

# REAL-TIME REPORTING AND INTERNET-ACCESSIBLE CELLULAR BASED COASTAL SEA LEVEL GAUGE

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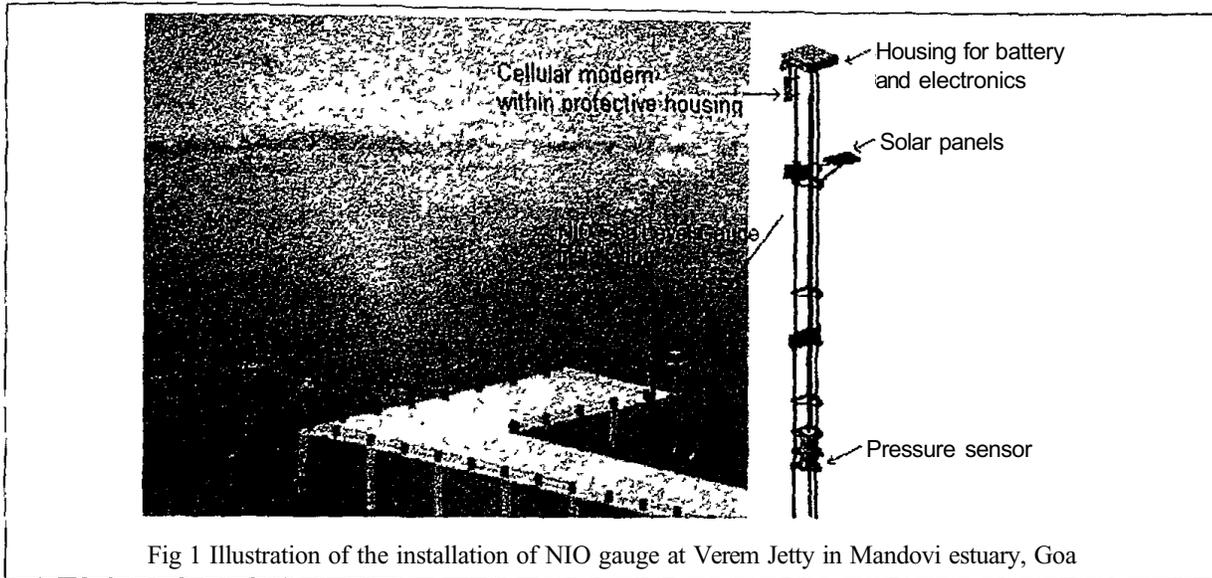
## Introduction

The 26<sup>th</sup> December 2004 Indian Ocean tsunami which spread all along the coasts of Indian Ocean rim nations and their islands was an eye opener to the grave consequences that resulted in the absence of a network of real-time reporting coastal sea-level gauges. Lack of real-time or near real-time information resulted in avoidable loss of many lives. This incidence, together with frequent storms that hit many coastal locations in India and the Indian Ocean rim regions and elsewhere in the world, points to the immediate need for development of real-time coastal sea-level data communication systems for the benefit of the coastal communities and the local administrators (Joseph and Prabhudesai, 2005). Further, real-time sea-level data would form an important input to storm-surge predictive models and warning systems. Given the popularity of internet in India and the world over, internet-accessible sea-level gauges would mean that the current coastal sea-level scenario can be viewed in real-time by anyone from any part of the world. Such accessibility would have significant practical utility during anomalous and disastrous state of the coastal seas. If an internet access to the sea-level gauge website is made available to television channels, real-time visualization of the coastal sea level and its trend from the previous day to the present instant can be seen by everyone including the common people who are known to make good use of television facility when anything particularly important happens in any part of the world. Providing internet-accessibility to the sea-level gauge website at other electronic and print media centres such as radio stations and the press would serve an equally important role in the quick dissemination of the current anomalous sea level scenario to the navigators, and the travelling communities. If a network of several real-time transmitting sea-level gauges along the Indian sub-continental coastline and islands is built and made operational, such a network would provide useful information to the mariners sailing in the coastal waters and also contribute to various engineering projects associated with coastal zone management. Moreover, the information obtained would be of great value to the national and international scientific community.

Thus, innovative and cost-effective monitoring systems that provide the requisite information on coastal sea levels are an important requirement at present. It is hoped that cellular-based real-time reporting and internet-accessible sea-level gauge developed would provide a cost-effective platform to fill the void that exist in the country at present.

## Description

The existing gauges in India and most of the Indian Ocean rim nations do not provide real-time or near-real-time sea-level information. The system developed and implemented by us incorporates multimedia cards, with storage capacity ranging from 128 to 1000 mega bytes. Additionally, real-time or near-real-time data access capability is also implemented for effective operational applications during anomalous sea-level conditions such as those occurring during storm surges and tsunami episodes.



The present gauge has incorporated pressure transducer as the sensing element. The data is normally sampled at 2Hz and can be averaged over a duration of 15 seconds to 15 min interval. The sea-unit of the gauge is mounted within a cylindrical protective housing, which in turn is rigidly held within the vertical legs and the interconnecting triangular collar of the mechanical structure used for mounting the entire gauge. The gauge and the data communication modem are powered from 12 volts 17 AH battery, which is charged by a solar panel. Fig. 1 illustrates the installation of the gauge at Verem Jetty in Mandovi estuary, Goa, India.

## Cellular based data communication

There are various communication technologies that could be utilised for real-time transmission of sea-level data. These include wired telephone connection, VHF/UHF transceivers, satellite transmit terminals, and cellular connectivity.

Wired telephone connections are severely susceptible to loss of connectivity during natural disasters such as storm surges, primarily because of telephone line breakage under the force of storm-winds (e.g., uprooted trees and broken branches). Communication via VHF/UHF transceivers is limited by line-of-sight distance between transceivers and normally offer only point-to-point data transfer. However, satellite communication *via* platform transmit terminals (PTTs) has wider coverage and, therefore, allows data reception from offshore platforms.

Nevertheless, data transfer speeds are limited to 9600 baud. Further, many satellites (for example; INSAT, GOES) permit data transfer only at predefined time-slots, thereby inhibiting continuous data access. While satellite communication is relatively expensive, wireless networking infrastructure and ubiquity of cellular phones have together made cellular communication affordable. Low initial and recurring costs are an important advantage of cellular data communication.

Various services exist for data communication; e.g., SMS, Data Call, and GPRS. SMS (short message service) is a common method of sending text messages of up to 140 bytes between cellular devices. This mode of transmission is probably the easiest to implement when the data size is small. However, the recurring cost can be substantial if data needs to be reported frequently. Further, keeping track of lost SMS can easily override its simplicity. Data Call is another alternative, which can also turn out to be expensive if data has to be frequently reported. Both SMS and Data Call services would require modems on the remote transmitting device as well as on the receiving- side. This adds to the hardware cost as well as software overheads on the receiving- side to check the data integrity for transmission errors. The main benefit of cellular connectivity with GPRS technology is that it utilizes radio resources only when there is data to send. In addition, GPRS offers improved quality of data services as measured in terms of reliability, response time, and features that are supported. Another advantage of GPRS over other data communication services is that it provides an 'always on' communication channel without incurring time-based costs. That is, there is no difference in costs whether data is collected with a fixed frequency.

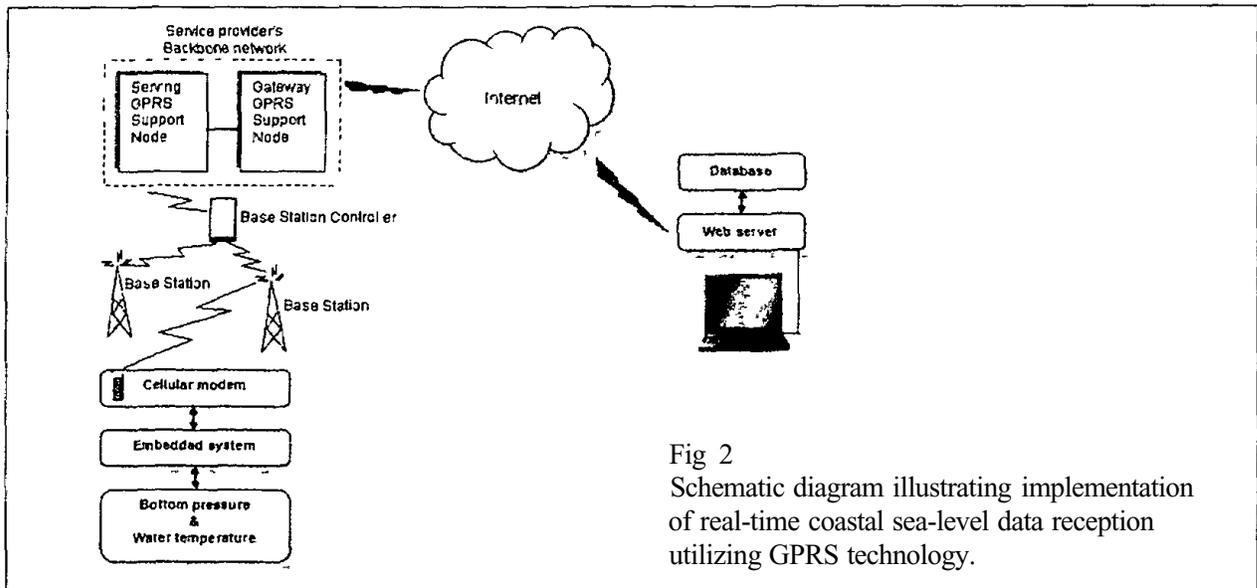


Fig 2  
Schematic diagram illustrating implementation of real-time coastal sea-level data reception utilizing GPRS technology.

The GPRS data transmission speeds are maintained at the order of 3 to 4 times that of a traditional cellular data connection. The GPRS allows data rates of 115 kilobits per second. Also, GPRS enables a constant TCP/IP connection with the internet so that data can be easily uploaded. Since data is posted on the internet server, there is neither a need for a modem on the receiving side nor a requirement to have special software at the server-side to collect data from the remote site. Fig. 2 illustrates implementation of real-time coastal sea-level data reception utilizing GPRS technology. GPRS modem with built-in TCP/IP stack incorporated in the present

design frees the host controller, which is responsible for acquisition of data from sea-level gauge, from communication overload. These modems need only a few simple commands to upload data on a remote FTP server.

Data communication is always initiated by the sea-level gauge. After communication link is established, a bidirectional data transfer is possible between internet server and the sea-level gauge. This is because GPRS Gateway Support Node (GGSN) uses Dynamic Host Configuration Protocol (DHCP) to assign private IP (Internet Protocol) addresses to cellular devices. This IP address is invisible to the internet network. Although GPRS is termed as an "always on" network, if there is no data exchanged beyond some timeout periods (in the present case, 1 minute), the connection is dropped and a new IP address is assigned to the cellular modem. Because of this scheme, the IP address of the cellular modem can change frequently. One obvious benefit of such a connection mechanism from the security point of view is that risk of attack from hackers and third party is reduced.

The software consists of two main components, namely; (1) embedded system software for data acquisition and communication with internet server, and (2) web-server based user-interface to visualise the received sea-level data. In the present application, 5-minutes averaged sensor output data is logged by the embedded system at 5-minutes interval. Subsequently, all the data logged from the previous day to the current time is uploaded to the internet server that is located at NIO, Goa, India. The data received at the internet-server is stored in its back-end database, and simultaneously presented in graphical format, together with the predicted fair-weather sea-level and the residual. The residual, which is the measured sea-level minus predicted fair-weather sea-level, provides a clear indication and a quantitative estimate of the anomalous behaviour of sea-level oscillation. The driving force for such anomalous behaviour could be atmospheric forcing (storm) or geophysical (tsunami). Fig. 3 shows the predicted fair-weather sea-level, observed real-time sea levels, and residuals from Verem jetty (Mandovi estuary), Goa, India. The scale of real-time display is dynamically adjusted based on the maximum elevation observed.

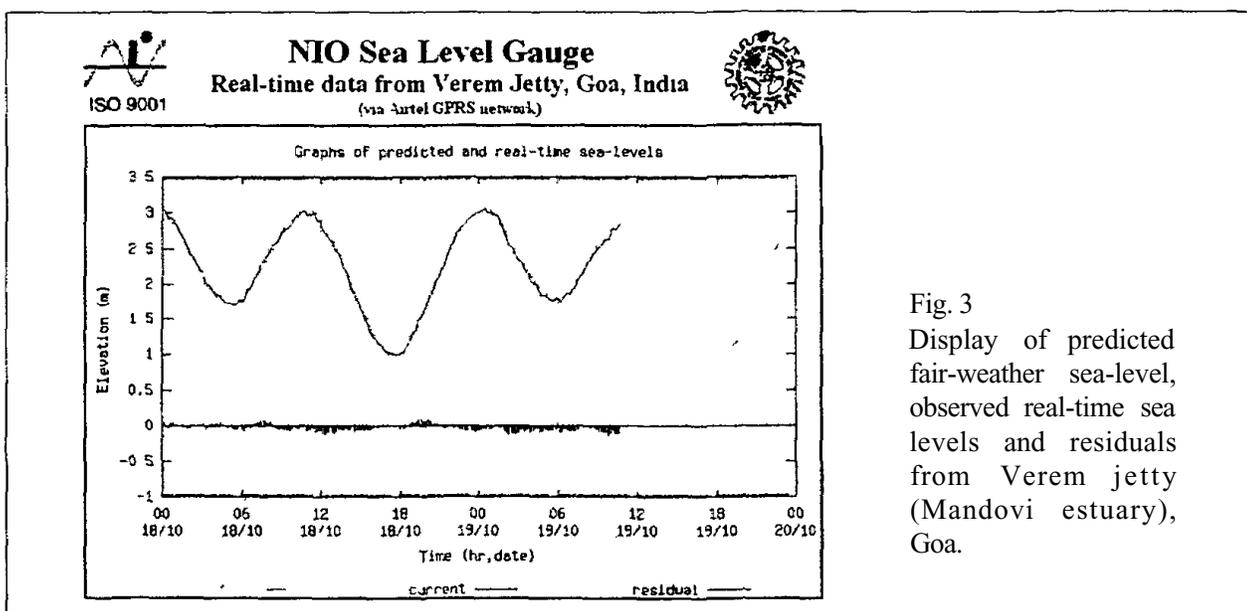


Fig. 3  
Display of predicted fair-weather sea-level, observed real-time sea levels and residuals from Verem jetty (Mandovi estuary), Goa.

## Communication performance evaluation

In order to examine the performance of data upload from the sea-level gauge to the internet server, a 100 kbytes of test data were uploaded continuously for 24 hours using standard File Transfer Protocol (FTP). Fig. 4 shows the percentage distribution of time taken (throughput) for successive FTP uploads during the above experiment.

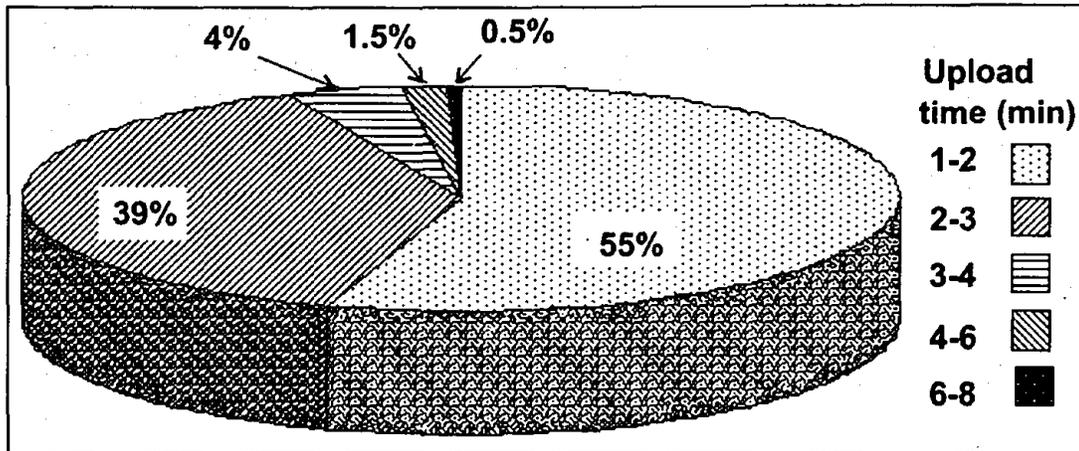


Fig. 4 Percentage distribution of FTP up-load time during a period of 24 hours for a 100 kb test data.

The minimum and maximum transfer times were 1.29 min and 7.1 min respectively, and the average time was 2.06 minutes. Data was transferred between sea-level gauge and the FTP server using Airtel GPRS service. On an average, 97.47% of data transfer attempts was found to be successful. Fig. 5(a) shows the time-series distribution of absence of Airtel GPRS connectivity during the period from 24<sup>th</sup> September to 17<sup>th</sup> November 2005. Fig. 5(b) illustrates percentage-wise distribution of the absence of Airtel GPRS connectivity for the months of September, October, and November 2005.

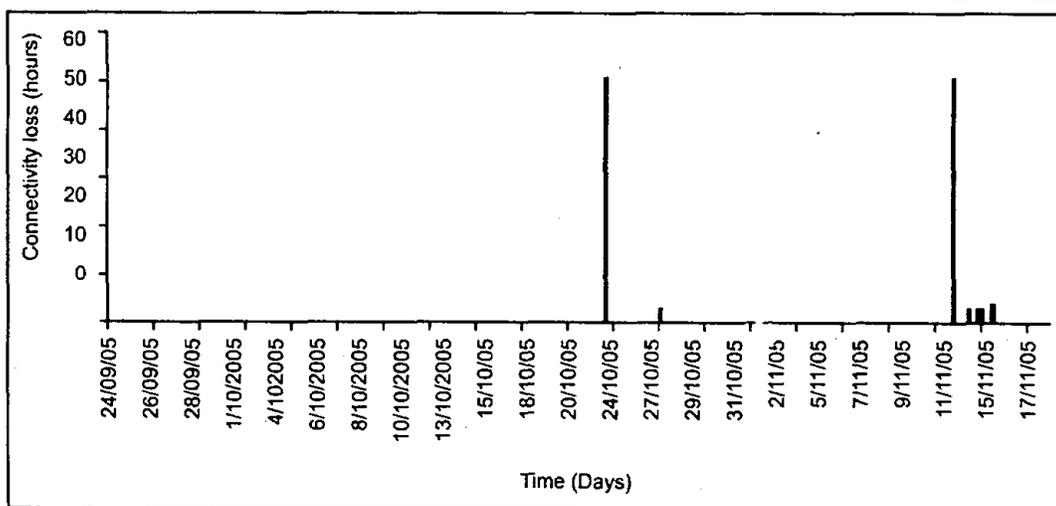
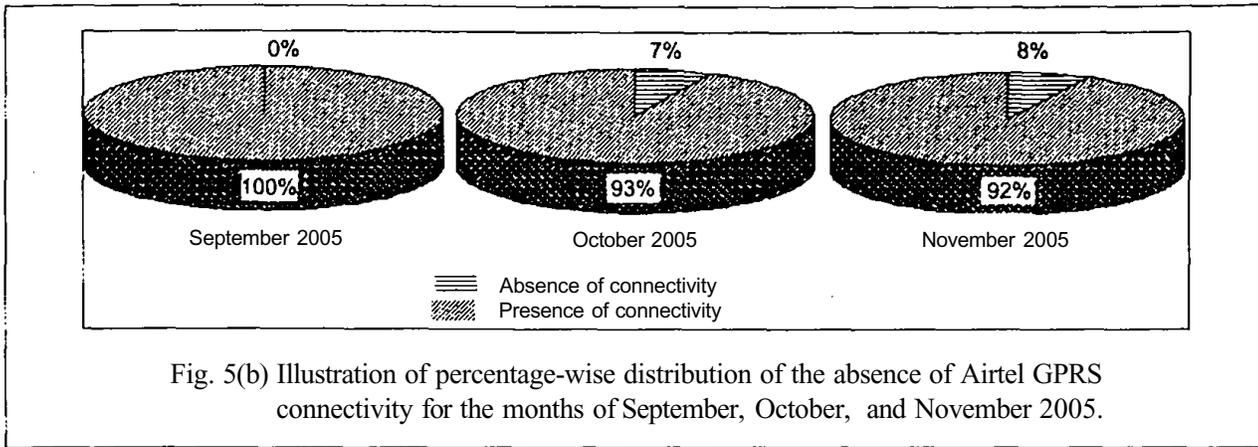


Fig. 5(a) Time-series distribution of absence of Airtel GPRS connectivity during the period covering from 24<sup>th</sup> September to 17<sup>th</sup> November 2005.



## Conclusions

A real-time sea-level reporting system utilizing exiting cellular communication infrastructure was described. Several issues involved in the implementation of internet-accessible sea-level gauge have been addressed. It is anticipated that the growth in communication infrastructure will further improve our capability in coastal sea-level data collection in real time and its utilization for running predictive models as well as warning and alert purposes. The architecture of the system described herein, and in operation. Since 24 September 2005, would complement the INSAT-based sea-level gauges that are proposed to be put in place by the Government of India by September 2007. In contrast to INSAT, where data transmission is restricted to certain time-slots, the system developed and implemented by NIO offers continuous data access.

The system can also be effectively used in dams and reservoirs for water resource management, flood management, sharing of water resources between States and neighbouring countries, and monitoring and implementation of Joint River Water Treaties with increased transparency.

## References

- Joseph, A., and R.G. Prabhu Desai, 2005, Need of a Disaster Alert System for India through a Network of Real Time Monitoring of Sea Level and other Meteorological Events, *Curr. Sci.*, 89: 864-869.