An Autonomous Surface Craft for Long-Duration, Multi-Disciplinary Sampling in Coastal and Estuarine Systems: Initial SCOAP Field Results

Dan Codiga
Graduate School of Oceanography
University of Rhode Island

Funded by NSF Ocean Technology and Interdisciplinary Coordination
Today’s talk

• Sampling needs for coastal/estuarine systems
• Operational challenges
• Available platforms and limitations
• Potential for Autonomous Surface Crafts (ASCs)
• Design of SCOAP (Surveying Coastal Ocean Autonomous Profiler), a large catamaran ASC
• Initial field results: an ADCP survey
• Vision for national network
Key field sampling goals in coastal & estuarine oceanography

- **To directly measure material transport**
  - salty/fresh water; harmful algal blooms; suspended sediments; oil spills; etc

- **Measure both currents and concentrations**

- **Capture spatial structure**
  - Horizontal: Resolution 1-2 km; cover 10s of km
  - Vertical: Full water column, ~1m resolution

- **Capture temporal variability**
  - Separate tidal and longer-timescale variations
  - Persistence of ~weeks!

---

Eastern Long Island Sound
Annual-mean Residual Circulation

Codiga & Aurin 2007
Field sampling challenges in coastal & estuarine oceanography

- Strong currents (typically tidal)
- Shallow and variable bathymetry
- Sea states: up to “open coastal”
- Irregular coastlines
- Heavy commercial, recreational, and fishing vessel traffic
- Fixed fishing gear
Traditional platforms

• Research vessel surveys
  – **Good spatial coverage** BUT ...
  – **Insufficient temporal coverage** (too costly to operate for long durations)

• Moorings
  – **Good temporal coverage** BUT ...
  – **Insufficient spatial coverage** (too costly for high numbers; also unsafe/unpermitted to litter heavily trafficked waterways with moorings)
## Newer mobile platforms

<table>
<thead>
<tr>
<th>Platform</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AUVs</strong></td>
<td>Good propulsion, Insufficient durations, e.g., REMUS (Hydroid)</td>
</tr>
<tr>
<td><strong>Subsurface gliders</strong></td>
<td>Good persistence, Insufficient propulsion to stem currents, e.g., Seaglider (iRobot/Kongsberg)</td>
</tr>
<tr>
<td><strong>Wave-driven ASCs</strong></td>
<td>Excellent persistence, Propulsion irregular; marginal to stem currents, e.g., Wave Glider (Liquid Robotics)</td>
</tr>
</tbody>
</table>

**ALL THREE:**
- Designed to use miniaturized/low-power sensors
- Not well suited for water depths of ~5-10 m or less

→ Suggests potential role for standard-propulsion ASCs
Available surface vessel platforms

- **Military Unmanned Surface Vessels (USVs)**
  - High speeds; persistence ~1-2 days
  - Too costly for oceanographic research budgets

- **Shallow/protected waters (rivers, harbors)**
  - Proven: hours-days durations
  - Not designed for seaworthiness or persistence
Surveying Coastal Ocean Autonomous Profiler

Large catamaran ASC
Manufactured by SeaRobotics (Stuart, FL)
Custom design guided by URI

Goals: Seaworthiness, Persistence, Nearshore/Shallow, Safety (Collision Avoidance), and Multi-disciplinary Sensor Capacity
Seaworthiness and Propulsion

• Stability in open coastal water sea states
  – e.g., Rhode Island Sound
  – 11m length, **5m beam**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Sig. wave height</th>
<th>Duty cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling</td>
<td>0 – 1.25 m</td>
<td>60%</td>
</tr>
<tr>
<td>Transition</td>
<td>1.25 - 2.5 m</td>
<td>30%</td>
</tr>
<tr>
<td>Survival</td>
<td>2.5 - 4.0 m</td>
<td>10%</td>
</tr>
</tbody>
</table>

• Propulsion to overcome strong currents
  – Dual electric thrusters
  – max speed 8-9 knots
  – Steering by differential thrust

• Ready for very shallow water: draft < 1 m
Efficiency and Persistence

• Hulls optimized for hydrodynamic efficiency to minimize fuel consumption
• Space for large battery bank, diesel generator, high capacity fuel tanks
• Goal of ~weeks-long persistence
  – Average speed 5 knots continuous 24/7
  – Repeat 15-20 km spatial coverage multiple times in a tidal cycle
Command/Control and Safety

• Communications to operator
  – Remote control: Line of sight RF
  – Supervised autonomy:
    Iridium satellite

• USCG unmanned vessel guidance/requirements
  – Red/white/red lights (2m mast)
  – Rigid replica Int’l Code Flag D
Collision Avoidance (CA)

- Automatic Identification System (AIS)
  - SCOAP detects AIS-equipped vessels & vice-versa
  - For non-AIS vessels: Broadband radar next goal; potentially visual/thermal imagery also

- Autonomy software: Mission Oriented Operating Suite Interval Programming (MOOS-IvP) “Helm”
  - Multi-objective optimization (Benjamin et al., 2013)
  - CA handling multiple targets, identified by multiple sensors (AIS, radar)
  - CA algorithm based on COLREGS (1972 USCG Collision Avoidance Regulations): currently undergoing tests
Sensors

• Currently: ADCP & weather station
• Future: Space/power for multi-disciplinary sensors
  – Winch system for lowered sensors
    • CTDO, pH, nutrients, optical sediment concentration, etc
    • No need for special miniaturized or low-power sensors
    • Facilitates direct measurement of material transport
  – Research quality meteorological suite
  – Sidescan, acoustic fish detection, etc
• As needed, could trade deployment duration &/speed for use of power-intensive sensors
Repeat-transect “Moving buoy” Concept of Operations

• Transect: ~20 km long, stations every ~2km
  – ~5 knots avg speed, 10 min each station
  – sample at all stations ~4 times/day

• At stations: vertical profiles of currents, winched sensor parameters (e.g. CTDO)

• Operational advantages of repeat transects:
  – Coast Guard approval feasible: slight modification from protocol for oceanographic moorings
  – ASC always on same transect, other vessels informed (via, e.g., CG Notice to Mariners)
Upper West Passage - Narragansett Bay
One Day ADCP Survey, Attended by Skiff
On-water footage
Vessel Performance

• Conditions
  – Tidal currents 25-30 cm/s
  – Waves typically 1-2 feet (peak 2-3 ft; min 0-1 ft)
  – Winds typically 5-10 kts (peak 15-20 kts; min 5 kts)

• At 60% thrust, speed ranged from 4 to 7 knots
  – Mainly dependent on wind

• Generally stayed within 1-2 m (!) of transect

• Fuel consumed: about 2.5-3 gallons

ADCP Survey

• 600 kHz, 1 m bin size, water depths ~8-14 m
• ~9 hours continuous sampling
• Completed 4-km transect ~16 times; once each ~30 min
• Captured ~full tidal cycle: before peak flood to after peak ebb
Preliminary ADCP Results: Northward current

-25 cm/s  +25 cm/s

Late Flood

Early ebb

West end  ← 4 km →  East end
Peak ebb
National SCOAP Network?

Inshore of National Glider Network

- Bays, estuaries, inner shelf
- Mid-shelf
- Shelf break

SCOAPs

Gliders
Questions?

- More information at project website:
  http://www.po.gso.uri.edu/~codiga/scoap/SCOAP.htm