# Monitoring Wind Waves in Nantucket Sound off South Cape Beach

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MOTIVATION: Waquoit Bay National Estuarine Research Reserve has over two decades of coastline migration data, but did not have any quantitative data on near-shore waves causing beach erosion and longshore sand transport.

GOAL: Develop wave imaging system, calibrate Arm&Float wave gauge, compare with wind data and develop wave height prediction model.
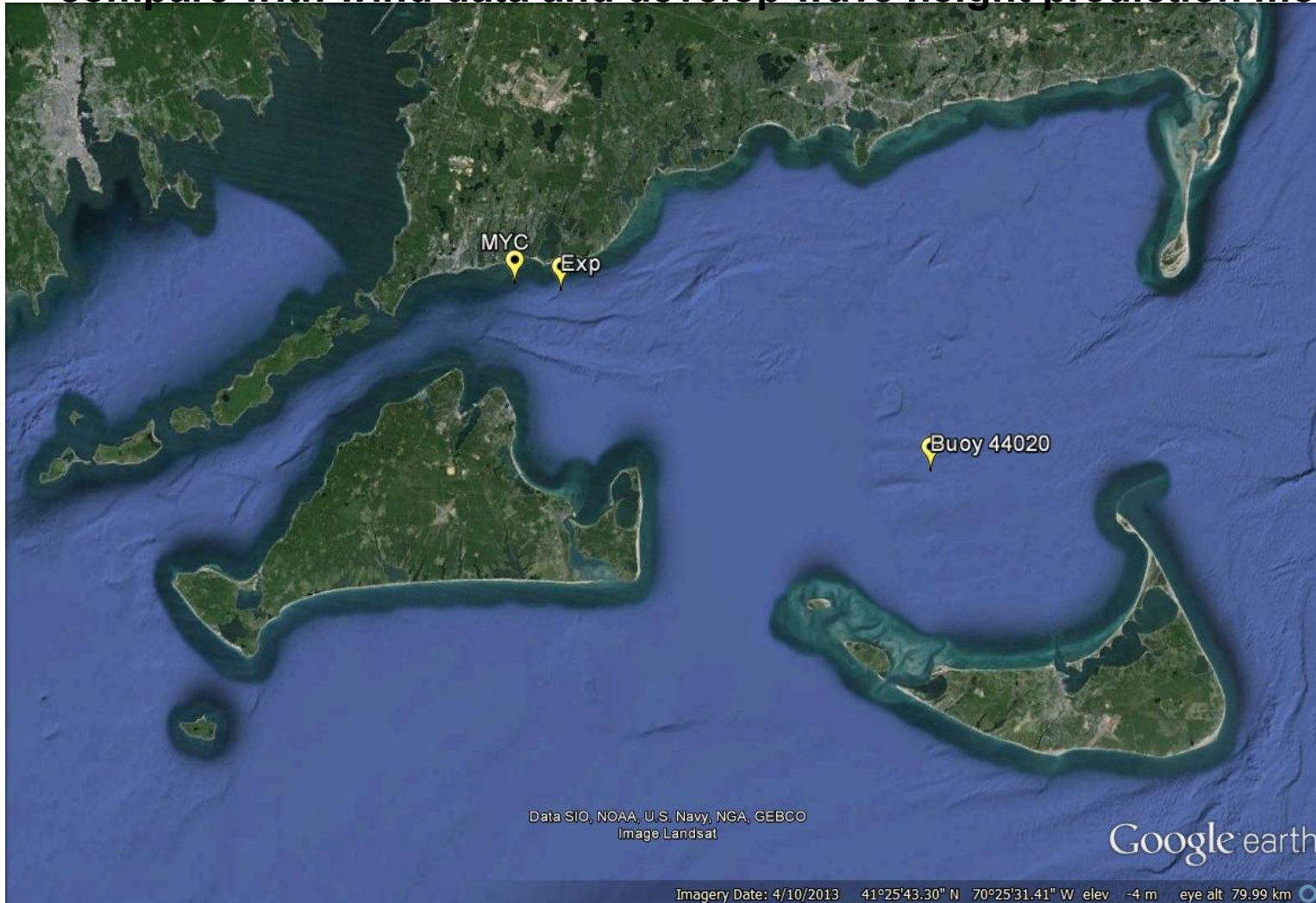
MYC, Exp – locations of meteo station and Wave Experiment site

Deployment August 2015

Buoy 44020 NOAA meteo and Wave buoy in Nantucket Sound

Instrumentation

Arm-and-Float water level gauge: measures position and acceleration of water surface. Logging every 6 min in burst mode at 4Hz for 64 sec.

Image capturing of the water surface relative to graduated staff in 64 sec bursts at 1.5 frames per second.

Comparison of Arm-and-Float data (blue) and Image data (green, red dots) during 64 sec burst


Arm-n-Float Gauge vs Image Proc
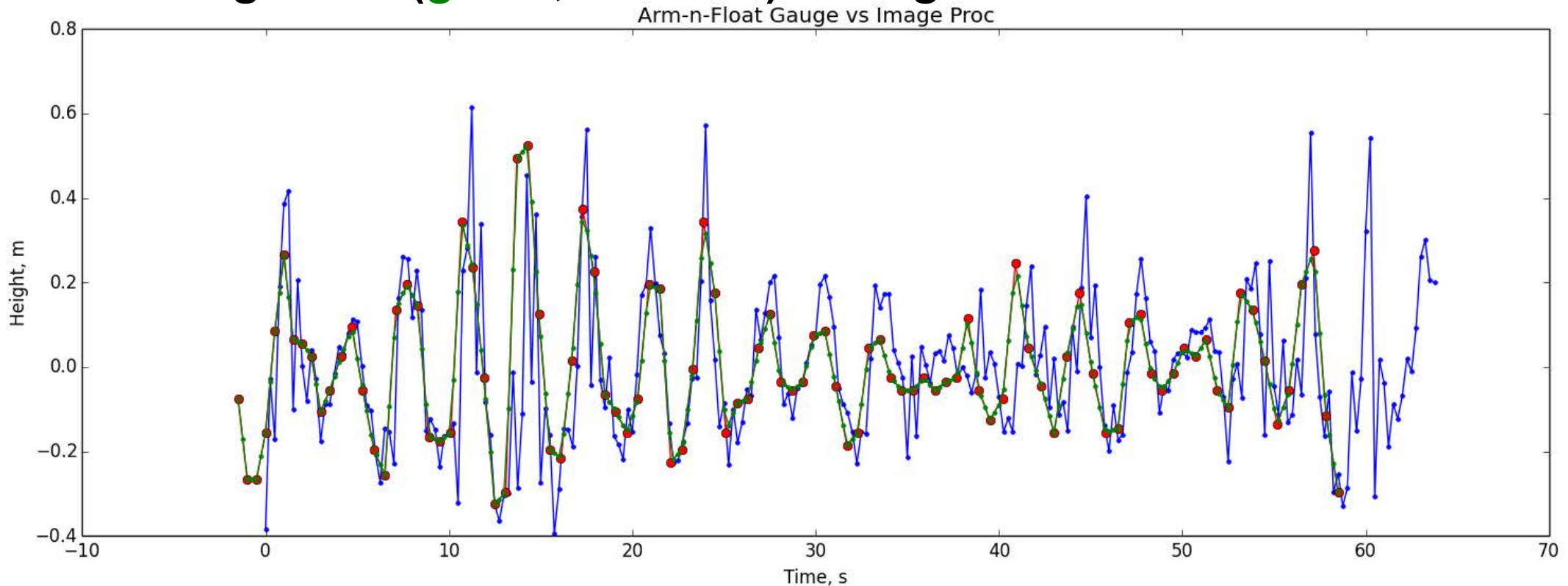
Good agreement in amplitude of waves, but timing of digital camera images slightly varies

Quantitative comparison: subsample water level gauge data at same rate as image data and compare standard deviations

STD(Water Level Gauge) = 0.161 m; STD(Image Processing) = 0.166 m   agree within 3%

# **Wind** from Menauhant Yacht Club (MYC) and **Wave Height** from Arm-and-Float gauge at South Cape Beach

Significant Wave Height (WVHT) is commonly defined as 4*STD(surface elevation)
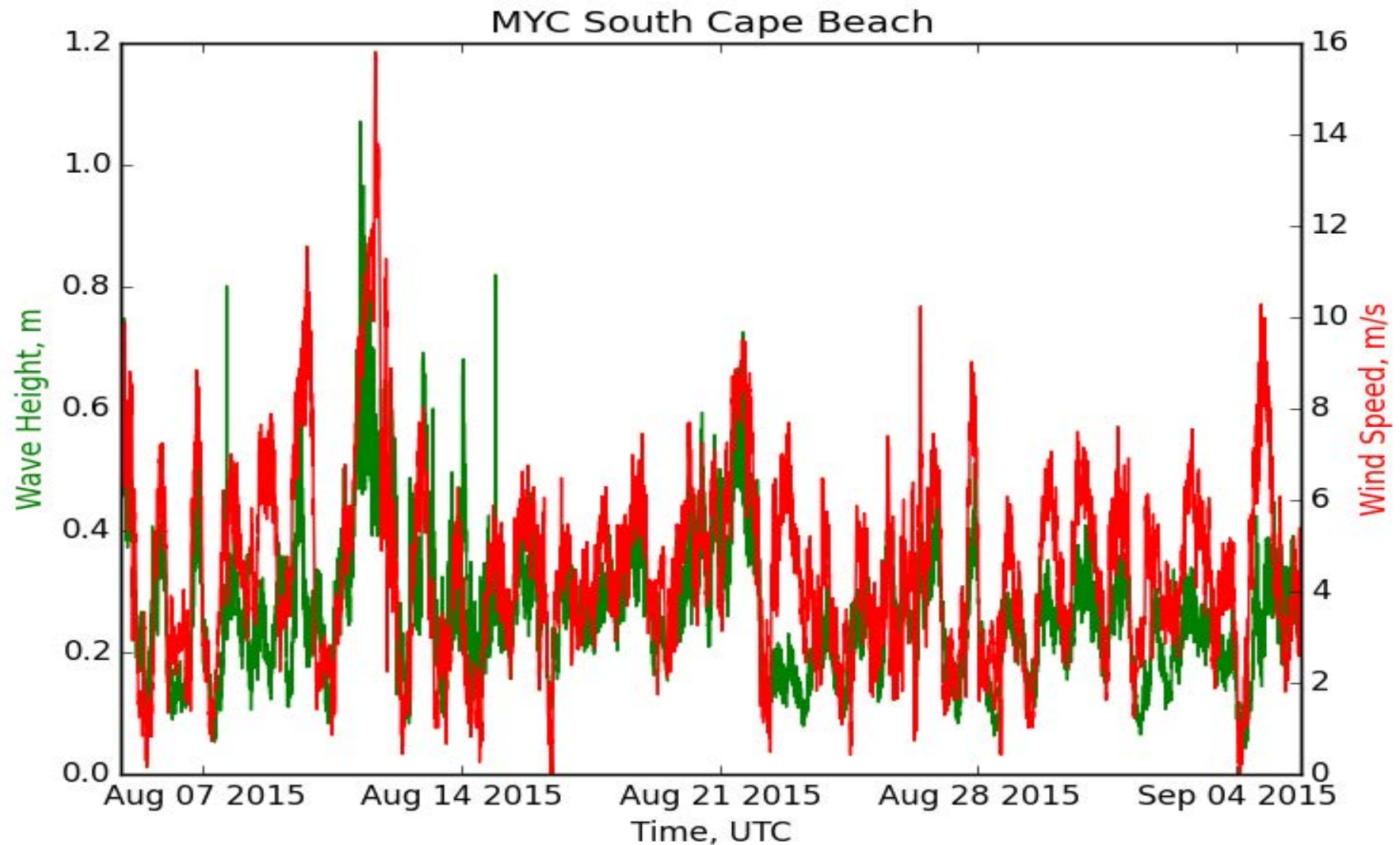
Relationship between Wind Speed and Wave Height at South Cape Beach

Waves lag winds about 48 minutes on average
Wave Heights are roughly proportional to Wind Speed and depend on wind direction
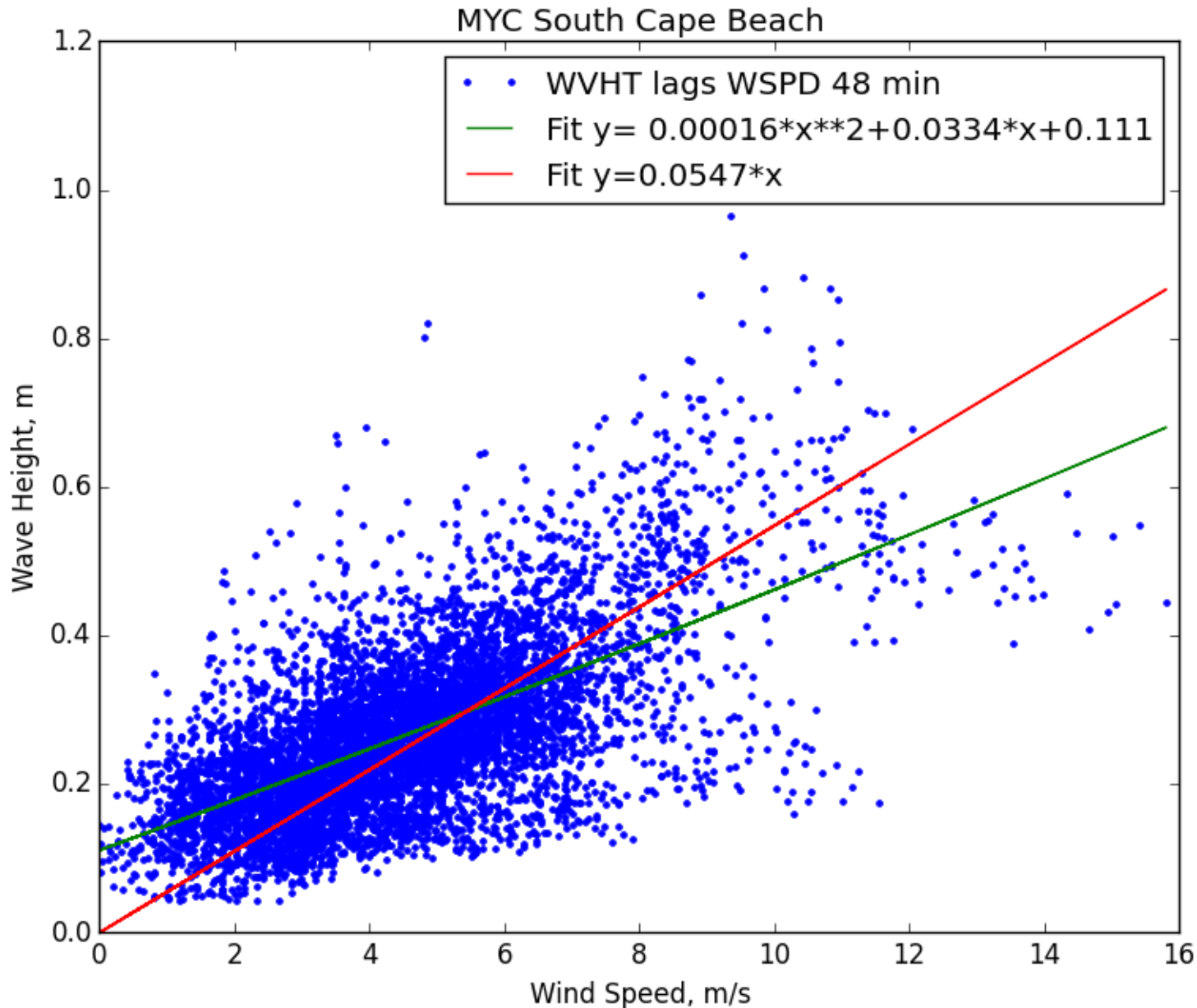
Rational Explanation of Wind-Wave Relationship

Energy Balance:

(Power input by wind into waves) = (Energy flux of Waves to the Beach)

Power input = Wind Stress * Cg * L,

Wind Stress = rho_air * WSPD**2 * CD
(density of air *Wind Speed squared * Drag Coeff)
Cg – Wave group speed
L – Fetch of the waves, distance the waves travel
CD – drag coefficient ~ 0.001
   = (0.44+0.063*U)*0.001 according to Smith (1980)

Energy flux = Wave Energy Density * Cg =
   = 1/16 * rho_water * g* WVHT**2 * Cg
(1/16 * density of water * gravity * wave height squared * Cg)

Therefore

$$VWHT = k * WSPD,$$

where k= 4*sqrt(rho_air/rho_water*CD*L/g) = 0.06 s for Fetch L=3km

Relationship between Wind Speed and Wave Height in the middle of Nantucket Sound

Different Quadratic Law because of no wave breaking at the beach
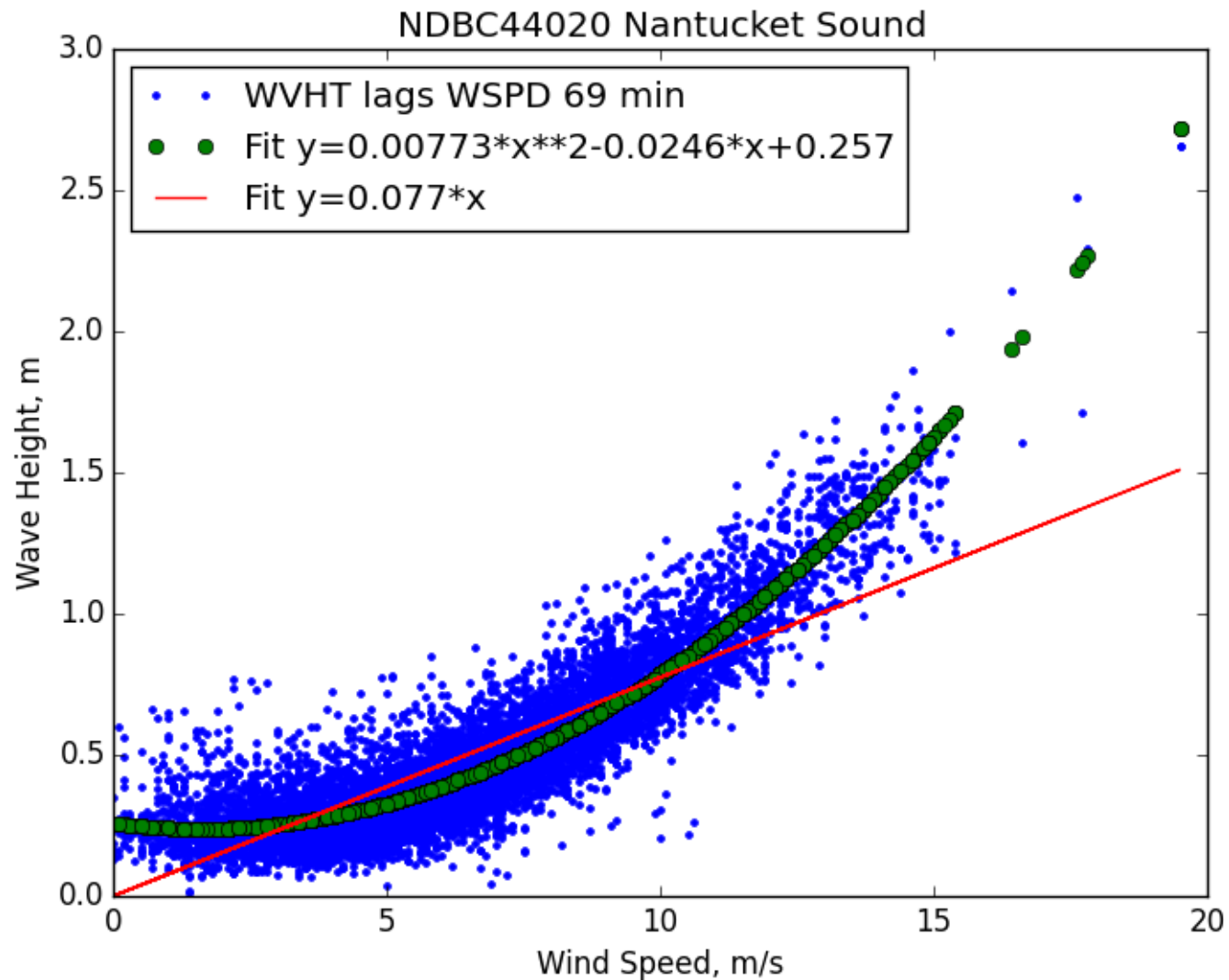
NDBC44020 Nantucket Sound

- · · WVHT lags WSPD 69 min
- ● ● Fit y=0.00773*x**2-0.0246*x+0.257
- —— Fit y=0.077*x

Waves arrive at the beach in groups
with approximately every 10th wave being larger than the rest

Two Wave Fit
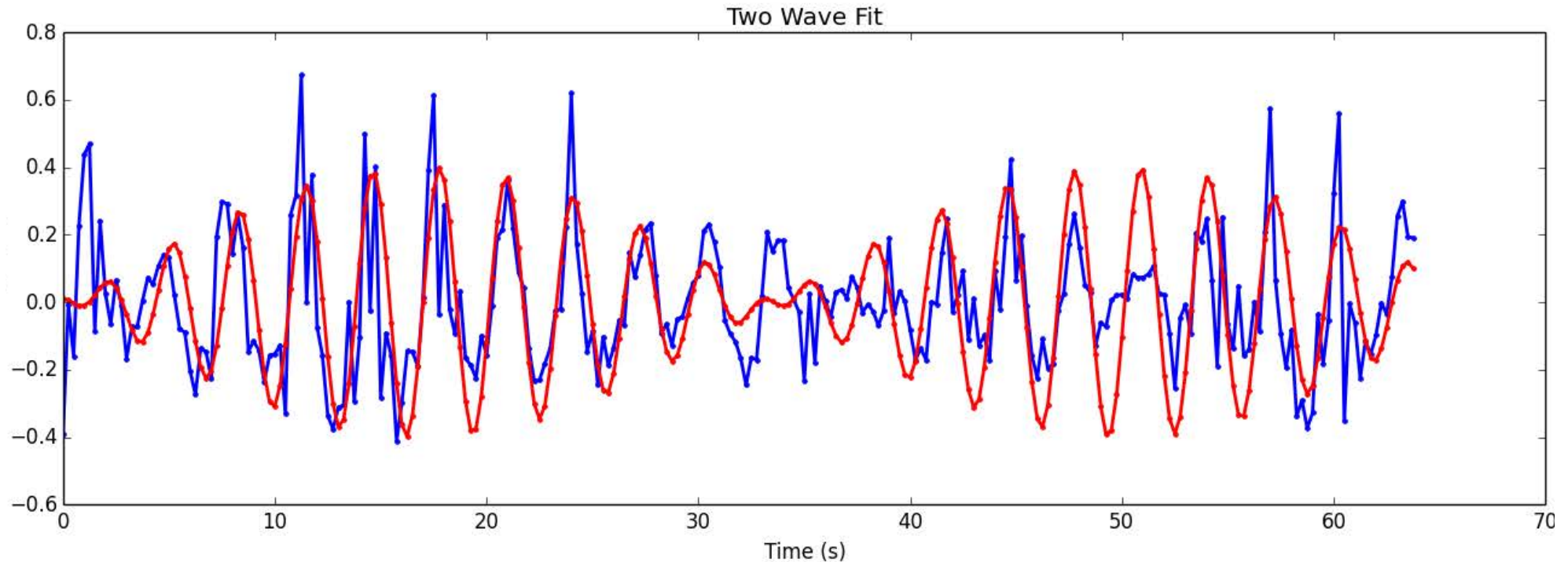
a typical 64 second record from our wave gauge (blue) can be modeled by a sum

of two waves of equal amplitude but frequencies (or periods) differing by 10%

$$sin u + sin v = 2\cos\left(\frac{1}{2}(u-v)\right) \times \sin\left(\frac{1}{2}(u+v)\right)$$

The best fit (red) has the following periods: T_1=3.0 s T_2=1.1*T_1=3.3 s

Summary

Arm-and-Float Water Level Gauge and Image Capturing System give consistent results

Wave Height at the South Cape Beach is roughly proportional to Wind Speed

$$\text{WVHT (m)} = 0.06 \text{ (s)} * \text{WSPD (m/s)}$$

In the middle of Nantucket Sound Wave Heights are quadratic with Wind Speed

Waves arrive at the beach in groups with approximately every 10th wave being larger than the rest, which can be modeled by a sum of two waves with periods differing by 10%