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A drifter for measuring water turbidity in rivers and coastal oceans

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ABSTRACT

A disposable instrument for measuring water turbidity in rivers and coastal oceans is described. It transmits turbidity measurements and position data via a satellite uplink to a processing server. The primary purpose of the instrument is to help document changes in sediment runoff from river catchments in North Queensland, Australia. The 'river drifter' is released into a flooded river and drifts downstream to the ocean, measuring turbidity at regular intervals. Deployment in the Herbert River showed a downstream increase in turbidity, and thus suspended sediment concentration, while for the Johnstone River there was a rapid reduction in turbidity where the river entered the sea. Potential stranding along river banks is a limitation of the instrument. However, it has proved possible for drifters to routinely collect data along 80 km of the Herbert River. One drifter deployed in the Fly River, Papua New Guinea, travelled almost 200 km before stranding.

1. Introduction

Suspended sediment concentration in rivers is often inferred from measurements of turbidity (e.g. Gippel, 1995; Minella et al., 2008) and traditionally, these measurements are obtained as a time series of data from an instrument moored at a fixed point, or manually sampled using a hand-held device lowered from a boat (e.g. Furnas, 2003; Pavanelli and Bigi 2005). In this paper we report on a 'river drifter', which is a disposable instrument that can measure turbidity as it drifts with the current, transmitting the data in near-real time. It has the potential of being relatively inexpensive compared with manual sampling. The instrument also offers significant safety advantages, as measuring turbidity in flooded systems, for example, is usually dangerous. The drifting measurements give an alternative perspective on sediment changes, which would be difficult or expensive to emulate with fixed point (Eulerian) measurements. In particular, an instrument that drifts with the flow can measure changes in turbidity that are due to inflow from tributaries. For example, a tributary with higher water turbidity would be expected to result in increased river turbidity downstream of its entry point. Sediment sources and sinks can thus be identified.

The original motivation for the development of the river drifter came from concerns that increased soil erosion due to agricultural activity in river catchments is adversely affecting the adjacent Great Barrier Reef (GBR) (e.g. Wolanski and Spagnol, 2000; Devlin et al., 2001; Lambrechts et al., 2010; Wolanski et al., 2008). Considerable effort has been expended over the last decade to improve agricultural practices to reduce soil erosion and nutrient loss however, one challenge is obtaining sufficient data from the catchments to identify the main sources and sinks of sediment. To date, this has been done almost entirely by using moored instruments, often attached to road or railway bridges, and by intensive manual sampling. These methods are very effective, but in some circumstances a drifting measurement is beneficial.

The design brief for this project was to develop an instrument that would be:

- cheap enough to be considered disposable
- able to measure position using GPS
- able to measure turbidity in the range 0–300 nephelometric turbidity units (NTU)
- light enough to be thrown into a flooded river from a river bank and not represent a navigation hazard when it enters the sea
- able to transmit the data to a web site in near real time (typically every 30 min)

From a technical standpoint, measuring water turbidity, measuring GPS position and communicating via satellite are routine tasks. However, there were several significant questions at the beginning of the project which cast doubt on its feasibility. In particular, these were:

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(a) Would the drifter remain in the river stream without becoming stranded on the river banks, which in North Queensland are invariably heavily vegetated and ideal for trapping floating objects? If the drifter became stranded within only a few kilometres of its release position, it would not provide a useful quantity of data to measure changes. Ideally, the drifter would need to travel many tens of kilometres to be useful.
(b) Would it be possible to maintain reliable satellite communications from a floating device that could not have a large antenna due to its small size, and would often be almost awash due to waves and turbulence in the flow?
(c) What would the rate of recovery of the instruments be? They are designed to be inexpensive, but obviously recovery of some fraction of instruments would drive down costs. Given that the satellite communication and the GPS fix means that an instrument's position is generally known, it was expected that some of the drifters that became stranded on river banks would be recoverable. In addition, drifters that reach the sea may float back on shore and be recovered by "beach-combers".

In this paper we give a description of the instrument design and function, along with examples of its deployment in rivers and river plumes at sea that address these questions.

2. Technical description

It was important to keep costs down for the instrument to be considered disposable, and thus mass produced parts were used wherever possible. The instrument (Fig. 1) consists of a waterproof case ("Pelican 1050",16 cm by 9.3 cm by 7 cm) connected to a vertical pipe (50 cm in length) upon which a Honeywell turbidity sensor (APMS-11GVCF-KIT) is mounted. The sensor has a range from 0 to 300 NTU and is designed for use in commercial washing machines. To measure turbidity, it transmits light from an infrared (IR) laser diode and measures the light scatter at about 20° from the original direction of the laser light. Because it does not measure 90° scatter, it does not strictly measure true NTU as defined by international standards (ISO 7027). The turbidity sensor is modified by the inclusion of a filter placed in front of the light detector, which eliminates visible light but allows IR light to pass through. This allows the sensor to operate in environments of relatively high ambient light, such as the surface of a river or sea.

Calibration is required prior to deployment with typical calibration curves shown in Fig. 2. The sensor is placed in a series of solutions of known turbidity to provide a range of readings for the calibration. All the individual units have a similar form to the calibration curve with a roughly linear range from 0 to 100 NTU, but sensitivity declines rapidly up to a maximum value between 250 and 300 NTU. Resolution and accuracy is generally around 2 NTU and 10% respectively for values below 150 NTU.

The electronics consist of an Atmel megaAVR microcontroller, a GPS-11,058 module, a Globalstar Simplex STX2 satellite transmitter, a micro SD card interface, voltage regulators, a battery and antennas. The microcontroller controls and interfaces with all the other modules. The Honeywell turbidity sensor outputs a 0–4 V signal representing the measured turbidity. This voltage is read using a 10bit analog to digital converter on the microcontroller, and a single measurement is recorded as the average of 100 readings taken over a 10 s period. The GPS-11,058 module contains a Venus634FLPx GPS receiver that communicates to the microcontroller using NMEA formatted messages. To save power, the GPS receiver is put into standby mode between measurements. With no nearby obstructions, obtaining the first location fix takes approximately 30 s, and subsequent fixes take less than 3 s. The location accuracy increases over time as more satellite fixes are obtained.

A GPS and turbidity measurement is recorded every 5 min, and a new message is sent to via the satellite transmitter every half hour. Six location and turbidity readings are compressed into one 36 byte message. The first position is absolute, and the remaining five are expressed relative to the previous position, and so this difference must be less than 0.0415° latitude or longitude for valid data. Satellite communications are one-way, and three transmission attempts are made per message over a 30 min period, providing high reliability with rapidly changing satellite coverage. More detailed data are saved locally to an SD card, which can be used to fill in missing data due to satellite communication gaps if the drifter is recovered.

The drifter is weighted with approximately 1.5 kg of chain, and floats with about 3 cm of freeboard on the casing. The total weight of the instrument, including the ballast, is approximately 3 kg. A drogue can be attached to the drifter to reduce relative motion between the drifter and the water but for applications in rivers this was not used as it would greatly increase the chances of the instrument being caught on bank vegetation. The instrument is deployed

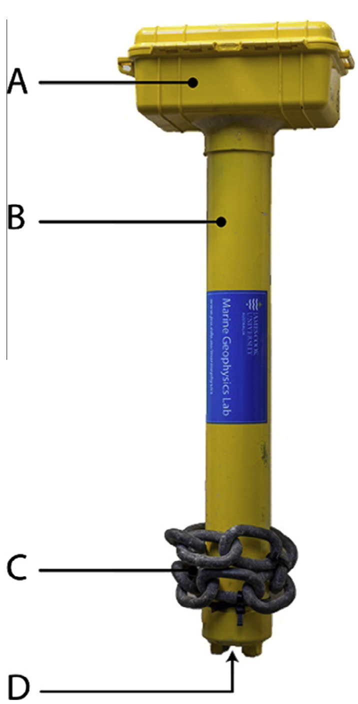

Fig. 1. Photograph of river drifter showing: waterproof case housing the electronics components (A), 50 cm pipe (B), ballast (C), and turbidity sensor (D).

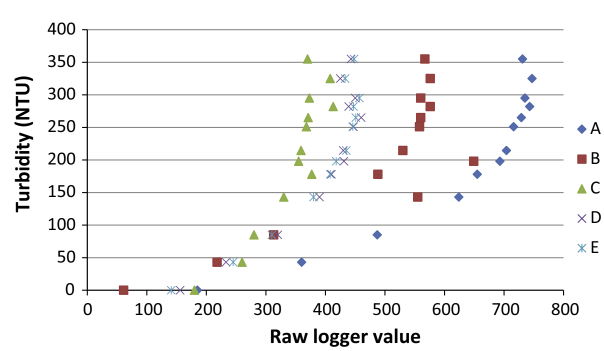

Fig. 2. Individual raw calibration curves for five Honeywell washing machine turbidity sensors (APMS-11GVCF) for 5 different units.