MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

OBSTACLE AVOIDANCE CONTROL FOR THE *REMUS* AUTONOMOUS UNDERWATER VEHICLE

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As the Navy continues its development of unmanned underwater vehicles, the need for total autonomous missions grows. Autonomous Underwater Vehicles (AUV) allow for advances in mine warfare, harbor reconnaissance, undersea warfare, and more. Information can be collected from AUVs and downloaded into a ship or battle group's network. As AUVs are developed, it is clear forward-look sonar will be required to be able to detect obstacles in front of its search path. Common obstacles in the littoral environment include reefs and seawalls, which an AUV will need to rise above to pass. This thesis examines the behavior and control system required for an AUV to maneuver over an obstacle in the vertical plane. Hydrodynamic modeling of a *REMUS* vehicle enables a series of equations of motion to be developed to be used in conjunction with a sliding mode controller to control the elevation of the AUV. A two-dimensional, 24° vertical scan forward look sonar with a range of 100 m is modeled for obstacle detection. Sonar mappings from geographic range-bearing coordinates are developed for use in MATLAB simulations. The sonar "image" of the vertical obstacle allows for an increasing altitude command that forces the AUV to pass safely over the obstacles at a reasonable rate of ascent and pitch angle. Once the AUV has passed over the obstacle, the vehicle returns to its regular search altitude. This controller is simulated over different types of obstacles.

KEYWORDS: Autonomous, AUV, Obstacle Avoidance, Sliding Mode Controller, Hydrodynamic Coefficients, *REMUS*

MOLECULAR DYNAMIC MODELING AND SIMULATION FOR POLYMERS

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Polymers have been widely used in various engineering applications. For more than a quarter century, the materials have been utilized intensively for the binding materials for composites. The material properties of the binding materials called matrix materials play an important role for the composite material behaviors. As a result, the objective of this study was to understand the mechanical properties of polymers. In particular, the goal was to develop insights as to how a molecular level structure is connected to the bulk properties of materials assuming homogeneity. To this end, molecular dynamics was used to model and simulate the polymeric behaviors. Polymeric chains were modeled using the bead and spring model along with interacting potentials. The study examined the effects of different sizes, densities, and numbers of molecules per chain on the shear moduli of the polymers. Furthermore, some preliminary study was also conducted for metallic particle reinforced polymer composites.

KEYWORDS: Molecular Dynamics, Shear Modulus, Polymers, Metallic Potential, Embedded Atom Method, Lennard Jones Potential

A DECISION SUPPORT SYSTEM FOR THE OPTIMAL DESIGN OF BASE-MOTION ISOLATORS

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Transient analysis of large structural systems is a computationally demanding process, which in the past has prevented dynamic redesign and optimization. Large structures, such as buildings or ships, subjected to random base motions use isolators to minimize strain energies, which may cause damage or structural failure. This research focuses on the optimization of isolator parameters in order for structural systems to withstand potentially catastrophic transient vibrations. Many non-linear hysteretic, viscoelastic, and sliding friction isolators were numerically modeled using the scientific programming language, MATLAB. The existing programs used to solve the Voltera integral formulation for Transient Structural Synthesis (TSS) and the Recursive Block-by-Block (RBB) algorithm were investigated and enhanced to yield greater accuracy and increased computational speed. The final product is a user-friendly Decision Support System (DSS) for use with both civil and military applications. Based on different types of base motions and the inherent dynamics of the structure, this Decision Support System (DSS) is capable of optimizing isolator parameters to meet a user specific objective.

KEYWORDS: Structural Dynamics, Structural Isolation, Nonlinear Transient Analysis, Structural Synthesis, Decision Support System, Recursive Block-by-block, Convolution, Wen, Hysteresis, Earthquake

PERFORMANCE AND FLOW REGIMES IN PLANE 2-D DIFFUSERS WITH EXIT CHANNELS AT LOW REYNOLDS NUMBERS

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A numerical study on laminar incompressible flows in 2-D straight walled diffusers in the low Reynolds number regime (105-1048) is presented to investigate performance and various flow regimes that might exist. Tail channels are situated downstream the diffusers. Geometries with area ratios AR=1.15 to 5 and non-dimensional lengths of L/W1=1 to 48 are considered. Results are presented in terms of flow regime maps for Reynolds numbers of 105, 210, 314, 420, 629, 1,048 and pressure recovery coefficients maps for Re numbers of 105, 210, 314, 420 and 629. In addition, time resolved simulations of impulsively starting flow are considered at Re=210, 314 for 12 geometries on the flow regime map. Four flow regimes can be distinguished depending on diffuser geometry. With increasing divergence angle the flow goes from attached to symmetrically separated to asymmetrically separated and finally to a non 2-D pattern respectively.

KEYWORDS: Diffusers, Low Reynolds, Diffuser Performance, Diffuser Flow Regime

DRAG OPTIMIZATION OF LIGHT TRUCKS USING COMPUTATIONAL FLUID DYNAMICS

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There are 80 million light trucks on the road today with suboptimal aerodynamic forms. Previous research has found that several miles per gallon can be saved by specifically tailoring truck bodies for reduced aerodynamic drag. Even greater savings can be made if the shape of the trucks is numerically optimized. This could reduce fuel consumption in the United States by billions of gallons per year.

The purpose of this research is to develop and quantify optimal light truck canopy designs using computational fluid dynamics (CFD). Both two-dimensional and three-dimensional models are used to do this. Initially, this research focuses on quantifying and generalizing the effects of traditional automotive aerodynamic accessories, such as canopies and air dams. Once the effects of various form factors are quantified, an optimization of the canopy is performed. This thesis demonstrates a method for drag reduction using CFD and traditional numerical optimization techniques. Lastly, the optimized forms are physically constructed and their effects on fuel economy are compared to the CFD prediction.

KEYWORDS: Shape Optimization, CFD, Drag, Canopy, Air Dam, Light Truck, Miles Per Gallon, MPG, Fuel Efficiency, Fuel Economy

MASTER OF SCIENCE
IN
METEOROLOGY

EVALUATION OF EM PROPAGATION MODELS USING DATA FROM WALLOPS ISLAND EXPERIMENT (2000)

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The Royal Navy and the United States Navy emphasize utilizing the environment to achieve a tactical edge. Such approaches are outlined in Sea Power 21. This thesis recognizes accurate characterization of the physical battlespace as vital to concepts of both self-defense (Sea Shield) and strike (Sea Strike). Electromagnetic (EM) propagation is presented as a vital factor in the performance of a wide variety of ship, land, and airborne sensors and weapon systems. Atmospheric influences on EM propagation are related to gradients of temperature and humidity within the atmosphere. It is emphasized that modern maritime warfare is increasingly concentrated in the coastal theatre, an area in which atmospheric variability is often at maxima in both the vertical and horizontal. This thesis examines, using currently available technology and operational methods, how well the physical EM battlespace is described. Propagation models from the U.K. and U.S. are used to evaluate the propagation environment within the coastal zone, using measured data collected from the East Coast of the USA at Wallops Island during 2000, as a comparison. The main findings relate to the large potential errors, due the inability to measure and characterize the variability of the coastal environment under simulated, operational scenarios.

KEYWORDS: EEMS, AREPS, RF Propagation, Refractivity, Coastal Variability, Wallops Island, Surface Ducting and Evaporative Ducting Effects, Operational Simulation

MASTER OF SCIENCE
IN
METEOROLOGY AND PHYSICAL OCEANOGRAPHY

THE CIRCULATION AND VARIABILITY IN THE WESTERN ARCTIC OCEAN-MODEL RESULTS

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Circulation in the western Arctic Ocean is not well understood. To address some of its outstanding questions, volume transport and property fluxes are investigated using a coupled ice-ocean model of the pan-Arctic region configured at a 1/12-degree and 45-level grid. Results for analyses are from the last 23 years of a 70-year integration forced with realistic 1979-2001 atmospheric data. Velocity at three depth intervals, mean transports, and fluxes are investigated to identify the main current pathways and directions. Variability is determined by comparison of results a decade apart.

Mean velocity fields describe a climatological circulation pattern that is cyclonic in nature with increased intensity during the late 1980s and early 1990s. The meander through the Chukchi Borderland Pass is the main pathway for boundary flow across the Chukchi Plateau. The northern Chukchi Plateau is modeled as a region of major volume, heat, and freshwater transport into the Canada Basin interior. It also appears to be an area of net upward heat transport, which may be available for melting ice. Northward flow along the eastern side of the Northwind Ridge is identified as a mechanism for advection of freshwater from the Chukchi shelves into the interior.

KEYWORDS: Arctic Ocean, Oceanography, Modeling

PREDICTABILITY OF JAPAN/EAST SEA (JES) SYSTEM TO UNCERTAIN INITIAL/LATERAL BOUNDARY CONDITIONS AND SURFACE WINDS

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Numerical ocean modeling usually composes various initial- and boundary-value problems. It integrates hydrodynamic and thermodynamic equations numerically with atmospheric forcing and boundary conditions (lateral and vertical) from initial states of temperature, salinity, and velocity. Past observations, historical datasets, and climatological datasets of the ocean have contributed greatly to the knowledge of the data fields of initial condition, atmospheric forcing, and boundary conditions. Change in either initial or boundary condition leads to a variety of model solutions. It is necessary to specify realistic initial and boundary conditions to achieve better understanding and prediction of the ocean behavior. However, uncertainty often exists in both initial and boundary conditions. Up to now, most studies on ocean predictability have usually been for one particular type of model input uncertainty within the three types of uncertainty (initial conditions, open boundary conditions, atmospheric forcing function). This thesis investigates the response of ocean model to the three types of model input uncertainty simultaneously using Princeton Ocean Model (POM) implemented for the Japan/East Sea (JES).

KEYWORDS: Initial Conditions, Wind Forcing, Lateral Boundary Transport, POM, JES

AN ESTIMATION OF THE ABILITY TO FORECAST BOUNDARY LAYER MIXING HEIGHT AND WIND PARAMETERS THROUGH FORECAST VERIFICATION OVER FORT ORD

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Conducting controlled burns at Fort Ord requires specific meteorological and operational criteria. A minimum five-mile per hour offshore wind flow in conjunction with a minimum lower vertical mixing height of 1500 feet is meteorologically required. Burn contractor operational constraints require these meteorological parameters to be forecast 72 hours prior to burn. In this thesis, forecast verification percentage baselines for offshore and onshore winds were established. These 24, 48, and 72 hour forecasts were verified by 1200 UTC analyses at 850 mb and profiler observations. The observations were from the surface to 1500 feet. From these baselines the forecast skill when including a second burn prescription parameter, lower vertical mixing height, is inferred. Resulting forecast verification percentages using profiler observations of offshore wind flow were less than 40% at all forecast durations. Results indicate that during the burn season (July through December) the synoptic scale forecasts do not adequately represent the local wind field over Fort Ord. As the burn season progresses, synoptic scale forcing becomes stronger and mesoscale forcing weakens over Fort Ord, favoring forecast verification with profiler observations. Lastly, the inferred forecast skill of both offshore wind flow from the surface to 1500 feet and the minimum vertical lower mixing height simultaneously at all durations is 10%.

KEYWORDS: Forecast Verification, Doppler Wind Profiler Observations, AVN Simulations, Fort Ord, Chemical/Biological Defense

SUBTIDAL CIRCULATION OVER THE UPPER SLOPE TO THE WEST OF MONTEREY BAY, CALIFORNIA

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Moored current meters were used to describe currents over the continental slope off Monterey Bay, California, from March 1998 to March 2003. The water depth at this location was 1800 m and current observations included depths of 16-88 m, 210-290 m, 305 m and 1200 m, although measurements at 16-88 m were not continuous. Poleward currents dominated the flow between 24 and 305 m. At 305 m the mean flow was 3.9 cm/s toward 334°. Surprisingly, at 1200 m the mean flow reversed and was 0.8 cm/s toward 169°. The principal axis for the flow at 305 m (1200 m) was 349° (350°), the semi-major axis was 9.4 cm/s (5.8 cm/s), and the semi-minor axis was 3.4 (2.0 cm/s). The direction of the principal axis and the mean flow at 1200 m was aligned with the bathymetry to the east of the mooring site.

The seasonal cycle at 305 m was dominated by an acceleration of the poleward flow from a minimum near zero on April 15 to maximum, 25 cm/s, on July 15. This flow resulted in an increase of temperature at 305 m of 1.2° C due to geostrophic adjustment and a corresponding 10 cm increase in sea level due to steric effects. The acceleration of alongshore flow was out of phase with the alongshore pressure gradient, which was greatest in mid-April. At 1200 m, the temperature increase (0.2° C) only lasted from April 15 to June 1, after which equatorward flow increased and temperature decreased.

Mesoscale variability dominated the velocity measurements with maximum variance at about 60-day periods. At 305 m, the eddy kinetic energy was greatest (smallest) in October (December), 40 cm^2/s^2 (4 cm^2/s^2) while at 1200 m the maximum (minimum) occurred in July (February), 5 cm^2/s^2 (0.5 cm^2/s^2). Poleward events were stronger at 305 m while equatorward events were stronger at 1200 m.

The three first empirical orthogonal functions explained 90% of the temporal variability of the horizontal currents. The first, second, and third Z-score represented flow along the principal axis, undercurrent vs. Davidson current, and upwelling modes, respectively. While the seasonal patterns for the

first two modes agreed with seasonal variability described above, the seasonal variability of the upwelling mode (6% of the variance) indicated that the waters between 16 and 88 m flowed onshore during the spring and summer upwelling period.

KEYWORDS: California Current System, Seasonal and Mesoscale Circulations off Monterey, CA

VISIBILITY OVER LAND FROM CONTRAST ANALYSIS OF MULTI-SPECTRAL SATELLITE OBSERVATIONS

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The objective of this thesis is to investigate the viability of using contrast reduction in multi-spectral satellite observations to characterize surface visibility reduction due to heavy aerosol loading. Two methods are explored. First, the spectral distribution of standard deviation of surface reflectance over a homogeneous background (urban, agriculture, or forested) is plotted for three aerosol conditions (dust, smoke, and low aerosol loading). Second, the same cases are analyzed using a pixel-to-pixel differencing of surface reflectance. The spectral distributions of the means for the resulting difference fields are constructed. Each aerosol type was found to exhibit a relatively unique spectral distribution for both methods. Each background was found to exhibit a characteristic amount of contrast in the absence of heavy aerosol loading. The unique spectral characteristics for each aerosol-background combination may be correlated to aerosol optical depths or surface visibilities with corrections for sensor view angle variations, Rayleigh scattering, and masking of clouds and surface water. The spectral distribution-aerosol optical depth correlation can be used to build an empirical model for aerosol optical depth and surface visibility retrievals from satellite observations. This method may be applied to multi-spectral or panchromatic imagery, unlike current aerosol optical depth retrievals over land.

KEYWORDS: Visibility, Aerosol, Satellite Observations, Aerosol Optical Depth Retrieval, Over Land, Contrast