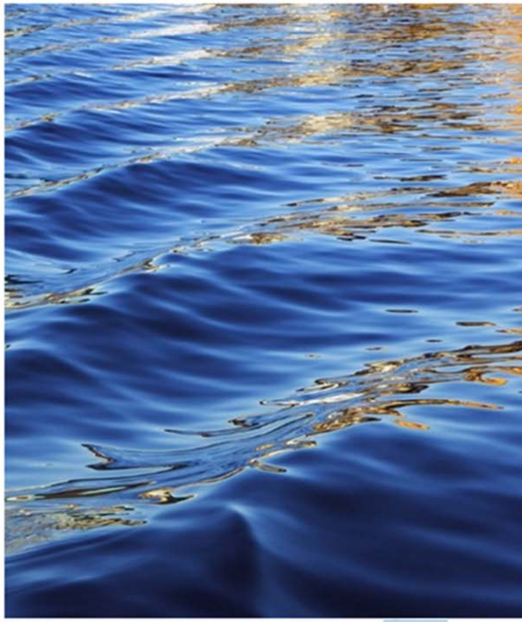
Development and Applications of GNSS Drifters with Water Quality Measurements in Shallow Rivers and Estuaries



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QUT Sunshine Coast COUNCIL USC AUSTRALIA

Background

Why studying shallow water bodies?

- about 60% of global population live along coast
- more than 8 in 10 Australians (85%) lived within 50 km of the coastline of Australia (ABS, 2001 population estimate)

Photo credit: Visit Brisbane: http://www.visitbrisbane.com.au/

Environmental Flow

WATER EVENTS

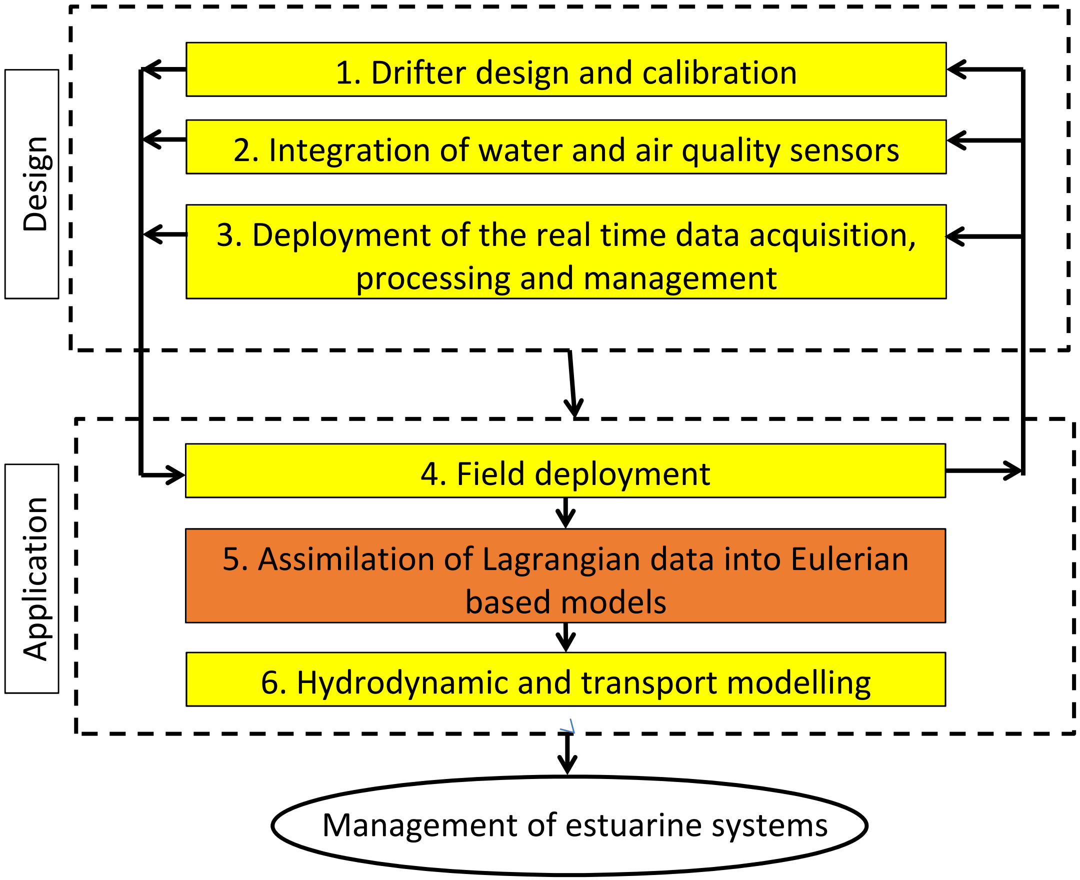
- Natural
- Man Made

POLLUTION

- Urban
- Industrial
- Agricultural

Advances in real-time satellite monitoring of flow in rivers and estuaries (RTFLOW)

- **ARC Linkage 2016-2019**
- **QUT and USC research collaboration with Sunshine Coast Council**



Overview of drifter fleet capability

Scales of interest in estuary		Drifter capabilities		
		High resolution	Medium resolution	Low. Res (Off-the-shelf)
O [1 m]	Position error	~ 2 cm*	~ 20 cm*	~ 3 m*
O [0.01 Hz]	Frequency	10 Hz	1 Hz	1 Hz
	Cut-off freq	1 Hz	-	0.01 Hz

* Position error

- Preliminary challenges
  - Waterproofing, post-processing and noise removal
  - Choice of coordinate and extraction of Lagrangian time and length scales

RT-Flow

- Operation in shallow rivers and estuaries
- Simplicity and affordable

High positioning accuracy

- Raspberry Pi 3
- Ublox M8T receiver and antenna
- 4G wifi hotspot
- 20000mAh power bank

Single frequency RTK solution

(10 cm)

Water quality measurements

- Atlas Scientific sensors: pH, Dissolve oxygen and Conductivity
- Turbidity and temperature sensor
- Voltage isolation boards

Continuous WQ measurement

(0.5 Hz)

Tracking and monitoring

- NeCTAR cloud server
- Thingsboard IoT platform

Real-time visualization and management

Sensor Integration

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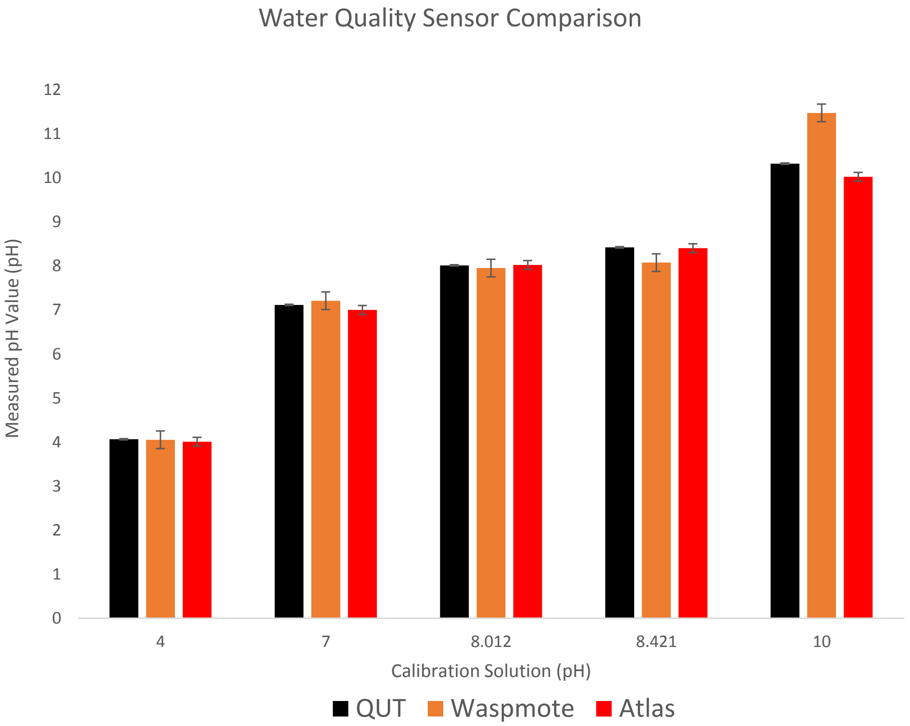
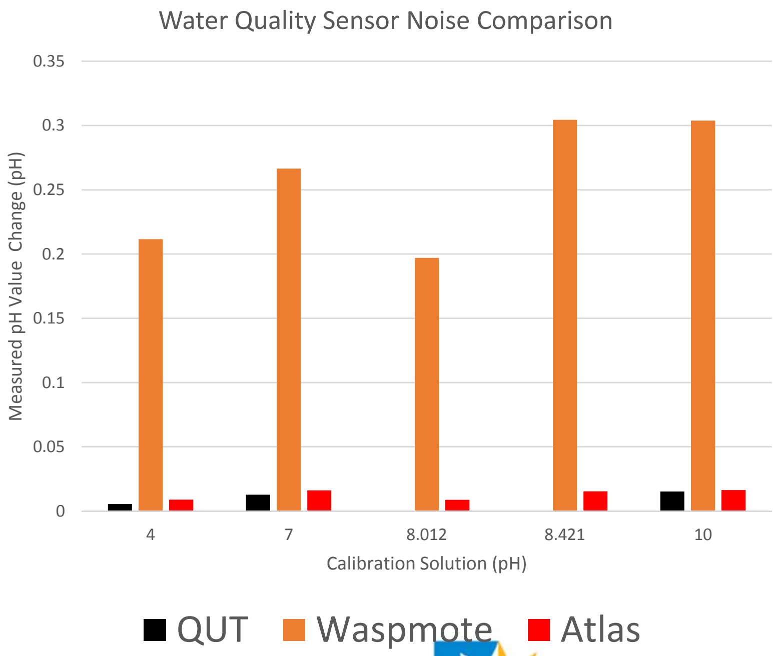
WQ Sensor Calibrations

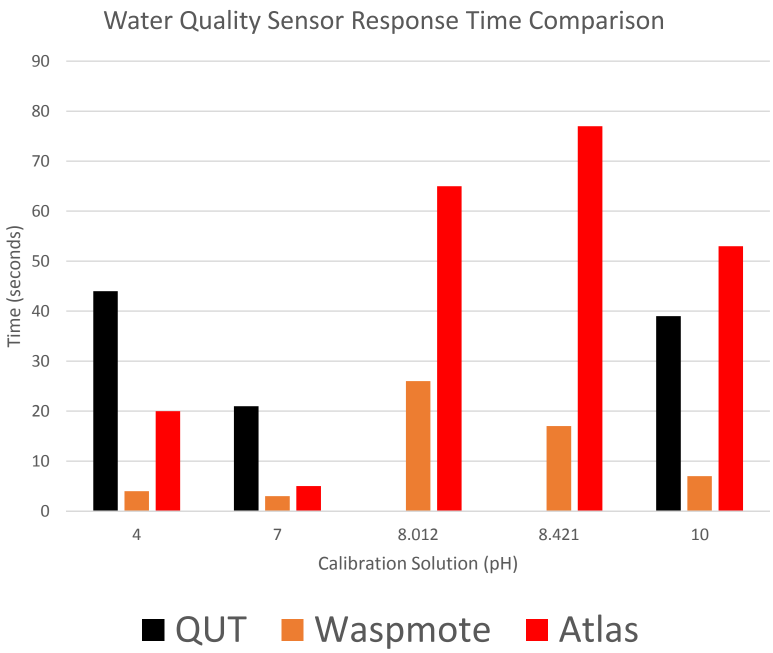
QUT Sensor (Multi 3430)

- Computer Integrated Tracking
- pH, Conductivity, DO and Temperature Sensor
- Approx $3500 AUD
- Developed by WTW a Xylem Brand



WQ Sensor Calibrations





Turbidity Sensors

- Amount of cloudiness in water caused by sand, salt, bacteria and chemical precipitates, etc
- Commercial turbidity sensors are relatively large and expensive (> $3000)

SOLUTION

- Washing machines!

METHODOLOGY

- Turbidimetric

BENEFITS

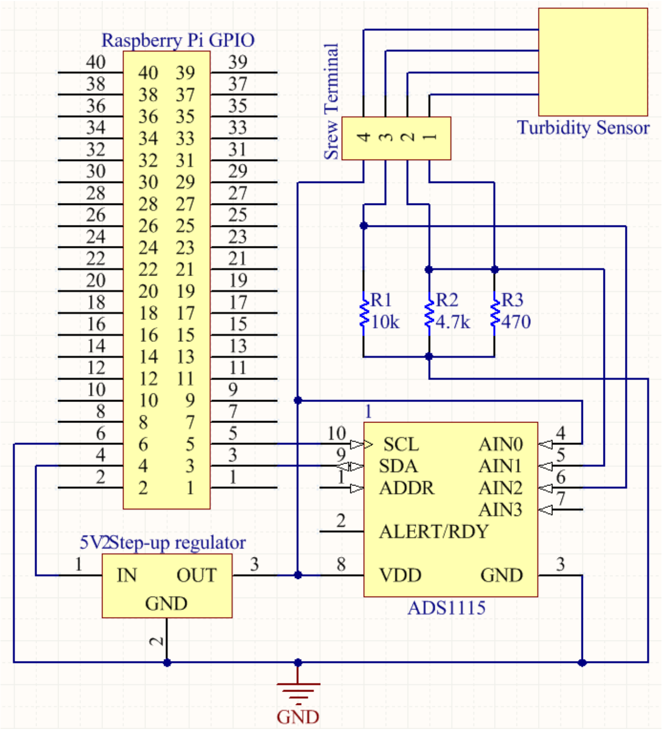
- Cheap ($20 - $30)
- Operating Range (0-4000 NTU)

CHALLENGES

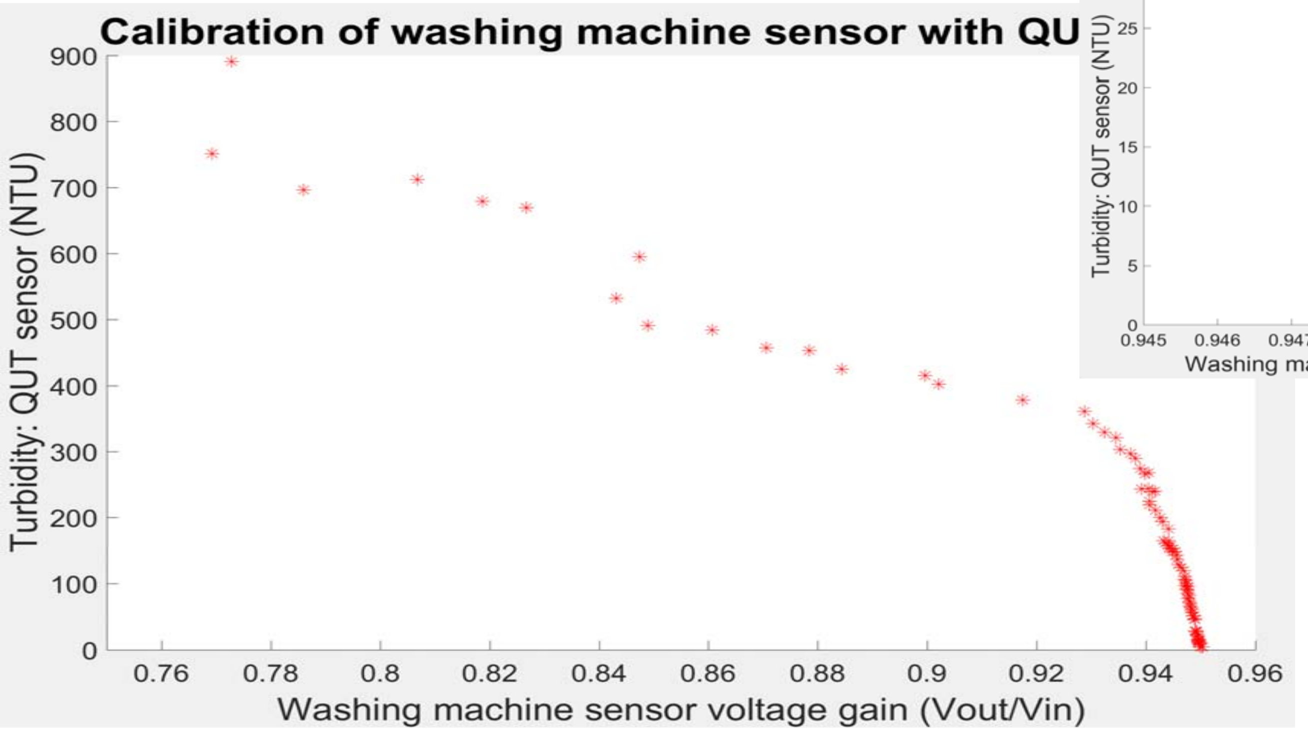
- Calibration
- Operating conditions
- Water quality relationships

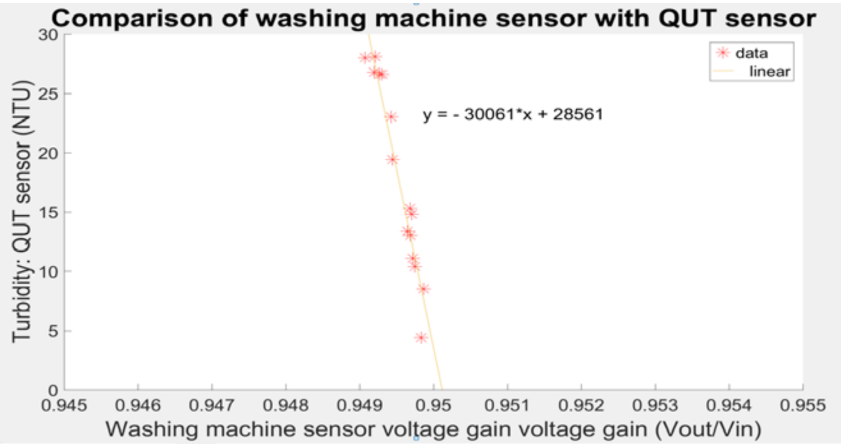
Circuit evolution

- Drifter project microcontroller:
- Connection: Through the General Purpose Input Output (GPIO)
- Analog to Digital Converter (ADC): 16-bit
- Stable power: Step-up/Step-down DC voltage converter



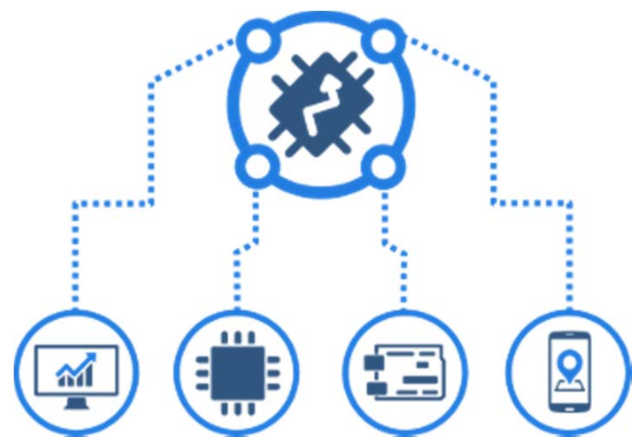
Calibration





Cloud Tracking and Monitoring Server

- Nectar Cloud facility
- Thingsboard IoT platform – open source
  - Data collection
    - MQTT, CoAP, HTTP
  - Data visualization
    - Real-time charts and maps
  - Data processing
    - Define processing rules
  - Device management
    - Event trigger and alarm
  - Horizontal scalability

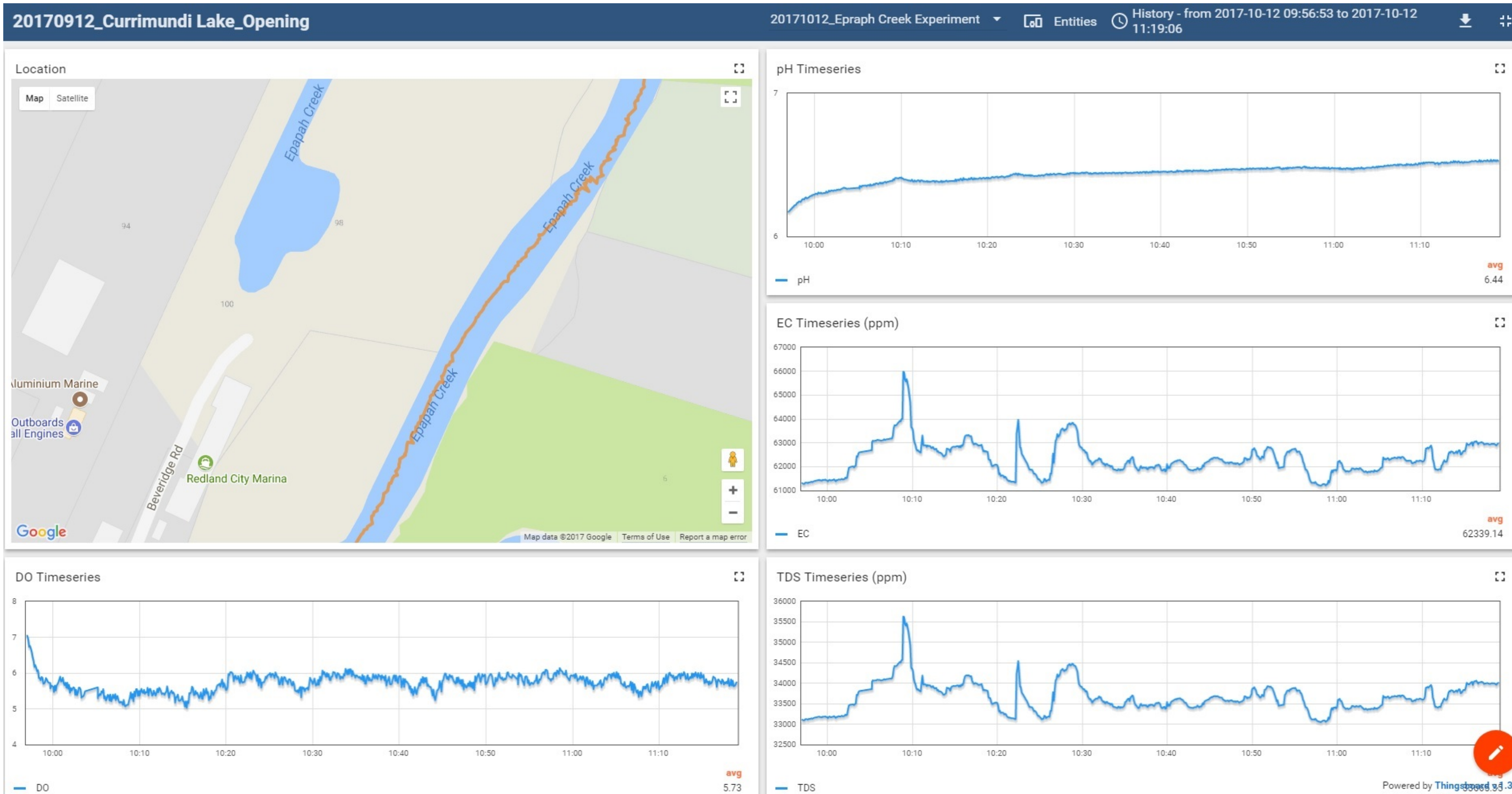


Field Trips

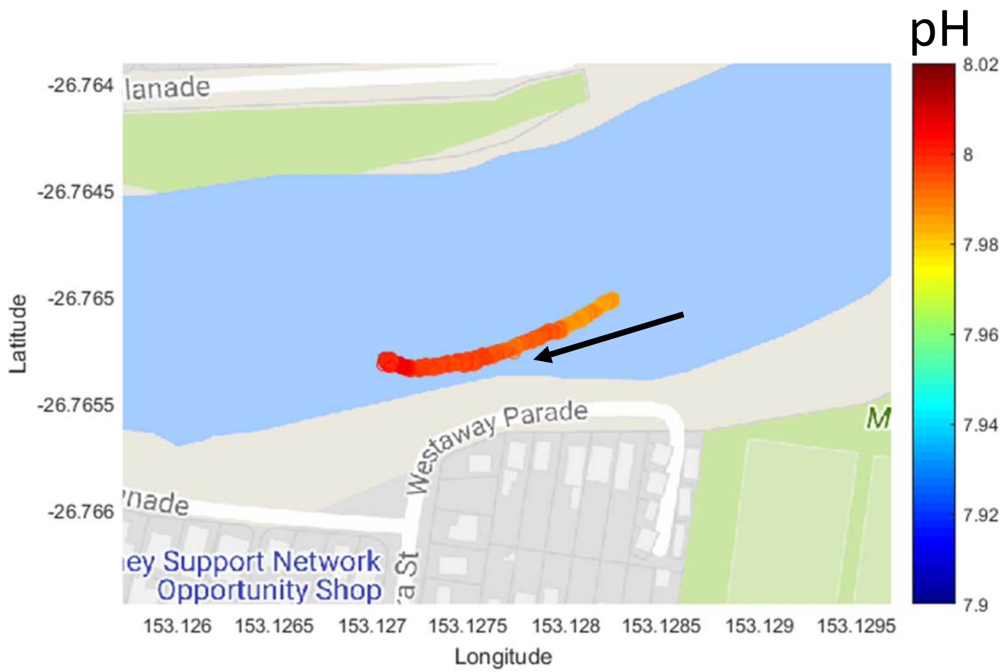
- http://203.101.225.66:8080/home

Currimundi Lake

Epapah Creek


20170912_Currimundi Lake_Opening
20171012_Epraph Creek Experiment
Entities
History - from 2017-10-12 09:56:53 to 2017-10-12 11:19:06
Location
Map
Satellite
Epapah Creek
Aluminium Marine
Outboards
all Engines
Beveridge Rd
Redland City Marina
Map data ©2017 Google
Terms of Use
Report a map error
pH Timeseries
pH
avg
6.44
EC Timeseries (ppm)
EC
avg
62339.14
DO Timeseries
DO
avg
5.73
TDS Timeseries (ppm)
TDS
Powered by Thingsboard v1.3.0

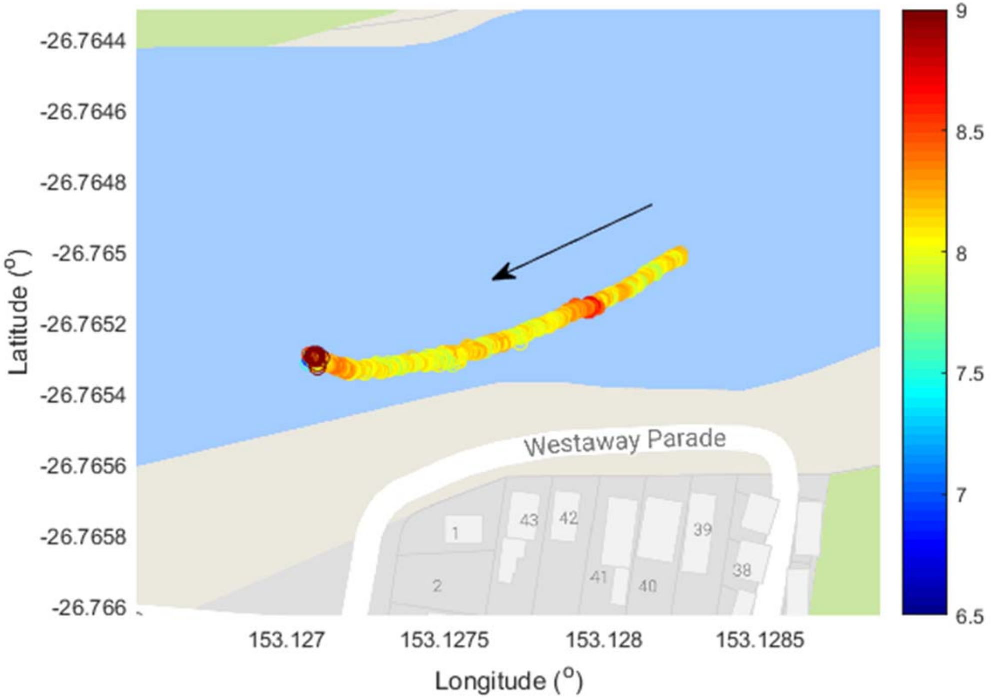
Proof of concept for drifters with water quality sensor



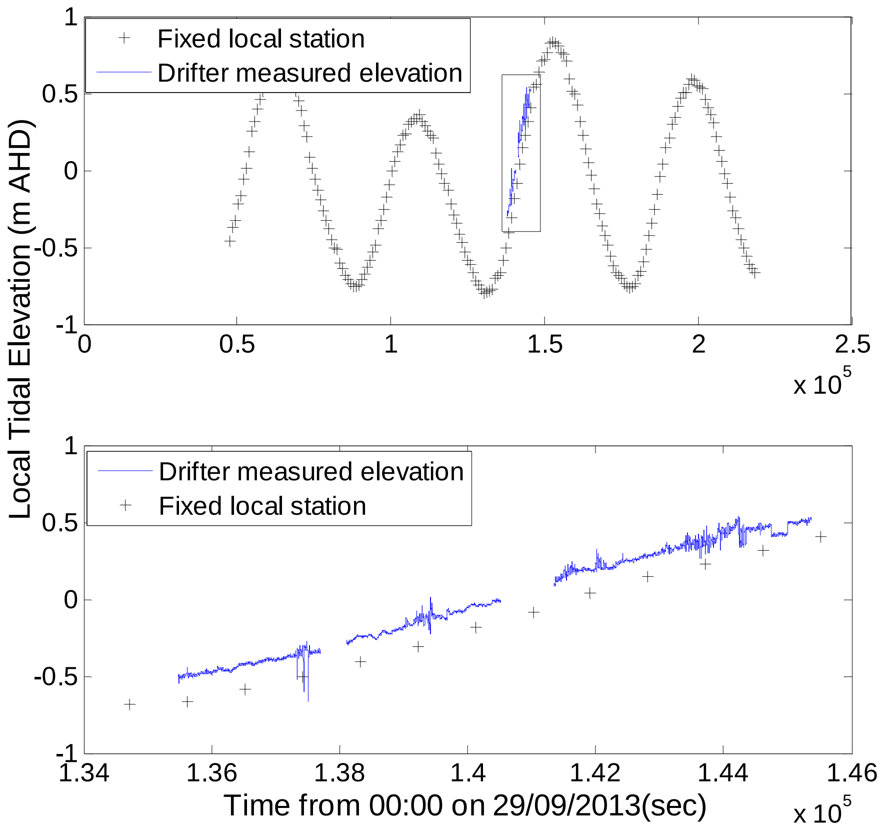
Proof of concept for drifter with water quality sensor

50 minutes deployment of RT-Flow at Currimundi Lake during opening

Dissolve oxygen (mg/L)

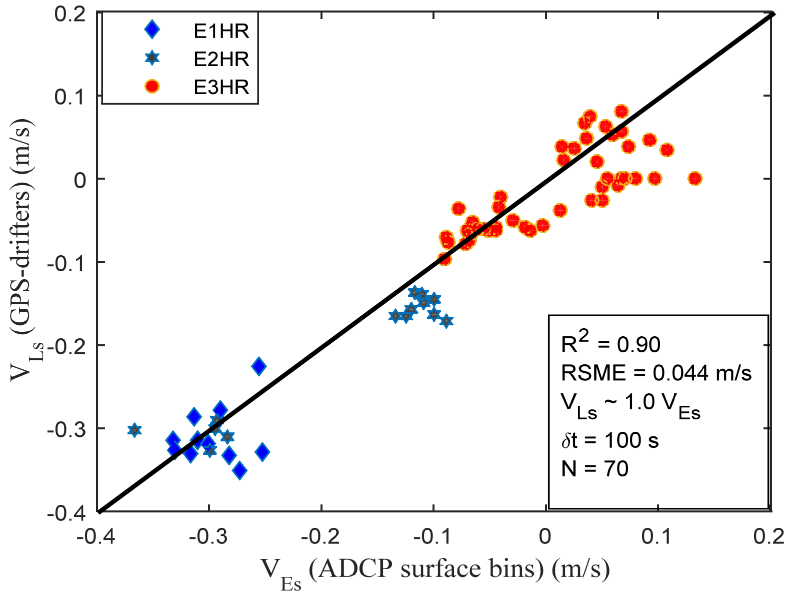


Application 1: height with HR-drifter



- GPS drifter vertical position component validated using fixed location tidal height measurements.
- This shows that the GPS drifter data is sensitive to height measurement and thus could be used to monitor both both velocity change and height during flood .

Application 2: Streamwise velocity estimates



- Quality controlled
- DOF > 5.
- Run test : passed
- Max time = 100 s
- Max distance = 60 m

- Very good correlation ($R^2 > 0.9$) in streamwise direction
  - Correlation reduces with distance from the surface
- Poor correlation ($R^2 < 0.2$) in cross stream direction
  - Cause by quick change in direction of flow within the chosen radius

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Application 3: Mixing and Water quality

Effect of mouth conditions and opening operation on dynamics of Currimundi Lake

- Baseline experiment 1: open inlet (April)
  - Tide, rivers, wind and run -offs
  - Tide dominated

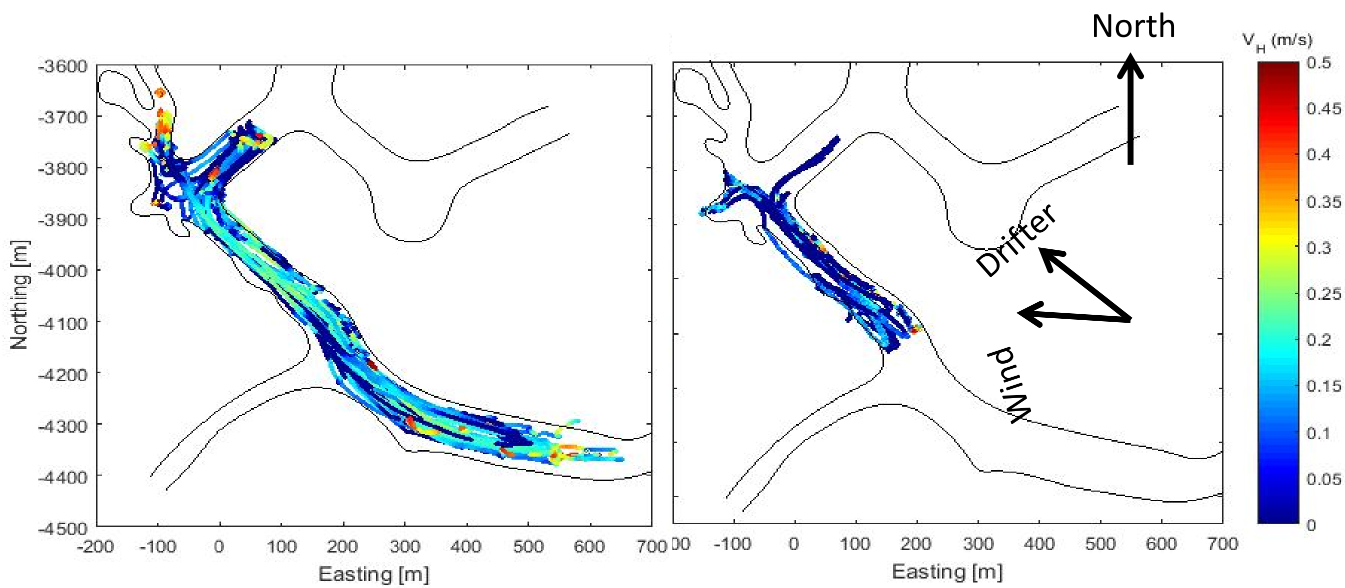
- Baseline experiment 2: closed inlet (September)
  - Wind, river and run-offs
  - Limited tidal influence

- Mouth opening operation (October)

Questions are:

- What is mixing quality?
- Magnitude of diffusivity?
- What are the dominant mechanisms governing dispersion in the system?

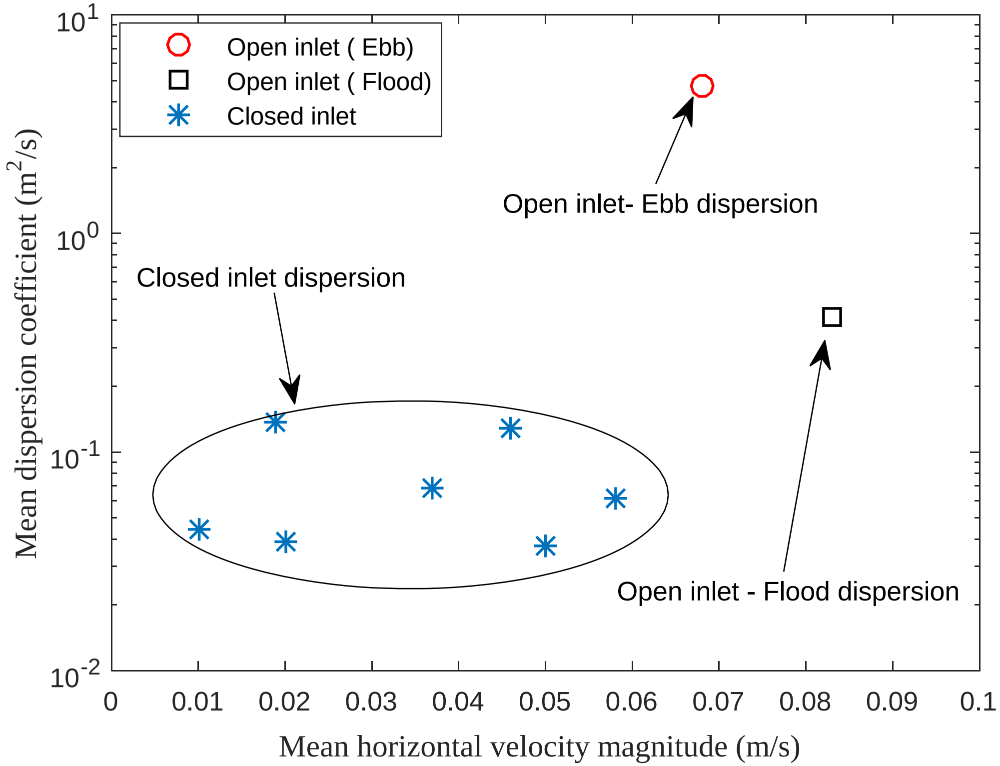
Results : Flow velocity variability (u)



Open inlet experiment containing trajectories driven by for both ebb and flood tides

Closed inlet condition, drifters travelled in ebb-ward direction about 20° aligned with dominant surface wind direction

Mixing parameter: Dispersion coefficients (K)



Evolution

- Custom PCB to reduce electronic footprint
- Additional sensors (Temperature, Nitrate, etc)
- Simplified operation for field staff with provision of operation manual
- Event trigger and alarm
- Configuration options for different application
  - Lora & Lorawan gateway, zigbee
  - Low-power module for up to a month operation
  - Solar power for permanent placement

Capabilities

- Solution is extendable to include additional sensor
- Can provide valuable tool to locate source of pollutants into waterways
- Lower cost compared to fixed instruments for equivalent area coverage
- Better spatial coverage
- Adaptability to individual need
- The GNSS monitoring system offers a flexible and low maintenance alternative to current fixed station
- RTK solution provides Lagrangian measurement which may be useful to improve water modelling in the case of climate changes and flood events.