PROJECT WAVTOP: A STUDY OF WIND WAVES AND TURBULENCE AND THEIR EFFECTS UPON VERTICAL MIXING OF OIL AND POLLUTANTS

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The tanker accidents of the AMOCO CADIZ and ARGO MERCHANT, disastrous as they were, both happened where strong advection occurred. Similar spills occurring in the Mediterranean Sea are of graver concern where flushing action of tides and currents are minimal.

Cleaning oil spills in the open sea is yet a primative and inefficient operation, almost totally at the mercy of wind and sea conditions. Available equipment, although costly, is exceedingly limited in its use in open sea; e.g., none of the entire 30,000 tons of crude oil from the ARGO MERCHANT was recovered due to huge seas which precluded use of oil containment systems. Specifically, we lack knowledge of the dynamics of the surface layer under various wind conditions needed to better design appropriate systems.

The United States plans to service supertankers several kilometers offshore at "Deep Sea Ports" to transfer oil to pipelines so as to prevent ship disasters in harbors or bays - which could take tens or hundreds of years to clean up. The U.S. Coast Guard, being responsible for oil spill prevention and clean-up supports research to study how oil slicks (and other surface pollutants) mix downward by action of wind waves and turbulence. Theoretical models and laboratory tank studies have been conducted to explore mechanisms and define parameters. Laboratory experiments show that (1) whitecaps initiate mixing of oil through the sea surface and (2) the ambient wave motions and turbulence mix oil further downward. (The downward mixing from wind waves is a critical phenomena as was seen from the AMOCO CADIZ disaster; the worst result yet may be the mixed oil reaching the shallow bottom sediments where effects may be realized for years to come).

These results dictate that we examine whitecaps and further, to assess the kinetic energy and Reynolds stresses associated with the motions of waves and smaller scale turbulence, both as a function of depth and wind and sea states (see Shonting, 1967). Project WAVTOP was initiated to perform these field observations (Shonting and Temple 1978).

The objectives of project WAVTOP are:

1. Determination of parameters which control vertical mixing of oil and their relation to wind energy input.
2. Development of a wind wave and turbulence system to measure such parameters at sea from floating or fixed stable platforms.
3. To relate and compare field data with theoretical and laboratory studies and apply data to numerical models of vertical mixing.

A system was constructed to register wave motions using ducted impeller meters waves (Smith, 1978). A self contained microcomputer system was developed which programs sampling and digitized signals from six meters and a wave staff and records the data on digital cassettes. Calibrations were performed at MIT towing tank.

Preliminary observations were made in Narragansett Bay both from an AESOP, stable spar buoy (Shonting and Barrett, 1970) and from a long pier on Gould Island. Records were made of vertical (w') and horizontal (u') particle motions from 10 to 600 cm depths beneath the wave troughs under varying wind and wave conditions. Kinetic energy (proportional to the variances $\overline{u'^2}$ and $\overline{w'^2}$) auto spectra and Reynolds stresses ($-\rho\,\overline{u'w'}$; ρ being density) were estimated at simultaneous depths. Supplementary data included time lapse cinima of whitecaps and wind velocities.

Preliminary results: (1) The WAVTOP sensing system is completed. The self contained, portable system can be airfreighted and easily assembled for observations in oil spill areas. It offers a complete monitoring capability-particle velocity components, dynamic pressure, and free surface elevation. (2) Observations revealed that kinetic energy of fluctuations attenuate exponentially with depth as was shown by Shonting (1967). Vertically integrated kinetic energy correlates well with the cube of wind speed with a phase shift indicating a downward energy flow of 0.5-2 cm/sec. Auto spectra of velocities reveal high frequency resolution. Reynolds stresses at 30 cm/depth range from 2-10 dyne/cm^2 for wind speeds of 4-5 m/sec. It is anticipated that results of the WAVTOP studies will increase our capability for predicting the fate of oil and other chemical or biological pollutants in the sea.

It is strongly urged that pollution and mixing study and monitoring programs be developed for specified areas of the Mediterranean. Two platforms from which WAVTOP observations are suitable are the following:

1. BOHRA II: The 900 ton French Buoy Laboratory is ideal as a platform for studying pollution/oil mixing processes in the ocean sea and in deep water (see Levine, Goodman, and Shonting, 1977). The BOHRA II (which has been moored in 2500 m depth, 100 km south of Marseilles) has the capability to conduct many types of experiments since it can monitor meteorological phenomena and support sensors such as the WAVTOP system and tethered thermister buoys (e.g. see Shonting and Massey, 1978).

The sources of chemical and biological pollution have their origins at coastal points around the Mediterranean. (Petroleum contamination can of course be released in the open sea by transiting oil tankers while flushing their tanks.) Efforts are being made to organize a pollution monitoring program in the Mediterranean. To compliment this effort, the BOHRA II has attributes applicable to pollution monitoring since it can sustain an entire laboratory facility in the open sea for indefinite periods. Its use would be as a control center for conducting continuous open sea monitoring of pollutants in the surface layers and atmosphere and further, to sustain special experiments as with the WAVTOP systems.

2. CNR Research Tower - Venice. This facility is quite suitable for making near shore wave and turbulence observations where small fetches are required and local weather conditions are well monitored and predicted. These WAVTOP measurements could be coordinated with wave set up and atmosphere tide studies being as were undertaken by LSDGM Venice (Cavaleri, Ewing, and Smith, 1977).

The WAVTOP system will be used to study wave and turbulence dynamics at areas where vertical mixing of oil (or other pollutants) are occurring, even at artificial spills or simulations. Studies of this sort should be conducted in the Mediterranean at areas where it is critical to understand the mixing of pollutants into the depths and the bottom sediments.

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