Absolute Sea Level Rise Estimation at Alexandria Using Tide Records and GPS Observations

Prof. Ahmed. A. SHAKER , Prof. Abdollah. A. SAAD
Survey Department ,Shoubra Faculty of Engineering-
Banha University / EGYPT

Prof. Dalal ALNAGGAR , Dr. Hoda Faisal
National Water Research Center
Ministry of Water Resources and Irrigation

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Problem Definition

- The sea level is rising in the last decade, with different rates for different regions of the Earth.
- Using tide gauge data alone, can't distinguish between true sea level variations and changes in ground level at a tide gauge site.
- GPS monitoring can be used to decouple vertical land movements from change in relative MSL, so that tide gauge can provide estimates of changes in absolute MSL.
- Consequently, a sea level monitoring system has been installed at Alexandria tide gauge site containing a GPS receiver as a geodetic monitoring technique to perform this task.

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- Implementation
  a. Tide Gauge Instrument
  b. Meteorological Device
  c. GPS at the Tide Gauge Station
  d. GPS Data, IGS , ITRF
- Data collection and processing
- Results
- Future Plan

Tide Gauge Instrument (Wave and Tide Gauge WTG904 Series 3)

- The utilized tide gauge is a high-accuracy temperature-compensated self-contained instrument for measuring and recording tide and wave data.
- The apparatus has a built-in battery-backed 64KB RAM memory. It records measurements up to 90 days.
- The tide is calculated continuously and recorded automatically every 10 minutes.
- The measuring depth range of the gauge is from 0 to 35 meters, with accuracy of measurements = 0.2 cm.

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Meteorological Device (WMS-14 from Omega Inc.)

- The WMS-14 instrument has five accurate and reliable sensors for collecting different types of meteorological data.

- The accuracy measures of the five sensors are:

For barometric pressure:	± 5 mb
For Wind Speed:	± 3 mph
For Wind Direction:	± 2 º
For Rain precipitation:	± 1 %
For Temperature:	± 2o F
For Relative Humidity:	± 3%

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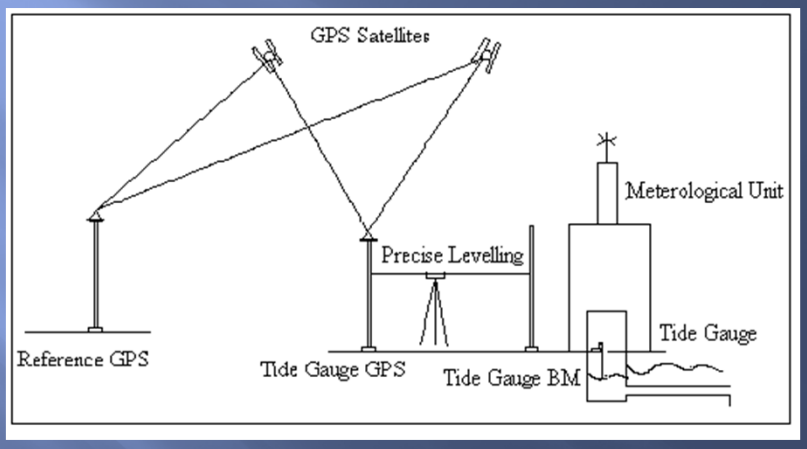

Established Sea-Level Observation System

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Available data:

A- Tide gauge observational data

- From 1944 till 1964, From 1965 till 1983 and from 1984 till 2000
- New observations using the new installation from 2001 till 2003 including 8760 tidal measurements for each year

B- GPS observational data

- Continuous GPS data at sample rate of 30 sec (477 days)

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Data processing:

- Process GPS data of the TG GPS station with the IGS stations on a 24-hour basis.
- The tropospheric delays are mitigated by using Saastamoinen model.
- Constrain the IGS stations to their precise coordinates relative to the most recent ITRF definition.
- The obtained height time series of the TG GPS station is firstly fitted to a linear regression model in a least squares sense.
- Any height residual that is greater than three times the WRMS is removed.
- Another linear regression model is fitted to the clean height time series to obtain a revised linear velocity estimate of the TG GPS station height.

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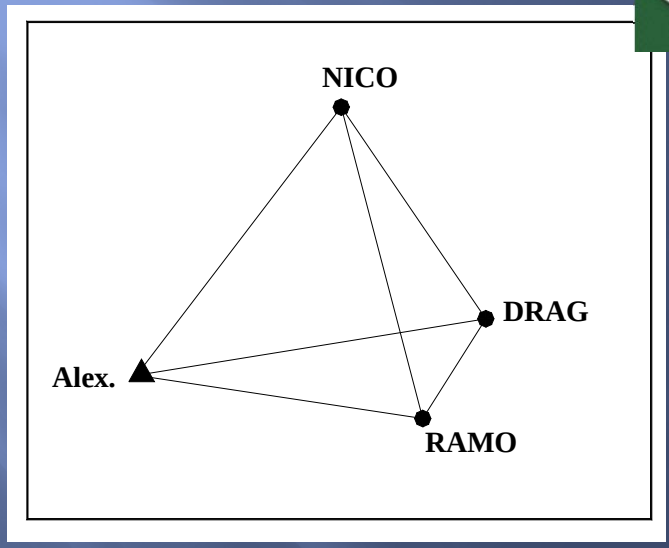
IGS global GPS stations



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Coordinates of utilized ITRF2000 stations (m)

Station	X ± σX	Y ± σY	Z ± σZ
NICO	4359415.849 ±0.004	2874116.974 ±0.003	3650777.712 ±0.003
RAMO	4514722.017 ±0.008	3133507.725 ±0.006	3228024.574 ±0.006
DRAG	4432980.874 ±0.128	3149431.992 ±0.110	3322110.339 ±0.099

Rate of velocities of utilized ITRF2000 stations (m)

Station	RX ± σRX	RY ± σRY	RZ ± σRZ
NICO	-0.1350 ± 0.0017	0.0139 ± 0.0012	0.0138 ± 0.0014
RAMO	-0.0179 ± 0.0032	0.0161 ± 0.0024	0.0148 ± 0.0023
DRAG	-0.0369 ± 0.0354	0.0104 ± 0.0305	0.0074 ± 0.0275

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GPS Data Processing

- Daily final IGS precise orbit (SP3 format) .
- Daily ionospheric estimated file .
- The Saastamoinen tropospheric model with 1-hour interval for the estimation of the zenith delay is applied.
- Cut-of angle was increased to 25 in order to get rid-of near-ground multipath reflected signals cause by many obstructions surrounding Alex. Station.
- Compute the corresponding coordinates for each station at each processed day of the available time series as follow :

$$X(t) = Xo + RX * (t - 1997)$$
$$Y(t) = Y0 + RY * (t - 1997)$$
$$Z(t) = Z0 + RZ * (t - 1997)$$

where,

t	is the date, in years, of the processing day
Xo, Yo, Zo	are the given ITRF2000 coordinates at epoch 1997

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Results :
a- Vertical displacement

From Tide Gauge

- A MSL trend of Alexandria has been attained.
- Mean sea level at Alexandria has risen 19.1 cm from 1906 to 2003
- Rate of change is **1.7 mm/year**

From GPS

- A new linear regression model is fitted to the clean height time series. This model produces a **revised linear velocity estimate** of the TG GPS station height that is equals **-0.47 ± 0.08 mm/year**.

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Results :
a-Vertical displacement

- Having estimating the height trend and the sea rise rate then the absolute sea level rise rate may be determined by:

- Abs. sea level Rise= relative sea rise rate
  + land deformation rate
  =1.7+(-0.47)=2.17 mm/year.

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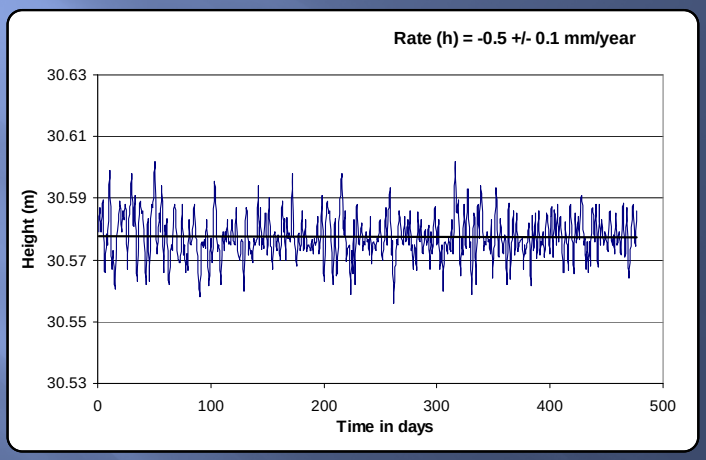

Revised GPS height time series and velocity estimates

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Results :
b: Horizontal displacement

- The same analysis procedure has been applied to the horizontal coordinates of the GPS at the tide gauge station.
- The horizontal coordinates time series (Northing and Easting) have been obtained.
- The revised trends for the **Northing** and **Easting** components have been estimated as **4.2 ± 0.9** mm/year and **6.3 ± 1.1** mm/year respectively (vector length of 7.4).
- Similar results have been reported by El-Fiky [2000], where the analysis of GPS observations collected at Helwan revealed that it moves northward, relative to the Eurasian plate, at a rate of 6 mm/year.

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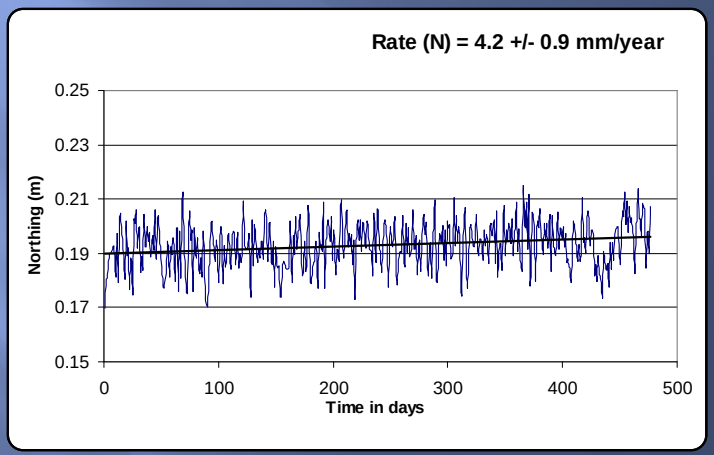

Horizontal coordinate time series (Northing) and velocity estimates

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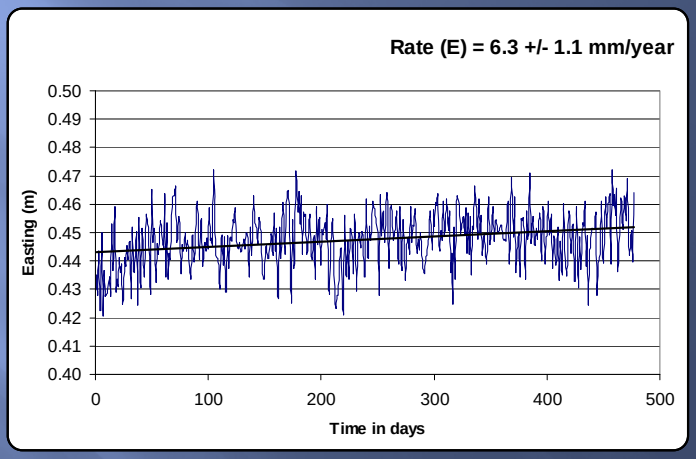

Horizontal coordinate time series (Easting) and velocity estimates

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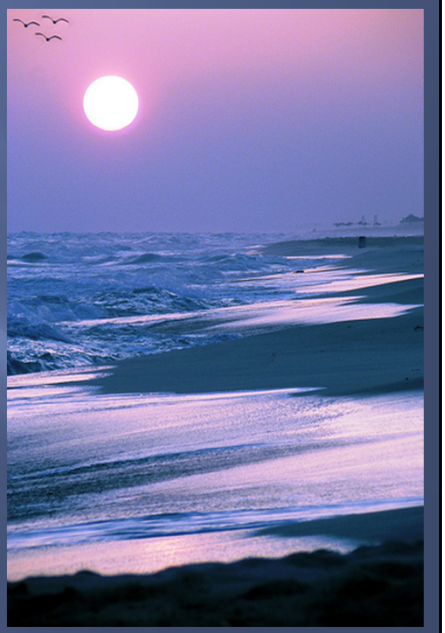
Future Work:

- The time span of the utilized data sets are relatively short. More accurate results need more continuous GPS measurements at the Alexandria tide gauge station.
- Tide Gauge stations should be established at other well distributed places at the Egyptian north coast with similar investigation and further analysis.
- Constructing similar stations along the coasts of the Mediterranean is a must for building an integrated VL. Control network.



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Thank You

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