

# Estimating Sub-surface Dispersed Oil Concentration Using Acoustic Backscatter Response

by

Christopher Fuller, James Bonner, Shahidul Islam,  
William Kirkey, Temitope Ojo

*Clarkson University*

*Potsdam, NY USA*

*And*

*Beacon Institute for Rivers and Estuaries*

*Beacon, NY USA*



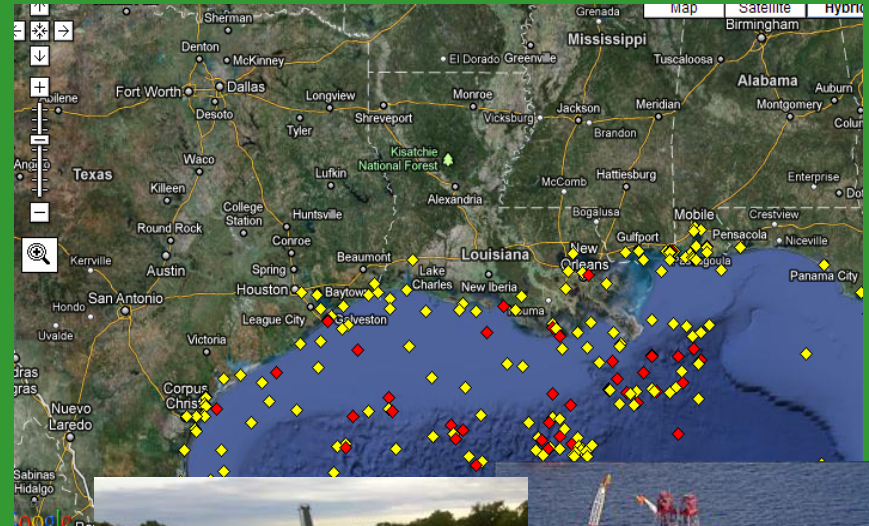
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# Purpose

- Extend capability of existing ADCPs
  - Measure 3-D water velocity based on Doppler shift acoustic echo
  - Remotely measure sub-surface dispersed oil plumes.
- Benefits
  - Survey large areas rapidly
    - Echo sounders were used to track *Deepwater Horizon* oil plume
      - » Not quantitative
  - Able to survey complete water column instantaneously.
    - Range gating (i.e. based on signal time of travel)
    - Much faster than accomplished with conventional sampling methods
      - » Grab samples
      - » Point source measurements
  - Potential for continuous monitoring applications

# Applications

- Offshore oil and gas
  - Required current monitoring
  - Broad coverage in deep water
- Ships of opportunity
- Both scientific and operational benefits
  - hazardous currents
  - nekton migration (ABS)



# Acoustic Backscatter

- ABS response determined as function of sonar equation
  - $\text{Log}_{10} \text{SSC}_{\text{measured}} = A * \text{ABS} + B$
  - SSC previously evaluated as mass concentration
  - Mass relationships applicable to conserved PSD
  - Previous study showed ABS-suspended volume concentration log linear relationship was maintained over variable PSD
- ABS requires correction for attenuation due to beam spreading and water absorption,  $f$  (distance from transducer).

# Rayleigh Scattering Equation

$$TS_R = 10 \text{Log} I_0 \left( \frac{\pi^2}{\lambda^4} (5/2)^2 \sum_{p=1}^n \left( \frac{4}{3} \left( \frac{d_p}{2} \right)^3 \pi \right)^2 \right)$$

- $TS_R$  = target strength
- $I_0$  = source acoustic intensity at the scatter
- $\lambda$  = acoustic wavelength,  $d_p$  = particle diameter
- $TS_R$  may be calculated using LISST-100 PSD data
- Defines ABS as a function of PSD (previously validated with standard clay particles)

# Experimental Methods

- ABS response to standard oil suspensions in laboratory test tank.
  - ABS measured with Teledyne RDI ADCP
  - Controlled shear to standardize PSD and suspended oil mass load
- Oil load measured as volume fraction
  - LISST 100
  - Also provided PSD
    - Allowed evaluation of Rayleigh backscatter

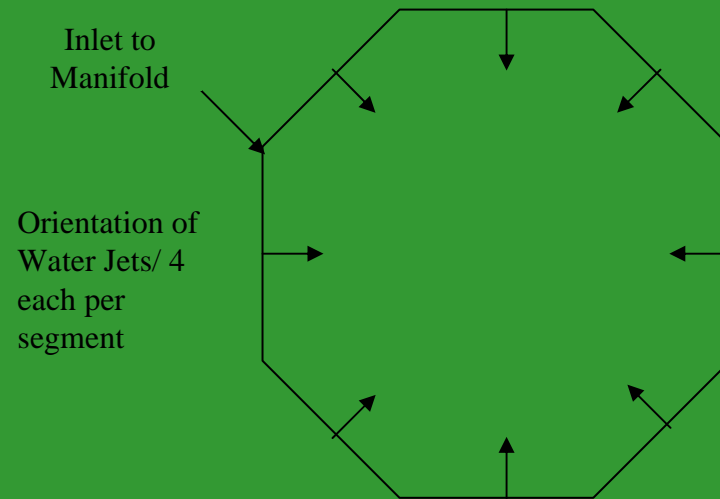
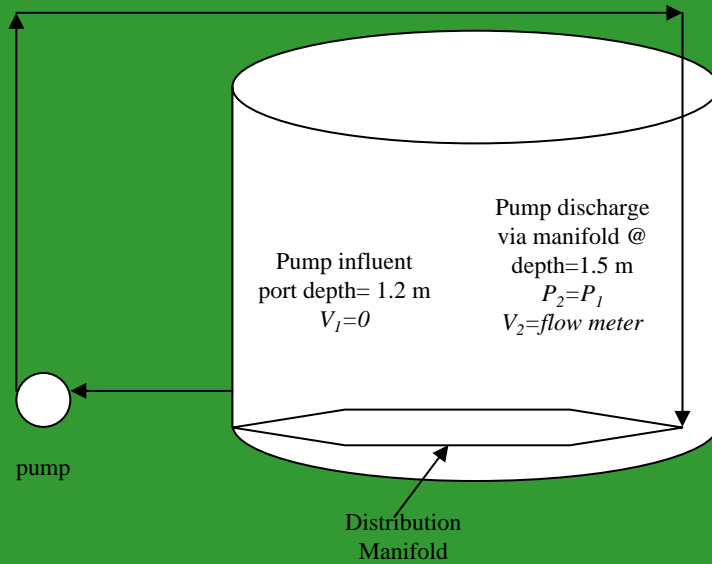
# Acoustic Backscatter Measurements

- Teledyne RD Instruments StreamPro
  - 2400 kHz



- Measure velocity profiles using Doppler shift and range gating
- 2400 kHz
- Nominal range- 2 m
- ABS measured as raw echo intensity
  - Required conversion to dB
  - Depth corrected for attenuation (beam spreading and water absorption)

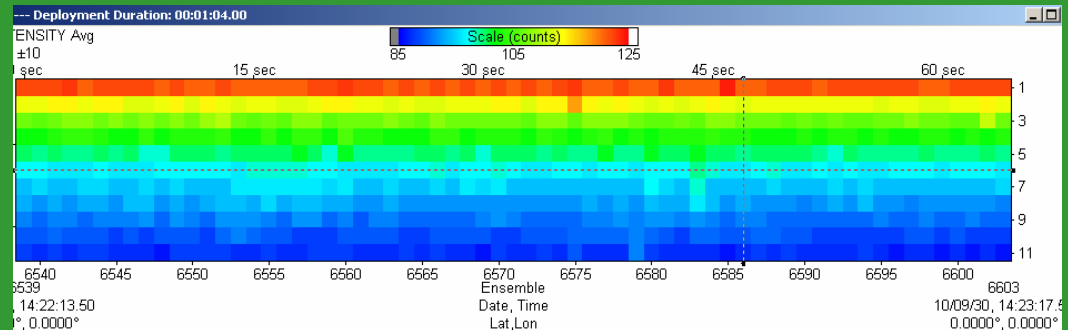
# Test Tank Schematic



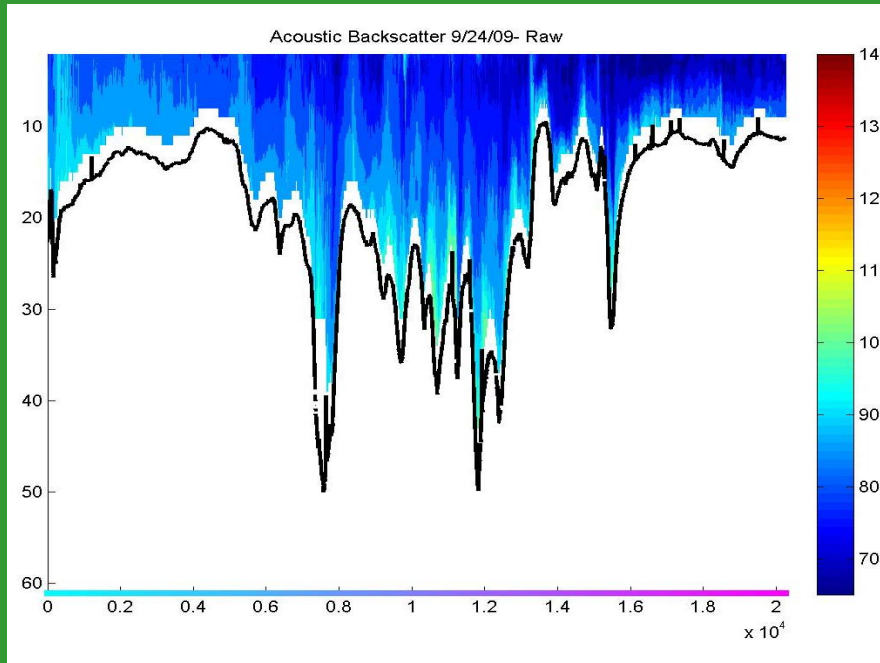


# Data Processing

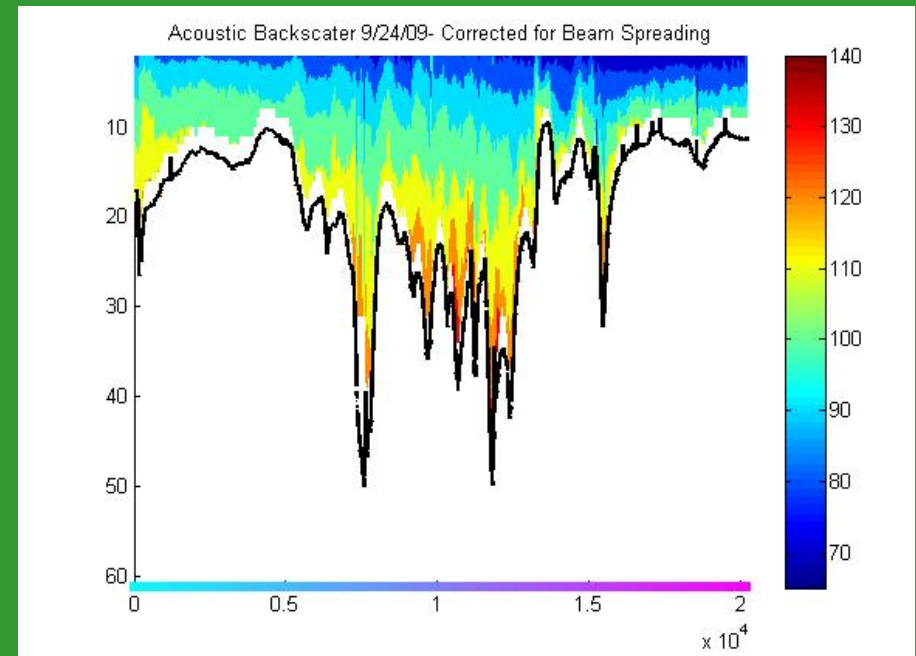
- Correct for signal attenuation
  - Beam spreading
  - Water absorption
  - Sediment adsorption
- Allows application to distance depth bins
  - Without need for independent calibration curves



# Sample of Field Collected ABS



Raw back scatter

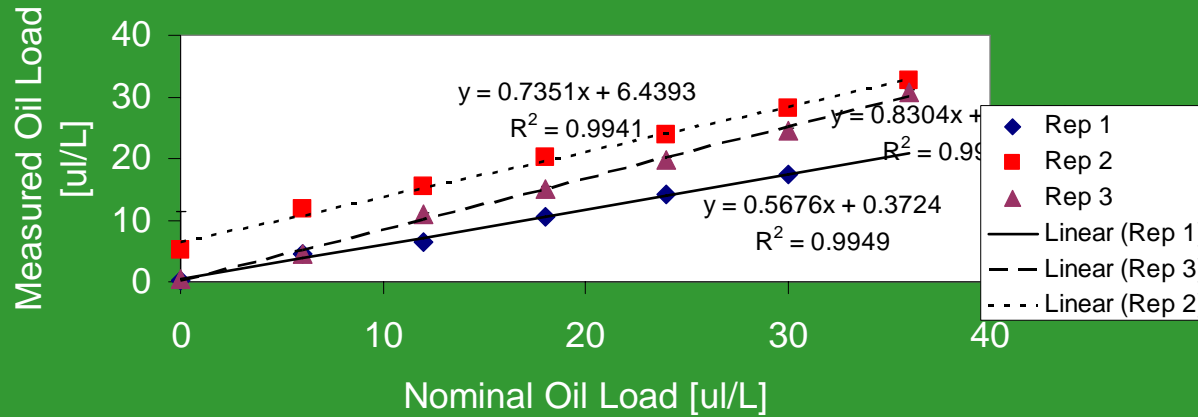


Corrected back scatter response

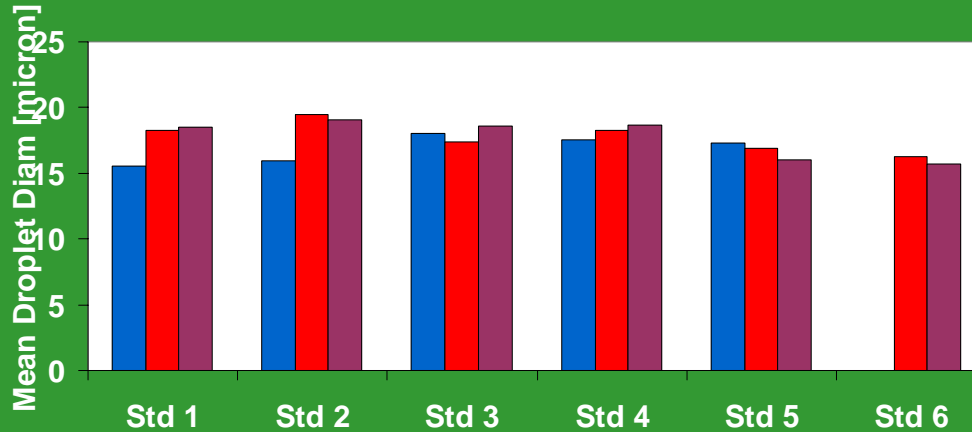
Elevated ABS at depth indicative of suspended solids.

# Oil Droplet Suspensions

Nominal vs Measured Oil Load

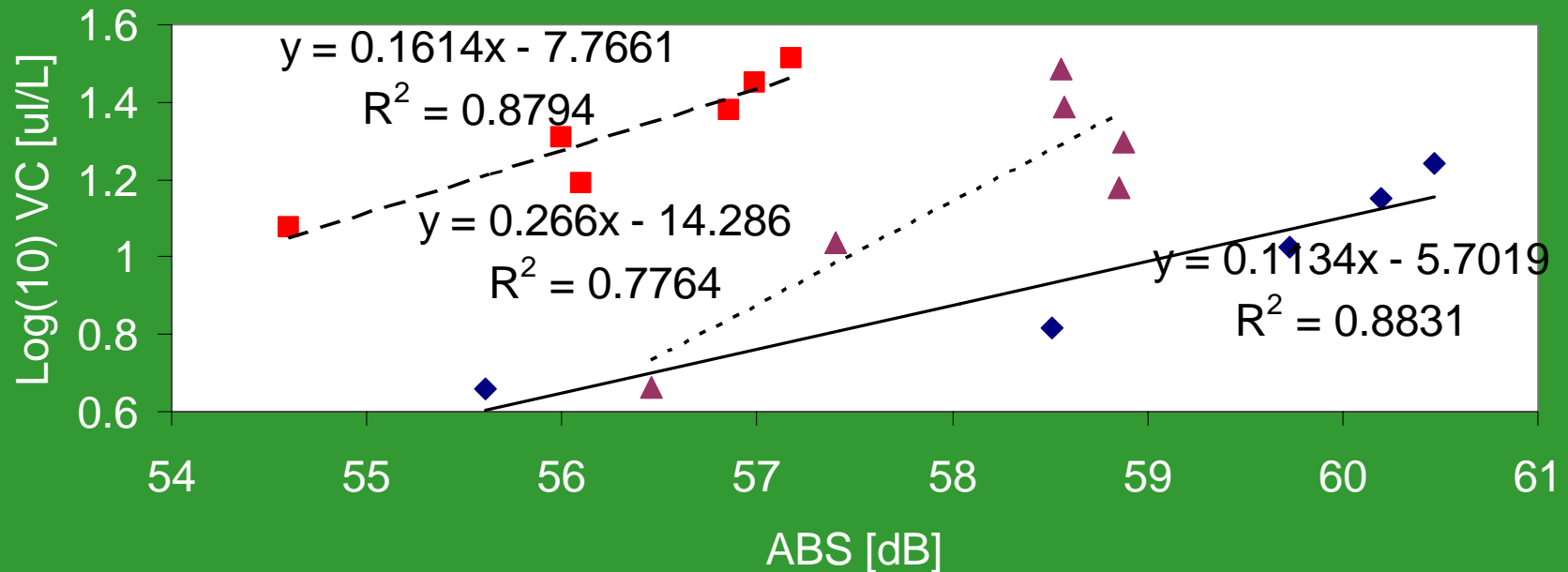


Mean Droplet Diameter ( $d < 100 \mu\text{m}$ )



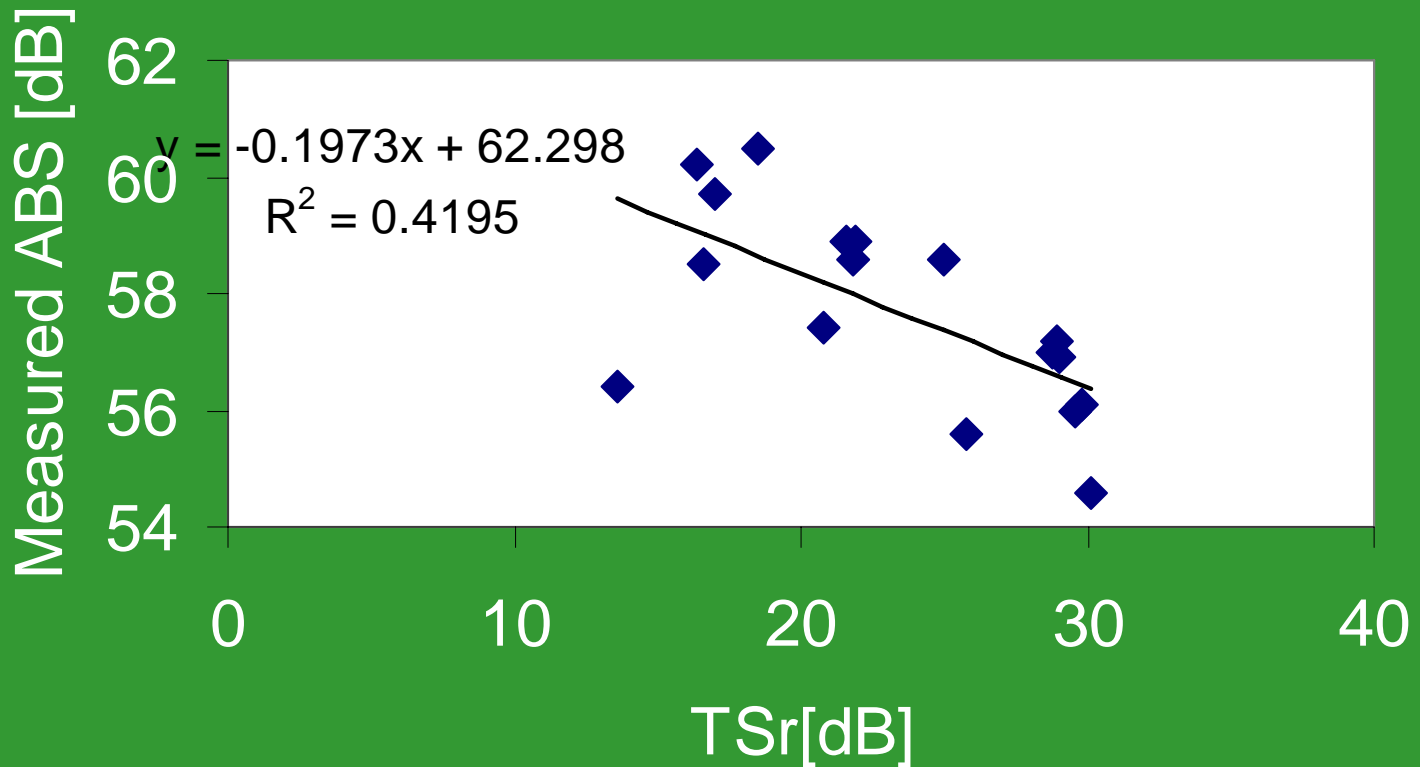
# ABS Oil Droplet Response

Depth Bin 6 ABS Response Dispersed Oil



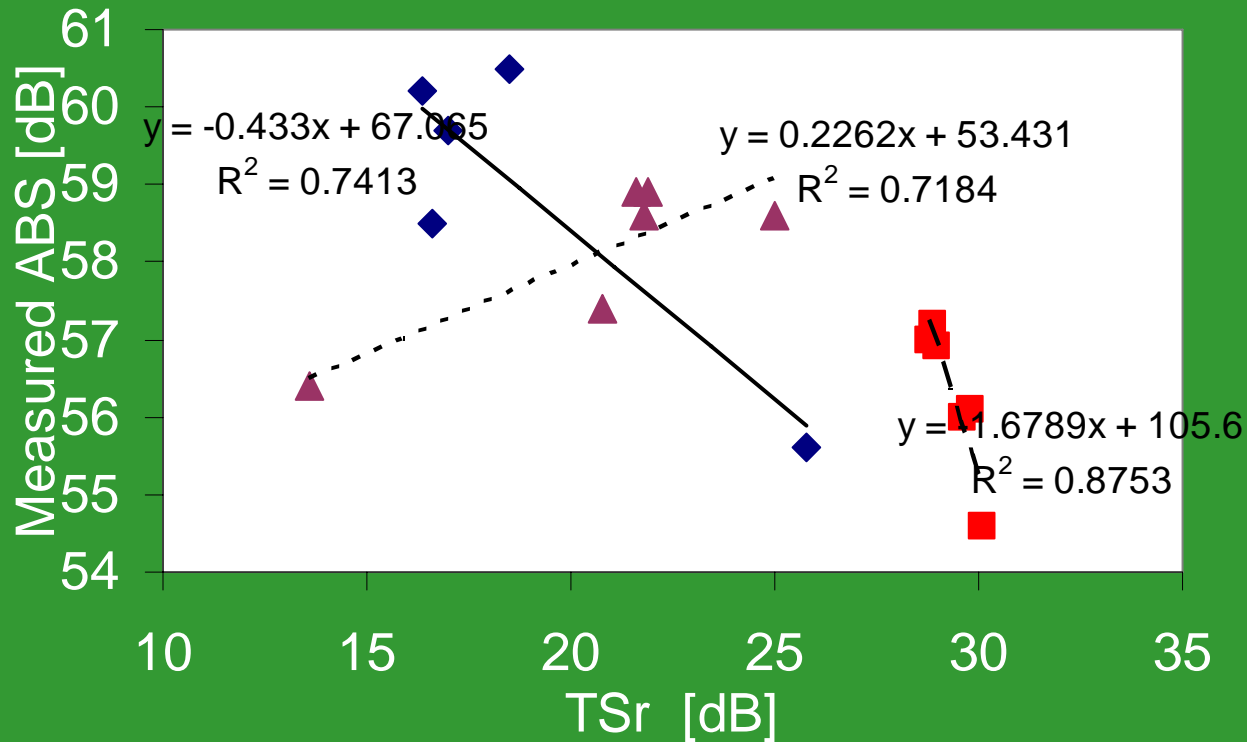
1. Log-linear response within each replicate
2. Difficult to reproduce slopes between replicates

## TSr vs Measured ABS (depth bin 6, all replicates and conditions)



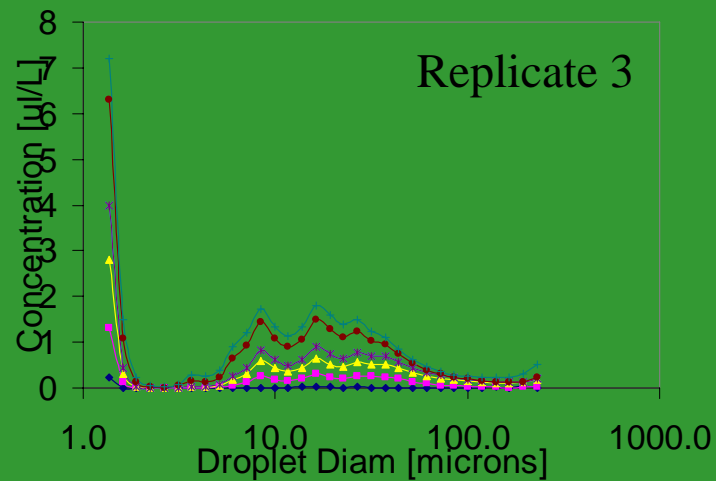
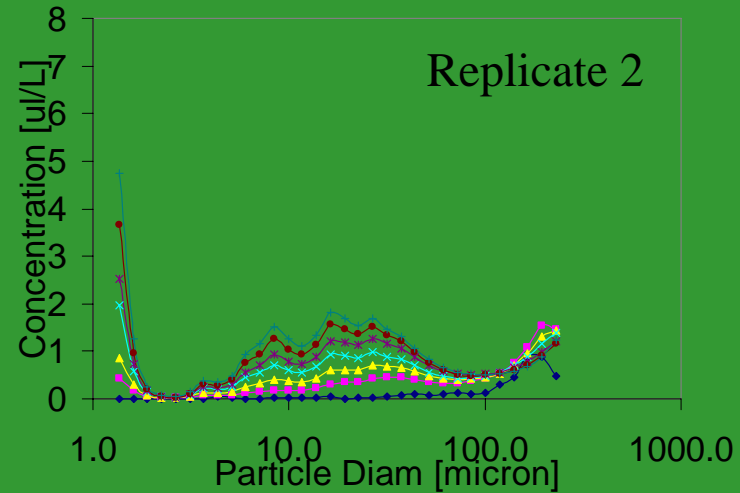
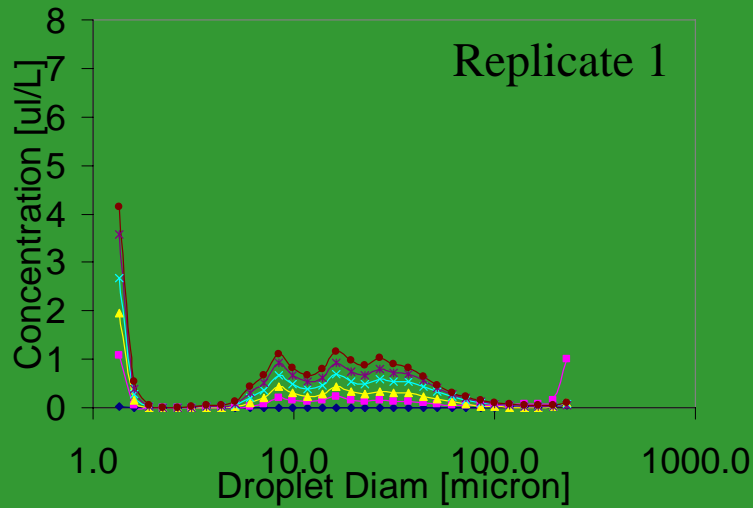
1. No correlation indicated between measured ABS and  $TS_R$
2. Indicates that replicate variability not a function of PSD

## Measured ABS vs TSr

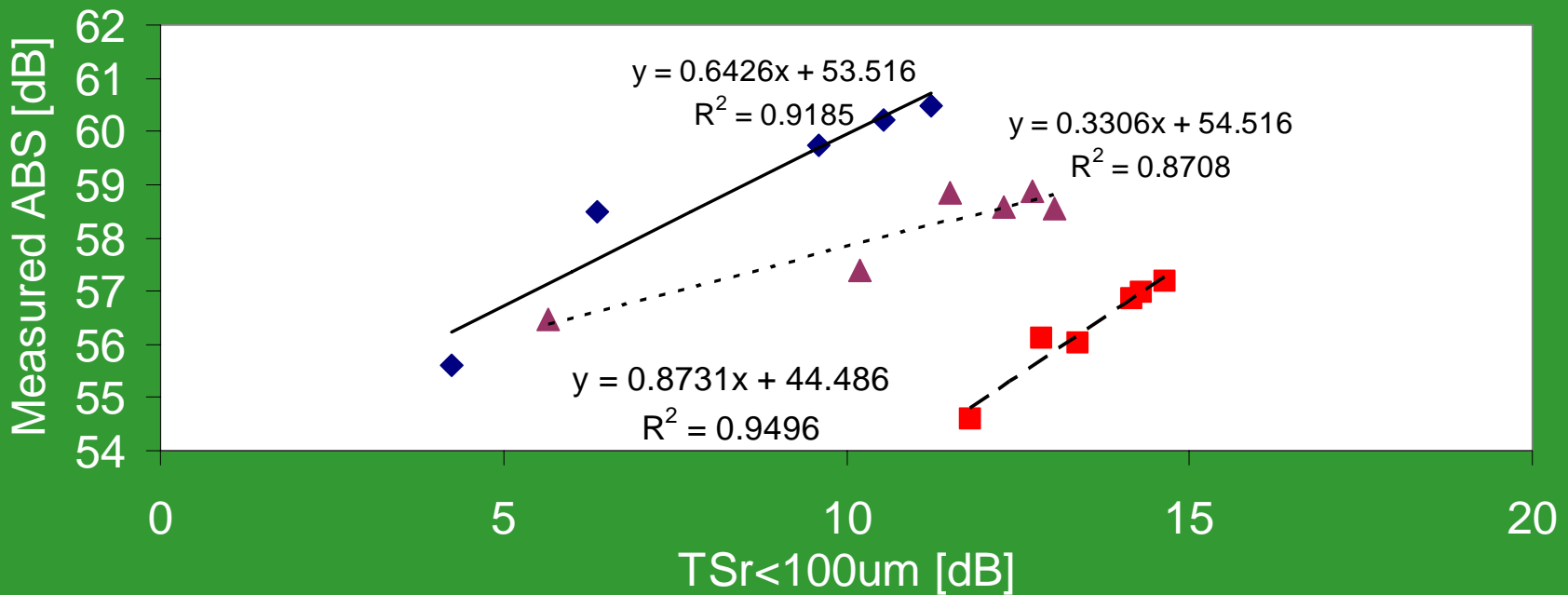


1.  $TS_R$  affected by ambient particle load especially when larger than oil droplet.
2.  $TS_R$  is proportional to the 6<sup>th</sup> power of the droplet radius.

# Droplet Size Distributions



## Measured ABS vs TSr <100 um



1. Measured ABS response is a function of oil droplet PSD.
2. Method has sensitivity required to measure variable droplet concentration in presence of interfering ambient particles.



# Conclusions

- ABS shows log-linear response oil droplet volume concentration.
  - In presence of interfering ambient particles.
  - Able to detect changes in relative concentrations.
- Replicate variability suggest the current ADCP configuration is not suitable for quantitative field work.
  - ADCP designed to measure Doppler shift, not echo intensity.

# Cont.

- Future studies
  - Improve ADCP echo intensity measurement capability.
  - Evaluate during spill of opportunity.

# Acknowledgements

- Beacon Institute for Rivers and Estuaries