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The Acoustic Backscatter Sensor

Preliminary results and inter-comparison with OBS and LISST sensors

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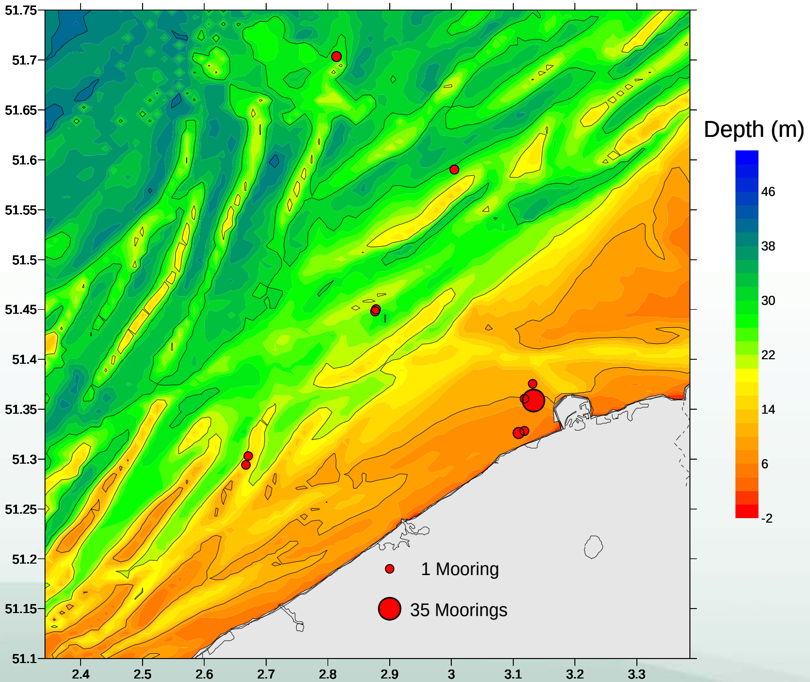
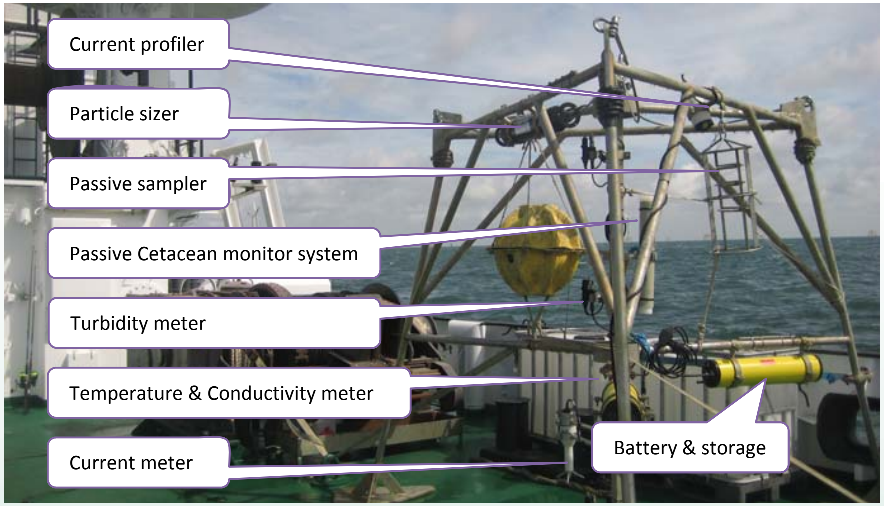
Data acquisition

- Tripod moorings BCS 2004 – today
  - >80 moorings, >2000 days of data
  - Oceanographic sensors
    - ADP, ADV – current meters
    - CT-sensor – temperature, salinity
    - Optical (OBS) and acoustic backscatter sensors (ADV, ADP) – SPM
    - LISST 100x – particle sizes in suspension
    - C-POD – passive cetacean monitoring
    - Passive sampler – chemical monitoring

Data acquisition

- Tripod moorings BCS 2004 – today





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Acoustic Backscatter Sensor

- 2013: Acquisition of new sensor:
- Aquatech’s AQUAscat 1000s
  - Survey model
  - 4 integrated transducers
  - 0.5, 1, 2 and 4 MHz

Observation Methods

Basic Principles and Background

Time series and comparison with OBS and LISST

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Observation Methods

Function \ Collection Method	Manual	Pump & traps	Turbidity	Laser	**Acoustics**
Flexible Sampling	No	No	Yes	Yes	**Yes**
Maintenance	Low	High	High	High	**Low**
Effect of Bio-fouling	Low	Low	High	High	**Low**
Online Capability	No	No	Yes	Yes	**Yes**
Unattended operation	No	Yes	Yes	Yes	**Yes**
Profiling	No	No	No	No	**Yes**
Reference Samples	No	No	Yes	No	**Depends**

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Basic Principles

Transducer transmits pulses of ultrasound equal in length to the bin: e.g. 13.33 s approximately equivalent to 1 cm bins

Sound waves travel through water

Sediment in water scatters sound, which is picked up by transducer. Different size sediment scatters sound more or less depending on frequency of sound

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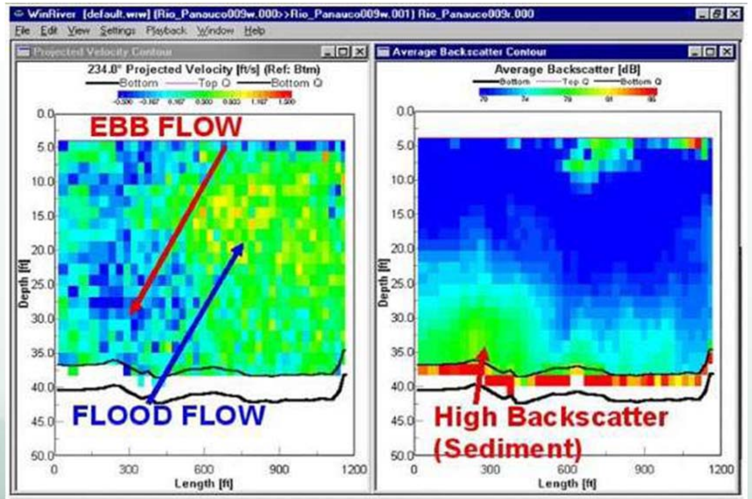
Acoustic Doppler Current Profilers

- Doppler velocity calculation needs strong backscatter signals
- Most DCPs provide backscatter intensity as a QC measure
- Backscatter strength can be used for *qualitative* assessment of suspended sediment concentration (previous work by SUMO team)



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Backscatter Equation

System constant

Measured signal

Range from transducer

$$V = \frac{k_s k_t}{r\psi}\sqrt{M}.e^{-2r\alpha}$$

Attenuation

Mass concentration

Range modification factor

Form function [f(size, frequency)]

$$k_s = \left(\frac{F_m}{\sqrt{a_s\rho_s}}\right)$$

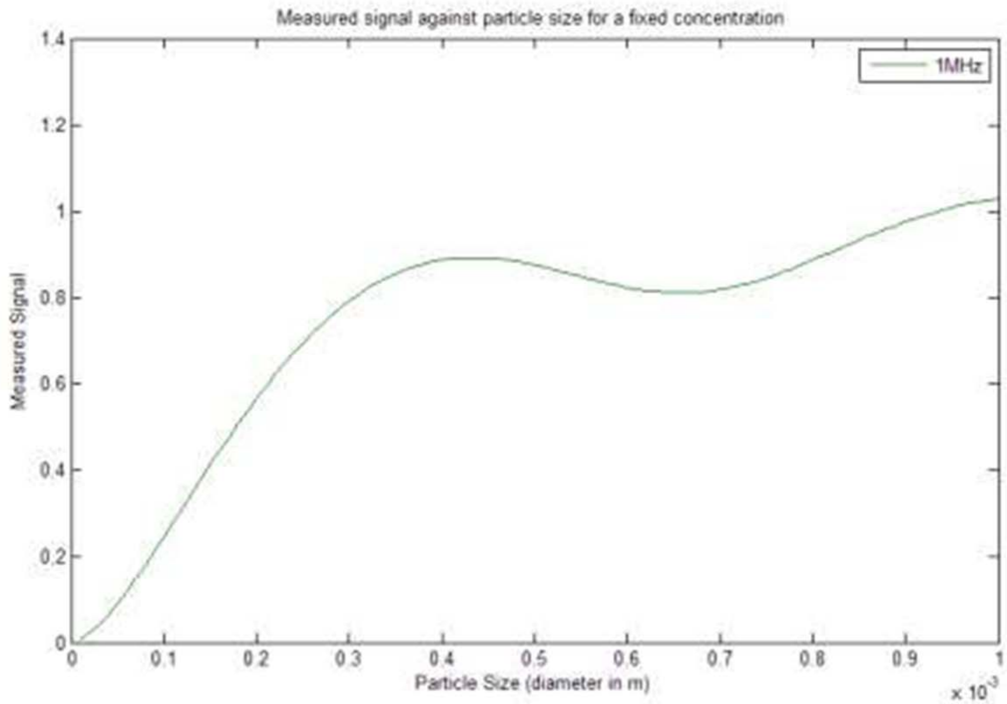
Mean sediment radius

Sediment density

Thorne and Hardcastle, 2002

Single Frequency limitation

- Measured signal varies with particle size
- Requires physical samples to be taken



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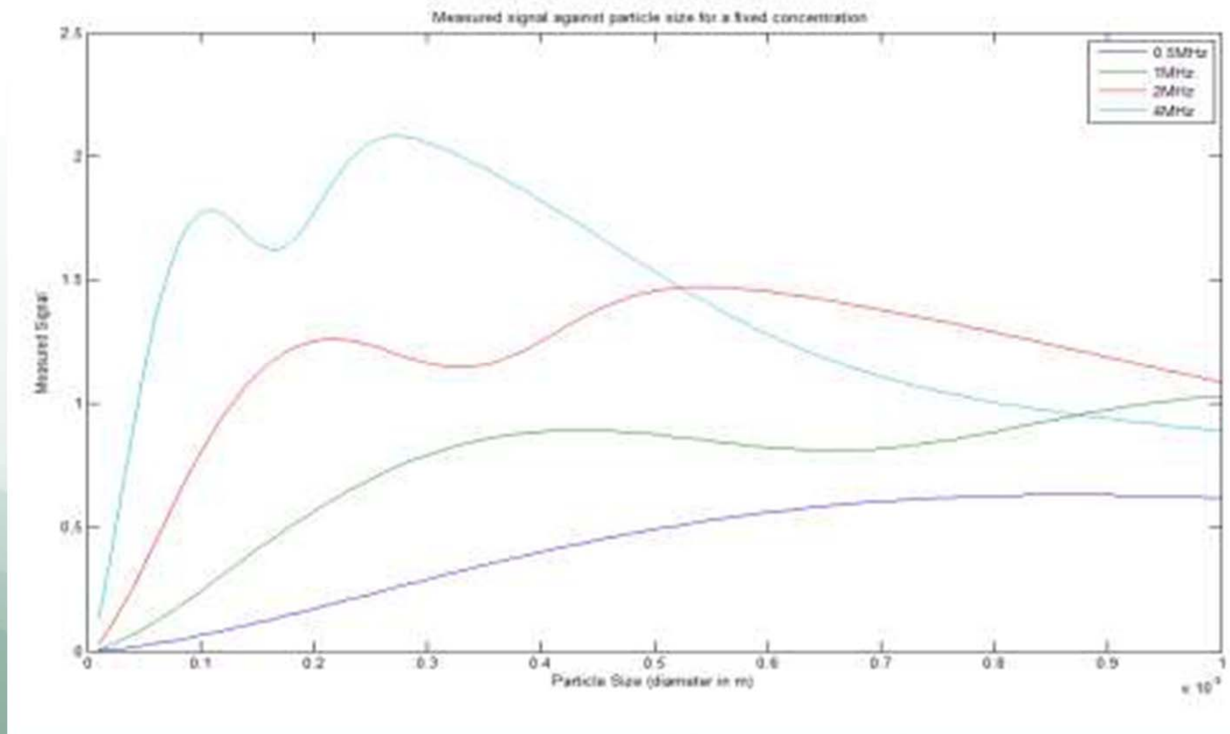
Multiple Frequency Benefit

- Use the size dependent response to different frequencies to determine particle size.
- Calculate concentration using particle size information



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Calibrating the sensor

- Calibrate to calculate k_t
- Performed at manufacturer's lab
- Tank typical Ø 0.4 m by 2.1 m
- Water and sediment re-circulated
- Homogenous mixture of sediments
- Pump sampled data at 60 cm
- Average 3600 profiles

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ABS to SPM conversion

- Explicit Method
  - Requires mean particle size to be known and constant over profile
  - Use for fine sediments outside multi-frequency range
  - Use when only one frequency is available for inversion
- Implicit Method
  - Estimates particle size profile from multiple frequencies
  - Use when multiple frequencies are available for inversion
- Direct Calibration
  - Requires known mean particle size and concentration at a given range and time to allow calibration of instrument in situ
  - Use when accurate samples are available and as a cross check

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Implicit Inversion

- Multi-frequency inversion of grain size & concentration
- Requirements
  - Minimum and maximum mean grain size
  - Calibration coefficients (k_t) supplied with instrument
- Other input variables
  - Environment for speed of sound (C, T, D)
  - Sediment grain size distribution
- Algorithm
  - For each range cell, search for mean grain size using backscatter ratios of all selected frequency channels
  - Calculate suspended sediment concentration using the chosen mean grain size
  - Use calculated concentration to calculate attenuation (α) for subsequent cell
- Output
  - Profile time series of mean grain size (µm) and concentration (g/l)

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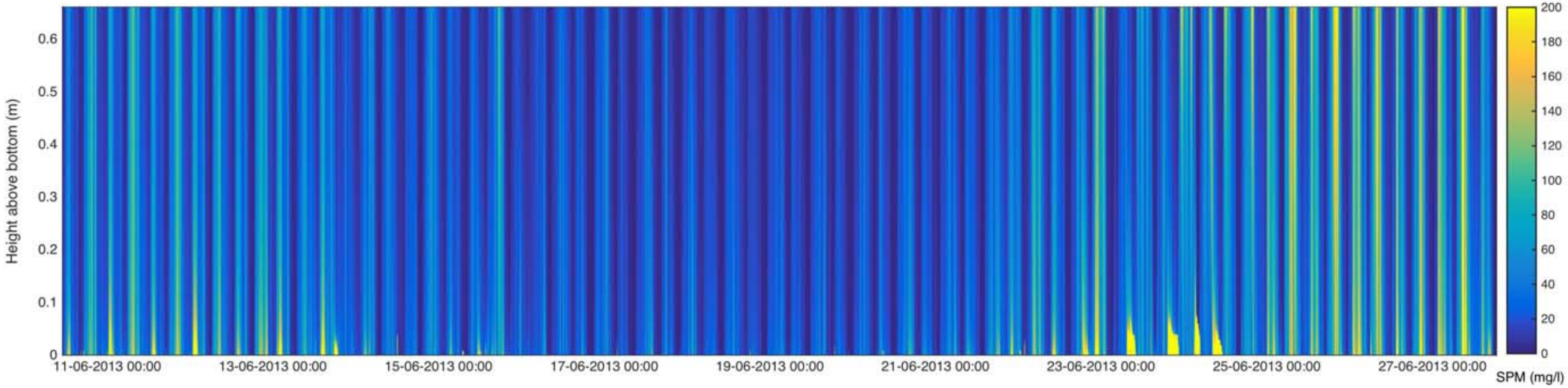
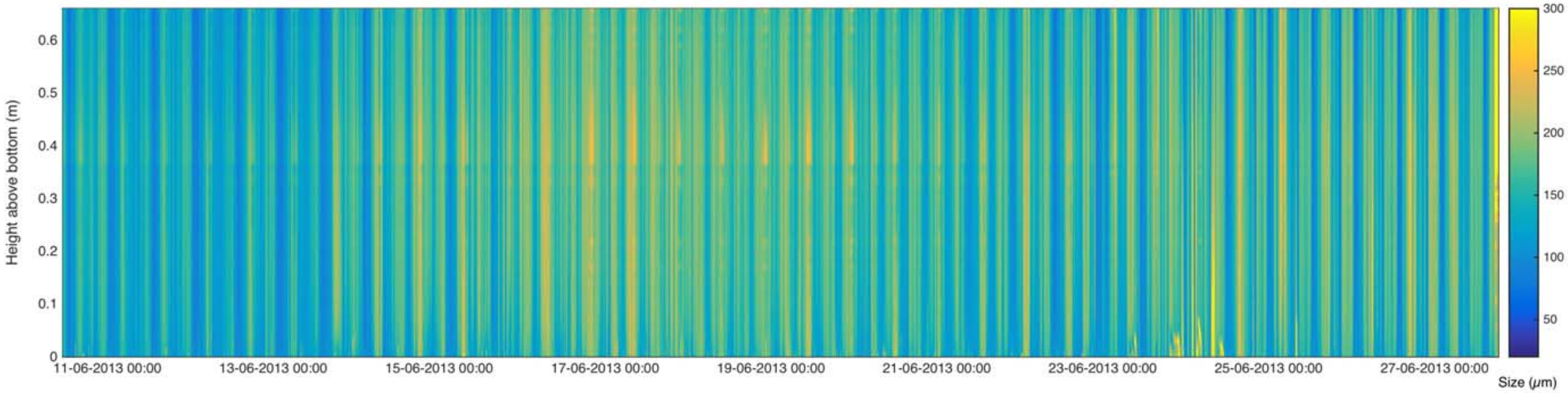
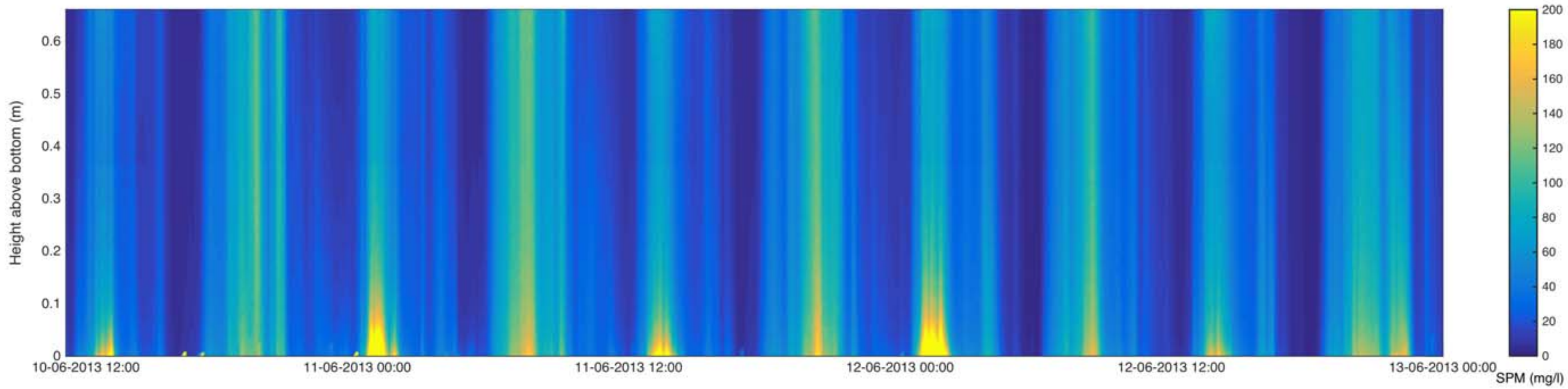
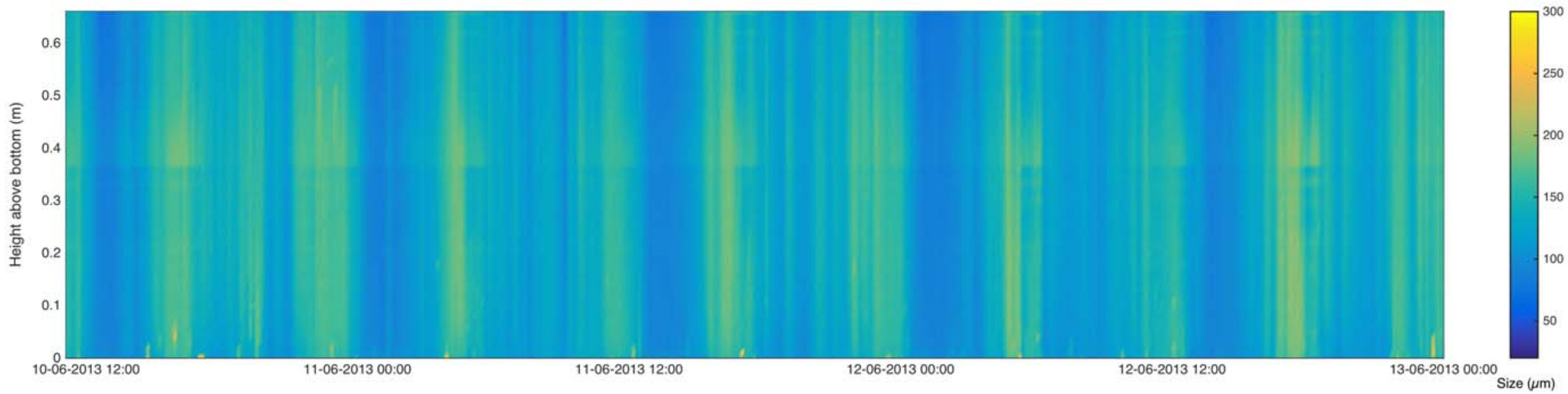
June 2013 mooring



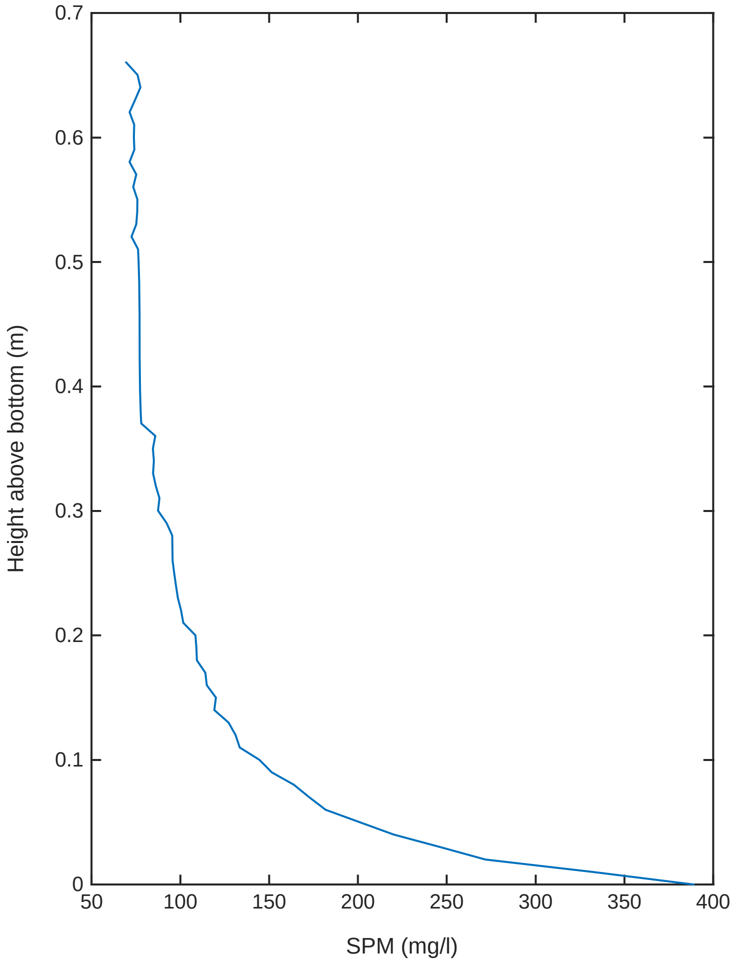


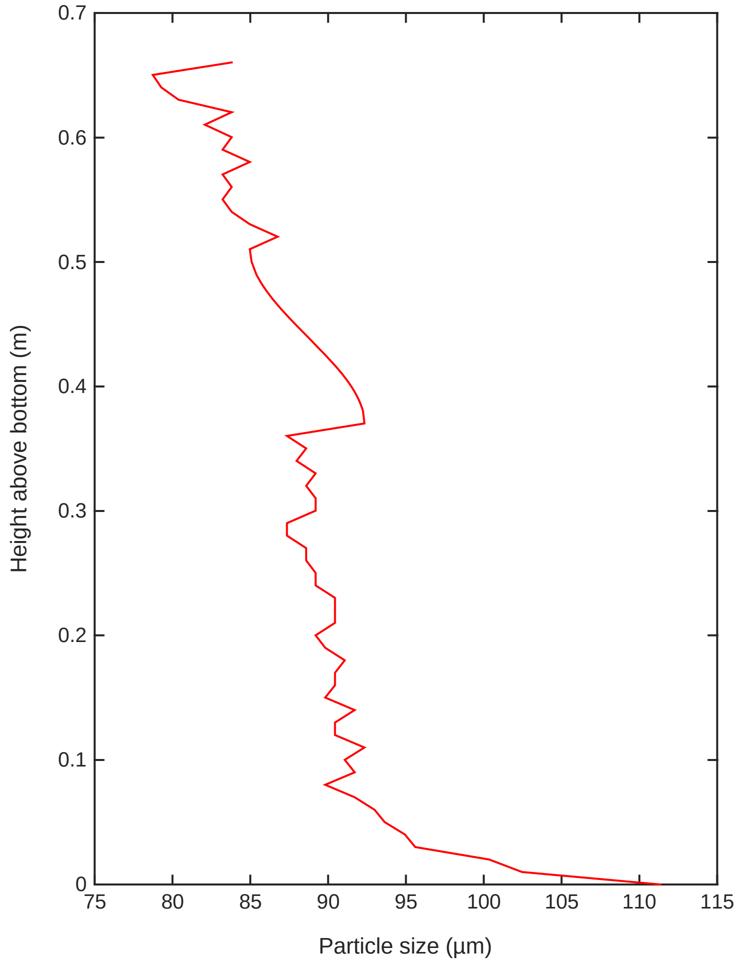
June 2013 mooring



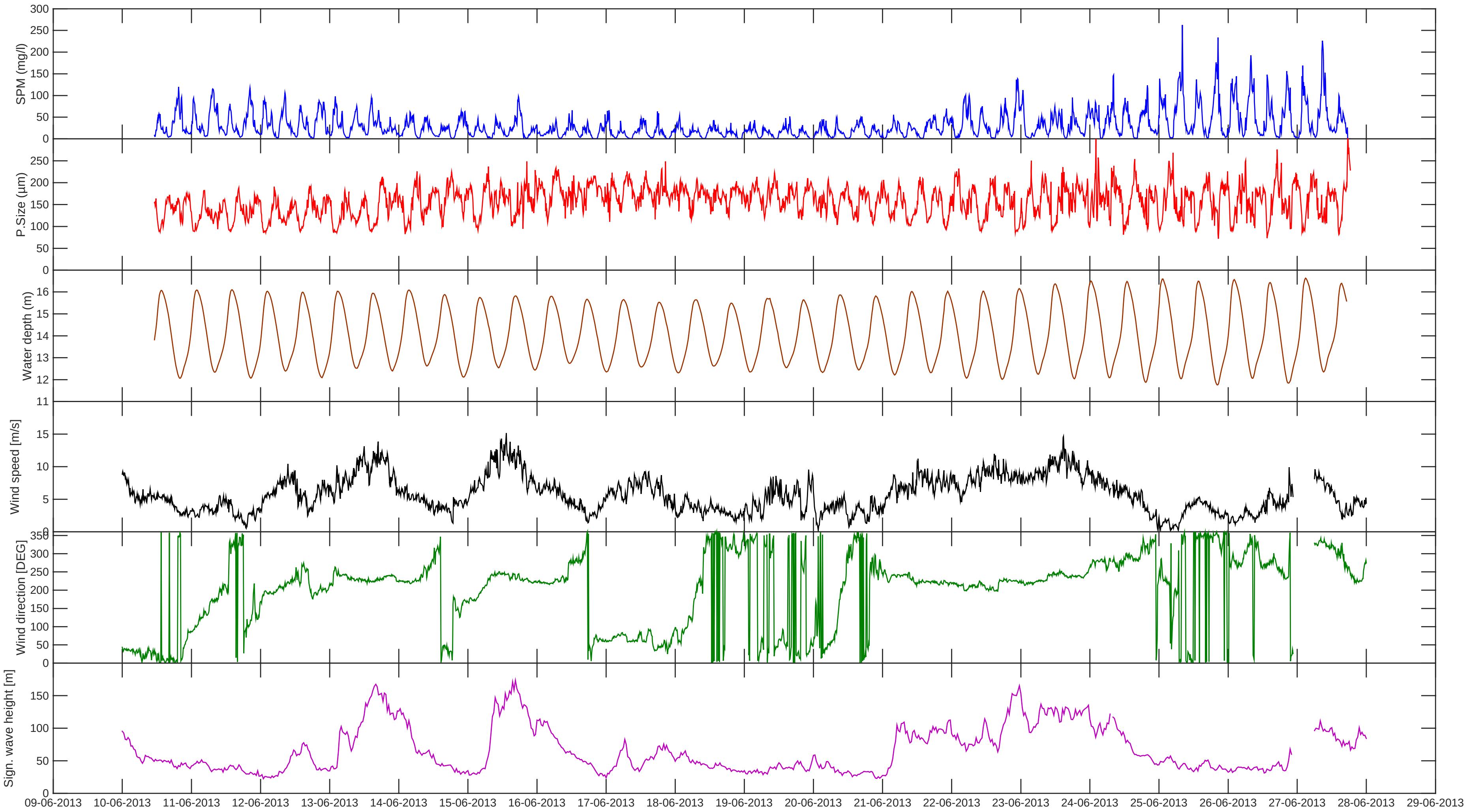


ABS profile


Height above bottom (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
50
100
150
200
250
300
350
400
SPM (mg/l)


Height above bottom (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
75
80
85
90
95
100
105
110
115
Particle size (µm)

ABS Time series



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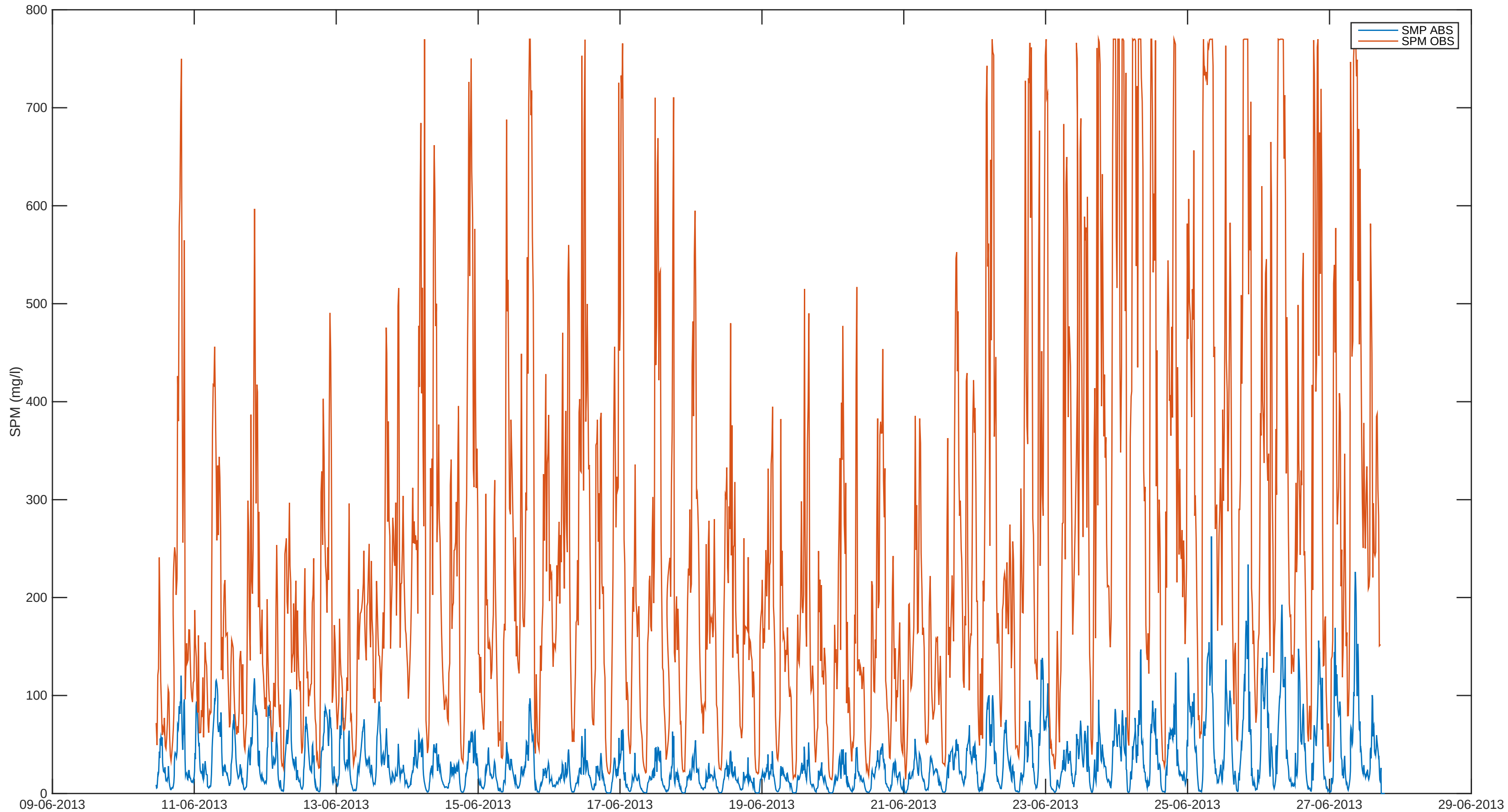
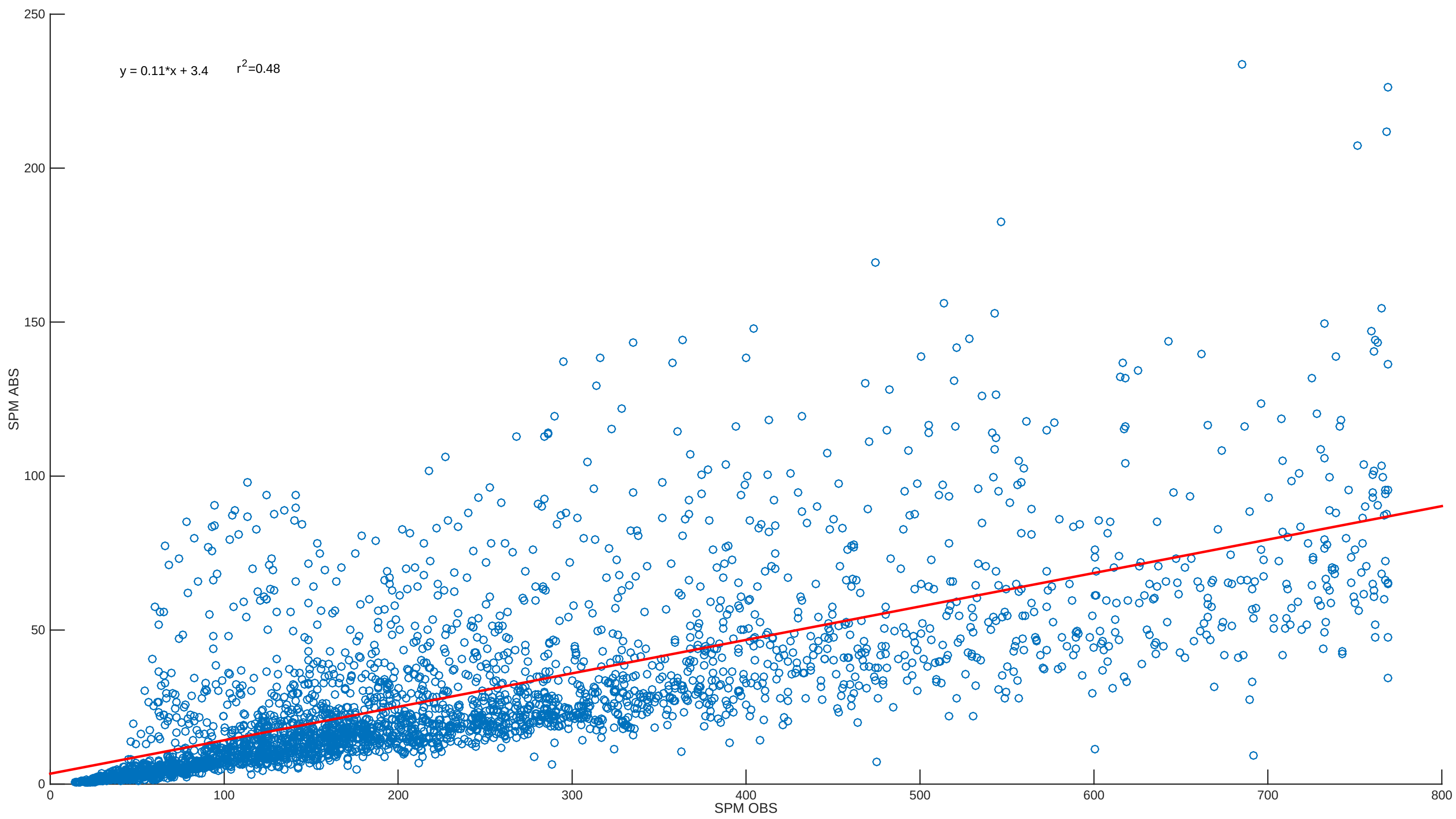
ABS vs OBS

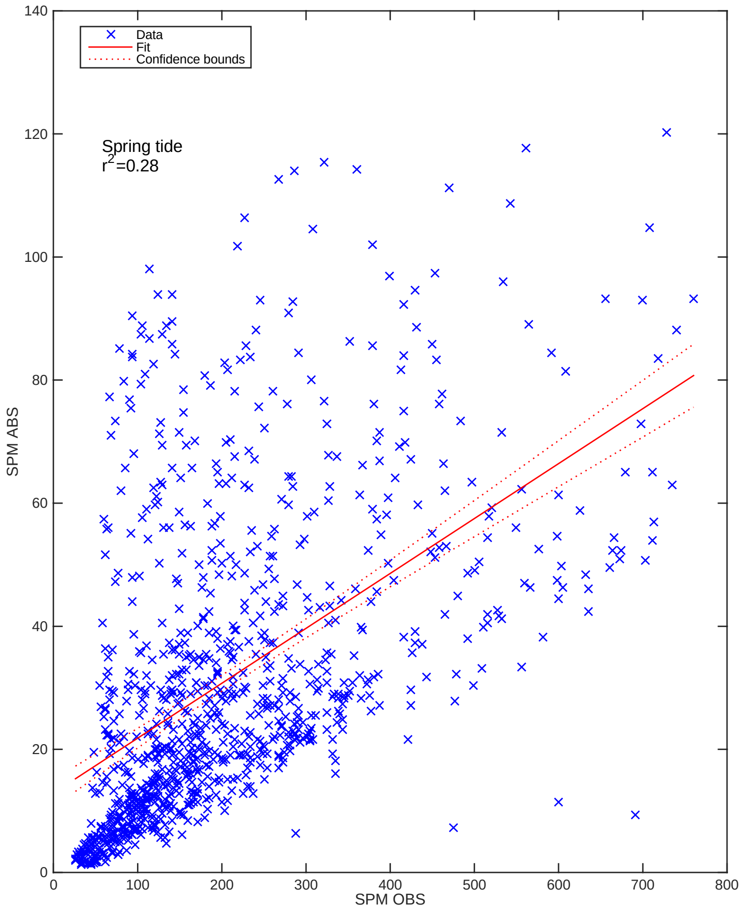


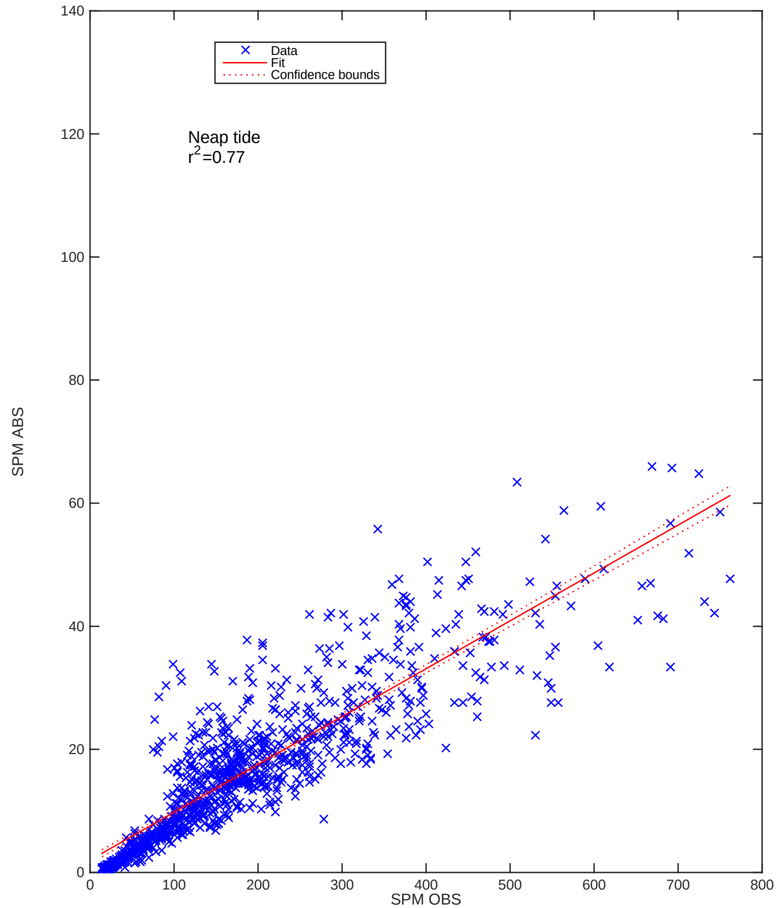
ABS vs OBS



y = 0.11*x + 3.4
r^2=0.48
SPM ABS
SPM OBS
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800

ABS vs OBS


Data
Fit
Confidence bounds
Spring tide
r^2=0.28
SPM ABS
SPM OBS
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800


Data
Fit
Confidence bounds
Neap tide
r^2=0.77
SPM ABS
SPM OBS
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800

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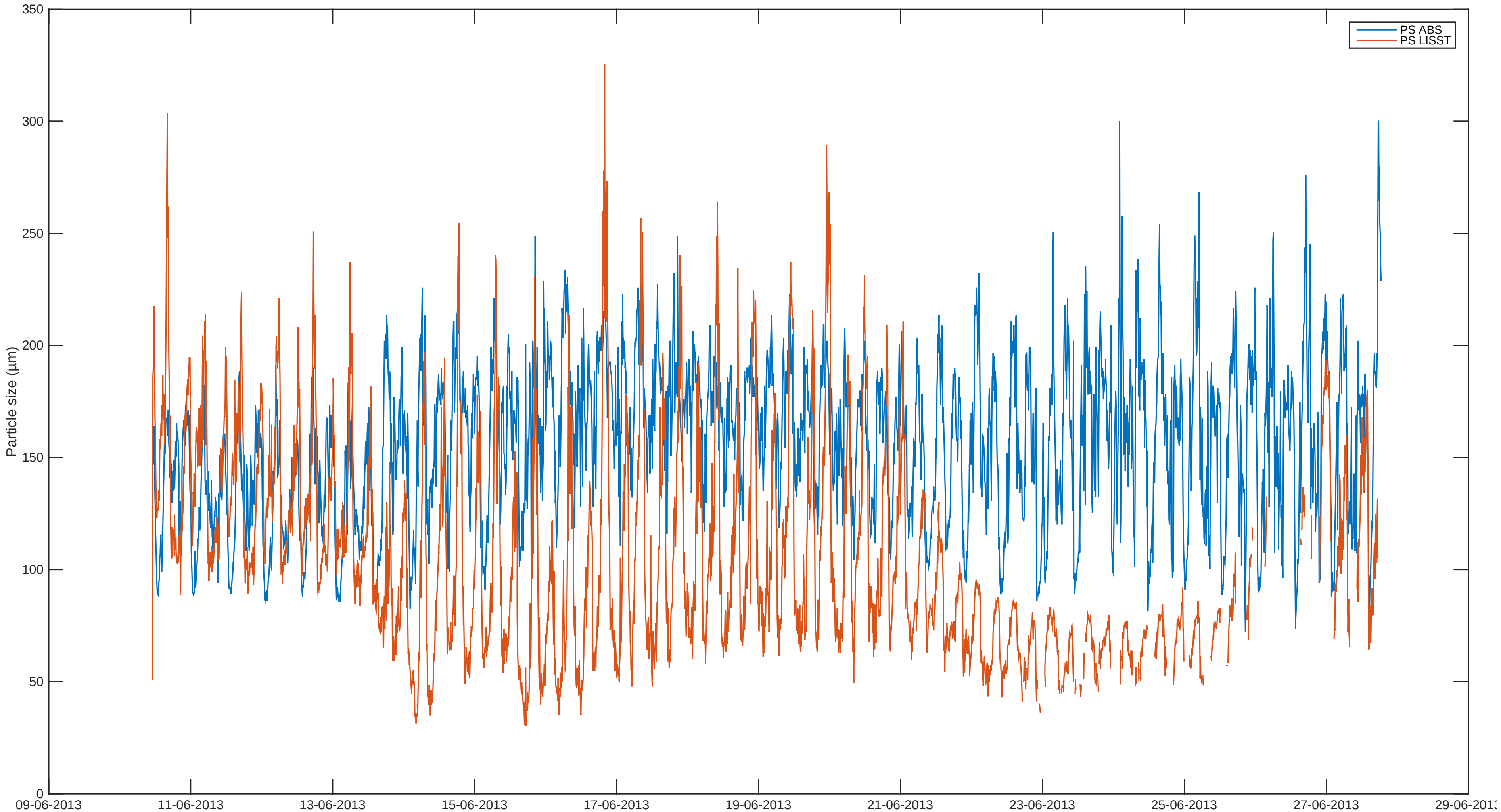
ABS vs LISST



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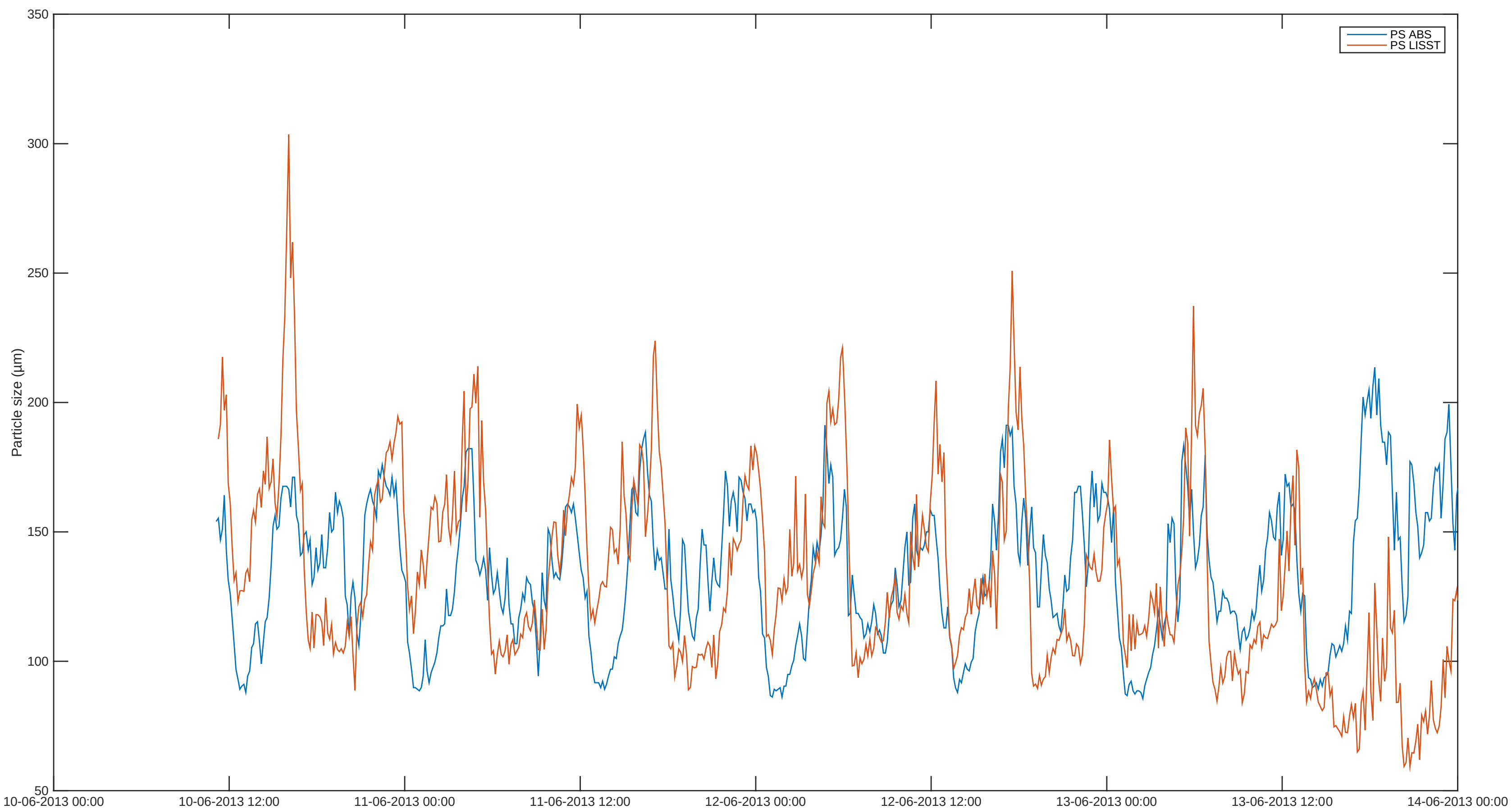
ABS vs LISST



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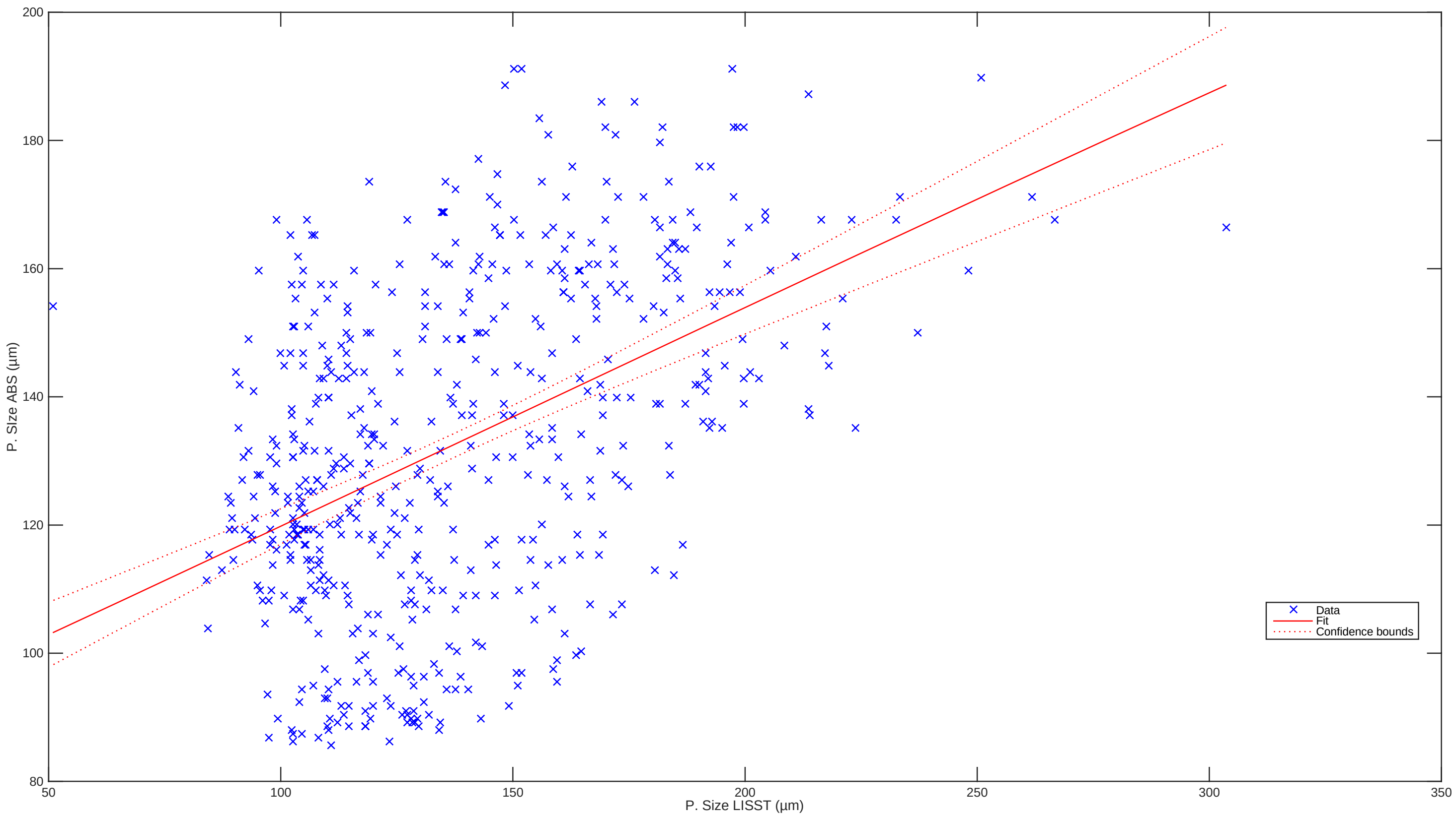

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Conclusions

- Promising technique
  - Discrepancy ABS ><OBS
    - ρ_s limited to sand and glass ballotini in current version of toolbox
    - Limited sensitivity ABS/OBS?
  - Discrepancy ABS >< LISST
    - LISST more sensitive to bio-fouling
    - 2m height difference

→More data needed

→in situ (13h cycle) and in lab comparison of sensors / calibration