Modern Height System for Tonga

For Supporting Infrastructure, Climate Change Mitigation, & Resilience

Workshop Applications of Global Navigation Satellite Systems, Suva, Fiji

24 – 28 June 2019

Geodetic Survey
Ministry of Lands & Natural Resources
Tonga

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Focus of the Presentation

- Re-cap heights fundamentals
- Tonga's current height system
- The Plan
- Conclusion

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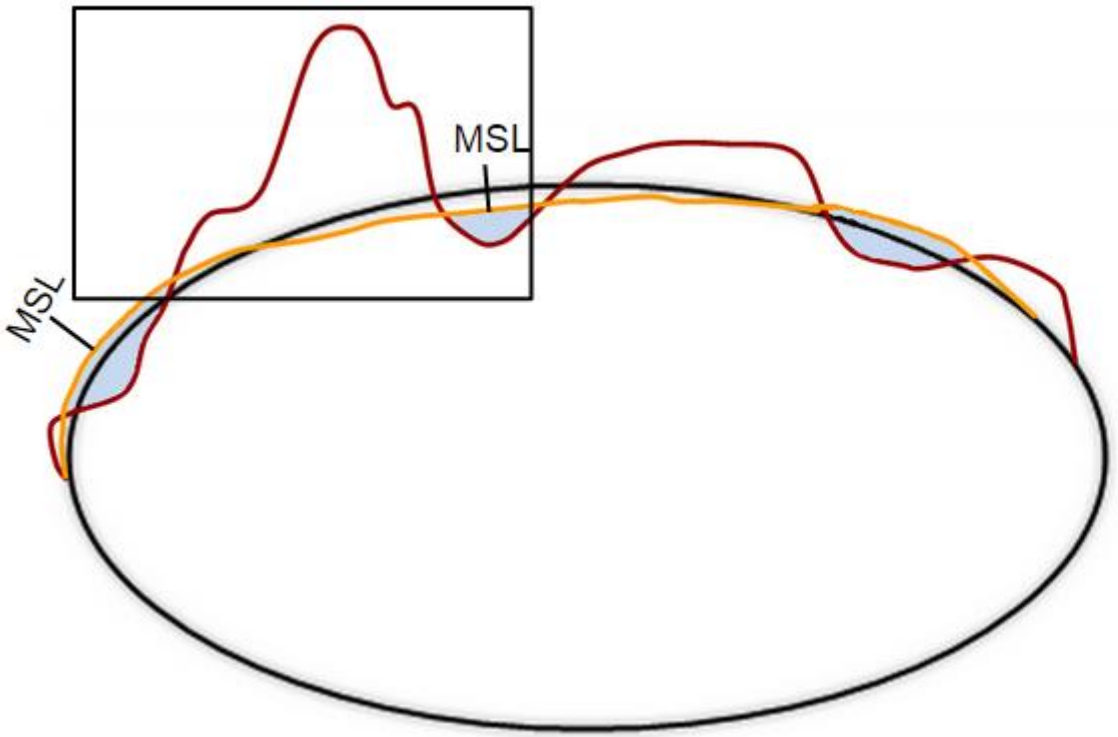
Height Surfaces



Earth Surface

Ellipsoid

Geoid

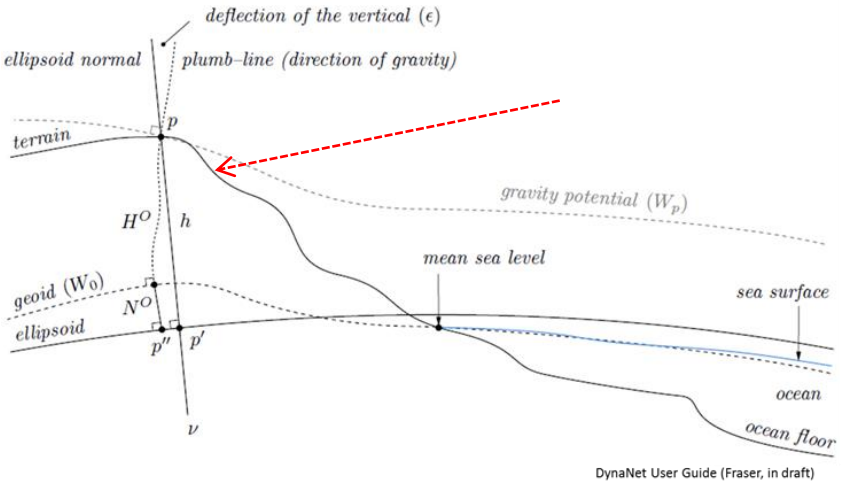
MSL: Mean Sea Level

Height System-Recap

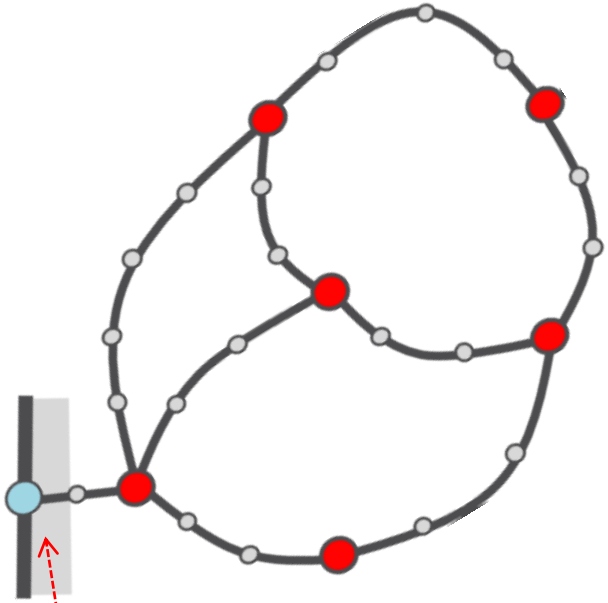
- Two types of height systems:
  1. Physical – based on Earth's gravity field and measured along the curved plumbline (e.g. orthometric heights)
  2. Geometric – not based on gravity field (e.g. GNSS ellipsoidal heights)
- Purpose: become more aware of the different **reference surfaces** and different **paths**

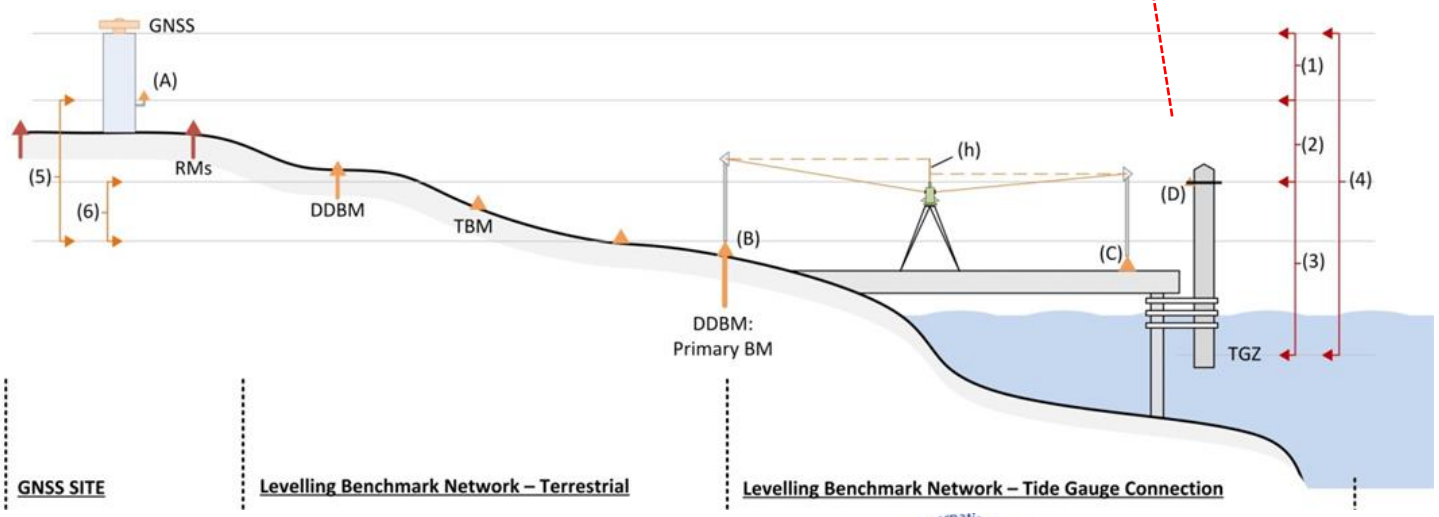
Brown 2016

Physical Heights



DynaNet User Guide (Fraser, in draft)





Dawson 2016

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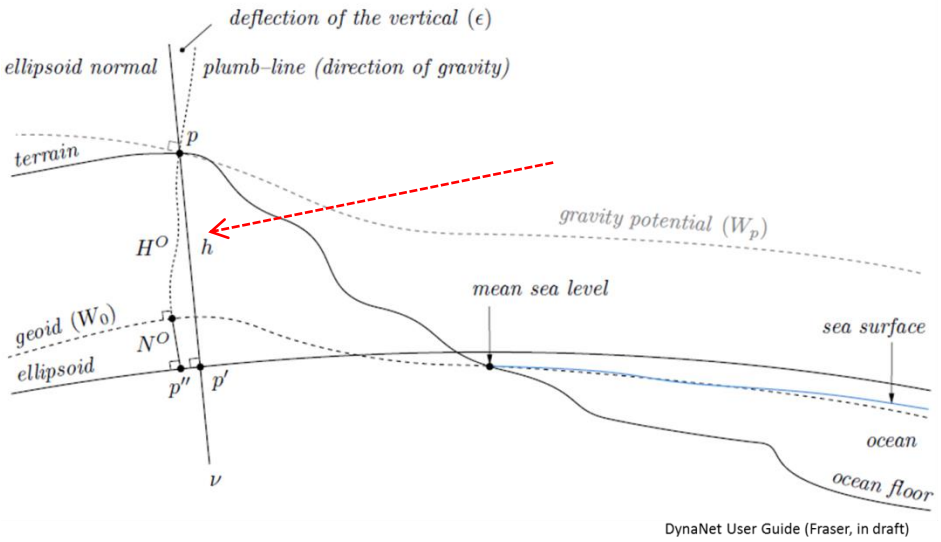
Geometric Heights



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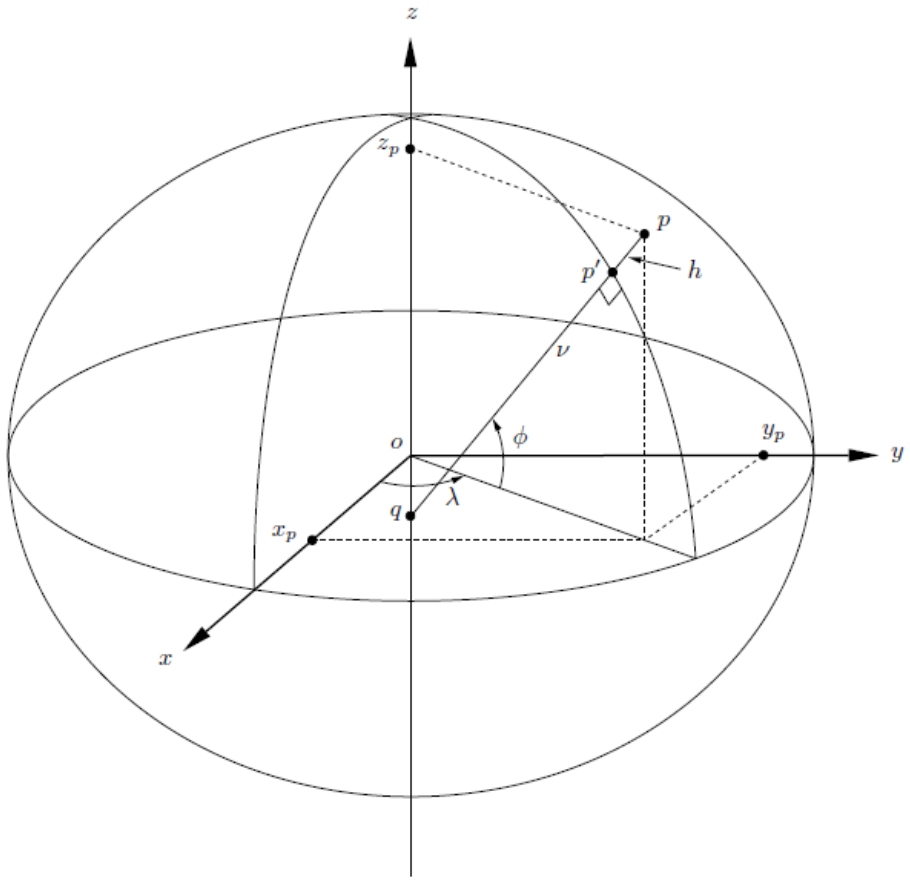

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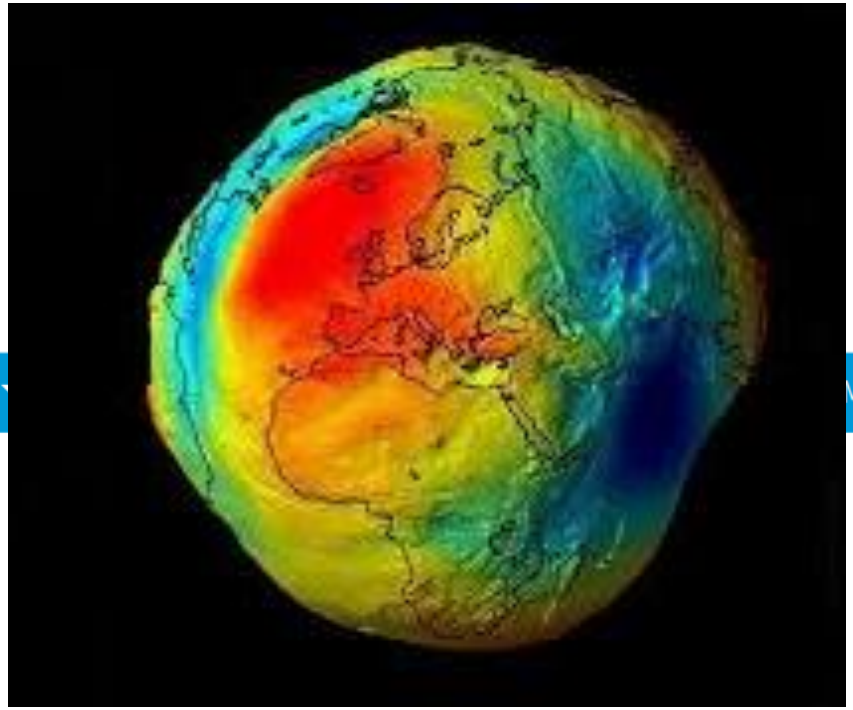
Geoid Model



National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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HOME » OCEAN FACTS » WHAT IS THE GEOID?

What is the geoid?

The geoid is a model of **global mean sea level** that is used to measure **precise surface elevations**.

- EGM08

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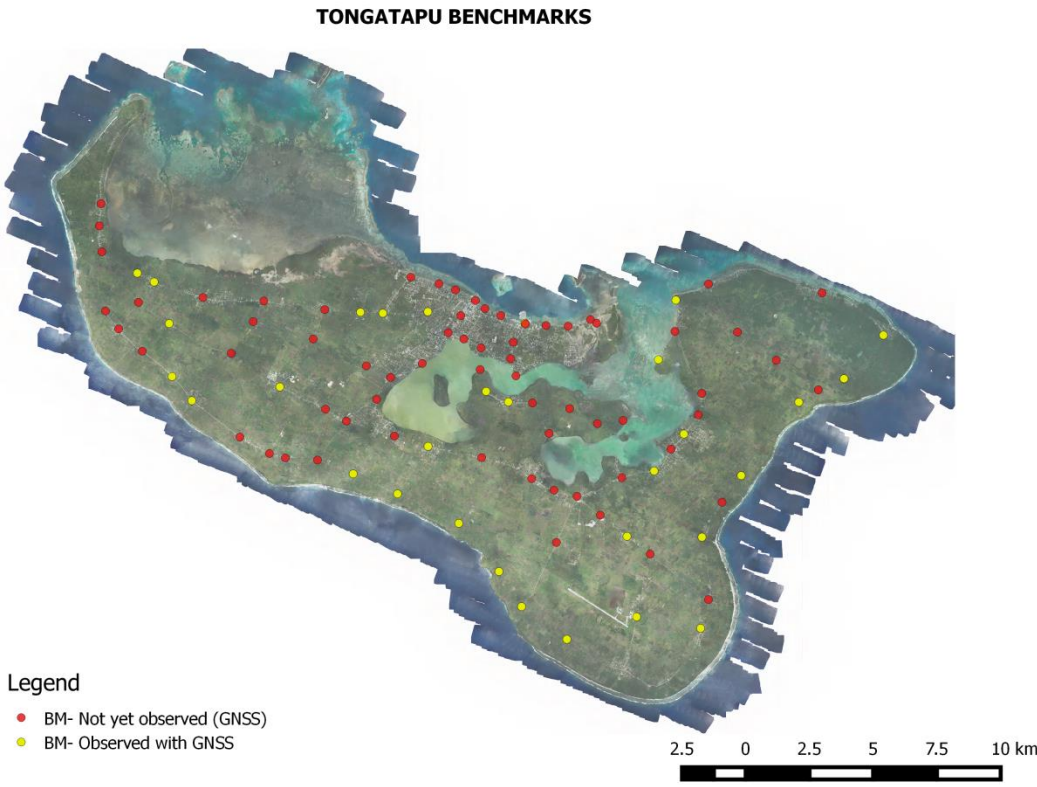
Height Systems

- Traditionally people prefer to know their height relative to sea level (physical height surface)-Levelling and BMs:
  - 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 (geometric)
- These height systems aren't aligned, but can be connected (e.g. using geoid models)
- It is important to understand how these systems are different and how data from these systems can be used together

Brown 2016

Current Height System

- MSL 1990
- Levelling network only in main island
- BMs with MSL & Ellipsoid height
- Include deep BMs under the Pacific Sea Level & Geodetic Monitoring Project (PSLGMP)



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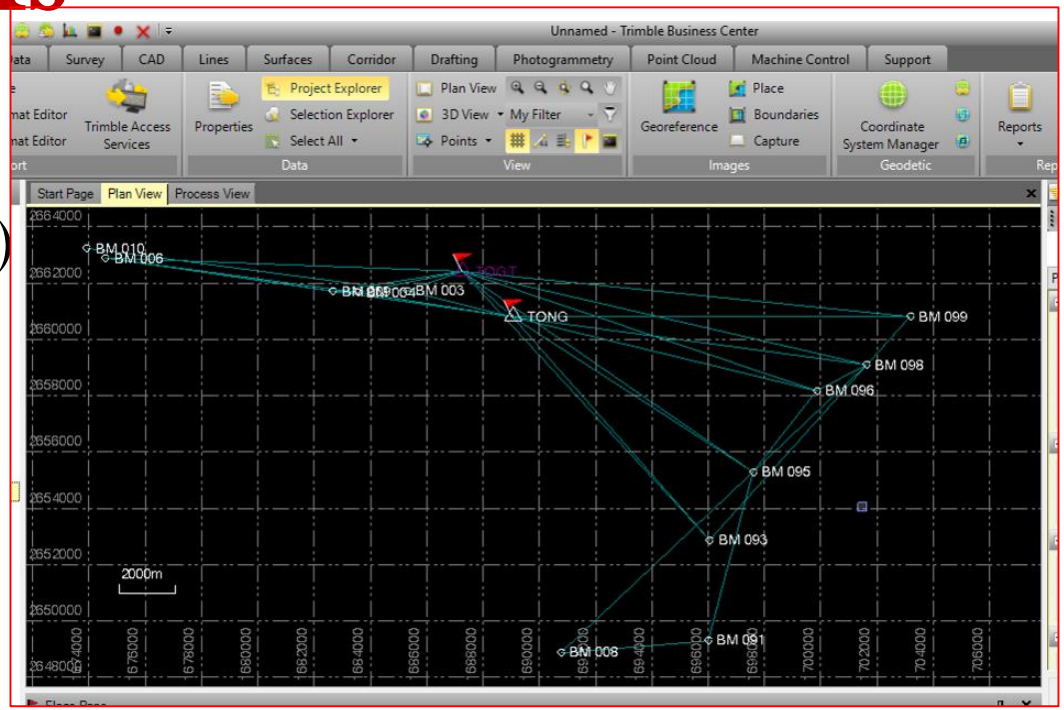
GNSS and BMs

- Determine ellipsoid height of all BMs
- Most of these BMs has not been used- locating them is a challenge
- N = h - H

GNSS and BMs

- Process data using TBC (Trimble Business Centre)
- Use data from two CORS
- AUSPOS to process data



3.2 Geodetic, GRS80 Ellipsoid, ITRF2014

Geoid-ellipsoidal separations, in this section, are computed using a spherical harmonic synthesis of the global EGM2008 geoid. More information on the EGM2008 geoid can be found at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/.

Station	Latitude (DMS)	Longitude (DMS)	Ellipsoidal Height(m)	Derived Above Geoid Height(m)
0468	-21 08 12.03094	-175 12 55.79982	55.086	2.430
4244	-21 07 26.79044	-175 19 31.28223	57.724	4.942

Protect Worksheet

UnProtect Worksheet

Worksheet is currently PROTECTED

Ministry of Lands,Survey, Natural Resources and Environment, Kingdom of Tonga

Geodetic Database

Update Geodetic Code sheet

MSL Ht MSL1990

Ellipsoid-MSL Ht

EMG2008

Geodetic Code	Name	Status	Date of Entry	Mark Condition	Island Group	TMG E	TMG N	TGD2005 Latitude (deg min sec)	TGD2005 Longitude (deg min sec)	TGD2005 Ellipsoidal Height	TGD2005 Order	Orthometric Height	Height Datum	N Value	N Value	Diff between N values
TONG	Tonga CGPS	Draft	14/10/2005	Reliable	Tongatapu	1689071.96	2660752.47	21 08 40.96762 S	175 10 45.20056 S	56.326	0					
TFUA	FUAM 013	Draft	14/10/2005	Reliable	Tongatapu	1690760.51	2650750.71	21 14 05.50042 S	175 09 42.66367 S	80.392	1	27.471	MSL 1990	52.921		
THKM	Ha'akame	Draft	14/10/2005	Reliable	Tongatapu	1702534.95	2658376.73	21 09 53.00244 S	175 02 57.64801 S	59.013	1	6.246	MSL 1990	52.767	51.770	-0.997
TGPU	TGPU 001	Approved	14/10/2005	Reliable	Tongatapu	1675568.98	2657717.32	21 10 24.50542 S	175 18 32.04453 S	62.307	1	8.665	MSL 1990	53.642	52.390	-1.252
T001	Kings Terminal	Approved	14/10/2005	Reliable	Tongatapu	1692973.81	2649949.73	21 14 30.69906 S	175 08 25.58965 S	84.757	2	32.114	MSL 1990	52.643	51.790	-0.853
T005	TTY30	Approved	14/10/2005	Reliable	Tongatapu	1673425.63	2669603.24	21 03 58.78533 S	175 19 50.66871 S	69.306	2	15.260	MSL 1990	54.046	52.570	-1.476
T006	Astro (Nuku'alofa)	Approved	14/10/2005	Reliable	Tongatapu	1687136.14	2662107.32	21 07 57.63727 S	175 11 52.81962 S	54.713	3	1.220	MSL 1990	53.493	52.290	-1.203
T007	TON1	Approved	14/10/2005	Reliable	Tongatapu	1689123.71	2661232.97	21 08 25.32667 S	175 10 43.59824 S	54.509	2	1.119	MSL 1990	53.390	52.240	-1.150

Ellipsoid Height

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MSL in Outer Islands

- Climate Resilience Sector Project
  - Monitor Tides
  - By NIWA

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MSL in Major Outer Islands

- Hydrographic Survey
  - New nautical Chart
  - iXblue

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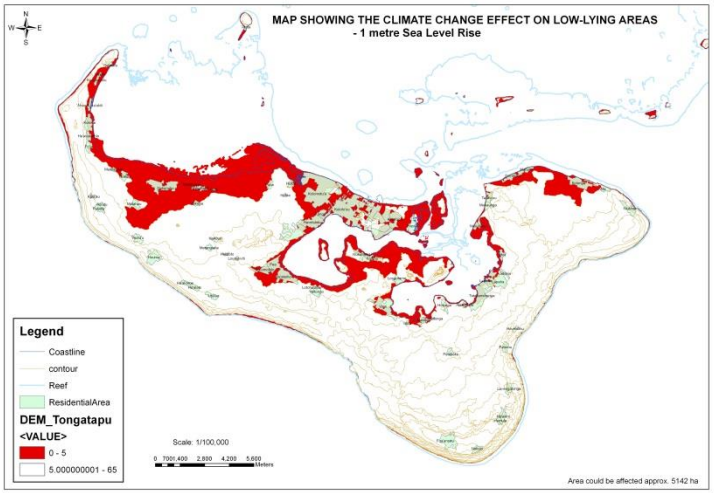
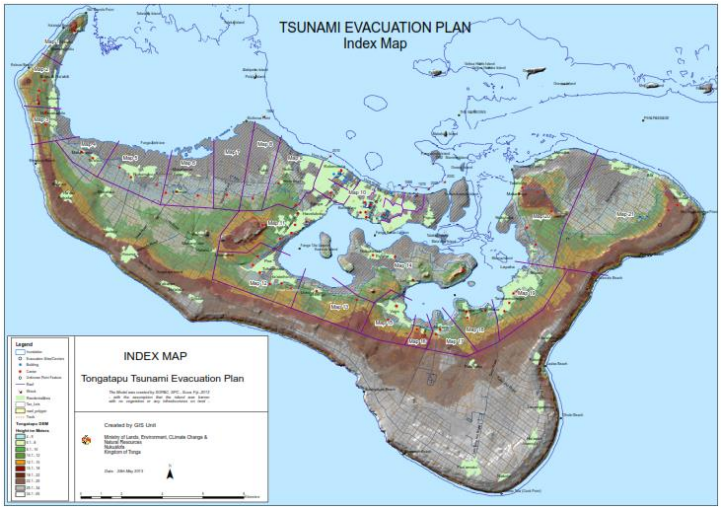
Why the NEED?





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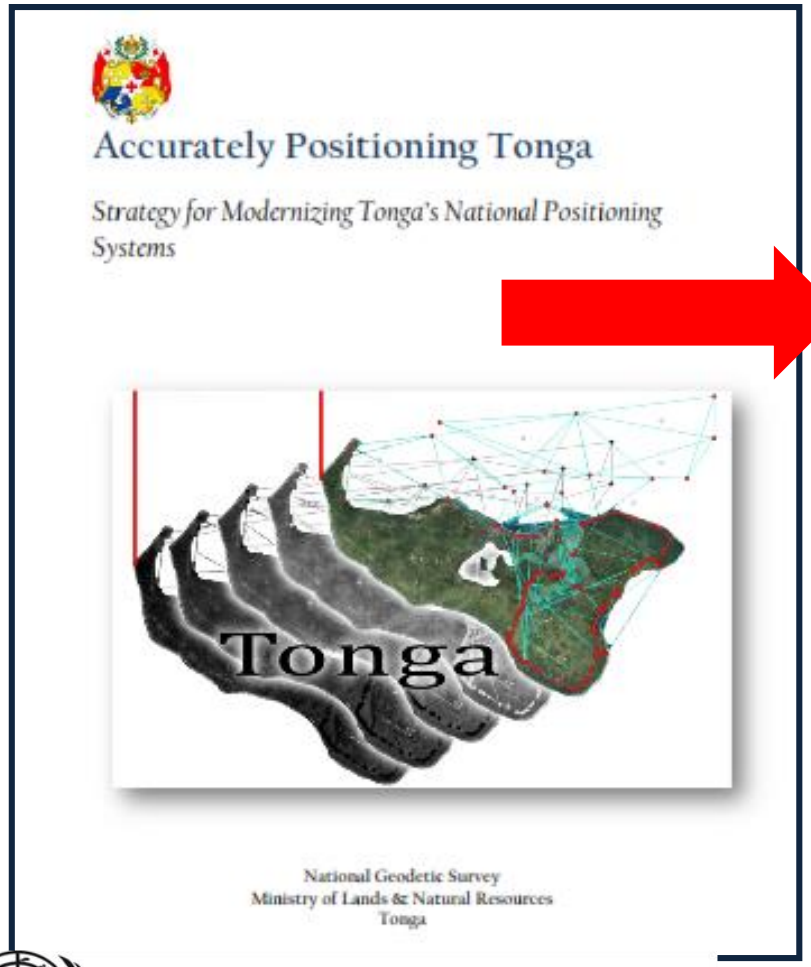
The Way Forward



2. **Develop an accurate height system and geoid model for Tonga that supports climate change mitigation and resilience.**

   a. **Unifying Tonga through a modern height system**
      - *Develop a geoid model for Tonga*
      - *Develop a Vertical Reference Frame for Tonga*

   b. **Accessing accurate heights at community level**
      - *Establish MSL network on major islands in Tonga*

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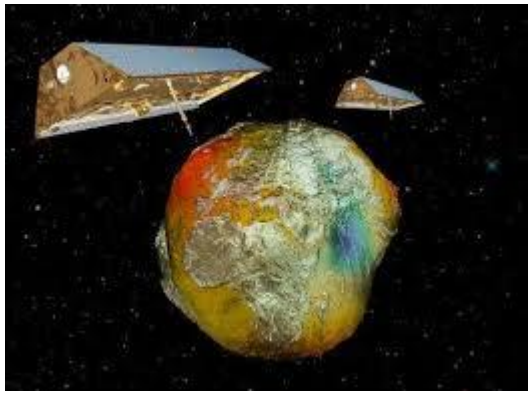
Tonga Geoid Model

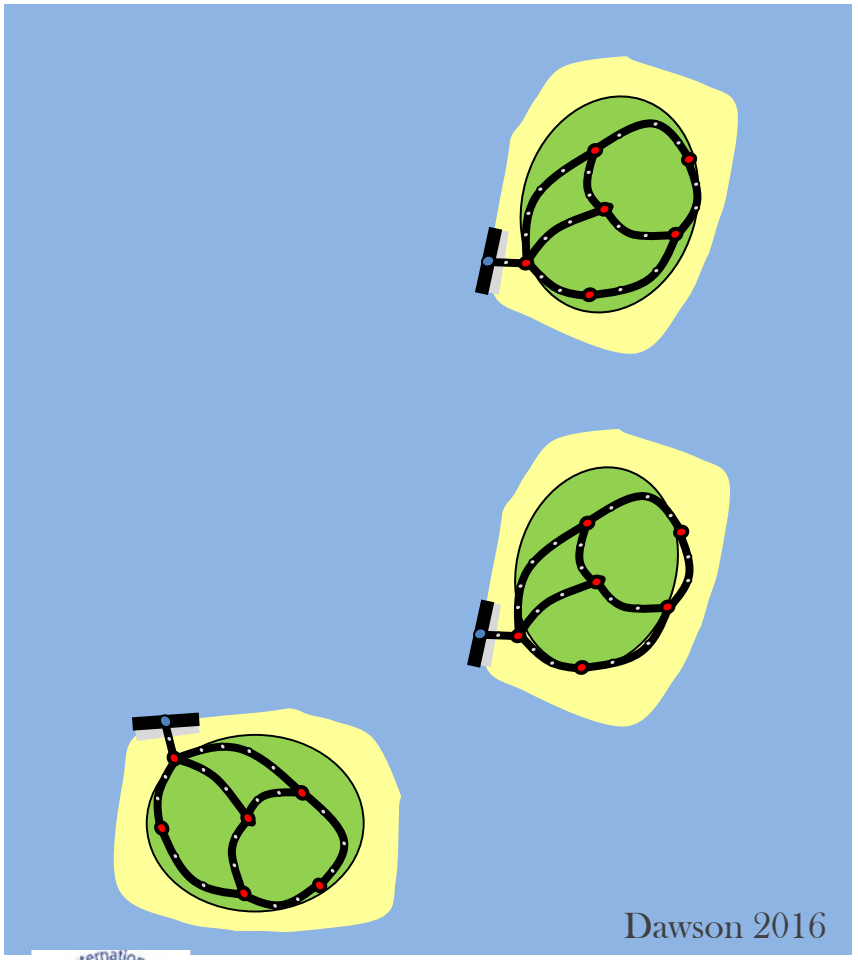


Gravity Measurements

- gravity satellite missions (e.g., GRACE, GOCE),
- Satellite altimetry,
- Localised airborne gravity,
- Land gravity data

Accessible Height at Community level

- Tide observations and distribute MSL height
- Challenge-linking islands
- Orthometric height from GNSS ellipsoid height minus N value from Tonga Geoid Model
- Orthometric height distributed through GNSS campaign



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Conclusion

- Significance of a modern height system to Tonga & islands in Pacific-sea level rise, storm surge, flooding, tsunami etc.
- Geoid Model to determine the N value
- GNSS to replace long and expensive levelling run in distribution of orthometric heights
- Gravity measurement technologies is a challenge
- Authoritative Height system covering the whole of Tonga