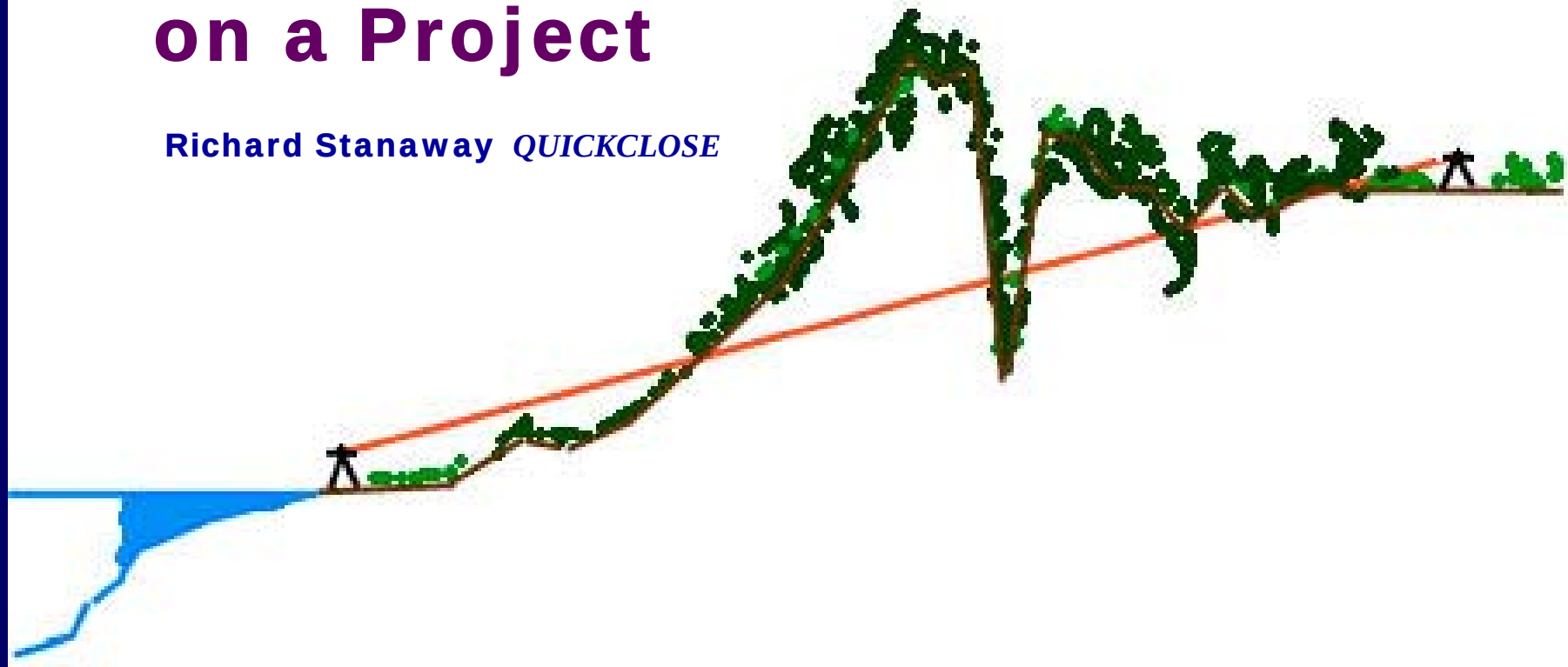
Using GNSS to establish a Height Datum on a Project

Richard Stanaway *QUICKCLOSE*



43rd Association of Surveyors PNG Congress
Lae International Hotel, Lae 12th - 15th August 2009

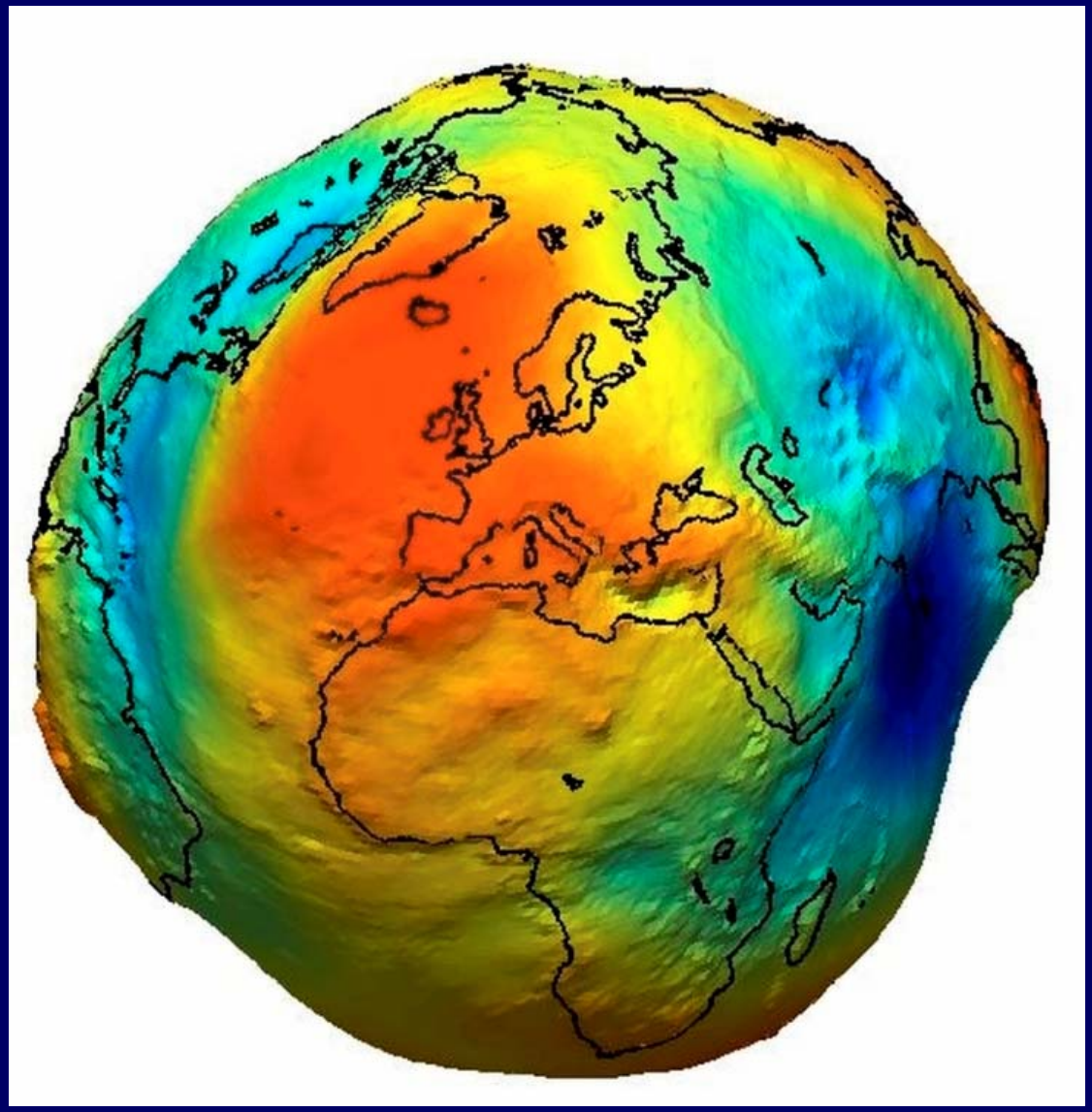
Overview of GNSS Heighting

Height systems and Geoid models

Preliminary Tidal Monitoring

Measuring ellipsoid Heights

Working with height datum offsets



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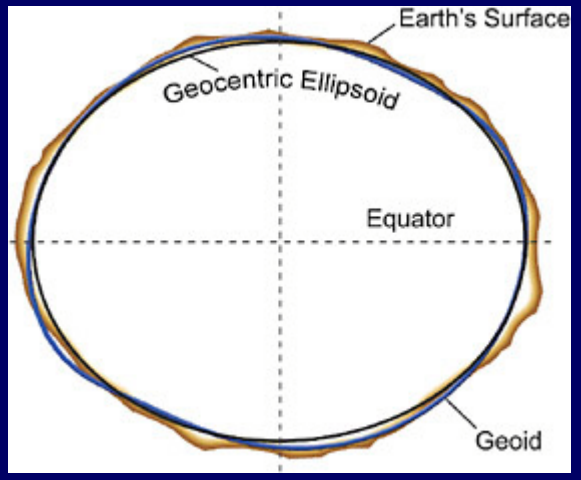
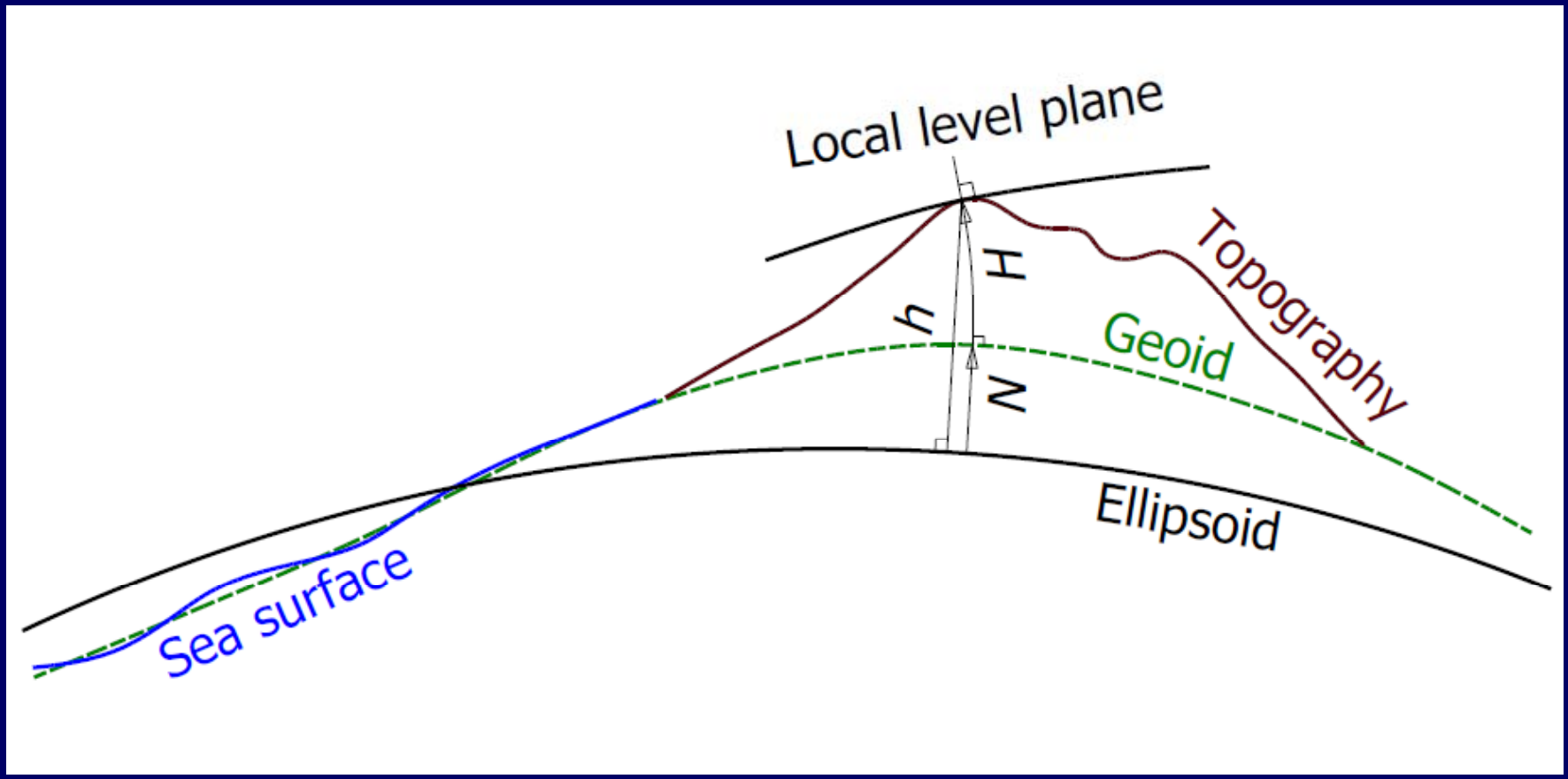
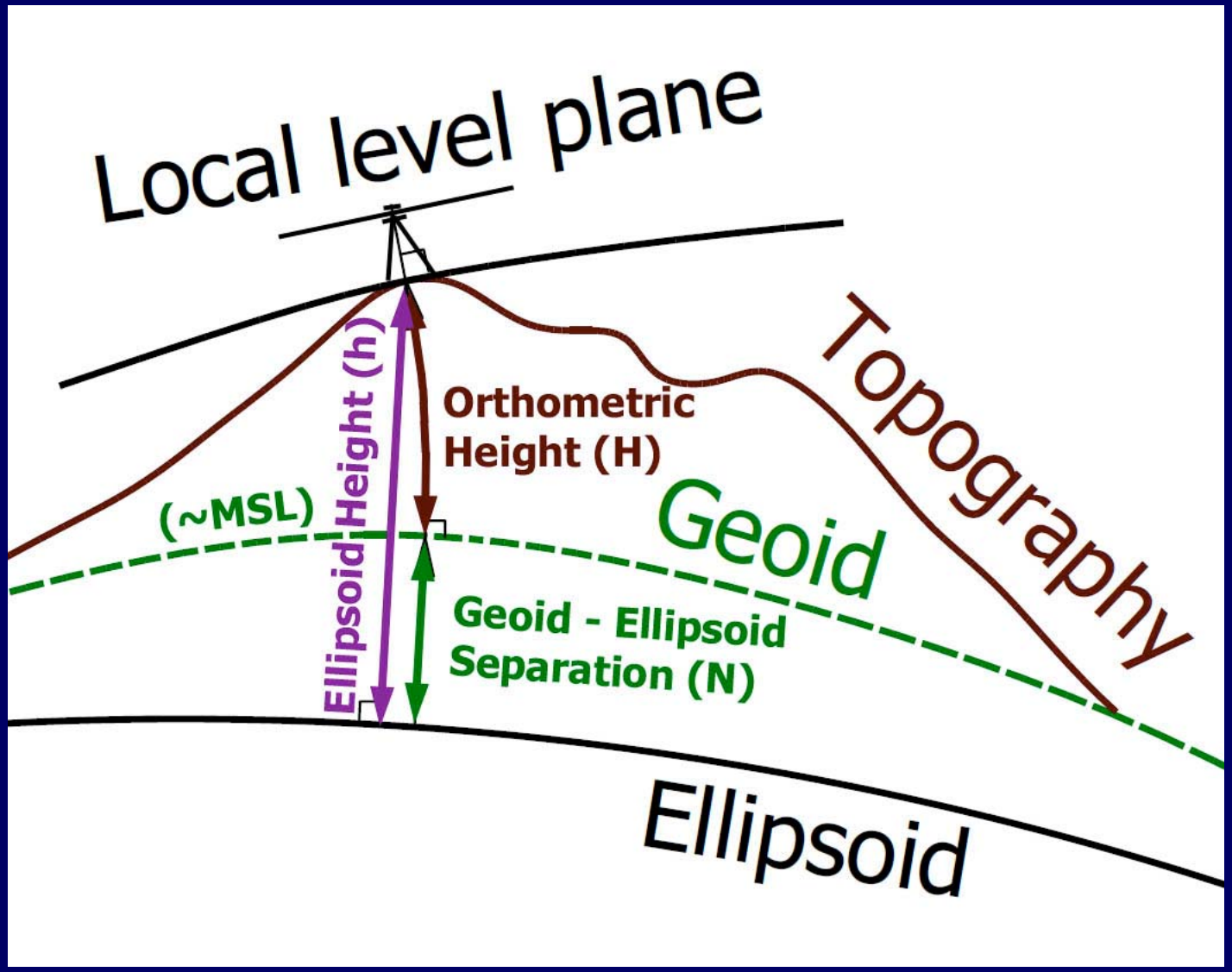


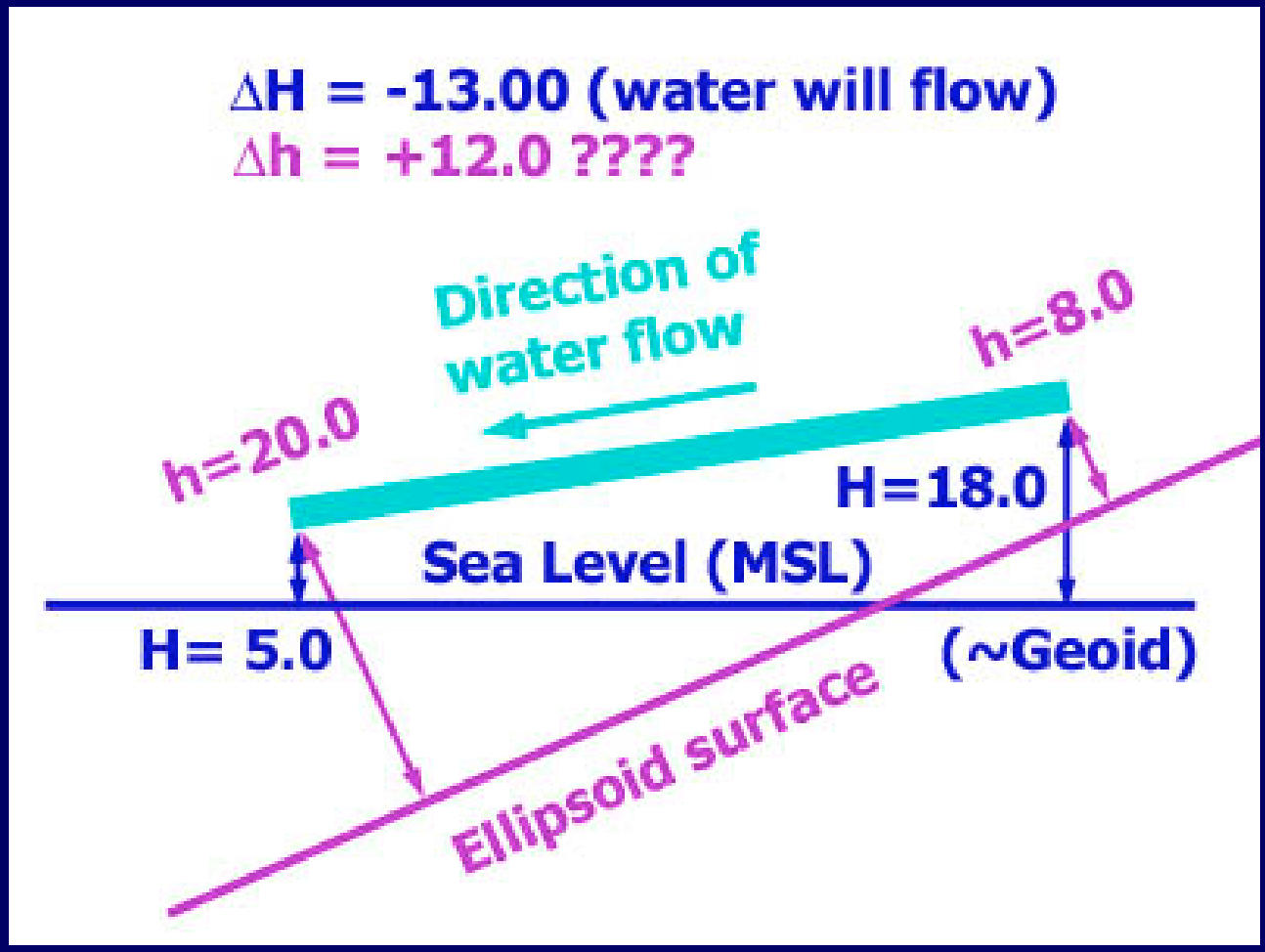
The Geoid



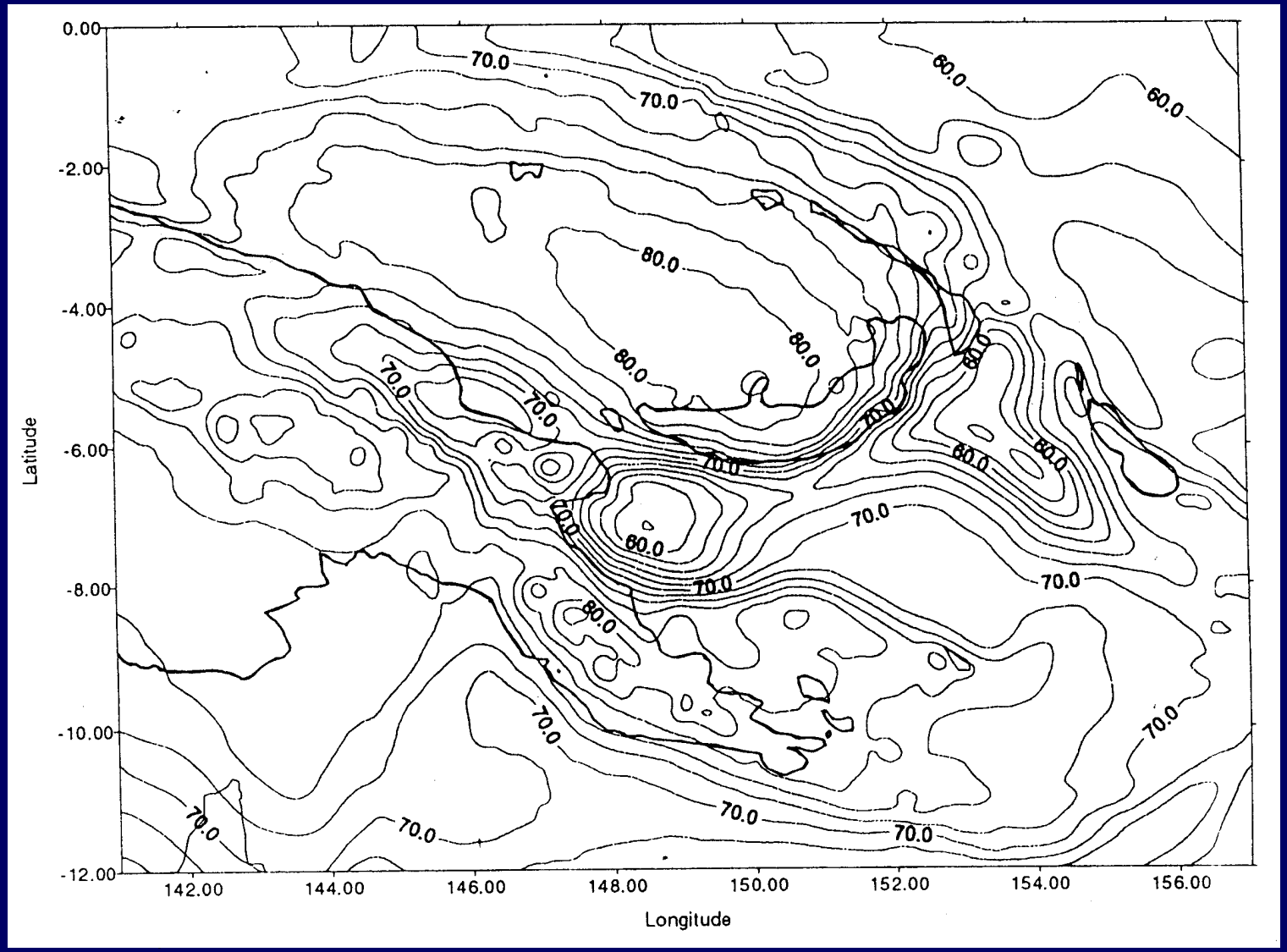
Heighting Surfaces


Local level plane
Topography
Orthometric
Height (H)
Ellipsoid Height (h)
(~MSL)
Geoid
Geoid - Ellipsoid
Separation (N)
Ellipsoid

$H = h - N$ $N = h - H$



Water can flow uphill!!!



(Kearsley & Ahmad)

The PNG Geoid

Vertical Datums & accuracies in PNG

MSL traditionally derived from:

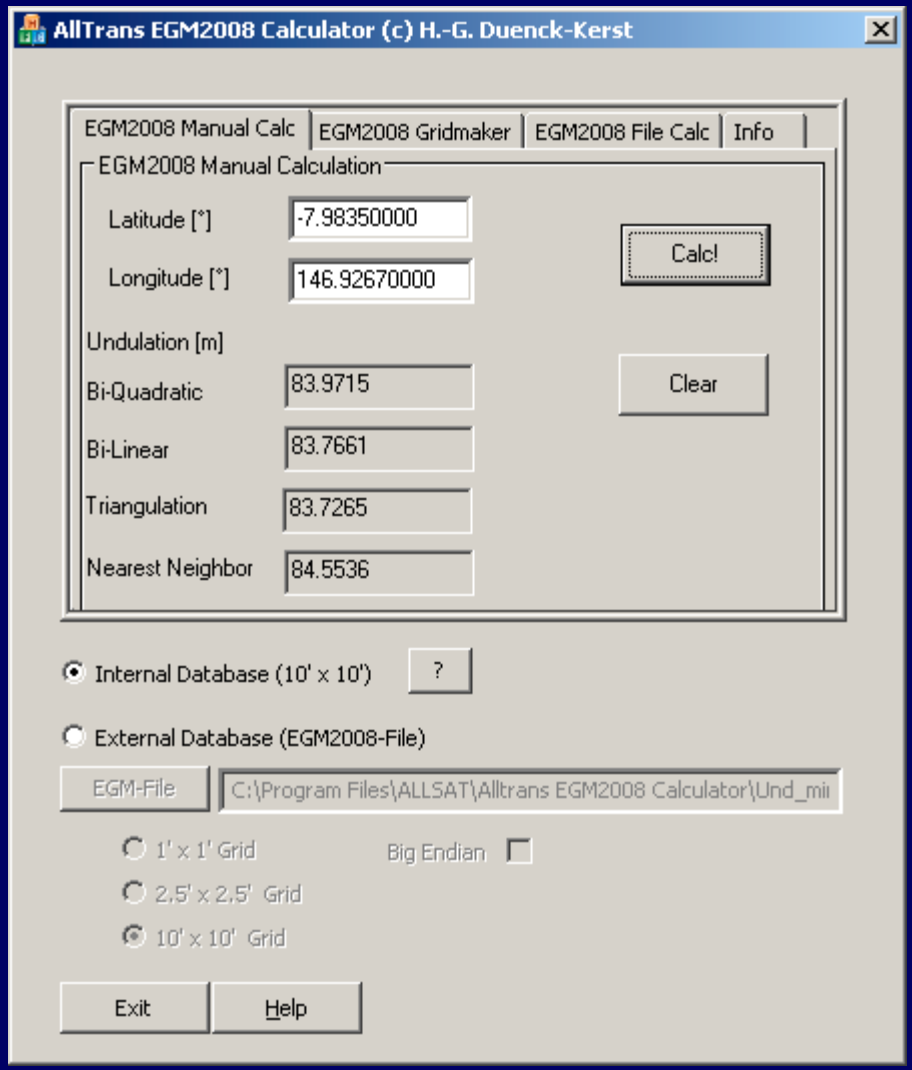
Trigonometric Heighting	Single Ray +/- 5m / 100 km Reciprocal Ray +/- 1m / 100 km
Geometrical Levelling	0.2 m / 100 km
Terrestrial Gravimetry	1 m / 100 km
Barometric Altimetry	10 m / 100 km

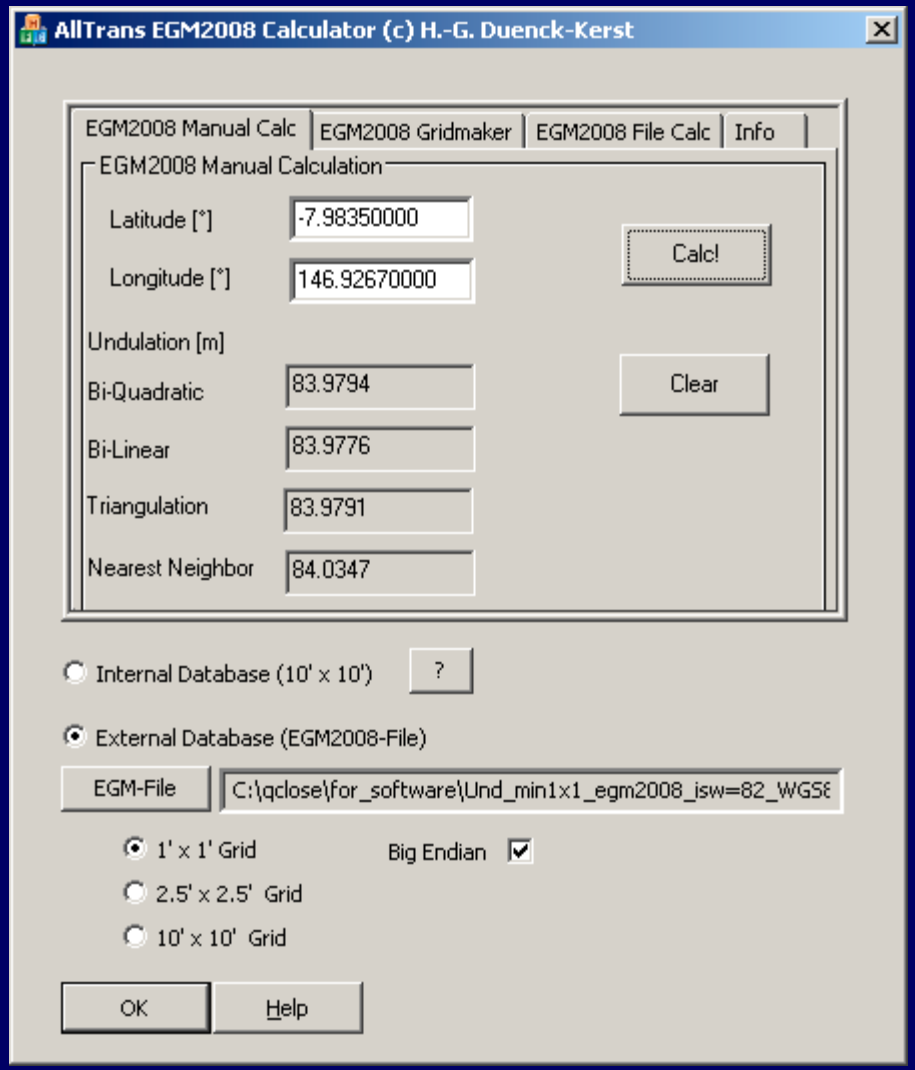
GNSS Heighting

GNSS Heighting	Ellipsoid Ht. 10 mm / 100 km
Satellite Gravimetry	0.1 m / 100 km

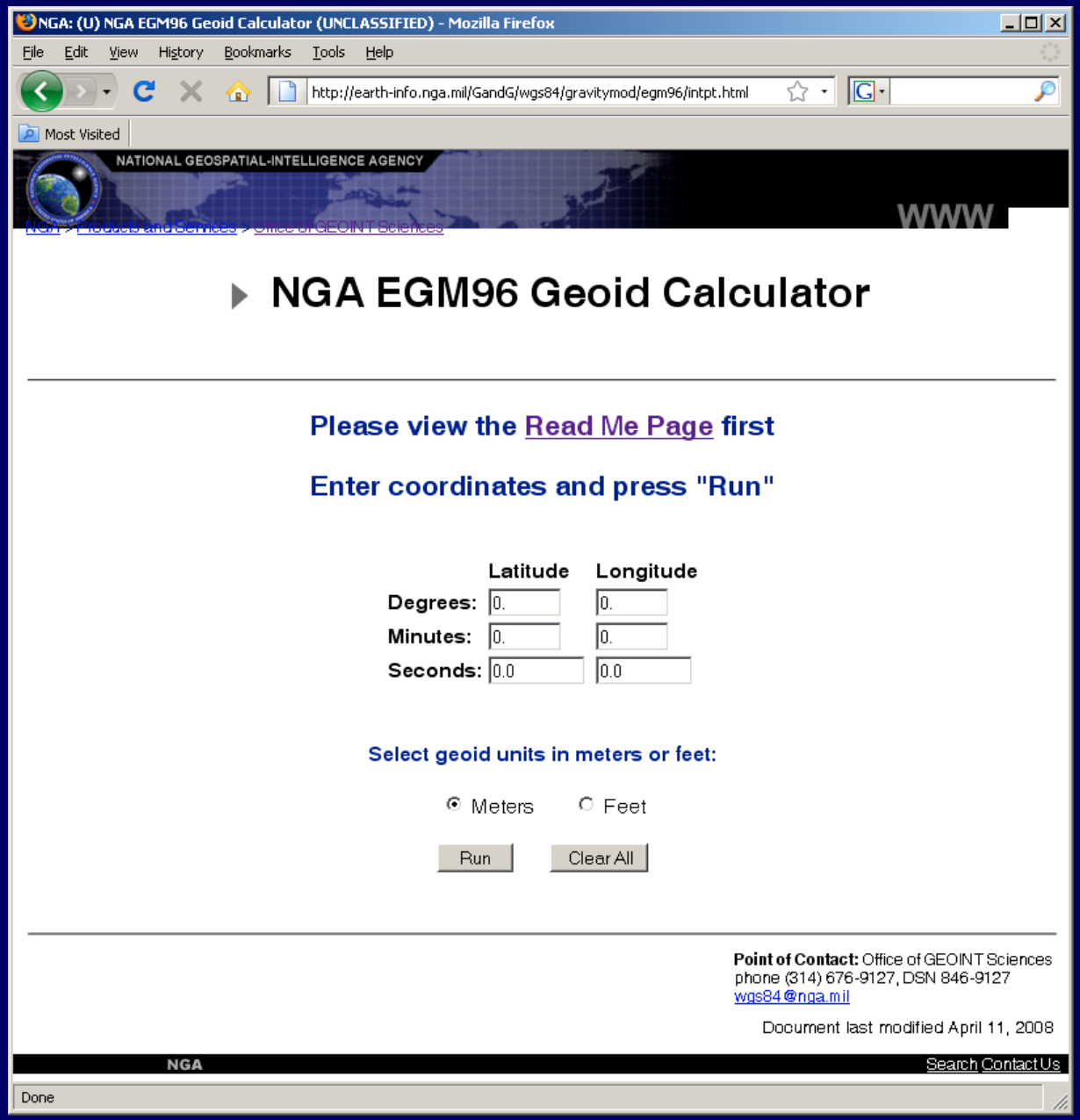
Geoid Models

PNG Geoid & EGM96	1.2 m / 100 km
EGM2008	0.2 m / 100 km





AllTrans EGM2008 Calculator



EGM96 Online Calculator

NGA: EGM2008 - WGS 84 Version - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/egm08_wgs84.html

Most Visited

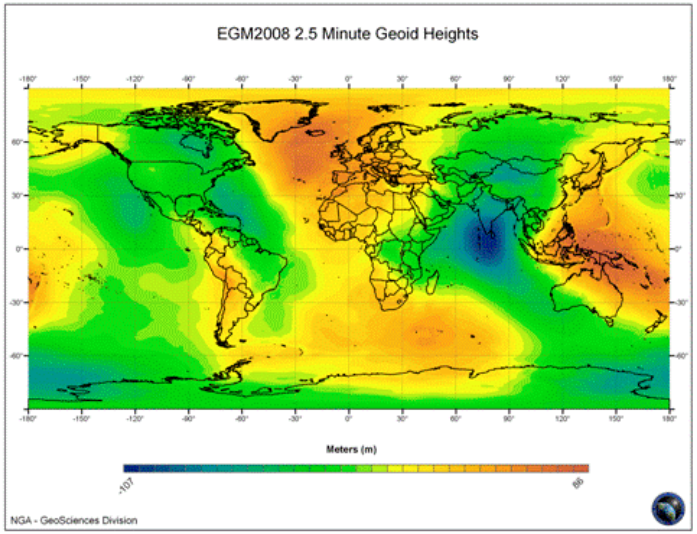
NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

WWW

EGM2008 - WGS 84 Version

Introduction

The official Earth Gravitational Model EGM2008 has been publicly released by the U.S. National Geospatial-Intelligence Agency (NGA) EGM Development Team. This gravitational model is complete to spherical harmonic degree and order 2159, and contains additional coefficients extending to degree 2190 and order 2159. Full access to the model's coefficients and other descriptive files with additional details about EGM2008 are provided herein.



Those wishing to use EGM2008 to compute **geoid undulation values with respect to WGS 84,** may do so using the self-contained suite of coefficient files, FORTRAN software, and pre-computed geoid grids provided on this web page. For other applications, the previous release of the full "Geoscience" package for EGM2008 can be accessed through the link at the bottom of this web page.

The WGS 84 constants used to define the reference ellipsoid, and the associated normal gravity field, to which the geoid undulations are referenced are:

- a=6378137.00 m (semi-major axis of WGS 84 ellipsoid)
- f=1/298.257223563 (flattening of WGS 84 ellipsoid)
- GM=3.986004418 x 10^{14} m^3s^{-2} (Product of the Earth's mass and the Gravitational Constant)
- ω=7292115 x 10^{-11} radians/sec (Earth's angular velocity)

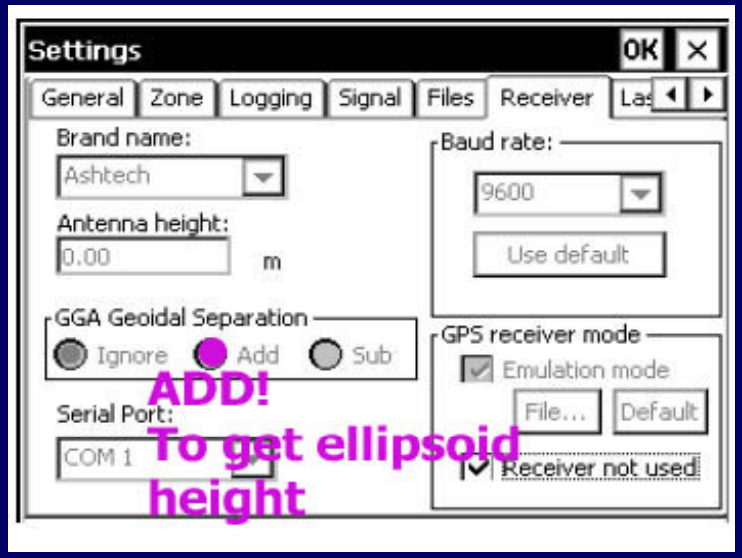
All synthesis software, coefficients, and pre-computed geoid grids listed below assume a **Tide Free** system, as far as permanent tide is concerned.

Note that the harmonic synthesis software provided below applies a constant, zero-degree term of -41 cm to all geoid undulations computed using EGM2008 with the height_anomaly-to-geoid_undulation correction model (also provided). Similarly, all pre-computed geoid undulations incorporate this constant zero-degree term. This term converts geoid undulations that are intrinsically referenced to an ideal mean-earth ellipsoid into undulations that are referenced to WGS 84. The value of -41 cm derives from a mean-earth ellipsoid for which the estimated parameters in the Tide Free system are: a=6378136.58 m and 1/f=298.257686.

Done

Using OmniStar for Heighting

+/- 18 metre MSL errors from OmniStar GGA



Add GGA Geoidal separation to recover ellispoid Ht

OR, ensure that software has EGM96/EGM08

Working with height datum offsets

Computing the offset

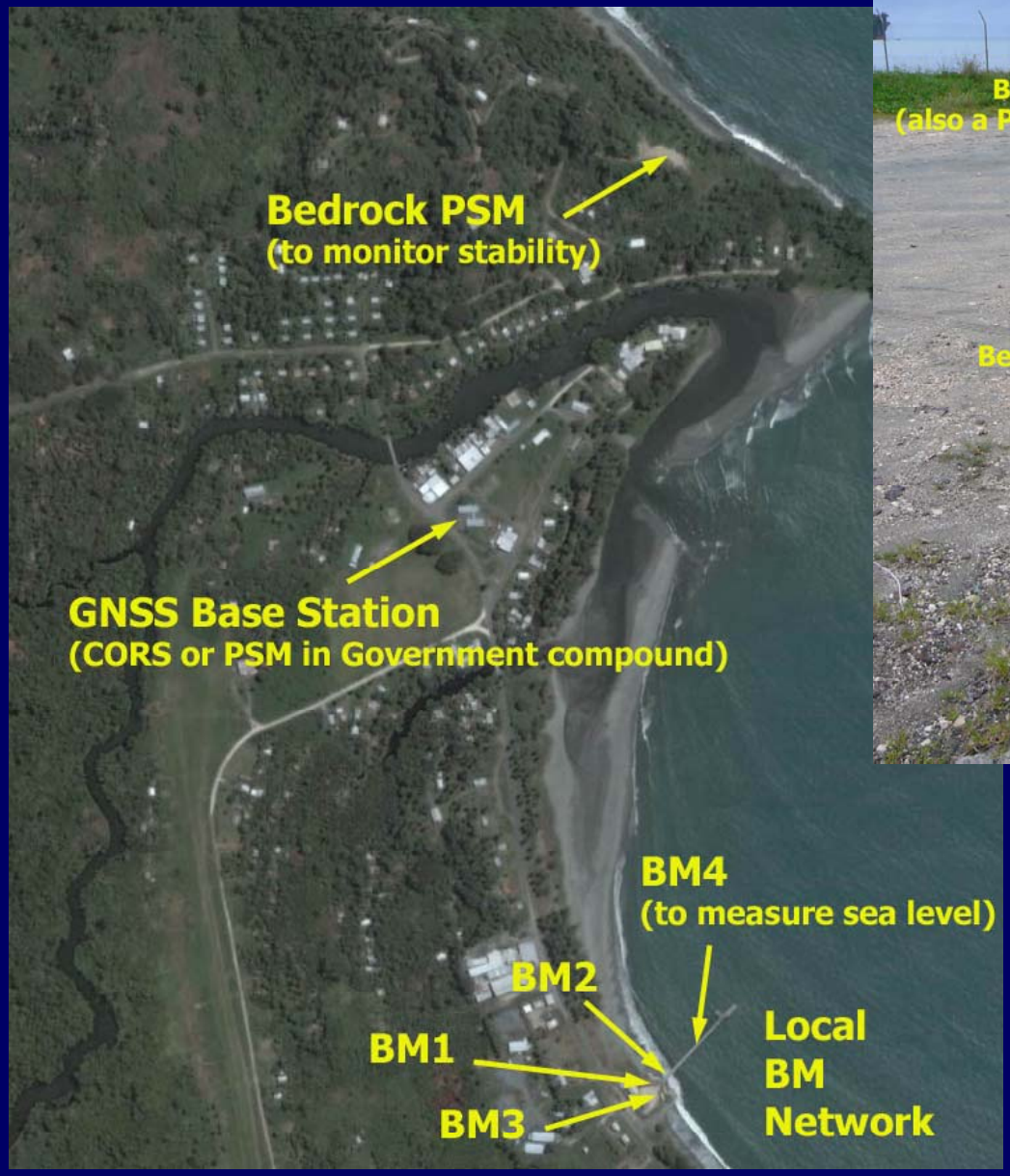
$$o = RL_{LOCAL} - h + N$$

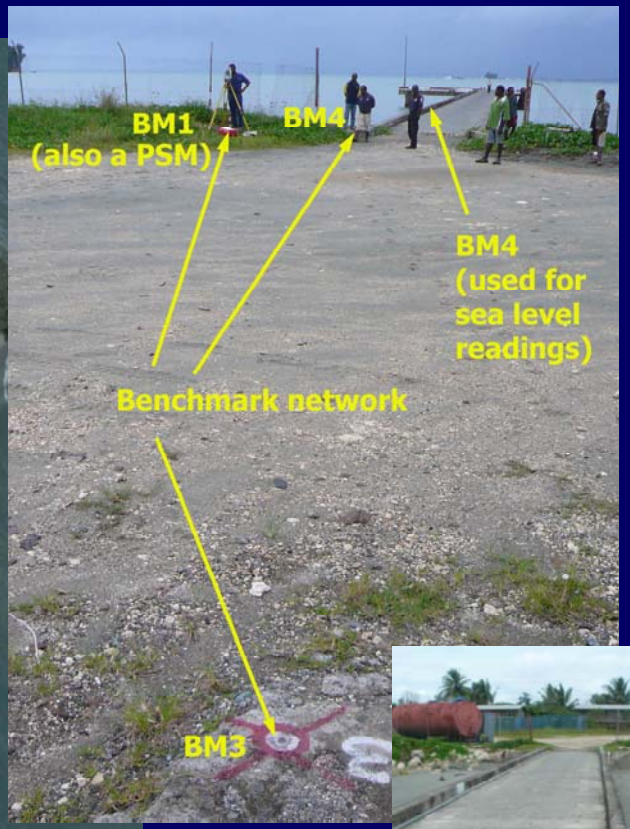
Applying the offset

$$RL_{LOCAL} = h - N + o$$

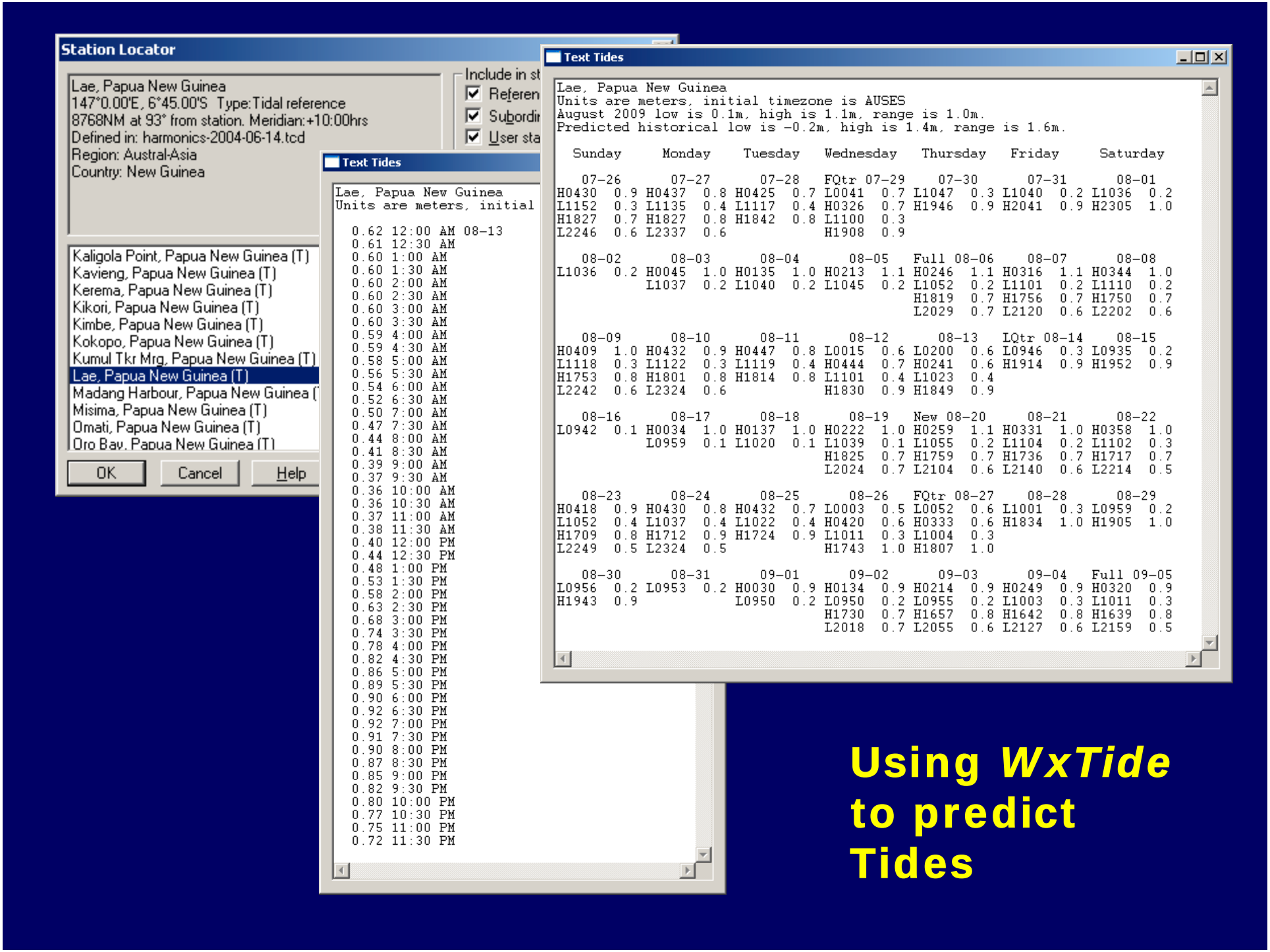
False ellipsoid Ht for RTK

$$h_{FALSE} = RL_{LOCAL} + N$$





An MSL benchmark network


Station Locator
Lae, Papua New Guinea
147°0.00'E, 6°45.00'S Type:Tidal reference
8768NM at 93° from station. Meridian:+10:00hrs
Defined in: harmonics-2004-06-14.tcd
Region: Austral-Asia
Country: New Guinea
Include in st
Referen
Subordi
User sta
Kaligola Point, Papua New Guinea (T)
Kavieng, Papua New Guinea (T)
Kerema, Papua New Guinea (T)
Kikori, Papua New Guinea (T)
Kimbe, Papua New Guinea (T)
Kokopo, Papua New Guinea (T)
Kumul Tkr Mrg, Papua New Guinea (T)
Lae, Papua New Guinea (T)
Madang Harbour, Papua New Guinea (
Misima, Papua New Guinea (T)
Omati, Papua New Guinea (T)
Oro Bay, Papua New Guinea (T)
OK
Cancel
Help
Text Tides
Lae, Papua New Guinea
Units are meters, initial
0.62 12:00 AM 08-13
0.61 12:30 AM
0.60 1:00 AM
0.60 1:30 AM
0.60 2:00 AM
0.60 2:30 AM
0.60 3:00 AM
0.60 3:30 AM
0.59 4:00 AM
0.59 4:30 AM
0.58 5:00 AM
0.56 5:30 AM
0.54 6:00 AM
0.52 6:30 AM
0.50 7:00 AM
0.47 7:30 AM
0.44 8:00 AM
0.41 8:30 AM
0.39 9:00 AM
0.37 9:30 AM
0.36 10:00 AM
0.36 10:30 AM
0.37 11:00 AM
0.38 11:30 AM
0.40 12:00 PM
0.44 12:30 PM
0.48 1:00 PM
0.53 1:30 PM
0.58 2:00 PM
0.63 2:30 PM
0.68 3:00 PM
0.74 3:30 PM
0.78 4:00 PM
0.82 4:30 PM
0.86 5:00 PM
0.89 5:30 PM
0.90 6:00 PM
0.92 6:30 PM
0.92 7:00 PM
0.91 7:30 PM
0.90 8:00 PM
0.87 8:30 PM
0.85 9:00 PM
0.82 9:30 PM
0.80 10:00 PM
0.77 10:30 PM
0.75 11:00 PM
0.72 11:30 PM
Text Tides
Lae, Papua New Guinea
Units are meters, initial timezone is AUSES
August 2009 low is 0.1m, high is 1.1m, range is 1.0m.
Predicted historical low is -0.2m, high is 1.4m, range is 1.6m.
Sunday Monday Tuesday Wednesday Thursday Friday Saturday
07-26 07-27 07-28 FQtr 07-29 07-30 07-31 08-01
H0430 0.9 H0437 0.8 H0425 0.7 L0041 0.7 L1047 0.3 L1040 0.2 L1036 0.2
L1152 0.3 L1135 0.4 L1117 0.4 H0326 0.7 H1946 0.9 H2041 0.9 H2305 1.0
H1827 0.7 H1827 0.8 H1842 0.8 L1100 0.3
L2246 0.6 L2337 0.6 H1908 0.9
08-02 08-03 08-04 08-05 Full 08-06 08-07 08-08
L1036 0.2 H0045 1.0 H0135 1.0 H0213 1.1 H0246 1.1 H0316 1.1 H0344 1.0
L1037 0.2 L1040 0.2 L1045 0.2 L1052 0.2 L1101 0.2 L1110 0.2
H1819 0.7 H1756 0.7 H1750 0.7
L2029 0.7 L2120 0.6 L2202 0.6
08-09 08-10 08-11 08-12 08-13 LQtr 08-14 08-15
H0409 1.0 H0432 0.9 H0447 0.8 L0015 0.6 L0200 0.6 L0946 0.3 L0935 0.2
L1118 0.3 L1122 0.3 L1119 0.4 H0444 0.7 H0241 0.6 H1914 0.9 H1952 0.9
H1753 0.8 H1801 0.8 H1814 0.8 L1101 0.4 L1023 0.4
L2242 0.6 L2324 0.6 H1830 0.9 H1849 0.9
08-16 08-17 08-18 08-19 New 08-20 08-21 08-22
L0942 0.1 H0034 1.0 H0137 1.0 H0222 1.0 H0259 1.1 H0331 1.0 H0358 1.0
L0959 0.1 L1020 0.1 L1039 0.1 L1055 0.2 L1104 0.2 L1102 0.3
H1825 0.7 H1759 0.7 H1736 0.7 H1717 0.7
L2024 0.7 L2104 0.6 L2140 0.6 L2214 0.5
08-23 08-24 08-25 08-26 FQtr 08-27 08-28 08-29
H0418 0.9 H0430 0.8 H0432 0.7 L0003 0.5 L0052 0.6 L1001 0.3 L0959 0.2
L1052 0.4 L1037 0.4 L1022 0.4 H0420 0.6 H0333 0.6 H1834 1.0 H1905 1.0
H1709 0.8 H1712 0.9 H1724 0.9 L1011 0.3 L1004 0.3
L2249 0.5 L2324 0.5 H1743 1.0 H1807 1.0
08-30 08-31 09-01 09-02 09-03 09-04 Full 09-05
L0956 0.2 L0953 0.2 H0030 0.9 H0134 0.9 H0214 0.9 H0249 0.9 H0320 0.9
H1943 0.9 L0950 0.2 L0950 0.2 L0955 0.2 L1003 0.3 L1011 0.3
H1730 0.7 H1657 0.8 H1642 0.8 H1639 0.8
L2018 0.7 L2055 0.6 L2127 0.6 L2159 0.5
Using WxTide
to predict
Tides

Compute Ellipsoid Height

Static baseline from PNG94 control

or, AUSPOS or NRCan

AUSPOS **www.ga.gov.au/bin/gps.pl**

NRCan www.geod.nrcan.gc.ca/online_data_e.php

Computing MSL and geoid correction

Compute RL on Prediction Datum

$$RL_{PRED} = RL_{EGM} + D$$

Compute LAT

$$RL_{LAT} = RL_{PRED} - low$$

Compute HAT

$$RL_{HAT} = RL_{PRED} - high$$

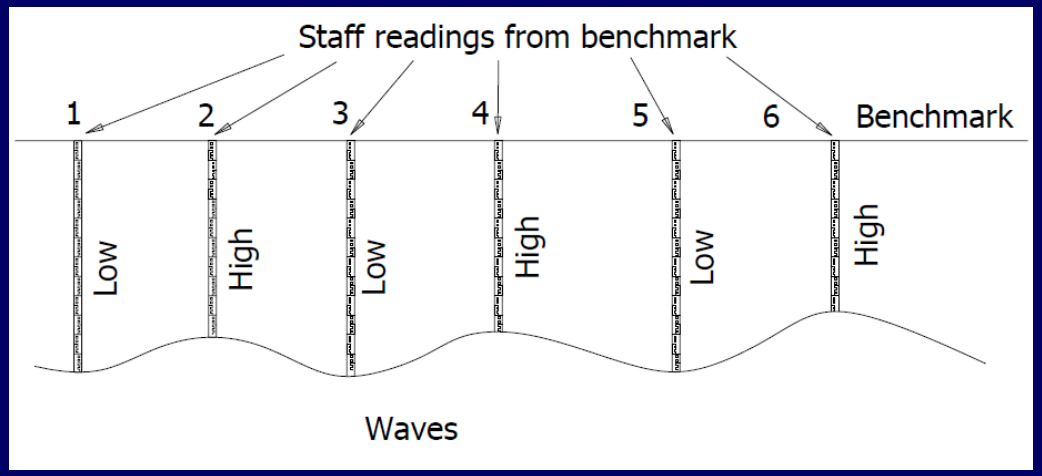
Compute MSL

$$RL_{MSL} = (RL_{HAT} + RL_{LAT}) / 2$$

Compute correction to Geoid model (zero order term)

$$c = RL_{MSL} - RL_{EGM}$$

Direct measurements of sea level from a BM



Measurement is average of 3 wave tips and 3 wave troughs within 3-4 minutes

Worked example

$RL_{EGM2008}$ of BM4 = 3.766 m

PNG Date (2009)	PNG Time (UT +10 hr)	Predicted Height (from WXTide)	Staff Reading (from BM4)	EGM08 RL (3.766 - staff reading)	Predicted minus EGM2008 (D)
May-20	03:00 PM	0.87	2.30	1.47	-0.60
May-20	04:00 PM	0.91	2.28	1.49	-0.58
May-21	09:00 AM	0.57	2.53	1.24	-0.67
May-21	12:00 PM	0.44	2.68	1.09	-0.65
May-21	01:00 PM	0.53	2.67	1.10	-0.57
May-21	05:00 PM	0.95	2.16	1.61	-0.66
May-21	06:00 PM	0.96	2.13	1.64	-0.68
May-21	10:30 PM	0.74	2.34	1.43	-0.69
May-22	04:30 AM	1.21	1.98	1.79	-0.58
May-22	08:00 AM	0.79	2.41	1.36	-0.57
May-22	10:00 AM	0.42	2.78	0.99	-0.57

Mean D = -0.62

$$RL_{PRED} = RL_{EGM} + D$$

$$RL_{PRED} = 3.766 + -0.62 = 3.15$$

Low = -0.20 (from *WxTide*)

High = 1.80 (from *WxTide*)

$$RL_{LAT} = RL_{PRED} - low$$

$$RL_{LAT} = 3.15 - -0.20 = 3.35$$

$$RL_{HAT} = RL_{PRED} - hat$$

$$RL_{HAT} = 3.15 - 1.80 = 1.35$$

$$RL_{MSL} = (RL_{HAT} + RL_{LAT})/2$$

$$RL_{MSL} = (3.35 + 1.35)/2 = 2.35$$

$$c = RL_{MSL} - RL_{EGM}$$

$$c = 2.35 - 3.766 = -1.42$$

Tide Gauge network - Lae

Precise levelling (UniTech students 2002)

Absolute height change

South Pacific Sea Level and Climate Monitoring Program (SPSLCMP)

Manus

Sea Level monitoring