Study of Sea Surface Temperature (SST) and Sea Level Rise (SLR) Along the Coast of Karachi using Satellite Data, Pakistan

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INTRODUCTION

This study aims to explore the trend of sea-level rise (SLR) along the coast of Karachi, Pakistan using satellite radar altimetry (SRA) and tide gauge data. With rising sea levels, developing countries like Pakistan lacking infrastructure, resources, and heavily populated vulnerable coastal communities will be among the world's most affected regions. Pakistan is one of those countries, which are vulnerable to global warming and SLR. Although Pakistan is not a prime contributor to greenhouse gases, it is already encountering the adverse impacts of changing climate. These impacts consist of increasing glaciers melting, long-term droughts, cyclones, flash floods, heatwaves, early summers, and warm winters. The rise in temperatures may cause SLR in Pakistan coastal areas due to heatwaves, melting of glaciers, and sea water's thermal expansions due to increased sea surface temperature (SST). The rise in sea levels may cause soil erosion, seawater intrusion, flooding, and sinking of low-lying areas near the coastlines resulting in local population displacement [1].

STUDY AREA

The study site is the Arabian Sea shoreline near Karachi, Sindh. Karachi is the largest city in Pakistan (Figure 1). Out of 990 km long coastline of Pakistan, the spread of the Sindh coastline is about 270 km, including 100 km of Karachi shoreline. Karachi coastline begins at the Hub River's mouth (west) and ends at Korangi Creek (east). Karachi is the 7th largest city globally with an estimated Gross Domestic Product (GDP) of $114 billion, which is about 42% of the country's total GDP [2], and therefore, known as the economic hub of Pakistan.

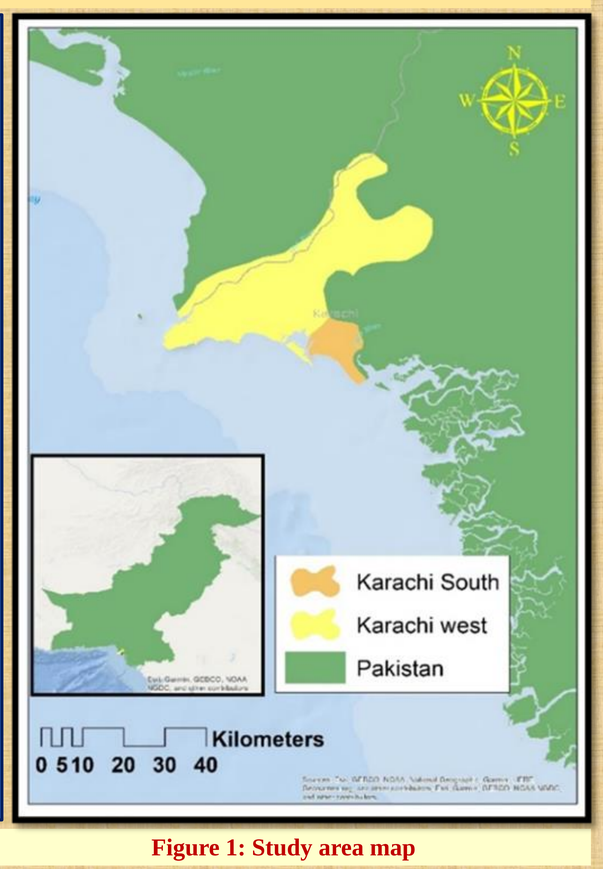
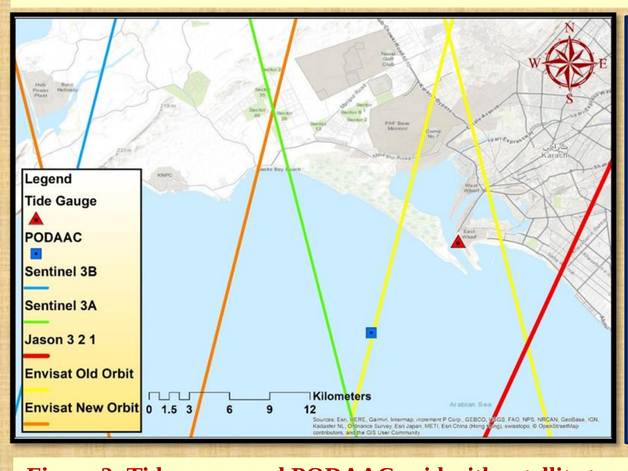


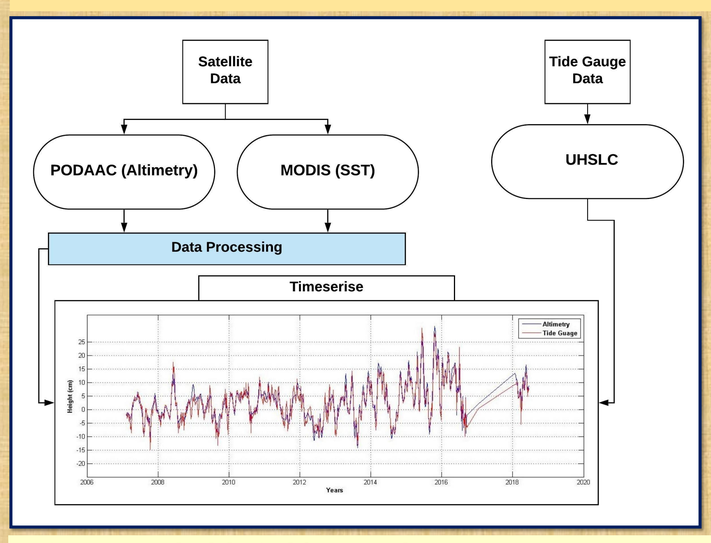
Figure 1: Study area map



The location of the tide gauge station nearest to the study area. Multi-mission satellite tracks are also plotted in different colours representing the paths of Jason, Envisat (old and new orbits), and Sentinel A & B satellites. The nearest PODAAC grid to the Karachi gauge station can be visualized in Figure 3.

Figure 2: Tide gauge and PODAAC grid with satellite tracks

METHODOLOGY



The gridded Sea Surface Height Anomalies (SSHA) above a mean sea surface is available on a 1/6th degree grid with a 5-day temporal resolution. This product contains interim heights and is generally refined with a time lag of a few weeks.

Figure 3: Methodological framework

The methodology presented in Figure 3 correlates the study datasets. First, the data were collected from different sources. Tide gauge data were obtained from the University of Hawaii Sea Level Center (UHSLC) website. The multi-mission altimetric data were obtained from the Jet Propulsion Lab's Physical Oceanography Distributed Active Archive Center (PODAAC).

As rising SST directly contributes in SLR, for this analysis satellite SST data is obtained from MODIS Terra, L3 SST Thermal Monthly 4km Daytime data product was used to investigate the trend of SST.

RESULTS

The sea surface anomalies were derived from the multi-mission altimetric and tide gauge data. Both datasets show a decent agreement for the entire time-series from Jan 06, 2007, to Apr 21, 2018 (gauge data for 2017 were missing). The results gave an R^2 value of 0.8955, RMSE = 2.1 cm, and a correlation of 0.94, as shown in Figures 4 and 5.

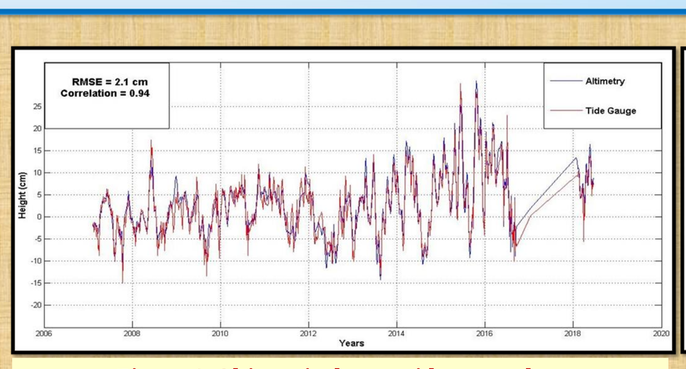


Figure 4: Altimetric data vs tide gauge data

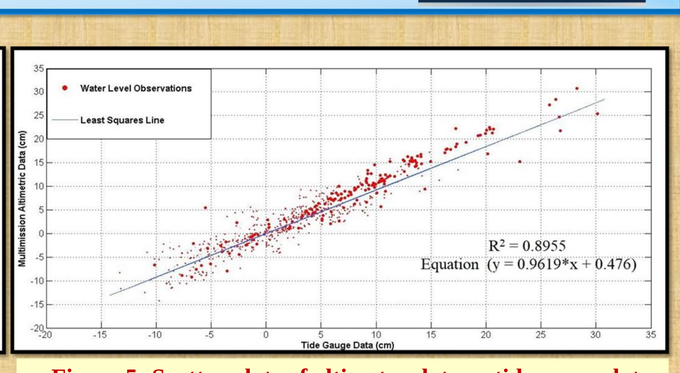


Figure 5: Scatter plots of altimetry data vs tide gauge data

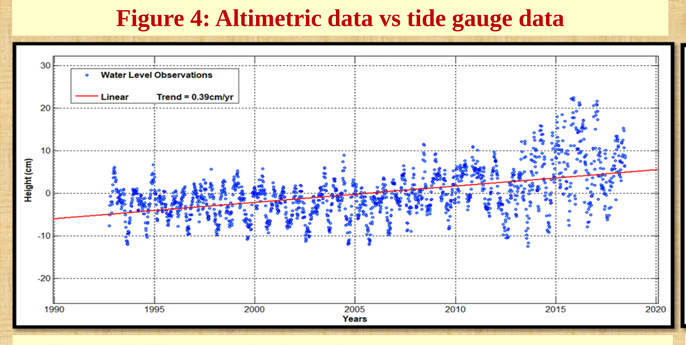


Figure 6: Trend analysis of altimetric data for sea surface heights

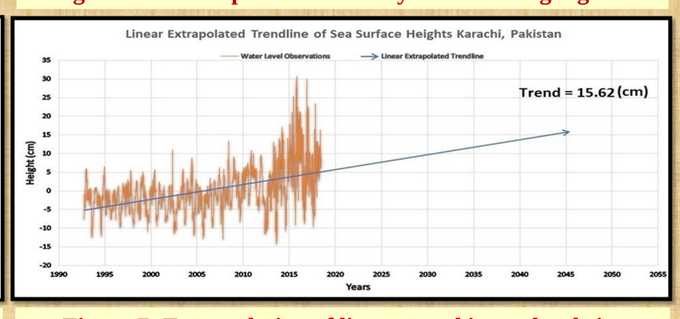


Figure 7: Extrapolation of linear trend in sea level rise

The linear trend analysis of multi-mission altimetric data of sea surface anomalies shows a rise of 3.9 mm/year from 1993 to 2018 (Figure 6). Further, the multi-mission altimetric data were linearly extrapolated from 2019 to 2045 using a linear regression line to forecast with a 95% confidence level. It is speculated that a 15.62 cm gradual rise of sea level in the next 25 to 30 years will be observed at Karachi as indicates in Figure 7.

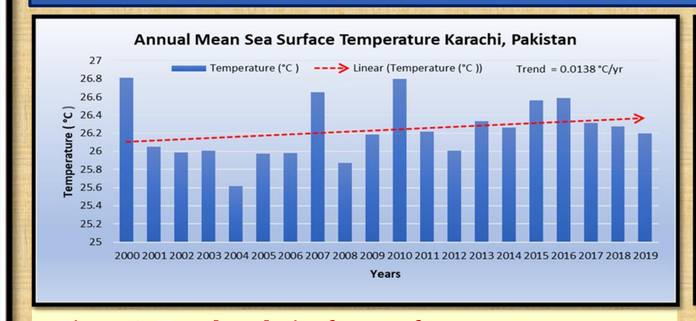


Figure 8: Trend analysis of sea surface temperature

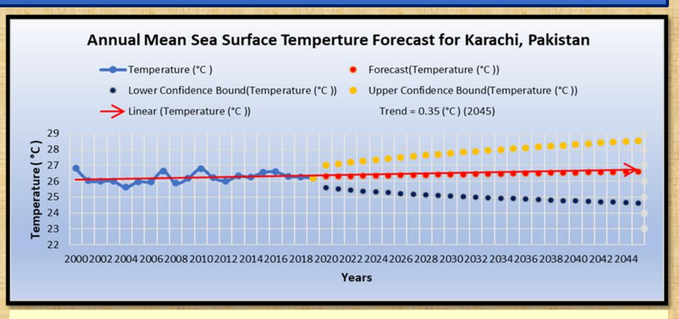


Figure 9: Sea surface temperature forecast

The trend analysis of SST is performed using historical time-series data of the last 19 years from 2000 to 2019. It has been observed that SST has a low rise of 0.0138 °C /year with a slightly increasing trend, as shown in Figure 8. The future SST values were forecasted employing a linear regression line with a 95% confidence level. The predicted values for the next 25 years show a much higher rise of 0.35 °C until 2045 (Figure 9). This rise may directly contribute to the rising sea level around the coast of Karachi. According to a study, the global SST is predicted to increase by 1.9 °C by the end of the 21st century, which will cause a global sea-level rise of 56 cm [3].

CONCLUSIONS

The comparison of the multi-mission altimetric dataset with tide gauge data for Karachi leads to exciting findings. It can be concluded that overall the study datasets show a decent agreement with an R^2 value of more than 0.80. The trend analysis of altimetric data shows a sea-level rise of 3.9 mm/yr. The future prediction of sea surface heights by linear extrapolation shows an increase of 150 mm in the next 25 years. In other studies, the sea level rise is predicted as 1.1 mm/year, which may cause a horizontal beach loss of 110 mm per year or 1.1 m of beach loss in a decade [4]. One study found that the Karachi coastline has experienced a 2.43 ± 0.45 m/yr of erosion [5]. Further, a similar trend analysis is carried out for SST using historical data, which shows a rise of 0.0138 °C per year. Based on these historical values, the SST for the next 25 years is forecasted. The forecasted SST shows a higher value of 0.35 °C till 2045.

REFERENCES

1. *Khan, Tariq & Ahmed Khan, Faisal & Jilani, Rahmatullah. (2008). Sea surface temperature variability along Pakistan coast and its relation to El NiNo-southern oscillation.*
2. *Jaffery, R. (2018), Impact of Climate Change on Karachi May be One of Pakistan's Biggest Threats. Inter Press Service News Agency.*
3. *Aral, M.M.; Guan, J. Global Sea Surface Temperature and Sea Level Rise Estimation with Optimal Historical Time Lag Data. Water 2016, 8, 519.4.*
4. *Tariq Masood Ali Khan, D. A. Razzaq, Qamar-Uz-Zaman Chaudhry, Dewan Abdul Quadir, Anwarul Kabir & Majajul Alam Sarker (2002) Sea Level Variations and Geomorphological Changes in the Coastal Belt of Pakistan, Marine Geodesy, 25:1-2, 159-174, DOI: 10.1080/01490410275351680 4*
5. *Kanwal, S.; Ding, X.; Sajjad, M.; Abbas, S. Three Decades of Coastal Changes in Sindh, Pakistan (1989–2018): A Geospatial Assessment. Remote Sens. 2020, 12, 8.Author 1, A.; Author 2, B. Title of the chapter. In Book Title, 2nd ed.; Editor 1, A., Editor 2, B., Eds.; Publisher: Publisher Location, Country, 2007; Volume 3, pp. 154–196.*

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