Water Level Detector

(A story of an IoT device)

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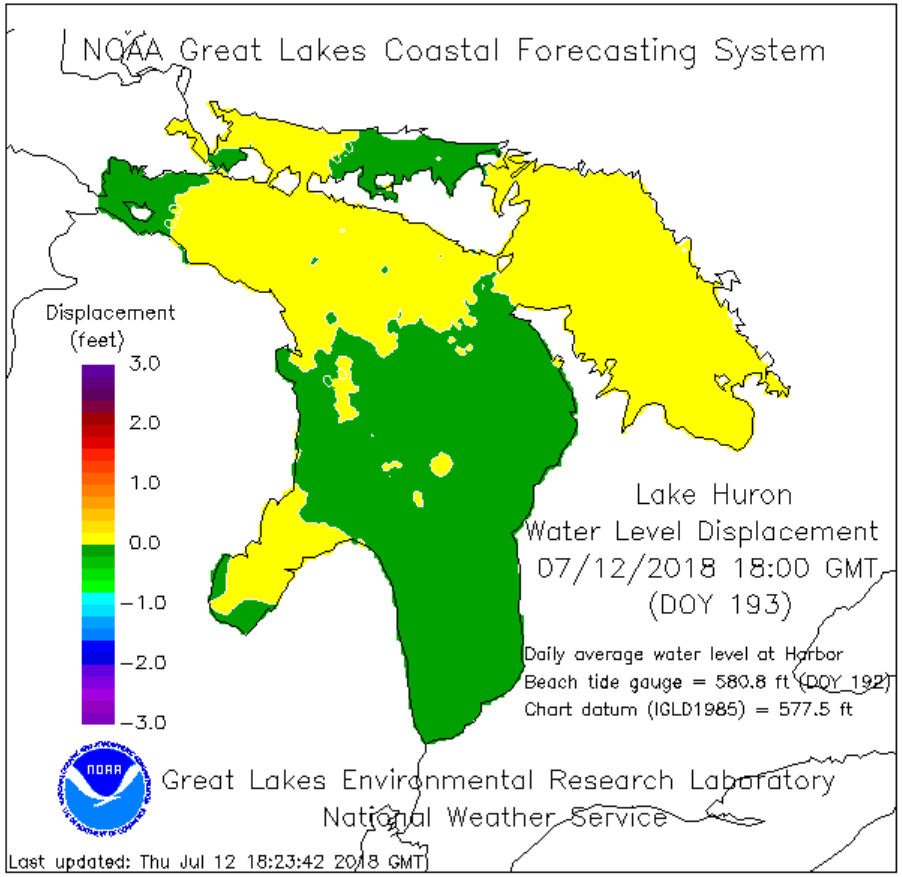
About Me

- retired telephony software engineer
  - switches, key systems, cellular networks
- messed with X-10 home automation
- lately into data collection and display
  - MQTT, openHAB, SmartiPi kiosks
- love the raspberry pi
  - Unix/Linux for 40 years

Motivation

- measure lake level
- capture "events" (beaver dam failure or seiche)
- nice to find period and height of waves
- nice to find information about wakes?
  - how many
  - how often
  - how big (height?, period?, duration?, power?, energy?)

Lake Huron Sloshing



https://www.glerl.noaa.gov/res/glcfs/ncast/hwl.gif

Requirements

- range: +/- 2 feet
- continuous measurement
- fairly decent resolution, say .1"
- for a wave of 1 second, would like 16 samples
- electronics must be kept dry

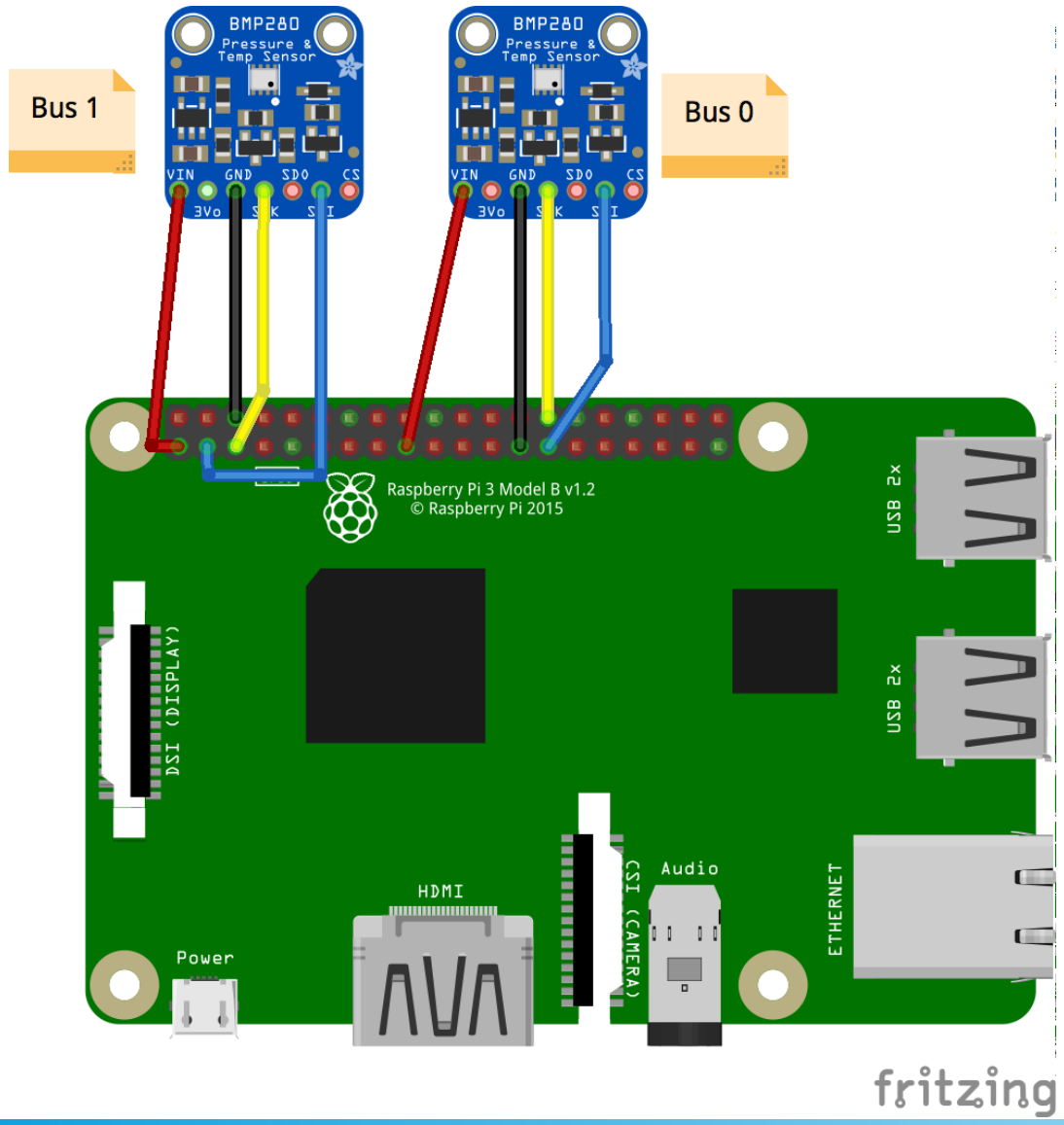
Selection of sensor

- pressure transducer
- ultrasonic
- float and shaft encoder
- water column pressure
- radar
- lidar (time of flight)
- 9-axis accelerometer, gyroscope, compass

Basic Setup

- Raspberry Pi model B (now a model 3)
- 2 pressure sensors
  - one ambient air pressure
  - one for water column pressure
    - encapsulation of sensor
  - both use same I2C identifier, so 2 buses
- heavy duty aquarium pump
- pressure tank

Fritzing Diagram



Use both I2C buses (No HAT or camera)

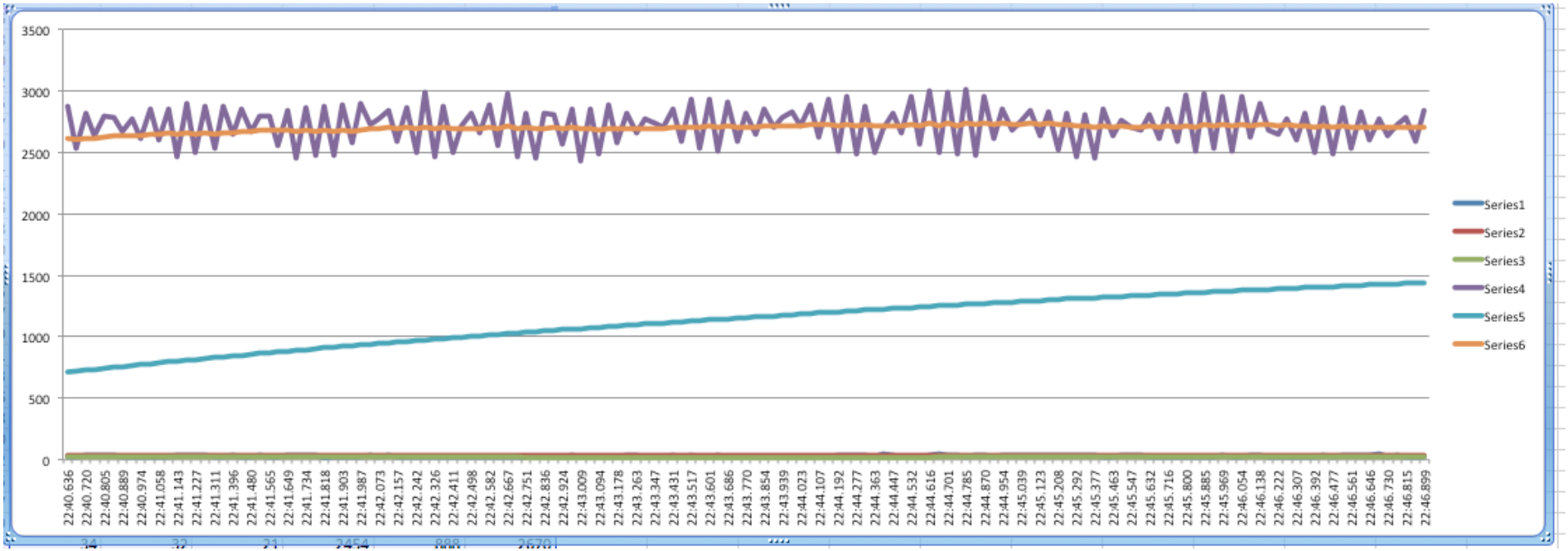
Originally used BMP085

Could have use SPI bus and chip select line to each BMP280 card

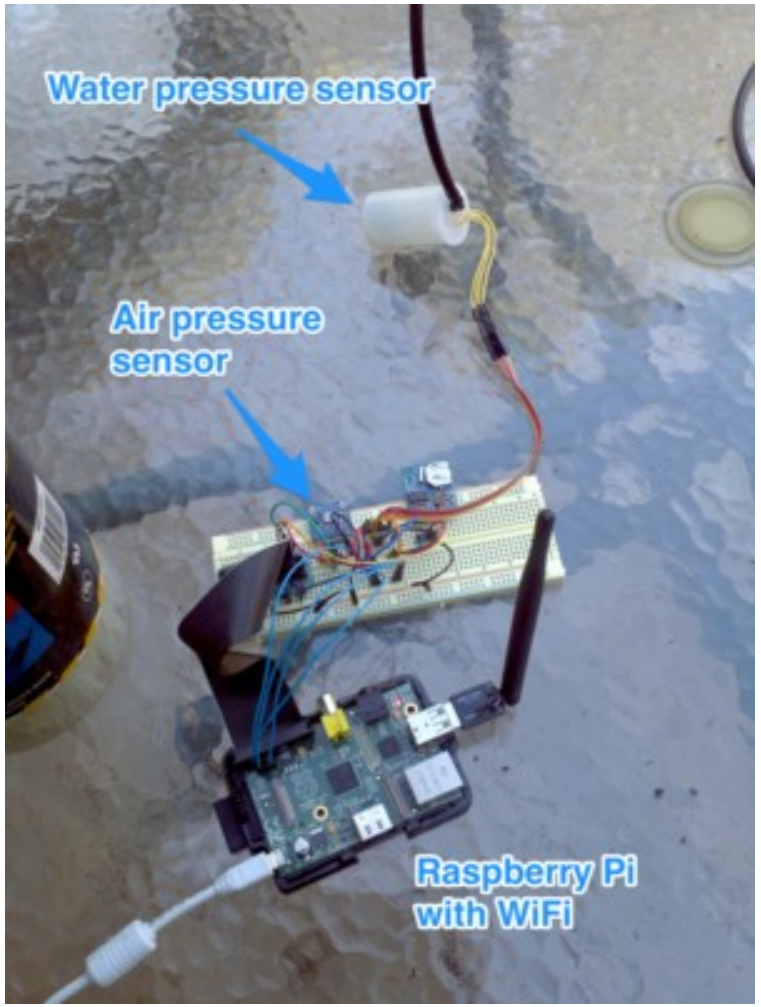
Proof of Concept

- Back yard testing
- Dunking air line into 10’ 4” vertical sewer pipe
- Tab delimited values
- Excel spreadsheet

First Measurement Data

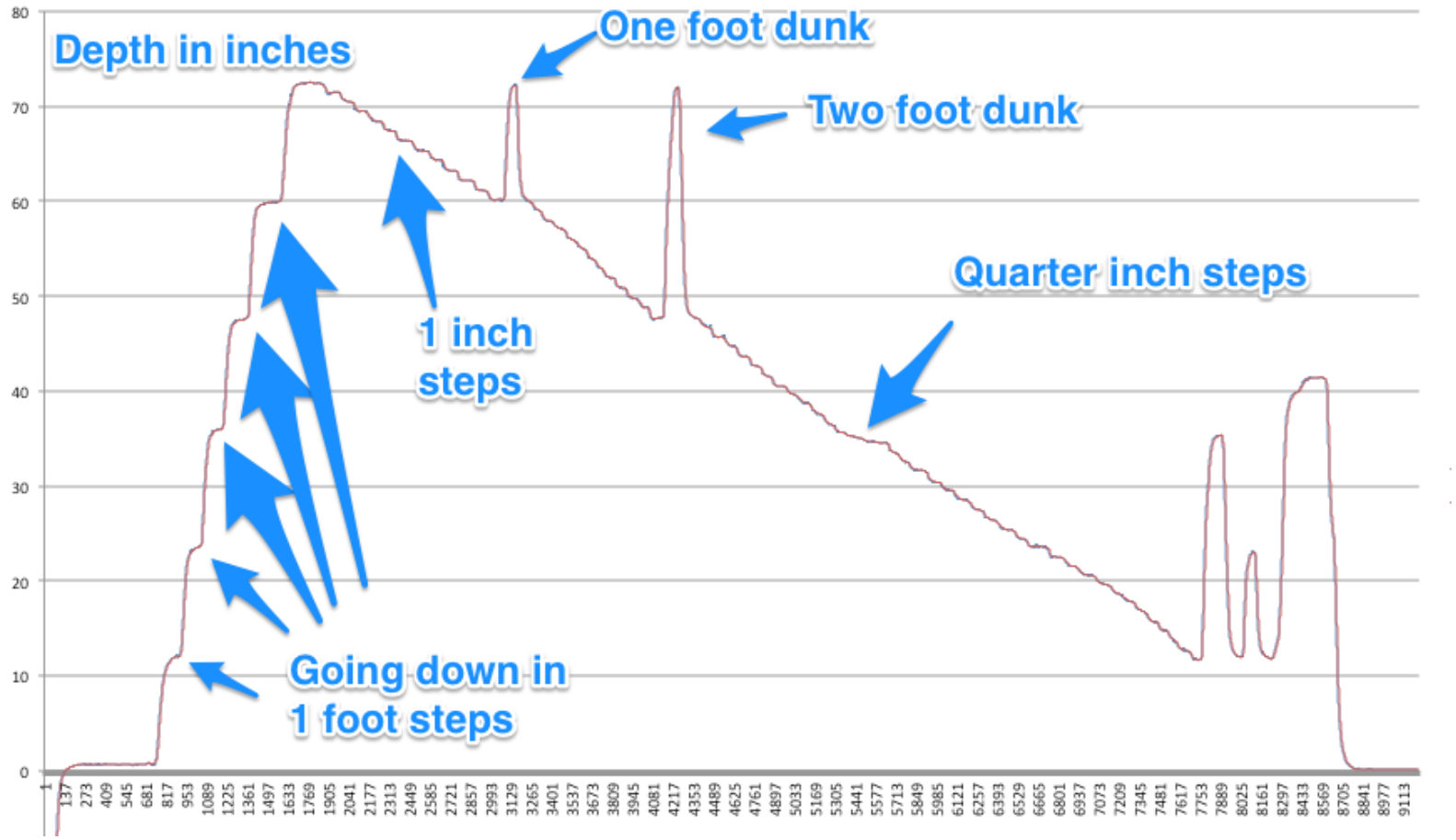


Basic Hardware



Portable Lake and Plunge Stick

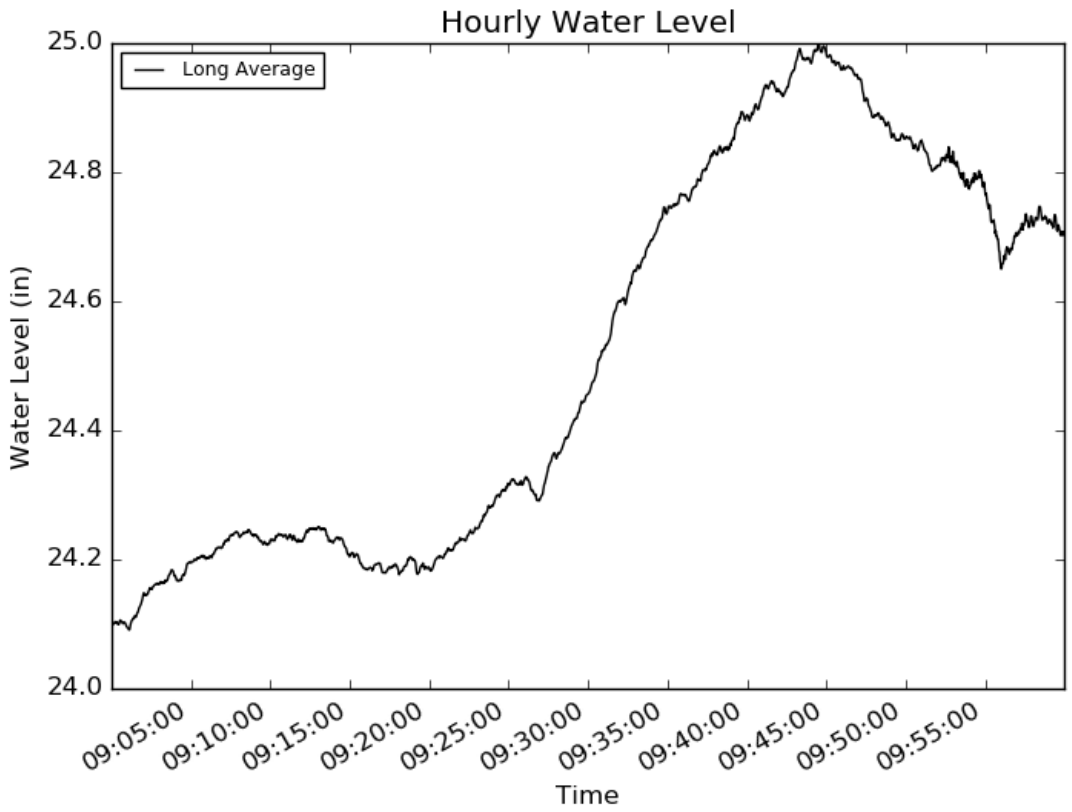
Results


Depth in inches
One foot dunk
Two foot dunk
Quarter inch steps
1 inch steps
Going down in 1 foot steps
80
70
60
50
40
30
20
10
0
1
137
273
409
545
681
817
953
1089
1225
1361
1497
1633
1769
1905
2041
2177
2313
2449
2585
2721
2857
2993
3129
3265
3401
3537
3673
3809
3945
4081
4217
4353
4489
4625
4761
4897
5033
5169
5305
5441
5577
5713
5849
5985
6121
6257
6393
6529
6665
6801
6937
7073
7209
7345
7481
7617
7753
7889
8025
8161
8297
8433
8569
8705
8841
8977
9113

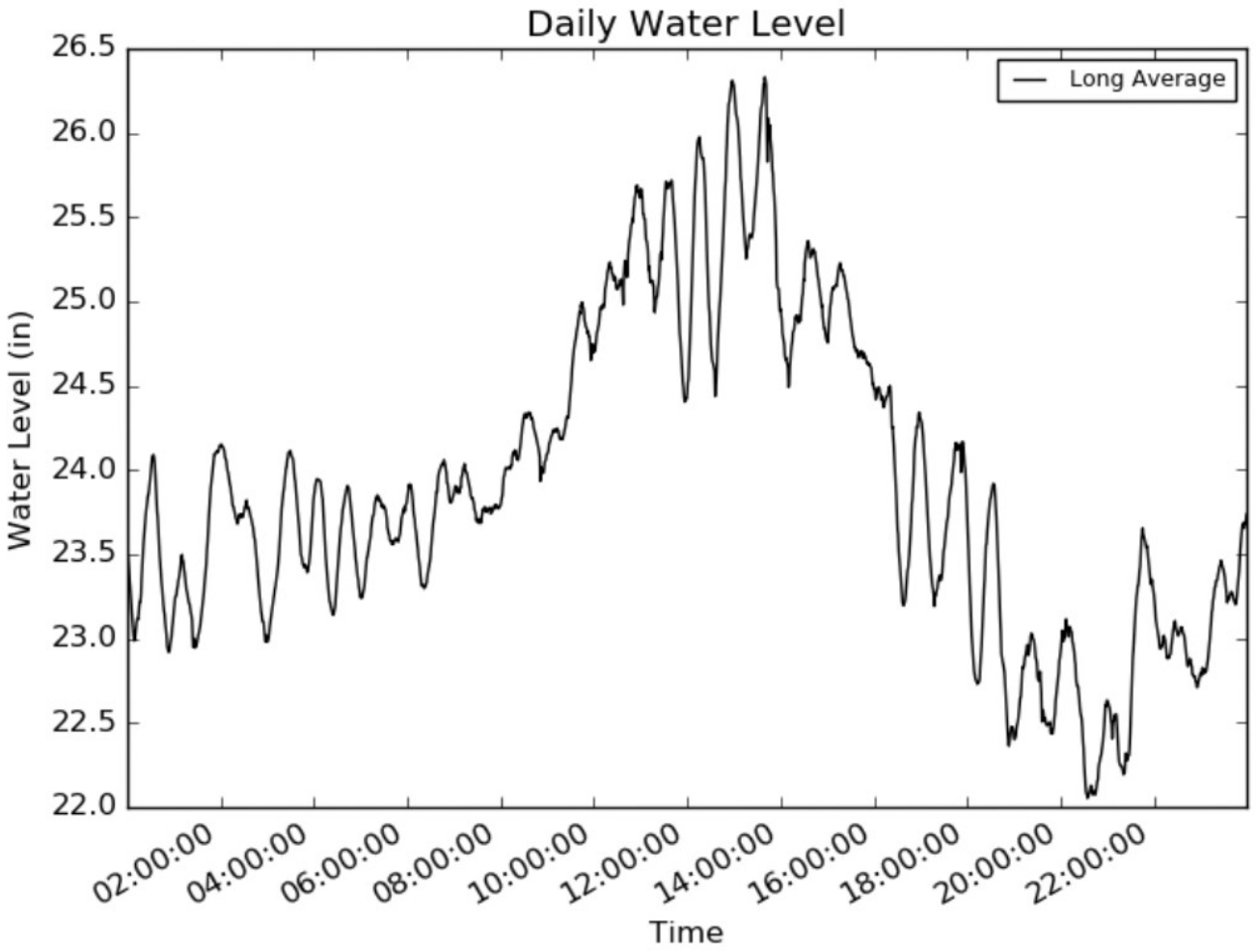
Round 1 Real Lake Testing

- python
- collector: comma separated values, csv
- analyzer: pyplot
- plots saved as hundreds of images
- intent to serve plots on an web page

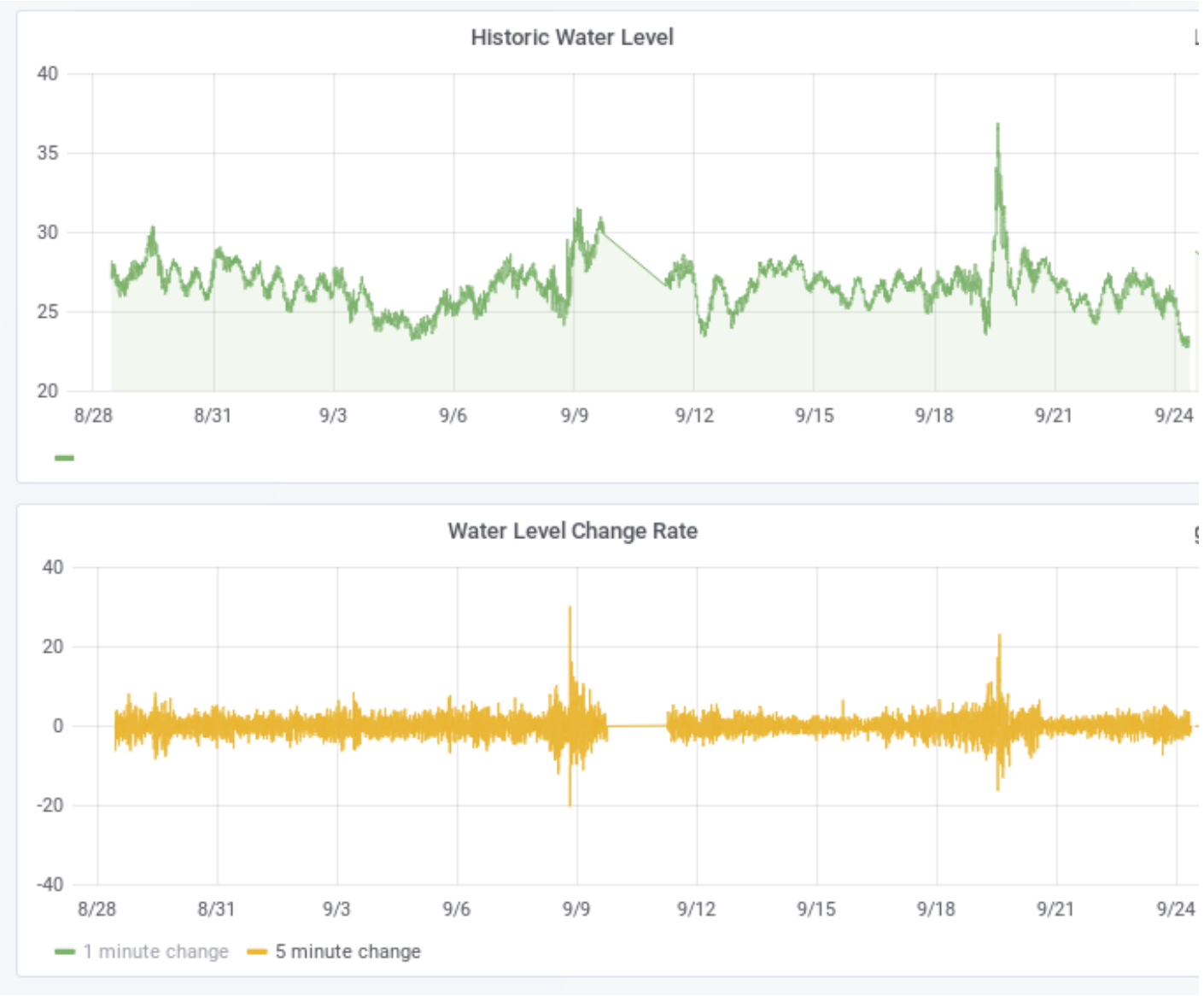
Results Hourly



Results Daily



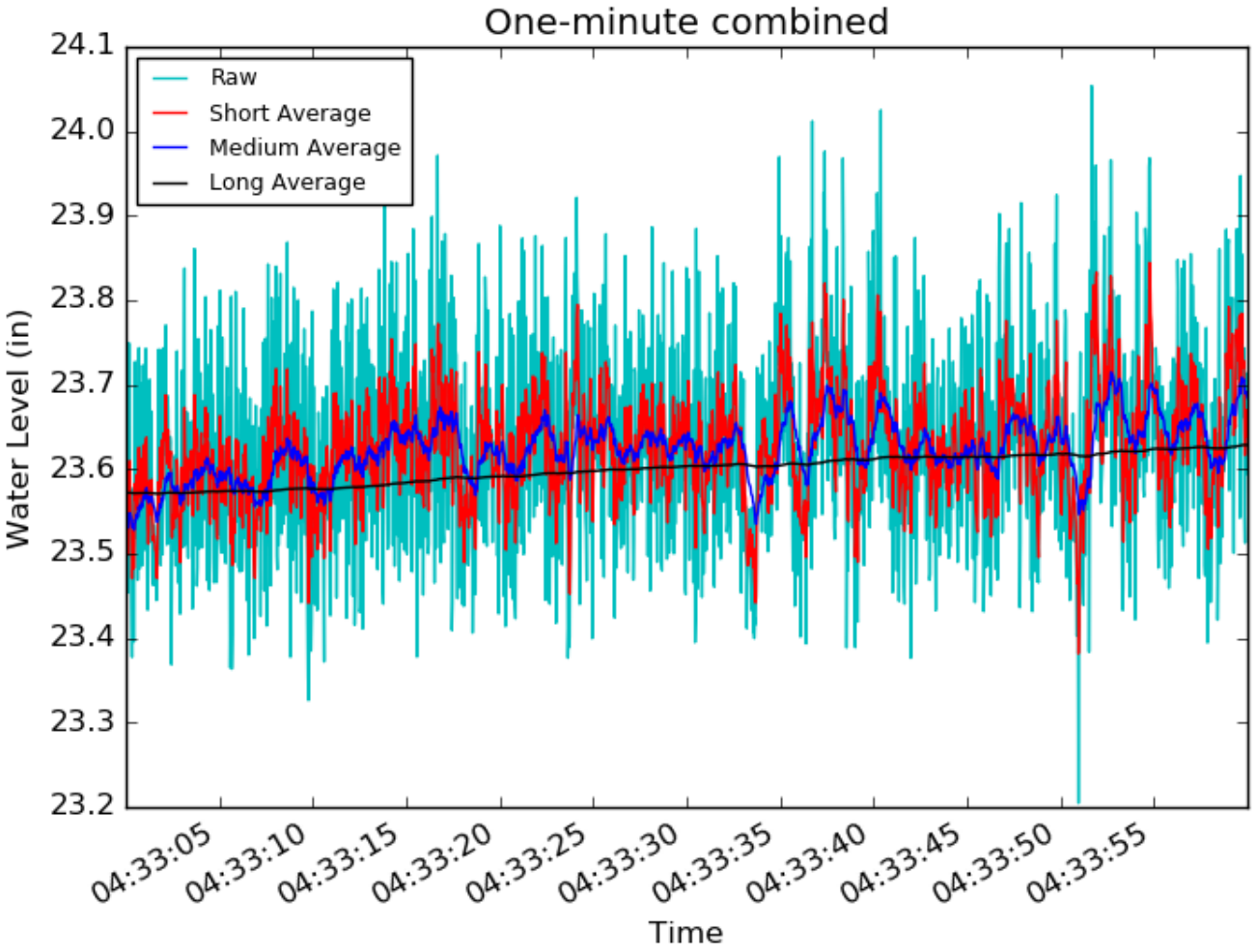
Seiche Examples



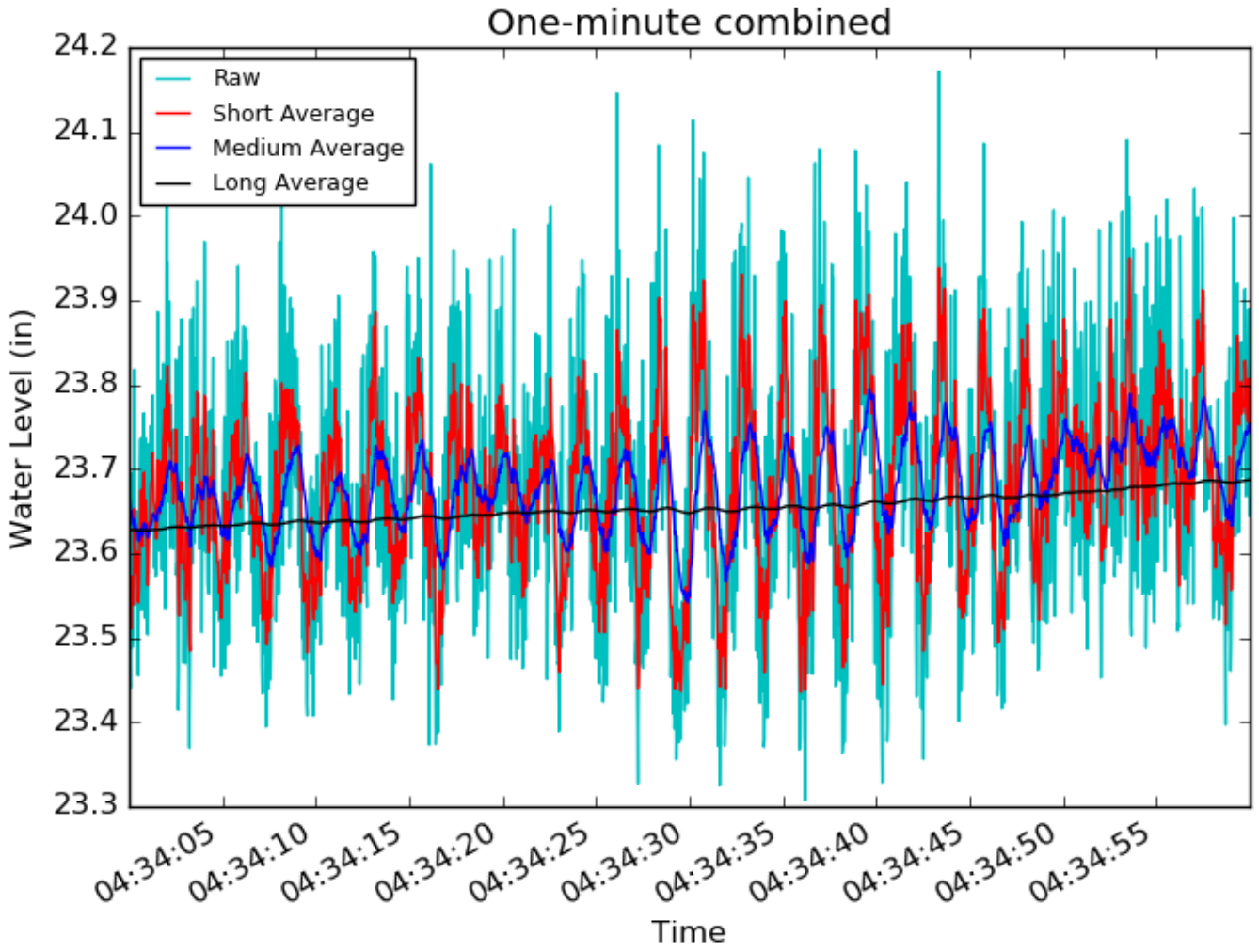

That's all Folks!


But Wait...
There's
MORE!

One Minute of Raw Data



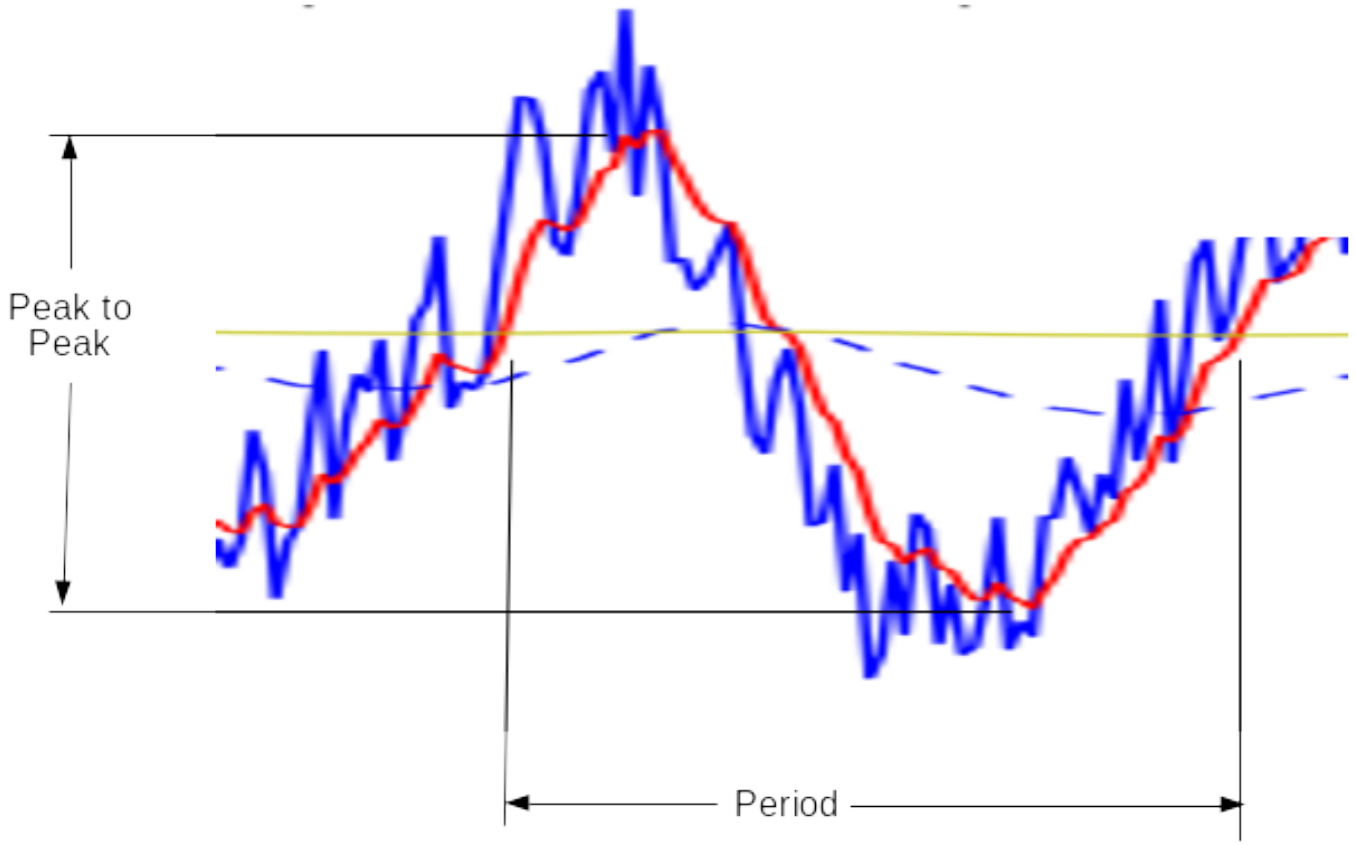
The Next Minute



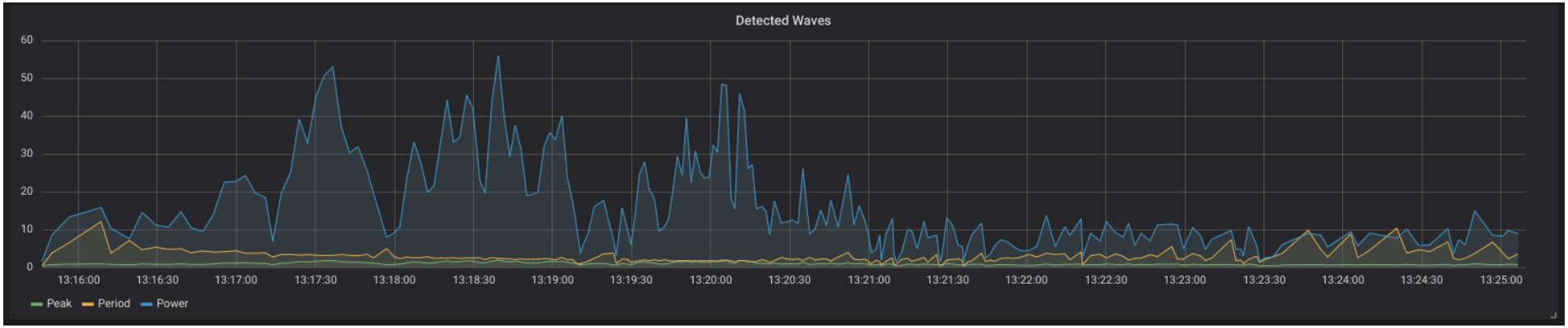
Refine the data

- running averages
  - ave = (ave *(n-1) + sample) / n = ave + x
    - x = (sample - ave)/n
- statistics
  - helps find errors
- zero crossing detectors
  - sea wave period and height
- calculating power
  - $period^2$ * height * water density * g

Zero Crossing Detector



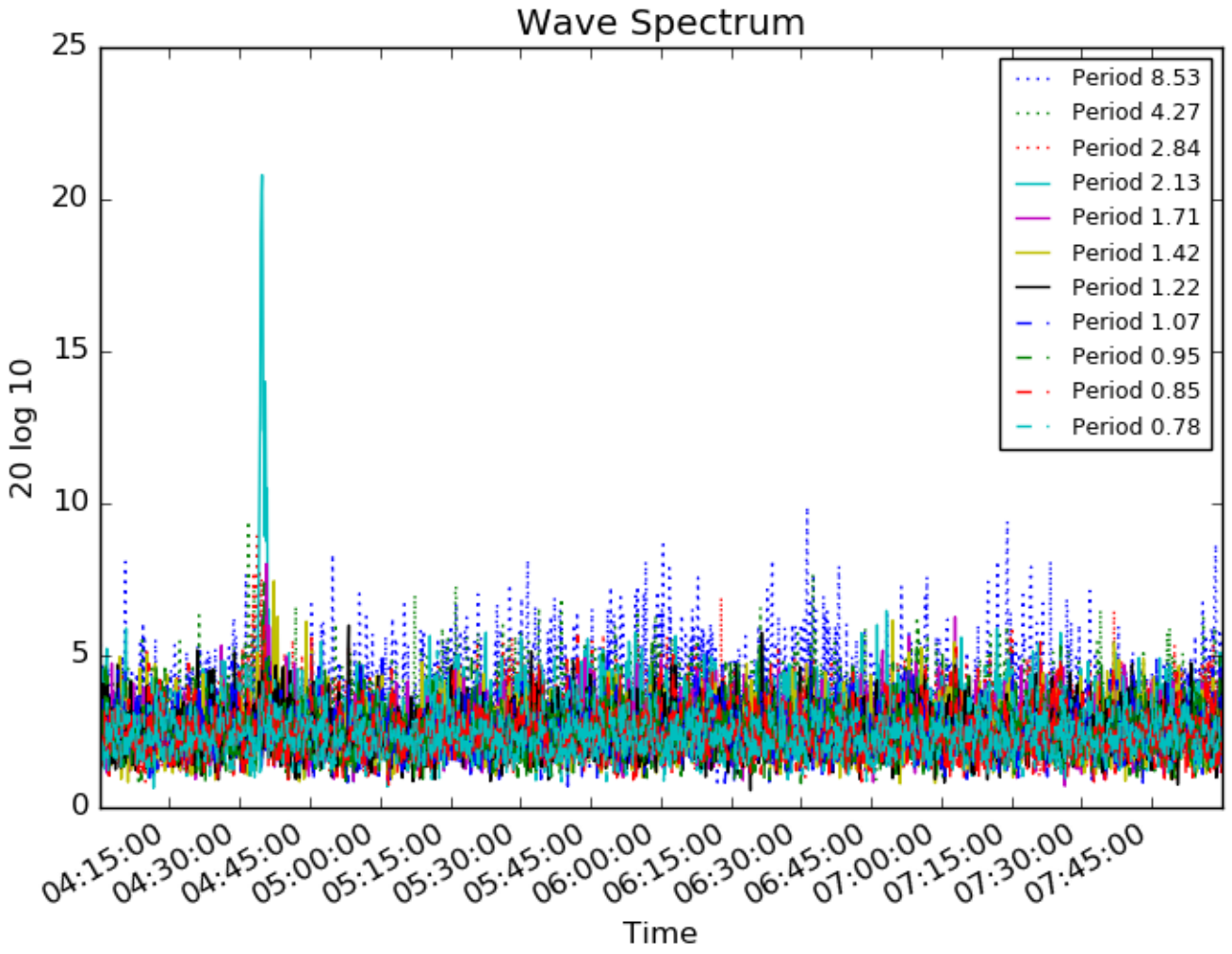
Power


Detected Waves
60
50
40
30
20
10
0
13:16:00
13:16:30
13:17:00
13:17:30
13:18:00
13:18:30
13:19:00
13:19:30
13:20:00
13:20:30
13:21:00
13:21:30
13:22:00
13:22:30
13:23:00
13:23:30
13:24:00
13:24:30
13:25:00
Peak
Period
Power

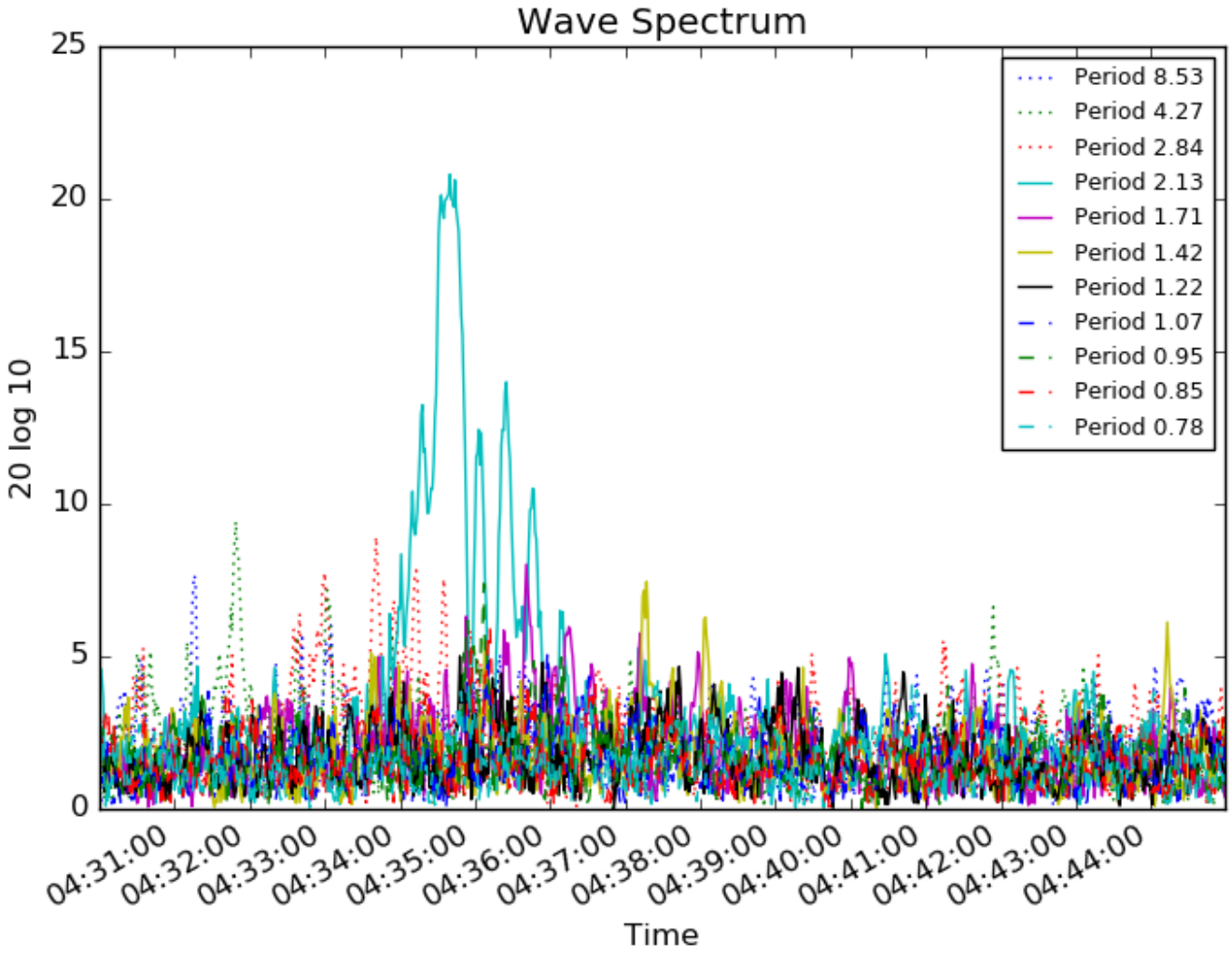
Fourier Transform

- Converts time domain into frequency domain
- Do this every second and plot frequency domain changes over time
- Uses a “real” FFT, not the full FFT
- FFT used in signal processing
  - modems >1200 baud, speech compression, MP3, QAM, QPSK, full duplex speakerphones, adaptive hearing aids, software defined radios,cellular phones, VoIP,

Simple 4-hour spectra



Simple 15-minute spectra



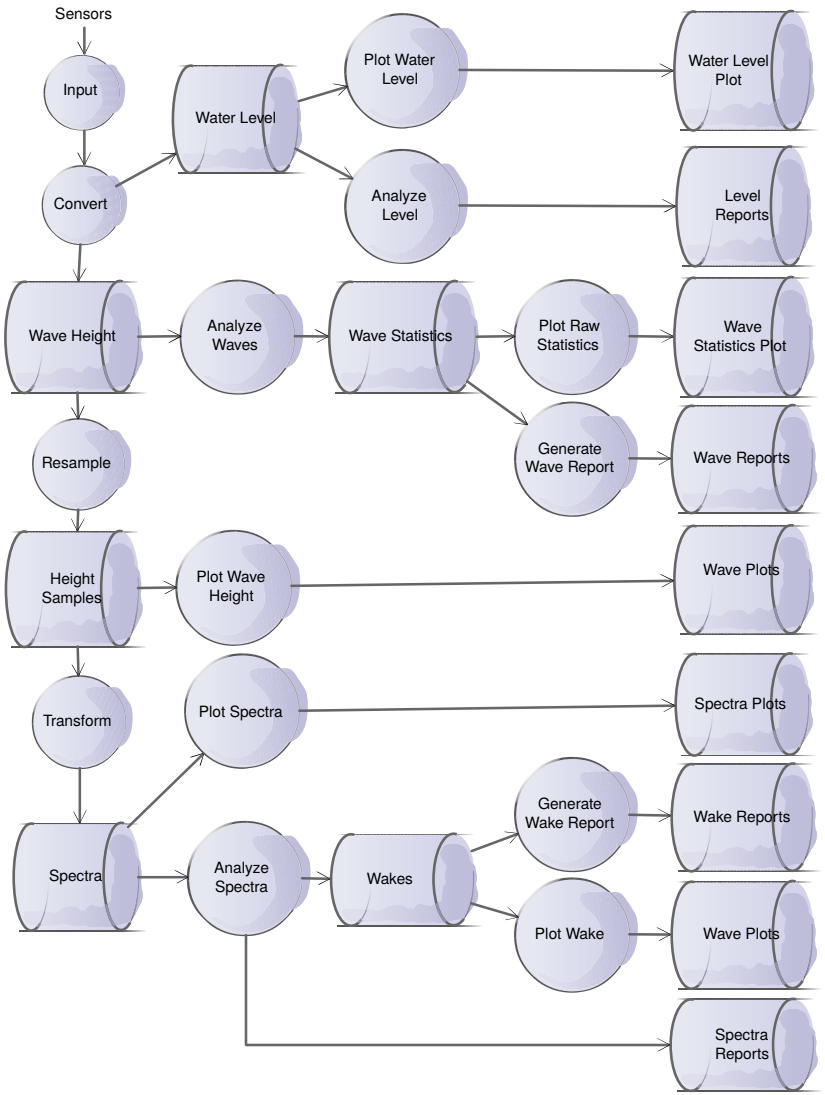
Round 2

- intent to use JavaScript interactive plot library
- mySQL
- pyplot
- failed database real-time test
  - lagged several minutes after a couple of days of data
    - 30 points per second
    - 2,000,000 points per day
    - never lost data

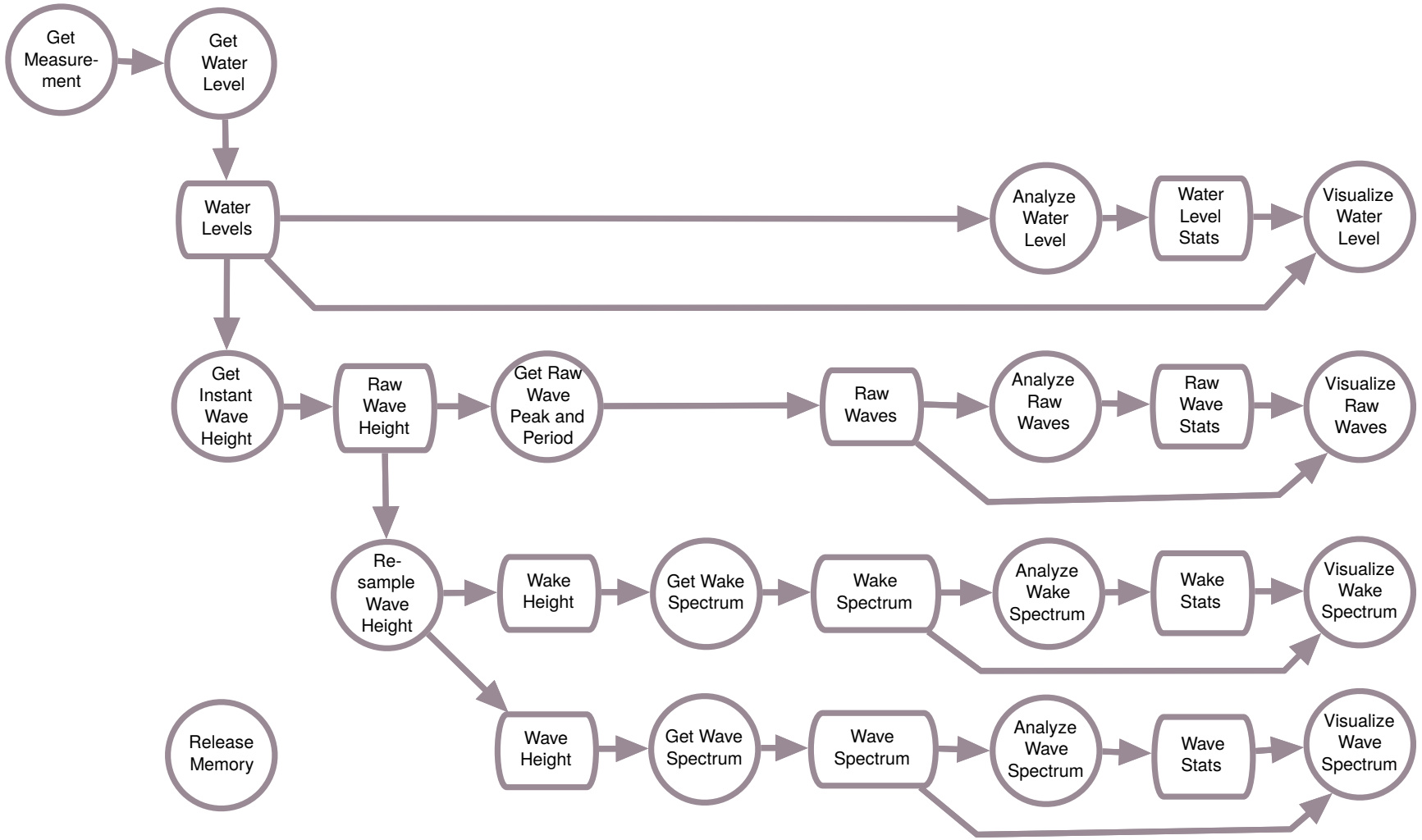
Round 3

- rewrite and refactor python (again and again)
- learned Python object oriented programming
- influxdb for storage
- Grafana for interactive plots
  - thanks to Craig Tucker and Charlotte IoT
  - … failed at around 6-8 million points
- reduced data at input… and success!
  - some evidence of data loss

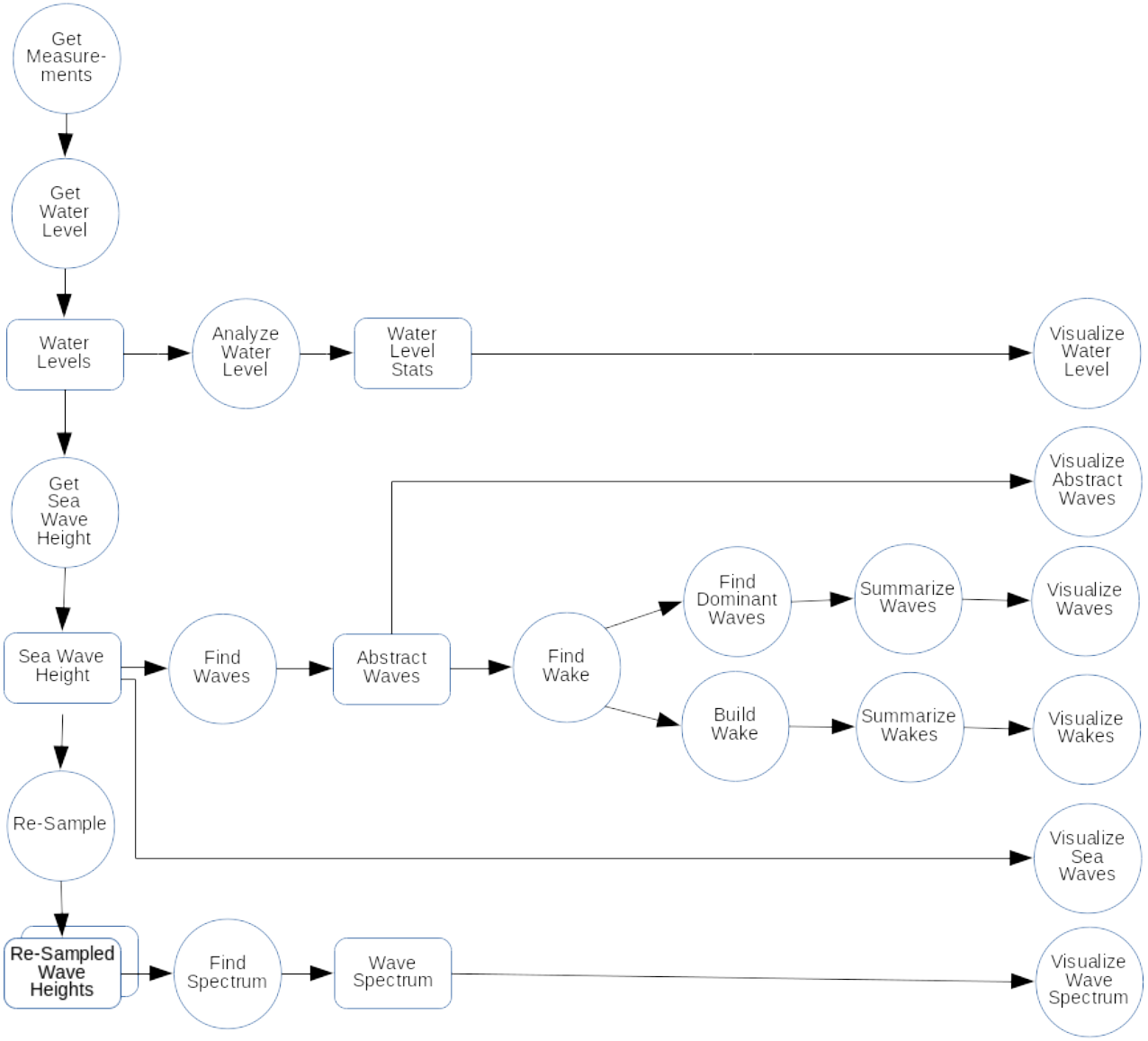
First Cut at Modularization



Second Cut at Modularization



Third Cut


Get Measure-ments
Get Water Level
Water Levels
Analyze Water Level
Water Level Stats
Visualize Water Level
Get Sea Wave Height
Visualize Abstract Waves
Sea Wave Height
Find Waves
Abstract Waves
Find Wake
Find Dominant Waves
Summarize Waves
Visualize Waves
Build Wake
Summarize Wakes
Visualize Wakes
Re-Sample
Visualize Sea Waves
Re-Sampled Wave Heights
Find Spectrum
Wave Spectrum
Visualize Wave Spectrum

New Theories

- The wavelengths produced by a boat will be less than or equal to its waterline length
  - Should be able to determine size of boat
- Longer wavelengths move through water faster than shorter wavelengths (AKA dispersion)
  - May be able to determine distance of boat

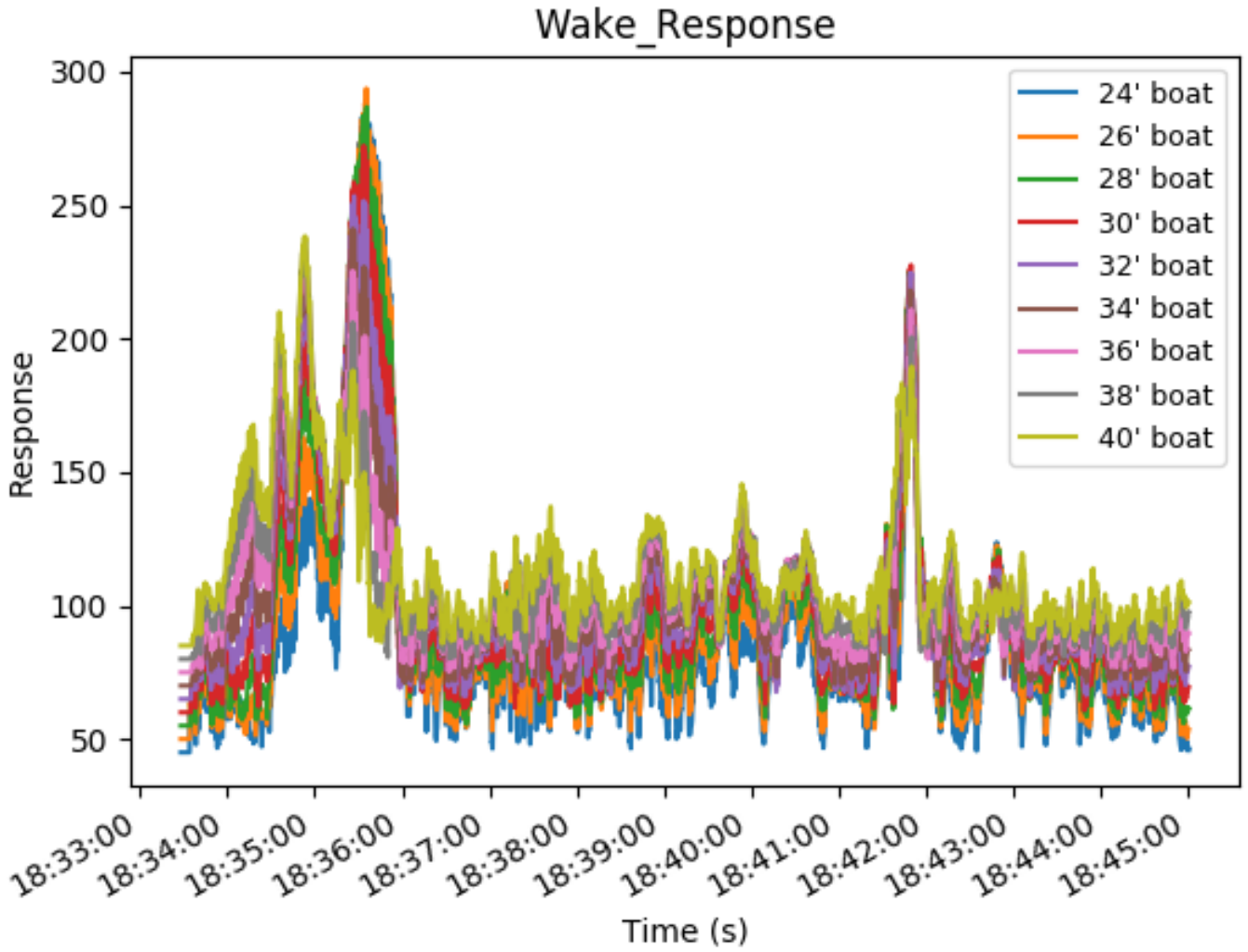
Wavelength Period Speed

Wavelength (feet)	Period (s)	Speed (feet/s)	Cover 1000 feet
10’	1.40	7.16	2’ 19”
20’	1.98	10.12	1’ 39”
30’	2.42	12.39	1’ 21”
40’	2.79	14.31	1’ 10’
50’	3.12	16.00	1’ 2.5”

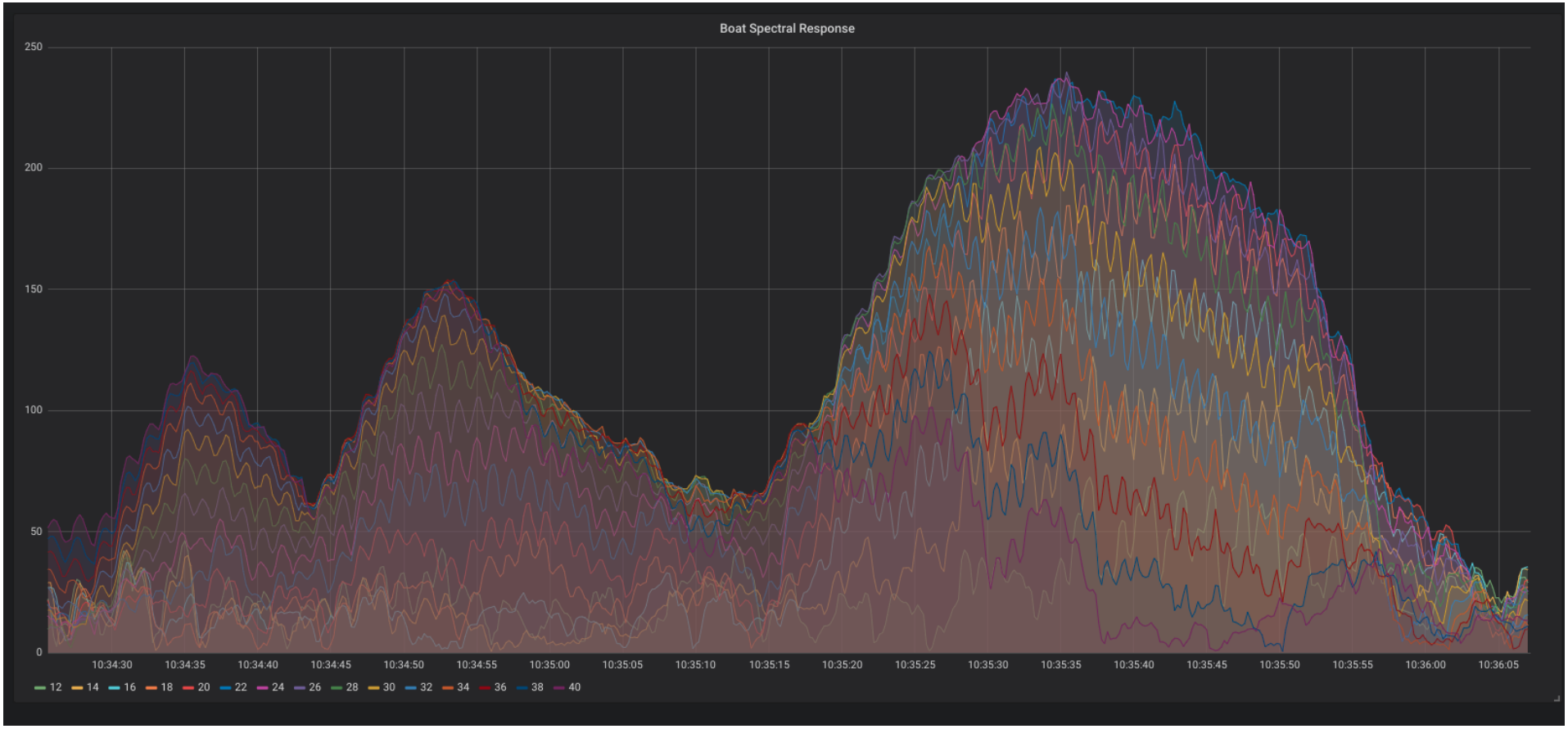
FFT Revisited

- wake problem is inverted from most apps
  - most focus on high frequency
  - this focuses on low frequency
- have to do an FFT for each period of interest
  - buffer is fixed at 1024 samples
  - change buffer period to be of interest
  - resample the input stream to fill buffer

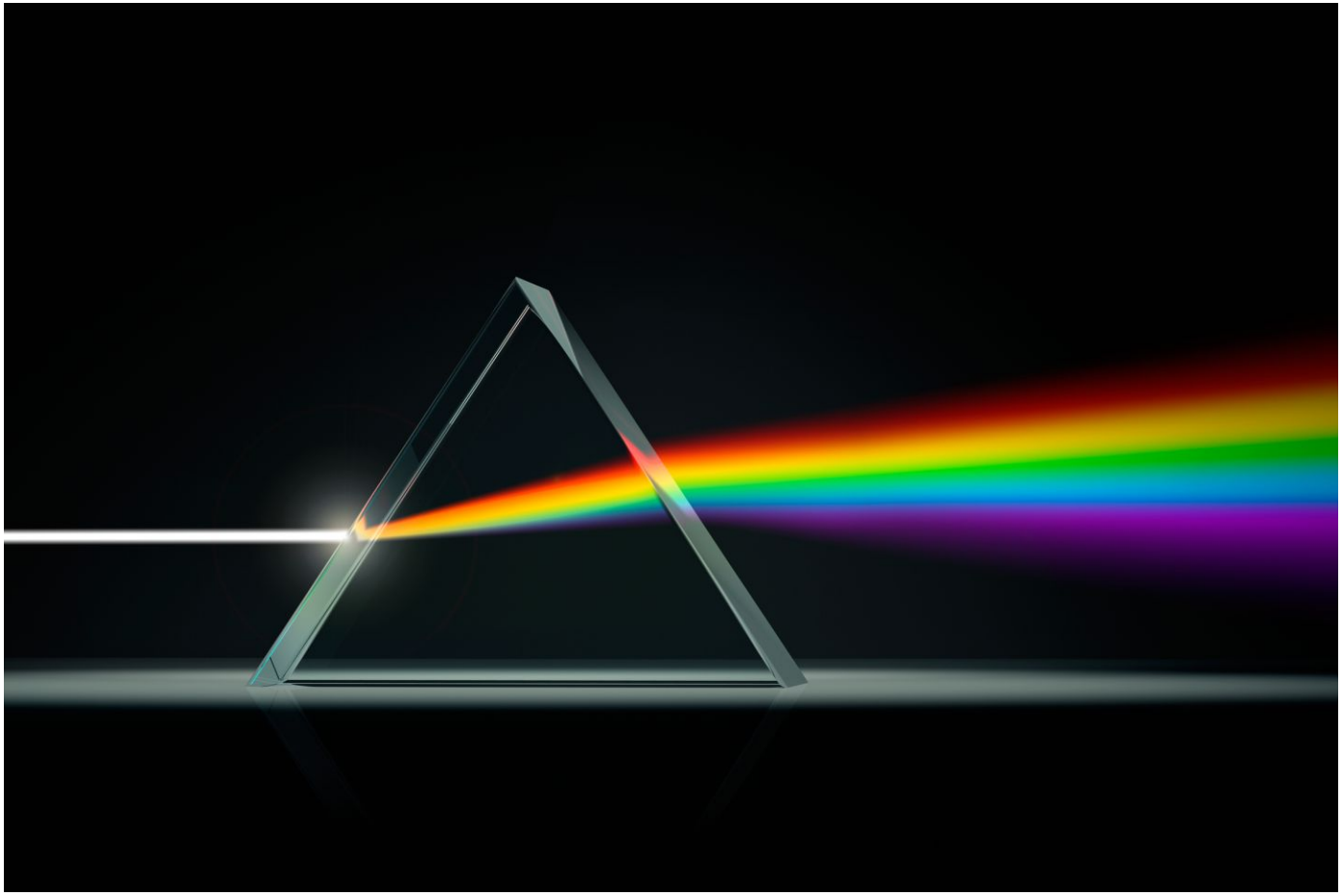
Boat Spectra (pyplot)



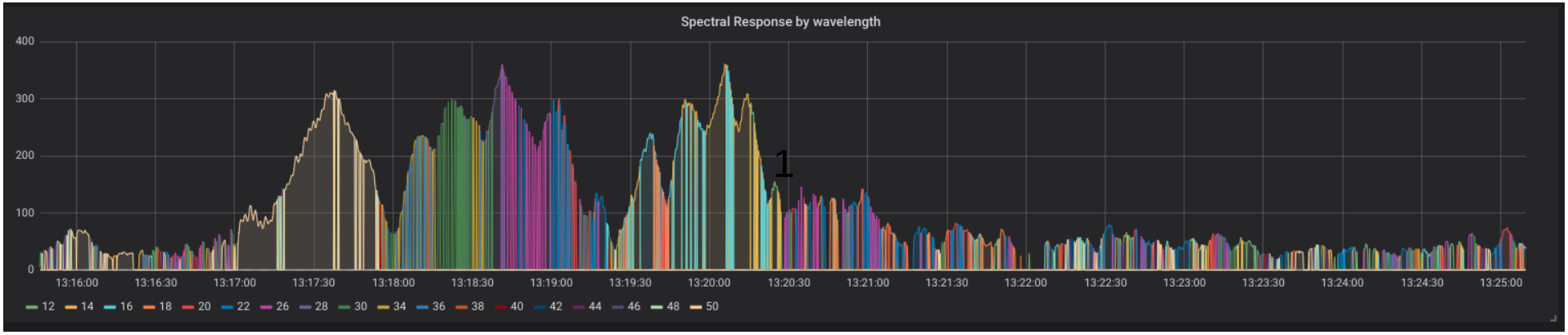
Boat Spectra (graphana)



Light Dispersion

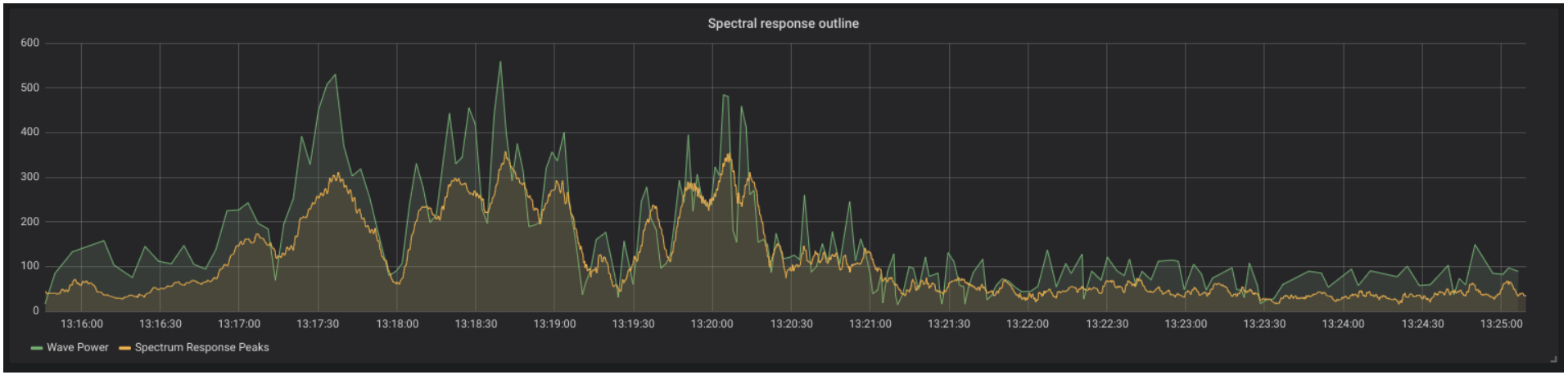


Six minute wake spectrum



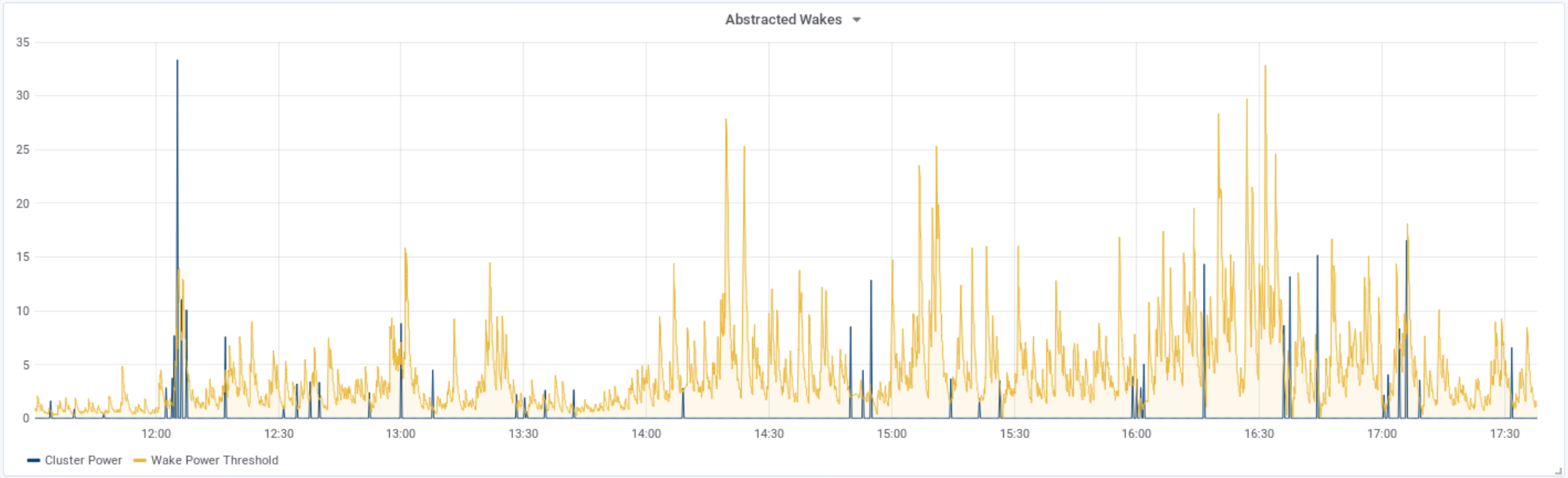
Labor day week

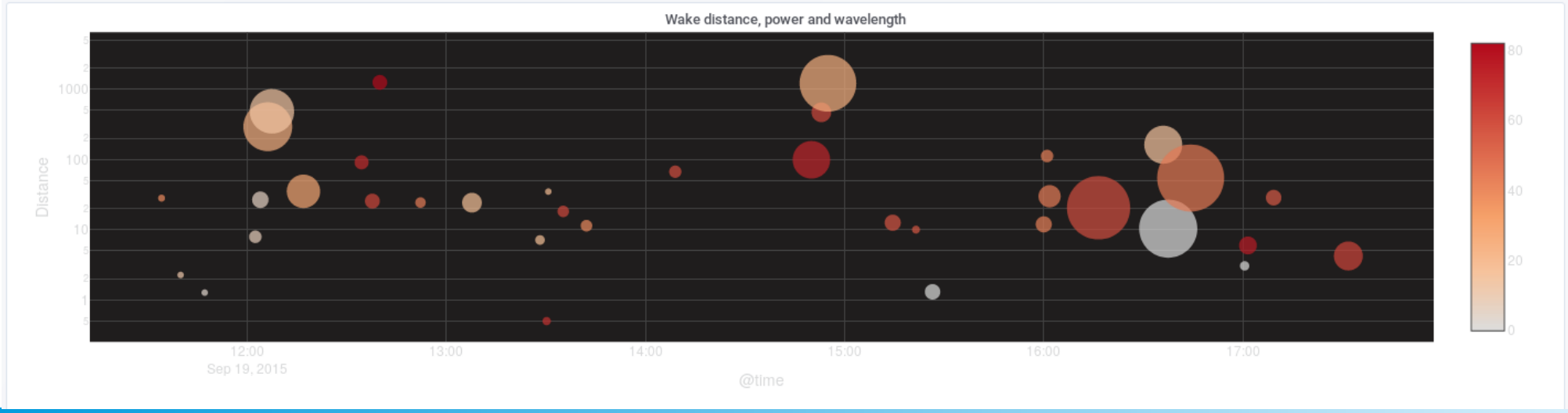
Power and Spectrum Superimposed



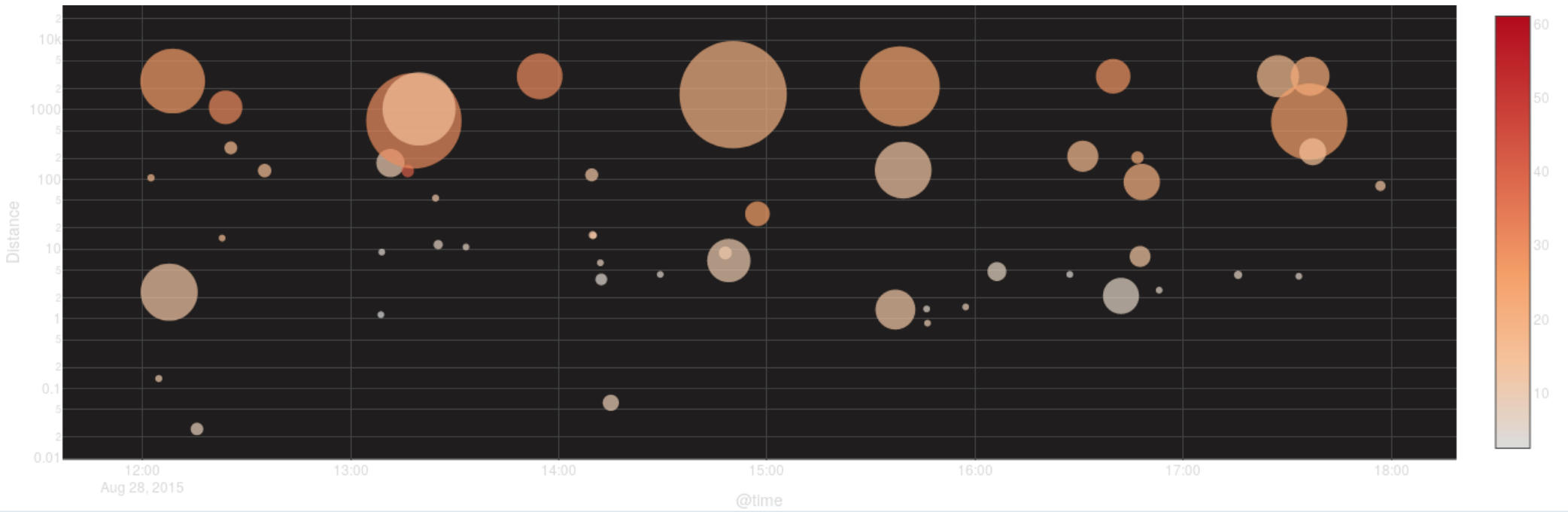
High correlation of simple power data with spectral data

Power to Wake to Bubble





Wake Distance, Wavelength, Power



Distance is vertical (logarithmic scale)

Time is horizontal

Size is power

Color is wavelength (darker = longer)

Issues

- wakes aren’t very high
  - need direct measurement to confirm (lidar?)
- long wake periods don’t seem right
- wake periods observation is about 1 s
  - not the 2 and 3 seconds measured
  - suspect formula or apparatus error
- wakes can be fairly well detected with zero-crossing and power calculation
- Missing a disturbances - not coherent?

Potential Applications

- Water level detector
- Fluid level detector
- Boating activity detector
- No wake zone monitoring
- Shoreline erosion monitoring
- Pool monitor (micro:bit?)

Thank You

- Questions?
- Comments?