An Acoustical Approach to the Study of Marine Particle Dynamics

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Many Thanks
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Office of Naval Research

Marine particle properties and dynamics

- Marine particles have optical and acoustical properties
  - Backscatter intensity is first-order correlated with mass concentration
  - Backscatter intensity per mass is dependent upon material properties of the scatterer
- Particle dynamics
  - Re-suspension/settling
  - Changes in particle size/composition
  - Aggregation
- Dynamic interactions may affect optical and acoustical properties of particles
  - Affected properties can affect predictability of suspended sediment concentration (implications for mass transport modeling)
  - Implications for applications in underwater communication

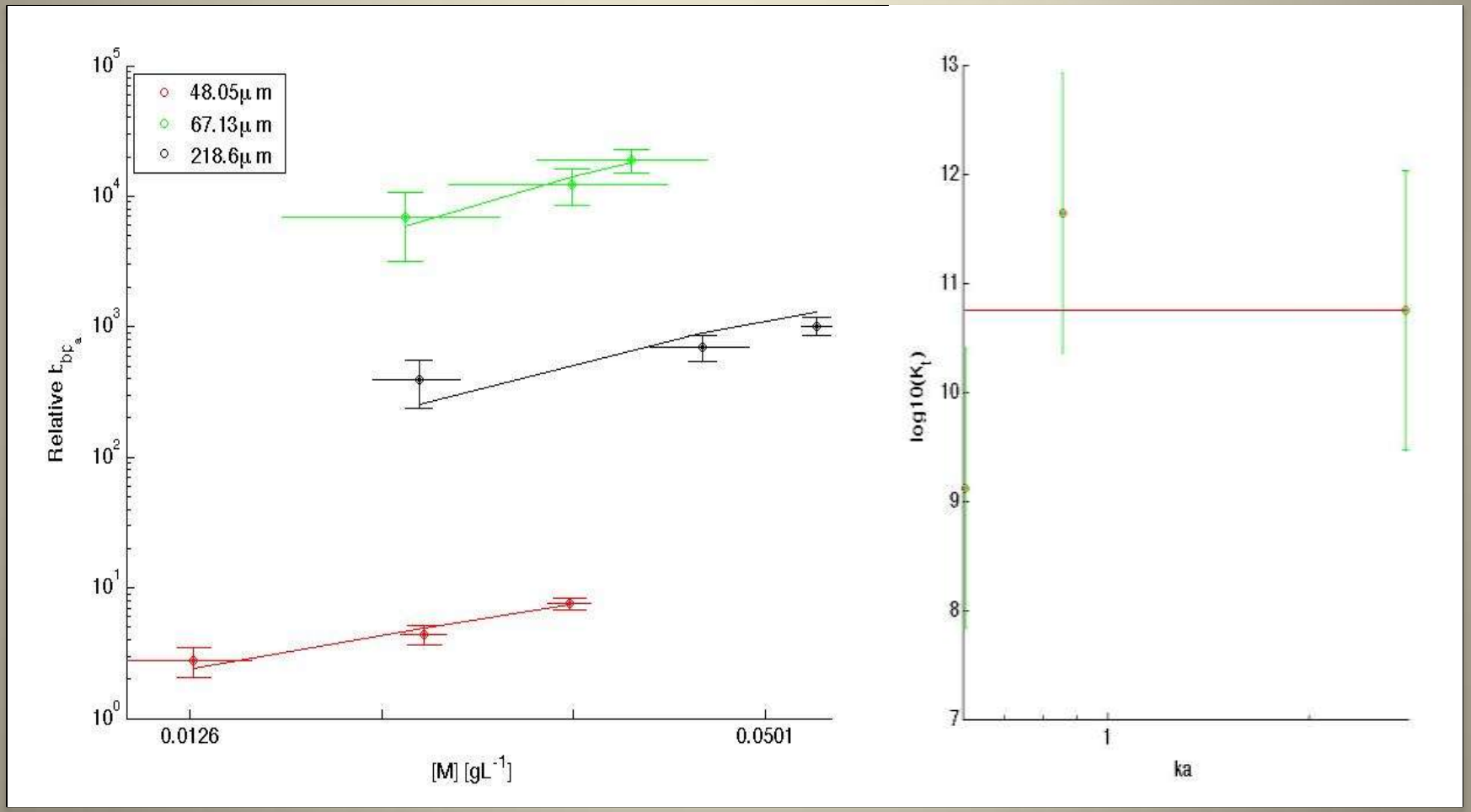
Quantifying marine particle properties and dynamics

- First-order variability in the water column
  - Previous studies have shown ABS, ADCP adept at measuring suspended sediment concentration
  - What about the ADV?
- Second-order variability in the water column
  - Optical properties of particles are affected by changes in composition and aggregation
  - What about the acoustic properties?
    - Disparate claims over instrument sensitivity to dynamical events

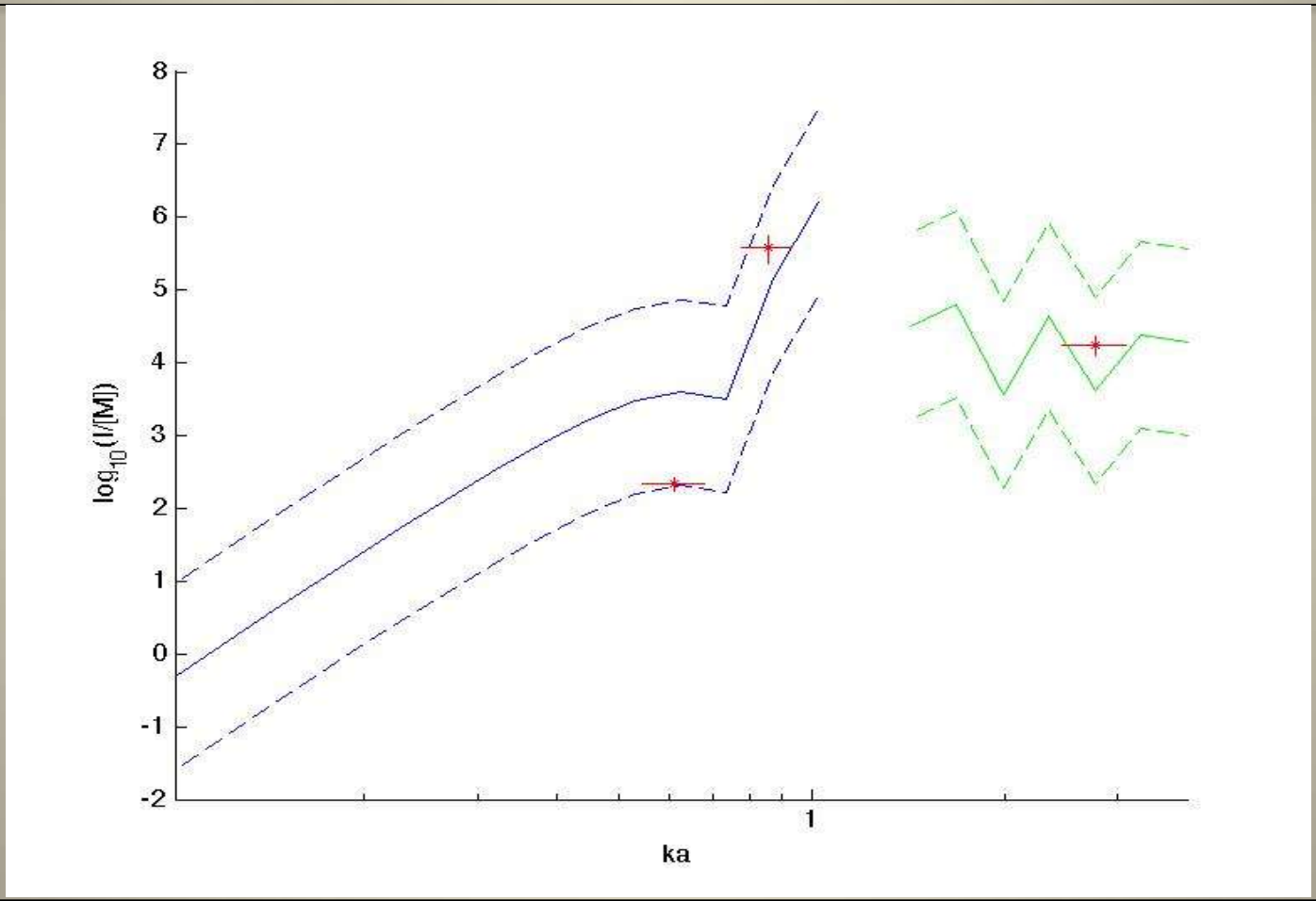
Laboratory Calibration of the ADV

- Assessed the backscattered acoustic intensity to increases in mass concentration
  - Concentration series performed with suspensions of particles of known size and composition
  - Multiple concentration experiments performed, each with a different size particle
- Characterized the mass-normalized backscatter to particle size
  - Compared results with acoustic scattering theory for suspensions of elastic particles with identical physical properties

Results, ADV Experiment



Results, ADV Experiment



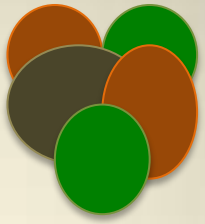
ADV Stats

- Linear response to mass, up to 0.08gL^{-1}
- Mass-normalized backscatter relates to particle size as expected from theory, within uncertainties in K_t
- ADV shows promise in solving the inverse problem of determining concentrations

- **What about particle dynamics?**
  - Optics: aggregates alter PSDs, variable composition affects index of refraction
  - Disagreement about aggregation affecting acoustic properties

Aggregates in the Ocean

- Particulate composition
  - Organic
    - plant and animal matter
  - Inorganic
    - sand, mud, minerals, metals



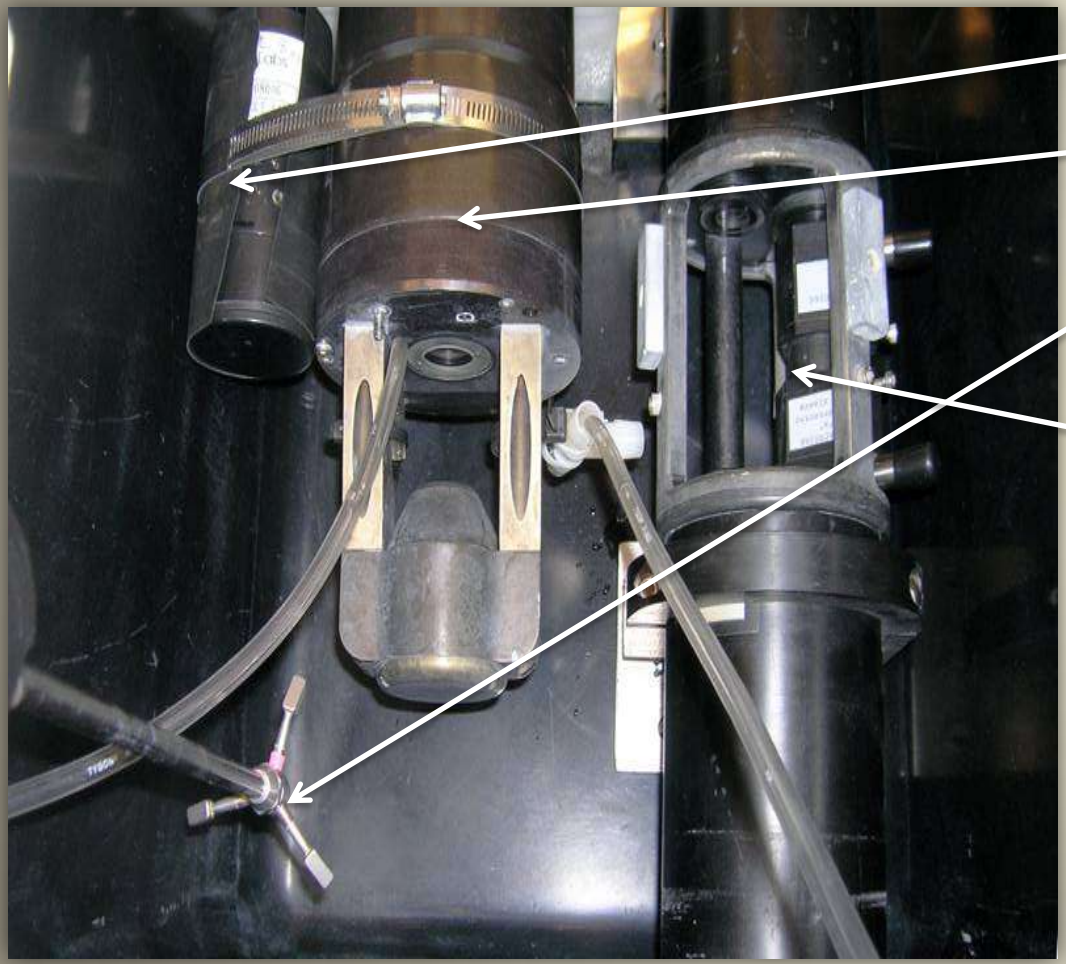
- Particles aggregate
  - Following re-suspension/settling events
  - In expulsion from hydrothermal plumes

- Aggregates may be composed of various things, variously packaged

Aggregates in the sink

- Small particles of bentonite clay
  - Suspended in water, 0.04 g/L
  - Add salt, wait
  - Flocs form by differential sedimentation
- Measure properties over time
  - Acoustically – backscatter (ADV)
  - Optically – backscatter (BB3), size (LISST), optical attenuation (ac-9)
- Measure concentration over time
  - Suspended particle mass (SPM) pulled from sampling depth

Aggregation Experiment



BB3, optical backscatter

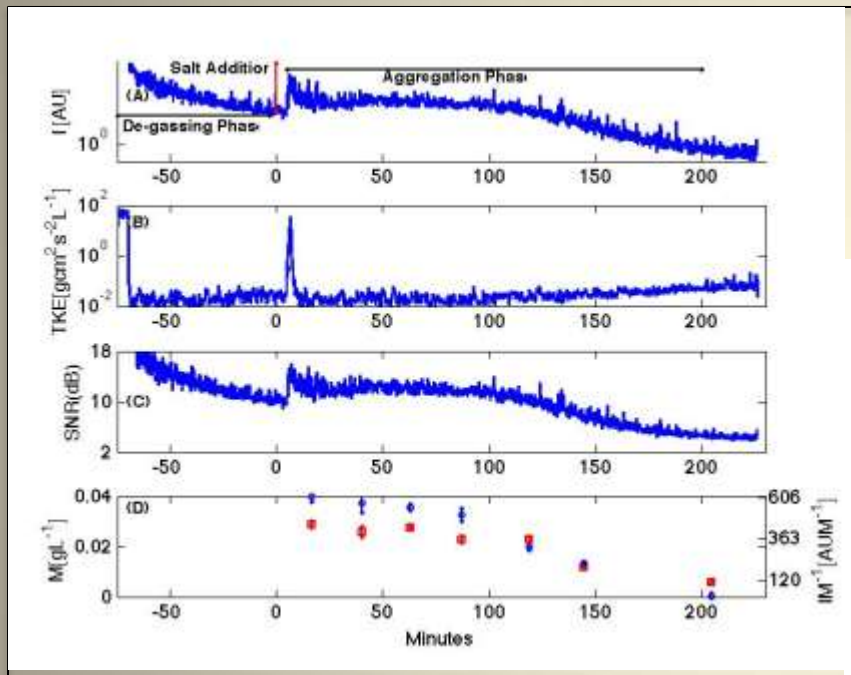
LISST particle sizer

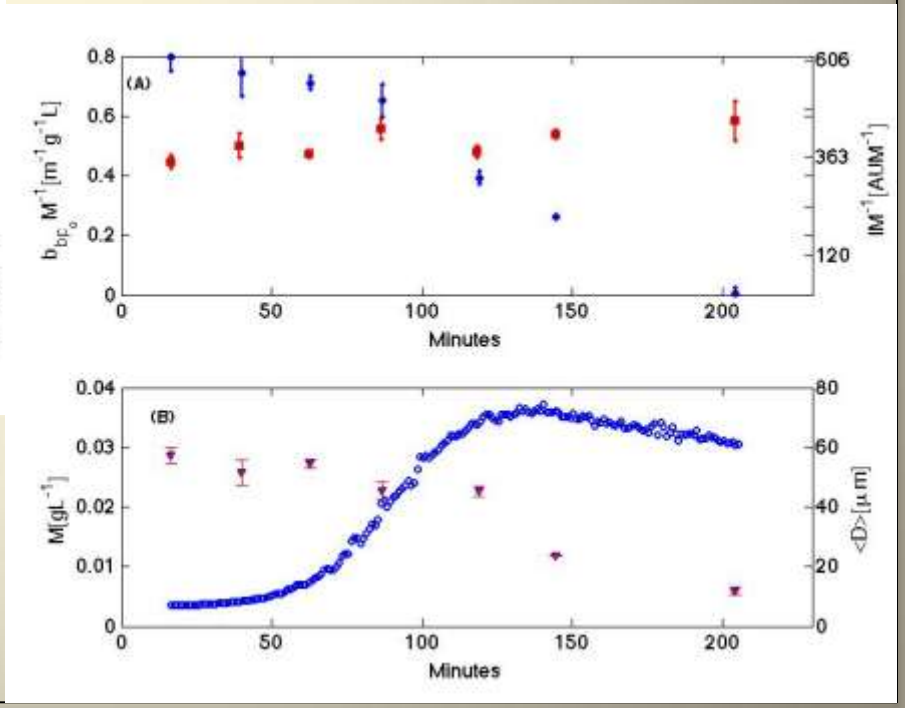
ADV, acoustic backscatter

ac-9, optical attenuation meter

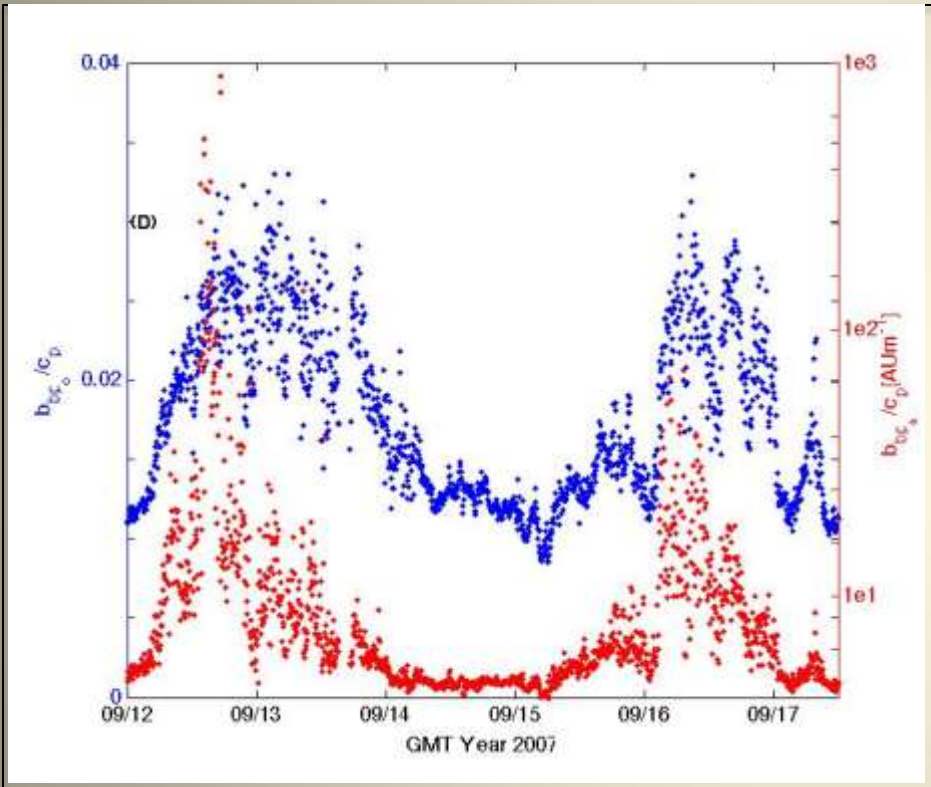
All sensors sampled from the same depth, SPM taken at depth, 9cm under the surface water

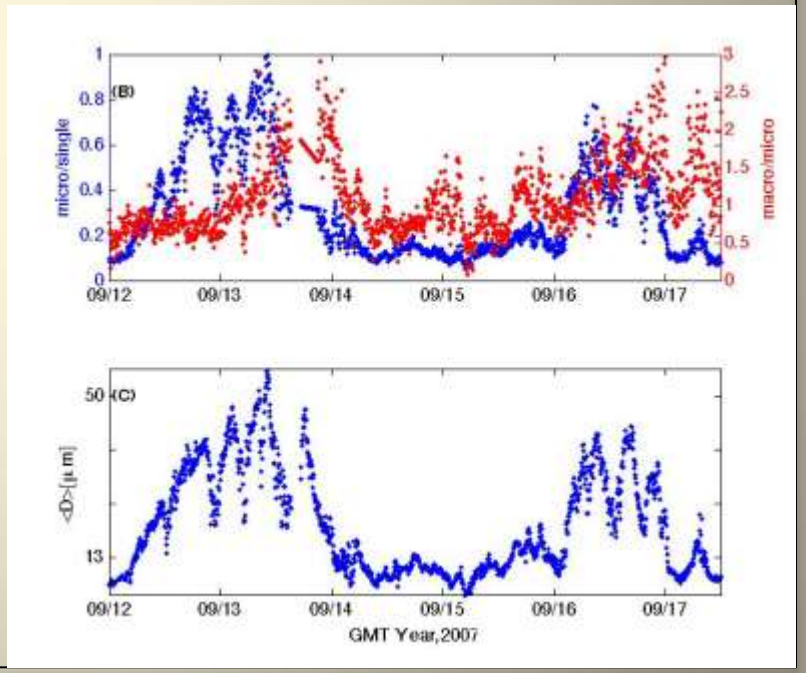
Results, Aggregation Experiment





Aggregation in the Field





Backscattering and Aggregation

- Results from lab experiment are consistent with field observations
- Aggregation affects optical and acoustic backscattering differently
- Mass-normalized acoustic backscattering is significantly decreased by aggregation
- Decrease may be attributed to acoustic absorption resulting from interactions between particles
  - Physical attributes of aggregates are different than solid particles
    - fractal, large fluid fractions promote different particle-particle/particle-fluid interactions
    - Implications for modeling acoustic backscattering
    - Implications for predicting suspended sediment concentrations

Acoustical Approach to Particle Dynamics

- Properties of particles are affected by dynamical interactions
  - Optical and acoustic backscattering are each affected differently
- Judicious co-deployments of optical and acoustical instrumentation can provide complimentary measurements
  - e.g., co-deployment may provide an indication of aggregation in-situ