Marine oil spill simulation: a scenario-based classroom application of meteorology and oceanography to environmental protection

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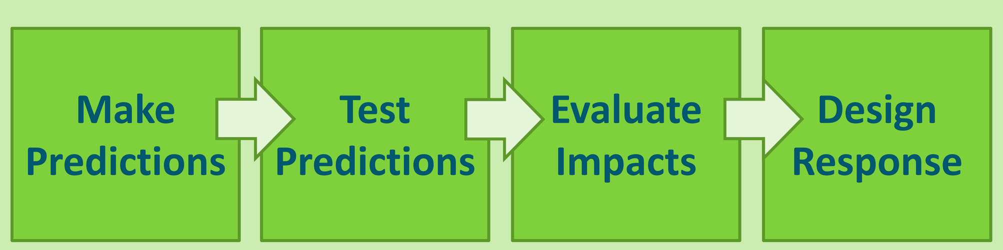
ABSTRACT

Predicting oil spill impacts and designing an effective response requires knowledge from several disciplines, including meteorology, oceanography, environmental chemistry, and marine ecology. In this poster, we describe an interactive computer modeling exercise that expands student understanding of principles in the natural sciences by applying them to an oil spill response scenario. Data and software packages used in this exercise are freely available from federal government websites, making possible the widespread use of the project at other colleges and agencies seeking to provide students with collaborative, hands-on opportunities to explore scientific concepts in the context of environmental protection.

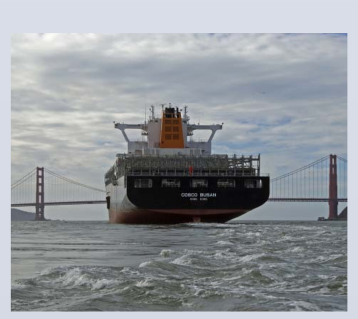
Overview

- Students use meteorological and oceanographic databases to **predict** the outcome of a major marine oil spill in a chosen location of the country.
- They **test predictions** by simulating the spill in GNOME™ v.1.3.7, software available from the National Oceanic and Atmospheric Administration (NOAA).
- Students also **evaluate** environmental impacts of the spill using a spatially explicit database of marine resources, also available from NOAA, and **design** an appropriate mitigation and response plan.



Scenario

Oil spill scenarios involve one of several coastal locations in the United States. Students choose a fictional scenario (below) and advise the Captain of the Port as to the most effective response strategy, assuming operations begin 48 hours after the spill event.



The M/V Cosco Busan after hitting the Bay Bridge and releasing oil on Nov 7, 2007. Credit: Jonathan R. Cilley, U.S. Coast Guard

Table 1. Scenarios from which students choose for the simulation.

Location	Event	Type	Oil Amount
Boston Harbor, MA	Barge-freighter collision	Diesel/No.2	2,000 bbl
Long Island, NY	Barge-freighter collision	No. 6 Fuel Oil	2,000 bbl
Tampa Bay, FL	Freighter-freighter collision	No. 4 Fuel Oil	2,000 bbl
Galveston, TX	Tanker grounding	Medium crude	5,000 bbl
Santa Barbara, CA	Oil platform blowout	Medium crude	10,000 bbl
Columbia River Estuary, OR	Bulk carrier ran aground	No. 4 Fuel Oil	2,000 bbl
Straight of Juan de Fuca, WA	Tanker collision w/bulk carrier	No. 4 Fuel Oil	2,000 bbl
Prince William Sound, AK	Tanker grounding	Medium crude	5,000 bbl

MAKE PREDICTIONS

Students **predict oil drift trajectories** in the 48 hrs after the spill by consulting meteorological and oceanographic datasets.

Meteorological Factors

Students forecast weather 48 hrs following the spill based on the following data products from the NOAA National Weather Service:

- **Surface analysis charts**
- **Upper-air (500-mb) charts**
- **NWS Marine forecasts**

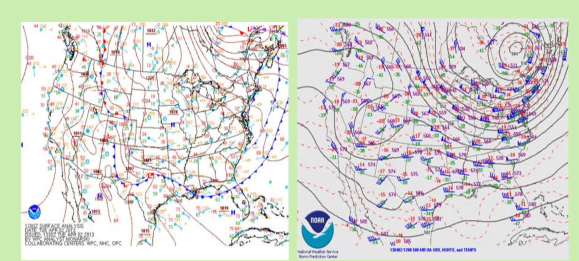


Figure 1. Examples of surface analysis and 500-mb charts used by students to forecast weather conditions. Source: www.nws.noaa.gov

Questions guide predictions:

- What is wind speed, direction, and duration at the time of the spill?
- Where is convergence and divergence aloft?
- From this information, forecast the movement of surface fronts and pressure over the next 48 hrs.
- What is the local weather forecast for next 48 hrs?
- How will weather conditions affect oil behavior, response operations?

Oceanographic Factors

Students predict the amount and location of oil remaining 48 hrs after the spill by consulting oceanographic data from the following sources:

- **NOAA Data Buoy Center**
- **NOAA Tides and Currents database**
- **Nat'l Geospatial Intelligence Agency's Atlas of Pilot Charts**

Questions guide predictions:

- What is the direction of wind-driven surface drift associated with prevailing winds in the region?
- How will speed and direction of prevailing offshore sea currents affect oil movement?
- What is the predicted height and direction of surface waves?
- Are tides an important factor in the oil's trajectory?
- What is tidal period and how will ebb and flood currents affect the movement of oil?
- Will geostrophic currents influence the oil's trajectory?

Example of data buoy from which students derive information on wave heights. Photo: PMEL/NOAA

Students combine the **database analysis** with prior knowledge from **lectures** about chemistry, meteorology, and oceanography to predict the distribution of oil remaining 48 hrs after the spill.

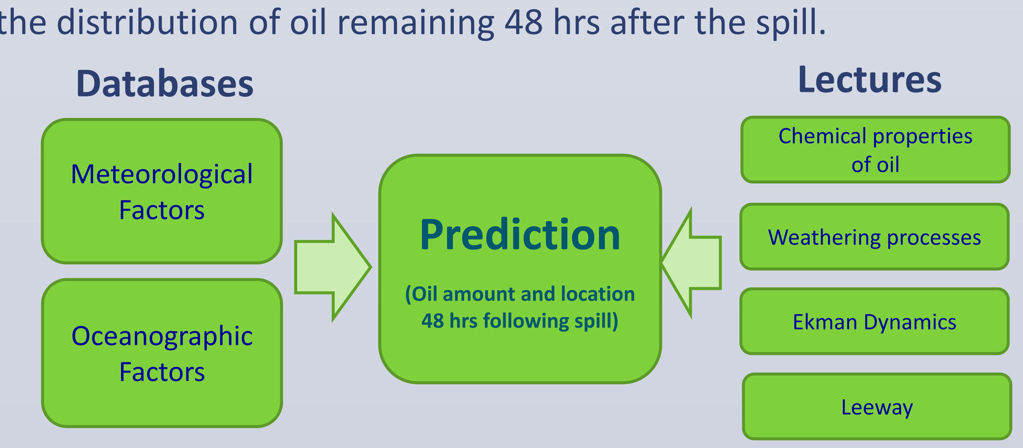


Figure 2. Combination of lecture topics and types of databases upon which students base predictions about the movement of oil in the 48 hours following the spill. Photo: PMEL/NOAA

TEST PREDICTIONS

Oil Spill Dynamics

Students **test predictions** in GNOME™ (General NOAA Operating Modeling Environment) v.1.3.7 (NOAA 2002b). GNOME simulates an oil spill with the chosen characteristics, at the chosen location, under the same environmental conditions.

Results include a map(s) of the probable location and amount of oil remaining at specific time intervals following the spill.

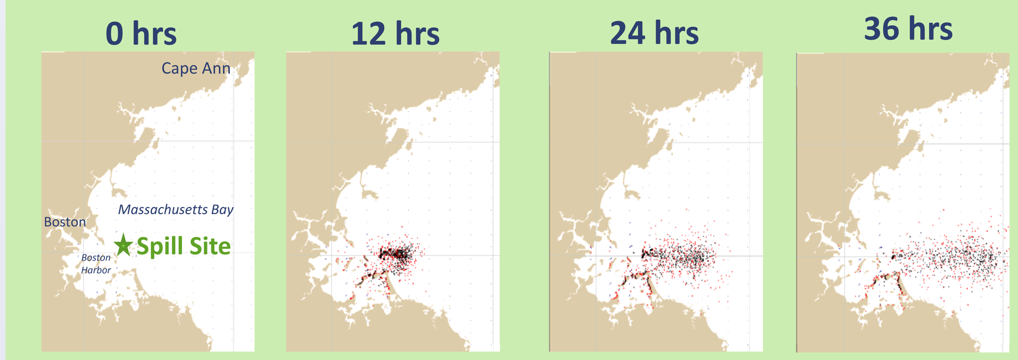


Figure 3. Example of graphical results. Barge collides with freighter, spilling 2,000 barrels of diesel fuel into Massachusetts Bay. Oil drift trajectories are displayed in a movie animation. Black dots represent the model's "best guess" as to distribution of spilled oil. Red dots represent the best guess ± 10% uncertainty (NOAA 2002b).

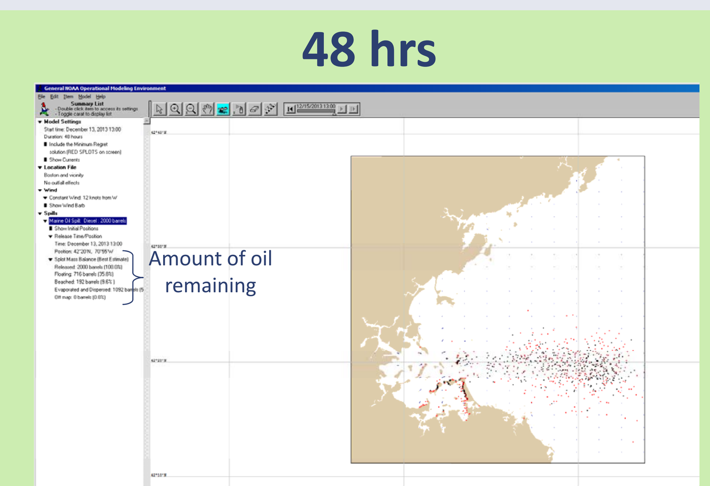


Figure 4. Example of final map in GNOME™ shows estimated amount of diesel fuel after 48 hrs. Students compare their predictions with model results.

Students compare the modeled results with their predictions, resolving differences and identifying misconceptions.

In addition to learning about oil spill science and response operations, students work in a collaborative learning environment, while exercising higher-level cognitive and multidisciplinary thinking.

Photos: USCGA cadets in Atmospheric and Marine Science (5441), modeling oil spills and preparing response recommendations. Photo courtesy of P. Tebeau

This exercise also gives students an opportunity to develop communication skills as they prepare a formal memo describing the recommended response strategy.

References

National Oceanic and Atmospheric Administration (NOAA). 2002a. Environmental Sensitivity Index Guidelines, v.3.0. NOAA Office of Response and Restoration, Seattle, WA.

NOAA. 2002b. GNOME™ General NOAA Oil Modeling Environment User's Manual. Environmental Sensitivity Index Guidelines, Version 3.0. NOAA Office of Response and Restoration, Seattle, WA. 94 pp.

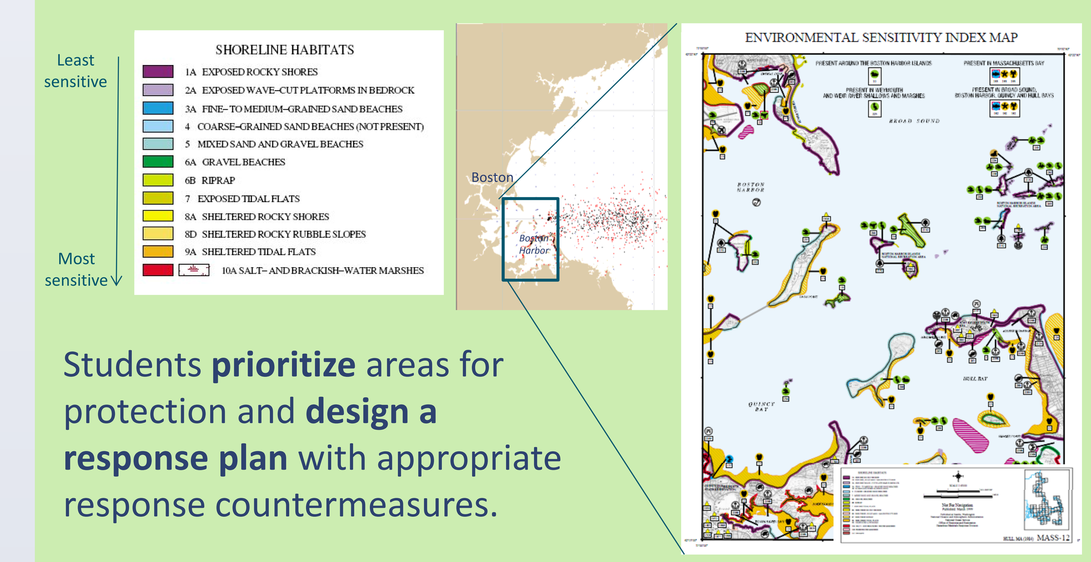
EVALUATE IMPACTS

Environmental Protection

Based on model results, students evaluate environmental impacts of the spill by referring to Environmental Sensitivity Index (ESI) maps for affected coastlines. These maps are available from NOAA's Office of Prevention and Response (NOAA 2002a).

ESI Maps contain site-specific information:

- shoreline habitat sensitivity
- seasonality and conservation status of biological populations
- vulnerable coastal infrastructure



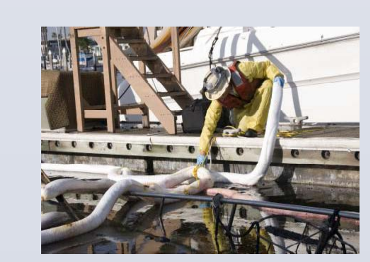
Students **prioritize** areas for protection and **design a response plan** with appropriate response countermeasures.

Figure 5. Environmental Sensitivity Index (ESI) maps from NOAA.

DESIGN RESPONSE

Countermeasures

Students identify **countermeasures** that address oil on the shoreline and still afloat. They learn about the advantages and disadvantages of response tools:



USCG photo by Petty Officer 2nd Class H.G. Dunphy.

- Booms
- Skimmers
- Chemical dispersants
- Sorbents
- *In situ* burning
- Pressure washing
- Excavation
- Sorbents
- Vacuum pumps
- No action

USCG Area Contingency Plans may be used to understand the actual availability of various response tools to first responders.

Communicating the Plan

Response plans are communicated to the instructor in the form of a 2-page memo containing a recommendation addressed to the Captain of the Port.

Conclusion

This exercise has been successfully incorporated into several courses at the Coast Guard Academy, with modifications to accommodate various audiences and learning objectives. All versions teach students about the multidisciplinary nature of marine oil spill response, incorporating principles from science, technology, and environmental science, as well as the role of human values in prioritizing environmental resources for protection.