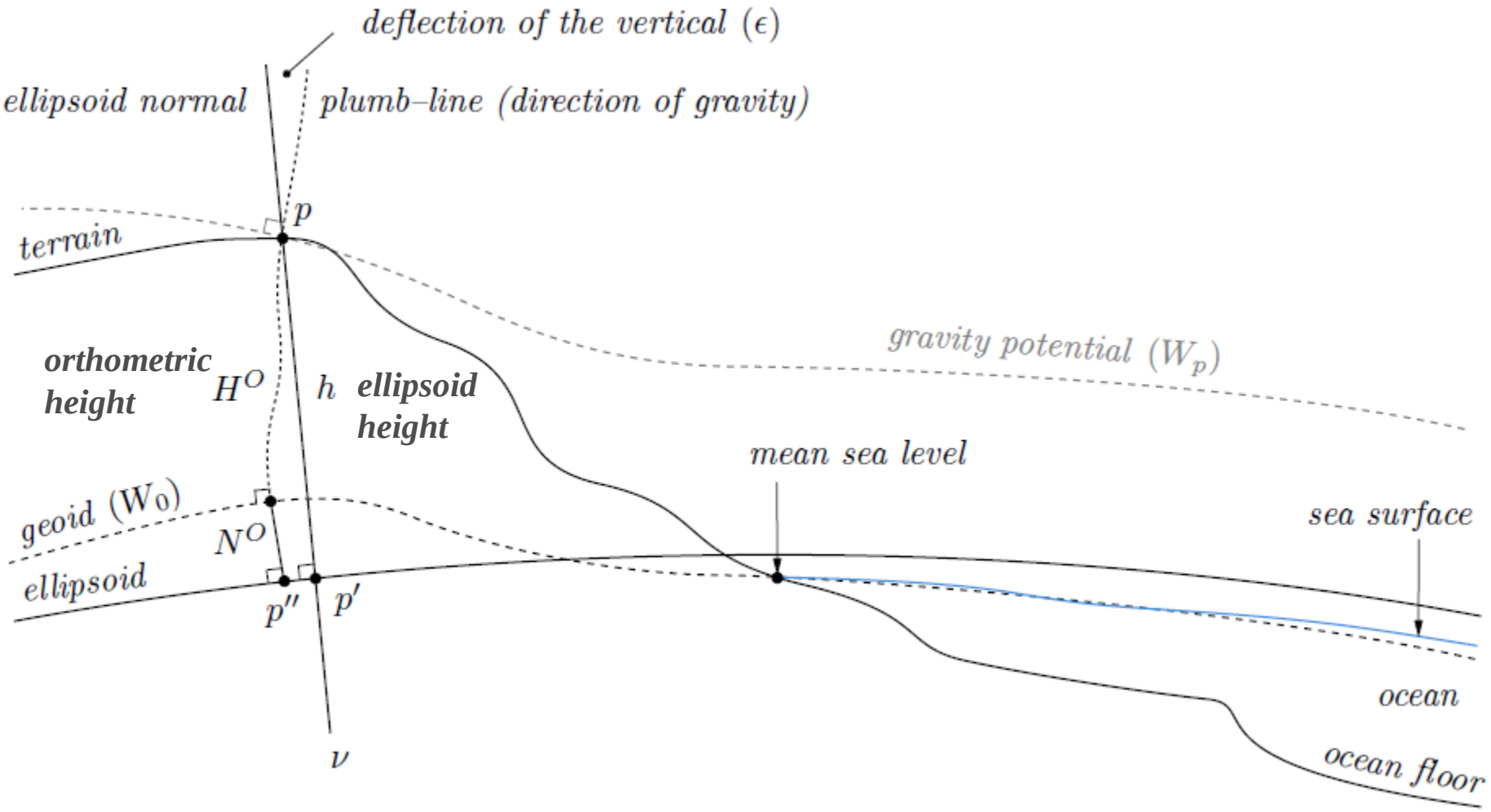
Geometric vs Gravitational Potential



Model to convert geometric GNSS heights to physical heights

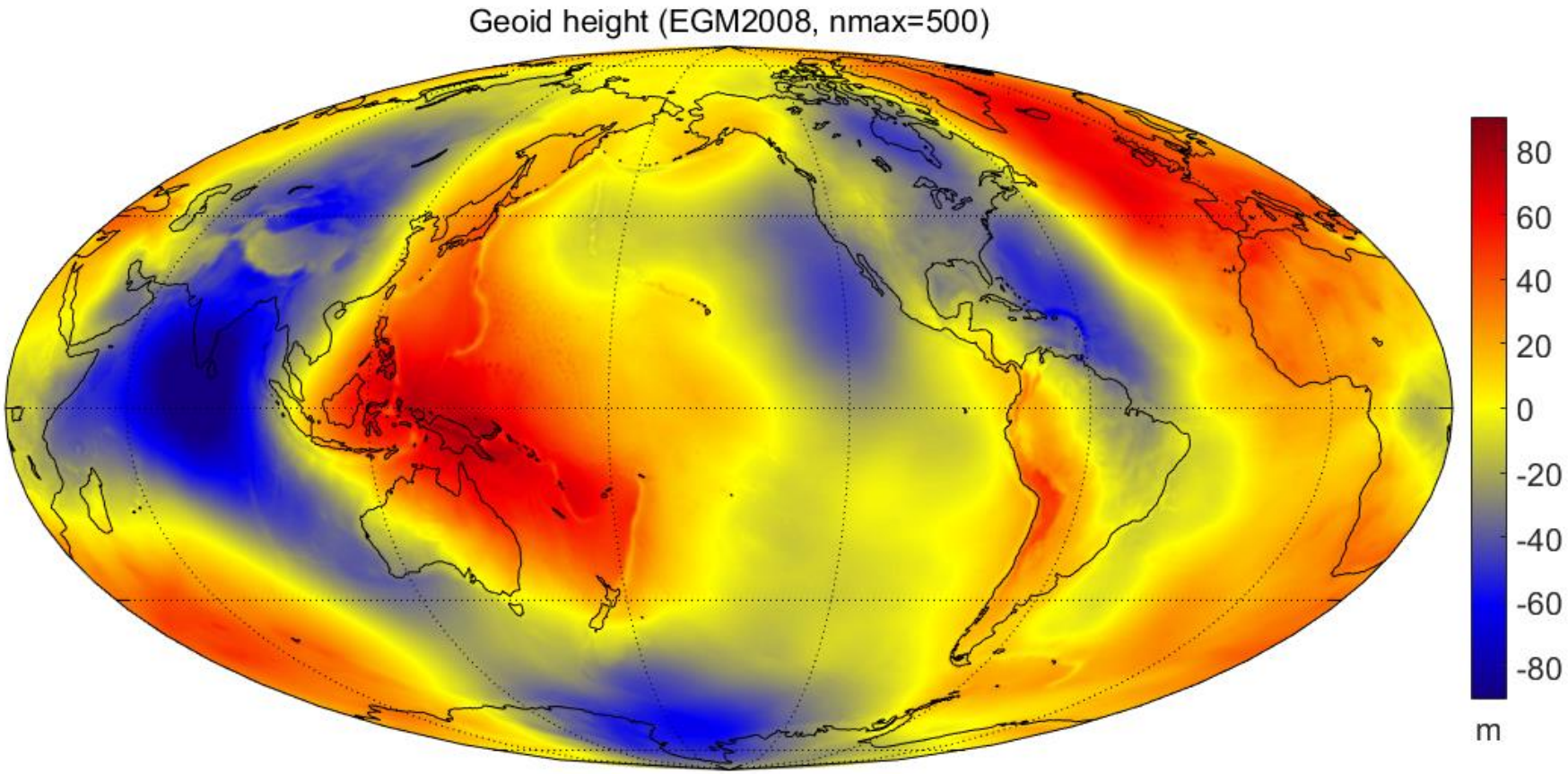


Physical Height System – orthometric



DynAdjust User Guide (Fraser, 2018)

Earth Geopotential Model 2008



Example: Tuvalu GNSS CORS

Converting from ellipsoid height to geoid height

$H = h - N$

H = above geoid height

h = ellipsoid height

N = geoid to ellipsoid separation (using a model)

$H = 38.380 - 34.839$

$H = 3.541$ m

Regional Geoids

- Locally enhanced versions of the global models
- Incorporate additional gravity observations from multiple sources: terrestrial, shipborne, airborne and altimetry
- These improve the accuracy of the geoid models from ~10 cm to ~ 2-5 cm

Reference Surfaces

Physical reference surface

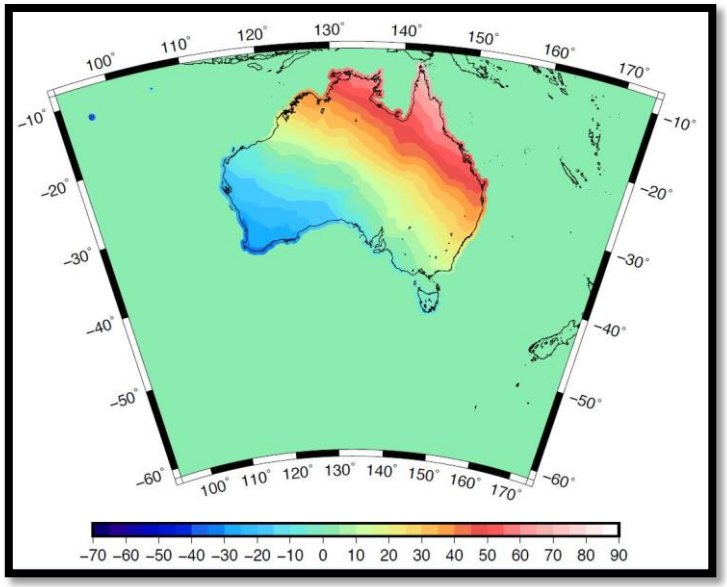
- Mean Sea Level
  - Fix MSL at a single point
  - Fix MSL at several points
- Arbitrary level at a single point

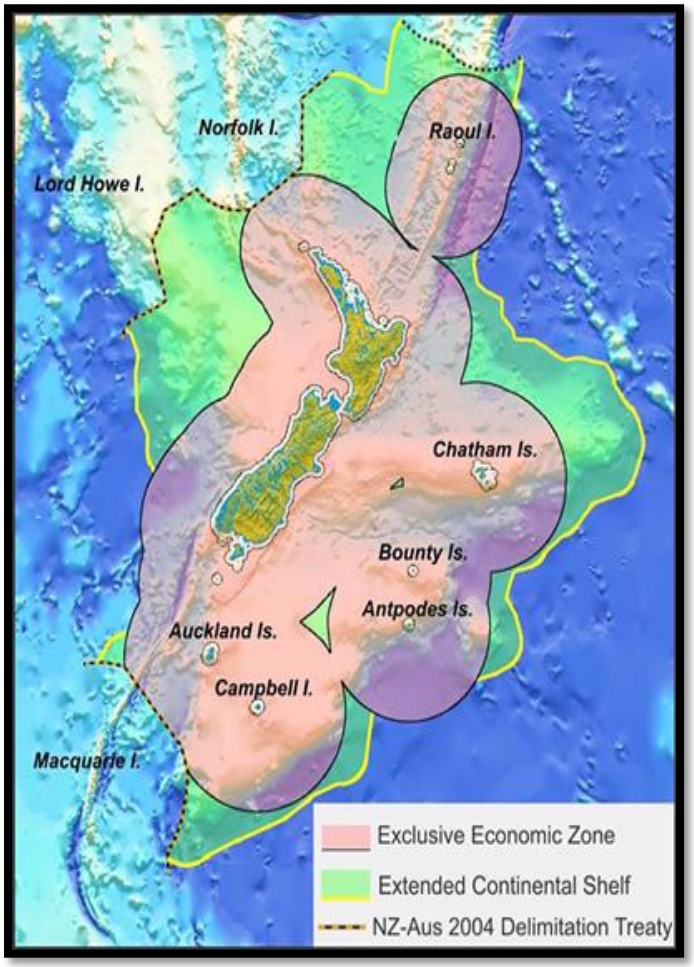
Virtual reference surface

- Geoid/quasigeoid model
- Ellipsoid

Desirable attributes for a geoid model

- Accessible - anywhere
- Consistent reference system
- Compatible with geometric datum
- Fit for purpose – meets user needs
- Maintainable and assessable



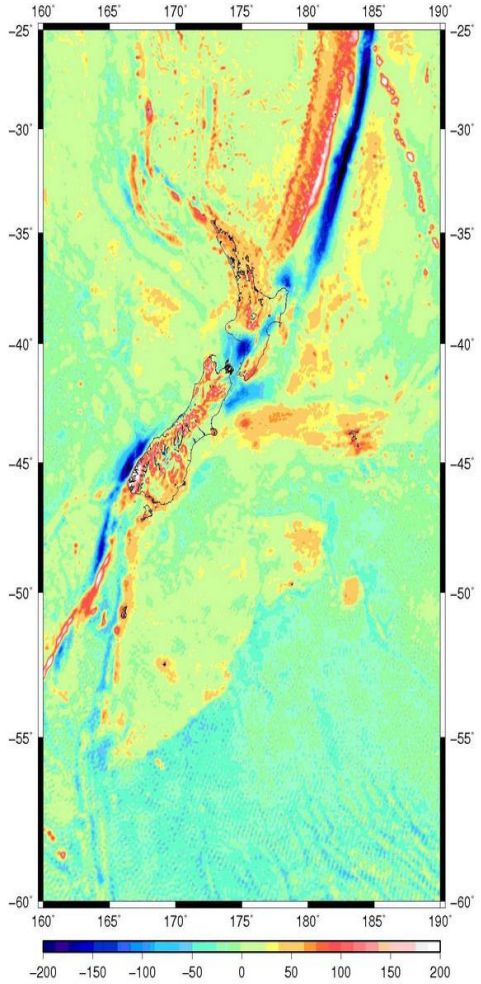


Creating a geoid model for your country

Land Information New Zealand
Toitū te whenua

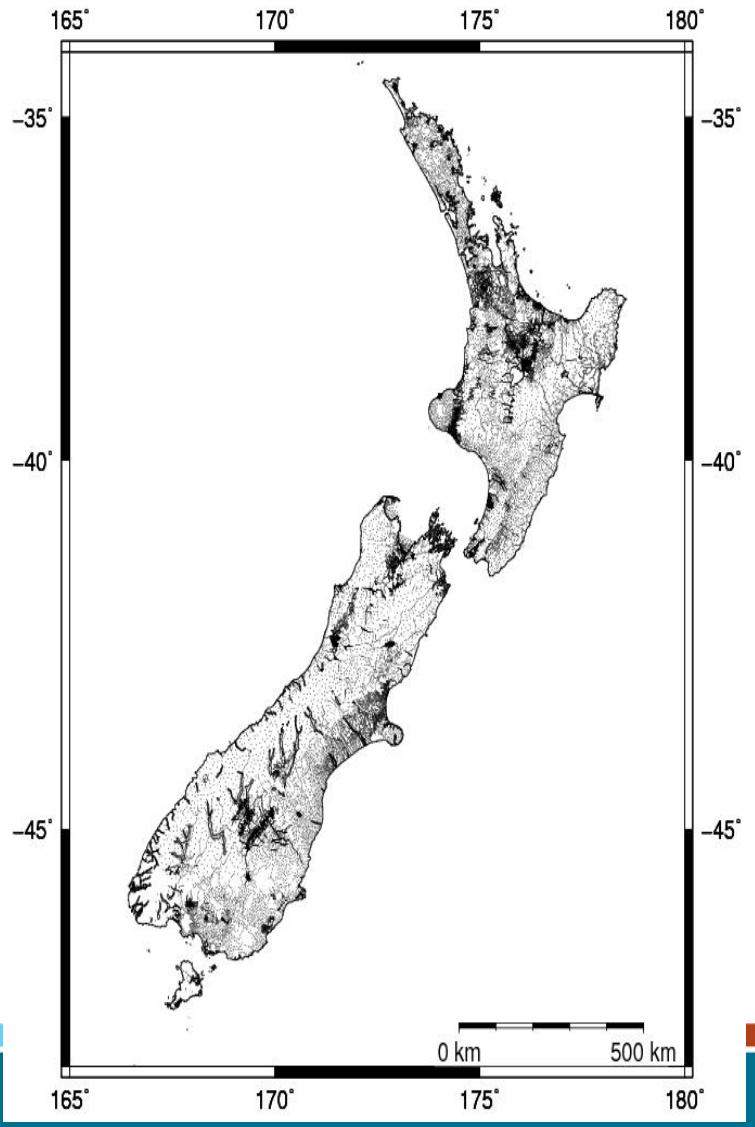
Datasets:

- Global Gravity Model - EGM2008



New Zealand Quasigeoid 2009

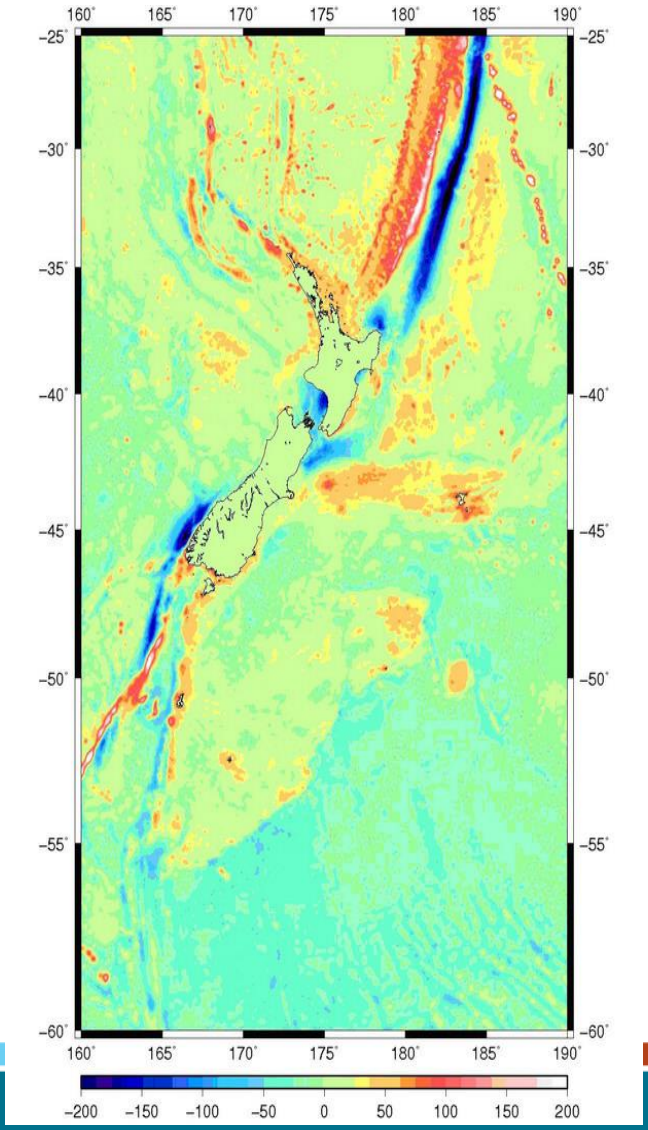
- Datasets:
  - Global Gravity Model - EGM2008
  - Land gravity data



New Zealand Quasigeoid 2009

Land Information New Zealand
Toitū te whenua

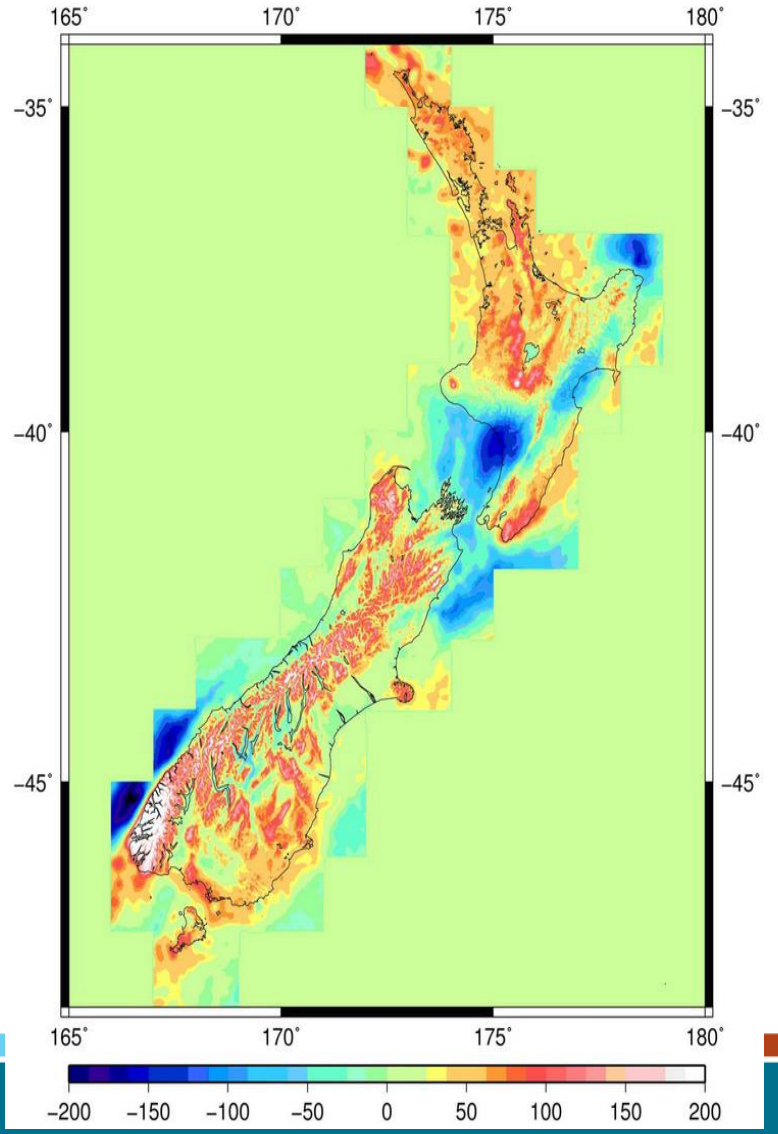
- Datasets:
  - Global Gravity Model - EGM2008
  - Land gravity data
  - Satellite altimetry data



New Zealand Quasigeoid 2009

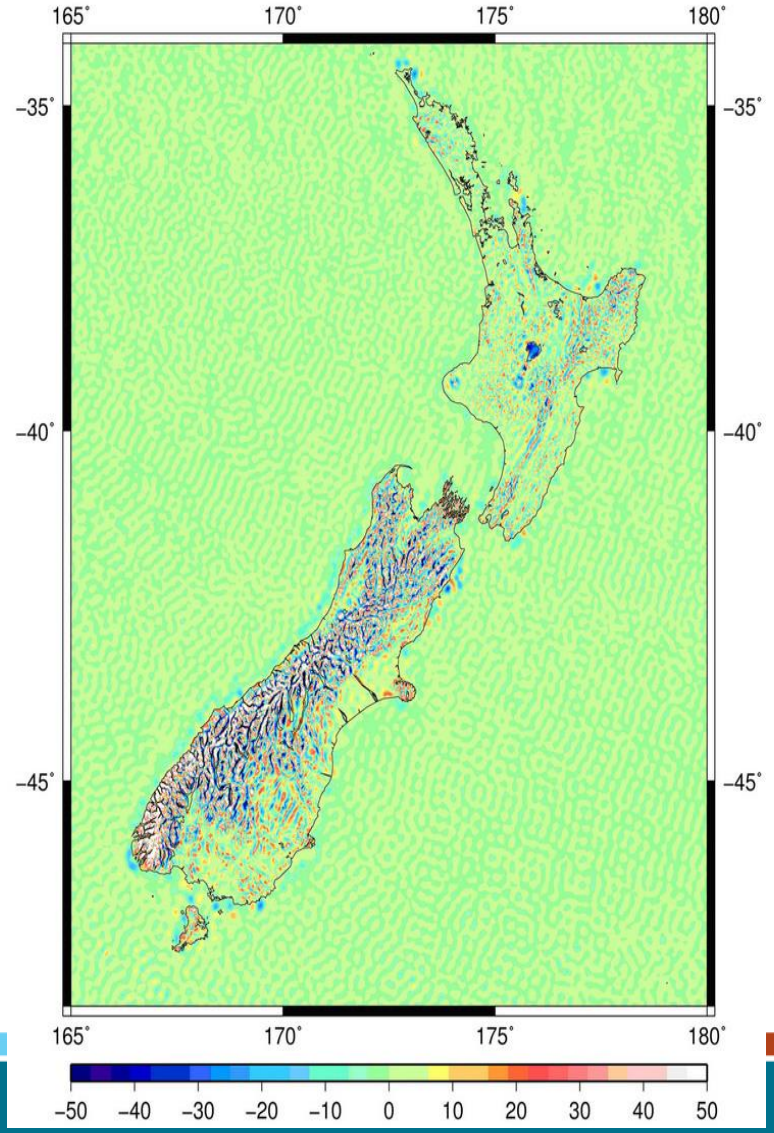
Land Information New Zealand
Toitū te whenua

- Datasets:
  - Global Gravity Model - EGM2008
  - Land gravity data
  - Satellite altimetry data
  - Digital elevation model



New Zealand Quasigeoid 2009

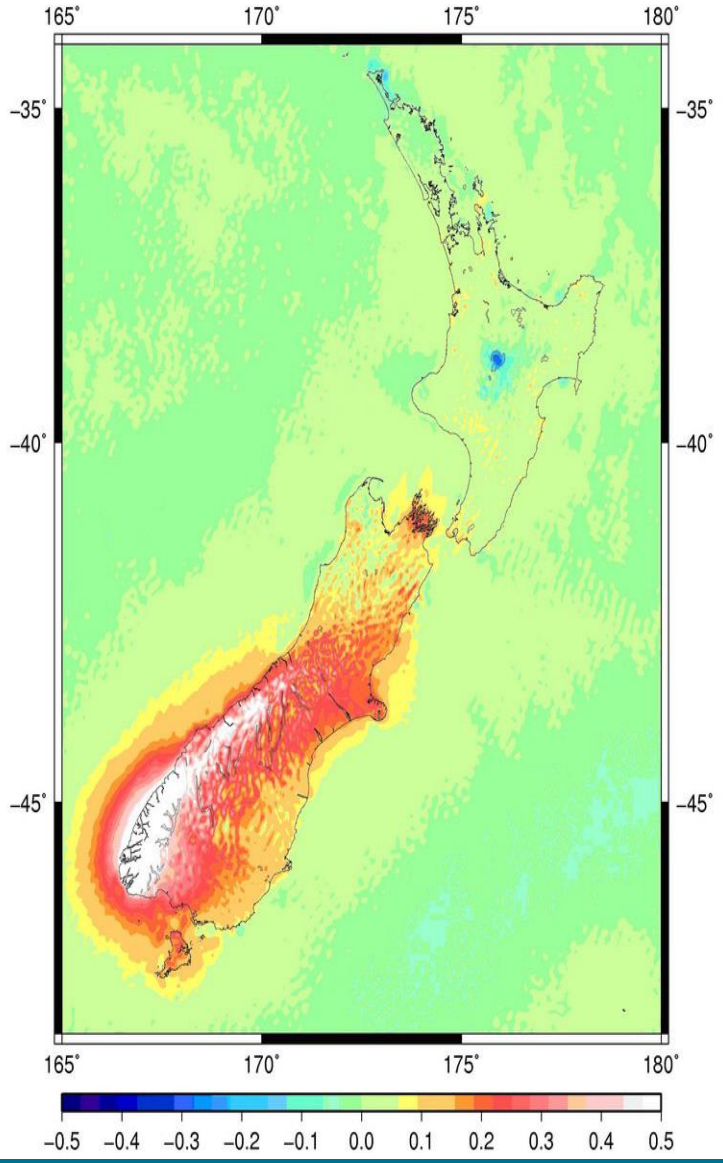
- Datasets:
  - Global Gravity Model - EGM2008
  - Land gravity data
  - Satellite altimetry data
  - Digital elevation model
- Subtract EGM2008



New Zealand Quasigeoid 2009

Land Information New Zealand
Toitū te whenua

- Datasets:
  - Global Gravity Model - EGM2008
  - Land gravity data
  - Satellite altimetry data
  - Digital elevation model
- Subtract EGM2008
- Create a residual geoid



New Zealand Quasigeoid 2009

- Datasets:
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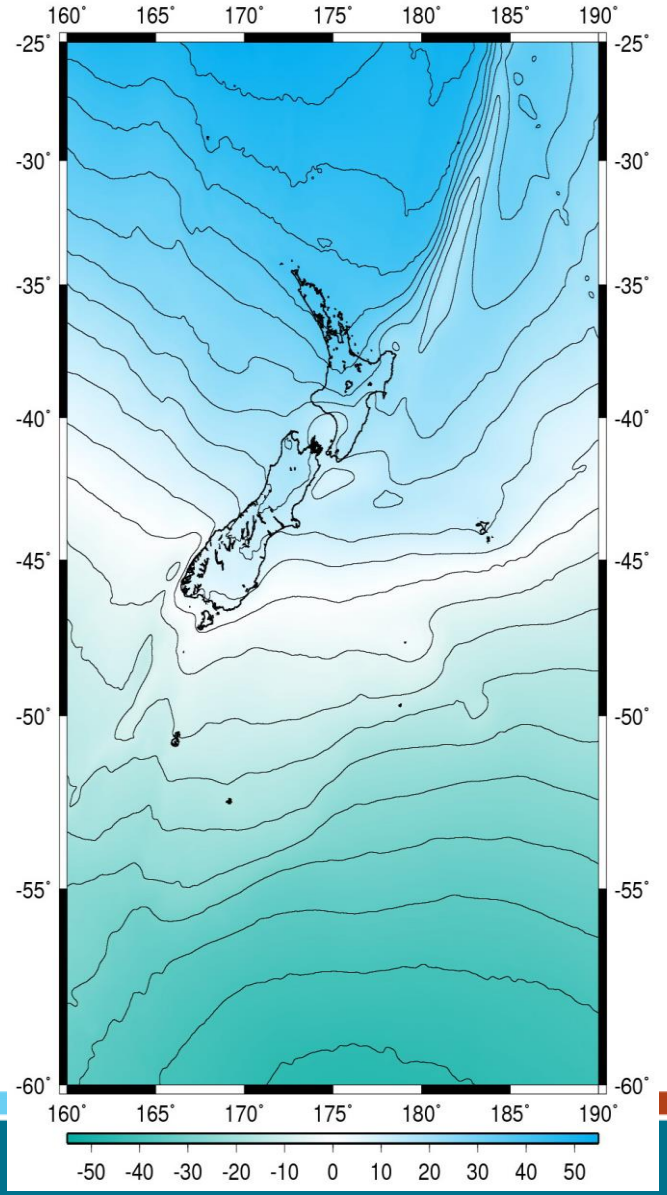
  - Land gravity data
  - Satellite altimetry data
  - Digital elevation model
- Subtract EGM2008
- Create a residual geoid
- Add back EGM2008



New Zealand Quasigeoid 2009

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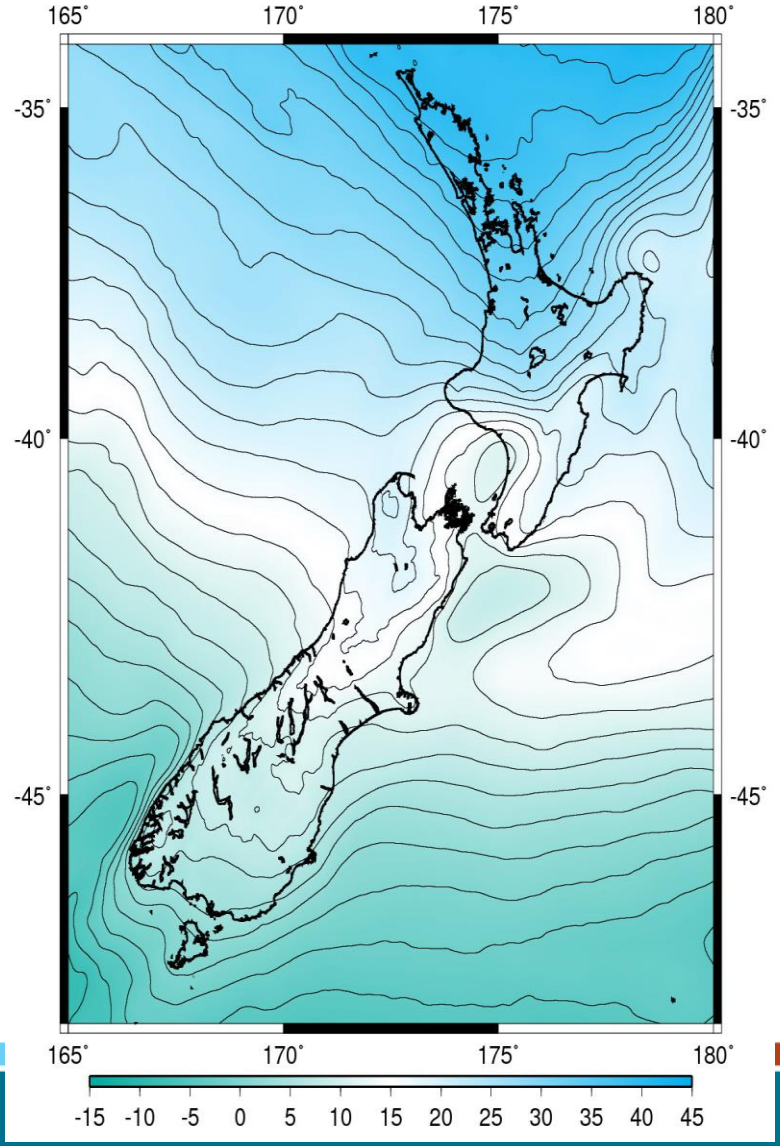
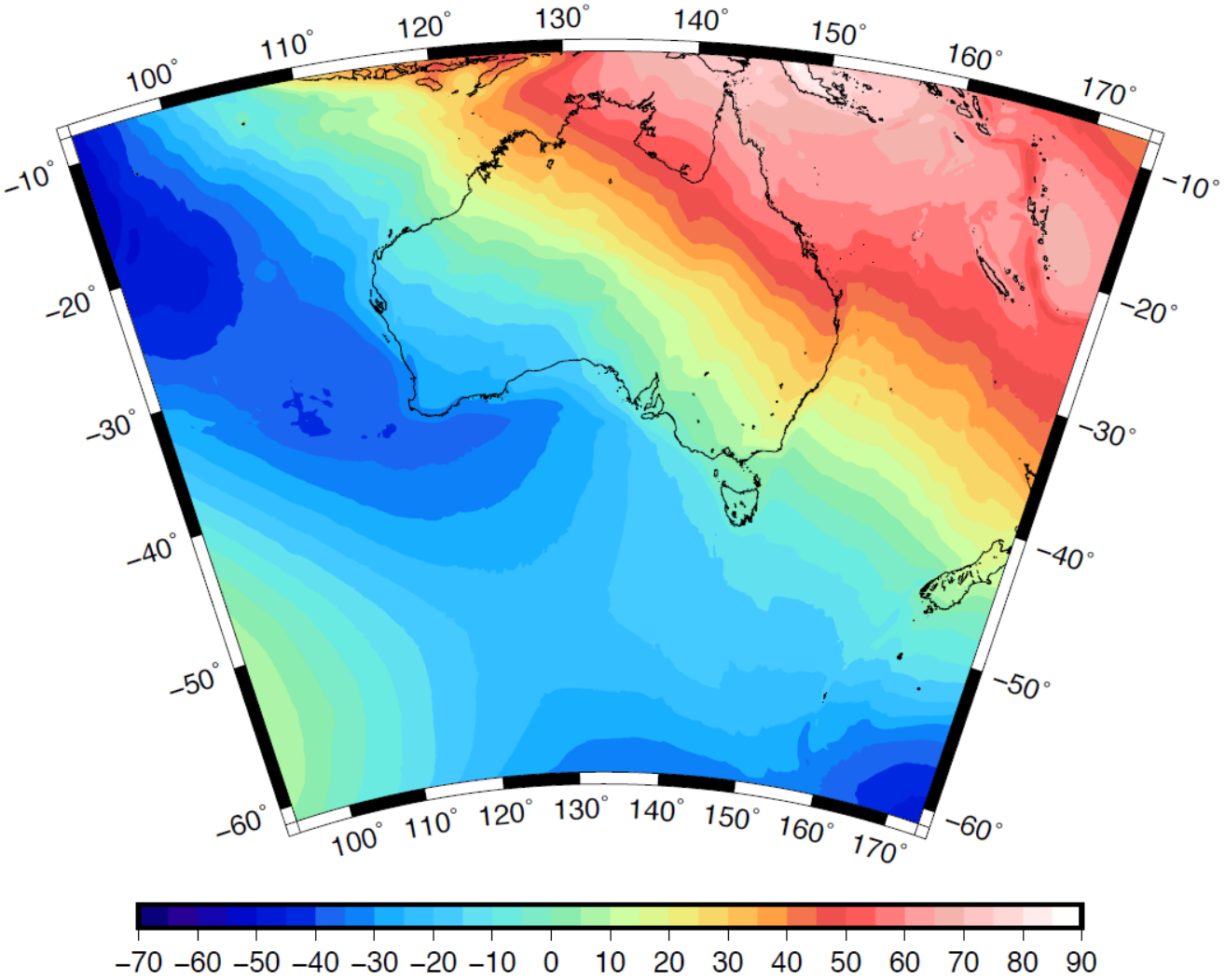
  - Satellite altimetry data
  - Digital elevation model
- Subtract EGM2008
- Create a residual geoid
- Add back EGM2008
- NZGeoid2009



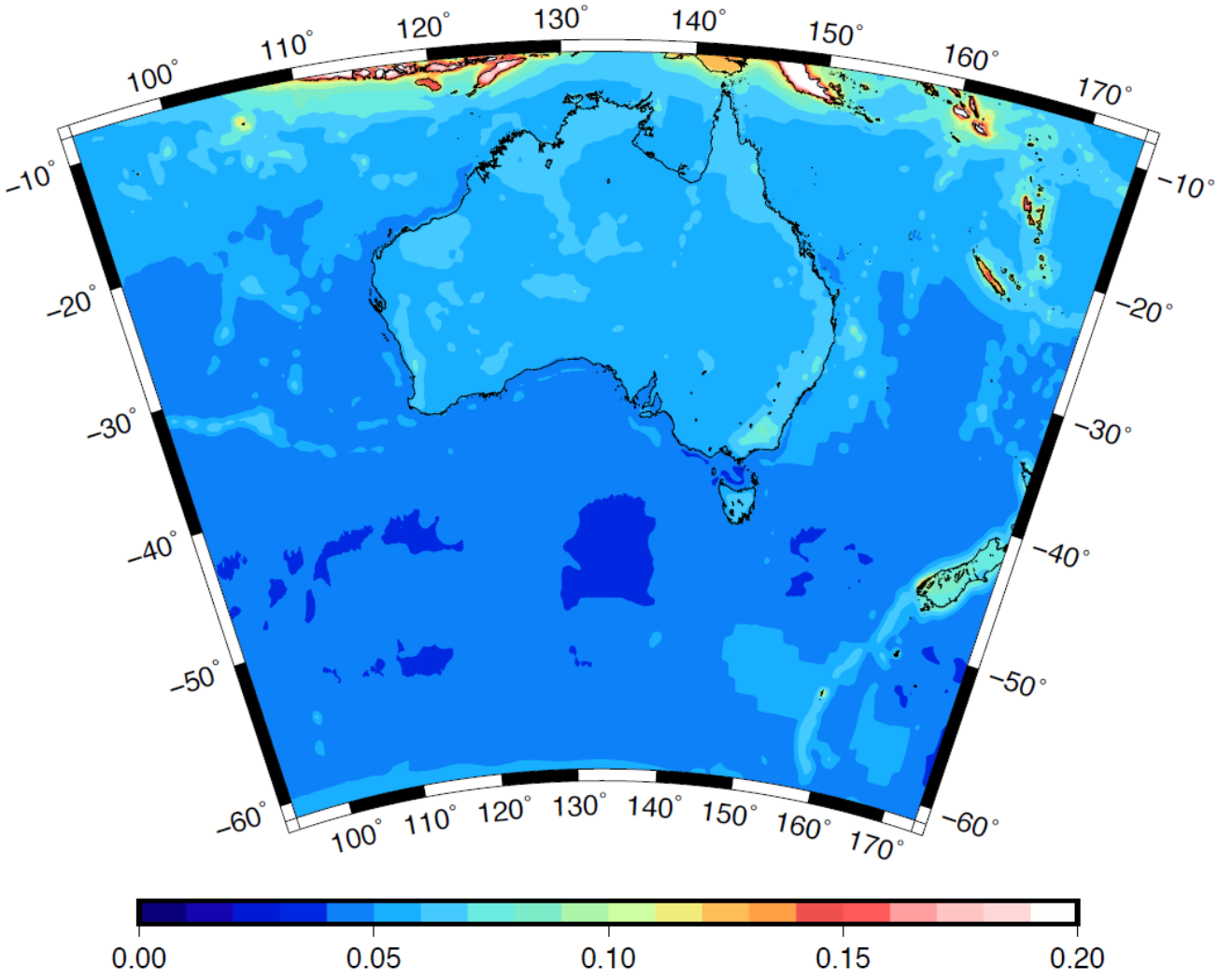
New Zealand Vertical Datum 2009

- Computed from existing datasets
- Provided nationally consistent vertical datum across the NZ continental shelf
- First consistent national vertical datum
- Included offsets to 13 local datums
- Accurate to ~6 cm
- A similar technique could be used in the Pacific to provide a nationally / regionally consistent height datum

Australia geoid model



Australia geoid model - uncertainty



Geoid based vertical datums

Advantages:

- No more national-scale levelling
- Accessibility to the vertical datum using GNSS

Considerations:

- Need terrestrial gravity data coverage to ensure reliability
- Lower accuracy over short distances compared to levelling
- Need to consider access by users without GNSS equipment

Concluding remarks

- Consistent, authoritative heights are really important for all governments and society
- The determination of national/regional height datum is complex (technical and implementation)
- Nationally consistent height datums generally lacking (weakness and an opportunity)
- Can global gravity models with enhancements from terrestrial gravity data be used to provide geoid models?
- Can nations work together in aid funding applications and staff training / resourcing to undertake this important task.

Discussion / Questions

Discuss the heighting requirements of Pacific Island nations

- What heighting data is available?
- What needs to be done to make the data ready?
- What do the users want?