Design and field validation of Lagrangian drifters with INSAT communication for oceanographic and meteorological applications.

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National Institute of Ocean Technology (NIOT) has successfully indigenously developed the Lagrangian drifter buoy which is built with geostationary based Indian satellite communication module for Meteorological/Oceanographic applications and it has been named Pradyu. The drifter buoy-Pradyu has been successfully interfaced with NTC type Sea Surface Temperature (SST) sensor, Smart GPS receiver, INSAT communication modem and designed with holy sock drogue acting as the sea anchor which was fabricated using nylon collapsible cordura material. Drifter buoy was indigenized following internationally accepted measurement scheme and data transmission protocol, which are mandatory on usage of data by international scientific community. This article consists of the design and field validation performed to evaluate in-house developed spherical Lagrangian drifter buoy.

[Key words: Lagrangian drifter, drag area ratio (DAR), mixed layer surface current, INSAT communication modem and SST measurements]

Introduction

NIOT has successfully indigenized the Drifter Buoy System Technology using Indian satellite communication link. It is free-drifting system with Drogue as sea anchor and it will measure the sea surface temperature and barometric pressure. These collected data is most widely used by the scientific community for the study of climate change, ocean water circulation modeling and weather forecasting purposes. Drifter buoy consists of two sections, the first section is the Surface Float which houses the necessary data acquisition electronics, battery pack and sensors like sea surface temperature, barometric pressure, salinity, global positioning system (GPS) and Indian satellite based mobile satellite service (MSS) terminal. Second section is drogue which acts as the sea anchor and connected to Surface Float by a tether wire. Ocean mixed layer current is derived from the GPS positional data obtained from Drifter. In order to ascertain the performances of the indigenously developed drifter buoy system-Pradyu, the indigenized drifter was deployed along with imported drifter which has measurement scheme as per the surface velocity project of the world ocean circulation experiment (WOCE). Presented test is carried out for validating drifter SST measurements and mixed layer current following characteristics of the drifter buoy which ensures the proper coupling of surface float and drogue with respect to the movement of water body due to mixed layer currents.

Buoy configuration

The Drifter Buoy system is an ocean observation platform and has many sensors as payload to measure the ocean parameters in regular interval and transmit it to an earth station through satellite communication. It has a surface float which is made of FRP EPOXY resins approximately 400 mm in diameter and thickness of 5 mm. All the electronic systems like Data acquisition card, GPS receiver module, INSAT communication module and Battery pack modules were rigidly mounted inside this 400 mm surface float. SST sensor mounted bottom side and INSAT based satellite modem fixed inside the surface float itself. Surface float is connected with Drogue - sea anchor using 3.2 mm thickness impregnated tether wire of length 12.5m. An embedded controller is used to control the sequential measurement of parameters, logging the data in the internal memory and transmitting it to
ground station via INSAT transmitter modules. High energy and light weight primary lithium battery pack is used for powering the drifter buoy for a period of 2 years.

Electronic hardware of drifter data acquisition and communication controller module is designed using low power sub components. Surface float and drogue is designed to withstand harsh marine conditions. Fig.1 presents a perspective view of the drifter buoy system and Fig.2, presents a schematic of the drogue and float. The density of the drogue 370 gram per square meter (GSM) is maintained slightly higher than the water density by distributing additional weight in the middle and bottom rings of drogue which makes the system to sink to nearly the full extent of the tether. The density difference however is maintained small enough to allow the surface float to remain in the sea surface.

Calculation of drag area ratio-dar
The movement of a Lagrangian drifter differs from the motion of the water mass
where it is located due to the tension exerted by the tethering wire.

**Table I — Design Calculation of Drogue Area Ratio (DAR)**

<table>
<thead>
<tr>
<th>Non Drogue Drag Components</th>
<th>Length</th>
<th>Diameter/Base</th>
<th>Frontal Area (m²)</th>
<th>Drag Coefficient (C)</th>
<th>Drag Area (CA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Float</td>
<td>NA</td>
<td>40</td>
<td>1257</td>
<td>0.47</td>
<td>591</td>
</tr>
<tr>
<td>Urethane below Surface Float</td>
<td>16</td>
<td>5</td>
<td>40</td>
<td>1.40</td>
<td>56</td>
</tr>
<tr>
<td>Pipe and cap below Surface Float</td>
<td>9</td>
<td>5</td>
<td>45</td>
<td>1.40</td>
<td>63</td>
</tr>
<tr>
<td>Tether</td>
<td>1125</td>
<td>0.35</td>
<td>394</td>
<td>1.40</td>
<td>552</td>
</tr>
<tr>
<td><strong>Total Tether Drag Area</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1262</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drogue Drag Components - Number of drogue sections : 5</th>
<th>Length</th>
<th>Diameter/Base</th>
<th>Frontal Area (m²)</th>
<th>Drag Coefficient (C)</th>
<th>Drag Area (CA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urethane above Drogue</td>
<td>16</td>
<td>5</td>
<td>40</td>
<td>1.00</td>
<td>40</td>
</tr>
<tr>
<td>Pipe and cap above radial hub</td>
<td>9</td>
<td>5</td>
<td>45</td>
<td>1.00</td>
<td>45</td>
</tr>
<tr>
<td>Drogue</td>
<td>122</td>
<td>60</td>
<td>36600</td>
<td>1.40</td>
<td>51240</td>
</tr>
<tr>
<td><strong>Ratio of Drogue Drag Area to Non Drogue Elements Drag Area (R)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40.60</td>
</tr>
</tbody>
</table>

This tension arises from the vertical velocity gradient in the ocean. Generally, the surface floats velocity due to waves and currents is much higher than the drifter velocity. Therefore its drag forces will be different; this difference being what produces a relative force on the drifter that modifies its motion. Drag forces are equal to the projected area of the element times the water velocity times the drag coefficient. In this design the DAR ratio is achieved more than 40 to maintain the drifter drift rate of 10-30 cm/s with the wind speeds of up to 15 m/s which ensures the mixed layer surface velocity measurement within 2 cm/sec\[^4\].

As much as the ratio between the drag on the drifter and the external drag is large enough, the drifter movement will be due to the water mass influence rather than to external forces. It is possible to estimate the difference between the drifter velocity and the water mass velocity as a function of that ratio. This ratio is called Drag Area Ratio-DAR of drifters. Let us define the drag area ratio R as

\[
R = \frac{C_d A_d}{\sum C_s A_s}
\]

Drag Area Ratio = \frac{\text{Drogue Drag Area}}{\sum \text{Non Drogue Elements}} \geq 40

In this equation, C is the drag coefficient and A is the projected area. s and d sub-indexes are used to indicate the surface elements (Surface floats, wire) and drogue respectively. Desired velocity difference, or slip velocity \(U_s\), may be estimated from wind data and the vertical gradient of the current velocity according to the following relationship.

\[
U_s = aR^{-1}U_w + bR^{-2}\Delta U
\]

Where \(U_w\) is the wind velocity and \(\Delta U\) is the vertical velocity gradient. The capability of the drifter to follow the water movements increases
when the slip velocity is small. Still the slip error\cite{5} could be reduced by applying the wind velocity correction factor. Table I presents the areas, drag coefficients, drag areas, and drag area ratio for the Pradyu-drifter when tethered to 15m depth.

**Results & Discussions**

In order to test and validate the performances of the indigenously developed drifter’s sea surface temperature measurements and surface mixed layer current following characteristics, we have deployed Pradyu system along with drifter imported from Marlin Yug, Ukraine in the Bay of Bengal region.

Fig. 3—Drifter Buoy deployed at Bay of Bengal on 8th March, 2013.

Both the drifters were deployed on the same day at the same location with a few minutes time gap. Fig.4 indicates the trajectories of the drifters during 45 days.

Fig.4. Drifters Track Comparison (Green track- Drifter buoy-Pradyu and Yellow track-Imported drifter)

Drifter’s-Pradyu current following characteristic was found to be in line with the imported drifter in the eddy current loop\cite{6} area specifically, which occurs in the coastal region off-Srilanka and Ramnad-Tamilnadu, India. Besides, the drift rate of Pradyu system was found to be well within the design criteria of 10-30cm/s @ wind speed 15m/s when the drifter is in the deep sea area. Drift rate of both the systems was found to be a little higher in the shallow water region which is due to the strong influence of coastal currents. Also fig.4 suggests that both the period of rotation of the drifters and the separation between them is rather coherent in time, with both buoys following a motion very close to solid body rotation. Similarly SST observations for the period of 30 days observed with measurement of significant peak temperature anomaly occurred on a few days of March 2013, which was very precisely detected by Pradyu. Fig.5. Temperature plot illustrates that both the SST measurement found to be in phase with each other.

Fig. 5—SST Plot of Pradyu (Red line) and imported drifter buoy (Blue line)

Water temperature from both systems shows good agreement during 30 days measurement. Also it depicts the imported drifter’s (Marlin Yug, Ukraine\cite{7}) SST sensors inability to detect and follow peak temperature anomaly which occurs due to water warm pool in certain area. Besides, Pradyu’s SST data has been back validated with satellite based AVHRR\cite{8} observations, it matches with the temperature
anomaly declared by NOAA-AVHRR observations for the given period.

Conclusion

The drifter buoy-Pradyu configuration, the calculation of its drag area ratio and a field comparison carried out on proto type system are presented. Drag area ratio of the Pradyu drifter is similar to that of standard holey-socked drifters, its field behavior being analogous to the behavior of the imported drifter. Main advantage of this development is that it is implemented with INSAT-Indian satellite based transmitter module for online data transfer. Compactness is achieved and durability has been proved. Mass production of drifter buoy is planned and more systems will be made in place for future utility. Drifter-Pradyu measurement capability may be further enhanced by adding more sensors like Salinity, Barometric pressure, Chlorophyll, Wind speed & direction and other drogue monitoring sensors.

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References


