Use of Digital Holographic Cameras to Examine the Measurement and Understanding of Sediment Suspension in the Nearshore

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COASTAL PROCESSES WITH PLYMOUTH UNIVERSITY

NATURAL ENVIRONMENT RESEARCH COUNCIL

PARTICLE IMAGING WITH PLYMOUTH UNIVERSITY

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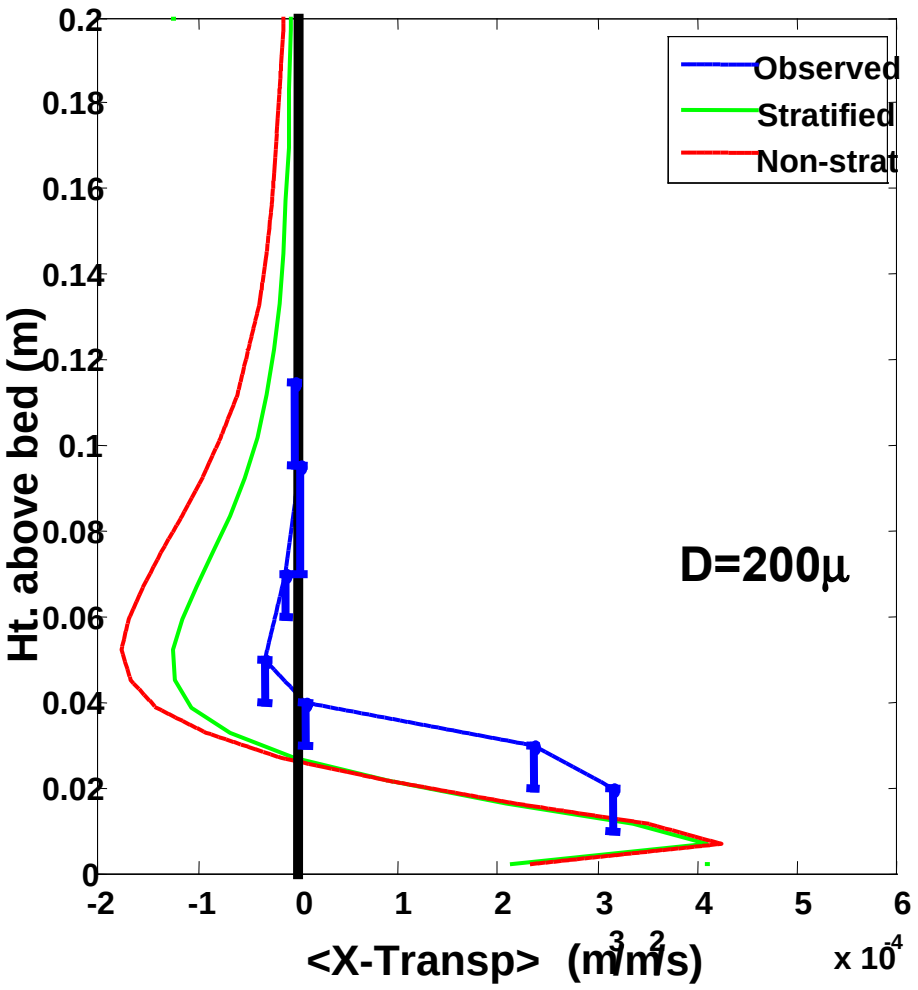
OUTLINE

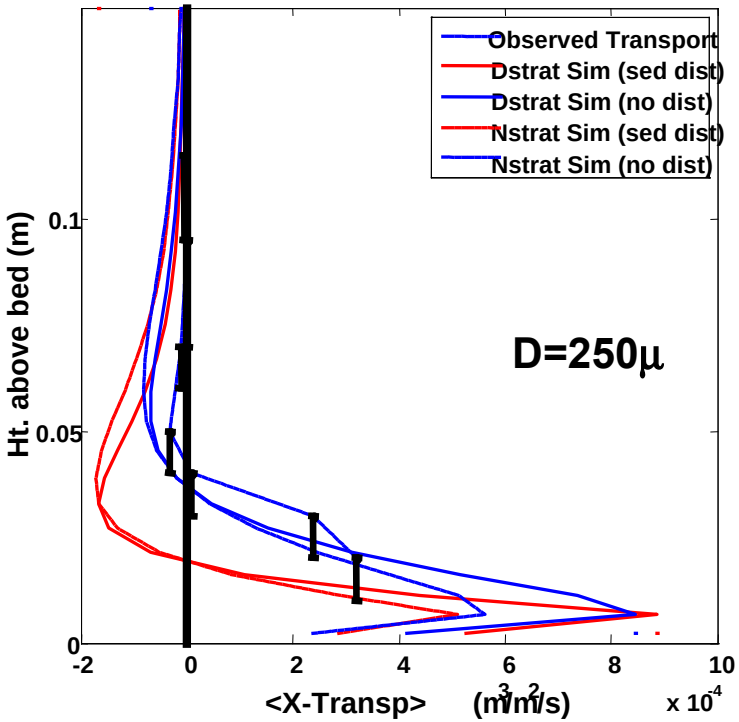
- Why suspended grain size important
- Praa Sands Experiment
- Technology
- Holo cam vs ABS comparison
- Grain Size Results
- Other Sensors
- Conclusions

Suspended Grain Size Importance

Study of suppression of turbulence by suspended sediment*

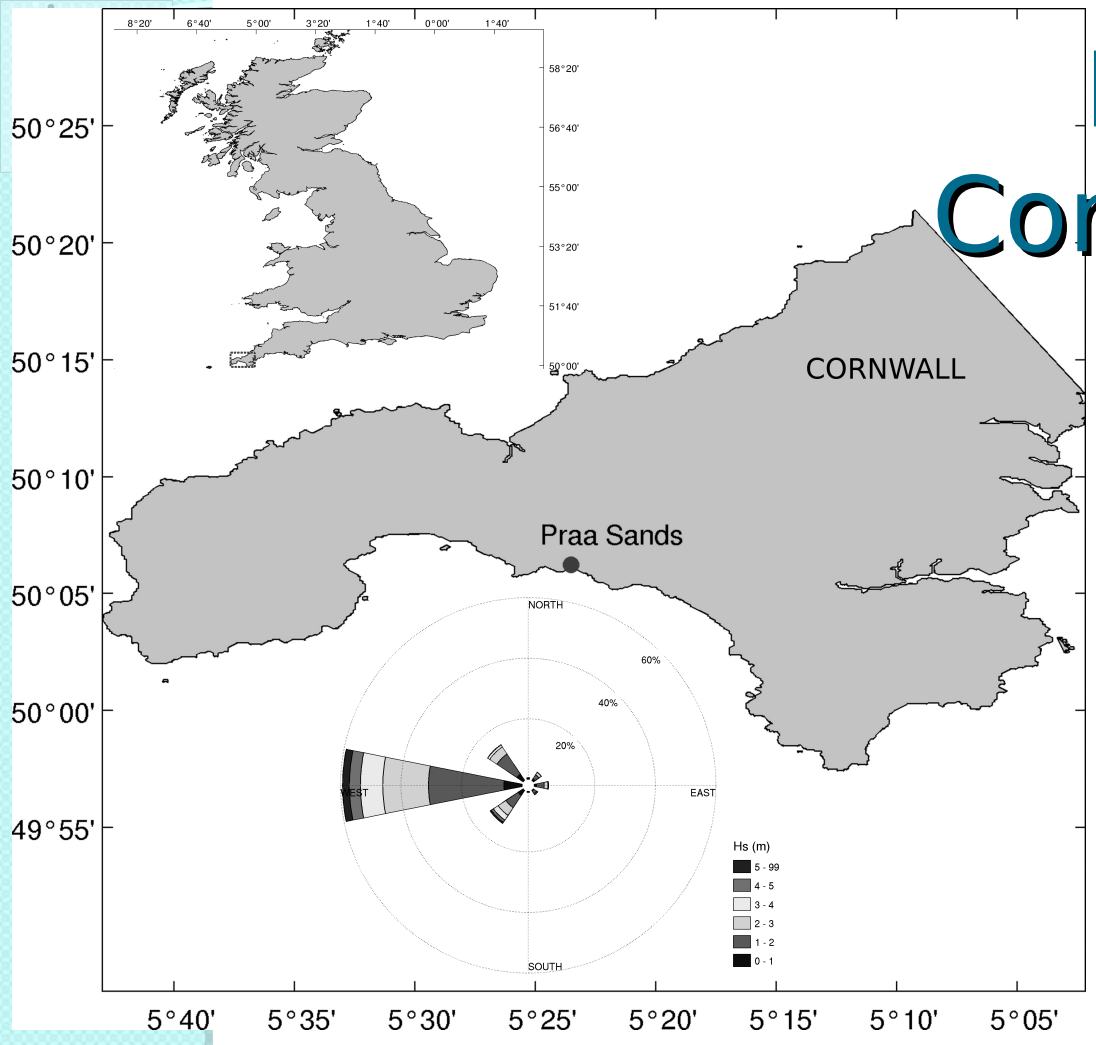


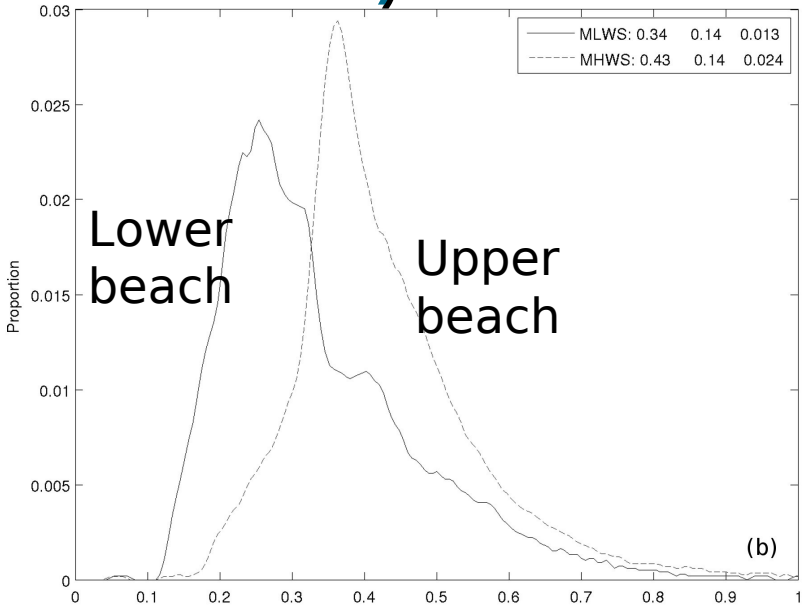
Effects of single grain size vs distribution

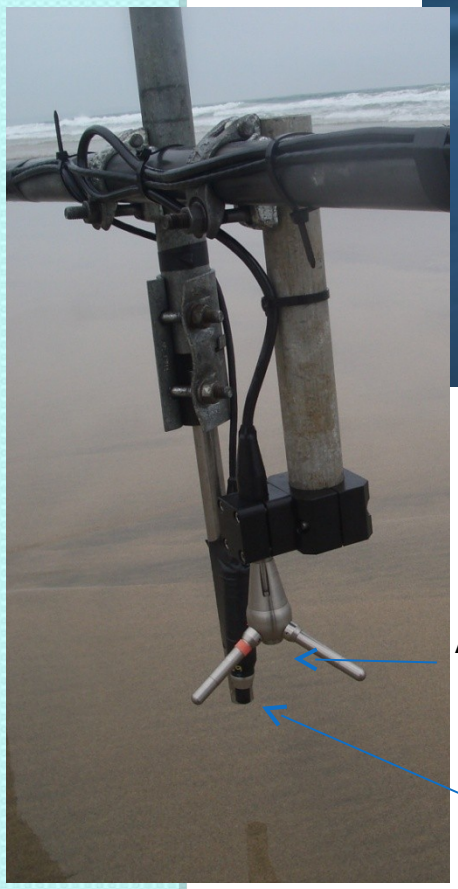


* Conley, DC, Falchetti, S, Lohmann IP & M. Brocchinin (2008), Jour. Fluid Mech. V. 610, pp

Praa Sands Experiment Cornwall, UK (May 2011)

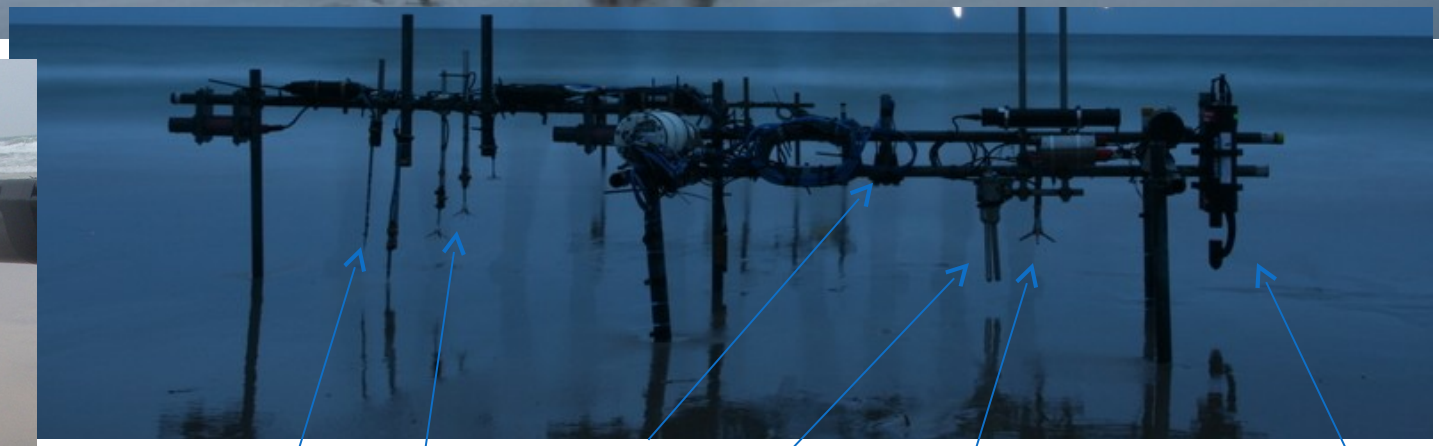






ADV (backscatter)

OBS



FOBS Vectrinos ABS Holocam ADV (backscatter) LISST-Holo

Co-located acoustic backscatter sensor (ABS) and Holocam, plus other measures of SSC from FOBS, ADVs and OBSs

13 separate instruments for SSC located within +/- 10ml

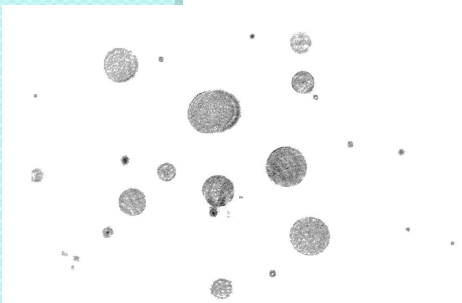
Particle Holography I

First deployment of holographic camera in surf zone - able to quantify relative abundance of sand, bubbles and other particles, their size distributions and volumetric concentrations

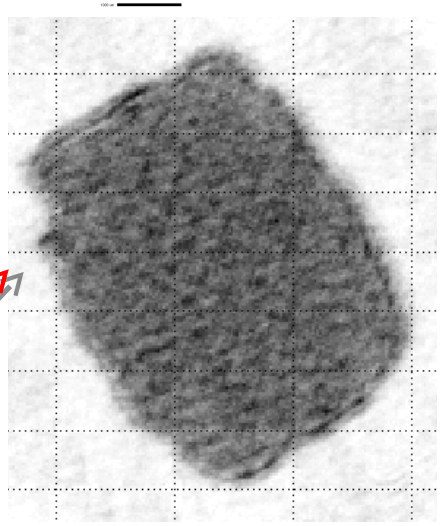
Particle Holography II

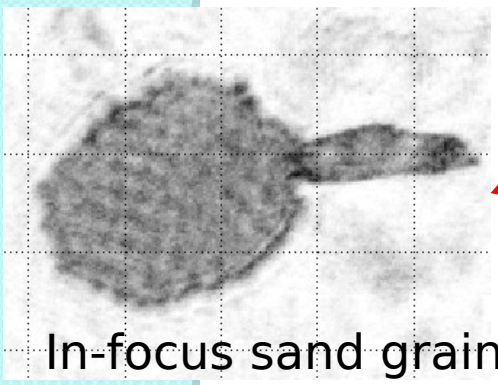
- Image of laser diffraction pattern is recorded at 5 Hz.
- Patterns can be refocused to provide original particle shape
- Shape information helps identify particle type
- Volume concentration available from equivalent sphere assumption

In-focus diatom chains

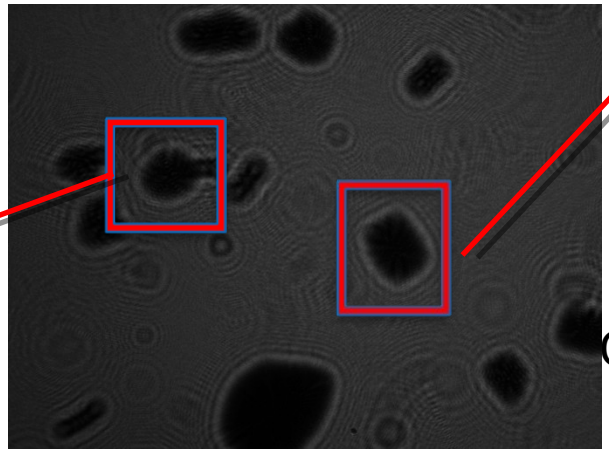


In-focus bubbles





In-focus sand grains



10cm above bed

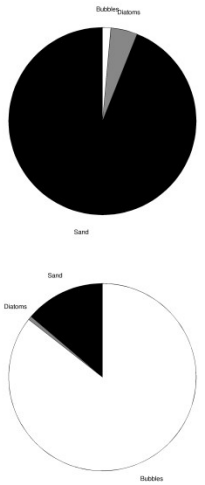
Graham & Nimmo-Smith (2010), Limnol. & Oceanog. Methods 8, 1-15

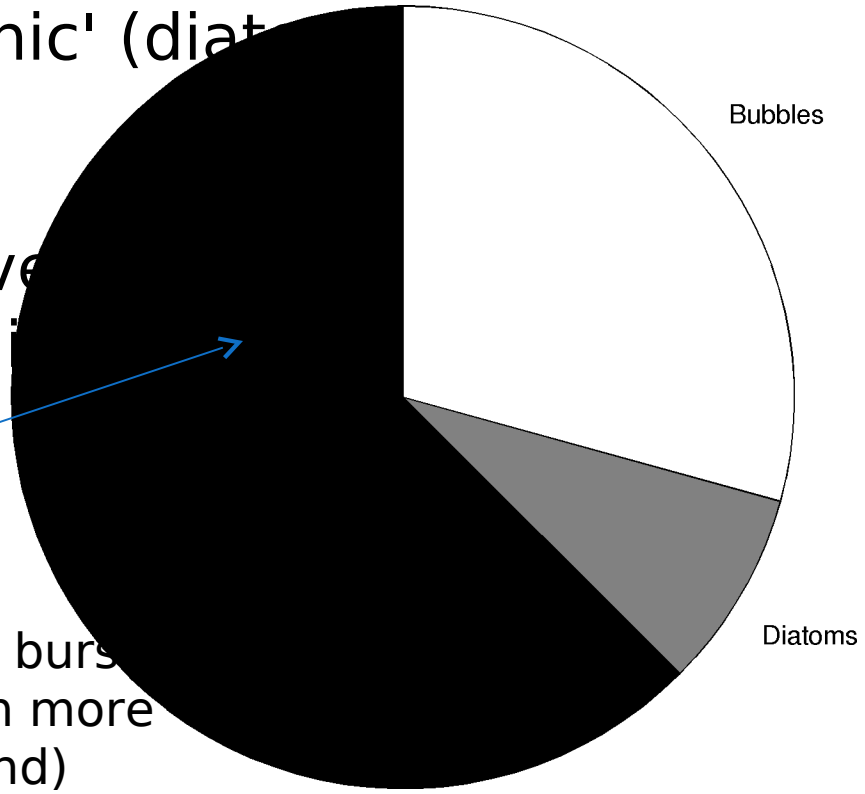
Image Analysis

- 11 bursts from a range of flow conditions (mobility number 30 to 150) and water depths 0.5 – 3m

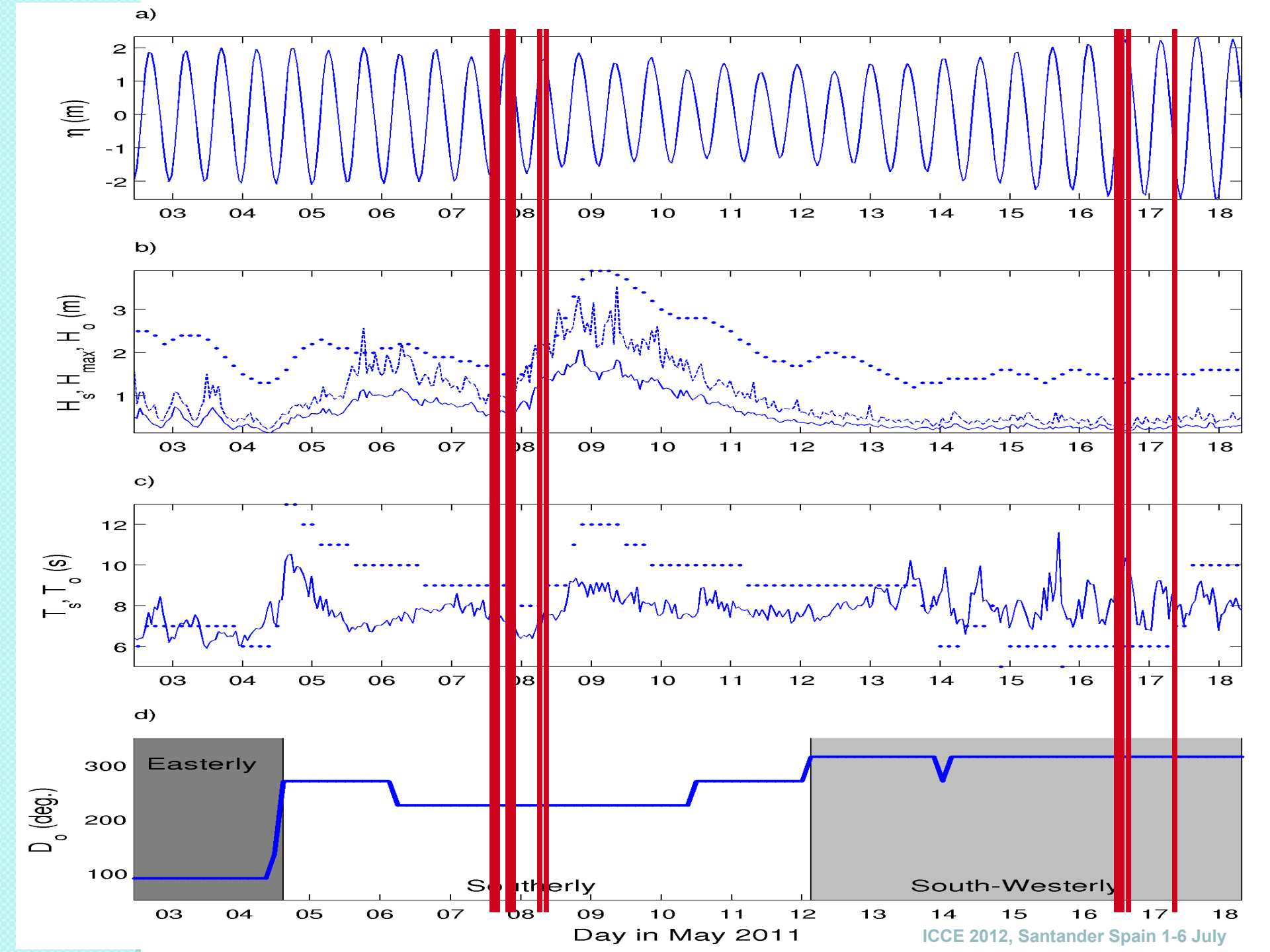
- Holographic images manually processed - each particle classified into 'sand', 'bubble', and 'organic' (diat chains)

- Total of 2785 images have analyzed by hand, containi
15009 sand grains
1973 diatom chains
and 7032 bubbles

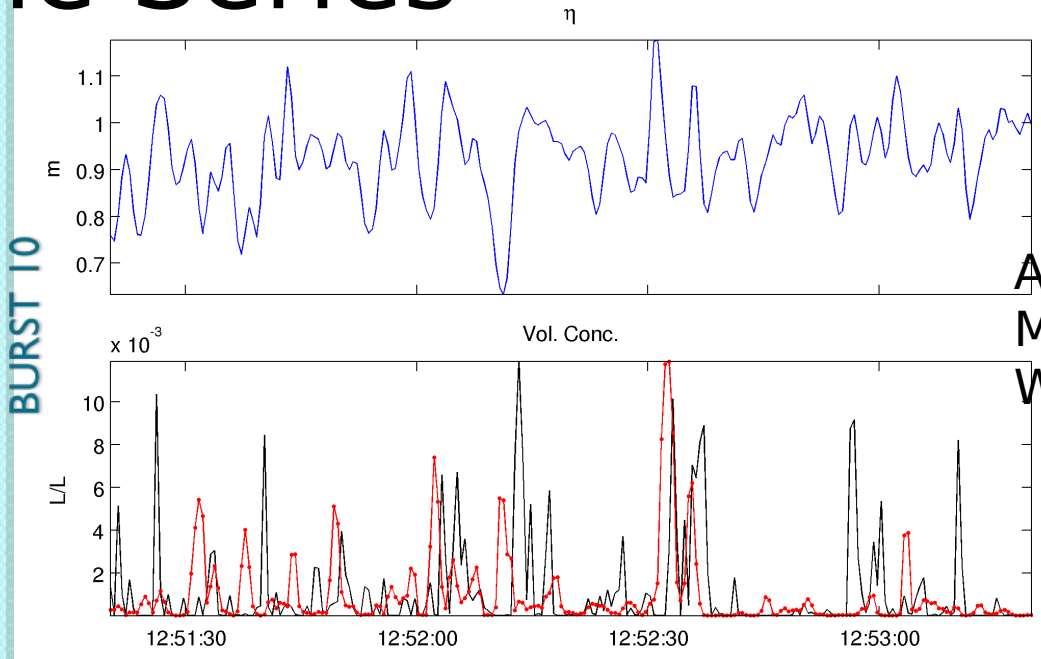




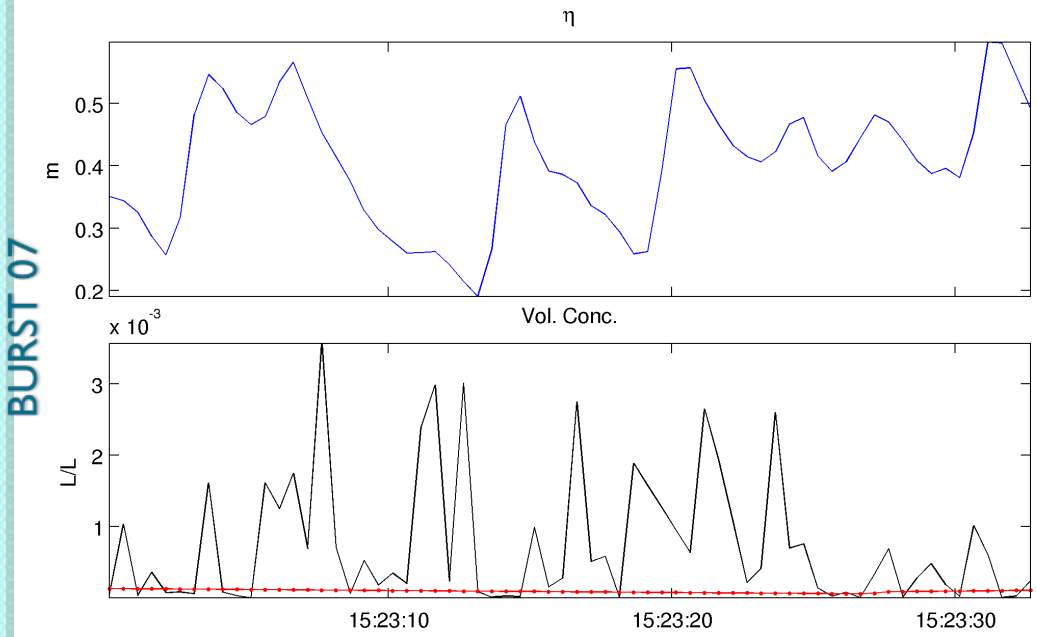
Relative abundance of
frequency based on 11 burs
(relative volumes much more
heavily weighted to sand)


a)
η (m)
b)
H_s, H_max, H_o (m)
c)
T_s, T_o (s)
d)
D_o (deg.)
Easterly
Southerly
South-Westerly
Day in May 2011

Time Series

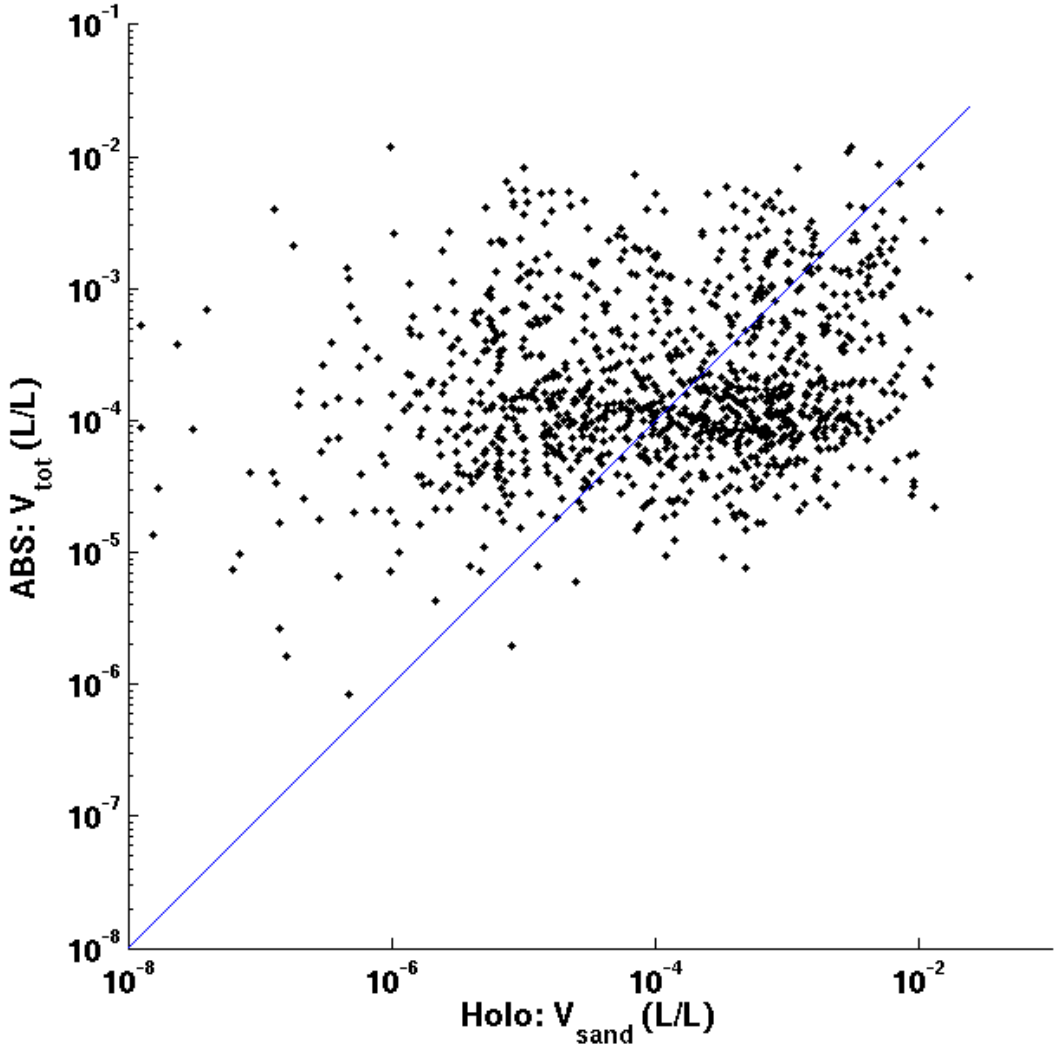


A 119s burst from tide 25
Mobility number: 47.07
Water depth: 0.92m



A 32s burst from tide 8
Mobility number: 141.07
Water depth: 0.42m

Instantaneous Comparisons

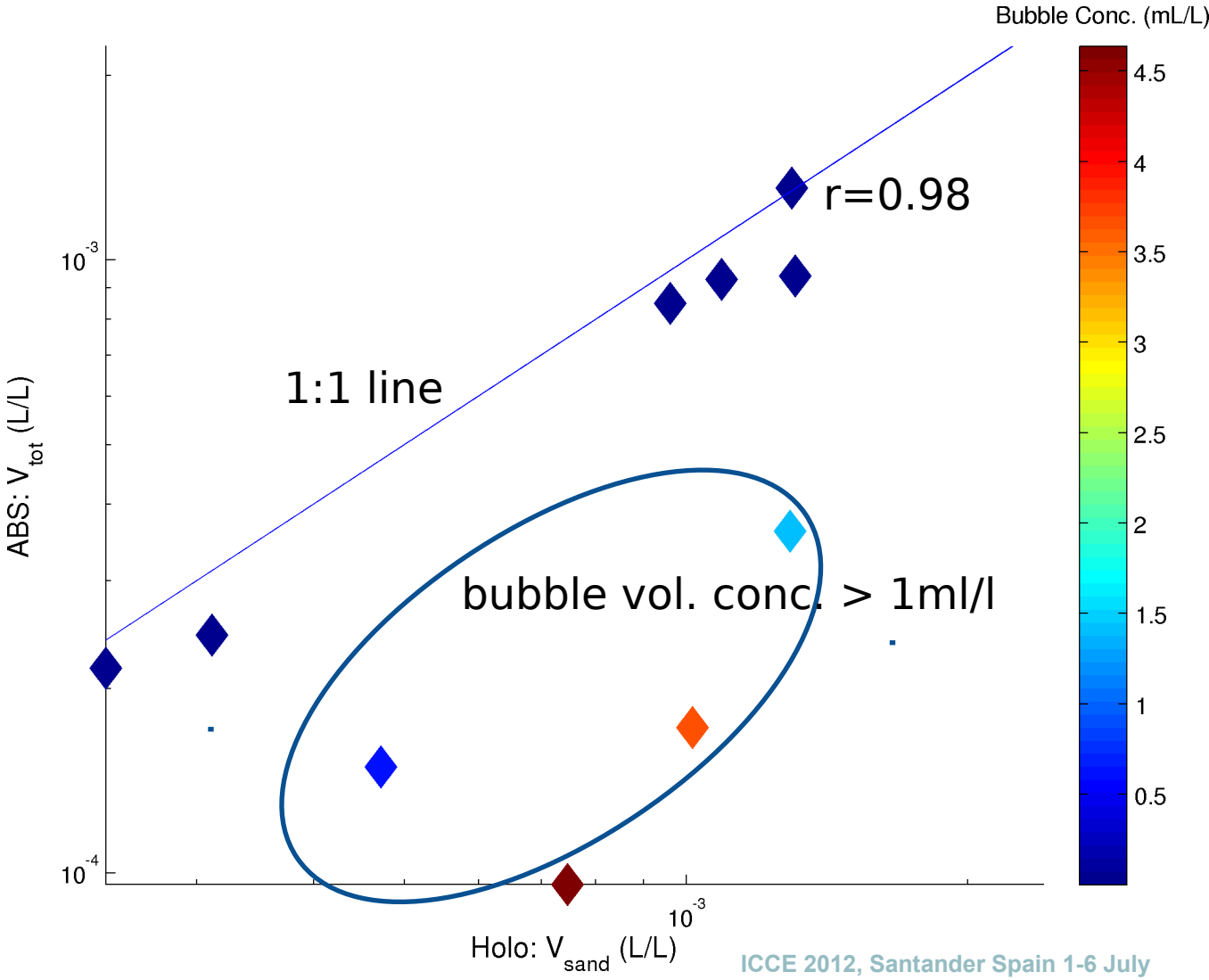


- Practically no correlation at 5 Hz (r=0.14)

Mean Concentrations

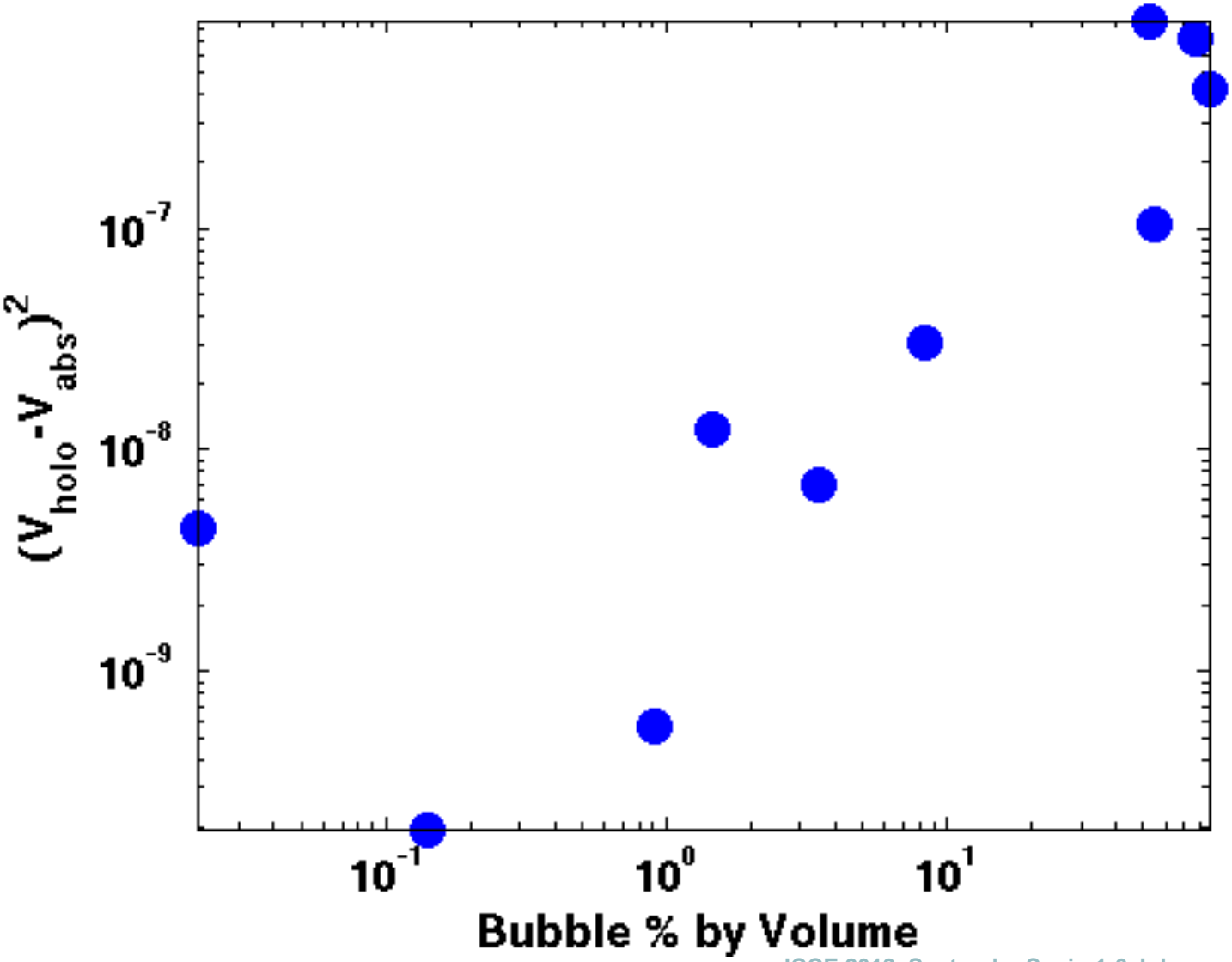
- Burst averaged data is very well correlated (r=0.87). Suggests that correlation length scale for instantaneous sediment < 3m.

- When bursts with bubble volume > 1 ml/l are removed, correlation increases to r=0.98



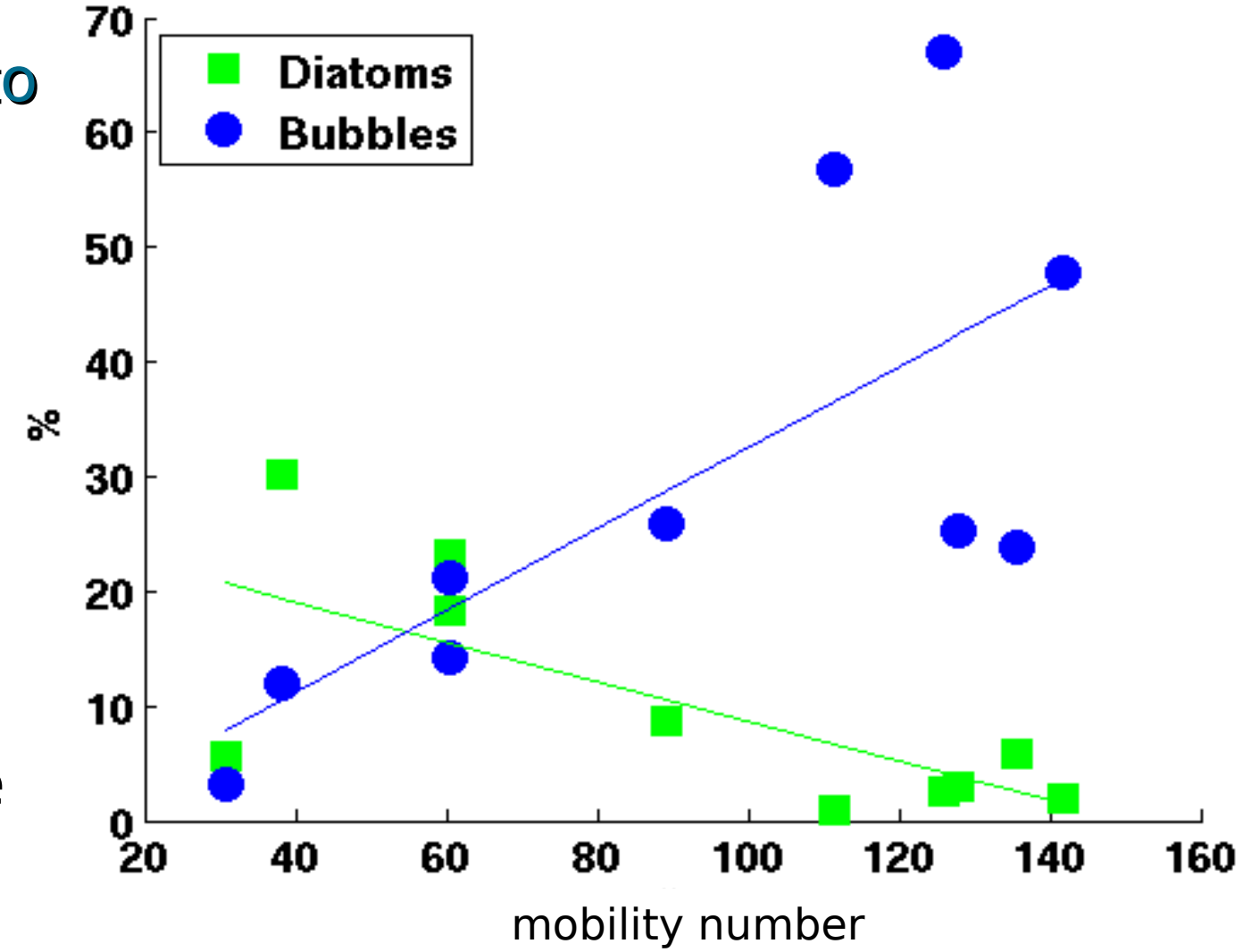
Error relation-bubble volume concentration

- Clear relation between bubble volume concentration and discrepancy.
- Relationship is clearly non-linear with higher bubble volumes negating sediment concentration measurem



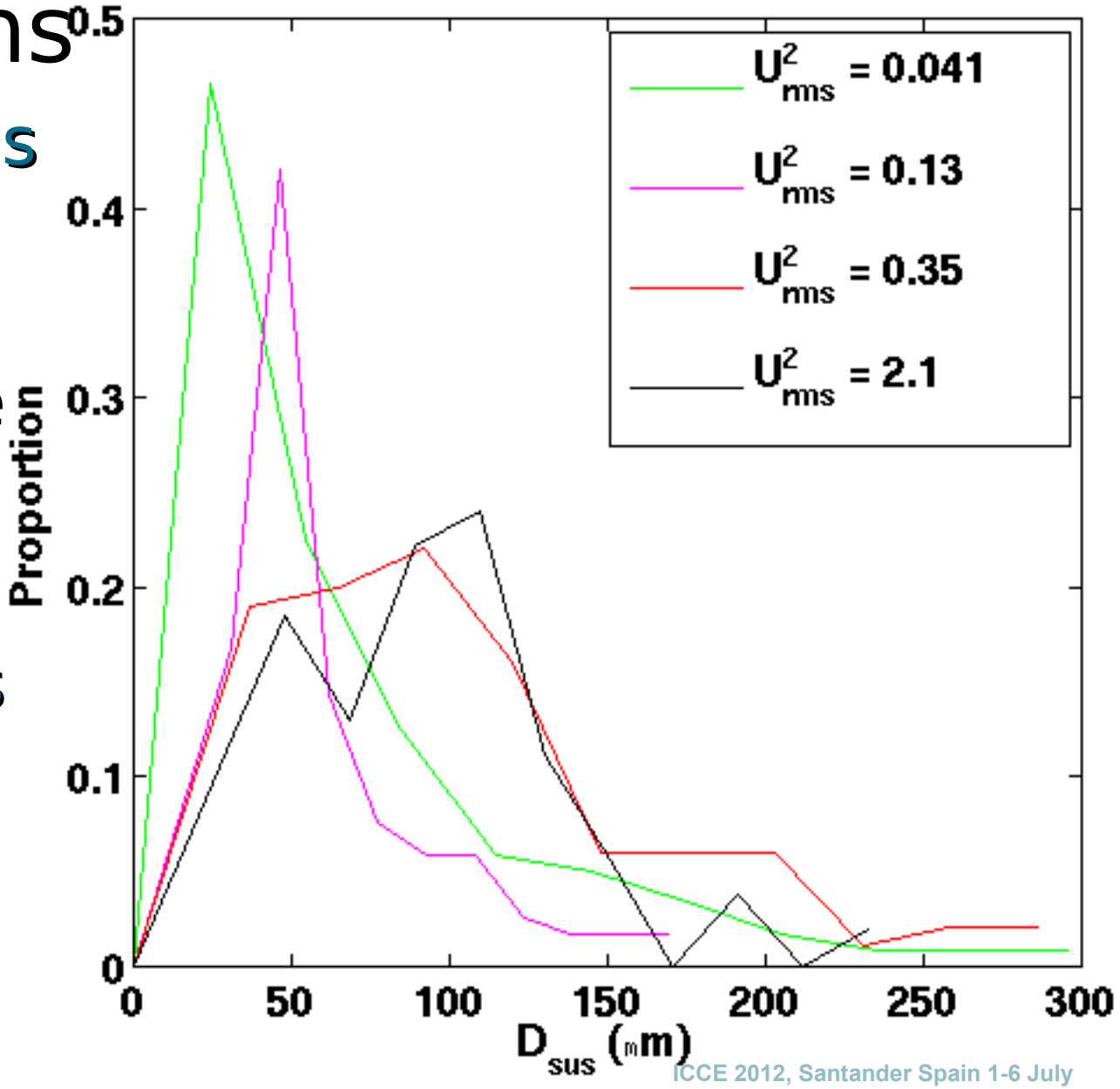
Relative Abundance Bubbles & Biology

- Bubbles proportional to mobility number
- Diatoms inversely related to mobility number.
- Bubbles relation same when compared to H/h.



Suspended Grain Size Distributions

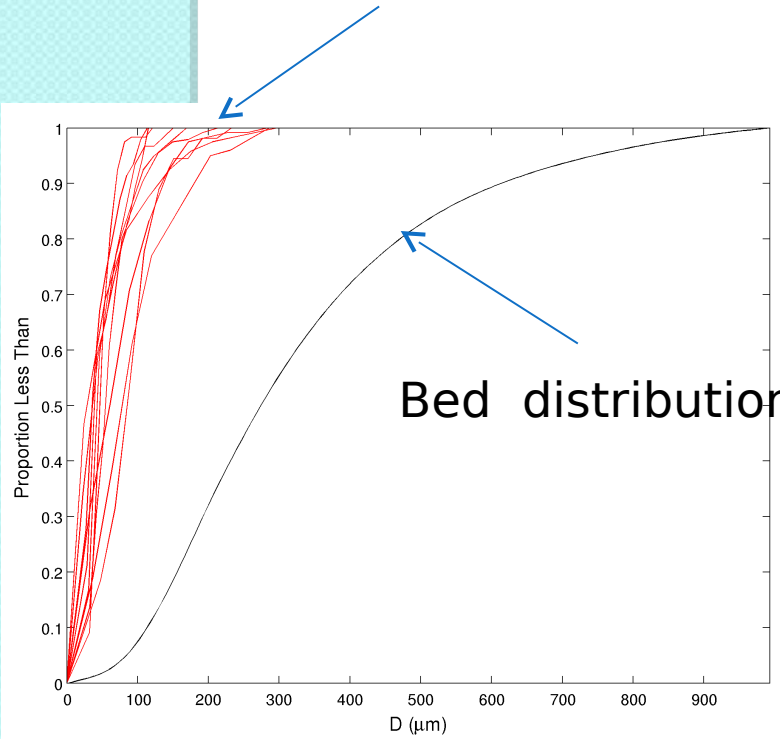
- Distributions in lower intensity flows biased towards fine grains
- Suspended distributions significantly finer than source material (10 cm above bed)

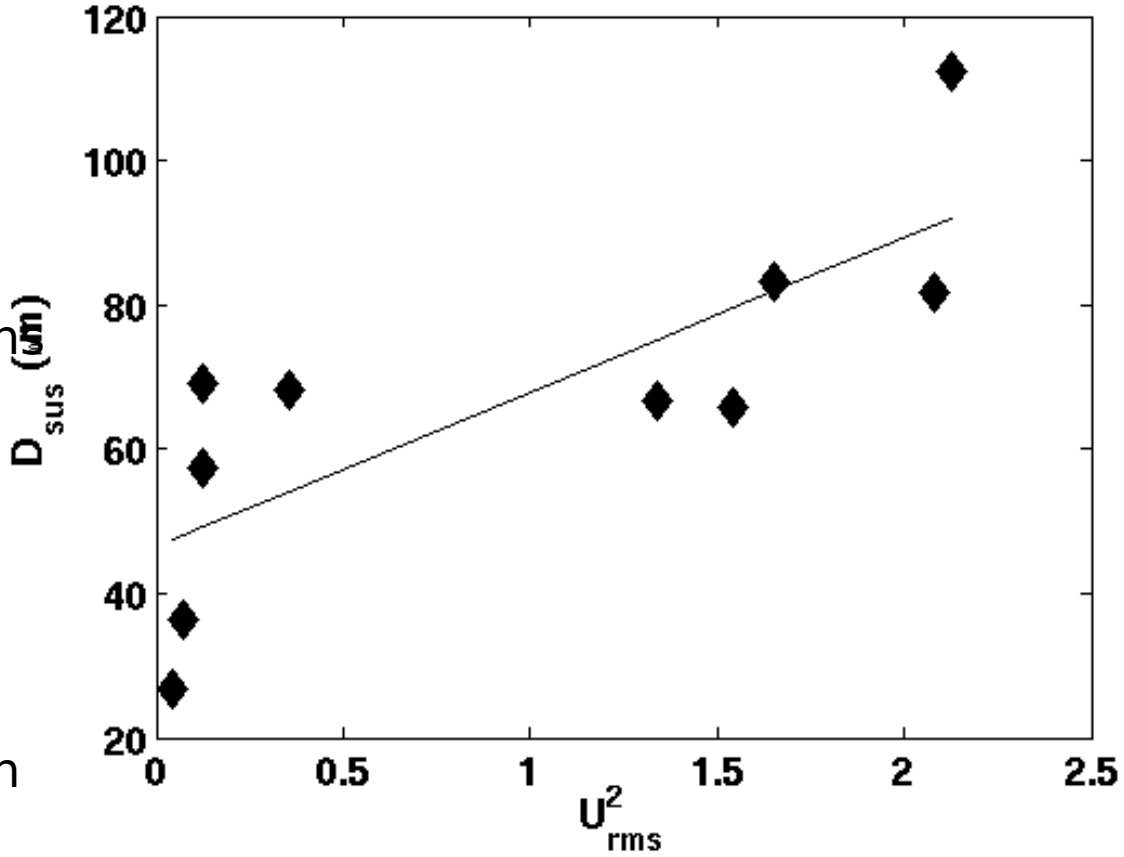


Mean Suspended Grain Size

As flow intensity increases, mean grain size increases.

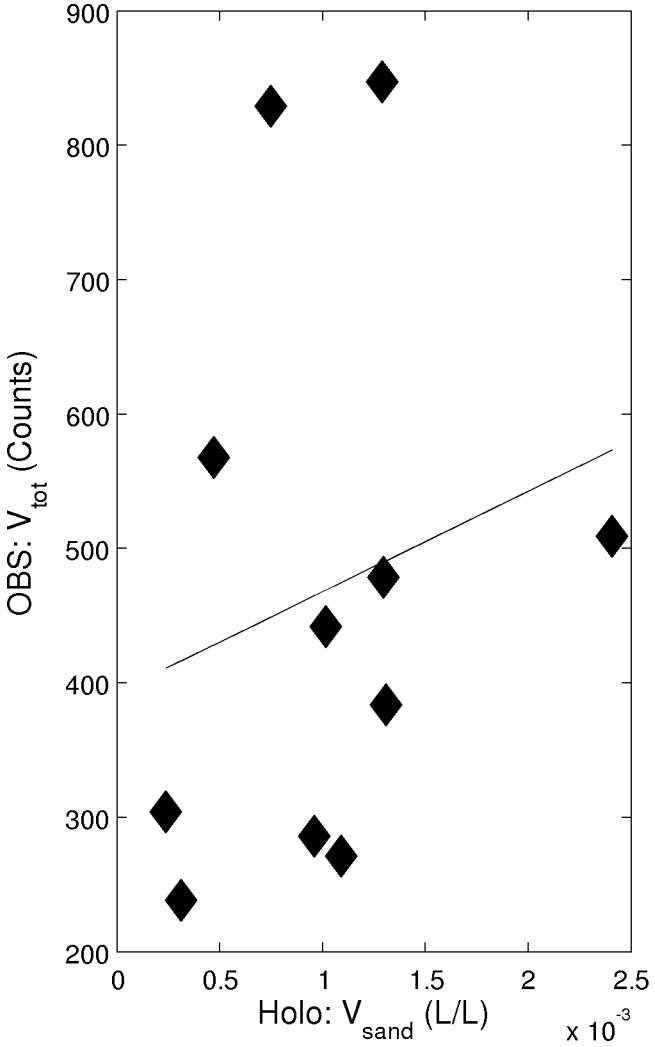
ze-distribution of suspended grain



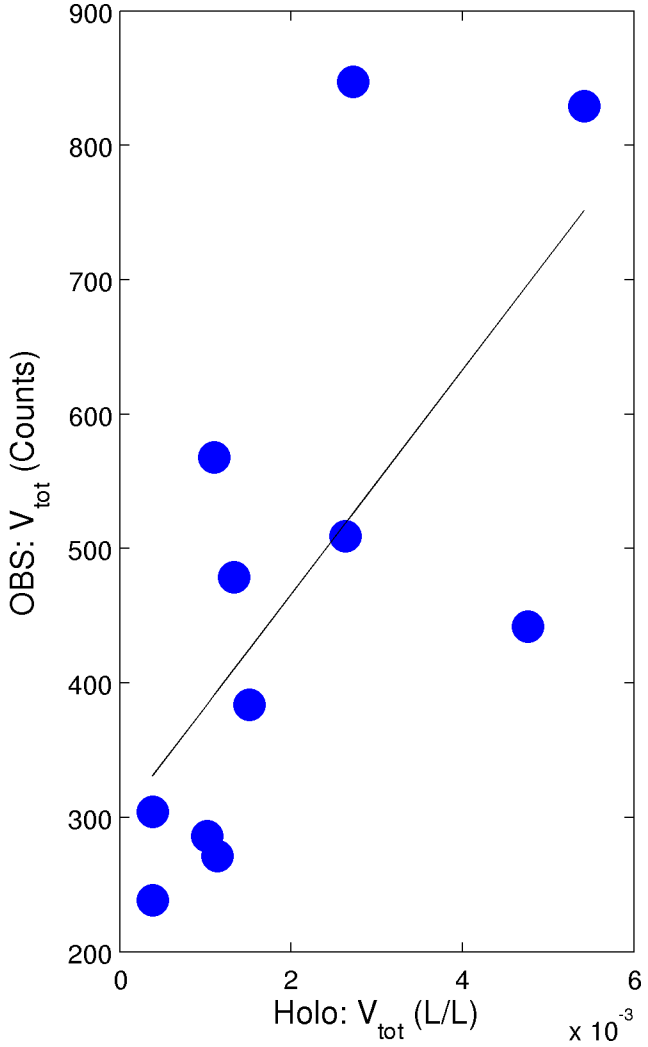


Holocam & OBS Comparison (10 m separation)

- Correlation between OBS & Holocam derived sand C low (r=0.22)
- Sand+bubble_diatom concentration better correlated (r=0.67).
- OBS clearly responds to everything.



Just sand concentration



'bulk' concentration

Conclusions

- Holographic camera is a highly useful instrument for determining in-situ size distribution information.
- ABS (1,2,4MHz) very good job at burst-averaged SSC estimation when bubble concentrations are low (<1ml/l)
- Appears to be a relation between error in ABS concentrations and relative bubble volume concentration.
- Suspended sediment grain sized distribution skewed towards finer grain sizes but shifts to larger grain size with increased flow intensity.
- OBS relatively poorly related to SSC and overly-sensitive to bubbles.

Thanks for your attention.

- Project website:

`http://www.research.plymouth.ac.uk/tssar_waves/`

- In-line digital holography website & software:

`http://holoproc.marinephysics.org/`

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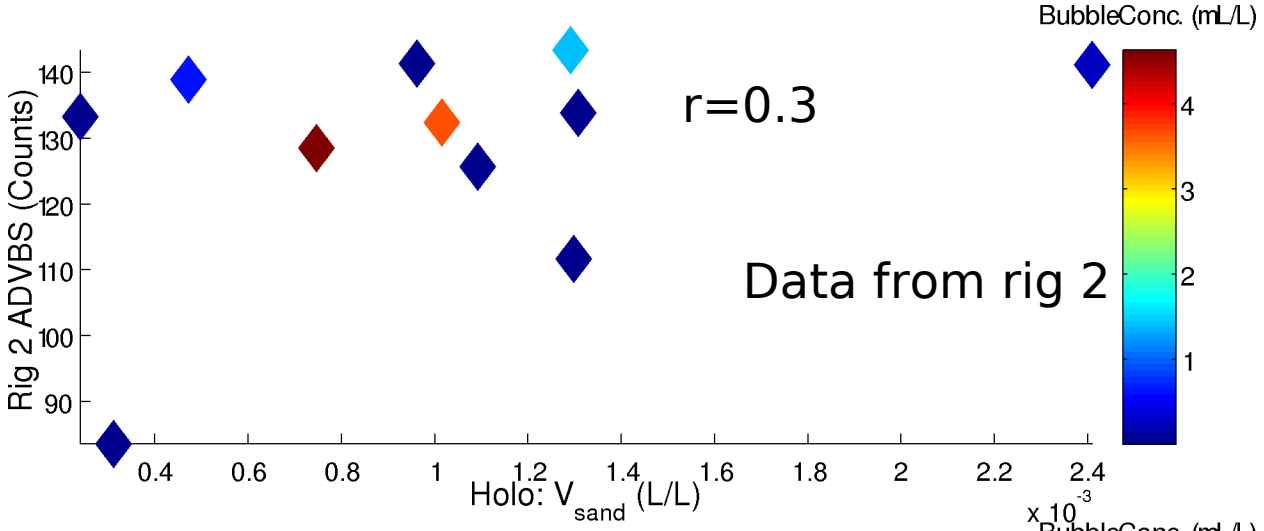
Burst-averaged SSC: Holocam versus ADV backscat

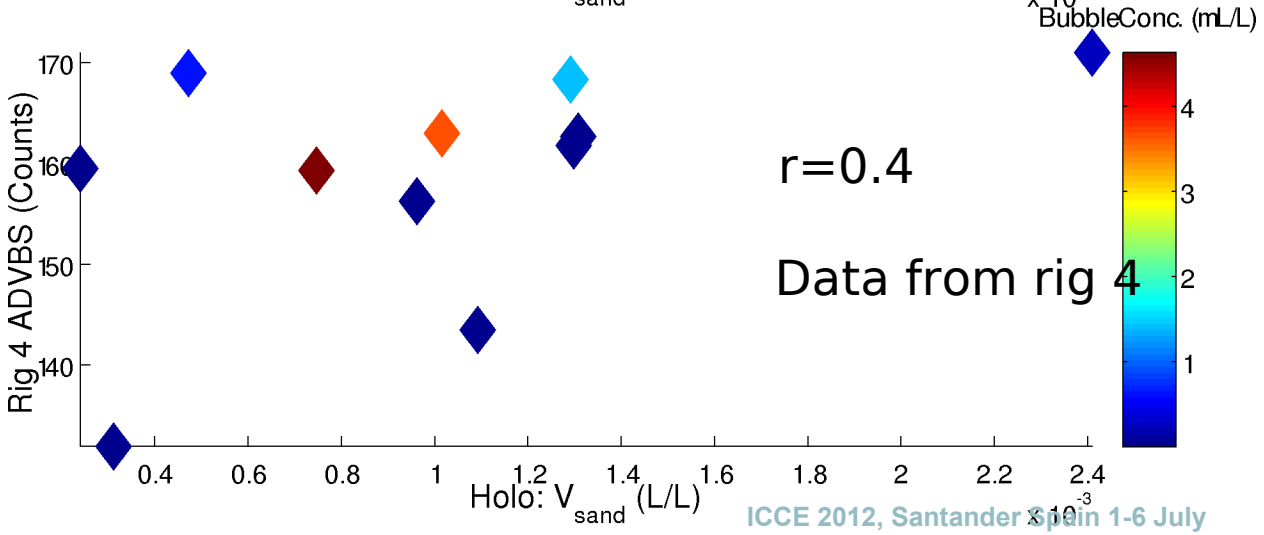
relationship between concentrations of sand and ADV backscatter amplitudes was greatest in the Z or vertical component,

but nevertheless was relatively poor (r=0.3 - 0.4)

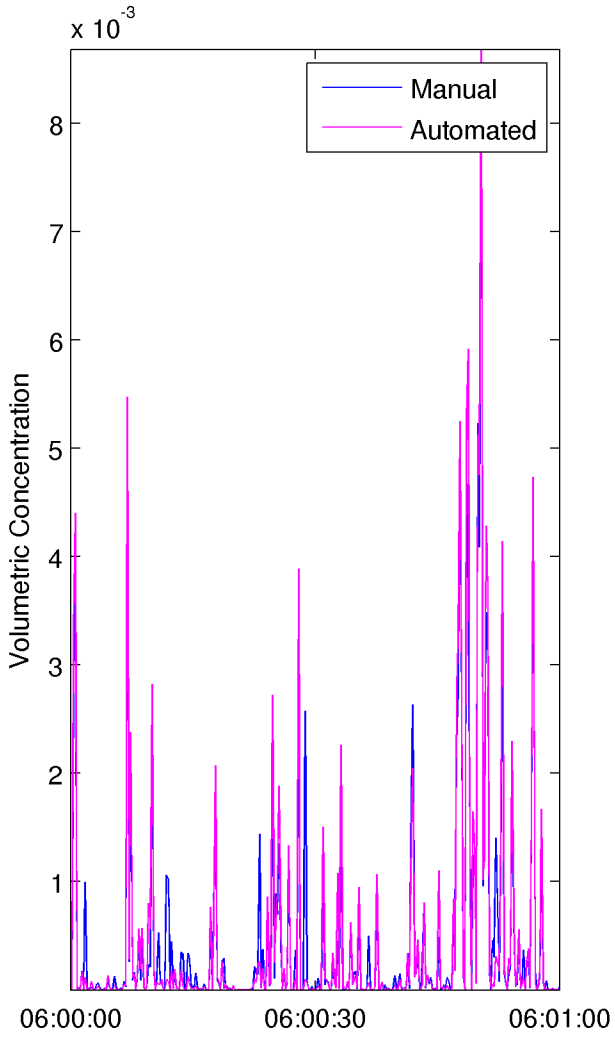
and did not improve when only bubble concentration less than 1ml/l were considered.

Acoustic frequency at 6MHz too high for these coarse sand grains (acoustic wavelength small compared to particle diameter) but



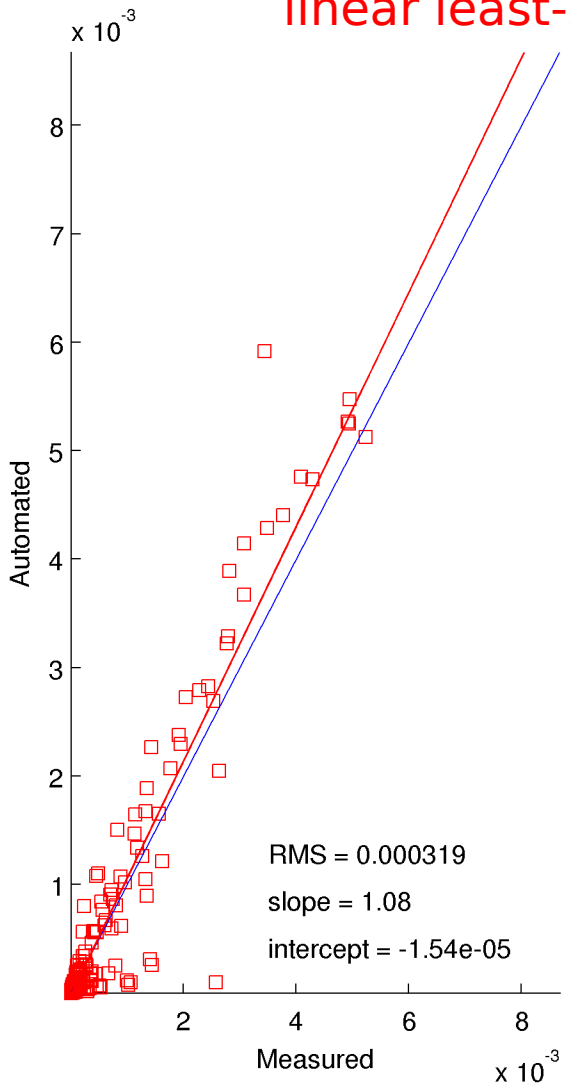


anual versus automated analysis: total concentrations



linear least-squares fit

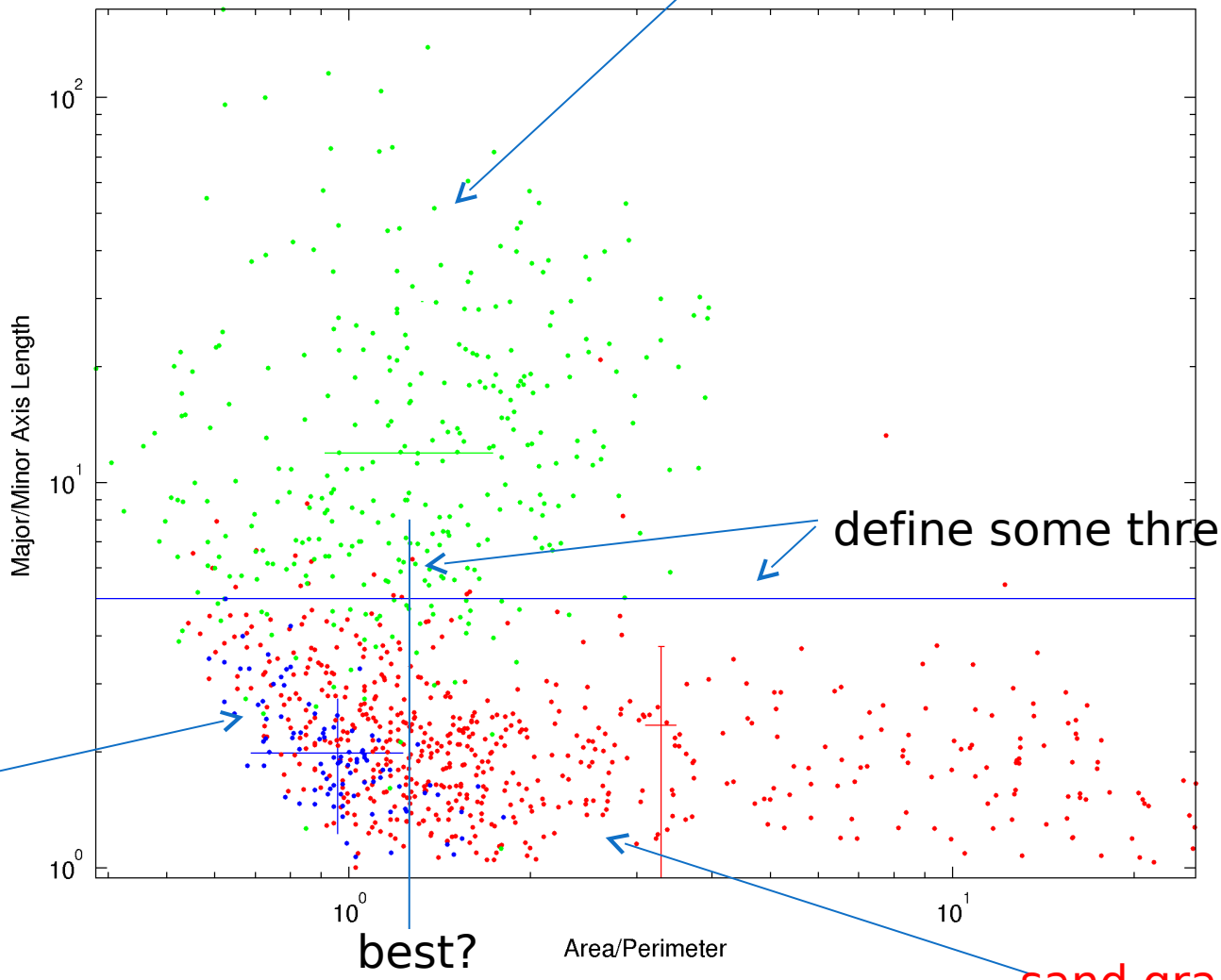
1:1 line



automated analysis overall does a very good job at measuring bulk concent

ow best to automatically classify particles?

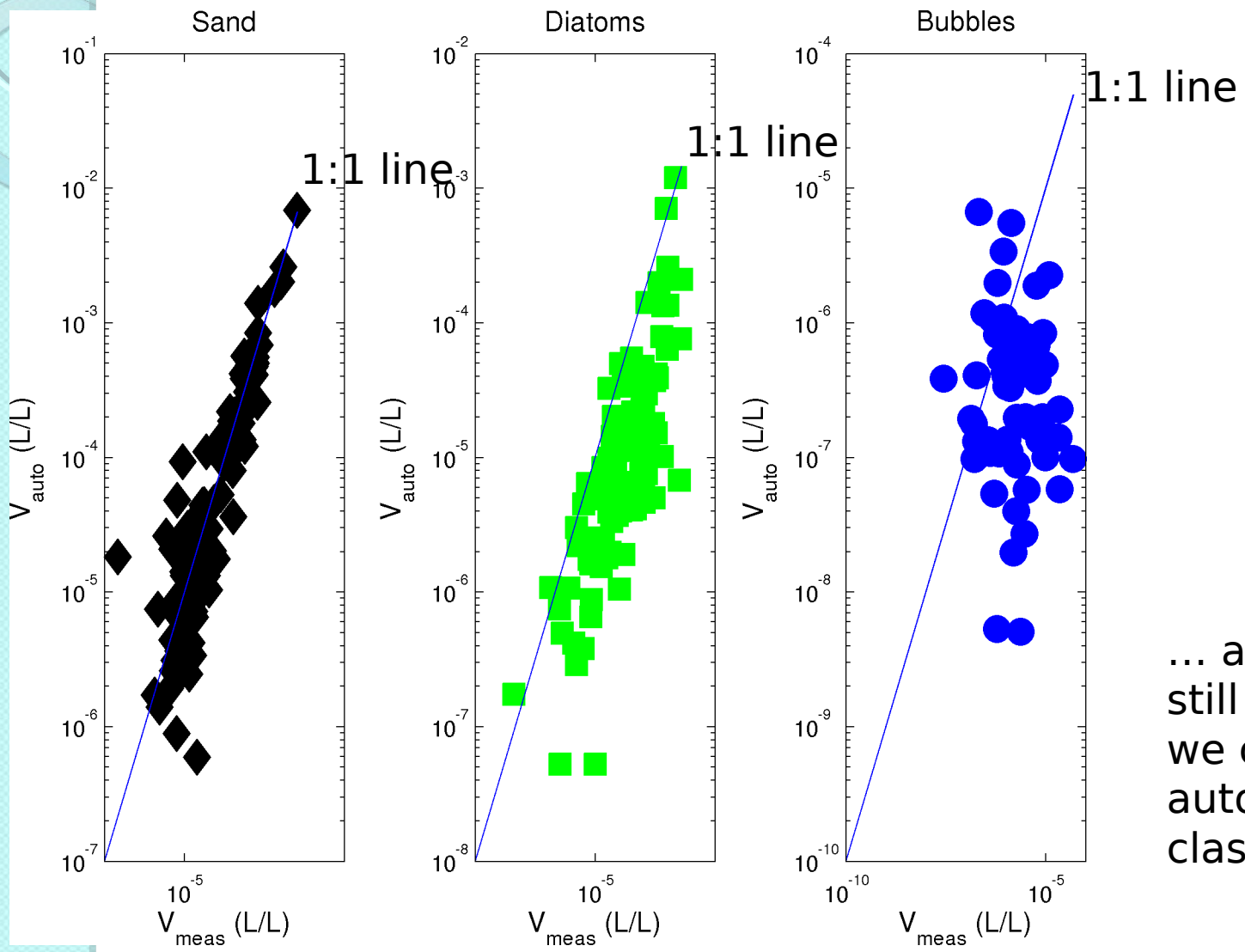
simple way is by co-variation of shape ratios:



Good

Bad

Ugly



… a bit of work still to do until we can trust the automated classifications