Ocean Temperature Dependence on Depth and Time of Day

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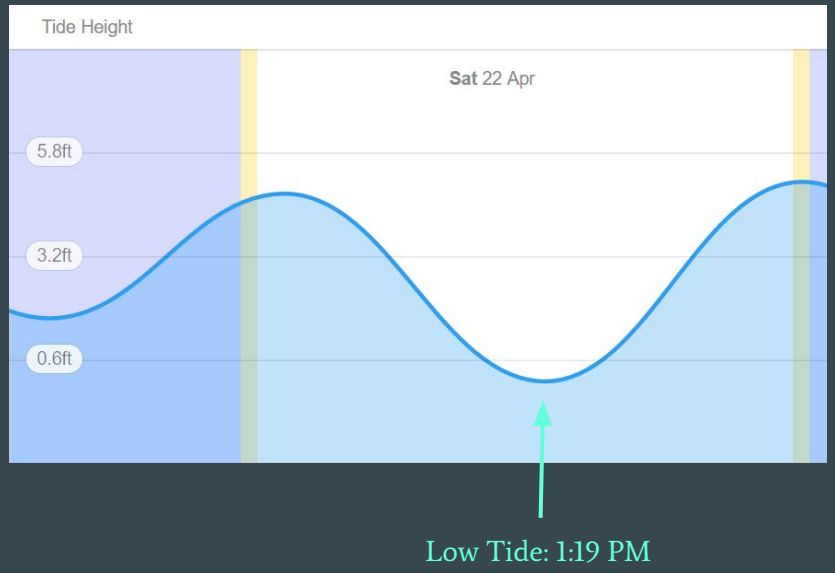
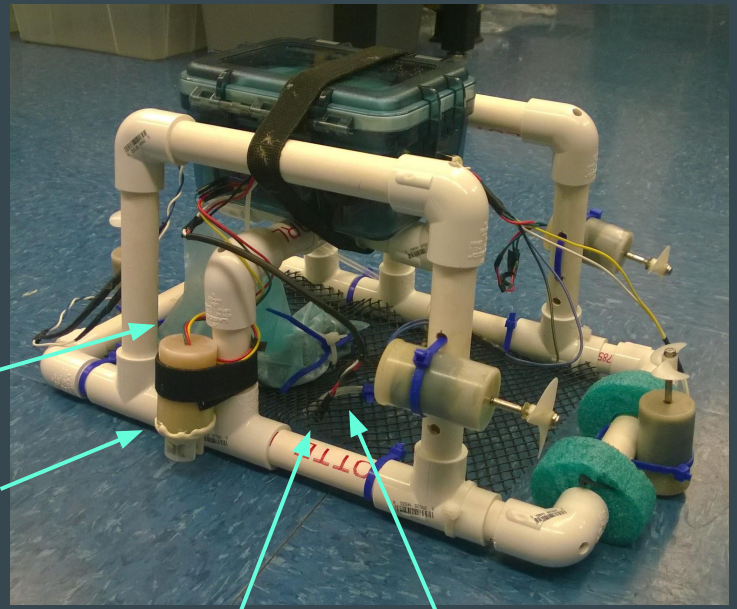
Project Goals

- Original Goal: Investigate how tide and depth affect temperature and turbidity at a waypoint.
- Revised Goal: Investigate how temperature changes with depth and time of day.



Measurement Sensors and Robot Construction

- MPX5700 Pressure Sensor
- MCP9701A Low-Power Linear Temperature Sensor
- TSW-10 Turbidity Sensor

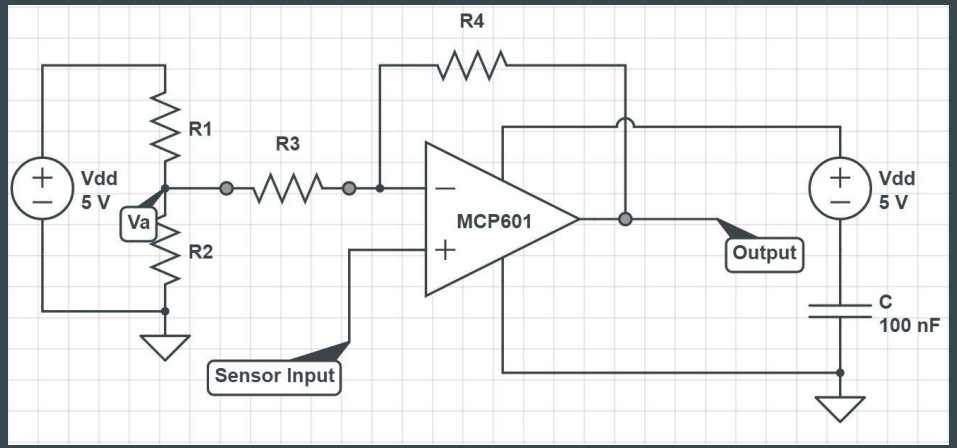


Op-Amp Sensor Amplification

Linear Sensor Responses

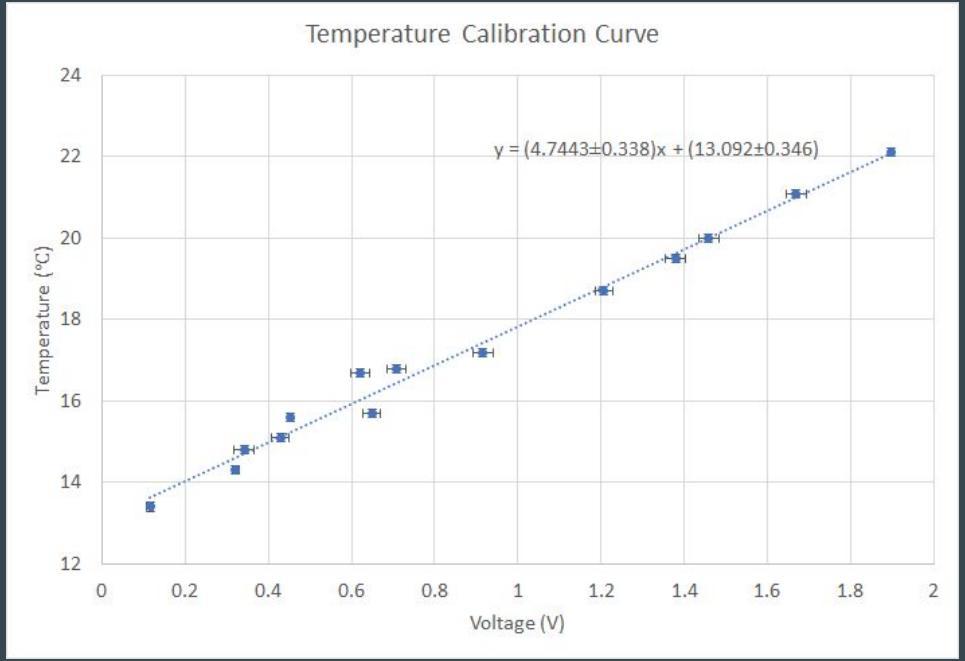
Imposed Condition: R2 << R3

$$V_{out} = V_{sensor}\left(1 + \frac{R_4}{R_3}\right) - V_{DD}\left(\frac{R_2}{R_1 + R_2}\right)\left(\frac{R_4}{R_3}\right)$$



Circuit Design: Temperature

Desired Range	Designed Voltage	Actual Voltage
12.4 ± 0.1°C	0.588 ± 0.019 V	0.000 ± 0.004 V (Railed)
22.0 ± 0.1°C	2.82 ± 0.02 V	1.847 ± 0.148 V



Circuit Design: Turbidity

Desired Range	Designed Voltage	Actual Voltage
0 ± 1 NTU	3.342 ± 0.054 V	3.300 ± 0.004 V (Railed)
430 ± 1 NTU	0.172 ± 0.052 V	1.94 ± 0.79 V

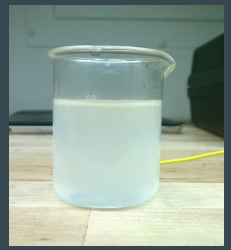
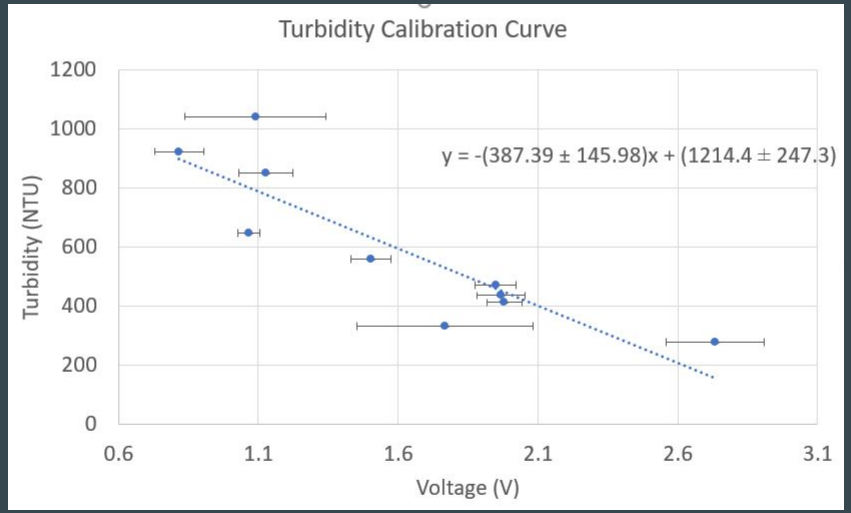
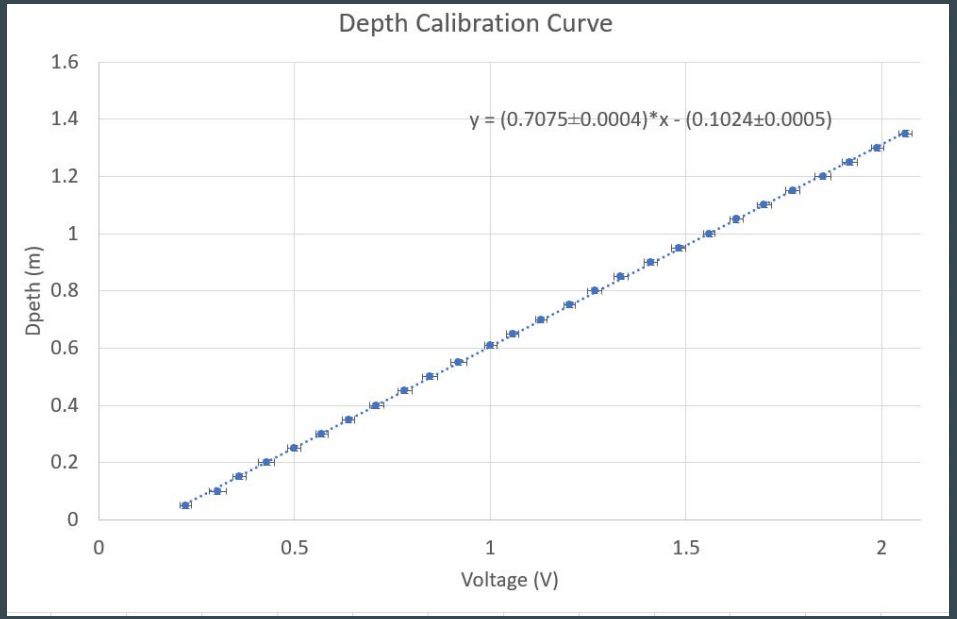


Figure 1: Sample at 194 NTU. This is more turbid than seawater yet still rails our circuit.



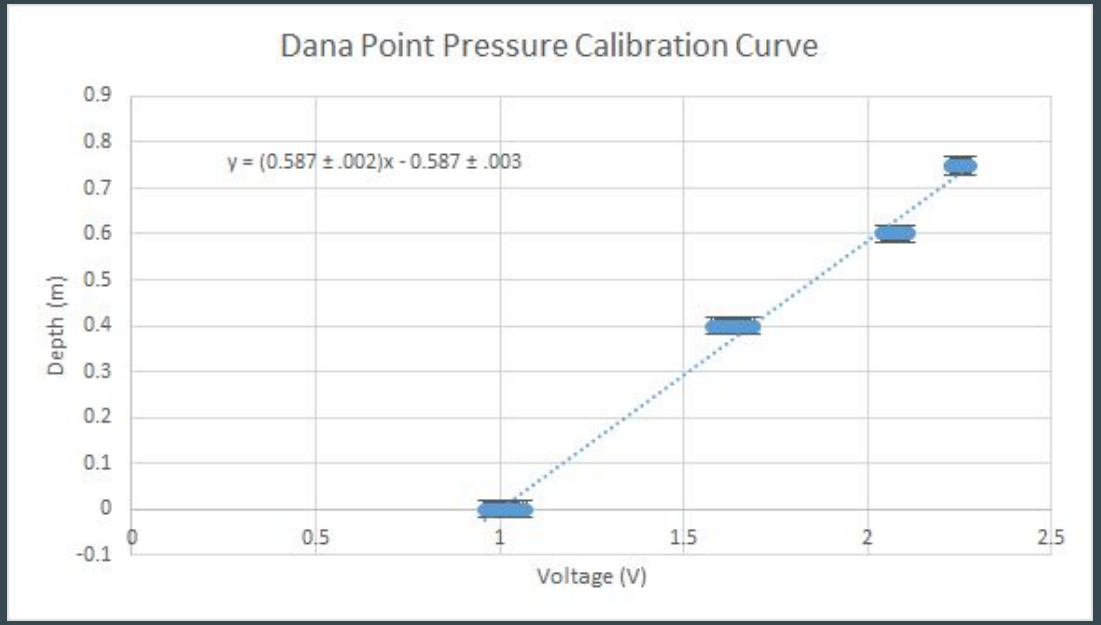
Circuit Design: Pressure

Desired Range	Designed Voltage	Actual Voltage
0.0 ± 0.01 m	0.264 ± 0.024 V	0.1448 ± 0.0019 V
2.0 ± 0.01 m	3.34 ± 0.025 V	2.9714 ± 0.0022 V



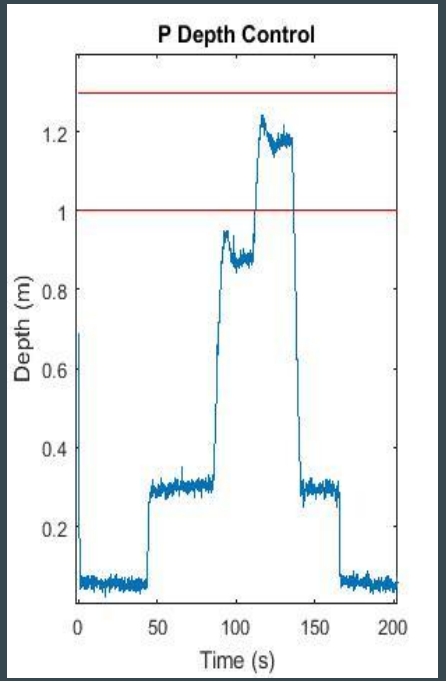
Pressure Re-calibration

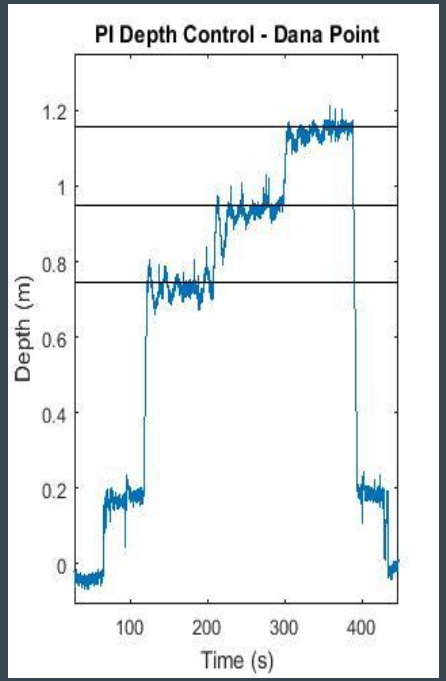
- Change in:
  - Elevation
  - Water density
- Higher uncertainty
  - Careful measurement was impractical

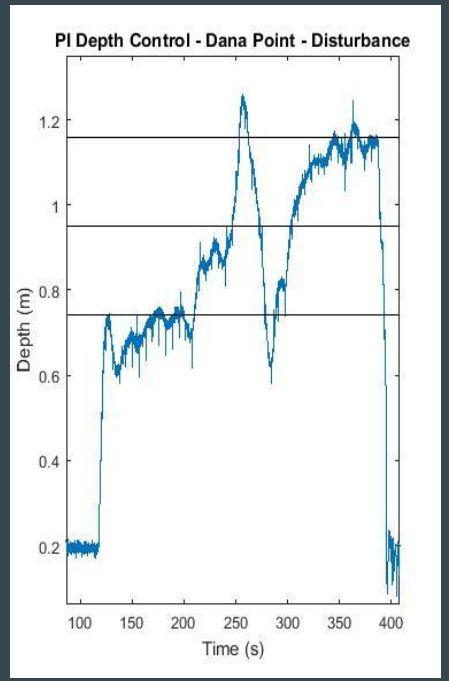


Software Modifications (Depth PI Control)

- Even with careful ballasting, error was ≒ .1m for P control
- PI control has longer settling time, so data acquisition periods were longer at Dana Point





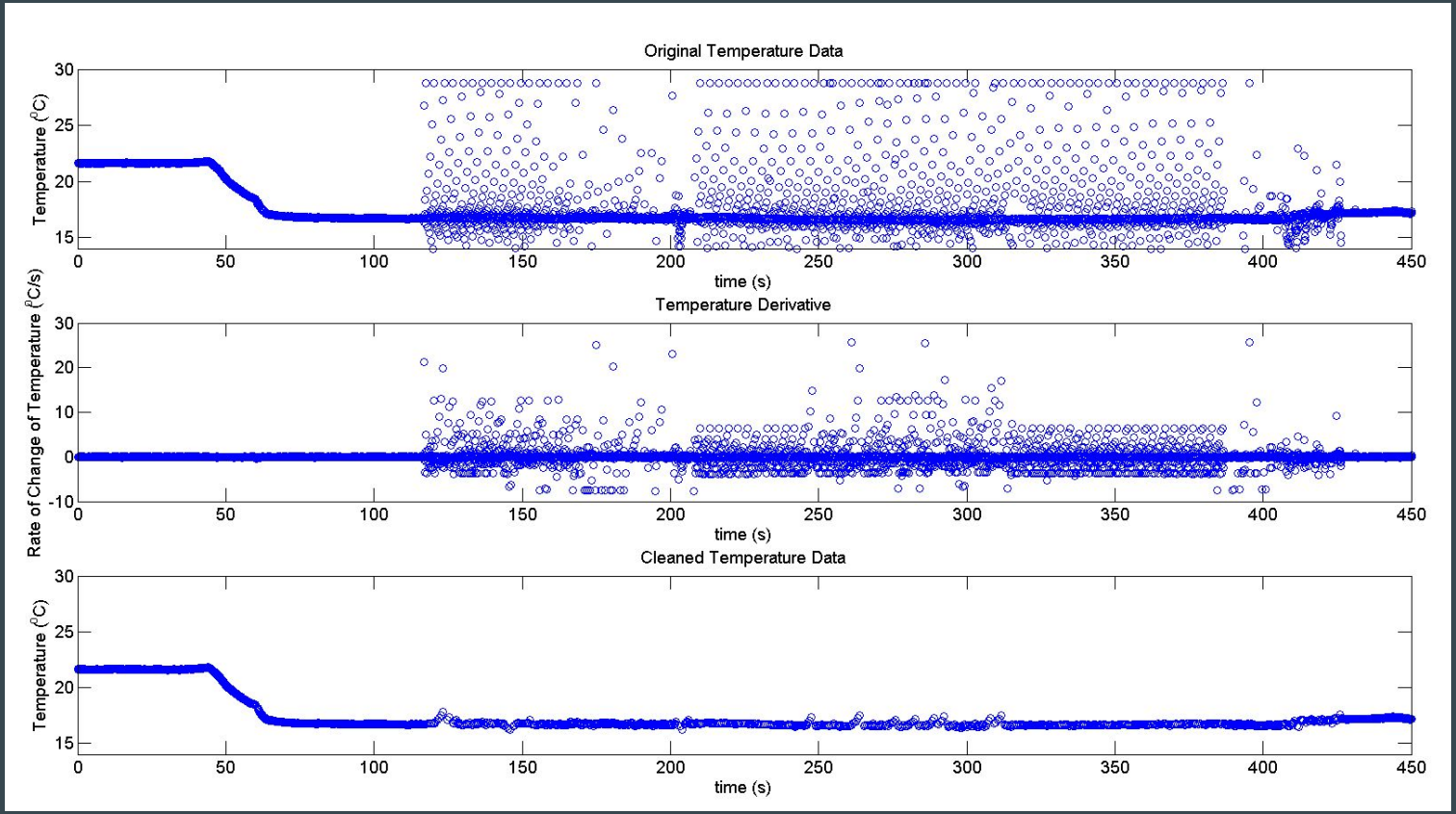


Data Collection: Procedure

- Manually deployed and recovered robot near buoy
- Deployer remained nearby to divert beach-goers

Deployment location within 5 ft radius of 33.462390, -117.705245

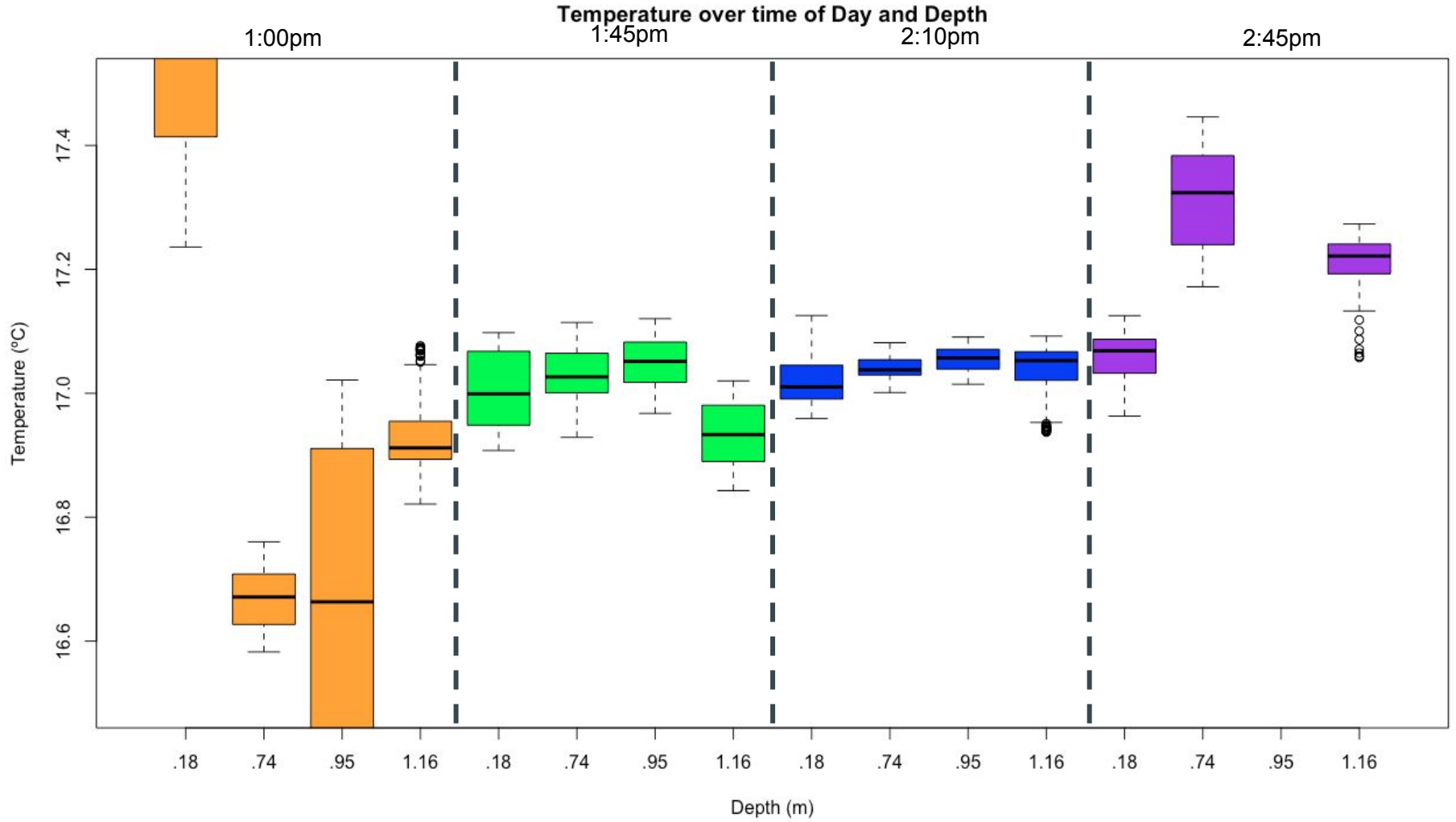
Data Analysis

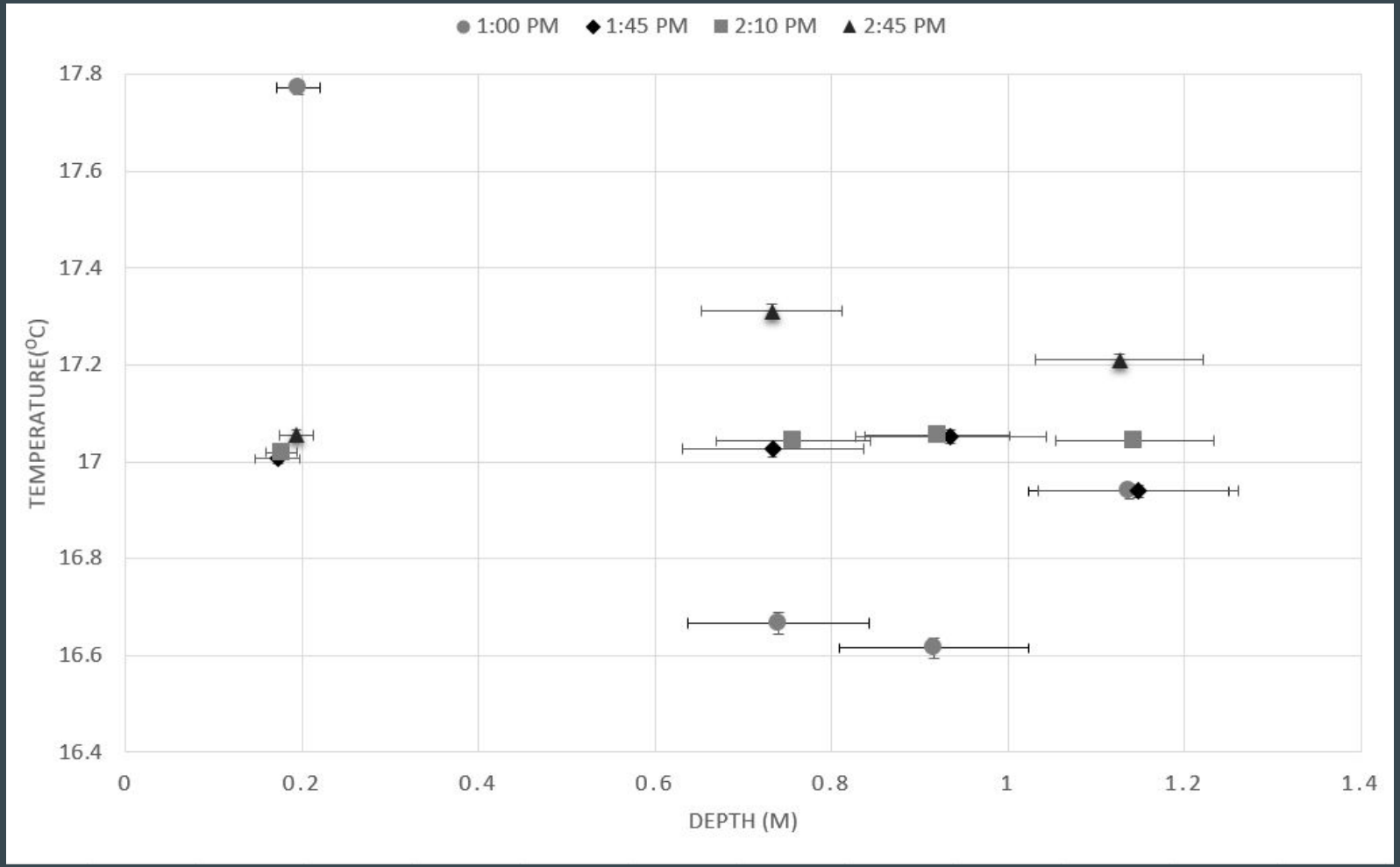


Statistical Analysis

- Analysis of variance tests used to compare mean temperatures
  - ANOVA
  - Kruskal-Wallace

- Temperature compared over course of deployment
- Temperature at a certain depth compared across deployments


Temperature over time of Day and Depth
1:00pm
1:45pm
2:10pm
2:45pm
Temperature (ºC)
16.6
16.8
17.0
17.2
17.4
.18
.74
.95
1.16
.18
.74
.95
1.16
.18
.74
.95
1.16
.18
.74
.95
1.16
Depth (m)

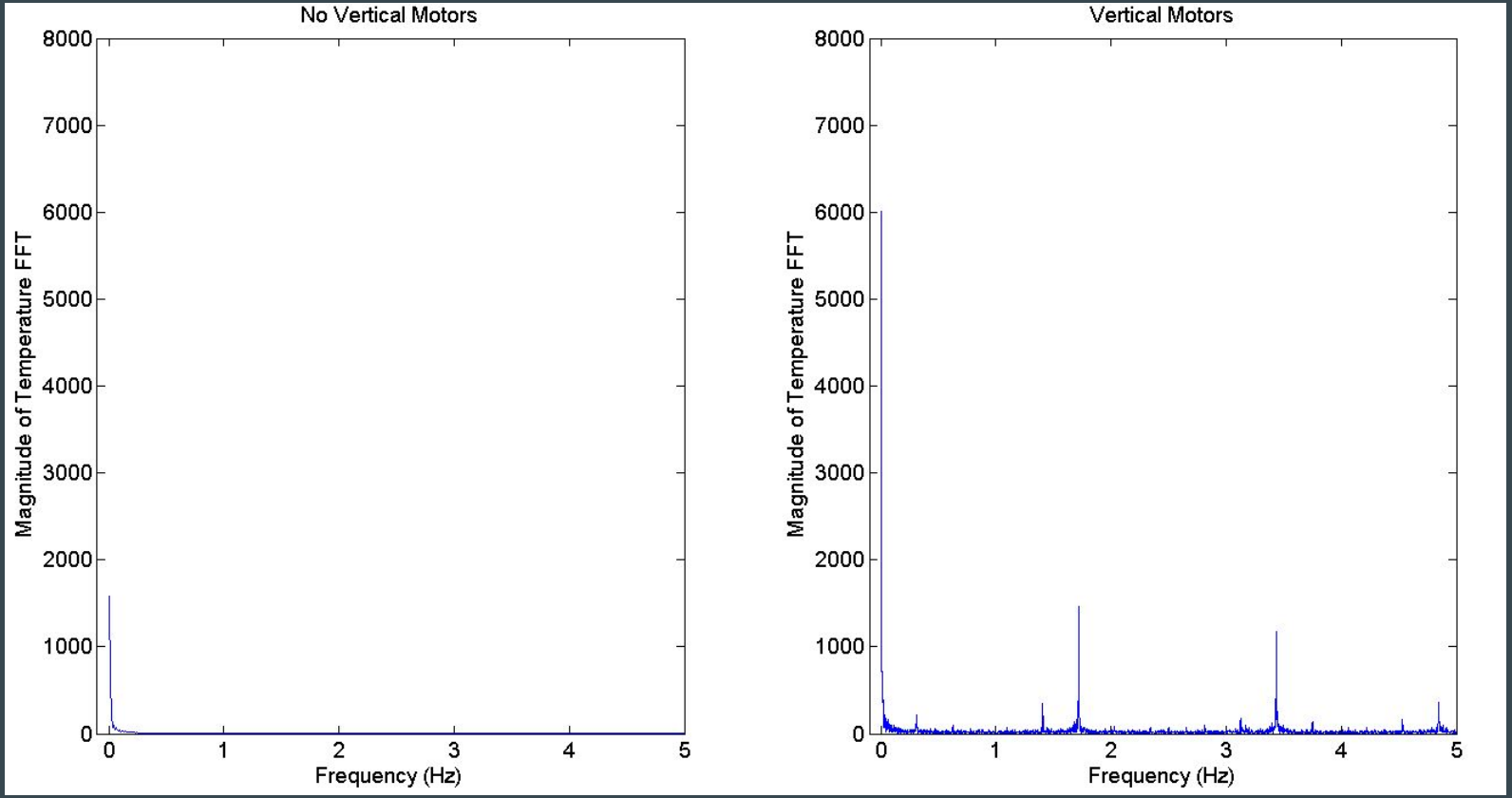

1:00 PM
1:45 PM
2:10 PM
2:45 PM
17.8
17.6
17.4
17.2
17
16.8
16.6
16.4
TEMPERATURE(°C)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
DEPTH (M)

Suggestions for Further Study

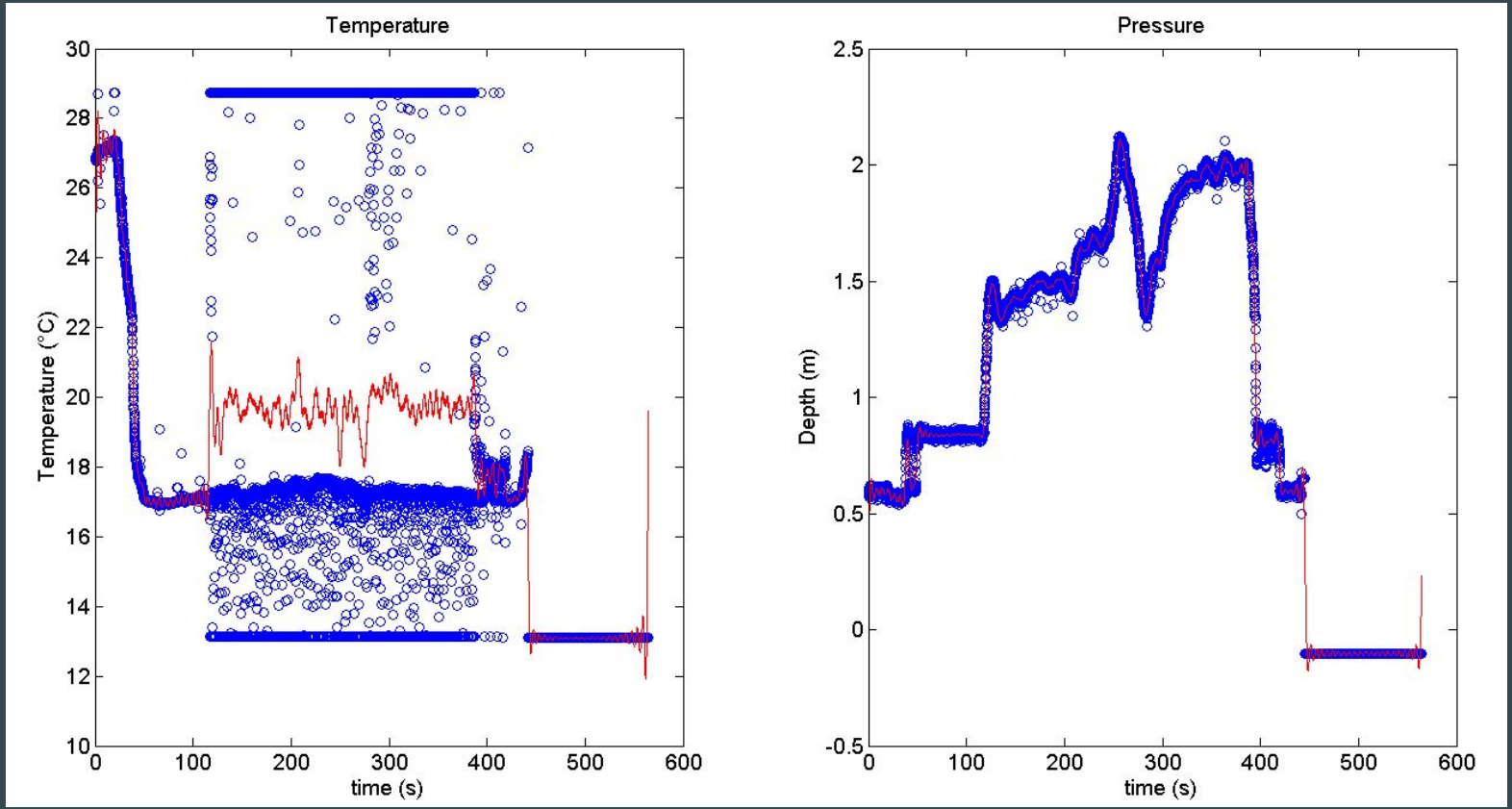
- Re-design turbidity amplification circuit
- Implement full PID control
- Locate and fix the source of noise when vertical motors turn on
- Accurate pressure calibration at Dana Point
- Larger data set - multiple days

Questions?

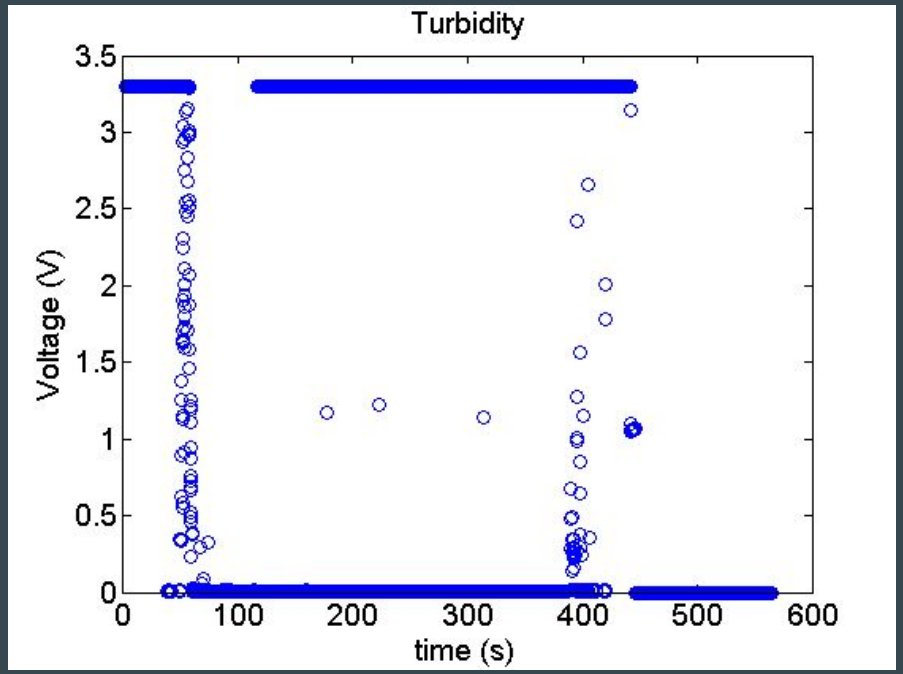
FFT

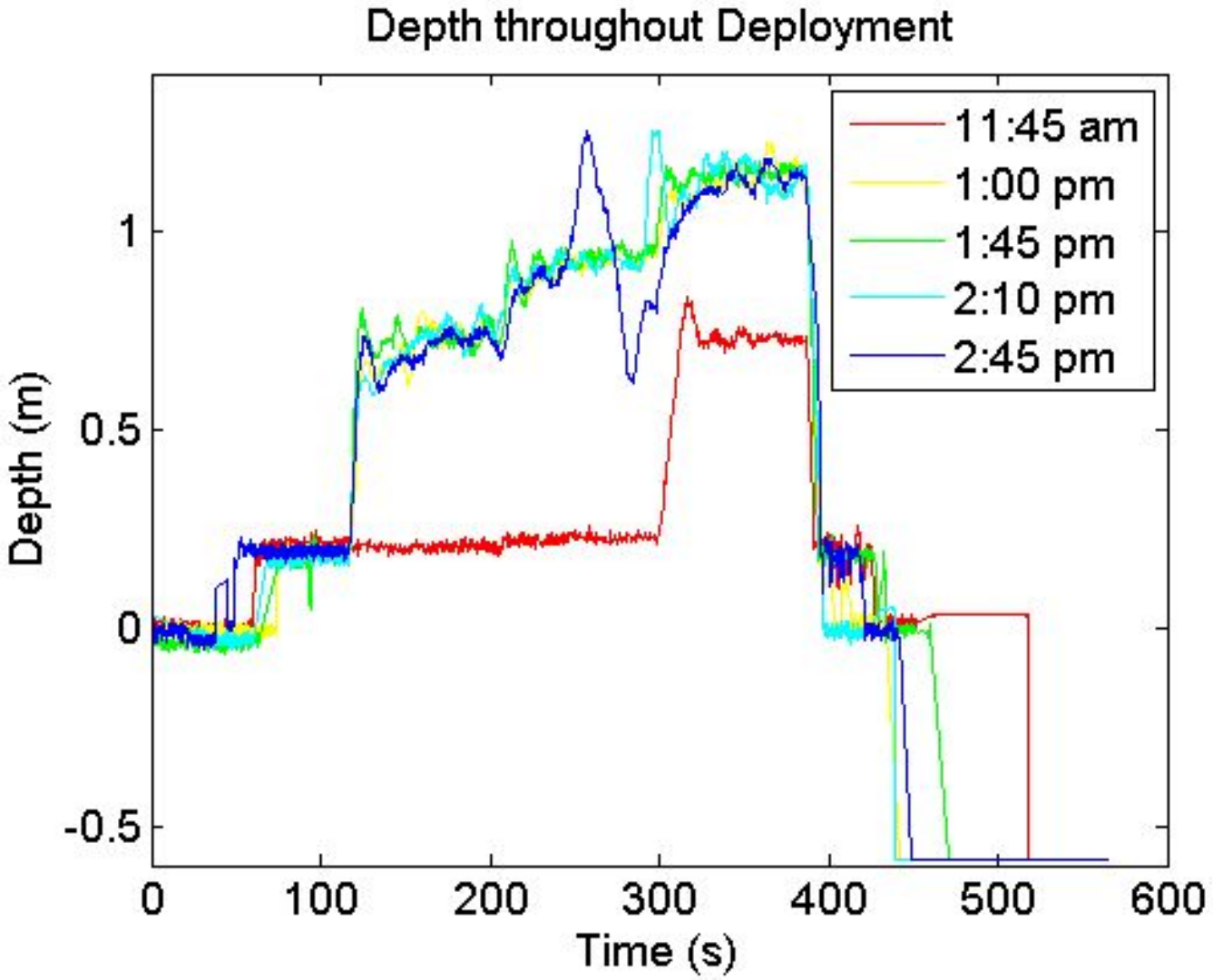

No Vertical Motors
Magnitude of Temperature FFT
Frequency (Hz)
0
1000
2000
3000
4000
5000
6000
7000
8000
0
1
2
3
4
5
Vertical Motors
Magnitude of Temperature FFT
Frequency (Hz)
0
1000
2000
3000
4000
5000
6000
7000
8000
0
1
2
3
4
5

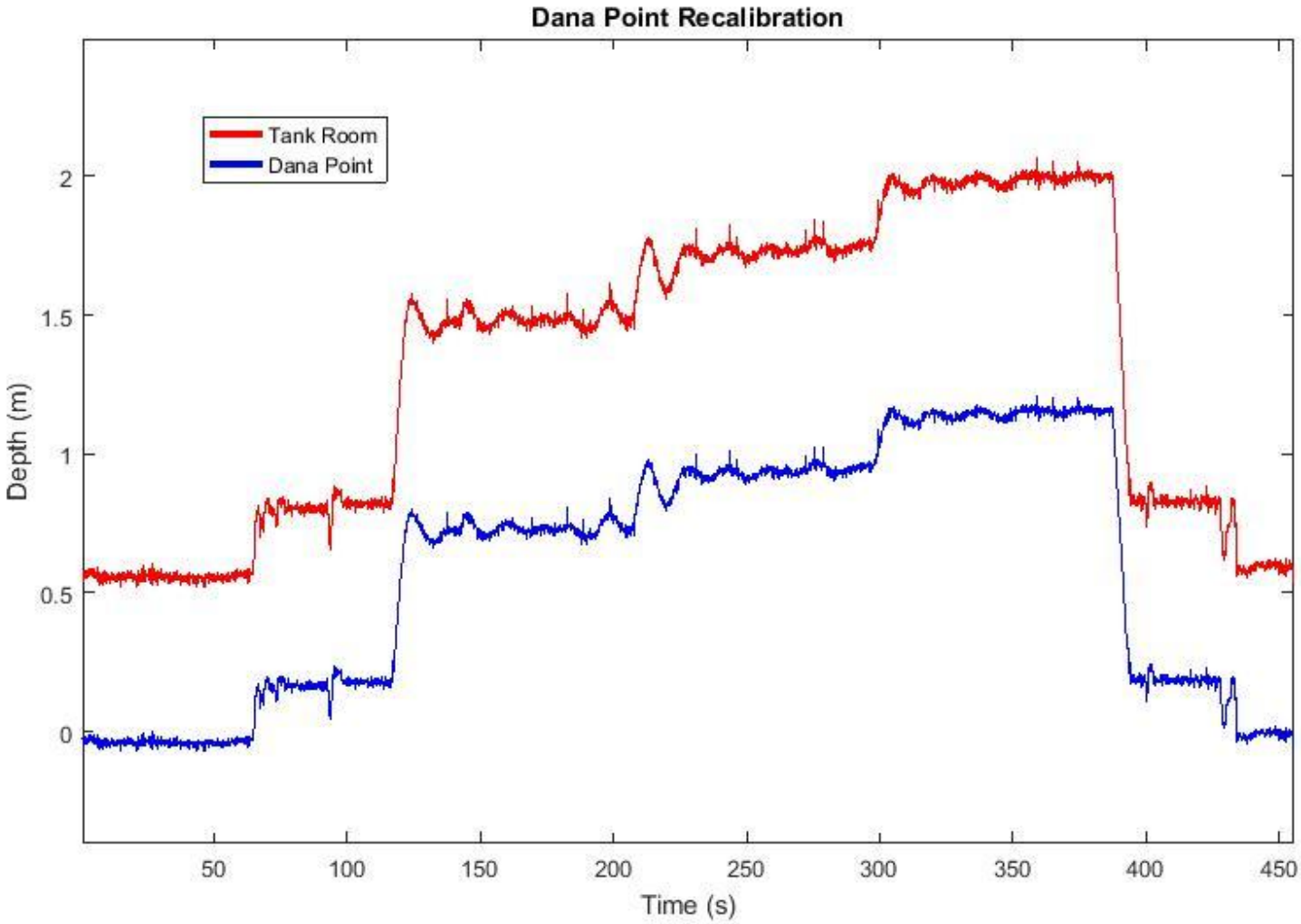
Fourier Transform Filtering



Turbidity Railing




Depth throughout Deployment
11:45 am
1:00 pm
1:45 pm
2:10 pm
2:45 pm
Depth (m)
1
0.5
0
-0.5
0
100
200
300
400
500
600
Time (s)


Dana Point Recalibration
Tank Room
Dana Point
Depth (m)
Time (s)
2
1.5
1
0.5
0
50
100
150
200
250
300
350
400
450

qq plot for normal distribution