Development of Low Cost NavIC Based Environment Monitoring (NEMo) Drifters

Dr. S.V.V. Arun Kumar & Kanika Jakhar
Indian Space Research Organization (ISRO)

December 11, 2019
ICG-14, Bengaluru
Motivation

- About 60% of world’s population lives along the coast.
- “Rip Current” is a rare known fact but results in drowning around 40 people yearly along the Indian coast.
- Many drownings are underreported due to lack of awareness and less attention.
- No dedicated lifeguarding system exists in India to safeguard these innocent lives.
- No regular water quality checks in the beaches – risk of harmful pollutants to beachgoers.
- The existing methods are expensive and risky.
What are Rip Currents?

- They are strong, narrow, seaward flow of waters usually found in surfzone of many beaches worldwide.
- Typical speed range: 0.5-3 m/s
- Sometimes, speed can be >5 m/s
- It can drown even the strongest Olympic swimmers.
- Important for transport and cross-offshore mixing of heat, pollutants and nutrients.
- They are Silent killers
Why NEMo Drifters?

- **Coastal properties**: Extreme temporal and spatial variability.
- **Traditional Techniques**: Localised, Expensive and Risky
- **Available drifters**: Experimental and unavailable for purchase
- Commercial drifters cost more than US $1 million each and have only GPS.
- Basic measurements of temperature, salinity, DO and pH – unavailable
- These parameters are key **Water quality indicators**.
- To monitor pollution in rivers, lagoons, beaches etc.
- More number of drifters required for detailed maps - Low cost!
Drifter block diagram

Location: NavIC

Sensors DATA: pH, Salinity, temperature, DO

On-board computer

Microcontroller

DATA Storage: MicroSD Card

Transmission to Server

Satellite Terminal

Battery: 1-2 months

Transmission to Server (UDP)

Sim800

DATA Storage

MicroSD Card
Proposed solution

Hardware

- Low-cost multi-GNSS chip connected serially with a micro-controller to provide NMEA data.
- Low-cost pH, temperature, Dissolved oxygen (DO), conductivity (salinity) sensors
- Location and sensor data sent by Sim800 Module/ Satellite Terminal.
- DATA stored to microSD card
- Battery: 12V
- Electronics water-proofed in specially designed PVC enclosure (IP65/67)

Software

- Code: C++ (Arduino IDE).
- Sampling Frequency: 1 Hz.
- NMEA Data: Date & Time, Latitude, Longitude, Speed extracted and transferred via SPI protocol.
- Data sent via Sim800 when GSM network is available (5 s).
- Data sent via MSS satellite terminal when GSM network is lost/unavailable (1 min).
- Client application for real-time visualisation and data downloading.
Data collection and transmission

Loop

Read Temp.
Send Temp to other sensors for compensation

Read pH

Read Location from NavIC

Read Conductivity

Read D.O.

Store in microSD card

Is GSM network available?

Yes
Send data to Sim800 for transmission

No

Have 60s passed?

Yes
Send data to satellite terminal for transmission

No
Wait 1s
Design was inspired from a Roly-poly toy.
Drifter was made from off-the-shelf PVC parts and low-cost GNSS receiver (EMLID Reach®).
GNSS receiver stores raw carrier phase and pseudo range internally from GPS, GLONASS, GALILEO, Beiduo, SBAS etc.
Flanges were introduced to increase the current drag and bottom circular disc to reduce the wave impact.
Minimum surface area above sea surface to reduce the wind impact.
Very simple design but efficient at sea..!
Also attempted with the NavIC receiver.

<table>
<thead>
<tr>
<th>Item</th>
<th>Price in US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMLID Reach L1 GNSS receiver module</td>
<td>$200</td>
</tr>
<tr>
<td>Tallysman Antenna</td>
<td>$60</td>
</tr>
<tr>
<td>PVC Pipe and other connectors</td>
<td>$30</td>
</tr>
<tr>
<td>20,000 mAh Power bank</td>
<td>$10</td>
</tr>
<tr>
<td>Manufacturing cost</td>
<td>$100</td>
</tr>
<tr>
<td>Total cost</td>
<td>$400</td>
</tr>
</tbody>
</table>

4GB Memory
Intel Edison Processor
Ublox receiver
WiFi, Bluetooth
USB powered

Drifter was positioned stationary under the open sky and recorded the data for 1 hour (simultaneously in a base station).

Processed both the data using RTK-Lib s/w to get PPK solution.

It is helpful to assess the positional error of the receiver.

The maximum northing and easting position errors were ±0.01 m (1 cm) with a standard deviation of 0.003 m and 0.002 m respectively.

The relative errors in the easting and northing were ±0.02 ms\(^{-1}\) (2 cms\(^{-1}\)) with a standard deviation of 0.004 ms\(^{-1}\).

The low relative errors in position and velocity indicate the present drifters are capable to measure currents of an order greater than 0.02 ms\(^{-1}\).
Fast Fourier Transform (FFT) has been applied to both stationary and field observations. The position and velocity spectra were computed as an average of eight overlapping sections of 4096 points Hanning windowed at the 95% confidence level. The position spectra of the stationary measurements have magnitudes of $10^{-4}$ to $10^{-2}$ m$^2$s$^{-1}$. The velocity spectra of stationary drifter have magnitudes of $10^{-9}$ to $10^{-8}$ m$^2$s$^{-1}$. The lower magnitudes indicate a lower relative error when compared with the previously designed GPS drifters.
● It has been observed from the data that the SNR is above 100, quite high as compared to the past receivers (Mac Mahan et al. 2009).

● Therefore receivers are capable to measure the positions and velocities of lower frequency motion in the surf zone.

\[
SNR_{xx}(f) = \frac{S_{xx}(f) - S_{rr}(f)}{S_{rr}(f)}
\]

Error spectrum of drifter in motion

Error spectrum of stationary drifter
In order to get precise position, we have used Reach RS ($700) as a base station (stationary) and recorded the raw logs.

Drifter and base were simultaneously operated and both the datasets were post processed in RTKLib open source software to get a differential solution (PPK).
Experiments carried out

Professional Swimmer released the drifter in mid surf zone

RK Beach, Visakhapatnam one of the dangerous sites of Rip currents in India

Drifter

Rhodamine-B dye patch along with drifter in the rip current
Rip current measurements from GNSS drifters

NavIC drifter experiment

Max Vel = 0.6 m/s

NavIC vehicle tracker is customized to take measurements at 2Hz interval

Calangute, Goa
Other major applications of drifters

- Rip current dynamics (spatial & temporal structure)
- Search and Rescue
- Oil spill monitoring
- Bloom tracking
- Pollution dispersion monitoring in the surf zone
- Bathymetry mapping
- Nourishment effects
- River and estuarine flood monitoring
- Forensic investigation
- Military and Naval Coast Guard application
- Coastal research
Thank You