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16. ABSTRACT

A workshop on Government Oil Spill Modeling Activities was convened by the Environmental Data and Information Service (EDIS) of the National Oceanic and Atmospheric Administration (NOAA), November 7-9, 1979. The meeting was held at the National Aeronautics and Space Administration (NASA) training facility at Wallops Island, VA. The workshop brought together oil spill model users and modelers for the purpose of fostering joint communication and increasing understanding of mutual problems. The workshop concentrated on defining user needs, presentations on ongoing modeling programs, and discussions of supporting research for these modeling efforts. Specific user recommendations include the development of an oil spill model user library which identifies and describes available models. One user concern was the development of models for the long-term rate and effect of spilled oil. Users further designated the top and bottom meter of the water column as regions of primary concern with regard to nearshore impact. (Author extracted)

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Proceedings of the Workshop on Government Oil Spill Modeling November 7-9, 1979, Wallops Island, Virginia

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Washington, D.C.
February 1980

U. S. DEPARTMENT OF COMMERCE
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CONTENTS

I. EXECUTIVE SUMMARY

Organization

A workshop on Government Oil Spill Modeling Activities was convened by the Environmental Data and Information Service (EDIS) of the National Oceanic and Atmospheric Administration (NOAA), November 7-9, 1979. The meeting was held at the National Aeronautics and Space Administration (NASA) training facility at Wallops Island, Va. The workshop brought together oil spill model users and modelers for the purpose of fostering joint communication and increasing understanding of mutual problems. Attendees included representatives from the Bureau of Land Management (BLM), the U.S. Geological Survey (USGS), the Environmental Protection Agency (EPA), Brookhaven National Laboratory (BNL), the U.S. Coast Guard (USCG), and NOAA components of the National Marine Fisheries Service (NMFS), the National Weather Service (NWS), the Office of Marine Pollution Assessment (OMPA), and the Great Lakes Environmental Research Laboratory (GLERL).

The workshop concentrated on defining user needs, presentations of ongoing modeling programs, and discussions of supporting research for these modeling efforts. The basic goals were to assure that our current efforts are consistent with user needs and to provide a forum for technology transfer.

The morning of November 7 was devoted to half-hour presentations by various model users. The afternoon and the following day were devoted to 1-hour presentations of the EDIS, USGS, USCG, NWS, OMPA, EPA, BNL, BLM, GLERL, and NASA modeling efforts. The last morning was used to finalize recommendations and hold panel discussions on operational structure, model research goals, and user needs.

Recommendations

A consensus among workshop participants was that a forum such as this should be convened periodically to maintain a dialog between oil spill model users and modelers. The theme developed throughout the workshop was that model users should be given a more responsible role in model development. Ideally, this input should concern the type and complexity of the model.

Specific user recommendations include the development of an oil spill model user library which identifies and describes available models. One user concern was the development of models for the long-term fate and effect of spilled oil. Users further designated the top and bottom meter of the water column as regions of primary concern with regard to nearshore impact.

Users and modelers developed the following characterization of oil spill models:

> Type I models: Multiple trajectory models for long-term strategic forecasts based on archived data,
>
> Type II models: Single event (highly structural) models for specific day-to-day tactical forecasts, usually based on up-to-date data, and

Type III models: Type I or Type II models implemented in a receptor (reverse) mode such that one can project areas from which trajectories would impact resources.

Modelers identified the need to incorporate data concerning oceanographic and meteorological frontal locations in future modeling efforts. The use of satellite data presents a potential solution to this problem. Improved information concerning the weathering of oil at sea was also identified as a major issue.

Although various government modeling efforts are very similar, this apparent redundancy is considered appropriate in that it allows for specific agency mission needs to be most efficiently addressed and different scientific approaches to the trajectory problem to be developed. A mechanism should be developed for the central coordination of all government oil spill modeling efforts.

II. PANEL RECOMMENDATIONS

Three working panels were designated during the final day. These working groups concentrated on the topics of opertional structure, model research goals, and user needs.

Panel Discussion: Operational Structure

One panel was convened to outline the various government oil spill modeling activities. The discussion was chaired by Roy Overstreet of NOAA (OMPA). The following are specific recommendations resulting from this discussion. Table 1 represents an outline of the operational structure of the principal Federal oil spill modeling activities. Specific recommendations of the group were:

1. Improve communications among USCG, NWS, and OMPA forecasters during spill response.

2. Develop easy-access files of available environmental data.

3. Systematically archive environmental data collected during spill response. This requires planning.

4. Encourage close coordination between Brookhaven/NMFS and Brookhaven/OMPA in Bering Sea circulation and ecological modeling.

5. Increase the emphasis on better estimates of over-the-water wind field for both operational and climatological trajectory models.

Panel Discussion: Model Research Goals

A second panel was convened to outline future oil spill modeling research goals. This discussion was chaired by Kenneth J. Lanfear of DOI (USGS) and produced the following recommendations:

1. Establish electronic data exchange. Oil spill modeling activities of NOAA, USGS, and the Coast Guard involve large data bases, and coordination could be improved if procedures are developed to facilitate exchanging large amounts of data by direct computer linkage. The NOAA/USGS Coordinating Committee should consider this matter.

2. Develop improved models that incorporate more advanced dynamics of oil spill movement. These models should consider the relationship between wind velocity and slick movement in terms of physics, rather than empirical factors.

3. Expand the oceanographic data base, particularly near the coasts.

4. Study further the weathering of oil in and on water.

Table 1.--Operational structure of principal Federal oil spill modeling activities

Organization	Principal activity	Product	User
BLM	Oil spill risk analysis	Oil spill magnitudes and frequencies for pipelines, marine transportation routes, port facilities, and handling procedures Oil spill trajectories	BLM, USCG, State and local agencies
Brookhaven National Laboratory	Ecosystem analysis studies of stresses on shelf productivity, physical and biological data analysis Coastal oceanography	Ocean circulation models, contaminant transport model, biological models	BNL, DOE, PROBES, NOAA/MESA, NOAA/OCSEAP, State and local agencies
EPA	Experimental and theoretical studies of properties, effectiveness, and ecological effects of oil dispersants Water quality modeling	Improved understanding and guidelines for dispersant use, circulation and contaminant transport models	EPA, NOAA, BLM, petroleum industry, State and local agencies
NASA	Air-sea interaction studies Remote sensing Laboratory studies Theoretical studies	Improved understanding of air-sea interaction processes as related to the transport of spilled oil, areal oil spill and water mass boundary maps	All groups concerned with contaminant transport processes in the upper mixed layer
NOAA:			
EDIS	Climatological models for oil spill contingency planning based on NODC and NCC archived oceanographic/meteorological data	Climatological oil spill atlas, for contingency planners Climatological oil spill trajectory forecasts	NOAA, USCG, BLM, petroleum industry, State and local agencies
	Oil weathering and "leeway" studies	Prediction of short-term fate of spilled oil	
ERL	Studies of seasonal circulation, meteorology, mixing and transport processes in coastal waters and Great Lakes	Oceanic, estuarine, and Great Lakes circulation and contaminant transport models	NOAA, EPA, USCG, BLM, State and local agencies

NMFS	Resource ecology, fisheries management	Ocean circulation models, ecosystem models, OCS impacts to shelf resources	NMFS, BLM, PROBES, other agencies involved in asssing
NWS	Application of NWS weather forecasting capability to the prediction of spilled oil movement	48-hour weather forecasts, planetary boundary layer model, operational drift model for oil spill movement forecasts, dynamic upper mixed-layer and oil behavior model	NWS, all agencies involved in oil trajectory predictions and cleanup operations
OMPA	Operational and climatological transport model development and application	Ocean and estuarine circulation models	NOAA, BLM, USGS, USCG, State and local agencies
	Oceanographic and meteorological and field studies (HMSST)	Strategic (long-term) oil spill trajectory predictions, operational forecasts of hazardous materials movements	
USCG:			
Academy	Long Island Sound oil spill transport model	Real-time oil spill movement forecasts	Long Island USCG Command
Oceanographic unit	Real-time oil trajectory models	Continuously updated 6-hour oil spill forecasts	Local USCG Commands
R&D	Arctic oceanographic and ice studies	Behavior of oil in Arctic environments, Arctic water and ice motions, Arctic oil spill model	USCG, NOAA, BLM, State of Alaska, North Slope Borough, and other local interests
USGS	Oil spill risk analysis	Spill occurrence probabilities, climatological oil spill trajectories and impact probabilities, recreational and biotic resource distributions, relative environmental hazards of OCS development in different areas	USGS, BLM, NOAA, State and local agencies

*Supported in part by DOE, NOAA, and NSF.

5. Study the subsurface movement of oil.

6. Develop improved techniques and procedures for transmitting satellite imagery for operational oil spill cleanup activities.

7. Investigate the roles of oceanographic and meteorological fronts in controlling oil spill trajectories.

8. Study the role of ice in influencing oil spill movement.

9. Examine further the probabilities of oil spill occurrence to permit more detailed evaluations of production and transportation alternatives.

Panel Discussion: User Needs

A third panel was convened to discuss user needs. This section was chaired by David E. Amstutz of DOI (BLM). In this discussion, oil spill model users were divided into two distinct groups. The first group is concerned with determining and assessing impacts from oil spills which have not yet occurred. The second group deals with real-time spills. The models used by the two groups are identified as Type I and Type II, respectively. The model types are described below as are user needs, which understandably differ between model types.

Type I models are probabilistic in nature. The spill is hypothetical, and the driving forces which determine its trajectory are derived from stochastic summarizations. These models are used primarily to support environmental assessments of proposed actions which are subject to the National Environmental Policy Act of 1969. Principal users include BLM (for proposed OCS lease sales), USGS (for proposed OCS development plans), NOAA (in support of assessments made by DOE, DOT, etc.), and USCG (in oil spill contingency planning). These models make use of a climatological representation of the ocean currents and an added drift induced by local wind. Ocean currents are represented deterministically, while wind drift components, for which far greater amounts of usable data are available, are treated stochastically. Tidal motions have been incorporated in nearshore and embayment areas where they may be deemed to contribute to advective transport.

The spatial resolution of these models, expressed in terms of trajectory impact locations, need be no better than the estimated areal extent of the simulated spill (on the order of 10s of kilometers). Type I models obviously can treat only the large spills, e.g., greater than 1,000 barrels. Estimation of the areal extent of a hypothetical spill involves considerable uncertainty, given the broad range of observed spill sizes (spanning four orders of magnitude) and our lack of understanding of spill dispersion and spreading. All of the Type I models treat advection only on the surface. This is done because of a lack of information concerning subsurface behavior and transport, and not because of a predetermination of lesser importance. Some Type I models incorporate potential impact targets such as spawning areas, fish migration routes, and areas of commercial fishing. All of the Type I models contain representations of shorelines as potential targets. Few of the Type

I models explicitly include oil weathering algorithms, and a very limited number attempt to quantify impacts as opposed to physical contact. Type I models can be used to compute spill trajectories for real-life spills provided their use is intended to project in time and space beyond present limitations imposed by local weather forecasts.

Locally induced wind drifts are generally treated by the wind factor approach. There are differences of opinion on the percentage of wind speed to be used (1 to 6 percent) and on the deflection angle (0° to +20°). Most of the Type I models use drift speeds near 3 percent of the wind speed and deflection angles of either 0° or +15°. Given the uncertainties in spill size, the unmodeled consequences of oil weathering, and our inability to portray subsurface behavior and transport, these variations in drift percentage and deflection are acceptable. It can be shown, for example, that variations in percentage wind drift up to at least 1 percent are negated by uncertainties in spill size alone. Variations in deflection angle result in potentially greater variations in impact locations; they are, however, offset in large measure by uncertainties in the climatological portrayals of ocean circulation employed. Ongoing research on the matter of surface drift is very important, not so much to clarify the wind factor parameters, but rather to enhance our understanding of the physics of surface drift so we may model the dispersion and spreading of oil at sea. This aspect of oil spill modeling is critical to the assessment of the consequences of oil spills.

Type II models are deterministic in that the spill has occurred, or is expected to occur, in real time, and thus the driving forces acting on the spill are determined from real-time or forecastable parameters. Principal users are the USCG (for containment and cleanup purposes) and NOAA (generally in scientific support of the on-scene coordinator).

Type II models can be used in a larger number of geographic areas than Type I models. The Type II models are more effectively applied to nearshore, embayment, and harbor areas. Type II models provide more than trajectory information to the extent that containment measures require accounting of parameters such as wave height, current velocities, and maximum wind speeds. Discussions during the workshop nevertheless focused on trajectory matters alone.

There is a greater need for more accurate representation of the wind factor in Type II models than in Type I models. The success of Type II models depends on forecast wind speeds and directions. From a practitioner's view, the advantages of working with Type II models include the high quality of output data concerning the spill in question. Disadvantages include the limited response time (a few hours) and the real-time, potentially adverse, consequences of model inaccuracies. In conclusion, there is need for research into the dispersion, spreading, and subsurface transport of oil spills. Dispersion and spreading are critical to determination of areal extent and final consequences of an oil spill. There is also a need for substantial research into oil weathering processes (e.g., water column accommodation, dissolution, evaporation, and emulsification).

A listing of available models (a model library) was also deemed desirable by the panel members. It was agreed that such a listing of models must contain discussion of input data requirements, methods of computation, and model outputs. Assumptions used in both models (explicit and implicit) should be itemized to the extent practicable. A continuation of data exchange was endorsed. Finally, it was agreed that more effort be made to document instances of model validation which have used data from actual spills.

III. ABSTRACTS OF INVITED PAPERS

The following is a collection of abstracts of invited papers. More information about individual talks can be obtained from the author.

Oil Spill Modeling Needs and Programs

David E. Amstutz
DOI (BLM)

The Outer Continental Shelf (OCS) Lands Act, as amended, requires the Secretary of the Interior to make publicly owned oil and gas resources available to help meet the Nation's energy needs. Within the Department of the Interior (DOI), the Bureau of Land Management (BLM) carries out the leasing process; the U.S. Geological Survey (USGS) estimates volumes of oil and gas which may be produced from the offshore lands and supervises leases once they have been sold. Since OCS leasing involves actions which can impact the environment, the leasing process is subject to the National Environmental Policy Act of 1969 (NEPA). NEPA in turn requires that BLM produce environmental impact statements before each of the scheduled lease sales. The current Administration has, in addition, committed itself to prepare environmental impact statements addressing offshore and lease development. These latter statements are to be prepared by USGS and will be written after the leases in a particular area have been sold and explored but before production of oil and gas. Leasing, exploration, and development are three steps between the decision to dispose of the public resource and the actual production and transportation of oil and gas from the lease areas.

These assessments of environmental impact treat the natural environment as well as socioeconomic considerations. Topics include: the impact of oil spills on marine life and shorelines, the impacts of drilling fluids and cuttings on benthic communities, space-use conflicts between offshore structures and fishing grounds, onshore employment and land use, and degradation of air quality.

Lease sale environmental assessments prepared by BLM are supported in part by a studies program which has been operative for the past 5 years. BLM environmental studies and impact assessments are intended for lease sale decisionmaking and for developing mitigating measures such as lease stipulations, regulations, and, in some cases, monitoring.

Oil spill risk analysis modeling is performed within the Department of the Interior jointly by BLM and USGS. Input data are provided by BLM, the modeling work itself is performed and formally reported by USGS, and the model results are used in impact assessment by BLM. The analysis is performed to enable consideration of lease tract deletion and transportation alternatives. The modeling work is undertaken from a cumulative perspective and includes spill simulations from existing transportation routes and, where applicable, from assisting Federal leases.

Oil spill risk analysis is a probabilistic problem in all its aspects. The analysis treats events which may or may not occur over the next two to three decades (the expected production life of offshore leases).

Three goals within BLM are to: provide adequate environmental input data to the existing USGS model, sponsor research which will yield practical improvements to existing models, and sponsor research which enables more thorough assessments of the consequences of physical contacts which oil spill models project. Pursuit of these goals has yielded considerable information which is incidentally of value to those engaged in the study of real-time spills.

Problems related to data stem from: the lack of existing knowledge of America's coastal regions, the impossibility of phasing all relevant environmental studies with the lease sale schedules, and the great difficulty in devising ways to better assess the impacts of oil spills. Some less obvious problems encountered during consideration of oil spill modeling are noteworthy. For example, one can simulate tanker spills to occur along tanker routes, but these simulations do not account for grounding and breakup of vessels off course (Argo Merchant). The consequences of an oil spill are very much a function of how that spill occurs, for example, a platform blowout into the atmosphere (Ekofisk) or into the water column (Ixtoc), a grounded tanker breakup near shore (Amoco Cadiz), or an offshore pipeline rupture. The behavior of spilled oil is also a function of its physical and chemical properties. These properties of oil can vary as much or more with well depth as they do horizontally. At the preleasing stage in unexplored regions there is generally little or no knowledge of oil properties available.

The occurrence of oil spills, their behavior, fate, and effects are highly publicized and emotionalized in this country. Although damage has occurred from some accidental spills (which we are addressing here) and probably will occur in the future, we must not lose sight of the fact that oil is introduced to the marine environment through a variety of deliberate, accidental, and natural means. Deliberate discharges (direct and indirect) account for 88 percent of the nearly 2 billion gallons introduced annually to the world oceans; 10 percent is from natural seeps, and 2 percent stems from offshore production (Boyd, et al., 1976).

*Boyd, D. B., C. Butes, and J. R. Harrold, 1976. "A statistical picture regarding discharges of petroleum hydrocarbons in and around U.S. waters." In Sources and Sinks of Hydrocarbons in the Aquatic Environment, AIBS, Washington, D.C., pp. 37-51.

Transport Modeling on the Alaskan OCS

Roy Overstreet
DOC (NOAA/OMPA)

NOAA's Outer Continental Shelf Environmental Assessment Program (OCSEAP), under Bureau of Land Management (BLM) sponsorship, is supporting the development and application of spilled oil transport models, the results of which are used by BLM in assessing impacts of oil and gas development on the Alaskan continental shelf. The area of concern extends from the eastern Gulf of Alaska to the Canadian Arctic border. Models currently in use are of three general types: (1) a diagnostic model applicable to open coastal regions in which the basic flow is governed primarily by geostrophic and Ekman dynamics; (2) wind-driven, hydrodynamic models for use in shallow coastal seas, embayments, and estuaries; and (3) a model of sea ice motion in the Arctic, where moving ice may determine pollutant trajectories for much of the year. Data input needs for these models are met by accompanying oceanographic and meteorological field observations. A major data requirement is an improved description of coastal winds, which in many Alaska areas differ radically from those either measured at land stations or inferred from synoptic weather maps. Information from coastal wind studies is used in determining both the basic flow and likely oil trajectories, accounting for possible differences in oil slick/surface water motions. The presence of winter ice cover in some regions has required modeling the motion of ice itself and the development of the capability to model the current during conditions of complete or partial ice cover. The latter is relatively new and is at present being applied to winter simulations in the northern Bering Sea. For pollutant transport predictions in nearshore regions, where flow dynamics are not well understood, the development of empirical circulation models should receive greater attention.

National Marine Fisheries Service Oil Spill Modeling Needs

Elaine Chan
DOC (NOAA/NMFS)

The National Marine Fisheries Service (NMFS) is responsible for the management and protection of living marine resources. An important NMFS function, the assessment of oil spill impacts, calls for a rapid response capability to predict accurately or assess where, when, and to what extent natural resources will be or have been affected. To accomplish such assessments we often rely on the field or laboratory data superimposed on, and in conjunction with, the output of oil spill models.

This discussion of NMFS user needs addresses the two major areas of technical needs and program needs. Our technical needs call for data from the entire field of model output with an emphasis on the verified conceptual models including, but not limited to, the following information:

1. Horizontal and vertical distribution and concentration of various petroleum fractions over time.

2. Probability of impact by geographic area or resource type.

3. Behavior of oil in water (dissolution, evaporation, emulsification mixing, deposition, and relationship to suspended or bottom sediment).

4. Weathering of oil (biodegradation, photochemical oxidation).

The distribution and behavior of oil in surface water, near the benthic interface, and in the intertidal zone is especially significant for biological assessment efforts.

Our program needs are dictated by the necessity to respond quickly with complete, defensible assessments.

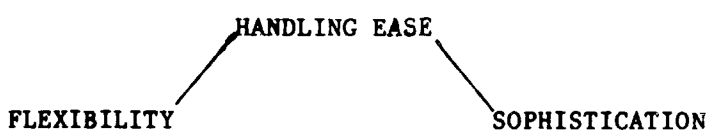
For user convenience and access, NMFS recommends the establishment of a central data base to serve as a library for all modeling data from fragmented sources. A direct communication link between users and modelers should be set up to permit modelers to incorporate data from users in model verification and to better fulfill user needs.

U.S. Coast Guard Oceanographic Unit Oil Trajectory Modeling System

Dale L. Thompson
DOT (USCG Oceanographic Unit)

The Oceanographic Unit has been involved in real-time modeling routinely since late 1977. It is a support effort to assist the various Coast Guard commands having responsibilities for pollutant containment and cleanup. Their primary need for a quick response drives our forecasting system. More accurate, but slower, impact assessment-type forecasts would be unacceptable.

Our experience suggests that each model must be developed in light of the system within which it is to be used. To illustrate this, I submit the following figure, the value of which lies in its ability to demonstrate what I call the "Compromise Triangle":



This figure shows the dilemma of designing the ideal model versus what we settle for in a real-life situation. The term "flexibility" implies that the model can be used in any environment, at any location, and with any oil.

"Sophistication" denotes a higher order solution to the drift problem--Ekman drift, spreading, evaporation, Langmuir cell terms, vertical diffusion, etc. Also we must consider both the quality and quantity of inputs. By "handling ease" I combine both the ease of implementation by the forecaster and an output format which can be readily transmitted to, and understood by, the user. Finally, let me add another part to the concept. The data processing facilities available set the level upon which the compromise triangle must then be worked out for each particular system and needs.

The two models most frequently used by us are vector addition schemes, printing out a drift position after summing vectors. They are as presented in May at the Princeton Oil Spill Conference by Don Murphy in the paper we coauthored. One model adds sea current, tides, and leeway (the infamous 3.5 percent); the other model uses sea current, tides, a wind current, and a similar leeway factor. The resultant drift positions are put on a nautical chart, spreading superimposed, and the chart telecopied to the user. Accompanying it is an explanatory page.

In certain areas we have highly localized models. One, developed by Captain Kollmeyer and Cadet Thompson, does a reliable forecasting job in New York Harbor. Its handling ease is high, but its flexibility limited (its southern boundary being the Verrazano Narrows Bridge).

This compromise triangle illustrates the reasons for the forecasting system the Oceanographic Unit has developed. It leans first to flexibility, then to handling ease, by necessity. This gives our model system a low turnaround time, but also associated lower modeling precision. Fortuitously, our users' needs are satisfied with first-order drift physics solutions. We believe we have reached an acceptable compromise for the Coast Guard. Should the intensity of spills increase, greater resources in manpower and computers will be allotted. That will raise the triangle's level, and the compromise process will reoccur. The model must be constructed to fit the system within which it exists and the associated demands on that system.

Applications of the USGS Oil Spill Trajectory Analysis (OSTA) Model to Decisions Regarding OCS Oil Development

Kenneth J. Lanfear
DOI (USGS)

The U.S. Geological Survey Oil Spill Trajectory Analysis (OSTA) model is designed to predict the likelihood that oil production on the outer continental shelf will result in oil spills occurring and contacting environmental resources. Although they are a major element of the model, oil spill trajectory simulations are only an intermediate result of a larger effort. Decisions concerning leasing alternatives can be very complex, because they often involve multiple objectives, such as protection of estuaries, sandy beaches, and fishing grounds, as well as achieving certain levels of energy resource production. The OSTA Model has been recently modified to produce a number of tables and figures designed to facilitate decisionmaking; these include histograms which compare probabilities of oil spill impacts for several production and transportation alternatives, and special maps which indicate segments of the coastline likely to be affected by oilspills. Methods have been developed for using the results of the OSTA model for choosing optimum leasing strategies to achieve goals of protecting environmental resources while maximizing oil production.

Development of Forecast Methods to Predict Oil Spill Fates and Trajectories in the Ocean

Celso S. Barrientos
Kurt W. Hess
DOC (NOAA/NWS)

Forecast methods to predict the fate and trajectory of oil spills in the ocean are being developed in the Techniques Development Laboratory (TDL) of the National Weather Service (NWS). An operational model for oil spill movement forecast is being implemented in NWS. The model will be available for routine use in the event of oil spills and for assessment studies of probable impacts of oil spills.

Fates and movements of ocean oil spills depend on the oceanic and meteorological conditions during the spill. These environmental factors include atmospheric stability, atmospheric pressure fields, wind speed and direction, air and water temperature distribution, ocean currents, waves, and air and water turbulence. Methods for specification or prediction of these variables are being developed. The development of the forecast methods is being done under contracts by various universities and within TDL. Forecast techniques for the different parameters are integrated into a forecast model in NWS.

The National Weather Service Modeling Program

Kurt W. Hess
DOC (NOAA/NWS)

The National Weather Service (NWS) continues its development program for single-event oil spill behavior modeling. As a temporary measure a simplified "drift" model was designed for quick access and usage. Particles representing oil are driven by a boundary-layer wind model based on NWS surface predictions. The resulting streaklines are plotted for each forecast period. The program is available via a portable computer terminal. The more advanced two-dimensional oil model is rapidly approaching operational status. Water currents are produced by a dynamic model of the continental shelf region. Bathymetry is retrieved automatically from a data base. Surface currents are computed and combined with winds to drive the oil slick model. This model will also be accessible by computer terminal.

Response to the Campeche Oil Spill

John Robinson
DOC (NOAA/OMPA)

Initial assessments of the United States coastal impact from the IXTOC well blowout in early June 1979 were publicly minimized by United States and Mexican officials, because of possible early capping, ongoing contaminant operations, and possible use of dispersants. Also, previous open ocean spills had not traveled farther than about 200 miles at sea, whereas the distance from the well to the Texas coast was 500 to 600 miles. During early July, satellite photographs indicated that oil had actually been advected hundreds of miles from the well site, thereby invalidating the initial minimum United States impact assessments.

These data, combined with oil spill trajectory estimates, made it clear that there would be an impact along the Texas coast in early August. Although there was a possibility of a large-scale environmental disaster, authorities had at least a month to prepare for the impact. This area has a wealth of DOI (BLM) and EPA baseline data collected for OCS purposes. Thus the groundwork has been accomplished to allow the assessment of the environmental damage due to a large oil spill.

Actual beach impact occurred along the southwest Texas coast on about August 5. Initial beach impact was reduced after storms cleared the beaches of oiled sand. It has been estimated that the oil has moved 200 to 300 yards offshore.

Climatological Oil Trajectory Modeling for Long-Term Predictions and Contingency Planning

Joseph M. Bishop
DCC (NOAA/EDIS)

Over the past 4 years, the Environmental Data and Information Service (EDIS) of NOAA has developed a multiple trajectory oil spill model. The model is based on the archived wind and current data available within EDIS's National Climatic Center (NCC) and National Oceanographic Data Center (NODC). The model was originally designed for assessment of possible environmental impact due to construction of a deepwater port off the Texas coast, but has been used effectively in the Argo Merchant and Campeche oil spills for a rapid estimate of impact areas. The successful use of this model for climatological assessments of large ocean spills leads to the conclusion that this type of climatological forecasting technique should be a part of our overall response to major oil spills.

Although the utility of this approach has been shown in these two examples of large open-ocean oil spills, a better application of this climatological (Type I) model is in contingency planning (prespill resource allocation). In this mode, one can map most probable impact zones over known local resources (biological or economic). Such a use has been initiated in a recent EDIS publication produced for use by the 3d Coast Guard District contingency planners, couples key environmental data (both physical and biological) with climatological oil spill trajectory forecasts.*

*Bishop, J. M., 1980. "A Climatological Oil Spill Planning Guide, No. 1, The New York Bight." National Oceanic and Atmospheric Administration, Washington, D.C., 126 p.

A Surface Oil Spill Model for the Great Lakes

R. L. Pickett
DOC (NOAA/GLERL)

This paper describes an operational forecast model for the movement of surface-pollutant spills on the Great Lakes, with special emphasis on oil spills. Oil spills are of particular concern, because of their environmental impact and the substantial quantities of oil transported on the Great Lakes, both as cargo and as fuel. The Great Lakes Environmental Research Laboratory (GLERL) undertook this modeling effort, because a number of models were being developed for oceanic spills, but none were being developed for those on the Great Lakes. The resulting model, SPILSIM, is a batch-oriented model derived from oil spill models from the Canada Center for Inland Waters (CCIW) and NOAA's Pacific Marine Environmental Research Laboratory (PMEL). It predicts the movement of an insoluble surface spill anywhere within the Great Lakes, given spill size and location and surface currents and winds in the area of interest. Modifications to make the model interactive are straightforward. Implementation is on the NOAA/ERL CDC 6600 computer, but the program structure is such that implementation on another computer system is quite feasible. The computer language is FORTRAN. A card copy of the program and a report (A Surface Spill Model for the Great Lakes, by J. D. Boyd) that details the model are available from F. Rodante, Head, Computer Systems Group, GLERL, 2300 Washtenaw Avenue, Ann Arbor, MI 48104.

Modeling Theory: A Perspective of Approach

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We present a model-theoretic framework encompassing the diversity of approach to oil spill modeling. We discuss the implications of modeling in the context of oil spill model equivalence. In addition, we present the concept of the "experimental frame of reference." The rigorous definitions of "base model," "homomorphic simplification," "validation and verification," and "model realization" allow a unified and unambiguous comparison of existing models. We develop a hierarchy of validity relations useful for the development of perspective in any area of modeling effort.

On-Scene Trajectory Modeling for the U.S. Response to the IXTOC 1 Blowout

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During the spill event associated with the IXTOC 1 well blowout, the U.S. National Contingency Plan was activated. In anticipation of this, the NOAA Hazardous Materials Response Project requested the Hazardous Materials Scientific Support Team (for physical processes) to supply trajectory information through the scientific support coordinator. This was done, beginning June 12, 1979. During the summer, this plan required a variety of activities, including: 1) collecting available background information, 2) carrying out observational field programs, 3) coordinating data and information presented by other researchers (Federal, State, and private), and 4) analyzing trajectories.

During the spill, trajectory models were used in basically three different forms. The first was in a long-term statistically controlled form (strategic) for planning callup and retirement of scientific or cleanup units. The second was a short-term localized forecast (tactical) for input into day-to-day response planning. The third was in a receptor mode that identified danger zones that could impact specific, high-valued regions. This in turn was used to develop optimal mapping strategies for overflights.

The basic model for IXTOC 1 studies was a new version of OSSM (On-Scene-Spill-Model) incorporating a number of advanced features. In addition, several auxiliary programs to analyze circulation data were also used for the first time in a real spill situation. Both hindcasts and forecasts from the models have provided useful input to the overall response program.

Long Island Oil Spill Drift Prediction Model

Captain Ronald C. Kollmeyer
DOT (USCG Academy)

Because of the sensitive nature of the Long Island area and the complex nature of the surface currents in the Sound, the On-Scene Coordinator (OSC) must be able to predict oil spill trajectories accurately in order to deploy cleanup equipment and to protect sensitive areas. Present oil spill movement prediction models are inadequate for this need and are not readily accessible to the OSC.

The goal of the project is the production of a real-time prediction model that will forecast the movement and spread of an oil spill in Long Island Sound. Upon command, the model will, for a given period, produce a time series of charts displaying the location, shape, and concentrations of the oil spill.

The model will be constructed on the computer facilities provided by the Department of Computer Science, U.S. Coast Guard Academy. Captain R. C. Kollmeyer will be the overall project coordinator. A close liaison will be maintained among all interested and contributing units. At present, the following Coast Guard units are involved:

1. Coast Guard Academy,

2. Commander, CG Group, Long Island Sound,

3. USCG Research and Development Center, and

4. USCG Oceanographic Unit.

The oil drift mechanisms to be modeled will include the following:

1. predicted tidal currents,

2. Stokes drift, considering both duration and fetch limitations,

3. leeway of oil slick caused by the wind, and

4. wind drift currents of the surface layer.

A relatively sophisticated computer graphics output is desired in the form of segment maps showing the spill, its location, areal size, and concentration gradients. These maps would be produced on a time basis, showing the oil spill's predicted location every 15 minutes from the time of the spill.

The preparation of the tidal current data set will include the use of overlays for the NOS tidal current charts to allow their transfer to the model matrix. A scaling program (inverted smoothing) will then determine the currents for all other points on the matrix for each of the 13 current charts available. Currents along the shore boundaries will be made zero unless other information is available.

A planned program of verification and testing will be developed as part of the model completion. Procedures will be proposed by which small oil spills in Long Island Sound may be monitored and used in a hindcast mode. In addition, a testing progam will be drafted that would use oil drift simulators which can be tracked and compared with model predictions.

Arctic Oil Spill Research

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The severe Arctic environment, along with the remoteness of the region, poses unique problems for oil spill response efforts. Because of ice, available trajectory models will be inadequate to predict the fate of Arctic oil spills in many cases. Moreover, oceanographic data for input to drift models are inadequate, even for the relatively simple case of an open water spill.

The Coast Guard Research and Development Center is working on methods to predict the areal extent and subsequent movement of oil spills in ice-infested regions. Under scrutiny at present is the movement of potential spills along the North Slope of Alaska, with the possibility of the movement of oil from a major spill in the Canadian Beaufort Sea toward the United States.

Three main research efforts are now underway.

1. Laboratory studies to determine small-scale oil/ice interactions and oil weathering for a broad range of oil types;

2. Nearshore ice dynamics, particularly during summer breakup; and

3. Drift studies in the southern Beaufort Sea.

Perturbation Analysis of the New York Bight

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The physical transport of pollutants, their modification by the coastal food web, and transfer to man are problems of increasing complexity on the continental shelf. In an attempt to separate cause and effect, a computer modeling technique is applied to problems involving the transport of pollutants as one tool in assessment of real or potential coastal perturbations. Approaches for further model development of the biological response within the coastal marine ecosystem are discussed. Our present perturbation analyses consist of 1) a circulation submodel, 2) a simulated trajectory of a pollutant particle within the flow field, and 3) a time-dependent wind input for each case of the model. The circulation model is a depth-integrated, free surface formulation that responds to wind stress, bottom friction, the geostrophic pressure gradient, the coriolis force, and the bottom topography. The transport diffusion model is based on Lagrangian mass points, or "particles" moving through a Eulerian grid. The trajectories of material moving on the surface and in the water column are computed. It has the advantage that the history of each particle is known. With these models, we have been able successfully to: 1) reproduce drift card data for determining the probabilities of a winter oil spill beaching within the New York Bight, 2) analyze the source of floatables encountered on the south shore of Long Island in June 1976, and 3) predict the trajectory of oil spilled in the Hudson River after it had entered the New York Bight Apex. For future analyses, the shallow water model can be modified or replaced with a numerical model that contains a more sophisticated parameterization of the physical circulation. Also, the particle-in-cell model can be modified to explicitly include chemical reactions and interactions with the biota. A model should be used in the context of the level of resolution or aggregation that is known about the ecosystem and the management decision to be made. Models are used also as an aid in selecting situations that merit further analysis with more comprehensive ecological reasoning.

The USGS Oil Spill Trajectory Analysis Model

William B. Samuels
DOI (USGS)

The USGS oil spill trajectory analysis model (OSTA) is used to calculate the probability of oil spills occurring and contacting environmental resources and sections of the coastline. A grid system is superimposed on the study area with a maximum of 480 units on a side. The dimension of the grid cell is variable depending on the size of the study area. Locations of environmental resources, proposed and existing lease tracts, and oil transportation routes (pipeline and tanker) are determined by their positions in the model's grid system. Data from different map projections can be digitized and fitted into the model's grid system by coordinate conversion subroutines. A maximum of 31 categories of resources and up to 100 segments (2 different sets) of the coastline can be included in the analysis.

Oil spills are simulated in a Monte Carlo fashion. Typically, 500 simulated oil spills are launched per season from each launch point (platform location, pipeline, or tanker route). Spills are transported by monthly currents and by winds sampled from wind transition matrices. These matrices, composed of 41 wind velocity states, are based on historic wind records. They are constructed for each season for up to six wind stations. Surface ocean currents are incorporated in a deterministic manner by representing monthly current fields in the model's grid system. The spill movement algorithm consists of computing the vector sum of a wind and current vector for successive 3-hour increments. Each grid cell in the path of the spill is checked for the presence or absence of each environmental resource. Spill movement ends in one of three ways: 1) the spill contacts land, 2) the spill decays at sea, or 3) the spill moves off the map.

Conditional probabilities of contact are reported for 3-, 10-, and 30-day travel times. Oil spill occurrence is treated as a Poisson process, in which the exposure variable is the volume of oil produced or transported. Scenarios outlining proposed oil production and transportation are constructed for various alternatives. The overall risks are determined by combining spill occurrence probabilities for each of the potential oil spill launch points with the conditional probabilities. Recent applications of the model have been: Sale 55 (Northern Gulf of Alaska), Sale 53 (Northern and Central California), and Sale 46 (Kodiak Island).

Modeling Oil Slick Breakup

Richard Griffiths
(EPA)

The U.S. Coast Guard has developed a model that predicts oil slick spreading, evaporation, and breakup into droplets. The spreading submodel uses the Fay-Hoult expressions for three regimes of spreading. The evaporation submodel characterizes the oil as several components with different boiling points and vapor pressures, and each component is "evaporated" independently. The droplet formation submodel predicts the maximum and minimum droplet sizes as functions of sea state, and a size distribution between the two that decreases monotonically with increasing droplet size is discussed. The three submodels interact to predict the gradual weathering and dispersion of an oil slick. This presentation concentrates on the oil droplet formation model, the assumptions and approximations used, their implications, and research needs to improve the model. It is shown that the formulations for maximum and minimum droplet sizes depend on the analytical formulations used to characterize the waves (Pierson-Moskowitz, in this case), and that insufficient data exist to verify any one of the several assumptions that can be made about the size distribution.

Oceanographic Research of Air/Sea Interaction Processes

Norden E. Huang
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To understand the dynamics of the movement of oil slicks at sea one must begin with a basic understanding of various air/sea interaction processes. Recent basic oceanographic research at NASA Wallops Flight Center has, among other topics, been involved with:

1. the relationship between mean wind velocity, windstress, and ocean wave development;

2. the surface elevation probability distribution and statistics of wind-generated waves; and

3. the variation of the equilibrium range coefficient for a wind-generated gravity wave field.

Differential Oil Velocity--Fact or Fiction?

Peter L. Grose
DOC (NOAA/EDIS)

The differential oil velocity is the speed that a floating oil lens travels faster than the surrounding surface waters. This paper presents the rationale for such a velocity to exist, observational evidence for its magnitude, and its implications on modeling the weathering and fate of the oil.

A theoretical model, developed by J. Milgram at MIT in 1977, explaining the mechanism for the generation of a differential velocity for oil lenses is discussed. This theory relates the differential vorticity through the oil and through water. Thus, one should expect oil lenses to move faster than the Stokes drift velocity directly downwind (actually, in the same direction as the mean propagation of vorticity of waves).

Limited observations at sea using dye source markers as a surface reference indicate that the oil lenses move at about 1.1 percent of the local wind speed in overtaking the dye sources. Elongation of the tails of dye emitted from the sources is a rough measure of the local Stokes drift velocity. Simultaneous dye tail elongation measurements indicate that this Stokes drift velocity is also about 1.1 percent of the wind speed. Both speeds are directly down wave.

In terms of trajectory forecasting, differential velocity may not be important, as the presence of oil may decrease the surface currents enough to compensate for the additional speed of the oil. Therefore, a value of 3.5 to 4.5 percent of wind speed (the same as for water without oil) is probably a realistic speed for oil related to wind. In any case, the error thus induced is probably less than the uncertainties of the environmental conditions used in the forecast.

However, the existence of a differential velocity will have a marked influence on the rates of weathering and fate of the surface oil. Drag forces on the oil lens proportional to the differential velocity will compress the lens, increasing its thickness and decreasing the surface area over which evaporation and photooxidation take place. At the same time, the added shear directly under the oil lens will increase the exchange rates for oil accommodation into the water column as well as continually supplying nutrients for biodegradation. Thus, if a differential velocity does exist it has profound implications on how oil weathers and where it ends up. Additional field measurements are required to strengthen the case of the differential velocity.

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