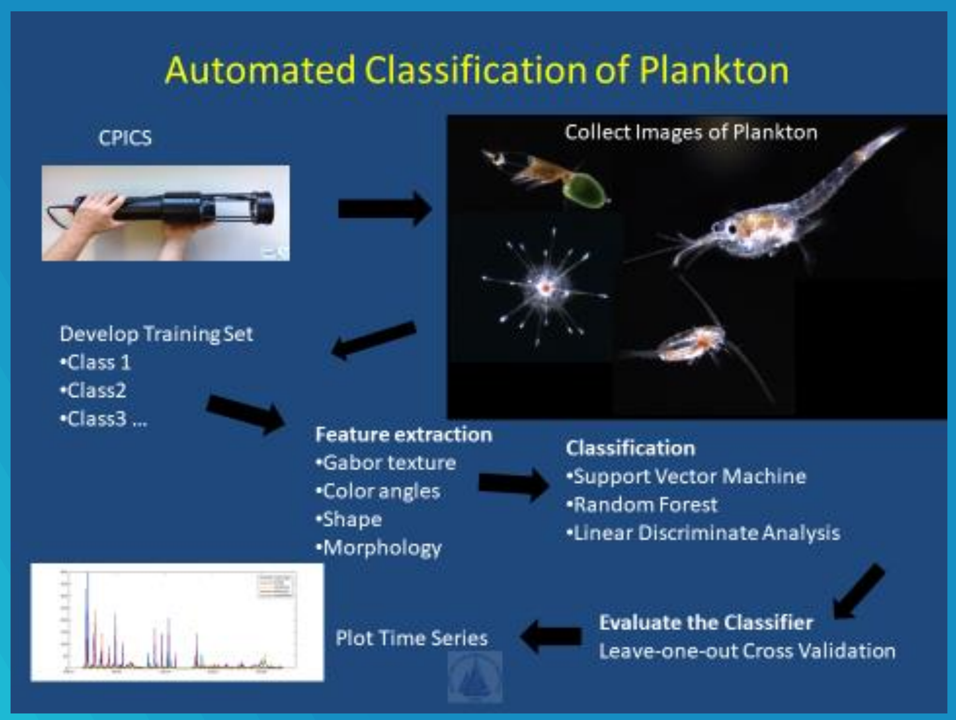
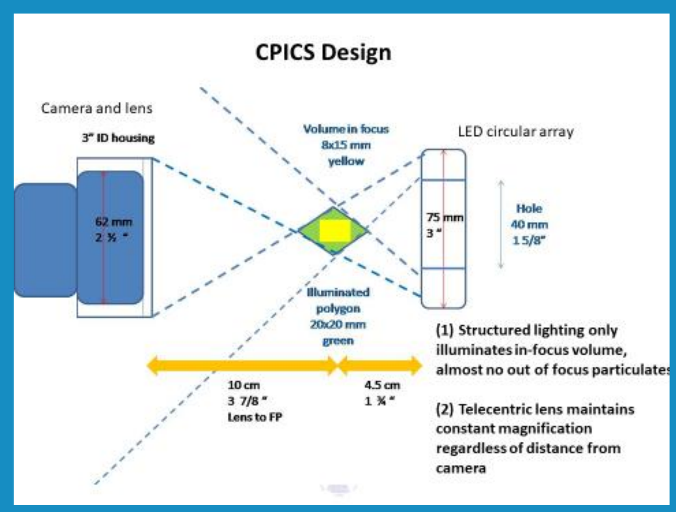
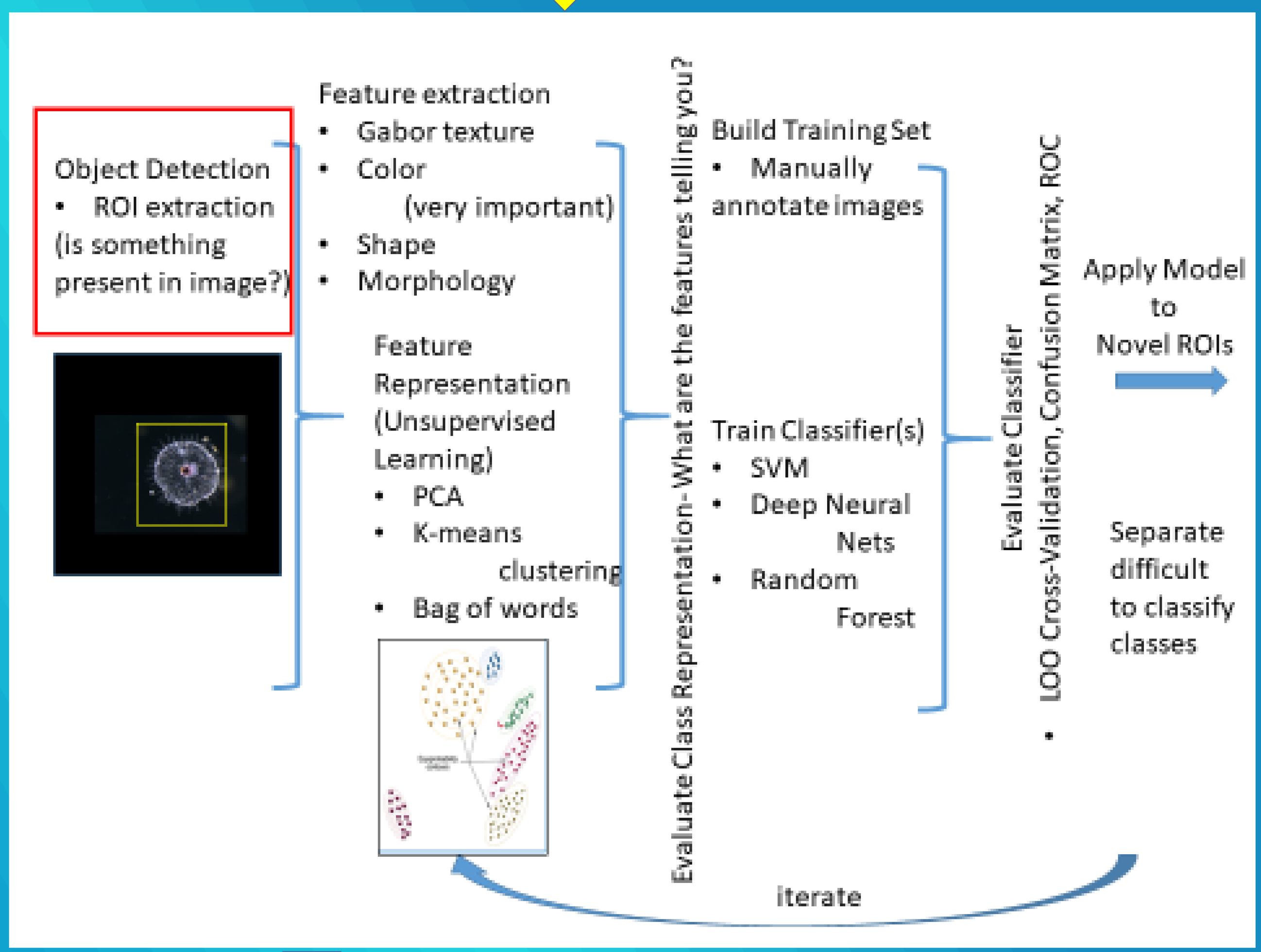
# Characterization of the Biological Pump using CPICS: The Continuous Plankton Imaging and Classification Sensor

Scott M Gallager , Steve Lerner, Jared Schwartz, Cameron Fairclough
CoastalOceanVision, Inc.



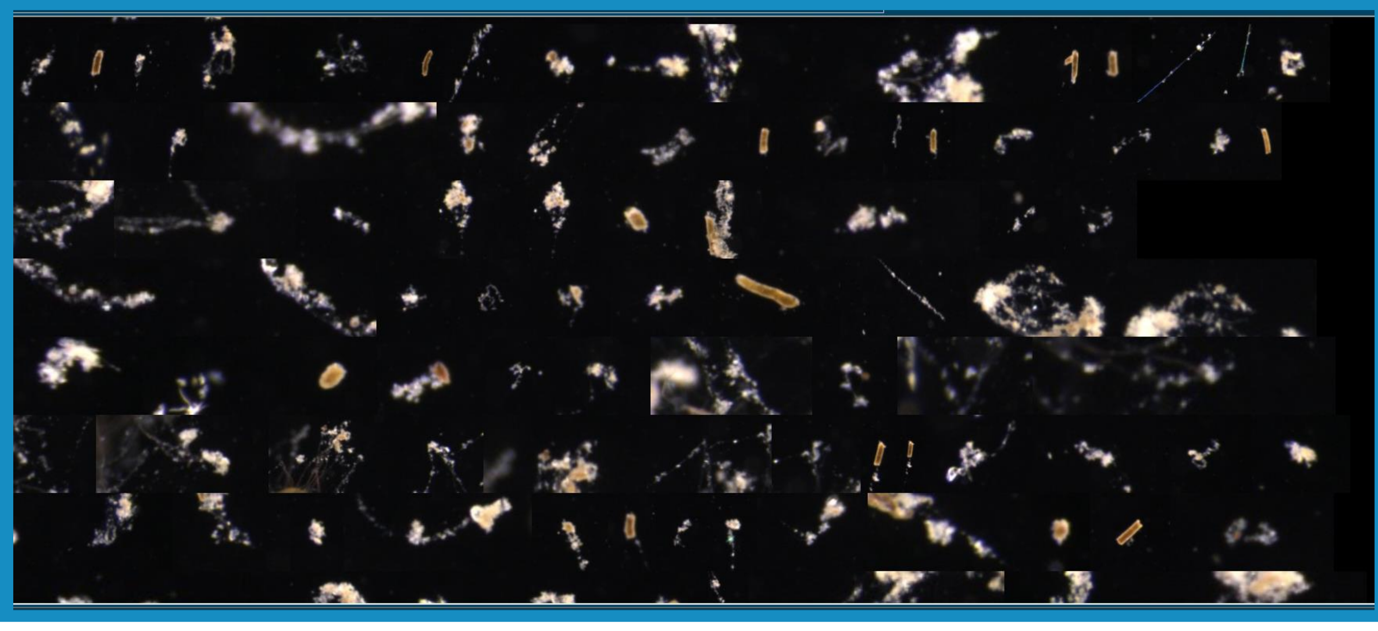



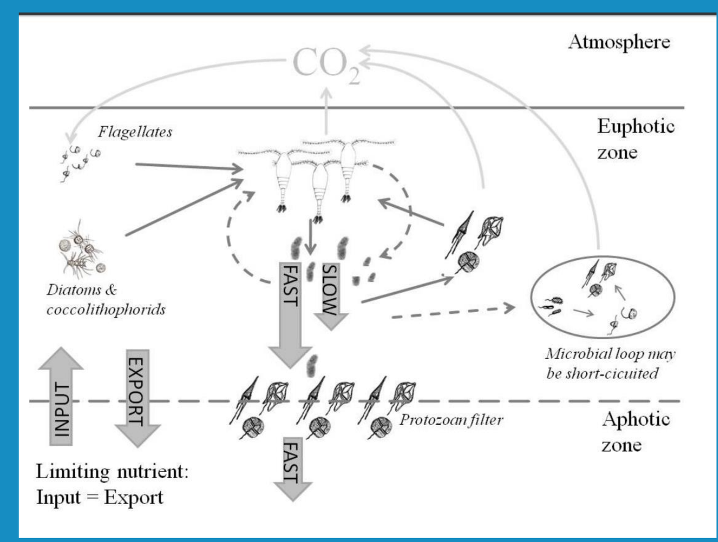

CPICS uses darkfield Illumination and diffraction limited telecentric lens




CPICS classifier workflow starting With ROI segmentation from the full frame, training of a class set, extraction of a feature set (Gabor texture, color angles, Shape- FFT, and morphology- max/min size, circularity, etc.) followed by unsupervised training (PCA) to reduce dimensionality, then Random Forest and CDNN deep learning, and validation

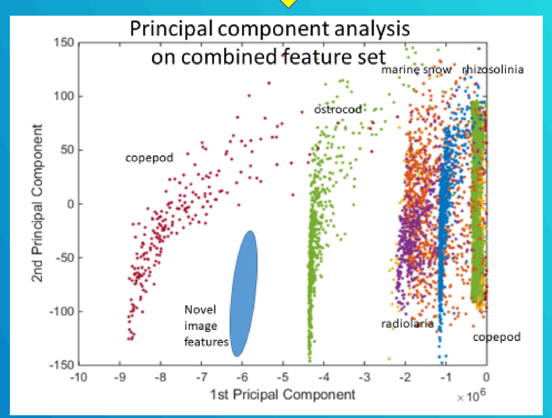
CPICS imaging of particulates, faecal pellets, and Marine Snow



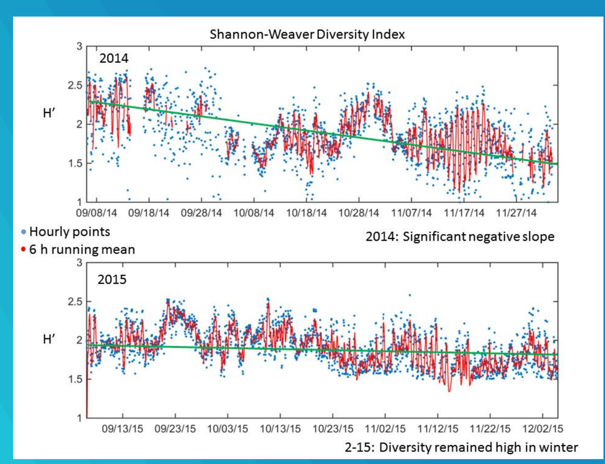



Morten Hvitfeldt Iversen, 2009 Dissertation

Conceptual diagram of carbon production and recycling by plankton, and export to the seafloor. Flux could be modulated By certain species near surface such that depth-specific flux could be highly variable.

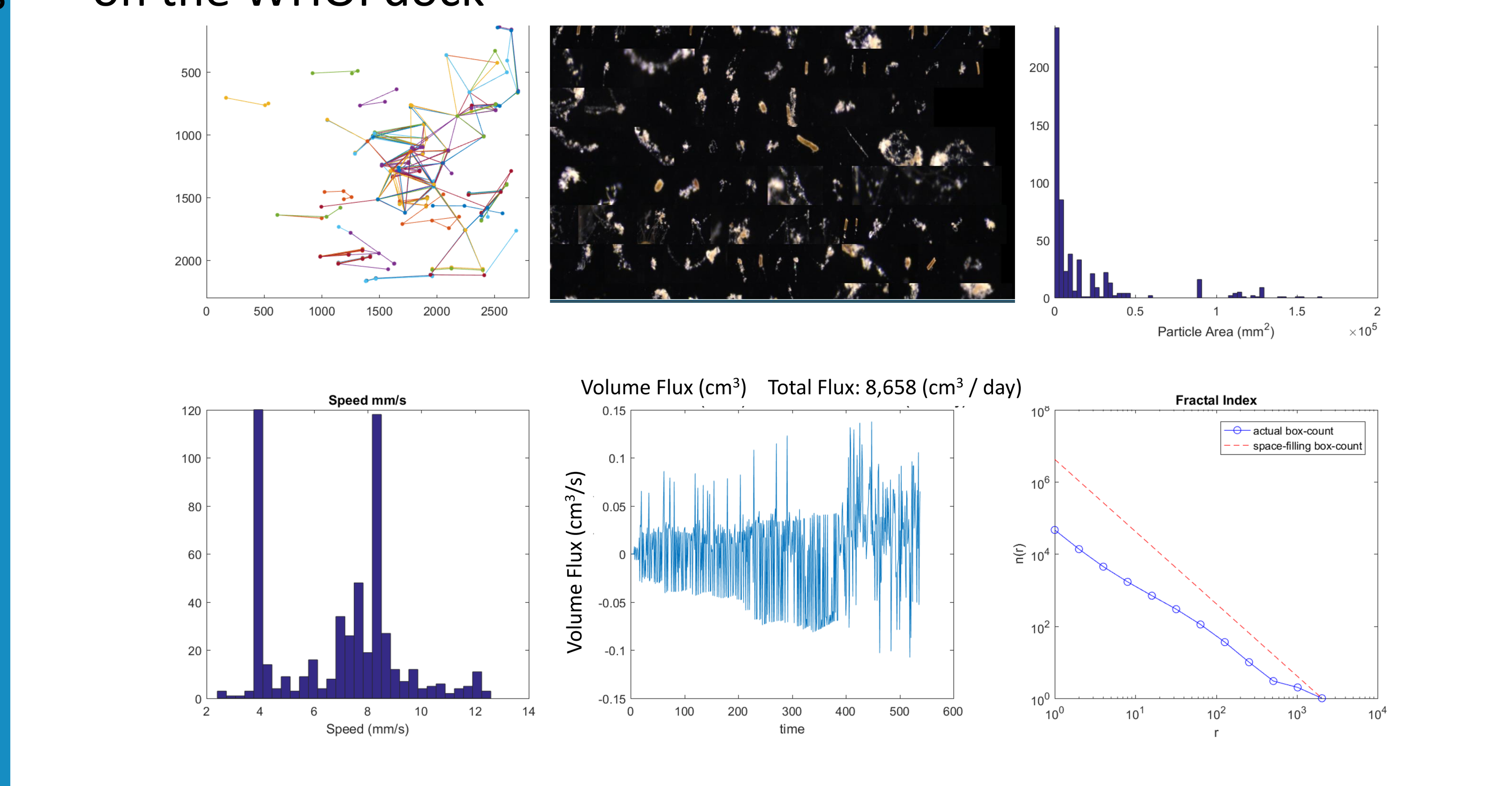


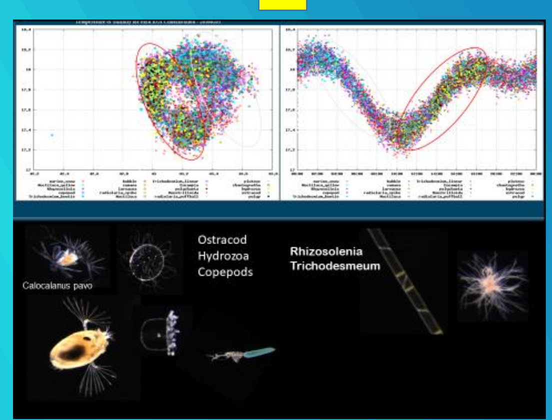

Unsupervised PCA to detect new classes



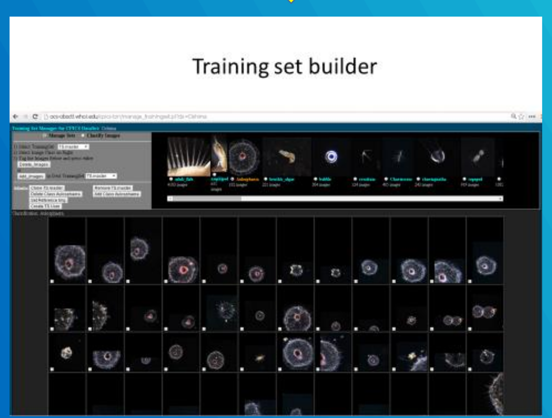

Two year time-series of 21 species of plankton Note loss of diversity in 2015

Real-time display of accumulative flux of matter through CPICS on the WHOI dock



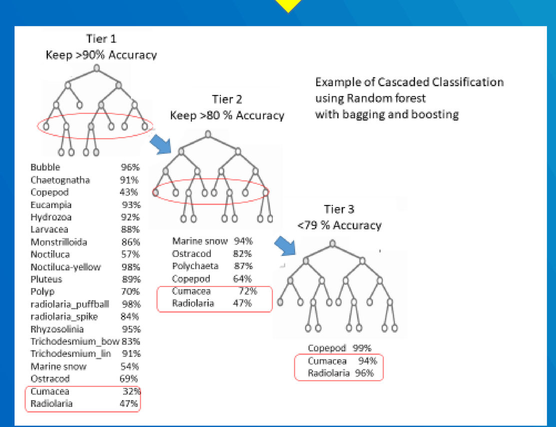
Real-time data products of plankton relative to physics




Training set Builder on the website

Cross validation

| Manual Class | Classification Confusion Matrix | | | | | | | | | | | | | | | | Num Images | Percent Correct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Eucampia | Monstril | Noctiluc | Noctiluc | Rhyzosol | Trichode | Trichode | bubble | chaetogn | cope_cra | hydrozoa | larvacea | pluteus | polyp | radiolar | radiolar | | |
| Eucampia | 337 | 4 | 0 | 1 | 0 | 1 | 1 | 0 | 9 | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 359 | 93.87 |
| Monstrilloida | 2 | 252 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 260 | 96.92 |
| Noctiluca | 2 | 7 | 365 | 5 | 7 | 6 | 0 | 8 | 14 | 0 | 1 | 7 | 0 | 0 | 3 | 4 | 429 | 85.08 |
| Noctiluca_yellow | 4 | 9 | 0 | 264 | 3 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 284 | 92.96 |
| Rhyzosolinia | 1 | 2 | 0 | 0 | 260 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 276 | 97.46 |
| Trichodesmium_bowtie | 0 | 0 | 0 | 0 | 0 | 88 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 88 | 100.00 |
| Trichodesmium_linear | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 100.00 |
| bubble | 0 | 9 | 0 | 0 | 0 | 1 | 0 | 280 | 7 | 0 | 0 | 3 | 0 | 4 | 0 | 0 | 304 | 92.11 |
| chaetognatha | 2 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 233 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 243 | 95.88 |
| cope_crazy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 100.00 |
| hydrozoa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 | 0 | 0 | 0 | 0 | 0 | 46 | 100.00 |
| larvacea | 2 | 3 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 152 | 0 | 0 | 0 | 0 | 159 | 95.60 |
| pluteus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 8 | 100.00 |
| polyp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 31 | 100.00 |
| radiolaria_puffball | 6 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 7 | 0 | 1 | 2 | 0 | 0 | 347 | 1 | 367 | 94.55 |
| radiolaria_spike | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 56 | 56 | 100.00 |




Random forest classifier

Flux through the imaging volume of the CPICS on the WHOI dock

8,658 ($cm^3$ / day) = 8,658,000 $mm^3$

Mass (µg) = 8.1 x Volume ($mm^3$)

= 6,640 µg /day (Alldredge, 1997)

x 30% = 1,992 µg/day POC

x5% = 332 µg/day PON

Example calculation

Conclusion: CPICS (Continuous Plankton/Particle Imaging Sensor) Is able to quantify the flux of matter through its imaging volume.

Next step : Deploy CPICS on Lagrangian floats at specific density contours to follow particulate flux at depth while quantifying and classifying particulates in real-time. Communications from buoy could be acoustic or satellite at surface.