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Numerical Modeling of Oil Slicks Transport using Finite Volume Method with Wet-Dry Fronts

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1. INTRODUCTION

Hydro-environmental transport of oil spills has been simulated by Finite Volume Method. Eulerian approach is applied across the model, based on non-linear shallow water Reynolds-Averaged Navier-Stokes (RANS) equations, and effects of Coriolis force, viscous terms, surface wind stresses and bed friction stresses are included. The standard k–ε model gives a turbulence model for the mean flow structure. Wet-dry fronts are treated whitin the numerical model. The new model deploys many significant processes: advection, surface spreading, evaporation, dissolution, and emulsification. In this work, a highly-accurate algorithm based on a 4th degree accurate shape function has been used for the hydrodynamic model, which is not present in similar models. The fate and transport of oil spilled in water is dominated by complex physicochemical processes that depend on oil properties, hydrodynamic and environmental conditions. The evaporation process, together with dissolution and the mousse formation, leads to an increase in the volume and density [6].

Oil transport, oil exploration and oil storage facilities are all possible sources of spills. The 1991 Persian Gulf (Kuwait War) oil spill was estimated at 143 million liters or 38 million gallons [1]. The fate and transport of spilled oil is governed by the advection due to current, wave and wind; horizontal spreading of the surface slick due to turbulent diffusion, gravitational, inertia, viscous and surface tension forces; emulsification; weathering processes such as evaporation, dispersion and dissolution; interaction of oil with shoreline; photochemical reaction and biodegradation.

The chemical and biological processes generally occur a long time after the oil spill [1]. Tkalich [15] applied a consistent Eulerian approach across the model; the slick thickness is computed using layer-averaged Navier-Stokes (LNS) equations, and the advection-diffusion equation is employed to simulate oil dynamics in the water column. To match the observed balance between advection, diffusion and spreading phenomena, a high-order accuracy numerical scheme is developed. Wang and Shen [16] showed that the amount of oil released at sea is distributed among a large number of particles tracked individually. Oil particles are driven by a combination of current, wave and wind induced speed and move in a 3D space. Horizontal and vertical diffusion are taken into account using a random walk technique. Perianez [13] developed a numerical model that simulated the dispersion of contaminants, including oil spills, in the Sea. The hydrodynamic was solved in advance and includes a barotropic model for