First Annual Partners’ Meeting
Under Ice Mapping of Oil Spills and Environmental Hazards with a Long-Range AUV

Arctic Domain Awareness Center (ADAC)
A DHS Center of Excellence

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Long Term Objective:

- Develop AUV based approach for long-range sampling and detection of a wide range of petroleum hydrocarbons to inform first responders
  - Monitor and then report
  - Help in the response phase of a spill in order to reduce damages
  - Damage assessment

- Provide a versatile, easy to use survey tool that can be tasked to provide baseline surveys but commandeered during an emergency
  - Worst case scenario – Crude oil blowout
  - Most likely scenario – Diesel or some other fuel oil from grounding
- Ideal system is easily to use and interpret, transportable, commercially available, proven, reliable, broad selectivity for different compounds in oils and sensitive enough to be valuable for the response.

- It should be easy to calibrate, not demand frequent calibration, low payload power and small.

- Last, the sensor should be reliable enough that when more than one is used the results can be easily compared/married.
Long-Range AUV provides flexible, high-endurance platform

Can be deployed from land or sea and controlled remotely

Can carry a diverse suite of interchangeable payloads

Can transmit data packets over tens of km’s or via Iridium to anywhere in world

Can operate over a week per deployment, e.g. covering a 1000 sq Km area (e.g. a 32 x 32 km box with 2 km grid)
The Latest Hot Vehicle: Tethys Long-Range AUV

- 2.3 m long, 0.3 m (12”) diameter, 110 kg dry weight.

- Propeller-driven: 0.5~1 m/s speed. Buoyancy engine enables neutral buoyancy and drift mode.

- Low-drag and low-power design: 2000 km at 1 m/s, 4000 km at 0.5 m/s.

- Example sensors: CTD, DO2, nitrate, fluorescence/backscatter, ADCP, turbulence sensor, water sampler (in development), and Environmental Sample Processor (in development)
NASA satellite data reveals how this year's minimum sea ice extent, reached on Sept. 9 as depicted here, declined to a level far smaller than the 30-year average (in yellow) and opened up Northwest Passage shipping lanes (in red). (Credit: NASA Goddard's Scientific Visualization Studio) 2011
Oil gushing from Macondo well. (BP via Associated Press)
Overview

Drilling ship Kulluk runs aground

57°05’27”N, 153°06’27”W
Accomplishments

- Example scenarios
  - Water column oil sensor selected
  - Gap identified for ice-locked oil
Phases of an Oil Spill Response

- Notification: A reporting source makes notifications to unit personnel, federal, state, and local.

- Preliminary Assessment & Beginning of Action: First responders make an evaluation of the magnitude, severity of the spill, and threat to human life and the environment in the affected area. If a responsible party does not self-report, on-scene coordinators will identify potential responsible parties.

- Containment, Countermeasures, Cleanup, & Disposal: Responders control the source of the spill and implement measures to mitigate effects to the environment. Regulatory agencies and the Responsible Party establish a Unified Command (UC). The UC refers to Area Contingency Plans for cleanup.

- Proportionally Scale Operation: Majority of the cleanup is complete. Unified Command scales back equipment and personnel working on the response, as appropriate. Crews continue with the last portions of the cleanup.

- Documentation & Cost Recovery: Collection of documentation for multiple purposes, especially for natural resources damage.

- Natural Resource Damage Assessment: Injury to the environment, wildlife, and habitat are evaluated and estimated as a result of the spill for cost recovery from the responsible party. Trustees along with public input review, approve, and implement restoration projects.
Step 0. Baseline

BEFORE

AFTER
Step 1. Notification

“A reporting source makes notifications to unit personnel, federal, state and local”

Typically, the “reporting” is pretty obvious. A boat/barge/tanker runs aground or hits a bridge, a pipeline on land breaks near a major roadway or populated area, or an explosion occurs whether on land or in the ocean.

If we stick to the maxim that “oil spill response” is all about limiting damages then the fastest “report” will likely lead to the lowest damages. In the Arctic, these obvious indicators of a spill may not be so obvious, and hence there is a compelling argument to have vehicles “looking” for spills routinely and not just when there is a perceived problem.
“First responders make evaluation of magnitude, severity of the spill and threat to human life and the environment in the affected area....”

Clearly the capacity to provide as much information as fast as possible is paramount at this stage where a wide range of certainty is acceptable... how do you triage your assets to reduce damages?

We should be asking ourselves about using vehicles for the not so obvious like under ice.
Step 3. Containment, Countermeasures, Clean-up and Disposal

“Responders control the source of the spill and implement measures to mitigate effects to the environment. Regulatory agencies and the Responsible Party establish a Unified Command (UC). The UC refers to Area Contingency Plans for cleanup.”

In the Arctic, how do you control the source if you cannot find it? How and where do you place your assets without the necessary and timely intelligence?

This is an excellent example that even with the best circumstances during a response, damages still occur.
“ Majority of the cleanup is complete, Unified Command scales back equipment and personnel working on the response, as appropriate. Crews continue with the last portions of the cleanup.”

This goes hand-and-hand with Step 3. Intelligence about the extent of oiling is critical during the development of the response. How do you know the oil is no longer present or accounted?

We see vehicles playing a huge role. Even if it takes some time to get in theatre. Somebody still has to tell the responders that the threat has been controlled.
Step 5. Documentation and cost recovery

“Collection of documentation for multiple purposes especially for natural resources damage”

We see vehicles providing valuable intelligence here, too. It is equally, or even more important, to document the areas that were not oiled. The data from the response is often used when switching to damage assessment.
“Injury to the environment, wildlife and habitat are evaluated and estimated as a result of the spill for cost recovery from the responsible party. Trustees along with public input review, approve and implement restoration projects.”

This is an extension of step 5. Vehicles that take photos would be quite useful (even if they are just stored and not communicated via model; long time lag here).
The sensor best satisfying the selection criteria is fluorescence based (AquaTracka). This evaluation informed by current literature, discussions with colleagues, and past experiences of the WHOI project team.

There are numerous “commercial off-the-shelf; COTS sensors available (e.g. Company, et al 2013).

While mass spectrometers can provide more detailed insights into the chemical composition of the oil, they have not yet reached maturity to be plug and play.

- They are expensive,
- Demand a PhD level analyst,

In addition, we suggest adding a camera that can be tasked for characterizing oil on the surface, or in a down-looking configuration, for evaluation of impacts on benthic habitats.
We must recognize that oils differ in their chemical composition and hence capacity to be detected. We believe that there are three possible types of products:

1. Diesel fuel oil—ship traffic and energy
2. Fuel oil—ship traffic and energy
3. Crude oil—exploration, extraction, transport

It is most likely that diesel fuel and fuel oil are more likely to be released in the near future with increased traffic. But a typical COTS fluorometer should be capable of detecting some fraction of compounds in each of these three products.

Broad range of potential ice conditions
Gaps and Lessons Learned

- Oil trapped in ice/under ice is challenging to detect from air or sea
  - Scenario → blowout or pipeline leak
    - Oil will rise to the ice (not pool), move into brine channels
    - Brine channels + Ice growth = reverse oreo
    - HD cameras and lights might not find anything
    - Need additional through ice detection
Everybody is working on forensics

We should be working on a way to prevent and respond to the next disaster

It’s all about reducing damages!

1. Find a release as fast as possible
2. Provide intelligence to the Unified Command that allows them to make the most well informed decisions on using their response tool box, again a logistically and infrastructure challenged area.
3. Be able to provide imagery that documents where oil went and where it did not go. We need to invest in training better first responders and providing the best technology (response) rather than investigating the effects (insurance adjusters).
4. Santa Barbara Refugio oil spill illustrates this
Next Steps

- Adapt AUV simulator to evaluate survey scenarios
  - Vehicle model including environmental sensors
  - Incorporate environment model
    - Bathymetry,
    - Currents
    - Temperature and salinity profiles,
    - Oil (point source, advective dispersion)
    - Possible ice cover

- Purchase sensor
<table>
<thead>
<tr>
<th>Model</th>
<th>Modeler</th>
<th>Purpose</th>
<th>Prediction</th>
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</thead>
<tbody>
<tr>
<td>Cook Inlet Operational Forecast System</td>
<td>Rich Patchen and Lyon Lanerolle, NOAA</td>
<td>Model Cook Inlet circulation</td>
<td>Water levels and 3D currents, temp and salinity</td>
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<tr>
<td>(CIOFS)</td>
<td></td>
<td>Model 3D circulation with tides; assimilate in situ and remotely sensed data to enable nowcast and forecast</td>
<td>3D temperature, salinity and current; 2D sea level</td>
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<tr>
<td>ROMS 3D Data Assimilation (3DVAR)</td>
<td>Yi Chao, NASA Jet Propulsion Lab (JPL)</td>
<td>Forecast the state of the atmosphere (hourly to 48 hours)</td>
<td>The 3-D state of a host of atmospheric, meteorological and surface variables</td>
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<td>PWS-WRF Model</td>
<td>Peter Olsson, UAA AEFF</td>
<td>Oil spill response modeling</td>
<td>Oil Movement</td>
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<td>GNOME/CATS</td>
<td>Glen Watabayashi, NOAA/ORD/ERD</td>
<td>Wave height guidance for marine forecasters</td>
<td>Significant wave heights, wind waves. It also produces period and direction for wind waves as well as primary and secondary swells</td>
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<tr>
<td>NOAA Wave Watch 3 model with nested Alaska grid</td>
<td>Eddie Zingone, NOAA-NWS</td>
<td>Distrib.of water level and velocity, impact of hydrokinetic devices on flow and sediment transport</td>
<td>Water level, depth- averaged velocity, sediment transport, impact of hydrokinetic devices</td>
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<tr>
<td>Delf3D</td>
<td>Tom Ravens and UAA grad students, UAA</td>
<td>Estimate time and spatial evolution of directional wave spectra.</td>
<td>2D (frequency/direction) wave spectra where frequency spectra and integral properties of the sea-state (height, period, and direction) are derived</td>
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<td>Time dependent discrete spectral wave model</td>
<td>Bob Jensen, USACE</td>
<td>Investigate the development and evolution of gyres before/during Port expansion, and the influence on navigation operations and dredging requirements.</td>
<td>Water surface elevations and hydrodynamic fields throughout Cook Inlet, Knik and Turnagan Arms.</td>
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<td>ADCIRC Model for Port of Anchorage, Expansion &amp; Deepening</td>
<td>Ray Chapman, USACE</td>
<td>Study 3D dynamics and inundation processes; simulate movements of belugas for analysis of mudflats topography</td>
<td>Hourly water level, temperature, salinity, 3D velocity field, flooded/exposed area (location of moving shore line)</td>
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<td>Princeton Ocean Model with Wetting &amp; Drying, POM-WAD</td>
<td>Tal Ezer (Old Dominion) and Lie-Yauw Oey (Princeton)</td>
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http://www.aoos.org/cook-inlet/cook-inlet-models/

Woods Hole Oceanographic Institution
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Evaluation Process

- Develop survey options:
  - Grid surveys (different resolutions)
  - Perimeter surveys (fast)
  - Adaptive surveys (use onboard intelligence to find and map oil efficiently (example in next slide)
- Develop metrics for survey performance
  - In consultation with stakeholders
- Conduct comparative runs
  - Different environments, difference survey options
- Meet with Stakeholders

Next Steps
Simulator – Next Steps

Chukchi Sea Surface Currents
11-8-2014 9:00 AKT

Preliminary Data

Point Lay ← 10 kt Wind

Wainwright
Cape Simpson
Barrow

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Next Steps

Tethys AUV tracking of upwelling front starting from 5/29 [17:59] (PDT), 2013