Research motivation

To develop a GPS based Tide Gauge (GPTG) and to test its ability to monitor Sea Levels.

The GPTG would provide the ability:

► to measure an absolute change of MSL.

► to measure accurately the level difference between two distinct tide gauges.

Monitoring Sea Levels Using GPS - The Difference Between the Mediterranean and the Red Sea Levels as a Test Case

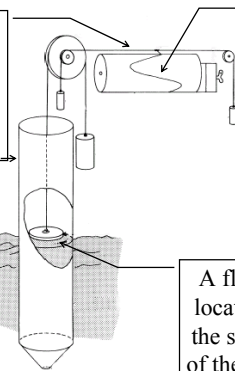Chai Ben-Michael and Gilad Even-Tzur

Department of Mapping and Geo-Information Engineering
Faculty of Civil and Environmental Engineering
Technion - Israel Institute of Technology

Shaping the Change, XXIII International FIG Congress
8-13 October, Munich, Germany

Float operated Tide Gauge

The float is connected by a cable and a set of pulleys to a weight, a pen and to a recording drum

As the water rises (or descends) the cable movement creates an angular movement that is proportional to the change in water level.

Stilling Well, mechanically restricts the flow of water into and out of the well, to eliminate short period changes (waves)

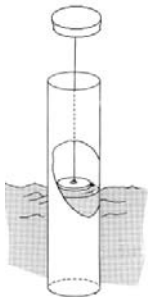A float is located on the surface of the water

Orthometric and Ellipsoidal heights

"h = H + N"
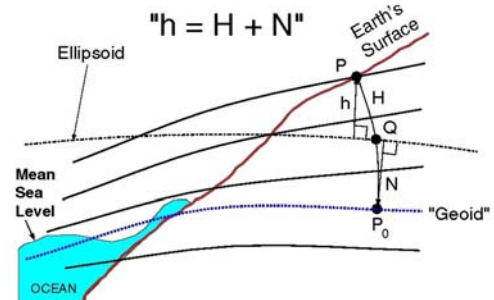
h (Ellipsoid Height) = Distance along ellipsoid normal (Q to P)
N (Geoid Height) = Distance along ellipsoid normal (Q to P_0)
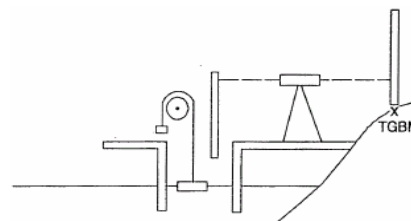H (Orthometric Height) = Distance along Plumb line (P_0 to P)

GPTG - structure

The GPTG is based on a float tide gauge principles

The SW is build from a PVC pipe with a flat bottom and side inlets

Tide Gauge Benchmark

A BM that provides the reference point for the sea level measurements is connected to the tide gauge.

GET1   A geoid is an equipotential surface which (approximately) coincides with the mean ocean surface.
Gilad Even-Tzur; 20-09-2006
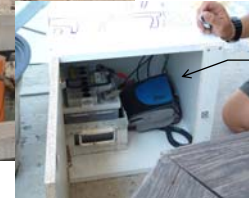
Proof of Concept Test

The GPTG was located in the Tel-Aviv marina, close to a long term operating reliable TG and close to a permanent GPS station.

The test lasted 29 hours, on July 5th 2004.

GPTG - structure

A GPS antenna pole is molded into a buoy by rigid connection and transfers the vertical movement from the buoy to the phase center.
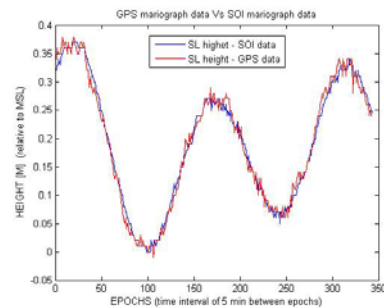
A GPS receiver is used as the recording drum

Mediterranean Sea

Tel-Aviv

Eilat

Red Sea

An implementation of the device for connecting two distinct tide gauges was carried out.

Its goal was to determine the GPTG ability to measure the sea levels difference between the **Red Sea** and the **Mediterranean Sea** accurately.
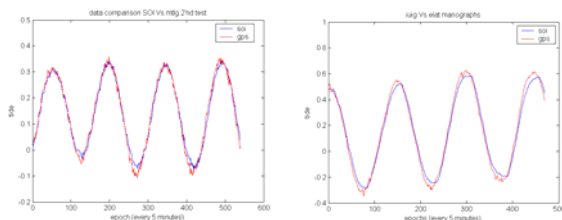
Proof of Concept Test - Results

Comparison of TG data versus the GPS data

The results from both instruments can be treated as identical with a standard deviation of 13mm and a correlation factor of 0.993.

Tel-Aviv versus Eilat Test - Results

Tel-Aviv	
Height diff between TGs	18.36 m
Std for single measurement	18.8 mm
Std for average	0.8 mm

Eilat	
Height diff between TGS	16.35 m
Std for single measurement	39.4 mm
Std for average	8.8 mm

Tel-Aviv versus Eilat Test
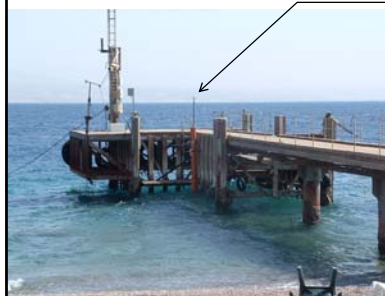
A second device was built and installed in Eilat. The instruments were operated in Tel-Aviv for 52 hours and in Eilat for 39 hours, on September 2004.

GET3   After the first field test proved that a GPTG could provide sea level measurements at the same accuracy level as a conventional TG

Gilad Even-Tzur; 20-09-2006

Sea level difference between the Red-sea and the Mediterranean

► MSL was calculated for the Mediterranean and for the Red sea for a period of 12hrs 25min.

► Barometric data from Tel-Aviv and Eilat was used.

► Undulation data was retrieved from the Survey of Israel undulation model.

Tel-Aviv versus Eilat Test - Results
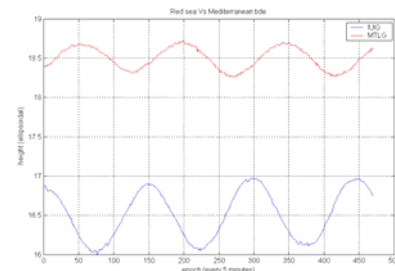
Sea level variations of the Mediterranean Sea (red line) and the Red Sea (blue line) in ellipsoidal reference system

Height difference calculation

Ellipsoidal Difference:

$$\Delta h_{Eilat \to TelAviv} = \overline{h}_{TelAviv} - \overline{h}_{Eilat} = 2.035m$$

Undulation Difference:

$$\Delta N_{Eilat \to TelAviv} = N_{TelAviv} - N_{Eilat} = 2.07m$$

Eilat sea level relative to Tel-Aviv Sea level:

$$H_{Eilat} = \Delta h_{Eilat \to TelAviv} - \Delta N_{Eilat \to TelAviv} + H_{TelAviv}$$
$$= -0.035m$$

Height difference calculation

Undulation calculation:

Ellipsoidal height	Acc	Undulation	long	lat	
18.36[m]	0.08	18.57[m]	34.7677	32.0871	Tel-Aviv
16.35[m]	0.04	16.50[m]	34.9176	29.5017	Eilat

Height corrections due to barometric pressure:

height correction	barometric pressure [mb]		
dh [m]	Eilat	Tel-Aviv	date
0.035	1013.5	1016	Sep. 26th
0.049	1012.9	1016	Sep. 27th
0.013	1013.5	1014.8	Sep. 28th
0.020	1010.9	1012.9	Sep. 29th

Summary and Conclusions

► The development and manufacturing of a prototype of a GPS based float operating tide gauge was successful.

► It seems that the GPTG is capable of delivering the same level of accuracy (1cm) as a traditional TG with reliable results.

► The comparisons between the Red Sea level and the Mediterranean Sea level showed a difference (3.5cm) within the error margin of the undulation model.

► The ability to absolutely and relatively determine MSL changes was established.