



Improved Official Geoid Model for Israel, 2009

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Israel

FIG Working Week, Eilat, May 3-4-5-6-7-8, 2009



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RESEARCH PROJECT for the Survey of Israel

CONTRIBUTIONS by
Israel Geophysical Institute, Dr. Michael
Rybakov, Dr. John Hall, Profs. Bernhard
Heck and Kurt Seitz (for the late Prof. Hans-
Georg Wenzel), Dr. Nikos Pavlis, Profs. Petr
Vaníček and Marcelo Santos

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UNDULATION PREDICTION

Undulation field relatively smooth
(7 meter over 350 km)

Two methods to Interpolate:

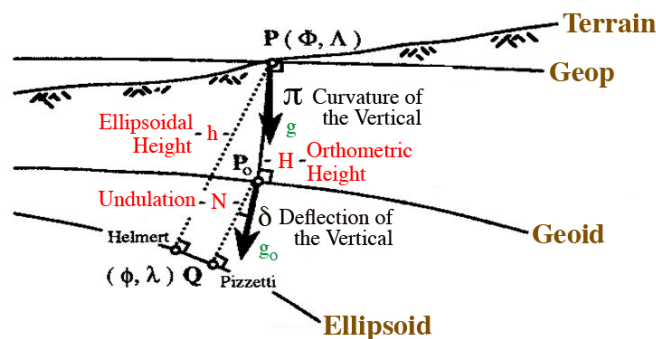
- Mathematically (kriging, GIS tools)
- Physically (gravity data)

The Mathematic method requires a dense network of anchor points.

Anchor Point

Where both Orthometric Height (H) and Ellipsoidal Height (h) are known. The Undulation (N) transforms

between them: $H = h - N$



ILUM 1.2 - Anchor Points



RCR process

RCR: Remove-Compute-Restore

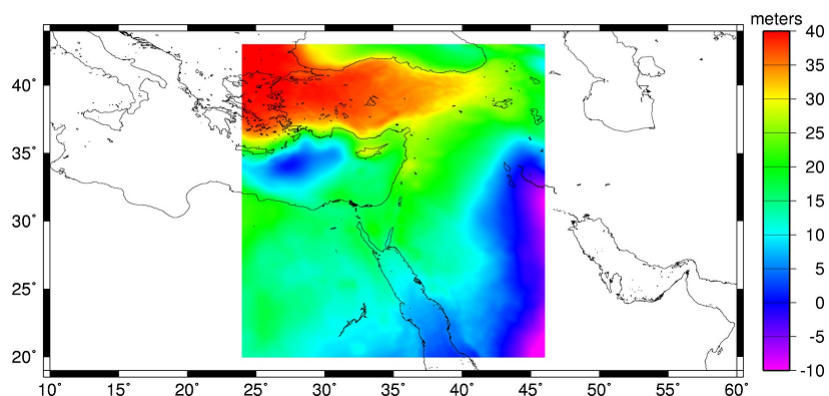
- **Remove** all known contributions to undulations at anchor points (global gravity model, local gravity and topographic effects) - to obtain residual undulations
- **Compute**: Interpolate at desired locations
- **Restore** by adding back all known contributions

Project DATA Sources

- Global gravity model – [EGM 2008](#)
- [Bouguer gravity](#) anomalies to 2° beyond Israel (converted to Free-Air anomalies, with DTM)
- Observed [gravity](#) in Israel, converted to Free-Air anomalies

EGM2008 Undulations

Geoid_Ht_WGS84.2x2.egm2008_tf.s0-2190.ISRAEL, 11/03/08

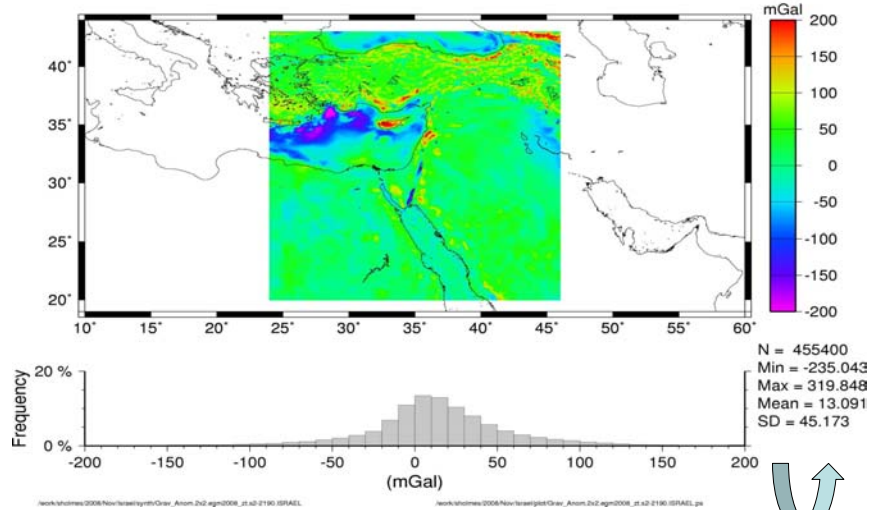


(849 Anchor points) minus (EGM2008) undulations

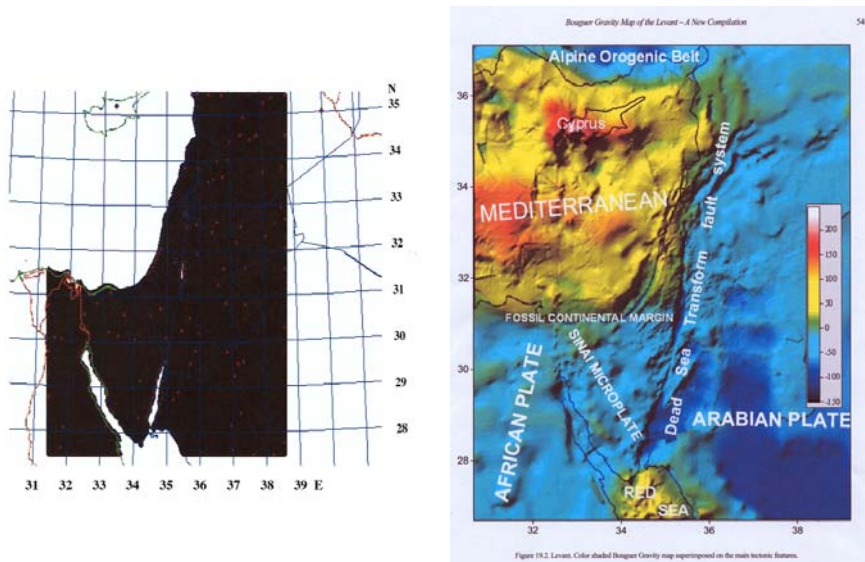
Average [m]	S. Dev [m]	Min [m]	Max[m]
-0.28	0.21	-0.99	0.35

EGM2008 FA Anomalies

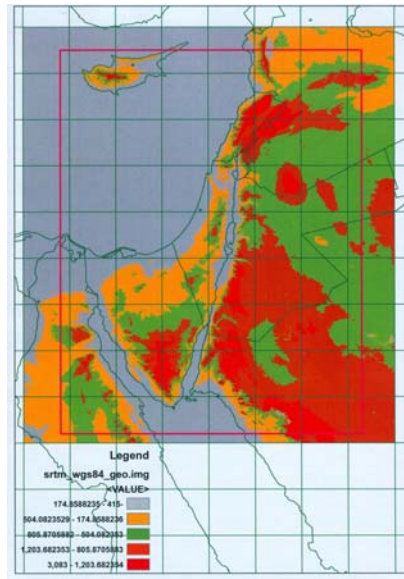
Grav_Anom.2x2.egm2008_zt.s2-2190.ISRAEL, 11/04/08



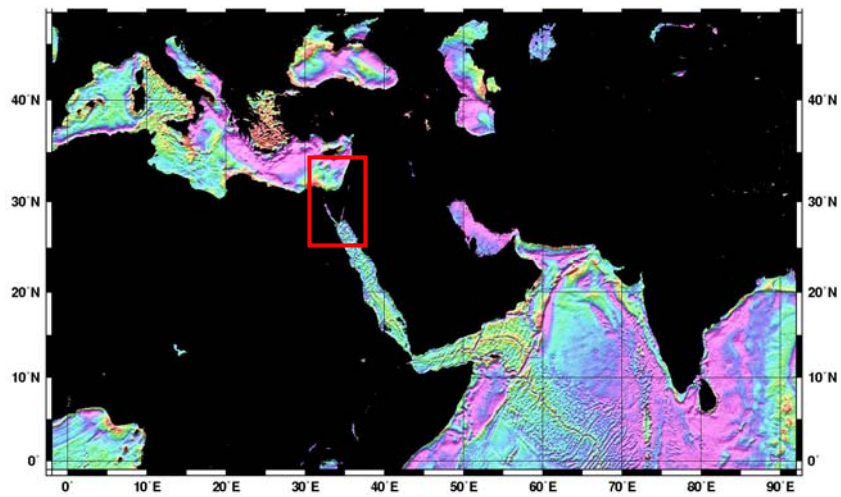
Bouguer Anomalies



SRTM data

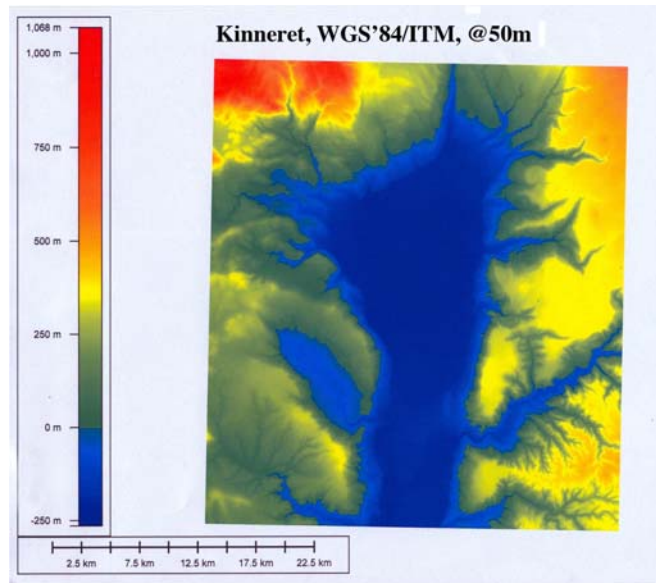


Marine Gravity

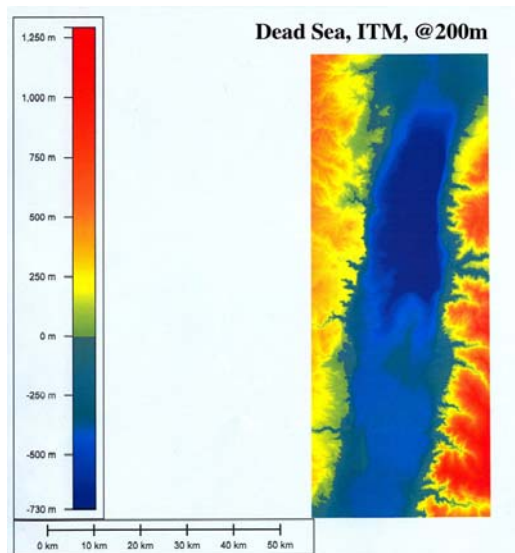


David T. Sandwell and Walter H. F. Smith, Marine Gravity Anomaly from Satellite Altimetry, Version 15.2

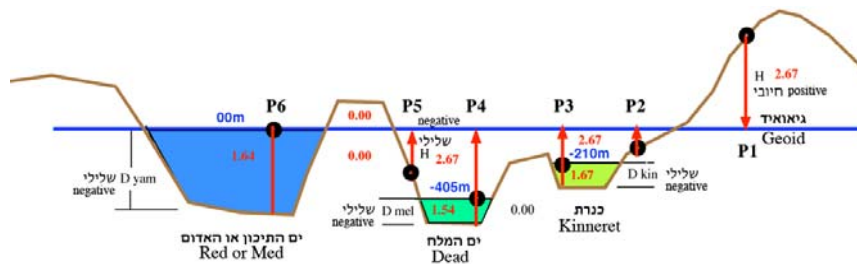
Kinneret DTM



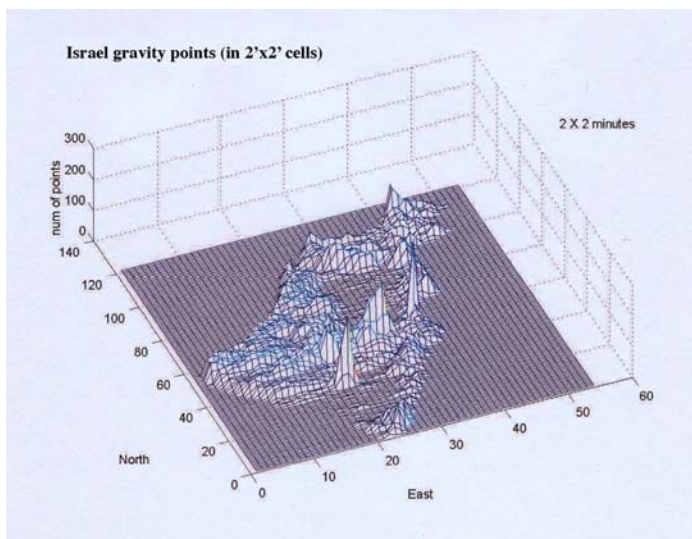
Dead Sea DTM



FA from BOU Anomalies



Israel Gravity



FA Area Coverage

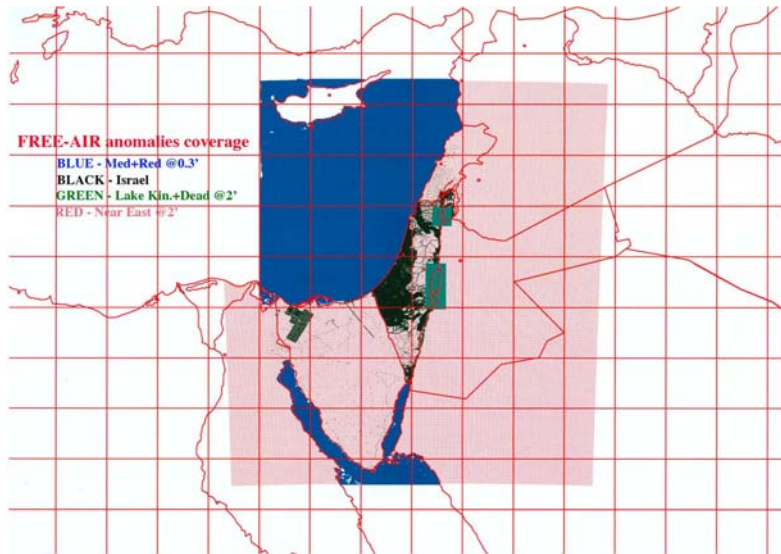


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Gridding Free-Air anomalies

Problem: Discrete points, with area "holes"

Solutions: Correlations (Surface fitting - or height-correlations)

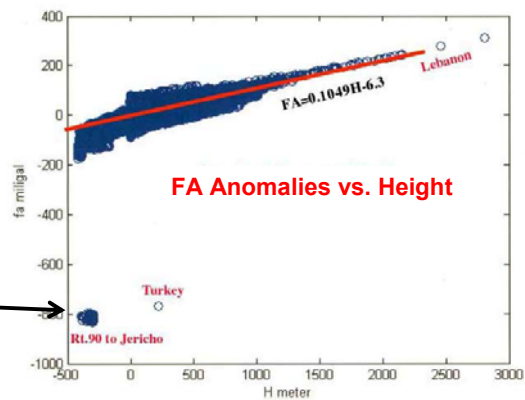
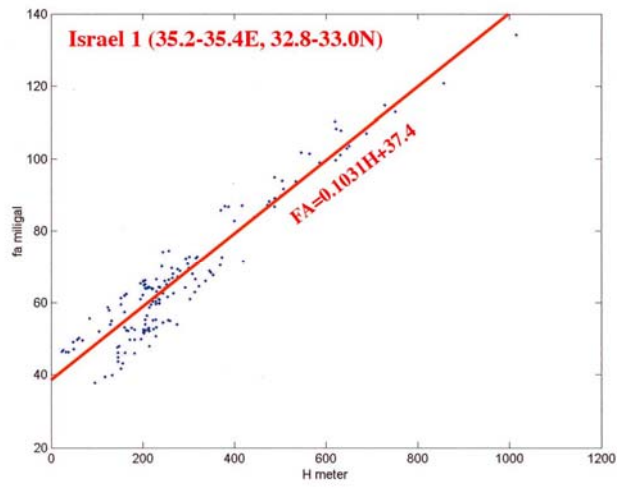


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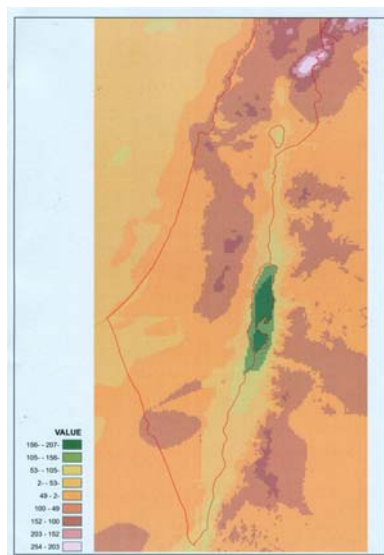


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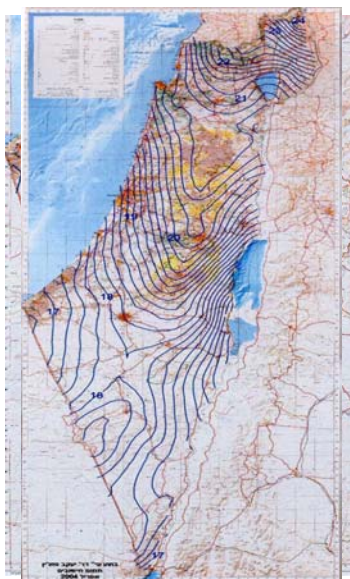
FA Anomaly vs. Height



FA Anomalies at 1'



Test Area



Remove – Restore process

At anchor points:

- **Remove** all known contributions to observed undulations (**N**) (global model EGM2008; Stokes integration; Indirect Effect, I.E.)
- Obtain residual undulations; develop to a surface.

At desired points:

Predict residual undulations from the surface (P.R.U.)

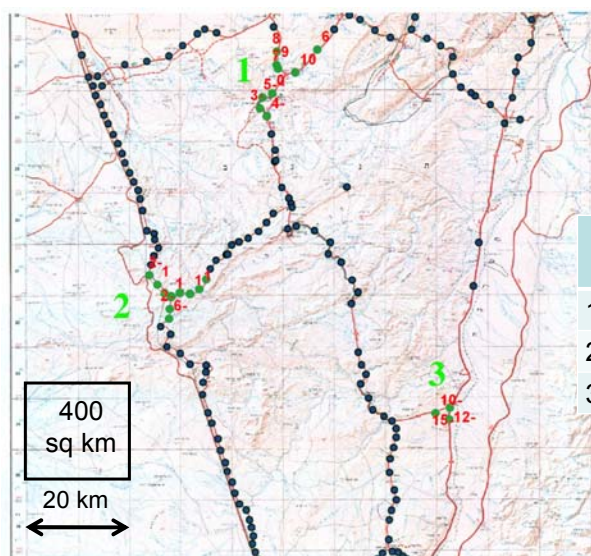
- **Restore** all known contributions
- Obtain predicted undulations (P.U.)

• Example:

EAST	NORTH	H	P.R.U.	EGM08	Stokes	I.E.	P.U.	N	Diff.
34.963	32.283	53.52	-0.652	19.984	0.391	0.000	19.723	19.674	-0.049



Test Results



	Area (km sq)	Min (cm)	Max (cm)
1	500	-3	10
2	200	-6	1
3	800	-15	-10

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Customer Interface

Undulation Project

Calculating Undulations (N)

Point Name:

Lambda (WGS84 [DMS]): ° ' "

Phi (WGS84 [DMS]): ° ' "

h (Ellips Height [meter]):

N (Undulation [meter]): **17.89 [m]**

H (Orthometric [meters]): 642.78 [m]

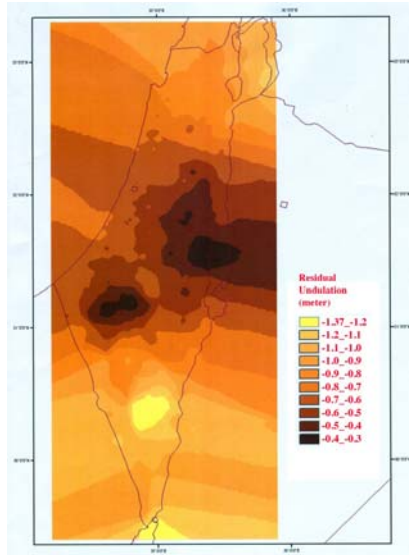
Remove/Restore process
from ILUM1.2
"Improved Geoid MODEL
for Israel"
Dan Sharni, 2009

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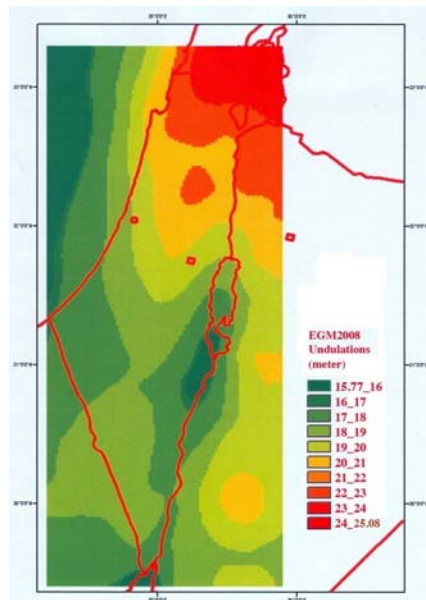


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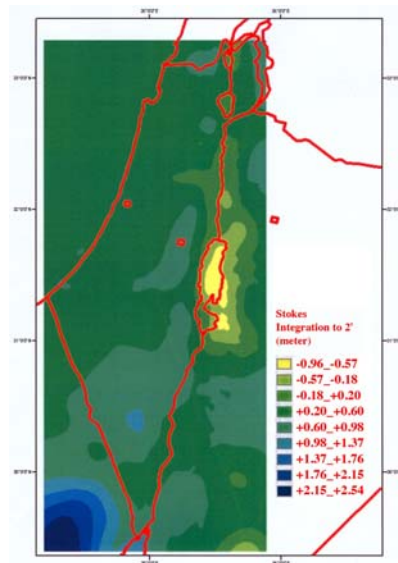
Residual Undulation



EGM2008 Undulation



Stokes Integration




Geoid for Israel

Geoid from LEVELING and GPS – or from GRAVITY.

- LEVELING** in Israel: MSL not accurate
Tie from the Net is tenuous
Observations over 50+ years
No proper Orthometric Correction
Not all loops included
No simultaneous Adjustment
(Hierarchic forcing of 2nd degree into 1st)
- GPS** (for Elevations) in Israel:
Not same epochs as leveling (obviously)
Short-period observations
- GRAVITY:** UNB Geoid Program Suite
(modified Stokes-Helmert procedure)
EGM2008




UNB Geoid - 1



An Introduction To The Stokes-Helmert's Method For Precise Geoid Determination

Huaining Yang, Petr Vanicek, Marcelo Santos, Robert Tenzer

University of New Brunswick, Department of Geodesy and Geomatics Engineering, Fredericton, N.B., E3B 5A3, Canada, Email: l574t@unb.ca



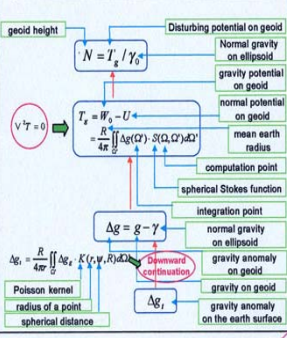
Introduction

The geoid plays a very important role in geodesy. It can not only be seen as the most natural shape of the earth, but it also serves as the reference surface for most of the height system. Geoid is the equipotential surface of the Earth gravity field that best approximates the mean sea level. Such a reference surface is needed for a number of modern mapping, oceanographic and geophysical applications.

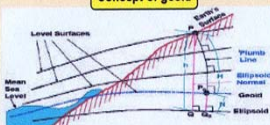
Methods to compute the geoid

> Geometric method (GPS/leveling)
 The simplest method is to use GPS/leveling points, where both the geodetic and orthometric heights are given. From these data the point geoid height can be calculated with a simple subtraction. Orthometric heights can be derived from a surveying technique called "leveling".
 Unfortunately this solution can not provide high-resolution geoid, due to the distribution of the GPS/leveling points.
 > Gravimetric solution
 Stokes-Helmert's method, one of gravimetric solutions, is adopted and developed in University of New Brunswick.

The way to understand Stokes-Helmert's method



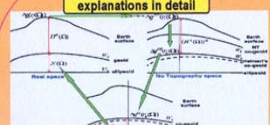
Concept of geoid



Level Surface = Equipotential Surface.
 N (geoid height) = Distance along ellipsoid normal (P₀ to Q₀).
 H (orthometric height) = Distance along plumb line (P to P₀).
 h (geoidic height) = Distance along ellipsoid normal (P to Q).
 These quantities are related by the expression H = h - N.

UNB Geoid - 2

explanations in detail



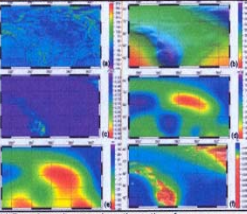
(Q) a point at the earth surface, (Q₀) a point at the geoid surface, (h) co-geoid height in Helmert space, (h₀) orthometric height in Helmert space, (h₀)⁰ orthometric height in NT space, (h₀)⁰ gravity anomaly on earth surface in NT space, and (h₀)⁰ gravity anomaly on geoid surface in NT space, and (h₀)⁰ gravity anomaly on geoid surface in Helmert space.

The space characterized by the mass distribution obtained after Helmert's condensation is called Helmert's space. The quantities given in Helmert's space are denoted by superscript h. Compare with this, the space is called real space, and the space after being removed all topographical masses is called No-Topography space (NT space) or Bouguer space.

At first we can get (h₀)⁰. Then (h₀)⁰ is transformed to (h₀)⁰. This step is numerically realized by subtracting the effect on the gravitational attraction of the topographical and atmospheric masses. Thus the gravitational field in NT space becomes harmonic. To obtain (h₀)⁰, (h₀)⁰ is downward continued from the earth's surface onto the geoid surface. (h₀)⁰ is evaluated by adding the effect of the condensed topographical and atmospheric masses on the gravitational attraction to the geoid-generated gravity anomalies. (h₀)⁰ is calculated by solving the Stokes formula in the Helmert gravity space. To obtain the final geoid in the real space, the primary indirect topographical effect on the geoid height is subtracted from (h₀)⁰.

parts of preliminary results

Based on this theory the UNB geoid software package (SHGeo software) for precise geoid determination was developed covering all aspects of the gravimetric geoid computations. This software uses standard input data.



a) Free-air gravity anomaly on the earth surface.
 b) Secondary indirect effect of topographical masses attraction.
 c) Geoid-quasigeoid correction.
 d) Helmert's reference gravity anomaly.
 e) Reference co-geoid height.
 f) Primary indirect topographical effect.

Conclusions

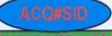
The geoid could be regarded as a reference surface for geo-referencing, positioning and navigation, and also be used in conversion of GPS heights to orthometric height. The theory and the software package of Stokes-Helmert's method for precise geoid determination have been developed to enable the geoid computation to an accuracy of one centimeter in grid spacing 5' by 5'. The actual accuracy will, of course, depend on the available data, their accuracy and their spatial distribution. Because the computation of several programs is done in 1 by 1 grid regions it is rather time consuming. It would take a few months to finish the geoid computation covering the whole Canada in full-time work.

Reference

Tenzer R. et al., 2003. Stokes-Helmert's Geoid Software Reference Manual.
 Vanicek P., Tenzer R., Huang J., 2003. The role of No Topography space in the Stokes-Helmert technique for geoid determination. Annual scientific meeting, Canadian Geophysical Union, May 10-14, 2003, Banff, Canada. (oral presentation).
 Vanicek P., Martinec Z., 1994. The Stokes-Helmert scheme for the evaluation of a precise geoid. Manuscripta Geodastica, No. 19, Springer, pp. 119-128.
 Vanicek P., Huang J., Novák P., Paplatakis S.D., Vároneau M., Martinec Z., Featherstone W.E., 1999. Determination of the boundary values for the Stokes-Helmert problem. Journal of Geodesy, Vol. 73, Springer, pp. 180-192.

Acknowledgments

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GEODE Sixth Annual Scientific Conference, May 30-31, June 1st, 2004, Gatineau, QC

Improved Geoid for Israel: SUMMARY

- The Remove & Restore **process** was proved significant (few cm prediction accuracy)
- The developed **software** can be easily adapted to updated data
- The Geoid from the UNB-program-suite will be tested and **applied** to Israel



THANK YOU.

SHALOM!

