Questions and Answers

Spill Trajectory Analysis

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Some of the most commonly asked questions about spill trajectory prediction are:

What is a trajectory analysis and how does it differ from a trajectory model ?

Trajectory modeling uses a mathematical model to predict the movement of spilled oil. It can be as simple as taking three percent of the wind speed as the velocity of the center of the oil slick, or as complicated as a sophisticated computer model containing thousands of lines of code. By itself, a trajectory model has limited usefulness in spill response. The application of any model or mathematical procedure to describe the movement of spilled oil or other pollutants is subject to all sorts of errors and represents a simplification of the real world. Clearly, a model's usefulness depends on the value of its input data, its software design, and how its results are interpreted.

Ultimately, the information available for estimating the movement and behavior of the spilled oil, along with an understanding of the uncertainty inherent in the model predictions must be factored into spill response plans. Hundreds of model runs may be required to provide the necessary guidance gleaned from the variety of possible scenarios. The trajectory expert may also want to consider other environmental and operational factors that are unknown to the model, no matter how sophisticated it is. This total process is called *trajectory analysis*. The ultimate usefulness of trajectory analysis depends on the relevance of the advice generated to actual response decisions. Almost always, trajectory analysis is more than just a map of where the oil may go.

When do I need trajectory analysis ?

One thing that seems to be universally true in spill response, particularly at the beginning of a spill, is the necessity for the on-scene coordinator to ration and distribute limited manpower and equipment to maximize the effectiveness of the cleanup effort. This requires understanding which resources are at risk and *when* they are at risk. If the spill is in a confined area or next to the beach with strong onshore winds, this is a relatively easy question to answer. However, for more complex situations and larger spills, a thorough, scientifically based analysis may be necessary to ascertain who will be hit and when they will be hit.

Understanding oil spill trajectories is a difficult job. When oil spills into the marine environment, a number of different processes occur. Unfortunately, our level of understanding of the atmosphere, the ocean, and spill behavior makes it impractical (and sometimes dangerous) to provide the necessary analysis to do this task as automated software packages usable by the non-expert. Naively, it might be assumed that you could just do a simple vector addition of the surface current with a percentage of the surface wind to get the net slick transport vector. You could do this, *if* you knew the currents (and their spatial and time variation), winds, and the right percentage of wind strength to choose.

For example, it is quite common in spill trajectory simulations to lump all of the wind effects together into a wind drift factor, which is usually taken to be three percent of the wind speed. This is an extremely useful approach, but it does simplify a great deal of what is going on. When the oil initially forms a slick, surface drift might add up to something closer to
4.5 percent of the wind speed. As the oil weathers to tar balls and over-washing takes place, the oil may spend a significant part of its time below the surface and away from the effects of the wind. Then, the drift factor may be below three percent. A sophisticated model should be able to simulate time-varying wind drift factors, but even then there will still be the need for observational feedback during actual spills. Observations made of the actual spill movement allow the trajectory expert to adjust the model appropriately.

Moreover, the wind-induced surface current is not uniform. A closer look shows that the actual surface flow is unstable and tends to break up into more complex patterns called Langmuir cells. The end result is an uneven distribution of streaks and streamers oriented in the direction of the wind. Many models act as if oil spills form a more or less continuous layer of oil. Once the oil breaks into streaks and streamers, this is obviously not the case. Over any particular region the major portions of the oil may only cover a relatively small fraction of the surface. Proper trajectory analysis adjusts for situation. Automated, "shrink wrapped" software packages usually are not flexible enough to do this.

How is trajectory analysis used most effectively?

In spill response the inherent uncertainties in understanding the future spill situation suggest that spill analysis should be aimed at supporting a "minimum regret" strategy rather than a "maximum win" strategy**.** To put this into context, a "maximum win" strategy would be one where the very best estimate of winds, currents and initial distribution of the spilled oil were collected, with the resulting forecast presented as the definitive threat requiring response action. This is where a standard model would produce a most-probable scenario. A "minimum regret" strategy, on the other hand, would use available analysis techniques to investigate the sensitivity of various estimates to errors in the input data and would explore the implications of alternate, plausible scenarios. For example, the strategy would take into account the significance of an atmospheric frontal passage six hours before the slick's forecasted time of arrival. The strategy would also draw on any historical data, such as those suggesting a coastal current reversal this time of year, modifying the trajectory estimate accordingly. As this type of analysis takes place the investigator is exploring situation space. Briefing documents can then provide the response organization with the "best guess" while simultaneously covering alternate possibilities that might present a significant threat. The major difference between these two approaches is that the "minimum regret" strategy can identify less likely, but extremely dangerous or expensive, scenarios that may require alternate protection strategies.

How do remote sensing and trajectory analysis interact during a spill incident?

Remote-sensing, visual overflights by trained observers and surface drifters in concert with trajectory analysis is a very powerful combination. The former is useful in calibrating trajectory predictions, which can help to direct the (often expensive) observing aircraft to look for oil, and help identify false-positive observations.

A spill trajectory analysis without real data collected on oil location will soon become divorced from the reality of the spill event. On-scene measurements of winds and currents using buoys or drifters will reduce the errors in trajectory prediction.

Remote sensing and spill tracking devices are, however, no substitute for trajectory analysis. While remote sensing is useful in determining spill location, it is a tool that only tells you where the oil is *now*, not where it is going in the future. To properly deploy cleanup resources, you need to anticipate future spill location and possible shoreline impacts. Also, all methods of observing and tracking the oil have limitations on when they can perform properly. If environmental or spill conditions are outside the sensor's window of operability, trajectory analysis provides a method of estimating present oil location in the interim.

Is there a difference between spill models used for contingency planning and those used for actual spill response?

Trajectory models that use historical weather data help establish the range of possible scenarios and are thus very useful in spill-response planning. The Minerals Management Service and NOAA have used them effectively for this purpose for many years. Great care must be taken in setting up such contingency models to ensure that they truly represent the geophysical conditions they are attempting to model. Since the conclusions of planning models cannot be immediately compared to an actual spill, a poorly designed use of them can result in a false picture of the spill threat for a particular region.

However, for a real spill, the initial spill notification provides more information to establish the possible spill risk than will reliance on statistical calculations. A rough guess based on the actual conditions at the time of the spill is usually superior to a guess based upon climatological data. For example, if you were considering a picnic for tomorrow, would you base your plans on the seasonal average weather for the picnic site or would you prefer the actual weather forecast? Winds and currents are functions of time and may vary considerably during an actual spill from the their average values. In fact, it is often the extreme conditions of winds and tides that lead to a spill in the first place.

Is it possible to run a spill model using anecdotal information about the area and just "paint in" an estimate of the currents ?

During every spill response, NOAA tries to gather anecdotal information about local sea conditions. Fishermen, in particular, often are knowledgeable about natural convergence areas where oil or rafting birds may collect. However, to enter such current data and extrapolate it to possible locations where the oil will move can easily result in a current pattern that is scientific nonsense. Basic, common sense principles such as the conservation of water are usually violated with such patterns.

Bathymetry, shoreline, and vorticity considerations must, at minimum, be considered when developing acceptable current patterns. Depending on the spill location and circumstances, other parameters such as bottom friction and wind stress may also need to be included. Creating a scientifically sound current pattern to be used in a spill model is almost always the most difficult part in preparing a spill trajectory forecast. It is also something that is as difficult to automate as surgery would be in a medical emergency. Just as anyone contemplating a surgical procedure would want the services of a skilled physician, anyone wanting a good current pattern (or valid trajectory analysis) would want it estimated by someone with a sound physical oceanography background.

Is it true that the more complicated and larger the model, the better spill prediction it will give?

It is fundamental to understand that any model of oil spill movement cannot represent all the complex processes that are occurring in the marine environment. It is critical to know not only what the model says, but also what it cannot say. Trajectory analysis should operate at the level of the available data and required output. A very sophisticated model that needs large amounts of unavailable information to run is not much help in a spill emergency. A common example is a three-dimensional, hydrodynamic program that has to be calibrated with vertical water profiles of current, salinity, and temperature data before it can generate meaningful current data.

It is often more practical at spills to ensure that the input information used is as consistent and accurate as possible. Also it is important to understand the possible errors in this data and how such errors will affect the accuracy of trajectory predictions. This allows the analyst to tell the on-scene responder not only where he or she thinks the oil will go but also gives the error bounds on the estimate.

It is essential that spill analyses quickly assimilate new data. In operational response this requirement is typically far more important than trying to include progressively more complex representations of dynamic processes that cannot be supported with real-time data corrections. For example, although their weather models are quite complicated, the National Weather Service continually updates the models with on-scene measurement.

It is important to remember that the very best full-scale representation of the spill process is the actual spill itself. If the spill analysis techniques cannot recognize this fact and take advantage of it, then the results will be substandard no matter how complex the algorithmic representations and colorful the data presentation turn out to be. Off-the- shelf models, operated by inexperienced users, are not able to provide this level of flexibility or expertise that trained analysts, using appropriate modeling techniques, can provide.

NOAA's HAZMAT Division has produced a standard for displaying trajectory model results. This standard ensures that trajectory information from different models is presented in a consistent format and provides a basis for comparison of different predictions. Copies of this standard are available by faxing the Division at 206/526-6329.